FORSPEF: an operational service for the prediction of Solar Energetic Particle Events and Flares

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Solar flares, CMEs and SEPs:

Background

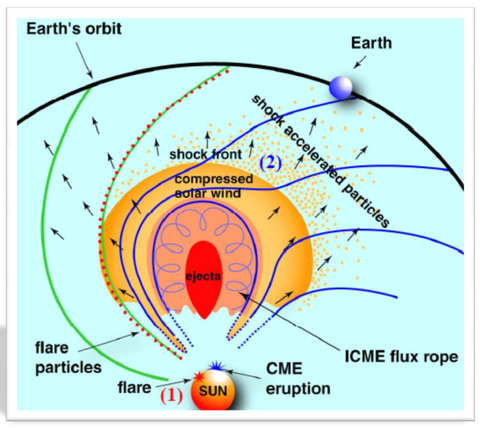


*Figure 1. Solar Particle Events and their parent solar events (**solar flares – [1]** and **coronal mass ejections – [2]**)*

>The **Solar Particle Events** appear when particles released by the Sun, accelerate at higher energies.

> Causes of SPEs: **solar flares** and/or **Coronal Mass Ejections** (CMEs)

> Particles are finally guided to the observing point by the Interplanetary Magnetic Field (IMF) lines.

The FORSPEF system:

> The ***main objective*** of **FORSPEF** is to develop a web based tool capable of making ***3-tier*** forecasts of **Solar Particle Events (SPEs)** and **Flares** in order to support the **ESA launch operations.**

> The **basic operations** of the **FORSPEF system** is presented in ***Figure 2***

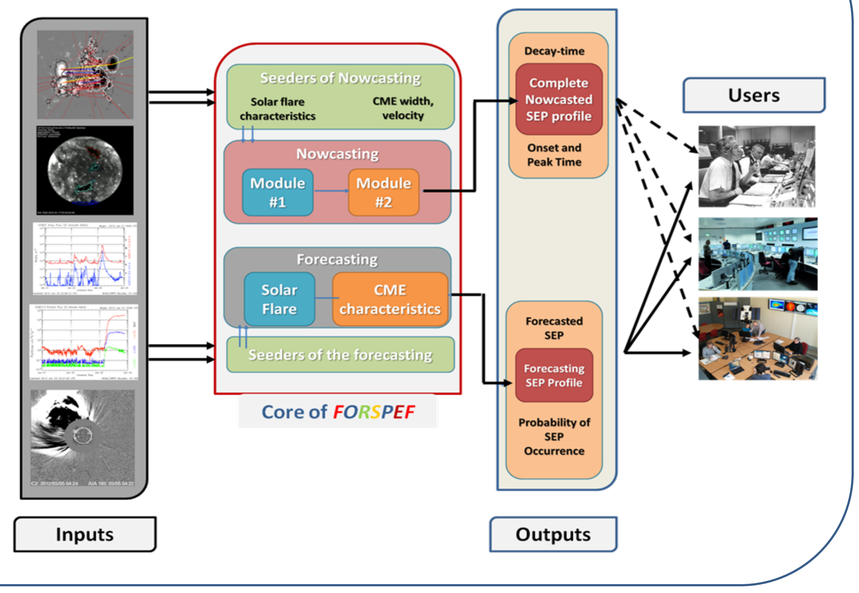


Figure 2 A conceptual block diagram of the FORSPEF system

Forecasting Solar Flares:

✓The **Solar Flare Prediction** will rely primarily on the "**effective connected magnetic field strength**" (B_{eff}) prediction metric (*Georgoulis and Rust, 2007; Georgoulis, 2008*) and secondarily on the **total unsigned magnetic flux**, in case B_{eff} cannot be applied easily (active-region location beyond 60º in central meridian distance).

✓Detection will be performed on periodically downloaded *latest* solar magnetogram data from SDO/HMI. These data correspond to the full-disk line-of-sight (LOS) solar magnetic field component (see ***Figure 3***).

