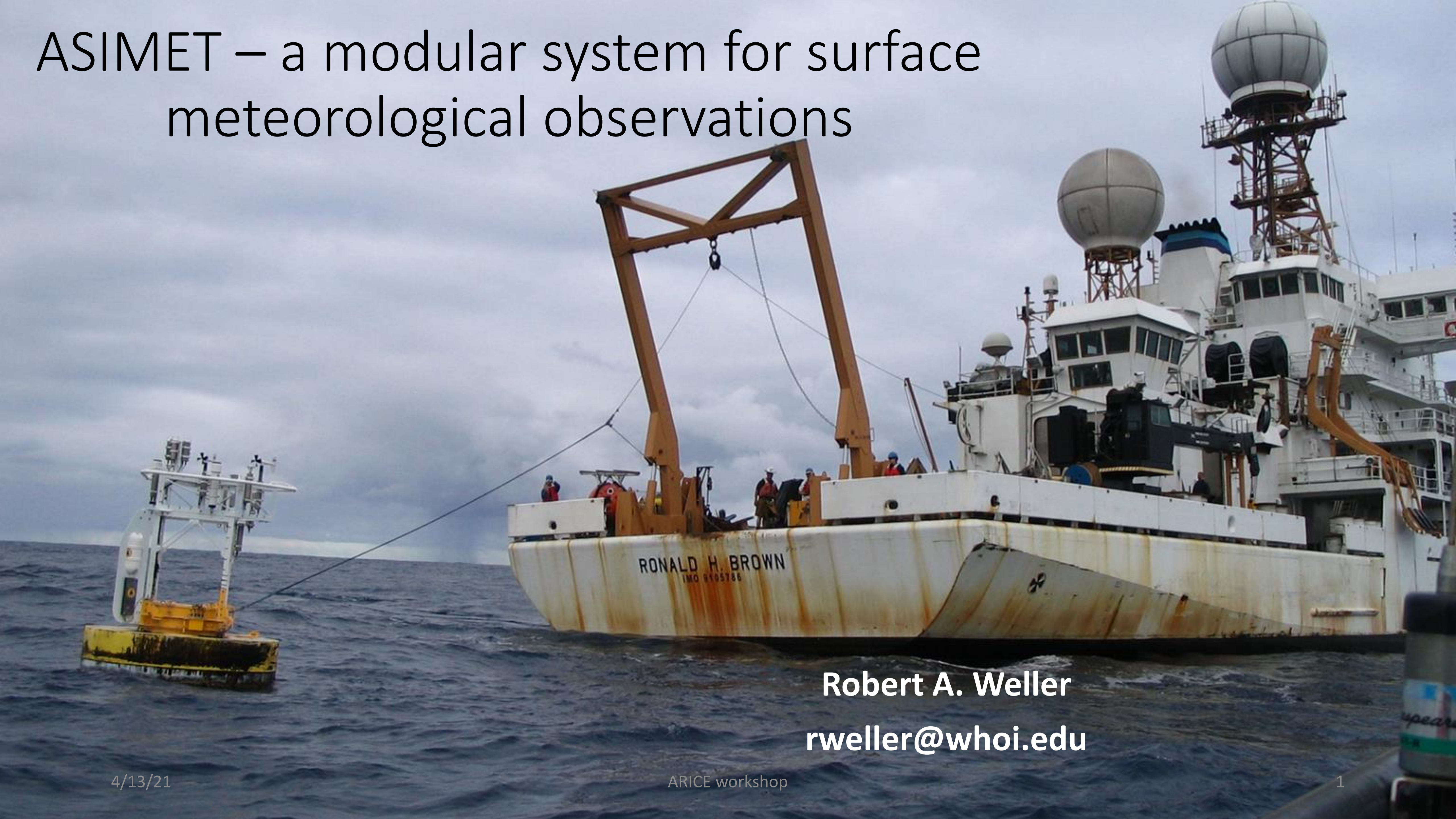
ASIMET – a modular system for surface meteorological observations



Robert A. Weller

rweller@whoi.edu

The need:

- Measure surface meteorology (wind vel, bar. pressure, air temp/humidity, incoming shortwave and longwave, rain) reliably, unattended, with high accuracy
- Long lived – low power consumption
- Redundancy – in power, in data storage
- Modular approach, each module carries calibration and ID information, does conversion to engineering units, also stores raw data
- Modules able to stand alone or be RS485 linked to power supply and data logger
- Signal conditioning and A to D as close as possible to sensor
- Durable, modules housed in stock titanium tubing
- Ease of use – RS232 direct link to each module, logger

The usage:

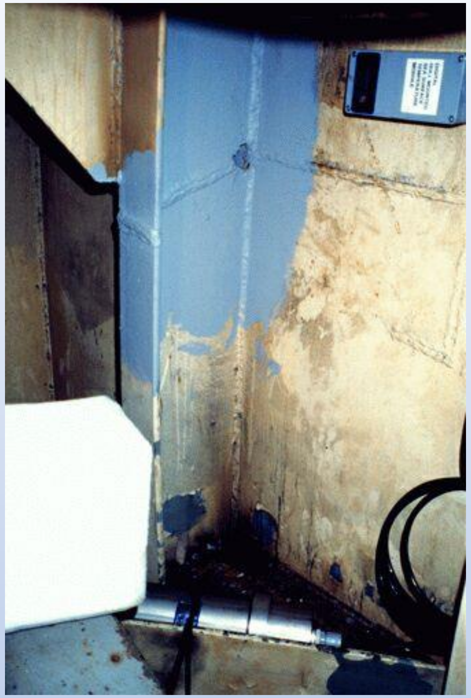
- Research vessels – U.S. UNOLS ships, NOAA Ronald H. Brown
- A land station in Saudi Arabia (KAUST)
- Moored buoys
  - NOAA funded Ocean Reference Stations
  - NSF funded Ocean Observatory Initiative, one off Greenland
  - Indian Bay of Bengal buoy
- Commercially available
  - WHOI supports engineering, upgrades, calibration
  - Star Engineering
  - International buyers

Volunteer observing ships:

- Hand carry
- Rapid on/off the ship
- Provide data display on bridge
- No extensive wiring – acoustic through hull link to SST sensor bonded to hull - RF links to other modules

Volunteer observing ships:

Bow tower installation Sealand Enterprise



SST sensor bonded to hull plating, acoustic transduce attached by bolts to ship’s frame; can communicate to the bridge.

Above deck, RF links

Research ships:

RH Brown

RV tower - down

ASIMET
rain
gauges

RV Oceanus

Temporary install of ASIMET, close up of wind sensor, RF link

Land station:

Coastal meteorological
tower on KAUST campus

Instrument package similar to buoy’s (same sensors):
Solar and infrared radiation, air temp, humidity, winds,
barometric pressure, precipitation,
(all transmitted via satellite)

Tom Farrar, WHOI

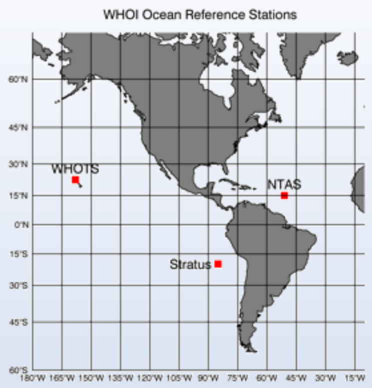
OOI moored buoys:

Global and coastal surface buoys have ASIMET systems.

