The Diurnal Cycle of Salinity

Aquarius Science Team Meeting
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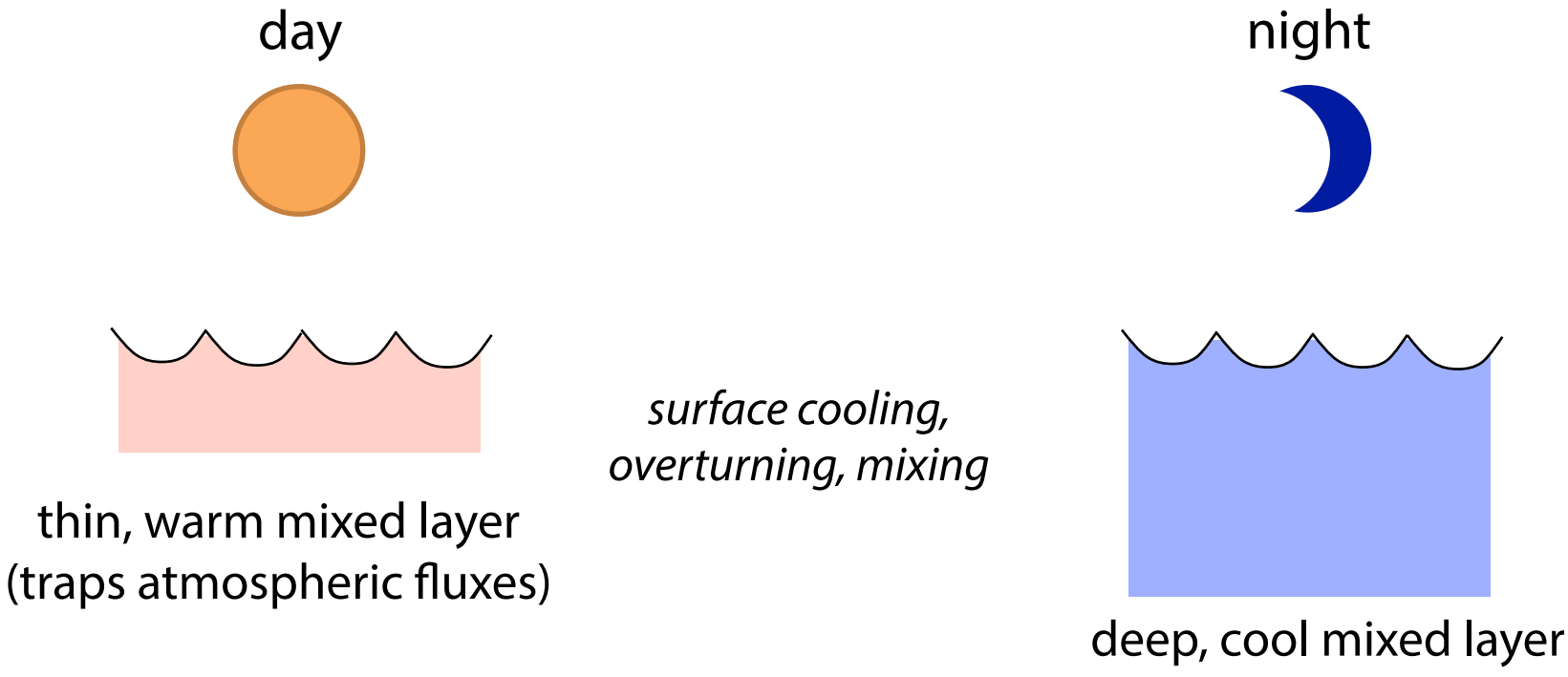
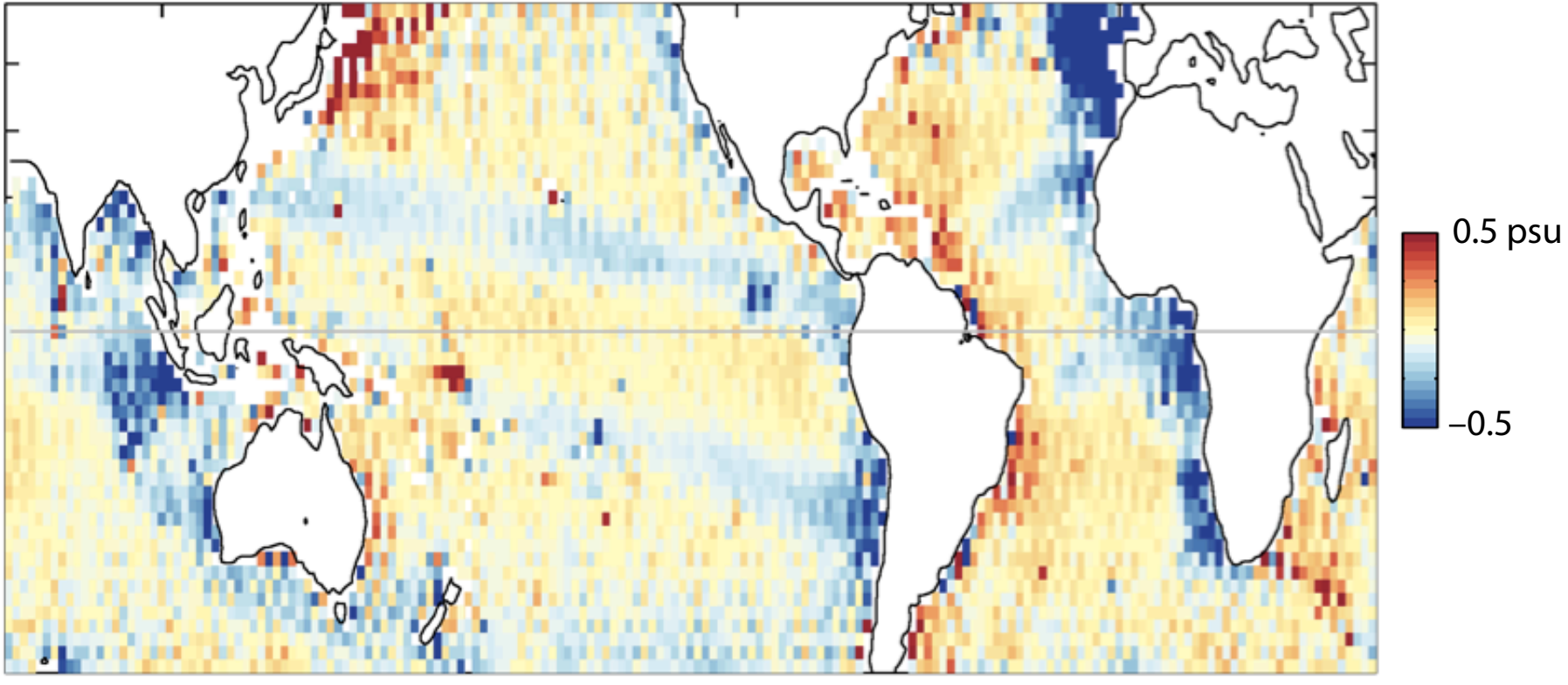
Diurnal variations in solar radiation affect SST, mixing, etc.
– can improve climate modeling of air-sea processes



