High-Resolution Climate Data from Research and Volunteer Observing Ships:
A Strategic Intercalibration and Quality Assurance Program
A Joint ETL/WHOI Initiative

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- **Requirement:** There is a need for air-sea flux measurements of high accuracy and high time resolution
  - Intensive field programs
  - Satellite retrievals
  - NWP/Climate model products
  - Climate monitoring
- **Relevant quantities**: Turbulent fluxes (stress, sensible and latent heat), radiative fluxes (solar and IR), precipitation, bulk meteorology.
- **Potential**: Present technology allows measurements of net heat input to the ocean from ships and buoys to an accuracy of about 10 W/m^2, but this accuracy is not being realized on most platforms
- **Solution**: Implement a multi-faceted program of quality assurance, intercalibration, and data archiving.
  - Research Vessels (NOAA, UNOLS, Navy, Coast Guard,..)
  - VOSClim
- **Strategy**: Create a ship flux measurement group
  - Construct a state-or-the-art portable flux standard that can be installed on any ship to obtain best possible characterization of the relevant variables
  - Construct a distributed set of sensors to be place with ship sensors for side-by-side intercomparison
  - Work with each ship operator to improve sensor suite, placement, connection methods, processing, etc
  - Perform a computational fluid dynamics ICFD) assessment of the flow distortion effects for specific sensor locations
  - Set up a web site with a Flux Manual detailing procedures and best practices for measurements from ships and flux estimation methods

How Good Do We Need to Be?
GOAL-1: Measure net surface heat flux to ±10 Wm^{-2}

$$\Delta H = \sqrt{\Delta H_l^2 + \Delta H_s^2 + \Delta R_{ns}^2 + \Delta R_{nl}^2 + ..}$$

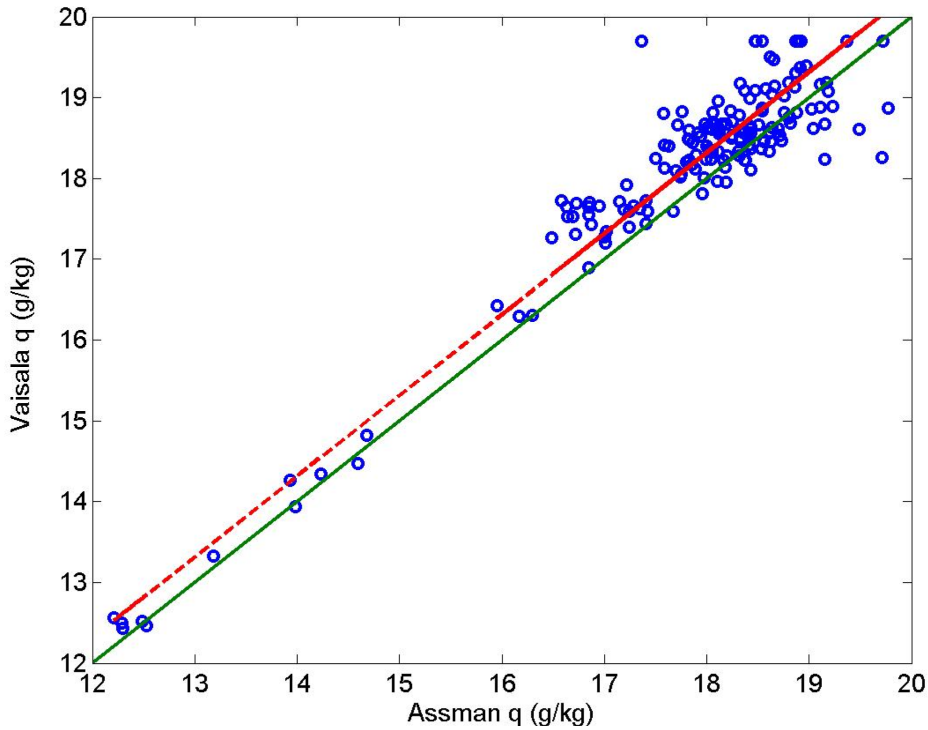
$$H_s \approx \rho_a c_{pa} C_h U (T_{skin} - T_a)$$

