Consistency evaluation of seasonal signals in ITRF2020

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Data (1/2)

- **Data**:
  - ITRF2020 input data from IAG technique services, see (Altamimi et al., 2022), this meeting
  - ITRF2020 seasonal parameters provided at https://itrf.ign.fr/en/solutions/itrf2020
  - NT-loading displacement model from GGFC at http://loading.u-strasbg.fr/ITRF2020/ (Boy, 2021)

- **Station selection: : minimal time series length**
  - 150 points for SLR (weekly) + epoch greater than 1993.0 (Lageos II)
  - 150 points for DORIS (weekly)
  - 150 points for VLBI (~ daily sessions)
  - 1000 points for GNSS (daily)

391 stations

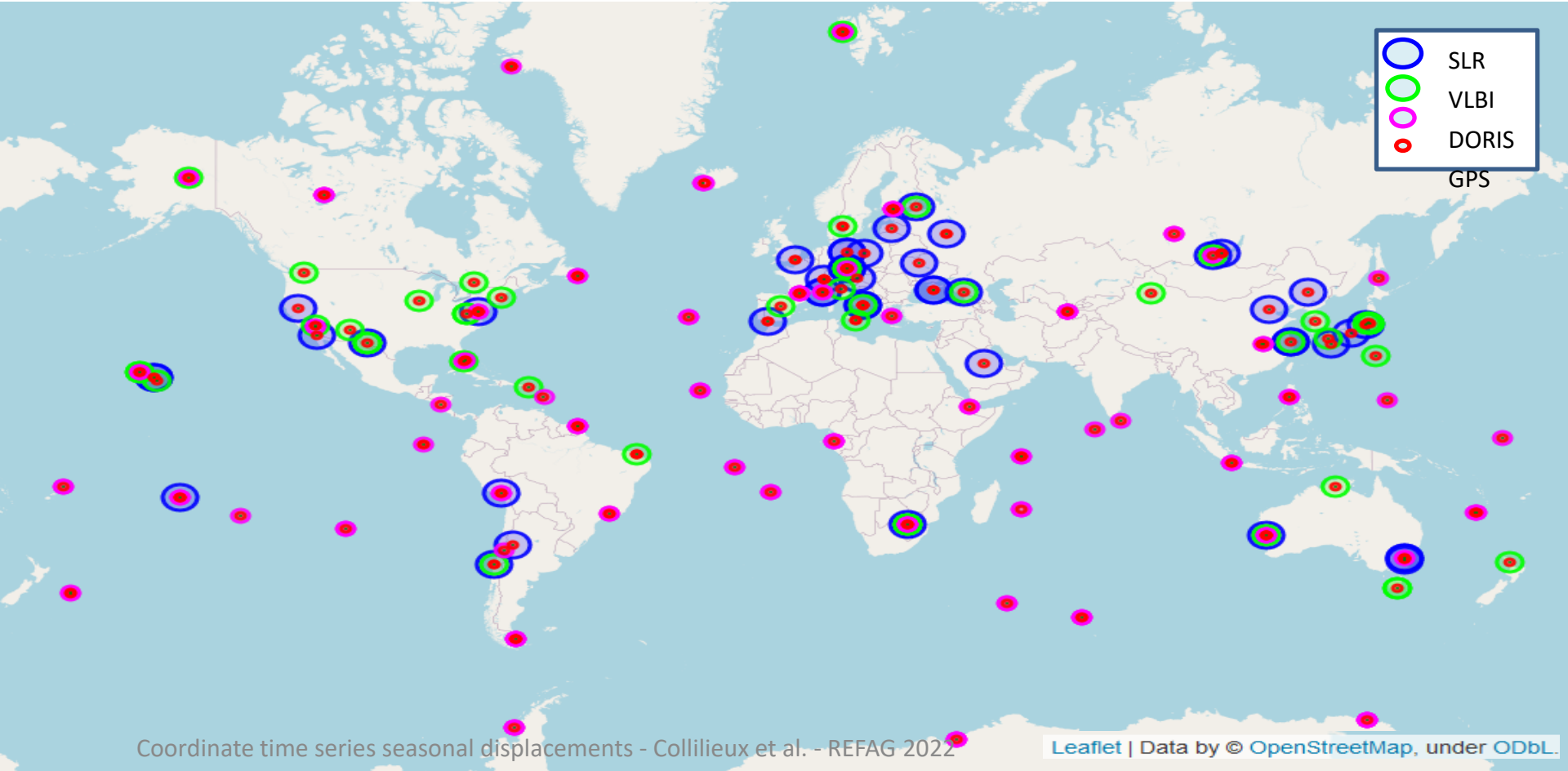
⟹ 180 GNSS; 121 DORIS; 45 SLR; 45 VLBI

111 sites

⟹ - 4 tech. : 4 sites ; 3 tech.: 16 sites ; 2 tech.: 91 sites

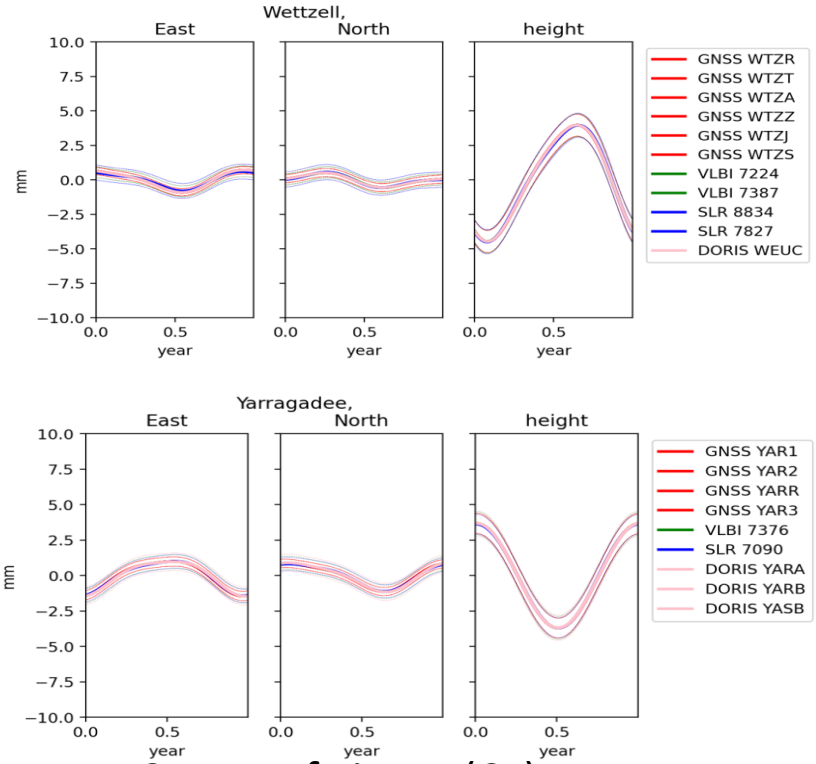
- 13 sites with more than 6 series, 56 sites with 3 to 5 series, 46 sites with 2 series only.

