

# **GOP Repro2 (1996-2014)**

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# **GOP Repro2 - main characteristics**

- Bernese GNSS Software V5.2
- GPS only solution 1996-2013 (GLONASS to be included later)
- E08\_1788 absolute antenna model (priority of individual)
- GMF/VMF1 for ZHD + ZWD (resolution 1 hour)
- Chen & Herring MF horizontal gradients (resolution 6 hours)
- Network: full EPN following the predefined intervals
- Reference frame: IGb08 (fiducial stations routinely checked)
- Ambiguity resolution: L5 + L6 - QIF

# GOP Repro2 - solutions (1996-2014)

All solutions done in a single run using parallel mode, thus input data, pre-processing, outlier rejection and other is common.

- **GOP0 - GMF, 3 deg cut-off, ZTD(1h) + GRD(6h)**
- **GOP1 - VMF1, 3 deg cut-off, ZTD(1h) + GRD(6h)**
- GOP2 - VMF1, 7 deg cut-off, ZTD(1h) + GRD(6h)
- GOP3 - VMF1, 10 deg cut-off, ZTD(1h) + GRD(6h)
- **GOP4 - VMF1, 3 deg cut-off, ZTD(1h) + GRD(6h) + ATL**

□ GOP Repro1, NMF, 3 deg cut-off, ZTD(1h), no GRD! (I05 and I08 ATX-reference frame)

Solution	North [mm]	East [mm]	Up [mm]
GOP-Repro1/I05	3.01	2.40	5.08
GOP-Repro1/I08	2.64	2.21	4.94
<b>GOP0</b>	<b>1.20</b>	<b>1.30</b>	<b>4.14</b>
<b>GOP1</b>	<b>1.23</b>	<b>1.33</b>	<b>3.97</b>
GOP2	1.24	1.33	4.01
GOP3	1.26	1.34	4.07
<b>GOP4</b>	<b>1.14</b>	<b>1.24</b>	<b>3.73</b>


# GOP-repro2 - new strategy tropo

## Daily boundaries estimates


- **Old:** using only 1 DAY solution (NEQs) → daily discontinuities
  - ▢ Weekly coordinates fixed → *CRD weekly discontinuities (only a minor impact on ZTD)*
- **New:** DAY + stacking with DAY-1 + DAY+1 solutions → no discontinuities
  - ▢ Weekly coordinates fixed → *CRD weekly discontinuities (only a minor impact on ZTD)*

## • Weekly boundaries

- **Old:** using only 1 DAY solution (NEQs) → weekly discontinuities
  - ▢ Weekly coordinates fixed for all days of the GPS week → *a minor impact*

**ZTD** 

- **New:** DAY + stacking with DAY-1 + DAY+1 solutions → no discontinuities

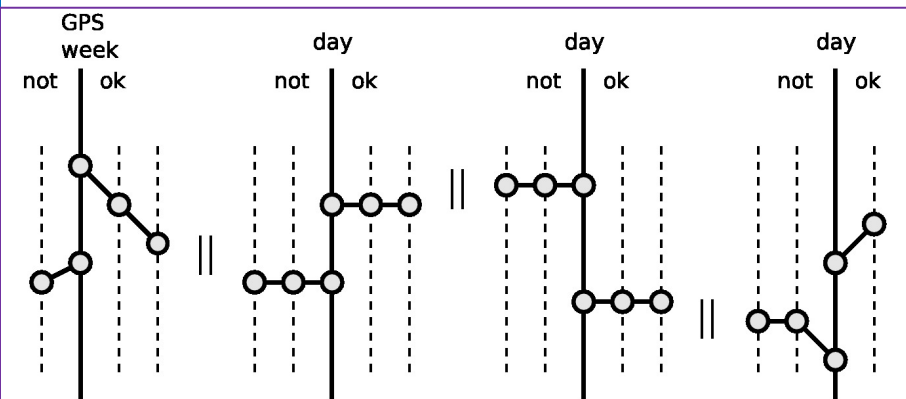
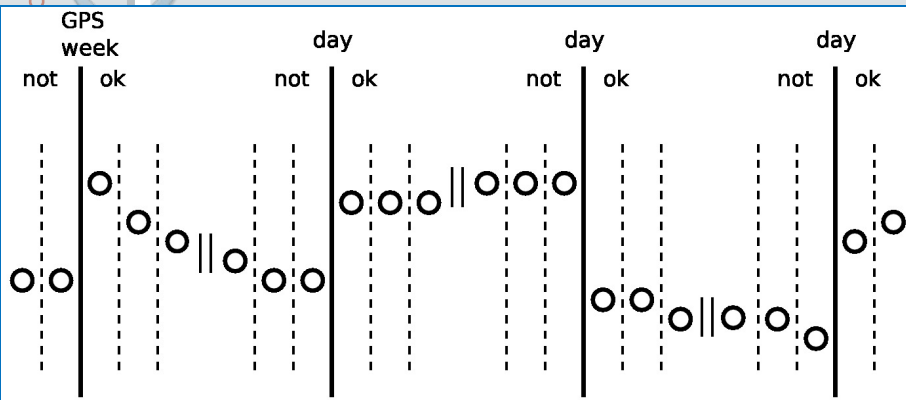
**CRD** 

- ▢ Weekly coordinates fixed consistently for all stacked 3 days → *a minor impact*

