A National Oceanographic Partnership Program Award

Scatterometer-Derived Operational Winds and Surface Pressures

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http://manati.wwb.noaa.gov/quikscat/ (NOAA/NESDIS near real time products)
http://coaps.fsu.edu/scatterometry/ (all COAPS scatterometry activities)

Long-term goals

Enhanced products based on satellite-derived ocean surface winds will be distributed to Navy and commercial vessels, and civilian forecasters, with improved accuracy and much greater ease of interpretation. Two additional products, based on these improved observations, will also improve the ease and speed of interpretation and ocean modeling. A third product will provide an improved alternative for ocean modeling. The technology will be transferred to NOAA/NESDIS for routine use and distribution.

Objectives

In a few sentences, please identify the scientific or technological objectives of this effort.

(1) Currently observations that are suspected of being associated with rain events are flagged and ignored. This practice discards many useful observations. An improved flag will be developed to flag only the relatively small fraction of observations where rain has a substantial adverse impact. The improved product will be validated.

(2) The ease and speed of interpretation of the observations will be improved for operational activities (civilian, military, and commercial) by processing the data in a manner that highlights the meteorological features of interest. Objective (3) contributes to this goal.

(3) Surface pressures will be derived from the improved wind products. Surface pressures are routinely used by weather forecasters, whereas, surface winds require considerably more effort to interpret. Furthermore, the surface pressure can be compared to weather prediction products to identify large scale errors in the forecasts.

(4) Surface stresses will be determined directly from the signals observed from the satellite. These are ideal for ocean modeling. They can also be used to improve estimates of wind-related ocean spray, which is of tactical interest.

(5) Surface winds and stresses will be gridded for operational ocean modeling at relatively fine spatial resolution.

(6) Transition of technology to NOAA/NESDIS.

Approach and work plan

The team members working on the specific aspects of our plan (discussed below) are indicated by their names in bold print.

Ocean vector wind data from QuikSCAT have been available in near real-time from NOAA/NESDIS [**Chang**] to the operational forecasting community since early 2000. The near real-time classification for QuikSCAT implies ocean vector wind product availability within 3 hours of scatterometer measurements of the ocean surface. QuikSCAT transmits data back to ground stations only once per orbit, so approximately 102 minutes of the 3 hour time budget is consumed in data collection alone. These data are automatically retrieved at COAPS [**O'Brien** and **Bourassa**], processed, and forwarded to operational users [**Bernstein**, **Clancy**, and

Hawkins]. These operational centers forward the data products to the end users, gather feedback, and return it to COAPS for improvement of the products.

Currently, all winds vectors coincident with suspected rain events are flagged as rain contaminated. A theory-based model and observations (**Weissman** et al. 2002, 2003; [**Weissman** and **Bourassa**]) indicate that for many rain events the wind signal is only slightly altered by rain. A tropical cyclone-related application (Sharp et al. 2001) supports this finding. Theory suggests that rain contamination will be a serious problem only when the rain rate exceeds a wind speed dependent threshold. We will use existing proxies for rain rate (Jones et al. 2000a,b; **Weissman** et al., 2002, 2003). In areas of rain contamination, we will estimate wind speed and direction through our pressure fields (for which rain has little impact). The partners in this collaboration are unique in their ability to develop rain impact flags.

NAVOCEANO [**Rigney**] will provide ship observations for validation of our products. COAPS has considerable experience in processing research vessel observations (Smith et al. 2001), and in using these observations for validation of scatterometer winds (**Bourassa** et al., 1997, 2003).

Surface pressures will be determined [**O'Brien** and **Bourassa**] from the satellite winds through the technique of Hilburn et al. (2003). This approach blends forecast pressures with wind observations, to create an improved pressure product. This product will be validated with ship and buoy observations.

Stresses will be calculated directly from scatterometer backscatter [**Weissman** and **Bourassa**], similar to the technique of **Weissman** and Graber (1999) for a previous instrument, without making assumptions required for wind-derived stresses. Scatterometers respond to the short water-waves, which respond more directly to stress than to wind speed. Historically, scatterometers have been calibrated to 10m wind speeds due to the relative paucity of stress observations. A SeaWinds stress algorithm is being developed by **Weissman**.

Relatively fine spatial resolution gridded wind fields are produced as prototypes for operational oceanography [**Bourassa**]. The quality of these fields is indirectly evaluated through the accuracy of the ocean model results for two regions: the Gulf of Mexico [**O'Brien** and **Bourassa**] and the eastern Pacific [**Kindle**].

