3

Wind

I time the wind: Now it is calm (7:11 PM). I hear the wind coming (7:13). Now more quickly. The wind is on us (7:14), and we heel 20, 30, 40 degrees. . . . I grab the wind indicator, push back the hatch, and rush outside to measure the wind. The red disc flies to the top of the scale, 63 knots. The cold is terrible. I slam the hatch, shake the snow from my hair and run to the stove.

—Hal Roth aboard *Whisper*
at anchor near Cape Horn, 1973

THE WEATHER—WHICH IS TO SAY THE WIND—that has bedeviled ships down the centuries is unique to Cape Horn. Individual storms don't necessarily blow harder than anywhere else, no harder, say, than a bad autumn nor'easter in New England or a winter storm in the North Sea, and only a few twist themselves into category-four hurricanes. From the human, on-deck perspective, it makes little difference which ocean you're floating on when the atmosphere gets moving at highway speeds—you're in for a severe pummeling. However, these winds, these nor'easters, hurricanes, and North Atlantic storms, are seasonal. New England is mainly gale-free in June and July; the Caribbean gets no hurricanes for Christmas; and even the surly northern seas stretch out and relax a little in summer. Down by the Horn, however, there is no seasonal respite. Extreme violence is just as likely in high summer (November through February) as in the dark of winter—because the atmospheric machinery that causes storms never shuts down. That's what makes Cape Horn weather unique.

A kid captivated by the adventure and the language, I never thought to ask *why* Cape Horn was so stormy. Had I understood then how science could enrich fantasy, I would have pursued the matter. But there would not have been a lot of readily available information. Until fairly recently, few scientists had asked the question, because the field of study was too vast, and since no one went down there, understanding the Southern Ocean was low on everyone's to-do list. Then, in the middle of Cold War mindlessness, something truly enlightened took place. Scientists from multiple nations and disciplines joined forces to explore the relationship between Earth and outer space. What, they wondered, did solar activity in the upper atmosphere, auroras and cosmic rays, have to do with geomagnetism, and what part did the oceans play in the relationship? This cooperative spirit of discovery would soon dissolve into *Sputnik* hysteria, but during the eighteen months between July 1, 1957, and December 31, 1958—the International Geophysical Year—scientists and governments turned their concerted attention southward, to Antarctica. It was the perfect laboratory because it was unaltered by technology or human population, pure in every way. Antarctica, in its extremes, resembled interplanetary space. The Cold Warriors agreed to make no territorial or commercial claims on Antarctica, leave it forever to nature and peaceful inquiry (Argentina and Chile demurred). Cape Horn seafaring was on no one's mind during IGY, yet in Antarctica, scientists verified the cause of Cape Horn wind: It was their laboratory, Antarctica itself.

Here is a continent about the size of the United States and Mexico combined, permanently locked in ice. There is land beneath the ice, but not much, two scraggly mountain ranges and rock islands—nowhere higher than 1,500 feet, while the dome of ice that covers the land climbs to ten thousand feet. The unimaginable weight of ice has compressed the bedrock seven thousand feet. Antarctica is determined and defined by ice, it *is* ice. Some 95 percent of the earth's fresh water is locked up in Antarctic ice. This ice never melts (at least at this writing). In winter (May through September), the pack spreads outward over the surrounding ocean, adding another fifteen million square kilometers to the continent; in summer it retreats by calving tabular bergs the size of Manhattan. But it never melts.

The Arctic by contrast is generous and relatively gentle in summer. The Arctic is a frozen ocean surrounded by continents; Antarctica is a frozen continent surrounded by oceans. This is more than a geographical tidbit. Oceans moderate temperature by retaining heat far longer than land. So when, in summer, Arctic ice retreats poleward, ocean water spreads warmth over Siberia, Alaska, northern Scandinavia, and Canada, and temperatures climb well above freezing. Life explodes headlong in the sea and on land, caribou, musk oxen, bears, wolves—only the Serengeti compares for the sheer numbers of animals on the move. Eight thousand years ago, the Inuit followed them into the High Arctic, found it accommodating, if harsh, and maintained a stable, layered culture, pockets of which still exist.

