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Challenges in Modeling Altimetry SSH and Gravimetry OBP

Contents:

1. Altimetry SSH and Gravimetry OBP
2. Model development
3. Results (bad and good)

Altimetry SSH and GRACE OBP

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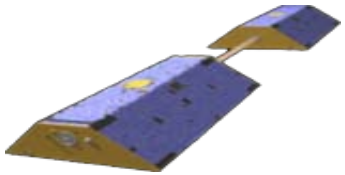
TOPEX/Poseidon

Launched 2002

Grace



Sea Surface Height

$$P_b = \int_{-H}^{\eta} g\rho dz$$

Ocean bottom pressure (OBP)

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OBP is the contribution from SSH and density changes—a difference of two large terms

Total OBP:

$$p_b = p_a + \int_{-H}^{\eta} g\rho dz \approx p_a + g\rho_0\eta + \int_{-H}^{0} g\rho dz$$

Inverted barometer:

$$\eta^{ib} = -\frac{p_a}{g\rho_0}$$

$$\frac{1}{g\rho_0}\frac{\partial p_b}{\partial t} = \frac{\partial(\eta - \eta^{ib})}{\partial t} - \left(-\frac{1}{\rho_0}\int_{-H}^{0}\frac{\partial \rho}{\partial t}dz \right)$$

GRACE OBP Anomaly

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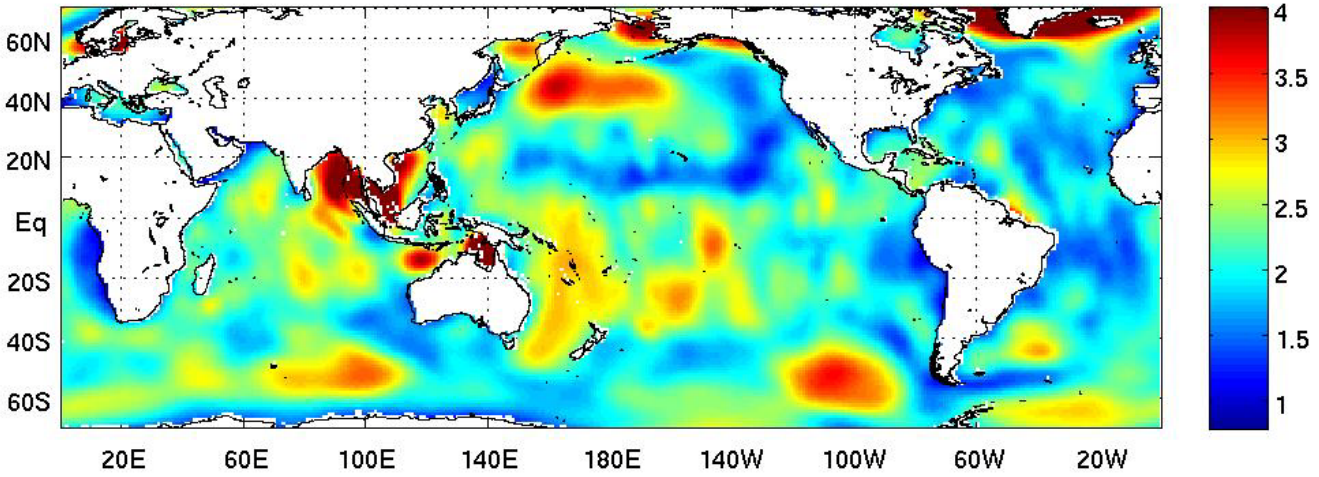
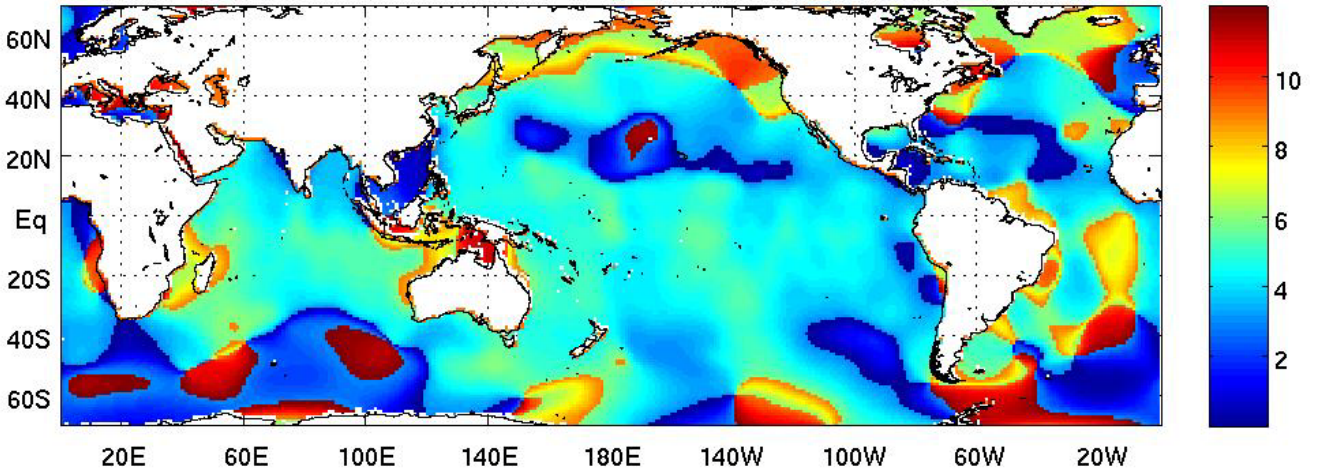
a) Annual amplitude (GRACE OBP)



b) Annual phase (GRACE OBP)



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Challenges for Ocean Models

Altimeters & Model

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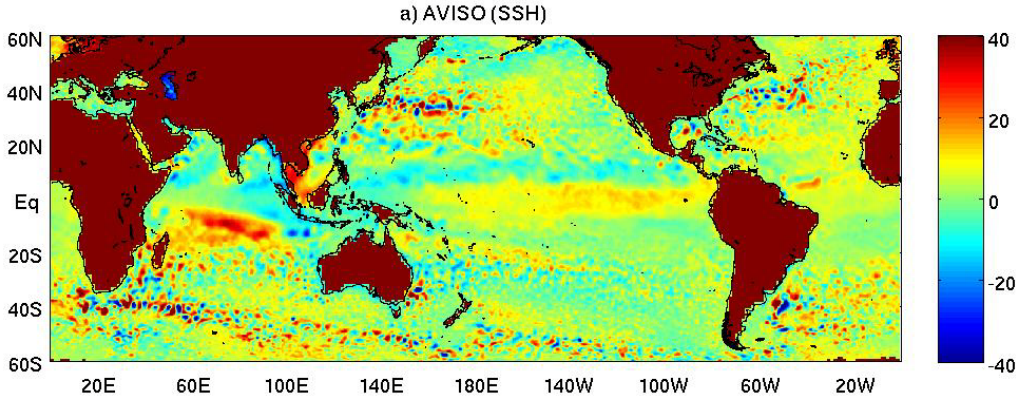

