Forward modeling with atmosphere, hydrological and ocean models: the ins & the outs. Impact on geodetic positioning

Jean-Paul Boy

Ecole et Observatoire des Sciences de la Terre
Strasbourg, France.

jpboy@eost.u-strasbg.fr

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

Ecole et Observatoire des Sciences de la Terre

UNIVERSITÉ LOUIS PASTEUR STRASBOURG

Forward modeling with atmosphere, hydrological and ocean models: the ins & the outs. Impact on geodetic positioning

- Model availability and general characteristics
- Surface displacements
  - Choice of the reference frame (degree 1 Love numbers),
  - Ocean response to pressure forcing (IB vs barotropic ocean),
  - Comparison with GPS observations (*Gégout et al., 2008*),
- Geocenter motion
- Time-variable gravity
  - GRACE KBRR (*Luthcke et al., 2008*),
  - JASON reprocessing (*Lemoine et al., 2008*).
- Conclusions

Atmospheric model availability

NCEP Reanalysis:

1948 – now, 6-hourly, T62 (~ 300 km), 28 sigma levels

available by ftp in almost real time

ECMWF Reanalysis (ERA40)

1957 – 2002, 6 hourly, T159 (~ 125 km), 60 hybrid levels

NCEP Operational (GFS):

Since May 2005, 6-hourly, T382 (~ 35 km), 64 sigma levels

available by ftp in real time, but only for a few days

ECMWF Operational

Since Feb. 2006, 6-hourly or 3-hourly, T799 (~ 25 km), 91 hybrid levels

Some other models (JMA, GEOS, etc.)

Hydrological model availability

GLDAS

3 different soil models (Noah, CLM & Mosaic)

1979/01 to 2008/01 (1 degree, 3 hours)

2000/03 to 2007/12 (0.25 degree, 3 hours) for Noah

(soil moisture, snow equivalent height & canopy water)

ECMWF Reanalysis (ERA40)

1957 – 2002, 6 hourly, T159 (~ 125 km)

(soil moisture & snow equivalent height)

ECMWF Operational

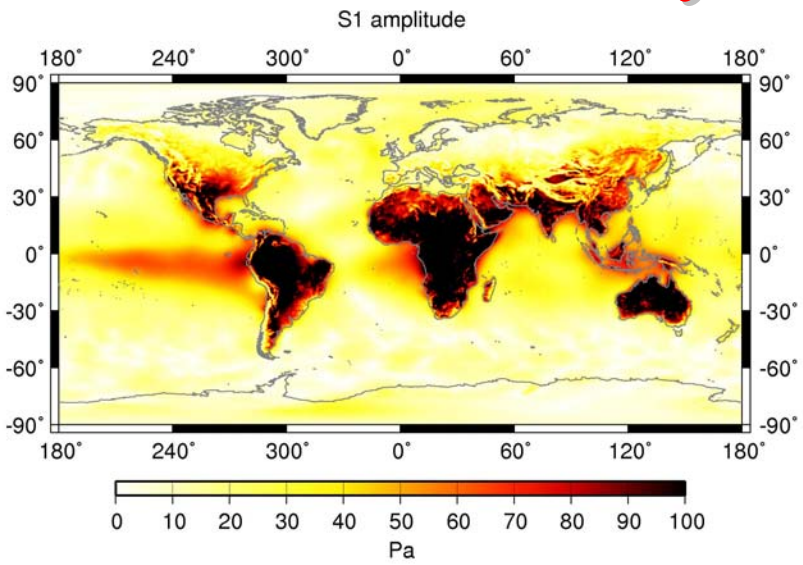
Since Feb. 2006, 6-hourly, T799 (~ 25 km)

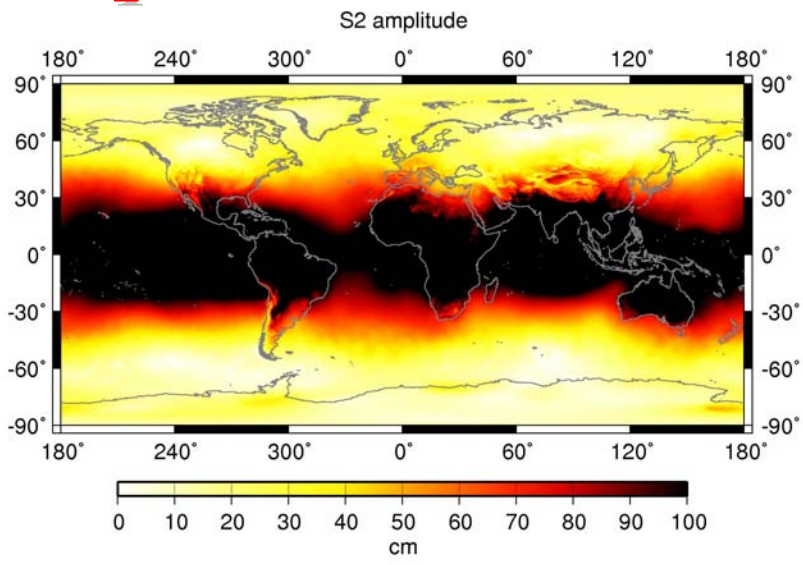
Major change in the soil properties in Nov. 2007

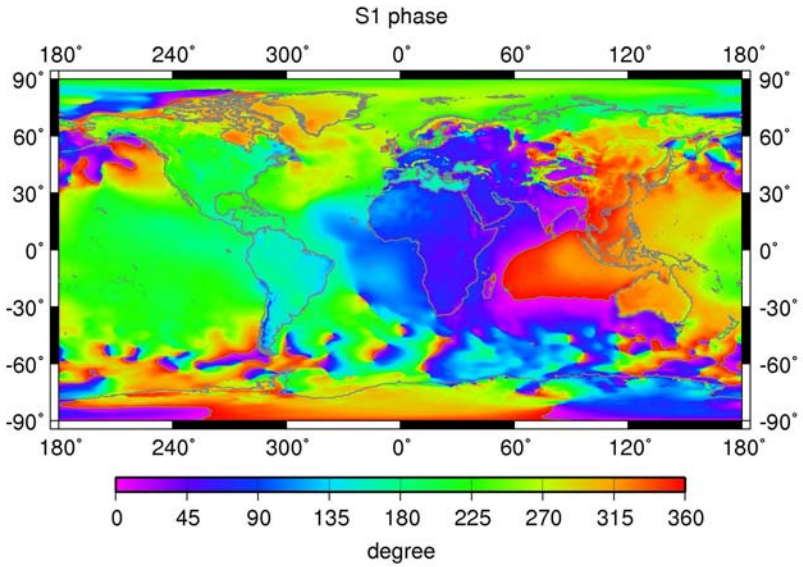
(soil moisture & snow equivalent height)

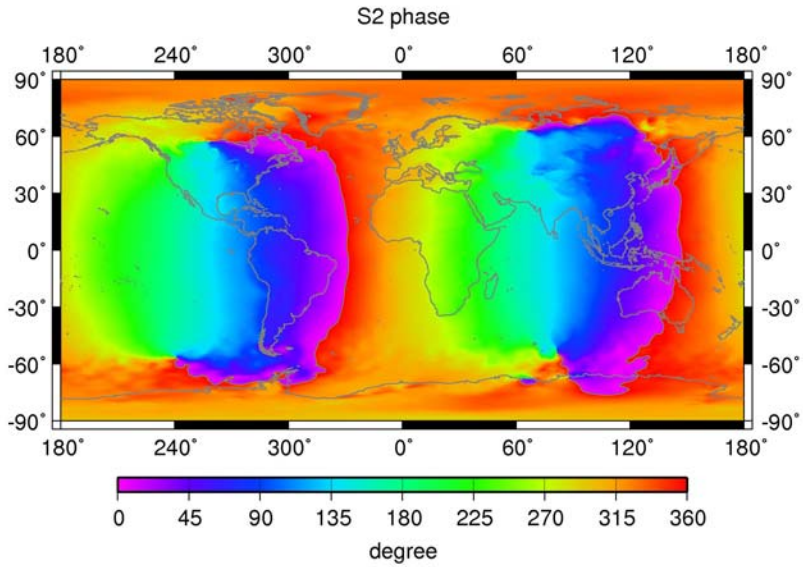
Some other models (WGHM, LaD, etc.) but never in near real time.

