The multivariate properties of the Ensemble Optimal Interpolation in the Gulf of Mexico

François Counillon

PhD Student

Supervisor: **Ola M. Johanessen**, Laurent Bertino, Geir Evensen

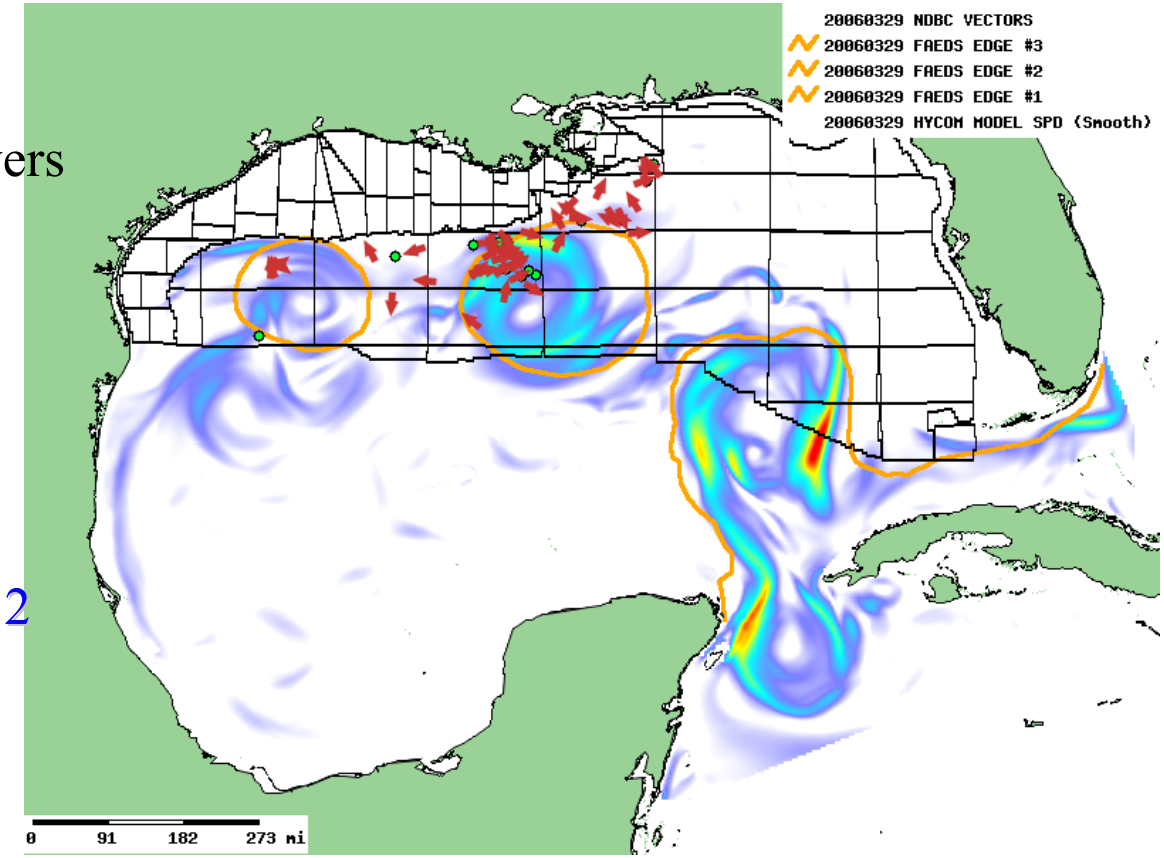
Project: NFR

Outline

- Model characteristics
- Data assimilation
- EnOI formulation
- Parameter alpha
- Localisation
- Multivariate correlation
- Linear assumption
- Results

Gulf of Mexico model

- Using HYCOM 2.1.03
- Grid size of 5 km, 22 Hybrid layers
- GEBCO 1 minute bathymetry
- Forcing from ECMWF
- Nesting condition from: TOPAZ 2



Picture of Stephen Robin
Ocean Focus

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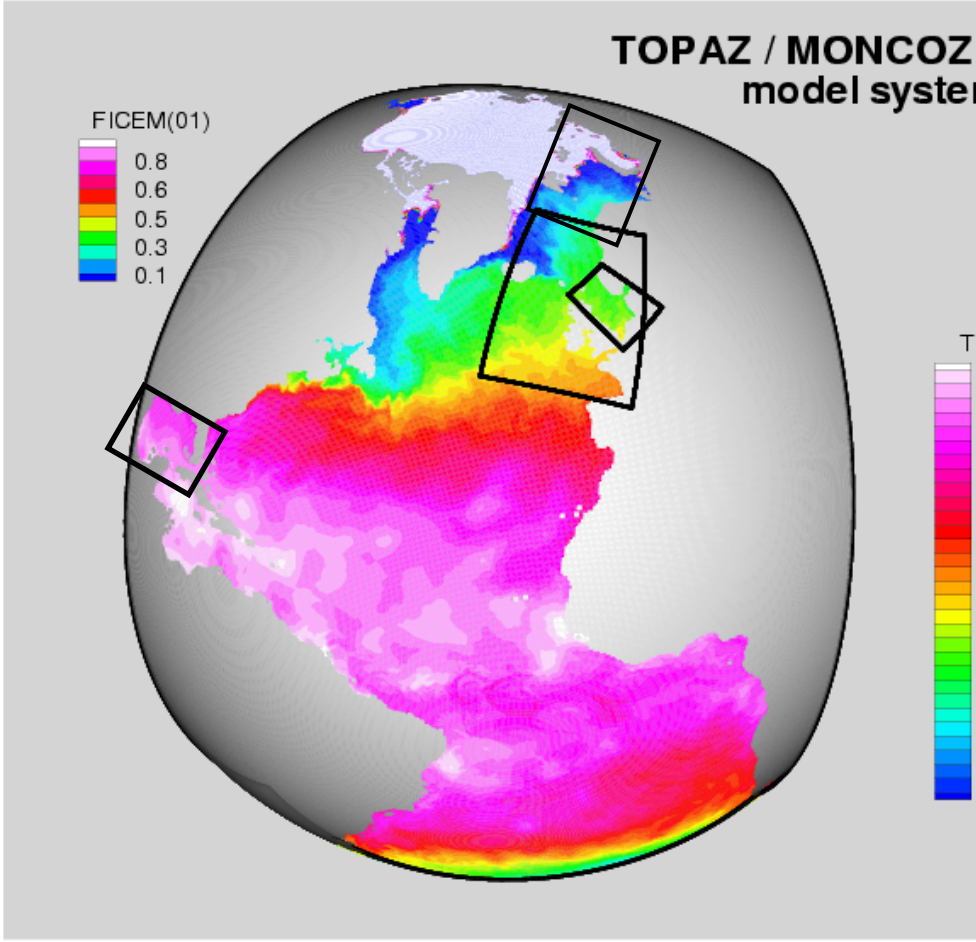
TOPAZ 2 model system

- TOPAZ: Atlantic and Arctic
  - HYCOM (http://www.hycom.org)
  - EVP ice model coupled
  - 18-35 km resolution
  - 22 hybrid layers
- EnKF, (http://enkf.nersc.no)
  - 100 members
  - Sea Level Anomalies (CLS)
  - Sea Surface Temperatures (Reynolds)
  - Sea Ice Concentrations (SSM/I)
- Runs weekly since Jan 2003
  - ECMWF forcing
  - Validation http://topaz.nersc.no
  - Nested systems run daily or weekly



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Data assimilation

• High resolution model can reproduce the mesoscales dynamics and their variability in the GOM.
• Eddies are clearly visible in the altimetry. We expect assimilation of SLA to correct the position of the fronts and to change the water column properties accordingly.

