Continuous Strife for Better Coverage and More Details in Ocean Surface Winds Measurements – from Midori and ADEOS-2 to GCOM

W. Timothy LIU, Hua HU, Wenqing TANG, and Xiaosu XIE
Jet Propulsion Laboratory, California Institute of Technology
M.S. 300-323, 4800 Oak Grove Dr.
Pasadena, CA 91109, U.S.A.

ABSTRACTS

The series of joint U.S.-Japan spaceborne scatterometers missions to provide continuous measurements of ocean wind vectors is reviewed. Examples of the scientific impact of the continuous effort in improving spatial resolution and coverage are provided,. The plan for future missions is reviewed.

INTRODUCTION

Today, many citizens believe that operational numerical weather prediction (NWP) will give us all the wind information we need, until a hurricane suddenly intensifies and changes course, or the delay of monsoon brings drought, or the Pacific Trade Wind collapses before an El Nino. When prediction fails and disaster hits, then we remember that NWP depends on models which are limited by our knowledge of the physical processes and the availability of data. Spaceborne microwave scatterometers are the only proven instruments that will give us real measurements of ocean surface wind vector (both speed and direction) under clear and cloudy conditions, day and night. They give us not only a near-synoptic global view, but also details not possible using NWP models. Such coverage and resolution are crucial to understanding and predicting the changes of weather and climate.

JOINT U.S-JAPAN MISSIONS

The NASA Scatterometer (NSCAT), was launched in September 1996 on the Japanese spacecraft Midori. The six fan-beam antennas provide 600-km swaths on both sides of the spacecraft, covering 73% of global ocean at 25-km resolution daily. The antennas made observations at 45°, 115° and 135° azimuth angles. The incident angles vary from 22° to 59° for the fore-and aft-beams and from 18° to 51° for the mid-beam. The unexpected destruction of the solar array caused the early demise of NSCAT, after returning 9 months of data. SeaWinds was launched on NASA Mission QuikSCAT in June 1999. SeaWinds uses pencil-beam antennas in a conical scan, measuring horizontal polarized backscatter at 46° and 54° incident angles for horizontal vertical polarized backscatter respectively. SeaWinds has a continuous 1,800-km swath and covers 93% of the global ocean in a single day with the capability of producing wind vector at 12.5-km spatial resolution. An identical SeaWinds instrument will be launched on the Japanese spacecraft ADEOS-2 in February 2002. Fig 1. Compares the daily coverage of NSCAT and SeaWinds with those European scatterometers, ERS 2, and the improvement is obvious. The ERS scatterometers covers less than 50% of the global ocean daily with 50 km spatial resolution between 1992 and 2000.

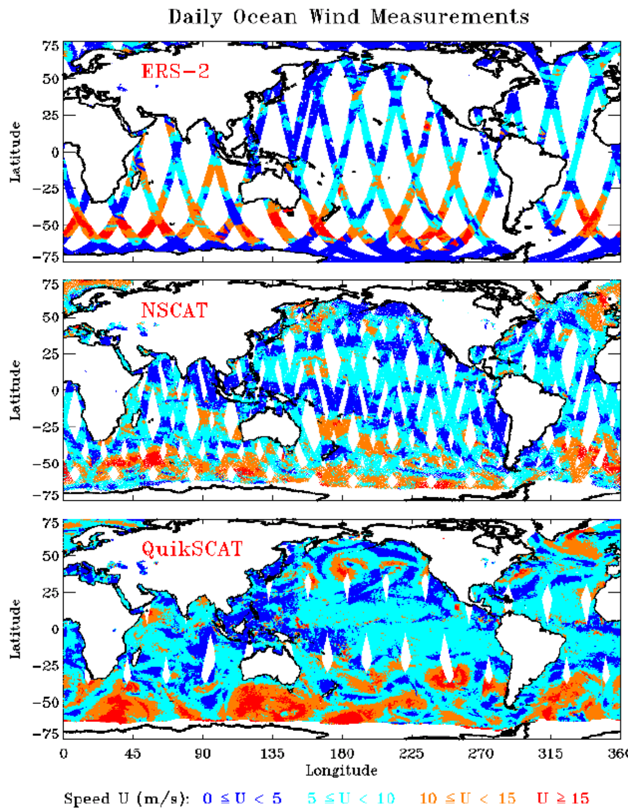

Fig. 1 Typical daily coverage by the scatterometer on ERS-2 (upper), NSCAT (center) and QuikSCAT (lower).

