Impact of IERS Conventions (2010) on VLBI-derived reference frames

Robert Heinkelmann & Harald Schuh

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Motivation

- The global geodetic observing system (GGOS) has set its product goals to be 1mm (position) and 0.1 mm y^{-1} (velocity) accuracy
- Of course this goal can only be achieved, if state-of-the-art models are consistently applied
- IERS and other conventions are necessary for ensuring the consistency of products determined by a combination of various observation techniques or analysis centers
- IERS Conventions specify those models, which have to be applied for all space-geodetic techniques
- This talk wants to address, that not all the models specified by IERS Conventions, however, are in deed the current best available ones

Outline

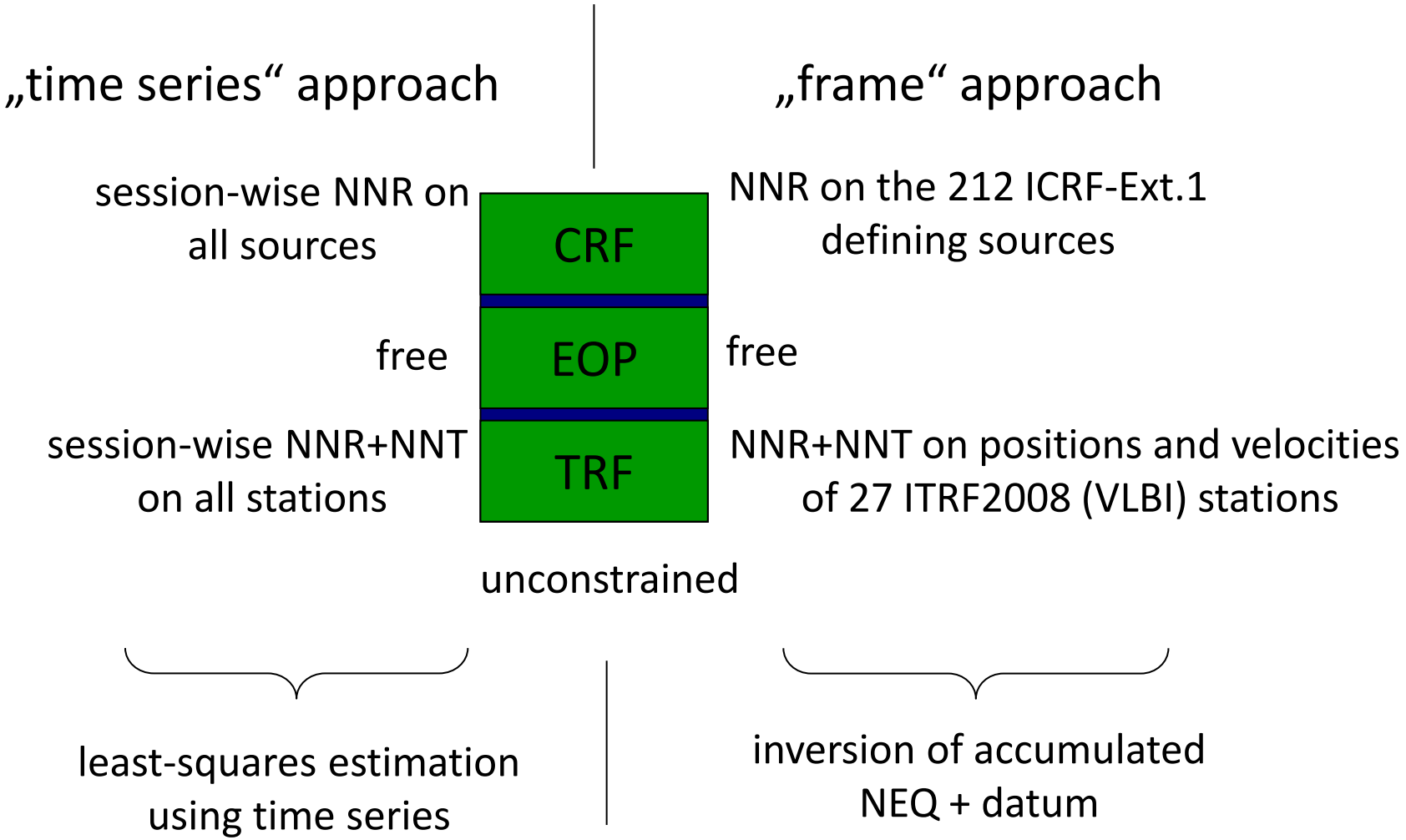
- Beside other model changes some updates from IERS Conventions 2003 to the current 2010 version are:

IERS Conventions	**2003**	**2010**
Reference Frames		
CRF	ICRF-Ext.1	ICRF2
TRF	ITRF2000	ITRF2008
Ephemerides	DE/LE 405	DE/LE 421
Displacements of reference points		
Ocean loading	Scherneck, no convention	Scherneck, 342 constituent tides (Agnew implementation)
Atmosphere loading	no convention	Ray & Ponte (2003), van Dam
Pole tide	mean pole (2003)	mean pole (2010)
Ocean pole tide	no convention	Desai (2002)

VLBI solution setup

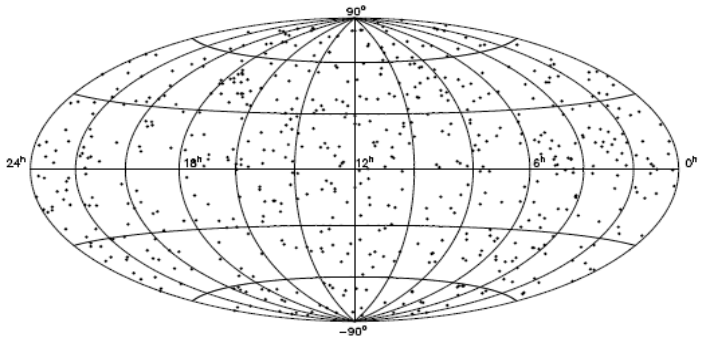
- 2044 X-/S-band IVS VLBI sessions between 1984.0 and 2001.0 (for testing ITRF2000 against ITRF2008) excluding VCS sessions
- 46 common, non-mobile sites, excluding SYOWA (only observed 4 sessions)
- 538 common radio sources of ICRF-Ext.1 and ICRF2 observed at least 4 times per session
- Reference solution applies the standards and conventional models of IERS Conventions (2003) + IVS analysis standards (Nothnagel, 2008)
- Test solutions subsequently apply one new model of IERS Conventions (2010)

VLBI solution setup

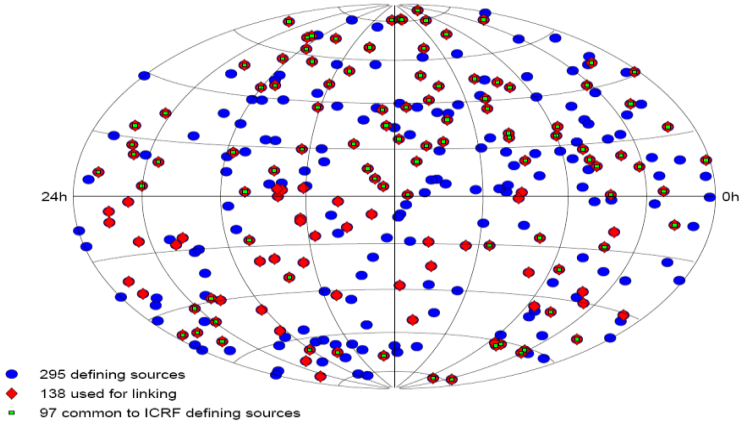


ICRF-EXT.1 vs. ICRF2

- ICRF-Ext.1 (IERS, 1999):
  212 defining, 294 candidate, 102 other, 59 new, 667 total
  (here 538 in common)
  - Axes stability: 20 μas
  - Mean positional error: 250 μas



- ICRF2 (IERS, 2009):
  295 defining, 1114 candidate, 39 other, 1448 total
  (here 538 in common)
  - Axes stability: 10 μas
  - Mean positional error: 40 μas



