Warning and Mitigation Technologies for Travelling Ionospheric Disturbances Effects

TechTIDE

D5.1

Data Gathering and methodology

Version 1.0

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Abstract

The aim of this WP5 is to specify the impact of TID in EGNOS, N-RTK and HF systems through statistical correlation of the performance data recorded from system operators and of TID detection results. The analysis will be applied on data for at least one solar cycle.

At a deeper level, this deliverable 5.1 is devoted to collect and organize a long time series of records in order to perform the design of the database and the definition of the strategy for gathering service performances and monitor outputs.

Following this approach, the strategy comprises the following steps:
1. A data set composed of 71 days has been selected according to the events list in WP3 (drivers) and the EGNOS degradation list provided by ESSP. Tests detailed on WP5.3 are going to be executed on this 71 days data set.
2. Definition and design of the database, in such a way it allows an easy and understandable reading of the monitors, drivers and performance of database.
3. Determination of the strategy for measuring the degradation of the EGNOS service at specific locations and even at wide regions.
4. Definition of the strategy for measuring the degradation of the NRTK services.

Document history

Version	Date	Edited by	Reason for modification / Remarks
1.0	04/10/18	José Miguel Juan, Jaume Sanz	Original version
1.1	31/10/18	José Miguel Juan, Jaume Sanz	Modified based on comments received by the Executive Board

Disclaimer

Executive Summary

The goal of WP5 is to assess the capability of the different monitors, described in WP2, for warning about the degradation in the performance of three different positioning services: EGNOS, NRTK and HF geolocation.

For this purpose, in WP5, a database is being building which contains the outputs of the different methodologies and the degradation values of the above mentioned services. The structure of such database is defined in this document,

Moreover, one of the key points for assessing such warning capabilities is to have a list of confident values about the degradation of the services. This document describe how these values are obtained for the three services.

1. Data set

A series of data corresponding to 71 days has been chosen according to the event lists in WP3 (drivers) and the EGNOS degradation list. The data set is presented in annex 1.

For NRTK we have selected the data from the CATNET during more than 150 days, see below.

For HF geolocation we will use a set of 150 days gathered with a finder placed in Germany.

2. Definition and design of the database.

The organization of the data series has been achieved following a hierarchical order of levels, separating events by year at the first level, day of the year (DoY) at the second level, and Edrivers, methodologies, EGNOS perfomance, NRTK and HF are placed at a third level. The “Methodologies” folder contains the 8 TID detection methods: HF-TID method, HF interferometry method, GNSS MSTID analysis, GNSS TEC gradient algorithms, TaD 3d mapping of the electron density, HTI technique to monitor wave activity, CDSS-MSTID detection method and the AATR index indicator. Each of this methodology contains two folders, the first one called “Plots” with figures regarding the results of applying the techniques, and a second one called “Data” with the information used to make the plots. At the first level it can be found a folder called “Formats”, with explainatory documents regarding data and plots formats as well as work package deriverables and information.

It is intended to allow users to have access each folder of the data base. Figure 1 depicts this organization.

