VIIRS SST assimilation in the US West Coast Ocean Forecast System (WCOFS)

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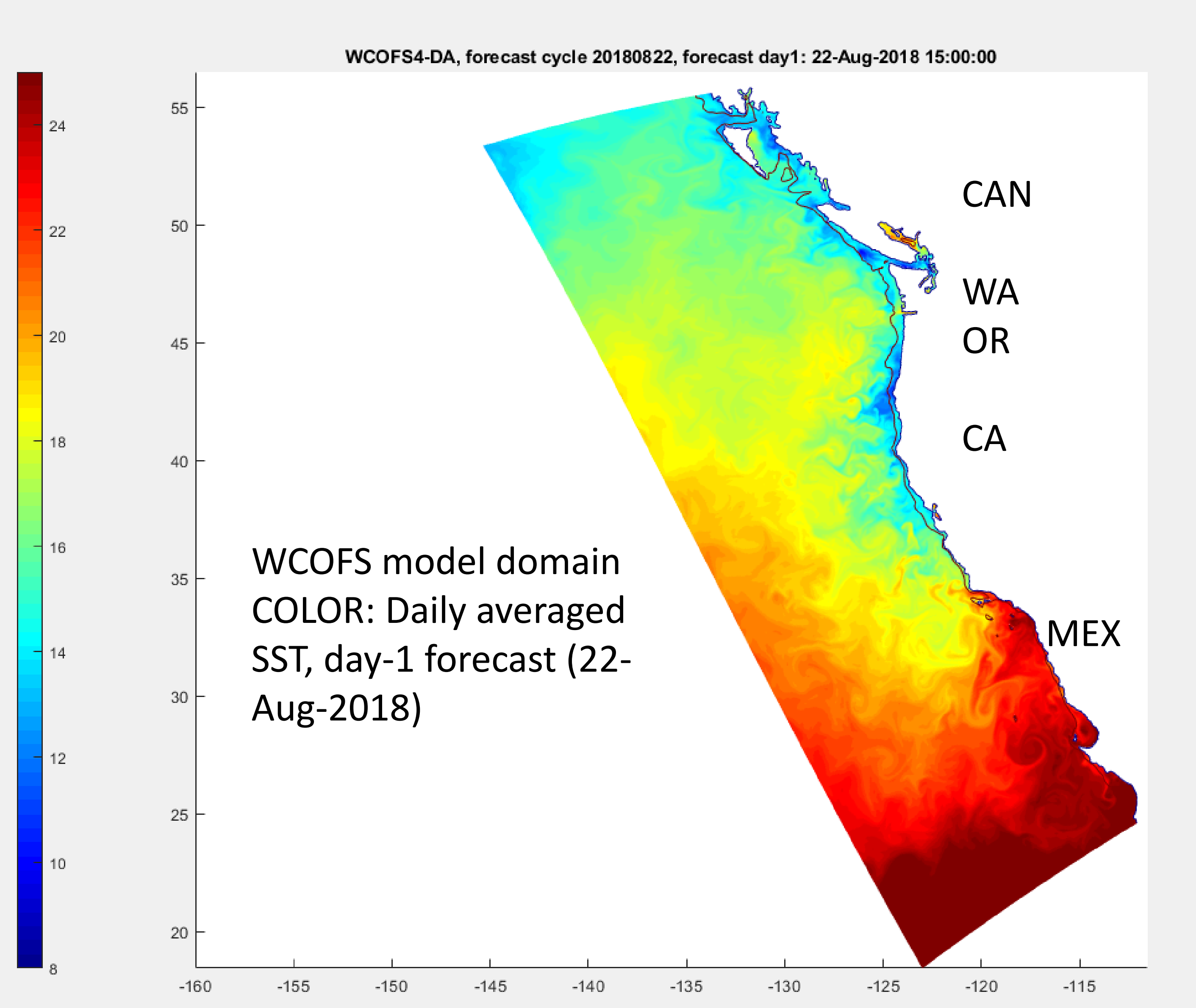
WCOFS:
- provides daily updates of 3-day forecasts (SST, currents, total sea level, etc.)
- is based on a high-resolution 3D ocean circulation model and 4DVAR data assimilation
- assimilates VIIRS SST to improve forecast accuracy (both SST and currents)

Users:
- navigation
- fisheries
- environmental hazard response (incl. oil spills)
- search and rescue
- base for coupled physical-bio-geo-chem forecasts



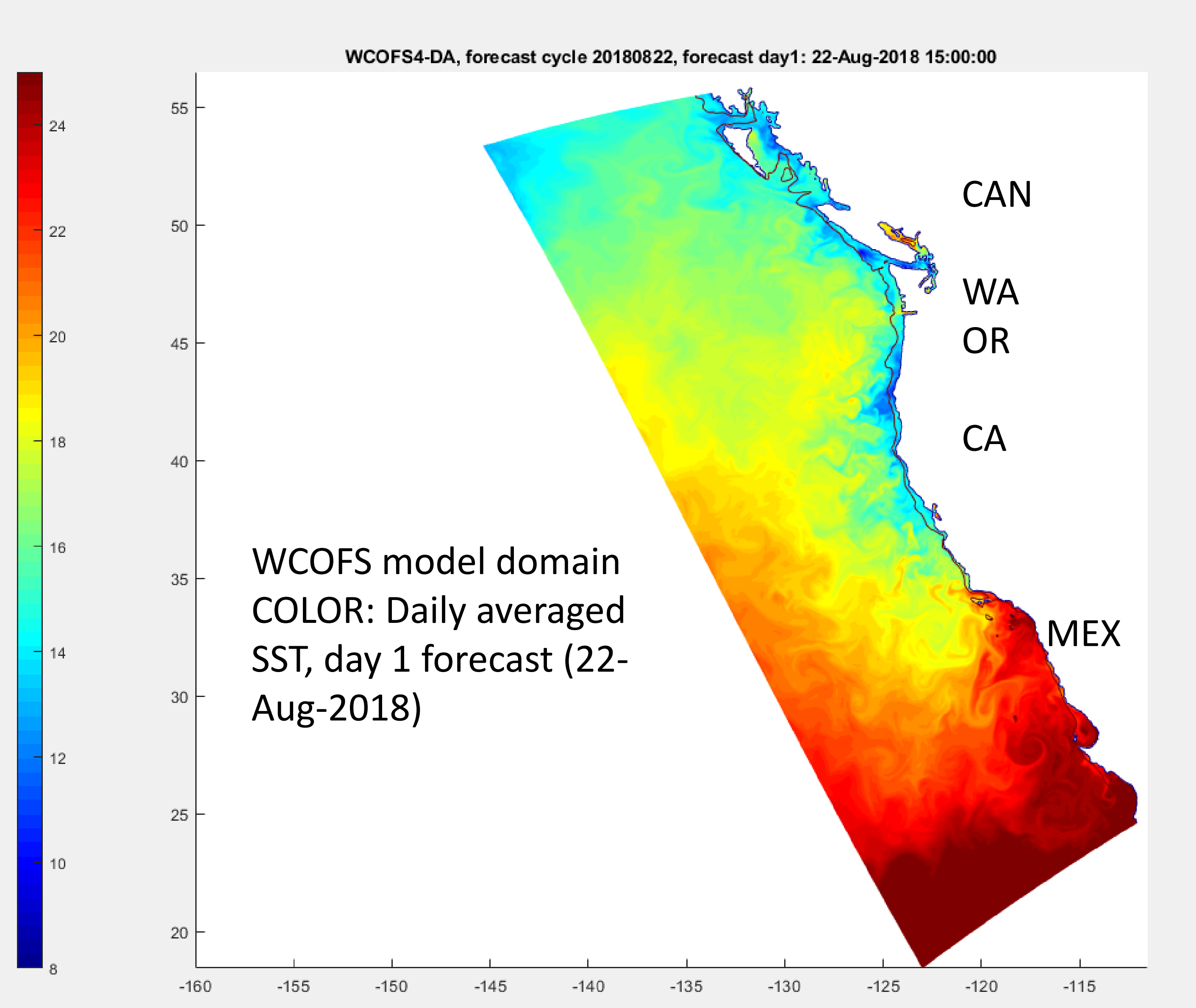
WCOFS, system design:

Regional Ocean Modeling System (ROMS)
2-km horizontal resolution*
NAM atmospheric forcing [NCEP]
RTOFS Boundary Conditions [NCEP] + TPXO tides
Rivers (Columbia, Fraser, small rivers in Puget Sound)

Assimilated data sets:

- SST VIIRS L3U [NESDIS/STAR]
- HFR surface currents [IOOS, NDBC]
- (planned) alongtrack altimetry [NESDIS/STAR]

** This is the target resolution. The model was initially tested without assimilation at the 2-km resolution. Data assimilation and real-time forecasts are currently performed at the 4-km resolution.*



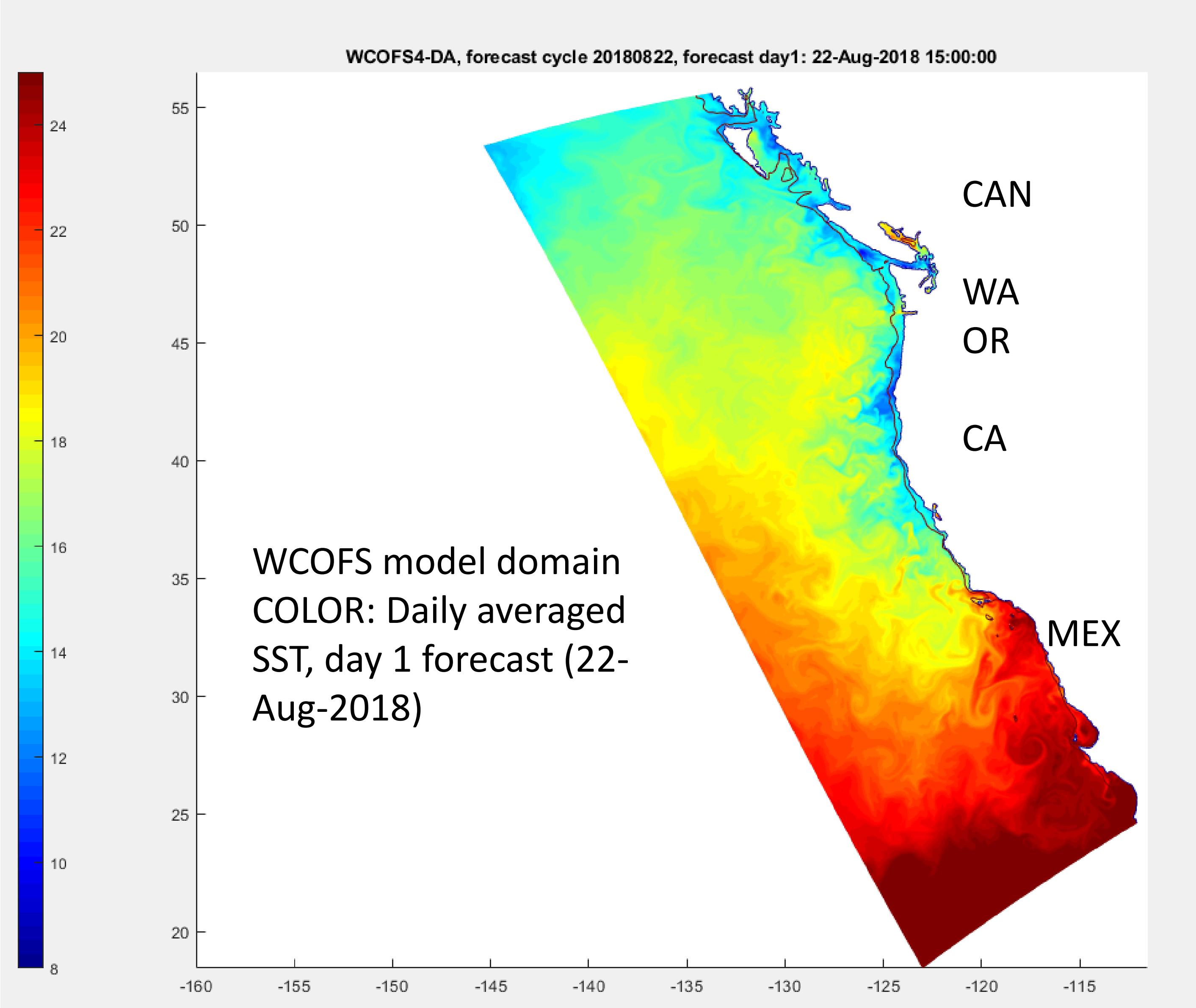
WCOFS skill assessment (no DA):

Kurapov, A. L., N. A. Pelland, and D. L. Rudnick, 2017: Seasonal and interannual variability in along-slope oceanic properties off the US West Coast: Inferences from a high-resolution regional model, J. Geophys. Res. Oceans, 122, 5237–5259, doi:10.1002/2017JC012721.

Kurapov, A.L., S. Y. Erofeeva, and E. Myers, 2017: Coastal sea level variability in the US West Coast Ocean Forecast System (WCOFS), Ocean Dynamics, 67: 23. doi:10.1007/s10236-016-1013-4.

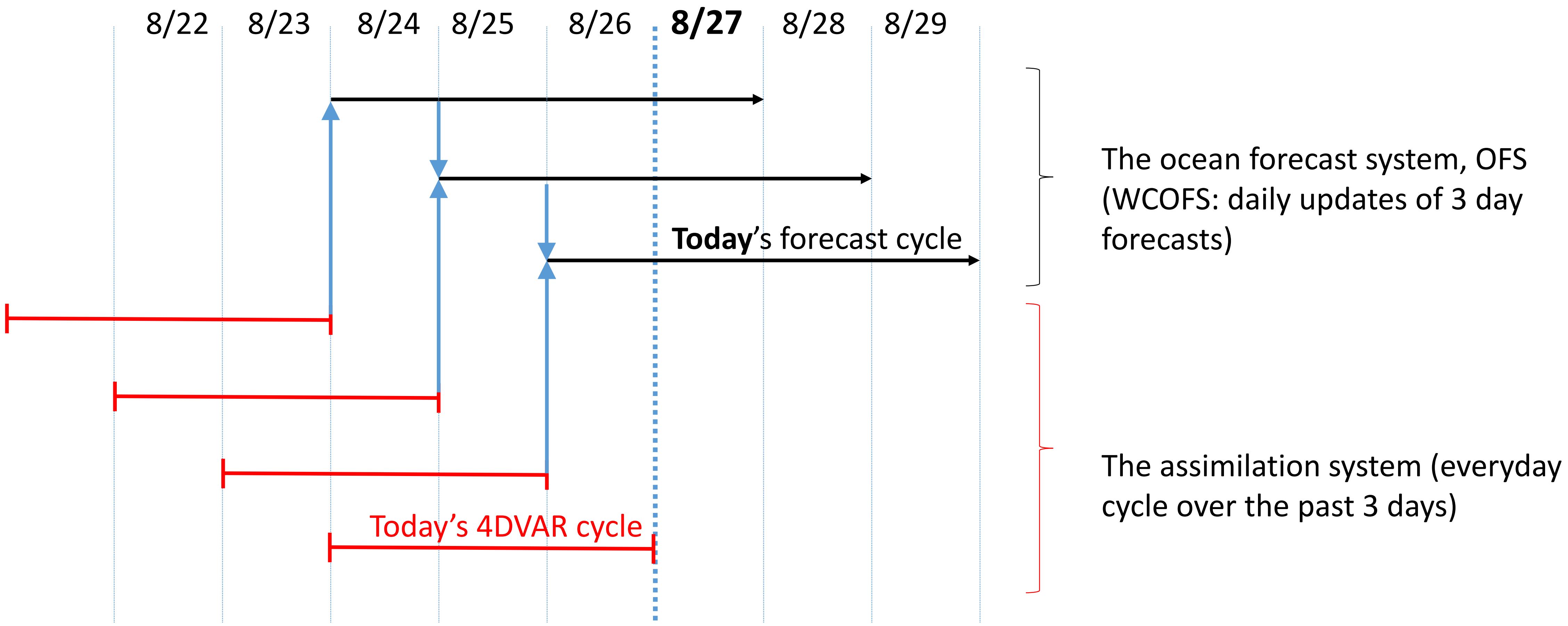
WCOFS, present status:

- developed and tested at CSDL and transitioned to NOS/COOPS for real-time testing
- run routinely in the near-real-time regime with data assimilation since 2 Aug 2018 (still in the "developmental mode")
- intermediate 4-km resolution for assimilation and forecasts (target is 2-km resolution forecasts)
- assimilates VIIRS L3U SST and High-Frequency Radar (HF) surface currents; altimetry assimilation will be added in the future
- 3-day forecasts are updated daily

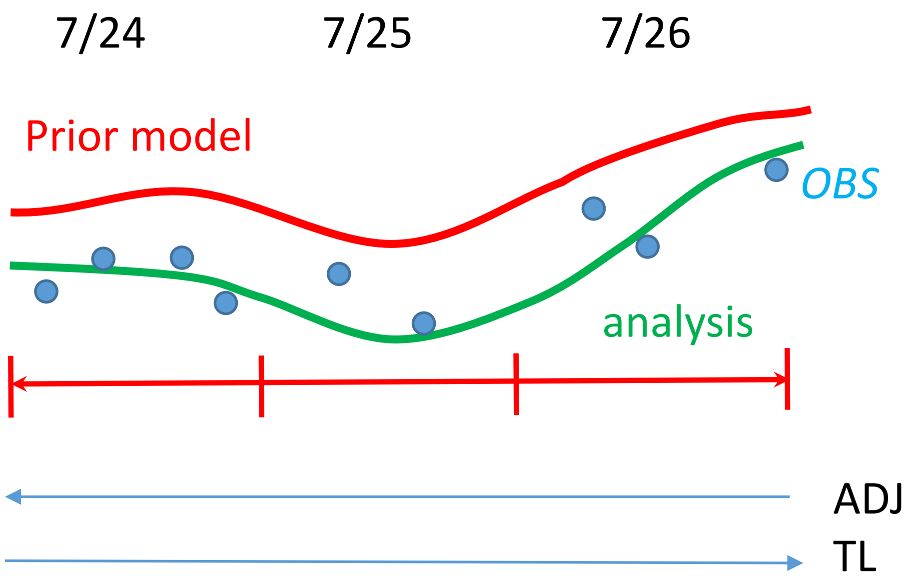


DA methodology: 4-dimensional variational DA (4DVAR)

Every day, the ROMS 4DVAR is run to improve the ocean state estimate at the beginning of the 3-day window. Then the 3-day nonlinear analysis is run over the same period. **Initial conditions for the forecasts are sampled from the DA analysis**



The 4DVAR cycle:



(VIIRS L3U: we assimilate data from individual granules, at their respective times)

(a) Over a given time interval (here, 3 days) use available observations to correct initial conditions for the analysis

(b) The cost function is minimized:

$$J(u) = \|u - u^{PRIOR}\|^2 + \|OBS - HM(u)\|^2$$

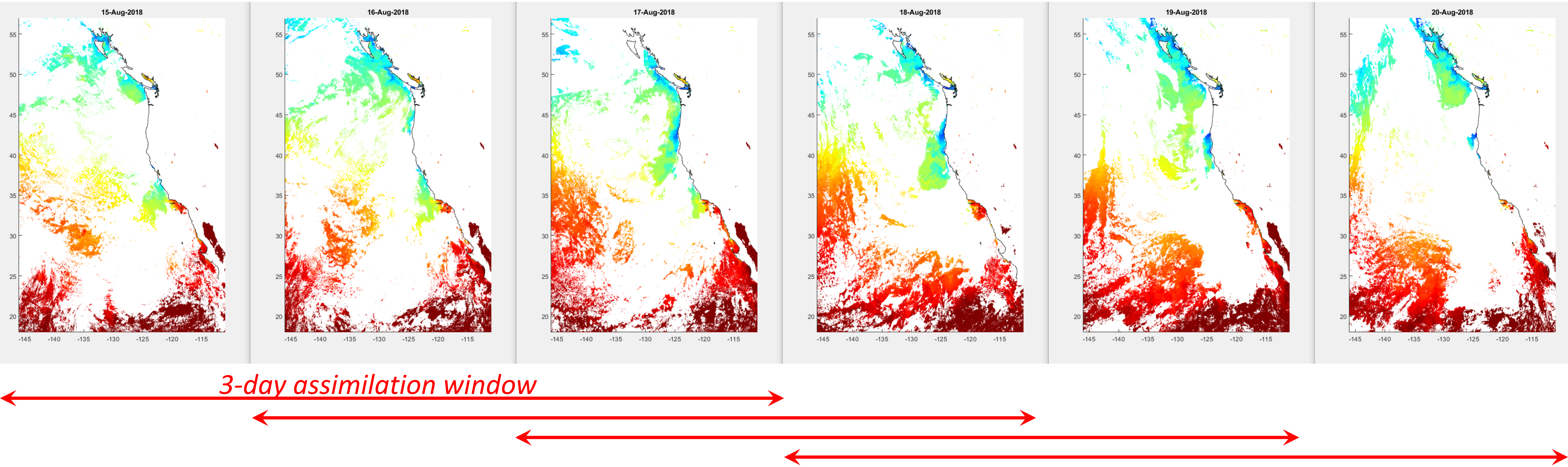
where

u: improved initial conditions on 7/24
u^{PRIOR}: prior initial conditions
M: model, propagating initial conditions in time
H: data functionals (sampling the model solution at obs. locations and times)

(c) The minimizer is found iteratively, using repeatedly the <u>tangent linear (TL)</u> model and its <u>adjoint (ADJ)</u> counterpart

The advantage of using the 4DVAR system (*shown are VIIRS L3U daily mozaics, 15-20 Aug 2018*):

- dynamically-based time and space interpolation
- the estimate is close to the prior where data are not available



- opportunity to include data from multiple satellites

(*not implemented here*)

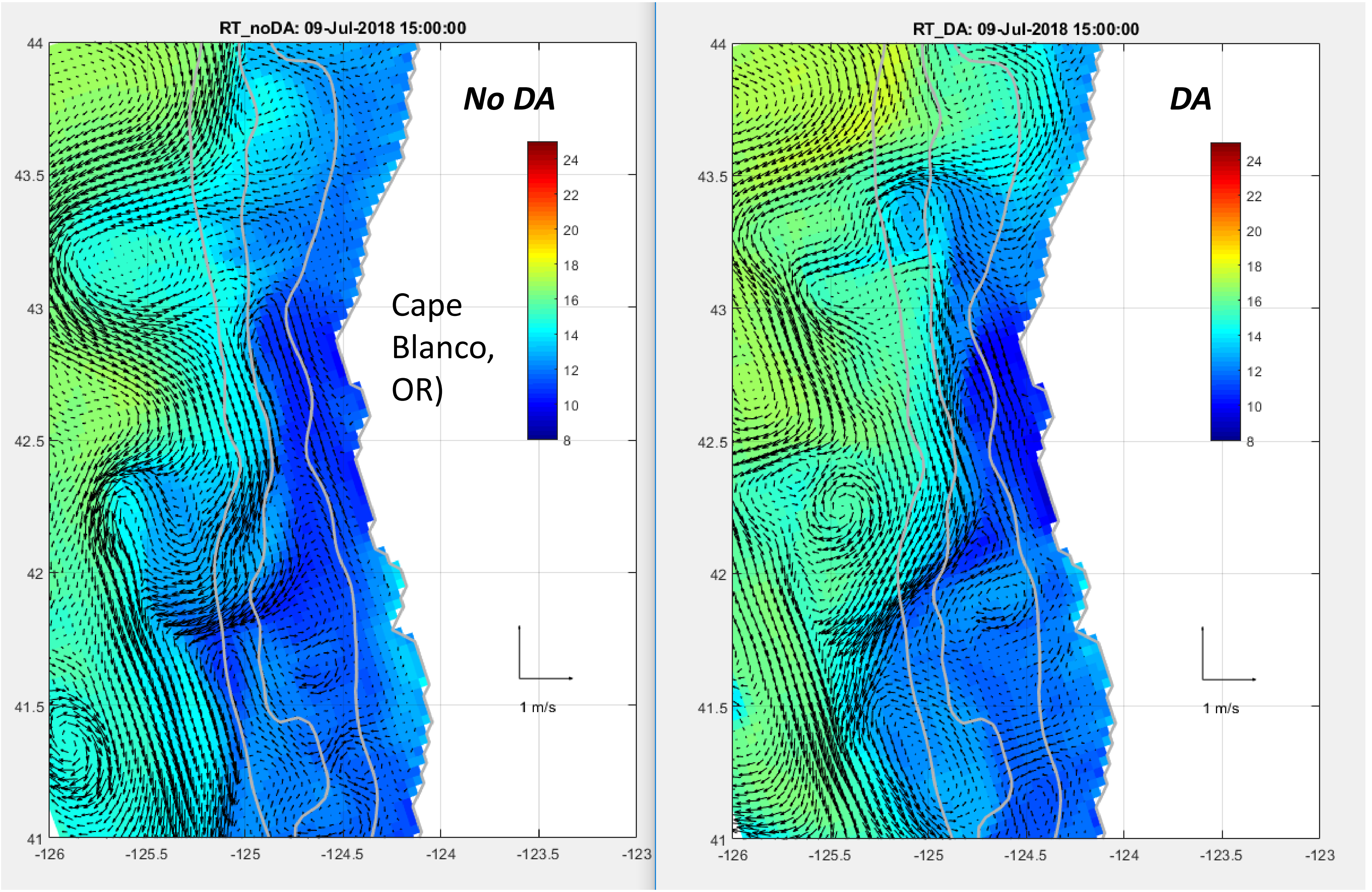
(potential challenges: DA convergence, biases between different sets)