The ocean likewise warms the fringes of Antarctica, but not by much because the continent is composed not of land, but of ice. The only exception, the rocky arm of the Antarctic Peninsula reaching northward from under the ice to form the bottom of the Drake Passage, has a climate more akin to that of Cape Horn than to the rest of Antarctica. It's the only place on the continent where the temperature climbs above zero. Now that hunters are prohibited, wide varieties of seals, whales, and birds flourish in the krill-rich boundary waters. But inland, on the ice, Antarctica is all but lifeless. Ancient lichens, certain bacteria survive, but the largest land animal is a flightless midge about the size of a housefly.

Antarctica is by far the highest of the continents, with an average elevation of 6,000 feet. Composed of ice, it is the coldest of the continents. And it is also the windiest. Wind is directly related to high altitude and deep cold. Cold air is heavy; it wants to fall. Because the ice never melts, the air is always cold, and because the dome of ice is two miles high, the air plunges downslope at insane velocity. Russian scientists at their station near the Pole of Relative Inaccessibility (a wonderful name for the geographic center of the continent, which is not the same as the South Pole) clocked winds at 215 mph. Typically, these falling winds, called "katabatics," blow 60 to 80 mph every day in the winter, only somewhat less in summer, but they seldom stop. Nothing can live in the teeth of a wind like that.

I talked with climatologists at the National Oceanic and Atmospheric Administration (NOAA) who are building computer models to demonstrate a causal relationship between cold, deep-welling ocean water from Antarctica and, among other phenomena, the El Niño occurrences half a world away. This work is part of a beautiful new model of global climate called, perhaps too prosaically, the Conveyor Belt Theory. It holds that climate everywhere is stabilized by the vertical, circular exchange of deep-running cold water from the poles with warm surface water from the tropics. When this conveyor belt is interrupted, instability results, and when the machinery shuts down for a prolonged period, huge-scale changes, such as ice ages, occur. So if this frozen continent sends shivers all the way to the equator, it's naturally going to influence Cape Horn, only 600 miles from the tip of the Antarctic Peninsula. Antarctic cold sentences Cape Horn—the Drake Passage—to storms in greater number than anywhere else on earth.

Antarctic cold pressing northward butts up against warm air over the southern reaches of the Atlantic, Pacific, and Indian oceans. Cold confronts warm between 40 and 60 degrees South latitude all the way around the world. (There are sixty nautical miles in each degree of latitude, and so 40 degrees South latitude lies 3,200 miles north of the South Pole.) Inherent in the disparity between warm air and cold is a disparity in atmospheric pressure, the thing that barometers measure. High pressure and low never meet peaceably. They abrade and accost each other like rival street gangs in overlapping neighborhoods.

We're talking about why Cape Horn is uniquely stormy, about the broad patterns that produce many storms, so we can brush by the physics of individual storm formation. Suffice it to say that something like abrasion, like friction, along the intersection of warm and cold drags up waves of unstable air with high pressure on one side of the wave, low on the other. When conditions are right, as they are so often down by the Horn, the waves bend back on themselves to form circles of low pressure, essentially craters in the atmosphere, with the lowest pressure located in the center. In weather language, these are called *depressions,* another word for storm.

All wind, from afternoon breezes at the seashore to Hurricane Andrew, results from the "downhill" flow of air from regions of high pressure toward regions of low pressure as the atmosphere tries to equalize itself. Summer-afternoon sea breezes are light because the disparity in pressure is not very great. But in the Southern Hemisphere south of 40 degrees South, storms are ferocious because the disparity between Antarctic cold and oceanic warmth, the *gradient*, is extremely steep and deep. The deeper the gradient slope within the depression, the faster the wind rushes in to fill it, which is why a plunging barometer alarms mariners. And since the Antarctic cold presses unrelentingly northward to engage the warmer air and water, since the combatants never leave the field, there can be no peace south of 40 degrees South, at least not for long.

