

Tropospheric Products validation in the GNSS SIRGAS Network.

CIMA, Centro de Procesamiento Ingeniería Mendoza Argentina

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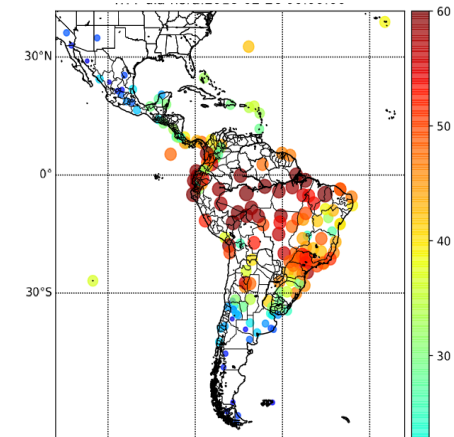
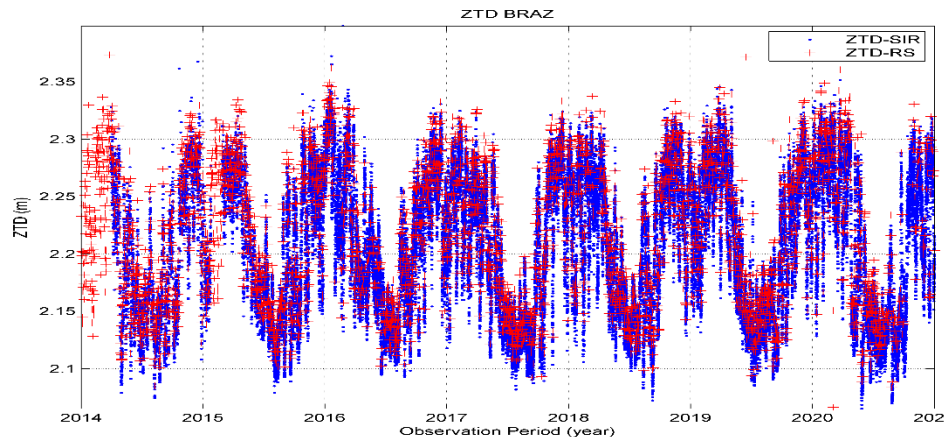
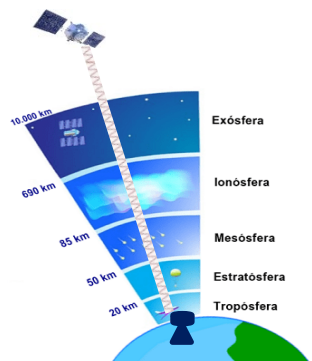
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EN ACCION CONTINUA...



(1) Facultad de Ingeniería. Universidad Nacional de Cuyo, Argentina

(2) Facultad de Ingeniería. Universidad Juan A. Maza, Argentina.

(3) Consejo Nacional de Investigaciones Científicas y Tecnológicas, Argentina



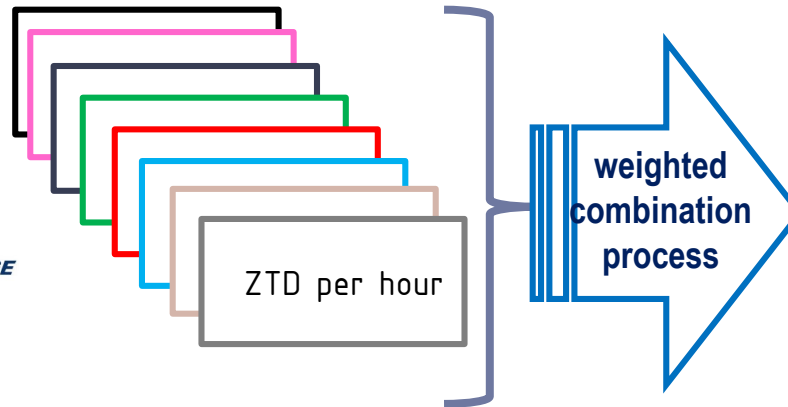
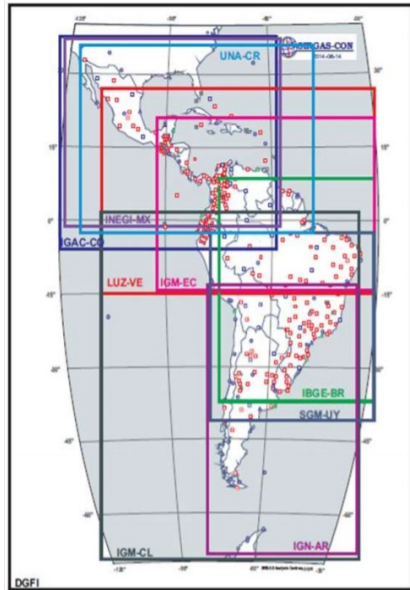
SIRGAS, Sistema de Referencia Geocéntrico para las Américas

- Materialized by more than 400 permanent GNSS stations.
- Densification of the ITRF in Latin America and the Caribbean.
- Rigorously processed at weekly bases.

Zenit Total Delay (ZTD) estimation

OPERATIONAL SIRGAS PROCESSING		
Software	Bernese v5.2	
Observations	GPS+GLONASS	
Sampling interval	30 seconds	
Orbits and EOP	Final IGS products	igswwwD.sp3 igswww7.erp
	Pre-processing	GMF (Böhm et al., 2007) and VMF (Böhm et al., 2006)
A-priori topsphere modeling and mapping function	Parameter estimation	VMF + Gridded VMF1 coefficients
	Estimation of horizontal gradients	CHENHER: Model described in Chen and Herring (1997) (24 hours)
	Parameter spacing	1 or 2 hours

The ACs ZTDs are the **input data** for the weekly SIRGAS combined tropospheric products



24 ZTDs per day, per station
8 SIRGAS Analysis Centres
3 ZTD values for each station per hour

SIRGAS
tropospheric
products

ZTD p/h ; σ_{ZTD}
 \approx 400 GNSS stations
7 years (2014-2020)