NB: We are not assimilated SST in order to more clearly determine the multivariate impact of SLA assimilation.

Ensemble Optimal Interpolation:

- Covariance are based on an historical ensemble composed of 2.5 year weekly model output (135 members) without assimilation
- Covariance are 3D multivariate
- conservation of the dynamical balance of the model
- Temporal invariance of the covariance matrix
- Numerically cheap

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EnOI

$$X^a = X^f + \alpha\, A'A'^T H^T (\alpha\, HA'A'^T H^T + \varepsilon^o \varepsilon^o)^{-1} (Y - HX^f)$$

Kalman Gain — obs-model

X : model state (η,t,s,u,v,thk); (a:analysis; f:forecast)

A': centered collection of model states ($A' = A - \bar{A}$)

Y : observations

H : interpolates from model grid to observation

ε^o : Observation error

α : rebalance ensemble variability to realistic level

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Parameter α

α is introduced within 0..1, to rebalance the ensemble variability to the one of the observation

Ensemble variability > instantaneous variability

Too low value of α ⟶ too little efficiency
But
Too large value of α ⟶ side effect

Persistent population of cyclonic and anticyclonic eddies
The variability of SLA remains relatively constant
α=1 in our case

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Localisation

Can an observation in the western GOM help resolve the circulation in the eastern part?
Until what range does an observation can be useful?

Are we keeping the dynamical balance ?
Oke (2006) has shown that we keep the geostrophic balance as long as the radius is bigger than the decorrelation radius.

Ensemble multivariate properties

- We study here the correlation induced by an increase of SSH at 2 characteristic locations.

Two target points:

1. West of the Loop Current
2. North of the Loop Current

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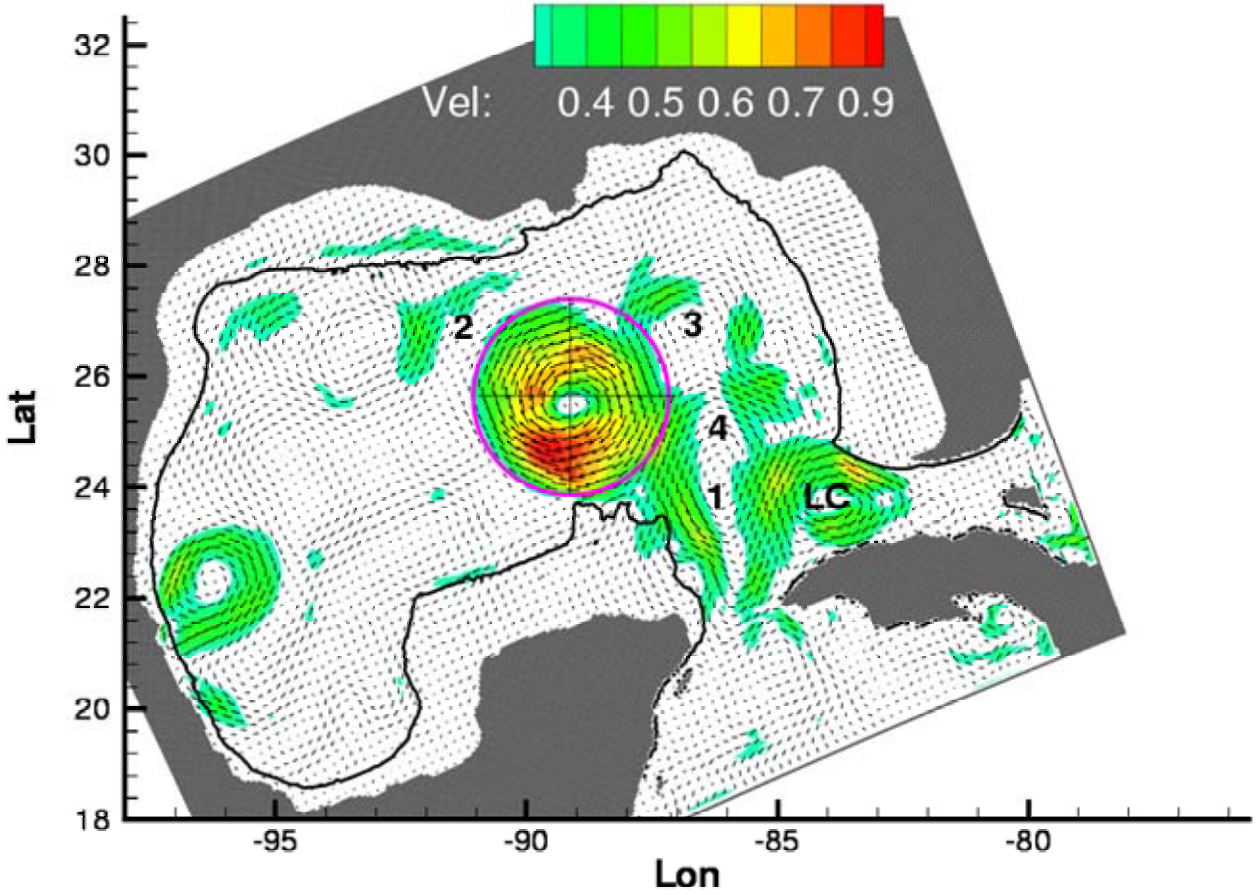
Target point 1: Correlation SLA vs Velocity



corr_vel=sqrt(corr_u^2 +corr_v^2)
arrows represent correlation
pink circle corresponds to the radius of local assimilation
number describes positive corr with growth of cyclones

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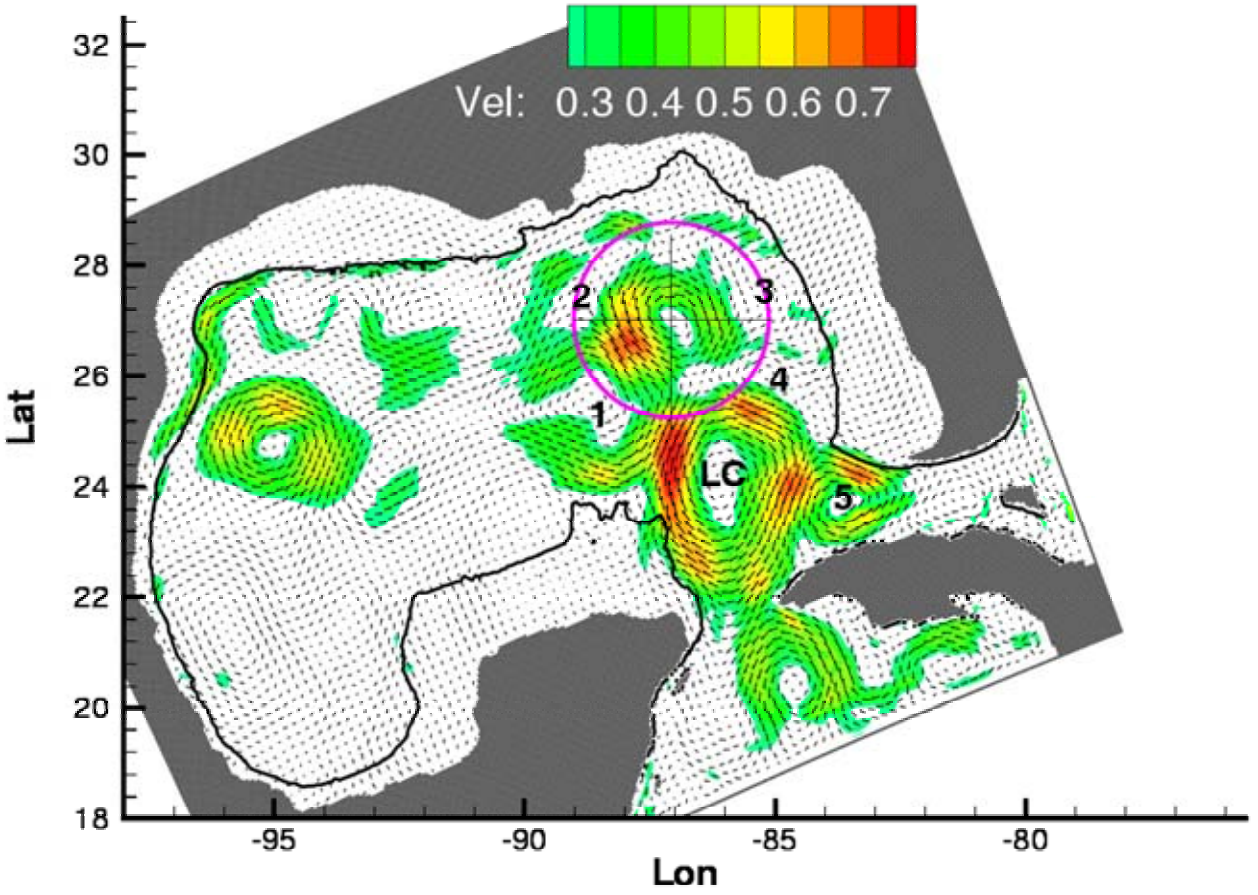
Target point 2: Correlation SLA vs Velocity