…Do diurnal salinity variations matter?
e.g. in regions where salinity controls mixed-layer depth

Aquarius mean ascending–descending difference:

(V3.0 CAP L2 data, 3-yr average, 2° bins)

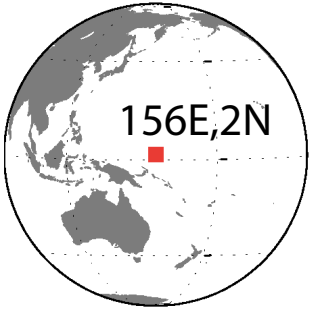


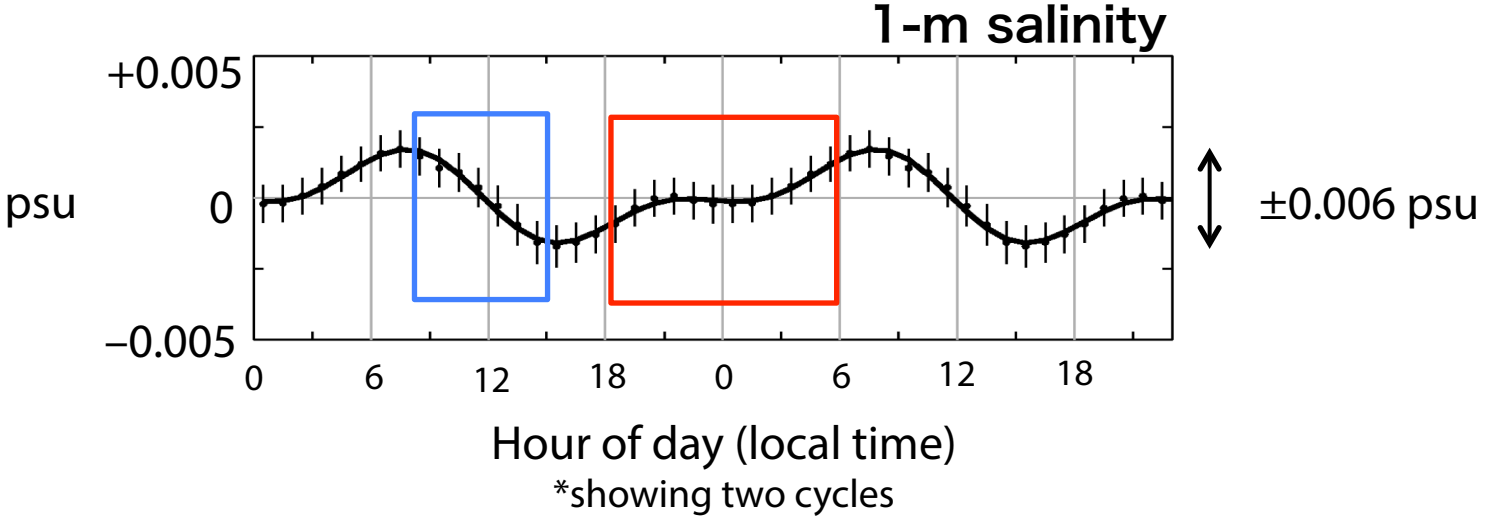
Ascending = evening, descending=morning

Does diurnal salinity account for any of this signal?

Diurnal salinity from TAO buoy data at 1 m depth

1. One year of hourly data
2. high-pass filter
3. bin by hour of day

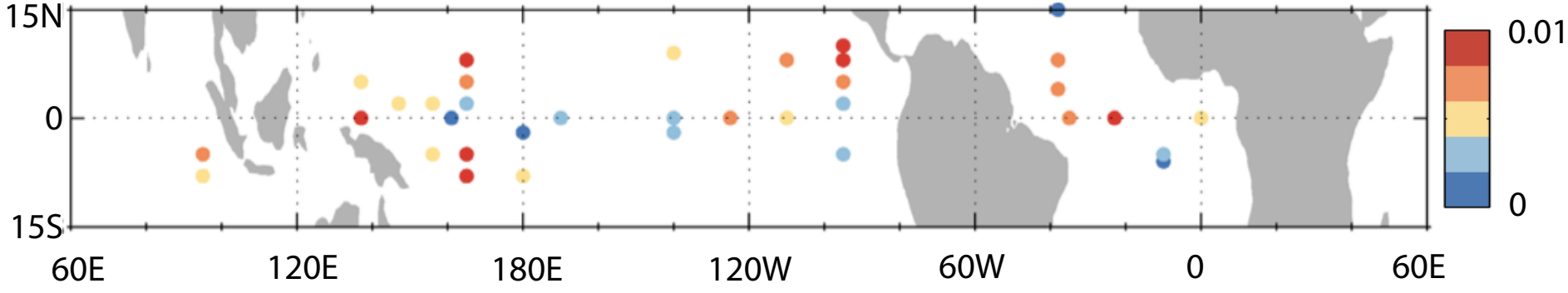




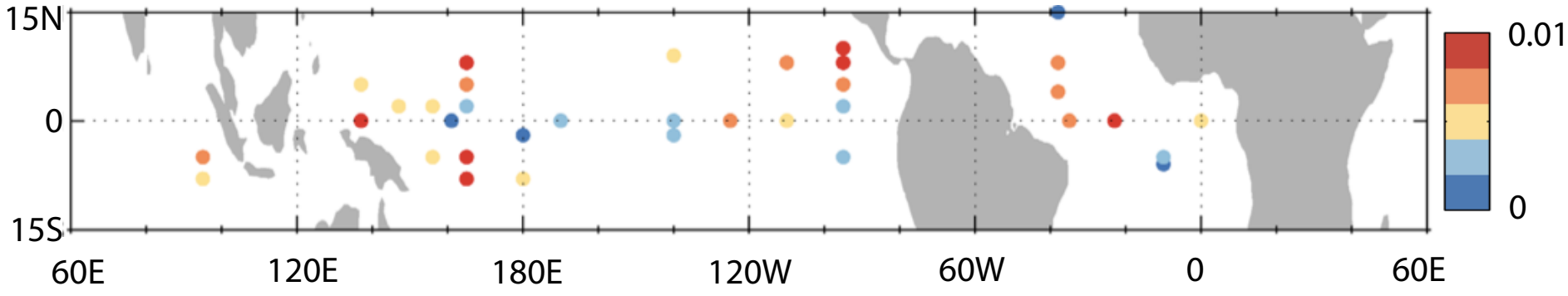
Daytime freshening
(min S at 3pm)