Filter applied
 $\sigma > 0.02$ m
Discarded

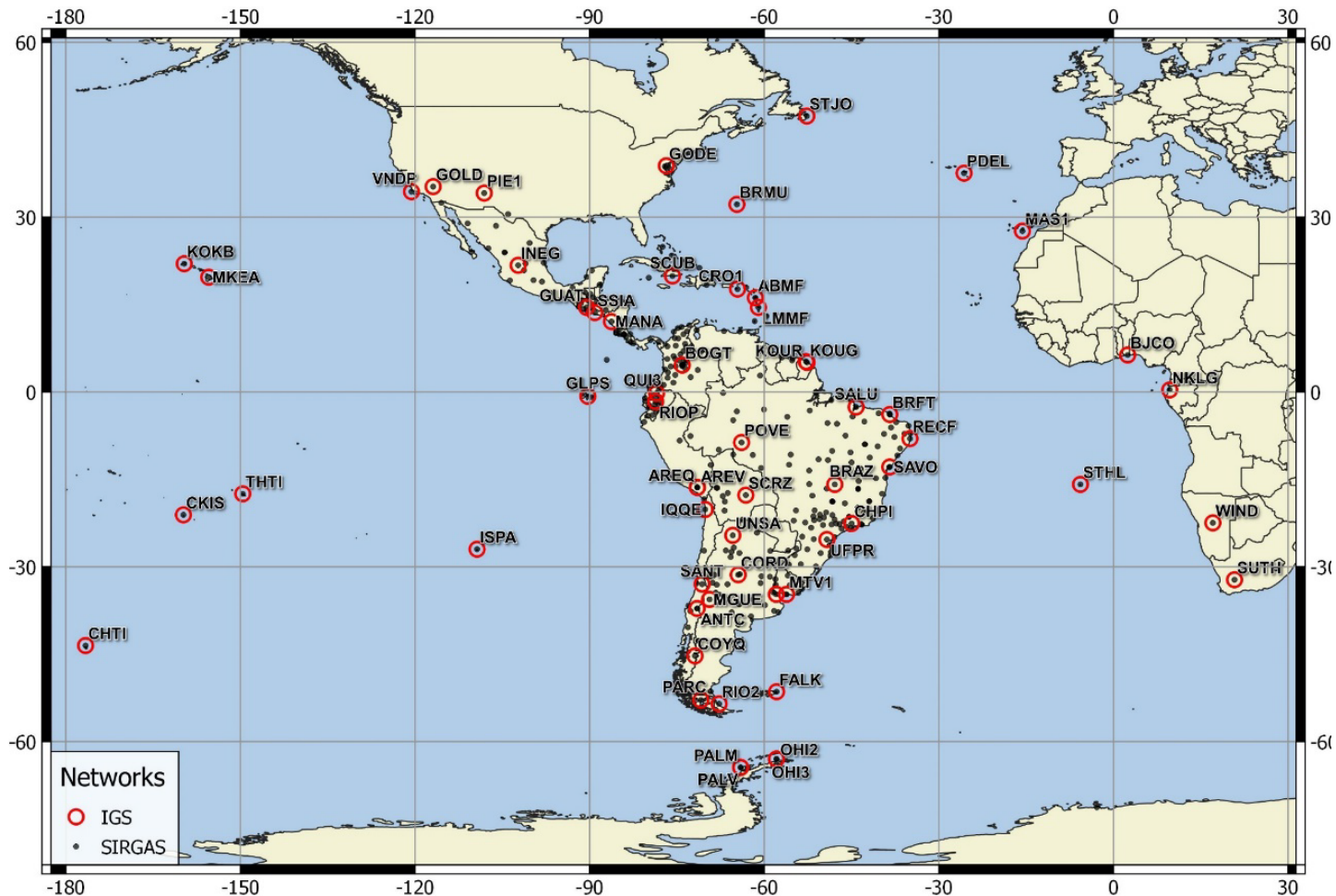
Redundancy
Each station is
processed by 3 ACs

Internal precision of SIRGAS final ZTDs
Mean RMS = 1mm
(in the 90% of estimated values)

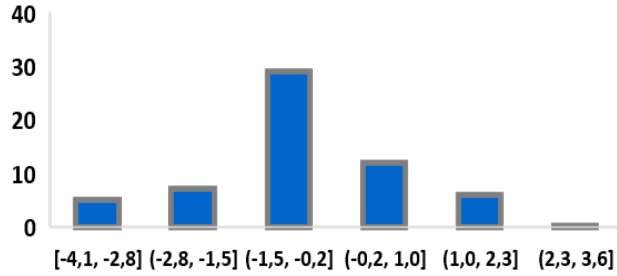
ZTD_{GNSS_SIR} validation wrt ZTD_{IGS}

External precision analysis of the final SIRGAS ZTDs

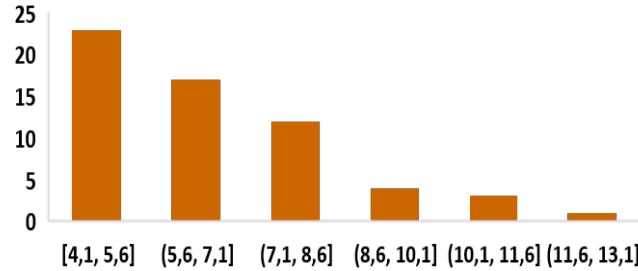
60 GNSS_{SIR} stations / IGS stations (distributed in different regions)



Histogram. Bias ($ZTD_{IGS} - ZTD_{SIR}$) [mm]



Histogram, RMS ($ZTD_{IGS} - ZTD_{SIR}$)



