High resolution ensemble forecasting for the Gulf of Mexico eddies and fronts

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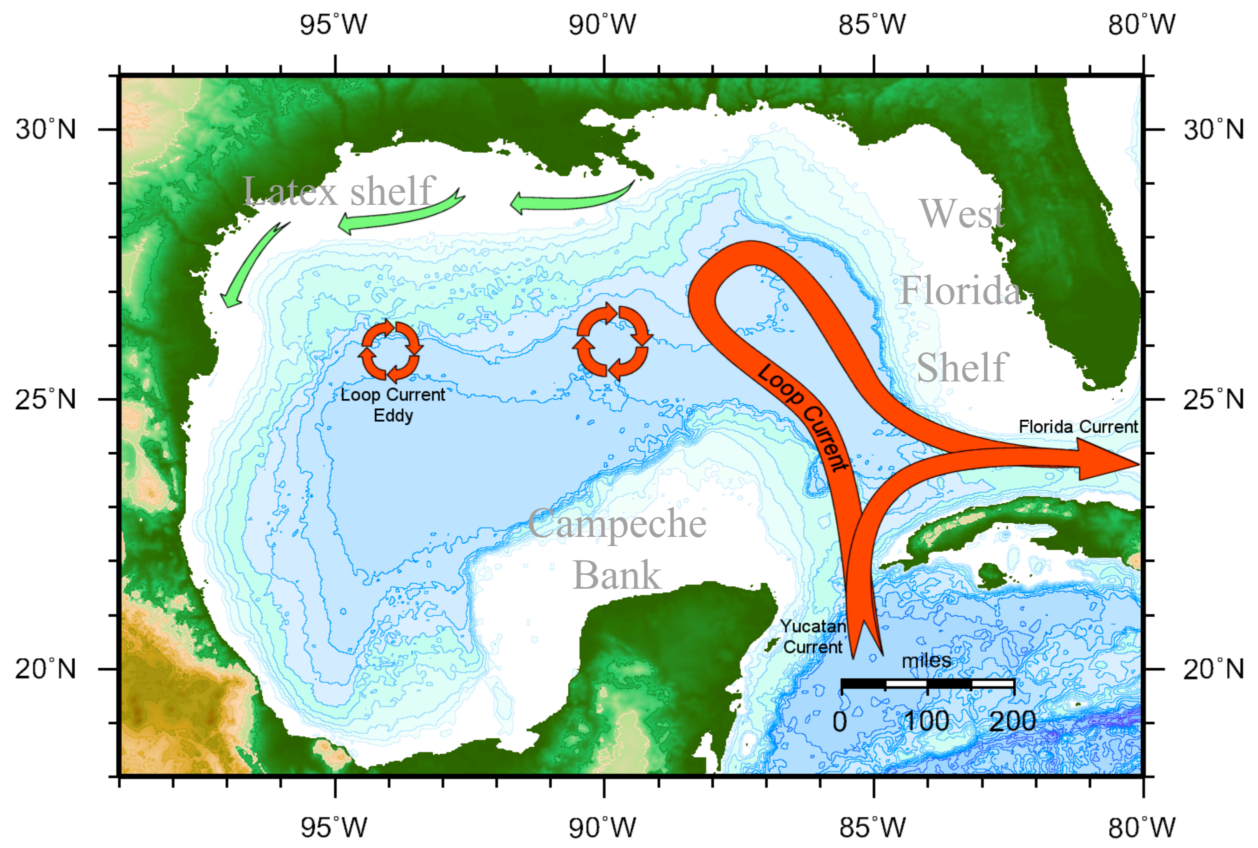
LOM 2007

Project: NFR

Outline

- Circulation in the Gulf of Mexico
- Objectives
- Data assimilative system
- Perturbation sources tested for our ensemble run:
    - Initial state
    - Lateral boundary
    - Atmospheric forcing
- Ensemble forecast accuracy is tested for eddy Yankee
- Comparison of the ensemble spread against the actual error
- Sensitivity study of “assimilation strength” on the forecasting skill

Dynamics in the Gulf of Mexico



Objectives

High resolution data assimilative model are able to forecast the shedding event.(*Chassignet et al. 2005, Oey et al 2005, Kantha et al. 2005*)

