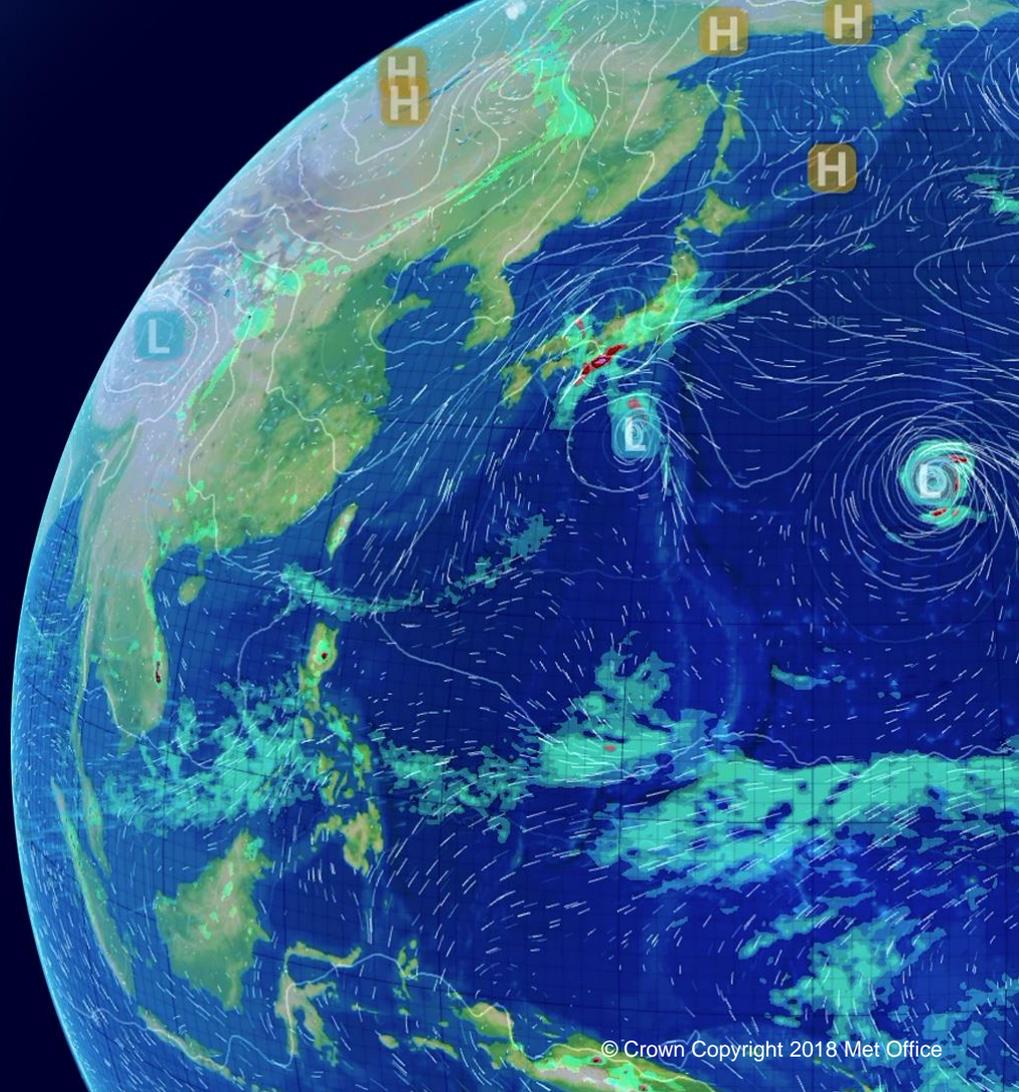


# Updates to the coupled ocean- atmosphere forecasting system at the Met Office

Jonah Roberts-Jones, Chris Harris,  
Catherine Guiavarch



# Outline

- Introduction of coupled O-A forecasting system
- Assessment of coupled system via comparison to FOAM ocean-only system
- Use of SLSTR SST in coupled forecasting system
- Next coupled forecasting system and initial results
- Future work