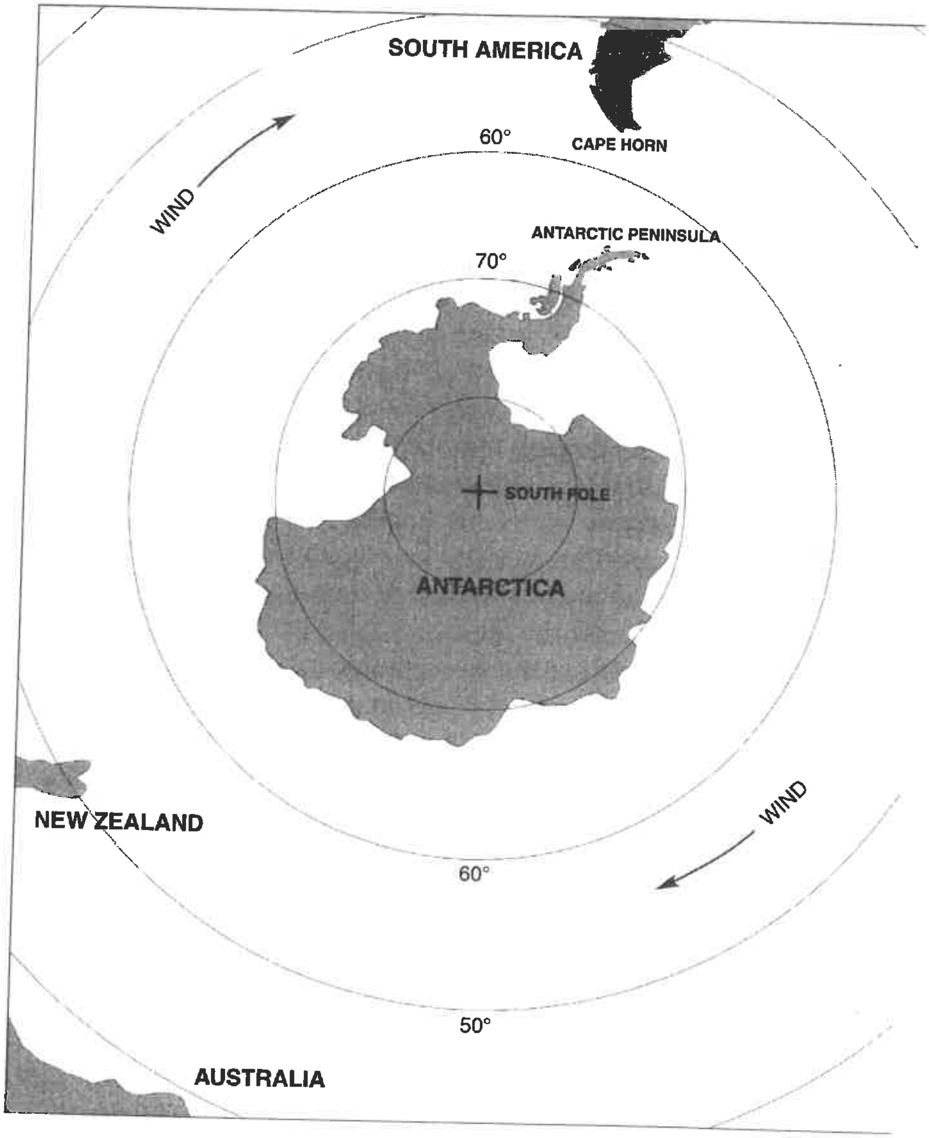
Because the earth is not stationary, because it rotates on its axis, two things happen to the storm. First, it begins to spin around its own axis, or the center of lowest pressure. The wind flowing downhill from high to low pressure bends as it heads toward the center, essentially spiraling in—just as water circles the drain as it flows from a bathtub, and for the very same reason, the rotation of the earth. It's called the Coriolis effect. Second, the rotation causes the storm to move over the earth in the same direction as the rotation, like a top spinning on an inclined surface. (They resemble miniature earths in that they both rotate on their own axis and orbit something much larger than themselves.) Southern Hemisphere storms rotate in a clockwise direction and circle the earth from west to east. Almost all heavy weather, therefore, approaches Cape Horn from the west out of the vast, empty reaches of the Pacific. And this is why rounding the Horn from the Atlantic to the Pacific, to windward, is a lot tougher than going the other way.

