Near-surface SST and SSS variability: modeling and observations

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Global Modeling and Assimilation Office
GSFC, NASA

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Outline

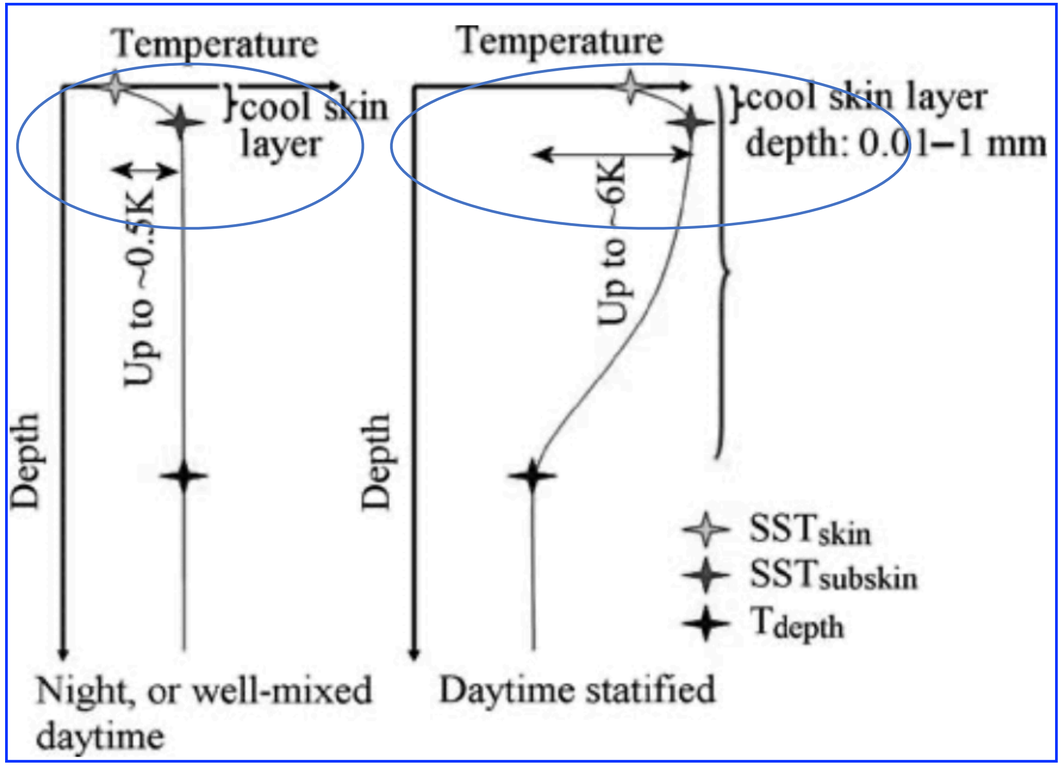
- Variability of SST, SSS: from SPURS-1 and -2 Moorings
  - In the top 10 m
  - Impact of time averaging
- Modeling approaches:
  - High vertical resolution
  - A hybrid approach:

    resolution + parameterization
- Summary

Observations

Models

Satellites do not directly measure SST or SSS!

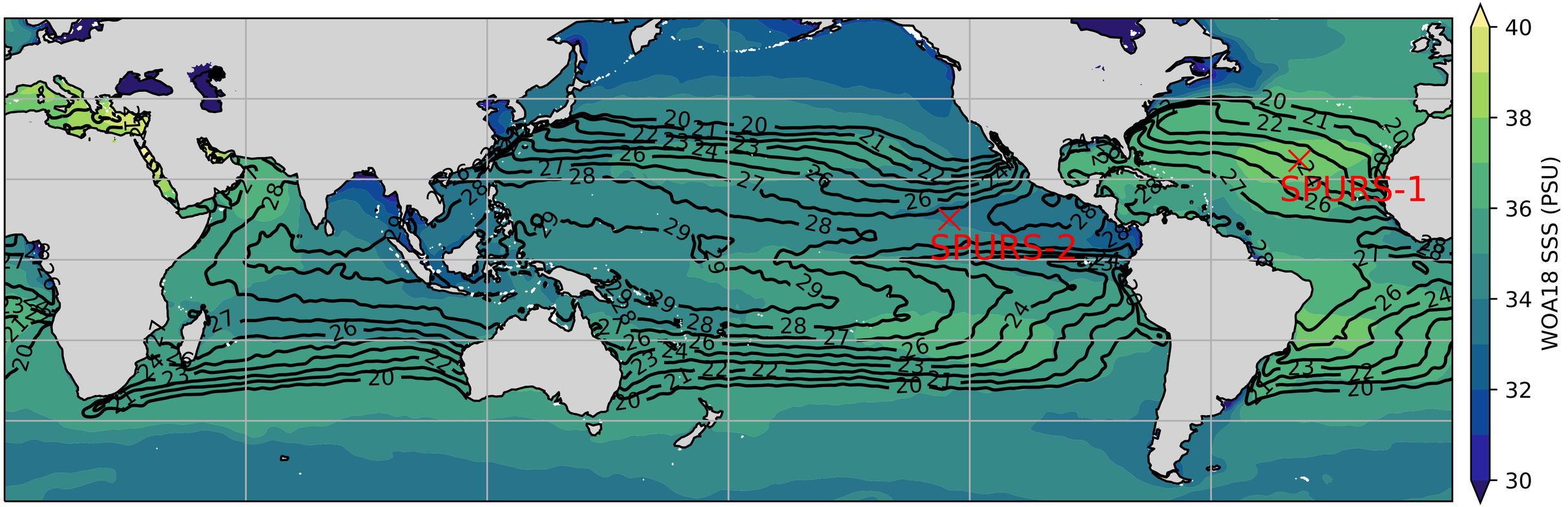


Oceanography From Space, Chap 14. by Minnett, P. J.