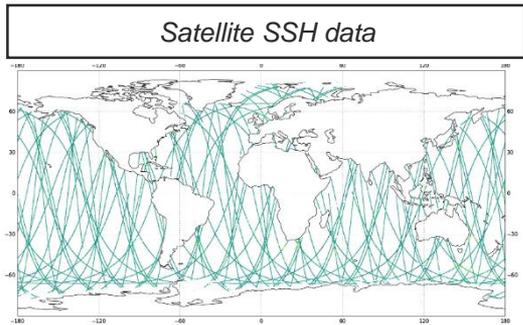
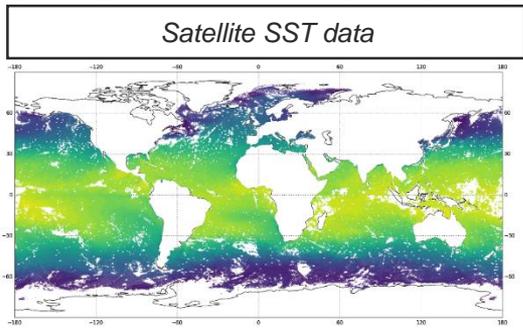
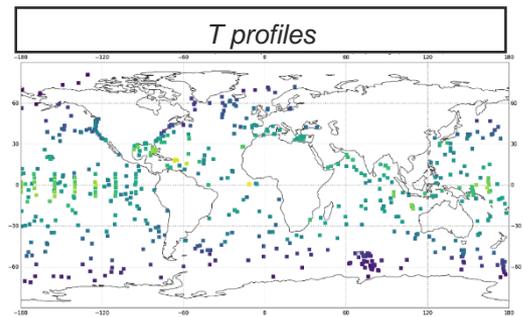
# Coupled O-A forecasting system

# Coupled O-A forecasting system

- Atmospheric-Ocean coupled system with ‘weakly coupled’ data assimilation (CPLDA) has been running operationally since late summer 2016 and delivers products to CMEMS (<http://marine.copernicus.eu>).
- Runs at atmospheric resolution of ~40km (n320), ocean resolution of ~30km (orca025).
- CPLDA uses sub-daily 6 hourly cycling; generates TM24 “best-estimate” analyses at 06Z, 12Z, 18Z and 00Z.
- Atmosphere and ocean 10 day forecasts are generated once daily in the 00Z cycle
- The 00Z cycle also includes a series of catch up cycles to get late observations (TM18, TM12, TM06 and TM00).
- Coupling frequency is hourly.

# Weakly coupled DA

- Background fields come from the coupled model
- Separate analyses are carried out in each of the atmosphere and ocean components
  - Ocean DA: NEMOVAR 3D-VAR with FGAT
  - Atmosphere DA: incremental 4DVAR with VarBC
- Same ocean observations assimilated as used in FOAM ocean-only system (T & S profiles, satellite and in-situ SST, satellite altimeter SSH and satellite sea ice conc)
- The assimilation increments are added back into the coupled model using IAU for ocean, direct initialisation for atmosphere
- Assimilation time window for both component is set to be 6 hours (which matches that used in the Atmospheric NWP model)

