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GPS WATER VAPOUR MEASUREMENTS

Summary of Experience ground-based GPS at KNMI

(Submitted by Siebren de Haan, KNMI, The Netherlands)

Summary and purpose of document

This document contains information on the use of GPS observation at KNMI; Integrated Water Vapour measurements for nowcasting purposes (COST-716 monitoring); Slant Water Vapour measurements from GPS to recover three dimensional water vapour fields; Investigation of the quality of slant delay measurements for use in NWP within the European Project TOUGH; and Investigation of high temporal frequency signals from GPS to assess the atmospheric stability.

Action proposed

The meeting is invited to take information provided in the document in discussing GPS water vapour measurements.

Summary of Experience ground-based GPS at KNMI

Siebren de Haan, KNMI, Februari 2005

Overview

The use of GPS observation at KNMI is currently in a transition phase: from research to operation. International research is embedded in the European TOUGH project, while preparation of operational GPS processing for meteorological purposes is incorporated in the EUMETNET program EGAVP. The latter is lead by DMI with partners UKMetoffice and KNMI.

National research and operation are and will be in close contact with Delft University of Technology. The research is nationally sponsored.

At KNMI there is currently no experience in processing. Experience is achieved for development/research of the use of GPS data:
1. COST716 monitoring: Integrated Water Vapour measurements for nowcasting purposes.
2. Slant Water Vapour measurements from GPS to recover three dimensional water vapour fields.
3. Investigation of the quality of slant delay measurements for use in NWP within the European Project TOUGH.
4. Investigation of high temporal frequency signals from GPS to assess the atmospheric stability.

(Near) future
1. An implementation project will start June 2005 with the anticipated end result of an operational GPS processing system.
2. The Dutch GPS network will most likely be enlarged from 9 to 29 stations (unfortunately not all freely accessible)

COST716 monitoring

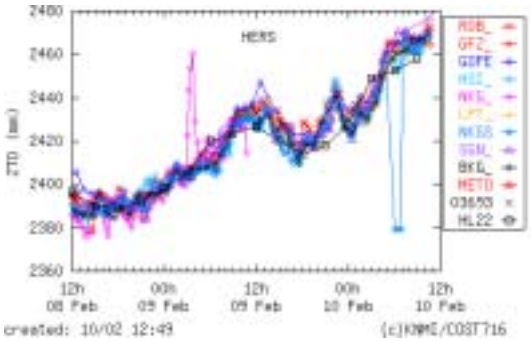
The COST716 action was a scientific collaboration between geodetic and meteorological institutes. The primary objective was :
- to asses the operational potential on an International Scale of the exploitation of a ground based GPS system to provide near real time observations for Numerical Weather Prediction and Climate Applications

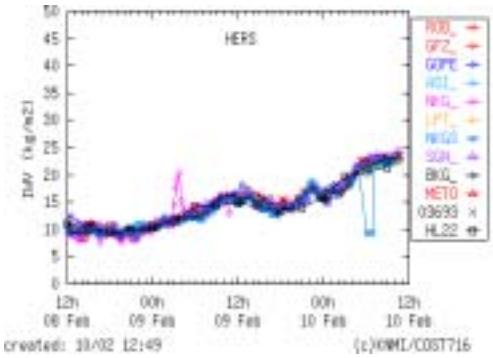
Secondary objectives were:
- Development and demonstration of a prototype ground based GPS system
- Validation and performance verification of the prototype system
- Development and demonstration of a data exploitation scheme for NWP and analysis of data exploitation techniques needed for climatic applications
- Requirements for an operational implementation of a ground-based GPS system on an international scale

At KNMI a monitoring site has been set up (see http://www.knmi.nl/samenw/cost716) This site is still operational, although the COST716 action ended in March 2004. The data currently shown on this site is delivered within the TOUGH project a European 5th framework project initiated by COST716. The total number of operational sites is

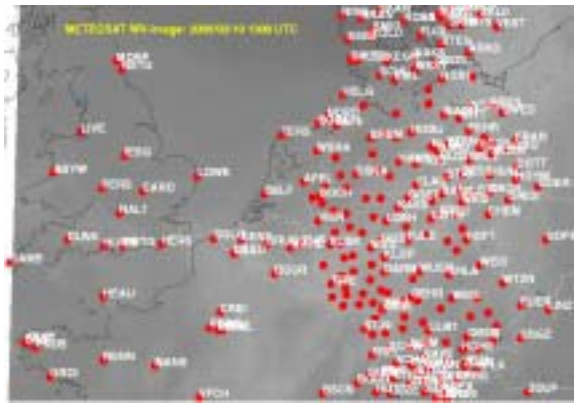
currently over 500 the distribution of these sites is shown in the figure below.