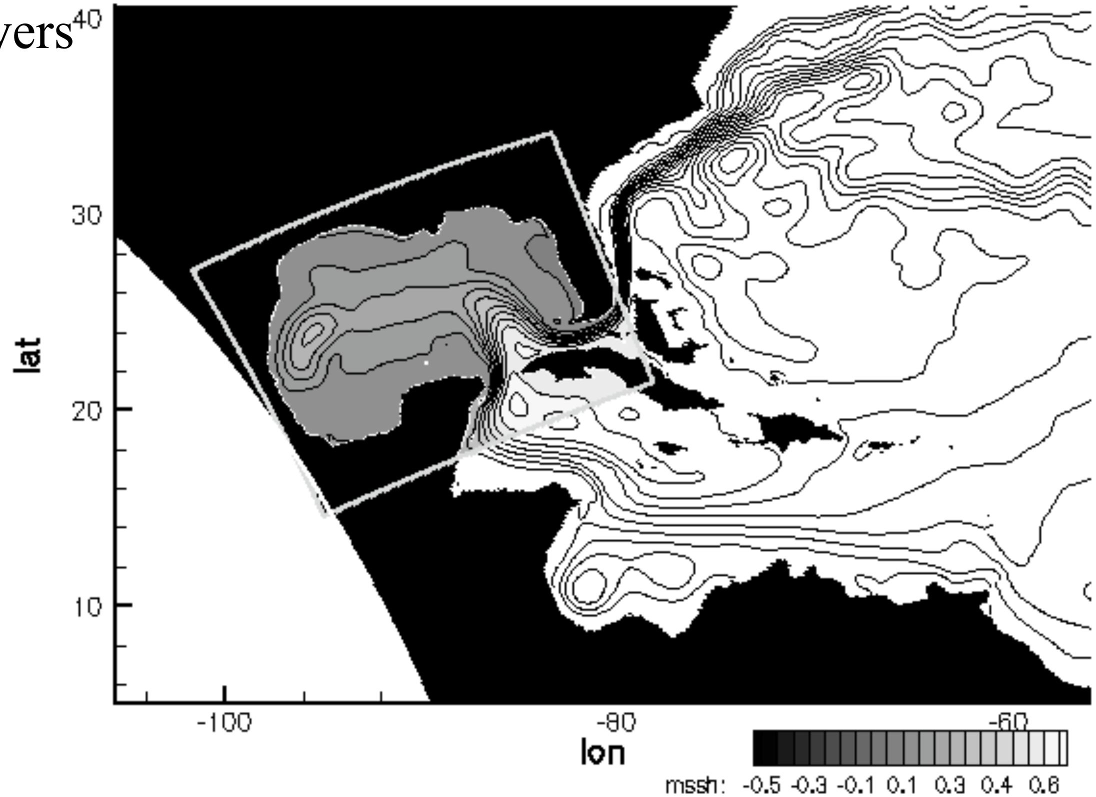
An increased accuracy is needed during highly dynamic event but the forecast capability is limited by the measurement accuracy (~30 km)

Yin et al. 2007 show that a bred-ensemble can give more accurate forecast with perturbation of the initial state

Here we analyzed if we could obtained additional information from a more complete perturbation system

Data assimilative system

- TOPAZ3 ($1/8^{o}$) gives lateral boundary condition to a high resolution model ($1/22^{o}$)
- The high resolution model assimilates altimetry map (EnOI)
- Using HYCOM with 22 hybrid layers
- Forcing from ECMWF



Perturbation system

We need to find perturbations that contribute to the forecast error in our HYCOM configuration

1. Perturbation of the initial state, because neither the model nor the measurements are correct

2. Perturbation of the inflow through the Yucatan Straits, because it affects the position of the Loop Current and the timing of the shedding event (*Maul 77, Bunge 02*)

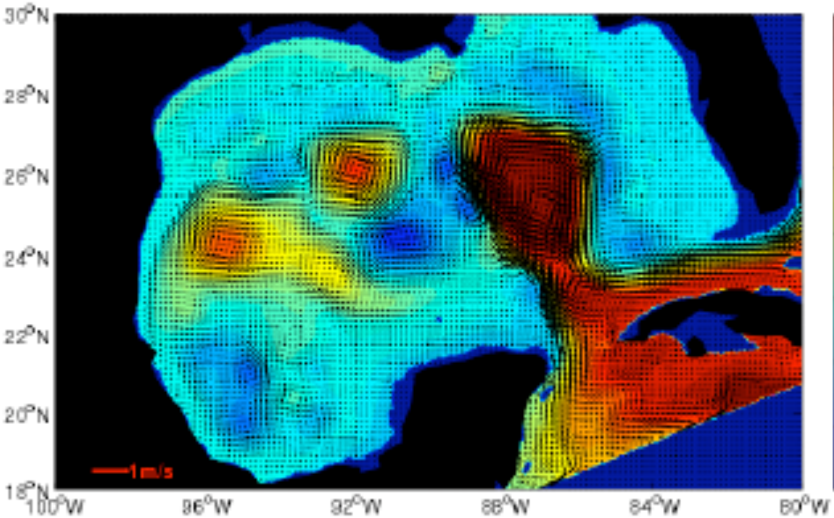
3. Perturbation of the atmospheric forcing can have an impact on the stability of the flow (*Oey et al. 03*)

