Using World Interplanetary Scintillation Systems for Space Weather Predictions

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http://ips.ucsd.edu/

Space Weather Predictions using IPS

Introduction:

IPS Space Weather Predictions

IPS Tomographic Analyses:

ISEE, Japan; The UCSD iterative kinematic prediction technique; Used primarily with ISEE observations, Other data sets can fill in; Used in space weather prediction elsewhere including at the CCMC, the KSWC, Jeju; RAL, UK; used at NICT, Japan.

IPS tomographic analysis displays:

Combined analysis from multiple IPS data sets, 3D-MHD forward modeling.

Magnetic field component forward-modeling – Br, Bt:

Part of the model package developed at UCSD.

Interesting Developments:

Bn determination via a simple technique (under development)

Thomson Scattering Analysis (Data Fitting Model at the CCMC)

Space Weather Predictions using IPS

The Solar Mass Ejection Imager (SMEI)

Jackson, B.V., *et al.*, 2004, *Solar Phys.*, 225, 177

Launch 6 January 2003
Closure 28 Sept 2011

Interplanetary Scintillation (IPS) Analysis (Data Fitting Model at the CCMC)

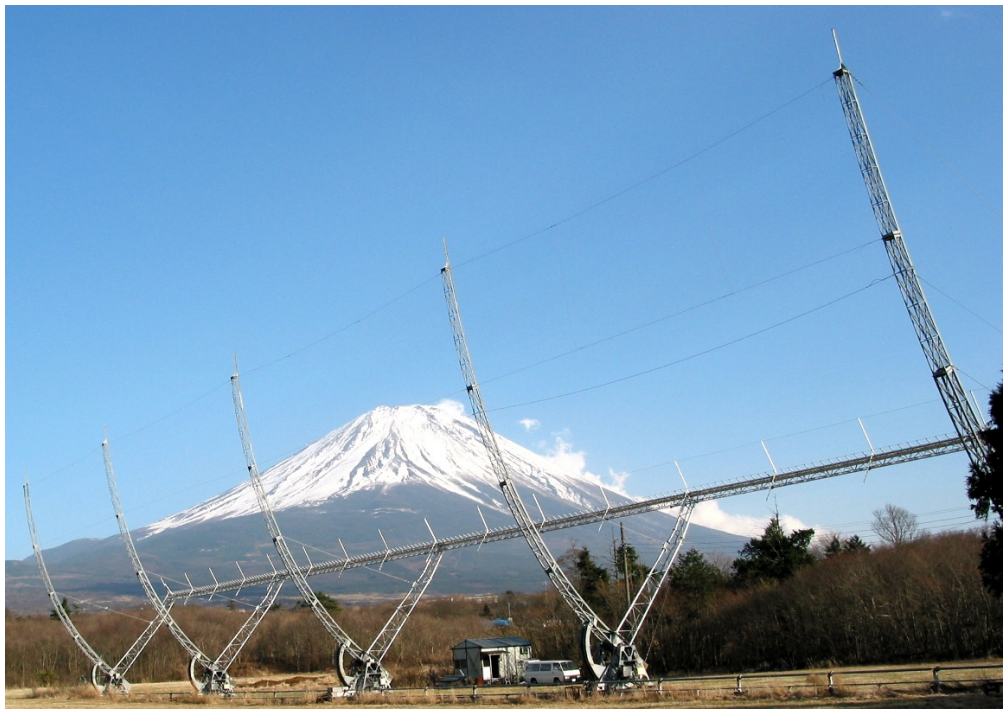
1 gigabyte/day; total ~4 terabytes

Simultaneous images from the three SMEI cameras.

Space Weather Predictions using IPS

DATA

IPS Heliospheric Analyses ISEE (STELab)



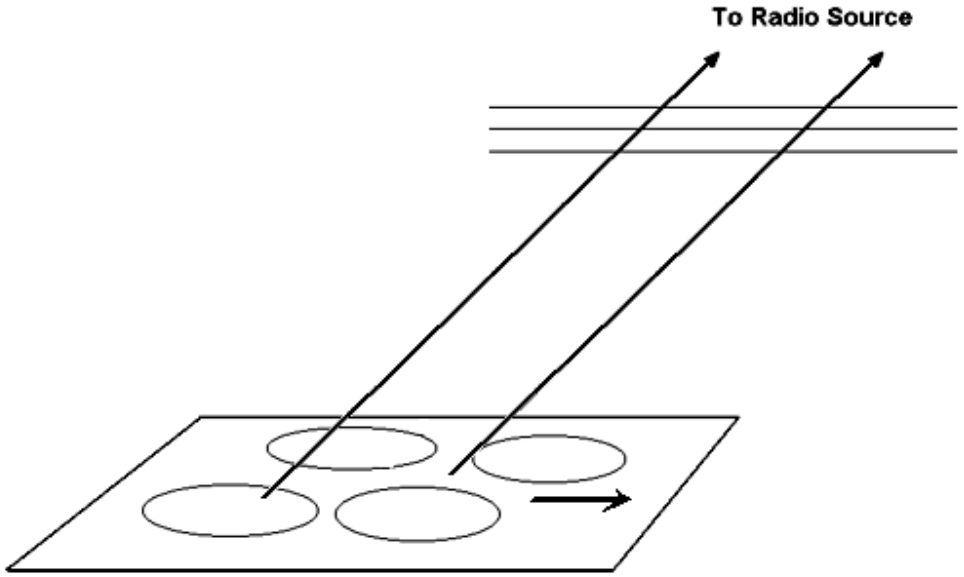
ISEE IPS array near Mt. Fuji

ISEE IPS array systems

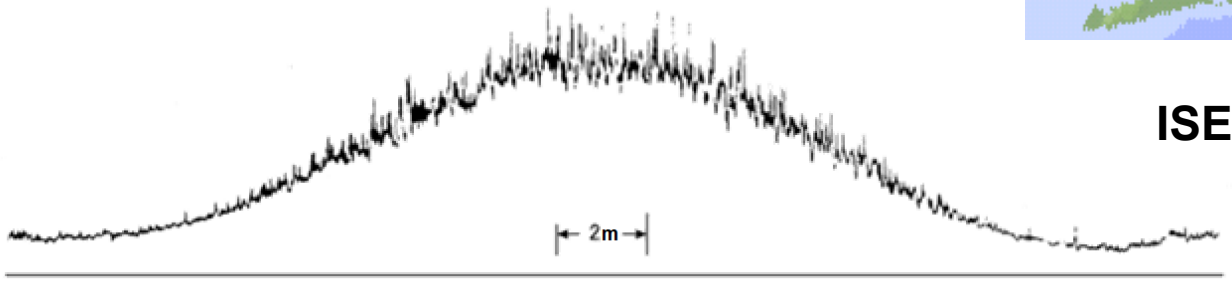
Space Weather Predictions using IPS

DATA

IPS Heliospheric Analyses ISEE (STELab)



IPS line-of-sight response



ISEE IPS array systems

Space Weather Predictions using IPS

Current ISEE Toyokawa IPS System

ISEE IPS array in Toyokawa
(3,432 m^2 array now operates well – year-round operation began in 2011)

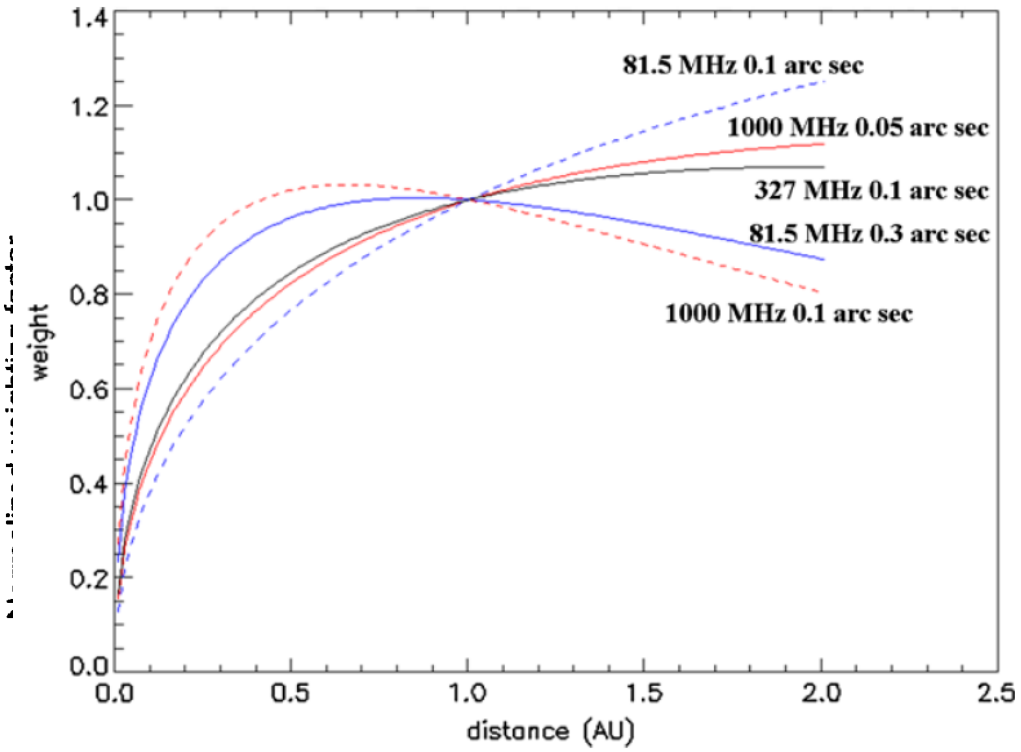
UCSD IPS Predictions

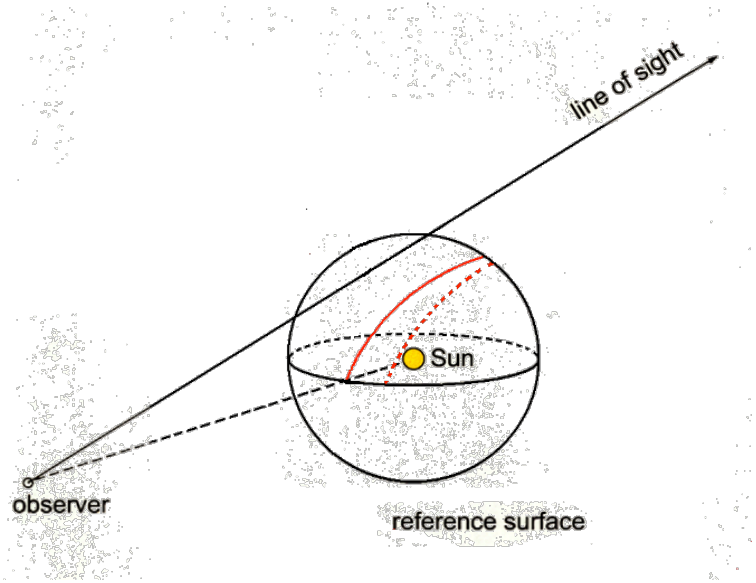
ns using IPS

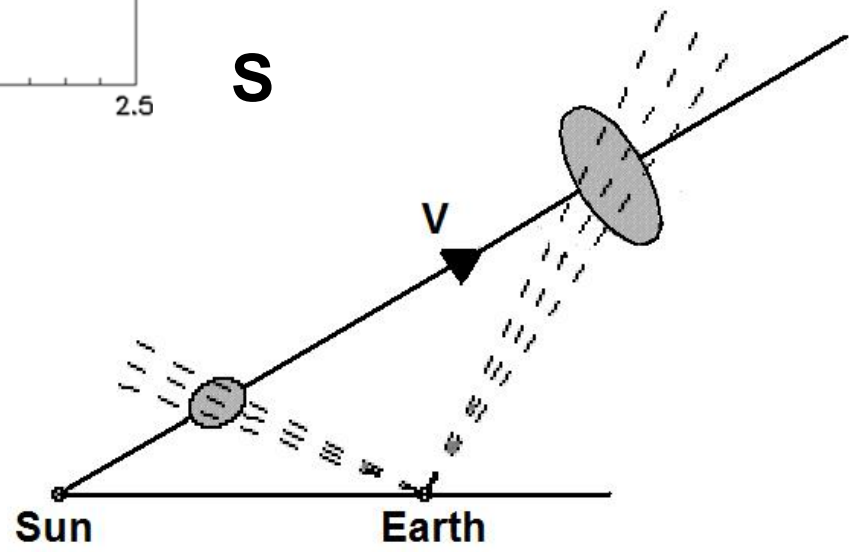
2008, *Adv. in Geosciences,* 21, 339-360.

neric C.A.T. analyses:
line-of-sight distribution
sky location to form the
surface of the 3D
uction.

