Tropospheric Products validation in the GNSS SIRGAS Network.

CIMA, Centro de Procesamiento Ingeniería Mendoza Argentina

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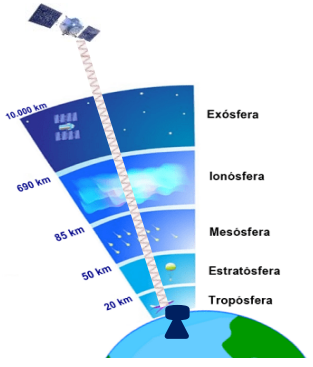
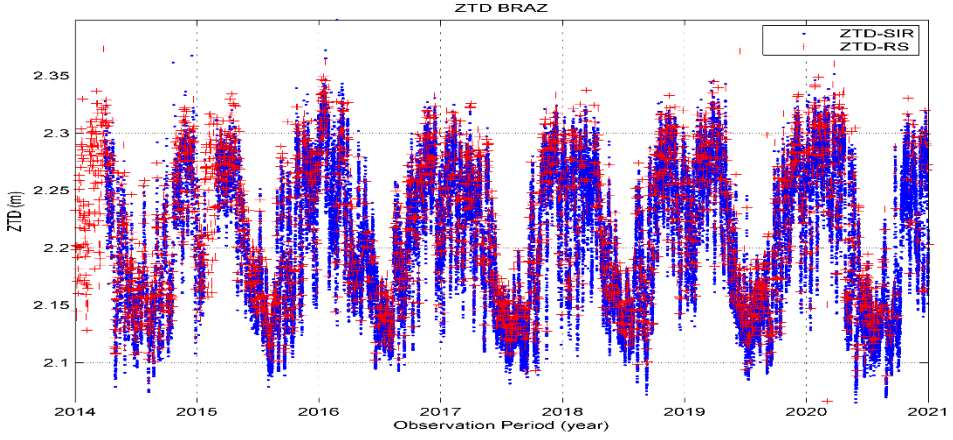
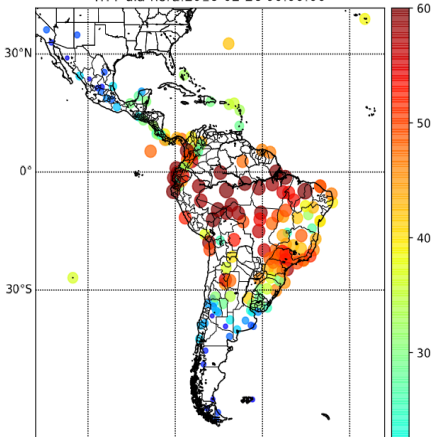






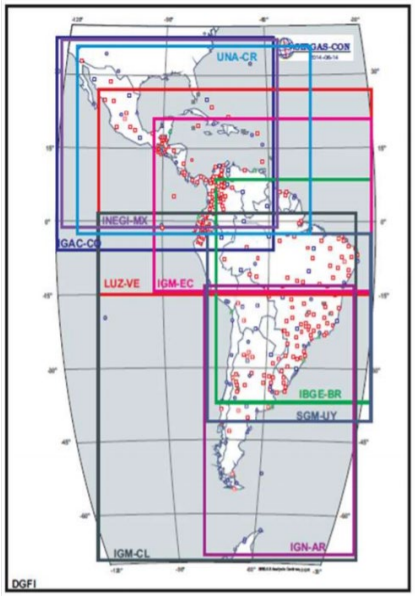
SIRGAS, Sistema de Referencia Geocéntrico para las Américas

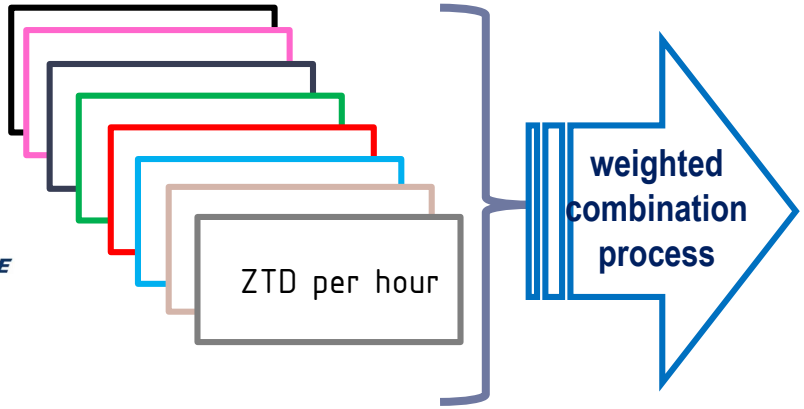
- Materialized by more than 400 permanent GNSS stations.
- Densification of the ITRF in Latin America and the Caribbean.
- Rigorously processed at weekly bases.

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	igswwwwD.sp3 igswwww7.erp
A-priori toposphere modeling and mapping funtion	Pre-processing	GMF (Böhm et al., 2007) and VMF (Böhm et al., 2006)
	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}

≅ 400 GNSS stations
7 years (2014-2020)

