Enhancing predictability of the Loop Current variability using Gulf of Mexico Hycom

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General framework:

- Study of the **Loop Current** (LC) in the Gulf of Mexico (GoM) and associated processes (dynamics, connectivity)
- Improve the LC **predictability**
- Use of Hycom model, which has proved efficient in simulating the GoM

Approach:

- Perform ensemble of simulations to study the model **sensitivity** to various parameters
- Perform data assimilation (DA) experiments to test the **efficiency** of various DA schemes and the **performance** of observation networks

Model Configuration:

- Hycom 1/25 degree, 26 vertical layers
- Atmospheric forcing: **COAMPS** (27 km, 3h)
- IC: NCODA simulation run at NRL(altimetry, SSH and in-situ data assimilated)
- BC: climatology from 4 years of Hycom Atlantic simulation
- First simulation: year 2004

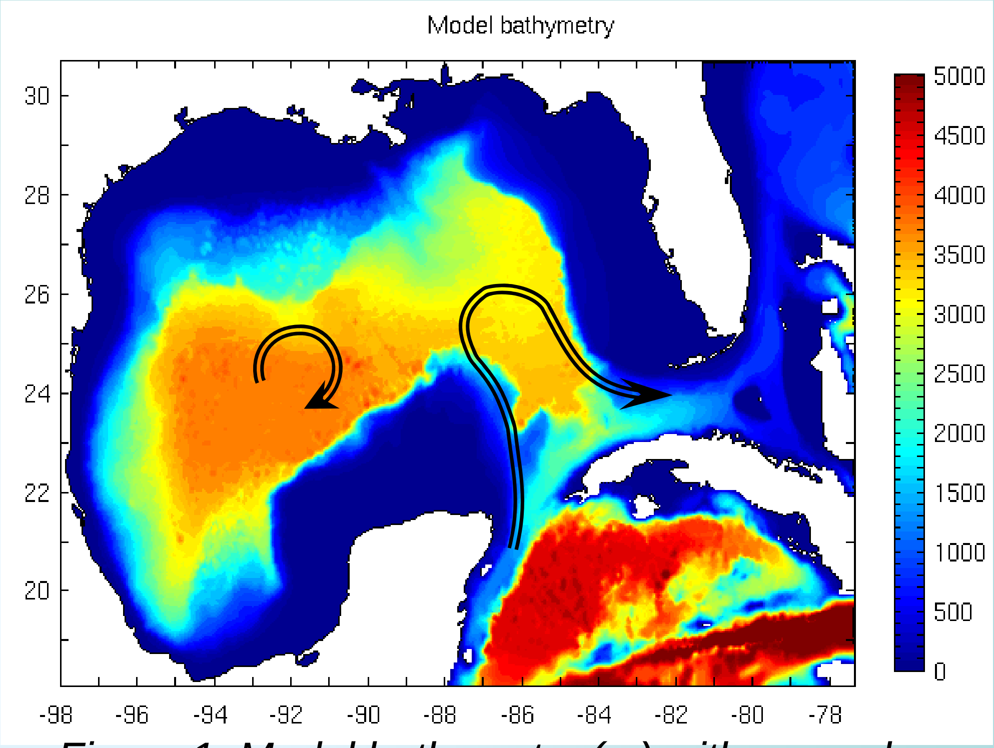


Figure 1: Model bathymetry (m) with examples of dynamical features (LC and eddy)

Preliminary work presented here:

- Brief description of the reference simulation
- Validation (altimetry, SST)
- Influence of boundary conditions

Reference simulation

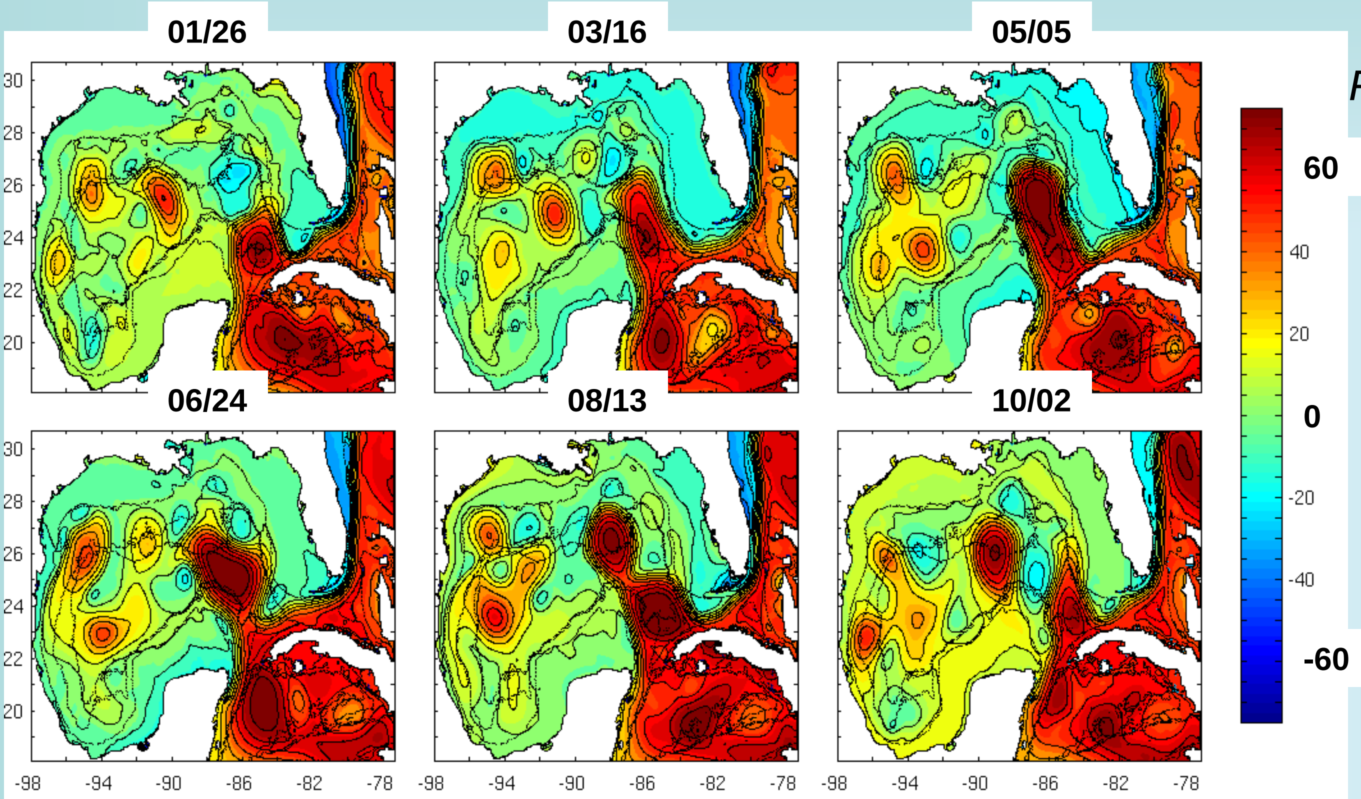
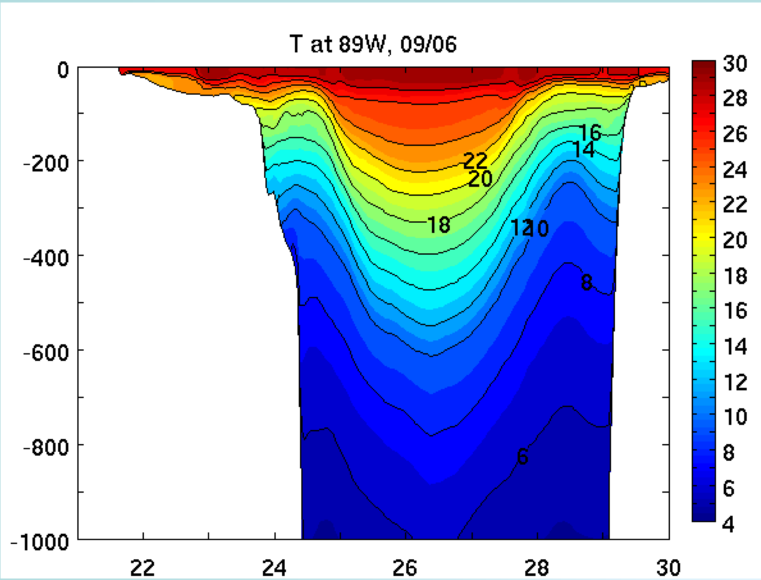


