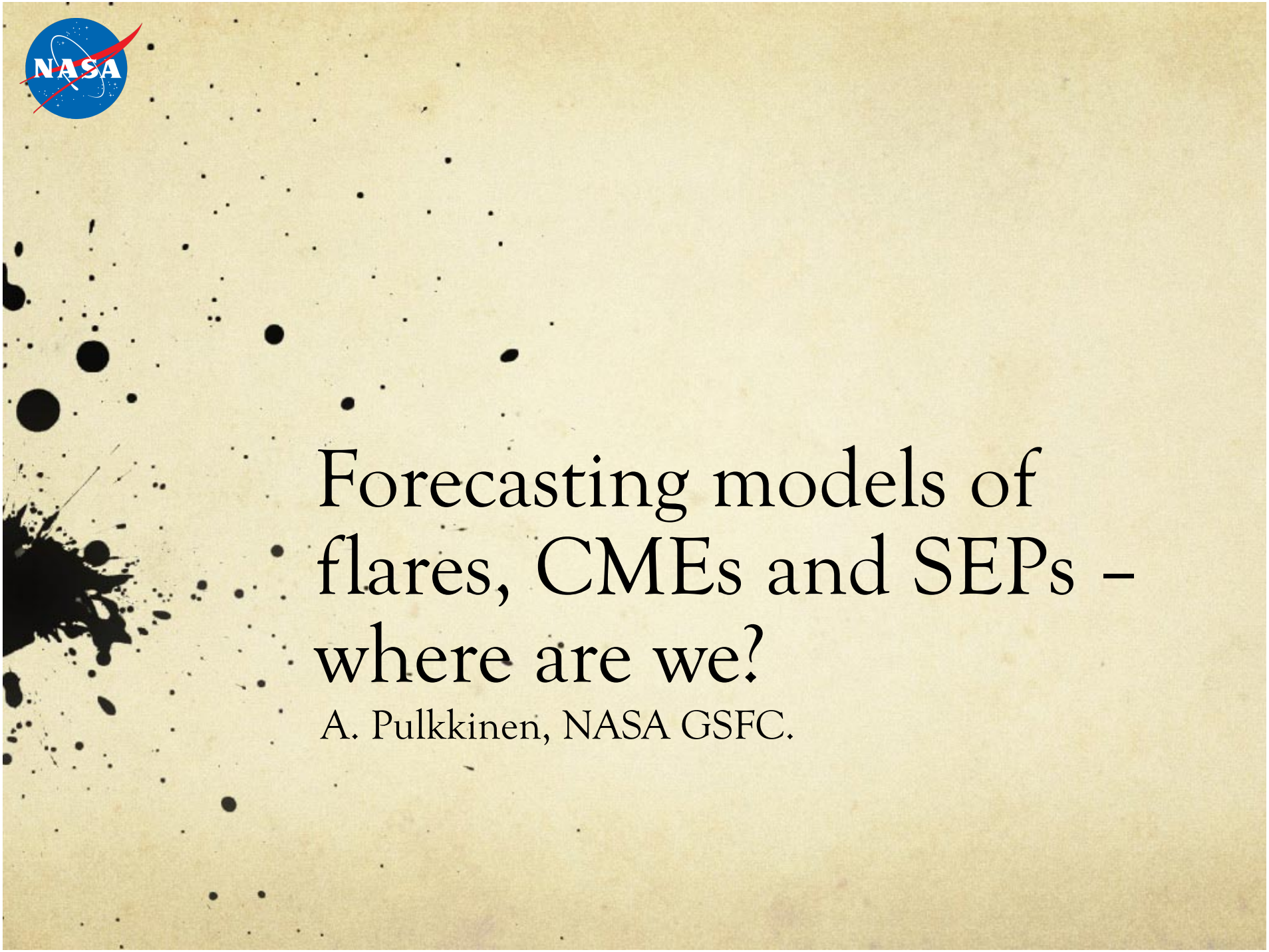
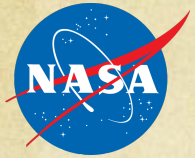


Forecasting models of flares, CMEs and SEPs – where are we?

