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

The United States is prone to a range of severe weather phenomena. Each year, Americans cope with an average of 10,000 thunderstorms, 5,000 floods, and 1,200 tornadoes, as well as landfalling hurricanes. Some 90 percent of all Presidentially-declared disasters are weather related, causing approximately 600 deaths per year and $14 billion in damage. According to the American Meteorological Society, weather is directly linked to public safety, and about one-third of the U.S. economy (about $4 trillion) is weather sensitive.

Sectors of the U.S. economy increasingly recognize the impacts of weather, water, and climate on their businesses, and are becoming more sophisticated at using weather, water, and climate information to make better decisions. To meet this growing demand for information and to improve the timeliness and accuracy of warnings for all weather related hazards, the NWS will continue to enhance observing capabilities, improve data assimilation to effectively use all the relevant data NWS and others collect. NWS will also improve collaboration with the research community, make NWS information available quickly, efficiently, and in a useful form (e.g., the National Digital Forecast Database or NDFD) and include information on forecast uncertainty to help partners and other users make fully informed decisions.

With about 4,700 employees, the NWS provides a national infrastructure to gather and process data worldwide from the land, sea, and air. This infrastructure enables data collection using technologies such as Doppler weather radars, satellites operated by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), data buoys for marine observations, surface observing systems, and instruments for monitoring space weather and air quality. These data feed sophisticated environmental prediction models running on high-speed supercomputers. NWS' highly trained and skilled workforce uses powerful workstations to analyze all of these data to issue climate, public, aviation, marine, fire weather, air quality, space weather, tsunami, river and flood forecasts and warnings around the clock. A high-speed communications hub allows for the efficient exchange of these data and products between NWS components, partners, and other users. NWS forecasts and warnings are rapidly distributed via a diverse dissemination infrastructure including NOAA Weather Radio. Finally, outreach, education, and feedback are critical elements to effective public response and improvements to NWS services.

The National Weather Service (NWS) provides climate, water, and weather warnings and forecasts for the United States, 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 United States 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 multilateral forums to promote international hydrometeorological and space weather policy. This includes activities that facilitate the exchange, coding, and monitoring of data and forecasts. Operational activities such as the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program serve to improve the products and services of NWS.

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

- Organic Act of 1890 created the U.S. Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the U.S. 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 United States is signatory. This sets international policy for safer shipping and cleaner seas. The United States implements the convention through Executive Order 12234 of September 3, 1980 -- Enforcement of the Convention for the Safety of Life at Sea. Among the obligations of the agreement is to provide meteorological warnings and forecasts to ships at sea using charts and radio messages.

SERVICES AND ORGANIZATION

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 9 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 RFCs and the NCEP centers. These centers are the: Hydrometeorological Prediction Center, Storm Prediction Center, Aviation Weather Center, Environmental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Weather Prediction 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

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 continental United States. 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 ultraviolet alert is being produced for the entire nation. The Public Weather Service

Program 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, in partnership with the Department of Homeland Security, NWS forecasters provide meteorological support for response to 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 on the Internet, in gridded binary format (GRIB2) available via anonymous file transfer protocol and hypertext transfer protocol, in XML via a Simple Object Access Protocol (SOAP) service, and in Geographic Markup Language (GML) or Keyhole Markup Language (KML) via an experimental Web Feature 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 and Wind Gusts. In addition, the forecast elements Quantitative Precipitation Forecast (QPF), Snow Amount, Sky Cover became operational on July 8, 2008. Experimental forecast elements include Convective Outlook Hazard Probabilities, and Climate Outlooks. For more detailed information on NDFD, please see http://www.nws.noaa.gov/ndfd/.

STORM-BASED WARNINGS

The NWS previously issued and disseminated warnings for tornado, severe thunderstorm, flood and marine hazards using geopolitical boundaries. Realizing the continuing need to improve the specificity and accuracy of warnings for tornadoes, severe thunderstorms, floods and marine hazards, the NWS began implementation of Storm-Based Warnings on October 1, 2007. The primary goal of warning by storm-based polygon is improved warning service to the public by minimizing the alerting of areas not in the path of the storm. Storm-Based warning methodology allows the forecaster the opportunity to be spatially specific, eliminating large areas needlessly warned when compared to warning by county. Using GIS software to calculate the size of warned areas, it was shown that warning by polygon decreased the average area warned by almost 75 percent compared to warning by county. More information on Storm-Based Warnings can be found here: http://www.weather.gov/sbwarnings/.

AVIATION WEATHER SERVICES

NWS' Aviation Weather Services Program 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 development of 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 four-dimensional (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 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 today, the NWS WFOs prepare Terminal Aerodrome Forecasts (TAF) four times a day, with amendments as needed, for more than 625 public-use airports in the United States 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), the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu, Hawaii, 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 entire globe four times a day (see 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 enroute 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) 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 clouds 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, At-

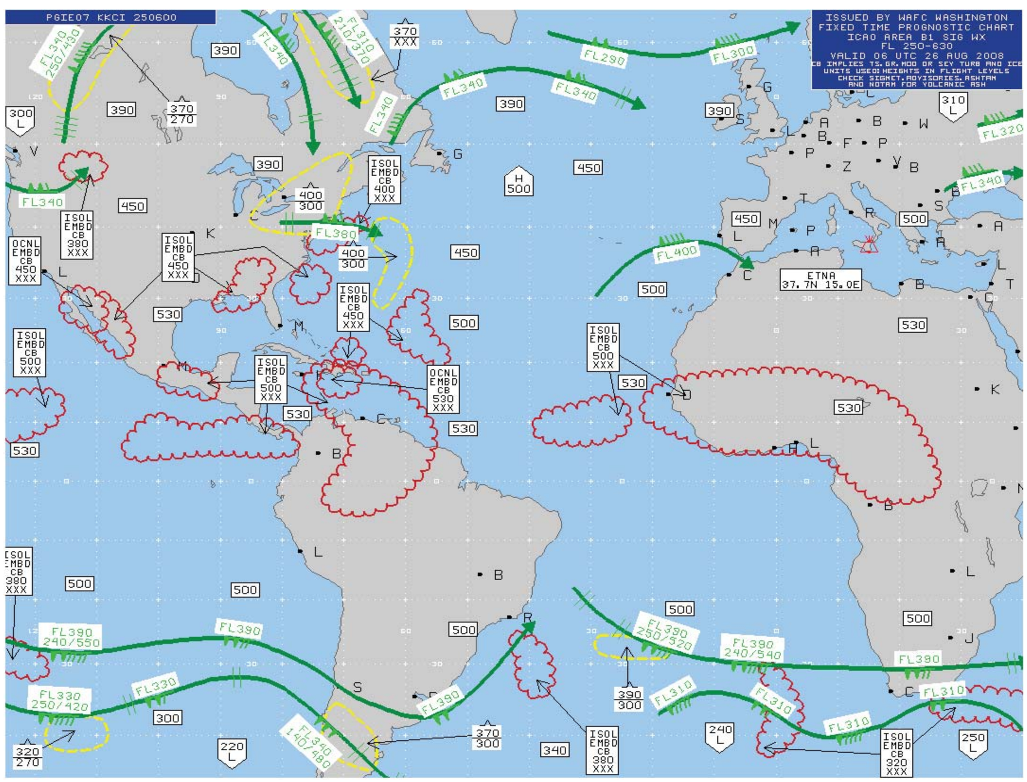

Figure 3-DOC-1 Aviation Weather Center Global Hazard Product

lantic, western portions of Europe, the Pacific, and Eastern Asia.

The United States, in agreement with the ICAO, operates two Volcanic Ash Advisory Centers (VAAC). NESDIS' Satellite Analysis Branch and NWS' NCEP share management responsibility for operating the VAAC in Washington, D.C. Alaska's VAAC is run by NWS' 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 U.S.-controlled oceanic Flight Information Regions (FIR). The VAAC in Anchorage, Alaska, is responsible for the Alaska and Anchorage FIRs.

MARINE WEATHER SERVICES

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, ice, and tsunamis. NWS forecasters at 46 coastal and Great Lakes 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.

The Marine Weather Program develops plans, policies, and procedures for the delivery of marine and coastal weather products and services. 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. The program also works with the Office of Operational Systems for 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 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. It works with the Navy, the USCG, the U.S. Maritime Administration, and the U.S. Army Corps of Engineers (COE) to safely operate the Nation's Marine Transportation System. It works with the DOD, FEMA, and COE to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; 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, DOD, and Department of Homeland Security for forecasting services for hazardous material spills, marine area search, rescue, and recovery operations, and security needs.

FIRE AND INCIDENT SUPPORT WEATHER SERVICES

The NWS provides 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 onsite 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 onsite forecast preparation and briefings. In the early morning, NCEP's Storm Prediction Center issues outlooks for days 1, 2, and 3-8, 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 space shuttle Columbia recovery effort or the Greensburg, Kansas Tornado response).

TSUNAMI WARNINGS

Tsunami warnings, advisories, watches, and information statements for Hawaii and interim watch statements for the Indian Ocean, Caribbean Sea, and South China Sea are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii. Tsunami warnings, advisories, watches, and information statements for the west and east coasts of the continental United States and Canada, Alaska, the U.S. Virgin Islands, and Puerto Rico are prepared 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 warnings, advisories, watches, and information statements to WFOs, Federal and State disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public; watch guidance is issued to International users.

CLIMATE SERVICES

Climate prediction products and other services relate to time periods from two weeks to one year in the future, including seasonal forecasts and hazard assessments. NCEP's Climate Prediction Center (CPC) 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. The program encourages collaborative arrangements among Regional Climate Centers (managed by NOAA/NESDIS), 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) and CPC work as a team to provide hydrologic forecast and warning services to minimize loss of life and property 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 forecast river stages at approximately 4,000 locations. HPC provides the quantitative precipitation forecasts, which serve as the primary forecast input for NWSRFS. RFCs also provide long-term water supply forecasts used by water managers in the western United States, 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 collaboratively with the RFCs to monitor hydrologic conditions 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 the NWS' Hydrologic Services Program. For example, the NWS works very closely with the U.S. Geological Survey (USGS), the COE, the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation, the Bureau of Land Management, and FEMA on water related issues including stream gauging, support for flood mitigation activities including flood inundation mapping, 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 United States.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS) to provide hydrologic forecasts with lead times ranging from minutes to months. 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 prepare for and 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 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 (http://www.weather.gov/ahps) that feature user-friendly menus and maps allowing users to zoom in to areas of interest. AHPS also provides 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 gridded water quantity and quality condition forecasts via a national digital database which assimilates hydrometeorological data, and 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 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 monitoring the environment. The NWS manages programs that produce surface and atmospheric observations in support of a wide range of customers, such as the aviation, climate monitoring, modeling, and research communities. NWS Headquarters establishes policy and standards for all observations and standards and coordinates with other Government agencies and international organizations. 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 the users of our products; and
- Strengthen the link between user requirements and technology research and development.

NOAA'S COOPERATIVE WEATHER OBSERVER NETWORK (COOP)

COOP is the Nation's largest and oldest weather network. Modernization of a portion of COOP under the Historical Climatology Network Modernization (HCN-M) 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 inter-annual 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.

NATIONAL DATA BUOY CENTER (NCEP) AND VOLUNTARY OBSERVERING SHIP (VOS) PROGRAM

The NDBC designs, develops, operates, and maintains a network of data-collecting buoys and coastal stations worldwide. The NDBC also implements U.S. participation in the VOS program, which is an international collaboration under the World Weather Watch of the World Meteorological Organization. On any given day, crew members on about a thousand ships participating in the VOS program around the world observe the weather at their location, encode the observations in a standard format, and send the data to World Weather Watch participants via satellite or radio. NWS forecasters use the marine observations from the NDBC data buoy network and the VOS reports to examine conditions for forecast preparation and to verify forecasts after the period of the forecast has passed. Other users rely on these observations and forecasts for commercial and recreational marine activities.

