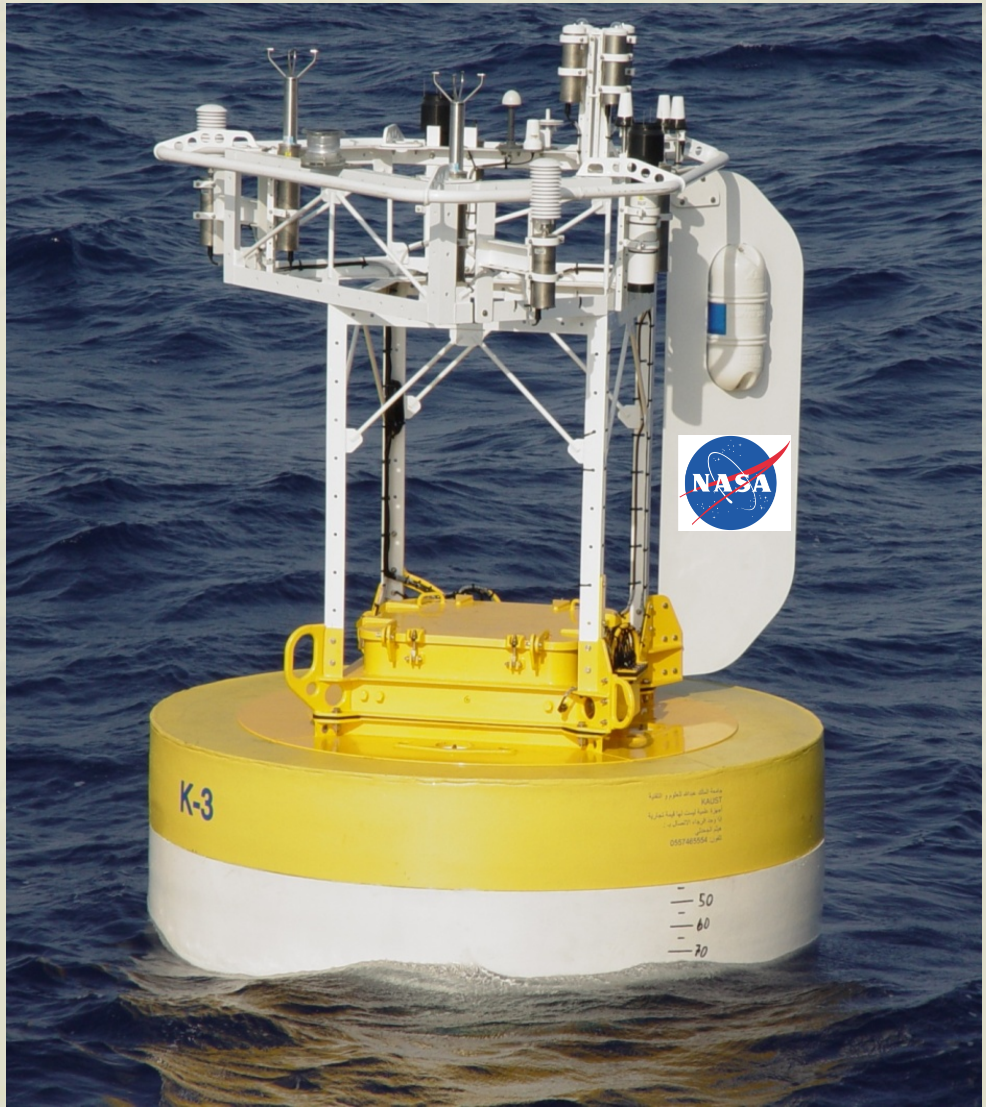
A surface mooring for SPURS

Tom Farrar
Al Plueddemann
Jim Edson



Goal of surface mooring:

→ Collect accurate measurements of surface freshwater fluxes, the evolution of upper-ocean salinity, and other quantities that influence upper-ocean salinity and upper-ocean dynamics.

→Vertically integrated budget equation: (hats indicate deviations from vertical average)

$$\frac{\partial S}{\partial t} = -\vec{u}\cdot\nabla S + \hat{S}_{-h}\left(\frac{\partial h}{\partial t} + w_{-h} + \vec{u}_{-h}\cdot\nabla h\right) - \frac{Q_{-h}}{h} + \frac{(E-P)S}{h} - \frac{1}{h}\nabla\cdot\int_{-h}^{0}\hat{\vec{u}}\hat{S}\,dz$$

↑ = Terms that can be estimated from mooring data

◯ = Terms that cannot be estimated from mooring data

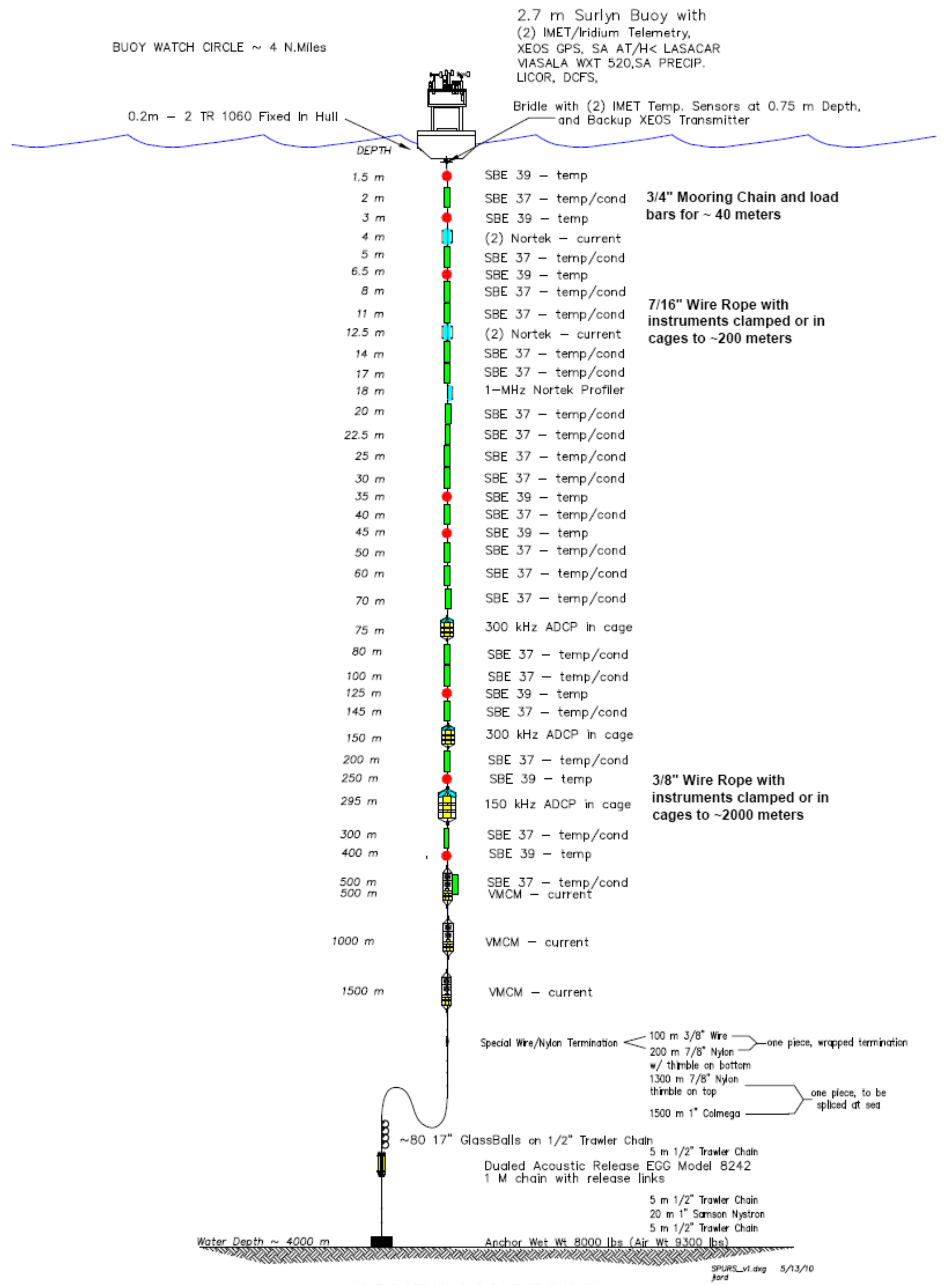
Approach:

(1) Measurements of surface meteorology and radiation with dual IMET packages

(2) Enhanced SPURS IMET measurements (focus on E-P)

(3) Direct turbulent flux measurements (wind stress, latent heat flux/evap, sensible heat flux)

(4) Measurements of T, S, and U with good vertical and temporal resolution



SPURS MOORING
Draft

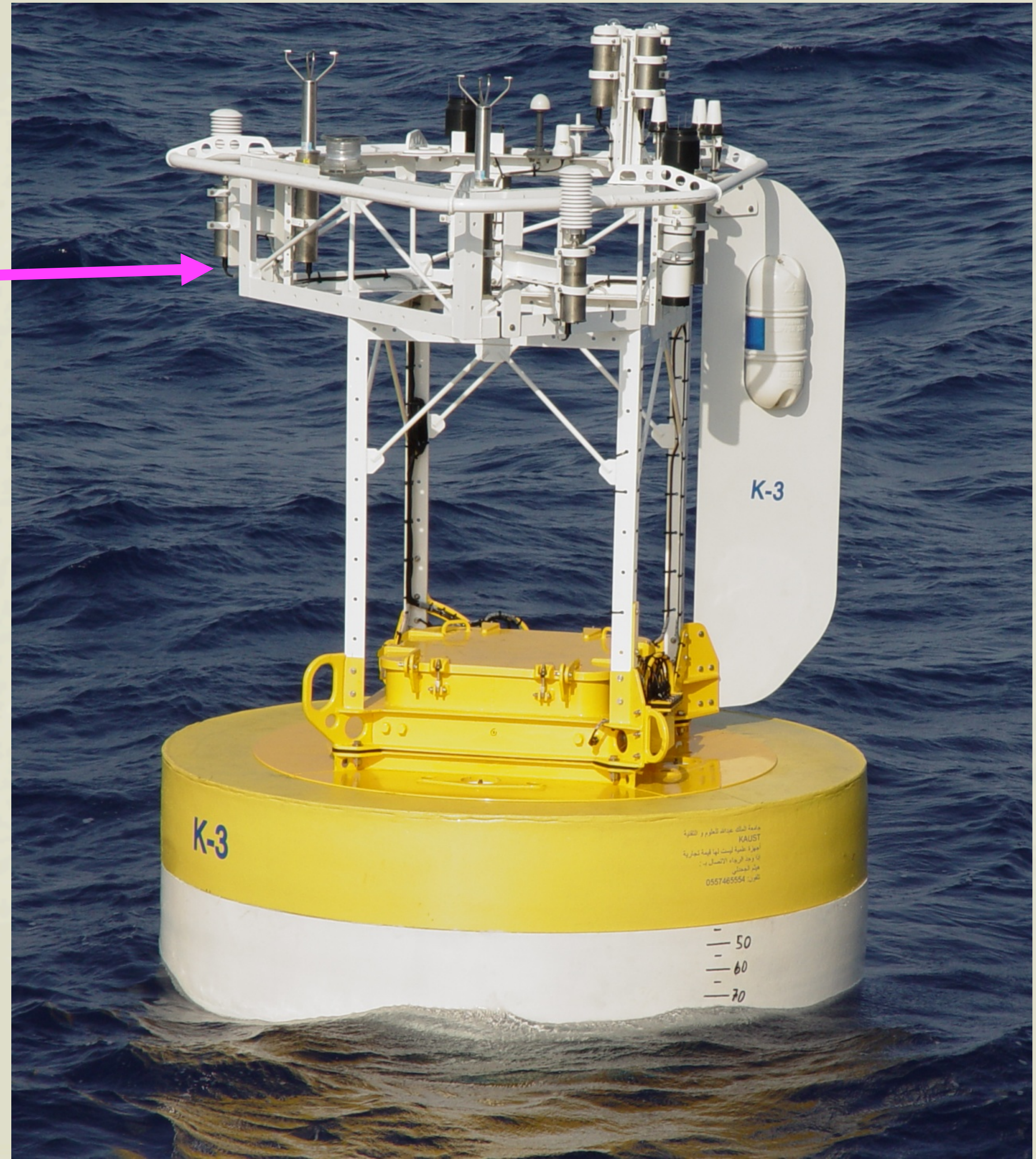
Core buoy sensor suite

Shortwave and longwave radiation, air temp, humidity, winds, barometric pressure, precipitation, SST (75 cm), sea surface salinity (75 cm), surface waves
(all transmitted via satellite)

IMET Sensor Suite (Colbo and Weller, 2009; Hosom et al., 1995)

→These measurements will be made redundantly to ensure a complete and accurate time series.

→All of these data, and bulk flux estimates, will be available in near real-time.



Two extra rain gauges for SPURS:

→Flow distortion around rain gauges is a well-known source of error. We plan to deploy a Hasse rain gauge (right) designed to minimize this error.

→We also plan to deploy a Vaisala WXT520, which includes an acoustic sensor to measure impact of rain drops on a metal disc.

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A Ship Rain Gauge for Use in High Wind Speeds

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Institut fuer Meereskunde, Kiel, Germany

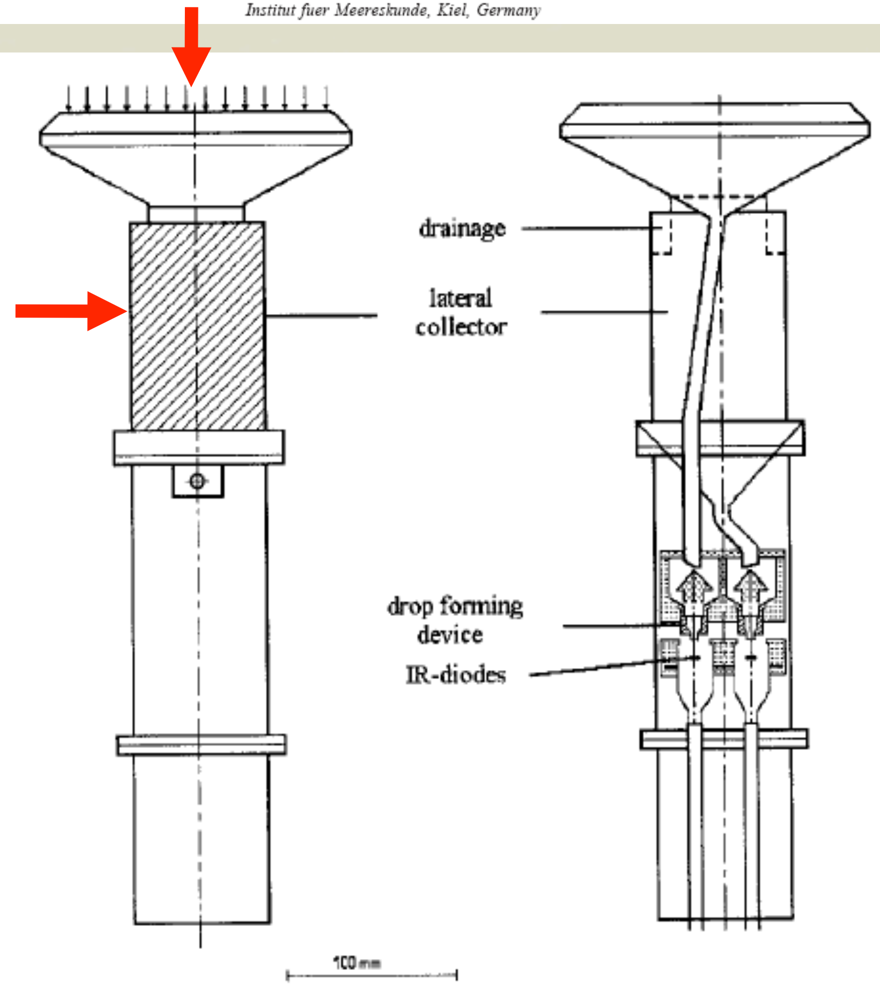
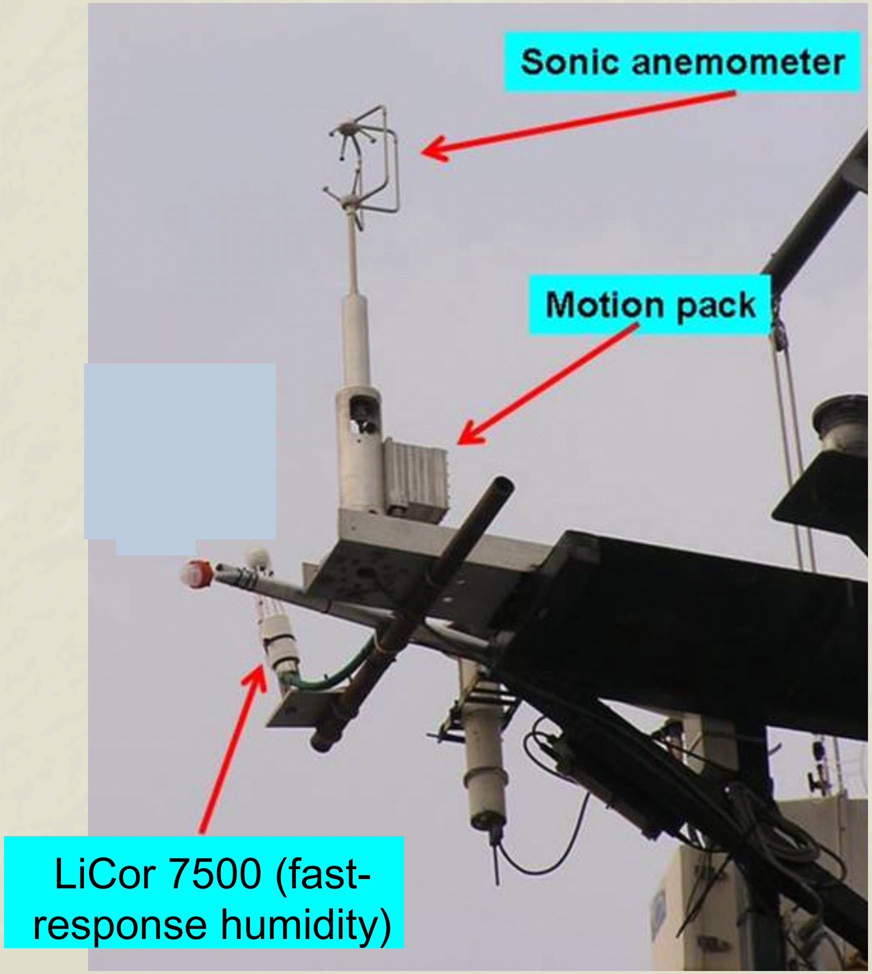


FIG. 1. Side view (left) and vertical cross section (right) of the ship rain gauge. Rain is collected at the horizontal orifice (arrows) and at the lateral collector (shaded). There are five vertical T-bars at the circumference of the lateral collector that hinder rainwater from wandering around the cylinder and being blown off in lee (not shown in the diagram). Horizontal sampling area is 200 cm², and the lateral sampling cross section is 106.6 cm². Total length is 48.5 cm and weight is 4.0 kg.

