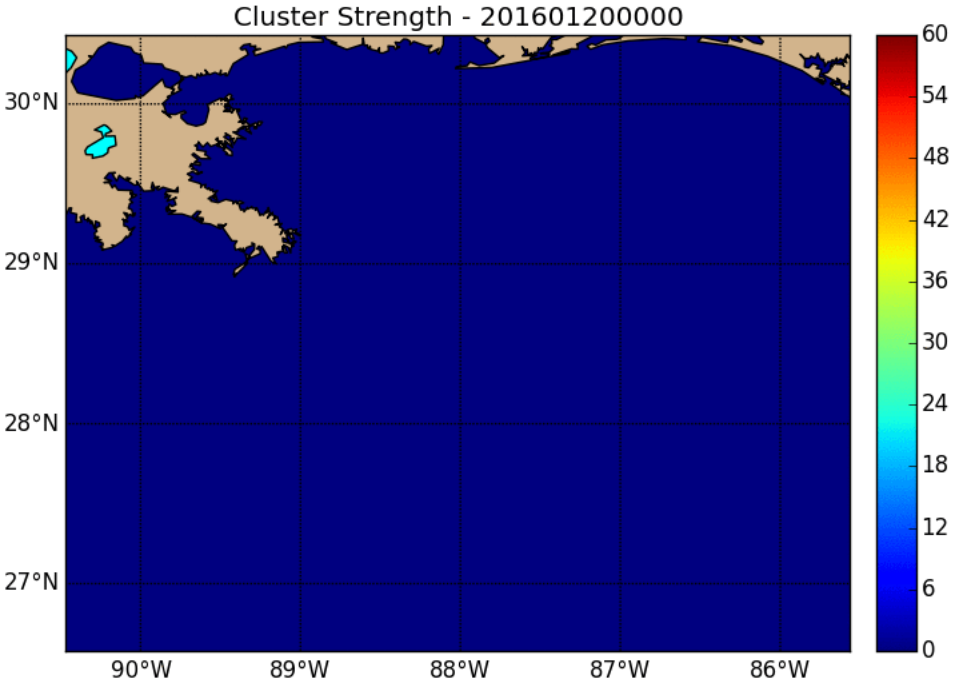
Modeling, data assimilation and adaptive sampling in CARTHE

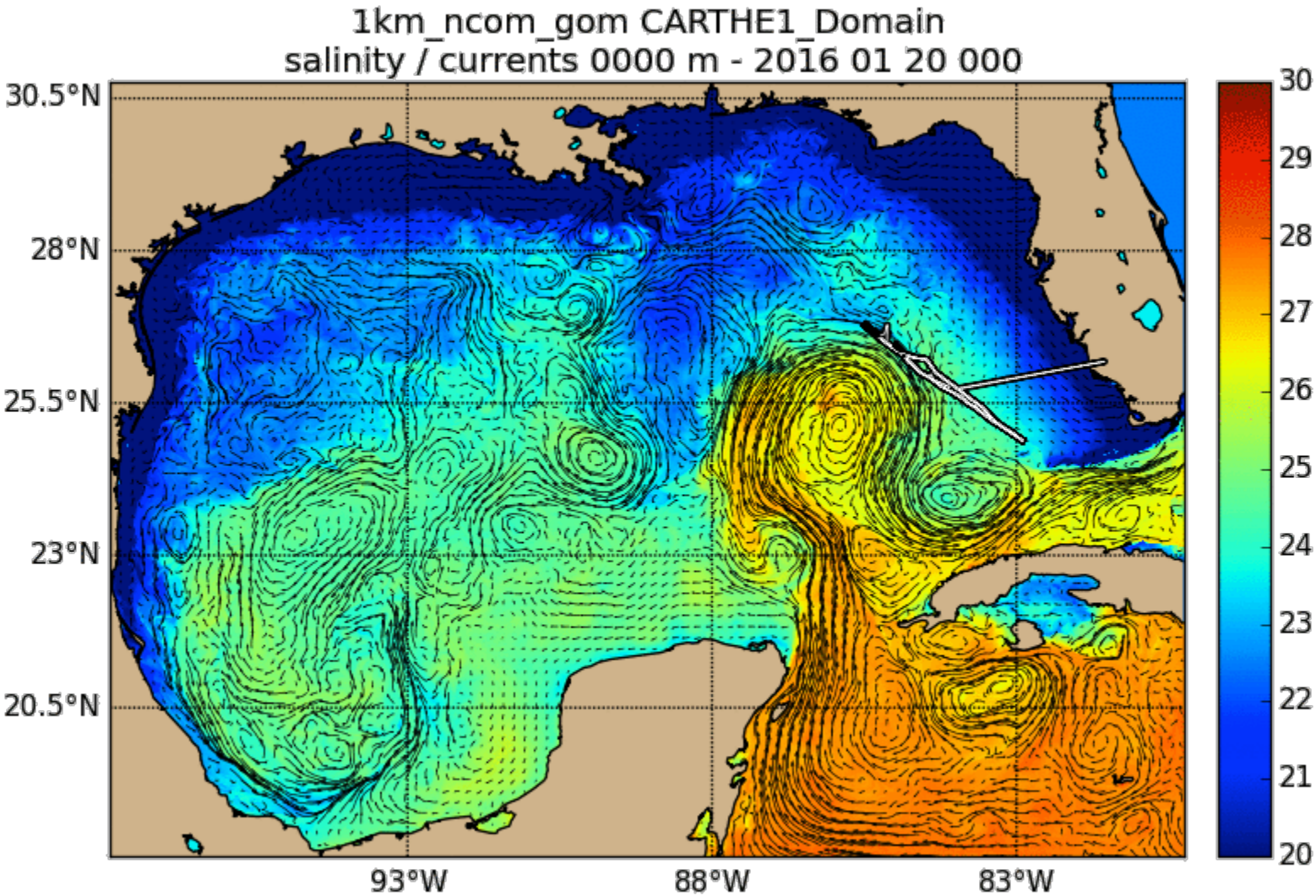
Reference	Resolution	Vertical layers	Assimilation	Rivers	Atmosphere
1km dly	1 km	50	3DVar altimeter, SST, in situ T&S	Observed	COAMPS hourly
1km clm	1 km	50	3DVar altimeter, SST, in situ T&S	Climatology	COAMPS hourly
250m	250 m	35	3DVar altimeter, SST	Climatology	COAMPS hourly
4DVar	3 km	50	4DVar altimeter, SST, drifters	Climatology	COAMPS hourly

Matt Carrier, Hans Ngodock, Travis Smith, Pete Spence, Brent Bartels

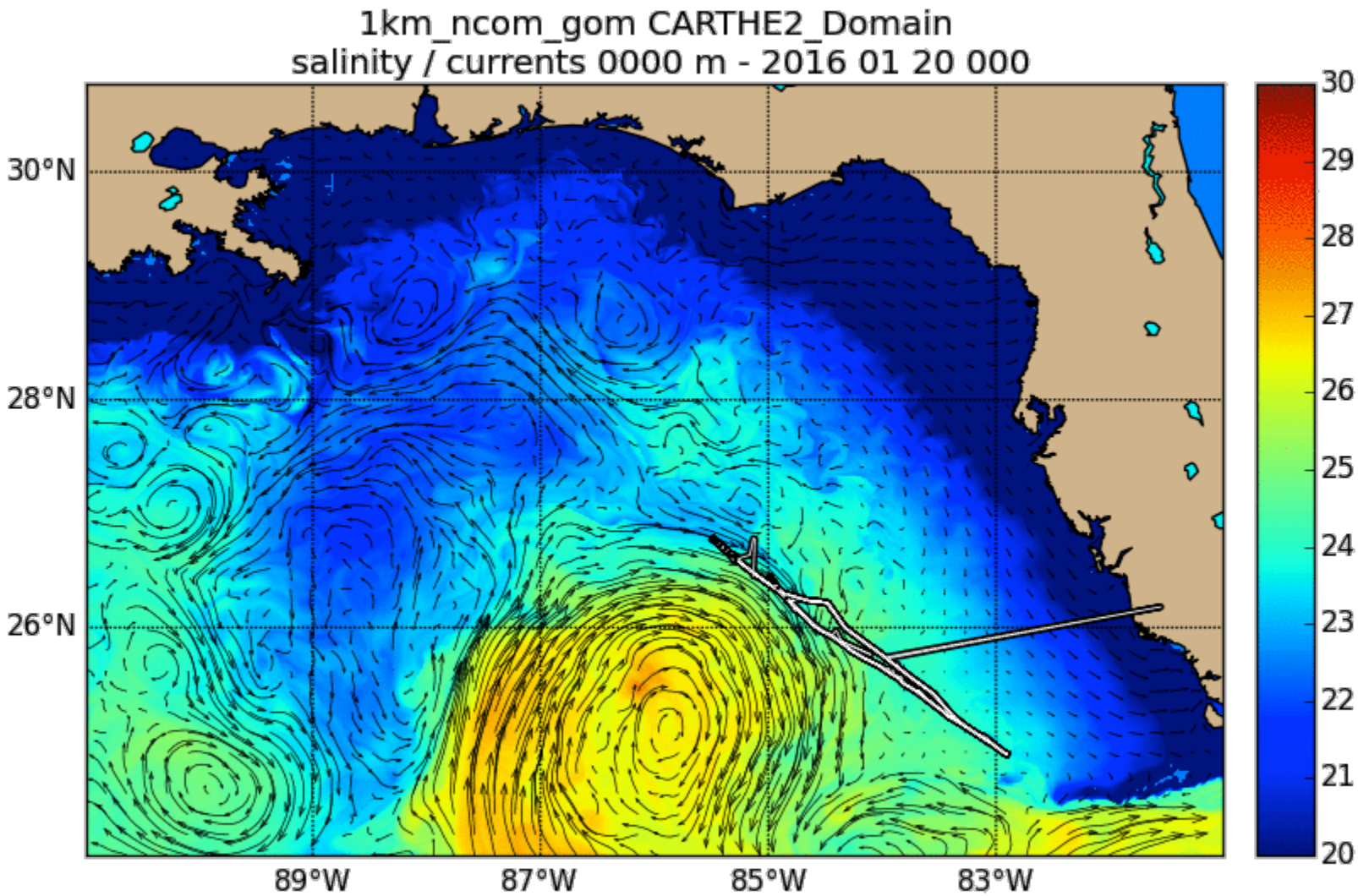
- Major features are synoptically represented (> 100 km scale)
- Submesoscale features are the challenge (< 100 km scale)
- Hydrology significantly impacts ocean surface currents



