EUMETNET
European Meteorological Services Network

E-GVAP

The EIG EUMETNET GNSS Water Vapour Programm

EUREF annual symposium 2019, Tallinn

Compiled by Henrik Vedel

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- **EUMETNET is the meteorological version of EUREF.**

- **E-GVAP was started in order to provide GNSS derived estimates of atmospheric delays and integrated water vapour for usage in operational meteorology.**

- **This is done in close collaboration between geodetic and meteorological institutions. The setup of E-GVAP followed common R&D projects on GNSS meteorology.**

- **A MoU between EUREF and EUMETNET encouraging and governing the collaboration was made many years ago.**

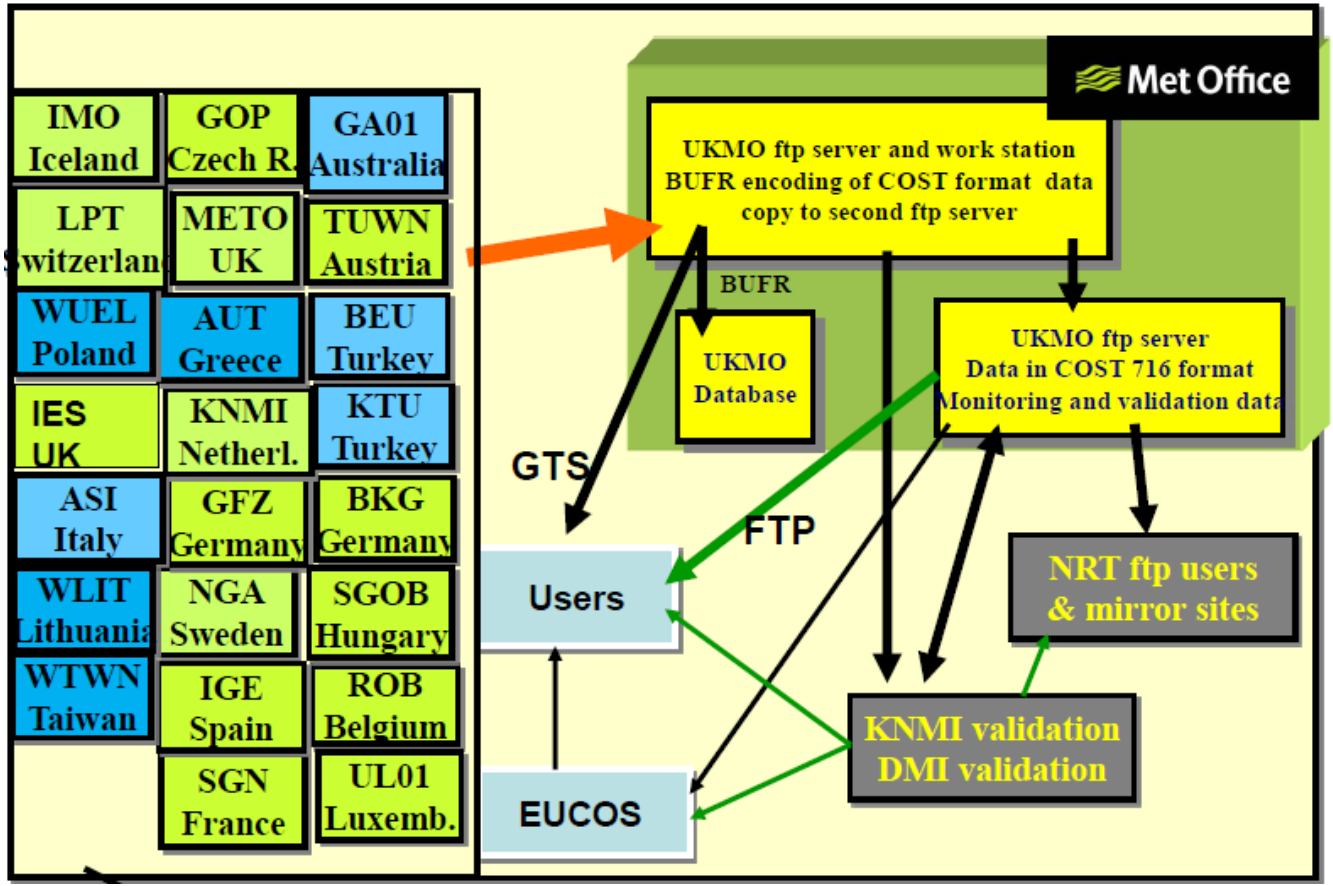
E-GVAP members at start of 2019

1. DHMZ (Croatia)
2. DMI (Denmark)
3. FMI (Finland)
4. OMSZ (Hungary)
5. IMO (Iceland)
6. Met Eireann (Rep. Ireland)
7. KNMI (Netherlands)
8. Meteo France
9. MeteoLux (Luxemburg)
10. MeteoSwiss
11. met.no (Norway)
12. IPMA (Portugal)
13. RMHMS (Serbia)
14. RMI (Belgium)
15. SMHU (Slovak Rep.)
16. AEMET (Spain)
17. SMHI (Sweden)
18. UK Met Office
19. ZAMG (Austria)
20. MOA (Cyprus)
21. DWD (Germany)
22. ARSO (Slovenia)
23. Latvia

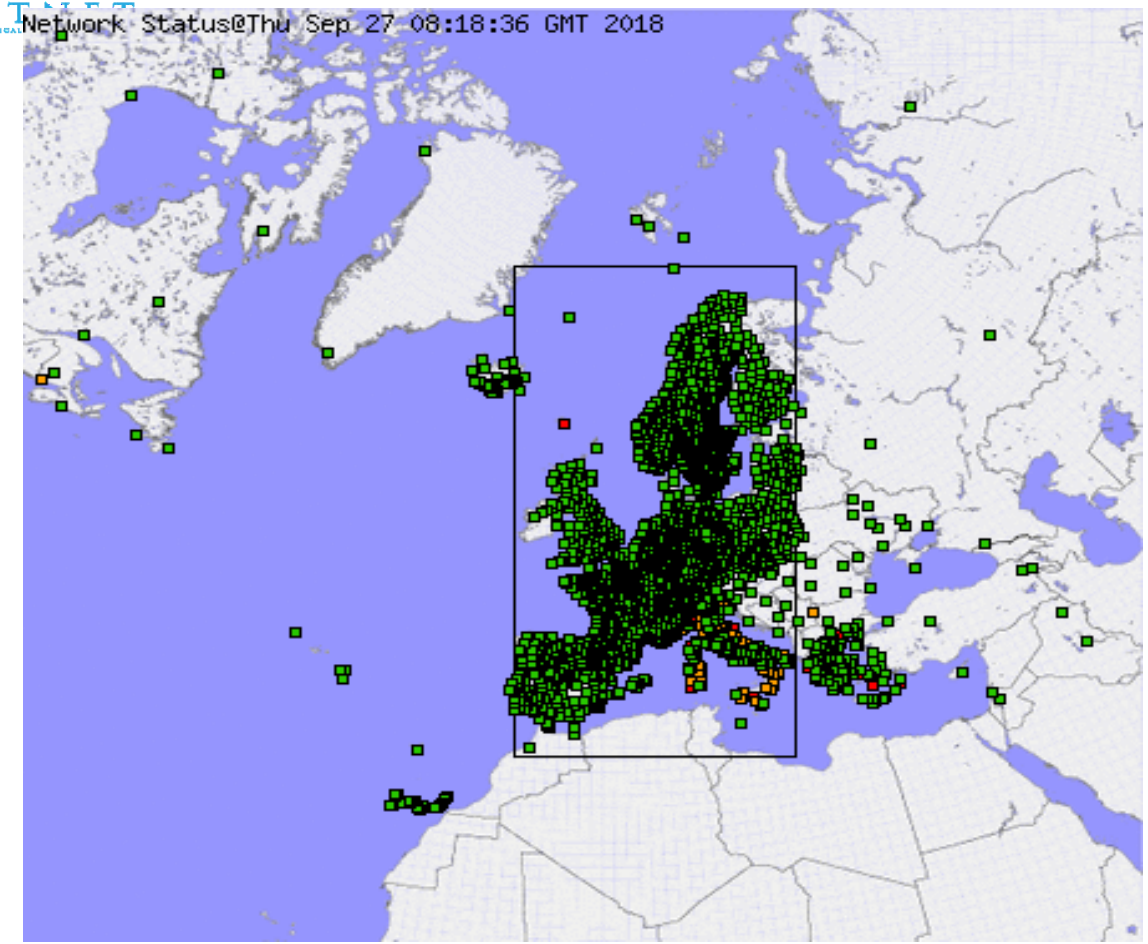
GNSS Analysis centers (ACs), start of 2019.