S



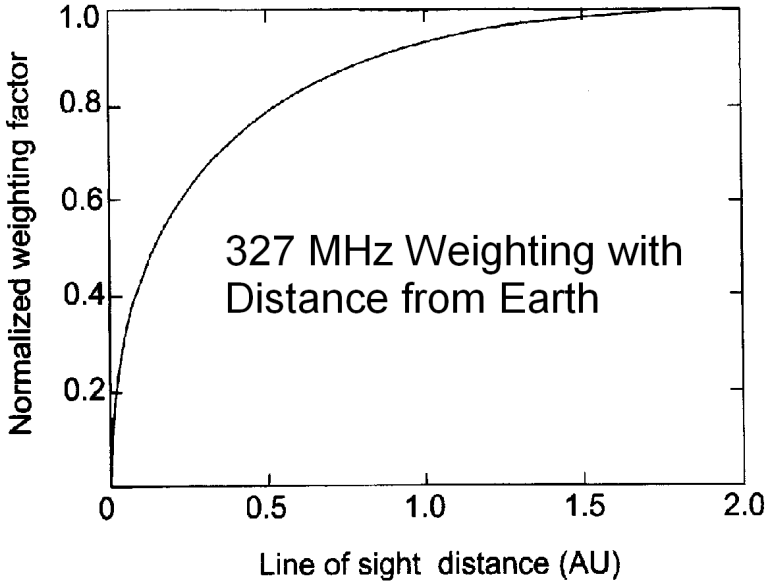


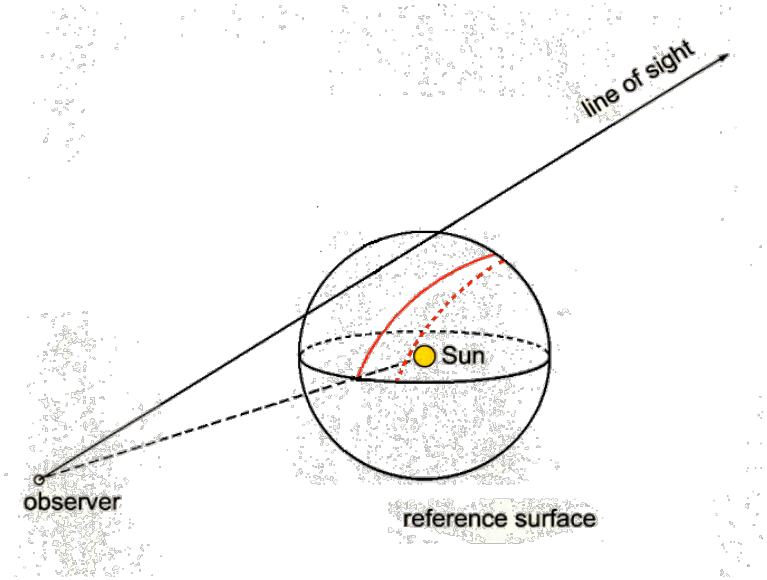


Sample outward motion over time

Space Weather Predictions using IPS

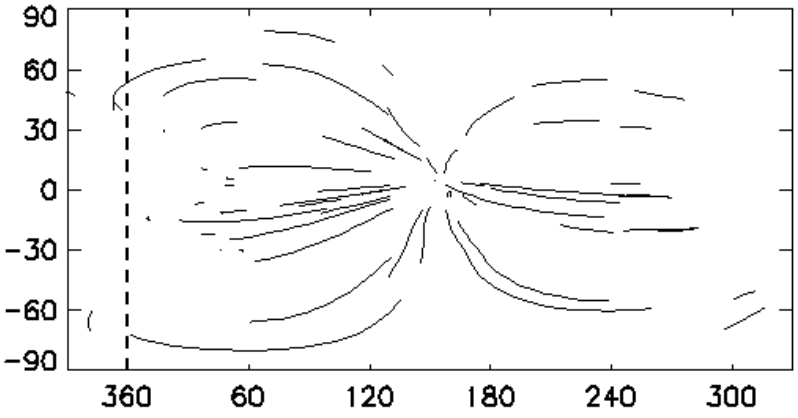
IPS line-of-sight response Jackson, B.V., *et al.*, 2008, *Adv. in Geosciences,* 21, 339-360.





Heliospheric C.A.T. analyses: example line-of-sight distribution for each sky location to form the source surface of the 3D reconstruction.

ISEE IPS



14 July 2000

Space Weather Predictions using IPS

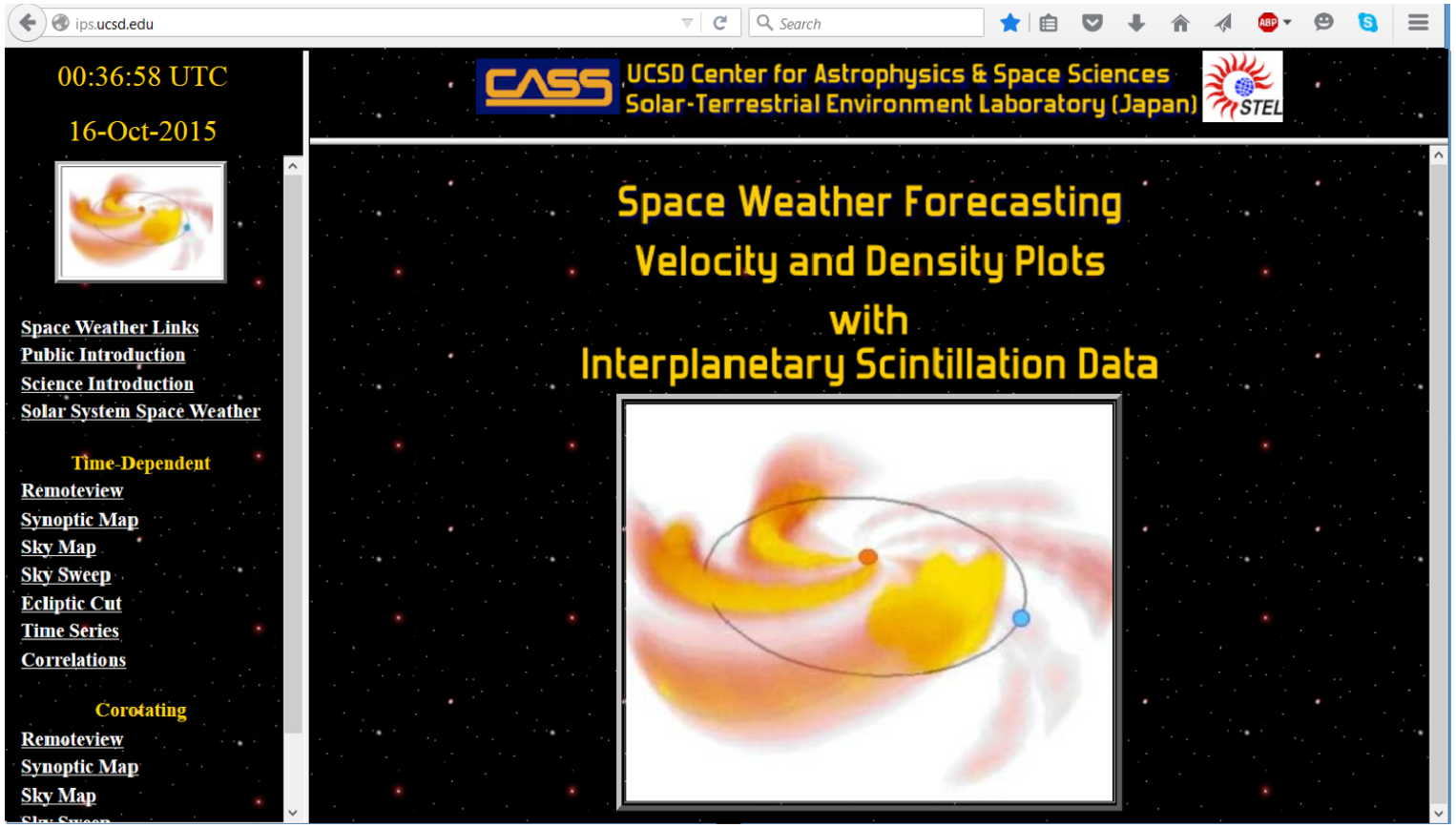
Jackson, B.V., *et al*., 2011, *Adv. in Geosciences,* 30, 93-115.

http://ips.ucsd.edu/

Current Prediction Analyses

UCSD IPS analysis

UCSD Web pages



Web Analysis Runs Automatically Using Linux on a P.C.

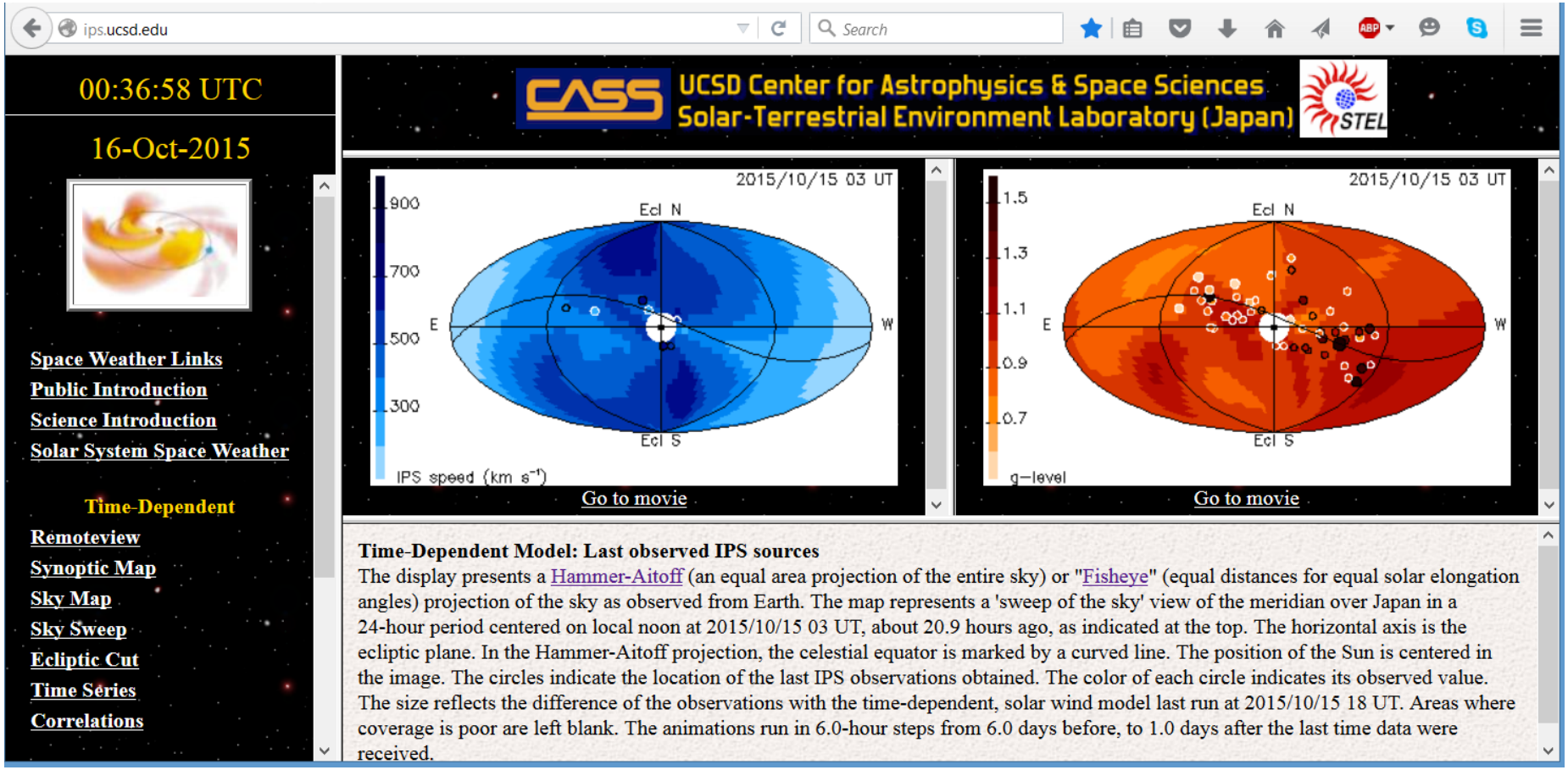
Space Weather Predictions using IPS

http://ips.ucsd.edu/

Skysweep View

Jackson, B.V., *et al.*, 2011, *Adv. in Geosciences,* 30, 93-115.

UCSD IPS prediction analysis



Web analysis runs automatically using Linux on a P.C.

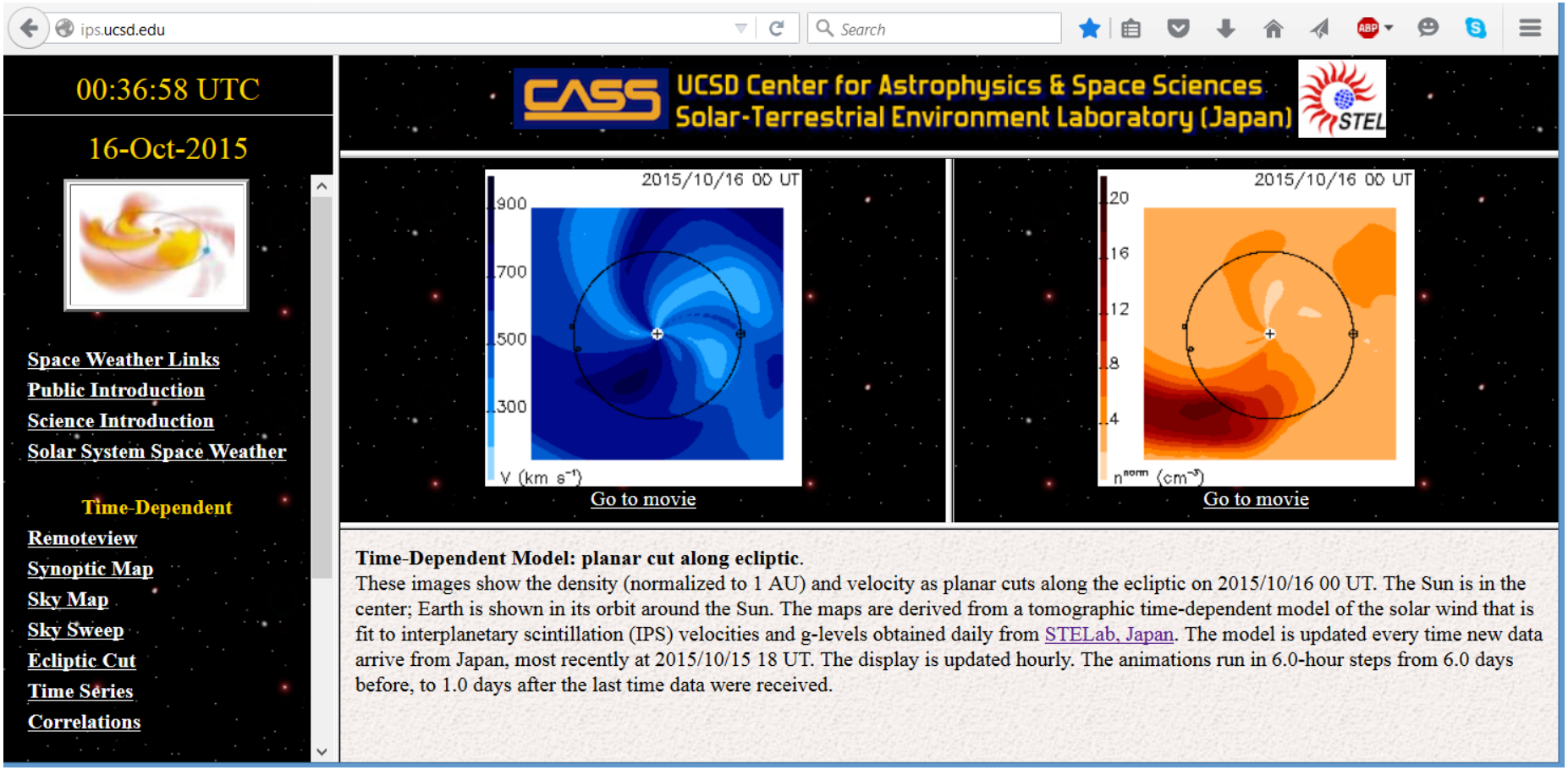
Space Weather Predictions using IPS

http://ips.ucsd.edu/ **Ecliptic Cut**

Jackson, B.V., *et al.*, 2011, *Adv. in Geosciences,* 30, 93-115.