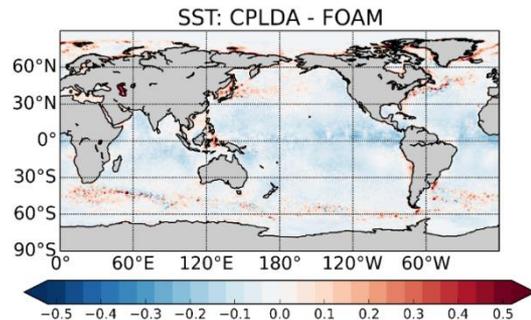


# Assessment of coupled O-A forecasting system

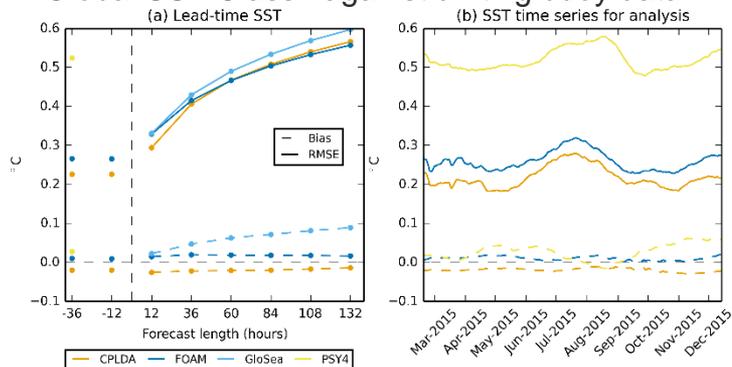
# Comparison of CPLDA with FOAM (SST)

- Description of system and results in Guiavarc'h et al (2018) in Ocean Science discussion <https://www.ocean-sci-discuss.net/os-2018-170/> (currently pre-print)
- CPLDA system has been assessed by comparing with ocean-only FOAM (and Mercator 1/12° PSY4) for 2015
- CPLDA colder than FOAM outside of the boundary currents.
- Validation using Class4 against drifting buoys shows improved CPLDA SST RMSE relative to FOAM. Overfitting?
- Lots more results in paper.

Global annual mean SST differences



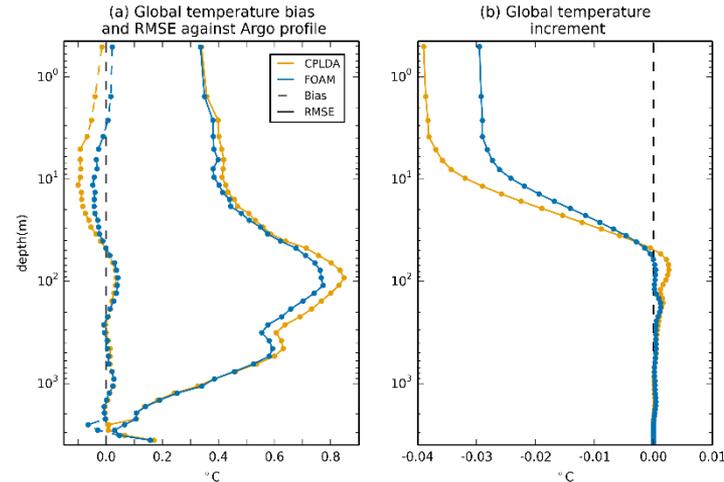
Global SST Class4 against drifting buoy data



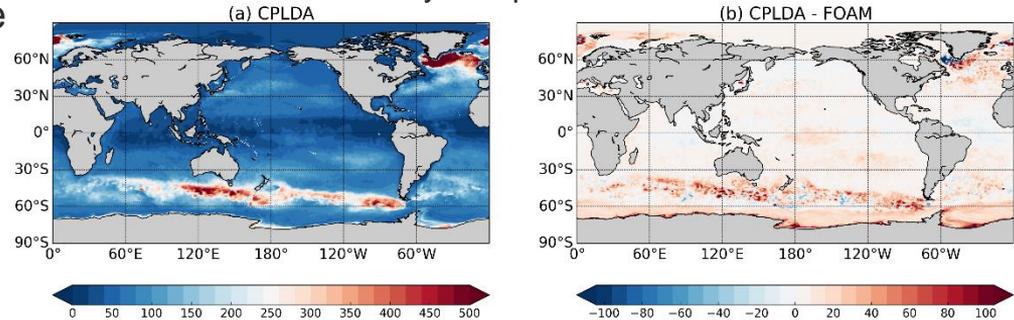
# T profile validation

- Increased sub-surface cold bias and over deep MLD in CPLDA c.f. FOAM.
- Partly explained by vertical propagation of surface T increments.
- Over time, noise in the increments causes a deepening of the MLD.
- A negative surface increment weakens the stratification and deepens the MLD then the subsequent positive surface increment is projected deeper (King et al., 2018).
- Shorter assimilation window in CPLDA => noisier increments than FOAM => cold sub-surface bias in CPLDA.