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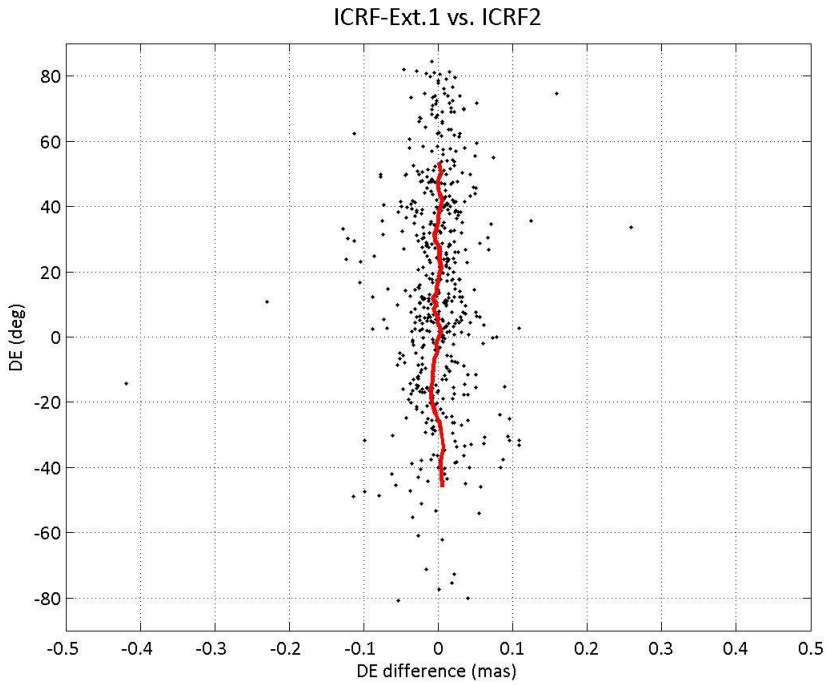
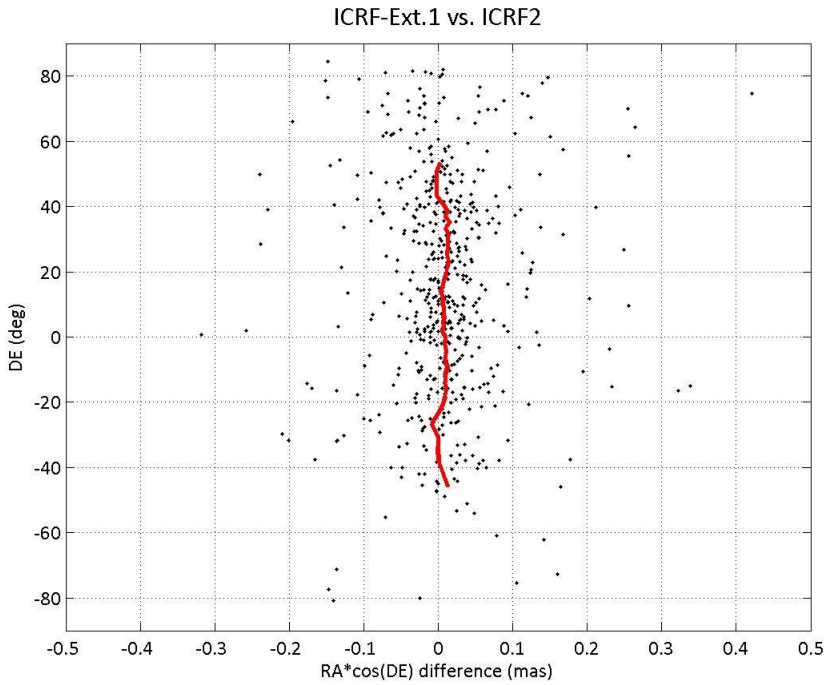
ICRF-EXT.1 vs. ICRF2

- CRF: no systematic differences in DE or RA, standard deviation is about 10 μas (at the axes stability level of ICRF2)





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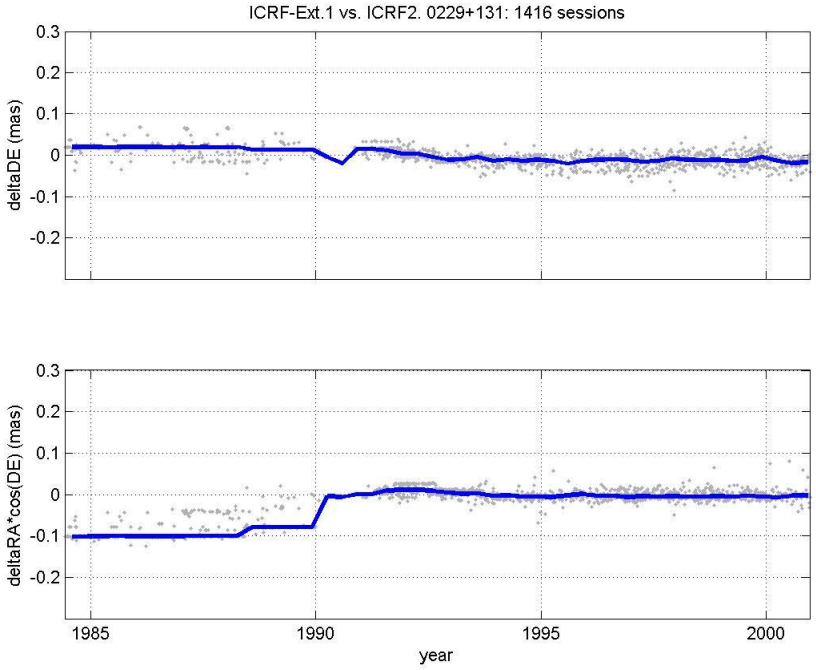
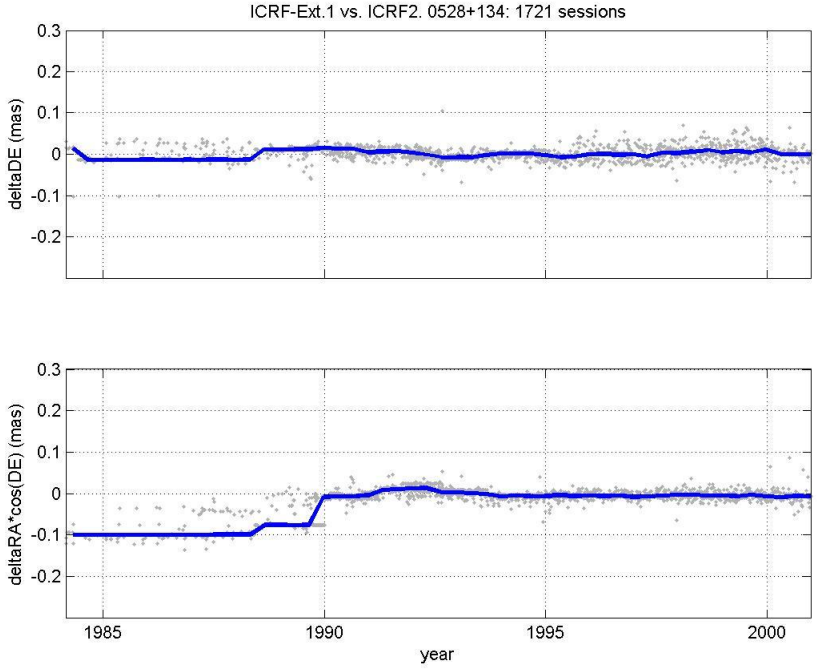
ICRF-EXT.1 vs. ICRF2

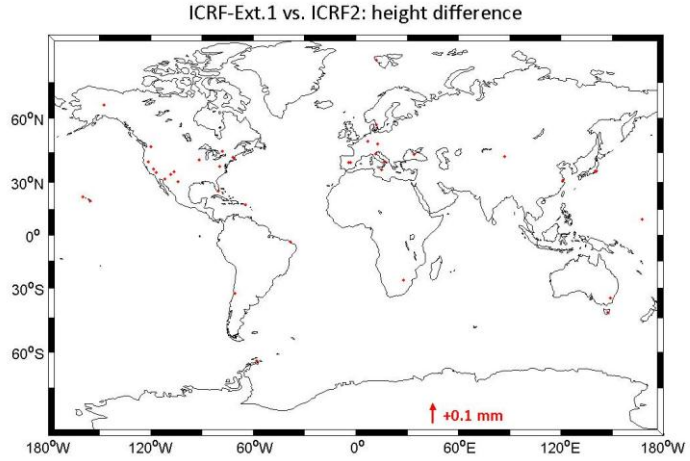
- Radio source time series: Several sources show a shift in the RA-differences at 1990 of about 100 μas
- Before 1990 too few (about 15) sources were observed per session
  → not enough to correctly adjust radio source coordinates on a session basis

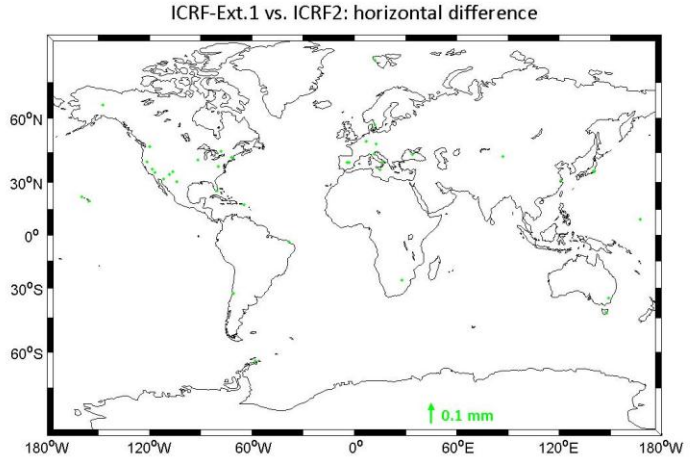


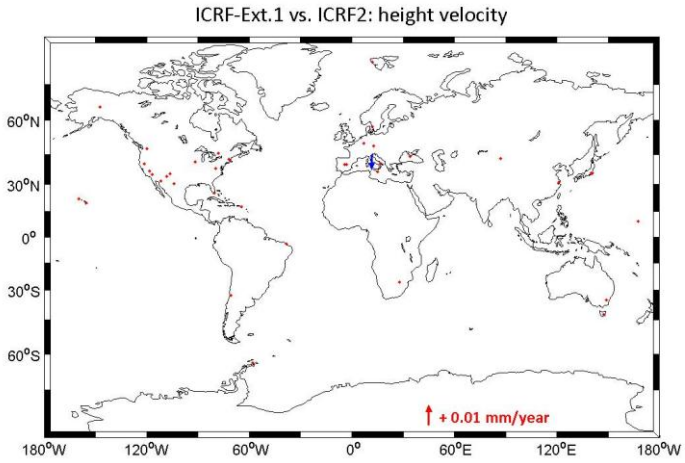


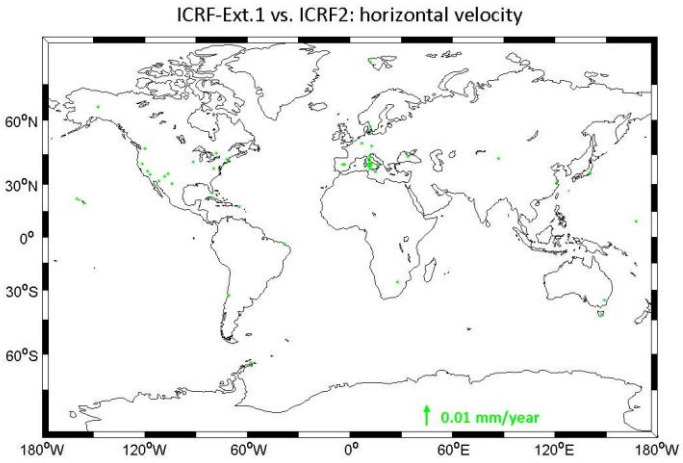
ICRF-EXT.1 vs. ICRF2

- TRF and station time series: no significant effect, small DE-/RA-differences among ICRF-Ext.1 and ICRF2 and good de-correlation of sources and stations









