

# 1st-Year SHINE Project Report: Evaluation of Coronal & Heliospheric Models Installed at CCMC

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J.G. Luhmann<sup>3</sup>, D. Odstrcil<sup>2,4</sup>, C.N. Arge<sup>5</sup>, I. Sokolov<sup>6</sup>, P. Riley<sup>7</sup>

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A. Mendoza, A. Taktakishvili. Thanks to the model providers.

6<sup>th</sup> CCMC Workshop

Key Largo, Florida

January 18, 2012

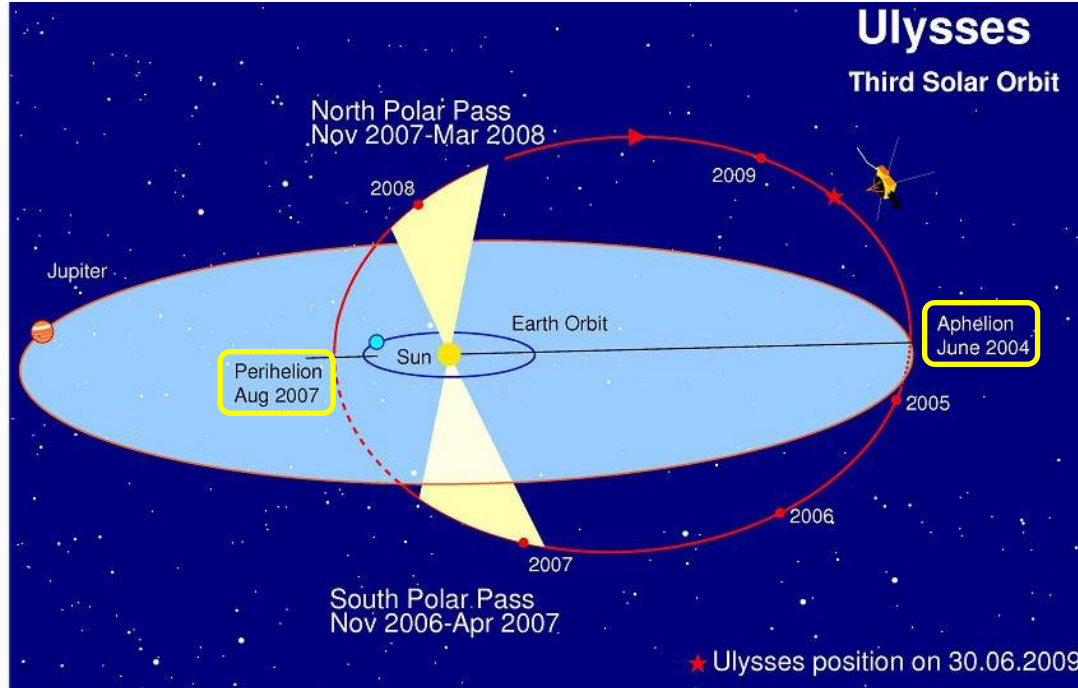
# Introduction

- ❖ Photospheric magnetograph synoptic map:  $1^\circ$  resolution
- ❖ Wang-Sheeley-Arge (WSA) model:  $2.5^\circ$  resolution (0.94  $R_s$ )
- ❖ Enlil model
  - To 10 AU, the grid is  $1024 \times 45 \times 180$ , *i.e.*,  $1.66 R_s \times 2^\circ \times 2^\circ$
  - To 2 AU, the grid is  $1024 \times 120 \times 360$ , *i.e.*,  $0.42 R_s \times 1^\circ \times 1^\circ$
  - 27 days for  $360^\circ$ ,  $1^\circ$  for 0.075 day = 1.8 hours (3.75  $R_s$ )
  - New version uses the variable field from the synoptic maps and coronal models, so it has better IMF tracing
- ❖ Space Weather Modeling Framework (SWMF)
  - 1-16  $R_s$ : the smallest cell is 0.023  $R_s$
  - 16-400  $R_s$ : the smallest cell is 0.39  $R_s$ , and increases to 6.25  $R_s$  at the boundaries
  - Most of the Ulysses trajectory: a resolution of 3.125  $R_s$

**Part I.**  
**Spacecraft (ACE & Ulysses)**  
**Observations vs. Enlil Model**  
**Results for Carrington Rotations**  
**(CRs) 2016-2018 (May-July 2004)**

Jian, L.K., C.T. Russell, J.G. Luhmann, P.J. MacNeice,  
D. Odstrcil, P. Riley, J.A. Linker, R.M. Skoug, J.T.  
Steinberg, *Solar Phys.*, 273, 179-203, 2011.

# Why CRs 2016-2018?



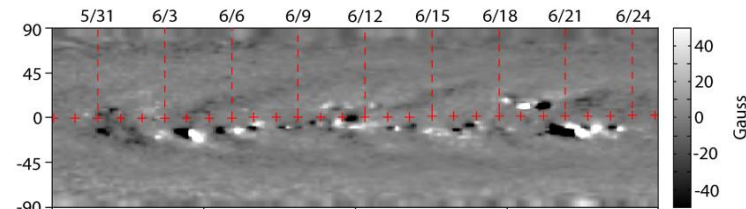
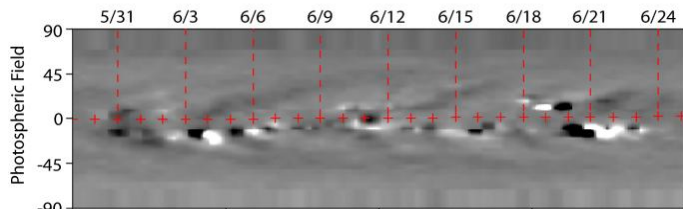
- Ulysses made 3 aphelion passes at 5.4 AU in its lifetime: Feb 1992, Apr 1998, and June 2004
- In the 1<sup>st</sup> aphelion pass, the coverage of 1-AU solar wind observations was poor
- In the 2<sup>nd</sup> aphelion pass (rising phase), no well-defined recurring stream interaction regions (SIRs) or CIRs occurred at 1 and 5.4 AU
- In the 3<sup>rd</sup> aphelion pass, ACE and Ulysses encountered two CIRs each CR from 2016 to 2018

# Coronal Sources: CR 2017 as An Example

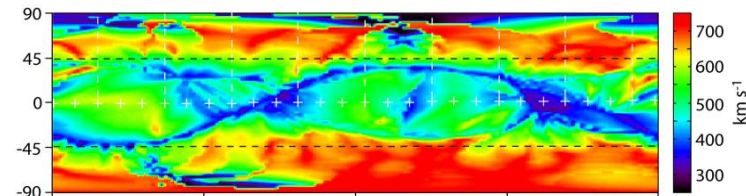
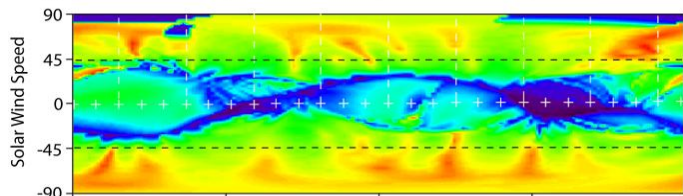
MWO: Mount Wilson Observatory

NSO: National Solar Observatory at Kitt Peak

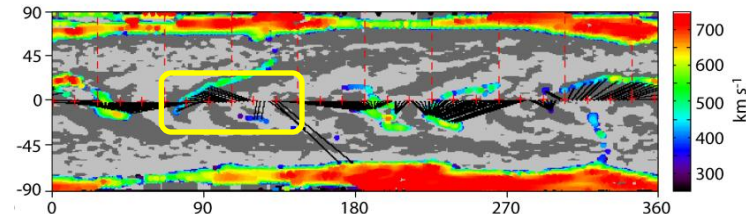
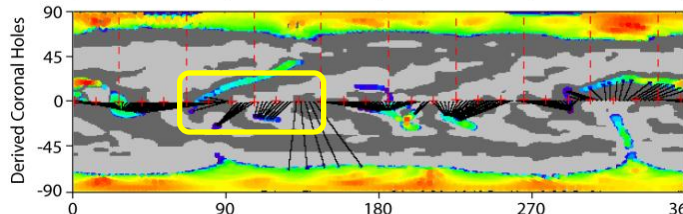
Photospheric  
Field



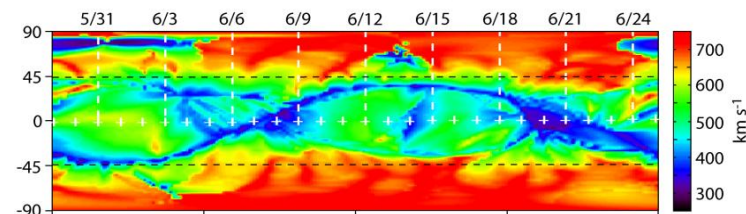
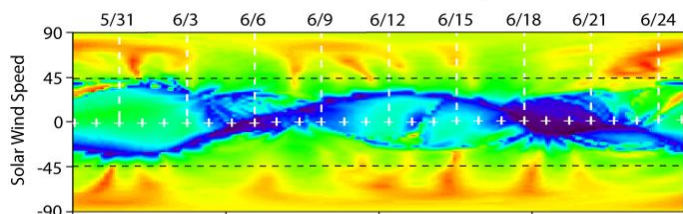
Solar Wind  
Speed  
at 21.5 Rs



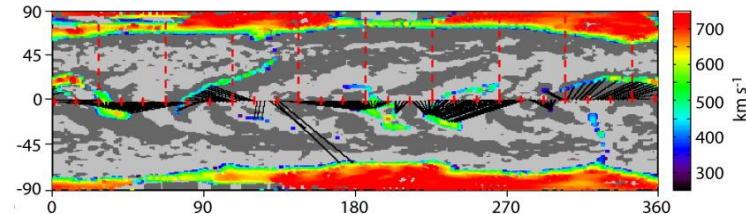
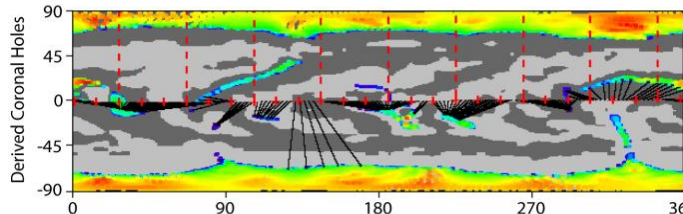
Coronal  
Holes



Solar Wind  
Speed



Coronal  
Holes



Longitude [°]

Longitude [°]

WSA v1.6

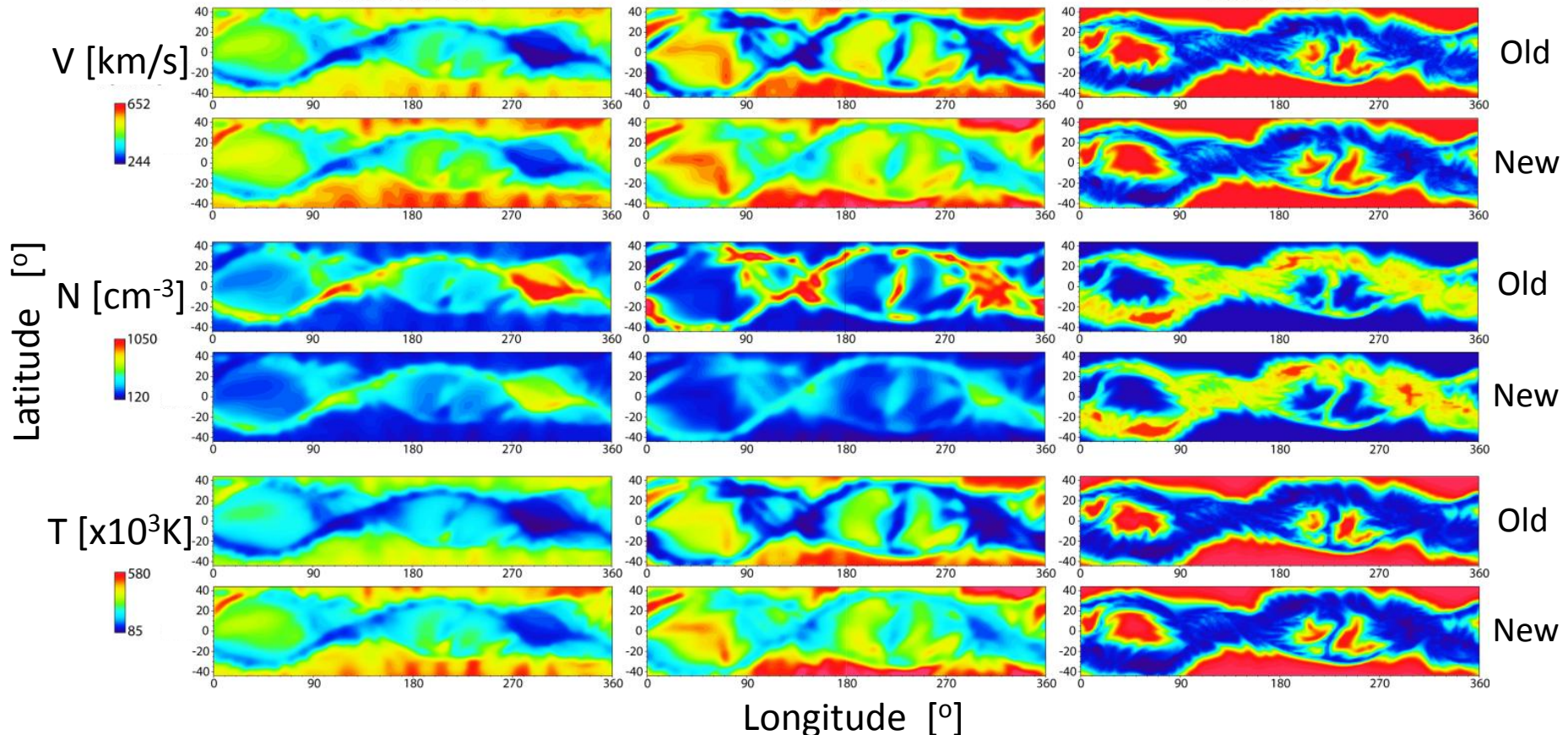
WSA v2.2

# Inner Boundary of Enlil Model at 0.144 AU (31 Rs)

MWO-WSA-Enlil

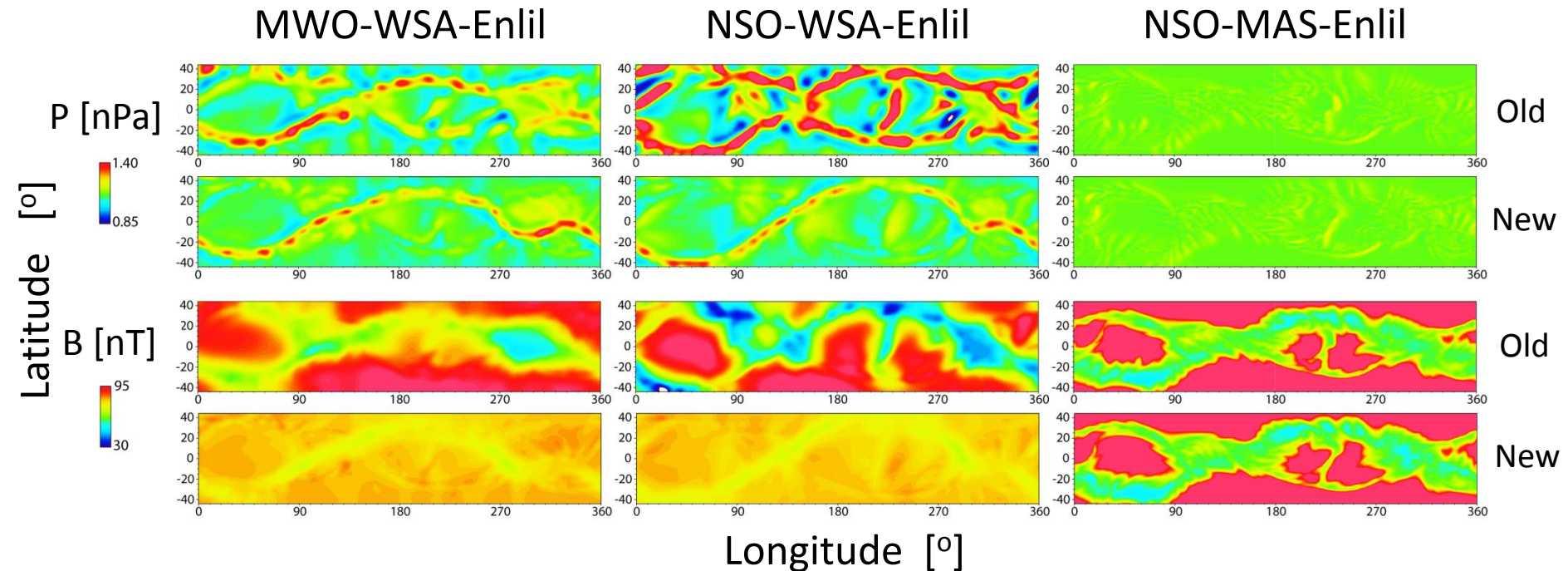
NSO-WSA-Enlil

NSO-MAS-Enlil



- The latitudinal span of slow-wind belt is **wider** from NSO than MWO, by  $\sim 10^\circ$
- The NSO-MAS-Enlil run produces more  $V$  and  $T$  discrepancies and a less  $P$  discrepancy for slow and fast wind regions than the other two runs, likely in part due to an *ad hoc* speed correction at 30 Rs