AC	Institution
AUT	Aristotle Univ. of Thessaloniki Analysis Center, Greee.
ASI	e-geos/Telespazio, Italy
BEU	Zonguldak University of Technology, Turkey
BKG	Federal Agency for Cartography and geodesy, Germany
CONH	US data, only available by bilateral agreed ftp download.
GA01	Geoscience Australia
GFZ	Helmholz Centre Potsdam, GFZ German Res. Cen. f Geosciences
GOPE	Geodectic Observatory Pecny, Czech Republic
IES	Inst. of Eng., Surv. And Space Geodesy, Univ of Nottingham, UK
IGE	Instituto Geografica National, Spain
IMO	Icelandic Met Office
KNMI	Royal Meteorological Institute of the Netherlands
KTU	Karadeniz Technival Univ. Analsis Center, Turkey
LPT	SwissTopo, Switzerland
METO	UK Met Office
NGA1	Lantmateriet (Swedish Mapping, Cadestre and Land Reg. Authority), Gavle, Sweden
ROB	Royal Observatory of Belgium
SGN	Institut Geographique National, France
SGOB	Satellite Geod. Obs, IGCRS + Technical Univ. Budapest, Hungary
TUWN	Technical University Vienna, Austria
UL01	University of Luxembourg, Fac. Of Science and Communication
WUEL	Wroclaw University + Inst. Of Geodesy and Geoinformatics, Poland
WLIT	Lithuania, setup and run by WUEL
WTWN	Taiwan, setup by WUEL, monitored and run in Taiwan. New

NRT GNSS ZTD data flow



Coverage



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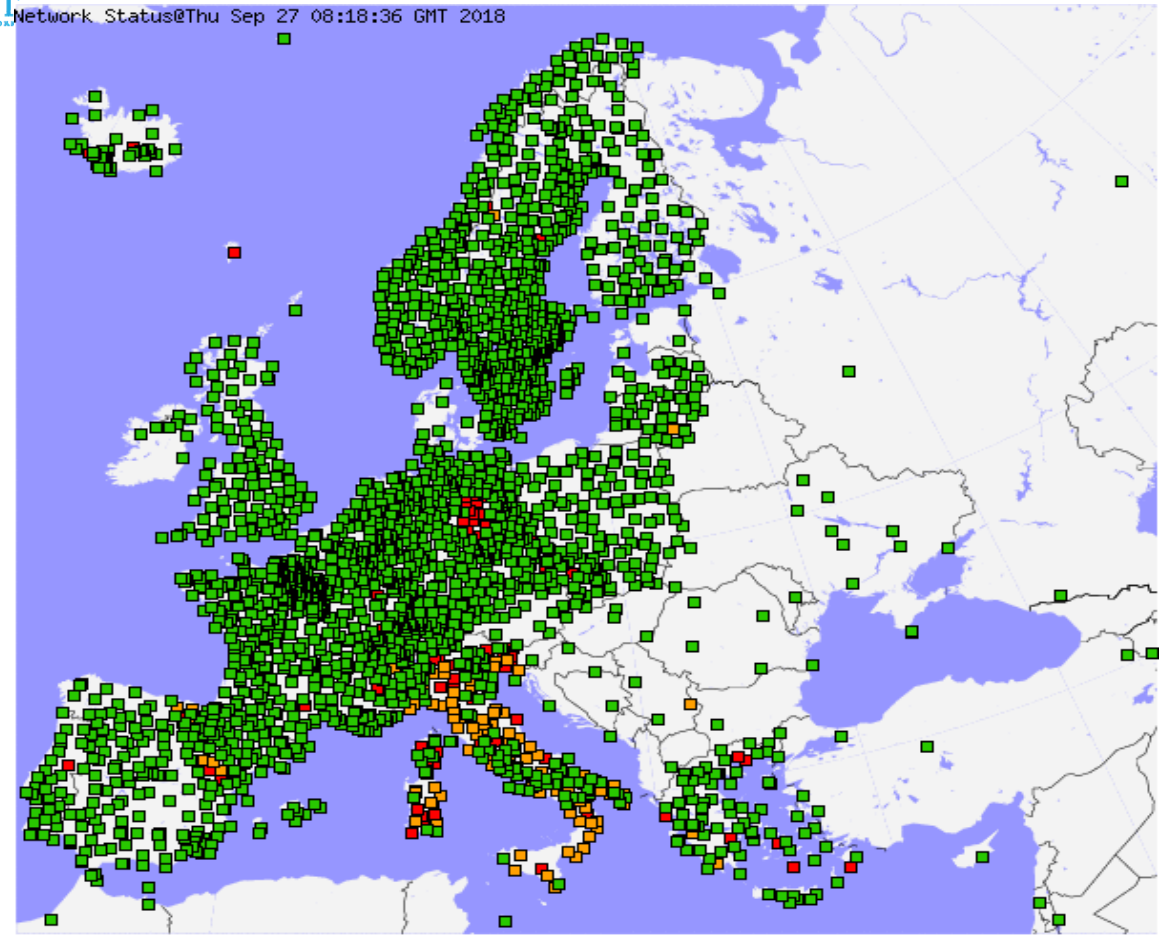

