ISTF/5 - SP/04
Agenda Item 4b
17/02/15

GIMA
(GBAS Iono Monitoring Assessment)

LATO – 15th and 16th October 2014

EUROCONTROL

Agenda

I. Introduction / Project organisation

II. Data selection

III. Data processing

IV. Step 1 (RINEX processing)

V. Step 2 (Automatic gradient screening and selection)

VI. Validation

VII. Step 4 (Gradient validation) - First Results

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I. Introduction / Project organisation

IONO project (SESAR 15.3.4)

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Consortium Organisation

- EGIS Avia – Prime Contractor
- DSNA (Egis Avia Sub-contractor)
- CNES (Egis Avia Sub-contractor)
- ENAC (Egis Avia Sub-contractor)
- CLS (Egis Avia Sub-contractor)
- M3S (Egis Avia Sub-contractor)

1. Ionosphere monitoring campaign
2. Ionosphere impact modelling
3. Evaluation of mitigations

RINEX →

GIMA project (SESAR 15.3.7)

EUROCONTROL ⟷ egis

Development of a European ionosphere threat model

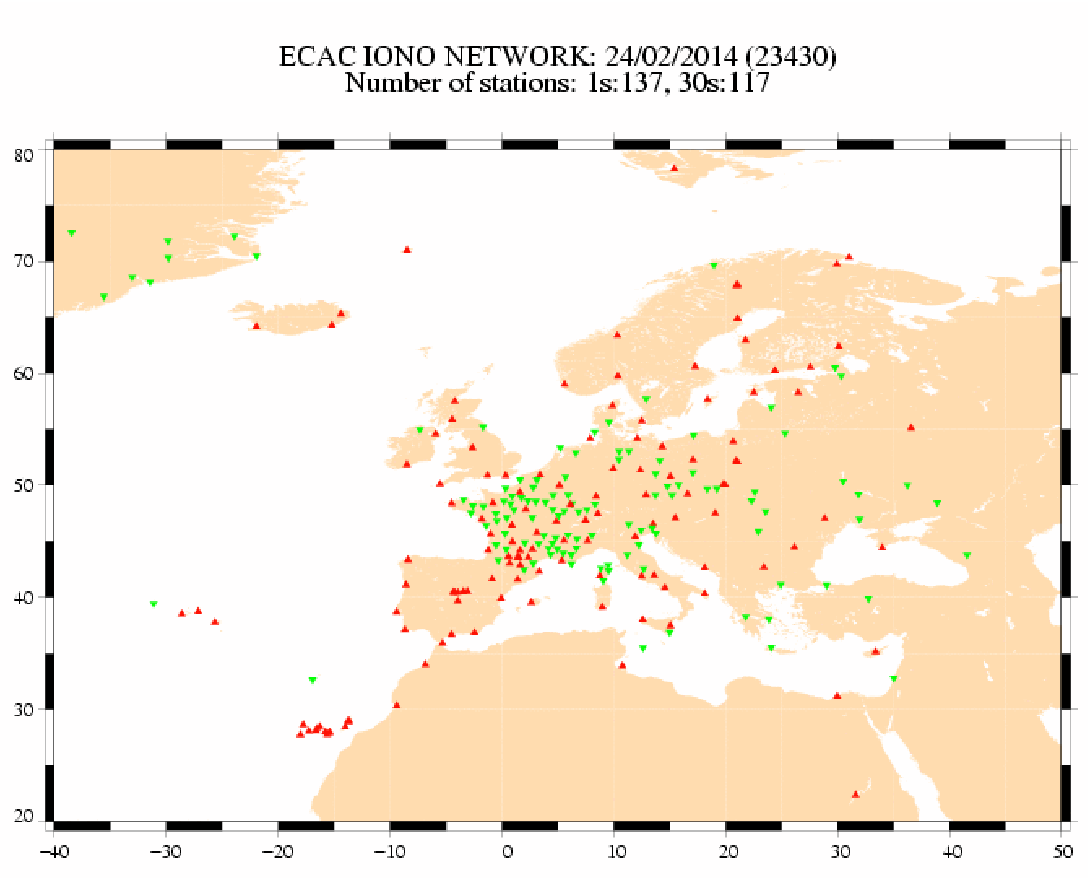
↑ LTIAM

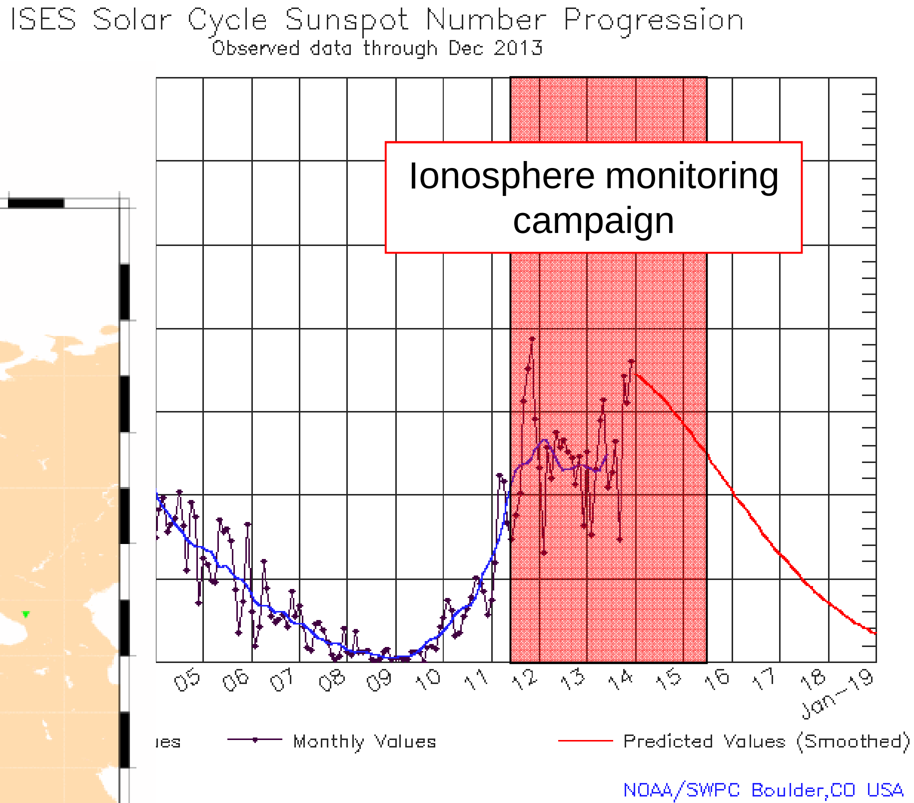
FEDERAL AVIATION ADMINISTRATION

↑ Scintillation data

esa – ESA MONITOR project

II. Data Selection: IONO stations



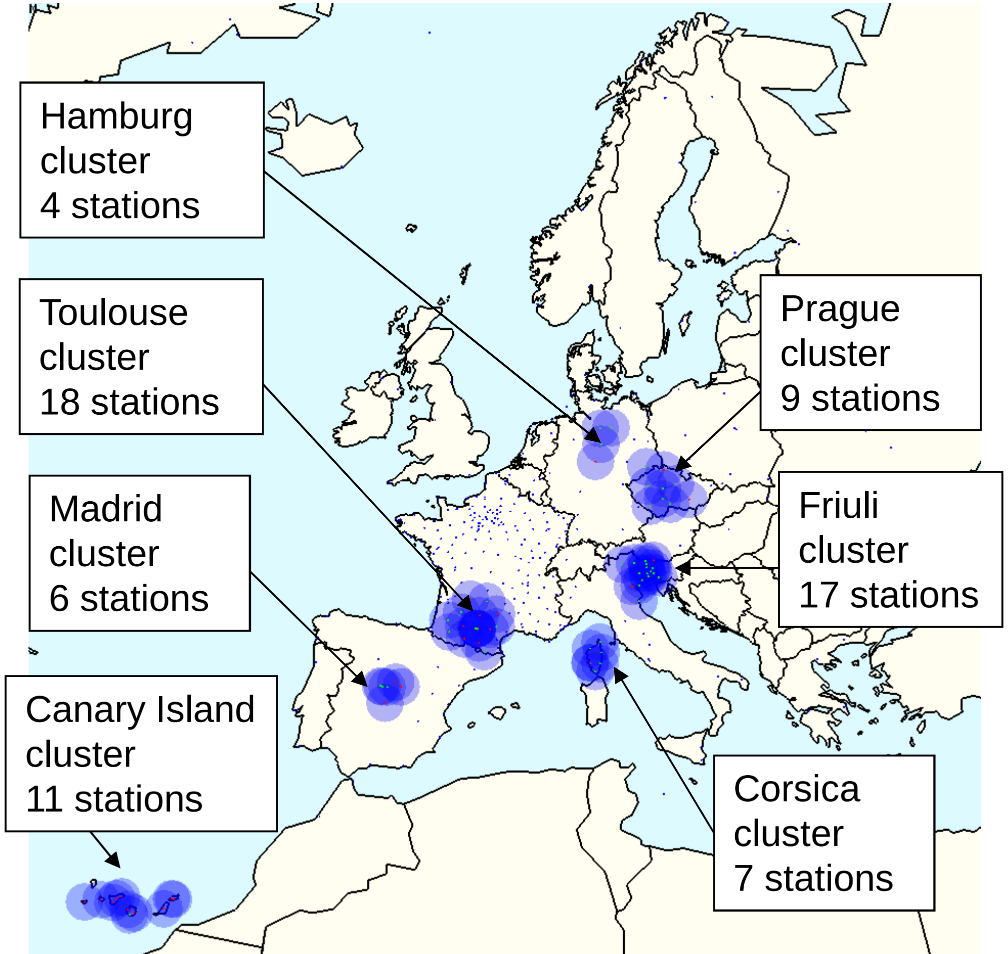


Data are retrieved from existing networks (~240 stations): EUREF, EDCN, EGNOS, Fiule, GEODAF, GNET, GRAFCAN, GREF, IGS, RGP

II. Data Selection: GIMA station clusters

GBAS implementation map (flyGLS.net)

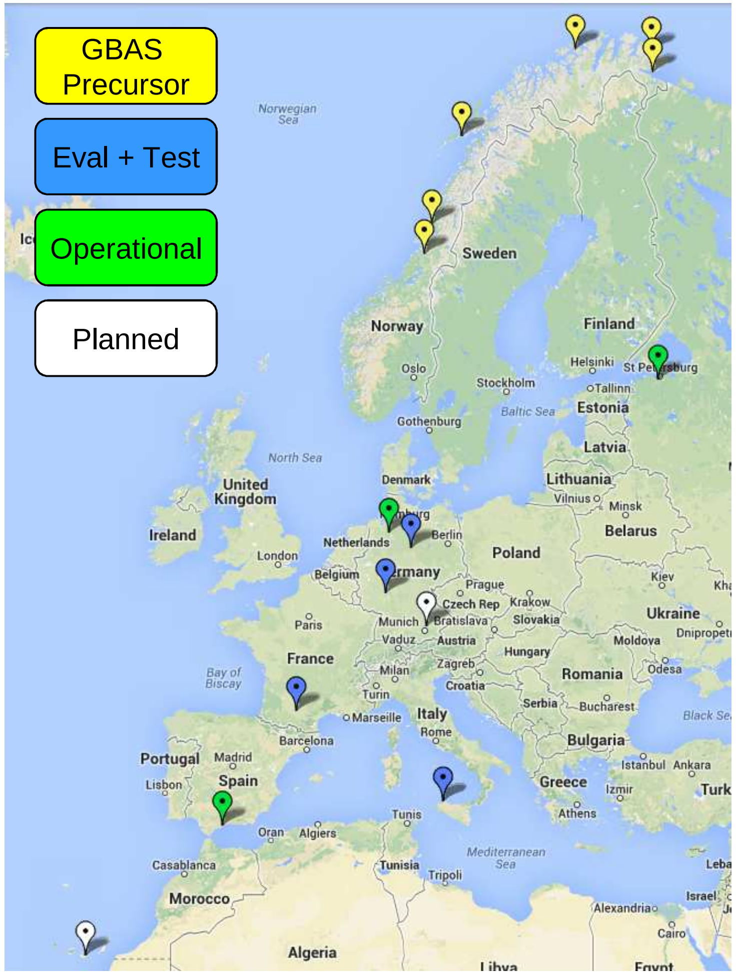
GIMA clusters (7 clusters – 72 stations)



