Demonstrating the Socioeconomic Benefits of Improved Hurricane Forecasting.

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Earth Science Applied to Southern United States Disaster Management

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Abstract

In the last decade, the states along the Atlantic coast have been battered with a large number of hurricanes. From 1994 to 2003, forty-eight hurricanes, tropical depressions, and storms, hit Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Maryland, Delaware, New Jersey, Rhode Island, Massachusetts, Pennsylvania, New York, Vermont, New Hampshire, Maine, Arkansas, Kentucky, Tennessee, Ohio, Oklahoma, and West Virginia. Among these states the ones that have had the most severe damage are the southern coastal states.

Every year millions of dollars are spent on hurricane preparedness and post hurricane damages. With improved forecasting, the potential to reduce hurricane expenses has greatly increased. Due to the frequency of severe storms along the southern Atlantic coastline, local policy makers, including Governor Warner of Virginia, have expressed significant interest in improved weather modeling capabilities. In response to this need, NASA is currently investigating ways to enhance weather prediction. More accurate and reliable predictions can be made with NASA resources, which will lead to increased community readiness and response. This will ultimately save lives as well as money. There is evidence that the implementation and integration of the advanced technologies available from FEMA, NOAA, and NASA such as HAZUS®-MH, CAMEX, WAVEWATCH, and the Afternoon Satellite Constellation will allow scientists to better understand hurricane behavior. This in turn has the potential to help local governments reduce pre-hurricane costs and may also alleviate post-hurricane costs.

Introduction

After the devastating effects of Hurricane Isabel in September of 2003, the states affected came to the understanding that there was a correlation between improved hurricane forecasting and socioeconomic benefits. Thousands of people experienced power losses, damage to their property, and psychological trauma. More accurate hurricane predictions can be made with NASA's assistance, thus enhancing hurricane preparedness by increasing community awareness. In order to accomplish this, it is necessary to understand how hurricanes form as well as their characteristics in order to better predict hurricane forecasting.

The Atlantic Hurricane Season is June 1 through November 30. The water temperature must be 80°F for the development of a hurricane. The west coast of Africa, near the Cape Verde Islands, produces tropical waves every few days and spurns the formation of tropical storms. The conditions for the augmentation of a tropical storm include a pre-existing weather disturbance, warm ocean water, atmospheric moisture, and relatively light upper level winds. When these conditions are prevalent then the storm begins to strengthen. As the storm intensifies, the water vapor raises quickly causing violent seas and storm surges.

Each year an average of ten storms develop over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Typically, six of the ten storms develop into hurricanes. In an average three-year period, approximately five storms strike the United States coastline, and two of the five are considered major natural disasters. In the last decade the states along, and near the Atlantic coast have been battered with forty-eight storms.

When a hurricane is projected to hit your city, how do you know whether or not you should evacuate? When a major hurricane is heading toward shore, the emergency preparedness staff gathers to decide how, when, and where to evacuate residents who are in the projected path of the storm. Depending on the location, an effective evacuation requires a significant amount of lead-time because all representatives from impacted counties, neighboring states, and the Red Cross, must coordinate the process. The Florida Keys and areas around New Orleans require up to seventy-two hours notice, and points along the coast of South Carolina require up to thirty-six hours.

Primary information received by the public are bulletins issued by the National Hurricane Center. Information arrives every three hours on a hurricane's position, and every six hours on its intensity. Forecasters rely on satellites, such as the Geostationary Operational Environmental Satellite (GOES) built by NASA and operated by NOAA, which provides timely water vapor and temperature measurements. With data on position, air temperatures, water vapor content, wind speeds, and the barometric pressure of the storm system, mathematical models are able to forecast the movements and changes in the strength of a hurricane. The National Hurricane Center then depends on the state and county managers to take the forecasts and tailor them to community needs.

In September of 1999, when hurricane Floyd hit North Carolina, not only were coastal regions greatly damaged, but also, inland regions received much unexpected flooding. Along with the hundreds of millions of dollars worth of damage on homes, businesses, and other properties, many of which were uninsured, thousands of people were evacuated, and fifty-two lives were lost.

