Developments in Near-Real-Time Tropospheric Delay Estimations

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(http://pecny.asu.cas.cz/meteo/)

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Processing Parameters

'EUREF' [from BKG] (13) : BOGO, BOR1, BRUS, GOPE, GRAA, HOFN, ONSA, PENC, PFAN, REYK, UPAD, WTZR, ZIMM

'IGS' [from CDDIS] (8) : KIRU, STJO, GODE, CRO1, KOUR, HRAO, SUTH, NSSP

Meteo : BOGO, BRUS, PENC, ZIMM, GRAA, (GOPE)

Processing strategies:

Coordinates	: heavily constrained
Residual check	: 20 mm
Elev. cut-off	: 15°/8° [cos(z)]
Ambiguities	: free/fix (QIF)
TZD	: per 20 minutes, all site [ABS: 1m / REL: 0.0025m]
Apriori TZD	: Saastamoinen
Gradients	: no/yes [1-2-6-12 / day]
Orbits	: CODE P2/IGR (2-daily arcs)
Satellite exclusion	: day-to-day consistency check [Total-RMS: 0.5m / 5m]
Orbit improvements	: Argument of Latitude (AoL) [0.01"]
	: AoL + 2 RPR [1.10e-8 m/s2]

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Aspects of Near-Real-Time Processing

A) Satellite selection/exclusion. Using 2-daily orbit arcs we check day-to-day consistency between daily ephemerides. Hence, we derive Total-RMS residual criterion for later satellite exclusion procedure (SEP). This strategy is preffered against the usage of predicted SP3 accuracy code. CODE P2 product are applied due to early availability before the noon (each new 2-daily arc is usually switched at every midday).

B) Periodical instabilities. Due to prevailing bad satellites in period 12-13 UTC (8-15 UTC) together with decreasing quality when forthcoming to the end of used arcs (large residuals), the periodical instability occures each day. (There is any good solution up to now to avoid this problem!)

C) Partial orbit improvement. Estimating Argument of Latitude (AoL) for each satellite we tried to improve predicted orbits partially in along-track direction – the most uncertainty modelled component. Additionally the other variants uses 2 radiation pressure coeffiecients (direct D0 and Y-bias Y0) or along-track stochastic parameters.

D) 1H+24C vs. 4H processing. 1H+24C solution uses 1H-data processing together with the combination of the last 24 hours, while 4H variant always processes the last 4-hourly data independently. In the first case we extract last-hour values, in the second case already the 3rd-hour values. Hence, in both variants we can check the consistency in the results, in the 4H solution even one hour ahead. The 4H results have usually weakly lower stability (is more dependent on the quality of all used orbit arcs); it was also tested for ambiguity-fixed solution (but seems to be unsuccesful). The both variants spend approximately the same CPU time.

Aspects of Near-Real-Time Processing

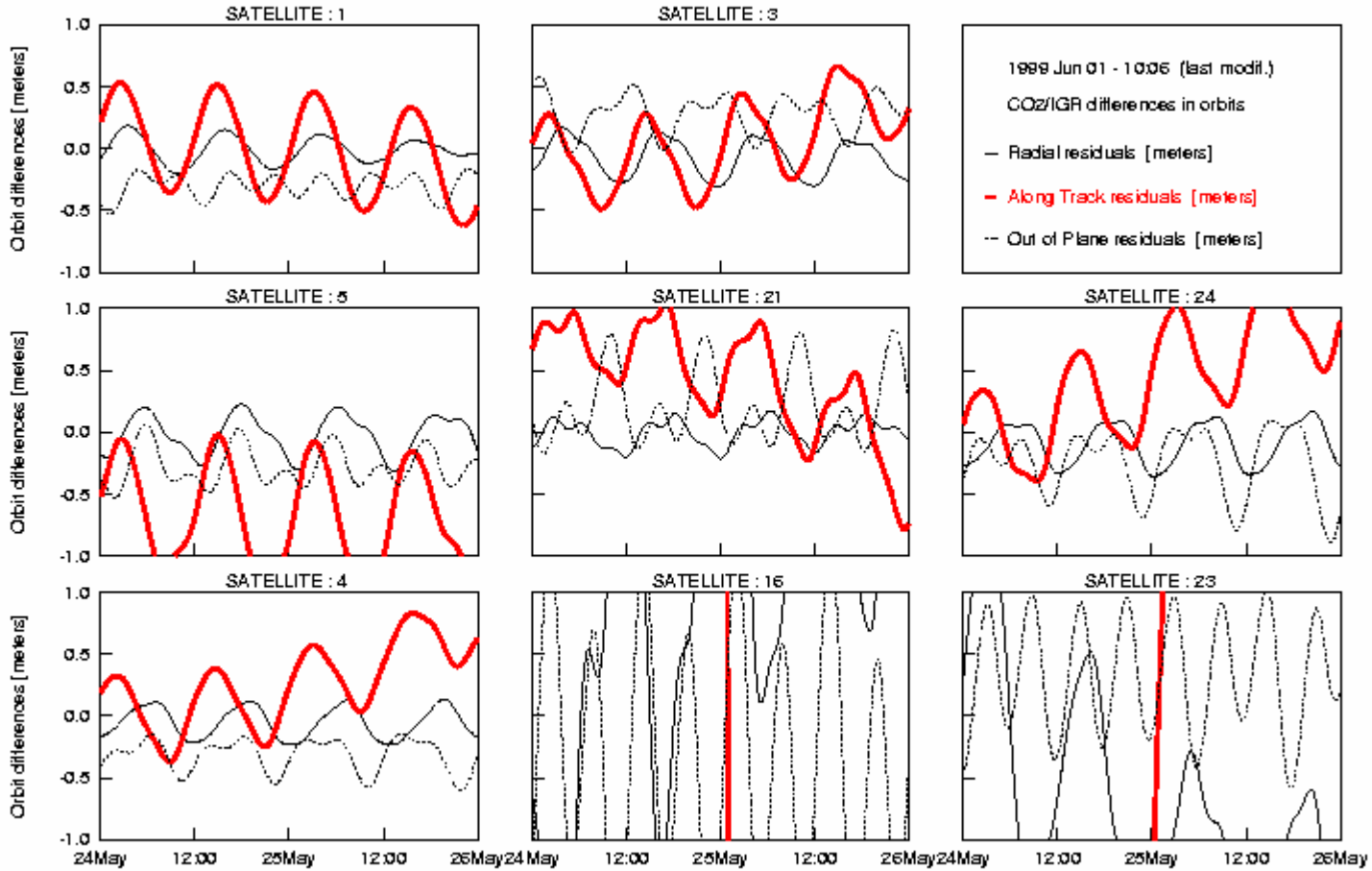
(Continuation)