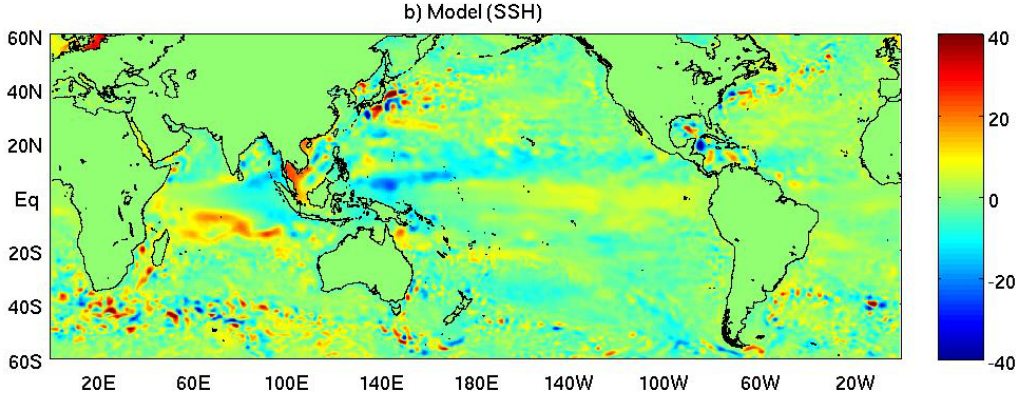

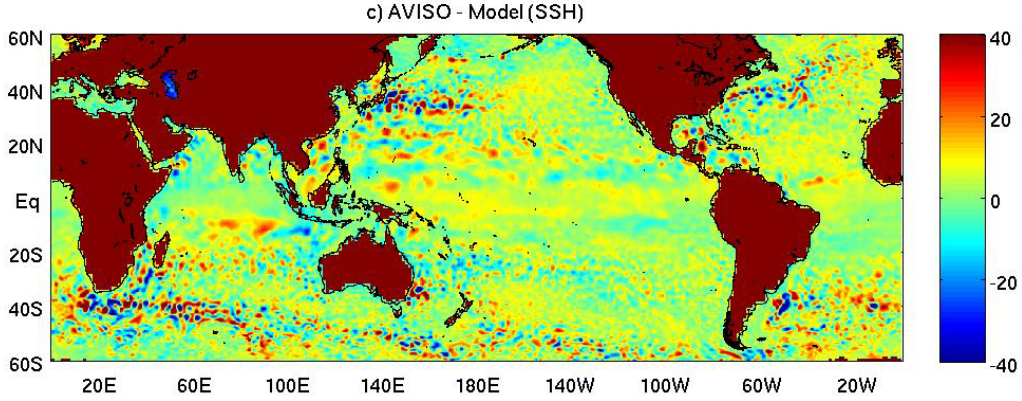

1. **The difference between Data and Model is about the variability of data itself in the eddy field.**
2. **Data assimilation can reduce this error, but costly.**

GRACE & Model

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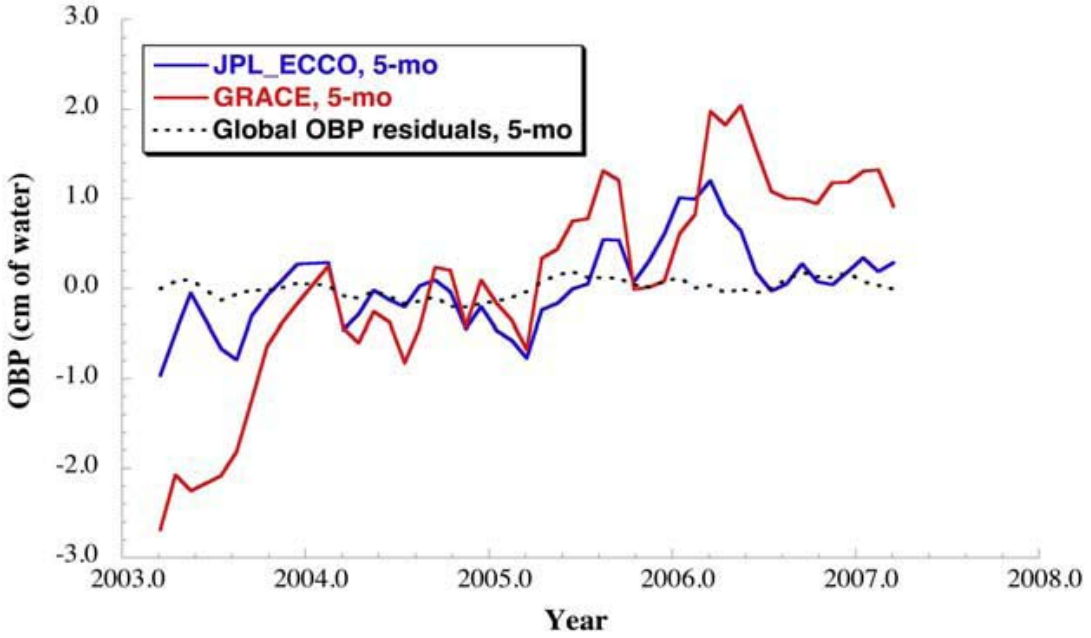

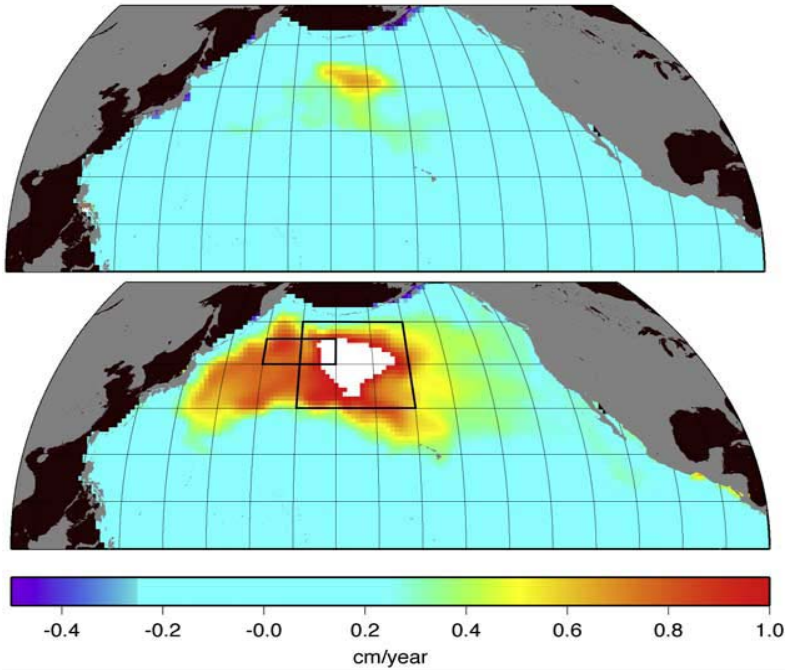

Chambers & Willis (JGR, 2008)