Enhanced graphics that emphasize the meteorologically-relevant features will be developed [**O'Brien** and **Bourasssa**]. All these products will be generated in near real-time. One product will show pressure fields derived from the scatterometer in addition to modeled pressure fields (analysis and forecast fields interpolated to the time of the scatterometer observations). Another product will using moving vector code (**Bourassa** et al. 1998). The moving vectors highlight meteorologically interesting features without the distracting errors associated with rain contamination and missing data. Pressure and rain graphics will also be included in the second product. These graphics (and identical information in digital form) will be made available to NWS local offices, Marine Prediction Center [**Chang**], FMNOC [**Clancy**], and other operational centers [**Bernstein** and **Hawkins**]. Feed back from these sources will lead to better products, and perhaps to products that are tailored to various applications.

The programs used to create our new products are written in a computer language that that is practical for transfer to NOAA/NESDIS's computer systems [**Bourassa** and **Chang**].

<u>Work Completed</u>

Surface pressure is calculated on the grid resolution of the scatterometer observations (currently 25 km) through techniques that have been qualitatively shown to be effective (Harlan and **O'Brien** 1986; Brown and Zeng 1994; Foster et al. 1999; Zierden et al. 2000). Improvement to this technique [**O'Brien** and **Bourassa**] have been completed at COAPS (Hilburn et al., 2003), and the pressures (Fig. 1) have been quantitatively evaluated. The same observations are used to create enhanced graphics (Fig. 2) that are easier to interpret.

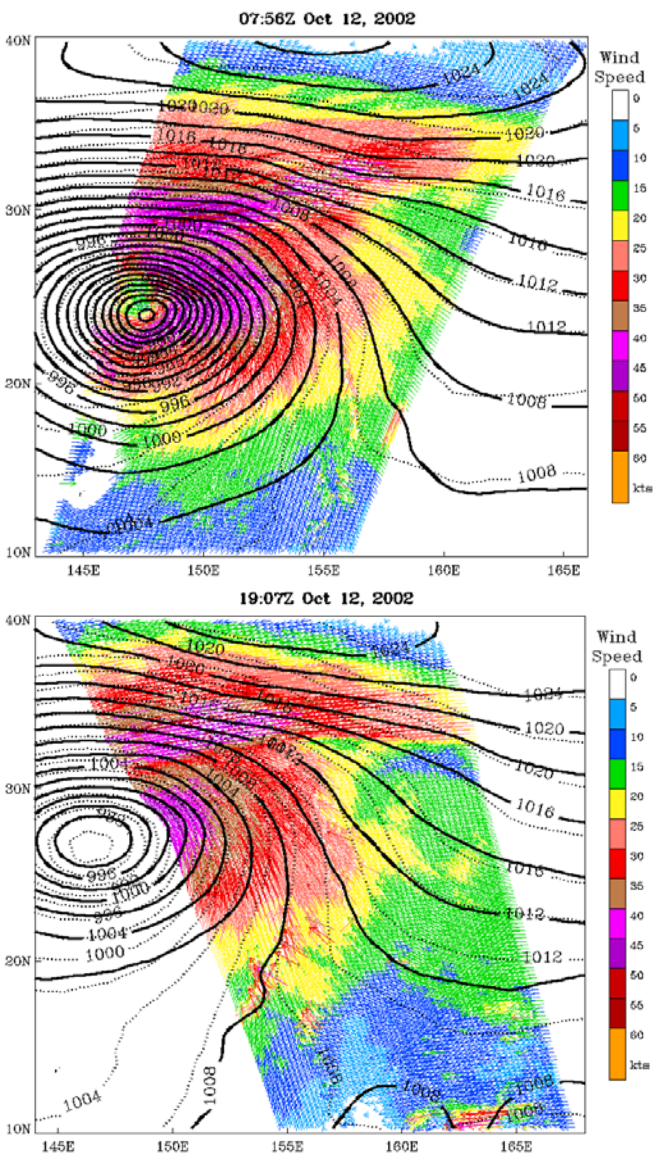

Fig. 1. The forecast pressure fields are interpolated to the time of the scatterometer overpass. Large scale differences between the forecast (dashed) and scatterometer derived (solid) pressure patterns (Hilburn 2003) indicate systematic biases, and provide improved guidance for interpreting the forecast. These graphics are being made available to forecasters of tropical storms.

