Call for space geodetic solutions corrected for non-tidal atmospheric loading (NT-ATML) at the observation level

IGN INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

UNIVERSITÉ DU LUXEMBOURG

Xavier Collilieux, Tonie van Dam, Zuheir Altamimi

Global Geophysical Fluid Center

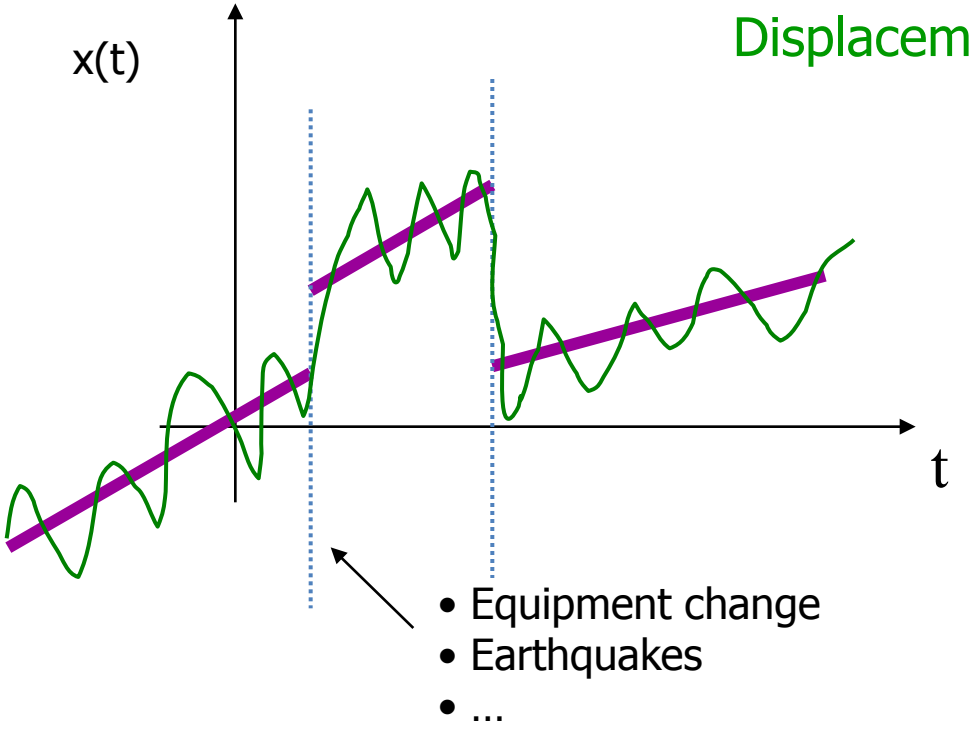
Outline:

- Context
- Why correcting for non-tidal atmospheric loading?
- Call for participation: your help is needed
- Discussion

Context (1/3)

Instantaneous pos. $\Big|_{\text{theoretical}}$ (t) = Ref. coordinate (t) + Modeled displacements (t)

Ref. coordinate (t) = $X(t_0) + V\,(t-t_0) + \Sigma_i\, dX(t-t_i) + \Sigma_i\, dV(t-t_i)$



Displacement models include:

- Solid Earth tides
- Pole tides
- Tidal ocean loading
- Atmospheric tides

http://www.iers.org/TN36/

Context (2/3)

http://www.iers.org/TN36/

IERS[1] conventions 2010 (Petit et Luzum (eds.), 2010)

- Accuracy < 1 mm
- Independant from space geod. If possible

Tidal Loading models

Class 1

Recommended to be used a priori

Non-tidal Loading models

Class 3

Useful but not recommended

Class 2

conventional

[1] IERS: International Earth Rotation and Reference Systems Service

Context (3/3)

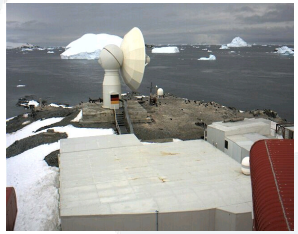
How non-tidal ATM loading effects are accounted for up to now by the technique service Analysis Centers?