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION (NCEP)

NCEP delivers to the Nation and the world, analyses, guidance, forecasts, and warnings for phenomena related to weather, the oceans, climate, terrestrial water, and land surface, as well as space weather. NCEP provides science-based products and services through collaboration with a broad range of partners and users to protect life and property, enhance the Nation's economy, and support the Nation's growing need for environmental information. NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products, and two central support centers. Each service center depends on the central support centers for observational infrastructure including quality control, data assimilation systems, numerical weather, ocean and climate modeling functions, and communication and product distribution systems in order to produce value-added forecast guidance products for NWS field offices and other users.

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 6-72 hours. All Tornado and Severe Thunderstorm Watches issued anywhere in the continental 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 forecast between days 4-8 for organized severe thunderstorms over the contiguous United States is also available on a daily basis. The SPC also issues one and two day Fire Weather Outlooks for the continental United States, defining areas with critical, extremely critical, and dry thunderstorm fire conditions and potential for defined areas. A 3-8 day Fire Weather Outlook is now operational.

HYDROMETEOROLOGICAL PREDICTION CENTER

The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services to support the daily public forecasting activities of the NWS and its customers, and 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. A Model Diagnostic Discussion product, which discusses model trends, biases and differences, is issued four times per day. Additionally, HPC serves as the backup to the National Hurricane Center. From September 15 through May 15, 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 low pressure systems impacting the continental 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. In December 2007, HPC began issuing daily products for the 4-8 day range from its newly established experimental Alaskan Desk. This Desk is part of NCEP's commitment to providing meteorological support for areas outside of the continental United States.

AVIATION WEATHER CENTER

The Aviation Weather Center (AWC) issues warnings, forecasts, and analyses of weather hazardous to aviation. These efforts support the FAA's Air Traffic Control (ATC) responsibility to safely and efficiently manage the national airspace. The AWC provides wind and flight hazards (e.g., convection, icing, turbulence) forecasts for flight planning and enroute aircraft operations for the United States, the Gulf of Mexico, the Caribbean Sea, 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 through a collaborative process involving AWC forecasters along with aviation forecasters from commercial airlines, Center Weather Service Units, and the Meteorological Service of Canada. The AWC is a major component of the U.S. World Area Forecast Center (WAFC), and is an international Meteorological Watch Office. As such, the AWC incurs a mutual backup responsibility with the other WAFC in Bracknell, England. Each office covers an overlapping two thirds of the globe. The resulting products are furnished as an obligation of international treaties.

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 data assimilation systems, as well as global, regional and mesoscale models of the atmosphere, land surface, and ocean. 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 NOAA's Hurricane Forecast Improvement Project (HFIP) 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. The CPC develops and maintains data bases 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 the next week (days 6-10) to seasons out to a year in advance. These products cover land, ocean, and the atmosphere extending into the stratosphere. CPC's products include probabilistic 1-month and 3-month 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 WEATHER PREDICTION 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 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 (north of 30 °N) and North Pacific (north of 31 °N) 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 SOLAS. The OPC provides weather and sea state warnings and forecasts for the offshore waters of the United States and the high seas of the Northern Hemisphere north of 30 degrees out to five days 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 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 mission of the Tropical Prediction Center (TPC)/National Hurricane Center (NHC) is to save lives, mitigate property loss, and improve economic efficiency by issuing watches, warnings, forecasts, and analyses of hazardous tropical weather, and by increasing understanding of these hazards. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry. TPC/NHC services include public and marine advisories, watches, and warnings out to five days 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. The TPC is also home to the Joint Hurricane Testbed, by which new technology, research results, and observational advances are transferred smoothly and rapidly into improved tropical cyclone analysis and prediction products.

NCEP CENTRAL OPERATIONS (NCO)

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 maintains and manages the modeling supercomputers and is responsible for running the computer applications that generate all NCEP model 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 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 supports 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 also manages two supercomputers; one located in Gaithersburg, Maryland, and the other in Fairmont, West Virginia, as backup. Each day, the operational machine processes up to seven billion 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 three other offices that provide national products. They are the Alaska Aviation Weather Unit, the Anchorage WFO, and the WFO Honolulu/Central Pacific Hurricane Center.

The Alaska Aviation Unit provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for Alaska and surrounding areas. 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, the Bering and Chukchi Seas, and the Cook Inlet. WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides aviation, marine, and tropical cyclone products. 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 West to 160 degrees East longitude, and in the Oakland Flight Information Region south of 30 degrees North latitude through ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for the 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 degrees North 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

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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 Global Systems Division).

Hydrologic Research

The NWS develops, implements, and provides operational support for improved hydrologic, hydraulic, and hydrometeorological models. NWS also manages hydrologic data, as well as enhanced quality control procedures 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 multi-sensor precipitation 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 product user.
- 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 SWPC 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, and by obtaining and processing new observations. Activities include:

- Developing the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from a wide variety of sources will enable the model output to be useful to radio communicators, as well as Global Positioning System (GPS) and Loran users.
- Developing models to characterize and predict geomagnetic storm intensity, both 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

NWS provides training to its workforce to enhance the professional and scientific development of its staff in support of its 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. NWS training is also supported by a partnership with the COMET program 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 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, the NWS is working to develop an organized curriculum to supply the necessary knowledge, skills, and abilities for all positions.

INTRODUCTION

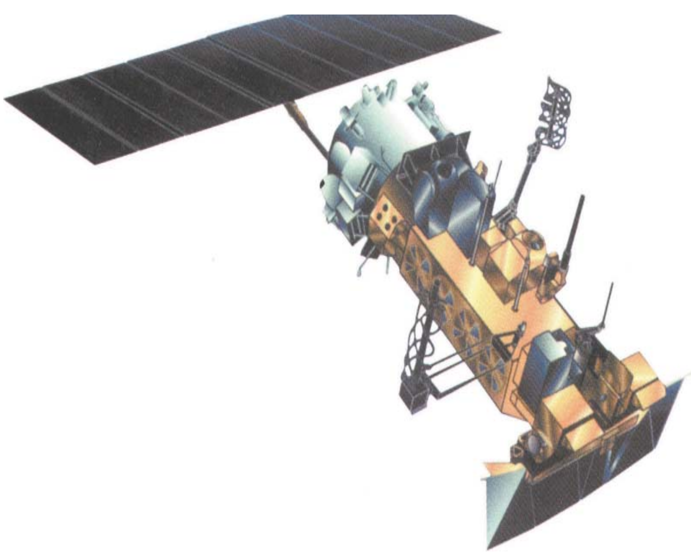
The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) oversees the daily operations of U.S. civil operational environmental satellite systems as well as NOAA's data centers, which develop global, national, and regional da-tabases to support meteorology, oceanography, geophysics, and the space environment.

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 us-ers. These satellite types are the Polar-orbiting Operational Environmental Satellites (POES) and Geostationary Operational Environmental Satellites (GOES).

POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITES (POES)

Polar-orbiting satellites circle the Earth in an almost north-south orbit, passing close to both poles. These satellites ensure that data for any region of the Earth are no more than six hours old. Data from POES support global weather forecasting models, long-term global climate change research, and hazard detection and mitigation. NESDIS operates six polar orbiters. The NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. MetOp-A, a European environmental satellite with three instruments provided by NOAA, is the primary morning satellite; NOAA-17 serves as the backup morning satellite; and NOAA-18 is the primary afternoon satellite. NESDIS also manages the command, control, and communications functions of the Department of Defense's (DoD's) Defense Mete-orological Satellite Program (DMSP).

Figure 3-DOC-2. Polar-orbiting Operational Environmental Satellite



NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

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. In addition, NPOESS will continue to provide surface data collection and search and rescue capability. The first NPOESS satellite will begin to collect and disseminate data on Earth's weather, at-mosphere, oceans, land, and near-space environment in 2013. The NPOESS Integrated Program Office (IPO), in consultation with the Polar-orbiting Operational Environmental Satellite (POES) and Defense Meteorological Satellite Program (DMSP) program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued uninterrupted data services. The NPOESS program is managed by the Tri-Agency IPO, employing per-sonnel from the Department of Commerce (DOC), the National Aeronautics and Space Administration (NASA), and DoD. During Fiscal Year (FY) 2009, activities will include, but will not be limited to, assembly, integration, and testing of sensors on the NPOESS Preparatory Project (NPP) satellite; preparation for NPP launch in 2010; pre-launch calibration and validation for NPP; development and testing of sensor flight units for NPOESS; Critical Design Review for NPOESS; expansion of the Antarctic Data Relay site; completion of the Interface Data Processing Segment (IDPS) software builds; Mission Operational Readiness Review for NPP; and NPP Ground Readiness Review. Also in FY 2009, NOAA will work to support remanifesting the Clouds and Earth's Radiant Energy System

(CERES) instrument and the Total Solar Irradiance Sensor (TSIS) and to develop infrastructure for data records archive, access, and assessment. These efforts support the Administration's commitment to restoring high priority climate sensors that were de-manifested from NPOESS in 2006. NOAA is also working with the Office of Science and Technology Policy (OSTP) and the Office of the Federal Coordinator for Meteorology (OFCM) on development and assessment of mitigation options to address the loss of space environmental sensing capability being de-manifested from the planned NPOESS spacecraft and potential loss of the Advanced Composition Explorer (ACE) spacecraft solar wind data.

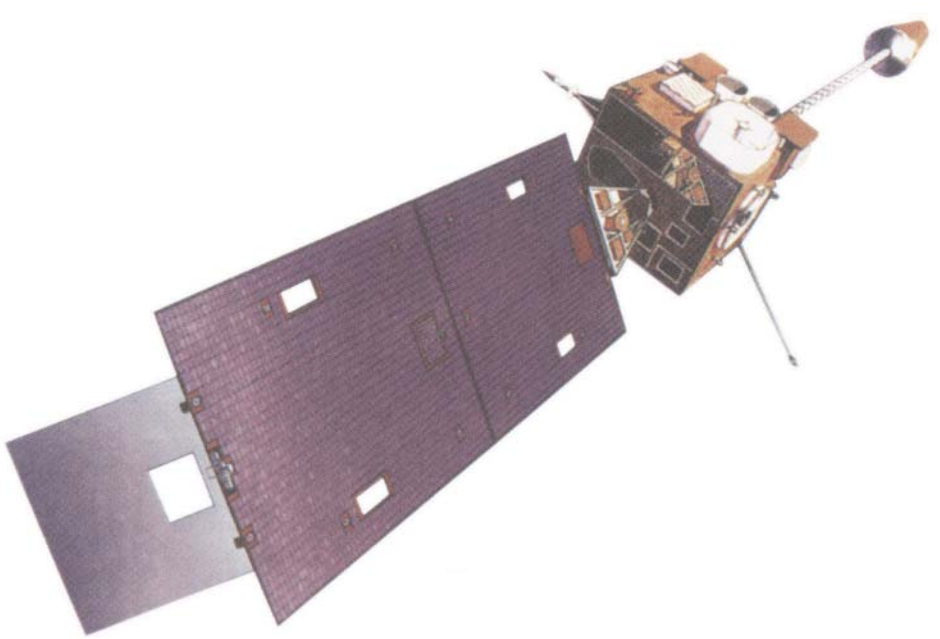
GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES)

The GOES spacecraft, in contrast to the POES spacecraft, circle the Earth in a geosynchronous orbit. This means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. These satellites provide continuous monitoring necessary for effective, detailed, and extensive near-term severe weather monitoring and forecasting and long-term environmental monitoring. Each operational satellite continuously views nearly one third of the Earth's surface. GOES-East at 75°W and GOES-West at 135°W provide data on the United States and the Western Hemisphere. GOES-East monitors North and South America and most of the Atlantic Ocean. GOES-West monitors North America and the Pacific Ocean basin. GOES-13 is the on-orbit spare at 105°W and is available for operational deployment when needed. GOES-10 was retired from active service for the United States in December 2006. This satellite is at 60°W and is providing enhanced monitoring for South America through the Global Earth Observation System of Systems (GEOSS) in the Americas initiative. In FY 2009, the next spacecraft in the current GOES series will be launched. GOES-O is slated to launch in April 2009 and will become an on-orbit spare (GOES-14) to support the current GOES mission.