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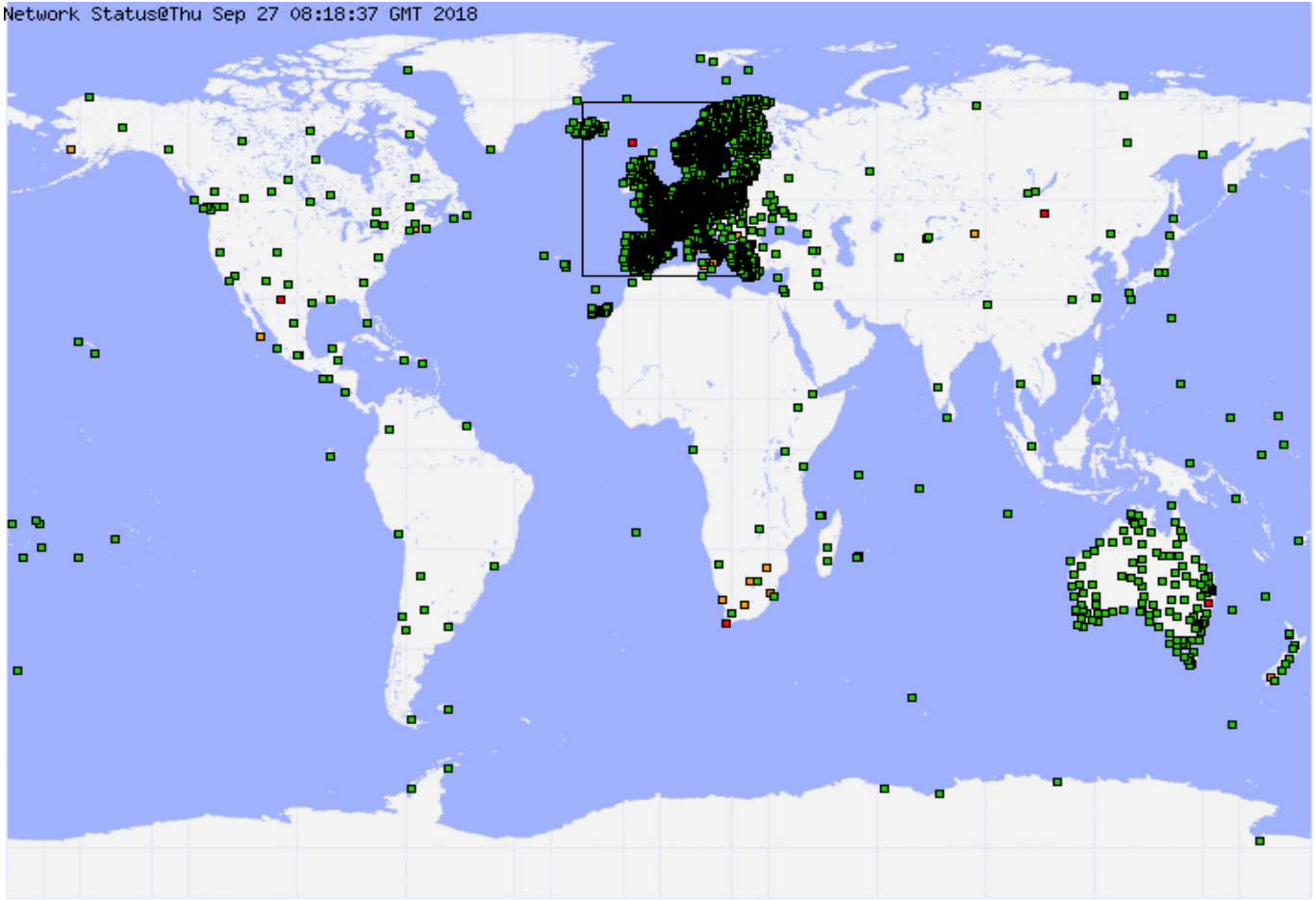
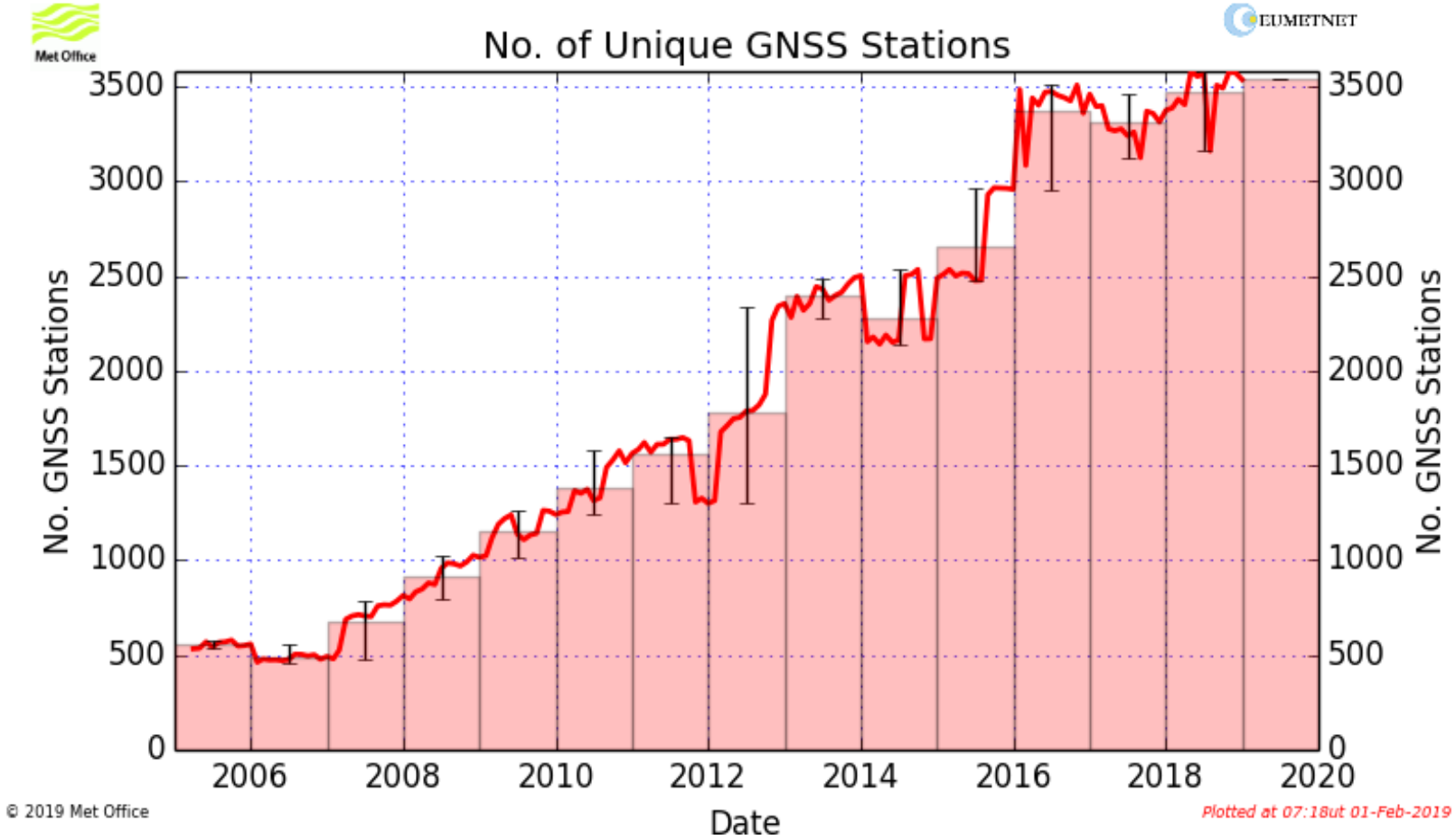
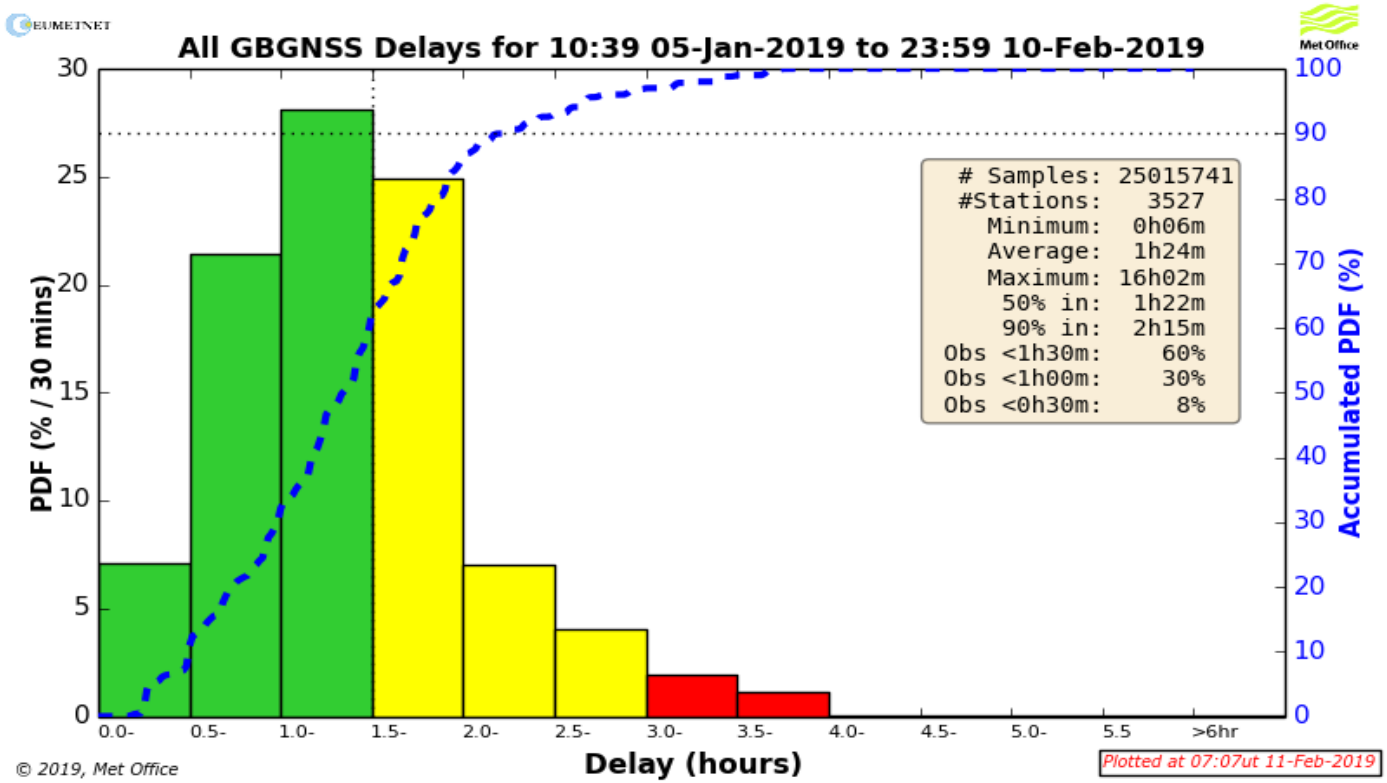