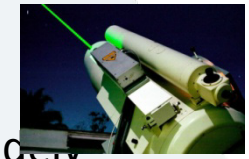
IVS applies non-tidal atmospheric loading corrections at the obs. level

IDS uses gravity potential model of the atmospheric effect (+ associated deformation effect k_n') but does not use station position corrections.

ILRS and IGS do not use any NT-ATML model for operational products

NB: for GRACE observation analysis, atmospheric models are widely used



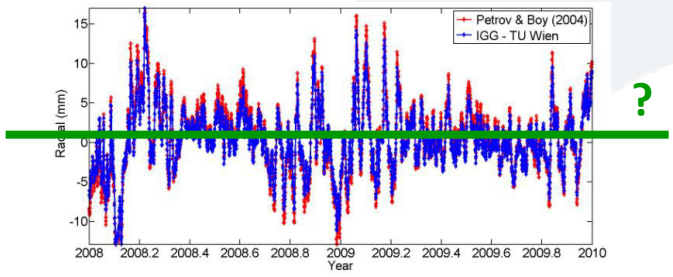


Why correcting for non-tidal atmospheric loading a priori? (1/3)

1) Magnitude of the displacements

Up to a few centimeters peak-to-peak

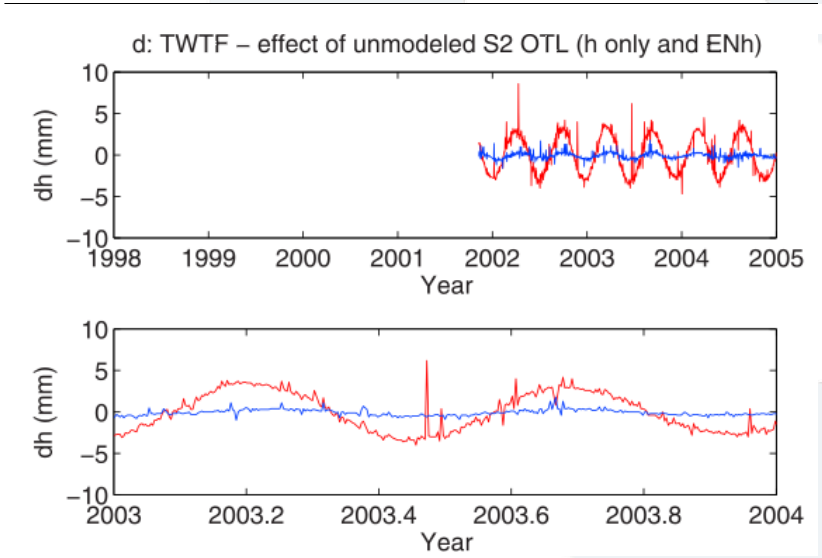
- Biased station positions if few data available



Problem solved if corrections applied at the observation level or a posteriori

2) If not corrected, high frequency ground displacements may leak into low frequency signals in the estimated position time series

Fig. by Penna et al. (2007)
Error in the height if semi-diurnal tidal ocean loading are not corrected



Problem solved if corrections applied at the observation level only.
BUT NT-ATM loading should be accurate for frequency higher than 1/14 cpd

Why correcting for non-tidal atmospheric loading a priori? (2/3)

3) Some part of the loading displacement may leak into estimated parameters other than station positions if NT-ATML loading corrections are not included

Problem solved if corrections applied at the observation level only

Note:

Correlations reported for
• Troposphere parameters if station positions are fixed (Boëhm et al., 2009)
• GPS satellite estimated empirical accelerations can absorb loading signals if not constrained enough (Dach et al., 2011) but they seem constrained enough in current processing (at least for CODE group).
=> No clear evidence of this effect yet.