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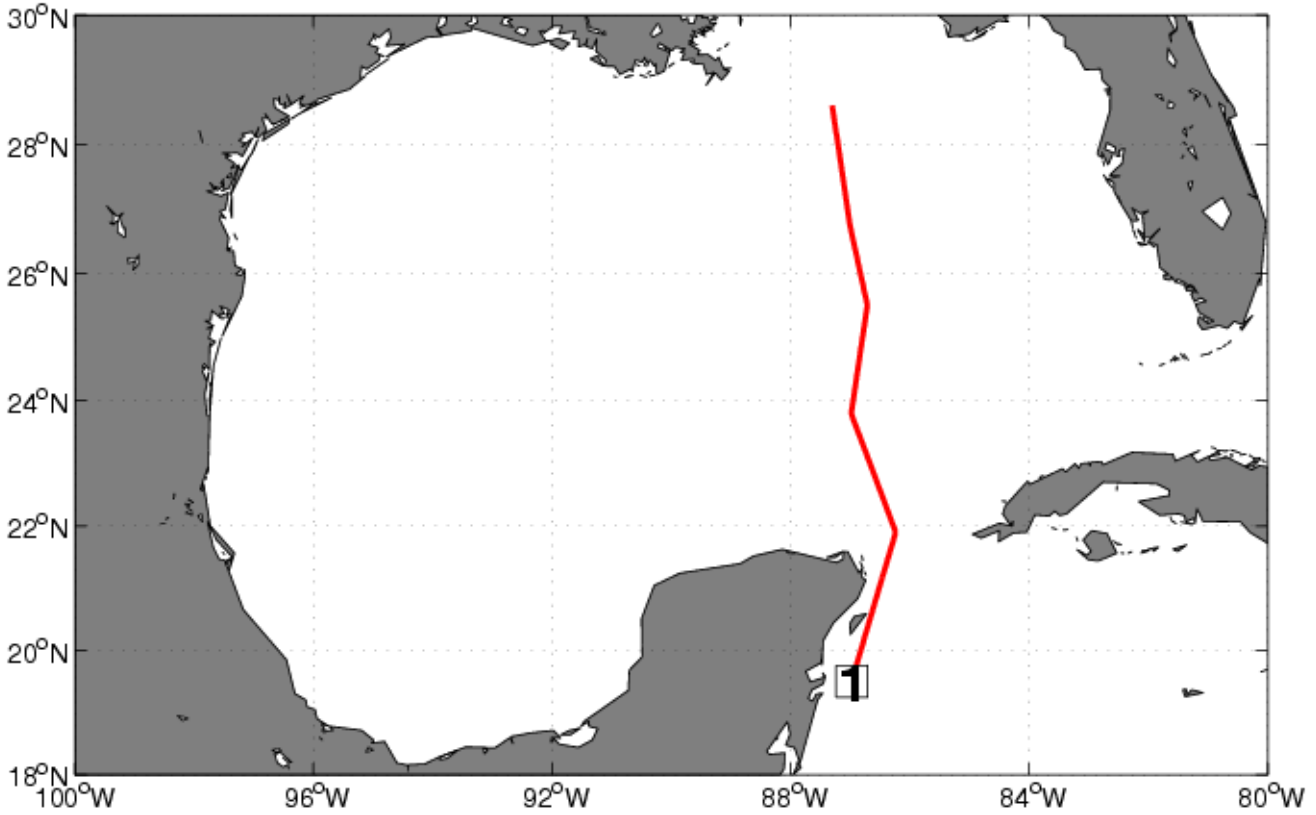
Section for the 2nd Target point



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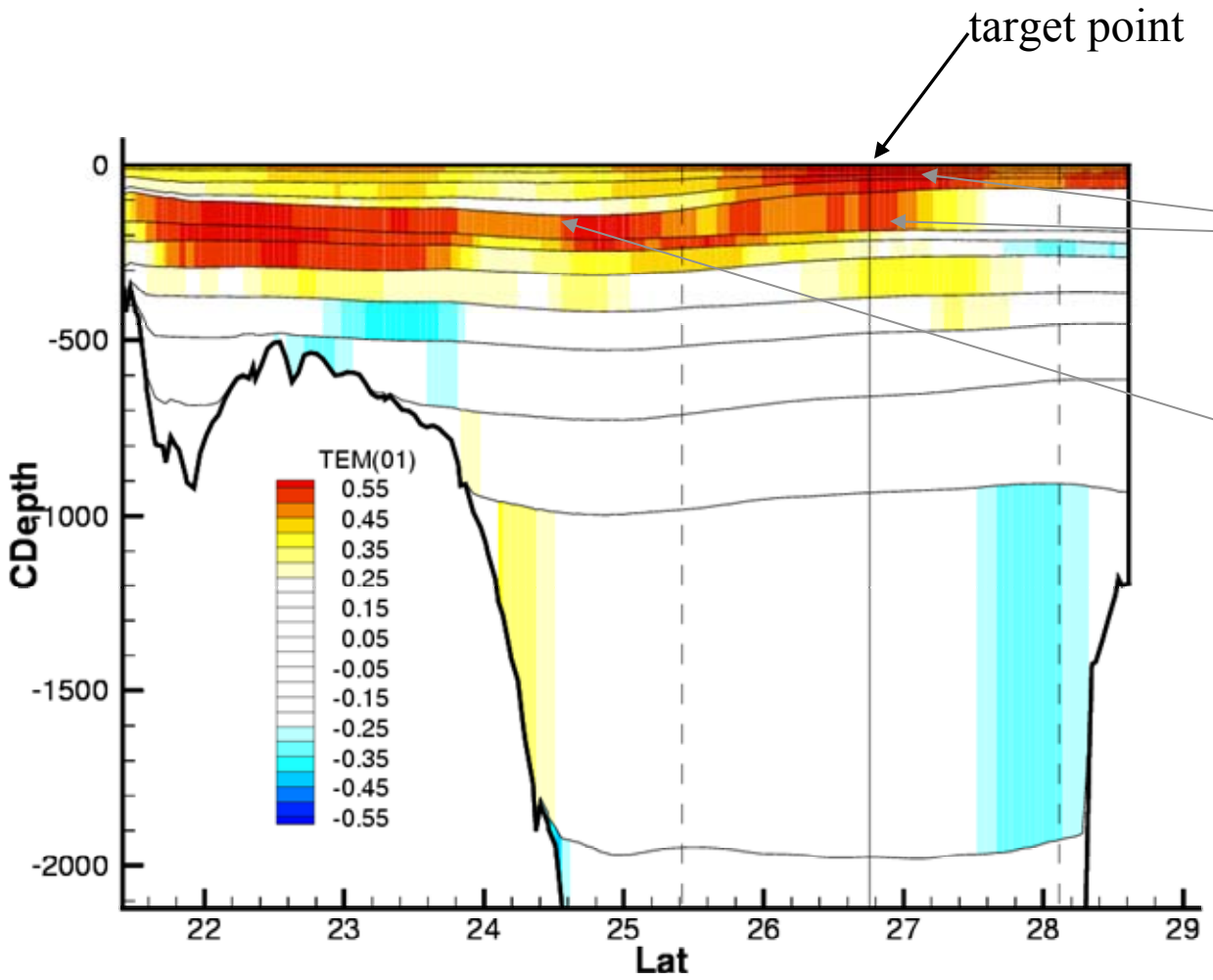
Correlation SLA vs Temperature