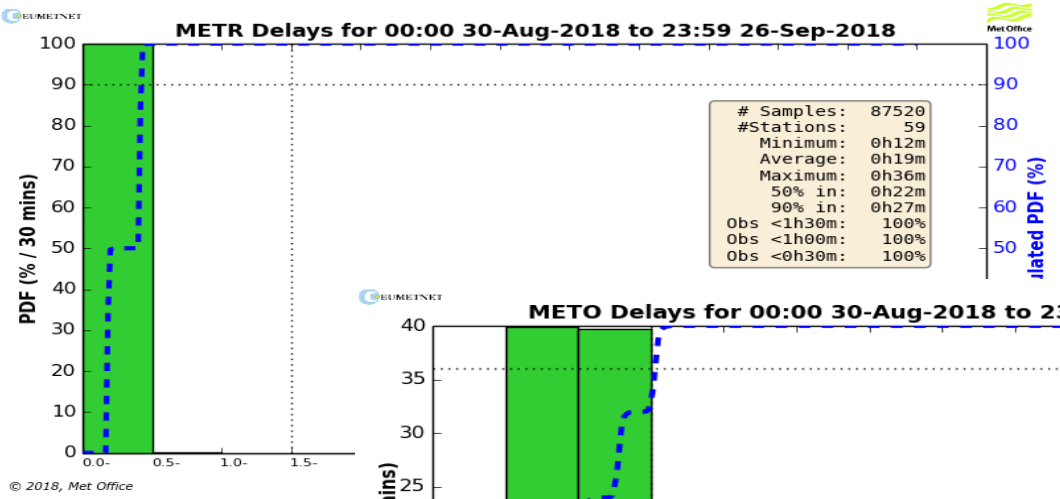

Met Office
EUMETNET
No. of Unique GNSS Stations
No. GNSS Stations
Date
0
500
1000
1500
2000
2500
3000
3500
2006
2008
2010
2012
2014
2016
2018
2020
© 2019 Met Office
Plotted at 07:18ut 01-Feb-2019

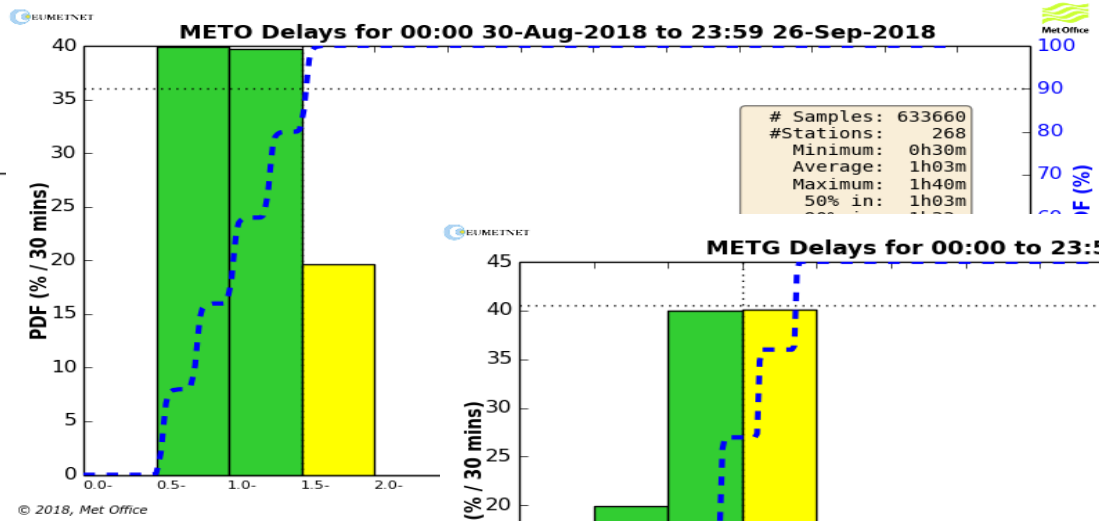
Timeliness (all data)

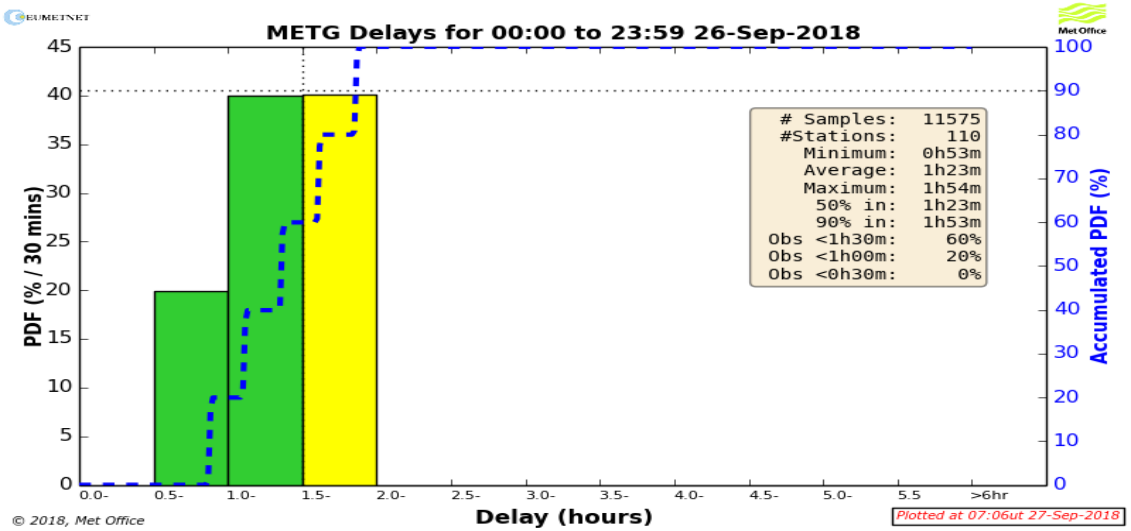


- **E-GVAP just started in a new phase, 2019 – 2023.**

- **The main E-GVAP product is expected to remain provision of ZTD (and associated IWV).**
- **Enhanced coverage, both in Europe and beyond is still very important.**
- **Due to developments in operational NWP (numerical weather prediction), with higher spatial resolution (1 to 2.5 km) and more frequent cycling (hourly), there will be specific focus on:**
  - **Improved timeliness**
  - **Enhanced information content through production and assimilation of ZTD gradients and STDs.**
- **This is expected to benefit prediction of high impact, convective phenomena, such as thunderstorms and associated cloud bursts.**
- **Assimilation tools ZTD gradients and STDs are being made.**


