Ocean Upwelling Slows Wind Jet off Africa's Coast

Each April residents of Socotra Island in the Arabian Sea are busy fetching food and other supplies from the mainland to prepare for the southwest monsoon that will prevent them from navigating safely for the whole summer. Off the coast of Somalia, near-gale winds start blowing steadily in the second half of May, often at speeds above 15 m/s. This wind jet, the Findlater Jet, is part of the planetary-scale South Asian summer monsoon system. Steered by the coastal mountains of Africa, the Findlater Jet has been seen as a broad and smooth jet, but new satellite observations reveal it is strongly modulated by sea surface features a few to several hundred kilometers in size (Figure 1). These new results are reported in recent articles by **Shang-Ping Xie** (International Pacific Research Center) and his collaborators, **Gabriel Vecchi** (Princeton University), and **Albert Fischer** (Université Pierre et Marie Curie), who used observations by NASA's QuikSCAT, the joint US–Japan Tropical Rain Measuring Mission (TRMM), and the joint US–France TOPEX/Poseidon satellites.

The southwest monsoon wind jet drives near-surface offshore Ekman transport, forcing cold and nutrient-rich water to rise from depth off the coast of Somalia and Arabia. This upwelling fertilizes the western Arabian Sea just off the barren desert, making it one of the most productive oceans in the world. The highly variable coastal upwelling includes cold filaments or patches formed by nearly stationary ocean eddies (Figure 2).

In response to the monsoon and its general downward Ekman pumping over a large portion of the Arabian Sea, the Somali Current becomes an intense western boundary current. Figure 2 (left panel) shows the averaged mid-summer sea surface height based on satellite observations, superimposed on sea surface temperature (SST). After the Somali Current leaves the coast south of Socotra Island around 9–10°N, it breaks into several nearly stationary anticyclonic eddies. The eddy off the Somali coast is known as the Great Whirl (I). Northeast, centered at 57°E, 9°N, the sea surface height map has another eddy-like structure (II), visible on a 10-year averaged field. A third anticyclonic eddy appears yet further to the east. The eddies shape the Somali upwelling into two nearly stationary cold filaments or wedges. Near the coast, the intense upwelling keeps the water below 20°C. The Great Whirl draws this cold coastal water offshore, first eastward and then southward. Eddy II generates a secondary cold wedge on its eastern flank.

These cold wedges are associated with marked changes in the surface wind, disrupting the Findlater Jet in its path: Wind speeds are less than 10 m/s over the cold filament south of Socotra but increase to 15 m/s over the warm water east of the island (Figure 1 inset). This surprising covariation between SST and wind is another example of the recent discovery by Xie and his colleagues at IPRC and elsewhere, that SSTs and winds correlate positively in regions of cold-warm ocean fronts. This ubiquitous feature of air-sea interaction near major ocean currents is probably due to SST modulation of atmospheric static stability and vertical wind shear: When wind blows over cold ocean surfaces, the atmosphere becomes stably stratified, preventing the mixing with faster winds from aloft and slowing down the surface wind. Indeed, a research cruise in the western Arabian Sea noted such increased atmospheric stability and suppressed surface turbulent heat flux over a cold filament.

The SST-induced mesoscale features in the wind field create strong Ekman pumping (Figure 2, right panel). A wind curl pattern favoring downwelling tends to be on the windward side, while an upwelling favorable curl pattern, on the leeward side of the mainly north-south oriented cold filaments. Ekman pumping velocity associated with these wind patterns is 1 m/day, large enough to modify the thermocline topography substantially in a month, the lifetime of these ocean eddies. (The thermocline perturbation associated with the Great Whirl is about 60 m.)

Since the intense Somali current and the Great Whirl are known to result from the basin-scale wind structure, attention has focused on ocean processes in understanding the evolution of the eddy features. The present study shows, however, that the eddies affect the regional wind, and this air-sea coupling may contribute to their evolution. Very likely, this wind pattern has also a significant impact on the local dynamics and marine ecosystem.

Xie, S.-P., 2004: Satellite observations of cool ocean-atmosphere interaction. *Bull. Amer. Meteor. Soc.*, **85**, 195–208.

Vecchi, G.A., S.-P. Xie, and A.S. Fischer, 2004: Ocean-atmosphere covariability in the western Arabian Sea. *J. Climate*, **17**, 1213–1224.