They measure brightness temperature: highly sensitive to ***upper*** ocean variables

Observations

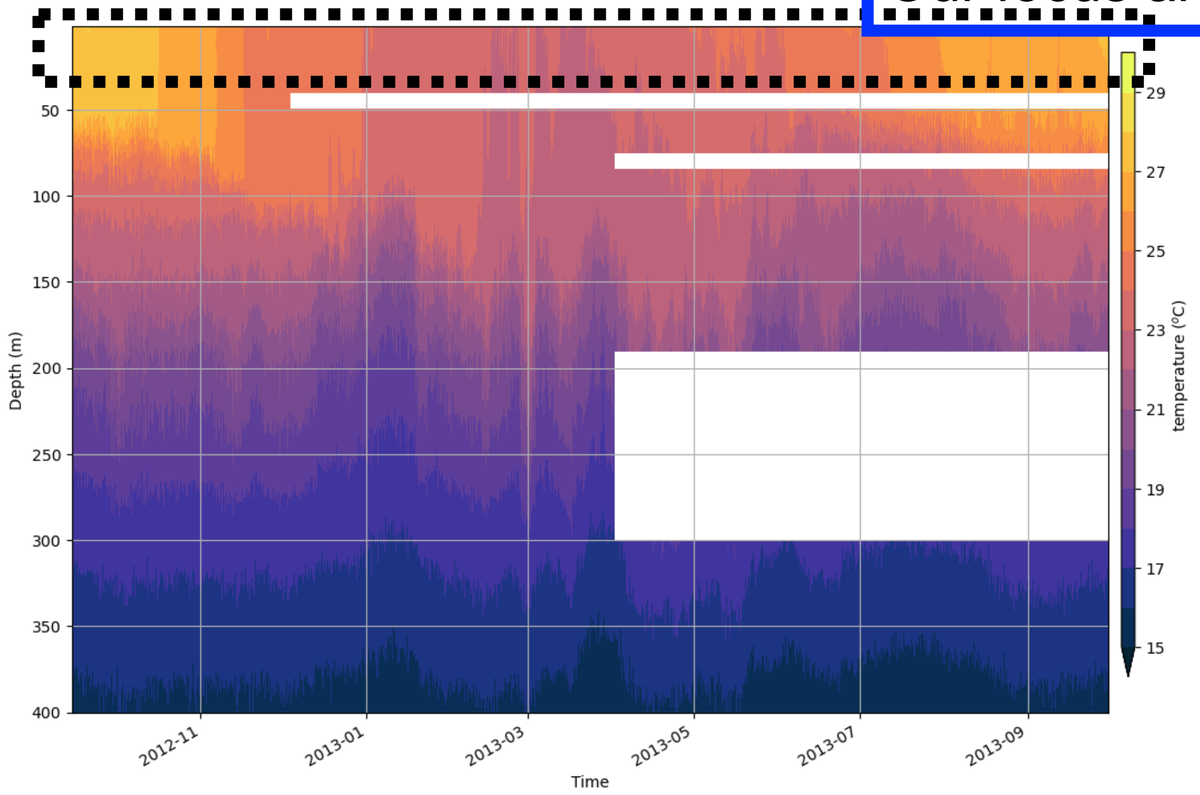
SPURS-1 and -2 Moorings



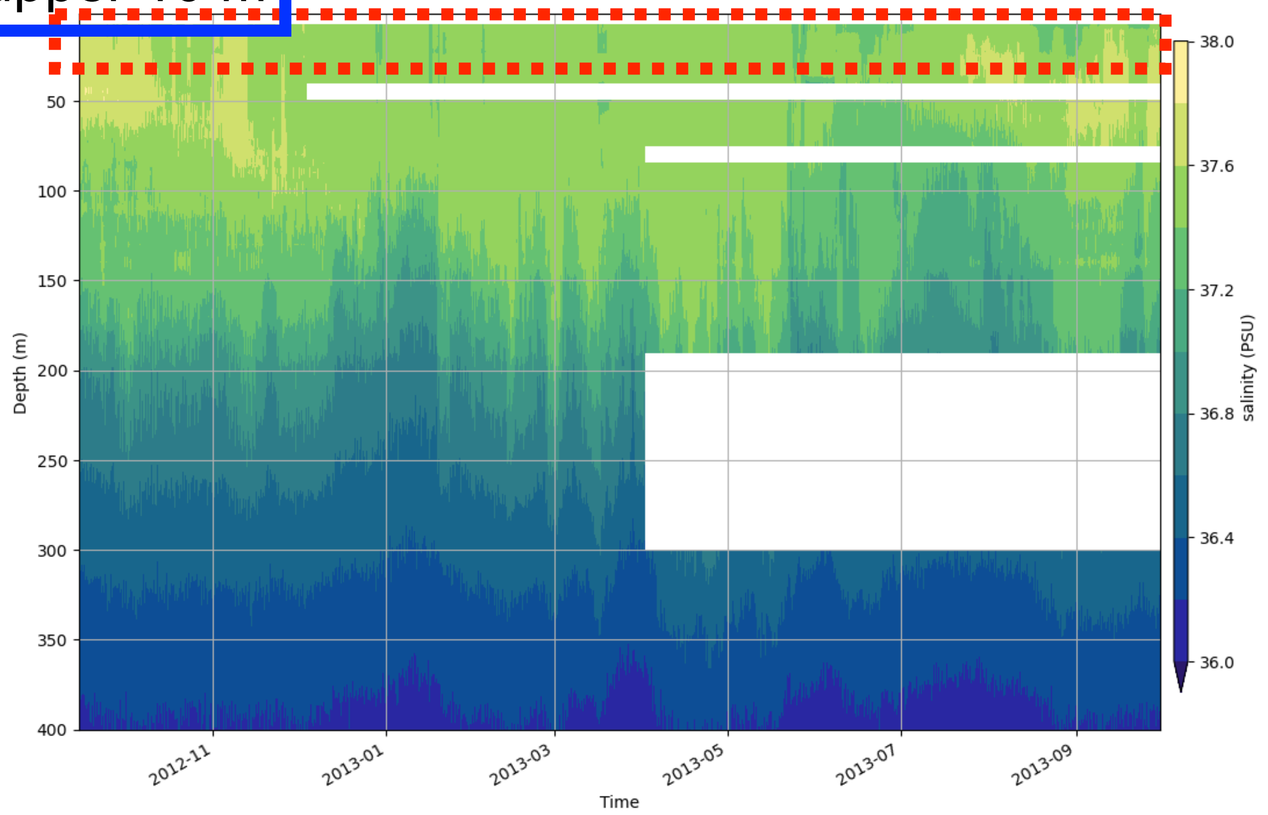
Campaign	Dates	Sampling rate	Number of sensors < 10m	z within 10m
SPURS-1	Sep, 2012- Mar, 2013	300 sec	7	1.3, 2.1, 3., 4.4, 5.2, 6.5, 8 m
SPURS-2	Aug, 2016- Nov, 2017	300 sec	4	1., 2.1, 5.2, 8.5 m