Direct measurement of turbulent vapor fluxes to infer latent heat flux (i.e., evaporation)



Jim Edson, U. Connecticut

Requires measurement of humidity, 3D velocity, and platform motion at high frequencies (say ≥ 10 Hz).

→The 3-axis sonic anemometer gives velocity and sound speed fluctuations.

→The LiCor infrared hygrometer gives water vapor fluctuations.

→Together, the sonic anemometer and infrared hygrometer allow direct measurement of sensible and latent heat flux and wind stress.

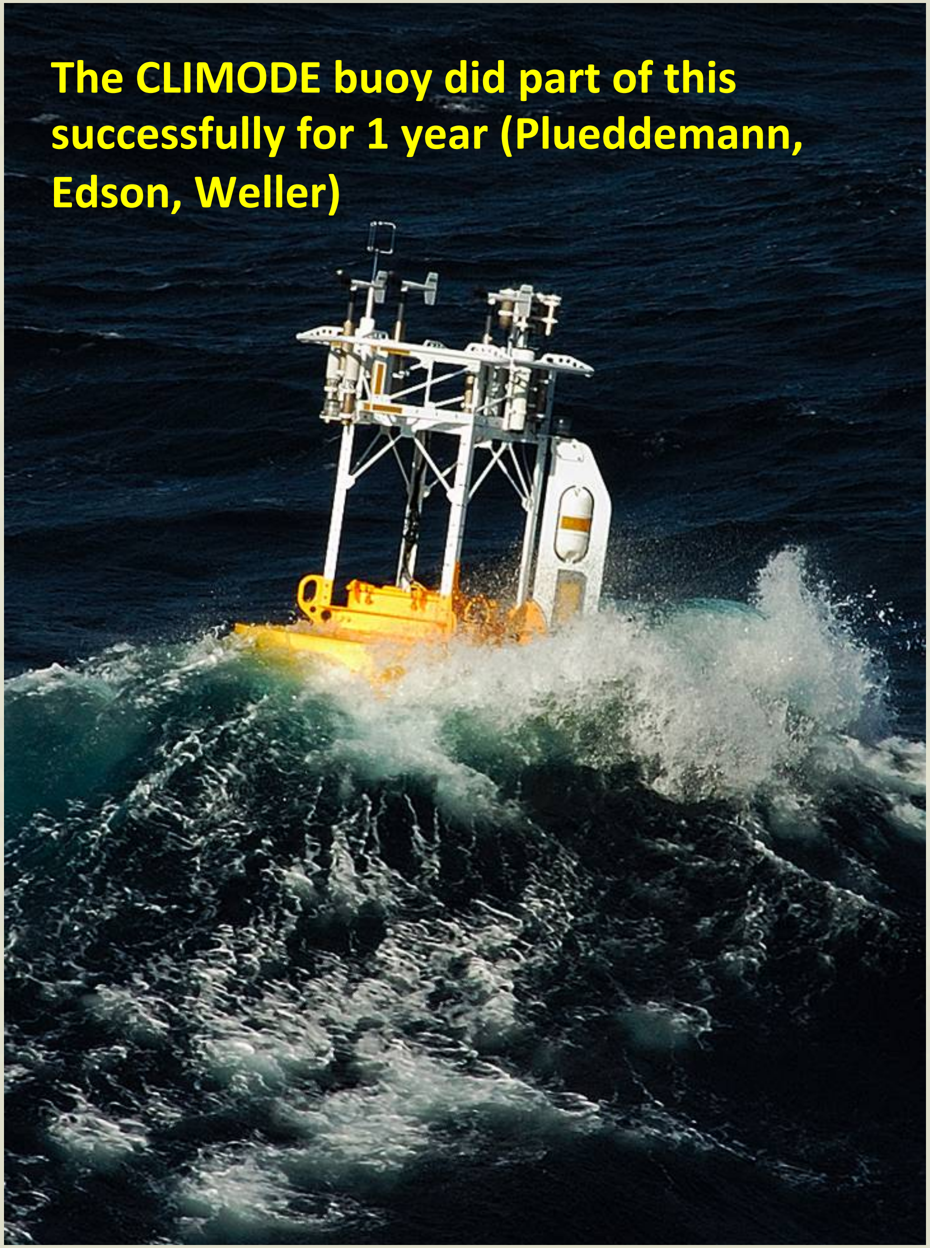
Direct covariance measurements of latent heat flux

Benefits:

→direct measurements of latent/sensible heat flux and wind stress over the full year
→direct measurements from a buoy avoids some problems with ship measurements (flow distortion, measurement height)
→The direct flux measurements can be used to verify and improve bulk formulas for the region

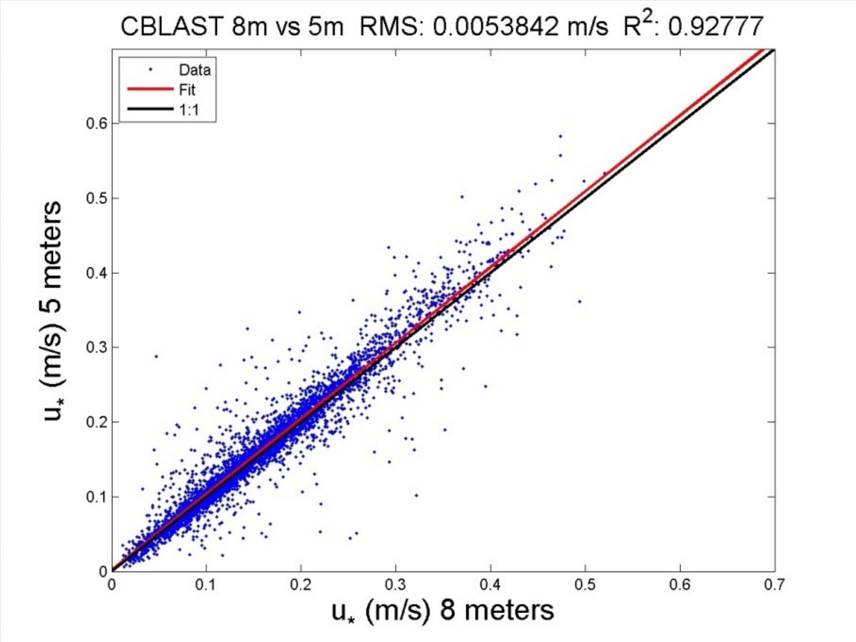
Challenges:

→power consumption
→contamination of LiCor optics

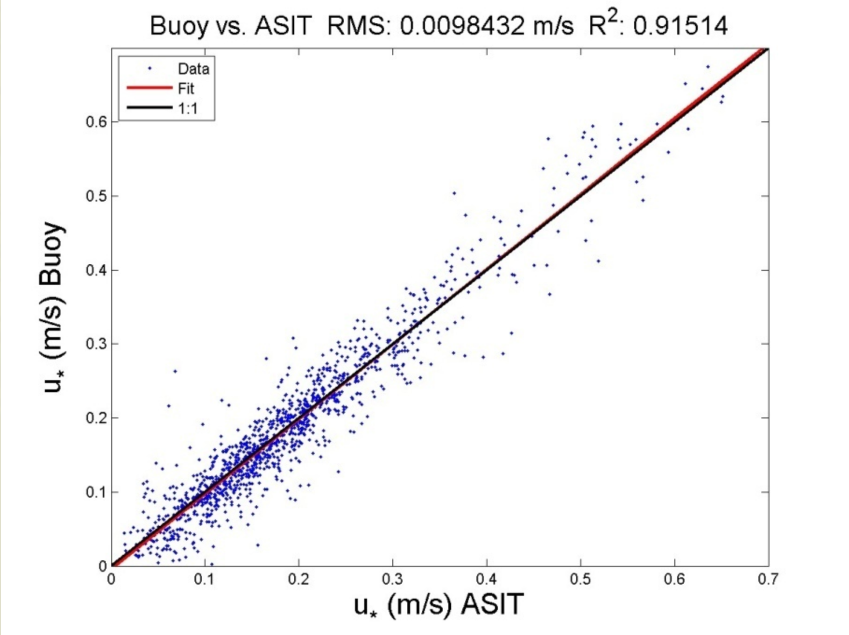


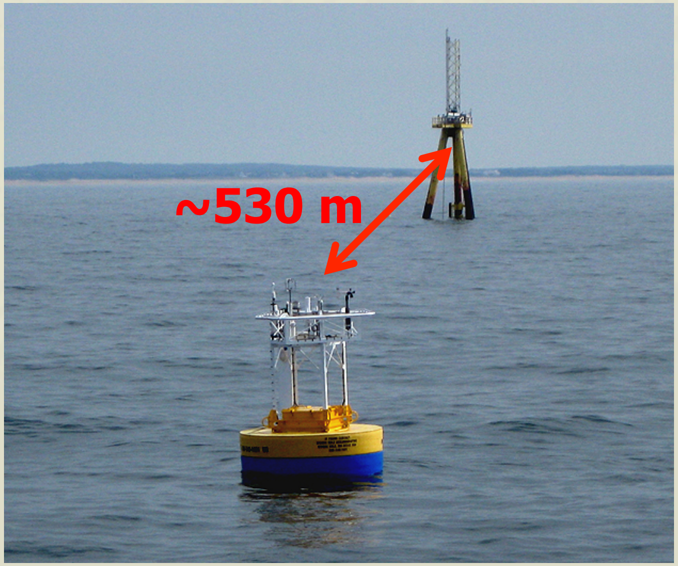
Buoy vs. Fixed Tower

5 m vs. 8 m
on tower



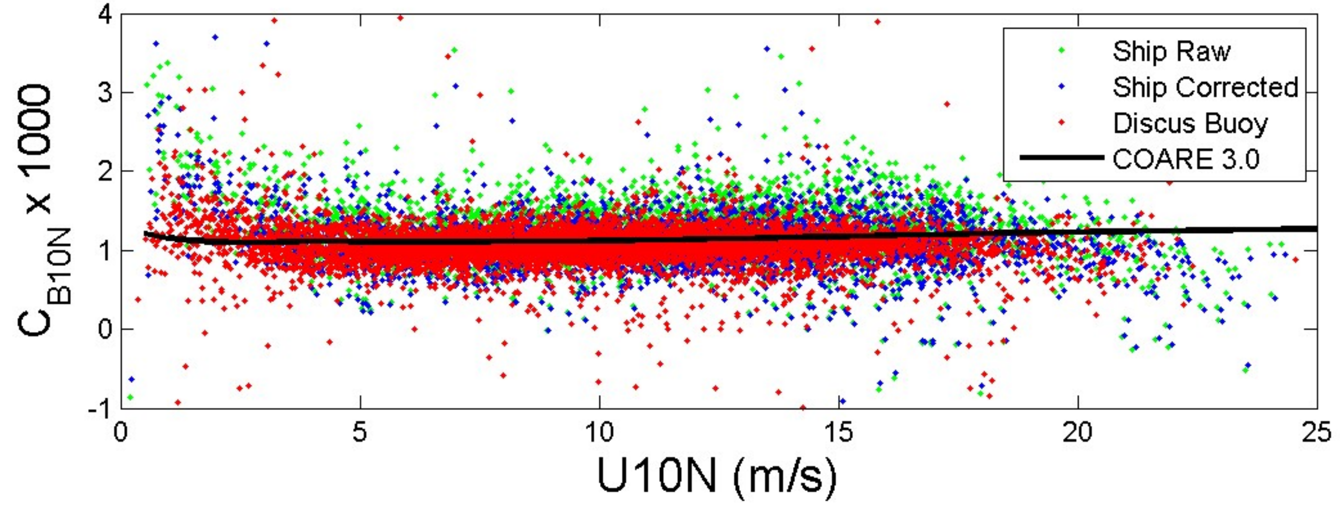
Buoy vs.
tower

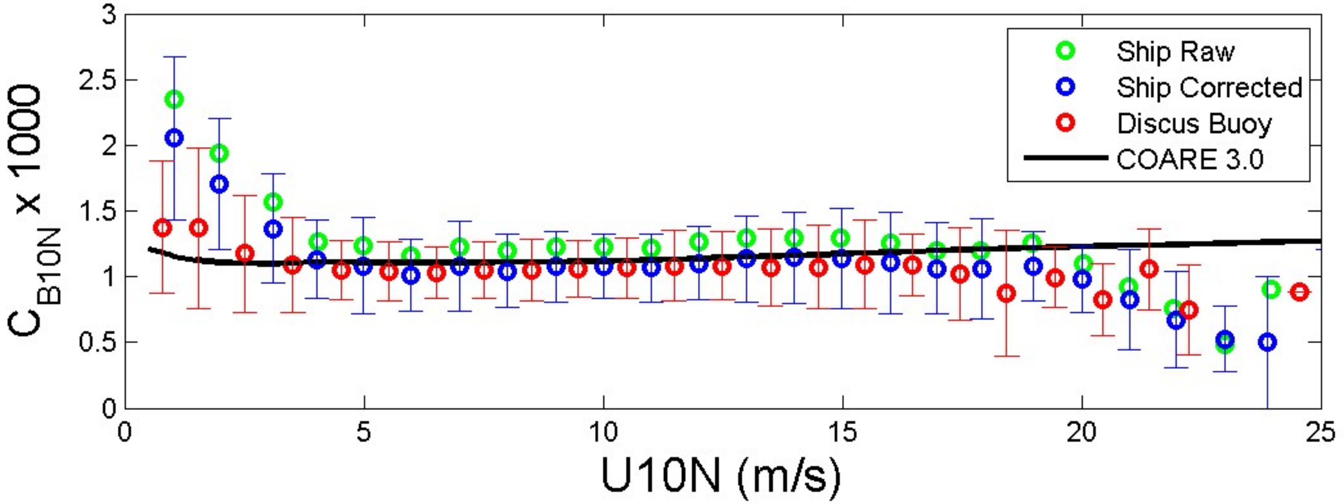




Buoy vs. Ship

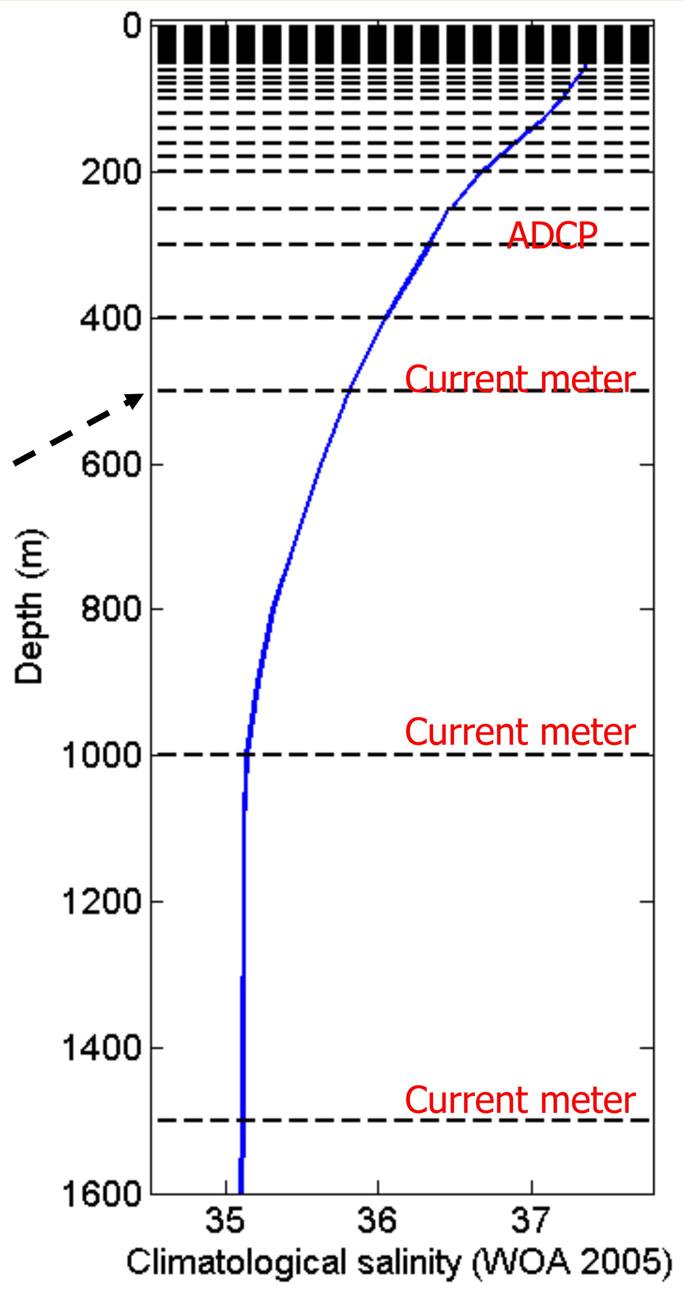
15 months of buoy data vs. 2 months of ship data





Subsurface measurements

Temperature/conductivity measurements
(SBE37s and SBE16s)
(<5 minute sampling interval)



