A mechanistic synthesis of turbulence measurements made during SPURS-2

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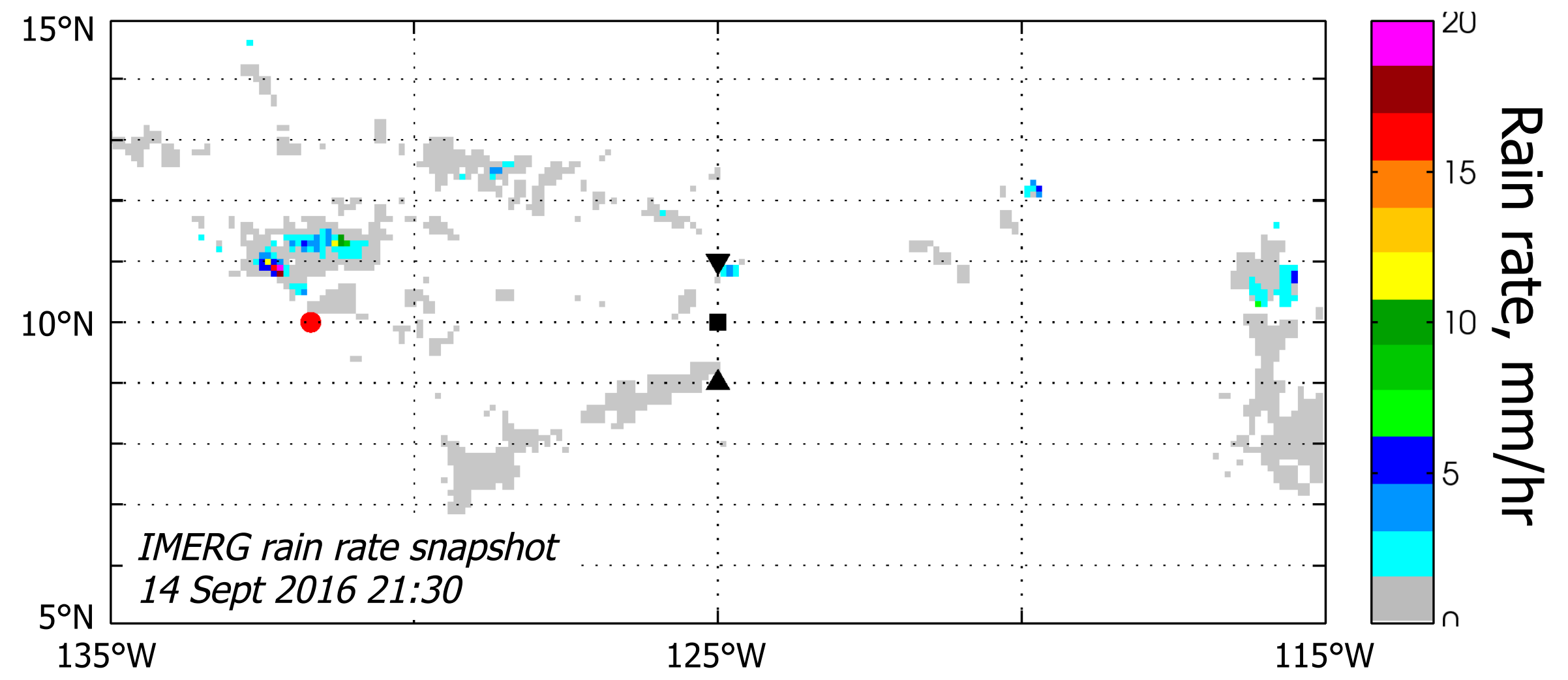
Objective: understanding the physics of how rain gets mixed into the ocean.



IMERG rain rate snapshot
14 Sept 2016 21:30

Tropical rainfall is patchy.

How does it get integrated into the ocean?

We know that rain and wind control the strength and evolution of rain-induced salinity anomalies.

