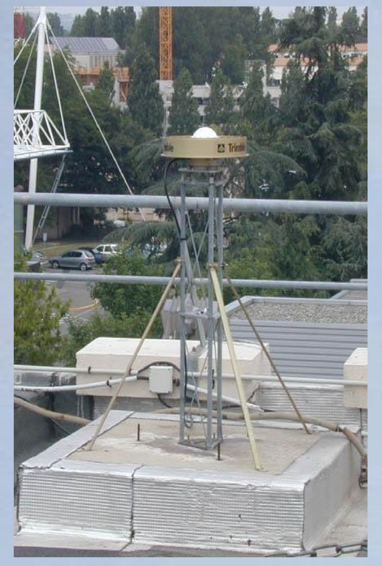

The GPS site at Toulouse (TLSE), France

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

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The GPS site at Caussols (GRAS), France

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 global Numerical Weather Prediction (NWP) model from the European Centre for Medium Range Weather Forecasting (ECMWF) as well as the regional climate model of the Rossby Centre (RCA).

Objective

The overall goal for the possible 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 a data from 26 ground-based GPS sites (see Fig. 1) in our analysis, covering the period 2001 – 2005 (inclusive).

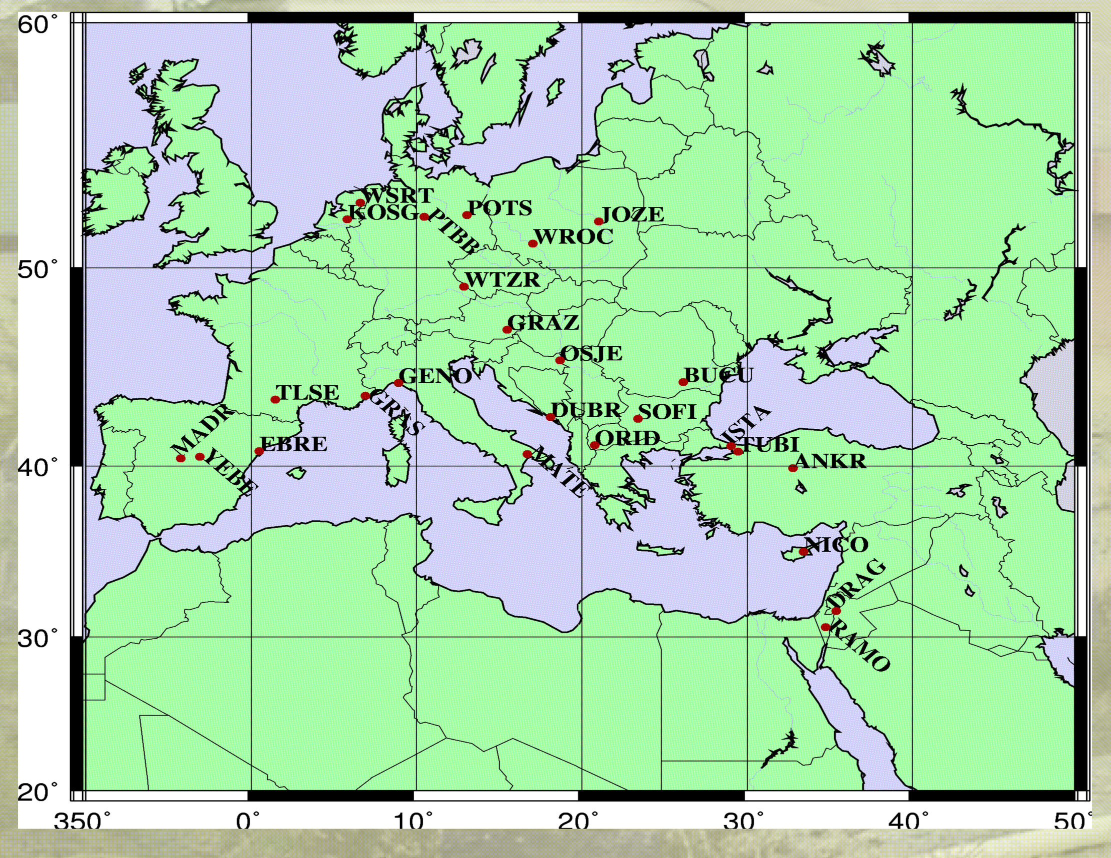

Fig 1: Geographic distribution of all GPS stations used in the analysis.