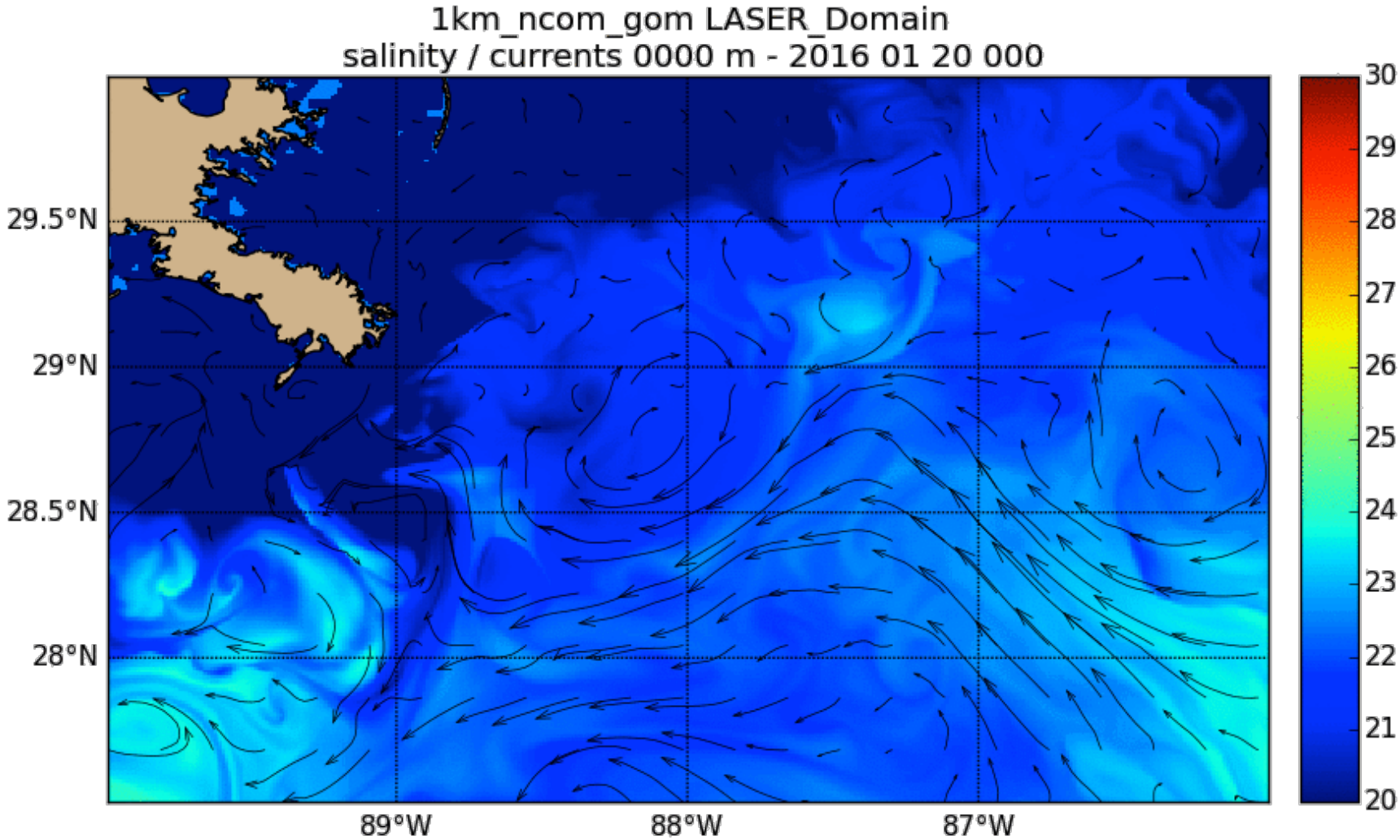
1 km dly – The big scale

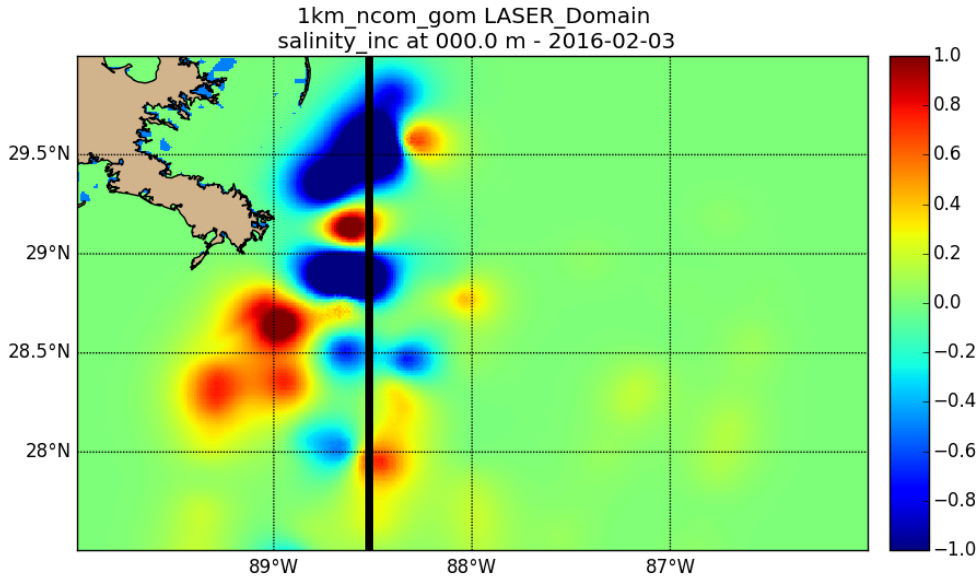


1 km dly – The medium scale

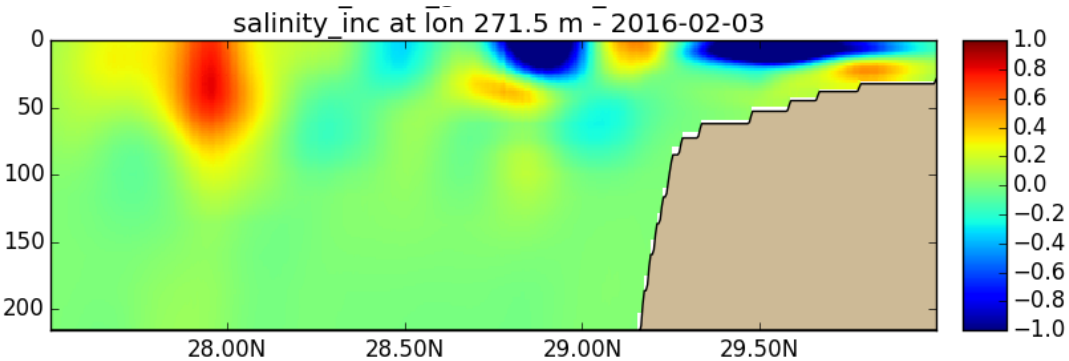


1 km dly – The small scale

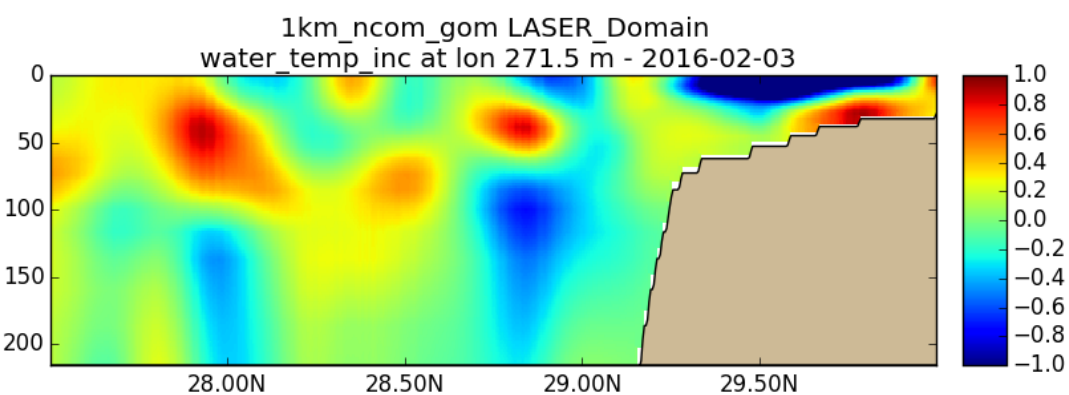




Surface salinity increments given satellite and in situ observations



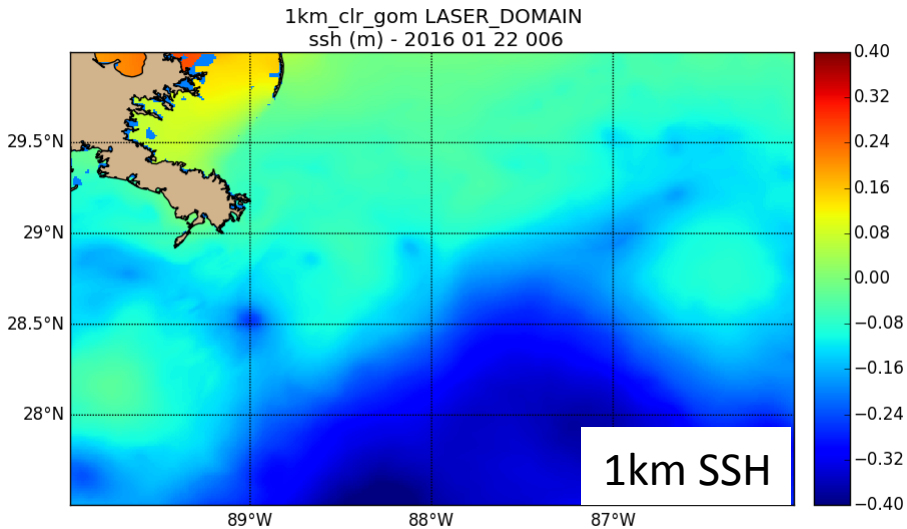
Salinity increments along transect at 88.5°W



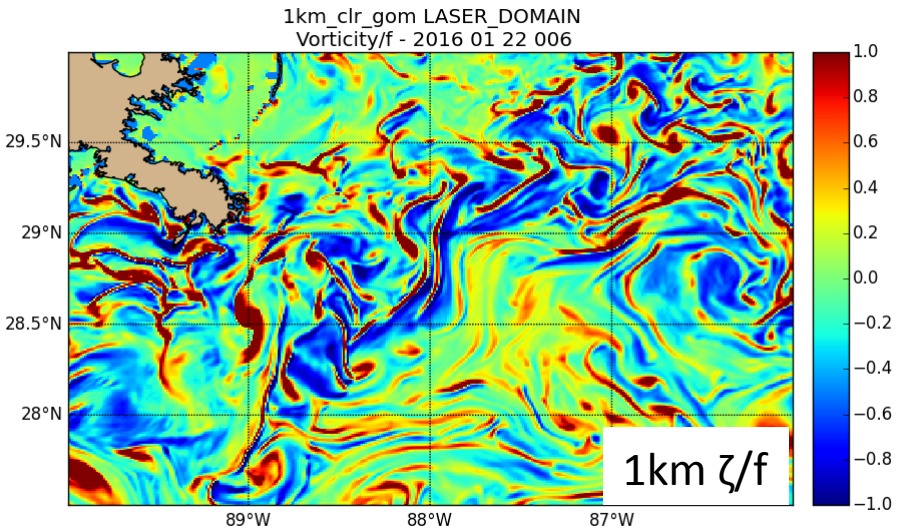
Temperature increments along transect at 88.5°W

Reinforcing the point

SSH – Jan 22

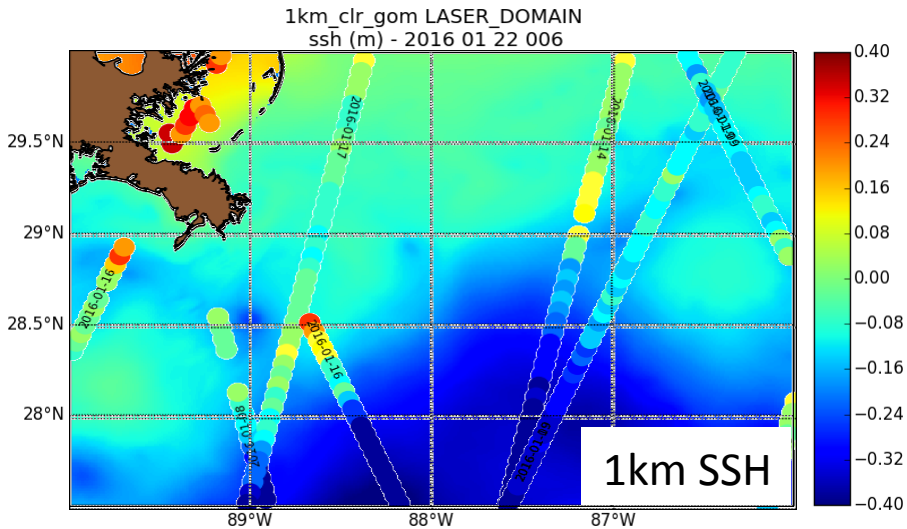


Relative Vorticity

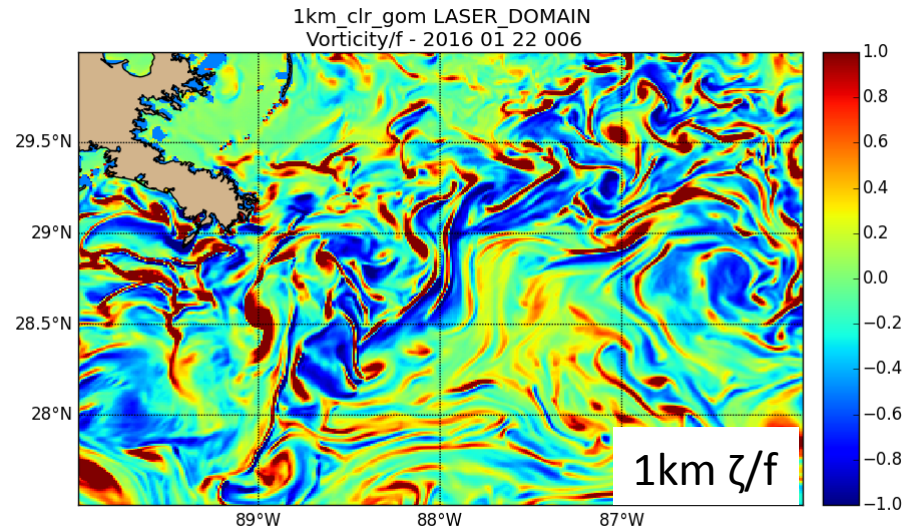


Reinforcing the point

SSH – Jan 22



Relative Vorticity



Most recent 10 days of altimeter SSHA overlaid on model SSH on Jan 19, 06 GMT

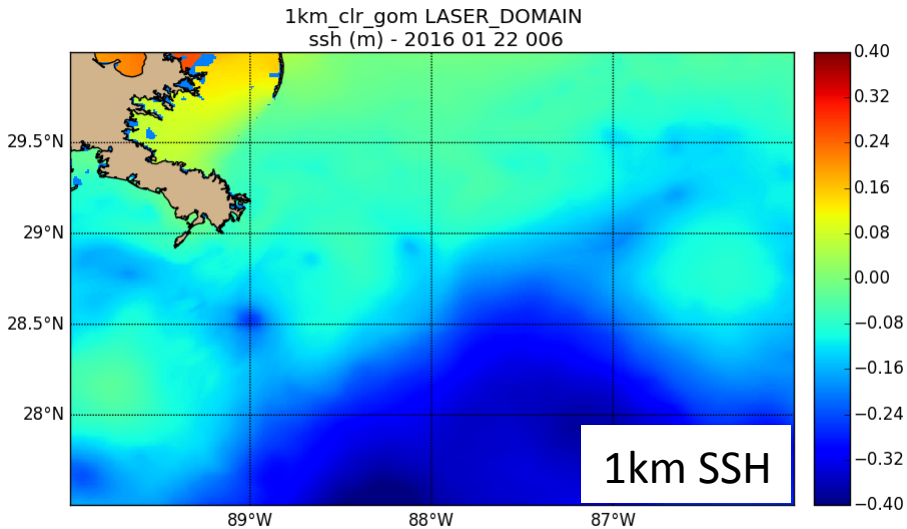
Most recent tracks are Jan 19 (3 days prior)