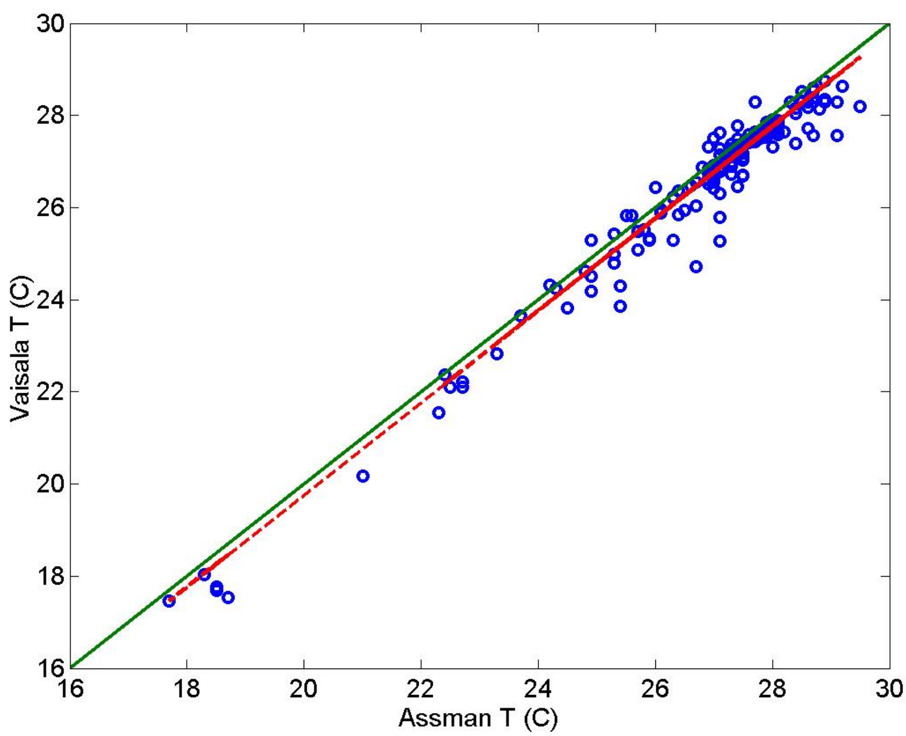
Table 1. Measurement uncertainty estimates from Fairall et al., 1996a.

Variable	Units	50-min rms	Bias
U	m s^{-1}	0.3	±0.2
T, day	K	0.3	±0.2
T, night	K	0.2	±0.1
q	g kg^{-1}	0.3	±0.2
T_s	K	0.1	±0.2
q_s	g kg^{-1}	0.1	±0.2
H_s, cov	W m^{-2}	3 ± 20%	±2
H_l, cov	W m^{-2}	5 ± 20%	±4
☺, cov	N m^{-2}	0.015 ± 30%	0.002
⌧☺⌧, ID	N m^{-2}	15%	0.002

BIAS = Average sensor − Average correct value

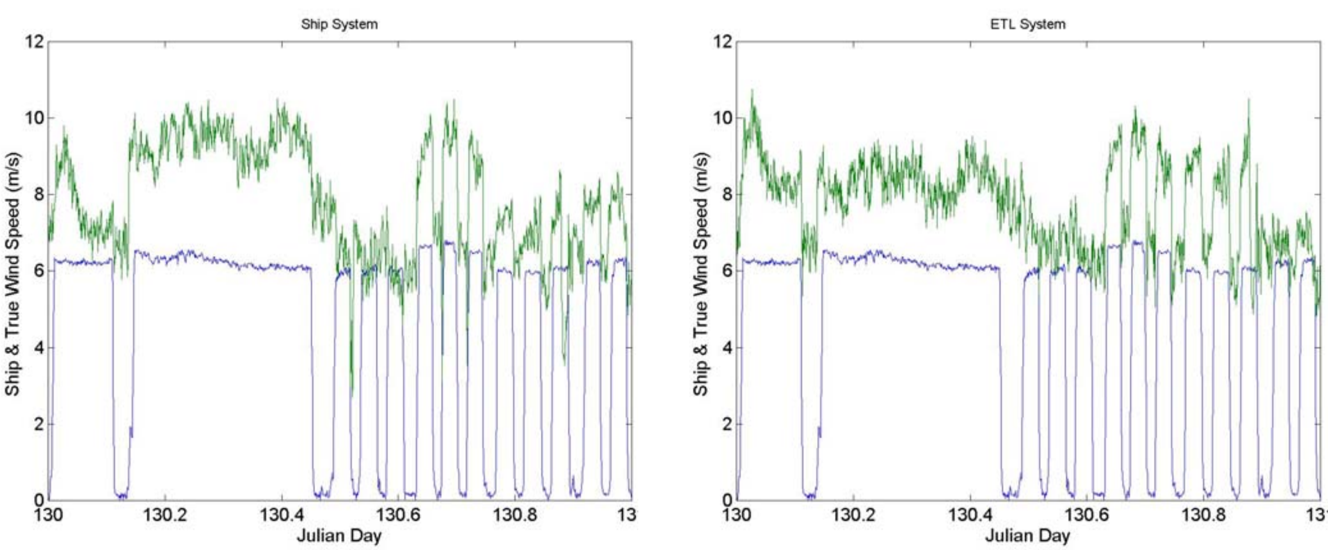
Sample Bias Estimates for Mean Temperature and Humidity





