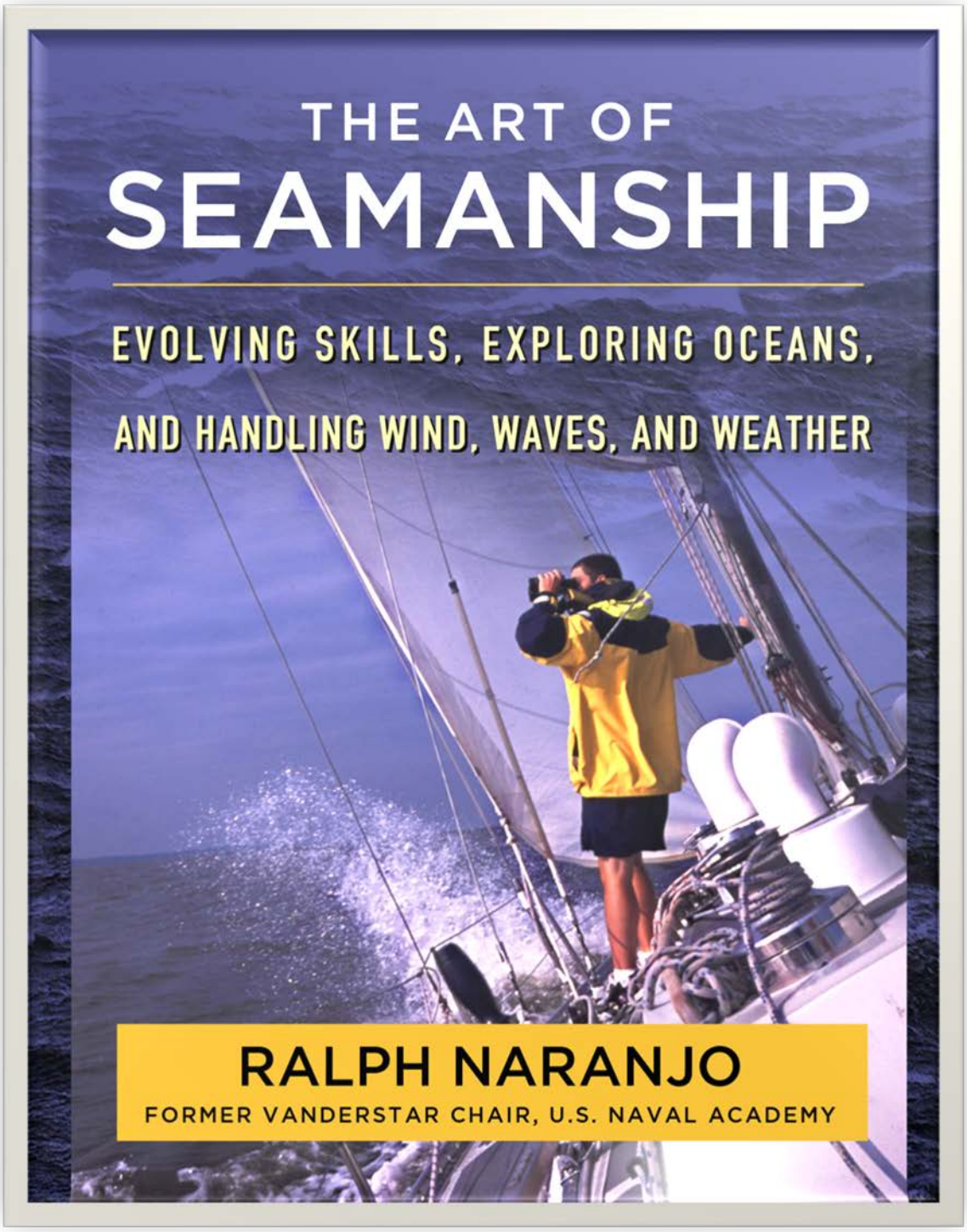


The excerpt below is from The Art of Seamanship (to be published by McGraw Hill in the spring of 2014). It illustrates the importance of developing weather awareness, and how thunderstorms can change the routine aboard coastal and offshore sailboats.

Coping with Thunderstorms

A thunderstorm cell is also a conveyor belt for moisture, which is carried aloft in the warm updraft and then returns to earth as precipitation. The result is a rain signature that causes the cell to show up clearly on radar. Mature storms carry warm, moist air to astounding heights—35,000 to 50,000 feet--and they not only convert water vapor into rain, but in many cases cause raindrops to coalesce into icy pellets of hail that grow larger and larger as the pellets shuttle up and down in vertical loops. Eventually the towering anvil-shaped thunderhead becomes unstable, and the vast amounts of water and ice held aloft yield to gravity, causing powerful downbursts and outrushings of rain- and hail-laden wind that can momentarily exceed 100 knots. These terrific bursts of energy often occur in the vicinity of what's called a *shelf cloud,* and except for a direct lightning strike, they constitute the most destructive feature of a thunderstorm.