Data (2/2)

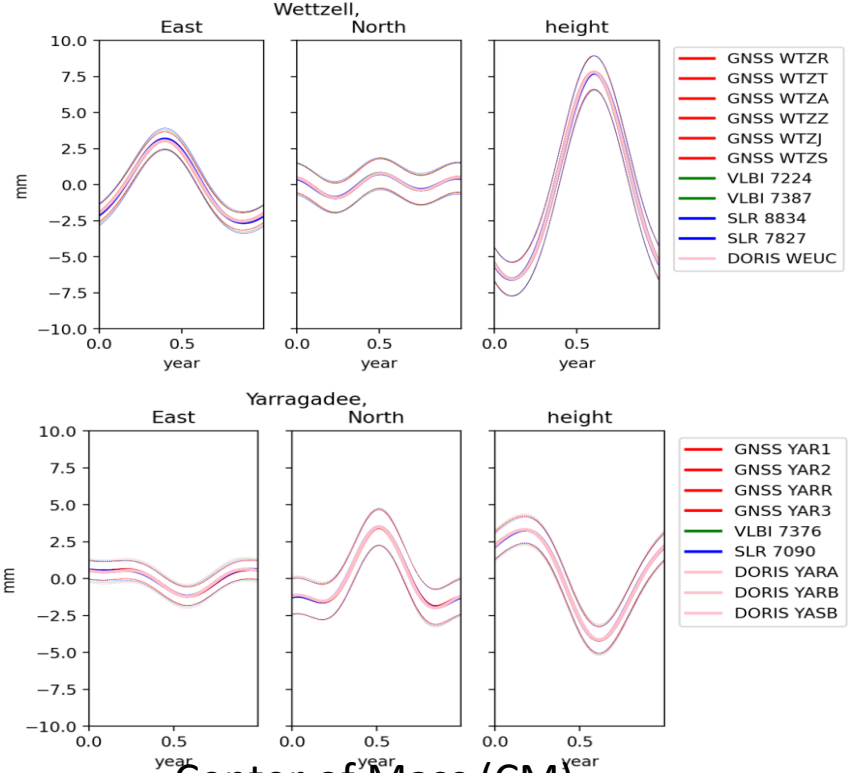

SLR
VLBI
DORIS
GPS
Leaflet | Data by © OpenStreetMap, under ODbL.

Background: ITRF2020 seasonal displacement parameters (1/2)

- Estimated seasonal parameters have been equated within co-location sites at ± 0.1 mm
- Provided in CM or CF frame, see (Rebischung et al., 2022), this meeting



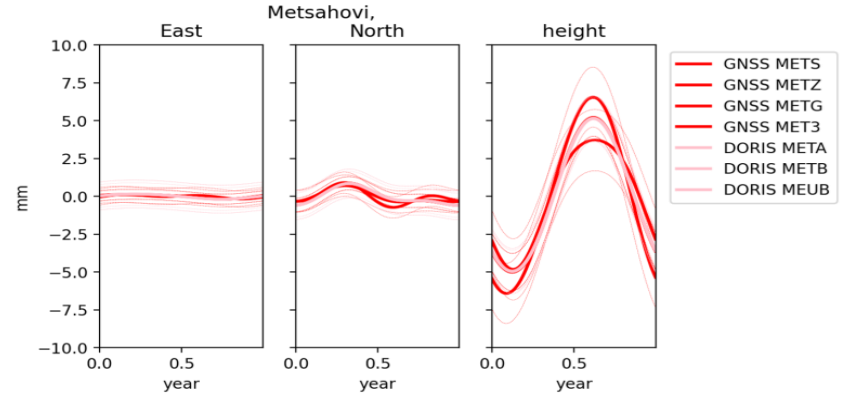
Center of Figure (CF)

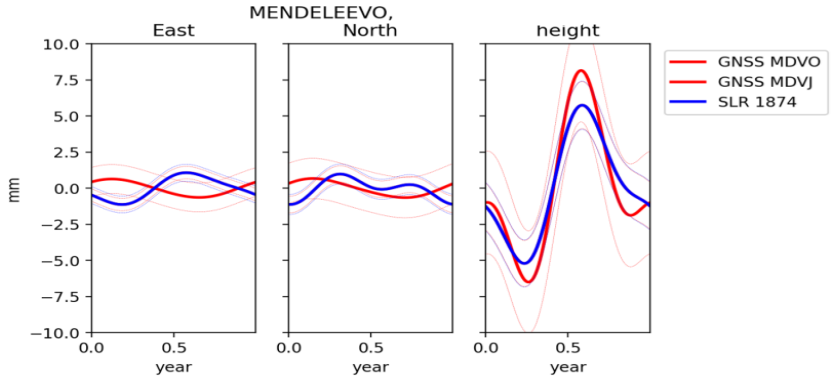


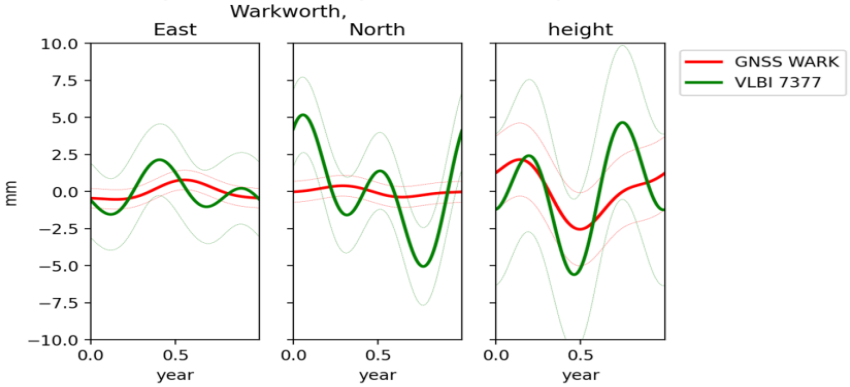
Center of Mass (CM)

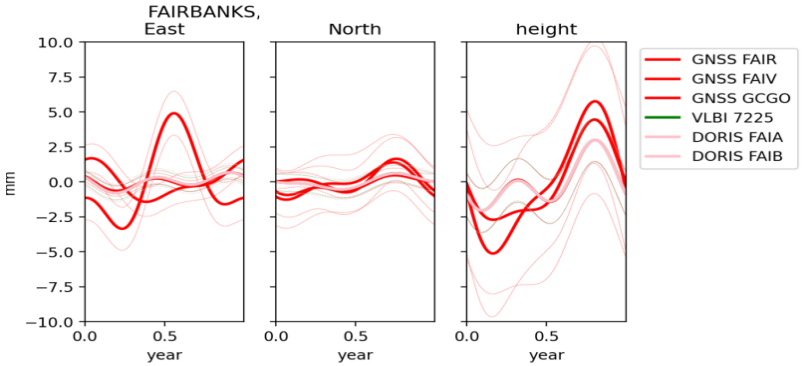
Background: ITRF2020 seasonal displacement parameters (2/2)

- Seasonal station displacements at some co-location sites have been loosely constrained due to inconsistencies. A few examples (CF frame):









Station seasonal displacement computation: strategy (1/2)

Strategy: Computation of station individual seasonal parameters from ITRF2020 results