These big ("synoptic scale") storms are exclusively oceanic. They depend for fuel on ocean warmth and moisture. Deprived of it—as when they pass onto large landmasses like continents—the storms break apart, weaken, and die out. Tropical hurricanes, for instance, live only as long as it takes them to cross the Atlantic from their birthplace off the bulge of Africa to the coasts of Central or North America. Nor'easters cross the Atlantic going the other way, but when the crossing is complete and they slam into the wall of Western Europe, their lives have ended. The point is all Northern Hemisphere storms are trapped between continents, because the oceans that spawn and nurture them are all bounded by continents.

But that's not true of the Southern Hemisphere. The two halves of the earth couldn't be more different. The Northern Hemisphere is crowded with continents—all of Europe, Asia and North America, much of Africa and South America. Only the two smallest continents, Australia and Antarctica, lie wholly south of the equator. Eighty-one percent of the Southern Hemisphere is covered by ocean. In addition to the constant presence of the steep gradient conditions that spawn depressions, this absence of land is the other aspect that makes Cape Horn waters uniquely violent. Maybe we can best illustrate this vast oceanic system by following an idealized storm around the world. The consensus of scientific opinion is that single storms seldom make it all the way around intact. But the oceanographers and climatologists I pestered all agreed that it's possible, probably happens, there being nothing to stop it.

Let's place the center of our storm on 50 degrees South latitude as if that parallel were a rail, then send the storm around the world to see what it hits. Fifty South slices through the stalk of South America 239 miles north of Cape Horn (at 55 degrees 59 minutes South) in the middle of the Patagonian desert. Since big storms track eastward, let's begin on the Atlantic side of South America. The storm would cross the South Atlantic without brushing any land except two tiny, obscure islands, Gough and Bouvet. It would pass so far south of Africa that the residents of Cape Town wouldn't get their shoes wet. On across the bottom of the Indian Ocean it would go, disturbing no one unless they happened to be anchored on Crozet or Kerguelen Island. Residents of Adelaide and Melbourne on the far southeastern bulge of Australia, over 600 miles from the storm center, might need their umbrellas. Only Tasmanians and New Zealanders on the South Island would call this a storm, rain with hard, gusty wind. Now passing east of New Zealand, our storm would step out into the largest expanse of nothingness on the globe, 7,000 miles across the Pacific to Cape Horn.

This world-round band of open water south of any continental influence (except from Antarctica) has a straightforward name that evokes from the sea-struck the same mix of fear and fascination as Cape Horn itself: the Southern Ocean. Though it takes its components from the very bottoms of the Atlantic, Indian, and Pacific oceans, the Southern Ocean is unique in that it is unified by meteorological conditions, not the landmasses that contain it. In modern weather parlance, the Southern Ocean is "zonally uniform," characterized by the endless march from west to east of large-scale depressions and smaller "disturbances"; or, to put it differently, by



Map 3.1 Southern Ocean Circulation

dependably violent weather, if not tomorrow, then before the week is out. And the only land that sticks itself down deep in the Southern Ocean, into the flow of storms, is the narrow stalk of South America, at the bottom of which stands Cape Horn. And it had to be rounded.

As the wind's velocity increases, so does its *force*. That's a fairly obvious statement, but for sailors, there's cruelty lurking in the physics. Wind velocity is measured in nautical miles per hour, or knots (one doesn't say "knots per hour"). One knot equals 1.15-statute mph. But anemometer readings, the actual numbers, are meaningful only insofar as they relate to the wind's *force,* the blunt-trauma impact on anything trying to stand upright in the face of it—masts, sails, rigging, people. And here's where the cruel physics comes in.

Wind force is equal to the square of the velocity. That is to say, if the wind speed doubles, the force quadruples. When the velocity of the wind triples, its force increases by a factor of nine. Furthermore, because cold air is heavier and denser (containing more air molecules for equal volume), cold wind packs more wallop than warm wind. Forty knots down by the Horn contains far more force than forty knots in the Gulf Stream.