To be better prepared for the next hurricane North Carolina has joined with the Federal Emergency Management Agency (FEMA). The state began a statewide effort to update all floodplain maps. To better prepare for future storms, precise elevation data must be acquired. The state decided on using airplanes with remote sensing technology mounted on them. These sensors are called LIDAR, Light Detection and Ranging. The data can be collected and processed quickly and accurately; vertical accuracy up to twenty centimeters. The elevation data provided by LIDAR can be combined with soil type and land cover data. The resulting data provides information for detailed flood mapping and flood forecast modeling. When a storm is coming, the visual predictive tools, which are available online for easy to use accessing, convince statewide residents that they are at high risk for flood damage. The LIDAR enhanced maps are a huge improvement with floodplain maps. These maps replaced ten-year old maps. North Carolina is collecting data in phases throughout 2001 and 2003.

Emergency managers are concerned about making the right decisions when it comes to hurricanes and public safety. When mandatory evacuations are ordered the public responds well. When evacuations are recommended however, fewer people respond. Due to these community reactions improved hurricane forecasting is needed; it is a nightmare to not evacuate and find that you should have.

The direct impact of improved hurricane forecasting clearly lies in reducing the extent of the coastal area ordered to evacuate. According to the United States Weather Research Program, the rough estimate of evacuating one mile of populated coastline is one million dollars. However, there is little impact at the local level because policies are already in place and there would be no last minute changes allowed. Insurers do suspend writing of homeowner policies whenever an area is under a hurricane warning. So the area suspended is contingent upon where the warning is posted. There could be a larger impact on the planning by specific insurers in mobilizing claims adjusters and pre-positioning resources to help respond to the event. There may also be a larger impact on re-insurance (the insurance that insurance companies take out to protect themselves from extremely large losses). According to CNN, Hurricane Isabel cost the states affected over one billion dollars in insured losses.

Materials and Methods

To achieve the goal of demonstrating the socioeconomic benefits of improved hurricane forecasting, hurricane formation and dynamics were explored. Current technologies and future advanced technologies that could make hurricane forecasting more accurate and reliable were identified. The National Weather Service's (NWS) original hurricane path predictions were compared to the storm's actual path. Statistics on the economical expenses caused by hurricanes were obtained from FEMA.

Results and Discussion

Current Technology

Some of the NASA satellite missions which measure geophysical parameters as pertaining to hurricane forecasting include Terra, which measures surface temperature, TRMM, which is used to measure global precipitation, Aqua, which is used to gather information about the water in the Earth's system, GOES 12, which measures atmospheric temperature, atmospheric moisture, and cloud properties, and QuikSCAT, which measures wind speed and direction. More information about these satellite missions as well as other missions can be found in the Appendix. In contrast to the majority of the current missions that only provide 2-dimensional data, many of the future missions will provide 3-D vertical data, which has the potential to advance weather forecasting greatly. Two specific examples of the advancing technologies that have already been launched include TRMM and the Atmospheric Infrared Sounder (AIRS) experiment on NASA's Aqua spacecraft. Using data from AIRS, the thermal structure of Hurricane Isabel can be visualized as three surfaces of equal temperature, or isotherms (Fig. 1). The temperature profile is of importance because hurricanes are driven by the energy provided from warm waters. This is one example of how atmospheric researchers are utilizing NASA data to better understand the development and movement of hurricanes.

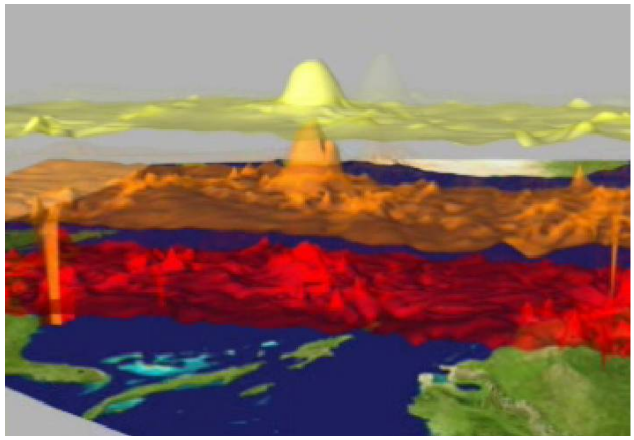

Figure 1 Image generated using data from the Atmospheric Infrared Sounder (AIRS) experiment on NASA's Aqua spacecraft. The thermal structure of Hurricane Isabel is visualized as three surfaces of equal temperature, or isotherms. The temperature decreases with increasing height (i.e. the lowest surface is the warmest). Image courtesy of NASA Goddard Space Flight Center.