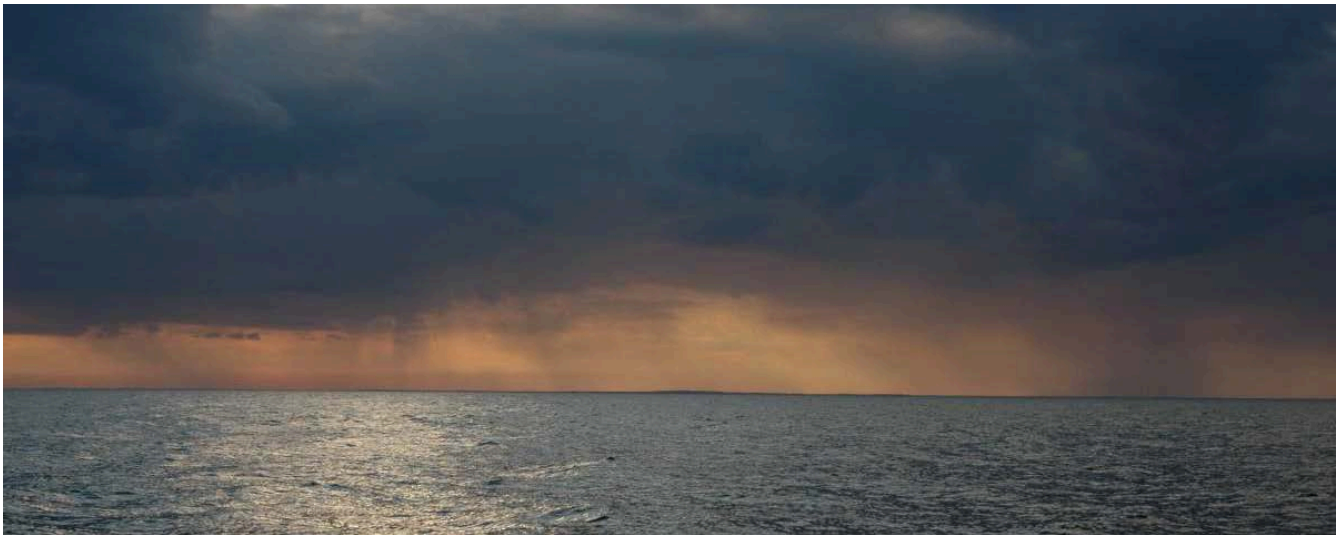
Hot, humid, calm summer days are ingredients for local thunderstorm development. More often than not these single cells towering up toward the stratosphere peter out at about 30,000 feet of altitude, making them relatively minor examples of convective activity that nevertheless pack a big punch in the gust-front region. Storms that continue to develop vertically, reaching as high as 50,000 feet, have the ability to deliver microburst gusts of 100 knots. Steering clear of such an encounter is worth a substantial diversion from your course. (*RJN Photo)*

When an isolated thunderstorm is spawned on a hot summer day, it is usually short-lived due to its fast rate of advance and the relatively short lifespan of most individual cells. The sea can be flat and the wind calm just prior to the arrival of a fully developed thunderstorm, with towering cumulonimbus clouds and an atmospheric lightshow being the only signs of what lies ahead.

But thunderstorms can also be embedded in warm fronts in the summer and in cold fronts year-round, and they are also a component of troughs (on NWS forecast maps), tropical waves, depressions, storms, and hurricanes. When associated with fronts or systems, thunderstorms can become both more numerous and more violent than an isolated cell developing from local heating of surface air. The cold air/warm air interface along an advancing cold front turbocharges the instability upon which thunderstorms thrive, because the cold wedge bulldozes under the warm, moist air ahead and forces it aloft. A fast-moving cluster of storms is referred to as a *line squall* and is usually found in the warm sector ahead of the advancing cold front. When multiple cells are involved, numerous encounters can prolong the bad weather.

Most cloud-to-cloud and cloud-to-ground (or sea) lightning bolts are massive static electrical discharges caused by the friction associated with air movement in a thunderstorm cell. Oppositely charged particles array themselves on cloud surfaces, and as the charge differential increases, a point is reached at which the insulating property of the intervening air is overcome by the voltage differential between the charges. A leader of contact conduit reaches out to bridge the gap, followed by the ionization of an air column linking the two opposite charges, and the result is a huge energy transfer.

The American Boat and Yacht Council (ABYC) recommends that all boats have a grounded and bonded electrical system that drains all static charges to a common ground point that is in contact with the sea. The purpose of this wiring is to make the vessel look electrically identical to the surrounding sea surface and not stand out as a statically charged hotspot. As a secondary safety feature, this wiring also helps to guide a direct strike toward the sea, but because lightning can ionize an 8-inch-diameter column of air, it is ridiculous to think that it will be carried safely to ground via the use of 8- or 10-gauge wire. At best, the grounding system will help guide the lightning along a path of least resistance, thus causing less damage.