Why correcting for non-tidal atmospheric loading a priori? (3/3)

Benefit for the IERS conventions

Current IERS conventions

$$\text{Instantaneous pos.}\Big|_{CM}(t) = \text{Ref. coordinate ITRF}\Big|_{\text{Time-averaged CM}}(t) + \text{Tidal-ATM loading}\Big|_{CM}(t) + \text{NT-ATM loading}\Big|_{CM}(t)$$

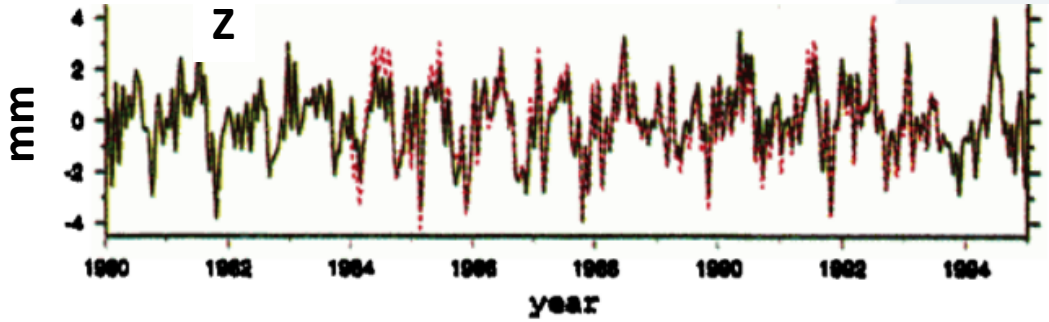


Figure 1: Geocenter variation from ECMWF (solid line) and NCEP (dashed line) series. ECMWF land-ocean mask was used in the inverted barometer (IB) model. Both series passed band-pass filtering with the cutoff period from 30 day to 10 year.

Include geocenter motion contribution

(Fig. Dong et al., 1997)

It looks very attractive to use a NT-ATM model. But do the available models reach the required accuracy? IERS conventions (2010) request 1mm or better (Ray et al., 2007)

Call for participation (1/5)

Motivation:

• Several studies using VLBI and GPS have shown that station position repeatability decreases significantly when NT-ATML corrections are applied (Petrov and Boy, 2004; Tregoning and Watson, 2009; Dach et al. 2011 etc…)

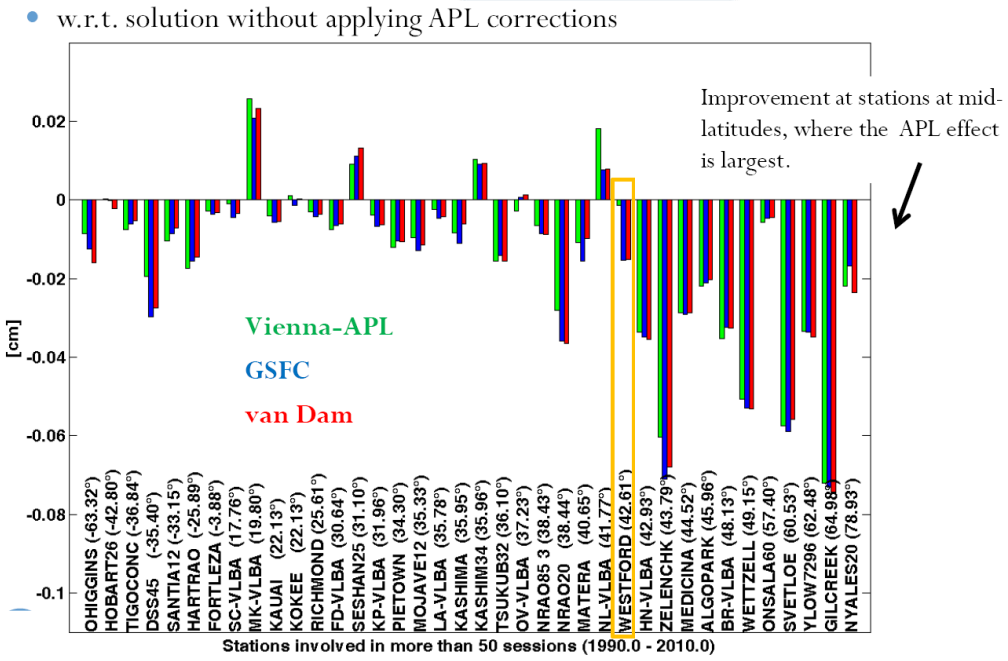


Fig. Height WRMS of **VLBI stations**

Spicakova et al. (2011)

• Few studies made for SLR and DORIS (see E. Pavlis's talk) -> Can previous results with GPS and VLBI be generalized to all the techniques?

