EUMETNET

Invitation for Submission of Proposals

PART 4:

OBSERVATIONS PROGRAMME REQUIREMENTS

Content: Chapter 10 E-GVAP 20171005

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CHAPTER 10: E-GVAP

CHAPTER VERSION CONTROL TABLE				
Version	Date	NOTES FOR OTHER CHAPTERS	Author	
	5/10/17	Changes to table 2.2.3. Text on E-GVAP in "Text from old chapter 2" (included in the last page of this file)	Henrik Vedel	

1.1. Introduction

1.1.1. Main objectives

The main purpose of E-GVAP is to provide its EUMETNET members with GNSS zenith total delay (ZTD) estimates and integrated water vapour (IWV) 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 now-casting.

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

In the fourth phase the current E-GVAP observing network shall continue. Further, the current attempts to expand into areas where coverage is currently poor, increase the homogeneity of data, validation and active quality control, and on reducing latency, moving to sub-hourly data processing and distribution shall continue. E-GVAP shall continue to help members access global data. Research in next generation GNSS products for meteorology and use of them should be monitored, and supported when feasible within E-GVAP resources.

As a result of recent progress in slant total delay (STD) estimation and current developments regarding assimilation of slants in high resolution NWP, E-GVAP shall in phase 4 enable operational distribution and monitoring of GNSS STDs, on top of the current work on ZTD.

1.1.2. Reference documents

Main documents:

- Programme Decision for the EUMETNET optional service E-GVAP-III
- E-GVAP end of year progress report and financial statement. Annual.
- Terms of reference for the E-GVAP expert teams. Updated wrt. E-GVAP-III.

Additional information documents:

- Product Requirement Document, version 1.0, available via E-GVAP homepage ("support")
- EUCOS QMP requirements to E-GVAP data.
- Answers provided by members in August and September 2017 to questionnaire on timeliness requirements for the next phase.
- MoU between EUMETNET and EUREF
- Reports and presentations from E-GVAP-III meetings. Can be found via egvap.dmi.dk and on EUMETNET Portal

Notice: For access to documents via the private part of the egvap.dmi.dk homepage system, use uid egvap, pw gps2user. For access to the ftp-server at UKMO with both ZTD data and monitoring and validation data and documents an institute specific uid and pw is needed. To obtain that, send an email to egvap@dmi.dk

1.1.3. History

E-GVAP was proposed to EUMETNET as an observing program by DMI, KNMI, and UK Met Office summer 2014, with the purpose of gradually turning achievements in ground-based GNSS meteorology from EU COST-716 Action and EU research projects TOUGH, MAGIC, and others, into an operational setting. E-GVAP began April 2005, it is currently in phase 3, lasting to end of 2018.

