Impact of new models for the ITRF2020 in VLBI analysis at DGFI-TUM

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Outline

- New models for ITRF2020
- Earth Orientation Parameters (EOP)
- VLBI station coordinates
- Source coordinates
- Summary

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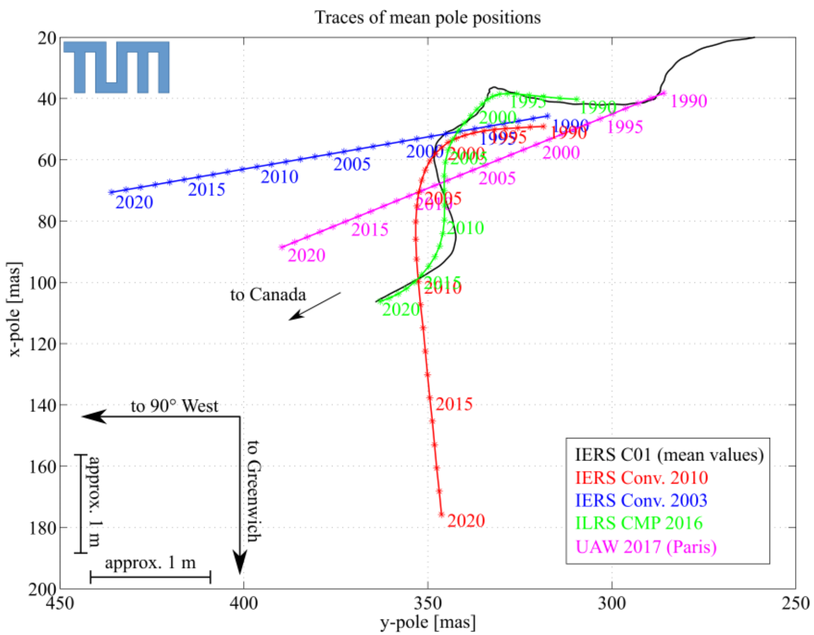
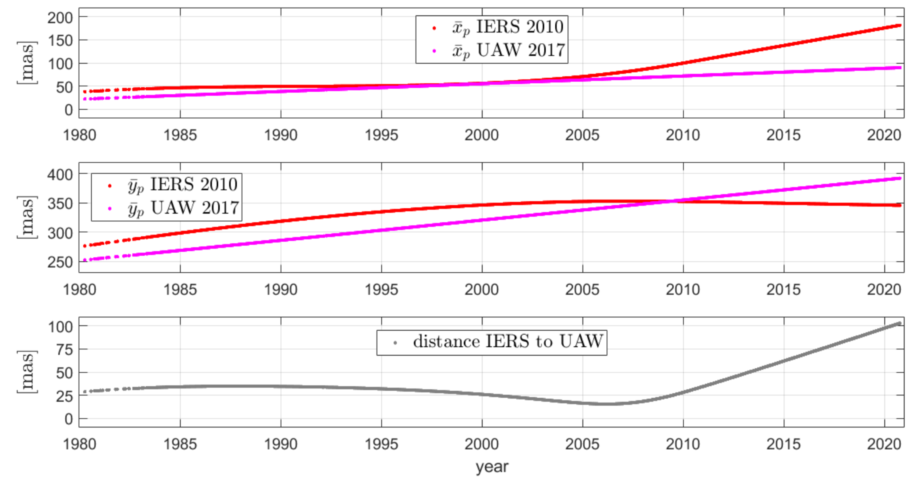
1) New secular pole

- At the Unified Analysis Workshop in 2017 (UAW 2017), it was decided to change the function for the Conventional Mean Pole (CMP) to a purely linear one:



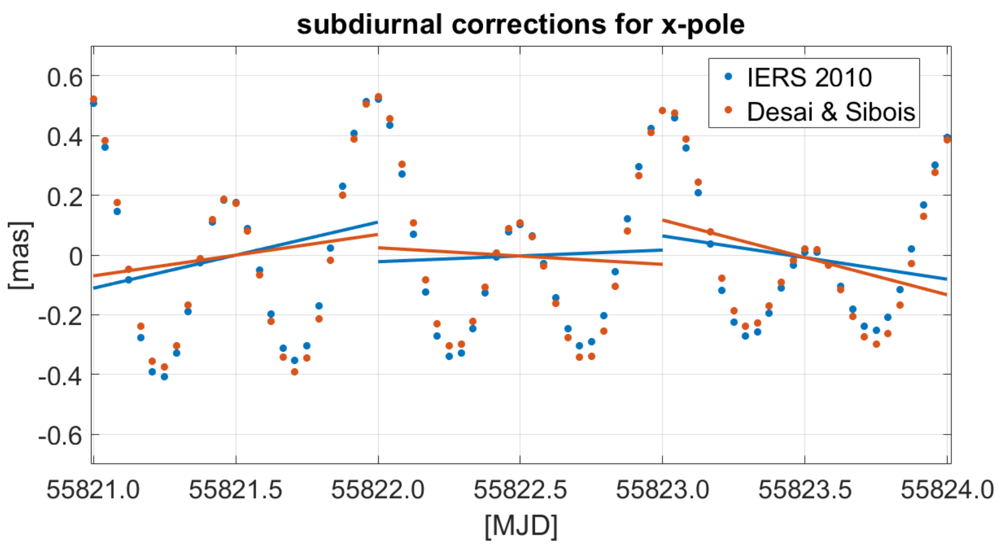


- The distance between the poles of the two models reaches its minimum in 2006, afterwards it is monotonously increasing.

- The CMP is used for the computation of site displacements due to pole tides and ocean pole tides, i.e. station heights will be affected (next to polar motion).

2) High-frequency EOP (HF-EOP)

