Sea Surface Salinity and Coastal Processes

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Motivations

What sets the coastal ocean apart?

- Larger SSS gradients
- Shorter length scales (often < Rossby radius, *O*(10-100km))
- Shorter time scales
- Upwelling/downwelling along coastlines
- Bathymetric control of circulation and tides
- River-ocean exchange (water, carbon, nutrients)
- Coastal hazards
- Enhanced biological productivity
- People and their many diverse coastal activities

40-60 km SMAP/SMOS/Aquarius left coastal scales & needs largely unmet

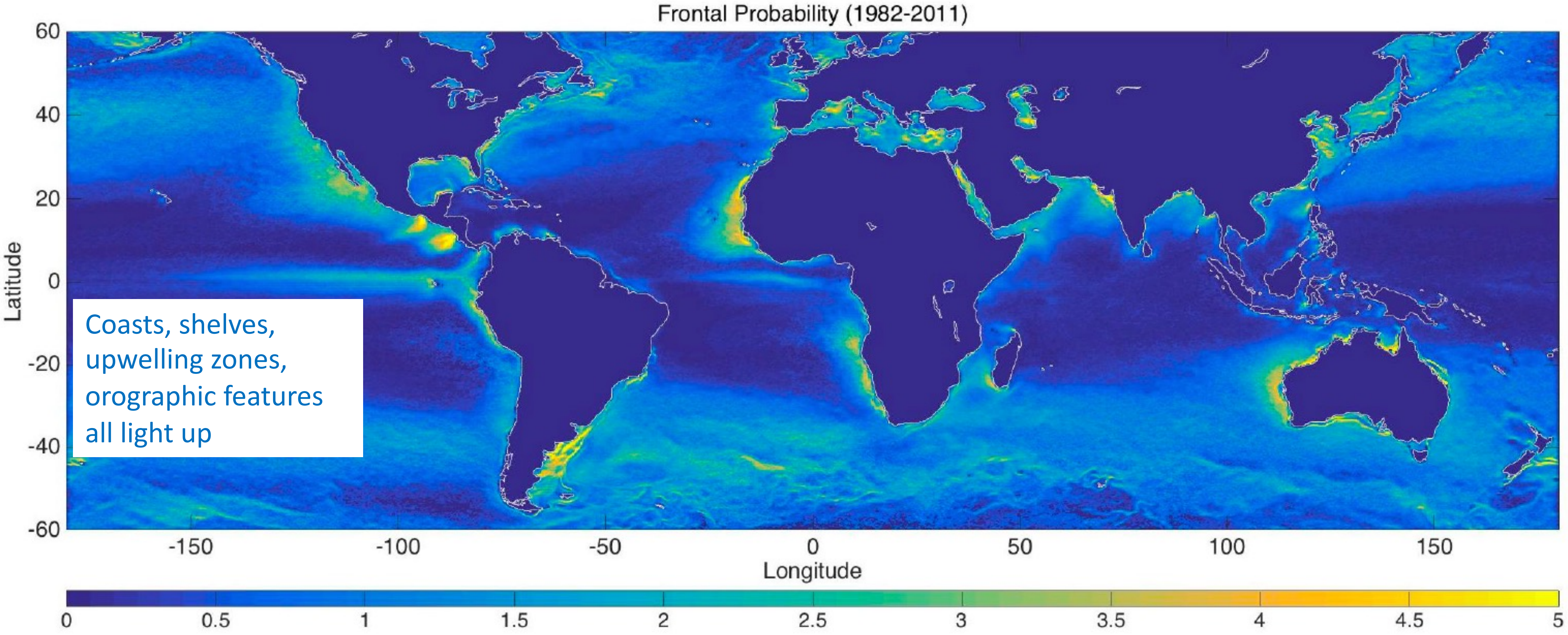
Motivations

Coastal zone satellite salinity data applications are many…

- Harmful Algal Bloom detection and prediction
- Water quality monitoring
- Carbon: Ocean acidification, coastal ocean CO2 fluxes, marine Carbon Dioxide Removal
- Coastal ocean forecasting for commerce/recreation/energy
- Coastal hazard forecasting
- Change due to climate impacts on many coastal concerns
- Fisheries management, biochemistry
- and on….. (see ESA user consultation reports?)

When going to 10 km – how to assess? Try SST

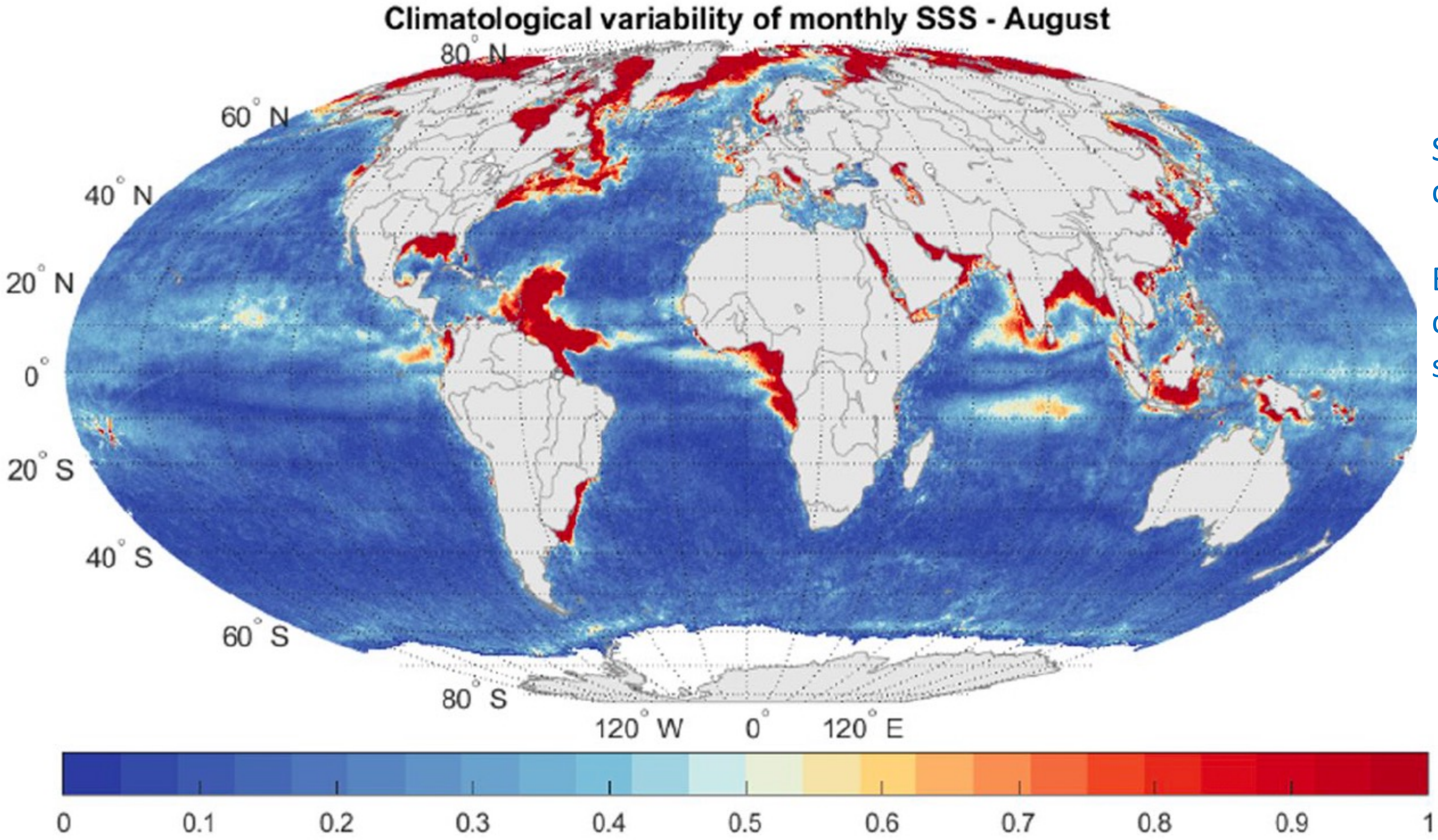
4km SST imagery used to detect persistent ocean fronts of L~25km , Mauzole (2017)