Nighttime
salinity increase
(max S at 8am)

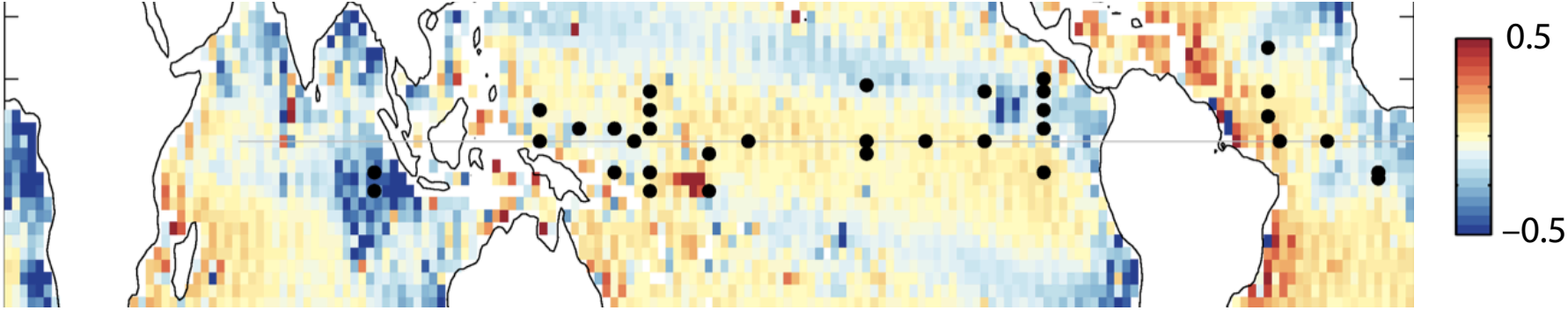
Diurnal salinity at all TAO moorings:



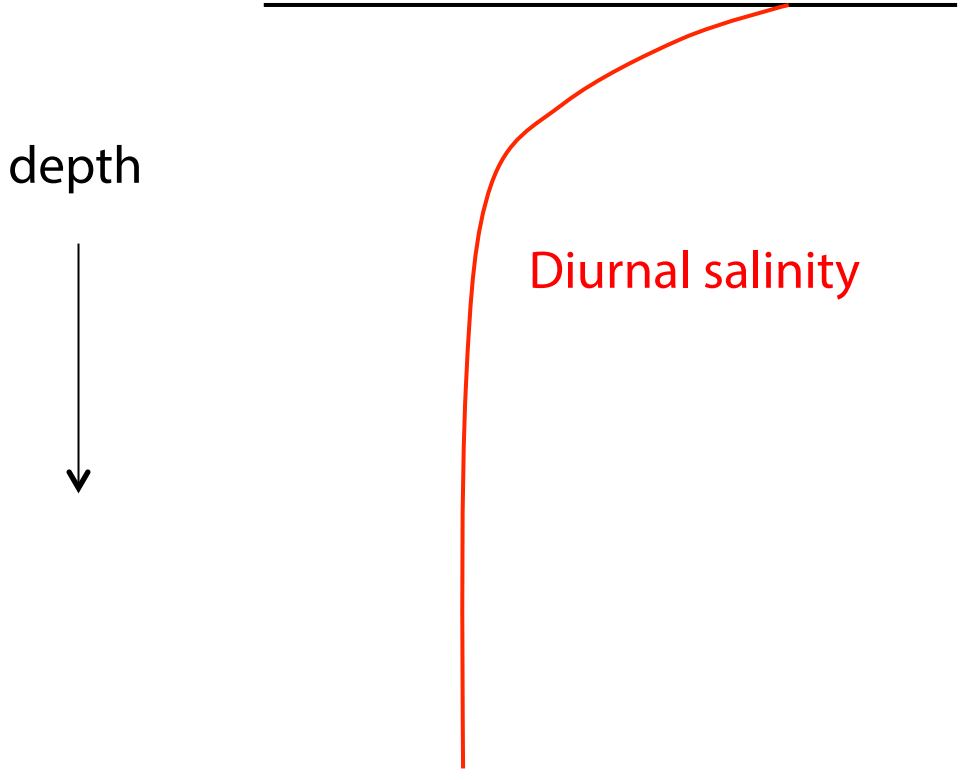
Diurnal salinity at all TAO moorings:



Aquarius ascending–descending salinity >> 1-m diurnal salinity

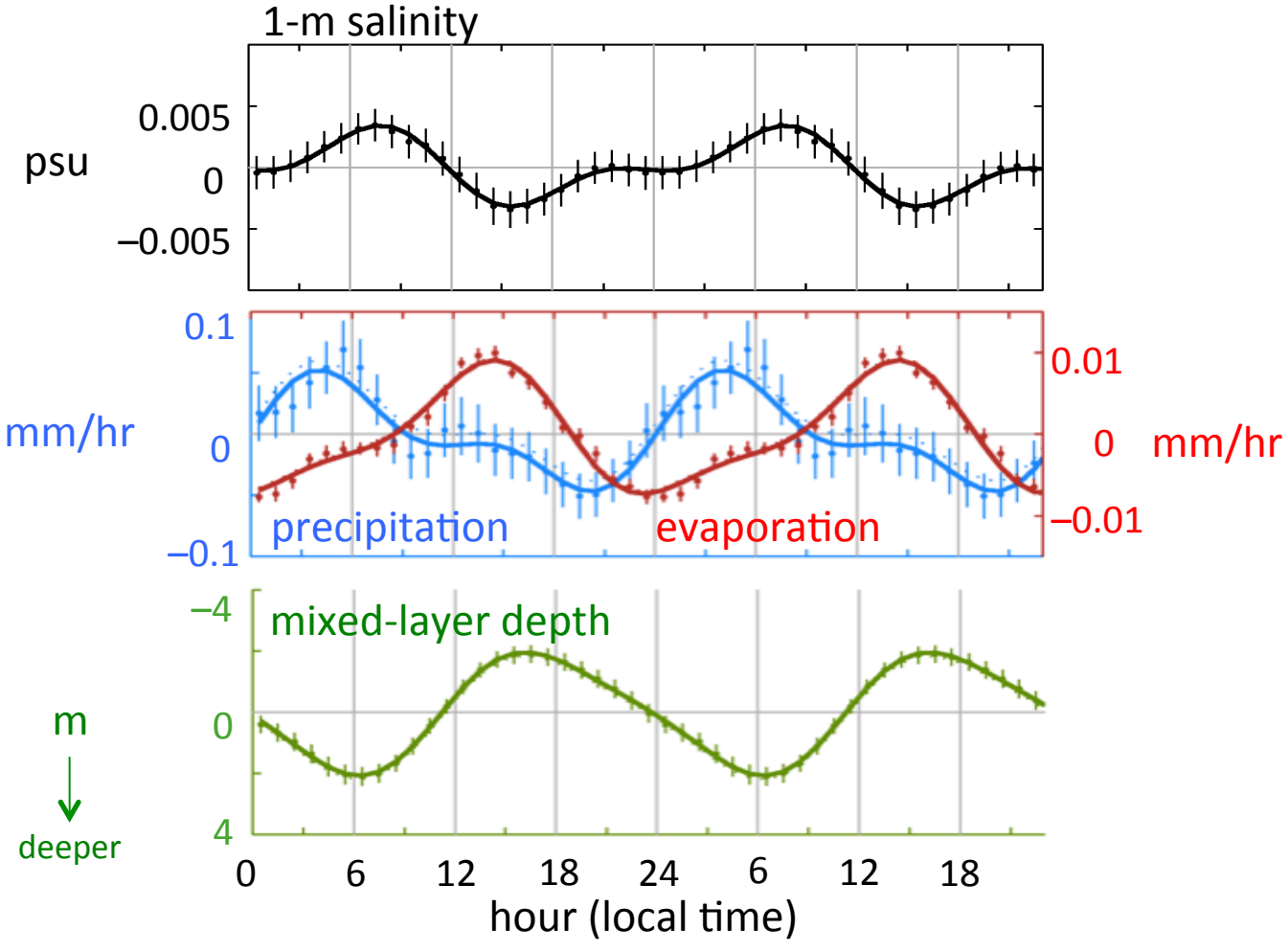


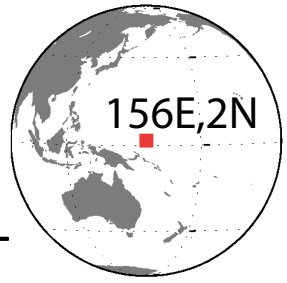
Diurnal salinity decays with depth.
Open question: how much?



Salinity at 1-m (buoy) depth ≈

precipitation	evaporation	advection	entrainment
$-\int \frac{P}{h_P}\bar{S}dt$	$+\int \frac{E}{h_E}\bar{S}dt$	$-\int \mathbf{u}_1 \nabla S_1 \, dt$	$-\frac{dh\Delta S}{h}$
assume h_p~3m	assume h_E~1m	negligible	h = mixed-layer depth





T

±0.006 psu

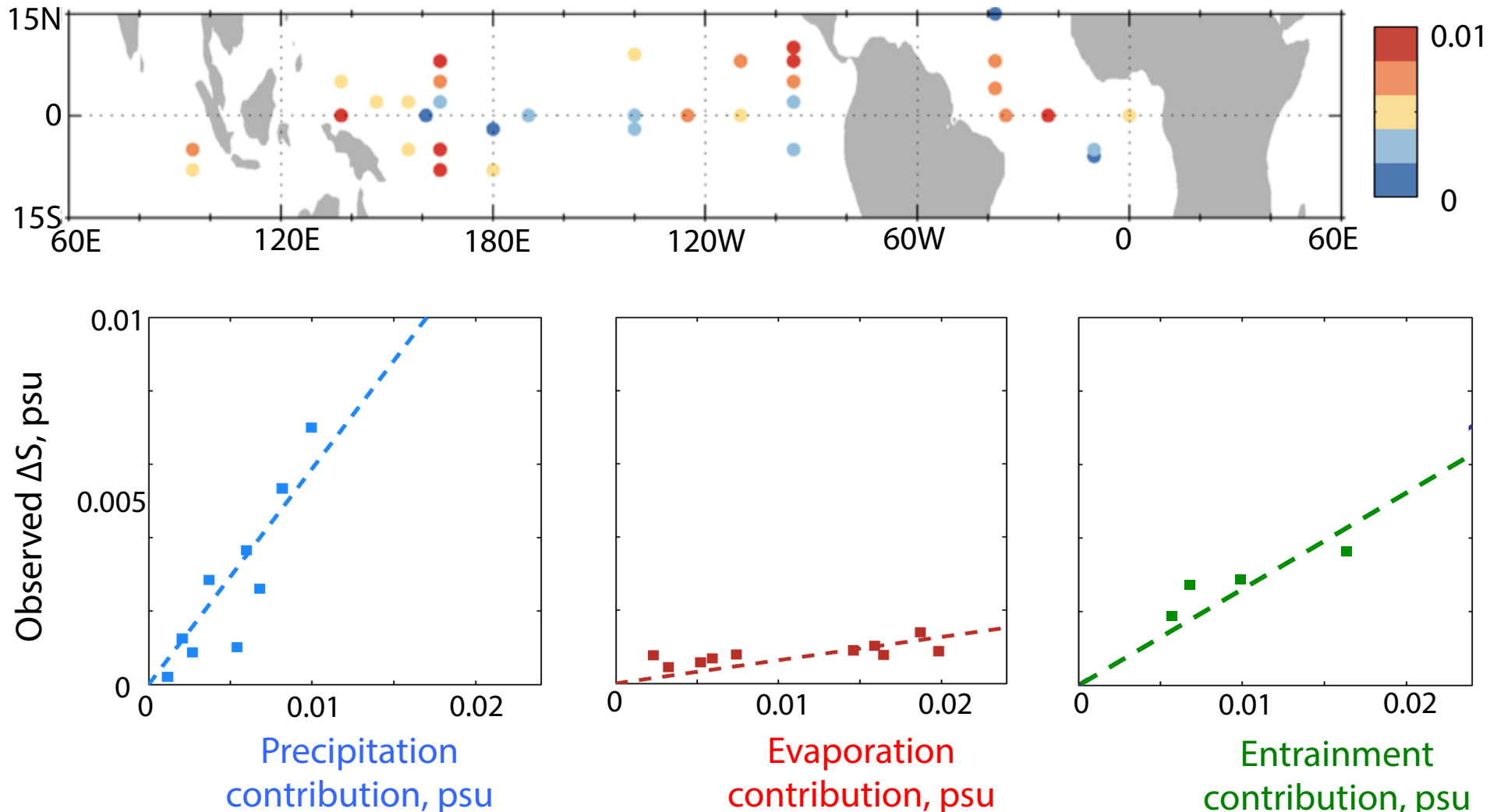
Estimated contributions:

precipitation
–0.004 psu

evaporation
+0.001 psu

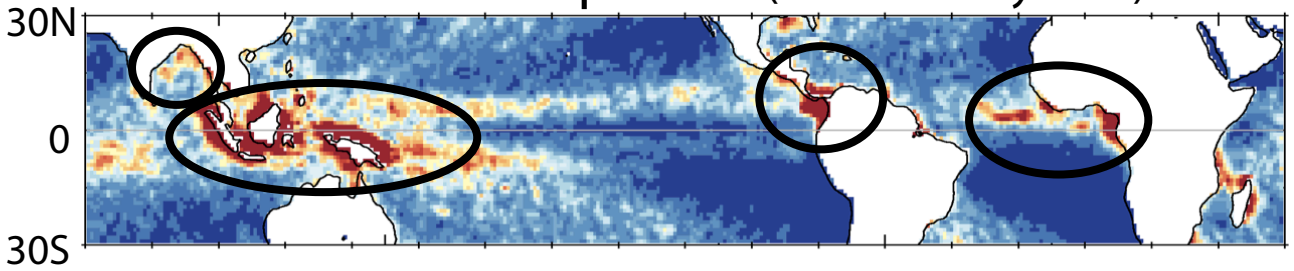
entrainment
+0.003 psu

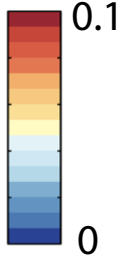
Precipitation & entrainment consistently dominate diurnal salinity