E) Post-processed variants. Different post-precessed variants using IGS rapid orbits (IGR) were tested: the data cut-off angle (plus elevation dependent weighting – ELW), ambiguity-fixed solution, gradient estimations. It can be shown some systematic biases occure comparing above strategies: lowering cut-off angle to 8° (+ ELW) usually encreases the ZTD values, as well the introduction of additional gradient estimation to ZTD encreases it, but ambiguity-fixed solution decreases it.

F) PWV accuracy. We estimated the accuracy of all the variants of our processing (NRT and post-processed) by comparing GPS derived PWV to radiosonde data stemming from nearby stations. Unfortunatelly, for some stations (ZIMM, BOGO, BRUS) the biases cannot be still evaluated due to the missing informations of mutual localization of the radiosondes and GPS sites. The result comparisons are evaluated and sorted considering the ZTD formal RMS from the estimation.

G) Extent of GPS network. Including the IGS sites from other continents we enlarged the processed GPS network. The estimation of absolute ZTD values (no site constrained) continued even in the period of last 14 days when CDDIS center was unreachable (Aug 21 – ???). At this time, the network consisted only of European hourly GPS sites available at BKG. For both periods the PWV results are compared separately to check the stability and biases stemming partially from the different extent of the network.

A1) CODE P2 : Predicted vs. Rapid Orbit Differences



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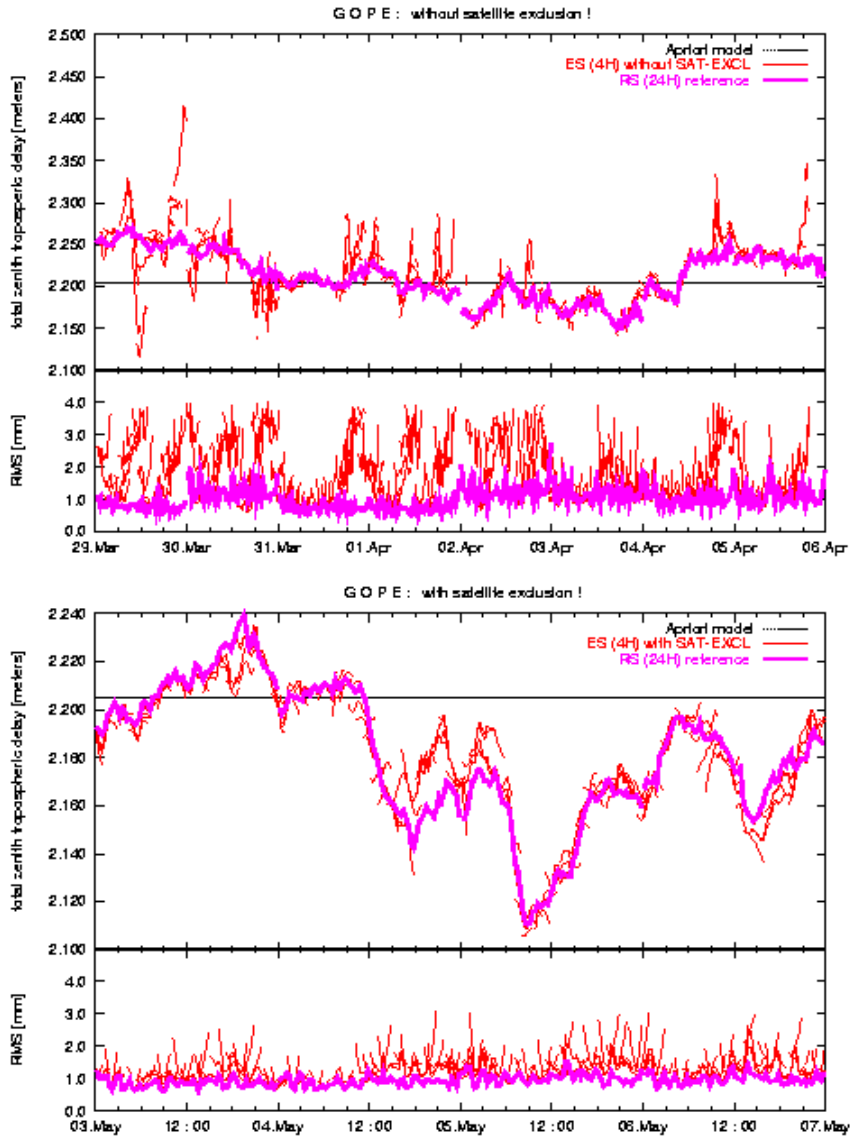
A2) Impact of Satellite Selection : ZTD Plot (GOPE)