Coasts, shelves, upwelling zones, orographic features all light up

When going to 10 km – how to assess? SSS

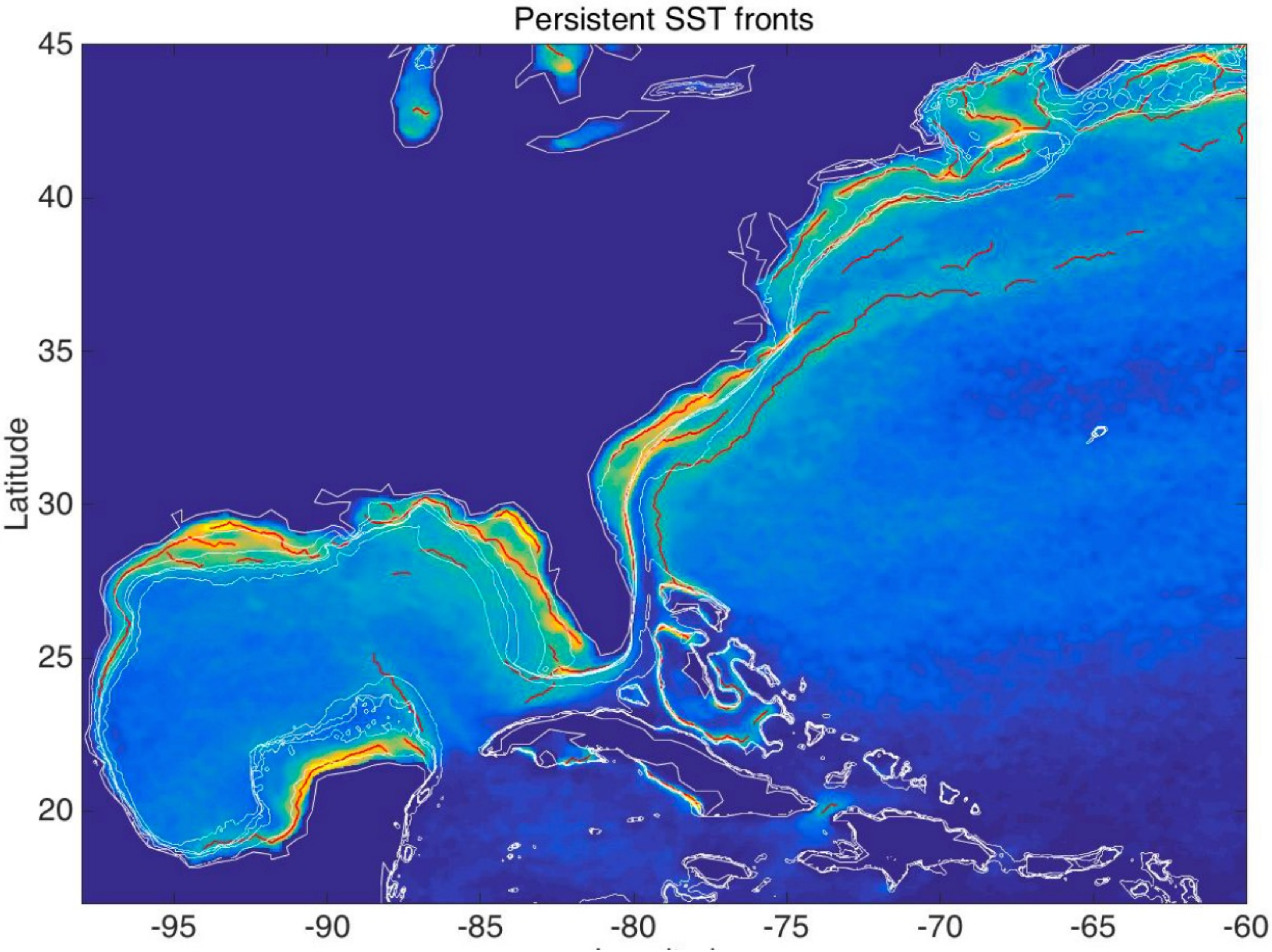
SMAP/SMOS variance map of sea surface salinity, Boutin (2021)



SSS picture is a bit different…

Big rivers dominate in global salinity variance

Some illustrations: 10 km L-band and coastal ocean circulation along US East coast ….



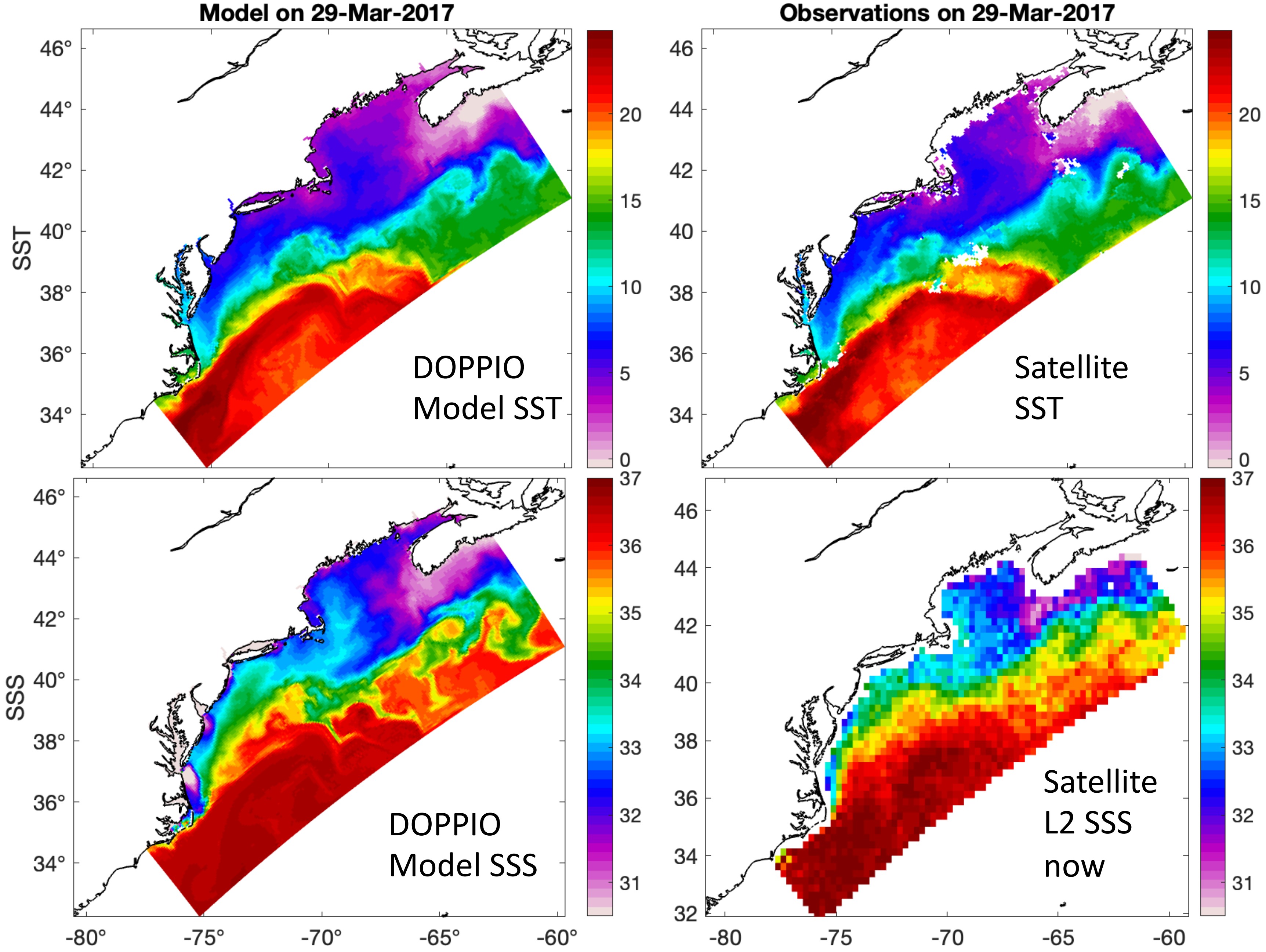
Zoom in on SST fronts along the US east coast

Exchange hotspots near the coast

Advective Currents apparent (Loop and Gulf Stream)

Bathymetry and rivers force much of the dynamics

Some illustrations: 10 km L-band and coastal ocean circulation along US East coast ….