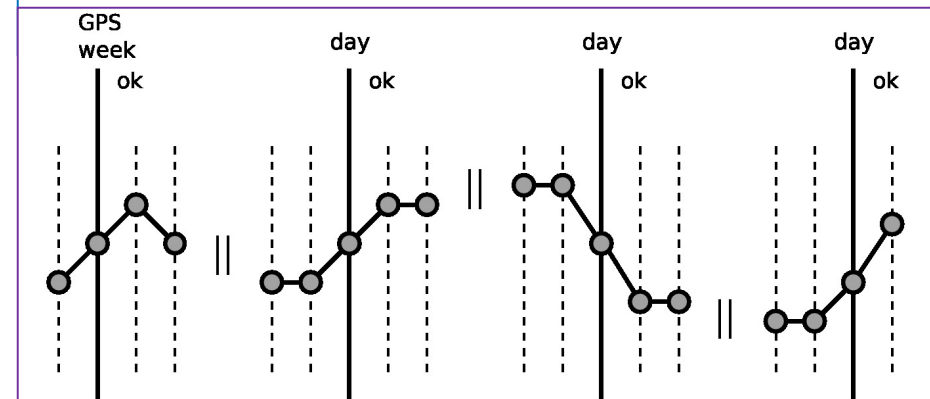
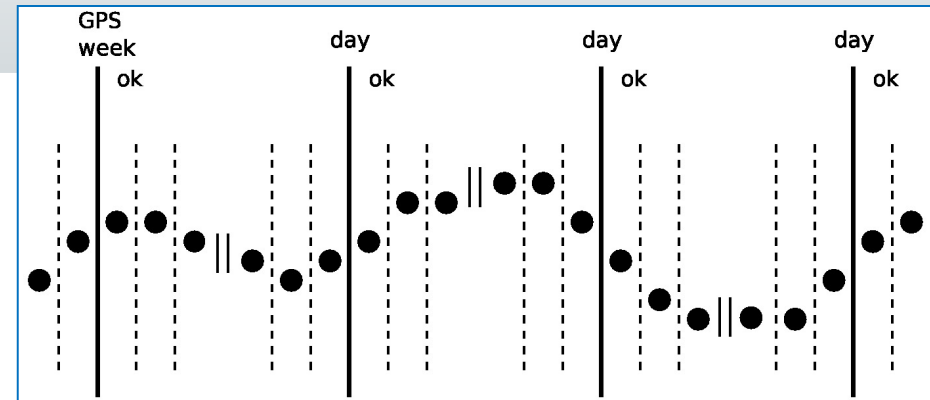
▢ *Last day of GPS week (Saturday) finally combined after data*

# GOP-repro2 - new strategy for tropo estimates

**OLD:** daily/weekly discontinuities **NEW:** continuous



time ->



time ->

Tropospheric parameter representation/output

Offset values at HR:30 (TOP, discrete representation)

Piece-wise linear (BOTTOM, original representation)

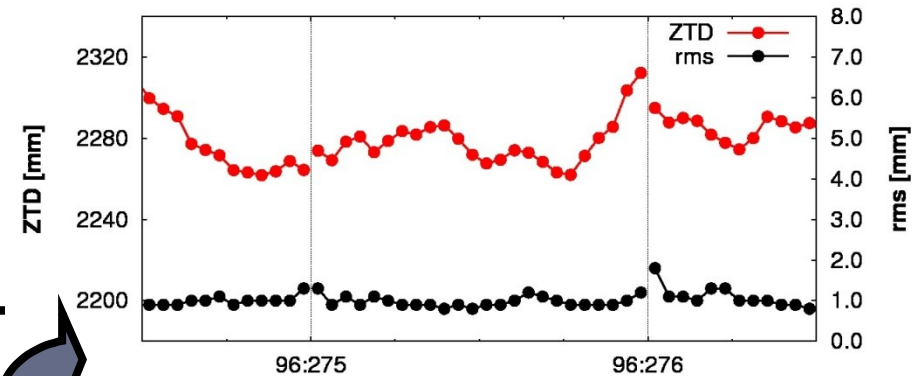
# GOP-Repro2 - new strategy

## (results)

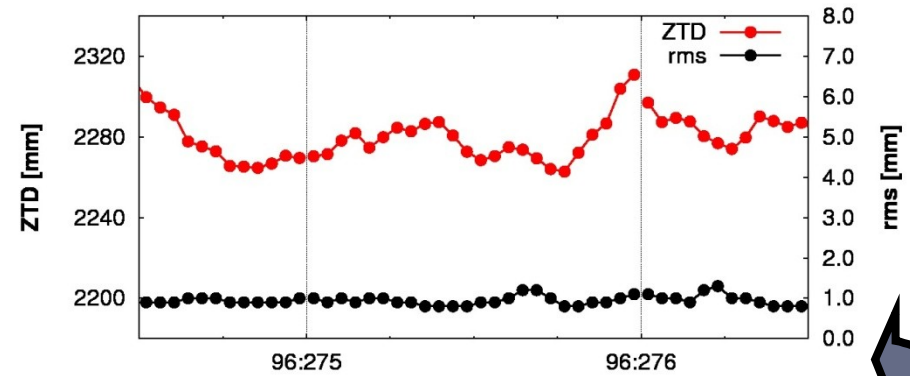
**OLD:** discontinuous

**NEW:** continuous

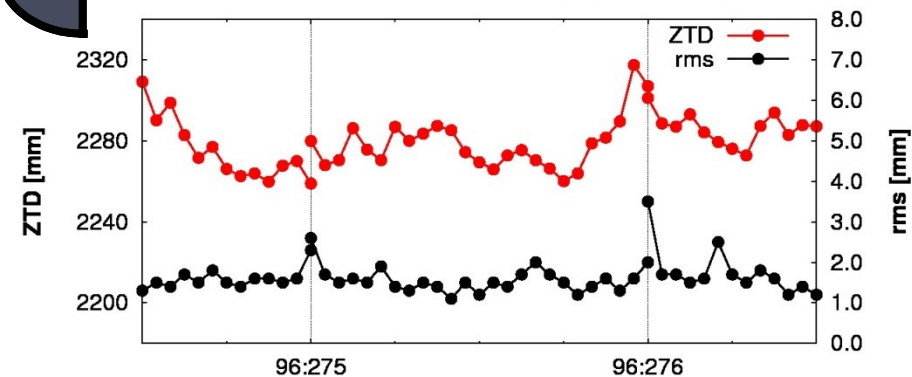
**GOP Repro1+ /GT0: daily [30min offset]**



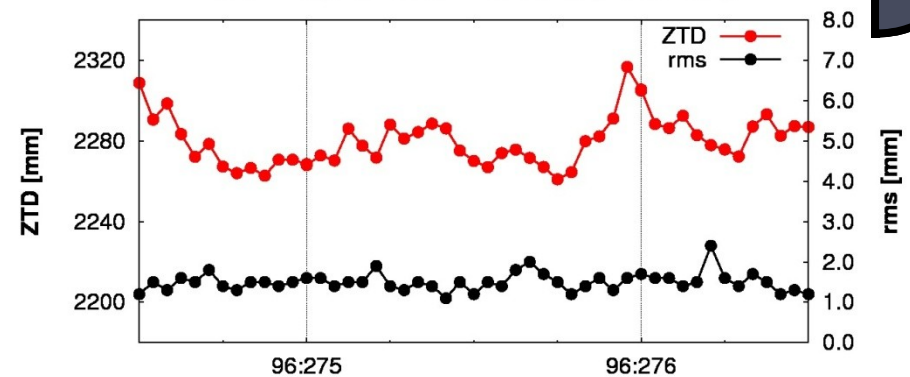
**GOP Repro1+ /GT3: 3-daily [30min offset]**



