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Impact of boundary conditions on high-resolution simulations in a western boundary current region: the Gulf of Mexico example

Session 3.4 - 07

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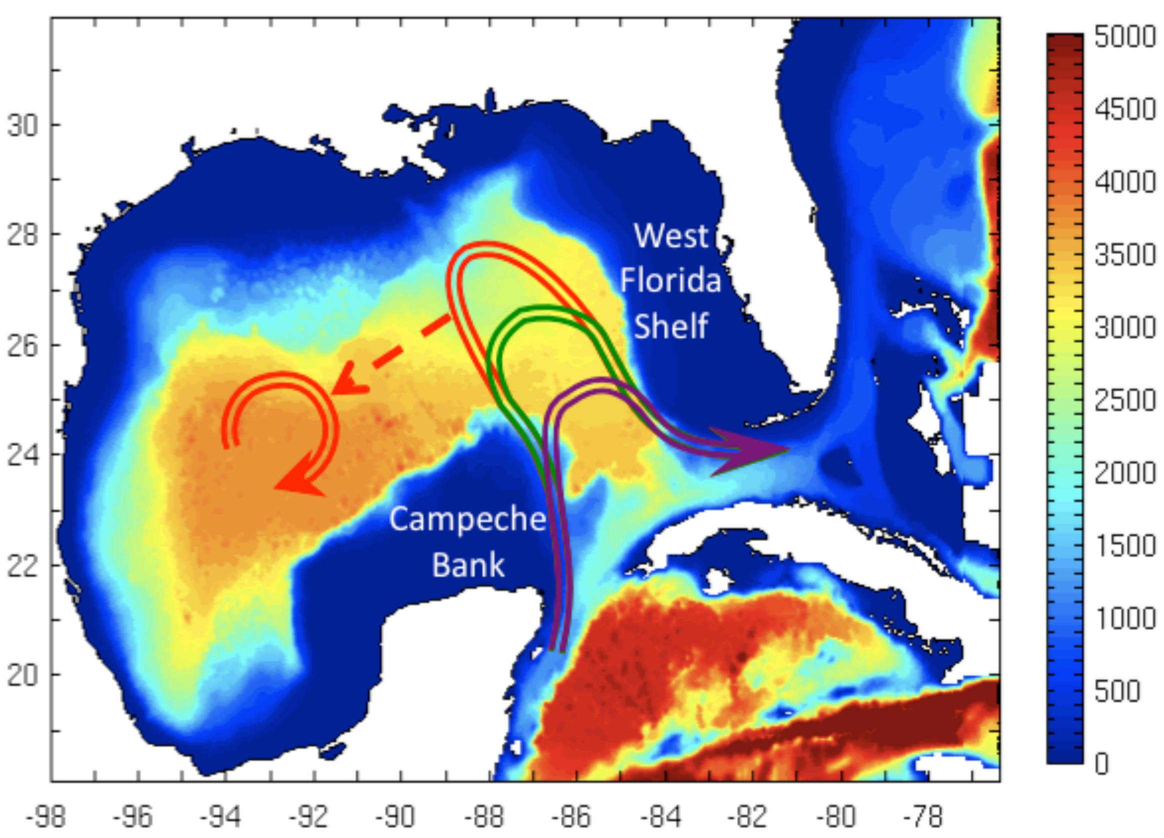
Summary:

The Gulf of Mexico is dominated by the Loop Current (LC), which is a portion of the North Atlantic western boundary current. The LC has a variable extension in time, after which it sheds a large, anticyclonic ring that drifts westward in the Gulf interior. The LC may interact with continental shelf areas inside the Gulf. Changes in the LC extension are not regular, and are dependent on the oceanic and atmospheric conditions in the Caribbean Sea, among other factors. In the prospect of regional modeling of the Gulf interior and coastal/shelf areas, the boundary conditions are thus important for a correct representation of the LC variability, hence of the full Gulf of Mexico dynamical system.

We present results from a high-resolution simulation of the Gulf of Mexico with the Hybrid Coordinate Ocean Model (HYCOM), nested in the daily, operational HYCOM daily fields. Thanks to increased resolution and improved forcing fields, we show improvements in representing coastal processes in the Gulf (here the Mississippi Rover outflow). A second simulation forced with bi-weekly, cyclic boundary conditions shows larger transport at the Yucatan Channel, with less temporal variability. These changes affect the LCE shedding, although large differences in LC cycle are not seen until several months.

