# RWC Belgium: annual report, July 2014

## *1 Organisational context*

The RWC Belgium is officially attributed to the SIDC (Solar Influence Data analysis Centre), which is one of the 4 departments (the Solar Physics department) of the Royal Observatory of Belgium (ROB). The Royal Observatory shares its main location on the plateau of Uccle (Brussels) with two other Belgian federal scientific institutes: the Royal Meteorological Institute (RMI) and the Belgian Institute for Space Aeronomy (BISA). These three institutes together are often referred to as the "Space Pool".
Even within the Royal Observatory, Space Weather expertise is not strictly concentrated within the SIDC. There are, for example, important contributions from the GNSS department within ROB. But also in the other Space Pool institutes Space Weather data are produced and analysed (*e.g.* local Dourbes magnetometers are operated by RMI). The SIDC in its operation as RWC Belgium benefits from collaborations with each of those partners. Additional funding for joint Space Weather related research and operations is provided by the Belgian Science Policy Office to these institutes under the name of the Solar Terrestrial Centre of Excellence.
In a broader context, the SIDC (in various partnerships with both the aforementioned institutes and other external partners) is taking part in several developments within the Space Weather segment of the ESA (European Space Agency) Space Situational Awareness (SSA) Program (*cfr. infra*).

## *2 Base data production and instrumentation*

This section provides a quick bullet point overview of the operational base data production facilities operated by the SIDC as well as the involvement in future instrument development. Many of these data are feeding directly into the Space Weather forecasting operations.

- USET White light/H-alpha/CaIIK images in continuous operation:
  - Improved pointing
  - Automated sunspot data extraction (to be completed): this should lead to the planned production of USSPS data in coordination with Catania.
  - Improved processing pipelines (to be completed)
  - Flare monitoring (to be started)
- ISSN: International sunspot number:
  - Revisit historical records
  - ISSN services bundled under the name SILSO
- Radio Observations from the Humain station:
  - Callisto: node in the e-Callisto network
  - Improved tracking
  - Recent technical problems due to lightning strike
  - Burst detection algorithm operational
  - Planned switch to digital receivers (SDR Software Defined Radio)
- PROBA2: LYRA and SWAP scientific operations
  - P2SC: PROBA2 Science Centre located at and operated by the SIDC
  - PROBA2 guest investigator Program
  - PROBA2 operations now under the ESA SSA program
- PROBA3: ASPIICS: PI Andrei Zhukov

- coronagraph: formation flying mission: 2e spacecraft is the occulter
- allows observation of the very low corona
- launch 2018, 2 year mission, non-continuous data

- ESIO: miniSWAP and miniLYRA as “hosted payload” instruments
- EUI development for Solar Orbiter