Filter applied
$\sigma > 0.02$ m
Discarded

Redundancy
Each station is processed by 3 ACs

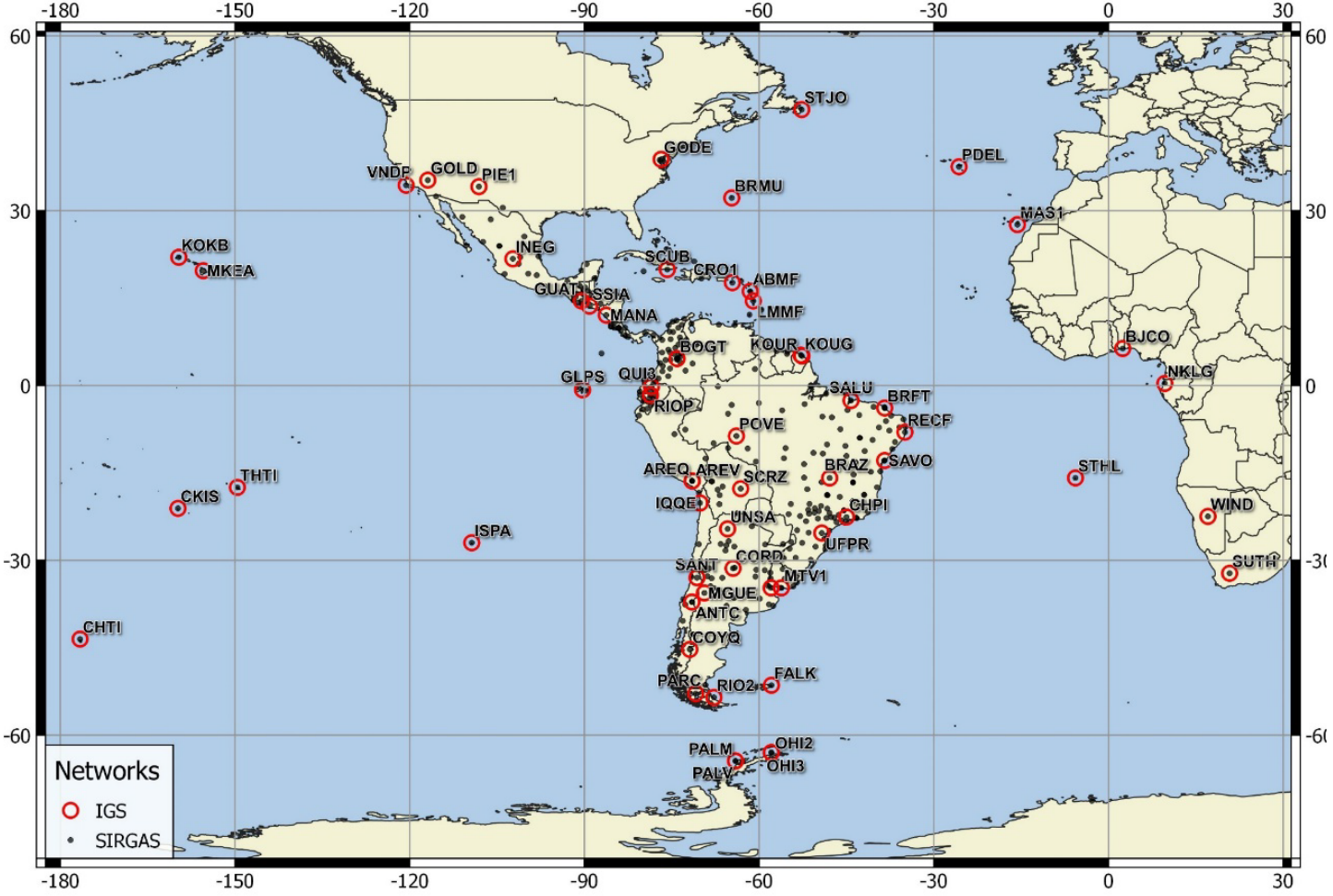
Internal precision of SIRGAS final ZTDs
Mean RMS = 1mm
(in the 90% of estimated values)

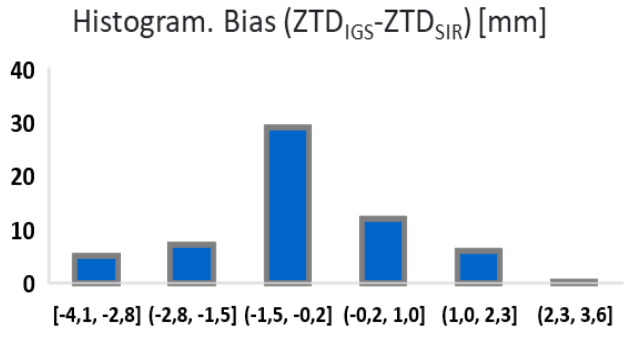
Mackern M.V., Mateo M.L., Camisay M.F., Morichetti P.V. (2020). **Tropospheric Products from High-Level GNSS Processing in Latin America**. International Association of Geodesy Symposia Series, Vol 152, open access, doi: 10.1007/1345_2020_121

