Unified Analysis Workshop 2011

Position Paper Session 2: Environmental modeling based on external data; Deficiencies, standards, and issues

Introduction

- The unprecedented accuracy of geodetic observations demands that more and more corrections and physical models must be based on data from disciplines outside the normal realm of geodesy [e.g., ocean and atmosphere loading (tidal and non-tidal), troposphere delays].
- The user community is rapidly moving away from the idea of corrections that are based on “simple” mathematical formulas (e.g. admittance factors)
- More and more demand for more precise corrections that are based on the analysis of large amounts of external data
- If the corrections are required for observation level data processing, the corrections must be made available to the user community with a minimum latency

Introduction

- Role of the GGFC
  - To archive parameters that are of geodetic value (e.g. elastic load effects, tropospheric delays, AAM, OAM, etc.) and that are derived from environmental models
  - To evaluate precision and if possible accuracy of products
    - existing problems
      - individual mass models do not conserve mass; interannual signals expected but what we get from combining the models might just be worthless
      - offsets due to changes in modelling
      - unrealistic trends in hydrology and ocean bottom pressure
  - To provide to community
    - timely manner
    - convenient and flexible format
  - Recommendations/documentation on how to use the models so that consistency can be achieved across all techniques
  - Inclusion of recommendations in the IERS conventions

General Tasks/Comments

- To work to improve the accuracy and consistency of the geodetic/geophysical models
- Assess the benefits of the models based on external data sets (hopefully large data sets for statistical significance)
- The models need to be applied consistently for the different space geodetic techniques (Angermann presentation)
- To reduce the noise in geodetic coordinate time series, while maintaining the integrity of the ITRF for scientific as well as geodetic applications

Troposphere Delay Modeling

- State of the art: VMF1/ECMWF and GMF/GPT as analytical backup
- Tasks (partially completed)
  - Provide other realisations, e.g.
    - VMF1-UNB based on NCEP data (Böhm presentation)
    - Pressure from ECMWF Interim data (MacMillan presentation)
  - Pressure for a priori hydrostatic zenith delay to agree with reference pressure for loading

Raytracing

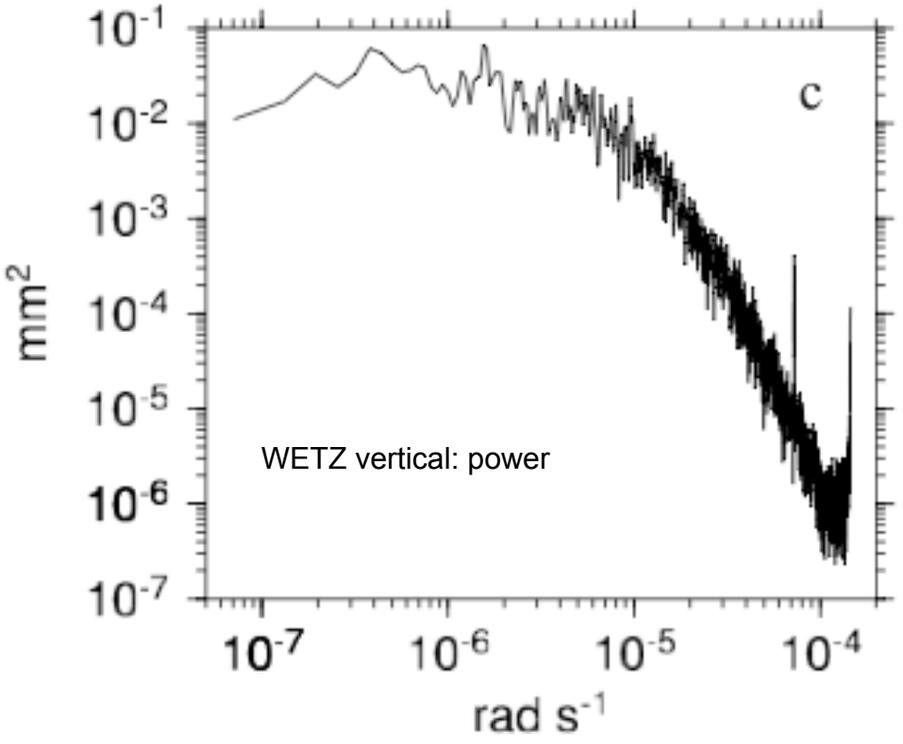
- There has been a successful comparison campaign of ray-tracing programs (Nafisi et al., 2011)
- Tasks:
  - Check the consistency of ray-tracing over the techniques (optical and micro-waves).
  - Investigate coordinate systems in numerical weather models (IAG IC SG by Hobiger)

