Exploitation of post-fit residuals in global GNSS network processing

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Introduction

- Global navigation satellite systems (GNSS) products such as GNSS clocks, orbits and phase biases are integral to a wide array of scientific and commercial applications
- Products are generated by analysis centre of the International GNSS Service (IGS) by processing observations from a global network of ground stations

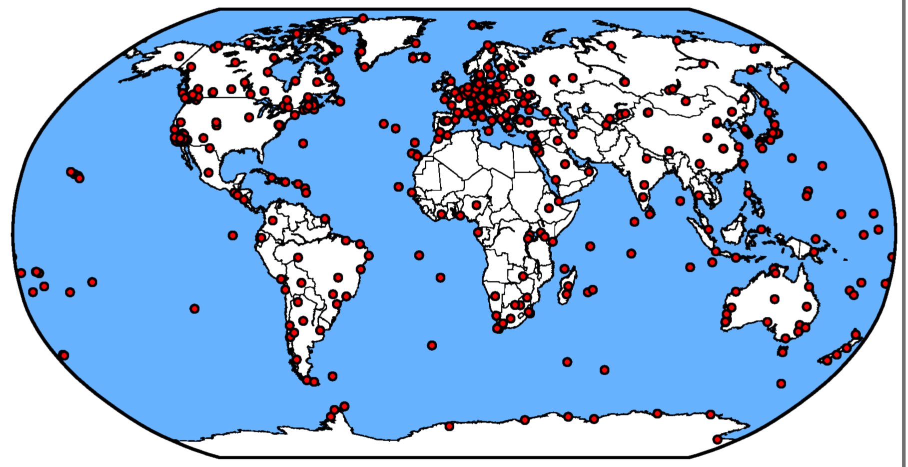

Fig.1: IGS station network for permanent GNSS processing

- Within global multi-GNSS network processing observation noise is assumed to be elevation-dependent and any spatial and temporal correlations are disregarded
- In this work we present the results of exploiting post-fit residuals for temporal correlations and their influences on the GNSS products such as orbits and station position time-series
- Furthermore, we present the current development in enhancing the cycleslip detection in GROOPS [1]

Processing strategy for estimating temporal correlations

- Iterative processing strategy wheras the post-fit residuals are computed by first using a simple a priori elevation based weighting model
- Estimated temporal correlation are reintroduced into the global GNSS processing by decorrelating the designmatrix by cholesky decomposition

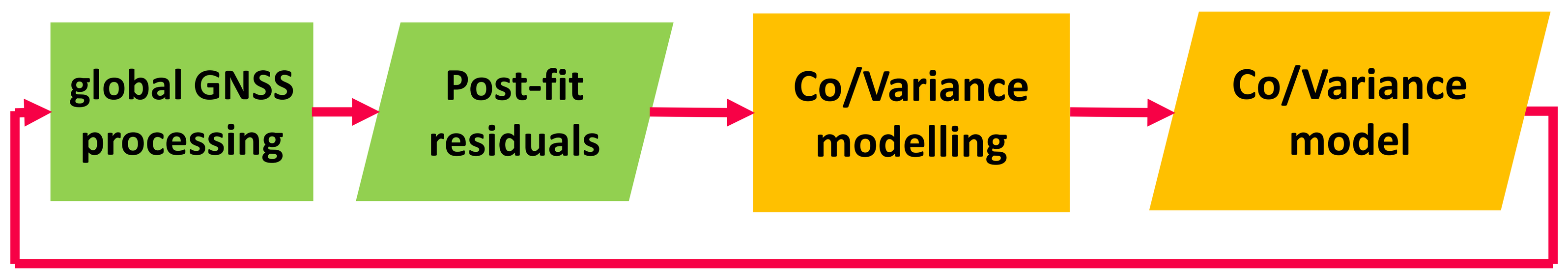

Fig.2: Work flow for the post-fit residual Co/Variance modelling

- Co/Variance modelling with autoregressive (AR) modeling is done exploiting post-fit residuals in a four step temporal corelation approach based on [2] and further enhanced for general global GNSS network processing by multipath-hemispheric-map filtering (MHM) [3] and other considerations [4]

