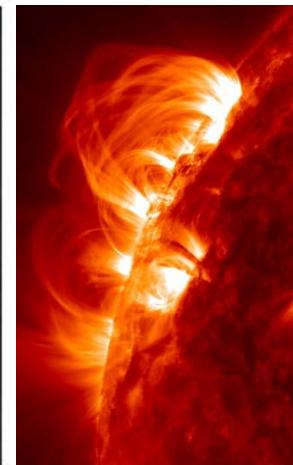


AOSWA Workshop

# Cause and Effect of Sep. 12-13, 2014 geomagnetic storm



K.-S. Cho<sup>1</sup>, R.-S. Kim<sup>1</sup>, S.-J. Kim<sup>1</sup>, J.-A. Hwang<sup>1</sup>,  
Y.-S. Kwak<sup>1</sup>, S.-H. Park<sup>2</sup>, P. Kumar<sup>1</sup> and S.-J. Jang<sup>1,3</sup>

<sup>1</sup>Korea Astronomy and Space Science Institute

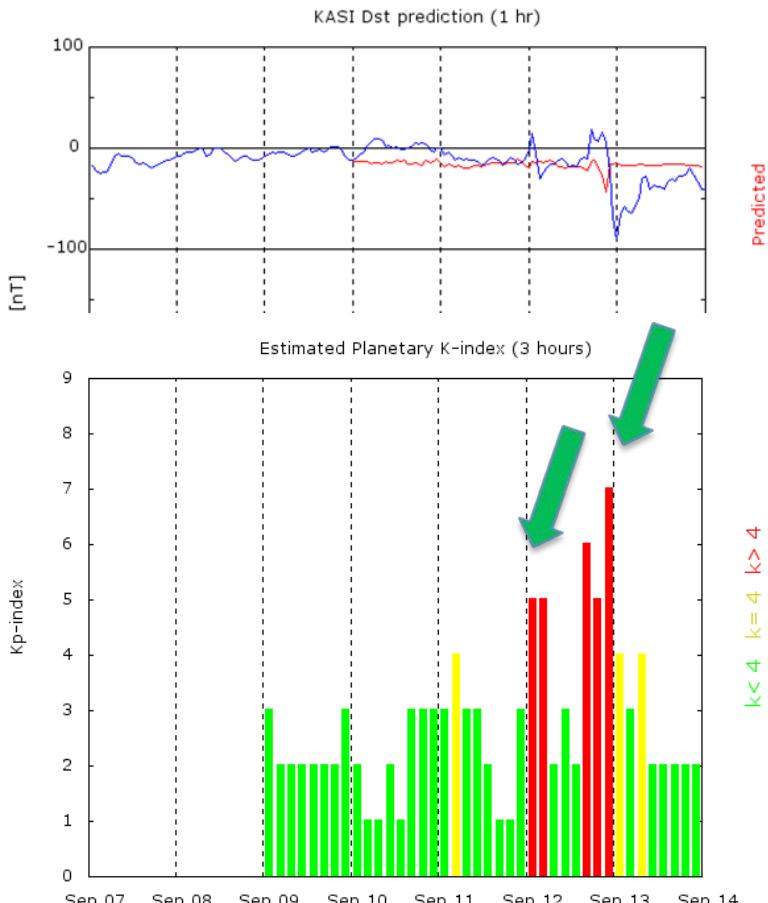
<sup>2</sup>National Observatory of Athens, Greece