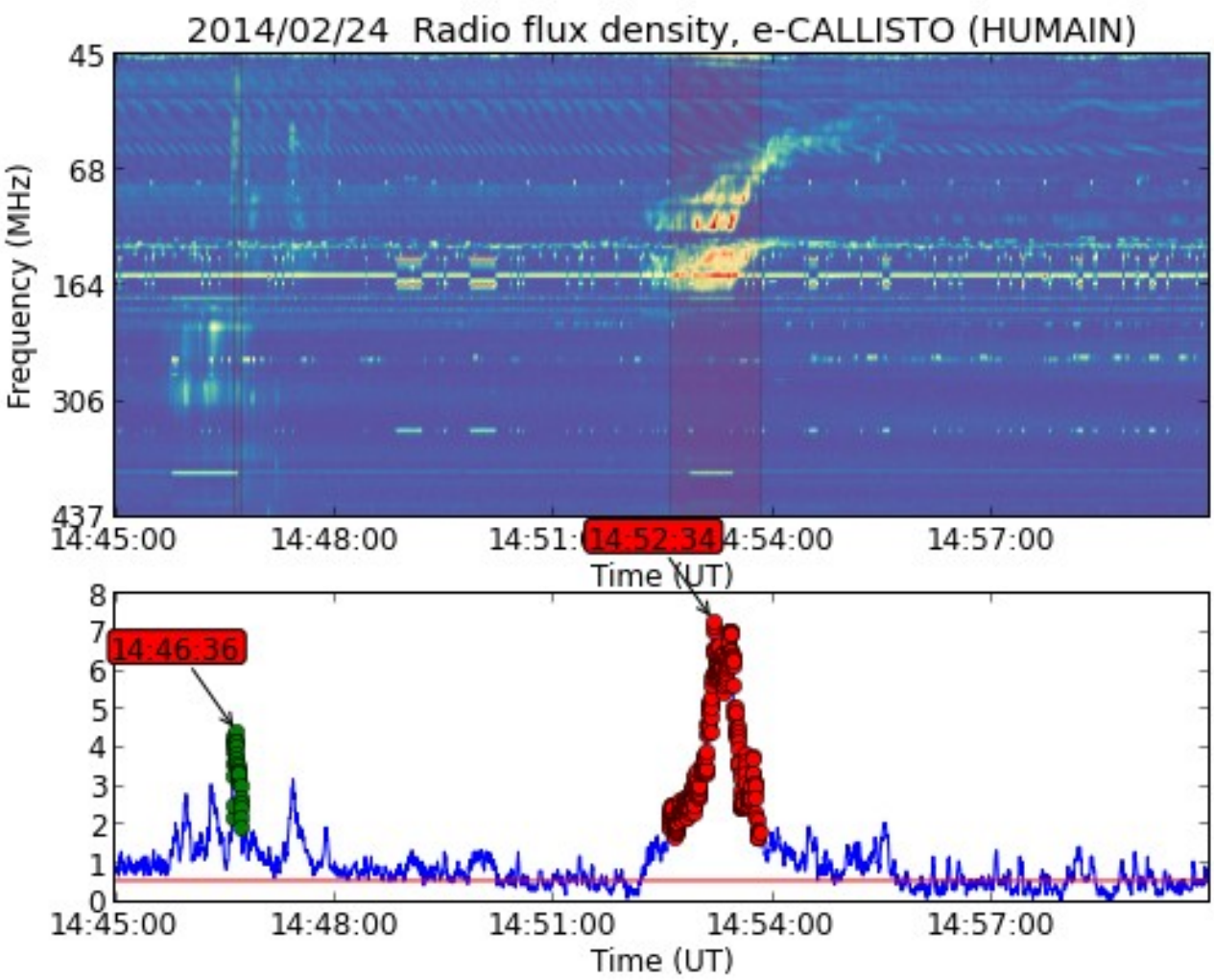



*Illustration 1: Automatic Burst detection by the Humain radio station*

# *3 Forecasting office*

## 3.1 Core products:

- Daily (and other frequencies) bulletin:
  - Regional/Full disc Flare predictions
  - F10.7 and K/A index predictions
  - Report on various indices

    - Textual report and forecast on Solar Weather/Solar Wind/Geomagnetic conditions
- Fast alerts:
    - Flaremail (based on GOES data, M5 onwards.
    - Cactus CME alert (based on LASCO/C2)
    - Presto (Human operated alert based on various sources, and used for event follow-up)

All operated 7/7, 10/24 (24/24 for automated detections) without interruption.
Development goals for these products: *cfr. infra.*

## 3.2 Recent developments

### *3.2.1 Upgrade of the central forecast production platform*

A major upgrade of the production platform was started of which the main components have been finalized. The upgrade provides:

- Unification of the back-end data storage: (almost) all forecast data (including both input received from e.g. other ISES stations ass well as output) are stored in a central database (this used to be scattered over files and databases).
- Unification and centralized management of all automated data inflow, automated processing routines and output procedures ("Previmaster"). (This used to be an inventive orchestration of individual scripts and cron jobs).
- The forecaster interface: ("Previweb"): a web based interface allowing the forecaster to conduct his/here forecast from anywhere. The interface now includes better presentation of basic information required by the forecaster in order to provide the forecast and better support for model guidance to the forecaster (integrated *vs*. external tools). The unified structure also allows to more easily plug in additional model data in the future to provide model driven assistance to the forecaster (or just update the existing model data continuously).
- The centralised and unified structure allows to more easily define and maintain different (flavours of) products (*cfr. infra*).
- The centralised and unified structure will allow to simplify the forecast verification processes such that they can be automated for continuous quality control and quality assurance.
- Planned: integration of alert follow-up workflow management.
- Planned: upgrade of the general user interface aspect. Including:
    - revision/upgrade of the Bulletin message formats (facilitating ingestion in client subsystems)
    - revision/upgrade of the Alert message formats (facilitating ingestion in client subsystems)
    - upgrade of the user subscription module.
    - Development and integration of flexible user interfaces to the data (*cfr infra*: *e.g.* Staff)

### *3.2.2 Various new product/system/interface developments*

Development of new products and interfaces occurred for a large part within consortia with external partners through external project funding (EU-FP7, EU-Horizon2020, ESA SSA). Integration in the nominal operations to be performed.

- FP7 COMESEP
    - Automated Proton/geomagnetic storm alert service (comesep.eu/alert/). Seeded and triggered by SIDC alerts.

- Proved very accurate in e.g. last February 25 event.