METR Delays for 00:00 30-Aug-2018 to 23:59 26-Sep-2018
Samples: 87520
#Stations: 59
Minimum: 0h12m
Average: 0h19m
Maximum: 0h36m
50% in: 0h22m
90% in: 0h27m
Obs <1h30m: 100%
Obs <1h00m: 100%
Obs <0h30m: 100%
PDF (% / 30 mins)
lated PDF (%)
© 2018, Met Office


METO Delays for 00:00 30-Aug-2018 to 23:59 26-Sep-2018
Samples: 633660
#Stations: 268
Minimum: 0h30m
Average: 1h03m
Maximum: 1h40m
50% in: 1h03m
PDF (% / 30 mins)
© 2018, Met Office


METG Delays for 00:00 to 23:59 26-Sep-2018
Samples: 11575
#Stations: 110
Minimum: 0h53m
Average: 1h23m
Maximum: 1h54m
50% in: 1h23m
90% in: 1h53m
Obs <1h30m: 60%
Obs <1h00m: 20%
Obs <0h30m: 0%
PDF (% / 30 mins)
Accumulated PDF (%)
Delay (hours)
© 2018, Met Office
Plotted at 07:06ut 27-Sep-2018

Timeliness criteria from new E-GVAP requirements

An essential aim in the next phase is improved timeliness, to fulfill requirements from local, rapid refresh NWP and nowcasting (see the approved E-GVAP requirements for details). The criteria to be used for timeliness are,

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	-

Table 1, timeliness criteria for the ZTD timeliness monitoring.

This discriminates be between two types of products, ZTDs produced by *hourly* versus *sub-hourly* processing. Remember, they also have different quality, but both in general meet the 15 mm std. dev. against NWP criteria.

In the next phase the time resolution of the timeliness monitoring will be enhanced to 5 min.

Metadata – Naming of sites

- For the moment the 4 character ”geodetic” name for GNSS sites is used in meteorology.
- In general meteorology used a 5 digit number for observation sites, this is being replaced by WIGOS identifiers, which are very, very long numbers. Possibly we will have to provide every GNSS site with a WIGOS is, before furthering the data within meteorology.
- Apparently naming is also becoming an issue in geodesy.

- All data uploaded to E-GVAP are checked for name clashes regarding the 4 character name. A list of ”occupied” and ”reserved” names is updated every day. This can easily be made available.
- This could be enhanced to include new geodetic name types.

bias [mm]	std. dev. [mm]	#site	AC	bias [mm]	std. dev. [mm]	#site	AC
-0.3	7.7	609	ASIC	0.3	9.8	113	METG
2.6	15.0	24	ASIR	-0.7	7.9	234	METO
-3.9	12.9	13	ASIS	-0.6	11.3	40	METR
-0.8	8.5	346	ASI_	2.9	9.4	110	MTGH
6.0	8.1	120	AUT1	0.8	8.4	235	MTRH
1.8	7.1	109	BKGH	-0.5	7.1	644	NGA1
2.0	6.0	98	BKG_	1.7	12.8	375	NGA2
0.7	9.5	452	CONH	3.3	9.2	273	ROBG
4.8	29.2	160	GA01	0.6	13.0	647	ROBH
0.0	6.5	625	GF1G	1.1	8.2	220	ROBQ
0.7	6.4	560	GF1R	0.4	11.9	737	ROBT
6.7	6.1	270	GFZ_	-3.3	8.8	516	SGN1
1.5	5.8	99	GOP1	2.0	9.0	516	SGN2
-0.2	9.2	96	GOPG	8.3	17.4	24	SGNC
-2.1	7.6	208	IES2	4.5	29.3	33	SGNR
2.3	20.8	343	IGE2	-1.5	9.2	444	SGN_
0.8	6.9	75	IM01	-3.6	12.4	57	SG01
-1.4	6.9	37	KNM3	2.0	6.9	31	TUWN
-2.3	9.6	28	KNM4	1.3	8.2	7	WLIT
-0.1	15.6	43	LPTX	5.9	13.8	18	WTWN
-0.9	9.8	208	LPT_	4.8	5.9	278	WUEL

Offset statistics per AC&solution

Similar, but for per site and AC.

3.2	11.8	12.2	2296	CHTD-ROBT
-0.9	12.6	12.7	2343	CHTD-SGN1
4.3	9.4	10.3	585	CHTD-SGN2
0.1	12.2	12.2	2498	CHTD-SGN_
-12.8	11.6	17.2	890	CHTG-ASIC
-5.6	12.6	13.8	2829	CHTG-ROBH
-5.5	13.2	14.4	2820	CHTG-ROBT
-16.0	14.3	21.4	2640	CHTG-SGN1
1.1	12.2	12.2	625	CHTG-SGN2
-7.8	13.9	15.9	2795	CHTG-SGN_
-0.8	30.9	30.9	455	CHTI-GA01
-1.9	7.1	7.4	1804	CHTI-GF1G
0.9	4.2	4.2	28	CHTI-GF1R
5.1	9.2	10.6	1660	CHTI-ROBG
-18.9	16.0	24.8	895	CHTL-ASIC
-17.3	20.0	26.4	1100	CHTL-LPT_
-22.6	21.2	31.0	2654	CHTL-SGN1
-10.3	10.8	14.9	600	CHTL-SGN2
-2.5	20.5	20.7	2790	CHTL-SGN_
4.1	9.6	10.4	2825	CHUM-ASIC
0.6	9.5	9.5	990	CHUM-GOPG
0.7	10.0	10.0	2875	CHUM-METG
4.7	10.1	11.2	2885	CHUM-MTGH
3.4	11.9	12.4	2848	CHUM-ROBG
1.4	6.5	6.7	2900	CHUR-ASIC
1.6	6.9	7.1	2023	CHUR-GF1G
2.4	8.4	8.7	379	CHUR-GF1R
-2.0	6.8	7.1	972	CHUR-GOPG
0.5	6.9	6.9	2904	CHUR-METG
1.6	6.9	7.1	2899	CHUR-MTGH
1.6	7.6	7.8	2901	CHUR-ROBG
6.8	8.2	10.7	2869	CHWK-ROBG
8.6	49.8	50.5	1089	CIEZ-IGE2
22.9	19.1	29.8	2565	CILA-ROBT
25.0	23.2	34.1	195	CILA-SGNR
1.9	9.6	9.8	2275	CIPV-ASI_