UCSD IPS prediction analysis

Fit to ACE and CELIAS data



Web analysis runs automatically using Linux on a P.C.

Space Weather Predictions using IPS

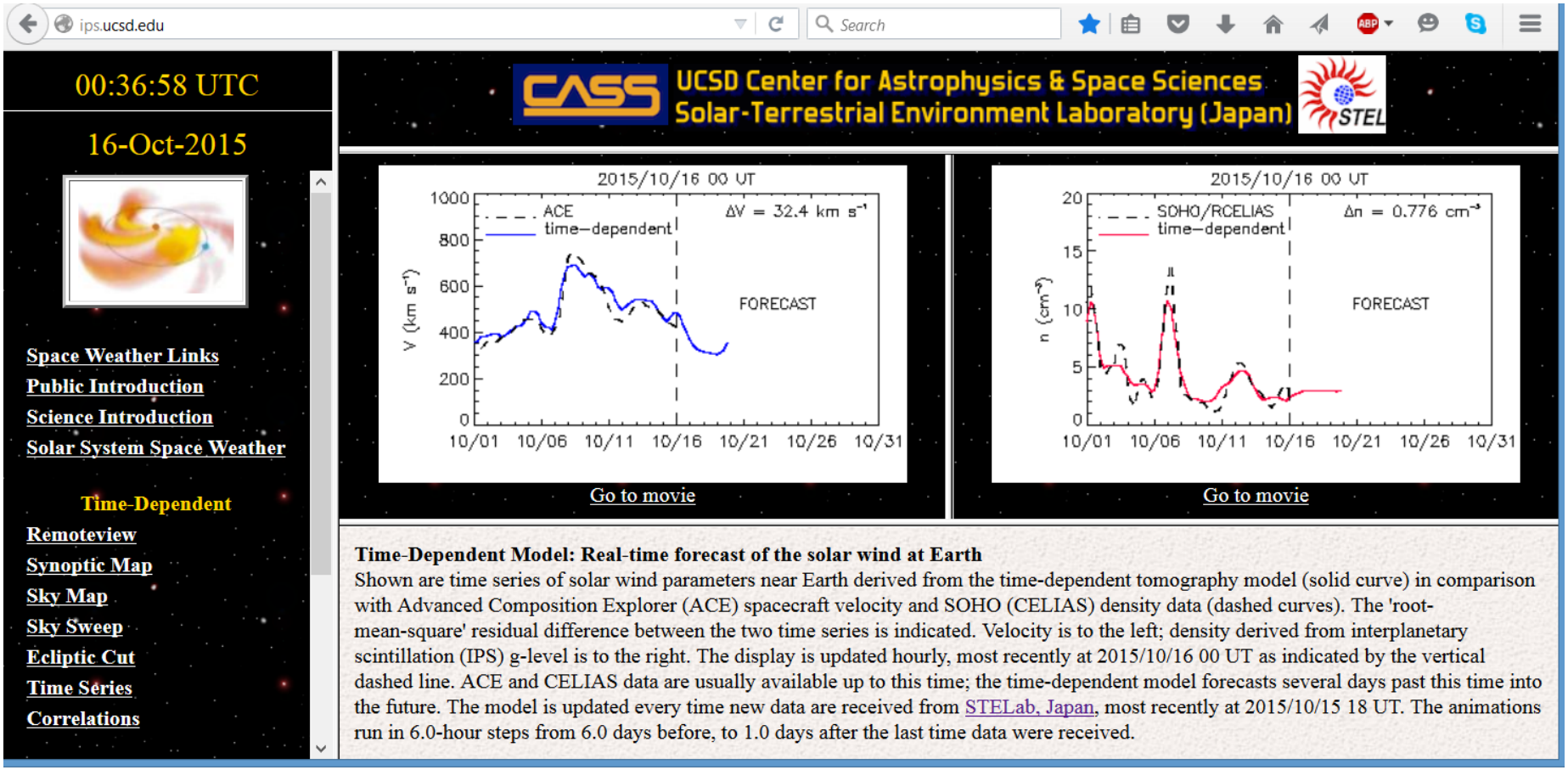
http://ips.ucsd.edu/

In-situ Analysis and Real-Time Prediction

Jackson, B.V., *et al.*, 2011, *Adv. in Geosciences,* 30, 93-115.

UCSD IPS prediction analysis

Fit to ACE and CELIAS data



Web analysis runs automatically using Linux on a P.C.

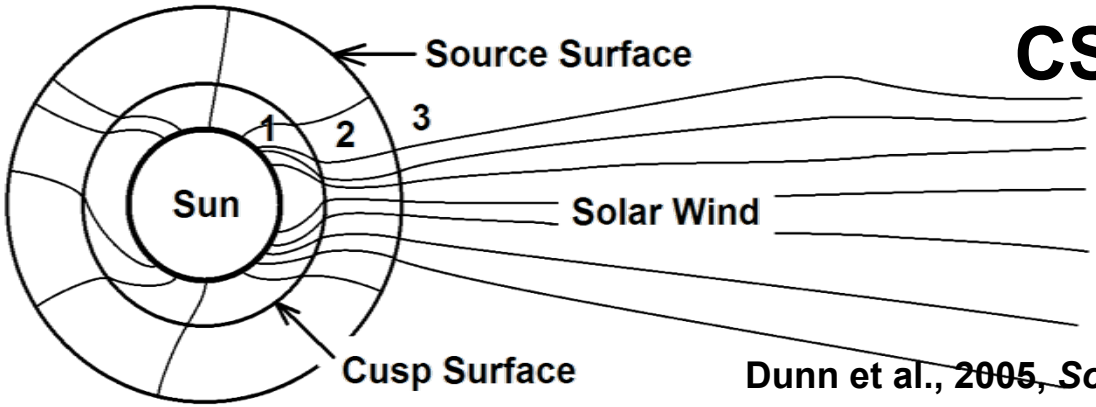
Space Weather Predictions using IPS

More Details

Magnetic Field

Space Weather Predictions using IPS

(Zhao, X. P. and Hoeksema, J. T., 1995, *J. Geophys. Res.,* 100 (A1), 19.)



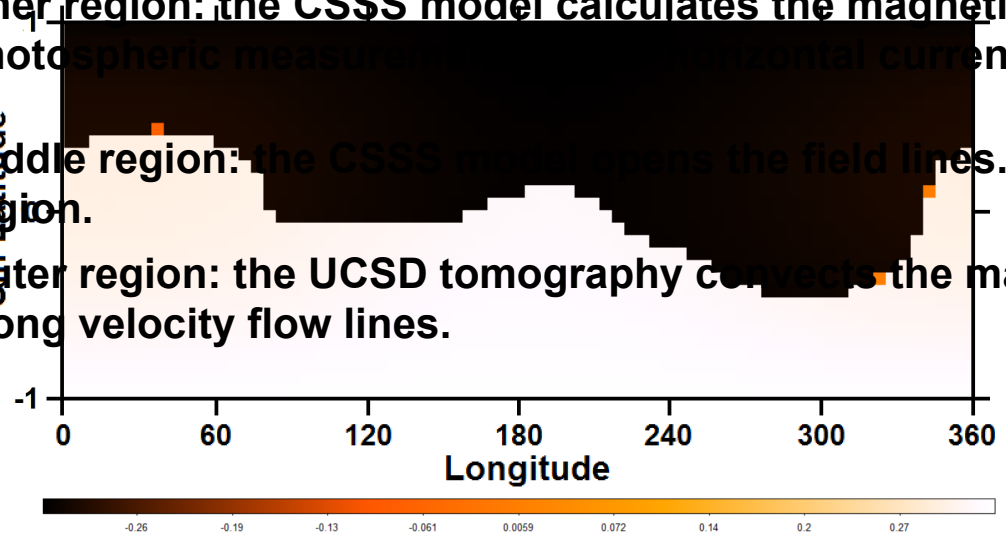
CSSS model

Dunn et al., 2005, *Solar Physics* 227: 339–353.

CSSS Model | UCSD Tomography

Source surface B_r field component sample

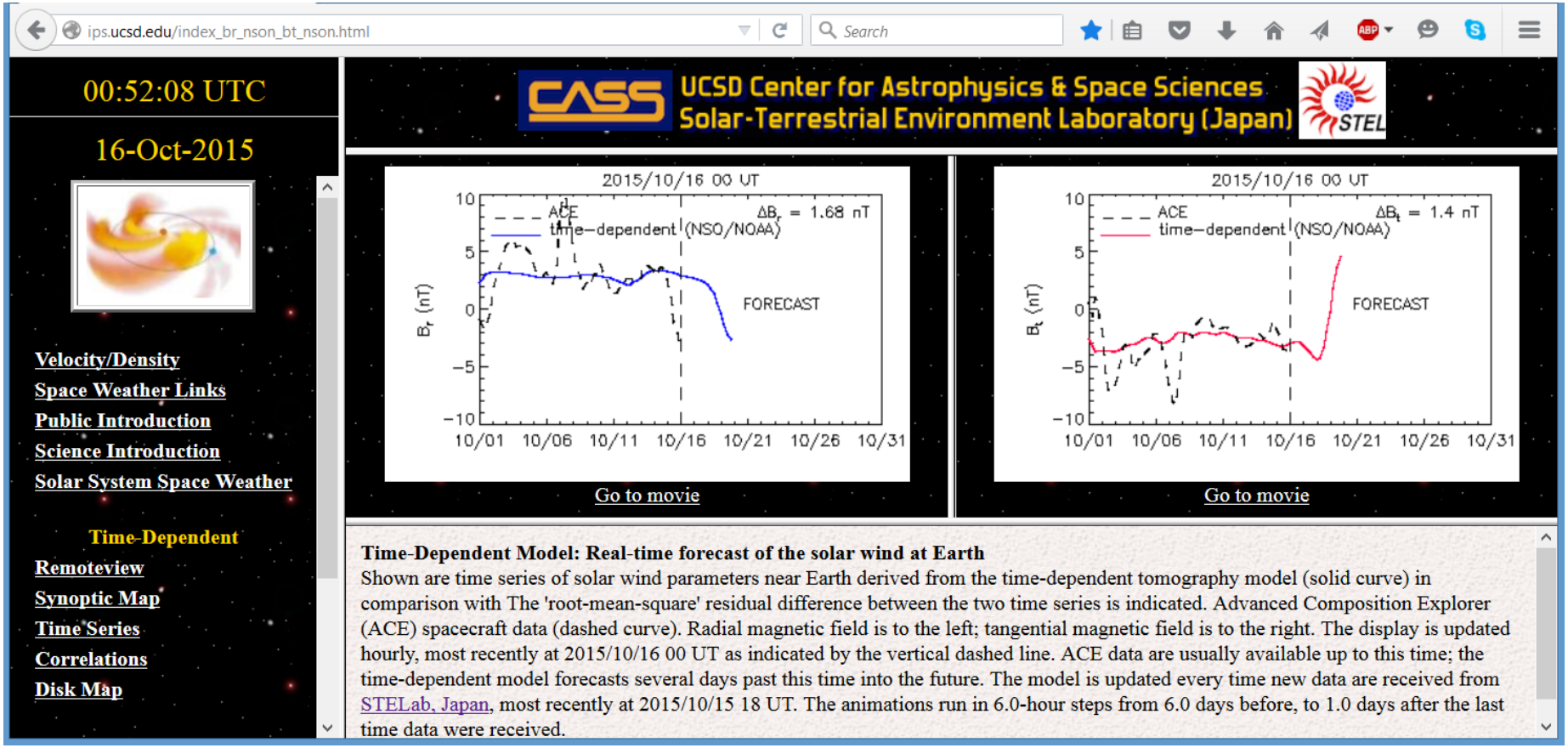
1. Inner region: the CSSS model calculates the magnetic field using photospheric measurements and a horizontal current model.
2. Middle region: the CSSS model opens the field lines. In the outer region.
3. Outer region: the UCSD tomography convects the magnetic field along velocity flow lines.