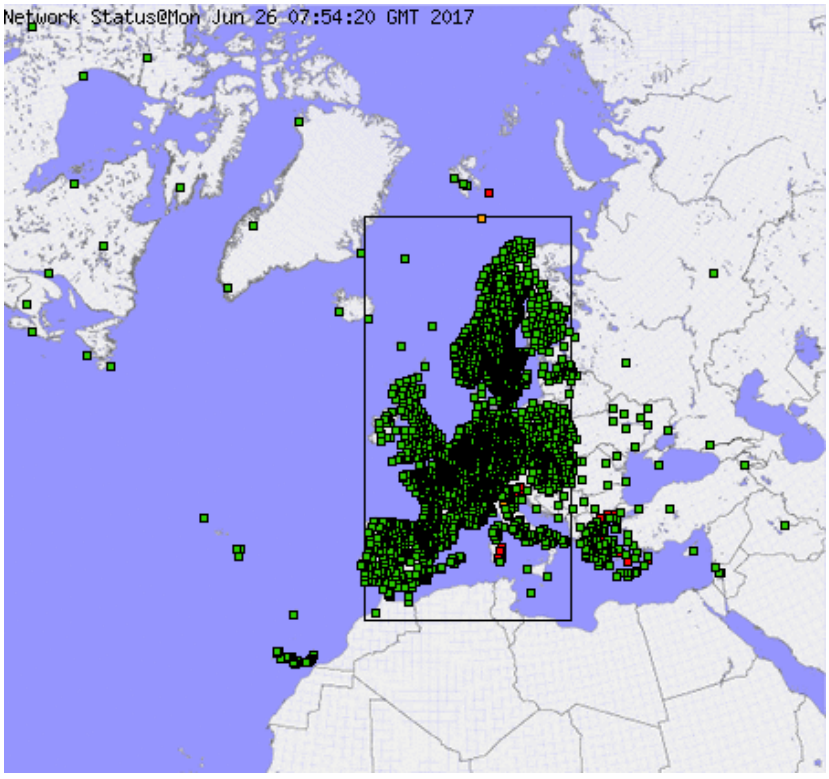
1.2. Present status

1.2.1. Network status

1.2.2. Current status (September 2017)

The E-GVAP processing, distribution, monitoring and validation system

The main deliverable in E-GVAP is the NRT ZTDs, which are estimated by processing data from high precision ground–based GNSS receivers. The estimation is done by analysis centers (ACs), the majority of which are geodetic institutions, a few are located at National Meteorological Services (NMSs). The reason for the many ACs is that often the raw GNSS data may not leave the country, or the institution owning the data. In many cases this data is of high value to the owners, whereas the ZTDs are not. The ZTD is not a direct observable, but one estimate out of many, derived when processing GNSS data for positioning, in order to get rid of various error sources, including the atmospheric effect upon the GNSS satellite signals. The processing for E-GVAP is in most cases done hourly, and in some cases, sub hourly. In E-GVAP-III sub hourly distribution of data was enabled. The uploaded files contain several ZTD estimates for each included GNSS site from within the time period the files cover. Figure egvap-1 shows the coverage.



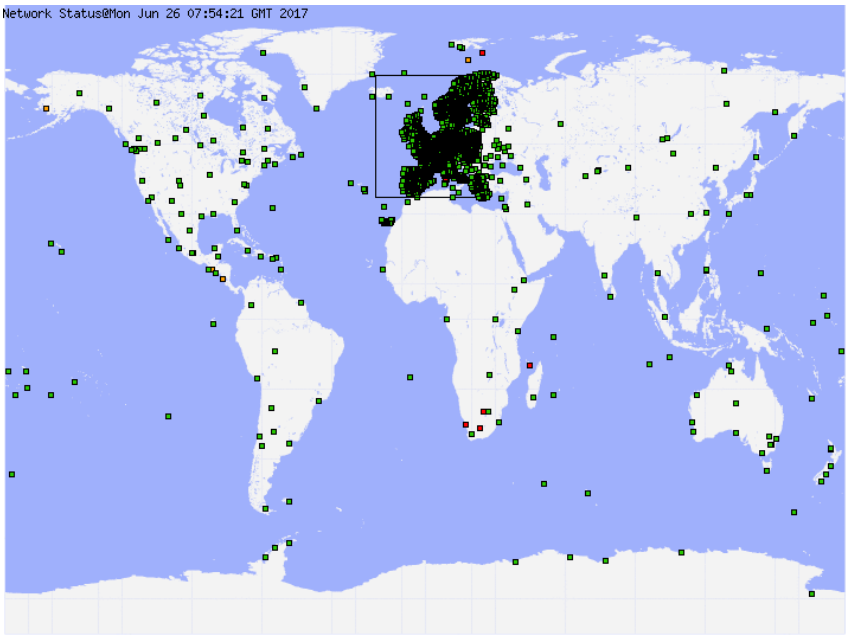


Figure egvap-1. E-GVAP observing network (see validation page for larger maps).

In Figure egvap-2 the institutions on the left side are the ACs. The blue represents ACs in non E-GVAP member countries. The ACs upload ZTD data to an ftp-server at UK Met Office (UKMO) in zipped COST 716 format, an ascii format. At UKMO the uploaded data are controlled in regards to name and position of the GNSS sites. GNSS site naming is not unique, and a database of names and positions is maintained at UKMO in order to rename eventual new GNSS sites to avoid duplicate names. The COST 716 data are then encoded into BUFR format and distributed via GTS. The COST files are moved to a second ftp-server, from where users can download the data if they prefer the COST format.