Figure 2: Time evolution of the SSH (cm) in the reference simulation

- ring shed late August
- presence of **sub-mesoscale cyclonic** eddies surrounding the LC ; they seem to play a role in eddy shedding

Reference simulation



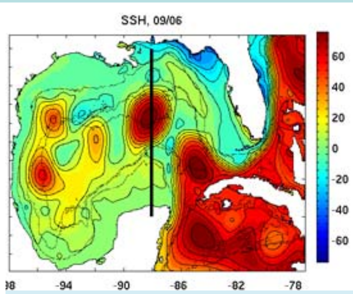
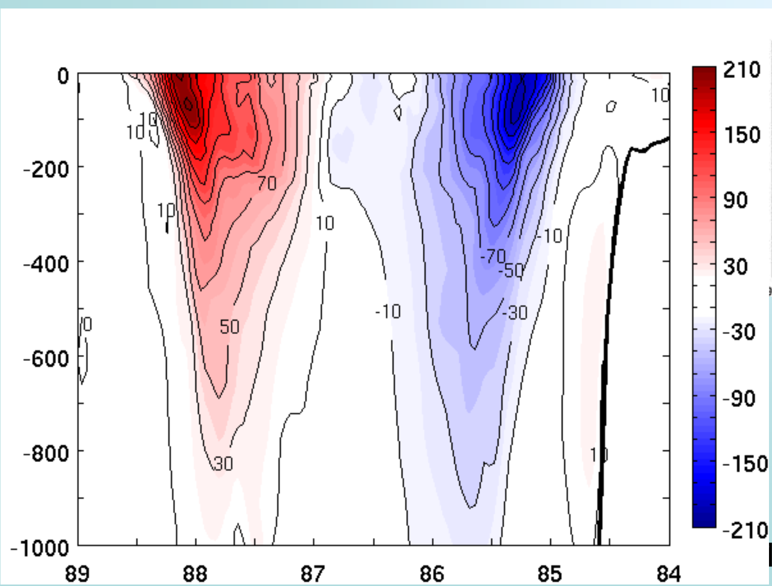
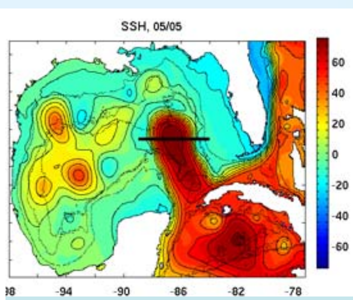


Figure 3: Vertical temperature (deg C) profile of the eddy after shedding (Sep. 6)

- realistic **dimensions** of the eddy (~350 km)
- realistic **vertical structure**





- realistic **vertical structure** of the LC

Figure 4: Vertical meridional current ($cm.s^{-1}$) profile of the LC (May 5)

Validation : the Yucatan Strait

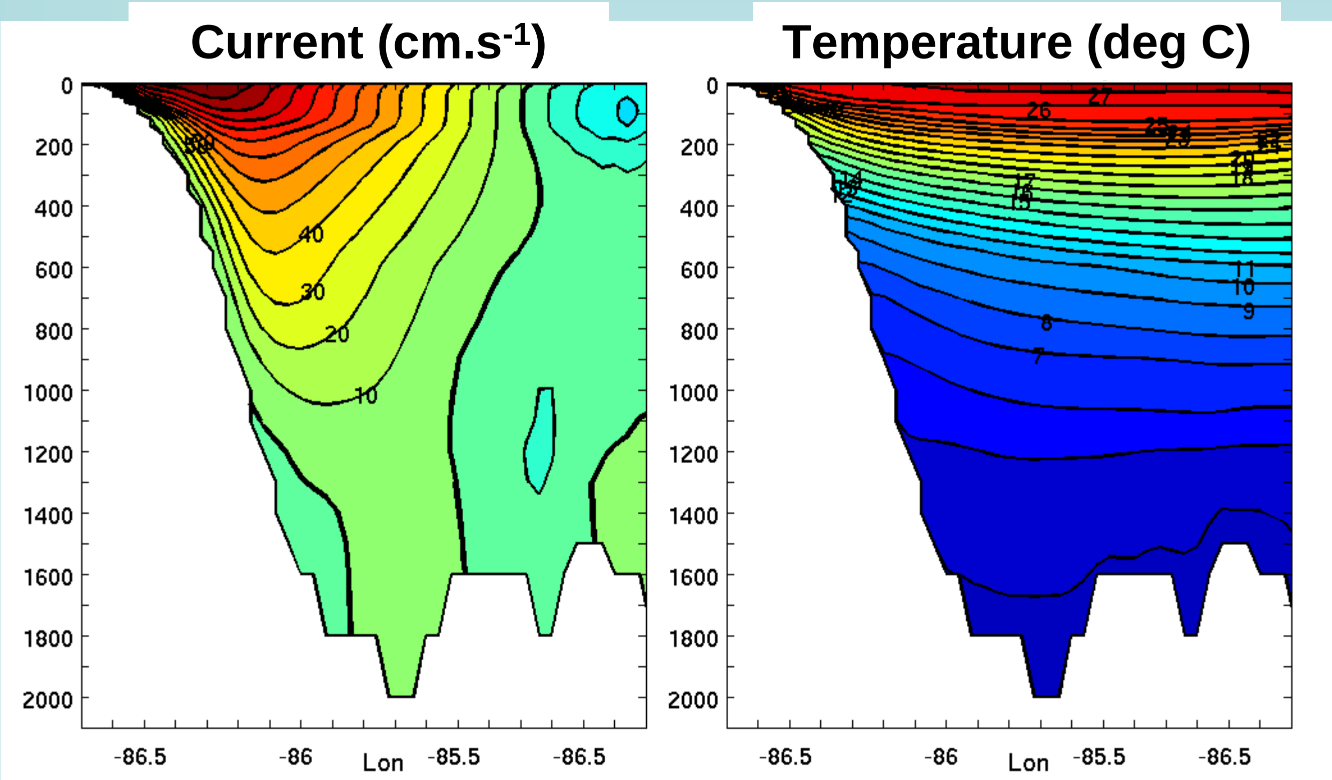


Figure 5: Temporal average of meridional current and temperature at the Yucatan Strait