# Inner Boundary of Enlil Model at 0.144 AU (cont.)

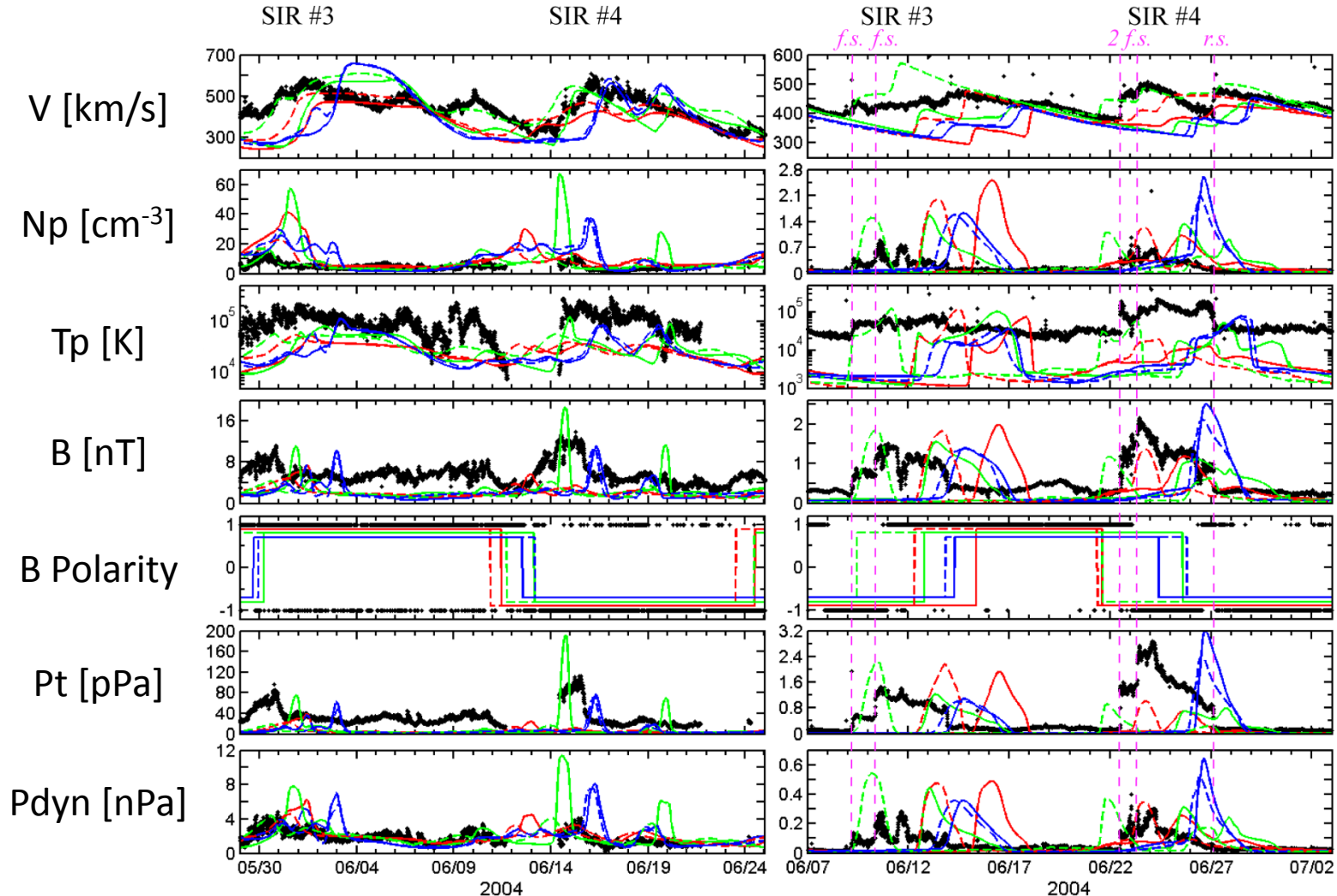


- The NSO-WSA-Enlil run looks like an **intermediate** solution between the other two runs
- Using the same models, the NSO-WSA-Enlil run produces more structured slow wind than the MWO-WSA-Enlil run, probably because **NSO** has more sensitive instruments and better corrections to the polar field for this CR than MWO
- Using the same synoptic magnetograph, the NSO-WSA-Enlil run shows more structure than the NSO-MAS-Enlil run, probably because **MAS** coronal model uses a simple adiabatic energy equation and a single polytropic index (Riley, Linker, and Mikić, 2001).

# Comparison of Spacecraft Observations and Enlil Model Results

1 AU

5.4 AU



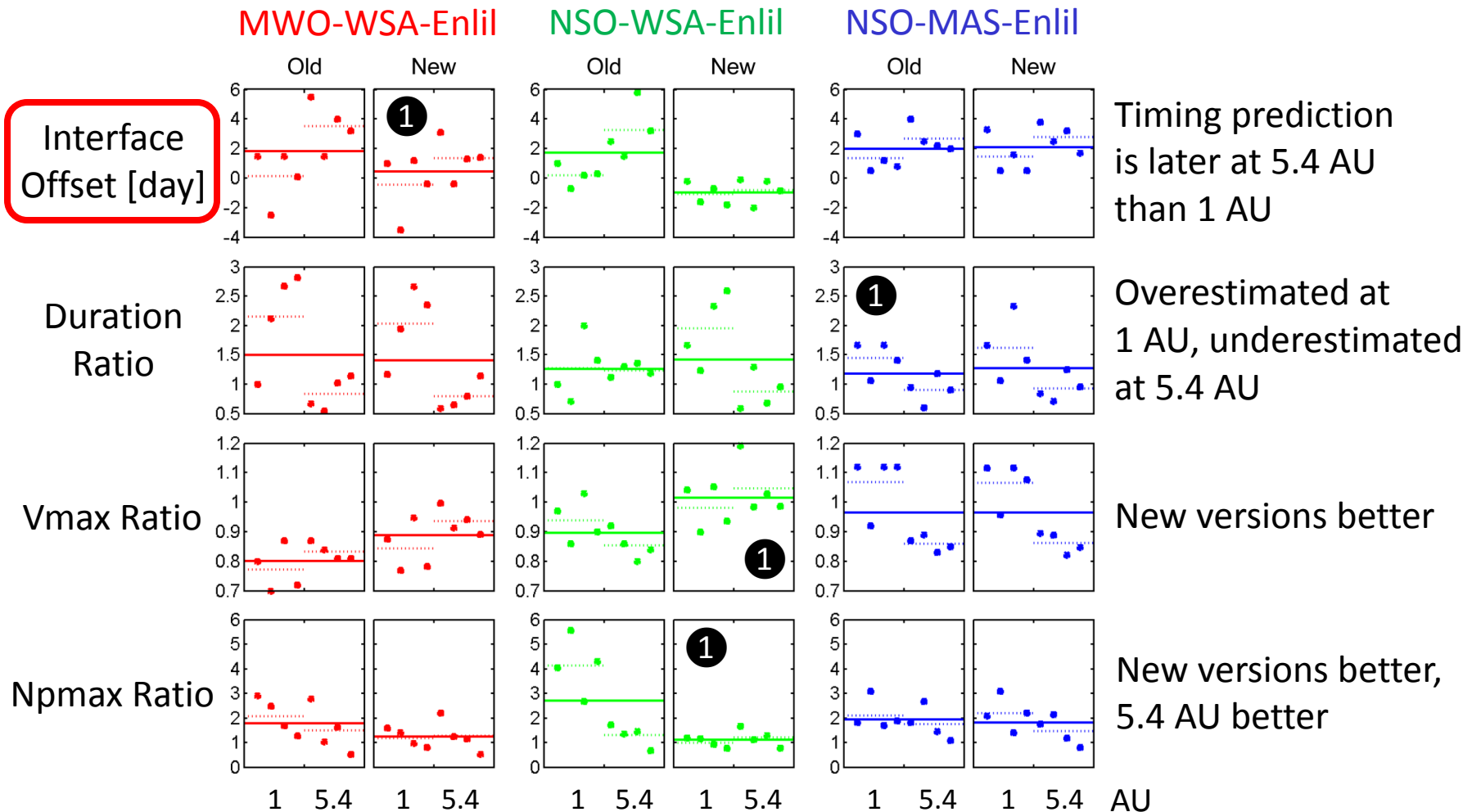
• ACE or Ulysses    — old    — new MWO-WSA-Enlil    — old    — new NSO-WSA-Enlil    — old    — new NSO-MAS-Enlil

HGI ACE: Latitude  $-1.0^\circ$  to  $2.1^\circ$  Longitude  $172.2^\circ$  to  $196.9^\circ$

Ulysses: Latitude  $-5.3^\circ$  to  $-6.5^\circ$  Longitude  $81.9^\circ$  to  $82.2^\circ$

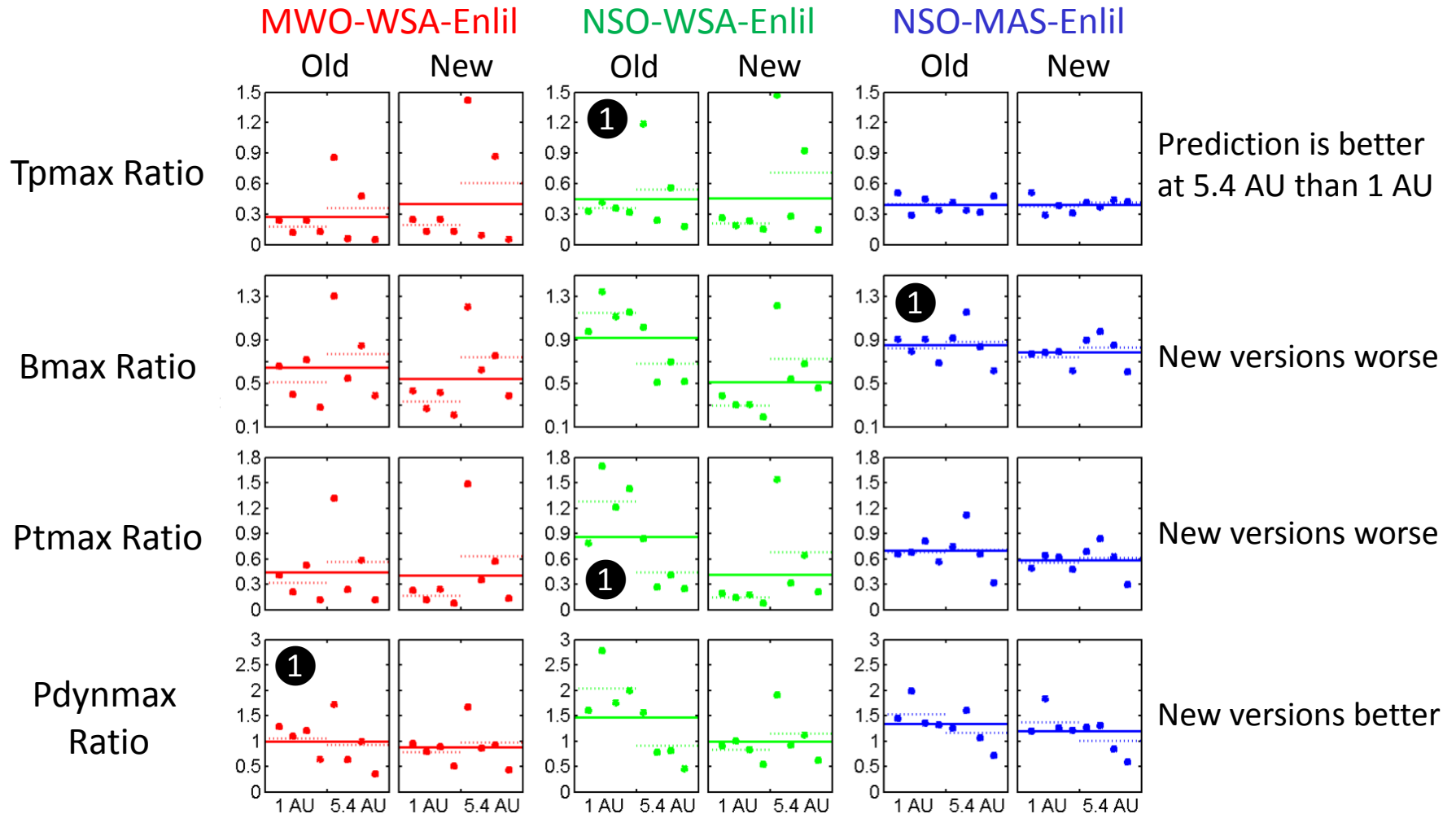


# Comparison of CIR Features



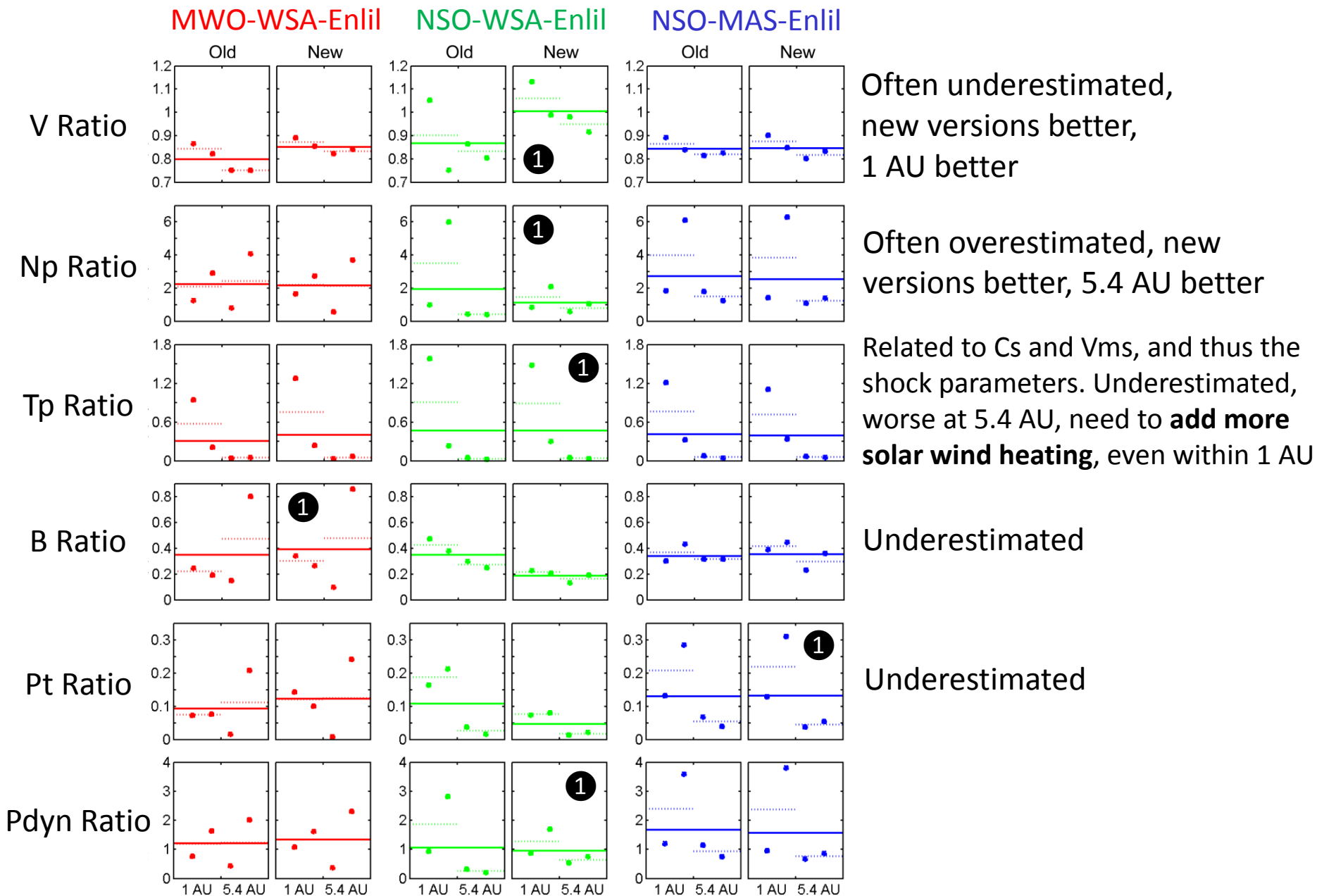
- The Enlil model can generally reproduce the field polarities and sector boundaries, and roughly capture the occurrence and features of SIRs
- The **new** version of models have **improved the prediction of timing, Vmax, Npmax**
- *The performance of different models can change the order from 1 to 5.4 AU*

# Comparison of CIR Features (cont.)



- All the models **underestimate** the maxima of Tp, B, and Pt
- The free parameters of the **new** version have not been pre-calibrated on as many CRs as the old version; the setting of the new scaling factor for B is not mature
- The MWO-WSA-Enlil and NSO-MAS-Enlil models **cannot** capture the transient and small SIRs at 1 AU

# Comparison of Baseline Slow Solar Wind



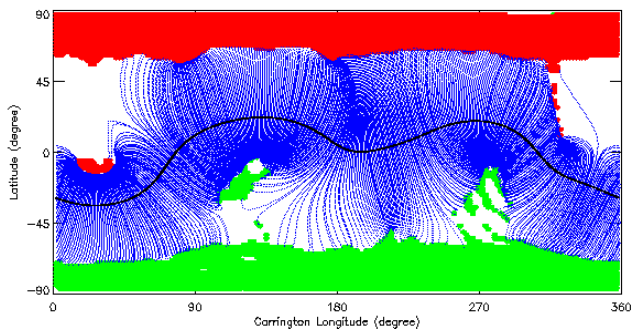
## Part II.

