Heliospheric Tomography - Results Using 3-D MHD Kernels

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Center for Space Plasma and Aeronomic Research, University of Alabama in Huntsville (UAH), Huntsville, AL, United States

Introduction:

IPS time-dependent kinematic model analysis:
A worldwide operation that includes magnetic field.

IPS-iterated 3-D MHD:
The 3-D MHD models iteratively fit to IPS observations.

What's Next?
An Ensemble Model (ENLIL with Cone Updated by IPS)
WIPSS (Worldwide InterPlanetary Scintillation Stations) network

Heliospheric Tomography - Results Using 3-D MHD Kernels

DATA

IPS Heliospheric Analyses at ISEE (STELab)

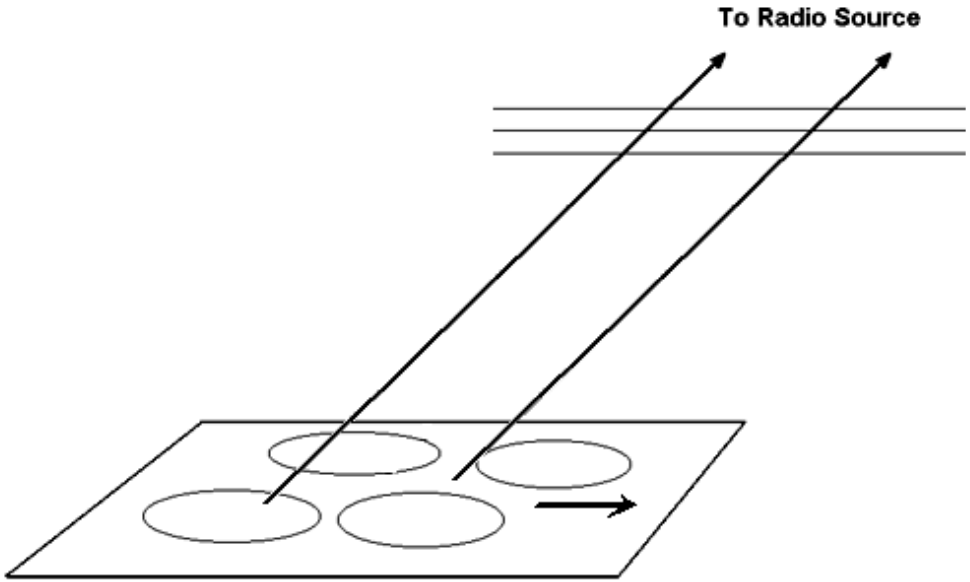
ISEE IPS array at Mt Fuji
327 MHz ~2600 m²

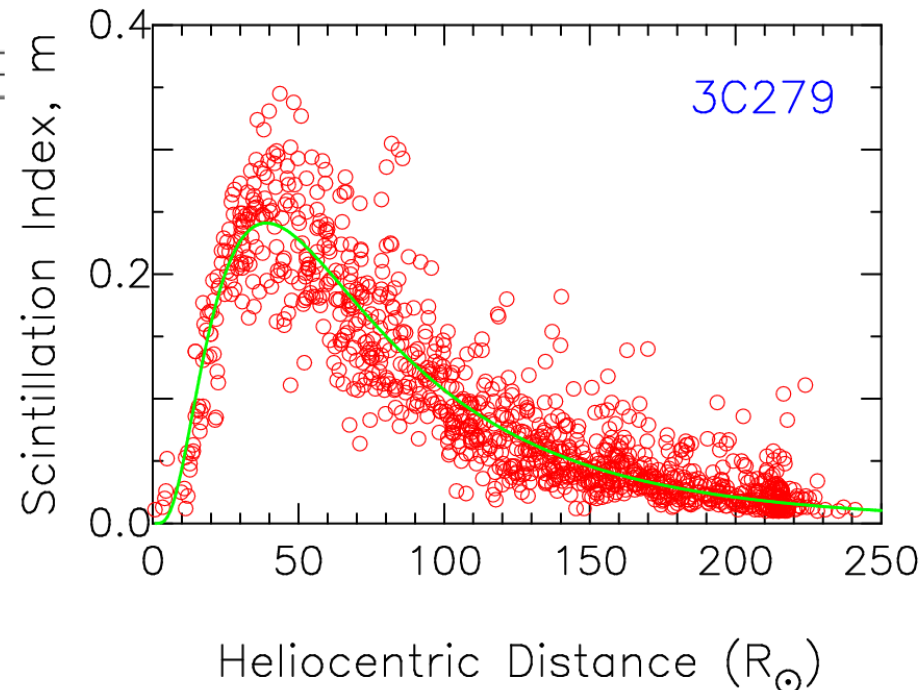
ISEE IPS array systems

Heliospheric Tomography - Results Using 3-D MHD Kernels

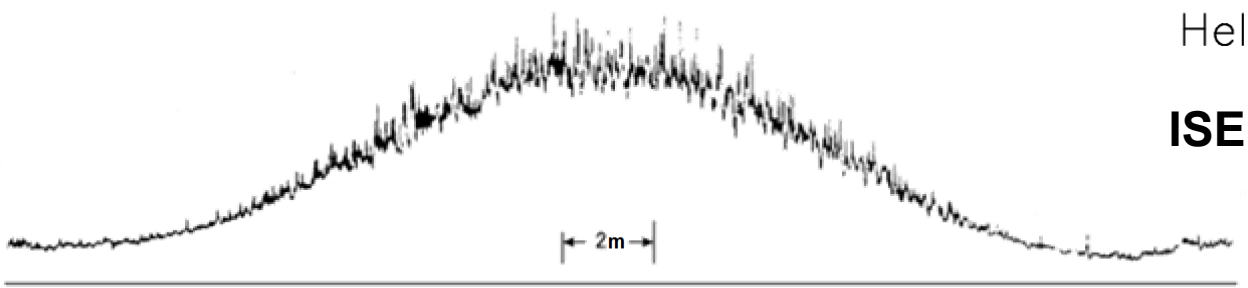
DATA

IPS Heliospheric Analyses ISEE (STELab)





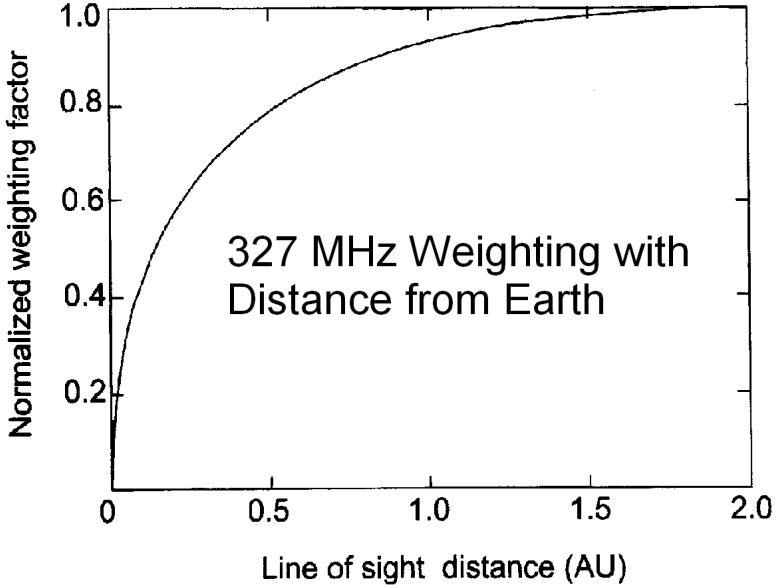
IPS line-of-sight response



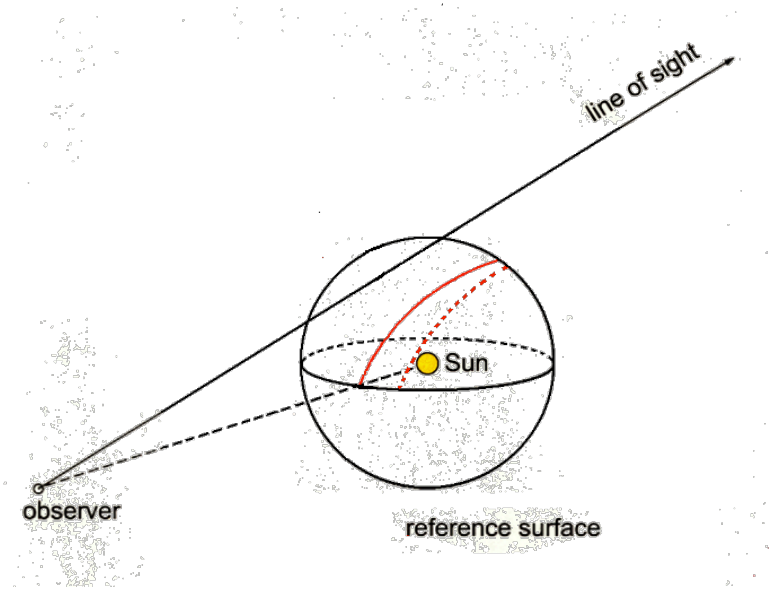
ISEE IPS array systems

Heliospheric Tomography - Results Using 3-D MHD Kernels

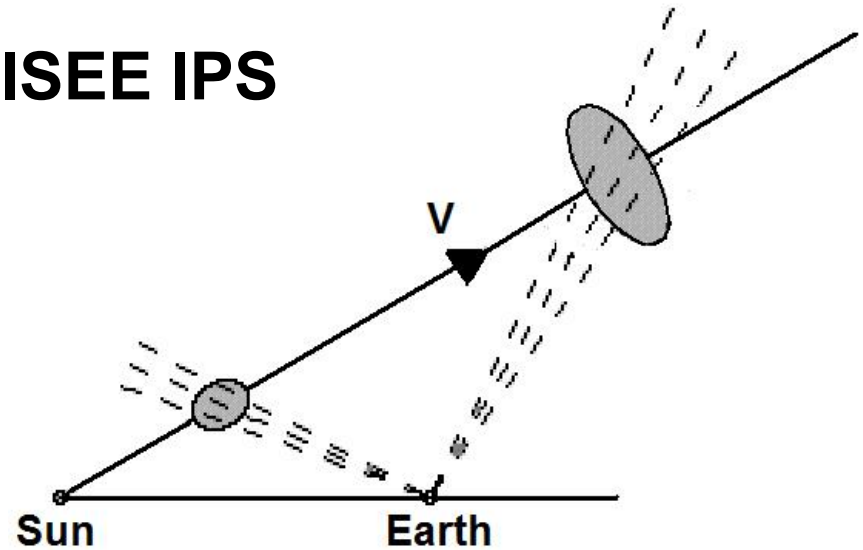
IPS line-of-sight response Jackson, B.V., *et al.*, 2008, *Adv. in Geosciences,* 21, 339-360.



