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Winds Over Ocean

Wind Speed (km/hr)

54 km/hr

0   36   72
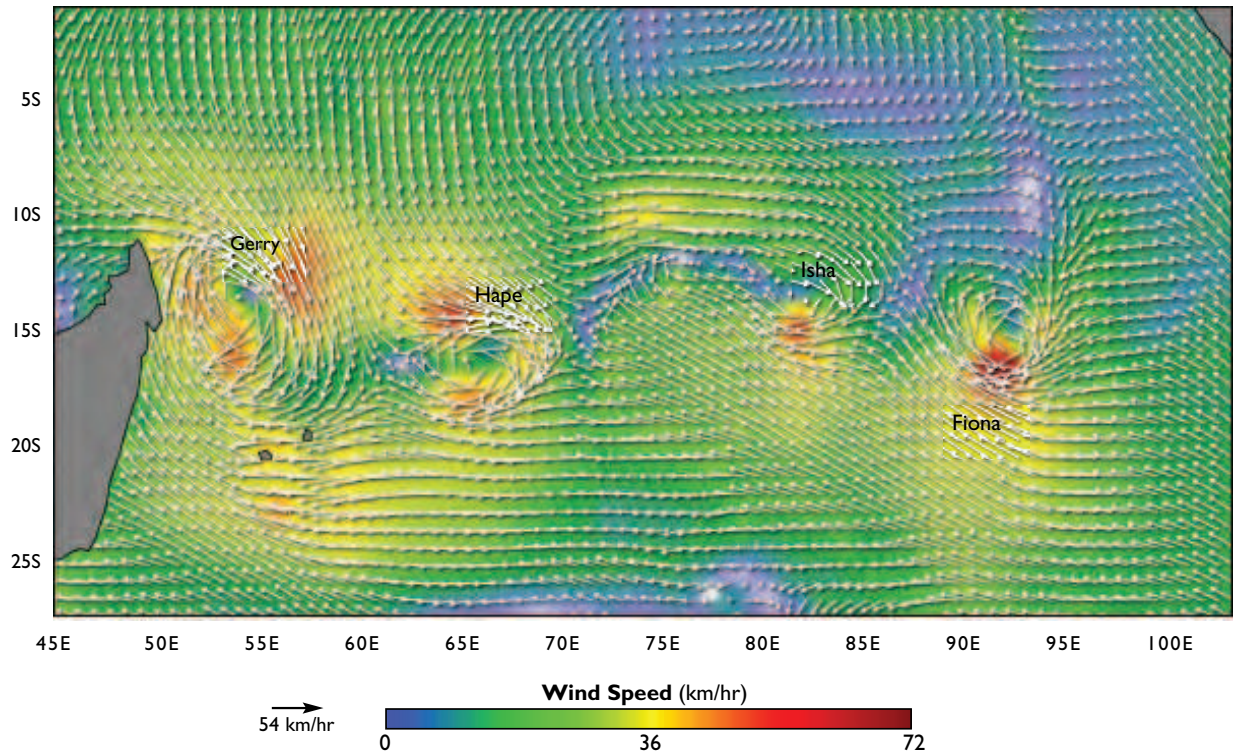
The direction of the wind (white arrows) is superimposed on a color map of wind speed, as measured by scatterometers on United States satellite QuikSCAT and the Japanese Advanced Earth Observing Satellite-2 (ADEOS-2) on February 11, 2003. The figure demonstrates the details of four tropical cyclones revealed by scatterometer winds and good coverage afforded by two scattermeters flying in tandem.

Sailors understand both the importance and the difficulty in getting information on wind over oceans. Textbooks still describe global ocean wind distribution in sailor's terms: doldrums, horse-latitude, trade-wind, and roaring forties. Just a decade ago, almost all ocean wind measurements came from merchant ships and there is no wind measurement in most part of the ocean, particularly under stormy conditions. Even today, the ability to predict weather accurately by computer models is limited not only by our knowledge of the physical processes, but even more so, by the availability of measurements, such as the winds over ocean.