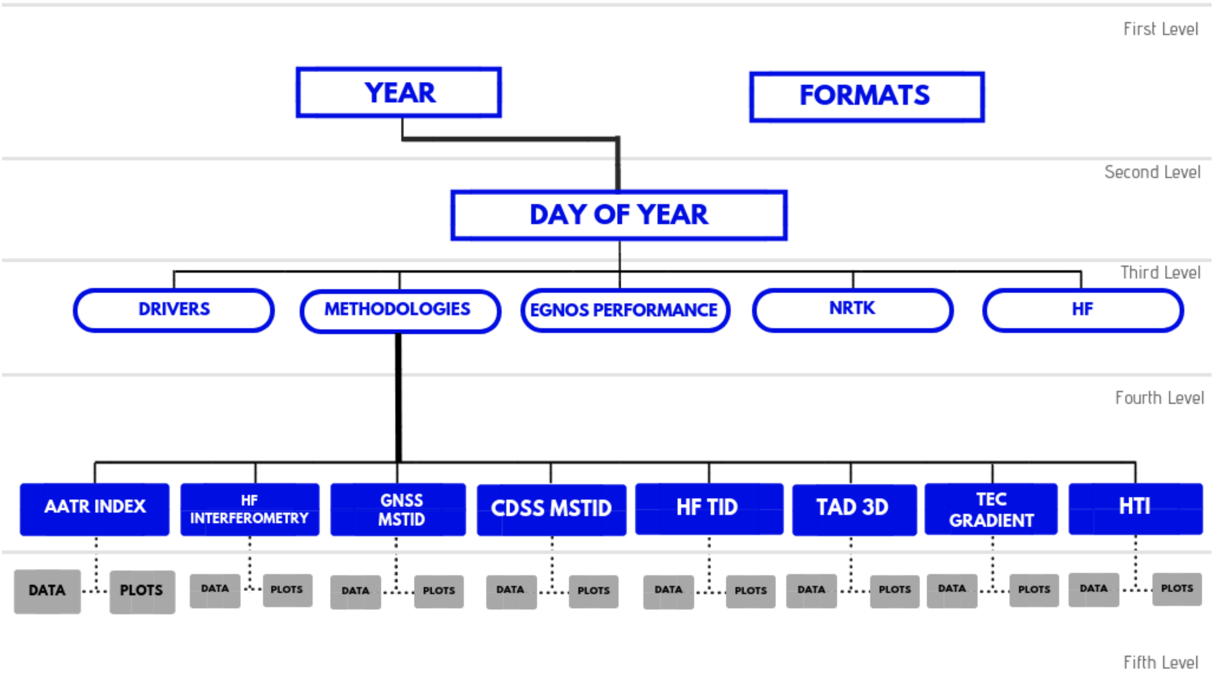


Figure 1: Data set structure

As an example for the indexing of a data file source from a particular day, let us say, the day 250 of 2017, any user will have to access the following path:

>> ~/2017/250/Methodologies/AATR/data/aatr_5m.17.250

The user can also check monitor results through plots of AATR index for that particular day, as it is shown in the figure 2. To reach this plot, user will have to follow the next path:

>> ~/2017/250/Monitors/AATR/Plots/aatr_map_2017250.png

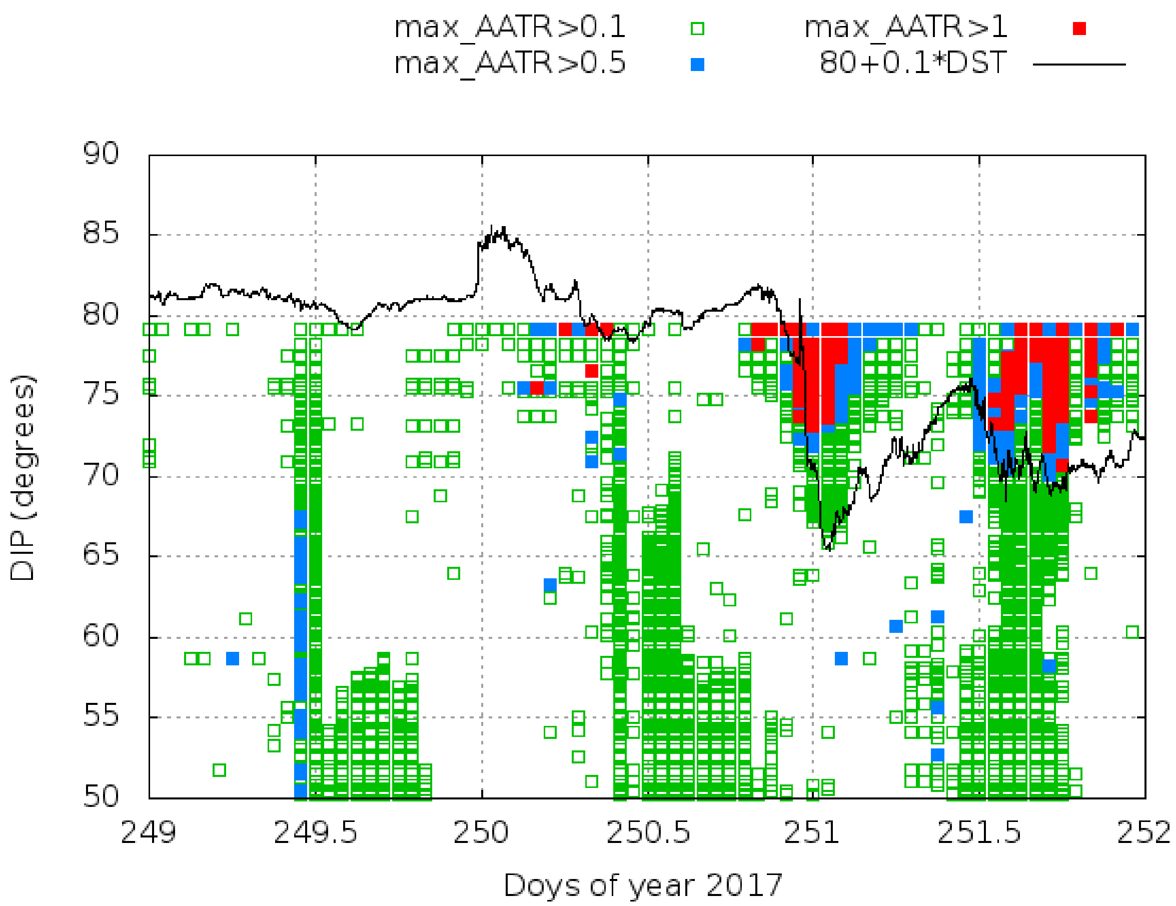
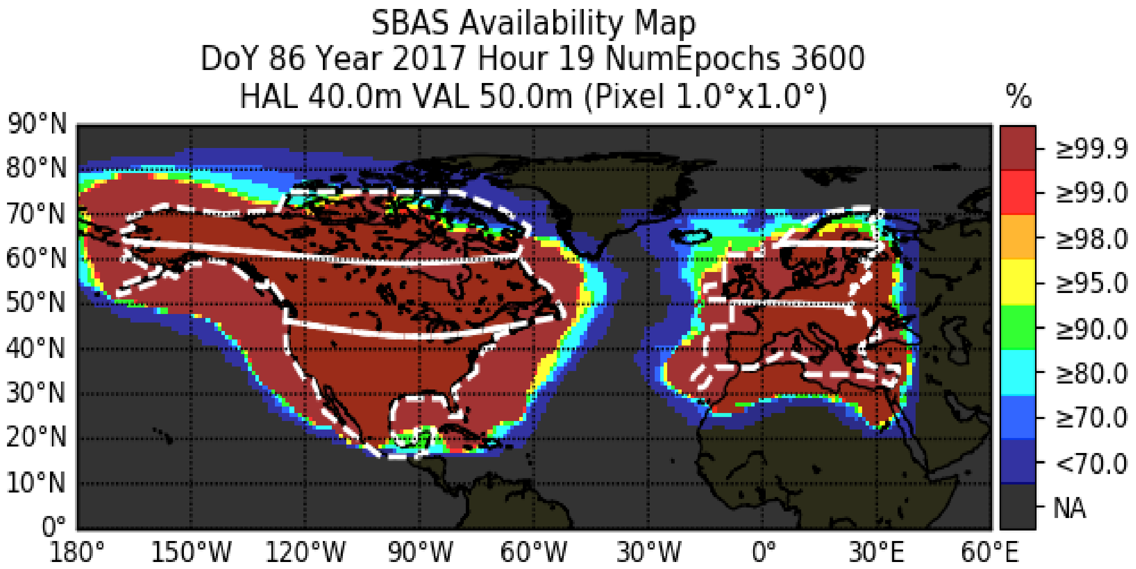