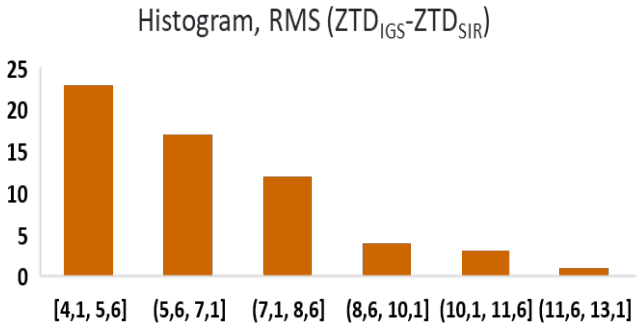
ZTD_{GNSS_SIR} validation wrt ZTD_{IGS}

External precision analysis of the final SIRGAS ZTDs

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







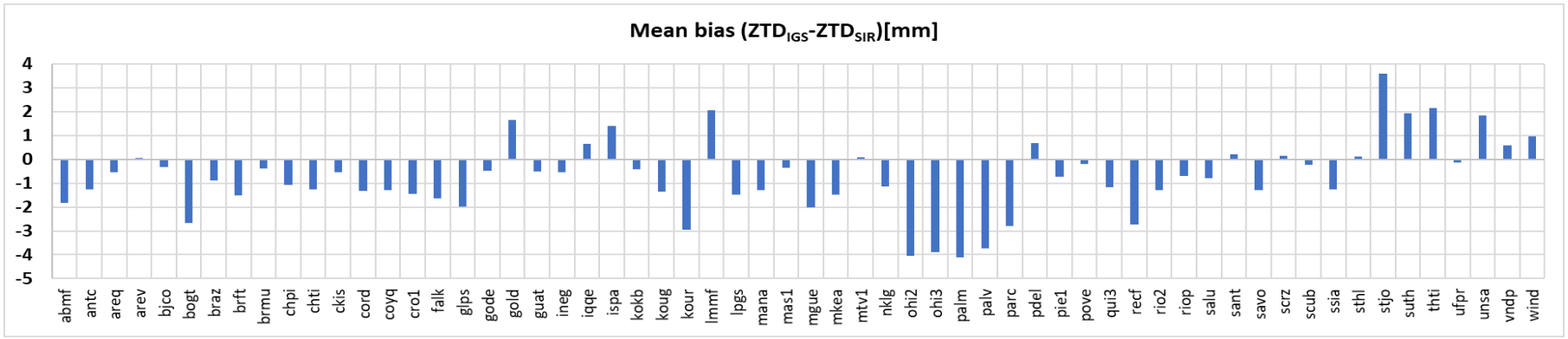
RESULTS

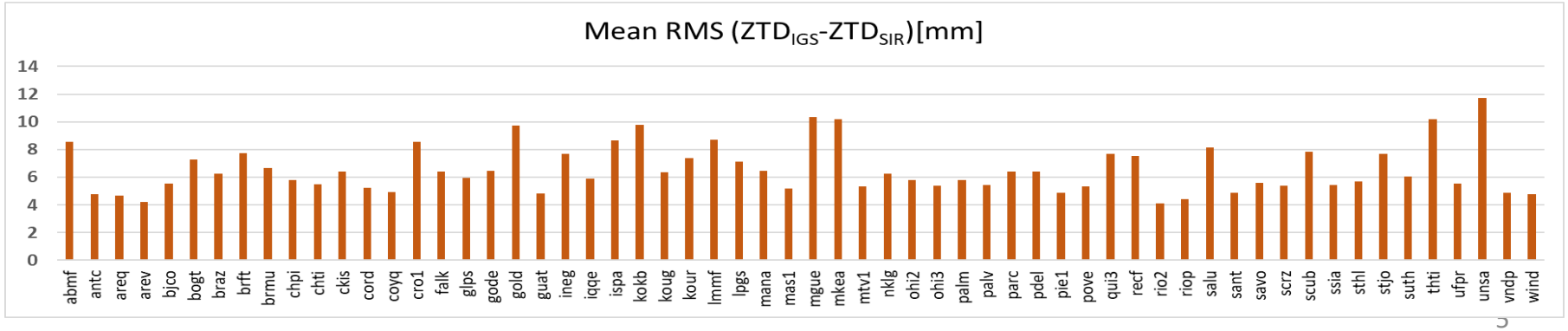
Mean Bias = 0.76 mm

(0.03 % of the mean value of ZTD)

Mean RMS = 6.6 mm

(0.29 % of the mean value of ZTD)





ZTD_{GNSS_SIR} validation wrt Radiosonde data (RS)

External precision analysis of the final SIRGAS ZTDs

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

Askne and Nordius, 1986
Rüeger, 2002

Input

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

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

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

Davis, 1985

$$ZHD = 0,002276738. \frac{P_{GNSS}}{1 - 0,00266. \cos(2\varphi) - 0,28.10^{-6}.h_{GNSS}} \quad (3)$$

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

Berg ,1948

ZTD dif = ZTD_{GNSS_SIR} - ZTD_{RS}

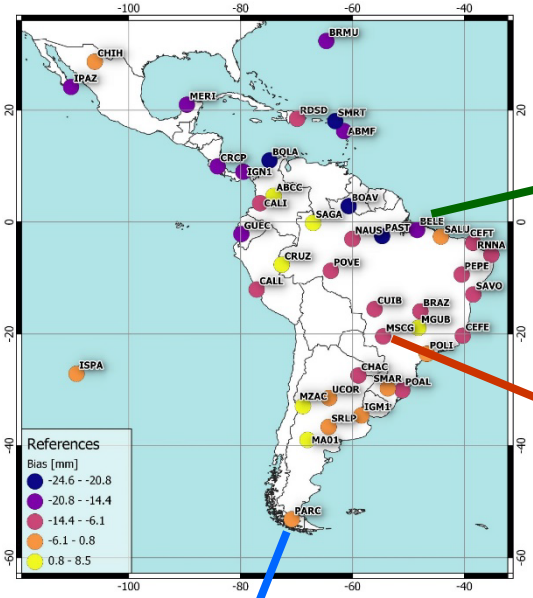
Experience:
42 $GNSS_{SIR}$ stations / radiosonde
within 30 km