<sup>3</sup>Kyunghee University, Korea

# Geomagnetic Storms during Sep. 12-13, 2014

- Two Geomagnetic Storms

- 09/11 23h UT : Kp=5, Dst = -20 nT
- 09/12 21h UT : Kp=7, Dst=-75 nT

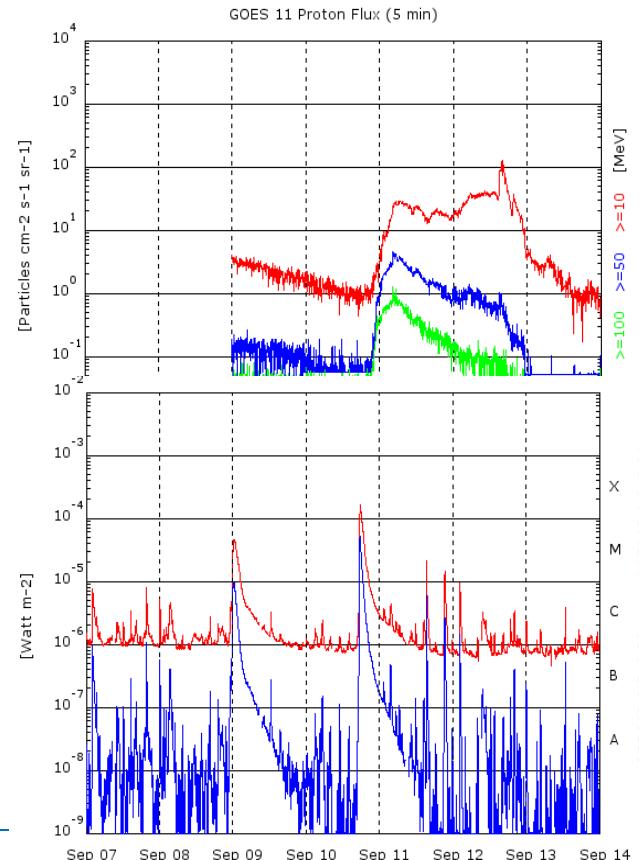


- 2 strong flares

- 09/08 23:12 M4.6 (N14E31)
- 09/10 17:21 X1.6 (N11E05)