Started ~2014

Irminger, PAPA continue

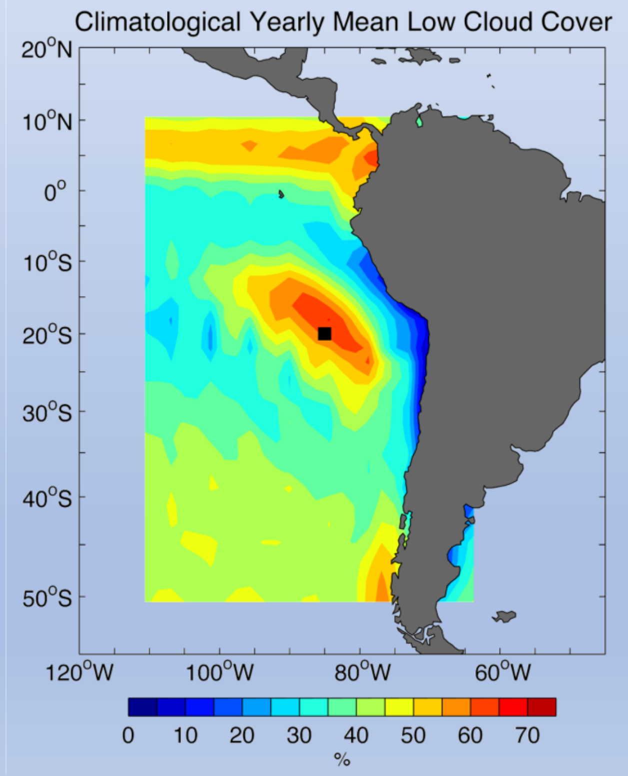
Three NOAA-funded Ocean Reference Stations (ORS)

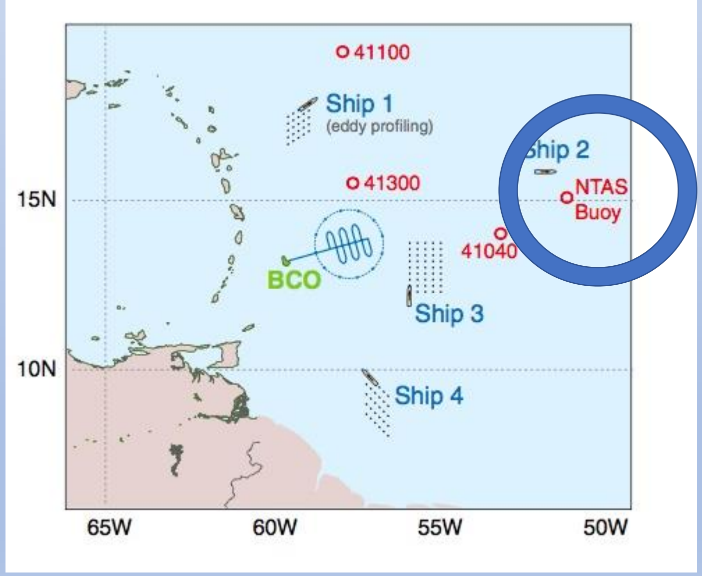


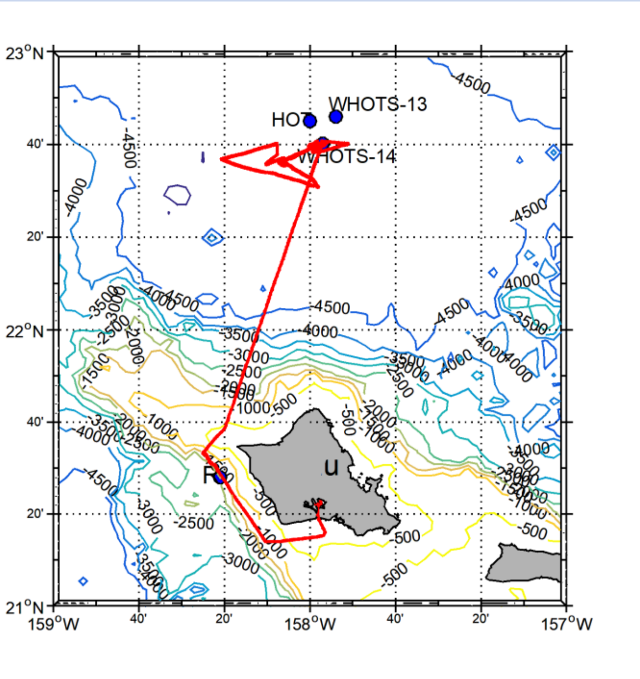
Stratus
since October 2000

NTAS
Northwest Tropical Atlantic Station
since March 2001

WHOTS
WHOI Hawaii Ocean Time Series
since August 2001







The Ocean Reference Station approach

Annual recovery and deployment of fresh buoy

- Overlap new mooring with old
- Ship carries bow tower and independent sensor set
- Ship days dedicated to ship versus buoy comparisons
- Each buoy has redundant sensor sets

Calibration

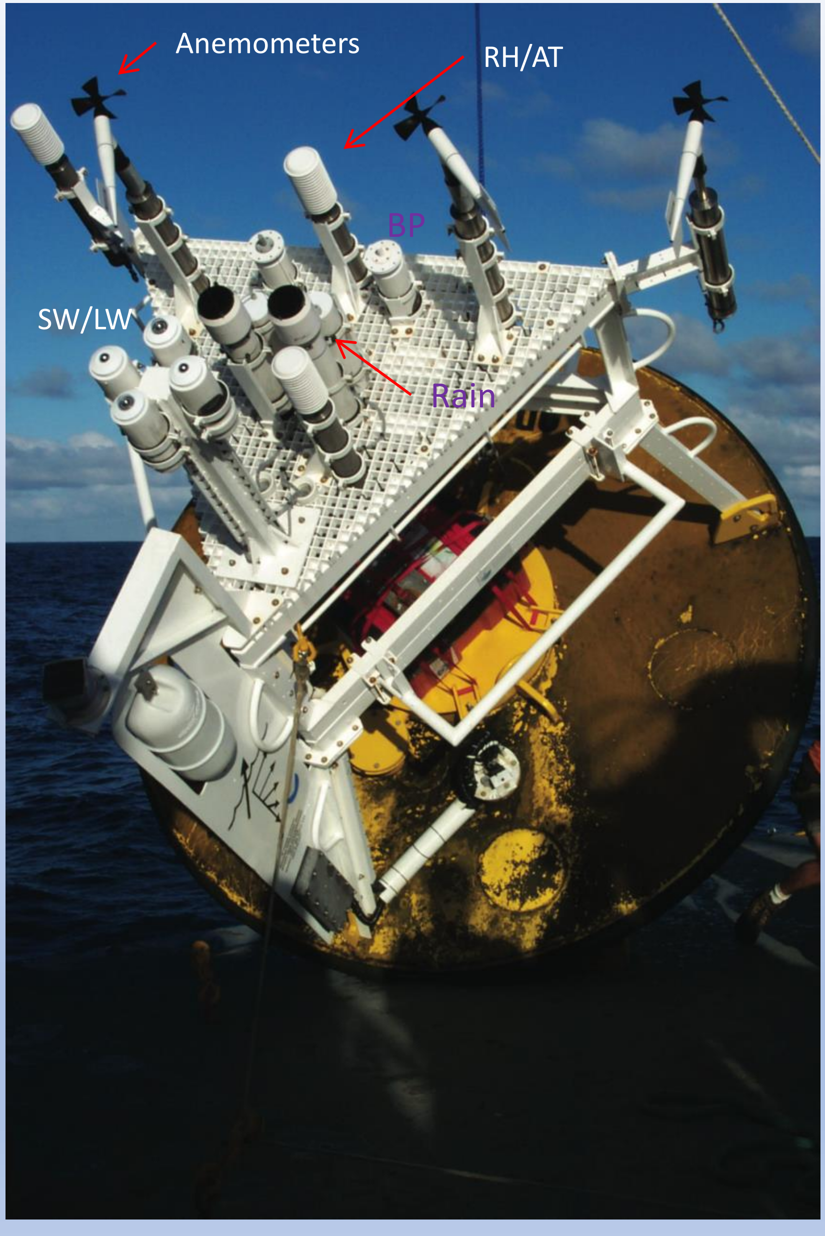
- Pre- and post-deployment

Data are withheld from GTS

- Establish time series as independent reference data
- Shared with modeling centers in delayed mode
- Modeling center data acquired for grid points near buoy