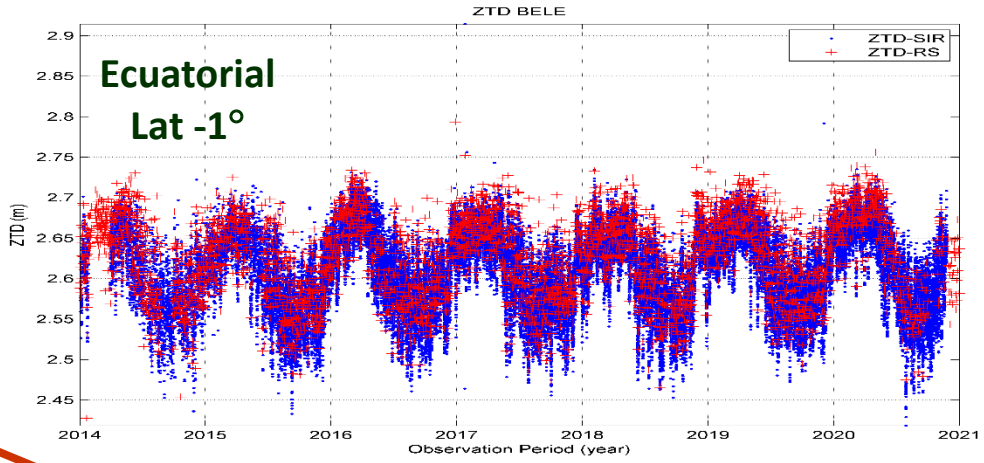
Output

ZTD_{RS} = ZHD+ZWD
00 and 12 h UTC

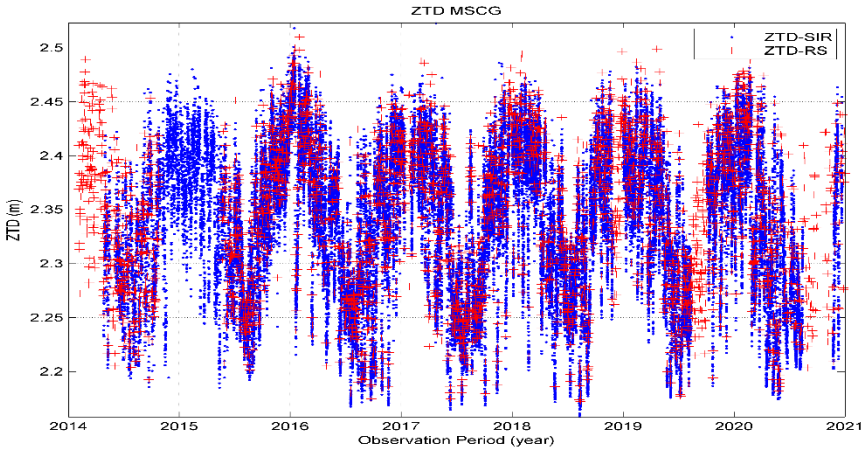
ZTD_{GNSS_SIR} validation wrt Radiosonde data (RS)

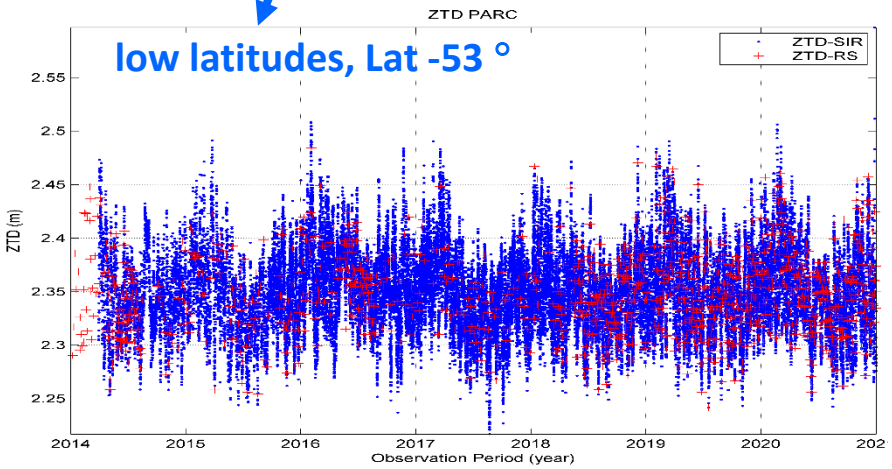
42 $GNSS_{SIR}$ stations / radiosonde in different regions