RESULTS

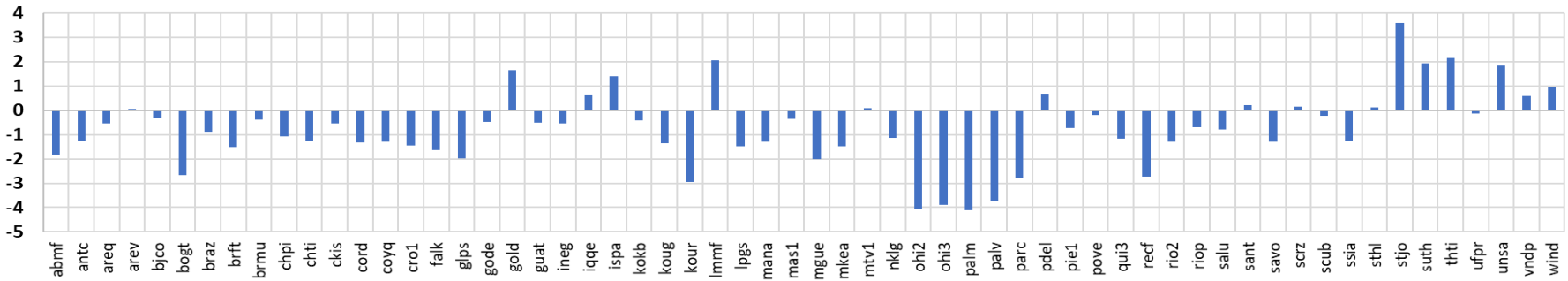
Mean Bias = 0.76 mm

(0.03 % of the mean value of ZTD)

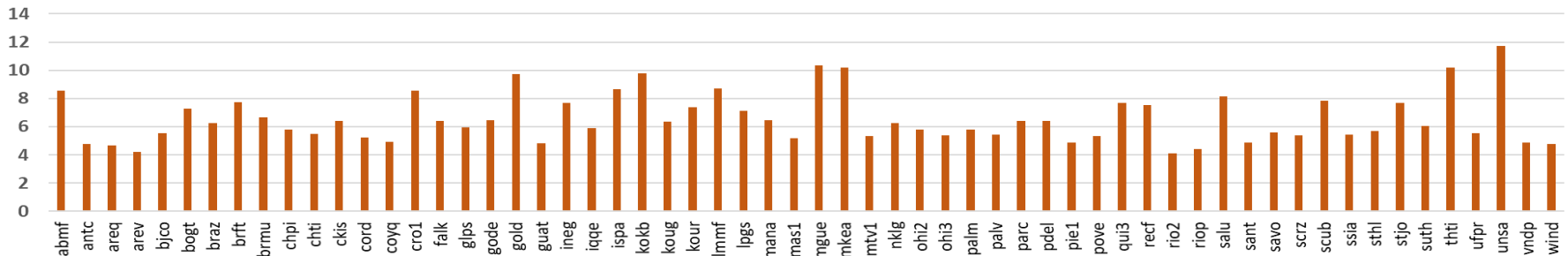
Mean RMS = 6.6 mm

(0.29 % of the mean value of ZTD)

Mean bias ($ZTD_{IGS} - ZTD_{SIR}$) [mm]



Mean RMS ($ZTD_{IGS} - ZTD_{SIR}$) [mm]



ZTD_{GNSS_SIR} validation wrt Radiosonde data (RS)

Radiosonde profiles were downloaded from Wyoming Weather Web
<http://weather.uwyo.edu/upperair/sounding>.

DATA: Precipitable water [mm] for entire sounding (PW o IWV_{RS})

Methodology

Mackern M.V. et al.,(2020). doi: 10.1007/1345_2020_121

Input

- 1) PW_{RS} (IWV), 00 and 12 h UTC
- 2) Temperature and dew-point from the profiles
- 3) P_{hRS}



Davis, 1985

$$ZWD = \frac{(22,9744 + \frac{375463}{T_m}) 0,4614991785}{10^5} IWV \quad (1)$$

$$T_m = \frac{\int_H^\infty e/T dz}{\int_H^\infty e/T^2 dz} \quad (2)$$

$$ZHD = 0,002276738 \cdot \frac{P_{GNSS}}{1 - 0,00266 \cdot \cos(2\varphi) - 0,28 \cdot 10^{-6} \cdot h_{GNSS}} \quad (3)$$

$$P_{GNSS} = P_{RS} (1 - 0.0000226 (h_{GNSS} - h_{RS}))^{5.225} \quad (4)$$

Askne and Nordius, 1986
Rüeger, 2002

$$ZTD \text{ dif} = ZTD_{GNSS_SIR} - ZTD_{RS}$$

Experience:
42 GNSS_{SIR} stations / radiosonde
within 30 km

Output

$$ZTD_{RS} = ZHD + ZWD$$

00 and 12 h UTC

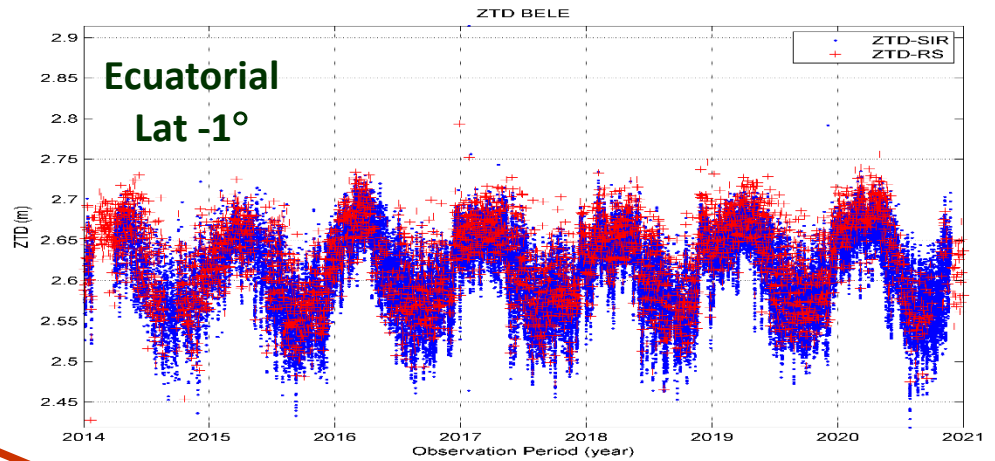
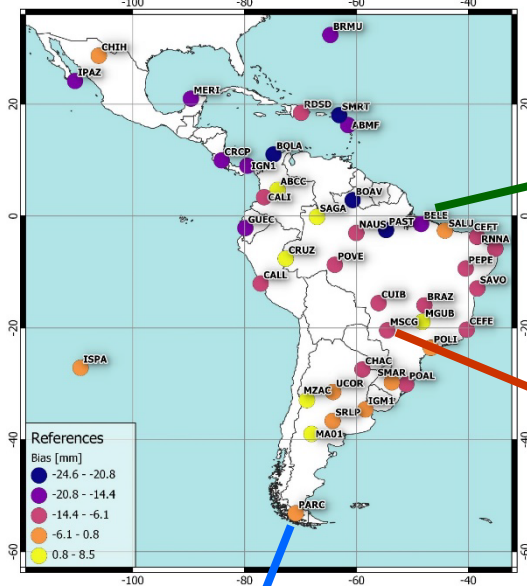