GLOBAL COVERAGE AND DETAILED STRUCTURE

The improved coverage and resolution of SeaWinds allow the study of small weather systems like hurricane that no NWP products can do [1]. Fig. 2, shows that QuikSCAT's

12.5-km spatial resolution allows the delineation of surface wind convergence associated with the multiple rain bands of Hurricane Floyd. It also shows that the winds from the Eta model is not even close to being able to resolve such rain bands. Eta is a regional NWP model producing operational wind products with the highest available spatial resolution (40-km). The standard products of SeaWinds, at 25 km resolution, similar to the resolution of NSCAT, show improvement over Eta products but is still insufficient to resolve the rainbands. Wind convergence is important because it feeds water vapor to the hurricane; as the water vapor rises, it condenses, releases latent heat, and fuels the hurricane.

SeaWinds detected close-circulation with intensity meeting the criteria of tropical depression long before their identifications by the National Hurricane Center (NHC) [2]. In the case of Hurricane Floyd, NHC declared her as a tropical depression on 7 September 1999, east of the West Indies. However, SeaWinds data were able to track the surface wind vortex all the way back to the African coast on 2 September 1999 [3]. The detection of surface vortices that lead to formation of tropical cyclones, with no clear signatures in clouds, is causing the re-examinations of old hypothesis on the generation and maintenance of the storms.

The fine resolution and improved coverage of SeaWinds data also reveal the atmospheric manifestation of the eastward-propagating tropical instability waves in the equatorial Pacific [4]. SeaWinds also reveals for the first time a pattern composed of alternate high and low winds streaks and lines of positive and negative curl of wind stress; they stretch a few thousand kilometers from the west side of the Hawaii Islands to beyond Wake Islands in the western Pacific. The positive feedback between the ocean and the atmosphere in maintaining these features is being studied with the help of a combination of spacebased data [5].

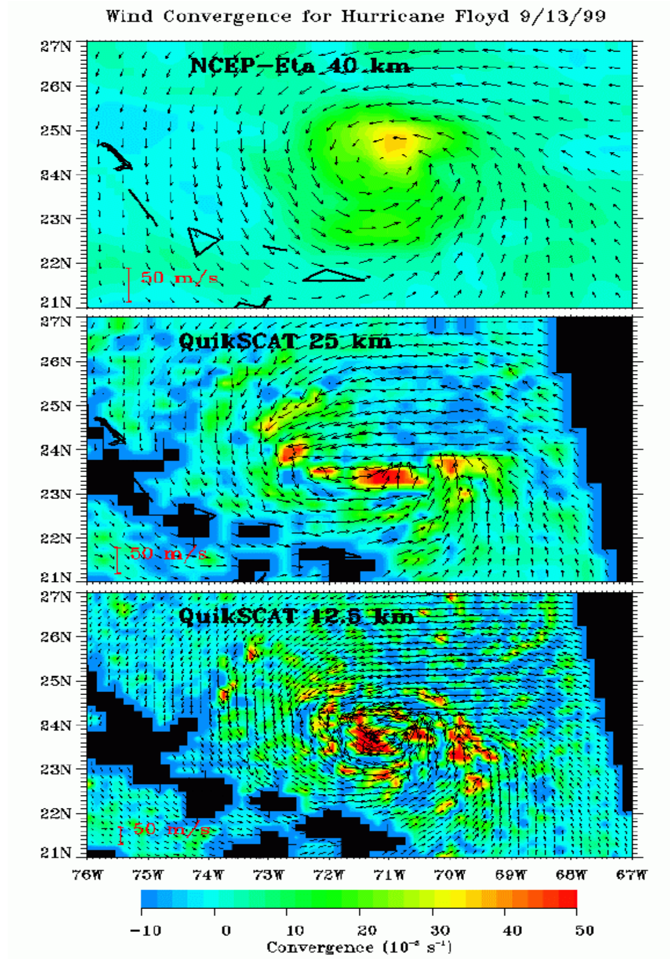

Fig. 2 Ocean surface wind vectors (black arrows) superimposed on wind convergence (color image) over Hurrican Floyd at three spatial resolutions.