- correct **vertical structure** w/r Candela et al., 2002, with northward **current close to the Yucatan** as expected, a bit more intense
- temperature **very close** to observed climatology
- realistic **transport** of 27.5±1.5 Sv

=> **confidence** in the LC inflow

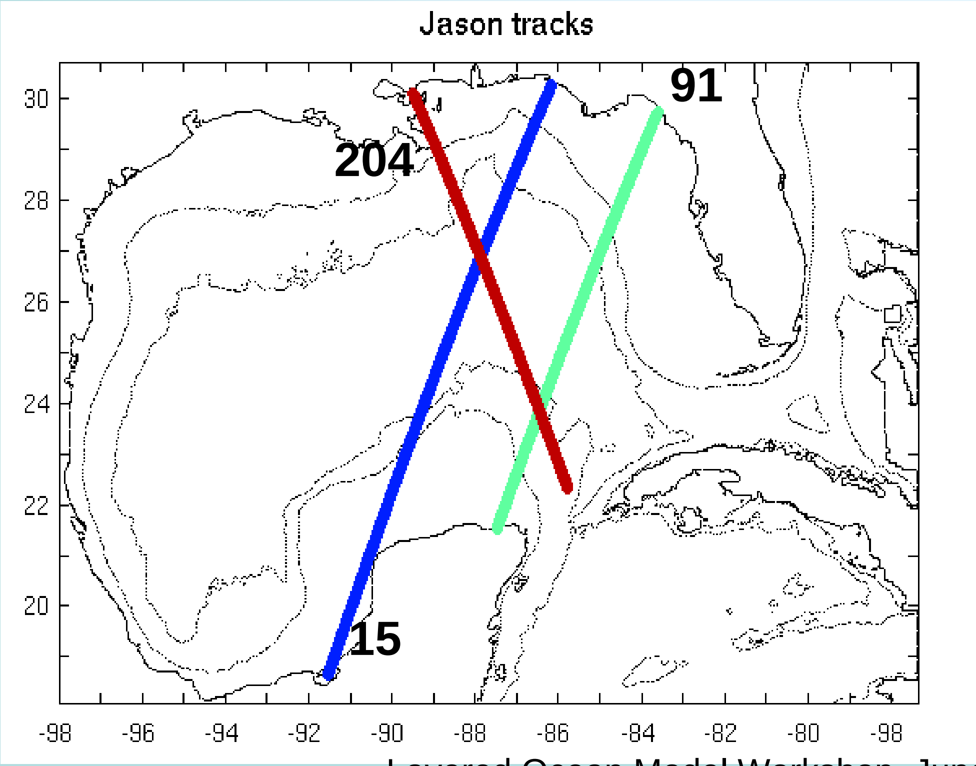
Validation : altimetry

Altimetry products:

• Along-track **Jason 1** sea surface height by CTOH (LEGOS, Toulouse, France)

• Post-treatment with X-track (Roblou et al., 2007) : remove temporal mean, tides effects, HF barotropic signal to access **Sea Level Anomaly**

• Local temporal average removed



• 3 tracks considered
• cover the domain of the LC extension

Figure 6: Jason 1 considered tracks

Validation : altimetry

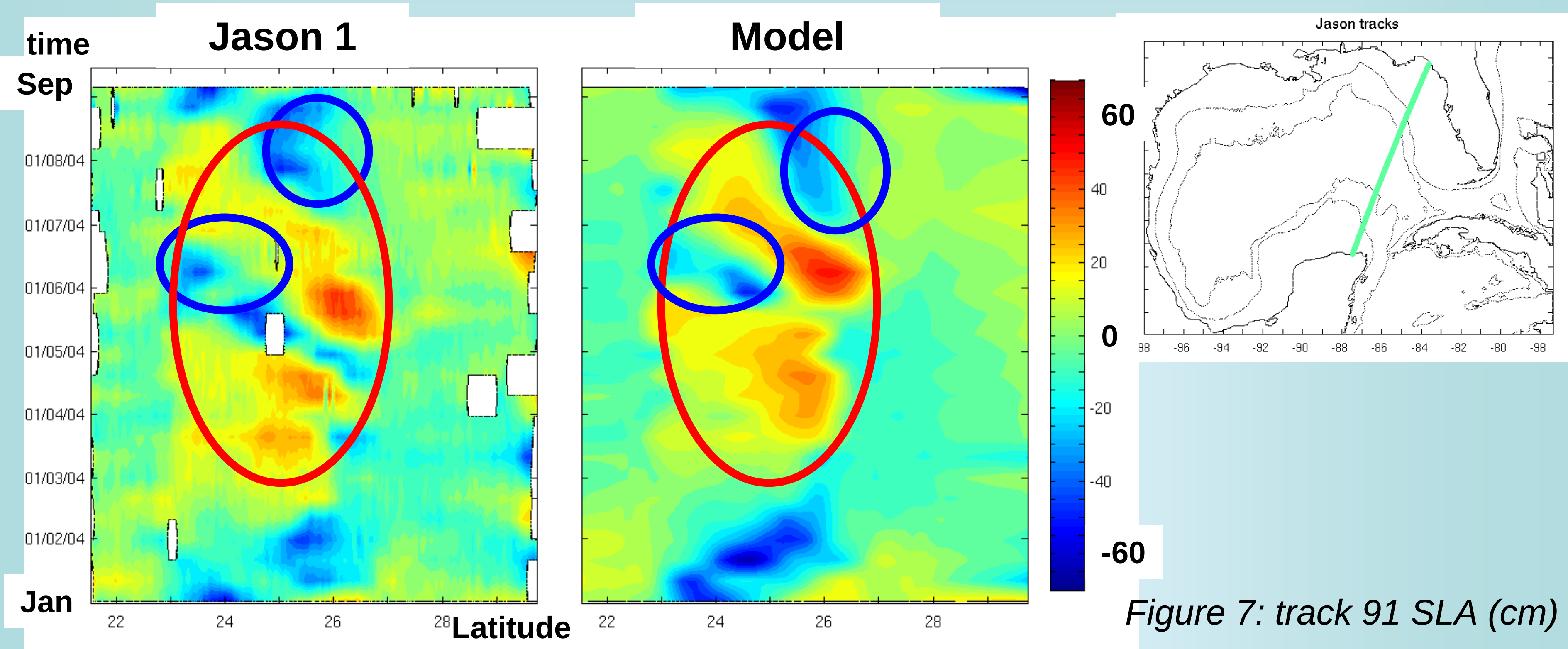


Figure 7: track 91 SLA (cm)

