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Benefits of double stations in permanent GNSS networks

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Swiss Permanent Network AGNES

- 30 stations
- since 1998 operational
- 50 km spacing
- GNSS since 2007.5 (22 antenna changed + but 8 double stations for reference frame monitoring)
- Analysed by Bernese GNSS

 Software together with EUREFand IGS stations (hourly + daily + weekly + multi-annually); and VRS3Net (real-time)



Double / Triple / Multi station concept Example Zimmerwald



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Benefits of Double Stations = Content of this presentation

- Long-term stability and reference frame monitoring using stations with uninterrupted time series
- 2. Sophisticated analysis methods are available for short baselines ("twins check each other")
 - Coordinate monitoring: L1 data analysis (instead iono-free L3) applicable for static and kinematic solutions
 - Troposphere checks
- 3. Comparison with ground truth from local ties









B3

B1

B2

Velocity precision and antenna change

B1 Coordinate jumps + relative velocity constraints ! 0.4 no antenna change antenna change + jump antenna change + jump known with 4 mm rms antenna change + jump known with 0.4 mm rms antenna change + jump known with 0.04 mm rms Formal error [mm / year] 0.3 3 years continuous = 10 years with 2 changes **GLONASS** 0.2 **GALILEO** 0.1 Changing technology every 5-7 years ? 0.0 5 15 10 20 0 time [years]

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Statistic of the length of an B1 observation interval

~75 stations (CH + Double stations + RTK-stations A + D)





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Weekly L3 repeatability: B2 HOHT-HOH2



20 1.40 mm North ---std 15 HOHT Weekly L3 network [mm] 10 5 solutions 0 Jorth -5 dinate repeatability of HOH2 -10 -15 North -----20 HOH₂ 20 East 0.79 mm std 15 10 [mm] 5 0 East -5 -10 East 🕨 -15 -20 40 Upʻ std 2.70 mm 30 20 [mm] 10 0 ٩ -10 Uр -20 -30 HOH₂ HOHT -40 2000 2002 1998 17/03/13 07:27 2004 2006 2008 2010 2012 YEAR Elmar Brockmann Federal Office of Topography swisstopo

Coordinate repeatability of HOHT

Short BSL repeatability: B2 HOHT-HOH2

Daily L1 baseline solutions

Conclusion:

Comparison Weekly L3 network vs. Daily L1 baseline:

- Repeatability increase by factor of 3 (factor 6-8 considering daily – weekly)
- artificial effects L3 /
 Tropo antenna model
 dependencies detectable



Coordinate repeatability of HOH2

Short BSL repeatability: ETHZ-ETH2 B2

20

Coordinate repeatability of ETH2



3-4 mm amplitude

-> Instable buildings



Short BSL repeatability: B2 ZIMJ-ZIMM





D **Short BSL repeatability: WAB1-WAB2 B**2



Coordinate repeatability of WAB2 20 North ---std 0.28 mm 15 10 North [mm] 5 0 -5 -10-15 E P -20 20 East 0.45 mm 15 std 10 East [mm] 5 0 -5 -10 -15 -20 -> Incredible ! 40 Up F 0.19 mm std 30 Twins check each other 20 Up [mm] 0.2 mm height repeatability 10 Й (daily L1 baseline solutions) -10 -20 -30 -40 2000 2002 2004 2006 2008 2010 1998 YEAR 17/03/13 02:53

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Kinematic short baselines (for static B2 station)







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Summary: GPS versus local tie

B3

0

L1 ok., L3+Tropo better agreement to local tie using Chokering

antennas, but still biased.

Bias of L3 w.r.t local tie limits the "absolute" accuracy in GNSS reference frame realization!



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Conclusion: Benefits of Double J Strong recommendation to



B2

B3



- years uninterrupted time in recommendation to station series and reliable velocities
 Sub-millimeter results are availat operator double stations for short baselines ("twins check each other"): detection: probleme " artefacts of L3 solutions; subdaily movement detection using kinematic L1 solutions; tropo qc
 - 3. Comparison with ground truth from local ties: detection of antenna phase center model problems and quantifying "absolute" reference frame accuracy





