Comparison of troposphere delays from GNSS and VLBI in R1 and R4 sessions

EVGA 2019 - Las Palmas de Gran Canaria

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19th March 2019

GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO INSTITUTO GEOGRÁFICO NACIONAL

Motivation and goals

- Motivation: VLBI analysis at National Geographic Institute of Spain. GNSS background.

- Goals: Address the following questions based on the analysis of R1 & R4 sessions for the period 2013-2018:

1. What are the differences of VLBI-based ZTDs with respect to different solutions of GNSS-based ZTDs in co-located sites?
2. Is there any subdaily pattern in the differences between techniques?
3. How GNSS-based ZTDs used as a priori value impact VLBI estimation?
4. What is the long-term behaviour of the wet and hydrostatic troposphere ties?

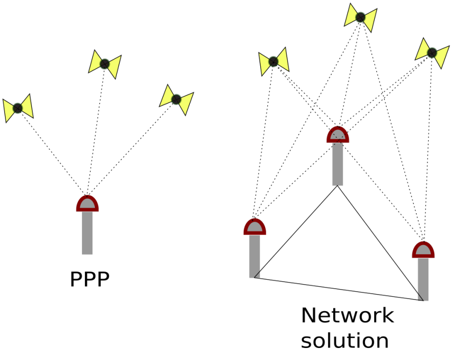
Q1. VLBI-GNSS ZTD differences

Q1: What are the differences of VLBI-based ZTDs with respect to different solutions of GNSS-based ZTDs in co-located sites?

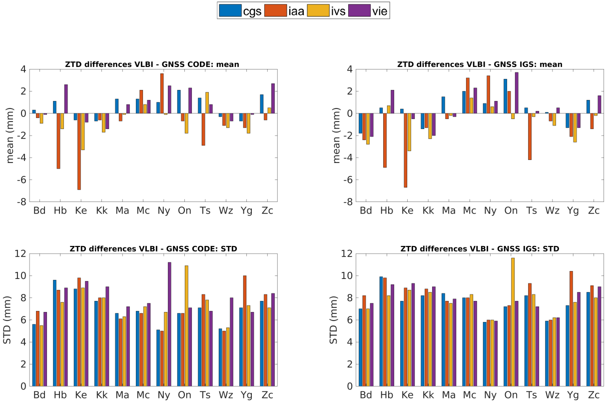
- Resources:
  - Co-located sites: Bd, Hb, Ke, Kk, Ma, Mc, Ny, On, Ts, Wz, Yg, Zc
  - VLBI-based ZTDs:
    - IAA
    - CGS
    - VIE
    - IVS combined solution
  - GNSS-based ZTDs:
    - CODE products: network solution. ZTDs estimated at 2 hours sampling.
    - IGS products: Precise Point Positioning (PPP). ZTDs estimated at 5 min sampling.
  - Period analysed: 2013-2018

2. VLBI-GNSS ZTD differences: subdaily analysis

- GNSS techniques



Q1. VLBI-GNSS ZTD differences

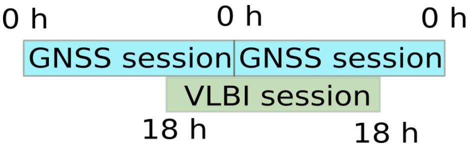


Solution	CGS	IAA	IVS	VIE
VLBI - GNSS CODE (units: mm)	0.7±7.0	-1.2±7.4	-0.7±7.2	0.8±7.9
VLBI - GNSS IGS (units: mm)	0.5±7.7	-1.3±8.3	-0.9±8.0	0.8±7.9

2. VLBI-GNSS ZTD differences: subdaily analysis

Q2: Is there any subdaily pattern in the differences between techniques?