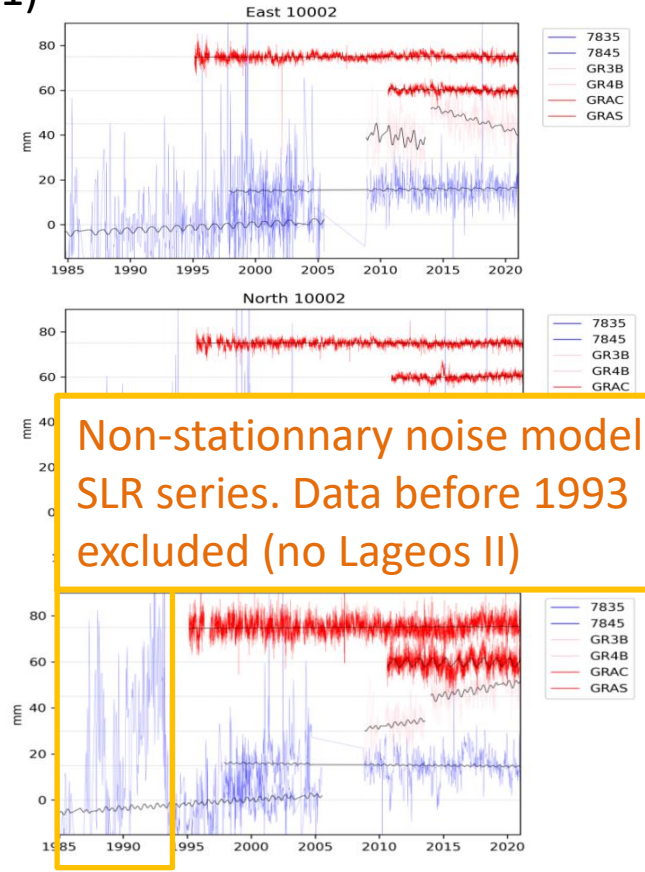
- Estimation of annual and semi-annual displacements in ITRF2020 residual position time series (additional outlier detection).
  Assumption: constant seasonal variations.
- Technique-specific station displacements =
  ITRF2020 seasonal displacements + residual seasonal variations
- Associated uncertainties : based on a variable white noise (VWN) + power law noise model (PL). Adjusted by restricted maximum likelihood on time series of residuals.

Advantage of the method:

- Seasonal variations are computed in the same reference frame. Reference frame biases have been removed in the ITRF2020 combination.
- Easy to carry out

Station seasonal displacement computation: strategy (2/2)

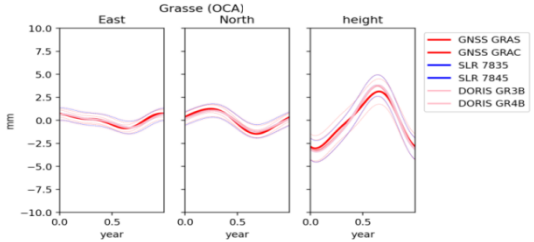
1) ITRF2020 Residuals



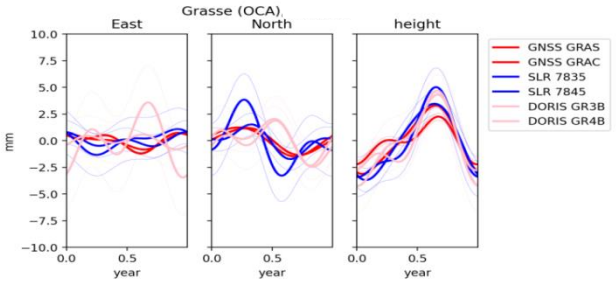
Non-stationnary noise model in SLR series. Data before 1993 excluded (no Lageos II)

+

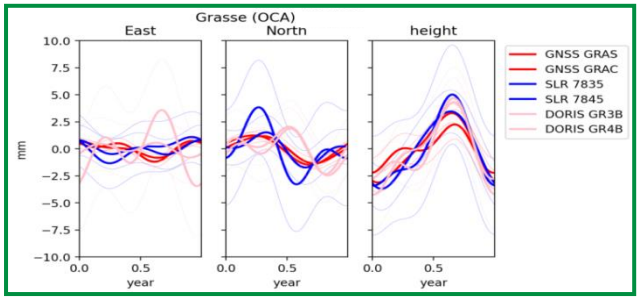
ITRF2020 seasonal displacements in CF



2)



3)



Formal errors based on variable white noise (VWN) model

Formal errors update

Formal errors based on variable white noise + power law (VWN+PL) model

* Light curves are 95% confidence intervals (1.96σ)

Impact of time-varying seasonal displacements and sampling effect (1/2)

- Discussion on the assumption of constant seasonal signals based on synthetic data: **GGFC loading model** (Boy, 2021). Is the seasonal signal fitted at space geodetic (SG) data observation epochs equal to the seasonal signal fitted from equally sampled data?

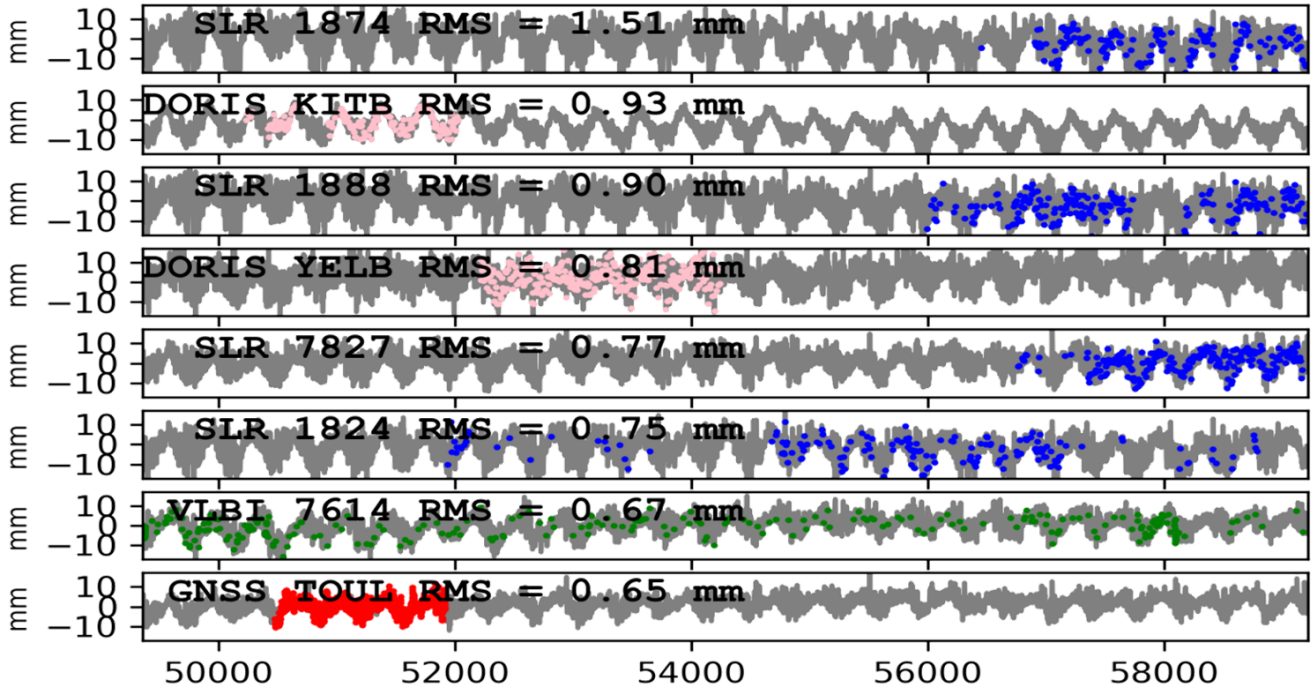


Fig. Grey: loading model (GGFC). Color: loading model sampled at SG data observation epochs

Series that show the largest differences between estimated constant seasonal signals using the whole dataset or only values sampled at observed epochs are shown.