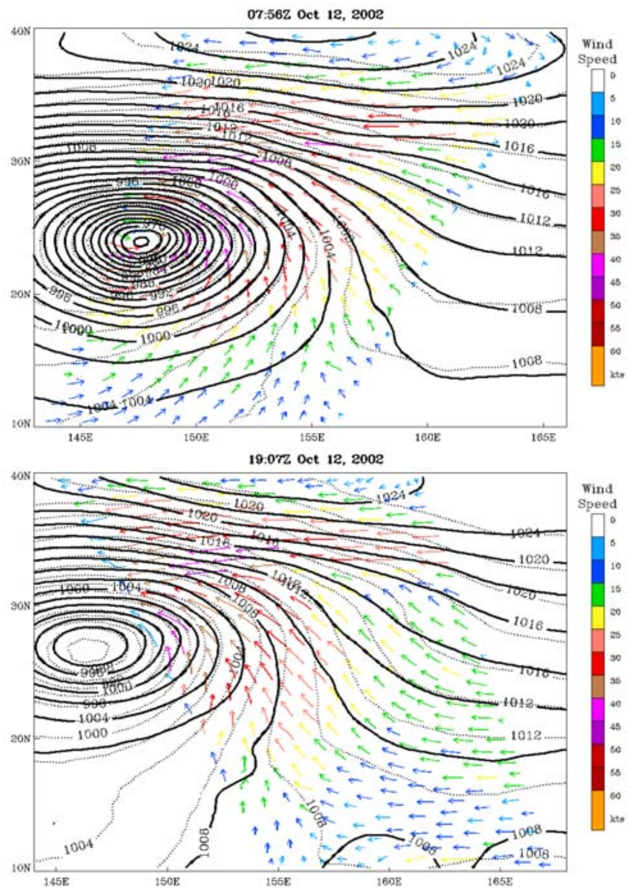

Fig. 2. For most operational activities there is little time to examine the fine details provided by the scatterometer. A streamline visualization technique is applied to thin the vectors in a manner that still highlights the operationally interesting data. These graphics are made available to FNMOC and forecasters of tropical storms, and this information will soon be made available in a digital form through the SeaSpace Corporation.

