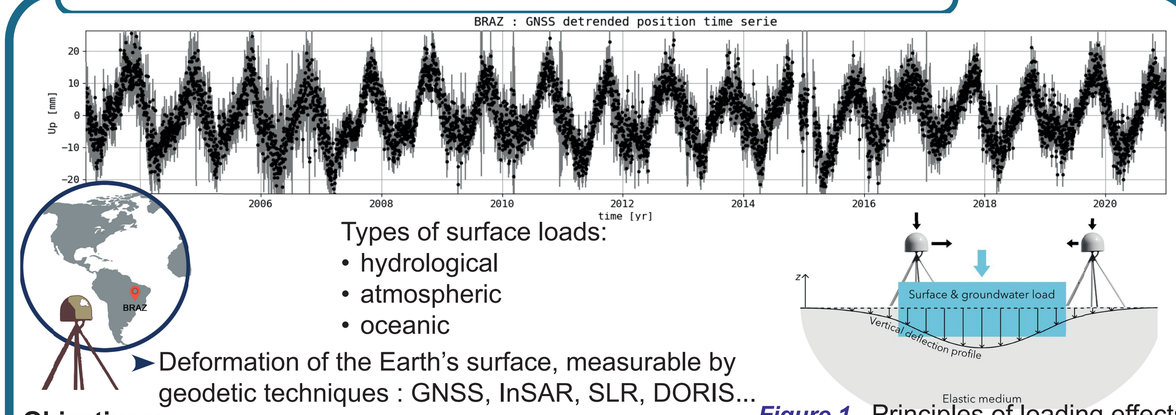
Comparative Analysis of Surface Loading Models for Predicting GNSS Surface Displacements

P2: 020

Julien Barnéoud[1,2], Kristel Chanard[1,2], Paul Rebischung[1,2], Kevin Gobron[1], Laurent Métivier[1,2], Zuheir Altamimi[1,2]

[1]Université de Paris, Institut de Physique du globe de Paris, CNRS, IGN, F-75005 Paris, France [2]Univ Gustave Eiffel, ENSG, IGN

1 - How do surface loads deform the Earth ?



Types of surface loads:
- hydrological
- atmospheric
- oceanic

➤Deformation of the Earth's surface, measurable by geodetic techniques : GNSS, InSAR, SLR, DORIS...

Figure 1 - Principles of loading effects (Larochelle et al., 2022)

Objectives:
- Analyse & compare loading correction models on GNSS time series
- Focus on the influence of station-specific characteristics: station monuments & geographic location

2 - ALIEDOCS project

ALIEDOCS: an online computation service for hydrological, atmospheric and oceanic loading. Composed of an **API**, a **database** and an **User Interface** (***Figure 2***). Developed and hosted by the Institut de Physique du Globe de Paris (IPGP-IGN).

Objectives:
- centralize access to loading models database
- visualize and compare loading models, include a wide range of options
- compute deformation time series at any point on the Earth's surface

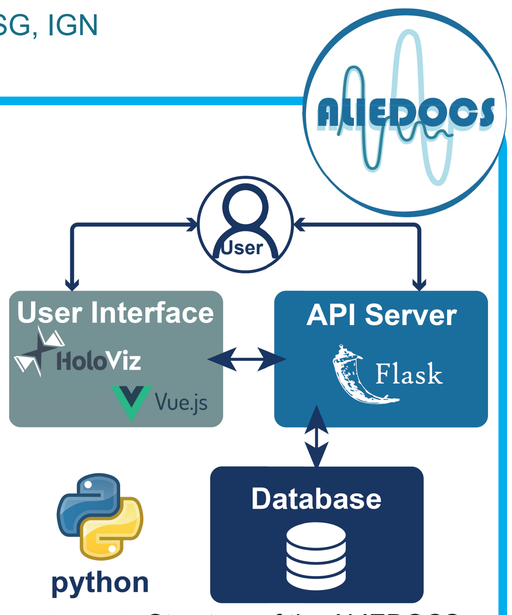


Figure 2 - Structure of the ALIEDOCS service

3 - Dataset

Loading models computed with Aliedocs service (see **2.**)
- hydrological, atmospheric and oceanic loading models (Beaudoing et al., 2020; Gelaro et al., 2017; Hersbach et al., 2023; Menemenlis et al., 2008)
- GRACE/-FO solutions (Dahle et al., 2019; Gauer et al., 2023)