- Proton event

- 09/11 02:40 126 pfu (N16W06,

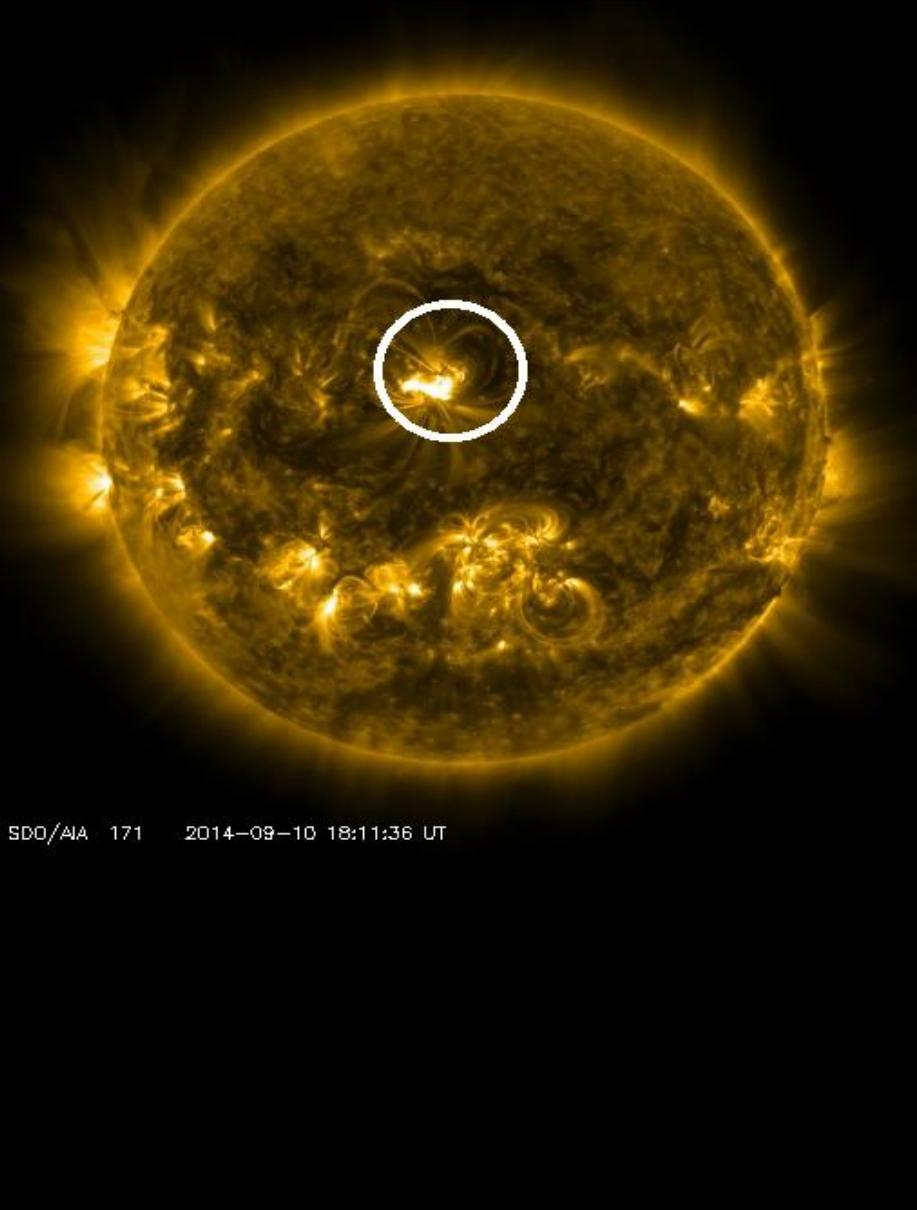


# 1. KASI Prediction and Service

Solar and Space weather group

N  
E      W  
S

2014 Sep. 11, 02:16 UT, Report from KASI



❶ 플레이어 발생시점 2014 / 09 / 10 / 17:21 (UT)

❷ 플레이어 종료시점 2014 / 09 / 10 / 18:20 (UT)

❸ 플레이어 최대세기 X1.6

❹ 프로톤 이벤트 최대시점 2014-09-11 21:20

❺ 프로톤 이벤트 지속시간(예상치) 27.4 시간

❻ 프로톤 이벤트 최대세기(예상치) S2

❼ 지구방향 CME 진행여부 발생안함

❽ CME 지구도달 시간 2014-09-13 04시 ~ 2014-09-13 16시

	Sep 11 *	<b>R1</b>	<b>S1</b>	<b>G0</b>
❾ 우주환경 예보 (UT)	Sep 12	<b>R1</b>	<b>S1</b>	<b>G0</b>
	Sep 13	<b>R0</b>	<b>S0</b>	<b>G1</b>
	Sep 14	<b>R0</b>	<b>S0</b>	<b>G0</b>

❿ 개요

계속 성장을 해 오던 활동영역 AR2158지역에서 X1.6 플레이어가 발생하였다. 태양중심에서 발생하였고 지구방향의 코로나 물질방출과 프로톤 증가가 함께 발생하여 9월 12일에는 프로톤의 증가에 따른 영향과 13일에는 지구자기장 폭풍에 의한 약한 영향을 받을 것으로 예상된다. 이 활동영역은 계속 주목해야 할 것으로 판단된다.

CONTACT PHONE\_042.865.3248

우주환경경보는 2014월 09월 10일 08:10부터 예보일지 작성시까지의 우주환경 상태

\* 예보일지 작성시부터 UT24시까지의 예보값

3일 예보 - Chrome

www.spaceweather.go.kr/popup/history/forecast/daily

3일 예보 (센터 제공)

### 우주전파환경 3일예보 (9.11 ~ 9.13)

[닫기](#)

## Report from RRA

국립전파연구원 우주전파센터 ([www.spaceweather.go.kr](http://www.spaceweather.go.kr))  
게시일시 : 2014. 9. 11 11:00

**가. 향후 3일간 경보 발생 확률**

구분	전파두절(R)		태양입자 유입(S)		지자기 교란(G)	
	R1-R2	R3 이상	S1 이상	G1	G2 이상	
9.11.(목)	75 %	30 %	90 %	1 %	1 %	
9.12.(금)	75 %	30 %	80 %	40 %	10 %	
9.13.(토)	75 %	30 %	50 %	40 %	10 %	

\* 경보발생 확률은 익일 변경될 수 있습니다.

