1. Name of Package (or Packages)

E-GVAP-III

(EUMETNET GNSS Water Vapour Operational Service, phase III)

2. Name of Member (or Members) and proposed Coordinating Member (or Coordinating Members if more than one Package)

Danish Meteorological Institute (DMI)

3. Executive Summary of Proposal

It is proposed that the E-GVAP setup developed and operated in E-GVAP phase I and II is maintained and further developed by the same team in E-GVAP phase III. This will result in a seamless continuation of the service, and an ongoing, fruitful collaboration with the geodetic community, through the network of contacts already established by the existing E-GVAP team, and through ongoing practical collaboration in the form of data exchange.

A gradual movement toward sub-hourly data processing and distribution is planned. An expansion toward East and South-East is planned, likewise an attempt to obtain global data. Active quality control, AQC, and de-central data dissemination via GTS is planned (including use of the WIS when it is ready).

An expert team on GNSS data processing will be used to gradually improve and homogenize the processing, and to enable close contacts with the analysis centers (ACs). An expert team on data usage will be used to compile examples of optimal use of E-GVAP data in NWP and nowcasting, to assist members their use of E-GVAP data.

Close contact to groups working on “next generation” GNSS meteorology is assured by maintaining the E-GVAP expert teams, by involvement in the application for an EU cost action on ground based meteorology, and by collaboration with other important projects, such as HyMeX.

The cost is expected to be 119 k€ per year. The same as for E-GVAP-II, and 10 k€ less than in E-GVAP-I.

Main Proposal

4. Overview of approach proposed.

The main purpose of E-GVAP is to provide its EUMETNET members with GNSS atmospheric delay and water vapour estimates in near real-time (NRT) for operational meteorology. A second purpose is to help advance processing of GNSS data for estimation of atmospheric properties of importance to meteorology, and help advance usage of such data in NWP and nowcasting.

The GNSS atmospheric delay data provide NRT humidity information to NWP and nowcasting systems based on ground based GNSS observations. The observing equipment is owned by geodetic institutions and installed with the purpose of precise positioning. This reduces drastically the price of the observing system to meteorology, but limits control, and requires a very close collaboration between meteorology and geodesy.

In the third phase the current E-GVAP observing network shall continue (the setup is described in the Observations Programme Requirements and the associated annex on E-GVAP) with expansion into areas

where coverage is currently poor. There shall be focus on increasing the homogeneity of data, on validation and active quality control, and on reducing latency, moving to sub-hourly data processing and distribution. Access to more global data will be attempted. Research in next generation GNSS products for meteorology and use of them will be monitored, and supported when possible, e.g. by using E-GVAP infrastructure to distribute and validate such products, and distribute information about their usage.

The main deliverable observations in E-GVAP are the near real time (NRT) zenith total (or tropospheric) delays (ZTDs), which are estimated by processing data from high precision ground –based GNSS receivers. The estimation is done by a number of analysis centres (ACs), the majority of which are geodetic institutions, but a few are located at NMS's. Many ACs are involved. The main reason is that often the raw GNSS data may not leave the country, or the institution owning the data. In many cases raw GNSS data represent a high value to the owners, whereas the estimates ZTDs do not. The ZTD is not a direct observable, but an estimate, one of out of many; derived when processing GNSS data for positioning in order to get rid of various error sources, such as the atmospheric effect.

The processing of GNSS data and the estimation of ZTD is gradually being refined (just as new NWP models and data assimilation systems can improve forecasting starting form a fixed set of meteorological observations). Many of the ACs involved in E-GVAP are world leading on this subject, and have a strong interest in using the meteorological geodetic collaboration to further this research. The possibility of improving future GNSS data processing by use of additional up to date atmospheric information provided by meteorology (instead of e.g. climatology), is a main reason for the geodetic interest in collaboration with meteorology. This is one reason to maintain the two expert teams in E-GVAP, as the meetings enable discussion of both operational and R&D aspects of both GNSS data processing and data usage.

The proposal is to run with as similar setup as in E-GVAP-II, both regarding responsible (coordinating) member, division of work between the involved institutions, and the people involved in the E-GVAP team. Since this setup is described in the Observation Programme Requirements and the E-GVAP specific annex to that, it will not be repeated here in detail.

In the technical proposal below, all requirements regarding milestones, targets, method statements from the Observations Programme Requirements are listed, and we expect to meet all of them within the a budget of 119 k€ per year.