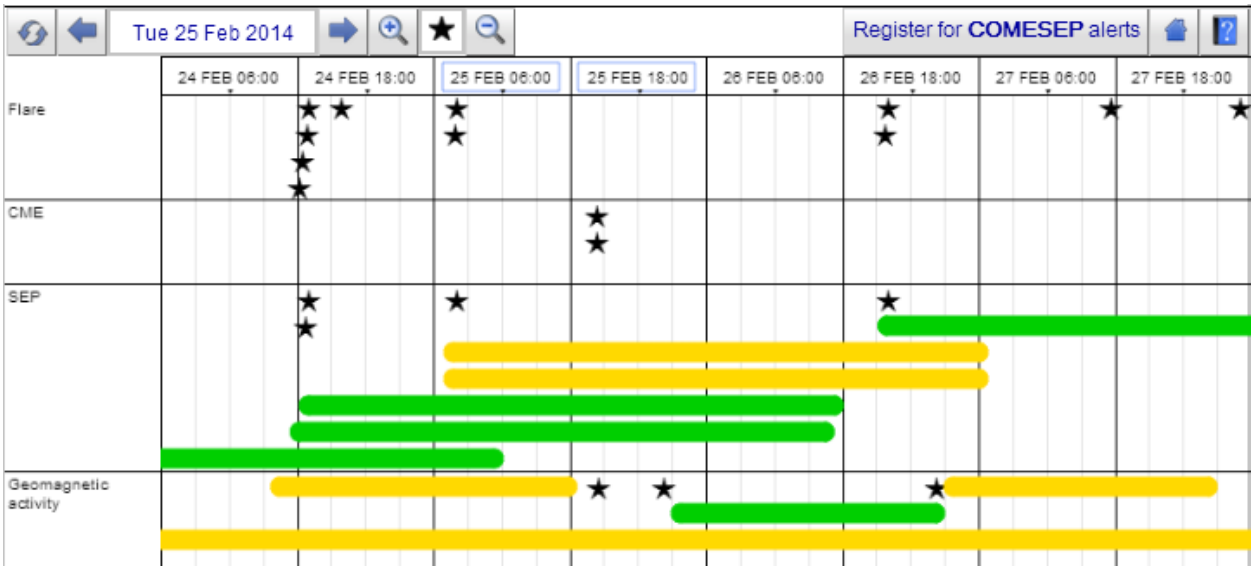



*Illustration 2: Example COMESEP visual alert interface.*

```
:Issued: 2014 Feb 25 0145 UTC
:Product: documentation at http://www.comesep.eu
#-----------------------------------------------------------------#
# COMESEP SEP Forecast message from BIRA-IASB (Brussels, Belgium),   #
# forwarded by the SIDC (RWC-Belgium)                               #
#-----------------------------------------------------------------#

Forecast for a SEP radiation storm following a X4.9 flare with peak at
2014-02-25 00:49UT. The expected risk level is MEDIUM for a SEP storm of
protons > 10 MeV (occurance probability: POSSIBLE; storm level: MODERATE).
The expected risk level is MEDIUM for a SEP storm of protons > 60 MeV (occurance
probability: POSSIBLE; storm level: MODERATE).

#-----------------------------------------------------------------#
# Solar Influences Data analysis Center - RWC Belgium               #
# Royal Observatory of Belgium                                    #
# Fax : 32 (0) 2 373 0 224                                        #
# Tel.: 32 (0) 2 373 0 491                                        #
#                                                                 #
# For more information, see http://www.sidc.be.  Please do not reply #
# directly to this message, but send comments and suggestions to    #
# 'sidctech@oma.be'. If you are unable to use that address, use     #
# 'rvdlinden@spd.aas.org' instead.                                  #
# To unsubscribe, visit http://sidc.be/registration/unsub.php       #
#-----------------------------------------------------------------#
```

*Illustration 3: Example COMESEP alert message.*

- FP7 AFFECTS
  - Alert products tailored to GNSS users (seeded and triggered by SIDC alerts)
  - Solar Demon: a flare (as well as dimming and EUV wave) detection algorithm based on SDO AIA 94 images. Running realtime with detection and flare localisation (with AR matching) mostly up to date within less than 20 minutes.
  - STAFF a graphical dynamic timeline plotting user interface: choose data and time, zoom

- SoFast: Solar flare detector on PROBA2/SWAP images
- Hellcats: extension of Cactus to HI

Many of these projects have resulted in valuable experience on multiple aspects to be addressed in the near future developments of the central forecasting office operations:

- Dynamic user interfaces
- Event and alert follow-up workflow management
- Definition of message formats for interoperability (interfacing to customer subsystems)

### *3.2.3 Other*

SW briefings: weekly overview by the forecaster, can be followed remotely by interested parties through WebEx. Please send me an email if you want to receive invitations to the Webex.

## Solar Demon - Flare Detection

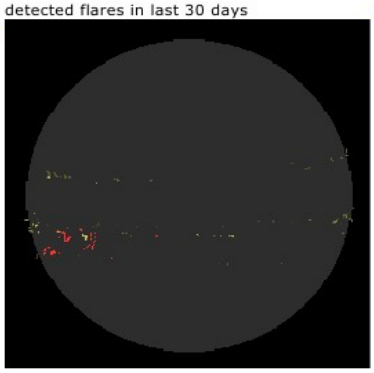
running in real time on SDO/AIA 94 QKL data
3 minute cadence, typical delay 15 minutes
(view all Solar Demon detection tools)

**Detector 24h operating status:**

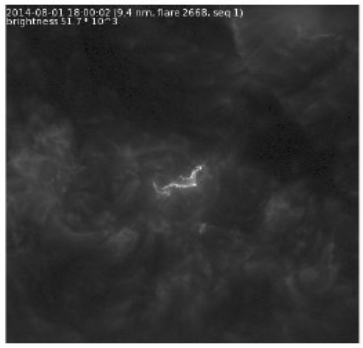
**Last processed image:**
0 hours and 19 minutes ago (2014-08-01 18:06 UTC)
**Last detected flare:**
0 hours and 19 minutes ago (2014-08-01 18:06 UTC)

**Filters (category)**
-- *All classes*
Only C class flares and above
Only M class flares and above
Only X class flares and above
**Filters (time)**
Show all
-- *Last week*
Last 30 days
Last 365 days