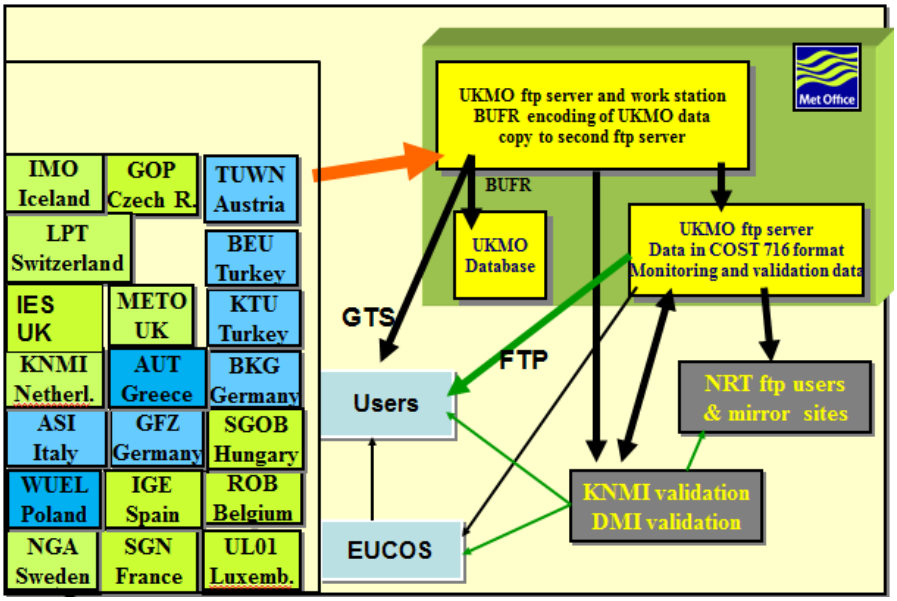


Figure egvap-2. Simplified schematic view of the data flow in E-GVAP. Each of the ACs in the left hand box uploads delay data to UK Met Office via ftp.

Some of the in-coming data is considered to be “non-operational”, for example data from a new AC, or from an AC experimenting with the processing of the GNSS data. The processing of GNSS data and the estimation of ZTD is gradually being refined. Some 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 non-operational data are not BUFR encoded and not put on the GTS, but made available on the ftp-server for download in COST 716 format.

Much resource is spent on assessing quality and monitoring timeliness of all incoming data, involving all 3 institutes in the E-GVAP team, and also the EUCOS QMP. For E-GVAP there is a "Product requirements document", available at the EUMETNET Portal and the E-GVAP homepage and ftp-server. Those requirements are WMO requirements on water vapour mapped into "delay space" to become ZTD requirements. There is also the EUCOS Performance Standards, with the E-GVAP component available as xx among the ref. documents. A user questionnaire on timeliness requirements in the next programme phase has been made Aug.-Sept 2017, see ref. doc xx. The results are listed in annex 1b. Some members use, or plan to use, very short cut-off times in their NWP-nowcasting, which will significantly tighten timeliness constraints.

At the EUCOS QMP, E-GVAP ZTD timeliness is monitored at DWD based on the arrival time of BUFR data. The statistics on data quality are deduced at DMI, based on O-B statistics from the UK Met Office global model, and then uploaded to the EUCOS QMP. In addition, the GNSS site list mentioned above is uploaded to the EUCOS QMP daily. Each uploaded data file contains several ZTDs from each site and AC, valid at different times during the period it covers, e.g. valid at 12:00 and 12:59 in an hourly file. Therefore the EUCOS QMP has two flavors of timeliness monitoring: one regarding the timeliness of the youngest ZTD and the timeliness of all ZTDs in the file. This because standard 3DVar uses only one observation from a site in the data assimilation, making one ZTD in time a minimum requirement.

The majority of the current monitoring and validation is done at UKMO and KNMI. Results are displayed via a server at KNMI, via links from the E-GVAP general homepage, located at DMI. See egvap.dmi.dk item "validation" for details and examples. Additional monitoring data is available at the UKMO ftp-site for data download, including very detailed timeliness monitoring. All incoming data are monitored, both operational and test, both against UKMO global model, against KNMI HIRLAM, in between ACs, and against radiosonde ZTDs where possible. A set of "supersites", that all AC should process are used for inter comparison.