5. Technical proposal

In accordance with the Observations Programme Requirements for E-GVAP, the following milestones will be set

Year 1

- Continuation of existing E-GVAP-II data processing and distribution.
- Establishment of contacts to geodetic institutions, Setup up of expert teams.
- Formalisation of contacts to EUCOS and EUMETNET Secretariat.
- Establish contacts with non-European suppliers and users with the objective of mutual data exchange globally.
- First version of active quality control software capable of automatically flagging ACs or delay data which the monitoring has found to be incorrect.

- Reports from expert teams and E-GVAP team.

Year 2

- Continuation of existing E-GVAP-II data processing and distribution
- Update of User Requirements (depending on user interest)
- Update of document of common, minimum requirements to GNSS data processing as regards access to data from individual sites, to satellite orbit and clock estimates, and timeliness and precision.
- Reports from expert teams and E-GVAP team.

Year 3

- Continuation of existing E-GVAP-II data processing and distribution
- Reports from expert teams and E-GVAP team

Year 4

- Continuation of existing E-GVAP-II data processing and distribution
- A review/discussion of the future route for European ground based GNSS observations for meteorology
- Draft proposal for the future of E-GVAP.
- Reports from expert teams and E-GVAP team

Year 5

- Continuation of existing E-GVAP-II data processing and distribution.
- Preparation for the next phase. Including enhancing the portability of the current system to ease potential takeover by another team, e.g., implementation into EUCOS as a mandatory programme, by using "standard" software where practical, and by documenting the setup, making it easier for other, to setup what cannot be copied directly.
- Reports from expert teams and E-GVAP team
- Final report

Types: M=mandatory, D=desirable.

Target no	Requirements	Type	Proposal
01	Ensure the operational E-GVAP system from E-GVAP-II is maintained and continues to run and to make its data, from the sites currently available in E-GVAP-II, available for assimilation and nowcasting	M	The setup for this already exists and runs at the institutes proposed to deliver the Operational E-GVAP-III Service.
02	Ensure continuation of the established, fruitful close collaboration with the geodetic community. Thereby increase the number of sites, in particular in regions with poor coverage and data, and increase the homogeneity, quality,	M	The proposed team has already a fine collaboration with the geodetic community. This will be continued. See also method statement 5

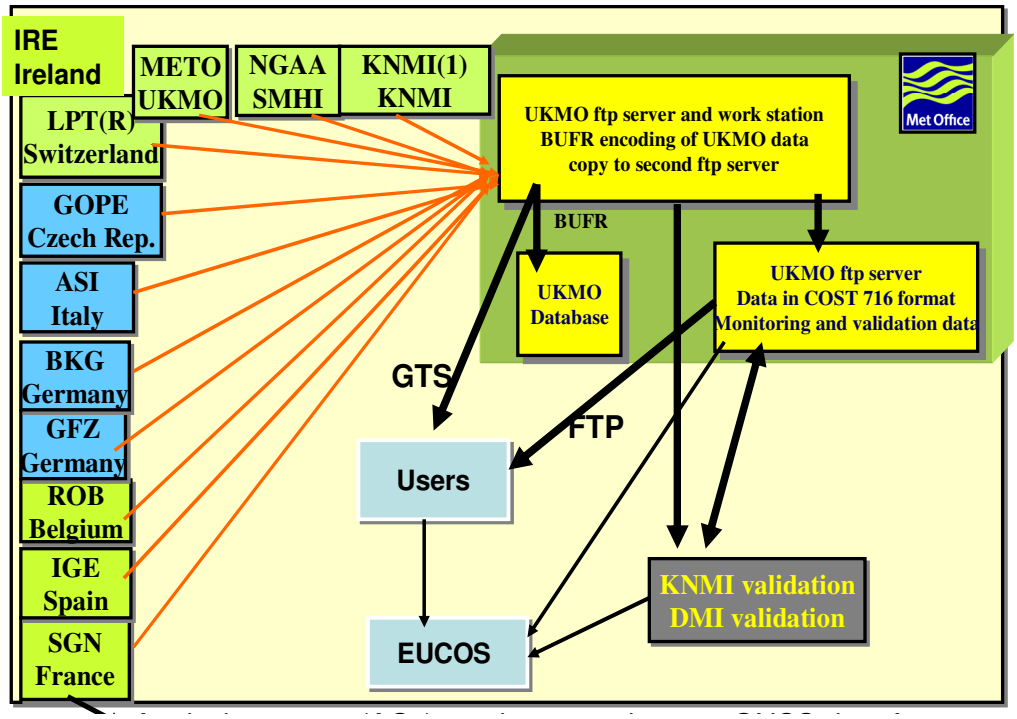
Target no	Requirements	Type	Proposal
	and timeliness of the NRT ZTDs.		
03	Further improve the construction of IWV maps and animations for use in nowcasting.	M	Production of IWV maps and animations will be continued. It will be attempted to improve the ZTD to IWV conversion, which suffers currently in regions from which few SYNOP data are available to the three E-GVAP team institutions.
04	Ensure that data server and data monitoring facilities have backups in case of failure, so minimising the risk of a complete lack of ZTD/IWV data.	M	The Met Office data servers and data distribution system to be utilised are already in an operational setting with backups. Moving toward de-central data dissemination will further improve robustness against single point failure. See also method statement 2.
05	Ensure running of sufficient monitoring and validation tools.	M	The current detailed monitoring and validation will be continued. Simplified, monthly validation overviews will be developed. Collaboration with the EUCOS QMP will be maintained.
06	Ensure running of AQC, to guard against use of data in case of sub-system (AC) widespread errors in DA.	M	Planned. See method statement 4.
07	Ensure operational migration to sub hourly processing and data distribution.	M	To be done by first enabling sub-hourly uploads, then have ACs convert to sub-hourly processing. Some ACs can start to deliver sub-hourly data right away, for other it will take some time. The bottleneck is limitations in access rate to the raw GNSS data, which is in many cases not controlled by the ACs.
08	Ensure close collaboration with the EUCOS team and EUMETNET secretariat.	M	Already existing, to be continued.
09	Ensure use of “supersites” for monitoring of system stability and errors.	M	The use of supersites will be maintained.
10	Ensure monitoring of progress in “next generation” GNSS meteorology, such as production and usage of ZTD gradients, STDs, and 3D water vapour fields derived by tomographic inversion of GNSS based STDs.	M	Accepted. See also target no 22 and method statement 7.
11	Ensure to report on the progress of water vapour /zenith total delay data assimilation research and promote the use of GNSS water vapour measurements in operational meteorology by the provision of suitable teaching material and	M	To be done via reports from the meetings of the expert team in data usage. See also method statement 6.