Figure 2: AATR index and DIP for 3 days (249,250 and 251)

The information before presented, with the same hierarchical organization, is placed to be consulted in the following ftp address: http://147.83.27.240/TechTIDE

3. Strategy for measuring the degration of the EGNOS service at specific locations.

The EGNOS service was assessed by implementing a strategy for measuring the degradation at specific locations. This not only provides plots of availability but also relates a table of coverage by regions, as it can be seen in figure 3. These regions have been designed in order to facilitate the statistical analysis, looking geomagnetic coordinates (for instance, MODIP) of locations. This information is also available hourly and daily, for data results of SBAS availability and continuity.



Percent Avail.	WAAS-North Coverage	WAAS-Mid Coverage	WAAS-South Coverage	EGNOS-North Coverage	EGNOS-Mid Coverage	EGNOS-South Coverage
≥70.0	92.79%	100%	98.27%	98.60%	100%	100%
≥80.0	90.71%	100%	98.16%	91.61%	100%	100%
≥90.0	86.86%	100%	96.65%	75.52%	100%	100%
≥95.0	82.05%	100%	93.84%	55.94%	100%	100%
≥98.0	78.85%	100%	93.51%	44.06%	99.79%	100%
≥99.0	77.40%	100%	93.41%	42.66%	99.59%	100%
≥99.9	76.12%	100%	93.41%	40.56%	98.96%	100%

Figure 3: SBAS Availability map

4. Measuring the degradation of NRTK services

Many of the NRTK systems work using the ionosphere-free combination (2 frequencies) of carrier phases, which means they are almost unaffected by MSTIDs.

We focus our study on the navigation performance degradation on the navigation using single frequency receivers. Indeed, such users need to correct ionospheric delays. This correction is computed by interpolating the ionospheric delays from the values at reference receivers at some tens of km from the user.

In this situation any MSTID (wavelength ~ 100km) travelling through the network can degrade the interpolation, and consequently the navigation solution. Similarly to the large scale perturbation, the goal is to relate the degradation in the NRTK navigation with the MSTID monitor outputs.

Using ionosphere free carrier phase measurements (reference), the kinematic navigation solution is at the level of few cm. This error is independent from the baseline wrt the reference receiver.

As it can be seen in figure 4, for the shortest baseline (PLAN), the single frequency solution, assuming no ionospheric gradient wrt the reference receiver (as it is done in RTK, depicted with red points), is even better than the ionosphere-free solution, but suffers a clear degradation with the increasing of the baseline, as it is seen for the other two receivers. This error increasing is mitigated, interpolating ionospheric delays from the reference receivers (NRTK solutions, in blue).