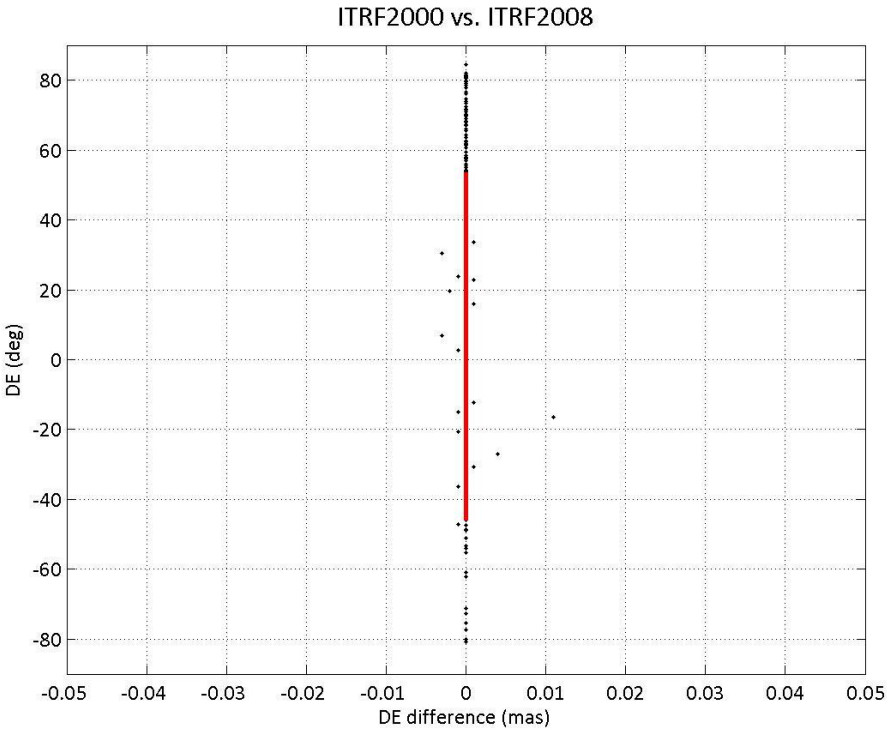
ITRF2000 vs. ITRF2008

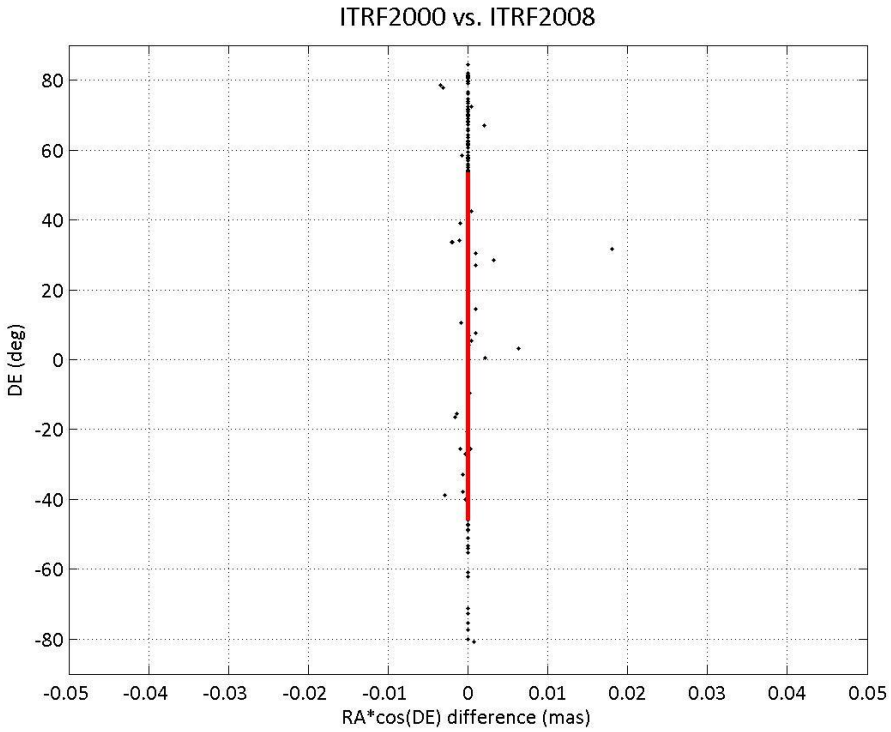
- ITRF2000 (Altamimi et al., 2002):
  136 VLBI stations, most of them mobiles with just a few occupations (here 46 in common)
  - Position 3-D wrms: 2 – 3 mm
  - Velocity 3-D wrms: 1 mm y^{-1}
  - Bad origin definition → drift of origin in z-direction

- ITRF2008 (Böckmann et al., 2010; Altamimi et al., 2011):
  113 VLBI stations, most of them mobiles with just a few occupations (here 46 in common)
  - Horizontal wrms: 1 mm, height wrms: 2 mm
  - Velocity 3-D wrms: 0.2 mm y^{-1}
  - No significant drift in z-direction

ITRF2000 vs. ITRF2008

- CRF: no effect,
  max. DE-/RA-differences about 10 μas (below axes stability level of ICRF2), good de-correlation of sources and stations





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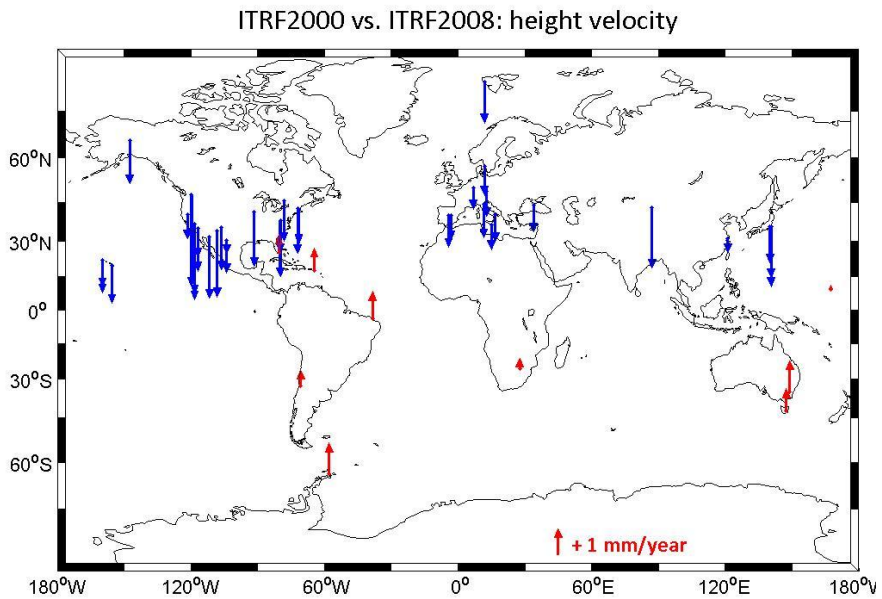
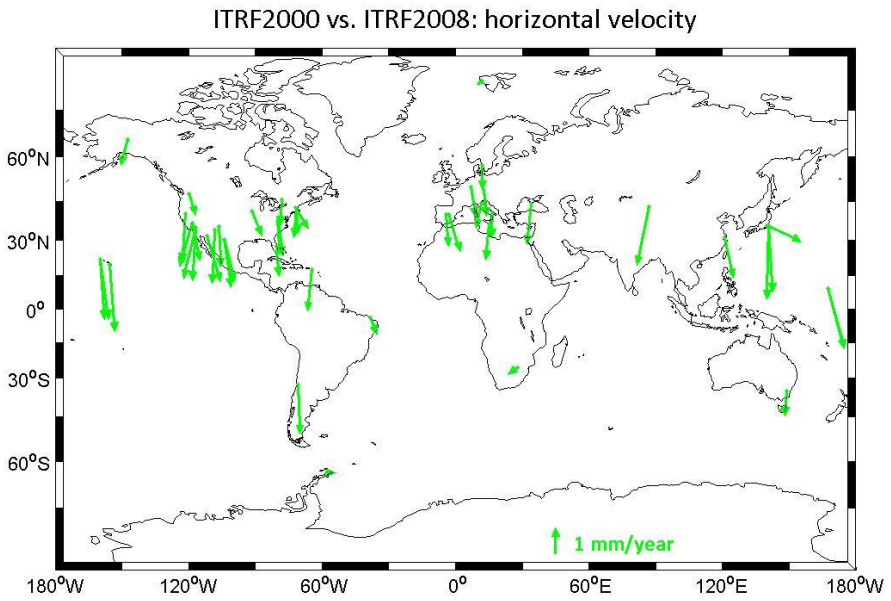
ITRF2000 vs. ITRF2008

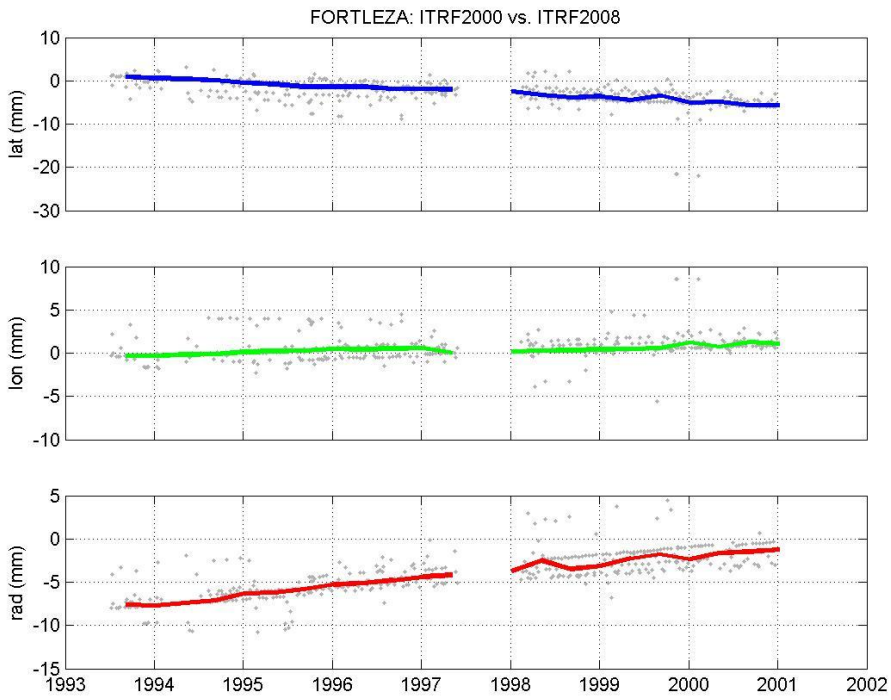
- TRF: large effects, most significant are the velocity differences,
  max. velocity differences at 3 mm y^{-1} level, most significant in height and north component (origin drift in z-direction!)