Joseph Conrad, who knew what he was talking about, suggested that in extreme conditions, the human psyche was a reliable measure of wind force. "It was off the Horn . . . ," he wrote in *The Mirror of the Sea.* "I was a youngster then, and suffering from weariness, cold, and imperfect oilskins which let water in at every seam. I craved human companionship. . . ." Conrad encountered the bo's'n, "(a man whom I did not like) in a comparatively dry spot where at worst we had water only up to our knees. . . . And just from that need of human companionship, being very close to the man, I said, or rather shouted: 'Blows very hard, boatswain.'

His answer was: 'Aye, and if it blows a little harder things will begin to go. I don't mind as long as everything holds, but when things begin to go it's bad.'"

That bo's'n would have feared gusts. Things often carry away in the gusts. No wind is steady, and heavy wind is particularly unsteady. The pitch of the noise climbs, the vessel heels, rigging creaks, shoulders hunch when the gusts come on, because in gusts the force increases with a jerk. A sail or fatigued piece of metal that might have survived a steady, gradual increase often disintegrates under the snap-load.

Wind is the prime cause of everything. Every aspect of life aboard is determined by the velocity and direction of the wind in relation to desired course. Wind can make life beautiful, evoking poetry from hearts of oak, and it can make life treacherous, narrowing it to the next handhold. But when worst comes to worst, it's not wind that sinks ships and boats, but the wind's agents—waves.

Three factors of wind combine to determine the size and shape of waves. Naturally, *velocity* matters, that's obvious. But *duration* is almost equally important. A brief blast of wind, like that in an isolated Gulf Stream squall, will not put up much of a sea, because water is heavy and takes a while to build up energy. The other factor is less obvious, that is, the distance the wind blows over open water. The technical word is *fetch*. A wind can blow hell for a long time over a small bay and still not set up large waves. People who live around the bay will say what big waves those were, and they were by bay standards, but not by ocean standards. To put it baldly, the faster, longer, and farther the wind blows, the higher the waves will be. And that's what makes the Southern Ocean and the Drake Passage unique in the world. Velocity, duration, and fetch: All three live in their most extreme form south of 45 degrees South. And south of 50 South, the fetch is literally endless—around and around the icy continent they go, wind, wind-driven current, and the waves with nothing in their way, nothing at all—except at Cape Horn.

Large waves may turn day-to-day life primitive and basic; cozy cabins become scenes of domestic violence, and fatigue comes quickly because energy must be spent just staying in one place. But ocean waves aren't normally lethal, because they just go up and down. An individual water molecule in a wave moves only a short distance forward, then falls back as the crest passes, describing a small vertical circle. Somebody compared it to a mouse running under a rug. Or as oceanographers put it, waves transfer energy but not mass—*until they break*. That's the difference between a passing wave and a catastrophe.

Many of us remember when on a day at the beach, the ocean betrayed our love by dropping a breaker on our heads, yanking us every which way at once before belching us up onto the beach in a jetsam heap. Beach waves break because the rising bottom trips their equilibrium and the crest topples over, and as every surfer knows, the shape and character of the break will be determined by the contour of the bottom. There is no bottom influence on ocean waves, but beach waves are a fair model of what happens in the ocean when the wind blows hard and long over distant fetch. The wave outgrows its own stability, the face flattens, and the wind shoves it over. There are various kinds of breaks, some more malicious than others, but in any case, breaking waves, transferring energy *and* mass, turn from agents of fatigue, contusion, and constipation into killers. A big breaking wave can exert a force of one ton per square foot on anything under it.

To determine whether waves in the Southern Ocean reach the breaking point more often than in other oceans would require a level of attention that the size and remoteness of the Southern Ocean has thus far precluded. But all the elements of instability are there. According to the *Sailing Directions*, "South of Tierra del Fuego, in the historically stormy region to the south of Cape Horn, there is a sharp rise in gale occurrence. Within the area 55 degrees to 60 degrees South, and 65 to 70 degrees West, where nearly 70 percent of the winds are from the west, gales are recorded in 20 percent of the annual observation." In that usage, *gale* is a technical term referring to wind speeds between 34 and 40 knots (shy of 50 mph). However, when the *Directions* states that gales occur 20 percent of the year, it means at least a gale, a gale and up. So that figure includes *storms* (48 to 55 knots), *violent storms* (56 to 63 knots), and a smattering of *hurricanes* (over 64 knots). And almost everywhere around the Southern Ocean those same conditions generally obtain. The waters can never rest. The numbers are very different in civilized oceans: In the waters around Nantucket, gales occur 2.4 percent of the year, and winds, figured on an annual basis, exceed 41 knots only 0.7 percent of the time. Gales and their heavier relatives circle the Southern Ocean like beads on a string, each setting up waves and swells that fan out and overrun slower-moving waves and swells, and then the whole system tries to squeeze through the Drake Passage.