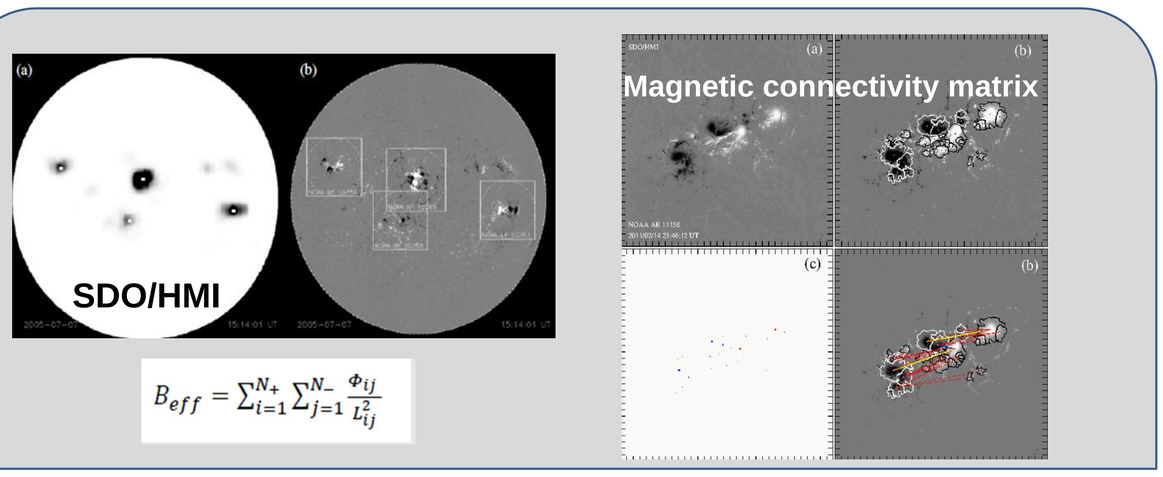


Figure 3. Illustration of the solar flare forecasting work scheme

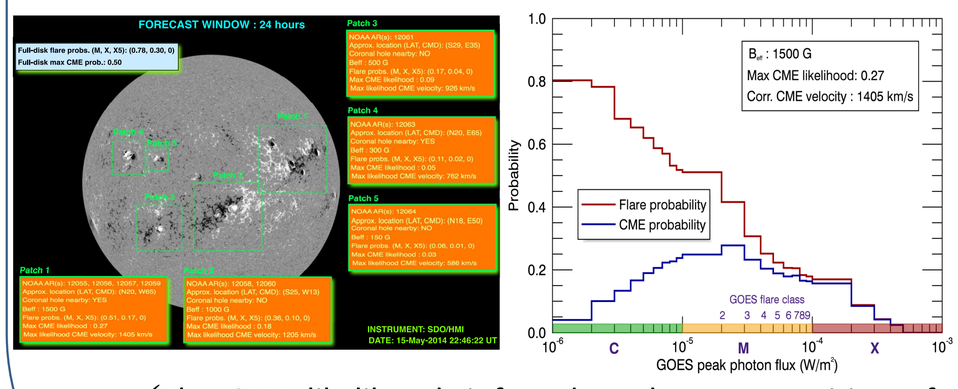


Figure 4. Mock-up image of an indicative output forecast window based on a full-disk SDO/HMI magnetogram of 2014 May 15 (left panel) and the corresponding derived probability for flares and projected CME characteristics (right panel)

✓The CME likelihood, inferred as the superposition of two sigmoidal fitting curves (namely those of the flare probability and the flare-CME association) presents a maximum at ~0.27;this can be treated as the maximum CME likelihood (see ***Figure 4 (right panel)***).

Forecasting Solar Particle Events:

✓The core of the SPEs prediction is based on a purely statistical approach. This has proven to be the key ingredient for SPE prognosis in a number of cases (*Balch, 2008; Laurenza et al., 2009; Nunez, 2011*). In the proposed scheme the statistics has been built for the first time upon **calibrated GOES proton data** and cover a wide time period from **1984-2013** (see ***Figure 5 (left panel)***).

✓ In ***Figure 5 (right panel)*** we present the flux of the flares (in W/m²) as a function of longitude (in degrees) for our total sample of events in our newly constructed database. One may notice that **lack of SPEs in the case of eastern and relatively weak flares** whereas the **majority of intense western flares are SPE flares.**

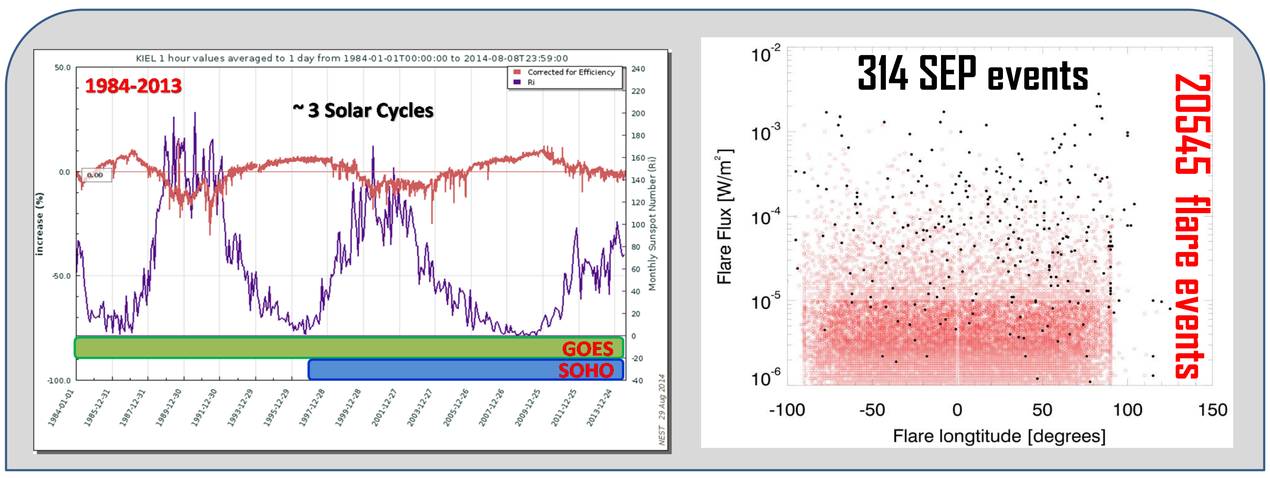


Figure 5. Time span of the database (left panel). The flares associated with SEP events are presented by the filled black circles and all other (non SEP flares) by the open red circles (right panel)