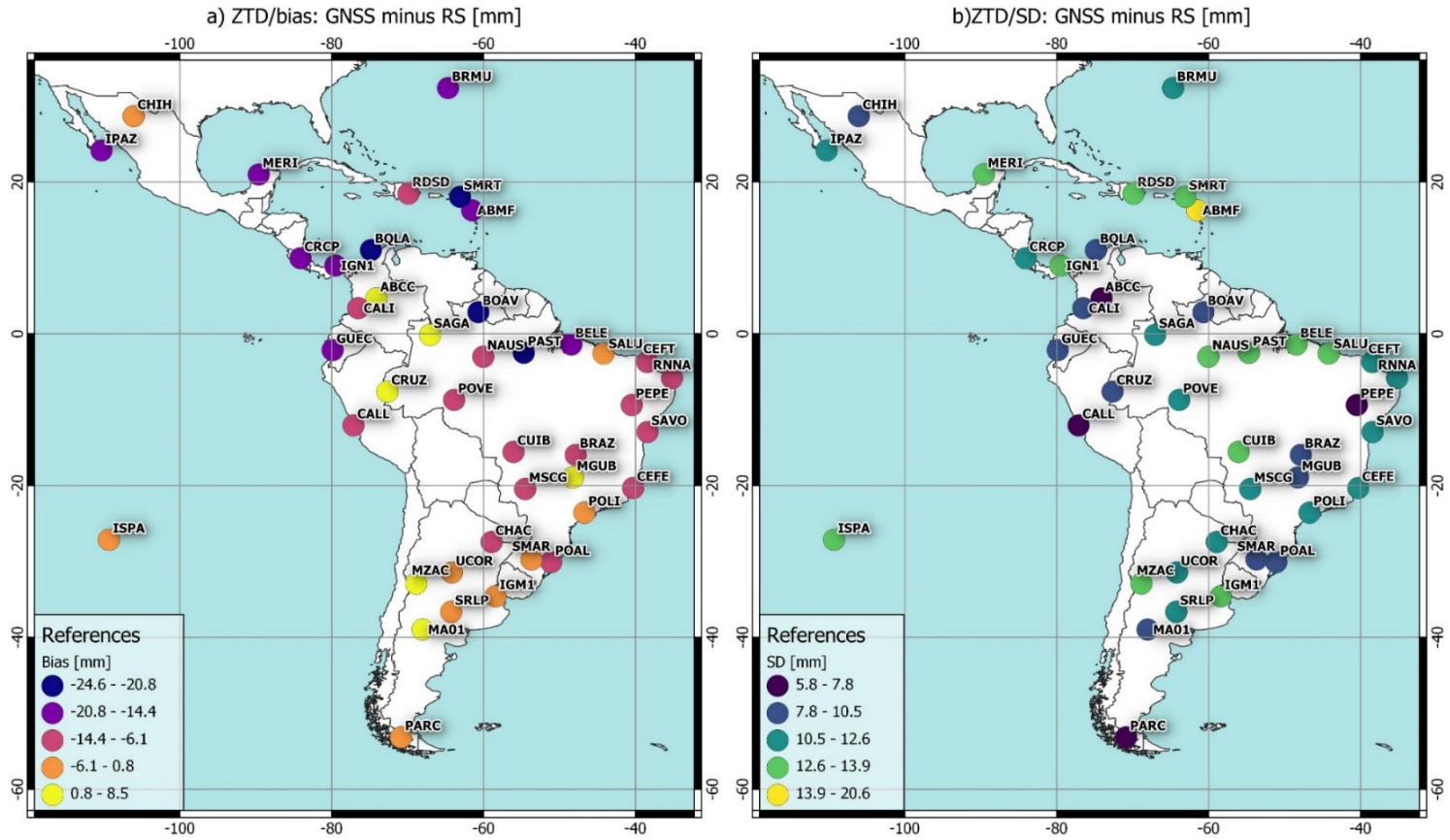
Subtropical
Lat -20°





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)

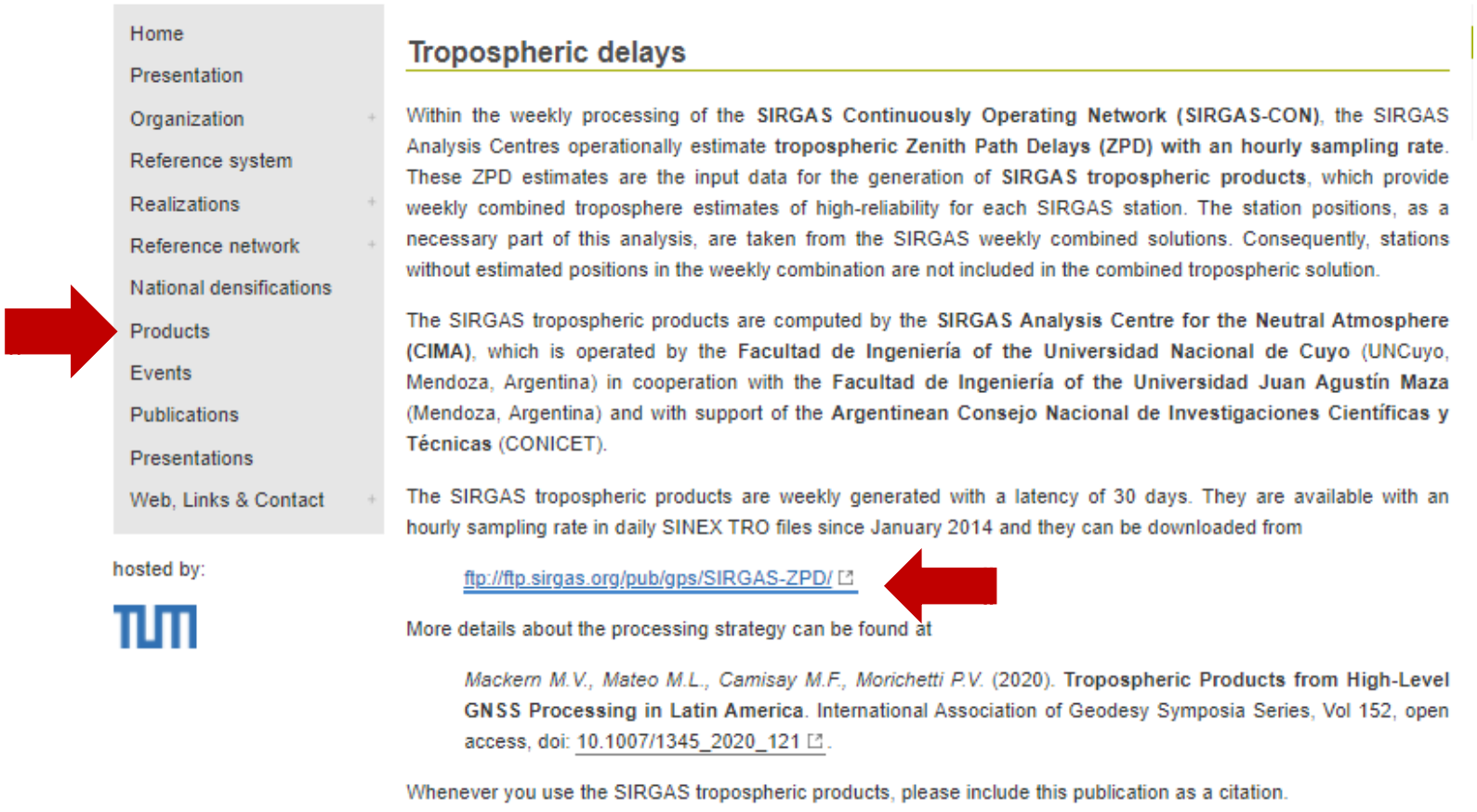
Mean SD = ± 11.4 mm (0.49 % of the mean ZTD)

Mean correlation coefficient = 0.97

Availability of SIRGAS tropospheric products

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

Where can they be downloaded?