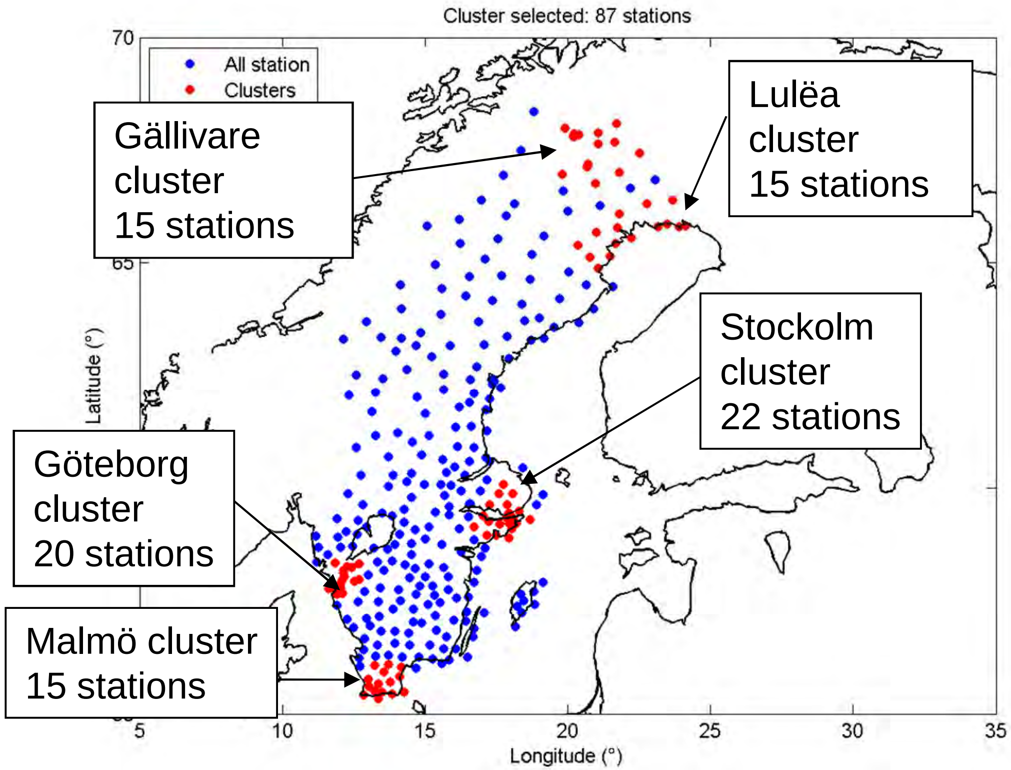
Data from year 2012 day 282

II. Data Selection: additional GIMA clusters

GBAS implementation map (flyGLS.net)



Additional clusters from mid-September 2014



Additional clusters from Sweden: **87 stations**

III. Data Processing: hardware

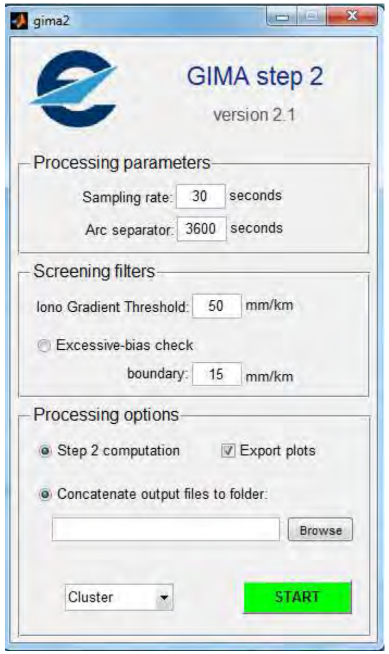
- <u>Network Attached Storage dedicated to RINEX archive:</u>
  - Data received: ~150 Gb every 3 month from Egis Avia consortium
  - Capacity: total capacity of 3 Tb => at least, 4 years of data can be stored
  - Integrity: data are stored on a RAID 1 system (2 disks are mirrored)
  - Possibility of future storage capacity extension

- <u>Computer dedicated to LTIAM processing</u>
  - HP Z420 Workstation
  - Processor: Intel ® Xeon ™ E5-1660v2 3.7GHz, 6 cores
  - RAM: 64 GB
  - Windows 7 Professional
  - MATLAB R2013b + Parallel Computing Toolbox

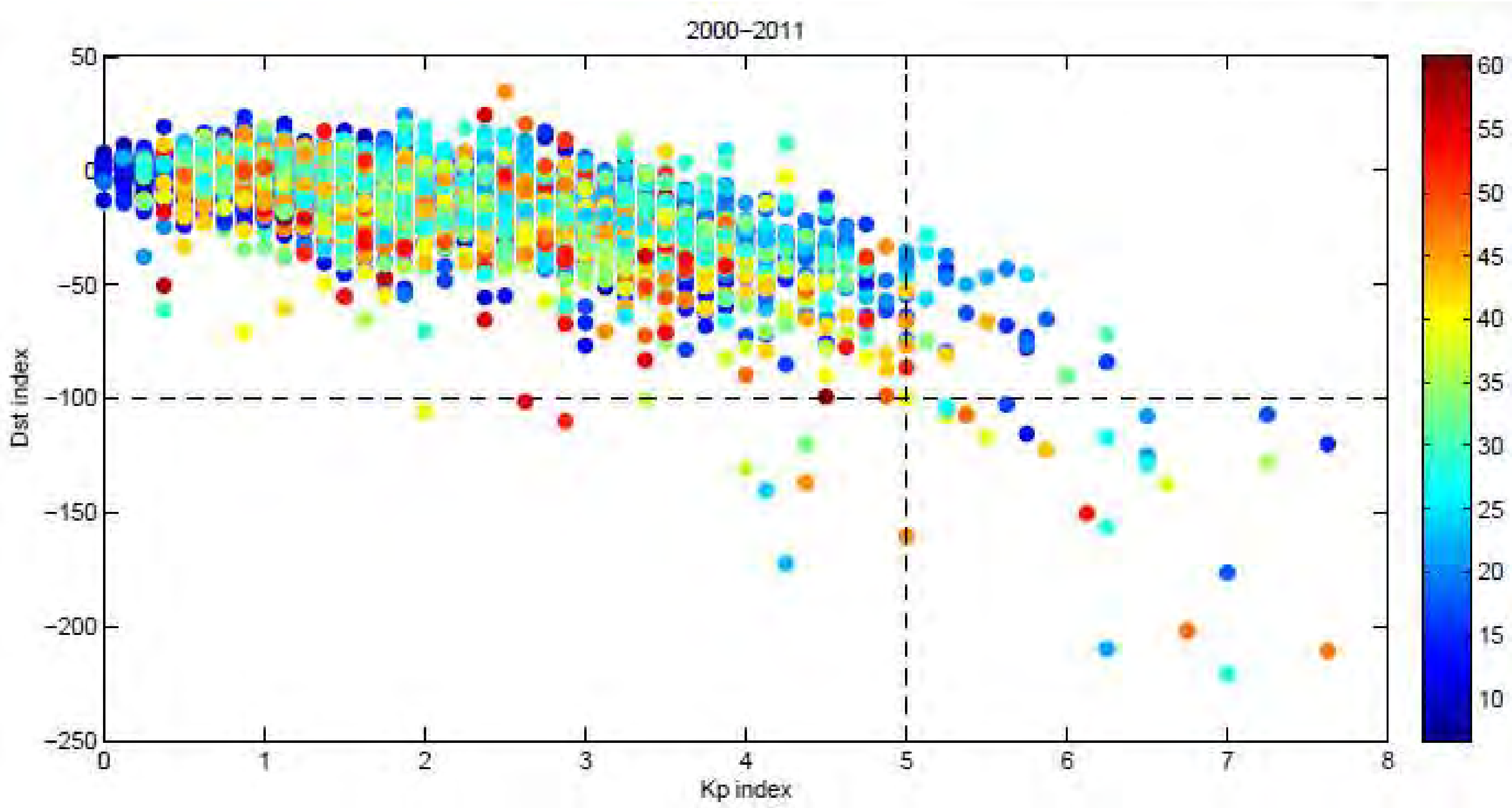
III. Data Processing: GIMA based on LTIAM