Target no	Requirements	Type	Proposal
	documentation (including to EUMETCAL).		
12	Ensure to follow the development of the WIS and VGISC. Prepare for the E-GVAP data monitoring and distribution system to become a DCPC relative to the WIS in parallel with other EUMETNET observing programmes.	M	To be done in collaboration with EUCOS and the other Operational Services in the Observations Programme. Started already in E-GVAP-II.
13	Ensure the coordination of meteorological exploitation of national sources of GNSS data by helping the NMSs achieve their cost-effectiveness goals.	M	For this reason we will maintain having a yearly plenary meeting in connection the expert team meeting. The plenary board consists of one person per E-GVAP member.
14	Ensure provision of meteorological support for expansion of GNSS observing networks, including provision of meteorological data as agreed in the EUREF EUMETNET MoU.	M	This established provision of meteorological data will be maintained. They are made available via password restricted ftp, to geodetic partners accepting not to exploit the data economically. An interest for additional meteorological data in the form of NWP fields is foreseen, which is unproblematic.
15	Ensure the exploration of possibilities for long-term central archiving of both raw (RINEX) and processed (ZTD) data for off-line research and potential future re-processing for climate applications.	M	To by done via EUREF and the expert team on data processing. In addition: A number of regional re-processing projects are being made by other groups. E-GVAP will compile a list of those to assist climate applications.
16	The new PM of each Operational Service will contact STAC in autumn 2013 in order to coordinate a succession plan for his/her service.	M	Accepted
17	Collaborate with the proposed EU COST Action on ground-based GNSS meteorology in case it is started.	M	Accepted. Started by proposed team in phase II. See method statement 7
18	E-GVAP Operational Service Team shall work on a further improvement of the portability of the infrastructure.	M	Accepted. In all development of new software we will consider carefully the portability aspect in order to both enhance portability and reduce complexity.
19	The E-GVAP Operational Service Team shall work towards fully INSPIRE compliant data production chains and INSPIRE compliant data itself.	M	It is planned to do this through a common EUCOS, WIS and VGISC approach for EUMETNET observational data to become INSPIRE compliant.
20	Attempt access to global data, to help members running global models	D	The recently started of processing of global data by E-GVAP AC will gradually expand. Attempts will be made to gain access to GNSS delay data from North America, Japan, and