Perturbation of the initial state

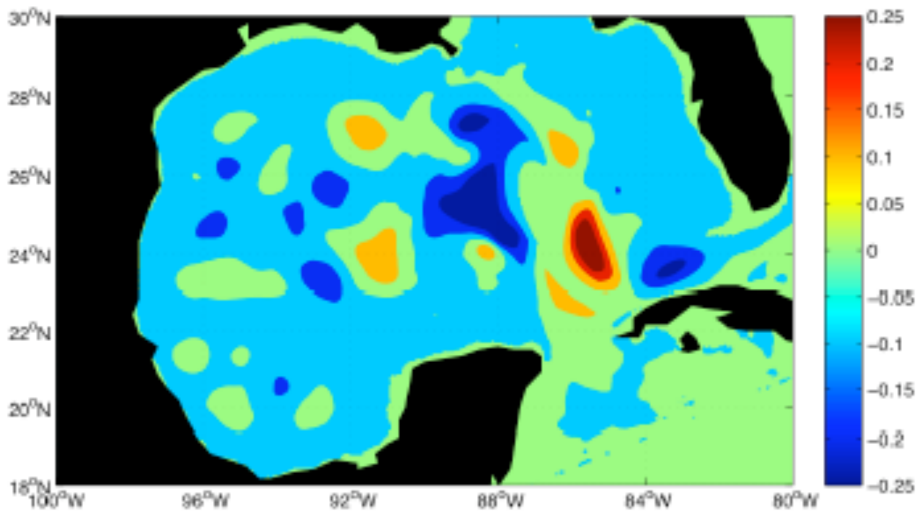
In the EnOI, α scale the variance of the historical ensemble to the level of the unknown instantaneous forecast error (assimilation strength parameter).

we sampled α between 0.2 and 2

Model response with the strongest assimilation after 4 weeks:



Control run



Anomaly with α=2

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changes the location and the orientation of the main features

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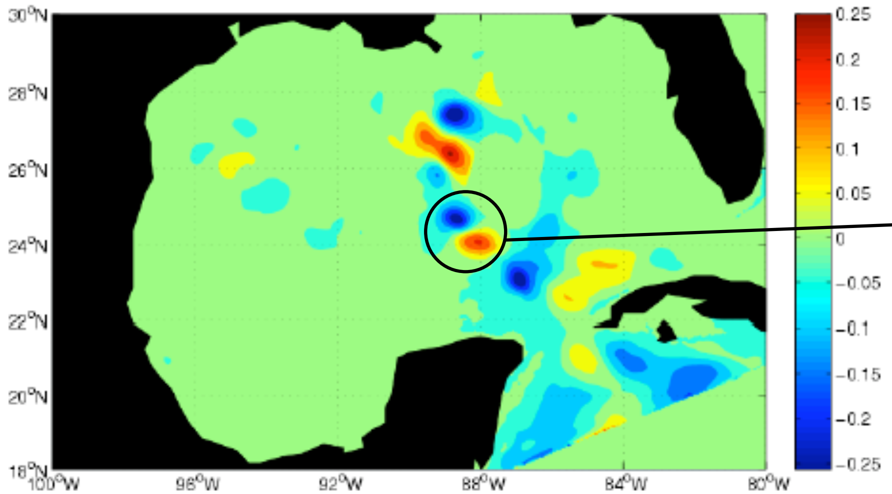
Perturbation of the lateral boundary condition

TOPAZ3 and the nesting routines provides high quality lateral boundary conditions to the high resolution model

We have applied a time lag

Frequency peak of the Yucatan Straits variability found between 20-40, and 5-10 days. (*Abascal et al. 2003*)