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



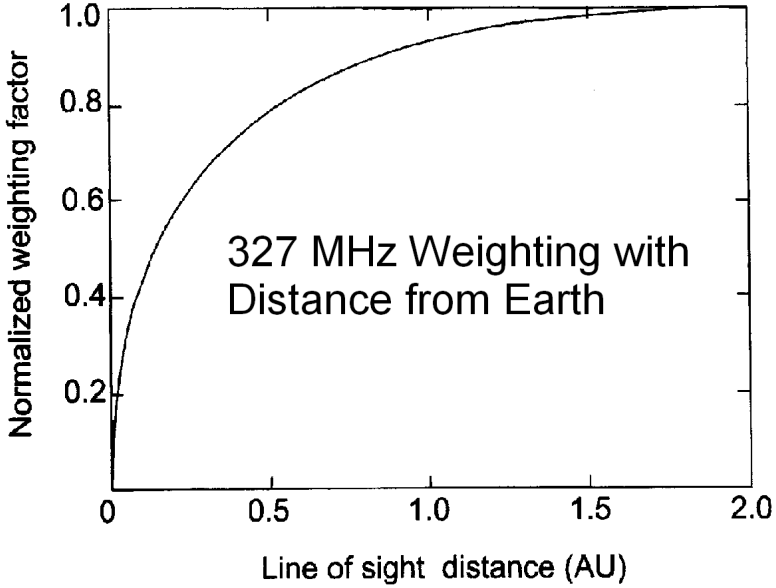
ISEE IPS



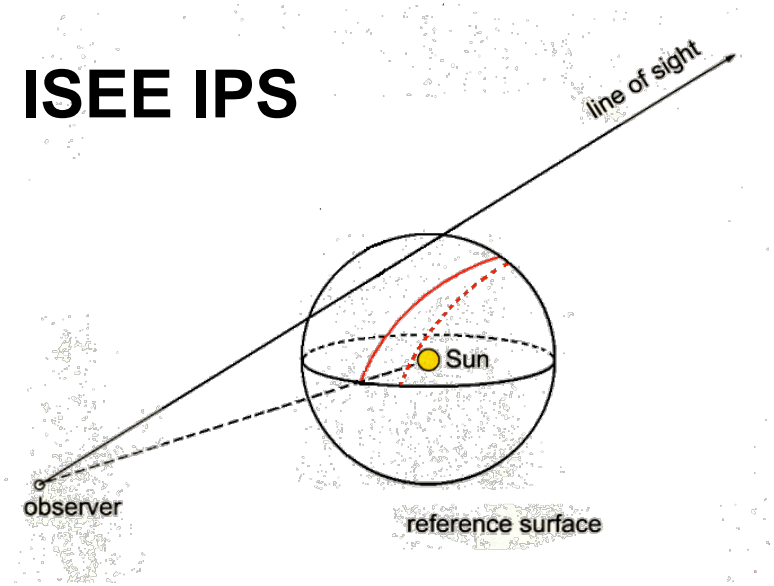
Sample outward motion over time

Heliospheric Tomography - Results Using 3-D MHD Kernels

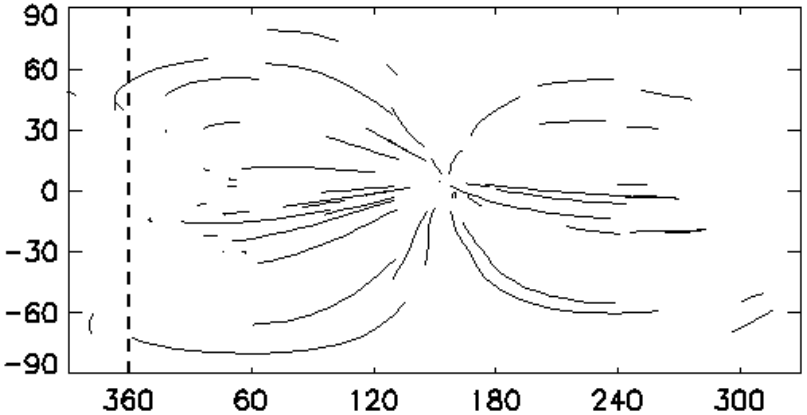
IPS line-of-sight response Jackson, B.V., *et al.*, 2008, *Adv. in Geosciences,* 21, 339-360.



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



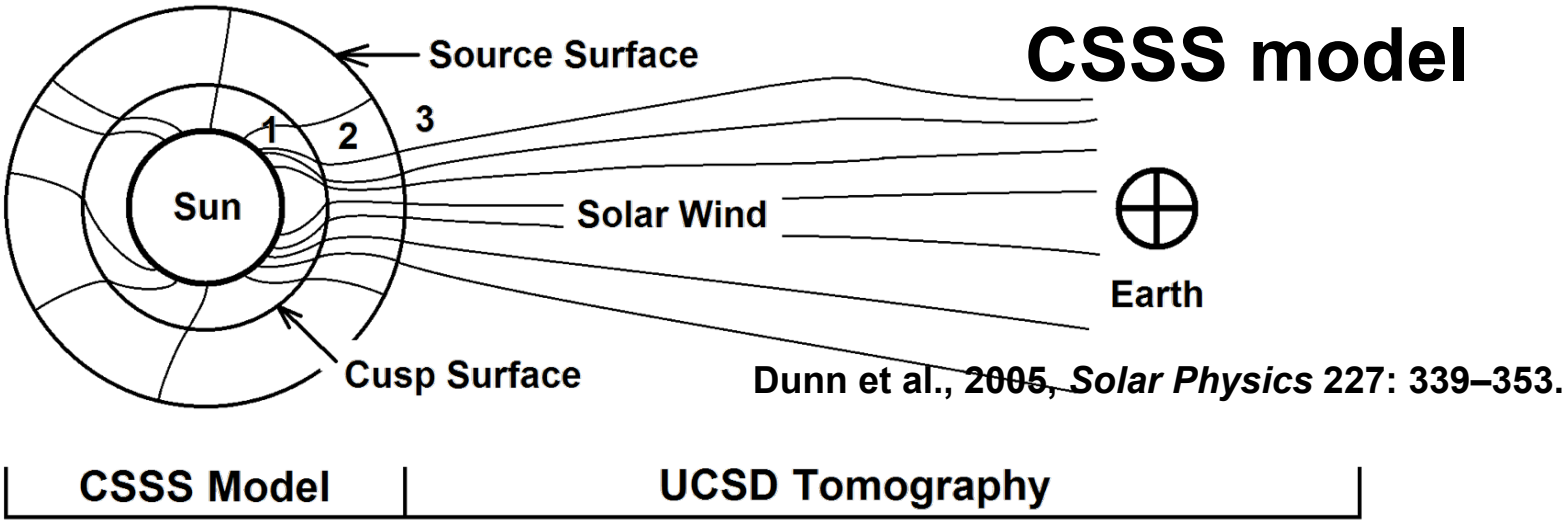
ISEE Lower Surface Boundary



13 July 2000

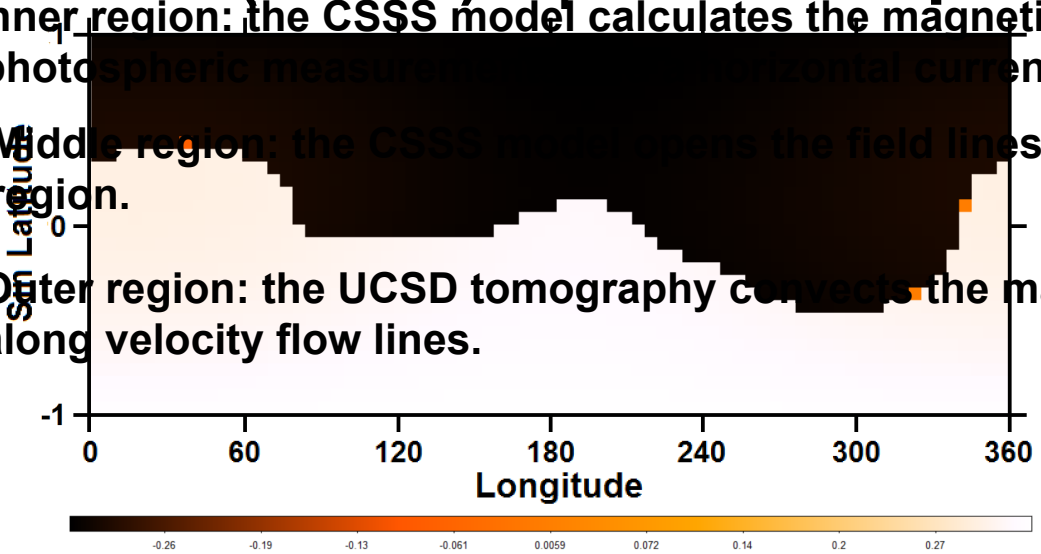
Heliospheric Tomography - Results Using 3-D MHD Kernels

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



Source surface (15 Rs) 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.



