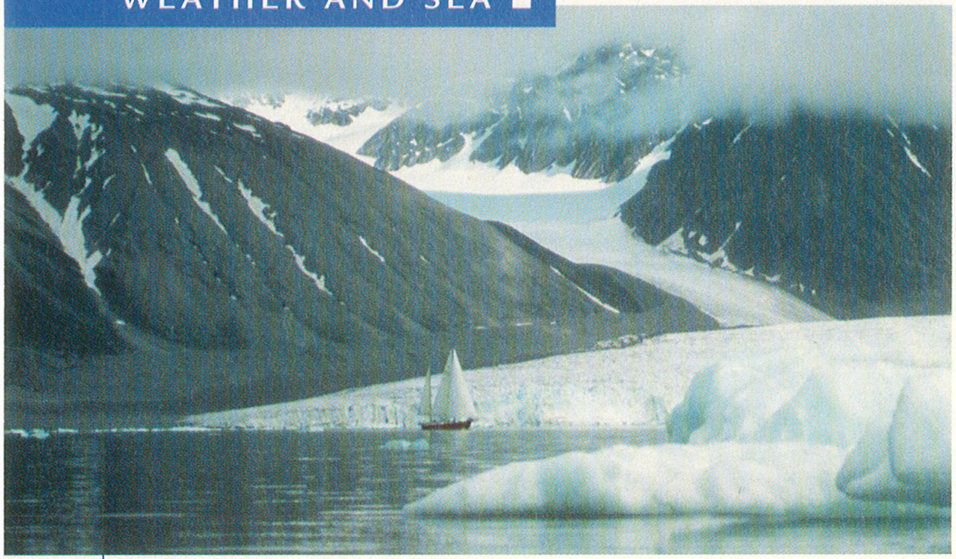


From the movement of ice packs in the Arctic came an understanding of why wind-driven currents don't follow the wind

BY BAYLOR FOX-KEMPER

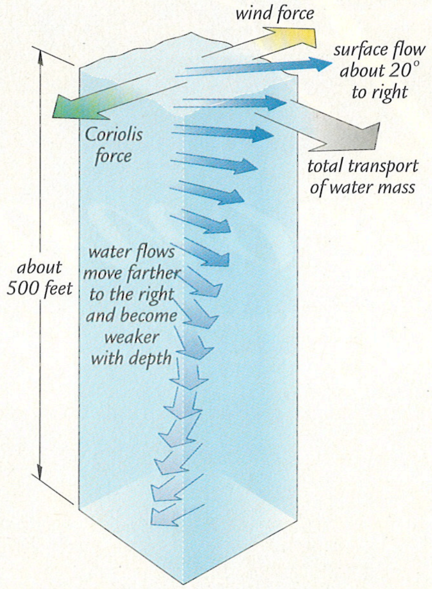
The Ekman current

The observations that led to the first mathematical theory in oceanography were made in 1893 by Norwegian explorer and scientist Fridtjof Nansen. Nansen sailed to the Arctic aboard the *Fram,* hoping to prove that there was water, not land, under the polar ice. During his three-year exploration, Nansen noticed that the floating ice packs and the ocean's surface current that carried them didn't move with the wind, but rather about 20 degrees to the right of the wind. Nansen suspected that the difference in direction resulted from the influence of the Coriolis force.

Coriolis and centrifugal forces are the two bookkeeping devices that account for the earth's rotation. Centrifugal force causes an object to be thrown outward from the center of rotation. The Coriolis force is subtler because it affects only objects that are in motion. Because of the earth's rotation, the Coriolis force pushes a moving object (in the Northern Hemisphere) to the right of its direction of motion. The faster the object moves, the more strongly it is pushed. In the Southern Hemisphere the Coriolis force pushes left.

Nansen observed that both the direction and the speed of the ocean current were constant; he concluded that the two external forces that affect that flow, the Coriolis force and the force of the wind on the ocean's surface, have to be in balance. To create this balance, the ocean current has to move the water mass (between the surface and about 500 feet deep) in a direction 90 degrees to the right of the wind. The Coriolis force, meanwhile, is pushing the water another 90 degrees to the right, directly opposite the surface wind.

Nansen's student Vang Walfrid Ekman developed a mathematical theory to explain why the surface ocean current flows only 20 degrees to the right of the wind while the total transport is 90 degrees to the right. Ekman's theory accounted not only for the external Coriolis and wind forces, but also internal forces within the water that transfer the wind's motion down to the deeper waters (to about 500 feet or so). Ekman's theory holds that surface water will move at a 45-degree angle to the right of the wind while deeper water flows at ever-greater angles to the right (see figure). Considering the surface and deeper water as a whole, the total movement of water mass is exactly 90 degrees to the right of the wind so the external forces are in balance. Because Ekman deliberately oversimplified the way the internal forces act, he came up with a 45-degree deflection instead of the 20 or so that Nansen observed.



Ekman's model considers the combined effects of water flow at the surface down to about 500 feet. The overall effect is that the total water mass moves at a direction that is 90 degrees to the right of the surface wind, though flow direction varies depending on depth. The Coriolis force balances the force of the wind, which produces a surface-water flow that (in the Northern Hemisphere) always is about 20 degrees to the right of the surface wind

Nansen's observations remain relevant and helpful today. If the wind blows steadily in one direction for at least a day, the resulting Ekman current will flow around 20 degrees to the right of the surface wind (or to the left of the surface wind in the Southern Hemisphere). However, in many places the Ekman current is only one component of the ocean's motion; other currents also affect it.

Farthest North, a selection of Nansen's writings, is available from the Modern Library, and the Fridtjof Nansen Institute has an excellent Web site, www.fni.no. *An Introduction to the Coriolis Force,* by oceanographers Henry Stommel and Dennis Moore, (1989, Columbia University Press) is a good resource.

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