- realistic **development of the LC** (timing, amplitude)
- presence of **cyclonic features** South and North of the LC
- general trend realistic on the **West Florida Shelf**

Validation : altimetry

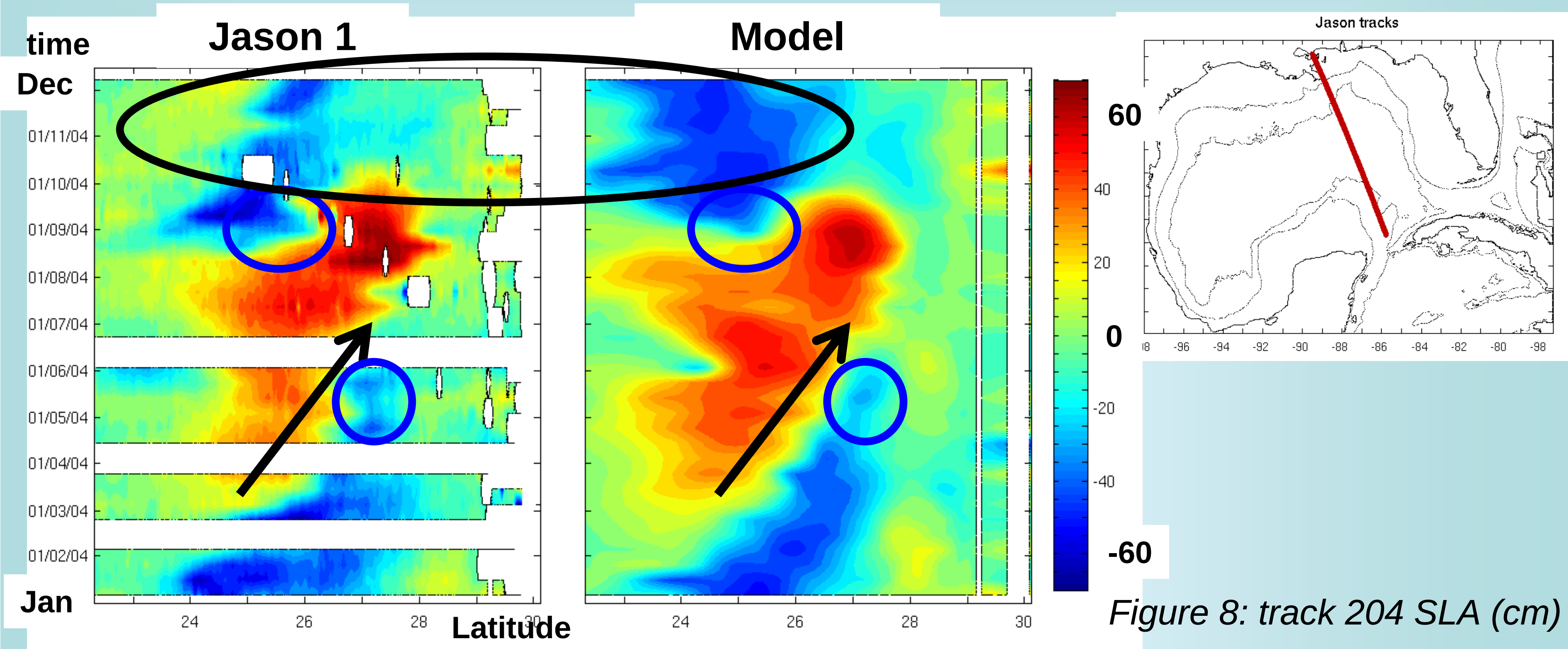


Figure 8: track 204 SLA (cm)

- extension of the LC towards the **North**
- presence of **cyclonic features** South and North of the LC
- less realistic after October

Validation : altimetry

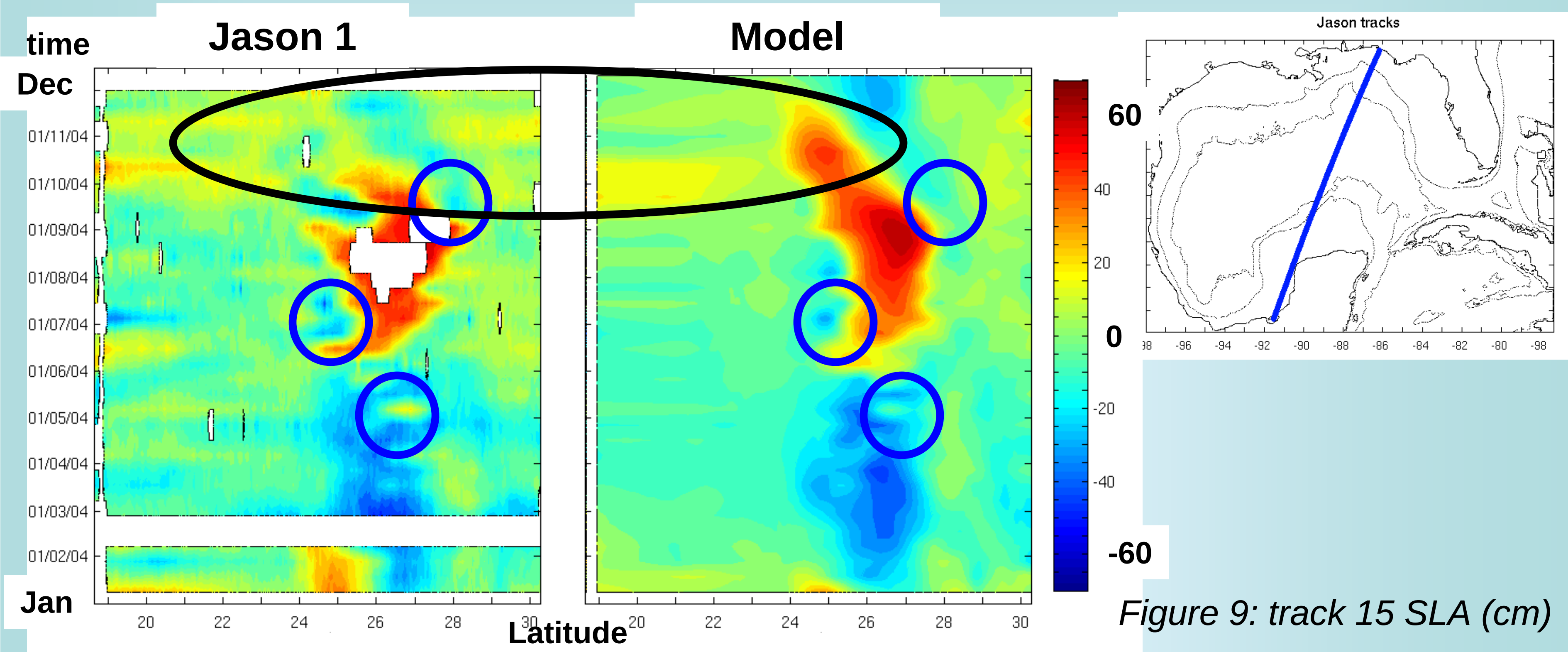


Figure 9: track 15 SLA (cm)