(1) The Gulf of Mexico (GoM)



GoM bathymetry (m) with examples of dynamical features (LC extension and eddy)

The Loop Current (LC)

- **connects** the Caribbean Sea to the Atlantic
- flows from a **retracted** stage to an **extended** one
- sheds a **large ring of warm water** and retracts
- **highly variable**: shedding interval 0.5 to 18.5 months (*Leben*, 2005)

Large variety of processes and scales in the GoM

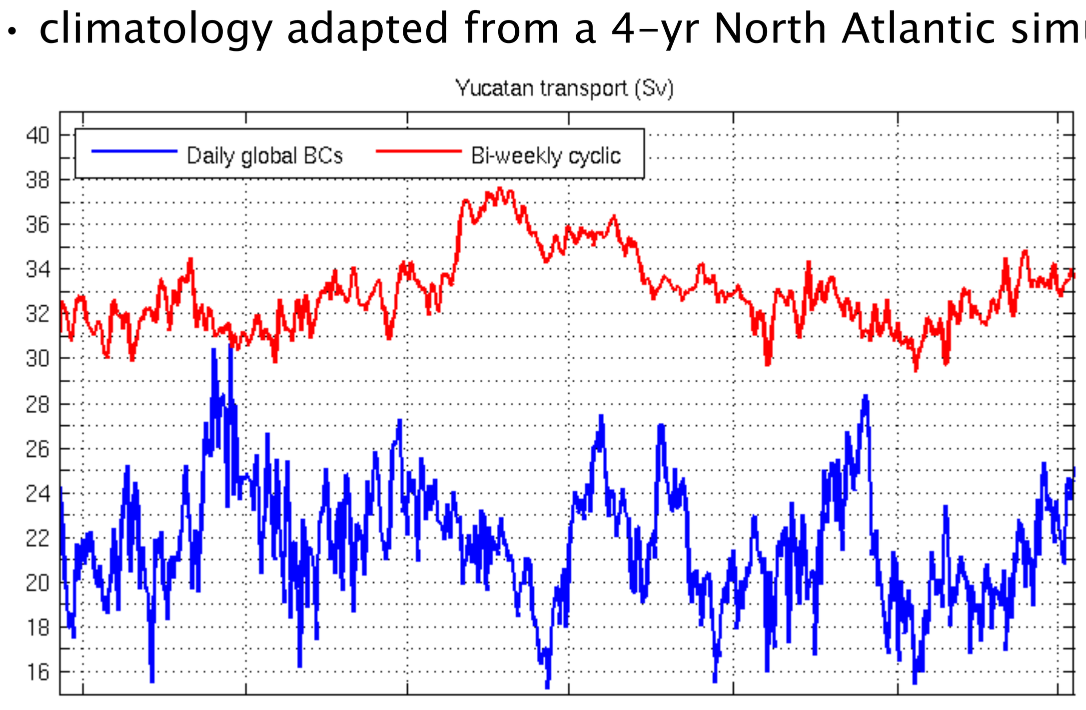
- LC is forced remotely (inflow from the Caribbean Sea), but major influence of local **mesoscale** (esp. LC frontal cyclones): need **high-resolution** to resolve LC frontal dyn.
- large **continental shelves** (Campeche Bank, West Florida Shelf): **high frequency** wind forcing fields are needed for correct dynamical representation
- presence of the **Mississippi River** (MR), largest river in North America, discharging at very narrow shelf area: large influence on the Northern GoM shelf + export toward deep GoM; need **realistic river forcing** + **high resolution** + high resolution wind field