Berg, 1948

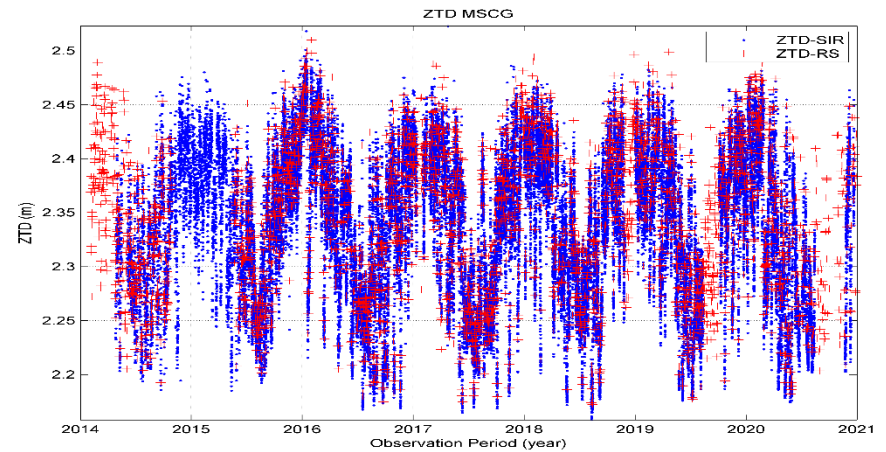
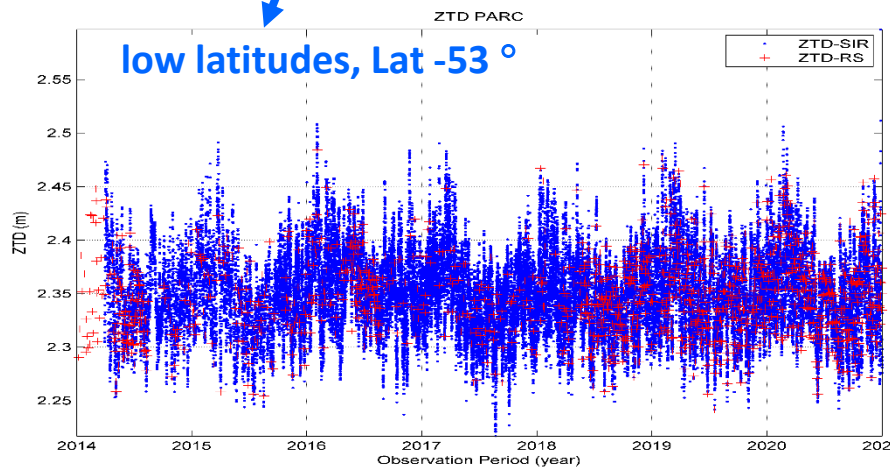
External precision analysis
of the final SIRGAS ZTDs

ZTD_{GNSS_SIR} validation wrt Radiosonde data (RS)