2.0	7.2	7.5	135	ZIGK-AUEL
5.4	5.4	7.6	1996	ZIM2-ASIC
4.9	9.4	10.6	2964	ZIM2-ASIR
7.4	6.5	9.8	2020	ZIM2-BKGH
8.0	5.9	9.9	420	ZIM2-BKG_
4.6	5.9	7.5	1864	ZIM2-GF1G
4.8	5.9	7.6	1760	ZIM2-GF1R
4.5	5.7	7.2	2315	ZIM2-IES2
-7.3	10.0	12.3	5162	ZIM2-LPTR
6.8	6.7	9.5	986	ZIM2-LPT_
-0.7	6.0	6.0	2470	ZIM2-METG
4.1	5.9	7.2	2475	ZIM2-METO
6.0	6.3	8.7	2510	ZIM2-ROBG
4.8	6.7	8.3	2510	ZIM2-ROBH
1.7	4.1	4.4	75	ZIM2-ROBQ
4.8	6.8	8.4	2500	ZIM2-ROBT
6.9	11.2	13.2	994	ZIM2-TUWN
6.7	6.6	9.4	986	ZIM3-LPT_
5.8	5.4	7.9	1996	ZIMM-ASIC
5.0	6.5	8.2	1964	ZIMM-ASI_
7.3	6.2	9.6	1020	ZIMM-AUT1
6.3	6.0	8.7	928	ZIMM-BEU1
6.1	5.8	8.4	420	ZIMM-BKG_
4.8	6.0	7.7	1916	ZIMM-GF1G
4.9	6.0	7.8	1872	ZIMM-GF1R
1.9	6.3	6.5	1812	ZIMM-GFZ_
5.6	6.1	8.3	1017	ZIMM-GOP1
5.1	5.7	7.7	2310	ZIMM-IES2
5.2	5.4	7.5	2336	ZIMM-IGE2
6.1	6.2	8.7	1020	ZIMM-IMO1
6.1	6.3	8.7	1020	ZIMM-KTU1
7.0	6.6	9.7	984	ZIMM-LPT_
0.4	6.0	6.0	2470	ZIMM-METO
6.7	6.9	9.6	1964	ZIMM-NGA1
6.2	6.3	8.9	2510	ZIMM-ROBG
4.8	6.9	8.4	2510	ZIMM-ROBH
4.9	7.0	8.5	2500	ZIMM-ROBT
7.2	7.9	10.7	1735	ZIMM-SGN1
2.0	8.3	8.5	1420	ZIMM-SGN_
-4.5	9.2	10.2	1018	ZJX1-CONH
-2.0	13.4	13.6	1008	ZMA1-CONH

3.2	11.8	12.2	2296	CHTD-ROBT
-0.9	12.6	12.7	2343	CHTD-SGN1
4.3	9.4	10.3	585	CHTD-SGN2
0.1	12.2	12.2	2498	CHTD-SGN_
-12.8	11.6	17.2	890	CHTG-ASIC
-5.6	12.6	13.8	2829	CHTG-ROBH
-5.5	13.2	14.4	2820	CHTG-ROBT
-16.0	14.3	21.4	2640	CHTG-SGN1
1.1	12.2	12.2	625	CHTG-SGN2
-7.8	13.9	15.9	2795	CHTG-SGN_
-0.8	30.9	30.9	455	CHTI-GA01
-1.9	7.1	7.4	1804	CHTI-GF1G
0.9	4.2	4.2	28	CHTI-GF1R
5.1	9.2	10.6	1660	CHTI-ROBG
-18.9	16.0	24.8	895	CHTL-ASIC
-17.3	20.0	26.4	1100	CHTL-LPT_
-22.6	21.2	31.0	2654	CHTL-SGN1
-10.3	10.8	14.9	600	CHTL-SGN2
-2.5	20.5	20.7	2790	CHTL-SGN_
4.1	9.6	10.4	2825	CHUM-ASIC
0.6	9.5	9.5	990	CHUM-GOPG
0.7	10.0	10.0	2875	CHUM-METG
4.7	10.1	11.2	2885	CHUM-MTGH
3.4	11.9	12.4	2848	CHUM-ROBG
1.4	6.5	6.7	2900	CHUR-ASIC
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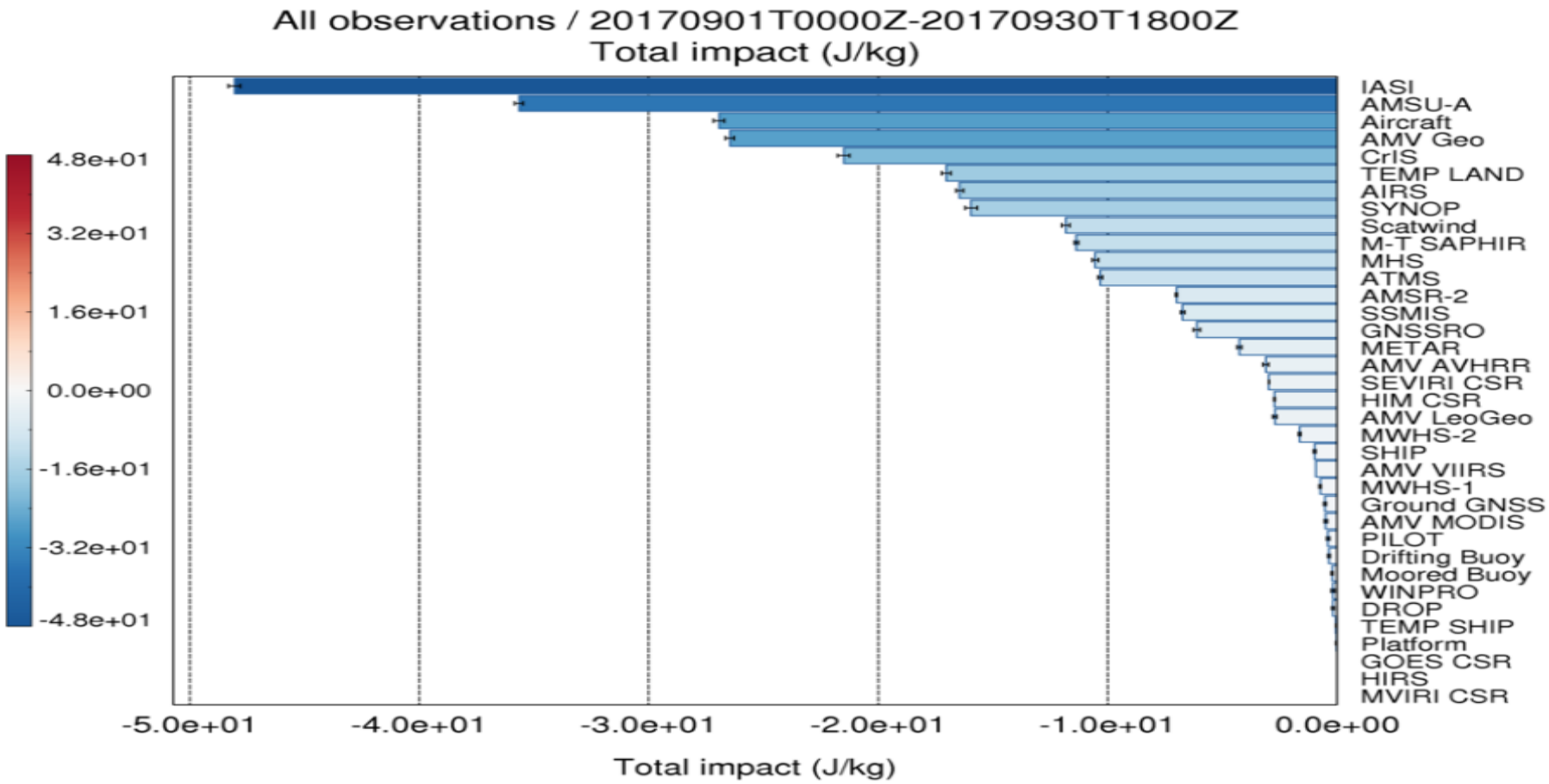
2.4	8.4	8.7	379	CHUR-GF1R
-2.0	6.8	7.1	972	CHUR-GOPG
0.5	6.9	6.9	2904	CHUR-METG
1.6	6.9	7.1	2899	CHUR-MTGH
1.6	7.6	7.8	2901	CHUR-ROBG
6.8	8.2	10.7	2869	CHWK-ROBG
8.6	49.8	50.5	1089	CIEZ-IGE2
22.9	19.1	29.8	2565	CILA-ROBT
25.0	23.2	34.1	195	CILA-SGNR
1.9	9.6	9.8	2275	CIPV-ASI_