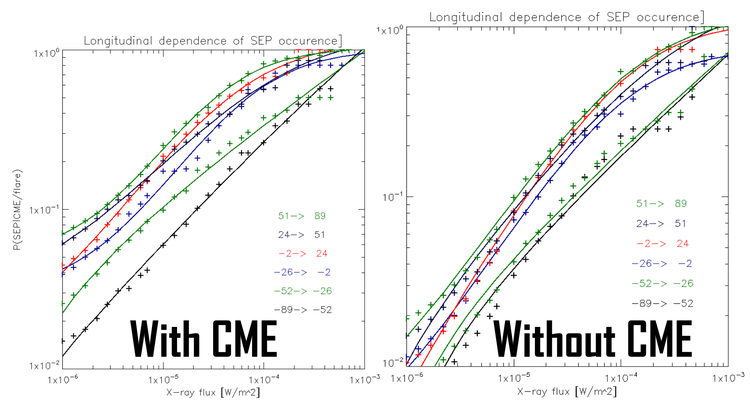
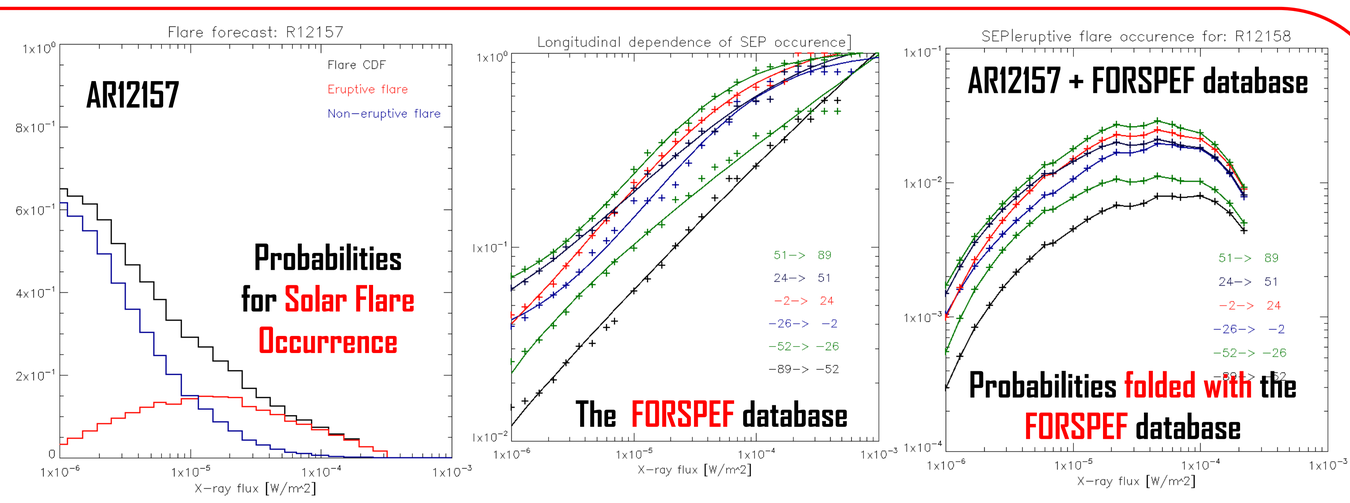


Figure 6. SEP probability of occurrence as a function of X-ray flux, for flares without CME (blue line) and flares with CME (blue line)

✓ FORSPEF provides the **probability of SEP occurrence** based on the information of solar flares with known characteristics (see ***Figure 6***).

✓The **occurrence of an SEP** – and the corresponding generated probability – **is controlled** by the **occurrence** (or **not**) of a **CME**.

Actual Work Scheme



For given **AR** the **probabilities of flare** and **CME occurrence** are derived

These probabilities are **folded with the FORSPEF database**

Conclusions

FORSPEF

> Incorporates **a novel method** for the **solar flare prediction** and **a new database of SEP events, solar flares and CMEs**.

> Makes use of **a uniform SEP dataset** (**GOES**), covering a **large time span** (**1984-2013**)

> Provides **forecasting of SEPs** based on **solar flare & projected CME** characteristics (e.g. speed)

This work has been funded through the FORSPEF: FORecasting Solar Particle Events and Flares, ESA Contract No. 4000109641/13/NL/AK

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