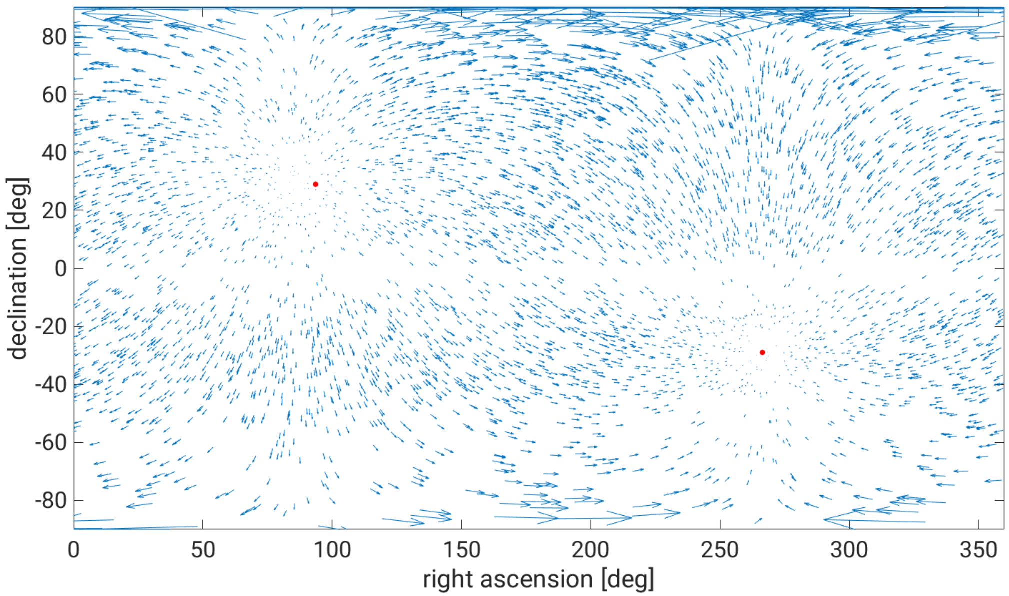
- There are subdiurnal variations in Earth Rotation Parameters (ERP), i.e. polar motion and ΔUT1, mainly due to ocean tides.
- The previous model of the IERS 2010 Conventions is based on TPXO4 and contains 71 tidal constituents (Petit and Luzum [2010]).
- The new model by Desai and Sibois [2016] was recommended by the *IERS Working Group on Diurnal and Semi-diurnal EOP Variations* (*https://ivscc.gsfc.nasa.gov/hfeop_wg/*)
- It is based on the TPXO8 model (Egbert and Erofeeva [2002]), and comprises 159 tidal frequencies.
- The deviations between the models lead to slightly different slopes for piecewise linear EOP estimates.



3) ICRF3 with Galactic Aberration (GA)

- The latest realization of the International Celestial Reference System (ICRS) is the ICRF3.

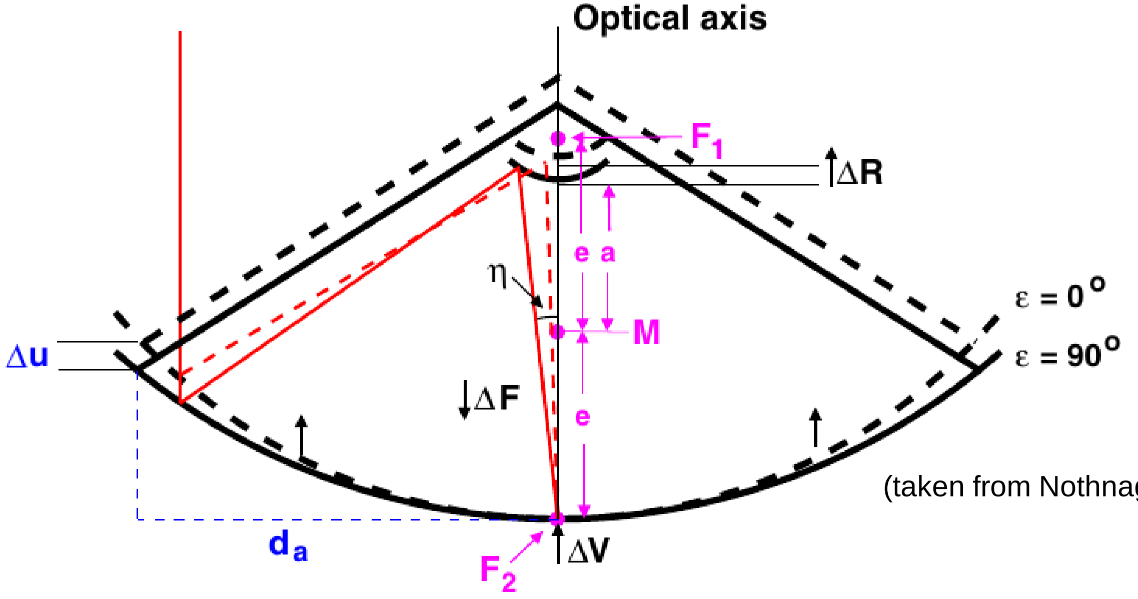
- For the first time, it includes Galactic Aberration (GA), which is generated by the acceleration of the Barycenter towards the Galactic Center:



- The ICRF3 positions and corresponding proper motions due to GA are used to create new a priori values for the source coordinates.

4) Gravitational deformation

- Due to gravitational deformation, the signal path length changes depending on the antenna´s elevation:



(taken from Nothnagel et al. [2019])

- For 6 antennas, tables with [elevation,delay] pairs are available (derived from separate studies for each antenna).

- If the gravitational delays are applied, the corresponding stations must not be included in the datum conditions (NNT / NNR).

Analysis approach

- At DGFI-TUM, we run the analysis software DOGS (DGFI Orbit and Geodetic parameter estimation Software).

- It makes use of the Gauss-Markov model and complies with the IVS recommendations (https://ivscc.gsfc.nasa.gov/IVS_AC/IVS-AC_ITRF2020.htm).

- Our ITRF2020 contribution is based on our official IVS solution dgf2020a, but without non-tidal atmospheric loading. About 5,800 legacy S/X sessions with at least three stations between 1979 and 2020 are considered here.

- For this presentation, we add each model successively and examine the impact on the estimated station positions, source coordinates and Earth Orientation Parameters (EOP):

  a) no new model
  b) plus secular pole
  c) plus HF-EOP
  d) plus ICRF3
  e) plus gravitational deformation (all models)