YEAR / DAY /

IGS SINEX format
SSSSddd0.yyzpd.gz

Integrated Water Vapor (IWV)

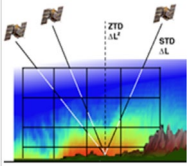
Calculation strategy

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

Input

"ERA5 hourly estimates of variables on single levels"

Weighted combination



ZTD

ZWD = ZTD-ZHD

IWV = Π . ZWD

Output

IWV
Each 1h, delay: 28 days

Mean sea level pressure

Berg ,1948

$$P_{GNSS} = P_{ref}.(1 - 0{,}0000226.(hGNSS - href))^{5{,}225}$$

$$ZHD = 0{,}002276738.\frac{P_{GNSS}}{1 - 0{,}00266.\cos(2\varphi) - 0{,}28.10^{-6}.h_{GNSS}}$$

Davis, 1985

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

Askne and Nordius, 1986
Rüeger, 2002

Mendes , 1999 $Tm = 50{,}4 + 0{,}789.Ts$

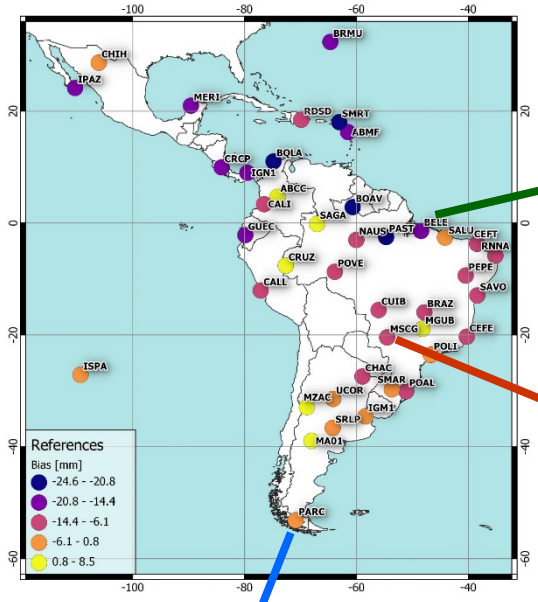
ERA5

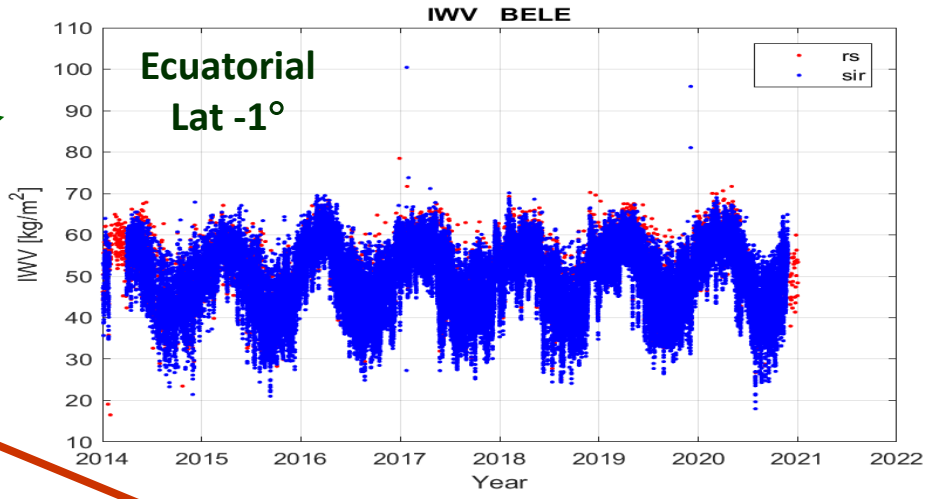
2m Temperature

Units:
ZTD, ZHD and ZWD [m];
IWV $\left[\frac{kg}{m^2}\right]$; P [hPa]; h [m] ; Tm and Ts [k]

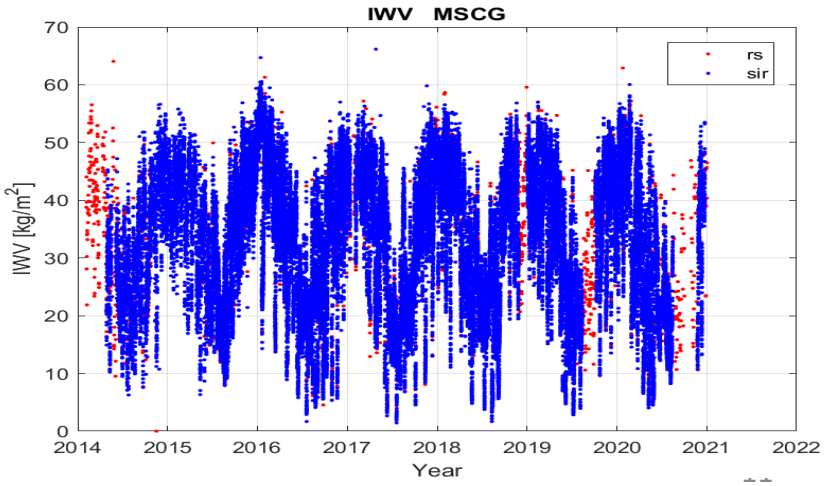
VALIDATION: IWV_{GNSS_SIR} wrt Radiosonde data (RS)

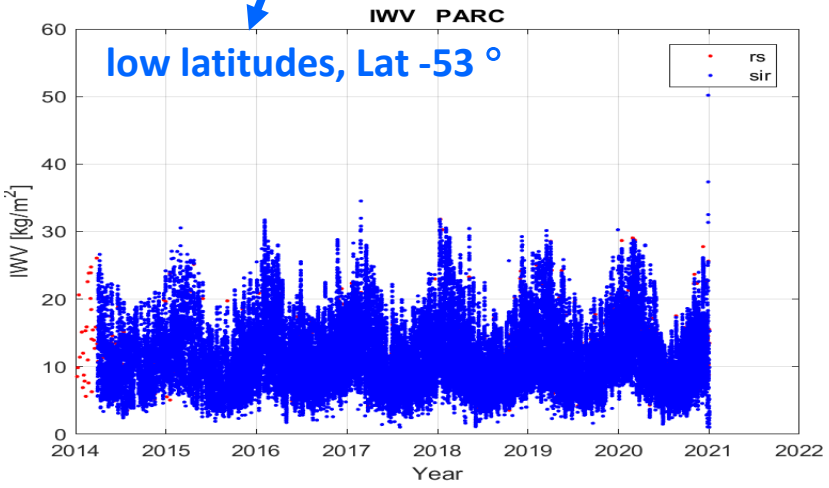
42 $GNSS_{SIR}$ stations / radiosonde in different regions