- LTIAM (Long Term Ionospheric Automated Monitoring):
  - Initially developed by Stanford and provided to EUROCONTROL by the US Federal Aviation Administration

- GIMA = LTIAM + ad-hoc modifications
  - > 70 modifications
  - Development of a Human Machine Interface
  - New cycle slip (CS) correction algorithm
  - Robustness improvement
  - Parallel computing (Matlab parallel computing toolbox)
  - Local RINEX folder
  - Process all data independently from Kp or Dst



III. Data processing: Correlation Kp, Dst, TEC



- Figure from “GBAS Ionosphere Study », Skyguide, presented at the CNS Expert Group, April 2014

III. Step by step approach

RINEX from IONO project

90% **Step 1 (based on LTIAM):** Process RINEX files Outputs : temporal series of processed data, including estimated ionospheric delays

90% **Step 2 (developed by EUROCONTROL):** Estimation of iono gradients and automatic selection of potentially iono gradient threats
Output: List of potentially iono gradient threats (station pair, PRN, date, maximum gradient, elevation angle)

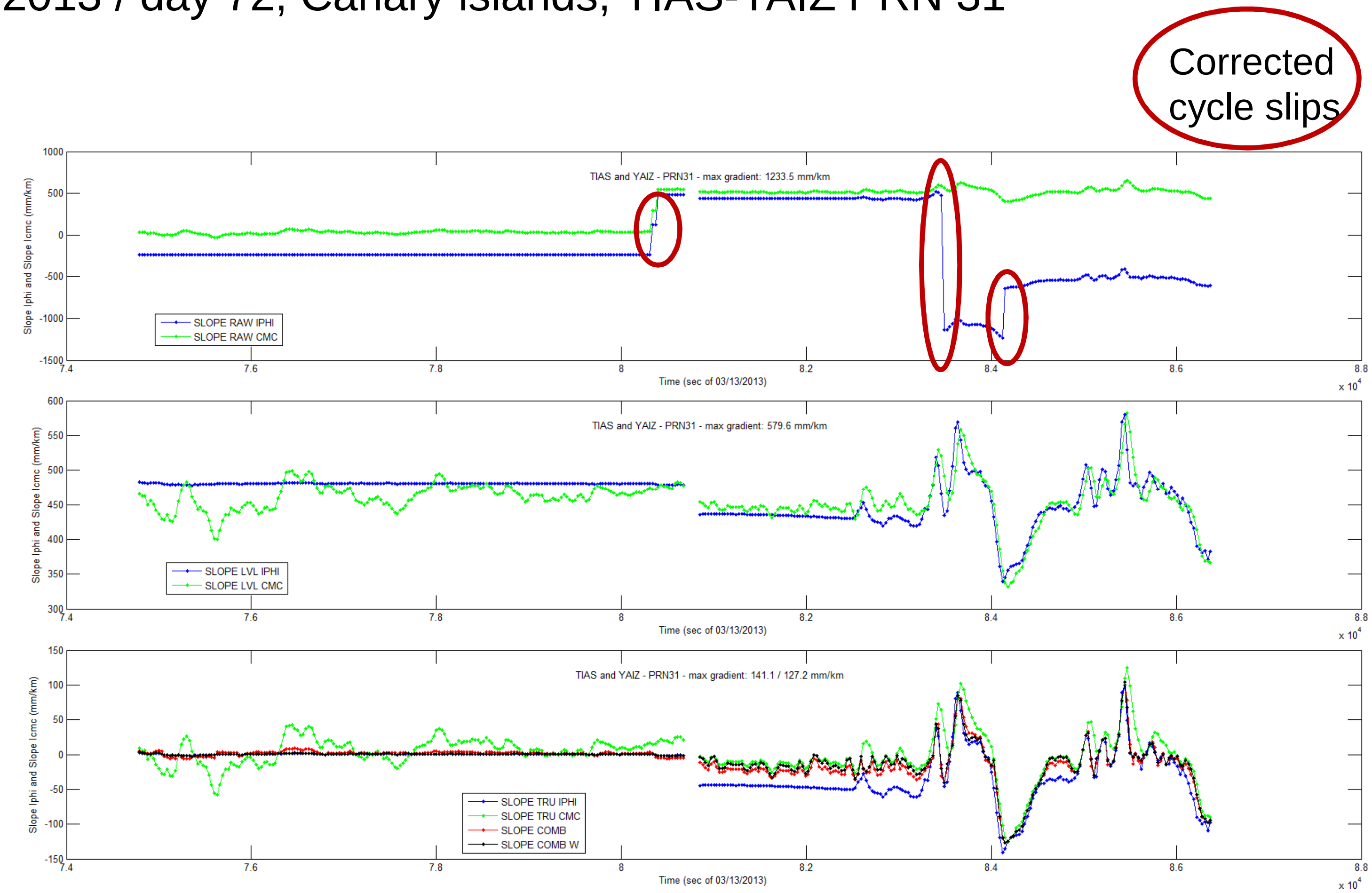
0% **Step 3:** Estimation of gradient speed
Output: Gradient speed of selected gradients