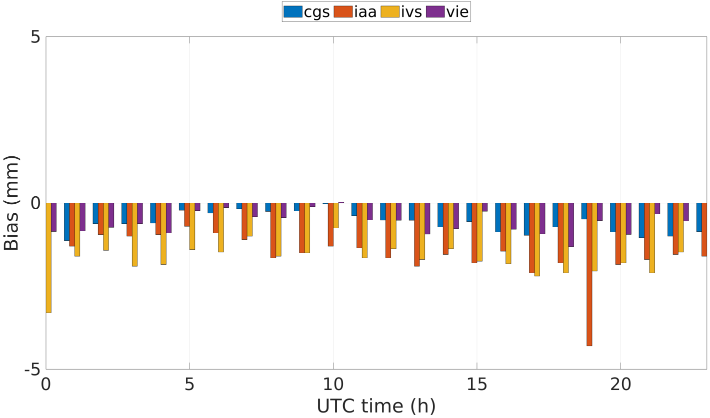
- VLBI and GNSS observation schema:



- Segment differences computed in the previous step by UTC hours.

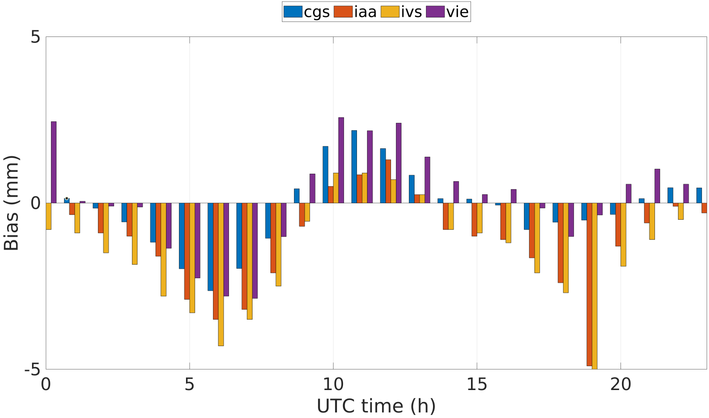
2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to CODE ZTD, segmented by UTC hours. Wettzell station.



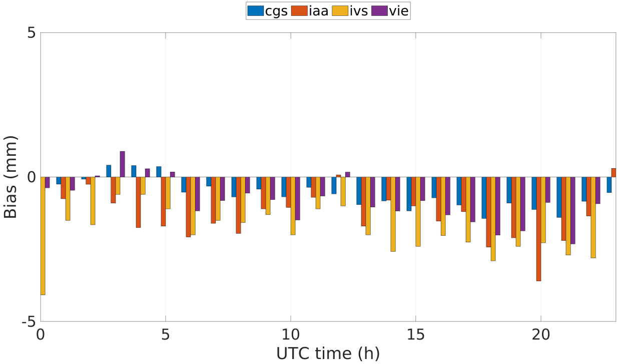
2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to IGS ZTD, segmented by UTC hours. Wettzell station.



2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to CODE ZTD, segmented by UTC hours. Yarragadee station.



2. VLBI-GNSS ZTD differences: subdaily analysis

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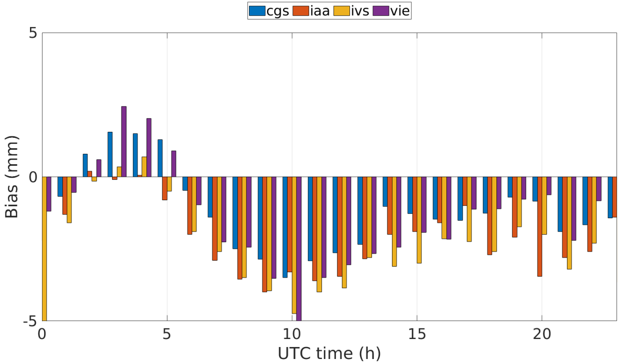
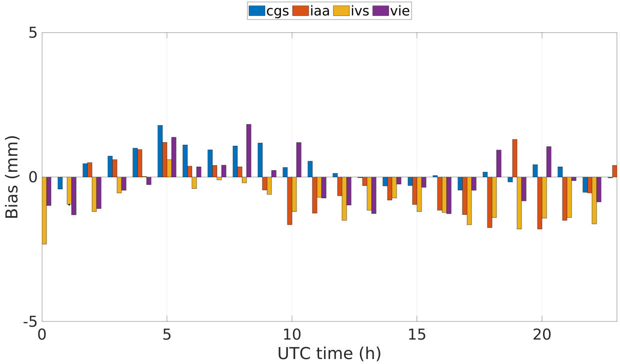