Currently, the technology that is available for hurricane forecasting has exhibited advancements in predictive capabilities. Upon more detailed comparison of the predicted path (Fig. 3) to the actual areas (Fig. 4) hit, it is clear that the lead time, or how far in advance an area is informed that it will be hit by a hurricane, is very accurate; however, the trajectory can still be improved upon.

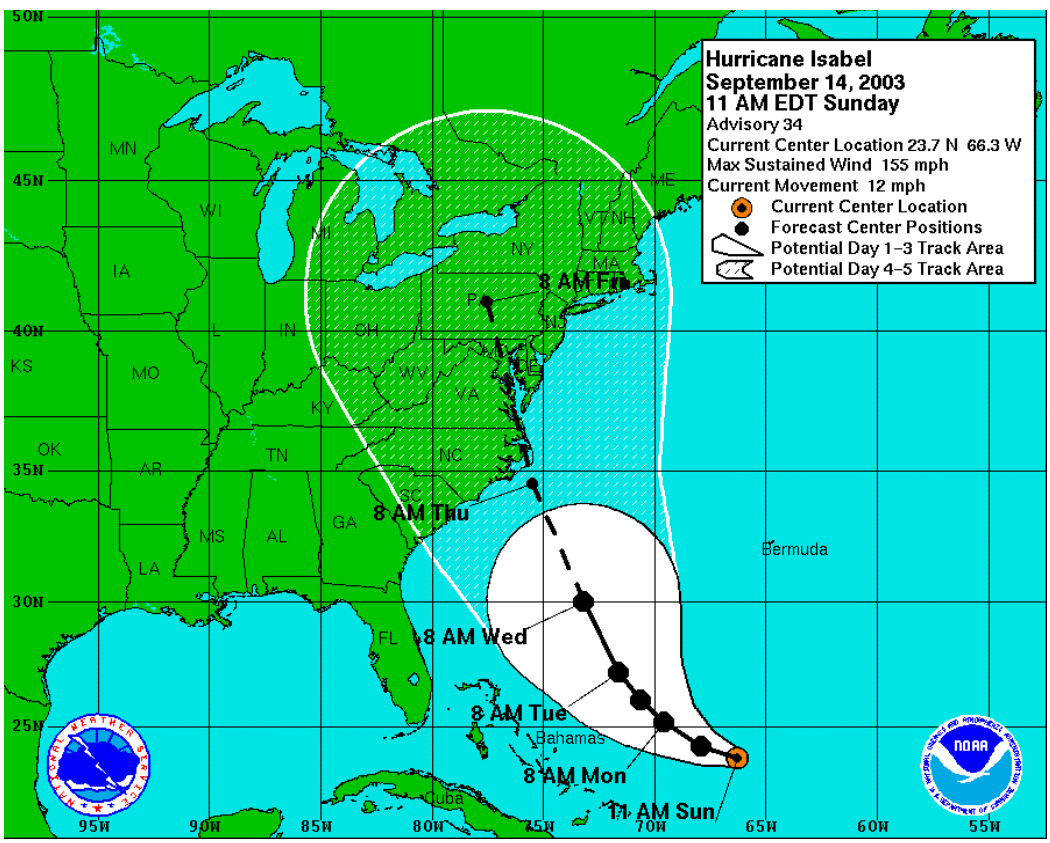

Figure 2 Five-day forecast track of Hurricane Isabel on September 14, 2003.