GRACE & (Altimeter-Argo)

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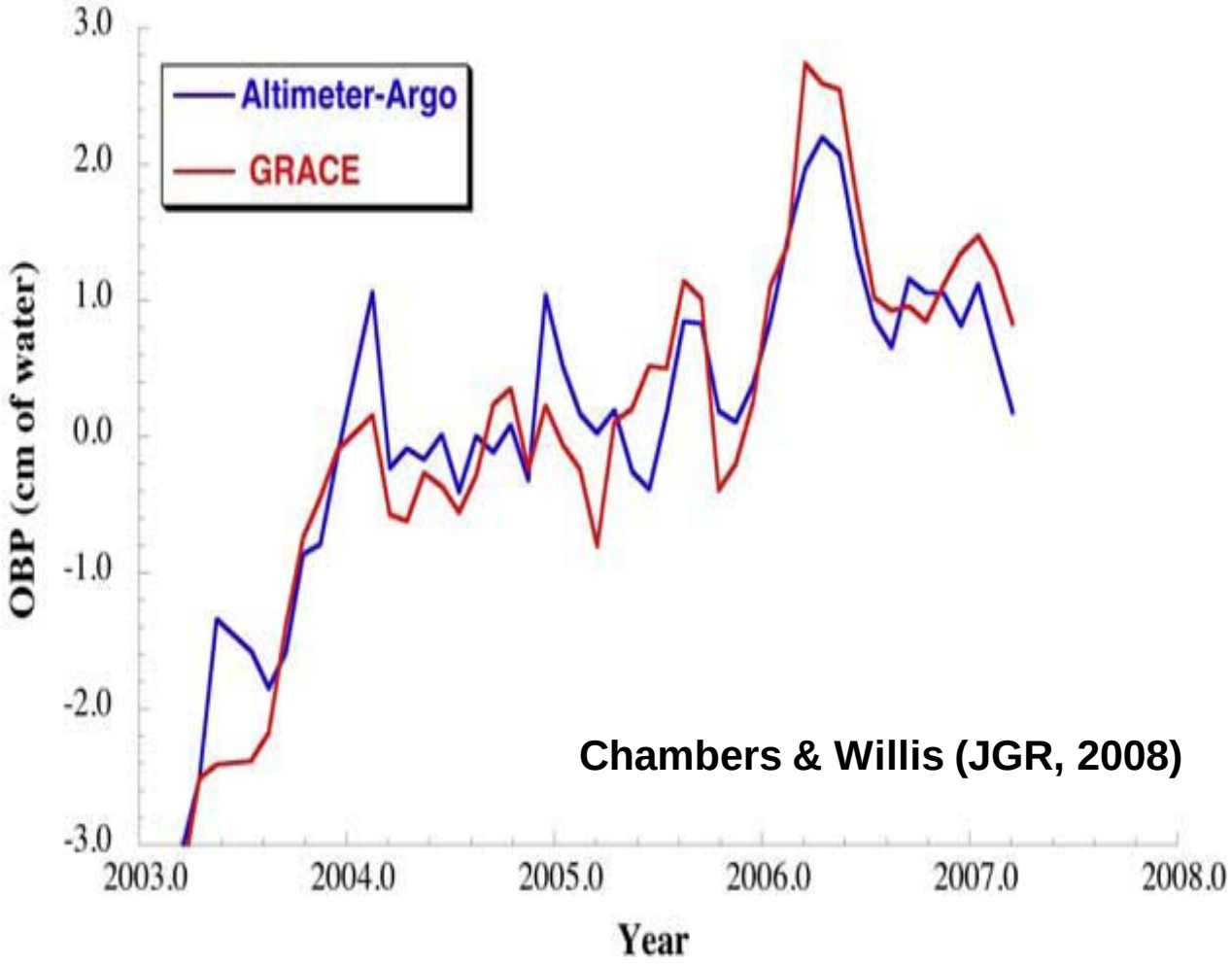

Chambers & Willis (JGR, 2008)

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Suggested Hybrid Coordinate System

$$p = -(p_b^{'} + p_c)s - (p_b^0 - p_c)C(s)$$

$$p_b = \int_{-H}^{\eta-\eta^{ib}} g\rho dz$$

[*Advances in Geosciences*, Song et al. 2009]:

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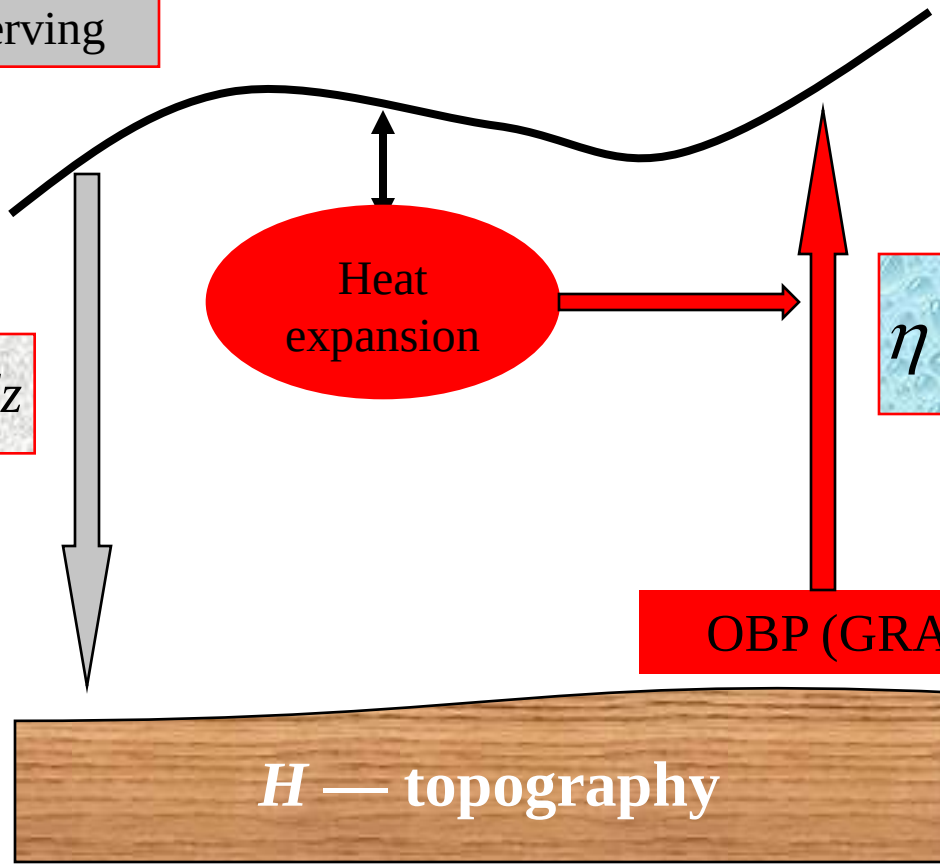
Schematics