RV Melville with bow mast running comparison with Stratus buoy

Modular ASIMET installation on Stratus buoy



Surface Buoy

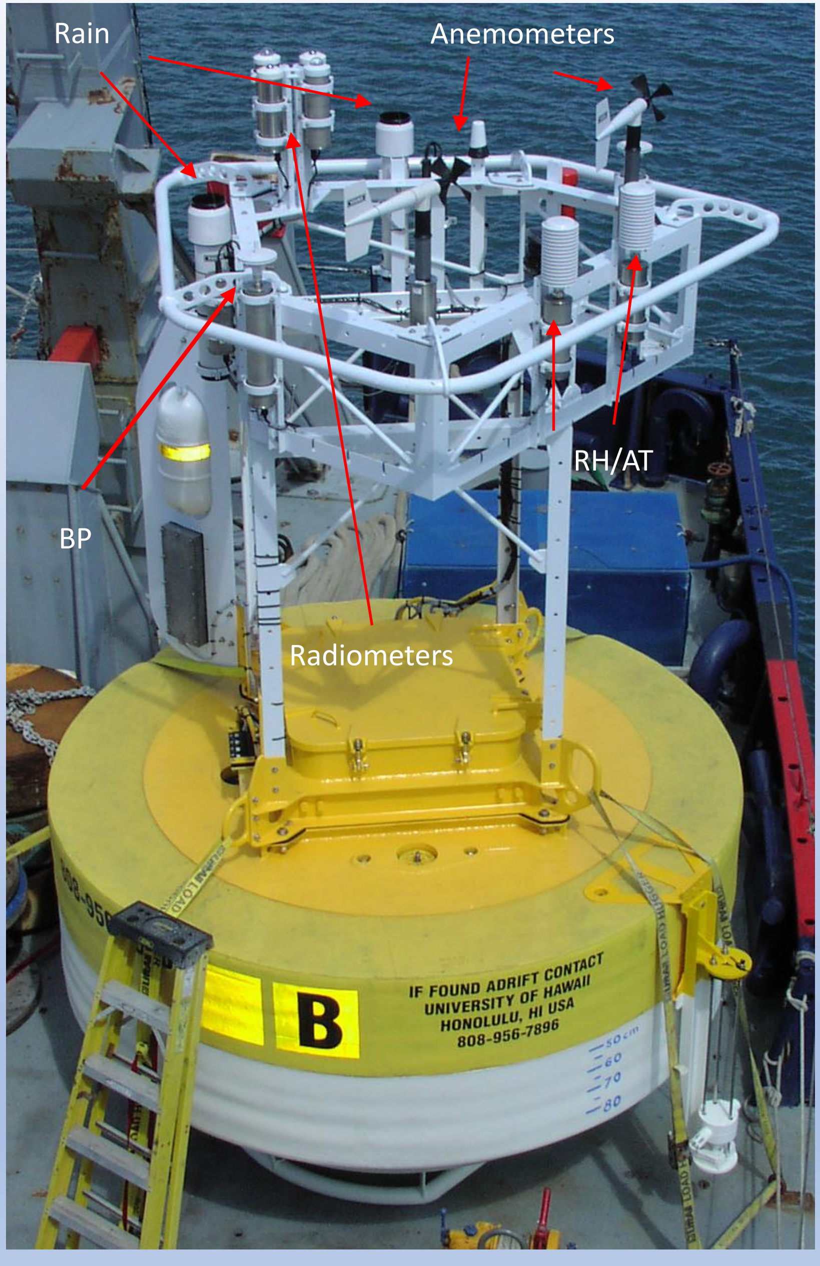
3 m tower – carries 2 to 3 redundant sets of bulk meteorological sensors

Buoy well – data logger, batteries, telemetry hardware

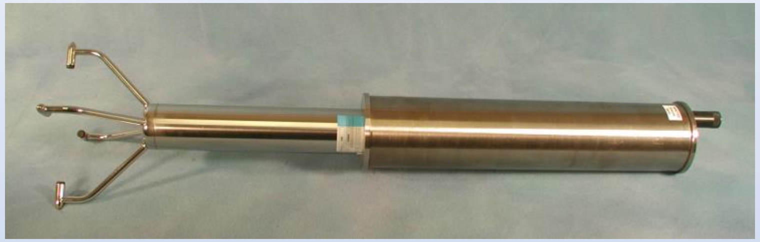
Deployments - up to 18 months, typically 12-14 months

Data return - 99% return of complete 1-minute time series of surface meteorology and air sea fluxes

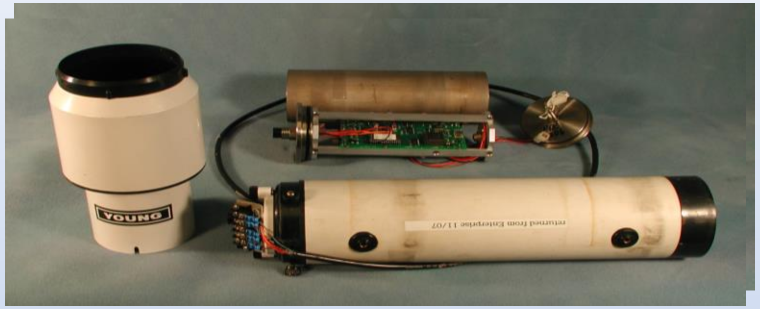
Stable - ~2,000 lb load on bridle, low pitch/roll, tilt



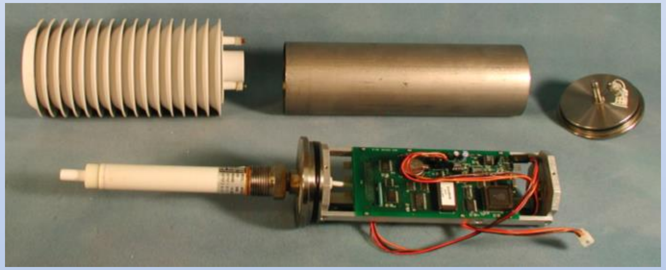
Modular, ASIMET system, providing ascii engineering units, with key information (e.g., calibration) stored internally



Sonic anemometer



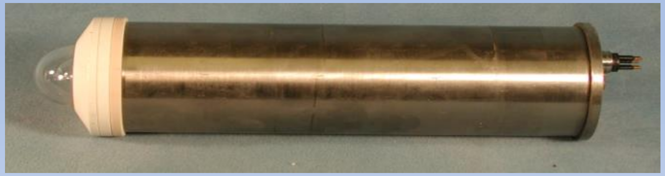
Siphon rain gauge



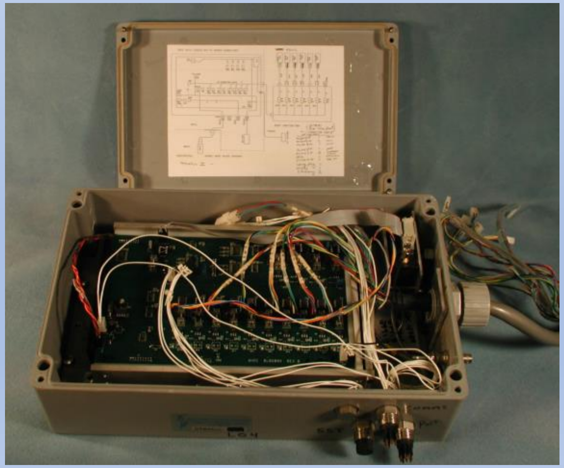
Humidity/air temperature

Barometer

Incoming longwave



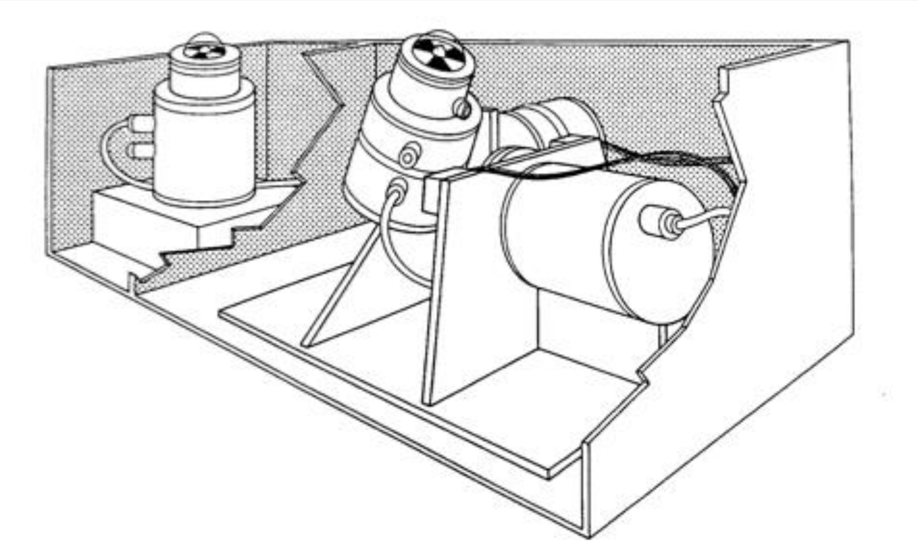
Incoming shortwave



Data logger

STAR ENGINEERING
1 Vaillancourt Dr.
North Attleboro, MA 02763, USA
Tel: 508-316-1492 :
Cell: 508-308-5749
www.starengineeringinc.com
Contact: Victor Neagoe

Understanding and improving sensors– example, radiation sensors



Measure buoy motion (pitch and roll), use measured motion to drive two-axis motion table on the roof, assess impact of pitch and roll on measured shortwave radiation (MacWhorter and Weller, 1991).