We don’t understand the physics that drives the evolution of these fresh anomalies, and hence produces the observed large-scale salinity structure in rainy regions

Expectation:

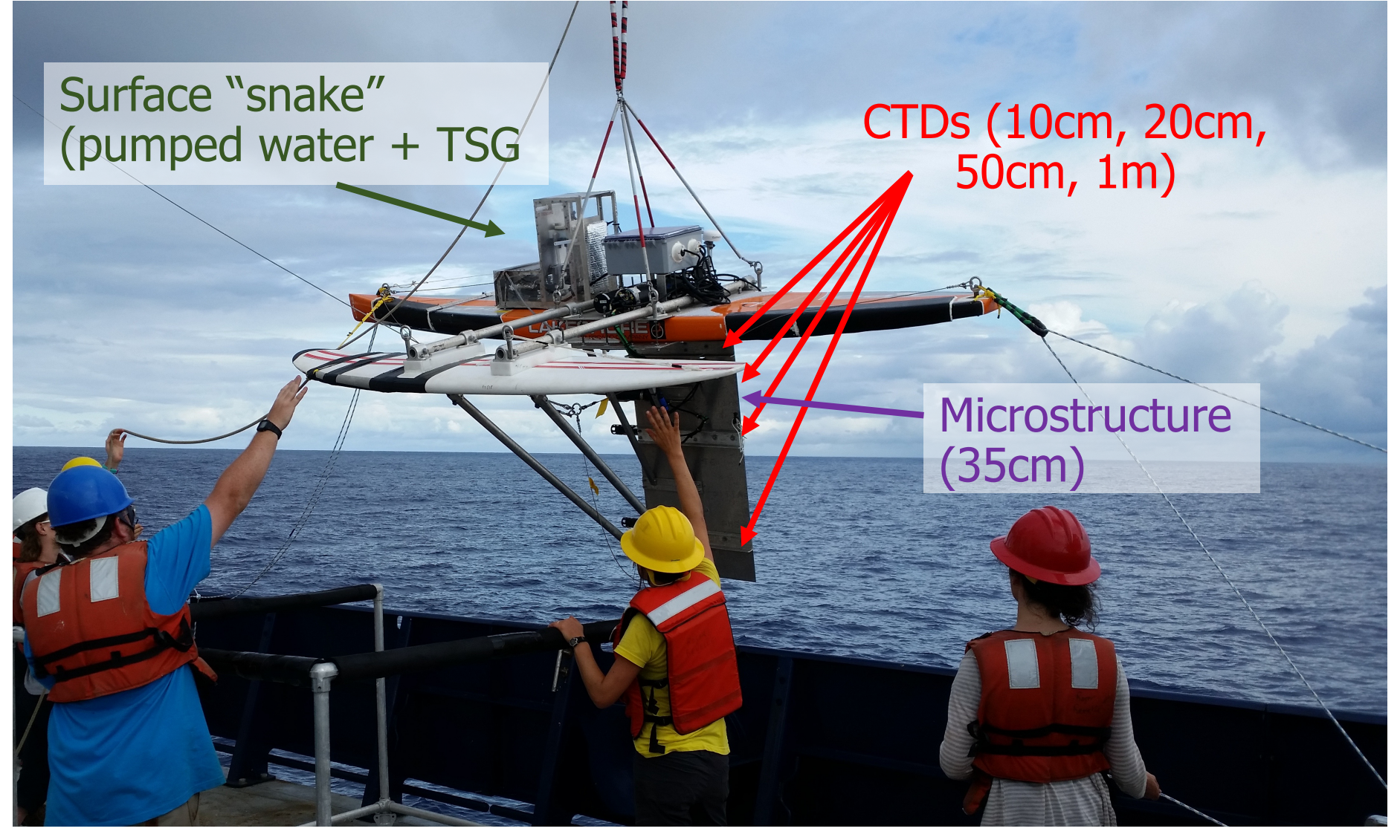
increased surface turbulence (e.g., from wind, raindrops, waves) mixes rain into the water column horizontally and vertically, resulting in a weaker near-surface salinity anomaly, weaker vertical salinity gradients, and a more wide-spread freshening.

Strategy: SPURS-2 experiment in the Eastern Tropical Pacific Ocean.