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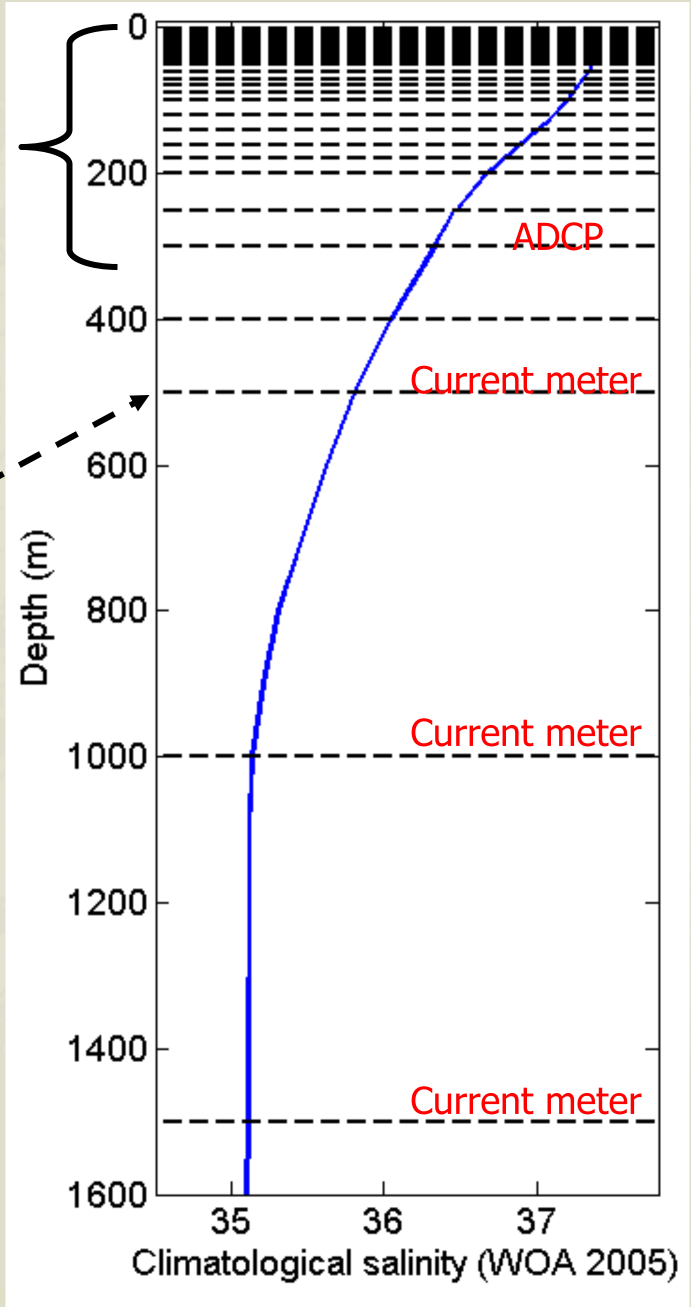

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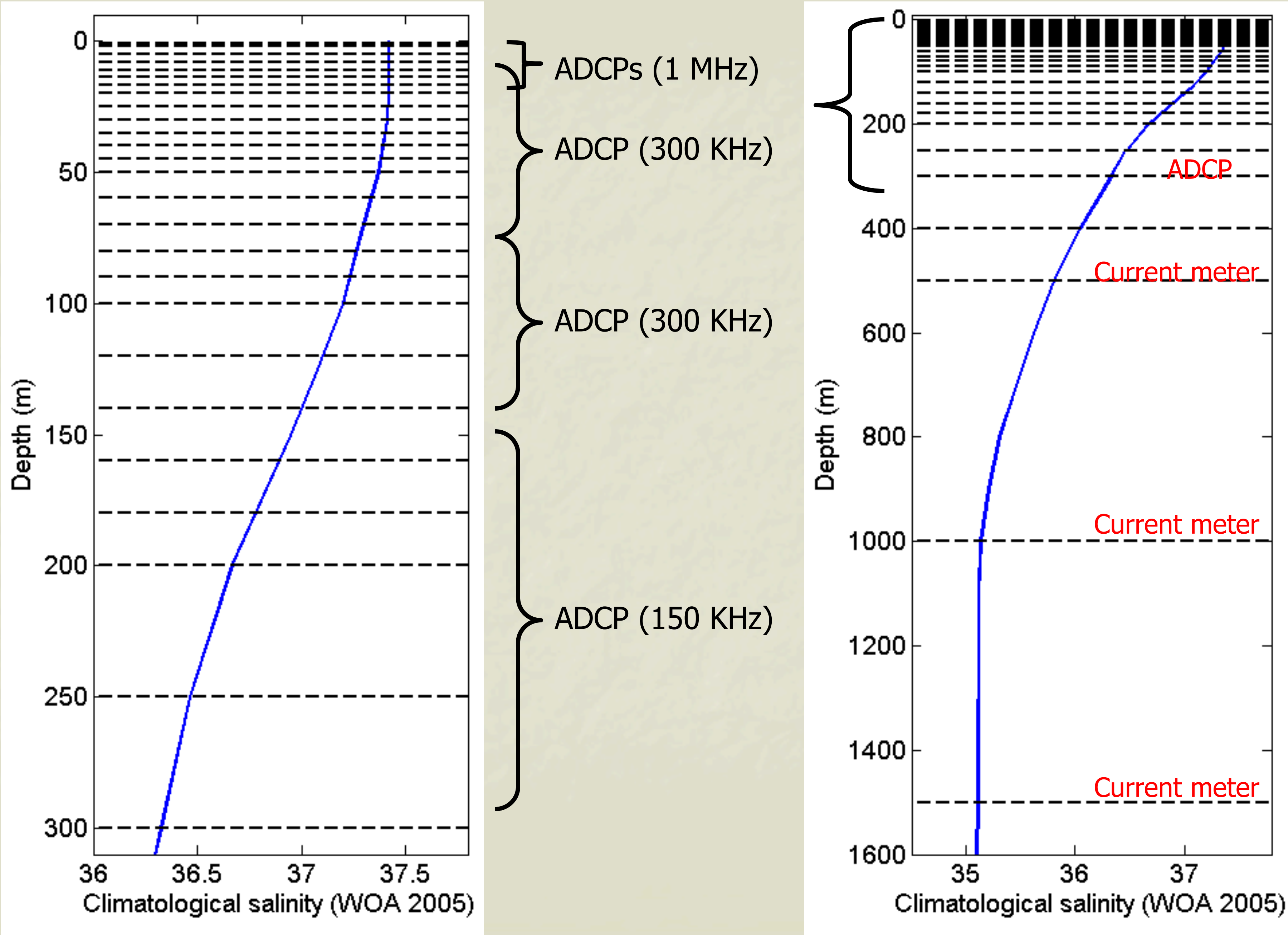
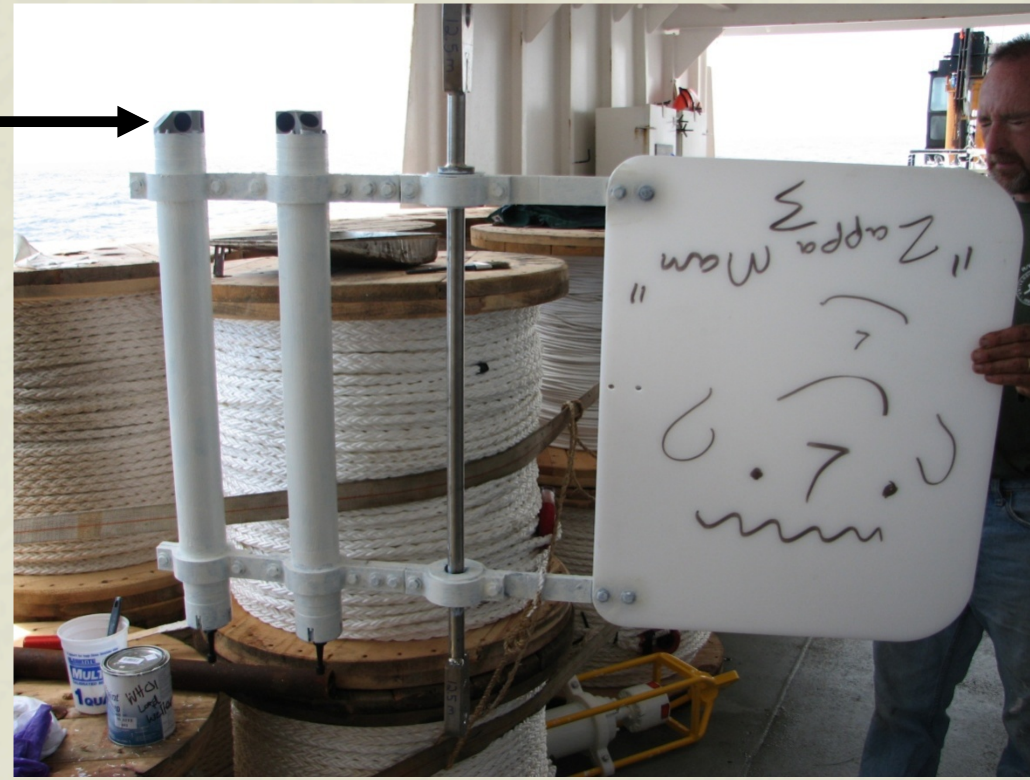


Pulse-coherent Doppler sonar for turbulent dissipation

A single horizontal beam measures a ~1.5-m profile with ~2-cm resolution, which can be used for inertial-subrange ("-5/3") estimates of TKE dissipation

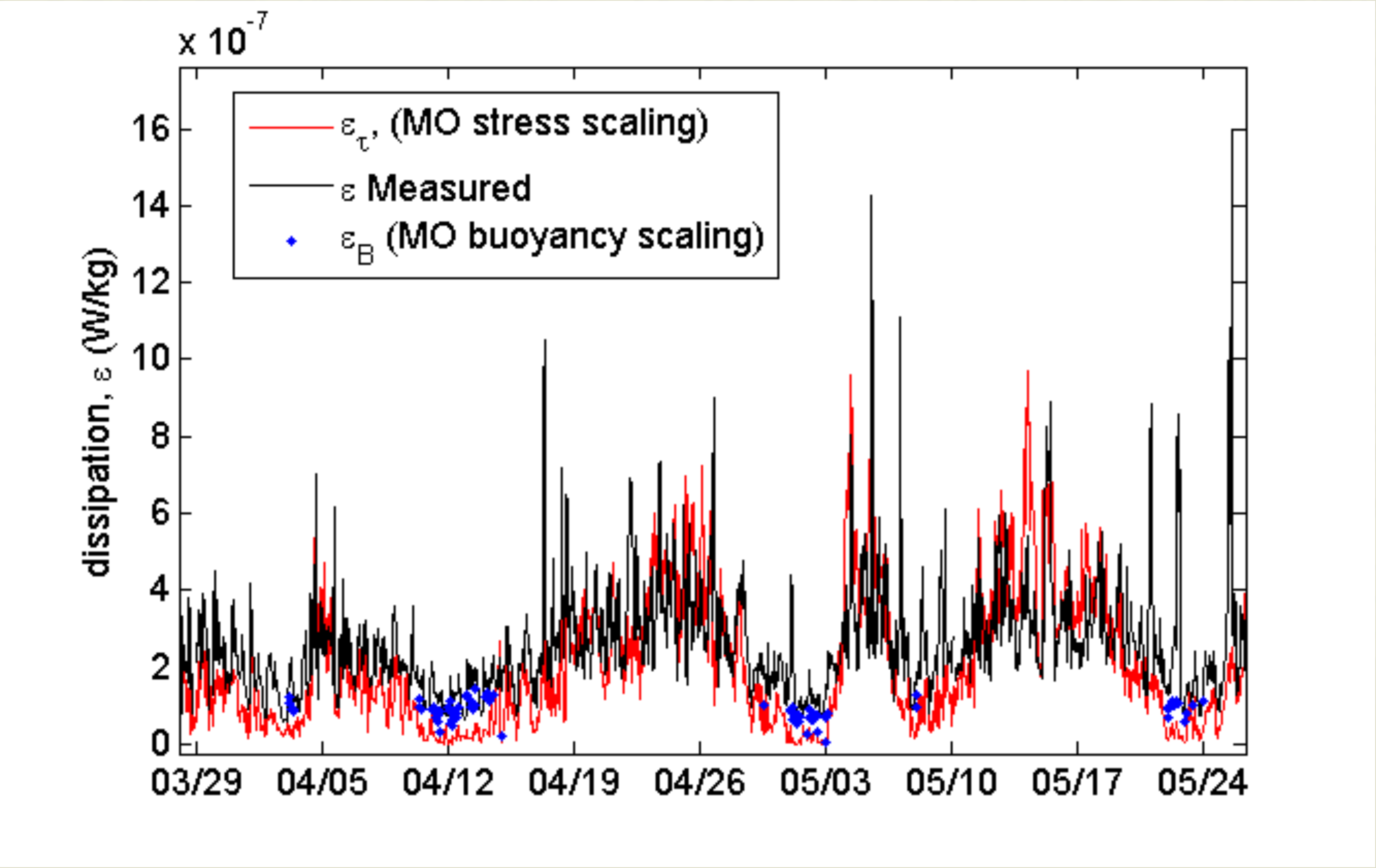


The instruments can collect about 540 profiles at 4 Hz, every hour for one year.

Chris Zappa and I deployed these on Bob Weller's surface mooring in VOCALS, and they performed better than we had hoped.

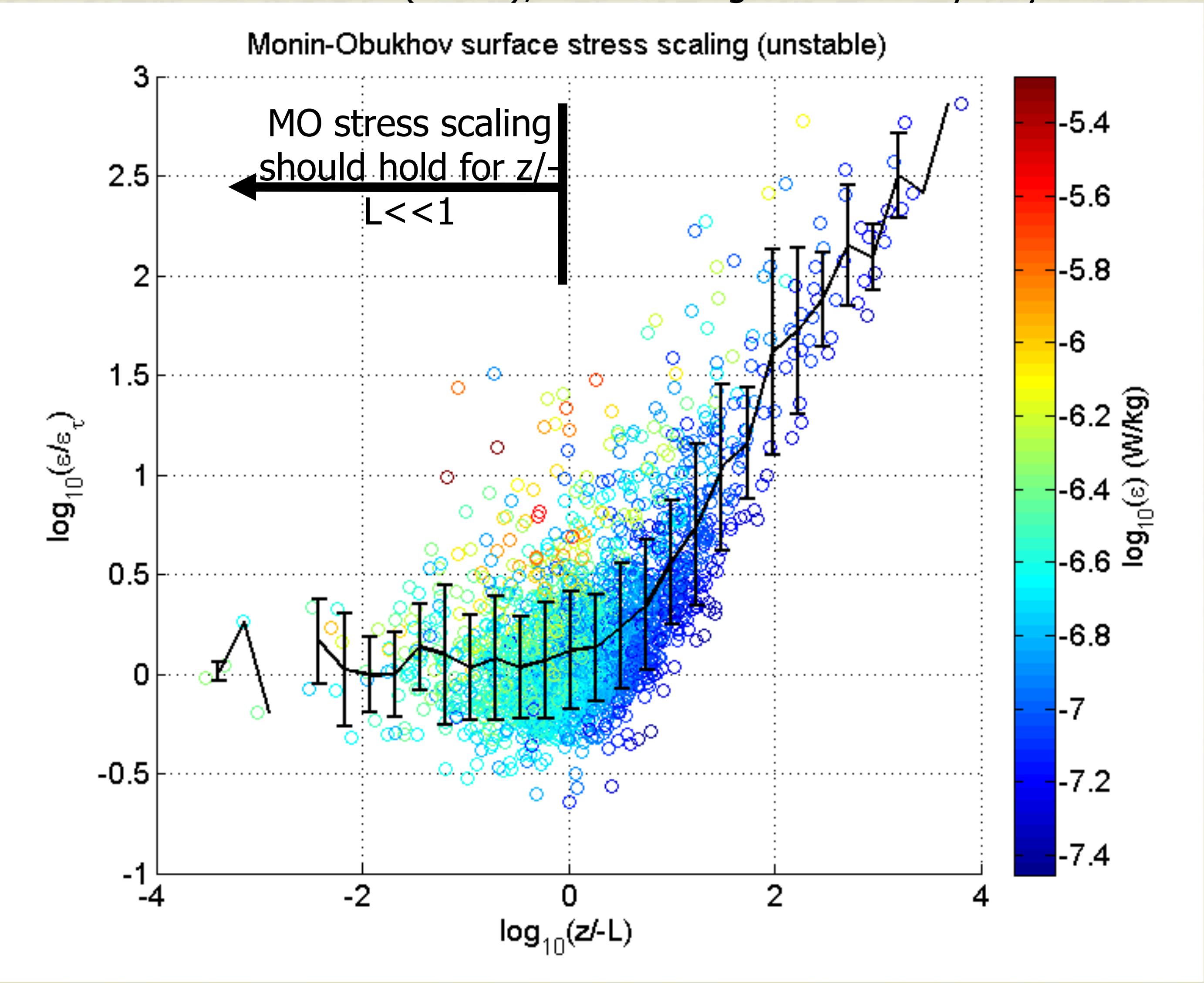
Pulse-coherent Doppler sonar for turbulent dissipation

