Validation of altimeter-derived seasonal sea level cycle with tide gauges over the Gulf of Mexico

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Objectives

- To confirm and quantify rapid changes in the seasonal sea level cycle over the Gulf of Mexico (GOM)
- To validate satellite radar altimetry data with tide gauge data of sea level
 - To show improved and homogeneous climate data record
 - > To understand why is seasonal cycle change happening in the GOM
- To compare model outputs of sea level
 - Are we there yet to use models for sea level hindcasts and forecasts?

Why the Gulf of Mexico?

- A very complex water circulation region
- A high coastal flood risk region
- A good number of tide gauge stations for validation
- Already observed sea level rise and seasonal cycle change with a positive trend in annual amplitude (*Wahl et al. 2014*)
- Models have consistently problems observing true-like sea level height over the GOM



Bathymetry over the GOM

Data

Sea surface height:

- AVISO Satellite altimetry data (1993-2013): a global, gridded, multiple altimeter product (up to 4 satellites at a given time: better in quality, not homogeneous)
- Permanent Service for Mean Sea Level (PSMSL) historical tide gauge data (1900-2014)
 - For a fair comparison, an inverse barometer (IB) signal is added back to altimetry data

Inverse barometer (IB) effect:

• IB is derived using the ECMWF global gridded ERA-Interim reanalysis product of mean sea level atmospheric pressure

Thermosteric sea level (TS):

• Thermosteric sea level anomalies for the 0-700 m layer from the NODC NOAA

Models:

- GMAO (Global Modeling and Assimilation Office, NASA-GSFC), 2D ocean model
- ECCO (Estimating the Circulation and Climate of the Ocean, MIT) ocean model output (ver4 rel1)



Validation of monthly altimetry+IB against tide gauge sea level anomaly

- Small trends of altimetry-gauge differences for 1993-2013: -0.4, -2 mm/yr
- High correlations: 0.89-0.95
- RMS differences: 3.29-5.37 cm





Secular trend in seasonal sea level cycle



Sea level anomaly over the Gulf of Mexico

> Thermosteric sea level data doesn't show a recent increase in sea level



Annual amplitude over the Gulf of Mexico



Standard deviation of annual amplitude over the Gulf of Mexico

Low seasonal sea level variability



Annual amplitude over the Gulf of Mexico

Both models underestimate annual amplitude change

Annual amplitude over the North Atlantic Ocean



> Models perform much better over the North Atlantic Ocean

Conclusions

- Sea level derived from altimetry is in a good agreement with tide gauge data for investigated stations along the Gulf of Mexico coastline
- Tide gauge data in the past 50-100 years over the GOM gives *a consistent positive trend in the seasonal sea level cycle* (amplitude 0.4-1 mm/yr and phase 0.28-1.14 deg/yr)
- This positive trend in the seasonal cycle is confirmed by altimetry in recent years
 - Altimetry product extends the observed signal in tide gauges to open ocean regions!
- Investigated models consistently underestimate seasonal sea level cycle over the GOM (GMAO model performs slightly better than ECCO (MIT) model)
 - > Models perform well over the North Atlantic region, but not over the GOM!

Future work

- Models hindcast and forecast data of sea level will be analyzed and accuracies of hindcast data assessed, once the models start performing better over problematic regions (e.g., the GOM) -> historical comparisons and climate monitoring
- Secular trend analysis including tide gauge, altimetry and model data will be continued over other global regions
- Thermosteric sea level will be investigated by using raw hydrographic data