ROMS regional DOPPIO data assimilating model results

What may be gained with 10 km (all weather) ?

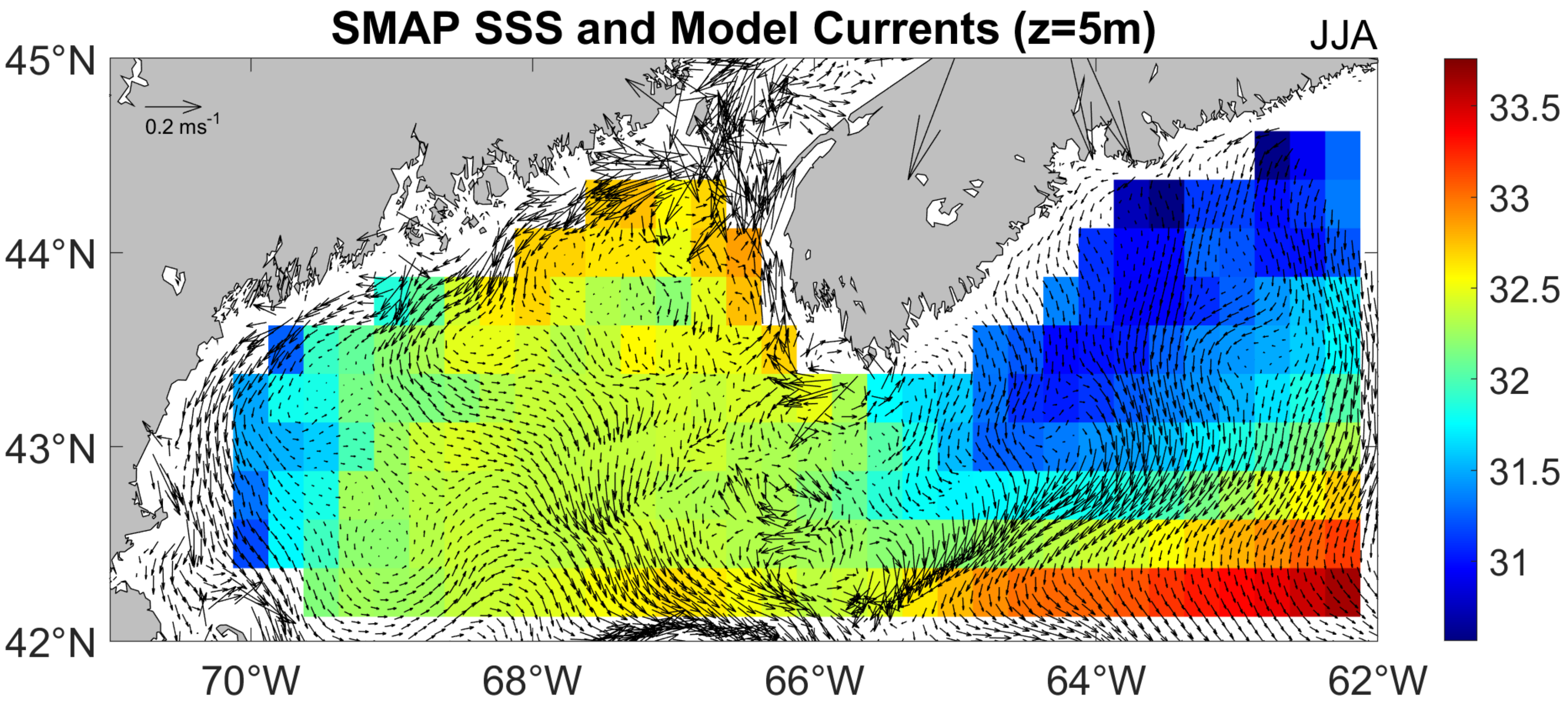
River/Estuary exchanges (Hudson, Delaware Bay, Chesapeake)

Shelf Break frontal interactions, vertical exchange

Shelf sea water mass advection

Model data assimilation will improve dramatically with higher SSS resolution

Some illustrations: 10 km L-band and coastal ocean circulation along US East coast ….



Gulf of Maine and Scotian Shelf area – coastal advection processes and freshwater fluxes

Freshwater flux coming from Nova Scotian shelf)(31 PSU)

Note the strong coastal current along coastal Maine region – mostly unresolved with SMAP