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE SERIES R (GOES-R)

Geostationary satellites remain the weather sentinels for NOAA–tracking hurricanes, severe storms, clouds, land, and ocean features. The next-generation geostationary satellite series, called GOES-R, will scan the Earth nearly five times faster than the current GOES, providing users such as meteorologists and government agencies around the world with about 60 times the amount of data currently provided. GOES-R is a collaborative development and acquisition effort between NOAA and NASA; their partnering takes advantage of each agency's expertise. In FY 2009, the GOES-R Program plans to award major contracts for the GOES-R Spacecraft and Ground Systems.

Figure 3-DOC-3 Geostationary Operational Environmental Satellite



CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR)

The Center for Satellite Applications and Research's (STAR's) mission is to transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine opera-tions and to offer state-of-the-art data, products, and services to decision-makers. 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 archiving and developing products from the 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.

STAR investigates how to develop satellite datasets that can be used to assess conditions on the Earth in a timely manner, predict changes, and study long-term trends in the environment. STAR works to create products that monitor 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; and expand its support to users.

NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC) serves as a national resource for climate information. This data center develops national and global datasets that are used by both government and the private sec-tor. NCDC's mission is to describe the climate of the United States. This data center also acts as the Nation's scorekeeper regarding the trends and anomalies of weather and climate. In addition to archiving a variety of in situ and airborne measurements, NCDC provides archive and access to historical satellite data from GOES and POES. NCDC's climate data are used in a variety of disciplines, including agriculture, air quality, construction, education, energy, engineering, forestry, health, insurance, landscape design, livestock management, manufacturing, recreation and tourism, retail, transportation, and water re-sources management. NCDC's data and products fulfill needs ranging from building code compliance to power plant and space shuttle design.

NATIONAL GEOPHYSICAL DATA CENTER (NGDC)

The National Geophysical Data Center (NGDC) provides stewardship, products, and services for geophysical data describing the solid earth, marine, and solar-terrestrial environments, as well as Earth observations from space. NGDC's data holdings contain more than 400 digital and analog databases, some of which are very large. As technology advances, so does the search for more efficient ways of pre-serving these data. NGDC also maintains the archive for the Defense Meteorological Satellite Program (DMSP) program, where NOAA provides satellite commanding and data processing support to the Air Force DMSP program. NGDC welcomes cooperative projects with other government agencies, nonprofit organizations, and universities and encourages data exchange. NGDC datasets are used by scientific researchers, the engineering community, disaster management planners, and the public for a wide variety of applications. This data center continually develops data management programs that reflect the changing world of geophysics. In addition, this center works closely with contributors of scientific data to prepare documented, reliable datasets and is continually seeking input on user requirements for data and informa-tion products. NGDC's vision is to be the world's leading provider of geophysical and environmental data, information, and products.

OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION (OSDPD)

OSDPD manages and directs the operation of the central ground facilities, which ingest, process, and distribute environmental satellite data and derived products to domestic and foreign users. OSDPD serves as the primary operating level interface with the civil sector users of data from operating earth sat-ellites. OSDPD manages the Search and Rescue Satellite Aided Tracking (SARSAT) system and is re-sponsible for coordinating and implementing the United States activities in the international satellite aided search and rescue program, COSPAS-SARSAT. OSDPD also evaluates the effectiveness of the opera-tional ground facilities and procedures in terms of the quality and quantity and assesses the timeliness of the products and services provided. It maintains an inventory of operational products and services and prepares assessments, recommendations, and plans for the initiation of new products and services. In addition, OSDPD provides interpretive analyses of global satellite data to support domestic and interna-tional hazard mitigation activities in the fields of tropical storm position and intensity analysis, airborne volcanic ash detection, heavy rain or snowfall estimates, and smoke and fire analysis.

NATIONAL OCEANOGRAPHIC DATA CENTER (NODC)

The National Oceanographic Data Center (NODC) is a national repository and dissemination facil-ity for global oceanographic data. This data center acquires and preserves a historical record of the Earth's changing environment that is used for operational applications and ocean climate research. NODC is an organization made up of the Oceanographic Data Center, National Coastal Data Devel-op-ment Center, World Data Center for Oceanography, and NOAA Central Library. These centers are inte-grated to provide access to the world's most comprehensive sources of marine environmental data and information. NODC provides end-to-end environmental data stewardship by managing the acquisition, processing, quality control, access, and long-term preservation of oceanographic data. The NODC ar-chive holdings include all the observational data acquired in its original form, as well as data records from national research projects and oceanographic products.

NOAA COOPERATIVE REMOTE SENSING SCIENCE AND TECHNOLOGY CENTER (CREST)

CREST is a multi-institutional center, led by the City University of New York (CUNY). Partner insti-tutions include The City College, Lehman College, the CUNY Graduate Center, Bronx Community Col-lege, and the New York College of Technology in collaboration with four partner institutions, which are Hampton University; University of Maryland, Baltimore County; University of Puerto Rico, Mayaguez; and Bowie State University. CREST programs and activities are aligned with the NOAA Strategic Mission of Environmental Assessment, Prediction, and Stewardship. They are organized into five thematic catego-ries: Science, Outreach, Education, Administration, and Awards and Recognition.

Dr. John Bates, from the National Climatic Data Center (NCDC), led the 2008 External Review for CREST and NCDC's education and outreach program. These programs support a number of CREST ac-tivities such as student education, training, and career development in NOAA-related sciences, including the CREST Summer High School Internship program, the NOAA Educational Partnership Program, and a 2007 NESDIS student summer workshop. Additional activities include exploring opportunities to inte-grate new satellite data in education; conducting science and service programs; and using new data inte-gration and visualization tools and technologies like Science-on-a-Sphere for environmental education and outreach.

SERVICES

OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION (OSDPD)

OSDPD ingests, processes, and distributes many hundreds of satellite products to various users, including NOAA's NWS. OSDPD manages the ground processing system that delivers critical satellite data and products to the NWS' numerical weather prediction (NWP) models. OSDPD also delivers near-real-time images from the Geostationary Operational Environmental Satellite (GOES) spacecraft, as well as images from polar-orbiting satellites, to the NWS Weather Forecast Offices (WFOs) through NOAAPORT and to the National Centers for Environmental Prediction (NCEP) offices located in Camp Springs, Maryland. Satellite data plays a critical role in the forecast process. NWP models use thousands of global observations from satellites to portray an accurate state of the atmosphere, land, and ocean surface for the models to initialize in their forecast cycles. Imagery from satellites is used in the weather forecast and warning process by the National Centers and by local WFOs. Satellite data over the oceans are usually the only source of environmental information over these data void regions.

NATIONAL ICE CENTER (NIC)

The U.S. NIC, sponsored by 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.

JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

Effective environmental prediction requires several elements. One of these is accurate, well-distributed observations of the Earth's environment and numerical models that embody the physical and chemical laws governing the behavior of the Earth's land surface, oceans, and atmosphere. Data assimilation is the mortar that binds these elements into successful prediction systems for weather, oceans, climatology, and ecosystems. JCSDA is a partnership between NOAA, the National Aeronautics and Space Administration (NASA), the U.S. Navy, and the U.S. Air Force dedicated to developing and improving our ability to exploit satellite data more effectively in the United States. JCSDA is a collaborative effort that allows the work required to assimilate the billions of satellite observations available daily to be shared by several agencies. This effort would otherwise be duplicated across the agencies. The goals of JCSDA are to:

- Reduce the average time for operational implementation of new satellite technology from two years to one year
- Increase the use of current satellite data in numerical weather prediction models
- Advance the common numerical models and data assimilation infrastructure
- Assess the impacts of data from advanced satellite sensors on weather and climate predictions

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM (NIDIS)

Drought events have far reaching impacts on many aspects of our daily lives, from water management to health to energy consumption and conservation. To mitigate these impacts, NOAA, other Federal and state agencies, partners, and countries, developed the plan for NIDIS. NIDIS is a dynamic and accessible drought-risk information system that was created in response to extended drought conditions, especially in the Western United States, over the past decade. In 2007, NOAA unveiled a new, interactive website called the U.S. Drought Portal (USDP) that allows the public and civic managers to monitor U.S. drought conditions; access forecasts; assess the impacts of drought on their communities; and learn about possible mitigation measures. This website is useful to other countries as nations work to coordinate drought preparedness, response, mitigation, and recovery activities. In FY 2008, NOAA began to institute geographic information system mapping capabilities in USDP. For FY 2009, NOAA will work to integrate enhanced geographic information system capabilities in USDP. Additionally, communities will be unveiled in the portal, serving as a location for subject matter experts to share improvements in drought monitoring, forecasting, and mitigation. These communities will also serve as a coordinating and communications mechanism for NIDIS regional pilot projects.

COMPREHENSIVE LARGE ARRAY-DATA STEWARDSHIP SYSTEM (CLASS)

CLASS stores large volumes of NOAA's complex data and information such as satellite, radar, and other data and derived products. This system helps NOAA more efficiently preserve the volumes and diversity of valuable environmental data and information being acquired by improved observations and enhanced data products. CLASS also supports convenient access to this data to users worldwide. In FY 2009, NOAA will systematically assess environmental datasets for inclusion within CLASS and plan for additional integration of legacy Information Technology (IT) systems supporting archives. In addition, CLASS will be ready to begin providing secure storage of and access to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) satellite data.

CLIMATE DATABASE MODERNIZATION PROGRAM (CDMP)

Climate data, such as wind speed and direction, precipitation, temperature, and pressure, are critical to many disciplines and enterprises, including economic research, engineering, risk management, energy resource management, and agriculture. Decision-makers in these and other sectors require easy access to these climate data. CDMP conserves and improves 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. Under CDMP, new digital databases of historical environmental data and information are created. As a result of this program, many existing digital datasets have been extended back in time, in many cases by a century or more. Additionally, the conversion of analog data sources to digital databases and datasets ensures that they are preserved efficiently and inexpensively over the long-term. There are more than 52 million images and over nine terabytes of data now available via web-based software to U.S. government employees and their contractors, educational institutions doing environmental research, and other researchers associated with NOAA projects. In addition, during the past few years over four million hourly weather records were keyed and integrated into the National Climatic Data Center's (NCDC's) digital database holdings.

In 2008, CDMP supported over 77 climate and environmental data rescue projects within NOAA. Most of this data and information was underutilized and unavailable for research and, in some cases, in danger of being lost due to poor quality. The majority of these NOAA rescue projects are multiyear tasks; many spill over into FY 2009 due to the complexity and extent of the imaging, keying, and/or data conversion. The first year of a new NOAA task usually involves a pilot or subset of the entire task, allowing CDMP managers to benchmark costs, time, and labor. CDMP also provided technical and programming support to various systems to help modernize software and delivery systems, making the data accessible to NOAA users. Some major NOAA continuing tasks include: upper air and surface international data rescue projects; geolocation of historical maps and charts; shoreline vectorization and geo-referencing; aerial photography image conversion; and imaging and keying marine logbooks and lightship data, tsunami event gauge records, and International Polar Year imaging.

GLOBAL OBSERVING SYSTEM INFORMATION CENTER (GOSIC)

GOSIC provides access to data, metadata, and information from the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). This system provides efficient access to data and information and unique tools for searching and accessing data, such as matrices and portals. This system 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 is a great tool for coordinating the various climate observing activities across NCDC and NOAA. GOSIC continues to play an important role in international and regional data access activities. As a formally registered service of the Global Earth Observation System of Systems (GEOSS) data access project, this will expand in 2009. GEOSS is a comprehensive effort to focus on the societal benefits of earth observations. Furthermore, as the World Meteorological Organization (WMO) moves toward a modernized and comprehensive WMO Information Service (WIS), GOSIC will play an important role in FY 2009 in the overall WIS architecture. From a regional perspective, GOSIC continues to play a significant role in aiding various Pacific Island National Meteorological and Hydrological Services in a number of critical data access and communication functions related to meteorological and climatological data in the region. It serves as a capacity building utility by providing Internet-based web services in concert with the Asia Pacific Data Research Center, which is a NOAA/NCDC funded activity at the University of Hawaii.

