Seasonal and Interannual Variability in the Ocean Surface Salinity along the US West Coast

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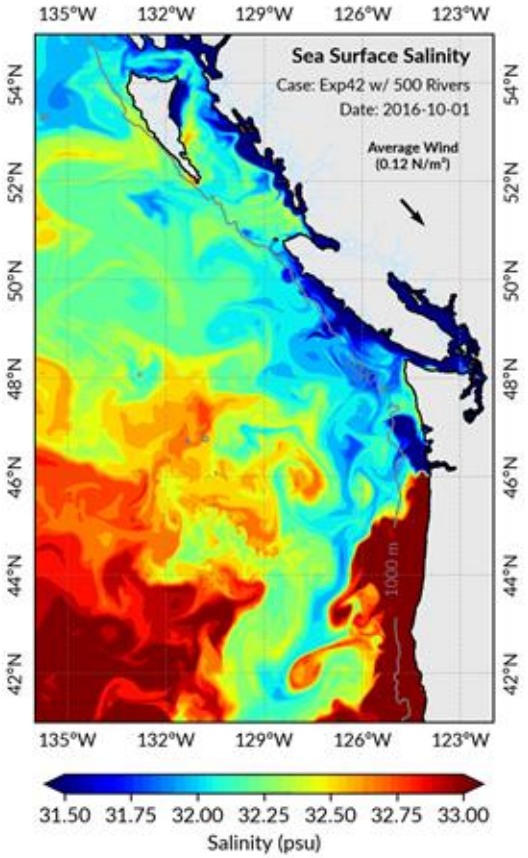
- Seasonal variability: influenced by terrestrial discharges, horizontal shelf-interior ocean exchange and vertical processes (EP, mixing)
- Interannual variability: correlates with PDO and NPGO cycles
- Opportunities for satellite SSS data assimilation



Salinity data used:

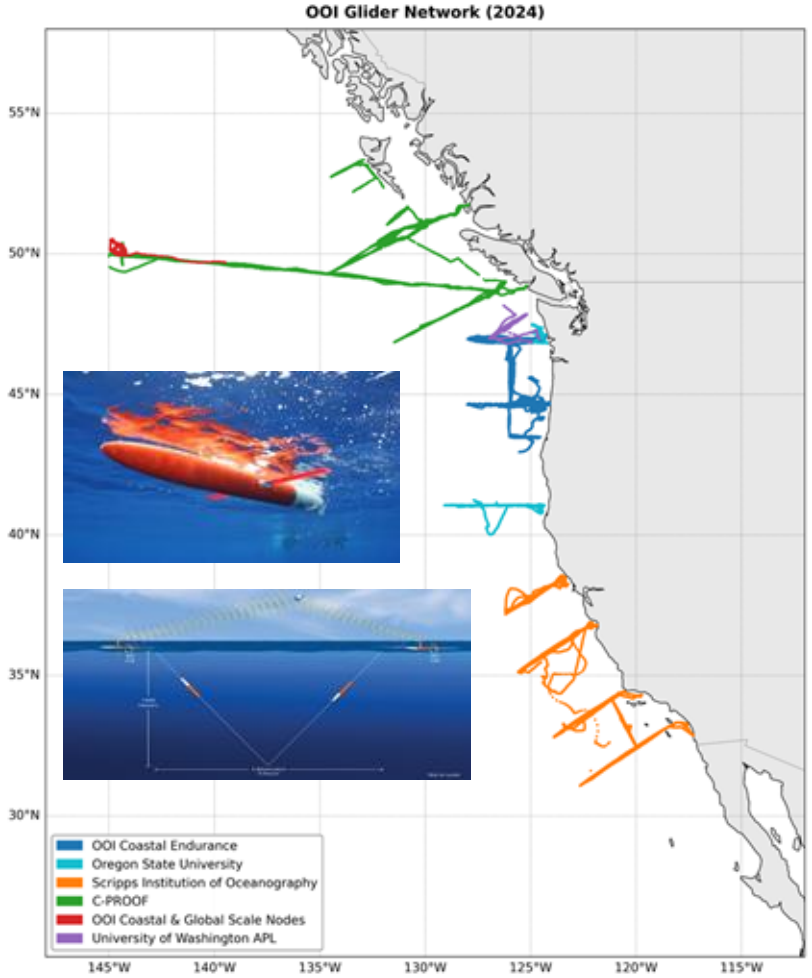
Satellite SSS:

- SMAP SSS v6 (Meissner et al., 2018, 2024)
- SMOS SSS L3 v10 (Boutin et al., 2018)

(mostly monthly averages, 8-day ave for SMOS-glider validation)

Argo: mapped 1x1 deg, monthly (BOA-Argo, Li et al., 2017) and individual profiles

