DETERMINATION OF THERMAL EXPANSION FROM COMBINED GRACE AND SATELLITE ALTIMETRY DATA

Alix LOMBARD (1), David GARCIA (2), Anny CAZENAVE (1), and Guillaume RAMILLIEN (1)

(1) LEGOS/CNES, Toulouse, France – Contact : Alix.Lombard@notos.cst.cnes.fr
(2) Applied Mathematics Department, University of Alicante, Spain

ABSTRACT. By combining sea level observations from altimetry with average gravity variations over the oceans from the GRACE satellite, it is possible to separate the steric (mainly thermal expansion) and ocean mass contributions to global mean sea level variations. We have analysed GRACE geoid data computed by Biancale et al. (2006). These geoid data are provided at 10-day interval from August 2002 to March 2005, with a spatial resolution of 400 km. These 10-day geoids have been expressed in terms of land water storage over the continents and ocean mass change over the oceans. We also analysed the global mean sea level using Topex/Poseidon altimetry data over the same period. Then removing the GRACE-based mean ocean mass time series to the Topex/Poseidon mean sea level allows us to estimate the mean steric sea level.

DATA AND METHOD

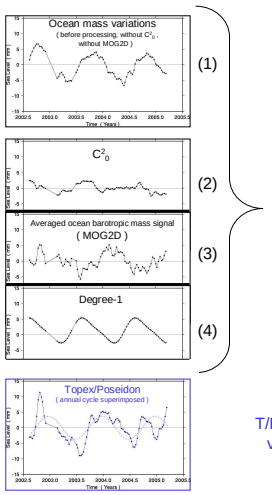
TIME VARIABLE GRAVITY DATA (by Biancale et al., 2006)

- 86 gravity fields at 10-day interval from August 2002 to March 2005, expressed in terms of normalized spherical harmonic coefficients from degree 2 up to degree and order 50.
- LAGEOS data : over 90% of the information on the degree 2.
- GRACE data : nearly 100% of the information on all the other harmonics.
- Corrections applied during the processing : Earth tides (IERS Convention 2003), ocean tides from the FES-2004 model (LEGOS), ECMWF 3-D atmospheric pressure fields every 6 hours, and the MOG2D barotropic ocean model have been taken into account in the raw data processing.
- As we study total ocean mass change, we restore the MOG2D barotropic ocean model (as the geoid solutions only contain corrections to the model).
- Degree-1 (C^1_0,C^1_1,S^1_1) coefficients are estimated from the variations of the Earth's center of mass computed by Chen et al. (1999).

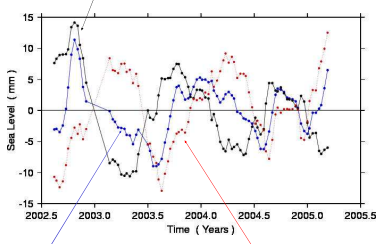
TOPEX/POSEIDON DATA

- Standard correction applied : tides, wet/dry tropo. corr., iono. corr., sea state bias (Chambers et al., 2003), instrumental drift and bias.
- NO Inverse Barometer correction applied.

60S - 60N AVERAGE OVER THE OCEANS



OCEAN MASS VARIATIONS
[(1)+(2)+(3)+(4)]



T/P sea level variations

Steric sea level : T/P minus GRACE

	Amplitude	Phase	Trend
OCEAN MASS (GRACE)	7.2mm	287.5°	-2.25mm/yr
TOTAL = MASS + STERIC (TOPEX/POSEIDON)	4.0mm	350.9°	0.01m m/yr
STERIC (T/P minus GRACE)	6.5mm	74.4°	+2.27mm/yr
STERIC (Levitus et al. (2005) CLIMATOLOGY)	5.1mm	84.6°	

RESULTS

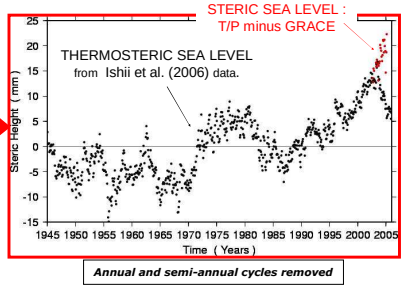
ESTIMATION OF THERMAL EXPANSION

- Steric sea level variations determined from combined Topex/Poseidon and GRACE data between August 2002 and March 2005, compares well with Levitus et al. (2005) Climatology (WOD04) - derived steric sea level, in terms of annual cycle (sea Table).
- Our results provide an estimate of the total steric (thermosteric + halosteric, for the entire water column) sea level time series using this method. Although the time span (2002-2005) is too short to get an robust estimation, in terms of trend, we obtain a 2.3 ± 0.2 mm/yr steric sea level trend (after removal of annual and semi-annual cycles) which compare well with previous estimates of thermosteric sea level trends for the period 1993-2003, which are of the order 1,5 ± 0.3 mm/yr (Willis et al., 2004; Levitus et al., 2005; Lombard et al., 2006; Ishii et al., 2006).