- agreement in the **small scale** features
- realistic trend on the **Campeche Bank**
- less realistic after October

Validation : Sea Surface Temperature (SST)

SST products:

• NOAA SST products (Reynolds et al., 2007) : blended SST from AVHRR + AMSR + in situ data, missing data interpolated using OI

• daily data, 0.25 deg resolution

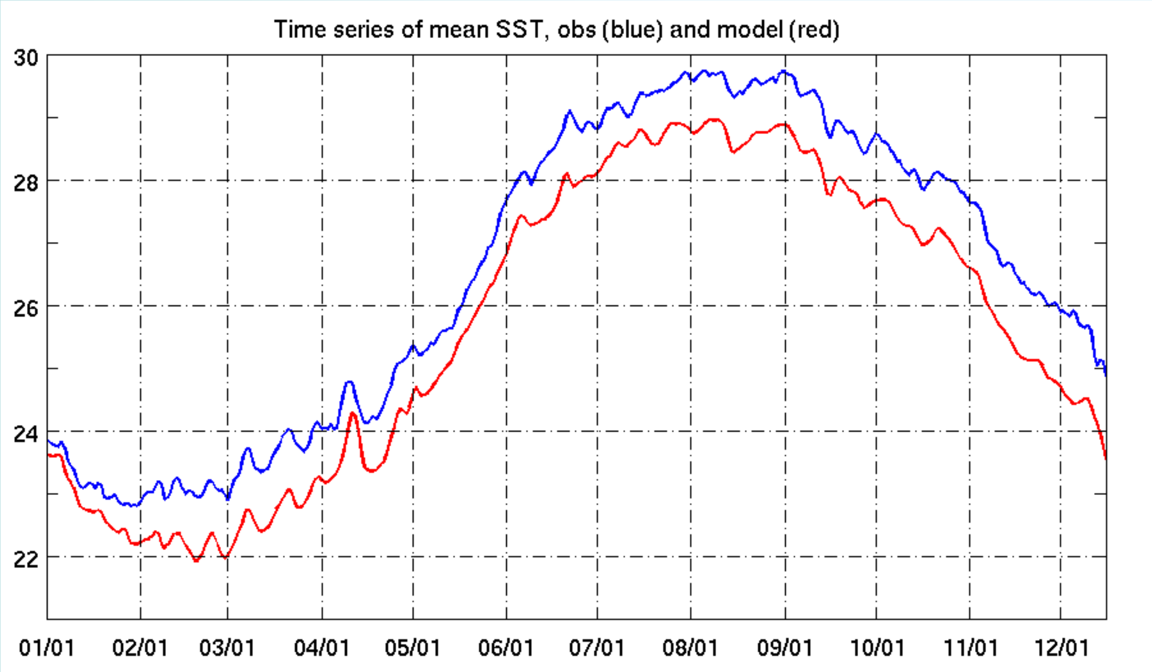


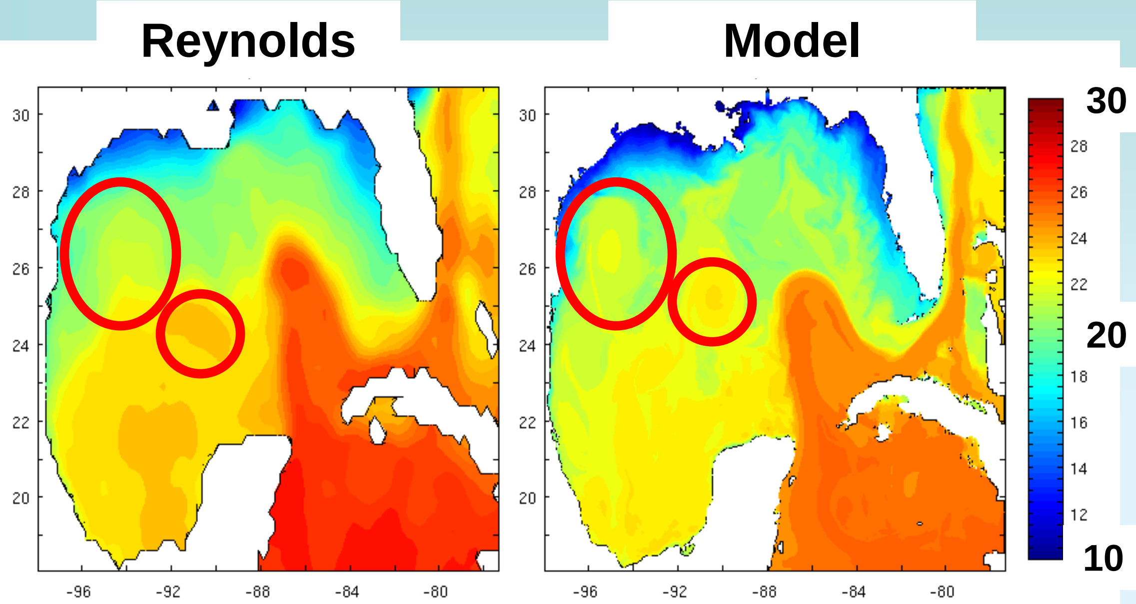
Figure 10: time series of 2004 daily SST average on the GoM domain (deg C) for the observations (blue) and the model (red)

• **cold bias** in the model, slowly increasing during the year (0.4 to 1.2 deg C)

• **realistic seasonal variations** in amplitude

• **realistic HF variations**

Validation : Sea Surface Temperature (SST)



