

## SECTION 3

# DEPARTMENT OF COMMERCE WEATHER PROGRAMS NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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



## NATIONAL WEATHER SERVICE

The National Weather Service (NWS) has the principal responsibility for planning and operating the basic climate, hydrologic, and weather services and certain specific applied services. The NWS provides climate, water, and weather warnings and forecasts for the 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, and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the United States and its possessions.
- Develops and operates national meteorological, hydrological, climate, space weather and oceanic service systems.
- Performs applied meteorological, hydrological, space environmental and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in international hydrometeorological and space weather activities, including the

exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

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

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for providing weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).

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

### SERVICES

NWS provides climate, water, and weather prediction services; including 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 one space weather forecast center that collect data, prepares local warnings and forecasts, and disseminate information to the public both directly through NOAA Weather Radio, and indirectly through the mass media. Forecast and warning services prepared at WFOs are derived in part from prediction guidance prepared by the nine National Centers for Environmental Prediction (NCEP). These centers are: Hydrometeorological Prediction Center, Storm Prediction Center, Aviation Weather Center, Environmental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Environment Center, Ocean Prediction Center, and NCEP Central Operations.

Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development both within

the NWS and externally from universities and private corporations.

Public Weather Services. The NWS Public Weather Service Program provides forecast, warning, and response services to the public, private meteorological firms, broadcast meteorologists, and those responsible for public safety, including Federal, state and local emergency managers and planners. NWS forecasters at WFOs routinely issue forecasts for every location in the Nation for sky cover, maximum and minimum temperature, wind speed and direction, precipitation, and hazardous weather information at least two times per day. NWS forecasters at WFOs 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. Additionally, NWS forecasters provide forecasts in response to nuclear hazard accidents or hazardous material spills.

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. The WFOs prepare Terminal Aerodrome Forecasts (TAFs) four times a day, with amendments as needed, for more than 550 public-use airports in the United States and its territories in the Caribbean and northwest Pacific. These offices also produce about 330 individual route-oriented forecasts three times a day for the 48 contiguous states and over the Pacific Ocean.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu prepare area forecasts three or four times daily describing general aviation weather conditions over the lower 48 states, the Gulf of Mexico, Caribbean Sea, Alaska, Hawaii and coastal waters respectively. The two specialized aviation

weather centers, along with WFOs in Honolulu and Guam, issue in flight advisories and warnings of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low level winds. The AWC also prepares forecasts of significant aviation weather over the continental United States four times a day for flight levels from the surface to 25,000 feet.

NWS Center Weather Service Units located in each of the 21 Federal Aviation Administrations (FAA) Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, airport towers, and Automated Flight Service Stations.

The NWS provides a service to international aviation as one of the International Civil Aviation Organization's (ICAOs) 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 of significant weather for approximately two-thirds of the globe four times a day for thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence and icing, and cumulonimbus cloud associated with the above, from 25,000 to 63,000 feet. 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, western portions of Europe, the Pacific, and eastern Asia.

Within the framework of the international airways volcano watch, the NWS, through NCEP, shares management responsibility with NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) for Volcanic Ash

Advisory Centers in Alaska and Washington.

The NWS, working closely with the FAA's Aviation Weather Research Program, developed new experimental and operational forecast products designed to improve aviation hazard forecast capabilities zero to six hours into the future (Figure 3-DOC-1).

New icing and turbulence products for meteorologists and end users are expected to become operational in FY 2004. Improved software tools to increase the number of terminal airports covered by a forecast are also under development.

Marine Weather Services. The NWS Marine Weather Program is the meteorological lead for the nation's marine and coastal weather services. Programs include detailed and routinely issued forecasts, as well as marine advisories and warnings for coastal waters, offshore, high seas, and the near-shore and open waters of the Great Lakes.

In addition, the NWS provides ice forecasts and advisories, issued primarily for the Great Lakes and the ocean waters surrounding Alaska, and also supports the Tsunami Warning Program. NWS forecasters at 46 coastal and marine WFOs, in collaboration with NCEP Centers, provide a range of services for tropical cyclones and coastal flooding, convective coastal and marine weather, and coastal hazards such as high surf and rip currents. Further, NWS staff provide services focused on the expanding and weather-sensitive U.S. coastal population, and those responsible for safety and transportation.

When necessary, coastal and marine WFOs will issue site-specific forecasts, to aid the protection of life and property, associated with significant man-made or natural environmental events or disasters including: vessels in peril, oil spills, aircraft crash recovery in marine areas, and volcanoes or tsunamis. As the NWS continues

## Maximum potential for icing in column

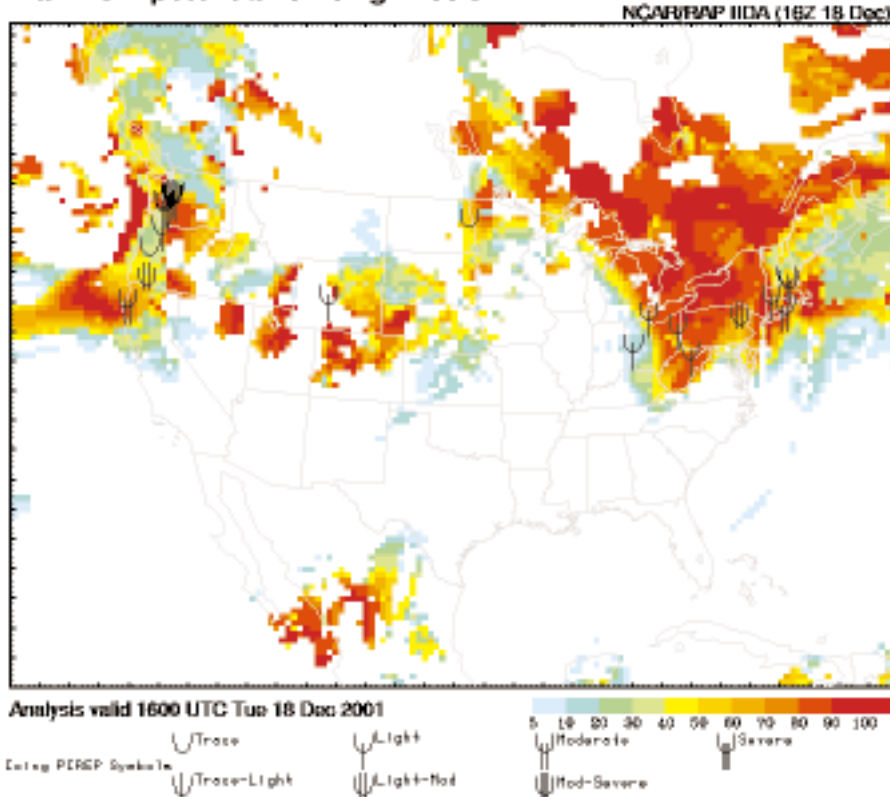


Figure 3-DOC-1. Current Icing Potential (CIP) Product. The FAA's Aviation Weather Research Program and the NWS developed this graphical icing product, updated every 3 hours, and available for user selected altitudes across the contiguous United States.

efforts in technological advancement, marine weather services will be provided in alphanumeric, gridded and graphical formats to customers and partners.

**Fire Weather Services.** NWS offices provide routine pre-suppression and wildfire weather support to federal and state land management agencies. NWS forecasters at WFOs 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 (IMETS) to large wildfires and coordination centers for on-site weather support. IMETS use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. In

the early morning, NCEP's Storm Prediction Center issues one and two day fire weather outlooks that highlight areas with critical and extremely critical fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters. In addition, areas where significant lightning activity accompanied by less than 0.1 inch of precipitation (dry lightning) is forecast are highlighted.

**Tsunami Warnings.** Tsunami watches, warnings, and information bulletins for the Pacific Ocean and Hawaii are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii, and for west coast of the continental United States and Alaska by the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observato-

ries, sea-level observing stations, and deep-ocean tsunami detection buoys which operate on a cooperative basis. The centers use these data to prepare and disseminate watches, warnings, and information bulletins to international customers, WFOs, federal and state disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public.

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

**Hydrologic Services.** The 122 WFOs and 13 River Forecast Offices (RFCs) work as a team, to minimize loss of life and property damage from flooding and to meet the water service needs of our Nation. The NWS WFOs work cooperatively with the RFCs to monitor the major river systems around the clock. The NWS WFOs are also responsible for issuing watches and warnings to protect life and property when the threat of flooding occurs. The NWS WFOs also continuously monitor the threat of flash flooding and urban flooding. On small streams, especially near the headwaters of river basins, water levels may rise quickly in heavy thunderstorms. Flash floods can begin before the rain stops falling. Flash floods also occur in or near



mountainous areas where torrential thunderstorm rains can quickly change a dry water course or small stream into treacherous torrents of water. Desert washes, particularly near mountains, can go from dry to flood within minutes as a result of thunderstorms many miles away from the flash flood site. Urban flooding can occur in any populated area and it is particularly aggravated by urbanization where natural cover has been removed by the construction of buildings, roads, and parking lots. Heavy rains can result in flash flooding, causing considerable damage to residential and industrial properties. When necessary, NWS WFOs will issue the appropriate flood watches and warnings.

The NWS partners with a variety of Federal and State Agencies to provide hydrologic services. For example, the NWS works very closely with the United States Geological Service (USGS), the United States Army Corps of Engineers (USACE), the Bureau of Reclamation (USBR), the Bureau of Land Management (BLM), and the Natural Resources Conservation Service (NRCS) on a variety of water-related issues including streamgaging, river and water supply forecasting, and water management. These agencies, in particular the USGS, provide a variety of critical hydrological data including river flow and stage, soil moisture, precipitation, and snow cover.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS), which will produce hydrologic forecasts with lead times of a few days to several months. NWS RFCs will produce river forecasts that not only account for precipitation on the ground, but will probabilistically account for estimates of future precipitation. These forecasts will greatly improve the Nation's capability to make informed, timely and effective actions to significantly mitigate the impact of major floods and droughts. AHPS will also provide better infor-

mation for use in managing water demands for irrigation, fisheries, hydro power, and other purposes. AHPS builds on the existing NWS infrastructure, including AWIPS, NEXRAD, and the NWS River Forecast System (NWSRFS). The NWSRFS is the system used by RFC hydrologists to produce forecast time series of discharges or stages at approximately 4,000 locations along the nation's rivers.

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

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

The NWS approach for improving observations consists of several efforts:

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

- Replace obsolete observing systems;
- Implement new observing technologies and communication systems that better meet the data needs of our customers; and
- Strengthen the link between user requirements and technology research and development.

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

NOAA's Cooperative Weather Observer Network (COOP), is the Nation's largest and oldest weather network. Modernizing the COOP is closely related to the President's Climate Change Research Initiative, providing a richer source of data to improve weather and climate forecasting and to contribute to climate change research. The COOP network is the primary source for monitoring U.S. climate variability over weekly to inter-annual time frames. These data are also the basis for assessments of century-scale climate change. The modernized COOP network will add to NOAA's vision of an end-to-end monitoring program that "takes the temperature" of the earth's systems. NOAA is also developing and implementing a Climate Reference Network (USCRN), which will compliment the COOP.

#### NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION.

Over the last several decades, NWS has made major improvements in forecasting synoptic scale (large scale, slowly evolving) weather. Further improvements will be realized in the

---

severe weather and flood warnings program as a result of improvements in higher resolution, centrally prepared weather guidance products out to Day 5, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations.

While the NWS field structure focuses more on warnings and short range forecasts, NCEP serves a broader, national mission where national centers provide products based on output from numerical models, statistical adjustments to model fields, and value added products prepared by national center forecasters. This NCEP product suite is transmitted to the WFOs in digital form, where forecasters use the products to prepare local forecasts.

NCEP is organized into seven science based, service oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions. NCEP delivers national and global climate, water, weather, and space weather guidance, forecasts, warnings and analyses to its partners and external user communities. These products and services respond to user needs to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value added forecast guidance 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, and excessive precipitation with emphasis on the first few hours of the forecast period. All

Tornado and Severe Thunderstorm Watches issued anywhere in the contiguous United States come from the SPC. Also, the SPC prepares Mesoscale Discussions which are technical discussions of developing mesoscale features and their impact on hazardous weather. For longer time periods, the SPC produces the Convective Outlook which are one, two and three day forecasts of the probability and intensity of both non-severe and severe thunderstorms (including tornadoes). The SPC also issues one and two day National outlooks for areas with critical and extremely critical fire potential out to two days.

Hydrometeorological Prediction Center. The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services (1) to support the daily public forecasting activities of the NWS and its customers, and (2) to provide tailored support to other government agencies in emergency and special situations. As part of this mission, HPC prepares Quantitative Precipitation Forecasts (QPF) used by the RFCs to develop local river and flood forecasts and by WFOs to develop local rainfall, snow and ice forecasts. The HPC provides special QPFs and coordinates with other federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community. Additionally, HPC serves as the backup to the National Hurricane Center.

Aviation Weather Center. The NCEP experts for aviation meteorology are concentrated at the Aviation Weather Center (AWC). The AWC provides weather warnings, advisories and forecasts to the aviation community under

an international agreement through the International Civil Aviation Organization. The AWC provides wind, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and en route aircraft operations for the United States, the Gulf of Mexico, the Caribbean Sea, the Atlantic and Pacific routes in the Northern Hemisphere and some routes in the Southern Hemisphere. The AWC also produces guidance products used by WFOs to support airport terminal forecasts. Thus, the AWC produces large scale, global aviation functions centrally, while the WFOs customize local aviation products based on centralized guidance provided by the AWC and local observations.

Environmental Modeling Center. The Environmental Modeling Center (EMC) improves NCEP's numerical climate, water, and weather predictions through data assimilation and computer modeling. To provide mesoscale predictions (thunderstorms, hurricanes, tornadoes, blizzards, etc.), ocean predictions and global weather and climate predictions, EMC develops, adapts, improves, and monitors data assimilation systems and global, regional and mesoscale models of the atmosphere, land surface, ocean, and atmosphere/ocean/land systems. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. As an example, EMC is a partner in the newly created 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, numer-

ical models, and forecast techniques to implement model improvements and improve NWS products. The EMC conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community. EMC also participates in ongoing interactive research programs such as the U.S. Weather Research Program's (USWRP) Hurricane at Landfall project and the community Weather Research and Forecast (WRF) model. Furthermore, EMC is participating in the Pacific targeting observation experiment. EMC research, coupled with increased model resolution, has resulted in a number of improvements in the 10 Km Meso Eta model precipitation, the 12 Km Meso Eta topography and winds, and hurricane track forecasts.

Climate Prediction Center. The Climate Prediction Center (CPC) provides operational monitoring and prediction of global and regional climate variability, with emphasis on applied research and partnerships, to improve understanding of the global climate system, weather and climate links, extremes and trends. CPC develops and maintains 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 next week (days 6-10) to seasons and out to a year in advance, and cover land, ocean, and atmosphere extending into the stratosphere. CPC's products include probabilistic long range outlooks for temperature and precipitation, the multi-agency U.S. Drought Monitor (Figure 3-DOC-2), a drought outlook, and El Niño Southern Oscillation 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.

Space Environment Center. The Space Environment Center (SEC) 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 SEC 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 SEC 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.

Ocean Prediction Center. The Ocean Prediction Center (OPC) provides atmospheric and oceanographic warning, forecast, and analysis products and services for the North Atlantic and North Pacific (north of 30 degrees) (see Figure 3-DOC-3) as part of the NWS mission of protecting life and property and enhancing economic opportunity. As part of this, OPC handles United States international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). The OPC provides weather and sea state warnings and forecasts for the high seas of the Northern Hemisphere north of 30 degrees for planning and operational purposes. OPC warnings and products go directly to ships and are vital for the protection of life and property at sea. The OPC also coordinates forecasts with and provides forecast guidance to WFOs with coastal responsibilities.

Tropical Prediction Center/National

Hurricane Center. The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific hurricane basins including the portions of the coastline threatened by such storms. In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility, south of about 31 north latitude and a portion of the southeast Pacific. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

NCEP Central Operations. The NCEP Central Operations (NCO) is responsible for NCEP operations, including access to real time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO maintains and manages the supercomputer and runs the computer applications that generate all NCEP model products. The NCO leads the technical transition between the research and development of numerical weather and climate prediction models and their operational use on the NCEP computer systems. In addition, NCO provides 24 hour information services and operational support for NCEP computing systems, including the network which ties together inter-



nal NCEP communications, NWS high performance computer systems, forecaster workstations, personal computers and a user service that support all NCEP centers. NCO has recently shown significant improvement at reliably getting products to customers.

Other NWS Offices with National Responsibilities. In addition to the NCEP centers, there are three other offices that provide National products. They are the Alaskan Aviation Unit, the WFO Honolulu/Central Pacific Hurricane Center, and the WFO Guam.

Alaskan Aviation Unit. The Alaskan Aviation Unit (AAU) provides weather forecasts to the aviation community under an international agreement through the International Civil Aviation Organization (ICAO). The

WFO Guam. WFO Guam provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for U.S. territories and Micronesia in the northwest Pacific south of 30° N latitude through ICAO international agreement.

WFO Honolulu/Central Pacific Hurricane Center. WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides products in aviation, marine, and tropical cyclone areas. In aviation, WFO Honolulu provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for central north Pacific from 140° W to 160° E longitude and south of 30 N latitude through

Honolulu provides weather and sea state warnings and forecasts for the high seas of the central north and south Pacific south of 30° N latitude. CPHC issues tropical cyclone advisories, forecasts, watches, and warnings for the central north Pacific including Hawaii.

### SUPPORTING RESEARCH

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

Meteorological Research. The NWS conducts meteorological research to devel-

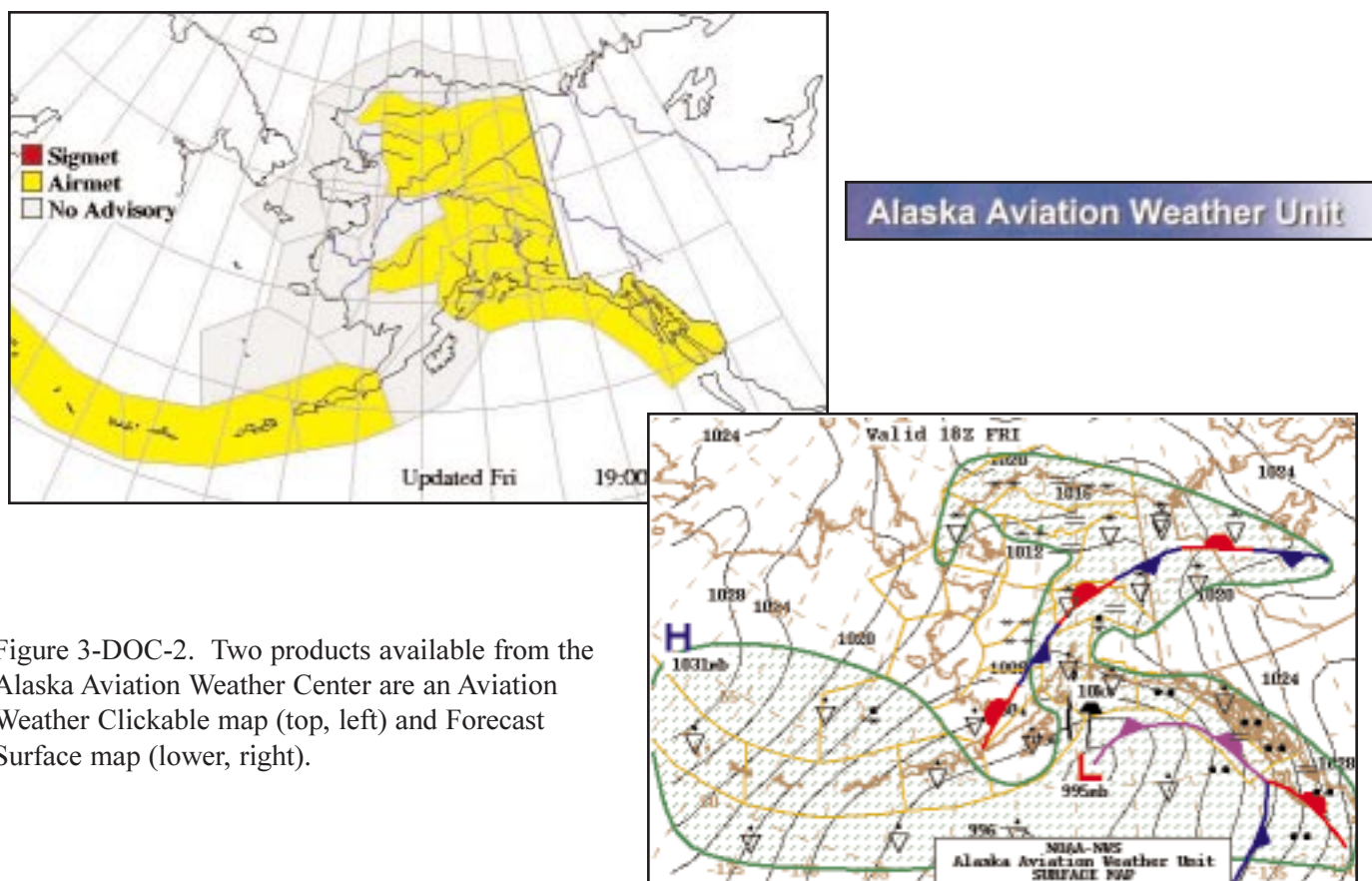


Figure 3-DOC-2. Two products available from the Alaska Aviation Weather Center are an Aviation Weather Clickable map (top, left) and Forecast Surface map (lower, right).

AAU provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for Alaska and surrounding areas (Figure 3-DOC-2).

ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). WFO

op, test, evaluate, and improve numerical models and analysis/forecast techniques for weather and climate prediction including:

- Techniques for predicting

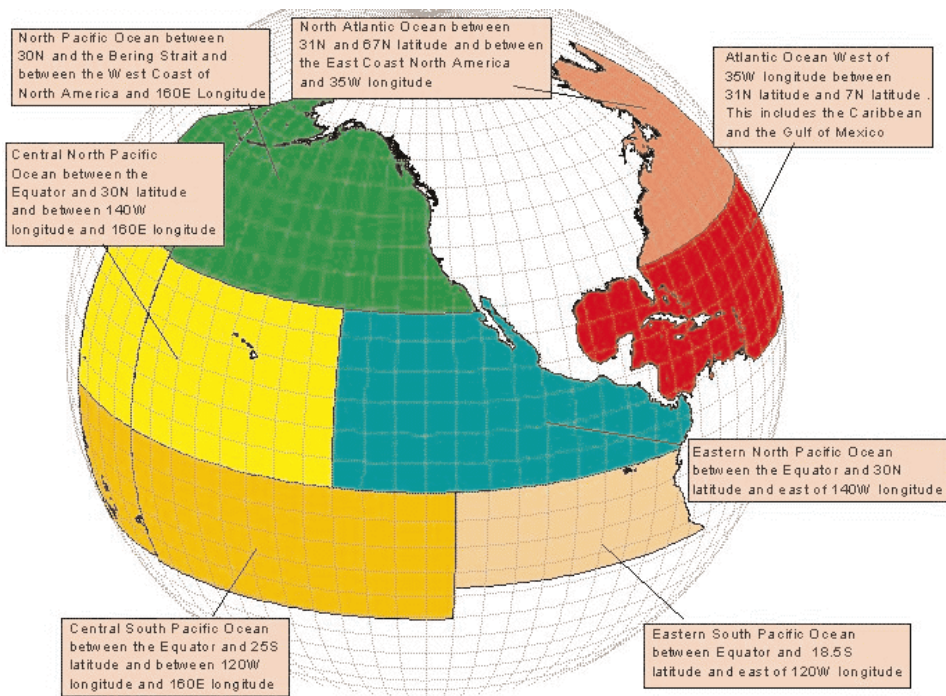


Figure 3-DOC-3. United States High Seas Forecast Areas of Responsibility.

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

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

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complimentary 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 initial conditions. 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 estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge and satellite rainfall estimates are merged to produce optimum rain-

fall analyses.

- Development of verification methods to assess the added-value of new science and technology to the customer.

**Space Weather Research.** Applied research improves the specification and forecast of conditions in the space environment by developing and implementing models and indices, as well as by obtaining and processing new observations.

- Developing of the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from widely dispersed sources will enable the model output to be useful to radio-communicators and GPS and LORAN users.
- Developing of models to characterize and predict geomagnetic storm intensity development, spatially and temporally.

**Support for Collaborative Research with the Academic Community and Other Partners:** The Collaborative Science, Technology, and Applied Research (CSTAR) program was established to bring NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services. The CSTAR Program issues a yearly request for proposals through which colleges and universities compete for 1-3 years of research funding. CSTAR supports short-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.** The NWS provides train-



---

ing to its workforce in support of the NWS mission and to enhance the professional and scientific development of its staff. Training deficiencies and requirements are identified and addressed via the National Strategic Training and Education Plan (NSTEP) process which is available on the NWS Web site [www.nws.noaa.gov/om/os/org/training/nstep.pdf](http://www.nws.noaa.gov/om/os/org/training/nstep.pdf)

The NWS provides staff training through a variety of in-residence and distance learning techniques. Hands-on, in-residence training is provided at three professional training facilities. The NWS Training Center (NWSTC) in Kansas City, Missouri, provides technical and management training; the Warning Decision Training Branch

(WDTB) in Norman, Oklahoma, provides training on how to integrate remotely sensed data toward improving the warning decision process; and the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, provides advanced meteorological education. These facilities along with other groups also provide distance learning, Internet modules, tele-training, webcasts and CD-ROM based training for access by the NWS workforce to ensure currency with the latest software, hardware and forecasting techniques.

In addition to providing the technical training cited above, the NWS is also working to develop and expand its

Leadership Academy. The goal of the NWS Leadership Academy is align the development of NWS staff with the advancement of science and technology to enable NWS to lead, perform, and serve with competitive advantage. The Academy is founded on a sequential and progressive approach designed to develop people and improve performance. From entry into the agency to senior career status, employees will be able to take advantage of courses and processes that are part of a powerful management and leadership learning environment.



The National Environmental Satellite, Data, and Information Service (NESDIS), part of the National Oceanic and Atmospheric Administration (NOAA), manages United States civil operational environmental satellite systems, as well as the three NOAA National Data Centers (NNDC) that develop global, national, and regional databases that support meteorology, oceanography, geophysics, and the space environment. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and development and management of environmental resources.

NESDIS was established as a NOAA line office on December 1, 1982. The merger of the former National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS) formed NESDIS.

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

Currently NESDIS is operating five polar orbiters. NOAA-16 and NOAA-17 are classified as the primary "operational" satellites and are part of the new series of polar orbiters, with improved sensors, that began with the launch of NOAA-15 in May 1998, followed by NOAA-16 on September 21, 2000, and finally, the newest, NOAA-17 launched June 24, 2002. The NOAA-12, NOAA-14 and NOAA-15 satellites continue to transmit data as stand-by satellites. The two primary POES

satellites are constantly circling the Earth in an almost north-south orbit, passing close to both poles. The orbits are circular, with an altitude between 830 (morning orbit) and 870 (afternoon orbit) km, and are sun synchro-



nous. One satellite crosses the equator at 7:30 a.m. local time, the other at 1:40 p.m. local time. The circular orbit permits uniform data acquisition by the satellite and efficient control of the satellite by the NOAA Command and Data Acquisition (CDA) stations located near Fairbanks, Alaska and Wallops Island, Virginia. Operating as a pair, these satellites ensure that data for any region of the Earth are no more than six hours old. Each satellite orbits the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research. NOAA also manages the command, control, and communications function of the DoD's Defense

Meteorological Satellite Program (DMSP) constellations.

An agreement finalized with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of the polar environmental mission (circa 9:30 a.m. LST), with United States-provided payload instruments and sensors, beginning in 2005. Thus, upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission.

On October 3, 1994, NOAA, the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA) combined the nation's military and civilian environmental satellite programs to create an Integrated Program Office (IPO) to develop, manage, acquire, and operate the national polar-orbiting meteorological satellite system, subsequently designated the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IPO is organizationally located within NOAA and is headed by a System Program Director responsible to the NPOESS Executive Committee. This committee, which consists of the Under Secretary of Commerce for Oceans and Atmosphere, the Under Secretary of the Air Force, and the NASA Deputy Administrator, serves as a board of directors to ensure that overall program plans also meet the individual needs of the three participating agencies.

The IPO concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DoD is responsible to support the IPO for



major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach. The first operational satellite and ground system will be delivered by the shared system performance prime contractor Northrop Grumman, and is expected to be available late in this decade depending on when the current NOAA DMSP programmed satellite assets are exhausted.

NPOESS will provide standard meteorological data, oceanographic, environmental, climatic, space environmental remote sensing information, as well as continue providing surface data collection and search and rescue capability. The IPO, in consultation with the NOAA and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services. The first NPOESS launch is planned for 2009. However, the NPOESS system is a launch-on-demand system. Based on this strategy, the first NPOESS satellite, referred to as C1, should be available in 2008 to support any potential on-orbit or launch failure of POES-N'. However based on the latest revisions the new launch date for C1 is November 2009. Additionally, due to damage to N' a replan effort is currently underway (See Table 3.1).

NESDIS is also responsible for operating two Geostationary Operational Environmental Satellites (GOES), they are referred to as GOES East and GOES West. Each satellite views nearly one third of the Earth's surface. The GOES-12 (East) satellite is positioned at 75° W longitude and the

equator and monitors North and South America and most of the Atlantic Ocean. The GOES-10 (West) satellite is positioned at 135° W longitude and the equator monitors North America and the Pacific Ocean basin. The two operate together to produce a full-face picture of the Earth, day and night. Thereby providing the kind of continuous monitoring necessary for intensive data analysis. They circle the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows them to hover continuously over one position on the surface. The geosynchronous plane is about 35,800 km (22,300 miles) above the Earth, high enough to allow the satellites a full-disc view of the Earth. Because they stay above a fixed spot on the surface, they provide a constant vigil for the atmospheric "triggers" for severe weather conditions such as tornadoes, flash floods, hail storms, and hurricanes. When these conditions develop the GOES satellites are able to monitor storm development and track their movements. Additionally, as part of a NOAA bilateral agreement with Japan, GOES-9 has been provided to the Japanese Meteorological Agency to replace their failing geostationary satellite. This will ensure Pacific geostationary satellite coverage for Japan, the U.S. and our allies. Finally, GOES-11 is being stored in orbit as a replacement for GOES-12 or GOES-10 in the event of failure of either of these systems.

## **ENVIRONMENTAL SATELLITE SERVICES**

Office of Satellite Operations. The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) and Command and Data Acquisition (CDA) stations, which command and

control, track, and acquire data from these environmental satellites.

OSO took over the command, control, and communications function of the DoD's DMSP constellation in 1998. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide DoD missions. DMSP is now operated from the SOCC at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution. A new ground system was developed for DMSP called Integrated Polar Acquisition and Control Subsystem.

Office of Satellite Data Processing and Distribution. The Office of Satellite Data Processing and Distribution (OSDPD) directs the operations of NESDIS central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the NWS and other domestic and foreign users including value-added customers, and provides coordination and customer services for satellite direct broadcast users and GOES scheduling. Satellite sources include the European, Japanese, and Indian operational geostationary satellites and other research or experimental sources, such as the NASA's Tropical Rainfall Measuring Mission (TRMM) and Earth Observing System (EOS; Aqua, Terra, and Aura missions), Japan's ADEOS-II, and the DoD's WindSAT mission. OSDPD processes and distributes these NOAA and non-NOAA environmental satellite products to the NWS Advanced Weather Interactive Processing System (AWIPS), National Centers and Weather Forecast Offices (WFOs), and other federal, state, and private sector organizations through dedicated satellite processing and server configurations, or through the NOAAPORT satellite point-to-point broadcast facility.

Data for NOAAPORT are remapped digital data and include satellite prod-

ucts and derived products, such as satellite precipitation estimates, high density wind direction and intensities at various atmospheric levels, quantitative precipitation estimates, and volcanic ash advisory messages. NOAA-PORT delivers GOES and soon to be added POES products in virtual real-time to the AWIPS. AWIPS is the newest NWS display and analysis workstation used in their national centers and field sites to integrate and display satellite data, model data, observations, radar and wind profiles for hydro-meteorological analyses. As the AWIPS satellite capabilities improve, NESDIS will shift focus from support of the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS). RAMSDIS currently supplies digital GOES and POES images to a group of NWS sites via the Internet for demonstration, evaluation, and familiarization purposes. RAMSDIS enables forecasters to perform operations, such as looping, enhancement curve changes, and local image recombination of satellite spectral channels.

NESDIS continues to support the Cospas-Sarsat Program through provision of satellites, ground stations, and alert data distribution services. The Cospas-Sarsat program (Figure 3-DOC-4) consists of Russia, the United States, France, and Canada providing the space segment and 29 other countries providing ground systems to relay distress alerts and participate in the management of the program. NESDIS operates and maintains the United States SARSAT Mission Control Center and fourteen Local User Terminals as ground stations.

The Local User Terminals receive 121.5/243/406 MHz emergency beacon signals directly from the satellites and process the information to provide the location of distress transmissions. In 2000, Cospas-Sarsat decided to terminate satellite processing of 121.5/243 MHz signals beginning

February 1, 2009. This decision was made in response to guidance from the International Civil Aviation Organization and the International Maritime Organization. These two specialized agencies of the United Nations are respectively responsible for international aviation and maritime search and rescue standards. The use of new emergency beacons that can use the Global Positioning System (GPS) to provide an accurate position continues to increase. Seven of the last fourteen 406 MHz beacon models approved are able to use GPS to transmit their position.

National Ice Center. The United States National Ice Center (NIC), under sponsorship of the United States Navy, NOAA, and the United States Coast Guard (USCG), is tasked with providing the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts, tailored to meet the requirements of United States national interests. NIC ice products are produced in a digital workstation environment using data from polar orbiting satellites, ship/shore station reports, drifting

buoys, meteorological guidance products, ice model predictions, and government partners including foreign ice services. The primary remotely sensed data sources used for global and regional-scale ice mapping are visible and infrared imagery from the POES Advanced Very High Resolution Radiometer (1.1km spatial resolution) and the DMSP Operational Linescan System (0.55km spatial resolution). In areas of extensive cloud cover, the NIC utilizes Special Sensor Microwave Imager (SSM/I) sensor data (19 and 37 GHz channels) processed using the CAL/VAL and NASA Team ice concentration algorithms. These algorithms produce 25km gridded mosaic ice maps that are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps. Higher resolution ice analysis products, used to ensure the safety of navigation and protect life and property at sea, are dependent upon the availability and use of Synthetic Aperture Radar (SAR) data from the Canadian RADARSAT. RADARSAT's ScanSAR wide mode produces a 500km wide swath with 100m spatial resolution. Images are



Figure 3-DOC-4. COSPAS-SARSAT System Overview

processed at four different ground stations and transferred to the NIC via dedicated communication lines or via the Internet within six hours of acquisition. The NIC Science team, which assists in the transition of pertinent scientific research to operations, is presently working on the transition of real-time SSM/I sea ice products to the NIC operations floor, conducting an evaluation of current SSM/I-derived sea ice algorithms, and the use of SSM/I data for initializing and evaluating the Polar Ice Prediction System (PIPS).

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. Specialized support services include specific regional support, ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Specific sea ice features analyzed include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads. Ice products are disseminated via the Internet ([www.natice.noaa.gov](http://www.natice.noaa.gov)) as simple electronic charts in Joint Photographic Experts Group (JPEG format), GIS-compatible coverages (ESRI ARC/INFO .e00 export format), and in the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDDED (SIGRID, SIGRID-2) format. Date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a metadata narrative.

Another of the NIC's responsibilities is oversight of the United States Interagency Arctic Buoy Program (USIABP). The USIABP was established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array

provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of seven government agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), NASA, National Science Foundation (NSF), and NOAA's NESDIS, OAR, and Office of Global Programs (OGP).

Office of Research and Applications. The Office of Research and Applications (ORA) provides guidance and direction for NESDIS research and applications activities. It coordinates the efforts of the Climate Research and Applications Division, Atmospheric Research and Applications Division, and Oceanic Research and Applications Division. These divisions conduct studies on the use of satellite data to monitor environmental characteristics and change and develop algorithms to produce satellite products for applications to operational weather and ocean analyses and prediction. Further, ORA participates in the development of new spacecraft and sensors for future systems. It also carries out a vigorous program to calibrate and validate satellite data to ensure its quality for long-term studies. Additionally, ORA through division participation, actively educates others on technology transfer programs through scientific presentations, technical reports, Internet-based tutorials, and training workshops at domestic and international sites.

The Joint Center for Satellite Data Assimilation (JCSDA). The JCSDA is formalized by a Memorandum of Agreement between NOAA and NASA, with affiliated partnerships with the U.S. Navy and U.S. Air Force.

This cooperative agreement will allow NOAA, NASA, and DoD to work together to take advantage of their combined science and technology resources in order to accelerate the use of existing and new satellite data. The JCSDA will provide a focal point for joint research and development of common models and infrastructure among its partners. As a result of its collaborative nature, the JCSDA will allow NOAA to improve numerical weather and climate prediction through the optimal use of data from existing satellites and to prepare for the incoming flood of new data from advanced satellite instruments such as NPOESS that will be launched during the next five to six years. The JCSDA is tasked with developing new and powerful techniques to assimilate data into numerical weather prediction (NWP) and numerical climate prediction models. JCSDA activities directly support the missions of NASA, NOAA, and as DoD as well as those of other organizations who share or rely on NOAA's environmental assessment, prediction, and stewardship mission. In addition, through its partnership and coordination with DoD and other agencies, the JCSDA will enhance the Nation's ability to respond to increased data reporting and data sharing needs brought on by the renewed emphasis on homeland defense and national security concerns.

The initial projects within the JCSDA will focus on fully exploiting uses of current satellite data. As a part of efforts to facilitate the transition from research into operations, early projects will focus on maturing the process of transitioning these data into operations and developing tools to support future assimilation projects. Five initial scientific priorities have been identified:

1. Develop a community-based radiative transfer model (CRTM) to be utilized by the JCSDA partners in their data assimilation systems. In next few years, the accuracy and capability of



the JCSDA CRTM will be significantly improved by including additional physical processes (e.g., atmospheric scattering) and better numerical techniques and better surface emissivity models to allow more satellite data which is affected by surface to be properly assimilated.

2. Develop the data thinning and configuration technology and methodology that will allow faster and efficient delivery of advanced satellite data to major NWP centers in the U.S. and other international partners.

3. Advance the techniques to assimilate satellite data in cloudy and precipitation regions by improving radiative transfer models and NWP cloud prediction scheme, thereby significantly increasing the fraction of satellite data being ingested into the assimilation systems.

4. Improve uses of satellite land products (e.g., green vegetation fraction, snow cover, snow pack parameters, surface albedo, land, and sea surface temperature) in NWP models.

5. Improve use of satellite data in ocean data assimilation by providing assimilated ocean data sets to the community for research purposes and providing access to and support of an operational ocean data assimilation system.

In addition, the JCSDA has a long term strategic goal of improving the transfer of data assimilation research into operations by fostering common data assimilation code components, including techniques for specifying observation errors, background error co-variances, and data selection and reduction.

The JCSDA approach is already generating measurable accomplishments. Recent accomplishments include:

1. Improved radiative transfer techniques.

- Microwave land emissivity model implemented in NCEP operational global data assimilation system (GDAS).
- Community fast radiative transfer

model implemented operationally in the GDAS.

- More AMSU-A data are used over land.

2. Improved uses of current satellite data.

- More AMSU-A data are used over land.
- Increased use of HIRS, AMSU-A data in stratosphere.
- SSM/I, TRMM precipitation products AMSU cloud liquid water GOES-10 IR radiances QuikSCAT winds.

3. More satellite data being used in NCEP operational models.

- SSM/I, TRMM precipitation products.
- AMSU cloud liquid water.
- GOES-10 IR radiances.
- QuikSCAT winds.

Polar-Orbiting Systems. The primary mission of the Polar-orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-16 and NOAA-17.

NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users of emergency beacons operating at 121.5 or 243 or 406 MHz. In addition to taking ther-

mal images of the earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

POES satellites carry four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); and the TIROS Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultra-Violet Instrument (SBUV/2). The AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR/3 series of instruments, which began with NOAA-15, measures in six spectral channels (0.63, 0.86, 1.6, 3.75, 10.8 and 12  $\mu\text{m}$ ) with a nominal spatial resolution of 1.1 km and global resolution of roughly 4 km. Though the AVHRR/3 measures 6 channels, only 5 are transmitted in the data stream. The AVHRR/3 provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping. TOVS is comprised of the High-resolution Infrared Radiometer Sounder (HIRS) and the Advanced Microwave Sounding Unit (AMSU).

The HIRS/3 is a discrete-stepping, linescan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40km. Multi-spectral data from one visible channel (0.69 $\mu\text{m}$ ), seven shortwave channels (3.7 to 4.6 $\mu\text{m}$ ), and twelve long wave channels (6.5 to 15 $\mu\text{m}$ ) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8 $\mu\text{m}$ . The mirror steps rapidly (<35 msec), then holds at each

position while the 20 filter segments are sampled. This action takes place each 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4 $\mu$ m in the visible and shortwave IR, and 1.3 $\mu$ m in the long wave IR band that, from an altitude of 833km, encompasses an area of 20.3km and 18.9km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: (a) AMSU-A2 with two channels at 23.8 and 31.4GHz and (b) AMSU-A1 with twelve channels in the range of 50.3 to 57.3GHz and one channel at 89.0GHz. The AMSU-B has five channels with frequencies centered on 89, 150, 183 $\pm$ 1, 183 $\pm$ 3, and 183 $\pm$ 7Ghz, respectively. AMSU-B, provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). AMSU-A has a nominal FOV of 3.3 $^\circ$  (48km on surface at nadir) and AMSU-B a field of view of 1.1 $^\circ$  (16km on surface at nadir). AMSU-A (AMSU-B) samples 30 $^\circ$  (90 $^\circ$ ) Earth views, covering  $\pm$ 48.95 $^\circ$  from the subsatellite point. In addition, the specialized 89GHz channel, with the capability to "see" through high and mid-level clouds to low level precipitation producing clouds, is utilized to determine the position and structure of tropical cyclones on a global scale. The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42km, or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

The SEM measures solar proton flux, alpha particle and electron flux

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

The NOAA-16 carries the SBUV/2. The SBUV/2 instrument is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. Ozone evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17. A new ozone profile retrieval algorithm (Version 8) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16, NOAA-17, and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, and NOAA-17. Experimental ozone products at high temporal resolution are also being produced from the GOES-8 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES total ozone values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems: the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental

Satellite Computer System (CEM-SCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland. PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDA's to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location, calibration, and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions that are disseminated to users throughout the world.

The POES Data Collection (and location) System (DCS) is provided through an international cooperative agreement with the Centre National d'Etudes Spatiales of France and is called the Argos DCS. The system provides a means to locate and collect environmental data from fixed and moving platforms; i.e., polar ice flows, ocean buoys, birds, mammals, etc in near-real time. The Argos DCS supports operational and research related environmental applications, e.g. meteorology, oceanography, and protection of the environment, with the majority of users being government/non-profit agencies and researchers. An instrument upgrade to incorporate a downlink message capability, called the Argos Advanced Data Collection

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM		GEOSTATIONARY SYSTEM	
Satellite Designator	Planned Launch Date*	Satellite Designator	Planned Launch Date*
NOAA-N	CY 2004	GOES N	CY 2004
METOP-1	CY 2005	GOES O	CY 2007
NOAA-N'	CY 2008**	GOES P	CY 2008
NPOESS-3	CY 2009	GOES Q	CY 2010
METOP-2	CY 2010	GOES R	CY 2012
METOP-3	CY 2012		

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

\*\* A replan effort is underway due to accidental damage to N'.