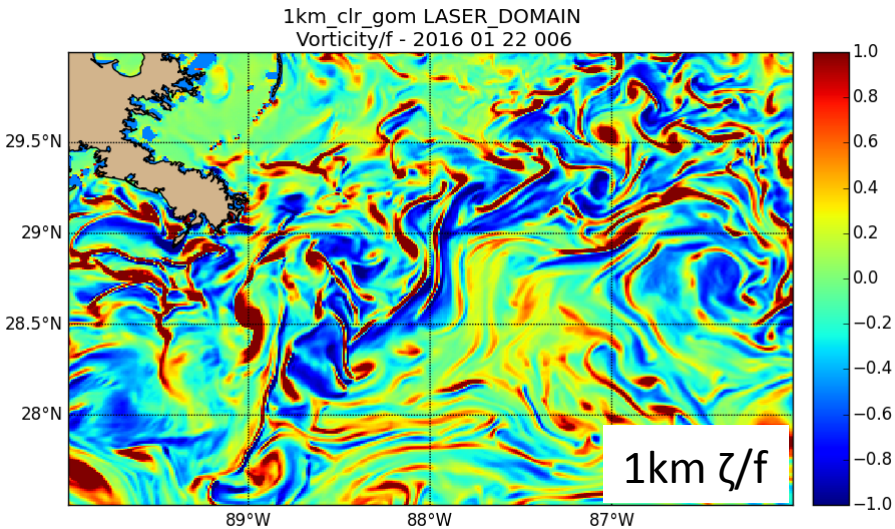
CryoSat-2 did not cover the area during these 10 days

