An Overview of COST Action 716: Exploitation of Ground-Based GPS for Climate and Numerical Weather Prediction Analysis

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Abstract. COST Action 716 is in the area of meteorology and is executed by the European Community. This paper describes the nature of a COST action, gives a brief description of meteorological applications of ground-based networks of Global Positioning System (GPS) receivers, followed by a presentation of the content of the COST Action 716—its present status, and the plans for future work.

1 Introduction—What is a COST Action

COST is a programme operated by the European Community (EC) in order to stimulate co-operation in the field of scientific and technical research. The funding for the actual research is obtained from other bodies, national as well as international and the COST activity funds the co-ordination. This means mainly travel costs for meetings, contributions to workshops/conferences, contributions to publications, and short term scientific missions (STSM) of researches to visit other partners and institutions stimulating valuable cooperation within the action.

COST is built up by "actions". Actions are grouped into different research areas, e.g., meteorology, telecommunications, and transport. The individual actions are defined by a Memorandum of Understanding (MoU) signed by the governments of the COST states wishing to participate in the action. At least 5 participants from different member states must sign the MoU in order to start the action. An action typically runs for 5 years. Presently almost 200 COST actions are running and in total, 43 countries participate in COST. These are:

– The 32 member states: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Norway, Poland, Portugal, Rumania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

– The other 11 states with participating institutions: Australia, Canada, Egypt, India, Israel, Japan, Kazakhstan, New Zealand, Russia, Ukraine, USA.

The highest body of COST is the Committee of Scientific Officials (CSO). It is composed of representatives from the member states of COST.

The Technical Committees (TC) are responsible for the different research areas.

There is one Management Committee (MC) for each COST action. It is in charge of the implementation, supervision and co-ordination of the work within the action and it is formed by not more than two representatives from each country that have joined the action and signed the MoU.

The information presented above is from the official COST website: `http://www.belspo.be/cost/` where more details can be found as well as links to the different actions.

Before we present the details of COST Action 716 in Section 3, we will briefly, in Section 2, review the area of ground based GPS meteorology. Finally, in Section 4, the plans for the future will be described.

2 Background of Ground-Based GPS Meteorology

Ground-based GPS meteorology has been developed during the last ten years or so. From being an important error source in the space geodetic techniques of Very-Long-Baseline Interferometry (VLBI) and static positioning using the Global Positioning System (GPS) the impoved quality and increased sampling rates of the data nowadays allows the atmospheric influence to be estimated simultaneously with the geodetic parameters (see, e.g., Tralli and Lichten (1990), Bevis et al. (1992), and Duan et al. (1996)). The total excess propagation time of radio waves penetrating the atmosphere is estimated using the space geodetic data. This term is often split up into two terms called the hydrostatic and the wet delay (Davis et

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al., 1985). Together with meteorological data, the pressure and the temperature at the ground, the water vapour content can be inferred. In addition to just estimating an equivalent atmospheric delay for the zenith direction first order linear horizontal gradients can also be estimated. Significant gradients have been estimated using both VLBI (MacMillan, 1995) and GPS (Bar-Sever et al., 1998) data.

For the application of measuring the water vapour content in the atmosphere above a site the VLBI technique is a very expensive method. Therefore, we will in the following just consider the use of GPS data.

We can identify three different applications for the atmospheric estimates using the GPS data:

(a). The GPS measurements can be used, as an independent observational data set, to validate numerical results from both Numerical Weather Prediction (NWP) and climate models.

(b). GPS data can be incorporated in the assimilation process of NWP models in order to improve weather forecasts.

(c). With a sufficient temporal and spatial coverage, the GPS method may provide a valuable data source to detect and study climate changes — the application of climate monitoring.

Application (a) has been successfully demonstrated by many groups. A relevant question here is of course how the GPS data themselves are validated. So far it has typically been achieved through comparisons using independent methods, such as integration of profiles from radiosonde launches and microwave radiometry. Typically the root-mean-square (RMS) difference of the Integrated Precipitable Water Vapour (IPWV) between GPS results and those from the other methods is in the range 1-2 mm (see, e.g., Emardson et al. (1998)).

In order to include the information available in the GPS data assimilation studies have been performed (Kuo et al., 1993) (Kuo et al., 1996) (Higgins, 1999). Work concentrating on developing an accurate data analysis scheme in order to get closer to real-time applications (necessary for (b) above) is carried out by several groups.

The climate application (c) can, however, only be addressed when a reasonably long history of GPS data has been archived. On the other hand, the improvement of the accuracy of the method is crucial for climate studies. Studies of long term trends in the water vapour content are difficult. Problems with the consistency in the data and their quality exist when using radiosondes (Gaffen et al., 1992) and microwave radiometry (Elgered and Jarlemark, 1998). The possibility to carry out a consistent processing of GPS data from both global and regional networks offer an interesting independent alternative.

Several research projects related to GPS meteorology are going on in Europe, supported by the EC as well as by national funding agencies. A fruitful cooperation between the space geodetic and the meteorological communities has started and the main task of our COST action, to coordinate and stimulate collaboration in this area, is well justified.