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

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

Instruments for NPOESS Series

VIIRS - Visible/Infrared Imager/Radiometer Suite  
CMIS - Conical Microwave Imager/Sounder  
CrIS - Cross-track Infrared Sounder  
ATMS - Advanced Technology Microwave Sounder  
OMPS - Ozone Mapper/Profiler Suite  
SES - Space Environment Suite  
DCS - Data Collection System  
SARSAT - Search and Rescue Satellite-Aided Tracking System  
ERBS - Earth Radiation Budget Sensor  
TSIS - Total Solar Irradiance Sensor  
ALT - Altimeter (Dual Frequency radar altimeter)

Instruments for GOES-Next Series

Imager  
Sounder  
SEM - Space Environment Monitor  
SXI - Solar X-Ray Imager (GOES M and N)

EUMETSAT Unique Instruments for METOP Series Satellites

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



---

System (ADCS), is planned for the NOAA-N' satellite and the NPOESS constellation. The Argos ADCS program will also incorporate other international satellite programs, such as the National Space Development Agency of Japan (NASDA) ADEOS II satellite and the European Organization for Exploration of Meteorological Satellites (EUMETSAT) METOP satellite series.

Geostationary Satellite Program. Two operational geostationary satellites, GOES-17 (75° W) and GOES-10 (135° W), provide coverage of virtually the entire western hemisphere for operational environmental services. Additionally, GOES-9 is now located over the western Pacific. The GOES-9 imager replaced the GMS as of April 1, 2003. The sounder is operating in an experimental mode. The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 $\mu$ m and 12.0 $\mu$ m wavelengths. However, beginning with GOES-12, the 12.0 $\mu$ m channel is replaced with a 13.3 $\mu$ m channel, with the goal of achieving more accurate cloud height assignments for mid- and upper-level atmospheric wind-velocity estimates. Also, the spatial resolution of the water vapor channel will improve to 4km from 8km.

GOES satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own meteorological surface, and hydrological application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-earth disk is normally scanned once every 3 hours and requires about 30 minutes

to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7½-minute interval (severe storm operations) rapid scans over the contiguous United States. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena. The five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55 $\mu$ m to .75 $\mu$ m) - 1 km
- Channel 2 (Infrared, 3.8 $\mu$ m to 4.0 $\mu$ m) - 4 km
- Channel 3 (Water Vapor, 6.5 $\mu$ m to 7.0 $\mu$ m) - 8 km (4 km starting with GOES-12)
- Channel 4 (Infrared, 10.2 $\mu$ m to 11.2 $\mu$ m) - 4 km
- Channel 5 (Infrared, 11.5 $\mu$ m to 12.5 $\mu$ m)- 4km(13.3 $\mu$ m at 8km starting with GOES-12)

The GOES-10 and GOES-12 sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and total ozone distribution. Products derived from the sounder include precipitable water and lifted index - a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full-Earth imagery, sectorized imagery, and local imagery. In routine operations, GOES-12 and GOES-10 provide hourly sounding coverage.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. This block of instruments is more extensive than on POES. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors,

and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DoD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users online via Internet and on a variety of computer media.

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

The GOES Search and Rescue Satellite-Aided Tracking (SARSAT) System is capable of providing an immediate distress alert, unlike the POES satellite SARSAT instruments which must come within line of site of a Local User Terminal, in order to relay the distress beacon back to the United States SARSAT Mission Control Center (USMCC). Newer state-of-the art Cospas-Sarsat 406 MHz emergency beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to the USMCC.

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important on-line access system, managed and operated by OSDPD and NOAA's National Climatic Data Center (NCDC), is the NOAA Operational Satellite Active Archive (SAA). The SAA ([www.saa.noaa.gov](http://www.saa.noaa.gov)) provides satellite data access, display, and electronic transfer. Available data types include AVHRR, ATOVS, DMSP (special sensor), and RADARSAT (authorized subscription users). Near-real-time images and interpretive analyses of tropical storms and hurricanes worldwide, ash from volcanic eruptions within the western hemisphere, heavy precipitation in the United States which cause flash flooding or blizzards, wild land fires and smoke within the United States, and northern hemisphere snow boundaries are located at [www.ssd.noaa.gov](http://www.ssd.noaa.gov). Specially enhanced and annotated imagery and image loops of environmental events, such as flooding, hurricanes and other severe storms, volcanic eruptions, fires, and dust storms are available from [www.osei.noaa.gov](http://www.osei.noaa.gov). This web site was set up for use by the news media and general public, and to provide once or twice per day satellite views of an environmental event for federal, state, and international governments and agencies. Also supporting the media, scientific organizations, and federal and state agencies is a specially designed web site featuring visualizations of satellite data, found at [www.nnvl.noaa.gov/](http://www.nnvl.noaa.gov/).

### **INTERNATIONAL SUPPORT FOR EMERGENCY RESPONSE**

Following the UNISPACE III conference held in Vienna, Austria in July 1999, the European and French space agencies (ESA and CNES) initiated the International Charter "Space and Major Disasters", with the Canadian

Space Agency (CSA) signing the Charter in 2000. In 2001, the NOAA (NOAA) and the Indian Space Research Organization (ISRO) also became members of the Charter, and in 2003 the Argentine Space Agency (CONAE) became a member.

The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each member agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property.

The International Charter was declared formally operational on November 1, 2000. An authorized user can call a single number to request the mobilization of the space and associated ground resources of the six agencies to obtain data and information on a disaster occurrence.

The call is received by a 24-hour on-duty operator who then checks the identity of the requester and verifies that the User Request form sent by the Authorized User is correctly filed. The operator passes the information to an emergency on-call officer who analyzes the request and the scope of the disaster with the User, and prepares an archive and acquisition plan using available space resources. Data acquisition and delivery takes place on an emergency basis, and a project manager, who is qualified in data ordering, handling and application, assists the user throughout the process.

### **SUPPORTING RESEARCH PROGRAMS**

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP/EMC and other major International NWP Centers, require higher quality satellite derived winds, particularly over the traditionally data void oceanic regions of the globe. The NESDIS GOES East and

West wind processing suites are totally automated and use a series of geostationary satellite images to derive wind estimates. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. The automated quality control of image registration is also an important component of the NESDIS GOES-East and West winds processing suite. Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned BUFR format. Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low-level high density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower-tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region, which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0 $\mu$ m and 7.3 $\mu$ m. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0 $\mu$ m channel peaks

around 450mb and the weighting function of the 7.3 $\mu$ m channel peaks around 550mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999. These wind products can be viewed at [orbit-net.nesdis.noaa.gov/goes](http://orbit-net.nesdis.noaa.gov/goes) and [cimss.ssec.wisc.edu/tropic/real-time](http://cimss.ssec.wisc.edu/tropic/real-time). Digital sounding and winds files are available through a GOES computer server within OSDPD.

Atmospheric Moisture and Stability Products. Research continues to improve the atmospheric moisture and stability products from the GOES-12 and GOES-10 sounder instruments. Precipitable water for three layers of the atmosphere: surface to 900 hPa; 900-700 hPa; and 700-300 hPa are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the earth's surface to the "top" of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation, locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this information provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to Eta Data Assimilation System (EDAS), which provides the initialization for the Eta, forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes. As of July 8, 2003, the hourly cloud-top information from the GOES sounder data are being assimilated

into the operational National Centers for Environmental Prediction (NCEP) Eta Data Assimilation System (EDAS). The regional Eta model joins the Rapid Update Cycle (RUC) model as two operational models assimilating GOES sounder cloud information to help improve the initial moisture and cloud field. At present, a blended GOES, SSM/I, and model-derived product is being evaluated. In addition, a precipitable water product has been developed from the POES AMSU sensor and is presently operational. In the near future, the blended product will include the AMSU-derived precipitable water. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events.

So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field, for example, to understand the time evolution of severe storms. Because channel noise has improved with each successive sounder instrument it is anticipated that the GOES sounder moisture and stability products with a horizontal resolution of approximately 50 km, will be generated at a high horizontal resolution of approximately 10 km in the fall of 2003 (Figure 3-DOC-5).

The increased horizontal resolution offers exciting possibilities for enhanced use of these products in mesoscale forecasting. For example, it improves the depiction of gradients in the retrieved products, such as moisture and atmospheric stability, which

focuses attention to a localized area of interest. These products can be viewed at [orbit-net.nesdis.noaa.gov/goes](http://orbit-net.nesdis.noaa.gov/goes) and [cimss.ssec.wisc.edu](http://cimss.ssec.wisc.edu). Digital versions of these products are available from POES and GOES computer servers within OSDPD.

Tropical Cyclone Monitoring. NESDIS continues to improve upon satellite-based techniques for estimating tropical cyclone positions and intensities, and for describing the internal structure of these storms. Recent sensors, such as AMSU and TRMM, among others, are being incorporated into the NESDIS operational tropical program, which supports the NWS and DoD hurricane programs. Real-time imagery and NESDIS tropical text messages can be viewed at [www.ssd.noaa.gov/SSD/ML/realtime.html](http://www.ssd.noaa.gov/SSD/ML/realtime.html). Research is also being performed to improve the forecasts of tropical cyclone formation and intensity change by making better use of satellite observations.

Precipitation Estimates. The Hydro-Estimator (H-E)--a fully automated adaptation of the semi-manual Interactive Flash Flood Analyzer (IFFA)--produces estimates of instantaneous precipitation rate based on GOES infrared data every 15 minutes. The H-E adjusts its computed rain rates for moisture availability, sub-cloud evaporation, orographic uplift, and other factors using Eta model fields. The resulting estimates are also the basis for 0-3 hour nowcasts of precipitation via an algorithm for extrapolating cell movement and development called the Hydro-Nowcaster. Other techniques being tested include the GOES Multi-Spectral Rainfall Algorithm (GMSRA), which uses four of the five GOES Imager channels for more precise rain area identification, and a combined GOES and microwave rainfall algorithm (developed at NRL/Monterey) which uses microwave-based rainfall estimates to modify its calibration. Real-time



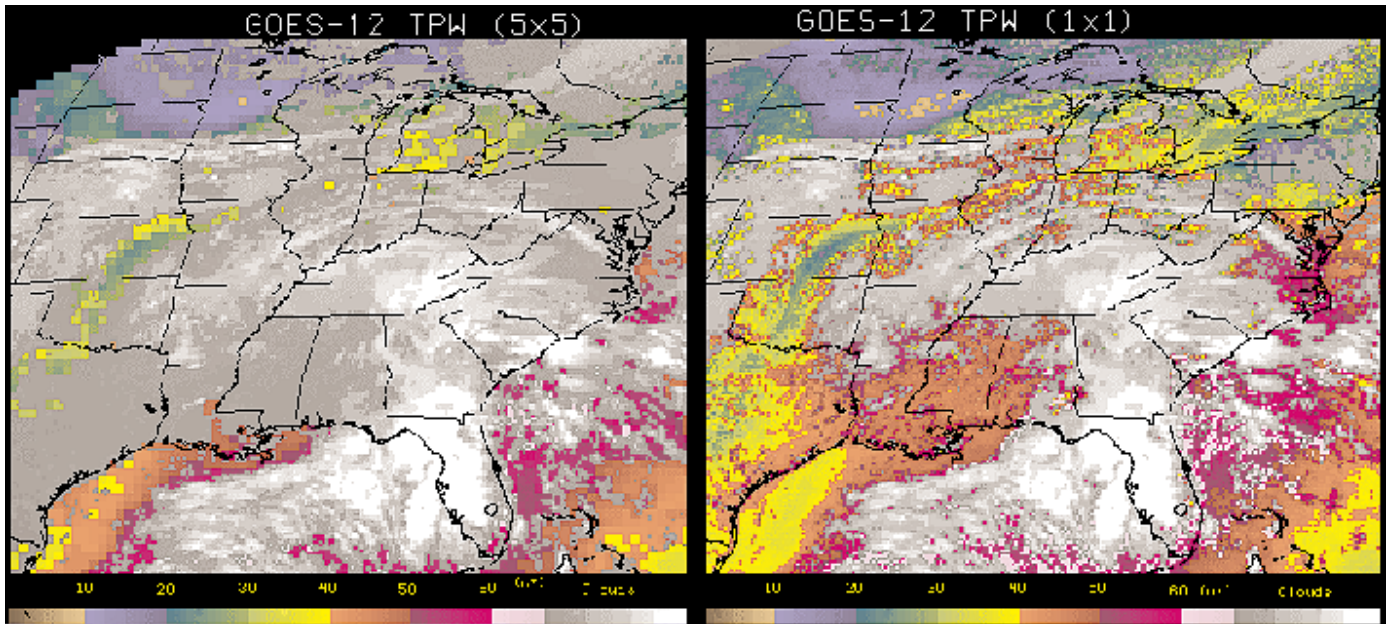


Figure 3-DOC-5. GOES-12 retrieved total precipitable water products at 50 km resolution (left) and 10 km resolution (right)

graphics from all three of the above techniques can be accessed at <http://orbit-net.nesdis.noaa.gov/arad/ht/ff/index.htm>, and real-time validation statistics for these algorithms are available at <http://orbit-net.nesdis.noaa.gov/arad/ht/ff/validation/validation.html>. The H-E is now also available to NWS field forecasters via AWIPS. In addition, an improved AMSU-B rain rate algorithm is being implemented, and a new precipitation algorithm has been developed using the AMSR-E is under development. The AMSU-B products are available at <http://orbit-net.nesdis.noaa.gov/arad2/MSPPS/index.html>, including global long-term estimates for climate monitoring and analysis. Finally, the POES-based microwave algorithms from the microwave sensors are being utilized to produce automated 24-hour Tropical Rainfall Potential (TRaP) forecasts worldwide (Figure 3-DOC-6). Real-time TraP graphics can be accessed at <http://www.ssd.noaa.gov/PS/TROP/trap-img.html>.

**Microburst Products.** Several experimental microburst and convective wind gust products are being tested. These products, including the Wind Index (WINDEX) to compute maxi-

mum possible convective wind gusts and the Theta-e Deficit (TeD) and Dry Microburst Index (DMI) to compute the potential for wet and dry microbursts, respectively, utilize sounder data from both GOES-East/West. They are produced hourly and can be viewed at [www.orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html](http://www.orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html)

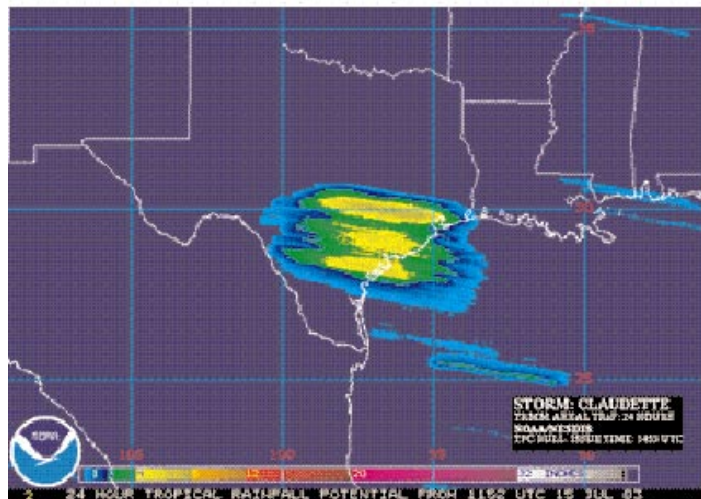
In addition, a new wet microburst index product, designated as the Wet Microburst Severity Index (WMSI) is being developed and will be implemented in the suite of GOES microburst products. The WMSI assesses the potential severity of wet microbursts by summarizing the physical processes of convective storm development and downburst generation. The WMSI algorithm incorporates such parameters as convective available potential energy (CAPE), to represent the process of updraft formation, and Theta-e Deficit (TeD) (Figure 3-DOC-7), to represent downburst development.

**Low Cloud and Aircraft Icing Products.** Fog and low clouds are a major source of air traffic delays and aircraft accidents. A nighttime, two-channel IR product from GOES has been developed to show regions where

low ceilings (<1,000 ft) are likely to be found. This product is used to signal deteriorating weather conditions before they are reported by airport weather stations. Fog products for the Continental United States and Alaska are available on the Web hourly at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/fog.html>.

Areas of "super-cooled" water clouds that can result in hazardous aircraft icing are detectable from GOES by means of an experimental, multi-spectral product that uses a combination of several IR temperature and visible brightness thresholds. A recent innovation has combined this icing image with the GOES cloud-top height analysis to create an ICing Enhanced Cloud-top Altitude Product (ICECAP) (Figure 3-DOC-8). The icing products are provided hourly day and night for the Continental United States, Alaska, and the East Pacific at <http://orbit-net.nesdis.noaa.gov/arad/fpdt/icg.html>.

**Geostationary Sea Surface Temperatures.** GOES-12 and GOES-10 are proving capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the



Stage IV Precipitation for the 24 h Ending 1200 UTC 16 Jul 2003

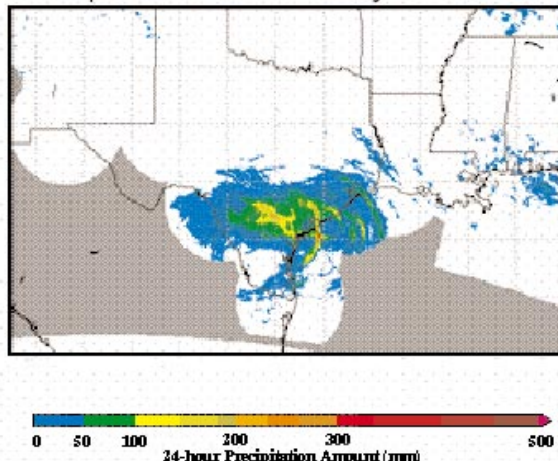


Figure 3-DOC-6. Tropical Rainfall Potential (TRaP) forecast for Hurricane Claudette (left) and corresponding Stage IV radar/raingauge estimates (right) for the 24 hours ending 1200 UTC 16 July 2003.

GOES measurements are close to that achieved from the polar orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. For the SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Additionally, a change in scene temperature over a short period of time may indicate the presence of clouds, thereby enhancing cloud detection.

The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations and good geographical coverage of SST estimates. For the first time, GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly in an experimental configuration since December 1998 for both GOES-12 and GOES-10. A global SST product is produced every three hours; regional SST products are generated every hour. These products were recently implemented operationally and can be accessed as digital files from the GOES computer servers within OSDPD.

**Volcanic Ash and Fire Monitoring.** A new technique has been developed

to compensate for the loss of a 12mm IR band on GOES-12 to help track hazardous volcanic ash clouds. The technique uses IR channels centered at 10.7 $\mu$ m, 13.3 $\mu$ m, and 3.9 $\mu$ m. Several recent eruptions of Soufriere Hills volcano on Montserrat in the eastern Caribbean have shown that this new product is helpful in monitoring ash cloud emissions, even at night. Figure 3-DOC-9 shows an area of volcanic ash (circled) from Soufriere Hills observed by GOES-12 using the new method. The experimental GOES-12 ash product can be viewed for several volcanically active regions at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html>. The analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) data from the NASA Terra and Aqua spacecraft has also yielded valuable information about optimum detection of volcanic ash using several spectral bands. A three-channel combination product based on the 8.6mm, 11mm and 12mm bands has been developed that provides effective discrimination of ash or sulfur dioxide gas with minimal false alarms. This algorithm could be applied to future products from NPOESS and GOES-R, which will have similar spectral bands. Ash cloud advisory statements are provided by NESDIS to the aviation community over southern North America and

northern South America, through the Volcanic Ash Advisory Center (VAAC) in Washington, District of Columbia. GOES infrared and visible images, aerosol and sulfur dioxide products from NASA's Total Ozone Mapping Spectrometer (when applicable), and operational volcanic ash products for the Washington VAAC area of responsibility are found at <http://www.ssd.noaa.gov/VAAC/washington.html>.

Fire and smoke monitoring algorithms are being developed to automatically detect fires and to monitor their growth and the associated smoke coverage. The GOES-8 split window data (at 4 $\mu$ m and 11 $\mu$ m) have been used to assess trends in South American burning practices over the past 6 years (1995-2000); GOES detected the most fire pixels in the tropical rain forest ecosystem in 1995. The application to clear sky human-initiated burning in South and Central America is now being adapted to monitor cloudy sky lightning and clear sky human-initiated fires in the Canadian provinces and the continental United States. The continual monitoring from GOES (as often as every 7½ minutes) can assist firefighters to plan evacuation and extinguishing activities. Studies with Brazil are underway to predict smoke transport and air pollution and health alerts for major cities. An AVHRR fire detection



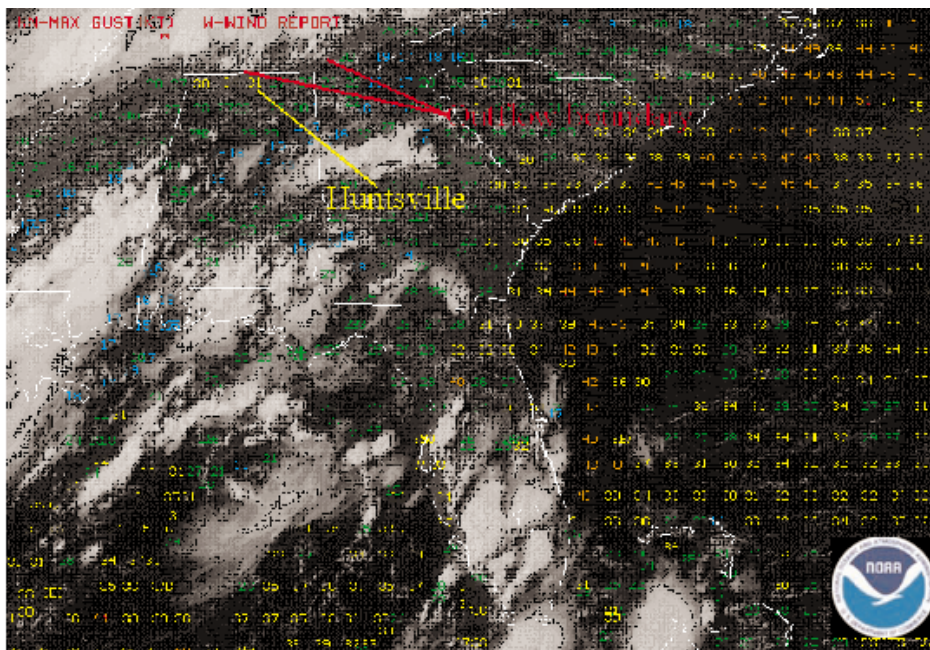


Figure 3-DOC-7. Example of GOES sounder-derived Theta-e Deficit (TeD) values plotted over a GOES visible satellite image from 2045 UTC July 30, 2002.

