Executive Summary

The long range precision of the National Meteorological Center's (NMC) prognostic guidance, the early and accurate warnings developed by NWS field forecasters, and the energetic dissemination activities of the media and government response organizations were unprecedented in preparing the public for this winter storm of incredible proportions.

Despite the strongly worded early warnings, the storm was responsible for some 200 deaths. The primary direct causes for these fatalities were tornadoes and coastal flooding in Florida. **In fact, Superstorm surge killed more people from drowning than Hurricane Hugo and Hurricane Andrew combined. The** primary indirect cause of fatalities was heart attacks brought on by overexertion while shoveling snow.

Due to the widespread geographic area affected, a DST was organized into several groups, two dispatched to assess warning and forecast effectiveness in the northern states, and two groups sent to survey damage and warning and forecast effectiveness in the south part of the affected area. The DST traveled from Florida to New England on the coast and to selected inland sites from Alabama to West Virginia to New York. Overall, the DST found that NWS did an extraordinary job in getting its message of warning across to the populace of nearly 40 percent of the Nation that felt the effects of the **Superstorm of March 1993.**

The Southern Survey Team

The southern survey team found that for the most part the information disseminated to the public, the media, and EMOs was timely and accurate. There were a number of separate hazards created by the storm for those in the southern states affected by the **Superstorm. As** the storm gathered strength over the Gulf, the first threat was from severe thunderstorms and tornadoes. As it neared landfall, high winds and coastal flooding became the primary hazard and finally, as the system moved up the Atlantic coast, very cold temperatures became the peril.

The perception and response to these various threats were uneven, however. The lack of personal experience with severe non-tropical storms resulted in a large number of people, and some EMOs, failing to fully appreciate the seriousness of the threat. For example, in recent history, severe coastal flooding has not occurred in Florida in storms other than hurricanes. It must be noted that a winter storm of this ferocity was simply beyond the scope of experience of anything the southeastern part of the country had faced in recent memory. The subsequent lack of response led to difficulties for the populace in preparing properly for the approaching storm throughout the southeast U.S., particularly in Florida. Many people and some EMOs were simply unprepared for the event.

The Northern Survey Team

In the northern states, the threat was mainly from the heavy snow and high winds causing blizzard conditions. There was also the threat of coastal flooding. The possibility of a blizzard got the public's attention, was understood, and resulted in appropriate reaction by the population.

Emergency preparedness officials, the media, and the public were highly complimentary of the accuracy and long lead time of the forecasts prior to the storm. Warnings and statements were perceived as timely and well-worded. The public and other users seemed to understand the potential magnitude and destructiveness of this severe winter storm.

For the northern states impacted by this event, it was not quite the "Storm of the Century." Although the storm set new snowfall and low pressure records in a number of locations, the surface winds attained, for the most part, only the lower ranges that were forecasted. Also, the times of maximum on-shore winds did not coincide with the time of high tide, thus only minimal coastal flooding occurred along the northeast Atlantic coast.

General Problem Areas Identified

There are several areas that the DST identified, that if corrected, would enable NOAA to perform its mission more effectively. These shortcomings are summed up in the Major Findings and Recommendations section and are discussed in more detail in the individual chapters of this report. In general there are three areas of concern that require attention to allow NOAA and NWS to more effectively safeguard the lives and property of the American public. They are the availability of observation data, improved communication with state and local EMOs, and improved public response to NWS warnings and forecasts.

1. Availabilitv of Observation Data. All along the Atlantic and Gulf coasts, the quality of marine forecasts and warnings suffers from insufficient ground truth data for NWS forecasters to use in formulation and verification of their products. This ranges from weather observation buoys offshore and near the coast, to observations from automated sites on the coast. It is impossible to adequately monitor coastal flooding along the majority of the U.S. coast due to the lack of real time data from the relatively few tide gages located along the coast. There are even fewer sites that monitor water levels on the sounds and bays so that flooding in those regions is even more poorly observed. The need for additional marine data has been highlighted in previous DST reports but, due to continuing budget constraints, the situation has not improved. Fewer sites are available now than there were several years ago.

2. Communication with Emergency Management Officials. Communication with EMOs is generally one way, i.e., from NWS to the EMOs via printed messages or in some cases via NOAA Weather Radio (NWR). While many offices attempt to provide full explanations of the coming or ongoing weather event, there are inevitable gaps. Also, there is generally no way for the EMOs to feed back information or ask questions other than through the telephone. There are just too many EMOs for NWS to speak to them individually. The use of the National Warning System (NAWAS) provides a good model for contacting a number of EMOs

at once, but this system does not reach all areas at the present time. During the **Superstorm** there were a number of instances in Florida where messages from NWS did not reach threatened people. A better system must be developed to surmount this shortcoming.