detected flares in last 30 days



Flare 2668




**Overview of flares**

| | est. class | start | peak | end | # | lat | lon | dist. R☉ | AR | est. flux | GOES flux | GOES peak time | | COMESEP | # det. | dimming |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **August, 2014** | | | | | | | | | | | | | | | | |
| 1 | M1 | 18:00 | 18:06 | 18:06 | 2668 | -10 | -12 | 0.33 | AR 2127 | 104.5 | 153.0 | 18:12 | 6 | 2 | 3 | |
| 1 | M2 | 14:48 | 14:54 | 15:42 | 2667 | -9 | -36 | 0.66 | AR 2130 | 167.7 | **204.0** | 14:48 | -6 | 98312 | 19 | |
| 1 | B4 | 13:57 | 13:57 | 13:57 | 2666 | -12 | -35 | 0.64 | AR 2130 | 3.6 | **24.7** | 13:56 | -1 | 0 | 1 | |
| 1 | C2 | 11:39 | 11:42 | 12:06 | 2665 | -9 | -37 | 0.68 | AR 2130 | 19.3 | 48.0 | 11:43 | 1 | 0 | 10 | |
| 1 | B5 | 05:24 | 05:27 | 05:30 | 2664 | -19 | -30 | 0.63 | AR 2131 | 4.9 | **14.3** | 05:23 | -4 | 0 | 3 | |
| 1 | B3 | 03:21 | 03:21 | 03:21 | 2663 | -18 | -57 | 0.88 | AR 2132 | 3.4 | **14.1** | 03:18 | -3 | 0 | 1 | |
| 1 | C2 | 01:18 | 01:21 | 01:48 | 2662 | -18 | -60 | 0.91 | AR 2132 | 24.7 | **31.6** | 01:17 | -4 | 0 | 11 | |
| 1 | C9 | 00:15 | 00:21 | 01:15 | 2661 | -17 | -60 | 0.92 | AR 2132 | 86.7 | **86.7** | 00:18 | -3 | 98308 | 21 | |
| **July, 2014** | | | | | | | | | | | | | | | | |
| 31 | B9 | 21:15 | 21:21 | 21:27 | 2660 | -12 | -48 | 0.79 | AR 2130 | 9.0 | **24.0** | 21:17 | -4 | 0 | 5 | |
| 31 | B6 | 18:54 | 18:57 | 19:03 | 2659 | -17 | -63 | 0.93 | | 6.3 | **19.8** | 18:55 | -2 | 0 | 4 | |
| 31 | C1 | 14:30 | 14:39 | 14:51 | 2658 | -18 | -67 | 0.95 | | 9.8 | **17.3** | 14:34 | -5 | 0 | 8 | |
| 31 | M2 | 10:30 | 11:18 | 11:54 | 2657 | -10 | -51 | 0.87 | AR 2130 | 207.2 | **255.0** | 11:14 | -4 | 98310 | 27 | |
| 31 | C1 | 09:21 | 09:24 | 09:27 | 2656 | -10 | -53 | 0.83 | AR 2130 | 10.9 | **18.6** | 09:21 | -3 | 0 | 3 | |
| 31 | C1 | 05:12 | 05:12 | 05:15 | 2655 | -10 | -55 | 0.84 | AR 2130 | 10.3 | **17.4** | 05:10 | -2 | 0 | 2 | |
| 30 | C2 | 18:48 | 18:54 | 19:06 | 2653 | -8 | -42 | 0.70 | AR 2127 | 17.9 | **36.1** | 18:48 | -6 | 0 | 7 | |
| 30 | C7 | 16:09 | 16:27 | 17:36 | 2652 | -11 | -40 | 0.69 | AR 2127 | 74.5 | **90.4** | 16:17 | -10 | 98308 | 30 | |
| 30 | C1 | 05:48 | 05:57 | 06:09 | 2651 | -8 | -49 | 0.78 | AR 2127 | 12.4 | **20.0** | 05:48 | -9 | 0 | 8 | |
| 30 | C2 | 02:48 | 02:51 | 02:57 | 2650 | -9 | -72 | 0.96 | AR 2130 | 17.8 | **37.0** | 02:46 | -5 | 0 | 4 | |