positive corr with:
Surface layer
SUW layer

Increase of the LCW inflow

Radius of assimilation

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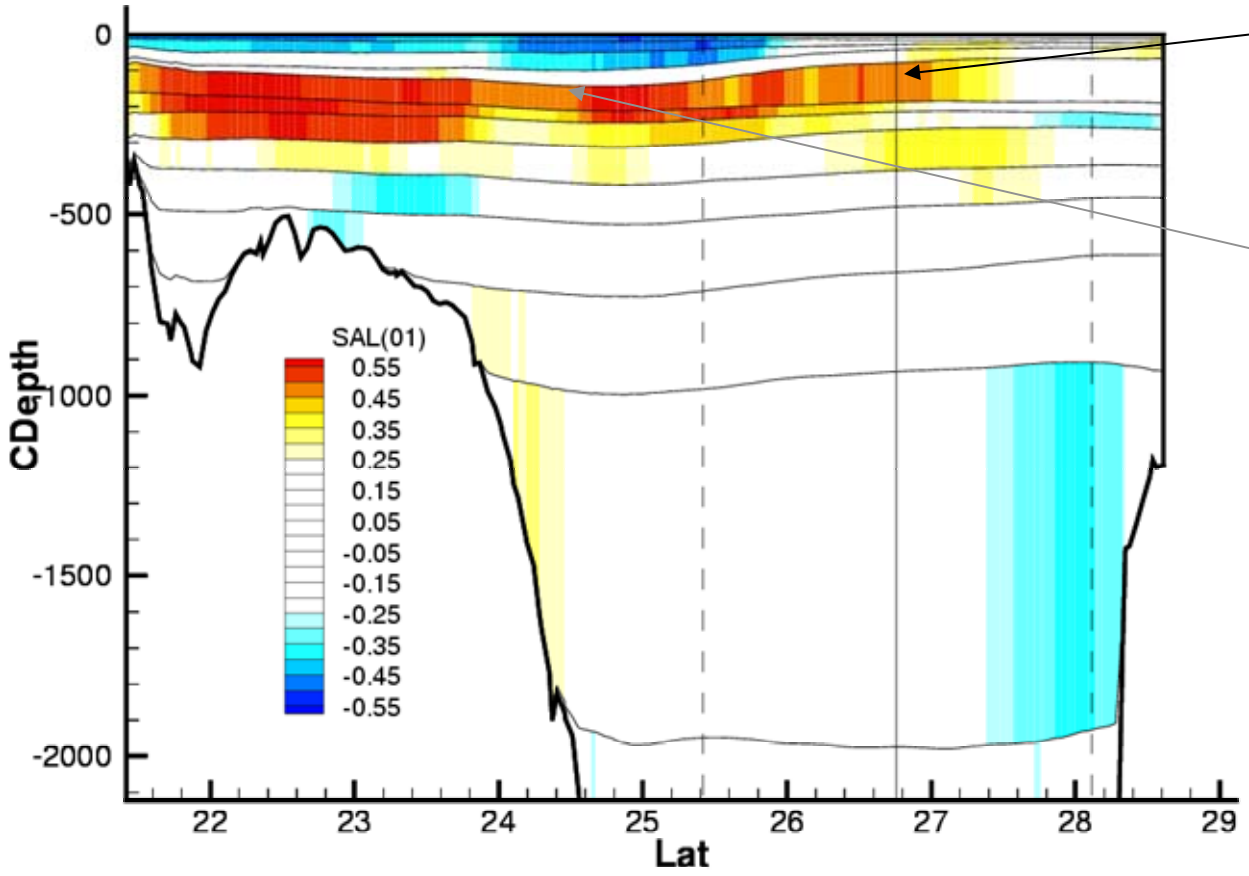
Correlation SLA vs Salinity



positive corr with:

SUW layer

Increase of the LCW inflow

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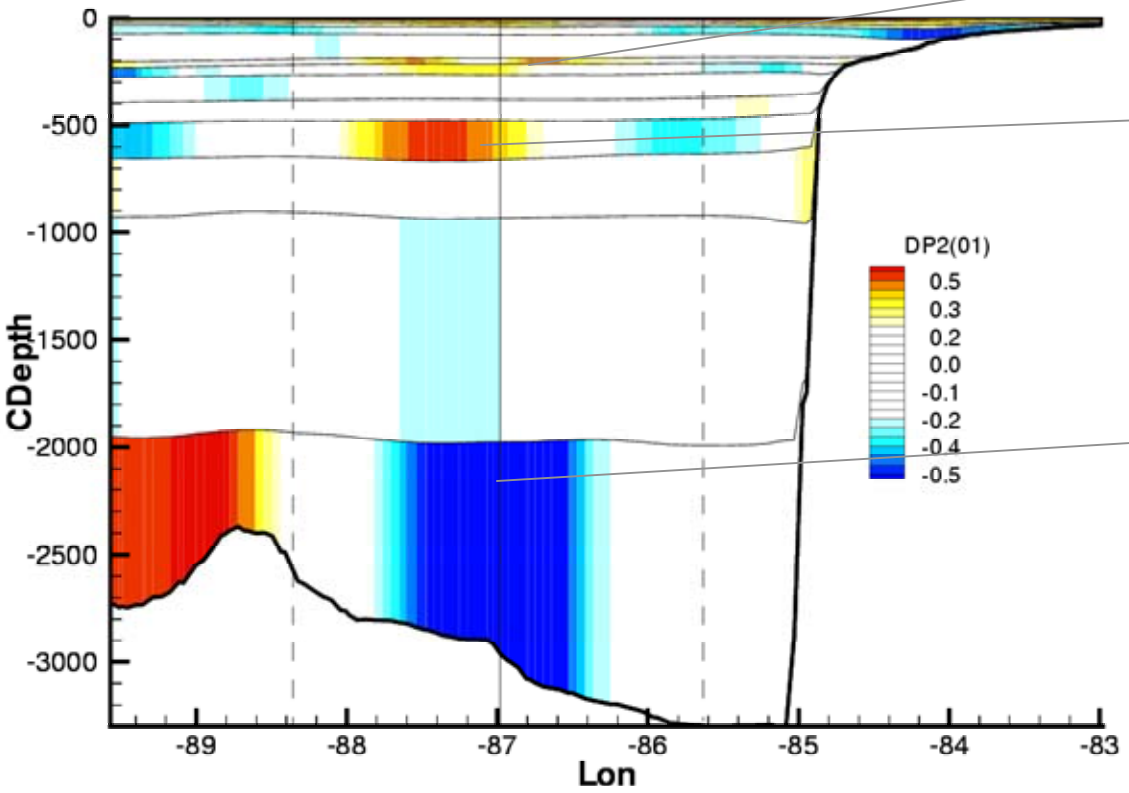
Correlation SLA Layer thickness