# Multi-Spacecraft Observations within 2 AU vs. Model Results for CRs 2056-2062 (May-Oct. 2007)

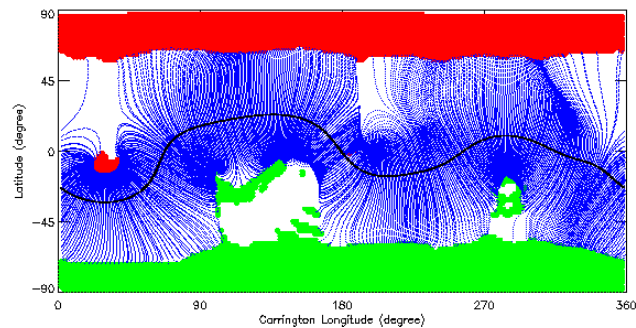
*In progress*

# Synoptic Coronal Hole Plot from NSO/GONG

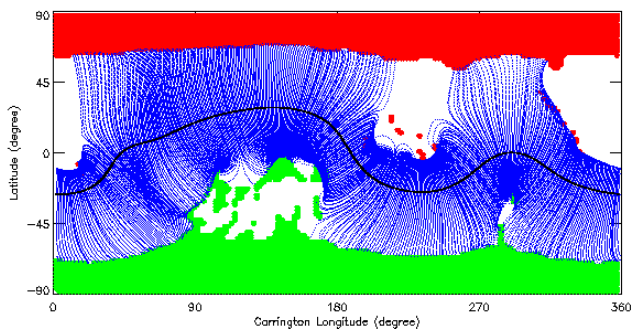
CR 2056



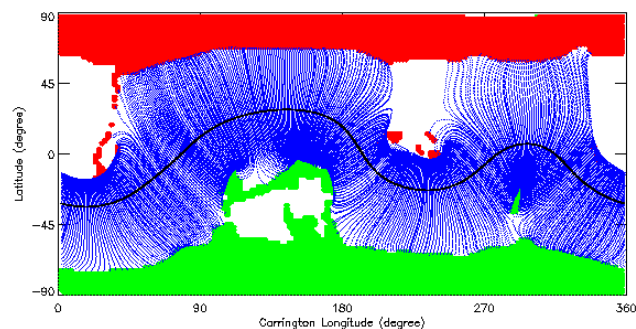
CR 2057



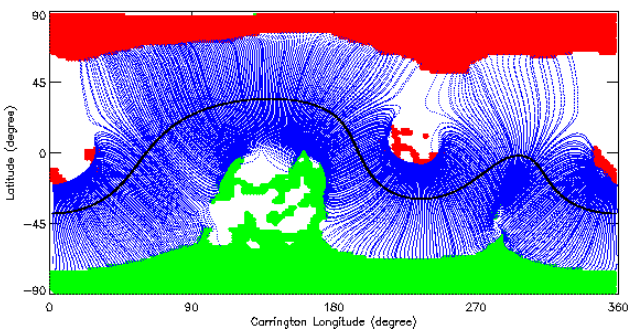
CR 2058



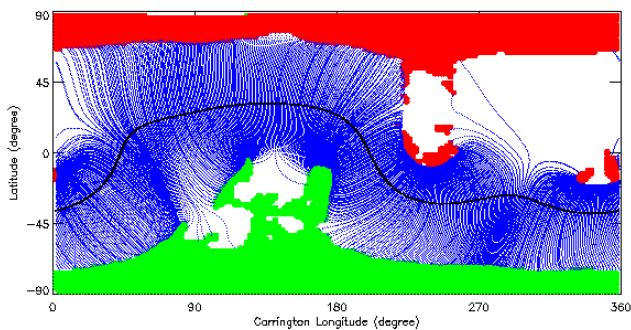
CR 2059



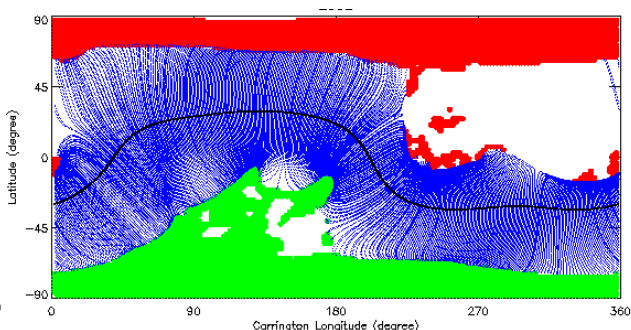
CR 2060



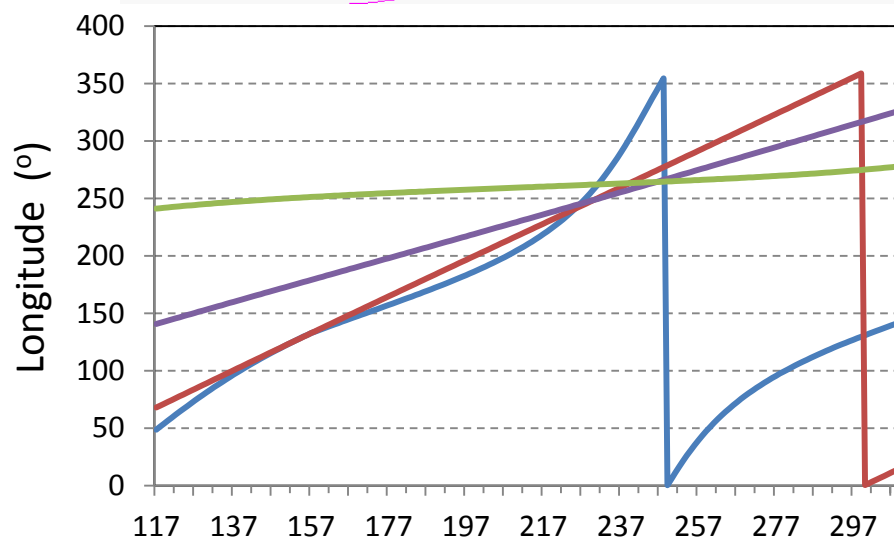
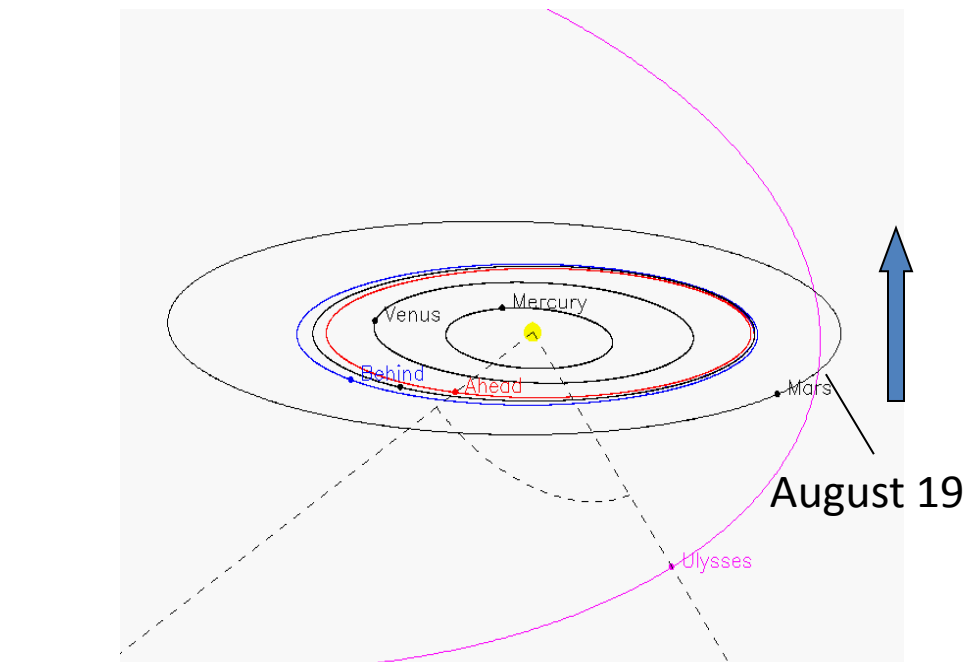
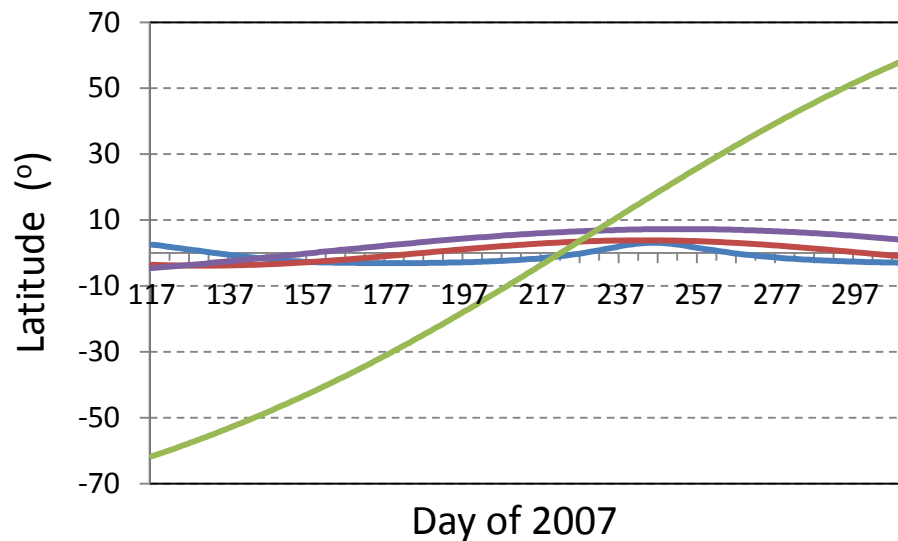
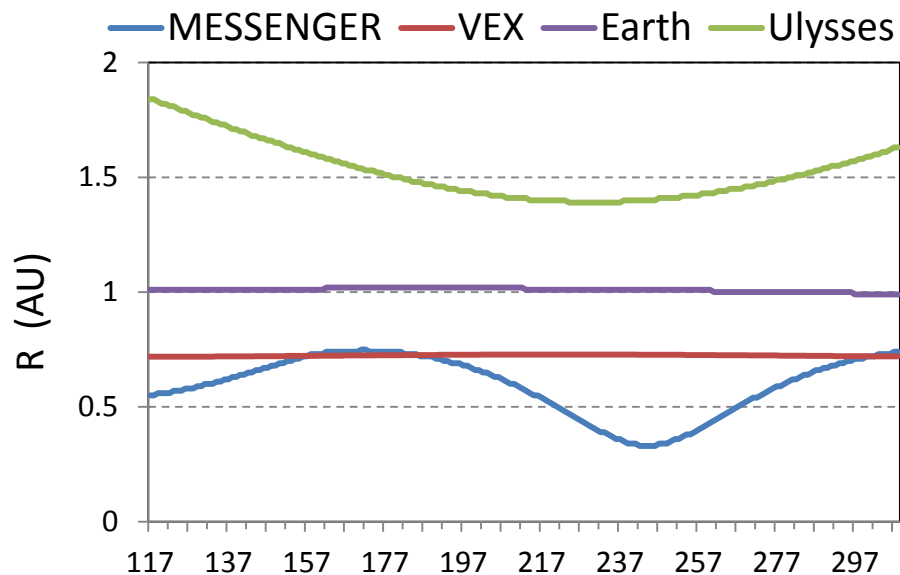
CR 2061



