SECTION 3

DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the Federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the NOAA Marine and Aviation Operations (NMAO).

NATIONAL WEATHER SERVICE

NOAA's National Weather Service (NWS) has the principal responsibility for planning and operating the basic climate, hydrologic, and weather services and certain specific applied services. The NWS provides climate, water, and weather warnings and forecasts for the U.S., its territories, adjacent waters, and ocean areas to help protect life and property and enhance the national economy. NWS data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. In support of this mission, NWS:

• Issues warnings and forecasts of weather, flood, Great Lakes, coastal and ocean conditions.

• Observes and reports the weather and the river and ocean conditions of the U.S. and its territories.

• Develops and operates national meteorological, hydrological, climate, space weather and oceanic service systems.

• Performs applied meteorological, hydrological, oceanic, space environmental and climate research.

• Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.

• Participates in international hydrometeorological and space weather activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

• Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.

• Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.

• Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.

• Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for providing weather observations and services to aviation.

• Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).

• Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

• International Convention for the Safety of Life at Sea (SOLAS) agreement to which the U.S. is signatory. This sets international policy for safer shipping and cleaner seas. The U.S implements the convention through Executive Order 12234 of Sept. 3, 1980 -- Enforcement of the Convention for SOLAS. Among the obligations of the agreement is to provide meteorological warnings and forecasts to ships at sea using charts and radio messages.

SERVICES

NWS provides climate, water, weather oceanic, and space weather prediction services; including watches, warnings, advisories, and forecasts 24 hours a day, seven days a week. These services are provided through a national network of 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and the nine centers of the National Centers for Environmental Prediction (NCEP). These offices collect data, prepare local warnings and forecasts, and disseminate information to the public both nationally and internationally through NOAA Weather Radio, satellite-based telecommunication systems, radiofacsimile, the media and the internet. Forecast and warning services prepared at WFOs are derived in part from prediction guidance prepared by the 13 RFCs and the nine NCEP centers.

These centers are: Hydrometeorological Prediction Center, Storm Prediction Center, Aviation Weather Center, Environ-mental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Environment Center, Ocean Prediction Center, and NCEP Central Operations.

Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development both within the NWS and externally from universities and private corporations.

PUBLIC WEATHER SERVICES

NOAA's NWS Public Weather Service Program provides forecast, warning, and response services to the public, private meteorological firms, broadcast meteorologists, and NWS partners who are responsible for public safety. These partners include Federal, state, and local emergency managers and planners. NWS forecasters issue short-duration watches and warnings for severe weather, such as tornadoes and severe thunderstorms, as well as long-duration watches, warnings, and advisories for hazardous winter weather conditions, high wind events, dense fog, and temperature extremes. NWS forecasters support several health related programs such as Air Quality, Heat Health, and the Ultraviolet Index (UVI). Ground based ozone concentration forecasts and an experimental smoke forecasting tool are now being produced for the CONUS. A nationwide air quality forecast capability including concentrations of ozone, particulate matter, and other pollutants is under development. Heat Health Watch Warning Systems (HHWWS) have been developed for select cities to provide advance notice of excessive heat events that produce the greatest number of weather-related deaths. These guidance systems will be expanded to other cities as resources are made available. Also, in partnership with the Environmental Protection Agency (EPA), a climatologically based UV alert is being produced for the entire nation. The Branch serves as the primary focal point for collaboration with Federal transportation agencies on weather issues related to surface transportation, with Federal, media, and private entities on the UVI, and with the World Meteorological Organization on the provision of public weather services to the international community. Additionally, NWS forecasters provide meteorological support both on-site and from WFOs for terrorist acts and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials.

Since 2004, the National Weather Service has created, and made readily available, forecasts in digital formats. NWS forecasters use their expertise to maintain an up-to-date digital forecast database of sensible weather elements. This information is stored in the National Digital Forecast Database (NDFD). Output from NDFD is available in the form of web graphics available over the Internet, in gridded binary format (GRIB2) available via anonymous file transfer protocol, or in XML via an experimental web service. NDFD data can also be converted to a file format that can be used with Geographical Information Systems (GIS). NDFD includes the following operational forecast elements: Maximum Temperature, Minimum Temperature, 12-Hour Probability of Precipitation, Temperature, Dew Point, Weather, Wind Speed and Direction, Relative Humidity, Apparent Temperature, Significant Wave Height, and Probabilistic Tropical Cyclone Surface Wind Speeds. Experimental forecast elements include Quantitative Precipitation Forecast (QPF), Snow Amount, Sky Cover, Wind Gust, and Convective Outlook Hazard Probabilities. For more detailed information on NDFD, please see http://www.nws.noaa.gov /ndfd/.

AVIATION WEATHER SERVICES

NWS' Aviation Weather Services Branch funds a broad range of initiatives designed to improve the delivery of aviation weather information to National Airspace System (NAS) users. These initiatives include the acquisition of aircraft mounted water vapor sensors, development of software, tools and training programs to enhance forecaster effectiveness, and products to improve weather information availability to the aviation community. The Aviation Weather Program also serves as NOAA's focal point in the development of the Next Generation Air Transportation System (NextGen). In order to accommodate the projected tripling of demand for air transportation, Congress established the Joint Planning and Development Office (JPDO) to develop and implement NextGen. The NextGen plan will increase NAS capacity by relying on 4D aircraft trajectories for air traffic management. It will rely on highly automated systems to route air traffic around areas of hazardous weather. These systems, and related decision support tools, will require a 4 Dimensional (4D) digital database of aviation relevant weather elements that will serve as a single authoritative source of aviation weather data. This 4D Database must be continuously updated, internally consistent, and utilize Network Enabled Operations to provide for common situational awareness. The 4D Database will give NOAA the ability to provide airspace users with the current and forecast weather conditions for any point in space, thereby providing for the safe and efficient movement of air traffic. This capability is required to have an initial operational capability by 2012, in order to support the planned automated air traffic management systems.

In order to operationally support the needs of aviation users, the NWS WFOs prepare Terminal Aerodrome Forecasts (TAFs) four times a day,

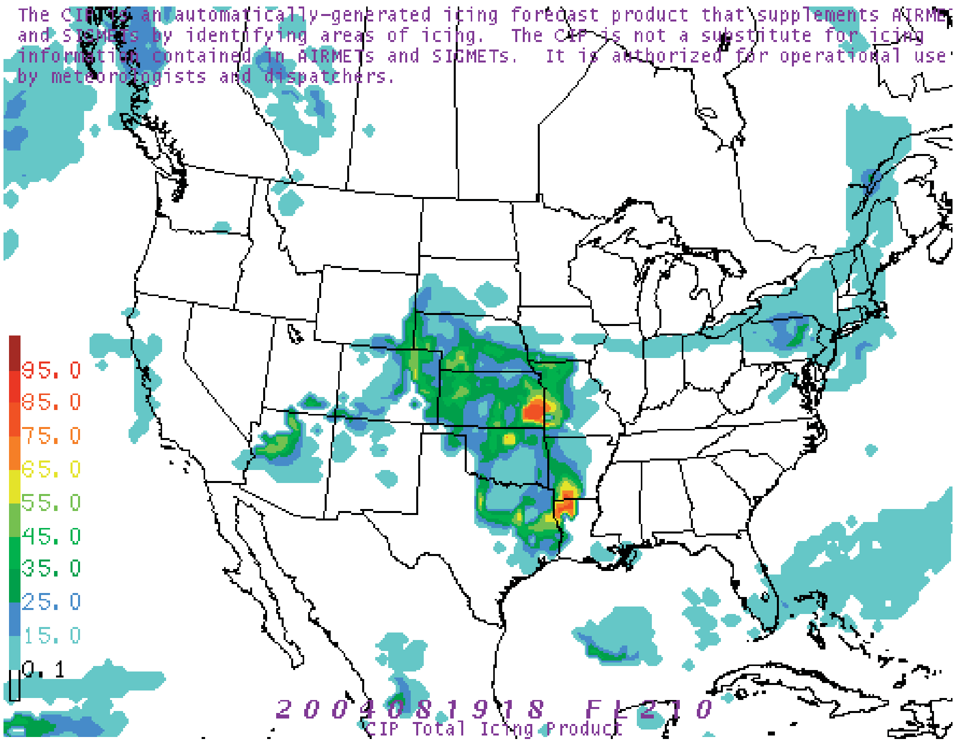

Figure 3-DOC-1. Current Icing Potential (CIP) Product. The FAA's Aviation Weather Research Program and the NWS developed this graphical icing product, updated every 3 hours, and available for user selected altitudes across the contiguous U.S.

with amendments as needed, for more than 625 public-use airports in the U.S. and its territories in the Caribbean and Pacific. These offices also produce about 241 individual route-oriented forecasts three times a day for the 48 contiguous states and over the Pacific Ocean.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu, HI prepare area forecasts three or four times daily describing general aviation weather conditions over the lower 48 states, the Gulf of Mexico, Caribbean, Alaska, Hawaii and coastal waters respectively. These three specialized offices also issue in-flight advisories and warnings of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low level winds. The AWC also prepares forecasts of significant aviation weather over the continental U.S. four times a day (Figure 3-DOC-1).

NWS Center Weather Service Units located in each of the 21 FAA Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, airport towers, and Automated Flight Service Stations. These units are operated by NWS, but funded through an Interagency Agreement with the FAA.

The NWS provides weather warnings, advisories and forecasts to international aviation as one of the International Civil Aviation Organization's (ICAO's) two World Area Forecast Centers. NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice a day for flight levels from 5,000 to 45,000 feet. The AWC prepares forecasts four times a day of globally significant thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence and icing, and cumulonimbus cloud associated with the above. The forecast charts also include information on volcanoes, radiological releases, jet streams and tropopause heights. This information is transmitted by the International Satellite Communications System with coverage in the Americas, Caribbean, Atlantic, western portions of Europe, the Pacific, and eastern Asia.

The United States, in agreement with the International Civil Aviation Organization (ICAO), operates two Volcanic Ash Advisory Centers (VAACs). NESDIS's Satellite Analysis Branch and NWS's NCEP share management responsibility for operating the Volcanic Ash Advisory Center in Washington, D.C. Alaska's Volcanic Ash Advisory Center is run by NWS's Alaska Aviation Weather Unit. The Washington VAAC area of responsibility includes the continental United States and southward through Central America, the Caribbean to 10 degrees South in South America, and the United States controlled oceanic Flight Information Regions (FIR). The Anchorage, Alaska, VAAC is responsible for the Alaska and Anchorage FIRs.

MARINE WEATHER SERVICES

The NWS Marine Weather Program is the lead for the nation's marine and coastal weather services. Programs include warnings, forecasts, and advisories for coastal waters, offshore, high seas, and near-shore and open waters of the Great Lakes. It leads programs for tropical cyclone, coastal flood, severe convective coastal weather, and coastal hazards such as high surf, rip currents, and tsunamis. NWS forecasters at 46 coastal and marine WFOs, in collaboration with NCEP's Ocean Prediction Center and Tropical Prediction Center, provide a range of weather services focused on the expanding and weather-sensitive U.S. coastal population and those responsible for its safety.

The program develops plans, policy

and procedures for the delivery of marine and coastal weather products and services from the coastal WFOs, the Ocean Prediction Center, the Tropical Prediction Center, and the Central Pacific Hurricane Center. It ensures marine and coastal forecast training needs are met. The program works with the Office of Science and Technology to prioritize tropical, marine and coastal science and technology development and approve new or improved product designs, and with the Office of Operational Systems to ensure the collection of marine and coastal observations and the delivery of marine and coastal products to users. The program creates internal and external partnerships, collects and validates marine and coastal service and mission needs, solicits feedback on products and services and validates whether these needs are met.

The program works with NOAA's NESDIS, the U.S. Navy and the U.S. Coast Guard (USCG) to provide ice warning and advisory services through the joint National Ice Center; with the Navy, the USCG, the U.S. Maritime Administration, and the Corps of Engineers to safely operate the nation's Marine Transportation System; with the Department of Defense, Federal Emergency Management Agency, and Corps of Engineers to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; with NOAA's National Ocean Service (NOS) on the PORTS and TIDES programs; and with the World Meteorological Organization to provide services to the international community. It also works in cooperation with NOAA's Office of Response and Restoration, the Department of Defense, and the Department of Homeland Security for forecasting services for hazardous material spills, marine area search, rescue, and recovery operations, and security needs.

FIRE/ALL HAZARD WEATHER SERVICES

NOAA's NWS offices provide routine pre-suppression and wildfire weather support to Federal and state land management agencies. NWS forecasters provide routine fire weather forecasts, forecast support for the National Fire Danger Rating System, and site specific forecasts during the local fire season over roughly three-quarters of the nation. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMET) to provide on-site support for large wildfires and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials. IMETs use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. In the early morning, NOAA's National Centers for Environmental Prediction's Storm Prediction Center issues outlooks for days 1, 2 and 3 to 8 that highlight areas with critical and extremely critical fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters. Areas where significant lightning activity accompanied by less than 0.1 inch of precipitation (dry lightning) is forecast are also highlighted. Additionally, NWS forecasters provide forecasts in response to hazardous material incidents or Incidents of National Significance (such as the Columbia Recovery effort).

TSUNAMI WARNINGS

Tsunami watches, warnings, and information bulletins for the Pacific Ocean and Hawaii are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii, and for the west coast of the continental U.S. and Alaska by the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories, sea-level observing stations, and deep-ocean tsunami detection buoys which operate on a cooperative basis. The centers use these data to prepare and disseminate watches, warnings, and information bulletins to international customers, WFOs, Federal and state disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public.

CLIMATE SERVICES

Climate prediction products and other services relate to the period of week two out to one year, including seasonal forecasts and hazard assessments. The NWS's Climate Prediction Center produces a suite of products covering these periods. The climate services program provides the strategic vision for climate services at NWS, oversees the program including the expanded regional and local climate services programs, and serves as steward of the climate observing system. It maintains strong ties with other countries; across NOAA lines, specifically through the NOAA Climate Office; with Federal agencies; the university community; and the private sector and encourages collaborative arrangements among the Regional Climate Centers (managed by NOAA/NESDIS), the State Climatologists, and NWS WFOs and regional headquarters to tailor climate forecasts for local users.

HYDROLOGIC SERVICES

The 122 WFOs, 13 River Forecast Centers (RFCs), and NCEP's Hydrometeorological Prediction Center (HPC) work as a team to provide hydrologic forecast and warning services which minimize loss of life and property damage from flooding and to meet the water service needs of our Nation. RFC hydrologists use a modeling system called the NWS River Forecast System (NWSRFS) to produce forecast time series of discharges or river stages at approximately 4,000 locations along the nation's rivers. HPC provides the quantitative precipitation forecasts serving as the primary forecast input for NWSRFS. RFCs also provide long-term water supply forecasts used by water managers in the western U.S., where decisions about water allocation and use are particularly critical now, with much of the West still feeling the effects of a long-term drought.

WFOs work cooperatively with the RFCs to monitor the major river systems around the clock. Using RFC guidance, advanced Doppler radar (NEXRAD) and telemetered rain gauge observations, WFOs continuously monitor the threat of flash flooding and urban flooding to provide timely flood watches and warnings to protect life and property.

Partnerships with a variety of Federal, state and local agencies are critical to NOAA's NWS Hydrologic Services Program. For example, the NWS works very closely with the United States Geological Service (USGS), the United States Army Corps of Engineers, the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation, and the Bureau of Land Management on a variety of water related issues including stream gauging, support of flood fighting activities, river and water supply forecasting, and water management. River stage observations and stage-discharge relationships provided by the USGS are critical to warning and forecast operations for the Nation's rivers. The NRCS furnishes snow measurements that are combined with advanced snow modeling and analysis provided by NOAA's National Operational Hydrologic Remote Sensing Center to support joint NWS-NRCS water supply forecasting in the western U.S.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS) to provide hydrologic forecasts with lead times ranging from minutes to months (Figure 3-DOC-2). AHPS builds on the existing NWS infrastructure, including AWIPS, NEXRAD, and NWSRFS. AHPS also provides Ensemble Streamflow Prediction, a feature that allows the NWS to quantify forecast uncertainty. This lets decision makers apply risk-based analyses as they respond to flooding, and as they try to balance competing demands on water supply, especially during periods of drought.

Flash floods, typically caused by intense, small-scale convection, are the leading cause of flood fatalities. Another AHPS capability, known as Flash Flood Monitoring and Prediction (FFMP), combines high-resolution radar rainfall observations with Geographic Information System (GIS) technology to provide more accurate and much more precise flash flood forecasts. The added precision provided by FFMP greatly reduces the false alarm rate of flash flood forecasts, making them more credible and leading to better public response, which will ultimately save lives.

AHPS services are provided as a suite of Web-based products (weather.gov/ahps), that feature user-friendly menus and maps which allow users to zoom in to areas of interest.

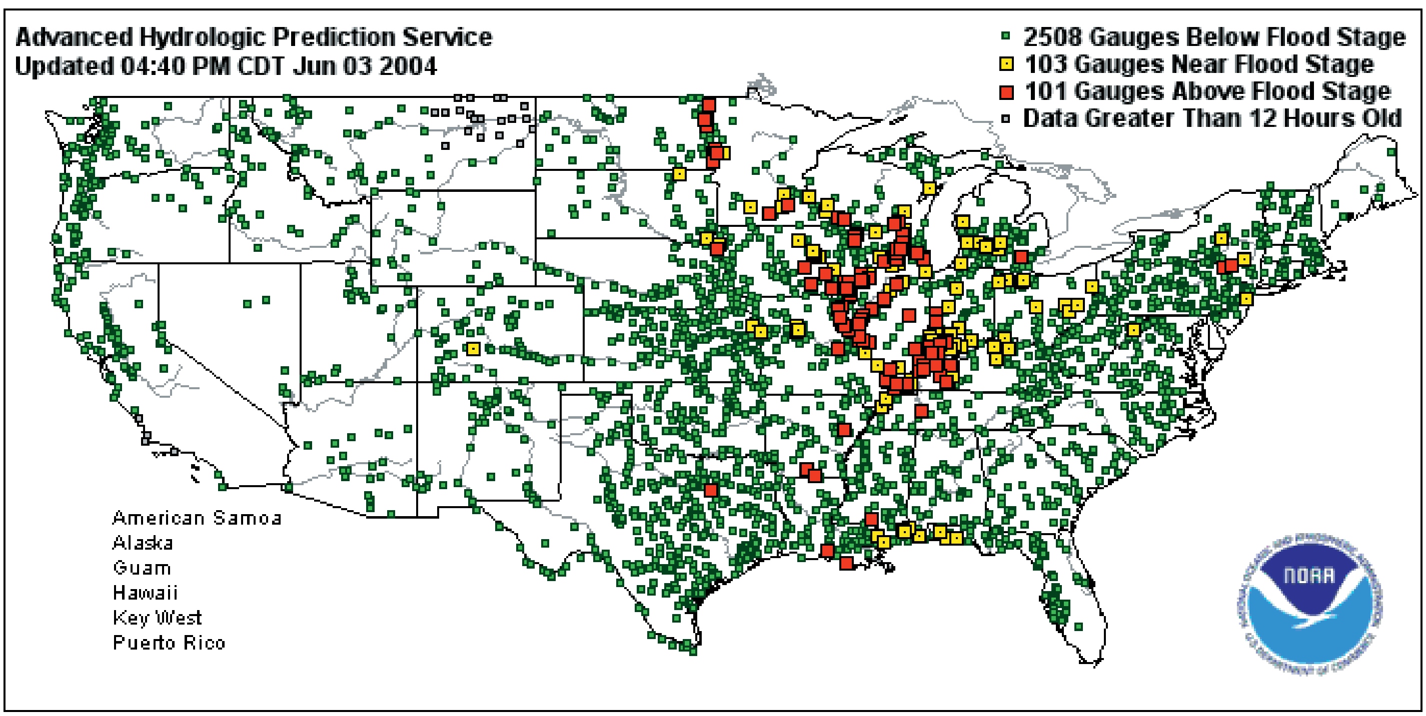

Figure 3-DOC-2. Map showing status of river conditions throughout the Nation. This map is included on the primary AHPS Web page and it provides access to more detailed local information on river conditions, including observations and forecasts at specific locations along rivers, as well as expected impacts that could result from flooding.

Clicking on an area of interest on the national map brings the user to a map of the NWS WFO serving that area which provides more detailed information on river conditions. AHPS also opens opportunities to improve NOAA's analysis and forecast capabilities related to coastal water conditions, through joint efforts with other components of NOAA (e.g., National Ocean Service, Office of Oceanic and Atmospheric Research).

The Water Resources Forecasting Activity is being implemented to build on AHPS and other NOAA services to deliver new services at a higher resolution (down to the neighborhood scale) with more information; such as soil moisture, soil temperature, snow pack, and surface runoff volume. It enables NOAA to provide nationally consistent water quantity and quality condition forecasts via: 1) a national digital database which assimilates hydrometeorological data and observations, and 2) a community hydrologic modeling system which brings the current state of science to NWS hydrology.

The national digital database will integrate fresh water resource observations and analysis components such as precipitation estimates, snowpack analysis, and soil moisture data. The goal of this database is to increase the amount, type, and accuracy of water resources information for use within the NOAA and by partners and other users.

The Community Hydrologic Prediction System (CHPS), facilitates the sharing of data and models between NOAA, other Government agencies, universities, and private sector research groups to advance water prediction science. CHPS will allow a new suite of high-resolution forecasts (including estimates of uncertainty) to be produced for streamflow, soil moisture, soil temperature, water quality, and many other variables directly related to watershed conditions.

OBSERVATIONS

Observations form the basis for forecasts and the monitoring and evaluation of the environment. Differing applications and requirements are associated with each of these functions. Forecast applications associated with watch and warning functions must be served immediately, while real-time availability is not a significant factor for climate monitoring. The range of differing applications will dictate how future instrument deployments will be conducted. This poses a constant challenge to the optimization of resources placed into in situ and remotely sensed observation platforms.

The fundamental application of observations is to deliver better products and improve services. This demands the link between improved services and observing systems be well defined. We need to determine the gaps in observations to meet varied requirements, emphasizing the importance of metadata and sensor calibration continuity. Coordinated efforts within the Federal community throughout all aspects of observations development, dissemination and use are needed for efficient utilization of resources.

The NWS approach for improving observations consists of several efforts:

• Make better use of data from observing systems that currently exist;
" Extend the system life of current observing systems to postpone technical obsolescence;

• Replace obsolete observing systems;

• Implement new observing technologies and communication systems that better meet the data needs of our customers; and

• Strengthen the link between user requirements and technology research and development.

The NWS manages programs that produce observations in support of a wide range of customers, such as the aviation, climate monitoring and research communities. As part of its responsibility, the NWS inspects all surface weather observing stations and certifies equipment and observers. NWS Headquarters establishes policy for observations and standards and coordinates with other Government agencies and international organizations.

NOAA'S COOPERATIVE WEATHER OBSERVER NETWORK (COOP)

COOP is the Nation's largest and oldest weather network (see Figure 3-DOC-3). Modernization of the COOP under NERON is consistent with the President's Climate Change Research Initiative, providing a richer source of data to improve weather, water and climate forecasting and to contribute to climate change research. The COOP is the primary source for monitoring U.S. climate variability over weekly to interannual time frames. These data are also the primary basis for assessments of century-scale climate change. The modernized network will add to NOAA's vision of an-end-to-end monitoring program that "takes the temperature" of the earth's systems.

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

NCEP delivers analyses, guidance, forecasts and warnings for weather, ocean, climate, water, land surface and space weather to the nation and world. NCEP provides science-based products and services through collaboration with partners and users to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value added forecast guidance prod-

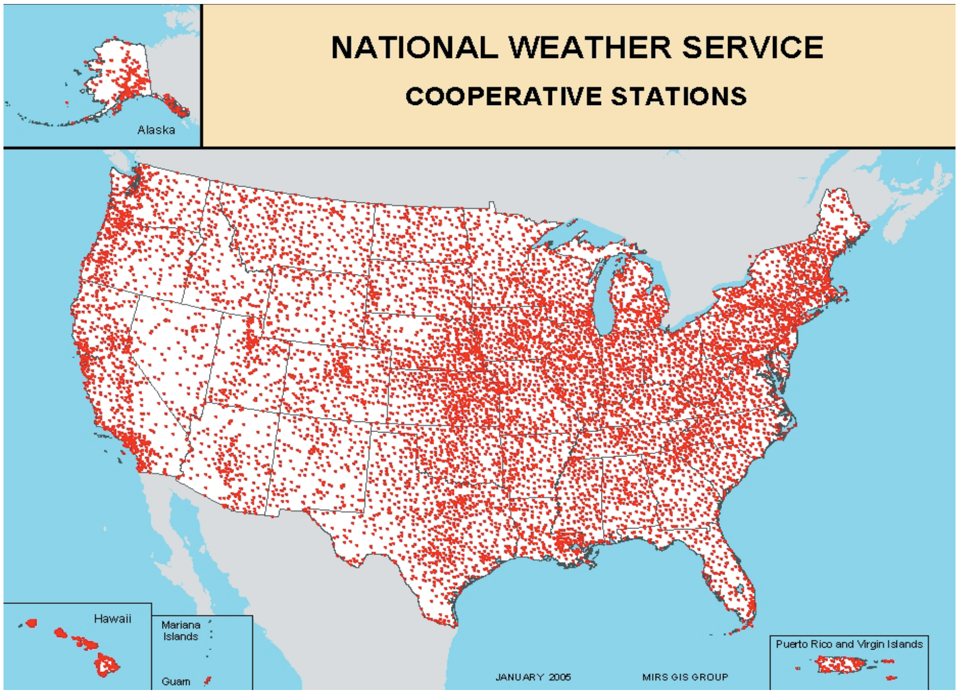

Figure 3-DOC-3. Map showing locations of Cooperative Weather Observer Network (COOP). Interactive web site can be found at *http://www.nws.noaa.gov/om/coop/wfo-rfcmap.htm*

ucts for NWS field offices and other users.

NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions.

STORM PREDICTION CENTER

The Storm Prediction Center (SPC) focuses on hazardous weather events, such as severe thunderstorms, tornadoes, extreme winter weather, fire weather, and excessive precipitation with emphasis on the forecast period that ranges from 2-8 hours to the next 6 to 72 hours. All Tornado and Severe Thunderstorm Watches issued anywhere in the contiguous United States come from the SPC in collaboration with local NWS Forecast Offices. Also, the SPC prepares Mesoscale Convective Discussions which are technical explanations of developing mesoscale features and their impact on hazardous weather. For longer time periods, the SPC produces the Convective Outlook which is the one, two or three day forecasts of the probability and intensity of both non-severe and severe thunderstorms (including tornadoes). A product depicting the day 4-8 forecast for organized severe thunderstorms over the contiguous United States has recently become operational. In addition, the SPC produces probabilistic Convective Outlooks in conjunction with the traditional categorical Convective Outlooks. These outlooks are issued for all Day 1, Day 2, and Day 3 periods. The SPC also issues one and two day Fire Weather Outlooks for the contiguous United States, defining areas with critical, extremely critical and dry thunderstorm fire conditions and potential for defined areas. An experimental 3-8 day Fire Weather Outlook is also available.

HYDROMETEOROLOGICAL PREDICTION CENTER

The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services (1) to support the daily public forecasting activities of the NWS and its customers, and (2) to provide tailored support to other government agencies in emergency and special situations. As part of this mission, HPC prepares Quantitative Precipitation Forecasts (QPF) used by the RFCs to develop local river and flood forecasts and by WFOs to develop local rainfall, snow and ice forecasts. The HPC provides special QPFs and coordinates with other Federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community. Additionally, HPC serves as the backup to the National Hurricane Center. From September 15 through May 15 of each year, HPC staffs a Winter Weather Desk for two shifts per day, issuing probability graphics for snow and freezing rain as well as a graphic depicting the position of lows impacting the 48 contiguous United States in 12 hour increments out to 72 hours into the future. HPC also operates International Desks with the mission of providing visiting scientists meteorological training with an emphasis on the operational use and application of numerical model products.

AVIATION WEATHER CENTER

The NCEP experts for aviation meteorology are concentrated at the Aviation Weather Center (AWC). The AWC provides weather warnings, advisories and forecasts to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, and flight hazards (e.g., convection, icing, turbulence) forecasts for flight planning and en route aircraft operations for the U.S., the Gulf of Mexico, the Caribbean Sea, the Atlantic and Pacific routes in the Northern Hemisphere and some routes in the Southern Hemisphere. In addition, every two hours, the AWC issues the Collaborative Convective Forecast Product (CCFP), a graphical representation of expected convective occurrence at 2-, 4-, and 6-hours after issuance time. Its purpose is to aid in the reduction of air traffic delays, reroutes, and cancellations influenced by significant convective events. It is produced March through October by a collaborative process involving AWC forecasters along with aviation forecasters from commercial airlines, Center Weather Service Units, and Meteorological Services Canada.

ENVIRONMENTAL MODELING CENTER

The Environmental Modeling Center (EMC) improves NCEP's numerical climate, water, and weather predictions through data assimilation and computer modeling. To provide mesoscale predictions (thunderstorms, hurricanes, tornadoes, blizzards, etc.), ocean predictions and global weather and climate predictions, EMC develops, adapts, improves, and monitors data assimilation systems and global, regional and mesoscale models of the atmosphere, land surface, ocean, and atmosphere/ocean/land systems. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. As an example, EMC is a partner in the NASA/NOAA Joint Center for Satellite Data Assimilation (JCSDA) designed to accelerate the use of research and operational satellite data in NCEP operational models.

The EMC integrates research and technology through collaborative model development projects. These interactions serve as an efficient and effective interface between NCEP and the scientific community that develop ideas, numerical models, and forecast techniques to implement model improvements and improve NWS products. The EMC conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community. EMC also participates in ongoing interactive research programs such as the USWRP Hurricane at Landfall project and the community Weather Research and Forecast (WRF) model. Furthermore, EMC is participating in the Winter Storm Reconnaissance Program in the Pacific through targeted observations aimed at improving forecasts across the country. In addition, at NCEP, led by the EMC, the ensemble approach has been applied operationally at the short- medium- and extended range. EMC efforts with collaborative development have resulted in improvements to mesoscale and global models, as well as advancements in hurricane track forecasts, climate forecasts and air quality forecasts.

CLIMATE PREDICTION CENTER

The Climate Prediction Center (CPC) provides operational monitoring and prediction of global and regional climate variability, with emphasis on applied research and partnerships, to improve understanding of the global climate system, weather and climate links, extremes and trends. CPC develops and maintains databases for determining current and historical climate anomalies and trends, and provides analyses and assessments of their origins and linkages to the global climate system. CPC products and services cover time scales ranging from next week (days 6-10) to seasons and out to a year in advance, and cover land, ocean, and atmosphere extending into the stratosphere. CPC's products include probabilistic monthly and three monthly outlooks (out to one year) for temperature and precipitation, a U.S. Hazards Assessment, the multi-agency U.S. Drought Monitor, a drought outlook, and El Niño Southern Oscillation (ENSO) discussions and outlooks, among many others. WFOs, as well as the public, private industry, and the national and international research community use CPC products and climate services. CPC also houses the Climate Test Bed (CTB) to accelerate the transfer of research and development into improved NOAA operational climate forecasts, products, and applications. CTB personnel include scientists from NCEP and other NOAA and non-NOAA organizations.

SPACE ENVIRONMENT CENTER

The Space Weather Prediction Center (SWPC) provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SWPC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SWPC issues to the public, its U.S. Air Force partners, and vendors of value-added services specific predictions of the space weather activity level for the next three days and more general predictions up to several weeks in advance, as well as weekly summaries of observed solar terrestrial conditions. SWPC serves as the international World Warning Agency for the International Space Environment Service (ISES). It exchanges international data- solar wind, X-ray, sunspot, corona, magnetic, and ionospheric measurements- in real-time and, from these data, provides and meets additional specific needs of other government agencies. The SWPC also distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use.