Air Tides (S1 & S2) from ECMWF 3-hourly surface pressure









$$p(\theta,\lambda,t) = A(\theta,\lambda)\cos(\omega t + \varphi(\theta,\lambda))$$

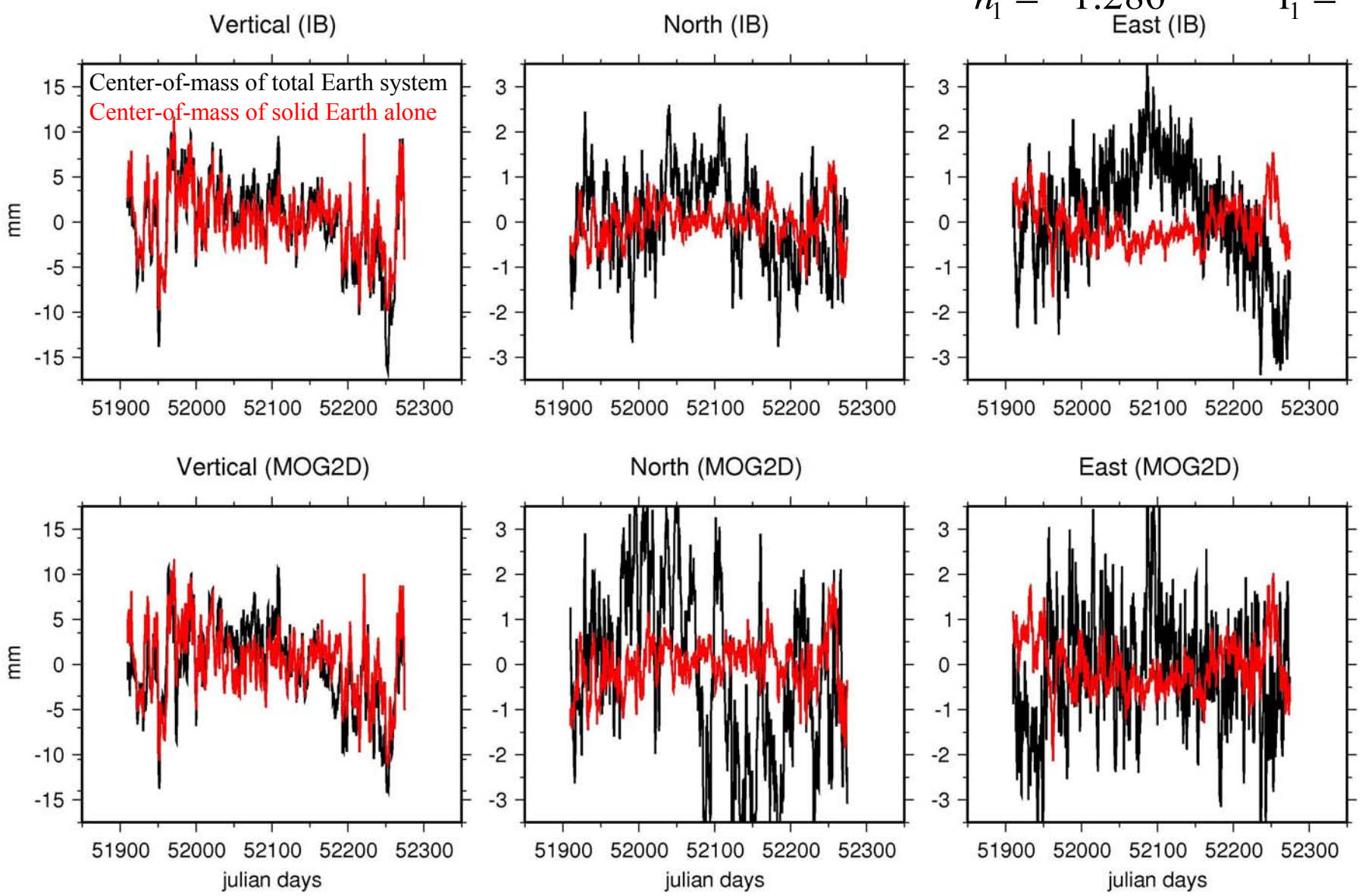
3 hourly data only available since 1997/12

Validity ?

Choice of the Reference Frame (degree 1 Love numbers)

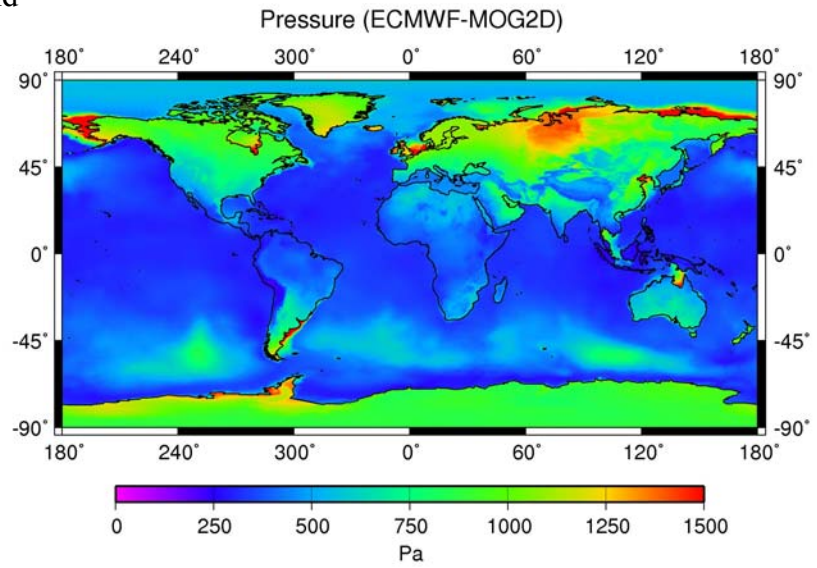
$h_1' = -0.286$ $\quad l_1' = +0.104$

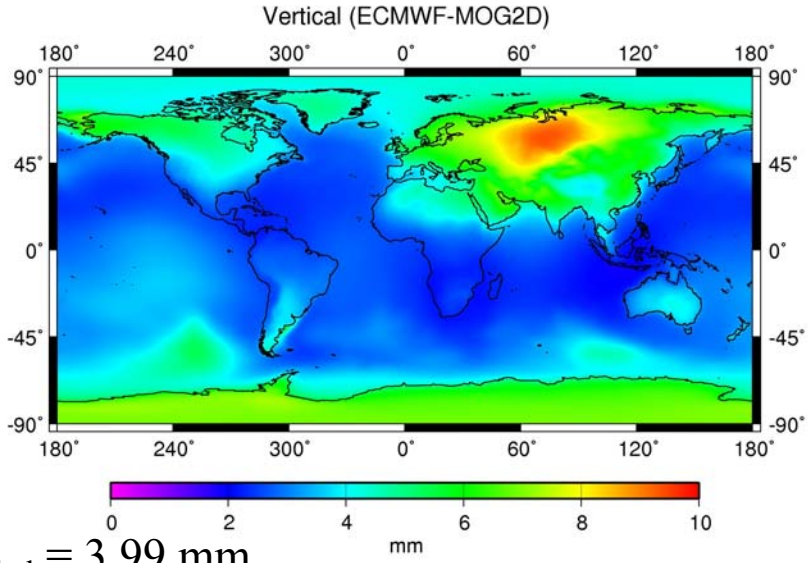
$h_1' = -1.286$ $\quad l_1' = -0.896$



RMS variations of atmospheric and induced oceanic loading

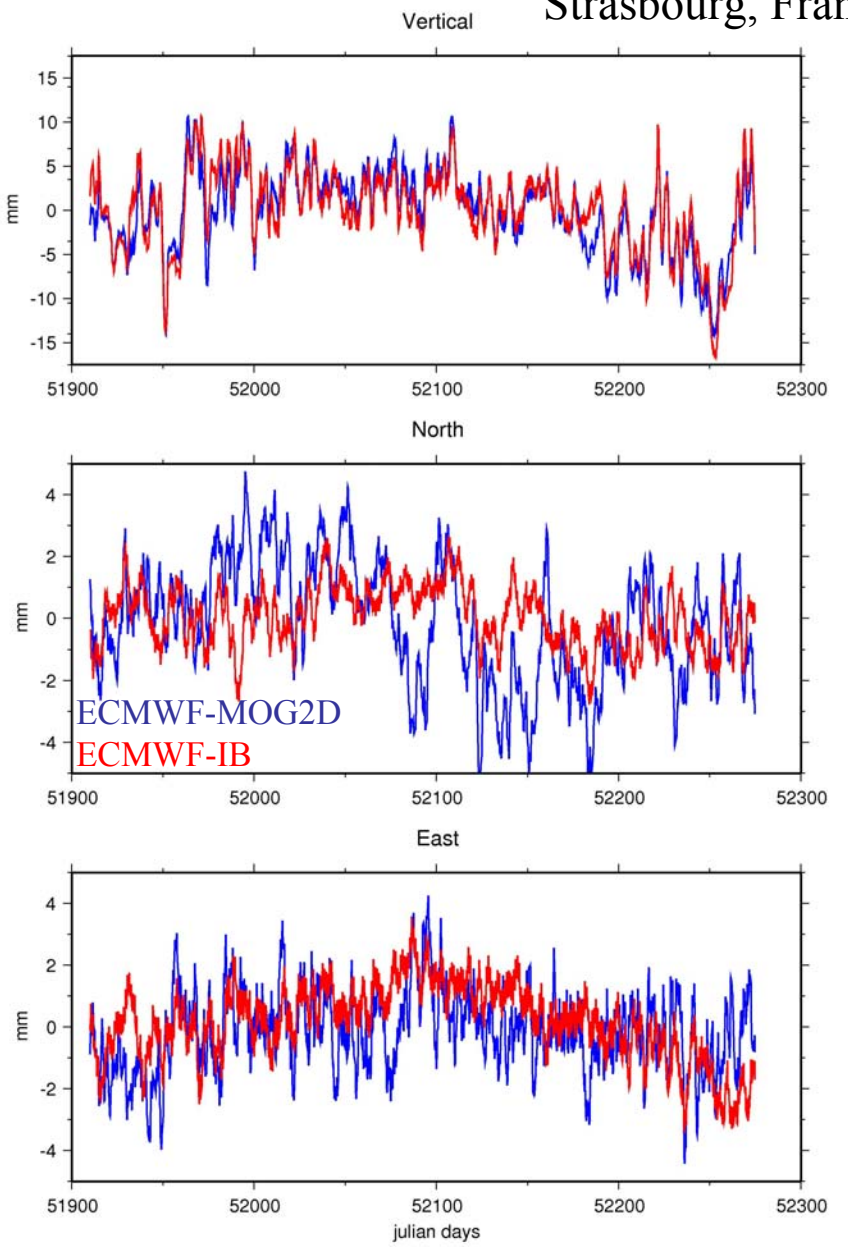
RMS_{Global} = 556.4 Pa
RMS_{Land} = 795.4 Pa