2D IWV map animated sequences for use by nowcasting systems are made by KNMI and UKMO in collaboration, and showed via the homepage system. The conversion from ZTD to IWV requires access to auxiliary data. The conversion is based on pressure and temperature from the most nearby SYNOP sites in the KNMI database.

The GNSS data processing is quite complex, it requires GNSS geodetic expertise to set it up. Auxiliary data are needed for the processing, including information about the orbits of the GNSS satellites, in some cases also data about the clock errors on the GNSS satellites are needed. Whereas the GNSS observing system itself is extremely stable, being based on time measurements, there is by the nature of the overall processing system a risk of correlated errors when something goes wrong. The NRT production makes access to information of sufficient quality time critical, and sometimes errors occur. Correlated errors are dangerous to data assimilation systems, and as a consequence active quality control (AQC) is being set up, in order to detect if an AC delivers data with correlated errors early enough to guard against their use ahead of data assimilation (DA). The AQC is based on inter-comparison of ZTDs from all GNSS sites processed by at least 4 ACs. This amounts to more than 100 sites in practice, much more than the order 10 supersites. The algorithms and initial setup of the AQC is made at DMI. The results of the AQC will be written to a flagging file that can be used in connection with DA.

To support (some of) the ACs research in GNSS data processing, E-GVAP makes radiosonde observations available to our geodetic colleagues (extracted at DMI, made available at UKMO ftp-server) and in certain cases NWP field data upon request.

1.2.3. IT Infrastructure

E-GVAP has no physical assets.

The E-GVAP setup, as currently configured, relies on the particular resources available to the Partners in the E-GVAP team at each of the three institutions, primarily computer hardware and software and databases. Most of the access to the equipment has been provided as in-kind contribution by the team institutions. The parts essential for distribution and monitoring of the data run on computers considered "operational" at the host institutions (safeguarded against various types of failures to individual computers, power, etc.). In particular this is the case for the part of the computer system at UK Met Office, which receives and delivers to users all the GNSS delay data within the Programme.

1.2.4. Achievements of the present phase

In the present phase geographical coverage has been much improved. In many regions already covered the spatial density of observations has been improved. Quality monitoring has been improved, both at the EUCOS QMP and the more detailed E-GVAP internal monitoring.

Sub-hourly distribution of data derived sub-hourly has started.

1.2.5. Still to be done

AQC is not finalized. However, it is expected to be running operationally before end of E-GVAP-III.

Sub hourly data processing started long ago, more recently sub-hourly data distribution has begun. More GNSS sites shall be included in sub-hourly processing, it will take several years because of limitations in the access rate to some of the "raw" GNSS data.

1.2.6. Budget

REVENUE:				k€
R1	Contributions from participating members			119
	Total revenue			119
COST:				
C1	Management	Salary	20	
		Travel	25	
		Management organization		
		Total		45
C2	Infrastructure			
C3	R&Development (software, instruments etc.)			18.5
C4	Monitoring, validation, and quality control			55.5
	Total cost:			**119**

Almost all non travel money is spent on salaries to E-GVAP staff. The high travel budget is because E-GVAP re-imburses the expert team members participation in the annual meeting. This is a necessary favor to the ACs, which provide E-GVAP with GNSS delay data for free, and essential in sharing best practices among the ACs.

1.3. Emerging issues

1.3.1. As concerns observations and data formats

A 4 year EU COST Action: GNSS4SWEC – Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate has just finished. The final report is now being made. E-GVAP personnel were heavily involved in the creation and running of GNSS4SWEC (outside E-GVAP hours). The action helped enlarge E-GVAP coverage. The action has included work

on estimation of STDs, which provide information about the local asymmetry of the water vapour field, as well as on enabling assimilation of STDs in NWP. From an observing programme perspective, distribution of STDs is not very different from handling of ZTDs. For that reason it is considered relatively straight forward to include distribution of STDs as an operational component of E-GVAP IV. In practice the movement toward use of STDs instead of ZTDs will be very gradual, as both production and usage of STDs requires tools that are not widespread today, but can be expected to be so towards the end of E-GVAP-IV. Use of STDs and ZTD gradients, instead of just ZTD, is expected to be of benefit in particular high resolution NWP. It is noted that during the same period a similar breakthrough is not expected for 3D water vapour estimation based on tomography, for that reason it is not suggested to include it as an operational component in the 2019-23 phase.