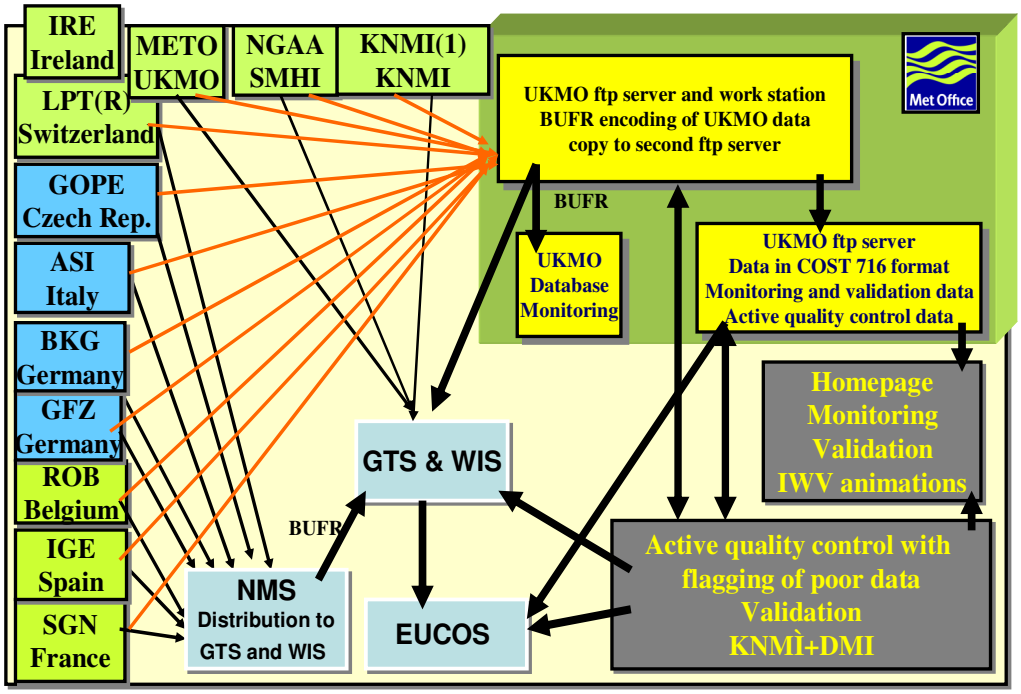
Target no	Requirements	Type	Proposal
			other non-European GNSS networks.
21	Attempt, in collaboration with the geodetic community, and possibly EUMETSAT, to improve quality and security of access to so-called "satellite orbit and clock estimates", which are used in the data processing by the processing centres.	D	Already started. Will be continued in collaboration with people in the expert team on data processing, EUREF, IGS, and EUMETSAT.
22	Attempt to support research in "next generation" GNSS meteorology, such as production and usage of ZTD gradients, STDs, and 3D water vapour fields derived by tomographic inversion of GNSS based STDs.	D	Accepted. Already started by the proposed team in phase II. See method statement 7.

Also include in this section your Method Statements using the following table format:

Method Statement Number 1
Describe how you plan to provide adequate Operational Service management and technical skills, as well as how you plan to optimize use of the budget and how is the team organized?
The E-GVAP-III team will consist of the same persons and the same members as in phase I and II. They have already demonstrated their ability regarding both management and technical skills, and the host institutions have demonstrated their willingness and capacity to provide access to necessary resources in the form of computers and databases. Regarding organisation and spending in an optimal way, see the section "Organisation" further down.
Method Statement Number 2
Describe the setup to be used for data upload and distribution including it's robustness against computer failure.
The current and planned future setups for data distribution are pictured in the top and bottom figure, respectively.



The receiving ftp-server and the distribution via GTS are already in an operational setting at the Met Office, ensuring backup in (most) cases of failure. The boxes left and top left represent the ACs. Green are those placed to current members of E-GVAP countries. In the future more ACs (certainly) and more members (hopefully) will appear. The members are all in the "Users" box on the first figure, and in the NMS box on the second figure.