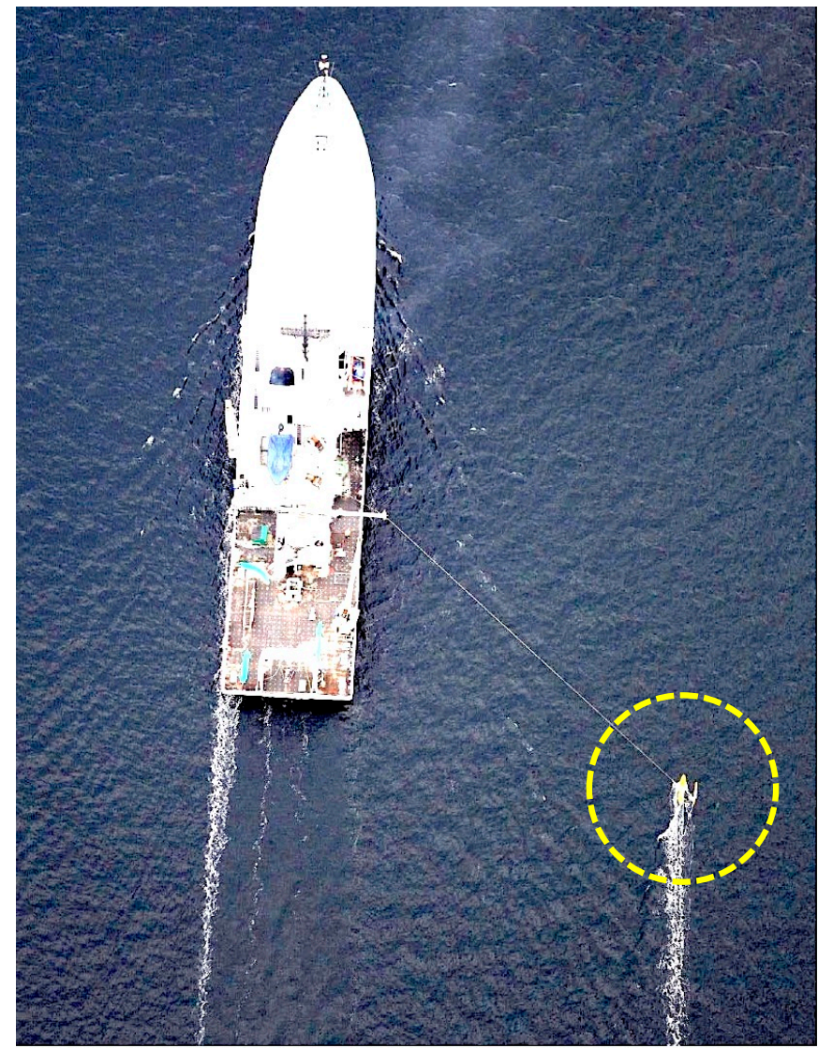
Our SPURS-2 objective: observe wind- and rain-driven surface dynamics in the open ocean, understand how turbulence controls mixing of fresh lenses.

(1) Surface Salinity Profiler (SSP) (see Iyer poster #AI14A-1545 this session)
Turbulence dissipation rate at 35 cm depth from a towed platform

Surface Salinity Profiler (SSP)