We chose the lag randomly between (-37 to 37 days) at the beginning of each run

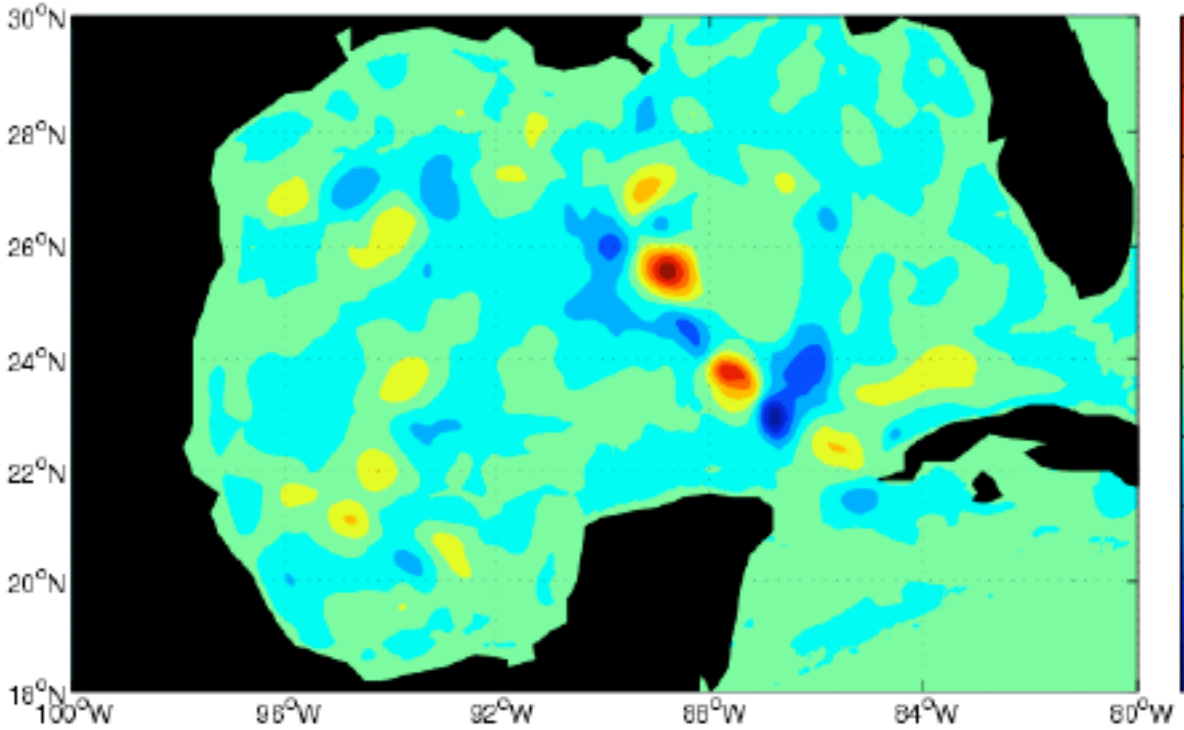


intensification of cyclonic eddies and meanders at the boundary of the LC

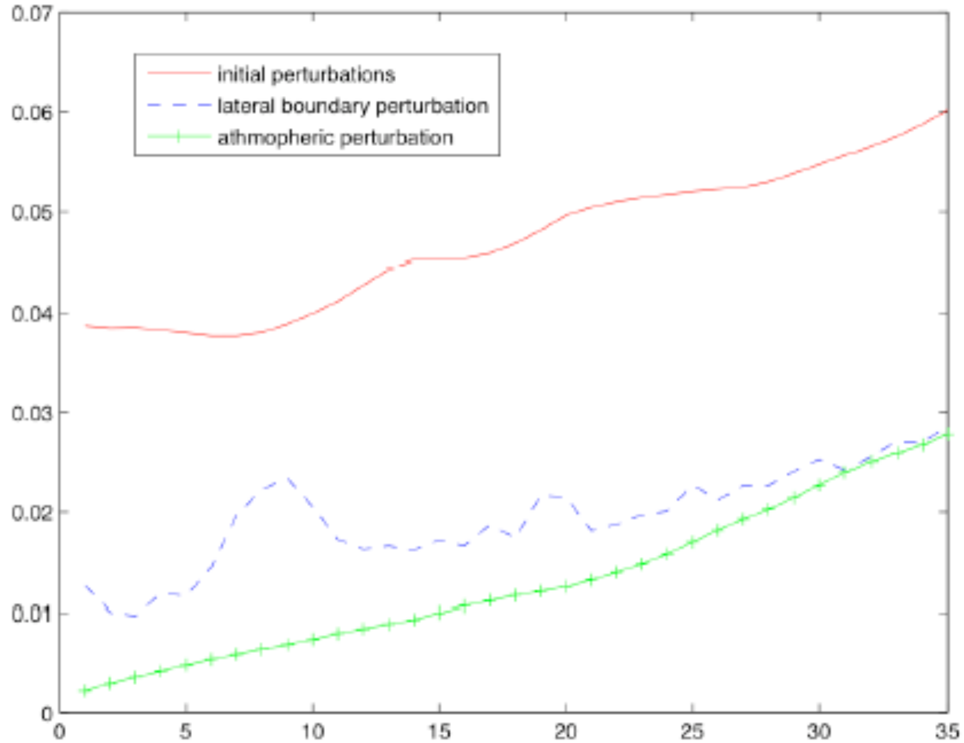
Example of perturbation obtained after 4 weeks with a 37 days lag in the boundary condition

Perturbation of the atmospheric forcing field

Random perturbation of the atmospheric forcing field (50 km decorrelation radius)
Example of anomaly obtained after 4 weeks of perturbation



Relative contributions and growth of the perturbation sources



1.Model sensitive to the 3 perturbation sources
2.Perturbation of the initial perturbation have larger contribution in the SLA error
3.The SLA error growth rate depends on the sources