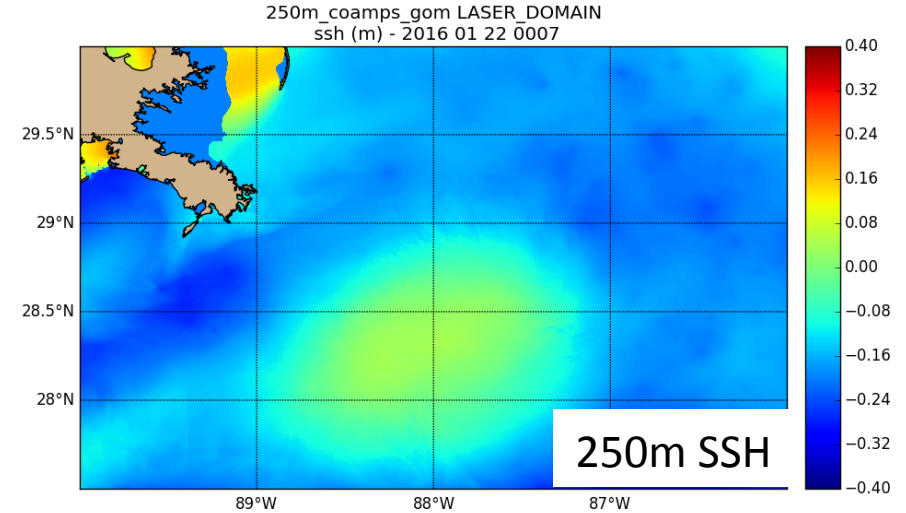
Reinforcing the point

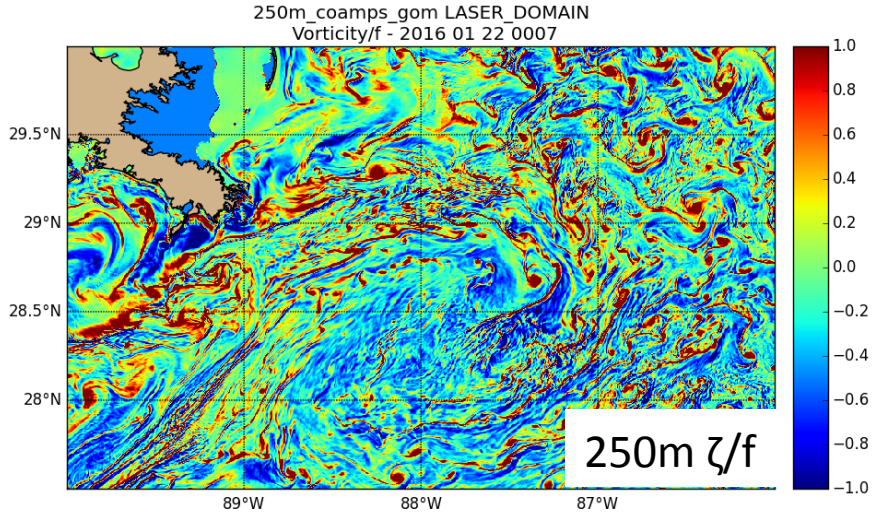
SSH – Jan 22

Relative Vorticity





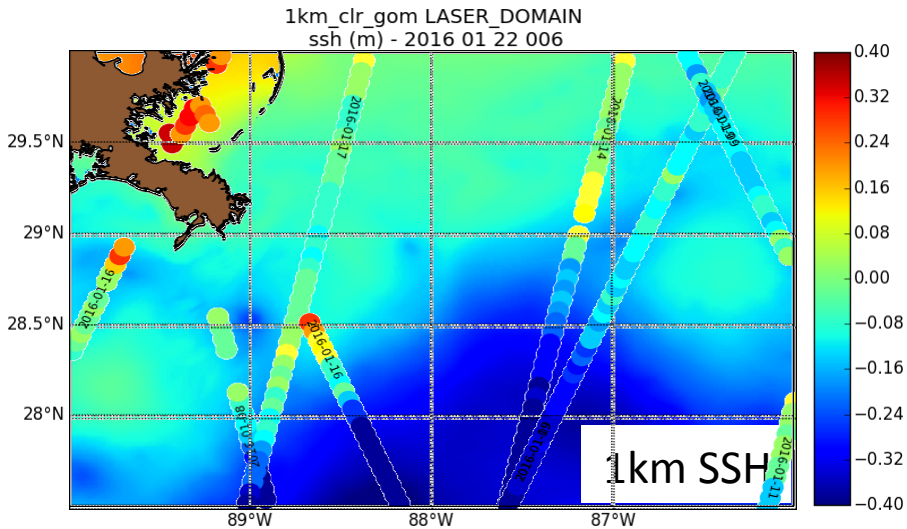


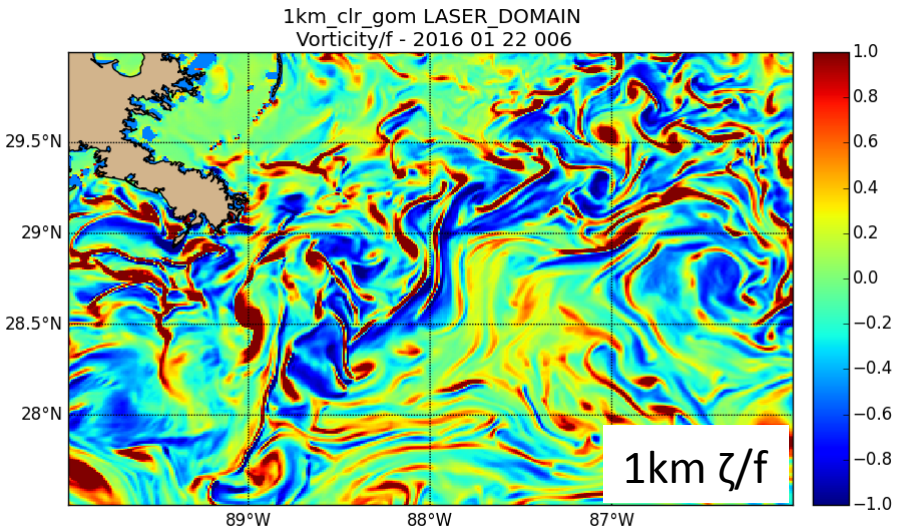


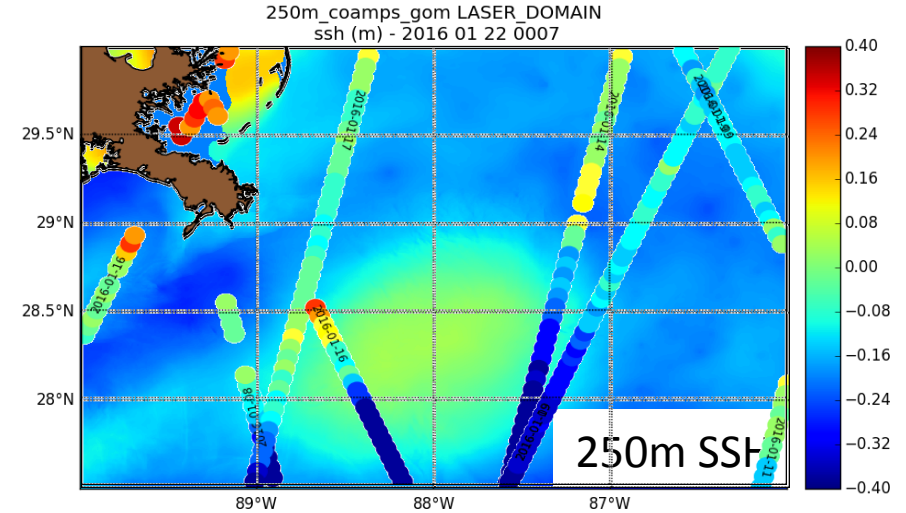
Reinforcing the point

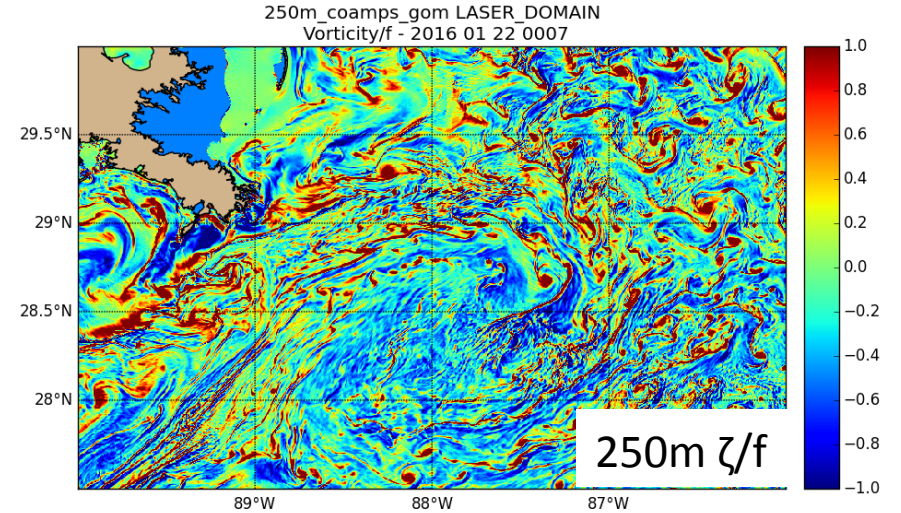
SSH – Jan 22

Relative Vorticity





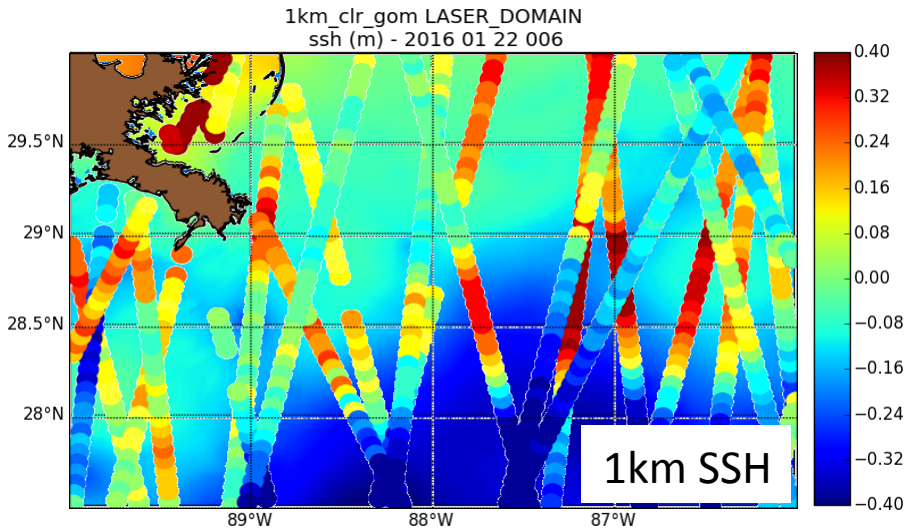


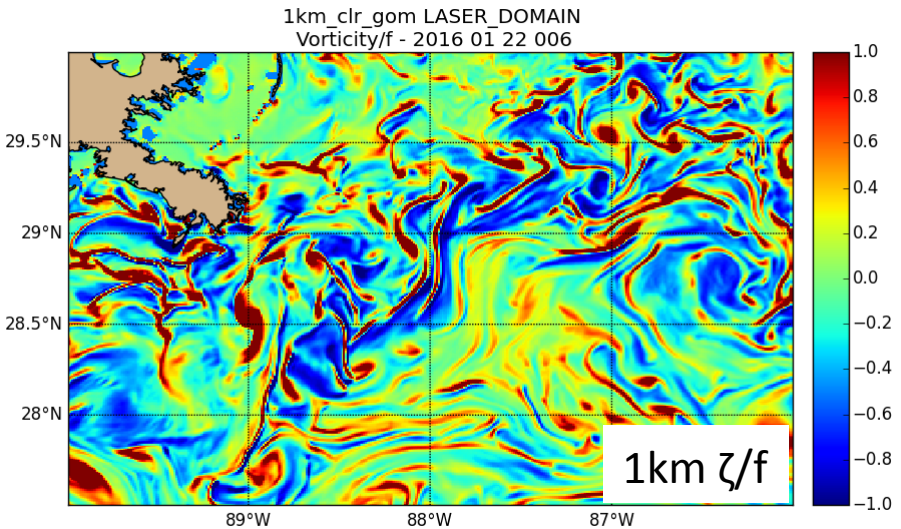


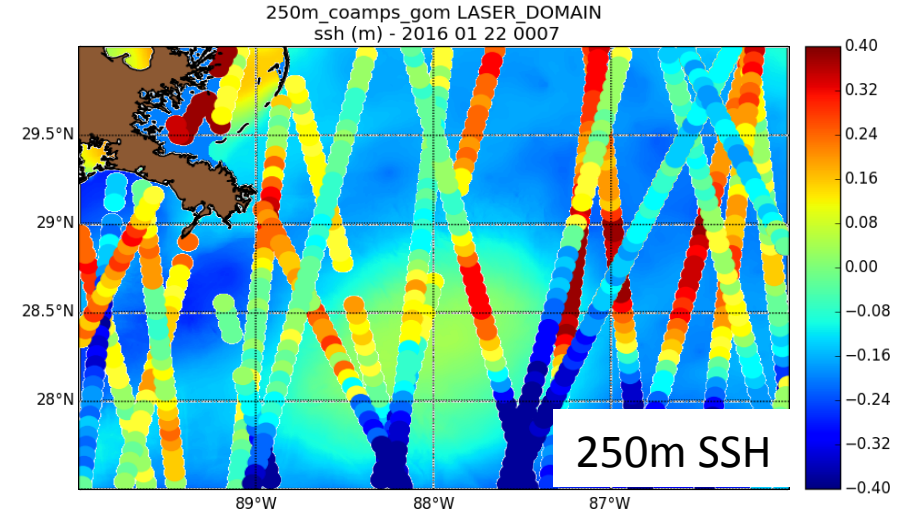
Reinforcing the point

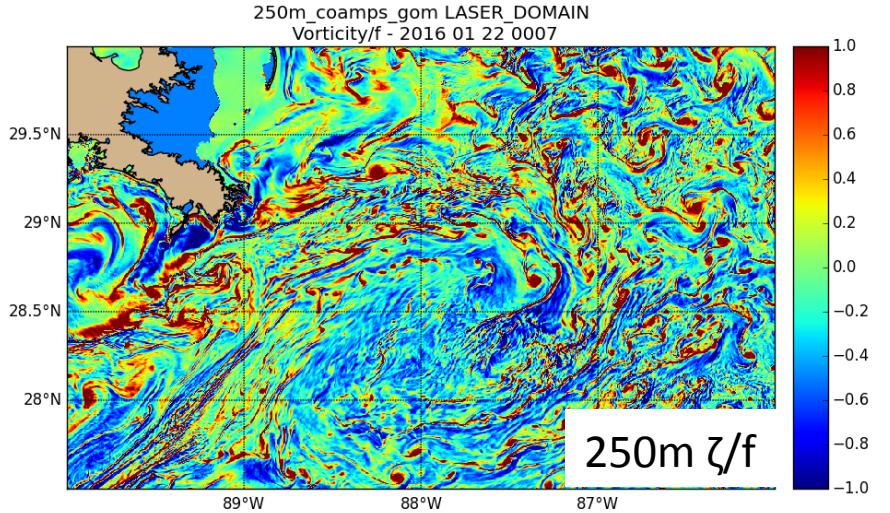
SSH – Jan 22

Relative Vorticity

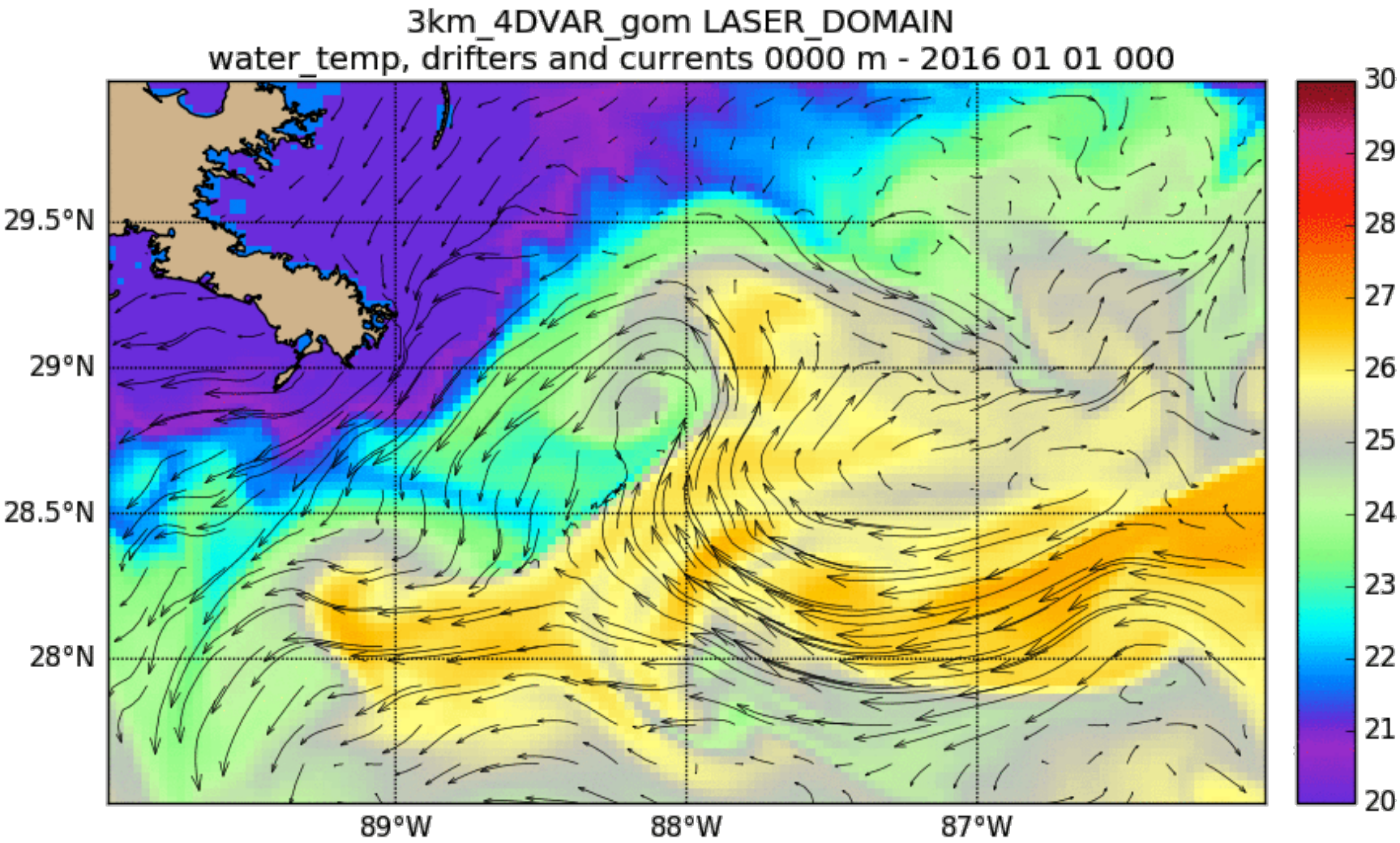








4DVar


3km_4DVAR_gom LASER_DOMAIN
water_temp, drifters and currents 0000 m - 2016 01 01 000
29.5°N
29°N
28.5°N
28°N
89°W
88°W
87°W
30
29
28
27
26
25
24
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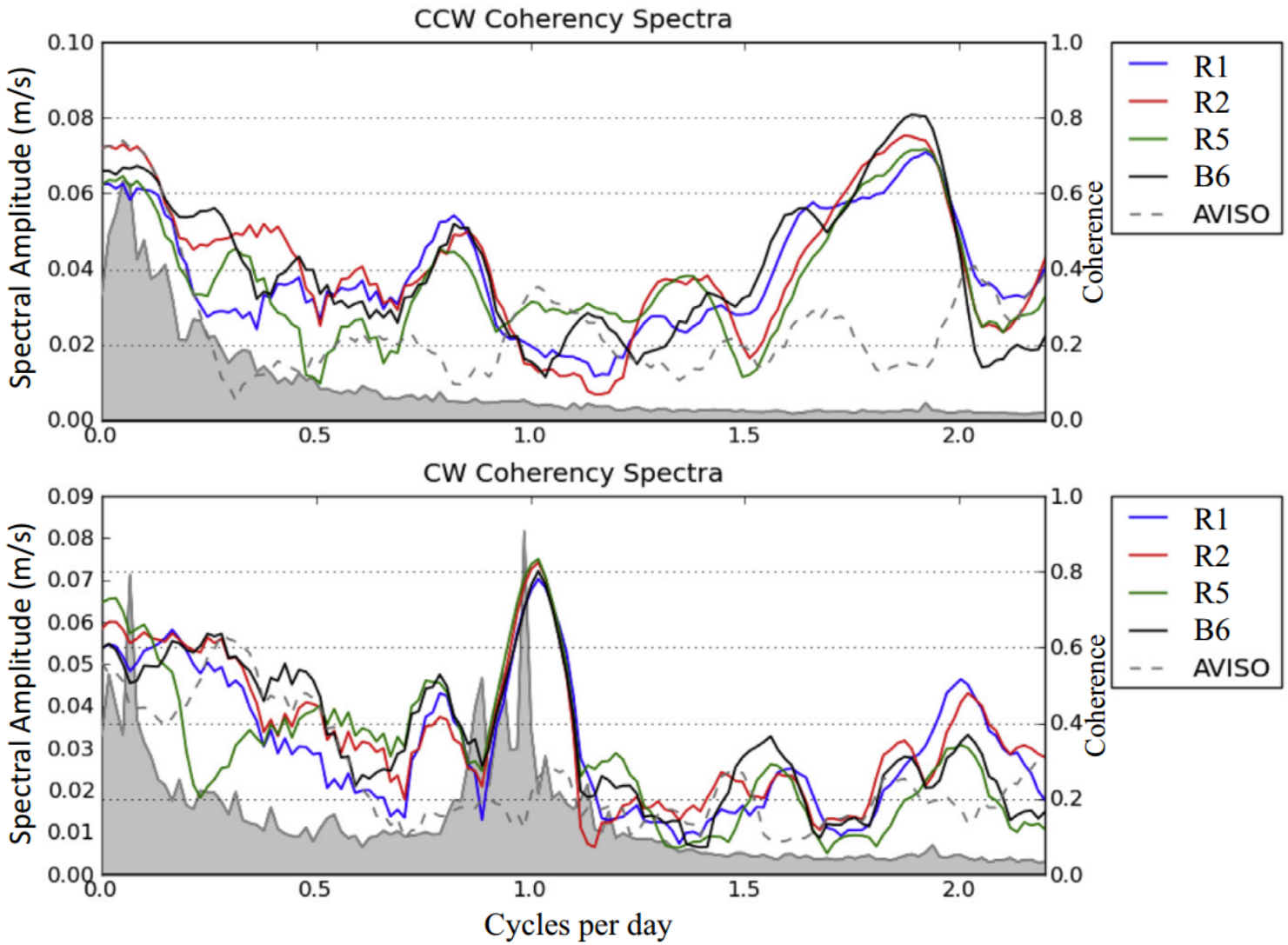
22
21
20