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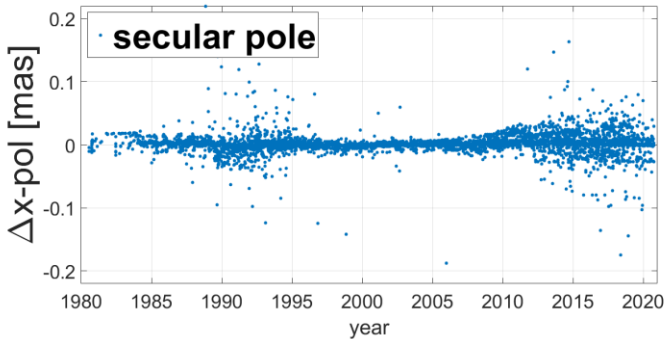
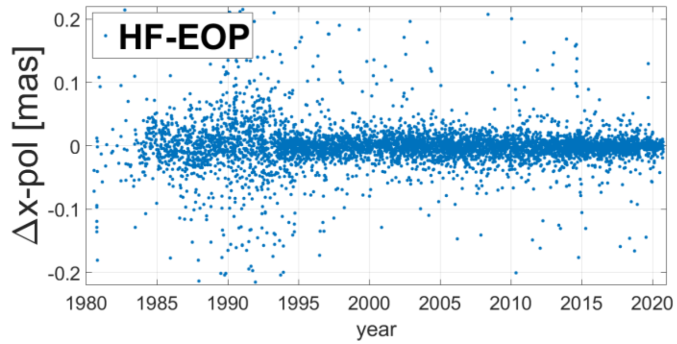
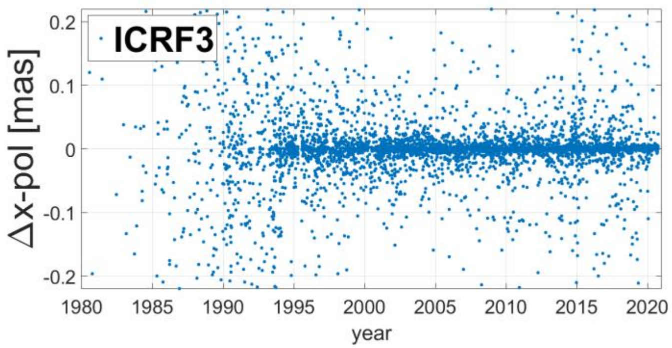
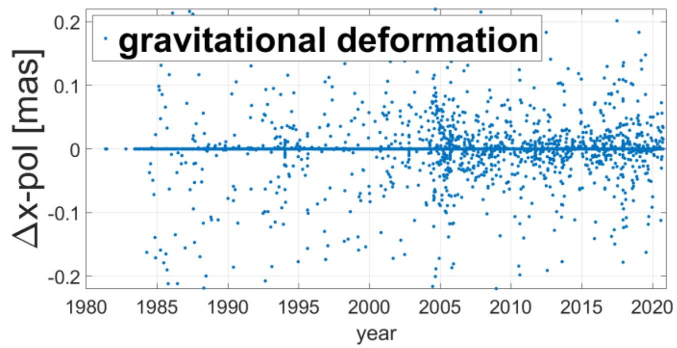
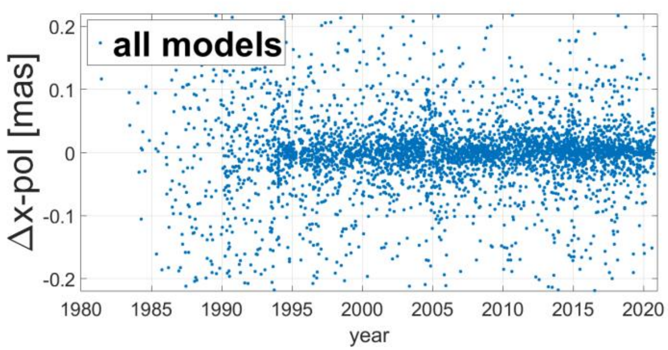
Changes in polar motion offsets by introduction of …





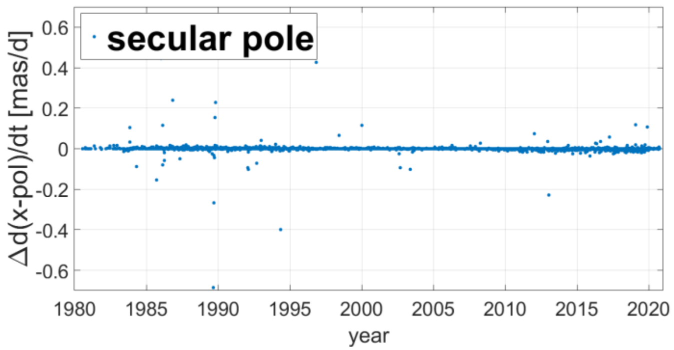


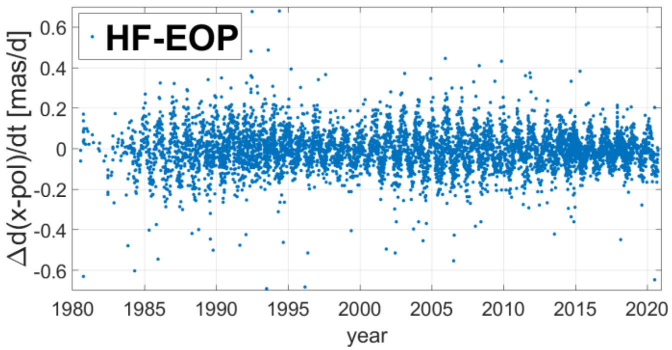


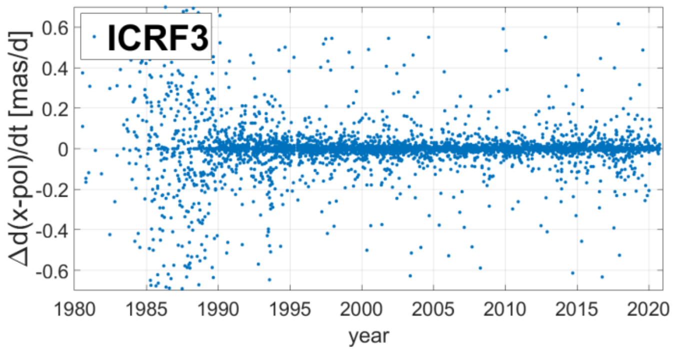


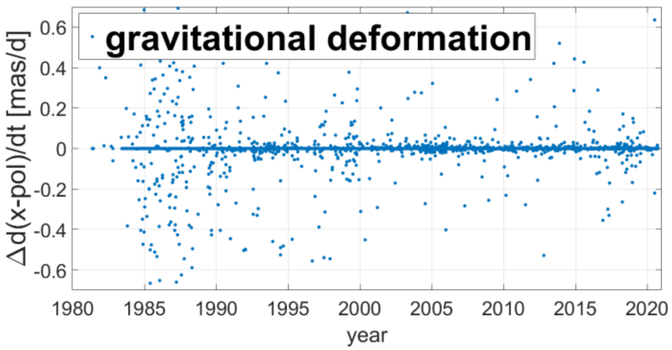
- Polar motion is affected by all models at a similar scale.
- In the first figure, the times when the secular poles of the two models differ most are clearly visible.

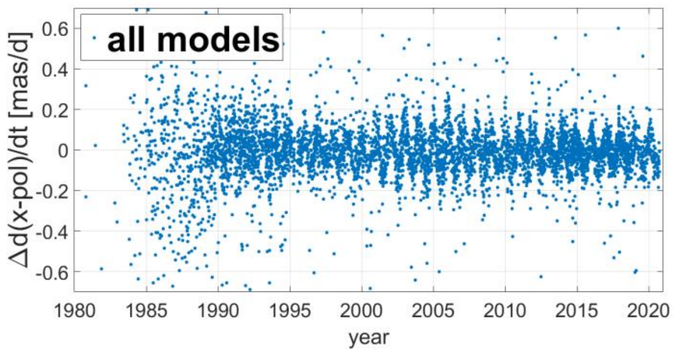
Changes in polar motion rates by introduction of …