- synthesis of observations from different platforms (SST, u-v, SSH, etc.) to obtain the best available ocean estimate

Impact on surface transports and SST (daily-averaged, day 3 forecasts):

Coastal jets follow closely the SST fronts

DA changes in SST yield changes in surface currents

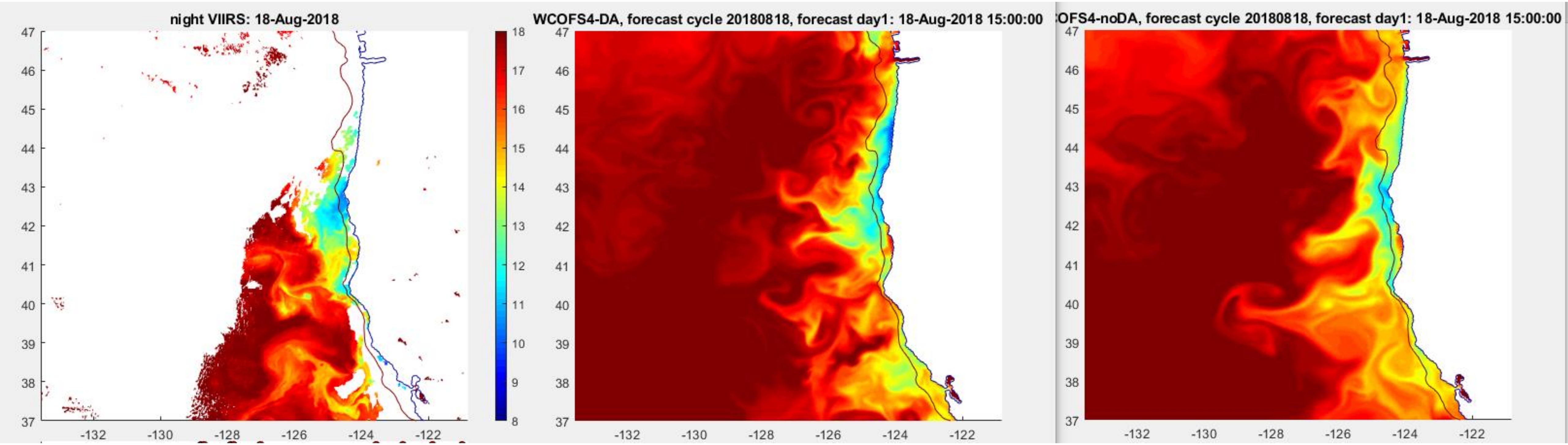


Assimilation of SST improves the upwelling front geometry in forecasts

18-Aug-2018: nighttime VIIRS

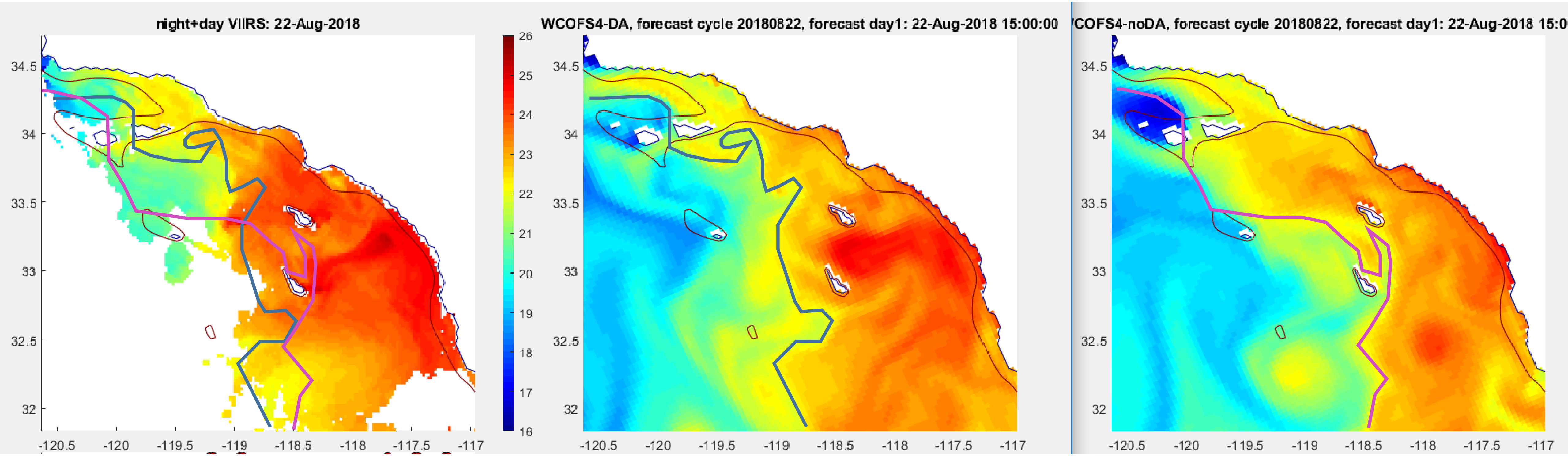
WCOFS4 DA (Day 1 forecast)

WCOFS4 , no DA



In Southern CA Bight:

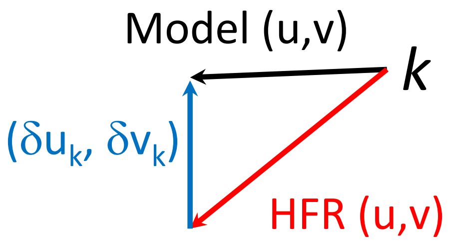
18-Aug-2018: night+day VIIRS | WCOFS4 DA (Day 1 forecast) | WCOFS4 , no DA