**GOP Repro1+ /GT1: daily [no offset]**



**GOP Repro1+ /GT2: 3-daily [no offset]**



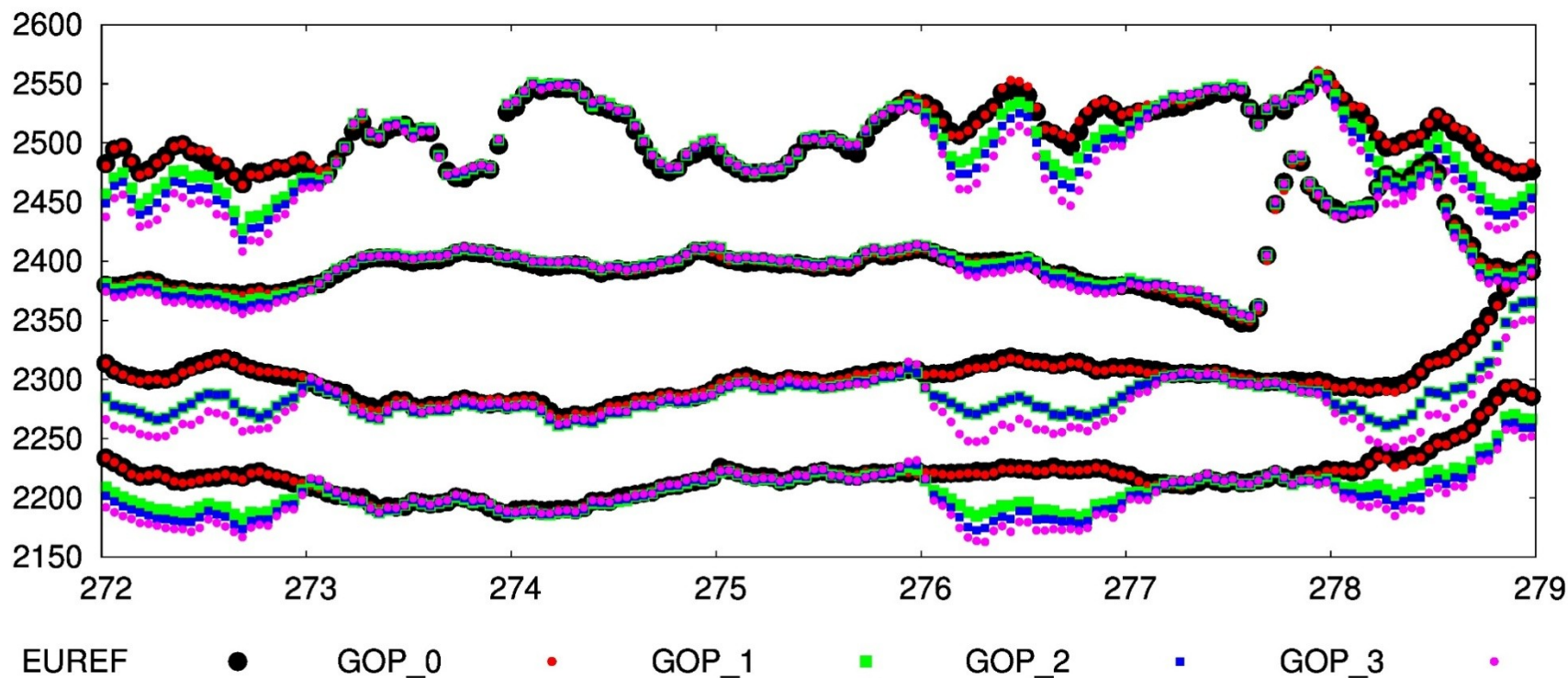
Offset values at HR:30 (TOP, discrete representation)

Piece-wise linear (BOTTOM, original representation)

# GOP solution delayed by 6 months

- VMF1 bug in BSW identified at SwissTopo (Feb 25, 2015)
- many DoYs affected, dependent on elevation cut-off
- → BSW update D\_052 - 6/3/2015 (D\_GRID.f90) fixed the problem.

*Plot shows the effect on stations: MALL, ONSA, GOPE, TUBO*

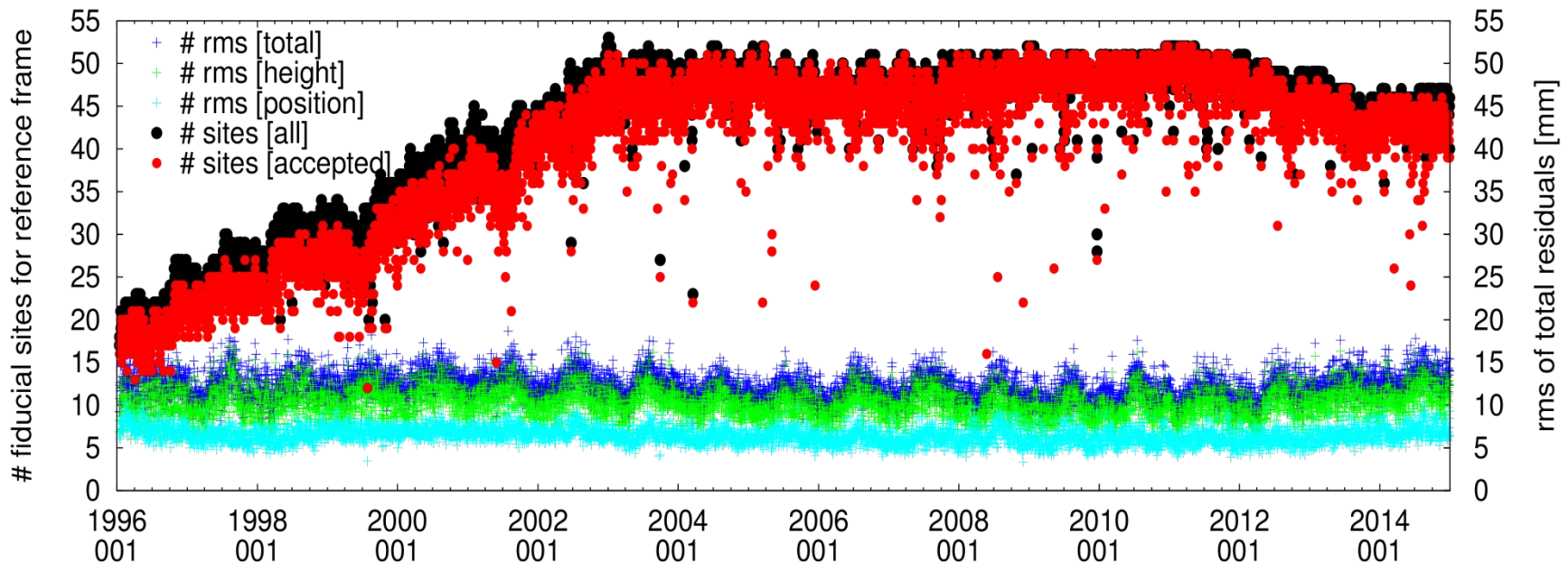




# GOP reference frame realization

- Reference frame realization using pre-defined fiducial stations
- Iterative check for reliability of fiducial stations