Same for Shelf Break frontal interactions at 42N 64-66W

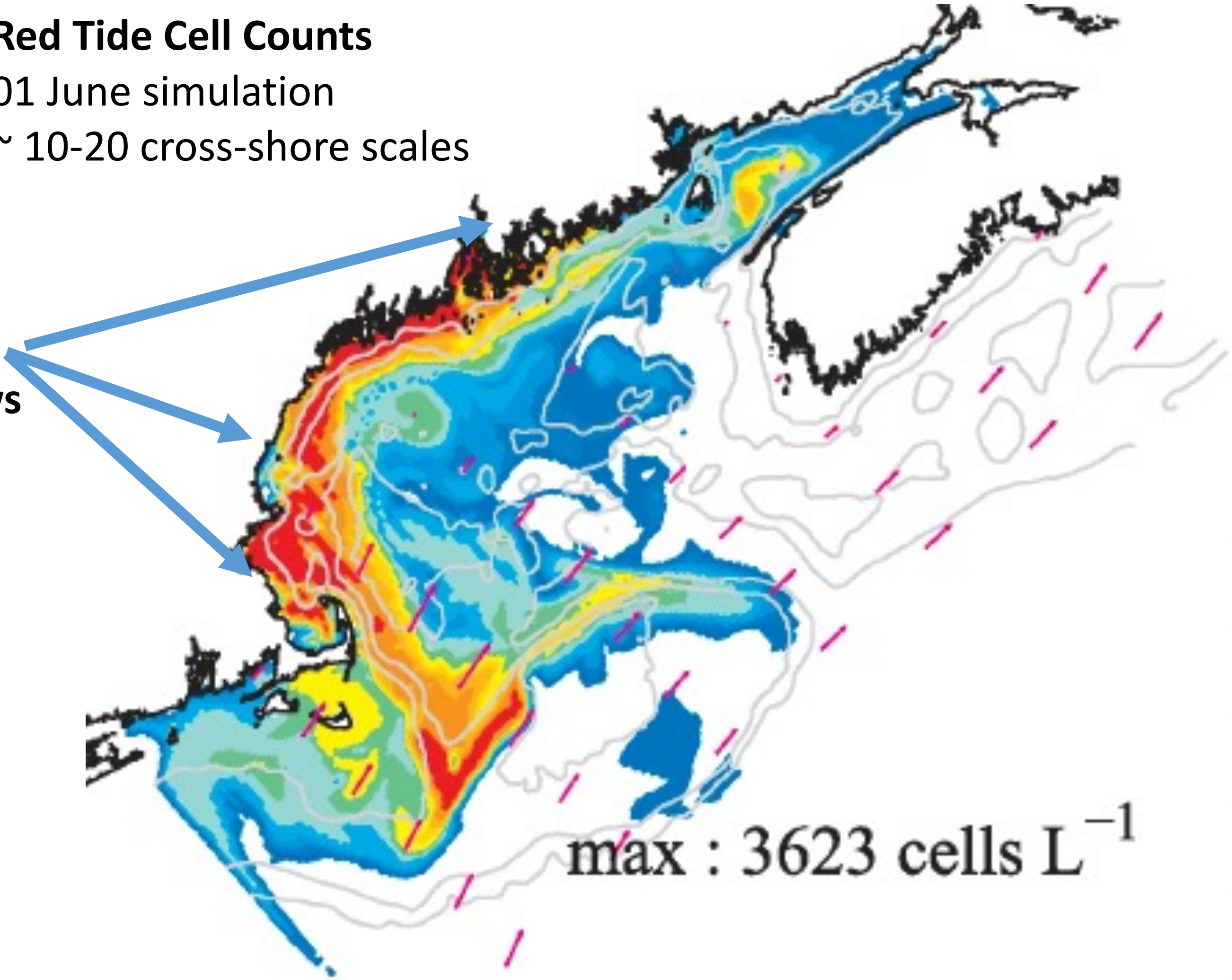
20 km

Clear SMAP SSS limits and mismatch in both resolution and near coastal coverage where advection/mixing/river inputs occur…

10 km L-band and coastal ocean circulation along US East coast ….

Maine Coastal Current
Red Tide Cell Counts
01 June simulation
~ 10-20 cross-shore scales

Three river inflows



Harmful Algal Bloom Detection and Forecasting

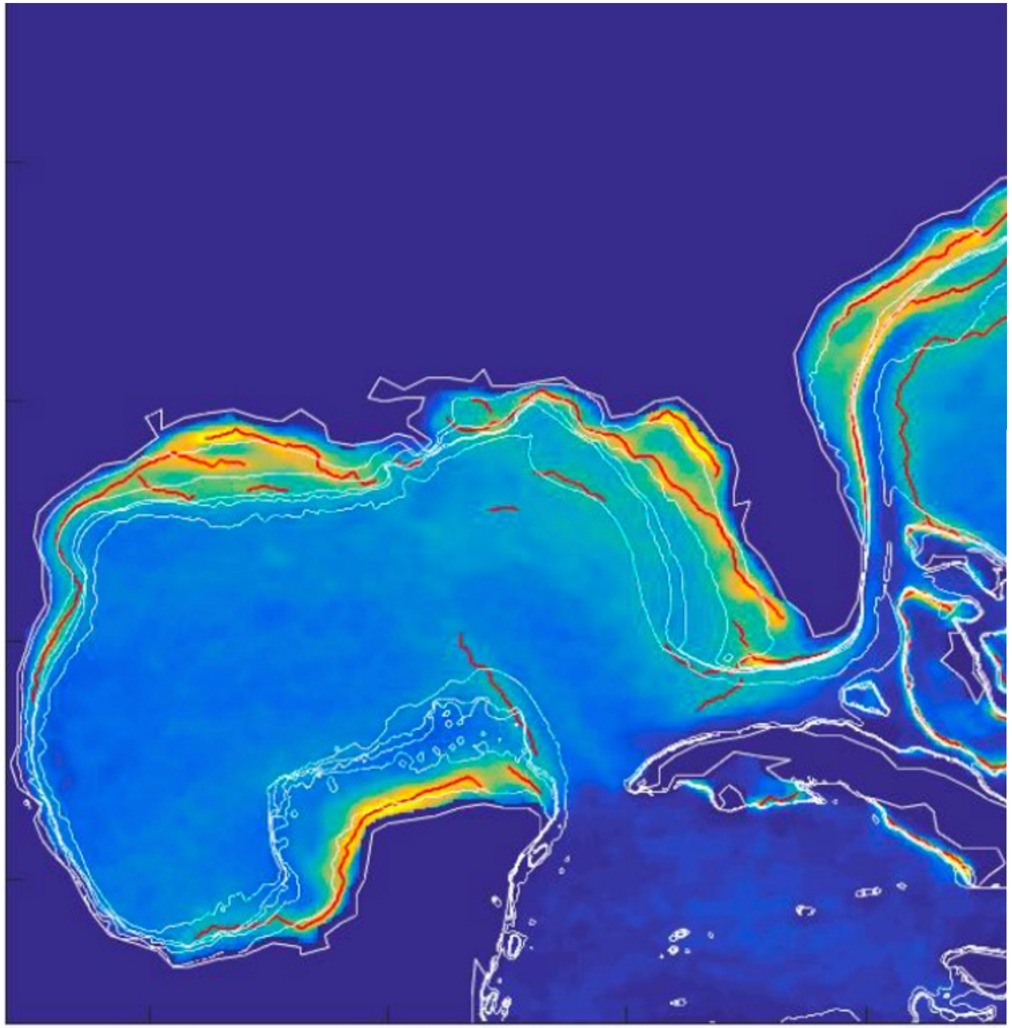
Gulf of Maine red tide cell prediction in summer are routinely tied 10-30 km variability in coastal currents tied to winds and run-off

Similar HABS monitoring programs in many US coastal regions

Surface salinity is a missing state variable along the coasts and 10 km would

McGillicuddy et al. (2010)

10 km L-band and coastal ocean circulation along US East coast ….



A good example combining land water and ocean water observations over the summer season in Gulf of Mexico (Fournier et al., 2016)

All weather SSS and SST at 10 km would allow finer scale coastal Gulf of Mexico land-ocean interaction studies