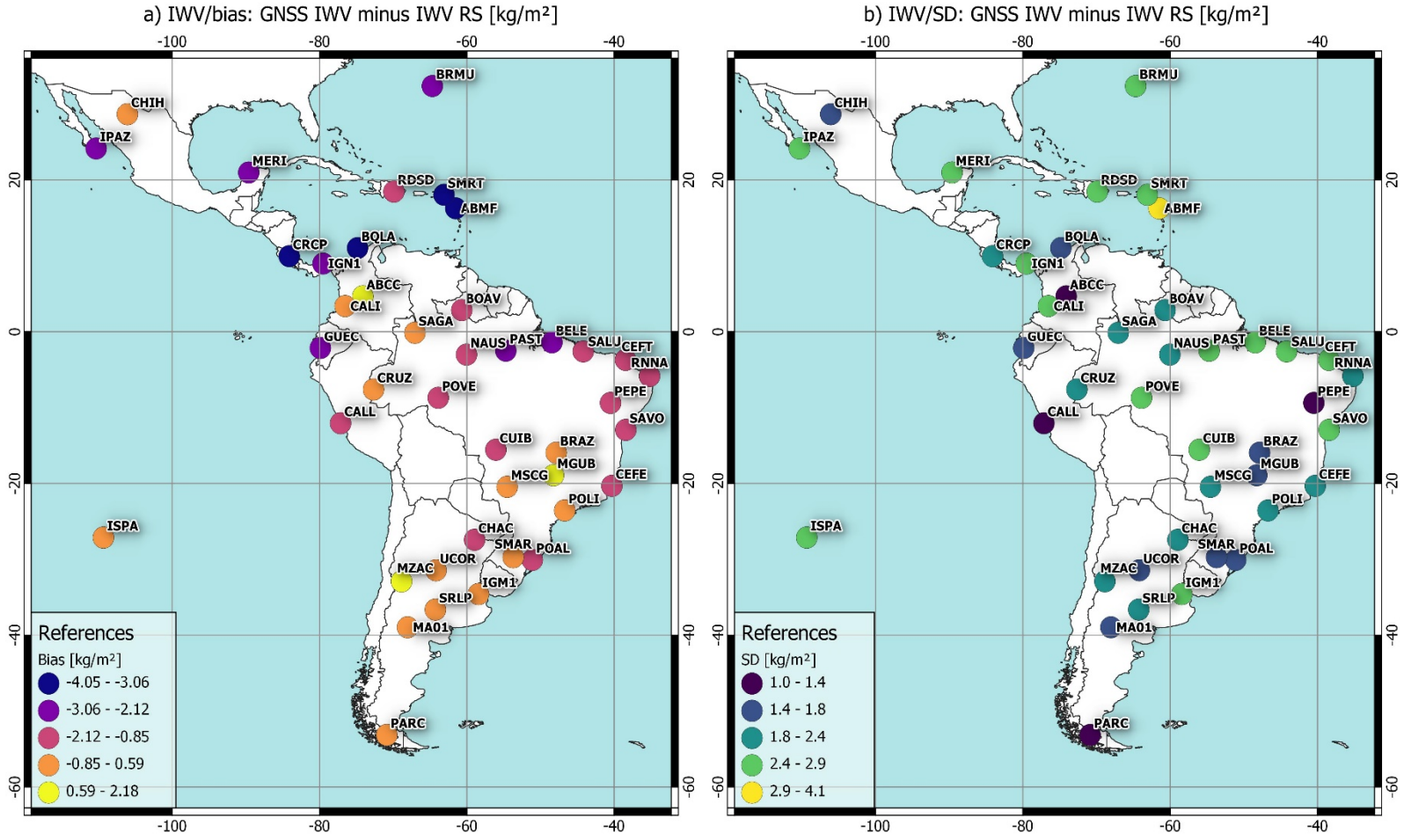
Subtropical, Lat -20°





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

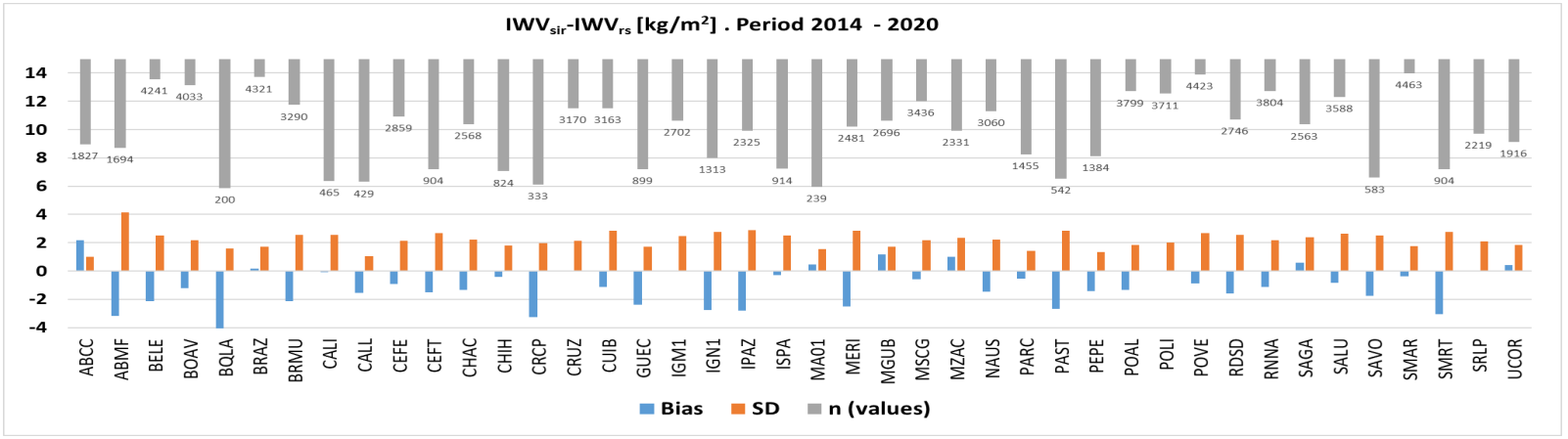
42 $GNSS_{SIR}$ stations / radiosonde within 30 km