Glider cross-shore / vertical sections



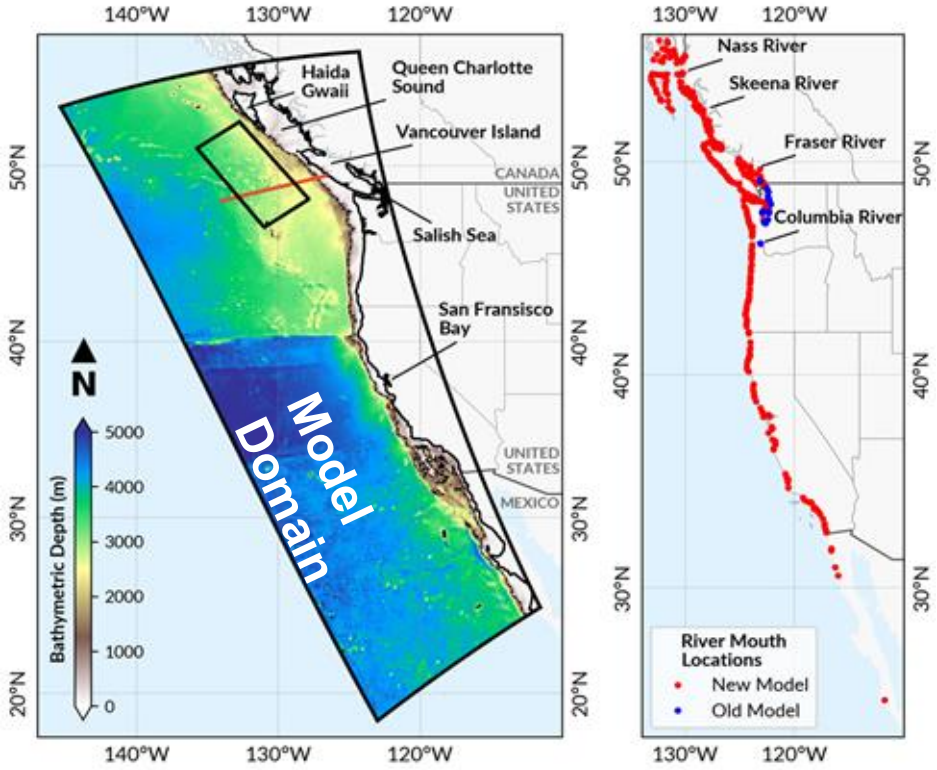
https://www.whoi.edu/what-we-do/explore/underwater-vehicles/auvs/spray-glider/

Seasonal SSS variability in the coastal transition zone (CTZ): analyses of a high-resolution model and observations

ROMS, 2-km resolution
No Data Assimilation
10-year simulation: 2008-2018

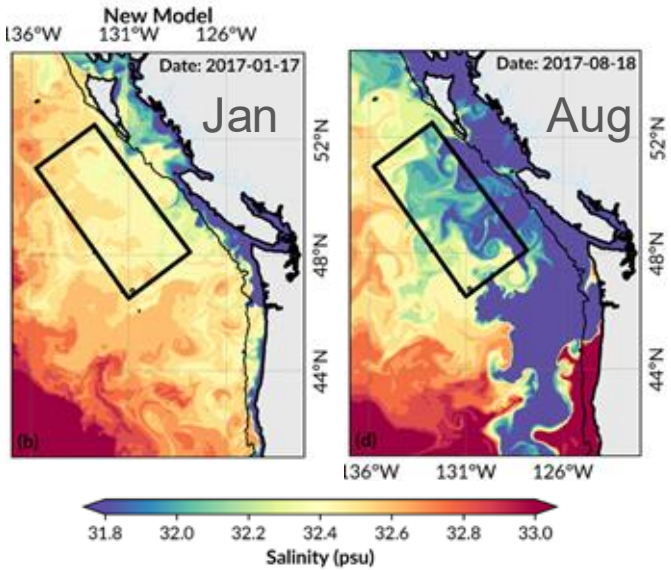
Old benchmark: limited river discharges (major Columbia and Fraser R. + 15 small sources in Puget Sound)

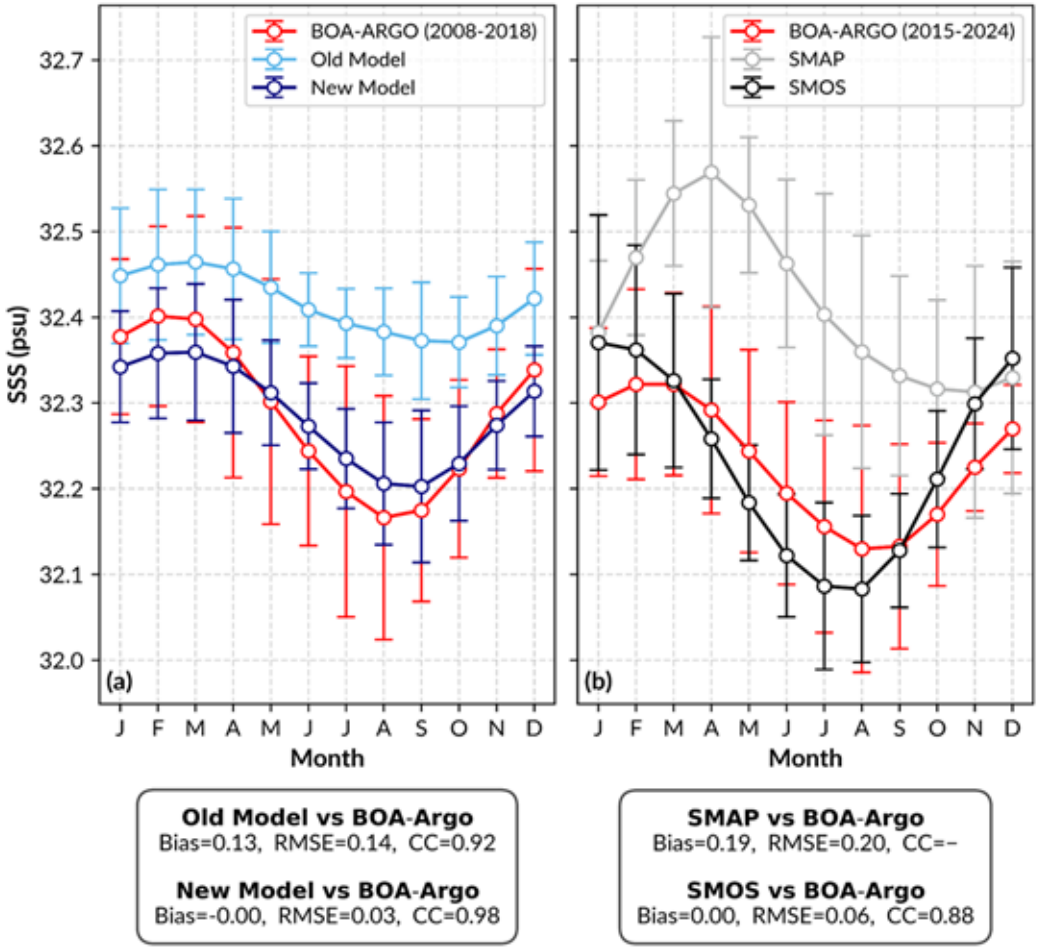
New model: 500 sources from GloFAS (twice as large total discharge as in the old model)