U.S. CLIMATE REFERENCE NETWORK (USCRN)

USCRN is a network of climate stations being developed to provide future long-term homogeneous observations of temperature and precipitation that can be coupled with long-term historical observations to identify and monitor climate change. USCRN data are used in climate monitoring activities to place current climate anomalies into historical perspective. Data from the fully deployed network of 114 stations in the conterminous U.S. (planned by the end of FY 2008) quantify the variance in surface air temperature and precipitation on a national scale. 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 system observations can be validated and verified. USCRN enhances the quality of and confidence in other observations; contributes to the rehabilitation of historical datasets; increases in the volume of data used to detect climate trends; and supports climate monitoring, evaluation, and forecasting. In FY 2009, contingent on available funding, USCRN will expand to Alaska with an eventual planned network of 29 stations.

For FY 2009, we plan to add soil moisture, soil temperature, and relative humidity sensors at 60 USCRN sites in support of the National Integrated Drought Information System (NIDIS). Measurements of soil moisture and soil temperature are one of the most critical parameters for understanding the state of drought throughout the country. The density of those few observing networks configured with soil sensors is woefully inadequate for systematic drought monitoring purposes at either the National or Regional Levels. The deficiency in the area of soil moisture and soil temperature observations and monitoring has a critical impact most notably on agribusiness and silviculture as well as forest fire responsiveness.

NOAA OPERATIONAL MODEL ARCHIVE AND DISTRIBUTION SYSTEM (NOMADS)

NOMADS is a collaborative approach, spanning multiple Government agencies and academic institutions, to address the growing need for remote access to high volume global climate model and numerical weather prediction model data. NOMADS is a network of data servers using established and emerging technologies to access and integrate model and other data. NOMADS enables users to share and compare model results. The goals of this system are to improve access to model data and information; improve weather forecasting; develop links between the research and operational modeling communities; foster collaboration between the climate and weather modeling communities; and promote joint product development to study multiple Earth systems.

In FY 2009, NOMADS will have access to increased bandwidth for user access to data, thereby allowing customers' access to download much larger volumes of data and directly supporting multiple research projects. Collaboration with national partners will continue and the incoming model data (into NCDC's archives) will continue to be accessible via NOMADS in near-real-time. There will be increased linkages with the NOAA Virtual Data System (NVDS) and its Geographical Information System (GIS) Services, providing access to model data via GIS interfaces.

CRYOSPHERIC RESEARCH

The National Snow and Ice Data Center (NSIDC), a center within the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder, receives funding from NOAA and other Federal agencies. NSIDC's research covers a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on Arctic sea ice, Antarctic ice shelves, and satellite-borne measurements. NSIDC has a valuable collection of analog archives, including many thousands of glacier photographs that are being scanned and made available online through the NOAA Climate Database Modernization Program. In addition, algorithms to detect snow, frozen ground, and sea ice in passive microwave images from the Defense Meteorological Satellite Program (DMSP) and NASA satellites have been developed at NSIDC. Current work includes "succession planning" or cross-calibration to continue the climate record as the current Special Sensor Microwave Imager (SSM/I) instrument becomes unstable and a new one comes into use. Other work at NSIDC 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, the ocean, and the atmosphere and the discipline of data management for scientific enterprise.

RESEARCH

ABRUPT CLIMATE CHANGE

During Fiscal Year (FY) 2009, the Paleoclimatology Branch of the National Climatic Data Center (NCDC) will conduct several studies on abrupt climate change. Specifically, this branch will produce new records of the Indian summer monsoon and conduct research modeling rapid changes in sea ice and rapid changes in the meridional overturning circulation in the Atlantic (a potent influence on large-scale weather patterns). The goal of this research is to create a long-term (multi-century) climate trend record, docu-menting natural variability and abrupt climate changes. These changes are not represented in existing models used to predict future climate change. This research will help scientists understand abrupt changes in climate that have occurred in the past and will likely occur in the future. The data produced will enable decision-makers and society to examine past abrupt climate changes and use the lessons learned to prepare to adapt to future changes.

SNOWFALL IMPACT SCALES

NCDC will extend the Northeast Snowfall Impact Scale (NESIS) to all climate regions of the conti-nental United States. NESIS was originally developed for the Northeastern United States to characterize and rank the severity of snow storms based on snowfall amount and the population of the affected area. NESIS uses a five category classification system: Extreme, Crippling, Major, Significant, and Notable. This index differs from other meteorological indices because it uses population information in addition to meteorological measurements, providing an indication of a storm's societal impacts. This research will benefit decision-makers and society because it will provide rapid assessments of the impacts of snow storms on populated areas of the United States. This information is useful to the Federal Emergency Management Agency (FEMA) and those in commodity markets who need to assess the impact of snow events on social and economic centers of the Nation.

This research work, conducted in cooperation with scientists at Rutgers University's Global Cli-mate Lab, will involve: generating map and tabular data related to the selection of candidate storms; populating the Geographical Information Survey (GIS) maps with station data; identifying candidate snow storms; providing quality control; creating event grids; testing an extension of the impact scale from the Northeast to other regions; and developing automated GIS scripts.

GLOBAL TROPICAL CYCLONE DATABASE DEVELOPMENT

NCDC will develop and maintain a global tropical cyclone best track dataset, which includes the intensity and position of tropical cyclones. This work will result in a "one stop shop" for a quality controlled, homogeneous, annually updated dataset. The dataset will benefit decision-makers and society by providing a comprehensive list of tropical cyclones to improve our understanding of hurricane extremes. Knowing where, when, and at what intensity past storms occurred, can help enhance hurricane forecasts. In addition, a global best track dataset may prove useful for tropical cyclone forecasting through a more thorough understanding of their genesis locations and seasonality. Finally, this research will help deci-sionmakers assess the coastal impacts of tropical cyclones and aid in a better understanding of changes in the frequency and intensity of these storms, which may lead to more robust or updated evacuation plans.

The global tropical cyclone best track dataset will incorporate the 2008 storm year (2007-2008 Southern Hemisphere) into the database; a continued analysis and comparison of previous seasons; and further quality data assessment as needed. The project aims to conduct some education and outreach efforts to make the community more aware of the dataset and its potential applications. In addition, the project will scope out previously undocumented tropical cyclone data that may exist at NCDC. Finally, a website for data dissemination will be developed and maintained.

CHANGES IN EXTREME EVENTS

NCDC will research observed changes in extreme events in the NCDC climate record. This will include investigations of changes in droughts, heat waves, and heavy precipitation. Observed changes will be compared to climate model results in an effort to look at climate change detection and attribution issues. Society recognizes the need to plan for the protection of communities and infrastructure from extreme events of various kinds and engages in risk management. More broadly, responding to the threat of climate change is quintessentially a risk management problem. Structural measures (such as engineering works), governance measures (such

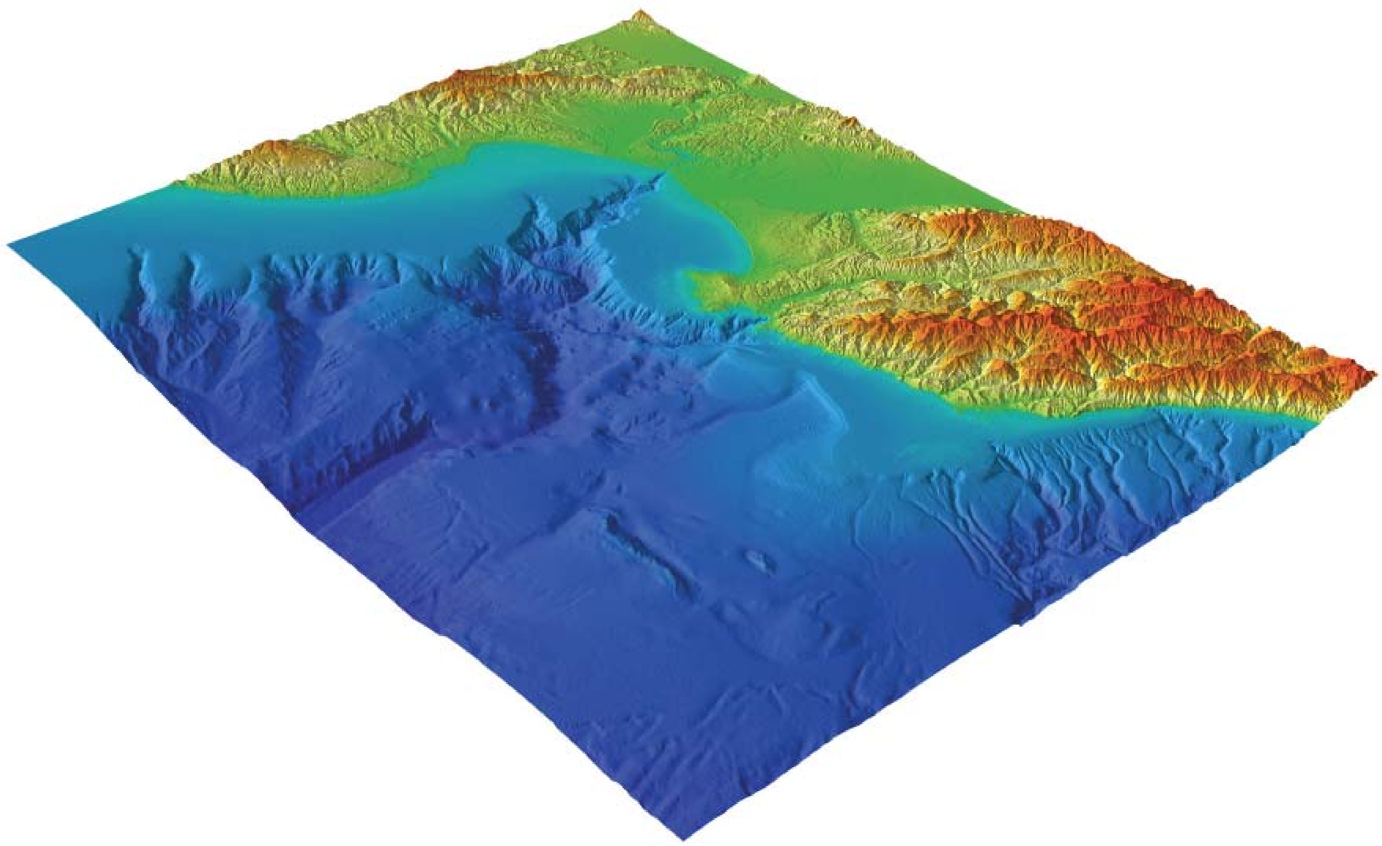


Figure 3-DOC-4 Coastal Digital Elevation Model at 1/3 arc-second for Monterey, California. Used for tsunami forecast and inundation mapping.

as zoning and building codes), financial instruments (such as insur-ance and contingency funds), and emergency measures practices are all risk management measures that have been used to lessen the impacts of historical extremes. To the extent that changes in extremes can be anticipated, society can engage in additional risk management practices that would encourage proac-tive adaptation to limit future impacts. (CCSP 3.3, Chapter 1, www.climatescience.gov/Library/sap/sap3-3)

NATURAL HAZARDS COASTAL INUNDATION MODELING AND MAPPING

Since 1900, over 200 tsunami events have affected the coasts of the United States and its territories causing more than 500 deaths. As such, Tsunamis are considered low-frequency but 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. To improve the tsunami forecast capability and mitigate the impacts of tsunami and other coastal flooding hazards, the National Geophysical Data Center (NGDC) will continue to develop high-resolution coastal digital elevation models (DEMs) for inundation modeling and mapping. NGDC is also researching how variations in the DEM methodology affect the inundation model results and comparing these results to past tsunami event data. The purpose of the research is to better understand how different data processing methods affect DEM development and to use this knowledge to develop the most accurate coastal DEM generating inundation results validated by historical data. Emergency managers in coastal communities around the United States and its territories use DEMs and the inundation results to guide evacuation planning. Improving DEMs will result in improved forecasts and improved inundation products supporting local community emergency managers and planners, thereby saving lives and money.