Spaceborne microwave scatterometers are the proven instruments of measuring ocean surface wind vector (both speed and direction) under clear and cloudy conditions, day and night. They give not only a near-synoptic global view, but also details not yet possible using weather prediction models. The coverage and details are illustrated by the four tropical cyclones that were observed in the same time, by two different scatterometers flying in tandem, as depicted above. Data from the scatterometer on QuikSCAT have been routinely assimilated in operational numerical weather prediction in the major centers of the world, and incorporated in the operational analyses by marine weather warning and forecast centers. Spacebased measurements of wind over ocean have made significant impact in weather forecast and are also used in many weather related research.
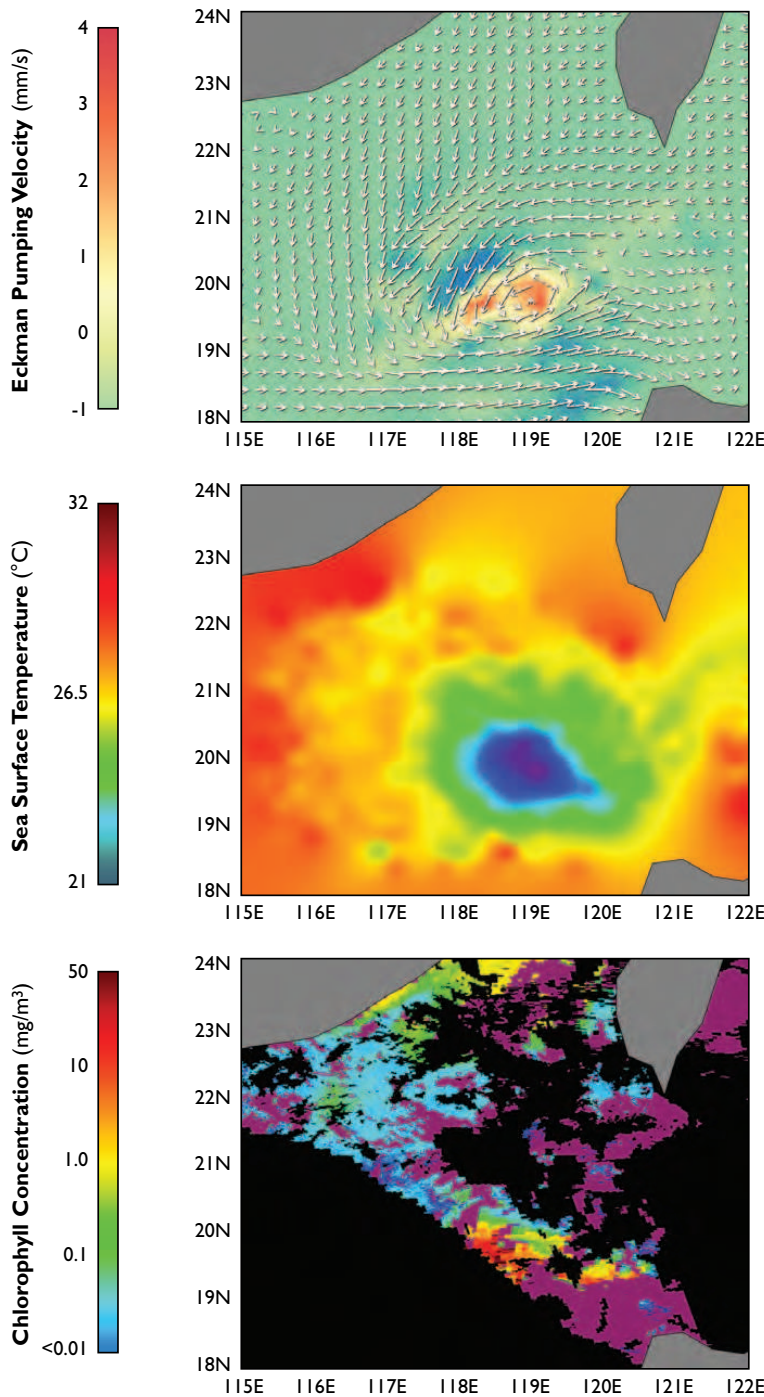
Effects of Typhoon Kai-Tak as: (top) wind vector (white arrows), measured by QuikSCAT, superimposed on the color image of Ekman pumping velocity on July 6, 2000; (middle) sea surface temperature observed by Tropical Rain Measuring Mission Microwave Radiometer (TRMM) on July 9, 2000; and (bottom) composite map of ocean color observed by SeaWiFS on July 12–15, 2000. Wind-driven ocean mixing and upwelling induce dramatic cooling and biological productivity; they have significant effect of the annual primary carbon productivity.