The data formats currently used in E-GVAP are prepared for distribution of ZTD gradients and STDs. However, they need to be revised to properly handle large amounts of STD data, as well as the BUFR format also being able to handle STDs at low elevations. Work on this has begun, but finishing the BUFR update and getting it accepted at WMO will take place in the next phase.

1.3.2. As concerns third parties

New ACs are expected to join E-GVAP in the next phase, thereby increasing geographical coverage. The existing MoU between EUMETNET and EUREF continues in the next phase.

Access to more NWP data by the geodetic people data is expected to become important in E-GVAP-IV, but very simple to provide. It is important to the meteorological – geodetic collaboration.

1.3.3. As concerns users' needs

The requirements in part 3.1, by the EUCOS performance standards, and not the least the answers to the E-GVAP specific questionnaire done in August-September 2017 (see ref. docs.) demonstrate an increased need for fast access to E-GVAP data. This has been reflected in the programme requirements for phase IV. In addition several users are preparing for the use of STDs, wherefore distribution of STDs has become a mandatory part of the E-GVAP requirements. GNSS4SWEC demonstrated the feasibility.

1.3.4. Corresponding strategic challenges (e.g. ESIG)

1.4. Requirements including tables of M U and N

For the future, the E -GVAP Programme shall continue along the following lines:

1. Continue the E-GVAP observation network, with a focus on improvement of GNSS data availability, quality, and timeliness with the aim to improve European coverage with data that meets the requirements set by member's NWP models and nowcasting
2. Enabling and starting operational distribution and monitoring of STDs, on top of the continued distribution of ZTDs. ZTD is expected to remain the backbone of E-GVAP in phase IV.
3. Monitoring and helping the research on the next generation processing and use of GNSS data in meteorology, in order to obtain more detailed atmospheric information from the same basic measurements, by collaboration with European institutes and programmes involved in ground-based GNSS meteorology R&D.

In the subsections below the requirements are divided into Mandatory (M), Really useful (U) and Nice to have (N).

1.4.1. Programme management

Objectives: Management, including cooperation within EUMETNET and liaison with geodesic institutions.

Programme-specific skills needed for the PM and Project team

In order to liaise with “geodesy” the team must include personnel with experience of working with the European and national GNSS geodesy communites. The Programme team needs insight into both usage (assimilation and now-casting) and production (GNSS data processing) of ground based GNSS data, and a good understanding of the E-GVAP setup and meteorological data formats and data distribution. In order to perform the quality control, access to all delay data delivered to E-GVAP, including the test data stream, is necessary. To assist members in using E-GVAP data, and in monitoring and aiding “next generation” GNSS meteorology, the team should include personel who are active in GNSS assimilation and research.

Resources to be provided by the incoming Coordinating Member

The computer resources currently provided at DMI and KNMI, and part of those provided at UKMO, are provided as in kind contributions.

Resources to be provided by the Participants

The members of E-GVAP-IV will be required to establish or further enhance collaboration with national geodetic institutions, with the purpose of obtaining either GNSS based estimates of zenith total delays (ZTDs), or "raw" GNSS data that can be processed to estimate ZTDs at an existing analysis center (AC) with sufficient capacity. The E-GVAP team shall continue to guide on this.

Expert teams and meeting schedule E-GVAP has two experts teams (see ToR), one on GNSS data processing and on data usage. They meet annually at a common meeting to which also the members are invited. The meetings are an essential part of furthering the collaboration between geodesy and meteorology which is vital to E-GVAP performance. The presentations from the meetings provide material on best practices regarding both GNSS data processing and usage.

