# Fine Resolution Satellite-Based Winds for Episodic Events


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***Abstract* – Improvements are made to regularly gridded wind fields, based on SeaWinds scatterometer observations, with the goal of better representing episodic wind forcing for meteorological studies and for forcing ocean models.**


## I. INTRODUCTION

There is considerable call for marine wind products for forecasting, research, and commercial activities such as fishing and offshore oil drilling. Traditional in situ wind observations are sparse and the output of general circulation models (GCMs) is questionable, particularly so for episodic forcing [1]. Space-borne scatterometer (SeaSat, ERS-1/2, NSCAT, and SeaWinds) observations of wind speed and direction over the ocean surface have greatly enhanced the coverage, observational density and accuracy of marine winds [2,3]. The processing of scatterometer data is relatively easy (i.e., rapid and cost effective) in comparison to other remote sensing techniques such as synthetic aperture radar (SAR), and has much better coverage than winds derived from altimetry. The SeaWinds scatterometer is an active microwave sensor that covers approximately 90% of the ice-free ocean in one day, with an average of two observations per $25 \times 25 km^2$ grid cell each day. There is now a SeaWinds instrument aboard the QuikSCAT satellite as well as aboard the recently launched Midori 2 satellite.

Gridding techniques developed with NSCAT observations [2] have been improved and applied to SeaWinds observations. Global fields of 1° spatial resolution are produced from satellite observations of the winds over water. A 0.5°, 12 hourly, product is produced for the Gulf of Mexico. These wind fields are publicly available through the COAPS scatterometry web site (http://www.coaps.fsu.edu/scatterometry/). There greatest source of error in relatively fine spatial/temporal resolution of similarly constructed products is the accuracy of the background field, which is largely constrained by temporal sampling [4]. Several approaches to reducing this uncertainty have been examined, with the goal of producing high quality fine resolution gridded products and consequently realistic wind driven ocean currents.

## II. BACKGROUND

Daily wind products are used to study a wide range of meteorological and oceanographical phenomena with time scales from days to seasons. Observations over oceans are typically sparse in both space and time. Consequently, the initialization fields from GCMs (e.g. ECMWF and NCEP winds) have often been utilized as surface winds. These products have been of limited use in the study of episodic forcing due to large spatial grids and highly questionable parameterizations for the boundary layer. Alternatively, fields have been developed from long-term averages (at least monthly) of ship and buoy observations [5,6]. In both cases the spatial resolution is course, typically 2 to 10 degrees. Better temporal and spatial resolutions are desirable, and can be achieved [3]; however, the temporal resolution of such products is insufficient to examine episodic forcing.

Spaceborne scatterometers provide a high spatial resolution (~25 km) within their observation swaths, but no observations outside the swaths. The time taken to completely cover the world's oceans has been limited by the width of the observational swath, the choice of orbits, and operational restrictions. For example, without operational restrictions, the ERS-1/2 scatterometers cover the globe in approximately six days. This time scale is typical of synoptic events, suggesting that it would be impractical to use these scatterometers to thoroughly monitor events of comparable or smaller time scales. Furthermore, the sampling time required to remove sampling biases related to the orbital pattern has been found to be greater than one month for the ERS scatterometers [7]. The construction of daily surface wind fields, based on oceanic observations, was not practical prior to the NSCAT period of observations (Sept. 1996 through June 1997). NSCAT wind observations covered ~77% of the Earth in one day, and ~90% in two days. The advantages over ERS scatterometers were duo swaths (one on each side of the orbital trajectory), nearly continual operation (no mission constraints), and a lack of dropout. Additional advantages were improved accuracy in wind speed and direction [8]. Coverage of a single SeaWinds scatterometer is approximately double that of NSCAT. The NSCAT and QuikSCAT instruments have allowed the study of some episodic events [9,10,1] despite complications due to the limited temporal sampling.