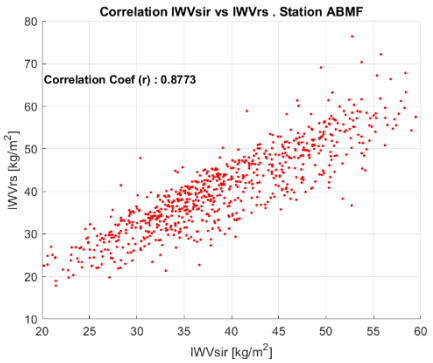


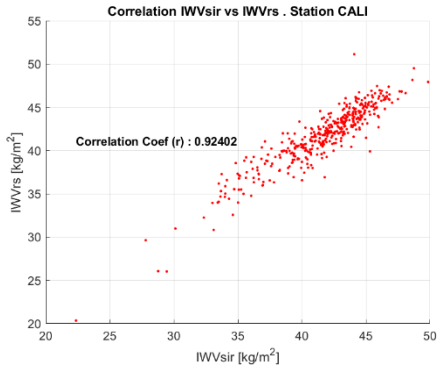
Mean Bias = - 1.08 kg/ m²
Mean SD = ± 2.22 kg/ m²
Mean correlation coefficient 0.96

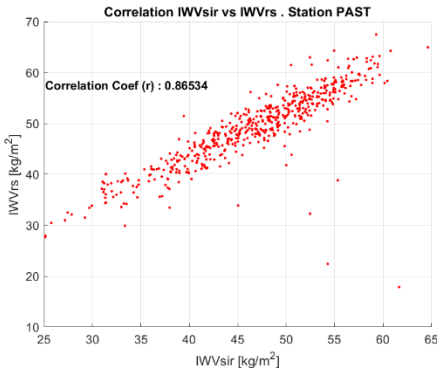
IWV_{GNSS_SIR} - IWV_{RS}

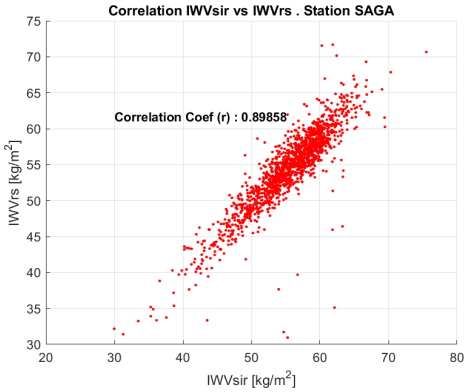
Period: 7 years (2014-2020)

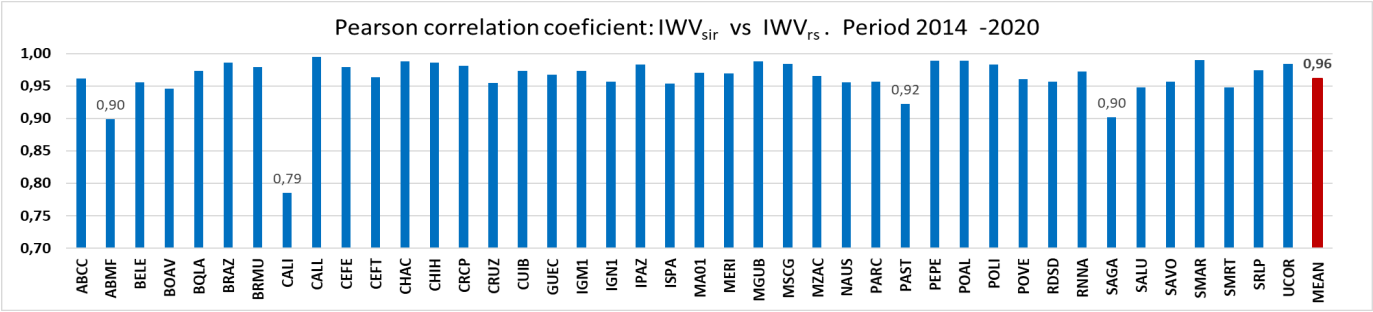












CONCLUSIONS

- **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 **junio-1996** en condición de IGS RNAAC SIR

IBGE
(Instituto Brasileiro de Geografia e Estatística)
→ desde **agosto-2008**

IGAC
(Instituto Geográfico Agustín Codazzi)
→ desde **agosto-2008**

LUZ
(Universidad del Zulia)
→ desde **enero-2010**

SGM
(Servicio Geográfico Militar)
→ desde **enero-2010**

IGM
(Instituto Geográfico Militar)
→ desde **enero-2010**

IGN
(Instituto Geográfico Nacional)
→ desde **enero-2011**

INEGI
(Instituto Nacional de Estadística y Geografía)
→ desde **enero-2011**

IGM
(Instituto Geográfico Militar)
→ desde **enero-2013**

UNA
(Universidad Nacional)
→ desde **enero-2013**

USCH
Universidad de Santiago de Chile
→ desde mayo 2019