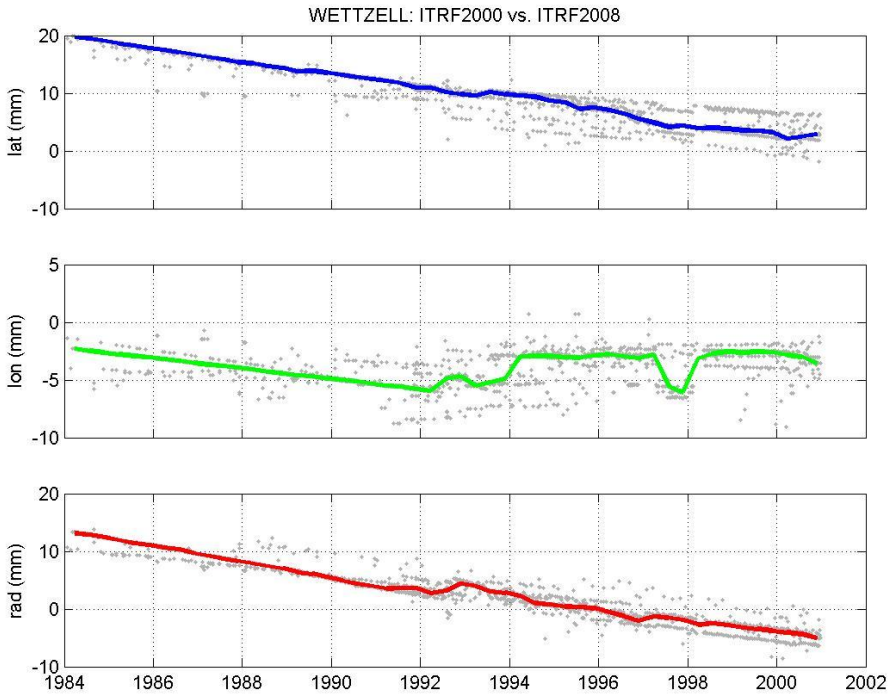




ITRF2000 vs. ITRF2008

- Station time series: large drift effects (also in East direction) → velocities of ITRF2000 are bad.
  Some non-linear characteristics in station coordinates → various types of VLBI sessions have different potential to correctly adjust station coordinates



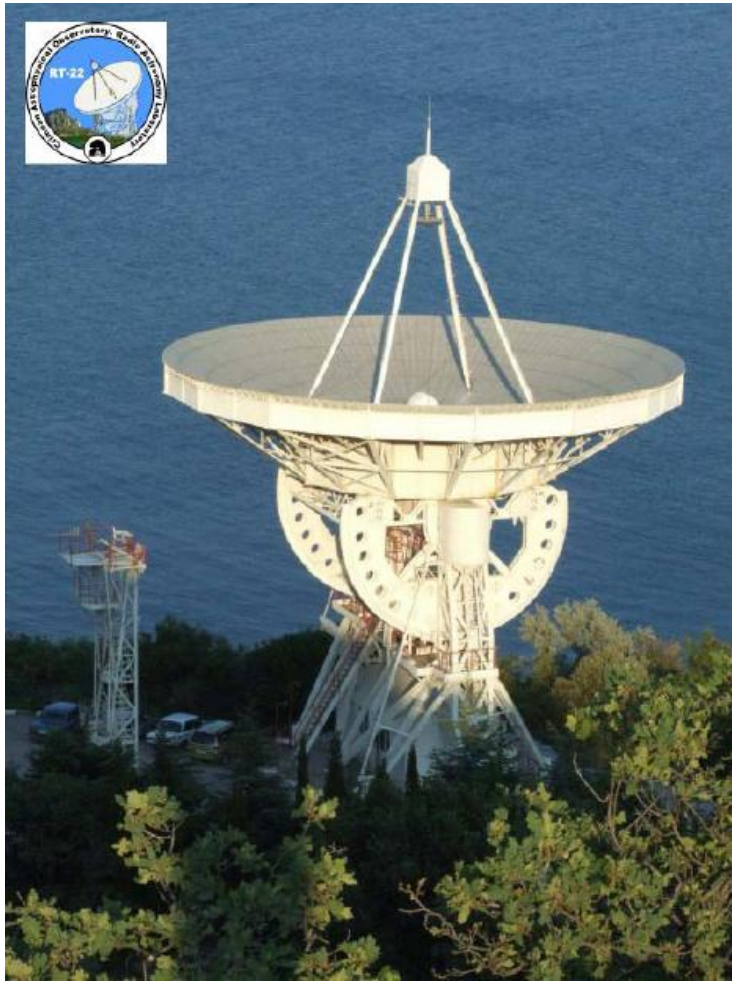


Ocean loading old vs. new

- Ocean loading deformation computed by Scherneck, based on the FES2004 (Letellier, 2004) ocean tide model

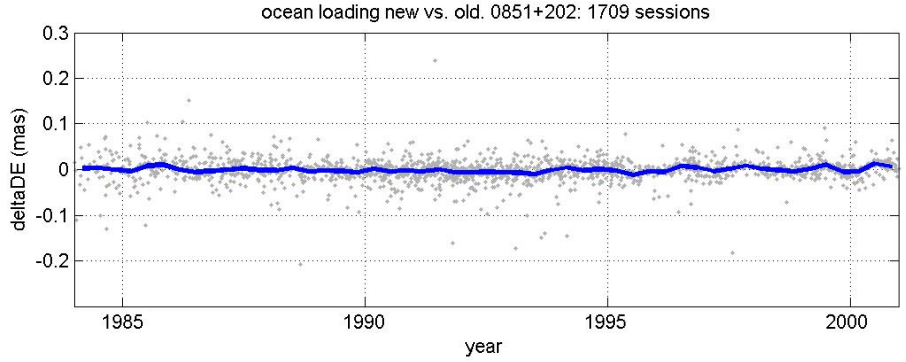
- Old: no convention (using the 9 main tides)

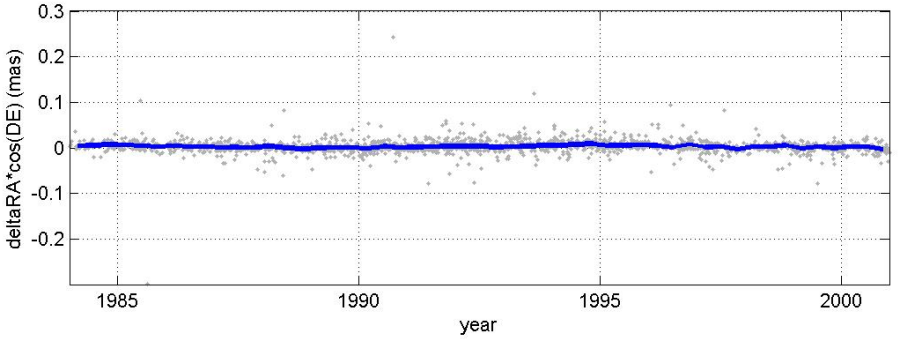
- New: using the 342 tidal constituents obtained by admittance theory (Agnew implementation)