Space Weather Predictions using IPS

(Jackson, B.V., *et al.*, 2011, *Adv. in Geosciences,* 30, 93-115)

http://ips.ucsd.edu/ **Earth Radial and Tangential Magnetic Field Magnetic Field Extrapolation**



Web Analysis Runs Automatically Using Linux on a P.C.

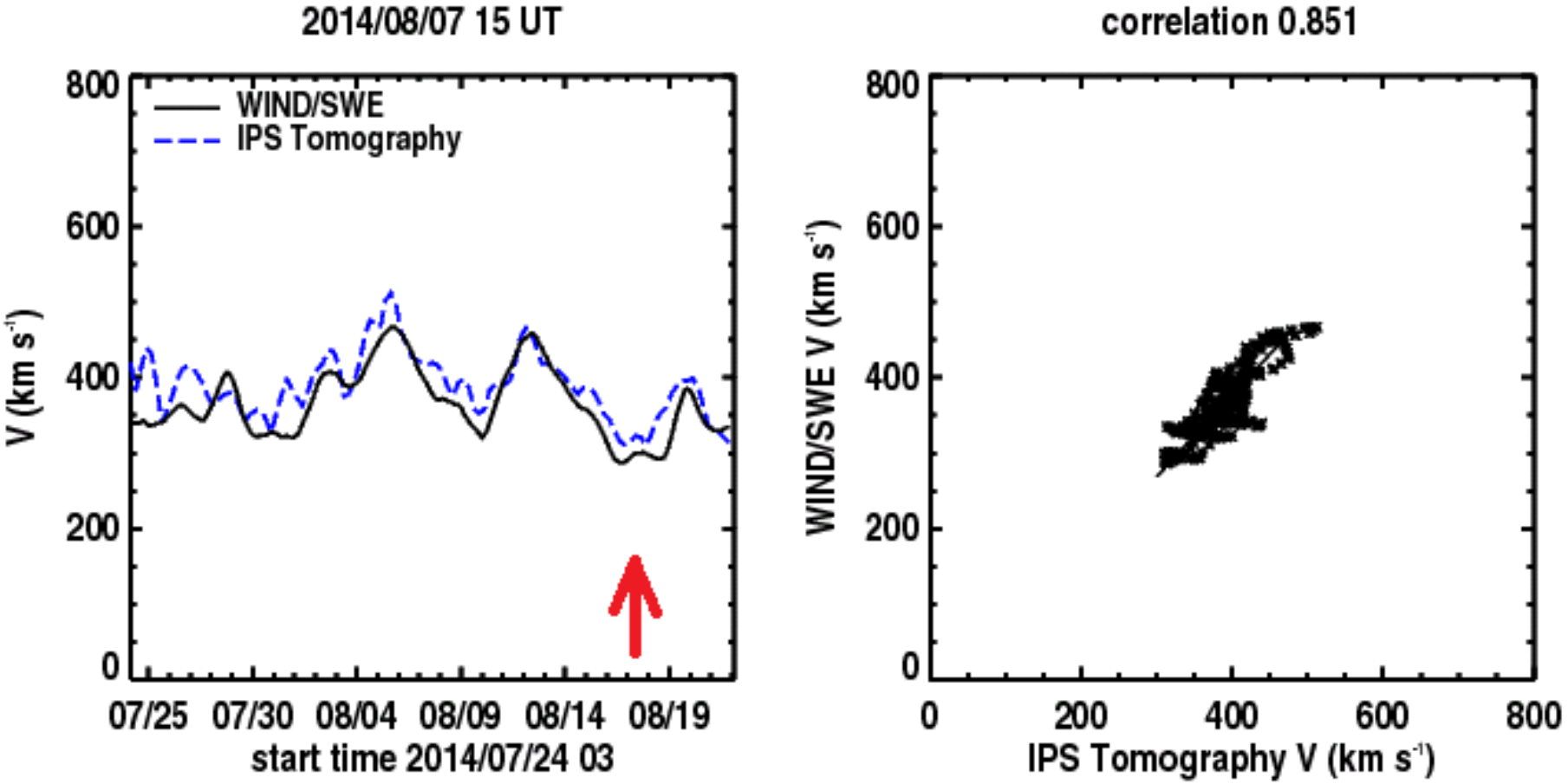
Space Weather Predictions using IPS

http://ips.ucsd.edu/

Jackson, B.V., *et al.*, 2011, *Adv. in Geosciences,* 30, 93-115.

UCSD Sample Analysis (CME 08/13/2014)

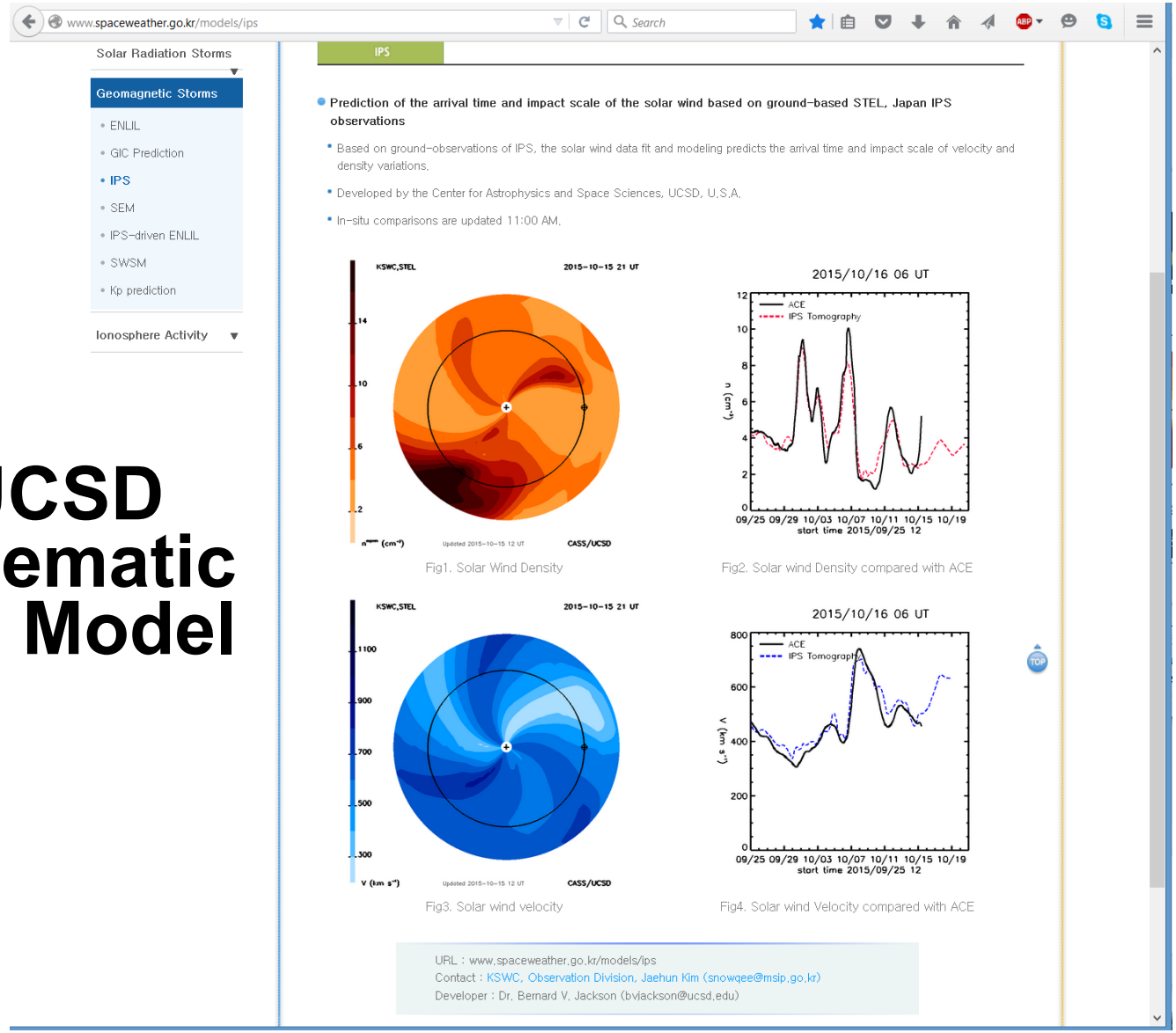
ISEE Time Series 07/25 – 08/22 2014



Space Weather Predictions using IPS

IPS Prediction (KSWC)

http://www.spaceweather.go.kr/models/ips

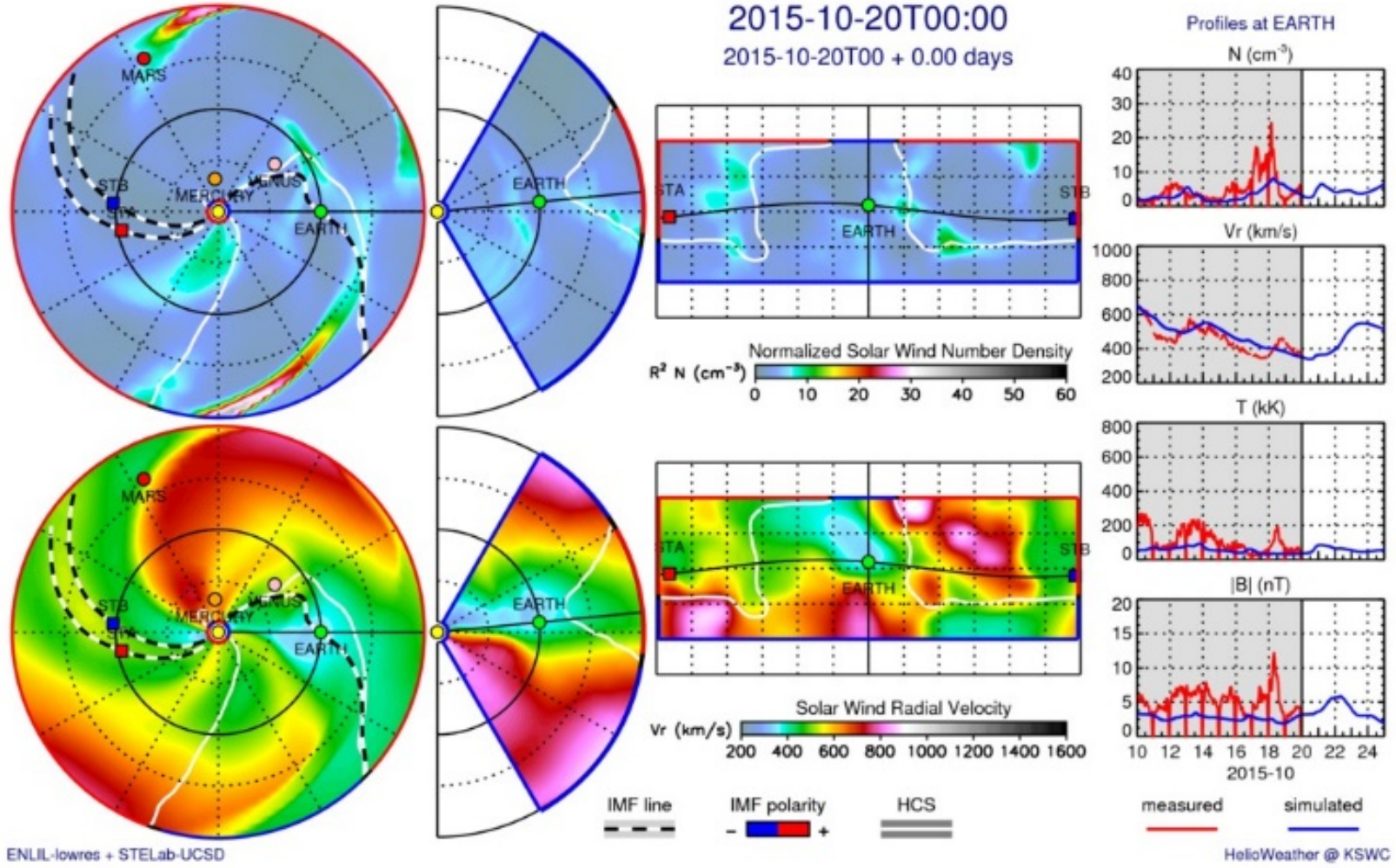


UCSD Kinematic IPS Model

Space Weather Predictions using IPS

IPS Prediction (KSWC)