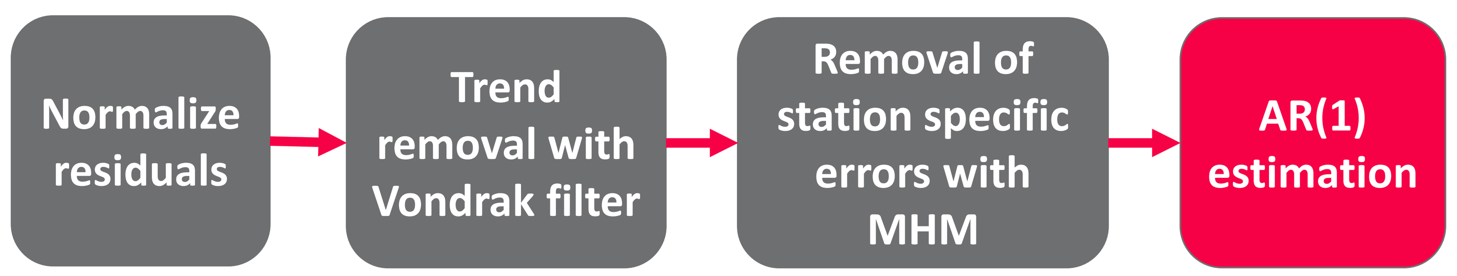

Fig.3: Flowchart for the four step remporal correlation estimation with post-fit residuals and AR processes

Analysis scenario

- Same models, procedures as were used in the TUG repro3 [5]
- 200 stations were investigated in the time span from 2011 till 2020 with GPS and Galileo
- Each year investigated was split into 60 day intervals to compensate for yearly changes within the temporal correlations [4]
- For each GNSS and observation type a stochastic model was estimated independently (e.g. L1CG* and L1CE* handled seperately

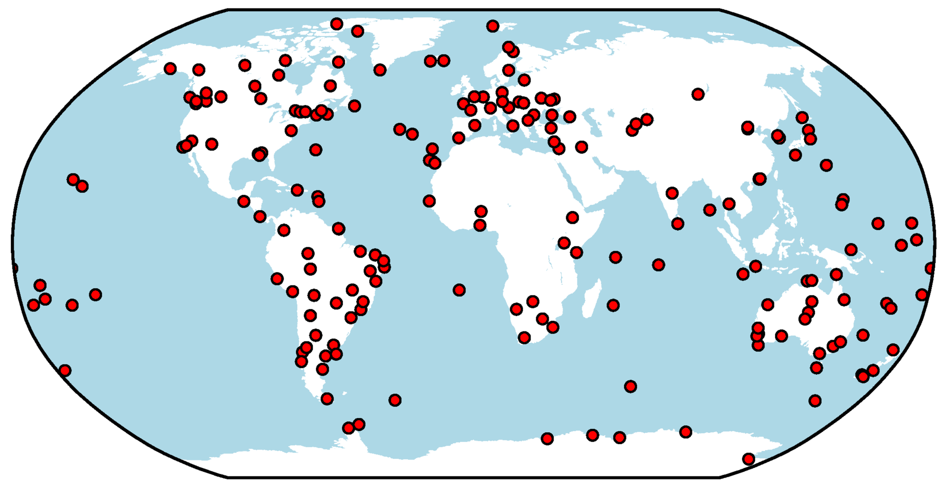

Fig.4:Selected stations investigated for the analysis

Impact of temporal correlations on station position timeseries

- Station position time series of the reference solution and the solution using temporal correlations were compared in the IGB14 reference frame by changes in the Root-mean-square-error (RMS)
- Orbit quality evaluated by midnight orbit discontinuities RMS

