Mapping High Sea Winds from Space

Wouldn't maps be useful that show where gales are common over the ocean? They would come in handy, for instance, for setting shipping routes, selecting oil rig placements, planning wind farms, or preventing coastal erosion. Such maps, however, have not been available because ships try to avoid places where they expect to hit high winds. The coming of satellites carrying scatterometers that scan surface winds uniformly over the ocean now makes the systematic observation of winds over the ocean possible without any danger. IPRC postdoctoral fellow **Takeaki Sampe** and research team leader **Shang-Ping Xie** have taken advantage of this new data to create such wind-frequency maps.[1]

Sampe and Xie examined the twice-daily data relayed by the NASA QuikSCAT satellite from September 1999 to August 2006. After removing rain-flagged data, they counted the number of observations with wind speeds greater than 20 m/s (40 knots or about 46 mph) for each calendar month at each grid point, and then determined for each grid point the percentage of the total valid observations that the wind speed was greater than 40 knots. With these percentages, they then created a monthly climatology of the frequency of high sea winds over the open ocean. This climatology is available as world maps at http://iprc.soest.hawaii.edu/~takeaki/highwind/. Figure 1 shows the maps for the December–February, and July–August periods.

Although typhoons and hurricanes are the most powerful storms on Earth, the maps show hardly any region in the Tropics where high winds occur more frequently than 1% of the time. The exception is east of Taiwan in summer, where the presence of tropical cyclones raises the frequency to 2–3%.

