Report of the Troposphere Coordinator

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Outline

- Key Milestone in the EPN Tropospheric Products
- GNSS-Meteorology Concept
- EPN ZTD Time Series
  - 2\textsuperscript{nd} EPN Reprocessing Campaign: EPN-Repro2 (1996-2014)
  - Operational Solution (2015-today)
- EPN ZTD data exploitation
- Summary and next steps
Key Milestone

- 2001: Special Project
- 2008: Routine Operation
- 2014: Troposphere Analysis Coordinator moved from BKG to ASI/CGS
GNSS-Meteorology Concept

Noise for Geodesy
Signal for Meteorology

Tropospheric delay

\[ L_{rec}^{sat} = \rho_{rec}^{sat} + c \cdot (\delta t_{rec} - \delta t^{sat}) + \lambda \cdot N_{rec}^{sat} - d_{iono} + d_{tropo} + \varepsilon_{\phi} \]

\[ d_{tropo}(\alpha, e) \equiv ZHD \times m_h(e) + ZWD \times m_w(e) + [G_N \cos \alpha + G_E \sin \alpha] \times m_G(e) \]

\[ N_d = k_1 \cdot \left( \frac{P_d}{T} \right) \quad N_w = k_2 \cdot \left( \frac{e}{T} \right) + k_3 \cdot \left( \frac{e}{T^2} \right) \]

Integrated Water Vapour
\[ IWV = \kappa (T_m) \cdot ZWD \]

EUREF 2018 Symposium, May 30, June 1 2018, Amsterdam, the Netherlands
Mean ZPD biases wrt weekly EPN troposphere solution

(EPN-repro2 + routine)

Year

ZPD Biases [mm]


ZPD STD [mm]

0 5

834 938 1042 1147 1251 1356 1460 1564 1669 1773 1877 1922

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EPN-Repro2 1996-2014
5 ACs

Operational 2015-today
16 ACs
EPN-Repro2 – from 1996 to 2014

EPN-Repro2 - From GPS wk 0834 to 1824
- 5 Input Solutions
- 3 main GNSS SW (Bernese, Gamit, Gipsy)

5 (+3) Solutions
- ASI (GIPSY, Full EPN)
- GOP (Bernese, Full EPN)
- LPT (Bernese, EPN sub-net)
- IGE (Bernese, EPN sub-net)
- MUT (GAMIT, Full EPN)

3 Bernese Solutions
- GOP (Full EPN network)
- LPT (EPN Sub-network)
- IGE (EPN Sub-network)

3 Solutions (Full EPN)
- ASI (GIPSY)
- GOP (Bernese)
- MUT (GAMIT)

Different software
Different networks

Same software
Different networks

Different software
Same network

COST ACTION ES1206 ‘GNSS4SWEC’ Working Group 3: ‘Use of GNSS tropospheric products for climate monitoring’

- First Reference data set: IGS Repro1 1995-2010 global
- **Second Reference data set: EPN-Repro2 1996-2014 Europe**

ZTD trends
EPN-Repro2 is a combined product.

**Research Question:**

Is there any ‘loss of information’ in performing the combination?

**Wavelet analysis:**

1. All 13 year-long time series have a very strong annual component
2. After removing it, finer features become visible
3. EPN spectra are similar

*Santos M.C., Pacione R., Balidakis K., Dick G., Wickert J., Heinkelmann R., and Männel B.: On the combination of neutral atmospheric delay estimates from different solutions, EGU GA 2018*
Wavelet as0 MATE

Santos M.C., Pacione R., Balidakis K., Dick G., Wickert J., Heinkelmann R., and Männel B.: On the combination of neutral atmospheric delay estimates from different solutions, EGU GA 2018
Santos M.C., Pacione R., Balidakis K., Dick G., Wickert J., Heinkelmann R., and Männel B.: On the combination of neutral atmospheric delay estimates from different solutions, EGU GA 2018
Operational Solutions

- **Period**: GPS weeks 1825 – 1996
- **16 ACs**: ASI, BEK, BEV, BKG, COE, IGE, IGN, LPT, MUT, NKG, RGA, ROB, SGO, SUT, UPA, WUT
- **Distributed Processing**: The EPN stations are distributed among the AC in such a way that each station is analyzed by at least three AC. This guarantees the reliability of the EPN products
- **GNSS SW**: GIPSY-OASIS (1 AC), GAMIT (1 AC), BERNESE (14 ACs)
- **Processing Options**: refer to ‘Guidelines for EPN Analysis Centres’

May, 23rd 2018: 323 EPN stations

<table>
<thead>
<tr>
<th>Station #</th>
<th>6 AC</th>
<th>5 AC</th>
<th>4 AC</th>
<th>3 AC</th>
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<tr>
<td>%</td>
<td>1</td>
<td>18</td>
<td>61</td>
<td>20</td>
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Operational – Total vs Combined Stations

- EIG EUMETNET Project coordinating the near real-time delivery of data from ~3000 GPS sites delivering > 14M ZTDs pcm.
- Focus is on GPS-only hourly processing, delivering only ZTD in 90mins.
- Operational assimilation at a few European National Met Services, many others under testing.
- Use of E-GVAP ZTDs has proven positive impact on NWP forecast skill.
- Surface T and P used for conversion to Integrated Water Vapour (IWV).
- Active Quality Control (AQC) in place.
- MoUs in place with EUREF and EUPOS.
Operational – Cumulative Solution

- Tropospheric cumulative solution T1981, EUREF mail 9326
- Next update: October 2018
Operational – E-GVAP vs EPN

Period: Jul 2008 - Feb 2018

E-GVAP Super-Sites → EPN stations
GNSS-derive IWV can be used to derive water vapor attenuation, $A_{wv}$ [1].

$A_{wv}$, plus dry air attenuation, get “clear sky” or gaseous attenuation.

Gaseous attenuation is used to derive total attenuation from beacon measurements in propagation experiments [2].

Como EPN IWV data are compared with Milano IWV radiometric measurements.

Distance Como-Milano: \sim 37.5 km.

Preliminary results satisfactory.

Courtesy of G.Siles (UPB)


Summary and next steps

- ZTD Products at the EPN stations available since 1996
- EPN-Repro2 selected as the 2° community reference data set by ‘GNSS4SWEC’ WG3
- Routine monitoring activities of the EPN AC troposphere solutions
- Routine inter-technique evaluation
- Next steps:
  - Horizontal Gradients evaluation
  - EVGA and EPN collocated stations
  - SINEX_TRO v2.0

Acknowledgment: e-GEOS work is carried out under ASI contract N. 2017-21-I.0