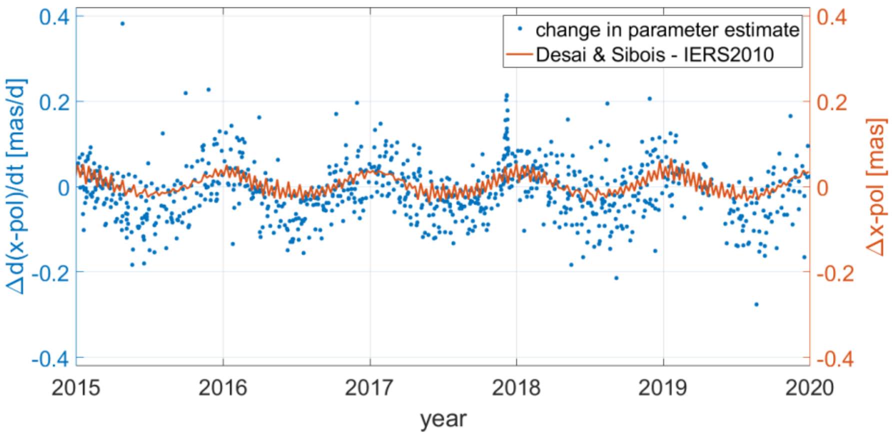


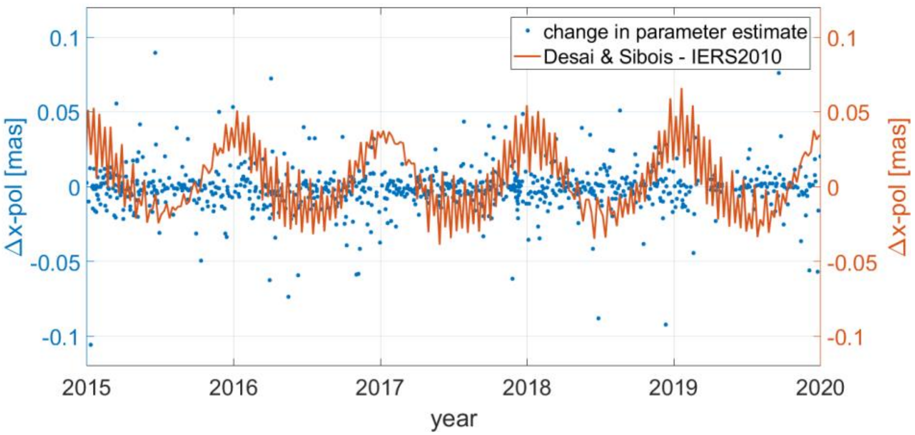




- Polar motion rates are mainly affected by the new HF-EOP.
- The annual signal stems from the periodic variations between the IERS2010 and Desai & Sibois models.

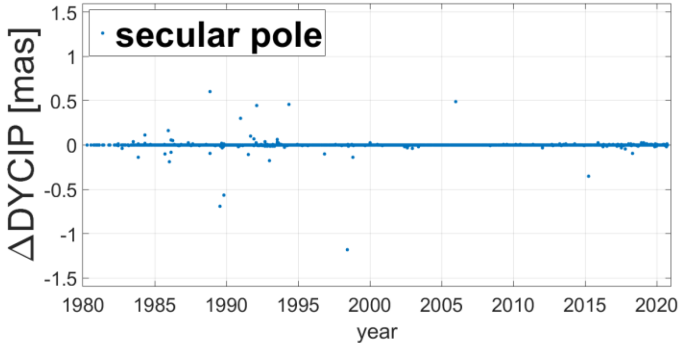
Annual signal for changes in polar motion rates by introduction of HF-EOP

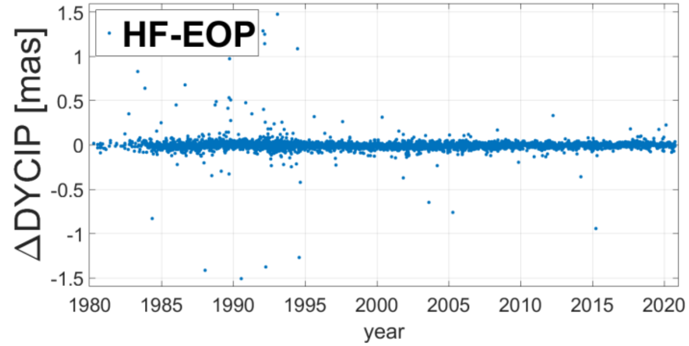


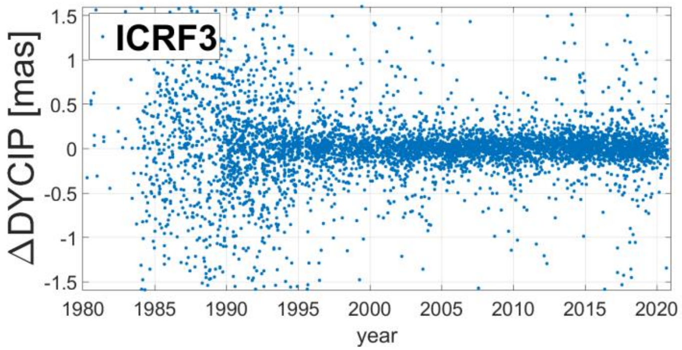


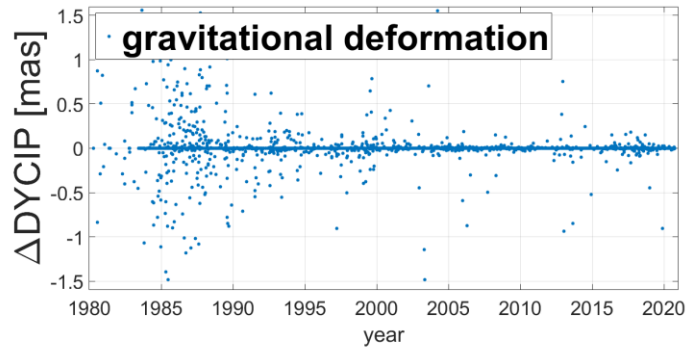
- The red line represents differences between the Desai & Sibois [2016] and the IERS2010 corrections for x-pole (weekly resolution).
- They reveal an annual signal, which also prevails for y-pole and ΔUT1. It is transferred to the differences between the estimated EOP.
- We estimate polar motion and ΔUT1 by a mid-session offset and a drift. The signal is mainly reflected by the rates (left Figure), while the offsets are much less affected (right Figure). This seems reasonable, since the HF-EOP corrections are sub-diurnal.