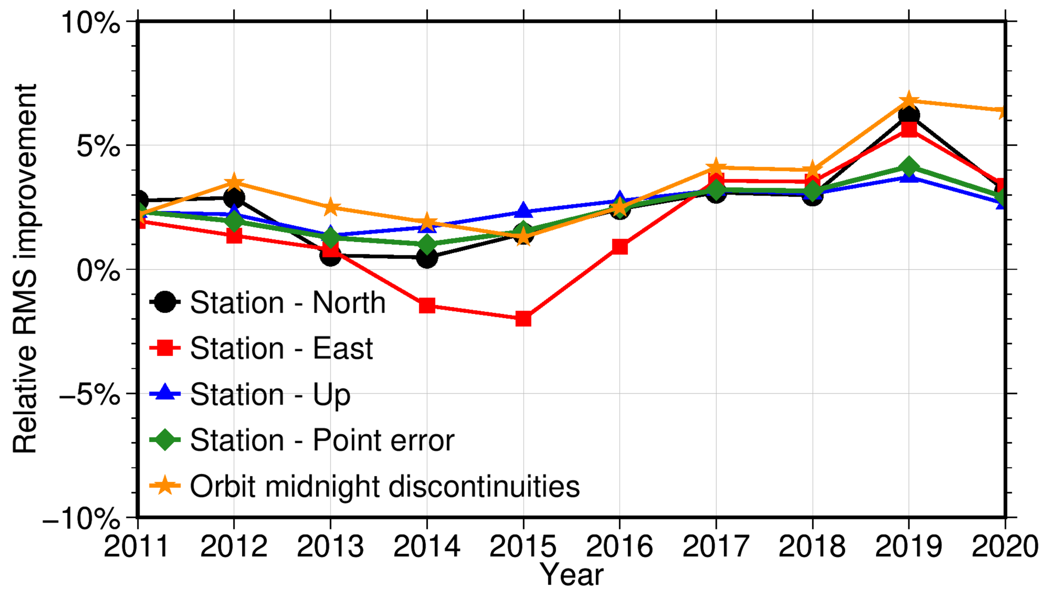

Fig.5: Average RMS improvement in the station position timeseries over the investigated timespan

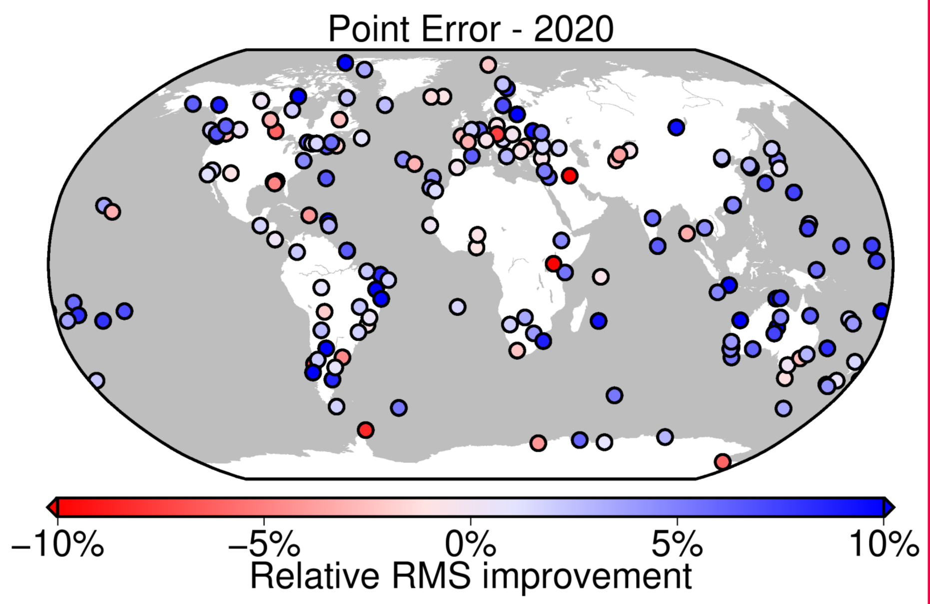

Fig.6: Relative improvement of the RMS for the individual station position timeseries in the year 2020