3. Improved Public Response to NWS Forecasts and Warnings. While not a problem in the northern areas where the warnings were limited to one problem (i.e., blizzard conditions), in the south there were several hazards associated with the storm. The public and some EMOs in the South did not fully understand the multiple threats and, therefore, provided an uneven response to those threats.

While NWS did a good job alerting the public in Florida and the Carolinas of the coming threat, the communication was sometimes ineffective since the public did not perceive the urgency of the situation. Florida residents are accustomed to hearing the terms "storm," "thunderstorms," and even "tornadoes" on a frequent basis. When the same expressions are used for a storm system recognized by NWS to be of much greater consequence, the urgency of the message is not conveyed to the public forcefully. As it was, many people were more concerned about the possibility of freezing pipes and crop losses later in the weekend than they were to the more immediate threat of severe weather and coastal floods.

In some cases this was even true of EMOs who got an individual phone call alerting them to the imminent conditions. This points out the continuing need for NW'S to provide education to the EMOs and the public at large regarding what NWS can do and what it cannot do.

Other than underforecasting the unprecedented coastal flooding conditions experienced on the west coast of Florida, overall NWS performance was remarkable for the accuracy of its long lead time predictions of the conditions experienced by the public in the eastern states during the **Superstorm of March 1993.**

Major Findings and Recommendations

A major function of any DST is to identify areas where NOAA and NWS can make improvements in the services provided to the public. To better focus attention on the most important issues, only the most significant Findings and Reconnnendations are listed here. Less important findings or recommendations are not included in this section but instead have been highlighted within the text of the Report through the use of bold printing.

Chapter 1 - The Event and Its Impact

Finding 1.1 - NWS could have made improvements to the Coastal Flood Watches and Warnings for the Florida Gulf Coast. A significant contributing factor to this problem was the insufficient number of Gulf of Mexico marine and coastal observations, water level measurements, and a lack of storm surge guidance products to assist in forecasting these events. NWS has never had sufficient marine observations nor enough real-time water level information. The need for these data were also noted as deficiencies in the DST Report on the Halloween Nor'easter of 1991. Chapter 4 and Finding and Recommendation 4.1 further address these problems.

Finding l.la - NWS does not have an operational dynamic numerical forecast model for predicting coastal surge and flooding associated with extratropical systems. Current guidance products are statistically derived and extend only from Cape Hatteras north. The lack of surge forecast capability is also evident for sound and bay flooding events as occurred in the Albemarle and Pamlico Sounds of North Carolina during the **Superstorm.**

Recommendation 1.1 - NOAA should accelerate development of a dynamic numerical prediction model capable of predicting coastal surge and flooding from extratropical storm systems. Also, models should be developed for major bays and sounds. Concurrent development of a coupled ocean-atmosphere prediction model is necessary to optimize initial conditions for the dynamic coastal surge model.

Finding 1.2 - The Storm Data Reports prepared at each WSFO are inadequate for the preparation of disaster survey reports because they generally do not include sufficient details, particularly on indirect deaths, or on clean up costs to local and state governments.

Recommendation 1.2 - Field offices must provide the DST comprehensive reports of direct and indirect deaths and injuries in a timely fashion (i.e., within 60-90 **days) after the event(s). These reports should also contain estimates of damage including the clean up costs incurred by local and state governments. The efforts to obtain complete data should include solicitation of articles from newspapers in the affected areas as well as information gathered from affected EMOs.**

Chapter 2 - Hydrometeorological Analysis

Finding 2.1 - As a result of automation of field office equipment, NWS has discouraged data archiving of model output and satellite imagery. Case analysis, model consistency studies, and research efforts have suffered as a result. Learning from past experience can be extremely valuable in predicting future weather events.

Recommendation 2.1 - NWS field offices should be able to readily retrieve or reconstruct guidance materials and satellite data for event analysis, long term archiving, and case studies.

Chapter 3 - Warning Services

Finding 3.1 - WSO Tampa did not use the correct product identifier/routing header in issuing the Coastal Flood Warning because it is not -normally authorized to issue those messages. However, in an emergency such as existed with the Miami office incapacitated by the loss of electric power, a WSO can issue Coastal Flood Warnings. Although we have no evidence, the use of the Coastal Flood Statement header instead of the Coastal Flood Warning category may have hampered warning dissemination.