A MoU exist between EUMETNET and EUREF about exchange of data on the European level, about conditions of usage and distribution, and encouraging collaboration on the national level (see ref. docs). On the national level it is the responsibility of the members to establish collaboration with the geodetic side. In some cases these are formulated as national MoUs. Both of the above types of agreements need no transfer or renewal due to a change in phase of E-GVAP. If necessary, the PM is to help members in establishing collaboration on the national level.

Target no	Requirements	Rate
1	Formalisation of contacts to Observation Programme and EUMETNET Secretariat, by March 2019. Establishment of contacts to geodetic institutions, Setup up of expert teams, by June 2019. Coordinate with STAC a succession plan for the Programme, by autumn 2019.	M
2	Close collaboration with Obs. PRG and EUMETNET Secretariat	M
3	Annual expert teams and members meeting. Periodic reports and expert team meeting presentations.	M
4	Ensure continuation of the established, fruitful close collaboration with the geodetic community.	M
5	Work to further improvement of the portability of the infrastructure.	M
6	Work towards INSPIRE compliant data production chains and INSPIRE compliant data itself.	M
7	Help draft proposal of requirements phase V of E-GVAP. By end 2022.	M

Method statements to be addressed by bidders:

** management team : who, with which experience, in charge of what?*

** exchanges with third parties, including the part of national focal points*

** main milestones if required (e.g. if new team)*

** How will you develop relationships with GNSS data providers and the geodetic institutions?*

1.4.2. Maintenance of operational services

OBJECTIVES Continuous running of observing programme for distribution and quality monitoring of GNSS based ZTD and IWV estimates.

Quality plan and quality measures, performance metrics (definition of success) (for both "Maintenance of operational service" and "Improvement of operational service")

The success of the Programme relies on its ability to deliver GNSS delay estimates, with the quality, timeliness, and geographical coverage needed by end users at the member institutions. Those are expressed in the EUCOS performance standards, section 3.1 of this document, in the compiled E-GVAP user questionnaire and timeliness, and in the E-GVAP product requirements document (see ref. docs.).

Current threshold/breakthrough/goal, made for regional and global NWP are that GNSS delay data is available for assimilation within 120/90/60 min of their valid time, and that the standard deviation of the GNSS ZTD errors is less than 15/10/5 mm (see the EUCOS requirement docs). Standard deviation is estimated by comparison to NWP and radiosonde, which, however, have errors of their own. Comparisons are also made between NRT GNSS ZTDs and ZTD derived from post processing, and ZTD derived by statistical combination of ZTDs from different ACs at the same site, in order to assess the quality of the NRT processing.

Local NWP with rapid updates requires improved timeliness. According to the user questionnaire with a maximum age of 15 min at one member, 40-45 min at the next-most demanding. Optimal goal is maximum age 5 min, whereas requirements to precision are unaltered from global and regional NWP.

In order not to reduce coverage too much when improving timeliness (as access to some GNSS site data will remain hourly for a while, outside control of E-GVAP and the ACs), it is foreseen that in E-GVAP IV many ACs will need to do both sub-hourly and hourly GNSS ZTD estimation. The timeliness and precision criteria for sub-hourly processing shall correspond to the criteria for local NWP and nowcasting. The timeliness and precision criteria of hourly processing shall correspond to the needs of regional and global NWP. In order to monitor and urge the conversion to more sub-hourly processing a measure of sub-hourly coverage has to be introduced. For this it is proposed to use the fraction of European GNSS sites for which sub-hourly data are available.

The precision criteria GNSS ZTD against NWP ZTD is in all cases std. dev. < 15 mm. Regarding timeliness the criteria are in the table below.

Level	Hourly ZTD estimation	Percentage	Sub-hourly ZTD estimation	Percentage
Threshold	120 min	-	30 min	90 %
Target	90 min	90 %	15 min	75 %
Goal	60 min	75 %	5 min	-

Where the percentages are the values to be used in the EUCOS QMP monitoring. The E-GVAP own timeliness monitoring shall be updated to a resolution of 5 min, to monitor timeliness in greater detail.

