Analysis of Non-Tidal Loading Deformation at VLBI Sites

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Introduction

Non-tidal load such as atmospheric pressure, and water mass redistributions (over land and ocean) can displace geodetic sites by few cm on annual to sub-diurnal periods affecting accuracy of VLBI technique. This study aims to compare non-tidal loading products retrieved from loading services and assess their influence on VLBI analysis by implementing it in Vienna VLBI and Satellite Software (VieVS).

Table 1: Loading services and models used in the study

Service	Loading	Model
VMF (Vienna Mapping Functions Data Server)	NTAL	ECMWF
IMLS (International Mass Loading Service)	NTAL	MERRA2
	NTOL	MPIOM06
	HYDL	MERRA2
EOST (École & observatoire des sciences de la Terre de l'Université de Strasbourg)	NTAL	ECMWF
	NTOL	ECCO1
	HYDL	GLDAS2
ESMGFZ (Earth-System-Modelling group GFZ)	NTAL	ECMWF
	NTOL	MPIOM
	HYDL	LSDM

Loading Models and Data Format

For each loading type, multiple models are available for deriving the loading products. Models are selected for each loading type of different services based on data availability, data time steps, update frequency and resolution. Data retrieved from different services are made compatible with VMF data format for comparison in VieVS.

Methodology

Identifying common stations among various loading services considering the availability of data (163 ITRF VLBI Sites)

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Model selection for each loading type of different services and extraction of 1 year (2020) data for CM-frame

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Direct Comparison – Site displacement time series of services, RMS of difference of site displacement between two services

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Indirect Comparison and influence of non-tidal loading on VLBI analysis- BLR, Station Height Standard deviation, and Reduction of variance coefficient comparison using VieVS

Implications and Outlook

- Variation in site displacement time series, particularly for HYDL of ESMGFZ (Figure 1) could be attributed due to the utilization of distinct models with varying resolutions by different services. Additionally, the separate treatment of SLEL in order to achieve global mass conservation in the case of ESMGFZ may contribute to this discrepancy. Other services incorporate partial mass conservation in both NTOL and HYDL. Higher RMS value evident in the comparison between GFZ and EOST (Figure 2) can also be attributed due to the same underlying factors.
- Variation in improvement of BLR among different services (Figure 3) is primarily due to HYDL and NTOL. BLR improvement is almost same among services when NTAL is only applied which represents consistency between ECMWF and MERRA2 data for non-tidal atmospheric loading.
- Standard deviation difference of time series of station height before and after applying NTAL loading shows that estimation of station coordinates improves upon application of loading models (Figure 4). Also, results from different services are consistent with each other.
- The presence of large R values (R > 1) in all services (Figure 5) currently lacks an explanation. In order to enhance our understanding of this phenomenon, we will incorporate a broader range of data spanning approximately 20 years. We expect that this extended timeframe will provide valuable insights and contribute to a more comprehensive analysis.