GOP Repro2 - Reference frame realization





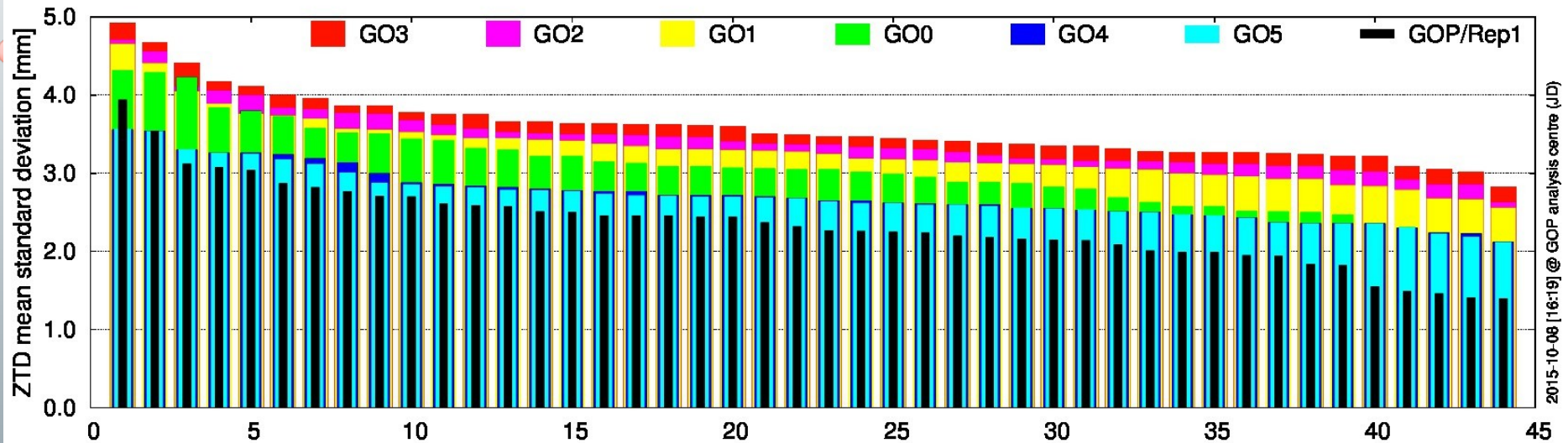
# ZTD: comparison to EUREF (statistics)

- Parameters: ZTD only
- Reference: EUREF combined solution (repro1 + final operational)
- Period: 1996-2014, initially pre-selected 30 EPN stations
- Statistics: mean over all selected stations

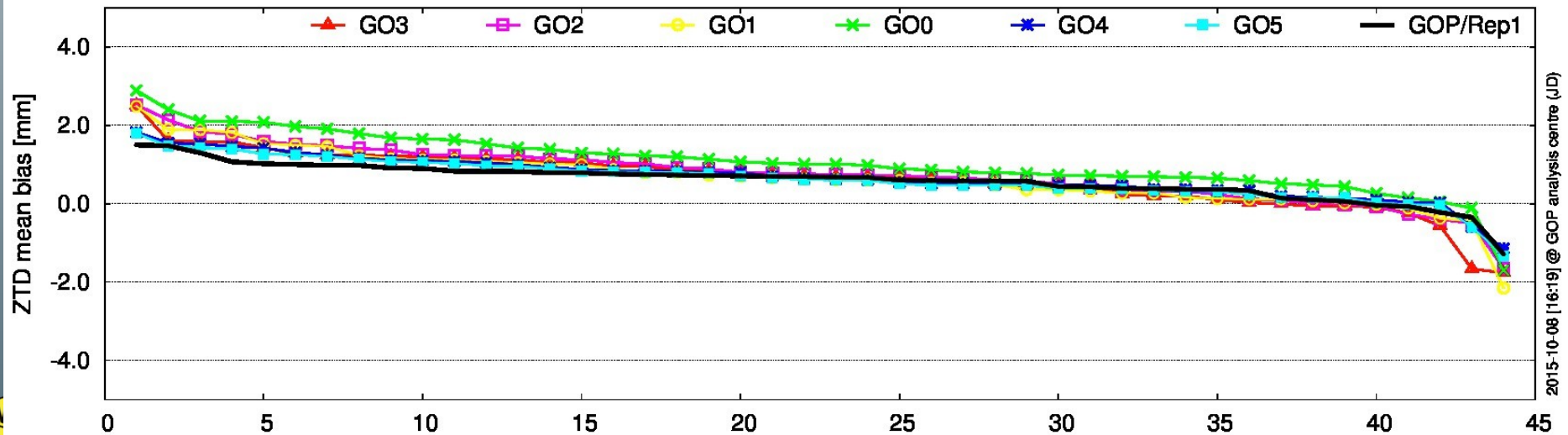
Solution	ZTD mean [mm]	ZTD sdev [mm]	ZTD rms [mm]	Pairs #	Excl #
GOP- Repro1/I08	0.68	2.27	2.45	134431	1339
<b>GOP0</b>	<b>1.01</b>	<b>3.05</b>	<b>3.25</b>	<b>145668</b>	<b>1435</b>
<b><u>GOP1</u></b>	<b><u>0.62</u></b>	<b><u>3.19</u></b>	<b><u>3.38</u></b>	<b><u>145668</u></b>	<b><u>1214</u></b>
GOP2	0.74	3.34	3.49	145668	1199
GOP3	0.72	3.47	3.61	145668	1173
<b><u>GOP4</u></b>	<b><u>0.63</u></b>	<b><u>2.65</u></b>	<b><u>2.79</u></b>	<b><u>145668</u></b>	<b><u>948</u></b>

# ZTD: comparison to EUREF (sites)

ZTD comparison: GOP Rep1/2 - EUR Rep1 (selected stations)