The old way:

Volume-conserving



$$P_b = \int_{-H}^{\eta} g\rho dz$$

$$\eta = \int_{-1}^{0} \{\Delta P / g\rho\} ds - H$$

New way:

Mass-conserving

Ocean & Ice

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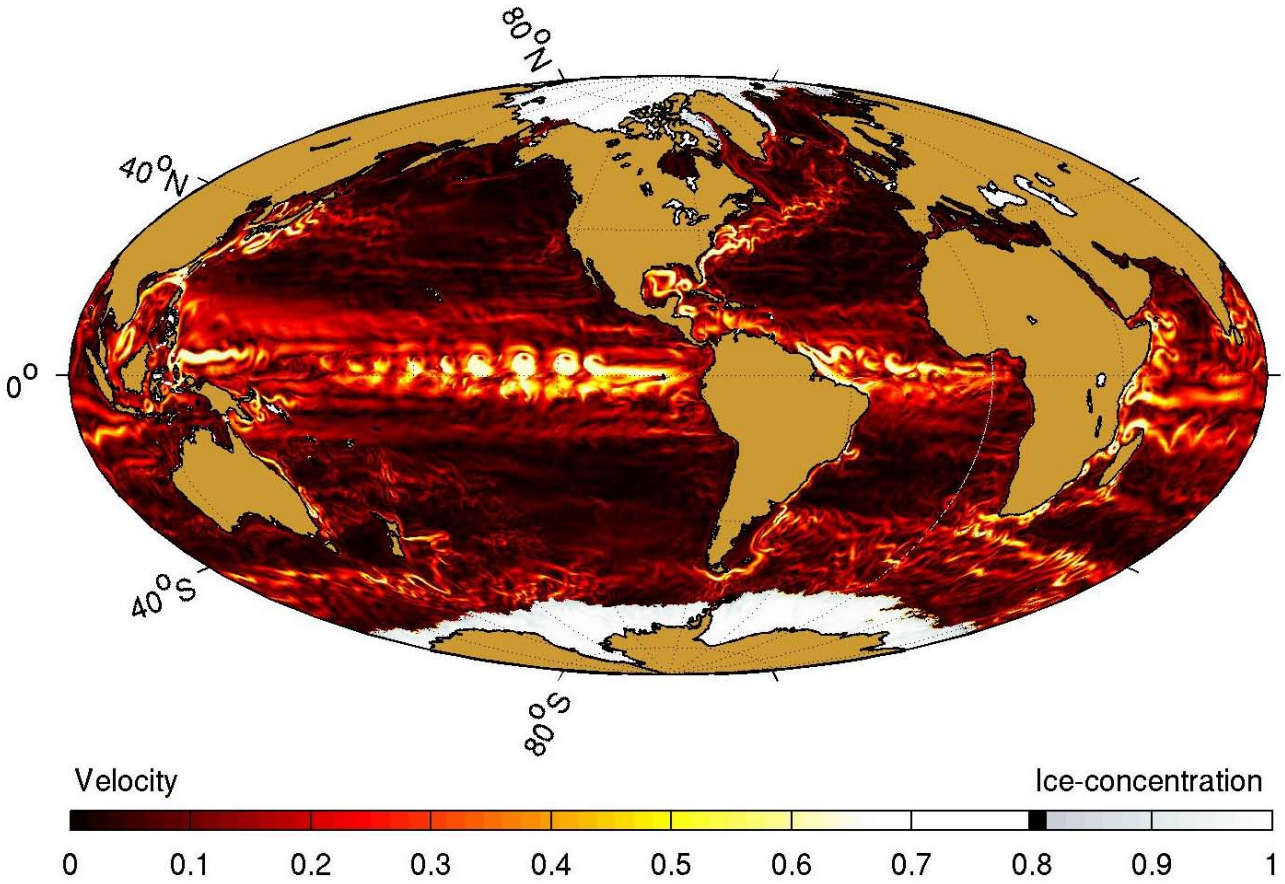

¼-degree with rotated north pole:

- couple sea-ice
- couple earthquakes
- seafloor deformation
- freshwater flux

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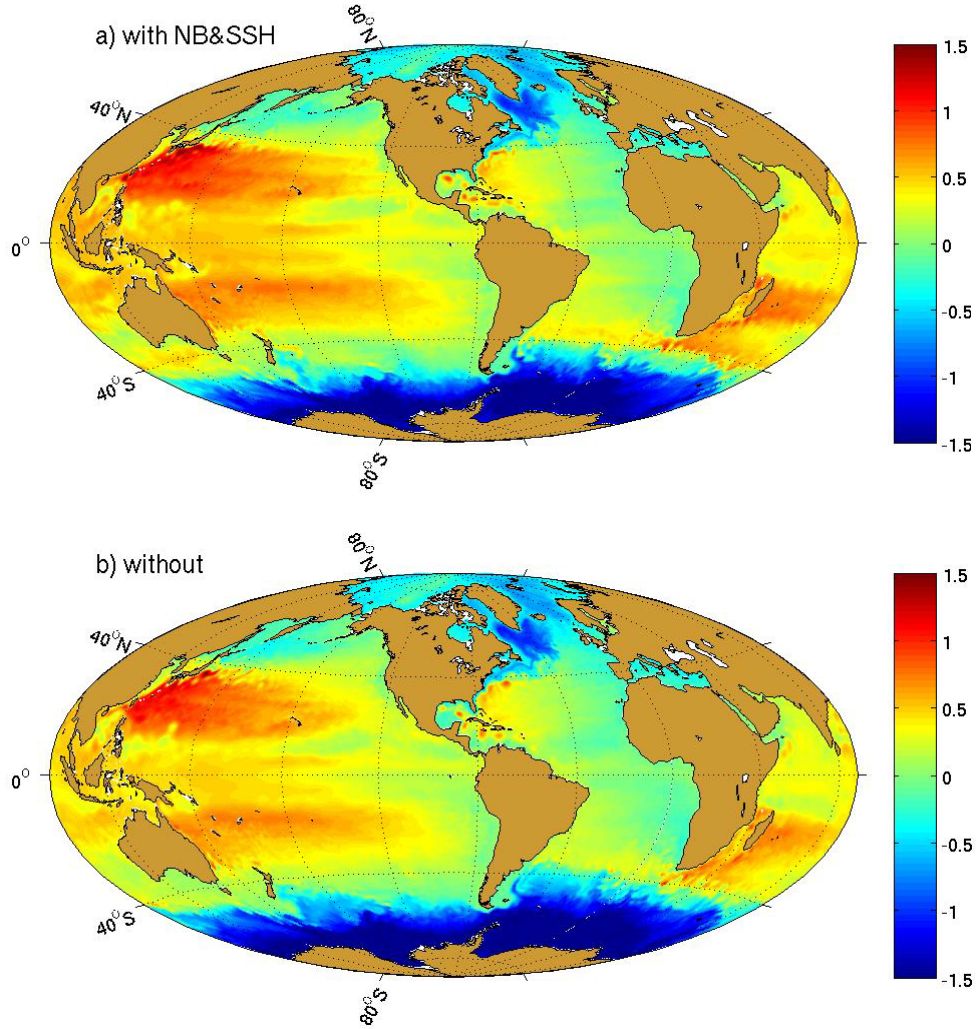
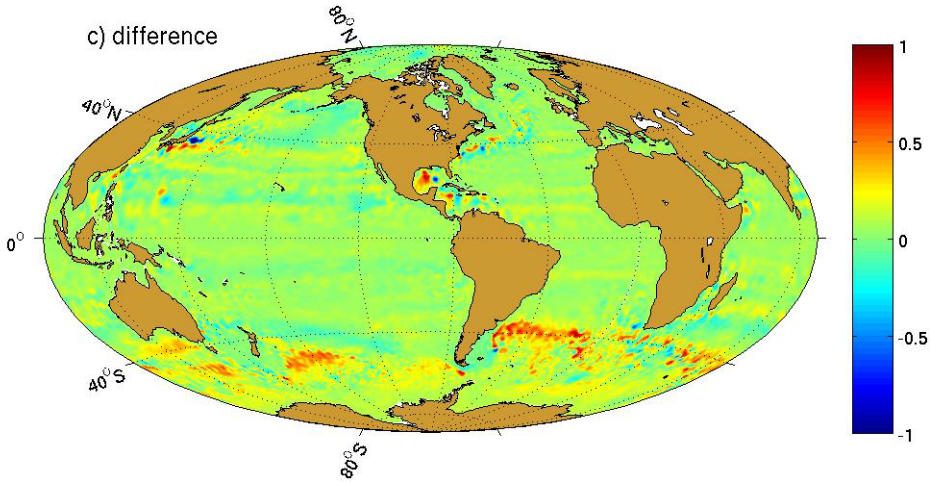
Difference in SSH (monthly averaged results)





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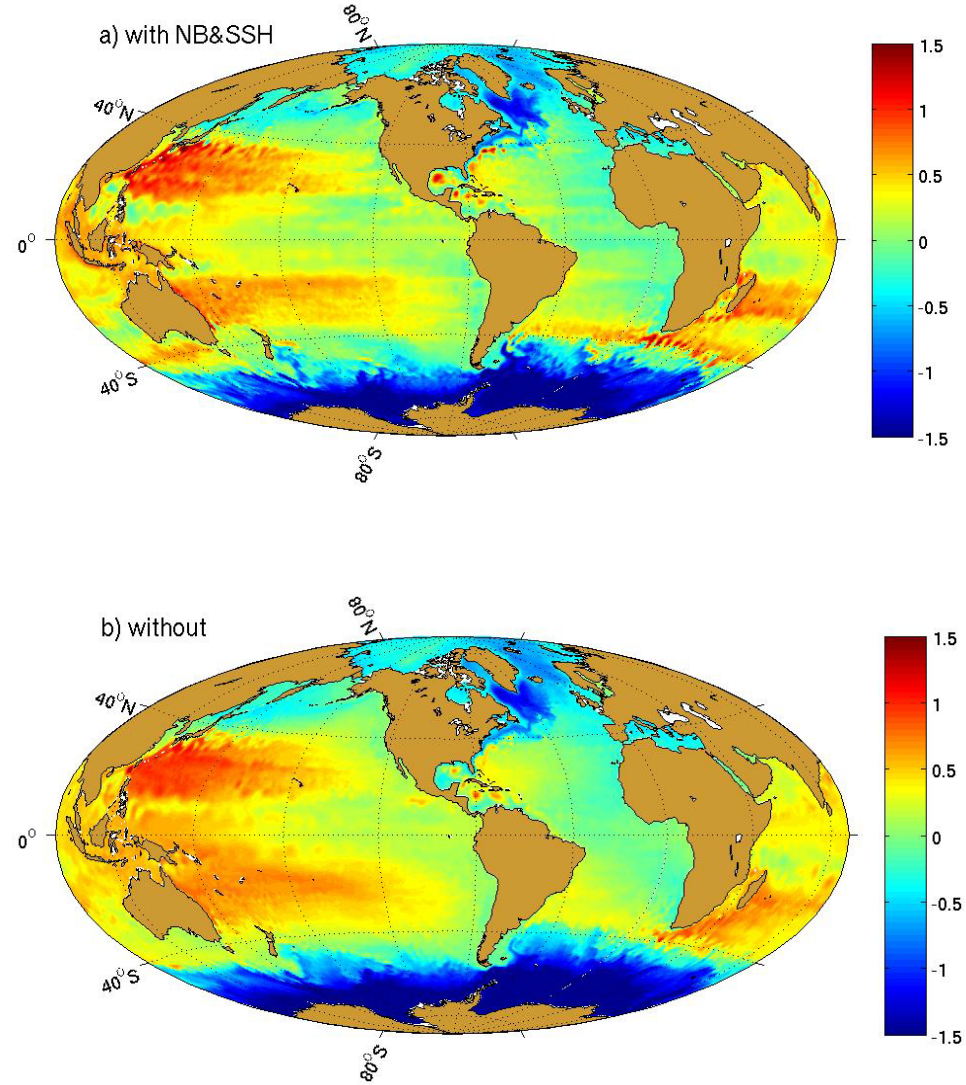
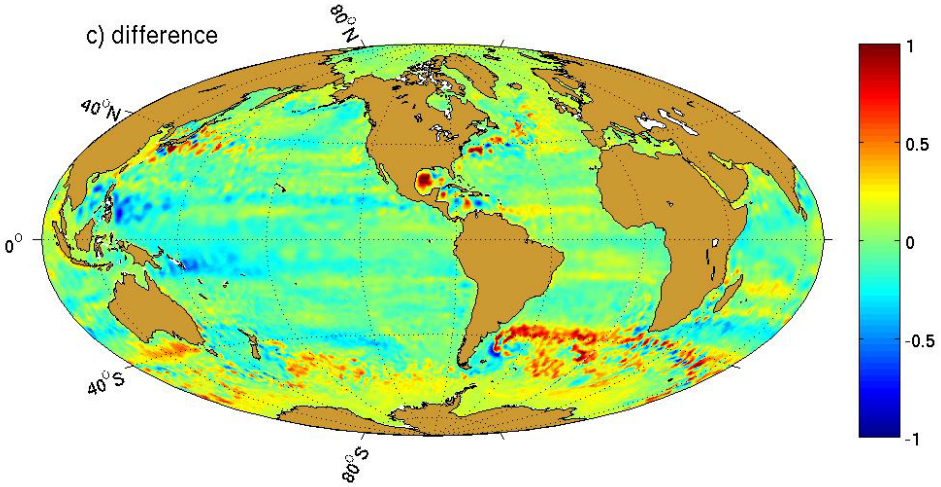
Difference in OBP