Real-Time Kinematic Model

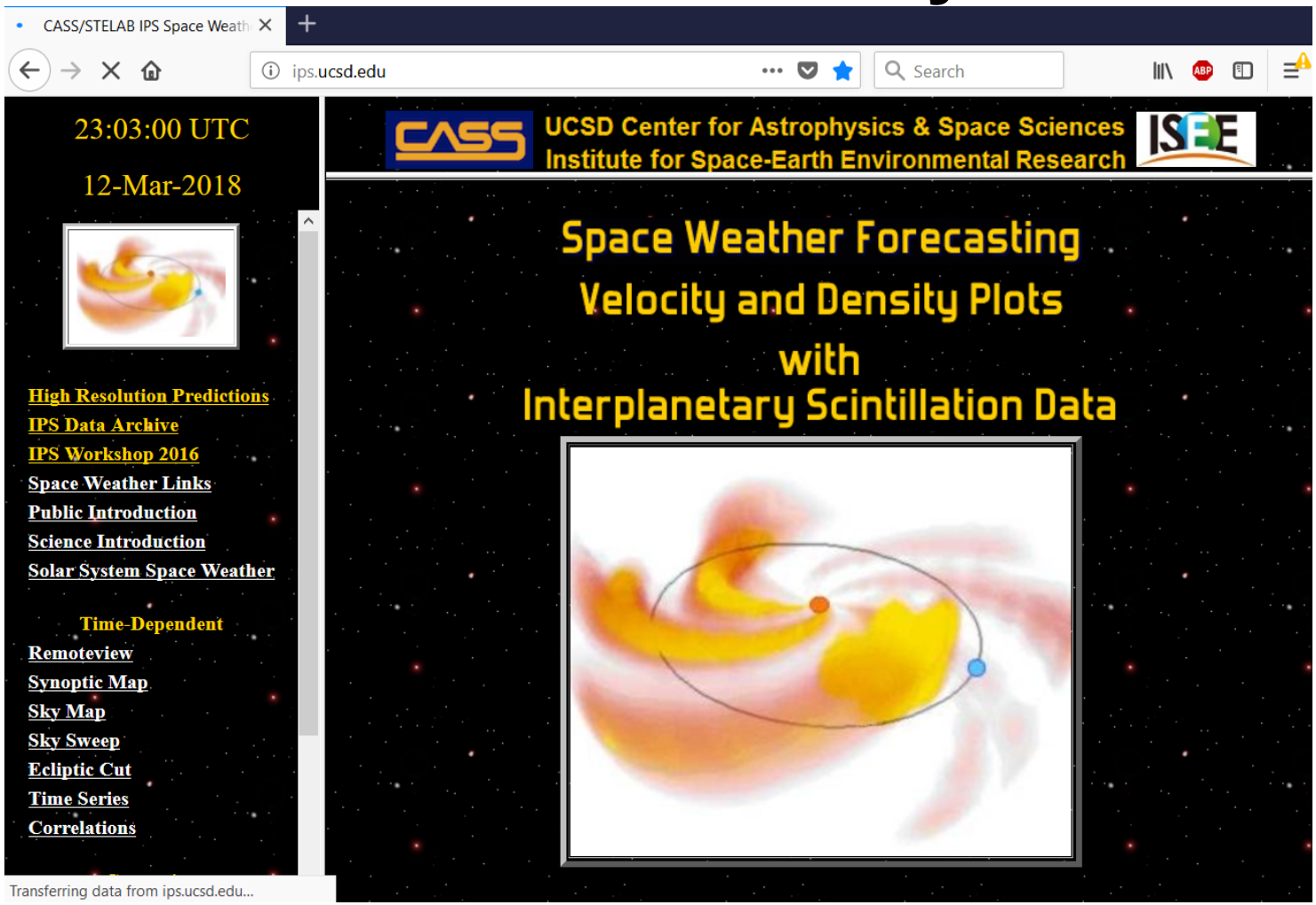
Heliospheric Tomography - Results Using 3-D MHD Kernels

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

http://ips.ucsd.edu/ or http://ips.ucsd.edu/high_resolution_predictions

UCSD Prediction Analyses

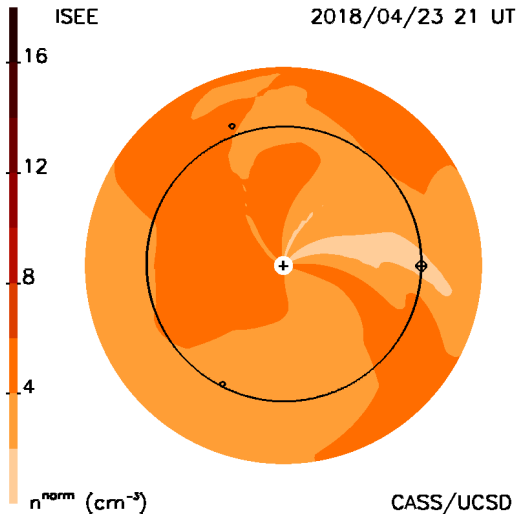
UCSD Web pages

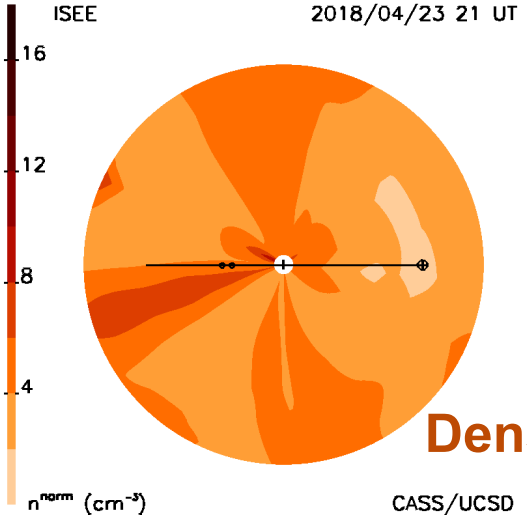


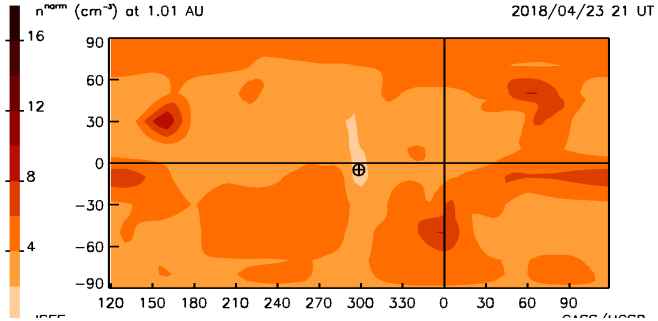
Web analysis runs "automatically" using Linux on a P.C.

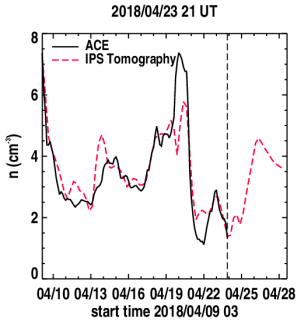
Heliospheric Tomography - Results Using 3-D MHD Kernels