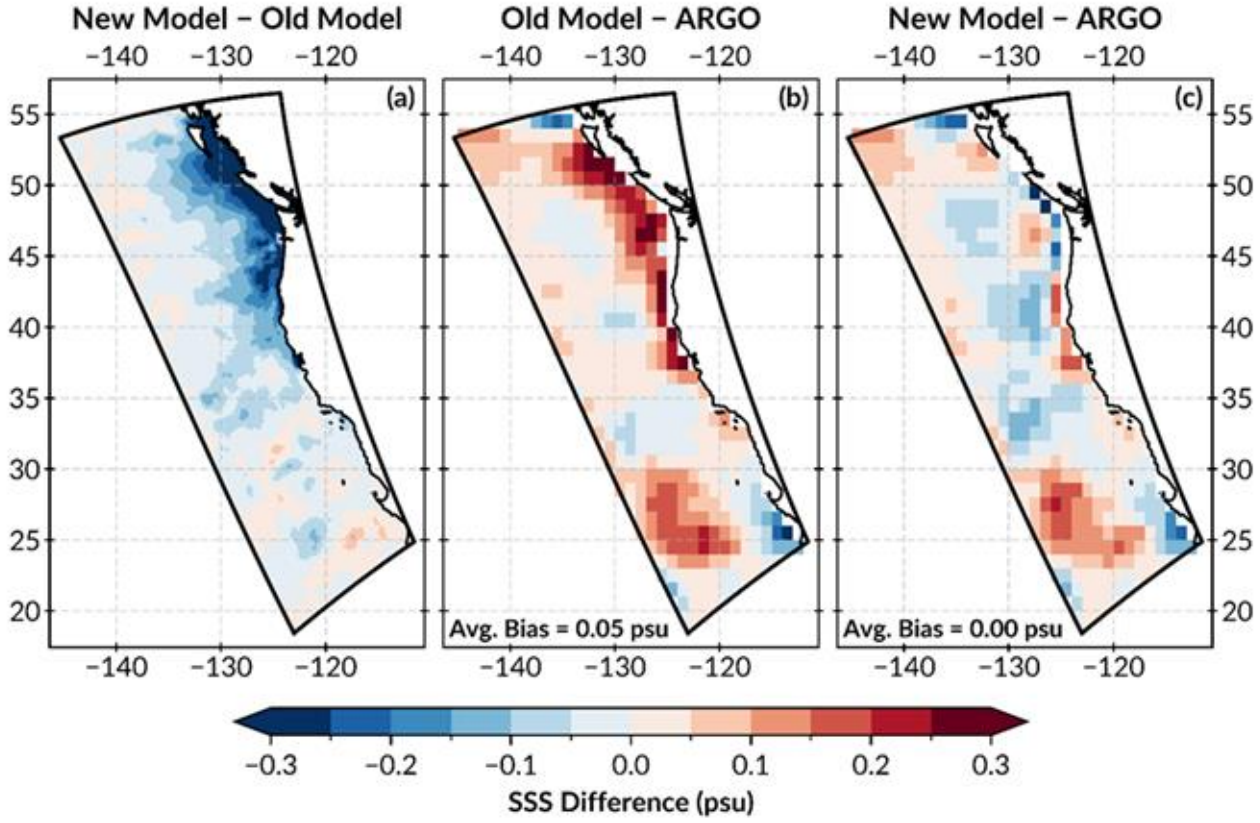
Adding all the discharges improve the modeled annual cycle in area-averaged SSS (black box off Vancouver Is.)

