### Atmospheric Water Vapor Content Inferred From GPS Data and Compared to a Global NWP Model and a Regional Climate Model

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**Motivation**

Water vapor is difficult and costly to measure with a high temporal and spatial resolution due to its large variability. Hence, using data from already existing continuously operating Global Position System (GPS) ground networks to estimate the water vapor content in the atmosphere is of great interest.

We have compared the Integrated Water Vapor (IWV) estimated from the GPS data and the numerical weather prediction (NWP) model from the European Centre for Medium Range Weather Forecasting (ECMWF) as well as the regional model of the Rossby Centre (RCA).

**Objective**

The overall goal for the use of GPS data in climate research is to determine to which extent these independent data can be used to discriminate between different climate models – both in terms of absolute values as well as long term trends – thereby improving the quality of the models and increasing the probability to produce realistic scenarios of the future climate.

**GPS Stations in the Analysis**

We used data from 26 ground-based GPS sites (see Fig. 1) in our analysis, covering the period 2001 – 2005 (inclusive).

**Models**

We have evaluated the IWV from two models. One is the global ECMWF model and the other is the regional RCA model run by the SMHI using ECMWF data at the boundary. Table 1 lists horizontal resolutions and number of vertical levels as well as the typical vertical layer thickness within three height intervals of the models.

![Image of GPS data analysis](image)

**Estimation of IWV From GPS Data**

The velocity of radio signals from a GPS satellite is lower in the atmosphere than that in vacuum since the refractive index is larger than one. The velocity of radio signals from a GPS satellite is lower in the atmosphere than that in vacuum since the refractive index is larger than one. Since the refractive index depends on the humidity, it is possible to infer the IWV from the estimations of these propagation delays (or the excess propagation path often expressed in units of length). A block diagram for the estimations of IWV from GPS data is given in Fig. 2.

The GPS data are processed by the GIPSY-OASIS II software [Webb and Zumberge, 1993]. One of the results is a time series of the propagation delays of the GPS signals in the atmosphere which can be divided into a wet part due to water vapor and a hydrostatic part due to other gases. The hydrostatic part can be accurately estimated in the atmospheric pressure using the ECMWF model data, while the wet part is related to the IWV (Emardson and Derks, 2003). Fig. 3 gives one example of the IWV estimated from GPS data.

![Image of IWV time series](image)

**Comparisons Between GPS and Models**

We have made the comparisons between GPS and the models using monthly mean values. We will look at the variability of the GPS data with respect to the corresponding values from the models. Fig. 5 gives one example of a monthly comparison between GPS and models in estimated IWV.

To the right is the comparison of the IWV estimated from GPS data and from the two models. The average IWV bias between GPS and models is 1.2 mm (see Fig. 4).

**Trends in Estimated IWV**

Although a five year period is too short for climate change studies we can still use the data to assess the stability and consistency of the linear trend of the estimated IWV around the GPS sites. Fig. 6 shows that the estimated IWV trends from GPS, ECMWF and RCA. Large negative trends are seen in Germany and Poland in all three cases. Stations in Italy and France give similar trends for the ECMWF model and GPS data, whereas the most eastern sites (except the two in Israel) give very inconsistent trends.

**Conclusions**

- All models have approximately the same performance in summer and winter.
- The GPS data are larger than the ones from the models.
- The differences in percentages we see in general a similar behavior for both seasons.
- The GPS data are more accurate than the ones from the models.

**References**


**Future Work**

- Test the algorithms for the GPS-data assimilation, especially we will assess different methods to take the height differences into account.
- Discriminate to which extent these independent GPS data can be used to discriminate between different climate models – in terms of absolute values over long time, seasonal and diurnal variability as well as long term trends.

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