Acknowledgement

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Results and Discussions

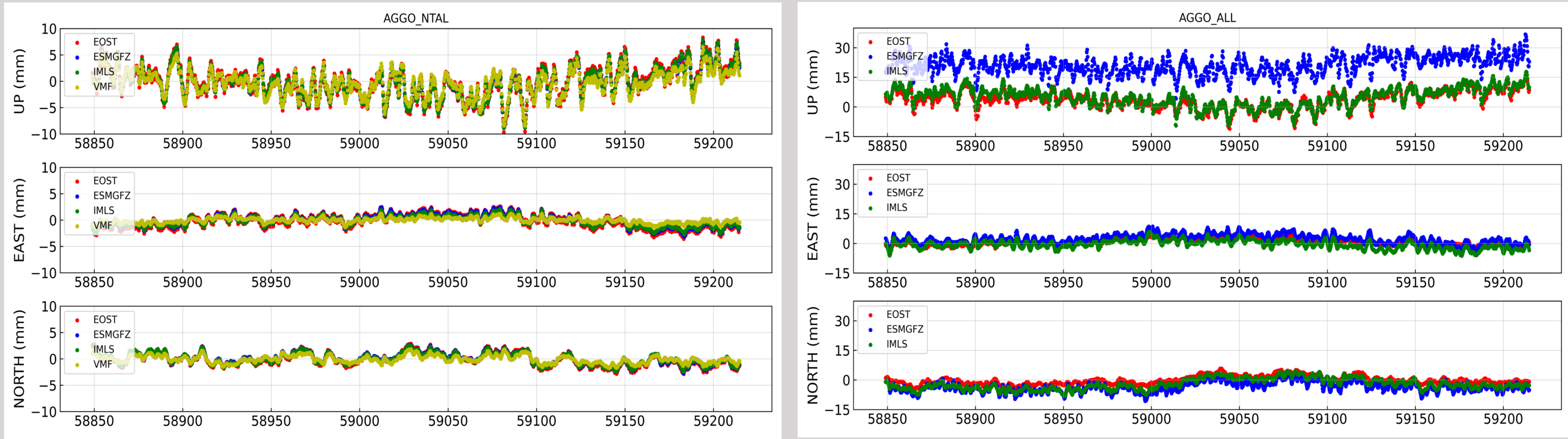

Figure 1. Time series of site displacement due to NTAL and due to all non-tidal loading in CM-frame at AGGO station. Site displacement time series due to non-tidal loading from different services are consistent with one another except in case of ESMGFZ. Site displacement in up direction is almost three times larger than site displacement in horizontal direction.

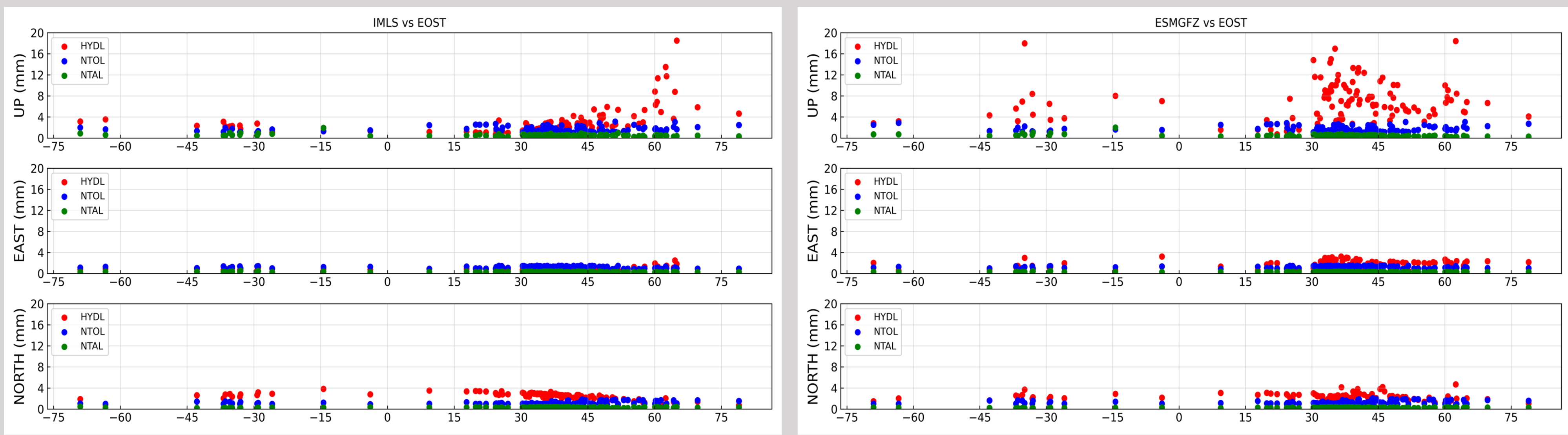

Figure 2. RMS values of difference of site displacement due to all non-tidal loading between IMLS and EOST (left) and between ESMGFZ and EOST (right). Large RMS values are mainly observed between 30°N to 65°N for UP direction. The RMS values between two services are maximum for HYDL component specially in case of ESMGFZ vs EOST (right) with mean value of 6.7 mm and maximum RMS value of 18.5 mm for UP direction.

