Kuroshio's Surprising Effect on Winds

The Kuroshio Current of the western North Pacific carries large amounts of warm and salty tropical water northward at average speeds of over 1 m per second (over 2 miles per hour). In winter, when cold and dry continental air blows over this warm current, intense convection takes place in the ocean, and huge amounts of heat and moisture are released to the atmosphere. Because of this heat transport, the Kuroshio is an important element of the Pacific climate system. Furthermore, the strong subsurface fronts that form along the Kuroshio have been known as fertile fishing grounds to Japanese fishermen for generations. In fact, the name Kuroshio, which means the 'Black Current' in Japanese, tells us that ancient fishermen used its dark color to identify the current and its fertile temperature front.

It is well established that the Kuroshio is driven by the basin-scale wind system over the North Pacific. Now, **Masami Nonaka** and **Shang-Ping Xie** have detected that the Kuroshio, in turn, has a distinct effect on the winds. Taking advantage of new satellite microwave observations that can see through clouds, they have drawn a map detailing the structure of the surface winds and how they are associated with the Kuroshio. The Kuroshio's effect on the winds has not been observed before because sea-wind measurements in the past have had to rely on sparse ship-based observations.

In images of the sea surface taken by the Tropical Rain Measuring Mission (TRMM) satellite, the Kuroshio can now be easily tracked and appears as a band of warm water. Its influence on the winds is detected in the region south of Japan, where the current shifts between alongshore and offshore paths. In 1998, the Kuroshio took an alongshore path and the TRMM sea surface temperature (SST) image in Figure 1a shows the warm current hugging the south coast of Japan. In 2001, the Kuroshio was in an offshore path, and Figure 1b shows the warm band flowing away from the coast for as far as 400 km around 139˚E.

The TRMM wind-speed measurements reveal an association between wind speed and the Kuroshio: The region of maximum wind speed tends to follow the Kuroshio's path, remaining right on top of the warm current (Figures 1c and d). This tendency is especially clear in 2001 when the bands of maximum SST and wind speed are collocated off the coast from 135˚ to 140˚E. In contrast, wind speed is markedly reduced over the cold-water pool left behind by the Kuroshio's offshore meander between 136˚–140˚E. In addition, a local wind speed minimum can be seen in 2001 over a pinched-off cold ring centered at 145˚E, 34˚N.

This SST-wind coupling persists further east along the Kuroshio Extension, all the way to the international dateline. The white lines in the left panel of Figure 2 show the evolution of unusually warm current flows as they propagate westward from January 1998 to 2002; the white lines in the right panel show the regions of higher winds, which propagate westward along with the regions of higher SST.

The wind co-variations seem to result from an adjustment of vertical wind shear to changes in static stability of the atmosphere near the surface. Analysis of the Japan Meteorological Agency's buoy measurements east of Japan indicate that when the sea surface is anomalously warm, the near-surface atmosphere is more unstable than usual. This greater vertical mixing brings down the high winds from above (see p. 5 on the winds over the Yellow and China Seas). The wind-stress anomalies induced by the Kuroshio account for only 20-30% of the mean stress. Yet, because this strong current is so narrow, the effect on upwelling is large, impacting the circulation and the ecosystems significantly.

The positive SST-wind correlation over the Kuroshio Current and its extension is opposite to what is usually found in regions of weak currents, such as those south of the Aleutian low. There, the ocean responds to the atmosphere, the higher wind speeds cool the ocean surface.

Whether and how the atmosphere reacts to changes in extratropical sea surface temperature has been under intense debate, and this missing piece has been a major obstacle in understanding how climate varies. This study establishes beyond a doubt that the ocean can significantly influence the atmosphere and the winds in the extratropics. The implication of this new evidence for climate modeling is far-reaching.