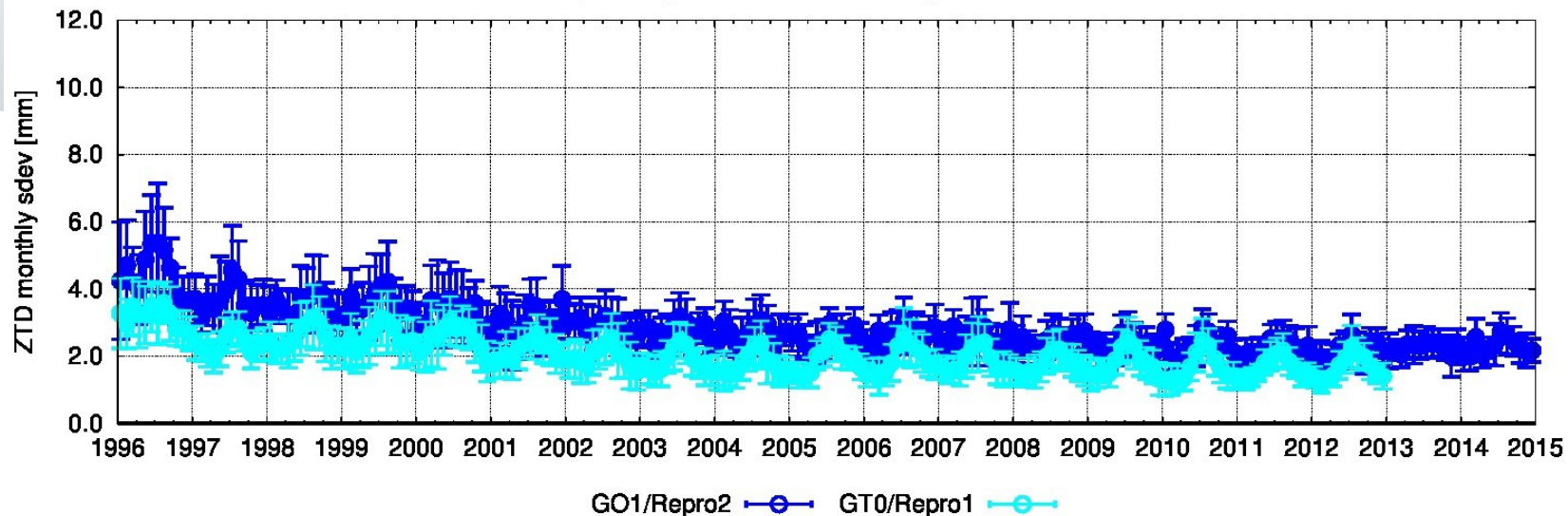


ZTD comparison: GOP Rep1/2 - EUR Rep1 (selected stations)

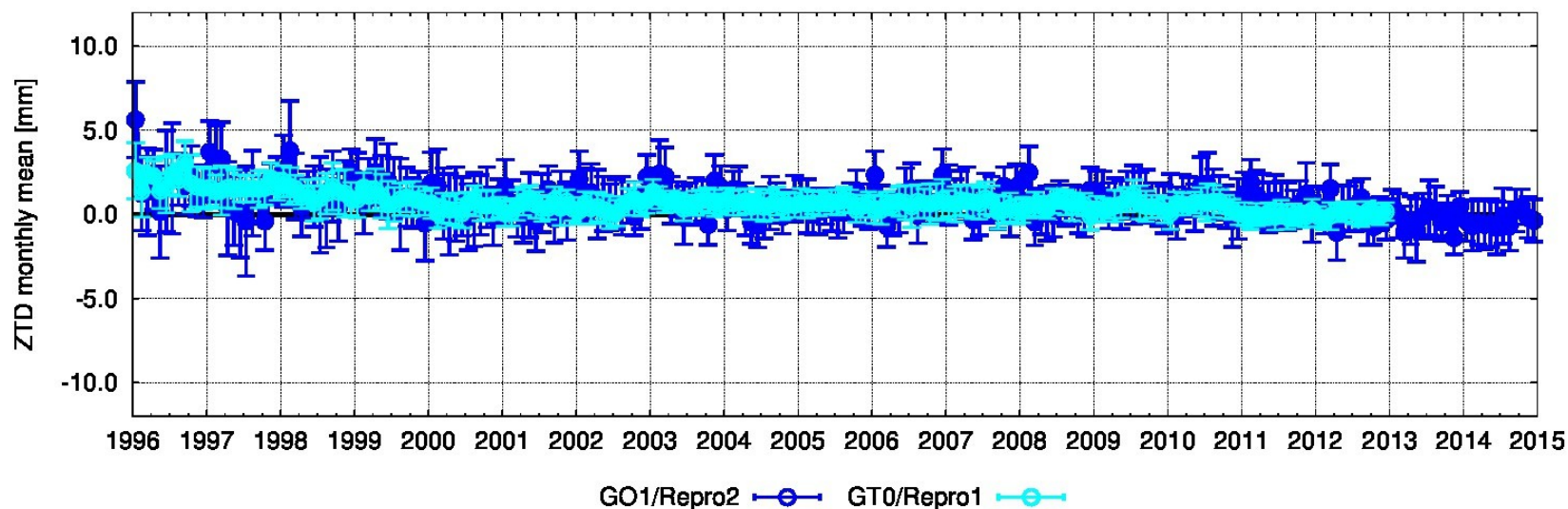


# ZTD: comparison to EUREF (time-

**ZTD monthly comparisons: GOP/Repro2 - EUR/Combined**



**ZTD monthly comparisons: GOP/Repro2 - EUR/Combined**



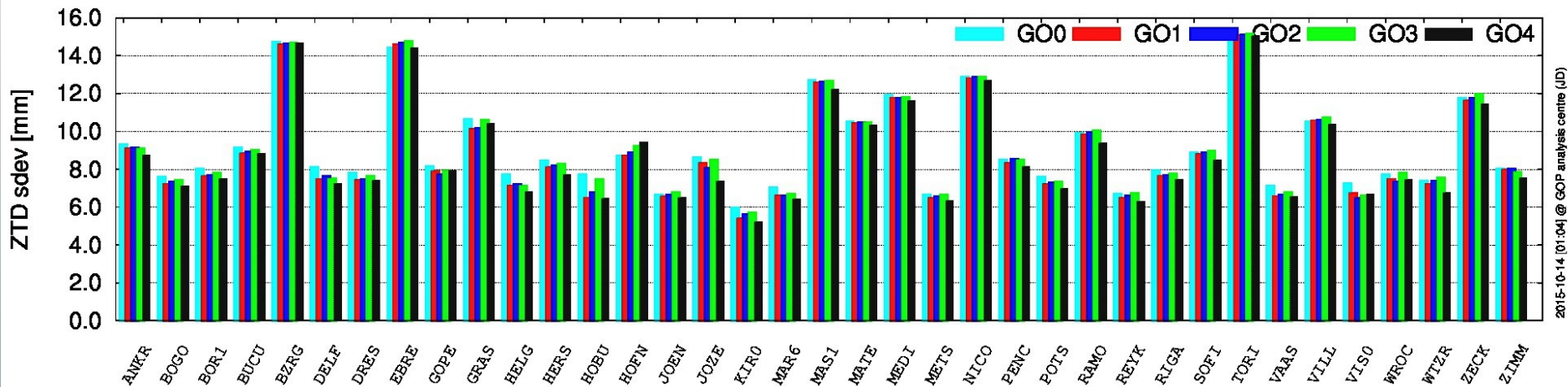
# GRD: comparison to ERA-Interim (statistics)