• Recommendation by attendees of the GGOS Unified Analysis Workshop: test NT-ATML model a priori in the data processing for 5 years of data

Call for participation (2/5)

- Would we expect any improvement of the ITRF?

  Example of analysis

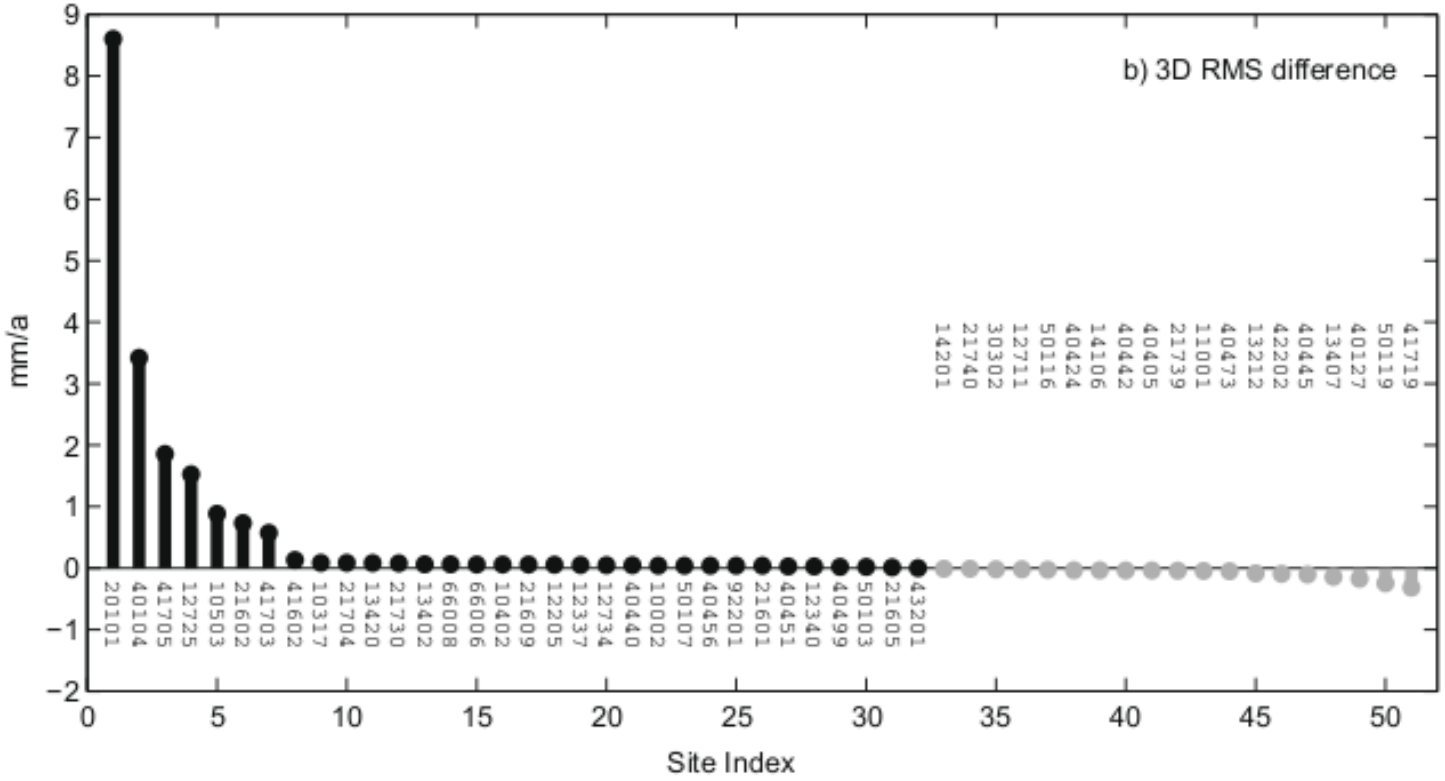


Fig. Improvement of the agreement between GPS, SLR and VLBI velocities at co-location sites when NT-ocean, NT-ATML and water loading models have been applied (Collilieux et al., ASR, 2010)