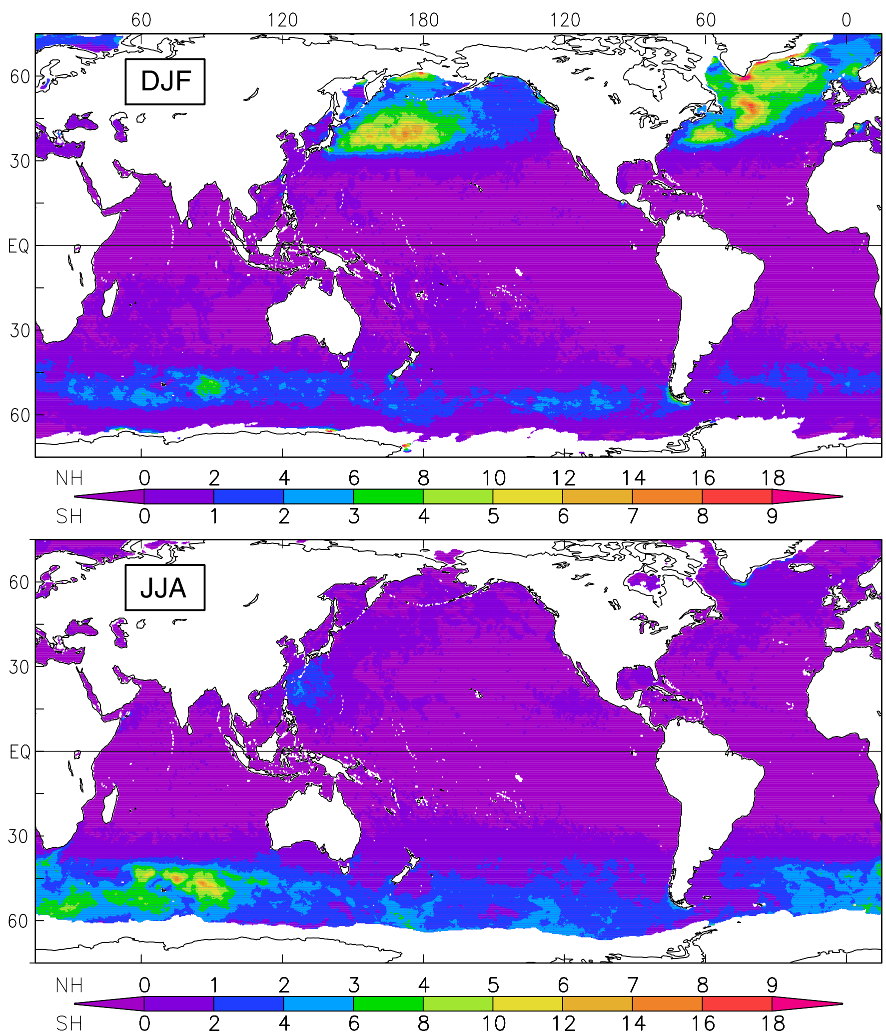

Figure 1. December–February (top) and June–August (bottom) climatology of the frequency of high-wind (>20 m/s) occurrence (%) based on QuikSCAT observations. Different color scales are used, with a reduction by a factor of 2 for the summer hemisphere. (Adapted from Sampe and Xie, 2007: Mapping high sea winds from space: A global climatology. *BAMS.*, 88 (12), 1965–1978.)

In contrast, at midlatitudes in both hemispheres, storms leave a strong signature in the monthly satellite images. Occurring more frequently during winter when north–south SST gradients are large, midlatitude storms are organized into storm tracks. In the Southern Hemisphere, the summer storm tracks remain vigorous enough to maintain a band of high winds, making the summer–winter seasonal differences less than in the Northern Hemisphere.

There are two further remarkable features in these maps. High sea winds are seen most frequently either over small-scale, but sharp ocean sea-surface temperature (SST) gradients or they are linked to orographic features. This occurs in the Atlantic, the Pacific, and the Southern Ocean.

Take the North Atlantic (Figure 2). Embedded in the broad winter storm track are smaller regions of frequent high sea winds. Bands of strong winds are found particularly frequently over the southern, warm flank of the Gulf Stream. In the midst of the stormy North Atlantic, however, is a calm spot southeast of Newfoundland, where cold waters border the warm current. During winter, this calm region registers winds above 40 knots only 2% of the time, whereas a few hundred miles away on a warm meander of the Gulf Stream, the frequency shoots up eightfold to 16%. The transition between calm and strong winds is sometimes so sharp that the front appears as a line visibly separating calm water on the colder flank and white caps on the warmer flank.

Photo courtesy of Takeaki Sampe

The powerful effect of orography is seen at Cape Farewell in Greenland. This is the place visited most often by strong winds. It tops the windiest place on the yearly average, with sea winds over 40 knots more than 16% of the time; it also tops the winter list, with such winds blowing more than 25% of the time. Indeed, where tall coastlines or where high mountains meet the ocean, winds often accelerate. Such regions are responsible for half of the top 10 entries in the wind maps of Sampe and Xie, and include such places as the Gulf of Lion, where the mistral shoots down from the Alps into the Mediterranean Sea.

In the North Pacific, high winds frequently occur in winter between 35°N–45°N over the western and central North Pacific, a region roughly corresponding to the North Pacific storm track and to the region of the largest meridional SST gradient in the North Pacific. The small-scale impact of the SST gradient on winds is not as evident as along the Gulf Stream, perhaps because the gradient is not as sharp as that created by the Gulf Stream.