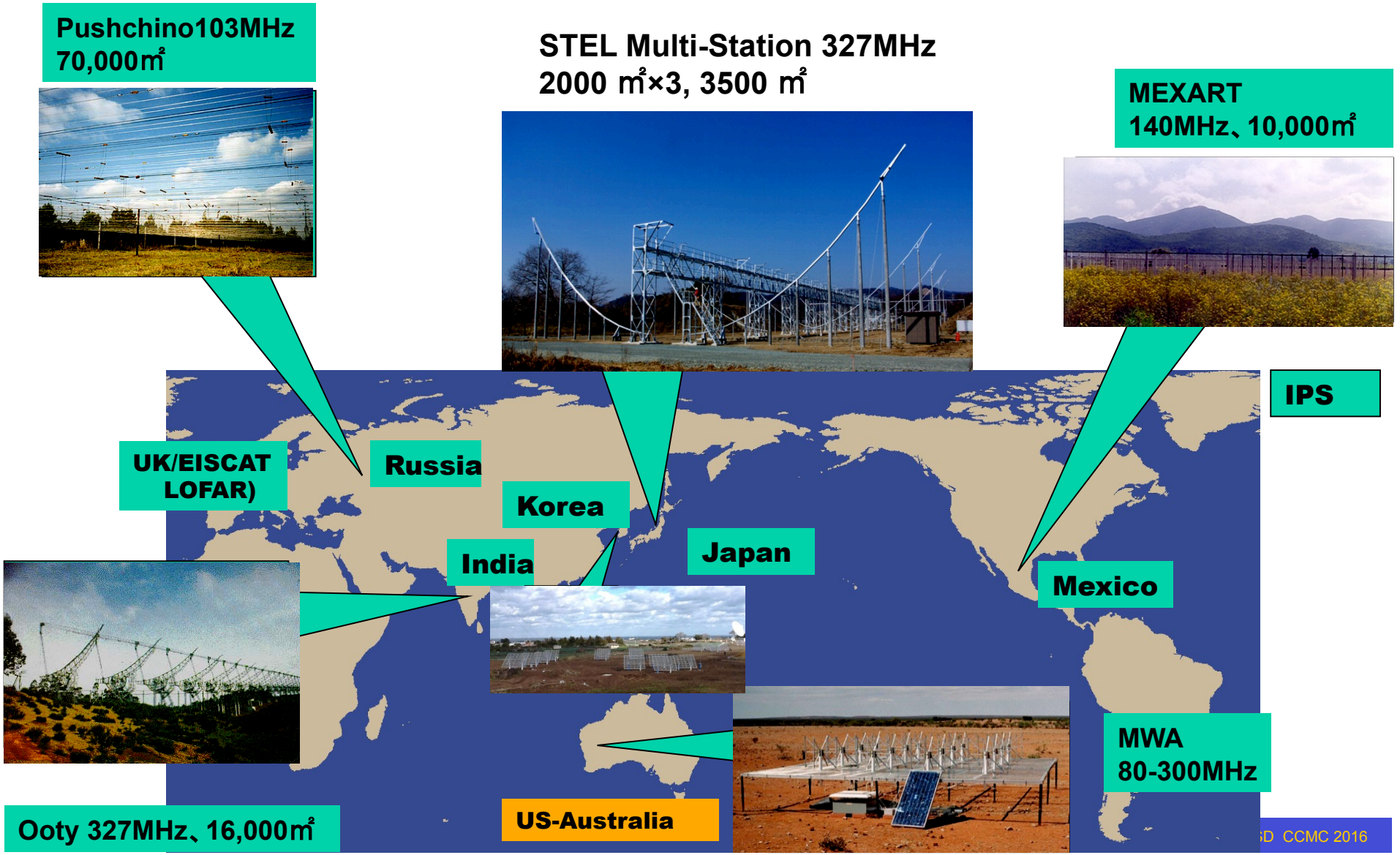
http://www.spaceweather.go.kr/models/ips



IPS-Driven ENLIL

Space Weather Predictions using IPS

World-Wide IPS observation network



Space Weather Predictions using IPS

Current Dedicated IPS Radio Systems

The Pushchino Radio Observatory 70,000 m^2 110 MHz array, Russia (summer 2006)
Now named the "Big Scanning Array of the Lebedev Physical Institute" (BSA LPI).

The Ootacamund (Ooty), India off-axis parabolic cylinder 530 m long and 30 m wide (15,900 m^2) operating at a nominal frequency of 326.5 MHz.

Space Weather Predictions using IPS

Other and Potential Future Dedicated IPS Systems

MEXART (Mexico)

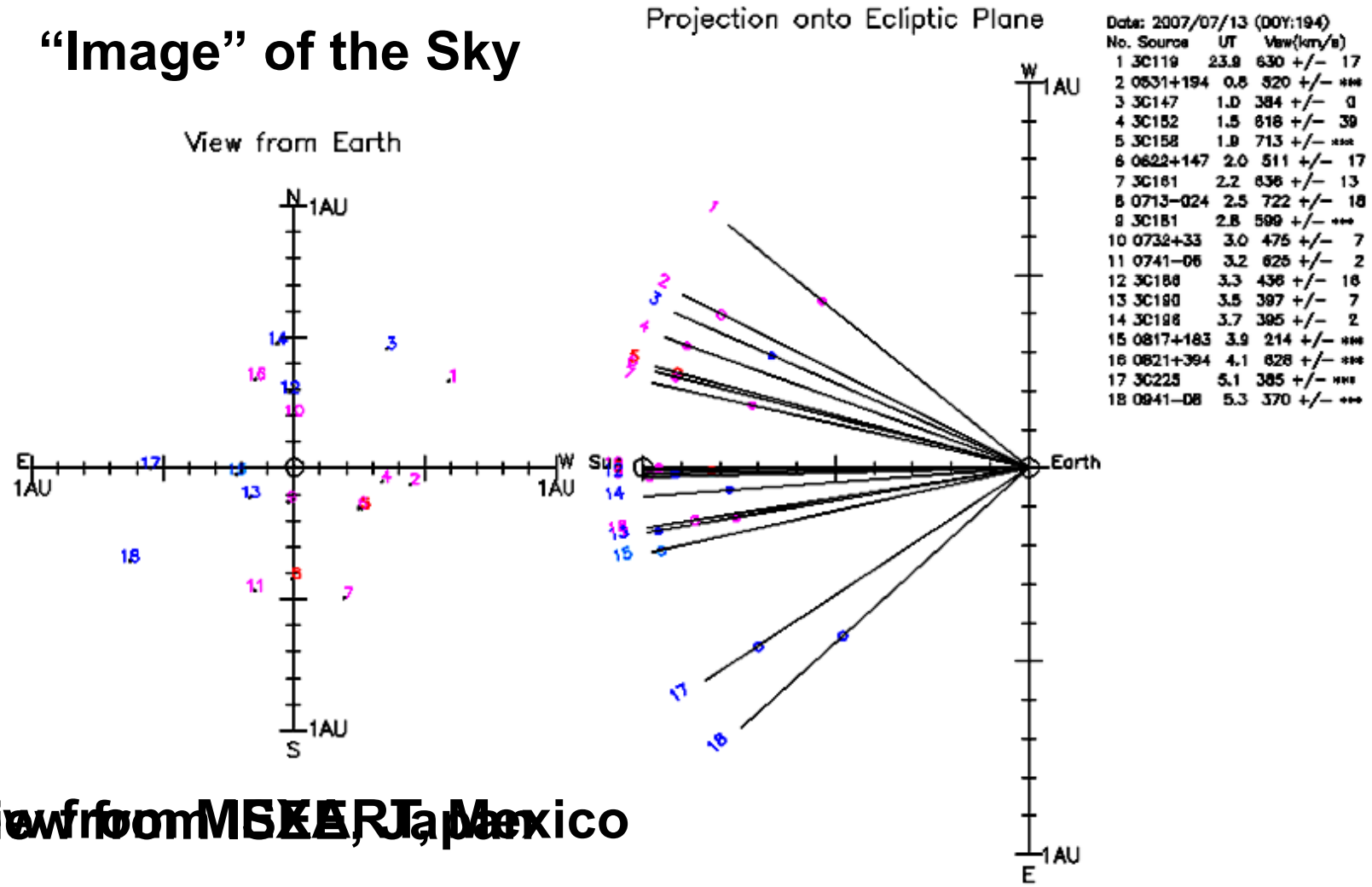
Dedicated IPS IPS 9,600 m^2
140 MHz IPS radio array
near Michoacan, Mexico

KSWC (South Korea)

Dedicated IPS 700 m^2 327
MHz IPS radio 32 tile array,
Jeju Island

Space Weather Predictions using IPS

"Image" of the Sky



View from MEXART, Mexico

View from STEL, Japan

Ecliptic Plane Projection

Space Weather Predictions using IPS

Third Remote-Sensing Workshop

20-24 October 2015 Morelia, Mexico

http://www.sciesmex.unam.mx/static/workshop2015/talks/

Space Weather Predictions using IPS

Recent Morelia Remote Sensing Workshop
(20-24 October 2015)

1) A standardized IPS format was settled upon.

2) All participants agreed to share their data and host websites to present their data in real time as soon as it becomes available.

3) At this time a new member joined the group of organizations that provide access to their IPS data set in real time from the world's largest (70,000 m^2) radio array currently operating; the 110 Mhz system at Pushchino, Russia.

Space Weather Predictions using IPS

Standard Data Format

Space Weather Predictions using IPS

Standard IPS Format

Ascii – Fixed Format

As: ftp://ftp.stelab.nagoya-u.ac.jp/pub/vlist/STEL2015.dat

Date	MidObsUT	Dur.	Site	Freq	BW	Source	Size	RA-J2000	Dec-J2000	Limb	Dist.	Lat.	PA	Elong	Vel.	V-err	g-value	g-err	Method	Vel.	V-err	g-value	g-err	Method
20150912	03:57:02	2.8	STEL	327	10	3C273	-999	12 29 06	+02 03 12	E	68.70	16.9	74.5	17.6	560	3	1.002	0.515	3-St. CC	-999	-999	0.919	0.301	1-St. PS

New item

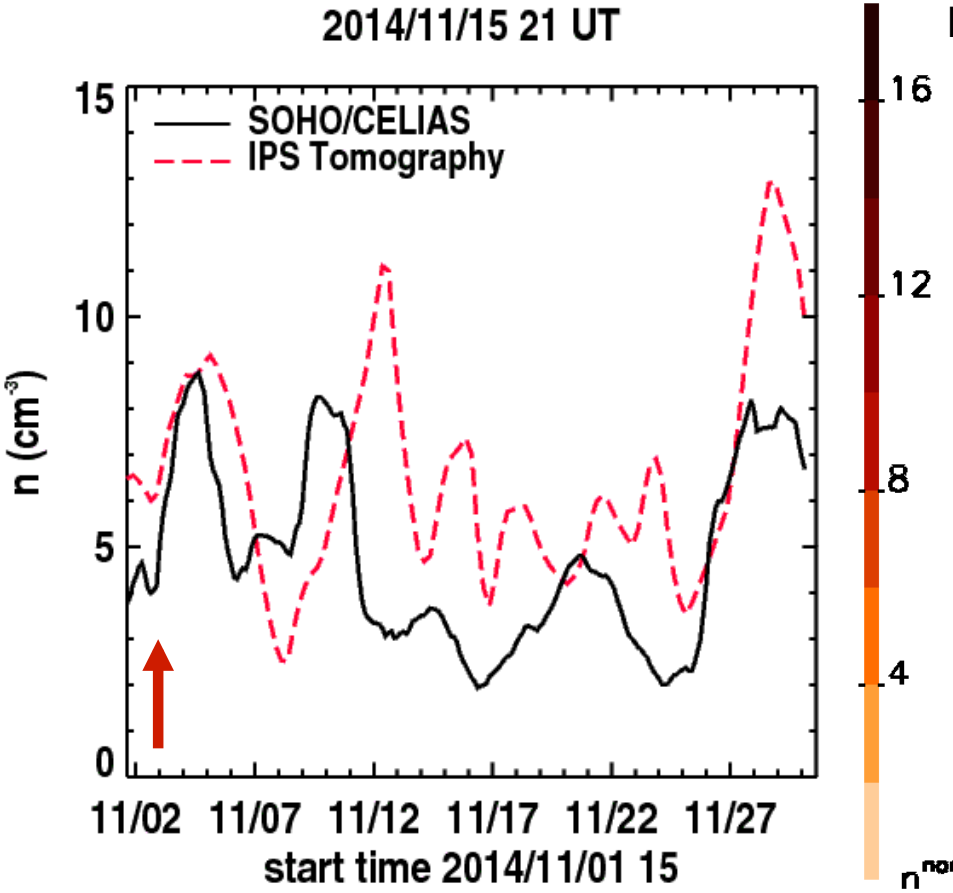
Used by UCSD tomo.