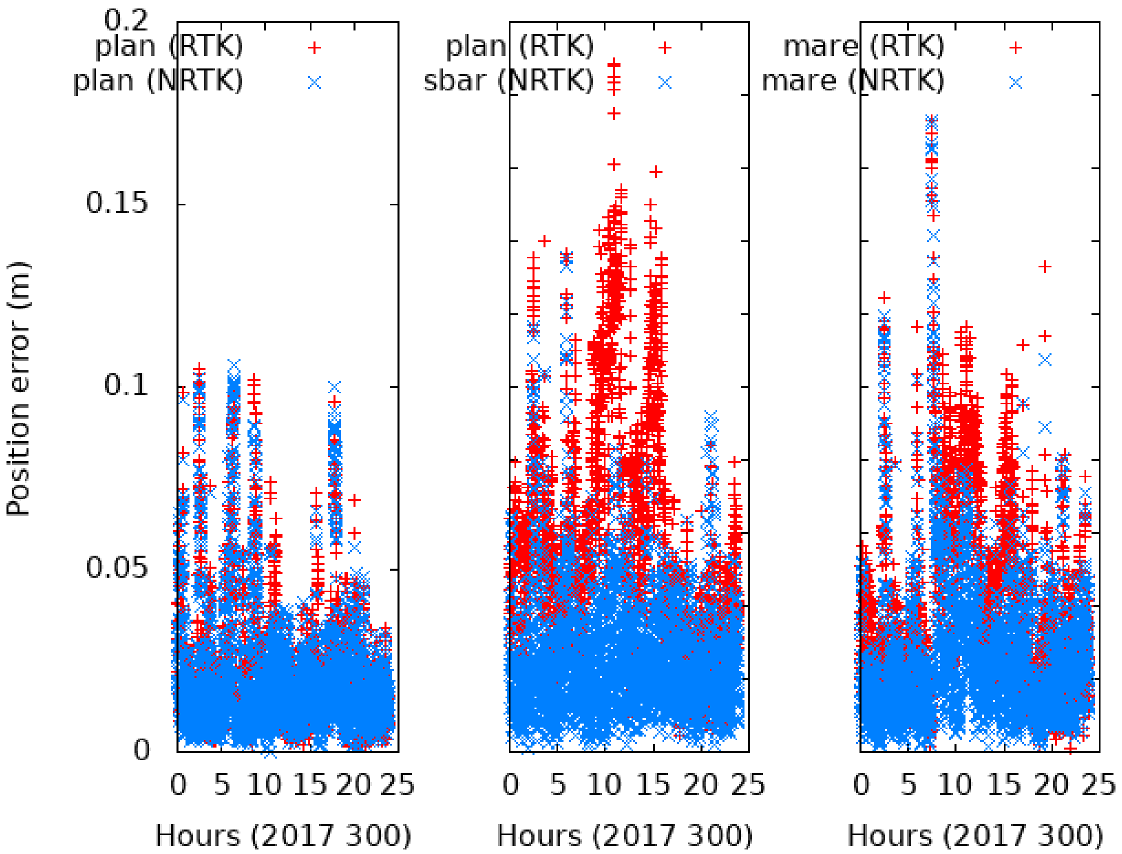


Figure 4: Degradation of NTRK service for 3 receivers in the CATNET NRTK network: PLAN, at 15 km from the reference receiver (GARR), MARE at 51 km from GARR and SBAR at 79 km from GARR

In order to obtain results about the degradation in the NRTK service we are using the data from the Institut Cartografic i Geologic de Catalunya (ICGC). This data can be downloaded from:

ftp://geofons.icgc.cat/rinex/

The data provided by ICGC cover the time period from 1996 up to the current year. However, we have started with the degradation references during the year 2017, since this is the year when all the methodologies are providing results.

5. Strategy for measuring the degradation of HF direction finding accuracy

HF communication is influenced by TIDs. In order to evaluate the impact on users operating HF direction finders a specific technical setup and a process chain was designed. GFP is operating an HF direction finder. In order to gain long-term experience concerning the quality of direction finder results, a continuous-monitoring approach was selected.

Based on the HFBC list and additional information, a set of transmitters was selected and azimuth values were automatically measured and stored in a database. The storage in a database enables efficient filtering and selection of specific transmitters, frequency ranges, or date and time.

Based on a list of TIDs, a matching is possible whether a specific azimuth measurement was done during a TID event. Thus, an assignment of all measured azimuth values is possible to individual TID time periods and to periods without known TIDs. Deviations can be calculated, e.g. by determining average differences (mean square error) between the measured values and the true azimuth value, which is known due to the known position of the transmitter. In summary, individual deviations can be calculated for measurements during each TID as well as during TID-free phases, enabling comparisons between these values.