A. Pulkkinen, NASA GSFC.

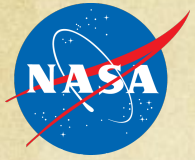
Contents

- Flares, coronal mass ejections (CME) and solar energetic particles (SEP) 101.
- Forecasting – what can we do now?
- Future.



Flares, CMEs, SEPs 101

- Generally speaking, solar flares and associated SEPs and CMEs convert free magnetic energy into heat, non-thermal particle acceleration, electromagnetic radiation, plasma waves and bulk flows – we want to capture these processes for predictive purposes.
- The flaring process can be divided into three steps:
  - Energy build-up.
  - Energy release.
  - Energy transport.



Flares, CMEs, SEPs 101

- Many large flares are associated with *coronal mass ejections* (CMEs) and *solar particle events* (SEPs).
- While the physics of the three phenomena are linked, we do not understand the details yet – predictive methods are still quite immature.

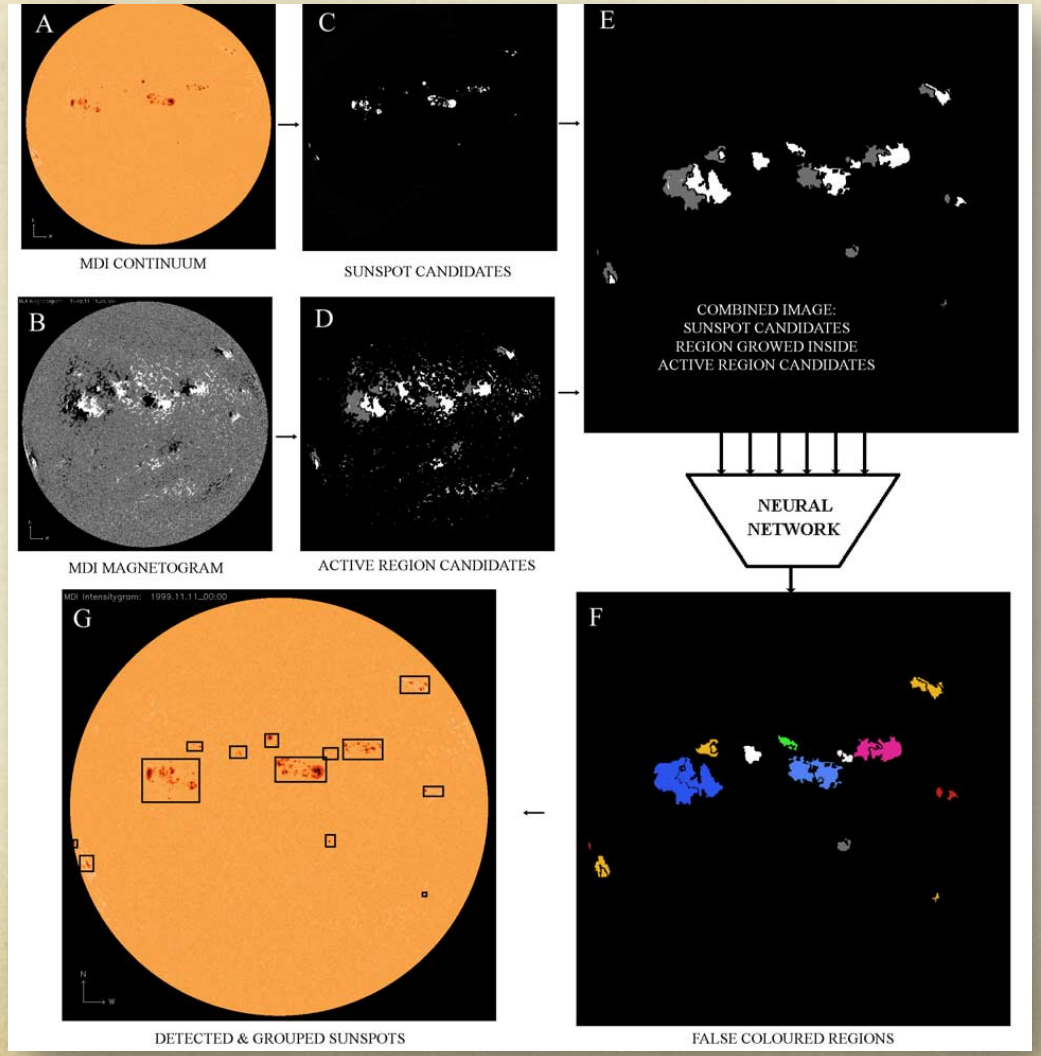
Flare, CME and SEP forecasts