At sea comparisons against Fairall's radiometers, including on stabilized platform.

Rooftop calibration facility.

Kipp and Zonen reference standards returned for calibration in Boulder.

Early shift from Eppley 848 shortwave sensors to Eppley PSP sensors.

Upgraded amplifier stability.

Understanding and improving sensors– example, radiation sensors

Degradation of optical black paint on incoming shortwave radiation sensor

- Eppley PSP, optical black paint aging
- Typically, reduced sensitivity
- Up to 9% change/5 years
- Most often, -4% to -6%/5 years

Shifting to pyranometers with more stable optical black coatings.

Rotating 3 calibration standards, once per year (one on roof, one out for calibration, one in drawer).

Overlap the standards.

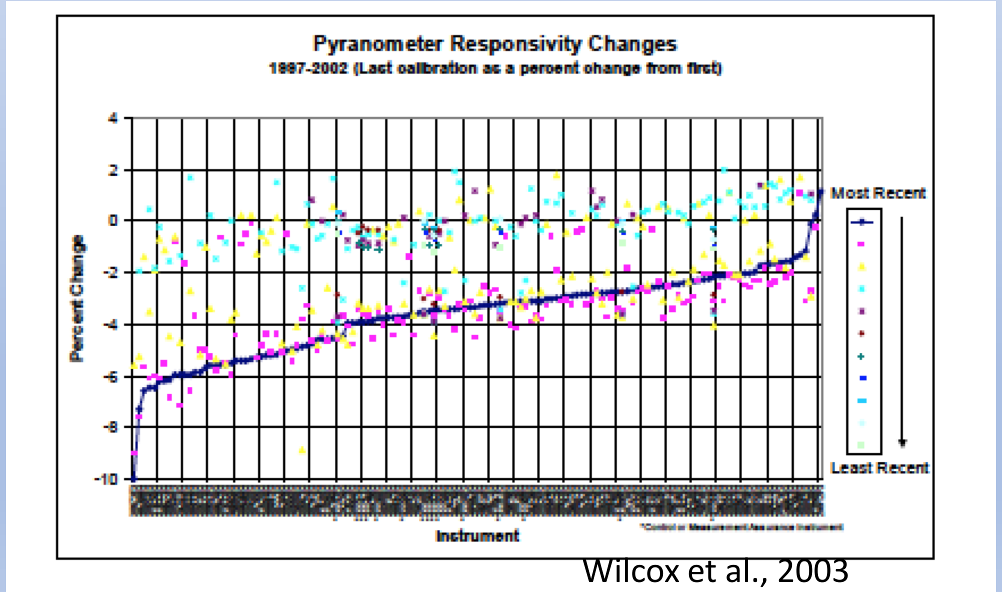
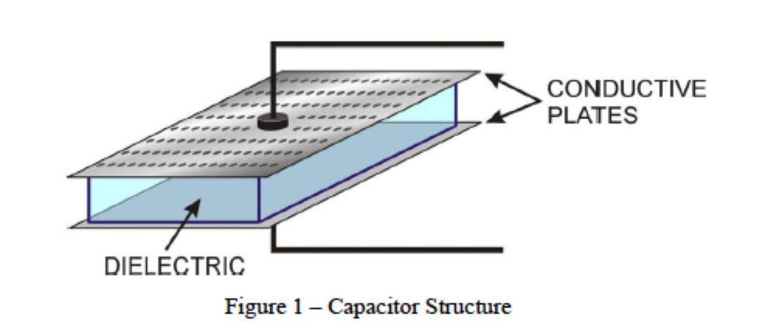
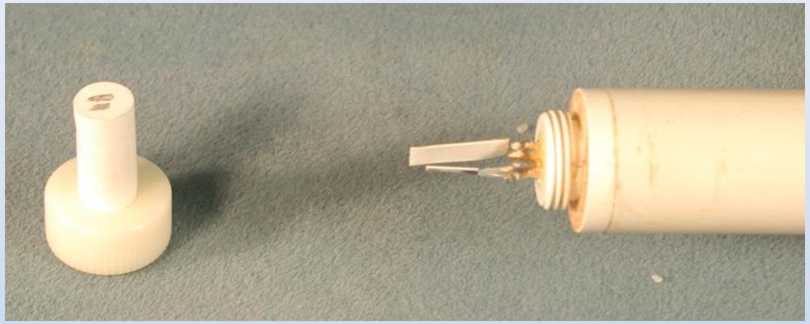


Figure 3. The 1997-2002 pyranometer responsivity changes.

Improving sensor performance – example, humidity and air temperature sensors



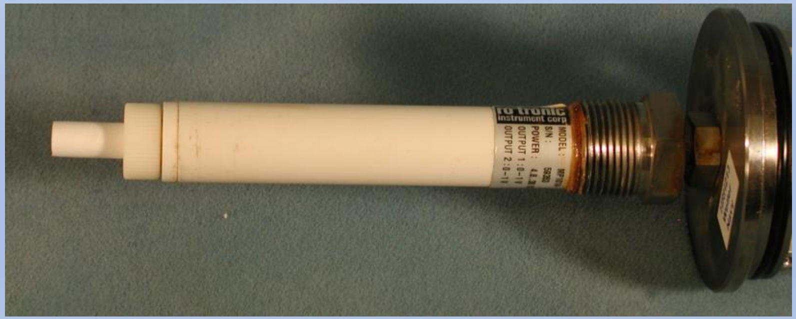
Thin film capacitive sensor (Bull, 2006)



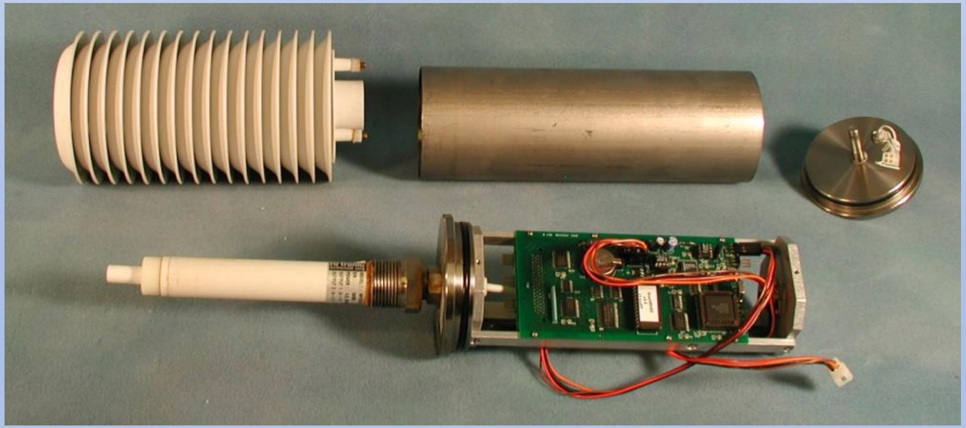
Porous Teflon filter

Rotronic sensor

Challenges: salt, solar heating, stability, accuracy, hysteresis, calibration



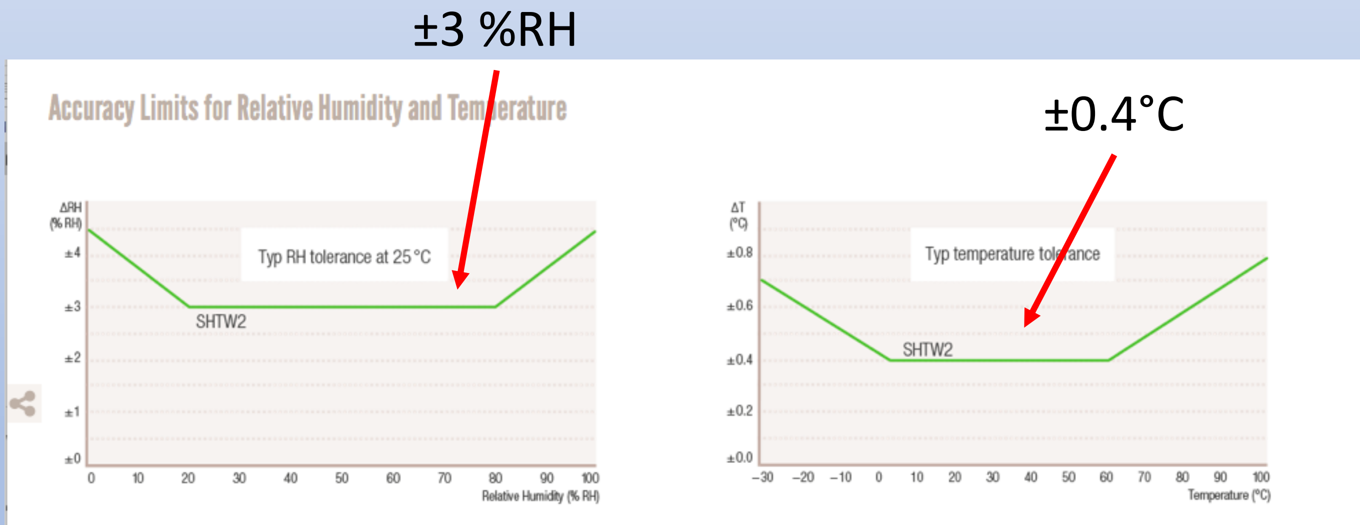
Sensor assembly



ASIMET RH/AT module with Gill multiplate shield

Improving sensor performance – example, humidity and air temperature sensors

Rotronic MP 101A analog sensor performance – air temperature accuracies degraded to worse than 0.5°C with change in circuitry by Rotronic, in warmer regimes (e.g. WHOTS), even worse