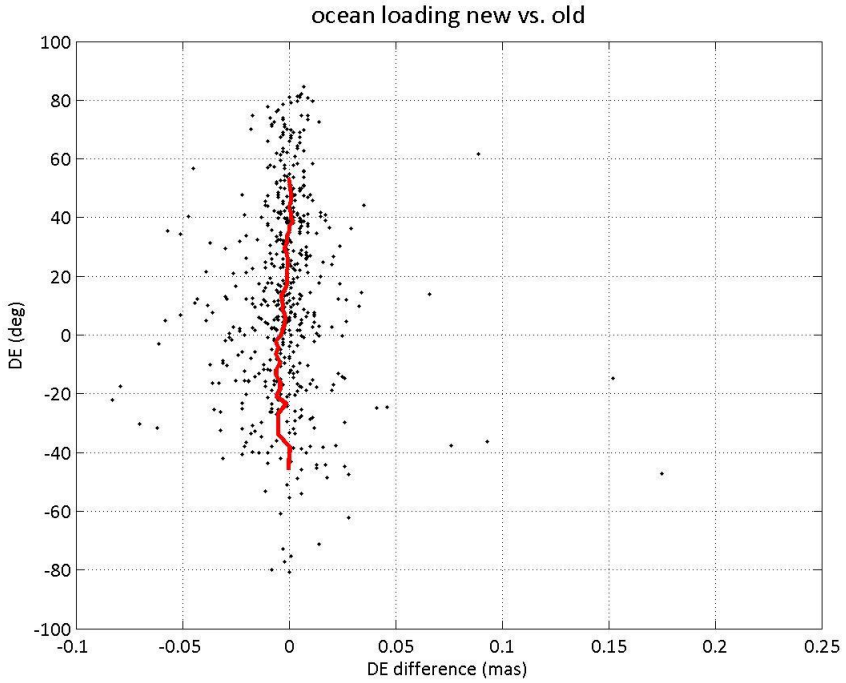


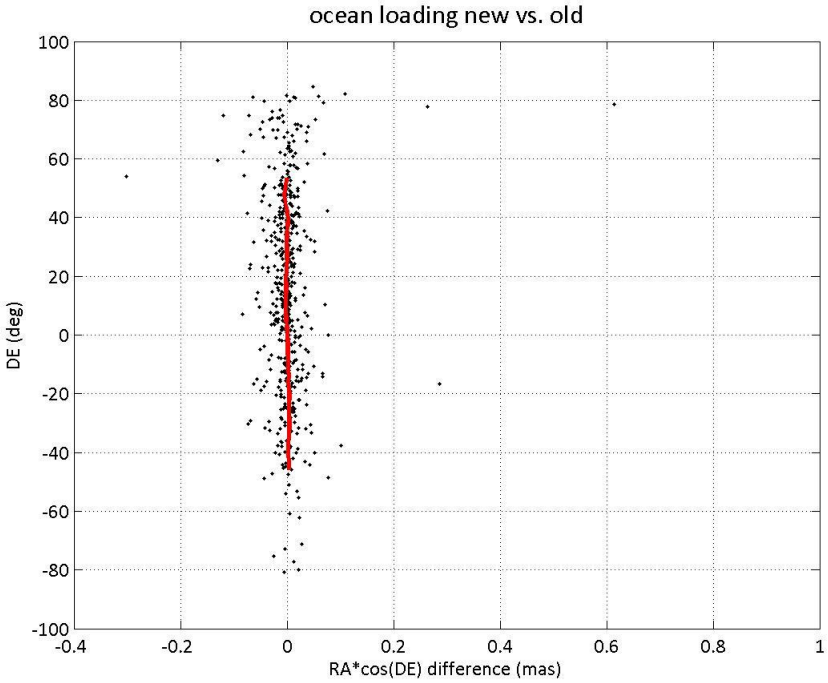
Ocean loading old vs. new

- CRF and radio source time series: noise around 40 μas level (mean positional error of ICRF2)





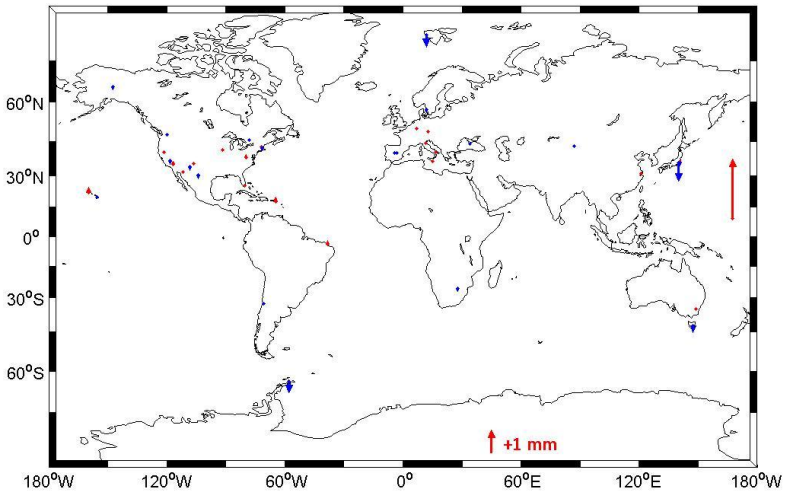




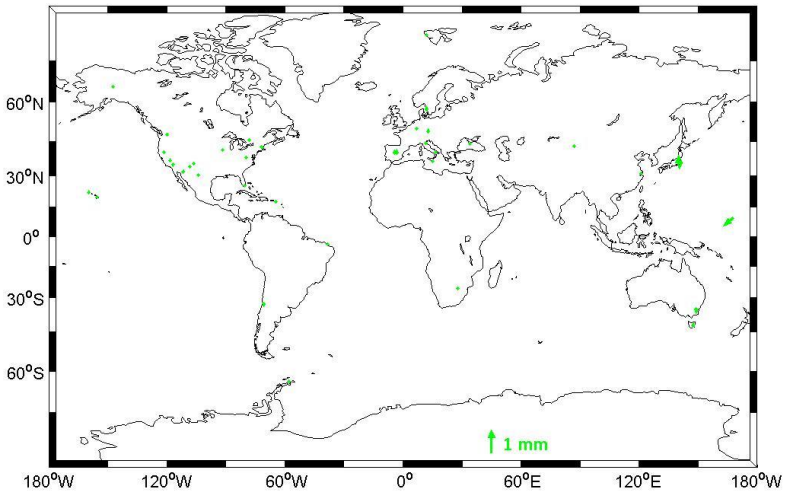
Ocean loading old vs. new

- TRF: No significant positional and velocity differences

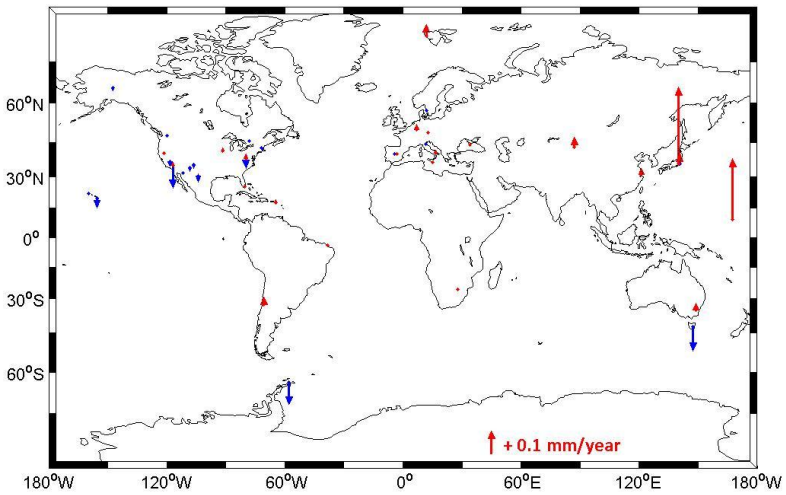
ocean loading new vs. old: height difference



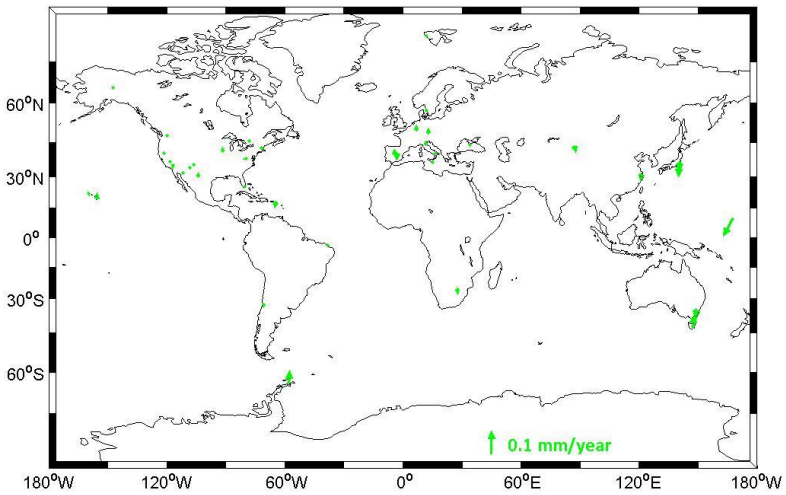
ocean loading new vs. old: horizontal difference