Note outflow boundary over southern Tennessee and high TeD values (>30K) over northern Alabama. The outflow boundary triggered a thunderstorm that produced a downburst wind gust of 61 knots at Huntsville, Alabama.

algorithm is being developed for use in monitoring fire and smoke outbreaks around the world. All these new techniques will be used to improve the current operational fire and smoke product (Figure 3-DOC-10) used by the NWS Storm Prediction Center (SPC) in their fire outlook product. Real time imagery of GOES and POES imagery in support of SPC can be found at: <http://www.ssd.noaa.gov/PS/FIRE/fire-s-fl.html>. A GOES Products and Services Catalog is available on line at [www.orbit-net.nesdis.noaa.gov/avad/fpdt/goescat/index.html](http://www.orbit-net.nesdis.noaa.gov/avad/fpdt/goescat/index.html). An up-to-date list and description of operational and experimental products with links to the real-time products are available from this web page. The Polar Products and Services Catalog is under development.

NPOESS "test bed" data sets. ORA scientists continue to play an important role in the evaluation of proposed contractor sensor design and retrieval methods during the ongoing selection process for NPOESS. ORA scientists have created a variety of "test bed" data sets that are being used in the

algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the requirements of all Environmental Data Records. Ozone

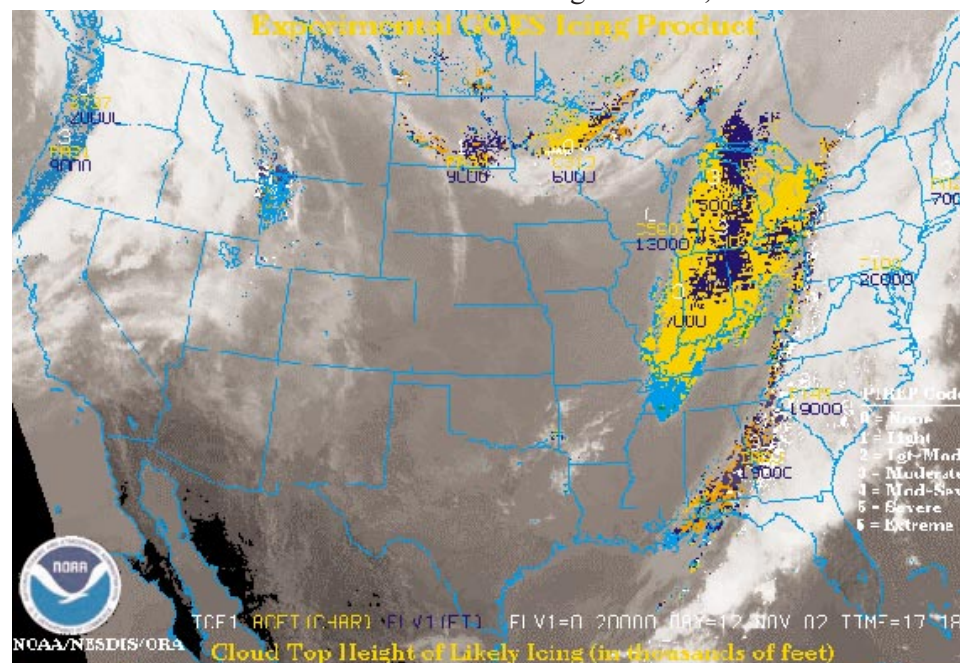


Figure 3-DOC-8. Areas of potential aircraft icing observed by GOES Imager, at 1800 UTC on November 12, 2002, are color-coded according to the estimated maximum cloud top height in 3,000 foot intervals, based on information from the GOES Sounder.

evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17. A new ozone profile retrieval algorithm has been developed by NASA and is now incorporated into SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16 and NOAA-17, and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, and NOAA-17. Experimental high temporal ozone products are also being produced from the GOES-12 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

Land Surface Parameters for Use in Weather Forecast Models. Satellite-derived fields of land surface characteristics are being prepared for use in NWP models. These include radiation products delivered in near real-time as forcing variables; surface characteris-



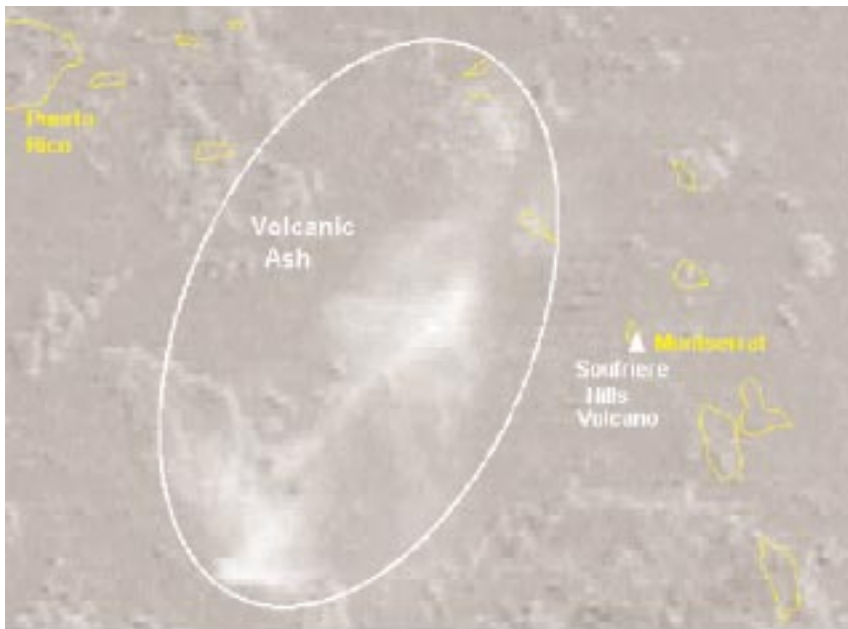


Figure 3-DOC-9. Volcanic ash from an earlier eruption of Soufriere Hills Volcano, Montserrat (circled) drifts westward across the Eastern Caribbean, as seen by GOES-12 at 1200 UTC, July 15, 2003.

tics, such as fractional green vegetation and albedo, that specify model lower boundary conditions; and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES-based (SSM/I and

AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and deliv-



Figure 3-DOC-10. Example of the current operational fire and smoke product used by the NWS Storm Prediction Center (SPC).

ered to Atmospheric Environment Service, Canada for evaluation. New techniques such as automatic edge detection and incorporation of new sensors such as AMSU and NASA's MODIS are in development to improve operational production of daily snow and ice extent products. These products are delivered as digital files to NWP models and to the NWS Climate Prediction Center and other users. Graphical imagery of operational northern hemispheric snow cover can be found on the Internet at [www.ssd.noaa.gov/SSD/ML/real-time.html](http://www.ssd.noaa.gov/SSD/ML/real-time.html) #SNOW.

Clouds from AVHRR. Algorithms are being developed, tested, and validated for determining cloud optical and microphysical properties from imager data such as the AVHRR. These algorithms are in addition to those already developed which estimate amounts and types for each observed cloud layer. The four cloud types are: L - Liquid Water Clouds; M - Mixed Phase Clouds; G - Glaciated Clouds (opaque); and H - High Ice Clouds (semi-transparent). Knowledge of cloud properties is important for both climate-scale and short-medium range forecasts. Accordingly, algorithms and processing systems to estimate cloud properties from imager data are being developed for both applications. Assimilation of cloud properties into NWP models is an objective of NCEP for improving short-medium range forecasts. Other applications of this work include the validation of simulated scenes to be used for the evaluation of new algorithm and instrument designs that is supported by the IPO. In addition, new algorithms are being developed to produce optimal estimates of cloud properties from both imager and sounder data, such as the merge of AVHRR and TOVS data.

Aerosols. Aerosol retrievals from an improved and extended unique

PATMOS-BUOY Dataset were analyzed to optimize the procedure used in the aerosol correction of sea surface temperature (SST) retrievals. Based on the results, a new aerosol correction algorithm for SST has been developed and delivered to OSDPD for the use with NOAA-16 and -17 data. The new correction algorithm uses aerosol optical depth in AVHRR/3 channel 2 (0.83  $\mu\text{m}$ ), only. The PATMOS-BUOY match up data set was also used for an extensive evaluation of the single-channel 3rd generation algorithm for aerosol retrieval from AVHRR. This aerosol algorithm has now been implemented in the operational aerosol observations (AEROS) obtained from the AVHRR instrument onboard the NOAA 16 and 17 satellites. The algorithm uses an improved treatment of atmospheric and surface effects, and provides aerosol optical depth data in three channels at 0.63, 0.83 and 1.6  $\mu\text{m}$  (Figure 3-DOC-11). The single-channel 3rd generation algorithm has also been implemented at NASA/LARC in the Clouds and Earth's Energy System (CERES) SSF processing of aerosol optical depth from the MODIS instruments on the Terra and Aqua satellites. Aerosol data from this algorithm is produced in addition to the primary MODIS multi-channel retrievals. The single-channel retrievals serve as back-up for the primary product. They also provide continuity with earlier NOAA/AVHRR aerosol retrievals, and facilitate the quantification of improvements offered by multi-channel retrievals over single-channel ones. A comparison of the two aerosol products shows an overall good agreement on a global scale. This implies that the simple single-channel algorithm performs well relative to the more sophisticated and comprehensive MODIS multi-channel algorithm. The major differences between the two products appear to be related to the differences in cloud screening and identification of glint regions that lead to differences in

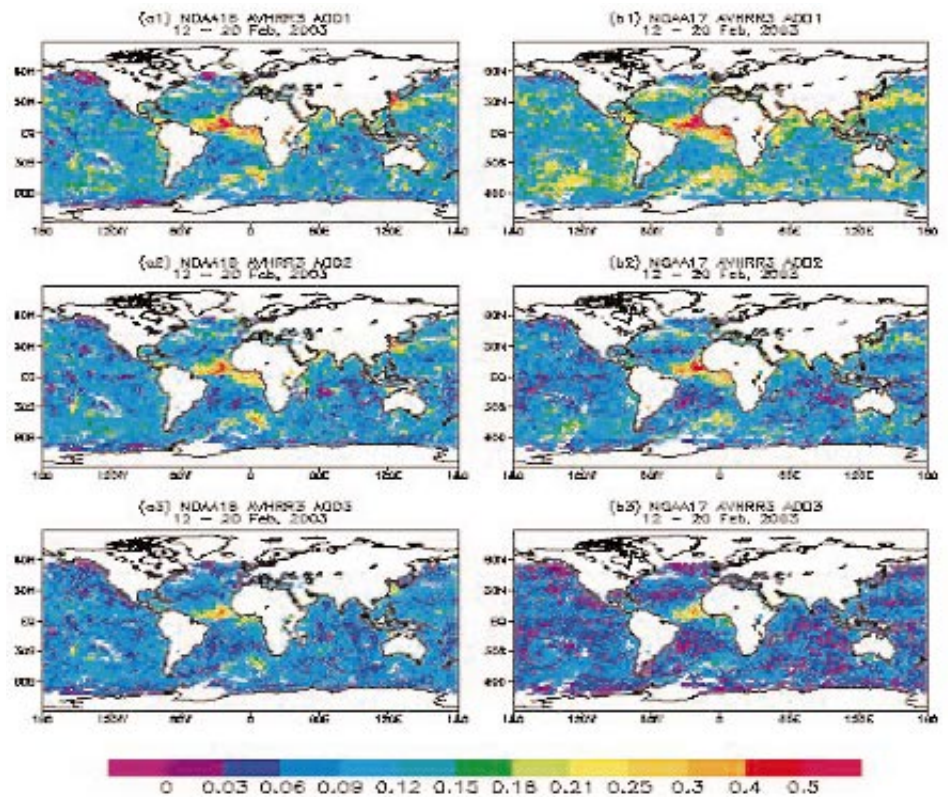


Figure 3-DOC-11. Global distribution of aerosol optical depth over oceans derived from AVHRR/3 channels 1 (0.63  $\mu\text{m}$ ), 2 (0.83  $\mu\text{m}$ ) and 3 (1.61  $\mu\text{m}$ ) onboard (a) NOAA-16 and (b) NOAA-17 satellites. Each point on the map represents an [8 day x ( $1^\circ$ )] average.

sampling. The lessons learned from these and follow up comparisons will be applied to improve the current operational algorithm, and in the risk reduction of aerosol retrieval from VIIRS on the NPOESS satellites. The feasibility of aerosol optical depth retrieval from GOES over most of South and North America has also been demonstrated. A comparison of GOES-retrieved aerosol optical depth with that observed at the AERONET ground stations showed good agreement.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance. Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the CEMSCS and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated

from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. NOAA will continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the AVHRR. The AVHRR flown on POES is recognized as an invaluable resource for satellite-based studies of the Earth system. The long-term records of geophysical products such as the Normalized Difference Vegetation Index (NDVI), columnar aerosols over the oceans, cloud morphology, and short-wave radiation budget play a central role in climate



and global change studies by providing a means to study the environment continuously. It is thus very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible (Channel 1: 0.58 - 0.68  $\mu\text{m}$ ), and near-infrared (Channel 2: 0.72 - 1.1  $\mu\text{m}$ ; Channel 3A: 1.58 - 1.64  $\mu\text{m}$ ) channels which do not have any onboard calibration devices. The major program elements are: (a) development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft; (b) enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond  $\pm 5$  percent; (c) evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST); (d) establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on the GOES, the visible channel of the High-resolution Infrared Radiation Sounder (HIRS), the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and (e) design of optimal onboard and vicarious calibration techniques for the visible and near-infrared sensors planned under the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The relevance and importance of these activities has been

recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV) and the Global Observing Systems Space Panel (GOSSP).

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

Calibration of Geostationary Operational Environmental Satellite Instruments. The wavelength configuration of channels on the GOES-12 Imager will be slightly different from that of its predecessors. A 13.3 $\mu\text{m}$  channel will replace the current 12 $\mu\text{m}$  channel. The new channel will employ a single detector with an 8-km field-of-view at the Earth's surface. The water-vapor channel at 6.7 $\mu\text{m}$ , which on GOES 8 through 11 observe the Earth with a single 8-km detector, will employ two 4-km detectors on GOES-12. To accommodate these revisions, the calibration processing in the ground system will be modified.

Pathfinder. Climate data sets of cloud amount, aerosol optical thick-

ness (AOT) over the oceans, and the Earth's radiation budget for clear and cloudy skies have been retrospectively generated from over 17 years of AVHRR data as part of the NOAA-NASA Pathfinder program. An improved data set spanning the period from July 1981 through the end of 1999 was completed in 2000. This data set is being utilized to study the relationship between the variation in global mean values of the absorbed solar radiation and variation in aerosol amount caused by major volcanic eruptions. The influence of the aerosol amount on variations in the global surface temperature is also under investigation. The analysis of time series of anomalies of the cloud radiative forcing has been shown to correlate well (spatially and temporally) with El Niño events. A second reprocessing of the entire data set is being proposed, where multiple-layered cloud data will be used. Land surface and ocean products such as the vegetation index and the sea surface temperature will be added.

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

Storm Signatures and Winds from Synthetic Aperture Radar. ORA scientists are currently studying ocean sur-



face wind signatures of atmospheric fronts and storms with synthetic aperture radar (SAR) imagery. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as coastal lee waves), atmospheric fronts, and coastal wind shadowing. Techniques for calculating wind speed (and under certain conditions direction as well) are also under development. Before the year 2003, four new wide-swath SAR satellites are planned for launch. If data acquisition and sharing arrangements can be made to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of United States coastal areas will be possible.

Ocean Color. Several programs at ORA are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys, and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near-infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the recently launched Moderate Resolution Imaging

Spectroradio-meter. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection of in situ measurements of these and other parameters relevant to ocean color in the surrounding region from ship. Data from both sampling platforms furnish a time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at ORA to routinely evaluate the accuracy of NESDIS operational ocean color products and to develop algorithms in order to remotely detect and predict the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch: NOAA's Early Warning System for Coral Reef Health. Like the rest of the world, most of the United States coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's, and an unknown but significant fraction of United States Pacific Territories. The widely distributed and isolated locations of many coral reefs preclude normal monitoring practices. In

1998, NESDIS established an experimental capability using POES satellites to conduct thermal bleaching surveillance of coral reefs on a worldwide basis. This experiment demonstrated remarkably accurate capabilities for early warning of El Niño-induced coral reef bleaching conditions over all global tropical ocean regions resulting in a series of special International Workshops on Satellite Monitoring of Coral Reefs being convened in June 1999, January 2001, and June 2003. In 2002 NESDIS successfully transitioned two existing experimental satellite reef health monitoring products into viable operational web-based products, such as the Coral Reef Hot Spot (Figure 3-DOC-12) and SST anomalies product. In addition, the proposed Coral Reef Watch (CRW) program provided support to NOAA's Coral Reef Information Service (CoRIS) promoting United States leadership in the emerging global "Virtual Coral Reef Ecosystem Monitoring Laboratory," and continues to provide support solid scientific basis for the development of future monitoring and assessment products and/or capabilities.

CoastWatch. NESDIS has responsibility for CoastWatch Program Management. This program managed

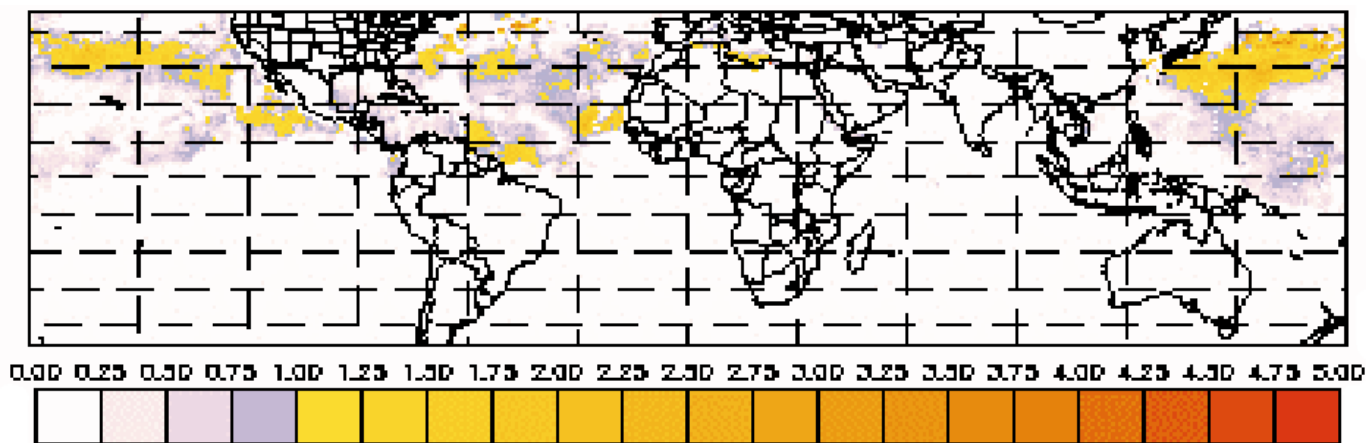


Figure 3-DOC-12. Global 50 km Coral Reef Hot Spot charts. These products highlight regions of extreme warm water that can be harmful to coral reefs. Areas in purple are approaching dangerous water temperatures (up to 1 degree Celsius more than the expected maximum SST) for coral reefs and those in yellow are at or exceeding dangerous water temperatures (1 degree or more warmer than the expected maximum SST).

in conjunction with other NOAA Line Offices makes satellite data products and in situ data from NOAA environmental buoys available to federal, state, and local marine scientists and coastal resource managers. For coastal areas in the Great Lakes, East Coast, and Gulf of Mexico, data from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's polar orbiting spacecraft are collected at Wallops Island, Virginia, and at Fairbanks, Alaska. These data are processed on NOAA computers in Suitland, Maryland, using a set of NOAA-developed multi-channel atmospherically corrected algorithms for determination of sea surface temperature. Data are then mapped (Mercator Projection) and sectored to predefined coordinates specified for each of the CoastWatch regions. Digital, high-resolution data products (1 km/4 km in a CoastWatch Binary Format) are then passed daily to CoastWatch Regional Nodes in the eastern United States (i.e., Southeast, Great Lakes, Northeast, Gulf of Mexico, and Caribbean). For Regional Nodes in the Pacific region CoastWatch local data acquisition and processing capabilities are in La Jolla, California; Anchorage, Alaska; and Honolulu, Hawaii. NESDIS in collaboration with the National Ocean Service has established a project that Nowcasts Sea Nettles in Chesapeake Bay. The nowcasting model uses a combination of satellite observations, hydrodynamical model of the bay, and a habitat model to predict the occurrence of sea nettles on a weekly basis. This project represents a collaboration between scientists from the University of Maryland Center for Environmental Science, the Virginia Institute of Marine Science at the College of William and Mary, and NOAA. The Internet is used as the primary telecommunications pathway for digital data distribution. Once products are delivered to the CoastWatch

Regional Nodes they become immediately available for local use. An ever-growing number of federal, state, and local organizations are establishing a formal relationship with local CoastWatch Regional Nodes for routine timely access to CoastWatch image products. More information about CoastWatch is available on the Internet at [coastwatch.noaa.gov/COASTWATCH/](http://coastwatch.noaa.gov/COASTWATCH/). Finally, The Coast Watch AVHRR products are undergoing a modernization effort which will provide the data in a new format (HDF) and use new processing software which will improve the earth locations of the products.

#### **NOAA NATIONAL DATA CENTERS (NNDC)**

The NESDIS is responsible for the management of the NOAA National Data Centers (NNDC). The NNDC's consist of three data centers: the National Climatic Data Center (NCDC) located in Asheville, North Carolina, the National Geophysical Data Center (NGDC) located in Boulder, Colorado, and the National Oceanographic Data Center (NODC) located in Silver Spring, Maryland ([www.nndc.noaa.gov](http://www.nndc.noaa.gov)).