- Optimally, from the physics viewpoint, we would like to forecasts eruptions and consequences using first-principles models.
- Current forecast methods can be classified roughly as *empirical*, *semi-empirical* and *first-principles*.
- Flare and SEP forecasts are currently empirical and/or semi-empirical. CME forecasts have entered the first-principles stage.
- We will demonstrate these using three different models to forecast flares, CME and SEPs (more models available via iSWA).

Automated Solar Activity Prediction (ASAP) model

- Empirical University of Bradford, UK model (Colak and R. Qahwaji, Space Weather, 2009).
- Uses SOHO/SDO continuum MDI/HMI continuum and magnetogram imagery to predict likelihood of flaring activity within next 24 hours.
- SOHO MDI data used to build the active region classification component of the model.
- NOAA sunspot classification and flare data for years 1982-2006 used for building the flare prediction component of the model.

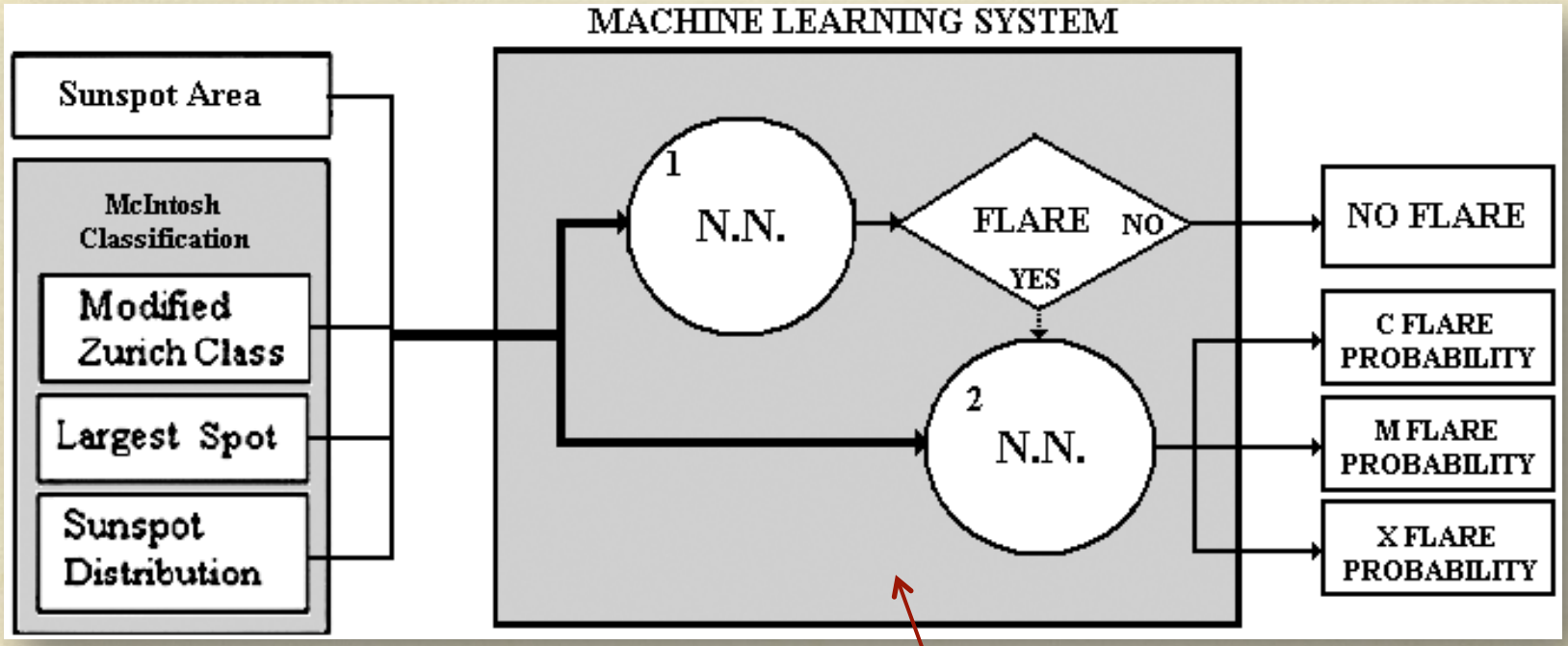
Automated Solar Activity Prediction (ASAP) model



