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Air-sea Interaction with Multiple Sensors – Seasat Legacy

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Abstract—**By flying a number of ocean observing sensors together, Seasat demonstrated potential of not only sensor synergism, but also science synergism, which has illuminated the path of spacebased air-sea interaction studies in more than two decades since its demise. Two topics - El Nino and tropical cyclone, are discussed as examples of the science synergism inspired by Seasat.**

Keywords-air-sea-interaction; hurricane; El-Nino; Kelvin waves; rain; wind

I. INTRODUCTION

Seasat is a proof-of-concept mission for a few microwave sensors in measuring a number of ocean parameters. The sensors include a radar altimeter, synthetic aperture radar, a wind scatterometer, and a scanning multi-channel microwave radiometer. They were used to measure vector wind, dynamic topography, sea surface temperature, atmospheric water, internal waves and sea ice features. The applications of these sensors are reviewed by Stewart [10] and Katsaros and Brown [1]. Besides showing the capability of each sensor, an important legacy is the concept that flying all these instruments together has more scientific benefit than flying each sensor individually.

The moisture and rain measured by the microwave radiometer provide correction for both the retrieval of wind and dynamic topography by the scatterometer and the altimeter [5,9,11]. Seasat demonstrated not only the sensor synergism, but also potential science synergism, which has illuminated the path for spacebased air-sea interaction studies in the two and a half decades since that time. Two topics – El Nino and tropical cyclones are discussed as examples.

II. EL NINO

The El Nino Southern Oscillation (ENSO), a major interannual climate signal with strong economic and ecological impacts, has provided fertile ground for synergistic application. Liu [3,4] used microwave radiometer on Nimbus-7 to visualize, for the first time, the major dislocation of atmospheric and

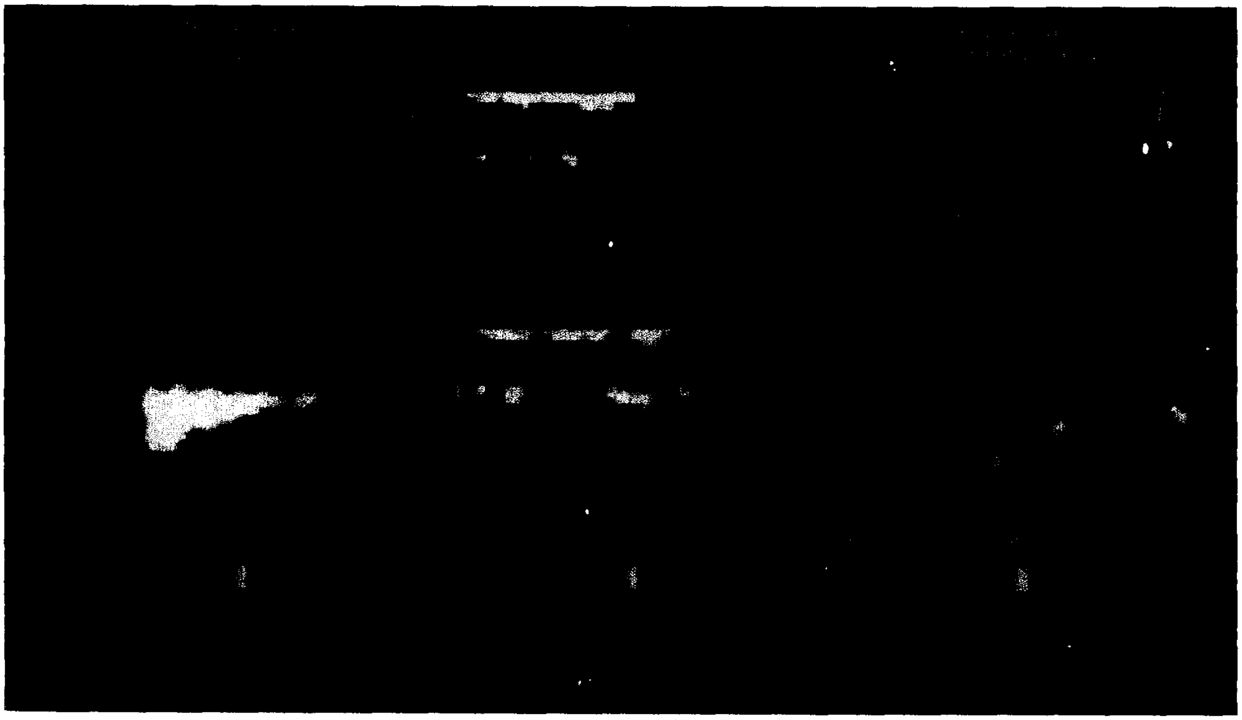

Figure 1. Distribution of (from left to right) precipitable water, surface wind speed, and sea surface temperature derived from Nimbus/SMMR observations. In the upper row are the averages of 1980 and 1981 for a calendar month and in the lower row are the distributions during ENSO.

