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Comparison of strategies for GPS integrated water vapour estimation using BBC2 cloud campaign data

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In early 2002, a new permanent GPS station Cabauw (CABW) designed for the atmospheric purposes became operational at the Cabauw atmospheric research observatory in the Netherlands. This station is equipped with a Trimble 5700 receiver and a Trimble Zephyr antenna installed on a 2-meter mast. GPS data acquired at Cabauw in May 2003 (May 1-24) during the BBC2 cloud campaign were collected and subsequently analysed using different strategies and approaches to assess their influence on water vapour estimation. Jet Propulsion Laboratory's GIPSY (GPS Inferred Positioning SYstem) software package was used to analyse the GPS data.

We obtained different types of GIPSY ZTD solutions for the CABW station allowing to intercompare two main approaches widely used for ZTD estimation from GPS regional networks: the network approach and the Precise Point Positioning approach. The solutions obtained are:

1. 'Final' PPP solution - a Precise Point Positioning solution utilizing Final JPL orbits and clocks.

2. 'Real-Time' PPP solution - a Precise Point Positioning solution utilizing Real-Time 15-min JPL orbits and clocks. Though data were processed after data collection (post-processing), real-time operation was simulated in this case.

3. 'Orbit fixed' network solution - a network solution using data from 17 GPS stations located in the West and North Europe. GPS orbits and ERP parameters were fixed, GPS clocks were estimated. IGS final products were used.

4. 'Orbit relaxation' - a network solution, in the framework of which both GPS orbits and clocks as well as ERP parameters were estimated. Data from the same network

of 17 GPS stations were used. In addition to these, 5 IGS stations with the positions fixed to ITRF2000 were included to support the orbit relaxation. IGS final products were used.

For each solution we experienced with a number of GPS data processing strategies to evaluate the impact of some processing parameters (minimum cut-off elevation angle, GIPSY's maximum acceptable postfit residual) and different constrain values for the zenith wet delays and troposphere gradients on the accuracy of ZTD estimates. We used a minimum cut-off elevation angle of 7° and 10° and a maximum acceptable postfit residual of 5 cm and 2.5 cm. In order to assess the accuracy of the corresponding GPS ZTD estimates, we converted them into IWV and compared with IWV estimates retrieved from the microwave radiometer and radiosonde measurements, which were carried out for the BBC2 campaign time period.

The following main conclusions were made from our comparisons:

1. The IWV values were overestimated with GPS in our case as compared to the radiosondes (RS) and WVR IWV values irrespective of a processing strategy chosen. The GPS-RS offsets ranged from 0.8 to 2.3 kg/m^2, whereas the GPS-WVR offsets ranged from 1.3 to 2.4 kg/m^2. The standard deviations were typically below 1 kg/m^2 for the GPS-RS differences and 0.9-1.3 kg/m^2 for the GPS-WVR differences.

2. The network solutions provided less biased GPS IWV values as compared to those obtained using the Precise Point Positioning solutions. The biasedness of the GPS IWV values obtained using the 'orbit fixed' network solution was minimal among all the solutions considered. However, the accuracy of the 'orbit fixed' IWV estimates appeared to be highly sensitive to a chosen processing strategy, the standard deviation was getting increased by 30-40 % when strategies with 7° minimum elevation cut-off angle and stochastically modelled troposphere gradients were used.

3. For all the solutions considered, the biasedness of the GPS IWV values decreased by 25-30 % when strategies with a minimum elevation cut-off angle of 7° were used. At the same time, the accuracy of the GPS-WVR and GPS-RS differences obtained using the two PPP solutions and the 'orbit relaxation' network solution did not change significantly.

4. The decrease of the maximum acceptable postfit residual from 5 cm to 2.5 cm had a little effect on the accuracy of the IWV results, except for the case of the 'orbit fixed' network solution with 10° minimum elevation cut-off angle.

5. The decrease of the random walk process noise for the troposphere wet delay from 12 $mm/\sqrt{h}$ to 3 $mm/\sqrt{h}$ led to diminishing the biasedness and improving the accuracy of the GPS-RS and (in a less degree) the GPS-WVR differences, but only

when the minimum elevation cut-off angle was set to 10°. The most significant effect was observed for the 'real-time' PPP water vapour estimates (by about 20 % for the GPS-RS differences). Variation of a random walk process noise for the troposphere gradients had only a minor impact on the water vapour GPS estimates, except for the case of the 'orbit fixed' network solution.

6. The PPP approach utilizing Final JPL orbits and clocks provided the most accurate results. The GPS-WVR and GPS-RS differences obtained using the 'real-time' PPP solution and the 'orbit relaxation' solution were less accurate by 10-20 % than those obtained using the 'final' PPP solution.