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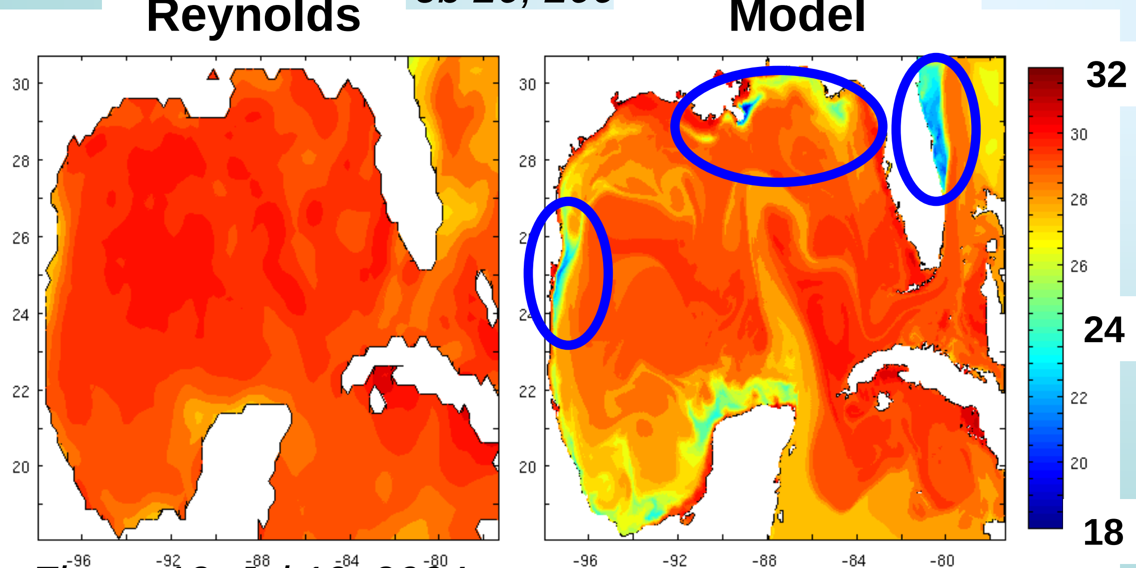

Figure 12: Jul 19, 2004 SST (deg C)

- model **cold bias** in the Caribbean Sea and the LC
- presence of **warmer waters** in the Campeche Bay, realistic extension to the North as filaments or eddies
- realistic presence of **cold waters** along the Northern coast

- **stronger gradients** in the model
- **upwelling** at the Yucatan Peninsula modeled
- waters along the Northern coasts **too cold** in the model

Validation : Sea Surface Temperature (SST)

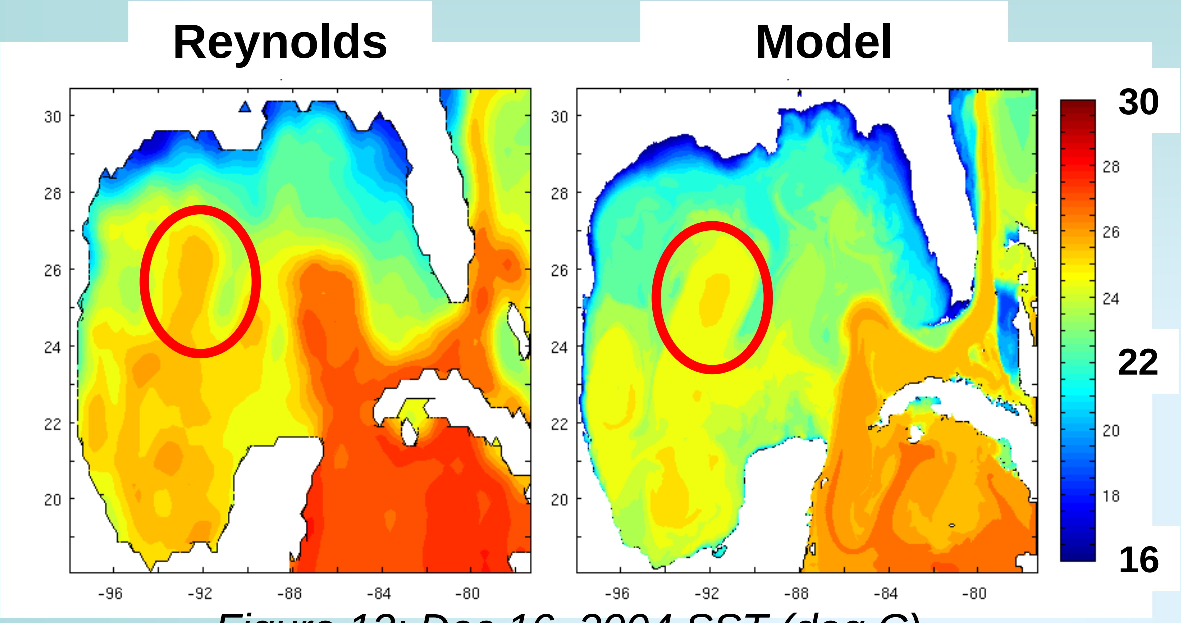

Figure 13: Dec 16, 2004 SST (deg C)

End of the simulation :

- **divergence** in the extension of the LC
- realistic **cold waters** along the Northern coast
- **realistic mesoscale** features in the GoM

From the altimetric and SST observations, despite a bias in SST and local divergences, the model seems able to simulate :

- the mean **seasonal evolution** of the GoM in sea level and SST
- the LC in **dimension** and **amplitude**
- the **cyclonic eddies** surrounding the LC
- **shelf dynamics** (upwelling, cold fronts)
- the **HF** SST response to atmospheric changes

Sensitivity study : perturbation of the inflow

- calculation of the first 10 EOFs of the boundary forcing currents (v at Northern and Southern boundaries, u at the Eastern boundary)
- add **random linear combination** of these EOFs to the initial forcing field :

$$(u,v)_m(i,j,t) = (u,v)_{ref}(i,j,t) + \sum_{k=1}^{10} \delta_k^m \lambda_k (u,v)_k^{EOF}(i,j)\,\zeta_k(t)\ ,\ \delta_k^m\ \varepsilon\ N(0,1)$$

=> add variability **of the same order as the temporal variability** of the reference boundary current