OCEAN PREDICTION CENTER

The Ocean Prediction Center (OPC) provides atmospheric and oceanographic warning, forecast, and analysis products and services out to five days for the North Atlantic and North Pacific (north of 30 degrees) (see Figure 3-DOC-4) as part of the NWS mission of protecting life and property and enhancing economic opportunity. As part of this responsibility, OPC handles U.S. international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). The OPC provides weather and sea state warnings and forecasts for the offshore waters of the U.S. and the high seas of the Northern Hemisphere north of 30 degrees for planning and operational purposes. OPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The OPC also coordinates forecasts with and provides forecast guidance to WFOs with coastal responsibilities. The OPC, the Tropical Prediction Center (TPC), HPC, and WFO Honolulu, HI collaborate daily to produce unified and seamless surface weather analyses covering from 30 degrees South to the North Pole, and from East Asia across the Pacific and Atlantic to Western Europe and Africa.

TROPICAL PREDICTION CENTER/NATIONAL HURRICANE CENTER

The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include public and marine advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific hurricane basins including the portions of the coastline threatened by such storms. In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility, south of 30 degrees north latitude and a portion of the southeast Pacific. TPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

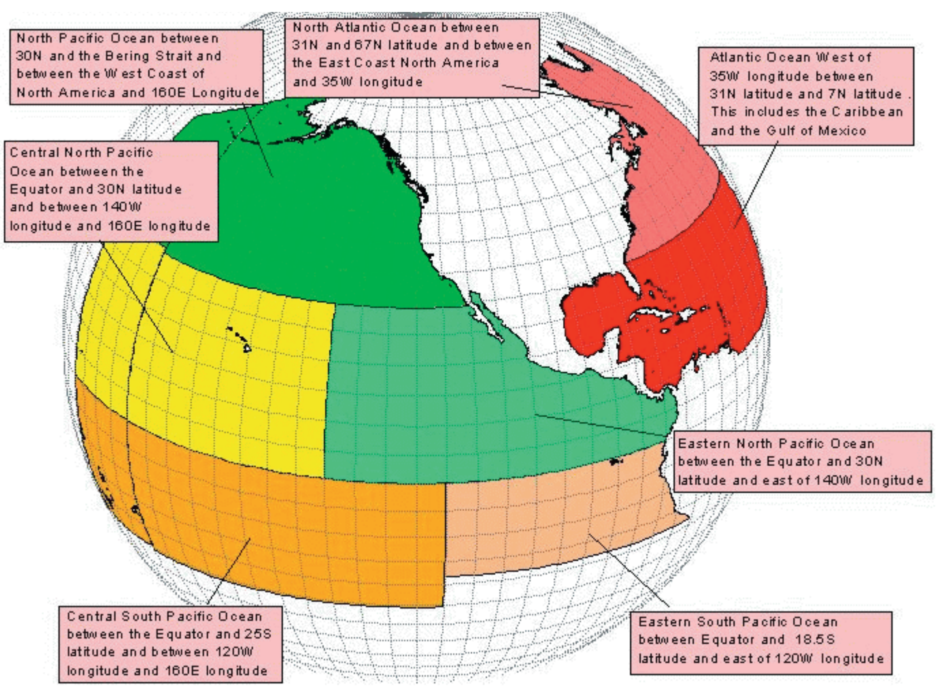

Figure 3-DOC-4. United States High Seas Forecast Areas of Responsibility.

NCEP CENTRAL OPERATIONS

The NCEP Central Operations (NCO) is responsible for NCEP operations, including access to real time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO maintains and manages the supercomputer and runs the computer applications that generate all NCEP model products. The NCO leads the technical transition between the research and development of numerical weather and climate prediction models and their operational use on the NCEP computer systems. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS high performance computer systems, forecaster workstations, personal computers and a user service that support all NCEP centers. Since an upgrade to NCEP's main computer systems and facilities in 1999, and throughout subsequent upgrades, NCO has delivered NCEP model forecasts and products to its users with a high degree of reliability and timeliness. NCO manages two supercomputers located in Gaitherburg, MD and Fairmont WV, representing an operational machine and backup, each of which operates with a sustained speed of 14 teraflops, has 2094 processors running at 1.9 gighertz speed, using 4608 gigabytes of shared memory, 150 terabytes of disk space and 75 terabytes of tape archive. Each day, the operational machine processes over 239 million meteorological observations (99.9 percent of which are from satellites), and generates more than 14.8 million model fields.

OTHER NWS OFFICES WITH NATIONAL RESPONSIBILITIES

In addition to the NCEP centers, there are two other offices that provide National products. They are the Alaska Aviation Weather Unit, the Anchorage WFO, and the WFO Honolulu/Central Pacific Hurricane Center.

Alaska Aviation Weather Unit

The Alaska Aviation Unit (AAWU) provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for Alaska and surrounding areas.

WFO Anchorage Marine and Ice Programs

The Anchorage WFO prepares offshore marine forecasts and warnings for interstate and international marine commerce traversing the Gulf of Alaska and the Bering Sea. They also prepare ice analyses and forecasts for the Arctic Ocean, Bering and Chukchi Seas, and the Cook Inlet.

WFO Honolulu/Central Pacific Hurricane Center

WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides products in aviation, marine, and tropical cyclone areas. In aviation, WFO Honolulu provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for the central north Pacific from 140 degrees W to 160 degrees E longitude and in the Oakland Flight Information Region south of 30 degrees N latitude through ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). WFO Honolulu provides weather and sea state warnings and forecasts for the high seas of the central north and south Pacific south of 30° N latitude. CPHC issues tropical cyclone advisories, forecasts, watches, and warnings for the central north Pacific including Hawaii.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather, water, and climate services to the public.

METEOROLOGICAL RESEARCH

The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques for weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.
- Techniques to improve prediction of seasonal to interannual climate variability and their impacts on weather variability.
- Techniques to improve incident data retrieval and display (with NOAA's Environmental Systems Research Laboratory's (ESRL) Global Systems Division).

Hydrologic Research

The NWS develops, implements and operationally supports improved hydrologic, hydraulic and hydrometeorological models and manages hydrologic data and enhanced quality control procedure to support national flood and water resources forecasting. Research encompasses the following areas:

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complementary models in the NWS River Forecasting System. Research, development and implementation of improved ESP procedures which improve forecast accuracy and quantify uncertainty at all time scales.
- Specialized flood and flash flood forecasting procedures using linked hydrologic, hydraulic and meteorological models. Major research areas include developing distributed hydrologic models that use high resolution precipitation data from the NWS radar network, improvement of cold region processes in watershed models, and assimilation of data to improve model initialization. Highly specialized hydraulic models for routing river flows will also provide information for generating maps of inundated areas.
- Development of improved multisensor precipitation estimates for input estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge and satellite rainfall estimates are merged to produce optimum rainfall analyses.
- Development of verification methods to assess the added-value of new science and technology to the customer.
- Development of the Community Hydrologic Prediction System (CHPS) to facilitate the sharing of data and models and allow for production of a new suite of high-resolution forecasts.

Space Weather Research

Research and development at SEC

emphasizes understanding of the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes are manifest in the climatology and disturbances of Earth's magnetic field, the ionosphere, the charged particle populations at satellite orbits, and the atmospheric density at high altitudes (including low-Earth orbit). This applied research is focused on areas where advanced applications can be devised and prototyped to improve the specification and forecast of conditions in the space environment by developing and implementing models and indices, as well as by obtaining and processing new observations.

• Developing of the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from widely dispersed sources will enable the model output to be useful to radio-communicators and Global Positioning System (GPS) and Loran users.

• Developing of models to characterize and predict geomagnetic storm intensity development, spatially and temporally.

Support for Collaborative Research with the Academic Community and Other Partners

The Collaborative Science, Technology, and Applied Research (CSTAR) program was established to bring NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services. The CSTAR Program issues requests for proposals through which colleges and universities compete for 1-3 years of research funding. CSTAR supports shorter-term research activities with colleges and universities through the NWS/Cooperative Program for Operational Meteorology, Education, and Training (COMET) Outreach Program. The NWS also funds specific applied research grants and cooperative agreements directly in support of hydrology and meteorology research needs.

TRAINING

NOAA's NWS provides training to its workforce to enhance the professional and scientific development of its staff in support of NOAA's NWS mission and strategic goals. Training deficiencies and requirements are identified and addressed via the National Strategic Training and Education Plan (NSTEP) process, described in NWS Instruction 20-102 and available at http://www.nws.noaa.gov/directives/020/pd02001002a.pdf

Training is provided through residence classes and workshops, distance learning methods, Internet modules, teletraining sessions, webcasts and CD-ROM based training. The NWS Training Center (NWSTC) in Kansas City, Missouri, provides technical, meteorological and hydrologic, and management/leadership training. The Warning Decision Training Branch (WDTB) in Norman, Oklahoma, conducts situational awareness and remote sensing training with modules that integrate data for improving the warning decision process. The Forecast Decision Training Branch (FDTB) in Boulder, Colorado, provides scientific and forecast-decision training. NWS employees also have direct access to scientific and managerial training materials through the Department of Commerce's Learning Center. NOAA's NWS training is also supported by a partnership with the Cooperative Program for Operational Meteorology, Education and Training (COMET) located in Boulder, Colorado.

The NWSTC, in addition to providing scientific and technical training, is working to expand its leadership training and development skills through NOAA's NWS Leadership Academy. The goal of the Leadership Academy is to enable NWS and NOAA employees to become world-class leaders. The Academy is founded on a sequential and progressive approach designed to develop professional skills and capabilities to improve employee performance. From entry into the agency to senior career status, employees can take advantage of courses and processes that are part of a powerful management and leadership learning environment. Finally, NOAA's NWS is working to develop an organized curriculum to supply the necessary knowledge, skills, and abilities for all

INTRODUCTION

The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) oversees the daily operations of the United States civil operational environmental satellite systems, as well as NOAA's National Data Centers (NNDCs) that develop global, national, and regional databases to support meteorology, oceanography, geophysics, and the space environment. NESDIS was established as a NOAA line office on December 1, 1982. The merger of the former National Environmental Satellite Service (NESS) and the Environmental Data and Information Service (EDIS) formed NESDIS. NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and the development and management of environmental resources.

NESDIS procures, launches, and operates two types of satellites to provide worldwide environmental data and information products and services to Federal agencies, state and local governments, and private users. These satellite types are the Polar-orbiting Operational Environmental Satellites (POES) and Geostationary Operational Environmental Satellites (GOES).

POES

The POES spacecraft circles the Earth in an almost north-south orbit, passing close to both poles. These orbits have an altitude between 830 km (morning orbit) and 870 km (afternoon orbit), and are sun synchronous. One satellite crosses the equator at 10:00 a.m. local time, the other at 2:00 p.m. local time. Operating as a pair, these satellites ensure that data for any region of the Earth are no more than six hours old. Each satellite orbits the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and long-term global climate change research.

NOAA also manages the command, control, and communications function of the Department of Defense's (DOD's) Defense Meteorological Satellite Program (DMSP) constellations. Currently NESDIS is operating six polar orbiters. The NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. NOAA-17 serves as the primary morning satellite and NOAA-18 the primary afternoon satellite.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS), the next generation of polar-orbiting satellites, will provide standard meteorological, oceanographic, environmental, and climatic information as well as space environmental remote sensing information. NPOESS will also continue to provide surface data collection and search and rescue capability. The Integrated Program Office (IPO), in consultation with the POES and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services. The first NPOESS launch is planned for 2013.

GOES

The GOES spacecraft, in contrast to the POES spacecraft, circles the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. There are three types of GOES spacecraft; two geostationary satellites, referred to as GOES-East and GOES-West, plus an on-orbit spare satellite. Each satellite continuously views nearly one third of the Earth's surface. The GOES-12 (East) satellite is positioned at 75 degrees W longitude at the equator and monitors North and South America and most of the Atlantic Ocean. GOES-11 (West) is positioned at 135 degrees W longitude at the equator and monitors North America and the Pacific Ocean basin. GOES-13 was launched in 2006, and is the on-orbit backup for NOAA's geostationary satellite constellation. These two satellites (and the on-orbit backup satellite) operate together to provide continuous monitoring necessary for effective and extensive weather forecasting, prediction, and environmental monitoring. The geosynchronous orbit is about 35,800 km (22,300 miles) above the Earth's equator.

ENVIRONMENTAL SATELLITE SERVICES

NATIONAL ICE CENTER

The U.S. National Ice Center (NIC), under the sponsorship of the U.S. Navy, NOAA, and the U.S. Coast Guard, is tasked with providing the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts tailored to meet the requirements of U.S. national interests. NIC uses data from polar-orbiting satellites to create guidance products and maps.

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery, short- and long-term ice forecasts, and legacy ice information and ice climatology. Specific sea ice features analyzed include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads.

Ice products are disseminated via the Internet in formats consistent with the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDDED (SIGRID-3) format (see www.natice.noaa.gov). The date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a metadata narrative.

Another NIC responsibility is oversight of the United States Interagency Arctic Buoy Program (USIABP). USIABP is a collaborative program that draws operating funds and services from the collective contributions of government agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and NESDIS, Office of Oceanic and Atmospheric Research (OAR), and the Office of Global Programs (OGP). USIABP was established in 1992, to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program.

CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR)

STAR's mission is to transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine operations and offer state-of-the-art data, products, and services to decision makers. STAR is an operations-driven research and development center, tuned to the needs of the Nation's users of satellite data products. STAR conducts diverse research on satellite remote sensing, including the study of atmospheric, oceanic, and land processes. STAR participates in the life cycle of all operational NOAA satellites-from defining the initial requirements for a satellite mission, through calibration and application of the data after the satellite is in orbit, to development of products from the data, to final archiving, and even reprocessing of data. STAR also works with data from non-NOAA satellites as well, for research, to transfer capabilities to NOAA, and to obtain even more observations of the Earth than what is available from NOAA satellites.

STAR is a leader in planning future satellite observing systems to enhance the Nation's ability to remotely monitor the environment. STAR also calibrates the Earth-observing instruments of all NOAA satellites to provide reliable measurements. STAR investigates how to develop satellite data sets that can be used in the following ways:

- Assess the current conditions on the Earth in a timely manner,
- Predict changes in the current conditions, and
- Study long-term trends in the environment.

STAR will create new products for monitoring atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risk of launching new, untested, and very expensive satellites and sensors; expand its support to users (for example, expanding the NOAA CoastWatch Program into a global OceanWatch); and train users of STAR products and applications.

JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

JCSDA is a geographically distributed center operated as a partnership between NOAA, NASA, the U.S. Navy, and the U.S. Air Force. This cooperative arrangement allows NOAA, NASA, and DOD to take advantage of their combined science and technology resources in order to accelerate and optimize the use of existing and new satellite data for numerical weather prediction (NWP). JCSDA provides a focal point for cooperative research and development of common modeling and data assimilation infrastructure among its partners. JCSDA will enable NOAA to improve NWP and climate prediction through the optimal use of data from existing satellites. In addition, JCSDA will prepare for a large volume of new data from advanced satellite instruments (such as those on NPOESS) that will be launched during the next five to six years. These efforts will also help guide the selection and specification of future satellite instruments to ensure that the most effective observing system possible is created. JCSDA is tasked with developing new and powerful techniques to assimilate data into NWP and ocean, climate, and air quality analyses and models. This center is also tasked with reducing the time elapsed from satellite launch to operational data use from two years to one year. The JCSDA activities directly support the missions of NASA, NOAA, and DOD as well as those of organizations who contribute to or rely on NOAA's environmental assessment, prediction, and stewardship missions. In addition, through its partnership and coordination with DOD and other agencies, JCSDA will enhance efforts to facilitate the transition from research into operations. Current projects focus on speeding available satellite data into operations and developing tools to support future assimilation projects. Six scientific priorities are being emphasized toward these ends.

- Development of a community-based radiative transfer model (CRTM). In the next few years, the accuracy and capability of the JCSDA CRTM will be significantly improved by including additional physical processes (e.g., atmospheric scattering), more efficient numerical techniques, and better surface emissivity models to allow more satellite data which is affected by surface to be properly assimilated.
- Development of data thinning and configuration technology and methodology: This allows faster and efficient delivery of advanced satellite data to major NWP centers globally.
- Advanced techniques to assimilate satellite data in cloudy and precipitation regions: Improving radiative transfer models and NWP cloud prediction schemes will significantly increase the fraction of satellite data being ingested into the assimilation systems and increase their impact.
- Improvement of the use of satellite land products in NWP models: For example, green vegetation fraction, snow cover, snow pack parameters, surface albedo, land, and sea surface temperature.
- Improvement of the use of satellite data in ocean data assimilation: This provides assimilated ocean data sets to the community for research purposes and providing access to and support of an operational ocean data assimilation system.
- Assimilate satellite derived aerosol, ozone, and trace gas product: This will improve forecasts of visibility and health index with state-of-the-art air quality forecast models, including chemical and biological process.

JCSDA has additional long-term strategic goals. One is to accelerate the transfer of data assimilation research into operations by fostering common data assimilation code components, including techniques for specifying observation errors, background error co-variances, and data selection and reduction. Another is to foster development of a workforce capable of meeting the data assimilation challenges of future. The JCSDA approach is bearing fruit. Recent accomplishments include:

- Improved radiative transfer techniques. CRTM was implemented operationally in the Global Data Assimilation System (GDAS); improved microwave surface emissivity models leads to more Advanced Microwave Sounding Unit-A (AMSU-A) data used over land, snow, and ice; and vetted CRTM components are made available to partners and stakeholders via internet.
- Improved uses of current satellite data. More AMSU-A data are used over land, snow, and sea ice due to an improved surface emissivity model; advanced data selection and assimilation techniques for infrared sounders increase use of the Atmospheric Infrared Sounder (AIRS) data; NOAA-18 AMSU data is used operationally in the National Centers for Environmental Prediction (NCEP) GDAS; OMI Ozone data from TERRA satellite result in improved global ozone analysis; and AIRS data used to predict NWP effectiveness of proposed designs for a future Geostationary Operational Environmental Satellite Series R (GOES-R) sounder.
- More new satellite data tested for use in NCEP operational GDAS and forecast models. Techniques to assimilate GPS Radio Occultation data is developed, has been tested, and will improve NWP: WindSat ocean surface wind data was tested in the Global Forecast System with positive impact; and JASON sea surface altimetry data was tested in the Global Ocean Data Assimilation System.

POLAR SATELLITE PROGRAM

The primary mission of the Polar-orbiting Operational Environmental Satellite (POES) system is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-17 and NOAA-18.

NOAA polar satellites carry instruments that provide atmospheric temperature and moisture profiles. They also provide multichannel images and carry a data collection and platform location system. In addition, the satellites are equipped with a Search and Rescue Satellite Aided Tracking (SARSAT) subsystem, which is used to detect and locate distress alerts from maritime, aviation, and land-based users of emergency beacons operating at 121.5, 243 or 406 MHz. In addition to taking thermal images of the Earth's surface and atmosphere, NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

The POES spacecraft carries four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); the Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultraviolet Spectral Radiometer, MOD 2 (SBUV/2).

• AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR/3 series of instruments measure six spectral channels (0.63, 0.86, 1.6, 3.75, 10.8, and 12 µm) with a nominal spatial resolution of 1.1 km and global resolution of roughly 4 km. The AVHRR/3 provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, fire detection, and snow and ice mapping.

• TOVS is comprised of the High-Resolution Infrared Radiation Sounder (HIRS) and the Advanced Microwave Sounding Unit (AMSU). The HIRS/4 is a discrete-stepping, line scan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from the Earth's surface to about 40 km. The Advanced Microwave Sounding Unit-B (AMSU-B), provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). The specialized 89 GHz channel is used to determine the position and structure of tropical cyclones on a global scale.

• SEM measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitudes. The two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

• The SBUV/2 instrument is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth.

GEOSTATIONARY SATELLITE PROGRAM

The GOES spacecraft host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 µm and 13.35 µm wavelengths. The geostationary satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own atmospheric, land, and ocean application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-Earth disk is normally scanned once every 3 hours and requires about 30 minutes to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7½-minute interval (severe storm operations) rapid scans over the contiguous U.S. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena. The 13.35 µm channel provides more accurate cloud height assignments for mid- and upper-level atmospheric satellite wind-velocity estimates. This trade-off notably impacts the sea surface temperature retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 degrees C. Also, the spatial resolution of the water vapor channel is improved to 4 km from 8 km.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center (NGDC) and provided to retrospective users online via Internet and on a variety of computer media.

Starting with GOES-12, a Solar X-Ray Imager (SXI) is being flown that provides near-real-time X-ray images of the sun for ionospheric changes that affect radio communications and mangetospheric variations that induce currents in electrical power grids and long distance pipelines. Also, these conditions can cause navigational errors in magnetic guidance systems, introduce changes in spacecraft charging, produce high energy particles that can cause single event upsets in satellite circuitry, and expose astronauts to increased radiation. SXI will observe solar flares, solar active regions, and coronal structures. Images from SXI will be used by NOAA and U.S. Air Force forecasters to monitor solar conditions that affect space weather conditions, including the dynamic environment of energetic particles, solar wind streams, and coronal mass ejections emanating from the sun.

GOES also carries a Data Collection System (DCS), which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gauges, seismometers, buoys, ships, and automatic weather stations. In support of NOAA missions, GOES DCS data are used in weather forecasts and warnings, reservoir control, and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the National Weather Service (NWS) NEXt Generation Weather RADar (NEXRAD) program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the Data Collection Platform data transmitted via GOES DCS.

SEARCH AND RESCUE SATELLITE AIDED TRACKING (SARSAT)

The GOES SARSAT System is capable of providing an immediate distress alert, unlike the POES spacecraft SARSAT transponders, which must come within line of site of a Local User Terminal in order to relay the distress beacon back to the U.S. SARSAT Mission Control Center (USMCC). Newer state-of-the-art COSPAS-SARSAT distress beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to USMCC. NOAA satellites helped save 272 people from potentially life-jeopardizing emergencies throughout the United States and its surrounding waters in 2006 - up from 222 the previous year. This is the highest number of rescues since 1999, when 294 people were rescued. Since its creation in 1982, COSPAS-SARSAT has been credited with more than 20,300 rescues worldwide, and 5,396 within the United States and its surrounding waters. Most of the rescues each year happen at sea.

COMPREHENSIVE LARGE ARRAY-DATA STEWARDSHIP SYSTEM (CLASS).

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important online access system, managed and operated by the Office of Systems Development (OSD), is the CLASS (see www.class.noaa.gov). CLASS provides satellite data access, display, and electronic transfer. Available data types include AVHRR, the Advanced TIROS Operational Vertical Sounder (ATOVS), DMSP (special sensor), and RADARSAT (authorized subscription users). While developed as an independent system, the Satellite Active Archive (SAA) serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). After the phase-out of the GOES-TAP system in 1998, many users now rely on GOES sectorized images, mapped to standard Advanced Weather Interactive Processing System (AWIPS) grids, available in near-real-time at www.goes.noaa.gov. Near-real-time images and interpretive analyses of tropical storms and hurricanes worldwide, ash from volcanic eruptions within the western hemisphere, heavy precipitation in the United States that cause flash flooding or blizzards, wild fires and smoke within the U.S., and northern hemisphere snow boundaries are located at www.ssd.noaa.gov. Specially enhanced and annotated imagery and image loops of environmental events, such as flooding, hurricanes, and other severe storms, volcanic eruptions, fires, and dust storms are available at www.osei.noaa.gov. This website was set up for use by the news media and general public, and to provide once or twice per day satellite views of an environmental event for Federal, state, and international governments and agencies. Also supporting the media, scientific organizations, and Federal and state agencies is a specially designed website featuring visualizations of satellite data, found at www.nnvl.noaa.gov.

CLASS is the NOAA implementation program for an improved architecture for archiving and servicing large-volume data. Advances in technology, including faster network access, web-based interfaces, and emerging discovery and analysis tools, will provide a one-stop capability to access the NOAA large array data sets. The CLASS objective is to establish a web-enabled browse, order, and retrieval delivery system that will enhance and increase the availability and accessibility of satellite, radar, and other data and derived products to customers worldwide. The CLASS integrated storage and web-based access and servicing system design incorporates many of the features and capabilities of the current Satellite Active Archive system built for the POES data stored on a robotic system located in Suitland, MD. The CLASS program has established dual sites, one in Asheville, NC, and another in Suitland, MD. There are plans to move the Suitland site to Boulder, CO. A third CLASS site is also slated for Fairmont, WV. NOAA POES and GOES data are currently available via the CLASS interface. CLASS data and product enhancements will be implemented in phases called campaigns. New major campaigns planned include NEXRAD, NPOESS, NPOESS Preparatory Project (NPP), Earth Observing System Long Term Archive, and the European Meteorological Operational Satellite Program.

ENVIRONMENTAL SATELLITE SERVICES - SUPPORTING RESEARCH PROGRAMS

WIND ESTIMATION

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP and other major International NWP Centers, require higher quality satellite-derived winds, particularly over the traditionally data void oceanic regions of the globe. The NESDIS GOES-East and GOES-West wind processing suites are totally automated and use a series of geostationary satellite images to derive wind estimates. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. The automated quality control of image registration is also an important component of the NESDIS GOES-East and GOES-West winds processing suite. Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to electromagnetic compatibility (EMC) and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned binary universal format for records (BUFR). Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low-level high-density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low-level flow in the outer storm vortex region, which is an important area in assessing storm motion. The GOES spacecraft have an atmospheric sounder that includes two water vapor channels centered at 7.0 μm and 7.3 μm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0 μm channel peaks around 450 mb and the weighting function of the 7.3 μm channel peaks around 550 mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999.

AVIATION

Aviation applications research focuses on detection and mitigation of hazards such as volcanic ash, in-flight icing, and fog and low ceilings. Remote sensing is the primary means of identifying and tracking volcanic ash clouds. An encounter with an airborne volcanic ash cloud can result in millions of dollars in damage to jet engines and the airframe, as well as the risk of engine stalls. Therefore avoiding these hazards is critical. In-flight icing causes significant aerodynamic drag and 5-10 percent of all fatal air crashes for smaller, general aviation and commuter class aircraft. Fog and low ceilings are a major reason for aviation delays, resulting in more than 2 billion in annual economic loss and account for about 25 percent of fatal aviation and maritime accidents.

ATMOSPHERIC MOISTURE AND STABILITY PRODUCTS

Research continues to improve the atmospheric moisture and stability products from the GOES-East and GOES-West sounder instruments. Precipitable water for three layers of the atmosphere (surface to 900 hPa, 900-700 hPa, and 700-300 hPa) are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the Earth's surface to the top of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation, locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this data provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to Eta Data Assimilation System (EDAS), which provides the initialization for the Eta forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes. As of July 8, 2003, the hourly cloud top information from the GOES sounder data is being assimilated into the operational NCEP EDAS.

The regional Eta model and the Rapid Update Cycle (RUC) model both assimilate GOES sounder cloud information to help improve the initial moisture and cloud field. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events. So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field, for example, to understand the time evolution of severe storms. For example, several of these derived images (lifted index, total precipitable water, and cloud-top information, etc.) are operational and then sent to the NWS AWIPS.

Because channel noise has improved with each successive sounder instrument, the GOES sounder moisture and stability products moved from a horizontal resolution of approximately 50 km to be approximately 10 km (see Figure 3-DOC-5). The increased horizontal resolution offers exciting possibilities for enhanced use of these products in mesoscale forecasting. For example, the finer resolution improves the depiction of gradients in the retrieved products, such as moisture and atmospheric stability, which focuses attention to a local area of interest. These products can be viewed at www.orbit.nesdis.noaa.gov/smcd/opdb/goes/soundings/index.html#products and http://cimss.ssec.wisc.edu/goes/realtime. In addition, these products are available from GOES computer servers within OSDPD or at www.ssd.noaa.gov/PS/PCPN/pcpn-na.html#SNDR.

TROPICAL CYCLONE FORMATION

The Tropical Cyclone Formation Probability Product indicates the probability of formation of a tropical cyclone. This product uses GOES imagery and global model analyses to provide an estimate of the probability that a tropical cyclone will form in the next 24 hours. The current operational product (www.ssd.noaa.gov/PS/TROP/genesis.html) covers the area of responsibility of the National Hurricane Center (NHC), but a general version is being developed that also covers the central and western North Pacific Ocean for use by the Central Pacific Hurricane Center (of NWS) and the Joint Typhoon Warning Center (JTWC) (of the Defense Department).

NESDIS has improved upon satellite-based techniques for estimating tropical cyclone positions and intensities and for describing the internal structure of these storms. Data from new sensors, such as AMSU and Tropical Rainfall Measuring Mission (TRMM), are incorporated into the NESDIS operational tropical program, which supports hurricane forecasting programs of the NWS and DOD. Real-time satellite images and text messages on tropical storms can be viewed at www.ssd.noaa.gov. NESDIS is also investigating how to use satellite observations to improve forecasts of formation of tropical cyclones, and even more important, changes in their intensity.

NESDIS works closely with the Hurricane Center to upgrade the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS), which relies upon GOES imagery, satellite measurements of sea surface height (via "altimetry") and global model forecasts. A companion model for typhoons (the Statistical Typhoon Intensity Prediction Scheme) is also being upgraded for use by JTWC in the Pacific.