*Illustration 4: Sample output of Solar Demon running in real time mode*

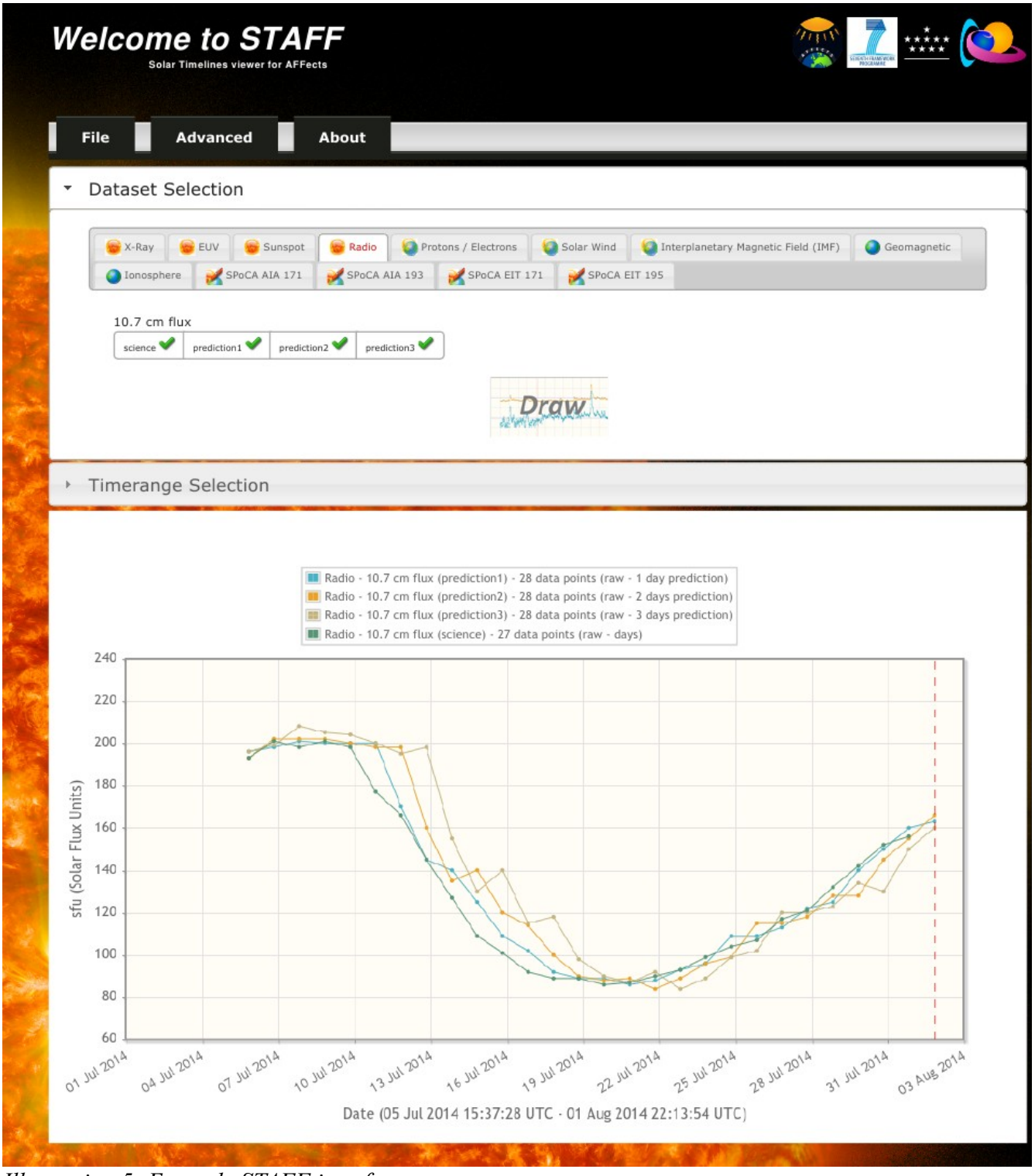



*Illustration 5: Example STAFF interface*

## 3.3 Operations in the ESA SSA framework

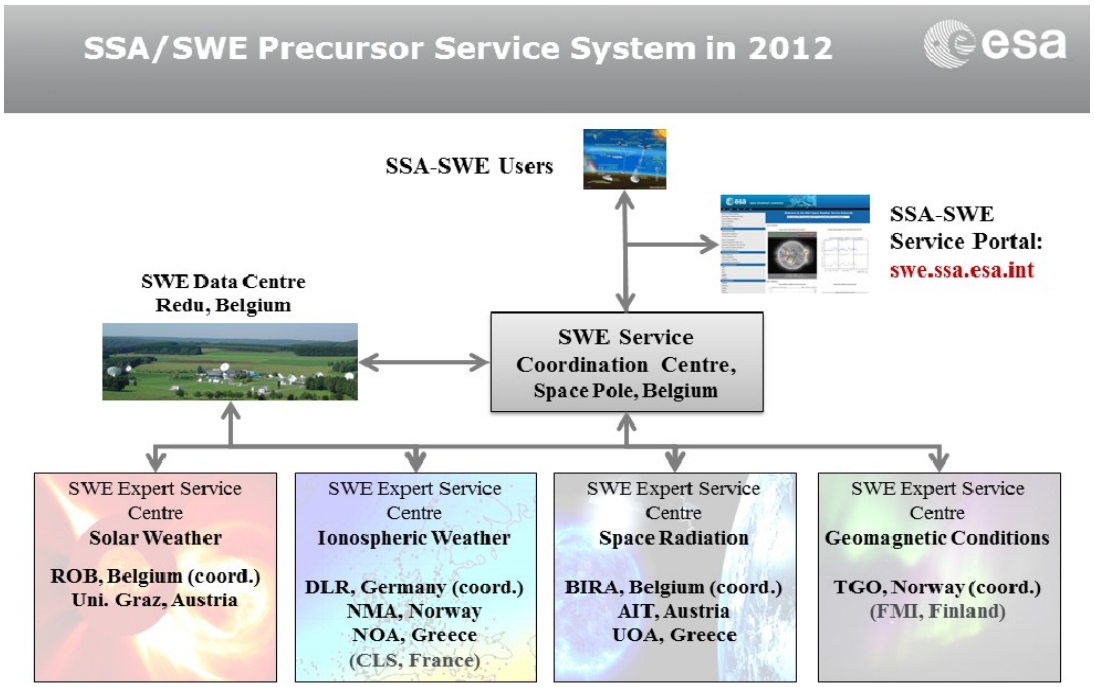



*Illustration 7: The federated ESA SSA SWE network during the precursor phase.*

The SSA program is an optional ESA program which is currently entering phase 2 following the earlier Preparatory phase. There are three segments in the program: Space Weather, Space Surveillance and Tracking, and Near Earth Objects.
The SIDC was, in various partnerships, involved in several of the Space Weather segment (SSA-SWE) contracts.

- SIDC takes the role (together with University of Graz) of the "Solar Weather Expert Centre" within the federated ESA SSA SWE network. The network is to be developed further and extended under a new ESA contract (ITT SSA P2-SWE-1) for which a bid was submitted in February → awaiting ESA decision.
- Under sister institute BISA lead (and private company partners) SIDC operates the central node of the network: the SSCC (Space Weather Services Coordination Centre), located at the Space Pool in Brussels. Contract near end, bid for new contract ITT was submitted → awaiting ESA decision.

*Illustration 8: April 3, 2014: During the official inauguration of the SSCC, Philippe Mettens, head of the Belgian Science Policy Office (left) and Thomas Reiter, ESA Director of Human Spaceflight and Operations (right) are cutting the ribbon.*

- As part of the SSCC operations, specific tailored Space Weather support was provided to some ESA missions:
  - GAIA launch (Mid December) and GAIA trajectory transfer (Early January).
  - Venus Express Aerobreaking campaign (May through to July). Customised daily SW message adjusted for the Venus position.