ocean loading new vs. old: height velocity

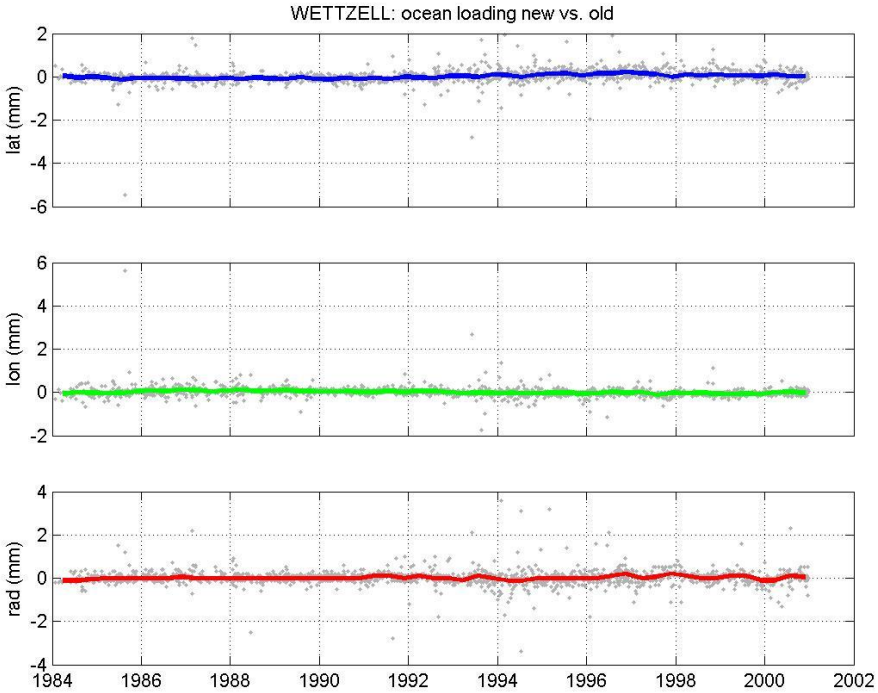


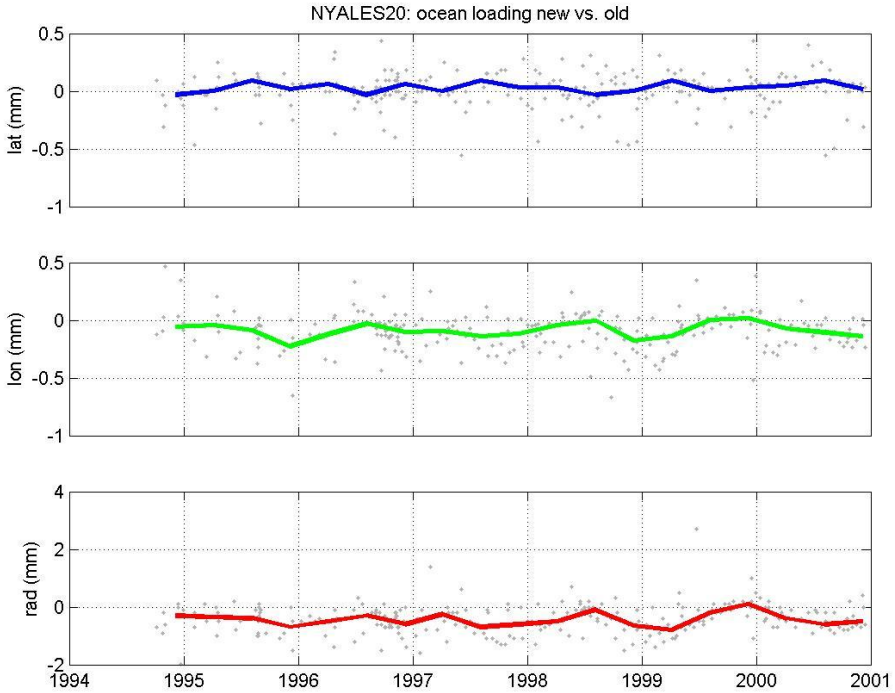
ocean loading new vs. old: horizontal velocity



Ocean loading old vs. new

- Only station time series at higher latitudes and marine locations show small positional shift below 1 mm



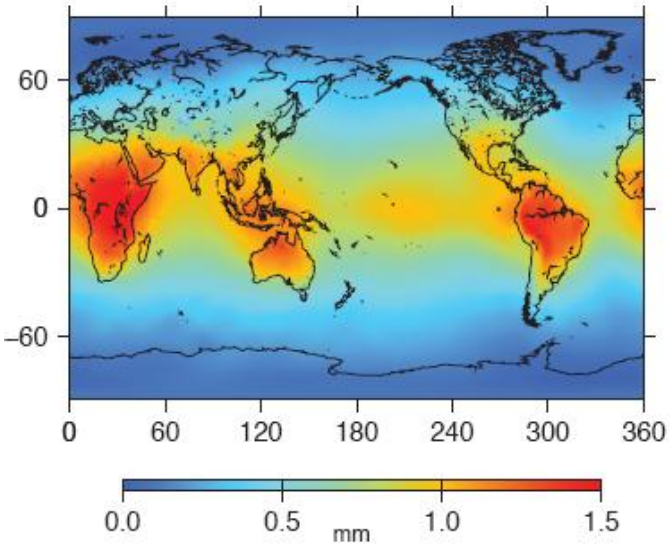


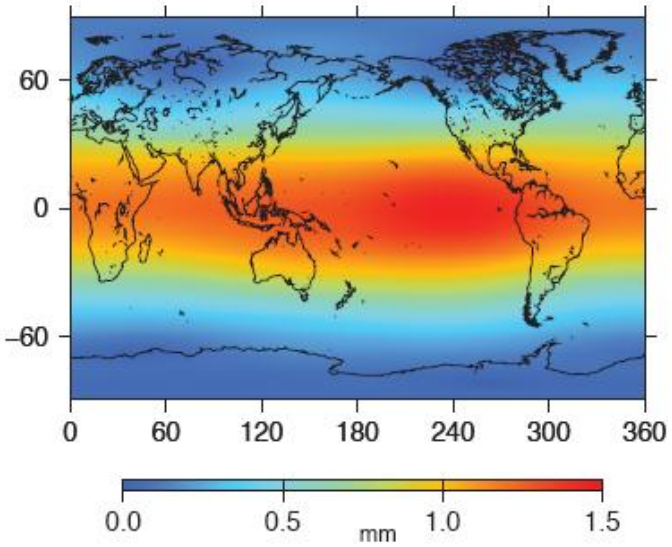
Atmosphere loading new vs. off

- Atmosphere loading deformation
- Old: no convention, Petrov & Boy (2004) – model was used for VLBI analysis depending on surface air pressure variations (NCEP)

- New: tidal (S1, S2) atmosphere loading, Ray & Ponte (2003) atmosphere tide model, implementation by van Dam

S1





S2

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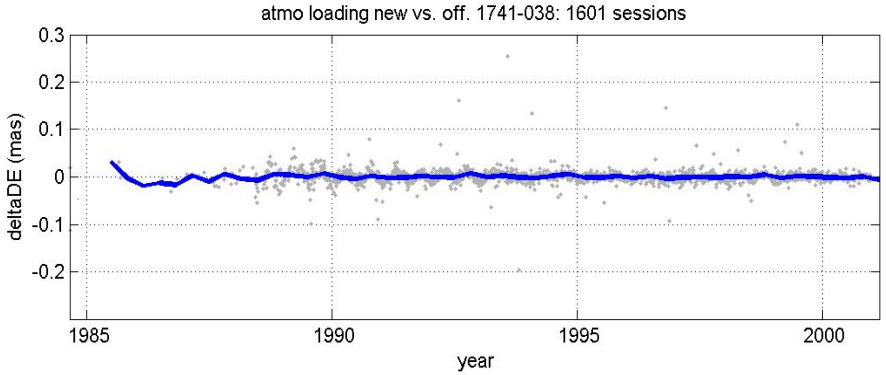
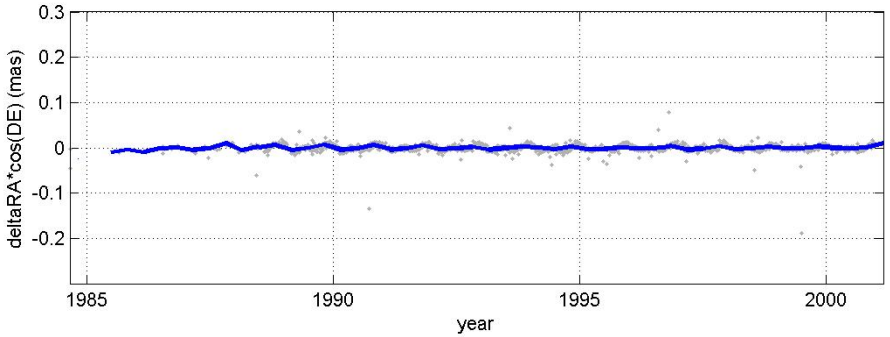
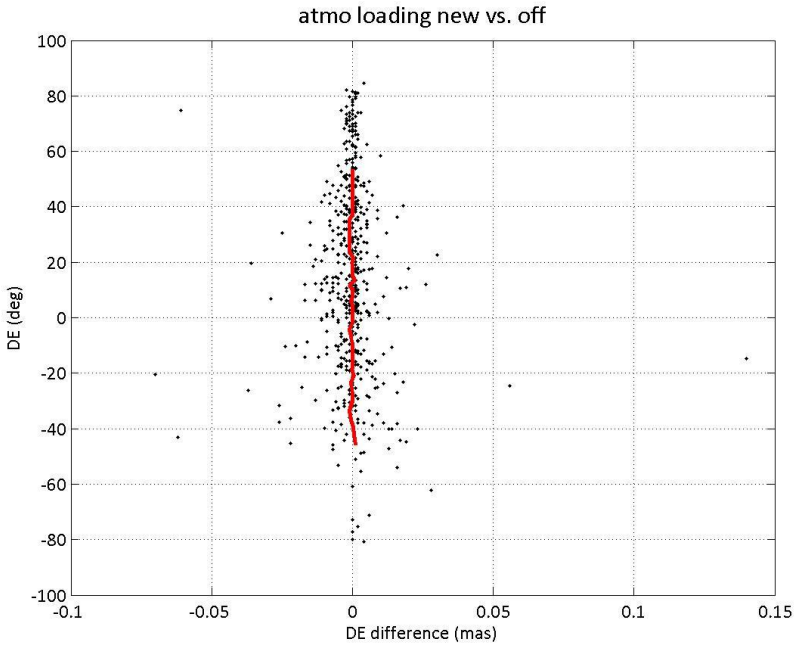
Atmosphere loading new vs. off

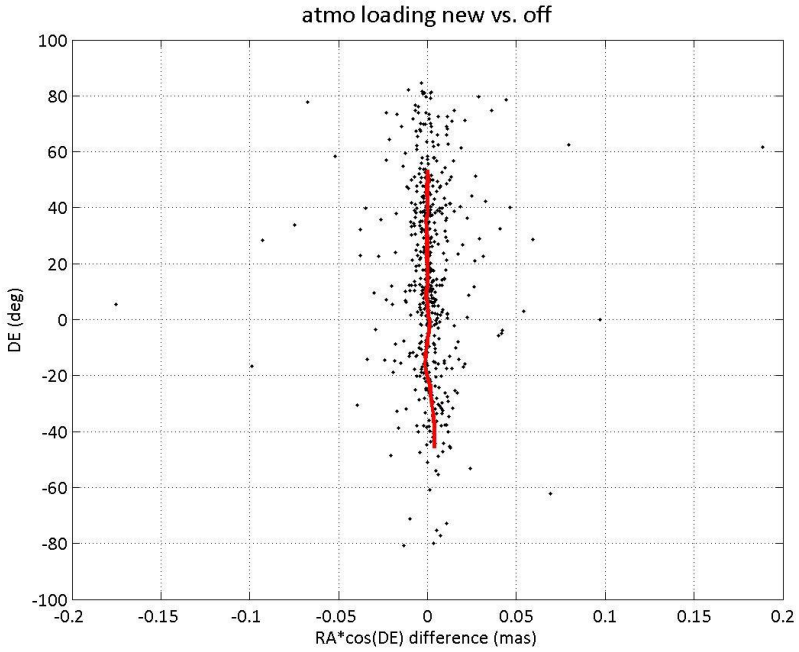
- Radio source time series: signals, max. 40 μas amplitude