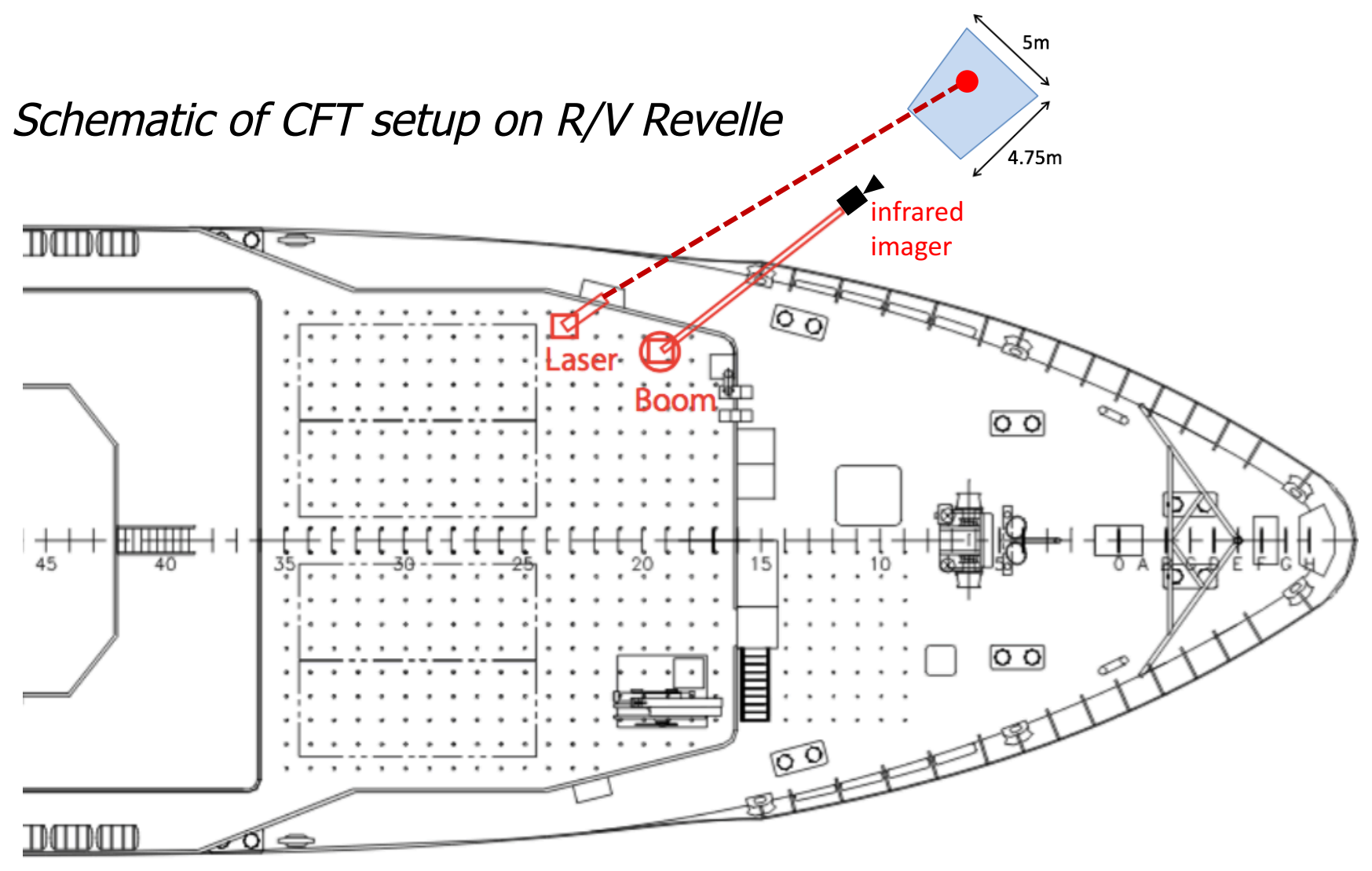


SSP is towed out of the ship’s wake

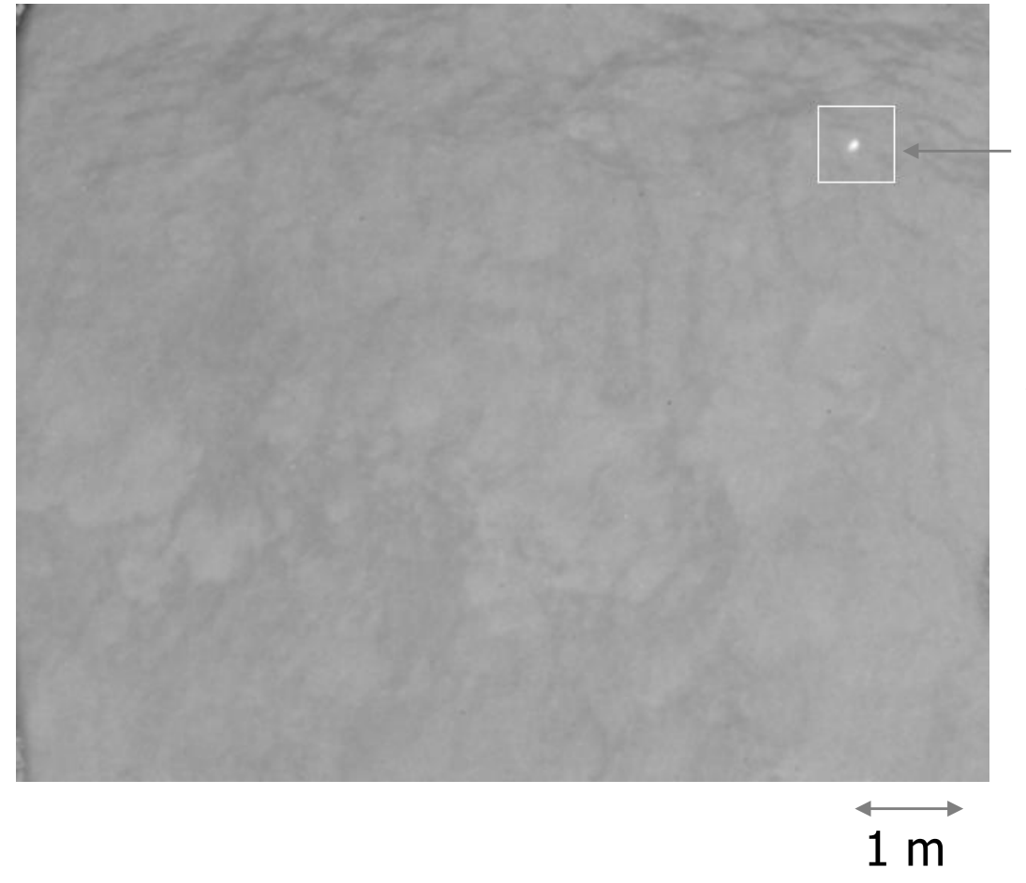


(2) Controlled Flux Technique (CFT) (see Asher poster #AI14A-1547 this session)
Surface dissipation rate is related to the cooling rate of a SST patch generated by heating the surface with a laser

Schematic of CFT setup on R/V Revelle



Example infrared image used for CFT analysis



Heated patch of water. Decay rate of patch temperature gives transfer velocity.

CFT produces k_H , the transfer velocity of heat.
This is related to TKE dissipation rate ε by