⇒ **Need for downscaling at the GoM scale**

(4) LC dynamics: impact of boundary conditions

Complementary experiment (1.5 year): cyclic boundary conditions

- climatology adapted from a 4-yr North Atlantic simulation at 1/12°

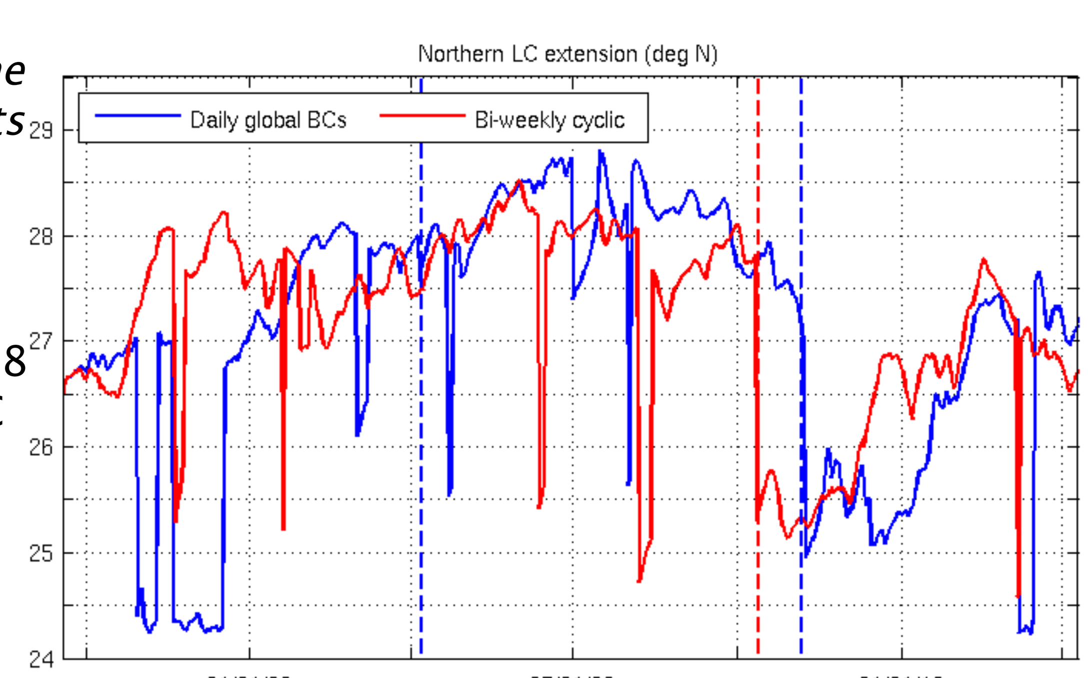


Transport at the Yucatan Channel (Sv) for the ref (blue) and cyclic BCs (red) experiments

tion methodology

- daily BCs from global operational HYCOM: low values for Yucatan transport, high temporal variability (including at high frequency)
- cyclic BCs: large transport values, low temporal variability
- transport series are in realistic range (Sheinbaum et al., 2002: 23.8±3.2 Sv; Rousset and Beal, 2010: 30.3±5 Sv)

Northern extension of the LC in for both experiments



- comparable LC extension in both experiments after initial long detachment in ref expt
- 1st ring shedding in April 2008 in the reference experiment (LC stays extended), in Oct 2008 in the cyclic BCs experiment
- longer experiment needed to show long-term impact on LC shedding period

⇒ **Changes in boundary conditions affect the LCE shedding, but take months before the LC cycle gets altered**

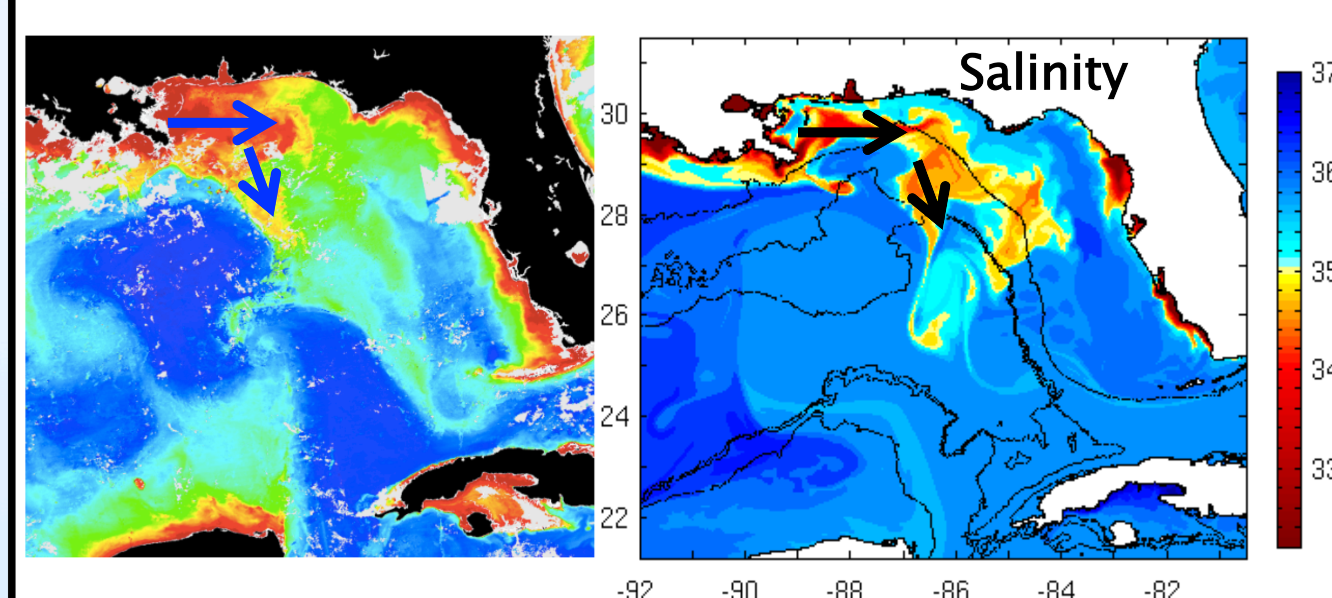
(2) Model implementation

- Hybrid Coordinate Ocean Model (HYCOM): blend isopycnal layers (deep interior), terrain-following layers (along steep bathymetry), and pressure-level (mixed layer)
- 1/50° resolution (~2 km)
- 32 vertical layers (adapted to model Mississippi River outflow + deep currents)
- atmospheric forcing: COAMPS model (27 km, 3 hrs)
- initial + boundary conditions: daily operational global HYCOM simulation (1/12°)
- free-running simulation over 2008-2012