McIntosh classification of the sunspot groups

ASAP active region detection and classification component (credit: *Colak and R. Qahwaji, 2009*).

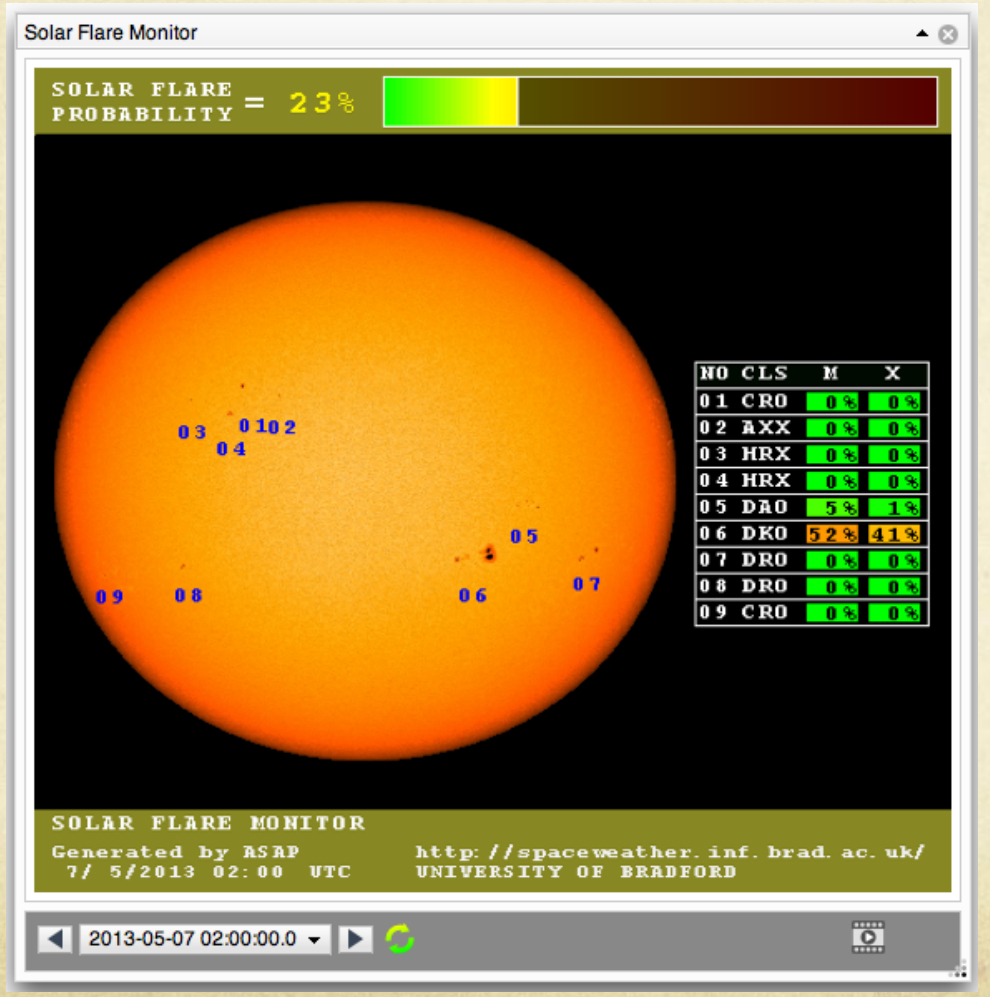
Automated Solar Activity Prediction (ASAP) model