**나. 지난 3일간 경보 내역**

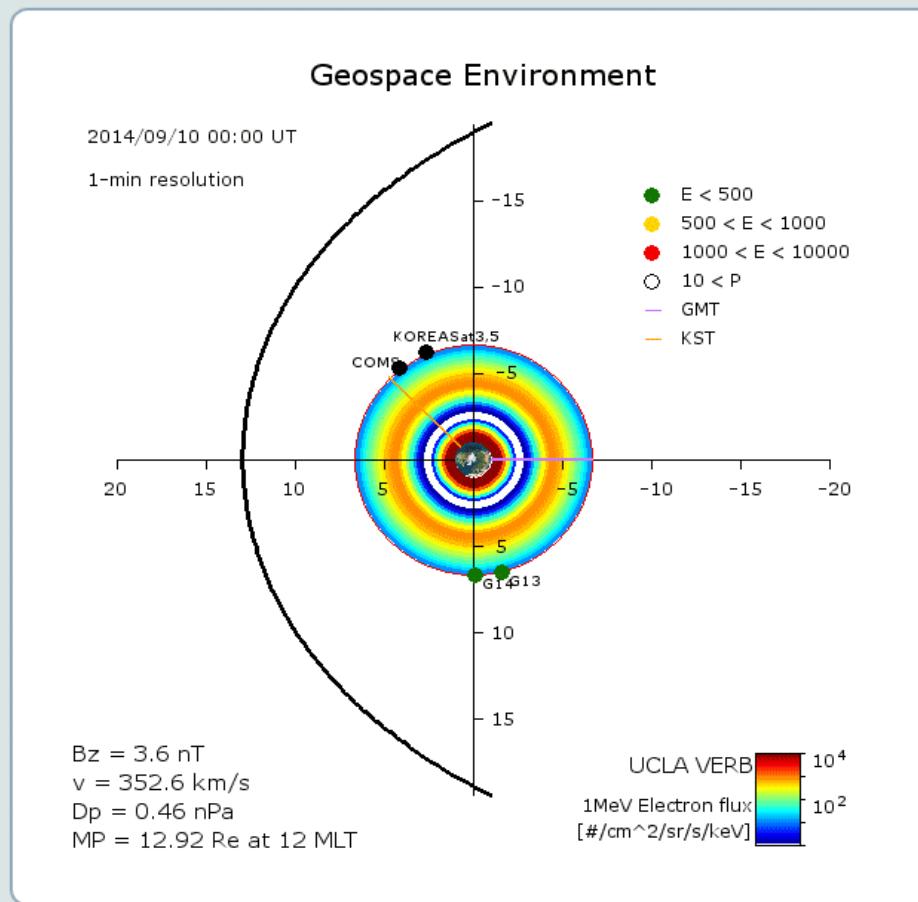
구분	발령일시	등급	종료일시	최대 측정값	비고
전파두절(R2이상)	9.11.(목) 02:35	R3	2014-09-11 03:22	X1.6	-
태양입자 유입(S)	-	-	-	-	-
지자기 교란(G)	-	-	-	-	-

**다. 우주전파환경 분석**

1) 오늘의 태양흑점 활동

흑점번호	위치	변화	
		크기	자기장 복잡도
2155	S21W22	유지(60->60)	유지(2->2)