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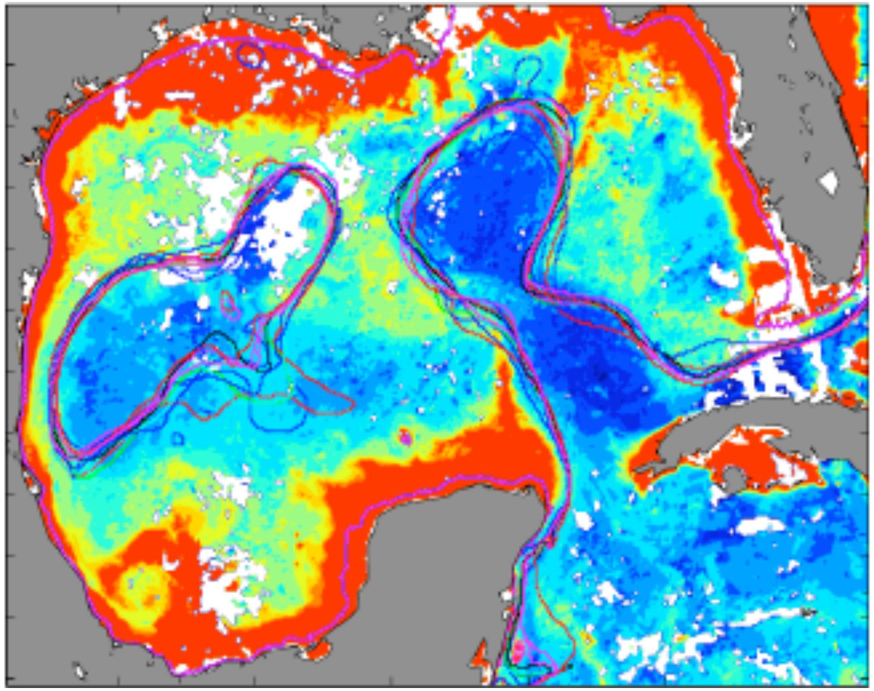
Ensemble Forecast

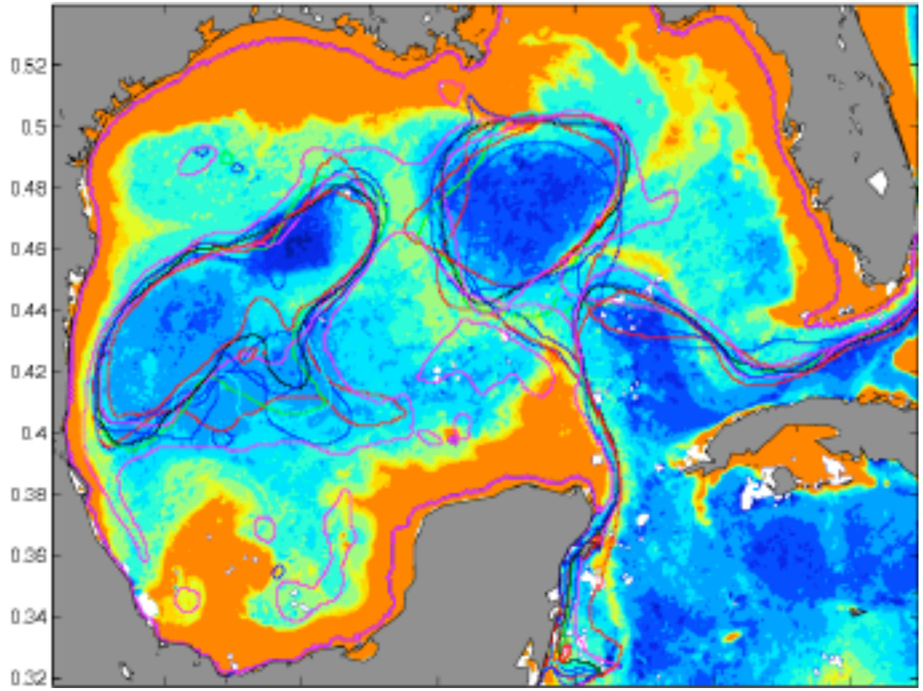
•Ensemble forecast skill is tested for “Eddy Yankee” that sheds around the 19th and reattaches around the 26th of July (2006)
•10 members
• Weekly assimilation and run for 14 days (up to the 7-day forecast)
•Run the ensemble for 7 weeks

Compare the ensemble front spaghetti with Ocean Color for the 2 last runs

Assimilation on the 2006/07/05



Nowcast (2006/07/12)



7-day forecast (2006/07/19)