no Satell-Excl vs. Satellite-Excl.



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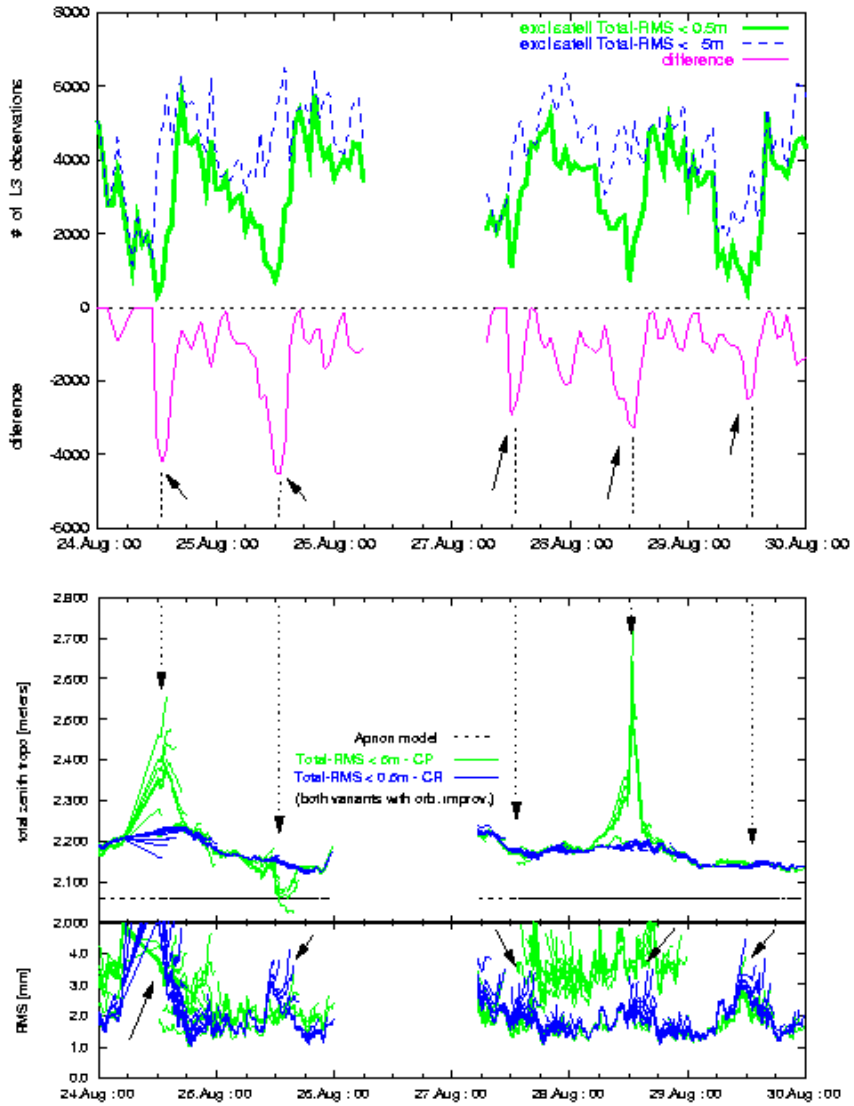
B1) Periodical Instability : ZTD Plot (PFAN)