CR 2062



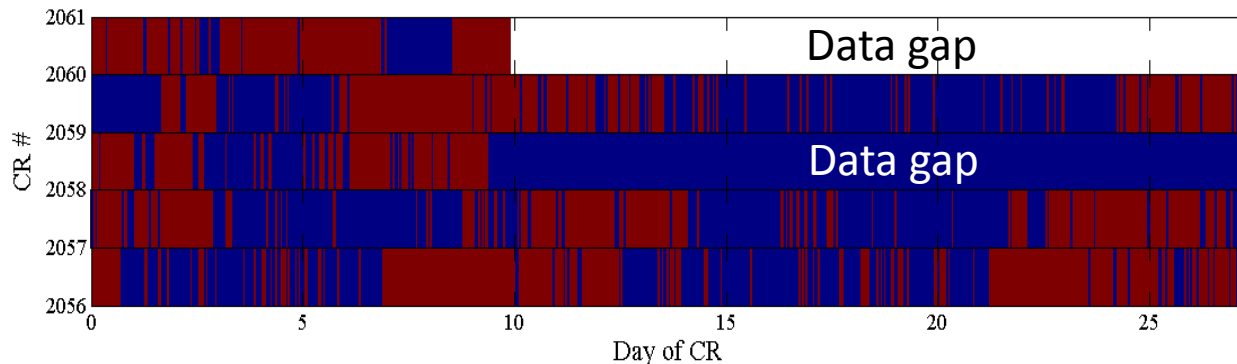
# Spacecraft Location for CRs 2056-2062



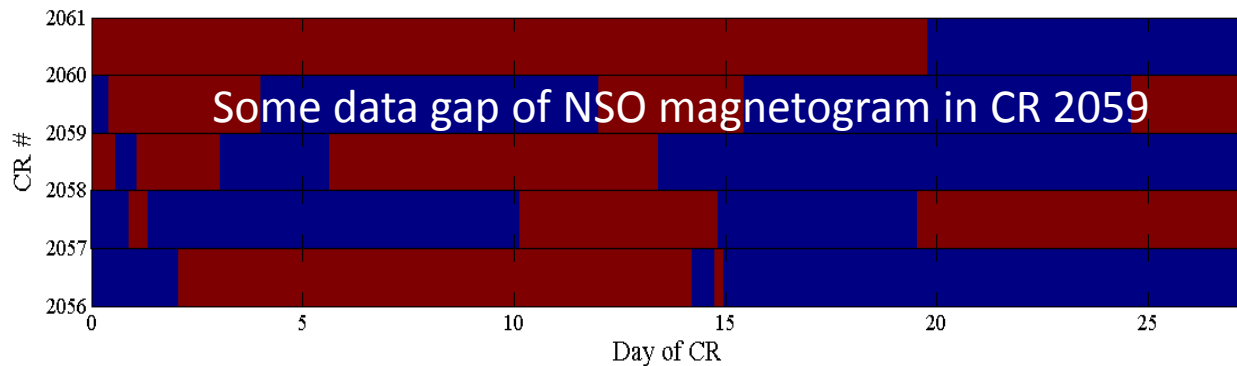
# IMF Polarity

# MESSENGER over CRs 2056-2060

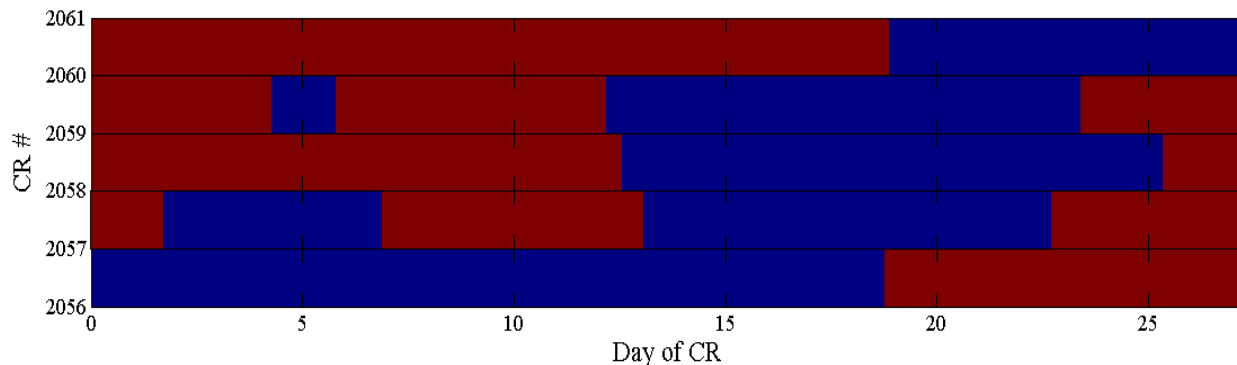
Observation



NSO-  
WSA-Enlil



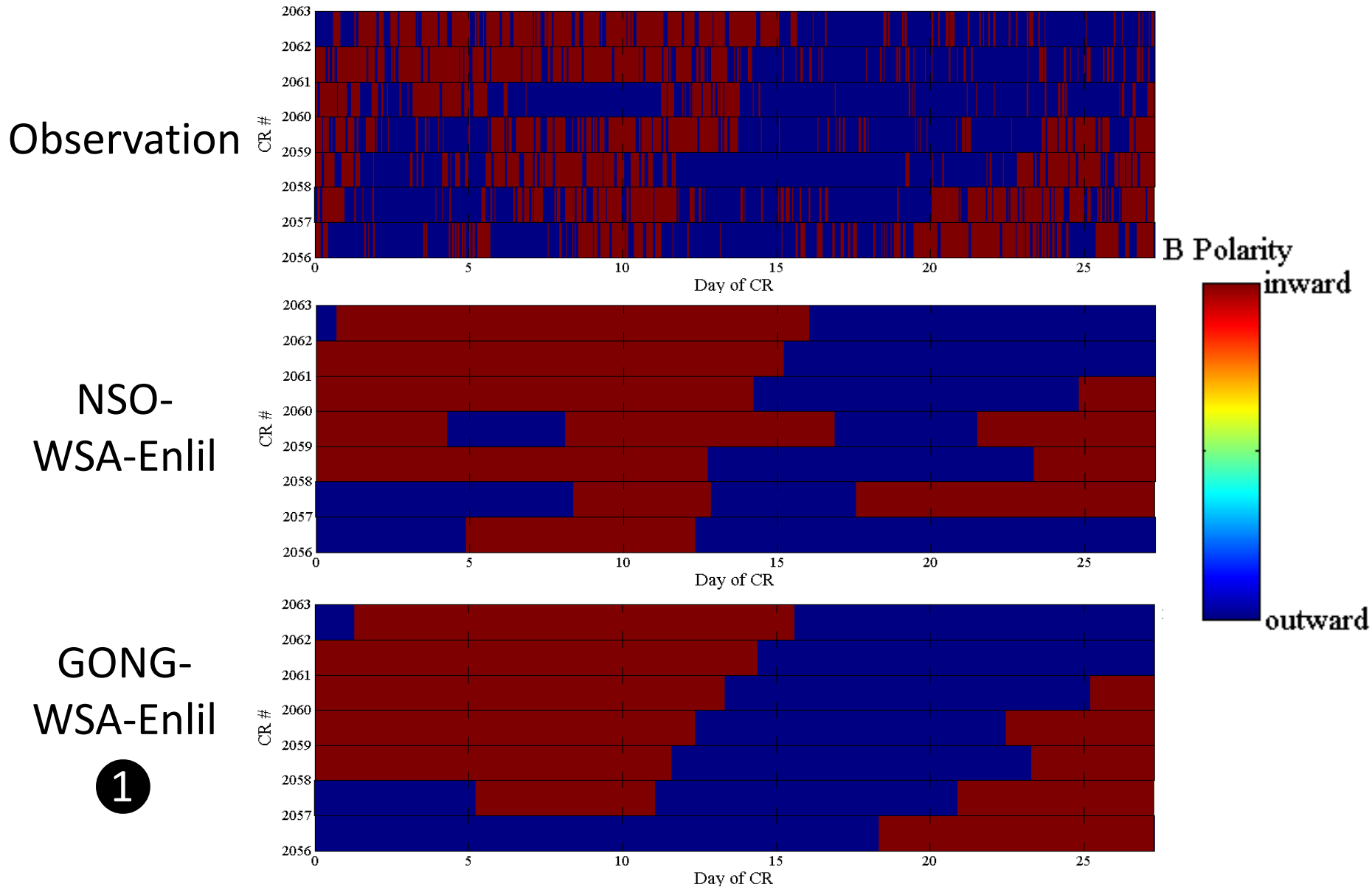
GONG-  
WSA-Enlil



1

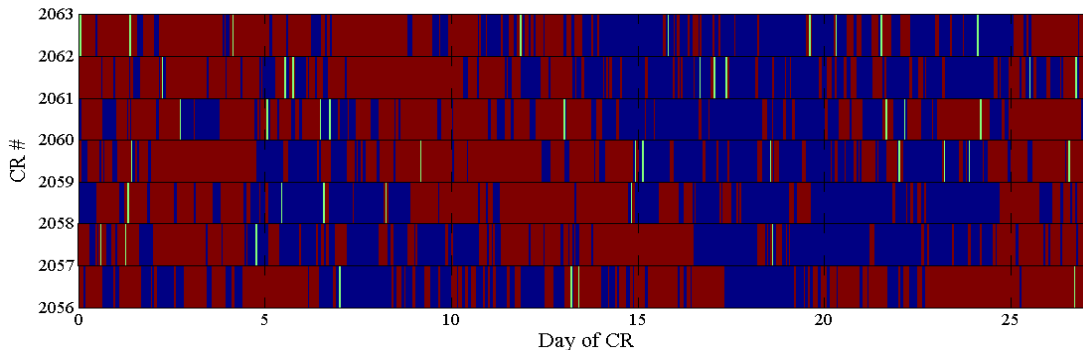


# Venus Express over CRs 2056-2062

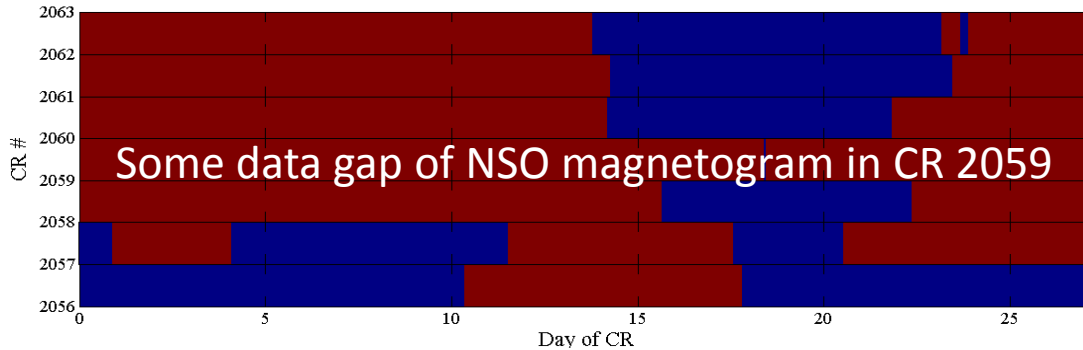


# Near Earth

Observation

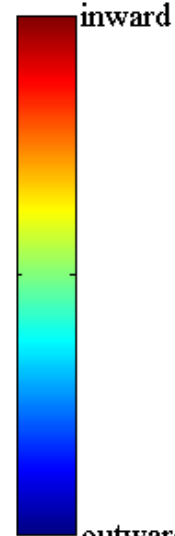


NSO-WSA-Enlil



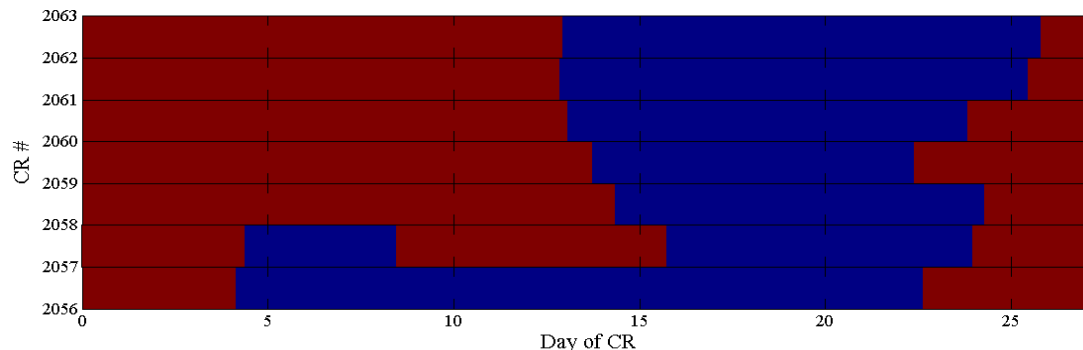
B Polarity

inward

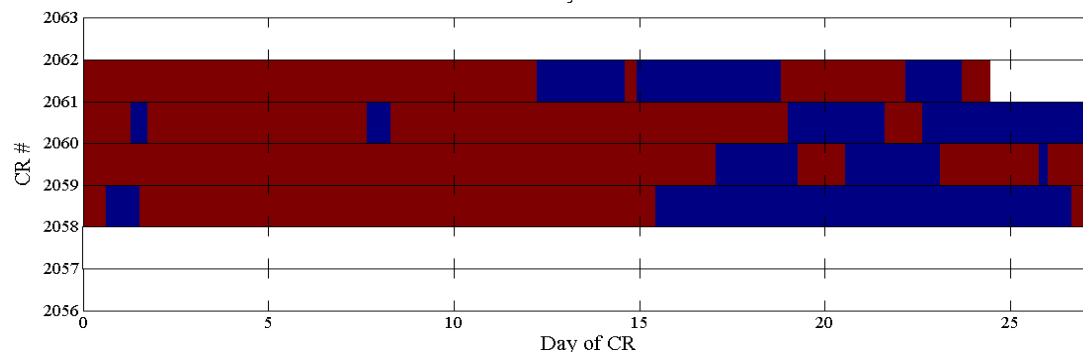


GONG-WSA-Enlil

1

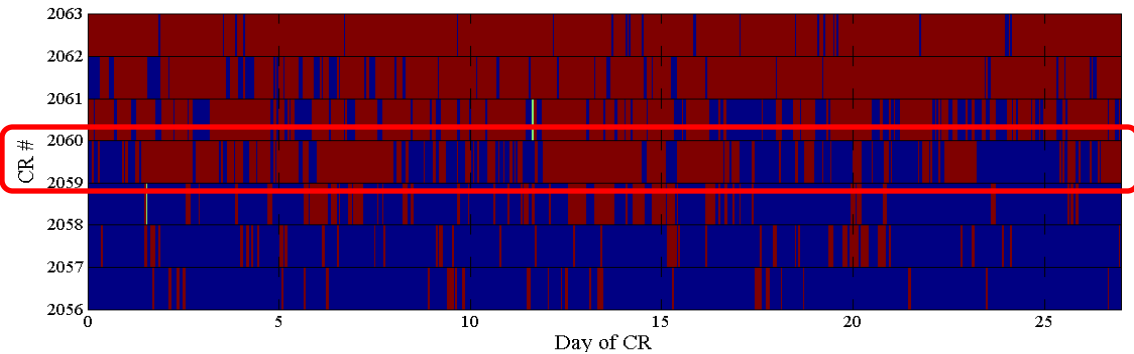


GONG-SWMF

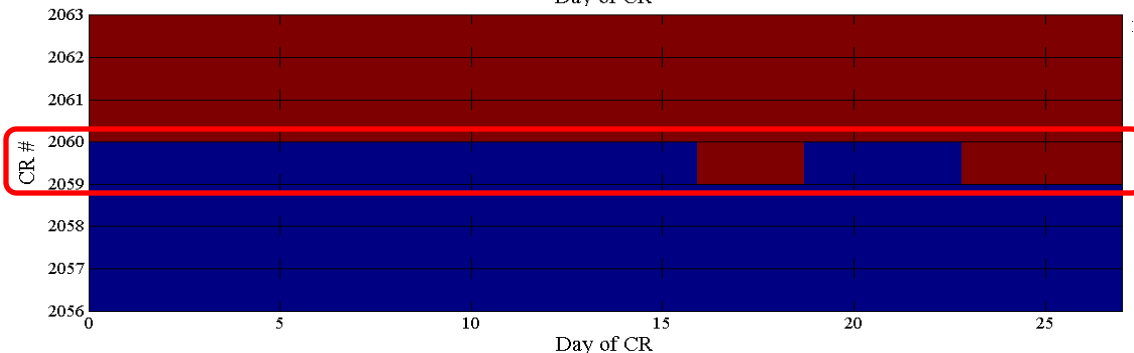


# Ulysses

Observation

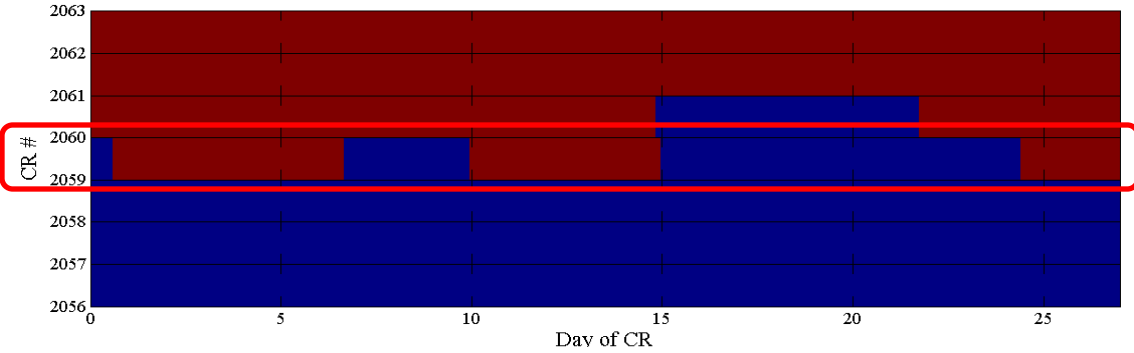


NSO-WSA-Enlil

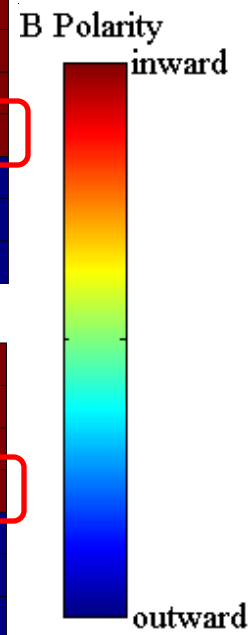
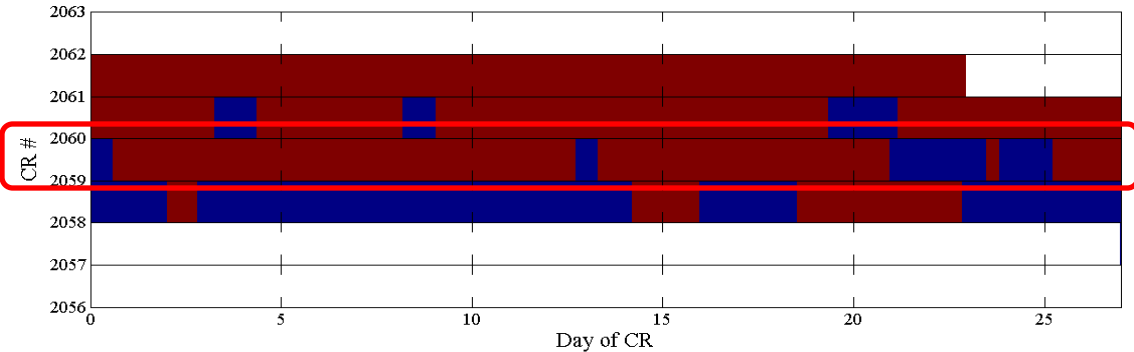