- Parameters: ZTD + N/E-gradients
- Software: using GFZ's ray-tracing software (Zus et al, 2012)
- NWM: global 1 × 1deg ECMWF's ERA-Interim reanalysis (Dee et al. 2011)
- Period: 1996-2014, initially pre-selected 30 EPN

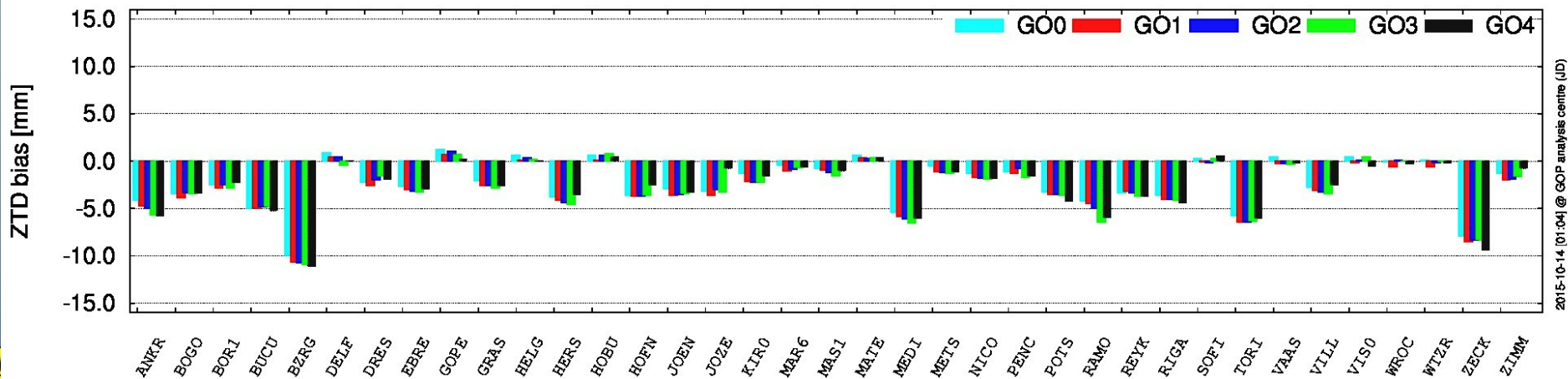
Solution	ZTD [mm]	N-grd [mm]	Egrd [mm]	Pairs #	Excl #
GT0 (Rep1)	-1.65 ± 7.93	-	-	21203	235
<b>GPO0</b>	<b>-2.01 ± 8.13</b>	<b>+0.01 ± 0.46</b>	<b>-0.05 ± 0.42</b>	<b>20410</b>	<b>244</b>
<b><u>GOP1</u></b>	<b><u>-2.55 ± 7.89</u></b>	<b><u>Not finished</u></b>	<b><u>Not finished</u></b>	<b><u>20407</u></b>	<b><u>263</u></b>
GOP2	-2.20 ± 7.73	Not finished	Not finished	20407	269
GOP3	-2.84 ± 7.87	Not finished	Not finished	20407	257

# ZTD: comparison to ERA-Interim (sites)

ZTD comparison : GOP/Repro2 - ERA-Interim



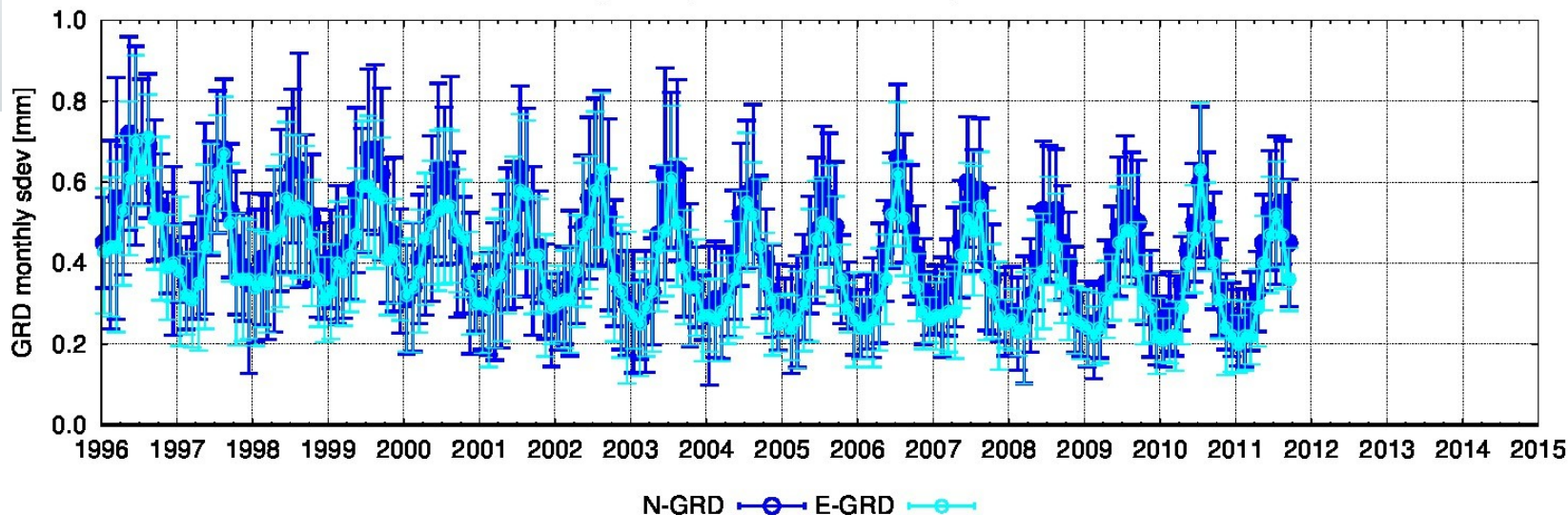
ZTD comparison : GOP/Repro2 - ERA-Interim