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

The three NOAA National Data Centers (NNDC) are responsible for the Scientific Stewardship of the

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

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

Climate Monitoring, Evaluation, and Prediction are critical to economic sustainability and environmental stewardship, as well as planning and responding to the quality of life changes that society will encounter in the 21st century and beyond. The challenge facing the Data Centers is not only ingesting and processing very large volumes of new data, but also the convenient and timely access to the data and information. Millions of paper pages and thousands of feet of microfilm/microfiche of recorded instrument measurements and other information dating back hun-

dreds of years are currently under the stewardship of the NOAA National Data Centers. Over the past 50+ years, many observations have been stored in digital form. There is now in place a program to convert analog records to digital form. The process will take many years to complete.

The development of a new generation of satellites over the next ten years {NASA's Earth Observing System (EOS), Next Generation Geostationary Operational Environmental Satellite (GOES), and the Joint (DoD/NASA/NOAA National Polar-orbiting Operational Environmental Satellite System (NPOESS)}, the Initial Joint Polar System (IJPS)/MetOp, and the enhancement of the operational Next Generation weather Radars (NEXRAD) {dual polarization} present major data management (stewardship and customer access) challenges to the NOAA Data Centers.

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

National Climatic Data Center (NCDC), Asheville, North Carolina. The National Climatic Data Center (NCDC) is the Nation's and the world's largest archive of climate data. The NCDC produces and maintains numerous data sets, products, and assessments and services many thousands of customer with data and products worldwide. The NCDC operates a World Data Center for Meteorology and a World Data Center for Paleoclimatology both collocated at NCDC. National and global data sets and assessments are produced that sup-

port economic and environmental decisions and plans affected by climate variations and change. The Center describes the climate of the United States through monthly State of the Climate reports. U.S. Air Force and U.S. Navy activities collocated with the NCDC make up the trilateral Federal Climate Complex (FCC). See [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov).

NCDC Activities include:

- Responsible for the long term stewardship (archive and access) of the Nation's weather and climate data, as part of the Federal Records Retention System (FRRS). The NCDC is an approved Agency Records Center and operates under the NARA Federal Records Center guidelines and policies for managing weather and climate data records and information.
- Perform the Scientific Data Stewardship functions inherent to the mission as the legislatively designated Nation's Climate Data Center. These include developing and operating the associated ingest, monitoring, quality control processing, access, archive, analysis and assessment, creation of climate data records (CDRs), and other product generation systems in support of national and international commitments.
- Partners nationally with federal agencies {such as, National Aeronautics and Space Administration (NASA), Department of Defense (DoD), Environmental Protection Agency (EPA), United States Department of Agriculture (USDA), Department of Energy (DOE), Department of State (DOS), National Science Foundation (NSF), United States Geological Survey (USGS)}, United States Global Climate Research Panel (USGCRP), many state agencies, all the NOAA Line Offices, Regional Climate Centers (RCC), State Climatologists (SC),

universities, and many others.

- Partners internationally with the World Meteorological Organization (WMO), International Council of Scientific Unions (ICSU), World Data Centers (WDC), Intergovernmental Panel on Climate Change (IPCC), UNESCO, and other nations through bilateral and multi-lateral agreements.
- Serves as a World Data Center (WDC) for Meteorology under the auspices of the International Council of Scientific Unions (ICSU). In this capacity, the NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries to support research and other activities.
- Serves as a World Data Center (WDC) for Paleoclimatology under the auspices of the International Council of Scientific Unions (ICSU). In this capacity, the NCDC assembles, archives, and provides access to global paleoclimatic data. Paleoclimatic databases are derived from worldwide geophysical data, namely tree-rings, stalactites and stalagmites, coral samples, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources.
- The six Regional Climate Centers (RCC) are supported under the auspices of the NCDC. These Centers provide regional expertise and contribute to the collection, QC processing, and access to regional and national observing networks. The RCCs also maintain a strong relationship with the State Climatologists (SC) and regional and local businesses providing tailored products and services, as well as conducting applied research on a regional basis. Their activities are integrated into national assess-



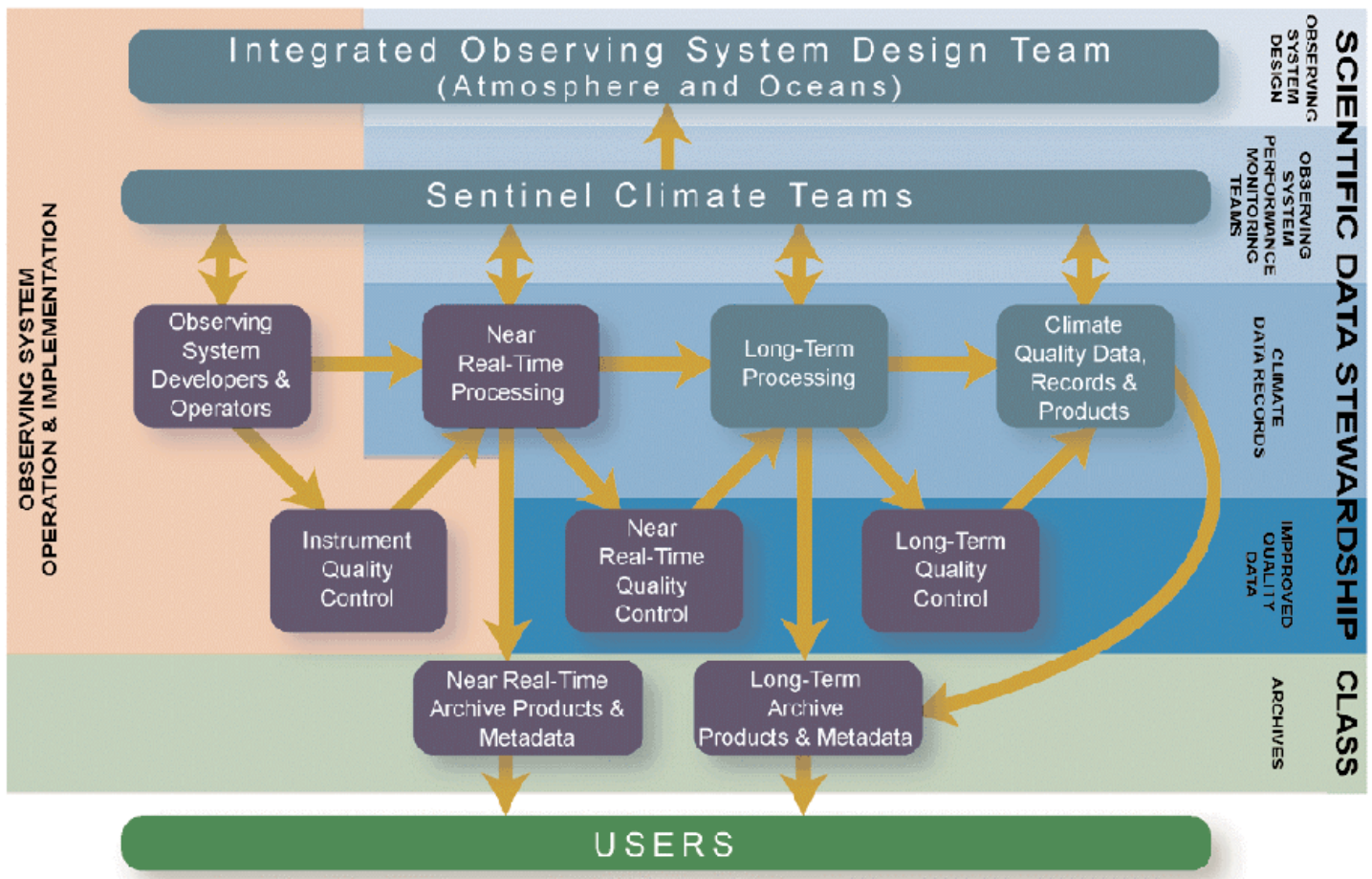


Figure 3-DOC-13. Scientific Data Stewardship -- Observations for Climate.

ments.

- Maintains a close working relationship with the State Climatologist (SC). The NCDC, the RCCs and the SCs form a vital component of a National Climate Services Program.
- Maintains and updates national and global baseline data sets and climate data records (CDRs) that are used for monitoring, evaluation, analyses, and assessments of climate variation and change on global and regional scales. Examples of these data sets include the Global Historical Climatology Network (GHCN), the United States Historical Climatology Network (USHCN), the Comprehensive Ocean-Atmosphere Data Set (COADS), the Comprehensive Aerological Reference Data Set (CARDS), and the Monthly Climate Data of the World (MCDW).

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

#### **SUPPORTING RESEARCH**

**NOAA Scientific Stewardship Program.** This program provides an

approach to the challenges of maximizing the performance, quality, and utility of climate observing systems, data, and information. Five fundamental principles provide the framework for this program: (1) Ensure Observing System Quality during the design phase and real time monitoring of performance; (2) Develop an end-to end Climate Processing System that includes the timely ingest, QC/QA processing, immediate access to new and long-term access to historical records, and the long-term safeguarding of the climate records for future generations; (3) Provide Basic Information Technology (IT) Support; (4) Document Earth System Variability through monitoring and evaluation of present, future, and past observations; and (5) Enable and Facilitate Future Research through periodic analysis and assessment of new and historical records (Figure 3-DOC-13). The employment of Scientific Stewardship

principles will ensure the "scientific integrity and long term utility" of climate records for a broad range of users.

Digital Access and Retrieval of Data and Information. Significant progress has been made to digitally ingest data in near real time and make these data available to users within hours instead of days or weeks from on-line disk and robotic tape storage systems. Improved access to the next Generation Internet (NGI) high-speed communication capabilities have accelerated the amount of data delivered directly from the field to the NCDC at the time or soon after the time near the time of observation. Data are now available from 10 to 400 times faster than ever before. One example of a very successful NWS/NESDIS/NCDC collaboration is the real time direct digital ingest and access to NEXRAD (WSR-88D) Level II data through NGI connections with 61 NWS sites and the POES and GOES satellite data. New and historical data are now accessible digitally by users from on-line disk and robotic tape storage systems. By the end of

CY 2004, 121 NWS NEXRAD sites will send Level II data in real time to the NCDC. The NCDC also receives on a daily basis the NEXRAD Level III data digitally from a NWS Central Collection facility.

Digital Health of the Network Monitoring (Observing System Performance Indicators) The Scientific Services Division has operationally implemented near real time Network Monitoring (Figure 3-DOC-14). The purpose of the Network Monitoring process is to improve the quality of new observations and the fidelity of the historical archives by providing real-time information on the health and status of NOAA's observing networks. The fully developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network. Anomalies and systematic performance problems are evaluated and reported to the network manager. The outcome will be improved observing system performance and higher quality data records.

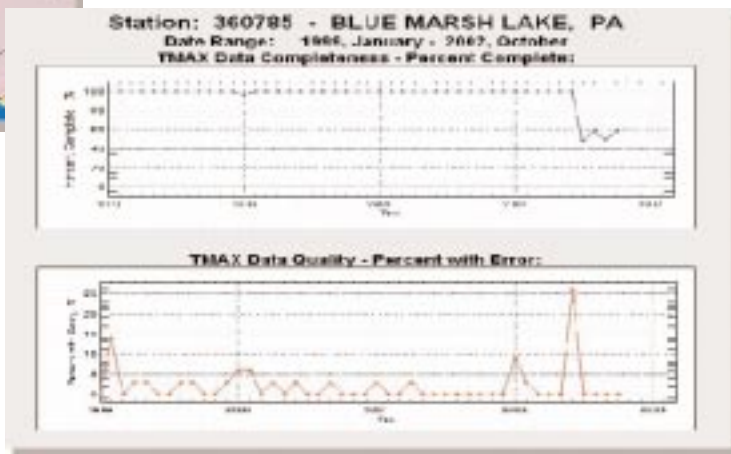
into the historical archives and associated data bases. The COOP Observing Network is regularly monitored and the plan is to add other networks, such as ASOS, Upper Air, etc. The USCRN program has a more rigorous operational daily monitoring system of hourly performance.

Assessments and Reports. A series of regular reports are released regarding several key climate issues of concern to the Nation. For example, the NCDC releases a monthly and annual *State of the Climate* for the U.S. and the *North American Drought Monitoring Report* (Figure 3-DOC-15) which is a collaborative effort between Canada, Mexico, and the U.S. The NCDC has established a new division, Remote Sensing and Applications Division (RSAD). The purpose of the RSAD is to capitalize on the identification and blending of key parameters from satellite and radar observing systems. These currently underutilized jewels of data and information will be also blended with in-situ observations to create a new generation of quality Climate Data Records (CDRs). Understanding and knowledge, as well as new products and services for research and practical economic and environmental uses, will be derived from this progressive approach to maximizing the true value of observations.

U.S. Climate Reference Network (USCRN). The Ten Climate Monitoring Principles described in the

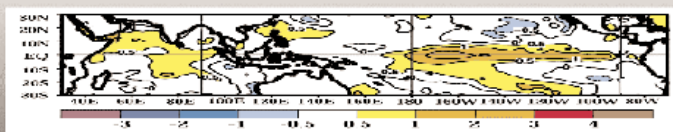


Figure 3-DOC-14. A network monitoring system provides Real-time information on the health and status of NOAA's observing networks.





# State of the Climate Report for 2002



National Climatic Data Center  
"World's Largest Archive of Weather Data"

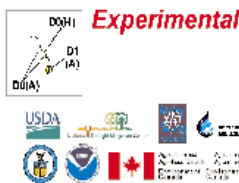
## North American Drought Monitor

March 2003

Released: Wednesday April 16, 2003

Analysts:  
Canada - Chester Schmitt  
Tad O'Brien  
Mexico - Miguel Cortez  
U.S.A. - Chester Schmitt  
Douglas LeComte  
Reprinted from project: <http://www.drought.gov>

Drought Severity  
 D1 (Anomaly) D1  
 D1 Drought - Moderate  
 D2 Drought - Severe  
 D3 Drought - Extreme  
 D4 Drought - Exceptional  
 Delineates dominant line peaks  
 A - Agriculture  
 H - Hydrological/Soil  
 H type = 40% impact



Experimental

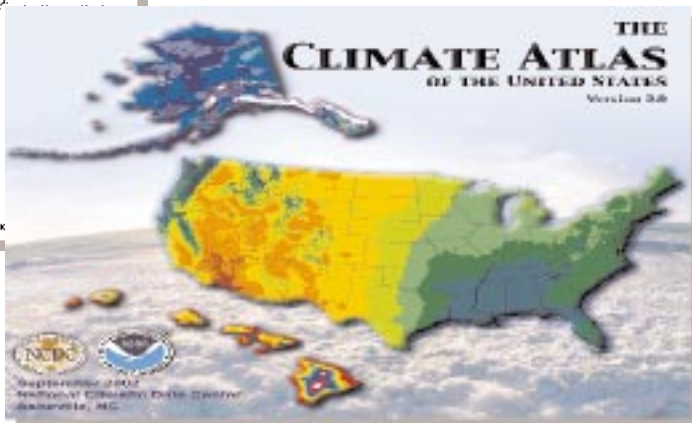
<http://www.drought.gov>

National Research Council (NRC) Report, Adequacy of Climate Observing Systems (1999), are being used to guide the design, deployment, and life cycle management of the U.S. Climate Reference Network (USCRN). The USCRN is the first U.S. observing system built with the primary purpose of providing climate quality measurements. The fully deployed network of ~ 298 stations will be able to explain at least to the 95 percent level the variance in surface air temperature and precipitation on the national and regional scales. The USCRN climate quality observations avoid the time dependent biases typically experienced with other surface observing networks. The USCRN will be the Nation's Benchmark Network providing a standard to which satellite, weather radar, and other surface systems (e.g., ASOS, COOP, mesonets, etc.) observations can be validated and verified. In essence, the USCRN will provide the means to enhance the quality and confidence in other observations, as well as contribute to rehabilitating existing histor-

ical databases and data sets. This will produce a significant increase in the volume of climate quality data and information that can be used in assessing past climate trends and change, as well as contribute to the present and future climate monitoring, evaluation, and forecast tasks. (See [www.ncdc.noaa.gov/crn.html](http://www.ncdc.noaa.gov/crn.html))

NOAA Operational Model Archive and Distribution System (NOMADS). NOMADS is a collaborative approach to provide access and data analysis capabilities for model and other data. The NCDC, in partnership with the National Centers for Environmental Prediction (NCEP) and the Geophysical Fluid Dynamics Laboratory (GFDL), initiated this project to address a growing need for remote access to high volume Global Climate Model (GCM) and Numerical Weather Prediction (NWP) model data.

Figure 3-DOC-15. NCDC releases a monthly and annual *State of the Climate for the U.S.* and the *North American Drought Monitoring Report* which is a collaborative effort between Canada, Mexico, and the U.S.



The NOMADS team has partnered with existing and development activities including CLASS, National Oceanographic Partnership Program's (NOPP), National Virtual Ocean Data System (NVODS), the Department of Energy's Earth System Grid, and the Thematic Realtime Environmental Data Distributed Services (THREDDS) developed through the National Science Foundation. NOMADS is a pilot project that uses a distributed client-server framework of data servers together with emerging technologies to access data stored in heterogeneous formats at geographically distributed repositories. NOMADS provides, for the first time, long-term stewardship of numerical and climate model runs and provides the regional modeling com-



---

munity with the data necessary to initialize local models. NOMADS will also provide the tools necessary to inter-compare model and observational data sets from around the world. Currently there are nine working NOMADS systems across the nation serving data in the distributed framework. (See [www.ncdc.noaa.gov/oa/model/model-resources.html](http://www.ncdc.noaa.gov/oa/model/model-resources.html))

Climate Database Modernization Program (CDMP) Digital databases of wind speed and direction, precipitation, temperature, and pressure are far more useful than paper and microfilm records. These databases support many disciplines, including economic research, engineering, risk management, and passive (solar, wind) energy enterprises. The Climate Database Modernization Program (CDMP) addresses access and utilization issues. The Program's goal is to make non-digital (paper/film) historical climate data digitally accessible and retrievable on-line via the Internet/WWW. The conversion of paper and microfilm records to digital databases and data sets will provide access to either optically scanned images of records or data manually keyed into digital data bases. Many of these records are being merged with the more recent digital databases extending the digitally accessible and retrievable time series to many decades, as well as hundreds of years in some cases. Forty million documents have been imaged and many thousands of observations manually keyed or digitized from the merchant and military ship records, America's military forts, U.S. cities, lighthouses, weather ships, and other sources. However, approximately two thirds of the paper and film-based climate data remain to be digitized. The CDMP provides an unprecedented and

unique opportunity to "rescue" valuable climate data dating back into the 1700s that are in jeopardy of permanent loss due to the deterioration of the paper and microfilm media. A CDMP web site will become available in FY 2004. The CDMP work will take years to complete.

NOAA Paleoclimatology Program. (Reassigned from the NGDC to the NCDC in FY 2003.) Paleoclimatic data is an important segment of documenting and reconstructing annual to century scale records leading to climate records dating back 10s and 100s of millennia. The incorporation of this program into the functions and activities of the NCDC will enhance the identification and understanding of climate change and variation. The NCDC Paleoclimatology Branch cooperates with many countries in research projects that combine the global paleoclimate database with the instrumental record to extend the climate record back in time for climate model verification and climate change studies. Objectives of the program are to cooperate with researchers in academia, NOAA and other agencies and to conduct original research to describe the global patterns of annual-to-millennial scale climate change, to understand the causes of climate change, to separate man-induced climate change from natural variability, and to validate the models that are used to predict future climates. (See [www.ncdc.noaa.gov/paleo/paleo.html](http://www.ncdc.noaa.gov/paleo/paleo.html))

Comprehensive Large Array-data Stewardship System (CLASS). The CLASS project has been underway since November 2001. CLASS is the NOAA implementation program for an improved architecture for archiving and servicing large-volume data. Advances in technology, including faster network access, web-based interfaces, and emerging discovery and

analysis tools, will provide a one-stop capability to access the NOAA large array data sets. The CLASS objective is to establish a web-enabled browse, order, and retrieval delivery system that will enhance and increase the availability and accessibility of satellite, radar, and other data and derived products to customers worldwide. The CLASS integrated storage and web-based access and servicing system design incorporates many of the features and capabilities of the current Satellite Active Archive (SAA) system built for the POES data stored on a robotic system located in Suitland, Maryland. The CLASS baseline calls for the establishment of two mirrored systems at Asheville, North Carolina and Washington, District of Columbia. CLASS data and product enhancements will be implemented in phases called campaigns. The major campaigns planned includes GOES, POES, NEXt generation weather RADAR (NEXRAD), NPOESS Preparatory Program (NPP), National Polar-orbiting Operational Environmental Satellite System (NPOESS), Earth Observing System (EOS) Long Term Archive (LTA) and the European Meteorological Operational Satellite (METOP) Program. The first new data campaign will be the GOES data and is expected to be on-line during the first quarter of FY 2004.

#### NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) ([www.nodc.noaa.gov](http://www.nodc.noaa.gov)) manages the world's largest collection of publicly available oceanographic data. NODC holdings include in situ and remotely-sensed physical, chemical, and biological oceanographic data from coastal and deep ocean areas. NODC customers reuse this data to answer questions about climate, and ocean and coastal phenomena.

Specifically, NODC data archive and access responsibilities support climate research and operational ocean observing system activities as follows:

- NODC performs ocean profile data management for internationally coordinated global ocean observing systems such as the Argo Ocean Profiling Network and the Global Temperature-Salinity Profile Program (GTSP) in cooperation with applicable JCOMM committees. NODC's objectives are (1) to safeguard versions of the Argo and GTSP near real-time and retrospective data and information and (2) to provide high quality data to a wide variety of users in a timely and useful manner. The Argo and GTSP data system present an excellent opportunity to improve ocean and climate forecasting, with consequent benefits for the protection of life and property and effective planning for the effects of seasonal to inter-annual climate variability.
- NODC produces regular updates of the World Ocean Data Base and World Ocean Atlas. The most recent version, 2001, includes over seven million profiles of scientifically quality controlled ocean temperature, salinity, oxygen, plankton, pigment, and nutrient data. The Atlas presents statistics and objectively analyzed fields for one-degree and five-degree squares generated from World Ocean Database 2001, observed and standard level flagged data. The ocean variables included in the atlas are: in-situ temperature, salinity, dissolved oxygen, apparent oxygen utilization, percent oxygen saturation, dissolved inorganic nutrients (phosphate, nitrate, and silicate), chlorophyll at standard depth levels, and plankton biomass sampled from 0 - 200 meters depth. Further information on both products are available at: [www.nodc.noaa.gov/OC5/indprod.html](http://www.nodc.noaa.gov/OC5/indprod.html).