Besides helping us to monitor and predict weather systems, winds measured by the scatterometer are critical to characterize, understand, and predict climate changes. Ocean is the largest reservoir of heat, water, and carbon on Earth, and the redistribution of these quantities through time and space modifies Earth's climate. Wind stress is the single largest source of momentum and energy to the upper ocean. A two-dimensional wind vector field is needed to compute the wind divergence and rotation that control the vertical mixing in the ocean; the
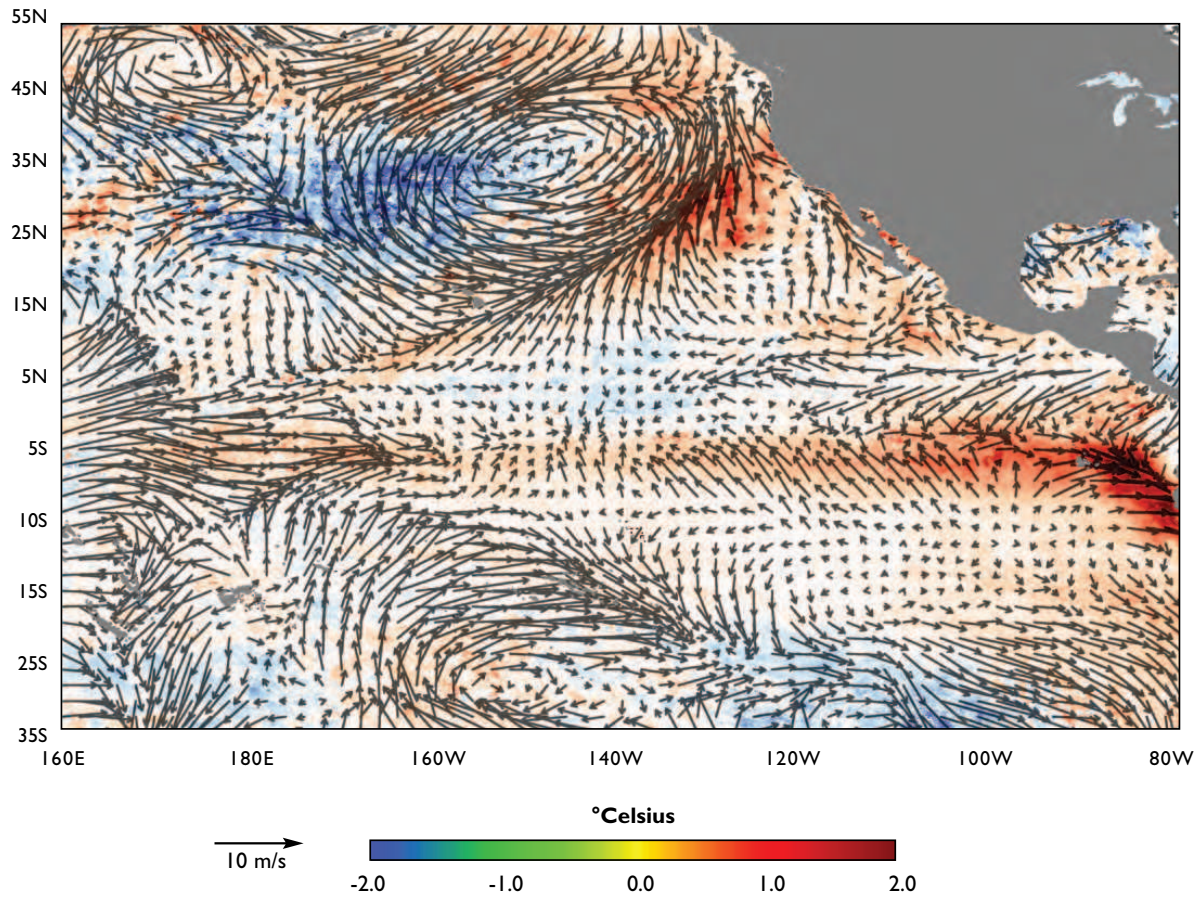
Wind vectors measured by the NASA Scatterometer represented by white arrows are superimposed on the map of sea surface temperature measured by the Advanced Very High Resolution Radiometer (AVHRR). The data are averaged over the last week of May in 1997, with the long term mean seasonal cycle removed. The figure shows that surface winds are related to the interannual ocean warming during an El Niño and the shifting of decadal temperature dipole in the mid-latitude.

mixing brings short-term momentum and heat trapped in the surface mixed layer into the deep ocean where they are stored over time, and brings nutrients stored in the deep ocean to the surface where there is sufficient light for photosynthesis. Through photosynthesis, carbon dioxide is transformed into organic compounds. The biological productivity may mitigate the greenhouse warming by absorbing carbon dioxide from the atmosphere and offsetting its increase emission from burning of fossil fuels. The stored heat and carbon in the ocean are distributed by horizontal currents, which are driven in part by winds. By moving heat from the warm tropical oceans to the cold high-latitude oceans, the wind-driven currents make Earth a more comfortable habitat.