Increase of the SUW layer thickness

Deepening of the active layer of the LC

React as a buffer layer satisfy the motionless abyss hypothesis

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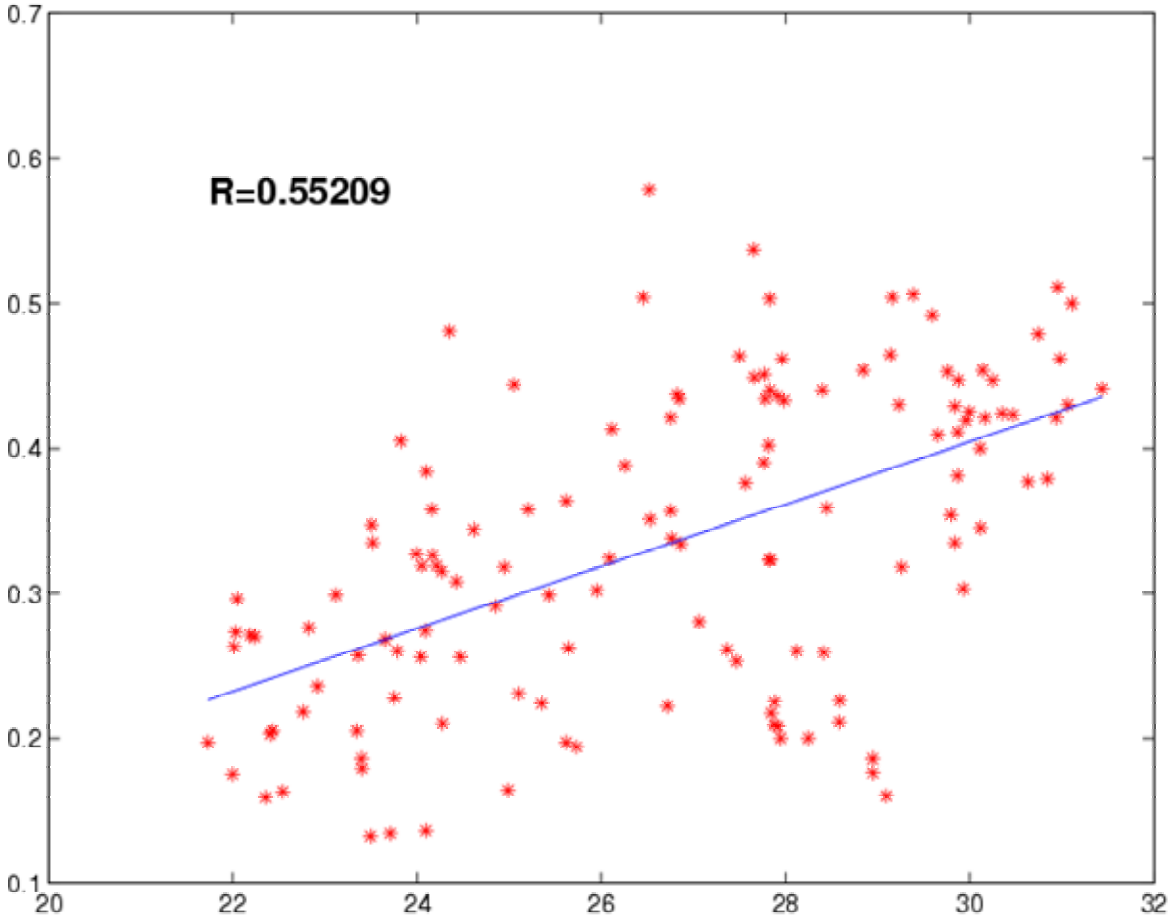
EnOI Linear assumption



Scatter plot between SST and SSH: Significantly linear

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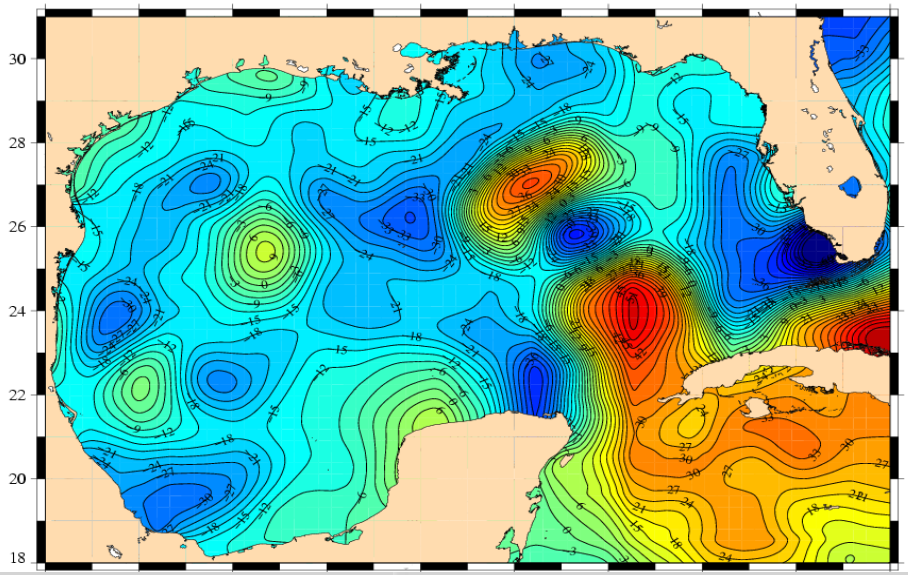
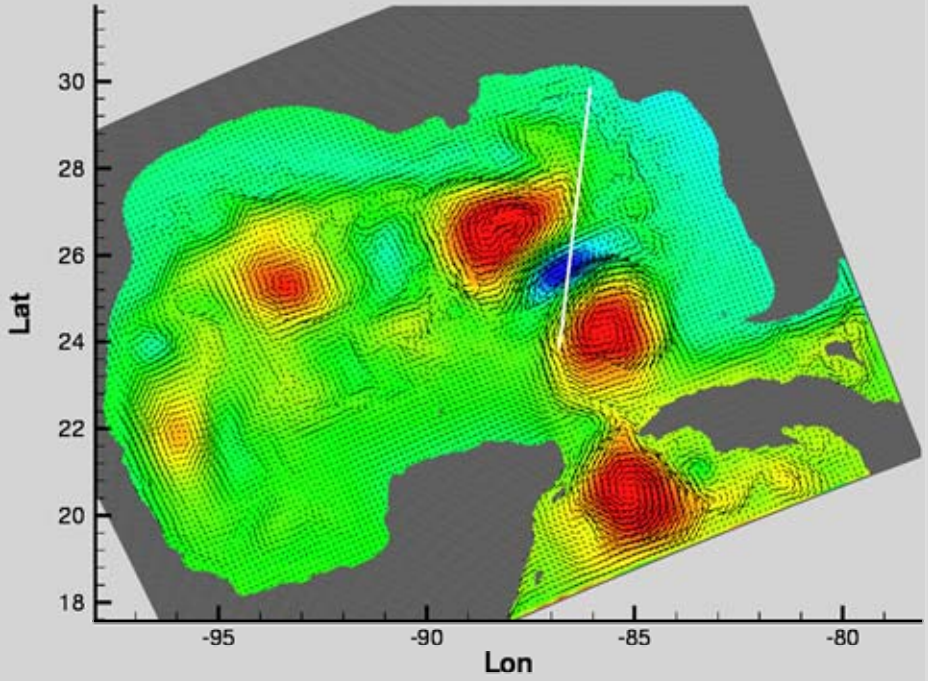
1