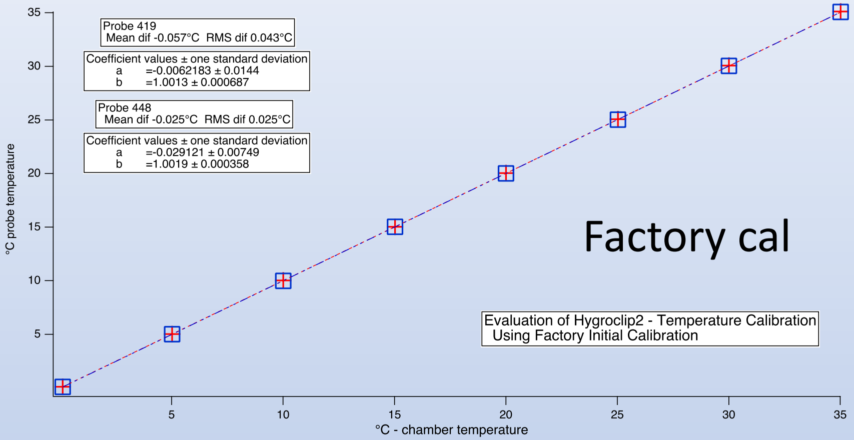


Sensirion RH/AT accuracy specifications

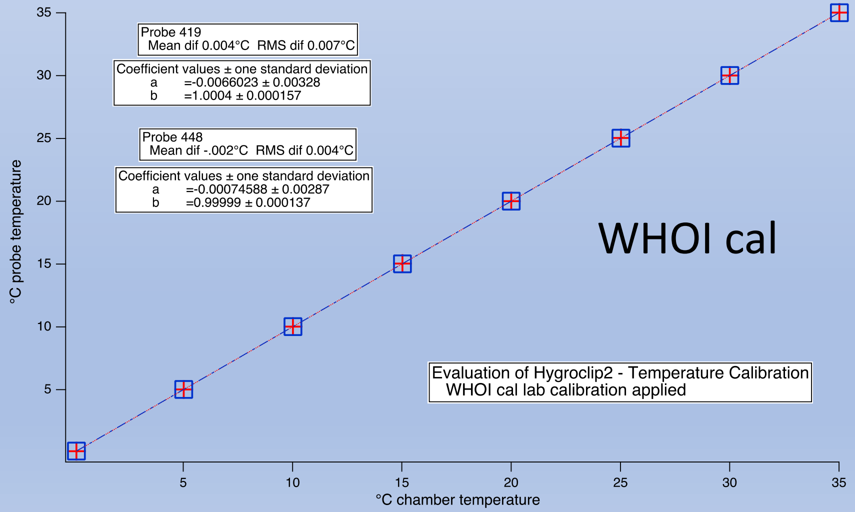
Many RH/AT sensors developed typically for HVAC and automotive industries tuned to perform best at 20°C and most not achieving the target accuracies needed for the ORS deployment

Improving sensor performance – example, humidity and air temperature sensors

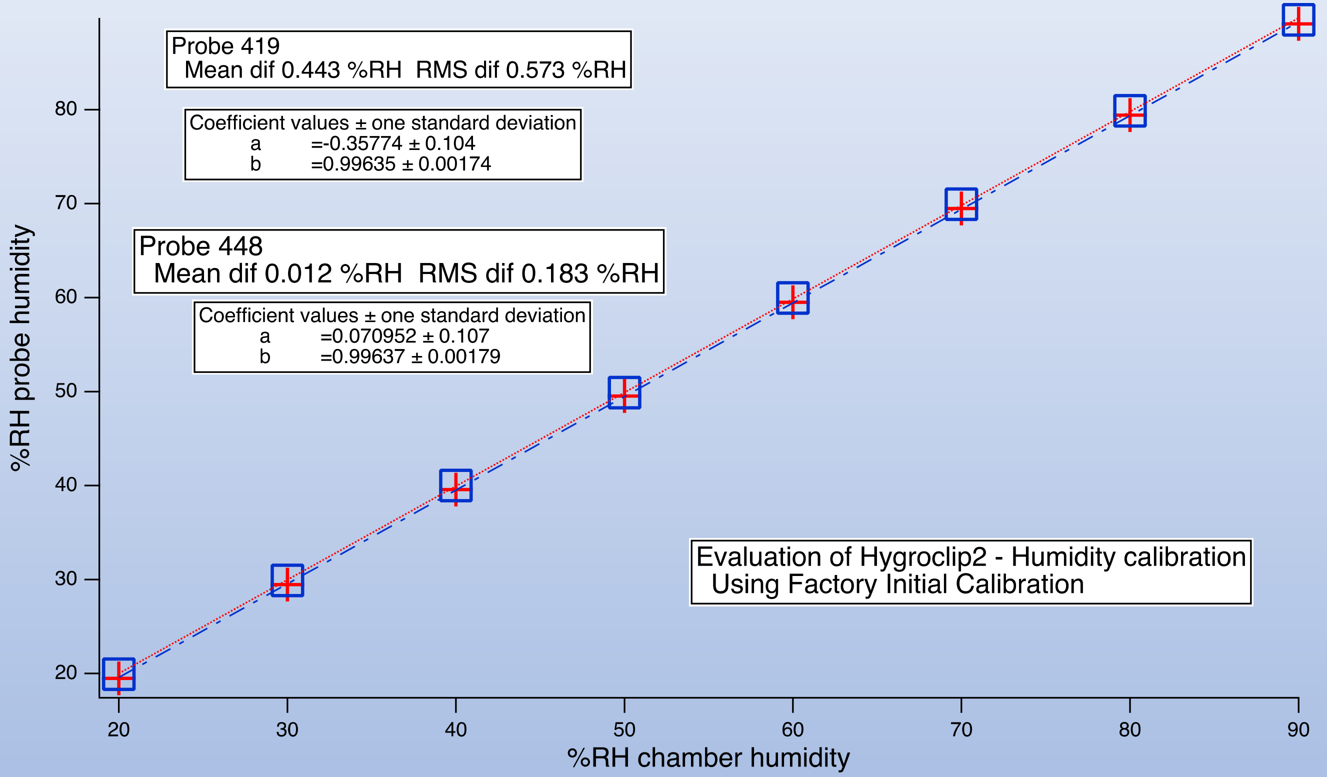
Two Rotronics Hydroclip2 sensors evaluated in WHOI cal lab