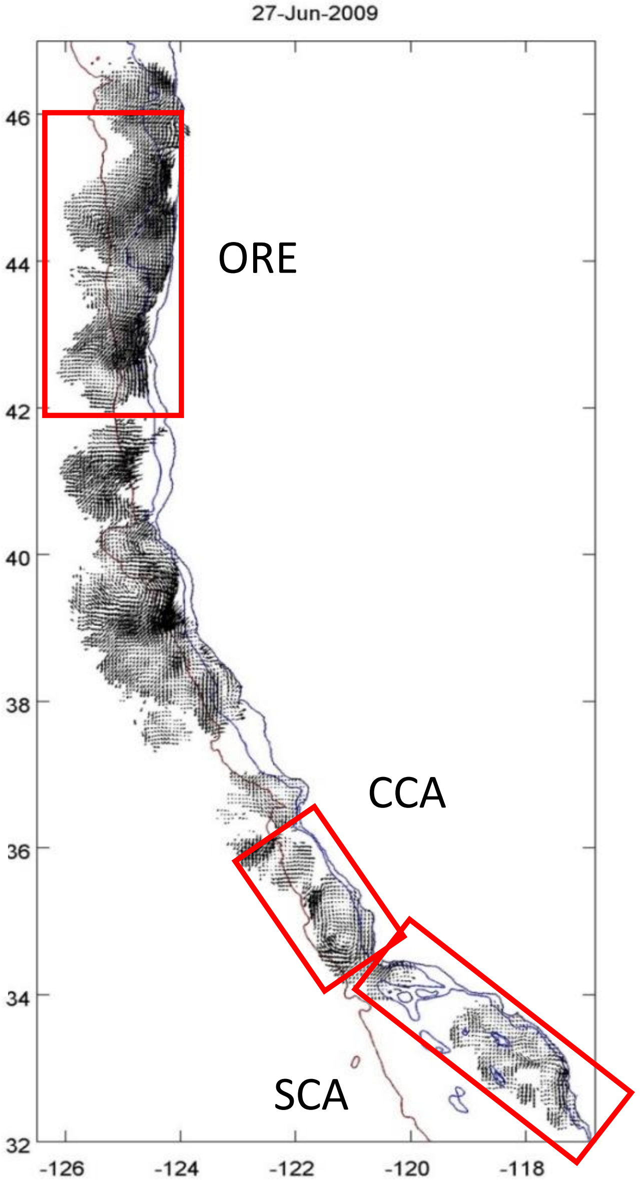
The geometry of the upwelling front is improved qualitatively, compared to the case without assimilation

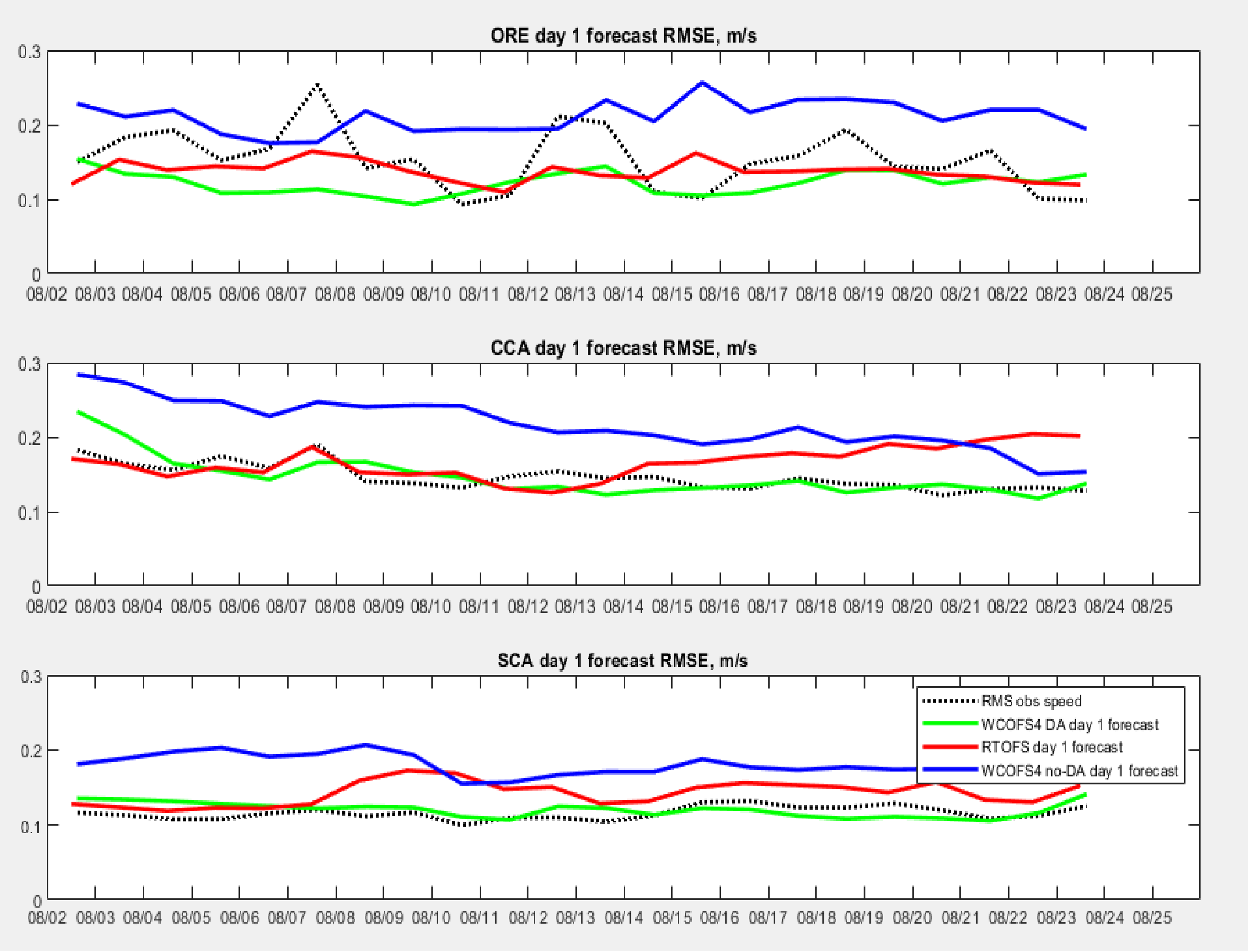
HFR – model RMSE,
Daily averaged (u,v), area-averaged in 3 regions
Day 1 forecasts

WCOFS4 no DA
Global RTOFS
WCOFS4 DA



$$RMSE = \left[\frac{1}{K}\sum_k \left(\delta u_k^2 + \delta v_k^2\right)\right]^{1/2}$$





Pre-assimilation data quality control (QC):

It does not matter how good the data are, we need to look at the data before they are assimilated

- to pick out outliers
- to identify new situations where QC flags can be raised
- to learn about the ocean and satellite technology

For example:

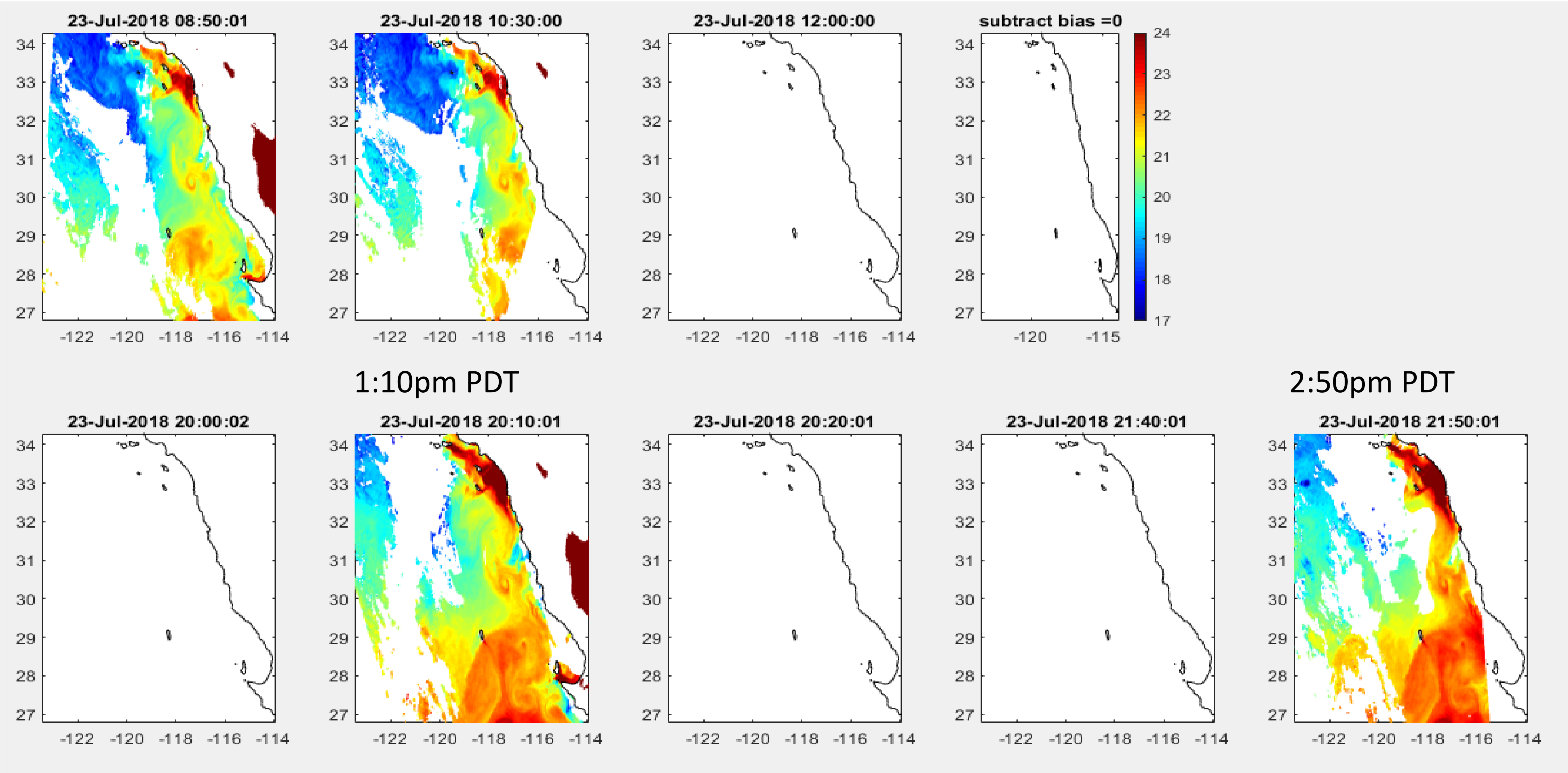
We assimilate L3U “sea_surface_temperature” minus “sses_bias”.
Looking closely at the data, we identify non-standard situations with either field
(*see graphics in the next slides*)