1. Observation
2. Forecast
3. Analysis

2



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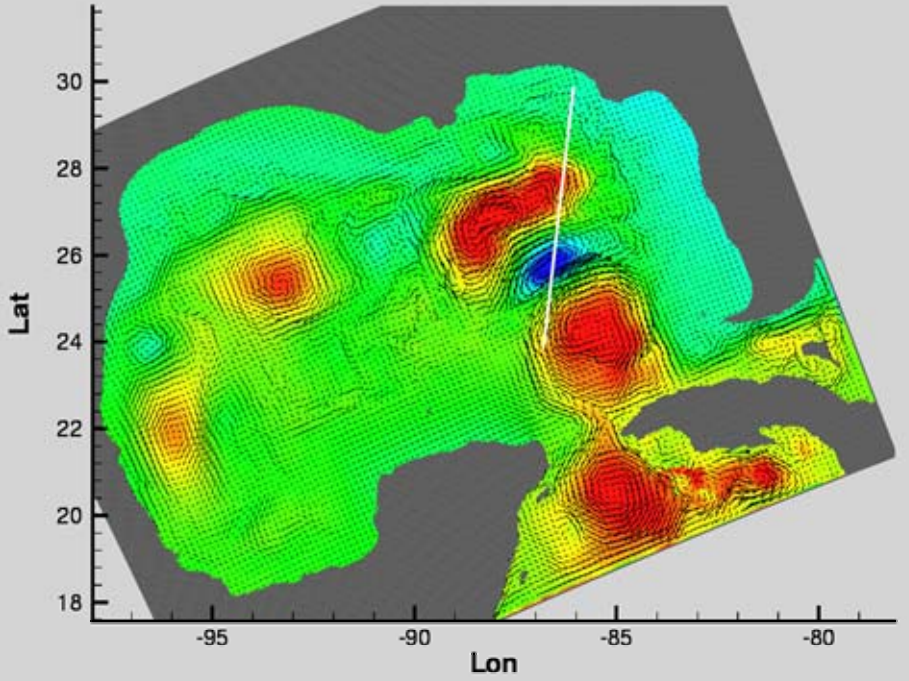
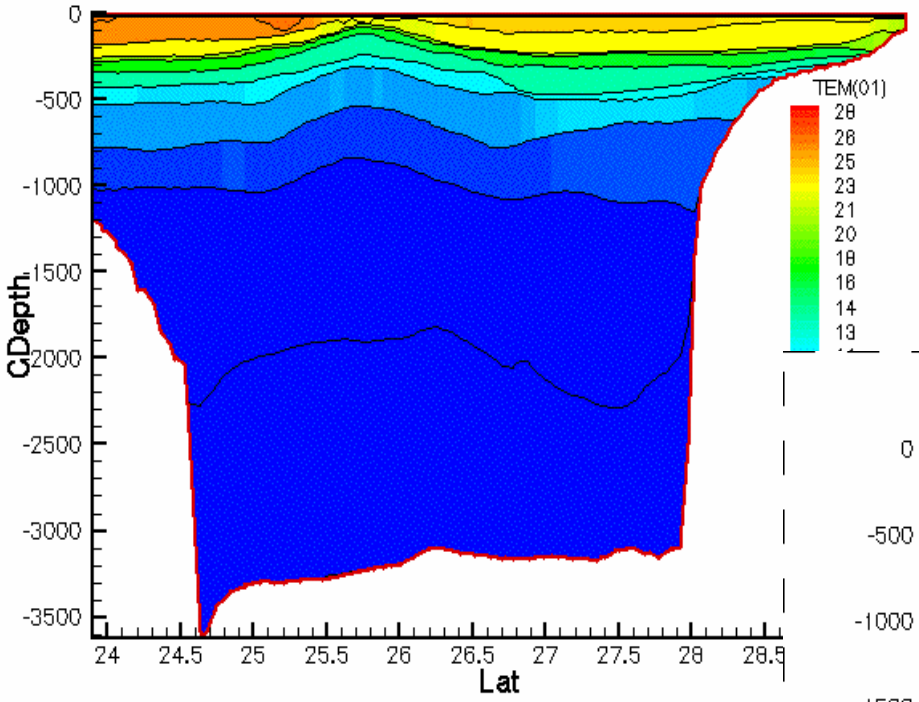
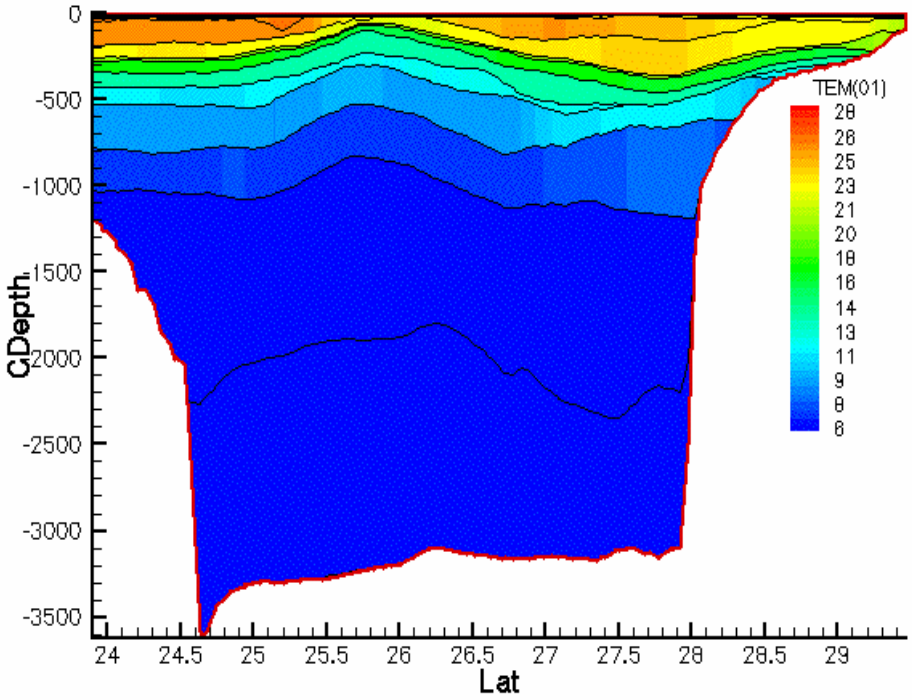