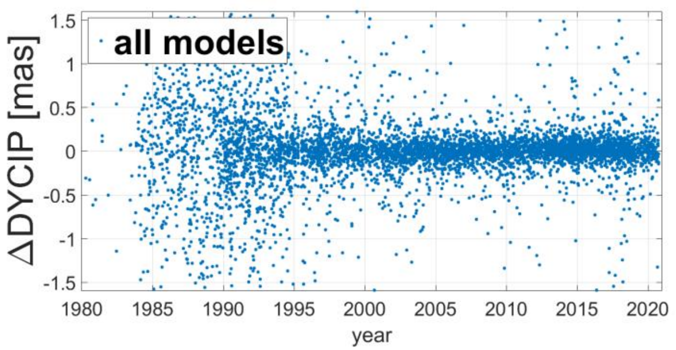
Changes in celestial pole offsets by introduction of …





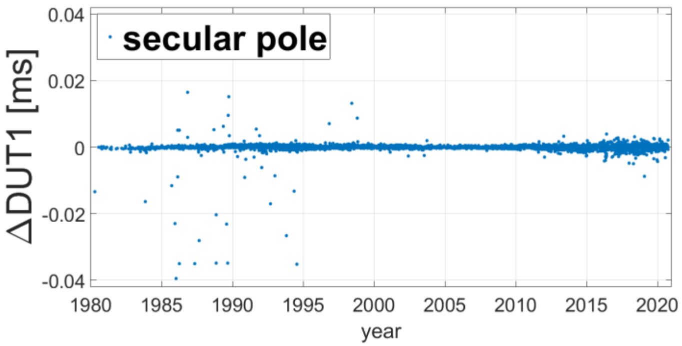


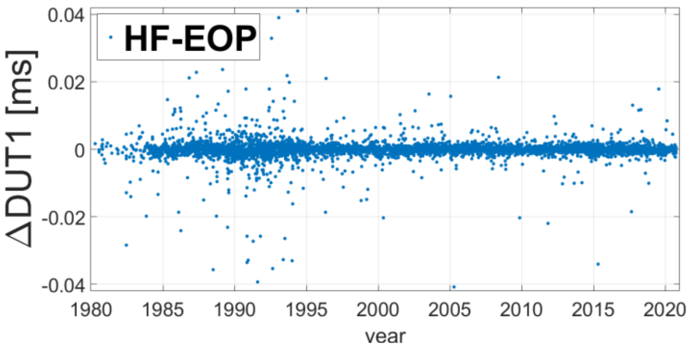


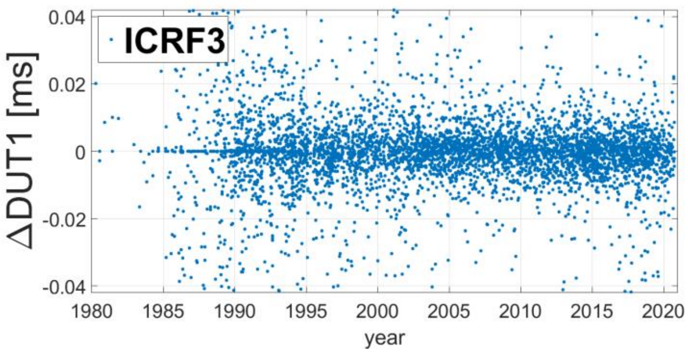


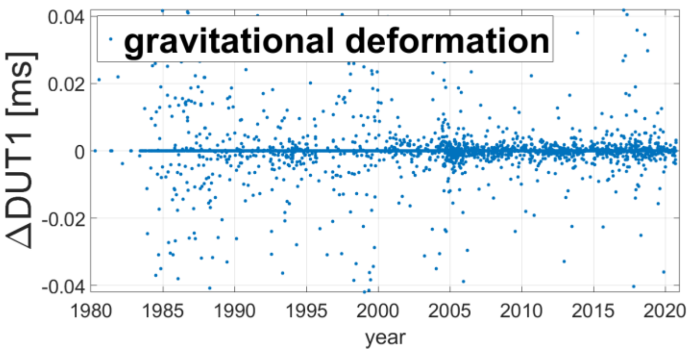
- Celestial pole offsets are mainly affected by the ICRF3.
- The magnitude of the corresponding changes is similar to the changes for the source coordinates (see below).

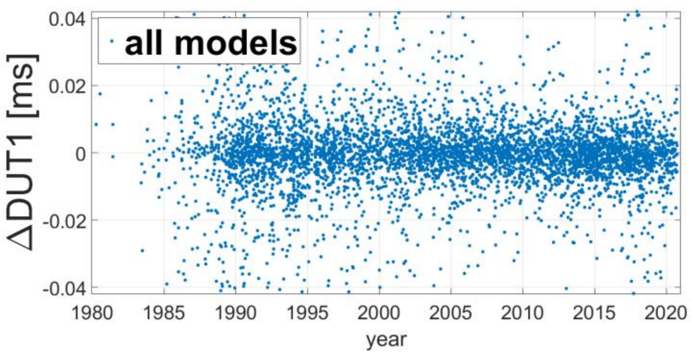
Changes in ΔUT1 by introduction of …











- ΔUT1 is mainly affected by the ICRF3 and the HF-EOP.
- LOD behaves like the polar motion rates, in particular there is the same annual signal for HF-EOP (± 10 μs/d).

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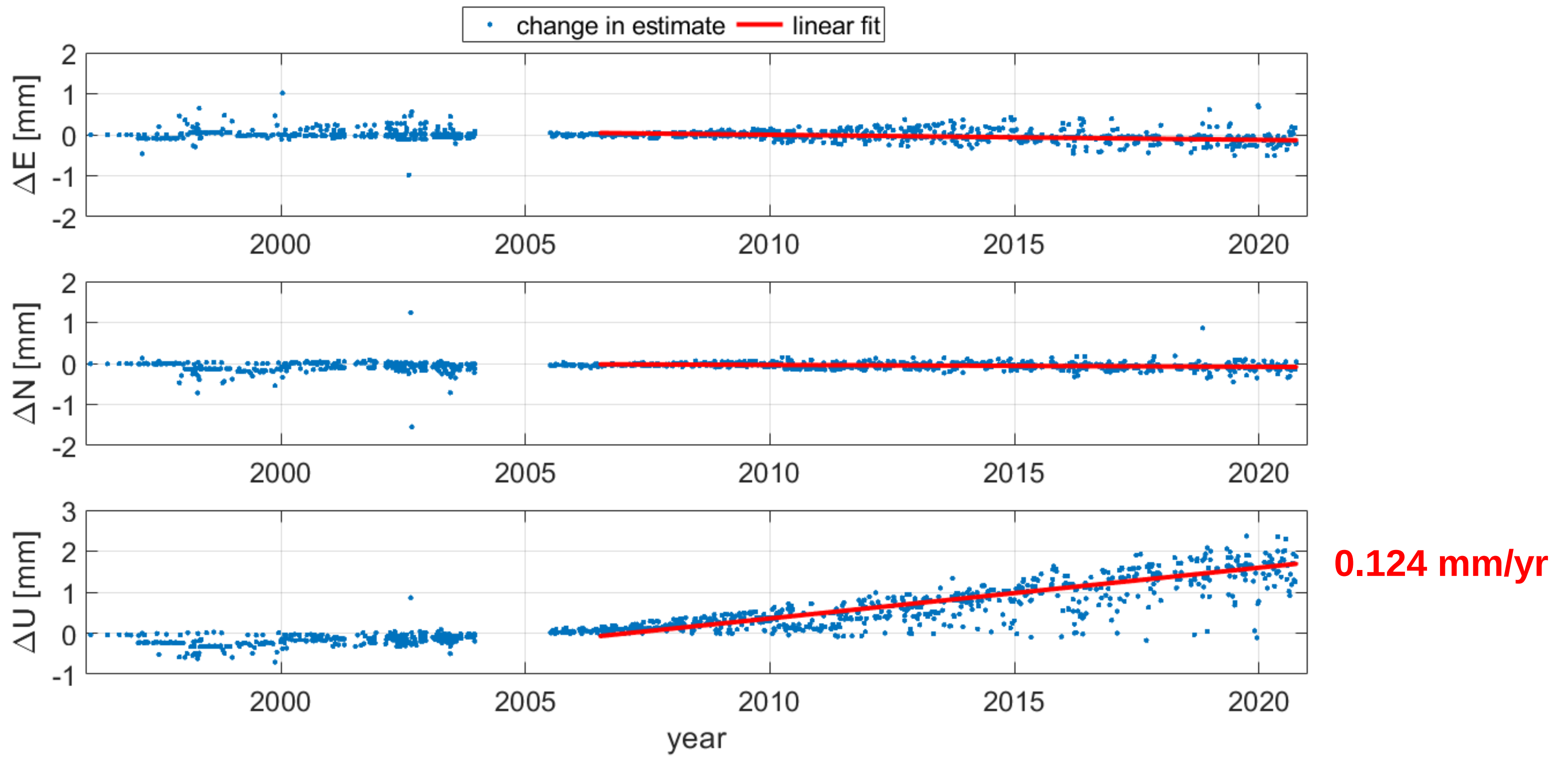
Impact of new secular pole on station coordinates