GONG-WSA-Enlil

1



GONG-SWMF

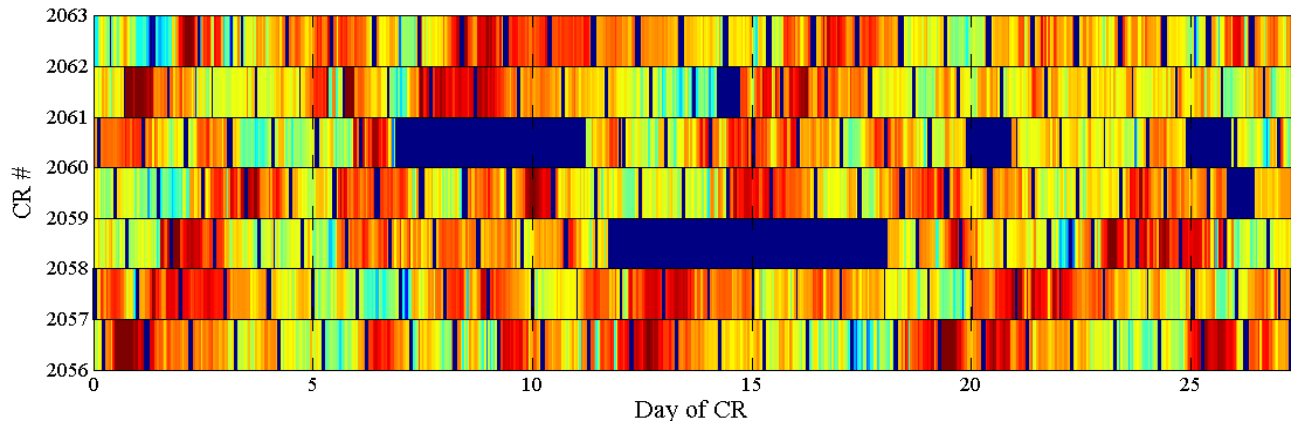


# IMF Strength



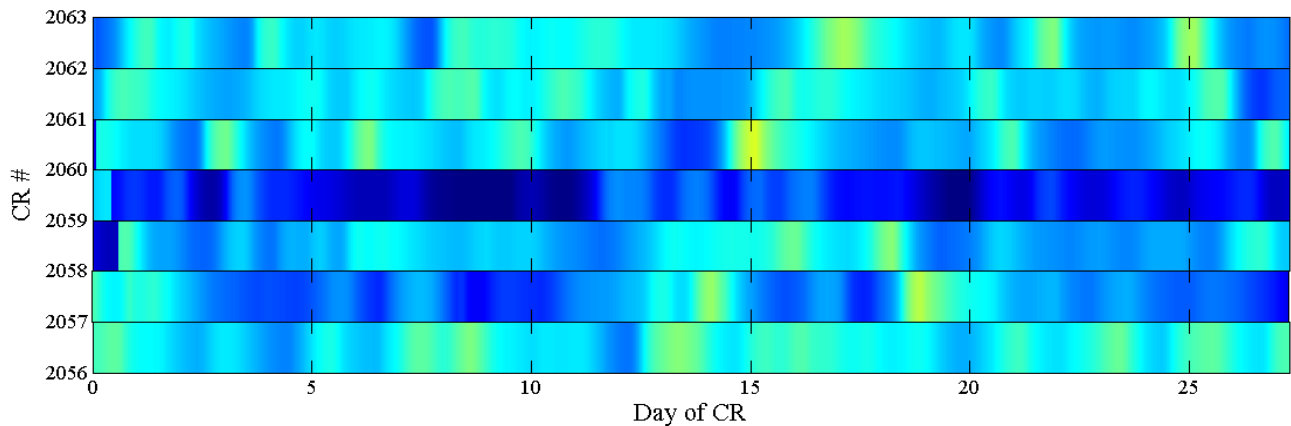
# Venus Express over CRs 2056-2062

Observation

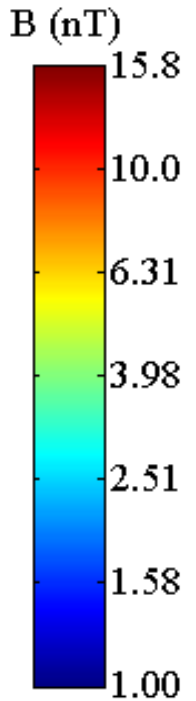
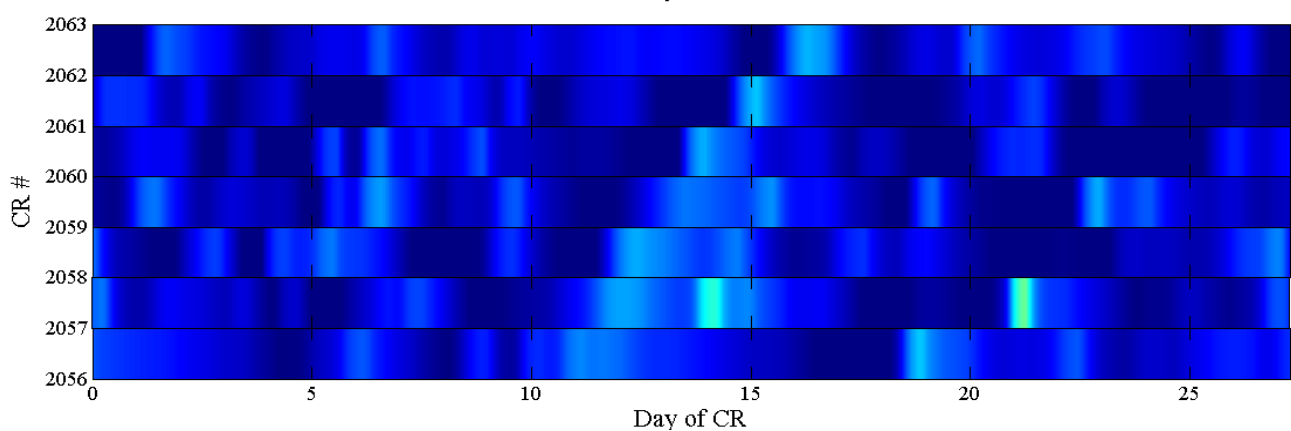


NSO-  
WSA-Enlil

1

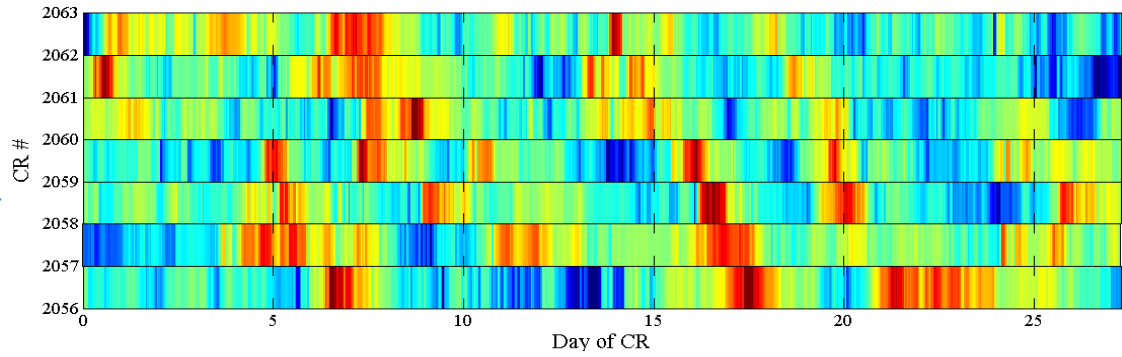


GONG-  
WSA-Enlil

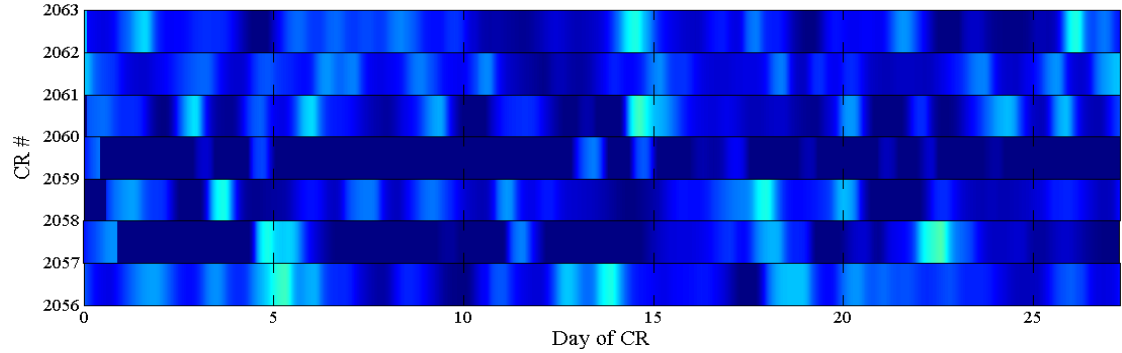


# Near Earth

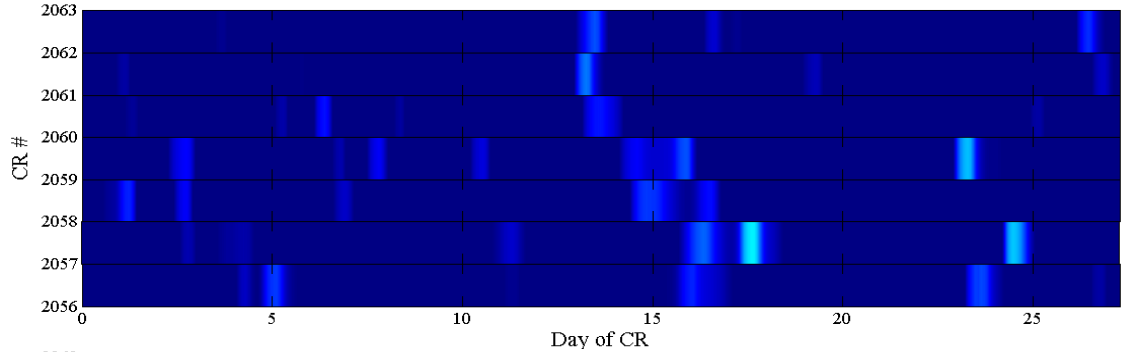
Observation



NSO-WSA-Enlil



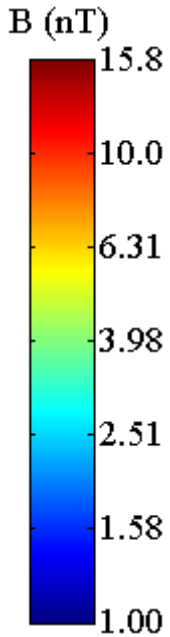
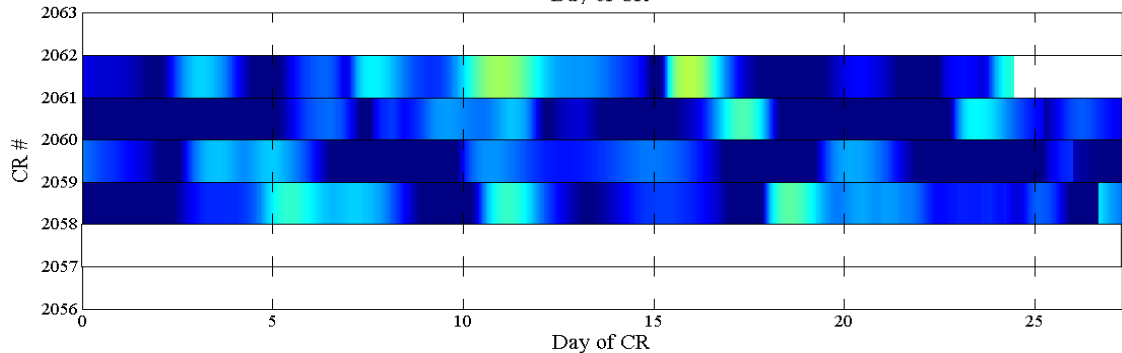
GONG-WSA-Enlil



GONG-SWMF

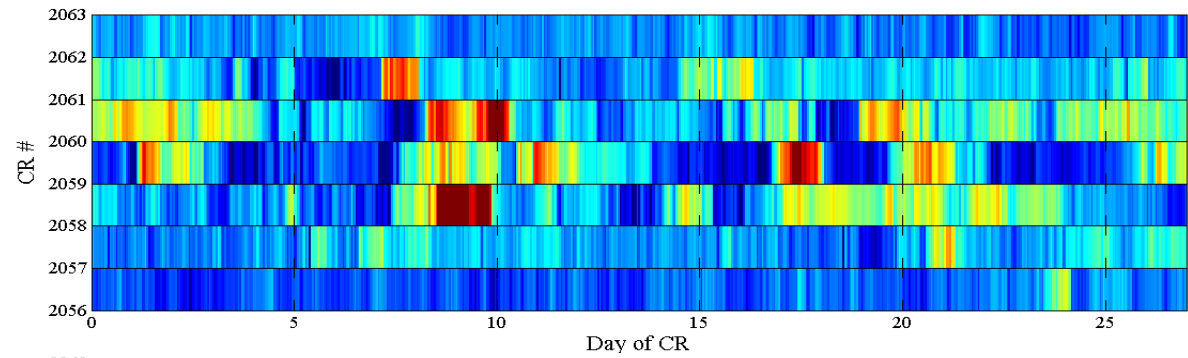
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*Stronger B  
compression*

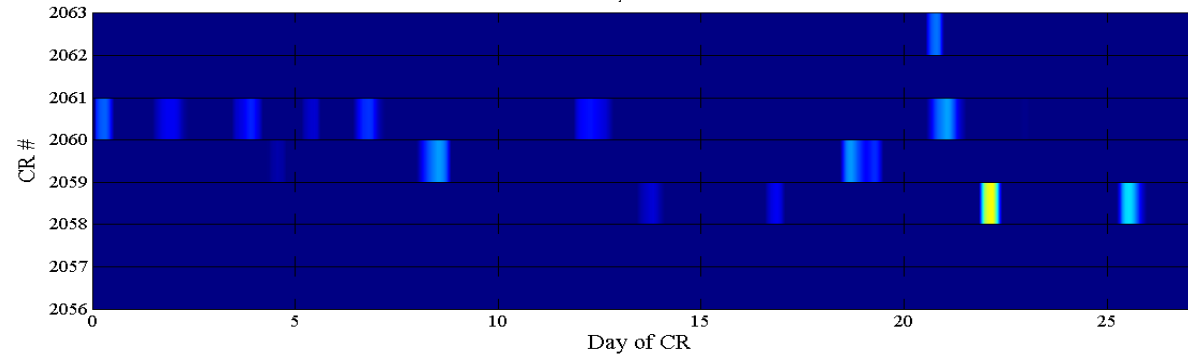


# Ulysses

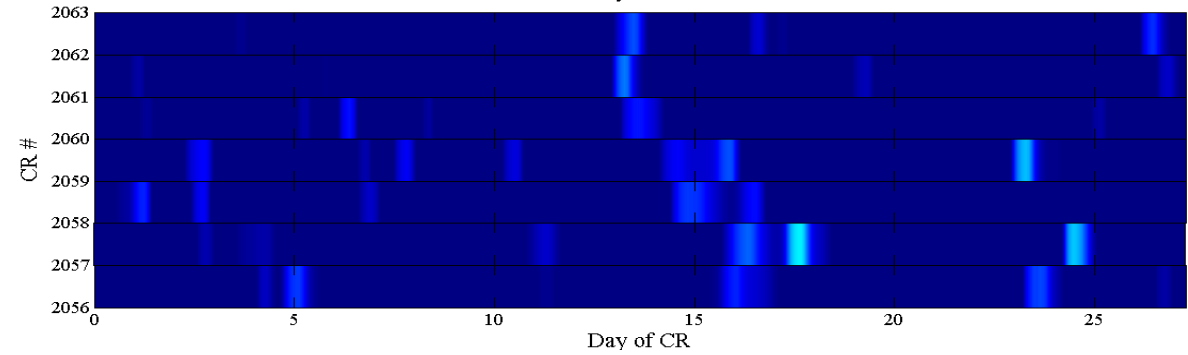
Observation



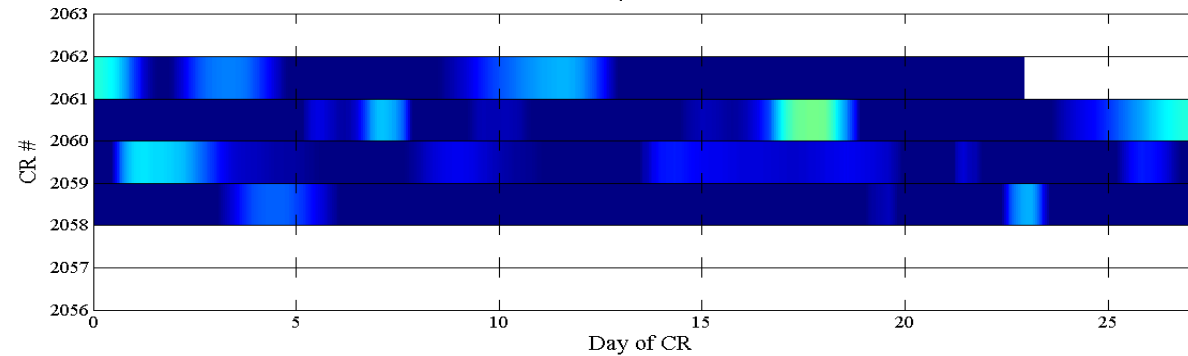
NSO-WSA-Enlil



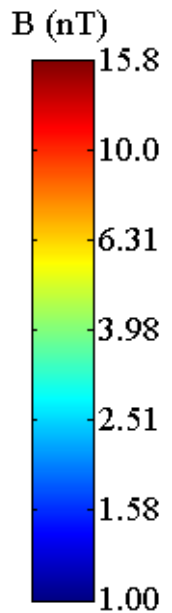
GONG-WSA-Enlil



GONG-SWMF



1



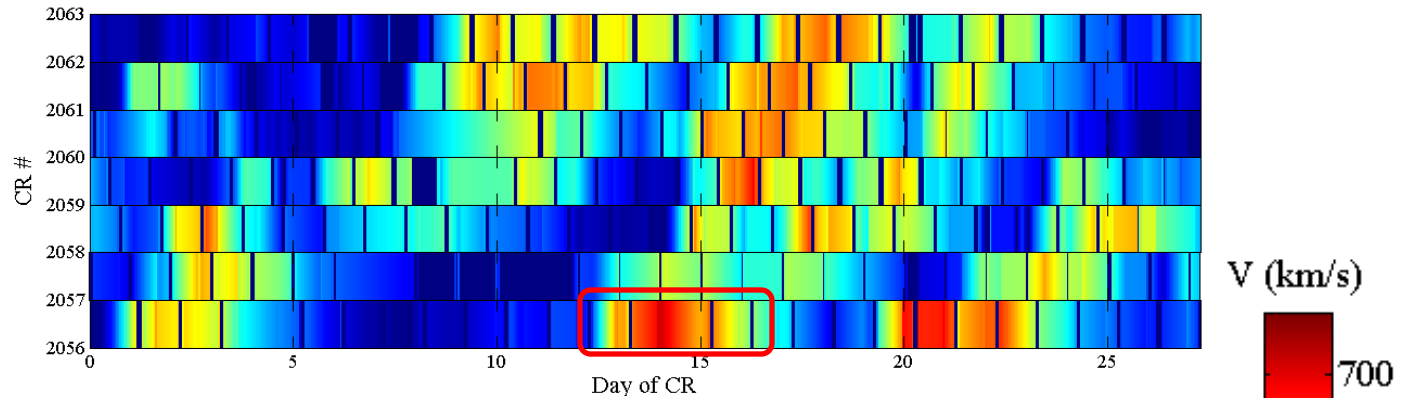


# **Solar Wind Speed**

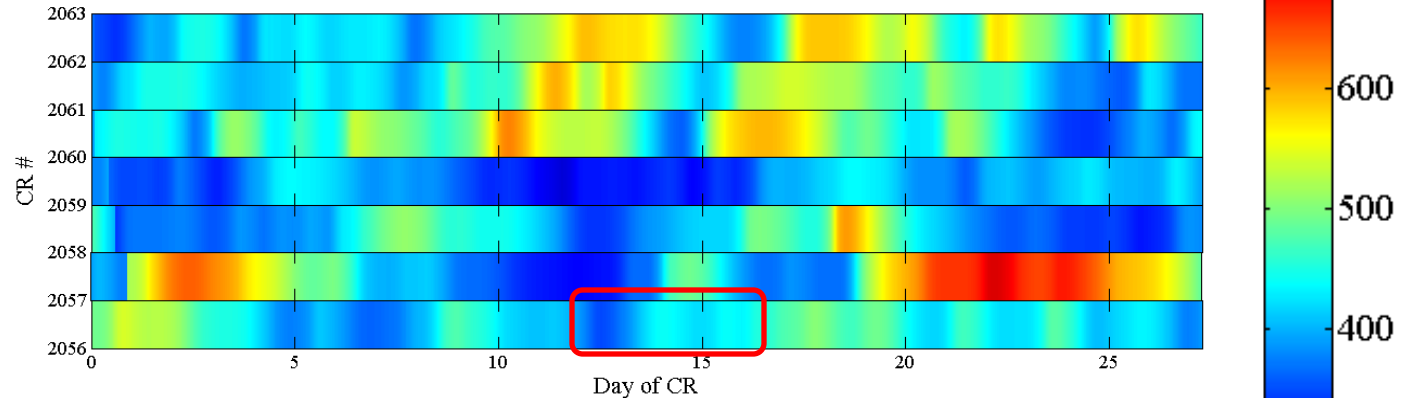
# Venus Express over CRs 2056-2062

## Observation

(many data gaps,  
excluding Venus  
encounters)