RMS_{Global} = 3.99 mm
RMS_{Land} = 5.31 mm

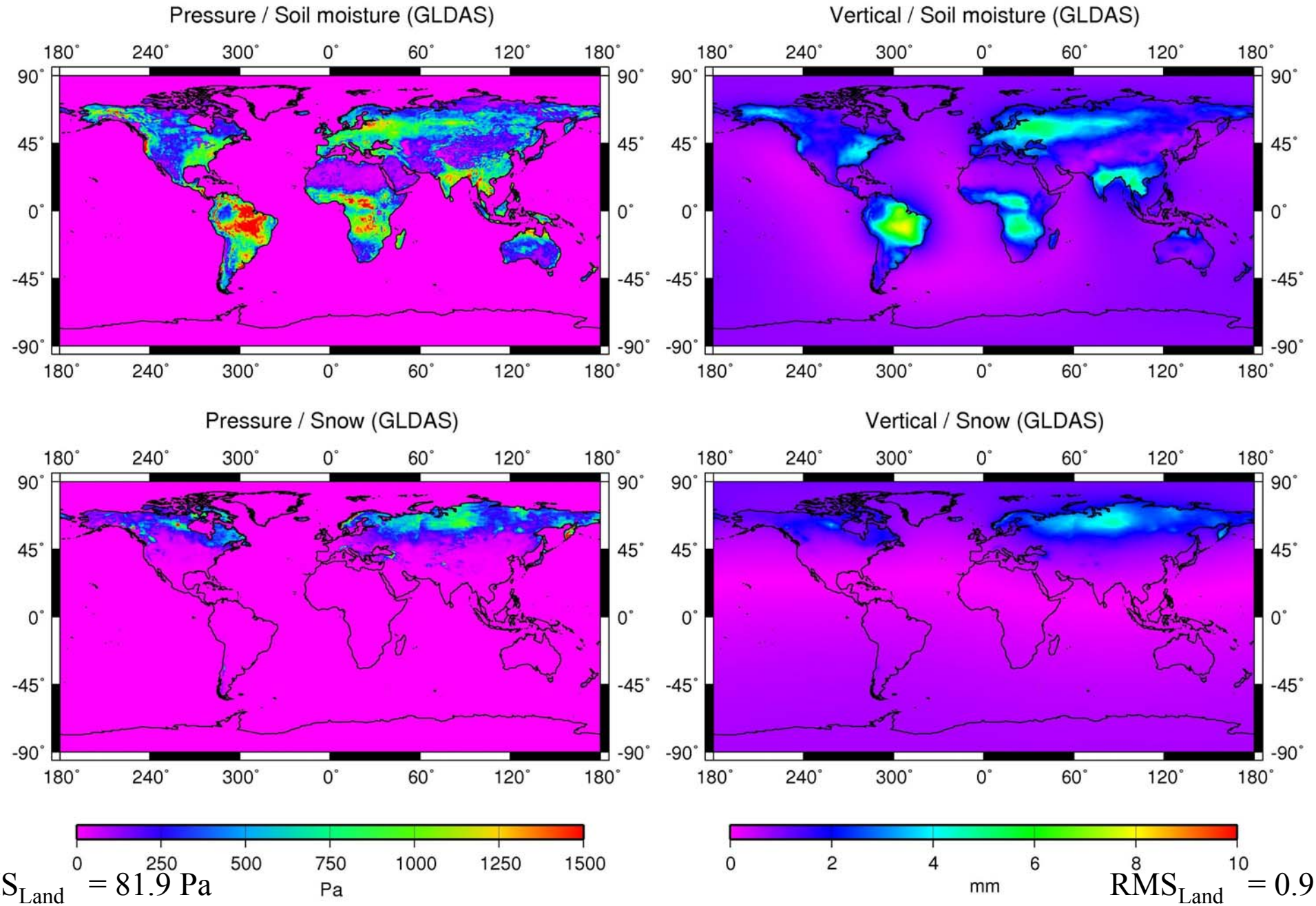
Strasbourg, France



RMS variations of hydrological loading

RMS_{Land} = 333.2 Pa

RMS_{Land} = 1.7 mm



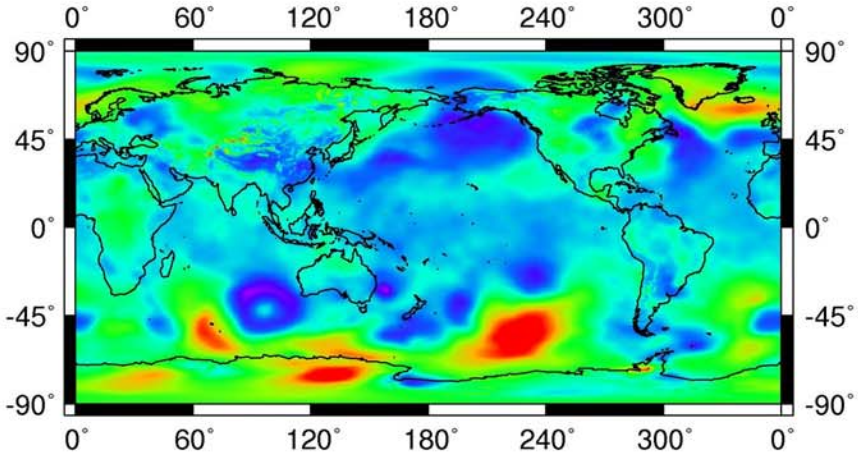
RMS_{Land} = 81.9 Pa

RMS_{Land} = 0.9 mm

RMS differences between different atmospheric models and ocean response

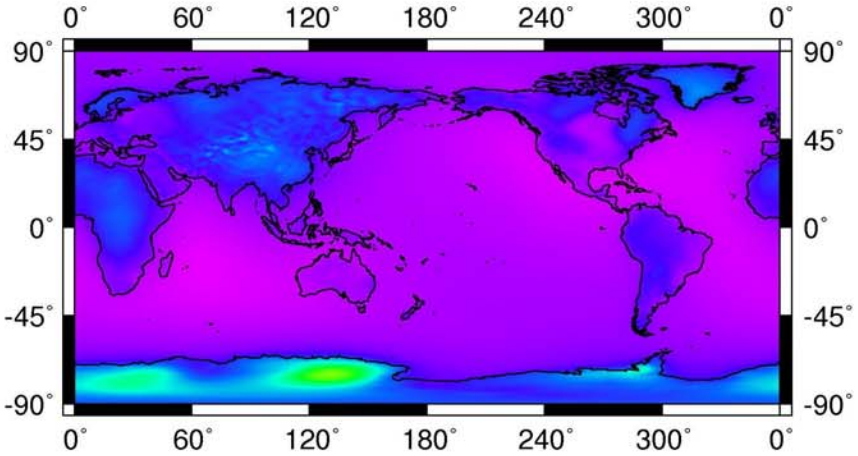
RMS_{Global} = 327.8 Pa
RMS_{Land} = 352.6 Pa

