Analysis of global climate variability from homogenously reprocessed ground-based GNSS measurements

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Overview

- Introduction
- GNSS Post-processing system
- Ground-based GNSS network
- Methodology
- Results
- Conclusions

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Atmospheric Water Vapour

- Could be measured as
  - Integrated Water Vapour (IWV) [kg/m^2]
  - Total Precipitable Water (TPW) [mm]

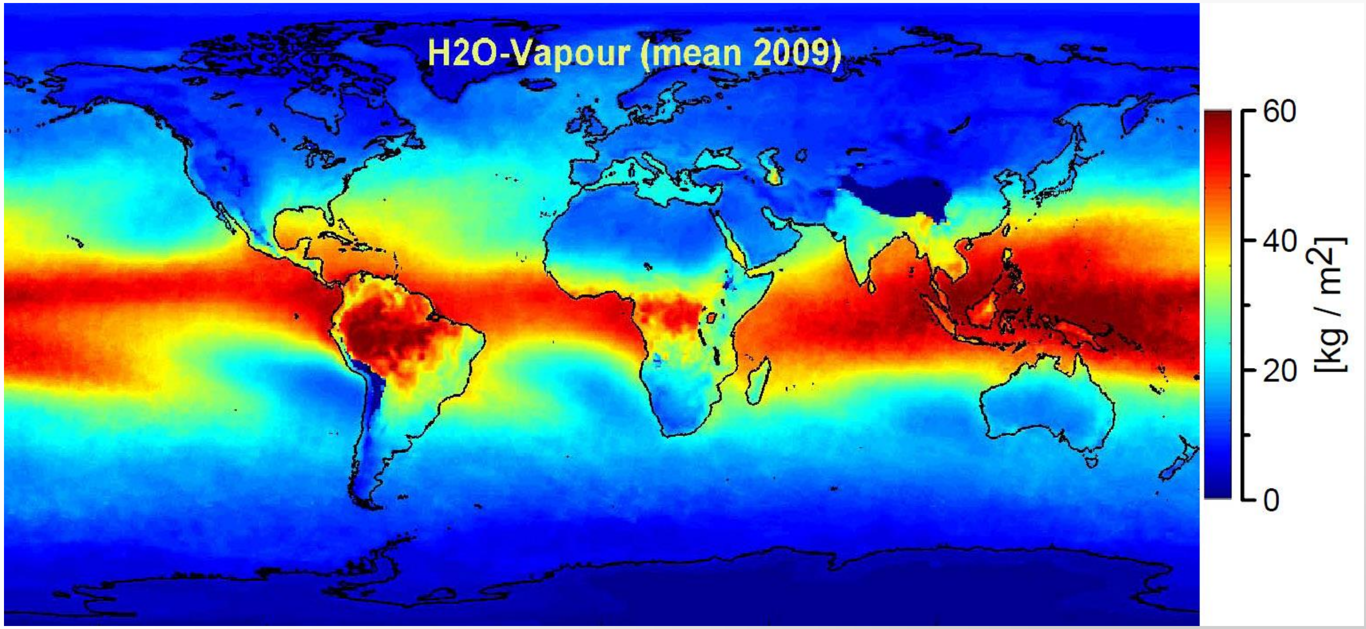
- Most abundant greenhouse gas

- Significant role in climate change

- Global distribution varies with maximum around the equator

Atmospheric Water Vapour

Example: Annual mean of IWV for 2009 (Taken by the ESA DUE GlobVapour Project)



(image source: http://www.globvapour.info/images/global_mean_water_vapor_column_2009.jpg)

- Maximum concentration of IWV is around the equator
- However, there is variation with longitudes as well

GNSS for Climate Monitoring

- The GNSS-derived Zenith Total Delay (ZTD) can be converted to IWV using surface pressure and temperature values
  - Relation: 1 kg/m^2 IWV ≈ 6 mm ZTD
- As of now, over 2 decades of global ground-based GNSS observations is available
- Homogeneously re-processed ZTD can be used to obtain long-term trends and variations in water vapour

GNSS Post-Processing System

- Processing characteristics of the post-processing system of the University of Luxembourg (UL):