PRECIPITATION ESTIMATES

Estimates of precipitation from satellites provide a valuable supplement to

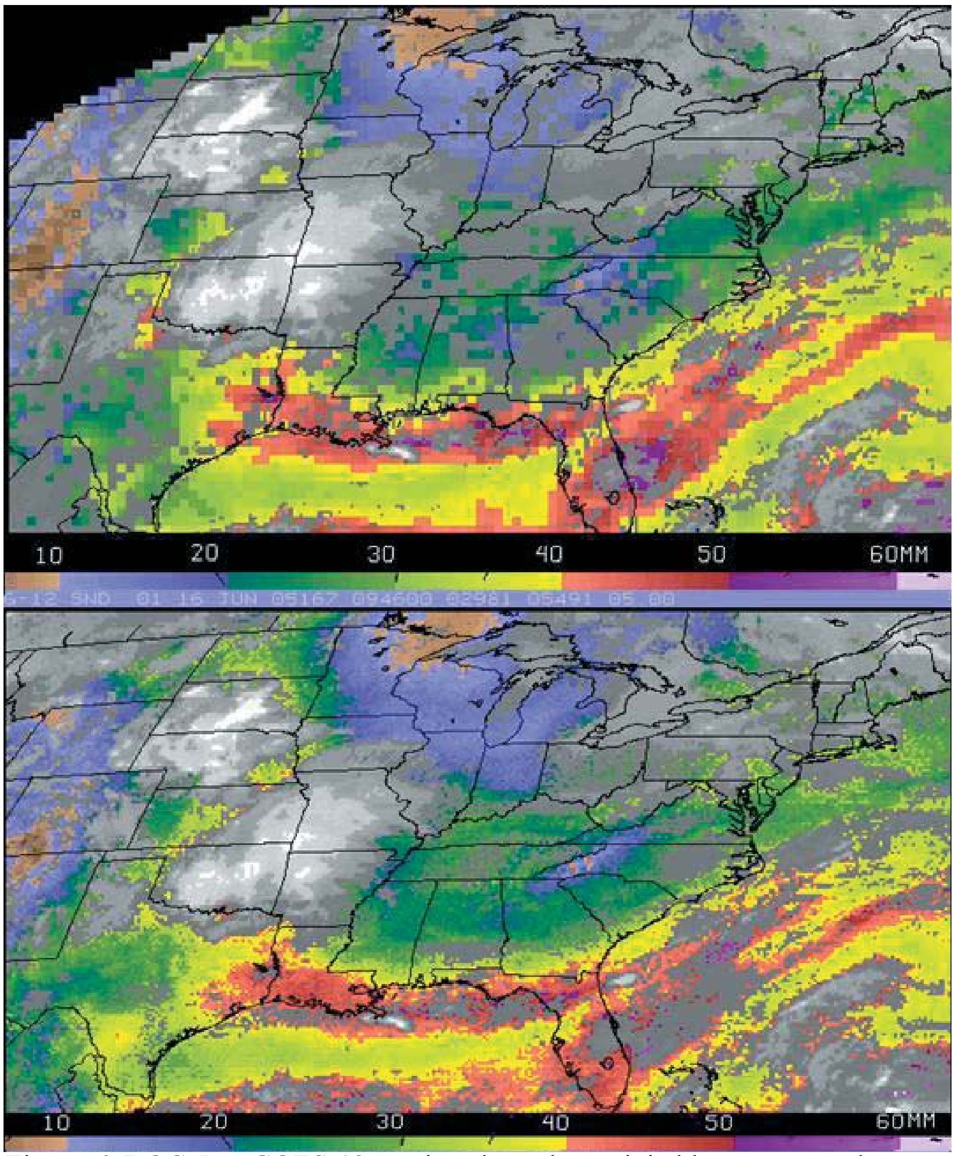

Figure 3-DOC-5. GOES-12 retrieved total precipitable water products at approximately 50 km resolution (top) and approximately 10 km resolution (bottom).

information from radar and rain gauges (see Figure 3-DOC-6). This information is particularly useful for such phenomena as tropical systems that are beyond the reach of the radar umbrella. For monitoring short-term rainfall events, the primary operational algorithm is the Hydro-Estimator (H-E), which estimates the instantaneous rain rate from GOES infrared images every 15 minutes over the continental United States and produces experimental estimates worldwide. H-E adjusts its computed rain rates for moisture availability, sub-cloud evaporation, uplift by mountains, and other factors using data from operational weather prediction models. Another algorithm approaching operational status is the GOES Multi-Spectral Rainfall Algorithm (GMSRA), which uses four of the five GOES Imager channels for more precise identification of raining areas. An experimental algorithm, called the Self-Calibrating Multivariate Precipitation Retrieval, attempts to combine the relative strengths of infrared-based and microwave-based precipitation algorithms to produce a more accurate result than could be achieved using GOES data alone. Real-time graphics of these and other algorithms plus real-time validation statistics are available at www.orbit.nesdis.noaa.gov/smcd/emb/ff. In addition, H-E is available to NWS field forecasters once per hour via AWIPS. In the future, both H-E and GMSRA will be available on AWIPS every 15 minutes and coverage will expand to Hawaii and Puerto Rico.

In addition to short-term rainfall monitoring, longer-term precipitation analyses are created using microwave data from an improved AMSU-B/Microwave Humidity Sounder (MHS) and the Advanced Microwave Scanning Radiometer (AMSR)-E. The AMSU-B/MHS products, which also include cloud properties and other related information, can be obtained at www.osdpd.noaa.gov/PSB/IMAGES/MSPPS_day2.html. These include estimates of equivalent snow water content, the discrimination of falling rain from falling snow, and snowfall rates (which are experimental).

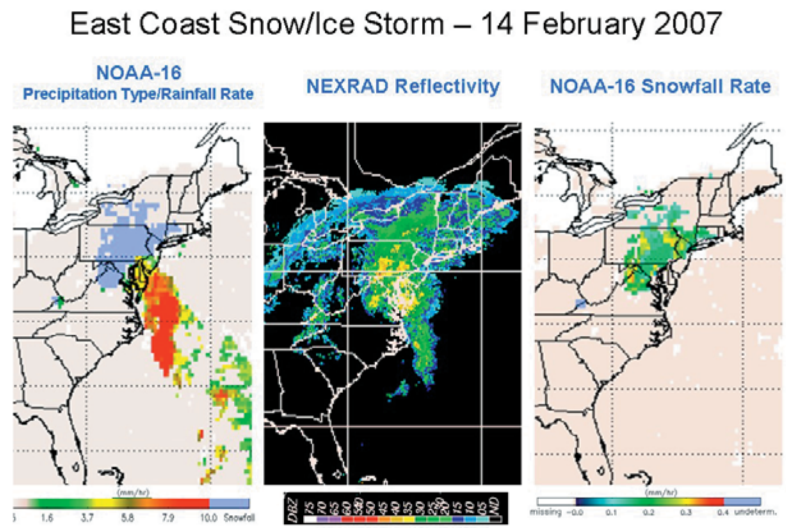

Figure 3-DOC-6. Left: Derived precipitation rates (in mm/hr) and falling snow, from the AMSU instrument on the NOAA-16 satellite; Center: radar reflectivity; and Right: experimental snowfall rate (in mm/hr) from AMSU, all for a high-impact East coast snow and ice event on February 14, 2007.

NESDIS cooperates with the U.S. Air Force and Navy to generate rainfall estimates from another satellite, DMSP, which carries the Special Sensor Microwave Imager (SSM/I) and Sounder (SSMIS) instruments. The rainfall products can be accessed at www.osdpd.noaa.gov/PSB/SHARED_PROCESSING/SHARED_PROCESSING.html.

These rainfall products are also used in direct forecasting applications. The Hydro-Nowcaster extrapolates H-E estimates forward in time up to 3 hours based on storm cell movement. The resulting nowcasts are available at www.orbit.nesdis.noaa.gov/smcd/emb/ff/hn.html. Meanwhile, forecasts for 24-hour rainfall from tropical systems that are about to make landfall are produced operationally for the entire globe by extrapolating microwave-based estimates of rainfall along the predicted storm track. These Tropical Rainfall Potential (TRaP) estimates are available at www.ssd.noaa.gov/PS/TROP/trap-img.html. The next efforts will produce an ensemble version of TRaP to enhance its accuracy and utility to forecasters (see Figure 3-DOC-7).

MICROBURST PRODUCTS

Convective storms can pose serious threats to life and property. Of great concern are those storms that produce downbursts, defined as strong convective downdrafts that result in an outburst of damaging winds on or near the Earth's surface. In addition, downbursts are a hazard to aircraft in flight, especially during takeoff and landing phases. In order to assist the operational forecaster in the prediction of this type of hazardous weather event, GOES sounder-derived microburst products have been developed and implemented. These sounder-derived products include the Wind Index (WINDEX) for estimating the magnitude of convective wind gusts, a Dry Microburst Index (DMI) for dry microburst potential, and Wet Microburst Severity Index (WMSI) for wet microburst potential.

The newest product of the suite, the Hybrid Microburst Index (HMI), indicates the potential for convective

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA-N	CY 2005
METOP-2	CY 2010
NPP	CY 2010
NOAA-N’	CY 2007
NPOESS-C1	CY 2013
METOP-1	CY 2006
NPOESS-C2	CY 2016
NPOESS-C3	CY 2018
METOP-3	CY 2015
NPOESS-C4	CY 2020

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES N	CY 2006
GOES O	CY 2008
GOES P	CY 2009
GOES Q	Cancelled
GOES R	CY 2012
GOES S	CY 2014
MTSAT-1R	CY 2005

*Launch date depends on performance of prior spacecraft and is subject to change.

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR - Advanced Very High Resolution Radiometer
SEM - Space Environment Monitor
SBUV - Solar Backscatter Ultraviolet Instrument (NOAA PM mission only)
HIRS - High Resolution Infrared Sounder
DCS ARGOS - Data Collection System
AMSU-A - Advanced Microwave Sounding Unit-A
AMSU-B - Advanced Microwave Sounding Unit-B
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
MHS - Microwave Humidity Sounder (NOAA-N/N' and METOP)

Instruments for NPOESS Series

VIIRS - Visible/Infrared Imager/Radiometer Suite
Microwave Imager/Sounder (to be determined by new competition for C2, C3, and C4)
CrIS - Cross-track Infrared Sounder
ATMS - Advanced Technology Microwave Sounder
ADCS - Advanced Data Collection System
SARSAT - Search and Rescue Satellite-Aided Tracking System
OMPS - Ozone Mapping and Profiler Suite - (Nadir & Limb for NPP, Nadir for C1 and C3, Limb demanifested from C1 and C3) **
CERES - Clouds and the Earth's Radiant Energy System (to be flown on C1 only)
ERBS - Earth Radiation Budget Satellite (follow-on to CERES, demanifested from C3)**
SEM - Space Environment Monitor
Alt - Altimeter (demanifested from C2 and C4)**
TSIS - Total Solar Irradiance Sensor (demanifested from C2 and C4)**

** Can be remanifested if funded by sponsor agencies.

Instruments for GOES-R+ Series

ABI - Advanced baseline Imager
HES - Hyperspectral Environmental Suite
SEI - Solar Instrument Suite
SEISS - Space Environment In-Situ Suite
GLM - Geostationary Lightning Mapper

EUMETSAT Unique Instruments for METOP Series Satellites

ASCAT - Advanced Scatterometer
GOME - Global Ozone Monitoring Experiment
GRAS - GPS Receiver for Atmospheric Sounding
IASI - Infrared Atmospheric Sounding Interferometer

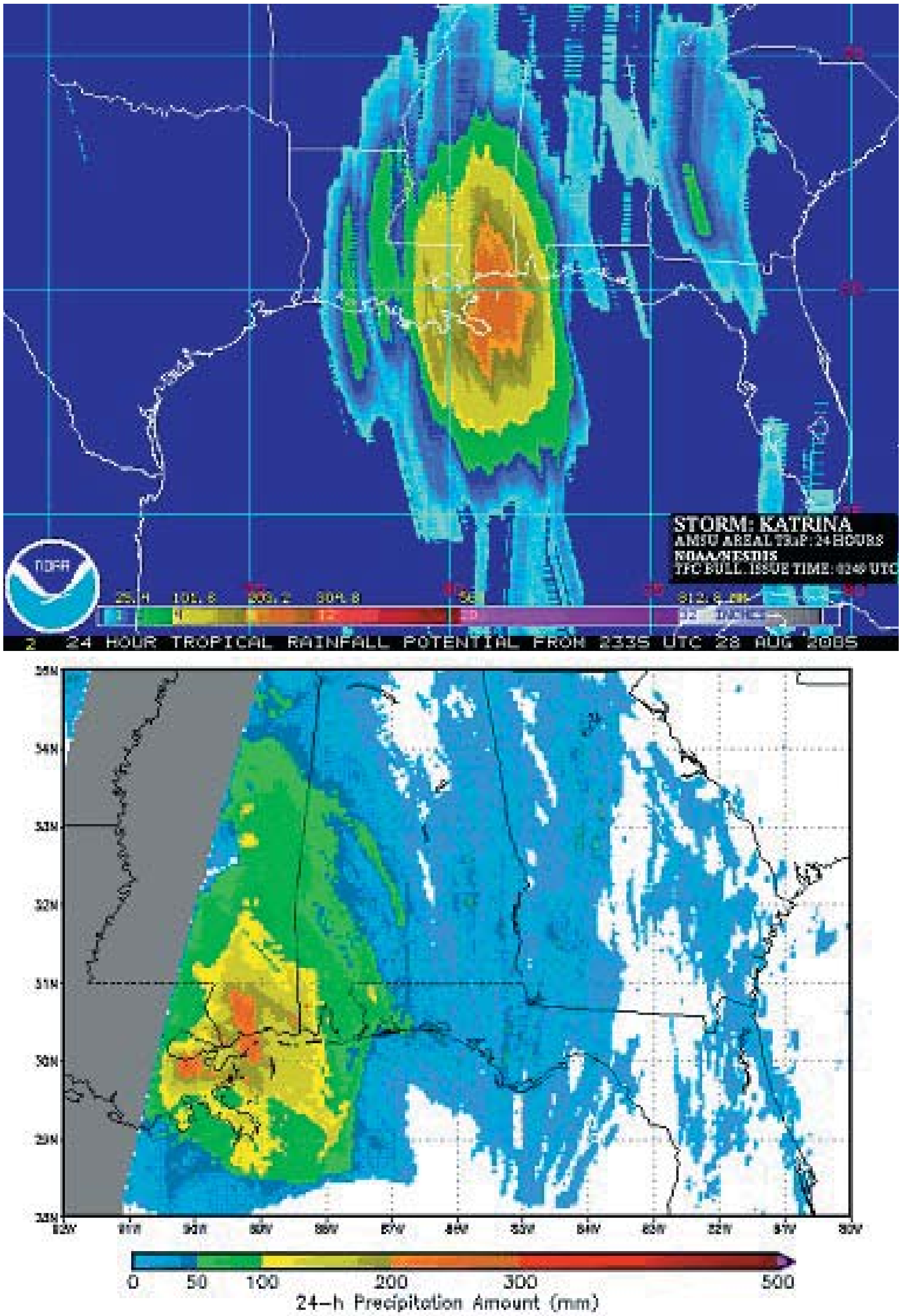

Figure 3-DOC-7. (Top) TRaP forecast map for Hurricane Katrina; expected rainfall amounts in 24 hours are shown as numbers in inches on the color bar, and as numbers in mm above the color bar; and (Bottom) corresponding ground truth from Stage IV radar+rain gauge measurements for 24 hours on August 29, 2005. (Data over the western portion image are missing due to storm-related communication failures.)

downbursts that develop in an intermediate environment between a wet type, associated with heavy precipitation, and a dry type associated with convection in which very little to no precipitation is observed at the surface (see Figure 3-DOC-8). For more information, visit www.orbit.nesdis.noaa.gov/star/Pryor_K.php.

AIRCRAFT ICING

Several upgrades to the GOES aircraft icing product have been implemented. New thresholds for the Band 2-4 (3.9-10.7 micrometer) brightness temperature difference versus visible brightness count corrected for solar zenith angle were employed in September 2003, followed by inclusion of cloud top heights from the GOES Sounder Cloud Top Product in February 2004. The latter combination, referred to as ICing Enhanced Cloud-top Altitude Product (ICECAP), was made available on the Web in February 2004. Finally, a correction to reduce the over-detection of icing caused by thin cirrus was employed in September 2004, based on a technique that uses Bands 4-6 (10.7-13.3 micrometers). Probability of detection (determined from the NOAA Forecast Systems Laboratory's Real-Time Verification System) is now consistently in the 55-70 percent range for the Continental U.S.

FOG AND LOW CLOUDS

GOES-12 visible and infrared (IR) data for a case of sea fog over the northeast United States in June 2003, was analyzed to determine if the fog could be discriminated objectively from other cloud types. The results were provided to the NWS Meteorological Development Laboratory, which is developing objective sea fog forecasting techniques using surface, model, and satellite data.

Figures 3-DOC-9a and 3-DOC-9b feature selected legacy products. The first image is ICECAP that indicates the vertical extent of possible icing conditions. The GOES Sounder is used to estimate the maximum height of the clouds (in color) where icing is possible. The last image is a fog product that displays regions of fog or low cloud (in yellow), and distinguishes fog from cirrus clouds (in blue).

GEOSTATIONARY SEA SURFACE TEMPERATURES

GOES-12 and GOES-11 are capable of measuring sea surface temperatures

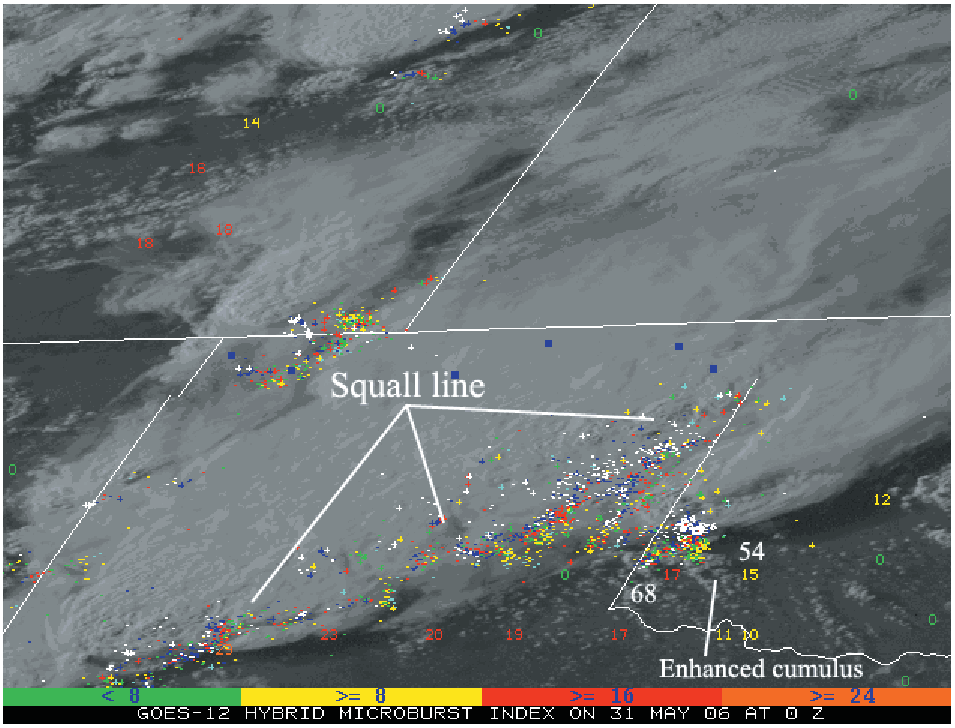

Figure 3-DOC-8. An Example of the GOES HMI Product

(SSTs) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar-orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. Unfortunately, the trade-off of replacing the 12.0 µm channel with a 13.3 µm channel notably impacts the SST retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 degrees C. For the SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Additionally, a change in scene temperature over a short period of time may indicate the presence of clouds, thereby enhancing cloud detection.

The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations, and good geographical coverage of SST estimates. GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly in an experimental configuration since December 1998, from both GOES-East and GOES-West. A global SST product is produced every three hours; regional SST products are generated every hour. These products were recently implemented operationally and can be accessed as digital files from the GOES computer servers within OSDPD.

VOLCANIC ASH

A new technique has been developed to mitigate the loss of the 12 µm IR band on GOES-12 to help track hazardous volcanic ash clouds (see Figure 3-DOC-10). The technique uses IR channels centered at 10.7, 13.3, and 3.9 µm. Several recent eruptions of Soufriere Hill's volcano on Montserrat Island in the eastern Caribbean have shown that this new product is helpful in monitoring ash cloud emissions even at night. GOES-12 ash product can be viewed for several volcanically active regions at www.ssd.noaa.gov/VAAC. The analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) data from the NASA Terra and Aqua spacecraft has also yielded valuable information about optimum detection of volcanic ash using several spectral bands. A

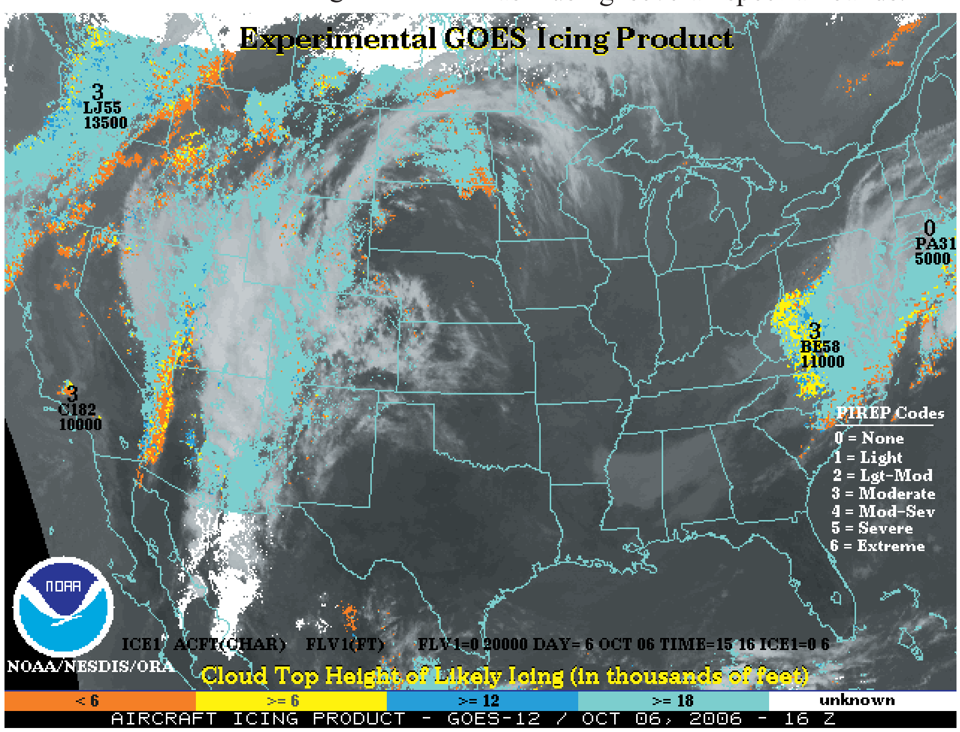

Figure 3-DOC-9a. Products depicting hazards to aviation. ICECAP indicates possible icing conditions and the vertical layer where icing would occur.

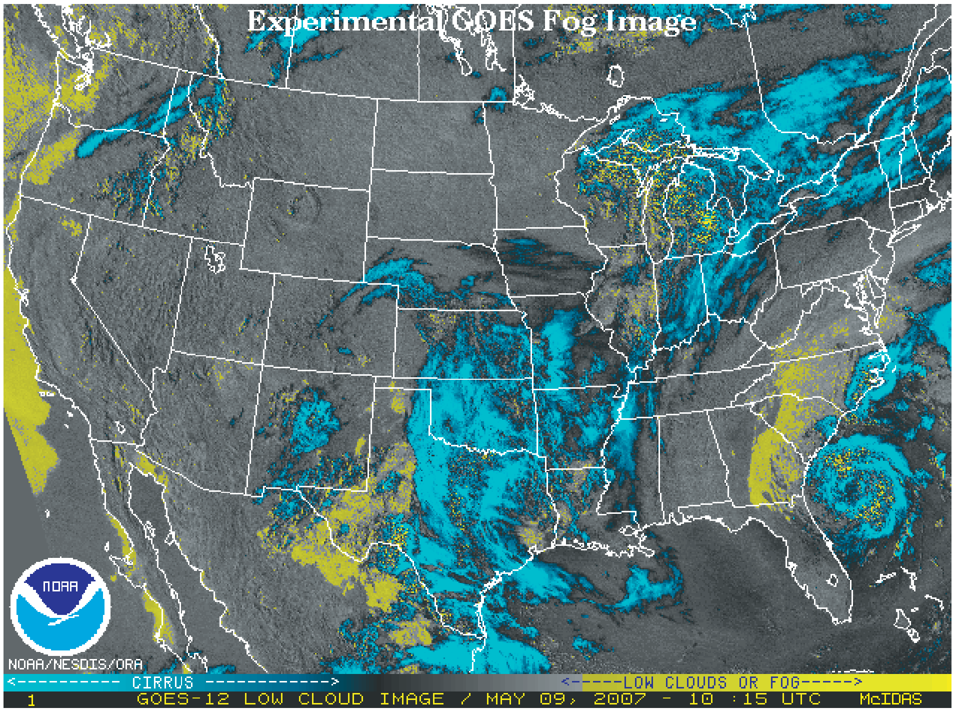

Figure 3-DOC-9b. A Fog product indicates where fog or low cloud (yellow) is present and distinguishes fog (yellow) from cirrus clouds (blue).

three-channel combination product based on the 8.6, 11, and 12 µm bands has been developed that provides effective discrimination of ash or sulfur dioxide gas with minimal false alarms. This algorithm could be applied to future products from NPOESS and GOES-R, which will have similar spectral bands. Volcanic Ash Advisories (VAA) with associated Volcanic Ash Graphics (VAG) and ash forecasts are provided by NESDIS to the aviation community. The region of coverage is the continental United States, Central America, northern South America to 10 degrees S, the Caribbean region, the Pacific Ocean south of Alaska and the Aleutians Islands, and, to the east of Japan, the Marianas Islands. The Volcanic Ash Advisory Center (VAAC) is located in Camp Spring, Maryland. GOES infrared and visible images, aerosol and sulfur dioxide products from NASA's Total Ozone Mapping Spectrometer (when applicable), and operational volcanic ash products for the Washington VAAC area of responsibility can be found at www.ssd.noaa.gov/VAAC/washington.html.

In addition to current operational products for volcanic ash, research into new and improved ways to detect volcanic ash continues. Relevant bands from experimental multi-spectral and hyper-spectral satellite instruments, especially those spectral bands scheduled to be on future operational satellites, are being probed in the development of new products for the detection of volcanic ash. That is in addition to the improved spatial, temporal, and radiometric resolution offered by next-generation satellites.

FIRE MONITORING

Geostationary and polar-orbiting meteorological satellites have been used to detect large active wildfires for over 20 years. NOAA, NASA, and the STAR Cooperative Institutes have developed the algorithms to utilize NOAA operational satellites, research satellites, and Defense Department satellites (DMSP) to monitor fires in real time. In the mid-latitudes, polar-orbiting instruments (MODIS and AVHRR) observe a given region several times each day, and more frequently near the poles. In its routine mode, the GOES Imager allows fire monitoring every 15 minutes over the United States and every 30 minutes over the rest of North, Central, and South America.

Automated algorithms include the MODIS Fire and Thermal Anomalies algorithm and the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA).

Current research includes the development of a near-real-time, operational global network for fire monitoring, to monitor fires as they occur and capture

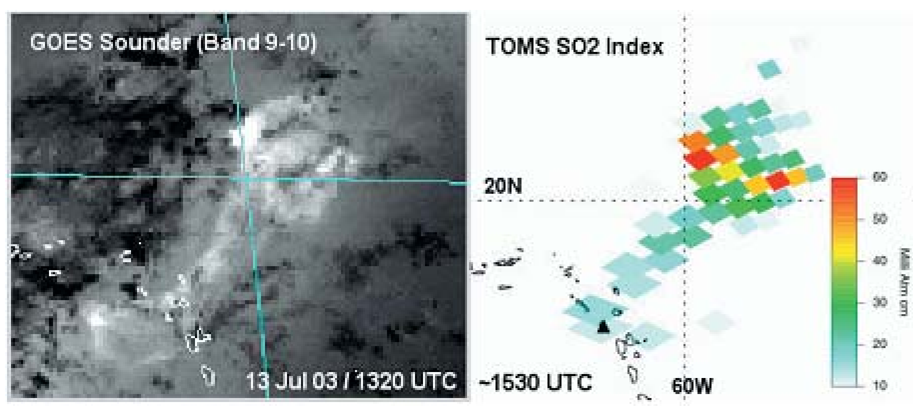

Figure 3-DOC-10. Comparison of GOES Sounder Band 9 minus Band 10 (left) versus the SO2 Index from the Total Ozone Mapping Spectrometer (TOMS) instrument (right) on July 13, 2003, are shown for the indicated times. The SO2 cloud was emitted from an eruption of Soufriere Hills Volcano, Montserrat (located shown in bottom of right hand image) that began around 0600 UTC, July 13, 2003.

the day-to-night signal around the globe. The GOES WF_ABBA product is being adapted to the European METEOSAT-8 and MTSAT-1R satellites. Plans are underway to adapt the WF_ABBA product to satellites of three other countries: China (FY-2C SVISSR satellite), India (INSAT-3D), and Russia (GOMS Electro N2). This suite of sensors in geostationary orbit will enable nearly global fire monitoring with significant overlaps in Asia. STAR has plans to derive similar but enhanced fire products with next generation polar-orbiting (NPOESS and MetOp) and geostationary (GOES-R) satellites.

Since 2002, the NOAA NESDIS Satellite Service Division has provided fire products online via the Hazard Mapping System (HMS) (www.firedetect.noaa.gov). The HMS is an operational interactive processing system that integrates fire products from seven different sensors on NOAA (POES AVHRR, GOES Imager, DMSP Operational Line Scanner [OLS]) and NASA (Earth Observing System [EOS] MODIS) satellites to produce fire and smoke product analyses for the United States and parts of Canada and Mexico. Automated algorithms including the MODIS Fire and Thermal Anomalies team algorithm, the GOES WF_ABBA, the AVHRR Fire Identification Mapping and Monitoring Algorithm (FIMMA), and the DMSP OLS algorithm are used to generate the fire products while smoke is delineated by an image analyst. Analyses are quality controlled by an analyst who inspects all available imagery and automated fire detects, deleting suspected false detects and adding fires that the automated routines miss. Graphical, text, and the Geographic Information Systems (GIS) compatible analyses are posted to the HMS website. All products are archived at NOAA's NGDC, which can be found at http://map.ngdc.noaa.gov /website/firedetects.

Over the past 10 years, the use of these satellite derived fire products has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change, emissions monitoring, aerosol and trace gas transport modeling, air quality, and land-use and land-cover change detection. The user community includes government agencies (such as NOAA, NASA, Environmental Protection Agency [EPA], and United States Forest Service [USFS]), resource and emergency managers, fire managers, international policy and decision makers, educational institutions, and the general public. At NOAA's National Severe Storms Laboratory (NSSL) Storm Prediction Center (SPC) GOES WF_ABBA fire products provided by University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) are used in fire weather forecasting. The SPC Fire Weather Analysis Page integrates the GOES WF_ABBA fire product with other meteorological data and fire weather and danger indices to provide an overview of existing fires and fire danger in the continental United States (see www.spc.noaa.gov/exper/firecomp). Since 2000, the Naval Research Laboratory (NRL) in Monterey has been assimilating the GOES WF_ABBA and MODIS fire products (as of 2003) into the NRL Aerosol Analysis and Prediction System (NAAPS) in near-real-time to both monitor and predict aerosol loading and subsequent transport around the world (see www.nrlmry.navy.mil /flambe/index.html). In Brazil, the National Institute of Space Research (INPE)/Center for Weather Forecasts and Climate Studies (CPTEC) has been assimilating the data into their air quality/transport models in real-time for several years (see http://tucupi.cptec.inpe.br/meio_ambiente).

Current research includes the development and implementation of a near-real-time operational global geostationary fire monitoring network to monitor fires as they occur and capture the diurnal signature around the globe. Initially the GOES WF_ABBA is being adapted to METEOSAT-8 and MTSAT-1R. Plans are underway to eventually adapt the WF_ABBA to FY-2C SVISSR (China), INSAT-3D (India), and the GOMS Electro N2 (Russia). This suite of geostationary sensors will enable nearly global geostationary fire monitoring with significant regions of overlap in Asia. Future activities include better utilization of current systems and long-term plans that ensure the capability to derive similar or improved and enhanced fire products with next generation operational polar-orbiting (NPOESS, MetOp) and geostationary (GOES-R, METEOSAT Third Generation [MTG]) series.

AEROSOL OPTICAL DEPTH

Satellite-measured aerosol optical depth has been shown to be a good proxy for the presence of pollution, especially where long-range transport is involved. STAR has provided the optical depth product in nearly real time since 2003. It is available at 30-minute intervals at a spatial resolution of 4 km by 4 km during the sunlit portion of the day. EPA and NWS have been using the product for monitoring and forecasting applications.

SMOKE CONCENTRATION PRODUCT

STAR developed an Automatic Smoke Detection Algorithm that uses the GOES fire product and the Aerosol Optical Depth product in a pattern recognition algorithm that identifies smoke from biomass burning. This algorithm tracks smoke plumes in the vicinity of fires and their transport. This hourly product is currently operational and is used by the NWS to verify its HYSPLIT smoke forecasts over the United States.