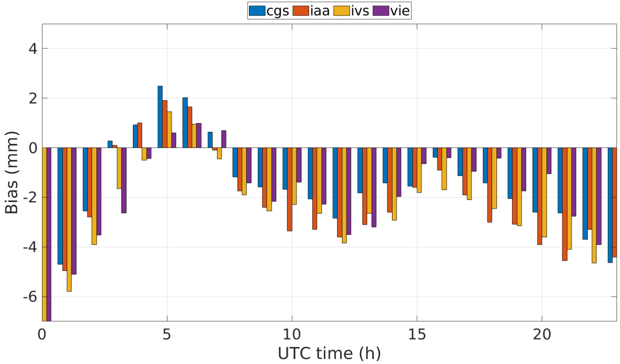
2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to CODE ZTD, segmented by UTC hours. Badary station.



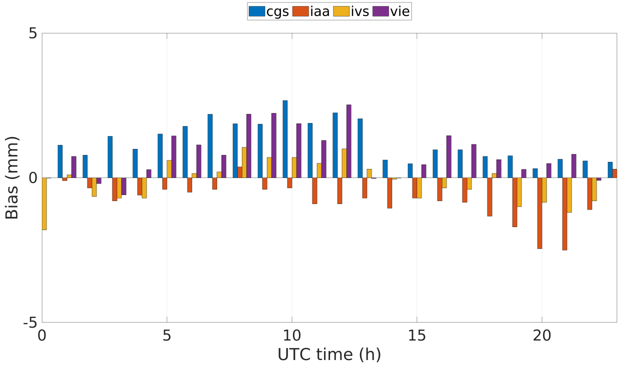
2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to IGS ZTD, segmented by UTC hours. Badary station.



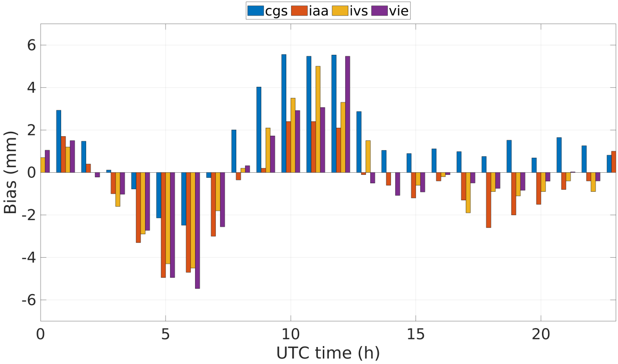
2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to CODE ZTD, segmented by UTC hours. Matera station.



2. VLBI-GNSS ZTD differences: subdaily analysis

- VLBI-GNSS ZTD differences with respect to IGS ZTD, segmented by UTC hours. Matera station.



3. GNSS-based ZTD as a priori value in VLBI processing

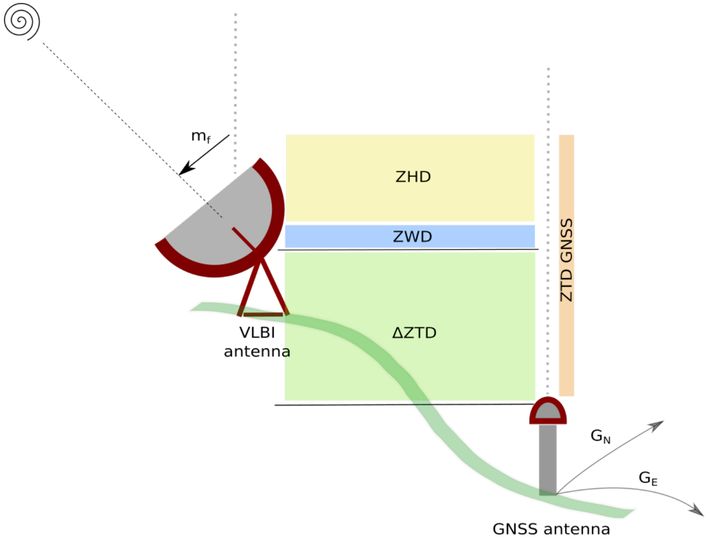
Q3: How GNSS-based ZTDs used as a priori value impact VLBI estimation?