Thunderstorm development is intense along the north wall of the Gulf Stream, another reason why a Cape Hatteras transit should be taken seriously. The region has a well-deserved nickname as a "graveyard of ships." Sand shoals reach miles offshore, and even in a modest gale, waves break as far from the shoreline as one can see. The only sailors in these nearshore waters are hardcore kite boarders and windsurfers. (*RJN Photo)*

The presence of a low-pressure trough is another key factor in the development of severe thunderstorms. We often think of weather in a two-dimensional context, neglecting the profound impacts of rising and descending air regionally (around highs and lows) and locally (in a thunderstorm cell). Near a surface trough of low pressure, which forms beneath a U-shaped dip (toward lower latitudes) in the upper-level jet stream, the instability of the surface air is increased, and thunderstorms are often more volatile. This is especially true when warm, moist Gulf of Mexico air is drawn into the equation and wind shear (directional changes with altitude) exists. This vertical twist can cause a rotational influence, leading to a tornado or waterspout. Although such "twisters" can be generated in bands of severe thunderstorms, they are more likely to be generated by isolated cells than by bunched cells in a densely packed line squall. When a tornado moves over water it becomes a waterspout, and these can cause significant damage to vessels, though such incidents are infrequent. Course changes to avoid these often slow-moving spouts make sense, as does carefully tracking them on radar. Small-craft radar operates on the X-band and does a great job of picking up the large water droplets associated with squalls, waterspouts, and thunderstorm cells, not only warning of their presence but also indicating their direction of movement.

An AM radio is an ideal receiver to pick up the static caused by lightning discharges—with more static indicating a more severe storm--and an inexpensive battery-powered portable radio can thus provide an early warning and is a useful piece of safety gear on board. When the

undersides of towering cumulonimbus clouds take on a rolling, lumpy, or fragmented appearance, sometimes with a visible green tinge, you are in the presence of *cumulonimbus mammatus,* another strong indicator of an imminent storm that will likely include hail. You may see a descending shelf cloud on a cell's leading edge, and yet another sure sign of an impending gust front is a wisp of noticeably colder air on a hot, sultry day.

Prudent sailors will often douse the mainsail and let the tempest pass while reaching along with a scrap of unfurled jib, a storm jib, or engine power and bare poles. Powerboaters may choose to power slowly into the wind and developing seas or run before the wind under such conditions. Faster vessels may be able to avoid the worst of these severe thunderstorms by taking evasive action. Short-lived winds in excess of 50 knots can push a moderate-displacement vessel at 6 knots with no sail set. If the seas are flat at the onset of a line squall or an encounter with a single cell, there's little time for seas to build, so the sole threat is the wind itself.

When the anvil-like cloud tops of a squall line begin to shear off, it's a sign that the cells are past their peak and the vertical heat transfer is starting to break down. Before expressing a sigh of relief and calling friends over for cocktails, make sure no new cells are building up and the squall line is moving away from your location. (RJN Photo)

One of the least understood facets of a marine weather forecast is the difference between a *weather watch* and a *warning*. Severe weather watches are issued when conditions are ripe for thunderstorm development. This does not mean that any storms have developed in the watch area; rather, it's a precautionary advisory justifying extra vigilance. When a warning is issued, it means that severe thunderstorms have been sighted in the watch area, and this should be a red flag to those about to leave the dock and a game-plan changer to those already underway.

Avoiding an encounter with a severe thunderstorm is always the best option, but being caught in shoal water or in a nasty inlet while attempting to get to safe shelter can be far worse than encountering the same conditions with sufficient sea room to keep free of collisions or running aground. Attempting to outrace a squall line with a mad dash toward the harbor is a gamble. It may make most sense to head for a part of the bay featuring less traffic, fewer obstacles, and a fair distance from the nearest hungry lee shore.

If thunderstorms have been spotted on Doppler radar and you are in their path but not yet underway, stay put, go below, and remain clear of the mast and chainplates. If struck by lightning, check the crew first, then look in the bilge for any sign of a leak. When lightning strikes, your vessel becomes part of the conductive pathway. The strike ionizes a column of air normally so high in resistance it's a good insulator. At such extreme voltages, lightning has the ability to jump gaps and find its way all around the boat. Providing as direct a pathway to the water as possible seems to lessen damage. (RJN Photo)

Know how fast you and your crew can react. If a blistering hot summer day is already punctuated by cold wisps or gusts, you've probably already waited too long to get rid of the genoa and prepare to reef or perhaps even strike the mainsail. When this cold-air warning bell catches you at anchor, it's time to add more scope and be ready to cope with storm-force gusts. If the lunch hook is down, big problems await, especially if a heavier anchor isn't ready to be released from its bow roller. Running the diesel and clutching it into forward during the gusts can take some of the load off the ground tackle. A dive mask for the helmsperson may be just the fashion statement needed when a gust front or microburst rolls into play. The irony along the U.S. East Coast is that most of the vigor of these thunderstorms will dissipate before they move offshore, and they won't spin back up until the moist air reaches the thermal boundary along the north wall of the Gulf Stream.