Call for participation (2/5)

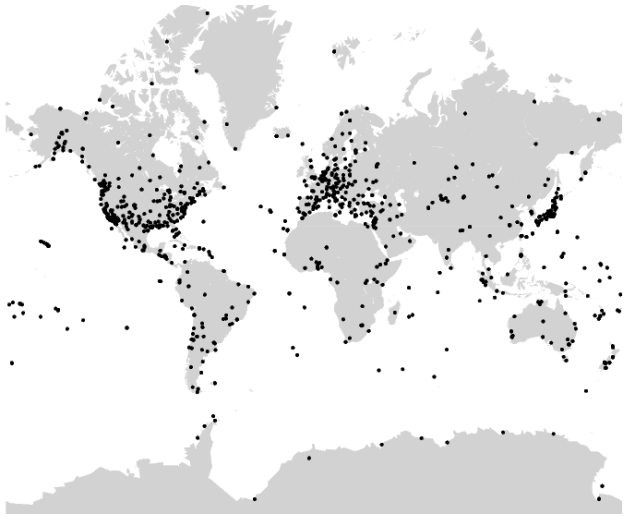
Loading model to be tested:

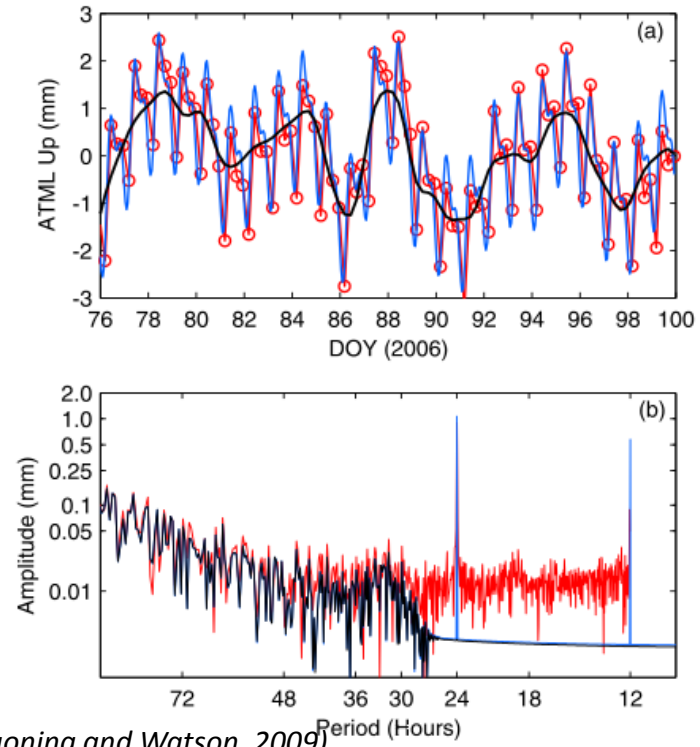
- Based on NCEP (6h) surface pressure data provided at 2.5 x 2.5 degree spacing over the Earth.

- Station displacements in the CM frame

- Sub-daily atmospheric tides have been filtered (Tregoning and Watson, 2009)

- Spherical coefficients of the potential changes up to degree and order 50





(Tregoning and Watson, 2009)