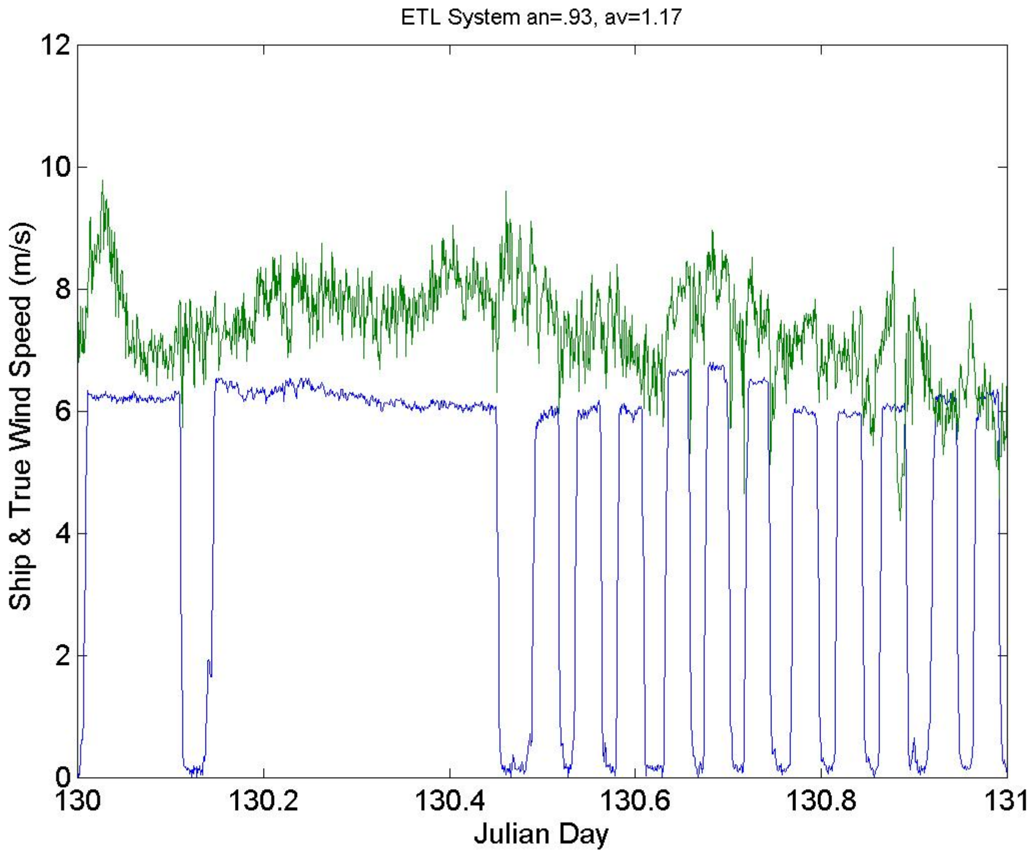
Comparison of Vaisala against hand-held standard: bias corrections on the order of 0.2 C and 0.3 g/kg.