GNSS time series:
- IGS repro3 campaign, ~1.300 stations (Rebischung et al., 2024)
- Nevada Geodetic Laboratory (NGL), ~ 11.000 stations (Blewitt et al., 2018)

GNSS station metadata:
- monuments (description, foundation, geology, height)
- antenna & receiver

extracted from sitelogs & monument table

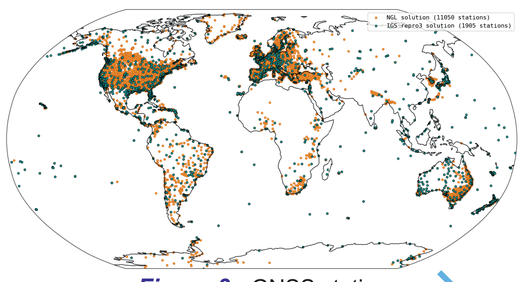


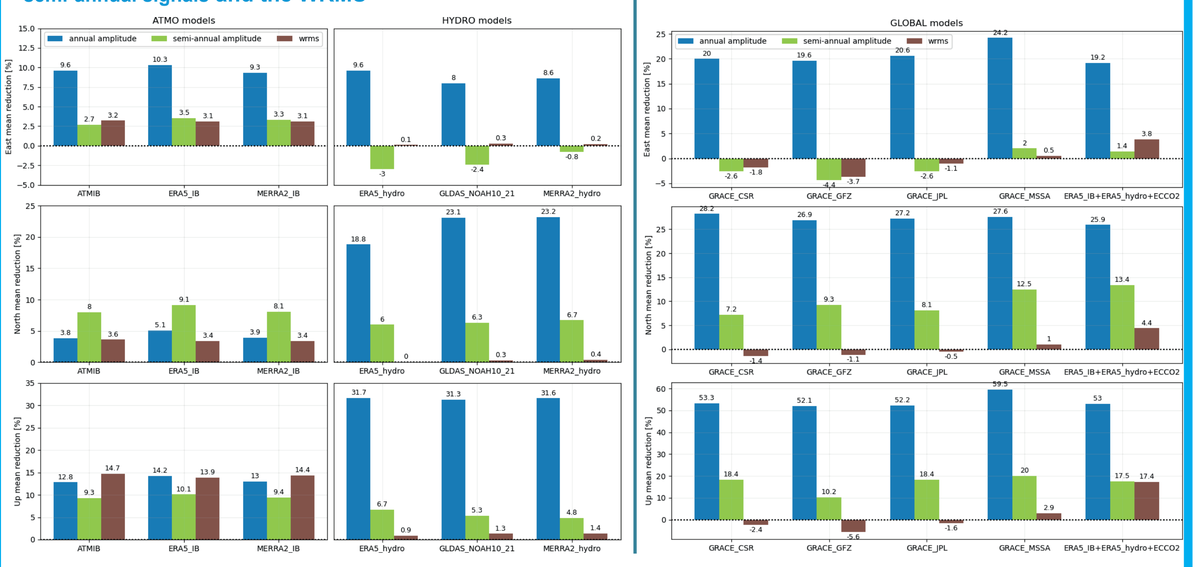
Figure 3 - GNSS stations