Impact of time-varying seasonal displacements and sampling effect (2/2)

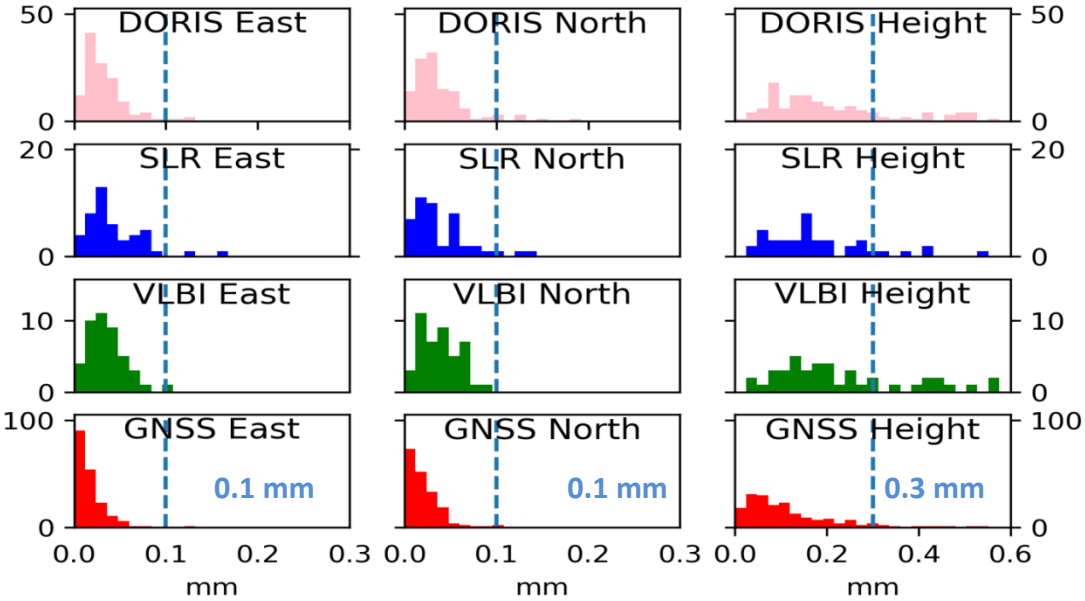


Fig. RMS between seasonal time series estimated from continuous load time series (GGFC)* over the time interval 01/01/1994 to 01/01/2021 and estimated from sampled time series* by space geodesy.

* Computed from daily load values

Conclusion: the sampling effect is evaluated as follows

- Horizontal : bias in the fitted seasonal generally smaller than 0.1 mm (RMS of the fitted seasonal series)
- Vertical : median RMS smaller than 0.2 mm for all techniques but 13% of SLR stations and 11% VLBI stations show RMS larger than 0.5 mm (6% for DORIS and 2% for GNSS).

Seasonal displacement agreement at co-location sites (1/3)