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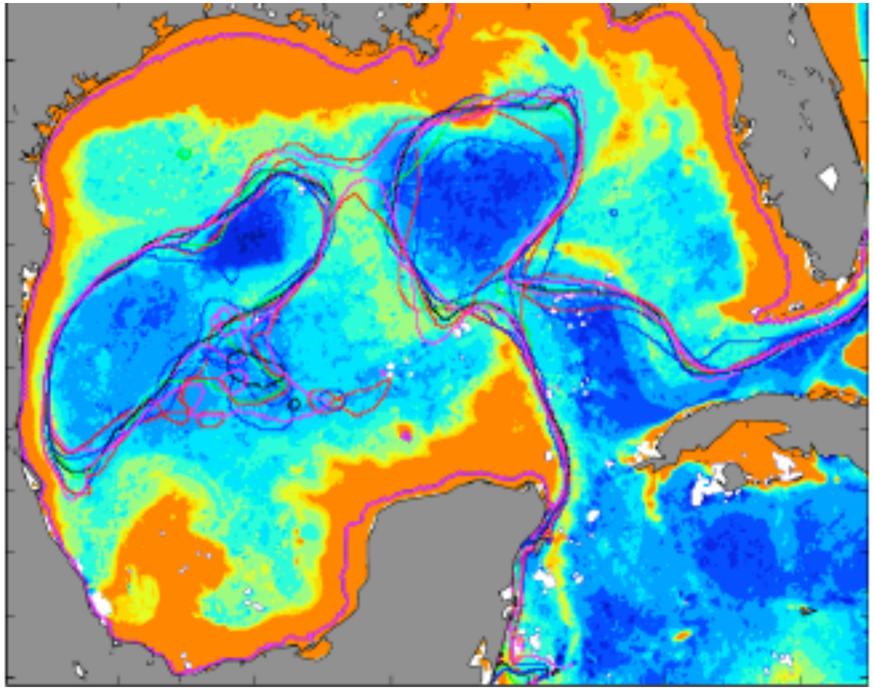
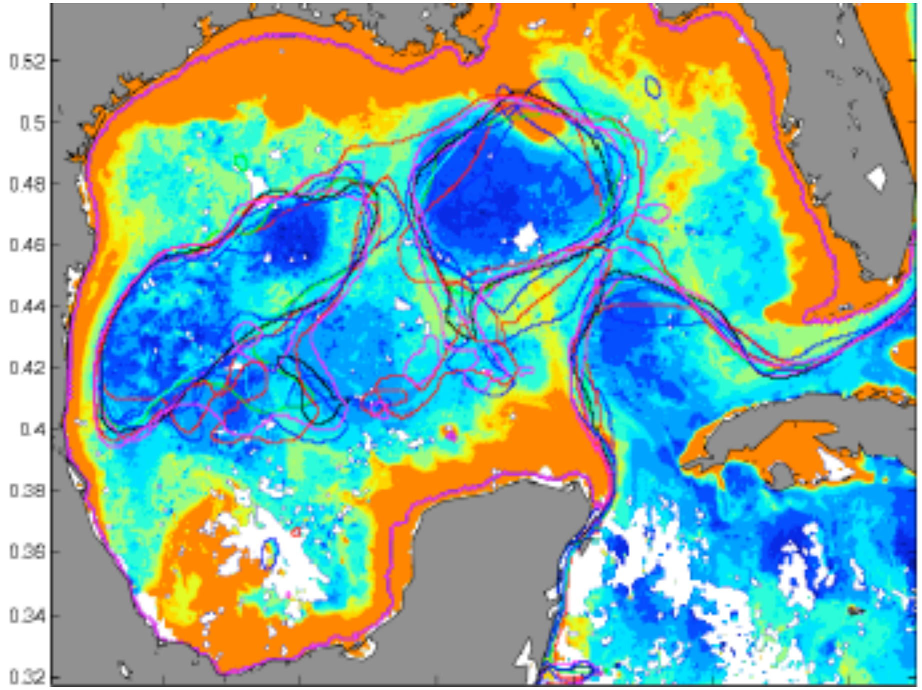
Assimilation on the 2006/07/12



Nowcast (2006/07/19)



7-day forecast (2006/07/26)