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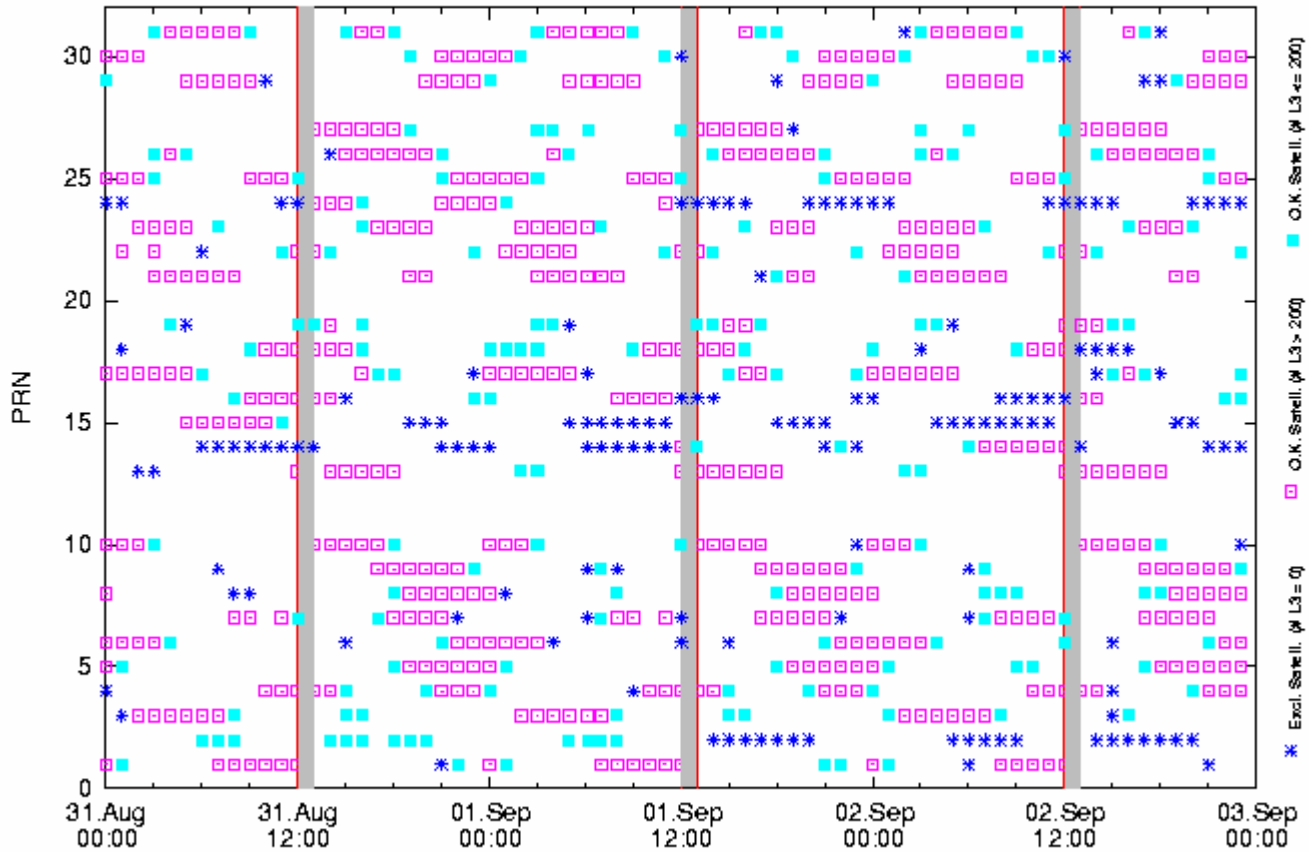
B2) Periodical Instability : ZTD Plot

Daily satellite availability – problematic periods marked (12-13 UTC)



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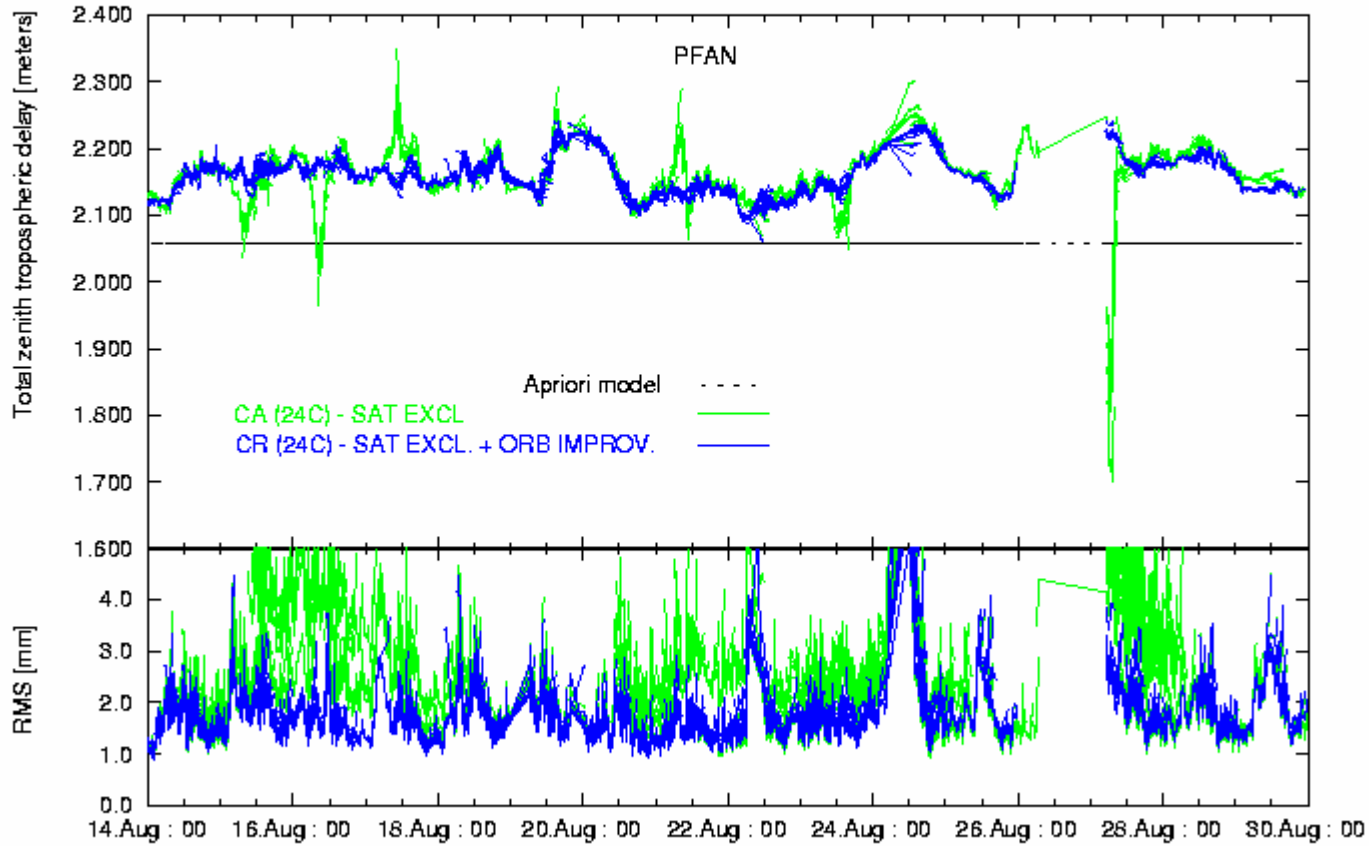
C1) Partial Orbit Improvements : ZTD Plot (PFAN)