NCEP / ECMWF

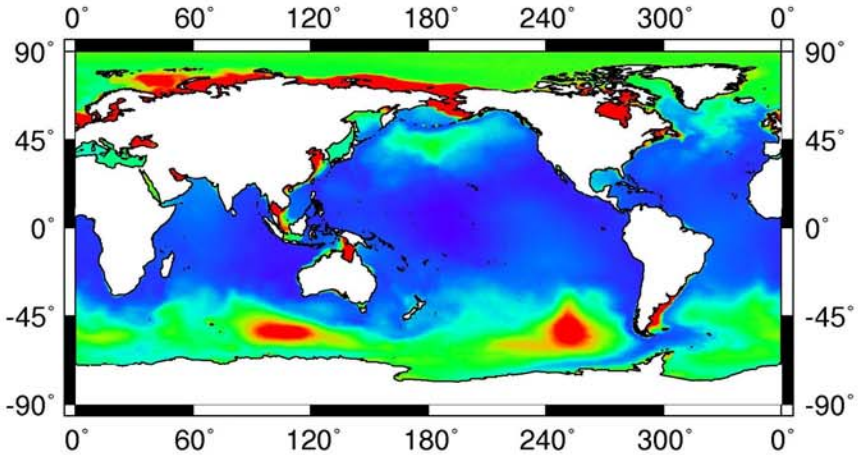


RMS_{Global} = 0.39 mm
RMS_{Land} = 0.70 mm

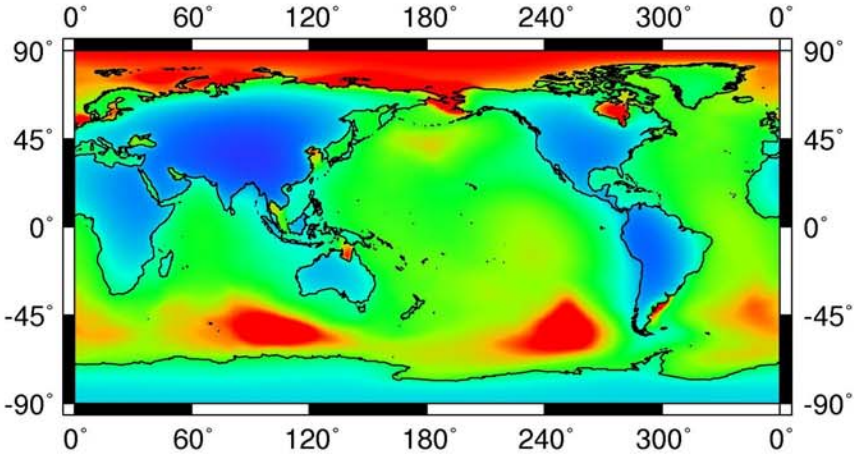
NCEP / ECMWF (IB)

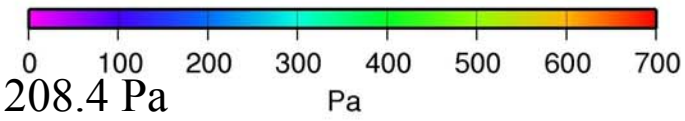


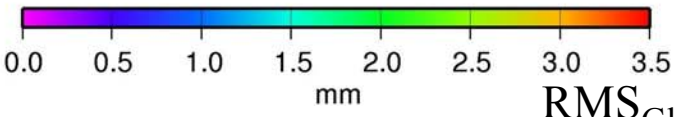
ECMWF-IB / ECMWF-MOG2D



ECMWF-IB / ECMWF-MOG2D







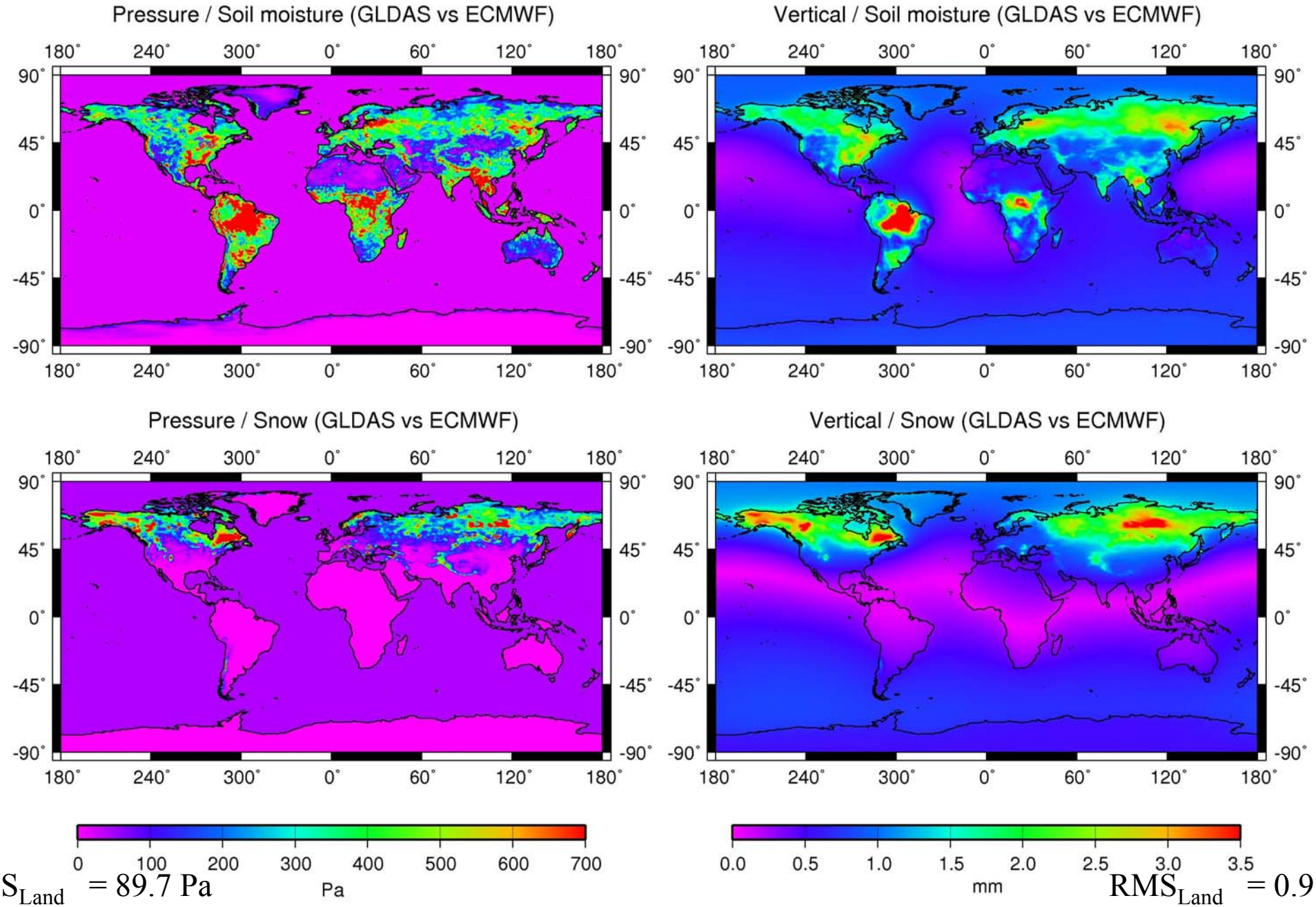
RMS_{Global} = 208.4 Pa
RMS_{Land} = 0.0 Pa