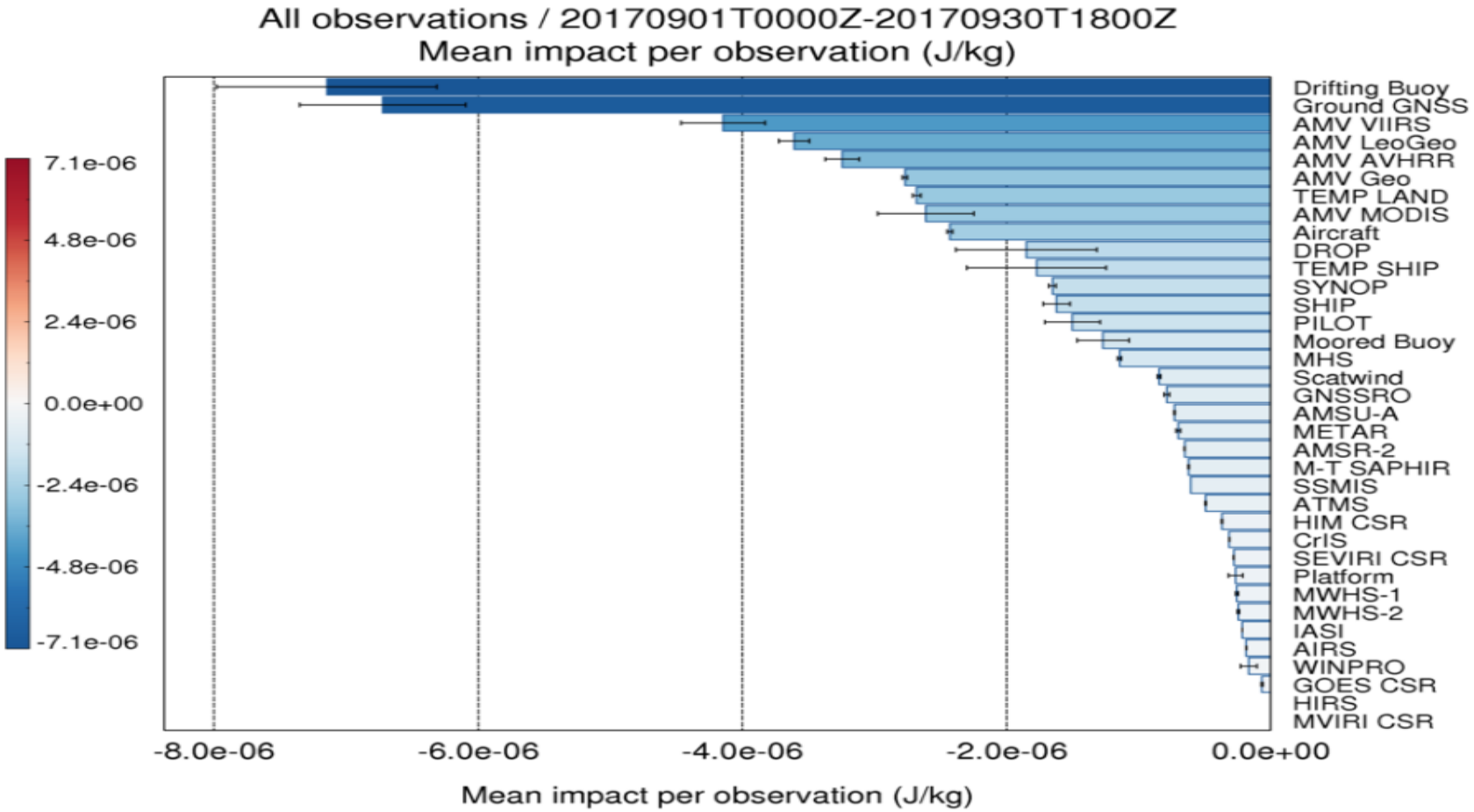
On the usage of GNSS ZTDs

- **Many NWP centers use the GNSS derived ZTDs in their operational models. Both in high resolution regional models and coarse resolution global models.**

- **The GNSS derived ZTDs have a positive impact on the analysis and on forecast skill.**



Impact per observing system in UK Met Office global model. Courtesy Owen Lewis

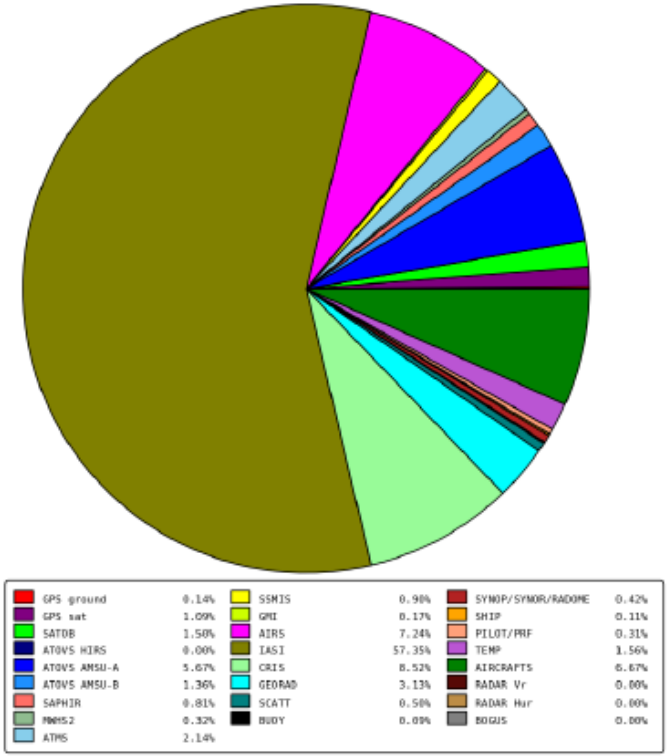


Impact per observation in UK Met Office global model. Courtesy Owen Lewis

GNSS in the operational models – Quick summary

Courtesy Patrick Moll, Meteo France

Proportions des nombres d'observations utilisees par type d'obs
analyses cut-off long - ARPEGE metropole dbl
observations conventionnelles et satellites
cumul du nombre d'observations utilisees sur la periode 2017101900 - 2017101918 : 285582



Part des DFS par type d'obs
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observations conventionnelles et satellites
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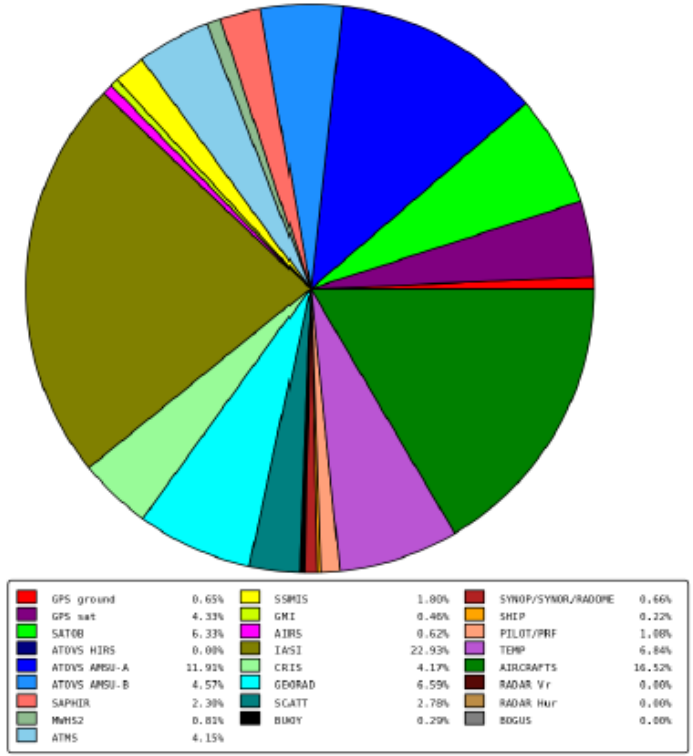
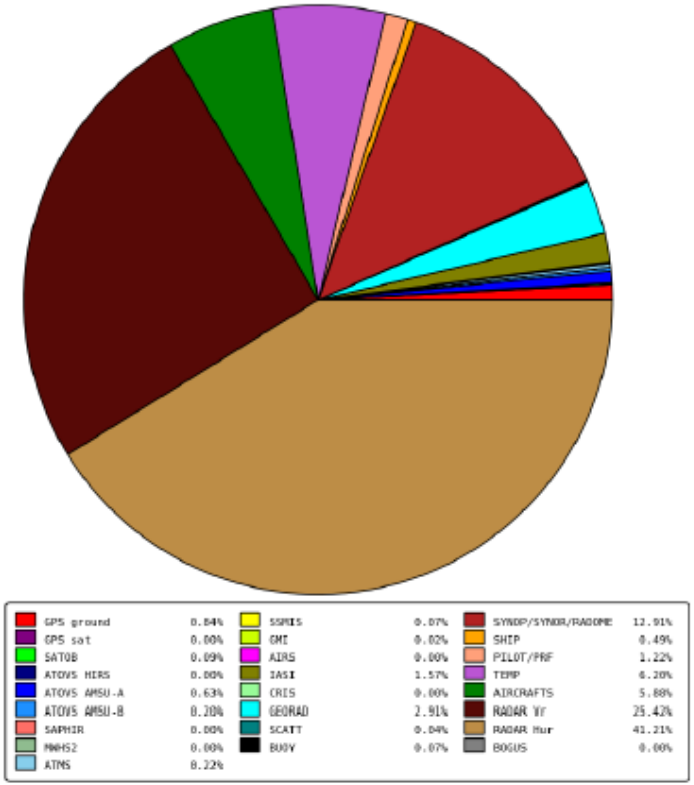