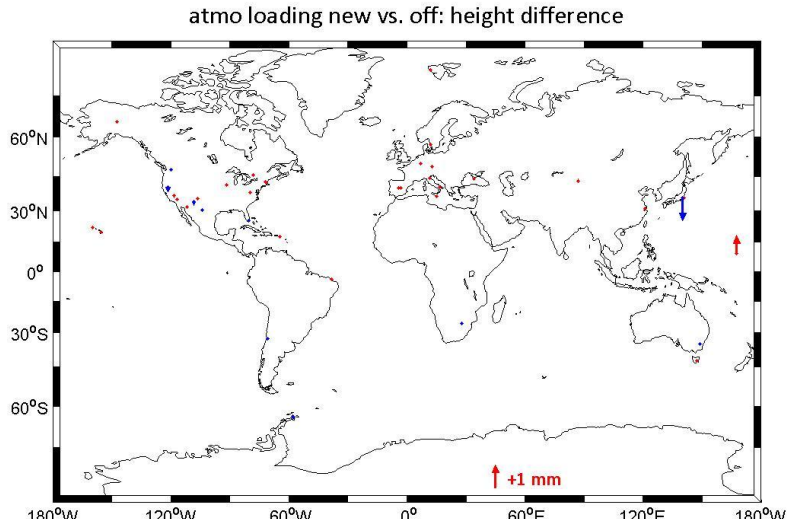
- CRF: no systematic effect, noise is about 20 μas

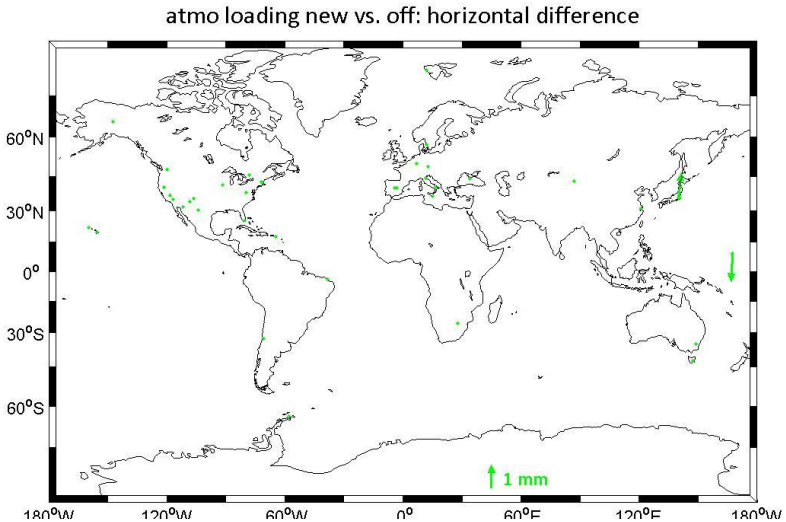


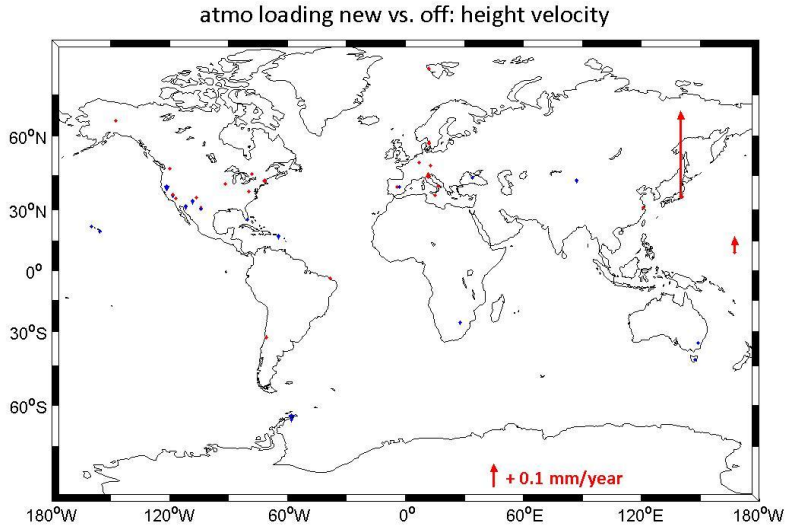


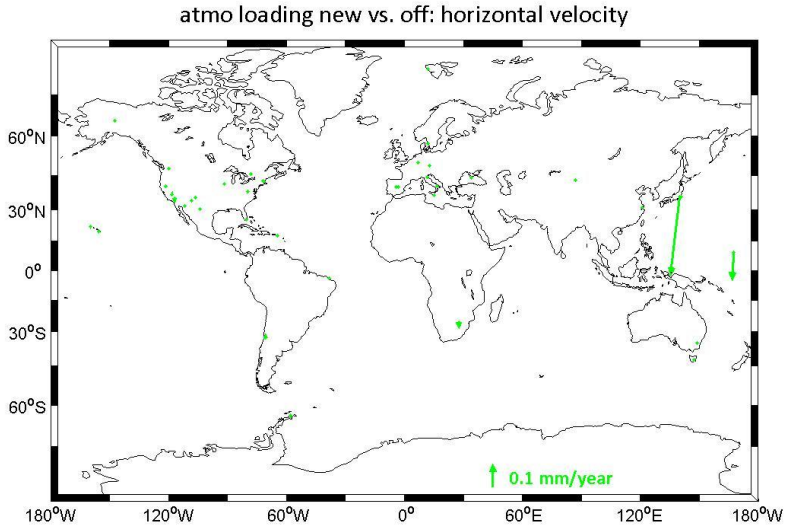
Atmosphere loading new vs. off

- TRF: no significant effect



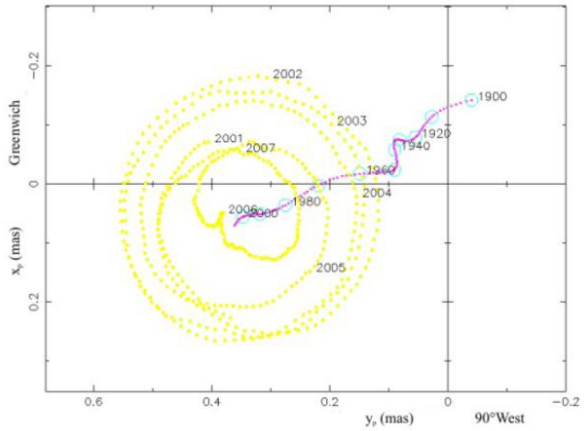




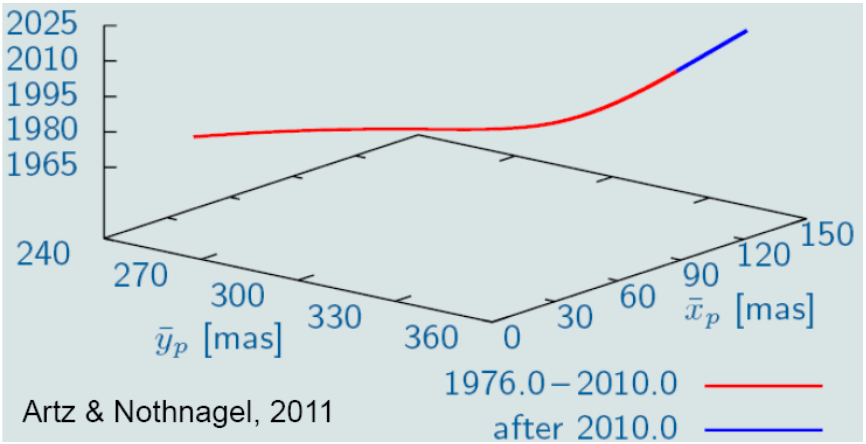


Pole tide old vs. new

- Rotational deformation caused by mass variations of solid Earth due to the secular variation of polar motion described by a mean pole

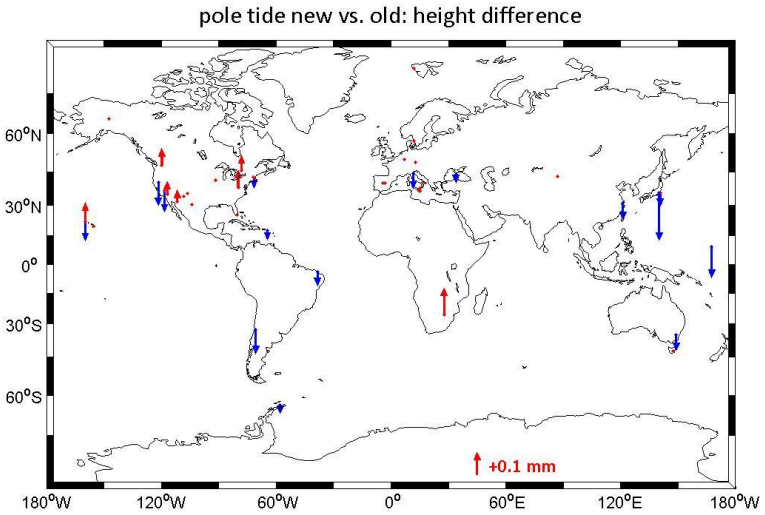


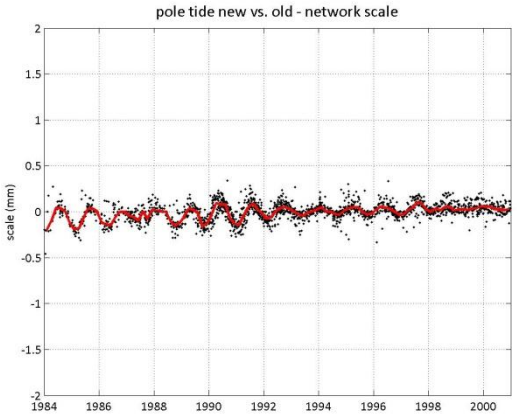
- Old mean pole: linear model
- New mean pole: Piecewise cubic-linear model