GEOMAGNETIC FIELD MODELING FOR IMPROVED NAVIGATION

The NGDC geomagnetism group develops and produces magnetic field models for navigation and pointing, which are used in a multitude of defense and civilian applications. Production of the World Magnetic Model, the standard magnetic model for the Department of Defense (DOD) and the North Atlan-tic Treaty Organization (NATO), is sponsored by the National Geospatial-Intelligence Agency. The geomagnetism group also leads the production and distribution of the International Geomagnetic Reference Field. These main magnetic field models represent approximately 90 percent of the magnetic field, influencing a compass on or near the surface of the Earth. In FY 2009, NGDC will continue research to de-velop improved magnetic models addressing the additional magnetic influences affecting navigation by land, sea, and air. 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 animations of the model results for the change in the magnetic field from 1590-2010, a 3-arc-minute World Digital Magnetic Anomaly Map and the extended magnetic reference model to spherical harmonic degree 720 as shown in the figure below. The NGDC-720 model corresponds to a 15-arc-minute model resolution.

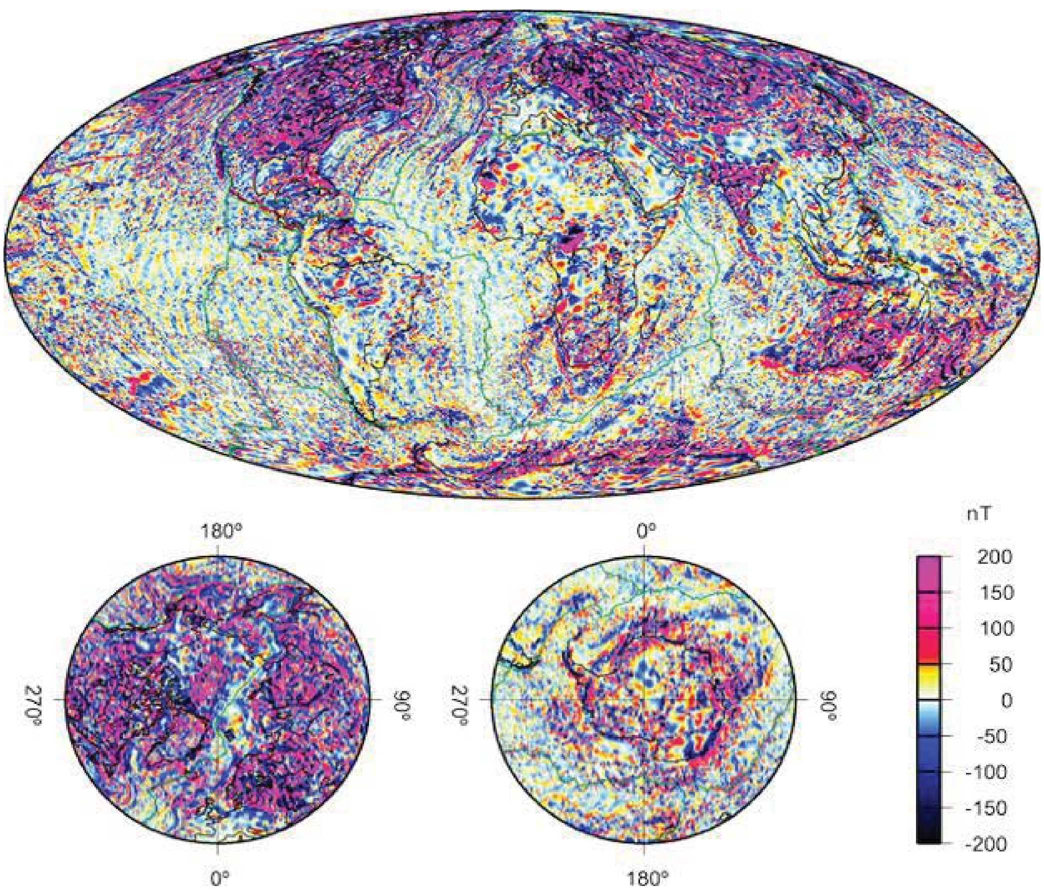


Figure 3-DOC-5. Vertical component of the crustal magnetic field at Earth's surface as given by the NGDC degree-720 model

Hurricane Applications of Lightning Measurements

The next generation NOAA geostationary satellites starting with the Geostationary Operational En-vironmental Satellite Series R (GOES-R) will have a new capability to measure total lightning. Although ground-based lightning measurements have been available for several years, this will be the first time that this data will be available with high time resolution over the open oceans where hurricanes form and grow. The improvements in the prediction of hurricane genesis and intensification have not kept pace with those for track forecasting. The lightning observations have the potential to provide a new source of information for tropical cyclone forecasting.

Research in FY 2009 will focus on the use of a new ground-based lightning network that can pro-vide some information of lightning activity over the tropical oceans. The World Wide Lightning Locator Network (WWLLN) can provide estimates of only about 25 percent of the lightning activity compared to what will be available from GOES-R, but it will provide a first look at the forecast potential of this new data source. The WWLLN data will be used to examine the relationship between lightning distributions and hurricane formation and intensification in combination with other factors known to be important such as sea surface temperature and atmospheric vertical wind shear.

Figure 3-DOC-6. GOES-12 1 km imagery shows Hurricane Dean near the Yucatan Peninsula

This work has the potential to help improve hurricane forecasts. The ability to better forecast how strong a storm will be when it reaches the coast will help to improve the reliability of hurricane watches and warn-ings, which are important for evacuations and other mitigation activities.

On the Front Lines of Weather Forecasting: Providing New Satellite Tools to Forecasters

Weather forecasters depend on a robust set of tools to do their jobs. The accuracy of a forecast is a function not only of the forecaster's knowledge of meteorology and local conditions, but also of their skill in interpreting information from numerical weather forecast models and meteorological observations. Sat-ellite imagery has been one of the most important observations in the forecasters' toolbox for more than two decades. However, raw satellite imagery provides only a very small amount of the information that satellites can provide. The range of satellite products has expanded rapidly over the last decade; these now include detailed characteristics of the Earth's surface (temperature, brightness, snow cover, and vegetation type) and atmosphere (vertical profiles of temperature and humidity, cloud properties, chemistry, and dynamics).

How does NESDIS get these advanced satellite products into the hands of the forecasters? The first step is interacting with the operational forecasters to find out what products will be most beneficial to them. Second, the data providers frequently visit the National Weather Service (NWS) forecast offices to provide online training on new satellite products. Equally important is developing a mechanism to deliver the satellite products so they can be incorporated into the forecasters' operational workflow. NWS forecasters display their model and observational data with the Advanced Weather Interactive Processing System (AWIPS), so getting new satellite products into the forecasters' hands means getting the information into the AWIPS data stream. Efforts in FY 2009 will focus on the transition of new satellite products to the AWIPS environment.

Precipitation Estimation from Satellites

Precipitation estimation data from satellites are vital information that supplement surface information measured by ground radars and rain gauges. Research is being performed to improve current satellite precipitation estimation capabilities through a wide range of techniques and satellite instruments. The range of applications using this information is wide and includes disciplines such as weather forecasting and warnings, hydrology, water resources, and climate. For example, in applications that need rapid time updates and fine scale structure, visible and infrared measurements from GOES satellites are used. For those applications that require longer time scales over larger geographical regions, passive microwave measurements from polar orbiting satellites are used.

In FY 2009, research will focus on merging the best properties from all satellite measurements (i.e., all of the sensors and satellites) to improve the precipitation estimates for the entire range of disciplines. In addition, scientists will use data from new sensors on research satellites, such as lightning information and space-borne radars, which will help NOAA develop better algorithms for future satellite missions. Society greatly benefits from this work through the generation of operational satellite products used by NOAA forecasters and scientists, which deliver advanced warnings to the public and longer term predic-tion used by policy makers.

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 and high impact weather, flooding, hazardous air quality 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.

OFFICER OF WEATHER AND AIR QUALITY (OWAQ)

Located at OAR Headquarters, OWAQ is an important focal point for facilitating and coordinating weather research in OAR and throughout NOAA. OWAQ implements the NOAA's component of the U.S. Weather Research Program (USWRP, http://www.esrl.noaa.gov/research/uswrp/) and the NOAA component of THORPEX: A Global Atmospheric Research Program (http://wwwt.emc.ncep.noaa.gov/gmb/ens/THORPEX.html, from which one can link to the North American and international THORPEX websites). OWAQ also does budget planning for and assists in prioritization of NOAA's weather and air quality research.

The United States Weather Research Program (USWRP)

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 interagency component of the USWRP has been dormant for the past two years. However, the NOAA component of USWRP has been quite active although the funding levels have been flat. The USWRP funds return to OWAQ from the National Weather Service (NWS) Office of Science and Technology (OST) in FY2009. OWAQ helps plan NOAA USWRP priorities, implements the program, and monitors progress. During the Fiscal Year (FY) 2008-2009 period, NOAA USWRP 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. Major components of the SIP activities include the Weather and Society*Integrated Studies (WAS*IS) workshops and training sessions that bring social science to the meteorological 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. In addition, 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 for heavy, flooding rains.

THORPEX: A Global Atmospheric Research Program

THORPEX is a 10-year international research program under the World Meteorological Organization that focuses on accelerating improvements in one 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 provided 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. The NOAA USWRP and the National Center for Atmospheric Research support activities within the third bullet.

The 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 is operational as an experimental product and includes the United States, Canada, and Mexico (as a user). NAEFS is 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 and 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 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 – spanning FY2008 and FY2009. It is taking place in the Southeast, East, and North Pacific and involves an intensive observing campaign. Most of the Pacific Rim countries are participating, including the United States and Canada. In addition, there is participation by Germany. The summer phase studies the formation, propagation and intensity modulation of West Pacific tropical cyclones. The ET phase studies 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 United States, Canada, and the Arctic. This phase links to the International Polar Year (IPY).

Office of Weather and Air Quality

In FY2008 and 2009, the funds remaining for science support after office operations and staff costs has decreased such that the Special Projects Initiative had to be terminated, at least for now. It supported innovative and competitive research in the OAR laboratories in weather and air quality. OWAQ is supporting the NOAA share of awards under the joint NOAA-NSF Communication of Hurricane Information solicitation. Four awards were made in FY2008 for two and three year performance periods for a total of over $1.5M OWAQ supports about 1/3 of the total. OWAQ also provides partial support for the Natural Hazards Center in Boulder, Colorado, the National Academies' Disasters Roundtable, the Subcommittee for Disaster Reduction of the Office of Science and Technology Policy's Committee for Environment and Natural Resources, and the U.S.-Japan Panel on Wind and Seismic Effects. The OWAQ Director is on the advisory boards for the first two activities and a member of subgroups on the latter two. In FY2009, the USWRP-THORPEX funding moves from the NWS Office of Science and Technology to OWAQ. Although the funds were located in NWS, OWAQ administered the funds and the USWRP and THORPEX projects and will continue to do so after the funds are transferred.

OBSERVING TECHNOLOGY - ATMOSPHERE

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 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. ESRL also 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 research activities in HMT-West this year focused on deployment of The National Severe Storm Lab's (NSSL) SMART-R radar system to observe heavy rainfall events over the American River Basin near Sacramento, California. Transition of new forecast products into NOAA operations is accomplished through regional testbeds such as the HMT and the Hazardous Weather Testbed (HWT). Sponsored by the NSSL in Norman, Oklahoma, the HWT also assists in the transfer of new remote observing 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.