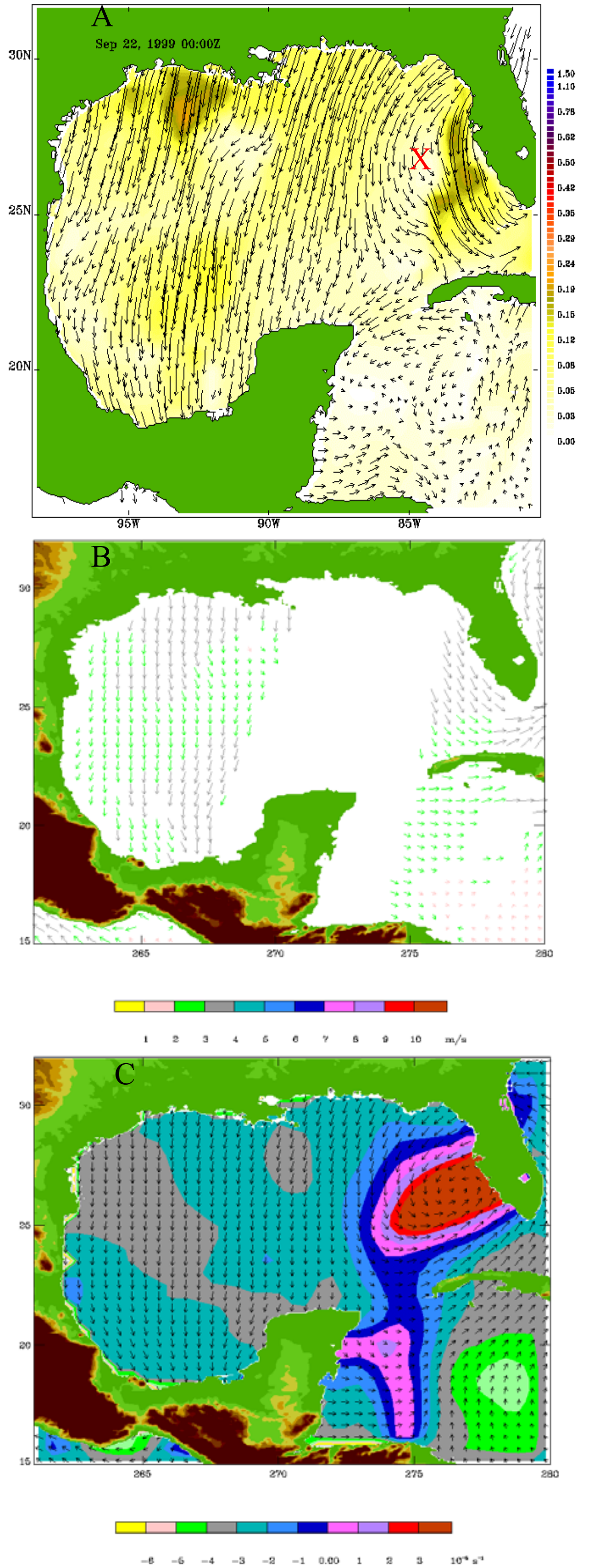


Fig. 1. Example (A) of a secondary minima (X) in surface wind speed off of the coast, and well behind the system, which was centered over southern Florida. There is no indication of the secondary minima in the observational component (B) of the variational method. The background field (C) contains a vorticity minima at the area in question, and is clearly the cause of this problem.

## III. METHODOLOGY

The production of daily wind fields, appropriate for forcing ocean models, requires that gaps in the coverage are filled by accurate estimates of the wind, and that the observational pattern is not evident in spatial derivatives of the wind field. Otherwise, the winds could excite spurious Kelvin and Rossby waves. For NSCAT observations, these goals were accomplished with a variational method [2]. This approach minimized a functional with three constraints: a misfit to observations, a misfit to vorticity of a background field, and smoothing with respect to the background field. An objective technique was used to determine the weights for these constraints [2]. The changes to the previous technique are the consideration of uncertainty in the observations ($\sigma_{Po}$) and improved background fields. The functional ($f$)

$$f = \sum_{i,j}^{I,J} \Big\{ \beta_a \sigma_{P_o}^{-2} \left[ \left(P_x - P_{x_o}\right)^2 - \left(P_y - P_{y_o}\right)^2 \right] + \beta_d L^4 \left[ \nabla^2 \left(P_x - P_{x_{bg}}\right)\right]^2 + \beta_d L^4 \left[ \nabla^2 \left(P_y - P_{y_{bg}}\right)\right]^2 + \beta_e L^2 \left[ k \cdot \nabla \times \left(\vec{P} - \vec{P}_{bg}\right)\right]^2 \Big\} \quad (1)$$

is minimized for the solution pseudostress ($P_x$, $P_y$). The terms with the small 'o' subscripts are the observations from the satellite, and the terms with the small 'bg' subscripts are the background field. The betas are weights, sigma is the uncertainty of the observational average within a grid cell, and $L$ is a grid-spacing dependent dimensionless length scale. The first term represents the misfits to the scatterometer observations, the second and third terms comprise a penalty function to smooth with respect to the background field, and the last term is the misfit to the vorticity of the background field.