NOAA SHIP Ronald H. Brown
Wind Speed Measurements

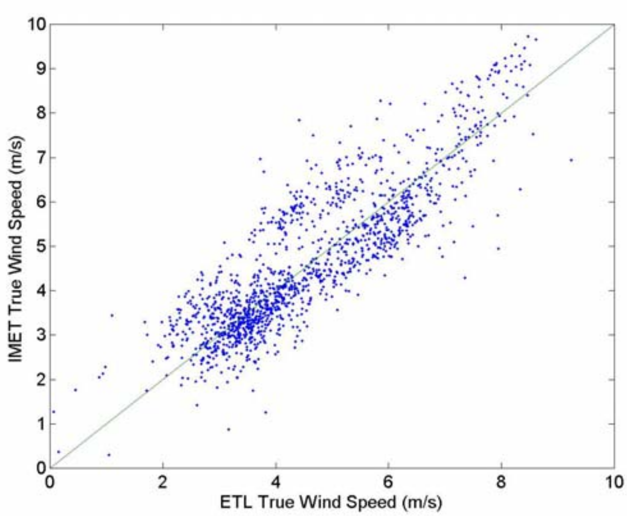


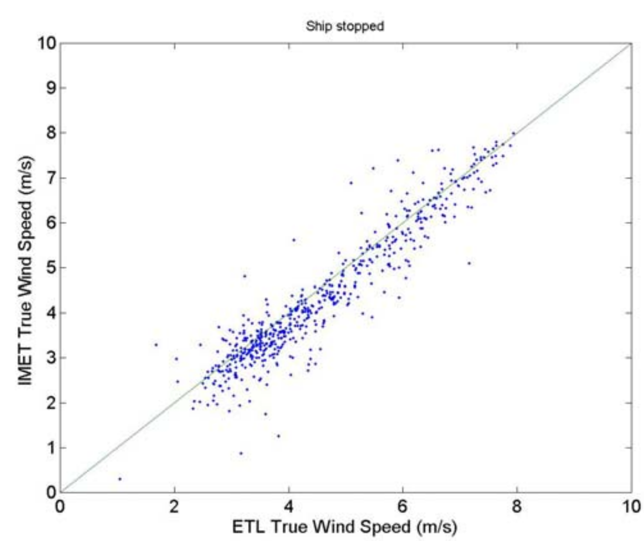
Wind speed measurements with IMET (left) and ETL (right). Blue line is ship speed.

Simple Flow Distortion Corrections



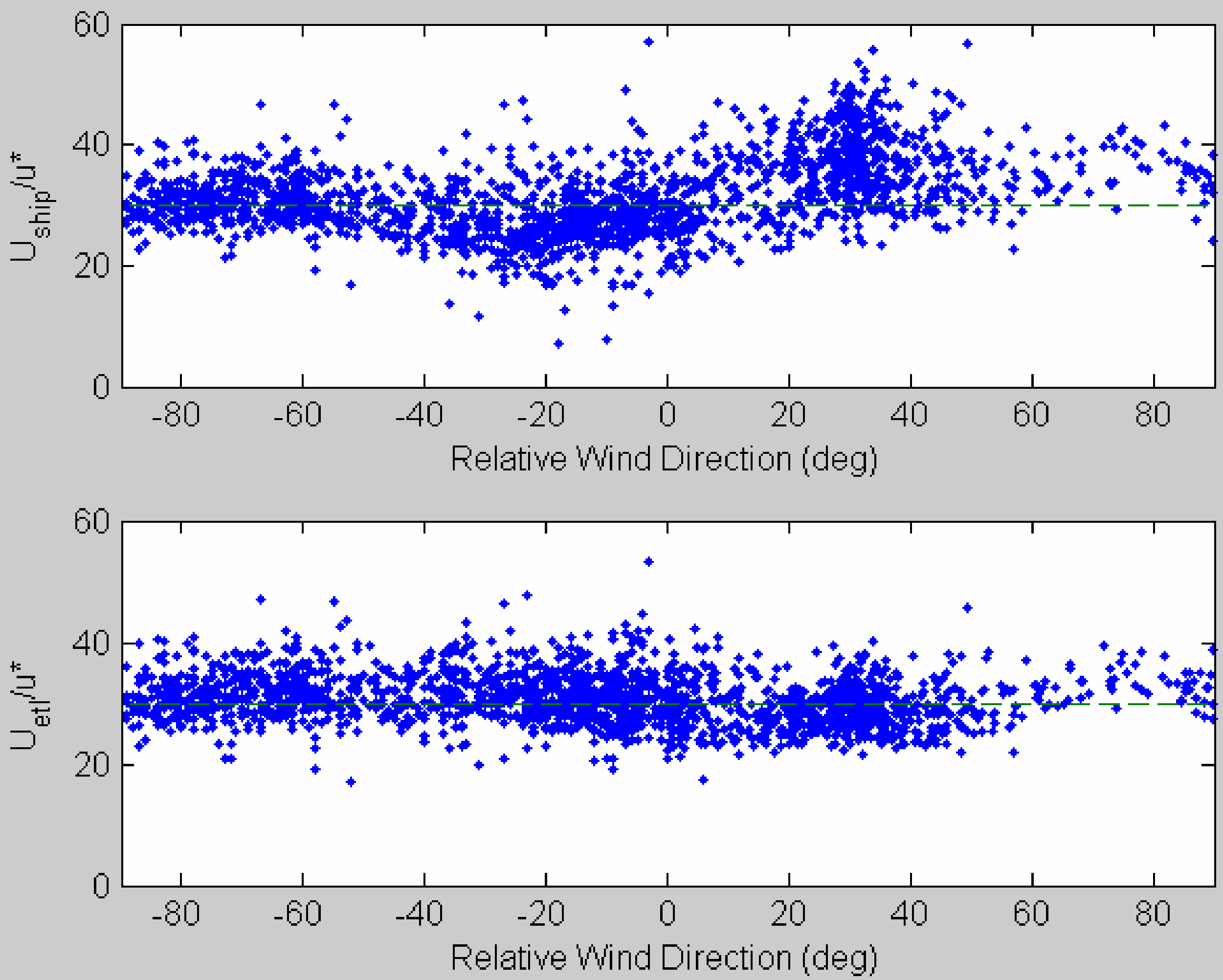
ETL sonic anemometer wind speed after simple flow distortion corrections.



