The Diurnal Cycle of Salinity

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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

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Daytime freshening  
(min S at 3pm)  

Nighttime salinity increase  
(max S at 8am)
Diurnal salinity at all TAO moorings:

Diurnal salinity amplitude (psu)
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 \(\approx\)

\[-\int \frac{P}{h_p} \bar{S} dt \quad + \int \frac{E}{h_E} \bar{S} dt \quad - \int u_1 \nabla S_1 dt \quad - \frac{dh \Delta S}{h}\]

assume \(h_p \sim 3m\)  
assume \(h_E \sim 1m\)  
negligible  
\(h = \) mixed-layer depth
Total ∆S: ±0.006 psu

Estimated contributions:
- Precipitation: −0.004 psu
- Evaporation: +0.001 psu
- Entrainment: +0.003 psu
Precipitation & entrainment consistently dominate diurnal salinity

Diurnal salinity amplitude (psu)

Observed ∆S, psu

Precipitation contribution, psu

Evaporation contribution, psu

Entrainment contribution, psu
Where diurnal salinity is expected to be strong:

Diurnal rain rate amplitude (TRMM 3-hrly data)

Climatological "stratification strength" (\(\Delta S/h\)) from the MIMOC product, an Argo-based climatology

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 $k$-$\varepsilon$ 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
(R²=0.89 over 8-month run)

Fresh events captured
(R²=0.77 over 8-month run)
Lens formation under rain with GOTM
Idealised rain (Gaussian pulse) + wind (sinusoid)

- Wind speed: 4±1 m/s
- Rain rate: peak 5 mm/hr
- Salinity anomaly relative to no-rain case

Salinity anomaly at z=1 m
Varying the strength of **rain**

**Weaker rain (2 mm/hr)**

Rain rate affects:
- Strength of salinity anomaly
- Lens thickness ($h_p$)

**Stronger rain (10 mm/hr)**
Varying the strength of wind

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