4 - Loading models comparison

IGS repro3 dataset

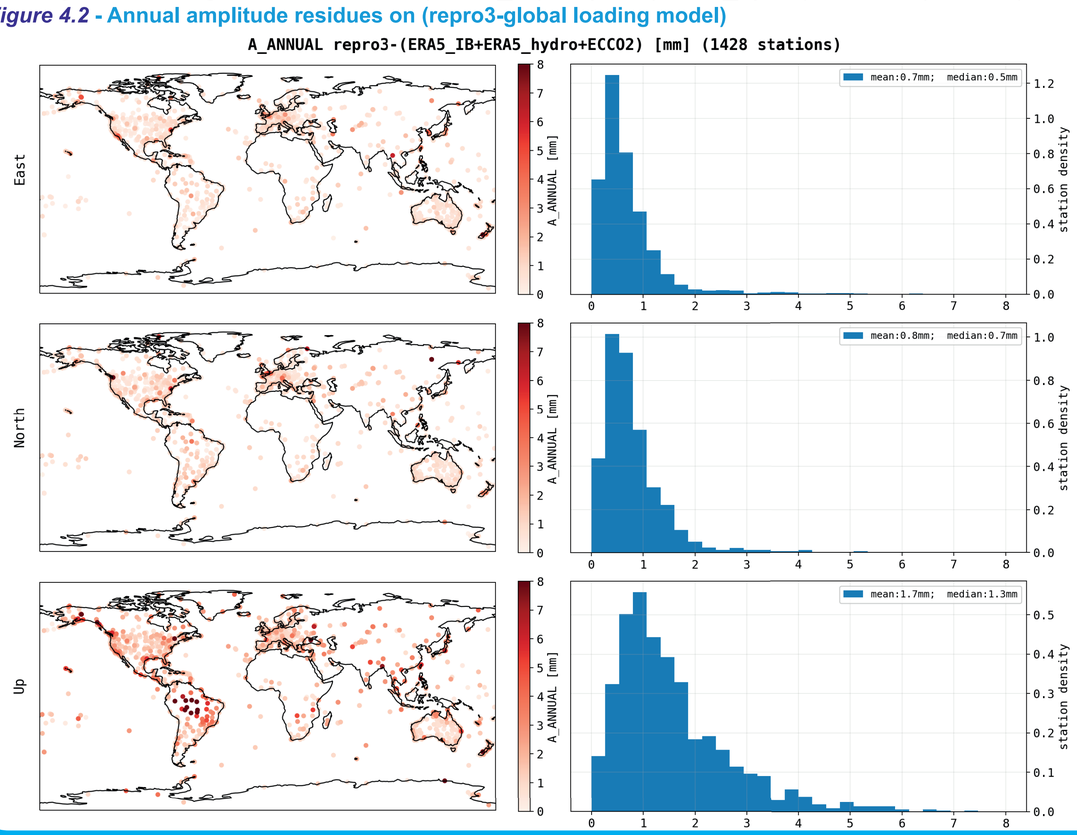
- Loading models comparison based on annual amplitude, semi-annual amplitude & WRMS

Figure 4.1 **- Loading models comparison: % mean reduction on the amplitudes of annual signals, the amplitudes of semi-annual signals and the WRMS**



- Build global loading model with atmo (ERA5_IB) + hydro (ERA5_hydro) + ocean (ECCO2)