EMISSIONS

Emissions from both natural and anthropogenic sources of burning contribute to poor air quality. Biomass burning (prescribed fires and wildfires) releases huge amounts of smoke (mainly primary particulates dominated by black carbon) and trace gases into the atmosphere. Power plants, oil refineries, and other industrial sources release nitrogen dioxide (NO2), formaldehyde (H2CO), sulfur dioxide (SO2), and other organic compounds, which degrade air quality as well. EPA compiles a National Emissions Inventory every year for a number of critical environmental management activities, such as tracking the Clean Air Act and Clean Air Interstate Rule. Emissions data are used to determine trends over time as well as to initialize air quality forecast models. One of the primary sources of uncertainty in air quality forecasts comes from the uncertainties in these emissions. STAR developed algorithms to derive emissions of aerosols (PM2.5) and trace gases from biomass burning. These products (example in Figure 3-DOC-11) will be provided to NWS in nearly real time for assimilation into models that forecast air quality.

THREE-DIMENSIONAL MAPPING OF AIR QUALITY

Satellite data have been useful in diagnosing long-range transport of pollutants because the transport occurs well above the ground where it is more easily detected by satellites. NOAA is interested in the arrival of pollutants transported over long distances into local surface air where it impacts local air quality. NASA launched the CALIPSO satellite in 2006, with a Lidar that can measure vertical profiles of aerosol backscatter ratio. When combined with measurements of the optical depth of aerosols in the whole column, these measurements provide a valuable three-dimensional look at pollution plumes. Additionally, combining data from multiple sensors will optimize the information on type of aerosol and location in space and time. Scientists of STAR's Satellite Meteorology and Climatology Division are co-investigators with NASA on the 3D Air Quality System, which will combine information from various sensors into 3-dimensional measures of air quality. The intention is to study the linkages between air quality and human health.

MODEL FORECASTS

The NWS now issues ozone forecasts and experimental aerosol (PM2.5) forecasts for the northeast. They will soon migrate to the Weather Research and Forecasting (WRF) model with integrated chemistry and meteorology. Satellite data have the potential to improve forecasts by providing initial and boundary conditions and constraining the emissions, where the largest uncertainties lie. In situ data collected during field campaigns will be very useful in verifying the forecasts. Assimilation of chemical data is in its infancy; only ozone data have been successfully assimilated and demonstrated to have an effect on forecasts of surface ozone. STAR is developing a methodology for assimilating aerosol data to improve forecasts of particulate pollution (PM2.5).

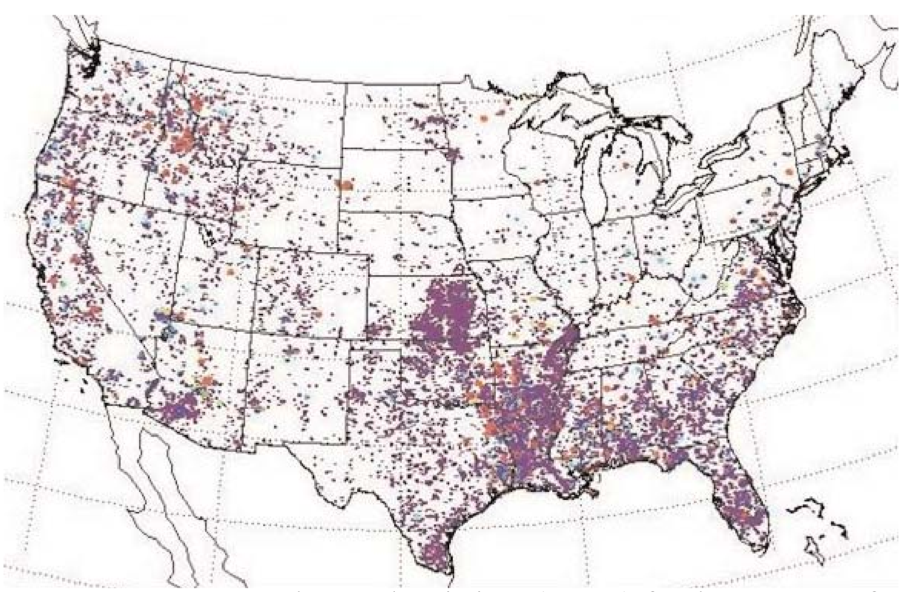

Figure 3-DOC-11. Annual aerosol emissions (PM2.5) for the year 2005 from biomass burning, observed by the GOES-12 Imager.

OBSERVATION OF AIR QUALITY WITH GEOSTATIONARY DATA

Measuring trace gases and aerosols from a geostationary satellite permit much higher sampling in time (see Table 3-2 and Table 3-3). For example, the Federal Aviation Administration (FAA) would like to have a total ozone product every hour from GOES-R to monitor clear air turbulence. Similarly, an ability to monitor concentration, type, and vertical location of dust would provide unprecedented information for air quality and climate applications. The ability to distinguish between different types of aerosols is extremely important for monitoring and forecasting air quality. It is hoped that GOES-R will provide profiles of at least four trace gases (O3, CO, CH4, and CO2).

While the current ozone data come from polar-orbiting satellites, the capability of geostationary satellites to provide measurements of ozone on the same time and space scales that existing air quality models and observation networks are using, will be a tremendous advantage. Hourly ozone measurements from geostationary satellites will have many benefits, including:

• providing more cloud-free observations, essential for a number of reasons; and

• monitoring diurnal changes of air quality.

ATMOSPHERIC WINDS FROM CLOUD MOTIONS

Atmospheric motion vectors (AMV) or wind vectors derived from a sequence of satellite images are an important source of global wind information, particularly over the world's oceans and more remote continental areas where conventional weather observations are lacking in time and space. These data are routinely used by the major NWP centers in the world and assimilated into regional and global prediction models. These data are also made available to NWS forecasters responsible for providing the public with day-to-day weather forecasts. In addition, these products are distributed to other countries.

Wind vectors are typically derived from the GOES imagery, providing coverage from approximately 60 degrees S to 60 degrees N latitude. The currently operational GOES wind products include IR cloud-drift winds, water vapor (WV) motion winds, and visible (VIS) cloud-drift winds.

Recent advances in models for NWP, at NCEP and other international centers, require higher quality satellite-derived winds, particularly over the data void oceans. A series of geostationary satellite images from GOES-East and GOES-West are used to calculate estimates of the wind, in a totally automated wind processing suite. The automated winds algorithm uses an objective pattern matching technique to estimate wind velocity and it assigns heights to these wind estimates by using brightness and temperature data from the water vapor and infrared channels of the satellite.

The winds processing suite now delivers approximately 20,000 wind vectors from both satellites at least twice a day to NCEP and to the Global Telecommunications System. NCEP uses these NESDIS wind products in their global and regional weather forecast systems.

The newest satellite wind products include low-level, high-density satellite winds from visible images. During the daylight hours, visible channel data can be used to see cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent images (15 to 30 minutes). The visible channel can show low-level cumulus clouds in most areas having partly cloudy skies. In tropical cyclones, visible winds can depict the low-level airflow in the outer storm region, which is an important area in assessing storm motion. Implementation of new algorithms and the visible wind products in the operational environment at NESDIS began in 1999.

The capability to derive winds from measurements made by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard the polar-orbiting Terra and Aqua satellites was first developed at CIMSS and is based upon established methodologies and algorithms used to derive wind observations from the GOES series of satellites. MODIS cloud-drift and water vapor wind observations from Terra and Aqua provide unprecedented coverage in the polar regions of the globe, areas where wind observations are sorely lacking.

The MODIS wind products have a significant positive beneficial impact on forecast accuracy in the Arctic and Antarctic, as well as in the extra-tropical latitudes of both the Northern and Southern Hemispheres. Given the positive results, the MODIS winds capability was transferred to the OSDPD/Satellite Services Division (SSD), which now routinely provides MODIS wind vectors to the user community. Ten NWP centers around the world now use the MODIS winds operationally.

In the United States, GOES has been used in operational forecasting for quite some time. Forecasters recognize the additional detail that can be captured from more frequent imaging in weather associated with rapidly changing cloud structures. The value of more frequent imaging is demonstrated by the inclusion of a 15-minute update cycle over the Continental United States sector in the current GOES schedule and by the multitude of special NWS operational requests for more frequent sampling at 7.5-minute intervals (Rapid-Scan Operations). On occasion, special periods of Super-Rapid-Scan Operations have been requested by the research community. That mode allows one-minute sampling in a limited-area over meteorological events of interest.

Recently, special GOES rapid-scan periods have been collected during several field programs and research initiatives designed to maximize observations in regions of high-impact weather events. Some examples include the NASA Tropical Cloud Systems Program, the Atlantic Thorpex Regional Campaign, and the TROpical Predictability EXperiment (TROPEX). In the first two campaigns, the data sets were used in real time in mission planning and in directing aircraft to targets of opportunity. In TROPEX, the data sets will be used to target "observing strategy experiments" run by modelers at the Naval Research Laboratory. In all three cases, the enhanced data sets are expected to be employed in case study analyses and numerical model impact studies.

INTEGRATED CAL/VAL ENTERPRISE SYSTEM

The users of numerical weather predictions require accurate calibration of satellite measurements. For satellite measurements having anomalies in radiances and/or large systematic biases, the data will be rejected during the data assimilation stage. It is also very difficult to use the satellite observations that are not quantified for their measurement precision. For climate studies, satellite instruments must be capable of measuring Earth system variables at high accuracy and stability over decadal (and ultimately, centennial) time scales. During a calibration workshop organized by the National Institute of Standards and Technology (NIST), NOAA, NPOESS-IPO, and NASA in November 2002, accuracy and long-term stability objectives for satellite measurement were established. The final report of the workshop defines the required absolute accuracies and long-term stabilities of global climate data sets, and it translates the data set accuracies and stabilities into the required satellite instrument accuracies and stabilities (e.g., for troposphere atmospheric temperatures, the measurement accuracy is 0.5 degrees K and stability is 0.04 degrees K/decade; for surface albedo measurement, the accuracy is 0.01 and stability is 0.002 degrees K/decade). Those requirements pose tremendous challenges to the post launch calibration of satellite sensors.

NESDIS/STAR has an excellent track-record in supporting the operational calibration of radiometers on polar-orbiting environmental satellites, transferring research results to operations and performing advanced research in satellite instrument calibration. In addition to our heritage in onboard and vicarious calibration, in recent years we have developed many additional components such as intersatellite calibration, on-orbit and prelaunch instrument characterization, and the incorporation of radiative transfer model calculations.

STAR also plays an important role in re-calibrating historical data to support climate studies, through the scientific data stewardship program. In recent years, STAR has developed comprehensive calibration/validation capabilities which are being incorporated into the Integrated Instrument Calibration/Validation System (ICVS). The vital components of the ICVS include pre-launch and on-orbit quantification of satellite instrument noise and online performance monitoring; linear and nonlinear thermal calibration; onboard ultraviolet (UV), vicarious visible and near-infrared calibration; independent verification of radiances through inter- and intra-satellite calibration; and radiative transfer calculations to isolate biases and anomalous contributors to the biases. Today, we can quantify the on-orbit instrument noise and biases with little ambiguity, significantly reducing the uncertainties for the data users in direct radiance assimilation in numerical weather prediction, physical retrievals, and climate monitoring and reanalysis.

With the ICVS framework, STAR is now in an excellent position for leading and coordinating the WMO Global Space-Based Inter-Satellite Calibration System (GSICS). GSICS integrates observations and products from different satellite systems through intercalibration. The intercalibration can quantitatively relate the radiances from different sensors viewing the same target and allow consistent measurements to be taken over the globe by all elements of the space-based observing system. Without intercalibration of the space-based component of the World Weather Watch (WWW) Global Observing System and of the Global Earth Observation System of Systems (GEOSS), the full benefit of the observations will not be realized for the environmental data stewardship.

During the 2005 hurricane season, ICVS was first applied for NOAA-18 on-orbit verification and led to an early delivery (45 days after the NOAA-18 launch) of high quality satellite observations for uses in NOAA computerized models that significantly improve the accuracy and extend the range of weather prediction for severe storms such as hurricane track, wind damage, and surface flooding. With ICVS, STAR scientists are able to provide an accurate analysis of the root cause of the NOAA-18 HIRS/4 anomaly and provide mitigation strategies for containing the noise and reducing the risk for future launches.

ICVS is also providing a root-cause analysis and diagnostics for DMSP Special Sensor Microwave Imager Sounder (SSMIS) radiance anomalies. SSMIS is the first conically-scanning microwave instrument that measures the Earth's radiation from 19 to 183 GHz and presumably provides improved atmospheric temperature and water vapor sounding under all weather conditions. It is a key sensor for NPOESS risk reduction studies. Unfortunately, the main reflector from the SSMIS antenna subsystem emits some radiation and contaminates the Earth scene signals. In addition, the warm calibration target is intruded by direct solar radiation and other stray lights, producing anomalous calibration counts in several latitudinal zones. These contamination sources cause anomalies in SSMIS radiances in Temperature Data Records (TDR) and Sensor Data Records (SDR), which change with latitude and season. As part of ICVS, SSMIS anomaly distributions (locations and magnitudes) are detected and corrected during the calibration process. Therefore, SSMIS data after the NOAA recalibration and processing is of improved quality for operational applications in weather and climate models.

NPP/NPOESS SENSOR CALIBRATION, PRODUCT DEVELOPMENTS, ENHANCEMENT, AND VALIDATION

STAR scientists continue to play an important role in the evaluation of NPOESS contractor sensor design and retrieval methods. This group provides the end-to-end support to the NPOESS program from instrument calibration to product validation and applications.

TABLE 3.2 TRACE GAS AND AEROSOL PRODUCTS FROM OPERATIONAL POLAR-ORBITING SATELLITES

Pollutant	Location	Satellite (Sensor)	User/Application
NO_2	Troposphere	IJPS (GOME-2)	NWS – Assimilation NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA – Model evaluation
SO_2	Troposphere Stratosphere (volcanic)	IJPS (GOME-2) NPP/NPOESS (OMPS) IJPS (IASI) NPP/NPOESS (CrIS)	NWS – Forecast model evaluation EPA – Model evaluation NOAA – Model evaluation
H_2CO	Troposphere	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA – Model evaluation
CHOCHO	Troposphere	IJPS (GOME-2)	EPA – Assessment work (emissions)
O_3	Column	IJPS (GOME-2) IJPS (IASI) NPP/NPOESS (OMPS) NPP/NPOESS (CrIS)	NWS – Assimilation

TABLE 3.2 (CONTINUED) TRACE GAS AND AEROSOL PRODUCTS FROM OPERATIONAL POLAR-ORBITING SATELLITES

Pollutant	**Location**	**Satellite (Sensor)**	**User/Application**
O_3	Profile (stratosphere)	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Assimilation
CO	Troposphere	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions) NWS – Forecast model evaluation
CH_4	Column	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions)
CO_2	Column	IJPS (IASI) NPP/NPOESS (CrIS)	NOAA – Climate monitoring
BrO	Stratosphere	IJPS (GOME-2)	NOAA – Climate monitoring NASA – Climate monitoring
OclO	Stratosphere	IJPS (GOME-2)	NOAA – Climate monitoring NASA – Climate monitoring
Aerosols	Troposphere	IJPS (GOME-2) IJPS (IASI) NPOESS (OMPS) NPOESS (CrIS) NPOESS (VIIRS)	NWS – Assimilation NWS – Forecast model evaluation EPA – PM2.5 monitoring

Sensor	Bands	Product	Applications
ABI	0.47 µm, 0.86 µm, 2.1 µm	Aerosol optical depth, type (dust vs. non dust), particle size (effective radius), and fraction of fine mode vs. coarse mode	EPA – PM2.5 monitoring NWS – PM2.5 forecasting NIEHS – Health impacts CDC – Health impacts
ABI	9.6 µm	Total column ozone	FAA – Clear-air turbulence NWS – Ozone forecasting
ABI	3.9 µm, 11 µm	Fire location, size, intensity and carbon consumption Aerosol and trace gas emissions	EPA – Assessments NWS – Forecasting
ABI	11 µm, 12 µm	Dust detection	EPA – Monitoring
HES	800 – 1000 cm^{-1}	Dust loading and height Volcanic ash detection, amount and height Smoke plume height	VAAC – Advisories EPA – Monitoring NWS – Forecasting
HES	1650 – 2250 cm^{-1}	Carbon monoxide Methane	EPA – Assessments NWS – Forecasting NOAA – Climate
HES	950 – 1050 cm^{-1}	Ozone profile	NWS – Forecasting
HES	600 – 800 cm^{-1}	Ash cloud height Smoke plume height	VAAC – Advisories NWS – Forecasting
HES	1100 – 1200 cm^{-1}	Sulfur dioxide	VAAC – Advisories

STAR scientists have also been participating in NPOESS operational algorithm teams (OAT) and all phases of the NPOESS sensor calibration process to assure that radiometric performance of NPP/NPOESS instruments will meet the scientific needs of NOAA and other agencies.

STAR scientists have also been providing significant technical support to the prelaunch calibration of major NPOESS instruments in the last few years. As early as 2001, STAR scientists contributed to the technical design of the several major NPOESS instruments and supported the investigation of prelaunch calibration issues using comparisons with current POES instruments and evaluating how they affect the calibration traceability between POES and NPOESS. Currently, STAR is providing technical examination of the calibration accuracy, NE T, and nonlinearity for several instruments such as the Advanced Technology Microwave Sounder (ATMS).

In the NPOESS post-launch calibration, STAR will focus on the characterization of on-orbit instrument noise and biases of all NPOESS instruments using the STAR integrated cal/val enterprise system and develop an online instrument performance trending system that monitors a selected number of key parameters.

It is critical to the NPOESS program and to the scientific community at large that the contractor scientific algorithms are assessed independently during the pre-launch phase so that potential corrective measures are taken early, avoiding sub-optimal results later in the process and/or delays in delivering the real-time data to weather centers and other customers after launch has occurred. STAR scientists have proposed a vigorous assessment of radiometric and geophysical performances of NPP/NPOESS instruments, in both pre-launch and post-launch stages. Further assessments will be made to check the robustness and the timing requirements for an operational use.

The contractor algorithms are being extensively compared in simulation and with real data, with operational products developed by STAR from EOS, POES, and DMSP platforms. STAR is a center with various proxy data sets and testbeds through simulations and real measurements for NPOESS instruments. NPOESS contractor algorithms are now being run at the STAR systems and assessed with the proxy data. Since the STAR team has dual experience with both the contractor algorithms and in the operational algorithms running at NOAA, there have been rapid advances in the assessment of the contractor's algorithms performances.

LAND SURFACE PARAMETERS FOR USE IN WEATHER FORECAST MODELS

Satellite-derived fields of land surface characteristics are being produced operationally for use in NWP models. These include radiation products delivered in near-real-time as forcing variables; surface characteristics, such as fractional green vegetation and albedo, that specify model lower boundary conditions; and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts and better precipitation forecasts. These fields now include POES-based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Plans are in the making to develop the AMSU-A Snow Water Equivalent (SWE) product for operational use. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and delivered to Atmospheric Environment Service, Canada for evaluation. New techniques such as automatic edge detection and incorporation of new sensors such as AMSU and NASA's MODIS are in development to improve operational production of daily snow and ice extent products. These products are delivered as digital files to NWP models and to the NWS Climate Prediction Center and other users. Graphical imagery of operational northern hemispheric snow cover can be found at www.ssd.noaa.gov.

LONG-TERM MONITORING OF NOAA-15 ADVANCED MICROWAVE SOUNDING UNIT-A (AMSU-A) PERFORMANCE

Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the Central Environmental Satellite Computer System (CEMSCS) and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. NOAA will continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

CALIBRATION OF THE VISIBLE AND NEAR-INFRARED CHANNELS OF THE AVHRR

It is very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible and near-infrared channels which do not have any onboard calibration devices. The major program elements are:

- development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by AVHRR and by calibrated spectrometers onboard aircraft;
- enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ±5 percent;
- evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to NIST;
- establishment of AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on GOES, the visible channel of HIRS, MODIS, and various sensors to be flown on the Environmental Satellite (Envisat); and
- design of optimal onboard and vicarious calibration techniques for the visible and near-infrared sensors planned under NPOESS. The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV) and the Global Observing Systems Space Panel (GOSSP).

To ensure global access to the results of the AVHRR calibration program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems, and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in NASA, NIST, EUMETSAT, China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the U.S., and academia both in the United States and abroad.

CALIBRATION OF GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE INSTRUMENTS

The GOES ground-system calibration processing was modified to accommodate the changes in spectral locations and field-of-view sizes of the Imager channels that became effective with GOES-12. Additional processing changes are being developed to accommodate the further changes that will be made to the Imager on GOES-N. The most notable of these is a tenfold increase in the time the Imager spends viewing its blackbody for calibrating its infrared channels. The increase is intended to improve calibration precision.

On November 24, 2003, the operational calibration processing in the GOES Imager's infrared channels was modified to deal with artificial depressions in measured brightness temperatures that occurred in the hours near local midnight. These depressions, reaching a maximum of approximately 1degree K (for a scene at 300 degrees K), were most pronounced in the infrared channels at the shortest wavelengths. We believe they were caused by effects of solar heating in the calibration measurements. The processing modification, which invokes a statistical technique to calculate the calibration coefficients near midnight, succeeded in minimizing the artificial brightness-temperature depressions. In addition to calibration, the product processing algorithms for several products will have been modified to accommodate the new channel configuration. FY 2004 saw considerable progress in the on-orbit calibration of the Imager's visible channel. This channel, lacking an on-board calibration device, can only be calibrated vicariously, i.e., with targets external to the satellite. Here we report results from two such targets. From eight years of observations of a stable Earth target (the Grand Desert in Sonora, Mexico), we estimated that the responsivity of the GOES-8 Imager's visible channel degraded an average of 5.8 percent per year. From routine observations of approximately 60 stars, we estimated visible-channel responsivity degradations of 4.86plus or minus 0.08 percent for the GOES-8 Imager (from 10/19/95 to 4/1/03) and 5.56 plus or minus 0.18 percent for the GOES-10 Imager (from 1/4/01 to 11/6/03). The difference between the GOES-8 degradation rates from the two methods is a topic of current research.

More information on GOES calibration topics, including the GOES-12 Imager channel changes, the correction for the midnight infrared-channel calibration errors, and the star- and desert-based vicarious calibrations of the visible channel, can be viewed at www.oso.noaa.gov/goes/goes-calibration/index.htm

OCEAN SURFACE WINDS

Calibration and validation studies are performed by STAR for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime, as well as precipitation regimes, where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future from which NOAA would have the opportunity to obtain near-real-time data streams. One of these sensors will be the first demonstration of the passive polarimetric technique, which is being relied on in the NPOESS design to meet the Nation's ocean surface wind vector requirements.

HIGH-RESOLUTION COASTAL WINDS AND STORM SIGNATURES FROM SYNTHETIC APERTURE RADAR

STAR scientists have developed techniques for deriving high resolution (1 km or less) winds from synthetic aperture radar (SAR) imagery and are using these derived winds to study ocean surface wind signatures of coastal wind phenomena of atmospheric fronts, hurricanes, and other storms. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as mountain lee waves), island and mountain wakes and vortex streets, gap flows, atmospheric fronts, and barrier jets. Application demonstrations are currently underway to provide high-resolution winds, imagery, and other SAR-derived products to operational agencies for evaluation. Demonstrations included near-real-time winds for Alaska coastal waters and SAR-derived hurricane winds. By the year 2007, there will be as many as four wide-swath SAR satellites. If data acquisition and sharing arrangements can be established to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of U.S. coastal areas will be possible. This increased coverage will allow use of SAR-derived marine and atmospheric products for operational purposes.

NOAA NATIONAL DATA CENTERS (NNDC)

NESDIS is responsible for the management of the NOAA National Data Centers (NNDCs). NNDCs consist of three data centers: the National Climatic Data Center (NCDC), located in Asheville, North Carolina; the National Geophysical Data Center (NGDC), located in Boulder, Colorado; and the National Oceanographic Data Center (NODC), located in Silver Spring, Maryland.

NNDC was established to be the Nation's primary repository for NOAA data. Since their inception, the role of the data centers has expanded in response to the introduction of new technologies useful to the centers and available to the users. Originally designed to archive only NOAA data, these centers now hold environmental data from a variety of sources, to include other U.S. government agencies, such as DOD and NASA, foreign governments, universities and cooperatives, and numerous commercial research programs.

The three NNDCs are responsible for the scientific stewardship of the Nation's environmental data and the development and operation of the associated ingest, monitoring, quality control processing, access, archive, analysis and assessment, creation of climate data records (CDRs), and other product generation systems in support of their national and international commitments and users. The NNDCs archive and provide access to numerous types of data. Each type of data provides a unique perspective for use in climate, oceanographic, space weather, and other geophysical research. It is often the combination of many of these data sets that lead to new discoveries and products that support activities, such as weather forecasting, risk (hazards-public safety and economic) mitigation, weather impact assessments, and climate assessments and predictions.

Data sets are typically divided into the method of collection: Remote (Satellites), Airborne, and in situ (surface: land and ocean). In situ includes radar, radiosonde, manual and automated surface observing systems, fixed and drifting buoys, etc. Observational data must be accompanied by comprehensive and complete station history data, referred to as metadata, as well as other ancillary and auxiliary documentation describing the data processing procedures (quality control and assurance) used prior to and after archiving the data.

Climate monitoring, evaluation, and prediction are critical to economic sustainability and environmental stewardship. The challenge facing the NNDCs is not only ingesting and processing very large volumes of new data, but also the convenient and timely access to the data and information. Millions of paper pages and thousands of feet of microfilm/microfiche of recorded instrument measurements and other information dating back hundreds of years are currently under the stewardship of the NNDCs. Over the past 50 plus years, many observations have been stored in digital form. There is now in place a program to convert analog records to digital form. The process will take many years to complete.

The development of a new generation of satellites over the next ten years (NASA's EOS, the next generation GOES, and NPOESS), the Initial Joint Polar-orbiting Operational Satellite System (IJPS)/MetOp, and the enhancement of the operational NEXt Generation Weather RADar (NEXRAD) (dual polarization) present major data management (stewardship and customer access) challenges to the NNDCs.

To meet these challenges, NESDIS has developed the CLASS program that will provide a significant portion, but not all, of the funding resources required to improve and maintain the information technology (IT) infrastructure required to support the mandated scientific data stewardship responsibilities for these incredibly large volumes of data.

NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC), a designated Federal Records Center, is the officially designated national archive for weather and climate data and information. NCDC is the world's largest archive of climate data. This center also produces and maintains numerous data sets, products, and assessments in order to service many thousands of customers worldwide. In addition, NCDC operates the World Data Center (WDC) for meteorology and WDC for paleoclimatology.

The NCDC mission is to provide stewardship and access to the Nation's resource of global climate and weather related information, and to assess and monitor climate variation and change. In support of that mission, the vision of NCDC is to be the most comprehensive and accessible source of high-quality meteorological data and information and to be a leading center of climate science expertise.

NCDC produces national and global data sets and assessments that support economic, national security, emergency and environmental planning and decisions, which are affected by climate variations and change. This center monitors the climate of the United States through monthly and annual State of the Climate reports. NCDC is co-located with the U.S. Air Force Combat Climatology Center and the U.S. Navy Fleet Numerical Oceanography and Meteorology Detachment. These three organizations make up the Federal Climate Complex, fulfilling much of the Nation's climatological needs.

This center conducts activities in four primary areas necessary to achieve its mission.

- Acquisition - receipt and quality assurance processing of weather and climate data.
- Archiving - long-term security, storage, and stewardship of these climate products.
- Access - efficient identification and delivery of appropriate weather and climate products to scientists, planners, policy makers, and the public.
- Assessments - monitoring current climate behavior and activity, and placing current climate conditions into relevant historical context.

As the Nation's climate scorekeeper and center of climate expertise, NCDC is frequently called upon to provide summaries, information, and historical comparisons of extreme climate events, as well as of the present state and long-term behavior of National and global climate. As part of its responsibility for monitoring and assessing the climate, NCDC tracks and evaluates climate events that have significant economic, security or societal impacts to the Nation and to the globe. Events include drought, hurricanes, tornadoes, blizzards, floods, and wildfires (see Figures 3-DOC-12 and 3-DOC-13). Such reports are accessible at several websites (see www.ncdc.noaa.gov /extremes.html and www.ncdc.noaa. gov/oa /climate/research /monitoring.html).

Figure 3-DOC-12. Remnants of a supermarket in Dumas, Arkansas, after a February 24, 2007, F3 tornado ripped through the town.

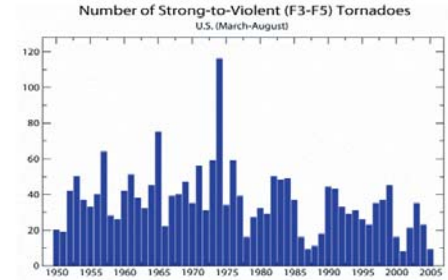

Figure 3-DOC-13. Number of strong-to-violent (F3-F5) tornadoes in the U.S. between March and August.

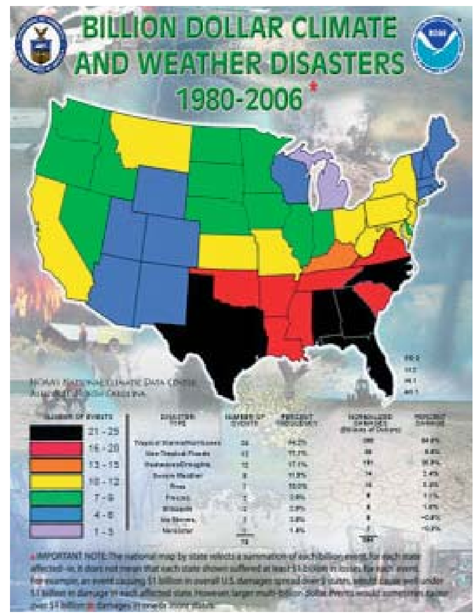

Figure 3-DOC-14. Billion-dollar Climate and Weather Disasters 1980-2006.

The importance of these monitoring activities is underscored by NCDC's assessment of billion-dollar weather disasters. From 1980 through 2006, the United States sustained 70 weather-related disasters in which overall economic costs reached or exceeded $1 billion (unadjusted) at the time of the event (see Figure 3-DOC-14). Twenty-two of these events occurred since 2000-an average of over three events per year, with an average cost to the Nation of $11.4 billion and 116 deaths per event.

In addition, NCDC utilizes its resources and expertise to provide applied climate guidance to decision makers in the form of assessments relating climate behavior to impacts on agriculture, transportation, energy, manufacturing, and other socioeconomic sectors. Examples of such guidance include the Residential Energy Demand Temperature Index (REDTI) and the assessment of climate change impacts on transportation (see Figures 3-DOC-15 and 3-DOC-16). The REDTI was recently developed to provide energy suppliers with a population weighted measure of trends in residential energy use, relative to air temperature.

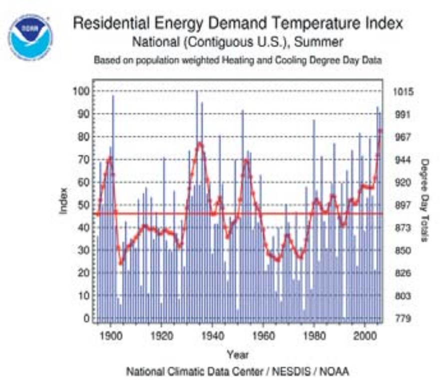

Figure 3-DOC-15. January Residential Energy Demand Temperature Index for the contiguous U.S. for the period 1895 - 2007.

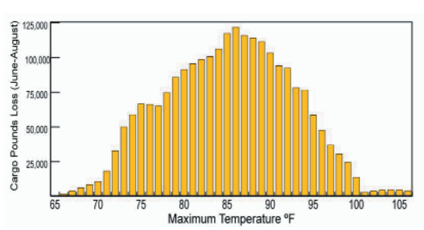

Figure 3-DOC-16. Potential loss in cargo/passenger weight from a commercial aircraft (Boeing 747) departing Denver International Airport (DIA) in 2030 based upon a projected warmer climate scenario.