Mean ΔT = 0.045 °C, RMS ΔT = 0.038 °C



Mean ΔT = 0.003 °C, RMS ΔT = 0.005 °C



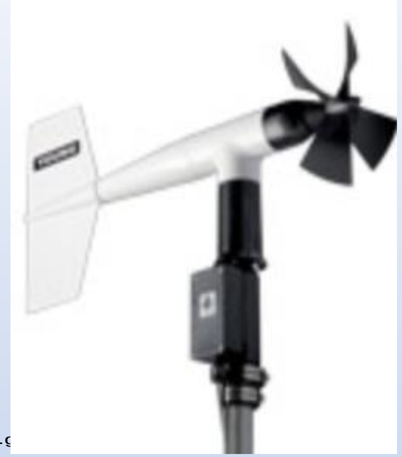
Humidity check , factory calibration

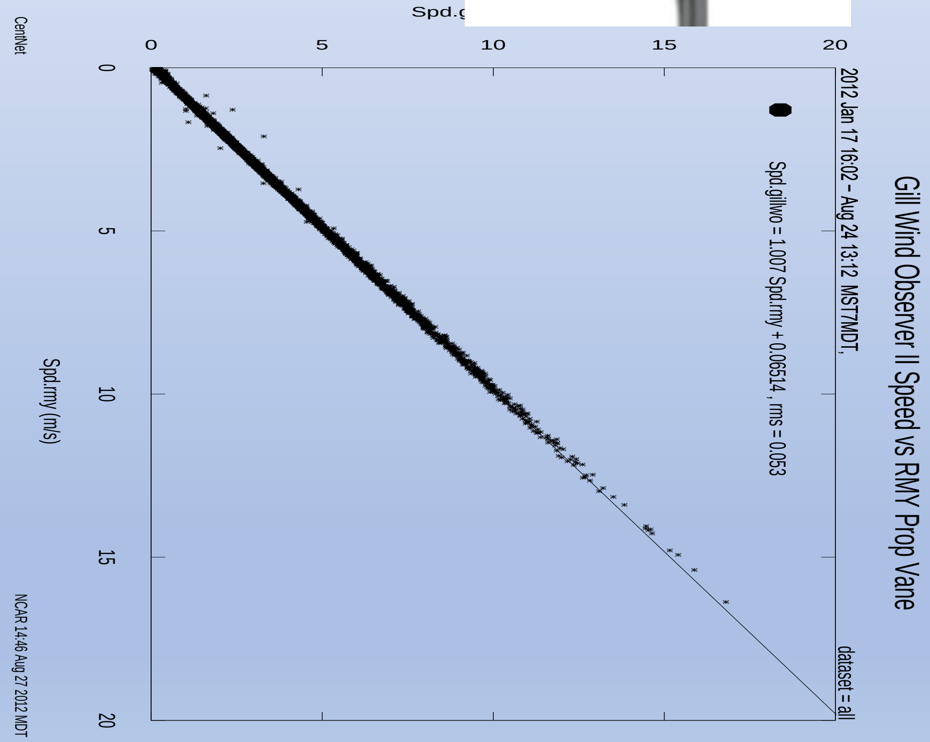
Mean ΔRH = 0.453 %RH. RMS ΔRH = 0.573 %RH

Mean ΔRH = 0.012 %RH. RMS ΔRH = 0.183 %RH

Wind speed sensors – verifying comparability of two-axis sonic to propeller-vane

- RM Young Propeller Vane
- Gill Wind Observer 2 D Sonic





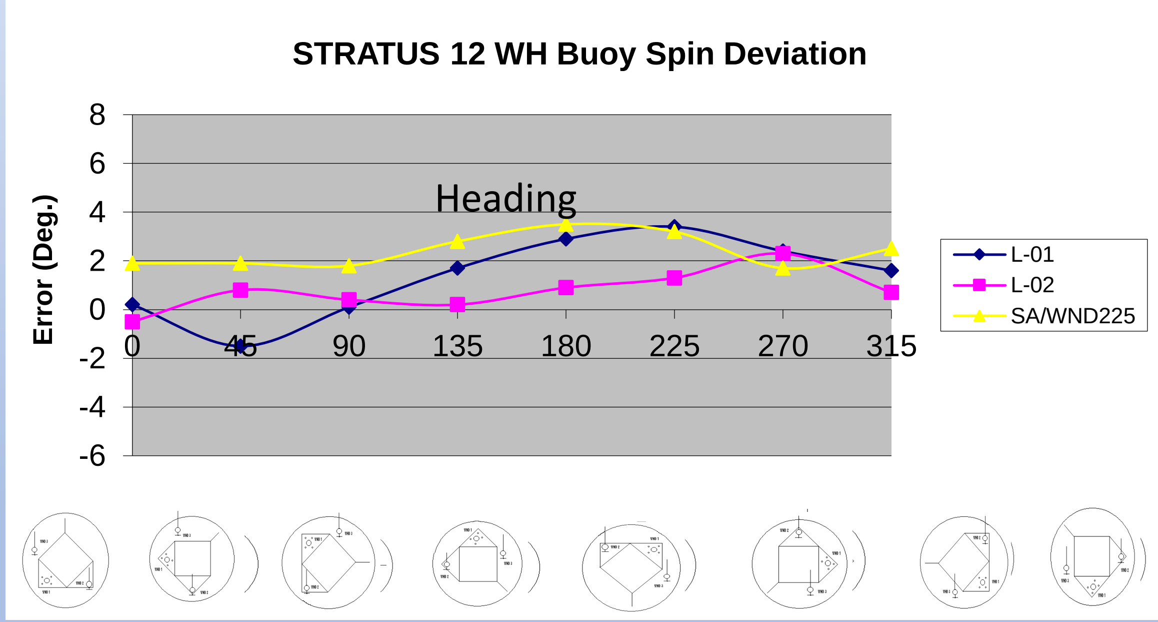
From Tom Horst, NCAR

Wind direction – validate compass/vane and investigate flow around tower

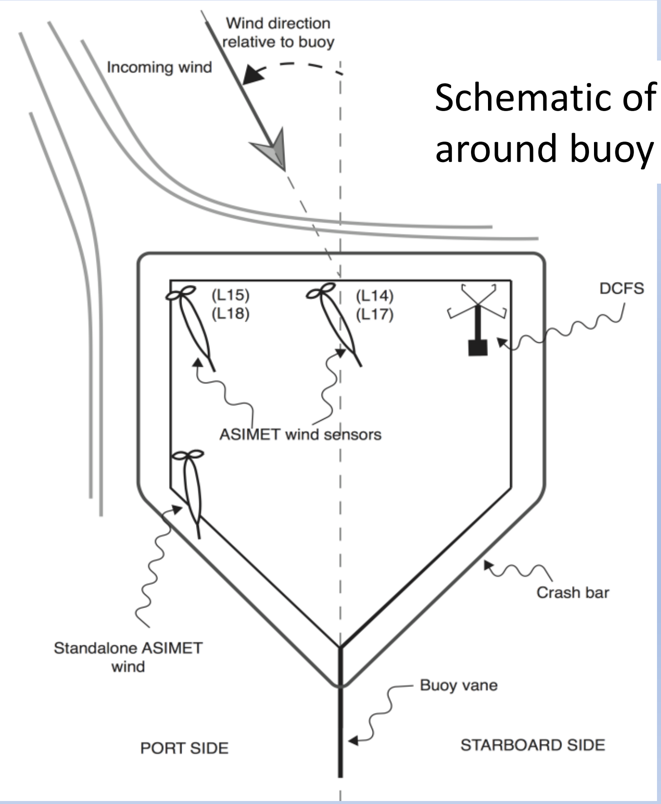
Where does inaccuracy stem from?

Challenges:

- *Performance of magnetic compasses*
- *Flow distortion by buoy structure*



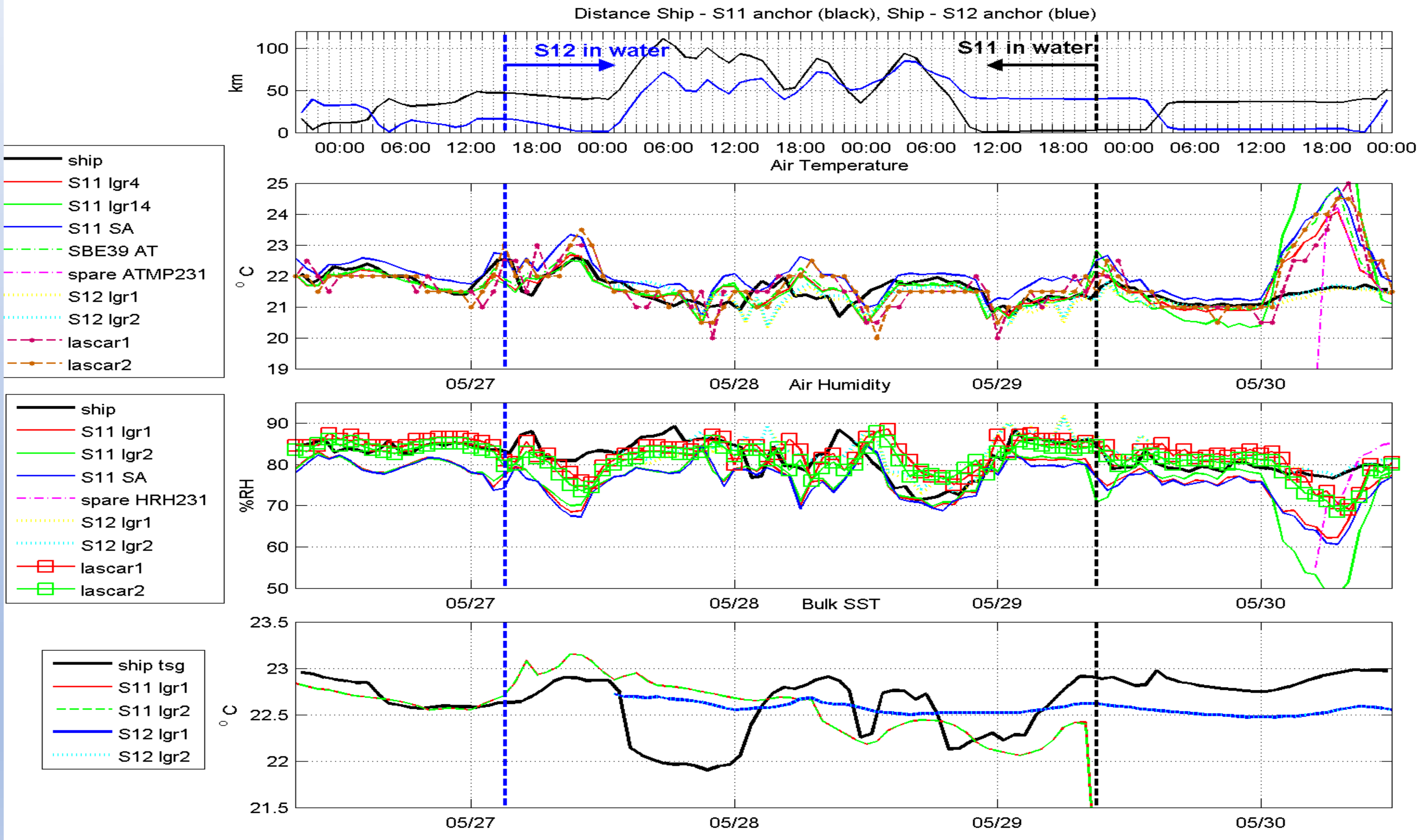
Buoy spin – turning buoy around and sampling observed heading relative to true heading



Schematic of flow around buoy tower

In the field intercomparisons
Example: RV *Melville* vs Stratus 11 and Stratus 12 buoys

10 air temp sensors and 9 humidity sensors in comparison



Distance – ship-buoy

Air temp – ship, two buoys

Relative humidity – ship, two buoys

Bulk sea surface temperature – ship, two buoys

Present surface meteorology capabilities in the field

Moored buoy accuracies

	Instant	Daily	Monthly
Incoming Longwave	7.5 W m^{-2}	4 W m^{-2}	4 W m^{-2}
Incoming Shortwave	10 W m^{-2}	6 W m^{-2}	5 W m^{-2}
Relative humidity	1% RH, 3% low wind	1%, 3% low wind	1%
Air temperature	0.2°	0.1°	0.1°
Barometric pressure	0.3 mb	0.2 mb	0.2 mb
SST	0.1°	0.1°	0.04°C
Wind speed	1.5% 0.1 m s^{-1}	1% 0.1 m s^{-1}	1% 0.1 m s^{-1}
Wind direction	6°	5°	5°
Precipitation	20%	20%	20%

The approach - present air-sea flux capabilities

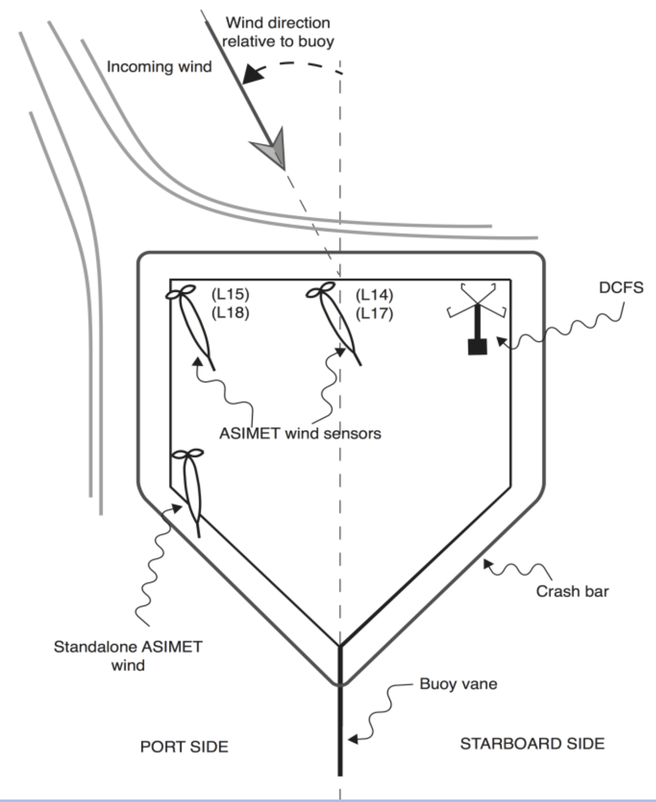
Moored buoy accuracies

	Instant	Daily	Monthly
Longwave	7.5 W m^{-2}	2 W m^{-2}	2 W m^{-2}
Shortwave	10 W m^{-2}	3 W m^{-2}	3 W m^{-2}
Latent	5 W m^{-2}	4 W m^{-2}	4 W m^{-2}
Sensible	1.5 W m^{-2}	1.5 W m^{-2}	1.5 W m^{-2}
Net Heat Flux	15 W m^{-2}	8 W m^{-2}	8 W m^{-2}
Wind Stress	0.007 N m^{-2}	0.007 N m^{-2}	0.007 N m^{-2}
Precipitation	20%	20%	20%

Notes:

1) Below 15 – 20 m s^{-1}, with bulk formulae
2) Supported by sensor redundancy, in-situ calibration by ship, shoreside QA/QC
3) There is need for DCFS and wave package for higher winds, sea states
4) Flow distortion by the buoy structure is an issue

Usage example: Assessing scatterometer winds using ORS data (Micha Schlundt)