Time series from 8.4-m depth versus Monin-Obukhov scaling predictions



Pulse-coherent Doppler sonar for turbulent dissipation

9 months of data (8.4 m), destabilizing surface buoyancy flux



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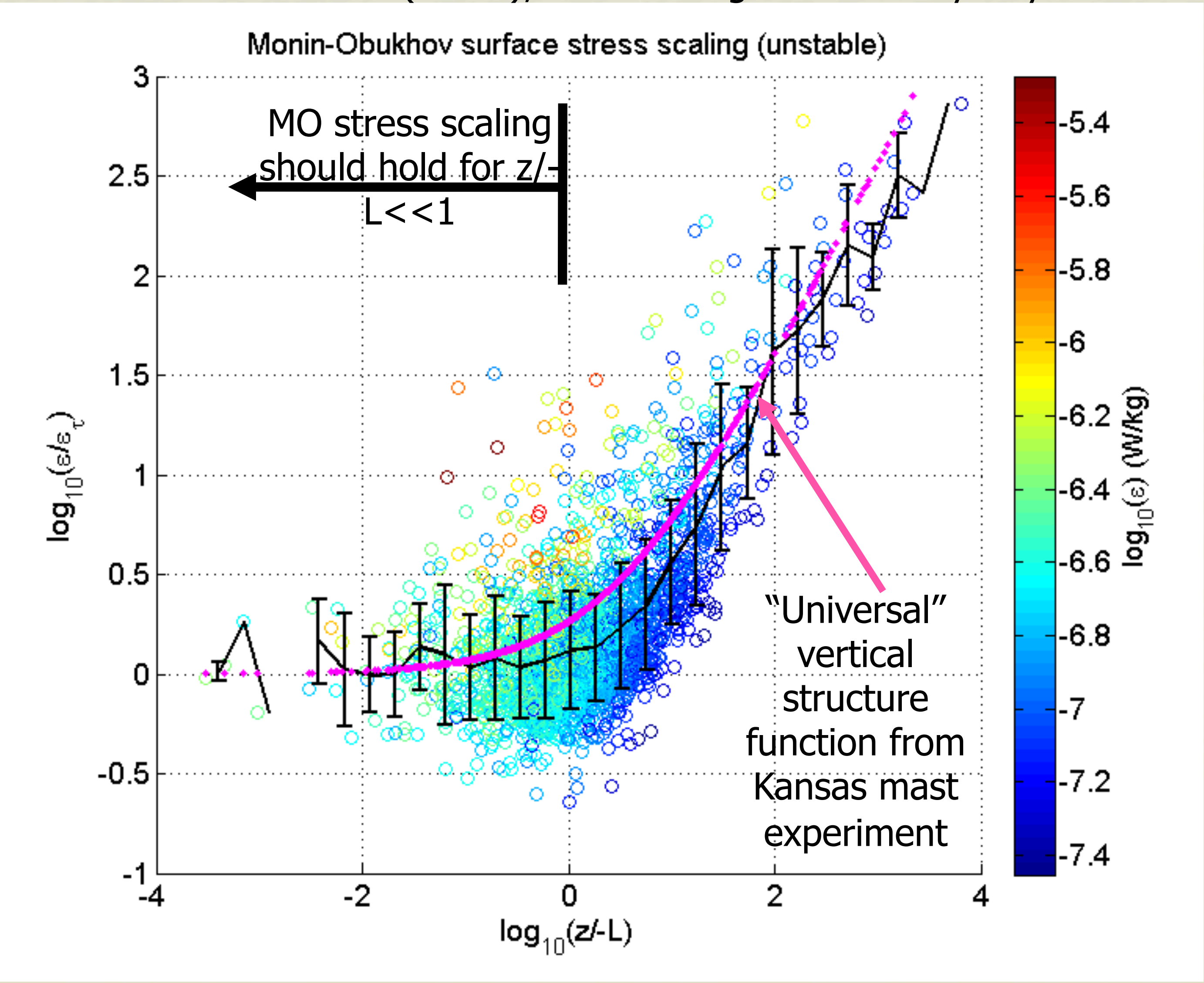
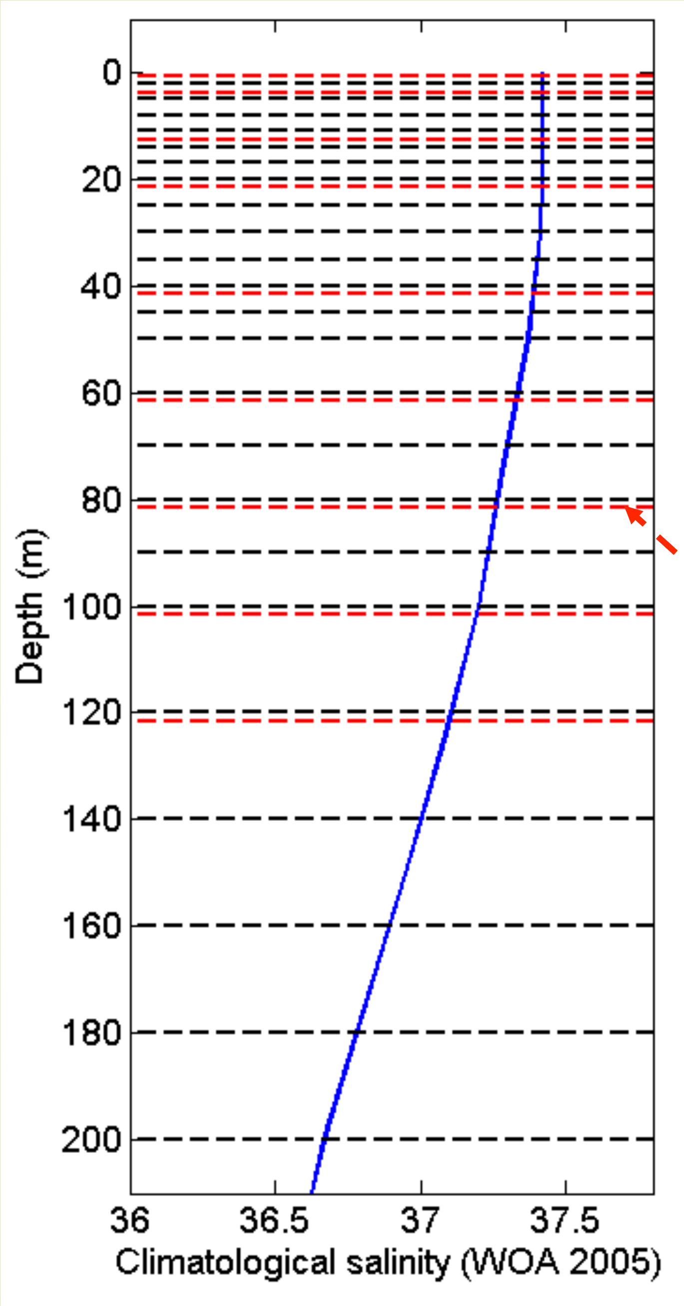


Pulse-coherent Doppler sonar for turbulent dissipation



Planned depths for pulse-coherent sonar (7 total)

→These measurements should provide temporal context for more conventional microstructure measurements in SPURS

→ They might allow useful estimates of the turbulent salt and heat fluxes

Approach:

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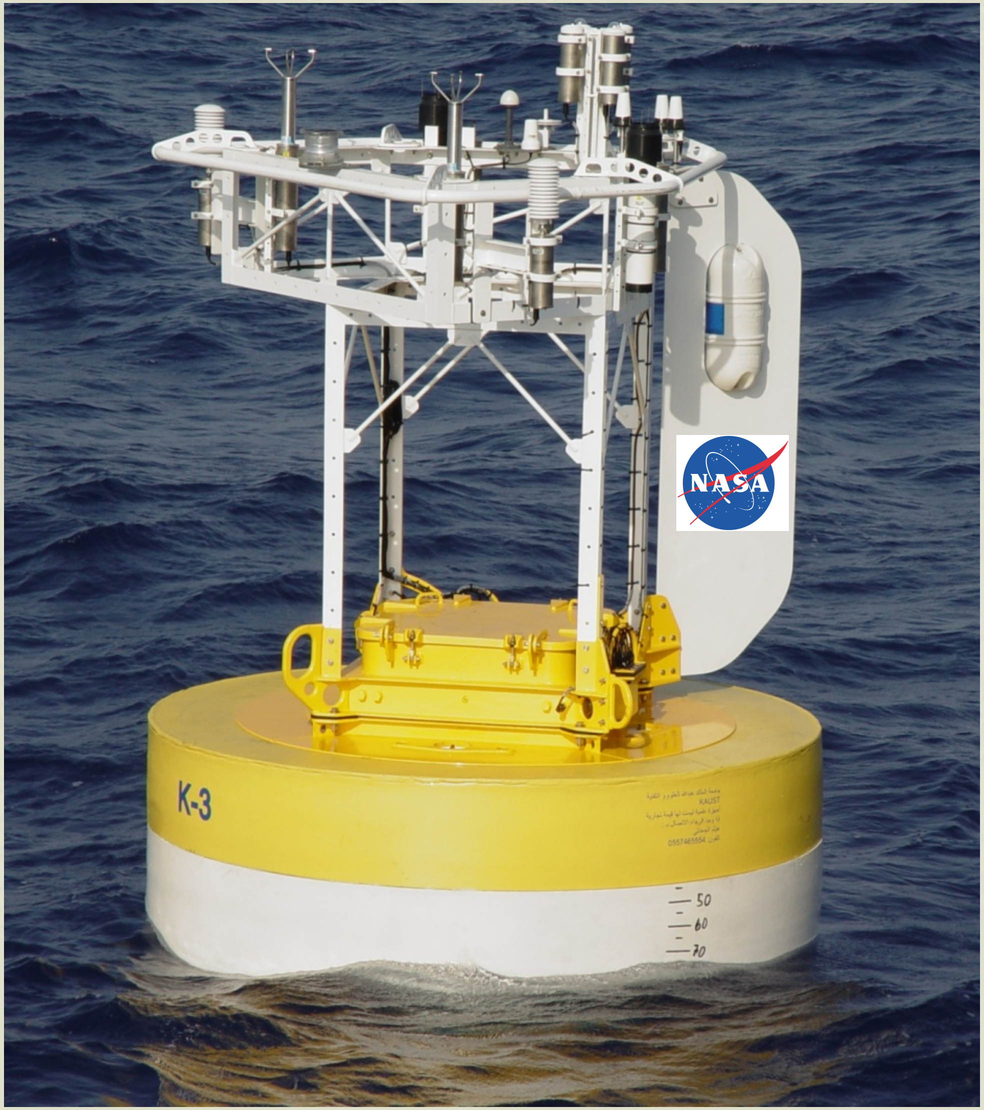
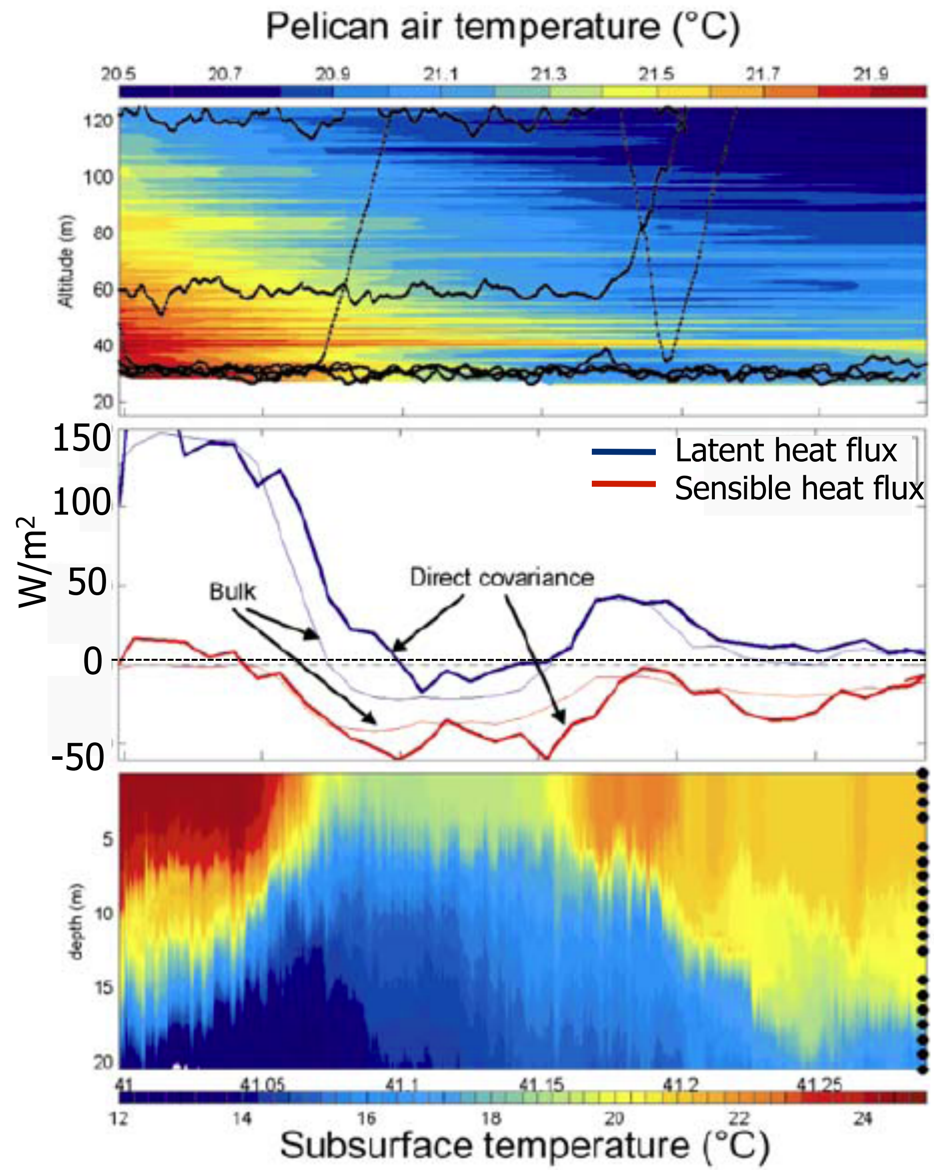
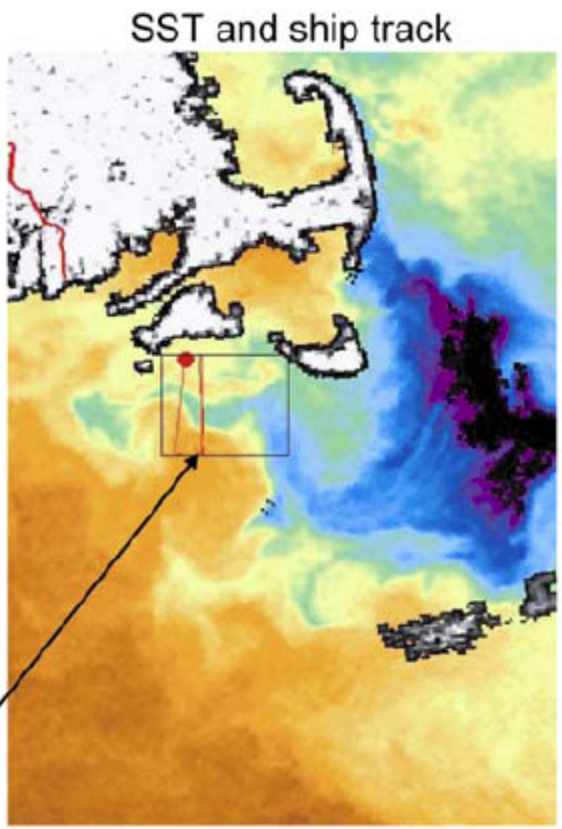