Temperature update

Forecast



Analysis



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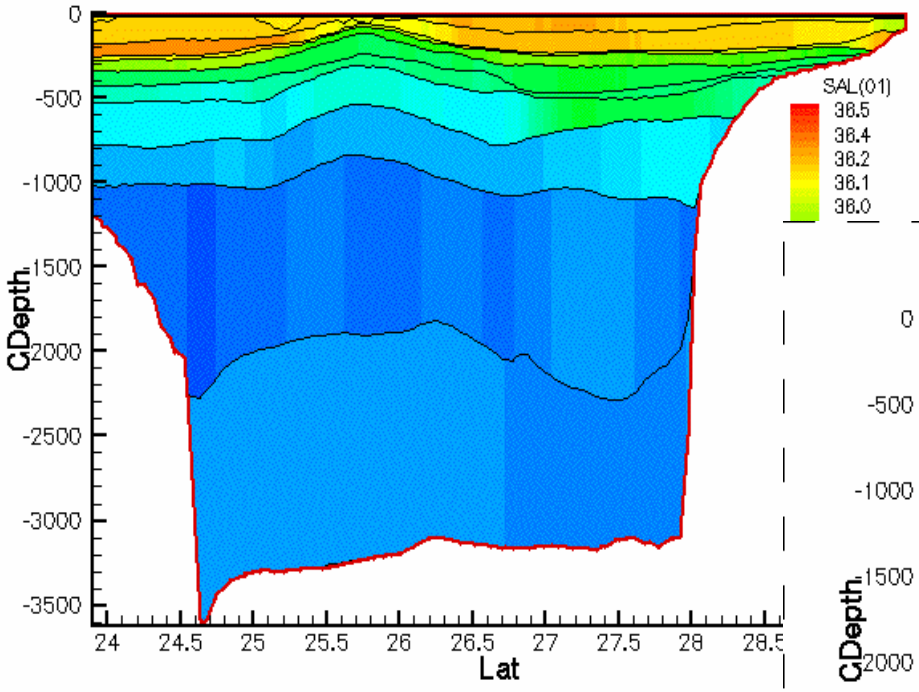
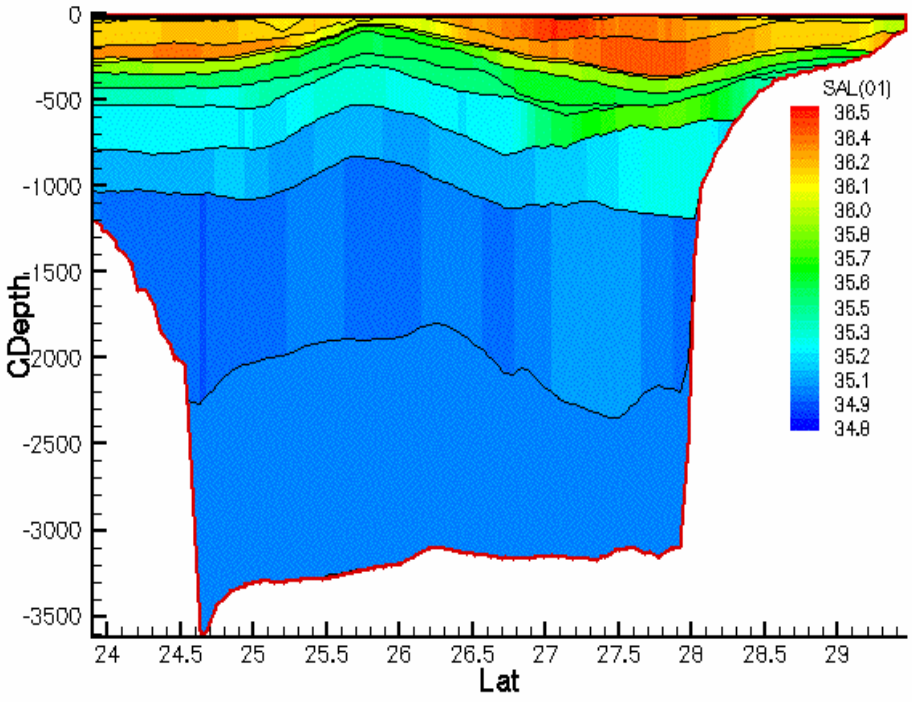
Salinity update

Forecast



Analysis



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Assimilation shock ? (1/2)

Forces the assimilation with α=2.5
(usually using 1)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Forecast

Analysis

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

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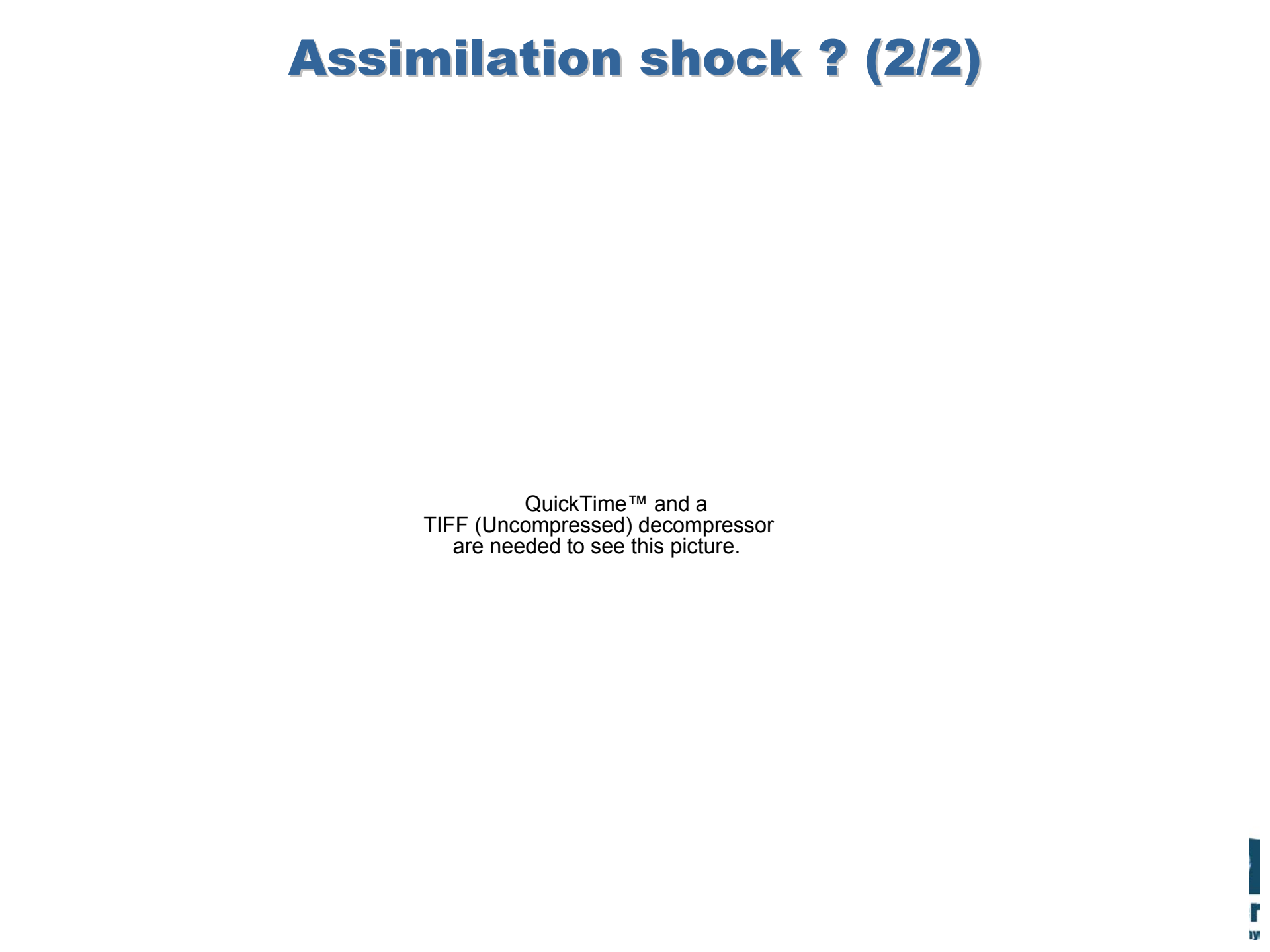
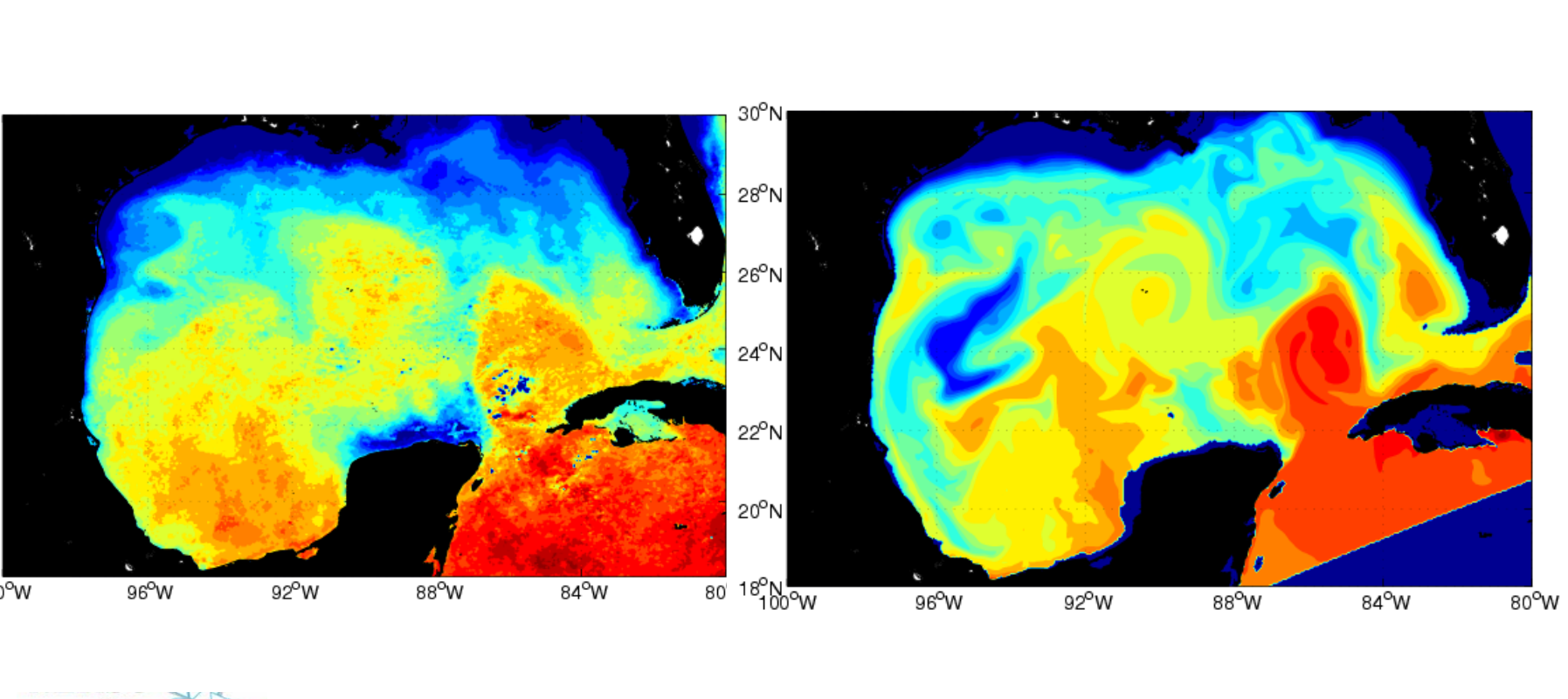
Assimilation shock ? (2/2)