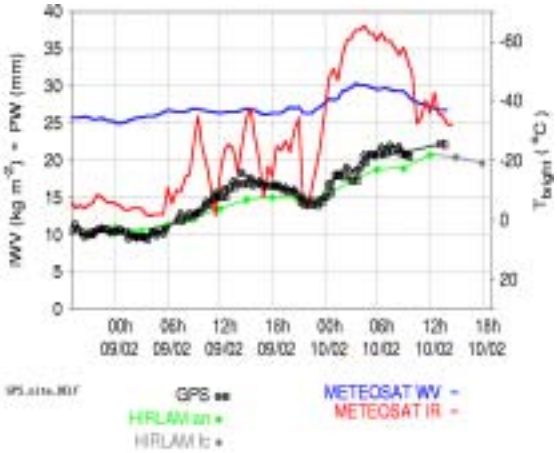
Currently, 12 processing centres are delivering GPS Zenith Total Delay (ZTD) estimates. From these ZTD values an estimate of Integrated Water Vapour is determined at KNMI. The majority of the processing centres deliverd the data within target set by COST716 (75% of the data within 1h45m). In the figure below the ZTD and IWV estimates for the site Hersmonceaux is shown.





By plotting the Meteosat Water Vapour brightness temperatures together with IWV a rough estimate of the water vapour distribution change can be obtained. Meteosat WV detects the amount of water vapour in the top of the atmosphere, while IWV is an estimate of the total column water vapour.

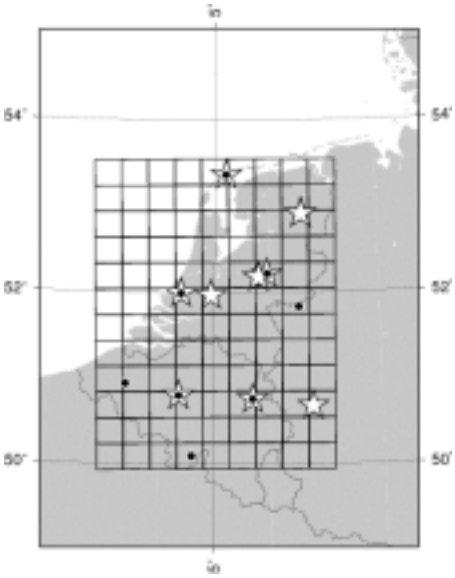




Also shown on these graphs is the forecast NWP IWV, together with all previous analysis values of IWV. (This work has been published in J. Applied Met.,43, 2004). This is a very experimental method and is not used in the operational forecasting procedures.

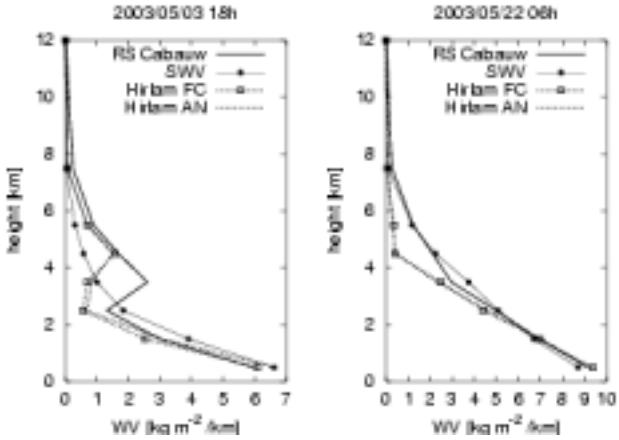
Slant Water Vapour measurements from GPS to recover 3D water vapour fields

In a national funded project, slant water vapour (SWV) measurements from GPS were used to reconstruct a three dimensional water vapour field. The region of interest is shown in the figure below, together with the horizontal distribution of the grid boxes. The vertical resolution was set to 1 km.



A standalone three dimensional variational assimilation system was employed to analyse the atmospheric state using GPS observations only. The high temporal resolution of GPS slants is exploited by using the water vapour field retrieved from the previous hour

as background in the assimilation.
The figure below shows the water vapour profile from the operational NWP model at KNMI (analysis and forecast), the observed water vapour profile by an experimental radiosonde launch and the result of the 3DVAR system.