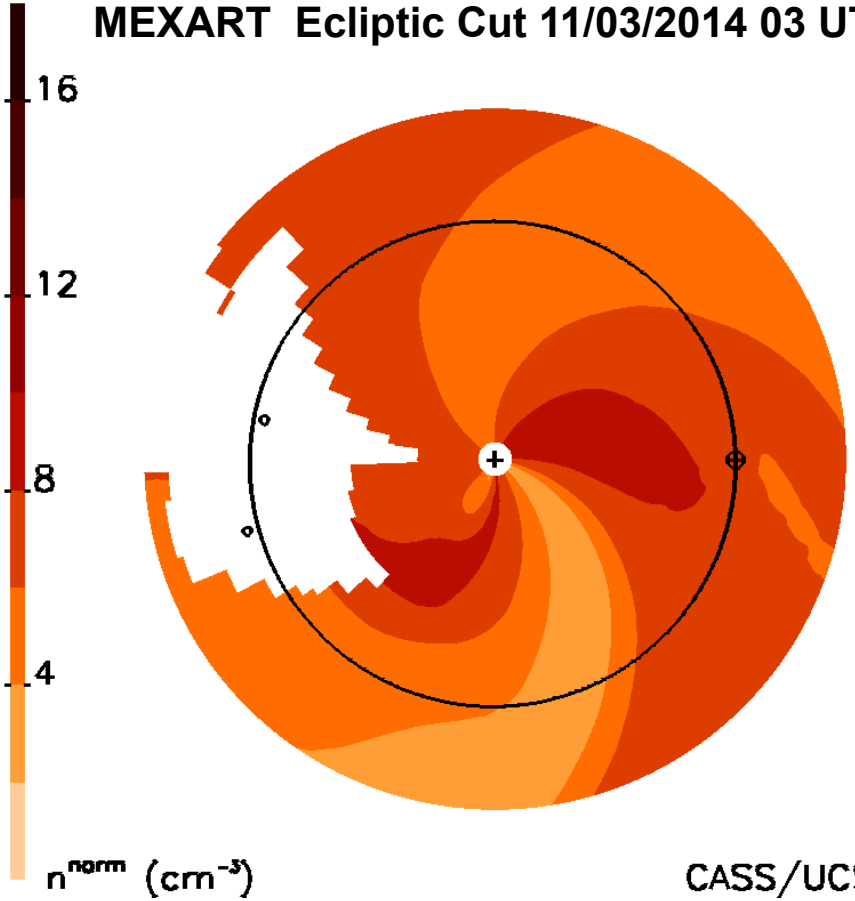
G-value, error

Space Weather Predictions using IPS

MEXART Analysis (Carrington Rotation 2156.7)

MEXART Time Series 11/02 – 11/29 2014

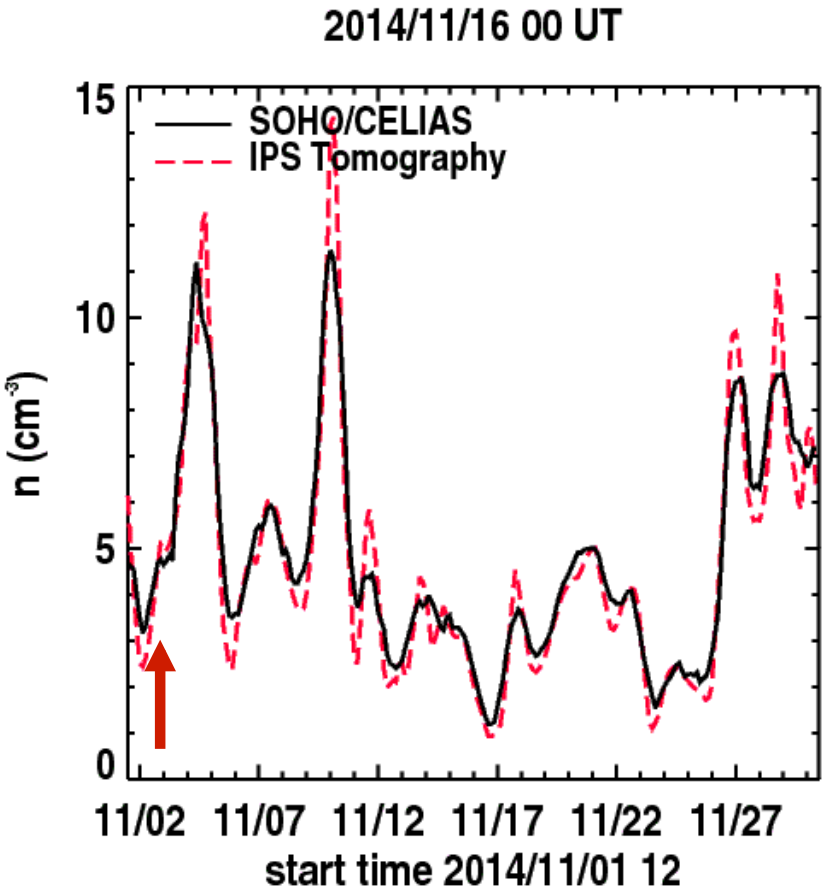


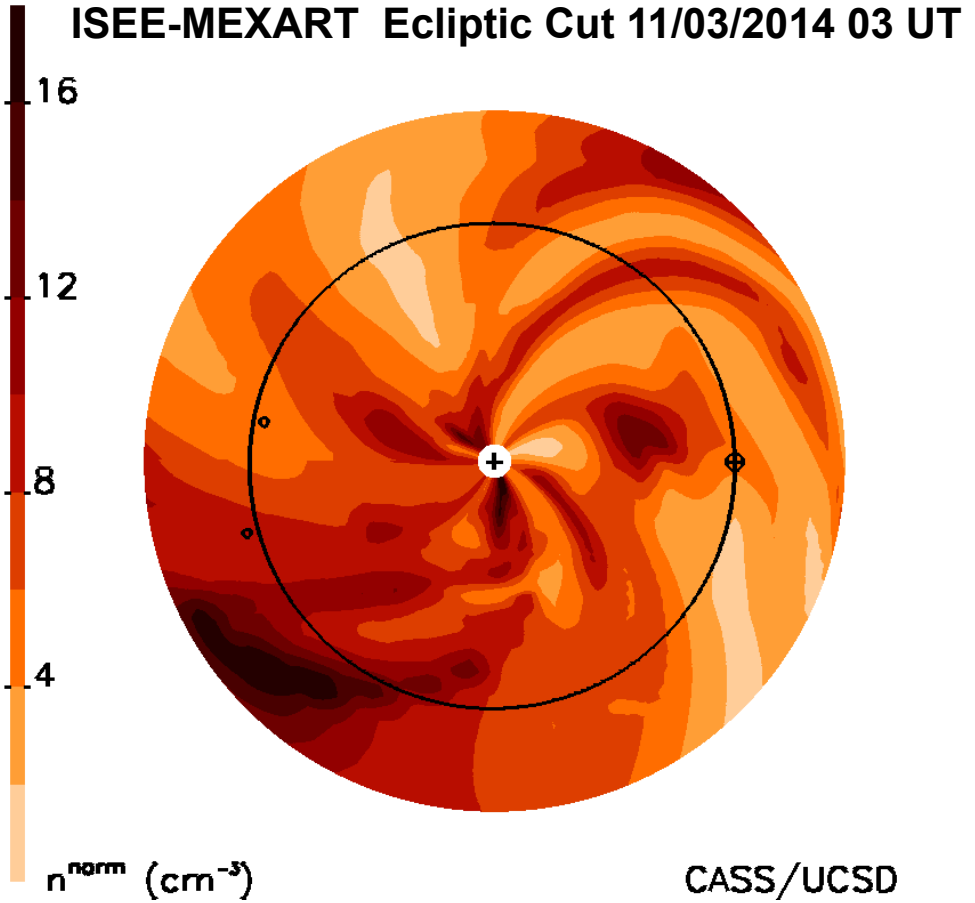


Space Weather Predictions using IPS

Combined ISEE and MEXART Analysis (Carrington Rotation 2156.7)

Combined Time Series 11/02 – 11/29 2014





Space Weather Predictions using IPS

The IPS analyses provide a really-great 3D-MHD test-bed

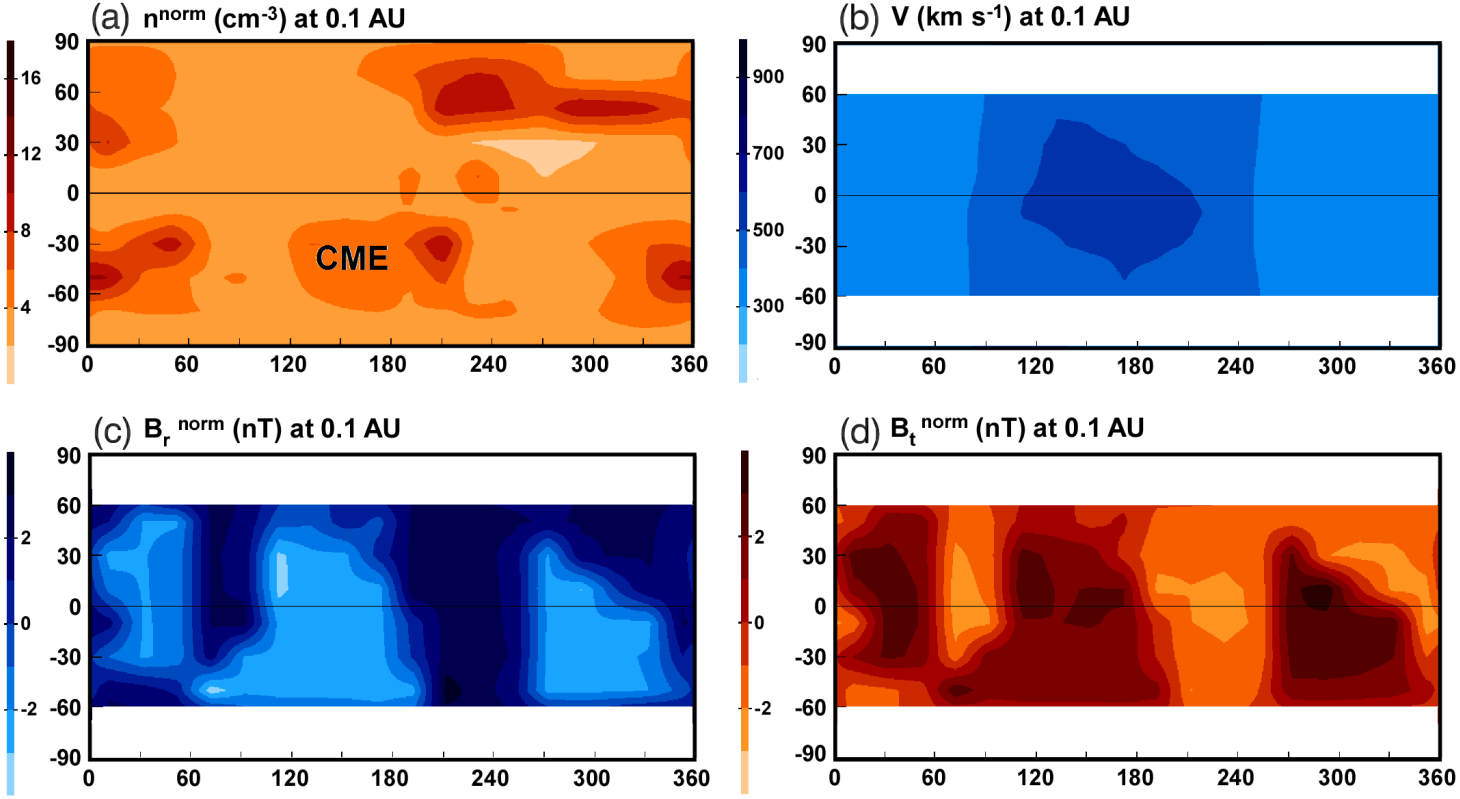
Space Weather Predictions using IPS

(Yu, H-S., *et al.*, *et al.*, 2015, *Solar Phys.*, doi: 10.1007/s11207-015-0685-0.)

(Jackson, B.V., *et al.*, ., 2015, *Space Weather, 13,* 104-115 doi: 10.1088/2041-8205/803/1/L1.)

IPS-Derived 3D-MHD Model Boundaries

2014 April 18 21:00UT at 0.1AU Boundary



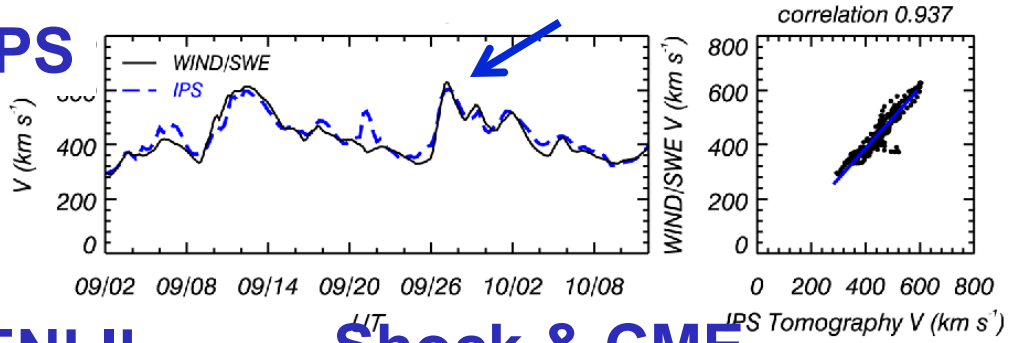
Updated every 6 hours at: ftp://cass185.ucsd.edu/data/IPSBD_Real_Time/ENLIL/ascii_data

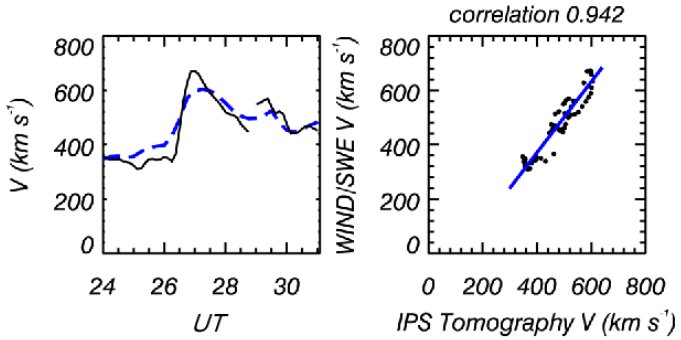
Space Weather Predictions using IPS

UCSD kinematic model and IPS-driven 3D-MHD models

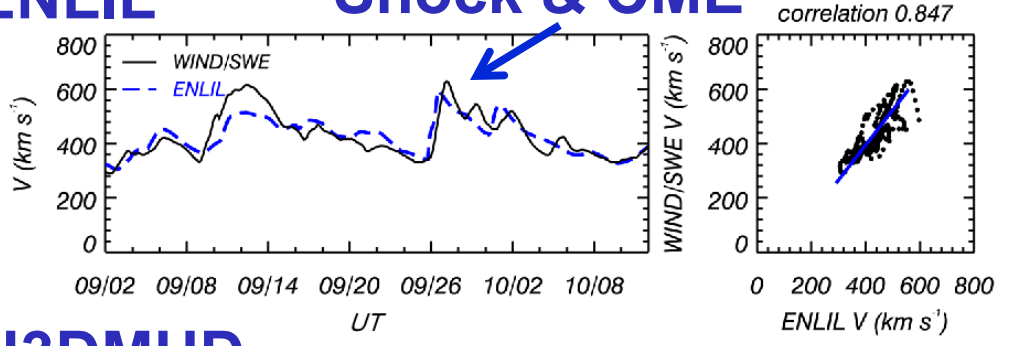
Velocity 1-Day Averaged *In Situ* | 6-Hour Averaged *In Situ*