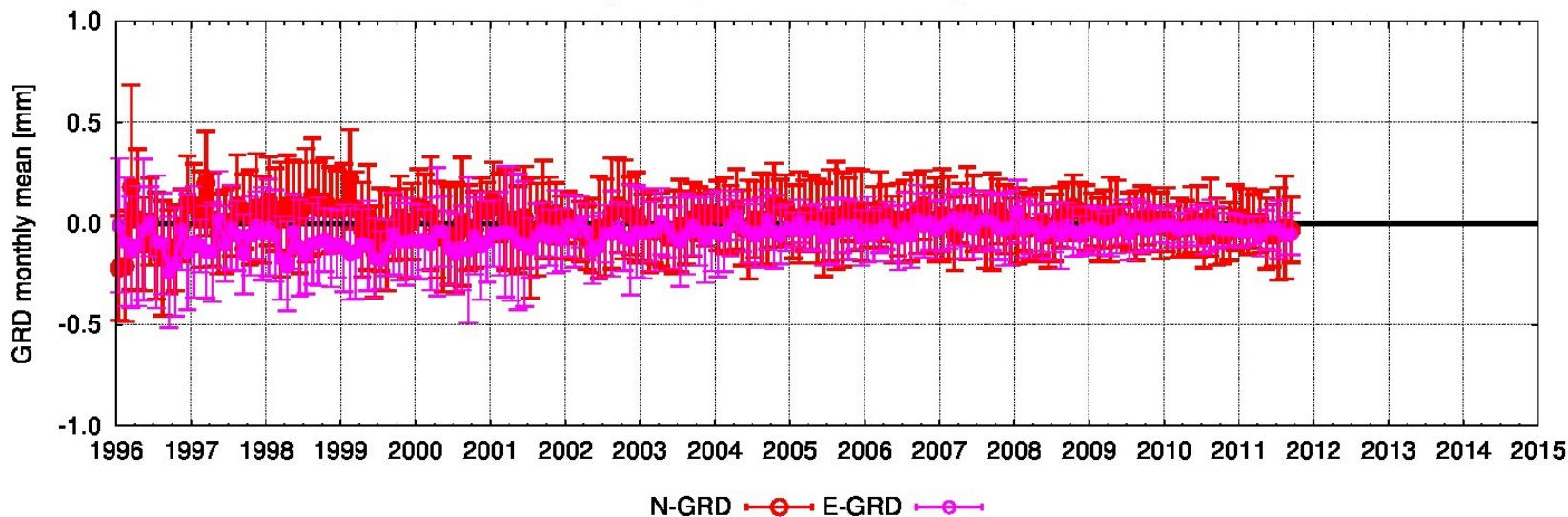


# GRD: comparison to ERA-Interim

GRD monthly comparisons: GOP/Repro2 - ERA-Interim



GRD monthly comparisons: GOP/Repro2 - ERA-Interim

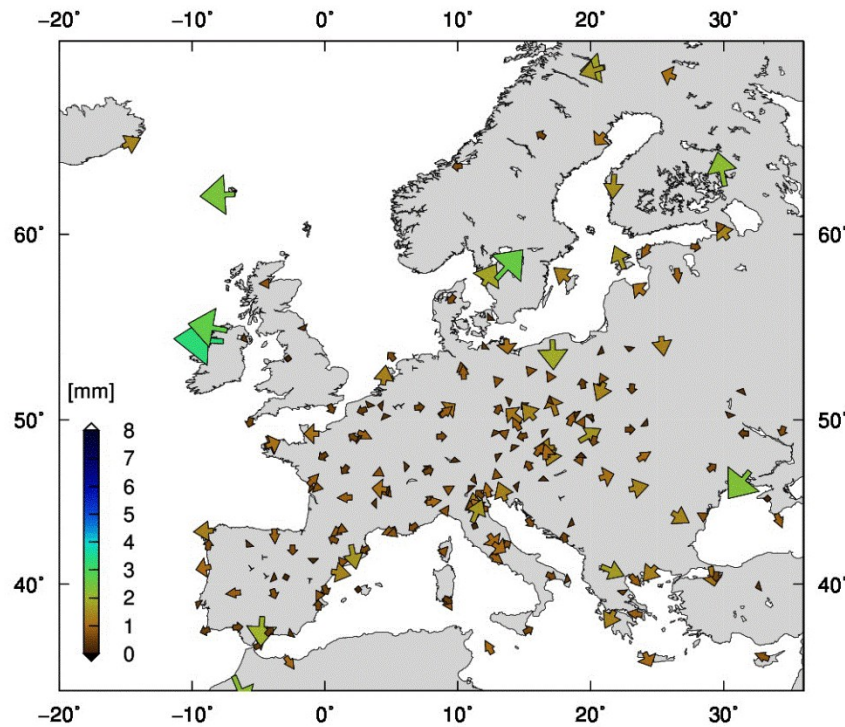




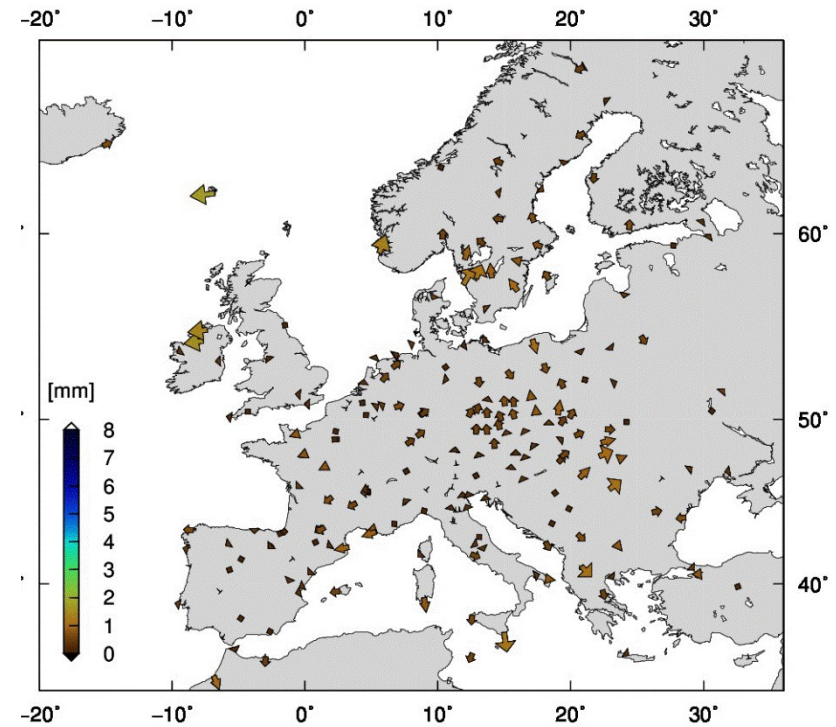
# GRD: comparison with ERA-Interim reanalysis