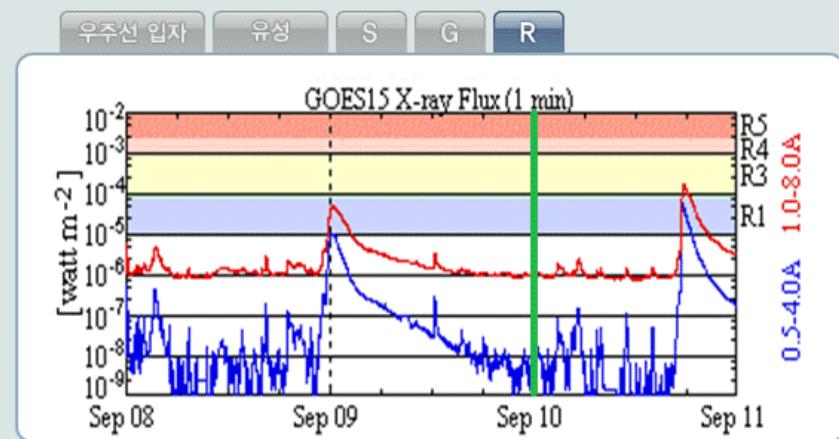
# 정지궤도 위성용 우주환경 감시



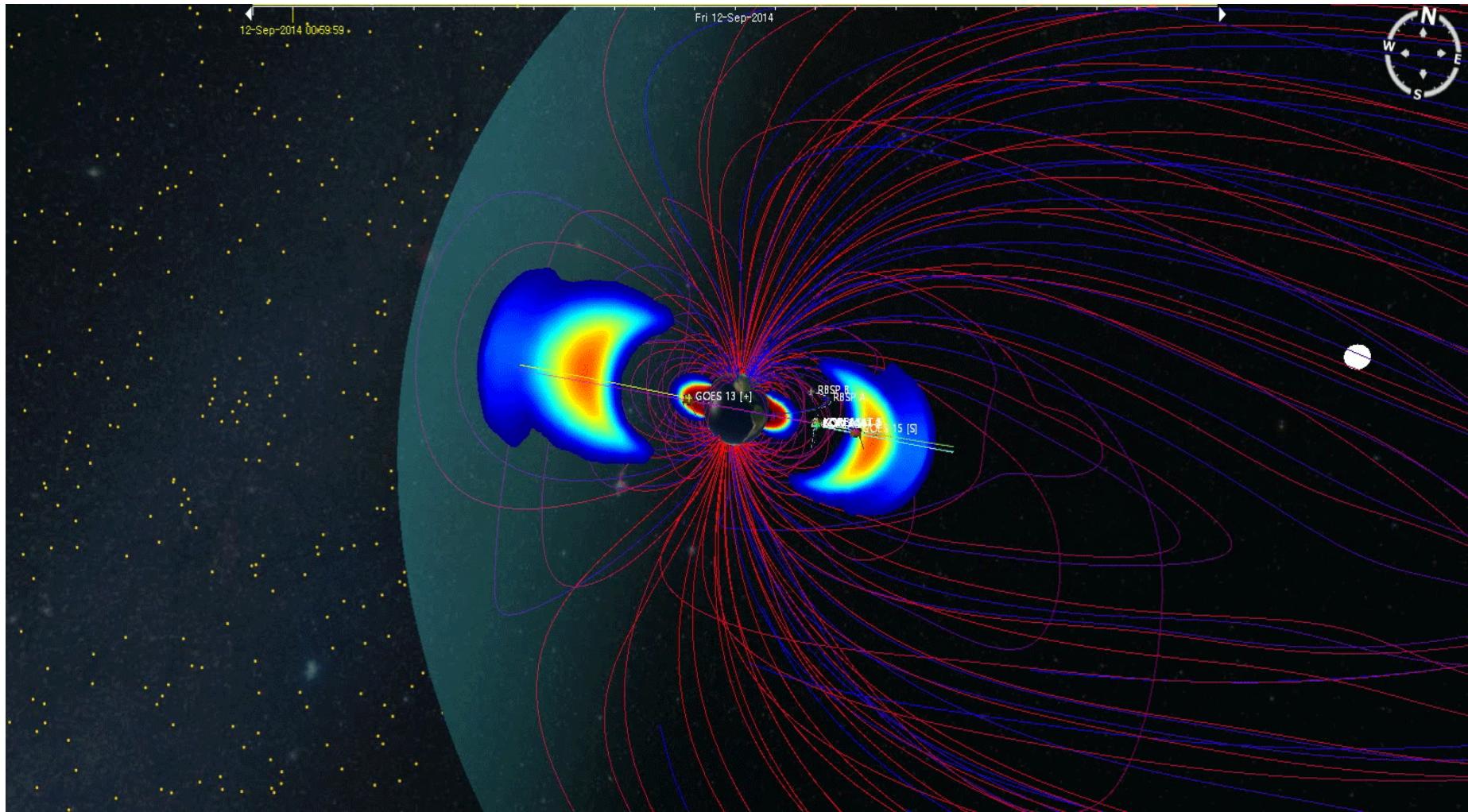
**우주환경 현황 및 예보**

구분	오늘 (9월 10일)	내일 (9월 11일)
태양 입자 환경	 영향 없음	 안정
지구 자기장 환경	 영향 없음	 안정