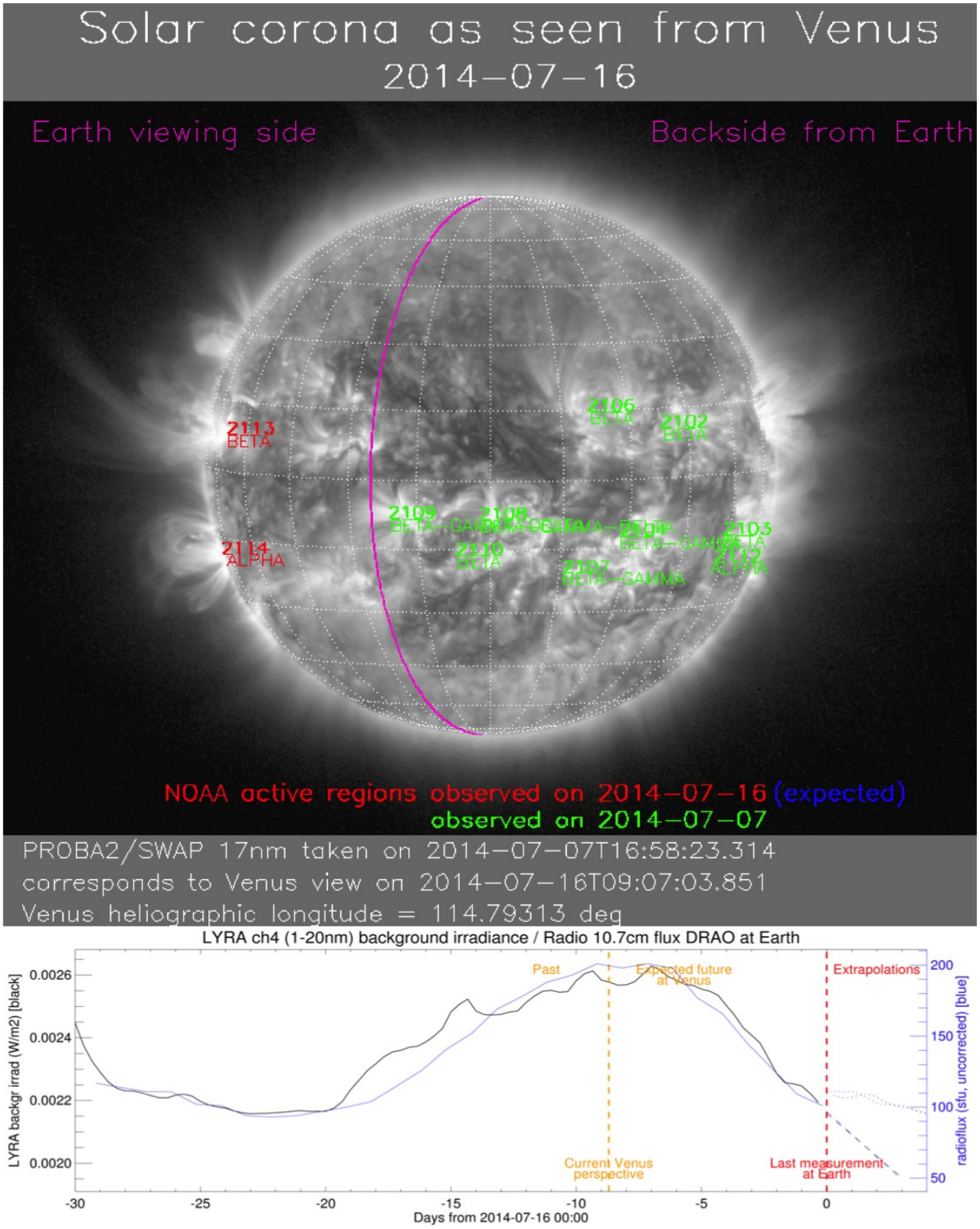



*Illustration 9: Part of the Venus Express Aerobreaking campaign SW support messages. Proxy to the Solar Corona as well as background irradiance as viewed from Venus position. Both are obtained from transformation of the corresponding earlier observations from Earth viewpoint.*

## 3.4 Customer/User impact summary

We have currently well over 2000 subscribers to our email services, with the most popular products: Presto, flaremail and daily Ursigram; in line with the priority products specified earlier.
Over the last years we observe increased (and more concrete) interest from many external parties: civil protection authorities, aviation authorities, defence, private communication companies (all of them not restricted to Belgium, but including surrounding countries and the European level). Space Weather is surely monitored through our products by many of these. The main conclusion from our contacts with these parties is the need to develop standards, interoperable formats and procedures.

## 3.5 Forecast Verification

### *3.5.1 What and how*

Verification analysis was performed on the following data sets:

- full disc flare predictions
- F10.7 predictions with 1,2 and 3 day lead time.
- K (max. predicted K over 48 hours) index compared to Chambon-la-Forêt (local Dourbes data gaps)

Comparison was to a number of model predictions:

- persistence
- recurrence
- corrected recurrence.

Applied methods were:

- error analysis with skill scores
- hit/miss statistics (binary contingency table): Probability of detection, False Alarm Ratio, Proportion Correctness, Biass, Heidke and True Skill Score.

### *3.5.2 Results*

- F10.7:
  - 1day lead: SIDC performs best
  - 2 and 3-day lead: persistence and/or corrected recurrence are, from a long term statistics point of view, performing better. (But only aiming at long term statistics can be misleading.)
- Flaring:
  - SIDC performs good
  - trend to underestimate M and X flares: This is not necessarily a bad thing, as it means few false alerts. The included methods which do not underestimate have a massive number of false alerts: What does the customer actually prefer?
  - Error analysis dominated by large periods with absence of large flares. Therefore skill analysis restricted to M and X flares. This confirms the statement above. The models often outperform in terms of Probability of detection, but in Proportion Correctness SIDC clearly outperforms the models.
  - Quite some variation in Skill scores between forecasters.
- K index:
  - SIDC performs good
  - low K is generally overestimated / high K is often underestimated: This is understood as a general problem in Event/Event level prediction: The communicated values are somewhat a

convolution of the probability of occurrence and the expected magnitude.