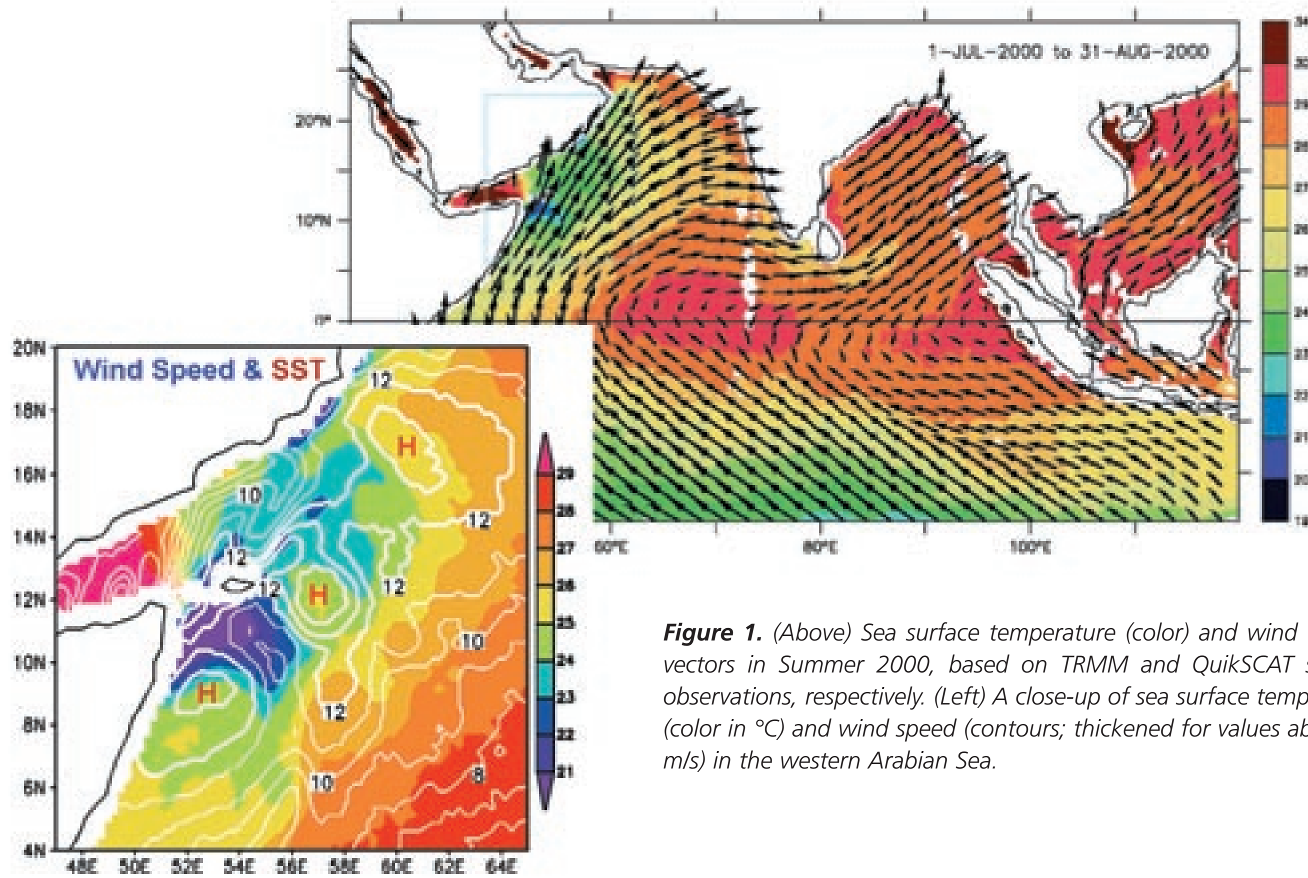

Figure 1. (Above) Sea surface temperature (color) and wind velocity vectors in Summer 2000, based on TRMM and QuikSCAT satellite observations, respectively. (Left) A close-up of sea surface temperature (color in °C) and wind speed (contours; thickened for values above 12 m/s) in the western Arabian Sea.

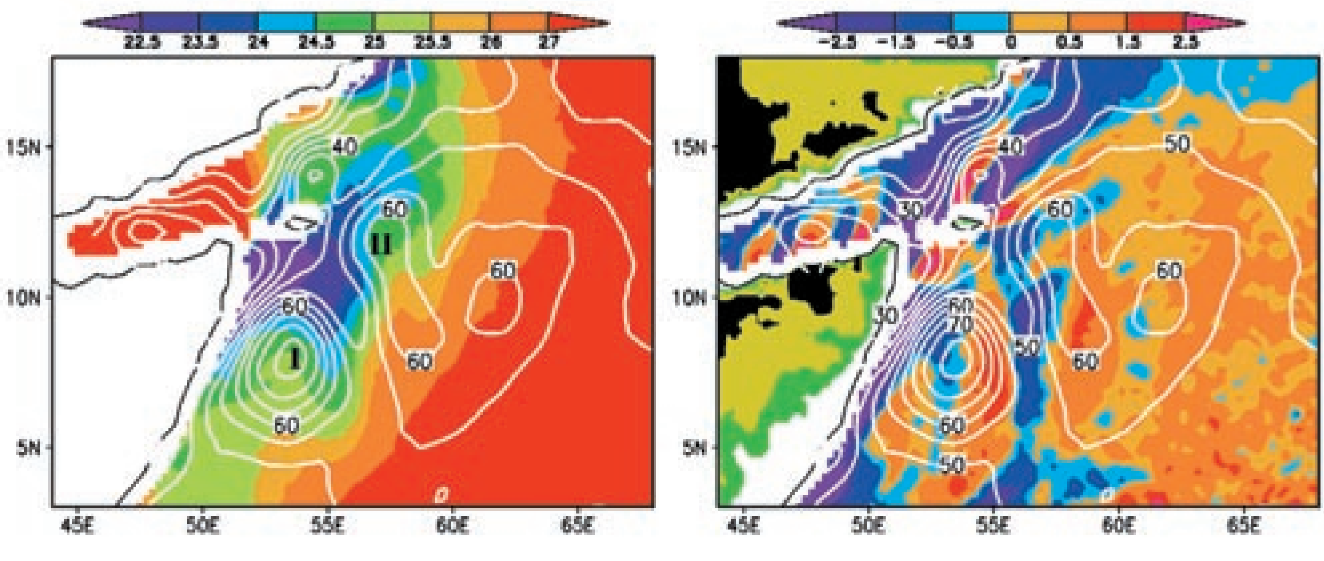

Figure 2. July climatology—sea surface height (contours in cm): - left - sea surface temperature (color); - right - Ekman pumping velocity (color in 10^{-5} m/s) and land topography (green > 250 m, grey > 500 m, and black > 1000 m). SSH based on satellite and in situ observations. SST and Ekman pumping based on TRMM and QuikSCAT observations, respectively.