42 GNSS_{SIR} stations / radiosonde in different regions

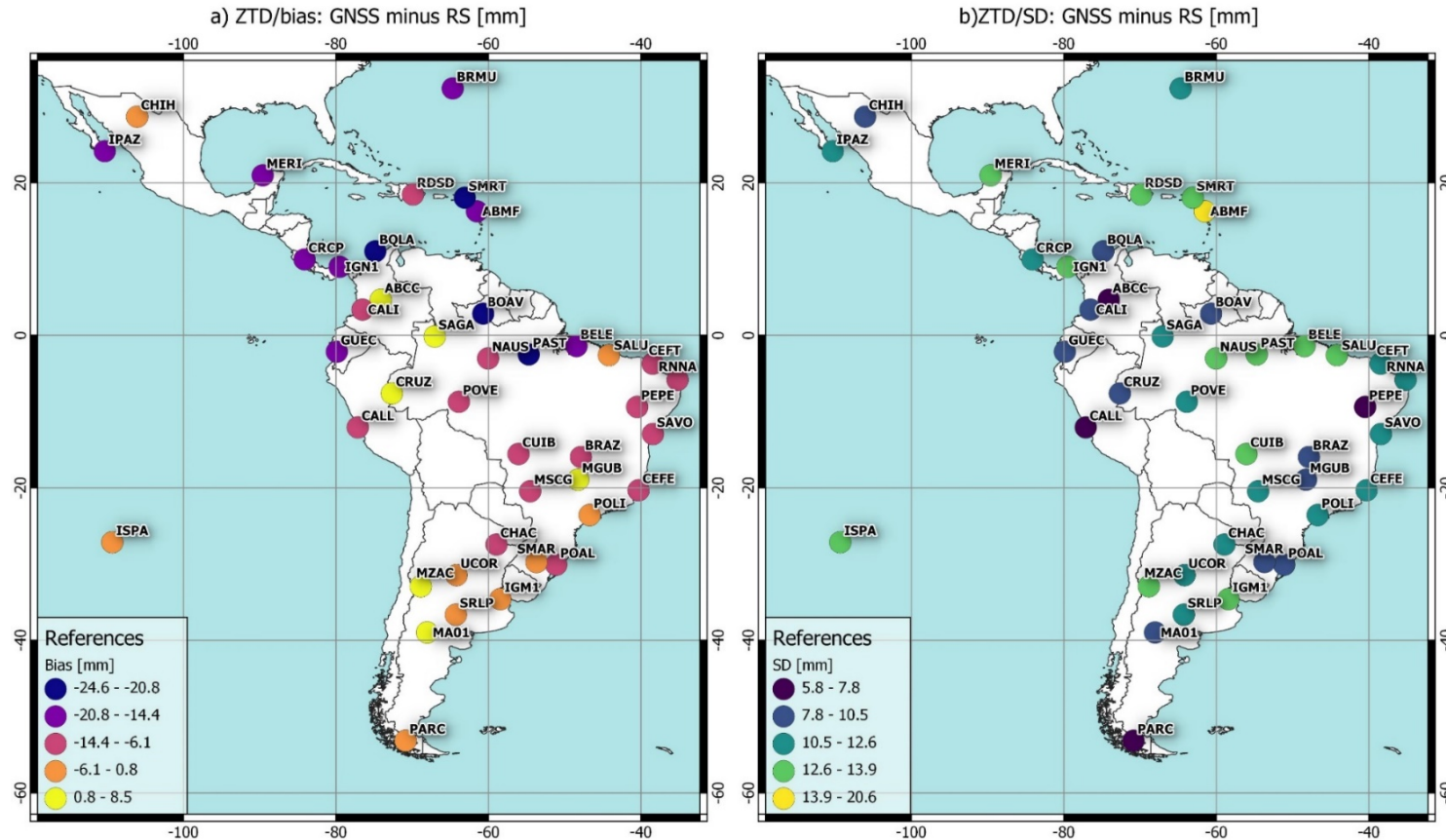


Subtropical Lat -20°



ZTD_{GNSS_SIR} validation wrt Radiosonde data (RS)

42 GNSS_{SIR} stations / radiosonde within 30 km



Results:

Mean Bias = - 8.6 mm (0.37 % of the mean ZTD)

Mean SD = ± 11.4 mm (0.49 % of the mean ZTD)

Mean correlation coefficient = 0.97

Availability of SIRGAS tropospheric products

<http://www.sirgas.org/en/tropo-delays/>

Where can they be downloaded?

Home

Presentation

Organization +

Reference system

Realizations +

Reference network +

National densifications

Products

Events

Publications

Presentations

Web, Links & Contact +

Tropospheric delays

Within the weekly processing of the SIRGAS Continuously Operating Network (SIRGAS-CON), the SIRGAS Analysis Centres operationally estimate tropospheric Zenith Path Delays (ZPD) with an hourly sampling rate. These ZPD estimates are the input data for the generation of SIRGAS tropospheric products, which provide weekly combined troposphere estimates of high-reliability for each SIRGAS station. The station positions, as a necessary part of this analysis, are taken from the SIRGAS weekly combined solutions. Consequently, stations without estimated positions in the weekly combination are not included in the combined tropospheric solution.

The SIRGAS tropospheric products are computed by the SIRGAS Analysis Centre for the Neutral Atmosphere (CIMA), which is operated by the Facultad de Ingeniería of the Universidad Nacional de Cuyo (UNCuyo, Mendoza, Argentina) in cooperation with the Facultad de Ingeniería of the Universidad Juan Agustín Maza (Mendoza, Argentina) and with support of the Argentinean Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

The SIRGAS tropospheric products are weekly generated with a latency of 30 days. They are available with an hourly sampling rate in daily SINEX TRO files since January 2014 and they can be downloaded from

<ftp://ftp.sirgas.org/pub/gps/SIRGAS-ZPD/>

More details about the processing strategy can be found at

Mackern M.V., Mateo M.L., Camisay M.F., Morichetti P.V. (2020). Tropospheric Products from High-Level GNSS Processing in Latin America. International Association of Geodesy Symposia Series, Vol 152, open access, doi: 10.1007/1345_2020_121

Whenever you use the SIRGAS tropospheric products, please include this publication as a citation.

YEAR / DAY /

IGS SINEX format
SSSSddd0.yyzpd.gz

Integrated Water Vapor (IWV)

Calculation strategy

ZTD (GNSS) c/1h, delay 21 days,
Pmsl , 2mT (ERA5) c/1h , delay 5 days

Input

Weighted combination

ZTD

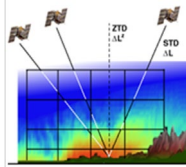
ZWD = ZTD - ZHD

IWV = Π . ZWD

Output

IWV

Each 1h, delay: 28 days



"ERA5 hourly estimates of variables on single levels"

Mean sea level pressure

Berg ,1948

$$P_{GNSS} = P_{ref} \cdot (1 - 0,0000226 \cdot (h_{GNSS} - h_{ref}))^{5,225}$$

P_{GNSS}

$$ZHD = 0,002276738 \cdot \frac{P_{GNSS}}{1 - 0,00266 \cdot \cos(2\varphi) - 0,28 \cdot 10^{-6} \cdot h_{GNSS}}$$

Davis, 1985

$$\Pi = \frac{10^5}{\left(22,9744 + \frac{375463}{T_m}\right) \cdot 0,4614991785}$$