Models

We have evaluated the IWV from two models. One is the global European Centre for Medium range Weather Forecasting (ECMWF) operational analysis. The other is the regional Rossby Centre Atmospheric (RCA) model ran by the SMHI using ECMWF data at the boundaries. Table 1 shows horizontal resolutions and number of vertical levels as well as the typical vertical layer thickness within three height intervals of the models.

Model	Δx (km)	Vertical levels	Layer thickness at different height intervals (m)			Time averages: $T=\Delta x/U$ (min)
			0–2.5 km	2.5–6 km	6–12 km	
ECMWF	50	60	25–340	370–550	580–780	90–45–30
RCA	18	24	100–480	570–910	1060–1700	30–15–10

Table 1: The horizontal resolutions and number of vertical levels for the two models. [*Willén et al., 2005*]

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. 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.

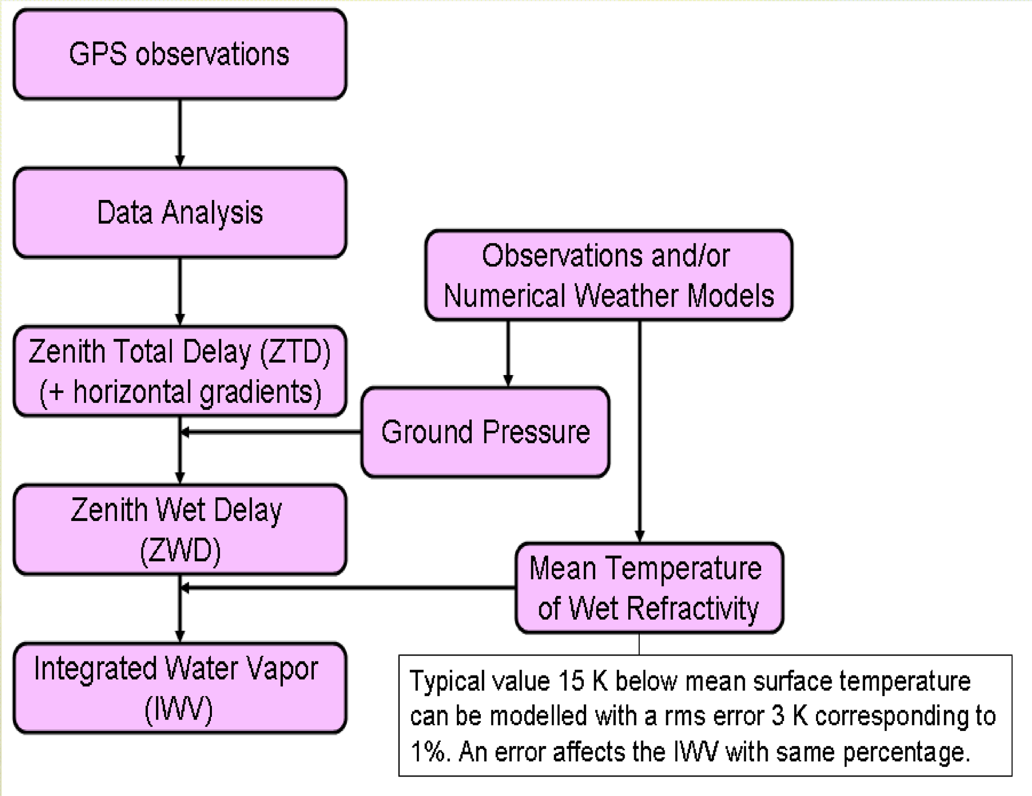

Fig 2: IWV time series are estimated from GPS observations.

The GPS data are processed by the GIPSY-OASIS II software [*Webb and Zumberge*, 1993]. One of the results is estimates of the propagation delay 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 if the atmospheric pressure at the GPS receiver is known, while the wet part is related to the IWV [*Emardson and Derks*, 2000]. Fig. 3 gives one example of the IWV estimated from GPS data.