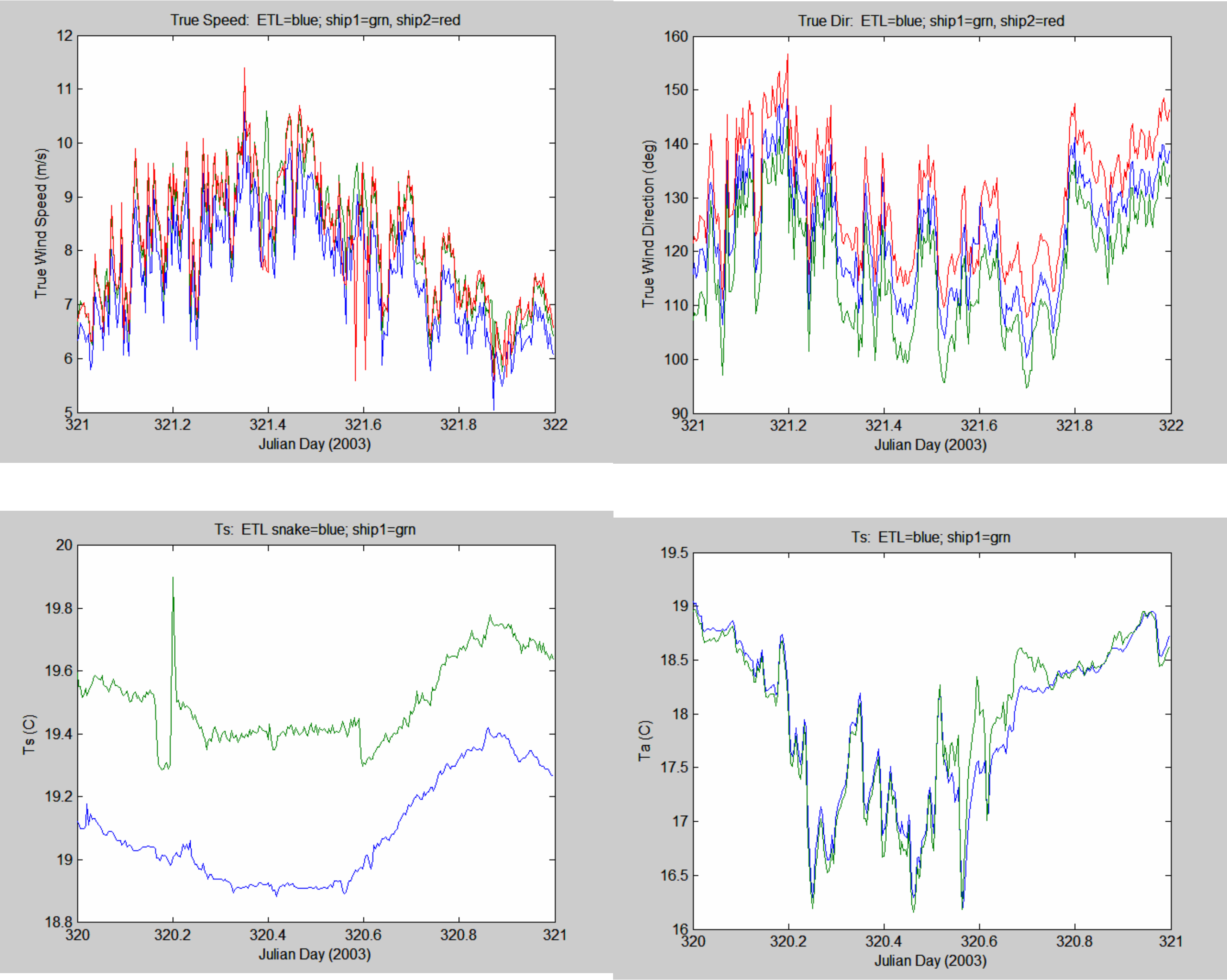


Corrected ETL sonic winds compared to raw IMET winds: left panel, all data; right panel, with ship stopped.