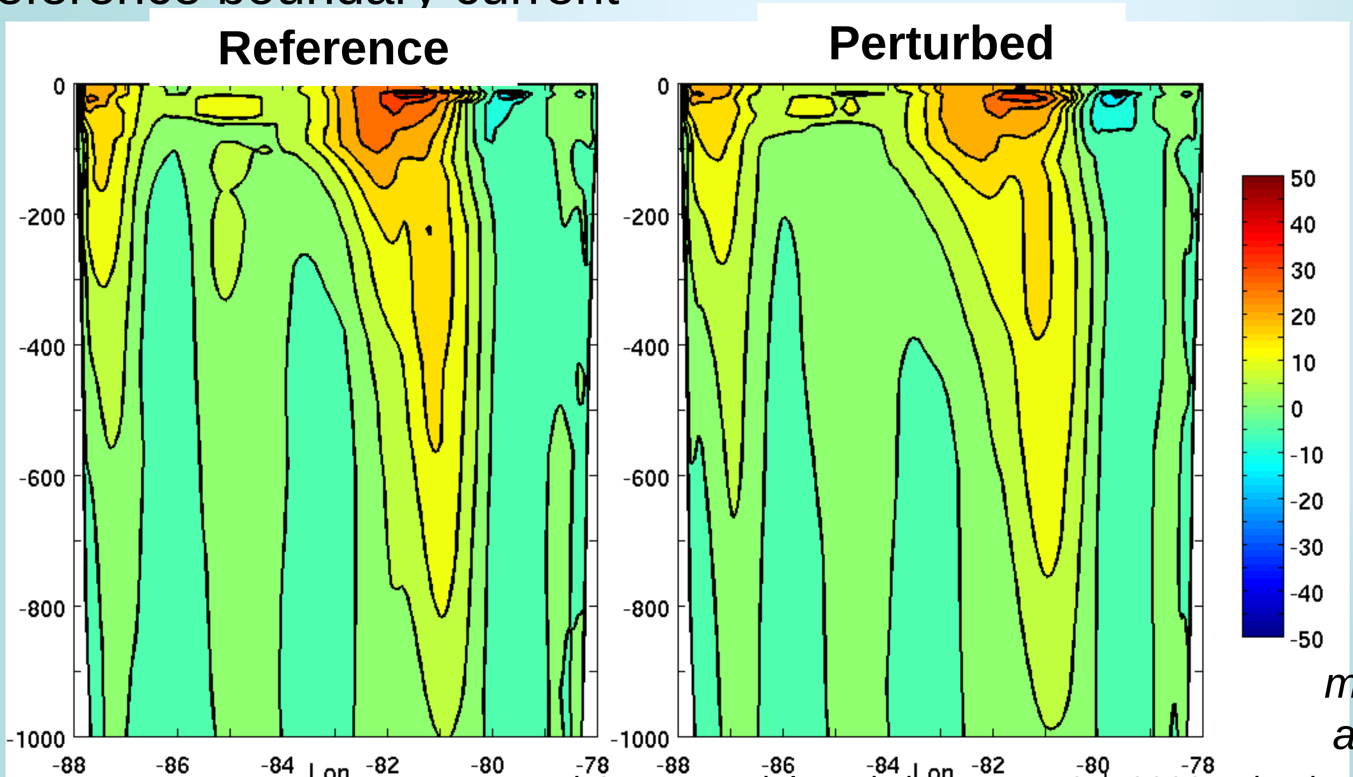

Figure 14: Initial meridional current ($cm.s^{-1}$) at the Southern boundary

Sensitivity study : perturbation of the inflow

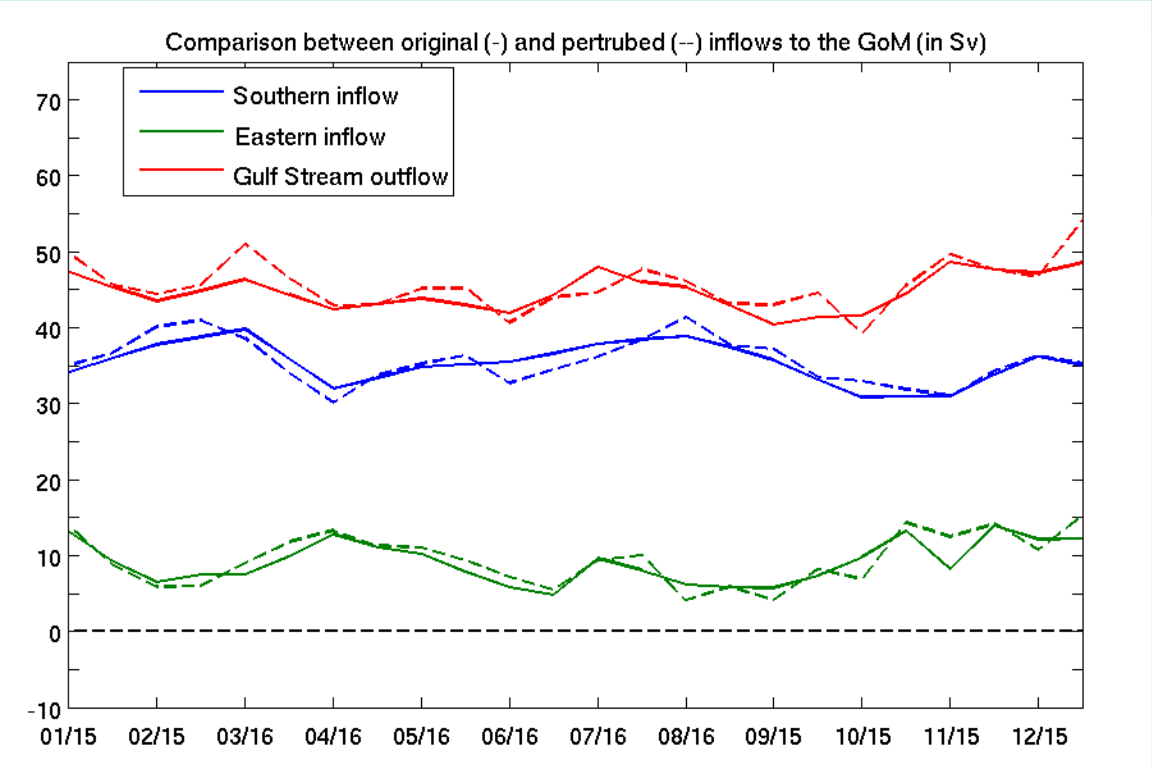

Figure 15: Time evolution of the transport (Sv) through the 3 open boundaries, for the reference (-) and the perturbed simulations (- -)

- transport remains **close to the reference**
- preserves **seasonal variations**
- variations can be considered representing **uncertainties** in the BC forcing

