EXECUTIVE SUMMARY

Introduction

The tropical cyclone forecast and warning program is an interdepartmental collaboration to provide the United States and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems. The three centers that cooperate to provide the operational forecast and warning services are the Tropical Prediction Center/National Hurricane Center (TPC/NHC), the Central Pacific Hurricane Center (CPHC), and the Joint Typhoon Warning Center (JTWC) (figure ES-1).

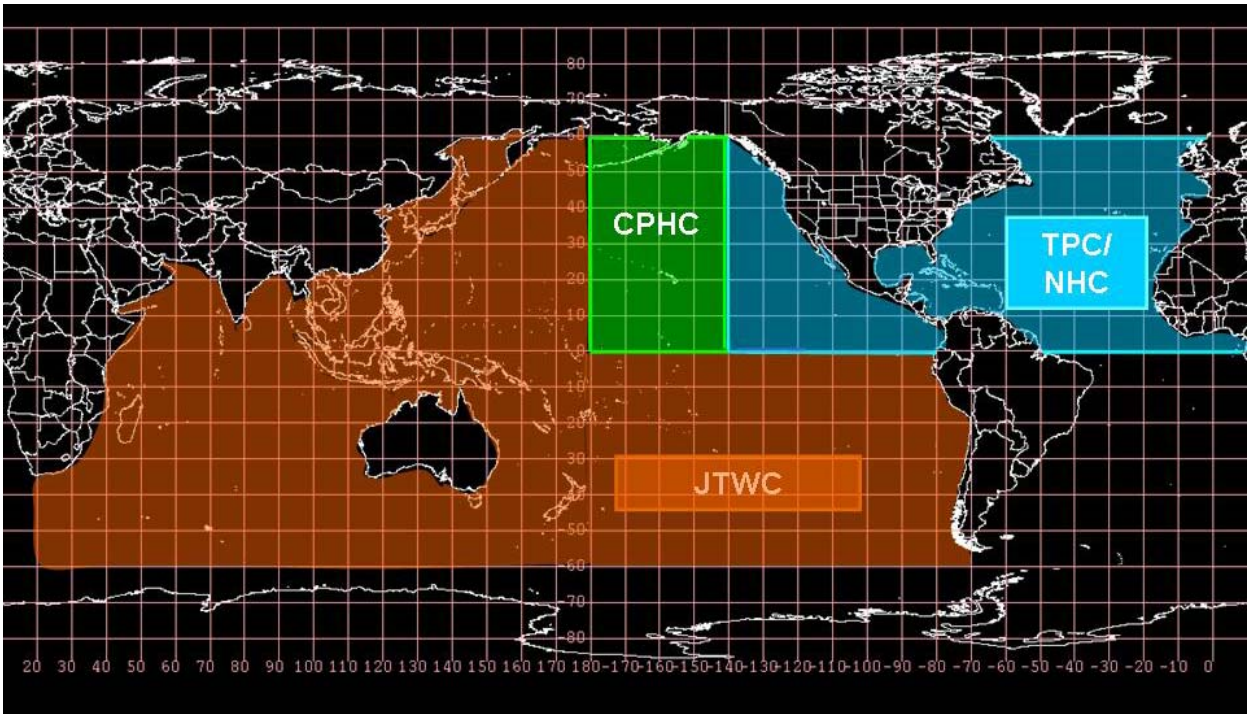

Figure ES-1. Areas of responsibility assigned to the operational tropical cyclone forecast and warning centers. The JTWC area of responsibility overlaps with those of the TPC/NHC and CPHC north of the equator in the central and north Pacific.

