Common Sensors for Research Applications

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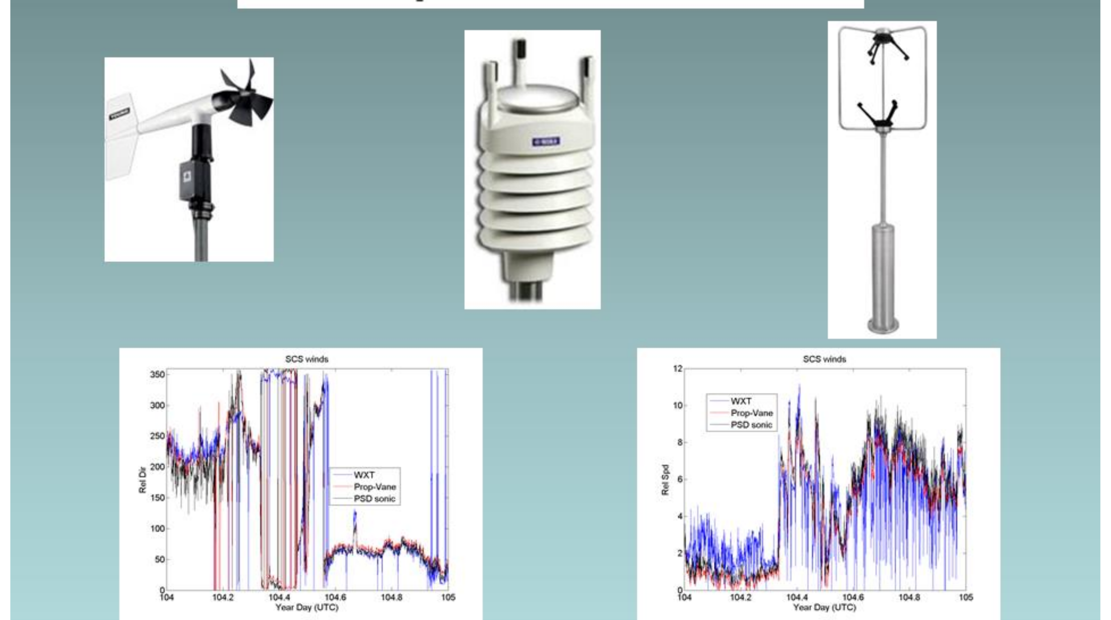
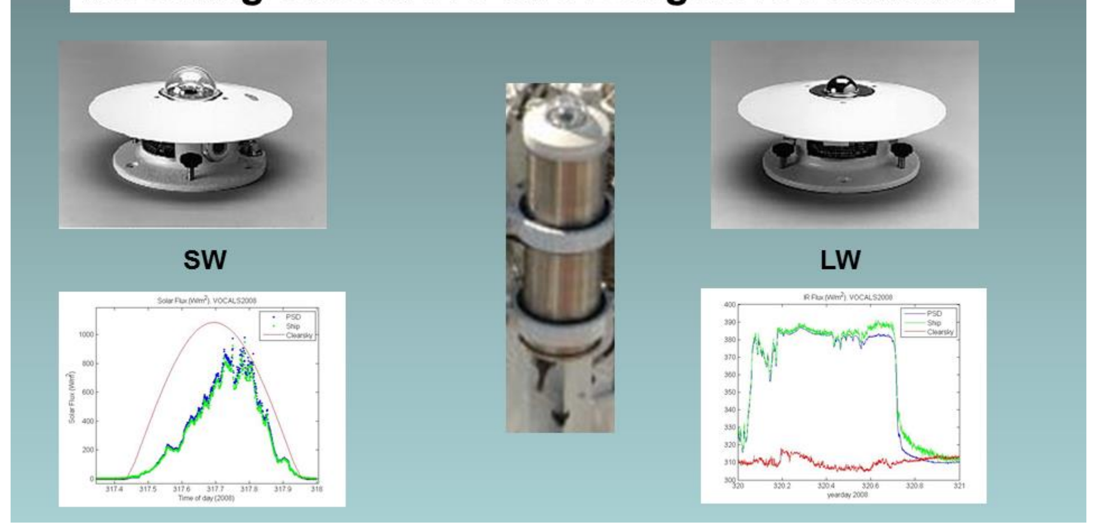
Wind Speed and Direction



Prop-vane anemometer, 2-D sonic anemometer, 3-D sonic anemometer
The two main methods of measuring winds are either mechanical or indirect via sound. They are often both obtained from a single instrument and are measured relative to the ship and therefore must be combined with the ship's heading, course, and speed to arrive at the true wind vector.
Plots show comparisons of True wind direction and speed from the three different wind sensors pictured