NCDC plays a key role in the newly developed National Integrated Drought Information System (NIDIS). NCDC produces weekly drought ranking maps. In addition, NCDC participates in the North American Drought Monitor, an important multi-national and multi-institution cooperative effort to assist decision makers by identify regions of developing, ongoing, and recovering drought conditions in near-real-time (see Figure 3-DOC-17). NCDC is partnering with several agencies to develop the U.S. Drought Portal (USDP), which will provide user communities with a critical link to information, products, and service providers, and will support the United States Group on Earth Observations (USGEO) concept "to provide seamless, timely access to integrated Earth observations data, information, and products within the next decade." The interagency nature of USDP necessitates common data and metadata standards to assure optimal interoperability. To this end, USGEO linkage to Federal Enterprise Architecture (FEA) for both governance and operational guidelines will need to be fully leveraged by USDP.

NCDC continually develops innovative visualization tools to improve data accessibility, interpretation, and understanding. For example, the NCDC NEXRAD Interactive Viewer and Data Exporter tool uses Java to provide a client-side interface to NEXRAD level II and III products residing at NCDC. Through the tool, a visitor may browse radar images, select custom overlays and animations, and export images and movies in a variety of formats. The NEXRAD Data Exporter allows for data export in both vector polygon (Shapefile, GML, Well-Known Text) and raster (GeoTIFF, ESRI Grid, HDF, NetCDF, GrADS) formats. This and other NCDC visualization tools are part of university course curricula, have assisted in Space Shuttle upper atmospheric electron distribution studies, used by the National Transportation Safety Board for accident investigations, and routinely used by government and university researchers, both nationally and internationally.

Operational programs

Operational programs are those at the core of the NCDC mission. These

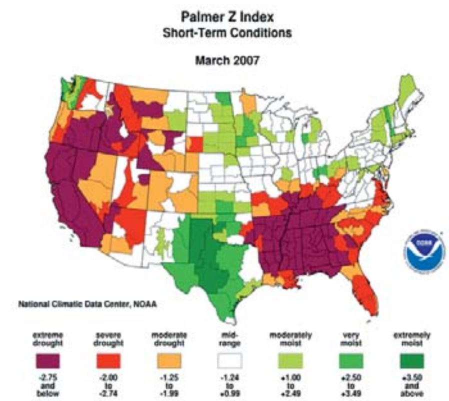

Figure 3-DOC-17. U.S. Drought Monitor Palmer Z Index for March 2007.

programs support ingest, quality assurance, archival, and access to environmental data, as well as the monitoring and assessment of the national and global climate.

Long-term stewardship (archive and access) of the Nation's weather and climate data, as part of the Federal Records Retention System. NCDC is an approved Agency Records Center and operates under the National Archives and Records Administration Federal Records Center guidelines and policies for managing weather and climate data records and information.

Scientific data stewardship functions inherent to the mission of the legislatively designated NCDC. These include developing and operating the associated ingest, monitoring, quality assessment processing, access, archive, analysis and assessment, creation of climate data records, and other product generation systems in support of national and international commitments.

National partnerships with Federal agencies (such as NASA, DOD, EPA, Department of Agriculture, Department of Energy, Department of State, National Science Foundation, U.S. Geological Survey, and the U.S. Global Climate Research Panel), many state agencies, all NOAA Line Offices, Regional Climate Centers, State Climatologists, universities, and many others. These partnerships aid in the collection and rescue, quality assurance processing, and access of data from regional and national environmental observing networks. In addition, they contribute to climate monitoring, national climate assessments, and a National Climate Services program.

International partnerships with the World Meteorological Organization, International Council of Scientific Unions, World Data Centers, Intergovernmental Panel on Climate Change, United Nations Educational, Scientific and Cultural Organisation (UNESCO), and other nations through bilateral and multilateral agreements. Examples are the World Data Center for Meteorology (archiving the data collected by internationally sponsored research programs and actively exchanging climate data with foreign countries to support research and other activities) and the World Data Center for Paleoclimatology (assembling, archiving, and providing access to global paleoclimatic data derived from worldwide collection of tree-rings, stalactites and stalagmites, coral samples, pollen and macro-fossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources).

Maintaining and updating national and global baseline data sets and climate data records that are used for monitoring, evaluation, analyses, and assessments of climate variation and change on global and regional scales. Examples of these data sets include the Global Historical Climatology Network, the U.S. Historical Climatology Network, the U.S. Climate Reference Network, the Comprehensive Ocean-Atmosphere Data Set, the Comprehensive Aerological Reference Data Set, and the Monthly Climate Data of the World.

Customer Service. Customers can access data, information, and products through a variety of means, such as real-time and near-real-time digital access and retrieval of new and archived historical observations through E-Commerce web-enabled capabilities (i.e., Internet), as well as through traditional methods (i.e., telephone, e-mail, facsimile, and traditional post). Digital access, retrieval, and delivery of data online and in a robotic storage system via the Internet is the primary and preferred customer service capability. Data and information can also be delivered on magnetic media (tape and disk), hard copy (paper and microfilm), electronic downloads, and staged for file transfer protocol (FTP) transfers. Many of the NCDC assessments, peer reviewed journal articles, published papers, and conference reports are also available online.

Climate Data Online (CDO) System. The CDO system is NOAA's primary means for distributing and providing access to in situ climate data. CDO includes both recent and historical data, useful for studies of particular weather events and for historical analysis of data for statistical and other research purposes. The general types of data currently included in the system, which continues to be populated, are surface hourly, daily, and monthly data, hourly precipitation data, and 15-minute precipitation data. As data integration efforts continue, the system will be greatly expanded to include numerous additional stations and data types. There are two methods to access climate data within CDO:

- The CDO homepage (see http://cdo.ncdc.noaa.gov): This provides numerous search and retrieval mechanisms, such as by region, country, state, climate division, county, and station, for any required times series.
- The GIS interface (see www.ncdc.noaa.gov): Click on "search by map" on the left hand side bar. The GIS tool set provides an array of methods to select regions and locations of interest, to overlay various layers of information, etc.

Supporting Activities

NCDC engages in an active research and development program to support the operational programs. Research activities and the development of new applications and technologies improve NCDC's ability to conduct its mission.

Scientific Data Stewardship Program. This program provides an approach to maximizing the performance, quality, and utility of climate observing systems, data, and information so that the scientific integrity and long-term utility of climate records for a broad range of users will be ensured. Five fundamental principles provide the framework for this program:

ensure Observing System quality during the design phase and real-time monitoring of performance;

- develop an end-to-end Climate Processing System that includes the timely ingest, quality assurance processing, immediate access to new and long-term access to historical records, and the long-term safeguarding of the climate records for future generations;
- provide basic IT support;
- document Earth System Variability through monitoring and evaluation of present, future, and past observations; and
- enable and facilitate future research through periodic analysis and assessment of new and historical records.

Digital Health of the Network (HoN) Monitoring (Observing System Performance Indicators). The purpose of the HoN monitoring process is to improve the quality of new observations and the fidelity of the historical archives by providing real-time information on the health and status of NOAA's observing networks. The fully developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network. Anomalies and systematic performance problems are evaluated and reported to the network manager. The outcome will be improved observing system performance and higher quality data records. As a result of HoN monitoring, many data quality issues can be identified and corrected before the data are incorporated into the historical archives and associated databases. The Cooperative Observer Program (COOP) Observing Network, the U.S. Climate Reference Network (USCRN), the Automated Surface Observing System (ASOS), the Global Climate Observing System Surface Network (GSN), and the Global Climate Observing System Upper Air Network (GUAN) are currently regularly monitored and the addition of other networks is planned. The USCRN program has a more rigorous operational daily monitoring system of hourly performance (see www.ncdc.noaa.gov/oa/hofn/global-insitu.html).

Assessments and Reports. A series of regular reports are released regarding several key climate issues of concern to the Nation. For example, NCDC releases a monthly and annual State of the Climate for the United States and the North American Drought Monitoring Report, which is a collaborative effort between Canada, Mexico, and the United States (see www.ncdc.noaa.gov/oa/climate/research/monitoring.html). Continuing study of the identification and blending of key parameters from satellite, radar, and in situ observing systems will lead to a new generation of quality climate data records. Understanding and knowledge, as well as new products and services for research and practical economic and environmental uses, will be derived from this progressive approach to maximizing the true value of observations.

U.S. Climate Reference Network (USCRN). The Ten Climate Monitoring Principles, described in the National Research Council Report, Adequacy of Climate Observing Systems (1999), are being used to guide the design, deployment, and life cycle management of USCRN (see Figure 3-DOC-18). USCRN is the first U.S. observing system built with the primary purpose of providing climate-quality measurements. Data from the fully deployed network of approximately 114 stations will quantify the variance in surface air temperature and precipitation on a national scale.

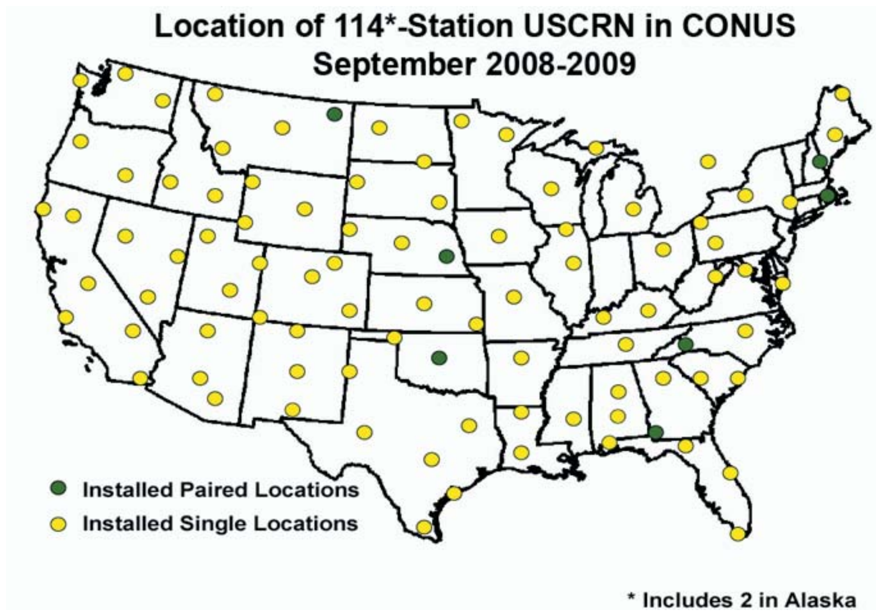

Figure 3-DOC-18. Current Climate Reference Network Site Locations.

The USCRN climate-quality observations avoid many of the time-dependent biases typically experienced with other surface observing networks. USCRN is quickly becoming the Nation's benchmark network, by providing a standard to which satellite, weather radar, and other surface systems (e.g., ASOS, COOP, Mesonet) observations can be validated and verified. In essence, the USCRN is providing the means to enhance the quality of and confidence in other observations, as well as contributing to the rehabilitation of existing historical databases and data sets. The results of these efforts will be a significant increase in the volume of climate quality data and information that can be used in assessing past climate trends and change, as well as contribute to the present and future climate monitoring, evaluation, and forecast tasks (see www.ncdc.noaa.gov/crn.html).

As of early 2007, 89 of the USCRN stations have been deployed (12 in the past year) and 25 more are currently funded, including two that are currently being installed. Of the 89, 84 stations have been commissioned. In addition, USCRN has attracted international attention, and in addition to one station that is currently operating in Canada, a second Canadian Climate Reference Network (CRN) station will be installed in the summer of 2007. Based on the success of USCRN, Canada intends to deploy an identical network of between 200 and 300 such stations. Also, under an agreement reached with the Russian Federation, a CRN station will be deployed at the research facility in Tiksi, Siberia, in the late summer of 2007. The station will be geographically equivalent to one deployed at Barrow, Alaska, and will vastly improve our understanding of the manifestations of climate change in the high latitudes.

NOAA Operational Model Archive and Distribution System (NOMADS). NOMADS is a collaborative approach to provide access and data analysis capabilities for model and other data (see Figure 3-DOC-19). NCDC, in partnership with NCEP and the Geophysical Fluid Dynamics Laboratory, initiated this project to address a growing need for remote access to high volume Global Climate Model and Numerical Weather Prediction model data. The NOMADS team has partnered with existing and development activities, including CLASS, National Oceanographic Partnership Program's, National Virtual Ocean Data System, the Department of Energy's Earth System Grid, and the Thematic Realtime Environmental Data Distributed Services developed through the National Science Foundation. NOMADS uses a distributed client-server framework of data servers together with emerging technologies to access data stored in heterogeneous formats at geographically distributed repositories. NOMADS provides, for the first time, long-term stewardship of numerical and climate model runs and provides the regional modeling community with the data necessary to initialize local models. In addition, NOMADS provides the tools necessary to inter-compare model and observational data sets from around the world (see http://nomads.ncdc.noaa.gov).

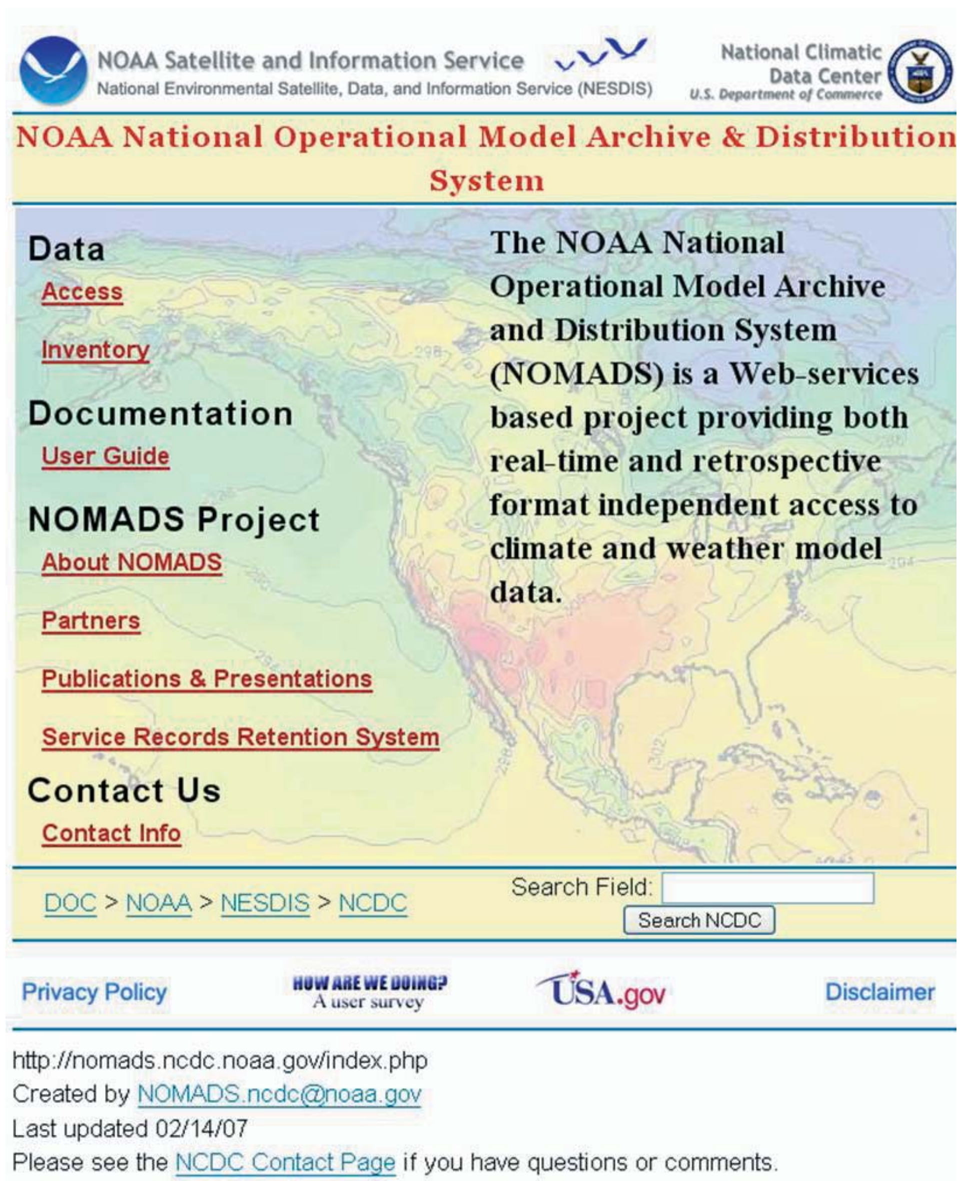

Figure 3-DOC-19. NOAA Operational Model Archive and Distribution System provides visualization and access to model data.

Climate Database Modernization Program (CDMP). Climate data, such as wind speed and direction, precipitation, temperature, and pressure, are of critical importance to many disciplines and enterprises, including economic research, engineering, risk management, energy, and agriculture. Decision making in these and other sectors requires the ease of access and use that only digital databases of these data can provide. CDMP is a concerted effort to ensure the conservation of and improve access to environmental data by identifying and transcribing these data from historical analog sources (i.e., paper, film, or other non-digital media) to digital formats that can be more safely, securely, and easily stored, accessed, retrieved, and handled. Under CDMP, new digital databases of historical environmental data and information are created. Many existing digital data sets are being extended back in time, in many cases by a century or more.

CDMP transcribes data from analog to digital formats by digitally scanning the original documents or images, by manually transcribing data and information from the original sources into a digital format, or both. These digital copies and manually-keyed digital data sets are made available to researchers via interactive Web-based interface tools, such as the Web Search, Store, Retrieve Display (WSSRD) located at http://noaa.imcwv.com (see Figure 3-DOC-20).

Additionally, the conversion of analog data sources to digital databases and data sets ensures the efficient and inexpensive long-term preservation of data that exist on non-digital media that may be deteriorating and excessively expensive to continue preserving.

Over fifty million documents have been imaged and many thousands of observations manually keyed or digitized from the merchant and military ship records, America's military forts,

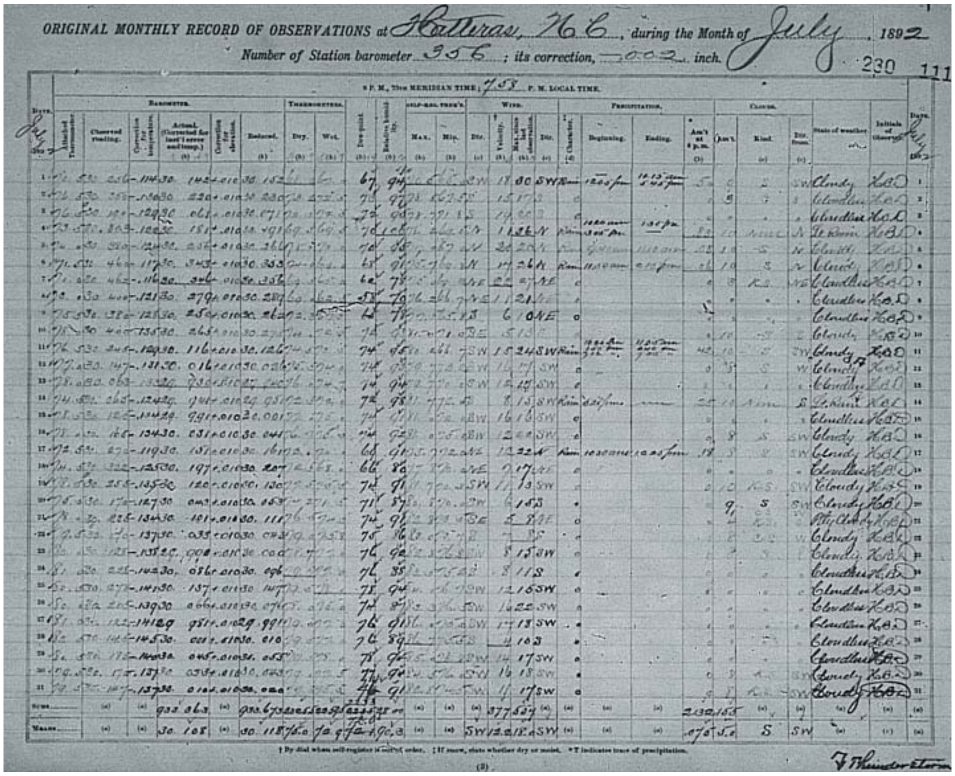
ORIGINAL MONTHLY RECORD OF OBSERVATIONS at Hatteras, N.C., during the Month of July 1892
Number of Station barometer 356; its correction, -.002 inch.

Figure 3-DOC-20. Scanned image of an original weather observation form from Hatteras, NC, for the month of July 1892, as scanned by CDMP and stored in the WSSRD system.

U.S. cities, lighthouses, weather ships, and other sources. The CDMP services currently extend into all NOAA operational line offices (see Figure 3-DOC-21). CDMP provides an unprecedented and unique opportunity to rescue valuable climate and environmental data dating back into the 1700s that are in jeopardy of permanent loss due to the deterioration of the paper and microfilm media (see www.ncdc.noaa.gov/oa/climate/cdmp/cdmp.html).

NOAA Paleoclimatology Program. Paleoclimatic data is an important segment of documenting and reconstructing annual to century scale records leading to climate records dating back 10s and 100s of millennia. The incorporation of this program into the functions and activities of NCDC enhances the identification and understanding of climate change and variation. The NCDC Paleoclimatology Branch cooperates with many countries in research projects that combine the global paleoclimate database with the instrumental record to extend the climate record back in time for climate model verification and climate change studies. Objectives of the program are to cooperate with researchers in academia, NOAA, and other agencies to: conduct original research to describe the global patterns of annual-to-millennial scale climate change; understand the causes of climate change; separate man-induced climate change from natural variability; and validate the models that are used to predict future climates (see www.ncdc.noaa.gov/paleo/paleo.html).

Air Quality Forecasts. NCDC archives NOAA's Air Quality Forecasts. The Air Quality Forecasts are forecast guidance of one-hour and eight-hour averaged ground-level (surface) ozone concentration. The guidance is produced twice a day, for hourly intervals through midnight on the following day (48 model hours), seven days a week for the northeastern United States initially, and then gradually will include the entire United States by 2009. NWS provides the data. These data provide ground-level ozone forecast guidance for state and local air quality forecasters and help the public limit adverse effects from poor air quality. This forecast guidance helps meet a congressionally directed national air quality forecast capability. These data will have received a high measure of quality control through computer and manual edits.

Global Observing System Information Center (GOSIC). GOSIC is now fully operational and online at NCDC. GOSIC began in 1997, as a research effort at the University of Delaware to aid the major global observing systems in providing more efficient access to data and information. GOSIC provides unique tools for searching and accessing data, such as matrices and

Figure 3-DOC-21. NOAA tasks supported by the CDMP.

portals. This allows users to search for specific data, such as data located at NCDC and other global data centers. GOSIC serves the global observing system community and has provided a great tool for coordinating the various Global Climate Observing System (GCOS) Lead Data Center activities across NCDC (see http://gosic.org).

NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) is an enterprise organization that provides scientific and public stewardship for national and international marine environmental and ecosystem data and information. NODC, the National Coastal Data Development Center (NCDDC), and the NOAA Central Library, with its regional branch assets, are integrated to provide access to the world's most comprehensive sources of marine environmental data and information. NODC maintains and updates a national ocean archive with environmental data acquired from domestic and foreign activities and produces products and research from these data that help monitor global environmental changes. These data include physical, biological, and chemical measurements derived from in situ oceanographic observations, satellite remote sensing of the oceans, and ocean model simulations. NODC manages and operates the World Data Center (WDC) for Oceanography, in Silver Spring, Maryland. Its personnel directly interact with Federal, state, academic, and industrial oceanographic activities; represent NESDIS on various interagency domestic panels, committees and councils; and represent the United States in various international organizations, such as the International Oceanographic Data Exchange. NODC represents NESDIS and NOAA to the general public, government agencies, private institutions, foreign governments, and the private sector on matters involving oceanographic data.

NODC Data Holdings

NODC manages the world's largest collection of publicly available oceanographic data. NODC holdings include in situ and remotely sensed physical, chemical, and biological oceanographic data from coastal and deep ocean areas. These were originally collected for a variety of operational and research missions by U.S. Federal agencies, including DOD (primarily the U.S. Navy); by State and local government agencies; by universities and research institutions; and private industry. NODC data holdings extend back over one hundred years and the volume is expected to grow exponentially as new ocean observing systems are deployed.

Through NODC archive and access services these ocean data are being reused to answer questions about climate change, ocean phenomena, and management of coastal and marine resources, marine transportation, recreation, national security, and natural disasters. Another significant user community is education, where these data and information products help teach each new generation of students about the oceans. Requests for oceanographic data and information have increased each year since NODC was established in 1961.

User Services

Each year NODC responds to thousands of requests for oceanographic data and information. Copies of specified data sets or data selected from NODC's archive databases can be provided to users on various media types or online. NODC data products are provided at prices that cover the cost of data selection and retrieval. Most data provided on the NODC website is free of charge.

NODC supports ecosystem stewardship through NCDDC, in Stennis, Mississippi, by providing access to the Nation's coastal data resources. NCDDC achieves this capability through the integration of diverse coastal data distributed in multiple repositories and provides data to users via the Internet using established and emerging technologies. They provide a searchable metadata catalog of coastal data, developing gateways to data repositories and using middleware technology that provides data in user specified formats.

Specifically, NODC data archive and access responsibilities support climate research and operational ocean observing system activities. NODC performs ocean profile data management for internationally coordinated global ocean observing systems, such as the Argo Ocean Profiling Network and the Global Temperature Salinity Profile Program (GTSPP) in cooperation with applicable Joint WMO/IOC Commission for Oceanography and Marine Meteorology (JCOMM) committees. NODC's objectives are: (1) to safeguard versions of the Argo and GTSPP near-real-time and retrospective data and information; and (2) to provide high quality data to a wide variety of users in a timely and useful manner. The Argo and GTSPP data system present an excellent opportunity to improve ocean and climate forecasting, with consequent benefits for the protection of life and property and effective planning for the effects of seasonal to interannual climate variability.

NODC produces regular updates of the *World Ocean Database and World Ocean Atlas*. The most recent version, 2005, includes over eight million profiles of scientifically quality controlled ocean temperature, salinity, oxygen, plankton, pigment, and nutrient data. The atlas presents statistics and objectively analyzed fields for one-degree and five-degree squares generated from the World Ocean Database 2005, observed and standard level flagged data. The ocean variables included in the atlas are: in situ temperature, salinity, dissolved oxygen, apparent oxygen utilization, percent oxygen saturation, dissolved inorganic nutrients (phosphate, nitrate, and silicate), chlorophyll at standard depth levels, and plankton biomass sampled from 0 - 200 meters depth. For more information on both products, go to www.nodc.noaa.gov /OC5/indprod.html.

The NOAA Marine Environmental Buoy Database is one of the largest and most frequently used data archives maintained by NODC (see www.nodc.noaa.gov/BUOY/buoy.html). This database holds wind, wave, and other marine data collected by the NOAA's National Data Buoy Center (NDBC) from moored buoys and the Coastal Marine Automated Networks (C-MAN) stations. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature.

NODC is developing a capability to provide public access to consistently-processed, climate-capable satellite data sets and applying them to various scientific problems. The first products provided in 2003 were Pathfinder reprocessed 9 km and 4 km sea surface temperatures. For further information, visit www.nodc.noaa.gov/sog.

NCDDC manages the Coastal Data Development (CDD) program. NCDDC's focus is to improve the quality of web-based search and access tools and implement web-based access to priority data sets from Federal, state, and local repositories. Geospatial display capabilities have been added that allow the user to link the data to coastal imagery, charts, and bathymetry to obtain a complete data picture of the ecosystem of interest.

To identify priority data sets, NCDDC coordinates with Federal, state, and local agencies, academic institutions, nonprofit organizations, and the private sector to create a unified, long-term database of coastal data sets available from a variety of sources. NCDDC develops and maintains a catalog of available coastal data; builds gateways to these sources; ensures the equality of the metadata; populates and updates the databases; and provides online search and access and geospatial display for the coastal user community.

The CDD program supports NOAA's ecosystem strategic goal that aims to build the capacity of Federal, state, local, and international managers to make decisions that protect, restore, and use coastal ecosystem services. The Earth's coastal ecosystems are home to a wealth of natural resources; the lives and livelihoods of people are linked to these national treasures. Sustainable growth of our coastal regions is critical to our economy by supporting commercial and recreational fishing, waterborne commerce, home construction, and tourism. Base activities aim to advance understanding and predict changes in the Earth's environment to meet the economic, social, and environmental needs of the United States. This supports the strategic goal of the Department of Commerce to "Observe, protect, and manage the Earth's resources to promote environmental needs."

<u>International Cooperation and Data Exchange</u>

A significant percentage of the oceanographic data held by NODC is foreign. NODC acquires foreign data through direct bilateral exchanges with other countries and through the facilities of the World Data Center for Oceanography, Silver Spring, which is collocated with and operated by NODC. This is part of the World Data Center System initiated in 1957 to provide a mechanism for data exchange, and they operate under guidelines issued by the International Council of Scientific Unions (ICSU).

Under NODC leadership, the Global Oceanographic Data Archaeology and Rescue (GODAR) project has grown into a major international program sponsored by the Inter-governmental Oceanographic Commission. GODAR is a comprehensive effort to locate, rescue, quality control, and disseminate historical global ocean profile data for use by the climate and global change research community.

<u>Data Management for Global Change Studies</u>

NODC provides data management support for major ocean science projects such as the Tropical Ocean Global Atmosphere (TOGA) program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). To promote improved working relations with the academic ocean research community, NODC established the following three joint centers with university research groups:

- Joint Environmental Data Analysis Center (with Scripps Institution of Oceanography, University of California at San Diego)
- Joint Archive for Sea Level (with the University of Hawaii)
- Joint Center for Research in the Management of Ocean Data (with the University of Delaware)

<u>NOAA Library and Information Network</u>

NODC also manages the NOAA Library and Information Network, which includes the NOAA Central Library in Silver Spring, MD; regional libraries in Miami, FL, and Seattle, WA; and field libraries or information centers at about 30 NOAA sites throughout the United States. The combined libraries contain millions of volumes, including books, journals, CD-ROMs, DVDs, audio, and videotapes.

The NOAA Central Library (see www.lib.noaa.gov) supports weather and climate research programs by providing a variety of information services, including:

- Access to print and electronic versions of American Meteorological Society journals
- Access to Meteorological and Geoastrophysical Abstracts (desktop access at the Silver Spring campus)
- Desktop access to Web of Science at several NOAA sites
- Assistance in obtaining site licenses for 169 National Weather Service field sites for electronic access to Monthly Weather Review and Weather and Forecasting
- Archival of historic collections of the Weather Bureau
- Rescuing hundreds of volumes of meteorological data publications

NATIONAL GEOPHYSICAL DATA CENTER

The National Geophysical Data Center (NGDC) staff archive, assess, and provide access to satellite and ground-based observatory data from national and international programs supporting research in meteorology, climatology, and space weather as well as solar-terrestrial physics, snow and ice, marine geology and geophysics, and solid Earth geophysics (see www.ngdc.noaa.gov). The National Snow and Ice Data Center (NSIDC), at the University of Colorado, is an affiliated partner with NGDC. The two national centers house and operate the World Data Centers for Solar-Terrestrial Physics, Marine Geology and Geophysics, Glaciology, and Solid Earth Geophysics under the auspices of the International Council for Science. Research activities focus on satellite remote sensing to assess the long-term changes of the land surface, the space environment, snow cover, and sea ice.