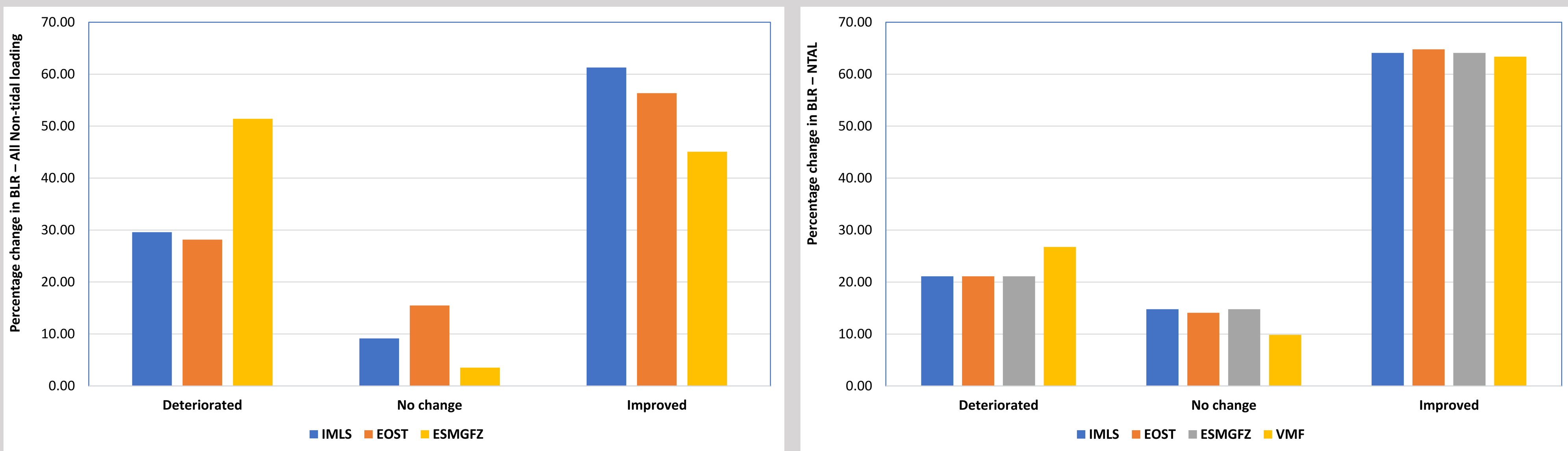

Figure 3. Percentage change in BLR before and after applying all non-tidal loading (left) and before and after applying NTAL loading only (right). Different services shows same BLR improvement when only NTAL is applied (78% of baseline improve/no change). However, after applying all non-tidal loading models, 71.83% of baselines improve or show no change in case of EOST, 70.4% of baselines improve or show no change in case of IMLS, and only 48.59% of baselines improve or show no change in case of GFZ.