## Class 4 T profile stats and average increments



## Annual mean Kara mixed layer depth in m



# Use of SLSTR SST in coupled O-A forecasting system

# Use of SLSTR SST in CPLDA

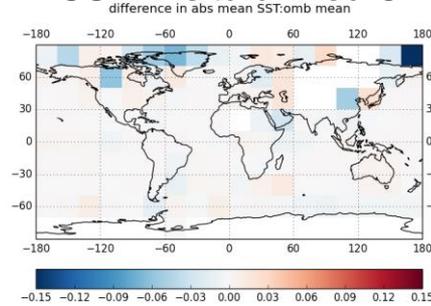
- Trials undertaken to make best use of Sentinel-3 SLSTR SST data in the coupled system.
- Can we use SLSTR data as reference against which to bias correct other satellite SST data sources?
- SNPP-VIIRS data was also trialled as possible reference data source, following it's use in OSTIA system.
- Satellite SST data bias corrected by;
  - Calculating match-ups between satellite and reference data set
  - Persistence based analysis of match-ups to generate estimated bias field
  - Biases removed from sat SST observations prior to assimilation
- Bias correction method has since been updated in new FOAM system.

# SLSTR and SST BC reference options

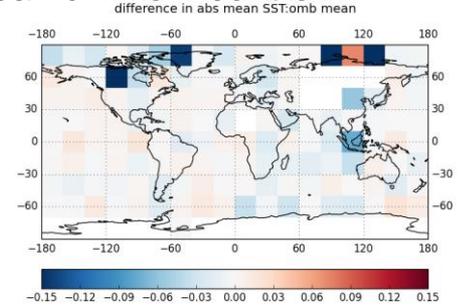
- Differences shown from control in which SLSTR data is not assimilated and in-situ data only used as reference
- Validated against in-situ data show positive result using SLSTR as reference across most regions.
- Using VIIRS as reference validates poorly particularly in Southern Hemisphere.

Experiment	Info
Asm-SLSTR	assimilates SLSTR, reference of in-situ only
Ref-SLSTR	assimilates SLSTR, reference of SLSTR and in-situ
Ref-VIIRS	assimilates SLSTR, reference of VIIRS and in-situ
Ref-SLSTR&VIIRS	assimilates SLSTR, reference of SLSTR, VIIRS and in-situ

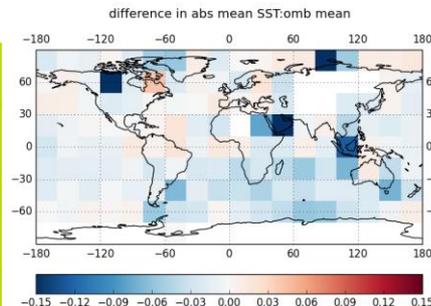
SST in-situ binned O-B mean diff from control