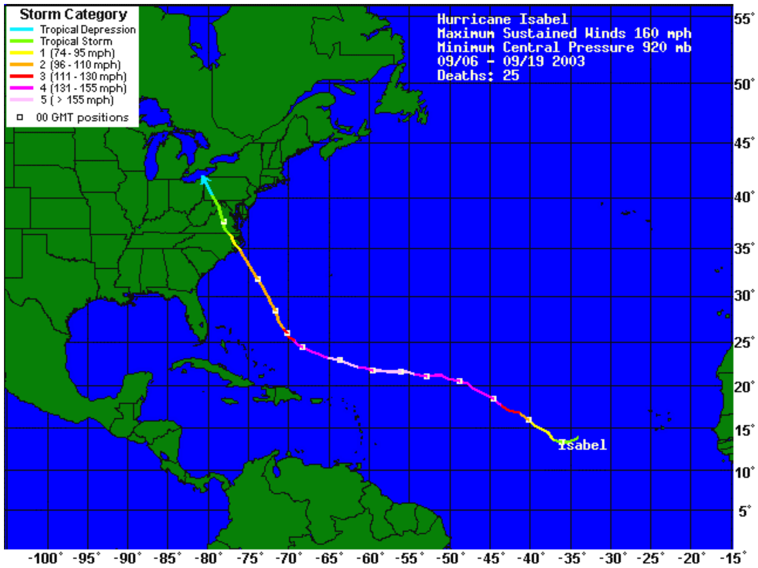

Figure 3 Actual path of Hurricane Isabel from September 6 – 19, 2003.

WAVEWATCH

The National Oceanic and Atmospheric Administration (NOAA) has a NASA recognized hurricane model WAVEWATCH III that predicts wind speed, wind direction, peak periods of waves, and wave heights. Knowledge of these predictions provides the coastal community, such as the Atlantic Fleet of the U.S. Navy, with information that can allow them to better assess whether or not they should leave the area.

An interactive online version of the WAVEWATCH model was used to generate sample outputs (Fig. 2). This model can forecast numerous aspects of the ocean, as previously mentioned, for up to 180 hours. Unlike previous models, the outputs generated can be seen in the traditional tabular data format or in the graphically. Every graphical output contains yellow boxes. Each yellow box indicates an output location for that individual point. Double-clicking on a yellow box will bring up detailed information of the wave height, wind speed, wind direction, and peak periods.

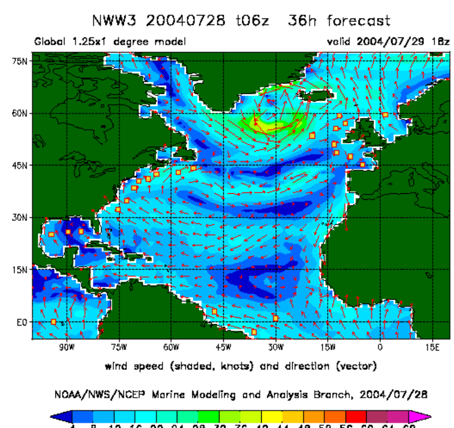

Figure 4 Sample output of predicted wind speed and wind direction from the interactive online NOAA WAVEWATCH (http://polar.wwb.noaa.gov/waves/main_int.html) model. At the bottom is a legend showing the variations in predicted wind speeds. The arrow denotes the predicted wind direction. Each yellow box indicates an output location for that individual point. Double-clicking on a yellow box brings up detailed information of the wave height, wind speed, wind direction, and peak periods.

Future Technology

Along with the missions previously mentioned, future NASA missions will be launched to advance weather forecasting and climatology in general. An example of this is the Afternoon Satellite Constellation, also known as the A-Train. The A-Train consists of 6 NASA missions: two major EOS (Earth Observing System) missions, three ESSP (Earth System Science Pathfinder) missions, and a French CNES (Centre National d'Estudes Spatiales) mission, all flying in close proximity with each other. Two of the spacecrafts, Aqua and Aura, have already been launched. The remaining 4: CloudSat, CALIPSO, PARASOL, OCO are expected to launch by 2007.

This constellation was designed with the intent that less than an hour after the first satellite begins gathering data, the remaining 5 will have collected concurrent data. This carefully planned mission allows for synergy, meaning that more information about the condition of Earth can be obtained from the combined observations.

CAMEX

The Convection and Moisture Experiments (CAMEX) are a collaborative effort between NASA and its partners to study atmospheric water vapor and precipitation processes using an array of aircraft, balloon, and land-based remote sensors. CAMEX-1 was sponsored in 1993 by NASA to gather aircraft remote sensing data and to research the use of these measurements. CAMEX-3 and CAMEX-4 focused on gathering tropical cyclone data including development, tracking, intensification, and landfalling impacts. Future CAMEX flights will provide even more insight into hurricane structure, dynamics, and motion.