ZTD + N/E-gradients estimated using GZ's ray-tracing software (Zus et al, 2012) from the global ECMWF's ERA-Interim reanalysis (Dee et al. 2011)

**Tropospheric gradients (GO4-Repro2, 2013-05-30:18)**

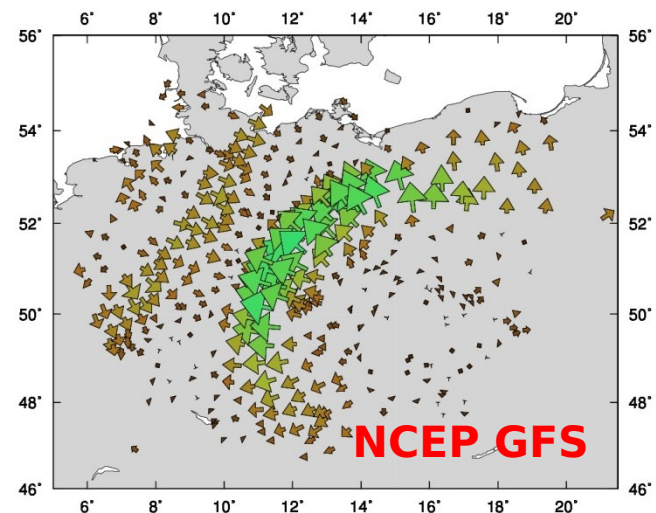
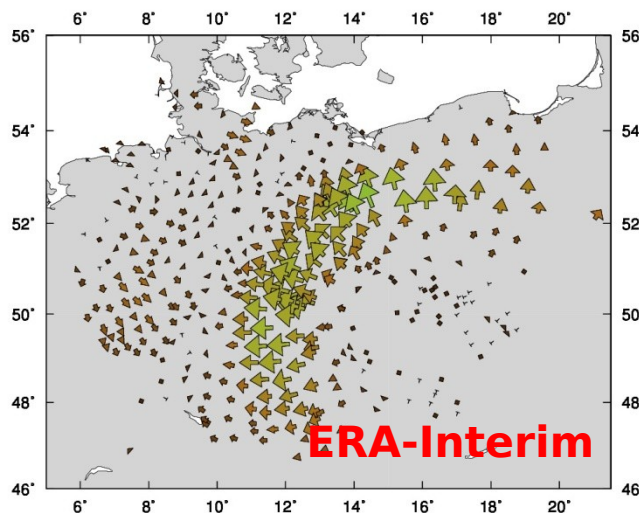
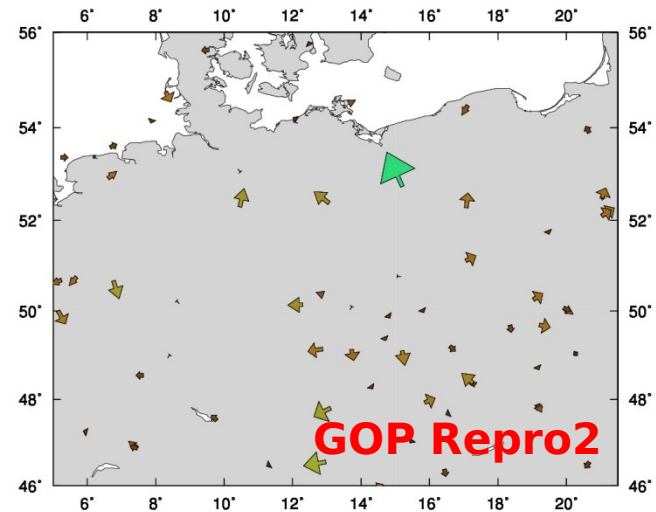
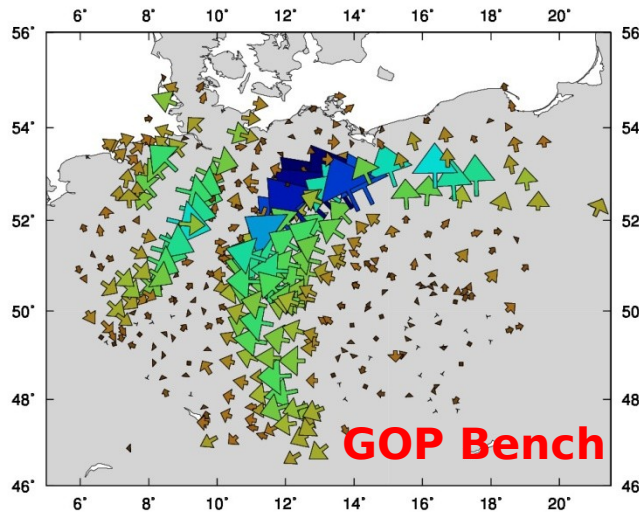


**Tropospheric gradients (ERA-Interim, 2013-05-30:18)**



# Dense network tropospheric gradients

May 31, 2013[18UTC] of ONSS4SWEC Benchmark



# Conclusions

- GOP-repro2 finished at July 2015
  - Unfortunately delayed by half-a-year due to redoing all the process
  - Repro2 outperformed GOPE repro1/I08 in general statistics
- Comparison with old Repro1 (EUREF/GOP)
  - Repeatability significantly worse than any Repro2 solution
  - Due to legacy models GOO Repro2 showed the best agreement in ZTD
- Several variants (elev. cut-off, MF, atmosph. loading effects)
  - NWM-driven MF (VMF1) improved height repeatability
  - Atmospheric loading improved repeatability in height (N/E slightly too)

# Conclusions (cont'd)

- Special focus to support GNSS4SWEC/WG3 and climate study
  - Combination of parameters (ZTD+GRD, COORD) across midnights/weeks
  - Strong effort for identification of station with problematic solutions
  - Providing tropospheric parameters in both HR:30 (and HR:00) epochs
  - Ongoing careful evaluation of tropospheric parameters
- Preliminary comparisons with ECMWF's ERA-Interim global numerical weather model
  - ZTD better for variant....
  - Gradients
  - Extreme gradients identified (even still smoothed)