Where diurnal salinity is expected to be strong:

Diurnal rain rate amplitude (TRMM 3-hrly data)

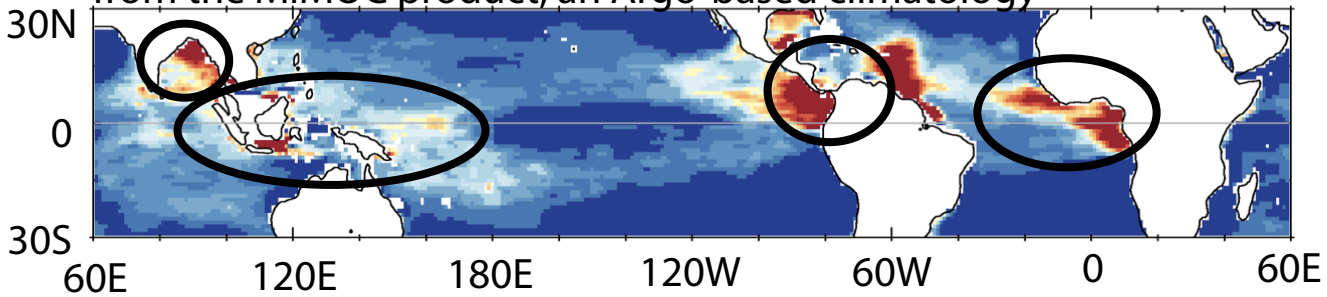


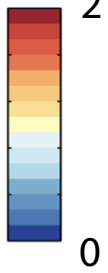


diurnal rain rate, mm/hr

Climatological "stratification strength" (ΔS/h)

from the MIMOC product, an Argo-based climatology

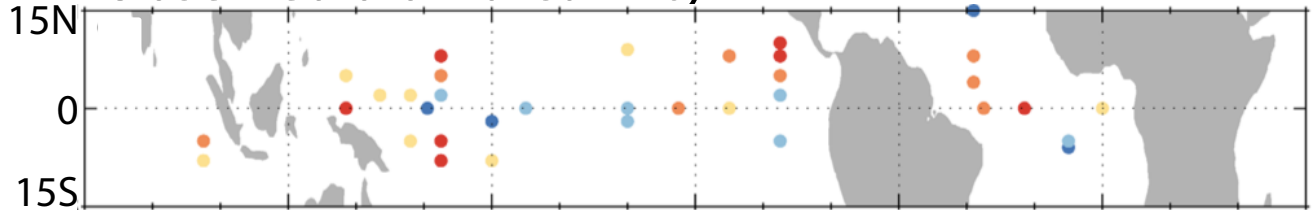


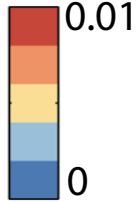


$\frac{\Delta S}{h}$

psu/m x 10^{-3}

Observed diurnal salinity





Diurnal salinity amplitude (psu)

Recap

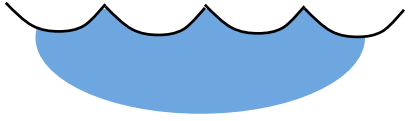
1. Diurnal salinity at 1-m depth is small but significant

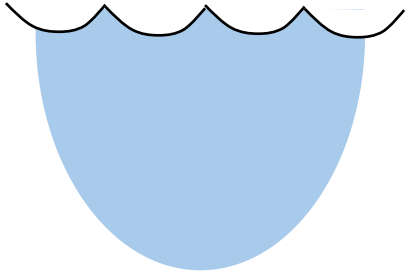
2. Rain drives diurnal salinity. Entrainment sets the phase.

3. Ascending–descending Aquarius differences are much bigger than 1-m diurnal salinity
   – but: 1cm signal is likely larger than 1m signal, so diurnal salinity could still affect Aquarius

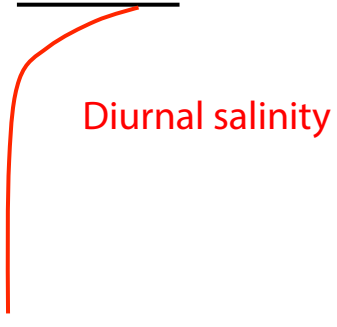
What we need to know to understand if diurnal salinity affects Aquarius:

1. What is the thickness / salinity anomaly of fresh pools?





2. How does salinity decay with depth in the upper few meters?



…1-d modeling

Generalized Ocean Turbulence Model (GOTM)