VIIRS L3U SST: no *sses_bias* subtracted. Separate granules over Southern CA and MEX

Night

Day

(times are UTC)

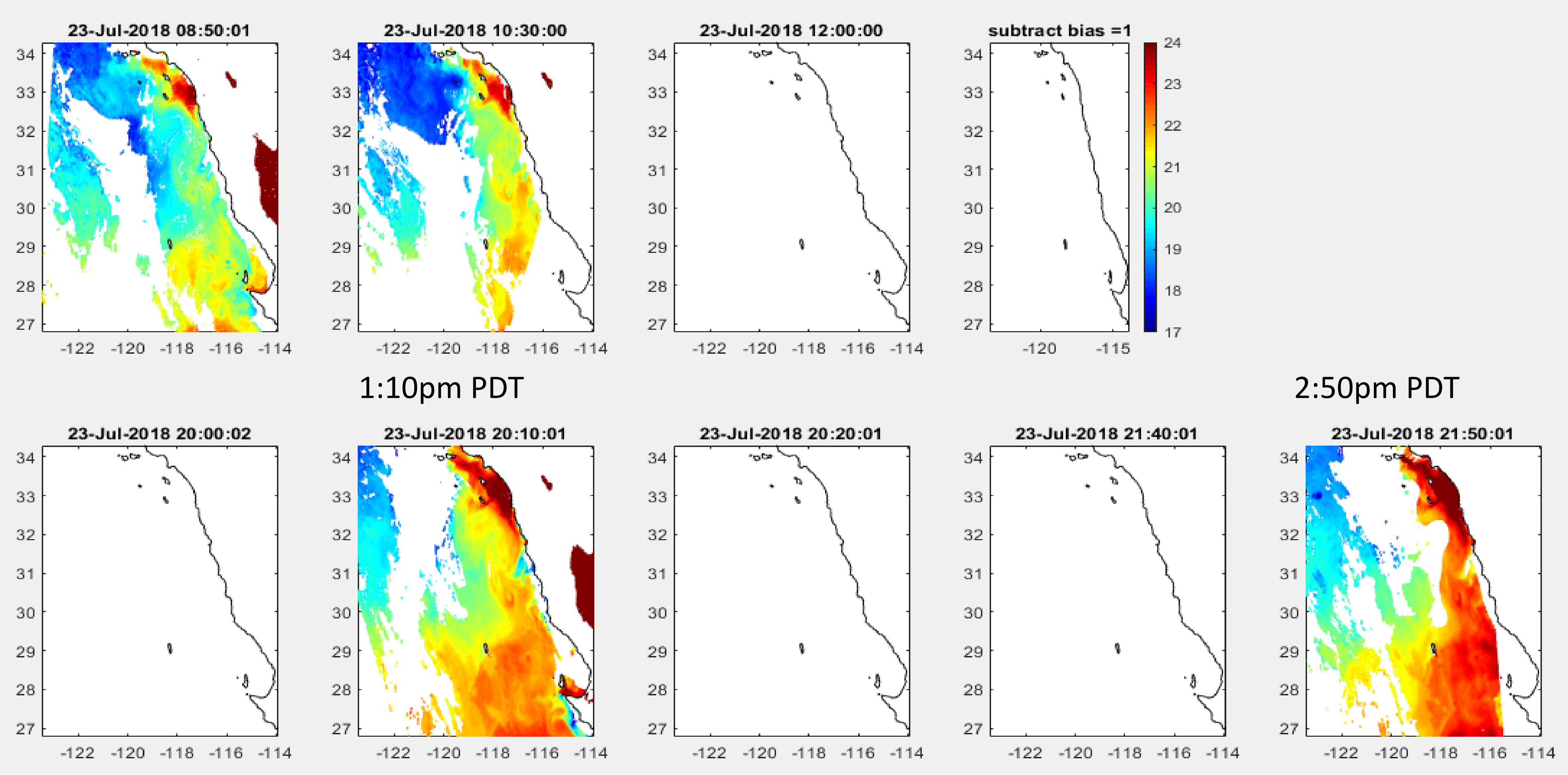


VIIRS L3U SST: **with** *sses_bias* subtracted. Separate granules over Southern CA and MEX

Night

Day

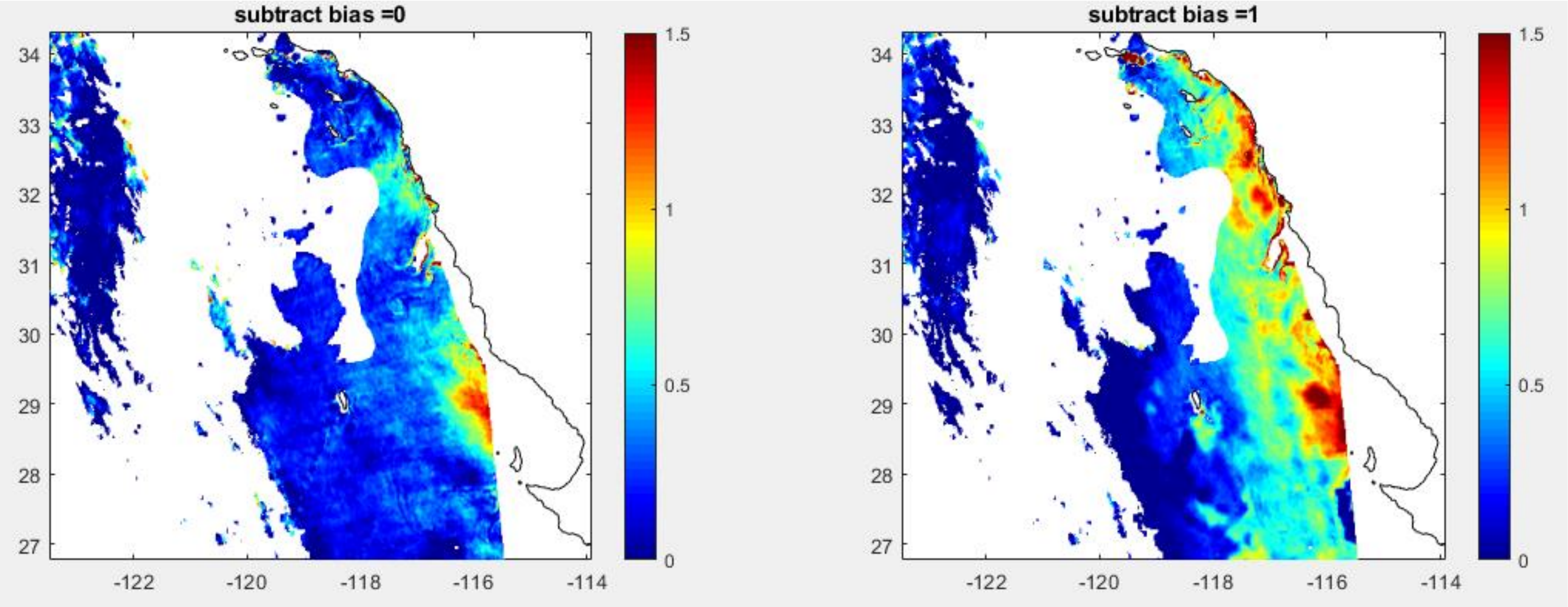
(times are UTC)