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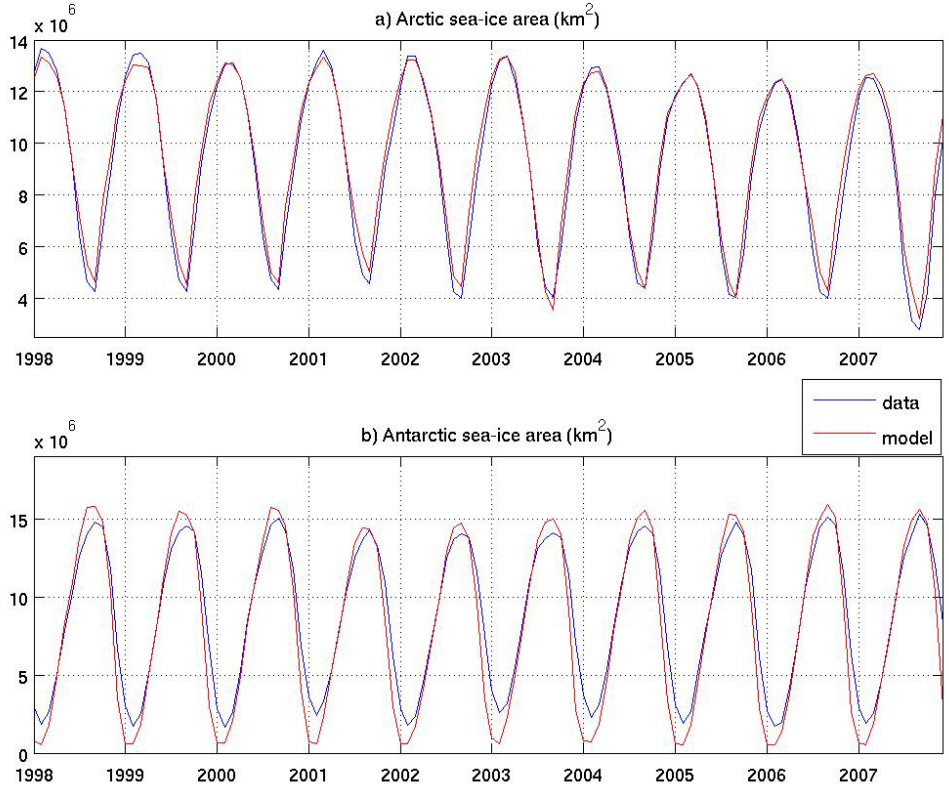
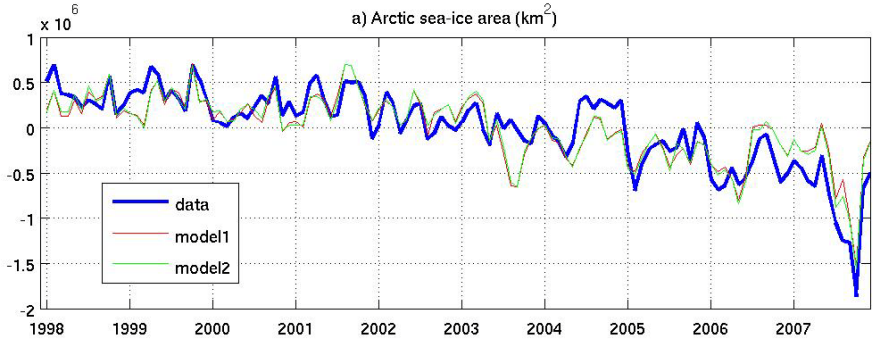
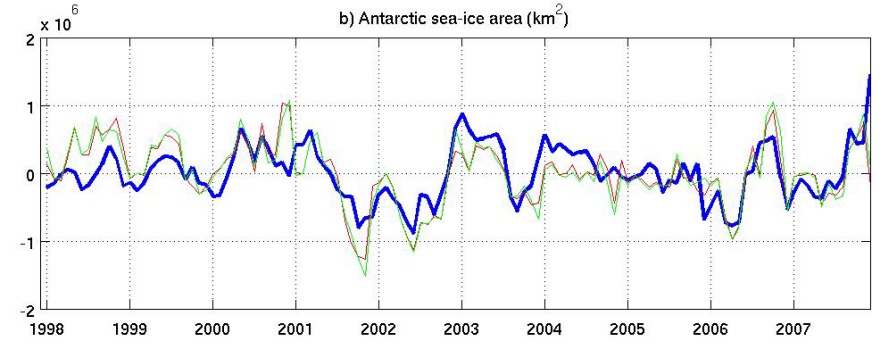
Sea-Ice Coverage Errors