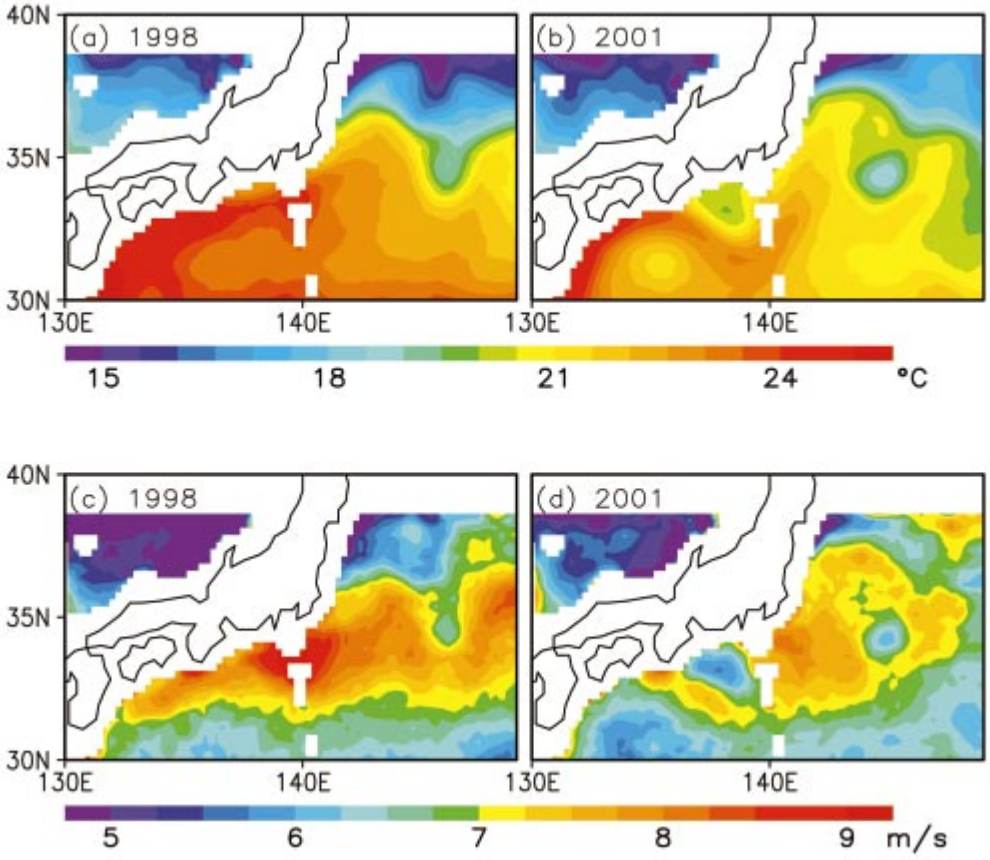

Figure 1: *April to June mean fields in SST and surface wind speed for 1998 (panels a and c) and for 2001 (panels b and d) based on TRMM Microwave Imager data sets. The shift between Kuroshio's straight (panel a) and meandering path (panel b) is accompanied by large differences in SST. The high wind speed over the straight warm SST path is markedly reduced when the warm water is replaced by cool water in the meandering path.*

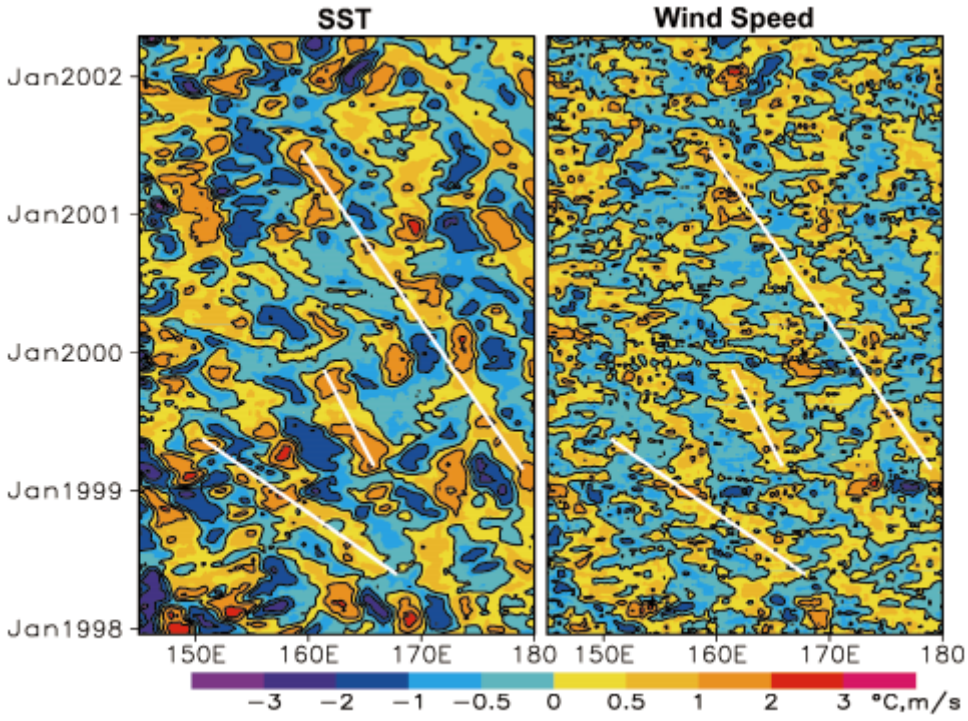

Figure 2: *Longitude-time sections of high-pass zonally filtered SST (left panel) and surface wind speed along 35°N (right panel), smoothed with a 3-week running-mean filter. For both SST and wind speed, weekly TRMM Microwave Imager datasets were used. Contour intervals for SST and for wind speed are 1°C and 1 m/s, respectively. Constant phase lines are plotted in white to facilitate comparison between the panels.*