[Khazaei et al. (Oce Dyn, submitted) https://www.researchsquare.com/article/rs-8328377/v1]





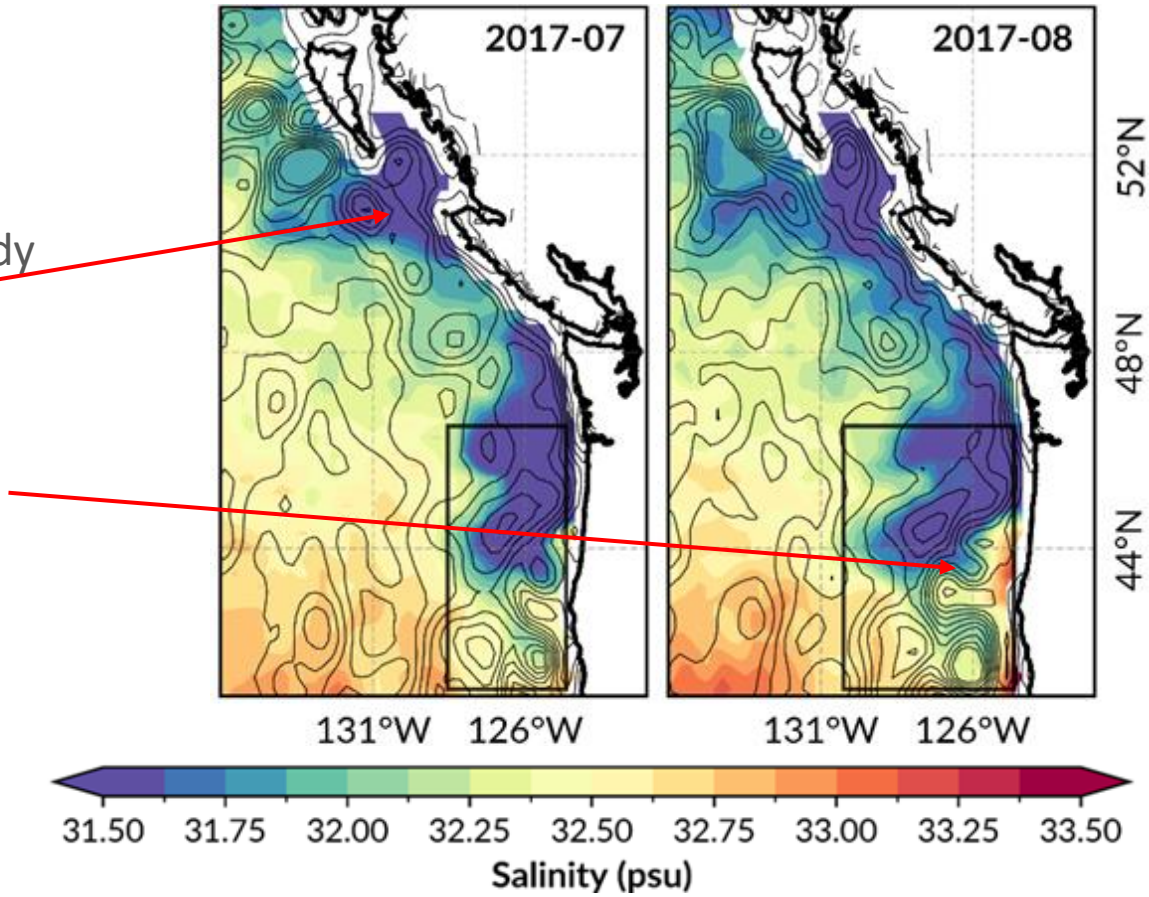
Time-averaged (2008-2018) SSS difference maps: Accounting for all the discharges removes bias over a large area from Cen CA to British Columbia



SMOS + CMEMS L4 Sea Level Anomalies:

Satellite SSS shows structures associated with

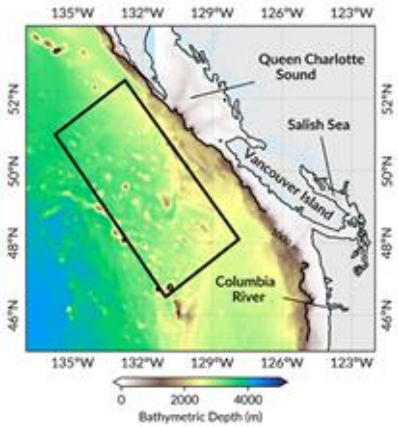
- the shelf-interior ocean eddy transport
- Upwelling inshore of the Columbia River plume