Variability of T and S: SPURS-1 Mooring

Our focus area: upper 10 m



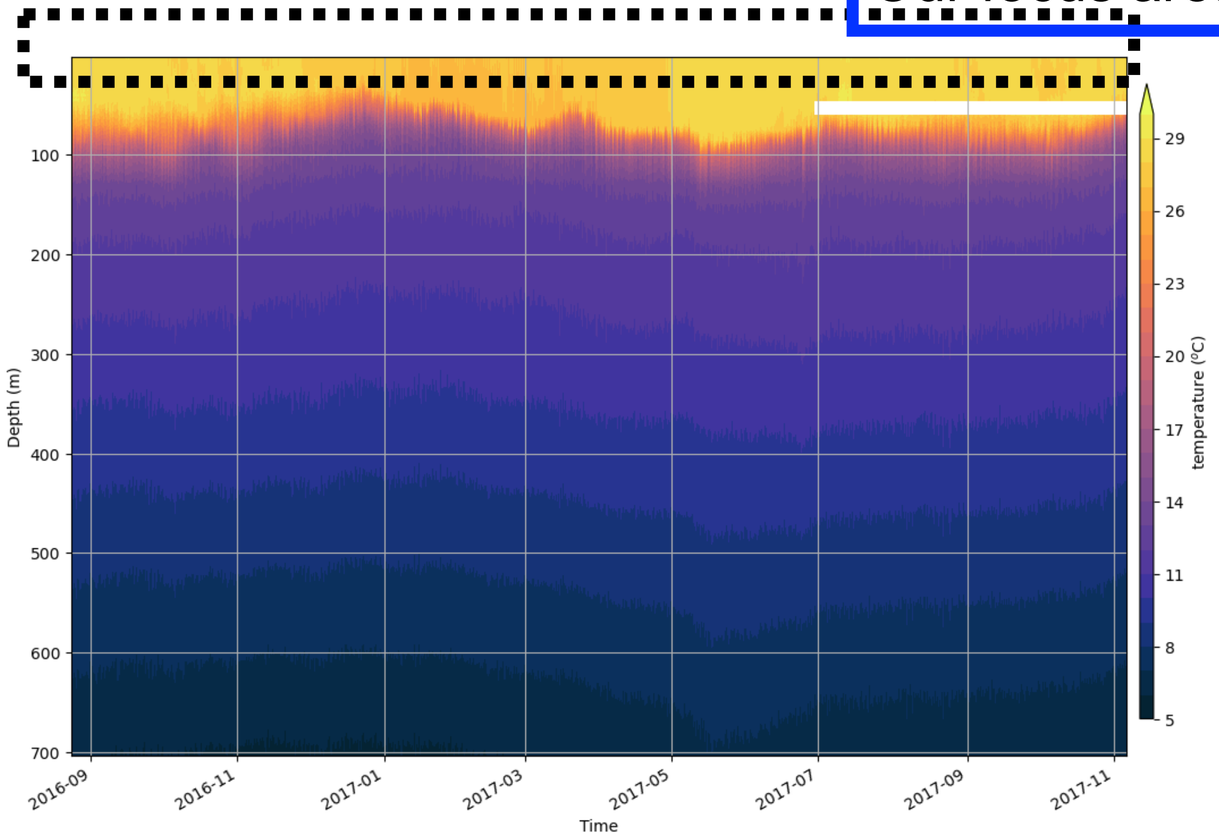
Temperature



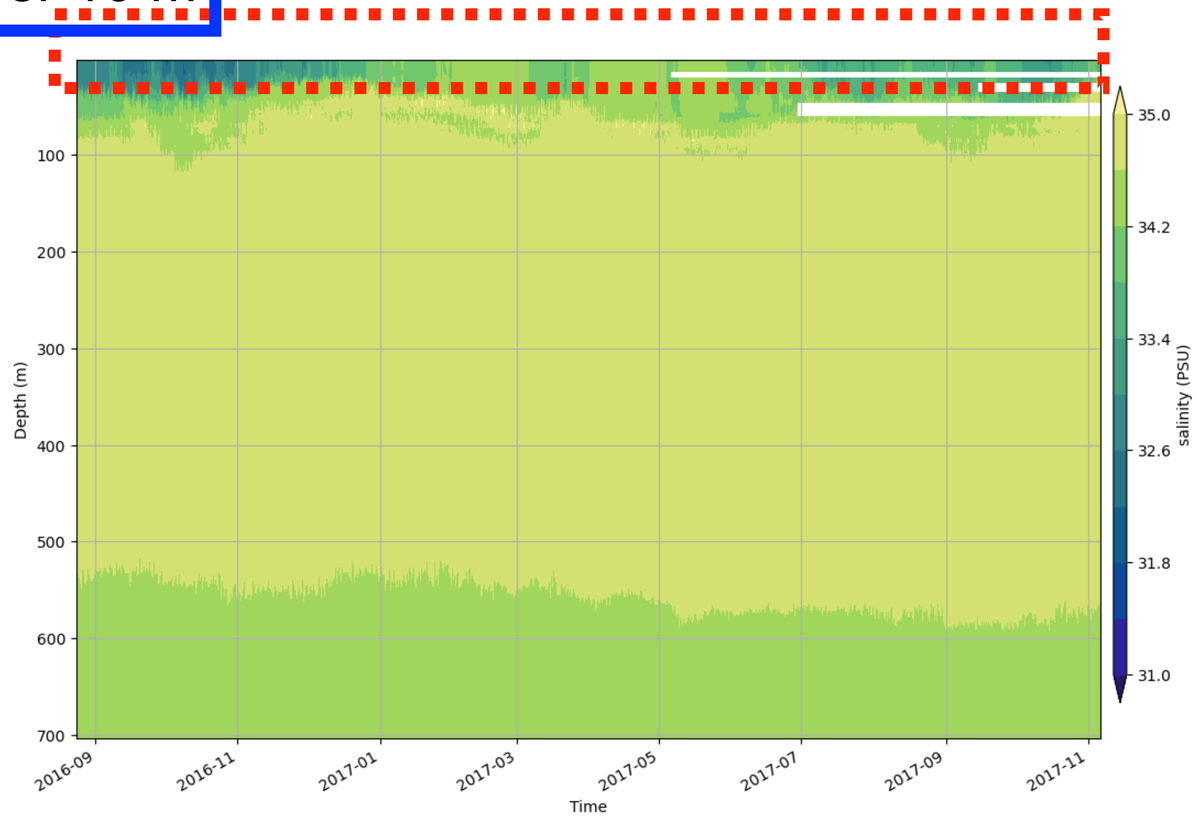
Salinity

Variability of T and S: SPURS-2 Mooring