w.r.t. to the longest GNSS series

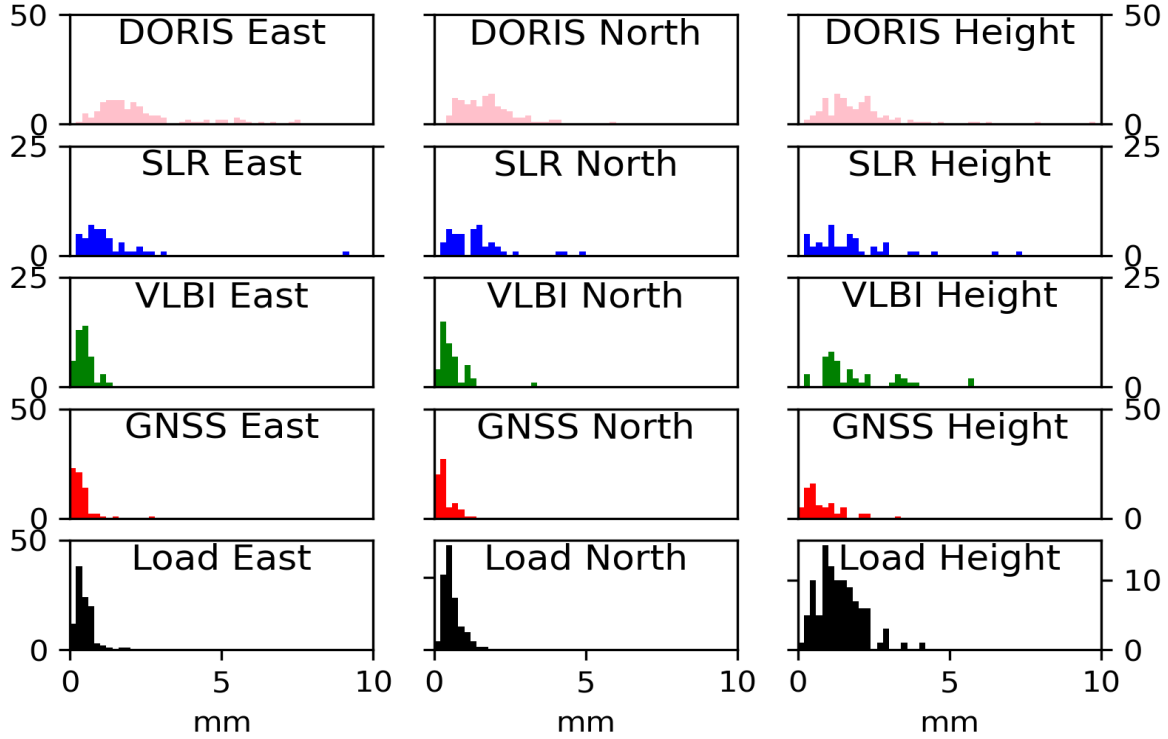
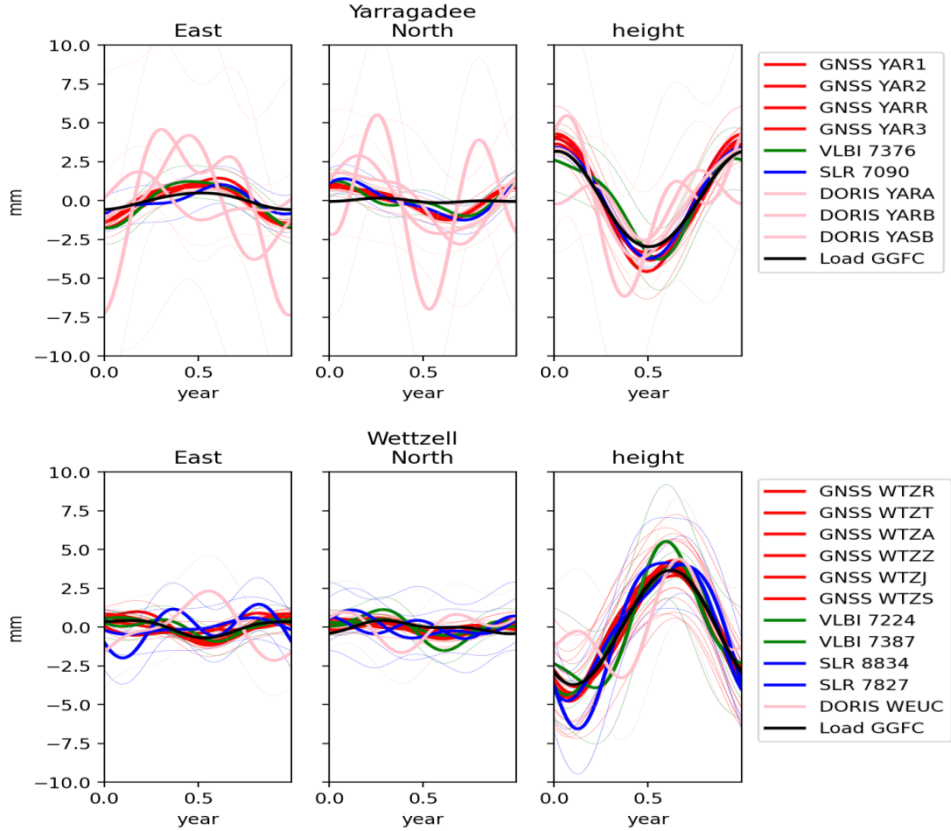
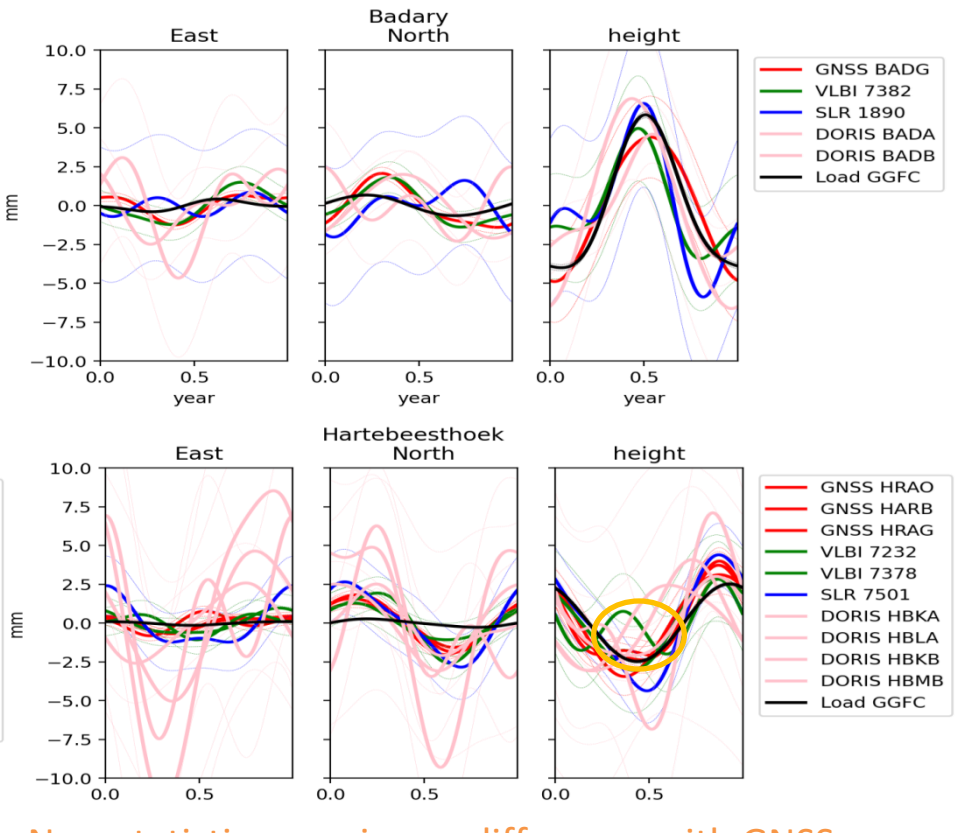


Fig. RMS of the difference between the seasonal series of the longest GNSS time series of the site and the other seasonal series from the same co-location site.

Seasonal displacement agreement at co-location sites (2/3)

- Co-location sites with 4 techniques

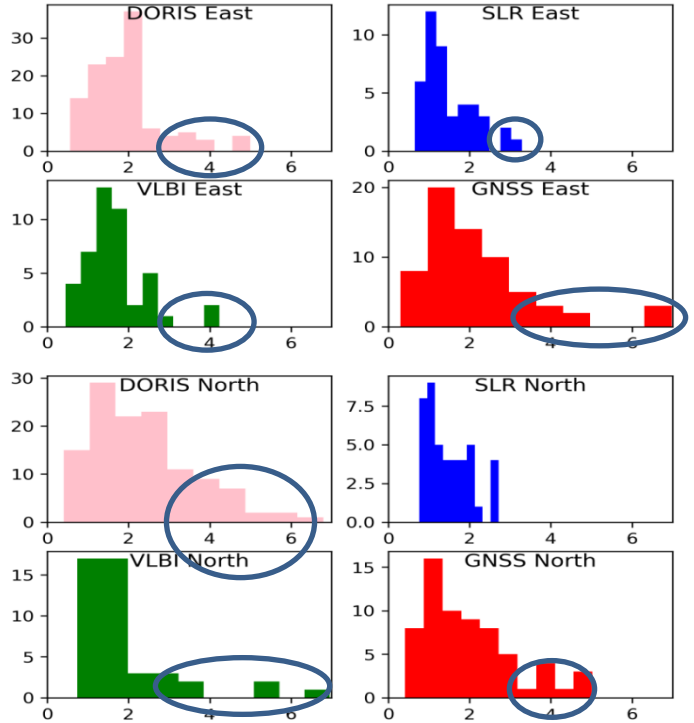


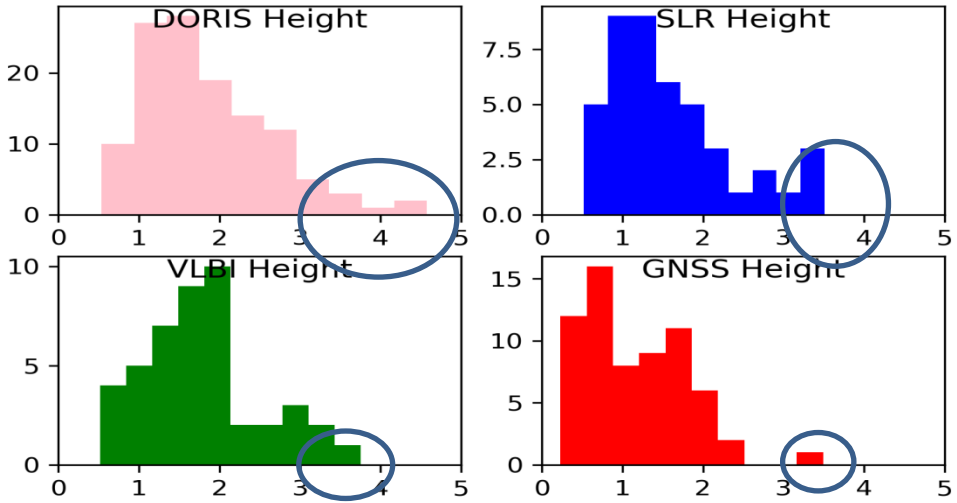


New statistics: maximum difference with GNSS accounting for formal errors (PL+VWN)

Seasonal displacement agreement at co-location sites (3/3)

Longest GNSS seasonal series vs others: ratio between the max value of the difference (absolute values) and standard deviation of the difference [from formal errors ($\sqrt{\sigma_{other}^2 + \sigma_{gnss}^2}$) VWN + PL model]. Series assumed uncorrelated.