Target no	Requirements	Rate
8	Ensure the operational E-GVAP system is maintained and continues to run.	M
9	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/STD data.	M
10	Ensure running of sufficient monitoring and validation tools.	M
11	Ensure running of AQC, to guard against use of data in case of sub-system (AC) widespread errors in DA.	M
12	Ensure provision of meteorological support for expansion of GNSS observing networks, including provision of meteorological data as agreed in the EUREF EUMETNET MoU.	M
13	Update Product Requirements Document as requested by expert team on data usage, members and Obs SET.	M
14	Continue the construction of IWV animations for use in nowcasting.	M
15	Coordinate the meteorological exploitation of national sources of GNSS data by helping the NMSes achieve their cost-effectiveness goals.	M

Method statements for bidders to address:

** Describe the setup to be used for data upload and distribution including it's robustness against computer failure.*

** Describe the setup to be used for E-GVAP quality and timeliness monitoring and validation, and for provision of validation statistics to the EUCOS QMP.*

** Describe setup of active quality control.*

1.4.3. Improvement of operational services

Objectives: Enhancement of ZTD production, with special focus on improved timeliness, expanding network in data sparse/empty regions, and delivery of IWV also in grib format. Provision of global GNSS ZTDs.

Based on the questionnaire on timeliness (see ref. docs.), moving to sub-hourly processing the timeliness threshold for sub-hourly data shall be 15 min, with 5 min as the optimal goal. It is necessary to realize that we will not in the short term get access to all "raw" data quickly enough to enable sub-hourly processing of all data. All ACs shall be encouraged to do sub-hourly processing. ACs that do not have sub-hourly access to all raw GNSS data shall be encouraged to run two lines of processing, computer resources permitting. A sub-hourly line with the data available, and an hourly line with the full set of GNSS sites. The E-GVAP timeliness monitoring shall be upgraded to usage of 5 min bins.

The Product Requirements Documents shall be kept up to data, by asking the users, e.g. in the form questionnaires and meetings, such as the Obs-SET meeting and the E-GVAP expert teams meeting.

To ease use of IWV in operational nowcasting IWV shall be made available in grib format, enabling members to visualise IWV evolution using their own visualisation software. Software enabling ZTD to IWV conversion to be made available to members – will improve IWV quality, as E-GVAP does not have high resolution SYNOP data from all member states.

See previous section regarding quality monitoring metrics.

Target no	Requirements	Rate
16	Ensure operational migration to sub hourly processing and data distribution.	M
17	Improve resolution of timeliness monitoring to 5 min bins, by end 2019.	M
18	Attempt access to global data, to help members running global models	U
19	Provide IWV in grib format, by end 2019	M
20	ZTD to IWV converting software and instructions to members, by end 2020	N
21	Ensure to report on the progress of ZTD/IWV data assimilation research and promote the use of GNSS water vapour measurements in operational meteorology.	M
22	In collaboration with the geodetic community, and possibly EUMETSAT, attempt to improve quality, security and timeliness of access to so-called ultra rapid "satellite orbit and clock error estimates". This will enable more ACs to do PPP data processing, which speeds up the processing and eases estimation of slant delays.	U

Method statements to be addressed by bidders:

including the continuation of on-going changes (with milestones)

improvements may concern :

reference to new EUCOS performance standards (breakthrough, goal)

technical improvements as concerns transmission and concentration

technical improvements as concerns observation

negotiation with third parties to get more data or cheaper data or more fundings

development of new observation products / improvement of current ones

-> list of tasks

mandatory or really useful

to be discussed : which level of requirement on objectives and milestones ?

1.4.4. New activities

Objectives: To enable distribution of STDs. To develop quality monitoring of STDs, and finalize formats to handle STDs. Gradually expand STD estimation to more ACs. Monitor and support development of "next generation" ground-based GNSS meteorology, in order to inform members about progress in ground-based GNSS meteorology and advance the field.

This shall include monitoring progress in (and support, resources permitting, of):

a) Production and usage of ZTD gradients and STDs
b) True real-time ZTD and STD estimation
c) Use of IWV and ZTD in nowcasting.
d) Production and usage of 3D water vapour fields derived by tomographic inversion of GNSS based STDs
e) Experimental estimation and validation of ZTDs from GNSS observations from ships.
f) Conversion of InSAR delay measurements to high res. ZTD maps by use of ground-based GNSS derived ZTDs.