GLAD (2012), drifter & model velocity spectra

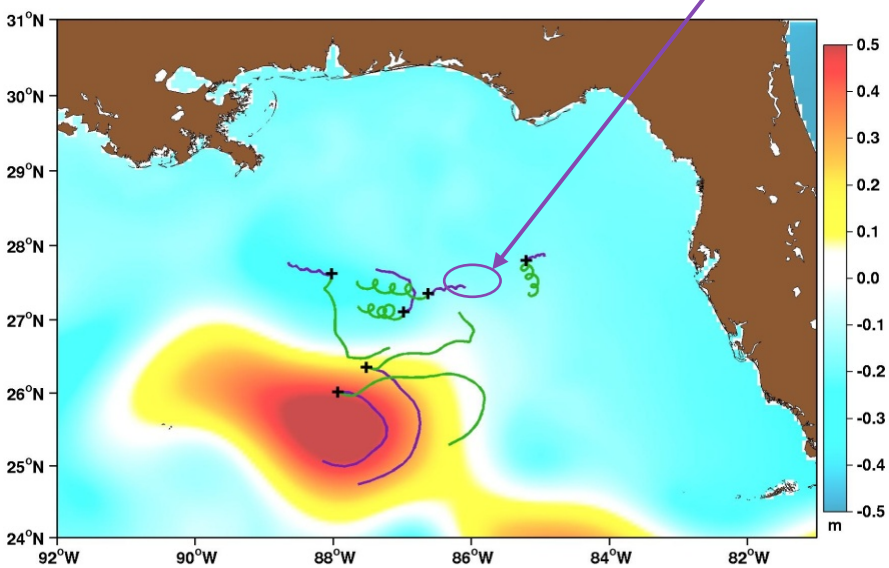


GLAD (2012), 4DVar results

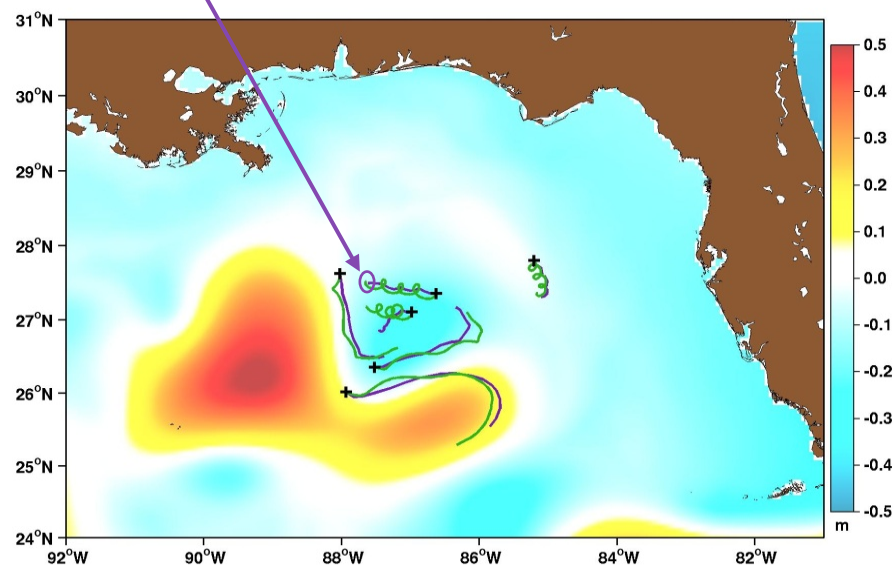
Velocity assimilation improves model representation of temperature, salinity, and sea surface height (in addition to the velocity itself)

Large trajectory errors with 3DVAR become small with 4DVAR

NCOM (3dvar) drifter vs GLAD drifter



NCOM (4dvar) drifter vs GLAD drifter



LASER challenges to ocean prediction

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Skill is lost at scales < 100 km with present regular observing systems (Jason-2, AltiKa, CryoSat-2, SST, ARGO, …)

In situ observations of sufficient density can advance the skill at smaller scales

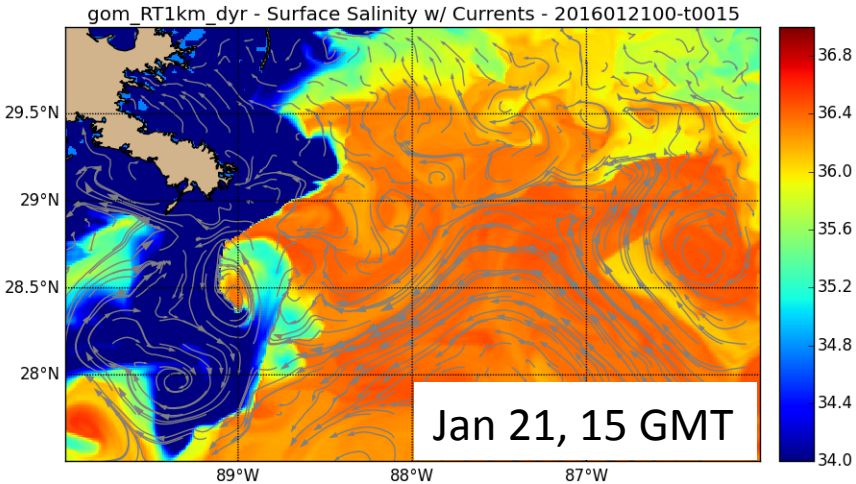
We do not yet know the general answer: what kind and how much?

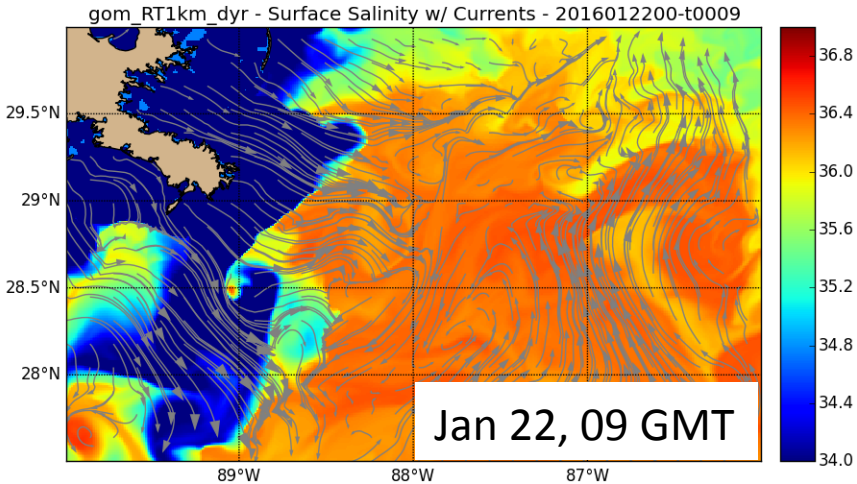
SWOT cal/val makes the answer easier with a known metric

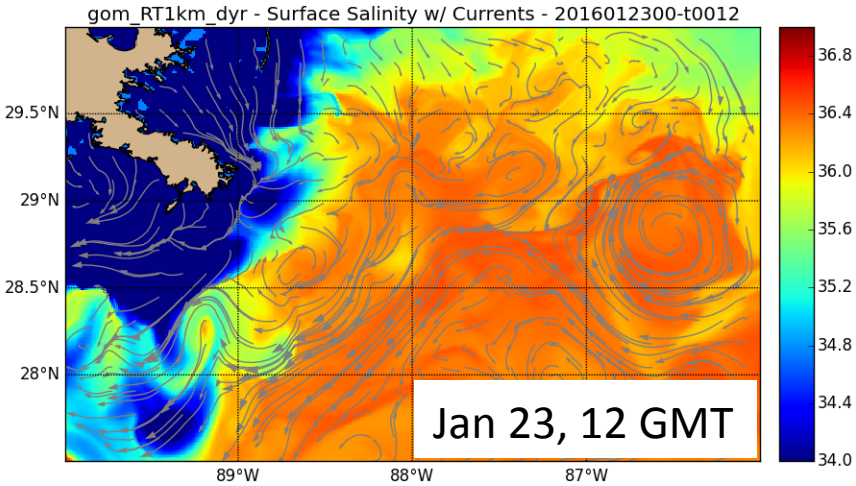
The metric motivates a sensitivity examination

What is the derivative of $SSH(x,y,t)$ with respect to a variable at another location? $\partial SSH(x,y,t)/\partial V_i(x_s, y_s, z_s, t_s)$

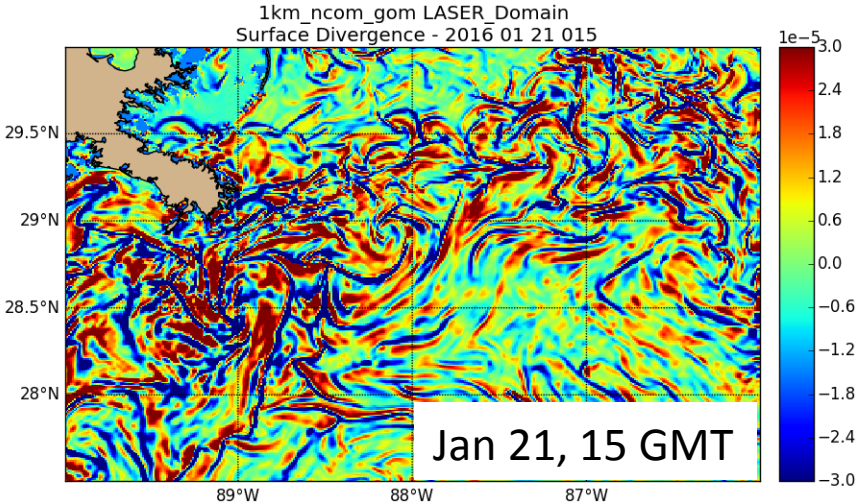
What is the error variance reduction of in $SSH(x,y,t)$ due to an observation of a variable at another location (representer function)?