FEMA HAZUS®-MH Risk Prediction Management Tool

Preliminary research on the capabilities of the FEMA Hazards United States Multi Hazards (HAZUS®-MH) software was conducted. FEMA HAZUS®-MH is a software program designed for analyzing potential losses from natural disasters. HAZUS® can project estimated damages that will ensue a community, breaking it down into types of buildings and the materials from which the buildings are constructed. Using this information, the government and local authorities can estimate post-hurricane damages that will aid them in preparing for the number of people that will have shortages and predict damage estimates and economic losses. Social impacts are also provided; impacts to people, requirements for shelters, and medical aid.

HAZUS® can be used in a variety of applications. It was found that if a hurricane is predicted to hit a certain area, users can enter all presently known factors about the hurricane, and a scenario will be generated. After all the conditions are entered by the user, HAZUS® analyzes the information and provides the amounts of physical, economic, and social damage estimates that corresponds to the intensity of the hurricane for the region specified. HAZUS® provides information that can assist the government and local authorities with the preparation for the aftermath of hurricanes. HAZUS® gives the authorities a relative idea of the extent of damage to expect. The accuracy of the predictions is based upon the creditability and the accuracy of the measurements that are inserted into the software. City planners and scientists that specialize in disaster management provide the highest level of information that can be used.

Expenses

The hurricane expenses for three major hurricanes: Floyd (September 1999), Claudette (July 2003), and Isabel (September 2003) totaled well over half of a billion dollars. Understanding the break down of this expense will aid us in the effort to reduce costs. For example, in the wake of Hurricane Isabel, Virginia spent over 257 million dollars repairing houses, disposing of waste, as well as individual loans. By gathering specific costs and statistics, better preparatory measures can be taken to reduce these costs.

More specifically, the economic impact of Hurricane Isabel on the City of Poquoson was examined. Removing tree and debris cost the Federal and State government $1,682,794. For C&D Disposal, vegetation management, and vegetative grinding, total costs were $735,196. It cost $235,558 for all labor and equipment, which included the police department, fire department, contract labor, public works, citywide labor, equipment rental, and equipment usage. Miscellaneous costs, including materials, emergency supplies, meals, generator usage, temporary quarters, hazardous waste removal, spoiled food, pump station repairs, city vehicles, and emergency communication cost the federal and state government $372,564.

Conclusions

Weather has a major impact on the community economically in various aspects, which include power losses, residential housing damage, and transportation. Effects from hurricanes and tropical storms account for a large portions of the yearly damage expenses caused by weather. The team was not able to run these models during this project term; however, the two models will be a priority of future team actions because of their ability to produce wind speeds and wind directions and their ability to assess post hurricane damage. The wind speeds and wind directions aid in improved hurricane predictions. The damage assessments can help lead to improved predictions to help reduce total expenditures.

There is evidence that the implementation and integration of the advanced technologies available from FEMA, NOAA, and NASA such as HAZUS®, CAMEX, WAVEWATCH, and the Afternoon Satellite Constellation will allow scientists to better understand hurricane behavior. This in turn has the potential to help local governments reduce pre-hurricane costs and may alleviate post-hurricane costs.

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References and Additional Information

A NASA Earth System Science Pathfinder Mission. 2004. 9 July 2004 <http://cloudsat.atmos.colostate.edu/>.

Aqua. 30 June 2004. 12 July 2004 <http://aqua.nasa.gov/>.

Aqua. 19 June 2003. 12 July 2004 <http://aqua.gsfc.nasa.gov/>.

Arnold, Jim. The Fourth Convection and Moisture Experiment. 1 April 2004. 29 July 2004 <http://camex.msfc.nasa.gov>.

CALIPSO. 2004. 9 July 2004 <http://www-calipso.larc.nasa.gov/>.

CAMEX-1 ER-2 Flights. 30 May 1997. 13 Aug. 2004 <http://www.ghcc.msfc.nasa.gov/irgrp/camex1_flights_tbl.html>.

CAMEX-2. 30 May 1997. 13 Aug. 2004 < http://www.ghcc.msfc.nasa.gov/irgrp/camex-2.html>.

CAMEX-3 Mission Description. 9 July 1998. 13 Aug. 2004 <http://ghrc.nsstc.nasa.gov/camex3/mission_desc.html>.

Coastal Remote Sensing. Charleston: NOAA Coastal Services Center, 2003.

Fourth Convection and Moisture Experiment (CAMEX 4). NASA. 21 July 2004 <http://geo.arc.nasa.gov/sgg/projectmg/projmg3.html>.

