Contribution of non-tidal oceanic mass variations to Earth rotation determined from space geodesy and ocean data

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Motivation

- The motion of the rotation axis with respect to the Earth’s surface can be observed precisely from space geodetic techniques.
- Underlying geophysical processes within and between the subsystems of the Earth that perturb the Earth rotation have to be separated for a better understanding of our planet.
- Global mass displacements and movements can be estimated from terrestrial and space observations and from assimilated models.

Can satellite altimetry estimate oceanic mass variations better than ocean models?
**Calculation method**

**Altimetry**
- sea level anomalies

**Ocean data**
- temperature and salinity variations
  - steric effect

**Ocean model**
- steric effect
  - sea level anomalies

Oceanic mass variations expressed in equivalent water heights

Global spherical harmonic analysis

Dimensionless normalized Stokes coefficients of degree two

\[ \chi_1 = -\frac{1}{1 + k_2^2} \cdot \frac{1}{\sqrt{\frac{3}{5}}} \cdot \frac{1.098 R^2 M_E}{C - A} \cdot \Delta C_{21} \]
\[ \chi_2 = -\frac{1}{1 + k_2^2} \cdot \frac{1}{\sqrt{\frac{3}{5}}} \cdot \frac{1.098 R^2 M_E}{C - A} \cdot \Delta S_{21} \]

Oceanic polar motion excitation functions
Data sources (1)

Altimetry

- Sea level anomalies (SLA) from TOPEX/Poseidon extended mission
  - Altimeter data: MGDR, Version C
  - Consideration of environmental and geophysical corrections, including inverse barometer correction
  - Mean sea surface of 2003 - 2005
  - Monthly mean (time series)
  - Roman Savcenko, Wolfgang Bosch (DGFI)

Ocean data

- Temperature and salinity climatologies of the WOA05
  - 24 depth level (0 - 1500m)
  - long-period monthly mean (averages)
  - http://www.nodc.nova.gov/OC5/WOA05

- Temperature and salinity fields from Masayoshi Ishii
  - 16 depth level (0 - 700m)
  - monthly mean (time series)
  - Masayoshi Ishii (Frontier Research Center for Global Change)
Data sources (2)

RMS of monthly mean SLA (TOPEX/Poseidon) [2003 - 2005]

RMS of monthly mean steric effect (M. Ishii) [2003 - 2005]

RMS of monthly mean residuals (SLA – steric effect) [2003 - 2005]

[cm]
### Data sources (3)

#### Ocean model

**Oceanic excitation functions from baroclinic ocean model OMCT**
- Forcing with ECMWF
  - wind stress
  - 2m-temp.
  - freshwater fluxes
- IB adoption
- Assimilation: no
- Mass conservation
- Monthly mean (time series)
- Maik Thomas (GFZ-Potsdam)

**Oceanic excitation functions from baroclinic ocean model ECCO (kf049f)**
- Forcing with NCEP reanalysis
  - wind stress
  - heat flux
  - freshwater fluxes
- IB adoption
- Assimilation: altimetry & XBT
- Mass conservation
- Monthly mean (time series)
Oceanic excitations

- Derived from sea level anomalies which are reduced by the steric effect from Ishii (1B)
- Derived from sea level anomalies which are reduced by the steric effect from WOA05 (1B)
- Derived from sea level anomalies which are reduced by the steric effect from OMCT (1B)
Oceanic excitations - compare

correlation: 0.52 – 0.87
rms [mas]: 5.4 – 11.0

correlation: 0.47 – 0.90
rms [mas]: 4.7 – 10.5
Atmospheric excitations

Correlation: 0.81 rms [mas]: 5.4
Correlation: 0.99 rms [mas]: 9.2
Land ocean distribution
Hydrological excitations

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correlation: 0.57  rms [mas]: 4.2

correlation: -0.22  rms [mas]: 10.9
Agreement w. geodetic excitations (C04)

- Correlation with C04
- RMS wrt C04 [mas]
Agreement w. geodetic excitations (C04)

- Correlation with C04
- RMS wrt C04 [mas]

- ECMWF, OMCT, Ishii, WOA05, ECCO

- atmo + ocean
- atmo + ocean + LDAS
- atmo + ocean + LAD
Agreement w. geodetic excitations (C04)

χ² wrt C04 [mas]

Correlation with C04

rms wrt C04

2003 2004 2005

χ²

ECMWF ECMWF ECMWF ECMWF NCEP ECMWF ECMWF ECMWF NCEP
OMCT OMCT* Ishii WOA05 ECCO OMCT OMCT* Ishii WOA05 ECCO

atmo+ocean
Agreement w. geodetic excitations (C04)

χ² wrt C04 [mas]

ECMWF ECMWF ECMWF ECMWF NCEP ECMWF ECMWF ECMWF NCEP
OMCT OMCT* Ishii WOA05 ECCO OMCT OMCT* Ishii WOA05 ECCO

correlation with C04

χ²

atmo+ocean atmo+ocean+LDAS atmo+ocean+LAD
Conclusions and Outlook

Adding hydrological excitations from LDAS do mostly raise the agreement with geodetic excitations.

Assimilated-model-only polar motion excitations seem to be better than combined polar motion excitations.

- Assimilated-model-only solutions are consistent
  - Errors of atmospheric model are compensated by ocean model

- Combined solutions may be inconsistent
  - Classical IB adoption
  - Uncertainties of steric effect
  - Uncertainties of atmosphere model
  - Uncertainties of oceanic mass movements from ocean model
Conclusions and Outlook

Adding hydrological excitations from LDAS do mostly raise the agreement with geodetic excitations.

Assimilated-model-only polar motion excitations seem to be better than combined polar motion excitations.

- Assimilated-model-only solutions are consistent
  - Errors of atmospheric model are compensated by ocean model

- Combined solutions may be inconsistent
  - Classical IB adoption (dynamic atmosphere correction)
  - Uncertainties of steric effect (new satellite mission SMOS)
  - Uncertainties of atmosphere model
  - Uncertainties of oceanic mass movements from ocean model
Thank you for your attention!
Agreement w. geodetic excitations (C04)