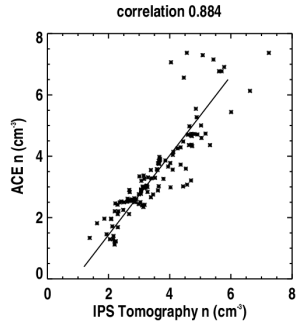
Last Night 2018/04/23 21UT



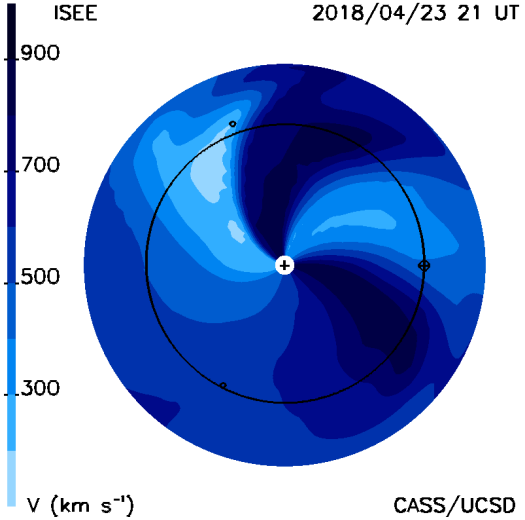


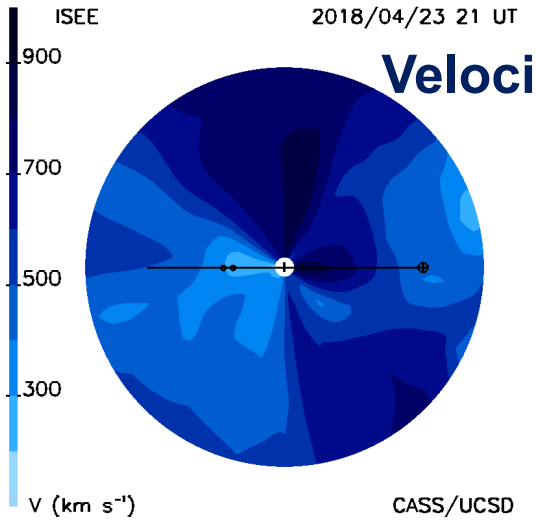




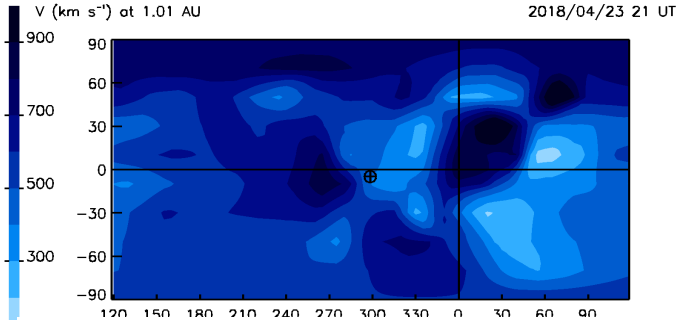


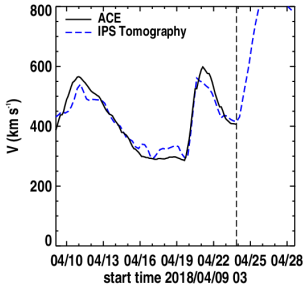
Density

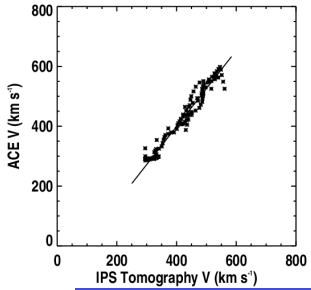




Velocity







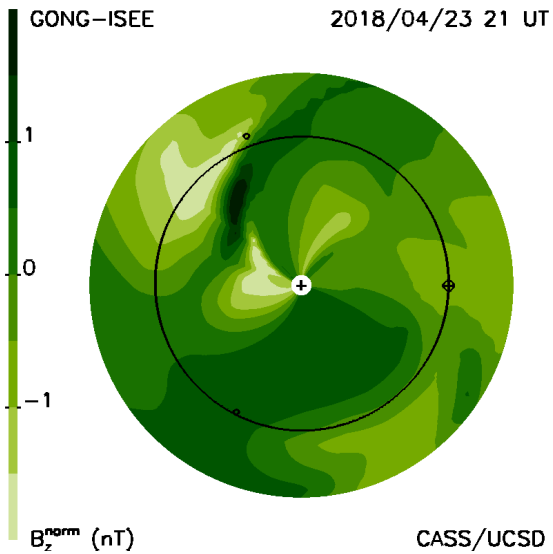
Ecliptic Cuts

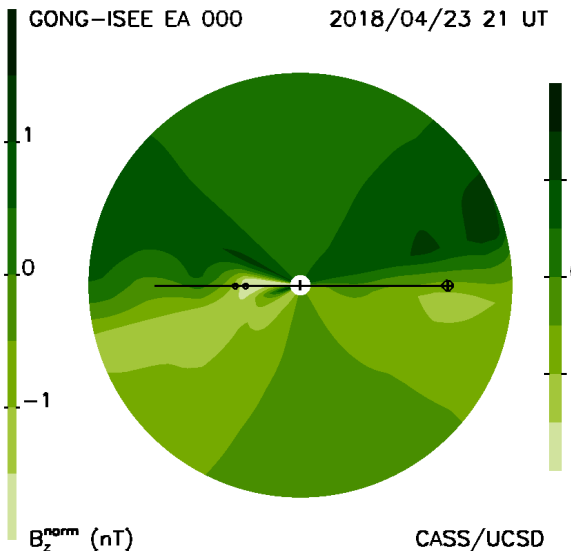
Meridional Cuts

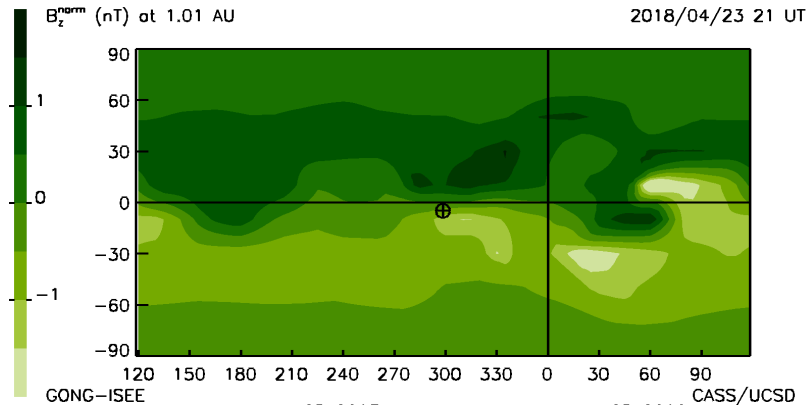
Heliospheric Tomography - Results Using 3-D MHD Kernels

Last Night 2018/04/23 21UT

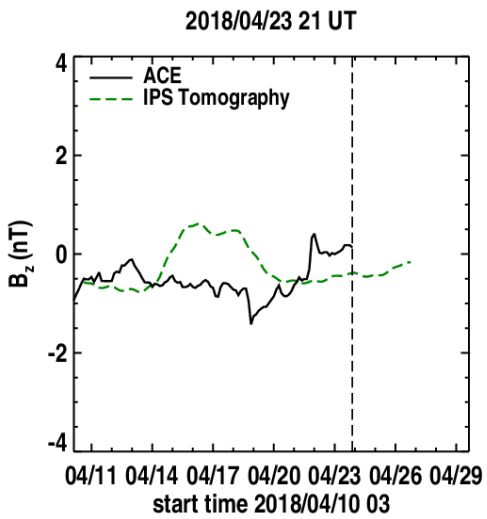
GSM Bz

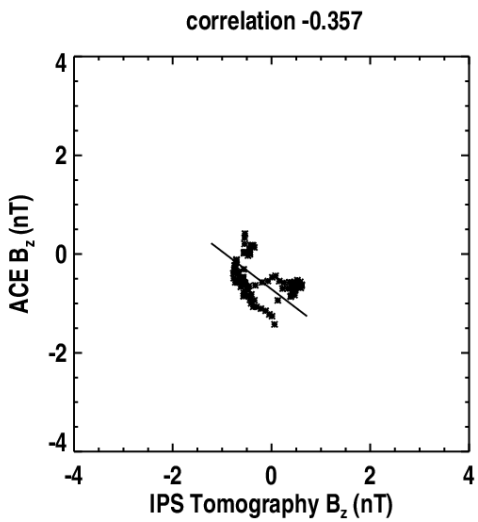




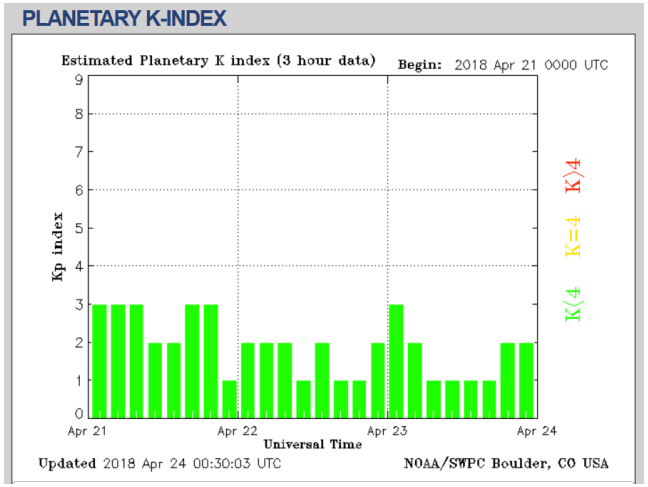


Carrington Plot





Time Series



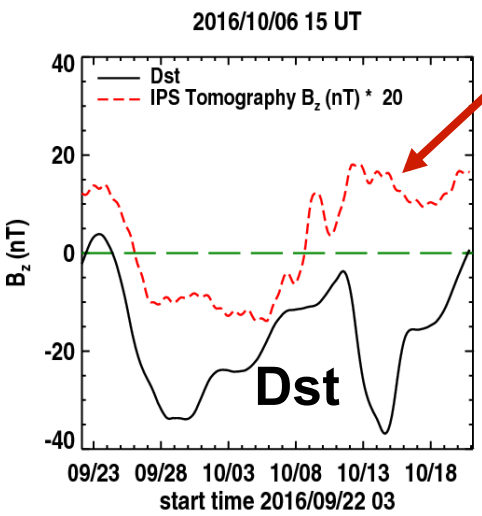
NOAA Kp Index

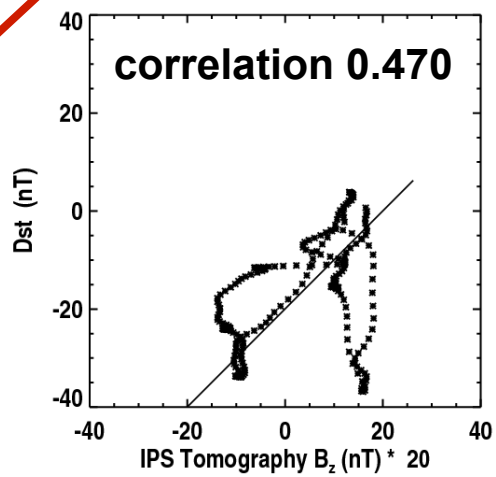
Heliospheric Tomography - Results Using 3-D MHD Kernels