- As with the flares an event/non-event statistics were performed counting K>4 as a geomagnetic storm. This confirms that the SIDC predicts well the event, certainly in Proportion Correctness but also in Probability of Detection (except, understandably, near Solar minimum).

These results have been submitted for publication in Journal of Space Weather and Space Climate.

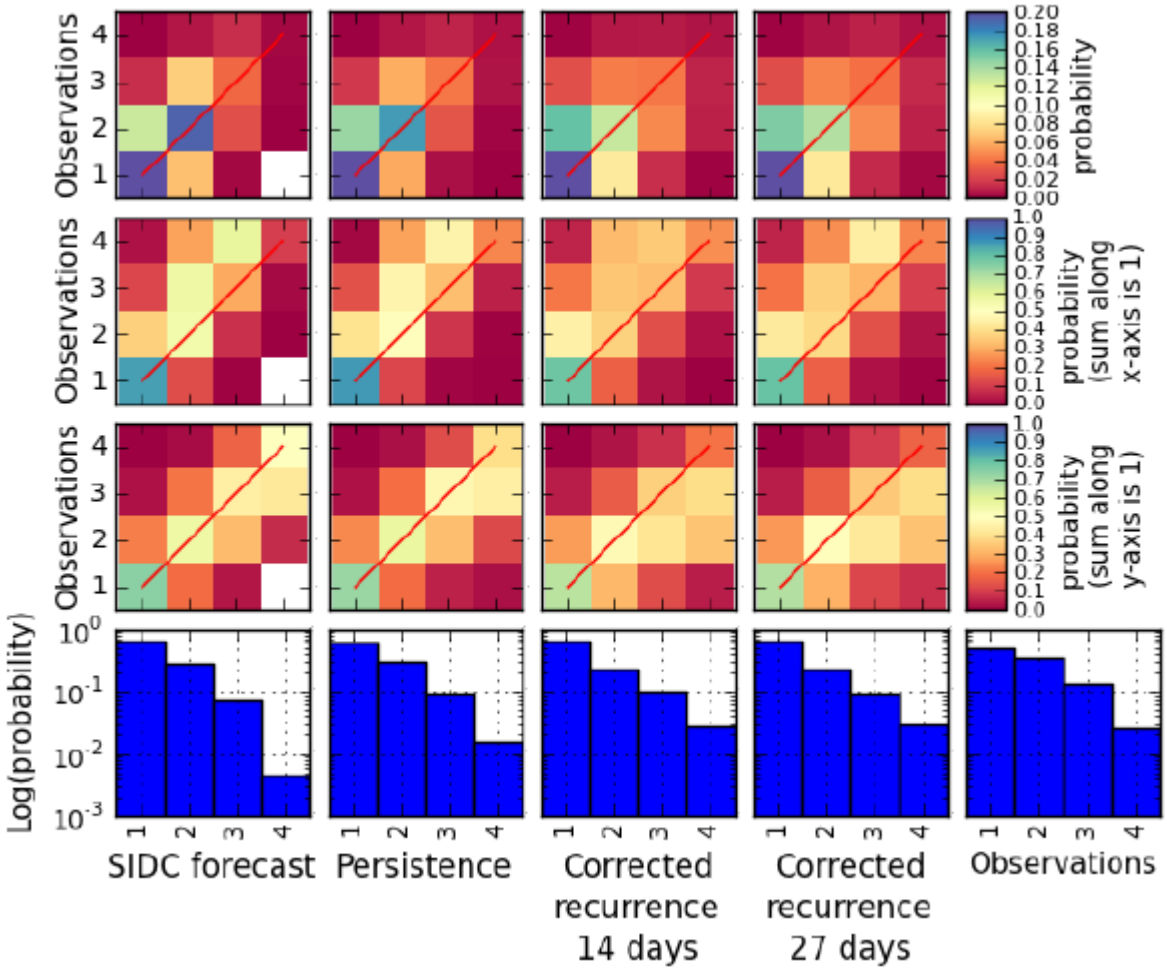



*Illustration 10: Flare prediction probability matrix: x-axis is the forecasted value, y-axis is the observed value. Second and third rows are normalised to show conditional probabilities respectively given that a certain value was observed and given that a certain value was predicted. This illustrates the trend to over/underestimate.*