No orbit improv. vs. AoL+2-RPR orbit improv. (offic. solution)



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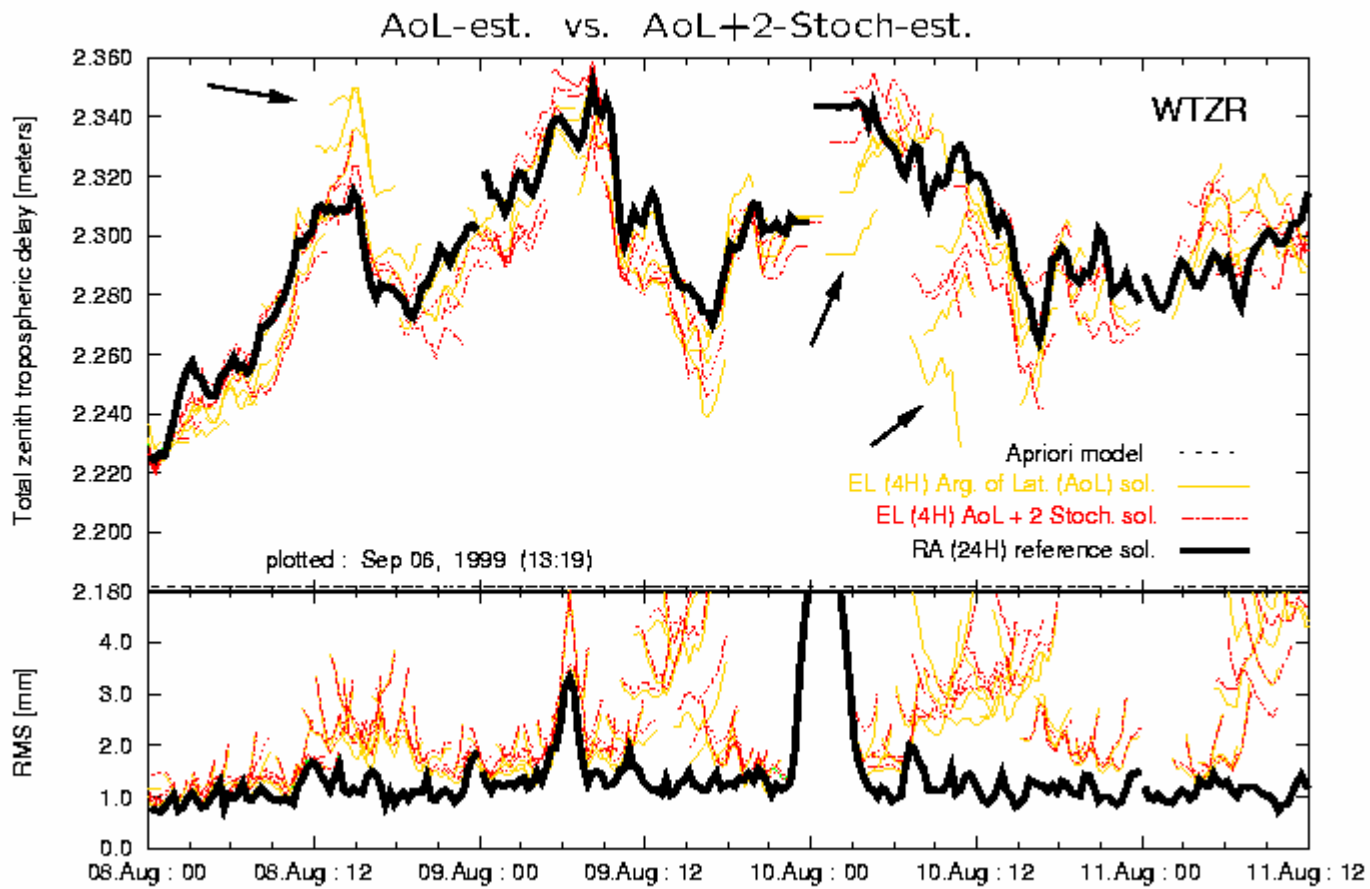
C2) Partial Orbit Improvements : ZTD Plot (WTZR)