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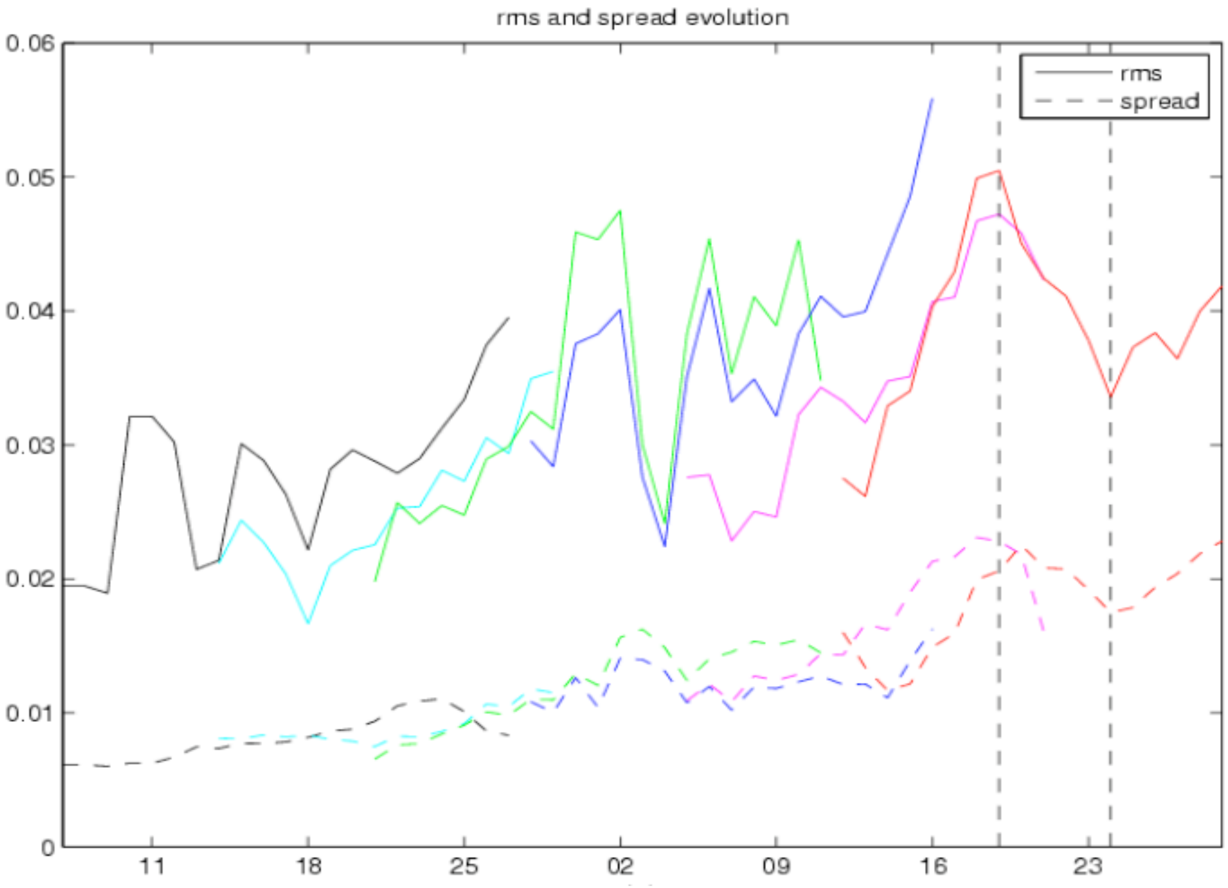
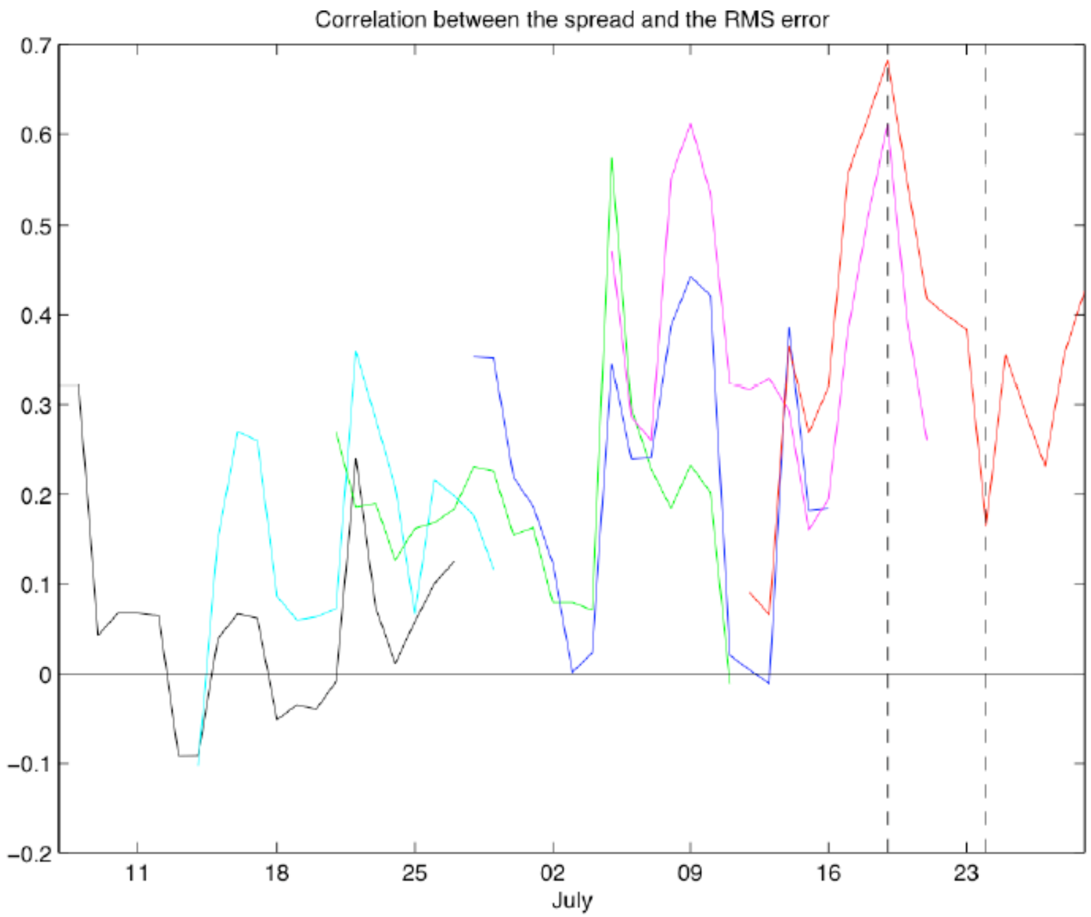
Evolution of ensemble spread and of the error (SLA)