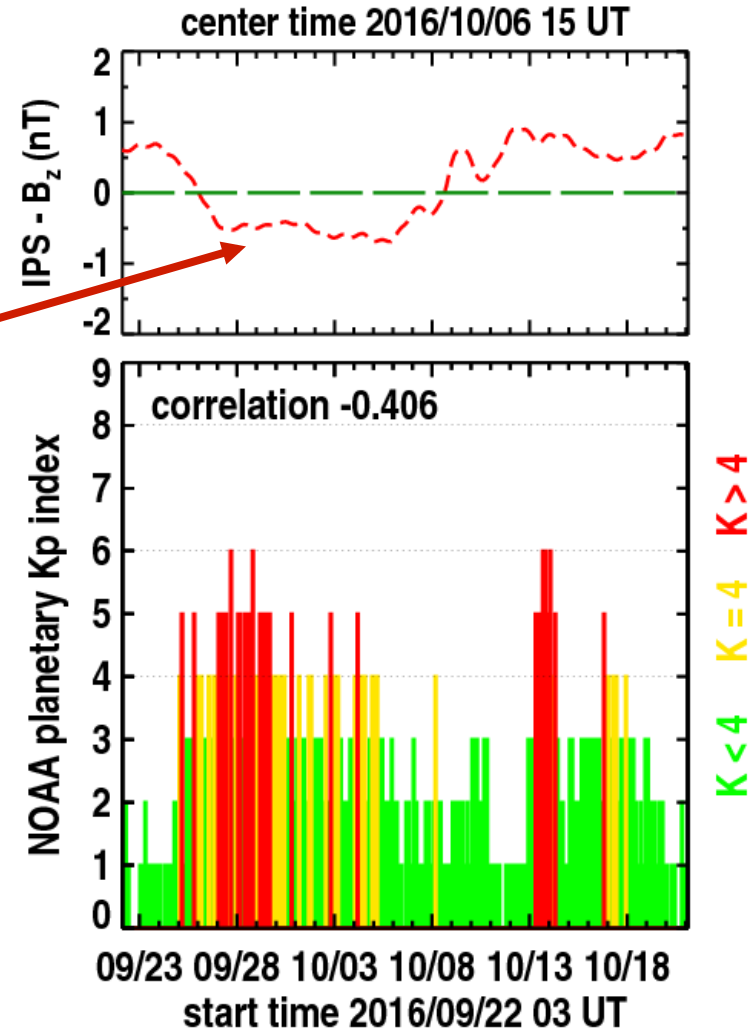
CR2182.0 2016 09/22-10/21 GSM Bz

Sample correlations for CR2182 between the tomography-derived Bz and Dst or Kp

CSSS-IPS Derived





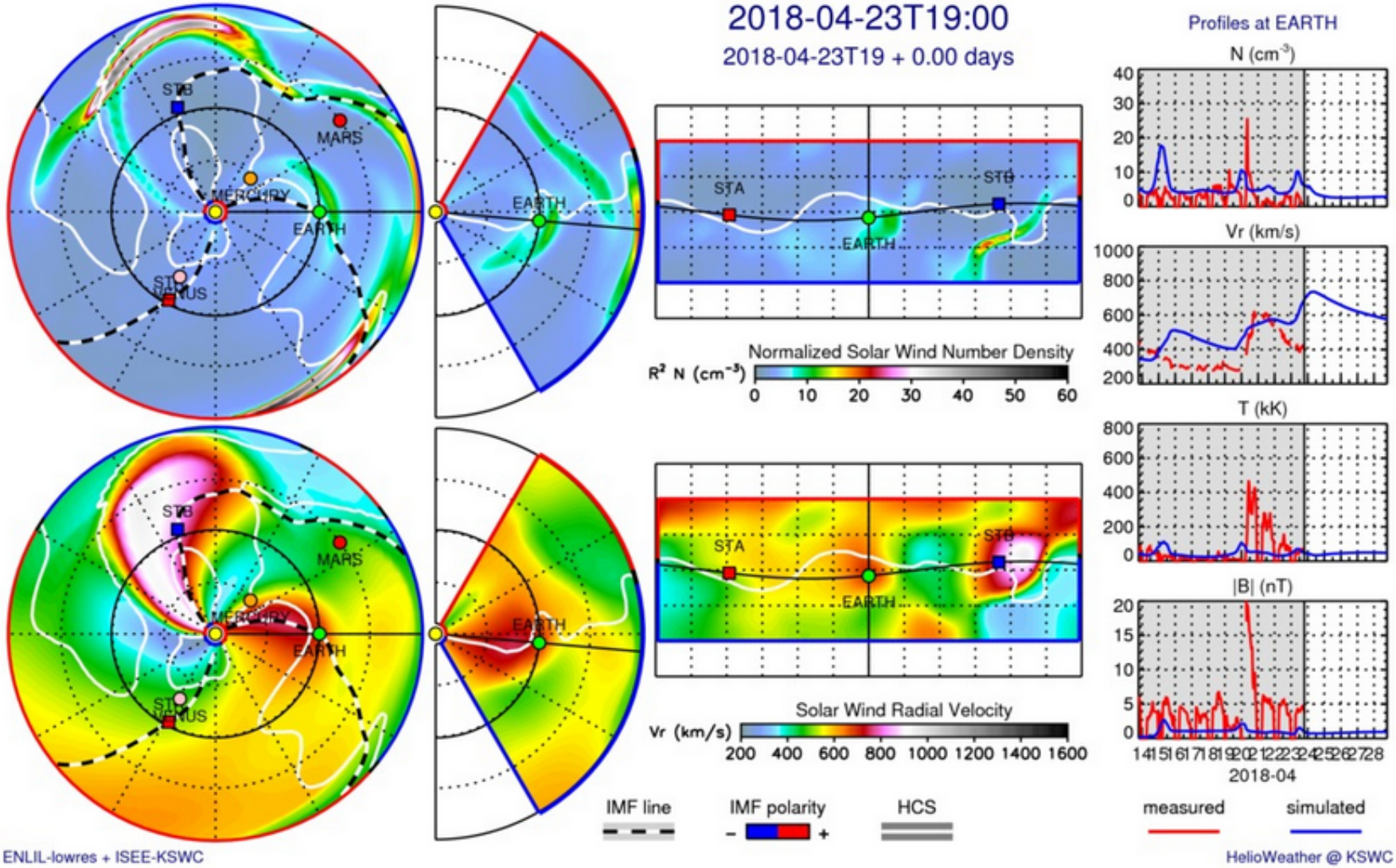


Real-Time IPS - Driven ENLIL

Heliospheric Tomography - Results Using 3-D MHD Kernels

Last Night IPS Prediction (KSWC)

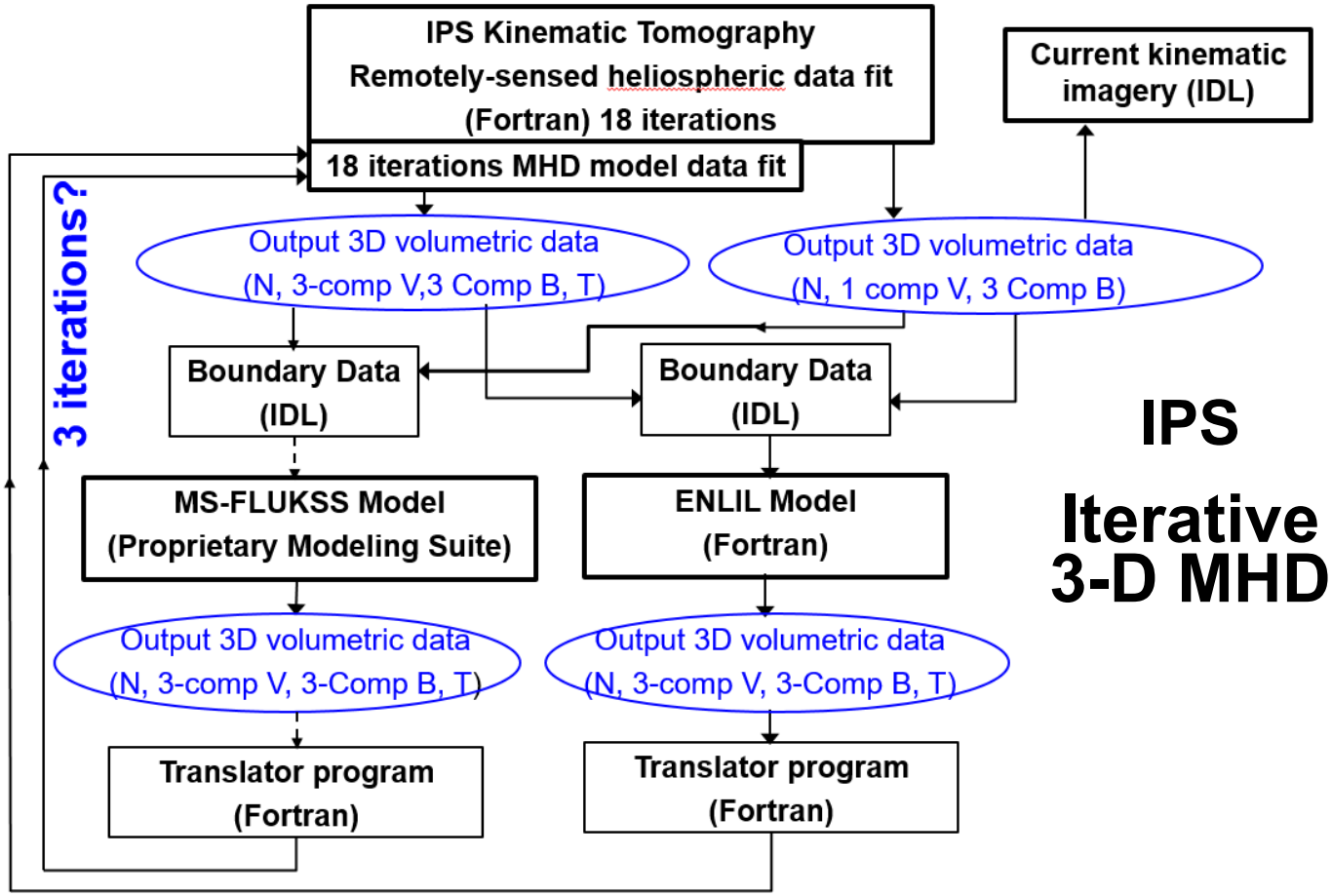
http://www.spaceweather.go.kr/models/ipsbdenlil



IPS-Driven ENLIL

IPS Iteratively - Updated 3-D MHD

The Iterative Process with 3-D MHD models



UHA MS-FLUKSS (Pogorelov)

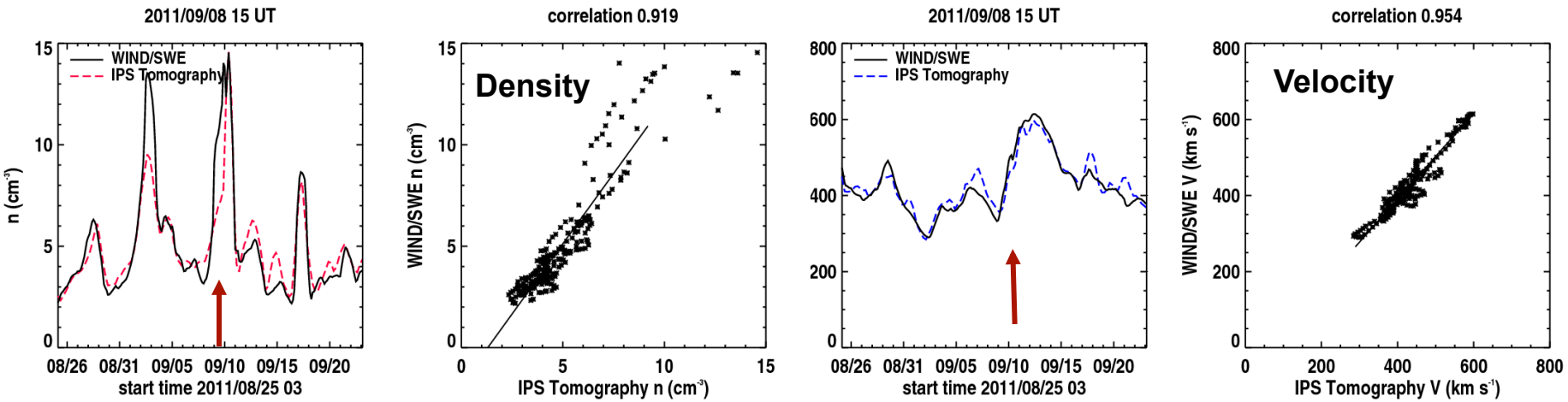
ENLIL (Odstrcil)