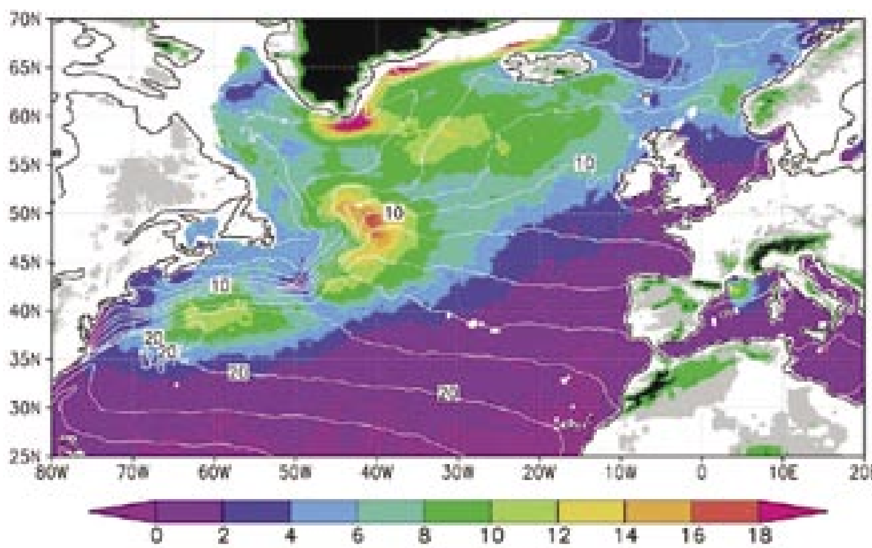

Figure 2. 2000–2006 QuikSCAT winter climatology of the frequency of winds higher than 20 m/s or 44 mph (color in %), and AVHRR sea surface temperature (white contours at intervals of 2°C). Topography higher than 500, 1000, and 1500 m is shown in gray, green, and black, respectively. (Adapted from Sampe and Xie, 2007: Mapping high sea winds from space: A global climatology. *BAMS*, **88**, 1965–1978.)

As in the Atlantic, orography is a major cause of high winds in the Pacific. For example, high winds are frequently observed south of Vladivostock, where the northwesterlies are forced through narrow mountain gaps; in the Taiwan Straits through which the northeasterly winter monsoon blows; and in the eastern Pacific, the Gulf of Tehuantepec, where the easterly trade winds shoot through a gap in the Sierra Madre.

In the Southern Hemisphere, once again gale winds blow most often over the warmer side of the Antarctic Circumpolar Current. The orographic impact on high winds is seen in several coastal regions, especially during austral winter, June–August, around Tasmania, the Cook Strait, and along the southern Chilean coast, with a maximum near Cape Horn.

Whether vertical mixing or pressure adjustments are the reason why high winds frequently occur near small-scale, but sharp SST gradients is still in debate. However, calculations over the Gulf Stream conducted by Minobe and his colleagues in the previous article suggest that surface wind convergences are closely related to Laplacian sea-level pressures.

The high-sea-wind-frequency maps generated by Sampe and Xie have both practical and scientific applications. Practical applications, as mentioned in the opening paragraph, are for such decision-making as oil-rig placement and ship-route planning. The maps could also come in handy for ships that want to avoid the brunt of a forecasted cyclone by steaming to nearby safer waters.

From a scientific point of view, high winds are important for Earth's climate. They draw tremendous heat out of the ocean, leaving behind cold, salty water that sinks to the bottom. The cold, salty water that sinks off the Greenland coast and that flowing out at the bottom of the Mediterranean are thought to be crucial for driving the deep global ocean circulation, the so-called conveyor belt. Changes in the strength and vigor of this conveyor belt have been implicated in the past in the sudden switch between colder and warmer climates, with temperature changes of up to 10°C over the North Atlantic and Europe.

Besides affecting heat flux and deep water formation, strong winds are important for air-sea gas exchange - including the greenhouse gas CO_2 - and ocean mixing. High winds, furthermore, spawn life by pumping up nutrients from ocean depths on which planktons feed. Finally, together with other recent work, the study shows the marked impact that sharp SST fronts can have on the atmosphere and climate.

As useful as these new high-wind-frequency maps are, the data from which they are derived still can use more precision. The current scatterometers do not measure accurately wind speeds above 60 mph and thus do not differentiate hurricanes according to category strength. The instruments do not see oceans within 25 km off the coast because of the scattering of radar waves by land surfaces. Xie and Sampe are looking forward to the next generation of scatterometers that will allow them to create maps with finer wind-speed gradations.

[1] T. Sampe and S.-P. Xie, 2007: Mapping high sea winds from space: A global climatology. ***BAMS***, **88**, 1965–1978.)

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