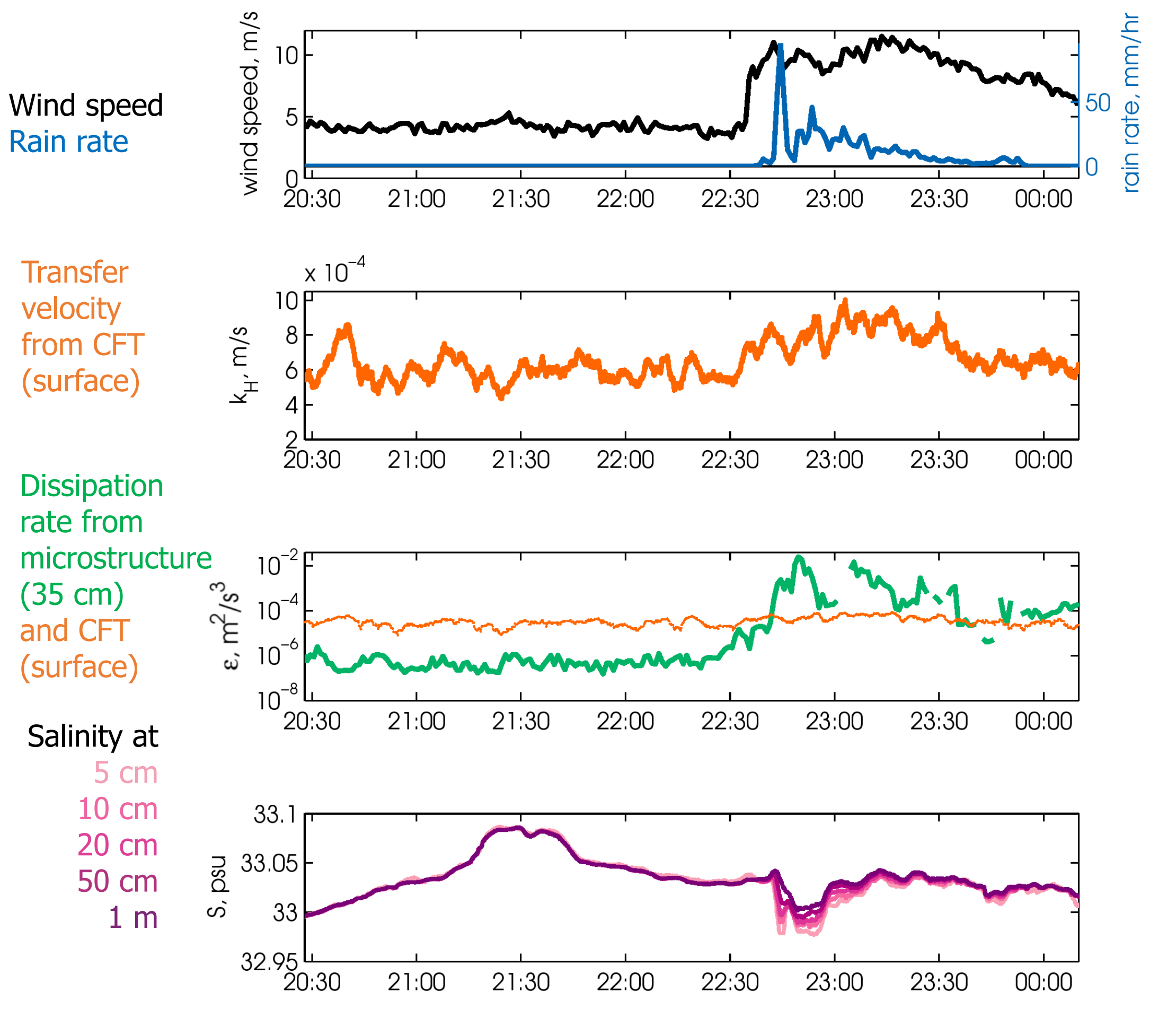
$$k_H \propto \frac{(\epsilon\nu)^{1/4}}{Pr^n}$$

ν = kinematic viscosity,
Pr = Prandtl number
n ~ 0.5

(3) Generalized Ocean Turbulence Model (GOTM)

- 1-d model using a two-equation k-ε turbulence closure scheme.
- Uses COARE bulk flux algorithm (rain impact represented as a horizontal stress).
- Wave breaking and internal waves are parameterized.
- Forced with observed atmospheric parameters at the SPURS-2 site.

Example rain event: strong rain and wind.



17 mm rain deposited in 1.5 hours, wind speed > 10 m/s.

Transfer velocity increases slightly with wind.

Dissipation rate at 35 cm follows wind closely; rain effect cannot be distinguished. Surface dissipation rate (from transfer velocity) shows much weaker variability.