RMS_{Global} = 2.11 mm
RMS_{Land} = 1.44 mm

RMS differences between GLDAS/Noah and ECMWF hydrological loading

RMS_{Land} = 236.9 Pa

RMS_{Land} = 1.2 mm

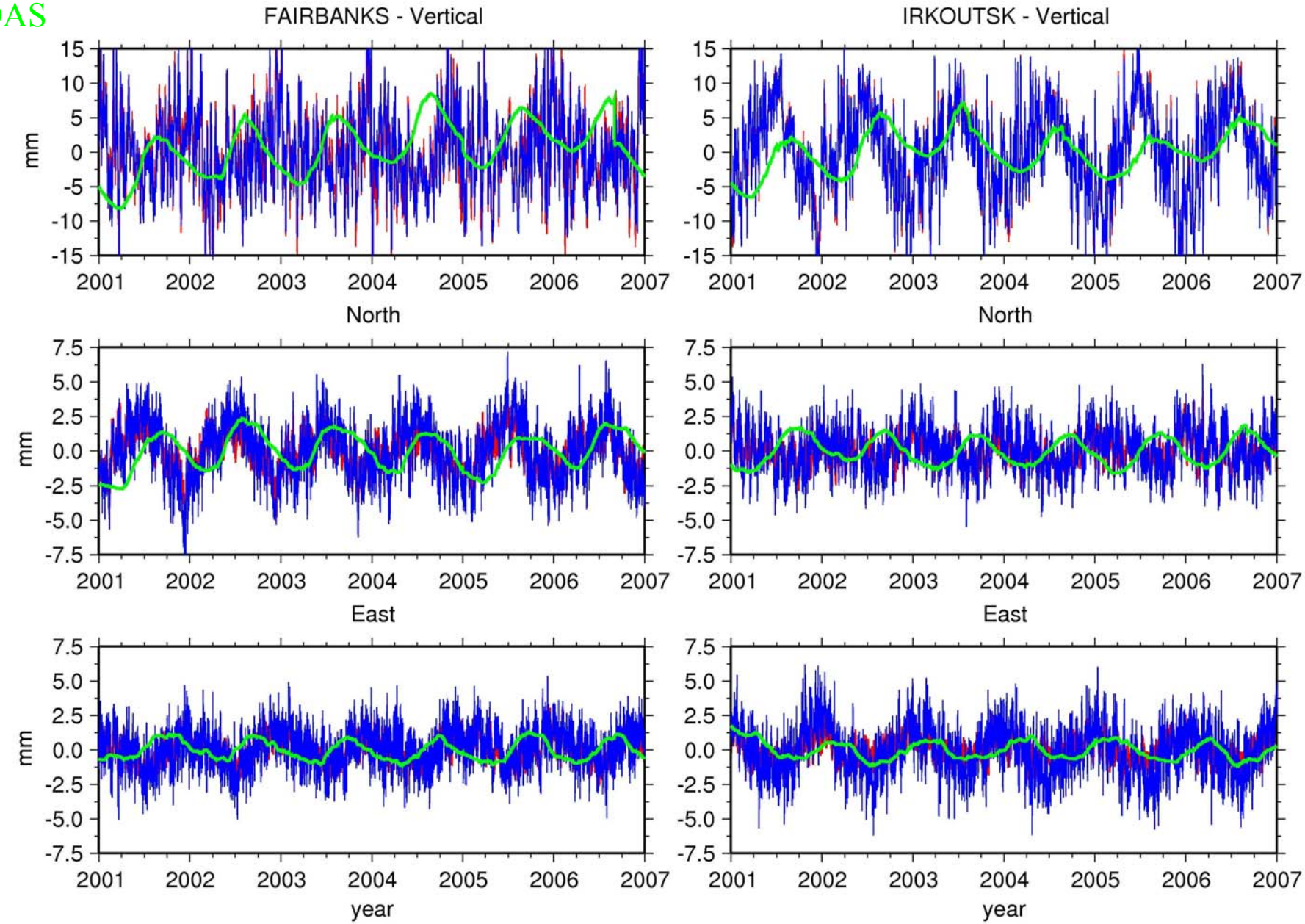


RMS_{Land} = 89.7 Pa

RMS_{Land} = 0.9 mm

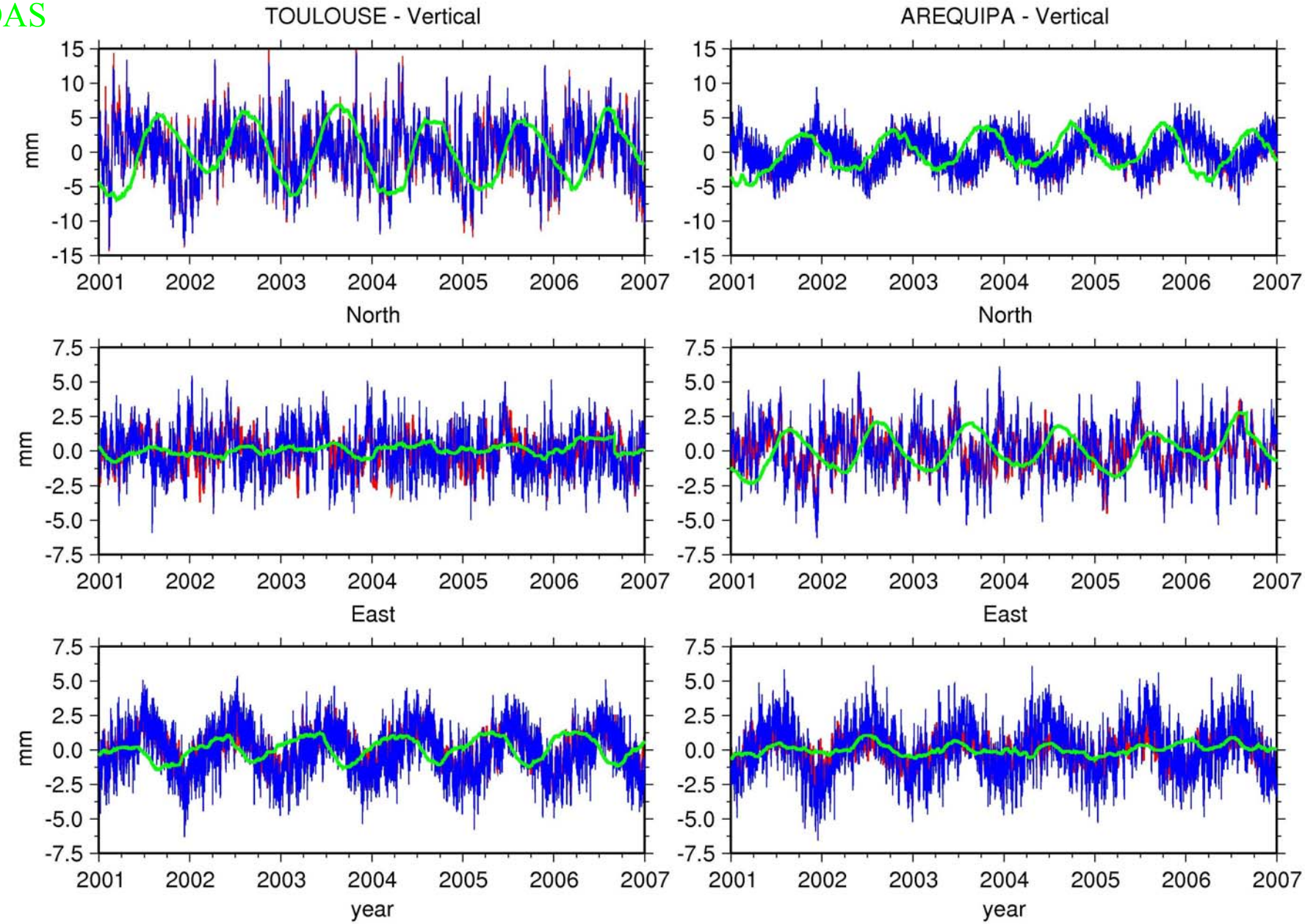
Examples of 3D displacement time series (High latitudes)

ECMWF – IB
ECMWF – MOG2D
GLDAS



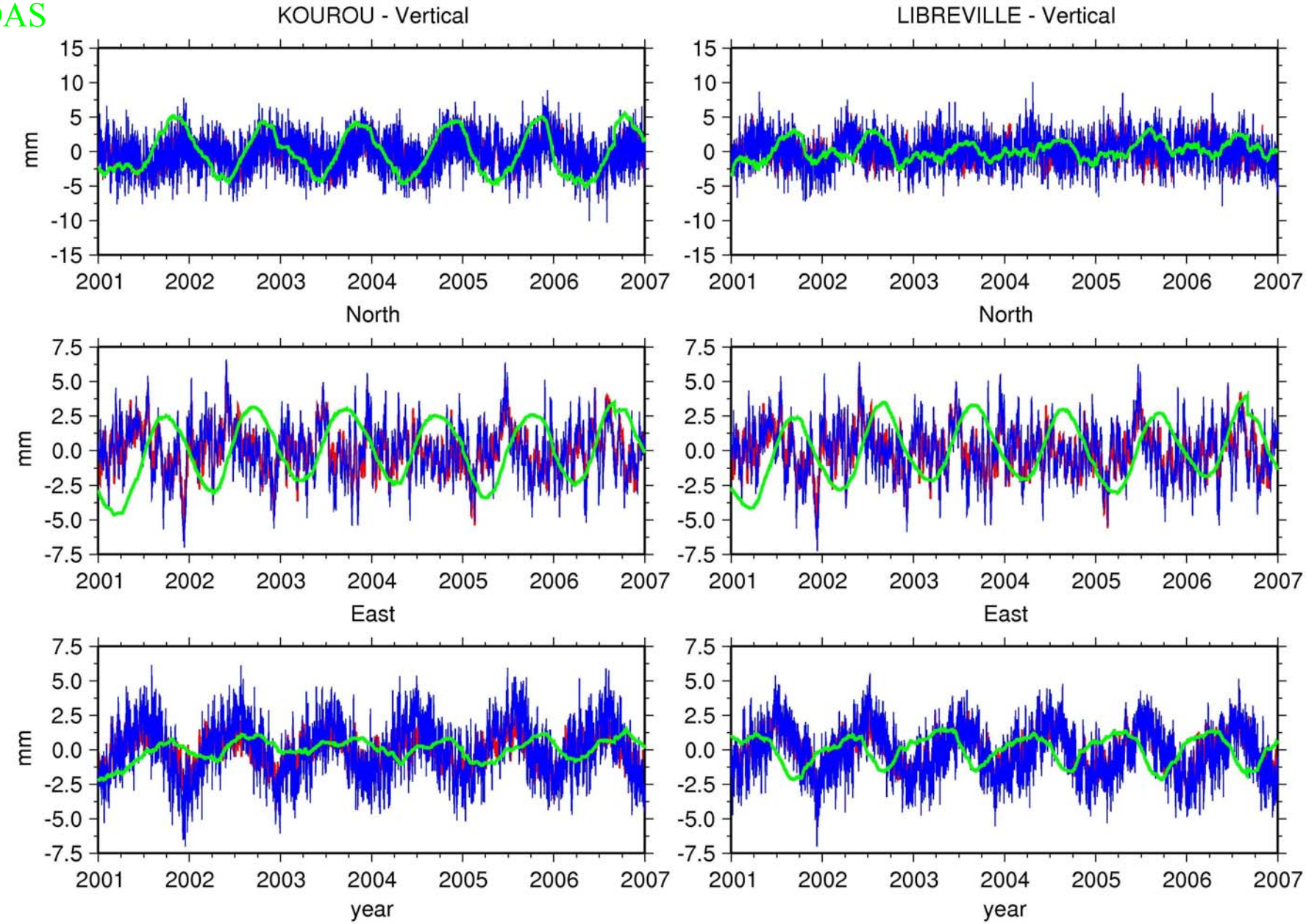
Examples of 3D displacement time series (Mid latitudes)