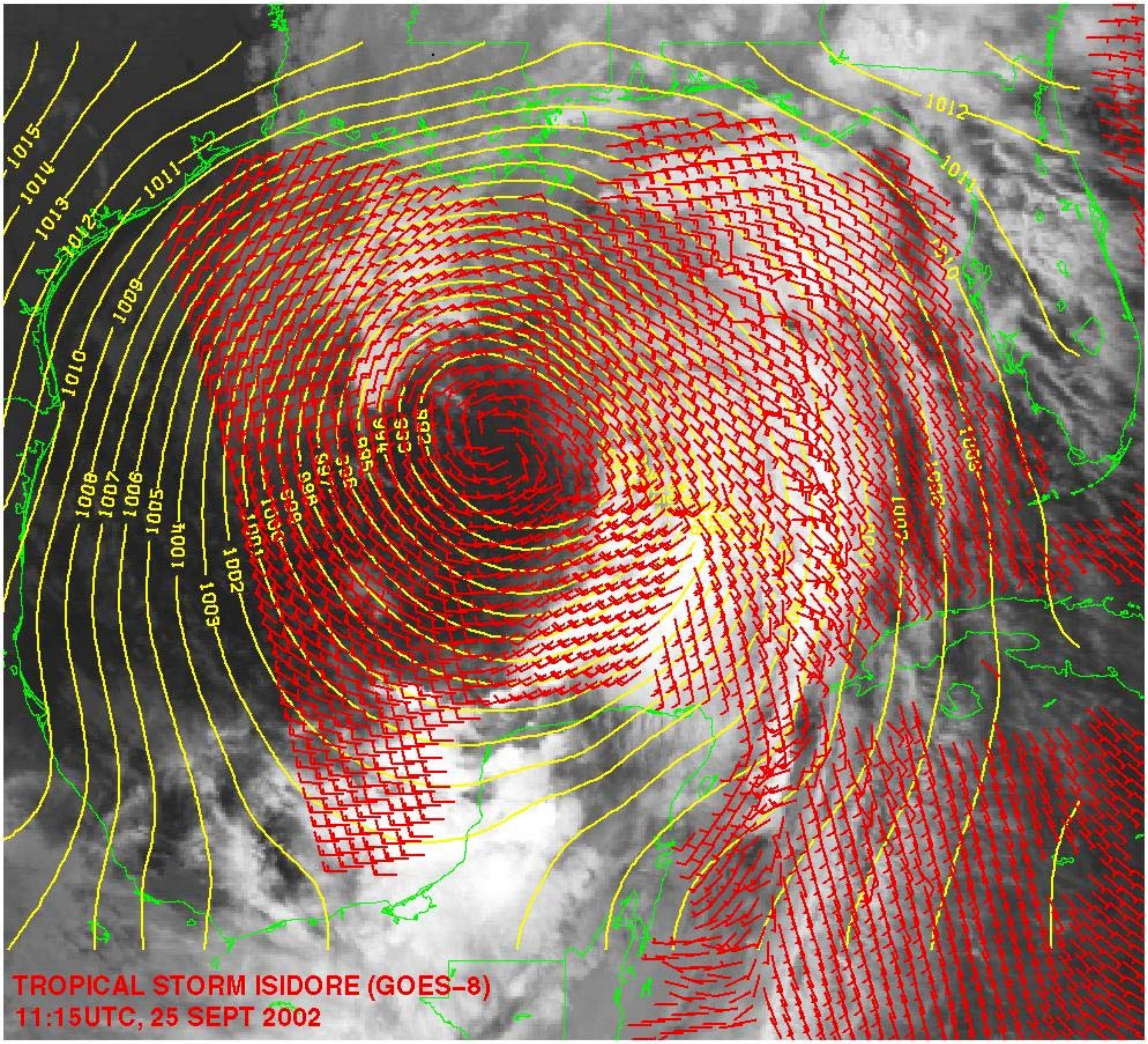

Fig. 3. The TeraScan software consists of several hundreds of functions for satellite and other data processing. Once the QuikSCAT wind data are converted to TeraScan data format, they can easily be overlaid and combined with other satellite and model data. This greatly facilitates weather analysis such as determination of cyclone centers and locations of front. An example of QuikSCAT surface wind and pressure data for Tropical Storm Isidore is shown. The background is a GOES-8 channel 4 infrared image, taken at 11:15 UTC, September 25, 2002. Upon entering the Gulf of Mexico, Isidore was down-graded to a Tropical Storm from its previous hurricane intensity. At the time of this image, the ocean surface wind speeds in the deep convective area are around 20 m/s, with gusts to 30 m/s. The surface pressure center was at 988.5 mb.

A technique has been developed to retrieve surface stress directly from radar singles returned to the satellite scatterometer (Fig. 4). This technique has just been developed: it must be further tested.

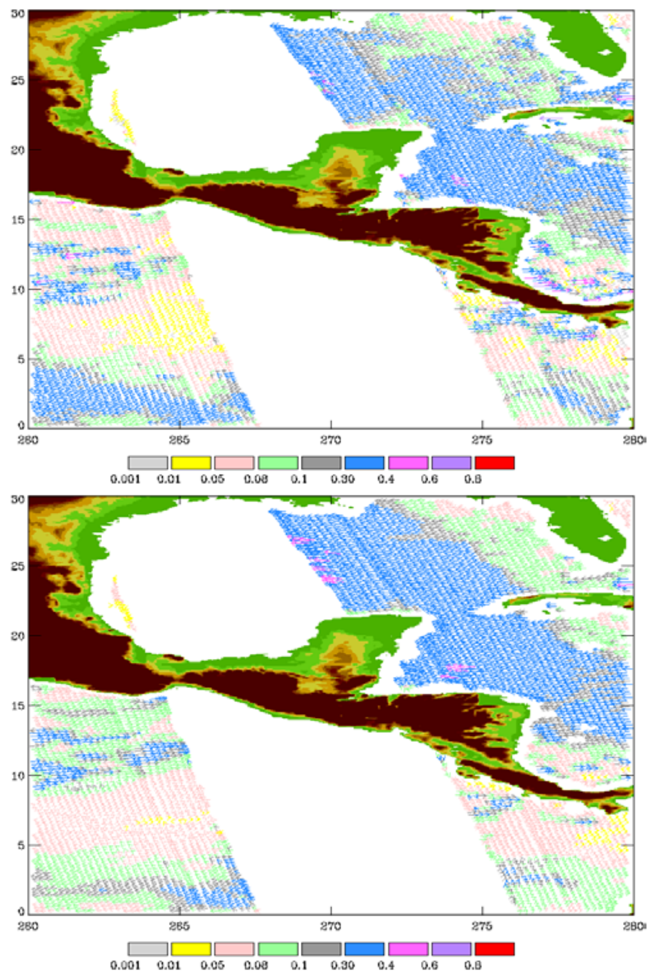

Fig. 4. Surface stresses [N m^{-2}] derived from scatterometer backscatter (left), and stresses derived from scatterometer winds (right). The scatterometer-derived stresses do not require a drag coefficient. Drag coefficients are dependent on several things including the sea state. However, a mean sea state is assumed in stressed derived from scatterometer winds. Consequently, variability related to sea state is lost unless that variability is observed through subtle variations in the frame of reference for the water waves to which the scatterometer responds (Bourassa 2003). Another likely source of systematic errors is biases in the drag coefficient (we believe this to be the dominant source of error). The direct calculation of stress bypasses both of these problems.