태양 복사 환경	 영향 없음	 주의

S: Solar Radiation Event, G: Geomagnetic Storm, R: Radio Blackout

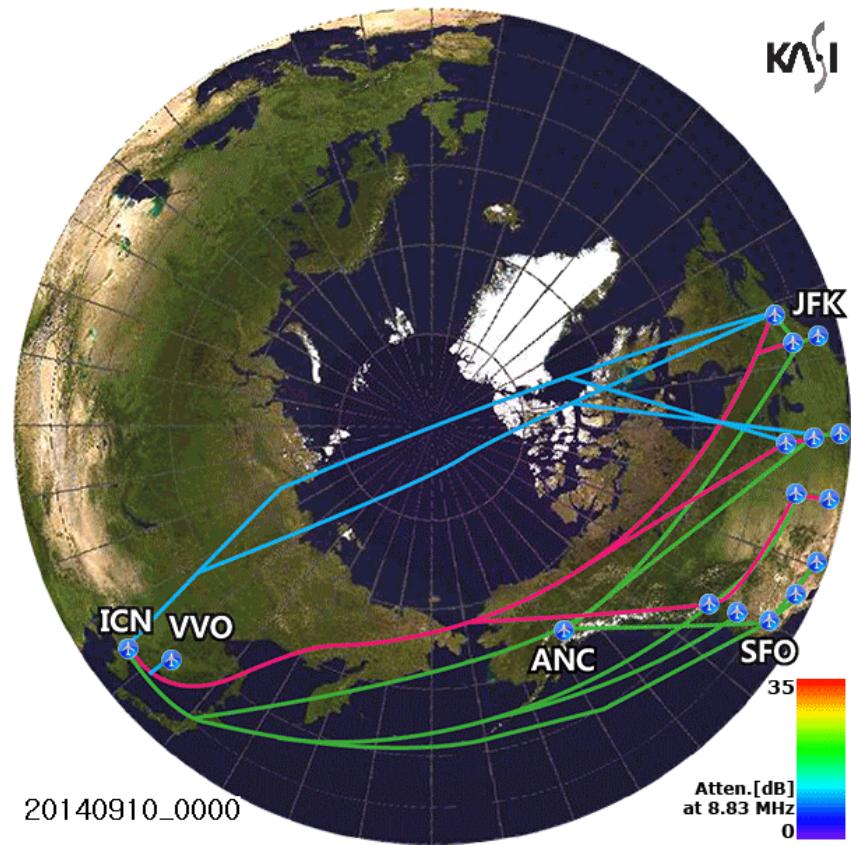
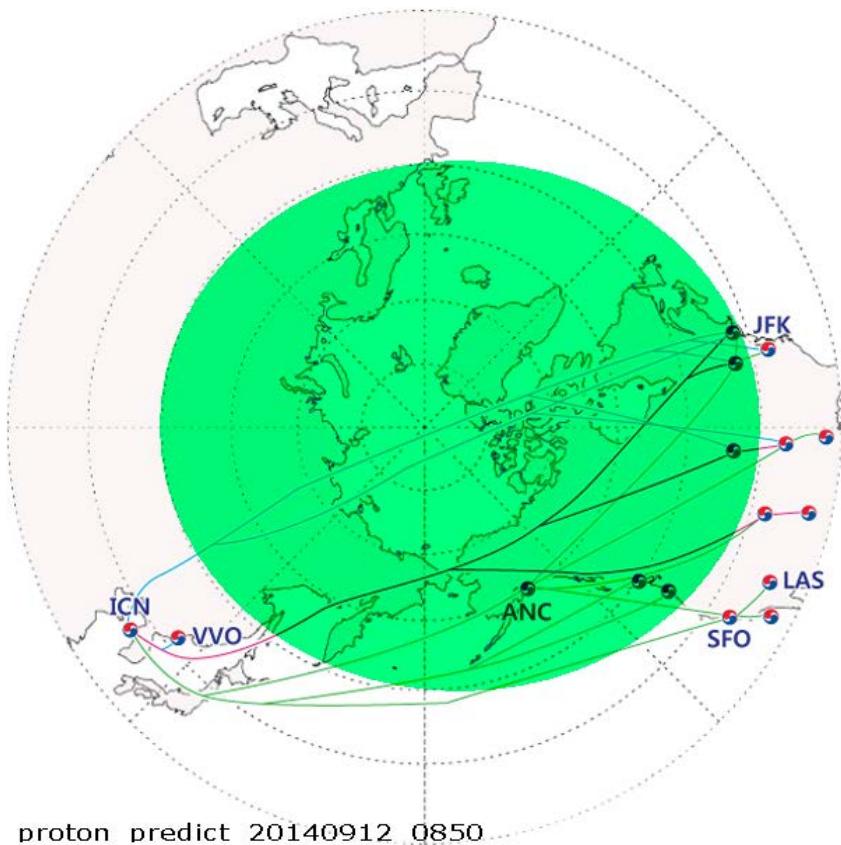