Askne and Nordius, 1986
Rüeger, 2002

Mendes , 1999

$$T_m = 50,4 + 0,789 \cdot T_s$$



ERA5

2m Temperature

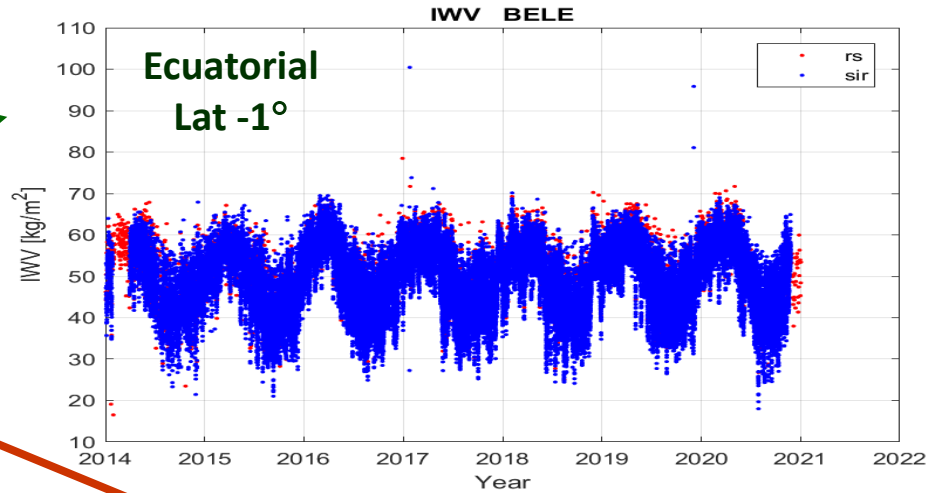
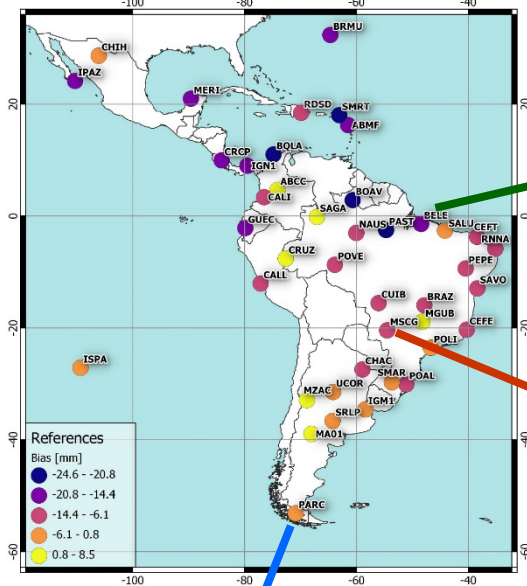
Units:

ZTD, ZHD and ZWD [m];

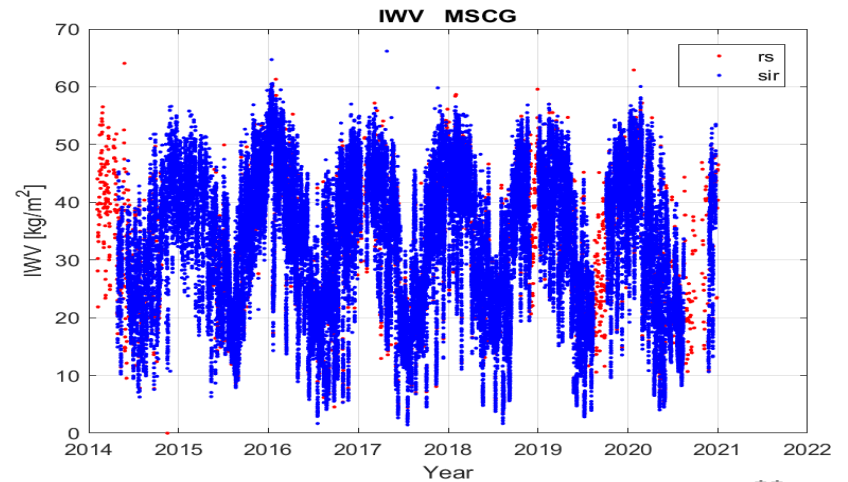
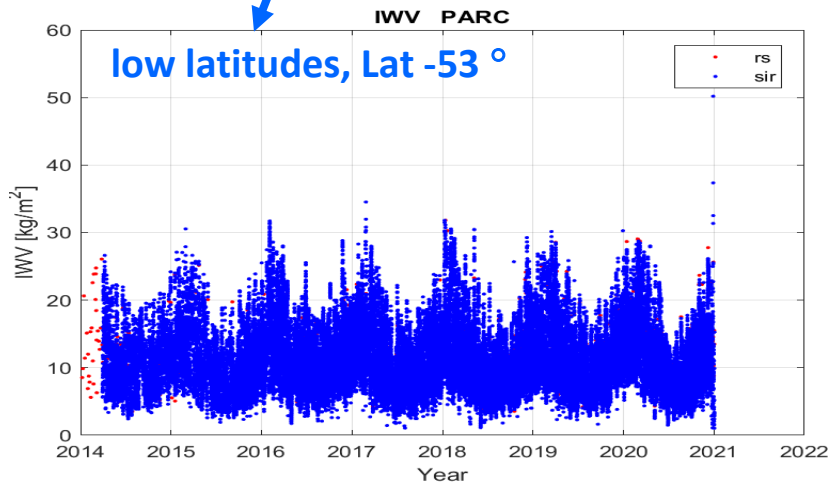
IWV $\left[\frac{\text{kg}}{\text{m}^2}\right]$; P [hPa]; h [m]; Tm and Ts [k]

VALIDATION: IWV_{GNSS_SIR} wrt Radiosonde data (RS)