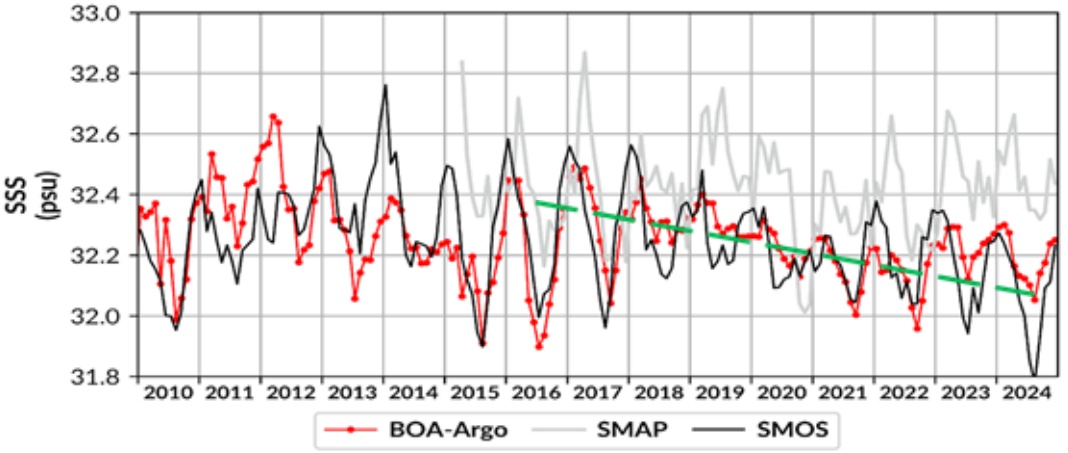


Interannual variability: freshening in the NorthEast Pacific (NEP), 2018-2024

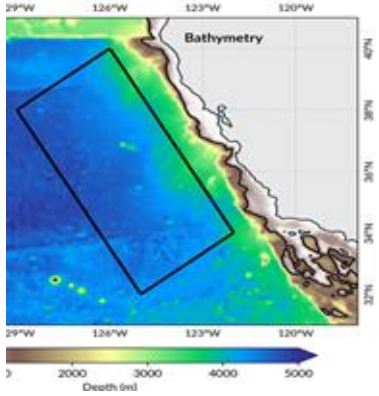
Box-averaged SSS

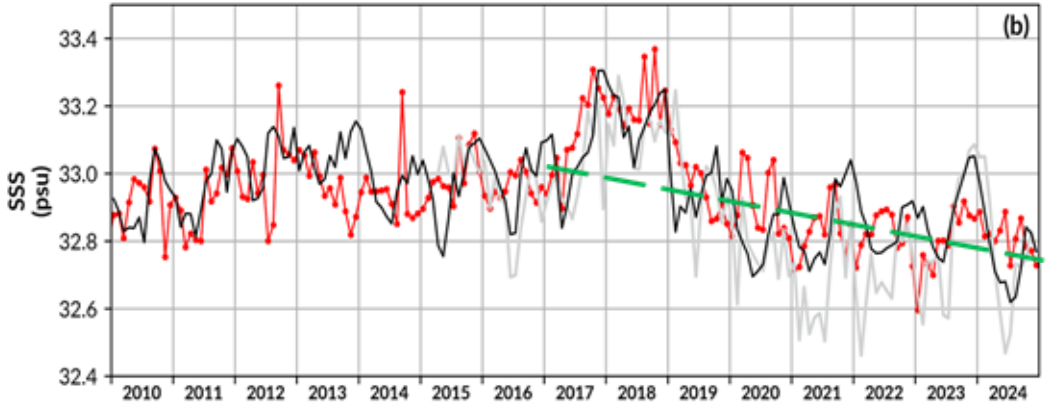
- off Vancouver Island





- off the Cen CA coast

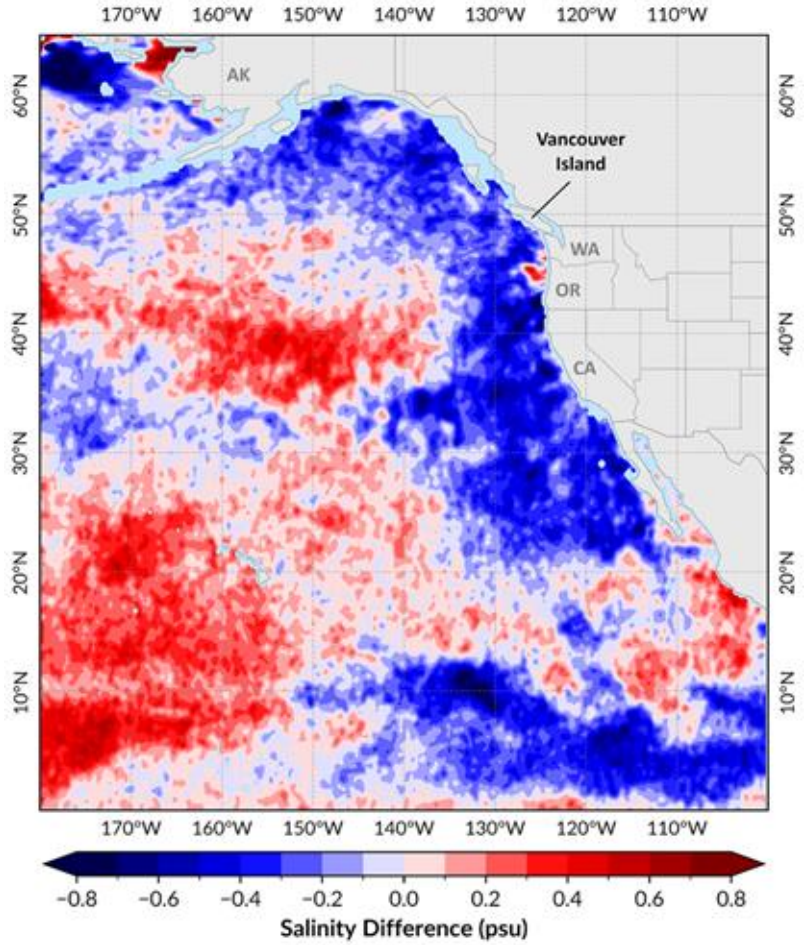




SMOS SSS difference:
summer 2024 minus summer 2018

- a PDO like pattern

(PDO = Pacific Decadal Oscillation mode of variability)