The change to local GTS ingestion will be gradual and mainly via national NMS, since the majority of the ACs have no GTS access. Use of the WIS is planned. The ftp-uploads to a central ftp-server will be maintained, in order to achieve maximum speed in the AQC, which requires all data at one location.
Method Statement Number 3
Describe the setup to be used for timeliness monitoring and validation and for provision of validation statistics to the EUCOS QMP.
The monitoring and validation will essentially be performed as today: Detailed, statistical timeliness monitoring will be done by the Met Office and made available via ftp and www. Detailed validation against KNMI NWP and in between ACs, and on the fly timeliness monitoring will be done by KNMI and made available via www, both graphically and statistically. Values of O-Bs will be extracted from the Met Office operational data assimilation system and made available via ftp. The EUCOS timeliness monitoring will be based on the arrival time of E-GVAP data to the DWD database (provided EUCOS remains at DWD?!) The EUCOS E-GVAP station list is the E-GVAP station list maintained at the Met Office and uploaded to DWD. The EUCOS validation statistics is based on O-B offsets statistics derived at DMI and uploaded to DWD. Currently DMI uses the Met Office O-Bs. Currently a simple, easy to overview monthly validation statistic for non experts is missing. That will be developed
Method Statement Number 4
Describe setup of active quality control.
AQC will be based on inter comparison of ZTDs from GNSS sites which are processed by at least 4 ACs. More than 100 sites, including the supersites, are available for AQC. The AQC will be done for hourly data batches. The result of the AQC will be a file listing ACs which are “safe” and eventual ACs which are “unsafe” to use in a given hourly period. The frequency and the timing of the AQC will be set in consultation with the operational users, in order to be optimal for their data assimilation. Initially AQC will be run at DMI, when a final version has been made, it will be transferred to the Met Office in order to be close to the relevant data servers. Subsequently a standalone AQC package, that interested users with particular needs can run themselves prior to data assimilation, will be made available.
Method Statement Number 5
• How will you manage and develop relationships with GNSS data providers and the geodetic

institutions?

By collaborating closely with EUREF, EUPOS and national geodetic institutions. We will continue to partake in the annual EUREF symposium (where national geodesists from all European countries gather) and to have a relatively large expert team on GNSS data processing. For this reason the E-GVAP travel budget is relatively high.

By providing meteorological data to the geodetic institutions. This will in the longer run lead to better GNSS data processing, an important point to maintain geodetic interest in production of GNSS delays for meteorology.

By encouraging national collaboration between geodesy and meteorology, both regarding sharing of data and sharing of facilities.

Method Statement Number 6

How will you promote use of E-GVAP data to members

- Make available from each yearly expert team meeting reports on the usage of ground based GNSS data in meteorology.
- Ensure that our expert team on data usage contains an expert representing each of the "large" NWP model consortia in Europe, providing thereby examples of assimilation in all the "common" NWP models
- Give in connection with meetings at member institutes presentations about production and usage of GNSS data, if there is an interest for that at the member institute. In addition all expert team meetings are open to everybody interested

Method Statement Number 7

How will you engage in development and usage of "next generation" ground-based GNSS meteorological products and collaborate with the proposed EU COST action in case it is realised?

This is done by including in the E-GVAP experts teams people working on production and usage of "next generation" products. As members of the E-GVAP team and some of the ACs associated with E-GVAP do that, this is straight forward and at almost no extra cost.

The E-GVAP validation and distribution system is by far the best in Europe for ground based GNSS. Within the resources available, we will assist work on next generation products by allowing distribution and monitoring via E-GVAP facilities.

Members of the current E-GVAP team, from all three institutions, are central in the formulation of the proposed EU Cost action. Jonathan Jones (Met Office) is the proposed chairman of the COST action.

It is planned to collaborate also with other European research projects, such as HyMeX (Hydrological cycle in Mediterranean Experiment), by enabling HyMeX to use E-GVAP data and distribute the additional HyMeX GNSS data via E-GVAP. HyMeX is very focused on getting access to extra data, which in the longer run will aid to the E-GVAP data coverage in Southern Europe and Northern Africa.

6. Organisation

The organization will be as during phase I and II. DMI will be coordinating member. DMI, KNMI and the Met Office in combination will provide manpower and infrastructure to support the Operational Service.

Person-wise the organization is described in section 8, “References and CVs”. Work-wise it is described briefly in other parts of this proposal, and in detail the E-GVAP specific annex to the Observations Programme Requirements on the current E-GVAP setup.

Third party agreements

An MoU exists between EUMETNET and EUREF. An MoU is to be made between EUPOS and EIG EUMETNET, possibly before end of 2012. An MoU is to be made with NOAA/NCEP on access to North American GNSS delays.

On the national level it shall be the responsibility of each member to establish collaboration with geodetic side. In some cases this will include a national MoU, in other not. Those MoUs do not require EIG EUMETNET acceptance, but E-GVAP can assist members in making such MoUs, which helps ensure a common approach.

Expert teams

It is planned, as in E-GVAP-II, to have two expert teams, one on data processing and one on data usage. Meetings are annual, and combined for the two teams.

The *expert team on data processing* will essentially consist of one expert per AC. This team is absolutely vital for the collaboration with the geodetic partners.