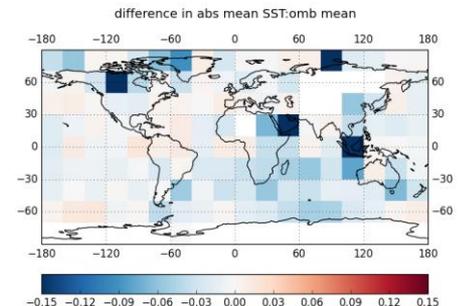
Asm-SLSTR



Ref-SLSTR



Ref-VIIRS

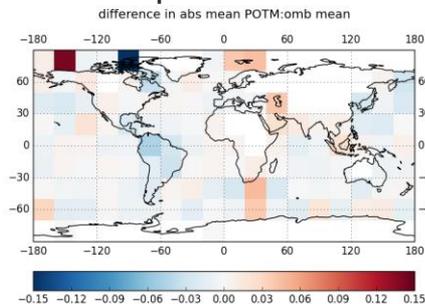


Ref-SLSTR&VIIRS

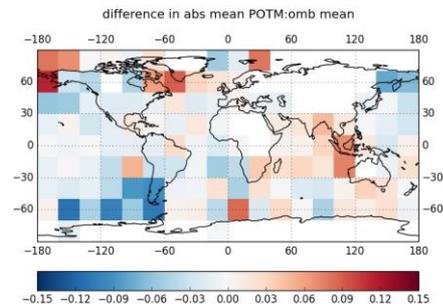
# SLSTR and SST BC reference options

- Differences shown from control in which SLSTR data is not assimilated and in-situ data only used as reference
- Results from top-level Argo validation (<10m) show a more confused picture
- Ref-SLSTR runs perform poorly in the Southern regions, SLSTR match-ups are attributing a large bias to the satellites in these regions.

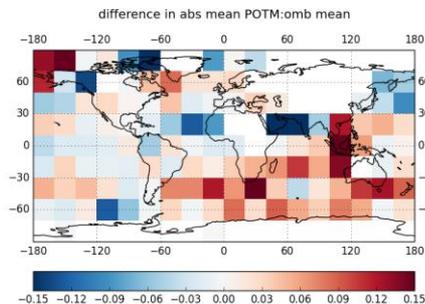
<10m prof binned O-B mean diff from control



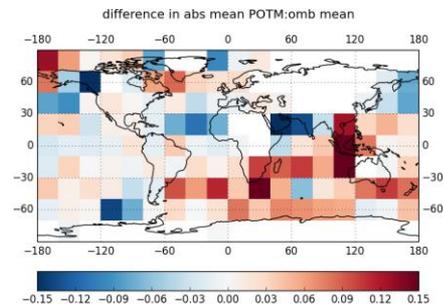
Asm-SLSTR



Ref-SLSTR



Ref-VIIRS

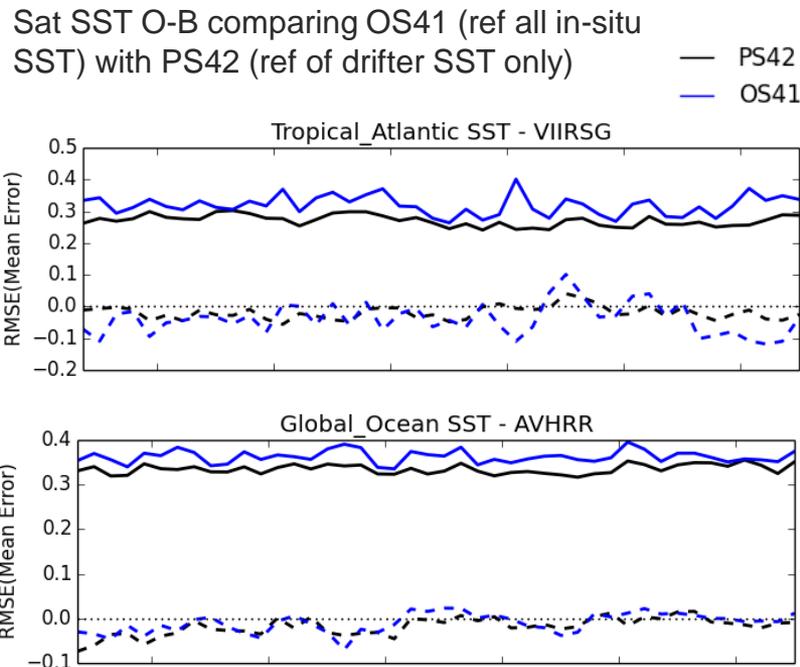


Ref-SLSTR&VIIRS

Experiment	Info
Asm-SLSTR	assimilates SLSTR, reference of in-situ only
Ref-SLSTR	assimilates SLSTR, reference of SLSTR and in-situ
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Ref-SLSTR&VIIRS	assimilates SLSTR, reference of SLSTR, VIIRS and in-situ

# SLSTR implementation

- The poor performance of SLSTR in the Southern regions relative to top-level Argo mean that operational implementation was to keep in-situ only as reference and assimilate and bias correct the SLSTR data.
- Further update to use drifting buoy data only in SST bias correction reference dataset (previously all in-situ), makes the SST analysis more consistent with the satellite obs.
- This removes large temporally noisy bulls-eyes in the bias fields caused by erroneous reference obs.