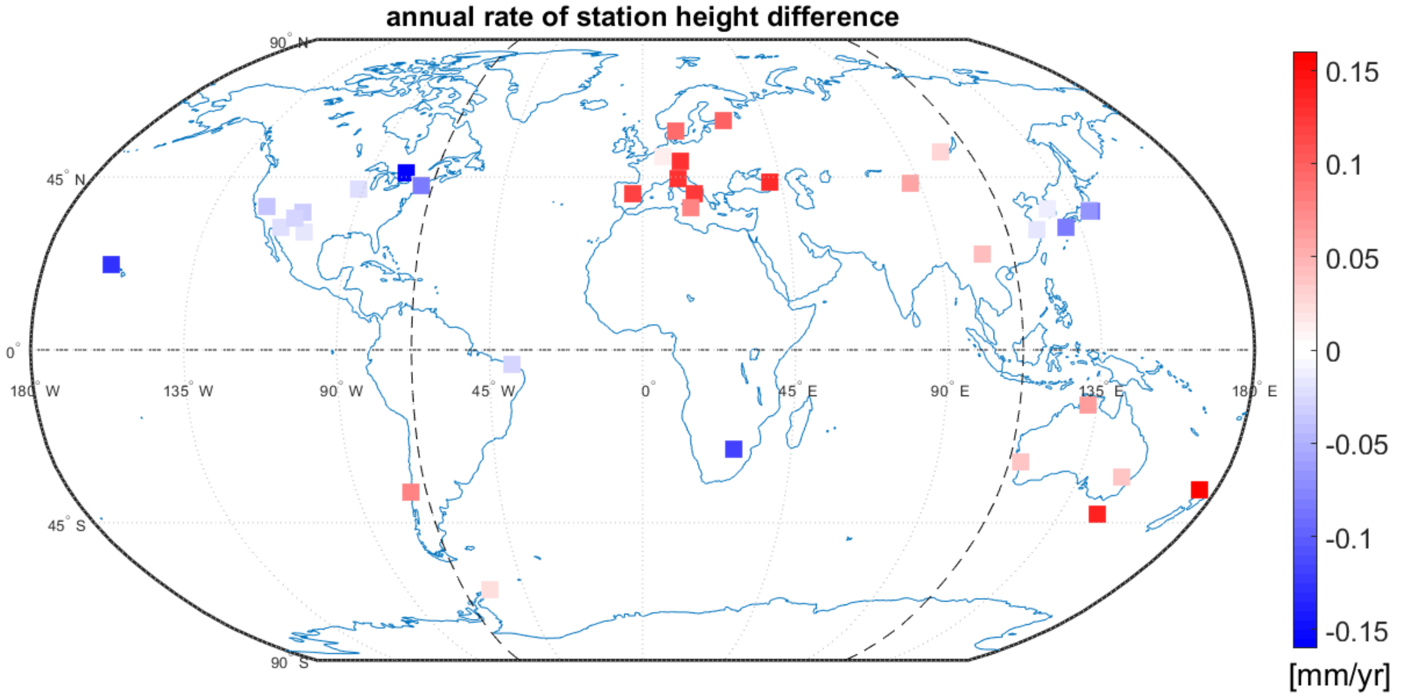
- The two CMP functions are closest in 2006, and their discrepancy monotonously increases afterwards.

- The VLBI station positions are affected systematically by the corresponding site displacements due to the (ocean) pole tides, compare MATERA, for example:



Impact of new secular pole on station coordinates

- In general, for each station, the station height either monotonously increases (red) or decreases (blue) with the new secular pole (starting from mid 2006):



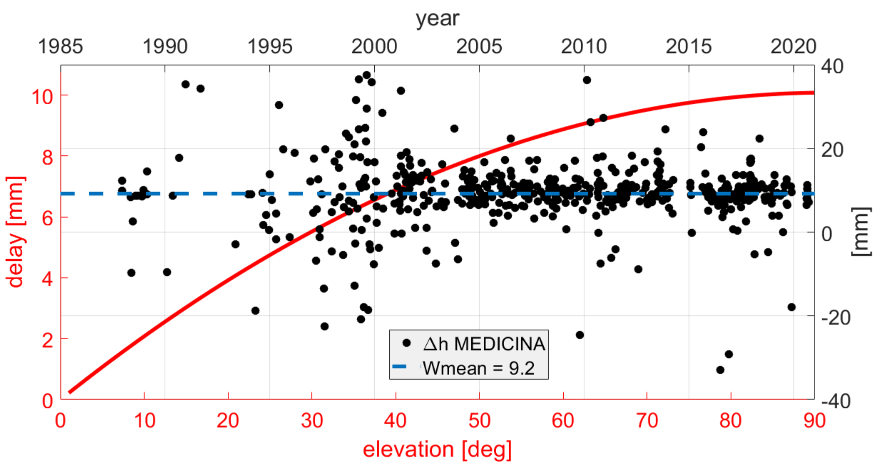
- The behaviour of the respective stations divides the Earth's surface into 4 parts (dashed lines): they are related to the direction between the old and the new secular pole.

