Assessment of the Zenith Wet Delay and Horizontal Delay Gradients Derived From Co-located Techniques

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The continuously operating IGS station ONSA

The Water Vapour Radiometer

Motivation

• An improvement of the estimates of the Zenith Wet Delay (ZWD) in GPS data processing will lead to an improved repeatability of the estimated site coordinates. Including horizontal gradients in the atmospheric model typically improves the overall accuracy of the solution.

• The quality of the GPS-derived ZWD and the horizontal gradients can be assessed by comparisons with independent data sets provided from co-located techniques, e.g. a Water Vapour Radiometer (WVR).

Co-located Techniques and Data Analysis

Water Vapour Radiometer

The WVR used has been in operation since 1980. The acquired data were analyzed to infer the equivalent ZWD in different directions, which are used to model the horizontal gradients as described by *Davis et al.* (1993):

$$\Delta\tilde{L}^z(\varepsilon,\phi,\Delta t) = \Delta L^z + V_L\Delta t + [\Xi_n \cos\phi + \Xi_e \sin\phi]\times\cot\varepsilon[1-10^{-6}N_s\csc^2\varepsilon]$$

where ε and ϕ are the elevation and the azimuth angles of the observations, Δt is the time counted from a reference time epoch for which the model parameters are estimated, $\Delta\tilde{L}^z(\varepsilon,\phi)$ is the equivalent ZWD, ΔL^z is the mean zenith delay, V_L is the zenith delay rate, Ξ_n and Ξ_e are the north and the east horizontal delay gradient components, respectively, and $10^{-6}N_s\csc^2\varepsilon$ is a correction due to the bending, where N_s is the ground refractivity. The temporal resoultion of the model estimates is 15 min.

Global Positioning System

The GPS data were processed using the GIPSY/OASIS II (*Webb and Zumberge,* 1993).The ionospheric free linear combinations (LC) were analyzed using the Precise Position Point (PPP) strategy (*Zumberge et al.,* 1997). The atmospheric delay parameters were estimated using a random walk with a standard deviation of 10 and 0.3 mm/$\sqrt{\text{h}}$ for the Zenith Total Delay (ZTD) and the horizontal delay gradients, respectively. The estimates are updated every 5 min. The Niell mapping functions were used. The GPS data were processed three times using the elevation cutoff angles: 5°, 10°, and 15°.

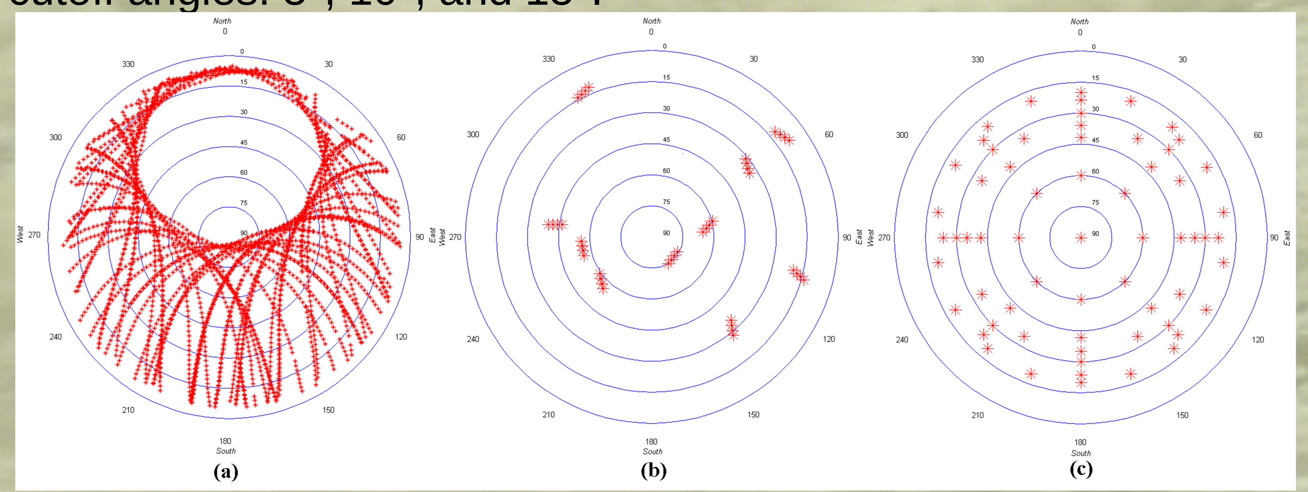

Fig 1: The sky distribution of observations by the ONSA GPS receiver during October 23, 2007 (a) for the whole day, and (b) for 15 minutes starting at 0:00 UTC, and (c) one cycle of 63 WVR observations, which takes about 15 min.