Previous QSCAT gridded wind products produced through this technique have used background fields constructed from 3-day binned QuikSCAT wind data, Gaussian smoothed over a five degree radius, where these scale represent three standard deviations in the Gaussian distributions [1]. Alternatively, a blended NWP and QSCAT product has been created by replacing the background with Eta-29 wind field. Both approaches lead to gridded fields with tremendous improvements over the Eta-29 wind fields [1]. However, the gridded QSCAT product suffered from excessive temporal blending in the background fields. Problems related to rapidly moving cyclones (e.g., Fig. 1) or fronts were traced to this temporal sampling problem.

## IV. RESULTS WITH THE NAVY COASTAL OCEAN MODEL (NCOM)

Shallow seas and wide continental shelves respond dramatically to local energetic episodic wind forcing, such as atmospheric fronts and tropical storms. High-resolution ocean models show great promise in simulating the ocean environment at these regional scales, but are often limited by the availability of gridded wind fields for surface fluxes that have high enough spatial and temporal resolution to adequately capture these strong events. Comparisons made between results of a numerical model [11] of the

Gulf of Mexico (GoM) forced by objectively gridded satellite scatterometer winds, Eta-29 atmospheric model forecast data, and a hybrid of the satellite and numerical weather prediction products indicated strengths and weakness of these approaches. Examples of these fields are shown in Fig. 2. The West Florida Shelf (WFS) region was chosen for as a testbed for examining how best to use satellite derived winds to force regional-scale ocean models. Validation of the model results with in-situ observations shows the strengths and weaknesses of using the different gridded winds for modeling the region [1]. Particular attention is paid to episodic weather events, such as tropical systems and atmospheric fronts, and showed substantial differences (Fig. 2) between the three products.

In this test region, the two scatterometer-based fields were clearly superior to the Eta-29 winds: observed currents and tide gauge anomalies were a much better match to observations. In extreme events, such as tropical storms, the limited cases indicated that the blended product (scatterometer observations with NWP background) was clearly superior. However, care should be applied before extrapolating this finding to other regions. The times of the scatterometer passes over the Gulf of Mexico are very close to the times corresponding to the NWP fields. Substantial interpolation of NWP fields is likely to result in many of the problems seen in the scatterometer product.

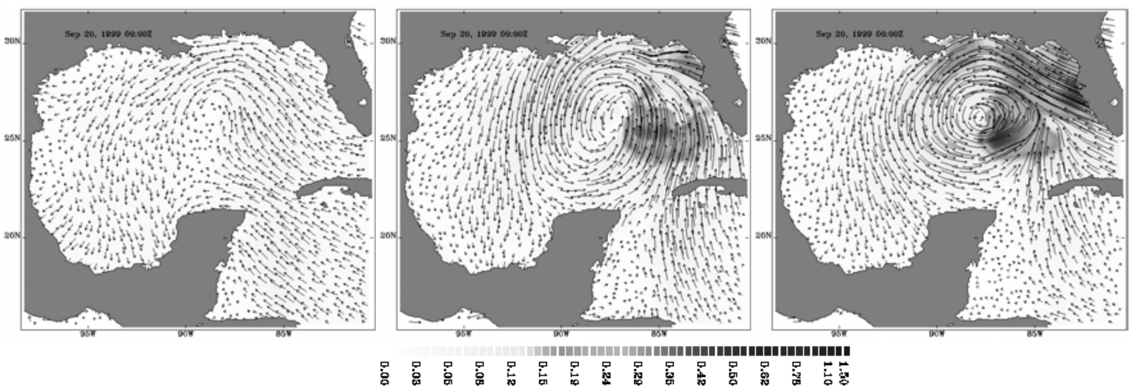


Figure 2: Wind stress (Pa) fields from the gridded ETA (left), QSCAT (middle) and QSCAT/ETA (right) wind stress fields on September 20, 1999, just prior to T.S. Harvey passing eastward over the WFS.

## V. IMPROVEMENTS IN SEAWINDS GRIDDED FIELDS FOR EPISODIC FORCING

The improved temporal coverage from two scatterometer is expected to greatly reduce errors related to temporal sampling [4]; however, data from the second scatterometer is not yet available for testing in this application. If the orbits of the two scatterometers are phased such that there is approximately 6 hours between observations, then it is plausible that a purely scatterometer based product could be as good or better than the product with an NWP background field. These improvements will contribute to improved accuracy in the pure scatterometer product as well as the scatterometer/NWP hybrid product.

Improvement in the wind fields are made by reducing the temporal width of the Gaussian filter used to create the purely scatterometer based background field. A factor of ten reduction in the temporal scale greatly improves the clarity of rapidly evolving features, albeit with a slight reduction of quality for most other conditions. Examination of the resulting fields indicates that the use of a constant spatial scale also contributed to blurring of fine spatial scale features. We are in the process of developing variable width spatial/temporal filters, for which the scales depend on uncertainties and characteristics of the wind field.

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