ESRL is taking a leadership role in implementing the International Earth Observation System including the development and testing of Unmanned Aircraft Systems (UAS) for providing global weather and climate observations. ESRL is one of several NOAA Research organizations collaborating with NASA and many external partners in support of this project. The goal 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 at 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, a gas chromatograph and ozone sensor developed by ESRL, a digital camera system provided by NASA, and an electro optical infrared sensor provided by GA-ASI. ESRL is also developing ultra-lightweight sondes to include in the UAS sensor package.

ESRL's Global Systems Division (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 over 400 GPS-Met stations, owned and operated by NOAA and other government agencies across the United States, and the data is distributed by GSD using a web interface. GPS can be used to calibrate satellite based observations of total precipitable water in the atmosphere, thereby increasing the usefulness of the space-borne sensors. When funds are available, this system will be transferred to National Weather Service 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 by the Meteorological Assimilation Data Ingest System (MADIS).

MADIS is a data management system developed and operated by GSD which ingests, integrates, quality controls and distributes surface and upper-air observational datasets to the meteorological community. Among these datasets are an integrated surface mesonet database containing high-frequency, real-time observations from over 30,000 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. In FY09, MADIS operations will begin transitioning to the National Weather Service operations to provide reliable 24/7 data availability.

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 and AOML also conduct Observing Systems Simulation Experiments (OSSEs) and Observing Systems Experiments (OSEs), including current collaboration on determining the potential impact of data collected by Unmanned Aircraft Systems (UAS) on the prediction of atmospheric phenomena, including hurricanes (discussed below).

ESRL 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, ESRL's Physical Sciences Division (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.

In association with the Center for Environmental Technology (CET) at the University of Colorado, PSD 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 United States. Studies of Environmental Arctic Change (SEARCH) Program. 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 in 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% of the Arctic littoral. Meteorological data from this newly reinstrumented 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 soon 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.

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 32 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.

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. 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, 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 that 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 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 have been 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. 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.

OBSERVING TECHNOLOGY - OCEAN

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 U.S. 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 sea surface temperature (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 pCO2 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's Pacific Marine Environmental Laboratory (PMEL), Brazil, and France, AOML contribute to the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), a project designed as an extension of the Tropical Atmosphere Ocean (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. 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. Four ATLAS moorings were recently deployed 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 a 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). Combined with satellites, Argo data 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. 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 GCOS, and the GOOS. The array is supported by the United States (NOAA) and Japan (JAMSTEC), with JAMSTEC responsible for the TRITON moorings west of 165oE longitude and NOAA responsible for the 59 moorings along and east of 165oE. Responsibility for maintaining the TAO Array has been transferred to the NWS/National Data Buoy Center, and the 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.

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.

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. Several regional testbeds have been created to research these hazards including the Hydrometeorological Testbed (HMT) and Hazardous Weather Testbed (HWT). PSD, GSD, NSSL and other partners participate heavily in these testbeds. Several storm systems were observed and unprecedented data sets were collected in FY2006 and FY2007. GSD has been a collaborator in the HMT from 2005 to the present. This has involved configuring high resolution ensembles, probabilistic quantitative precipitation forecasts, evaluation, and debiasing 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.

NSSL has developed a unique and vibrant collaboration with the operational forecasting community, which has recently been formalized with the establishment of the HWT. The mutual interests of forecasters from the NOAA Storm Prediction Center, researchers from NSSL and ESRL, 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 within the Spring Program 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 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 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 continues to focus on research and development of the NWS WSR-88D radar program and to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public. NSSL's research includes assessment and improvement of numerical models to forecast severe weather systems.

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 NWS. 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.

NSSL works with the 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.

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 Office of Climate, Water, and Weather Services. The research and development into QPE and QPF is being afforded by FAA and NCEP 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 stream flow 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 stream flow prediction, stream flow 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 a storm surge model. This system of coupled models, when fully integrated, can be used for land-use studies, algal bloom studies, pollution studies, and inundation studies of land-falling tropical systems.

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 HWT 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.

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 Aviation Impact Variable (such as icing, turbulence, ceiling and visibility, convective weather, volcanic ash) algorithms and decision tools for NWS forecast offices and FAA traffic management 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. In FY09, GSD will assist the NWS in evaluating development of the Advanced Weather Interactive Processing System (AWIPS) II system and will prototype enhancements for AWIPS II incorporating new science such as uncertainty grids for weather parameters. GSD has developed an AWIPS thin client system, FX-Net, which is used extensively by the NWS Incident Meteorologists in the field and agencies responsible for wildland fire fighting. In FY09, development will begin to couple an atmospheric prediction model with a fire spread model in order to address the wildland-urban interface fire spread problem. 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, NWS Center Weather Service Units coordination with the FAA) and for weather effects and early warnings in response to homeland security events (Geo-Targeted Alerting System and UrbaNet). Also, in FY09, GSD will continue to provide support to NWS aviation-support facilities in Ft Worth, Anchorage, and Leesburg, VA using FX-Collaborate applications. NSSL is collaborating with NWS and GSD to integrate some of NSSL's advanced single and multi-radar display capabilities into AWIPS.

The NextGen Air Transportation System, supported by the FAA, is helping to develop the capability to move relevant observation and forecast information into and out of a virtual weather database called the 4D-Cube. Data quantity, update frequency, timeliness, and latency are important performance considerations for this capability, called NextGen Network Enabled Weather. In addition, a Network Enabled Verification Service will help determine the content of a subset of the 4D-Cube data, to be called the Single Authoritative Source (SAS). The SAS will provide a common weather picture for all aviation decision-makers using weather information.

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 (TAM-DAR), WSR-88D Doppler radars; and weather satellites, especially Geostationary Operational Environmental 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 to provide highly detailed analyses and coupled numerical models (WRF-NMM and WRF ARW) to provide forecasts over areas hundreds of meters on a side. Efforts include methods for surface boundary detection and tracking, convective initiation, and heavy rain forecasting with a hydrologic emphasis for the HMT and HWT. LAPS has been installed for use in the US Space Centers for launches, in a DOD program for precision airdrops, and many other venues requiring high resolution weather predictions. 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. In FY09 and beyond, LAPS will work to effectively couple fire scale atmospheric models with simple and complex fire behavior models to provide critical decision support to incident commanders and land managers. LAPS will be transitioning to a more flexible 3-D variational format within the context of the Space-Time Mesoscale Analysis System (STMAS) that better exploits 4-D databases for optimal resolving of important meteorological systems.

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 Global Ocean Ecosystem Dynamics (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, NSSL and ESRL scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storm complexes. Example programs whose data have been and continue to be analyzed include (1) the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000, (2) the International H2O Project (IHOP), (3) the Thunderstorm Electrification and Lightning Experiment (TELEX) 2003 and 2004, and (4) the annual collaborative severe storm research by NSSL, the NWS/SPC, the Norman Weather Forecast Office, and collaborators through the Hazardous Weather Testbed Spring Program.

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.

The U.S. Southern Great Plains 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 boundary layer 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 the interpretation of lightning data. 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 Oklahoma Lightning Mapping Array (OK-LMA) and the University of Oklahoma Westheimer Airport 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. 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. A major forecast challenge for SPC forecasters is severe weather generated 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.

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 Program 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. Congress 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 Norman meteorological community in Oklahoma is being referred to as HWT/Norman and the groups in Alabama are being referred to as HWT/Huntsville. Working together, these groups will strengthen the nation's collective knowledge and understanding of these hazardous convective events.

Along with NCAR, NCEP, and the university community, GSD has collaborated on the development of the Weather Research and Forecasting (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 Rapid Update Cycle (RUC) model 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's Environmental Modeling Center (EMC) and the Geophysical Fluid Dynamics Laboratory (GFDL) on development of the FIM model (Flow-following Finite-volume Icosahedral Model).

OAR's Air Research Laboratory (ARL) research on the coupling between the air and the surface and the surface energy budget provides key information for improving numerical models. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as emissions from sources like volcanoes, 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 Physical Science 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 satellite observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during TRMM Ground Validation field campaigns. Collaborating with other TRMM researchers, the observations made during the field campaigns use profilers to calibrate scanning radars used for TRMM ground validation research and 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 hydrome The Atlantic Oceanographic and Meteorological Laboratory's (AOML) Hurricane Research Division (HRD), together with researchers at the GFDL, ESRL, and NESDIS's Satellite Applications and Research (STAR) division make up the NOAA core capability for hurricane research and development and is envisioned to be a major part of the new NOAA Hurricane Forecast Improvement Project (HFIP). HFIP builds upon and draws much of its NOAA expertise from these core research and development capabilities and is driven by the operational needs of the NWS. Within the NWS, the National Hurricane Center (NHC), the Central Pacific Hurricane Center, and the hurricane-modeling group at the Environmental Modeling Center (EMC) comprise the NOAA core operational hurricane capability.

The HFIP is a new effort to develop a unified 10-year plan to improve one to five day tropical cyclone forecasts, with a focus on rapid intensity change. HFIP is only feasible because of the core research and development capabilities at HRD, AOML, GFDL, and ESRL. The objectives of the HFIP are to coordinate hurricane-related research and development within NOAA (such as those mentioned above), and to broaden the interaction of the outside research community in addressing NOAA's operational hurricane forecast needs. The goals of the HFIP are to improve the accuracy and reliability of hurricane forecasts; to extend lead-time for hurricane forecasts with increased certainty; and to increase confidence in hurricane forecasts. These efforts will require major investments in enhanced observational strategies, improved data assimilation, numerical model systems, and expanded forecast applications based on the high resolution and ensemble based numerical prediction systems. The expected outcomes of the HFIP are high quality information with associated probabilities on high impact variables such as wind speed, precipitation, and storm surge. This will be achieved by reducing the average errors of hurricane track and intensity forecasts by 50%, improving the skill in forecasting rapid intensity changes (both increases and decreases), and by improved storm surge forecasting. The benefits of HFIP will significantly improve NOAA's forecast services through improved hurricane forecast science and technology. Specific metrics include:

- Reduce average track error by 50% for Days 1 through 5.
- Reduce average intensity error by 50% for Days 1 through 5.
- Increase the probability of detection (POD) for rapid intensity change to 90% at Day 1 decreasing linearly to 60% at Day 5, and decrease the false alarm ratio (FAR) for rapid intensity change to 10% for Day 1 increasing linearly to 30% at Day 5.
- Extend the lead time for hurricane forecasts out to Day 7.

While improving the POD and FAR for rapid intensity change within 1 day of landfall is a high priority, given the uncertainty in track forecasts of landfall, these improvements are needed at all lead times over the entire life span of the storm system.

NOAA needs to address two other areas to meet the HFIP goals: (1) expand the forecast tools and applications to the operational forecasters; and (2) develop a capability to evaluate observing strategies in order to inform NOAA of significant investments in new observing systems. Regarding the development of forecast applications, HRD has developed a number of these applications with support from programs such as the Joint Hurricane Testbed (JHT) intended specifically to improve the transition of research to operations. Under the USWRP and its participating agencies, OAR, NWS, and NESDIS established the Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida in 1999. 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. HFIP envisions 10 times the current number of projects in order to meet the goals and metrics outlined in the plan.

NOAA is supporting a number of Observing Systems Simulation Exercise (OSSE) studies to provide critical guidance on the optimal composite observing system for hurricane monitoring and prediction, including such future observing systems as those flying on UAS. The idea of an OSSE is to create a simulated atmosphere so that observation impact can be directly evaluated against the "true atmosphere". To execute this OSSE, not only must the future observations be simulated, but also the other operational observing systems, from a "nature run". The hurricane UAS OSSE is utilizing a global Nature Run developed by the European Center for Medium-Range Weather Forecasts (ECMWF) with ~40 km spatial resolution. Satellites currently provide most of the observations of a hurricane's environment, whereas much of the inner core observations are produced by the NOAA P-3 or G-IV aircraft. It is a formidable challenge to develop an OSSE, which explains why an international, multi-agency working group that includes NCEP/EMC, GSD, NASA, the Joint Center for Satellite Data Assimilation (JCSDA), and ECMWF are all involved in this effort. The numerical prediction model (different from that used to create the Nature Run) provides forecasts by assimilating the synthetic observation datasets into the model's initial state. By examining the forecasts made with assimilated synthetic data against the "true" atmosphere, and compare the results to forecasts made without such observations, the impact from the observations can be evaluated.