Comparison Between GPS and WVR Estimates

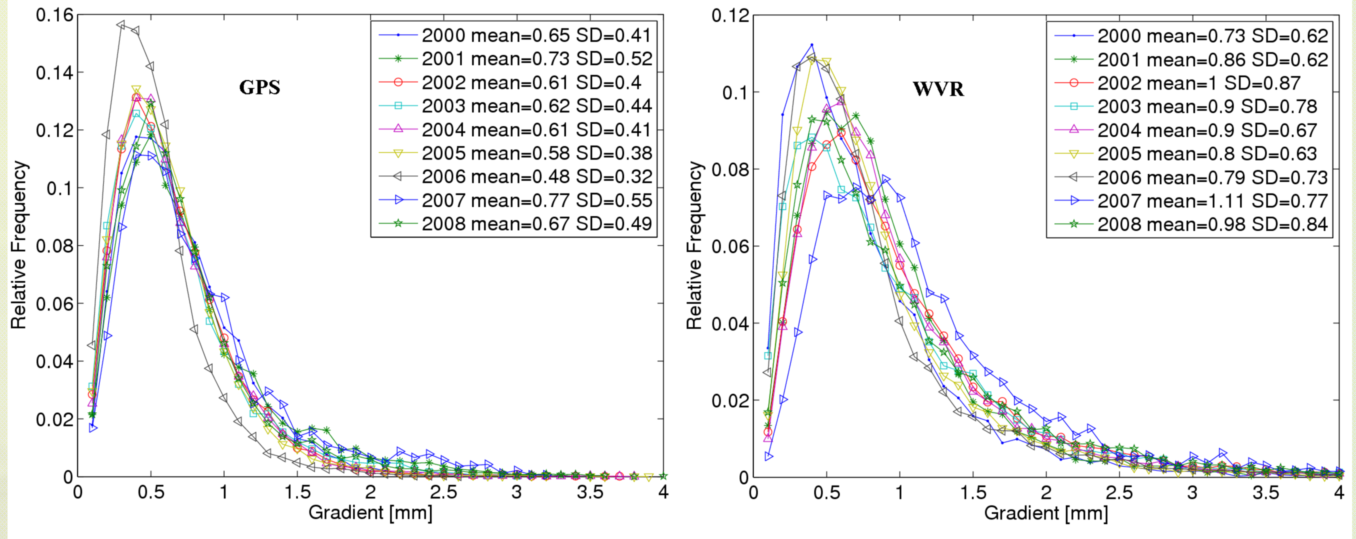

Fig 2: The annual relative frequency of the total gradients estimated from GPS and WVR for the years 2000–2008. Given are also the means and the standard deviations of the distributions for each year. When comparing the two methods we note the consistent results obtained for the years 2006 (small gradients) and 2007 (larger gradients).