6. Service degradation datasets registered in the TechTIDE test DB

All required performance degradation data are now registered in the TechTIDE test database. In the following table it is summarize the locations and time intervals for which references values in the degradation of the services are available. Second column indicates the starting date in the YYYY-DDD format, third column the ending date, the fourth column provides the regions and geographic areas for which the degradation values are recorded and the last column represents the level of ionospheric disturbance that can affect the services.

For EGNOS service, the day list can be consulted in the annex.

Service	Start date (YYYY-DDD)	End date (YYYY-DDD)	Location	Level of the perturbation that can affect the service
EGNOS (event list on WP3)	2017-001	2018-042	Europe	Few TECUs
HF Location	2017-352	2018-124	NE of Germany	Mainly azimuth (few degrees) – this is still under investigation
NRTK	2017-200	2017-365	CATNET (NE of Spain)	Few tenths of a TECU

Annex 1: 71 days data set

Table 1. Selected data set

Event	Year	Day	Source
1	2017	7	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
2	2017	29	event_list_WP5_EGNOS.pdf
3	2017	31	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
4	2017	32	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
5	2017	46	event_list_WP5_EGNOS.pdf
6	2017	60	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
7	2017	61	event_list_WP5_EGNOS.pdf
8	2017	74	event_list_WP5_EGNOS.pdf
9	2017	75	event_list_WP5_EGNOS.pdf
10	2017	78	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
11	2017	86	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
12	2017	87	event_list_WP5_EGNOS.pdf
13	2017	110	event_list_WP5_EGNOS.pdf
14	2017	111	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
15	2017	112	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
16	2017	121	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)

17	2017	137	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
18	2017	138	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
19	2017	139	event_list_WP5_EGNOS.pdf
20	2017	140	event_list_WP5_EGNOS.pdf
21	2017	146	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
22	2017	147	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
23	2017	148	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
24	2017	157	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
25	2017	158	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
26	2017	159	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
27	2017	160	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
28	2017	161	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
29	2017	162	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
30	2017	163	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
31	2017	164	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)

32	2017	197	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
33	2017	223	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
34	2017	234	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
35	2017	235	event_list_WP5_EGNOS.pdf
36	2017	243	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
37	2017	249	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
38	2017	250	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
39	2017	251	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
40	2017	252	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
41	2017	253	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
42	2017	255	event_list_WP5_EGNOS.pdf
43	2017	256	event_list_WP5_EGNOS.pdf
44	2017	257	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
45	2017	258	event_list_WP5_EGNOS.pdf
46	2017	259	event_list_WP5_EGNOS.pdf
47	2017	270	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
48	2017	278	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)

49	2017	285	event_list_WP5_EGNOS.pdf
50	2017	286	event_list_WP5_EGNOS.pdf
51	2017	311	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
52	2017	312	event_list_WP5_EGNOS.pdf
53	2017	317	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
54	2017	324	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
55	2017	325	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf)
56	2017	327	event_list_WP5_EGNOS.pdf
57	2017	328	event_list_WP5_EGNOS.pdf
58	2017	341	https://techtide-wiki.space.noa.gr/wiki/WikiPages/Work%20Packages/WP3/Events%20List (events_list_wp3.pdf, event_list_WP5_EGNOS.pdf)
59	2017	346	event_list_WP5_EGNOS.pdf
60	2017	351	event_list_WP5_EGNOS.pdf
61	2017	353	event_list_WP5_EGNOS.pdf
62	2017	355	event_list_WP5_EGNOS.pdf
63	2017	360	event_list_WP5_EGNOS.pdf
64	2018	11	event_list_WP5_EGNOS.pdf
65	2018	14	event_list_WP5_EGNOS.pdf
66	2018	15	event_list_WP5_EGNOS.pdf
67	2018	24	event_list_WP5_EGNOS.pdf
68	2018	27	event_list_WP5_EGNOS.pdf
69	2018	34	event_list_WP5_EGNOS.pdf
70	2018	40	event_list_WP5_EGNOS.pdf
71	2018	42	event_list_WP5_EGNOS.pdf