This plan, *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead*, provides a strategy for continuing to improve the effectiveness of operational forecasts and warnings through strategic coordination and increased collaboration among the major players in the operational and R&D communities. The plan represents extensive efforts by the Joint Action Group for Tropical Cyclone Research (JAG/TCR), established by the Federal Coordinator for Meteorological Services and Supporting Research in 2005 to respond to a principal action item, proposed at the 58th Interdepartmental Hurricane Conference in 2004, to develop a comprehensive strategy for tropical cyclone R&D to guide interagency efforts over the next decade. The action item was reviewed and supported by both the Interdepartmental Committee

for Meteorological Services and Supporting Research, in November 2004, and the Federal Committee for Meteorological Services and Supporting Research, in December 2004.

Chapter 1 of the plan illustrates the fundamental rationale for continuing the effort in tropical cyclone R&D to further improve tropical cyclone forecasts and warnings. It introduces the operational centers for the Nation's tropical cyclone warning service, serving both civilian and military needs, and the research and operations communities that support the operational centers (referred to as the community of practice).

Chapter 2 describes in more detail the community of practice. Understanding how this community works—its strengths and its limitations—is crucial for formulating and implementing a community-wide, comprehensive strategy for tropical cyclone R&D that can guide interagency efforts over the next decade. Chapter 2 also reviews recent and concurrent planning activities that were taken into account in formulating the research priorities.

Chapter 3 assesses the current capabilities and limitations of the Nation's tropical cyclone warning service. These capabilities constitute a classic end-to-end meteorological warning and forecasting system, from data collection through data assimilation and NWP modeling, to dissemination of warnings and forecasts, including end-user education, training, and outreach.

Chapter 4 uses the same end-to-end system structure to present the JAG/TCR's perspective on the future capabilities required to meet both current operational needs and emerging needs ***identified by the operational centers***. This perspective draws heavily on recent significant planning efforts, as well as on the expertise of the JAG/TCR members collectively and of the R&D and operational organizations they represent. The operational needs of the tropical cyclone forecast and warning centers, as summarized in section 4.1 of the plan, can be characterized by the following seven tropical cyclone–related, day-to-day operational forecast and warning categories (or a combination of these categories):

- Intensity
- Structure
- Track
- Sea state
- Storm surge
- Precipitation
- Observations

In Chapter 5, these future capabilities are translated into a set of research priorities, around which a comprehensive R&D strategy for the next decade can be built. Chapter 6 presents a summary of key findings and the JAG/TCR recommendations for next steps that can be taken by the cognizant Federal agencies and coordinating entities to begin implementation of this strategy.

As emphasized in the plan, meeting the operational needs in these categories will require continued advances in observations, data assimilation technologies, and tropical cyclone NWP models. Absolutely essential to these advances are sufficient human and infrastructure[1] resources

[1] Infrastructure resources are related to items such as computational power, network bandwidth, architectural/engineering requirements, and maintenance of applicable systems.

for tropical cyclone R&D and the transition of R&D results to operations, along with sufficient human and infrastructure resources for the operational NWP environment.

Findings, Recommendations, and Resource Estimates

The plan highlights several key findings, which are discussed in section 6.2. The JAG/TCR's recommendations that follow logically from some of the key findings, which are discussed in section 6.3, are summarized in table ES-1. Finally, section 6.4 summarizes new investments that are associated with the recommendations. The JAG/TCR estimates the additional operational and R&D resources required (above currently programmed budgets), to enable this Nation to meet the operational needs of the tropical cyclone forecast and warning centers, at $85 million per year beginning in fiscal year (FY) 2008 and decreasing to $70 million per year in FY 2017 (in 2006 dollars). As stated in the summary of this plan:

> *Vast improvements in tropical cyclone prediction are attainable with focused research efforts; enhanced transition of research to operations capabilities; strong interagency partnerships, coordination, and planning; and most importantly, sufficient resources—both human and infrastructure. The capability to gain skill in forecasting rapid intensity changes and to improve predictions of hurricane intensity and structure, sea state/storm surge, and precipitation is currently on the horizon, much as improving hurricane track was two decades or so ago. The ultimate goal is to prevent loss of life and injuries and to reduce the Nation's vulnerability to these potentially devastating storms. This goal can and must be accomplished for the good of the Nation.*