Our focus area: upper 10 m



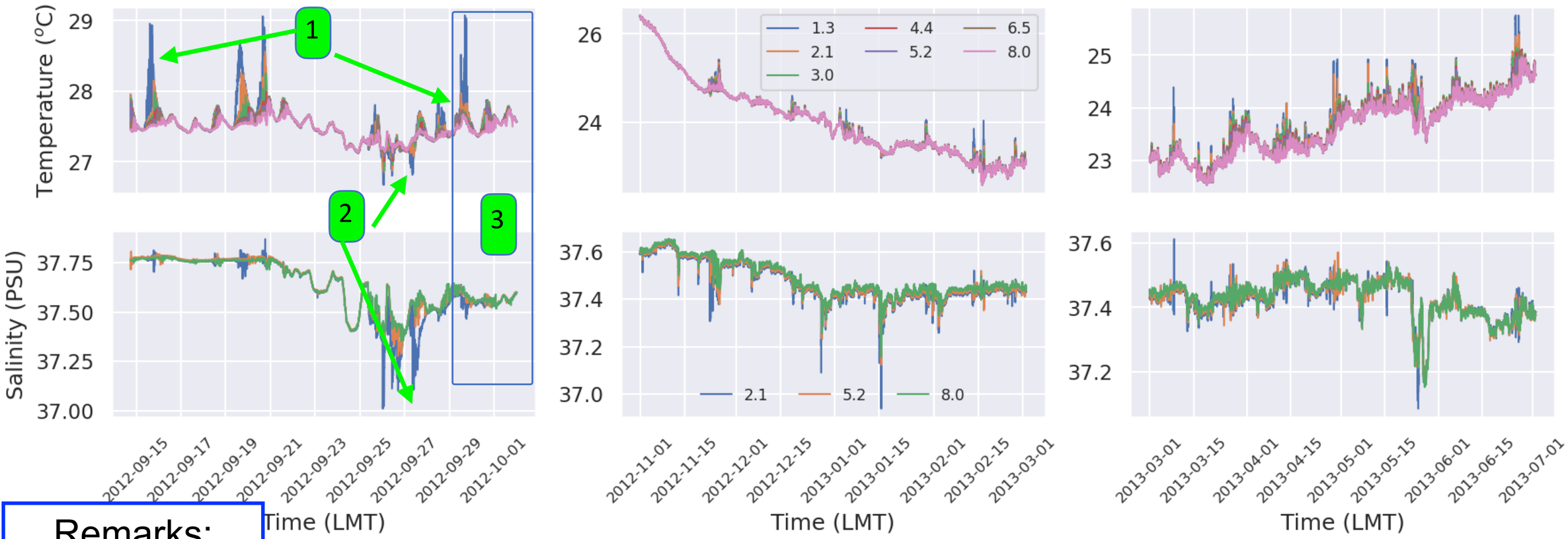
Temperature



Salinity

Variability in top 10 m

SPURS-1

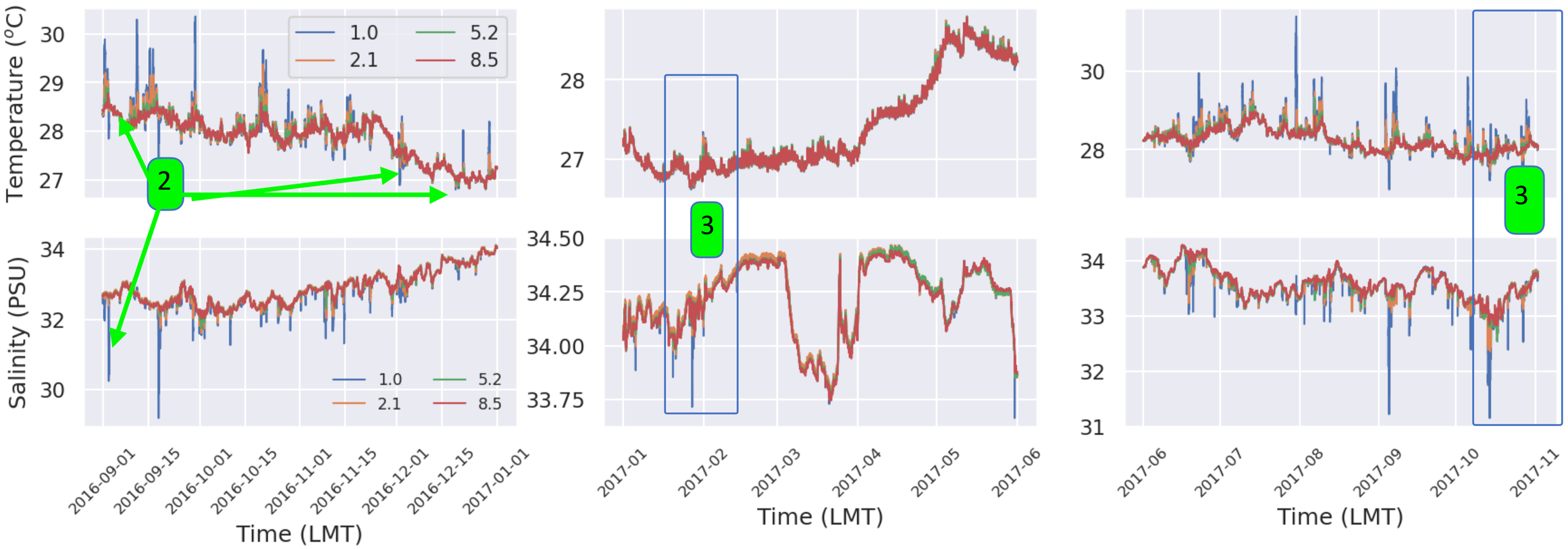


Remarks:

1. **Diurnal cycles in SST**: T(z=1.3 m) > T (8 m)
2. **Rain induced drop in SST, SSS**: T(z=1.3 m) < T (8 m), S(z=1.3 m) < S (8 m)
3. **Stronger diurnal SST cycles follow rain events** (fresh lens)**, if wind stress is weak**

Variability in top 10 m

SPURS-2



Remarks:

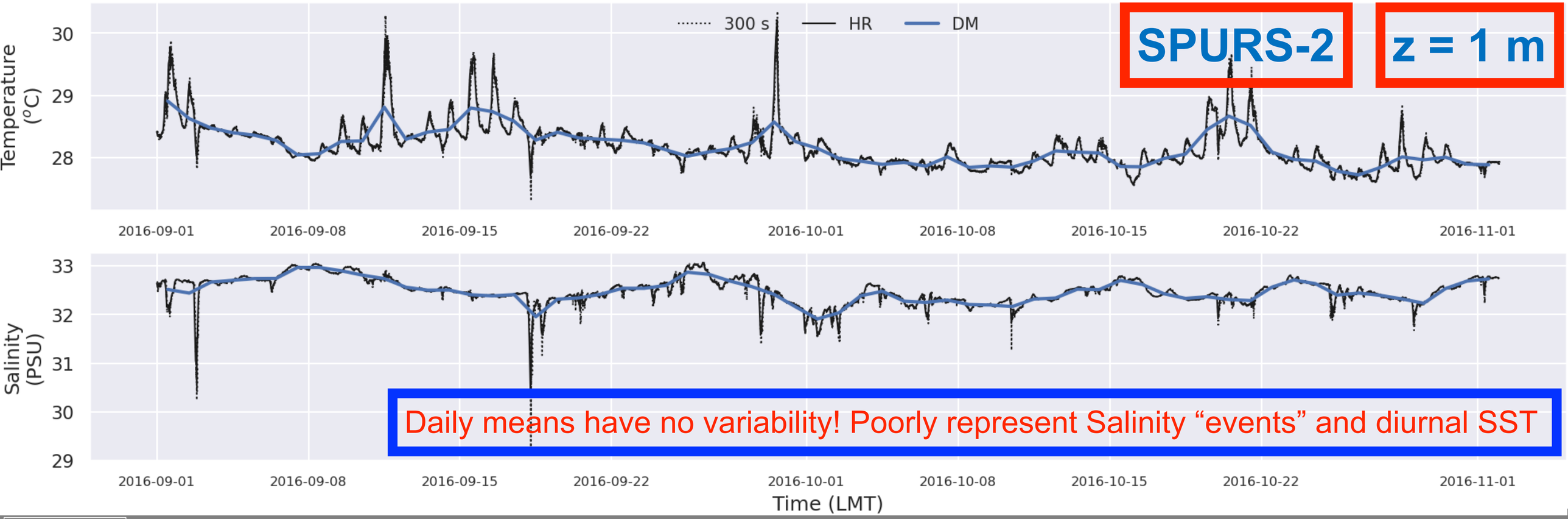
1. Diurnal cycles in SST: insolation and wind-stress. Time-scale: about 6- 10 hours.
2. Rain induced drop in SST, SSS: T drops to compensate for dip in S (needed for static stability). Time-scale: about 1- 3 hours, varies with duration/intensity of *event.* Intense dSST events follow…

Impact of time averaging (1)

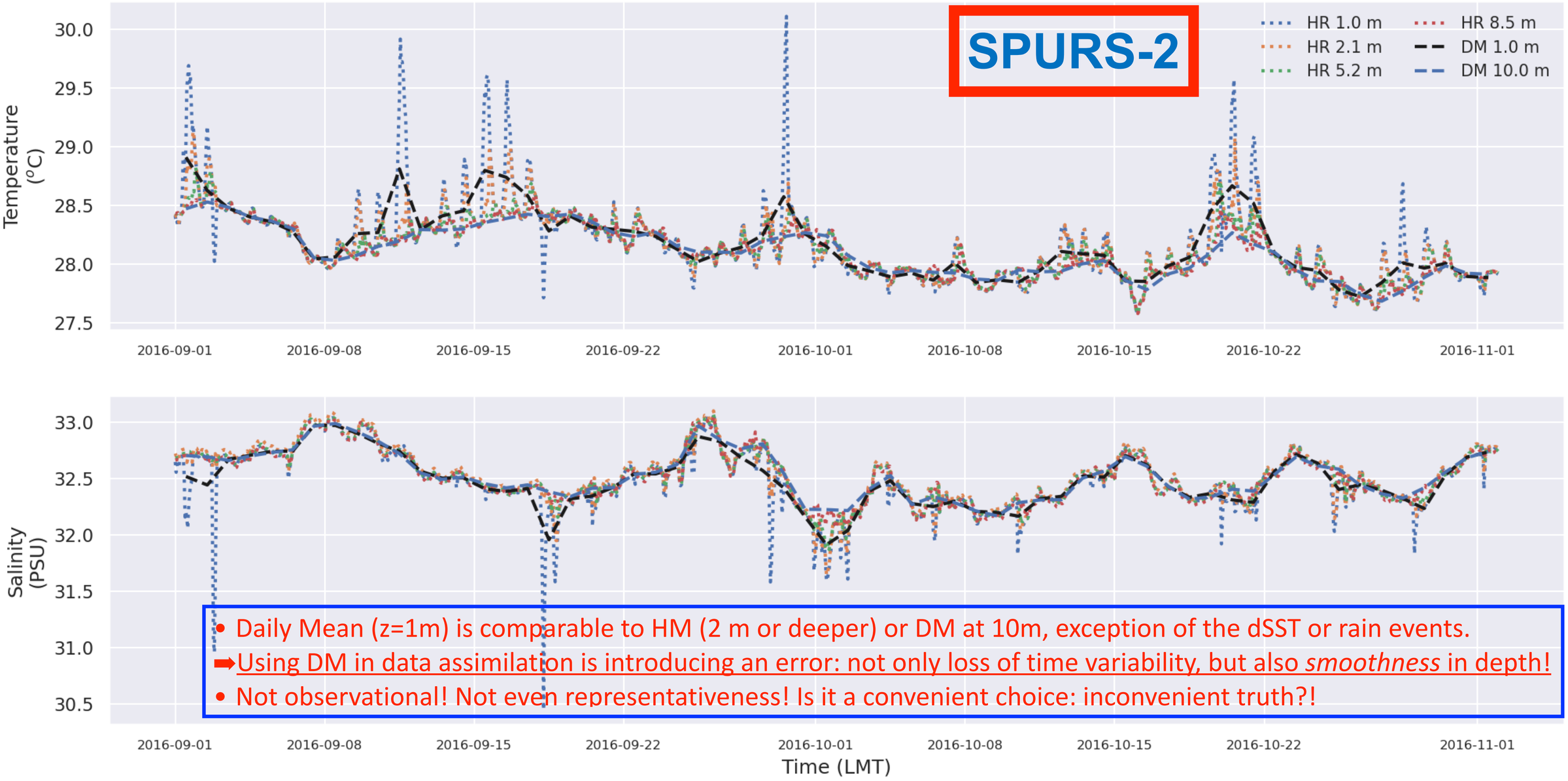
We saw variability:

- In time (e.g., hourly).
- In depth.

- What happens when we take daily averages?
- Most ocean assimilations systems assimilate daily average T,S profiles (e.g., EN4).
- Tropical moorings (now) report hourly T, S (z=1 m)



Impact of time averaging (2)



- Daily Mean (z=1m) is comparable to HM (2 m or deeper) or DM at 10m, exception of the dSST or rain events.

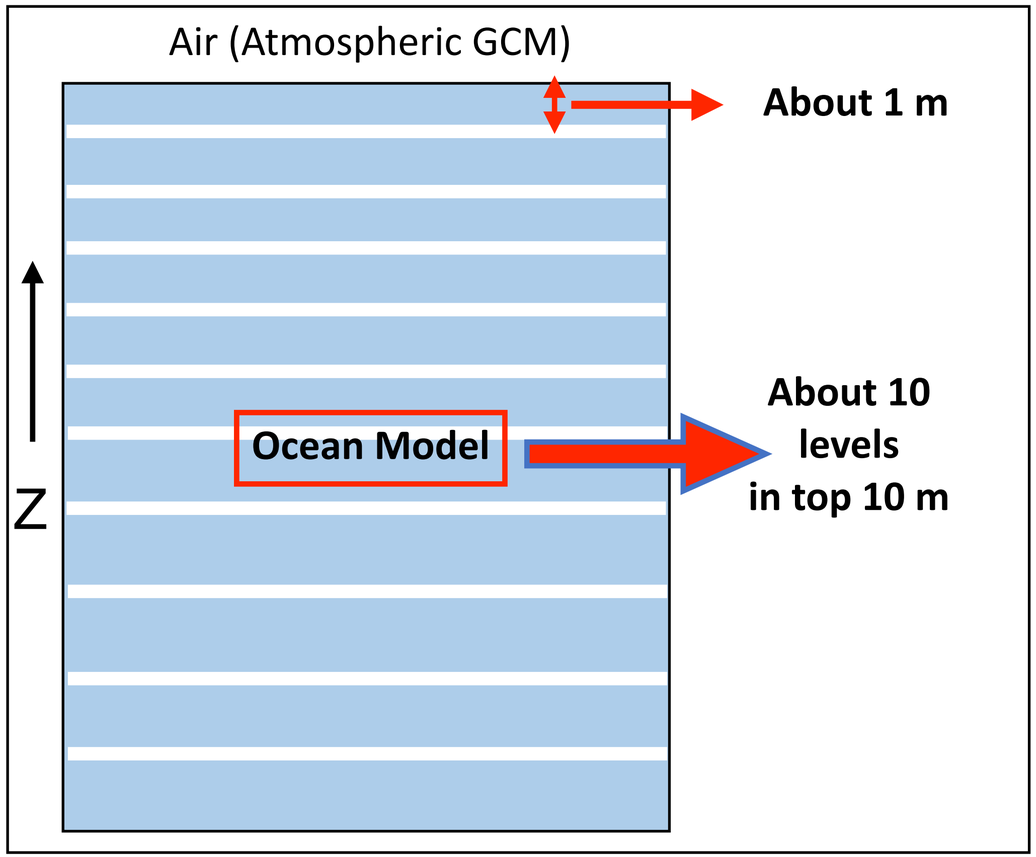
➡Using DM in data assimilation is introducing an error: not only loss of time variability, but also *smoothness* in depth!

- Not observational! Not even representativeness! Is it a convenient choice: inconvenient truth?!