ASAP flare prediction component (credit: *Colak and R. Qahwaji, 2009*).

"Black box" that tries to capture photospheric signatures pertaining to flare activity

Automated Solar Activity Prediction (ASAP) model



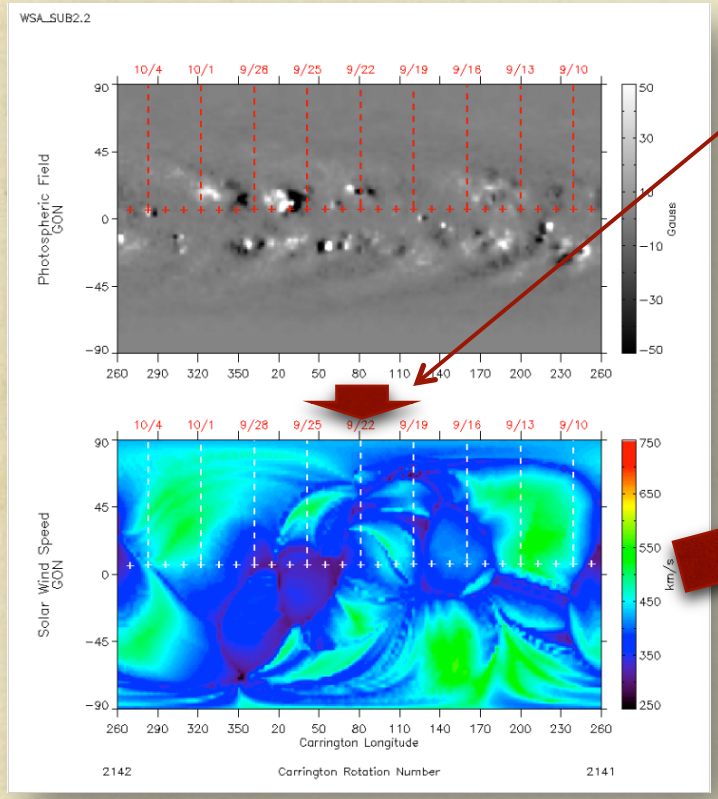
Example ASAP prediction (available via iSWA).