[www.nodc.noaa.gov/OC5/indprod.html](http://www.nodc.noaa.gov/OC5/indprod.html).

- The NOAA Marine Environmental Buoy Database (<http://www.nodc.noaa.gov/BUOY/buoy.html>) is one of the largest and most frequently used data archives maintained by the NODC. This database holds wind, wave, and other marine data collected by the NOAA National Data Buoy Center (NDBC) from moored buoys and C-MAN (Coastal-Marine Automated Network) stations. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature.
- NODC is developing a capability to provide public access to consistently-processed, climate-capable satellite datasets and applying them to various scientific problems. The first products provided in 2003 were Pathfinder reprocessed 9 km and 4 km sea surface temperatures. For further information see [www.nodc.noaa.gov/sog/](http://www.nodc.noaa.gov/sog/).

#### NOAA/NODC LIBRARY

NODC houses the NOAA Central Library ([www.lib.noaa.gov/](http://www.lib.noaa.gov/)) which supports weather and climate research programs by providing a variety of information services, including:

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

umes of meteorological data publications in danger of loss.

#### NATIONAL GEOPHYSICAL DATA CENTER

The National Geophysical Data Center (NGDC) ([www.ngdc.noaa.gov](http://www.ngdc.noaa.gov)) builds and maintains long-term archives of scientific data, with a special emphasis on scientific stewardship of data acquired by NOAA observing systems. Data holdings include bathymetry, solar, geophysical, space environment, and earth observing satellite data. The Center plays an integral role in the Nation's research into the environment, and at the same time provides public domain data to a wide group of users. The Center works closely with contributors of scientific data to prepare documented, reliable data sets, currently numbering more than 300 digital and analog databases. The Data Center continually develops data management programs that reflect the changing world of geophysics. NGDC also operates World Data Centers (WDC) for Solar-Terrestrial Physics, Marine Geology and Geophysics, Solid Earth Geophysics, and, in conjunction with the National Snow and Ice Data Center at the University of Colorado, the WDC for Glaciology, Boulder. These are operated under the auspices of the International Council of Scientific Unions. The secretariat for the Scientific Committee for Solar-Terrestrial Physics is located at NGDC. NGDC conducts research in satellite remote sensing and space weather.

NGDC provides data and scientific stewardship for the archives including data processing, access, management, archive, analysis, and research for databases collected on satellites and by ground-based observatories. Space environment data collected on GOES and POES satellites are archived at NGDC. Space environmental, meteorological and oceanographic data collected on DMSP satellites are archived

by the Solar-Terrestrial Physics Division. Data collected by ground-based observatories used in NOAA's space weather forecasts, warnings and alerts are managed at NGDC. The National Snow and Ice Data Center, which is affiliated with NGDC through the University of Colorado's Cooperative Institute for Research Environmental Sciences, manages cryospheric data from both ground-based and satellite instruments.

New technology presents new opportunities and challenges for NOAA's National Data Centers (NNDCs). WWW-based applications provide improved and more timely services that include data discovery, on-line catalogs and inventories, interactive data display, data mining, and data delivery. As a result, the number of users has increased dramatically. Since most of the new users are less familiar with the data than the research community, additional burdens are placed on the NNDC's to assure that data and products are provided in a display that is easy to understand and in a format that is easy to use. At the same time, new applications are under development, which increase the need for research quality data.

The DMSP Program at NGDC prepares research quality data from the raw data records recorded by scientific instruments on operational satellites for retrospective analysis and the official archive. Data sets include visible, infrared and microwave imagery, microwave soundings and in situ measurements of the space environment. The official archive is used to prepare data products, derive geophysical parameters including atmospheric and ionospheric principal components, and conduct research. New user services are provided through the Space Physics Interactive Data Resource ([www.ngdc.noaa.gov/dmsp](http://www.ngdc.noaa.gov/dmsp)).

The Space Weather program at NGDC prepares research quality data of the near-Earth space environment

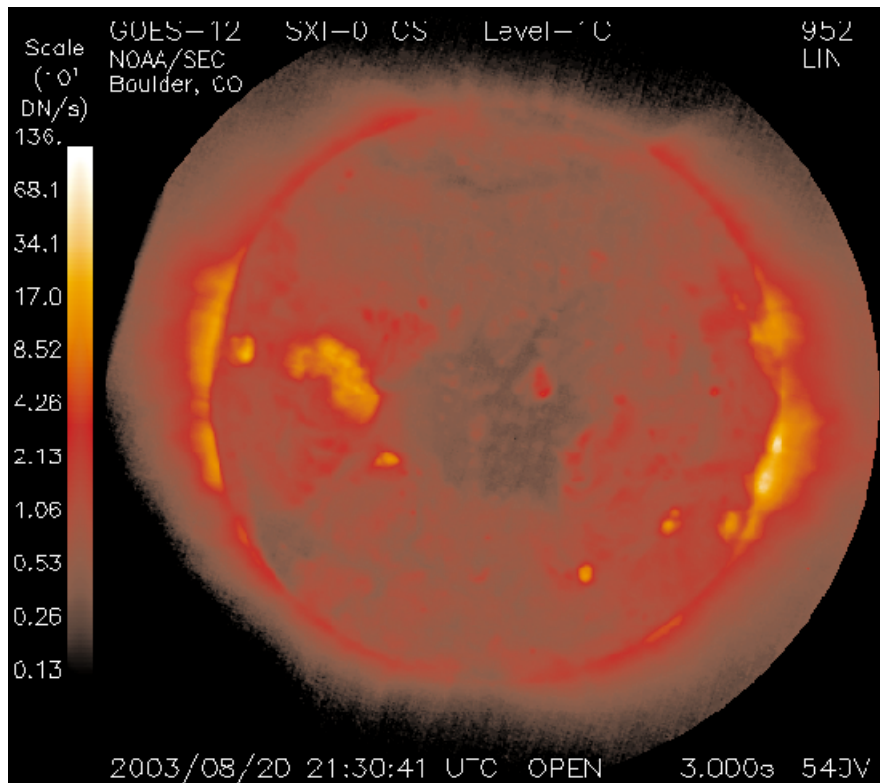


Figure 3-DOC-16. SXI generates three types of images whose exposure settings are optimized to observe coronal structures, active regions, and flares. This is a coronal structures image generated at 21:30 UTC on August 20, 2003.

for retrospective analysis and the official archive. GOES, DMSP, and POES satellites carry instruments that monitor the space environment; for example, the SEM instruments on GOES and POES and the SSIES, SSJ/4 and SSM instruments on DMSP. The successful launch of DMSP F-16 will greatly enhance the ionospheric data archives. Other data sets in the space weather archives include measurements of solar activity, solar flares, magnetic activity, magnetic storms, ionospheric parameters, and ionospheric storms collected by NOAA and other agencies. The STP program at NGDC archives measurements of total solar and solar spectral irradiance for use in climate studies ([www.ngdc.noaa.gov/stp/stp.html](http://www.ngdc.noaa.gov/stp/stp.html)).

The major new activity was the successful operation of the Solar X-ray Imager on GOES-12. The Solar X-ray Imager (SXI) is now operational. Images are generated each minute

(Figure 3-DOC-16) and are instantly made available via NGDC's website. Movies are generated every five minute that give a real-time look at current activity. Historical images and movies are also available for study on the website.

The National Snow and Ice Data Center (NSIDC) at the University of Colorado is associated with NGDC and maintains a catalog of cryospheric data sets of interest to meteorology and climatology. These include an on-line and analog collection of historical photographs of glaciers; temperature, pressure and position data from drifting stations in the central Arctic pack ice; ice thickness data from submarines; and data from operational sea ice chart digitizing projects. NSIDC acquires historical snow cover, meteorological, and sea ice records from the former Soviet Union. In addition to housing a NOAA collection of cryospheric data, NSIDC provides data management



services for a variety of cryospheric research programs sponsored by NASA and NSF. For example, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites. NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available at: [www.nsidc.colorado.edu](http://www.nsidc.colorado.edu).

## SUPPORTING RESEARCH

Environmental Remote Sensing. Operational meteorological satellite imagery provides a unique opportunity to monitor wildfires and population dynamics on a global basis, and sometimes nightly. The DMSP nighttime imagery are used to locate sources of visible and infrared emissions including city lights, lightning, wildfires, flaring gas, and boats. Research projects use the city lights to infer such diverse parameters as population density, economic vitality, and carbon dioxide emissions. More information is available at: [www.ngdc.noaa.gov/stp/stp.html](http://www.ngdc.noaa.gov/stp/stp.html).

Wildfires Monitored from Space. Operational meteorological satellite systems offer a unique opportunity to monitor wildfires because each satellite records nighttime visible emissions covering the entire globe each day. Instruments designed to detect clouds also "see" wildfires--many of which burn in very remote areas. NGDC has developed a unique capability to capture the nighttime emissions from both large and small wildfires. The system has been used to assist firefighters in developing countries. More information is available at: [www.ngdc.noaa.gov/dmsp/fires/globalfires.html](http://www.ngdc.noaa.gov/dmsp/fires/globalfires.html).

Detection of Change. NGDC has released version one of a pair of DMSP-OLS "nighttime lights of the

world" images processed specifically for the detection of change, covering the years 1992-93 and 2000. The images can be downloaded from: [dmsp.ngdc.noaa.gov/html/download.html](http://dmsp.ngdc.noaa.gov/html/download.html) (look under New Products). NGDC began work on methods and algorithms for producing high quality nighttime lights for use in change detection in early 2001. The digital OLS archive extends to mid-1992 but has numerous gaps in the first year. Images from 1992 and 1993 data were combined for the early product. The OLS detects lights from human settlements, fires, gas flares, and heavily lit boats (primarily squid fishing boats). The four types of lights have separated, based on location, brightness/persistence, and visual appearance. In addition to these four global cloud free products NGDC also provides key intermediate products: number of valid coverages, number of cloud free coverages, number of cloud free light detections, and the average DN of the cloud free light detections. However, the saturation of the visible band in the bright cores of urban centers remains a problem. This is a characteristic of the operational OLS data, which forms the bulk of the archive. It is difficult using OLS alone to adequately separate gas flares from human settlements. NGDC is investigating the use of persistent MODIS fire detections as a guide for locating gas flares in the OLS data. Likewise, the separation of city lights and fires is not entirely clean in some parts of the world with extensive fires. Another problem noted in the current product set is the effect of snow on the extent and brightness of the lights, which can be found in the northern hemisphere above ~40 degrees latitude. A good place to look for the effects of snow is in the Great Lakes region of the USA. NGDC plans to reprocess the products in the next several months using an improved cloud detection algorithm and screen for

snow using DMSP SSMI data. Preliminary cloud-free snow-free product sets indicate that snow effect problems will be reduced in the next release of the products.

NGDC also plans to process the entire digital OLS time series into annual nighttime lights composites and develop a cross calibration (when observed by multiple OLS sensors) for OLS nighttime data currently archived. The products contain a number of interesting phenomena that result from the expansion (and contraction) or lighting. The nighttime lights change image of Florida (Figure 3-DOC-17) is produced from the released data.

Space Weather The Space Weather program at NGDC conducts original research in space physics with an emphasis on space weather and climate applications. Research focused on numerical modeling of the ionosphere and magnetosphere is conducted with resident and visiting scientists from the United States and other countries. Research projects use the extensive integrated data bases archived at NGDC. In addition to building better models and improving our understanding of ionospheric and magnetospheric plasma processes, the research leads to improved data sets and new data products. NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch a numerical simulation of the atmospheric and space environment. More information is available at [www.ngdc.noaa.gov/stp/stp.html](http://www.ngdc.noaa.gov/stp/stp.html).

NGDC is leading a data-driven modeling project to build the first space climatology. The project, titled the Space Weather Reanalysis, is designed similarly to the NCEP/NCAR re-analysis project, and will construct the distribution of particles and electromagnetic fields in the near-Earth space environment over an 22 year period of time (two solar cycles).

Cryospheric Research at NSIDC research interests cover a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on arctic regions and satellite-born instruments. Their projects study the long-term record of snow and ice in the arctic and

mountainous regions, with a current emphasis on the response of the cryosphere to changes in large-scale atmospheric circulation patterns,. Algorithms to detect snow, frozen ground and sea ice in passive microwave images from DMSP and NASA satellites have been developed at NSIDC researchers have

developed models that describe the physical and mechanical properties of snow and ice in glaciers and avalanches.

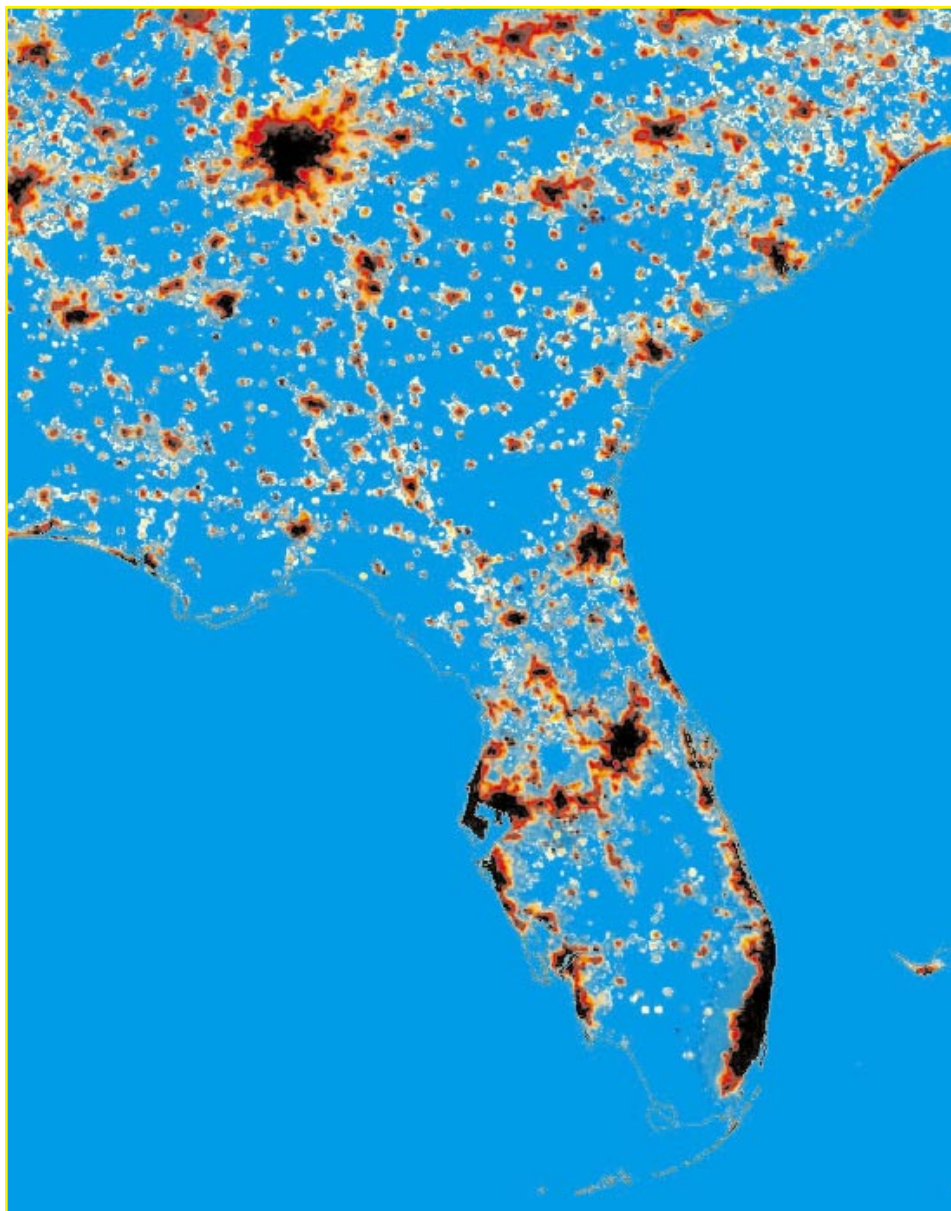


Figure 3-DOC-17. Nighttime lights change image of Florida

- Cyan = No lights and offshore (land / sea mask applied).
- Black = Bright lights detected in both time periods (at or near saturation).
- Red = Lights much brighter in 2000.
- Yellow = New lights in 2000.
- Light gray = Dim lighting detected in both time periods - little change in brightness.
- Blue = Lights dimmer or missing in 2000 (relative to 1992-93).





**OCEANIC AND ATMOSPHERIC RESEARCH LABORATORIES**

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various National Oceanic and Atmospheric (NOAA) meteorological, oceanographic, and space science missions. The activities of OAR laboratories are oriented toward providing the scientific and engineering understanding, tools, and techniques that form the basis of improved national weather and climate services.

Special emphasis is placed on improving severe weather 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. The key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall" (HaL) focus of the United States Weather Research Program (USWRP). They include more accurate prediction of track, intensity, surface winds, rainfall, and human impacts. Improving flood forecasts fall under the component of USWRP labeled "Improving Quantitative Precipitation Forecasting." In pursuit of improved utilization and dissemination of data, the OAR laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector. In addition, OAR labs conduct research to improve routine weather forecasts and improve the ability to forecast regional air quality and atmospheric deposition.

A significant focus of OAR in the weather and air quality area is the development of operational testbeds under the auspices of the USWRP. These testbeds are the mechanism

through which research is transitioned to operations. It is recognized by the USWRP that since NOAA is one of the forecast mission agencies in the program, and the program goals are predominantly operational ones, its most significant role in the USWRP is to provide the infrastructure and capabilities to efficiently and effectively test research products in an operational environment. The testbeds are the Joint Hurricane Testbed, the Mesoscale Numerical Weather Prediction Testbed, and the Joint Center for Satellite Data Assimilation. These testbeds are operated in partnership with other USWRP agencies. OAR's role is to provide directed research and operational testing, in partnership with the National Weather Service (NWS). In addition, the development of the Weather Research and Forecasting (WRF) modeling architecture, also under the auspices of the USWRP, will provide a common modeling structure to be shared by most of the testbeds and between the research and operations communities. Several OAR laboratories are involved in the WRF development in partnership with the NWS and other USWRP agencies.

Observing Technology

Two OAR laboratories in Boulder, Colorado, and one in Norman, Oklahoma, are heavily involved with developing new environmental observing system technologies.

The Environmental Technology Laboratory (ETL) in Boulder, Colorado, develops and evaluates new remote-sensing concepts and systems. This development and the associated environmental research directly support the Nation's forecasting and warning services.

The Forecast Systems Laboratory (FSL) in Boulder, Colorado, takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers

these technologies to NOAA operations and the private sector.

The National Severe Storms Laboratory (NSSL), located in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS.

FSL is investigating the use of super-pressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, lightweight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University and with launches near the Oregon coast. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle, and the instrument package was successfully recovered after descent by parachute.

In a related balloon development effort, the Idaho Falls Division of the Air Resources Laboratory (ARL) is refining its constant-level "smart" balloon, 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. The Idaho Falls group is also active in the development of high wind speed sensors, such as those used on aircraft and for studies of hurricanes. A specialized probe to measure turbulence during hurricanes is now

nearing completion, as a joint project with the Oak Ridge Division of ARL. The Oak Ridge group 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.

ETL and FSL 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, ETL has recently added a 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.

ETL scientists, in conjunction with the National Aeronautics and Space Administration (NASA), are also investigating the potential of a new observational platform featuring Unmanned Aerial Vehicles, or UAVs. The concept is to deploy specialized cameras called hyperspectral imagers on these remote-controlled, solar-powered aircraft. Recent developments indicate that UAV's will eventually be capable of flying indefinitely at altitudes exceeding 50,000 feet, higher than most weather events, but much lower than satellites, making them ideal observational platforms. Dubbed "Peacewing," ETL scientists envision many potential applications of this technology. Images from UAV-mounted cameras can be used to enhance satellite images of severe storms such as hurricanes. This platform can also be used to monitor the health of coral

reefs. It can also be flown over land to assess moisture content of soil and vegetation, both of which are indicators of drought and fire susceptibility. Peacewing is a perfect complement to satellite-borne sensors and ground based systems (Figure 3-DOC-18).

ETL has demonstrated that tornadoes



Figure 3-DOC-18. ETL envisions "Peacewings" becoming part of NOAA's observational platforms for severe storms and hurricanes.

can be detected well before touchdown by listening for their unique infrasonic signatures. Infrasonic antennas located in the central United States have been used to detect and locate numerous tornadoes. Verification has been provided by Doppler radar and visual sightings. This research effort is continuing and it is proposed that a network of these inexpensive infrasonic systems be deployed at WSR-88D sites to enhance early detection capability.

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

ETL continues development of lidars and infrared Doppler multi-frequency

radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multi-frequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes. In particular, ETL has demonstrated the potential application of Cold War-era over-the-horizon (OTH) surveillance radars for the large-scale mapping of ocean surface currents and winds. ETL is developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds.

The discussion of observing technologies would be incomplete without mention of the North American Atmospheric Observing System (NAOS) Program. The overriding purpose of NAOS is to make recommendations on the configuration of the upper air observing system over North America and adjacent water areas. Government organizations and universities in Canada, Mexico, and the United States support NAOS. About 15 agencies from these countries have representatives on the NAOS Council, which identifies issues, sets priorities, coordinates the work of the program, and seeks financial support. Eventually, the council will advise governments on how to:

- (1) improve the utility of existing observing systems and reduce costs,
- (2) design a cost-effective observing system for the 21st Century, and
- (3) evolve toward that system from the present one.

OAR representatives serve on the NAOS council and its two principal working groups.

The NSSL is known for its development of observational capability, both

---

remote and in situ, and in particular for its role in the development of the WSR-88D NEXRAD radar. NSSL is presently working 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. 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 first step in the processing is to prototype a new Radar Data Acquisition (RDA) unit for the WSR-88D capable of processing the additional information to produce the dual polarization information. In March 2002, dual polarized data were collected using the NSSL WSR-88D research radar located on the NSSL Norman, Oklahoma campus. NSSL is assisting the NWS with the next step, the development of a generalized dual-polarization solution for their network of WSR-88D radars.