20% **Step 4:** Manual validation of potentially iono gradient threats
Output: Ionospheric threat model

IV. Step 1 stages

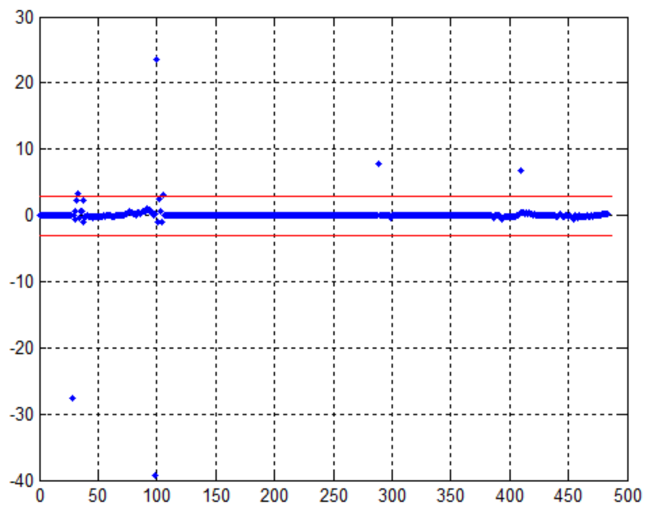
- Example: 2013 / day 72, Canary islands, TIAS-YAIZ PRN 31

- Raw data
- Cycle slip detection and correction
- Smoothing
- Leveling
- IFB estimation
- “True” data
- Combined and weighted gradient curves

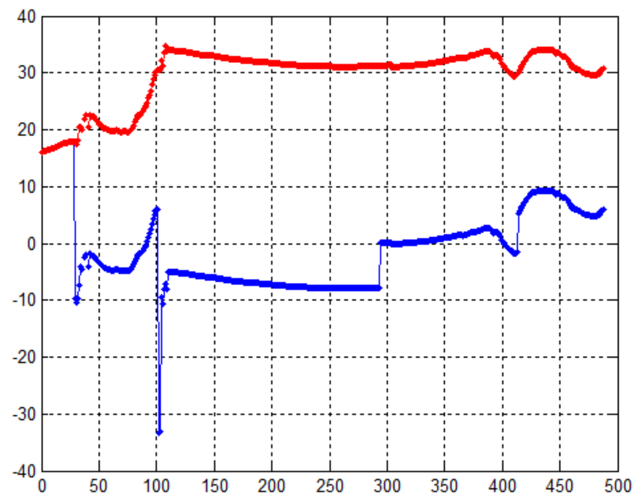


IV. Step 1: cycle slip correction algorithm

- Cycle slips detected by a statistical analysis of the differential iono delay:
  - Comparison against a threshold based on the data standard deviation
  - Polynomial fitting is used to obtain smooth corrections
  - Multiple consecutive data jumps are not corrected in order to not eliminate possible gradients
- Three consecutive iterations with different thresholds



- Differences between two consecutive Iphi delay samples: cycle slips when red lines (std thresholds) are exceeded.



- Blue curve: Iphi delay not corrected;
- Red curve: Iphi delay corrected.

IV. Step 1 status

- The 7 current clusters (Canary islands, Toulouse, Madrid, Corsica, Friuli, Hamburg, Prague) have been processed
- From 2012 day 282 to 2014 day 179
- Computation time : ~ 81 hours with parallel computing toolbox (72 stations) *
- Output file size : ~30 GB per processed year (7 clusters)

** Estimated computation time. Continuous processing not possible due to debugging process and adaptation of the tool to the parallel processing toolbox.*

V. Step 2 filters and status

- A gradient is identified as a potential threat if :
  - The phase gradient and combined weighted gradients exceed 50 mm/km;
  - Both phase and CMC data are available;

- The combined weighted gradient is calculated to reduce the number of false threat detections due to uncorrelated phase and CMC data:

$$S_{comb} = \sqrt{\left(S_{phi}\right)^{2a} \cdot \left(S_{CMC}\right)^{2(1-a)}}; \qquad a = \frac{ratio}{1+ratio^2}; \qquad ratio = max\left(\frac{S_{phi}}{S_{CMC}}, \frac{S_{CMC}}{S_{phi}}\right);$$

- Outputs:
  - List of potential iono gradient threats (date, cluster, station pair, PRN, maximum gradient, elevation angle, instant of the maximum gradient)
  - Gradient, iono delay and elevation angle figures of the selected gradients

- **Status**: the 7 current clusters (Canary islands, Toulouse, Madrid, Corsica, Friuli, Hamburg, Prague) have been processed from 2012 day 282 to 2014 day 179

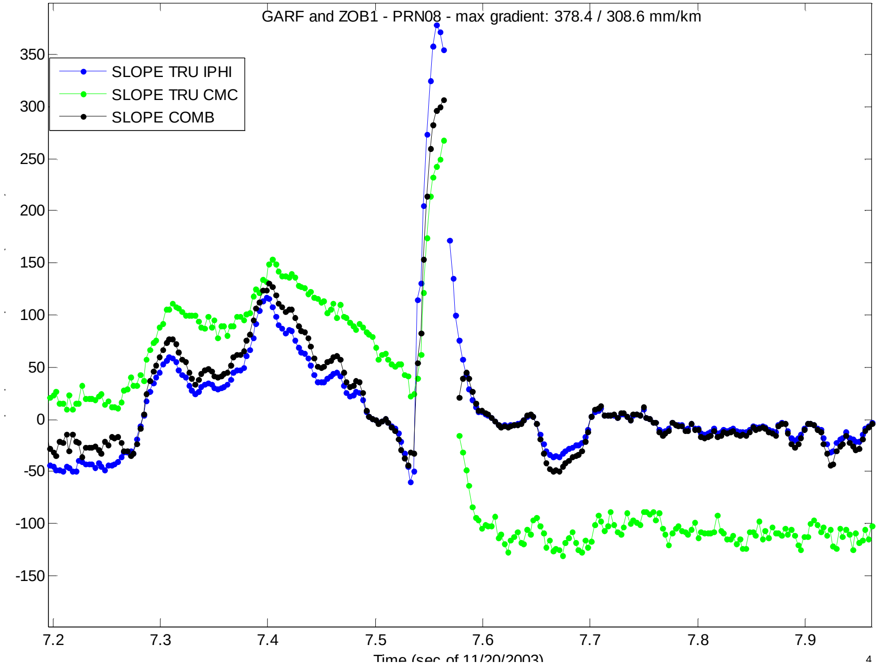
VI. Validation

- The new cycle slip correction implemented decreased significantly the number of false gradient detected

- However, this statistical approach may lead to over-correction that may mask real gradients.