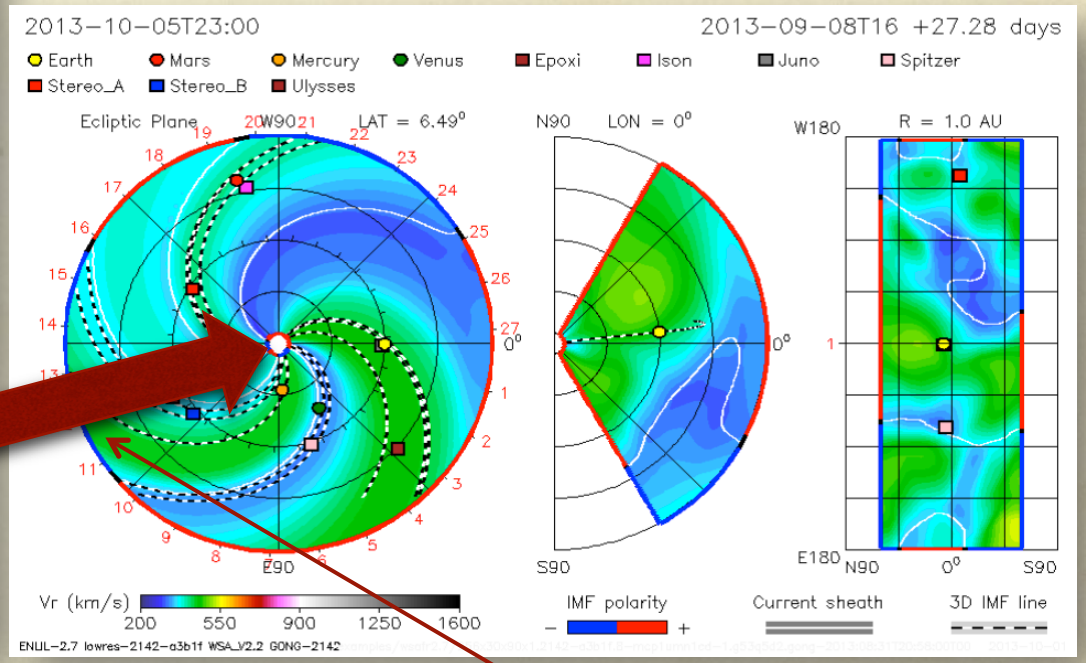
WSA-Enlil model

- Combination of semi-empirical and first-principles modeling of solar wind and CMEs (Odstricil et al., 1999; 2004; 2005).

WSA-Enlil model

Semi-empirical solution for solar wind flow at 21.5 Solar radii – photospheric magnetograms used as the driver data

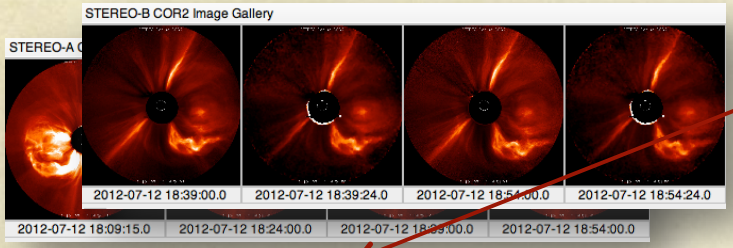




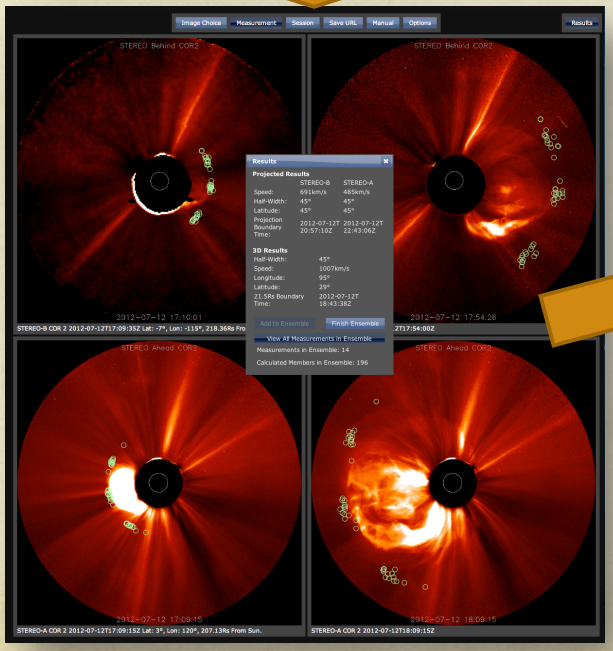
WSA-Enlil background solar wind solution (available via iSWA).