ECMWF – IB
ECMWF – MOG2D
GLDAS



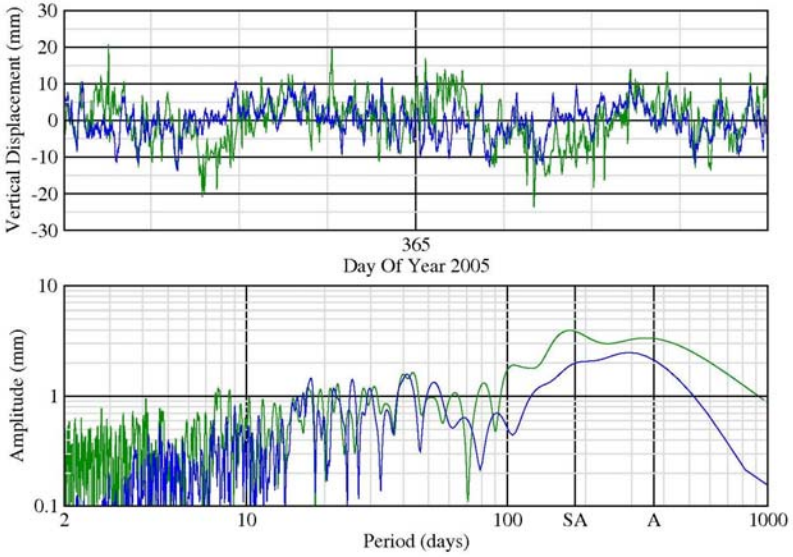
Examples of 3D displacement time series (Low latitudes)

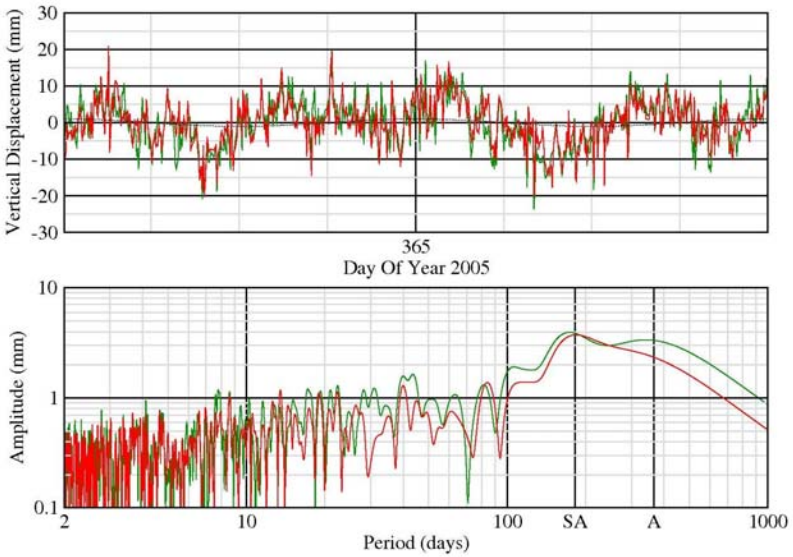
ECMWF – IB
ECMWF – MOG2D
GLDAS



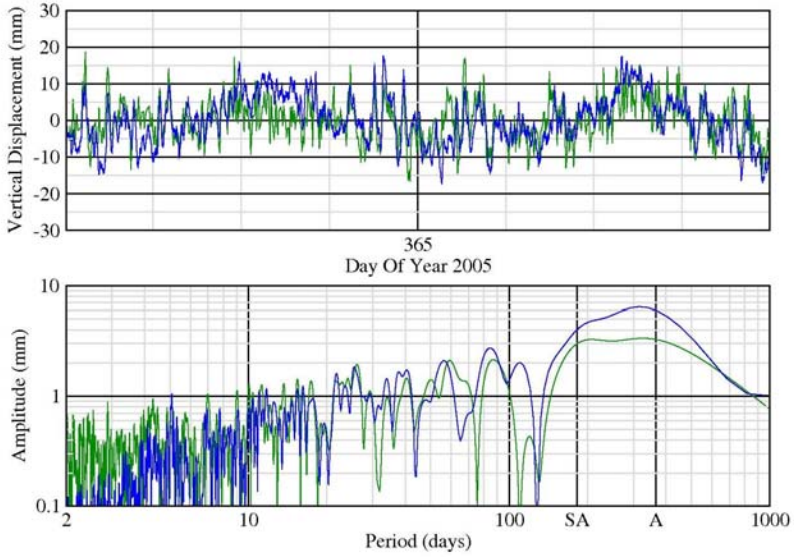
Vertical displacements from GPS

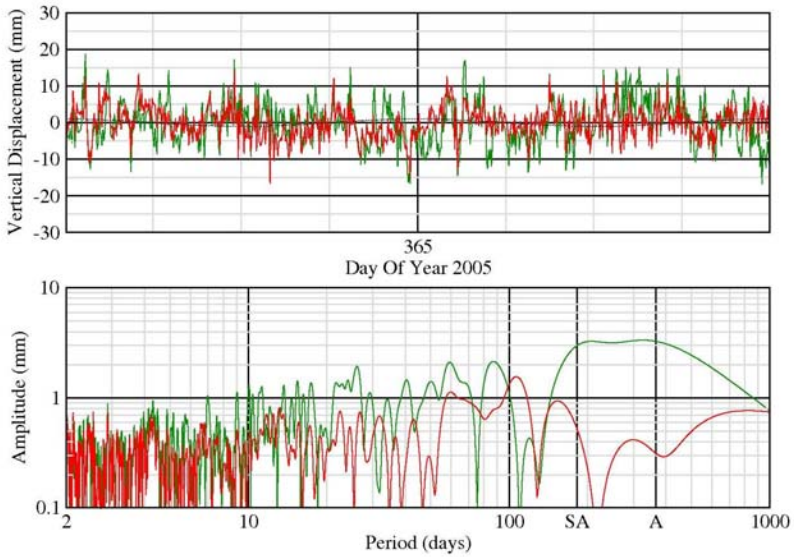
Ny Alesund (Svalbard)





Wettzell (Germany)





GPS observations

Modeled loading
(ECMWF-MOG2D-GLDAS)