#### Tropical Atmospheric Research

The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long-term study of tropical circulation and its impact on global climate. The Trans-

Pacific Profiler Network consists of an array of wind profilers that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50-MHz wind profilers, the network is incorporating 915-MHz lower tropospheric wind profilers developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will: (1) provide valuable improvements to the boundary layer and convective parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change. Routine wind observations are made at Christmas Island using 50-MHz and 915-MHz profilers. Lower tropospheric wind measurements using 915-MHz profilers are made at San Cristobal, Ecuador; and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua, New Guinea, at sites collocated with the Atmospheric Radiation CART Sites (ARCS) maintained by the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) program. The wind data are assimilated into the analyses and forecast models of NOAA's National Centers for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasting (ECMWF), and other meteorological centers. The data are also used by climate researchers to support investigations of the variability of tropical cir-

ulation systems. A recent focus of research with profilers has been to provide ground validation research in support of the NASA Tropical Rainfall Measuring Mission (TRMM). Profiler observations were made by AL during several TRMM Ground Validation Field Campaigns in 1998 and 1999. These observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during these campaigns. The profiler observations have been made available to the TRMM Science Team and can be viewed on the AL web page ([www.al.noaa.gov](http://www.al.noaa.gov)). The observations made during the field campaigns are the subject of collaborative research with other TRMM researchers with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team. One profiler is being maintained for TRMM at Legan, Kwajalein to obtain a longer term perspective on the structure of precipitating clouds and the variability of drop size distributions in oceanic precipitation. Validation of drop-size distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite data.

#### Severe Weather Analysis and Forecasting Research

The National Severe Storms Laboratory focuses on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. NSSL's research includes assessment



and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, with a focus on research and development, for the NWS WSR-88D radar program. In 2003, NSSL continued to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public. Knowledge gained from the Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX) campaigns in the mid- and late-1990's, 1998's Mesoscale Convective System (MCS) Electrification and Polarimetric Radar Study (MeaPRS) and the 2000 Intermountain Precipitation Experiment (IPEX) provided new understanding of severe thunderstorms, storm electrification, winter weather, and tornadoes and lead to improved methods to detect, model, and predict these storms (Figure 3-DOC-19).

NSSL works closely with the NWS WSR-88D Radar Operations Center (ROC). NSSL's involvement with the project to re-host the Radar Product Generator to an open systems computation platform (ORPG) was completed in November 2001. The ORPG system will ease the incorporation of new software applications and allow for integration of new hardware technology into the radar system resulting in less time needed for technology transfer. The NWS's ORPG deployment for 170 total radar sites, both operational and non-operational, began August 2001 and ran through 2002.

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. FSL develops and evaluates state-of-the-art workstations for forecast office environments. Specifically, FSL 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. By maintaining state-of-the-art capability for use in research and development of operational techniques, it continues to provide a mechanism to evaluate weather service requirements for AWIPS.

FSL 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); 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 which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. The system has been incorporated into the

AWIPS system and is being used by a number of other agencies, not only for various regions of the United States, but for a number of regions throughout the world.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. 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.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the Seattle NWS Forecast Office, the National Center for Atmospheric Research (NCAR), and the University of Washington. Support for the program is also being provided by the Office of Naval Research. This research improves understanding of the effects of prominent terrain on West Coast weather, with the ultimate goal of providing improved forecasts

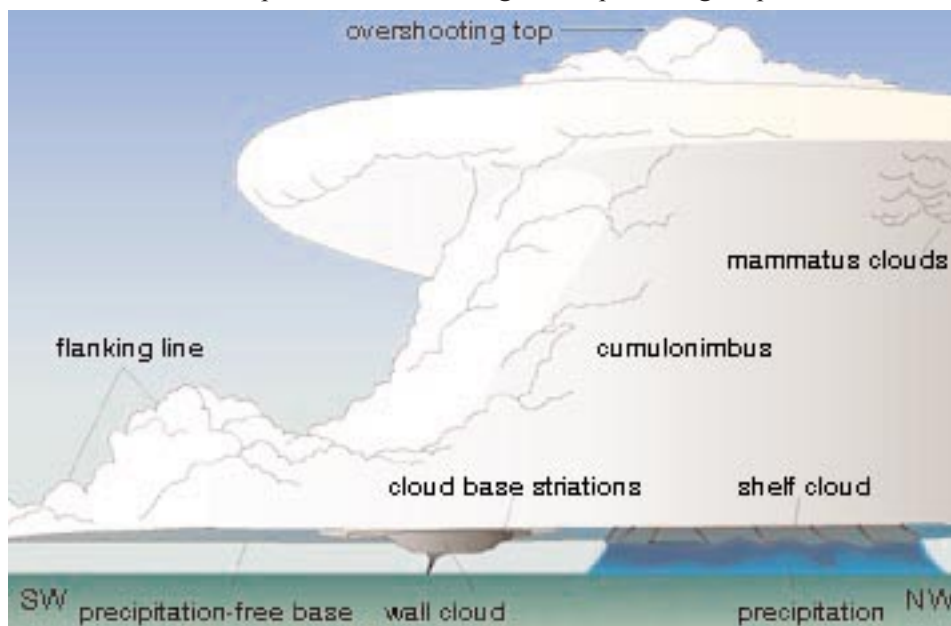


Figure 3-DOC-19. Schematic diagram of a thunderstorm

(Source: NSSL's VORTEX Project web site)

of coastal winds, precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in the 1990s, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low pressure system. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. Follow-up field programs in FY 2001 and FY 2002 focused on cloud and precipitation processes using special observations from research aircraft and land-based radars. The results are providing information on how to improve forecasts of Northwest weather.

#### Mesometeorology and Precipitation Forecasting and Warning Research

NSSL develops techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Experiments such as MeaPRS in 1998 and the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000 were conducted to improve the science behind the technology. MeaPRS was specifically designed to investigate mesoscale convective systems electrification processes and ways to enhance understanding of polarimetric radar measurements in preparation for possibly upgrading the NWS radars in the future. STEPS was

designed to improve our understanding of how severe storms become electrified and to better understand how variations in lightning flash type and flash rate relate to severe storm classification and storm evolution. Other studies underway are focused on the precipitation structure of mesoscale convective systems, the interactions between mesosconvective 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.

NSSL will continue to investigate various model convective parameterization schemes, along with techniques to improve model initialization through four-dimensional data assimilation in 2002. Also in 2002, NSSL conducted an experiment called the International H<sub>2</sub>O Project (IHOP). IHOP was a field experiment over the Southern Great Plains (SGP) of the United States. The chief aim of the 2002 IHOP campaign is improved characterization of the four-dimensional (4-D) distribution of water vapor and its application toward improving the understanding and prediction of convection. The SGP region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active convection.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve the nation's ability to forecast severe weather and to enhance severe winter weather guidance products. Data collected during the IPEX campaign held in 2001 should help. The data are being analyzed by NSSL, SPC and University of Utah scientists. The IPEX field and research program was designed to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain. Data analysis of IPEX continues in 2004.

Mesoscale Dynamics at the Geophysical Fluid Dynamics

Laboratory (GFDL) in Princeton, New Jersey, develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. (Figure 3-DOC-20).

The FSL implemented a Rapid Update Cycle (RUC) at NCEP ten years ago, in 1994. The RUC gave a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in April 2002. This new version operates at 20-km horizontal resolution with 50 vertical levels and provides updates every hour, thus, incorporating information from virtually all high frequency data sources: hourly wind profiles; WSR-88D (Doppler radar) velocity azimuth displays; ACARS reports (up to 65,000 per day); cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites; and surface observations. The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface.

Along with NCAR, NCEP, and the university community, FSL is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal is to have the WRF model

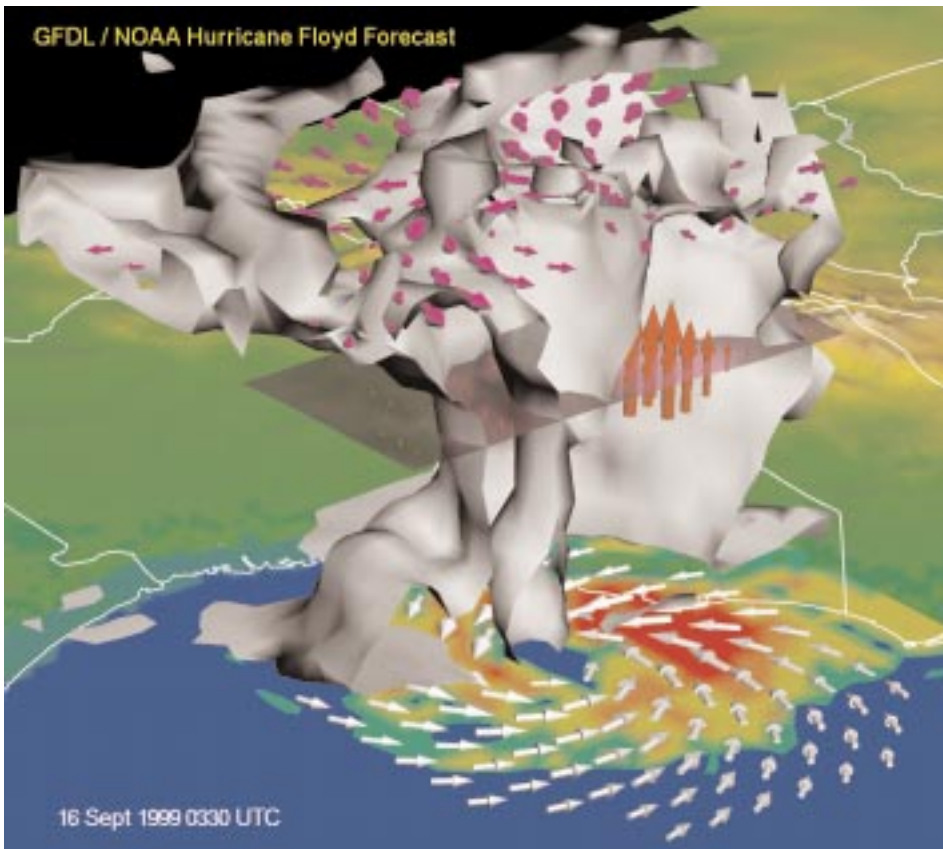


Figure 3-DOC-20. GFDL's 3-D model depiction of Hurricane Floyd

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.

The Air Resources Laboratory (ARL) is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. To this end, ARL maintains the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as the Eta model) and satellite outputs. ARL conducts research on the

surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos and industrial enterprises. In recent work, ARL is developing a new system for forecasting the dispersion of smoke from forest fires, in collaboration with the Association of South East Asian Nations and their Regional Haze Action Plan.

#### Hurricane Analysis and Prediction Research

The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide range of meteorological quantities, including standard flight-level data; precipitation charac-

teristics; remotely-sensed surface winds; vertical soundings; ocean thermal structure; radar reflectivity; and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especially of surface winds. It also carries out modeling and theoretical studies closely tied to the observational program and studies interannual and inter-decadal changes in hurricane activity.

The Gulfstream IV (G-IV) jet, also operated by AOC, has been used successfully in the hurricane environment since 1997. The G-IV extends the envelope of observations throughout the depth of the troposphere. Use of these aircraft presents an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are hurricanes' inner core, the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion, and the kinematics and thermodynamics of the near-surface boundary layer. The GPS-based dropsondes procured as the G-IV's main scientific payload play a vital role in these investigations because of their high vertical resolution and superior thermodynamic and wind sensing capability. The 1998 season constituted the first major field program for HaL carried out in collaboration with NASA's Third Convection and Moisture Experiment (CAMEX-3). The success of this campaign combined with follow-on missions in later years was unprecedented. NOAA and NASA aircraft flew a combined total of more than 100 scientific sorties in 1998 and 1999. Participation by the G-IV and NASA's DC-8 and ER-2 provided extensive in situ observations above the middle troposphere for the first time since the 1960s. In addition to airborne measurements, university teams with instrumented towers, mobile Doppler radars, and portable profilers coordinated with



HRD to obtain detailed measurements of near-surface conditions in most hurricanes that passed onshore during these seasons.

The motivation for acquisition of the G-IV was a statistically rigorous demonstration, based upon more than a decade of experiments with the P-3s, that intensive observations of the flows surrounding hurricanes can produce substantial (16-30 percent) reductions in track forecast errors. Data from multiple-aircraft experiments involving the G-IV and WP-3Ds should confirm the G-IV's ability to improve forecasts. Adaptive targeting of aircraft observations to regions where they will do the most good is a strategy to realize even further improvement.

The forecast system currently has limited skill in prediction of intensity. Through continuing research with the expanded aircraft fleet, the Nation can realize large (billions of dollars per year) economic benefits through more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically-based, skillful intensity forecasts. Because hurricanes inflict huge costs on the United States economy, even incremental improvements in forecasts have large benefit to expenditure ratios. The report on HaL by the USWRP Prospectus Development Team 5 (PDT5) contains a comprehensive, focused scientific strategy to realize these benefits (*BAMS*, 79, 305-323).

In addition to HRD research activities, OAR scientists carry out hurricane research at GFDL. GFDL's Hurricane Dynamics group performs hurricane modeling research to study the genesis, development, and decay of tropical storms using multi-nested three-dimensional computer models of the hurricane system and its surrounding environment.

In the early 1990's, this research model proved so successful for simulation of observed storm behavior that

the NWS adopted a version of it for use in operational forecasting. From the 1995 through the 1999 hurricane seasons, the GFDL Hurricane Prediction System provided the most accurate hurricane-track forecast guidance available and contributed substantially to the dramatic error reductions in official forecasts that have occurred since its introduction.

Under the USWRP and its participating agencies, OAR, NWS, and NESDIS established a Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida. It is anticipated that the JHT will continue to grow in FY 2004 as more resources become available. This testbed is where the hurricane research will be evaluated for operational use and those research products passing the test will be handed off to operations.

#### Numerical Analysis and Prediction Modeling

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Experimental Prediction, Mesoscale Dynamics, and Hurricane Dynamics (described above).

Experimental Prediction at GFDL develops and improves numerical models of the atmosphere-ocean-land system in order to produce useful weather forecasts with lead-times ranging from weeks to seasons and beyond. The group is pursuing several avenues of research to achieve such improvements. First, GFDL scientists are investigating methods of stochastic dynamic prediction in order to extract as much forecast information as possible from numerical prediction models, given imperfectly observed initial conditions. In addition, laboratory scientists are developing methods for the

assimilation of ocean observations into prediction models in order to improve the forecast of the atmosphere and the ocean.

#### Air Quality Research

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

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards. The 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. The 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, and specializes in the development of high-technology airborne instrumentation (for both aircraft and balloons). The Special Operations and Research Division (SORD), in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. SORD also serves as the main NOAA facility working with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA) of the University of Nevada system.

Air quality forecasting is a major theme of ARL research. Over the last several years, ARL has made ozone forecasts available to interested researchers, via the web, with focus mainly on the area surrounding the Great Smoky Mountains. In this area, ozone exceedances are reported with increasing frequency, and forecasts of ozone levels are being requested by federal and state agencies alike. The ARL effort in this regard is targeted through its East Tennessee Ozone Study (ETOS), which has been a focus for regional air quality attention for the last three years. In future years, it is planned to develop air quality forecast capabilities using the supercomputing center of the University of Nevada at Las Vegas, through the formal linkage with the CIASTA.

ARL operates 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-run 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. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing an air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

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 disper-

sion 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 Engineering and Environment Laboratory. ATL 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.

The Aeronomy Laboratory coordinates an air quality research effort-- the Health of the Atmosphere research. 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. AL, ARL, the Climate Monitoring and Diagnostics Laboratory (CMDL), FSL, and ETL participate in the research. The Health of the Atmosphere research goals are:

- Characterize regional ozone

episodes: Characterize the origin of ozone in rural areas, where crop and forest damage are of increasing concern. In 2000, a comprehensive air quality field experiment took place in the region around Houston Texas. This experiment was designed to investigate the complex chemical and meteorological factors that influence the air quality of that coastal region. The regional chemistry is of special interest because of the presence of large natural as well as anthropogenic sources of hydrocarbons (including the petrochemical industry) and because of the unique influence of coastal meteorology on air quality of the region.

- Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the 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.

In future Health of the Atmosphere research, the OAR Laboratories will integrate their meteorological, chemical, and forecasting expertise to build 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, a large fraction of the variation in those levels is driven by meteorology, both in the short term and longer term. Therefore, the key to assessing both the intended long-term improvements in air quality and the more-episodic

variations lies in understanding not only the atmospheric linkages between emissions and concentrations, but also in understanding the coupled chemical and meteorological processes. This "chemical meteorology" research will extend the current program focus on emissions/concentration linkages to include a predictive understanding of the role of synoptic, seasonal/interannual, and longer-term meteorological/climatological changes on the chemistry of the lower atmosphere. 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.

The Air Quality Research Subcommittee of the Committee on Environment and Natural Resources (CENR) will provide the interagency collaboration at the United States federal level. 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. NOAA is the public sector co-chair of NARSTO.

ETL uses its 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. ETL participated in field programs in FY 2002 designed to develop a deeper understanding of climate variability and source pollutants in the New England region (Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMAP) and NEPS, and to investigate the composition of air masses along the Pacific coast of North America as part of the Intercontinental

Transport and Chemical Transformation (ITCT) program. ITCT is a coordinated international research program designed to address the question, "How does the transport of chemicals from one continent influence the air quality in other continents, as well as regional and global climate?" ETL will be deploying a number of lidar systems and wind profiler radars in support of these programs.

#### SPACE ENVIRONMENT SERVICES AND THE SPACE ENVIRONMENT CENTER

NOAA and the Air Force jointly operate the National Space Weather Operations (SWO) group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. The SEC, working closely with the Air Force Weather Agency (AFWA), provides forecasts, alerts, indices, and summaries of disturbances occurring on the Sun, in space, in the geomagnetic environment, and in the upper atmosphere. The services are used by DoD, DOE, NASA, Department of Transportation (DOT), Department of Commerce (DOC), Department of Interior (DOI), the National Science Foundation (NSF), commercial users, and the research community to:

- Optimize the operation of technical systems that are adversely affected by disturbances in the space environment;
- Protect astronauts from harmful radiation; and
- Carry out research in the solar-terrestrial environment.

Examples of the adverse effects include loss or reduced efficiency of communication systems, radiation hazards to personnel and systems in high altitude aircraft and in space, degradation of surveillance and monitoring systems for defense, errors in navigation systems, perturbations of satellite orbits, and disruptions in power distribution networks. The United States Air Force operates a space weather



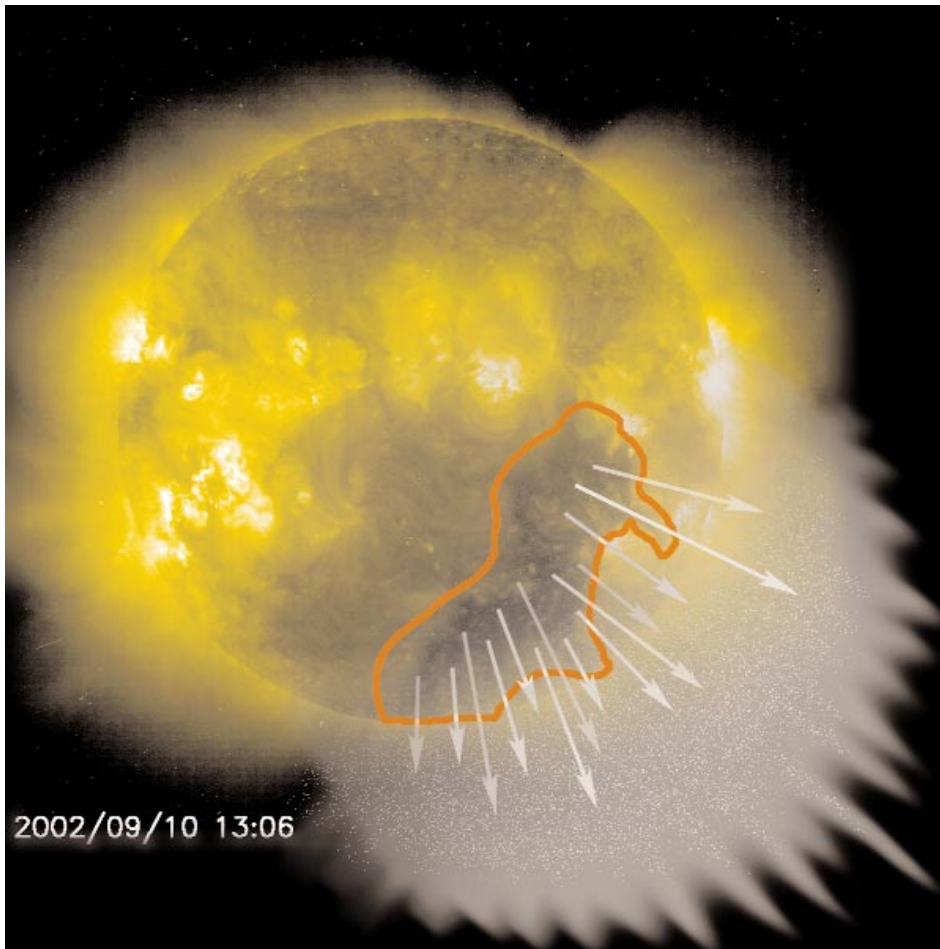


Figure 3-DOC-21. Coronal holes appear as dark areas of the corona when viewed in ultraviolet light. This large hole area seen here on 10 September 2002 had a direct impact on Earth. Coronal holes are often the source of strong solar wind gusts that carry solar particles into space. This one spewed a large stream of charged particles out to our magnetosphere and beyond. Solar wind streams take 2-3 days to travel from the Sun to Earth, so it probably originated from the Sun about 9 September. On September 11, the solar wind was erratic but definitely increased in velocity and density. Spaceweather.com reported that a moderate geomagnetic storm from the solar wind stream triggered aurora 11 September that were visible from the higher latitudes on Earth.