"Think chaos," advised Michael Carr, meteorologist, seaman, and author of *Weather Predicting Simplified*. He cautioned that neither Cape Horn nor the Southern Ocean was his province, but the several great round-the-world yacht races, fully crewed and single-handed, have drawn attention to the waters south of 50 South. Describing the system, Carr repeated the word *dynamic*. That's what I should bear in mind, the dynamics of the Southern Ocean circulation, everything spinning and churning and plowing eastward toward the Horn. He said he couldn't prove it due to the dearth of information, "but everything adds up to very large, breaking waves."

David Feit at the Storm Prediction Center, a branch of NOAA, said, "Remote, subject to large wind speeds over extraordinary fetch, fully developed sea states, and the odds all say you will experience dangerous breakers in the Drake Passage." Just consider the numbers, he added. Take the principle of Significant Wave Height. Let's say that 1,000 waves with an average height of 9 feet pass a fixed point in the ocean. Forecasters and wave modelers are concerned with the highest one-third of those waves, the "significant height." The average wave within that highest third will run to 14 feet (measuring from trough to crest). Ten percent of those will be 18 feet. And one wave in that 1,000 will be 24 to 31 feet high, or over three times the average. Here's the origin of the rogue wave, the anomalous giant, which the old Cape Horners called "niners." You could count on it, every ninth wave, and be ready. There's comfort in that, and sometimes science soothes anxiety by dispelling superstition and the inchoate shakes, but it doesn't seem to work that way with the science of wave growth.

William Van Dorn in his *Oceanography and Seamanship* displays a "commutative sea state diagram," a mathematical model of wave growth over time. The graph shows that in heavy conditions—60 knots of wind blowing for sixteen hours over a 500-mile fetch—the significant wave height will be 58 feet. Ten percent of those will average 72 feet. About 260 waves will pass in an hour, "the largest of which might exceed 117 feet!" Sixty knots is a hell of a lot of wind by anyone's standards, but reliable contemporary and historical eyewitnesses reported storms that blew 60 for weeks on end, and it didn't matter whether it was winter or summer. This is the place for 60 knots. Van Dorn contends that in such weather, the waves would be breaking 100 percent of the time.

Not all oceanographers would be comfortable with the Southern Ocean boundaries I've offered, from 40 South to about 60 South. They agree that this span of ocean is "zonally uniform," but they need to draw the outer rim down closer to the edges of the continent in order to focus on ocean phenomena—the Antarctic Convergence

Zone—that have little relevance to sailors trying to round the Horn. But all mariners since Magellan have recognized that when their bows crossed the Fortieth Parallel, they were entering an ocean entirely different from all the rest. Everything was exaggerated, accelerated in the "Roaring Forties" and the "Screaming Fifties." Big wind came on harder, faster, than in other oceans. Thermometers plunged along with barometers. Flying spray froze on the decks and in the rigging. Ships turned top-heavy under the clutch of ice, grew sluggish, unresponsive, and therefore vulnerable. The cold knifed through the bowels of the ships, and there could be no relief until they'd rounded the Horn and climbed back above 40 South into the other, normal ocean. Even the look of the Southern Ocean was different from the rest, gray and grim, death colors. But there were also those explosions of light when, for a time, the low murk parted and shafts of splendid brightness shone on the white crests like a hint of hope, and sometimes multiple rainbows arced across the horizon, intersecting. The fatigue, pain, and danger were all magnified, but so, too, was the magnificence of this ocean, its wildness. With each degree of south latitude, through the forties into the fifties, down to the Horn at nearly 56 South and beyond, the conditions inevitably worsened. Cape Horn sailors had a saying for it:

> Below 40 South there is no law,
> Below 50 South there is no God.