GNSS in the operational models – Quick summary

Courtesy Patrick Moll, Meteo France

Proportions des nombres d'observations utilisees par type d'obs
analyses cut-off AROME - AROME France dbl
observations conventionnelles et satellites
cumul du nombre d'observations utilisees sur la periode 2017110400 - 2017110423 : 12949



Part des DFS par type d'obs
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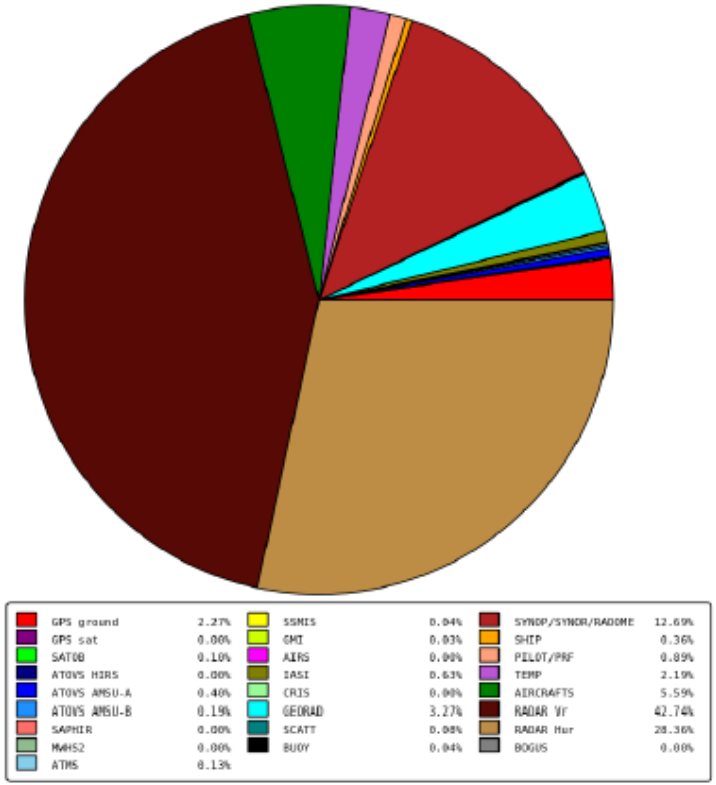
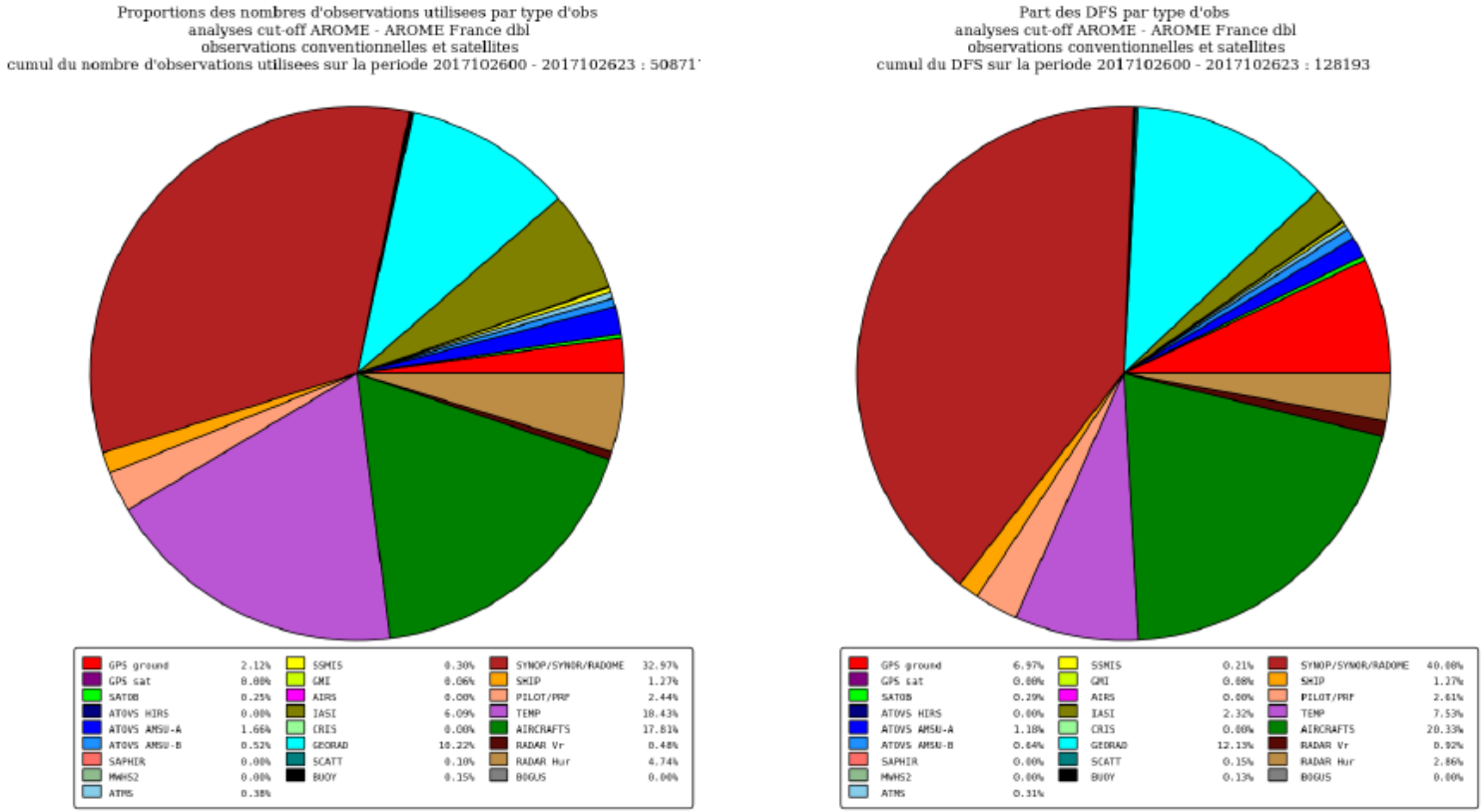


GNSS in the operational models – Quick summary



Courtesy Patrick Moll, Meteo France

Conclusion

- GNSS delays have a positive impact on the skill of weather forecasts.
- The NWP systems are not saturated with GNSS delays

- Higher resolution, rapid update NWP is exptected to enhance the benefit, by use of GNSS ZTD gradients or STDs, as well as from improved timeliness.

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