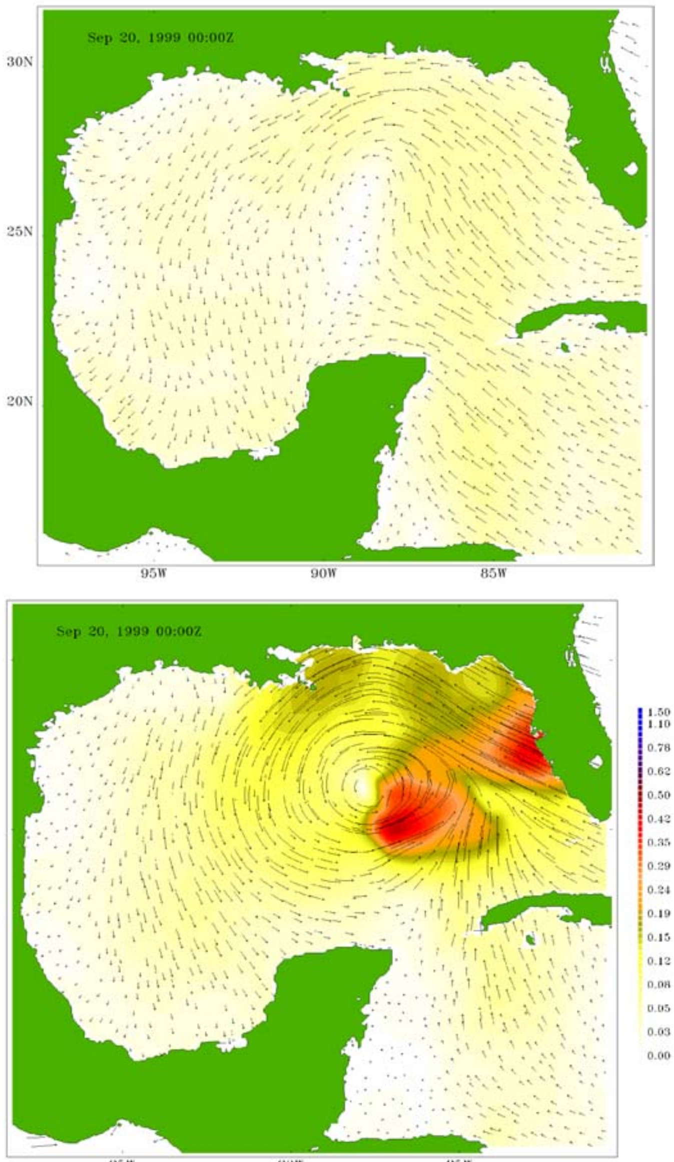

Fig. 5. Gulf of Mexico on 0Z 9/20/99. A simpler approach to that shown in Fig. 4 is to calculate stresses through the wind speed and a wind speed dependent drag coefficient (Large et al. 1994). The 22 km Eta numerical weather analysis (left) shows a tropical wave. The scatterometer wind based product (right), on a coarser 0.5° grid, shows a much deeper and more detailed Tropical Storm Harvey soon after the National Hurricane Center classified Harvey as reaching Tropical Storm strength. The scatterometer fields are available through our website.

The wind-derived stresses (Fig. 5) are used to force a high resolution (1/20th of a degree) model of the the Gulf of Mexico, as well as a portion of the Pacific Ocean off of California. The currents from the Gulf of Mexico model (not shown) are an excellent match to currents measured at individual buoys on the West Florida Shelf.