Comparison with SST

29nd of November (forecast+4)
After 2 years of weekly assimilation !

With SST not assimilated nor relaxed



No bias induced by assimilation on SST

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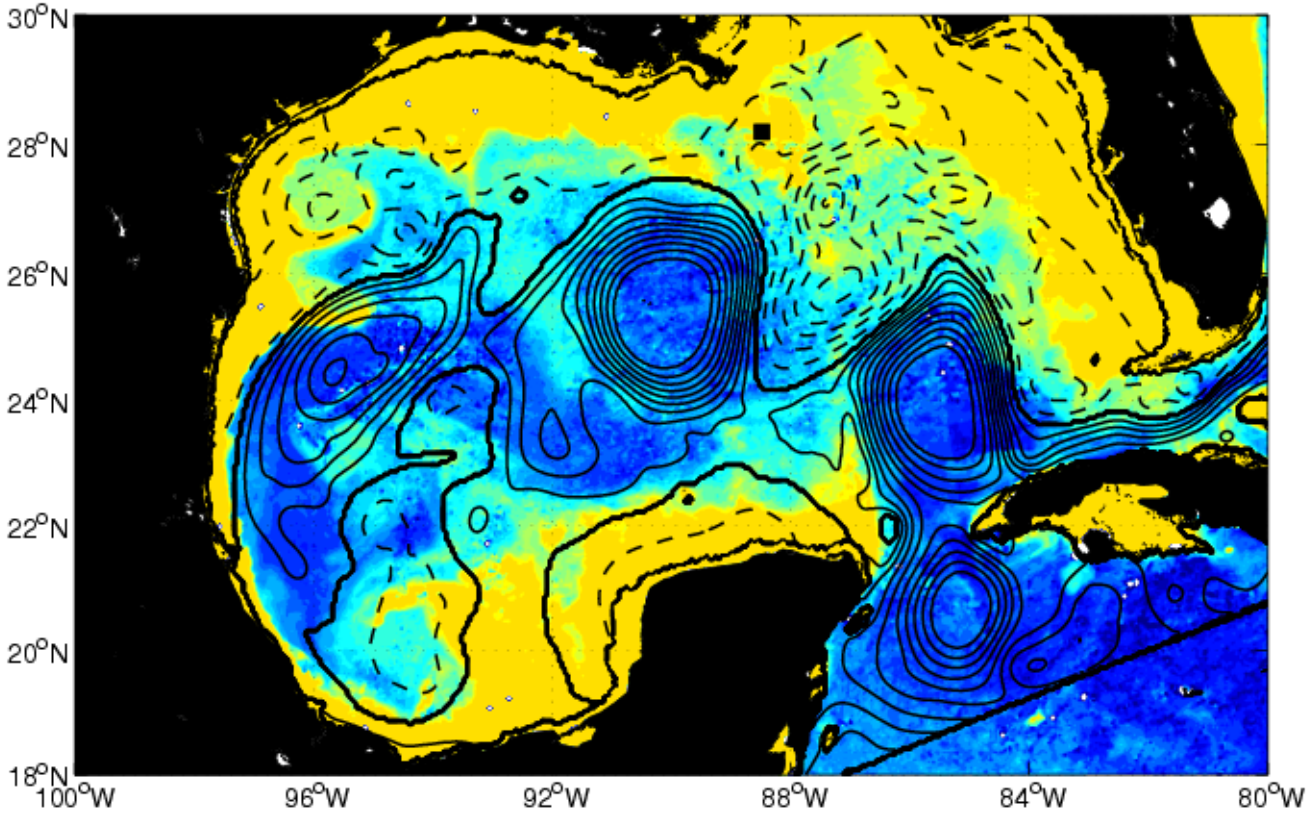
Comparison with OC

29th of November (4 days Forecast)



Overlay of model SSH isolines on a OC MODIS map (not assimilated)

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Future work

- **Comparing EnOI vs EnKF (NOPP project)**

- **Including track assimilation into EnOI (and other Kalman filter based DA method)**

- **Estimate the predictability with the use of stochastic forecasting (Financial support from Shell EP)**

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