Atmospheric Loading Corrections

- Atmospheric reference pressure
  - Why?
    - Reference for temporal estimates of crustal displacements
    - Calculation of the Earth's TVG due to atmospheric mass redistribution
    - Determination of total atmospheric mass
    - etc.
  - GRP proposed in: Wijaya D.D, Boehm J, Schindeleger M, Spicakova H, Karbon M, Salstein D, Schuh H (2011), Determination of atmospheric pressure loading corrections and a new concept of reference pressure, submitted to JGR Solid Earth

Atmospheric Loading Corrections

- ECMWF and NCEP surface pressure
  - Contains tidal and non-tidal components
  - Non-tidal part of the GCM's have been shown to be in error (van den Dool et al, 1997; Ponte and Ray, 2003)
  - To apply ATML loading, Ray and Ponte (2003) recommend removing tides in existing surface pressure models and using a more precise model
  - Petrov and Boy (2004) fit sinusoids at the S1 and S2 frequencies; does not remove the full signal
  - Tregoning and van Dam (2005) low pass filter
  - Bode and Biancale (2006) use higher temporal resolution data



Atmospheric Loading Corrections

- Tidal S1 and S2
  - Corrections for these tides should be applied as a Class 1 effect as set forth in the IERS conventions
  - Current IERS convention, Ray and Ponte (Annales Geophysicae, 2003); Ponte Ray (GRL, 2002)
  - Empirical evidence
    - SLR slight improvement (presentation by J. Ries at the Conventions workshop Paris)
    - GPS no evidence
    - VLBI no evidence (Böhm presentation later)