To meet NOAA's UAS program requirements, "Quick-OSSE" and OSE will be performed by GSD in collaboration with AOML for assimilating into high-resolution regional hurricane models the actual atmospheric data collected in the past by UAS aircraft (such as with hurricanes Noel and Ophelia). An OSE allows for the systematic impact of each contributing observing system to be evaluated by making "data denials" to the model's initial state. Thus, OSE allows determination of the forecast impact after the data is actually collected, as opposed to an OSSE, where an optimum sampling strategy can be explored in a controlled environment before aircraft are sent out into the field to take the measurements. Clearly, an OSSE permits testing of multiple flight strategies, sampling rates, and payload options to arrive at an optimized solution, whereas an OSE can only deal with the actual measurements taken from a flight made with a given payload. There is a middle ground between these two extremes – that being the Quick-OSSE approach, in which a very high-resolution regional numerical simulation is first made for a given case from the past in which actual data are available, but first by withholding the data from the model. Then, simulated data are extracted from this real-data simulation and assimilated into a lower resolution model that is different from the one chosen for the control run (e.g., different versions of the WRF model could be used for this purpose). A wide variety of sampling and payload options can thus be tested. The comparisons allow for some measure of guidance about improvements that could be made in the future testbed deployments of aircraft and sensor payloads.

HRD's capabilities are based on the use of in situ and remotely-sensed data collected by aircraft, satellites, and buoys, and computer model simulations of the inner core of tropical cyclones and their surrounding environment to improve track and intensity forecast guidance. These observations are primarily collected during the hurricane season using two NOAA turboprop aircraft and a Gulfstream-IV jet operated by NOAA's Aircraft Operations Center (AOC). The field program is used to carry out scientific experiments designed to address the goals stated above. Data sets gathered on these flights in all stages of the storm's lifecycle are used to support operational needs and form 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 capability.

Much of the research at HRD is going to improve forecasts of hurricane intensity change, however HRD scientists are also actively engaged with scientists in the other AOML divisions in projects related to seasonal hurricane forecasts, the impact climate change has on hurricanes, and the impacts hurricanes have on life and property. HRD also coordinates its programs with other NOAA organizations, e.g., AOC, NESDIS, and NCEP, in particular with EMC and NHC. A high priority since 2005 is the NOAA Intensity Forecast Experiment (IFEX) developed through a partnership involving HRD, TPC, EMC, and NESDIS. The goals of IFEX are the collection of data to directly aid the development and evaluation of the next generation operational Hurricane Weather Research Forecast (HWRF) model. HRD also maintains active research programs with, and receives funding from other governmental agencies, and arranges cooperative programs with scientists at NCAR and numerous universities. HRD's strengths provide NOAA with the capability to address the HFIP plan.

PSD's effort is focused on observation and parameterization of air-sea flux processes. Hurricanes are driven entirely by surface heat flux and their intensity is predominantly determined by friction at the surface (momentum flux to the ocean currents and waver). Recently PSD has been working with EMC to transition the PSD sea spray/flux parameterizations to HWRF. Historically hurricane models have used unrealistic surface flux parameterizations in order to achieve the observed central pressure – maximum wind speed relationship. However, as fully coupled (air –ocean –wave) models come online, it will be necessary to incorporate more realistic and physically based flux parameterizations. PSD is also working with ARL and HRD to advance critical observational technologies for research on surface properties, fluxes, and atmospheric boundary layer dynamics. This includes development of hardened surface-based in situ flux and sea spray sensors to mm-wavelength radars and GPS reflection systems for use on the NOAA P-3's and/or UAS platforms.

Via THORPEX funding (see page 3), PSD scientists have developed an efficient global ensemble Kalman filter (EnKF) data assimilation technique that has demonstrated in preliminary experiments the ability to initialize hurricanes much more accurately than existing data assimilation techniques used in NOAA. The current operational NOAA technique utilizes 3-dimensional variational analysis (3DVAR) and "vortex relocation." This technique has not been able to initialize hurricane vortices with sufficient intensity, and the analyzed vortex is often not preserved in short-term forecasts to the same extent that it is preserved under the EnKF, i.e., the forecast is subject to much less "spin-up." PSD is working in cooperation with GSD and HRD on further testing of EnKF techniques in global and regional models. Other data assimilation strategies are also being investigated jointly by GSD and HRD, including use of the NCEP version of the Grid-point Statistical Interpolation (GSI) for the HWRF model, the STMAS 3DVAR technique, and possible hybrid 3DVAR-EnKF approaches. One of the goals of this research is to ensure that the inner hurricane core data collected by the NOAA aircraft and other systems are represented properly in the HWRF model initial state.

GSD participates in a large number of modeling and data assimilation activities relevant to hurricane prediction beyond the OSSE and collaborative data assimilation studies mentioned above, including being a co-partner with the National Center for Atmospheric Research (NCAR) in the Developmental Testbed Center (DTC). The activities of the DTC include testing of select codes from the Weather Research and Forecasting (WRF) model for possible elevation to Reference Code, maintaining and supporting this Reference Code to the community, and testing and evaluating improvements made by the community in order to accelerate the infusion of new numerical weather prediction capabilities into operations. The DTC has recently begun working closely with NCEP in supporting the operational HWRF modeling system to the community. In addition, the DTC has extensive interactions with members of the hurricane research community, notably with HRD and PSD, related to new NWP technologies that show promise for improving hurricane prediction. HWRF consists of the NCEP version of the WRF model, known as the Nonhydrostatic Mesoscale Model (NMM), coupled to an ocean model (the Hybrid Coordinate Ocean Model, HYCOM), and a wave model used by both NOAA and the Navy (WAVEWATCH III). Quite recently, the WRF-NMM model component of HWRF as well as the NMM-based Hurricane Research System developed by AOML, have been ported to DTC supercomputer facilities at GSD and NCAR to enable NOAA Research to be able to work as a community with these hurricane forecast systems.

GSD is also participating in an experimental use of a very high-resolution ensemble version of its finite-volume, icosahedral global model (FIM) to address the need to improve medium-range hurricane track forecasts. This is being done to address fundamental issues of environmental predictability of tropical and other high impact weather systems under NOAA's Environmental Modeling Program, and to develop the necessary modeling techniques to improve NOAA's capability to accurately predict the evolution of these systems. Significantly improved forecasts of hurricane track and intensity out to 5 days and beyond would greatly improve the risk-based decision making necessary for the protection of life and property along the U.S. coastline from intense landfalling hurricanes. The purpose of running an ensemble forecast system is to attempt to improve both the accuracy and reliability of the forecast to greatly reduce the costs and disruptions due to emergency response. Large increases in NOAA supercomputing capabilities are dictated in significant ways by these needs, resulting in proposed R&D and operational computing advances by FY2011.

Three important activities begun in 2008 under the HFIP are the high-resolution modeling workshop and test plan coordinated by the DTC and the high-resolution predictability research effort utilizing the Texas Advanced Computing Center (TACC), and the development of an observing strategy analysis capability for the high-resolution regional hurricane model utilizing a number of data assimilation and inner core observing system simulation techniques.

The HFIP high-resolution modeling workshop coordinated by the DTC was held at NHC in March 2008, and the test plan developed from the workshop brings together seven model development teams from OAR (AOML, ESRL, GFDL), other Federal agencies (NRL, NASA), and academia (NCAR, TAMU, Wisconsin) to demonstrate the potential benefits of high-resolution ($\leq$1 km horizontal resolution) hurricane models. Each team agreed to "freeze" all variables that may contribute to the quality of the intensity forecasts except horizontal grid resolution, which will be tested at three resolutions: 1-2 km, 3-5 km and about 9 km. Thus the potential benefit of higher grid resolution can be evaluated for each of the participating teams by comparing their test runs at varying resolutions. Given the diversity of the model configurations overall, there is an excellent opportunity to create a multi-model ensemble metric for evaluation. Each team will run their model configuration for 60 cases from 10 storms selected by the NHC forecasters. "Truth" data for verification will come from the operational database at NHC including the final operational best track and archived tropical cyclone data. A verification team, made up of operational and research scientists, developed an agreed upon set of metrics for all simulations. All teams agreed to provide as many simulations as possible between September 2008 and February 2009. The verification results will be tabulated and presented to the teams at another workshop in March 2009. As part of this test a team from HRD and GSD are working together to develop a hurricane research system based on the WRF-NMM version 3 utilizing many of the operational physics packages.

The goal of the high-resolution predictability research at TACC is to make substantial progress on establishing the operational value of higher resolution modeling (global and regional - including ensembles) to improving overall forecast performance, one of HFIP's highest priority objectives. Other objectives include:

- Demonstration of the potential of on-demand computing to support operational hurricane forecast operations at NHC.
- Inform future research and development needs as relating to established HFIP goals and objectives toward the development and implementation of the next-generation hurricane forecast system.

HRD, with a HFIP high-resolution test team from Texas A&M University and GSD with support from the NOAA OCIO and NCEP are:

- Porting and establishing baseline performance for a version of the Advance Research WRF (ARW) and the GSD Finite-Volume Icosahedral Model (FIM) to the TACC;
- Demonstrating the capability to ingest operational data in real or near-real time;
- Developing global and regional model products for this season and delivering these products to NHC for evaluation; and
- Setting-up, running, and evaluating global and regional model ensembles (at 15-km horizontal resolution global and 4.5/1.5-km km horizontal resolution regional) for track and intensity on several cases from the high-resolution model test plan. Inform future ensemble research needs.

NUMERICAL ANALYSIS AND PREDICTION MODELING

The ESRL GSD continues to perform research and development on a high-frequency updated model/assimilation system within NOAA's operational atmospheric models, currently occupied by the Rapid Update Cycle (RUC). The RUC is heavily used by users especially within the aviation/transportation and severe weather forecaster communities, but also for public forecasts, marine, energy, and other applications. The initial version of the RUC was transitioned by GSD (its predecessor organization – PROFS) to NCEP (then, NMC) in 1994. Yearly upgrades have been made since then, of major proportion in 1998, 2002, 2005, and 2008.

GSD also has conducted forecast impact assessments with new observation types to consider potential operational use at NCEP including wind profilers, GPS-Meteorology precipitable water, TAM-DAR data, and METAR ceiling/visibility, and radar reflectivity, all resulting in operational implementations. The model updates every hour, incorporating information from virtually all high frequency data sources: hourly wind profiles; WSR-88D (Doppler radar) radar reflectivity, 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 heavily on the development of the 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 and NCEP are scheduled to replace the RUC with the WRF Rapid Refresh model in 2010, updated hourly and extended to Alaska, Puerto Rico, and the Caribbean Sea.

GSD has also developed a unique hourly-updated, radar-initialized, storm-resolving (3-km) model forecast capability, the High-Resolution Rapid Refresh (HRRR). The HRRR real-time forecasts have demonstrated utility of 3km for aviation and severe weather forecast users, and a likely key role for NOAA's Warn-On Forecast capability. GSD's effective method for radar reflectivity and lightning assimilation will also be applied to tropical storm forecasts within the hourly updated Rapid Refresh model using proxy reflectivity data from satellite based estimates or aircraft-measured reflectivity. GSD has demonstrated this in the hourly updated 13km RUC and the 3-km High-Resolution Rapid Refresh. The goal here will be to improve high-frequency updating of short-range NWP forecasts.

GSD has developed a fire weather forecast system running at 0.5 km to predict environmental winds in and around active fires. Coupled to this are USFS fire behavior models to better predict the movement and evolution of fire lines. This model can be nested in large scale models like the HRRR above. GSD has developed storm resolving initialization methods (hot start) for individual storm prediction for warn-on-forecast applications. This would include heavy rain forecasts for flash flood warnings.