GOES/POES Program. 2 July 2004 <http://goes2.gsfc.nasa.gov/spacecraft/n-q-mission.htm>.

GOES R. 2004. 3 July 2004 <http://www.osd.noaa.gov/GOES/dataFlow.htm>.

Holweg, Eric J. Pgs. 6-8. Mariner's Guide For Hurricane Awareness In The North Atlantic Basin. Aug. 2000. 8 Jun. 2004 <http://www.nhc.noaa.gov/HAW2/pdf/marinersguide.pdf>.

Hurricane Formation. 8 Jun. 2004 <http://www.hurricanetrack.com/formation.html>.

Isabel path may limit damage. 17 Sept. 2003. CNN.com. 20 July 2004 <http://money.cnn.com/2003/09/17/news/companies/isabel>.

Jason 2 (OSTM). 6 June 2004. 8 July 2004 <http://skyrocket.de/space/doc_sdat/Jason-2.htm>.

Kaufman, Yoram. In the Eyewall of the Storm. Earth Observatory. 20 July 2004 <http://earthobservatory.nasa.gov/Study/Camex/>.

Kerr, Richard A. Forecasters Learning to Read a Hurricane's Mind. 23 April 1999. 29 July 2004 <http://www.sciencemag.org/cgi/content/full/284/5414/563>.

Lawrence, Richard J. TRMM Satellite Validation Office. 23 June 2004. 14 July 2004 <http://trmm-fc.gsfc.nasa.gov/trmm_gv/>.

NASA CONNECT: The 'A' Train Express. NASA. 2 August 2004 <http://www1.nasa.gov/audience/foreducators/5-8/features/F_A_Train_Express.html>.

NPOESS. 4 May 2004. 12 July 2004 <http://www.ipo.noaa.gov/>.

NPP. 2004. 8 July 2004 <http://www.ball.com/aerospace/npp.html>.

Office of Satellite Operations. 2004. 12 July 2004 <http://www.oso.noaa.gov/goes/>.

Ocean Surface Topography from Space. 12 March 2004. 12 July 2004 <http://sealevel.jpl.nasa.gov/mission/topex.html>.

Ocean Surface Topography from Space. 2004. 4 July 2004 <http://sealevel.jpl.nasa.gov/mission/mission.html>.

PARASOL. 7 November 2002. 14 July 2004 <http://smsc.cnes.fr/PARASOL/>.

Reinhold, Tim. "Re: Hurricane Insurance." E-mail to the author. 22 July 2004.

Smith, Valerie. "Hurricane Expenses." E-mail to the author. 26 July 2004.

Terra The EOS Flagship. 23 May 2004. 13 July 2004 <http://terra.nasa.gov/>.

Terra. 4 March 2003. 13 July 2004 <http://eos-am.gsfc.nasa.gov/>.

The Fourth Convection and Moisture Experiment. 1 Apr. 2004. 3 Aug. 2004 <http://camex.msfc.nasa.gov>.

Tropical Rainfall Measuring Mission. 22 January 2003. 14 July 2004 <http://kids.earth.nasa.gov/trmm/>.

WAVEWATCH III. NOAA. 21 July 2004 <http://polar.wwb.noaa.gov/waves/main_int.html>.

Appendix

Present NASA Missions

Aqua – Aqua is the second Earth Observing System launched by NASA on May 4, 2002. It is in orbit collecting data on land, ocean, and the Earth's radiation. For six years, Aqua will be making daily observations of environmental measurements such as atmospheric temperature, cloud properties and sea surface temperature. We collected data from MODIS, which provided land and ocean coverage.

GOES 12 – Geostationary Operational Experimental Satellite built by NASA and is currently operated by NOAA. One of the many satellites of the GOES series is used to provide weather imagery and other sources of data to improve weather forecasting, severe storm tracking and meteorological research. Its measurements include solar activity, Earth's magnetic field, temperature and moisture profiles, cloud properties and information about the ozone layer. Specifically for our team's project, GOES 12 provided us with a series of images of Hurricane Isabel as it crossed the Atlantic Ocean and making landfall along the east coast.

QuikSCAT – Launched June 19, 1999, QuikSCAT still remains in orbit collecting a vast amount of wind data. This NASA mission has exceeded its three-year life span and is now assisting scientists in measuring sea surface wind velocity and direction and sea ice distribution. QuikSCAT's data is operated by NOAA and is used by the Navy for weather predictions. With the help of the Sea Winds instrument, QuickSCAT can lead to improved weather forecasting.