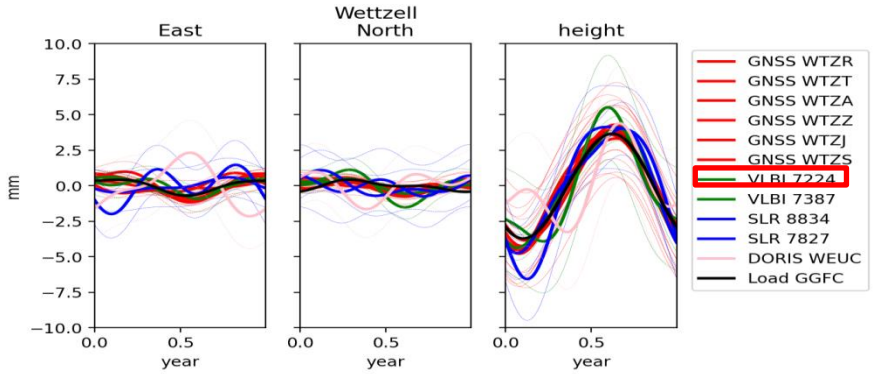
Sites with inconsistent signals

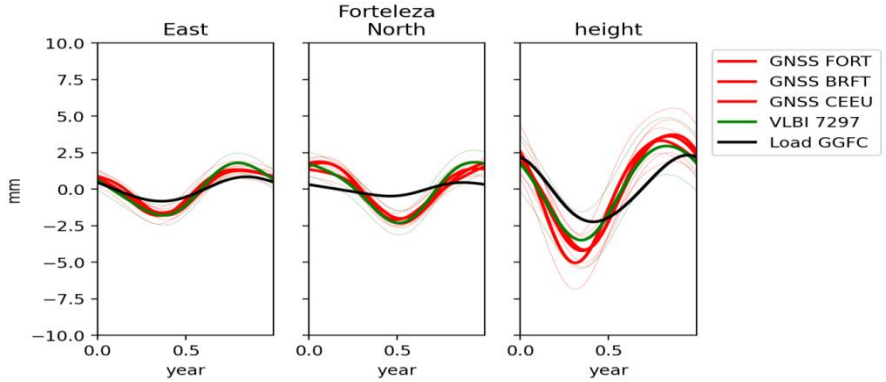
Overall interesting consistency !!