VieVS 3.1 has been modified to automatically:

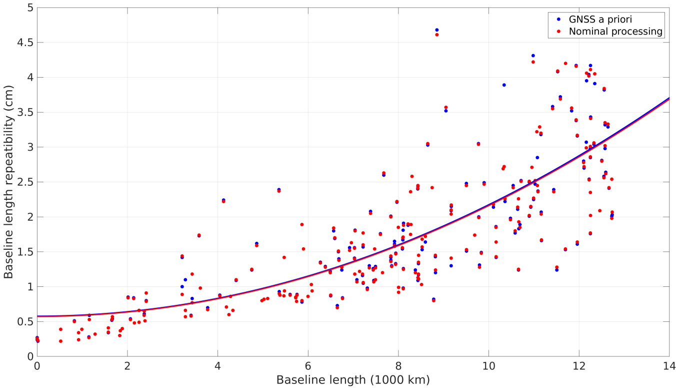
- Read ZTD and gradients from CODE troposphere files (TRO SINEX) for the current and following day and store the data in an existing VieVS structure.
- Extract GNSS coordinates from SINEX file and add antenna eccentricity.
- For each observation
  - Interpolate linearly GNSS ZTD and gradients to the VLBI observation epoch
  - Compute the zenith delay correction due to height difference $\Delta\mathrm{ZTD}$
  - Compute a priori ZWD as $\mathrm{ZTD}_{\mathrm{GNSS}} - (\mathrm{ZHD}_{\mathrm{VLBI}} + \Delta\mathrm{ZTD})$
  - Map ZHD and GNSS-derived ZWD to slant direction and add gradients contribution.

This rationale is only applied when GNSS data is available.

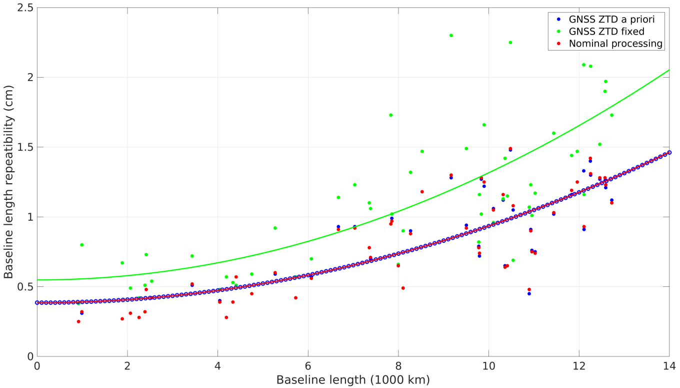
3. GNSS-based ZTD as a priori value in VLBI processing



3. Baseline repeatability - R1 & R4 2013-2018



3. Baseline repeatability - CONT17 A



4. Stability of troposphere ties

Q4: What is the long-term behaviour of the wet and hydrostatic troposphere ties?