- In order to mitigate this risk, GIMA version has been validated against the LTIAM version provided by the FAA on the Nov 20th, 2003 event

- When LTIAM measured a gradient of 384 mm/Km, gradient estimated with GIMA is 380 mm/km



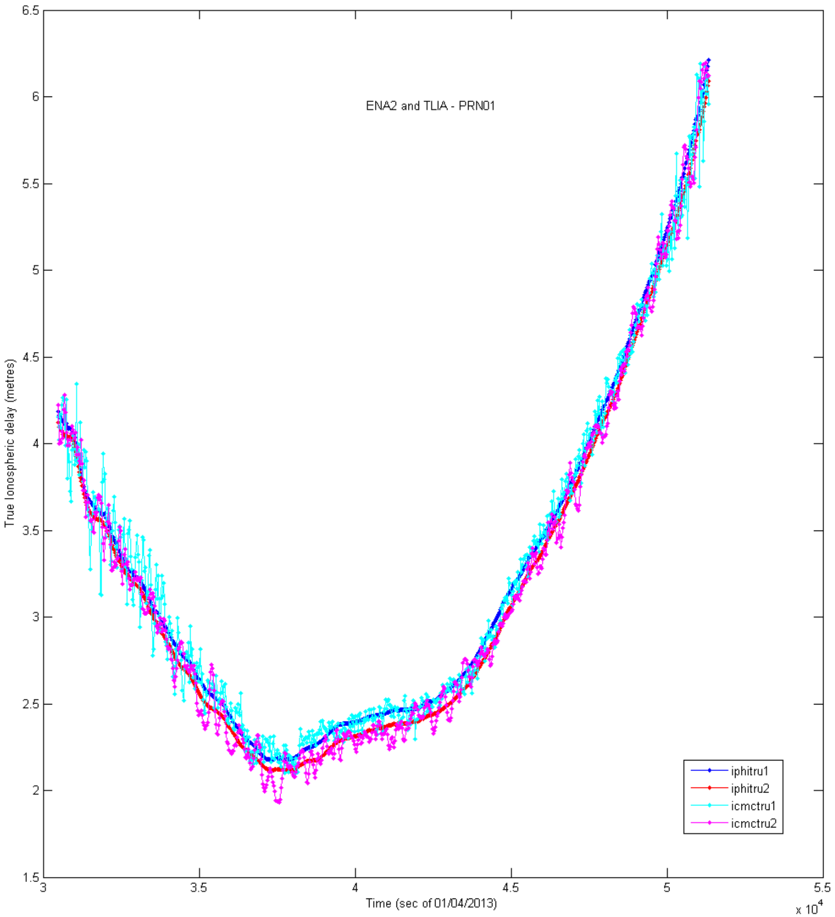
VII. Step 2 (Automatic gradient screening) First results – 1/3

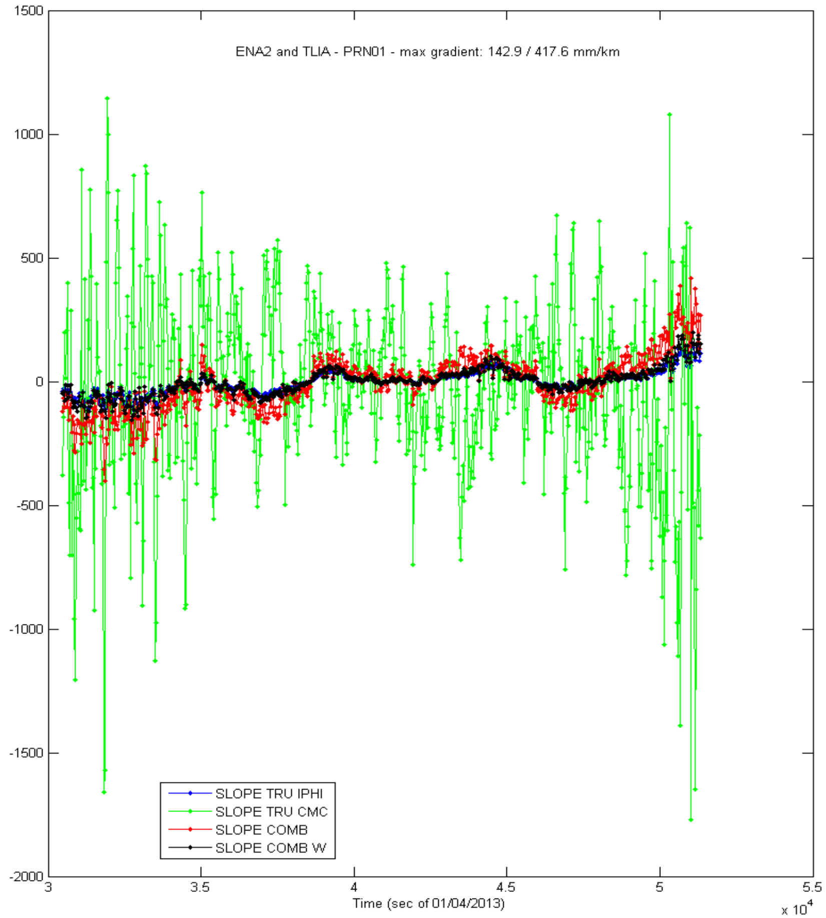
- High number of potential ionospheric gradients
- Most of the candidates are in the Canary islands and Toulouse clusters

Cluster	Nr. of potential iono gradients (not validated)		
	2012 (days 282-366)	2013 (days 1 - 365)	2014 (days 1-179)
All	1548	6809	14904
Canary Islands	712	5488	6233
Toulouse	777	1312	8502
Madrid	11	9	30
Corsica	48	0	139
Friuli	0	0	0
Hamburg	0	0	0
Prague	0	0	0

VII. Step 2 (Automatic gradient screening) First results – 2/3

- Identification and exclusion of unreliable station (tlia within Toulouse cluster)