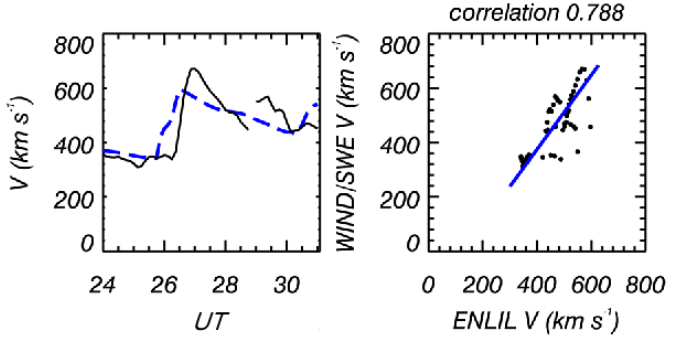
IPS



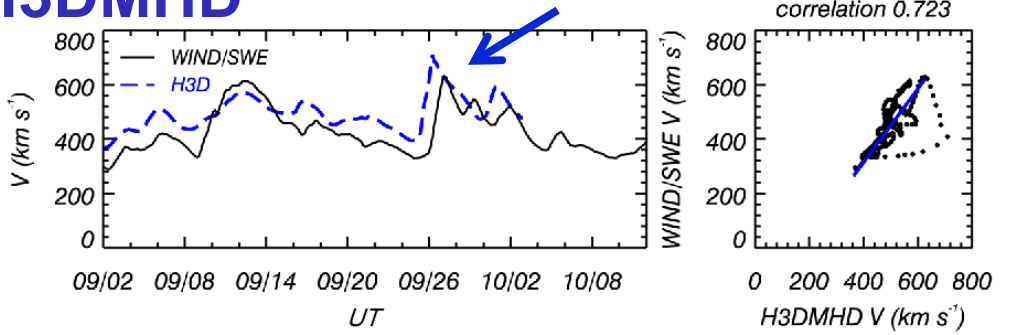


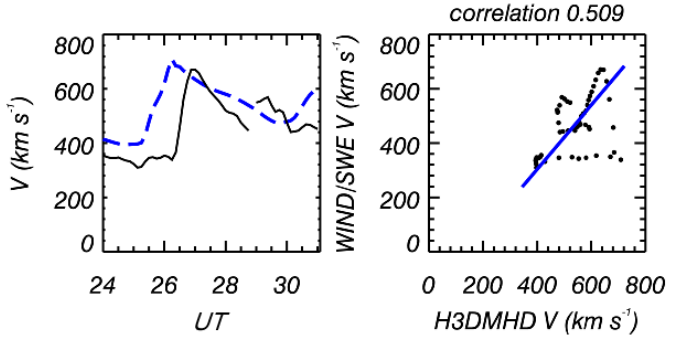
ENLIL **Shock & CME**





H3DMHD





start time 2011/09/02 | *start time 2011/09/24*

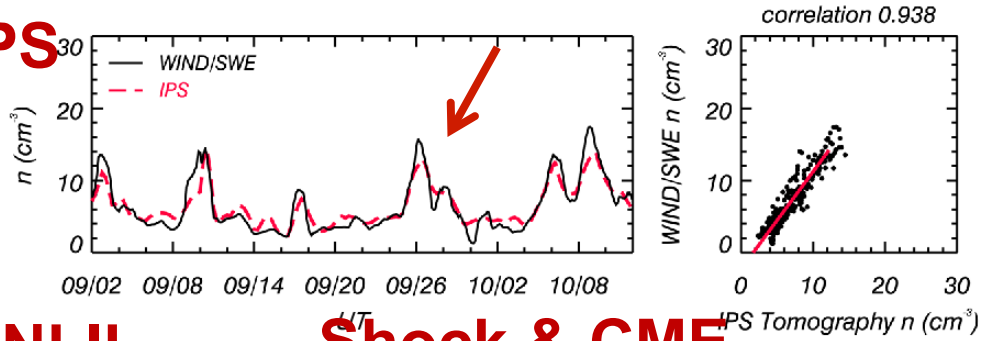
Space Weather Predictions using IPS

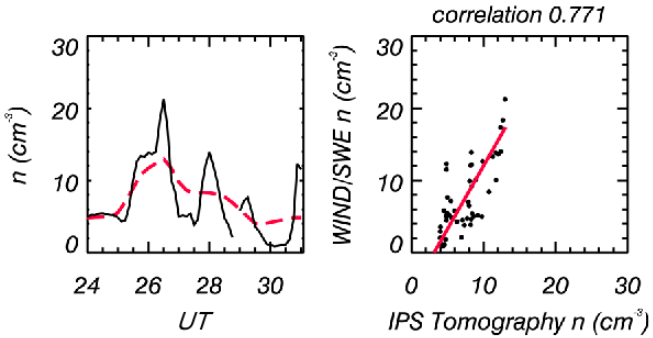
UCSD kinematic model and IPS-driven 3D-MHD models

Density 1-Day Averaged *In Situ*

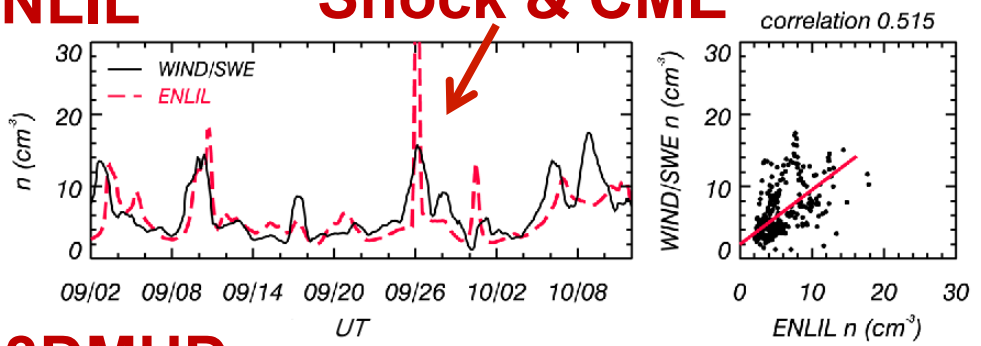
6-Hour Averaged *In Situ*

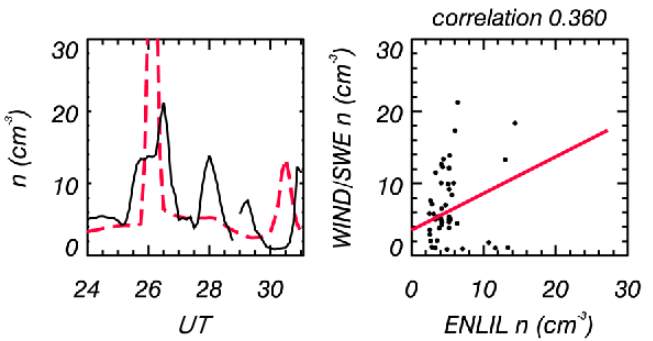
IPS



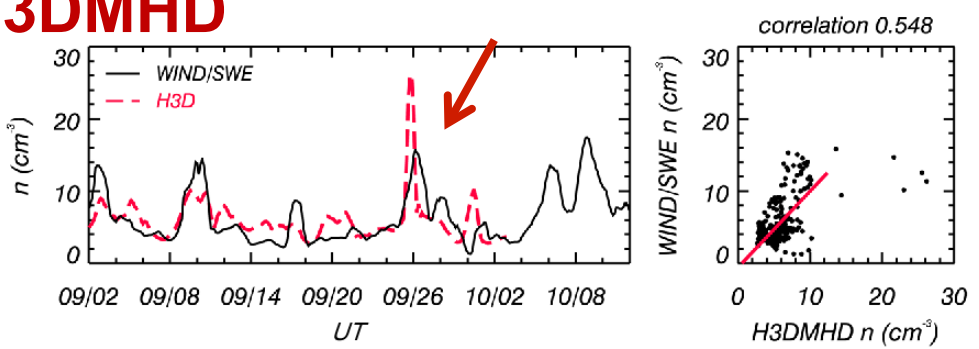


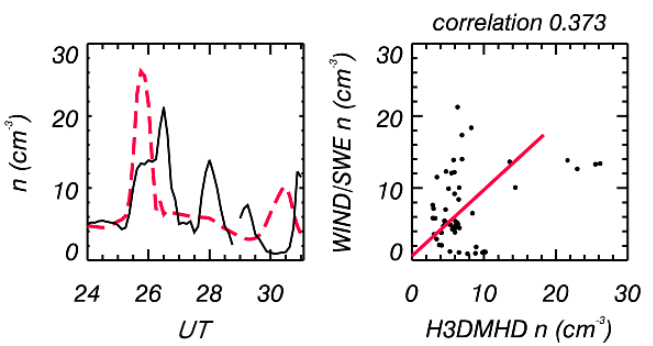
ENLIL **Shock & CME**





H3DMHD





start time 2011/09/02

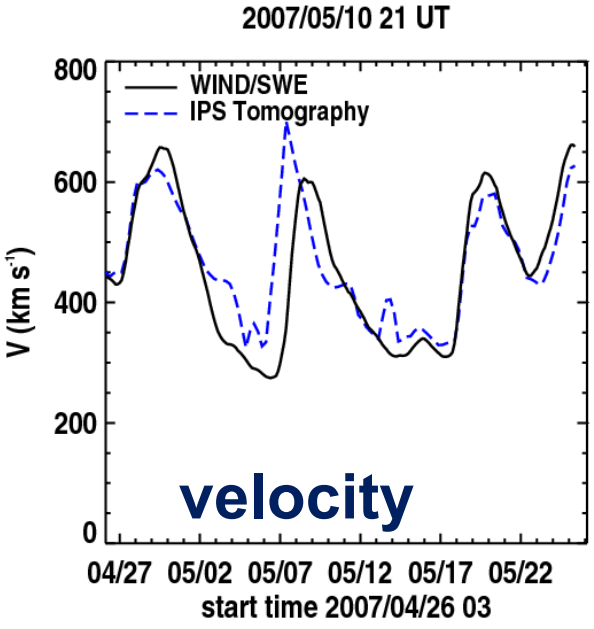
start time 2011/09/24

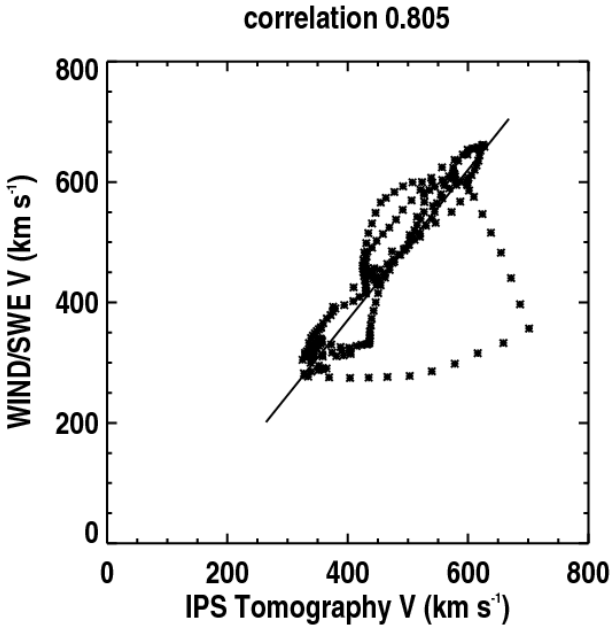
Space Weather Predictions using IPS

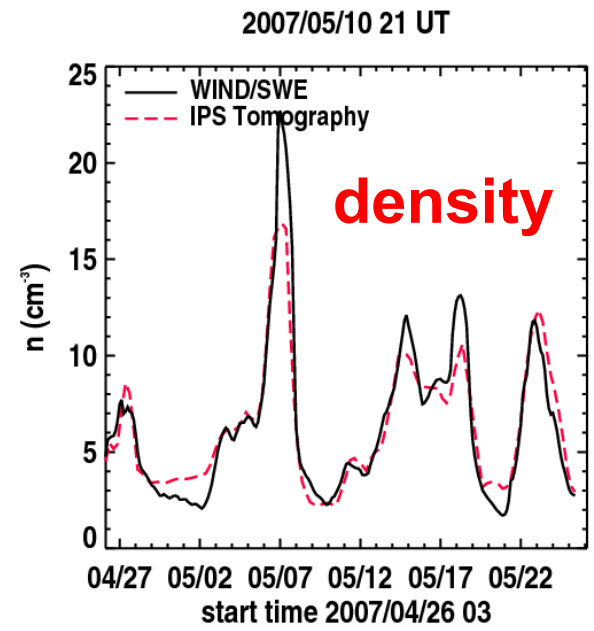
But what is really wanted is B_z

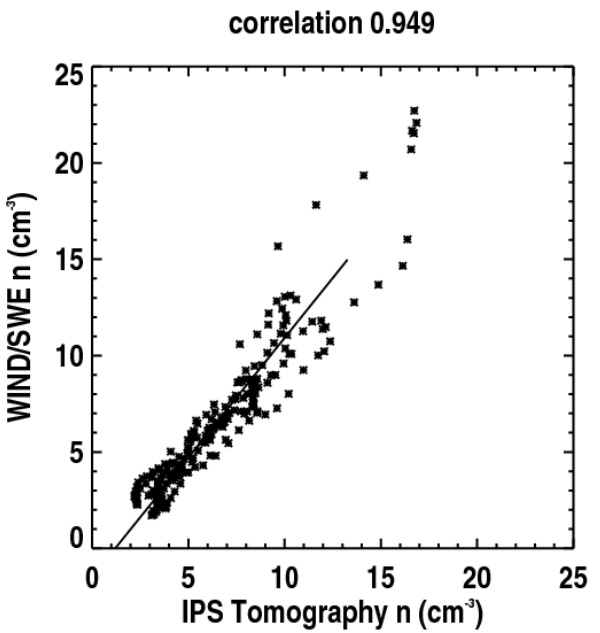
Space Weather Predictions using IPS

UCSD Archival IPS Analysis of V and D at WIND over Carrington rotation 2056 (April 27 – May 25, 2007)