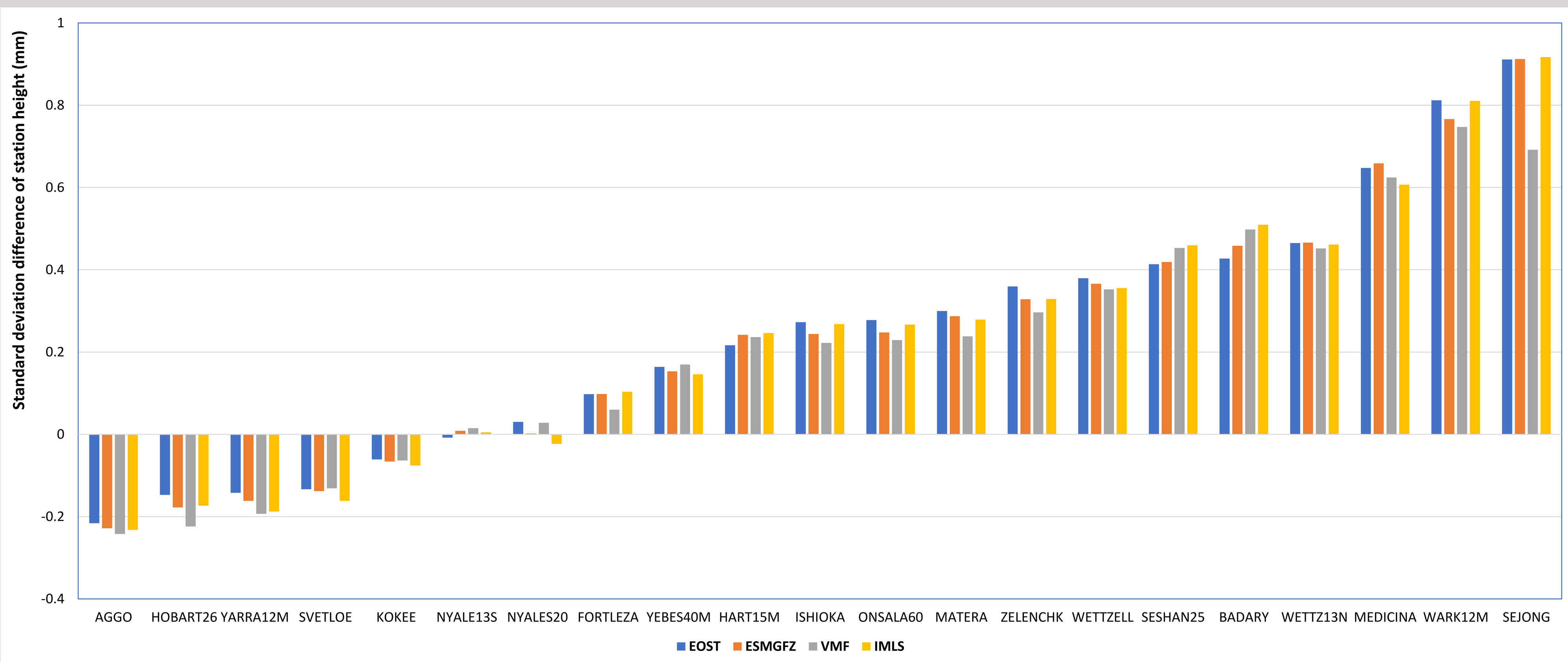

Figure 4. Standard deviation difference of time series of station height before and after applying NTAL of different services.

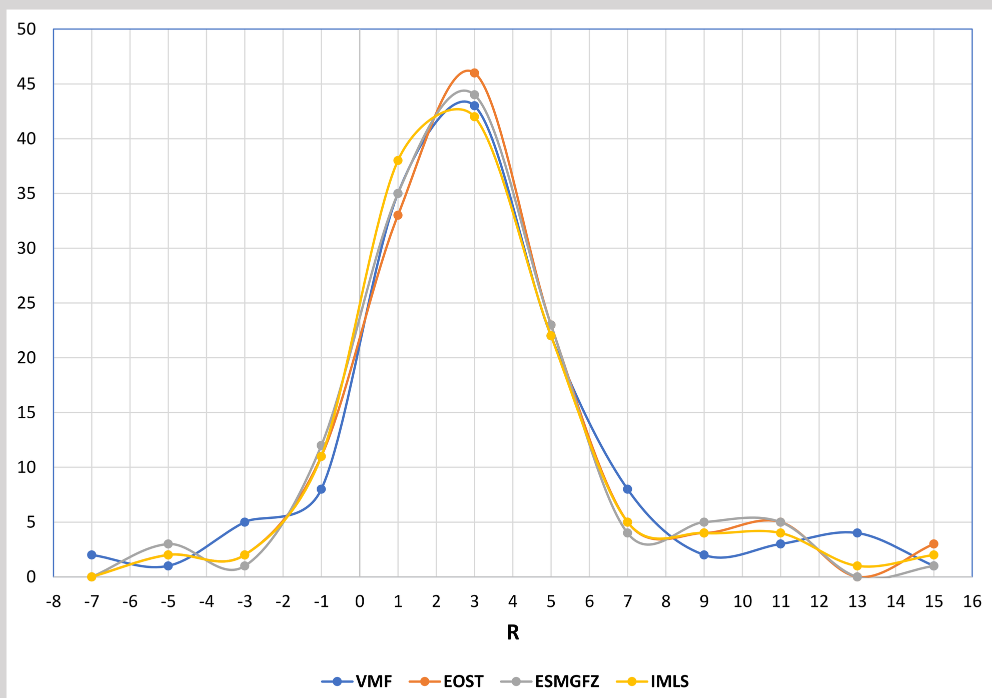

Figure 5. Histogram of distribution of Reduction of variance coefficient,

$$R = \frac{(\Delta\sigma^2 + \sigma_m^2)}{2\sigma_m^2},$$

Where $\Delta\sigma^2$ is the change in variance before and after applying loading models and σ_m^2 is the variance of the signal in the model and is determined through simulation within the VieVS framework. A perfect model would yield an R value of 1. Negative R values indicate a deterioration in results after applying the non-tidal loading model, while R values greater than 1 suggest that the improvement exceeds expectations. The weighted mean value of R is approximately 3 for all the four services.

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