The effect of wind on ocean heat and carbon storage was clearly demonstrated by Dr. I-I Lin and her collaborators, in their study of Typhoon Kai-Tak. They computed strong upwelling velocity stirred up by the counterclockwise spinning winds of the typhoon measured by the scatterometer on QuikSCAT, as the typhoon lingered over the South China Sea on July 6, 2000. In the aftermath, the sea surface temperature dropped by 9° Celsius. Cold water drawn up by the spinning of the winds caused the intense cooling. A few days after the typhoon had moved on, another satellite sensor began to measure a dramatic change in the ocean color, inferring 300-fold increase in phytoplankton. The nutrient rich water from the deeper part of the ocean sparked massive biological bloom, which provides important food source for marine life and was shown to have a significant effect on the carbon cycle.

The atmosphere and the ocean are turbulent fluids; processes at one scale affect processes at other scales. Adequate observations at significant temporal and spatial scales can only be achieved from the vantage point of space. The multiscale interaction connected by surface winds is illustrated in Figure 3. The westerly wind events at the equatorial western Pacific have a time scales of a few days to a week, but are shown to be associated with the collapse of the trade winds (steady winds from east to west in the tropical oceans) and the El Niño (equatorial warming in the Pacific), which occurs every few years. The westerly winds are shown to be connected to the 'Pineapple Express', the winds that transport moist and warm air from the tropical ocean, through Hawaii, to the west coast of the United States. This branch of the winds is associated with the displacement of a counterclockwise wind circulation during the El Niño episode, which in turn, shifted a warm-cold temperature dipole in the ocean. This ocean dipole had been present in the North Pacific for almost a decade. The approach of warm water induced severe ecological changes at the coast.

Ocean surface wind vectors are essential in monitoring and understanding ocean's influence on the water cycle over land and ice. The methodology of estimating the advection of moisture over the depth of the atmosphere using wind vectors measured by scatterometer and water vapor measured by microwave radiometer has been established and validated. The strong coherence of the precipitation in the eastern Amazon and the moisture advected across the Atlantic coastal line of South America is clearly evidented in the graph below over the time scales from 30 to 60 days.

We usually take wind information for granted because they are common in daily weather reports. When a hurricane suddenly intensifies and changes course, when a delay of onset of monsoon causes drought, and when an El Niño breaks out with the unexpected collapse of trade winds, we then remember the importance of continuous measurements of high quality winds over the ocean. By preserving and extending time series of spacebased wind measurement, without sacrificing their research quality, while infusing new technology for improved and expanded applications, we may be able to achieve the routine needs of operational weather forecast, encouraging new and enabling technology, and advancing scientific investigation in climate and environment changes all at the same time.
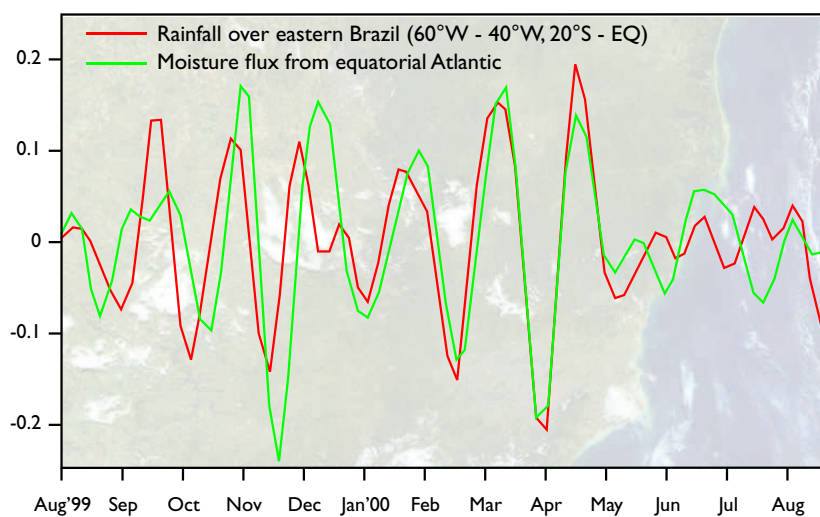
Comparison of rainfall measured by TRMM averaged over a region in the eastern Brazil (red line) and the moisture advection across the Atlantic coast of Brazil derived from QuikSCAT wind and TRMM water vapor (green line), at intraseasonal time scales (the time series was bandpassed through a 30–60 day filter).