Adaption of global fields as boundary conditions (Tendral, LLC)

- 1/12° Global HYCOM are implemented on sigma-2 levels (density estimated wrt. 2000 dbar), while the 1/50° GoM-HYCOM we use sigma-0 levels:
- fields from the Global HYCOM are extracted over the GoM and interpolated at 1/50°
- model fields are then projected on purely z-levels with high-resolution (1 m)
- fields are finally projected on the sigma-0 GoM vertical layers

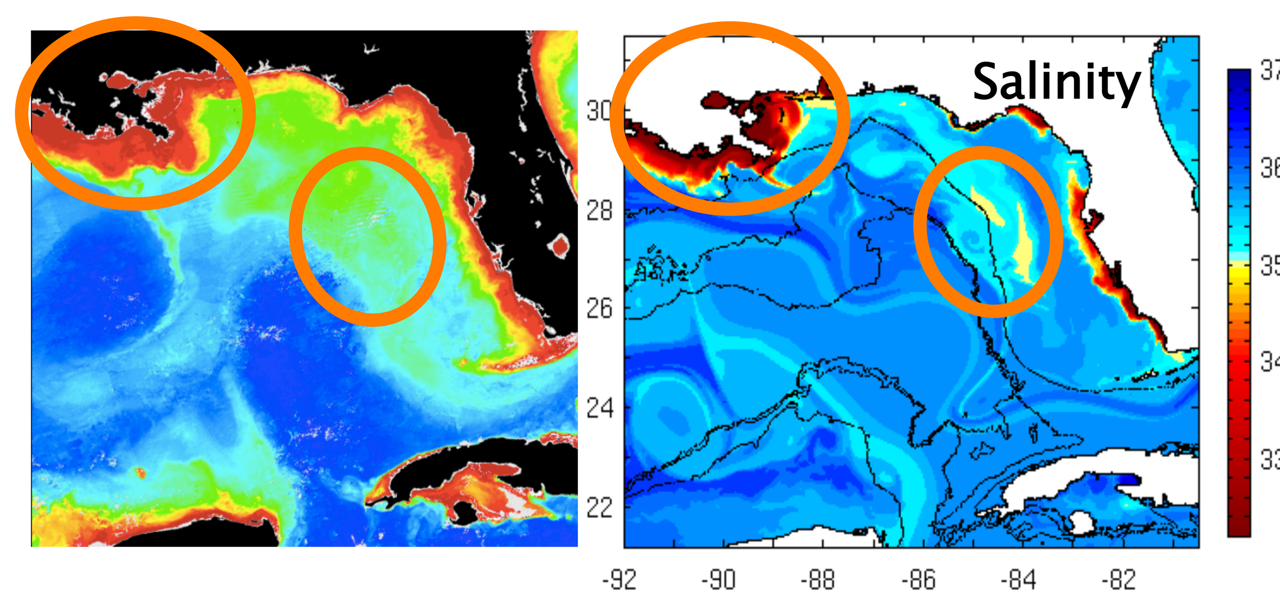
(3) Example of coastal improvement: Mississippi River



Modis chl. a. (left) and model surface salinity, July 31, 2011

- westerly winds: eastward advection of MR outflow on the shelf
- interaction with extended LC: exports toward the GoM interior

Same on Sept 15, 2011



- interruption of westerly winds and MR discharge: retraction of the river plume
- areas influenced by MR waters at the edge of the West Florida Shelf

⇒ **Correct representation of the Mississippi River plume thanks to: realistic river and atmospheric forcing + high resolution**

(5) Conclusions

Improvements in the GoM coastal dynamics

- Mississippi River outflow dynamics better represented thanks to realistic river and atmospheric forcing + high resolution
- Loop Current frontal dynamics better represented (Campeche Bank, Florida Keys)

Impacts of boundary conditions

- Larger transport at Yucatan from cyclic BCs are associated with later 1st ring shedding
- Despite differences in transport, changes in the LC take months to express
- Longer experiments are needed: work in progress

Acknowledgements

- The study was supported by NOAA (NAI7RJ1226 and NA11NOS4780045)
- Part of the data processing possible thanks to A. Srinivasan and Tendral, LLC.
- Computations were performed at the University of Miami Center for Computer Sciences (CCS)