COMPARATIVE STUDY OF GPS DERIVED ATMOSPERIC PARAMETERS

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Targeting Optimal Use of GPS Humidity Measurements in Meteorology

http://tough.dmi.dk/

In the framework of the EC TOUGH Project, ASI continuously provides Zenith Total Delay in Near Real Time to meteorological agencies. This activity started in June 2001 when ASI joined the COST 716 Near Real Time demonstration phase, processing a European network of about 15 stations. The network is made by 55 stations in September 2005 covering the Central Mediterranean area with Italy as primary region. The ZTD time series, 4-years long, are validated through comparisons with solutions from other processing centers on a subset of IGS/EUREF stations as well as with respect to radiosondes profiles and to the HIRLAM numerical weather prediction model.

NEAR REAL TIME ZTD PROCESSING

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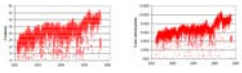
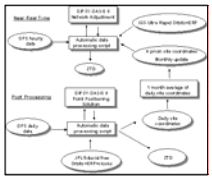


Evolution of number of stations (left) and GPS observations 5 min normal points (right) processed by ASI. Each diamond is an hourly solution.

Ground-based NRT network processed by ASI (September 2005)

On hourly basis an automatic processing collects all the hourly GPS data files available at the IGS/EUREF data centres so the NRT processing can not start until a sufficient number of hourly files are available. This "waiting time" is a bottleneck for the NRT processing and it is mainly due the delay in data delivery from the tracking sites to the data centres. About 80% of the hourly files are available within 15 min after the full hour and the NRT processing can not start before this "waiting time".

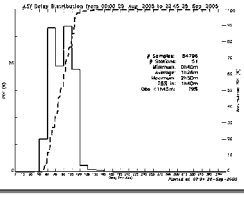
Analysis scheme for ZTD generation Near Real Time and Post Processing.



On daily basis a European network of about 100 stations is analyzed in post-processed mode (PP). The Precise Point Positioning approach is applied, fixing JPL fiducial-free satellite orbits, clocks and earth orientation parameters. The main goal of the PP solutions is to provide both ZTD estimates for climate applications and station coordinates, which will be fixed in the NRT data processing when enough accuracy (height coordinates repeatability less than 10 mm) is reached.

The GIPSY-OASIS II software is used for data reduction with the standard technique of network adjustment

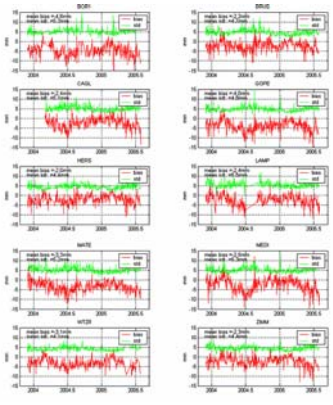
- •data analysed in sliding 24h-windows shifted by 1 hour,
- •IGU orbits fixed,
- •station coordinates fixed to values provided by combining 1 month of daily PP solutions, updated every 30 days in order to take into account the tectonic (secular) movements of the area,
- •ZTD products extracted only from the last hour,
- •random walk constraints are applied.



ZTD CONSISTENCY CHECK

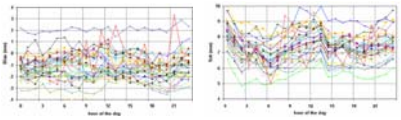
INTERNAL CONSISTENCY The GPS internal validation of zenith tropospheric delay is carried out taking into account 4-years ZTD time series in PP and NRT mode. On monthly basis the station bias ranges from –6 mm to 2 mm and the related standard deviation from 10 mm to 5 mm.

Time series of daily station bias and standard deviation ranges from –4 mm to -2 mm and the related standard deviation is about 5 mm.



Daily time series of station bias and std NRT vs PP (Jan 2004-Jul 2005)

The daily variation in ZTD bias and standard deviation is monitored as well. In order to do that we sort 2-years (2002-2003) of NRT and PP estimates in hourly bin and computed for each site and each hour of the day bias and standard deviation. No hourly dependence is observed.

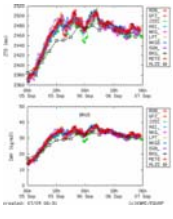


ZTD hourly bias (left) and standard deviation (right) of ASI NRT solutions vs PP, all solutions delivered in 2003-2004. Each line represents a station.

COMPARISON BETWEEN INDIVIDUAL NRT SOLUTIONS

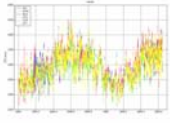
NRT ZTD estimates coming from different processing centres have been compared on a subset of IGS/EUREF stations. Comparisons are carried out for the period January 2004 - July 2005.

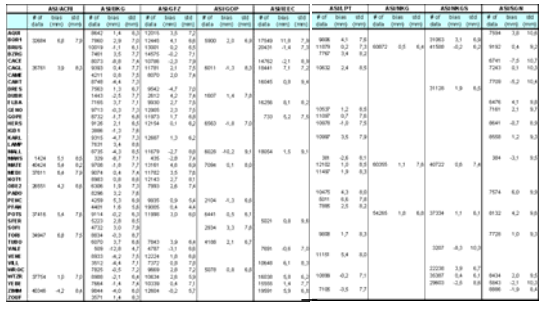
24h BRUS ZTD/IWV estimates from http://www.knmi.nl/samenw/egvap/validation/ztd_iwv.html



IGS/EUREF stations used for inter comparison of the results

ASI, ACRI, BKG, GFZ, GOP, LPT ZTD time series for site MATE, the time series clearly follows the same seasonal variation with values greater in summer than in winter.