Modeling

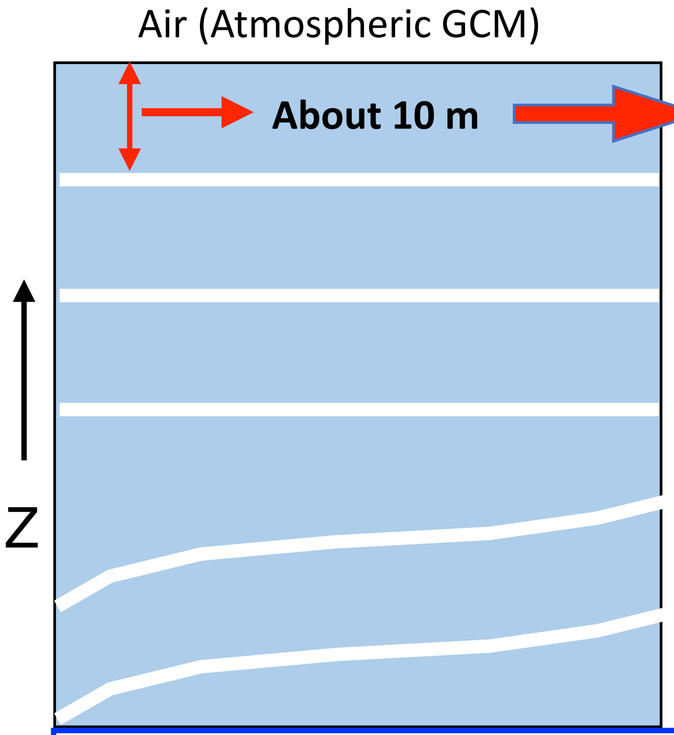
Modeling approaches

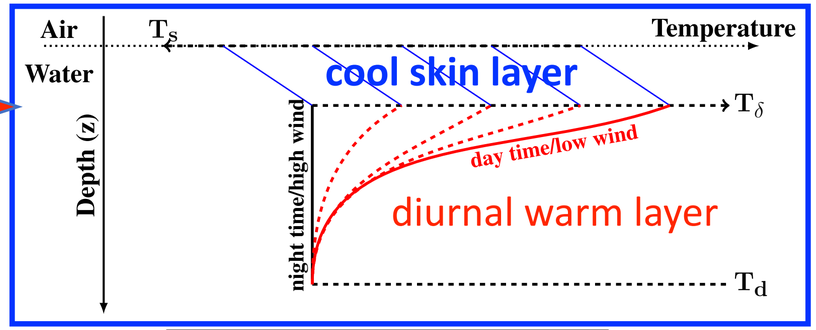
Ocean Model: *High* vertical resolution



Computationally Expensive
In coupled Model/DA

A *hybrid* approach





Parameterize variability of T, S

- *Carefully* chosen vertical levels/layers (Hybrid Coordinates)
- Parameterized SST(z), SSS(z) for direct radiance assimilation from satellites:
  - ✓up to mm (Microwave)
  - ✓micro-meters (Infrared)

Strongly coupled DA

High Vertical Resolution

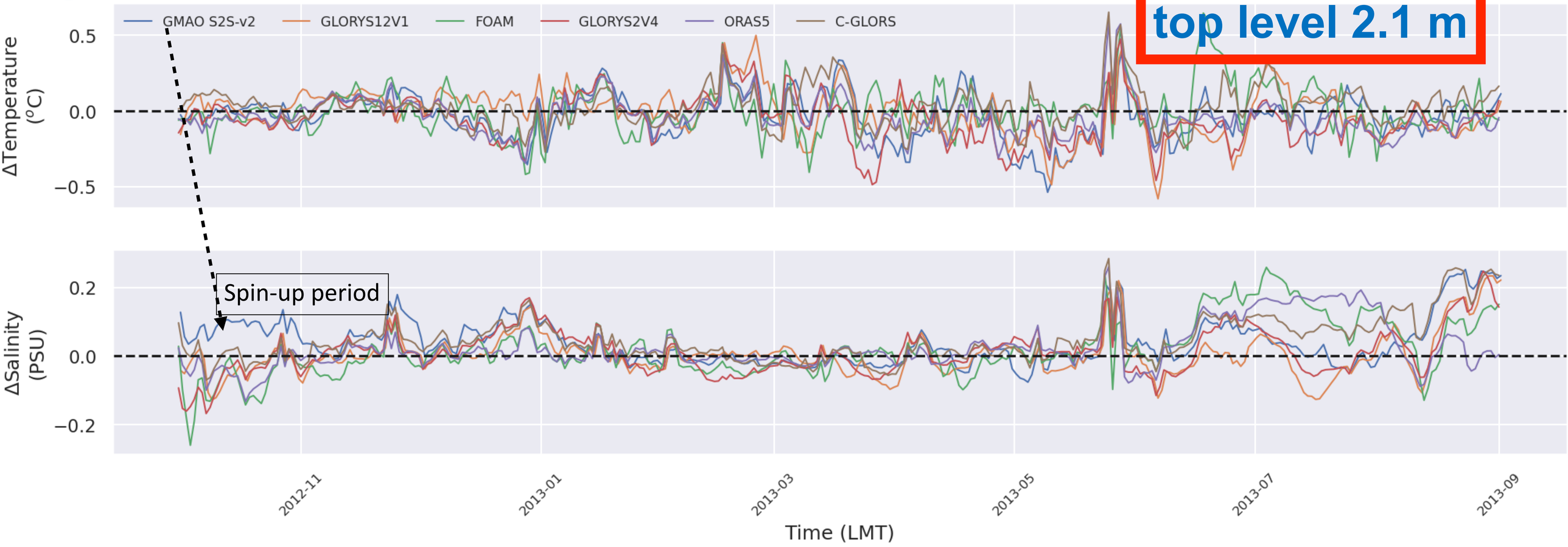
Inter-comparison of following products:

- All assimilate daily mean (DM) T, S profiles (EN3, EN4, WOD, etc).
- Except GMAO S2S-v2, all others have been downloaded from CMEMS.
- Compare DM [obs - product], because DM are the only ones available (to download)!
- DM obs *top* level T, S is compared with SST, SSS from product (s).

System	Model	Number of vertical levels	Horizontal resolution	Availability
GMAO S2S-v2	GEOS coupled model	40	1/2^o	
GLORS12V1	NEMO v3.1; ERA-I, ERA5 atm	50	1/12^o	
FOAM/GloSea5	NEMO v3.4; ERA-I atm	75 (1 m top)	1/4^o	
GLORYS2V4	NEMO v3.1; ERA-I atm	75 (1 m top)	1/4^o	
ORAS5	NEMO v3.4.1; ERA-I atm	75 (1 m top)	1/4^o	
C-GLORS	NEMO v3.4; ERA-I atm	75 (1 m top)	1/4^o	
GLO-CPL ORCA025	NEMO v3.4, UM v10.6 (weakly) coupled DA	75 (1 m top)	1/4^o	SPURS-2 only