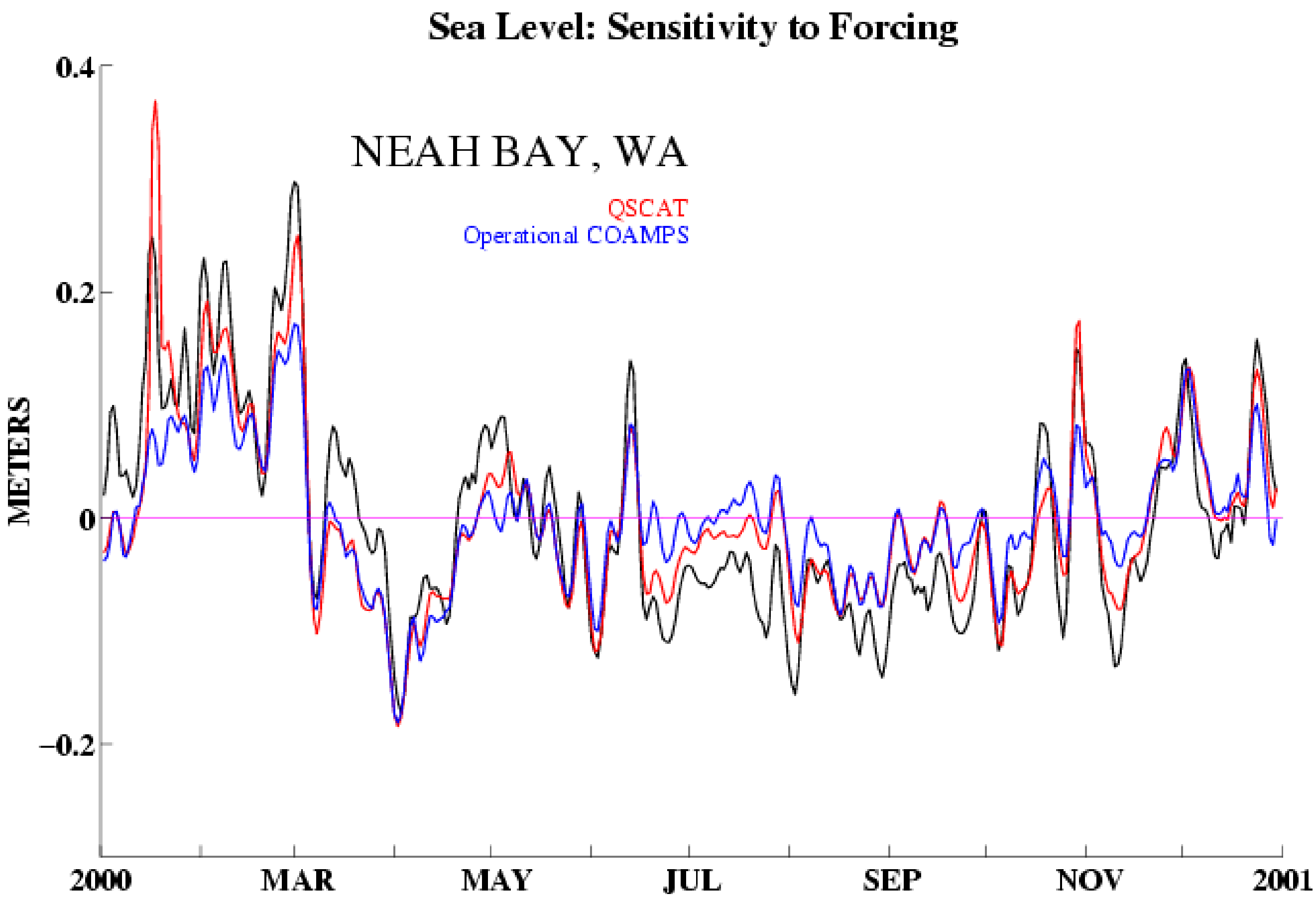

Fig. 6. Time series of daily sea level, smoothed by a 3 day running mean average, at Neah Bay, Washington for the year 2000. Black line denotes pressure corrected observed values from tide gauges. The red line represents model sea level from simulation forced by the QuikScat-derived winds while the blue line denotes the values from operational Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) simulation. The simulation forced by the scatterometer–derived winds yields a more accurate representation of the observed sea level than the experiment forced by the stresses derived from the operational COAMPS 10m winds. Although not shown, the experiment forced by scatterometer-derived winds resulted in a significant improvement relative to the simulations forced by the global operational models from European Center for Medium Range Weather Forecasting (ECMWF) and Fleet Numerical Meteorology and Oceanography Center (FNMOC).