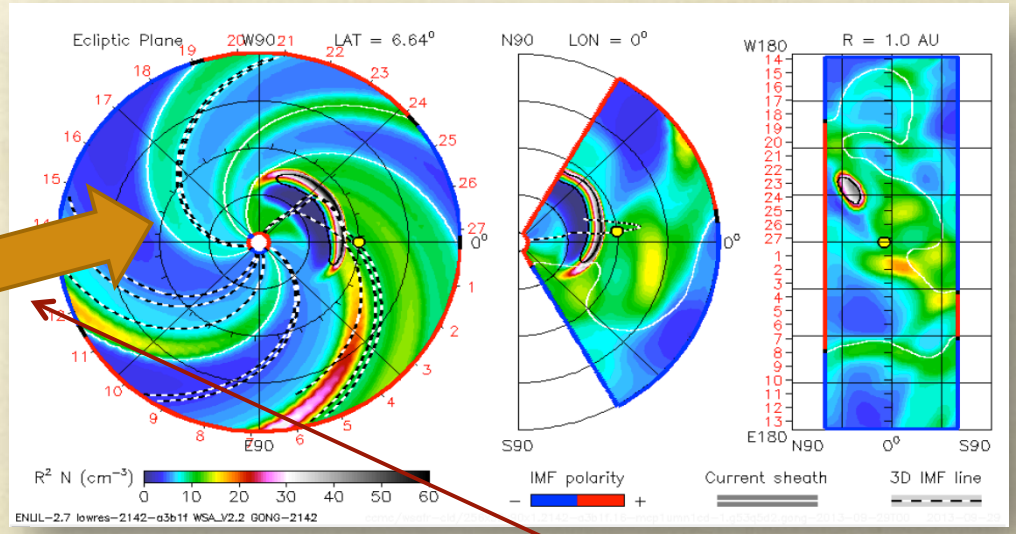
First-principles 3D solution for solar wind in the inner heliosphere

WSA-Enlil model



Coronagraph data used in a triangulation tool – STEREO A/B COR2 and SOHO LASCO C3 used as the driver data



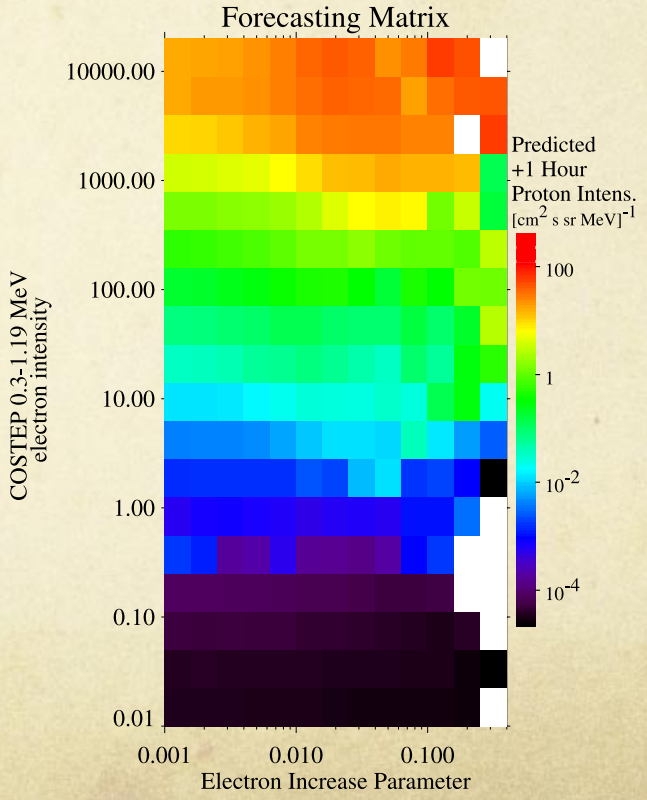


WSA-Enlil cone model for CMEs (available via iSWA).