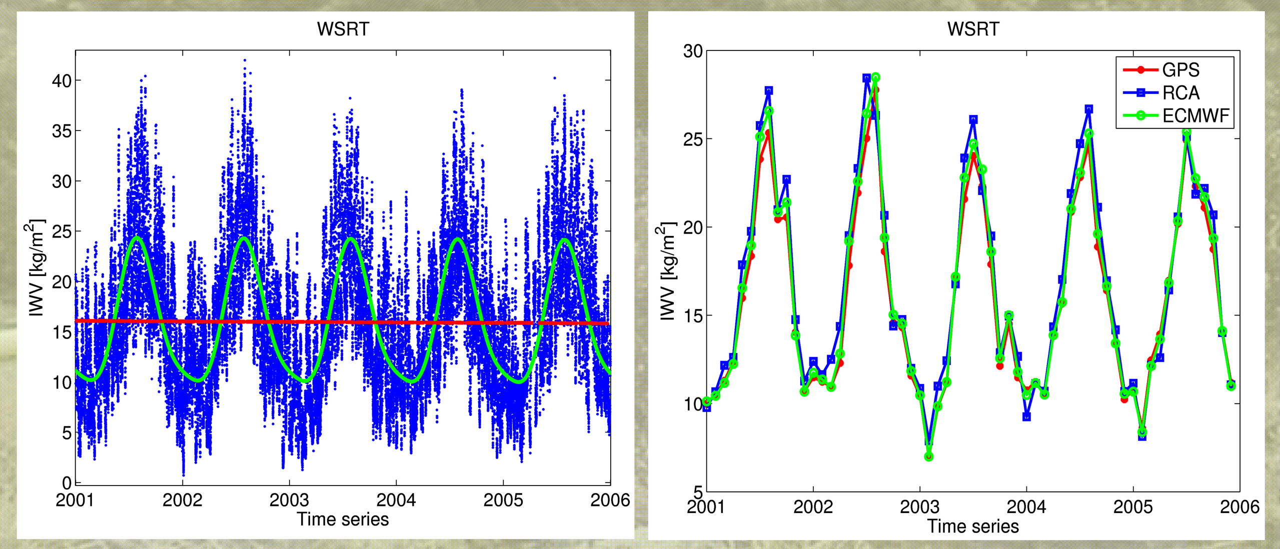

Fig 3: IWV time series (left) estimated from one GPS site: Westerbork (WSRT), The Netherlands with a fit for a seasonal (green line) and a trend component (red line). To the right is the comparisons of the monthly mean IWV estimated from: GPS (red), the ECMWF model (green), and Rossby Centre climate model (blue).

Comparisons Between GPS and Models

We have made the comparison between GPS and the models using monthly mean values, later we will look at variations over shorter time periods. Hence, the GPS data with original time series of five minutes had to be averaged into monthly values. Fig. 3 gives one example of a monthly comparison between GPS and models in estimated IWV.

Fig. 4 shows the average difference between IWV estimated from GPS data and from ECMWF and RCA models.

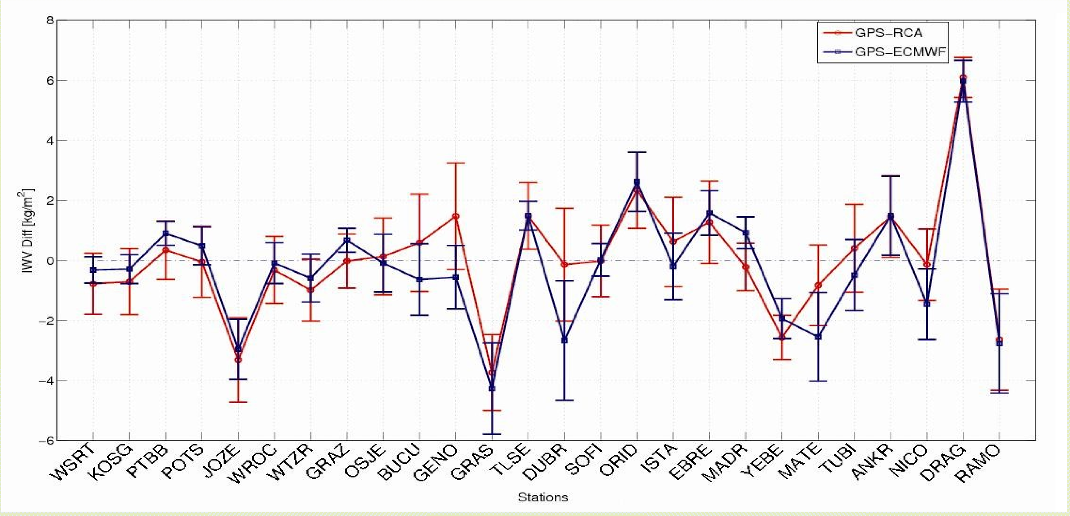

Fig 4: The average IWV bias between GPS and models. The errorbars represent the standard deviations of the monthly averages. See Fig. 1 for site names.