The *expert team on data usage* will be much smaller, consisting of selected experts on usage of E-GVAP data in NWP and nowcasting; primarily, but not exclusively, from the member institutions. All major NWP systems used by the members will be represented by the experts. The expert team on data usage is needed in providing feedback to the data processing experts and ACs, and in providing examples of optimal usage of E-GVAP data to E-GVAP members.

STAC/PFAC has asked whether one expert team would be enough. As mentioned above we need both types of experts. Because of the large difference in the fields of expertise between the two teams, it is in some cases natural and beneficial to communicate with only one of the two groups on a certain issue, and natural to have different members of the E-GVAP team to be chairman of the two types of expert team. For this reason two separately named expert teams is preferred. We see no negative effects from this.

E-GVAP reimburses E-GVAP experts for their travel costs in connection with expert meetings.

Proposed TORs for the two teams are found in annex 2.

Plenary board

The plenary board consists of a person from each E-GVAP member. The plenary meetings are held in connection the expert team meetings. The purpose of the plenary board is twofold: To provide input to the

E-GVAP team on the running of E-GVAP. And to learn, from listening to the experts teams about optimal use of E-GVAP data, and help bring this information back to the member institutions.

In practice the interest of plenary board members in plenary board meetings is very different across the member institutions. Since E-GVAP is an optional programme, and interaction with members is important, we find that as a minimum E-GVAP-III shall set out with a plenary board as in E-GVAP-III. Then the plenary board might itself decide to arrange things differently at a later stage. Obviously with acceptance from EIG Secretariat, STAC/PFAC and Assembly as required by EUMETNET rules.

E-GVAP *does not* reimburse plenary board members for their travel costs in connection with plenary board meetings.

A proposed TOR for the plenary board is found in annex 2

All E-GVAP meetings are open to anybody interested.

7. Financial

The budget below is identical to the table in section 2.7.4.2 of "EUMETNET, Invitation for Submission of Proposals, Part 4: OBSERVATIONS PROGRAMME REQUIREMENTS, Programme Phase 2013-2017, Final V1.0.

REVENUE:				k€
R1	Contributions from participating members			119
	Total revenue			119
COST:				
C1	Management	Salary	10.5	
		Travel#	25	
		Management organization		
		Total		35.5
C2	Infrastructure			
C3	R&Development (software, instruments etc.) *			27
C4	Monitoring, validation, and quality control			56.5
	Total cost:			**119**

The majority of the travel expenses are spent on the expert teams.

The budget will be divided between three involved institutes, as follows

DMI (coordination, liaison, quality control)	43 k€
KNMI (validation and quality control)	25.5 k€
UKMO (data server and distribution, monitoring, validation, quality control)	25.5 k€
Operational Service travel, incl. expert teams (but not plenary board)	25 k€
Total	119 k€

At all three involved institutions the access to computers, servers, and databases is provided in-kind. Notice that there is a surplus in E-GVAP-II, which will be carried into E-GVAP-III.

8. References and CVs

The E-GVAP team will consist of
Henrik Vedel, DMI
Siebren de Haan, KNMI
Jonathan Jones, Dave Offiler and Gemma Bennitt, Met Office.

Henrik Vedel, DMI, will be the coordinator, DMI the coordinating member.

The majority of the team members have been involved in E-GVAP since 2005. All members are only part time on E-GVAP, and all do work outside of their E-GVAP time which is related to and supportive of E-GVAP, for example in data assimilation and "next generation" GNSS meteorology. The team includes experts on both processing and usage of ground-based GNSS data in meteorology, and has strong connections to the vital geodetic institutions, as well as to scientists working in the field of "next generation" GNSS meteorology. Several members of the team are involved in the application for an EU Cost action on ground based meteorology.

Curriculum vitae for proposed coordinator Henrik Vedel
Born 1958, Danish

Education

PhD in physics from Niels Bohr Institute, University of Copenhagen, 1991
Cand scient (approx masters) in physics and mathematics from Univ. of Copenhagen, 1987

Employment record

1998 – present Scientist at DMI, currently senior scientist at Center for Meteorological Model Systems (CMM).

Previously working in the field of theoretical astrophysics

1994 – 1997 Postdoc at Theoretical Astrophysics Centre, Copenhagen.
1993 – 1994 Research assistant at Department of Physics and Mathematics, Univ. of Victoria, Canada.
1992 Postdoc stipend from Danish Res. Council. Working at Department of Physics and Mathematics, Univ. of Victoria, Canada
1990 – 1991 Guest researcher at NORDITA, Copenhagen
1987 – 1990 PhD stipend from SARC Foundation.
1986 Carlsberg student scholar-ship.