An example of likely condensation from CBLAST-Low

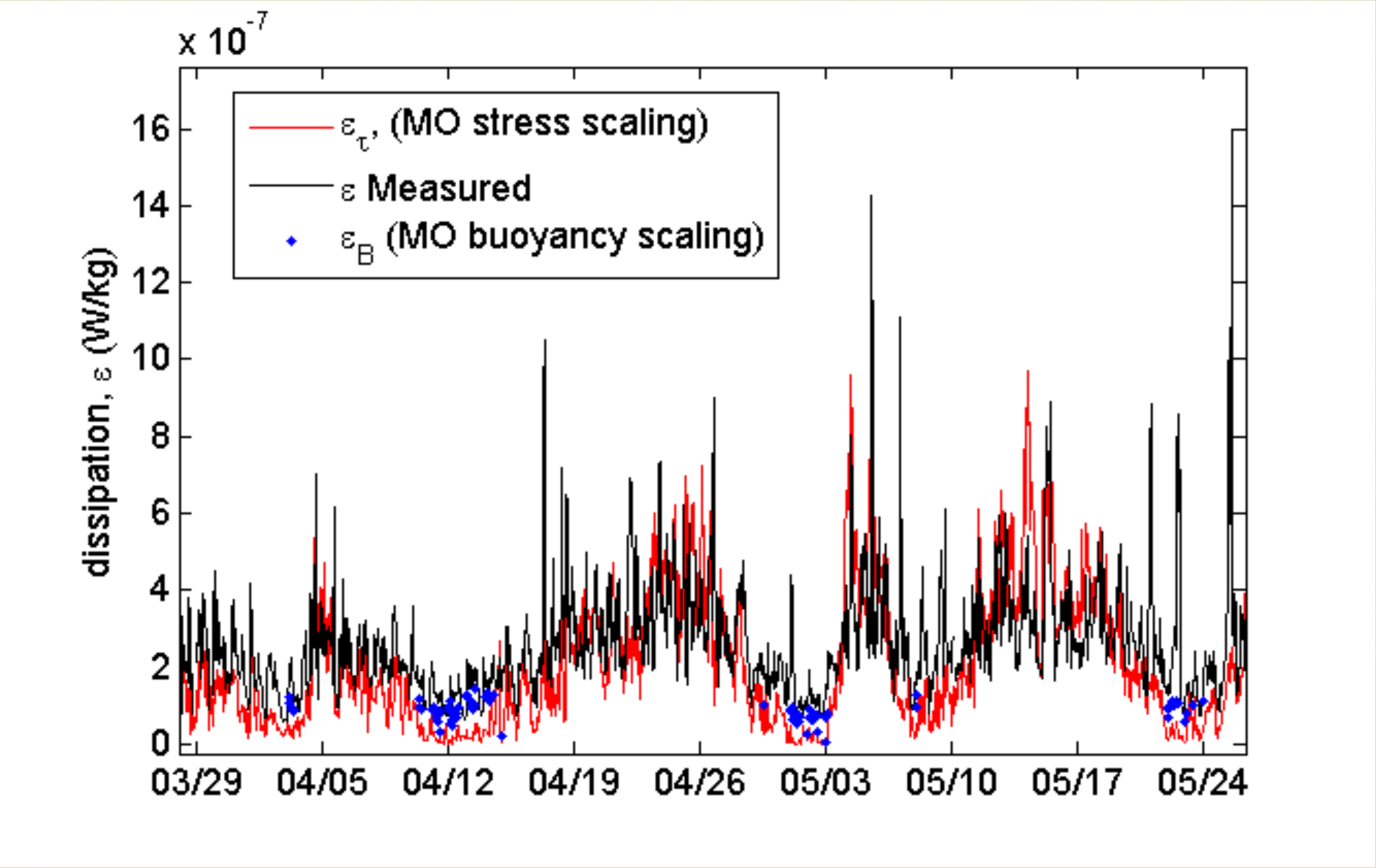


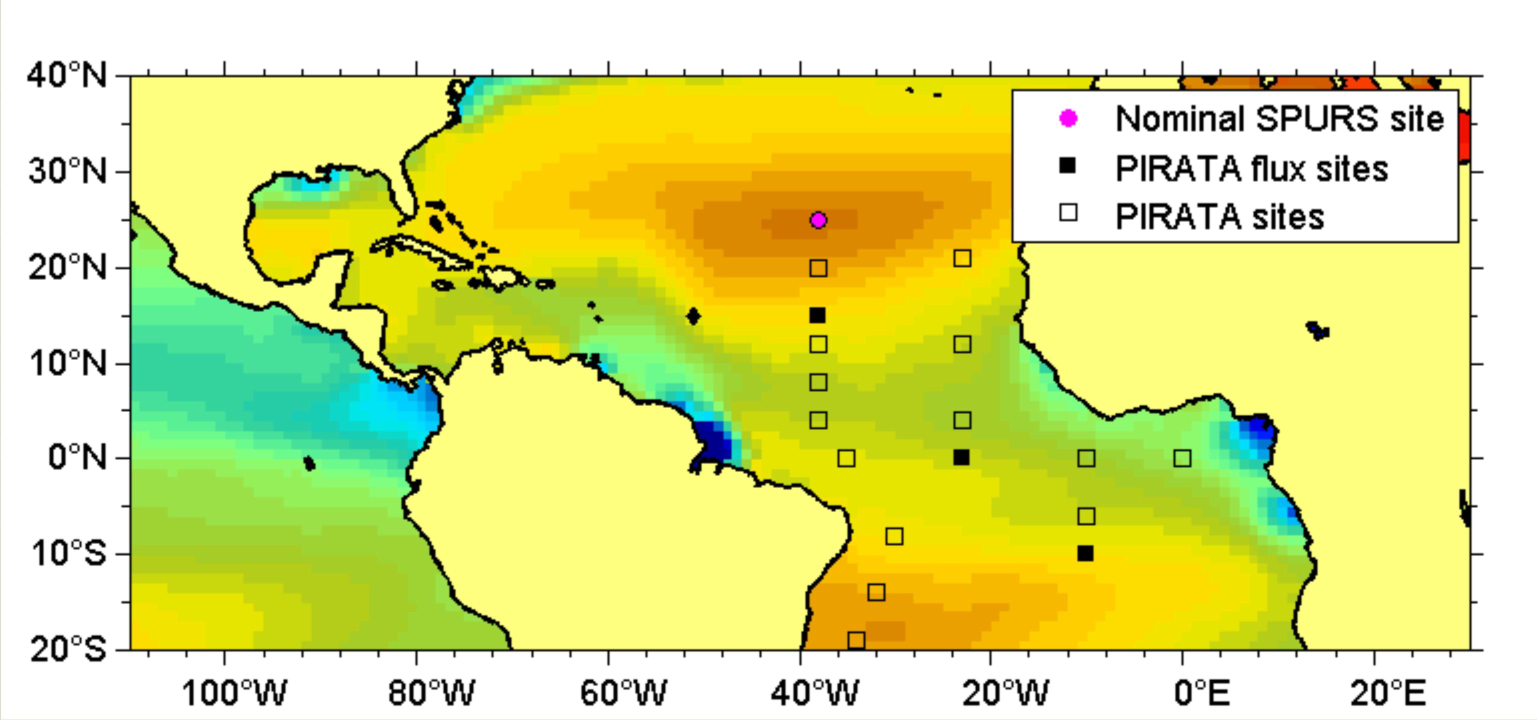


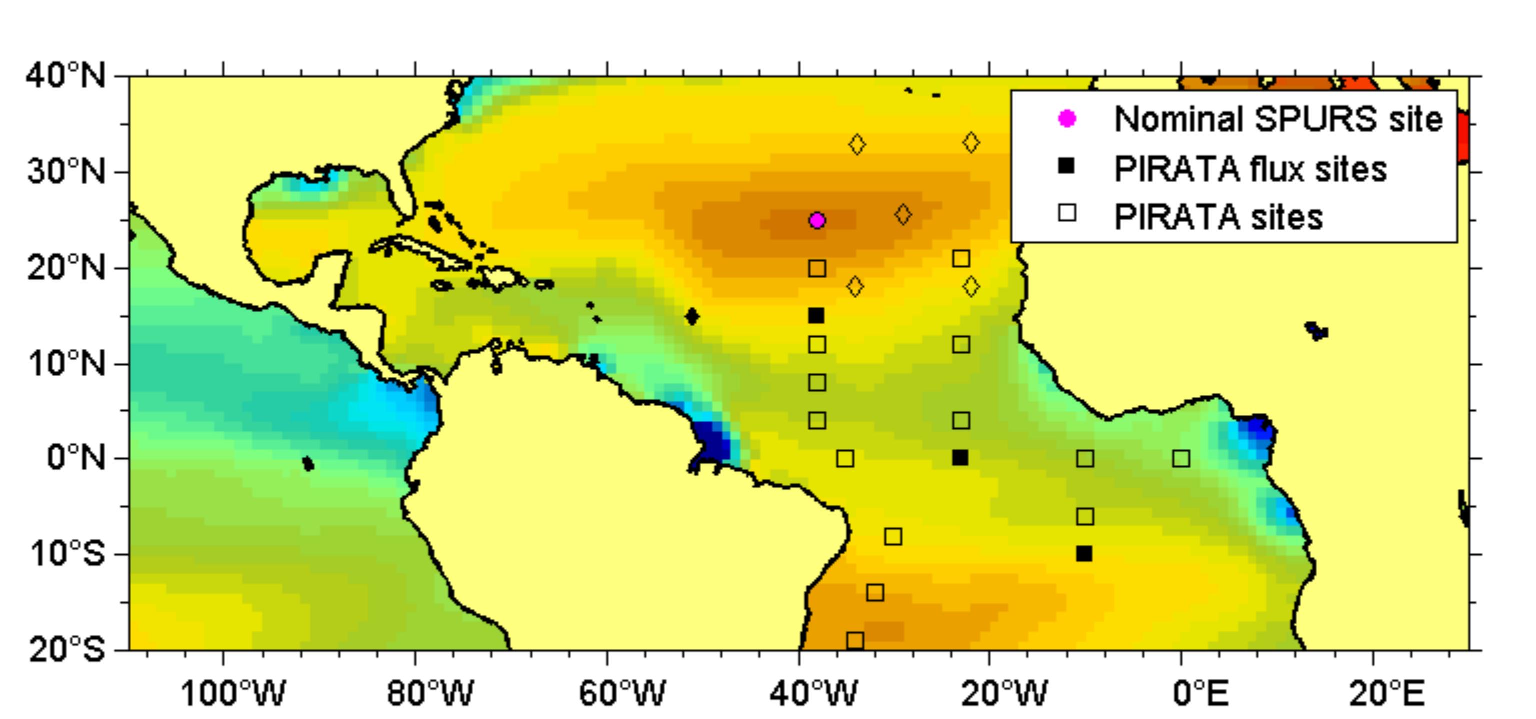
The negative latent heat fluxes measured by direct covariance are spurious, but they can only result from downward vapor transport

(From Edson et al., 2007)

Pulse-coherent Doppler sonar for turbulent dissipation




Nominal SPURS site
PIRATA flux sites
PIRATA sites
40°N
30°N
20°N
10°N
0°N
10°S
20°S
100°W
80°W
60°W
40°W
20°W
0°E
20°E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100°W
80°W
60°W
40°W
20°W
0°E
20°E

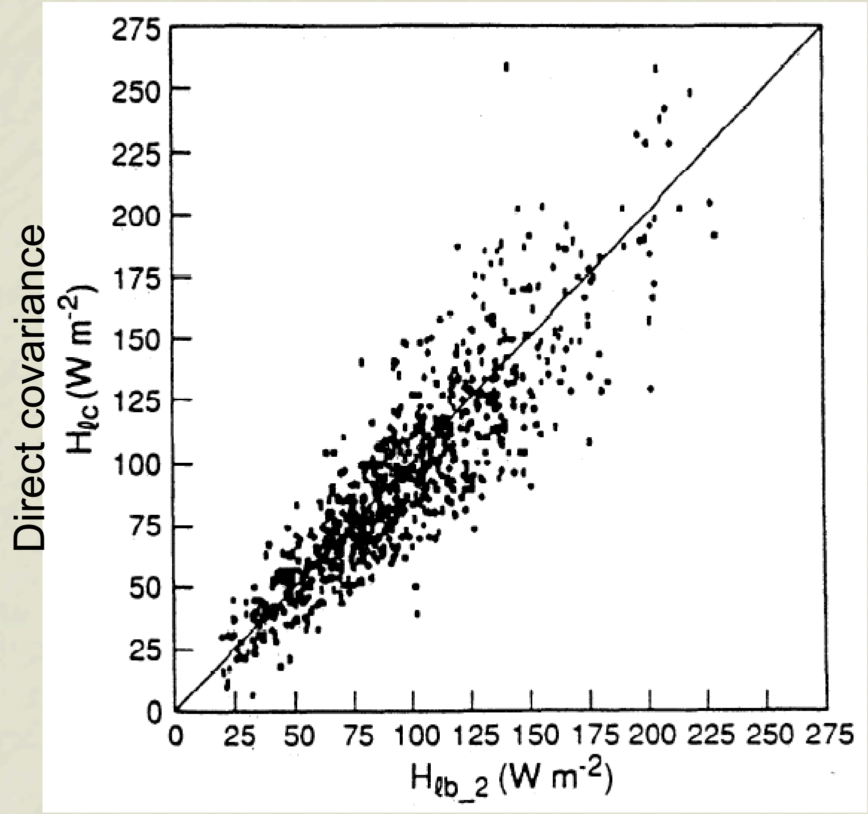
Bulk Formulas

Because the direct flux measurements require lots of power and some delicate instruments, these measurements are not typically made from buoys.

Instead, the relevant “bulk” properties are measured and used in parameterizations (i.e., bulk formulas) developed from direct measurements.

For example: $Q_{latent}=c_E(U_{10}-U_0)(q_{10}-q_0)$

Latent heat flux

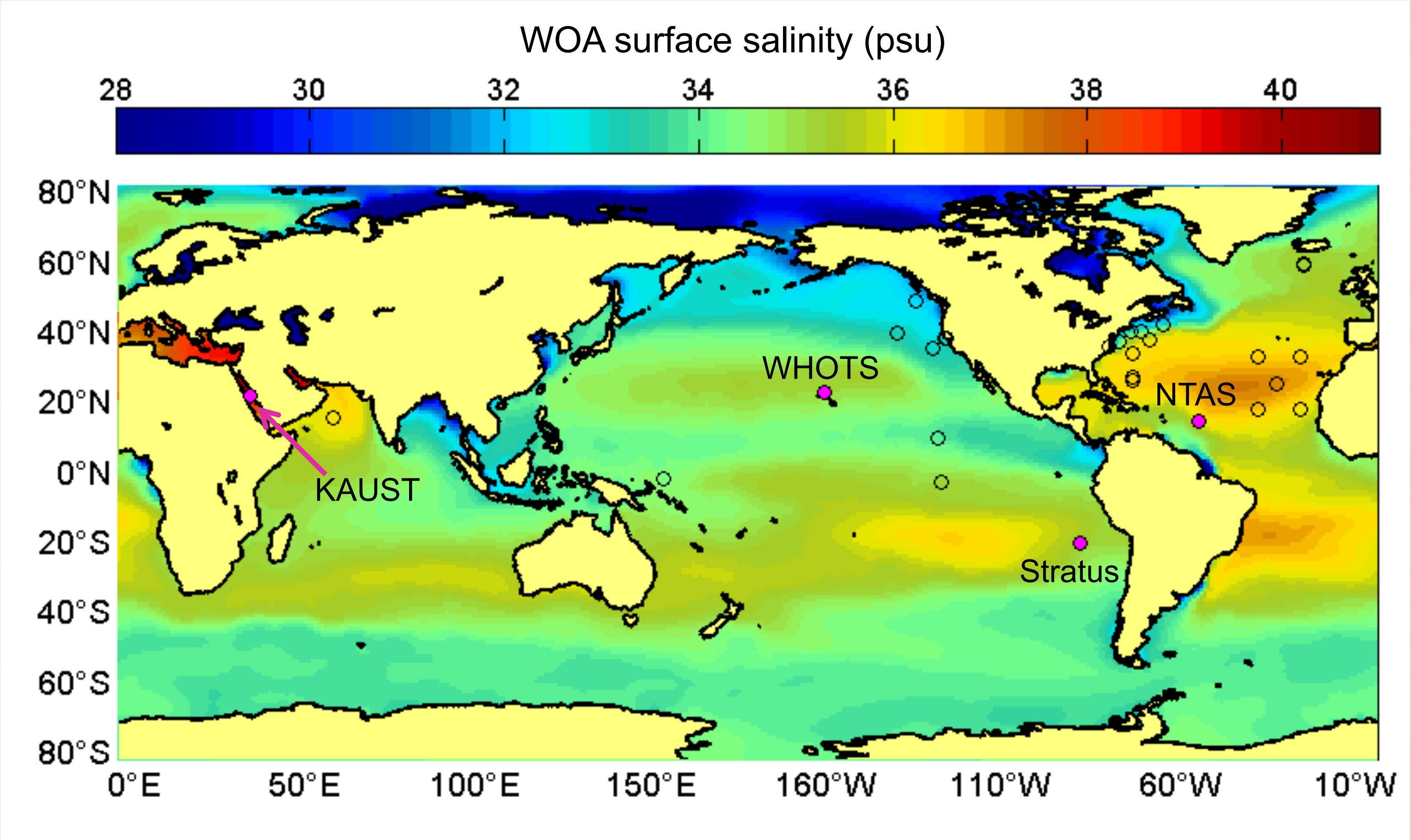


Bulk formula

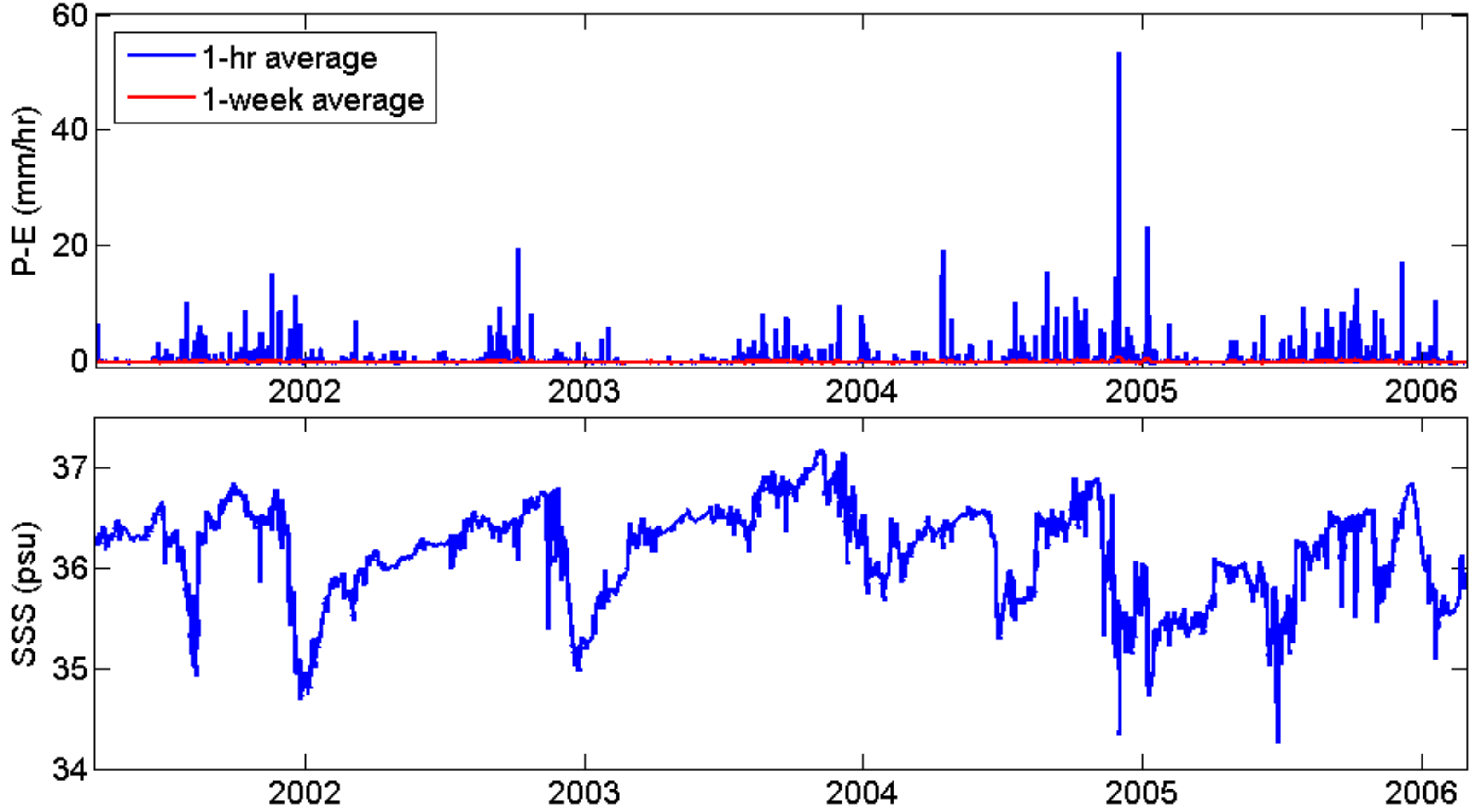
(From Fairall et al., 1996, TOGA-COARE)

