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Validation of Swiss GPS Data and Comparison with ERA40 IWV Fields

J. Morland(1), M. Liniger (2), H. Künz (2), S. Nyeki (1), I. Balin (3), C. Mätzler (1)

(1) Institute of Applied Physics, University of Bern, Sidlerstrasse 5, 3007 Bern, Switzerland, (2) Climate Services, MeteoSwiss, Kraehbuehlstrasse 58, Postfach 514, 8044 Zürich, Switzerland, (3) École Polytechnique Fédérale de Lausanne, Ch. des Pyramides, 14, 1007 Lausanne, Switzerland (June.Morland@mw.iap.unibe.ch / Fax: +41 (0)31 631 3765 / Phone: +41 (0)31 631 8678)

Introduction

Water vapour is a crucial component of the climate system and at the same time it is difficult to observe due to its high spatial and temporal variability. In view of the fact that water vapour feedback can approximately double the warming expected from greenhouse gases alone, it is essential to obtain reliable observations of water vapour and also to validate the modelling tools which are used to analyse water vapour in the present climate and to predict future changes.

Most GPS networks have been operating for less than a decade and cannot yet be used to directly detect changes in integrated water vapour (IWV). GPS networks can provide other services to the climate community, such as the validation of model and reanalysis data. GPS observations are not yet assimilated into the observing system and are therefore independent of the operational analysis and reanalysis data.

The Automated GPS Network of Switzerland consists of 30 permanent GPS stations distributed throughout Switzerland at altitudes between 300 and 3500 m. It has been operating since November 2000 and provides an interesting dataset for studying IWV observed over a wide altitude range.

Core

IWV measured by GPS was compared with that measured by coincident Precision Filter Radiometers (PFRs) at four locations: Payerne (491 m), Bern (570 m), Davos

(1598 m) and Jungfraujoch (3584 m). The bias in GPS relative to PFR was -0.2 mm at Payerne, + 0.5 mm at Davos and +1.0 mm at Bern. The GPS IWV observed at Payerne and Bern agreed with coincident measurements made by sonde and microwave radiometer to within 1 mm and 0.5 mm, respectively.

The GPS observations at Jungfraujoch, the highest station, showed a relatively constant dry bias of 1.3 mm compared to PFR. Because of the low integrated water vapour amounts at this altitude, this led to unphysical, negative IWV values being frequently reported. This was observed during a previous study (Guerova et al, 2003) and attributed to incorrect modelling of the antenna which has a heated radome to prevent snow and ice gathering on it. The Jungfraujoch GPS IWV observations were corrected based on a comparison with coincident PFR measurements. The corrected GPS values compared very well with water vapour measured by the Raman lidar at Jungfraujoch (Balin, 2004).

Nine GPS stations were chosen to give a good geographical representation of the Swiss network and also to cover the full range of altitude. The IWV observations made at these stations were then compared with ECMWF reanalysis (ERA40) IWV fields interpolated to the corresponding location. No altitude correction was made in order to avoid information loss. This meant that for most stations the model orography was higher than that of the GPS station in the Swiss plains and Alpine valleys and lower in the Alps. The GPS observations correlate well with the ERA40 IWV fields at all stations. The square of the correlation coefficient, the r^2 value, was greater than 0.9 at all stations except Andermatt (2318 m) and Jungfraujoch (3584 m, corrected data) where it was 0.85 and 0.6, respectively. At these stations, the model orogoraphy is more than 1000 m below the real surface.

When the model and GPS data were compared on a month to month basis, it was seen that the ERA40 IWV fields captured the timing and shape of large day to day IWV variations very well, but smaller variations on the time-scale of less than one day were not so well analysed.

The IWV difference between the ERA40 and the GPS observations was averaged over the November 2000 to August 2002 period. A strong negative relationship was found between this variable and the corresponding altitude difference between the model surface and the station. The intercept was -0.8 mm, which would tend to suggest either a dry bias in the model or a wet bias in the GPS observations. As expected, a corresponding positive relationship was found between the mean IWV difference and the mean difference between the model surface pressure field and the observed pressure at the GPS station.

Conclusions

IWV values calculated from the AGNES GPS network compare reasonably well with those from PFR, microwave radiometer and sonde, where coincident measurements are available.

The exception to this rule is the high altitude Jungfraujoch station where the GPS has a negative bias, leading to negative IWV values frequently being reported. This bias was corrected based on the relationship between GPS IWV and coincident PFR observations. After correction, the Jungfraujoch data compared well with IWV measured by the Raman lidar.

The ERA40 reanalysis IWV field is well correlated with the GPS observations at stations throughout Switzerland. This comparison indicates that the ERA40 data provide a good analysis of the water vapour situation in Switzerland in the investigated years. However, this may not have been the case before the assimilation of satellite observations in the global observing system in 1979, as already noted by Bengtsson et al, 2003.

References

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