Terra – The Earth Observing System has a variety of missions, including Terra, which is the first one created and launched. Terra is used to measure the Earth's environment and the continuous changes in the environment. This mission includes instruments, such as ASTER, CERES, MISR, MODIS, MOPITT, collecting a wide range of data, from stereoscopic images to the percent of the planet's surface covered by clouds. Our team took advantage of the measurements Terra provided and collected land and ocean data from one of its instruments, MODIS.

Topex/Poseidon – This dual agency mission with NASA and CNES records all data about the ocean topography. Exceeding its three-year life span, Topex/Poseidon is still up and running capturing all necessary measurements of ocean characteristics every ten days.

TRMM – Tropical Rainfall Measuring Mission is a joint project between NASA and Japanese government, used to measure tropical and subtropical rainfall. The measurements display the location of the rain and the pressure of the rainfall in horizontal slices. The data TRMM collects is essential because it predict wind patterns, ocean currents, floods, and droughts. It is also critical in displaying how a tropical storm or a hurricane develops.

Future NASA Missions

Aura – July 13, 2004, Aura was launched into orbit, with an approximate design life of six years. This mission, derived from POLDER (Polarization and Directionality of the Earth's Reflectances), will keep track of atmospheric chemicals and dynamics and geographic distribution of aerosols. There will be four instruments attached to this mission. Each instrument will contribute to the daily global observations of the Earth's ozone layer, air quality, and other climate characteristics. Aura is the last of the six missions in the A-train satellite constellation. The A-Train is a group of NASA missions that will cross the equator within a few minutes of each other. Eventually this Afternoon Constellation will be in orbit collecting a variety of data that will assist in the advancement of meteorological technology.

CALIPSO – The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations, formerly known as PICASSO-CENA / ESSP3, is a dual-agency mission with NASA and France. As one of the satellites in the Afternoon Constellation, CALIPSO will capture data on aerosol and cloud properties, atmospheric state, and predict future climate change.

CloudSat – This future NASA mission will be launched Spring 2005 providing scientists with vertical profiles of clouds, cloud liquid water, precipitation, ice water contents, physical and radiative properties. CloudSAT is more efficient than several of the previous missions because it will gather information that other missions are unable to collect and it will provide information about clouds that will improve weather forecasting.

GOES N-P – These series of GOES missions will be launched between the years 2004 to 2008. GOES N-P will contribute to weather, solar and space operations. It will also improve severe storm warnings, resource management and advancement in science.

GOES R – October 2012, GOES R will be launched to replace GOES N-Q. Its main goal is to be the main reliable operational environmental and storm warning systems to protect life and property. With its multiple instruments, the Earth's surface, space environment, and climate conditions will be monitored.

NPOESS – The National Polar-orbiting Operational Environmental Satellite System will be launched in the year 2010. This future mission will monitor global environmental conditions and collect data related to weather, atmosphere, oceans, land and near space environment. NPOESS will contain three polar orbiting satellites with a design life of seven years, which will lead to advanced 3-5 day seasonal and interannual weather forecasts, storm tracking and agricultural crop management. It is evident that this mission will not only assist our team, but other teams that are not weather related. NPOESS will host eight instruments collecting data ranging from humidity properties to cloud and aerosol properties.

NPP – Fall 2006, NASA will launch the NPOESS Preparatory Project, which is an advanced version of Terra and Aqua. This mission will monitor climate trends and global biological productivity. NPP will contain four instruments: the Visible Infrared Imaging Radiometer Suite, Cross-track Infrared Sounder, Advanced Technology Microwave Sounder, and the Ozone Mapping and Profiler Suite, collecting data similar to NPOESS.

OSTM – The Ocean Surface Topography Mission is a quad-agency mission with NASA, NOAA, European Organization for the Exploitation of Meteorological Satellites, and the Space Agency of France. Launched in the year 2006 with a design life of five years, OSTM or Jason-2, will provide measurements of climate and weather patterns and sea surface elevations.

PARASOL – As one of the six missions in the Afternoon Constellation, PARASOL will be gathering information on aerosols and clouds using a multichannel, wide-field view polarization sensitive camera. This mission will only host one instrument, POLDER.