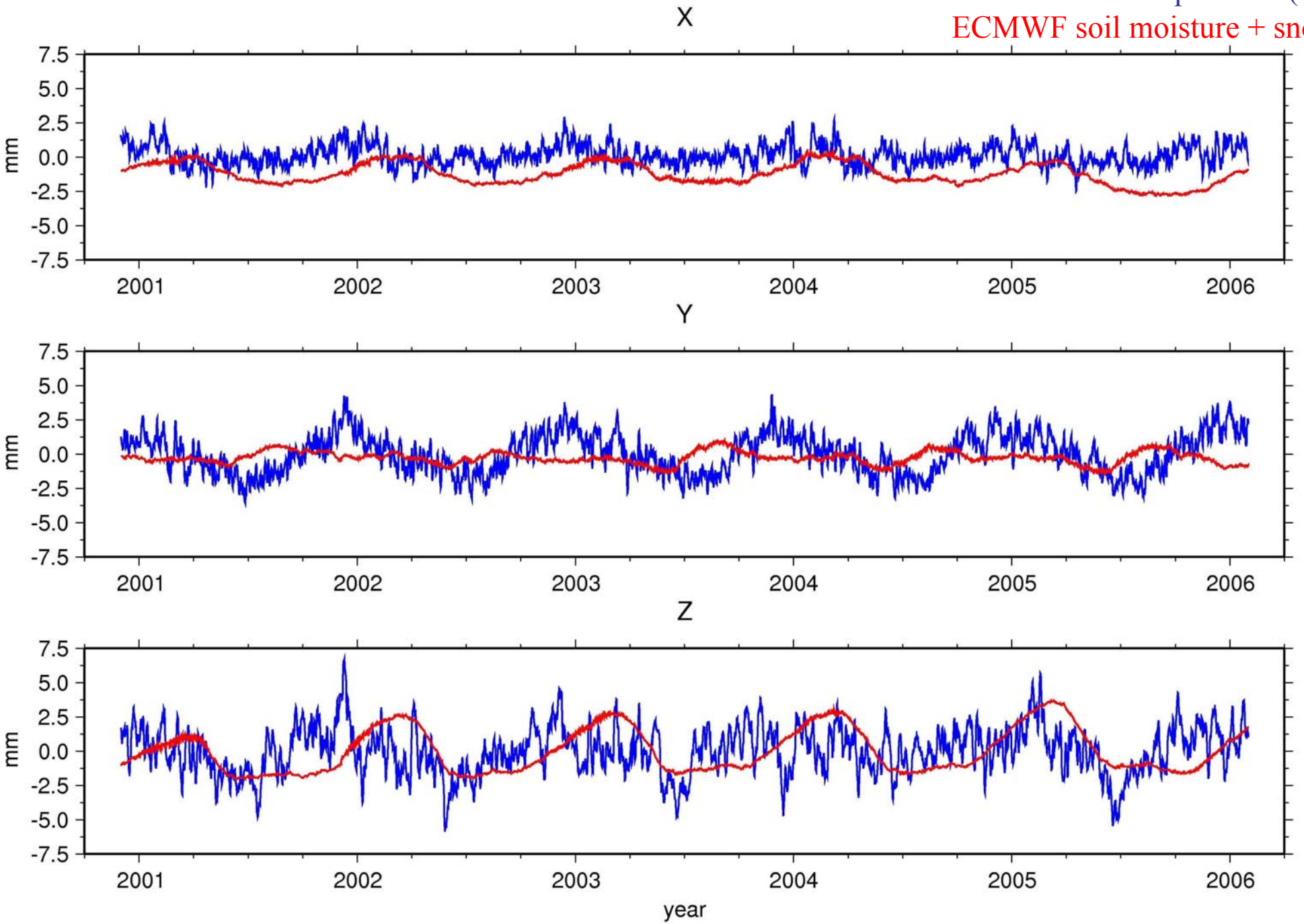
GPS solution without loading

GPS solution with loading

From Gégout et al. and Boy et al., EGU 2008.

Geocenter motion

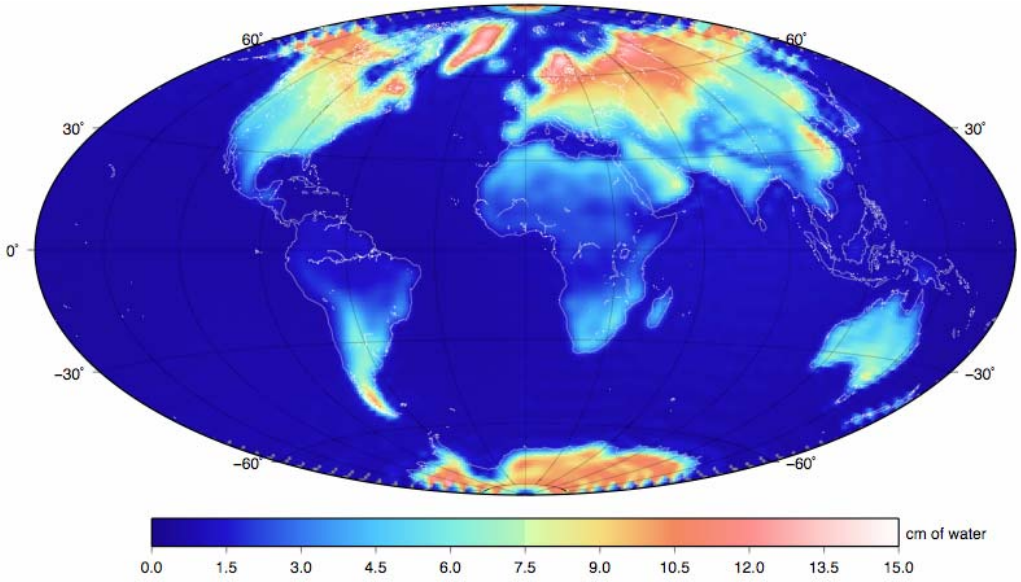
ECMWF surface pressure (IB)
ECMWF soil moisture + snow



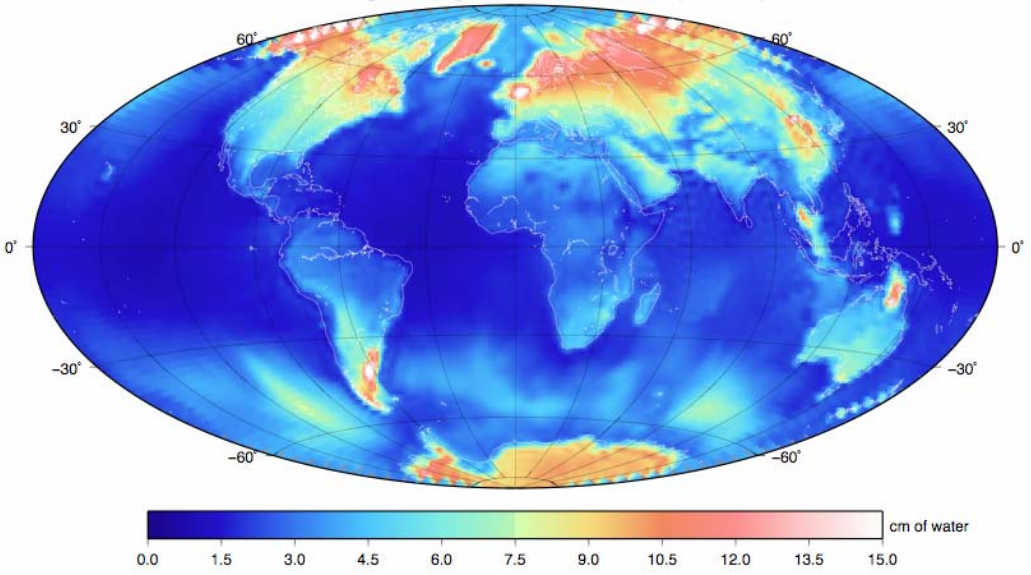
Atmospheric and oceanic loading effects on time-variable gravity

RMS Variations (2003/04 – 2007/04)

NCEP-6hr. (IB)