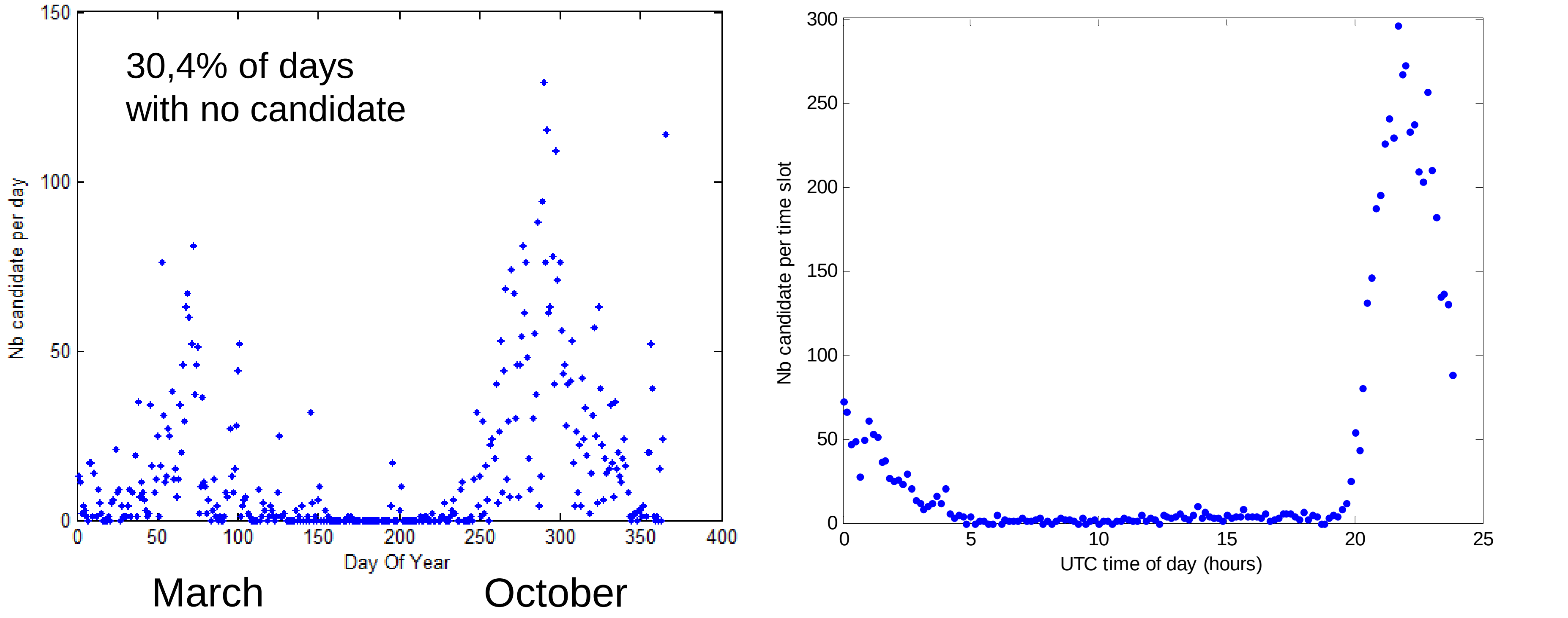
VII. Step 2 (Automatic gradient screening) First results – 3/3

- Potential ionospheric gradients when tlia station is removed:

Cluster	Nr. of potential iono gradients (not validated)		
	2012 (days 282-366)	2013 (days 1 - 365)	2014 (days 1-179)
All	777	5515	6516
Canary Islands	712	5488	6233
Toulouse	6	18	114
Madrid	11	9	30
Corsica	48	0	139
Friuli	0	0	0
Hamburg	0	0	0
Prague	0	0	0

VII. Step 2 (Automatic gradient screening) First results – 3/3

- Number of potential candidates per day and time for the Canary Islands - 2013:



⇒ Same characteristic as ionosphere scintillation

VII. Step 4 (gradient validation) first results

- <u>All clusters (*except Canary Islands*):</u>
  - Year 2013: no gradient observed
  - Year 2012 & Year 2014: validation is on-going

- <u>Validation strategies for the Canary Islands:</u>
  - Additionnal filters may be developped
  - Proceed by elevation groups:
    - > 60°
    - Between 45° and 60°
    - Between 30° and 45°
    - …
  - Proceed with different gradient threshold values:
    - > 100 mm/km
    - > 50 mm/km

✓ Elaborate statistical approaches from elevation groups and gradient thresholds values