Solution Type:	Precise Point Positioning	Double Differencing
Strategy:	PPP	DD
Processing Engine:	BSW5.2	BSW5.2
ZTD Output Interval:	2 hours	1 hour
Observation Window Used:	24 hours	24 hours
Processing Session Length:	24 hours	24 hours
GNSS Used:	GPS	GPS
A-Priori ZHD Model:	VMF	VMF
Troposphere Mapping Function:	VMF1	VMF1
Orbit Product Used:	COD Repro2	COD Repro2
Clock Product Used:	COD Repro2	COD Repro2
Antenna Models:	IGS08	IGS08
Coordinates Computed:	Yes	Yes
Elevation Cut-Off Angle:	3^{o}	3^{o}
Ambiguity Resolution:	Yes	Yes

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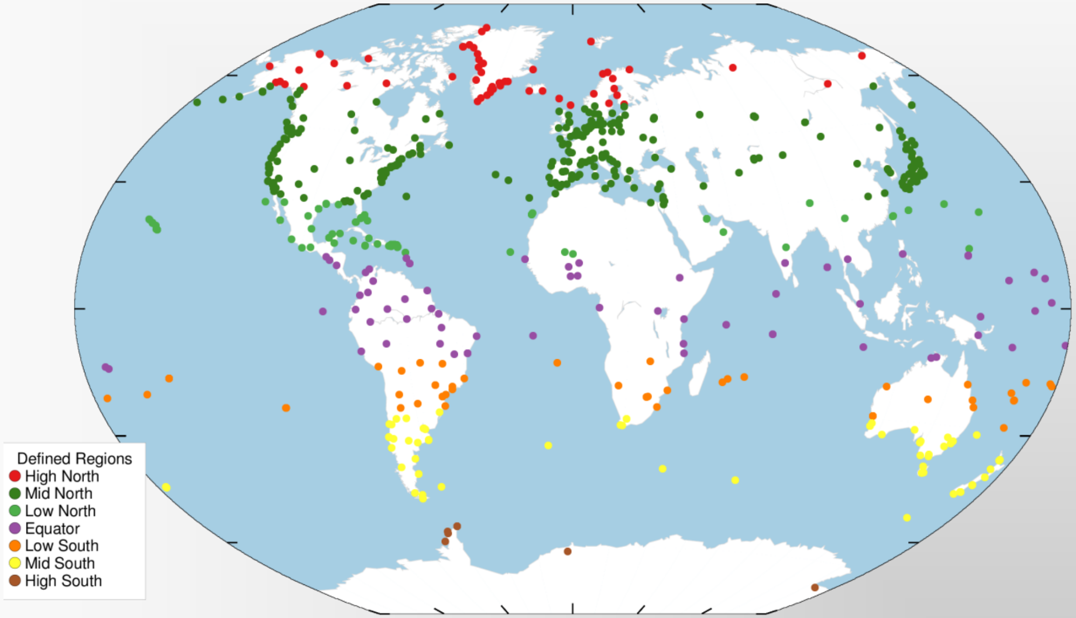
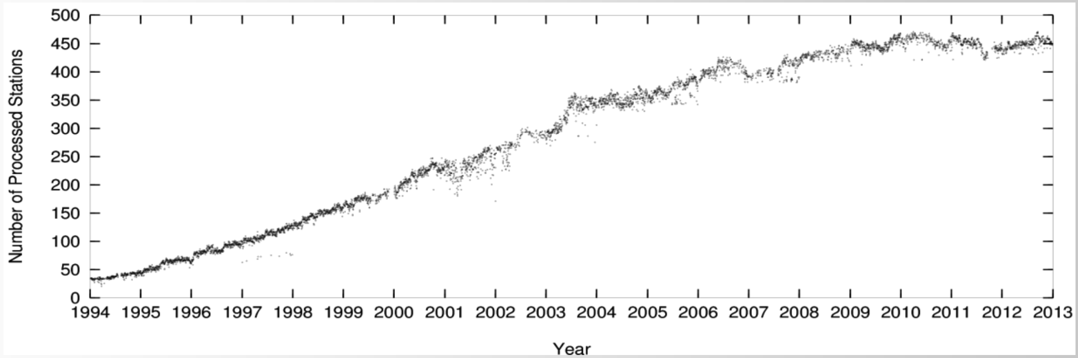
Test solution

Main solution

GNSS Post-Processing Network

- Global Network of over 400 stations
  - Divided into 7 latitude bands for this study