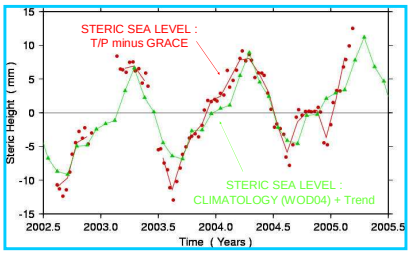
- Recent studies (M. Ishii, J. Willis, D. Chambers, pers. communication, 2006) using ARGO and other in situ data, find a negative trend over the period 2002-2005 (-2.5 +/- 0.2 mm/yr using Ishii et al., 2006 data). The ' TOPEX minus GRACE ' steric sea level does not show evidence of such a decreasing trend. Further investigation is needed to understand this problem.

LEVITUS CLIMATOLOGY

- We use the most recent climatology from Levitus et al. (2005) – temperature data down to 1500m – to estimate the monthly steric sea level variations.
- We add a 2.27mm/yr linear trend to the climatological steric time series, which correspond to the trend we compute using our 'T/P minus GRACE' steric sea level estimate.



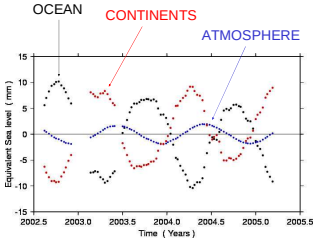
Annual and semi-annual cycles removed



GLOBAL EARTH WATER MASS BALANCE

- We checked that the land water storage averaged over the continental domain, is exactly the negative ocean mass averaged over the ocean domain, after taking into account the small atmospheric component.
- We find that over this 2½-year period, the trends correspond to a transfer of water mass from the ocean into continental reservoirs.

GLOBAL WATER MASS AVERAGES FROM GRACE DATA



	Amplitude	Phase	Trend
OCEAN	8.1mm	280.6°	-1.8mm/yr
CONTINENT	7.2mm	88.9°	+1.7mm/yr
ATMOSPHERE	1.8mm	156.4°	0.1mm/yr

$\Delta M_{ocean} + \Delta M_{continent} + \Delta M_{atmosphere} = 0$

CONCLUSIONS

- Our estimation of steric sea level variations agrees well with Levitus et al. WOD04 climatology in terms of seasonal cycle.
- However our GRACE-based estimate of steric sea level trend (+2.3±0.2mm/yr) between August 2002 and March 2005 does not agree with recent studies based on in situ temperature data (Ishii, Willis).
- We provide a global water mass balance that shows a negative contribution of land water storage to sea level rise (about -1.7 ±0.2mm/yr).

REFERENCES

- Biancale R., J.-M. Lemoine, G. Balmino, S. Loyer, S. Bruisma, F. Perosanz, J.-C. Marty and P. Gégout, "3 years of geoid variations from GRACE and LAGEOS data at 10-day intervals from July 2002 to March 2005", CNES/GRGS product, data available on CD-ROM, 2006.
- Chambers, D. P., J. Wahr and R. S. Nerem (2004), Preliminary observations of global ocean mass variations with GRACE, *Geophys. Res. Lett.*, Vol. 31, L13310..
- Chen, J. L., C.R. Wilson, R. J. Eanes and R. S. Nerem (1999), Geophysical interpretation of the observed geocenter variations, *J. Geophys. Res.*, 104, B2, 2683-2690.
- Ishii, M., M. Kimoto, K. Sakamoto and S.I. Iwasaki, Steric sea level changes estimated from historical ocean subsurface temperature and salinity analyses, *J. Oceanography*, 62, 155-170, 2006.
- Levitus S., J.I. Antonov and T.P. Boyer, Warming of the World Ocean, 1955-2003, *Geophys. Res. Lett.*,32, L02604, doi:10.1029/2004GL021592, 2005.
- Lombard, A., A. Cazenave, S. Guinehut, P.-Y. Le Traon, and C. Cabanes, Perspectives on present-day sea level change. *Ocean Dyn.*, in press, 2006.
- Willis, J.K., D. Roemmich, and B. Cornuelle, Interannual variability in upper-ocean heat content, temperature and thermosteric expansion on global scales. *J. Geophys. Res.*, 109(C12036), doi:10.1029/2003JC002260, 2004. .