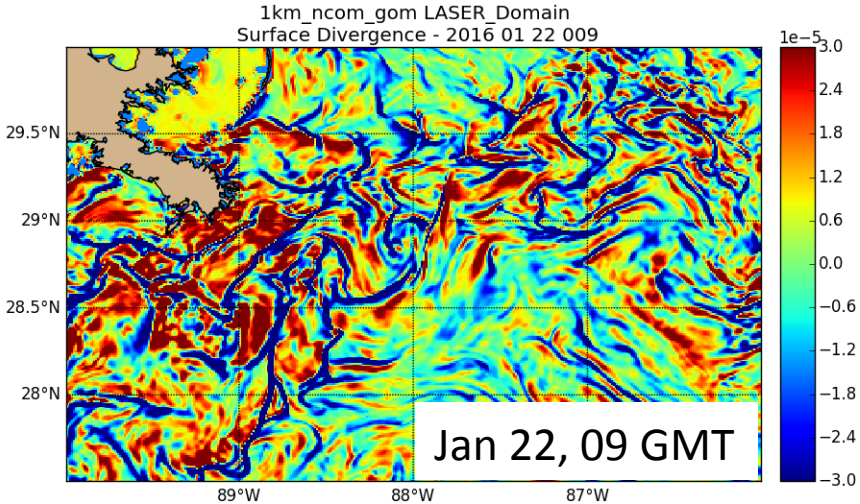


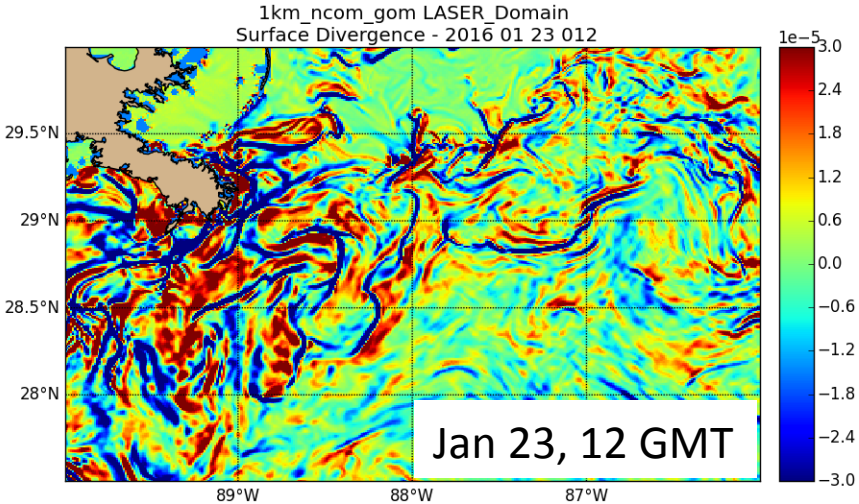




Different response in areas separated by sharp fronts



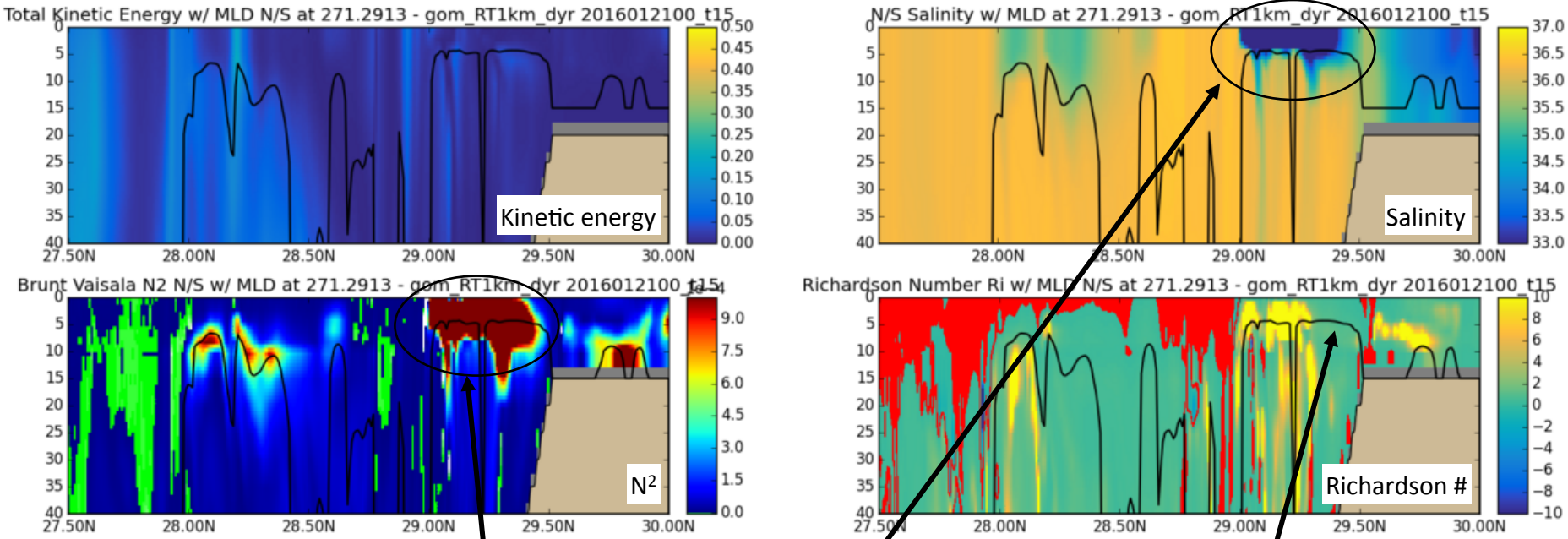




Snapshots surface divergence from the 1 km NCOM during LASER.

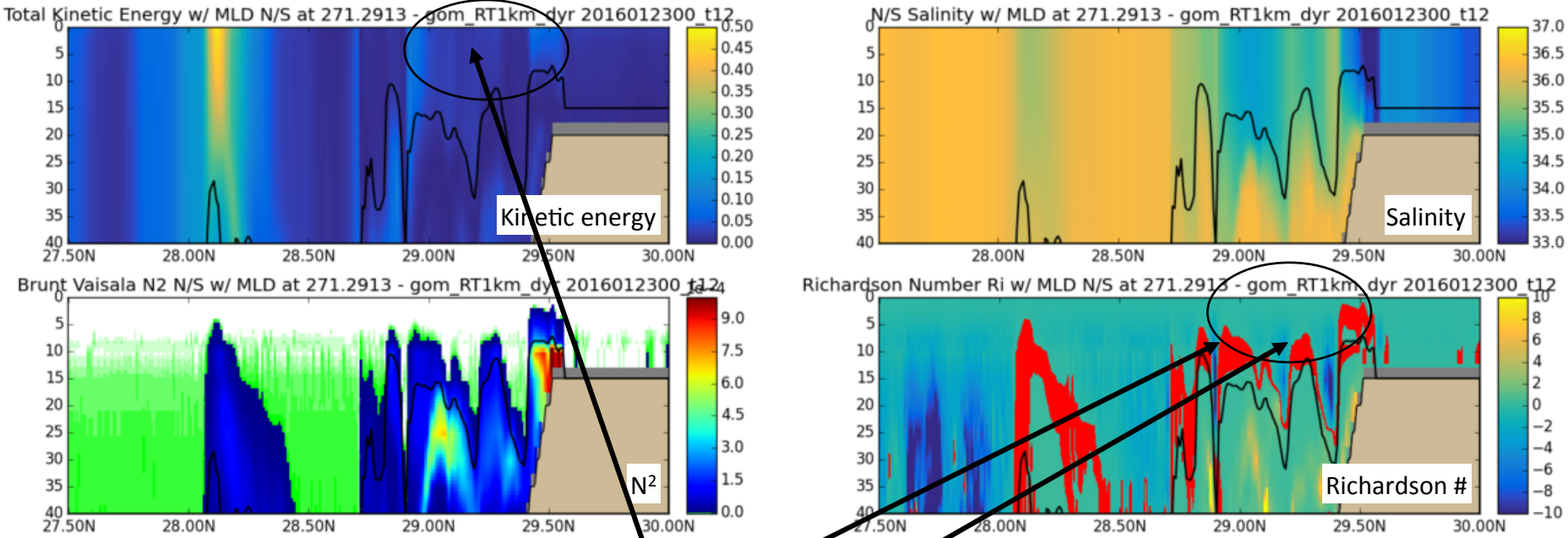
Notice the position of freshwater fronts and convergence on Jan 22, 09 GMT on the upper right.

There is a distinct convergence that is not strong when winds are weak (upper left) or after the surface fresh water has mixed down.



Jan 21, 2016 15 GMT
Transect along 271.2913°E
Note freshwater at surface from river runoff
Result is strong stratification
Black line in all plots is the same mixed layer depth computed from model density

Areas of red in the Richardson number are between 0 and 0.02



Jan 23, 2016 12 GMT

Transect along 271.2913°E

Mixing is extending down through the freshwater layer

Mixed layer depth is deepening

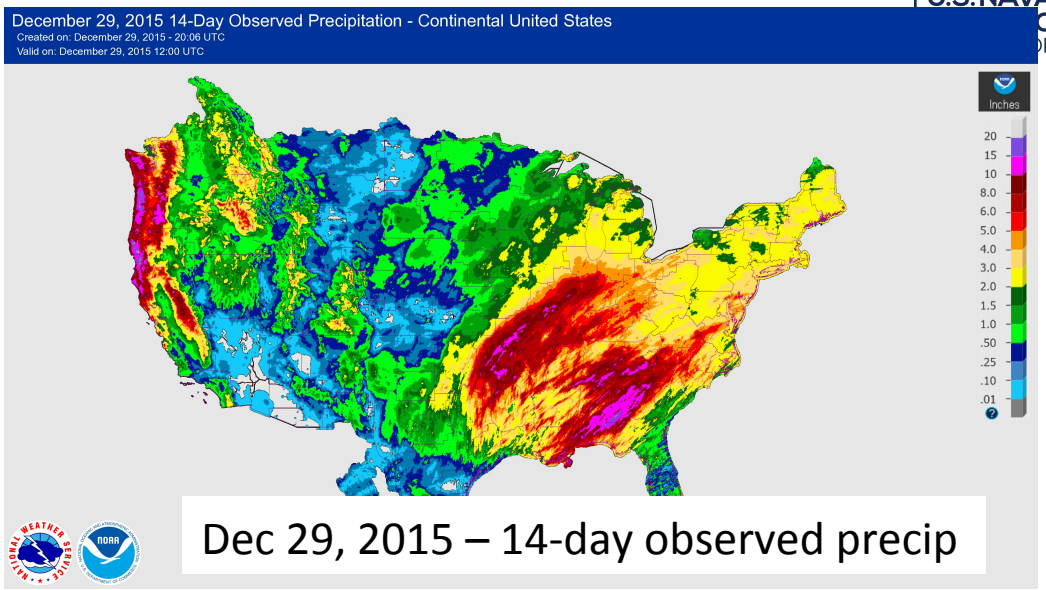
Kinetic energy is dropping as winds have dropped and energy is mixing downward

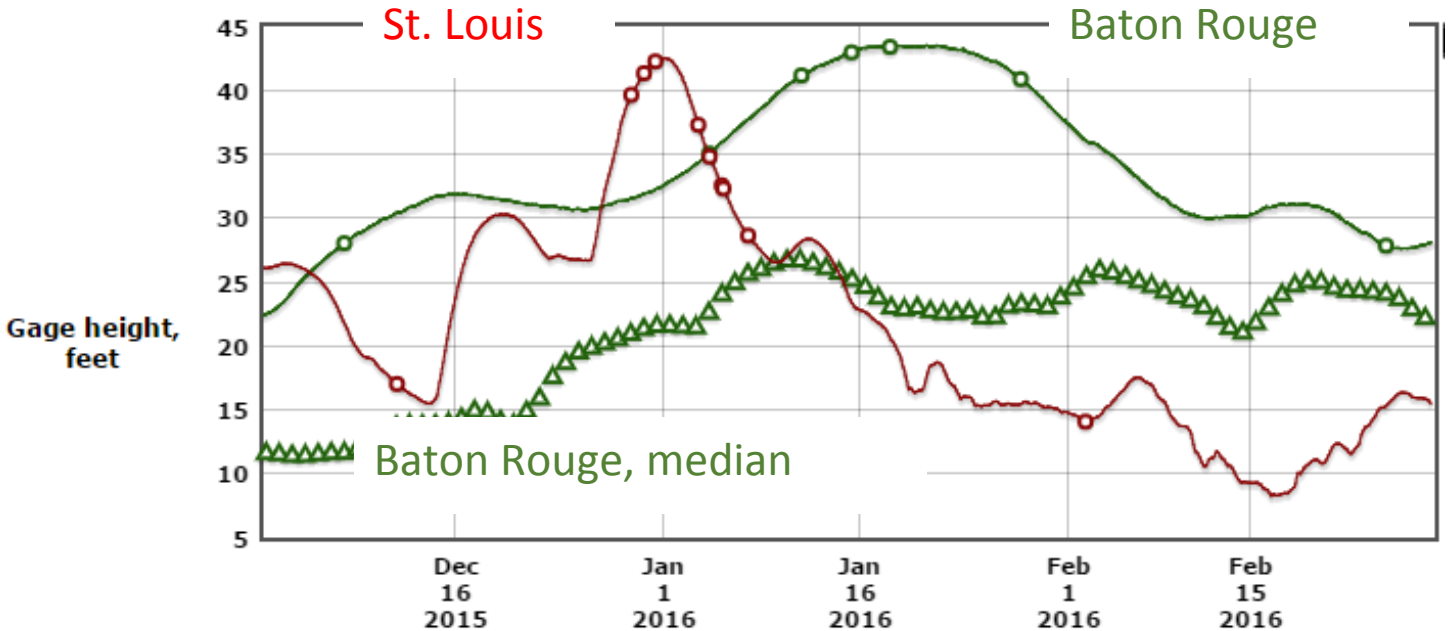
Areas of red in the Richardson number are between 0 and 0.02