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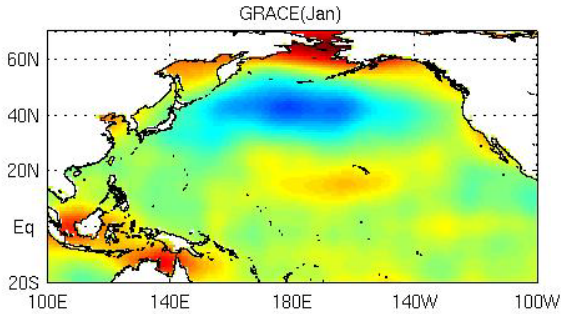
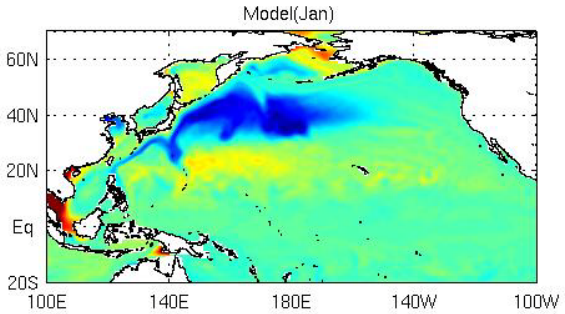
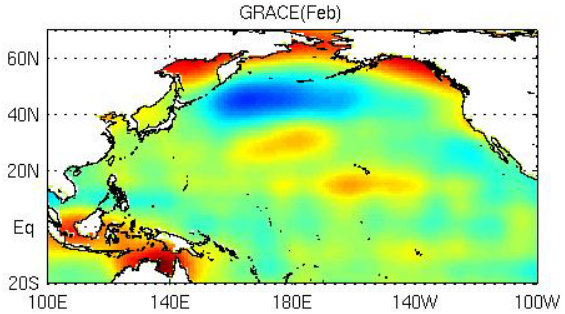
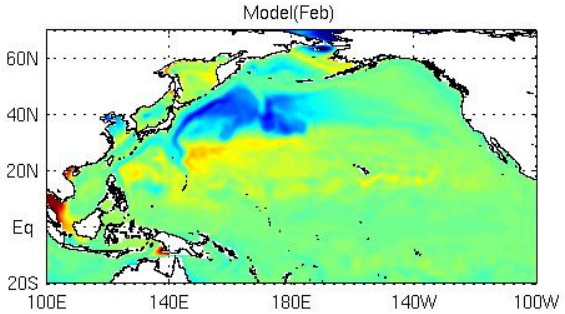
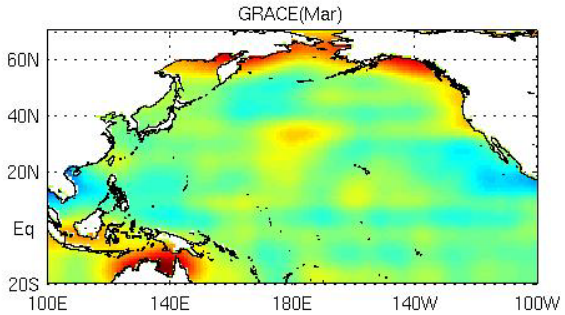
Focusing on the North Pacific

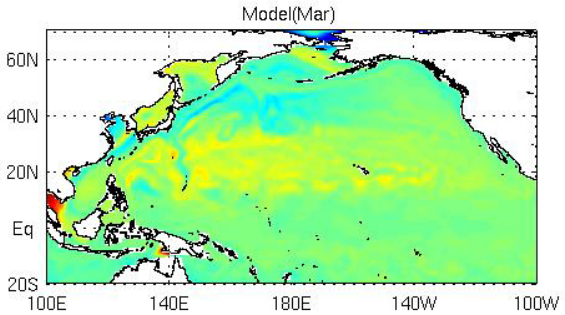












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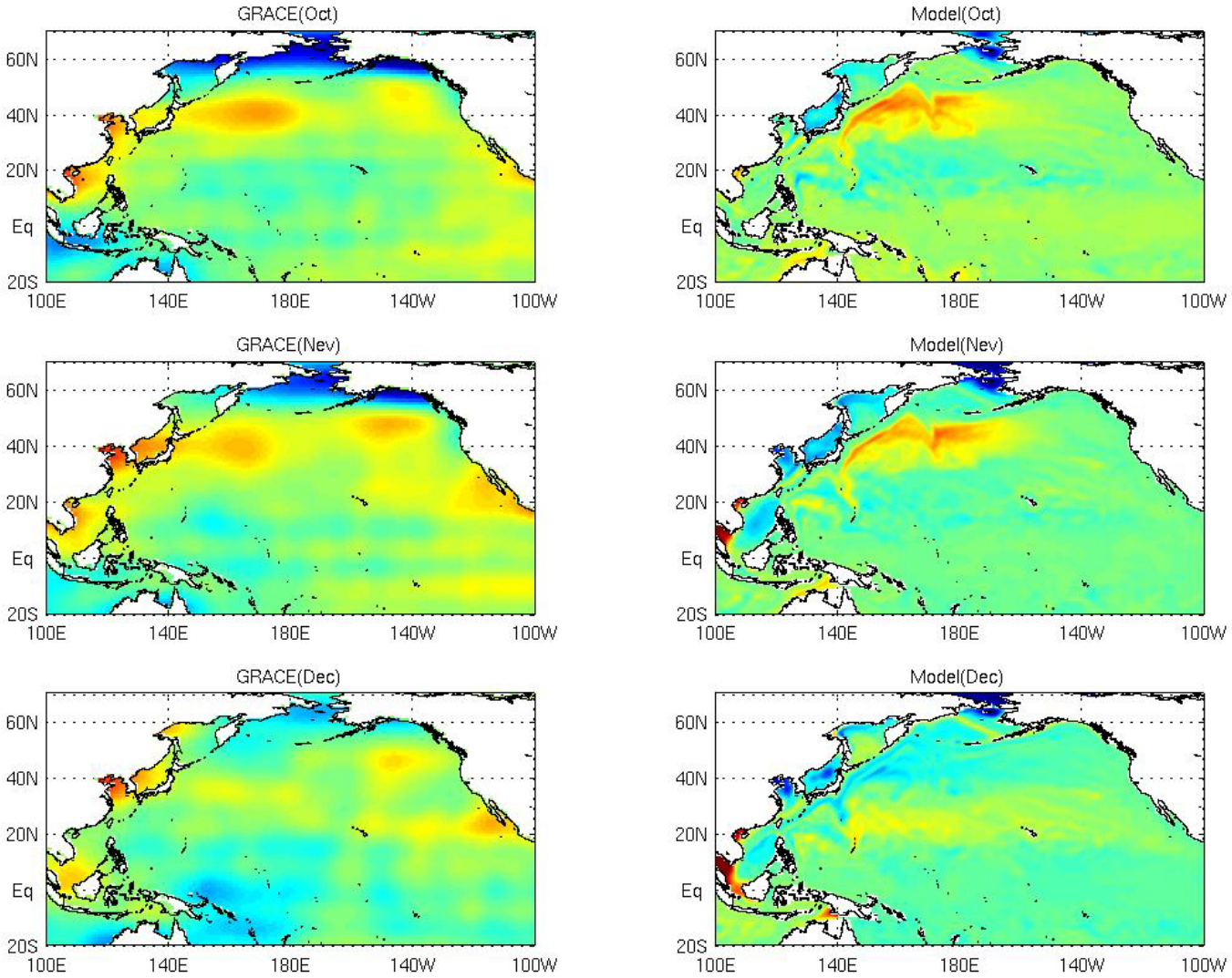