NGDC's vision is to be the world's leading provider of geophysical and environmental data, information, and products. NGDC's mission is to provide long-term scientific data stewardship for the Nation's geophysical data, ensuring quality, integrity, and accessibility. NGDC's vision and mission statements are consistent with the assigned responsibilities of the NOAA National Data Centers for scientific stewardship of the Nation's environmental data and the development and operation of the associated systems for ingest, monitoring, quality control, access, archive, analysis, and assessment of environmental data and other product generation systems in support of national and international commitments and users.

Long-term archive responsibilities for the Nation are provided by NGDC activities. NGDC maintains the Nation's archive for global tsunami and related hazard events, including tsunami events, triggers, run-up locations and heights, damage descriptions, and photographs. This information is essential for researchers focusing activity on at-risk areas. As part of NOAA's effort to improve tsunami research and warning, NGDC established a long-term archive for ocean bottom pressure and Deep-ocean Assessment and Reporting of Tsunamis (DART) data. NGDC also manages the sole archive of space weather data from GOES, POES, and DMSP satellites. NGDC maintains the only archive of raw data records and visible and near-infrared imagery collected on DMSP satellites for meteorological, oceanographic, and Earth surface studies. The space weather ground-based archives focus on data used in NOAA's space weather forecasts, warnings, and alerts. NSIDC manages cryospheric data from both ground-based and satellite instruments. These data stewardship and scientific stewardship activities for satellite and ground-based data include processing, management, analysis, and quality assessments.

Online WWW-based access services to these large databases continue to evolve at NGDC. Data discovery, browsing, and delivery are fairly mature functions. Data directories are managed by relational database management systems available to most search engines. Almost all of the data sets reside in robotic libraries and are accessible online, however, some data sets are easier to browse, display, and use than others. NGDC uses Web map-based access to the integrated hazards databases. Users can select events either through a geo-referenced map interface or via traditional search and retrieve engine. NGDC has several projects as part of the NESDIS program to digitize and make accessible the most important records in the huge historical archive. Interactive displays of multidisciplinary data sets and data mining are under development. NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch numerical simulations of the atmospheric and space environments.

The DMSP activity prepares calibrated and geo-referenced records from the raw data records recorded by the scientific instruments on DMSP satellites. Data sets include visible, infrared, and microwave imagery, microwave soundings, and in situ measurements of the space environment. User services are provided through the Space Physics Interactive Data Resource (see http://spidr.ngdc.noaa.gov/spidr). Research activities focus on the use of the nighttime visible and infrared imagery from the DMSP OLS. The nighttime lights product has been used to assess changes in power consumption both regionally and globally from 1992 to present. Nighttime lights have been used to support humanitarian relief services after natural disasters such as Hurricanes Wilma and Katrina.

GOES, POES, and DMSP satellite data of solar activity and the near Earth space environment managed by NGDC provide the long-term monitoring of space weather conditions. These data record the Earth's magnetic field, the electrically charged environment, and Solar X-rays from geosynchronous and polar sun-synchronous altitudes. Data from ground-based observatories recording solar activity, ionospheric characteristics, and geomagnetic variations complement, enhance, and provide ground truth for the satellite measurements. The Solar Geophysical Data bulletin containing solar and space weather data is published monthly. The space weather program at NGDC archives measurements of total solar and solar spectral irradiance for use in climate studies. Tabular listing of ionospheric parameters and ancient solar images are part of the digitizing and access program.

Supporting Research

Natural Hazards Classification and Risk Assessments. Tsunamis are infrequent high impact events that can cause a considerable number of fatalities, inflict major damage, and cause significant economic loss to large sections of the Nation's coastline. Since 1900, over 200 tsunami events have affected the coasts of the U.S. and its territories, causing more than 500 deaths. NGDC maintains the national archive for tsunami data and the global tsunami event database. As part of the national program and as required under Public Law 109-424, NGDC provides open access to the observational and event data, supporting NOAA's mission to provide reliable forecast and warning and to promote community resiliency. One of the newer data streams now managed by NGDC is from the DART network (see http://ngdc.noaa.gov/seg/hazard/DARTData.shtml). NGDC, working with the United States Geological Survey (USGS), just released the first complete assessment of the tsunami hazard for all U.S. coasts based on historic event data and seismic sources. NGDC is working with the Tsunami Warning Centers to provide nightly replication of the event database for tsunami warnings and with the NOAA Tsunami Research Center to improve the tsunami forecast models.

Environmental Remote Sensing. Operational meteorological satellite systems provide a unique opportunity to monitor features on or near the Earth's surface, sometimes on a nightly basis. DMSP nighttime imagery are used to locate sources of visible and infrared light emissions, including city lights, wildfires, gas flaring, and fishing boats. Research projects use the city lights to infer such diverse parameters as population density changes, regional economic vitalities, and global carbon dioxide emissions. More information is available at www.ngdc.noaa.gov/stp/stp.html.

Space Weather Climatology. The Space Weather program at NGDC provides scientific data stewardship for the Nation's operational space environmental data in accordance with Data Quality Act, Public Law 106-554, Section 515 (2001), NOA 212-15 (Dec. 22, 2003), 33 U.S.C. § 883e. NGDC scientists use long-term data records to develop space weather climatologies of the ionosphere, thermosphere, and magnetosphere. NGDC is also involved in the development of virtual observatories for space environmental data allowing the scientific research community seamless access to data sets residing at NGDC and other locations. Space weather climatologies are used to monitor changes in the near-Earth space environment and to determine probabilities for significant environmental events. Access to the NGDC space weather data and climatologies is provided at www.ngdc.noaa.gov/stp/stp.html.

Geomagnetic Field Modeling. The NGDC geomagnetism group develops and produces magnetic field models for navigation and pointing, which are used in a multitude of defense and

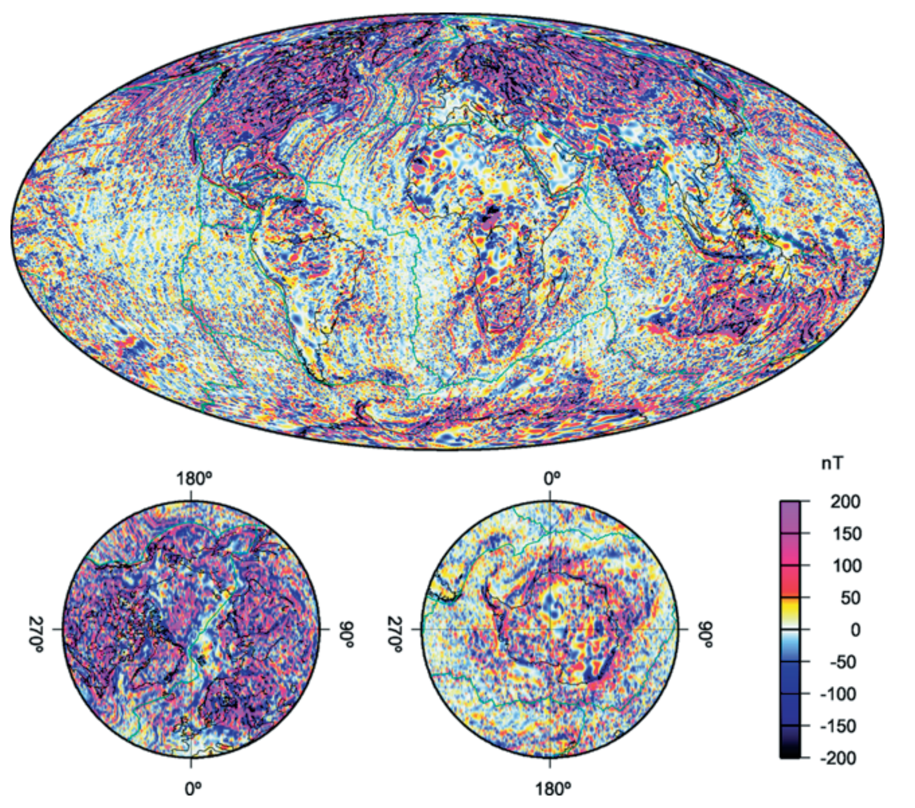

Figure 3-DOC-22. Vertical component of the crustal magnetic field at Earth's surface as given by the NGDC degree-720 model.

civilian applications. Production of the World Magnetic Model, the standard magnetic model for DOD and the North Atlantic Treaty Organization (NATO), is sponsored by the National Geospatial-Intelligence Agency. The geomagnetism group also heads the production and distribution of the International Geomagnetic Reference Field. Making use of its extensive holdings of satellite, airborne, and marine magnetic data, NGDC is developing new high-resolution magnetic field models. Recent products include a 3-arc-minute World Digital Magnetic Anomaly Map and the extended magnetic reference model to spherical harmonic degree 720 as shown in Figure 3-DOC-22. Additional information can be found at www.ngdc.noaa.gov/seg/geomag/geomag.shtml.

Cryospheric Research. NSIDC's research interests cover a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on arctic regions and satellite-borne measurements. Research projects within NSIDC examine the long-term record of snow and ice in polar and mountainous regions, as well as the hydrology of the southwestern U.S. Algorithms to detect snow, frozen ground, and sea ice in passive microwave images from DMSP and NASA satellites have been developed at NSIDC. With the International Polar Year providing the incentive, NSIDC made its popular Sea Ice Index data set available through Google Earth as shown in Figure 3-DOC-23. The Sea Ice Index allows users to see how current Arctic and Antarctic ice conditions compare with long-term trends. Other research includes developing models of the physical and mechanical properties of snow and ice in glaciers and the freeze-thaw cycles of soils in polar regions-the latter is an important component of hydrological modeling. Other areas of special interest and study are the interactions between sea ice and the ocean and the atmosphere. More information is available at http://nsidc.org.

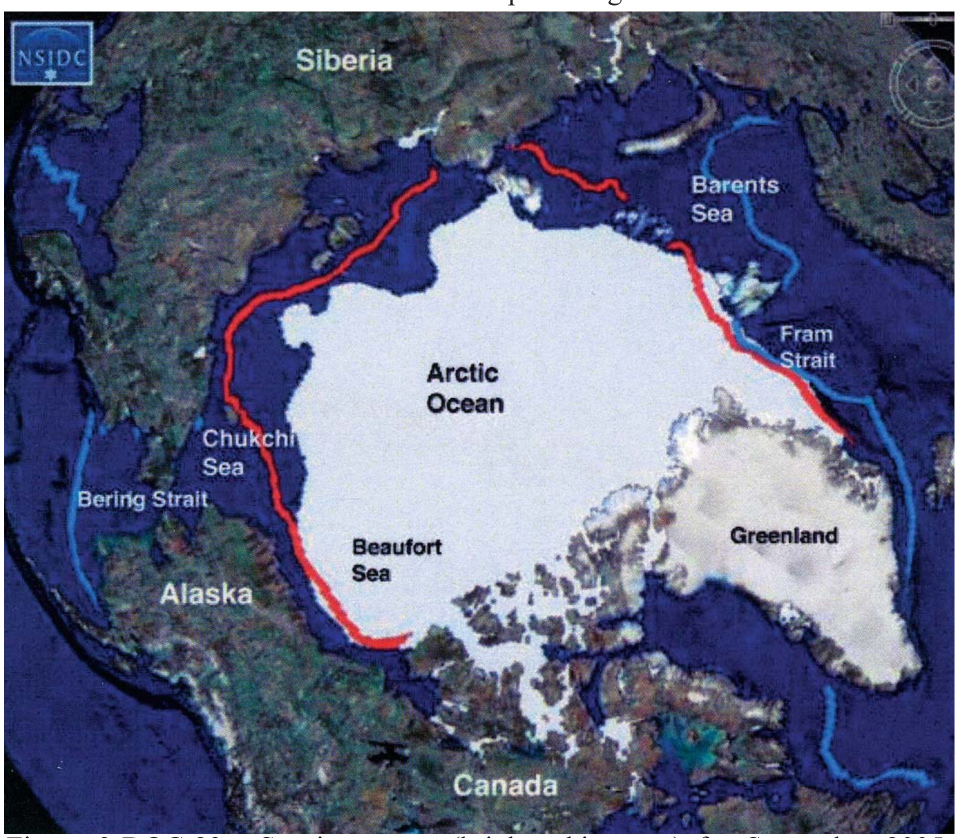

Figure 3-DOC-23. Sea ice extent (bright white area) for September 2005. Median ice extents based on the period 1979 to 2000 for September (red line) and March (blue line) illustrate the typical seasonal range.

OCEANIC AND ATMOSPHERIC RESEARCH LABORATORIES

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various National Oceanic and Atmospheric Administration (NOAA) meteorological and oceanographic missions. The activities of OAR laboratories provide the innovative ideas needed to improve our understanding of atmospheric, oceanic, and climate science and develop the practical solutions, tools, and techniques that form the basis of improved ocean, weather, water, and climate services.

In an effort to improve national resiliency and better protect lives and property, OAR places special emphasis on improving severe weather, flood, and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. OAR also places emphasis on enhancing our understanding of the global climate system and improving regional decision support tools for climate and weather.

OFFICE OF WEATHER AND AIR QUALITY (OWAQ)

OWAQ, located at OAR Headquarters, is an important focal point for facilitating and coordinating weather research in OAR and throughout NOAA. OWAQ implements the NOAA's component of the United States Weather Research Program (USWRP, http://www.esrl.noaa.gov/research/uswrp/) and the NOAA component of THORPEX: A Global Atmospheric Research Program (http://www.mmm.ucar.edu/uswrp/programs/nathorpex.html, from which one can link to the international THORPEX website). Also within OWAQ is the Special Program Initiative which is an internal OAR competition that provides awards to the OAR weather and air quality laboratories for innovative proposals. OWAQ also does budget planning for and assists in prioritization of NOAA's weather and air quality research.

<u>United States Weather Research Program (USWRP)</u>

The USWRP has been an interagency weather research and transition of research to application program. The member agencies have been NOAA (lead), NASA, NSF, the Navy, and the Air Force. The NOAA component of USWRP has been quite active although the funding levels have been flat. The USWRP funds reside in the National Weather Service (NWS) Office of Science and Technology (OST). OWAQ helps plan NOAA USWRP priorities, implements the program, and monitors progress. During the Fiscal Year (FY) 2007-2008 period, NOAA USWRP has provided the sole NOAA support for the Developmental Test Center (DTC, http://www.dtcenter.org/index.php) at the National Center for Atmospheric Research in Boulder, CO. The DTC is a test bed for the Weather Research and Forecasting (WRF) community model (http://wrf-model.org/index.php) and is a cooperative venture among NOAA, NSF, the Air Force, and the Navy. The USWRP provides most of the support for the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information or Societal Impacts Program (SIP) for short (http://www.sip.ucar.edu/). Its mission is to be a clearing house for socioeconomic information on weather, to increase knowledge among the weather community concerning the human and economic impacts of weather, to better determine the value of weather information, and to improve our ability to communicate weather information to all public and private sectors. Recent highlights of the SIP activities are the Weather and Society*Integrated Studies (WAS*IS) workshops and training sessions that bring social science to the metereological community and vice versa. The SIP also provides the bulk of the U.S. support for the societal and economic research and applications component of THORPEX (see below).

The NOAA USWRP also provides total support for the Joint Hurricane Testbed (JHT), (http://www.nhc.noaa.gov /jht/index.shtml) which transitions mature research products from the hurricane research community into operations through improvements in hurricane landfall decision support systems. Recently, the JHT has been emphasizing improving forecasts of hurricane intensity at landfall. Most recently, NOAA USWRP has invested in research and transition of research to applications to improve quantitative precipitation forecasts through NOAA's Hydrometeorological Testbed (HMT, http://hmt.noaa.gov/). The HMT seeks to improve regional precipitation forecasts, particularly heavy, flooding rains.

<u>THORPEX: A Global Atmospheric Research Program</u>

THORPEX is a 10-year international research program under the World

Meteorological Organization that focuses on accelerating improvements in 1- to 14-day global numerical prediction of high impact weather. THORPEX began in 2004. THORPEX is the weather component of the Global Earth Observing Systems of Systems (GEOSS) and provides the regional and global weather support for the International Polar Year (IPY, 2007-2008). The U.S. representative to the THORPEX international management committee resides in NOAA and NOAA is the lead agency in THORPEX, providing the U.S. funding contribution to the THORPEX international management. Key U.S. agencies that are participating in THORPEX, in addition to NOAA, are NSF, NASA, and the Navy. The main thrusts of U.S. THORPEX are:

- Understanding global scale atmospheric processes and phenomena
- Improving the science of prediction
- Providing socioeconomic research and applications

NSF, the Navy and NASA provide the bulk of support for the first bullet. All agencies support the second bullet and NOAA USWRP and NCAR support activities within the third bullet. NOAA/National Centers for Environmental Prediction (NCEP) has developed a North American Ensemble Forecasting system (NAEFS, http://www.emc.ncep.noaa.gov/gmb/ens/NAEFS.html) which has become operational in Fiscal Year 2007 and includes the U.S., Canada, and Mexico (as a user). NAEFS will be an important component of the THORPEX Interactive Forecast System (GIFS) to be available by the end of the THORPEX program period. NCEP is one of the ten operational centers contributing to the THORPEX Integrated Grand Global Ensemble (TIGGE) that provides global ensembles to the weather community. The NOAA USWRP-funded SIP (discussed above) provides U.S. support for the socioeconomic component of THORPEX. In essence, THORPEX underpins all ensemble, probabilistic atmospheric modeling in NOAA. It is the program in which key advances are made in ensemble techniques and atmospheric data assimilation with a significant portion of the applied research being done at OAR's Earth Systems Research Laboratory (ESRL). It is also provides the connection on the weather side to climate prediction at the intraseasonal scales that will eventually lead to a seamless weather-climate prediction system.

A major near-term field activity in which the NSF, the Navy, and NOAA are significantly involved is the THORPEX Pacific Asian Regional Campaign (T-PARC), (http://www.ucar.edu/na-thorpex/PARC.html). It has three phases: summer, extratropical transition (ET), and winter - most of the activity takes place in 2008. It takes place in the Southeast, East, and North Pacific and will involve an intensive observing campaign. Most of the Pacific Rim countries are participating, including the U.S. and Canada. In addition, there will be participation by Germany. The summer phase will study the formation, propagation and intensity modulation of East Pacific tropical cyclones. The ET phase will study the transition of tropical cyclones into mid-latitude storms that strike the Northeast Asian and U.S./Canadian West Coast. The winter phase will study the optimum use of targeted observations to improve the forecasts of high impact winter storms on the U.S., Canada, and the Arctic. This phase links to IPY.

<u>OAR/OWAQ Special Projects Initiative</u>

The Special Projects Initiative (SPI) began in Fiscal Year 2004 to provide funds, based on internal competition, among OAR laboratories with expertise in weather and air quality research, for innovative research. The competition emphasized inter-laboratory collaboration. Three proposals are being funded with a partial new competition planned for Fiscal Year 2008. The three proposals include:

1. Use of the NOAA-GIV High Altitude Jet to Investigate the Saharan Air Layer and Assimilation of Moisture Observations in the Tropical Cyclone Development": Atlantic Oceanographic and Meteorological Laboratory and the Cooperative Institute for Marine and Atmospheric Science
2. Improving Particulate Matter (PM) Forecasts and Evaluating Its Interaction with Atmospheric Radiation": Earth Systems Research Laboratory
3. Improving the Ability to Forecast Floods: A Proposal to Accelerate and Strengthen the Development of a Hyrdometeorological Testbed": Earth Systems Research Laboratory, National Severe Storms Laboratory

OBSERVING TECHNOLOGY

Meteorological, oceanographic, and climate research requires a strong network of observing systems providing data and information and consistent advancements to our observational capabilities. In support of NOAA's mission, OAR supports the advancement of our observing technology through the development and testing of new observing systems, observation techniques, and data ingest and dissemination systems. All OAR observing technology research supports the Global Earth Observing System of Systems (GEOSS) and further establishes OAR as a preeminent leader in meteorological, oceanographic, and climate research.

Numerous OAR laboratories and their related academic and private sector partners are heavily involved in developing new environmental observing system technologies. The Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) in Boulder, Colorado, takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The Physical Sciences Division (PSD) of ESRL evaluates new remote-sensing concepts and systems as they apply to specific problems of interest such as the impact of atmospheric rivers on severe west coast flood events. The transition of new forecast products into NOAA operations is accomplished through regional testbeds such as the Hydrometeorlogical Testbed (HMT) situated in the American River Basin near Sacramento California (http://hmt.noaa.gov/) and the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, which develops both new remote sensing systems and assists in the transfer of these technologies to the NWS. The Atlantic Oceanographic and Meteorological Laboratory (AOML) in Key Biscayne, Florida, develops, deploys, and manages in situ oceanographic observing systems across the global oceans. The Air Resources Laboratory (ARL) manages the deployment and operation of the Climate Reference Network for NESDIS and operates state-of-the-art chemical deposition measurements in support of model development. This environmental research, development and associated transition of products and services directly support the Nation's forecasting and warning services.

GSD is taking a leadership role in implementing the International Earth Observation System including the development and testing of Unmanned Aircraft Systems (UAS, formerly referred to as UAVs) for providing global weather and climate observations (Figure 3-DOC-24). ESRL/GSD is one of several NOAA Research organizations collaborating with NASA in support of this project. The goal of these missions is to evaluate the utilization of UASs for improved U.S. and global observing in areas too remote or dangerous for lengthy manned flights, e.g. the polar regions and hurricanes. High and medium altitude, long-endurance UASs (HALE and MALE-class) can fly in remote locations in dangerous flying conditions for long periods. This technology provides many scientific benefits such as sustained global high quality all-weather profiles of atmospheric composition (water vapor, aerosol, cloud water and trace gases), and high altitude vertical resolution and profiling. It also offers a rapid response platform for improved high impact weather forecasts at 1-day to 2-week lead times, and better climate change detection, attribution, and prediction in support of policy decisions. For testing purposes, the HALE-class UAS's integrated sensor package consists of such components as an ocean color sensor and passive microwave sounder developed by the NOAA's PSD, a gas chromatograph and ozone sensor developed by GMD, a digital camera system provided by NASA, and an electro optical infrared sensor provided by GA-ASI. GSD is also developing ultra-lightweight sondes to include in the UAS sensor package.

GSD has developed GPS-Meteorology, a ground-based research system (GPS-Met) that uses the Global Positioning System (GPS) to measure atmospheric water vapor in real-time, increasing the accuracy of precipitation forecasts in the hourly-updated numerical weather prediction model used by the National Weather Service for high impact weather events. This system collects and processes observations from 400 GPS-Met stations, owned and operated by NOAA and other government agencies across the U.S., and the data is distributed using a web interface. In collaboration with the NWS, this research system functionality currently in the Office of Oceanic and Atmospheric Research will transition to NWS operations so that system reliability and maintainability can be ensured and sites expanded for use by NWS forecasters, the research community, and the private sector, as well as incorporated into the weather prediction models. In addition, the GPS-Met observations for water vapor, an important greenhouse gas, are sensor and model independent providing the consistency necessary to support long term monitoring of water vapor for climate applications and a reproducible climate quality data record. The near real-time water vapor measurements from GPS-Met are distributed to forecasters by the Meteorological Assimilation Data Ingest System (MADIS) which ingests, integrates, quality controls and distributes surface and supper-air observational datasets to the meteorological community. Among these datasets are an integrated surface mesonet database containing high-frequency, real-time observations from over 21,000 surface stations operated by over 150 different organizations, and an integrated profiler database with observations from 100 wind and temperature profilers operated by dozens of different agencies. MADIS is now ready to be transitioned to the NWS operations to provide reliable 24/7 data availability.

Figure 3-DOC-24. Altair UAS.

GSD also continues to move ahead in GOES R3 work in the areas of assisting in the transfer of product improvements to AWIPS, namely looking at current GOES moisture bias and seeing how this compares to GOES R synthetic data using MODIS. In addition, GSD is working with the Cooperative Institute for Research in the Atmosphere (CIRA) in the application of CloudSat data to verify GOES derived vertical cloud structure. GSD also conducts Observing Systems Simulation Experiments (OSSEs).

PSD and GSD will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. Efforts include developing tools and techniques to integrate the data from surface-based and satellite-borne profiling systems for more effective use of these data in forecasts. In support of this effort, PSD has an active satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

Icing is a weather hazard that occasionally causes aviation disasters, especially in winter. In-flight icing forms on wings and other exposed surfaces as an aircraft flies through clouds that contain super-cooled liquid water droplets. Leveraging earlier work with polarization-sensitive cloud radars, PSD designed a new ground-based cloud radar and radiometer system to monitor clouds in the vicinity of airports and to provide automated warnings of icing conditions aloft. This instrument is the Ground-based Remote Icing Detection System (GRIDS). In addition, GSD continues to perform research and analysis to improve aviation forecasts.

PSD, in association with the Center for Environmental Technology (CET) at the University of Colorado is developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds. PSD/CET is also investigating the possibility of measuring soil moisture by L-band radiometers.

Starting in 2003, PSD and GMD have been working together with the Canadian Meteorological Service and Canadian Network for the Detection of Climate Change (CANDAC) to re-establish a new Arctic Atmospheric Observatory at Eureka, Ellesmere Island, Canada, in North East Canada as a part of the U.S. SEARCH (Studies of Environmental Arctic Change) Program (SEARCH). The Canadian Observatory is being designed to mirror many of the cloud, aerosol and radiation measurements that are already made at the GMD Baseline Observatory at Barrow, Alaska, that has been in continuous operation for 33 years. Since North East Canada and Barrow, Alaska, are in markedly different Arctic regimes the long-term measurements from these sites will be complementary in providing information to monitor Arctic atmospheric changes. Long-term data from these sites will be used to improve short-term and long-term forecast models, and improve satellite measurement of meteorological phenomena in the Arctic regions. Along with the National Science Foundation, PSD and GMD are helping to refurbish a historic meteorological station and establish an Atmospheric Baseline Observatory at Tiksi, in the Russian Arctic. This would be the first station of this type in a region that spans 75 percent of the Arctic littoral. Meteorological data from this newly re-instrumented site will continue a century of data collection that had deteriorated since the collapse of the Soviet Union, and expand measurements to complement those collected at Barrow, Alaska, and Eureka, Canada. The high quality of the data to be forthcoming from the Tiksi station should considerably enhance Arctic weather prediction and Arctic climate models.

PSD is engaging in a comprehensive observation program to improve operational weather forecast and planned climate model treatments of boundary layer forcing processes. This work centers on development and application of observing technologies for surface fluxes and key boundary-layer variables (profiles of temperature, humidity, wind, and cloud properties). Ship-based measurement systems have been developed and are now used routinely on NOAA research vessels to investigate model accuracies in the marine boundary layer. Recently, land-based systems have been developed and deployed. One point of emphasis is linking observed cloud properties (obtained with mm-wavelength cloud radars and microwave radiometers) to cloud effects on surface turbulent and radiative fluxes (this approach is termed cloud forcing). Ship-based and satellite retrievals of cloud and flux properties are being used. PSD is compiling a large data base to allow climatologically-oriented studies of model parameterizations. Future plans include expanding the observational capabilities to add scanning mm-radar capabilities for investigation of precipitation initiation (a critical issue in triggering deep convection in model domains).

The PSD satellite applications group has developed new techniques for monitoring atmospheric properties over the ocean surface including air temperature and specific humidity. Retrievals of these quantities were improved through novel use of satellite atmospheric sounders in combination with passive microwave imaging radiometers. The products are being applied to improved global estimates of the flux of heat between the ocean and atmosphere. PSD is also producing a new satellite-derived sea surface temperature product through the blending of infrared and passive microwave data. The technique takes advantage of the complementary strengths of the two sensor types. The product has significant meteorological applications through its use as an input to numerical weather forecast and climate models.

The NSSL is known for its development of observational capability, both remote and in situ, and in particular for its role in the development of the WSR-88D NEXRAD radar. NSSL continues to improve the WSR-88D software algorithms used by the NWS forecasters and is exploring ways to enhance the WSR-88D hardware using dual polarization techniques under the NEXRAD Product Improvement (NPI) activity. NPI planning, guidance, and funding involves NOAA, DOT/FAA, and DOD/Air Force.

Most weather radars, including the WSR-88D NEXRAD radar, transmit radio wave pulses that have a horizontal orientation. Polarimetric radars (also referred to as dual-polarization radars), however, transmit radio wave pulses that have both horizontal and vertical orientations. The horizontal pulses essentially give a measure of the horizontal dimension of cloud (cloud water and cloud ice) and precipitation (snow, ice pellets, hail, rain) particles while the vertical pulses essentially give a measure of the vertical dimension. Since the power returned to the radar is a complicated function of each particle size, shape, and ice density, this additional information results in improved estimates of rain and snow rates, better detection of large hail location in summer storms, and improved identification of rain/snow transition regions in winter storms. The signal processing requirements for dual polarization required an initial step of deploying a new Radar Data Acquisition (RDA) unit for the WSR-88D capable of processing the polarimetric signals. The new RDA deployment was completed in 2006.

In 2020, the WSR-88D radars forming this NEXRAD network will be over 23 years old. In about the same time frame, most of the Nation's aircraft surveillance radars will be nearing the end of their design life. Decisions on replacing or repairing and upgrading these National radar assets must be made over the next 10 to 15 years. We are now on the threshold of a revolution in civilian radar capability, enabled by the adaptation of established military radar technology to existing civilian applications, plus new capabilities beyond what current systems can provide. Historically, civilian radars with large rotating antennas like the NEXRAD weather surveillance network and the aircraft surveillance radars used by the Federal Aviation Administration (FAA) evolved from military radar applications. During the past several decades, a new generation of military radars has matured. These electronically scanning phased array radars with no moving parts (rotating antennas) were originally developed to track multiple airborne objects such as aircraft and missiles simultaneously. The unique beam agility, increased resolution, and faster full-volume scan rate of phased array radar can enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

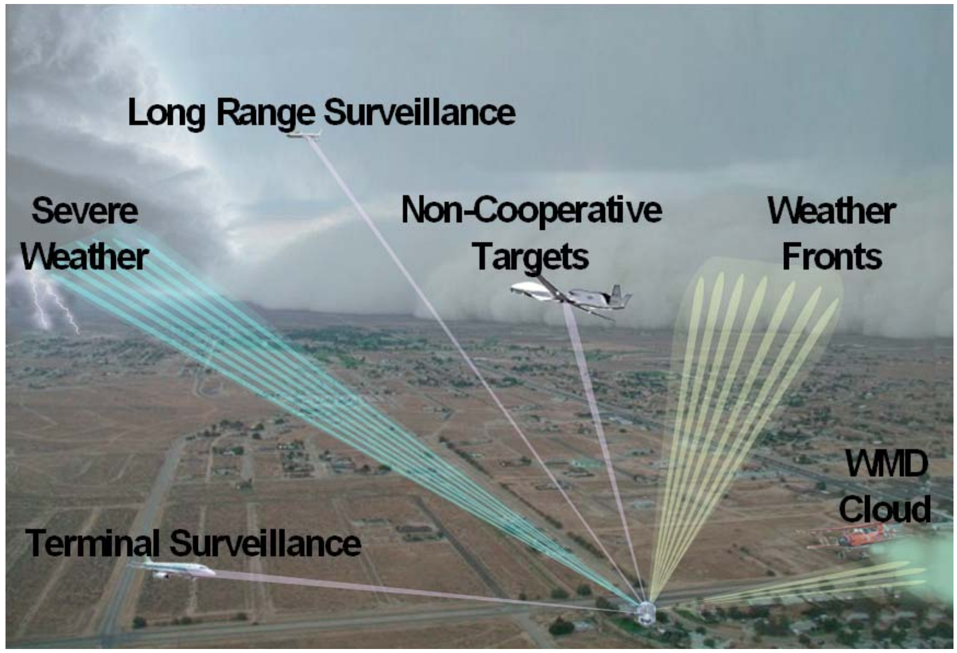

Figure 3-DOC-25. Electronically scanning phased array radars with no moving parts enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

Thus, a single network of multifunction phased array radar (MPAR) units could provide next-generation expansion of our current weather surveillance network, replace the Nation's aging air traffic surveillance radars, and meet homeland security and defense requirements for identifying and tracking non-cooperative craft operating over the U.S. homeland (Figure 3-DOC-25). MPAR will enable continued improvement of the Nation's severe weather warning system. It can provide adaptive sensing for warnings and nowcasts related to severe convective storms and the locally destructive effects of hurricanes (tropical cyclones) after they make landfall. Among the storm phenomena that could be tracked are tornadoes, strong wind gusts, hail, and locally heavy rains responsible for flash floods and mudslides. The enhanced weather surveillance provided by an MPAR network will provide economic benefits to domestic aviation and surface transportation systems. The agility and specificity of its multitasking beams will provide more detailed weather and atmospheric observations for urban meteorology, air quality nowcasts and forecasts, climate variability monitoring and forecasting, wildland fire monitoring and prediction, and atmospheric transport and diffusion modeling. The non-cooperative aircraft surveillance capability of an MPAR network would complement the cooperative surveillance strategy planned for the Next Generation Air Traffic System (NGATS), while also addressing new craft tracking requirements of the Departments of Defense and Homeland Security. While research at NSSL is establishing the proof-of-principle for new applications of weather radar in these and other areas, the adaptive flexibility of MPAR will be essential in transferring these promising radar techniques to operations.