Research interests in Geophysics

- GNSS meteorology
- Data assimilation methods in numerical weather prediction (NWP).
- Use of new observations in NWP, in particular GNSS observations and radar data.
- NWP models. Statistics.
- Validation and verification of NWP forecasts.
- Ensemble prediction.
- Climate monitoring and climate change.

Relevant project and project leader experience

- Programme manager of international project E-GVAP phase I and II (EIG EUMETNET GNSS Water Vapour Programme, http://egvap.dmi.dk) (15 partners in 15 countries, 2005-2009 and 2009-2012).
- Coordinator (and one of many researchers) of DMI project on nowcasting.
- Coordinator of EU research project TOUGH (Targeting Optimal Use of GPS Humidity Measurements in Meteorology, http://tough.dmi.dk) (15 partners, 13 countries, 2003-2006).
- Worked in PSO project on wind energy (See Giebel at al, Wind power prediction using ensembles, 2005, Risø Report, 1527)
- PI in ESA scientific pre-study for project ACE+ (On GPS Radio Occultation)
- PI in EU project MAGIC (Meteorological Applications of GPS Integrated Water Vapour in the Western Mediterranean, 1998 to 2001).

Other relevant project experience

- Experience as a scientist since 1998 with GNSS meteorology
- Co-convenor of sessions on "Atmospheric water vapour retrieval by space geodetic techniques" at EGU in 2010 and 2011 (with Rosa Pacione).
- Long time experience in computing and supercomputing
- Numerous short and long term work visits at scientific institutes.

- Work as article and project reviewer in meteorology, including GNSS meteorology (and astrophysics).
- Peer reviewed publications and invited presentations in both meteorology and astrophysics

Relevant reviewed publications in geophysics

- Pacione, R., B. Pace, H. Vedel, S. de Haan, R. Lanotte, F. Vespe, *Combination methods of Trophospheric Time Series",* 2010, accepted for publication in Advances in Space Research, Galileo Special Issue.
- Jaervinen, H., R. Eresmaa, H. Vedel, K. Salonen, S. Niemela, and J. de Vries, *A variational data assimilation system for ground-based GPS slant delays, 2007,* Quart. Jour. Roy. Met. Soc., vol 133, p. 969
- Vedel, H. and X.Y. Huang, *Impact of Ground Based GPS Data on Numerical Weather Prediction,* Jour. Met. Soc. Jap, 2004, **82**, 459
- Vedel, H. J. Haase, M. Ge, and E. Calais, *Impact of Trophospheric Delay data on precipitation in Mediterranean France and Spain,* Geoph. Res. Let., 2004, **31**, L02102, doi:10.1029/2009GL017715
- Vedel, H and M. Stendel, *On the direct use of GNSS refractivity measurements for climate monitoring,* OIST-4 Proceedings, ed. P. Stauning et al, Danish Met. Inst, Copenhagen, 2003.
- Haase, J., M. Ge, H. Vedel, and E. Calais, *Accuracy and Variability of GPS Trophospheric Delay Measurements of Water Vapour in the Western Mediterranean*, Jour. Appl. Met., 2003, **42**, 1547
- Walpersdorf, A, E. Calais, J. Haase, l. Eymard, M Desbois and H. Vedel, *Atmospheric gradients estimated by GPS compared to a high resolution numerical weather prediction (NWP) model,* Phys. Chem. Earth, 2001, **26A**, 147
- Vedel, H., K. S. Mogensen, X.Y. Huang, *Calculation of delays from meteorological data, comparison of NWP model and observed data,* Phys. Chem Earth, 2001, **26A**, 497
- Pugnaghi, S., M Boccalari, S. Faxlagic, R Pacione, R Santangelo, H Vedel, F Vespe, *Comparison of independent integrated water vapour estimates from GPS and sun photometer measurements and a meteorological model,* Phys, Chem. Earth, *2002, **27,*** 355

Selected other relevant publications

- Vedel, H. *Final Report for the TOUGH project,* 2006. Accepted by EU reviewers Oct 2006.
- Vedel, H, et al, *GPS Data Recommendations for European Numerical Weather Prediction*, 2006, TOUGH report D73
- Vedel, H and K. Sattler*, Impact study of assimilation of GPS slant delays,* 2006, TOUGH report D41.
- Vedel, H. K. Sattler, *HIRLAM 4DVar results and Impact of a temporal error correlation model in 4DVar*, 2006, TOUGH report D24
- Vedel, H, K Sattler, X.Y. Huang, *Ground based GPS ZTD impact experiments and case studies: 3DVar assimilation results,* 2006, TOUGH report D45
- Giebel, G., J. Badger, L. Landberg, H. A. Nielsen, T. S. Nielsen, H. Madsen, K. Sattler, H. Feddersen, H. Vedel, J. Tøfting, L. Kruse and L. Voulund, *Wind Power Prediction using Ensembles,* 2005, Risø report, Risø-R-1527(EN).