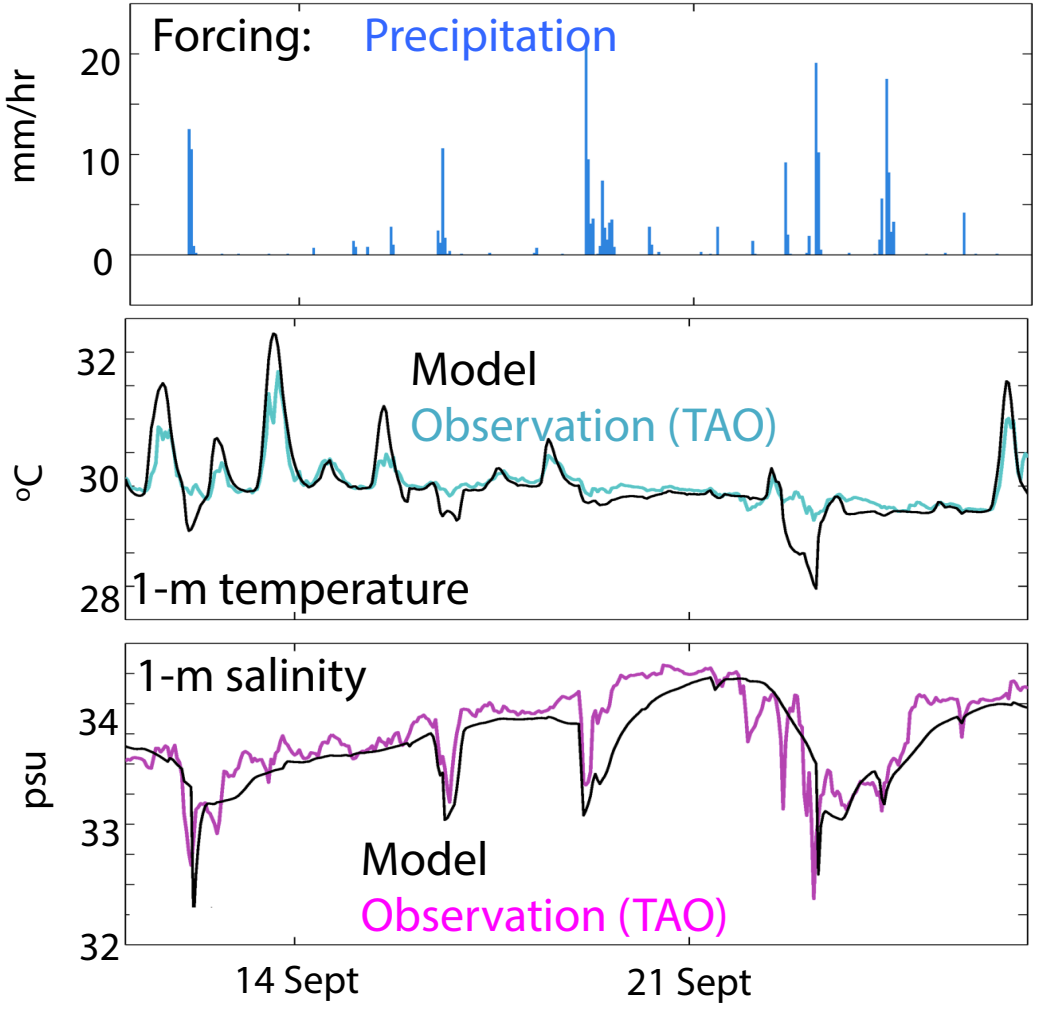
(Burchard & Bolding 2001, www.gotm.net)

1-d model:

- **2-parameter k-ε turbulence closure scheme**
- forced with hourly TAO observations (shortwave flux, wind, rain)
- T and S profiles initialized once per day (at sunrise)
- COARE bulk formula
- surface wave-breaking (Burchard, 2001) and internal wave parameterizations (Large et al., 1994)
- <5cm resolution within the top 5m (<30cm within the mixed layer)
- 1-min time step
- **has been used for diurnal/surface layer studies**

(e.g., Jeffery et al., 2008; Pimental et al., 2008)

Validation: GOTM vs TAO

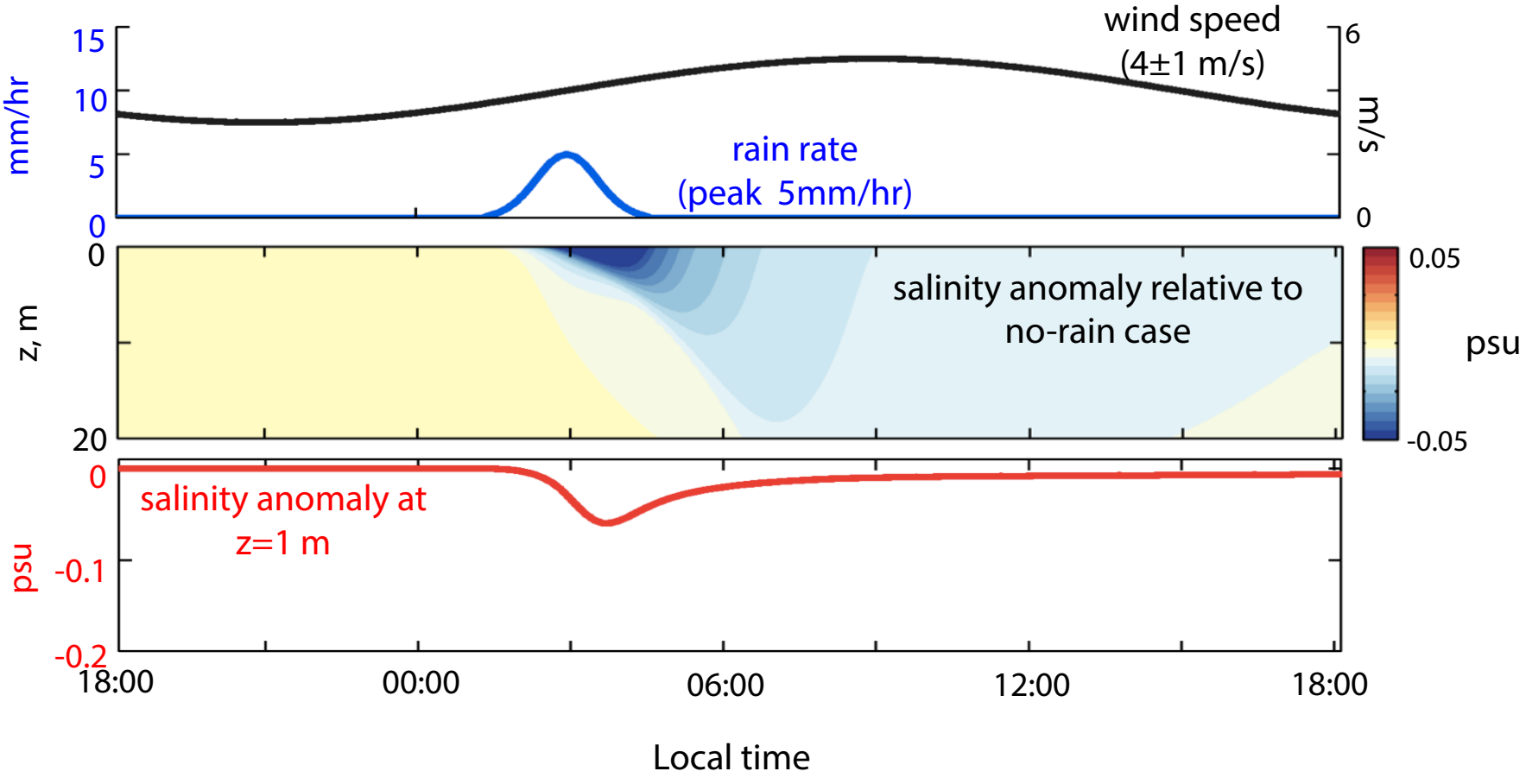


Diurnal warming well reproduced

(R^2=0.89 over 8-month run)

Fresh events captured
(R^2=0.77 over 8-month run)