Recommendation 3.1 - WSFO Miami, and all WSFOs with coastal flood responsibility, should clearly outline procedures to allow WSOs to issue coastal flood warnings when necessary. Normally, the WSO(s) would use the CFW category authorized for the parent WSFO (e.g., MIACFWMIA) to enable the widest dissemination possible. This problem will be alleviated in the modernized NWS as the coastal flood watches and warnings are decentralized.

Finding 3.2 - WSFO Miami was severely hampered by the loss of electric power and communications other than the telephone during the height of the coastal flooding events associated with the **Superstorm.** It appeared the WSFO staff tried to "tough it out" rather than being proactive and turning over warning and forecast responsibilities to appropriate backup offices.

Recommendation 3.2 - All NWS field offices should periodically review their procedures for initiating backup warning and forecast services.

Finding 3.3a - The WSR-88D Mesocyclone Identification Algorithm depicts an excessive number of mesocyclones. At. times it indicated several circulations even though matched storm-relative velocity images indicated only moderate gate-to-gate shear. The NWSO staff had to differentiate between true mesocyclones and false signatures while also deciding whether to issue a Tornado Warning or a Severe Thunderstorm Warning.

Finding 3.3b - Short-lived, weak to moderate (F0-F3) tornadoes, such as occurred at Chiefland and elsewhere over north central Florida, can still cause significant destruction and death. However, the WSR-88D does not always detect or permit prediction of such events using the existing algorithms.

Finding 3.3c - Range-folding obscured the velocity information in some tornadic storm echoes.

Recommendation 3.3 - Additional research is required to continue to improve the performance of the WSR-88D. In addition to the Mesocyclone Identification Algorithm problem, the problems associated with range-folding and the detection of weak tornadoes also require urgent attention by NOAA.

Chapter 4 - Data Acquisition, Communications, and Facilities

Finding 4.1 - High availability of buoy and coastal station observation data are vital to support the NWS marine forecast and warning program. The scarcity of marine weather observations greatly impacted the quality of NWS marine forecast and warning services during the **Superstorm.** A similar finding was noted in previous DST Reports.

Recommendation 4.1 - NOAA should pursue additional marine observation sources including collaborative efforts with state and private organizations.

Finding 4.2 - Real-time water level data is essential to NWS coastal flood warning and forecast program. The lack of timely access to water level gages greatly diminished NWS's ability to issue accurate and timely coastal flood warnings. The majority of the measurements from the NWLON of 189 coastal and Great Lakes reporting stations are not available automatically nor in real time. These reports would have provided critical observations and verification of coastal flood watches and warnings and would have been of significant value as the Superstorm crossed the northern Gulf of Mexico. Software problems that occurred at WSFO Boston further reduced tide gage data availability at NWS offices.

Recommendation 4.2 - NOS with NWS should develop and support an Implementation Plan to complete the installation of the NGWLMS. This plan should include real-time reporting capabilities and a method of transmitting water level measurements to NMC. NMC should transmit a collective of these observations to field offices. In addition, local NWS offices should have direct access to NOS gages in their CWA.

Finding 4.3 - **The** NGWLMS can support up to 11 ancillary measurements such as air temperature, atmospheric pressure, and wind speed and direction. Optimization of this additional capability could partially compensate for the scarcity of marine observations.

Recommendation 4.3 - NWS should take action to include the addition of environmental sensors at NGWLMS stations to measure additional parameters for relay in real-time to NMC for processing and dissemination on AFOS.

Finding 4.4 - Data from the WSR-88D at Eglin AFB was not available at WSO Tallahassee due to communication linkage drop outs during the Superstorm. The result was that during the height of the storm little radar data was available at Tallahassee.

Recommendation 4.4 - Communications problems between the Eglin AFB WSR-88D and the WSO Tallahassee PUP should be corrected by NWS and the communications link upgraded if needed.

Finding 4.5 - The volume of reports during widespread events such as major winter storms or significant severe weather outbreaks makes it difficult for NWS to use SKYWARN data quickly. Several NWS offices obtained spotter information via packet radio that provided a hardcopy form of the HAM spotter reports. This method was less disruptive and labor intensive than receiving HAM radio reports via phone.

Recommendation 4.5 - NWS should explore either purchasing packet radio receiving equipment or acquiring this equipment via cooperative agreements with such organizations as FEMA, state/local EMOs, and amateur radio clubs, to automate collection of spotter reports. An Operations Manual Letter will be issued shortly by NWS Headquarters that allows obtaining this type of equipment.

Finding 4.6 - The only significant problem with NWS facilities was with emergency power systems. A number of NWS sites had commercial and back-up power problems (emergency generators, UPS and battery failures) during the **Superstorm.**

Recommendation 4.6 - NWS offices should exercise their backup power contingency plans regularly. This should include operating the emergency generators routinely under full load conditions for a set period.