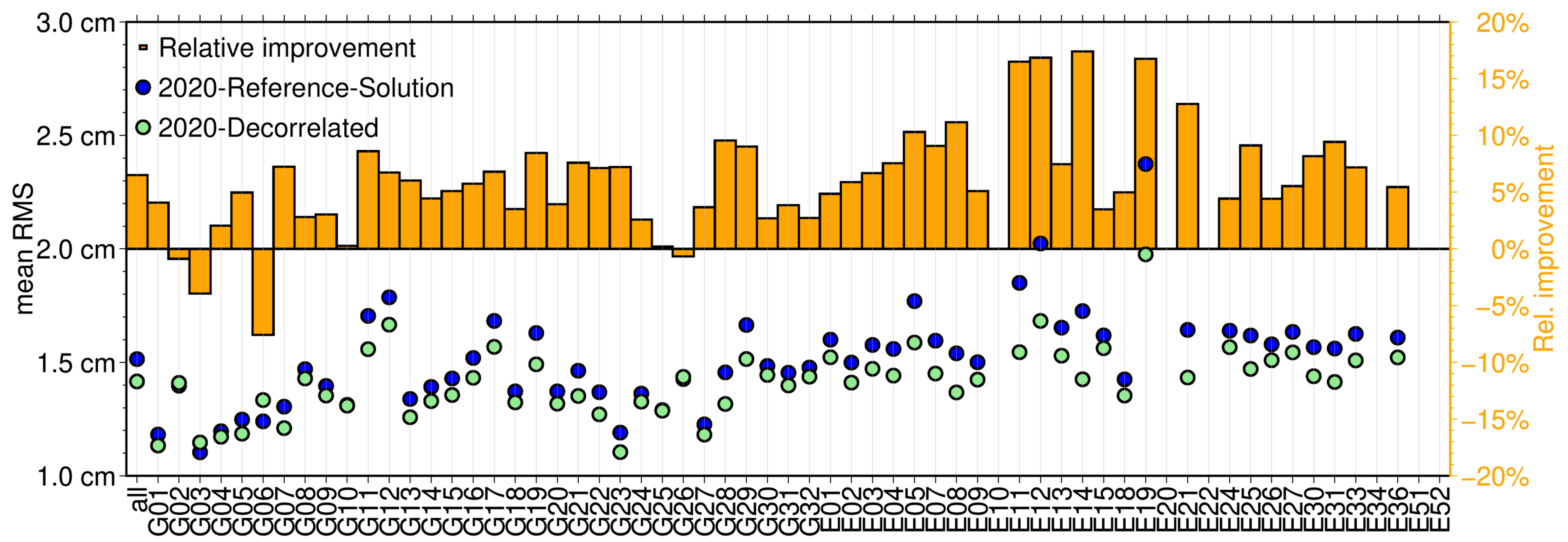

Fig.7: Average orbit midnight discontinuity RMS and the relative improvements from the reference solution for the year 2020

GROOPS cycleslip detection and post-fit residuals

- Idea is to expand the GROOPS [1] GNSS cycleslip detection [5] with an additional cycleslip detection step after the float solution of the evaluated stations
- Additional step allows more refined a priori info along with float residuals to increase robustness in high noise and low elevation observed phases