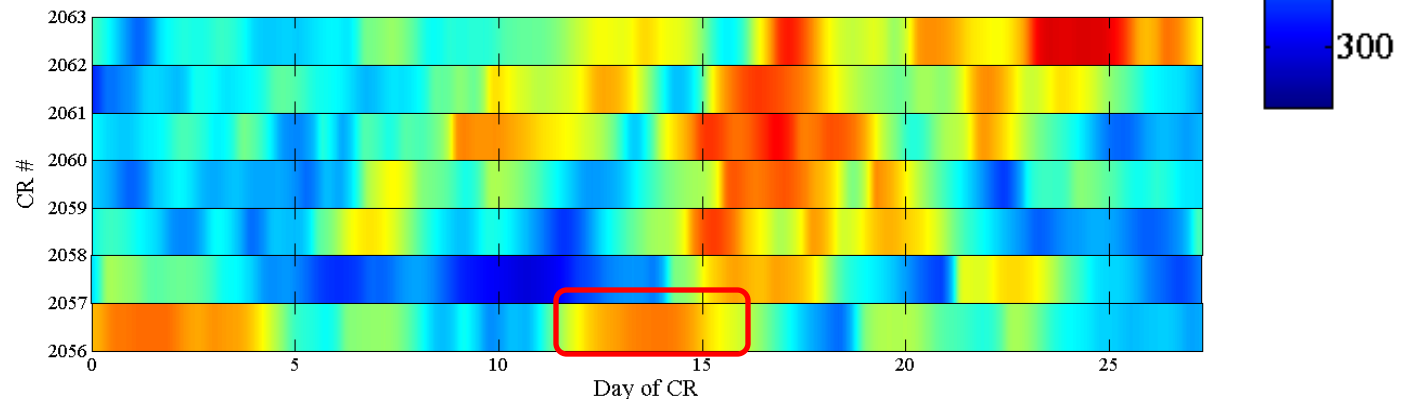


## NSO-WSA-Enlil



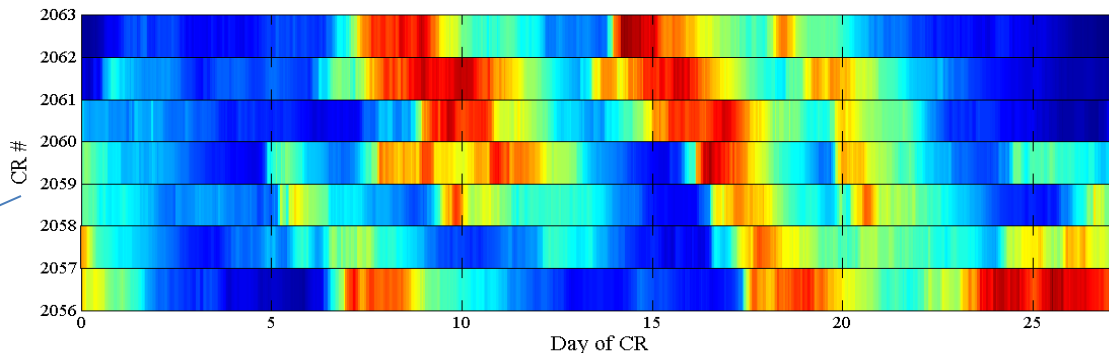
## GONG-WSA-Enlil

1

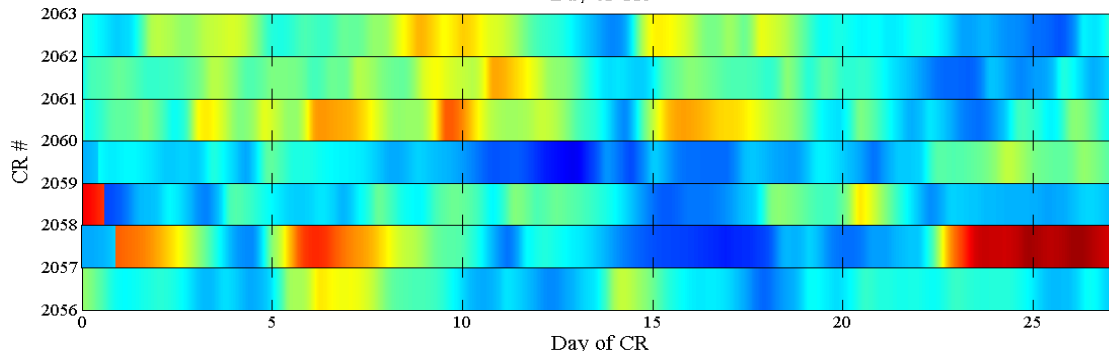


# Near Earth

Observation

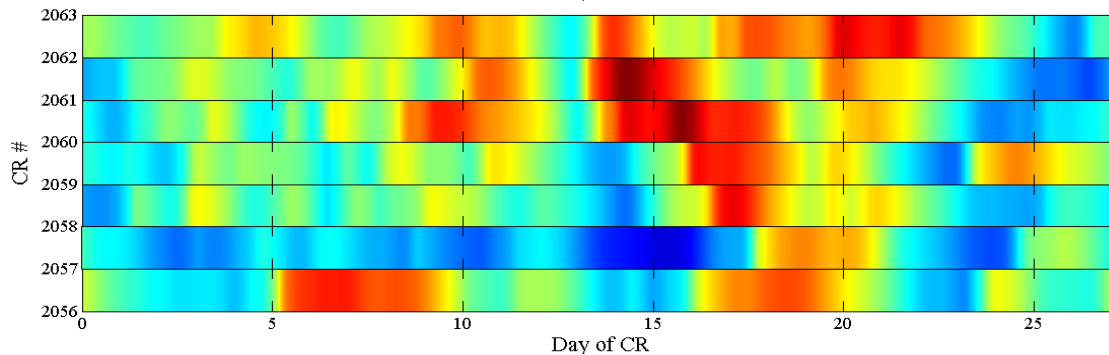


NSO-WSA-Enlil



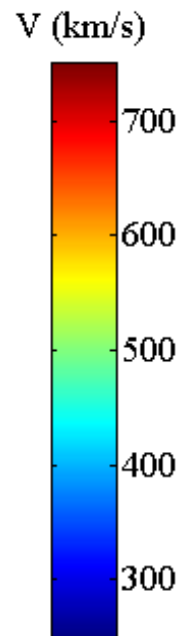
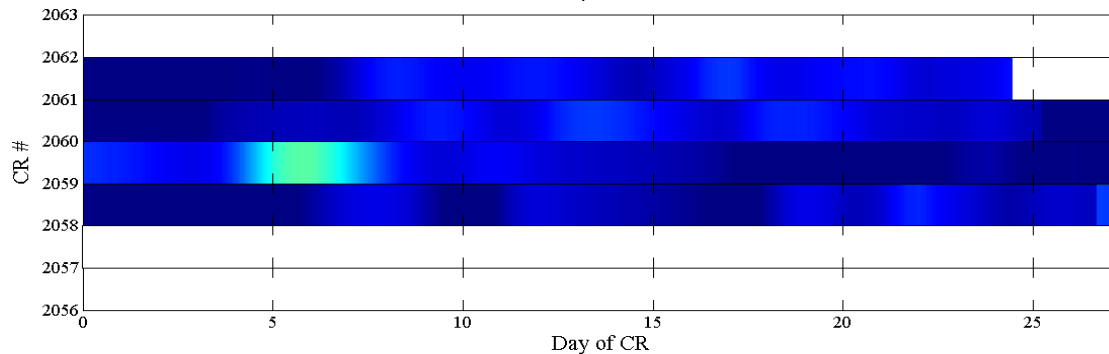
GONG-WSA-Enlil