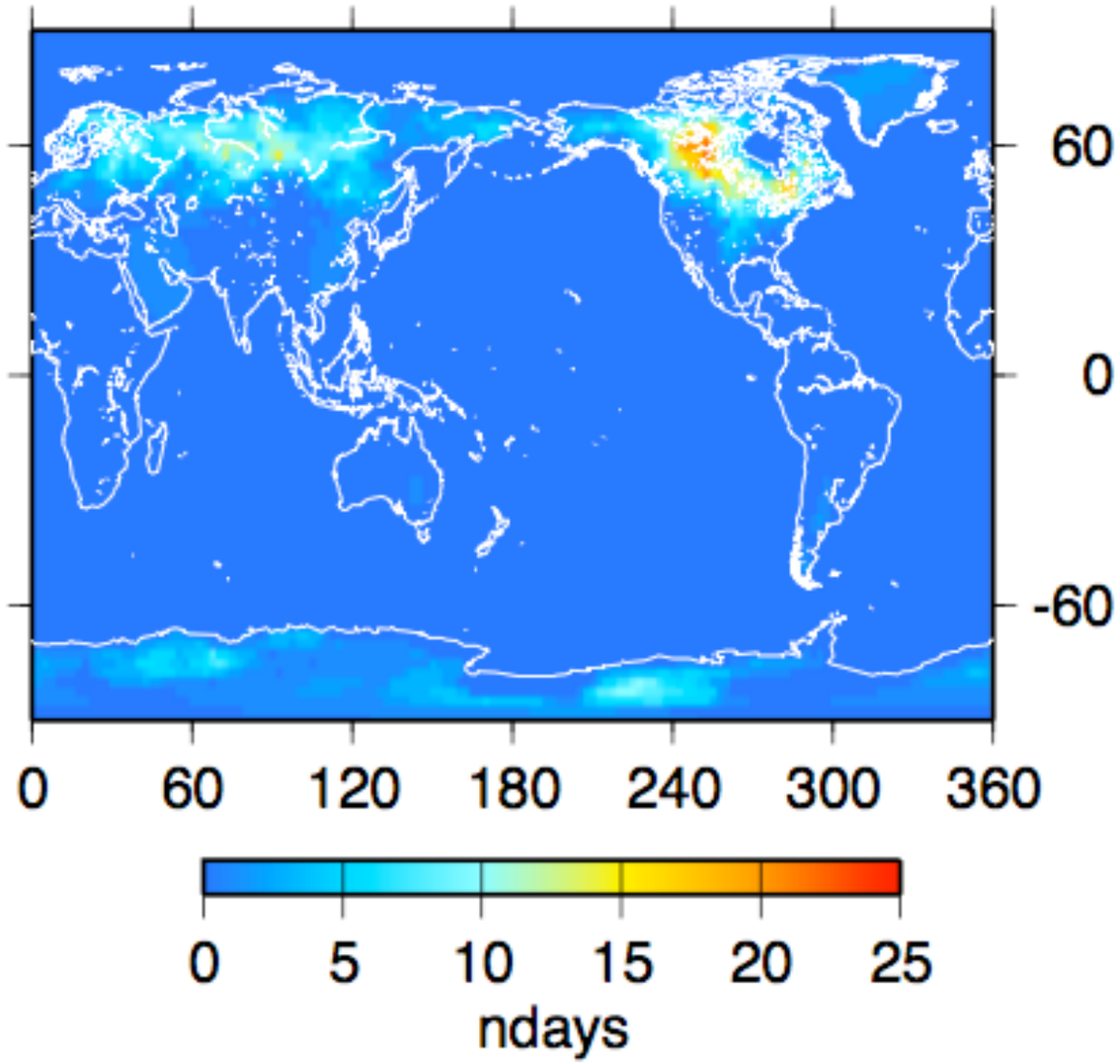
Atmospheric Loading Corrections

- Observation-level versus a posteriori mean: ATML Non-tidal component
  - Why?
    - the correlation between ATML and atmospheric delay estimates
    - changes in station positions during the day due to atmospheric loading will map directly into the atmospheric delay estimates that will be in error if the sub-daily loading is not accounted for
    - neglected loading corrections are absorbed the NNR/NNT conditions
  - Concerns
    - Does this issue arise often enough that we should risk compromising products downstream?
    - Errors in the models used for the corrections
    - GGOS: Determine ITRF w.r.t. CM at level of 1 mm.

Atmospheric Loading Corrections

- Observation-level versus a posteriori mean: ATML Non-tidal component

frequency of sub-daily vertical displacement between 2.5 and 5 mm



Böhm pers. comm. found 157 session where P changes by more than 20 mbars at a single station during a single 24 hour period; using obs. level corrections improved the RMS

Atmospheric Loading Corrections

- Observation-level versus a posteriori mean: ATML Non-tidal component
- Effects on positions
  - Tregoning and Watson (JGR, 2009); daily GPS => no improvement
  - Dach et al. (J. Geod., 2011) (presentation later)=> weekly GNSS; improvement
  - Böhm presentation later => no improvement

Atmospheric Loading Corrections

- Observation-level versus a posteriori mean
  - ATML effect on other estimated parameters
    - ATML required for precisely determining tropospheric effects (when coordinates are fixed)
    - VLBI
      - As a result of the sparse network, neglected loading corrections are absorbed the NNR/NNT conditions
      - BUT circumventing this problem does not necessitate the corrections being applied at the observation level; daily corrections could be applied at the TRF stacking level to avoid problems of sparse VLBI networks (Ray 2007; Collilieux personal communication)

Atmospheric Loading Corrections

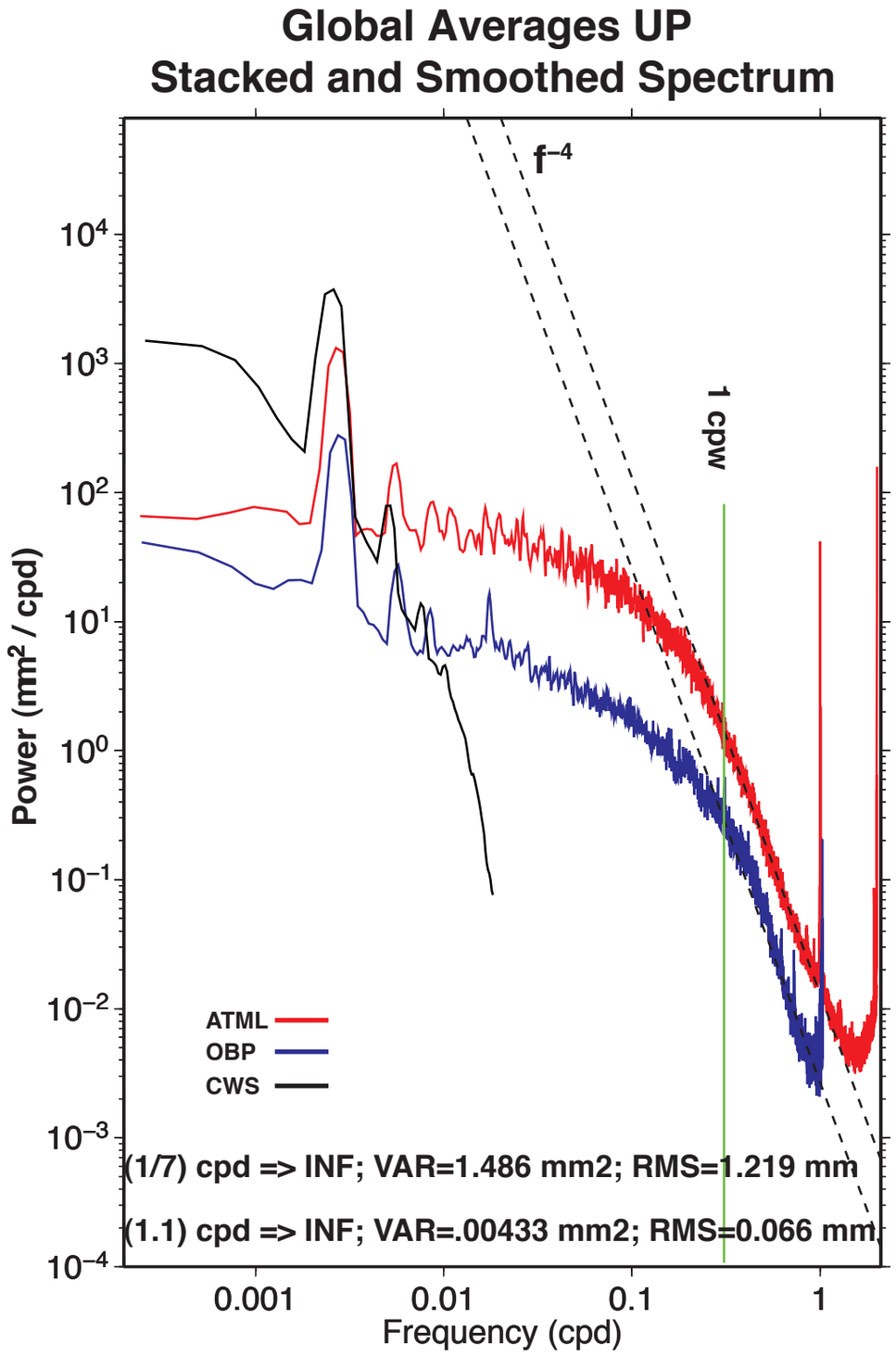
- Observation-level versus a posteriori mean?
- Issues against observation level corrections w.r.t. the integrity of the ITRF
  - Model deficiencies
    - data sets themselves are not perfect
    - offsets when models are changed
      - not in the reanalysis but for real time processing people will use the operational or forecast data sets
    - the ocean response: IB or some frequency dependent IB
  - if ATML is removed at the observation level for whatever reason, then the ATML signal needs to be replaced (exactly) before positions are used to compute the ITRF
    - suggestions of a replacing obs. level corrections with a daily mean pressure; idea must be validated
  - if what the data processors want/need is better atmospheric delay parameters,can an interative processing be undertaken:
    - processing 1: use obs level ATML to get the delays accurately
    - processing 2: use the accurate delays in reprocessing not using the obs level atml and not estimating delays