SST difference between two VIIRS granules obtained during the day, 1½ hours apart, 21:50 and 20:10 UTC (2:50 and 1:10pm local time)

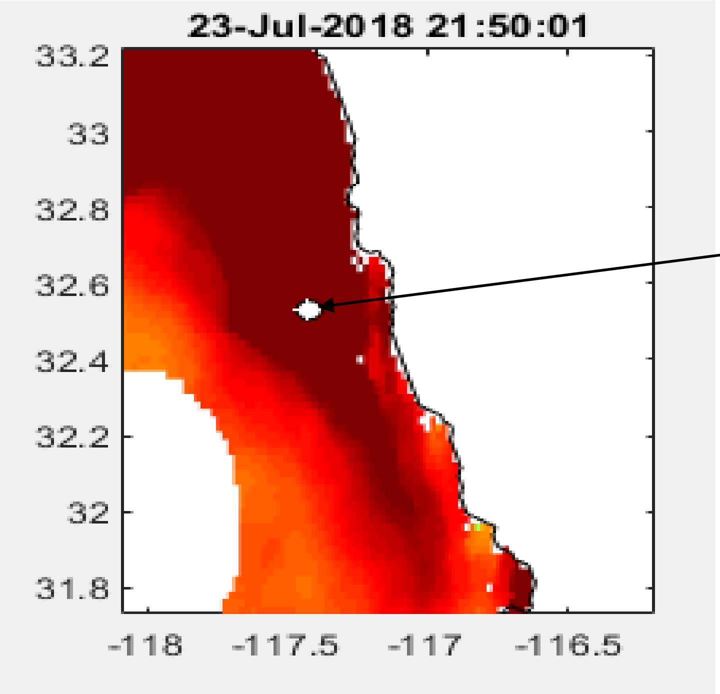
no sses_bias correction

w/ sses_bias correction



0.7-1.5^{o}C increase in SST over 90 min?
Enforced by sses_bias?

Mooring - VIIRS SST L3U comparison



https://www.ndbc.noaa.gov/station_page.php?station=46232

Solar Radiation & Ph | Mobile Protection In | Makefile learning tut | Jetdocs | New Tab | start [Jet Docs] | Using BBCP

Station 46232 - Point Loma South, CA (191)

Information submitted by [Scripps Institution of Oceanography]()
Waverider Buoy
32.530 N 117.421 W (32°31'47" N 117°25'17" W)

Site elevation: sea level
Sea temp depth: 0.46 m below water line
Water depth: 1143 m

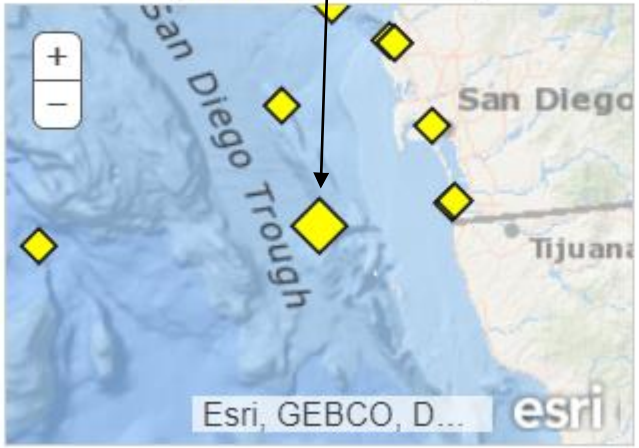
[Latest NWS Marine Forecast]()

[Search And Rescue (SAR) Data]()

[Meteorological Observations from Nearby Stations and Ships]()

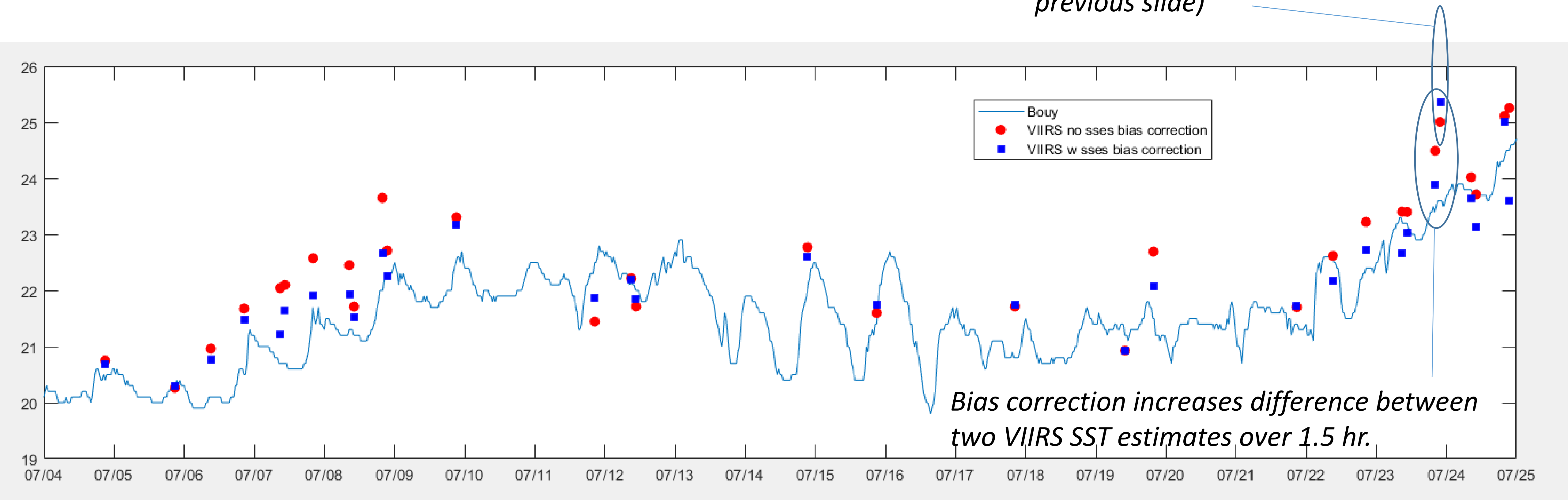
[Regional HF Radar Surface Current Observations]()

Oceans ▼



Line: Mooring temperature time-series (@0.46 m below surface)

7/23 20:30 UTC (as discussed in previous slide)



Bias correction increases difference between two VIIRS SST estimates over 1.5 hr.