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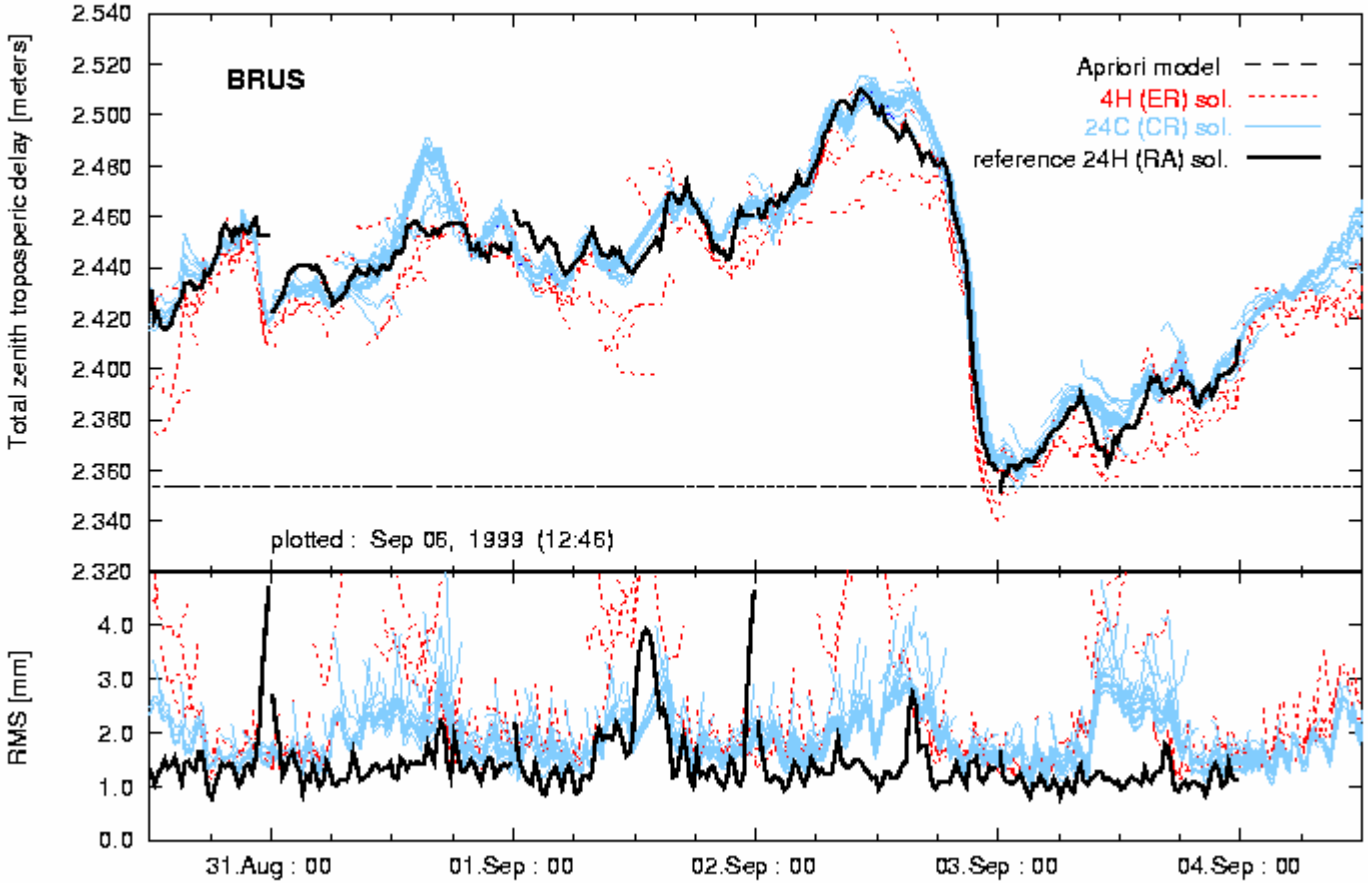
D1) 24C/1H vs. 4H (NRT processing) : ZTD Plot (BRUS)