Atmospheric Loading Corrections

- Tasks
  - Compare the ATML models available in terms of latency, resolution, **precision** (GGFC product centers)
  - Tidal models: is there anything better than the current IERS Convention of Ray and Ponte
  - Come to a consensus as a community for how to handle ATML in the data processing without affecting the ITRF
    - Demonstrate that the ITRF is not affected by ATML being applied at the obs level
      - Test adding back in a daily mean to data processed with ATML at the observation level. Do you get the same positions back?

Non-tidal Ocean loading (ntol) corrections

- stacked and smoothed PSD for 344 stations (up coordinate); 12 hourly OBP as input
- ATML: (1/7) cpd -> inf: Var = 1.486 mm^2; RMS = 1.219 mm
- ATML: (1/1) cpd -> inf: Var = 0.00433 mm^2; RMS = 0.066 mm
- We don't need to worry about sub-daily or sub-weekly changes in ntol
- RMS of du GPS 2.2 mm over a week or 5.8 mm over a day
- Atmospheric pressure variations much smaller than this suggesting that there is a very minor loss in GPS signal coherence over a day when loading corrections are applied
- ntol is even smaller than ATML so can be ignored as an issue at the observation level



Earth Rotation

- Diurnal and semi-diurnal tidal EOP variations driven primarily by the ocean tides
- This is the #1 non-bias error in present GPS (J. Ray pers. comm.)
  - Current model from R. Ray 1994 (IERS convention)
  - GPS has resonances due to the 12-hour orbital period; errors in the apriori subdaily EOP model aliases nearly 100% into the orbit parameters and from there into everything else (polar motion, LOD, e.g. anything with rate dependent parameters)
- Task: to develop better models for high-frequency Earth rotation parameters
  - Empirical models using VLBI, GPS or both => if model errors affect the observations, then the systematic errors in the GPS or VLBI will map 100% into the subdaily model estimates
  - Potential solution? Maybe revisit SLR ala Watkins and Eanes, 1994
  - Alternatively, improve the geophysical modelling

Earth rotation

- Improved models are available (R. Ray personal communication)
- BUT tests with GPS processing (J. Ray and S. Desai personal comm.) indicate that at some tidal frequencies the results improve at others the results degrade
- Nonetheless, there is an ongoing effort to improve these models

Other Issues?

Change in Schedule

- van Dam presentation will be canceled
- Those 10 minutes will be used to discuss the issue of the observation level ATML corrections
- Please contribute!