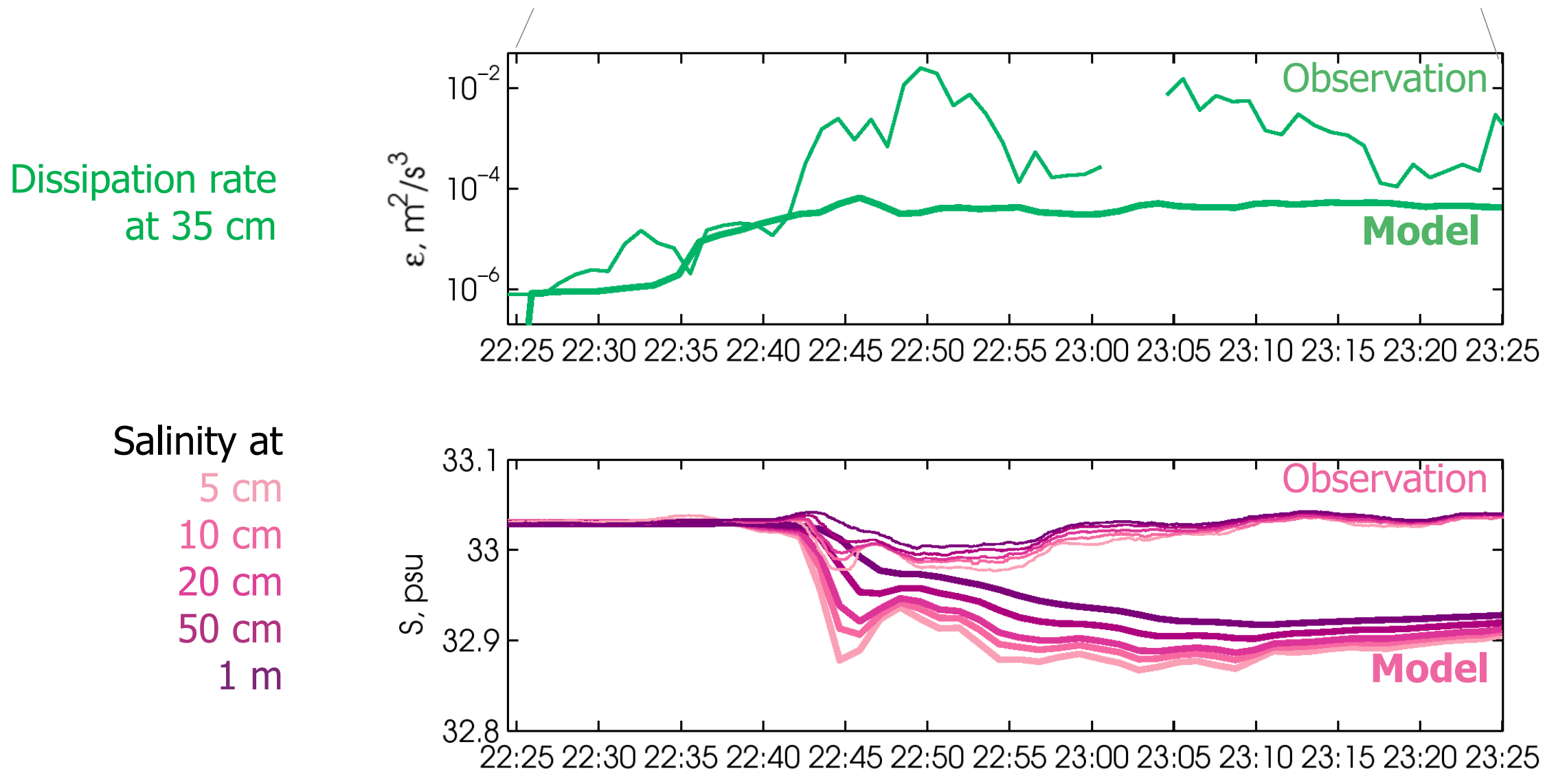
Weak (0.04 psu) salinity anomaly to at least 1 m depth despite strong rain: wind mixes away the fresh water.
Weak vertical salinity gradient between surface and 1 m.

Variability of transfer velocity and 35-cm dissipation rate is affected by both wind and rain (plus waves, currents, local stratification…)

It is difficult to separate the wind, rain, and other effects.

GOTM simulation of 14 Sept rain event: modeled turbulence is low.