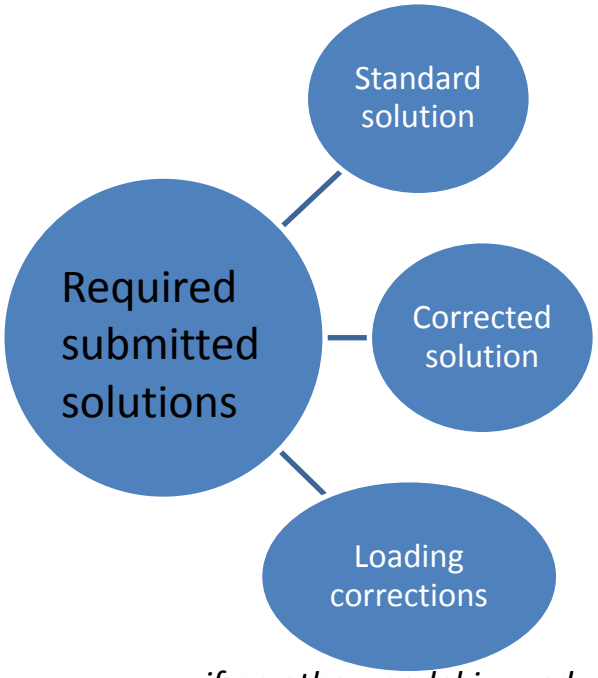
Figure 2. (a) Example time series of atmospheric loading deformation in the up component at Bahrain for the partial model used by *Tregoning and van Dam* [2005a] (red), our nontidal model (black) and our nontidal plus S1+S2 model (blue). (b) Power spectra of partial (red), nontidal (black) and nontidal plus S1+S2 (blue).

Call for participation (4/5)

Details on the requested solutions (1/2)

Time period: 2006.0 – 2011.0

Sampling interval: daily or weekly. Daily GPS are preferred



if an other model is used

Individual homogeneously reprocessed solutions: DORIS, GNSS, SLR or VLBI

Include Station positions, EOPs and if possible satellite antenna PCO, ZTD

Global network (for GNSS) with co-location sites included

Gravitational effect for satellite techniques:

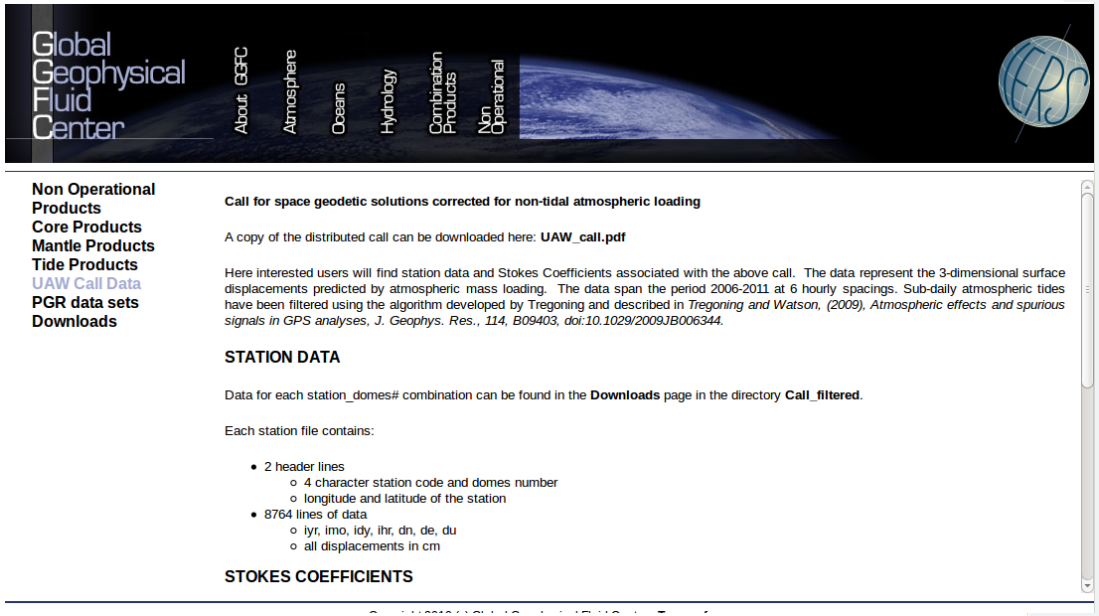
Spherical coefficients of the potential changes related to atmospheric mass fluctuations may be also used in the standard solution. This is recommended for LEO (Lemoine et al., 2010)

Tidal loading effect needs to be applied for the 2 solutions according to the IERS conventions

Call for participation (5/5)

Details on the requested solutions (2/2)

More details on the call at http://geophy.uni.lu/ggfc-nonoperational/uwa-call-data.html