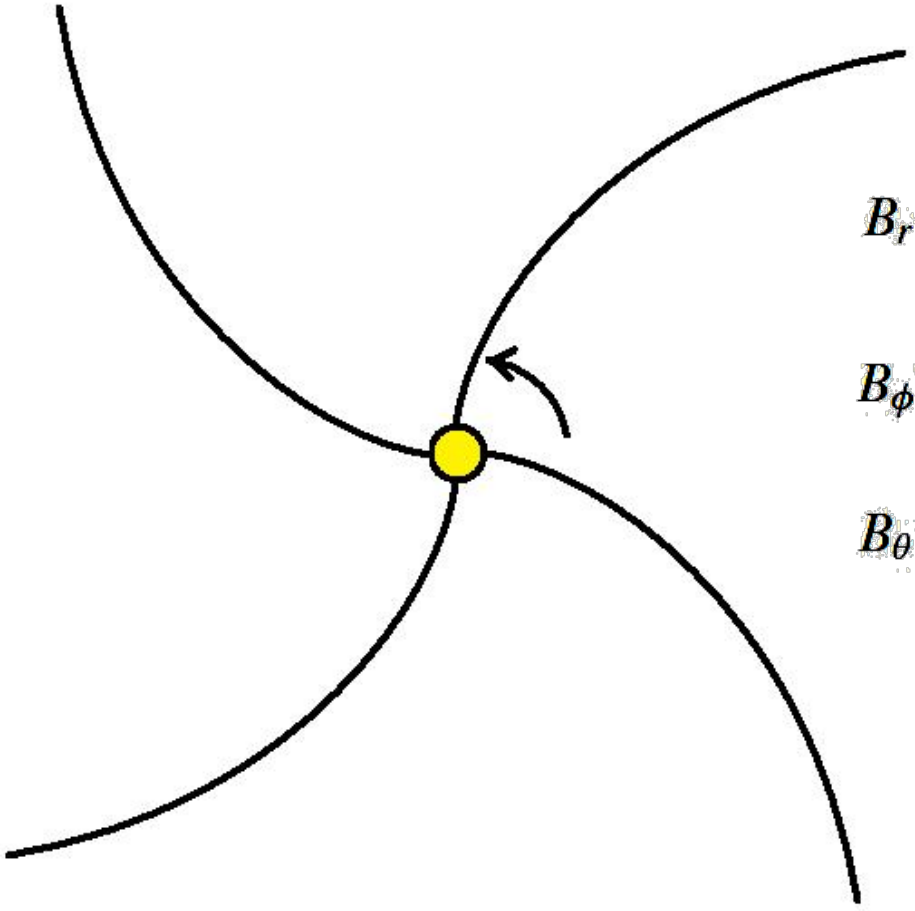








Space Weather Predictions using IPS



$$B_r(r, \phi, \theta) = B(r_0, \phi_0, \theta_0)\left(\frac{r_0}{r}\right)^2$$

$$B_\phi(r, \phi, \theta) = -B(r)\left(\frac{\omega r_0 \sin(\theta)}{V}\right)\left(\frac{r_0}{r}\right)$$

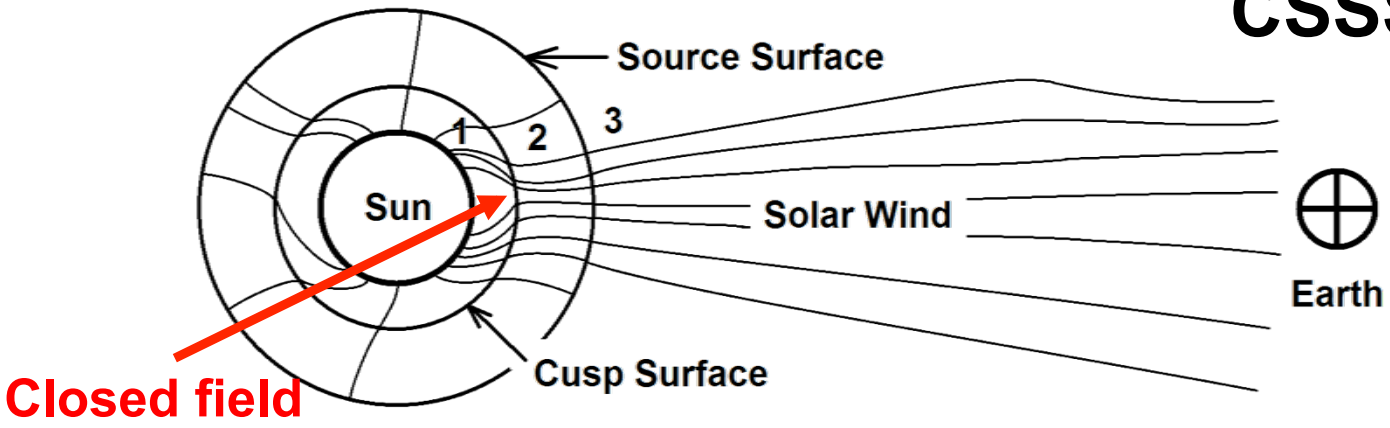
$$B_\theta(r, \phi, \theta) = 0$$

I have often wondered where the Bz in-situ field comes from. The Parker spiral analysis does not indicate how a normal field (north-south) can occur, and yet the field exists and is ever-present in the heliosphere.

Space Weather Predictions using IPS

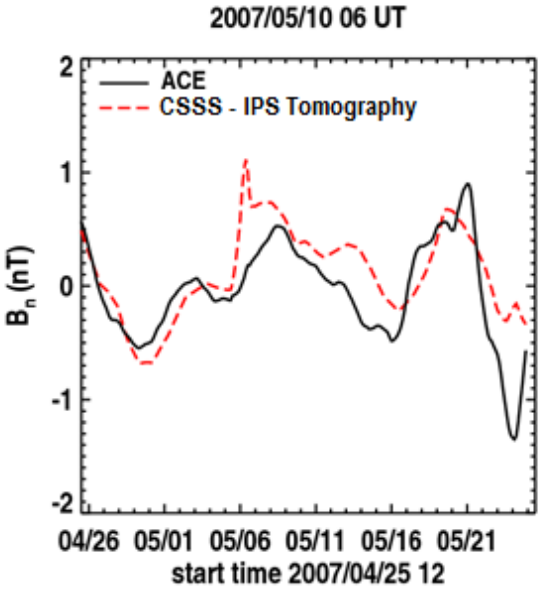
(Jackson, B.V., *et al.*, 2015, *ApJL,* 803:L1. 1- 5, doi:10.1088/2041-8205/803/1/L1.)

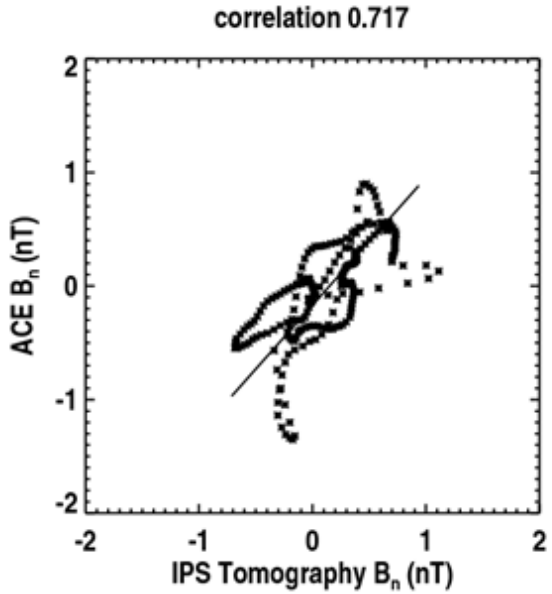
CSSS model



CSSS Model | UCSD Tomography

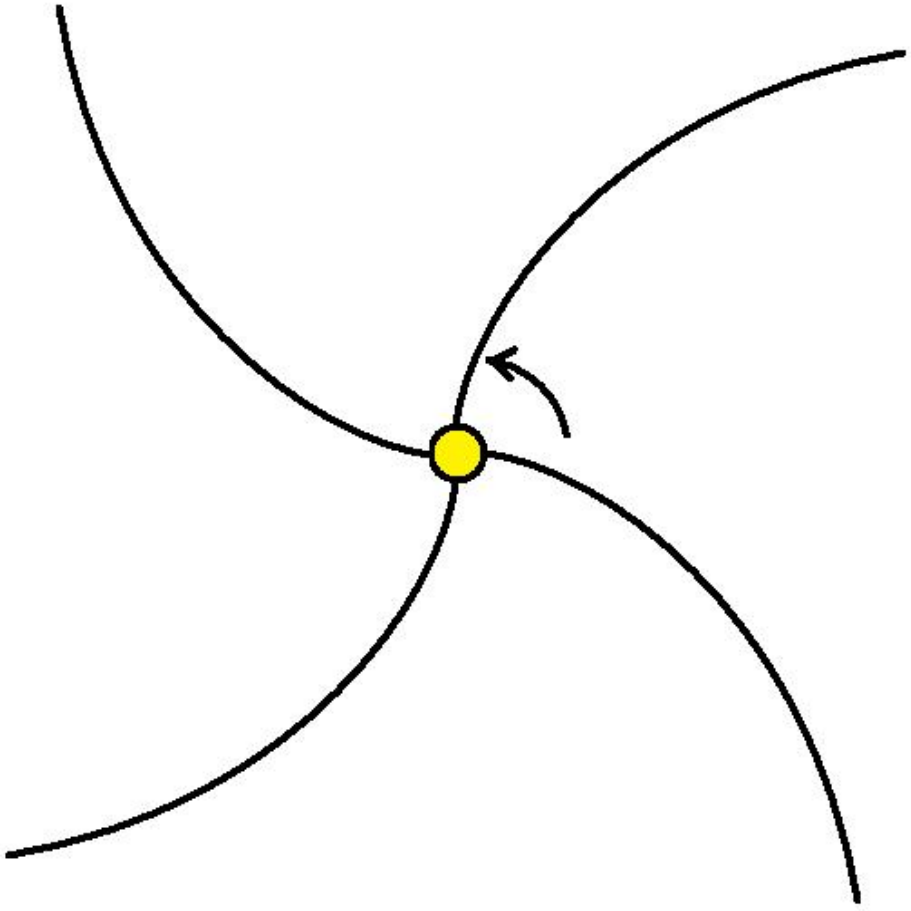
Extrapolated B_n closed field component for CR 2056

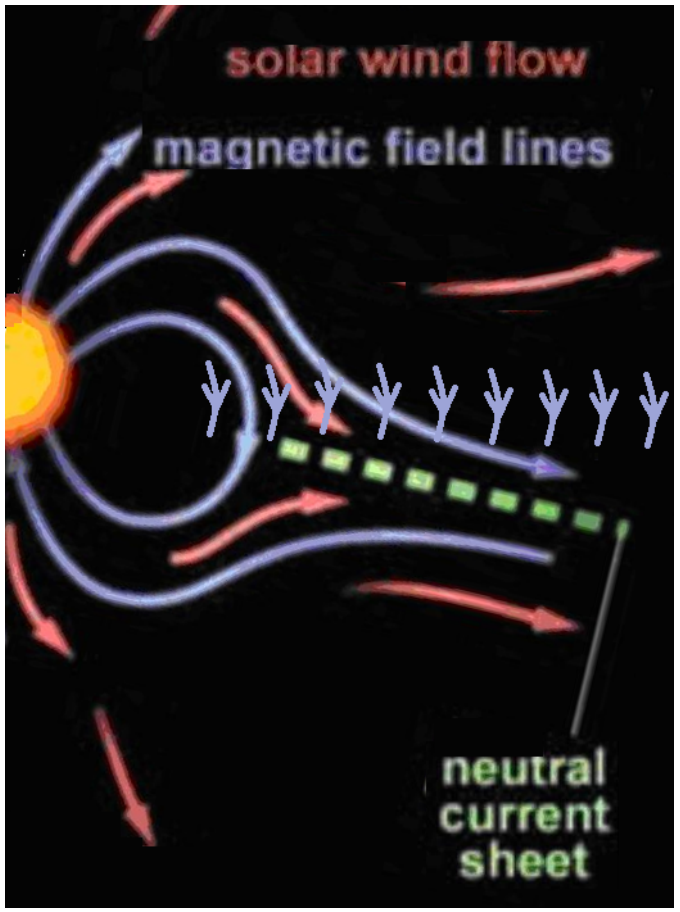




About 1/50th of the static flux $r^{-1.34}$ fall-off

Space Weather Predictions using IPS





I suggest that at least part of the B_n component comes from closed fields that escape from near the solar surface – perhaps through some non-static process.

Space Weather Predictions using IPS

Summary:

IPS Space Weather Predictions

IPS Tomography Analyses:

Making good predictions of in-situ measurements ahead of time keeps you "honest".

New Systems:

Incorporation of other systems into the analysis is now available, and helps other IPS sites standardize and edit their own data sets.

Interesting Developments:

The IPS analysis is a really-great test-bed for many different types of heliospheric scientific endeavors.