Heliospheric Tomography - Results Using 3-D MHD Kernels

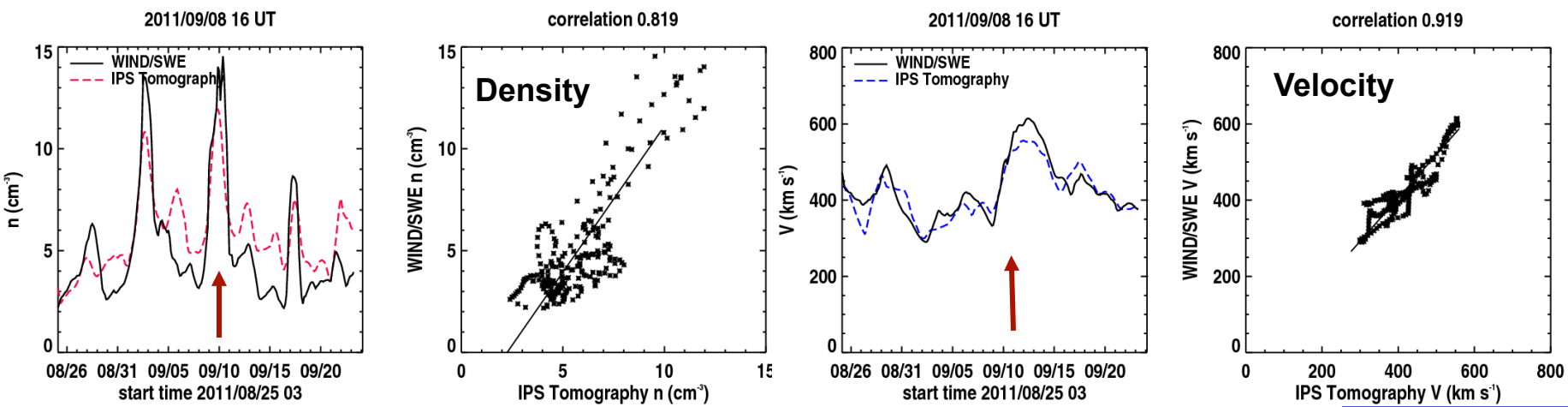
IPS Iteratively Updated ENLIL Model Density/Velocity

CR2114.0 (2011/09/10 03 UT CME at Earth)

Iteration 0 (Kinematic - IPS)



Iteration 2 (ENLIL - IPS)



Heliospheric Tomography - Results Using 3-D MHD Kernels

IPS Iteratively Updated ENLIL Model Density/Velocity

2011/09/10 03 UT CME at Earth

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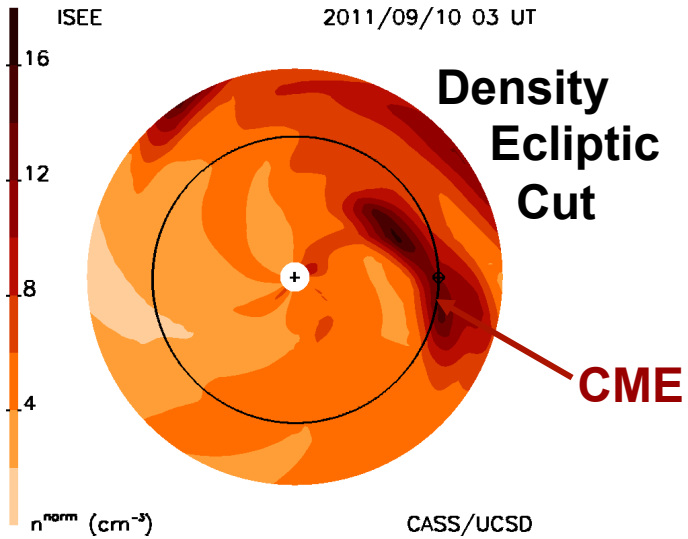

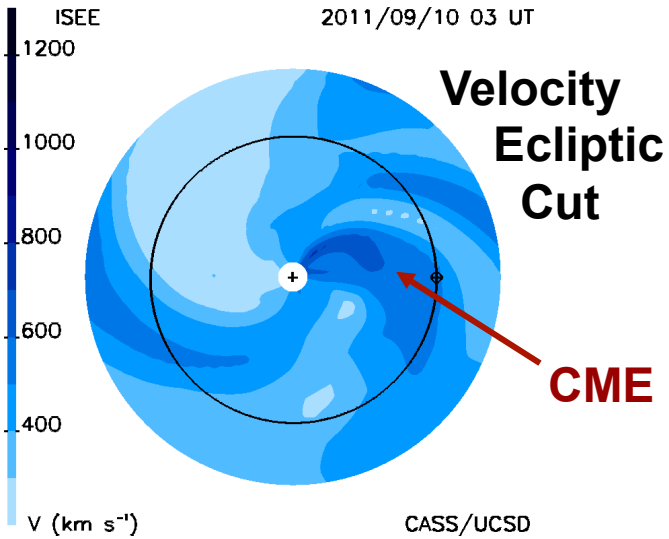

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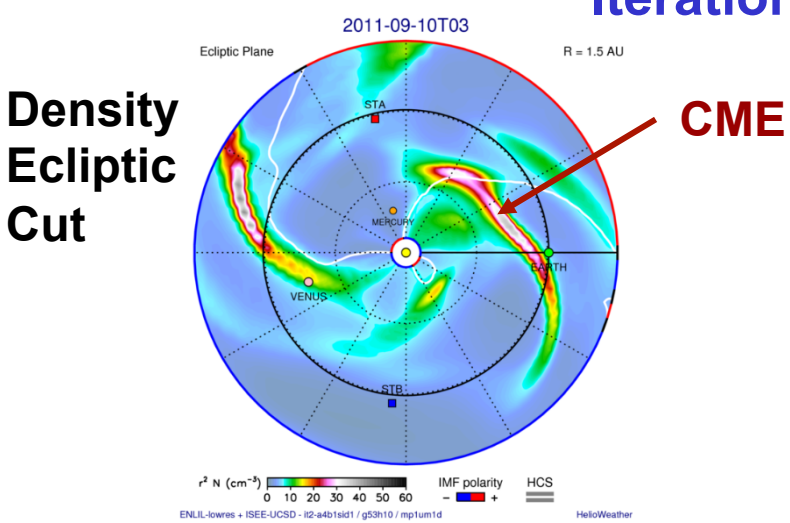
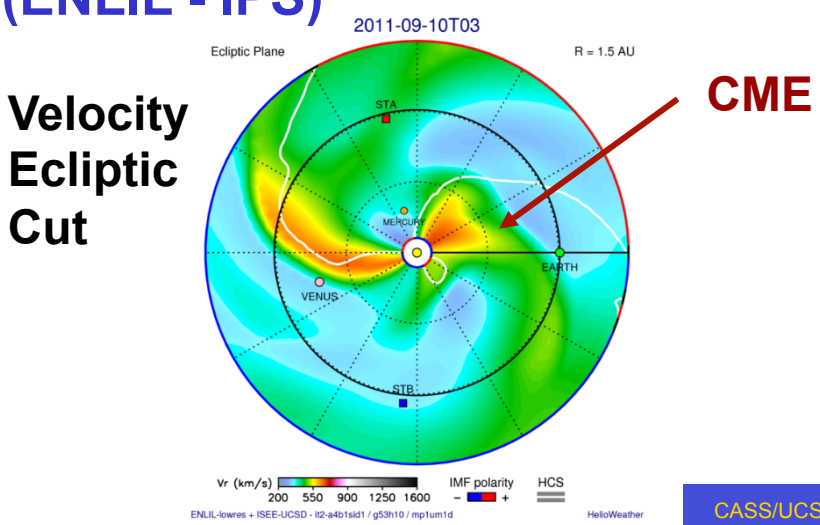
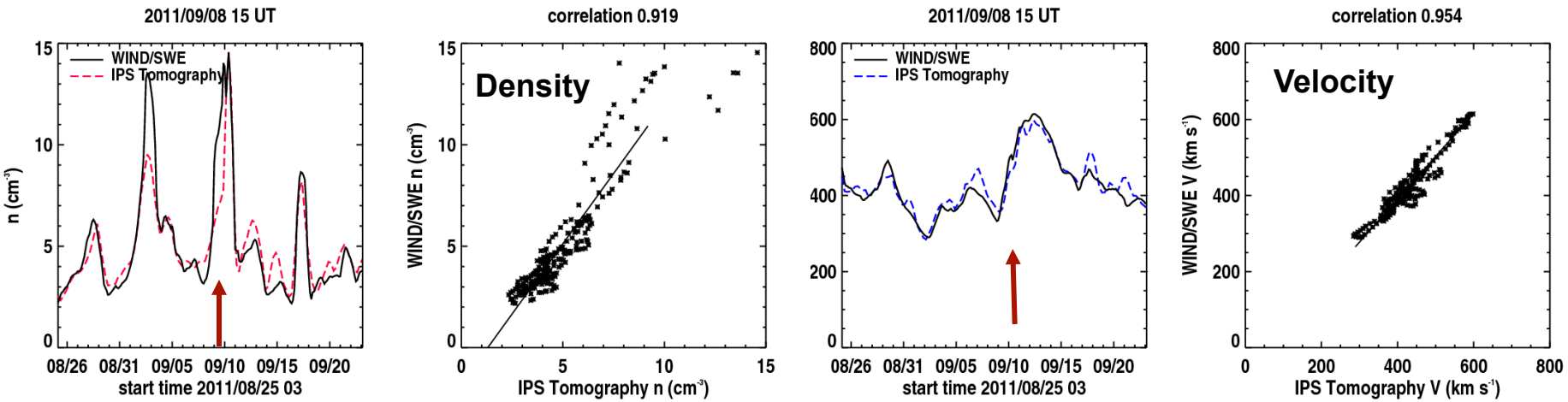