Deadline: 1st of July 2012

To submit time series, contact itrf@ign.fr and central_bureau@iers.org

Submissions will be analyzed by the IAG Working Group on “Modeling environment loading effects for Reference Frame“, GGFC and the ITRF Product Center

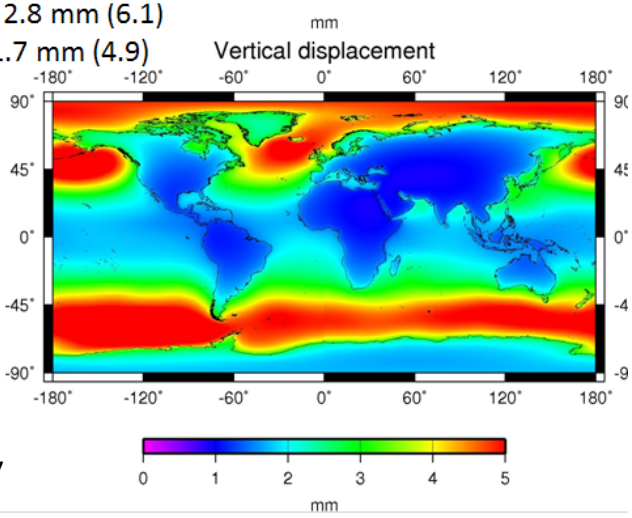
Discussion (1/2)

Accuracy of the models?

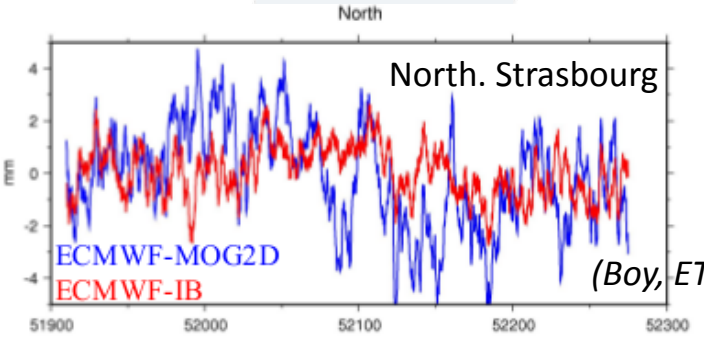
- IB hypothesis is not valid in the sub-weekly frequency band *(Petrov and Boy, 2004)* BUT this is exactly the frequency band where accuracy is needed to avoid aliasing

Effect of the modeling of the ocean response to changes in the atmospheric pressure forcing

RMS_{global} = 2.8 mm (6.1)
RMS_{land} = 1.7 mm (4.9)



(Courtesy of Jean-Paul Boy 2002-2010)



(Boy, ETS 2006)

Fig. Left) RMS of the differences between the IB assumption and MOG2D ocean model (CM)

- Is there other error budget of NT-ATML loading model than the one by *Petrov and Boy (2004)?* Evaluated at the level of 15% (Earth's model; ocean mask; pressure field; ocean response).

- Fritsche et al. (2011) have discussed the effect of the variation of total atmospheric mass. Should it be included? Max: ~ 0.5 mm in radial

Discussion (2/2)

How to evaluate the accuracy of available displacement models?

- What is the consistency between various models? Few studies available (see Valty's talk)

- How can we know that a model is accurate at the sub-millimeter level?

  Already published criteria:
  - Error budget of the model
  - Station position RMS changes
  - Estimation of admittance factor α: $\hat{X} = \hat{X}_0 + \alpha \cdot \Delta\hat{X}^0_{atm} + \Delta\hat{X}$
  - Residual of the observations adjustment decrease

  What is the threshold for each of those criteria?

Conclusions

What the call will help to answer:

- Will all technique frames benefit from NT-ATML corrections?
- Impact of the non-tidal atmospheric loading corrections on the combined TRF
- Does any parameter other than station positions absorb loading displacements?
- a priori vs. a posteriori corrections revisited for all techniques

What the call won't answer:

- Accuracy of the used model. Research effort is mandatory before any recommendation