GPS-derived trends in the atmospheric water vapour content: comparisons to other techniques and correlations with trends in the mean temperature

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Motivation

• Realistic and reliable Integrated Water Vapour (IWV) trends can only be obtained from homogeneous IWV time series.
• Systematic errors affecting the IWV time series, e.g. caused by multipath, may vary over time.
• A higher elevation cutoff angle may be desired for the IWV trend estimation due to the lower multipath impact combined with the fact that the formal stochastic error of the individual IWV estimates is not the limiting factor for trend uncertainties (Ning and Elgered, 2012).
• Assessment of the assumption about conservation of the relative humidity, implying a ratio between changes in the IWV and the temperature of 7 %/K (Trenberth et al., 2003).

The data sets

• Time period of 20 years (Jan. 1997 to Dec. 2016)
• Observations acquired from 13 GPS and 7 radiosonde sites (the distance between the GPS site and the nearest radiosonde site varies from 1 km to 119 km).
• IWV obtained also from ECMWF (ERA-Interim) after a vertical interpolation to the GPS antenna height.

GPS data processing

We have processed GPS data using two different elevation cutoff angles 10° and 25°, to estimate the atmospheric IWV.

Table 1: The models and parameters used for a standard GPS data processing.

<table>
<thead>
<tr>
<th>Model/Parameter</th>
<th>GPS processing software</th>
<th>Strategy</th>
<th>Mapping function</th>
<th>Elevation cutoff angles</th>
<th>Elevation-angle-dependent weighting</th>
<th>Ocean tide loading</th>
<th>Ambiguity resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS processing software</td>
<td>GIPSY v6.2 (Webb and Zumberge, 1999)</td>
<td>Precise Positioning</td>
<td>VMP1 (Beinbir et al., 2006)</td>
<td>10° and 25°</td>
<td>No</td>
<td>FES2004 (Lyard, et al., 2006)</td>
<td>Yes (Bertiger et al., 2013)</td>
</tr>
</tbody>
</table>

Reference


For further information

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Conclusions

• Using different elevation cutoff angles is a valuable diagnostic tool that can be used to validate the homogeneity of the IWV time series.
• When we use the GPS data to monitor the long-term change in the IWV, e.g., as linear trends, it is recommended to apply at least two different elevation cutoff angles in the data processing. Ideally the IWV trends obtained from the two solutions with significantly different cutoff angle elevations should be the same if there are no significant systematic errors in the time series, or any other elevation dependent phenomena that affects the observations.
• The ratios of IWV and temperature trends in Fig. 6 have large uncertainties because of the small dynamical range and that we only have 13 data points. Therefore we calculate the mean values of the trends in the IWV and of the trends in the mean temperature for all sites. These ratios – representative for the specific area and time period – are 5.40 %/K and 4.44 %/K for the GPS 10° and 25° solutions, respectively.

Fig. 1: The 13 GPS sites (red stars) and the 7 radiosonde sites (brown filled circles).

Fig. 2: Time series of the monthly mean IWV difference (GPS-ERA-Interim). Dark lines are the mean of IWV difference, and red lines indicate the date of the interventions.

Fig. 3: Correlations between the IWV trends (in kg/(m²·decade)) from the two GPS solutions and the reference data sets. No offset corrections for the interventions were carried out in the GPS data. The dashed lines show the perfect agreement.

Fig. 4: Correlations between the IWV trends (in kg/(m²·decade)) from the two GPS solutions and the reference data sets. GPS data were corrected for interventions. The dashed lines show the perfect agreement.

Fig. 5: The correlation of the IWV trends from the GPS data, without offset corrections (left) and with offset corrections (right) to the corresponding trends in the mean temperature given by the ERA-Interim data.