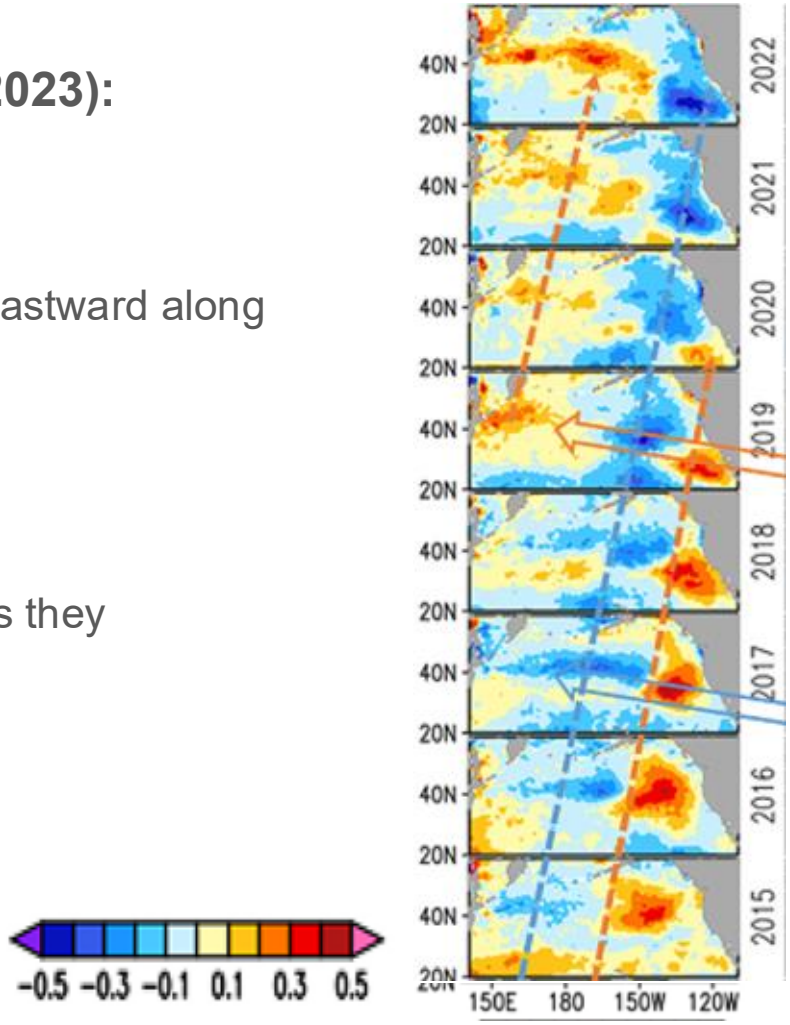
Grodsky, Reul & Vandemark (J Mar Sys, 2023):

Analyses based on Aquarius + SMAP

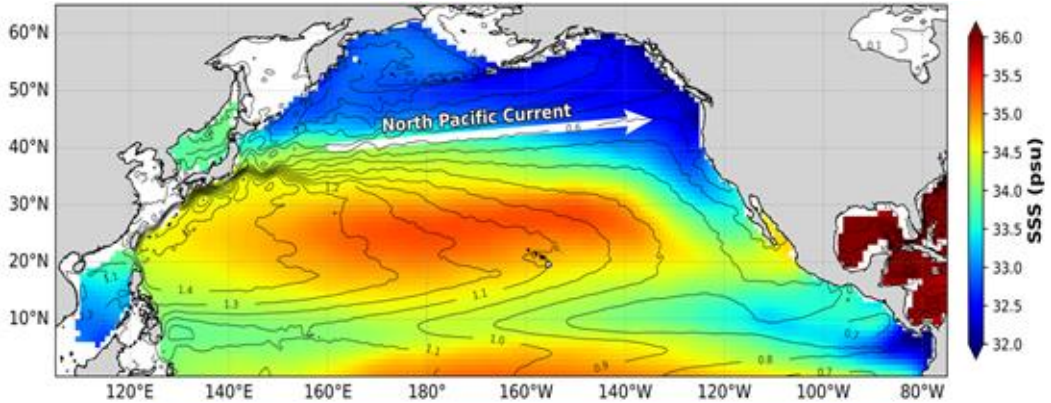
Positive and negative anomalies are propagated eastward along the path of the North Pacific Current (NPC)

2018-2022 freshening is tracked as a pattern transported/propagated across Pacific

Positive and negative SSSA anomalies intensify as they approach NEP



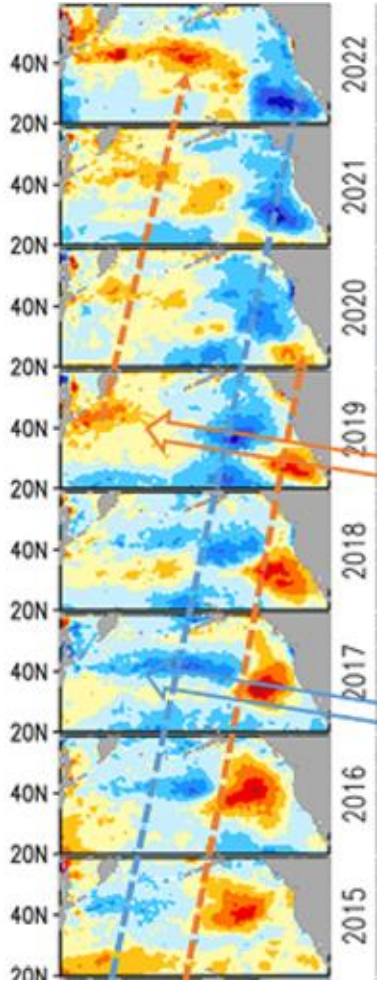
Mean SSH (CMEMS ADT, contours) SSS (Argo, color):
dS/dx<0 along the NPC path



dS/dt = - u dS/dx, S = <S> + S' , u = <u> + u'…

dS'/dt = - <u> dS'/dx - u'<S>/dx

Grodsky et al. 2023



Pacific Decadal Oscillation:

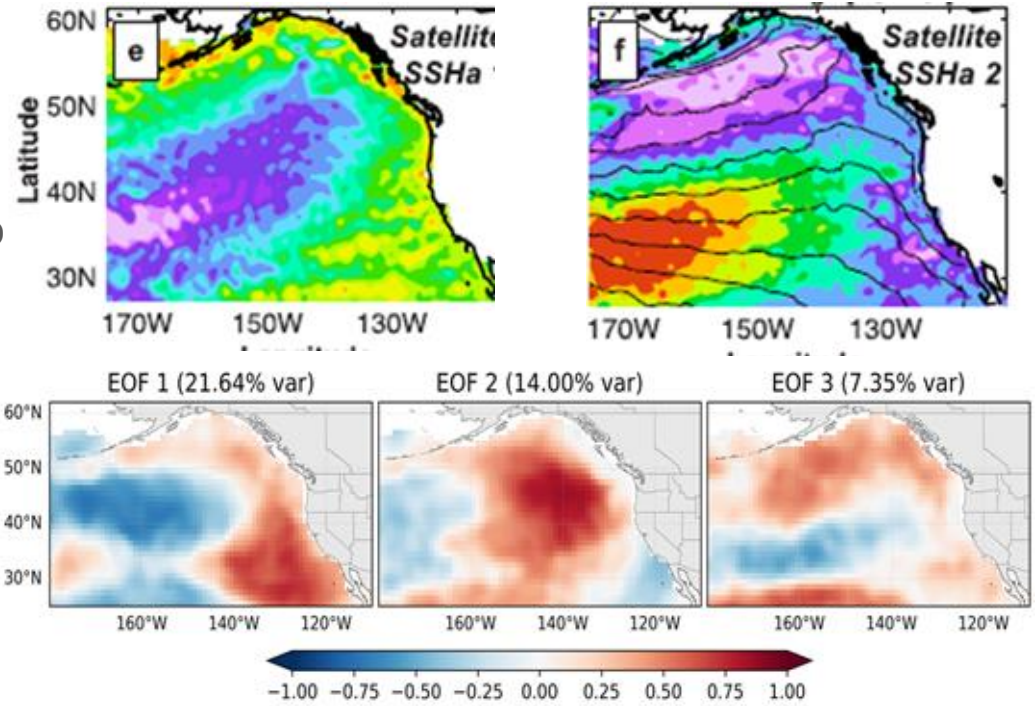
PDO = EOF1 of SSHa

North Pacific Gyre Oscillation (Di Lorenzo et al., 2008):

NPGO = EOF2 of SSHa

SSS EOFs (2004-2024, Argo):

- SSS EOF1: correlates with PDO
- SSS EOF2 and 3: correlate w NPGO
- Freshening 2018-2024 is due to a combination of the negative phases of PDO and NPGO (importance of -u'<S>/dx)



Correlation	PDO PC	NPGO PC
SSSa PC1	0.44	0
SSSa PC2	0	0.49
SSSa PC3	0	0.58

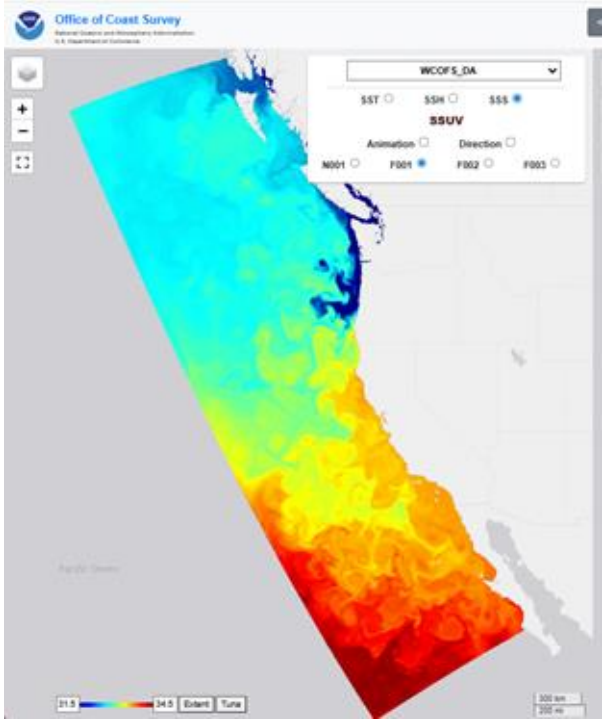
Opportunities for satellite SSS assimilation: explored in the context of the West Coast Ocean Forecast System (WCOFS) [Parisa Heidary]

ROMS 4-km
4DVAR DA (Altimetry, SST, HF radar surface currents 0-200 km from the coast)

Everyday updates of 3-day forecasts

Users and uses: ship routing, fishing operations, search&rescue, oil spill response