Table ES-1. JAG/TCR Recommendations

No.	Category	Recommendation
1	**Tropical cyclone NWP modeling**	The continued development and implementation of the next-generation tropical cyclone forecast systems, such as the HWRF Air-Sea-Land Hurricane Prediction System and the COAMPS Tropical Cyclone System, to improve tropical cyclone forecast guidance for TPC/NHC, CPHC, and JTWC forecasters regarding intensity, structure, track, sea state/storm surge, and precipitation should be a high priority for the Nation. a. Development and transition of research to operations: (1) The development efforts of the next-generation hurricane forecast systems should form the basis for projects supporting hurricane research and collaboration among experts from the university community, international researchers, the private sector, and other Federal agencies. (2) Sufficient human and infrastructure[a] resources should be provided to support development of advanced data assimilation and NWP modeling systems (see figure 6-1). (3) An interagency working group, under the auspices of the OFCM, should be formed to develop a plan to support the tropical cyclone NWP program. The plan should: (a) include procedures to enhance the flow of relevant research focused on improvements to the operational NWP systems; (b) improve the conduit by which the academic community could be involved in the next-generation hurricane model development and testing (e.g., through the JHT and DTC) and (c) account for having sufficient human and infrastructure[a] resources for development work and transition of research to operations activities, including sufficient resources to support collaborative ventures (see figure 6-1). b. Operations: Sufficient human and infrastructure[a] resources, including the capability to run ensembles with the HWRF Air-Sea-Land Hurricane Prediction System and the COAMPS Tropical Cyclone System, should be provided to NCEP/EMC and FNMOC for their operational NWP tropical cyclone model programs.
2	**Tropical cyclone research and research coordination**	a. **Research** (1) The JAG/TCR recommends strong support for activities focused on the tropical cyclone research priorities identified in chapter 5. (2) Results of social science research need to be an integral part of the hurricane forecast and warning program. With increased funding, a possible venue to pursue social science research questions is through the Joint Hurricane Testbed (without compromising current projects). (3) Sufficient and sustained funding is needed for analyses of field experiment data sets. b. **Research Coordination.** An element that is vital to the tropical cyclone R&D program is a formal, multiagency, coordination entity to perform the tasks described in section 6.2.1, paragraph #2. The JAG/TCR recommends that this coordination requirement and development of a research implementation plan be satisfied through the OFCM infrastructure.
3	**Strategic plan for tropical cyclone observations**	Through the OFCM infrastructure, a strategic plan for improved tropical cyclone reconnaissance and surveillance systems (manned, unmanned, spaced-based, etc.) needs to be developed. The plan should consider observations and observing strategies for tropical cyclone forecaster needs, data assimilation for NWP models, and NWP model diagnostics and verification.

Table ES-1. JAG/TCR Recommendations

No.	Category	Recommendation
4	**Tropical cyclone warning program review**	NOAA (including OFCM), along with Federal agencies, should continue to review and improve the Nation's hurricane warning program.
5	**Education, out-reach, and work-force development**	a. Education, training, and outreach efforts concerning the public's knowledge and appreciation of tropical cyclone impacts must continue, and they must be accorded the priority they deserve. b. To resolve the deficiency within this Nation in producing enough qualified (educated) personnel with the requisite NWP modeling education and training, there needs to be strong backing (advocacy) by professional organizations (e.g., American Meteorological Society, American Geophysical Union, American Association for the Advancement of Science), as well as long-term commitment from Federal agencies (e.g., NSF, NOAA, NASA) and from the academic institutions that are the principal providers of degreed personnel employed by agencies that conduct the Nation's sophisticated NWP activities.

[a] Infrastructure resources are related to items such as computational power, network bandwidth, architectural/engineering requirements, and maintenance of applicable systems.