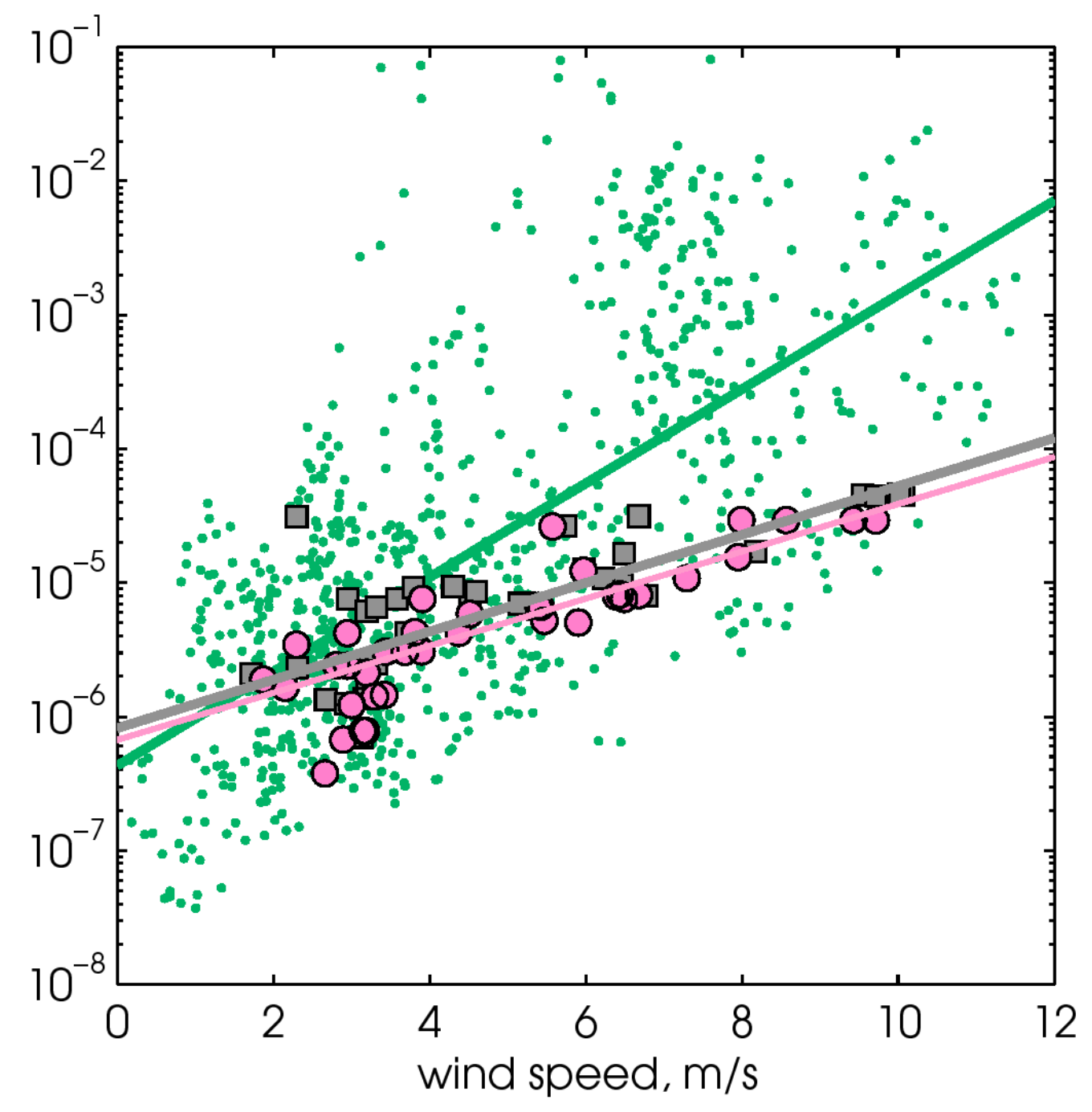
(forced with observed atmospheric parameters):



Observed dissipation rate >> modeled dissipation rate. The model is missing physics: waves? Rain impact?

Not enough mixing in the model → salinity anomaly and gradient are too strong.

Statistics for all 2016 microstructure measurements and modeled events: Modeled turbulence is systematically low.



Observed dissipation rate at 35 cm (all rain conditions)
Modeled 35 cm dissipation rate (rain events)
Modeled 35 cm dissipation rate (no-rain sensitivity tests)

GOTM systematically underestimates dissipation, and is worse at high wind speeds (based on observation-model comparisons).

Rain enhances turbulence only slightly in the model (based on no-rain sensitivity experiments).

Summary:

Wind appears to drive near-surface dissipation rate; the impacts of rain (and waves) are difficult to unravel.

Typical 1-d models (COARE + wave parameterizations) significantly underestimate near-surface turbulence dissipation rate, especially at high winds.

Models with too-weak mixing will produce unrealistically strong salinity anomalies.

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