The 100km horizontal resolution of the receiver network proved insufficient to resolve small-scale humidity structures, as can be seen from the figure. Especially in the vertical, to resolved resolution was poor. The above system may profit from a denser GPS network. A project report is about to be finalized.

Investigation of the quality of slant delay measurements for use in NWP within the European Project TOUGH

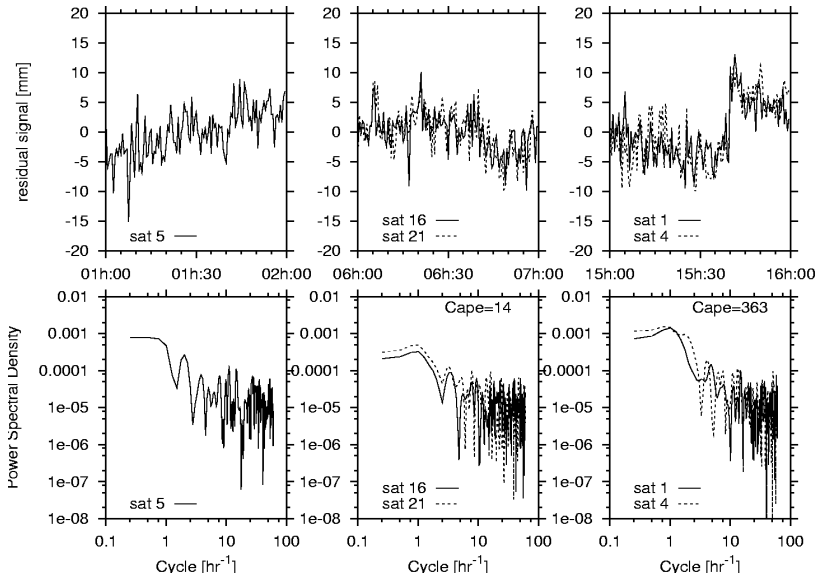
In the EU-FP5 project TOUGH (Toward Operational Use of GPS Humidity observations), methods are being developed for the assimilation of Total Slant Delays (TSD) in HIRLAM. Validation of TSD observations at 30s intervals has revealed that nonisotropic TSDs, which are alleged to contain small-scale humidity information, show little coherence with those computed from HIRLAM model fields and have a low signal-to-noise ratio (SNR). Averaging the data to 5-minute intervals proved a good compromise to improve the SNR while preserving the instantaneous character of TSDs. Coherence remained unchanged however.

High-resolution humidity observations from a dense GPS network can originate from the same air mass. This is expected to result in observation errors being spatially correlated. To describe the correlated nature of TSD observation errors a statistical covariance model has been constructed that will be used in forthcoming impact studies together with the results of the validation. It is expected that small-scale humidity information may be beneficial in specific cases

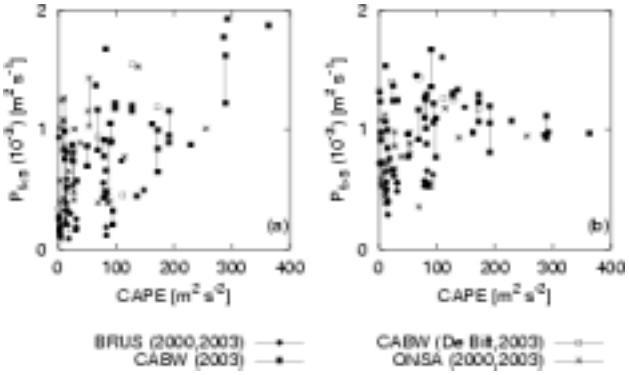
Investigation of high temporal frequency signals from GPS to assess the atmospheric stability

A method has been developed to detect the stability of the atmosphere based on high frequency GPS path delay observations. The GPS observations obtained from slant processing and mapped to the zenith, which sets the lower limit of useful observations to an elevation angle of 50 degrees. In the figure below the zenith delay for three different one hour windows are shown for individual satellites (top panels). Also shown is the

corresponding the power spectrum plots (bottom panels).



The convection parameter derived from these observations is the power of the GPS path delay signal for frequencies lower than 12 minutes (5 cycles per hour, $P_{f<5}$). Comparisons with the Convective Available Potential Energy (CAPE) obtained from radiosonde observations shows a correlation with the convection parameter obtained from GPS, see figures below.



This implies that, because of the continuous availability of GPS estimates and the good land coverage, this method of detecting atmospheric stability may be beneficial to forecasters. This work has been submitted to Journal of Applied Meteorology.