# Next generation coupled system

# Next O-A coupled forecast system

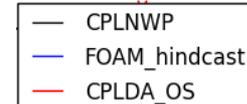
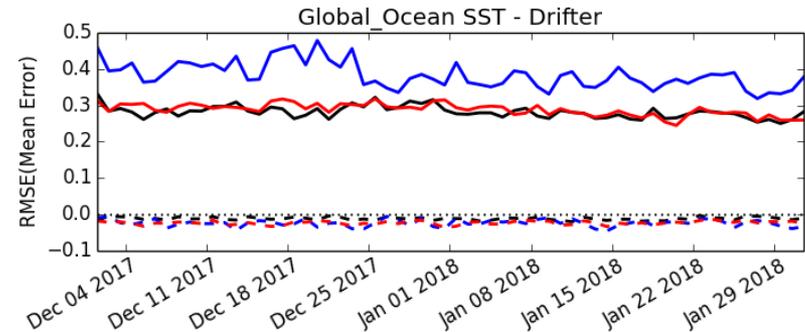
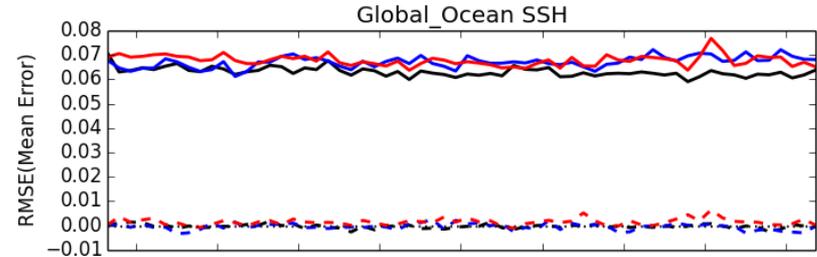
Developing new 'coupled NWP' system to replace current NWP system in 2020/2021

- Atmosphere changes include
  - higher resolution atmosphere (40km (n320) to 10 km (n1280))
  - coupled ensemble (at 20km) for hybrid En4DEnVar DA
- Ocean changes will include an upgrade to the ocean component to FOAM v14 equivalent
  - New scientific configuration ('GO6' on the extended ORCA025 grid)
  - Improved variational bias correction scheme for SSTs
  - Update of the MDT (from CNES-CLS09 to CNES-CLS13)

# Initial results

- Initial results for ~2 months.
- Assessment of new coupled system (CPLNWP) via comparison to ocean-only FOAM V14 hindcast (FOAM\_hindcast) and current operational CPLDA system (CPLDA\_OS) using assimilated observations.
- SSH results show reduced RMSE compared to current systems.
- Drifting buoy SST results show comparable RMSE to current CPLDA system (<FOAM). Cold bias relative to drifters is reduced, impact of drifters only as reference and possibly new bias correction method.

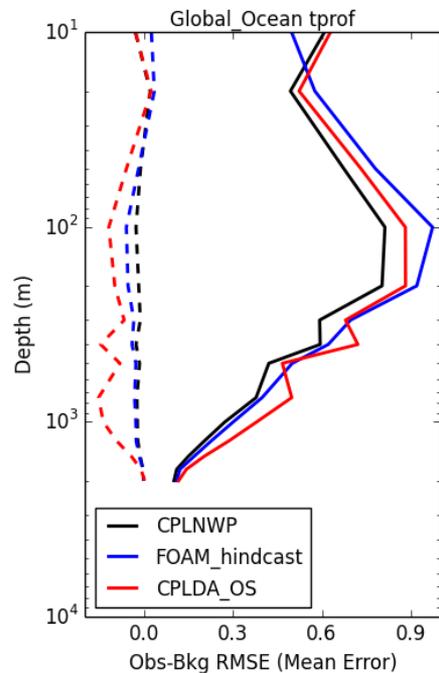
## Global SSH and SST stats against assimilated observations