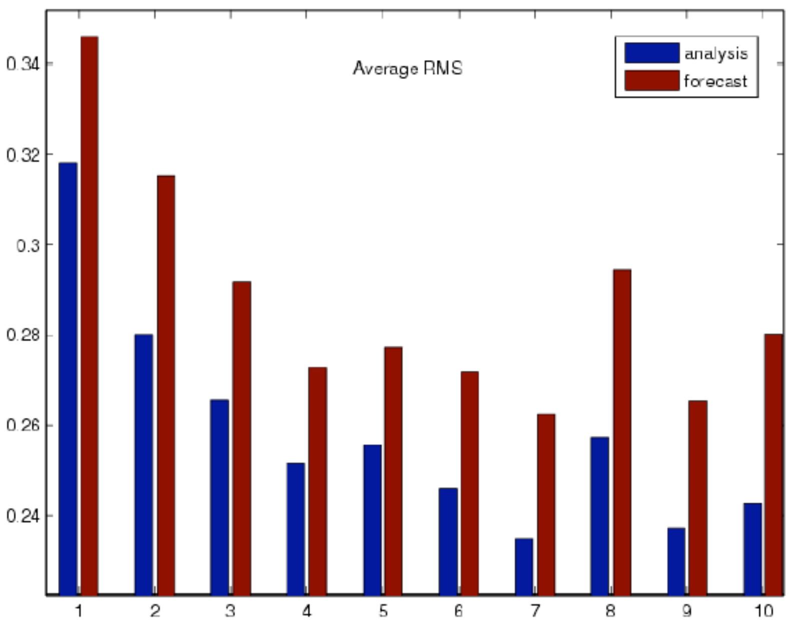
The ensemble spread and the real error vary in good agreement over time

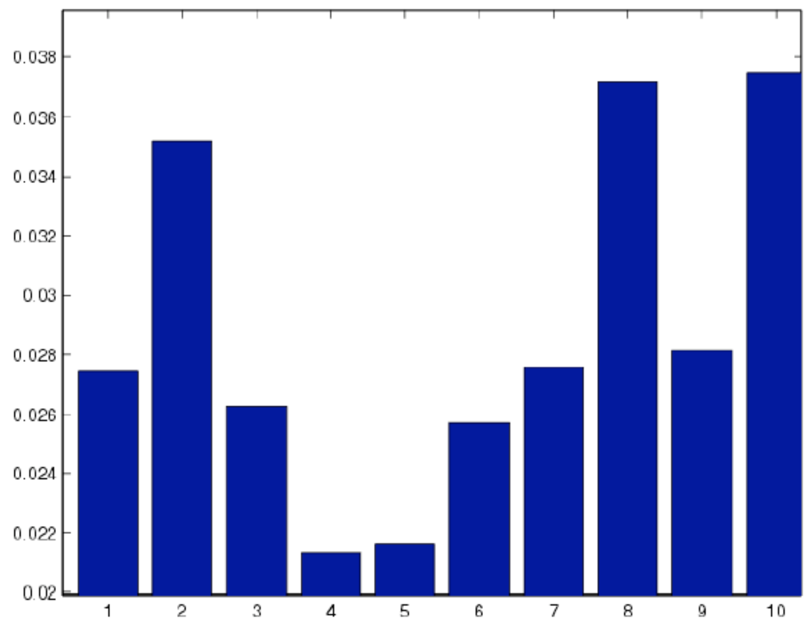
Spatial correlation of the Ensemble spread and the error



Good correlation when the error is large

Influence of α
"The assimilation strength"





Increasing α lower the RMSE initially but leads to faster increase consecutively.
For a 7-day forecast the optimal value in average is α=0.8

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Conclusion (1/3)

•Perturbation of the initial state control the replacement of the large scale features

•Perturbation of the lateral boundary condition controls the fast growth of cyclonic eddies and meanders at the boundary of the LC

•Perturbation of the atmospheric forcing control the slow growth of cyclonic eddies and meanders at the boundary of the LC

The model is sensitive in a different manner (scale, time response, growth) to the 3 different perturbation sources.

The perturbation system develop a significant spread after 4 weeks !

Conclusion (2/3)

- Analyze of the ensemble forecasting skill against eddy Yankee show that:
  - The ensemble reproduces well the dynamics of the shedding event.
  - The eddy and Loop current fronts are found among ensemble fronts, but the ensemble spread is underestimated for SLA
  - The ensemble spread and the SLA RMSE and correlated both in space and in time

A small ensemble can provide an additional confidence indices to our forecast.

Conclusion (3/3)

•A stronger assimilation reduces the error faster initially, but does not necessarily give the best forecast over time.

It is possible to tune α depending on the range of the forecast.

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