Since the horizontal resolution of ECMWF model is 50 km (see Table. 1), for some sites with mountains or valleys around a GPS station there could be significant difference in altitudes of GPS stations and the models. Fig. 5 gives the difference in height between the GPS site and the ECMWF model together with the average bias of IWV at the corresponding sites. It is clear that the main part of the bias is caused by the height difference (see especially ORID, DRAG, EBRE, GRAS, and RAMO). One exception is the site JOZE, where we believe that the bias is mainly caused by an inaccurate phase center model for the GPS antenna.

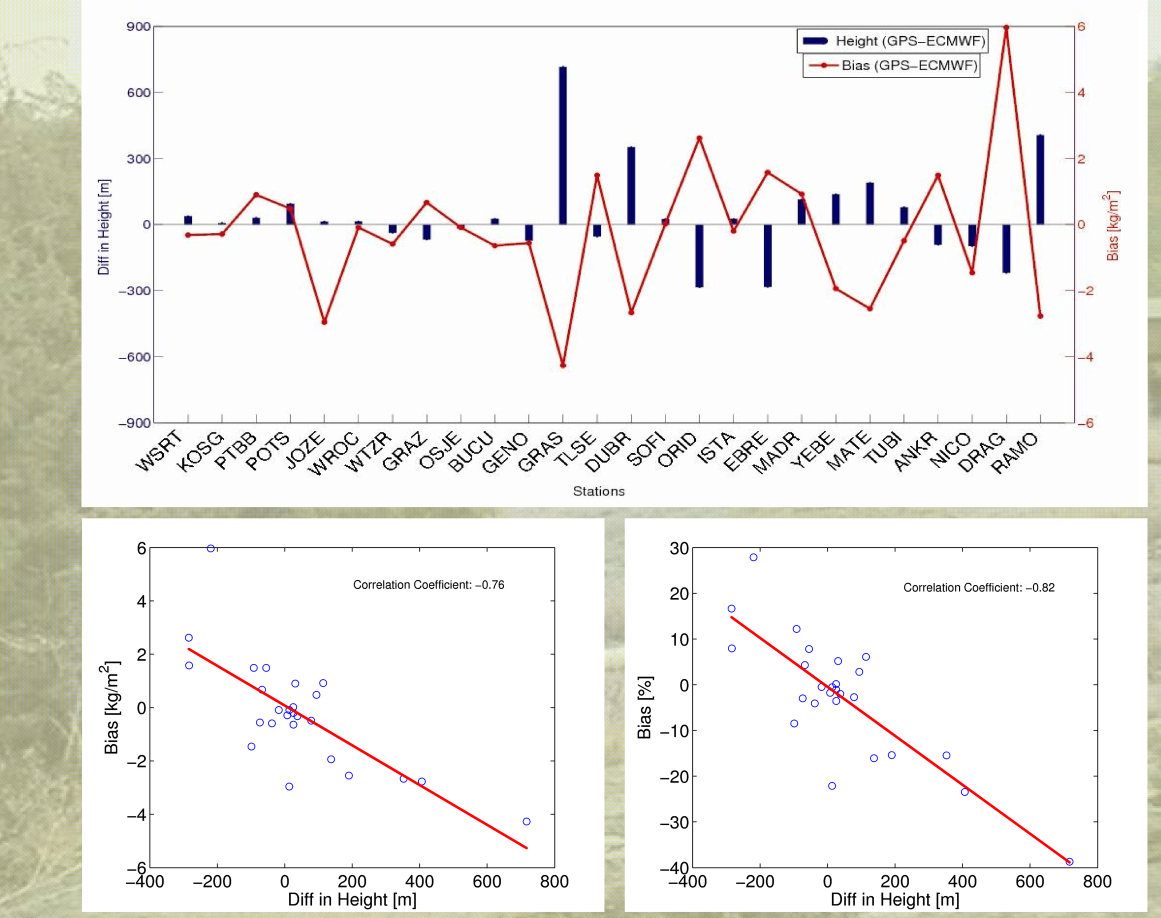

Fig 5: The height difference between the GPS and the ECMWF model and the average IWV bias for each site (top). The correlation between the height difference and the bias in absolute units (bottom-left), and in percentage (bottom-right).

It is also interesting to compare the difference between GPS and models for the summer (April-September) and the winter (October-March) seasons. When we choose to present the differences in percentages we see in general a similar behavior for both seasons. Again we note that the height difference is more important. In the future we will consider a model to correct for this effect.