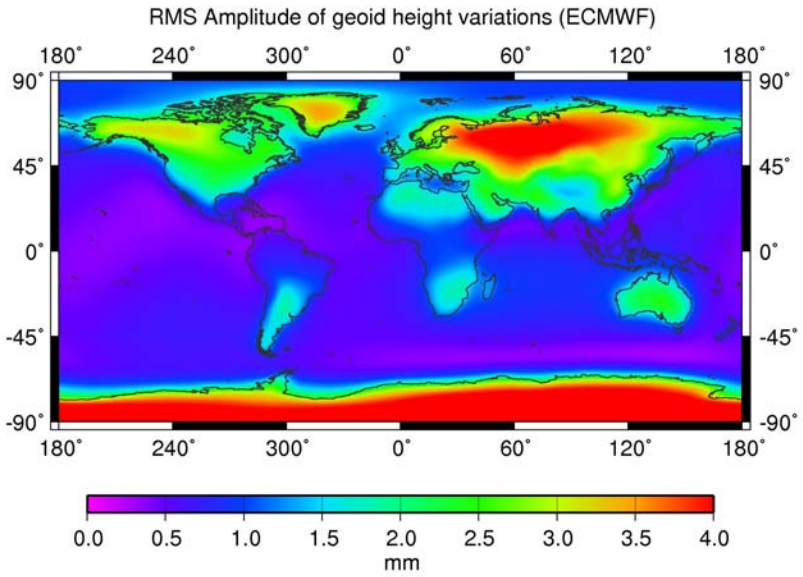


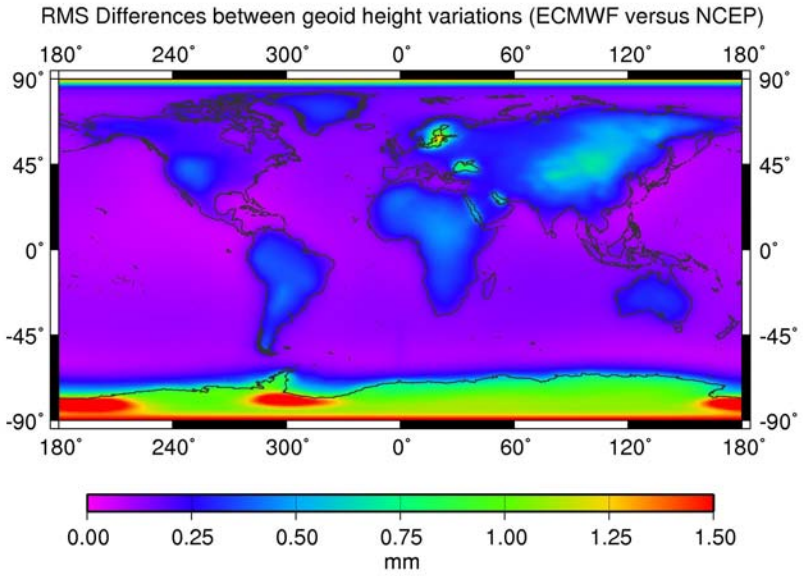
ECMWF-3hr. + MOG2D



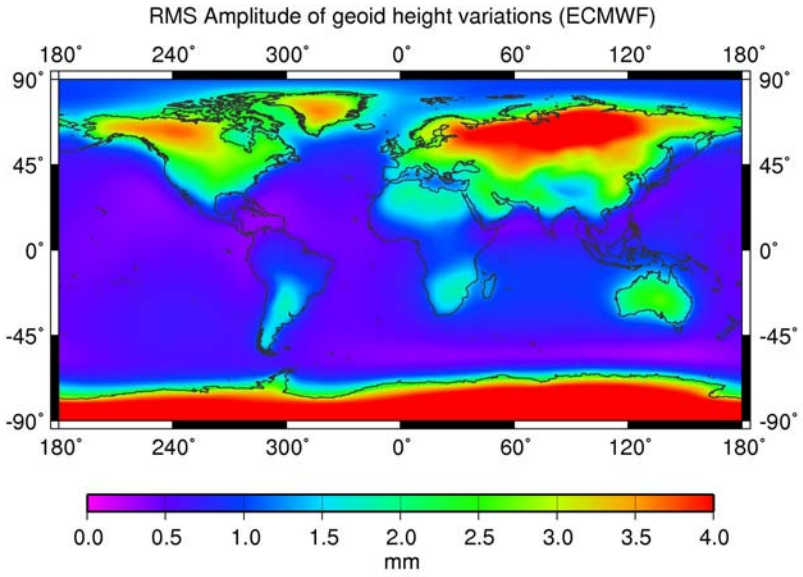
Time-variable gravity field
Differences between NCEP and ECMWF (IB)

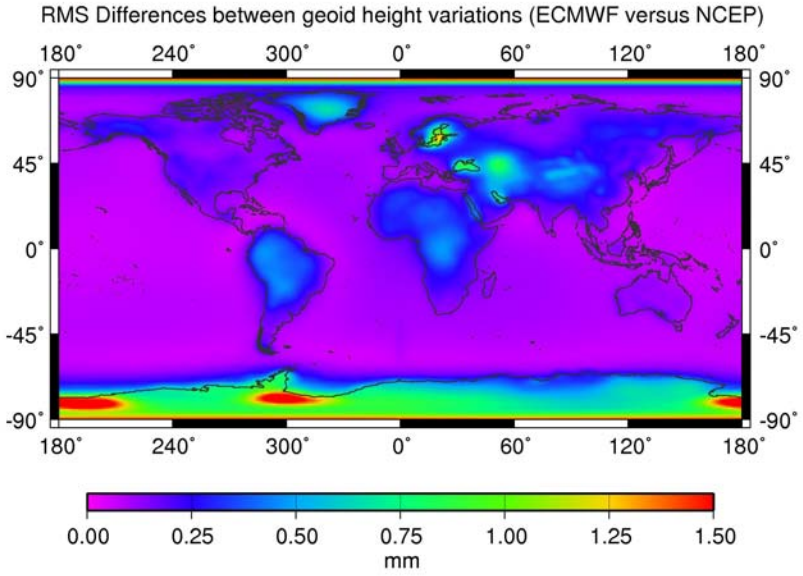
NCEP Reanalysis vs ECMWF Reanalysis (ERA40)



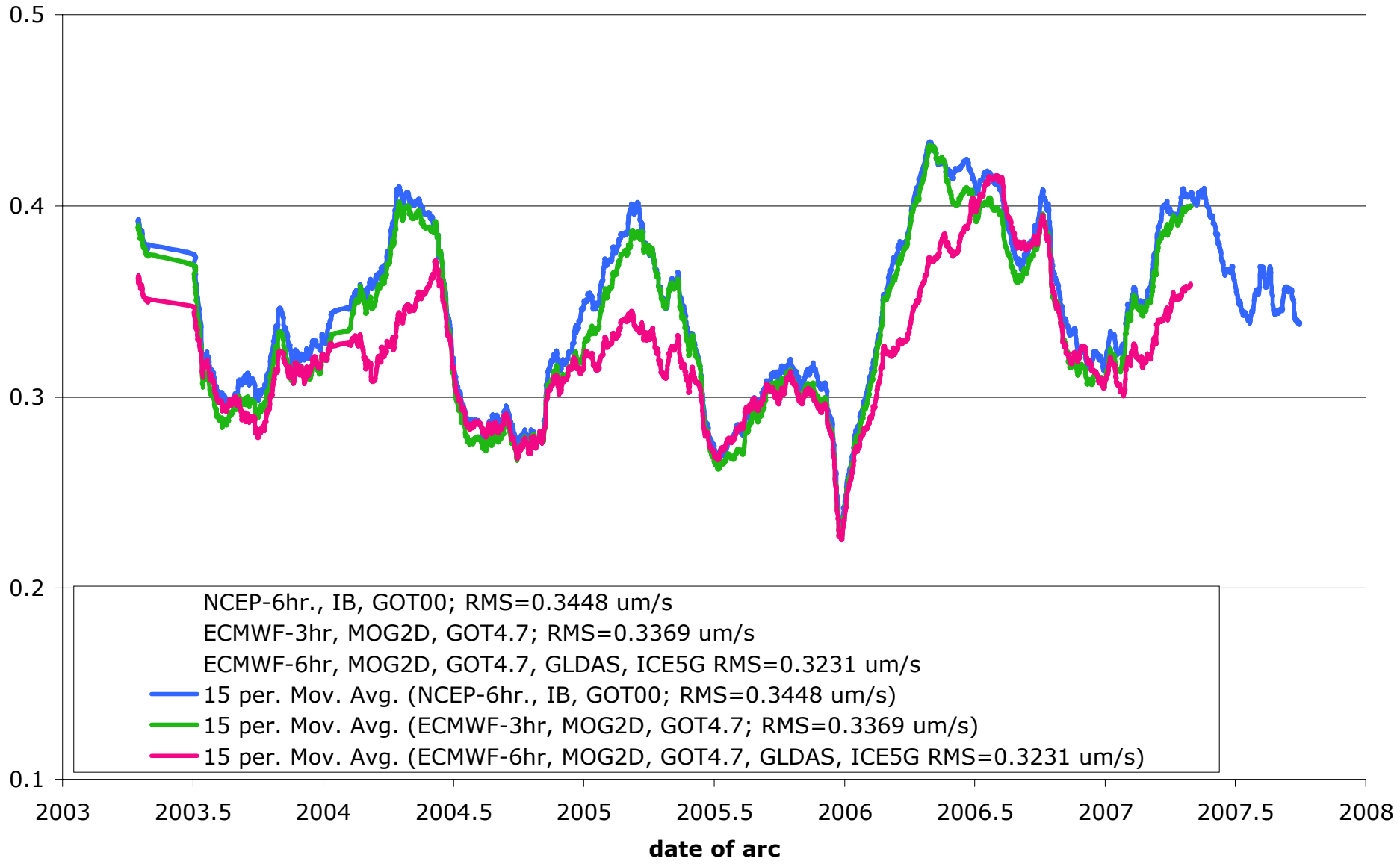


NCEP Reanalysis vs ECMWF Operational (actual)





GRACE residuals (KBBR)



* Filtered with 15-day moving average.

From S. Luthcke.

Reprocessing of JASON

Impact of the time-variable gravity corrections

Jason cycles 37-111 residual summary (January 2003 – January 2005)	DORIS (mm/s)	SLR (cm)	Xover (cm)
no time varying gravity	0.4034	1.484	5.579
NCEP – 6hr / IB	0.4033	1.444	5.564
NCEP – 6hr + annual 20x20 (grace)	0.4033	1.429	5.562
ECMWF – 3hr + MOG2D	0.4033	1.441	5.562
ECMWF – 3hr + MOG2D + GLDAS	0.4033	1.427	5.560

3-D displacements due to atmospheric loading of SLR/DORIS stations should also be added.

From Lemoine et al., EGU 2008.

Conclusion

- 3D displacements, geocenter motion & time-variable gravity field due to atmospheric loading can be processed in near real-time, assuming an inverted barometer ocean response.
  - ECMWF Operational
  - NCEP Reanalysis
- No high resolution reanalysis products available (ECMWF ERA40 ends in 2002/08).
- Batropic ocean models have been mostly developed for GRACE processing; MOG2D should be available since 1992 (T/P). However, there are not available in near real-time.
- No global hydrological models available in real-time, except ECMWF soil moisture & snow.
- Hydrological models should still have to be validated.

Atmospheric Loading provider

Surface displacements (SLR & DORIS), time-variable gravity field & geocenter motion due to atmospheric (ECMWF/IB) & hydrological loading (ECMWF):

ftp://ftp-eost.u-strasbg.fr/jpboy/APLO (atmosphere)

ftp://ftp-eost.u-strasbg.fr/jpboy/AGRA (atmosphere)

ftp://ftp-eost.u-strasbg.fr/jpboy/HGRA (hydrology)

Surface displacements (VLBI, SLR, DORIS & GPS) and time-variable gravity field due to atmospheric loading (NCEP/IB):

http://gemini.gsfc.nasa.gov/aplo/

http://gemini.gsfc.nasa.gov/agra/

(Petrov & Boy, 2004)