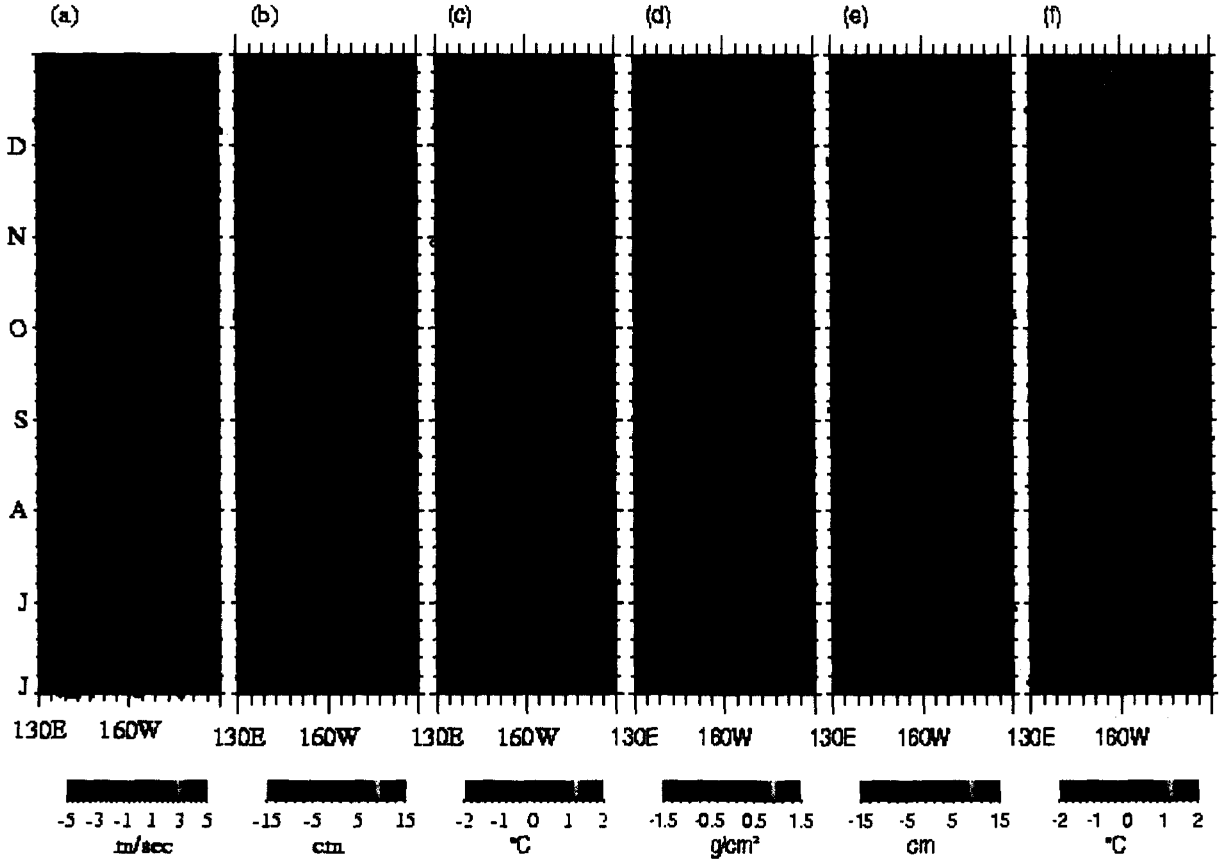

Figure 2. Time-longitude variation, along the equator, of the 1994-1993 difference in a) zonal wind component, b) sea level, c) sea surface temperature, and d) atmospheric water vapor, as derived from space-based observations and corresponding simulation of sea level e) and sea surface temperature f) by the Modular Ocean Model developed at the Geophysical Fluid Dynamics Laboratory [Bryan and Cox, 1972] when forced by realistic wind. The vertical axis represents the calendar months from June to December. The horizontal axis represents longitude, running from Indonesia across the Pacific to the Galapagos Islands. The zonal wind component is derived from observations by the microwave scatterometer on the European spacecraft ERS-1 [Freilich et al., 1993]. The sea surface height is derived from the observations by the microwave altimeter on the joint U.S.-French TOPEX/Poseidon Mission [Fu et al., 1995]. The sea surface temperature is produced through optimal interpolation of data from the advanced very high resolution radiometer blended with in situ data [Reynolds and Smith, 1994]. The atmospheric integrated water vapor is derived from observations by the special sensor microwave imager [Alishouse et al., 1990].

oceanic systems during the 1993 ENSO event. Fig. 1, produced right after the 1993 ENSO and discussed in [4], shows the displacement of the deep convection, represents by high precipitable water and surface wind convergence, in the west and central equatorial Pacific, and the suppression of the equatorial and coastal upwelling, indicated by higher sea surface temperature in the east.