Incoming Shortwave and Longwave Radiation



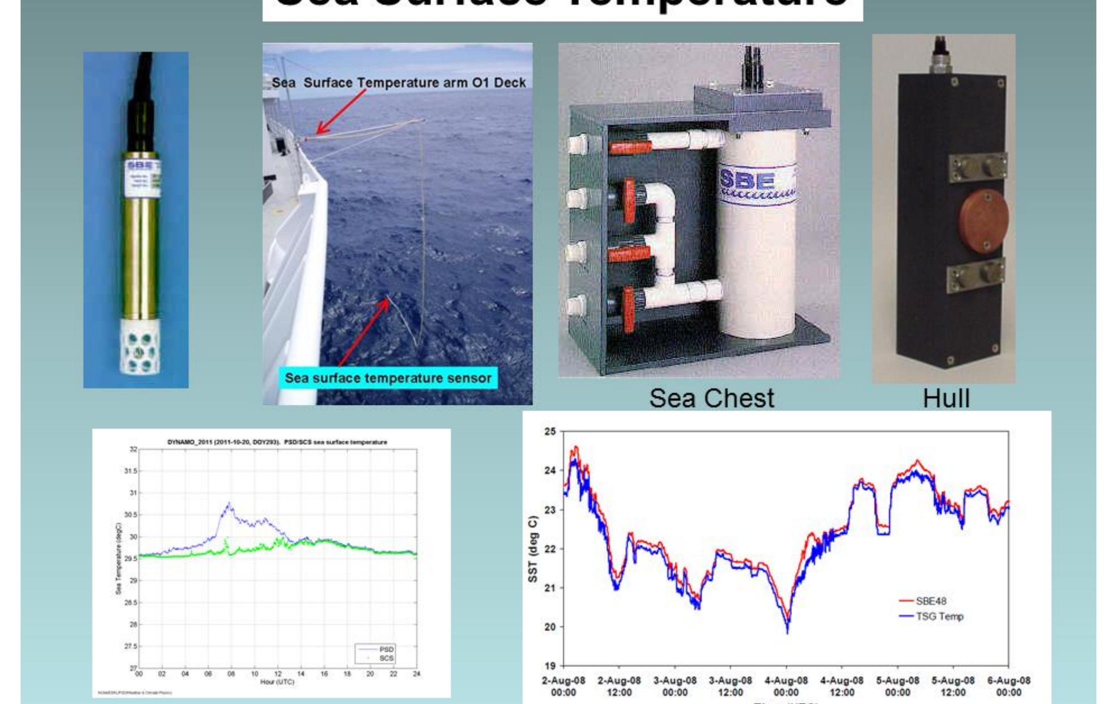
SW (Pyranometer) broadband solar radiance on a planar surface LW (Pyrgeometer) atmospheric infra-red radiation. Good quality radiometers are not cheap but very important to understanding the energy budget.
Plots show comparisons between ship (SCS) and Flux Standard (PSD) sensors along with modeled clear sky calculation for incoming SW and downwelling LW radiation.

Air Temperature and Humidity

Plots are comparisons between three different sensors. Red circles indicate where actual T/RH sensors are located. These fit up into a radiation shield shown on the right side. Radiation shields can either be naturally ventilated (top) or fan driven (bottom two).
Temp: thermistors (RTD), thermocouples del(R) = k* del(T)
RH: capacitance or resistance
The most common causes of error in air temperature measurement are sources of anomalous heating: the sun and the ship. Ventilation, whether natural (wind) or using a fan (aspirated), can limit anomalous heating. The ship itself is a massive source of heat, and almost any location aft of the bow will measure air that has passed over some area of warm steel. Most systems combine air temperature and humidity sensors in the same package (red circles), so they are subject to the same conditions of ventilation and screening from solar heating.

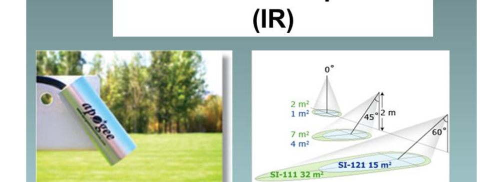
Just as there are many different shapes and sizes of ships, there are many different types and styles of meteorological sensors. Sensors can either directly or indirectly measure atmospheric parameters. Accurate ship measurements are important for many reasoning including model verification and satellite calibration/validation.
Direct measurements (counts, volts, resistance, capacitance) require a simple conversion to SI units. Indirect measurements such as signal intensity apply an empirical relationship to obtain say rain rate from the intensity signal measured across a know path.
Installing multiple sensors can be useful providing complimentary data in the very harsh and complex marine environment.