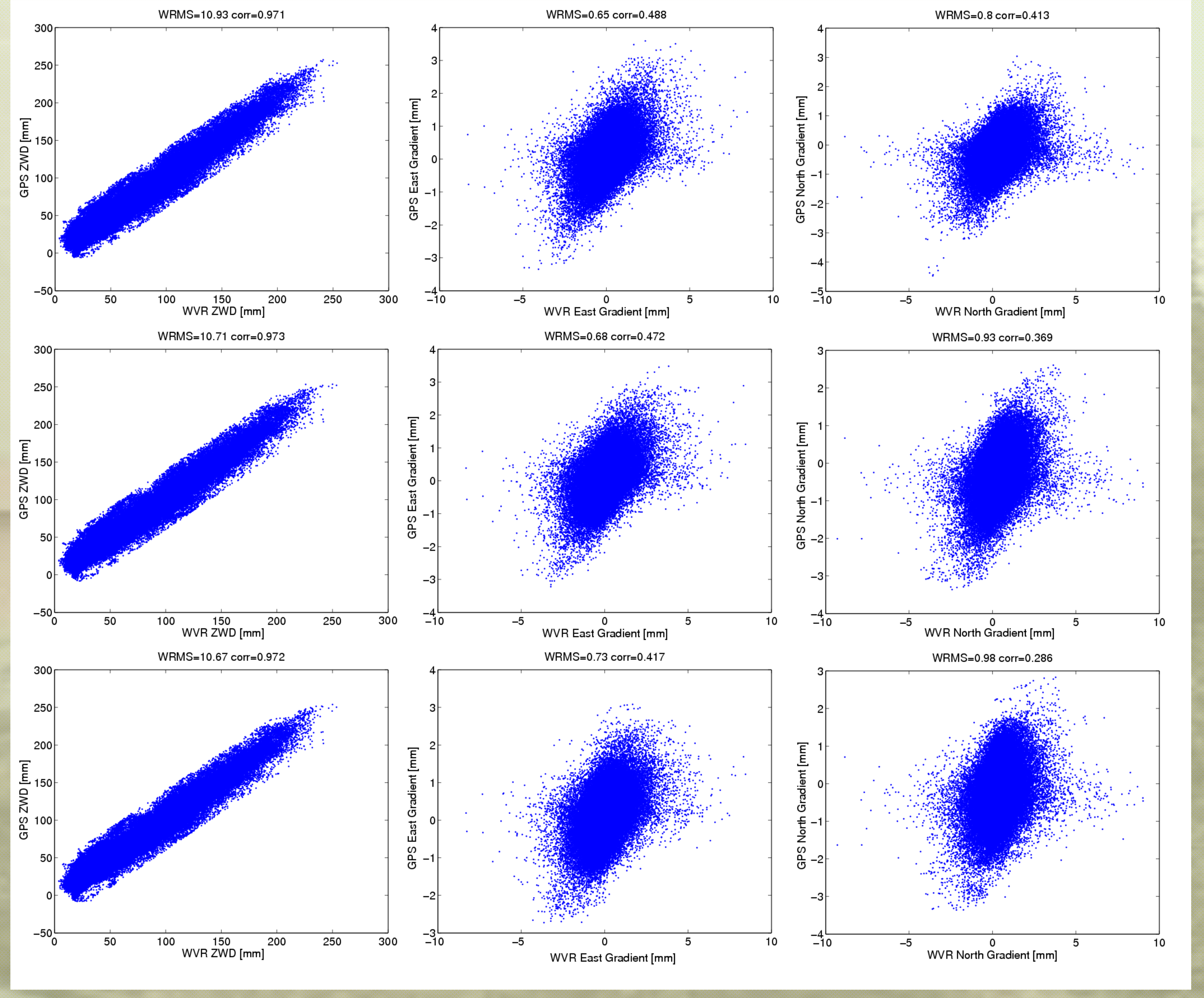

Fig 3: Scatter diagrams for the ZWD, the east, and the north gradients estimated from the WVR and the GPS observations. The GPS estimates use three different elevation cutoff angles: 5° (top), 10° (middle), and 15° (bottom).

Probably, due to the sparse sampling in terms of azimuth and elevation angles, including the GPS observations from low elevation angles give a better agreement with WVR estimates of the gradient components, in spite of the fact that the WVR observations are all above 15° .

The Weighted Root Mean Square (WRMS) difference for the gradients are reduced 12-20% after lowering the elevation cutoff angle from 15° to 5°, while an improvement of the order of 0.1 is seen for the correlation coefficients.