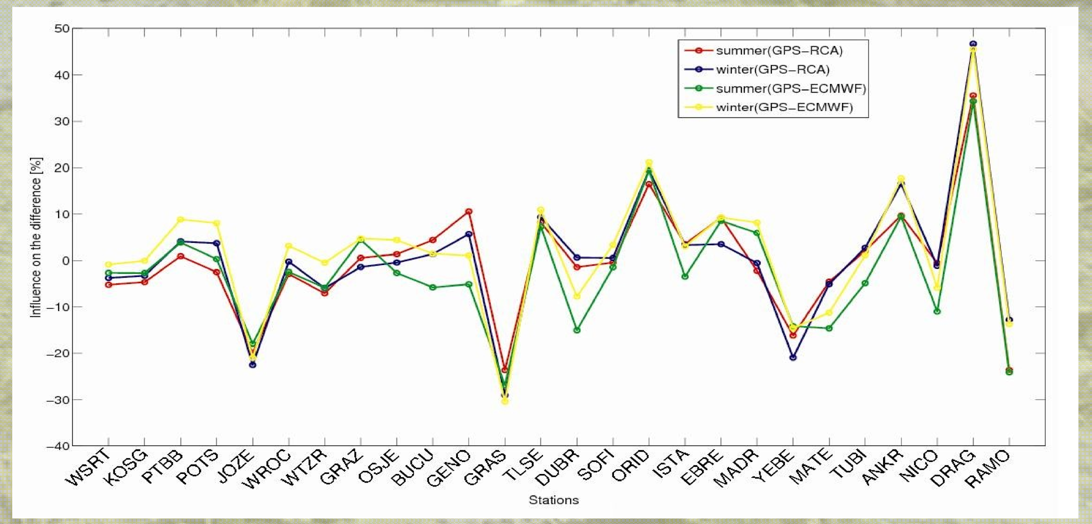

Fig 6: The IWV difference in percent for the summer and the winter period.

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. 7 shows 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.

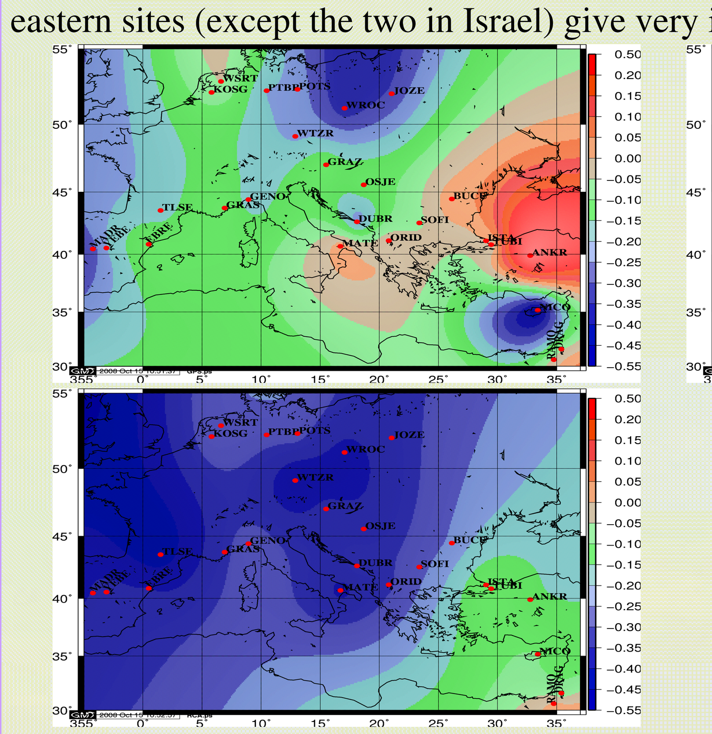

Fig 7: Linear trends in the estimated IWV from GPS data (top left), ECMWF model (top right) and RCA model (bottom left) for the five year period. Note that it is only relevant to compare the trends close to the sites (denoted by red dots).

Conclusions

- For most sites the ECMWF model gives a better agreement with the GPS data than the RCA model.
- Both models have approximately the same performance in summer and winter.
- IWV trends from nearby GPS sites seem consistent. For most sites IWV trends from GPS data are larger than the ones from the models.

Future Work

- Investigate IWV trends using data from more GPS sites and with longer time series.
- Improve the algorithms for the GPS-model comparisons, especially we will assess different methods to take the height differences into account.
- Determine 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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