Over-pressured “cone” transient inserted in the inner boundary to model CME propagation

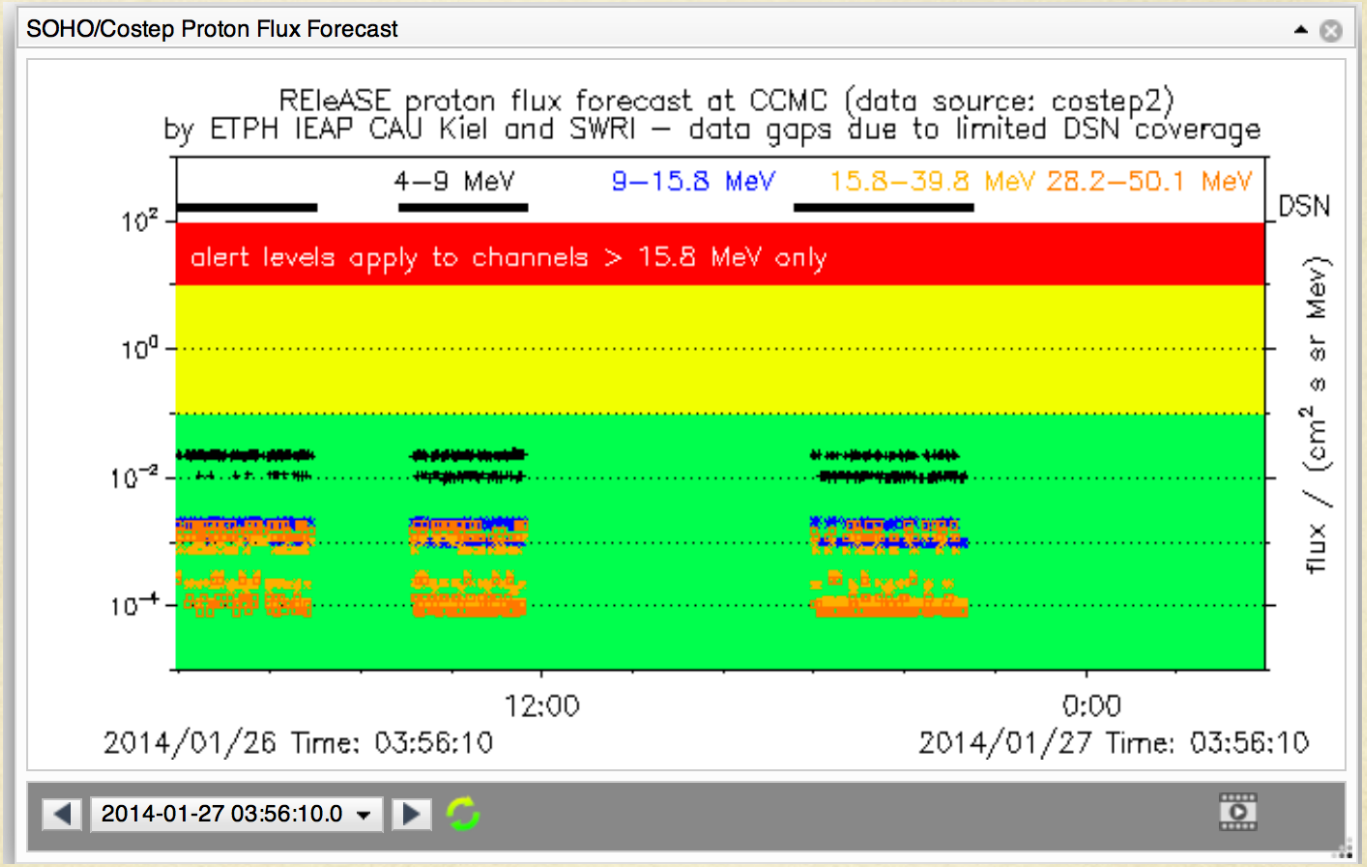
Release model

- Empirical model to predict energetic protons using ≈1 hour earlier arrival of energetic electrons (Posner, 2007).



Empirical relationship between energetic electrons and protons - SOHO COSTEP data used as the driver (Posner, 2007).

Release model



Release model energetic proton prediction (available via iSWA).

Future

- New NASA Living With Star projects attack the problem of first-principles modeling of solar eruptions from energy buildup to energy transport.
- Novel approaches will also include MHD description for CMEs coupled with kinetic description of the SEP component.
- These new models will be delivered to CCMC – stay tuned!