Sea Surface Temperature



Sensors from left to right: temperature profiling sensor typically used with CTD, "Seasnake" floating thermistor, ship intake, hull mounted.
Left plot shows comparison between "Seasnake" (blue) and ship intake sensor (green) with warming caused by heating from the sun of the "Seasnake". Right plot is comparison of ship intake (blue) and hull (red) sensors showing dampening and delay of hull mounted temperature sensor.

Sea Surface Temperature (IR)



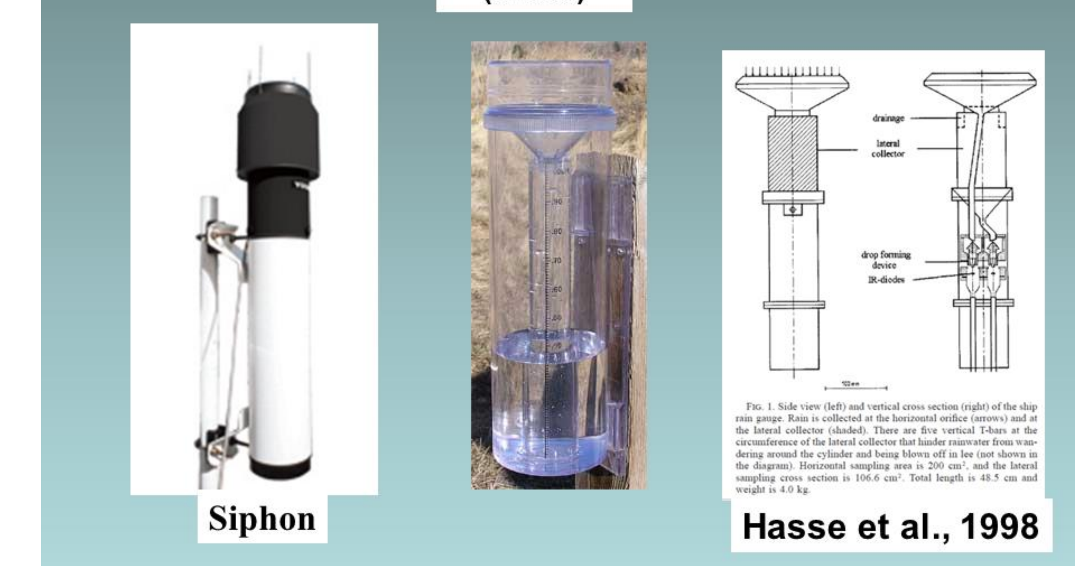
Indirect measurement using IR sensor. Total surface area viewed dependent on tilt angle of sensor.

Historically, sea surface temperature (SST) was understood to be the temperature measured from a ship by whatever means available and reported as SST irrespective of the depth of measurement. We now know that temperature in the ocean surface layer can vary with depth. It is the temperature of the sea-air interface itself that physically determines the magnitude of the turbulent heat fluxes and also the outward flux of longwave radiation.

In moderate to strong winds the water below the thin surface layer (skin) will be well mixed, and its "bulk" temperature will vary little in the vertical. During the day, however, penetration and absorption of solar radiation can produce a diurnal warm layer below the cool skin. Under clear skies and with light winds, as found in tropical oceans, this layer may be a few °C higher than in the bulk below.

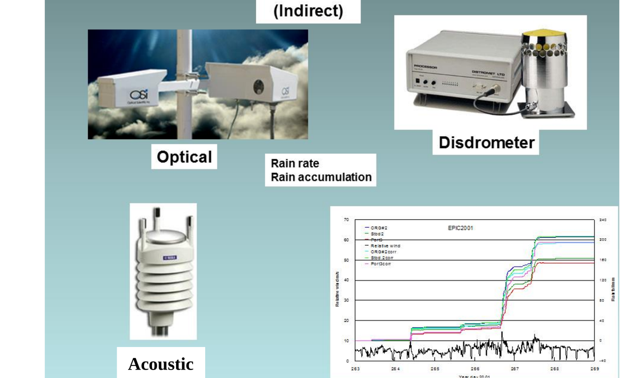
The true interface temperature cannot be measured with present technology, but the measurement of an infrared radiometer (at a few µm depth) comes close, and is sometimes available from shipboard or satellite sensors.

Rainfall (direct)



From left to right siphon gauge (common ship sensor), standard land precipitation gauge, and research proto-type gauge designed to minimize wind effects.