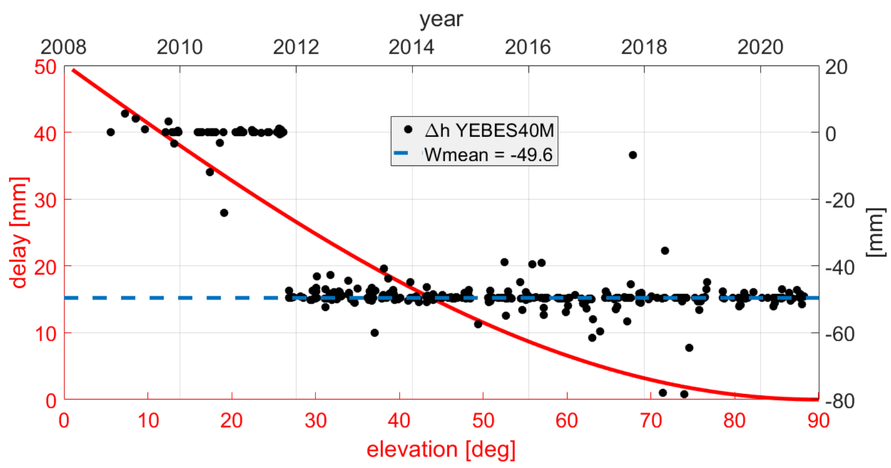
(Empirical) gravitational deformation model: impact on station coordinates

- Changes in station heights are proportional to $-\sin(e)$, with e being the elevation of the antenna (Sarti et al. [2011]). $\sin(e)$ is an increasing function of elevation e.

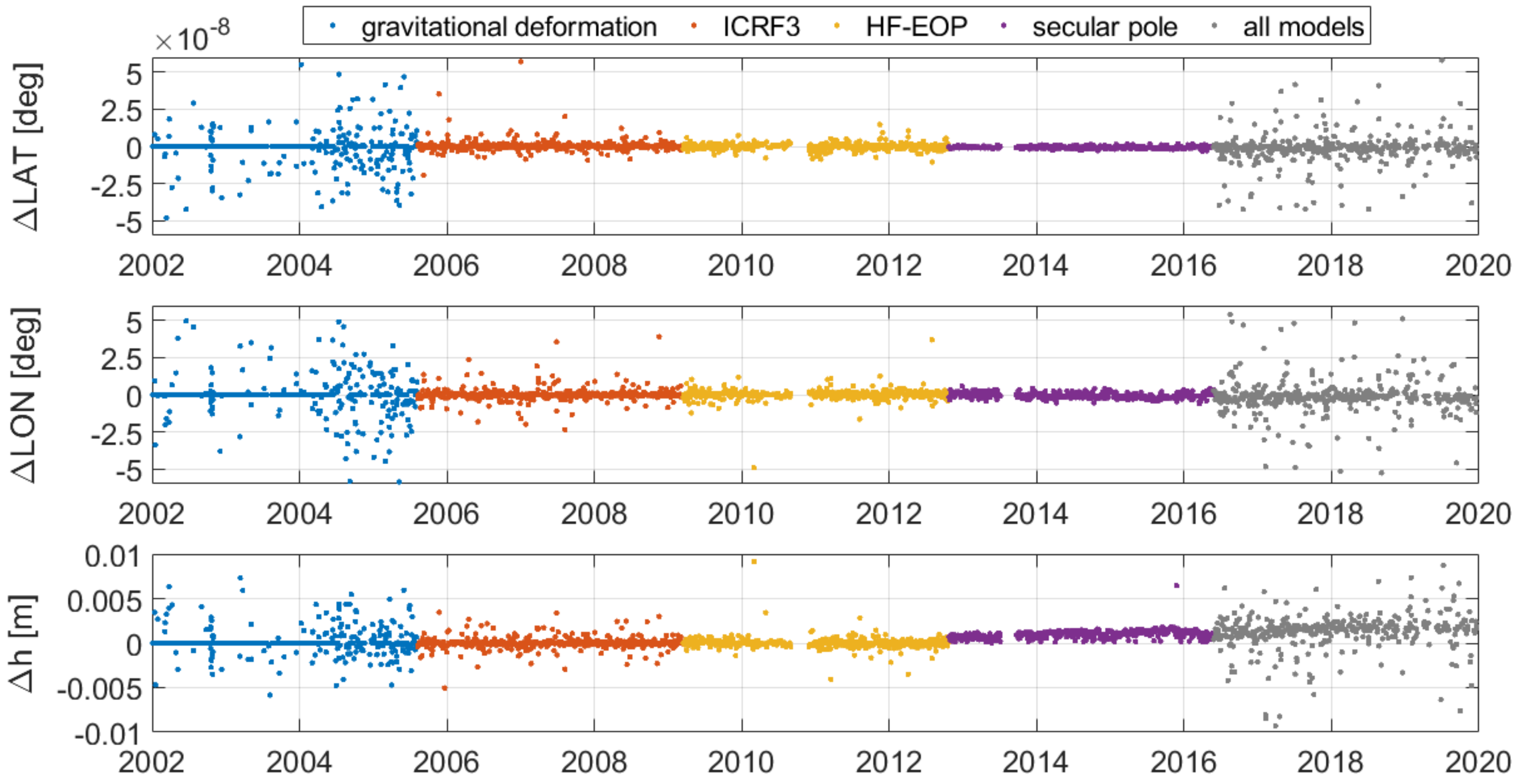
- The empirical delays $GD(e)$ by gravitational deformation are either increasing or decreasing functions of antenna elevation (red curves below).

- Hence, the consideration of gravitational deformation mainly affects heights: adding increasing [decreasing] $GD(e)$ leads to increasing [decreasing] heights h (black dots):