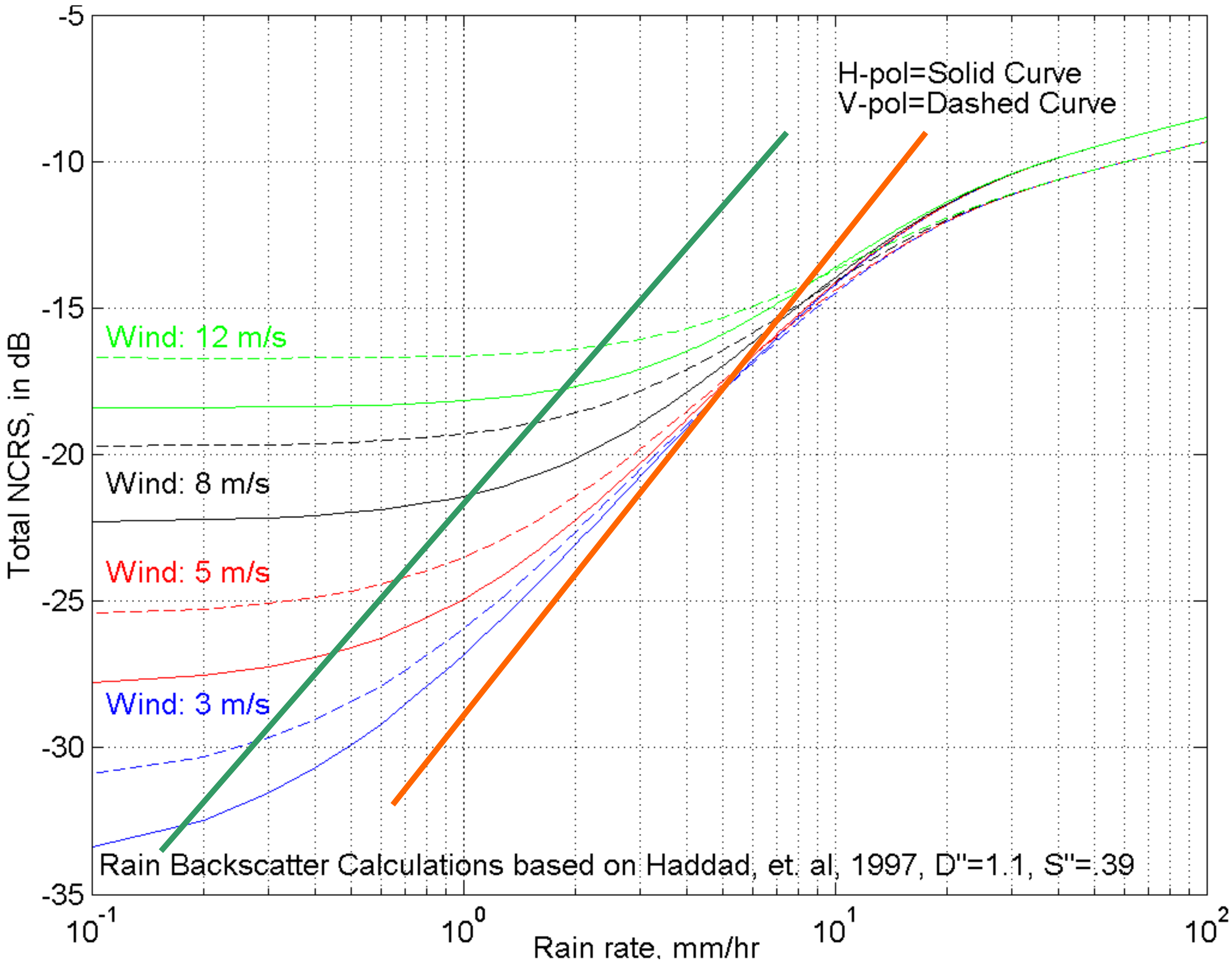

Fig. 7. Theoretical calculations of the SeaWinds signal as a function of rainrate for selected wind speeds (the curves). The scatterometer signal, for wind and rain conditions to the right of the orange line, is dominated by rain. Scatterometer signals for conditions to the left of the dark green line are dominated by wind, and the wind vectors can be retrieved regardless of the rain. Conditions to the right of the thick red line are dominated by rain rather than wind, and retrieval of a wind vector is highly unlikely to be successful. The wind signals from the strong wind speeds associated with extreme weather are often strong enough to allow retrieval of the wind vector. An understanding of this physics will allow us to create a rain impact flag. Calculations of rain-radar reflectivity were performed with tools and techniques developed by Dr. S. Durden, NASA/JPL.

An individual has been hired to work with the NWS/Marine Prediction Center (MPC) in evaluating the impacts of QuikSCAT ocean vector wind data in their warning and forecasting products. The first order of business was familiarize herself with the day-to-day operations of the MPC forecasters. This was accomplished by working operational shifts alongside the forecasters. A survey form was prepared based on this experience and it was distributed to the forecasters to ascertain the level of use of QuikSCAT data in their daily forecast process. A

QuikSCAT log was developed for the forecasters to record cases where they felt QuikSCAT influenced their decision making process. These logs will be used to help develop metrics that can be used to quantitatively determine the impact of QuikSCAT ocean vector wind data on operational marine forecasting at MPC.