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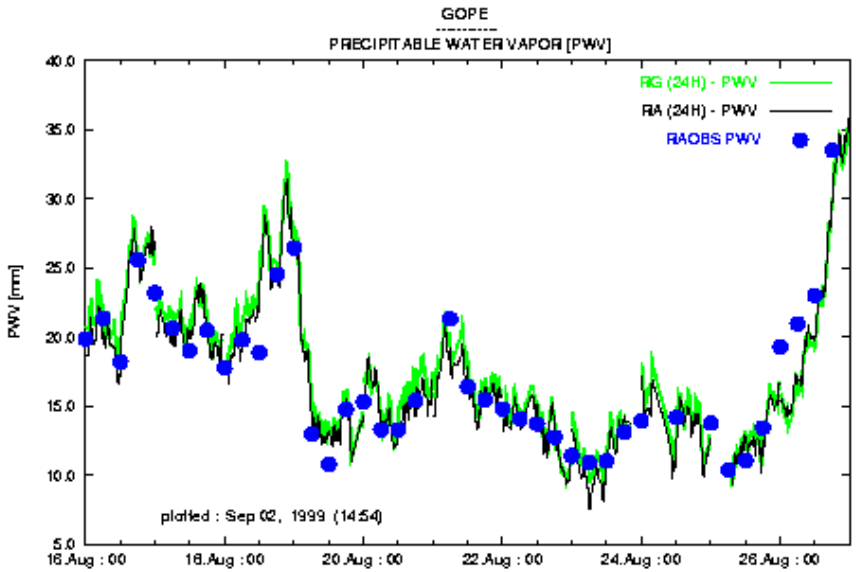
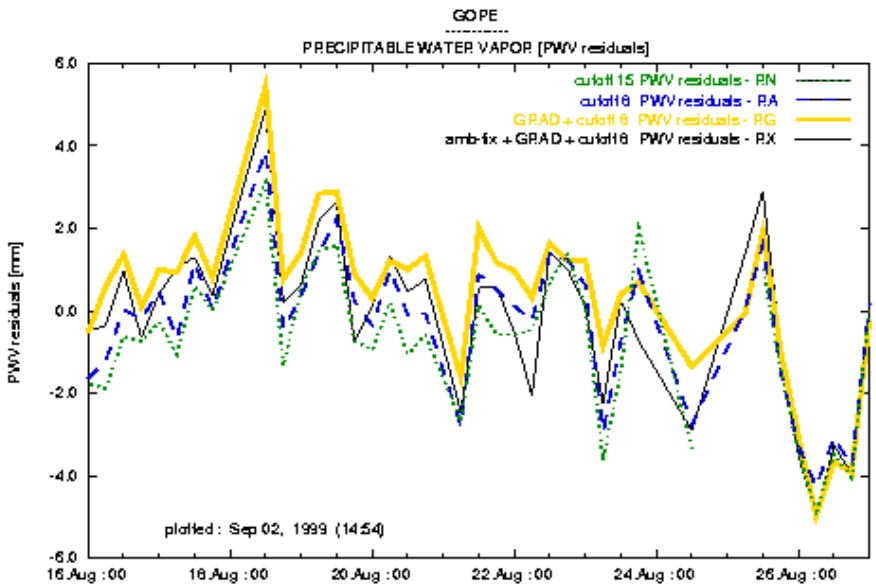
E1) Post-Processing Strategies : PWV Plot





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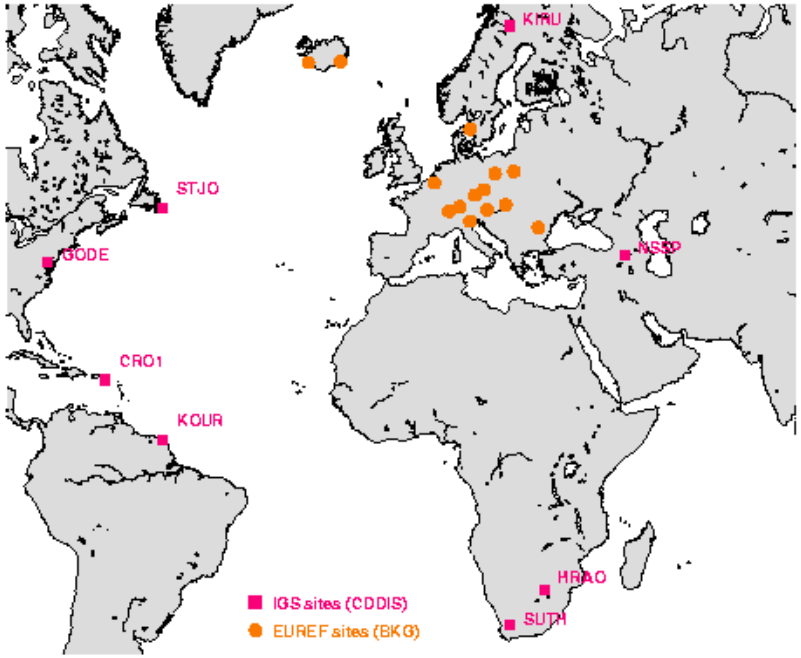
F1) PWV accuracy : Post-processed variants (GOPE)