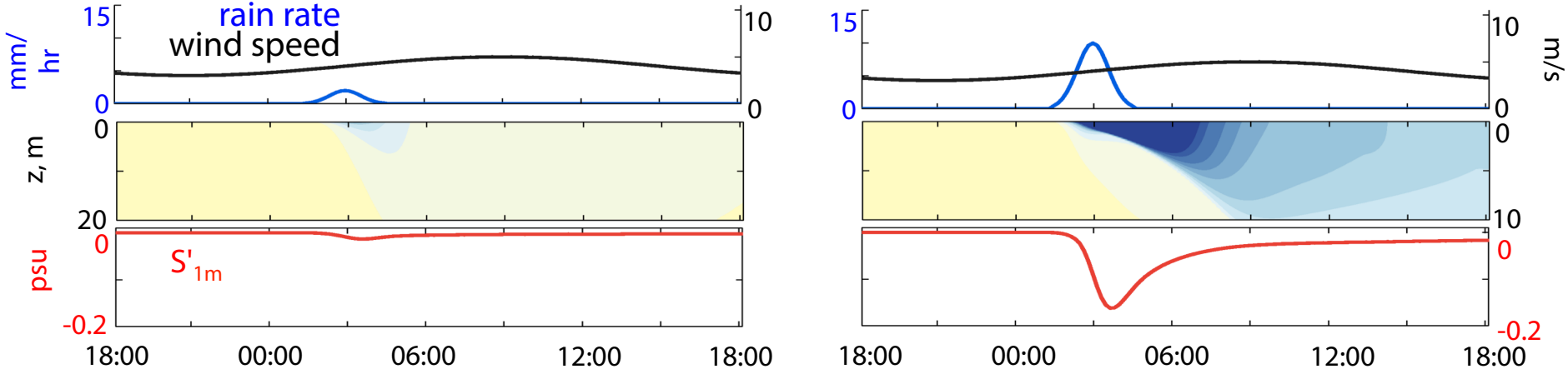
Lens formation under rain with GOTM
Idealised rain (Gaussian pulse) + wind (sinusoid)

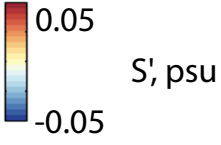


Varying the strength of **rain**

Weaker rain (2 mm/hr)

Stronger rain (10 mm/hr)





Rain rate affects:

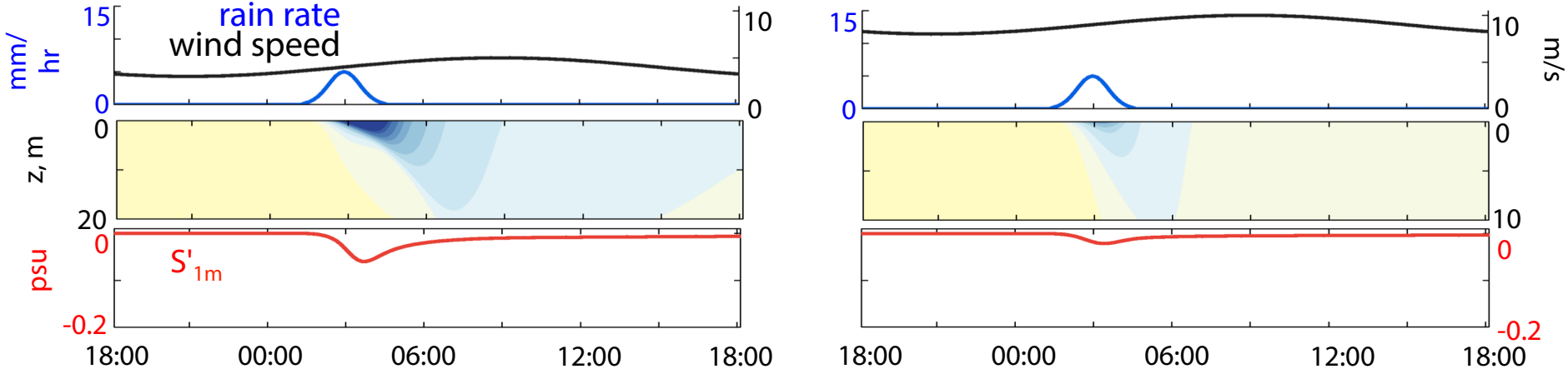
– Strength of salinity anomaly

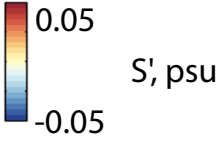
– Lens thickness (h_p)

Varying the strength of **wind**

Weaker wind (5 m/s)

Stronger wind (10 m/s)





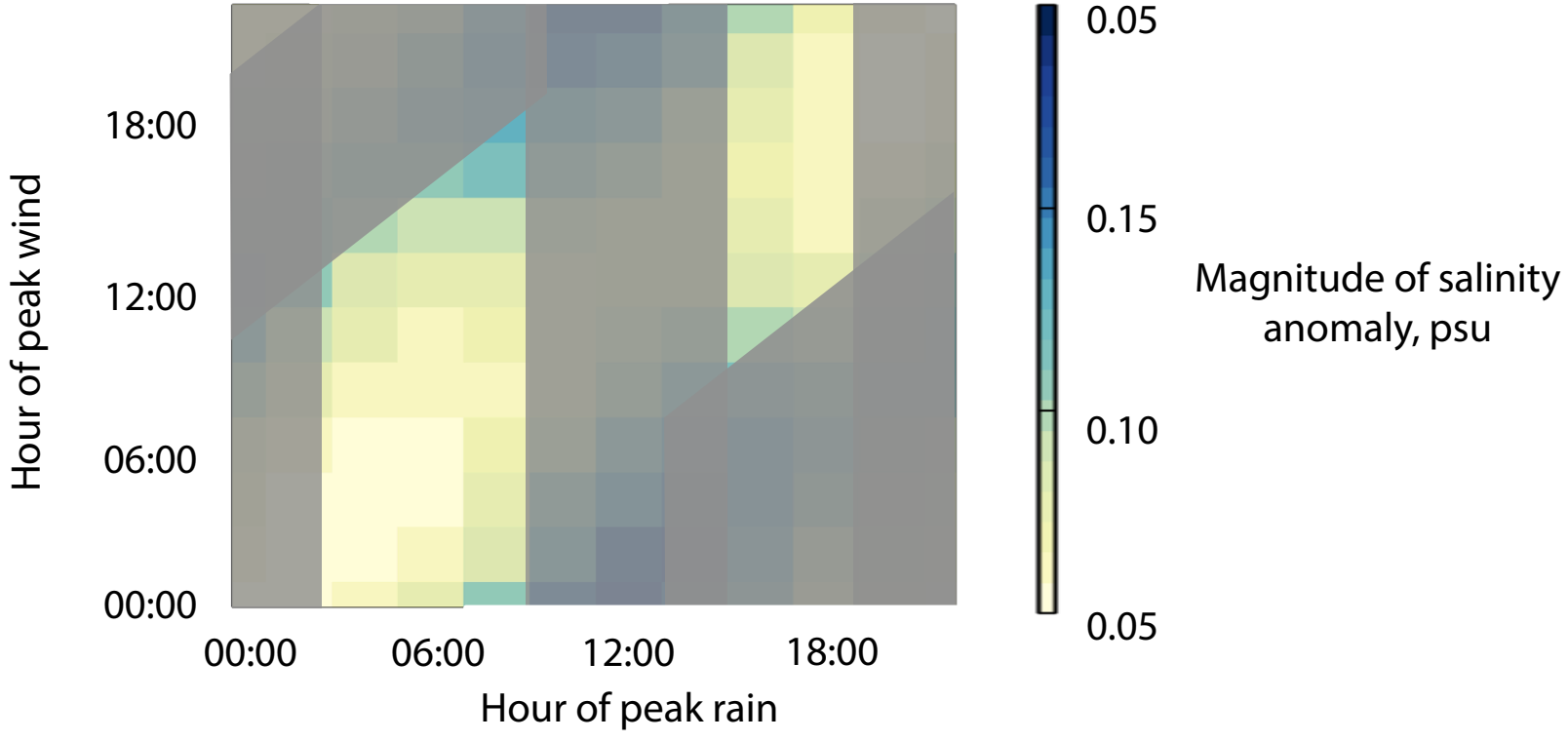
Wind speed controls:

– Strength of salinity anomaly

– Duration of salinity anomaly

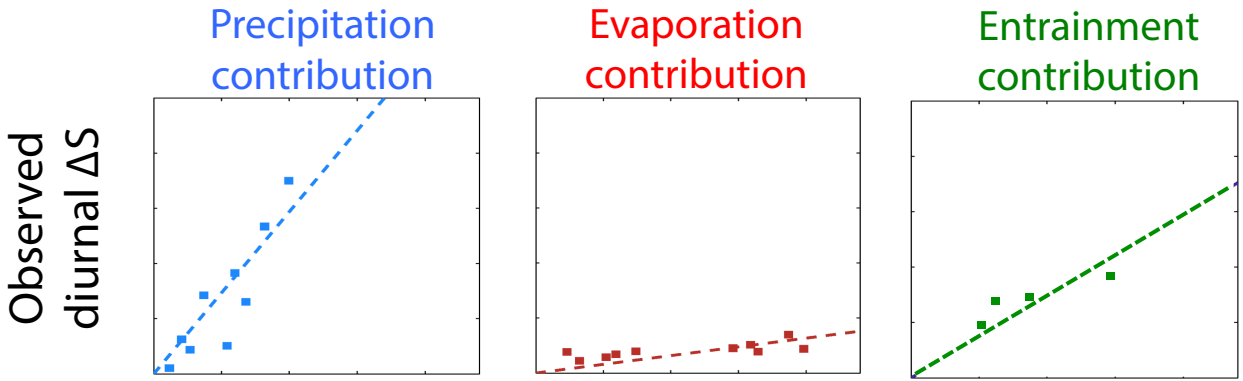
Strongest salinity anomalies when:

- rain coincides with weak winds
- surface mixed layer is thin (mid-day)

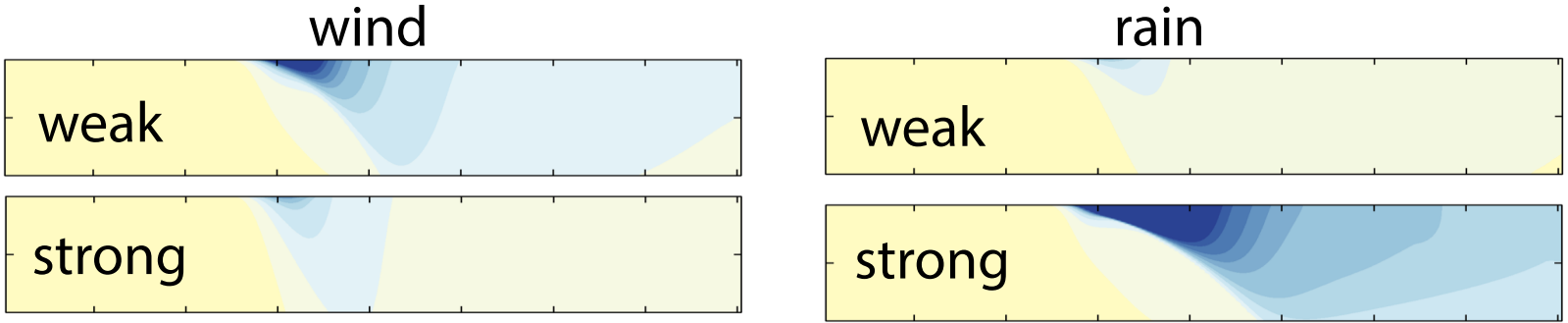


Summary

TAO mooring data show a significant, weak diurnal salinity cycle driven by rain + entrainment (Drushka et al., JGR, 2014)



A 1-d turbulence model shows that wind & rain strength significantly affects lens formation & salinity anomaly



References

Bernie, D., E. Guilyardi, G. Madec, J. Slingo, and S. Woolnough. 2007. "Impact of resolving the diurnal cycle in an ocean-atmosphere GCM. Part 1: A diurnally forced OGCM." Clim. Dyn., 29(6), 575–590, doi:10.1007/s00382-007-0249-6.

Burchard, Hans, and Karsten Bolding. 2001. "Comparative Analysis of Four Second-Moment Turbulence Closure Models for the Oceanic Mixed Layer." Journal of Physical Oceanography 31 (8): 1943–68. doi: 10.1175/1520-0485(2001)031<1943:CAOFSM>2.0.CO;2.

Cronin, M. F., and M. J. McPhaden.1999. "Diurnal cycle of rainfall and surface salinity in the western Pacific warm pool." Geophys. Res. Lett., 26(23), 3465–3468.

Fairall, C. W., E. F. Bradley, D. P. Rogers, J. B. Edson, and G. S. Young. 1996. "Bulk Parameterization of Air-Sea Fluxes for Tropical Ocean-Global Atmosphere Coupled-Ocean Atmosphere Response Experiment." Journal of Geophysical Research: Oceans 101 (C2): 3747–64. doi:10.1029/95JC03205.

Jeffery, C. D., I. S. Robinson, D. K. Woolf, and C. J. Donlon. 2008. "The Response to Phase-Dependent Wind Stress and Cloud Fraction of the Diurnal Cycle of SST and Air–sea CO2 Exchange." Ocean Modelling 23 (1–2): 33–48. doi:10.1016/j.ocemod. 2008.03.003.

Pimentel, S., K. Haines, and N. K. Nichols. 2008. "Modeling the Diurnal Variability of Sea Surface Temperatures." Journal of Geophysical Research: Oceans 113 (C11): C11004. doi:10.1029/2007JC004607.