Results

(1) The physical understanding of how rain influences the signal sensed by the scatterometer has been greatly improved. We have learned for what situations rain will overwhelm the wind signal (making retrieval of the vector winds impossible), and for which conditions rain has a small impact (making retrieval easy). This understanding is important to the development of a better rain flag.

(2) We have found that relatively high spatial resolution wind fields can be created with sufficient accuracy to greatly improve the accuracy of wind driven current in ocean models. These upper ocean results seem to be much more consistent with reality that previously achieved, allowing us to study the upper ocean on finer spatial/temporal scales than was previously possible.

(3) We have created an algorithm for determining surface kinematic stresses directly from scatterometer observations.

(4) Distribution of the data to a large variety of users builds an effective way of getting feedback from people working in the fields of oceanographic, meteorological, and environmental operation. The users reports that the near-real-time QuikSCAT wind data have been helpful for tropical cyclone analysis. The data are especially useful over the ocean surface where conventional observations are not available. The QuikSCAT data provide an additional tool for accessing storm intensity and early detection of tropical cyclones.

Impact and Applications

National Security

The pressure and enhanced graphics can be of use for tactical planning, ship routing, and marine (and marine aviation) safety in general. The gridded winds and stresses are extremely useful for modeling near surface currents, and the drift of objects due to these currents. The near real time gridded winds have already been shown to be effective for search and rescue activities, in collaboration with a NOPP project led by Gary Lagerloef.

Economic Development

There should be considerable increased efficiency in response to open ocean and coastal severe weather. The products produced in this study have been shown to be useful in evaluating critical biases in the forecasts from weather prediction models. Improvements in these areas will lead to less loss of work related to Nor'Easters and landfalling tropical cyclones. It will also help in the more efficient routing of ships.

The TeraScan users can obtain QuikSCAT wind data from SeaSpace free of charge. The data added to TeraScan user's existing sources of other satellite products and model analyses, and help achieve better analyses of weather systems. Providing this added service to TeraScan users has a positive impact on SeaSpace's business development.

Quality of Life

The extremely high quality near-surface currents modeled in the Gulf of Mexico should be of great help in increasing our knowledge of physical oceanography related to the Gulf's ecosystem and coastal resource management. Several of the organizations receiving the QuikSCAT wind data are involved in the areas of coastal resource management and public information service, such as the Earth Scan Laboratory at Louisiana State University and the Central Weather Bureau in Taiwan. It is particularly beneficial that QuikSCAT data provide large-scale information over the water surface where the conventional observations are not available.

Science Education and Communication

Animations based on the results from the Gulf of Mexico model are used, in a university course, to demonstrate important physical concepts.

Transitions

For the four NOPP evaluation factors below, please describe how the results (hardware, software, knowledge) are being utilized by others. Transition is taken to mean, "products which are being incorporated into more developmental (or operational) programs or have already been incorporated in other's plans."

National Security

The QuikSCAT derived wind data are being incorporated into SeaSpace Corporation's developmental programs. It adds a new component to SeaSpace's product lines.

The satellite-derived surface stresses and enhance graphics are being made available to the Navy for operational activities. The products were made available at the end of the reported period: details of the use are not available at this time.

Economic Development

These products are being made available to forecasters so that they can better evaluate model forecasts in the context of severe weather, for which the consequences of forecast quality can have tremendous impacts in lost work and damage mitigation.

Related projects

1) Analysis, Modeling and Science for NSCAT, SeaWinds, ADEOS Vector Winds (OSU, NASA):
Scatterometer winds are validated, gridded, and used for many science applications http://coaps.fsu.edu/scatterometry/ (all our scatterometry activities)

http://coaps.fsu.edu/~zierden/qscat/ (wind and pressure graphics for forecasters)

2) Numerical Modeling of Cross-Shelf Exchange Processes in the Gulf of Mexico (NASA): The circulation of the Gulf of Mexico is examined, with emphasis on the on transport to and from the shelf regions. Fine resolution scatterometer wind fields are used to force the model.

3) Quality-Evaluated Meteorological Data from Research Vessels (NOAA/OGP)

http://www.coaps.fsu.edu/RVSMDC/index.shtml (Research Vessel Data for Calibration)

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