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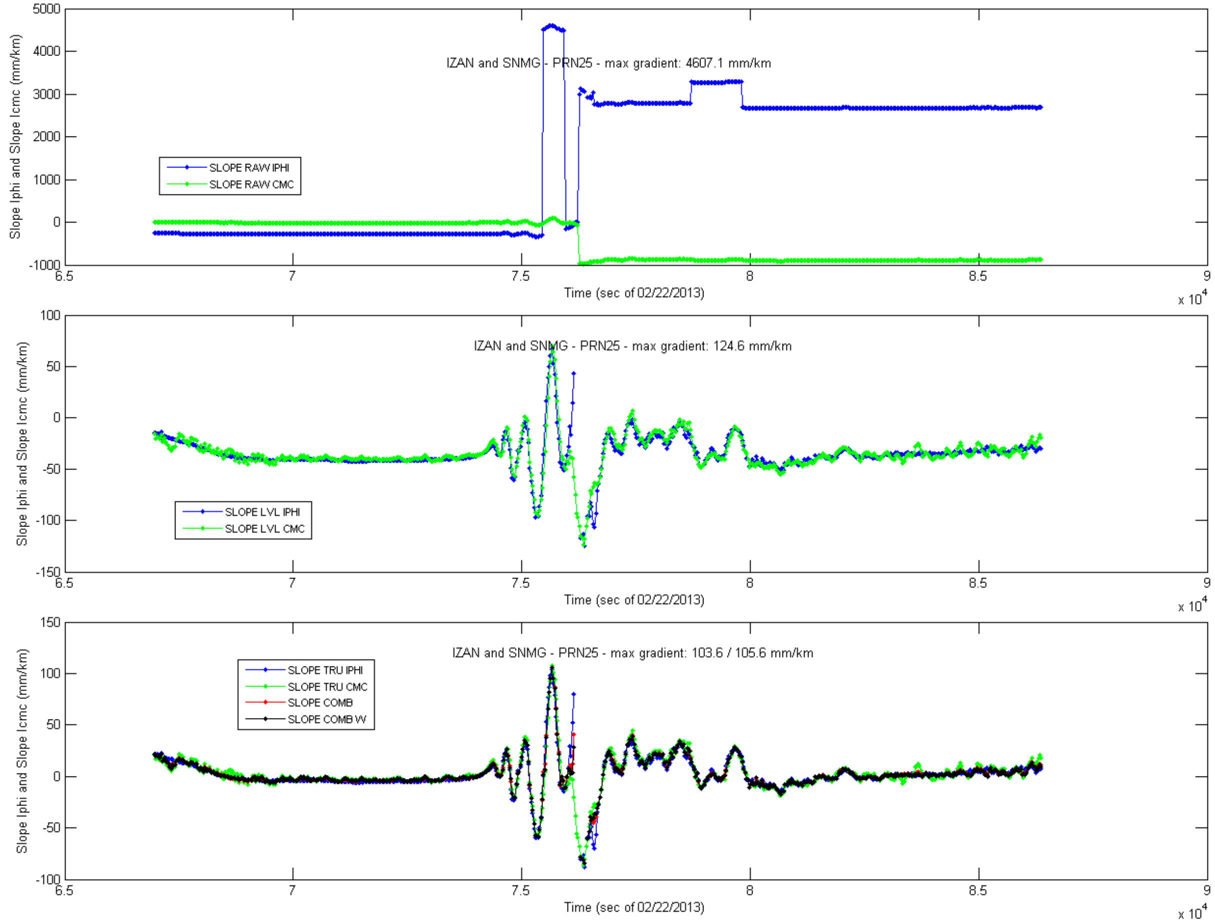
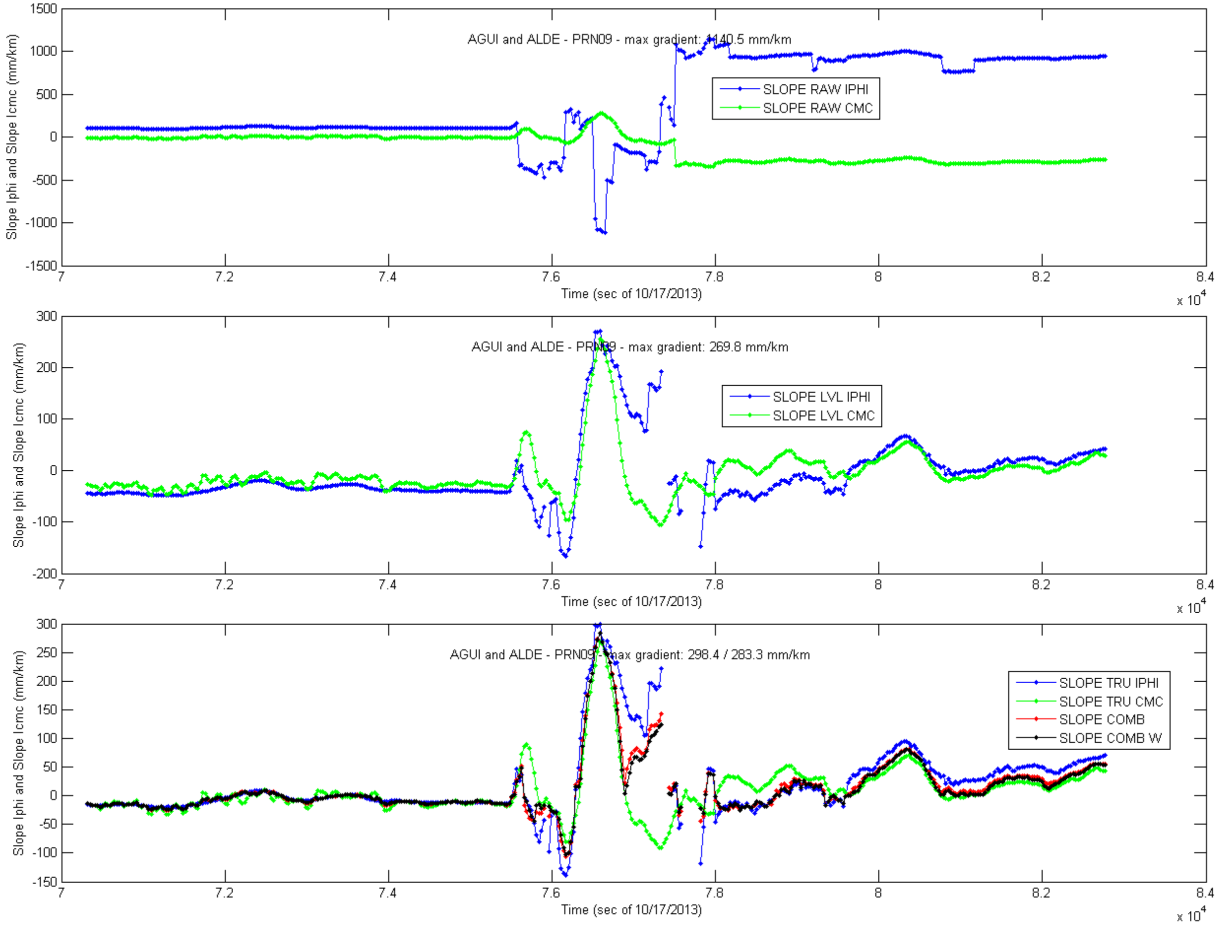
VII. Step 4 (gradient validation) first results

- 2013 / day 53, Canary islands cluster, Gradient ~105 mm/km
- Pair: IZAN – SNMG, PRN 25



VII. Step 4 (gradient validation) first results

- 2013 / day 290, Canary islands cluster, Gradient ~300 mm/km
- Pair: AGUI-ALDE, PRN 9



VIII. Conclusion

- The 7 clusters defined within GIMA project as well as Swepos clusters are consistent with the current European GBAS implementation plan

- Modifications implemented improved significantly the LTIAM robustness and the new cycle slip corrections decreased the number of false gradients detected
- Data from year 2012 day 282 to year 2014 day 179 have been processed

- There is a high number of potential gradients in Canary Islands
- Strategies for the manual validation:
  - Every gradient above 100 mm/Km will be manually validated
  - For gradients below 100 mm/Km, a statistical approach may be used

- <u>Next steps:</u>
  - Data from mid-2014 will be processed when available
  - Continuation of the manual gradients validation
  - Step 3: Gradient speed computation
  - Cross-check activities with Skyguide and NMA

Questions ? Please contact:

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