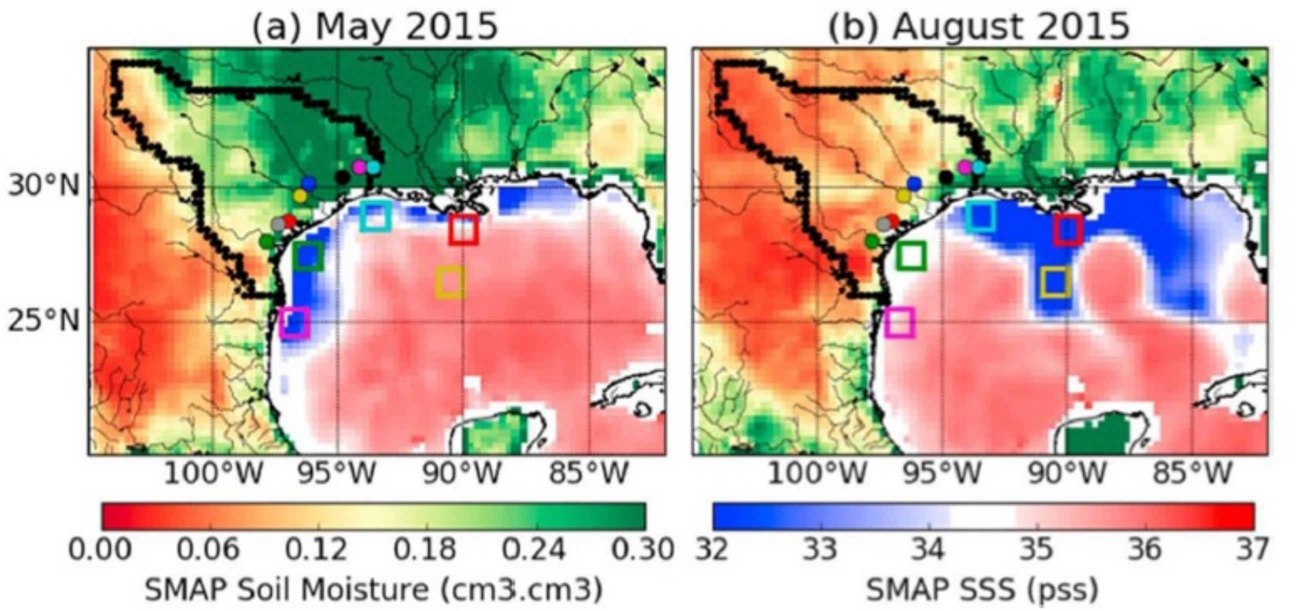
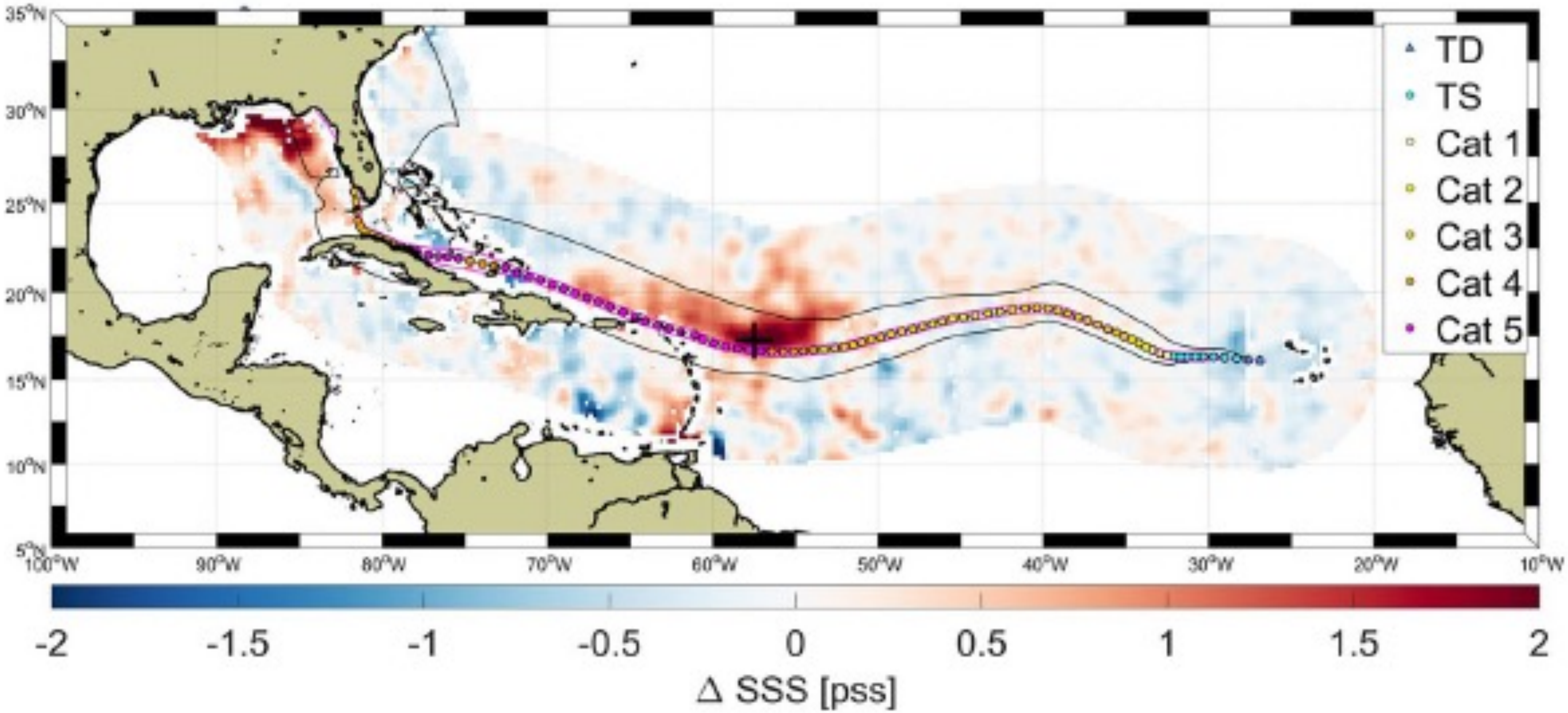


Fig. 2 SSS in the Gulf of Mexico and SM around the Gulf in May (**a**) and August (**b**) 2015 from the SMAP satellite. Adopted from Fournier et al. (2016b). The difference in the pattern of SSS and SM between these two months shows the impact of the severe storm over Texas in May 2015 on SM as well as SSS off the Texas shelf, which subsequently evolved into an unusual and large freshwater plume in the central part of the Gulf

Tropical Cyclones and upwelled salinity wakes as they interact with islands and coastal zone… (IRMA, Sept 2017).

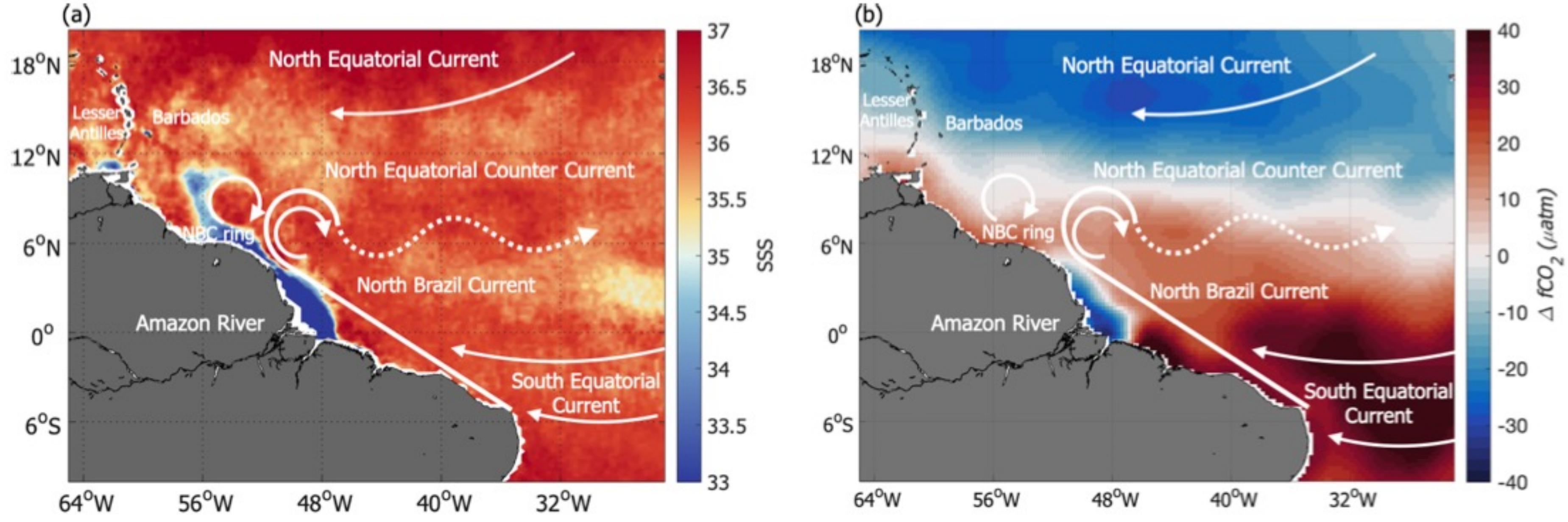
Enhanced resolution L-band data would impact several forecasts (wind/ocean) and impact assessments