Because an MPAR network would replace multiple existing networks, it offers an affordable option to the alternative strategy of continuing with the existing civilian radar capability by repairing and eventually replacing aging units. Due to technology breakthroughs in radio frequency components, fueled by the wireless telephony and digital communications industries, the cost of a key MPAR component-the transmit-receive elements in an MPAR antenna-has dropped by orders of magnitude over the past 5 years, and this trend should continue. For a number of reasons, the operations and maintenance costs for MPAR units appear to be a third area of substantial savings relative to continuing to repair and replace current radar units as they age.

Thus, with respect to both capabilities and cost, MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. Using multiple beams and frequencies that are controlled electronically, NSSL has demonstrated phased array radar reduces the scan time of severe weather from six minutes for NEXRAD radar to less than one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado warnings well beyond the current average of 13 minutes.

In support of improved understanding of the changing chemical composition of the atmosphere, the Field Research Division of the Air Resources Laboratory (ARL) has continued to refine its constant-level "smart" balloon. The smart balloon is intended to serve as a marker of parcels of air moving across the countryside and permitting samples to be made of the changes occurring in its composition. These balloons are being used both for air quality studies, such as the 2006 Texas study, and for hurricane research. The Field Research Division has also developed an Extreme Turbulence (ET) probe for measuring turbulence and surface fluxes in hurricanes. ET probes were successfully deployed into landfalling hurricanes in 2004, and plans are in place to eventually deploy them on moored NOAA buoys. The Oak Ridge Division of ARL continues to lead in the development of specialized sensors for measuring atmospheric turbulence. Their systems are now widely used for measuring the efficiency of coupling between the air and the surface, and have recently been selected for instrumenting the latest generation of research aircraft, manufactured in Italy. Future efforts will likely focus on instrumention of UAVs.

In addition to the many weather related observing systems, OAR also dedicates significant time to improving the development, deployment, and monitoring of oceanographic related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around the world, deploying some 900 new drifters annually and tracking approximately 1250 as part of the Global Drifter Program. Using research ships, ships of the Ship of Opportunity Program (SOOP), and United States Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified as operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution in real time to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, the Climate Program Office (CPO; housed within OAR), AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere as part of the Southern Hemisphere Drifting Buoy Program. The buoys measure atmospheric pressure at sea-level, air temperature, surface sea water temperature, and surface currents. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites. The buoys are a subset of the Global Drifter Program (see above).

NOAA supports measurements from thermosalinographs (TSGs) that are instruments mounted close to the water intake of research and cargo ships and that continuously measure the sea surface salinity and temperature along the track of the ship. AOML currently operates several TSG transects from three ships of the SOOP in support of the CO2 Observing System funded by the NOAA Climate Program Office. These TSG data will be used to calibrate and validate observations of the upcoming Aquarius NASA sea surface salinity satellite mission.

NOAA operates and maintains AMVER SEAS 2K, a Windows based real-time ship and environmental data acquisition and transmission system. The AMVER software creates a series of reports that describe point of departure, route, and arrival of a ship. The meteorological reports are transmitted using Standard-C and include ships in a real-time search and rescue database used by the U.S. Coast Guard. The SEAS 2K software acquires atmospheric and oceanographic data and transmits the data in real-time to the GTS and to operational databases to be used by scientists. SEAS 2K is employed on ships of the Volunteer Observing System (VOS), SOOP, and on NOAA, UNOLS, and U.S. Coast Guard vessels. SEAS 2K is now installed on more than 400 ships of the VOS and SOOP, and over 200,000 AMVER SEAS meteorological messages are transmitted per year and inserted into the GTS.

AOML operates a global XBT Program that utilizes approximately 30 ships of the SOOP and collaborates with international institutions that operate another 30 ships to monitor the global upper ocean thermal structure. This includes low and high density deployment modes. TSG and XBT data are placed in real-time onto the GTS and are being used to initialize weather and climate forecast models.

Together with NOAA/PMEL, Brazil, and France, AOML contributes to the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, inter-annual and longer time scales. We recently deployed four ATLAS moorings as the eastern extension of the PIRATA array. The moorings were built by PMEL and are similar to those deployed in the Pacific. Planned expansion of the PIRATA array into the hurricane genesis region of the Atlantic will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation.

In an effort to better understand and forecast climate, OAR has been deploying a global array of profiling floats since 2000. The broad-scale global array of temperature/salinity profiling floats, known as Argo, has already grown to be a major component of the ocean observing system with an intended deployment of 3000 floats. Argo floats are free-drifting profiling floats that spend most of their life "parked" at 1,000 or 2,000 meters depth in the ocean, regularly surfacing to make temperature and salinity profile measurements and providing those observations in real-time. As of June 2007, 2856 Argo floats have been deployed (95% complete). AOML is the U.S. Argo Data Assembly Center and the South Atlantic Argo Regional Center, in charge of all U.S. Argo deployments in the Atlantic. The Argo array is part of the Global Climate Observing System/Global Ocean Observing System GCOS/ GOOS) and is a major contributor to the WCRP's Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). Along with satellites, Argo provides a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.

The Tropical Atmosphere Ocean/TRIangle Trans-Ocean buoy Network (TAO/TRITON) array consists of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the ARGOS satellite system (Figure 3-DOC-26). Designed to improve detection, understanding, and prediction of El Niño, TAO/TRITON is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported by the United States (NOAA) and Japan (JAMSTEC), with JAMSTEC responsible for the TRITON moorings west of 165 degrees E longitude and NOAA responsible for the 59 moorings along and east of 165 degrees E. Responsibility for maintaining the TAO Array has been transferred to the NWS/National Data Buoy Center, and the Pacific Marine Environmental Laboratory (PMEL) continues to be involved by providing the instrumentation for the TAO surface moorings. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe.

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-

Figure 3-DOC-26. One of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean.

atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales. The PIRATA Array consists of 20 ATLAS moorings similar to those deployed in the Pacific, including moorings established within the hurricane genesis region of the Atlantic, which will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation.

A third research array, the Indian Ocean Moored Buoy Array, was initially established in 2000 by Japan, and later joined by India, the United States, Indonesia, and France. The U.S. contribution to this array utilizes PMEL's ATLAS moorings, similar to those in the Pacific TAO and PIRATA Arrays. The Array continues to expand toward its eventual goal of 47 sites and is designed to conduct research on the seasonal monsoonal variability in the Indian Ocean, its interactions with ENSO, and the Indian Ocean Dipole, an El Niño-like phenomenon in the Indian Ocean.

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As part of the backbone for the Integrated Ocean Observing System (IOOS), OAR supports the national ocean observation backbone through 29 deployed or planned operational ocean moorings as part of the Ocean Reference Station network. The operational ocean moorings provide measurements of high quality air-sea fluxes of heat, moisture, and momentum that will be used to make regional assessments of flux components from numerical weather prediction models and satellites. A partnership with the National Science Foundation's ORION program will greatly enhance the capacity of the network.

HIGH IMPACT WEATHER RESEARCH

In addition to research and development of observing systems and related technology, OAR also focuses on ways to improve our understanding and the predictability of severe weather systems and their associated hazards. Providing significant national leadership in this area, the National Severe Storms Laboratory (NSSL) focuses on research to better understand such hazards as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms with the goal of helping the National Weather Service (NWS) improve forecasts and warnings. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. NSSL's research includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, with a focus on research and development, for the NWS WSR-88D radar program. In 2007, NSSL continued to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public.

NSSL's vision for the warning decision process continues to evolve as scientists and engineers work toward integrating the next generation radar (MPAR) and storm-scale numerical models to create a storm-scale prediction capability for the National Weather Service. While it is not possible today, within the next decade NSSL envisions operational units using a "Warn on Forecast" methodology, e.g., a forecaster will use thunderstorm-resolving computer models for severe weather warnings in the same way as he/she does today with the current Doppler radar systems. NSSL believes that these enhancements to the operational weather capability will lead to a more accurate warning system which increases lead time and provides probabilistic information that enables the public to take the best reasonable action during a severe weather event.

During the spring and summer of 2006, NSSL conducted the Severe Hail Verification Experiment (SHAVE) with the goal of testing new technologies that will vastly improve the verification of severe weather events, as well as the climate record of those events (Figure 3-DOC-27). SHAVE researchers documented hail swaths from severe thunderstorms at a high spatial and temporal resolution by integrating real-time meteorological data into Geographic Information Systems (GIS). This integration permitted the SHAVE team (NSSL/CIMMS scientists and U. of Oklahoma students) to make verification phone calls to very

Figure 3-DOC-27. Photo taken May 11, 1982, by NSSL storm intercept team in the hail core of a supercell thunderstorm that later produced an F2 tornado.

specific locations. Rather than an average of 1-2 hail reports collected from each storm, SHAVE collected anywhere from 10-100 reports along the storm's paths at a much higher spatial resolution and with fewer time and space errors than in the official storm climate record (the Storm Data publication). Better verification data such as these are vital to future improvements to the warning process. These high-resolution data sets enable:

1. validation of new probabilistic warning techniques that would not otherwise be possible given the typically coarse spatial resolution of the severe event reports in Storm Data,
2. enhanced, independent verification of warnings issued by the National Weather Service, and
3. validation of high-spatial and temporal resolution hail detection tools.

NSSL works with the Federal Aviation Administration's (FAA) Aviation Weather Research Program (AWRP) to develop weather radar applications that enhance the safety and efficiency of the aviation community and the National Airspace System. Work is focused on both convective weather and winter weather, with special attention to treating all WSR-88D radars within the continental United States as a single network. Such treatment allows NSSL to produce a single, authoritative 3-dimensional grid of radar data. Intensive research is also directed to polarimetric radar applications unique to aviation needs. Examples include winter time quantitative precipitation estimation, detection of icing conditions, and data quality issues unique to FAA users.

Leveraging the technology developed for the SHAVE project, NSSL invited the public to assist in collecting data for a winter field project called the Winter Hydrometeor Classification Ground Truth Program. The response was overwhelming. Volunteers were asked to report their exact location and time, and what kind of winter precipitation they were observing (rain, freezing rain, snow, sleet/ice pellets, drizzle, freezing drizzle, graupel or snow grains) through a link on NSSL's Website. Over 2500 observations of winter precipitation around central Oklahoma were reported since the project began with the first winter storm of the year at the end of November.

The information collected from the public will be compared with winter precipitation data measured by dual-polarized Doppler radar. The project will help NSSL researchers refine and develop winter precipitation radar techniques and products. The call for volunteers first went out to schools, and was expanded to include the entire public. Local broadcast meteorologists and newspapers spread information about the need for volunteers, and the Norman National Weather Service Forecast Office provided announcements on NOAA weather radio and a link to the project Web site from their home page.

Researchers estimate they have data from 300 to 400 different locations, with more than half of the reports coming from the Oklahoma City metro area. These observations closer to the radar are especially valuable because the radar beam is still low enough to the ground to capture the characteristics of what the observers report. Volunteers were asked to check NSSL's home page for the "Project Status." When the project was "Active," they could spend as little or as much time as they wanted making observations. Not only did involving the public in data collection provide additional observations for NSSL researchers, it also was an effective way to increase awareness of winter weather hazards, winter weather safety and NSSL's efforts to improve techniques that identify these hazards.

The NSSL is collaborating with the NWS Office of Hydrologic Development (OHD) and the Office of Climate Weather and Water Services in the development, testing, and research-to-operations of a 'state of the science' approach to quantitative precipitation estimation (QPE) and short-term precipitation forecasts (QPF). The goal of this cross agency collaboration is to increase warning lead times for the detection and prediction of flash floods and river flooding. This effort is part of the Advanced Hydrologic Prediction Services (AHPS), which is an essential component of the NWS Climate, Water, and Weather Services. The research and development into QPE and QPF is being afforded by a Federal Aviation Administration and National Centers for Environmental Prediction collaboration towards the integration of radar networks into seamless high-resolution three-dimensional mosaics for use in aviation safety and atmospheric model data assimilation. NSSL has established the infrastructure and techniques for ingesting domestic and international weather surveillance radars, along with integrating satellite and surface observations, to facilitate research and development toward advance monitoring of the Nation's fresh water resources. The vision and objectives of the research is to improve the capability to effectively manage the Nation's fresh water resources and to mitigate the social and economic impacts of flooding through timely and accurate detection and prediction of precipitation.

NSSL continues to lead a project called CI-FLOW (Coastal-Inland Flood Observation and Warning) that uses NSSL's multi-sensor rainfall estimates to drive an NWS distributed hydrologic model that predicts streamflow to help NWS improve flash flood warnings. CI-FLOW is the primary component of NOAA's new Integrated Water Resource Services project called Coastal, Estuary Resource Information System (CERIS). In addition to the streamflow prediction, streamflow data from predictive models are used to drive three models run by academic collaborators at N.C. State University, a water quality model, estuarine model, and storm surge model. This system of coupled models, when fully integrated, can be used for land-use studies, algal bloom studies, pollution studies, inundation studies of land-falling tropical systems, for example.

NSSL is participating in NOAA's Hydrometeorological Testbed or HMT. The HMT is a NOAA-led research activity with several external partners (e.g., universities, water management groups, etc.). The objective of the overall HMT program, of which HMT-West is the first full-scale deployment, is to accelerate the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service and its River Forecast Centers. The research activities in HMT-West this year focused on deployment of NSSL's SMART-R radar system to observe heavy rainfall events over the American River Basin near Sacramento, California. Several storm systems were observed and unprecedented data sets were collected in FY2006 and FY2007.

NSSL has been working with U.S. Geological Survey (USGS) and NWS scientists to improve the debris flow warnings for Southern California. Recent fires in the foothills can lead to devastating debris flows (mudslides) when subsequent storms deposit relatively modest rains on those foothills. The USGS instrumented a burn area in 2006 (the Harvard fire region near Burbank California) and one in 2007 ("Day Fire") for high resolution studies in order to refine the warnings thresholds. NSSL contributed a mobile radar to make high-resolution radar estimates of precipitation over the Harvard burn area in 2006 and Day Fire area last winter. Five rainstorms were observed in 2006, of which 2 produced moderate debris flows. In 2007, unfortunately, La Nina conditions resulting in the driest winter on record resulting in very little useful data.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. GSD develops and evaluates decision tools for forecast office environments, including commercial and civil aviation. Specifically, GSD has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. GSD has developed an AWIPS thin client capability, FX-Net, which is used extensively by the NWS Incident Meteorologists in the field and agencies responsible for wildland fire fighting.

FX-Collaborate is an AWIPS capability developed by GSD that allows forecasters in different geographical locations to interact in real-time to develop a forecast. FX-Collaborate is being used to support decision aids for aviation weather (Volcanic Ash Coordination Tool, FAA traffic management units coordination) and for weather effects and early warnings in response to homeland security events (Geo-Targeted Alerting System and UrbaNet). NSSL is collaborating with NWS and GSD to integrate some of NSSL's advanced single and multi-radar display capabilities into AWIPS.

GSD will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Aircraft Communications, Addressing, and Reporting System (ACARS); Tropospheric Aircraft Meteorological Data Relay (TAMDAR), WSR-88D Doppler radars; and weather satellites, especially Geostationary Operational Environ-mental Satellite (GOES), are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more fully exploited in the Local Analysis and Prediction System (LAPS) which employs conventional analysis methods and 3-D variational methods (GSI and STMAS) to provide highly detailed analyses and coupled numerical models (WRF-NMM and WRF ARW) to provide forecasts over areas hundreds of kilometers on a side. Efforts include methods for surface boundary detection and tracking, convective initiation, and heavy rain forecasting with a hydrologic emphasis. LAPS has been installed for use in the U.S. Space Centers and in a number of DOD programs. GSD is working with the Department of Homeland Security to implement a high resolution forecast and dispersion system for major urban areas. LAPS is an integral part of an emerging wild fire forecasting system that assimilates airborne and ground sensor data and make short range predictions of the atmosphere in the vicinity of the fire.

GSD has been a collaborator in the NOAA HMT conducted in the American River Basin in Central California from 2005 to the present. This has involved configuring high resolution ensembles, probabilistic quantitative precipitation forecasts, evaluation, and de-biasing and calibration to better frame the uncertainty in heavy rain events. This has applications in warning on forecast and integrating into decision aids. Over the last two years 18 intensive observing periods have been supported and forecasts verified. The program has demonstrated the ability to produce high resolution probabilities in operationally critical thresholds of 1-2 inches in 6 hours for the west slope of the Sierras.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, forecast and warning improvements, and heavy rainfall events; much of the transfer is through courses at the NWS training center and through the Hazardous Weather Testbed at the new National Weather Center in Norman, OK. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and NSSL is participating directly in training programs, such as COMET in Boulder, Colorado, and the WSR-88D Operational Support Facility in Norman, Oklahoma.

Coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). Emphasis has shifted from the study of terrain effects on West Coast weather to coastal wind and air-sea interaction research in the Gulf of Alaska. Research partners include the NWS Forecast Office in Juneau, AK, with financial support for the research being provided by NSF and NOAA/NOS through the GLOBEC program.

MESOMETEOROLOGY AND PRECIPITATION FORECASTING AND WARNING RESEARCH

In support of NOAA's goal of protecting lives and property, OAR contributes to the development of techniques to improve short term forecasters of significant weather events. Through detailed case studies and regional climatologies, National Severe Storms Laboratory (NSSL) scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storm complexes. Field programs were carried out and followed by extensive analyses were conducted to improve the science behind technology advances. Example programs whose data have been and continue to be analyzed include:

- the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000,
- the International H2O Project (IHOP),
- the Thunderstorm Electrification and Lightning Experiment (TELEX) 2003 and 2004, and
- the annual collaborative severe storm research by NSSL, the NWS/SPC, the Norman Weather Forecast Office, and collaborators through the Hazardous Weather Testbed Spring experiments.

Other NSSL studies underway are focused on the precipitation structure of large storm systems (mesoscale convective systems), the interactions between meso-convective systems and the larger environment, the use of satellites to infer storm development and rainfall, short-range ensemble forecasting techniques, and winter storm forecasting procedures. Findings from these research activities lead

to supporting the forecasting of a variety of high impact weather events.

NSSL will continue to investigate various model convective parameterization schemes, along with techniques to improve model initialization through four-dimensional data assimilation. Advances continue in numerical simulation and forecasting at mesoscale and stormscale resolutions. Current research is using data assimilation by ensemble Kalman Filter method, as well as lightning data assimilation, to improve forecasting of convection. At stormscale, pure simulation is also employed for improving understanding of dynamics, microphysics, and lightning. Toward the goal of improving operational mesoscale model and human forecasts of storms and their environments, NSSL researchers investigate the convection initiation (CI) process and the types of observations required to represent CI and storms in both research and operational mesoscale analysis and forecast model systems.

In 2002, NSSL contributed expertise and ground-based mobile radar, mobile mesonets, and mobile sounding observations during the International H2O Project (IHOP) conducted on the U.S. Southern Great Plains (SGP). The chief aim of the 2002 IHOP campaign is improved characterization of the four-dimensional (4-D) evolution of water vapor and boundary layer (BL) structure with application toward improving the prediction of convective storms. The SGP region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active storms and convective systems providing most of the warm season precipitation east of the Rocky Mountains. Recent studies report a new method for objectively combining diverse radar and in-situ measurements to obtain internally consistent analyses of BL evolution and cloud formation with application to cases that illustrate the impact of drylines and cold fronts on the CI process. Given sound conceptual models of the CI process, forecasters in turn can interpret available observations more precisely to improve specificity and accuracy of storm forecasts. Another recent study reports the potential improvement of mesoscale model initialization via the assimilation of all types of real-time total and cloud-to-ground lightning observations to improve representation of ongoing convection and its integrated effects on model initial conditions.

NSSL has also made advances in interpreting lightning data in forecasting. This information will point to new ways for the National Weather Service to use lightning observations to improve forecasts and warnings of hazardous weather. NSSL operates state-of-the-science facilities that include the KOUN radar in Norman, which is a WSR-88D radar modified with polarimetric parameters to provide information about the particle size and water phase of precipitation and the Oklahoma Lightning Mapping Array (LMA). The OK-LMA is a network of 11 stations in central Oklahoma that continuously maps in high space and time resolution the structure of all types of lightning in three-dimensions out to a range of 75 km and in two-dimensions out to a range of 200 km. All the technology advances and research findings are aimed at NSSL's contribution to advances in forecasting high-impact weather events.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve the nation's ability to forecast severe weather and to enhance severe winter weather guidance products. Data collected during the IPEX campaign held in 2001 should help. The data are being analyzed by NSSL, SPC and University of Utah scientists. The IPEX field and research program was designed to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain. In addition, the SPC/NSSL collaboration has led to improvements in the way we understand convection initiated near the dryline and tornadoes spawned by hurricanes. A major forecast challenge for SPC forecasters is severe weather from elevated convection. Recent collaborative research shows the spatial and temporal distribution of such severe weather reports and begins to provide insight into processes that would improve our ability to forecast these events.

NSSL has developed a unique and vibrant collaboration with the operational forecasting community, which has recently been formalized with the establishment of the NOAA Hazardous Weather Testbed (HWT). The mutual interests of forecasters from the NOAA Storm Prediction Center, researchers from NSSL, and collocated joint research partners from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) inspired the formation of the HWT. The testbed's activities have been varied, including activities such as daily map discussions involving imminent severe weather, loosely-related research projects involving 2-3 collaborators, and periodic intensive collaboration periods with larger groups. But the cornerstone of the testbed has been the SPC/NSSL Spring Program, a series of annual experiments that attracts 50-60 researchers and forecasters to Norman each year.

The premise of each Spring Experiment is to provide forecasters with a first-hand look at the latest research concepts and products, while immersing research scientists in the challenges, needs, and constraints of front-line forecasters. In practice, this program gives forecasters direct access to the latest research developments while imparting scientists with the knowledge to formulate research strategies that will have practical benefits. The end result is not only better severe-weather forecasts, but important contributions to the scientific literature as well. Science partners in recent Spring Experiments have included NCAR, NCEP/EMC, OU/CAPS, and numerous academic centers.

The Norman meteorological community consolidated its diverse workforce into a common building in 2006. Numerous groups are adopting the collaborative spirit and innovative approach of the HWT. At the same time, the HWT is expanding to embrace these groups and provide the framework for development and implementation of new technologies in different areas, particularly those focusing on shorter-timescale forecasting challenges. For example, NSSL's Severe Weather Warning Applications and Technology Transfer (SWAT) team and the NWS Norman WFO are stepping into important leadership roles within the HWT.

NSSL anticipates that the proof of concept established through the annual NSSL/SPC Spring Experiment and the early years of the HWT will play an important role in bringing together the diverse elements of the Norman meteorological community and like-minded meteorologists from across the country. In fact, Congress recently provided seed funding to help foster a collaboration between the HWT, the University of Alabama at Huntsville, and NASA's Short-term Prediction Research and Transition Center (SPoRT), a joint center staffed by NASA research meteorologists also located in Huntsville, and the Huntsville WFO. The group in Oklahoma is being referred to as HWT/Norman and the groups in Alabama are being referred to as HWT/Huntsville. The HWT/Norman has decades of experience on severe weather and tornadoes characteristic of the central plains (long-lived supercell thunderstorms, for example), while the HWT/Huntsville has experience with the severe weather and tornadoes that are characteristic of the southeast U.S. (especially those spawned by land-falling tropical systems). Working together, we believe these groups will strengthen the nation's collective knowledge and understanding of these hazardous convective events, leading to significant contributions to the science and improved severe-thunderstorm and tornado watches and warnings for the public.

NSSL has been on the forefront of short-range ensemble forecasting and exploring the use of ensembles for forecasts of severe weather. During the summers of 2002 through 2004, NSSL was a partner in the New England High-Resolution Temperature Program. The role of NSSL was to provide several model forecasts and collect forecast data from NCEP and FSL and develop post-processing techniques to improve upon Model Output Statistics. A simple yet powerful bias correction approach was developed in which the past 12 days of model data and observations are used to bias correct today's forecasts. Results indicate that the bias-corrected ensemble forecasts improve upon MOS and also provide reliable probabilistic forecast information. In addition, a novel approach to providing reliable probabilistic quantitative precipitation forecasts was developed and tested. In 2003, NSSL in partnership with the SPC embarked on an experiment to test the value of human forecasters in creating ensemble initial condition perturbations. Results indicate that human-generated ensemble perturbations can contribute positively to ensemble skill for severe weather events, indicating that the knowledge and experience of forecasters needs to be put to better use as we learn how to design ensembles for a variety of end users. With ensembles a regular part of the NCEP operational suite, approaches such as bias correction and human- generated ensemble perturbations as crucial to making best use of the model forecast data for both routine and severe weather forecasts.

Mesoscale dynamics research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey, develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. Current research focuses on extending these activities to the global domain through state-of-the-art global atmospheric models. High resolution mesoscale and regional models provide a key scientific tool to explore, verify, and validate parameterizations of unresolved processes such as convective and stratiform precipitation in the global models.

In 1994, the Global Systems Division (GSD) of ESRL implemented a Rapid Update Cycle (RUC) model at the NWS National Centers for Environmental Prediction (NCEP) and continues to provide periodic follow up upgrades. The RUC provides a new analysis of surface and atmospheric conditions every hour as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in 2005. The 13-km version of NOAA's Rapid Update Cycle (RUC13) model became operational at 1200 UTC Tuesday, 28 June 2005, at the National Centers for Environmental Prediction (NCEP). This is a major milestone for improving the RUC high-frequency short-range forecasts for NOAA and external users, especially for aviation and severe weather forecasting. The main changes include higher horizontal resolution (from 20km to 13km), improved data assimilation especially for moisture/cloud fields, and improved cloud/precipitation physics. Most notable improvements are in surface and cloud/precipitation forecasts, resulting in part from assimilation of new observation types in the RUC13. GSD conducted assessments with new observation types to consider potential operational assessment at NCEP including wind profilers, GPS-Meteorology precipitable water, TAMDAR data, and METAR ceiling/visibility. The model updates every hour, incorporating information from virtually all high frequency data sources:

- hourly wind profiles;
- WSR-88D (Doppler radar) velocity azimuth displays;
- ACARS reports (up to 65,000 per day);
- cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites; and
- surface observations

Along with NCAR, NCEP, and the university community, GSD has collaborated on the development of the Weather Research and Forecast (WRF) model. The WRF model has become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry. GSD will replace the RUC with the WRF Rapid Refresh model by 2009, updated hourly and extended to Alaska, Puerto Rico, and the Caribbean Sea.

GSD scientists lead work with other scientists from NOAA/ESRL toward development of a new global model including use of the adaptive isentropic-sigma hybrid vertical coordinate successful with the RUC model, accurate finite-volume horizontal advection, and use of an icosahedral horizontal grid. ESRL is collaborating with NCEP/EMC and GFDL on development of the FIM model (Flow-following Finite-volume Icosahedral Model).

The Air Resources Laboratory (ARL) is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. To this end, ARL continues to work closely with the Chemical Sciences Division (CSD) of ESRL to maintain the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as the Eta model) and satellite outputs. ARL conducts research on the surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos, industrial enterprises, and nuclear accidents. In recent work, ARL is adapting a new system developed to forecast dispersion of smoke from forest fires, in a study performed in collaboration with the Association of South East Asian Nations, the U.S. Forest Service, and The Mediterranean Centre for Environmental Studies Foundation. The present program will provide interim products to the joint NOAA-EPA Air Quality Forecasting Program to improve smoke dispersion estimates in the particulate forecast model.

TROPICAL ATMOSPHERIC RESEARCH

The Tropical Dynamics and Climate Program of the ESRL Physical Sciences Division (PSD) is using precipitation profilers to study the structure, evolution and variability of precipitating cloud systems in the tropics and elsewhere. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. A recent focus of research with profilers has been to provide ground validation research in support of satellite precipitation measurement missions such as the NASA Tropical Rainfall Measuring Mission (TRMM). These observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during TRMM Ground Validation field campaigns. The observations made during the field campaigns are the subject of collaborative research with other TRMM researchers with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team. Validation of drop-size distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite data. The profiler-based precipitation research described above also can be used to provide calibration of NEXRAD scanning radars as has recently been demonstrated for Melbourne, Florida. In related activities PSD is carrying out hydrometeorological studies in collaboration with the NWS in demonstrating the value of hydrometeorological testbeds as a means of improving the transition of scientific advances to operations.

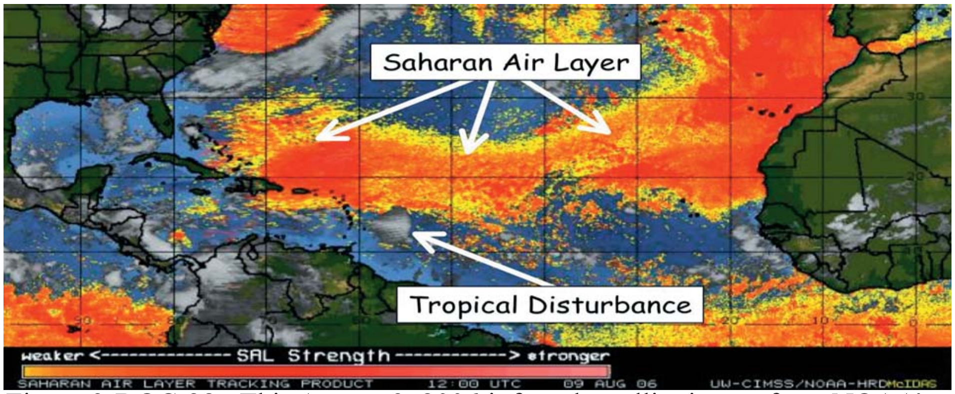

Figure 3-DOC-28. This August 9, 2006 infrared satellite image from NOAA's GOES satellite shows a Saharan Air Layer (SAL) outbreak (yellow to red shading) spanning nearly 4,000 miles across the North Atlantic. A tropical disturbance is indicated along the southern periphery of the SAL and was likely being suppressed by the SAL's dry dusty air and strong mid-level winds.