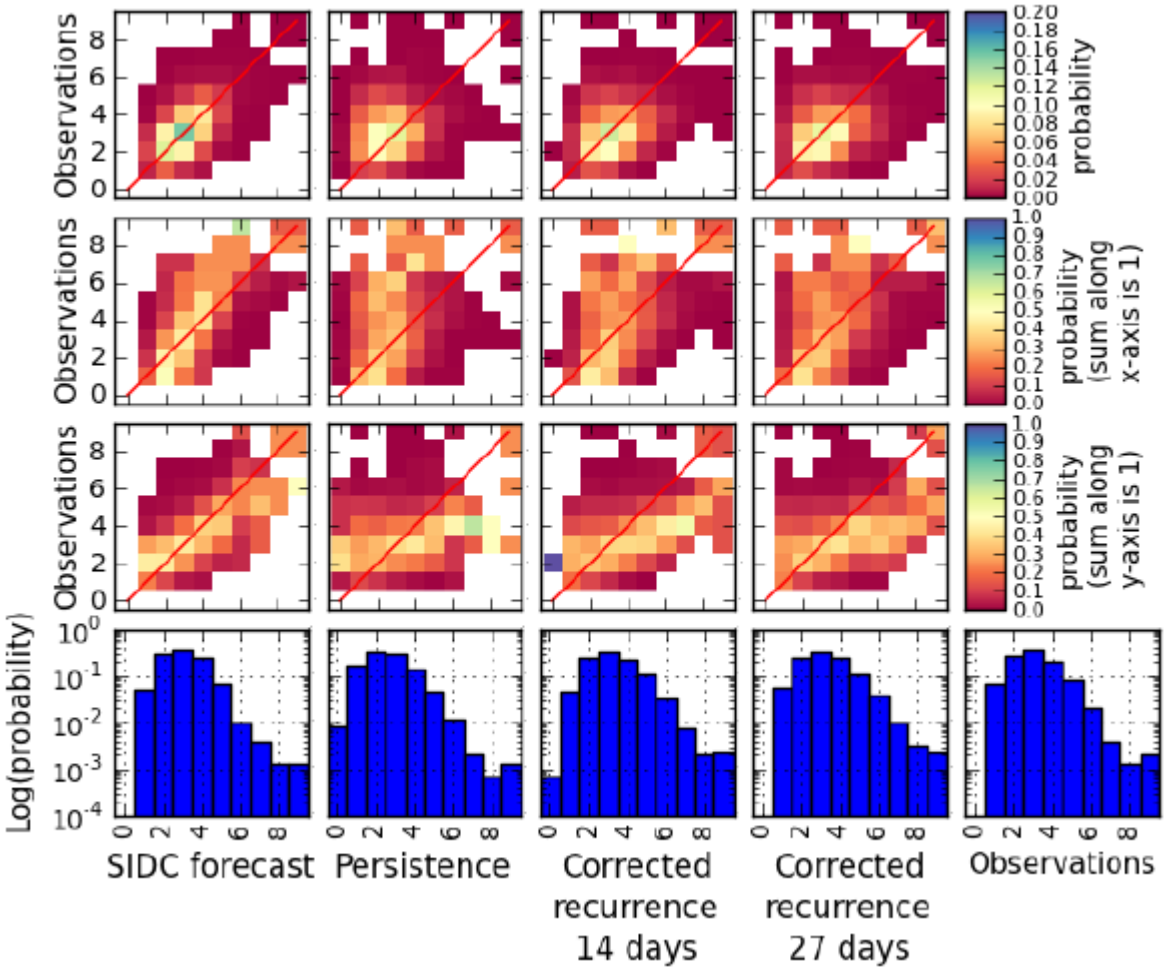



*Illustration 11: Geomagnetic storm prediction probability matrix: x-axis is the forecasted value, y-axis is the observed value. Second and third rows are normalised to show conditional probabilities respectively given that a certain value was observed and given that a certain value was predicted. This illustrates the trend to over/underestimate.*

### *3.5.3 Lessons learned and comments*

Performing meaningful verification analysis is not straightforward but is complicated by choosing the right statistic to be used. This is not only a technical problem. Problems already arise at the level of defining what is actually the meaning of your forecast. Take *e.g.* the ISES scales on flare predictions "eruptive= C-flares likely, probability > 50%". We often indicate this level while our more detailed predictions indicate probability levels say between 50% and 75%. This actually means we anticipate to be wrong 1 out of 4 days when we are making such prediction! Similar complications were already noted above such as the convolution of event probability with expected event level.

Another interesting subtopic in this area is the provision of error bars to the customer. It is again not straightforward to define how this has to be done. The first idea may be to use long term statistics from the verification analysis. However, when bluntly implemented that way, it is of limited use to the customer. We are in fact kicking off a study to investigate how we can, in a self consistent way, communicate and quantify to the customer the reliability of the forecast (which may vary from day to day depending on the conditions). This should for example adequately address the above identified

issue that the reliability of M and X flare predictions is much lower than that of C-flares. This would actually provide a more quantitative analogue of the current textual phrases “C flares expected with only a slight chance on an M flare” *vs.* “C flares expected with also an M flare possible”.

## 4 Research and data-distribution projects

In addition to the activities listed in the Forecast Office section for their direct relevance and impact on the forecast office operations, the RWC activities are further supported by continuous scientific Space Weather research. Publication statistics may be obtained from http://sidc.be/publications/.

The STCE funding mentioned earlier specifically enables to combine the expertise within the Space Pool institutes. Various workshops are organised within that STCE framework. This year:

- Modelling of antennas and calibration of radio instruments, June 6, 2014
- Physical Processes in Solar-Terrestrial Plasmas, 20, 22 and 23 May, 2014
- Long term solar changes, May 19, 2014
- Tomography and 3D reconstruction, April 7, 2014
- Science and science operations of the PROBA satellite fleet, March 31, 2014

In addition to pure research our services are also dedicated to the storage and dissemination scientific data. At least two initiatives need be mentioned here:

- Space Weather Helioviewer: Under an ESA-GSTP contract enhancements to the Helioviewer software are developed targeted at Space Weather research and operations. During the partial shutdown of the US federal government, resulting also in the shutdown of the Helioviewer server at NASA-GSFC in October 2013, a redundant server was set up at the Royal Observatory of Belgium.
- SDO data archive mirror, see http://sdoatsidc.oma.be/web/sdoatsidc/

## 5 Dissemination activities

- European Space Weather Week:
  - Week long conference gathering 300+ participants, scientists, users, operators as well as industry.
  - Last edition ESWW10, 18-22 November 2013: Antwerp
  - Next edition: ESWW11, 17-21 November 2014, Liège
- Space Weather for Engineers:
  - A training school targeted at industry personnel to learn how Space Weather may interfere with their technology and systems, and most importantly: how space weather information may help them to protect their technology and operations.
  - First edition: November 12-15, 2013. *HF communication, trans-ionospheric propagation and GNSS signal precision*
  - Second edition: October 15-17, 2014. *HF communication, trans-ionospheric propagation and GNSS signal precision*
  - 2015 edition: different topic tbd.