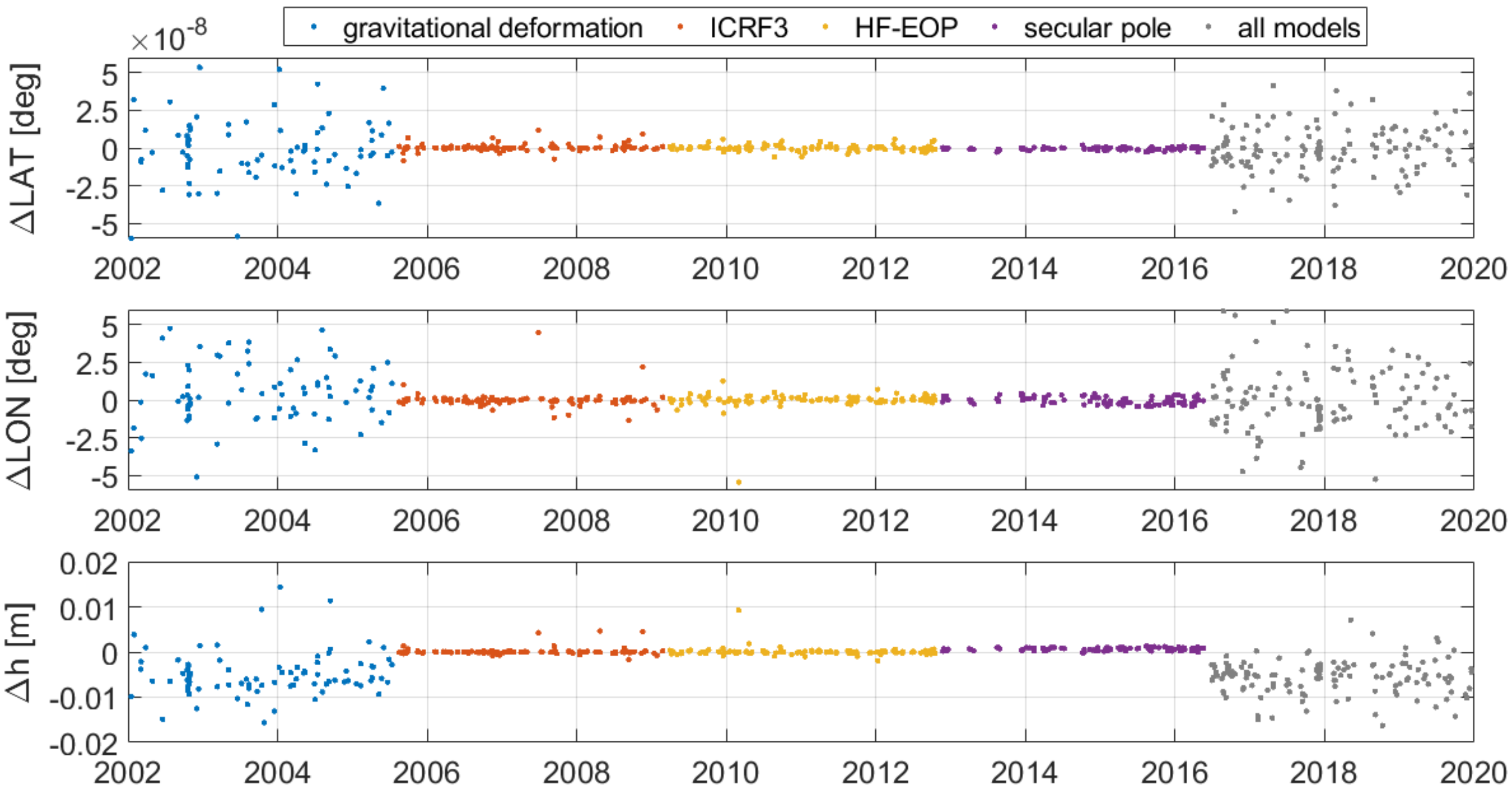


Change in coordinates for WETTZELL after introduction of…



➢ Except for the secular pole, the new models lead to hardly systematic variations of different magnitudes in the coordinates.

Change in coordinates for ONSALA60 after introduction of…



- This station has a gravitational deformation model, and it has the most significant impact of all new models.

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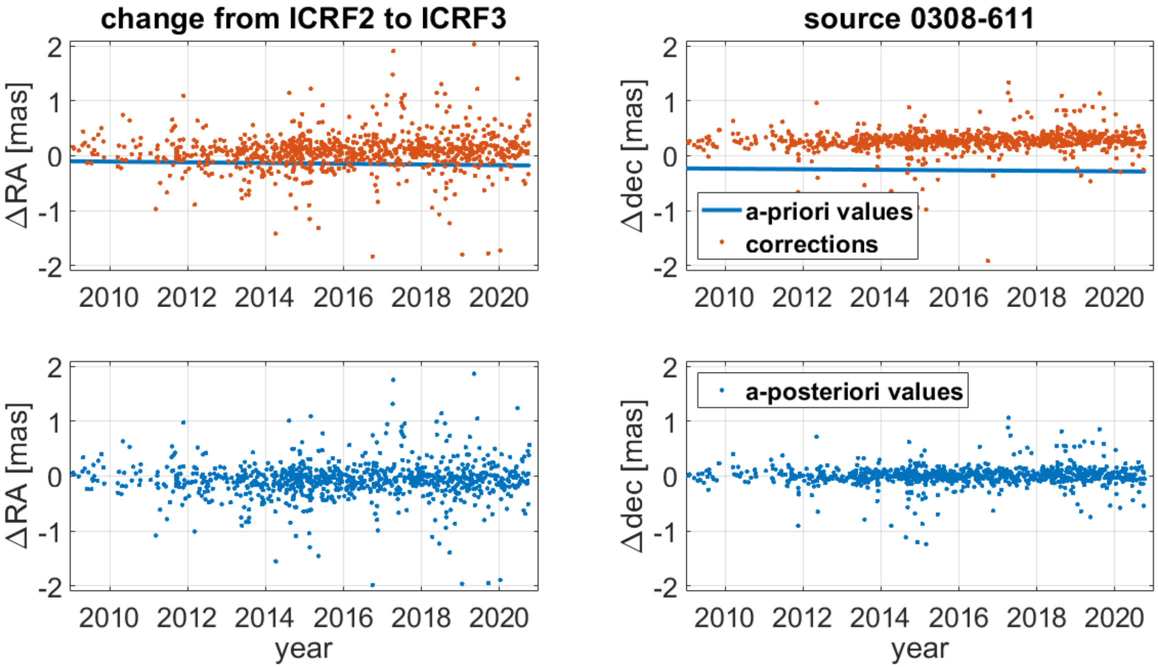
Impact on source coordinates

- The new secular pole and the gravitational deformation hardly have any effect on the source coordinates. For the HF-EOP, the impact is also rather small.

- The (by far) largest effect is introduced by the ICRF3.

- However, the changes in the corrections mostly have the opposite sign of the changes in the a priori values. Hence, the final estimates are not altered systematically:



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Summary

- The new geophysical models for the VLBI input to the ITRF2020 have different effects on the distinct types of estimated geodetic parameters.
- Starting from mid 2006, the new secular mean pole model leads to increasing differences in the estimated parameters, especially for the station heights. Whether they rise or fall depends on their geographical location.
- The sub-diurnal (ocean tide) corrections for polar motion and ΔUT1 of the previous conventional and the new model differ with an annual signal, which is propagated into the corresponding estimated EOP rates.
- The a priori source coordinates of the ICRF3 now contain a linear drift due to the Galactic Aberration (GA). The new corrections reveal an opposite drift to arrive at similar final coordinate estimates, which hence seem to already have reflected GA.
- Depending on the slope of the empirical gravitational deformation model, the heights of the corresponding stations either increase or decrease when the deformation is considered.
- So far, we did not observe a significant impact on the statistics of the estimation itself.

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Thank you very much for your attention!