* For series with more than 150 pts, SLR > 1993.0

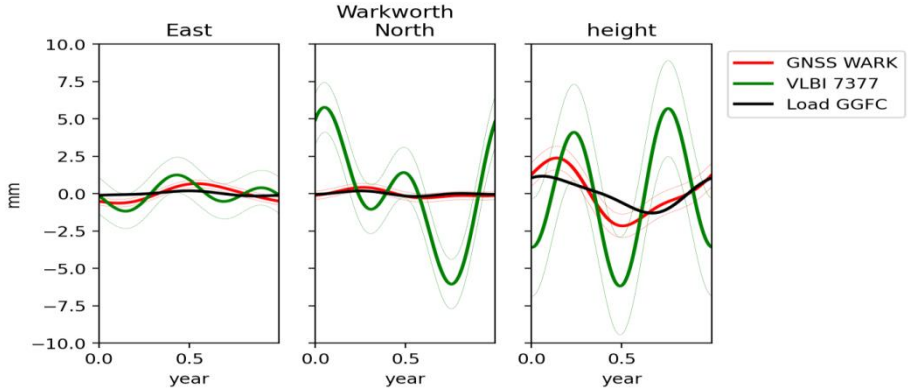
GNSS to VLBI

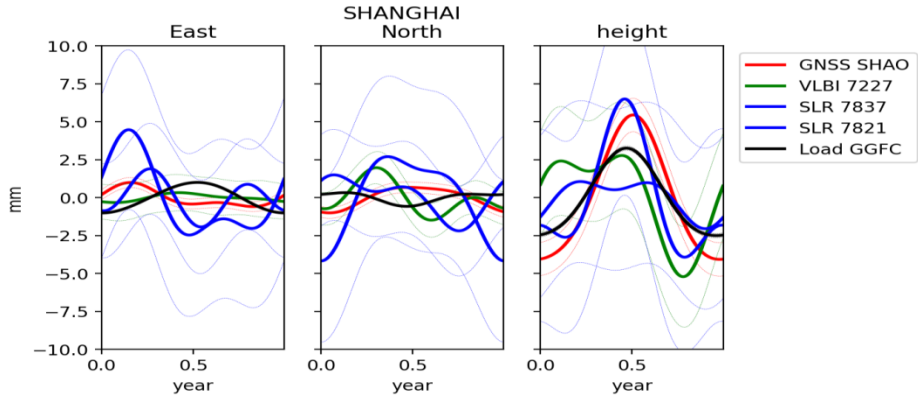
Good fit in vertical





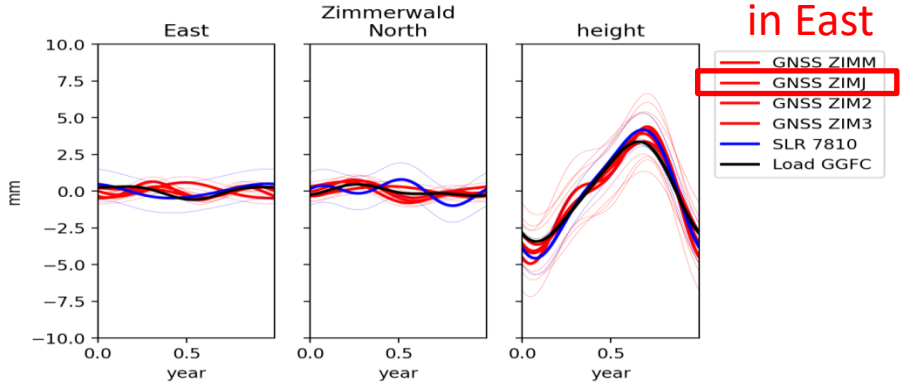
Bad fit in vertical



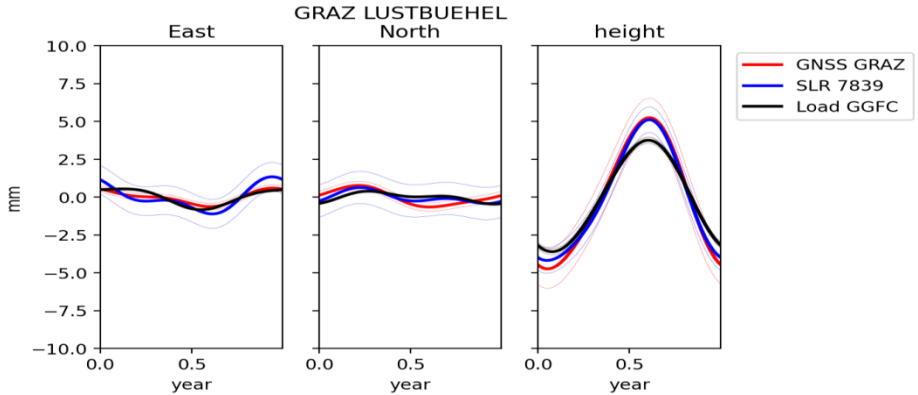


GNSS to SLR

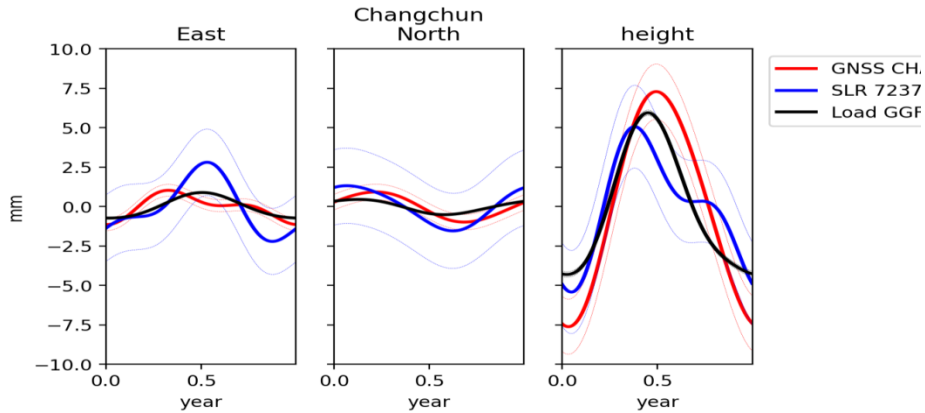
Good fit in vertical

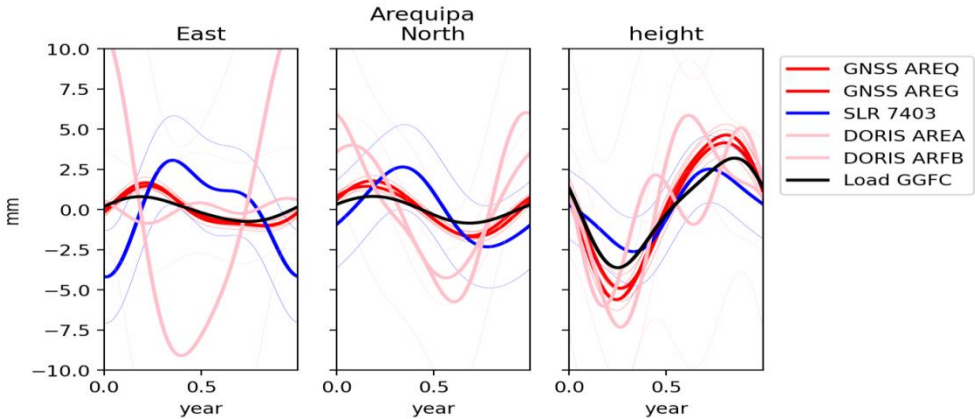


Inconsistent GNSS in East



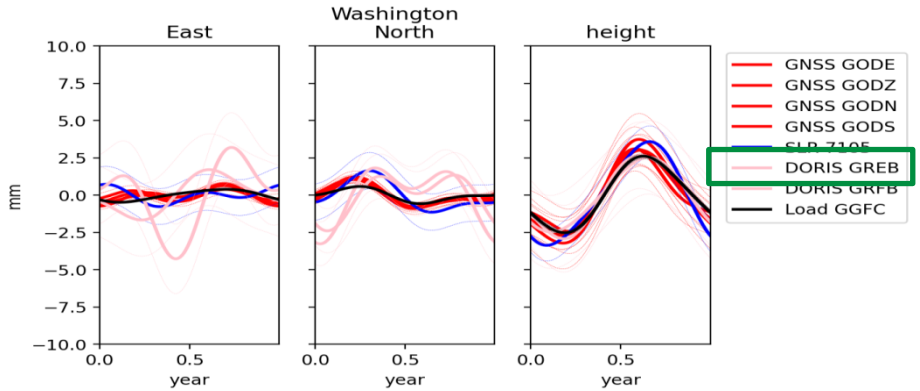
Bad fit in vertical

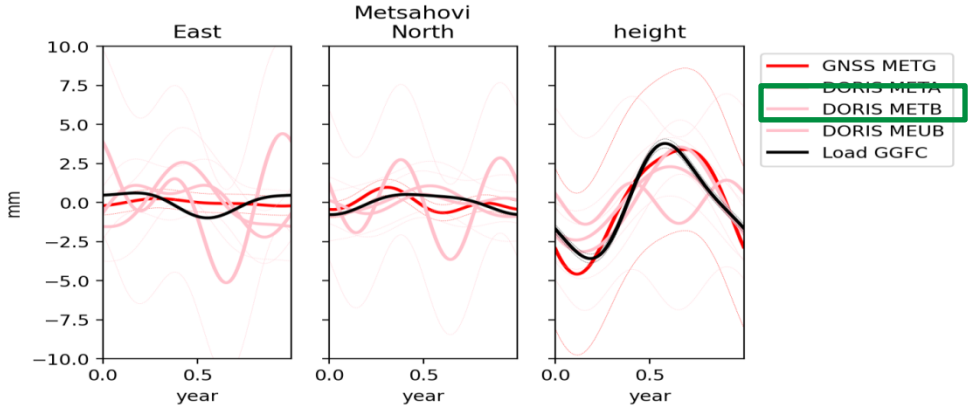




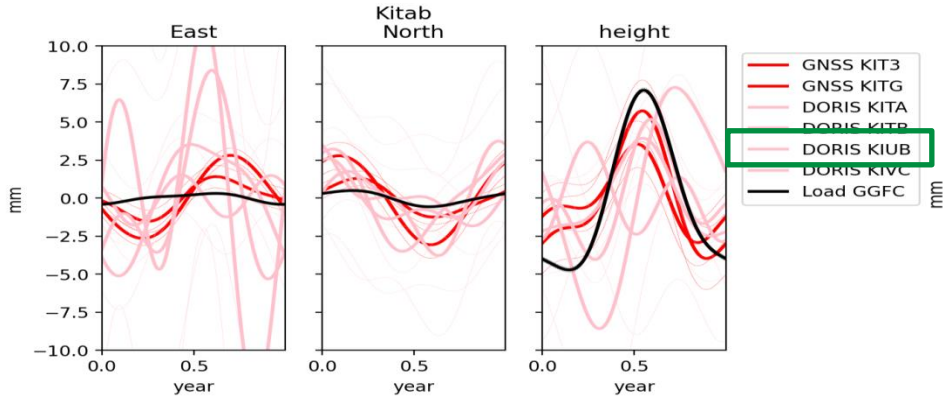
GNSS to DORIS

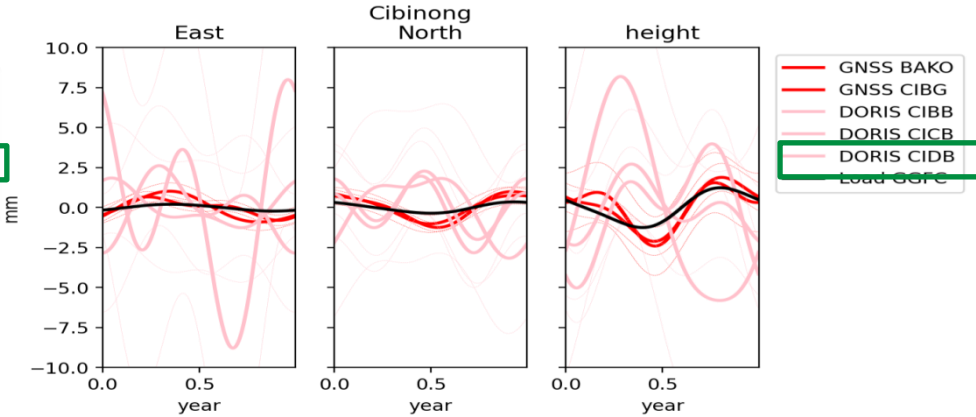
Good fit in vertical





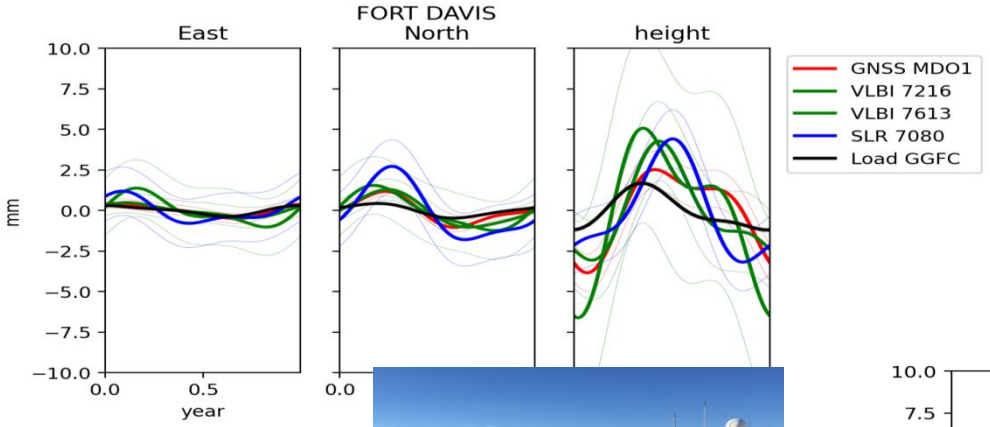
Bad fit in vertical

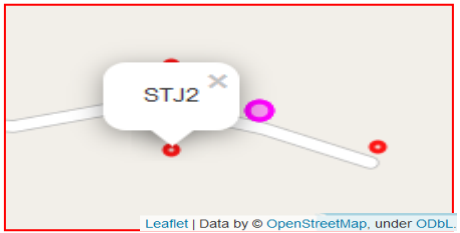


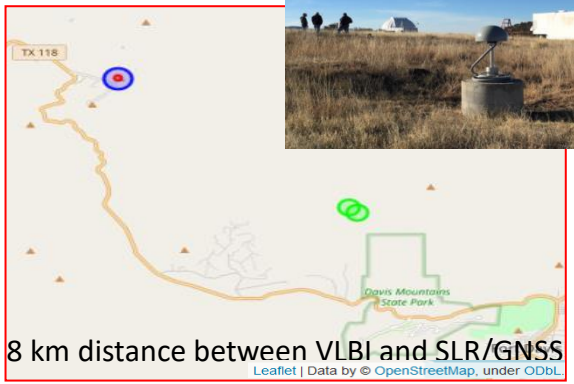


GNSS ?

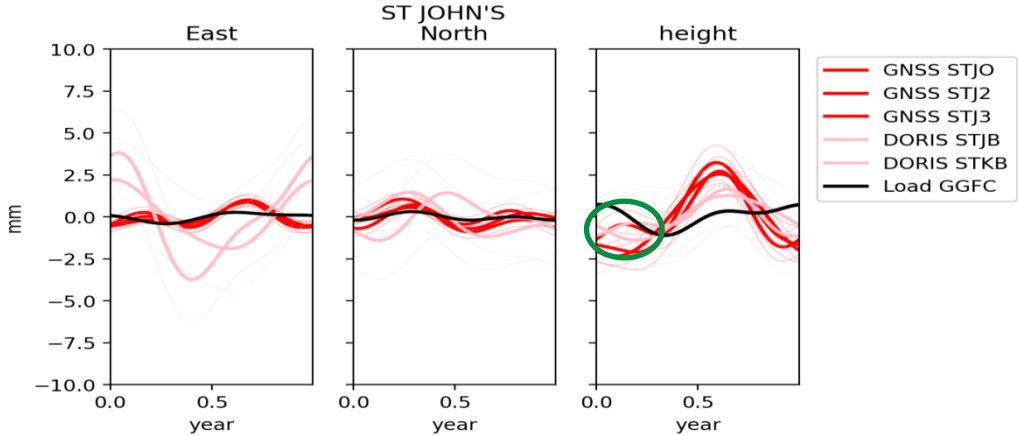
Bad fit in vertical







8 km distance between VLBI and SLR/GNSS



Source picture: https://igs.org/imaps/station.php?id=MDO100USA#gallery-4

Conclusion

ITRF2020:

- Seasonal displacements from different technique determinations have been constrained at co-location sites
- But non-unique seasonal displacement parameters provided in ITRF2020 for some sites
- Time-varying seasonal displacements have been averaged: ITRF2020 seasonal displacements are constant

Comparison of seasonal displacements:

- The RMS of height seasonal series differences between the longest GNSS series and other co-located series are smaller than 2.0 mm in vertical for
  - 72% of SLR and for 68% of VLBI series in vertical
  - 57% of DORIS series in vertical

  Larger than what is expected from sampling effect predicted by non-tidal loading models.

- But overall good consistency when considering realistic and uncorrelated seasonal signal fit standard deviations (VWN+PL): more than 90% of the SLR, VLBI and DORIS height seasonal series agree with GNSS at the 3σ level. More inconsistency for DORIS seasonal signals in horizontal (27% > 3σ). Our VWN+PL noise model for SLR is likely pessimistic.

- Good consistency implies:
  - **Combining seasonal parameters is relevant**
  - **The transfer of SLR origin to all other technique estimated seasonal signals in ITRF2020 should be satisfying. -> good confidence in ITRF2020 geocenter motion**

References

- Altamimi, Z., P. Rebischung, X. Collilieux, L. Métivier and K. Chanard (2022) ITRF2020: An overview of its features and results, REFAG 2022, this meeting

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