Formulation for the computation of hydrostatic (Saastamoinen, 1972) and wet (Brunner and Rüeger, 1992) troposphere tie corrections:

$$p = p_0 \left(1 - \frac{\gamma \left(H - H_0\right)}{T_0}\right)^{\frac{g}{\gamma R_L}},$$

$$\Delta ZHD = \frac{0.0022768 \left(p - p_0\right)}{1 - 0.00266 \cos\left(2\varphi_0\right) - 0.28 \cdot 10^{-6} H_0},$$

$$\Delta ZWD = \frac{-2.789 e_0}{T_0^2} \left(\frac{5383}{T_0} - 0.7803\right) \gamma \left(H - H_0\right),$$

H_0 : reference height (VLBI station)
e_0 : water vapor pressure at reference height [hpa]
T_0 : temperature at reference height [K]
$\gamma = -0.00065 \mathrm{K m^{-1}}$: average temperature lapse rate

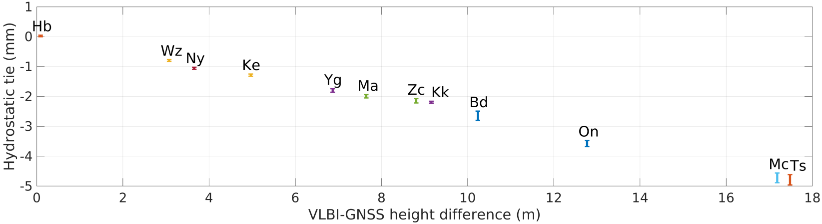
H : GNSS antenna height
p_0 : total pressure at reference height [hpa]
g : gravity at the site $\mathrm{ms^{-2}}$
$R_L \simeq 287.058 \mathrm{m^2 s^{-2} K^{-1}}$: specific gas constant

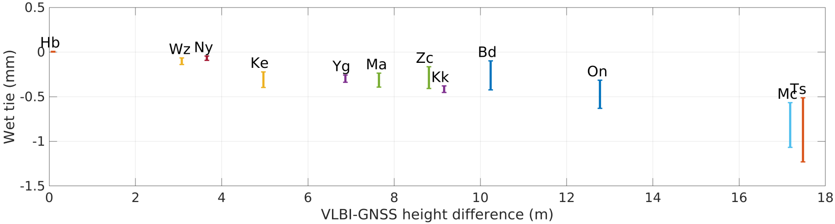
4. Stability of troposphere ties

Behaviour of GNSS troposphere ties for the period 2013-2018:

VLBI Station	GNSS station	$H_0 - H$ (m)	$\Delta\bar{ZWD} \pm \sigma_{\Delta ZWD}$(mm)	$\Delta\bar{ZHD} \pm \sigma_{\Delta ZHD}$(mm)
Badary	BADG	10.2	-0.3±0.2	-2.6±0.2
Hobart	HOB2	-0.1	0.0±0.0	0.0±0.0
Katherine	KAT1	5.0	-0.3±0.1	-1.3±0.0
Kokee	KOKB	9.2	-0.4±0.0	-2.2±0.0
Matera	MATE	7.6	-0.3±0.1	-2.0±0.1
Medicina	MEDI	17.2	-0.8±0.3	-4.7±0.2
Ny Alesund	NYAL	3.7	-0.1±0.0	-1.1±0.0
Onsala	ONSA	12.8	-0.5±0.2	-3.6±0.1
Tsukuba	TSKB	17.5	-0.9±0.4	-4.8±0.2
Wettzell	WTZR	3.1	-0.1±0.0	-0.8±0.0
Yarragadee	YAR2	6.9	-0.3±0.0	-1.8±0.1
Zelenchukskaya	ZELE	8.8	-0.3±0.1	-2.1±0.1

4. Stability of troposphere ties





Conclusions

The analysis of R1 & R4 sessions for the period 2013-2018 focused on troposphere delays leads to the following conclusions:

- VLBI-based ZTD show similar level of agreement in mean bias sense with CODE and IGS products.
- No subdaily pattern appreciated with respect to CODE ZTD. Subdaily pattern detected for IGS ZTD to be further analysed.
- GNSS-based ZTDs used as a priori value in VLBI processing do not affect estimation in terms of repeatibility.
- Long term analysis of troposphere ties shows stable behaviour of wet and hydrostatic ties, with standard deviation of wet tie below 0.4 mm for the set of stations analysed.

Questions? Thanks for your attention

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