Air-sea interaction buoys

Pink dots: Sites occupied by WHOI air-sea interaction moorings



Northern Tropical Atlantic Station (Al Plueddemann)



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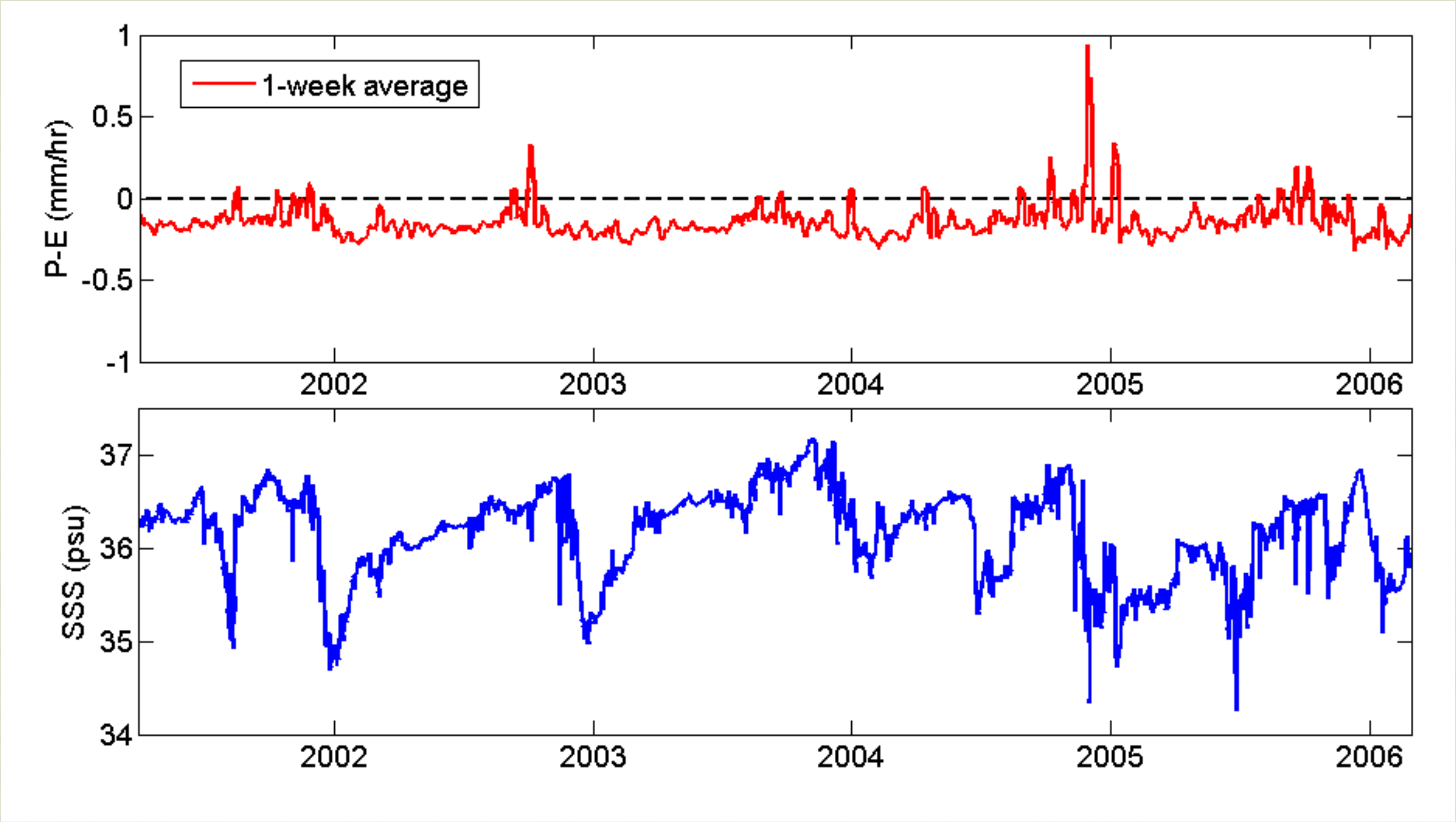

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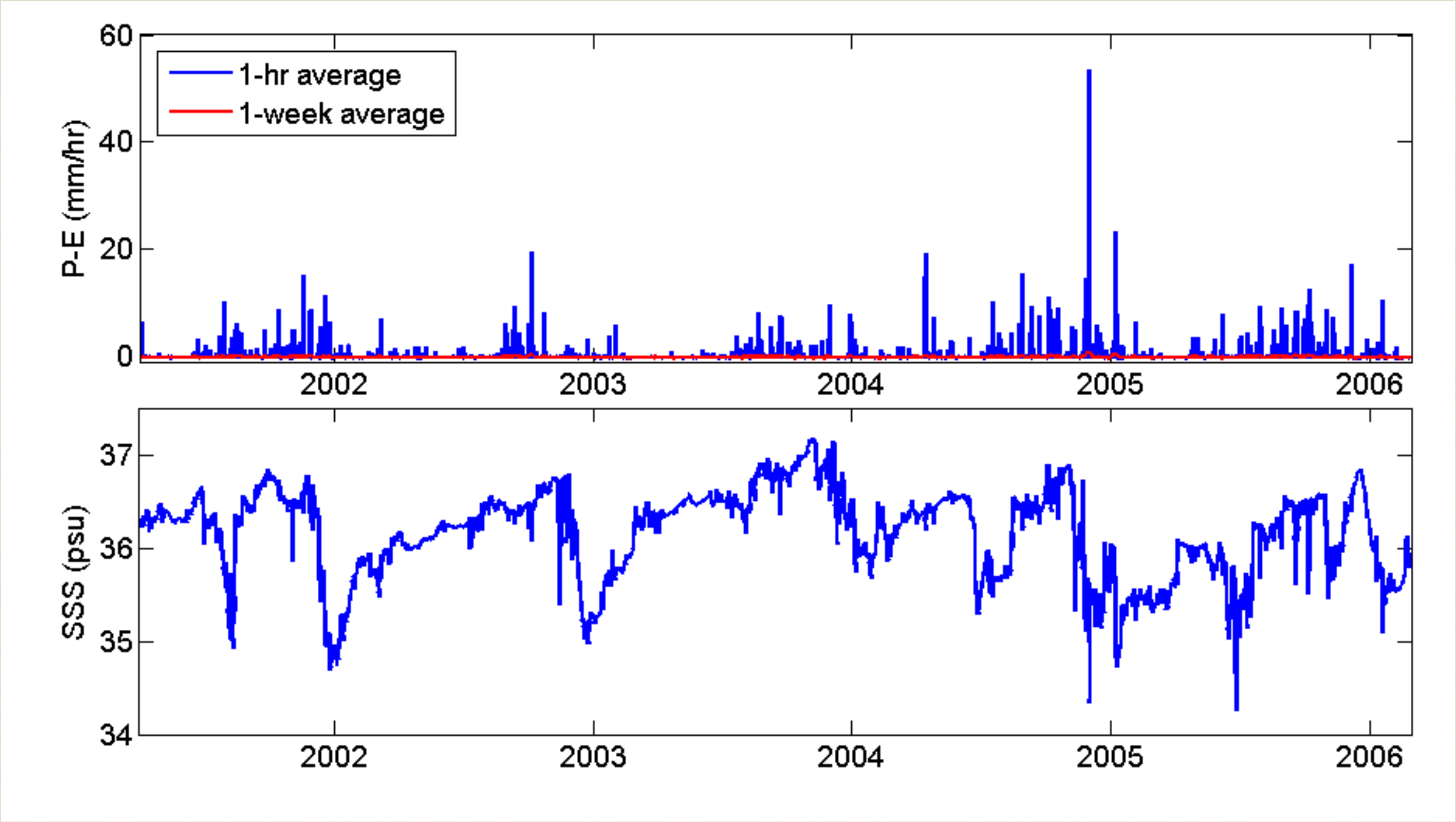

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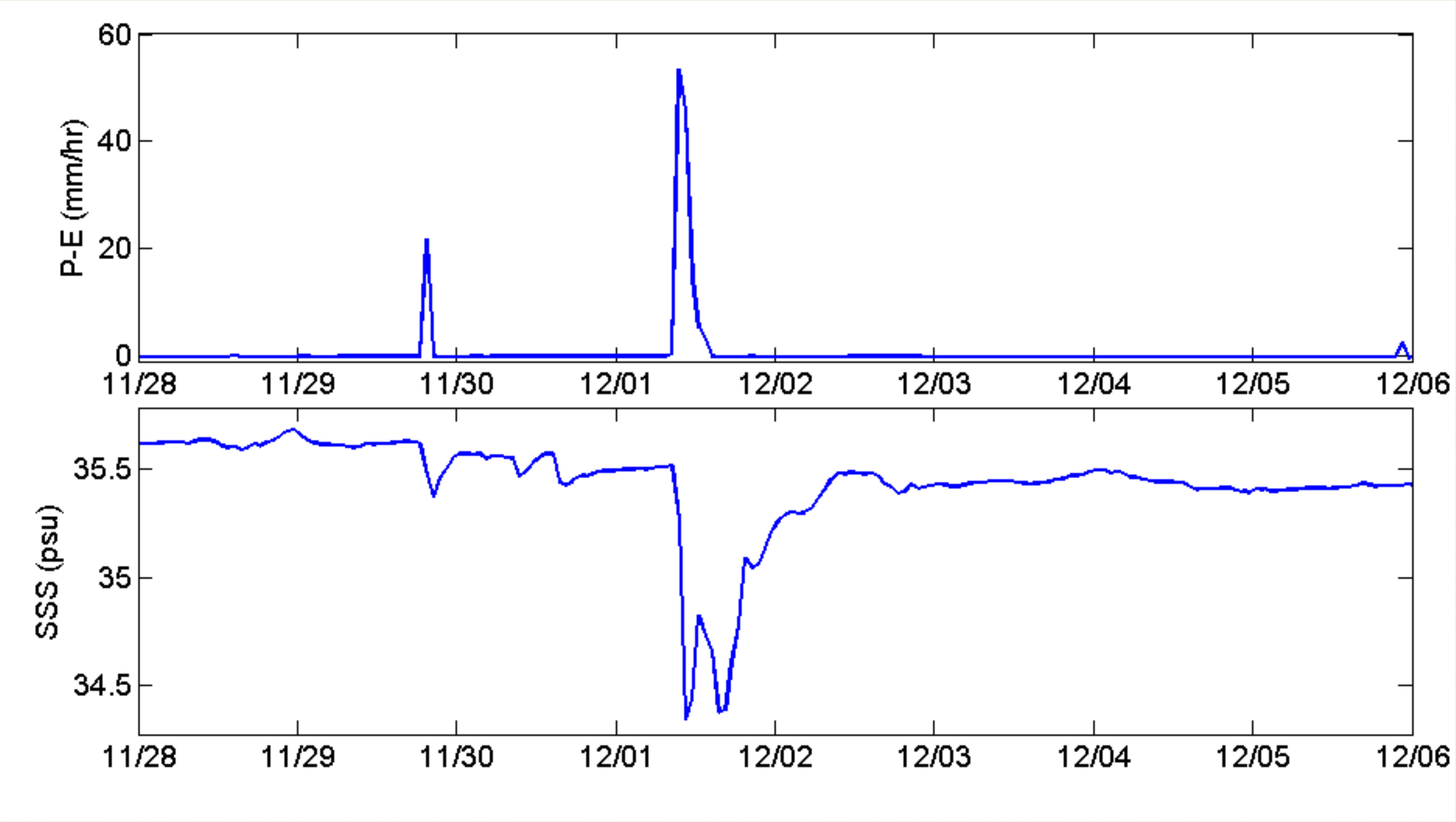

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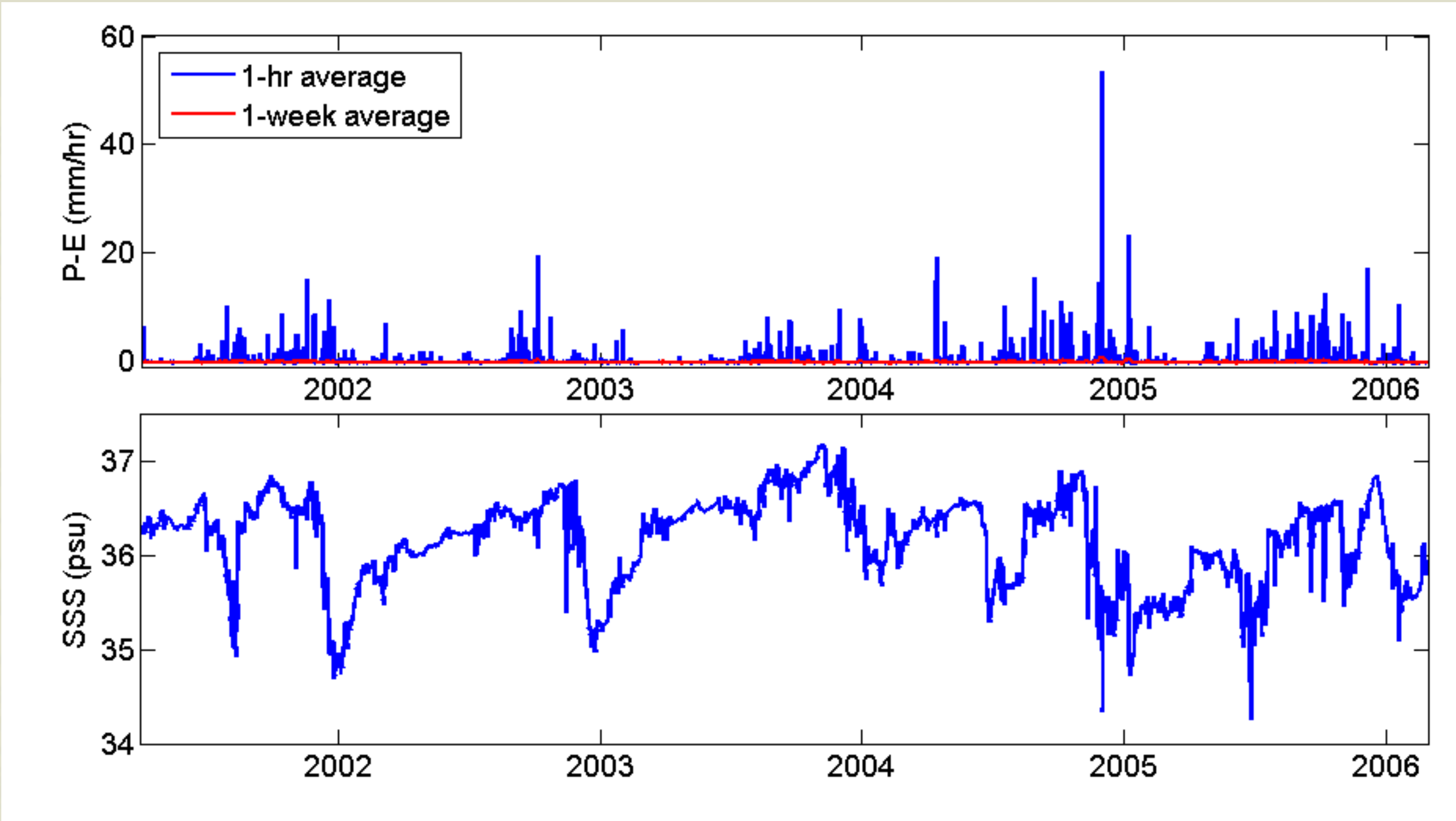
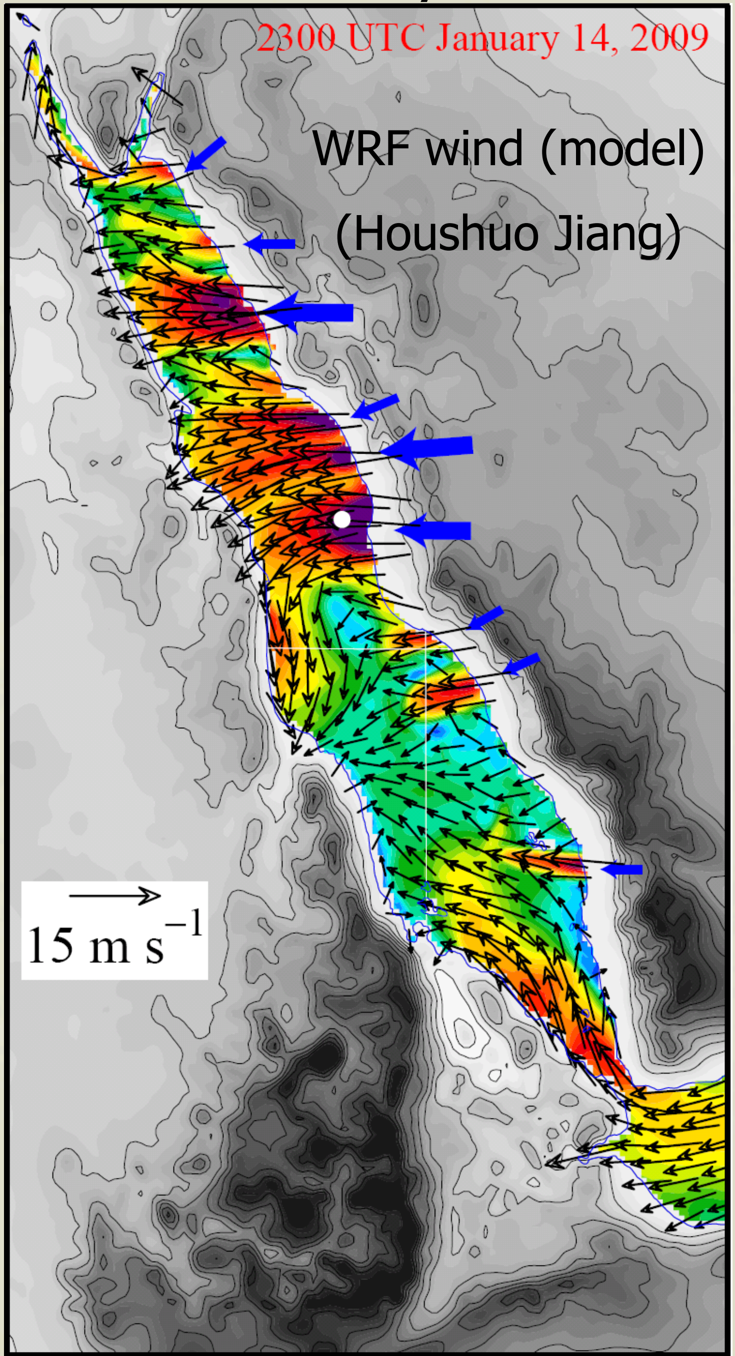
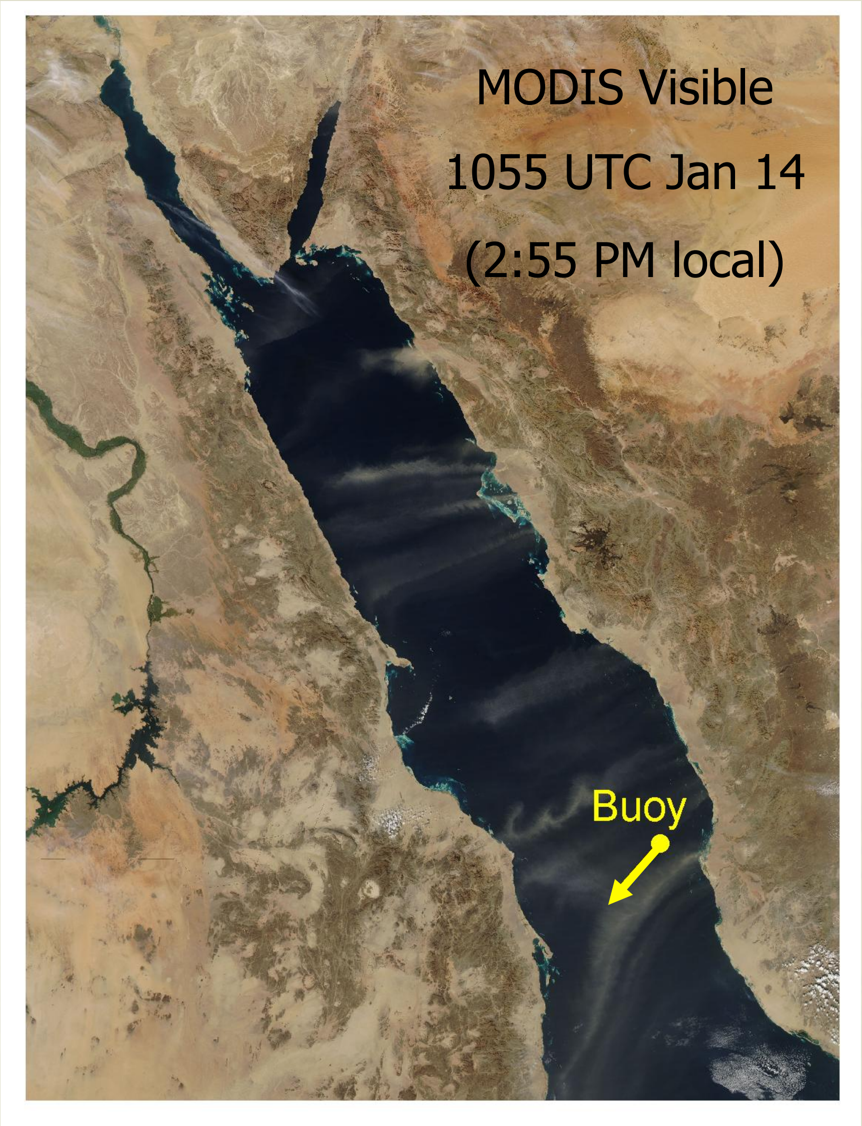
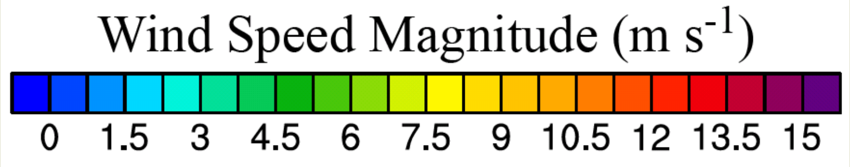