Target no	Requirements	Rate
23	Enable operational distribution and timeliness monitoring of STDs. by year 1.	M
24	Enable quality monitoring of STD data, by year 3.	M
25	Encourage more ACs to do STD estimation.	U
26	If true real-time ZTD and STD estimation matures, attempt to include among E-GVAP products.	U
27	If/when NRT 3D water vapour estimation matures, attempt to include among E-GVAP products.	N
28	Ensure monitoring and reporting on 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.	N
29	Experimental estimation and validation of ZTDs from GNSS observations from ships	N
30	Conversion of InSAR delay measurements to high res. ZTD maps by use of ground-based GNSS derived ZTDs	N

Method statements to be addressed by bidders
**How do you plan to quality control STDs?*
**How will you engage in development and usage of "next generation" ground-based GNSS meteorological products?*

1.5. Benefits to users/members

E-GVAP ZTDs enhance skill of members NWP when assimilated. See for example the recent compilation in Guerova, Jones, Dick, de Haan, Pottiaux, Bock, Pacione, Elgered, Vedel and Bender, *Review of the state of the art and future prospects of the ground-based GNSS meteorology in Europe,* Atm. Meas. Techn., 2016, vol. 9, p 5385-5406. It also showed that we are far from saturation – more ZTDs within the regions covered today is expected to further enhance skill.

E-GVAP expert team meetings provide material demonstrating how different expert users utilise the data in their NWP.

Use of GNSS IWV can benefit nowcasting. So far this has only been demonstrated in R&D, not in operational forecasting. In the next phase IWV shall be made available also as grib files (numbers as opposed to grafic), which will enable members to easily include E-GVAP IWV in the visualisation tools used by their forecasters.

E-GVAP data can be used to validate or enhance other measurements.

- Satellite based IWV, ZWD and ZTD/STD. Some satellites measure radiances in channels related to water vapour, can be validated against E-GVAP IWV. Satellites doing InSAR measurements are sensitive to ZTD/STD. They can be validated against E-GVAP data, but more importantly E-GVAP data can in the longer term future be used to convert InSAR delay measurements into very high spatial resolution ZTD maps.
- Radiosonde humidity verification (detection of mal-functioning humidity sensor by comparison of radiosonde and GNSS ZTDs or IWVs.)

Budget in the next phase

The E-GVAP budget is mainly spent on salaries and travel. In phase I the budget was 129,000 euros, in both phase II and III the budget has been 119,000 euros. An increase related to inflation is suggested.

Since the data distributed in E-GVAP are provided free of charge by the ACs, enhancements in the E-GVAP products, or new products, do not directly transfer into increased costs.

If STD production and distribution becomes very widespread it may require access to additional computer resources for quality control and provision of ftp-access.

1.6. Acronyms

AC	Analysis center (doing ZTD, possibly gradient and STD, estimation using GNSS data).
AQC	Active quality control (detection of AC problems by inter comparsion of ZTDs from several ACs.)
BeiDou	The Chinese GNSS system (under gradual implementation).
DA	Data assimilation
EUREF	EUROPEAN TERRESTRIAL REFERENCE SYSTEM 89. (European geodetic collaboration, somewhat like EUMETNET. Responsible for maintaining the European component of the global geodetic reference system.)
Galileo	The European GNSS system (under gradual implementation).
GLONASS	The Russian (former Soviet) GNSS system
GNSS	Global navigation system satellite, generic term.
GNSS4SWEC	Advanced Global Navigation Satellite System tropospheric products for monitoring servere weather events and climate. EU COST Action ES1206
GPS	The US GNSS system.
IWV	Integrated water vapour.
NRT	Near real-time
PPP	Precise point positioning, as opposed to standard “network solution”
STD	Slant total delay (by some called slant tropospheric delay)
ZTD	Zenith total delay (by some called zenith tropospheric delay)
ZTD gradients	North-South and East-West gradients of ZTD.
ZWD	Zenith wet delay.

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