Hydrological effects

Large rain events in Dec 2015

Far above climatological values



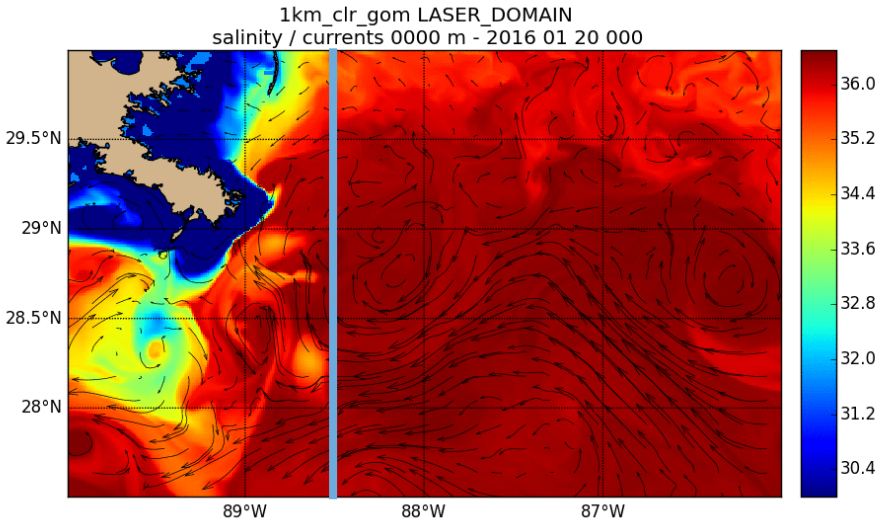


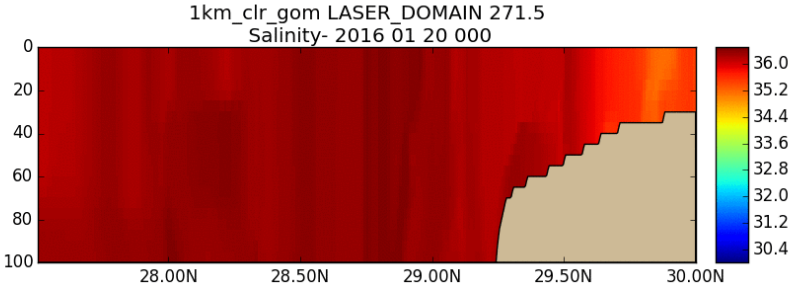
Effects of Mississippi discharge

U.S. NAVAL RESEARCH LABORATORY

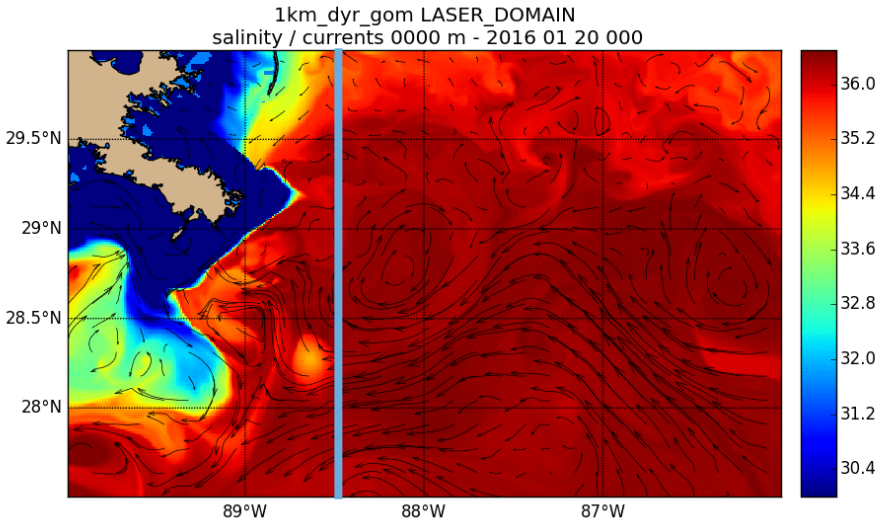
January 22, 2016 wind event

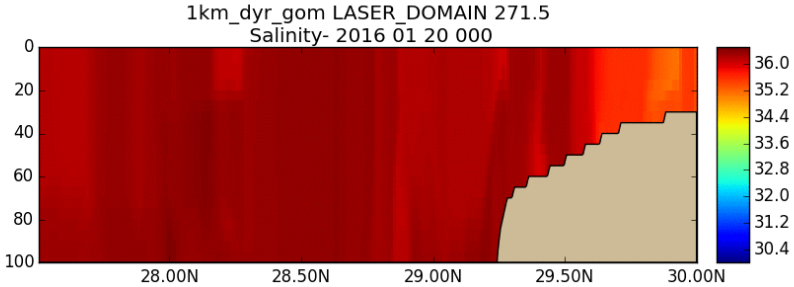
Climatological river transport

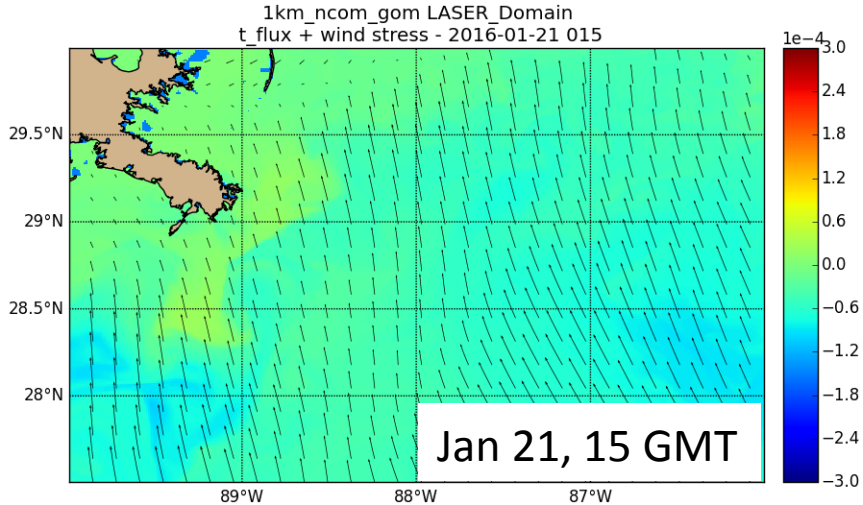


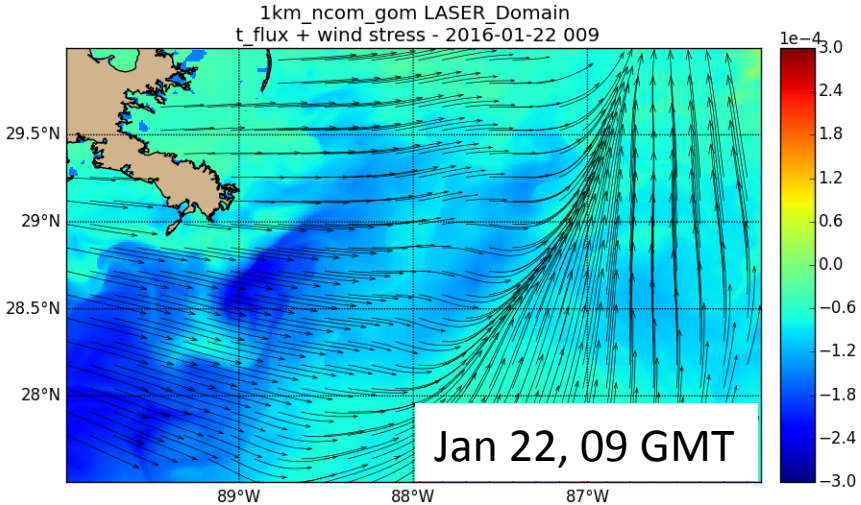


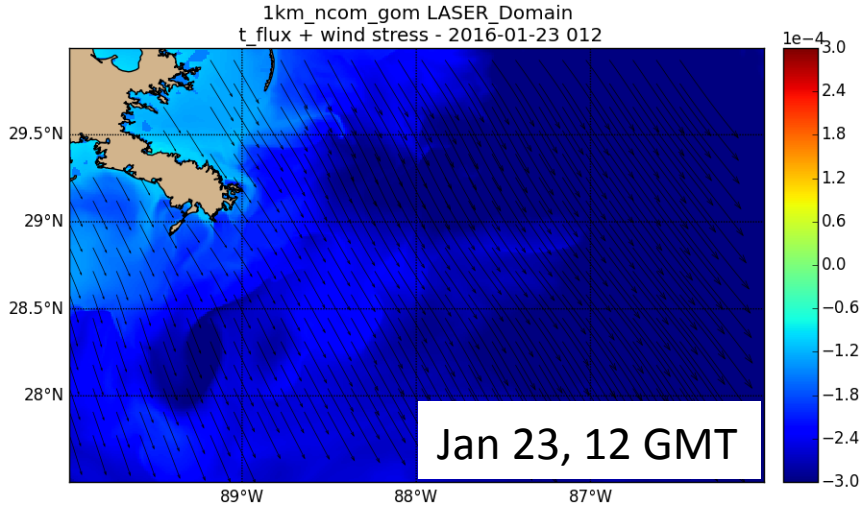
Observed river transport







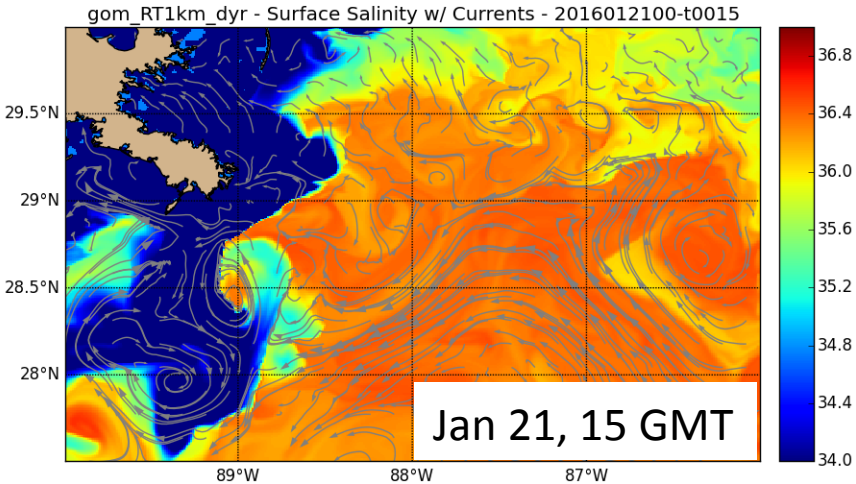


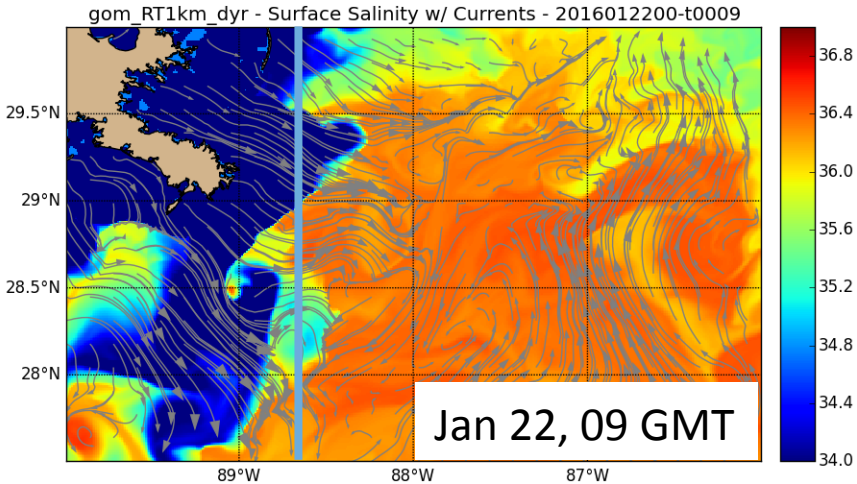


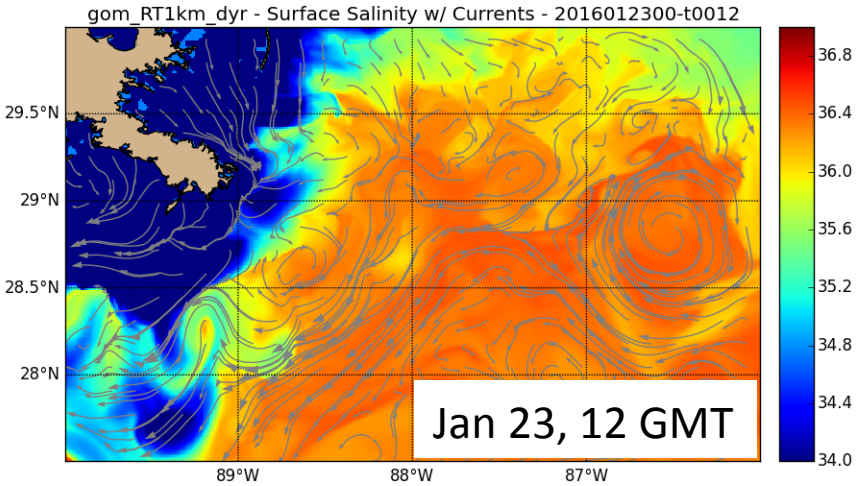
Snapshots of wind stress (vectors) and surface temperature flux (color) forcing the 1 km NCOM during LASER.