High Vertical Resolution

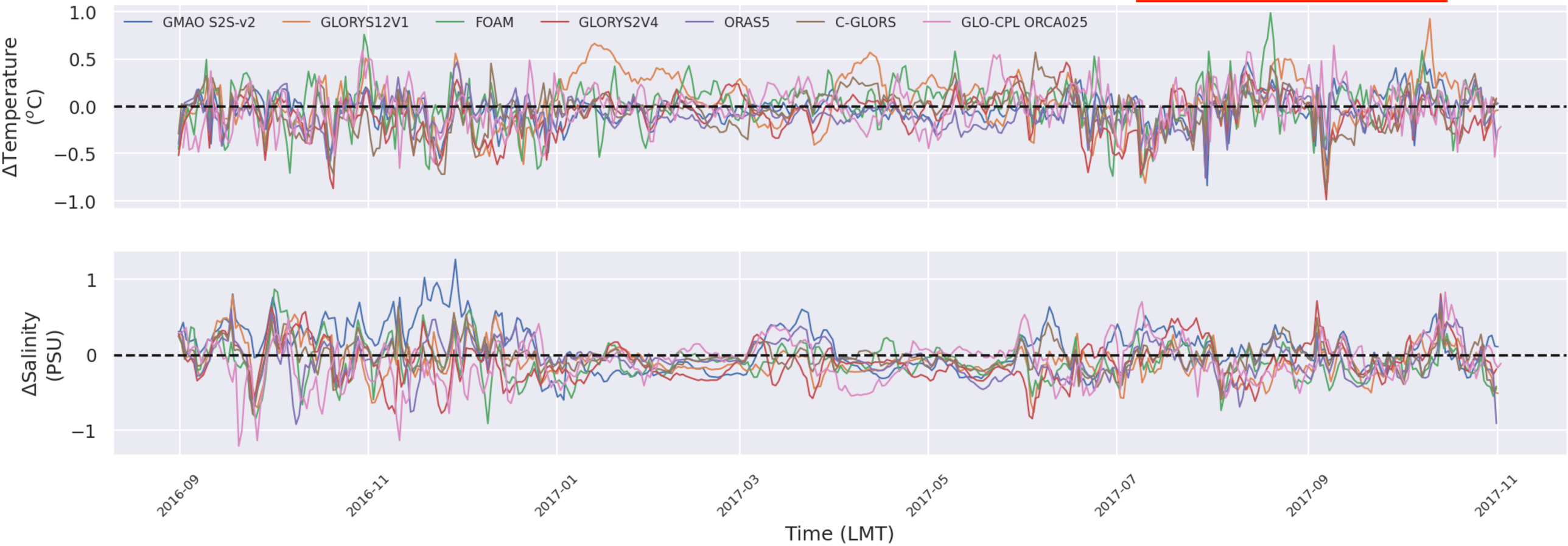
SPURS-1
top level 2.1 m



- Similar performance for all systems
- Recall: HR and DM (2.1 m) differ mostly for dSST (< +/ 0.5°C) and rain events (< +/- 0.5PSU).

High Vertical Resolution

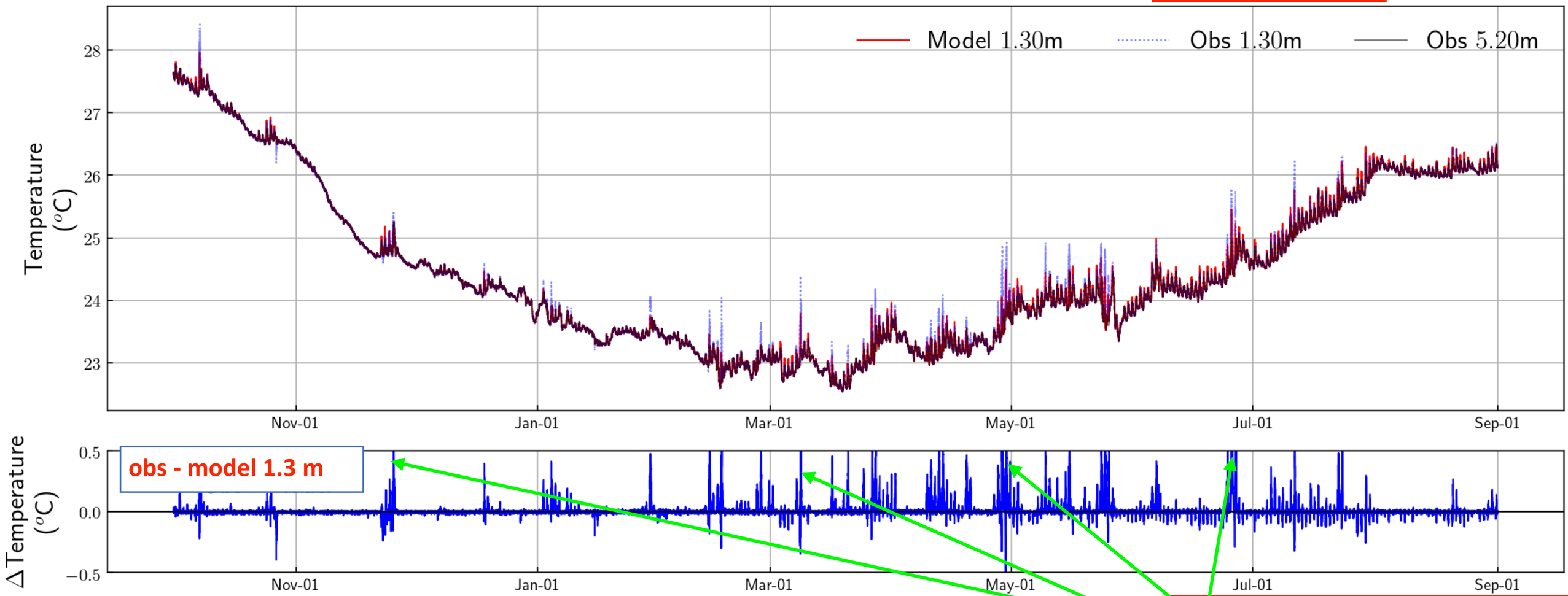
SPURS-2 top level 1 m



- More variability than SPURS-1, also **larger** differences from observed DM.
- Clearly model (resolution), assimilation, coupled DA, all have room for improvement.

Hybrid Approach: resolution + parameterization

SPURS-1



Magnitude of dSST (model) < observed

- Needs Tuning
- Computationally trivial!

Summary:

- Upper ocean is very dynamic - variability on time-scales of few hours:
  - Temperature: Frequent diurnal cycles (solar, wind).
  - Salinity: Fresh lenses after rain.
  - Co-variability of T and S.
  - Daily Means do not capture this variability. Assimilating DM observations for upper (10 m) ocean can lead to *incorrect or inconsistent* constraints: alias modeled 1 m variability to deeper T, S.
  - Hourly Mean observations of T, S are available (tropical moorings).
- **Models can resolve** upper ocean variability:
  - Sufficient number of vertical levels (or layer) - computationally expensive.
  - Hybrid approach of carefully chosen vertical grid and parameterization - needs tuning.
- These issues are **relevant** to:
  - Coupled Prediction and Data Assimilation Task Teams.
  - Coupled DA and seasonal predictions.

Acknowledgments

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- Woods Hole Oceanographic Institute (**WHOI**)
- Copernicus Marine Environment Monitoring Services (**CMEMS**)

Thanks for your attention!

Extra Slides

RIM SALINITY ANOM @ 10 m