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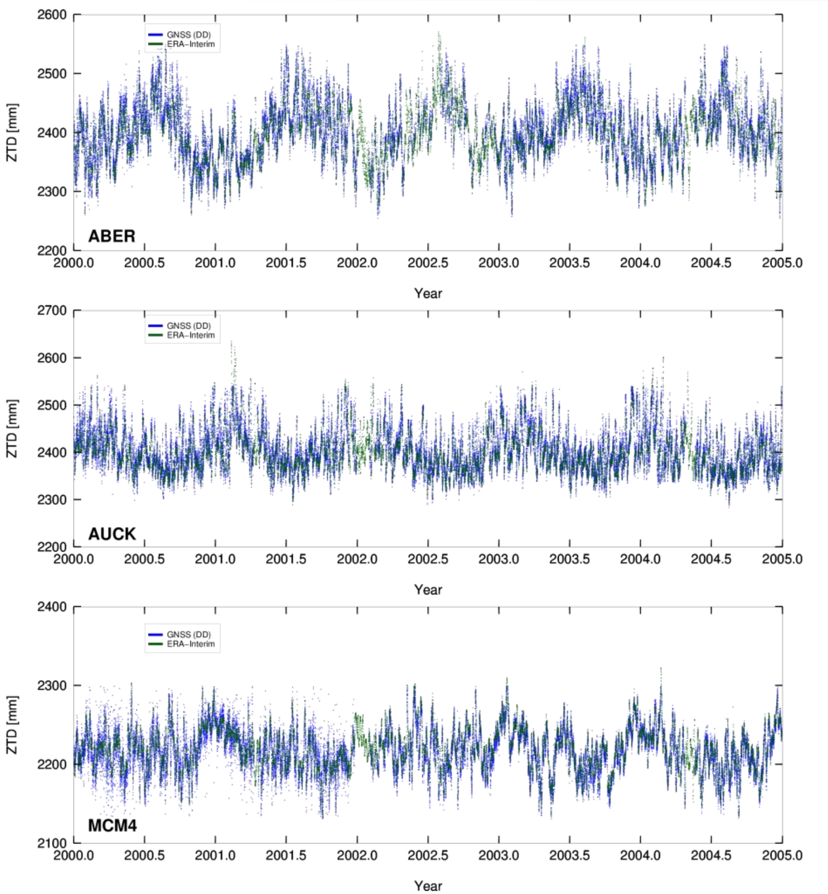
Validation of GNSS-derived ZTD

- GNSS-derived ZTD estimates compared to the ERA-Interim ZTD values
  - For 1 station from each region
  - For duration of 5 years



Station	Region	$Mean_{GNSS-ERA}$ [mm]	$STD_{GNSS-ERA}$ [mm]	$RMS_{GNSS-ERA}$ [mm]
ALRT	High North	-4.77	5.68	7.41
ABER	Mid North	3.63	11.28	11.85
BAHR	Low North	-7.34	15.83	17.45
ASC1	Equator	4.08	12.84	13.48
ALIC	Low South	9.51	14.52	17.36
AUCK	Mid South	3.98	12.71	13.32
MCM4	High South	-1.95	10.64	10.82

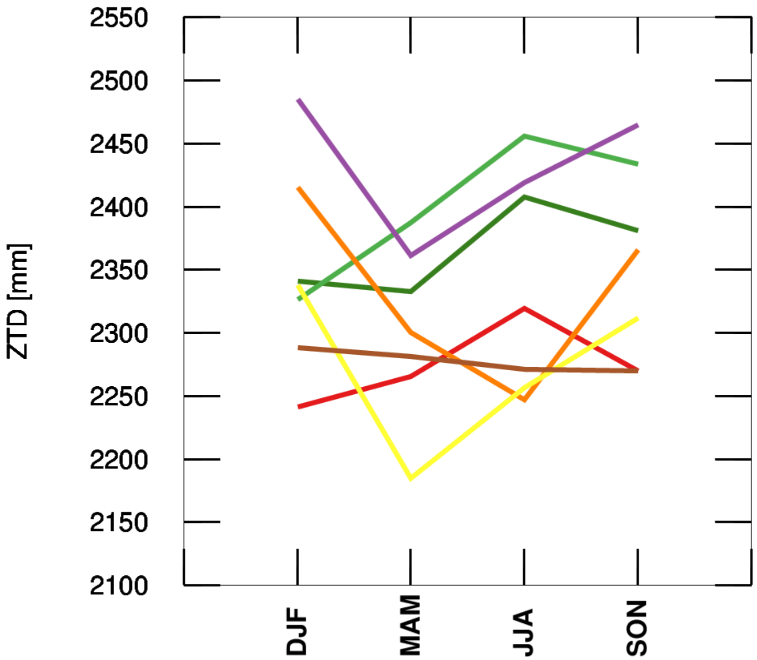
Trends in ZTD

- Regional trends computed for ZTD computed by averaging station-wise trends in each region
  - Stations with at least 70% observations used