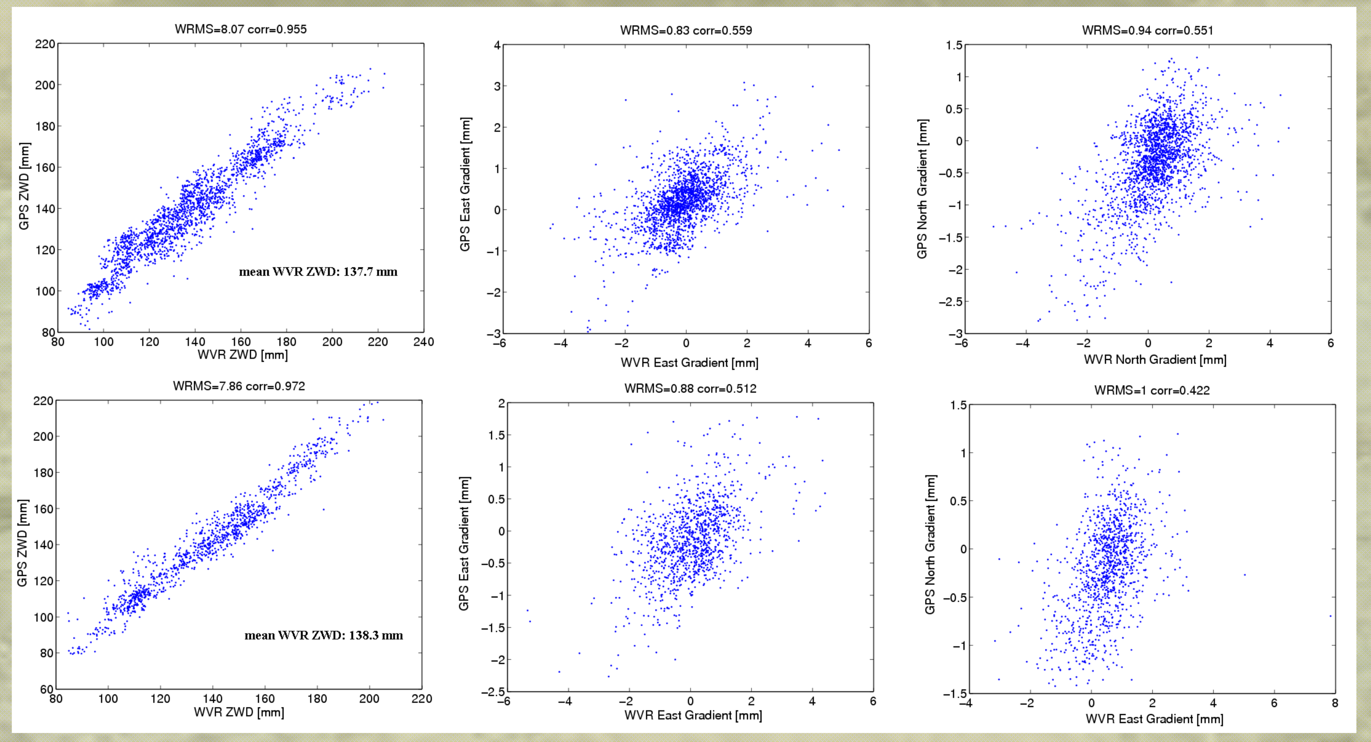

Fig 4: Results similar to Fig. 3, but using GPS estimates from 5° elevation cutoff angle solutions for August 2003 and August 2008 only. The month of August 2008 has more GPS measurements from lower elevation angles in comparison with August 2003. The top figures use data from August, 2008, where 10% of the GPS measurements were acquired between the elevation angles of 5° and 10°, and 23% were acquired between 10° and 15°. Figures at the bottom use data from August, 2003, where only 7% of measurements were acquired between the elevation angles of 5° and 10°, and only 20% were acquired between 10° and 15°. A decrease of the WRMS (up to 6%) is seen for both the north and the east gradient comparisons using more low elevation angle observations.

Table 1: Statistics of the difference of the ZWD and the horizontal delay gradients from GPS and WVR. Each subset was defined by a different magnitude of the WVR-derived total gradient (G_{wvr}).

		Zenith Wet Delay		East Gradient		North Gradient	
	No. of data points	WRMS [mm]	Correlation	WRMS [mm]	Correlation	WRMS [mm]	Correlation
All points	119984	10.9	0.97	0.65	0.49	0.80	0.41
$\lvert G_{wvr}\rvert$>2 mm	8523	12.9	0.96	1.61	0.63	1.77	0.50
$\lvert G_{wvr}\rvert$>1 mm	36151	11.4	0.97	1.01	0.58	1.19	0.50
$\lvert G_{wvr}\rvert$<2 mm	111357	10.8	0.97	0.54	0.45	0.70	0.41
$\lvert G_{wvr}\rvert$<1 mm	83251	10.7	0.97	0.46	0.37	0.60	0.32

The discrepancies between the GPS and the WVR gradients are likely due to poorly sampled azimuth and elevation angles of the GPS observations compared to the WVR. We also note that the horizontal delay gradient estimates from the WVR are for the wet part only, whereas the GPS estimates are the total horizontal gradients. The wet part normally dominates the gradients, which may not be true when large pressure or temperature gradients exist. Therefore, we suspect that the WRMS differences seen in Table 1 are partly due to hydrostatic gradients.

Conclusions

- The GPS-derived ZWD is highly correlated to the WVR-based ZWD with a WRMS around 10 mm.
- A low elevation cutoff angle improves the agreement between the horizontal gradients estimated from the GPS and the WVR data.
- The discrepancies are likely due to the less uniform distribution of GPS observations on the sky, and possibly due to that the GPS-derived gradients include also a hydrostatic component that is not sensed by the WVR.

References

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For Further Information

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