GSD has also led the development of WRF-Chem, a significant extension of the WRF model with a fully coupled chemistry with atmospheric physics. WRF-Chem is now used widely for air quality and other air chemistry research and various real-time demonstrations.

GSD has also pioneered the application of high resolution (3 km) ensembles for probabilistic quantitative precipitation forecasts aimed at hydrological prediction. The HMT effort previously described as been the catalyst for this effort. Work has focused on optimizing the ensemble by evaluating individual members, and debiasing precipitation forecasts and forecast probabilities.

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).

Mesoscale dynamics research at 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.

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 (see figure). 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. Insurers are raising underwriting standards and rates in hurricane-affected markets, and some insurers are withdrawing from some markets. Nonetheless, infrastructure is still 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 relatively 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.

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 volcanoes, 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.

AIR QUALITY RESEARCH

The principal mission of 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 the Environmental Protection Agency, Department of Energy and Department of Defense.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction to support operational predictions and emergency response. The division is researching mercury fate and transport through measurement and modeling studies.

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

Figure 3-DOC-7. A 42-hour forecast on September 4, 2008 of column-integrated total condensates (cloud water, rain water, snow, cloud ice, and graupel) using a prototype global atmospheric model to be used for future studies of climate change.

on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness 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."

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.

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. In 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. The Health of the Atmosphere research goals are:

- Characterize regional ozone and particulate matter (PM) episodes
- Characterize the factors that cause poor air quality in regions of the United States where excessive levels of ground-level ozone and fine particle

pollution are occurring.

- 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, 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 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 field 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 U.S. 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.

EARTH SYSTEM SCIENCE EDUCATION AND OUTREACH

Science On a Sphere® is a unique visualization technology that was invented by Dr. Sandy MacDonald, Director of the Earth System Research Laboratory (ESRL) in Boulder, CO. In August of 2005, NOAA received a patent for Science On a Sphere®. Using computers coupled with video projectors, the system presents NOAA's global science in an engaging three-dimensional representation of the Earth's features as if they were viewed from space. By September 2008, there will be 25 installations of NOAA Science On a Sphere in science and technology museums and centers, research laboratories, aquariums, and technology visitor centers in the United States and overseas, including the Smithsonian's new Oceans Hall, Another 6 museum installations are expected to be funded in FY09 through the NOAA Office of Education competitive grants program.

Science On a Sphere® maps directly to NOAA's mission goal to "Serve Society's Needs for Weather and Water Information" and its performance objective of enhancing environmental literacy and improving understanding, value, and use of weather and water information and services. This innovative technology is intended to educate multigenerational and now international audiences about ongoing NOAA research being conducted at many laboratories and to inspire students so that they might investigate scientific career paths. Over a half dozen international installations are planned for Europe, Asia, and possibly Australia. It is estimated that over 15 million people will be seeing SOS in FY09 worldwide.

ESRL is also developing a NOAA virtual world in the rapidly growing online world of Second Life and others as they are introduced via the web. Users can learn about NOAA's leading edge science and have experiences in the virtual world they cannot have in the physical world such as soaring through a hurricane on the wing of a hurricane hunter aircraft. The web site offers another way to attract the next generation of Earth system scientists. As the technology becomes more sophisticated, scientists may also use the site to collaborate on research, hold virtual meetings and give public presentations.

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 en-vironment for present and future generations. NOS is the primary civil agency within the federal govern-ment responsible for the health and safety of our nation's coastal and oceanic environment. Largely through the Tides and Current Program line, NOS acquires water levels, currents, winds, and other physi-cal oceanographic and meteorological data, and distributes these data and circulation predictions as ele-ments 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 transporta-tion, 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 warnings and storm surge forecasts. 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, which officially consists of 200 stations (4 additional stations will be-come part of the network by the end of FY09) 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 forecast activities, and the Climate and Global Change Program. A DCP NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS a 6-minute intervals and imbedded in those data streams are high-rate one-minute averages for tsunami use. The 6-minute interval GOES transmission capability also supports the NWS storm surge forecast 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 measurement and integration of real-time environmental observations, forecasts, and other geospatial information (Figure 3-DOC-7). PORTS® measures the coastal environment 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 18 existing PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. PORTS® are partnership programs in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS' existing installations is composed 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 U.S. 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 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 exten-sible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

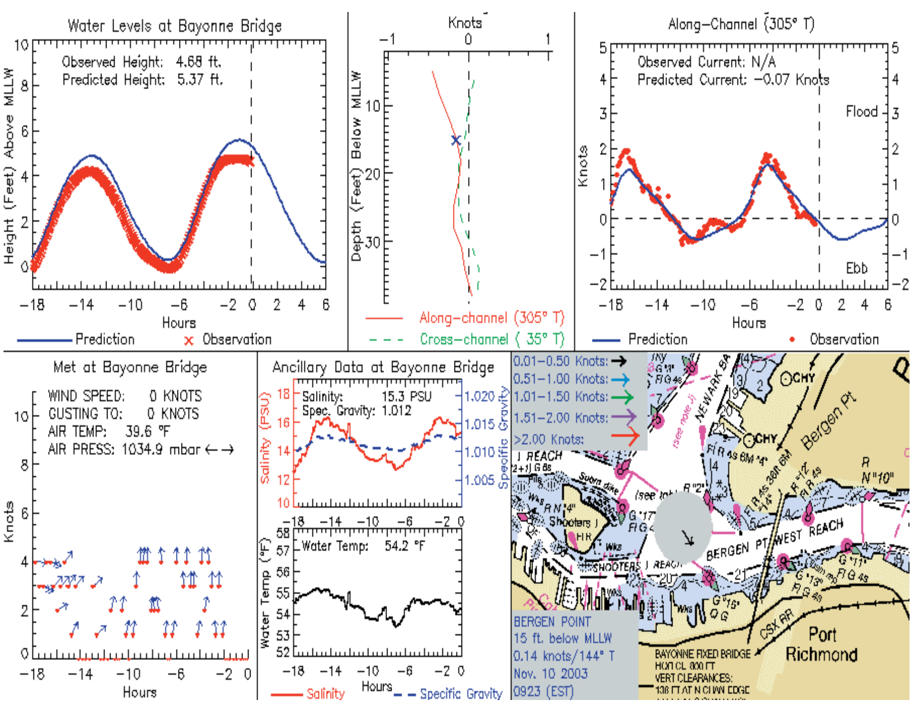
National Operational Coastal Modeling Program (NOCMP).

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, followed 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 mate-rials 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 24hour/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. 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-8. New York/New Jersey PORTS: Bergen Point Composite



NOAA Office of Marine and Aviation Operations

The NOAA Office of Marine and Aviation Operations (OMAO) operates a fleet of survey ships and aircraft to support NOAA mission goals. NOAA's ship fleet includes oceanographic and atmospheric re-search vessels. The NOAA aircraft fleet includes aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research; and aircraft that con-duct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

NOAA SHIPS SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA Ship RONALD H. BROWN, an oceanographic and atmospheric research platform, is the largest vessel in the NOAA fleet (274 feet). With its instruments and sensors, the BROWN sails worldwide supporting scientific studies to increase our understanding of the world's oceans and climate. The BROWN also carries a Doppler radar system to support at-sea meteorological observations.

NOAA Ship KA'IMIMOANA primarily supports the research programs of NOAA's Tropical Atmos-phere-Ocean (TAO) Project (real-time data from moored ocean buoys for improved detection, understand-ing 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, and carbon dioxide content.

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 FY2009, 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 ninth 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, after the Stratus project the BROWN will sup-port VOCALS-REx (**V**AMOS **O**cean-**C**loud-**A**tmosphere-**L**and **S**tudy – **R**egional **Ex**periment) off the coast of Chile. VOCALS-REx will focus on interactions between clouds, aerosols, marine boundary layer proc-esses, upper ocean dynamics and thermodynamics, coastal currents and upwelling, large-scale subsidence, and regional diurnal circulations, to the west of the Andes mountain range. The field experiment is ultimately driven by a need for improved model simulations of the coupled climate system in both the Southeast Pacific and over the wider tropics and subtropics

RONALD H. BROWN will also conduct the Northwest Tropical Atlantic Station (NTAS) project, which investigates surface meteorological forcing and oceanographic response in a region of the tropical Atlantic with strong sea surface temperature anomalies on decadal time. These issues are addressed through the analysis of surface mooring observations from a site near 15° N, 51° W. Following the NTAS project, BROWN will 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. OMAO vessels also support the NOAA National Data Buoy Center (NDBC) in recovery of buoys which have been disabled or gone adrift.

NOAA AIRCRAFT SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of air-craft 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 NOAA G-IV and WP-3D aircraft during the hurricane season of 2007 were very similar to the 2006 season with an exception being that the G-IV flew about half the number of hours in 2007 while the P-3s almost double their output over the previous year. All told, these three aircraft flew a total of 45 missions and 273 hours in the relatively quiet season.

The NOAA Gulfstream, G-IV (SP) (N49RF), provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere. 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 fore-casts 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.

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. 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. Because of the relatively slow hurricane season in 2007, with few storms threatening the United States, the use of the NOAA G-IV for hurricane surveillance was limited to only eight flights totaling 65 hours.

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 con-junction 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 alone from either a base in Alaska or Hawaii as the case may dictate. Use of the G-IV for the 2007 Winter Storms Reconnaissance program was significantly higher than for the Hurricane program. Operating solely from a base in Hawaii, this aircraft flew 24 missions for 160 hours during January and February.

A recently added mission for the G-IV, supporting the Hurricane Research Division's Saharan Air Layer Experiment (SALEX), is still ongoing each hurricane season, subject to the availability of atmospheric conditions and flight hours. 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. Typically the aircraft will operate from a forward base in Barbados, as it is the most eastern island in the western Atlantic Ocean.

NOAA's Chemical Science Division (CSD) of the Earth System Research Laboratory, located in Boulder, CO, is continuing to use the G-IV for some of high altitude air quality studies. CSD in past years has used instrumentation to measure ozone, CO and VOCs (volatile organic compounds). The Division has reaped a harvest of quality data piggy-backing on WSR missions and scientists from this organization have either published or presented a significant number of publications over the past few years utilizing the data obtained on the G-IV.

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. The aircraft research and navigation systems provide de-tailed 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.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also pro-vided storm data to the National Hurricane Center (NHC) in real-time, transmitting flight level data, GPS dropsonde messages, as well as radar images transmitted via its multiple aircraft-satellite data links. With the Stepped Frequency Microwave Radiometers (SFMR) now operational, increasing emphasis was placed on utilizing the NOAAWP-3D to map the surface wind fields in and around hurricanes and tropical storms in 2007. 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 landfalling 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 op-erated 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 more 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 2007, the two NOAA WP-3Ds supported several major research experiments in support of NOAA's Hurricane Research Division. During this past season these aircraft embarked on a new en-deavor, to obtain 3-dimensional horizontal wind fields in developing tropical systems and hurricanes utilizing their tail Doppler radars (TDR). This effort is part of a new initiative to obtain data that can be assimilated into the HWRF hurricane forecast model for the purpose of improving intensity forecasts. As this was a new effort, much of the 2007 flight program was spent developing the techniques and flight proce-dures to obtain the optimum set of data for ingestion into the models. Operating from bases in St. Croix, VI and Barbados, the P-3s flew numerous missions on a round-the-clock basis into Tropical Storms, Erin, Ingrid and Karen as well as Hurricane Felix and Tropical Depression #10. One of the P-3s also partici-pated in a joint UAS (Aerosonde) – aircraft mission into TS Noel in early November. Both of these ex-periments have continued through the 2008 season and will reoccur in 2009.

The NOAA WP-3Ds annually support both a summer and winter operation 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 under-flight validation of NOAA 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.

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. 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 dis-tributed 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.

In 2007 the Tunable Optical Profiler for Aerosol and Ozone (TOPAZ) LIDAR system was tested 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. This system was again used effectively during the 2008 field campaign along the Colorado Front Range and will reoccur in 2009.

Inclusion of a remote sensing aircraft also provided information on the three-dimensional resen-tativeness 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.