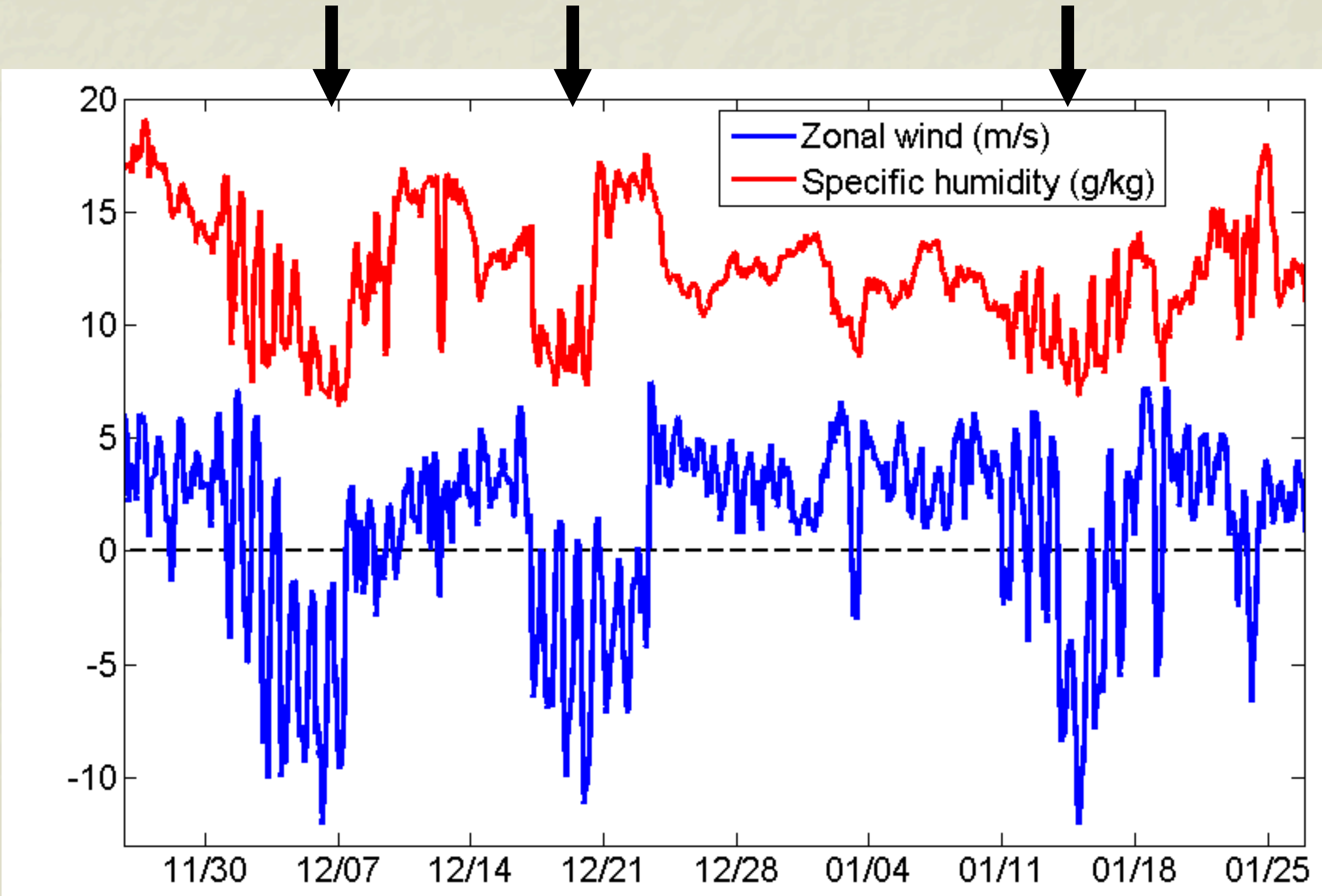
Red Sea dry-air outbreaks and mountain gap wind events







Red Sea dry-air outbreaks and mountain gap wind events



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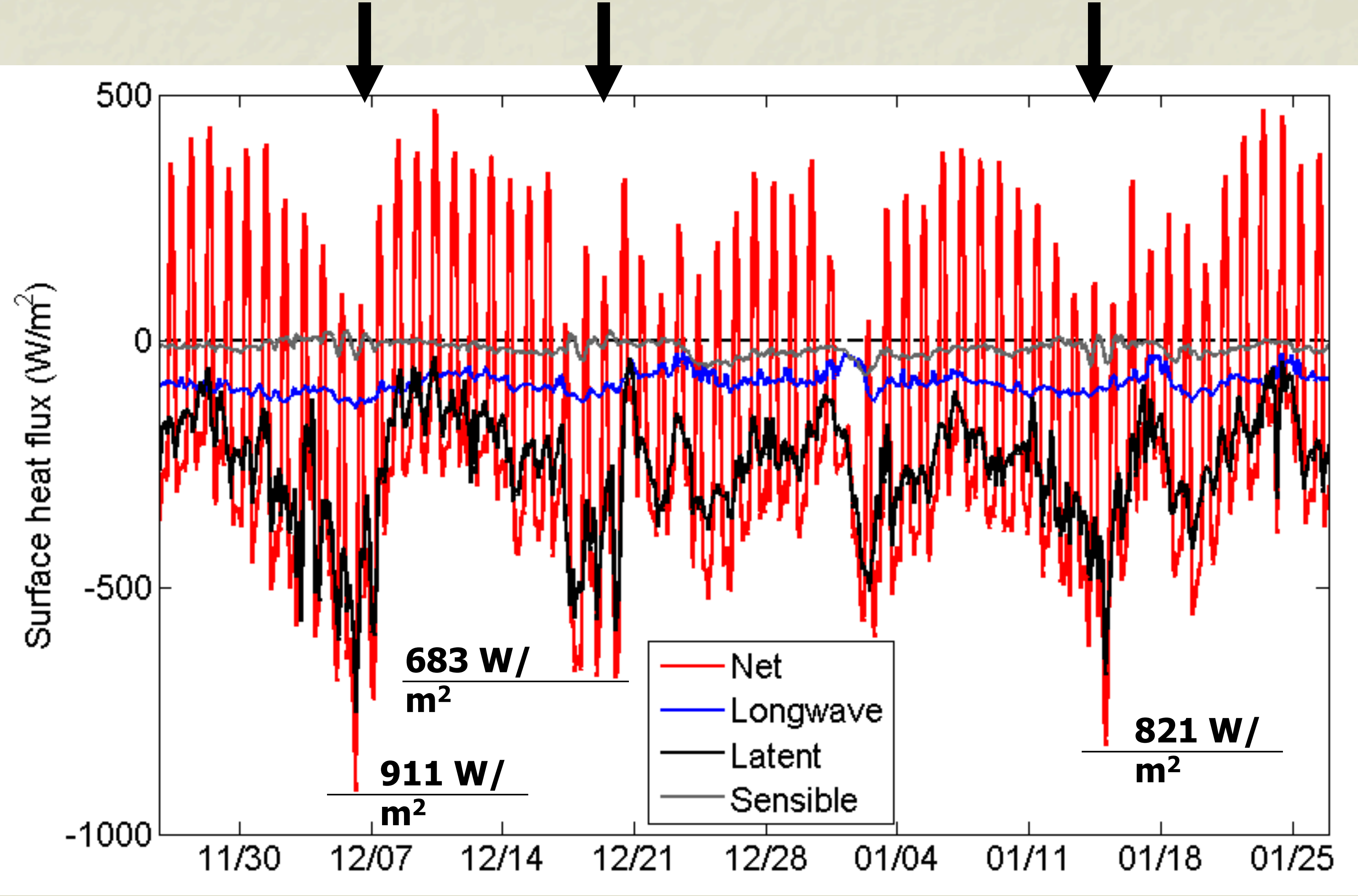

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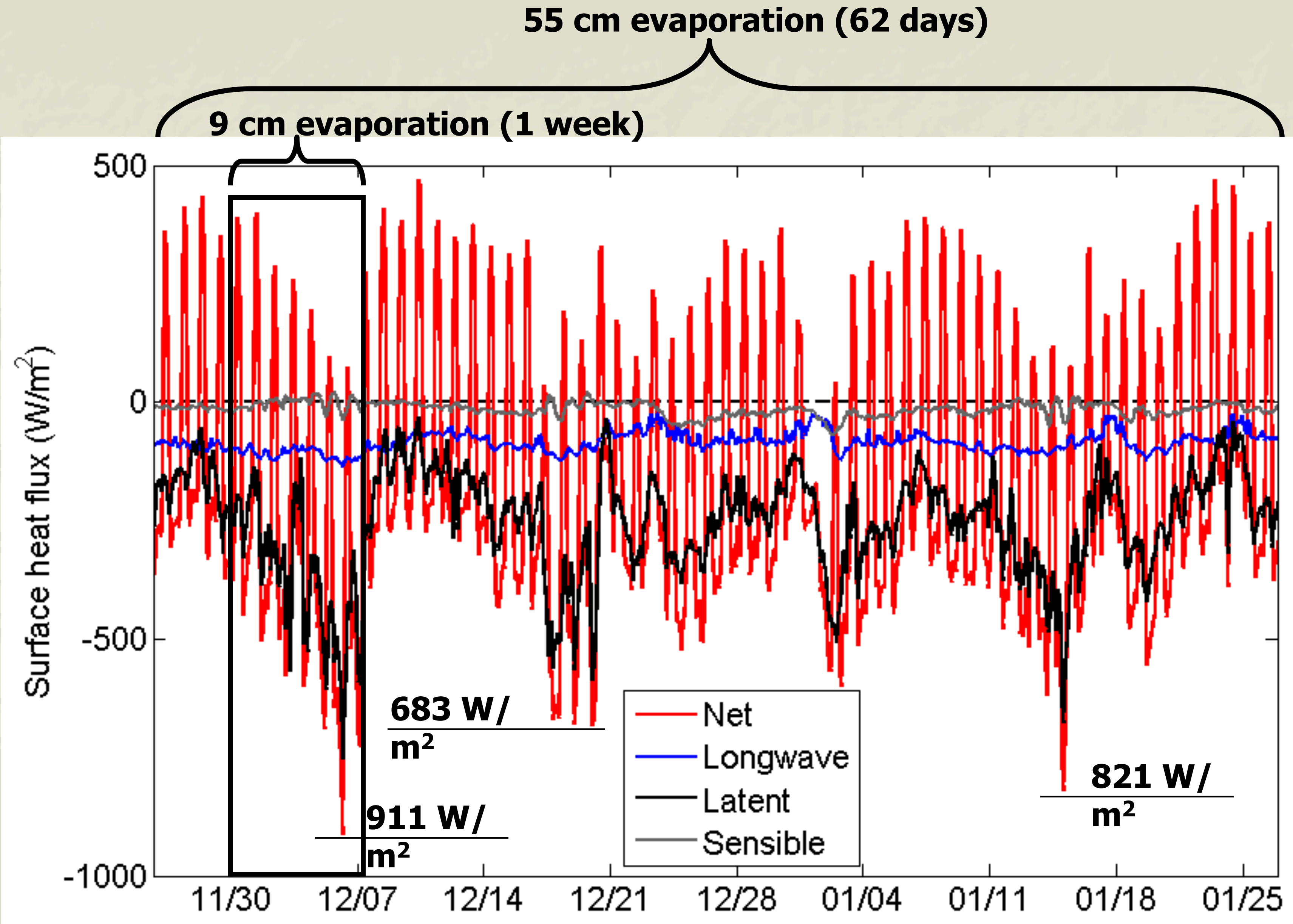