42 GNSS_{SIR} stations / radiosonde
in different regions



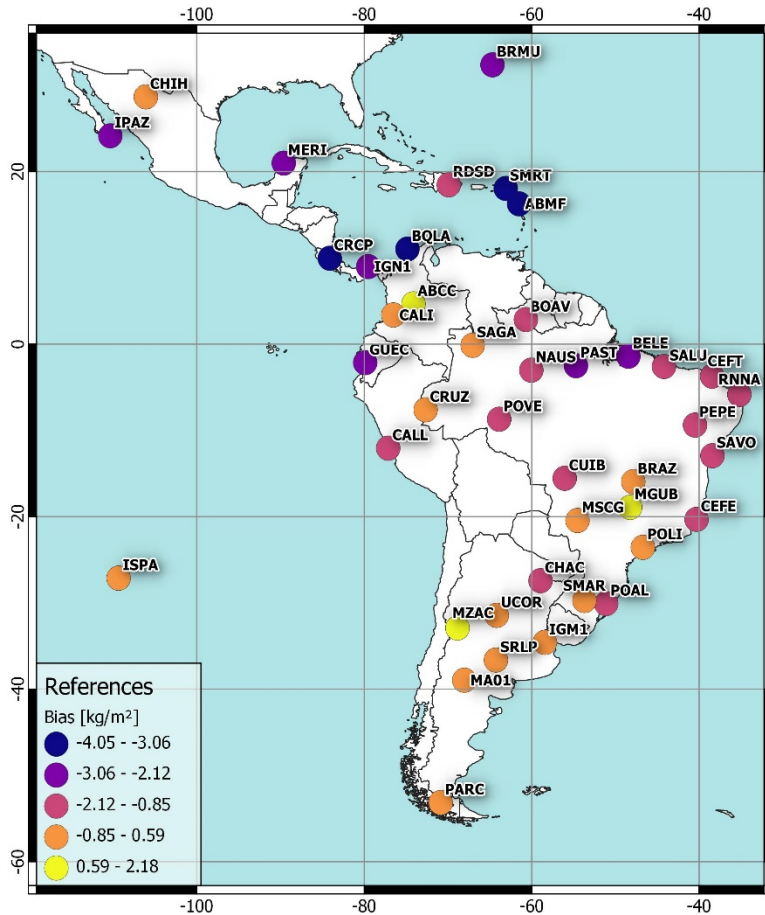
Subtropical, Lat -20°



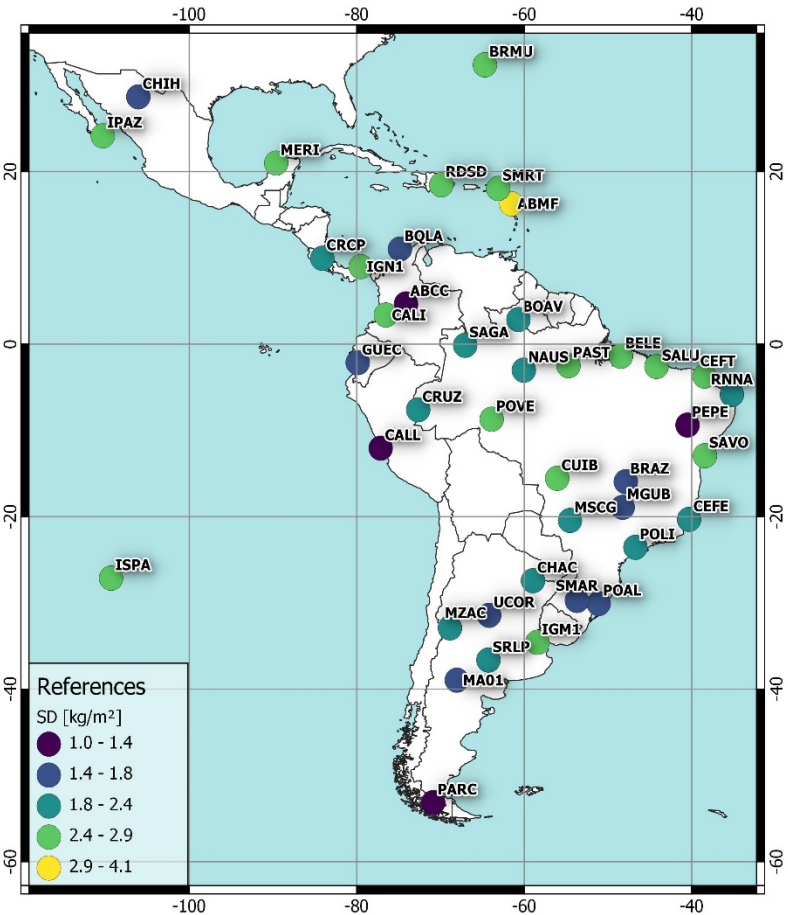
Validation : $IWV_{GNSS\ SIR} - IWV_{RS}$

42 GNSS_{SIR} stations / radiosonde within 30 km

a) IWV/bias: GNSS IWV minus IWV RS [kg/m²]