1



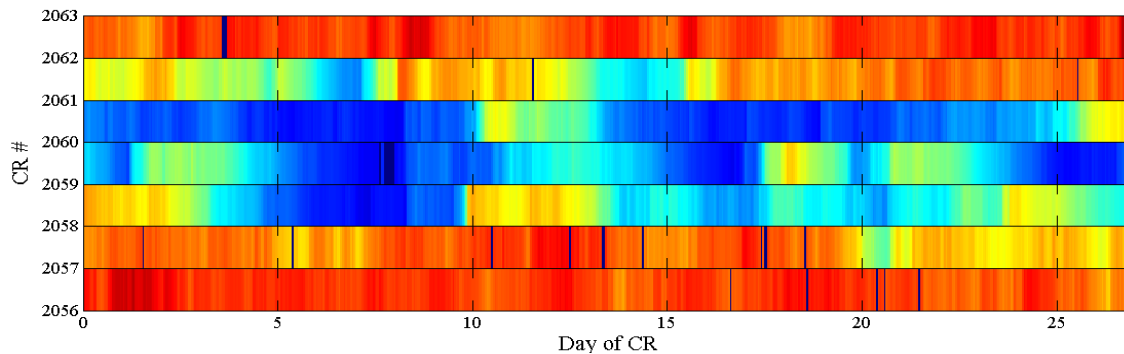
GONG-SWMF

*Too slow!*

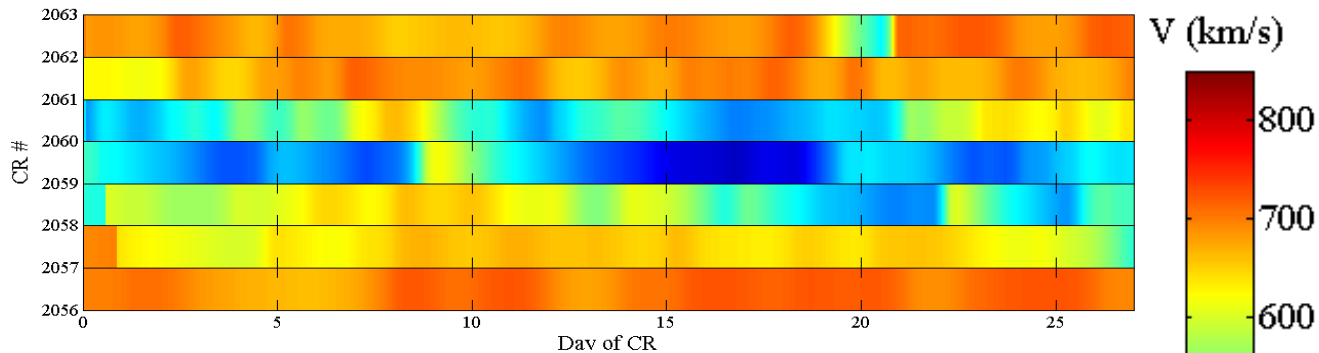


# Ulysses

Observation

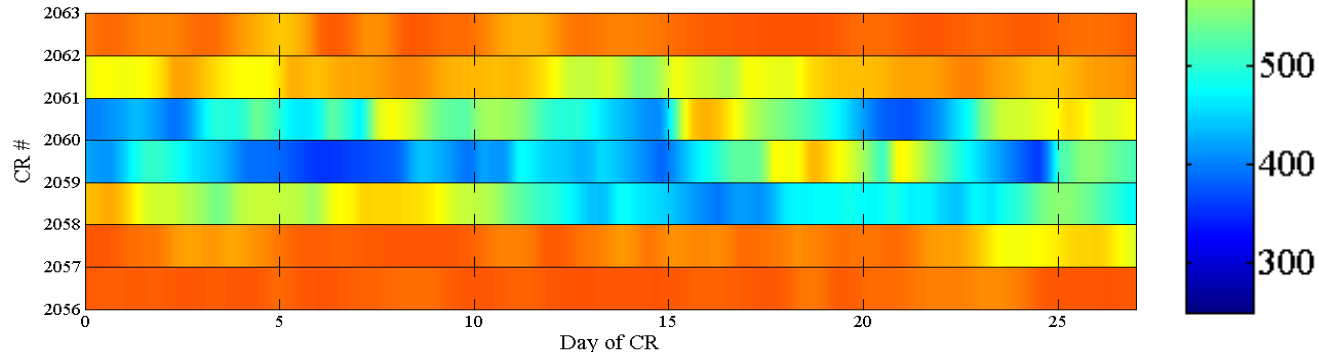


NSO-WSA-Enlil



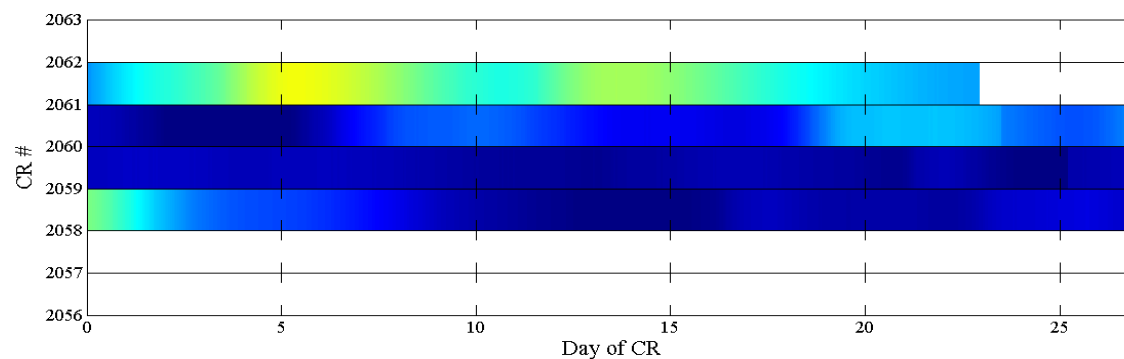
GONG-WSA-Enlil

1



GONG-SWMF

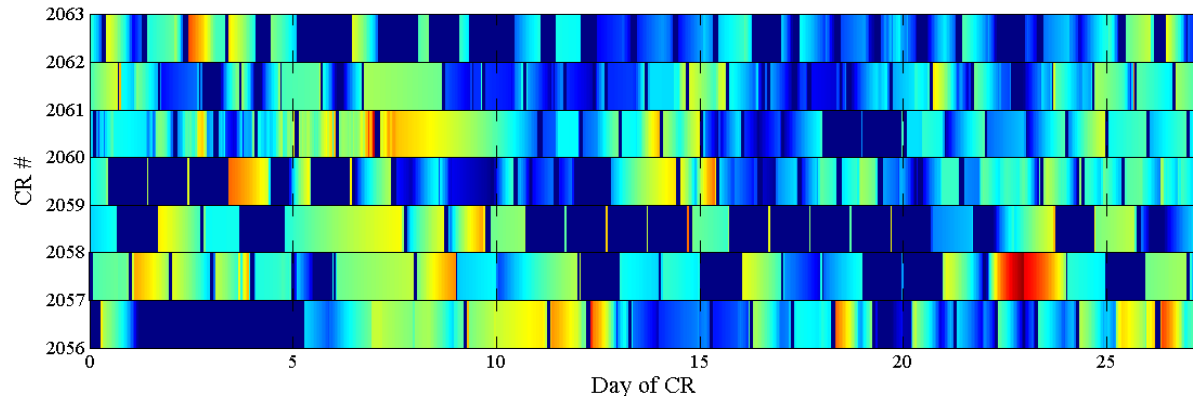
*Too slow!*



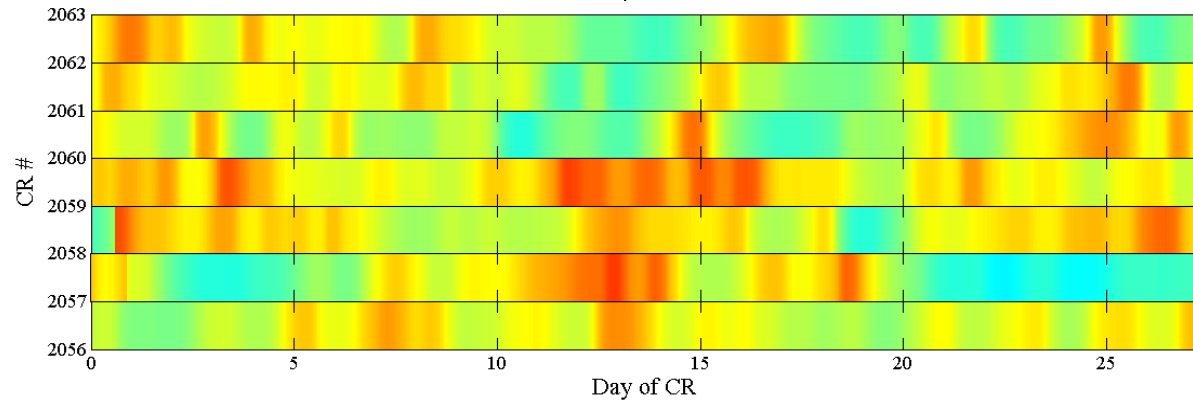
# **Solar Wind Density**

# Venus Express over CRs 2056-2062

Observation

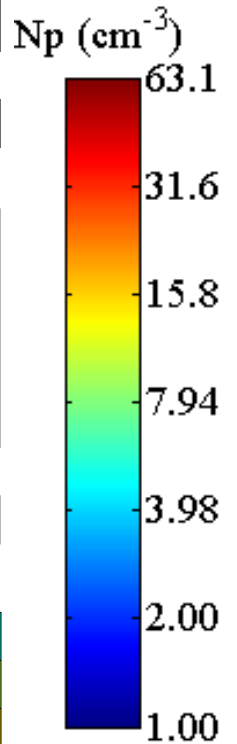
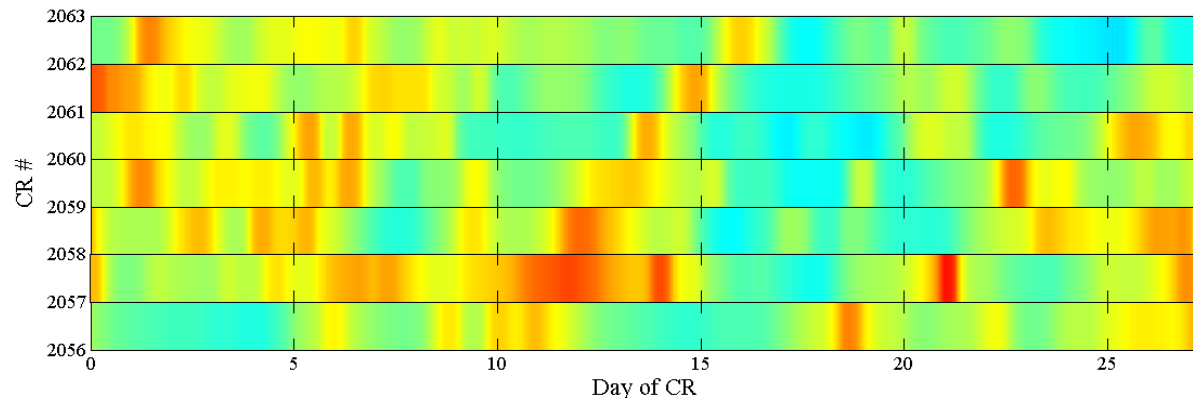


NSO-WSA-Enlil



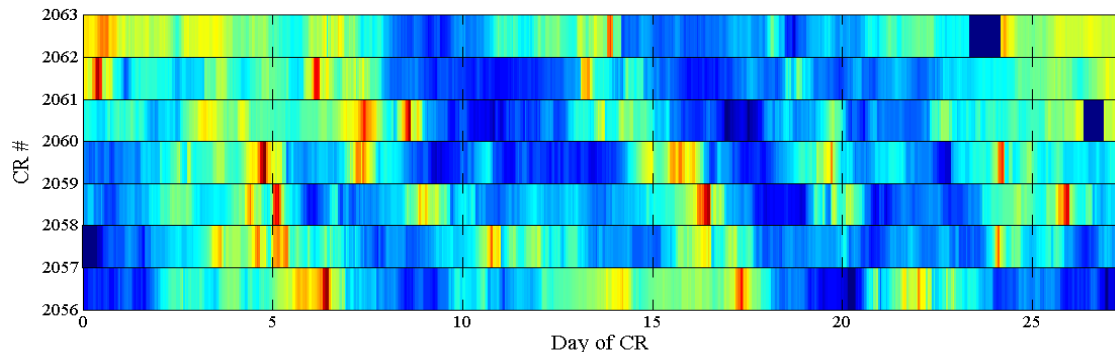
GONG-WSA-Enlil

1

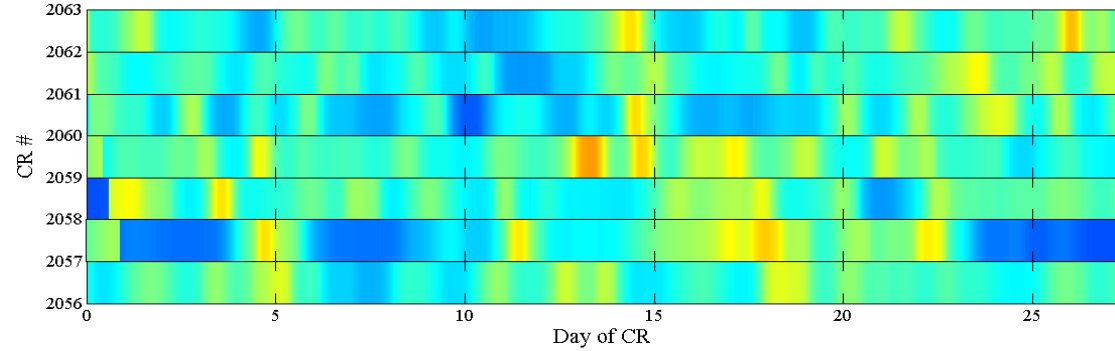


# Near Earth

Observation

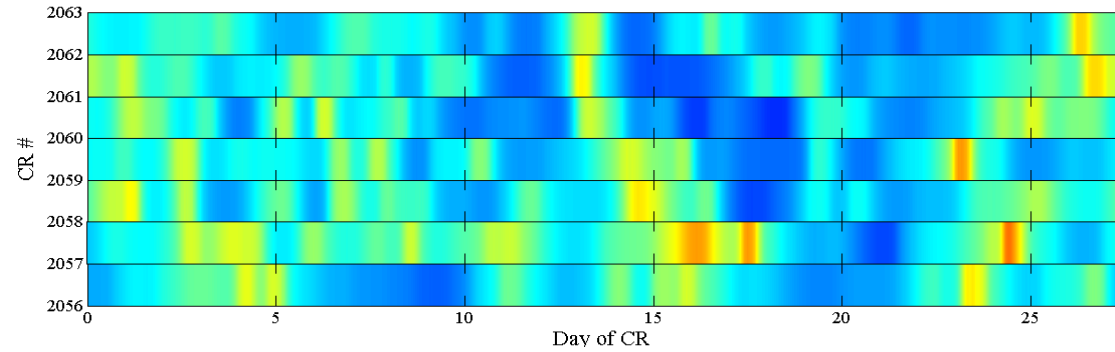


NSO-WSA-Enlil

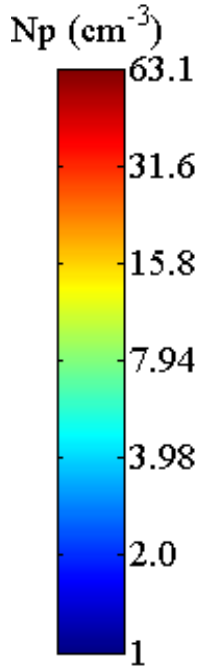
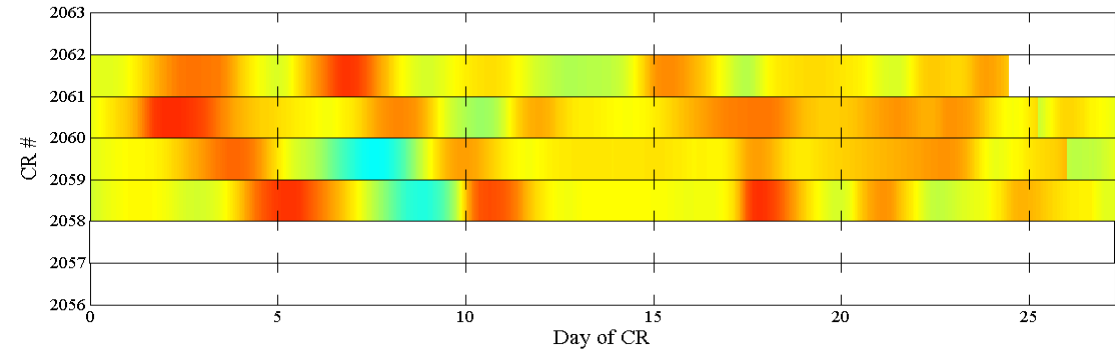


GONG-WSA-Enlil

1

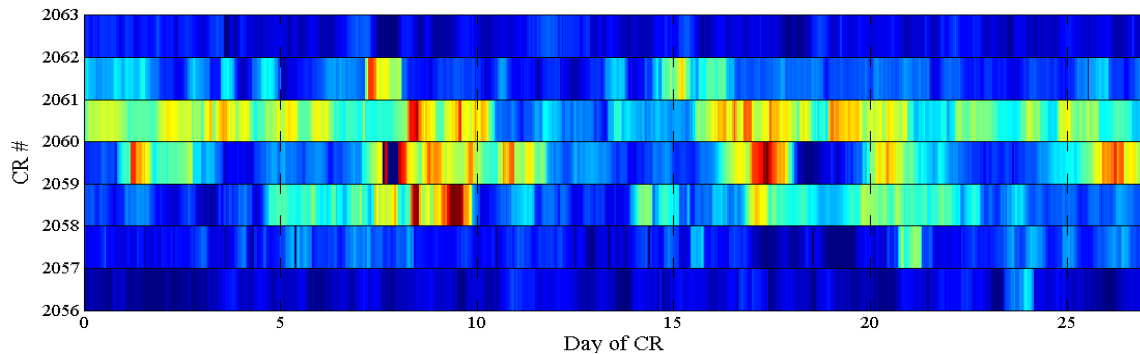


GONG-SWMF  
(Np of slow wind  
> Np observed)

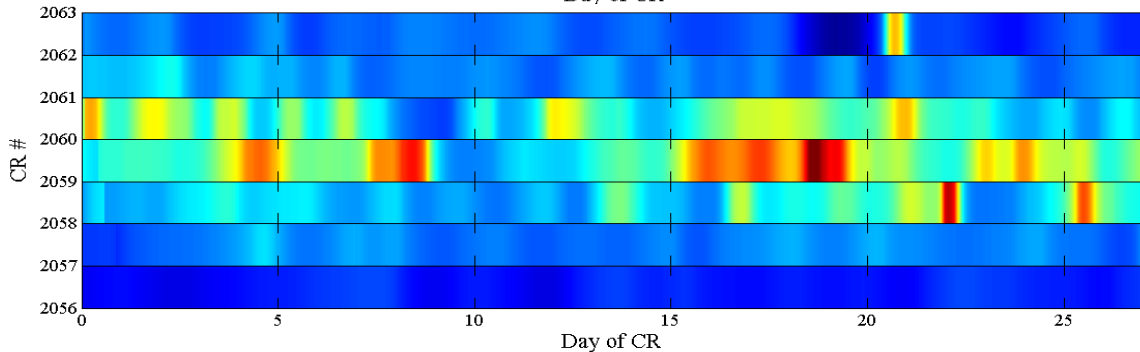


# Ulysses

Observation

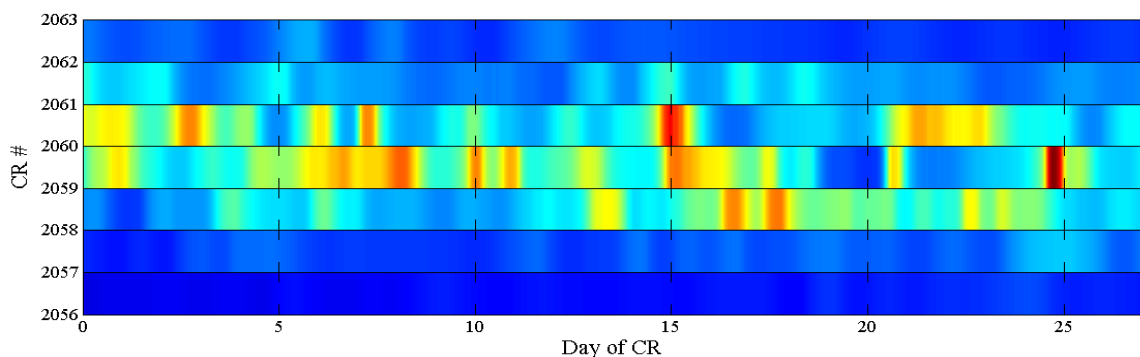


NSO-WSA-Enlil

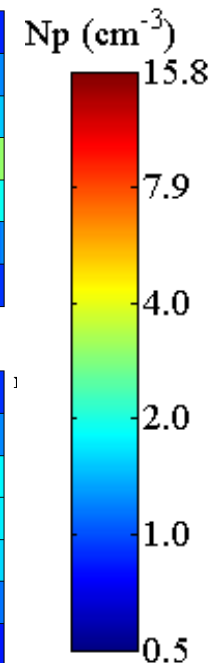
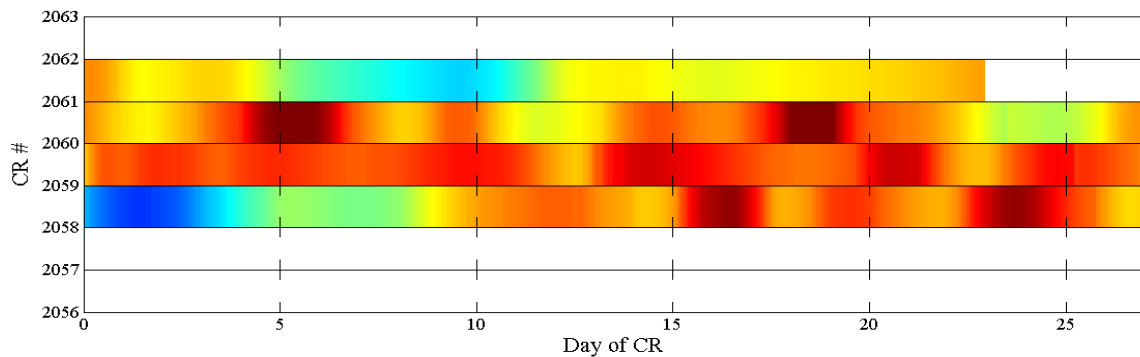