Figure 4.2 **- Annual amplitude residues on (repro3-global loading model)**

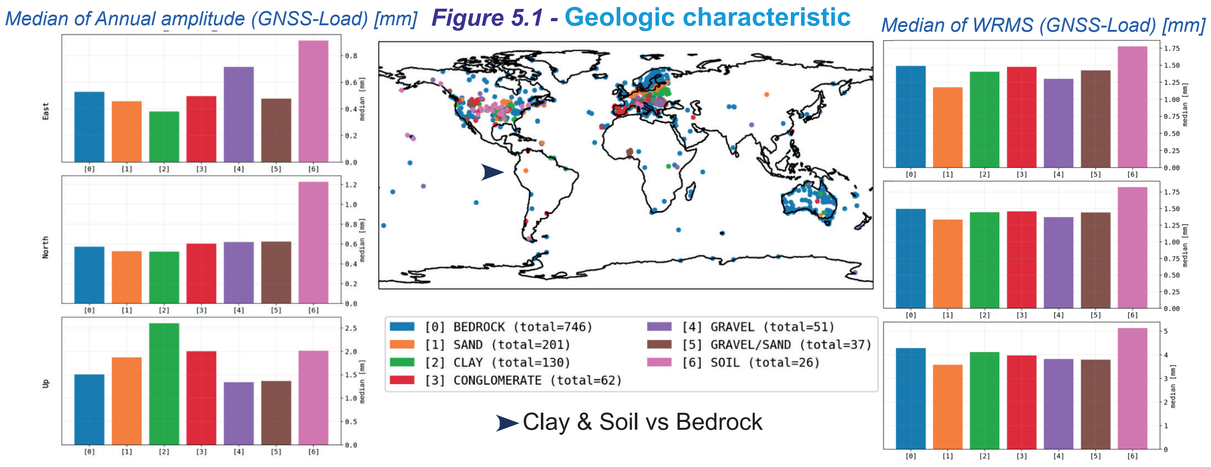


5 - Influence of station-specific characteristics on loading correction performances

Focus on NGL solutions (~11.000 stations), residual time series (GNSS - loading model).
Global loading model corrections (see **4:** ERA5_IB+ERA5_hydro+ECCO2)

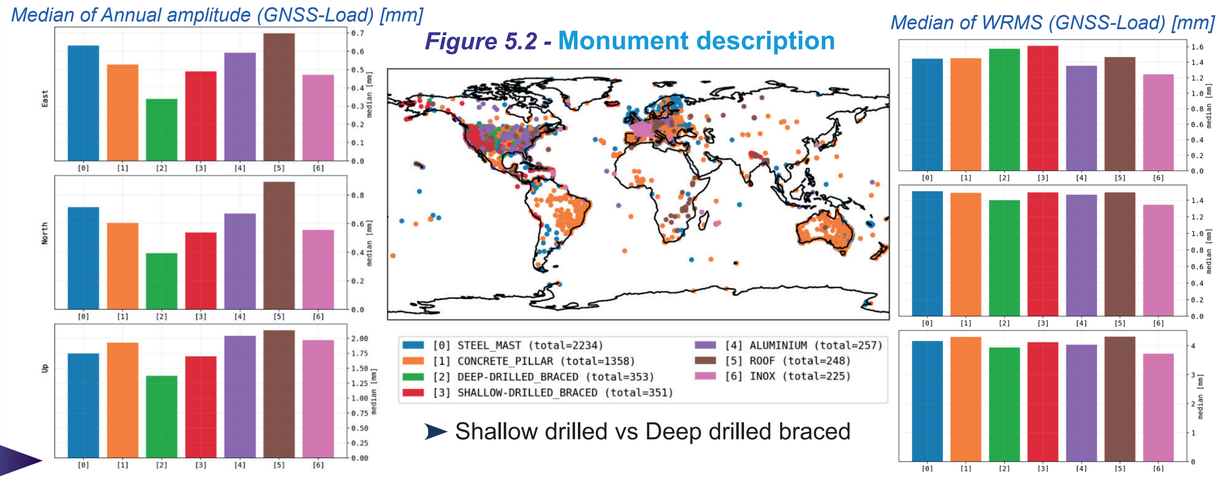
➤Investigated influence of station monument parameters, extracted from sitelogs:
- 'geologic characteristic'
- 'monument description'
- 'monument foundation'

Median of Annual amplitude (GNSS-Load) [mm] ***Figure 5.1 -*** **Geologic characteristic** *Median of WRMS (GNSS-Load) [mm]*