3 COST Action 716—Definition and Present Status

3.1 The Memorandum of Understanding (MoU)

The MoU defines the work to be carried out within the action. The MoU for COST Action 716 was produced during 1997–1998. An overview of the definition of the work to be carried out is presented in Table 1. This plan has been slightly modified by the MC compared to the original plan in the MoU. The MoU was signed by the fifth country in September 1998 and hence the action has been in force since then. The action will last for five years from this date, meaning that it will end in September 2003.

3.2 Activities during 1999–2000

The first meeting of the Management Committee (MC) was held in Brussels on January 8, 1999. The following fourteen countries were represented at the meeting: Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and United Kingdom. The action consist of four projects, each one handled by a working group (WG).

Chairman of WG 1 (*State of the Art and Product Requirement*) is Peter Pesec, Austrian Academy of Sciences. All national delegates have been given the responsibility to submit a summary of the status of relevant activities in each country. Based on this information the final report from WG 1 will be produced after this workshop.

Chairmen for WG 2, (Hans VanderMarel, University of Delft) and WG 3 (Sylvia Barlag, KNMI) were elected at the MC meeting in Delft in April 1999, and the members of these WGs were thereafter elected at the next MC meeting in Brussels in September 1999. More details on the WG activities can be found on the home page of the action: `http://www.oso.chalmers.se/geo/cost716`.

In order to get an idea of the present situation Figure 1 shows a number of continuously operating GPS sites which are useful for GPS meteorology. A map of this kind will of course quickly be outdated and the reader is welcome to submit additions/corrections to this map through the home page of the COST Action (see above paragraph). This feature will be available starting in August 2000.

It is also worth to mention that the density of GPS receivers is even higher in other areas, e.g., in Japan (Tsuji et al., 1994)(Naito et al., 1998) and in western California (Bock et al., 1993).

3.3 Plans for the next years

Within the COST Action 716 the preparations for the demonstration campaign carried out by WG 2, planned for early 2001 will continue. In parallel the meteorological applications dealt with in WG 3 will continue. These include studies of the impact of the GPS data, validation of the results, and recommendations for the future work in WG 4 (see Table 1).

Table 1. An Overview of the Contents in the Working Groups

Project 1 (WG 1)	Project 2 (WG 2)	Project 3 (WG 3)	Project 4 (WG 4)
State of the Art and Product Requirement	Demonstration	Applications	Planning for the Operational Phase
State of the art review and workshop - Theory (ground based) - Hardware - Software Error sources Additional data requirements Modifications needed to geodetic systems	Equipment field trials Operational reliability Code validation Sensitivity assessment to meteorological and site variables Consider possible quality control and validation measurements Near Real Time (NRT) network demonstration Met system Geodetic system and an international scale	Development of assimilation & data utilisation approach for: Numerical Weather Prediction Climate Impact and validation assessment Development of quality control and a performance monitoring scheme on-line scheme off-line trend and bias detection	Review of implementation options Logistics (include communications and coding standards) Assessment of optimal density Assessment of delta impact on current observing system Cost benefit analysis
Deliverables: Review report Equipment specification Critique of system Recommended software Specification of data exchange format	Deliverables: Trial report Demonstration system NRT data set on regional / continental scale	Deliverables: Impact assessment Recommendations for - Data exploitation - Quality control and performance monitoring	Deliverables: Cost benefit / analysis for enhancing observing system with GPS observations. Recommendations for international operational network

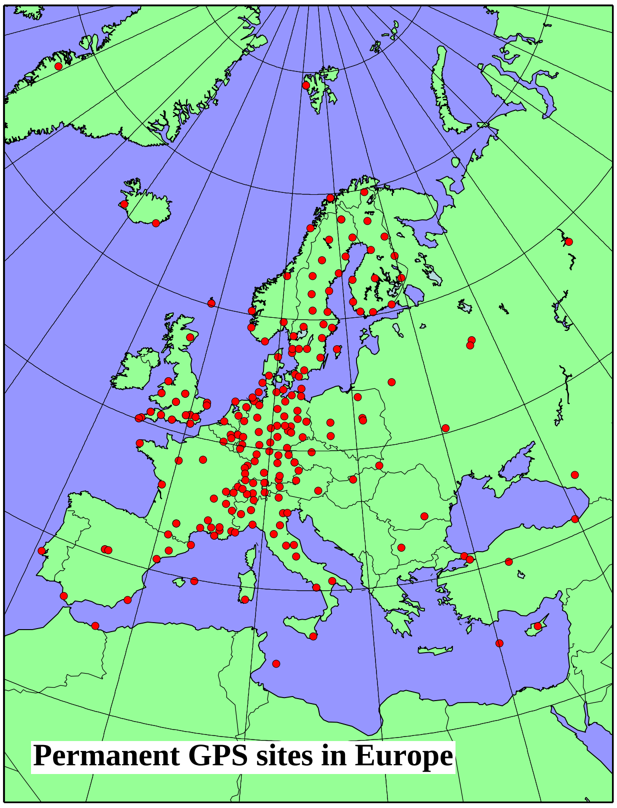

Fig. 1. Continuously operating GPS stations in Europe and nearby areas which are equipped with receivers capable of storing data to be used to obtain time series of estimates of the atmospheric propagation delay.

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