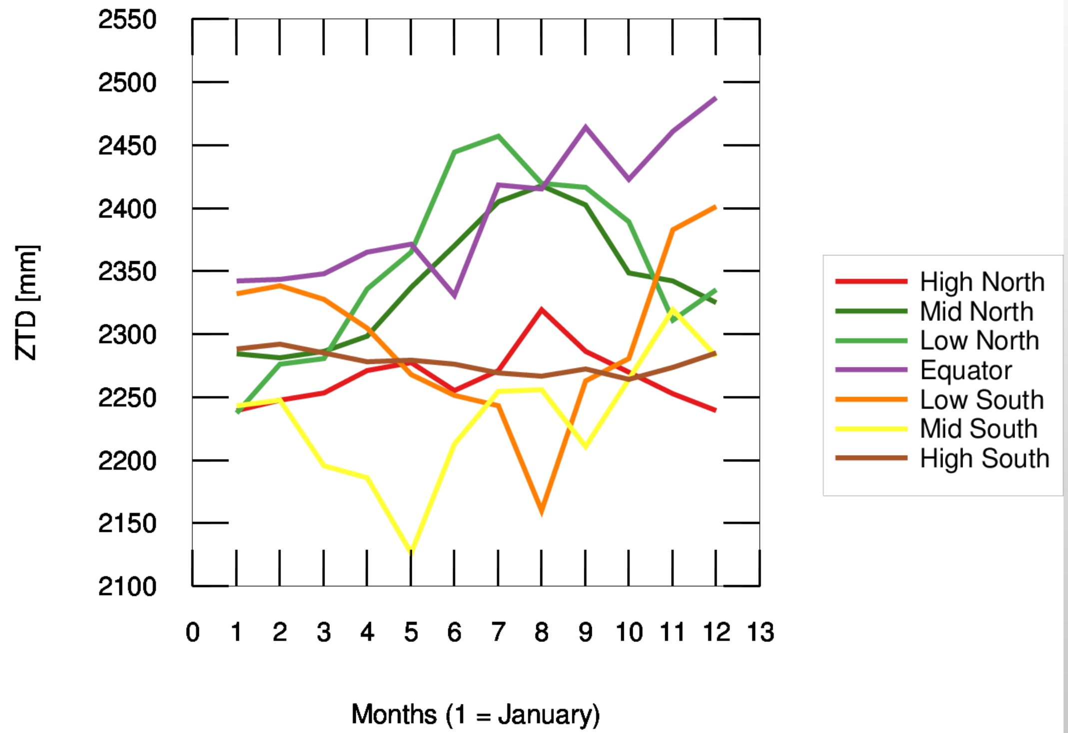
Region	Mean Trend (ZTD) [mm y^{-1}]
High North	0.049 ± 0.050
Mid North	0.271 ± 0.035
Low North	0.178 ± 0.053
Equator	0.312 ± 0.071
Low South	-0.641 ± 0.014
Mid South	-0.749 ± 0.337
High South	0.177 ± 0.021