Jan 21 – 24 is the time of a frontal passage.

Cold air behind the front results in negative temperature fluxes.

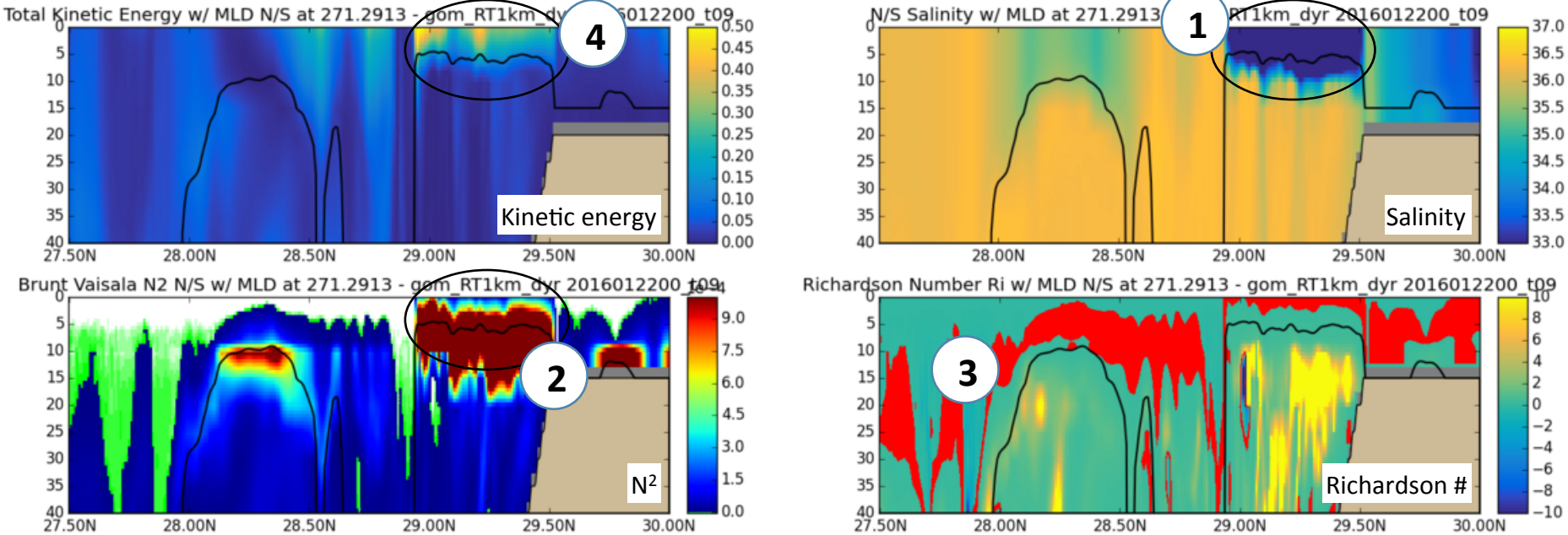






Snapshots surface salinity and surface currents from the 1 km NCOM during LASER.

The freshwater fronts weaken and dissipate toward the end of the event as fresh water mixes downward.

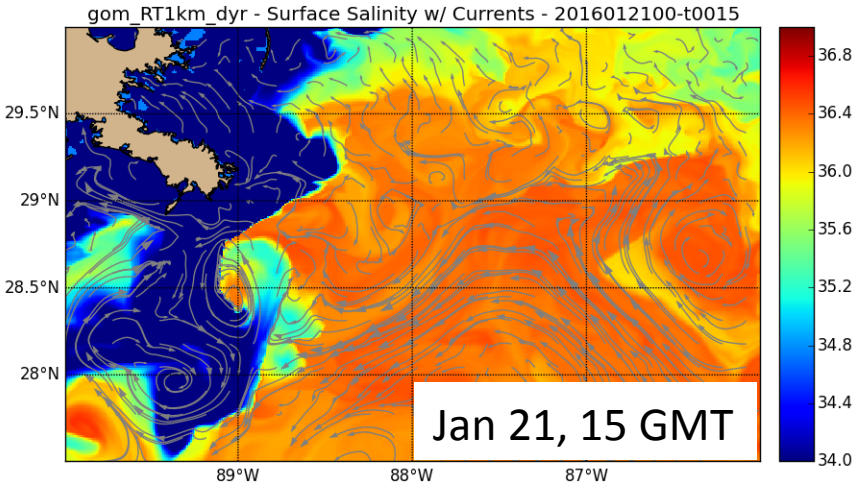


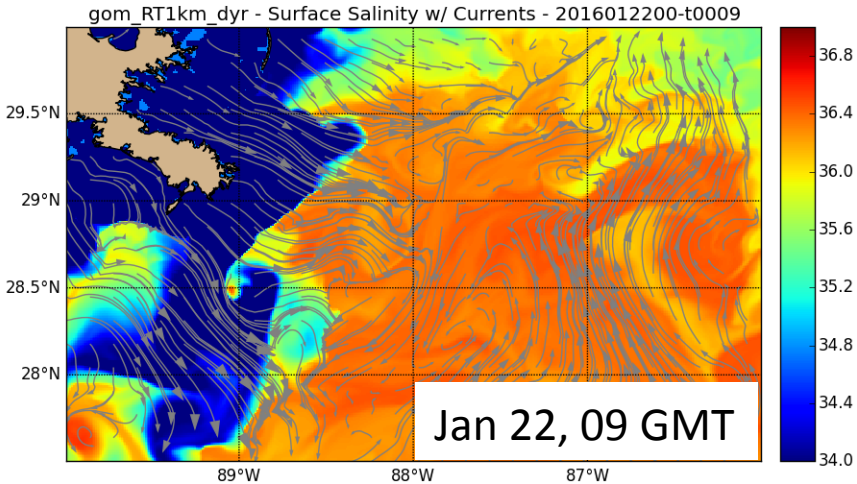
Freshwater extending down to 10 m (1) creates strong stratification (2)

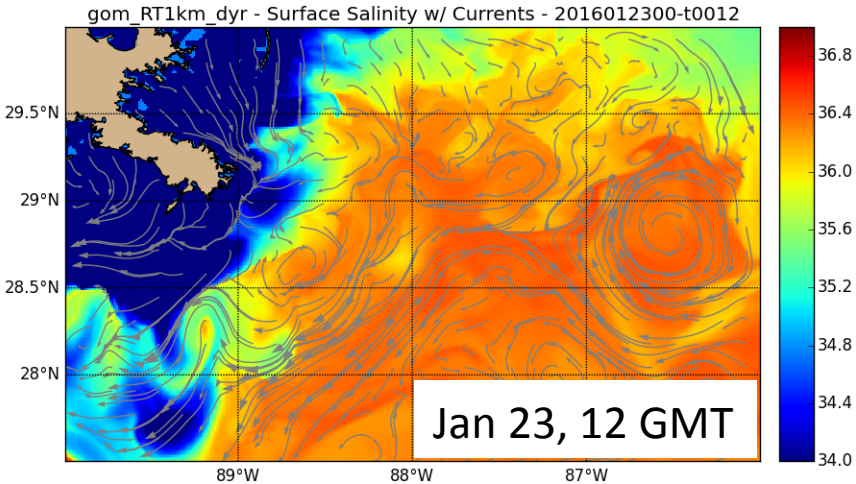
Richardson number ($N^2/((du/dz)^2+(dv/dz)^2)$) drops below critical value, and mixing initiates (3)

Kinetic energy is trapped (4) resulting in stronger surface currents

Areas of red in the Richardson number are between 0 and 0.2

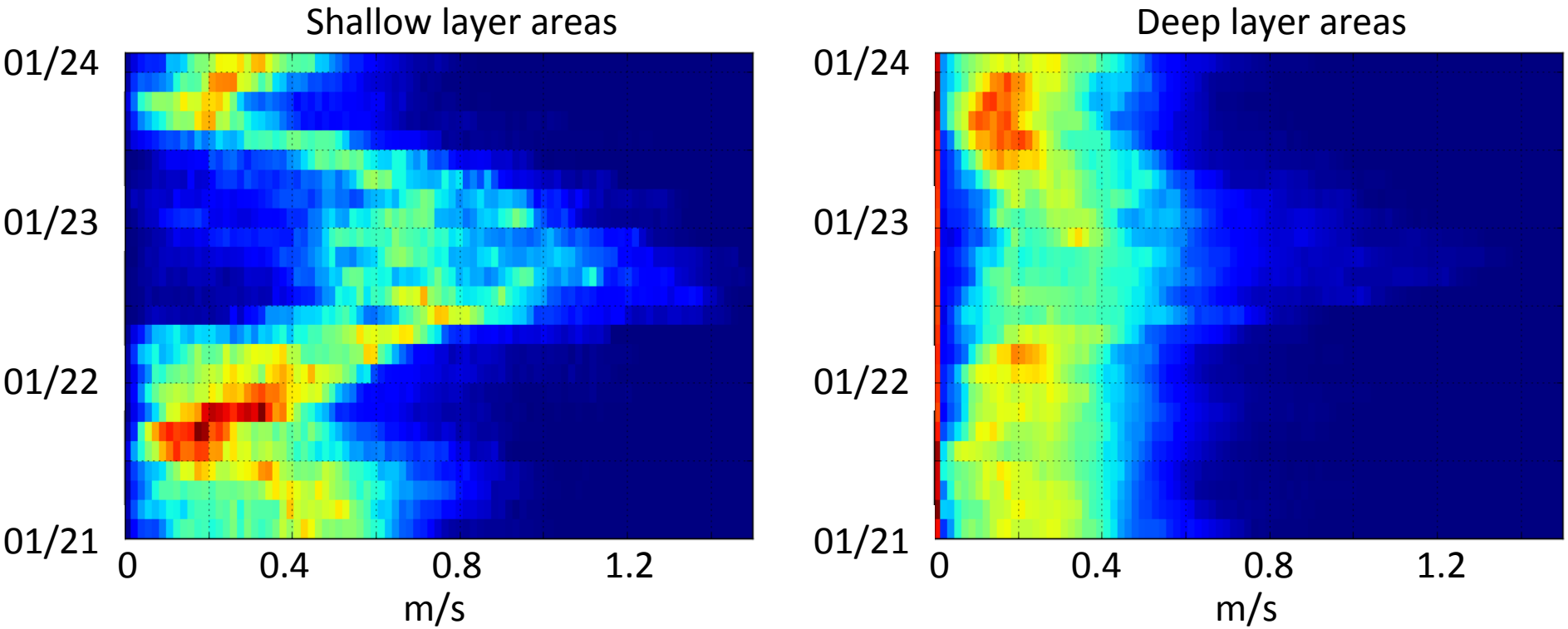






Let's separate strongly stratified from weakly stratified areas

What is the surface current response in each?



The LASER area of the previous plot is divided into two areas: shallow surface layers and deep surface layers:

Shallow: Surface salinity < 34.0, and N^2 > 10x10^-4 at some point in the upper 20 m, and Mixed Layer Depth < 20 m (a fresh surface water with a strong density gradient beneath)

Deep: Not shallow

The PDF of model surface speed in the two areas is shown over the wind event time period.

Shallow areas (left) indicate higher surface speeds during the wind event than deep areas (right).