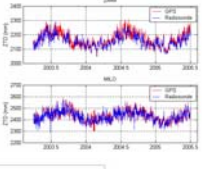
ZTD comparisons between processing centres. January 2004-July 2005

Considering the whole period, pair wise comparison of individual NRT solutions show a good agreement. The station bias is between ±7 mm that is about 1kg/m² IWV. The large bias in the comparison w.r.t GOP for the site MALL is due to a different values in the a priori height coordinate fixed for estimating ZTD as reported. Difference in the a priori height coordinate also explain ASI versus IEEC BOR1 and ELBA bias. The standard deviation is about 10 mm in the comparisons with respect to SGN, lower (7-8 mm) in all the other comparisons.

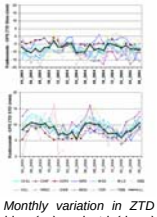
For most of the stations the daily bias ranges from ±10 mm and the std is less than 12 mm with a day to day scatter of about 2 mm.

GPS ZTD/IWV VALIDATION

GPS and radiosonde-derived ZTD calculated at 13 sites where radiosonde profiles were available nearby are compared for the period April 2003 - June 2005. Radiosonde profiles come from WMO GTS and are provided by the DMI. The radiosonde profiles are passed through a program developed in the framework of MAGIC Project that first checks the quality of the profiles and then determines ZTD, based on radiosonde reports. We have selected GPS and Radiosonde site with separation less than 60 km.



GPS and Radiosonde ZTD time series for Zimmerwald (Switzerland) and Milo (Sicily)



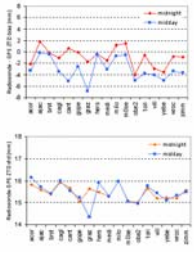
Monthly variation in ZTD bias (up) and std (down) of Radiosonde vs GPS

The mean and standard deviation of the residuals between Radiosonde and GPS derived ZTD are computed for each station for each month. Looking at the bias we can notice that GPS ZTD is greater than Radiosonde ZTD. The standard deviation has a seasonal dependence, it is about 10 mm in summer and 7 mm in winter. The overall bias is -7 mm and the standard deviation 9 mm. For the best site the std is near the level obtained in the comparisons carried out between different ACs, that is 7-8 mm, indicating that the agreement is in the limit of the precision of the GPS technique.

Radiosonde – GPS ZTD comparison table for the period April 2003-July 2005. Distance is the horizontal distance between the radiosonde launch and the GPS antenna, (GPS-RS) height is the altitude difference between the radiosonde launch and the GPS antenna.

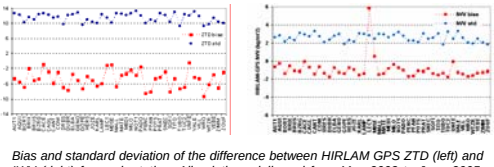
GPS site	RS code	Distance (km)	(GPS-RS) height (m)	# of data	Bias (mm)	Std (mm)	Correlation Coefficient
CAGL	16560	15	187	1893	-6,3	10,3	0,97
CANT	08023	59	-9,7	681	-11,4	10,5	0,79
GOPE	11520	29	101,4	2564	-4,7	6,8	0,94
HERS	03882	4	-21	1295	-3,9	7,8	0,91
MEDI	16144	15	-1	991	-9,1	8,7	0,97
MILO	16429	12	35	2032	-2,7	9,9	0,8
MRSE	16245	27	40	453	-0,9	8,6	0,97
OBE2	10868	27	107	833	-11	7,7	0,96
TORI	16113	59	-123	817	-9,5	9,5	0,96
VILL	08221	32	-38	512	-7,3	8,1	0,85
YEBE	08221	45	288	963	-9,9	8,9	0,84
WROC	12425	13	18	687	-10,6	6,7	0,96
ZIMM	06610	40	417	1258	-9,5	9,2	0,96

For each station we compute midday and midnight bias and standard deviation comparing noon and midnight radiosonde profiles with respect to GPS ZTD. While there is no significance difference in the standard deviation, the midnight bias in radiosonde minus GPS ZTD is higher than the midday one.

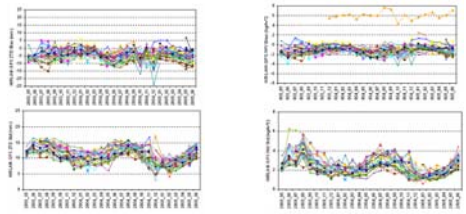


Midday and midnight bias (up) and std (down) in Radiosonde versus GPS

We compare **GPS-derived ZTD and IWV with HIRLAM model** from May 2003 to June 2005. The derivation of IWV from GPS-derived ZTD as well as the derivation of IWV from the HIRLAM model are performed by KNMI and results are available on ACRI-ST and DMI database for the purpose of the project. Bias and standard deviation are computed for each stations considering all the solutions delivered from May 2003 to June 2005. The average ZTD bias is –4.8 mm with a std of 11.5 mm. The average IWV bias and std are -0.9 kg/m² and 2.6 kg/m², LEC1 large bias can be caused by an altitude difference between LEC1 site and the closest synoptic station.



Bias and standard deviation of the difference between HIRLAM GPS ZTD (left) and IWV (right) for each station. All solutions delivered from May 2003 to June 2005. The stations are in alphabetical order.



Monthly Bias (up) and Std (down) of HIRLAM ZTD versus GPS ZTD (left) and IWV (right) . Each line is a different station.