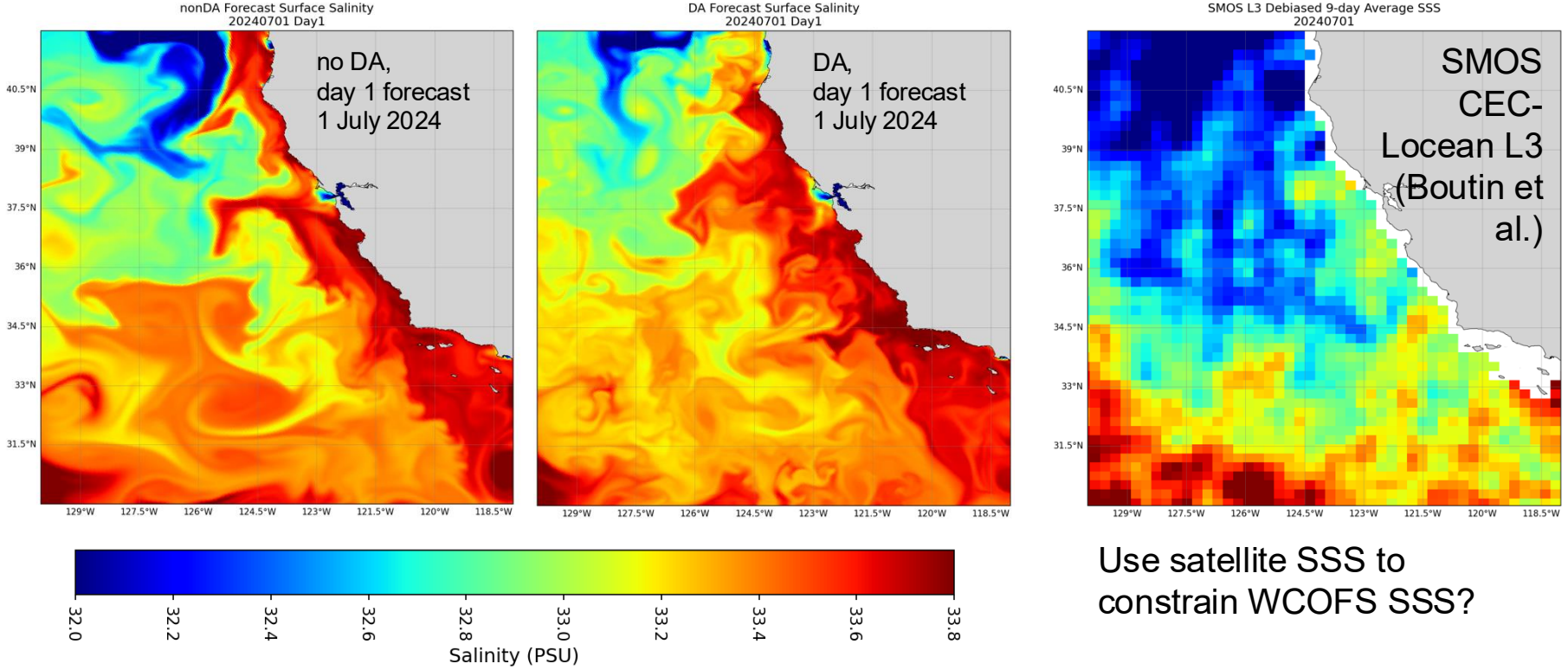
SSS needs: ballast water regulation, fishing (fronts, vertical stratification), SST and SSS is used as inputs to C-HARM harmful algae bloom predictor (Anderson et al.)



https://coastaloceanmodels.noaa.gov/WCOFS/viewer/

A challenge of constraining SSS:

DA (HFR uv + SSH + SST) yields a positive bias in SSS near the coast (a wider upwelling region)
Possibly, due to enhanced horizontal eddy transport of upwelled saltier waters in the DA system

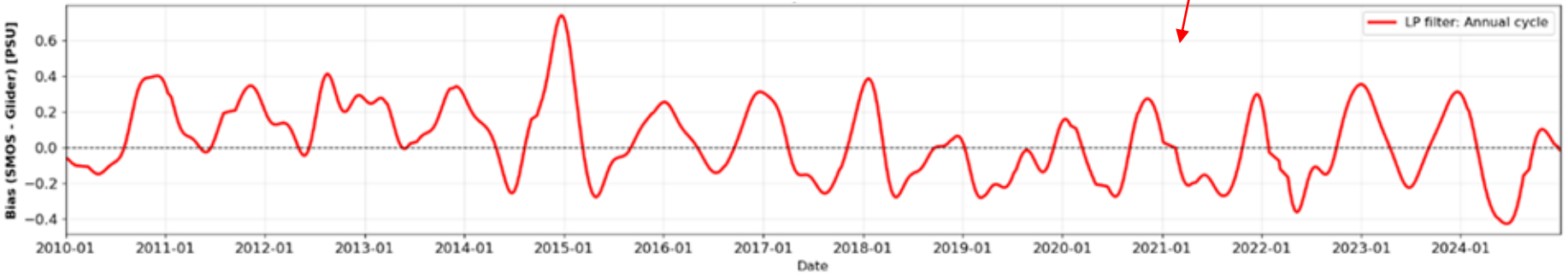


Use satellite SSS to constrain WCOFS SSS?

SMOS SSS CEC L3 minus glider salinity, top bin:

(120 day low pass filter)

=> *Seasonally varying bias*



Concluding remarks:

Useful SSS signal in the coastal transition zone:

- dynamical tracer to understand shelf-interior ocean interactions
- practical uses (freshened water fronts, currents along the front, surface mixed layer, SSS as input for statistical ecological models)

Away from major river plumes, the range of spatial variability is <1 psu

Interannual variability along the coast is as strong as the seasonal cycle (using “nudging to climatology” approach in the operational system would be limiting)

Present efforts to improve SSS in WCOFS:

- in-situ DA (Argo, gliders)
- SMOS assimilation combined with in-situ DA (tools to assimilate sat SSS as time- and area-averaged obs)
- Reduce seasonally varying bias in SMOS?
- “On-the-fly” bias correction in satellite SSS as part of 4DVAR formalism (Moore et al.)