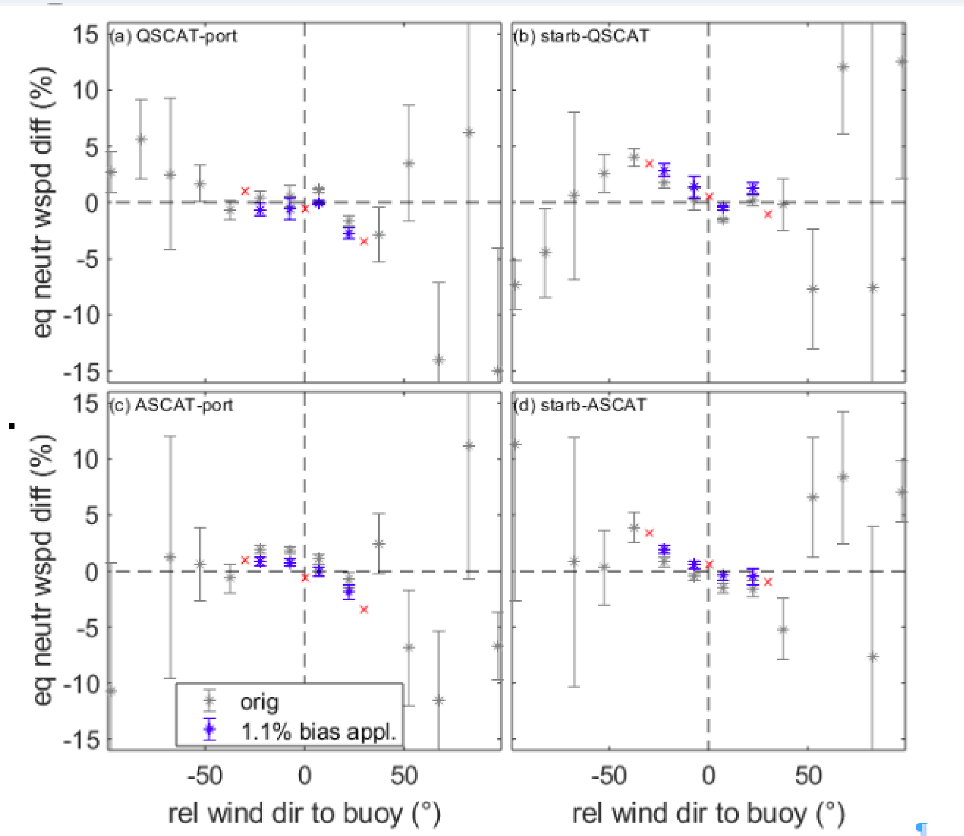


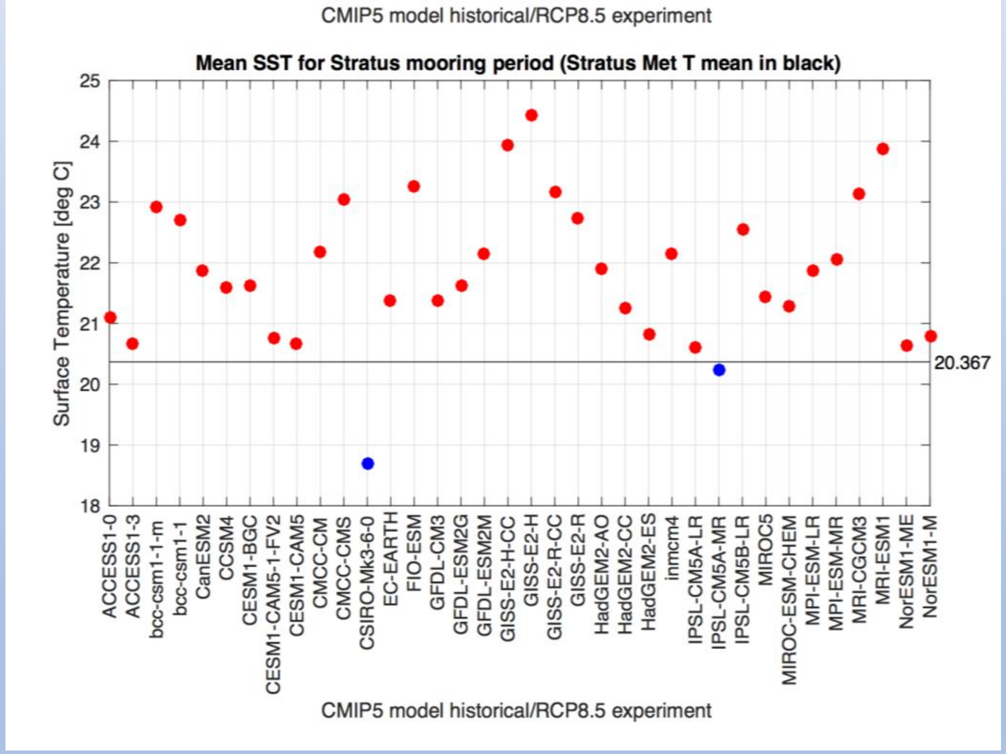
Figure 7. Equivalent neutral wind speed differences, when replacing (a) the starboard module with QSCAT, (b) the port module with QuikSCAT, (c) the starboard module with ASCAT, (d) the port module with ASCAT. Shown are the original bin averages (grey) and the bin averages within ±30° with 1.1%-bias corrected satellite data (blue).

Review ORS wind data, quantify flow effects. Pick best wind velocity record.

Use best ORS wind to evaluate QSCAT and ASCAT wind velocities. Small differences, possible 1.1% bias found in scatterometer data, blue shows that removed.

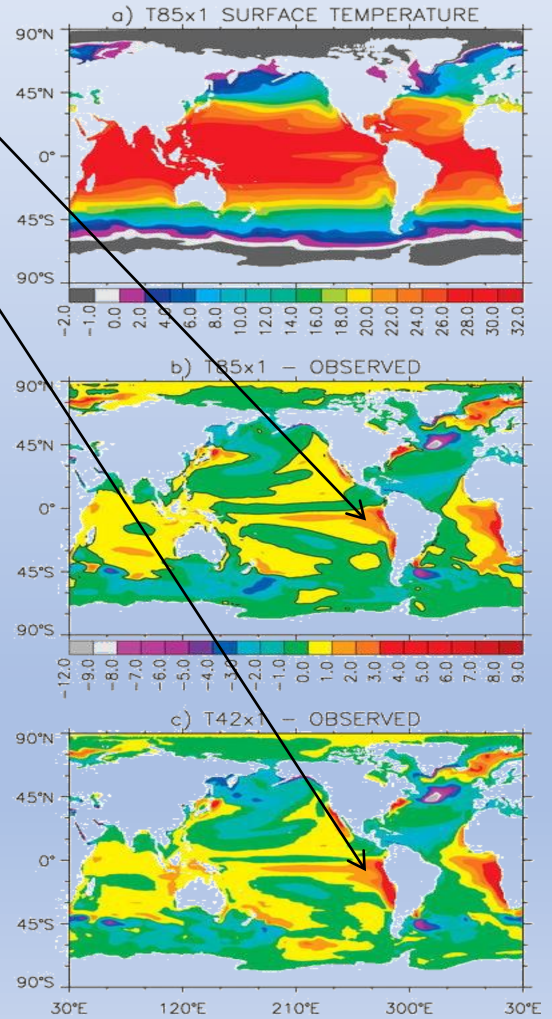
Usage example: explore the source of model biases

Comparisons of the Community Climate System Model 3 (CCSM3) with observations by Large and Danabasoglu (2006). Model SST, in particular, is too warm in the stratus deck region.



Climate models yield SSTs at Stratus that are too warm by up to 4°C

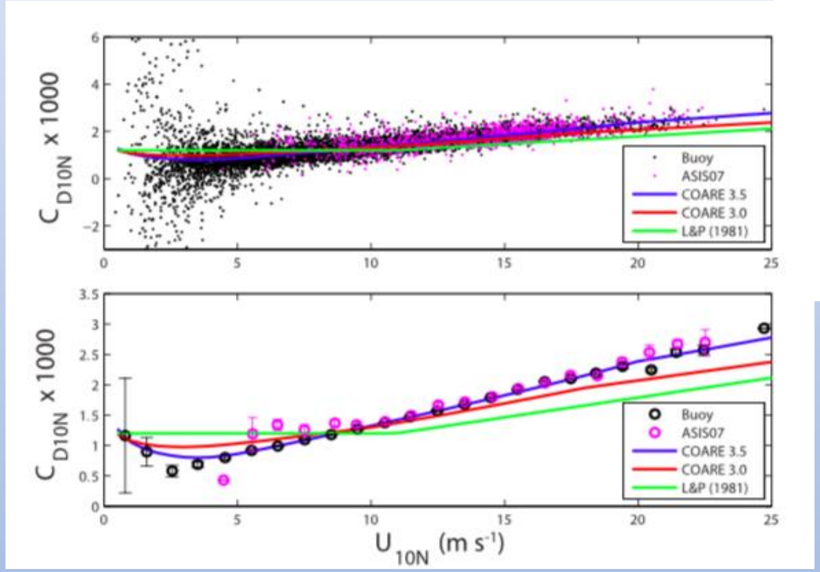
Eastern South Pacific SST bias in models



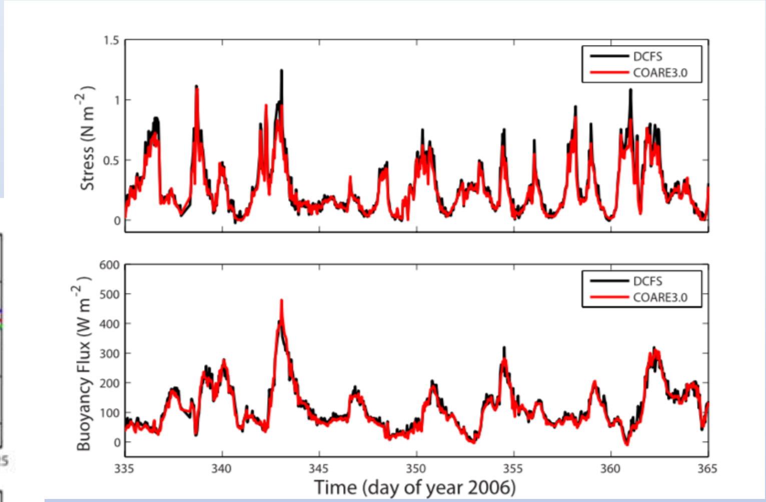
Usage example: Air-sea fluxes – surface heat flux and wind stress on a global basis: *enabling progress*

- Continuing improvements to bulk formulae, to in-situ sensing, to integration of Direct Covariance Flux Systems (DCFS)

Surface buoy in Gulf Stream



Drag coefficient versus wind speed (top); changes to drag coefficient for COARE 3.5



Buoy bulk stress and buoyancy flux with COARE 3.0 vs DCFS stress and buoyancy flux

Bigorre et al. (2013)

Questions and discussion