9. Authority to submit

Henrik Vedel have been authorized to submit this proposal by

Lars P Prahm, Director General
Danish Meteorological Institute

A signed letter to testify this will follow the two paper copies of the proposal being sent to the EIG EUMETNET Secretariat by ordinary mail.

Annex 1 Acronyms

AC	Analysis centre (doing ZTD estimation for E-GVAP using GNSS data)
AQC	Active quality control
DA	Data assimilation
EUPOS	European Positioning Determination System
EUREF	European Reference Frame
Galileo	The European GNSS system (under gradual implementation).
GLONASS	The Russian (former Soviet) GNSS system
GNSS	Global navigation satellite system (generic term)
GPS	The US GNSS system
GTS	Global telecommunication system
HyMeX	Hydrological cycle in Mediterranean Experiment
IGS	International GNSS Service
INSPIRE	Infrastructure for Spatial Information in the European Community
IWV	Integrated water vapour
NRT	Near real-time
NWP	Numerical Weather Prediction
STD	Slant tropospheric delay (also called slant total delay)
VGISC	Virtual Global Information System Centre
WIS	WMO information System
ZTD	Zenith tropospheric delay (also called zenith total delay)

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Annex 2 Proposed TORs for expert teams and plenary board

1) Expert team on GNSS data processing

Tasks

- Exchange knowledge on the GNSS data processing done for E-GVAP, leading to best practices and improved homogeneity of the E-GVAP GNSS atmospheric delay products.
- Exchange knowledge on "next generation" GNSS data processing.
- Provide advice to E-GVAP on technical and scientific matters.
- Liaise with geodetic community.

Membership

All ACs are members of this expert team. Each AC can send as many people to the expert team meetings as they like, but only one can be reimbursed by E-GVAP. From the E-GVAP team, each of the three team institutes have one member in the expert team on data processing. The chairman may invite selected experts on "next generation" GNSS processing not belonging to any of the ACs to give presentations at the meetings.

Procedures

The team meets once a year. The meeting is common with the meeting of the expert team on E-GVAP data usage. A member from the E-GVAP team is chairman of the processing expert team and responsible for the reporting. E-GVAP reimburses travel costs of the experts.

The meetings are open to anybody interested

2) Expert team on GNSS data processing

Tasks

- Exchange knowledge on usage of E-GVAP data in meteorology, thereby providing feedback to the E-GVAP data producers, and provide material assisting members in using E-GVAP data.
- Exchange knowledge on usage of "next generation" GNSS in meteorology.
- Provide advice to E-GVAP on technical and scientific matters
- Liaise with geodetic community.

Membership

The team consists of approximately one expert on E-GVAP data usage from each of the "large" NWP model systems utilised by E-GVAP members. From the E-GVAP team, each of the three team institutes have one member in the expert team on data usage. In addition experts on "next generation" data usage may be invited by the chairman.

Procedures

The team meets once a year. The meeting is common with the meeting of the expert team on data processing. A member from the E-GVAP team is chairman of the expert team and responsible for the reporting. E-GVAP reimburses travel costs of the experts.

The meetings are open to anybody interested

3) Plenary board

Tasks

- To provide member feedback to the E-GVAP team
- To learn about GNSS data usage, and help bring this information back to the member institutes.
- Liaise with geodetic community, by meeting AC representatives.

Membership

Each E-GVAP member has one representative in the plenary board, selected by the member.

Procedures

Meetings are annual, and in connection with the expert team meetings. The E-GVAP coordinator is Chairman of the plenary, and responsible for reporting. In case decisions are not unanimous a voting will be done, with one vote per member present. As long as decisions are not in conflict with EIG EUMETNET rules, the plenary is the upper ruling body in E-GVAP. The coordinator of E-GVAP may question such a plenary decision by bringing it to EIG Secretariat, STAC/PFAC or Assembly, in case he finds the decision not xxx. On matters where EIG EUMETNET rules require EIG Secretariat, STAC/PFAC or Assembly acceptance, the decision by E-GVAP plenary shall be seen as a recommendation to EIG Secretariat, STAC/PFAC or Assembly to accept the E-GVAP plenary decision. It is the responsibility of the E-GVAP coordinator to bring the matter forward to EIG Secretariat, STAC/PFAC or Assembly.

Plenary meetings are open to any body interested.