Fig 2 is a good demonstration of synergistic application of the three sensors by Liu et al. [6]. The intraseasonal westerly wind anomalies measured by the scatterometer are connected to the propagation of Kelvin waves across the Pacific measured by the altimeter, the subsequent increase in convective activities implied by the increase in precipitable water measured by microwave radiometer, and the warming in the eastern Pacific.

III. Tropical Cyclone

Tropical Cyclones are devastating when they are accompanied by strong winds and heavy rain. The coincident measurement of wind vector by the scatterometer and rain by microwave radiometer may reveal the interplay between the dynamics and the hydrologic balances of the storm. When applied to Hurricane Floyd, the high spatial resolution of ocean surface winds measured by QuikSCAT improves computation of the moisture transport, the vertical profiles of moisture sink and diabatic heating, and the difference between evaporation and rain-rate at the surface [8]. The close relationship between the dynamic and hydrologic parameters is visible in Fig. 3 as hurricane Floyd approaches the Bahamas on September 13, 1999. Surface winds feeds moisture into the hurricane. The moisture turns into rain, releases latent heat, and fuels the storm.

We understand relatively little about the extra tropical transition of tropical cyclones because of the complex thermodynamics involved, but we know that the mid-latitude storms resulting from tropical cyclones usually generate strong winds and heavy precipitation. The transition occurs over the busiest trans-ocean shipping lanes, and when the resulting storms hit land, they usually devastate populated areas. Liu et al. [7] studied the extra tropical transition of two typhoons by combining the surface winds from the scatterometer, NSCAT, and the precipitable water from the microwave radiometer,

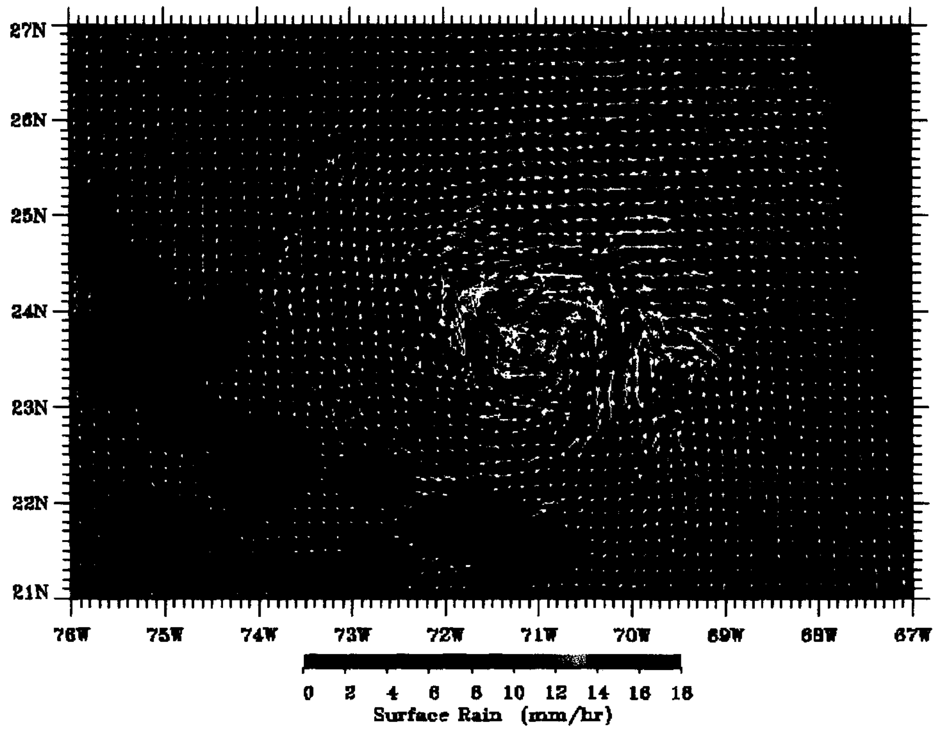

Figure 3. Hurricane Floyd is revealed by wind vectors (white arrows) from SeaWinds and surface precipitation (color image) from the microwave imager on September 13, 1999, along the ground-tracks of QuikSCAT and TRMM, which are approximately 78 minutes apart.

SSM/I. Katsaros et al. [2] gave a review of the study of tropical cyclone using spacebased data.

IV. Conclusion

With the help of the microwave radiometer, ocean surface evaporative cooling and rainfall can be estimated, providing the major components of thermal and hydrologic forcing of the ocean [4]. Together with wind stress measured by scatterometer, the major components of ocean-atmosphere exchanges can be estimated. The altimeter measures the dynamic responses of the ocean as manifested through sea level changes, and the microwave radiometer measures sea surface temperature under both clear and cloudy conditions, which is the surface signature of ocean thermal response to surface forcing. The optimistic hope of science synergism in Seasat time was finally realized; the whole is more valuable than the sum of individual parts.

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