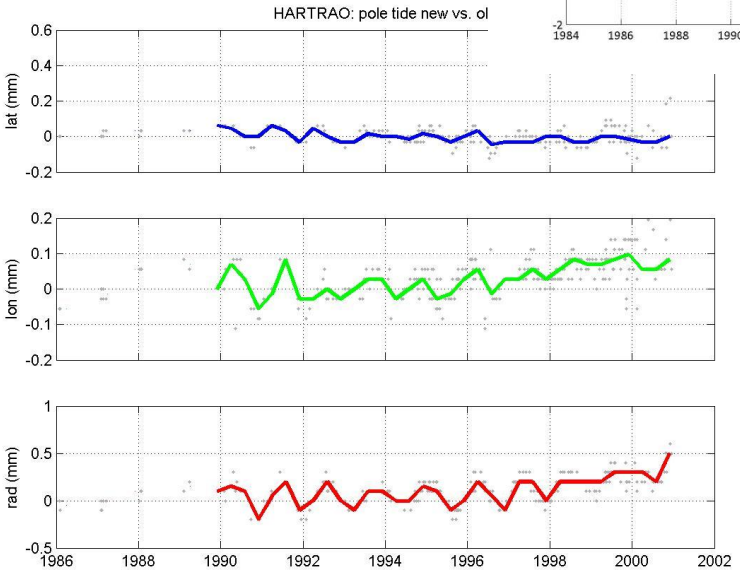


Pole tide old vs. new

- CRF and radio source time series: no effect
- TRF: very small effects below the wrms of TRF, small signal in session-wise scale parameter (0.2 mm amplitude)



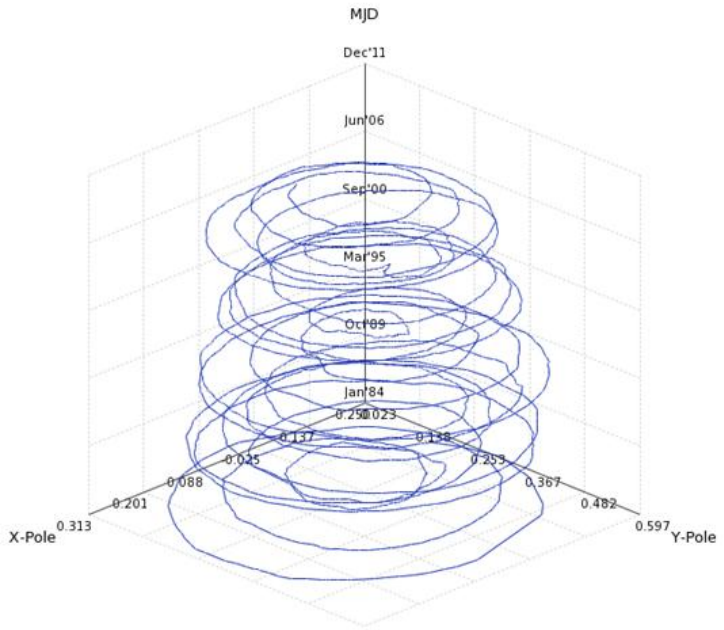




- Station time series: cubic effects, below 1 mm

Ocean pole tide new vs. off

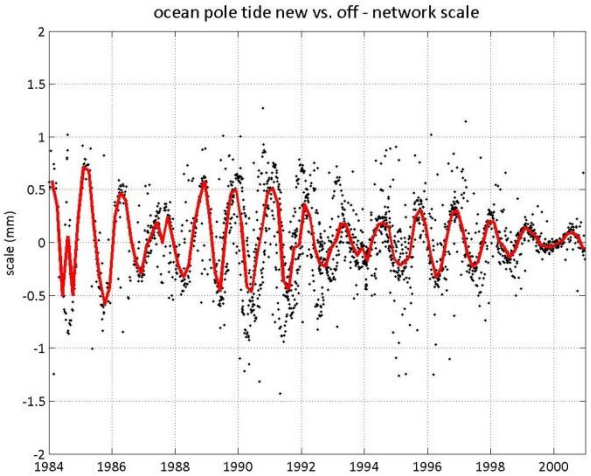
- Rotational deformation caused by ocean mass variations due to polar motion
- Polar motion is dominated by the 14 month Chandler wobble and annual variations
- Oceans are expected to respond in equilibrium at these long periods



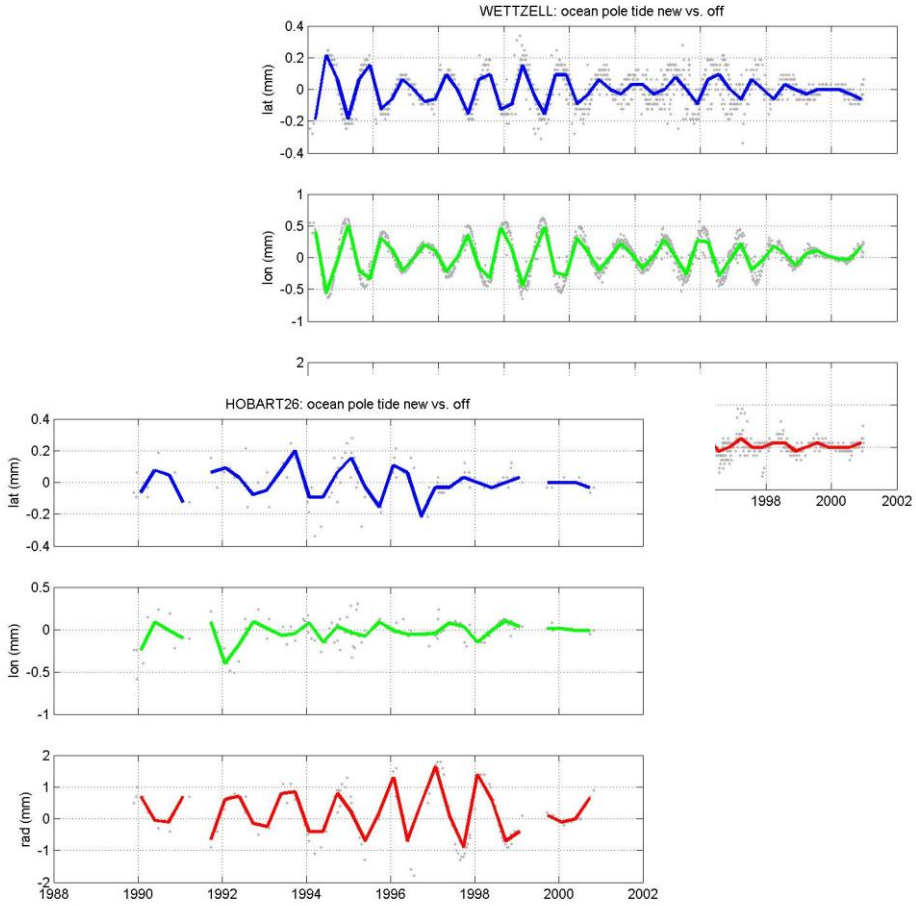
- Old: no convention (no model)
- New: Desai (2002) equilibrium model of the ocean pole tide

Ocean pole tide new vs. off

- CRF and radio source time series: no effect
- TRF: very small effects below the wrms of TRF, signal in session-wise scale parameter (0.5 mm amplitude)



- Station time series: polar motion signal with horiz. 0.5 mm, vert. 1.3 mm amplitudes



Ephemerides DE/LE 421 vs. 405

- Ephemerides effects on VLBI analysis are negligible
- Solid Earth tide modeling (Sun, Moon),
  difference between 421 (new) and 405 (old conventions)
  negligible
- VLBI delay model, gravitational delay (Sun, Jupiter, …),
  difference negligible
- No effects on VLBI CRF/TRF

Summary

Reference Frames	**TRF effects**	**CRF effects**
ICRF-Ext.1 vs. ICRF2	-	noise 10 μas
ITRF2000 vs. ITRF2008	velocities 3 mm y^{-1}	-
DE/LE 405 vs. DE/LE 421	-	-
Displacements of reference points		
Ocean loading: 9 main tides vs. 342 constituent tides	higher latitudes and marine locations, positions < 1 mm	noise 50 μas
Atmosphere loading: new model Ray & Ponte (2003), van Dam	-	signals with 40 μas amplitudes
Pole tide: new mean pole	cubic effect < 0.5 mm	-
Ocean pole tide: new model Desai (2002)	polar motion signals max. 1.3 mm amplitude	-

Comments

- ITRF2008 and ICRF2 are clearly more accurate than their predecessors; ITRF2000 should not be used
- The new ocean pole tide model shows good and significant results
- This tidal atmosphere loading model affects radio sources not stations, the benefit from this model is questionable
- The Petrov & Boy (2004) atmosphere loading model was significantly better than the conventional one → why do we not apply it?
- The application of new IERS Conventions (2010) models gives not only improvements and many of the improvements are not significant (at the sub mm – level)
- We recommend to carefully test new models before they are specified as being the current conventional models

Thank you for your attention.

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