Evaluation of Distortion Effects on Wind Speed from the Ronald H. Brown



Mean wind speed divided by inertial-dissipation friction velocity measurements. The surface stress is air density times u_*^2. ID friction velocity is relatively unaffected by flow distortion. Upper panel is uncorrected IMET data and the lower panel is the distortion-corrected ETL sonic anemometer. Flow distortion effects are apparent as local extrema at about ±25 deg. The variance of the upper signal is about twice that of the lower.

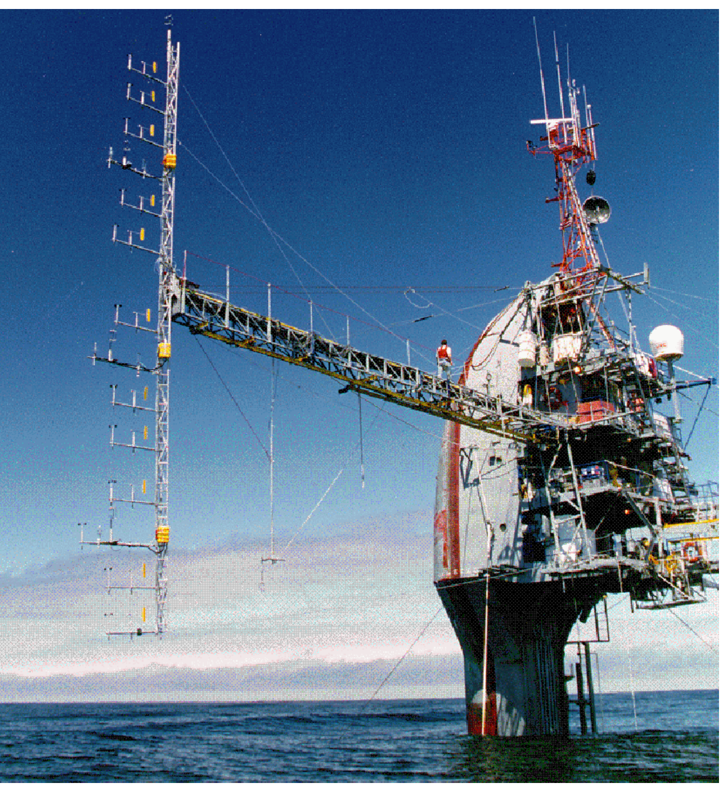


Recent sample comparison from the R/V Roger Revelle: upper left, wind speed; upper right, wind direction; lower left, water temperature.; lower right, air temperature

High-Resolution Climate Data from Research and Volunteer Observing Ships

- **Portable Flux Standard:** Essentially an improved, user-friendly, easy to install version of the existing ETL ship flux system
  - High-speed motion-corrected turbulence sensors (sonic anemometers, IR hygrometers)
  - Pitch-roll stabilized radiative flux sensors
  - Well characterized, well placed precipitation sensors
  - High quality aspirated mean T/RH, IR ocean skin temperature, seasnake SST
  - Full navigation system and 6 DOF ship motions
  - Measurements of surface waves
  - Calibrations by national facilities
  - Principally ETL
- **Distributed side-by-side sensor suite**:
  - Based on IMET sets
  - Wireless local network
  - Principally WHOI
- **Schedule for Flux Standard**:
  - FY04 Test concept on NOAA ship Ronald H. Brown using existing ETL flux system
  - FY05 Begin construction of flux standard. Field test on UNOLS ship
  - FY06 Complete construction of flux standard. Perform intercalibration study on one ship

- **Intensive Field Study**: Suggest a field study with FLIP, a typical R/V, and a buoy to investigate ship flow distortion, CFD solutions, and the distortion effects on bulk meteorological variables and turbulent fluxes.



Upper: R/V Roger Revelle and WHOI Flux buoy. Lower left: R/P FLIP. Lower right: direct flux sensors.