Reul N, Chapron B, Grodsky SA, Guimbard S, Kudryavtsev V, Foltz GR, Balaguru K (2021) Satellite observations of the sea surface salinity response to tropical cyclones. Geophys Res Lett 48(1):e2020GL091478. https:// doi. org/ 10. 1029/ 2020G L0914 78

10 km L-band andcoastal carbon/biochemistry/ocean color…

Amazon/ North Brazil Current Examples… 10 km L-band and rivers plumes, coastal productivity, and CO2 fluxes



Olivier et al. (2022)

Amazon shelf study at larger 100 km scale of CO2 air-sea flux in and outside of Amazon river outflow impacts

But missing all the dominant near coast Chlorophyll and its exchange seen in SST and Ocean Color data

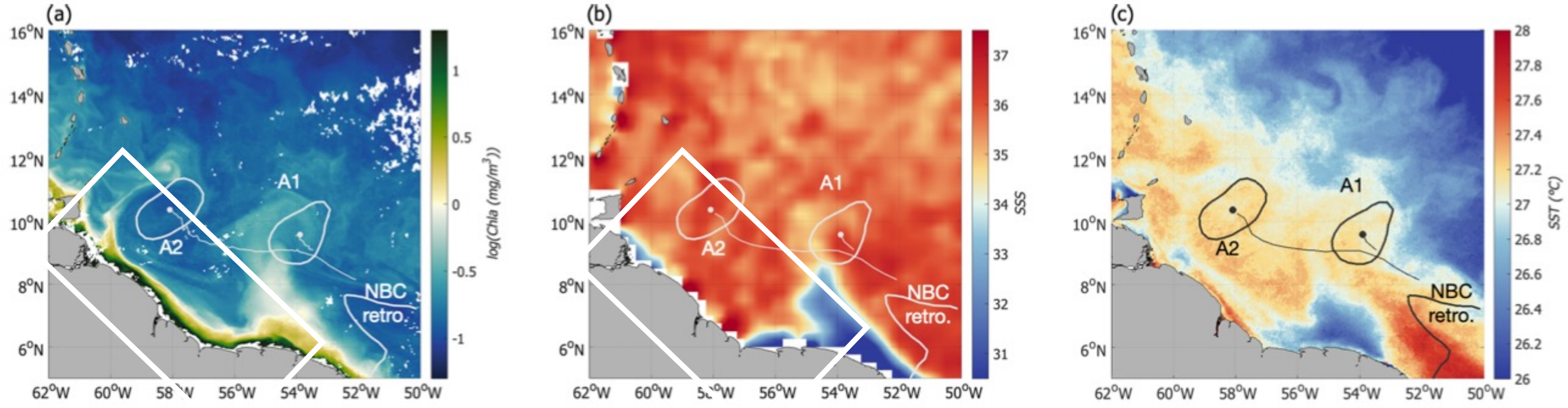


Figure 3. **(a)** Chlorophyll *a*, **(b)** SSS and **(c)** SST on 6 February 2020 with the contours of NBC rings A1 and A2, their centre, and their trajectory. The NBC retroflection is identified from the 0.51 m contour of the satellite-derived ADT.

Desired coastal salinity at scales of 10 km…

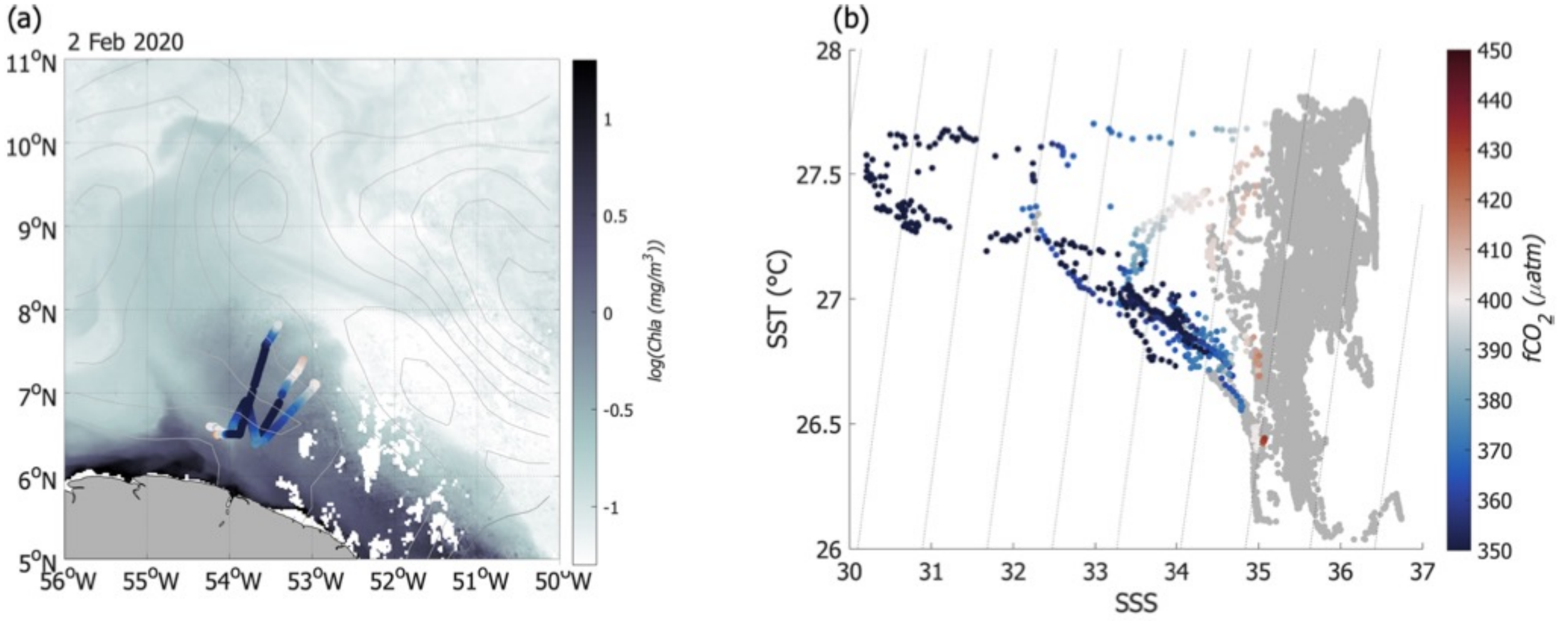


Figure 8. (a) RVs *Atalante* and *Merian* ship tracks in the freshwater plume (*Atalante*: 2 and 5 February; *Merian*: 2 February) colour-coded with fCO_2. The background represents the chl *a* on 2 February. **(b)** Corresponding T–S diagram colour-coded with fCO_2.