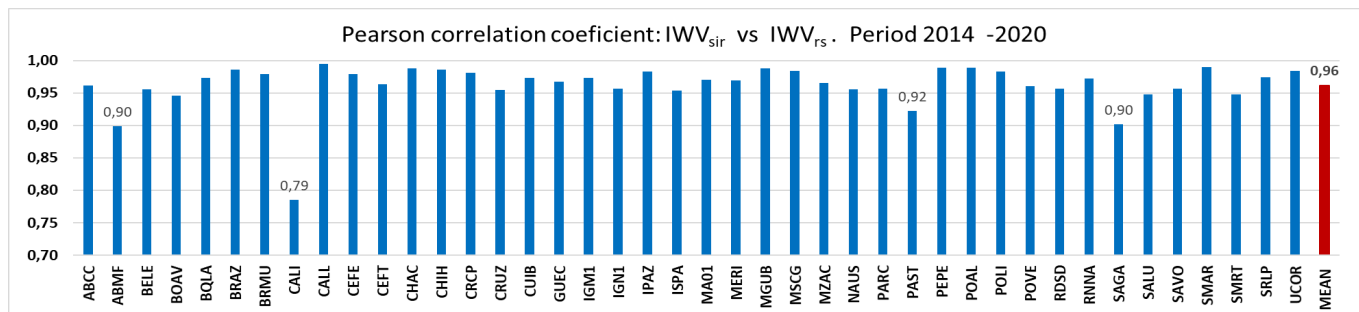
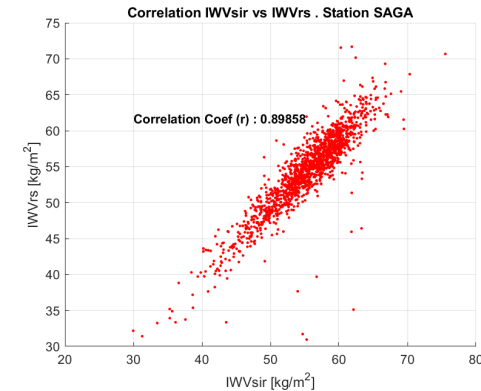
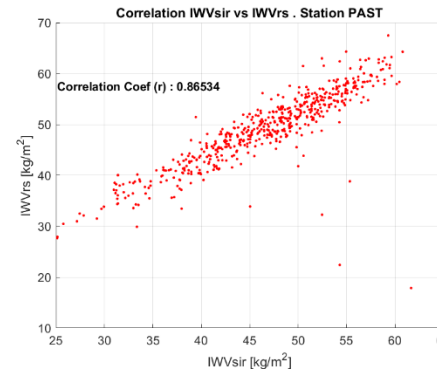
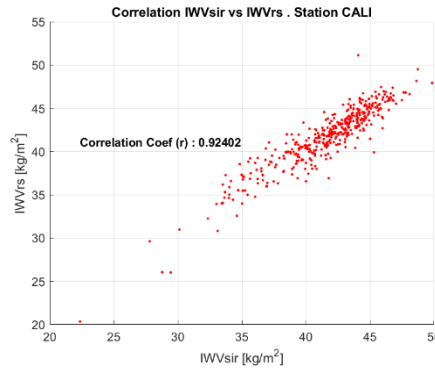
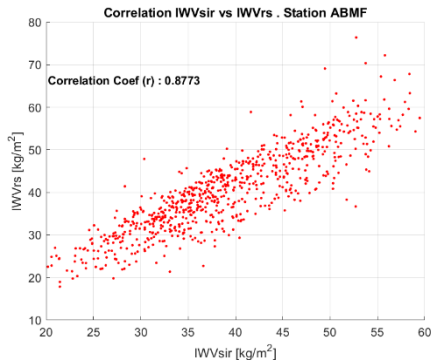
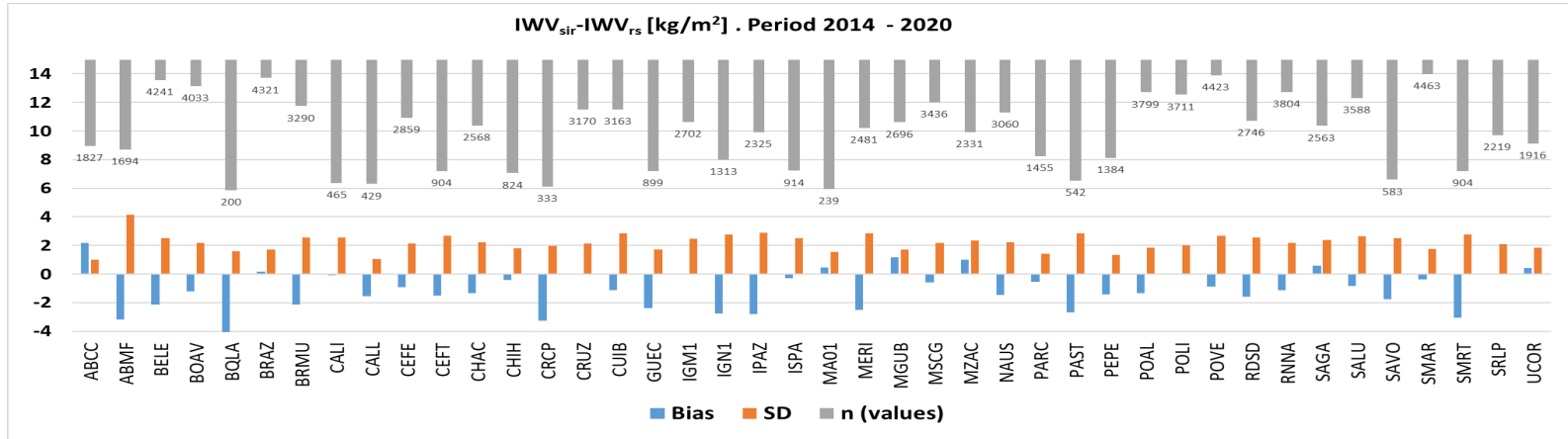
b) IWV/SD: GNSS IWV minus IWV RS [kg/m²]



Mean Bias = - 1.08 kg/ m²
Mean SD = ± 2.22 kg/ m²
Mean correlation coefficient 0.96

IWV_{GNSS_SIR} - IWV_{RS}

Period: 7 years (2014-2020)



CONCLUSIONS

- The ZTD final SIRGAS products are available from 2014, with an hourly interval, with a latency of 28 days
- The Internal precision of SIRGAS final ZTDs is 1mm .
- An External analysis could evaluate the accuracy of SIRGAS final ZTDs:
 - * respect to ZTD_{IGS} Mean Bias = 0.76 mm (0.03 % of the mean value of ZTD)
 Mean RMS = 6.6 mm (0.29 % of the mean value of ZTD)
 - * respect to RS Mean Bias = -8.6 mm (0.37 % of the mean value of ZTD)
 Mean SD = ± 11.4 mm (0.49 % of the mean value of ZTD)
 Mean correlation coefficient = 0.97

This results conclude that ZTD SIRGAS products are consistent over the entire region and provide a reliable time series of troposphere parameters, that could be used as a reference in further research

- The ZTD final SIRGAS products are used to calculate IWV products, they are available from 2014, with an hourly interval, with a latency of 28 days
- This indirect method allows the estimation of IWV with an accuracy of 2.22 kg/m² (mean SD), with a significant correlation with respect to the IWV_{RS} ($r > 0.96$), in line with previous studies.
- Based on the validation results, it is confirmed that the method applied for the calculation of IWV, can be used for the analysis of water vapor content, with an unparalleled densification both spatially and temporally (hourly), complementing the radiosonde records on continental territory. Highlighting the capability of the GNSS stations to provide IWV_{GNSS} estimates for a denser network

Thank you for giving us the opportunity to share our progress!!!

Acknowledgements

To GNSS station operators
To data centers
To processing centers
To the SIRGAS community



		DGFI-TUM (Deutsches Geodätisches Forschungsinstitut – TUM) → desde <u>junio-1996</u> en condición de IGS RNAAC SIR			IGM (Instituto Geográfico Militar) → desde <u>enero-2010</u>
		IBGE (Instituto Brasileiro de Geografia e Estatística) → desde <u>agosto-2008</u>			IGN (Instituto Geográfico Nacional) → desde <u>enero-2011</u>
		IGAC (Instituto Geográfico Agustín Codazzi) → desde <u>agosto-2008</u>			INEGI (Instituto Nacional de Estadística y Geografía) → desde <u>enero-2011</u>
		LUZ (Universidad del Zulia) → desde <u>enero-2010</u>			IGM (Instituto Geográfico Militar) → desde <u>enero-2013</u>
		SGM (Servicio Geográfico Militar) → desde <u>enero-2010</u>			UNA (Universidad Nacional) → desde <u>enero-2013</u>
					USCH Universidad de Santiago de Chile → desde mayo 2019