FUTURE PLAN

All wind retrieval from past and present scatterometers suffers, at various degrees, ambiguities in wind direction because of the sinusoidal relationship between the backscatter and wind direction. To mitigate the problem, radar measurements of the same area are made in different azimuth angles (angles between the wind and radar beam). Although SeaWinds has a continuous scan, the azimuth angles are too close together at the outer swath and too far apart near nadir, hampering selection of correct wind direction. Wind fields from operational NWP have usually been used as initial field for the iterative direction-choosing procedures (nudging). The dependence of retrieved wind directional error on the nudging fields (however unlikely) has yet to be vigorously examined. Rain drops in the atmosphere cause attenuation of backscatter return, and they also distort the ocean surface. Due the insufficient validation data, the relation between backscatter and wind vector under heavy precipitation is less well established.

As described by Tsai et al. [6], slight modification of the SeaWinds to receive cross-polarized backscatter, in addition to co-polarized ones will provide polarimetric capability that theoretically will eliminate the directional ambiguitiy problem. Wind vectors can then be retrieved with uniform accuracy across the swath independent of nudging wind field. Polarimetric scatterometry also has the potential of separating the rain effect in the atmosphere from that at the ocean surface, allowing improved wind retrieval under rainy condition. It also does not require full circular scan and may ease the accommodation requirement on operational spacecraft. A polarimetric scatterometer is being proposed by the U.S to fly on the Japanes spacecraft GCOM, to assure continuous high resolution and wide coverage of ocean surface winds.

While we strive to preserve the continuity of wind vector measurements, infusion of new technology is clearly needed to improve the measurements for extended applications and for easier accommodation on operational spacecraft. The scientific need and technology to provide sufficient measurements of ocean surface winds have been demonstrated, but inter-agency and international cooperation still have to be nurtured, and programmatic acumen and political will still must be nourished for success.

ACKNOWLEDGMENT

This study was performed at the Jet Propulsion Laboratory (JPL), California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA). It was jointly supported by the Physical Oceanography Program and the QuikSCAT Project of NASA. On-line access of scatterometers data are provided at http://airsea-www.jpl.nasa.gov.

REFERENCES

[1] Liu, W.T., H. Hu, and S. Yueh, 2000a: Interplay between wind and rain observed in Hurricane Floyd. *Eos, Trans. of AGU*, **81**,253 & 257.

[2] Katsaros, K.B., E.B.Forde, P. Chang, and W.T. Liu, 2001: QuikSCAT facilitates early identification of tropical depressions in 1999 hurricane season. *Geophys. Res. Lett*., **28**, 1043-1046.

[3] Liu, W.T., and H. Hu, 2000: Spacebased Scatterometer in Studies of Tropical Cyclones in the Past Two Decades. Presented at the Fall 2000 Meeting of the Amer. Geophys. Union at San Francisco.

[4] Liu, W.T., X. Xie, P.S. Polito, S. Xie, and H. Hashizume, 2000b: Atmosphere manifestation of tropical instability waves observed by QuikSCAT and Tropical Rain Measuring Missions. *Geophys. Res. Lett*., **27**, 2545-2548.

[5] Xie, S.-P., W.T. Liu, Q. Liu, M. Nionaka, 2001: Far-reaching effects of the Hawaiian islands on the Pacific ocean-atmosphere, Science, submitted.

[6] Tsai, W.-Y., S. Nghiem, J. Huddleston, M. Spencer, B. Stiles and R. West, 2000: Polarimetric Scatterometr: A Promising Technique for Improving Ocean Surface Wind Measurements from Sapce, IEEE Transactions on Geoscience and Remote Sensing, Vol. 38, No. 4, pp 1903-1921.