10 km should allow enhanced synergy with ocean color in many coastal ocean shelf seas and river plume regions… carbon and sediment dispersal – Amazon example here…

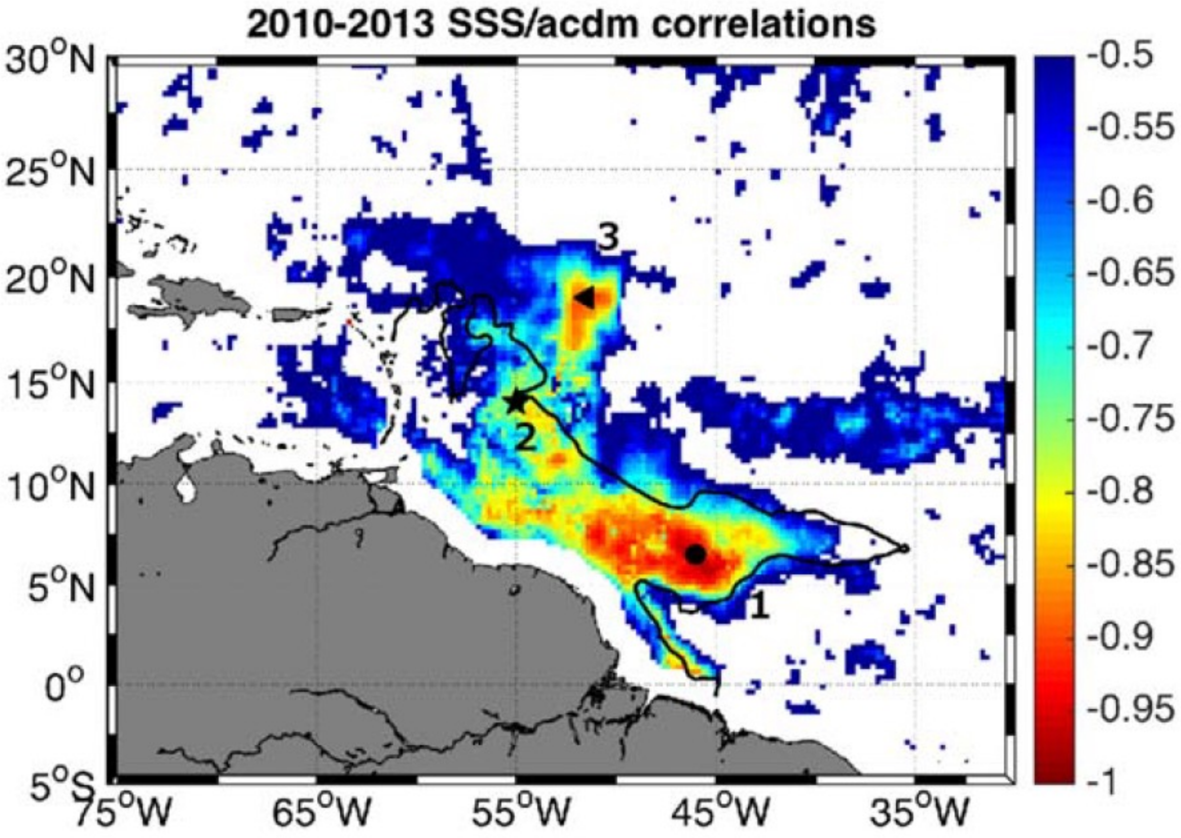
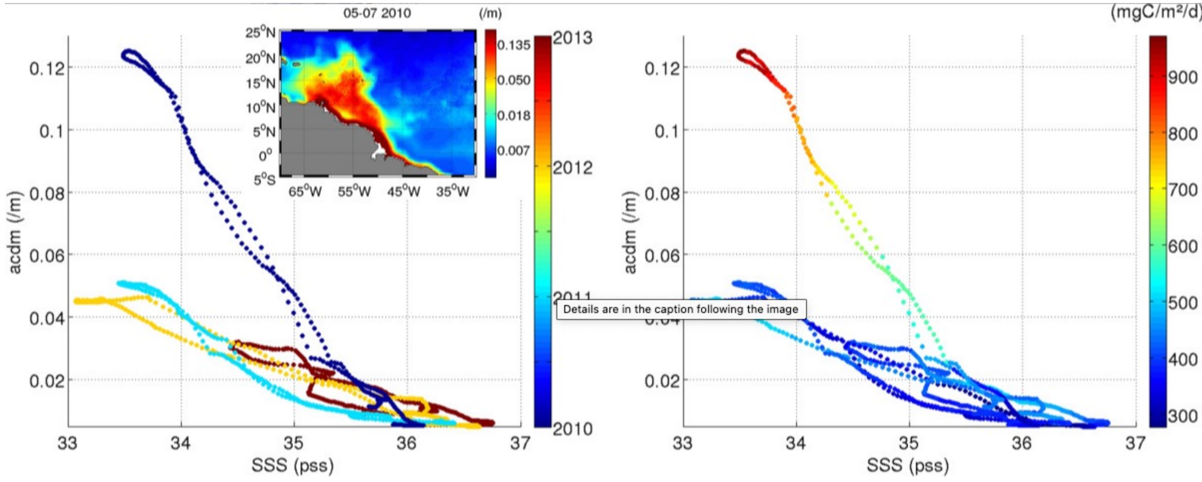


Figure 2. Correlation between daily ±5 days SMOS SSS and a_{cdm} for each 0.25 × 0.25° pixel. Only *p*-values (significance of the correlation) below 0.01 are shown. The square, pentagram, and triangle (labeled 1, 2, and 3) are representing the pixels with coordinates: [6.5°N 46°W], [14°N 55°W], and [19°N 51.5°W], respectively. The black thick line is the average location of the plume delimited by the 35.5 pss contour.

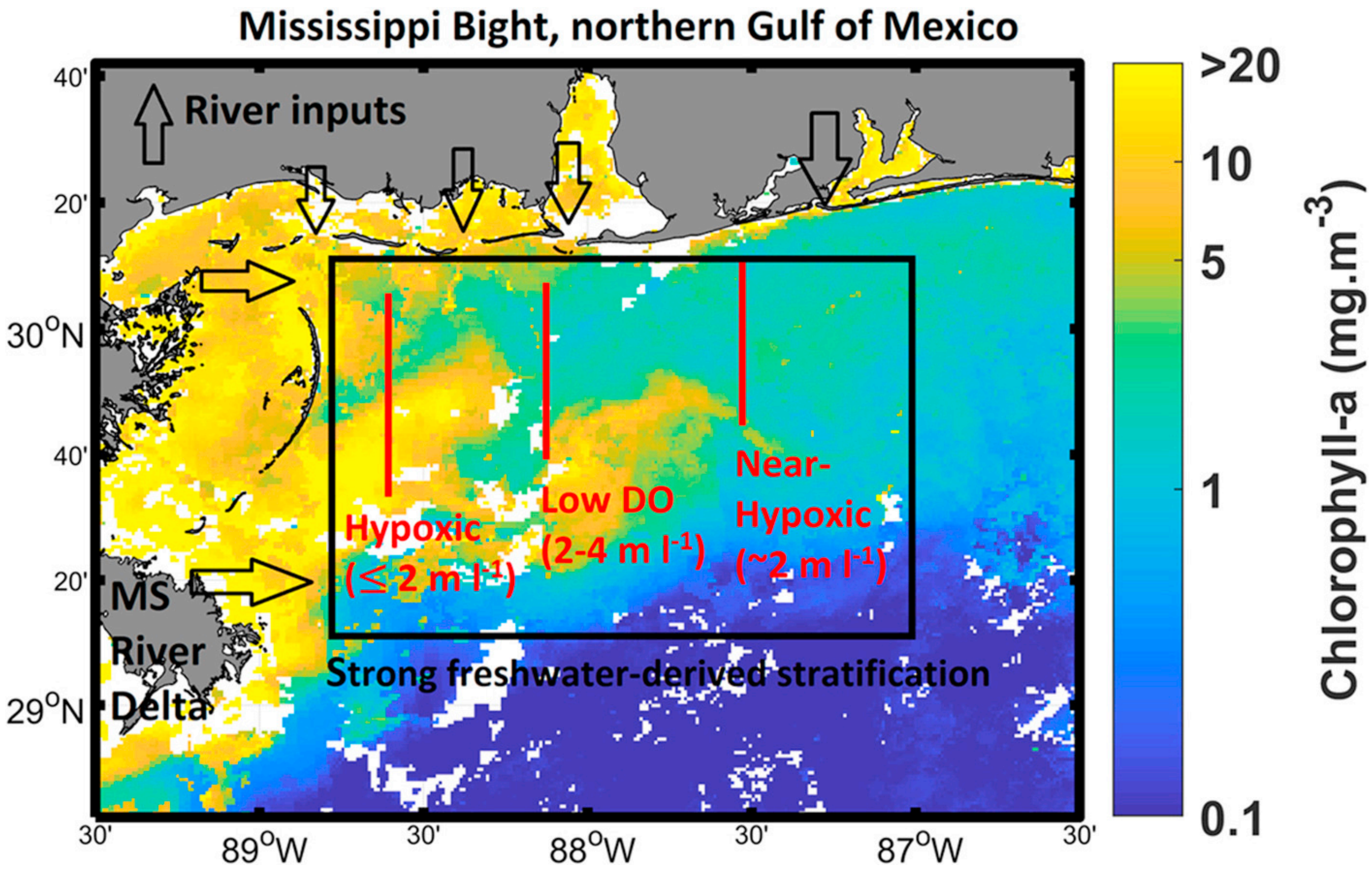
Recall Fournier et al. 2015 work with MODIS CDOM and salinity