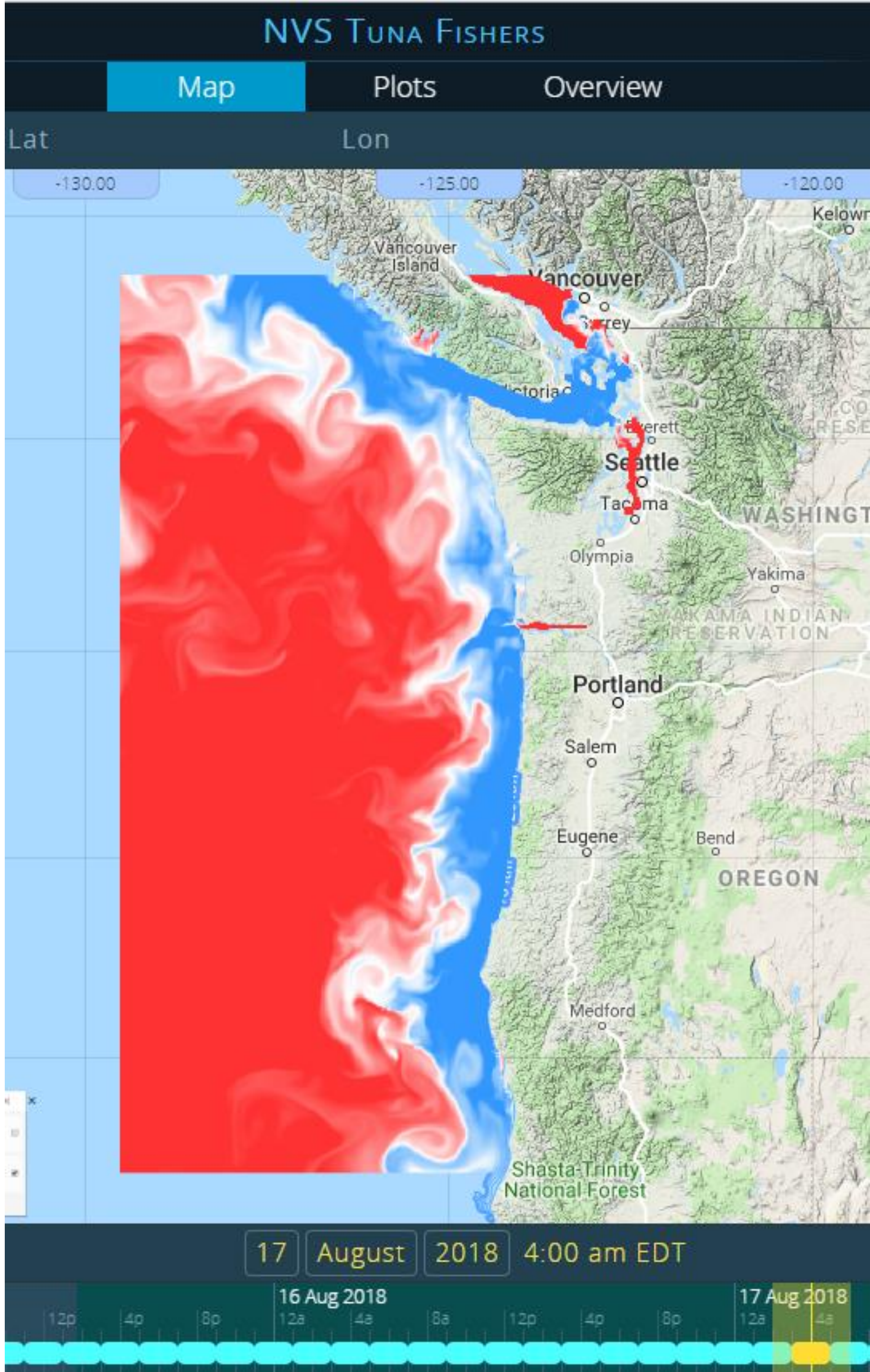
Statistics
(ΔT = sat SST – mooring T)

	No sses_bias	With sses_bias
mean(ΔT)	0.572	0.257
RMSE ($[\text{mean}(\Delta T)^2]^{1/2}$)	0.829	0.620

Stats are better with sses_bias subtracted

Outreach and Engagement:

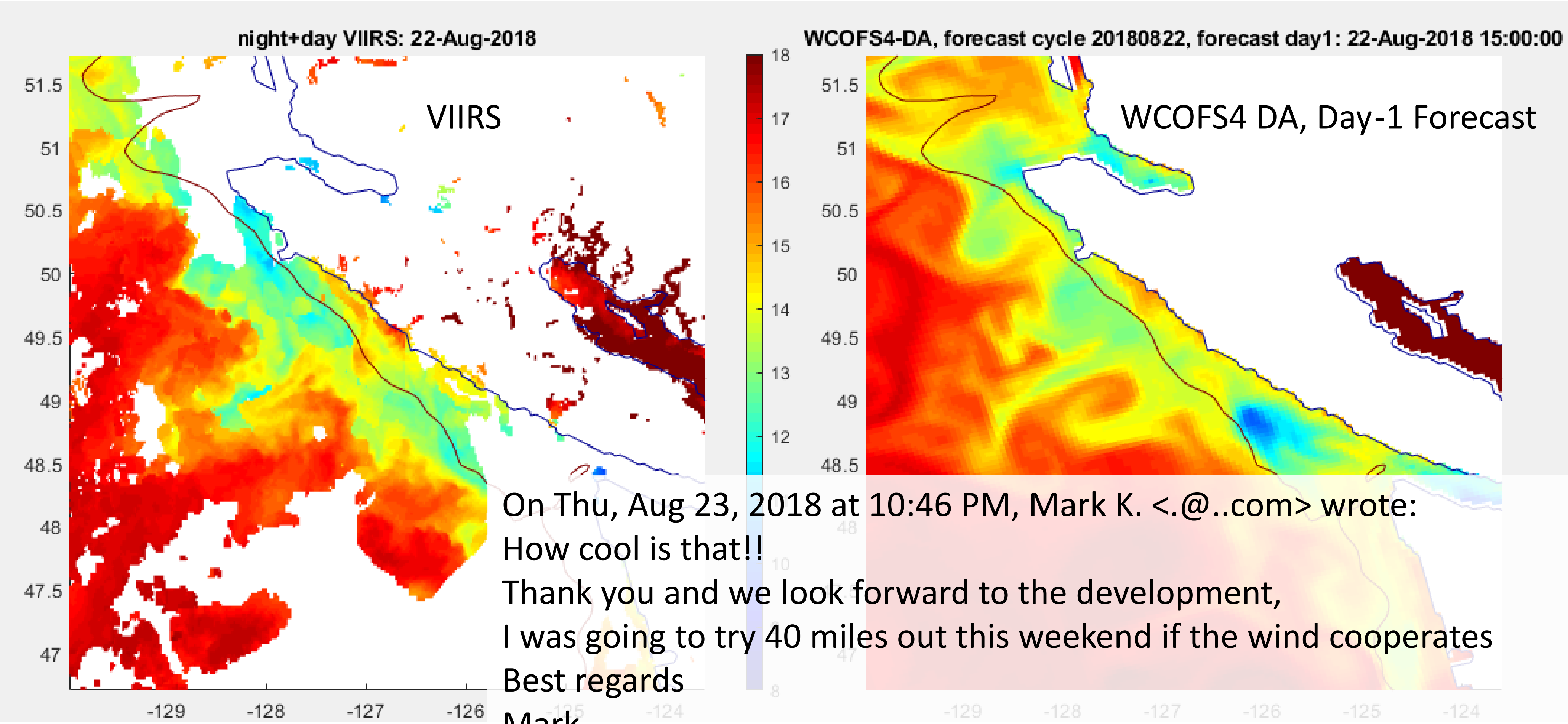
- NOAA ORR would love to use accurate surface velocity forecasts
- Fishermen (esp. tuna along the West Coast) love to see SST forecasts



Tuna forecast at NANOOS Visualization System (NVS), using OSU OR-WA OFS
NANOOS = IOOS Regional Association @ Pacific NW

On Wed, 22 Aug 2018 at 19:42, Mark K. <...@....com> wrote:
From: Mark K.
Subject: NANOOS: Map

How do I get the tuna map to move north to include all of Vancouver Island?



On Thu, Aug 23, 2018 at 10:46 PM, Mark K. <.@..com> wrote:
How cool is that!!
Thank you and we look forward to the development,
I was going to try 40 miles out this weekend if the wind cooperates
Best regards
Mark

SUMMARY:

JPSS VIIRS SST assimilation in the WCOFS helps to improve oceanic forecasts (SST fronts, currents)

4DVAR assimilation = time and space interpolation of sparse data sets using dynamically consistent covariances, provided by the solution of the TL and ADJ models

The DA-enabled forecast system provides SST and currents in the future

Pre-assimilation data QC and post-assimilation solution QC are essential components of any DA system

The forecasts of SST and currents will have their user base (thousands of fishermen, NOAA ORR, fishery managers, USCG etc.)

Many steps to improve WCOFS:
- improved resolution
- improved DA algorithm and implementation (more iterations needed to fit the data better)
- combine data from several radiometers
- better model error covariance
- include assimilation of altimetry (5 nadir satellites... information on surface geostrophic currents)