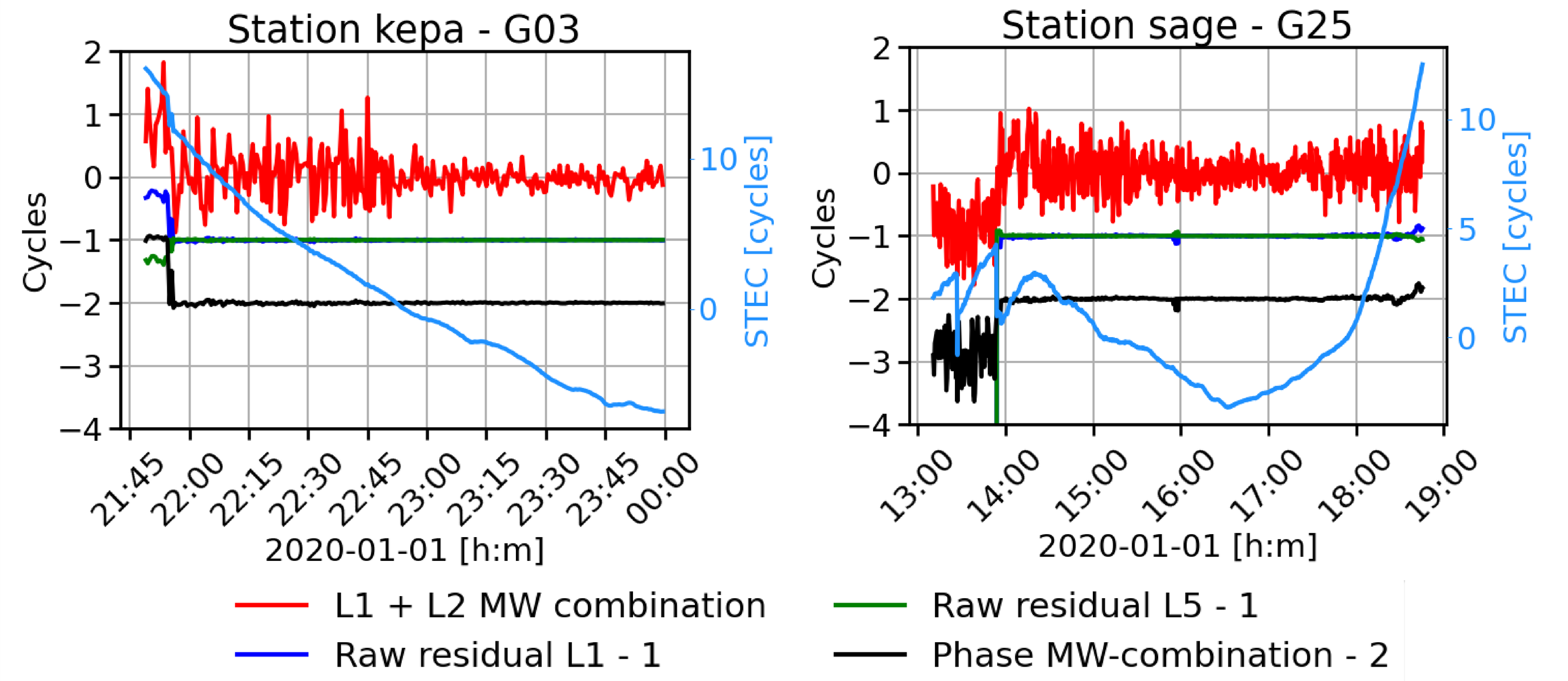

Fig.8: L1, L2 observation and residual MW combination, raw phase residuals and estimated STEC for station KEPA (SONEL network) and SAGE (SIRGAS snetwork) during cycleslip events

- Another issue arised with a number of GNSS stations showing temporal behaviour in their epoch wise ambiguities which require a new form of detection so that the stations can be excluded or downweighted in the GNSS processing chain

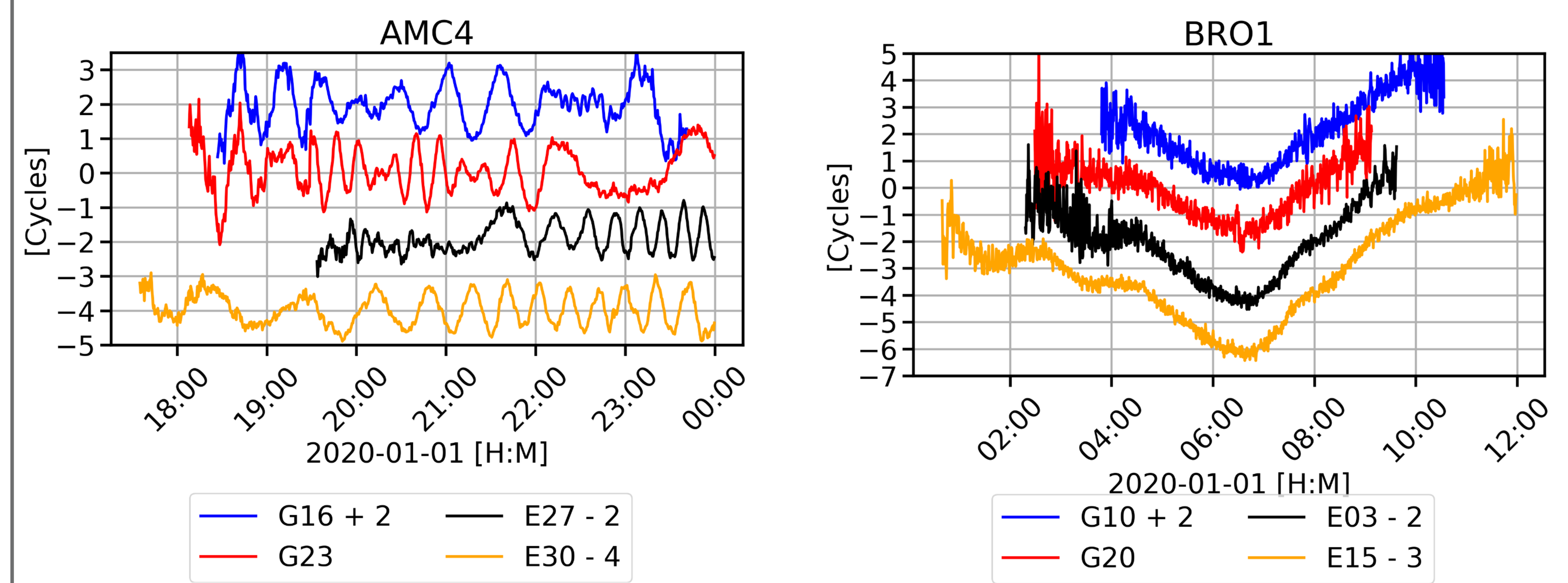

Fig.9: Temporal behaviour of MW combined phases of station AMC4 (IGS Network) and BRO1 (APREF Network)

Conclusion and Outlook

The inclusion of a more sophisticated stochastic modelling by post-fit residuals brought significant improvements within orbits and station position timeseries as well as other GNSS products. Especially in later investigated years were multi-GNSS becomes more prominent the improvements increased. Furthermore, we illustrate our idea for incorporating post-fit float residuals into cycle slip detection. This idea is still work in progress and further analyses are required to give a verdict. Also, a new issue arised with a number of stations having temporal behaviours in the ambiguities which require more research.

Acknowledgments

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