New input potential for ocean ecosystem models…

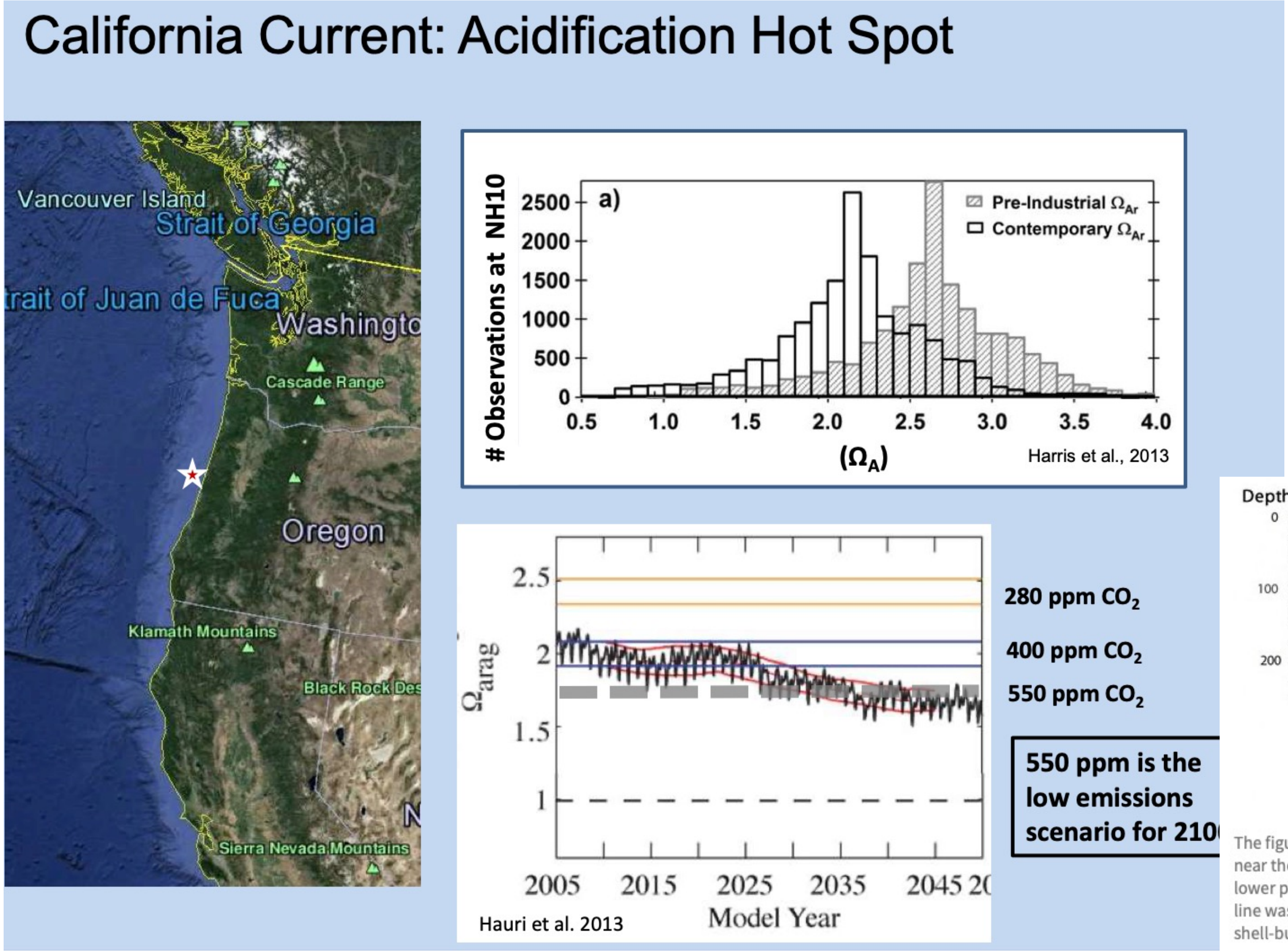
Note the missing coastal zone gaps > 100 km



Mississippi example… Desired all weather salinity scales in plume at < 25 km…

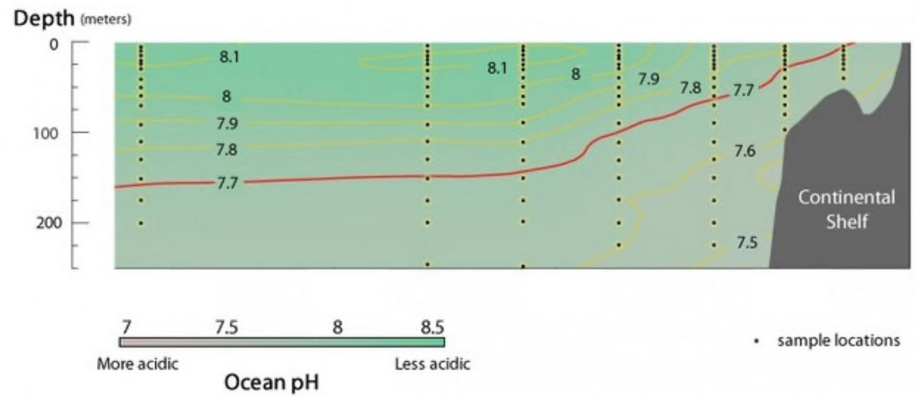


10 km L-band and coastal ocean acidification issues – NW Pacific Coast upwelling zones



Small scale ocean upwelling zones along numerous coasts are under intense study to assess present and future ecosystem responses to changing upper ocean carbonate levels

Resolving salinity and temperature at 10-20 km scales is required…



The figure provides a look at the pH of the water sampled at different depths along transect line 5 near the border of Oregon and California. The water upwelling onto the continental shelf recorded lower pH levels than water samples collected farther away from the shelf. The water below the red line was undersaturated with respect to aragonite, a common type of calcium carbonate used in shell-building.

10 km L-band coastal zone salinity - synergy with other missions should be direct

Coastal zone ‘all cloud conditions’ 10 km L-band data should open many new opportunities:

- With SST and ocean color – COINCIDENCE IS KEY (CIMR+)
- Resolving upwelling and coastal jets/currents
- NISAR, SWOT, VIS/Ocean Color, Geostationary – land-ocean interactions (carbon exchanges, run-off assessments)
- Look at recent coastal zone ocean color satellite application team efforts (PACE and GLIMR) + ESA CIMR groundwork
- Coastal hazards, TC cyclone impacts near coasts

Few questions…

Will quasi-coincident 'all weather' SST and SSS daily data at 10 km lead to shift in coastal and land-ocean exchange understanding? Is the coincidence required - and with ocean color or other data?

Is 10 km resolution high enough in the coastal zone where VIS observations and models are pushing 1-2 km - and many processes and scales sit inside of 10 km?

Are the observations required right next to the coasts or can we live with some land contamination masking?