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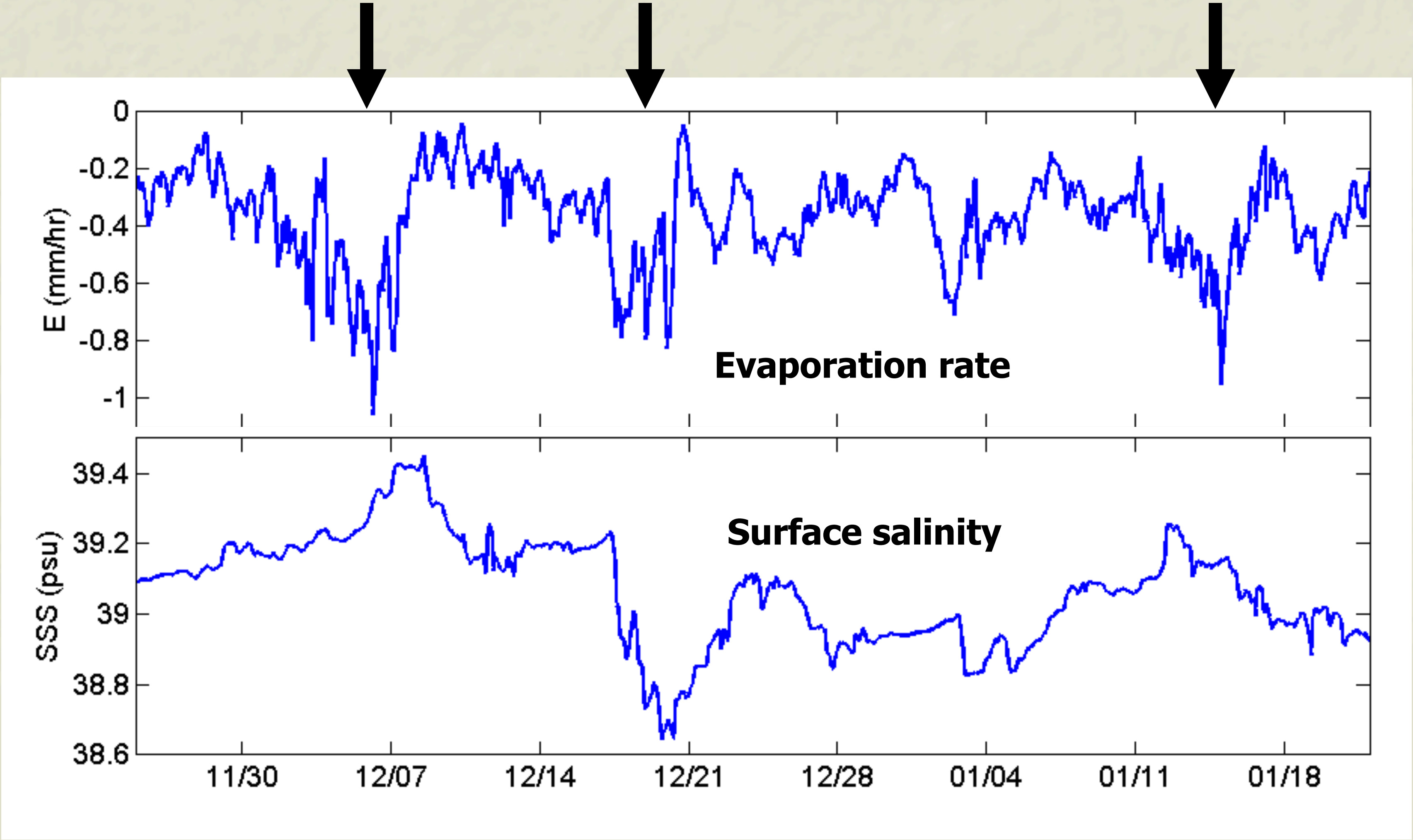
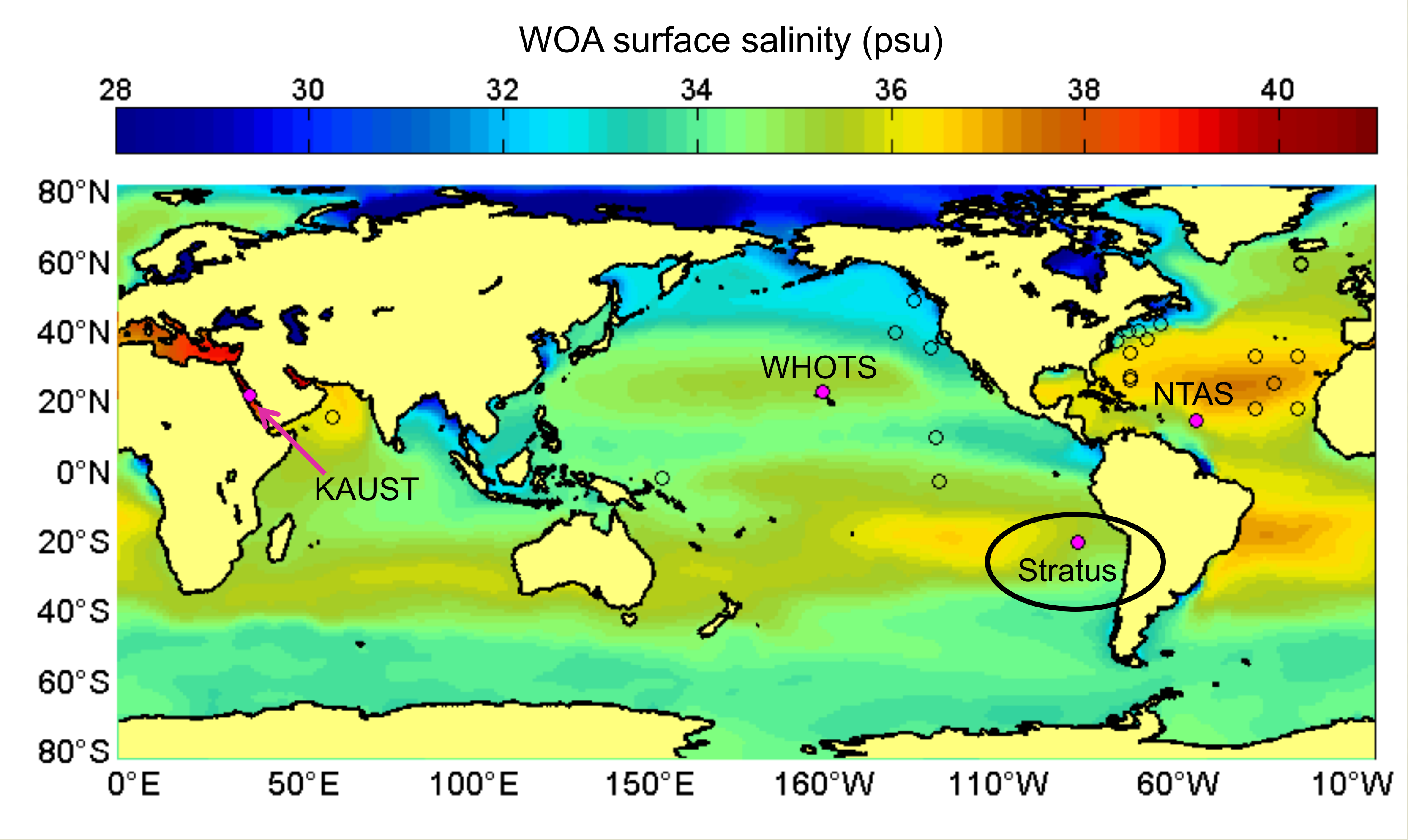
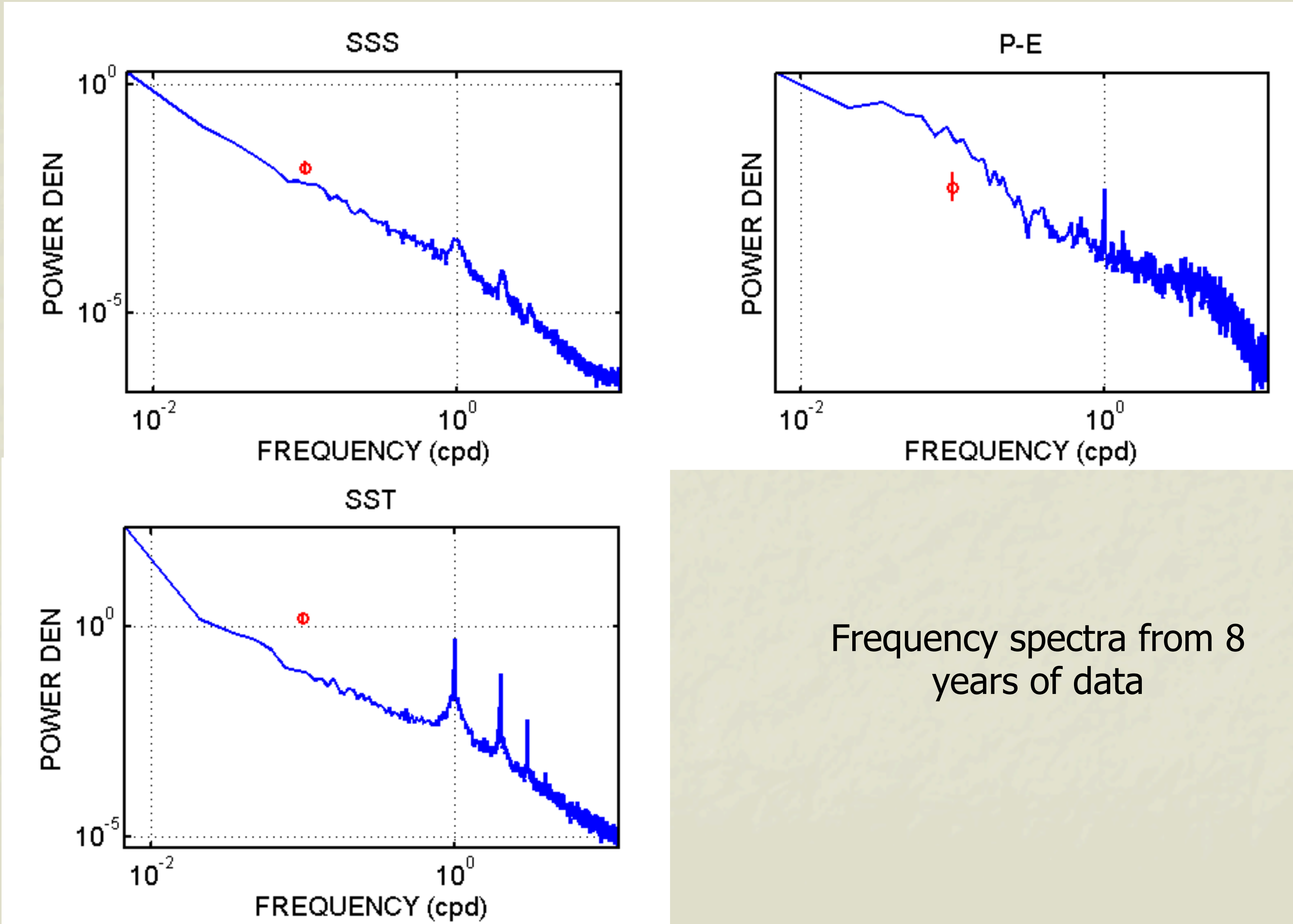


Air-sea interaction buoys

Pink dots: Sites occupied by WHOI air-sea interaction moorings

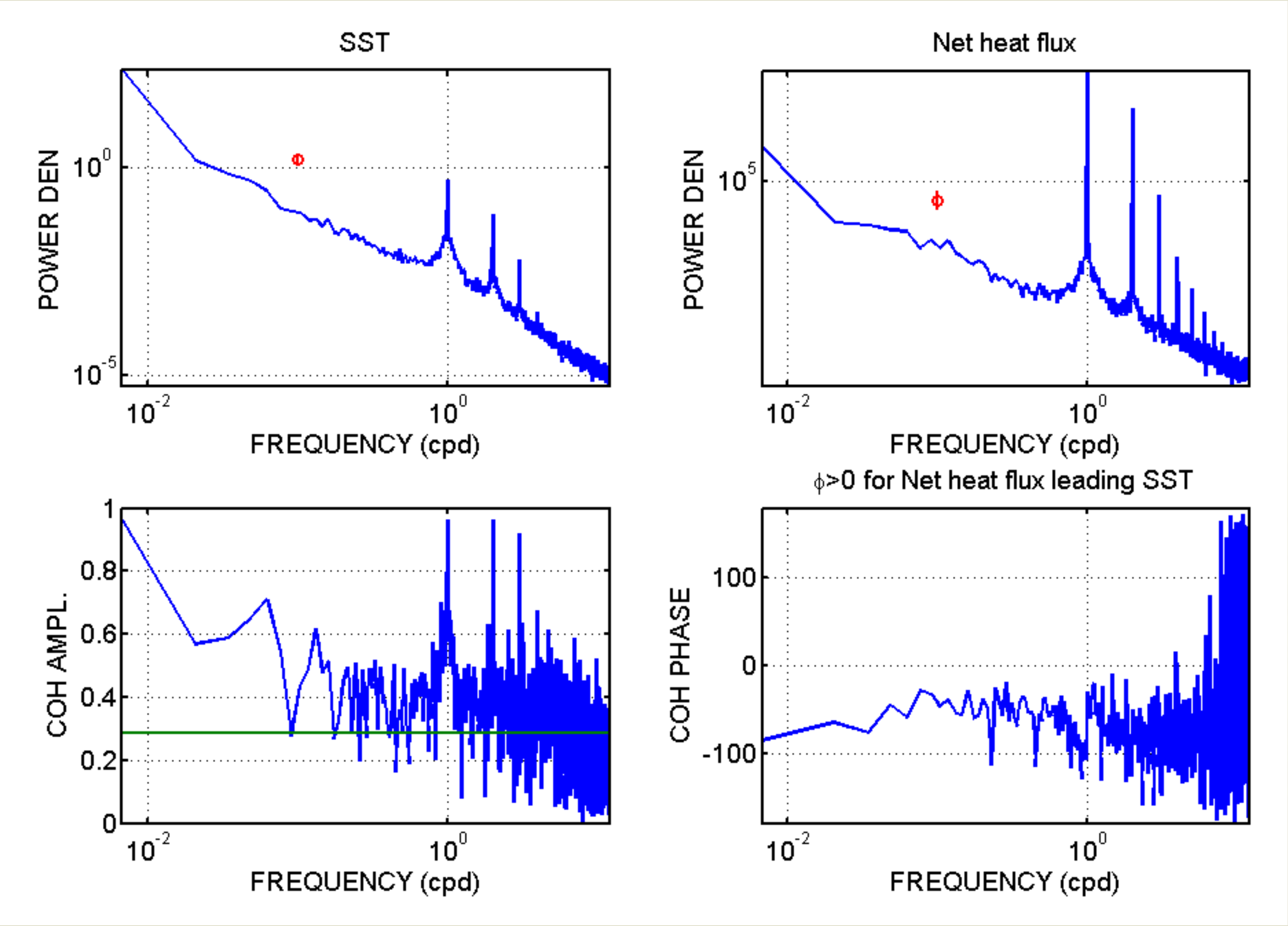


Stratus Ocean Reference Station (Bob Weller)



Frequency spectra from 8 years of data

Stratus Ocean Reference Station (Bob Weller)



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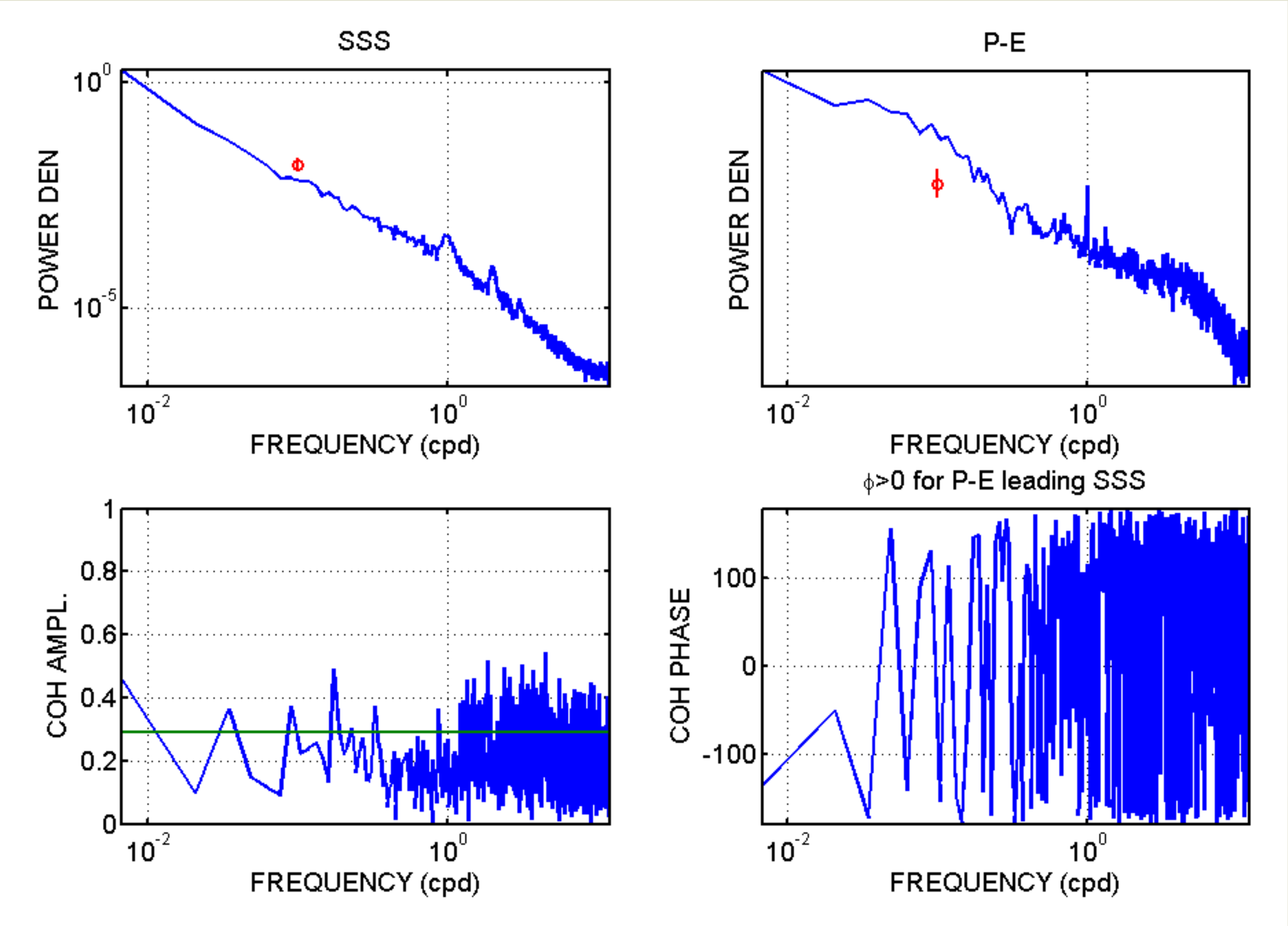

What gives?

We have looked at freshwater fluxes (including extreme events) and SSS at three sites, and I have shown no compelling evidence that SSS is related to the surface fluxes.

→Of course, the surface flux is one of many terms that can influence salinity in the surface layer:

$$\frac{\partial S}{\partial t} = -\vec{u}\cdot\nabla S + \hat{S}_{-h}\left(\frac{\partial h}{\partial t} + w_{-h} + \vec{u}_{-h}\cdot\nabla h\right) - \frac{Q_{-h}}{h} + \frac{(E-P)S}{h} - \frac{1}{h}\nabla\cdot\int_{-h}^{0}\hat{\vec{u}}\hat{S}dz$$

→Another point to keep in mind is that freshwater flux is generally a weak influence on surface buoyancy flux (and hence on mixed-layer dynamics and *h*):

$$B = \frac{g\alpha}{c_p}\left(Q_{solar} + Q_{longwave} + Q_{sensible} + Q_{latent}\right) + g\beta S(E-P)$$

Ratio $B_{heat}/B_{FW} \approx \dfrac{\alpha L_V}{c_p \beta S} \approx 4$

Surface fluxes of freshwater

Mostly due to evaporation and precipitation, but condensation can also occur on or near the sea surface

→Freshwater flux from condensation is not well documented, but we saw evidence for it in CBLAST-Low

→Evaporation can be determined by:

(1) Direct measurement of the turbulent flux of water vapor in the atmospheric boundary layer
(2) Indirect estimation from bulk formulas