Rainfall (Indirect)



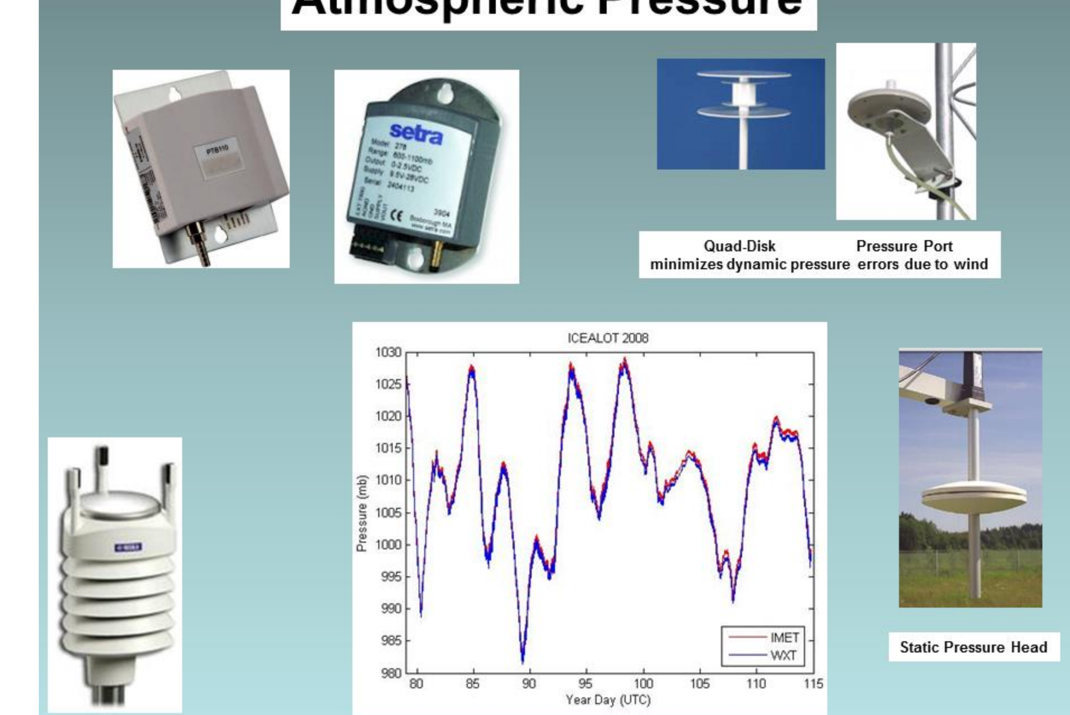
Indirect methods for measuring precipitation. Optical (most common for ships). Plot shows comparisons for different sensors and different locations with ship relative wind speed plotted along the bottom. All sensors capture the various rain events, but with differing degrees of accuracy.

Rainfall, particularly during convective storms, is perhaps the "patchiest" of all meteorological variables. Single point measurements from ships and buoys are generally less relevant for climate models than area-averaged values or spatial characteristics. Nevertheless, accurate point measurements over the ocean are invaluable for validating satellites and radar that do obtain spatial rainfall patterns, but must be calibrated against ground truth. Currently such validation is mostly obtained from rain gauges located on islands and atolls, which have been found to distort the rainfall field.

The main problem with shipboard measurements is error due to wind flow distortion that can lead to underestimation, depending on the location of the gauge. A well-positioned gauge adjacent to a wind instrument is better than several gauges scattered around the ship. The range of rain rates observed, from drizzle registering less than 1 mmhr-1 to tropical storms producing 200 mmh-1 (often accompanied by strong winds) also presents challenges for rain gauge design.

The net air-sea heat flux includes a component of sensible heat from rainfall. Examples include warm rain in Hawaii and the cold drops felt from mid-west storms even in the middle of summer. Over extended periods, the contribution is small, but during heavy storms it can be several hundred Wm-2.

Atmospheric Pressure



Pressure sensors are similar with varying response times and accuracies depending on your need. For shipboard use it is critical to have a dynamic pressure port connected to the sensor to reduce the dynamic wind effects (Bernoulli Effect). This pressure port should be located in a place on the ship least affected by flow around the ship's structure. Note: The actual pressure is measured at the height of the sensor and not the pressure port. The plot is a comparison of 2 different sensors.

Pressure is one of the state variables that define the thermodynamic properties of the atmosphere. Most weather stations house their barometric pressure sensor within the weather station display console. Therefore, placement of the weather station console receiver is an important consideration since the physical environment of the console will influence air pressure measurement readings. If possible, install the console at an indoor location where the temperature is as constant as practical (i.e., not affected by vessel heating, drafts, or the sun).

Rule of thumb is that 1 mb = 10 m change in altitude. Bernouli Effect: Increased velocity = decreased pressure