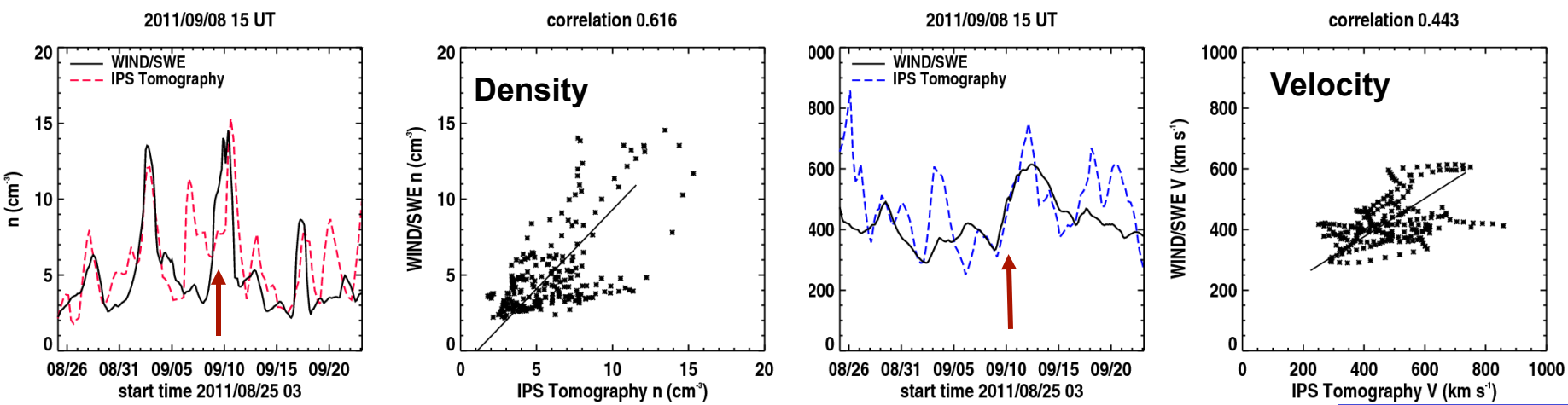
Heliospheric Tomography - Results Using 3-D MHD Kernels

IPS Iteratively Updated MS-FLUKSS Density/Velocity CR2114.0 (2011/09/10 03 UT CME at Earth)

Iteration 0 (Kinematic - IPS)



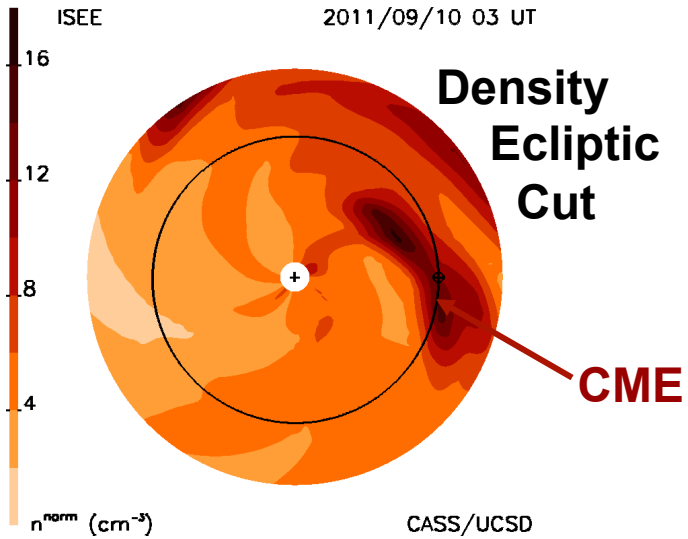
Iteration 3 (MS-FLUKSS - IPS)

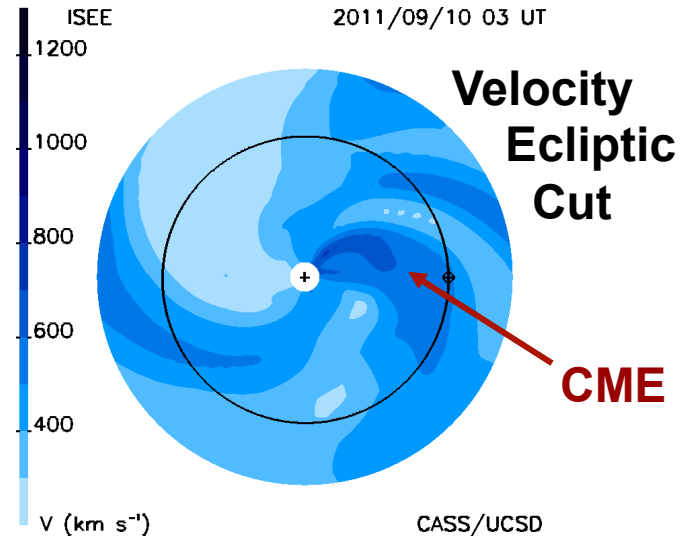


Heliospheric Tomography - Results Using 3-D MHD Kernels

IPS Iteratively Updated MS-FLUKSS Density/Velocity 2011/09/10 03 UT CME

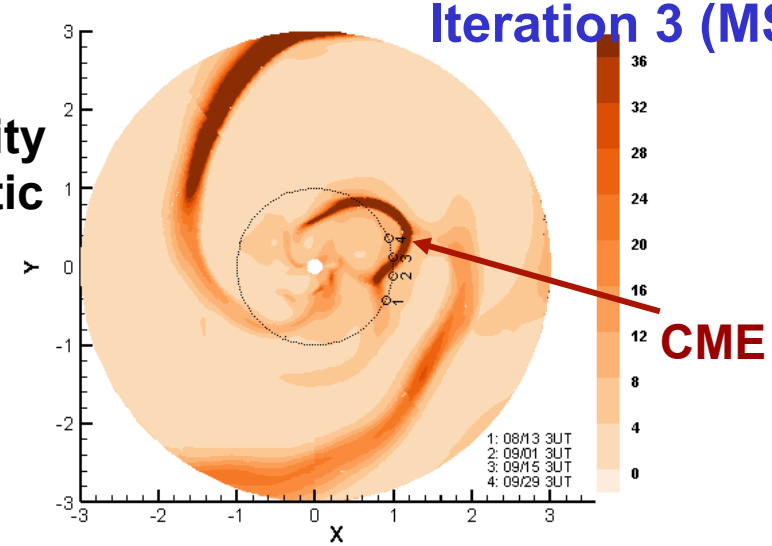
Iteration 0 (Kinematic - IPS)

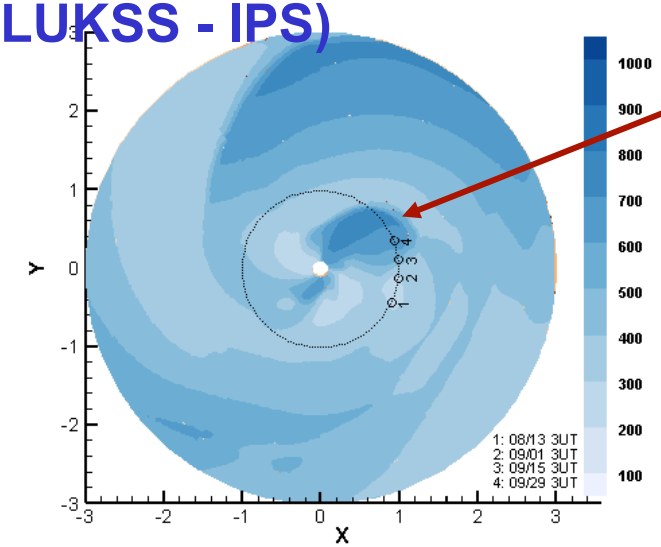




Iteration 3 (MS-FLUKSS - IPS)

Density Ecliptic Cut





Velocity Ecliptic Cut

So now that we have this technique, what can we do with it?

1) Compare 3-D MHD models and determine their differences not only in-situ, but at the lower boundary and in between.

2) Explore the non-radial heliospheric transport of various solar structures.

3) Compare the 3-D structure of poorly-known parameters (density, velocity) in the heliosphere with observed coronal features.

4) Explore the now-assumed and poorly-known model values (heating, gamma) provided in 3-D MHD models.

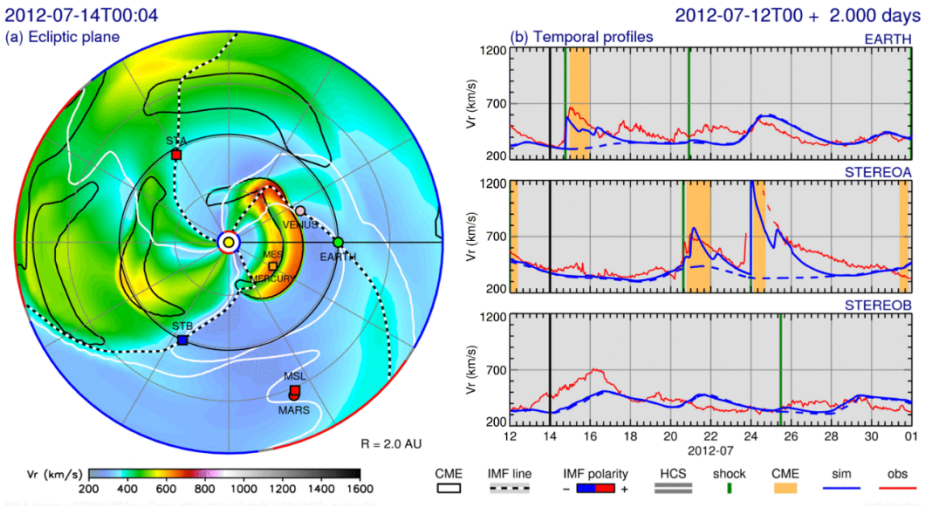
5) Better space weather predictions.

Next

IPS - Updated 3-D ENLIL with Cone

Next

Ensemble Model



→ **Update ENLIL with Cone by IPS**

Next

Better IPS analysis?