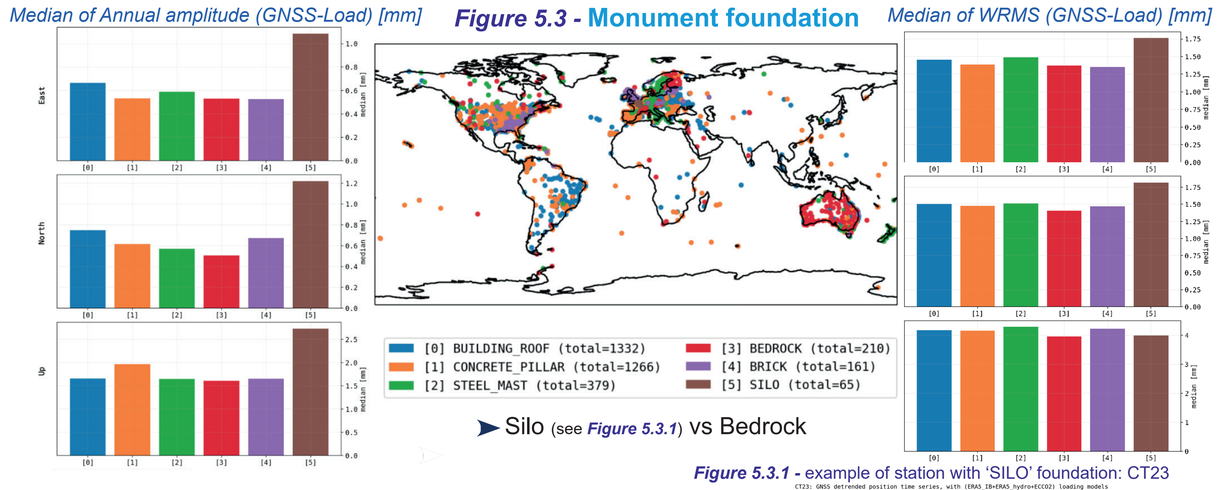
➤Clay & Soil vs Bedrock

Median of Annual amplitude (GNSS-Load) [mm] ***Figure 5.2 -*** **Monument description** *Median of WRMS (GNSS-Load) [mm]*



➤Shallow drilled vs Deep drilled braced

Median of Annual amplitude (GNSS-Load) [mm] ***Figure 5.3 -*** **Monument foundation** *Median of WRMS (GNSS-Load) [mm]*



➤Silo (see ***Figure 5.3.1***) vs Bedrock

Figure 5.3.1 - example of station with 'SILO' foundation: CT23

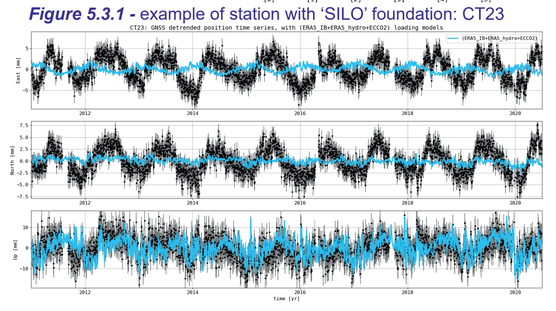
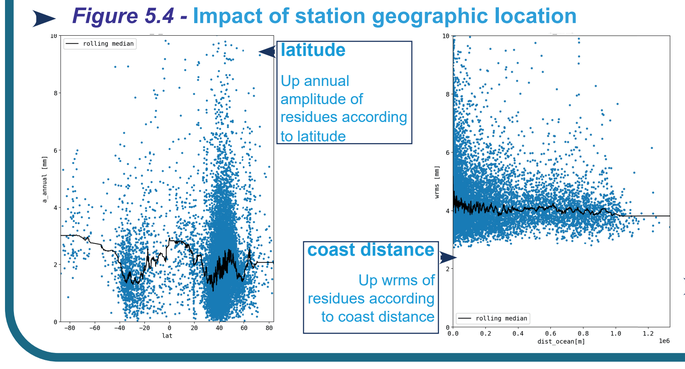


Figure 5.4 **- Impact of station geographic location**



➤*Other parameters considered, such as station height & depth, altitude, annual temperature variation: no signifiant bias.*

6 - Conclusion

Loading models (see **4.**):
- GRACE comparison: GRACE-MSSA provides better corrections of GNSS time series
- GRACE+dealiasing comparable with a global loading model (atmo+hydro+oceano) on annual and semi-annual reductions

Monuments (see **5.**): differences in GNSS time series corrected for loading effects according to station characteristics, such as geology ('CLAY', 'SOIL' vs 'BEDROCK') or monument foundation ('BEDROCK' vs 'SILO').
Similar results with (ERA5_IB+ERA5_hydro+ECCO2) model & GRACE_MSSA

- Outlook: focus on stations with abnormal motions compared to their neighbors and try to identify specific characteristics.

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Contact : julien.barneoud@ign.fr