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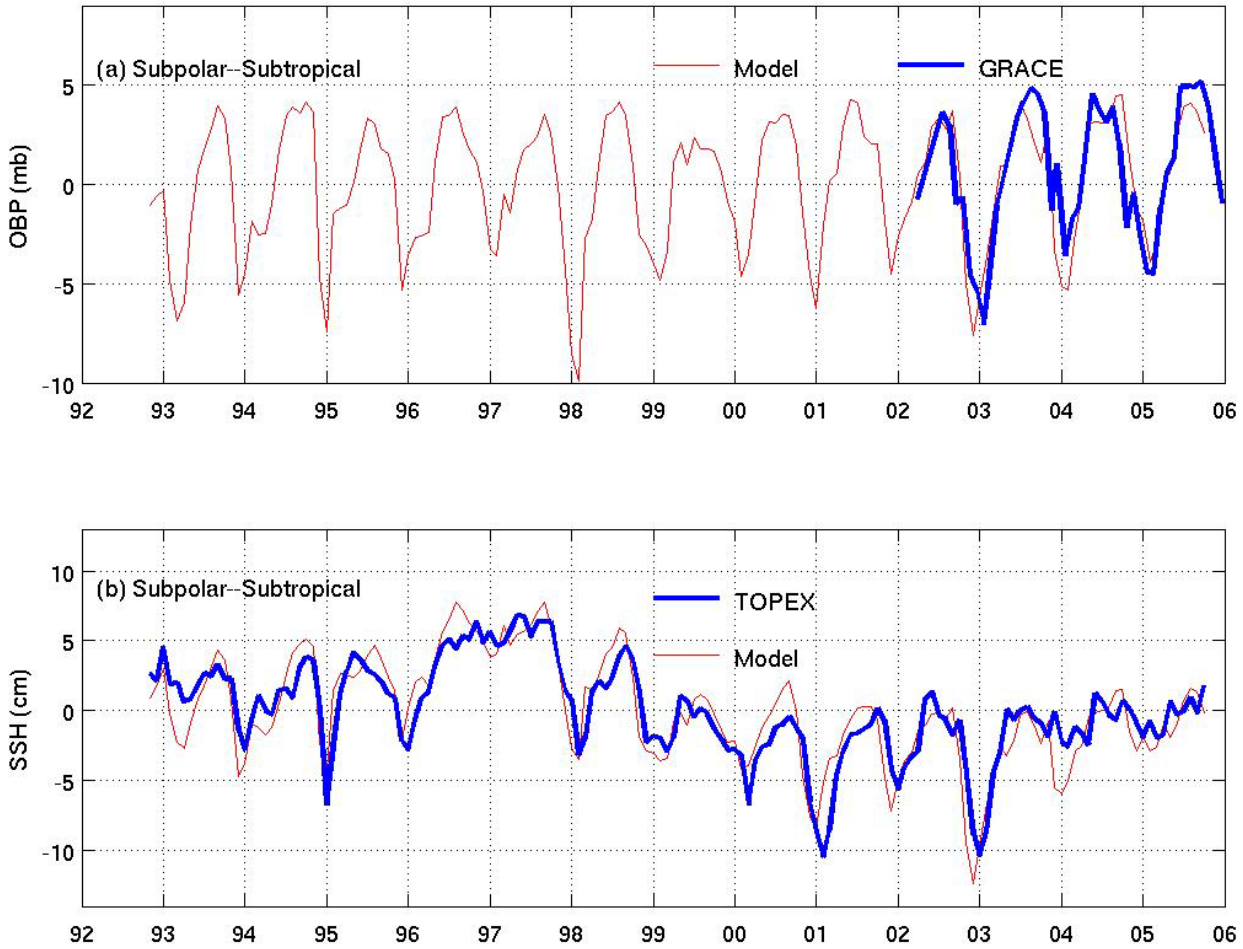
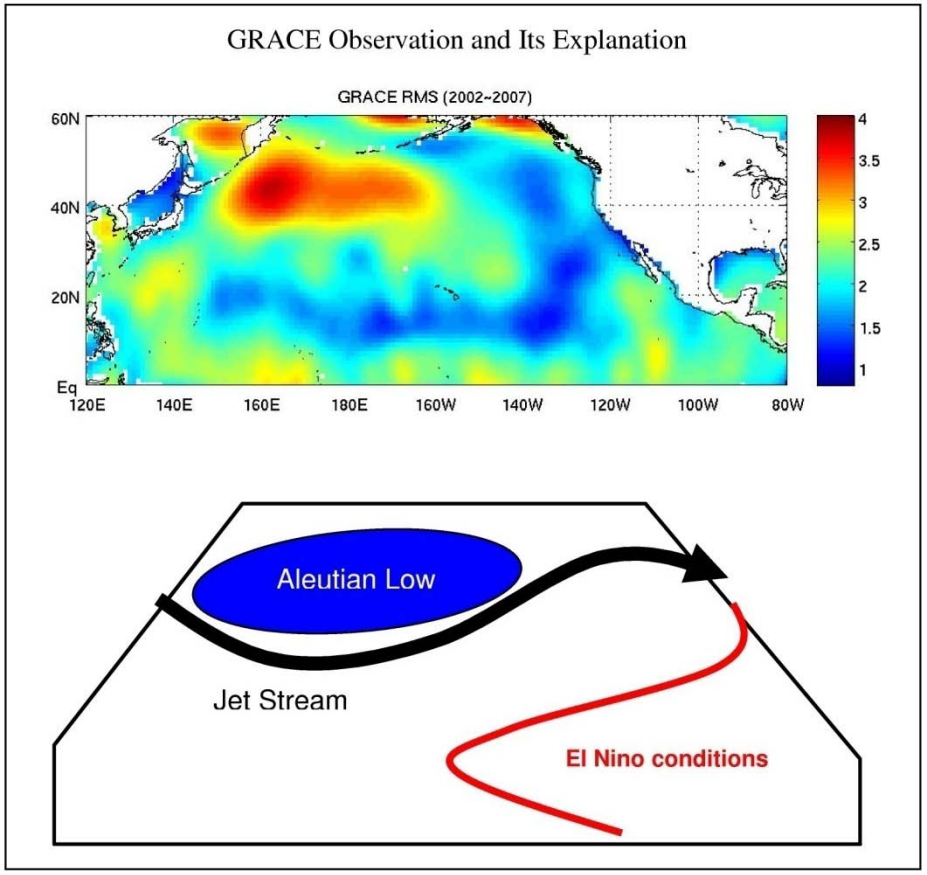


GRACE Reveals North Pacific Oscillation and ENSO Linkage



Song & Zlotnicki, *IJRS*, Nov. 2008

Problem: The explanation of the GRACE-observed ocean-bottom-pressure oscillation in the North Pacific has been challenging.

Result: By examining the atmospheric circulation, we confirm that the GRACE-observed oscillation in North Pacific is a result of ENSO, the Aleutian Low, and Jet Stream variation.

Significance: The result explains how ocean and atmosphere couples and improves our understanding of climate change with GRACE.

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Discussion & Summary

1. Simultaneously model SSH and OBP accurately is numerically challenging.

2. Non-Boussinesq physics (heat & freshwater fluxes) and topography-following are the two key features in representing altimetry SSH and GRACE OBP correctly.

3. We have some progress, but more effort is needed.