GONG-WSA-Enlil

1



GONG-SWMF

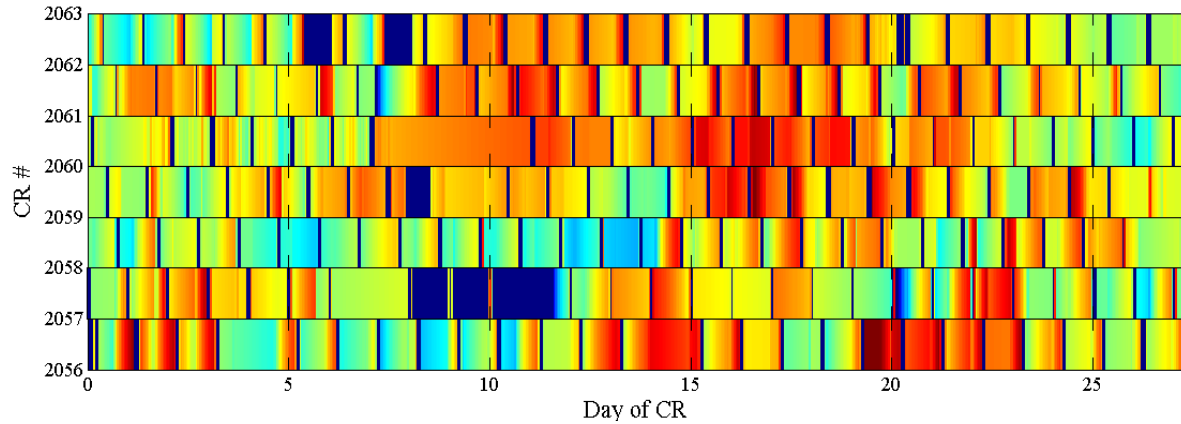




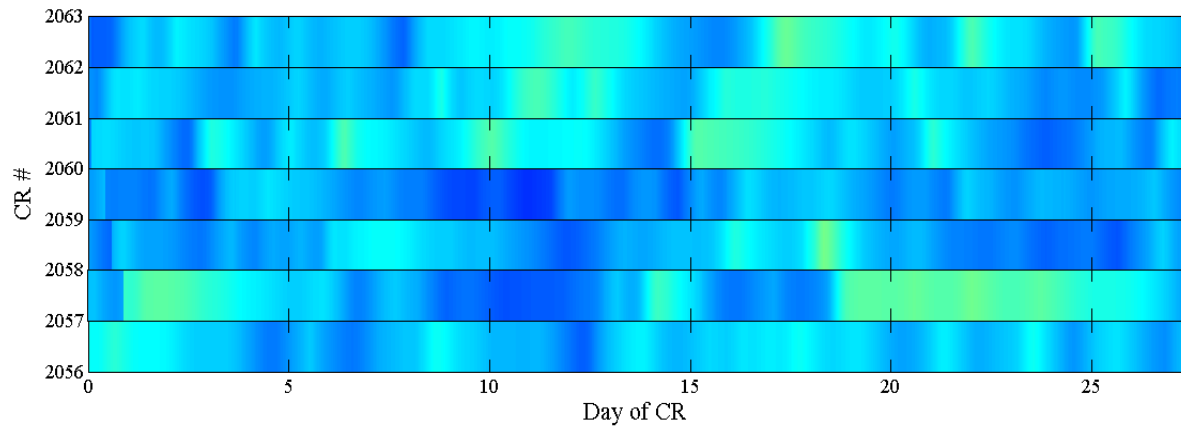
# **Solar Wind Temperature**

# Venus Express over CRs 2056-2062

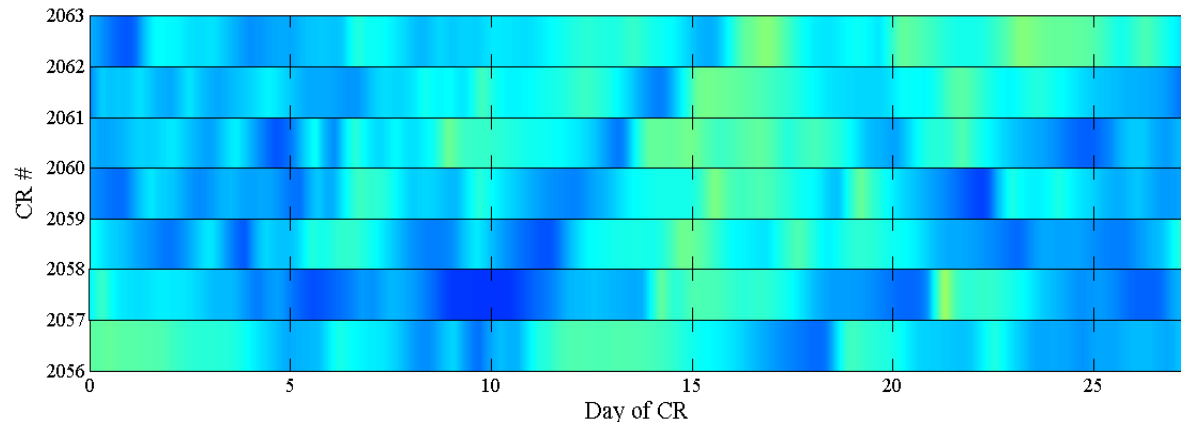
Observation



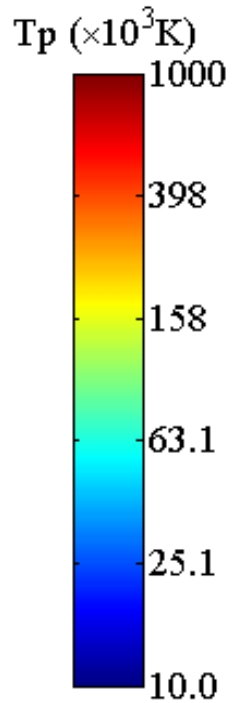
NSO-WSA-Enlil



GONG-WSA-Enlil

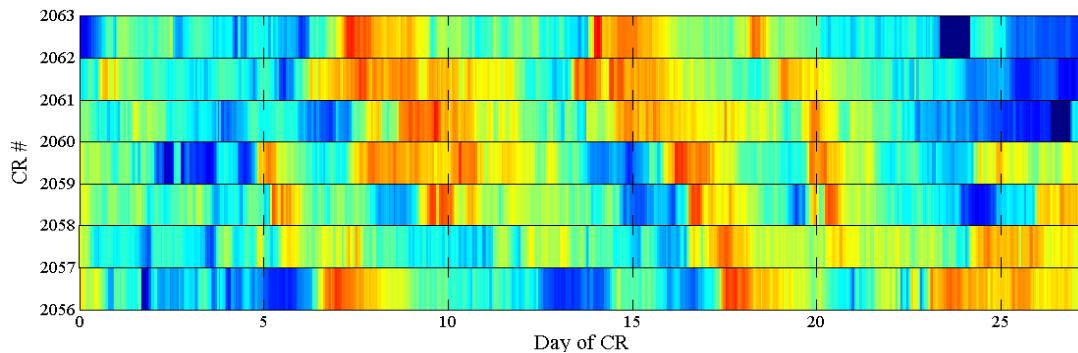


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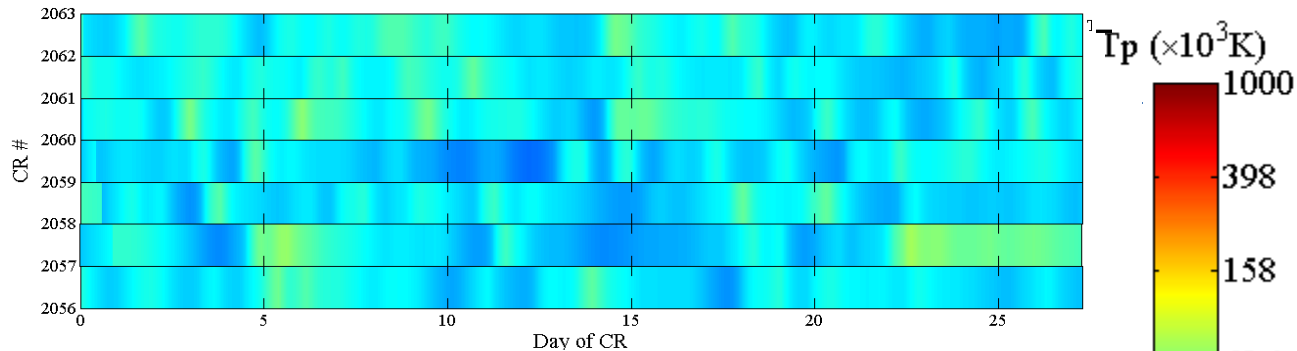


# Near Earth

Observation

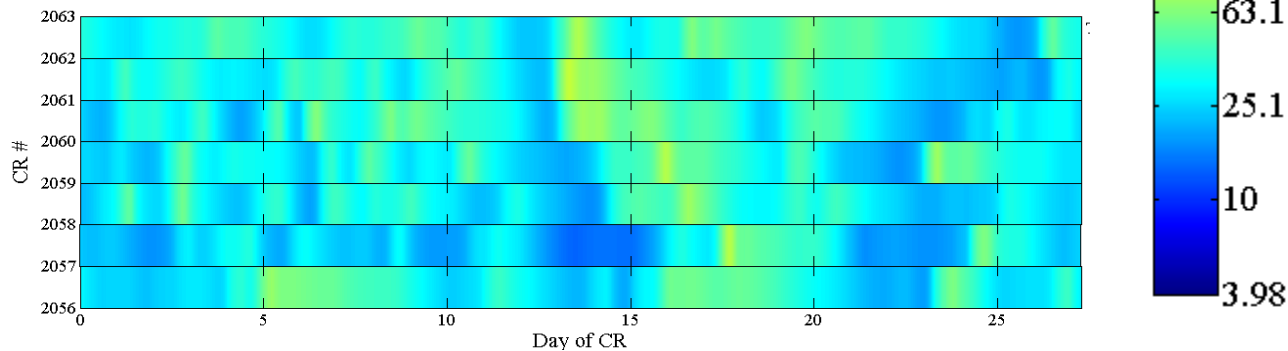


NSO-WSA-Enlil



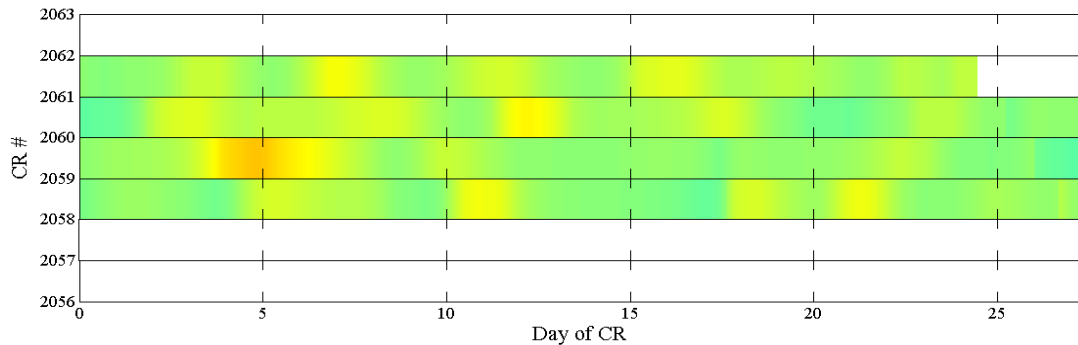
GONG-WSA-Enlil

1



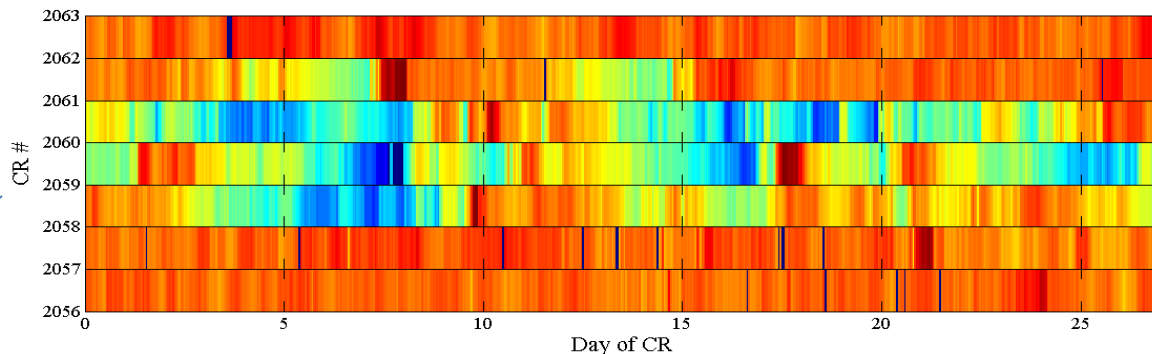
GONG-SWMF

(slow wind  $T_p$  is high)

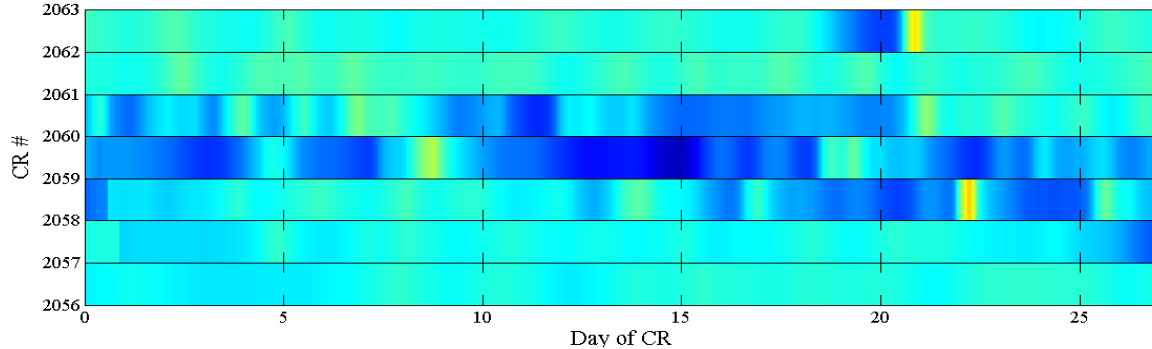


# Ulysses

Observation

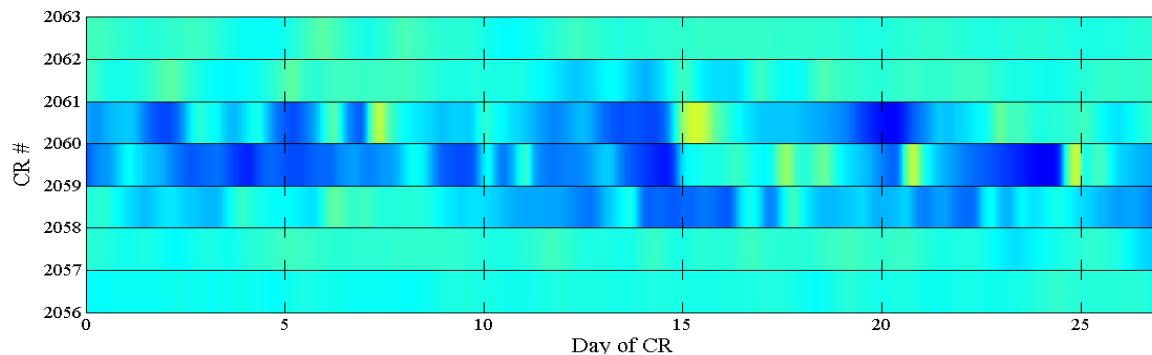


NSO-WSA-Enlil

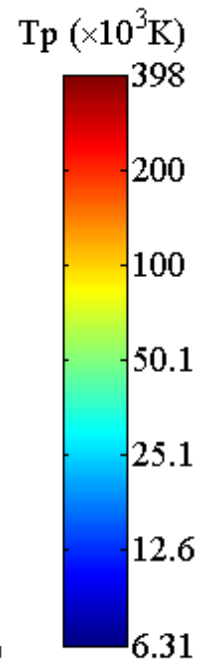
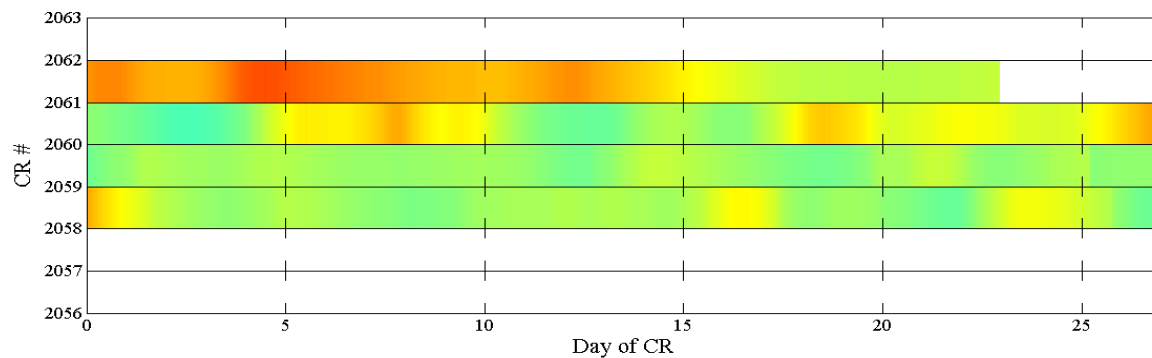


GONG-WSA-Enlil

1



GONG-SWMF



# Discussion and Conclusions

- **Timing** is a big issue for space weather forecasting
- The Enlil model v2.7 provides a **better prediction of CIR timing and fast wind speed** than v2.6. It uses a higher scaling factor for real time IMF prediction, and the factor varies with observatory
- All the models **underestimate B and Tp**, except the SWMF model for slow-wind temperature.
- Different sources of synoptic maps cause significant difference in modeling results, so as different models using same synoptic maps
- Among the NSO-WSA-Enlil, GONG-WSA-Enlil, & GONG-SWMF models
  - The GONG-WSA-Enlil model gives better IMF polarity, V, Np, and Tp prediction than the other two
  - The SWMF model gives slower and denser solar wind in general, and its slow wind is hotter than observation. It can get stronger B compression

# Future Work

1. Obtain the results at more locations from SWMF model
2. Run more CRs of SWMF model for parallel comparison
3. Add the new version of CORHEL model into the comparison
4. Evaluate the additional solar wind heating needed in the models
5. Run more CRs and more observatories for all the models to gain better statistics
6. Evaluate the capability of capturing small-scale solar wind structures
7. Assess the continuity of successive CRs
8. Examine synoptic maps vs. daily updated maps