HURRICANE ANALYSIS AND PREDICTION RESEARCH

The Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division (HRD) mission is to advance the understanding and prediction of hurricanes and other tropical weather. HRD's research is based on a combination of models, theories, and observations, with particular emphasis on the utility of the data obtained with research aircraft. The goals of this research are to:

1. Advance the prediction of tropical cyclone intensity change by improving understanding of the processes that modulate internal storm dynamics and storm interactions with the atmosphere and ocean;
2. Improve the prediction of tropical cyclone tracks by enhancing understanding of the interactions between a tropical cyclone and its environment through an optimal analysis of field observations;
3. Improve the understanding of and ability to predict tropical cyclone frequency and intensity on intraseasonal, interannual, decadal and longer time scales; and
4. Enhance the ability to diagnose and predict the impact of tropical cyclones on life and property through wind, rain, waves, and storm surge.

These goals are accomplished by:

1. designing and conducting research experiments in the hurricane to collect and provide data for research, and operational applications;
2. analyzing these data sets and publishing the research in the refereed literature;
3. developing new technology and applications based on this research to improve NOAA's products;
4. developing and testing hurricane models to improve models' ability to simulate nature, improve forecasts, and to optimize hurricane observing through the use of observing system simulation experiments (OSSEs), and
5. providing outreach to the public through the WWW, conferences, presentations, and other means.

Much of HRD's research is based on the in situ and remotely-sensed observations in the inner core of tropical cyclones and their surrounding environment9Figure 3-DOC-28). These observations are primarily collected in NOAA's annual field program using the two NOAA turboprop aircraft and jet operated by the NOAA Aircraft Operations Center (AOC). The field program is used to carry out scientific experiments designed to address the goals stated above. Data sets gathered by these experiments, combined with dynamical and statistical models and theoretical development, range from global to microscale, forming the cornerstone of research in HRD. Because of this extensive field experience, HRD scientists are recognized internationally for their knowledge of tropical cyclones as well as their expertise in technological areas such as airborne Doppler radar, dropsondes, cloud microphysics, and air-sea interaction, to name a few. These assets make HRD unique worldwide, and provide NOAA a unique capability.

HRD coordinates its programs with other NOAA organizations, e.g., NOAA's Aircraft Operations Center (AOC), NESDIS, and NCEP, in particular with EMC and NHC. HRD maintains active research programs with, and receives funding from other governmental agencies, in particular, the Department of the Navy's Office of Naval Research (ONR) and the National Aeronautics and Space Agency (NASA).

In program areas where it is beneficial to NOAA, HRD arranges cooperative programs with scientists at the National Center for Atmospheric Research, and at a number of universities.

Under the USWRP and its participating agencies, OAR, NWS, and NESDIS established a Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida, in 1999 (http://www.nhc.noaa.gov/jht/index.shtml). This testbed is where the hurricane research is evaluated for operational use and those research products passing the test will be handed off to operations.

NUMERICAL ANALYSIS AND PREDICTION MODELING

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Climate Dynamics and Prediction, Weather and Atmospheric Dynamics, and Atmospheric Physics and Chemistry.

The Goal of the Climate Dynamics and Prediction Group is to develop and use computer models of the atmosphere-ocean- ice-land system in order to:

• identify and elucidate the physical and dynamical mechanisms which maintain climate and cause its variations on seasonal to centennial time scales

• assess and understand the predictability of the climate system on seasonal and longer time scales, including the El Niño phenomenon

• evaluate the impact of human activity on the Earth's climate system

This group is charged with studying and modeling climate phenomena on seasonal to multi-century time scales. The group's work is highly relevant to key elements of the NOAA Strategic Vision, especially Mission Goal 2 to "Understand climate variability and change to enhance society's ability to respond". In addition to examining a wide range of climate time scales, various members of the group have expertise spanning the expansive set of complex and interconnected parts that together constitute the Earth's physical climate system (this includes the atmosphere, ocean, land surface and sea ice). Group members participate in the development, testing, application, and analysis of numerical models of the climate system. Running on supercomputers, these models are the research tools used by group members to both advance our understanding of the Earth's climate system and to generate products relevant to assessment and policy decision support.

The Weather and Atmospheric Dynamics Group at GFDL improves our understanding of atmospheric circulations ranging in scale from hurricanes to extratropical storms and the general circulation, with an emphasis on extreme weather events and the interplay between weather phenomena and climate variability and change, using high resolution atmospheric modeling as the central tool. This effort is augmented by the Atmospheric Physics and Chemistry group, which performs research to improve our understanding of the interactive three-dimensional radiative-dynamical-chemical-hydrological structure of the climate system from the surface and troposphere to the upper stratosphere and mesosphere on various time and space scales. This is achieved by employing meteorological observations in conjunction with models for diagnostic analyses of atmospheric processes, and evaluating and improving parameterizations employed in weather and climate models; modeling the interactions between clouds, convection, radiation and large-scale dynamics to understand their roles in climate and climate change; and modeling the physics, chemistry and transport of atmospheric trace gases and aerosols to investigate the impact of future emissions on regional and global air quality, and to investigate the regional and global climatic effects due to changes in natural and anthropogenic radiatively-active species.

Together, these groups use the models to address problems of critical interest to the Nation. For example, there is now a very high degree of confidence that anthropogenic effects have already altered the climate system and that this forcing will increase in the coming decades. At the same time, insurers are abandoning hurricane insurance markets, and infrastructure is being built or rebuilt in areas vulnerable to sea-level rise and hurricanes at the same time sea-level rise seems to be accelerating and hurricane activity is high. Water resource management, urban planning, and agricultural decisions are being made even as observations and models suggest the potential for persistently drier conditions. The trend towards an ice-free Arctic has major social, economic, and policy implications, as well as the potential to accelerate global warming. Energy technologies that might affect global change need to be examined. The Nation must plan for the geopolitical challenges of global warming, because many of its most severe effects are expected in regions where fragile governments are least capable of responding to them.

To prepare for and confront these effects, an understanding of the regional impacts, the role of extreme events and abrupt change, and their interactions with natural variability are being developed so that decisions can be made with the best possible scientific information. Over the last half century in general and the last few years in particular, NOAA's Geophysical Fluid Dynamics Laboratory has demonstrated world leadership in pushing the boundaries of climate prediction. Through direct participation in producing the Intergovernmental Panel on Climate Change 2007 Assessment and the Administration's Climate Change Science Program Synthesis and Assessment Reports, GFDL's premier climate science capacity and recent investment in computer model infrastructure allow NOAA deliver essential climate forecast information at the regional and local level and provide an invaluable and unique opportunity for the Nation to make critical progress in global change science.

AIR QUALITY RESEARCH

The principal mission of the Air Resources Laboratory (ARL) is to

improve the capability to forecast changes in air quality and atmospheric deposition. Deposition is the factor that links the pollutant characteristics of the air with the terrestrial and aquatic environments. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media-- aquatic, terrestrial, and biospheric. The core of ARL research relates to studies of the atmosphere as a component of the total environment. Much of this work is in collaboration with other parts of NOAA (principally NCEP) and with other agencies, such as EPA, DOE, and the DoD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards, and for the provision of ozone and particulate matter forecasts in support of the joint NOAA-EPA Air Quality Forecasting program.

The ARL Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. Recent efforts have focused on the air-surface exchange of mercury in polar and coastal environments and of nitrogen (both oxidized and reduced) over agricultural soils.

The ARL Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The ARL Special Operations and Research Division (SORD) in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency prepared-ness and emergency response activities. ARL participates in two national networks that direct research attention on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-developed Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. ISIS and SURFRAD are presently operated by Global Monitoring Division (GMD) of ESRL. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing an air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. ARL also provides forecast support to NOAA's emergency response systems with emphasis on chemical, nuclear, and volcanic events. For this application, ARL develops and couples advanced dispersion models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. The models in question are now widely accepted. The Hazardous Atmospheric Release Model (HARM) is operationally employed at a number of DOE locations. The ARL Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model is now operational in many countries, including China and Australia, as the national dispersion forecasting capability. It also serves the NWS in this role. Registered users can also access HYSPLIT products via the Internet. HYSPLIT is the major product employed in the operations of the Regional Specialized Meteorology Center (RSMC) set up as a joint undertaking of ARL and NCEP under the auspices of the World Meteorological Organization (WMO). The WMO/ RSMC is the source of dispersion products in the event that a pollution plume (in this case, radioactive) crosses international boundaries.

The provision of dispersion forecasts by ARL scientists extends to two specific areas of special relevance - the Nevada Test Site and the Idaho National Laboratory. ARL maintains staffs of dedicated dispersion meteorologists at each location, where site-specific models are developed and run using data generated by dedicated regional networks of meteorological sensors. These sites also serve as research testbeds for improving ARL's dispersion models, such as the HYSPLIT model.

Each of ARL's divisions also participates in a cooperative agreement designed to explore the synergy that can be accomplished by collaboration between the government and private industry. The focus is the use of private sector data to address homeland security threats and potential local accidental events, as well as protection of the general population through the provision of better data in response to weather and climate related events. The intent of the program is to address threats where most of the population lives - in cities - exploring the use of the large non-government database that is available to most cities for use in the next generation of computer models.

The Chemical Sciences Division (CSD) of ESRL coordinates the Health of the Atmosphere air quality research effort. NOAA's Health of the Atmosphere research is focused on the atmospheric science that underlies regional and continental air quality, with the goal of improving our ability to predict and monitor future changes, leading to improved scientific input to decision-making. CSD, ARL, GMD, GSD, PMEL, and PSD participate in the research. The Health of the Atmosphere research goals are to:

• characterize regional ozone and particulate matter (PM) episodes;

• characterize the factors that cause poor air quality in regions of the U.S. where excessive levels of ground-level ozone and fine particle pollution are occurring.

In the summer of 2006 a, major field study was carried out to characterize air quality in New East Texas. Ground-based measurements, ship and aircraft measurements, forecasting, and modeling analyses were applied in the research. Among the processes investigated were the role of nighttime chemistry in the formation of ozone and PM pollution, the role of the sea-breeze/land-breeze circuit in influencing Houston's air quality, and the role of the marine boundary layer as a conduit for the movement of pollutants throughout the region.

• Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMoN) and the ozone profiling networks).

• Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere to improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment.

Under the future Health of the Atmosphere research umbrella, the OAR Laboratories integrate their meteorological, chemical, and forecasting expertise to support an assessment and prediction capability for regional air quality that incorporates the influence of multiple-timescale meteorology/climatology. While the ambient levels of pollutants like ozone and fine particles are clearly dependent on pollutant emissions, the variation in those levels is also influenced by meteorology, both in the short term and longer term. Therefore, assessing both the intended long-term improvements in air quality and the more-episodic variations requires an understanding, of pollutant transport, transformation, and loss. Research efforts will also focus on an evaluation and improvement of the tools used to forecast future air quality and the observing systems needed to evaluate their skill.

CSD and GMD, working with collaborators throughout North America and Europe, are using ozonesonde releases to characterize the vertical distribution of ozone over North America. Coordinated ozonesonde releases have been conducted in conjunction with field intensives in New England (2004) and Texas (2006). The data collected has provided new insights into the import of ozone from Asia, transport aloft and the role of lightning in ozone formation in the upper free troposphere.

CSD conducts laboratory studies of the chemical processes that are responsible for ozone and fine particle formation and transformation in the atmosphere. These studies are designed to elucidate the chemical mechanisms and quantify the kinetic and thermodynamic parameters needed to properly represent these processes in predictive models.

CSD develops and deploys lidars that are capable of characterizing the vertical structure of ozone and aerosols in the atmosphere. These instruments are deployed on NOAA research aircraft, ships (Figure 3-DOC-29), and at surface sites to characterize the regional distribution of ozone and PM in three dimensions. The data collected provides detailed information on the regional and inter-regional horizontal transport and vertical mixing of ozone and PM pollution.

CSD develops fast response instrumentation for use on mobile platforms (ships and airplanes) that are capable of characterizing the atmospheric pollutant mix. These instruments are designed to characterize the chemical composition of the atmosphere, as well as the optical (scattering and absorption) and physical (e.g. size distribution) properties of ambient PM.

PSD and CSD use their suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments as well as in complex orography. These

Figure 3-DOC-29. The research vessel, Ronald H. Brown.

instruments are deployed at surface sites and on NOAA research ships during the regional air quality intensives such as the Texas air quality study.

CSD works with GSD and PSD to develop and evaluate air quality models. These models are used to aid in the interpretation of data collected during regional fields studies and to produce prototype air quality forecasts. The detailed physical and chemical data collected during intensive field studies are used to diagnostically evaluate these models and their components.

The Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) provides interagency collaboration at the United States Federal level. NOAA co-leads the AQRS. On the broader international arena, the coordinating body is the North American Research Strategy for Tropospheric Ozone (NARSTO), a tri-lateral public/private partnership focused on ozone and particulate matter research in the United States, Canada, and Mexico.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the Federal government responsible for the health and safety of our nation's coastal and oceanic environment. Largely through the Tides and Current Program budget line, NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program to provide a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. NOS also provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings. NOS manages several observing systems and programs, however four in particular are heavily linked to the capability of NOAA to meet weather and water needs of the nation.

NATIONAL WATER LEVEL OBSERVATION NETWORK (NWLON)

NOS manages the NWLON, 200 stations located along the coasts of the United States and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other Federal programs with data and supporting information, such as the NOAA Nautical Charting Program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program. An DCP NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS at 6-minute intervals and imbedded in those data streams are high-rate 1-minute averages for tsunami use. The 6-minute interval GOES transmission capability also supports the NWS storm surge warning program when expected elevations are predicted or observed during coastal storms and hurricanes. This capability for high-rate data has recently been implemented at almost all NWLON by the introduction of 6-minute interval GOES transmissions. Although not all NWLON stations are presently equipped with meteorological sensors, an increasing number of stations are each year. Water level and meteorological data are automatically formatted into bulletin format for inclusion into the NOAA AWIPS pipeline.

PHYSICAL OCEANOGRAPHIC REAL-TIME SYSTEM (PORTS®)

PORTS® is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, bridge air gap and many meteorological parameters, e.g. winds, air temperature and barometric pressure, needed and requested by the mariner to navigate safely.

The 13 existing PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements (Figure 3-DOC-30). PORTS® are partnership programs in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS's existing installations is comprised of over 100 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments, i.e. winds, barometric pressure, etc. Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS® provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur. An extensible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

NATIONAL OPERATIONAL COASTAL MODELING PROGRAM (NOCMP)

NOCMP serves a variety of users with oceanographic nowcast forecast products for ports, estuaries and the Great lakes. The integration of PORTS® technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available. The Chesapeake Bay Oceanographic Forecasting System (CBOFS) is an NOS project that provides forecasts of total water level within the Bay in addition to the astronomical tidal prediction. The New York/New Jersey Harbor nowcast/forecast model came on line in 2003, fol-

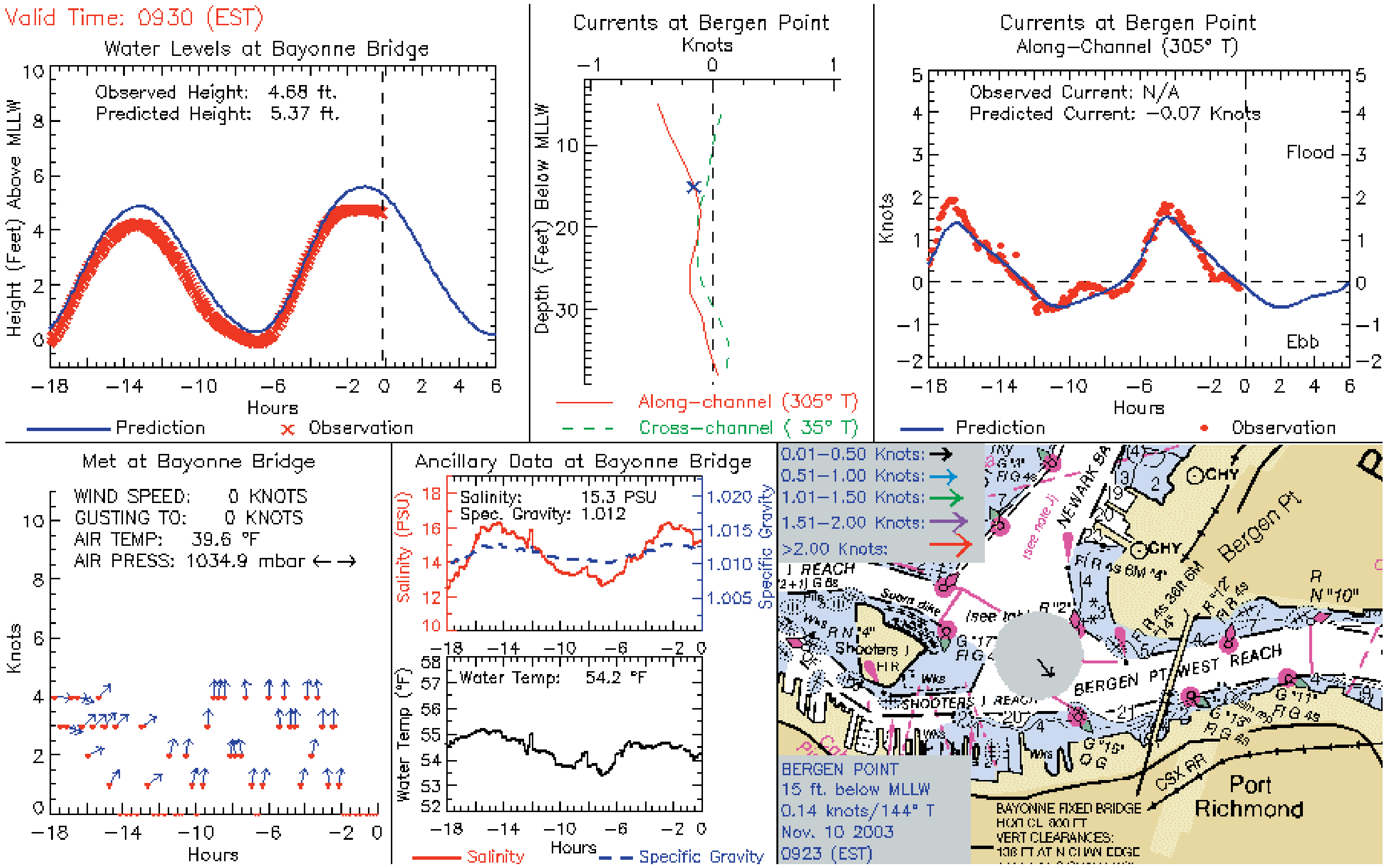

Figure 3-DOC-30. New York/New Jersey PORTS: Bergen Point Composite.

lowed by a Houston/Galveston Bay nowcast/forecast model in 2004. Newer models include the St. Johns River, FL and the Great Lakes. In cooperation with OAR and NWWS, the NOS CO-OPS now runs 5 models as part of the Great Lakes Operational Forecast System (GLOFS) providing forecast guidance for water level , wind, currents and water temperature. Also, ongoing research will enable PORTS® or similar systems to incorporate biological and chemical sensor systems and forecast models as required and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management and homeland security.

THE NOS CONTINUOUS REAL-TIME MONITORING SYSTEM (CORMS)

CORMS was designed to operate on a 24-hour/7-days a week basis to ensure the accuracy and working status of tide and current observations acquired via the NWLON and PORTS® programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications (Figure 3-DOC-31). CORMS ingests real-time data from all field sensors and systems, including the operational nowcast/forecast models, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data. CORMS is especially vigilant during storm and tsunami events to ensure the full set of products and services is being disseminated in a timely fashion. An advanced version of this system, CORMS AI, is presently in developmental stages.

Figure 3-DOC-31. PORTS sites in the New York and New Jersey linked by CORMS.

NOAA Marine and Aviation Operations (NMAO) operates a wide variety of specialized ships and aircraft to support NOAA mission goals. NOAA's ship fleet includes oceanographic and atmospheric research vessels. NOAA's aircraft fleet includes aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research; and aircraft that conduct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

Figure 3-DOC-33. NOAA Ship KA'IMIMOANA

NOAA SHIPS SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA Ship RONALD H. BROWN, an oceanographic and atmospheric research platform (Figure 3-DOC-32), is the largest vessel in the NOAA fleet (274 feet). With its instruments and sensors, RONALD H. BROWN travels worldwide supporting scientific studies to increase our understanding of the world's oceans and climate. An advanced meteorological scientific Doppler radar makes the ship a unique attribute to the research fleet.

NOAA Ship KA'IMIMOANA (Figure 3-DOC-33) primarily supports the research programs of NOAA's Tropical Atmosphere-Ocean (TAO) Project (real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña). These research programs are designed to improve our understanding of the role of the tropical ocean in the world's climate. The ship deploys, recovers, and services deep sea moorings that measure ocean currents, ocean temperatures, and atmospheric variables, throughout the equatorial Pacific Ocean. In addition to data from these moorings, the ship measures upper ocean currents, surface salinity, carbon dioxide content, and takes upper air atmospheric soundings while underway.

Figure 3-DOC-32. NOAA Ship RONALD H. BROWN

RONALD H. BROWN and KA'IMIMOANA annually support the Tropical Atmospheric Ocean (TAO) Array by servicing approximately 60 ATLAS and current meter moorings in the central and eastern equatorial Pacific.

In FY 08, the RONALD H. BROWN will work in cooperation with the Woods Hole Oceanographic Institute to conduct mooring recovery and deployment operations of the Stratus Ocean Reference Station (the sixth setting) under the stratocumulus clouds off Chile and Peru. The ship will conduct meteorological and air-sea flux observations to document and establish the accuracy of the moored metrological observations, and to observe the oceanic and atmospheric variability. This region is of critical importance to climate predictability. Additionally, during the Stratus project the BROWN will support in the deployment of a Deep-ocean Assessment and Reporting of Tsunami (DART) mooring off the coast of Central America.

The RONALD H. BROWN will also conduct the Pirata Northeast Extension

(PNE) study to improve understanding of the West African monsoon and its influence both on the regional environment as well as its role in Atlantic Tropical cyclone development. Following the PNE cruise the BROWN will conduct a CLIVAR/CO2 project that will determine the changes in anthropogenic CO2 distributions and fluxes in the Pacific. After the CLIVAR/CO2 work the vessel will begin a GasEx study to quantify air-sea CO2 fluxes in the Southern Ocean carbon sink region utilizing newly developed direct flux measurement techniques.

NMAO when able supports NDBC in recovery of buoys that have been disabled or become adrift.

NOAA AIRCRAFT SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of aircraft based at MacDill Air Force Base in Tampa, Florida. Three of its twelve aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the nation.

Operations of the G-IV and two WP-3D during the hurricane season of 2006 were strikingly different from 2005. Whereas these three NOAA aircraft flew 123 missions logging 897 flight hours in 2005, they only flew 36 missions totaling 123 flight hours in 2006. Interestingly enough, there were no surveillance or reconnaissance missions flown on hurricanes that year. Ten missions were flown in and around Hurricane Helene, but all of these were for research purposes. During 2006, the second AOC P-3 participated in an air quality study in the Houston and Dallas, Texas areas from the NASA site at Ellington Air Base, TX.

The NOAA Gulfstream, G-IV (SP) (N49RF), provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere (Figure 3-DOC-34). With an operating ceiling of 45,000 ft, the G-IV is a critical tool for obtaining the data necessary to improve hurricane and winter storm track forecasts and for research leading to improvements in hurricane intensity forecasts. The G-IV is also being used for air chemistry studies where a high altitude capability is required. In 2006, researchers also studied the role of Saharan dust on tropical storm development and intensity.

Figure 3-DOC-34. NOAA Gulfstream G-IV (SP)

The NOAA G-IV annually supports Hurricane Synoptic Surveillance missions where the aircraft flies in the environment surrounding the storm at a high altitude releasing GPS dropsondes at pre-selected locations (Figure 3-DOC-35). The data from these vertical atmospheric soundings are transmitted from the aircraft to the NCEP computer site where they are incorporated into the hurricane computer models to improve hurricane track forecasts. The dropsonde directly measures temperature, pressure, and humidity as it falls through the atmosphere to the surface, and computes wind speed and wind direction using a full-up GPS receiver. Recent estimates of the improvement in hurricane track predictions utilizing this aircraft and dropsonde are between 20 and 30 percent, resulting in a savings of $10 million or more per hurricane in warning and preparedness costs.

The NOAA G-IV also annually supports the Winter Storms Reconnaissance Program in an effort to improve forecasts released 24 to 96 hours before winter storms in the United States. This aircraft, in conjunction with the Air Force Reserve's WC-130s, utilize the GPS dropsondes to collect data on developing severe winter storms over the Pacific Ocean that will seriously impact the continental U.S. and Alaska. During one month of the two-month season, both aircraft operate in tandem, one from Alaska and the other from Hawaii, to collect data both north and south of the jet stream simultaneously. General improvement in forecast accuracy of up to 20 percent has already been seen, and even higher percentage improvements on individually targeted events have been realized from this program. Typically, during the final month of the program, the NOAA G-IV operates independently from either the base in Alaska or Hawaii as the case may dictate.

A recent additional mission for the G-IV was the support of the Saharan Air Layer Experiment (SALEX). The outbreaks of dry Saharan dust have been shown to have a dampening effect on the development of tropical cyclones in the Atlantic, and the G-IV, with its high altitude and dropsonde capabilities, is the ideal tool to study this phenomenon. Operating from Barbados, the most easterly island in the western Atlantic, this aircraft flew

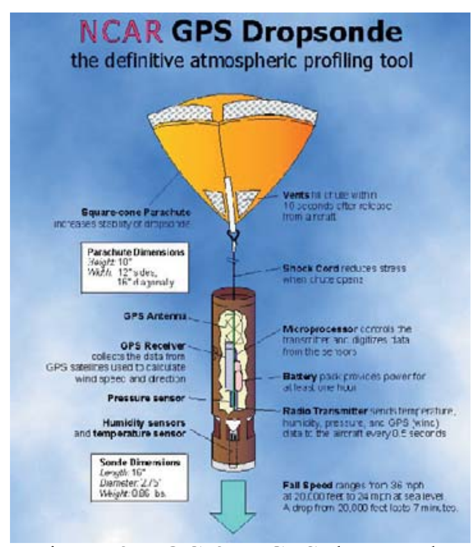

Figure 3-DOC-35. GPS dropsonde

six missions in 2006 on an a continuing study of the dust outbreaks.

NOAA's Chemical Science Division (CSD) of the Earth System Research Laboratory, located in Boulder, CO, is presently expanding its air chemistry capabilities on the G-IV beyond just ozone measurements with the addition of a proton transfer reaction mass spectrometer (PTR_MS). The PTR_MS provides in-situ measurements of volatile organic compounds (VOCs). A second instrument, which measure carbon monoxide (CO), is also being tested aboard the aircraft.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, is supported by two WP-3D Lockheed Orion aircraft (N42RF and N43RF) which carry a full array of state-of-the-art environmental research instrumentation (Figure 3-DOC-36). The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. NOAA's Aircraft Operations Center (AOC) develops and calibrates specialized instruments, integrates user-supplied instrumentation into its automated data recording systems, and processes and analyzes data sets collected during various field programs.

Figure 3-DOC-36. NOAA WP-3 Orion

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provided storm data to the National Hurricane Center (NHC) in near real-time, transmitting flight level data, GPS dropsonde messages, as well as radar images via its multiple aircraft-satellite data links. With the Stepped Frequency Microwave Radiometers (SFMR) now on-line, increasing emphasis was placed on utilizing the NOAAWP-3D to map the surface wind fields in and around hurricanes and tropical storms in 2006. Real-time surface wind speed maps are critical to providing more accurate forecasts of the extent of hurricane and storm force winds.

The AOC aircraft also augment the Air Force Reserve reconnaissance aircraft during particularly active storm periods when tasking requirements exceed their available resources.

Each year, one of the NOAA WP-3Ds participates in a Hurricane Awareness Tour targeting, alternately, the Gulf and East coast regions of the U.S., those areas that are most vulnerable to land-falling storms. This educational outreach effort is directed at both middle-grade school children, the age group most likely to see, learn and convey a message home, as well as the general public. These tours are operated in concert with the participation of officials from NHC, the Red Cross, FEMA and other local and state emergency management personnel. This is becoming an increasingly popular and successful venture as coastal populations grow and the threat of an increasing number of storms place more people in harm's way.

During 2006, the two NOAA WP-3Ds supported three major research experiments. In support of NOAA's Hurricane Research Division, one of these aircraft participated in the Saharan Air Layer Experiment (SALEX), along with the Center's Gulfstream G-IV, flying missions into Hurricane Helene from a base in Barbados.

The NOAA WP-3Ds annually support both a summer and winter operation in support of a NESDIS satellite validation program. Operating in regions of high winds and heavy precipitation, one of the WP-3Ds, equipped with microwave scatterometers and radiometers, provide underflight validation of NOAA satellite-mounted QuickScat and WindSat sensed ocean surface wind vectors. Traditional venues for these operations are Alaska or Newfoundland in the winter and the Atlantic and Caribbean regions during the summer hurricane season.

During the summer of 2006, N43RF joined several other aircraft, operating in the Houston, TX area, and in the vicinity of the NOAA Ship Ronald H. Brown, operating in the Gulf of Mexico in the Texas Air Quality Study. Packed completely with an impressive array of in-situ chemical samplers and carrying three instrument pods mounted beneath its wings, the aircraft took measurements of a wide range of chemical constituents at low altitudes over the urban and rural landmass as well as the marine boundary layer. Additionally, atmospheric profiles were made from the surface to the maximum altitude capability of the aircraft (~25,000 ft). A number of flights at a wide range of altitudes were made over and around the metropolitan areas of Houston and Dallas. This research was in support of the Chemical Science Division of the NOAA Earth System Research Laboratory (ESRL).

In FY2006, AOC received a supplemental budget (Hurricane Katrina Supplemental)of approximately $13.5M to acquire a third P-3 aircraft, to buy dropsondes and to make major improvements to the WP-3D instrumentation. The upgrades to be made on the existing WP-3Ds include improvements to the radar data system, new tail Doppler radar antennae, upgrades to avionics and navigation systems including replacement inertial navigation units with GPS, new cloud particle measuring systems, a new generation GPS dropsonde and a new research data system. The 3rd P-3 has been acquired to provide an additional platform to support non-hurricane related research missions that are scheduled to occur during the hurricane season in future years. An additional $4.6M in capital acquisition funds were received in FY2007 to further modify and ready this aircraft to carryout these specialized NOAA research missions.

A NOAA AC-695A Commander 1000 (N45RF) and a NOAA AC-500 Shrike (N51RF) are used annually to conduct important snow pack surveys in the northern and western continental U.S., Alaska, and southern Canada (Figure 3-DOC-37). During these survey flights, the gamma radiation sensors aboard these aircraft measure the naturally occurring terrestrial radiation emitted from the ground to obtain snow water-equivalent estimates. This data is transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC) up to three-times a day from each aircraft, and after further processing the data is distributed to NWS field offices within five minutes of receipt from each aircraft. These data are used by the NWS to forecast river levels and potential flood events resulting from snowmelt water runoff. Hydroelectric power interests and other water supply managers also use the data to regulate water storage and delivery.

An important component of the 2006 Texas Air Quality Study was a differential absorption lidar (DIAL) deployed on a NOAA DeHavilland Twin Otter (DHC-6) aircraft for remote sensing of local and regional ozone and aerosol distribution. Airborne remote sensing enables tracking of plumes from urban areas and point sources, identification of isolated regions and layers of high ozone concentration, observations of atmospheric layering as characterized by aerosol structure, and investigation of local meteorological effects such as sea breezes and urban heat islands on pollution transport and mixing. Inclusion of a remote sensing aircraft also provided information on the three-dimensional representativeness of in situ observations made on the NOAA WP-3D and other aircraft during those periods when the flight tracks of the two aircraft sample the same region.

Figure 3-DOC-37. NOAA JetProp Commander - N45RF.