The magnetic field lines in a coronal hole extend out into the solar wind rather than coming back down to the Sun's surface as they do in other parts of the Sun. Although they are usually located near the poles of the Sun, coronal holes can occur other places as well.

(SOHO web site: [soho.nascom.nasa.gov/pickoftheweek/old/12sep2002/index.html](http://soho.nascom.nasa.gov/pickoftheweek/old/12sep2002/index.html))

operations center at AFWA to provide space weather support, including products from the SWO group, to DoD assets. The AFWA operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman Air

Force Base, New Mexico. The AFWA's space weather operations group at Offutt Air Force Base, Nebraska, shares space weather data and support responsibilities with its civilian counterpart at SEC.

SEC serves as the international World Warning Agency for the

International Space Environment Service (ISES) (Figure 3-DOC-21). It exchanges international data- solar wind, X-ray, sunspot, corona, magnetic, and ionospheric measurements--in real-time and, from these data, provides and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use. There is also a substantial and rapidly growing customer base in the private sector.

SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DoD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, in situ magnetic field, and plasma data from the Space Environment Monitor (SEM) on GOES and the polar-orbiting NOAA satellites. Data are collected, stored, and displayed for analysis and products and distributed to outside customers primarily via the Internet ([www.sec.noaa.gov](http://www.sec.noaa.gov)), by NOAA Weather Wire, and digital data links (primarily operated by other agencies). Radio broadcast, mail, and recorded telephone messages are available to users as well.

Research and development at SEC emphasizes understanding of the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes are manifest in the climatology and disturbances of Earth's magnetic field, the ionosphere, the charged particle populations at satellite orbits, and the atmospheric density at high altitudes (including low-Earth orbit). SEC research is focused on areas where advanced applications can be devel-

---

oped and prototyped to improve space weather services, whereby the Nation is served through alerts and warnings of those conditions that can be often hazardous to technological systems in space and on the ground, and human activities in space.

Solar Terrestrial Models and Theory: SEC work is also devoted to research of Earth's space environment and the application of this research to space weather operations. The staff has expertise spanning from solar physics to Earth's upper atmosphere, and maintains close collaborations throughout the research community. They publish regularly in scientific journals, and work directly with the SEC SWO group and the Systems Division to develop state-of-the-art capabilities for the NOAA/SEC forecast center.

Solar Terrestrial Instrumentation and Data: The group ensures that space environment data are processed, validated, interpreted, and disseminated in an efficient, effective, and timely fashion. The group develops analysis tools for working with data from a variety of spacecraft, including the NOAA geosynchronous and polar orbiters, and spacecraft in the solar wind. Data access is provided through customized data-analysis routines and individualized displays. In addition to enhancing the utility and value of the primary data through research and analysis, the group explores sources of new data and improved monitoring to support.

Solar Influences and Imaging: SEC conducts research into understanding processes on the Sun and the effects of solar activity on the near-Earth space environment. The group leads in the development of techniques to process and interpret both ground-based and space-based solar imagery, and has special expertise in solar X-ray imaging. To support space weather operations, the staff examines both short and long-term solar influences on human activities in space and on the ground.

Satellites: Developing space moni-

toring instrument specifications, receiving and validating data from these instruments, analyzing and presenting data, and archiving data in the National Geophysical Data Center (NGDC) are all aspects with which the SEC is involved. The SEM instruments on the GOES and the Polar-orbiting Operational Environment Satellite (POES) are among SEC's major responsibilities. The SEM suite on POES includes energetic particle monitors and Solar Backscatter UltraViolet (SBUV) instrument. The SEM instruments on GOES include magnetometers, energetic particle monitors, and solar x-ray intensity measurements. In addition, SEC cooperate with other agency satellite missions to provide real-time space weather information. These include the NASA missions: WIND, ACE, and IMAGE. SEC always emphasizes improvement of space weather observations.

Solar X-Ray Imager: A Solar X-ray Imager (SXI) telescope was launched in 2001, checked out, and put in on-orbit storage aboard the GOES-12 satellite, which became operational in April 2003. The SXI provides images of the solar atmosphere on time scales of an image every minute. The SXI telescope, based on recent research instruments flown on American and Japanese satellites, enables observations of the three-dimensional structure of solar disturbances as they develop and propagate in the solar atmosphere. The new instrument will fill an important gap in the ability to model and predict space weather disturbances as they propagate from the Sun to Earth. First level integration of the SXI data into space weather operations was completed early in FY 2002; so all was in readiness to integrate SXI data into operations when they first became available.

GOES NO/PQ satellites: SEC will be completing full implementation of

the ingest, processing, analysis, and distribution of data from the new instruments that allow measurements of the environment immediately surrounding the satellite. The measurements, of low energy but dense radiation, will improve the capability to specify conditions that can interrupt or disable satellite operations. The use of models being developed in the research community and evaluated for operational use in SEC will allow the new measurements to be extrapolated throughout near-earth space. With the combination of new measurements and models, the environment can be specified at any location for the hundreds of satellites in geosynchronous orbit around Earth.

Expanded use of the NOAA Space Weather Scales and New Products: Use of the NOAA scales for classifying space weather disturbances continued to increase through FY 2003. Several new alert categories have been developed and implemented to make use of the scales in response to users who find the scales offer more useable information than previous, often overly technical alerts.

SEC has proposed and implemented additional space weather products, including new alerts and graphical products; these have been assigned World Meteorological Organization (WMO) codes to facilitate the SEC program to integrate space weather products into the NOAA suite of weather services. This continues a series of implementations of space weather products into the NOAA Family of Services.

New products describing the location and intensity of the energy put into the atmosphere by the aurora were put in place in FY 2001; this effort has continued, using data from the POES.

SEC will participate directly in interagency programs directed at improving our understanding of the space environment. These include the Living With a Star Program (a NASA program), and three



cooperative campaigns covering the Sun, Earth's magnetic field, and the ionosphere.

Use of Global Positioning System (GPS) to measure the ionosphere: SEC, in cooperation with FSL and with support from the DoD, will continue to develop a capability to measure the ionosphere, including its electron content and height, through use of the DoD Global Positioning System (GPS). By recording thousands of GPS signals each day and using data assimilation techniques that allow the measurements to be reversed, the ionosphere can be mapped, and predicted, in greater detail than with current measurement systems.

VOLUNTARY OBSERVING SHIP (VOS) PROGRAM: OAR operates a global VOS program that provides real-time meteorological and oceanographic data from selected vessels. Data are collected with the Shipboard Environmental Data Acquisition System, which transmits the information to NOAA via the GOES system. The information is then disseminated nationally and internationally using existing data networks. Presently,

there are over 120 vessels in the program which record and transmit surface meteorological information four times per day at synoptic hours. Of these vessels, about 60 vessels are also equipped to collect expendable bathythermograph data.

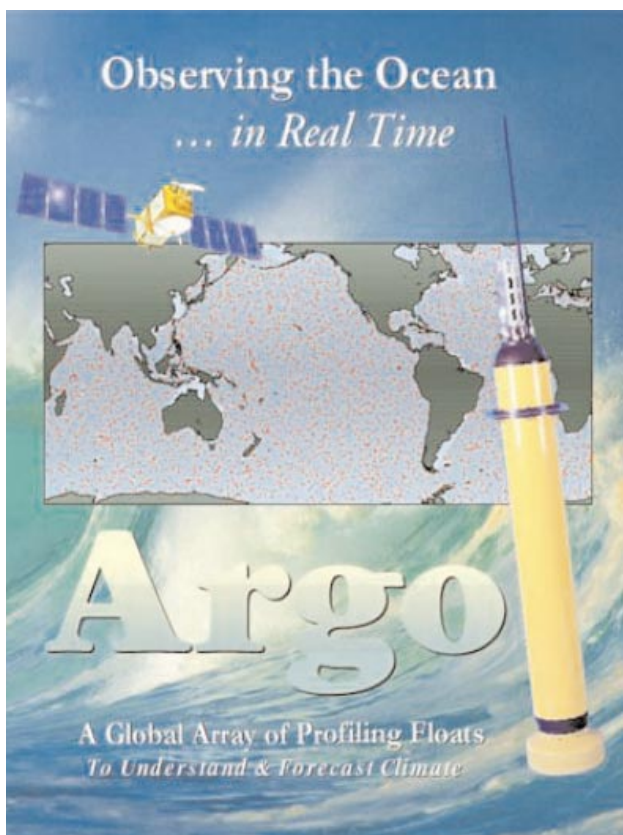
Southern Hemisphere Drifting Buoy Program. In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, the Office of Global Programs (OGP; housed within OAR), AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological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

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 Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported primarily by the United States (NOAA) and Japan (JAMSTEC) with contributions from France

(IRD) and Taiwan (NTU). The mooring array is operated and maintained by the TAO Project Office located at PMEL in Seattle, Washington, which has responsibility for project management, operations and logistics. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe.

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, inter-annual and longer time scales. It consists of an array of 12 ATLAS moorings similar to those deployed in the Pacific.

Global Drifter Program. AOML manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700. Using research ships, VOS, and United States Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified 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 to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys





---

provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

ARGO--Global Array of Profiling Floats--will deploy a global array of 3,000 profiling floats to better understand and forecast climate. ARGO floats will be "parked" at 1,000 meters depth and will profile the water column from the surface to 2,000 meters

depth. Observations will be made in real-time. Along with satellites, ARGO will initiate the oceanic equivalent of today's operational observing system for the global atmosphere.

NOAA Ship RONALD H. BROWN. NOAA recently installed and deployed a 5-cm Doppler precipitation radar to conduct studies of atmospheric processes over the ocean (Figure 3-DOC-22). The system has been shown to not only be effective for studying convective processes but also

processes associated with marine stratus clouds. In August-October of 2000, ETL installed and tested a novel phased array, electronically stabilized radar for measuring wind profiles above the ocean. This profiler has been used to monitor winds in several upcoming field experiments (e.g., EPIC 2001, PACS 2001, AIRMAP 2002).



Figure 3-DOC-22. NOAA Research Vessel Ronald H. Brown.







agement through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g. winds, barometric pressure, and visibility, needed and requested by the mariner to navigate safely. Highway and railroad bridge mounted "Air Gap" sensors for water level detection are presently being developed and are included in future plans for PORTS®.

The 10 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's existing installations is comprised of over 26 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments, i.e. winds, barometric pressure, etc. (Figure 3-DOC-23). Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS® provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur. An extensible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart

Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

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 last year and will be followed by a Houston/Galveston Bay nowcast/forecast model in 2004. Also, ongoing research will enable PORTS® or similar systems to incorporate biological and chemical sensor systems and forecast models as required and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management and homeland security.

The NOS Continuous Real-Time Monitoring System (CORMS). CORMS was designed to operate on a 24hour/7 days a week basis to ensure the accuracy 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-24).



Figure 3-DOC-24. PORTS sites in the New York and New Jersey linked by CORMS.

## OFFICE OF NOAA CORPS OPERATIONS AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) provides aircraft support to many NOAA missions, several of them associated with the Natural Disaster Reduction Initiative (NDRI). In particular, AOC operates a fleet of aircraft to support NOAA's research and development programs to improve weather, marine, and climate services (Figure 3-DOC-25). AOC provides three large aircraft for hurricane reconnaissance and surveillance support to NOAA's National Hurricane/Tropical Prediction Center (NHC/TPC), as well as flight services to other federal agencies and international programs approved by NOAA's Aircraft Allocation Council. AOC's light aircraft and helicopters provide hydrologic data for soil moisture forecasts, aerial photography and remote sensing for nautical and aeronautical charting, and living marine resources surveys.

AOC was established in October 1983, through a consolidation of all existing NOAA organizations and elements operating NOAA aircraft. This consolidation was accomplished to achieve a more efficient, more economical, and safer operation of NOAA aircraft. Fourteen aircraft, located throughout the United States, are managed by AOC from its home base at MacDill AFB in Tampa, Florida.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, are supported by two WP-3D Lockheed Orion aircraft which carry a full array of state-of-the-art environmental research instrumentation. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. 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 provided storm data to the NHC in near real time, transmitting flight level data, dropwindsonde messages, as well as radar images via its aircraft-satellite data link. The AOC aircraft also augmented the Air Force Reserve reconnaissance aircraft during particularly active storm periods when tasking requirements exceed their available resources.

AOC has integrated into its operations a high-altitude jet, the G-IV, which is used for hurricane surveillance. This aircraft flies in the environment surrounding hurricanes at altitudes up to 45,000 feet. The G-IV dispenses GPS dropwindsondes and transmits the resulting profiles of thermodynamic and wind information to the National Center for Environmental Prediction (NCEP) and the NHC for



inclusion into their computer prediction models. Recent estimates of the improvement in hurricane track predictions is between 20 and 30 percent, and these improvements have resulted in savings of \$10 million or more per hurricane in warning and preparedness costs. With its high-altitude capability, the G-IV is the central focus for additional research leading to improvements in hurricane intensity forecasts. The G-IV aircraft is also beginning to



Figure 3-DOC-25. NOAA AOC WP-3D Lockheed Orion and G-IV aircraft.

be used for air chemistry studies and other research in the upper troposphere.

Land falling hurricanes, a major subject of the United States Weather Research Program and NDRI, receive particular attention from AOC aircraft. During the 2002 hurricane season, the G-IV and WP-3D aircraft flew a combined total of nearly 350 surveillance, reconnaissance, and research hours on tropical storms including those that made or nearly made landfall in the continental United States. AOC's two P-3's conducted three major research experiments during the hurricane season in support of the Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division (HRD), the University of Miami's Rosenstiel School for Marine and Atmospheric Sciences (RSMAS), and the National Environmental Satellite, Data and Information Service (NESDIS). Both WP-3D's participated in a study of the impact of ocean heat content on hurricane intensity for HRD and RSMAS and collected a phenomenal data set on two major hurricanes, Isidore and Lili.

NOAA 42, carrying a suite of scatterometer instruments developed by the University of Massachusetts, conducted an Ocean Winds Experiment collecting data on ocean surface winds in high wind, high precipitation condi-

tions to calibrate and validate similar sensors located aboard NOAA satellites. In support of this project, NOAA 42 flew a number of missions into Hurricane Gustav, Tropical Storm Hana, Hurricane Isidore and Hurricane Lili. Data sets for a wide range of wind speeds, up to almost 150 kts, and for rain rates up to in excess of 40 mm/hour were obtained during this program.

During the hurricane season NOAA 43, in support of HRD and RSMAS, commenced the first year of a three-year program in support of the Office of Naval Research's high wind

Hurricane Isidore and Lili.

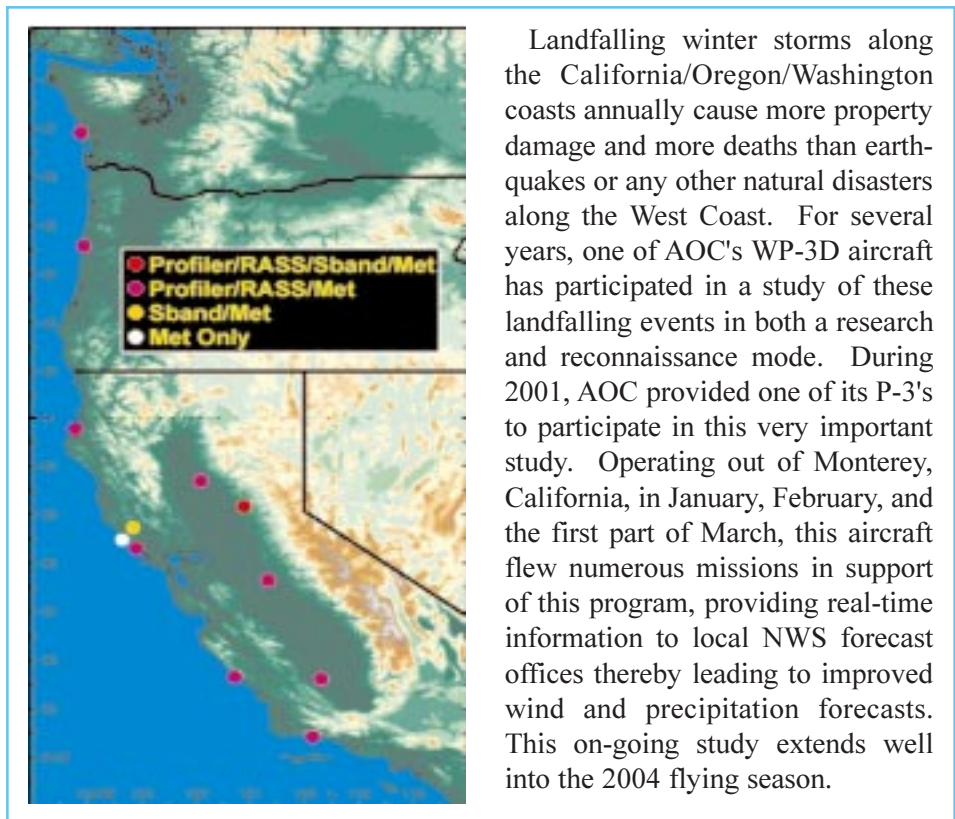
The Synoptic Ocean/Atmosphere Measurements endeavor was a major research project with the long-term goal of understanding the upper ocean's role in hurricane intensity changes. This project, which involved examining variability of the ocean's heat content caused by vertical current shear and advection of horizontal currents using expendable bathythermographs (AXBT), current probes (AXCP) and CTD probes, achieved a major success during the 2002 hurricane season as a world class data set was obtained on both Hurricane

experiments, Improvement of Microphysical PaRAMeterization through Observational Verification Experiment (IMPROVE), will be used to guide the design of cloud and precipitation microphysical parameterizations for the WRF numerical weather prediction (NWP) model now under development. The WRF is anticipated to become the principal NOAA/NCEP model for short-term forecasting. The aircraft also successfully completed two joint experiments, Ocean Winds Winter for NESDIS and a continuation of the ongoing Pacific Land-falling Jet Experiment (PACJET), from a base in Portland, OR in January and February 2002.

In April 2003, a completely reconfigured NOAA 42 participated in the International Transport and Chemical Transformation (ITCT) experiment for NOAA's Aeronomy Laboratory, operating from Monterey Peninsula airport in Monterey, California. During this experiment, the scientists aboard this flying chemistry laboratory investigated how the emission, chemical processing, and removal of compounds of anthropogenic origin influenced the regional budgets of ozone and fine particles, and to what extent North America is affected by upwind pollution sources whose emissions are transported by the prevailing winds across the Pacific to the U.S. west coast.

NOAA 43 spent the balance of 2003 undergoing depot level maintenance at the Naval Air Station in Jacksonville, Florida. Following its return to AOC and reinstallation of equipment, it participated in the annual Hurricane Awareness Tour, this year along the Gulf Coast.

NOAA 49, AOC's high altitude G-IV, had a busy winter season flying numerous winter storm missions for NCEP from Honolulu International Airport in Hawaii in January and February. During this period, the aircraft also flew several missions in sup-



Landfalling winter storms along the California/Oregon/Washington coasts annually cause more property damage and more deaths than earthquakes or any other natural disasters along the West Coast. For several years, one of AOC's WP-3D aircraft has participated in a study of these landfalling events in both a research and reconnaissance mode. During 2001, AOC provided one of its P-3's to participate in this very important study. Operating out of Monterey, California, in January, February, and the first part of March, this aircraft flew numerous missions in support of this program, providing real-time information to local NWS forecast offices thereby leading to improved wind and precipitation forecasts. This on-going study extends well into the 2004 flying season.

Coupled Boundary Layer Air Sea Transfer Experiment (CBLAST) Experiment and the Synoptic Ocean/Atmosphere Measurements project. The first year's effort for CBLAST was aimed at perfecting both the instrumentation to be used in the project as well as operational flight strategies to obtain measurements in the hurricane boundary layer. The CBLAST objectives were successfully accomplished on missions into both

Isidore and Hurricane Lili. Data obtained in the latter storm may be of great significance in determining why Lili went from a Category 4 storm to a Category 1 storm in 24 hours.

Outside of the hurricane season NOAA 42 had a very active year engaging in four additional research experiments flown out of Seattle, Washington, Portland, Oregon and Monterey, California. The observations made during the first of these



port of an FAA-sponsored clear air turbulence project. The data obtained from dropwindsondes and aircraft sensors will be used to improve forecasts of potential commercial aircraft turbulent events in the jetstream region over the North Pacific.

The AOC Shrike Commander N51RF and Turbo Commander N53RF aircraft flew 514 hours in support of the Snow Survey Program during 2002. Each aircraft is loaded with the world's premier gamma radiation spectrometers, enabling the aircraft to measure the very low levels of naturally occurring gamma radiation. This naturally occurring radiation is emitted from trace elements of potassium, uranium and thorium radioisotopes in the upper 20cm of soil. Water mass in the snow cover blocks the terrestrial radiation signal. The deeper the snow, the weaker the signal picked up by the sensors. Consequently, analysts can use

the difference between airborne radiation measurements made over bare ground and snow-covered ground to calculate an equivalent value with an error of less than one cm. Water equivalent snow measurements are invaluable to the hydrologists of NOAA's NWS, who use the data to estimate snow melt runoff and provide early warnings of potential flooding. Agencies within the state governments, the Environment Canada, and the United States Army Corps of Engineers also use the data as a water resource management tool, estimating reservoir recharge and predicting river flow rates into various bodies of water, such as like the Great Lake.

AOC's Twin Otter, N48RF was used in the BRACE (Bay Region Atmospheric Chemistry Experiment) project flown in the Tampa Bay region of Florida. Atmospheric forms of nitrogen and other pollutants were

sampled in-flight via state-of-the-art scientific instruments, while seven ground sites measured in-situ simultaneously. The high levels of nitrates and ammonia in the Florida coastal waters have been recognized as a serious problem, causing a decline in the native sea grasses which support the rest of the ecosystem. Marine aquatic life such as shrimp, fish, crabs and manatee depend on adequate levels of sea grass for their existence. Airborne measurements give the researchers advantages by directly reading the pollutants exiting from exhaust stacks, in addition to the dispersed values obtained at the ground sites. Inorganic compounds such as ozone, carbon monoxide and sulfur dioxide were also measured.



Hurricane Isadore's feeder bands. (AOC Photo)