24H SOL	ZTD-RMS [mm]	nobs #	PWV-bias [mm]	PWV-sig [mm]	Remarks
RN	2.0	58	- 0.77	1.62	15 cut-off [no weight.]
	2.5	95	- 0.82	1.67	
	3.0	113	- 0.79	1.62	
	10.0	136	- 0.79	1.85	
RA	2.0	90	- 0.47	1.63	8 cut-off [elev-dep-weight.]
	2.5	120	- 0.43	1.58	
	3.0	126	- 0.42	1.55	
	10.0	141	- 0.43	1.79	
RG	2.0	78	+ 0.40	1.61	8 cut-off + 2 gradients
	2.5	117	+ 0.26	1.73	
	3.0	127	+ 0.29	1.69	
	10.0	141	+ 0.32	1.89	
RX	2.0	83	- 0.04	1.61	8 cut-off + amb-fix + grad
	2.5	106	- 0.25	1.69	
	3.0	117	- 0.22	1.71	
	10.0	133	- 0.13	1.71	

G1) GPS Network Extent



		whole network			European network		
24H SOL	ZTD-RMS [mm]	nobs #	PWV-bias [mm]	PWV-sig [mm]	nobs #	PWV-bias [mm]	PWV-sig [mm]
RA	2.0	63	- 0.10	1.47	29	- 1.33	1.68
	3.0	92	- 0.10	1.40	37	- 1.22	1.64
	10.0	105	- 0.17	1.77	39	- 1.14	1.64
RG	2.0	58	+ 0.74	1.55	22	- 0.50	1.47
	3.0	93	+ 0.76	1.47	37	- 0.87	1.66
	10.0	105	+ 0.74	1.80	39	- 0.79	1.66
RX	**2.0**	**57**	**+ 0.30**	**1.45**	**27**	**- 0.73**	**1.70**
	3.0	**83**	**+ 0.17**	**1.50**	**37**	**- 1.11**	**1.81**
	10.0	**97**	**+ 0.22**	**1.54**	**39**	**- 1.02**	**1.81**
RN	2.0	43	- 0.40	1.47	16	- 1.72	1.62
	3.0	80	- 0.43	1.40	36	- 1.61	1.76
	10.0	100	- 0.49	1.78	39	- 1.59	1.75

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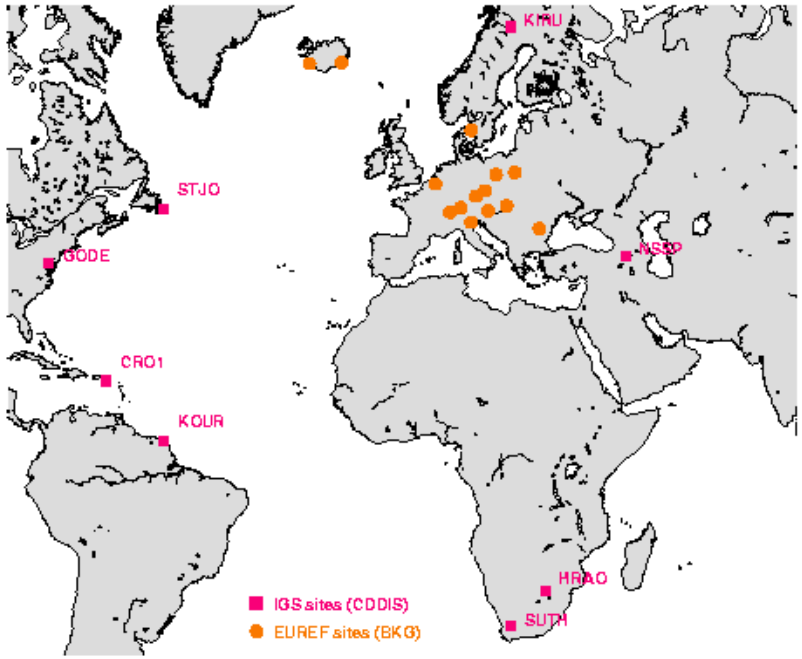
G1) GPS Network Extent



		whole network			European network		
24H SOL	ZTD-RMS [mm]	nobs #	PWV-bias [mm]	PWV-sig [mm]	nobs #	PWV-bias [mm]	PWV-sig [mm]
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Summary

Specific NRT processing strategy :

- effective combination of satellite selection/exclusion procedure together with partial orbit improvement was proved as a significant cotribution

Final GOP results : (`http://pecny.asu.cas.cz/meteo/`)

- our best NRT variant – CR (24C/1H): Arg. of Lat. + 2-RPR using 2-daily orbits and day-to-day Total-RMS < 0.5m exclusion criterion – shows significantly improved stability of the NRT results
- post-processed variant – RX (24H): 8° elev-cut-off + ambig.-fixed + 2 gradients/day – shows the smallest bias in comparision to PWV from radiosondes

Future investigations :

- orbit improvement studies (NRT upgraded orbits ?)
- empirical study of orbit error impact for tropospheric estimates
- systematic bias study (gradients, ambig.-fixed in NRT ?)
- GPS network density and extent (and distribution of processing)
- effective time interval for tropospheric corrections
- NRT ionospheric model estimates
- study of 'low-cost' one-frequency GPS aparature usage ... etc.