Chapter 5 - Coordination and Dissemination

Finding 5.1 - Use of the HHL by NWS Eastern Region forecasters was very effective in producing a well-coordinated watch and warning effort, providing continuity across forecast boundaries. However, in at least two instances during the **Superstorm,** the HHL malfunctioned at one of the offices involved in the coordination calls. Also, NWS Southern Region should encourage its coastal WSFOs with access to the HHL to participate in the calls. Inland offices are not connected to the HHL.

Recommendation 5.1 - Coastal WSFOs in NWS Southern Region that are connected to the HHL should be included in the coordination calls when appropriate. The HHL should be tested at least weekly at each office on the system to detect outages. Finally, NWS should establish a system that allows all NWS offices to coordinate actions during major storms such as a NAWAS-type system connecting all NWS offices.

Finding 5.2 - State and local EMOs acquire NWS warnings and forecasts using differing transmission systems ranging from telephone to dedicated computer systems. These variations can cause delays and unequal delivery of NWS products to EMOs.

Recommendation 5.2 - NWS, in coordination with FEMA, should actively develop reliable links to relay NWS watches, warnings, etc., to state and local EMOs. Automated retransmission systems are preferable because they are faster than manual systems. The time saved can save lives. These systems should also provide two-way communications to enable EMOs to query NWS and relay storm reports.

Finding 5.3 - NAWAS is used by NWS to alert many EMOs to watches, warnings, and advisories of impending hazardous weather. However, the system is not in place at a uniform level of government from state to state, or within all states. This hinders NWS's ability to provide urgent information to EMOs.

Recommendation 5.3 - NWSH should assist FEMA in developing a policy that establishes NAWAS uniformly, preferably at the county level.

Finding 5.4 - In many EMOs, NWWS is not monitored continuously due to other work being performed. There were instances during the **Superstorm** that EMOs reported that so much information being transmitted that they did not notice warnings immediately. This caused delays in their responses to those warnings.

Recommendation 5.4 - A means of distinguishing warning information from routine messages must be found for NWWS. For example, on the Weather Channel warnings are displayed on a red background to indicate they are urgent. A possibility is to program NWWS so that if a short-fuse warning is issued (e.g., tornado, severe thunderstorm, flash flood) NWWS would print "WARNING" or 'TORNADO WARNING?' as appropriate in large letters on a page prior to the actual warning message. This would indicate that an urgent transmission rather than a routine message was to be transmitted next.

Finding 5.5 - Some offices, most notably WSO Jacksonville, were not fully informed about upstream severe weather due to a lack of coordination with adjacent offices.

Recommendation 5.5a - Active coordination with adjacent/nearby offices should be a high priority during severe weather conditions. WSR-88D-equipped offices should contact nearby NWS offices if the WSR-88D is indicating potentially severe weather in a county for which another office is responsible and the severe storm in question is within 124 nm of the Doppler radar.

Recommendation 5.5b - NWS offices must remain in contact with each other to ensure coordination of efforts and to be aware of approaching weather. This should include reviewing warnings and statements, including local storm reports from surrounding offices, and routine review of observed data.

Finding 5.6 - Some Florida EMOs were unprepared for a storm as strong as the **Superstorm.** In particular, they were not ready for the extreme coastal flooding that occurred. The EMOs felt there should have been more urgency from NWS and comparisons made to hurricanes since that is the primary threat they prepare for each year.

Recommendation 5.6 - NWS must be clear, concise, and specific in its messages. This should include SPECIFIC warning advice. To say "strong wind" means different things to different people.

Chapter 6 - Preparedness Activities

Finding 6.1 - The most often heard complaint during the Survey, particularly in the northern areas where the event lasted for over 24 hours, concerned the volume of data and length of the products sent to the media and other users.. In many cases they were simply overwhelmed with information.

Recommendation 6.1 - NWS offices **should keep their statements as short as possible. For example, they should not reuse call-to-action statements repeatedly. Shorter, more frequent, statements are preferred to ones that are all inclusive. The broadcast media in particular will not use lengthy messages.**

Chapter 7 - Media and Public Response

None.

Overall Finding - NWS's performance during the Superstorm of March 1993 was remarkable. Early recognition of the storm's threat and aggressive communications with EMOs, media, and the public of the extreme danger led to timely issuance of watches, warnings and statements.

Overall Recommendation - NWS should be appropriately recognized for the excellent service provided to the Nation before and during the Superstorm that resulted in saving hundreds of lives and millions of dollars.