# Initial results

- Initial results for ~2 months.
- Assessment of new coupled system (CPLNWP) via comparison to ocean-only FOAM V14 hindcast (FOAM\_hindcast) and current operational CPLDA system (CPLDA\_OS) using assimilated observations.
- Reduced bias in the temperature profile relative to the current CPLDA system.
- RMSE is reduced c.f. other systems, both coupled systems show increased RMSE at surface.

Global temperature profile stats against assimilated observations



# Summary

- Overview of coupled O-A system at the Met Office
- Ocean component generally compares well to FOAM ocean-only system, but CPLDA has over-deep MLD and associated sub-surface cold bias due to vertical propagation of surface increments.
- CPLDA system now assimilates SLSTR SST data, due to question marks over data in southern oceans data was not used as reference in bias correction of other satellite SST data.
- Introduced the next coupled system, initial results look promising.

# Future work

- Trialing and further assessment of the next iteration of new coupled O-A forecast system.
- Operational CPLDA system is under continual development, currently adding new SST (NOAA-20 VIIRS and Sentinel-3B SLSTR) and SSH observations (Sentinel-3B altimetry)
- Experiments to look at impact of shorter assimilation window comparing ocean-only FOAM system with 6 and 24 hour assimilation windows.
  - Allow decomposition of the effect of coupling from the effect of the shortened window when interpreting system results.
  - Impact of shorter window on error covariance parameters.
  - Assess possible over-fitting of coupled system to SST observations

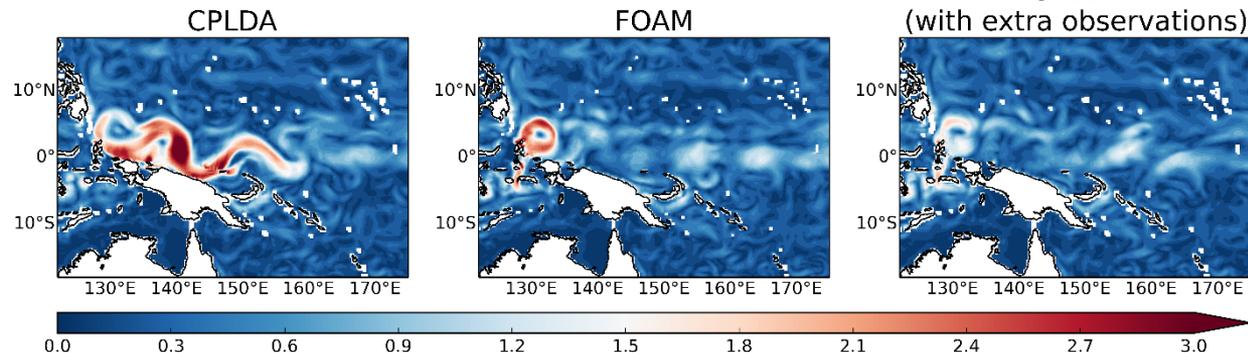
# Questions?

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# Surface current validation

- Spurious currents were initially observed in CPLDA in Western Tropical Pacific during April & Nov 2015.
- Alleviated by the updated scheduling which meant more SSH obs assimilated.
- CPLDA stats against CMEMS 15m current product calculated from drifting buoys are similar to FOAM.
- Moderate correlation to obs in CPLDA & FOAM. Mercator PSY4 >0.6, better representation of mesoscale due to increased resolution?

Average surface currents 5-11<sup>th</sup> Nov 2015



Density plot for 15 m velocity vs drifter obs (CMEMS)