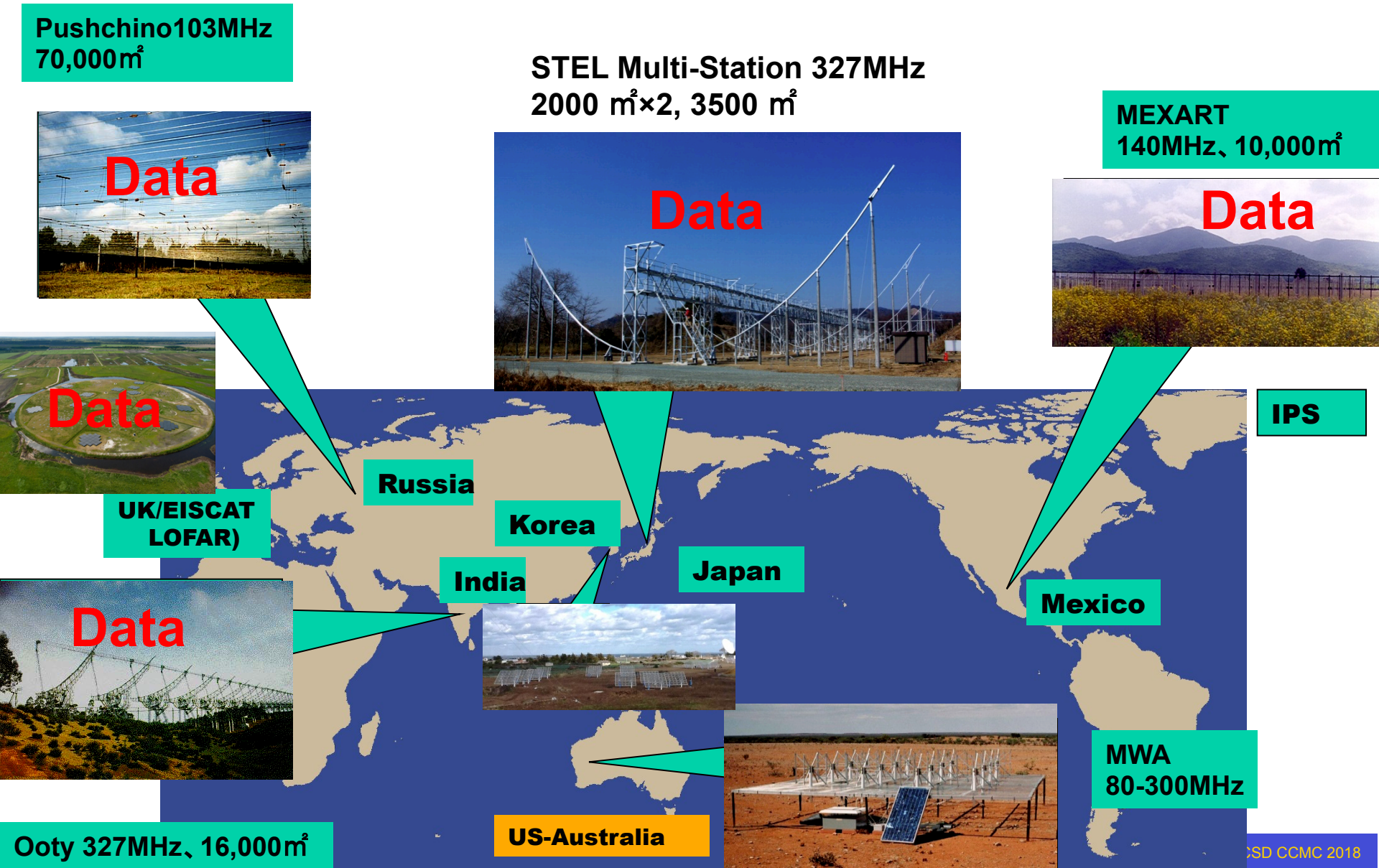
A New Organization Name

WIPSS

(Worldwide InterPlanetary Scintillation Stations) Network

Heliospheric Tomography - Results Using 3-D MHD Kernels

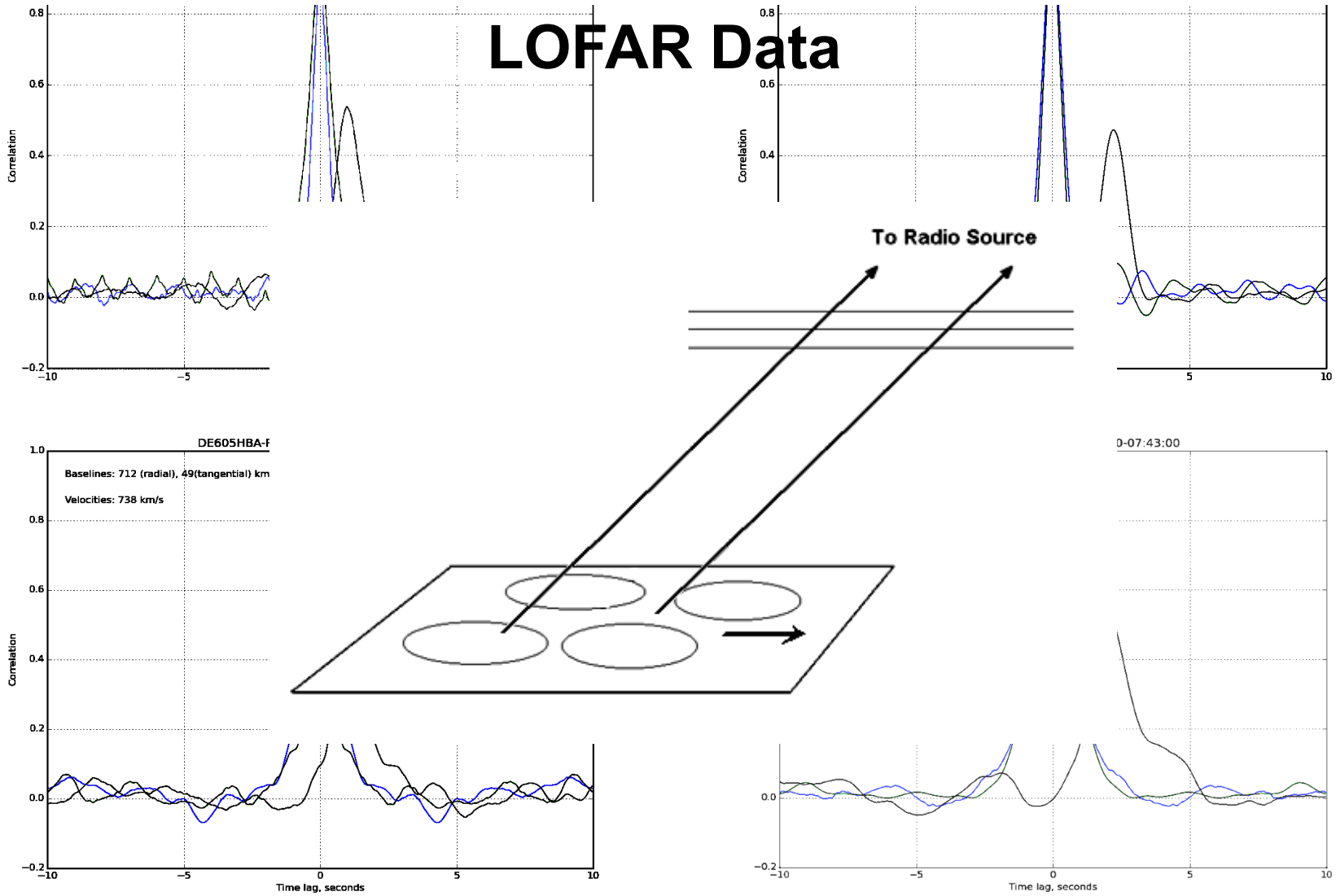
World-wide IPS stations network



Heliospheric Tomography - Results Using 3-D MHD Kernels

Multi-Site Analysis for IPS systems for Velocity

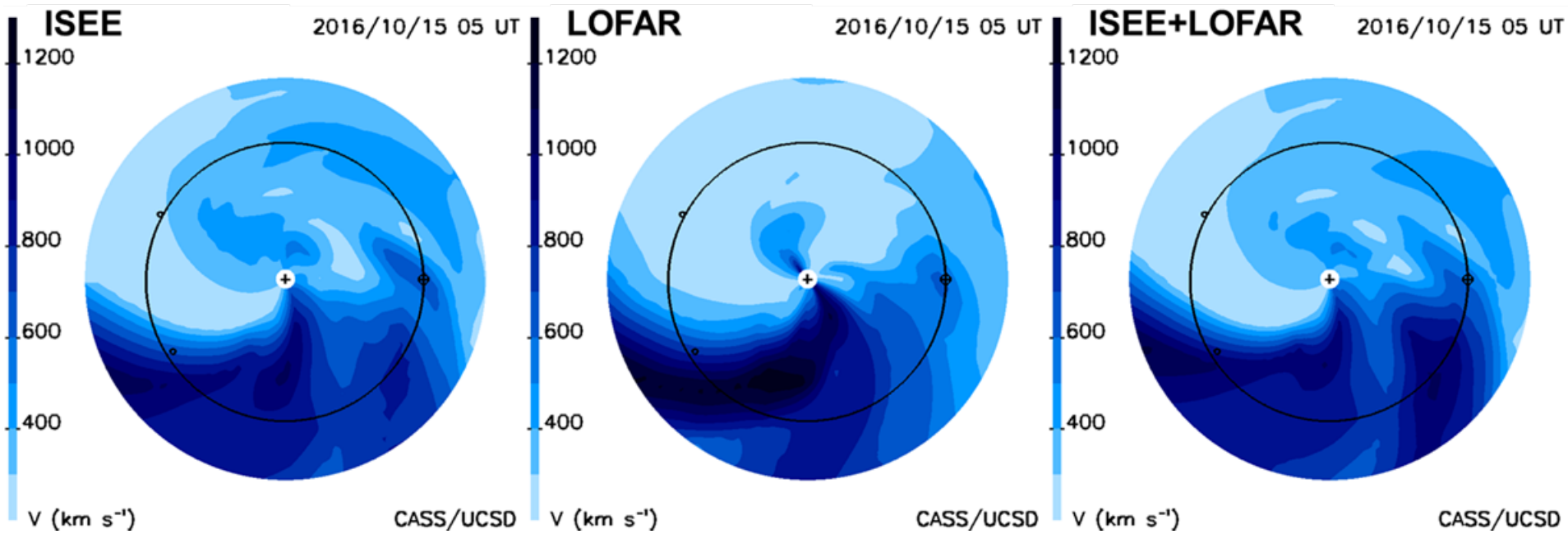
LOFAR Data



Courtesy Richard Fallows, ASTRON, The Netherlands

Combination of IPS Station Analyses

(October 2016 LOFAR Campaign)



ISEE (304 LOS/CR) | **LOFAR (263 LOS/CR)** | **Total (567 LOS/CR)**

LOFAR analysis, images, courtesy of M.M. Bisi, R. Fallows

Conclusion:

IPS time-dependent kinematic model analysis:
A worldwide operation that includes magnetic field.

IPS-iterated 3-D MHD:
The 3-D MHD models iteratively fit to IPS observations.

What's Next?
An Ensemble Model (ENLIL with Cone Updated by IPS)
WIPSS (Worldwide InterPlanetary Scintillation Stations) network