Sensitivity study : perturbation of the inflow

Evolution of the perturbed simulation

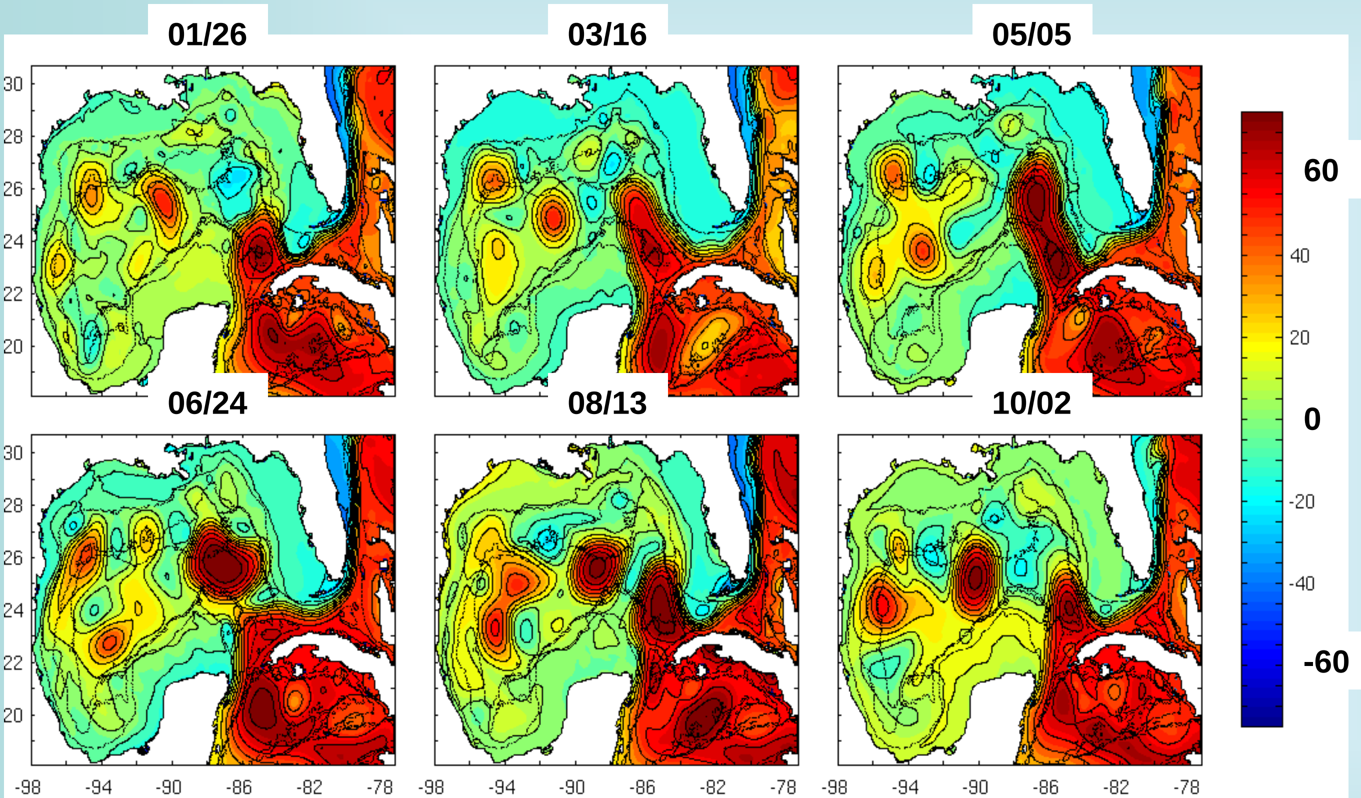

Figure 16: Time evolution of the SSH (cm) in the perturbed simulation

- amplitudes and dimensions comparable to the reference
- ring shed **2 months earlier** than the ref simulation (June)

Sensitivity study : perturbation of the inflow

Evolution of the difference in SSH (≈ model uncertainty)

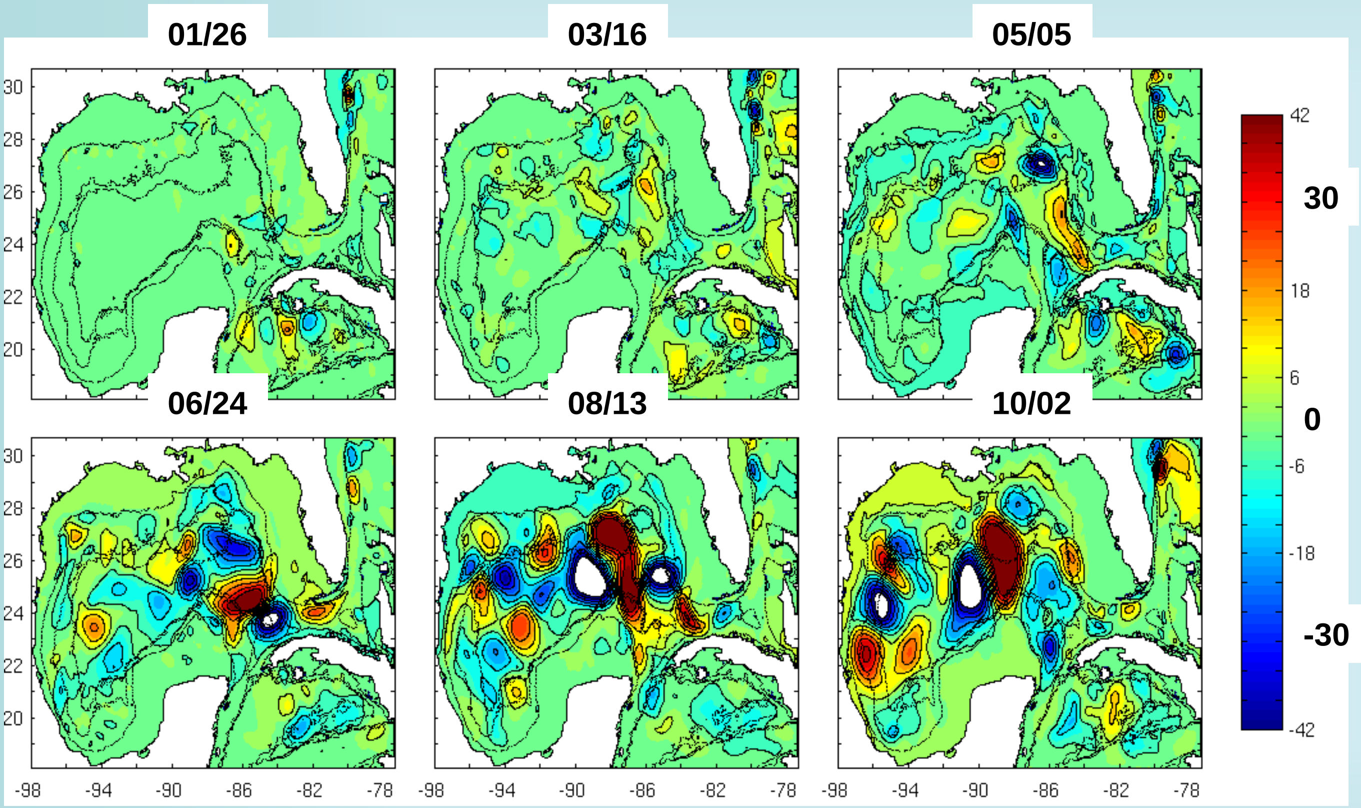

Figure 17: Time evolution of the difference in SSH (cm) between the reference and the perturbed simulations

- SSH differences **spread from the boundaries** to the whole GoM
- larger on the **deep part**
- amplitudes grow **close to the LC**+ affect **sub-mesoscale cyclonic** eddies

Conclusions:

• We have a **realistic** Hycom simulation in the GoM for year 2004; this configuration seems **suitable for the study of the LC dynamics**

• Perturbations of the **lateral boundary** inflow affect the LC circulation and are a **source of model error** that can be considered for LC sensitivity study

Future work:

• Test the impact of **atmospheric forcing** when using coarser NOGAPS forcing

• Perform a **long free run** (2003 to 2008)

• Perform an ensemble of perturbed simulations to better assess the **model error** associated to BC uncertainties and test observation arrays performances (RMS technique, Le Henaff et al., 2009)

• Perform **OSSEs** to test various DA schemes and obs networks

Thanks!