Variability in ZTD

- Monthly and seasonal means of ZTD computed



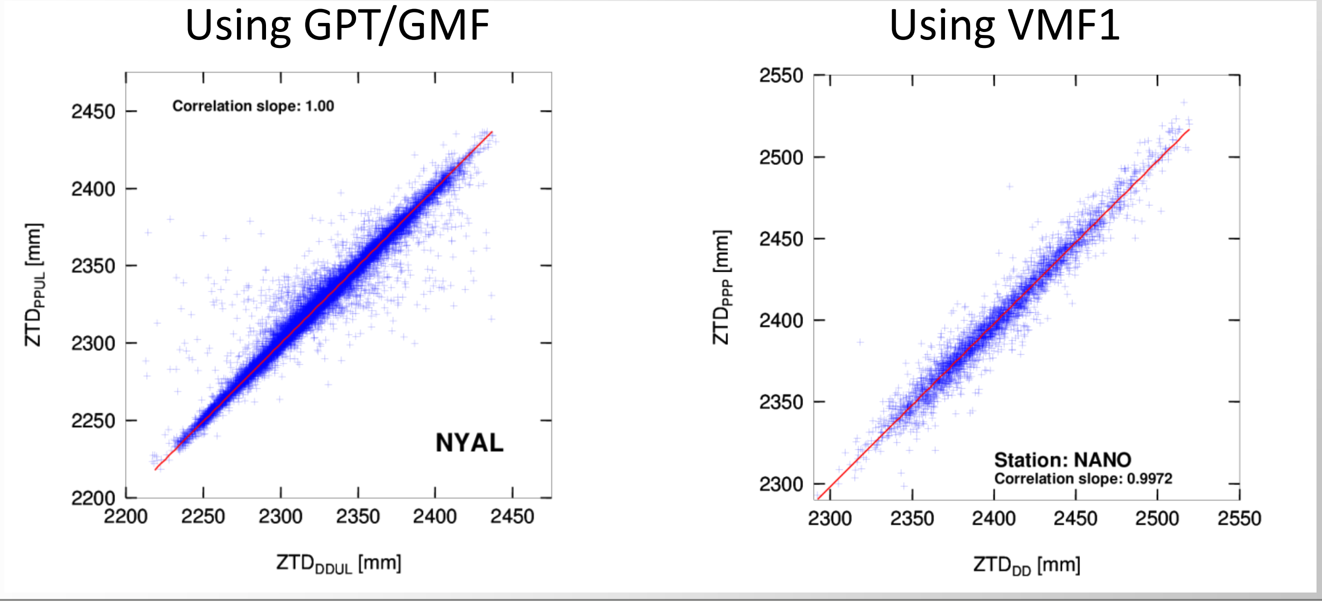
Seasonal Means of ZTD



Monthly Means of ZTD

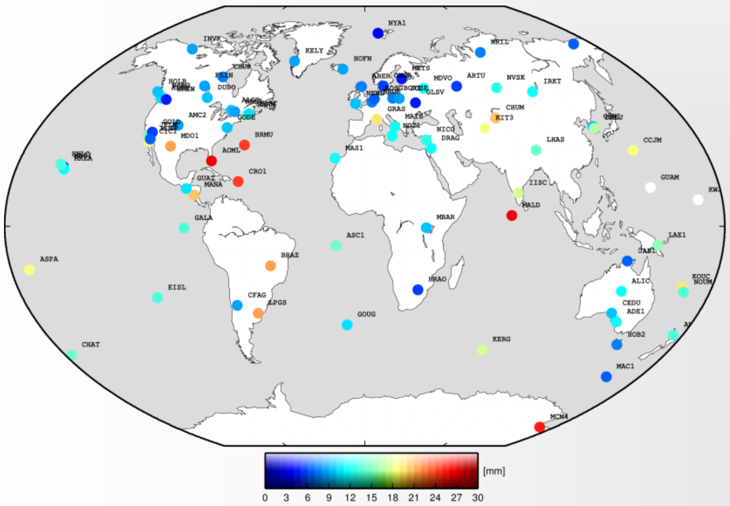
Comparison of Precise Point Positioning and Double Differencing for Climate Monitoring

- Precise Point Positioning (PPP) is computationally more efficient than the Double Differencing (DD) strategy
- Therefore, it is of interest to compare PPP and DD based ZTD estimates

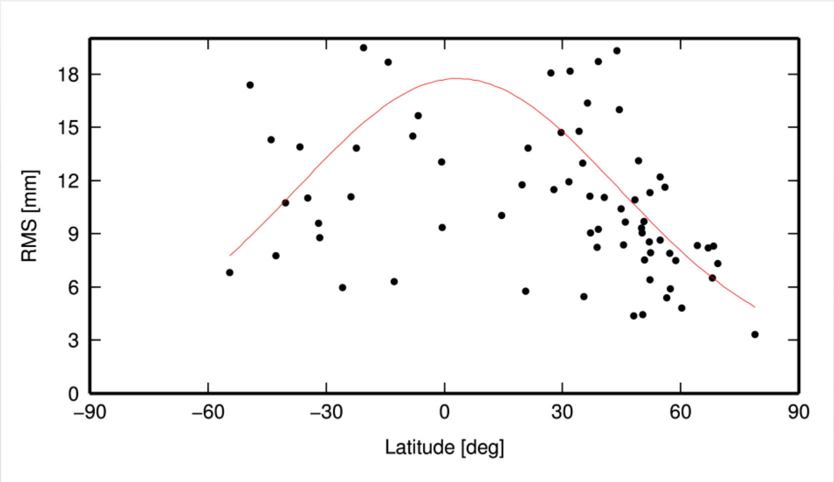


Comparison of Precise Point Positioning and Double Differencing for Climate Monitoring

- Global Picture (using GPT/GMF):



Global Distribution of RMS (ZTD_{PPP}-ZTD_{DD})

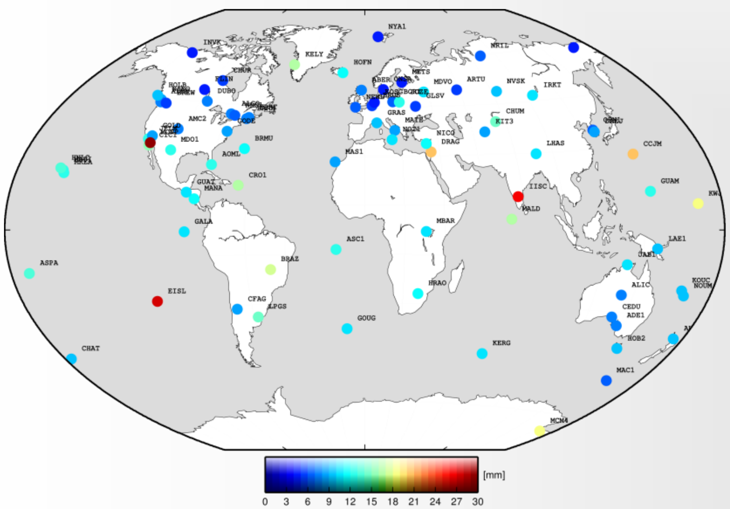


Latitude Dependence of RMS (ZTD_{PPP}-ZTD_{DD})

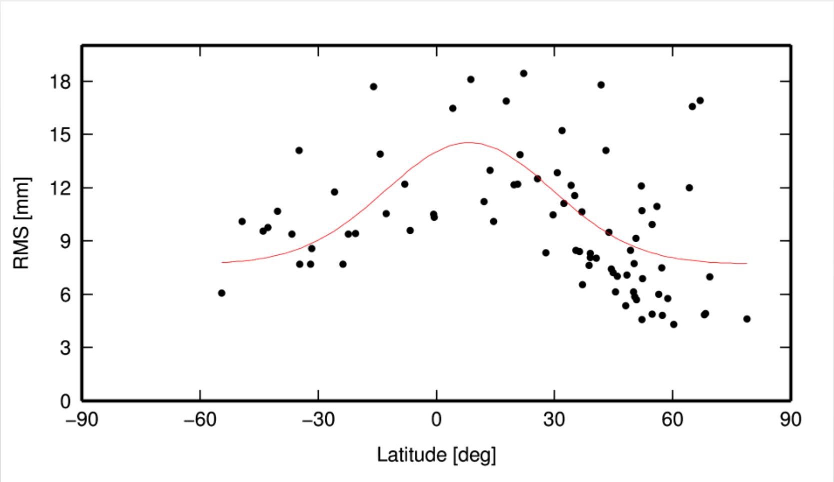
Mean = -1.35 ± 12.98 mm, RMS = 14.09 mm

Comparison of Precise Point Positioning and Double Differencing for Climate Monitoring

- Global Picture (using VMF1):



Global Distribution of RMS
(ZTD_{PPP}-ZTD_{DD})



Latitude Dependence of RMS
(ZTD_{PPP}-ZTD_{DD})

Mean = -0.68 ± 10.13 mm, RMS = 10.59 mm

Conclusions

- GNSS Post-processing system of the University of Luxembourg introduced
- Post-processed GNSS-derived ZTD dataset used to compute trends in ZTD for 7 regions
- Millimeter-level agreement found between GNSS-derived and ERA-Interim based ZTD estimates
- Negative ZTD trends found for the Low South and Mid South regions
- Positive ZTD trends found for northern, equatorial and High South regions
- ZTD estimates from PPP and DD processing strategies compared
  - A high correlation and millimeter level agreement found between the two
  - Bias between PPP and DD ZTD estimates have a maximum around the equator
  - Using VMF1 reduces the bias between PPP and DD ZTD estimates

Thank you!