# Real-time simulation of RB



VERB provided by UCLA

# North Polar Route monitoring



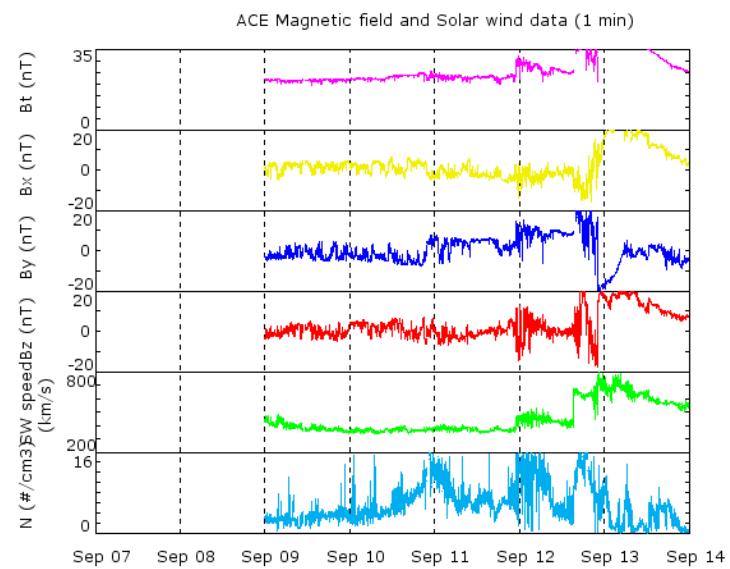
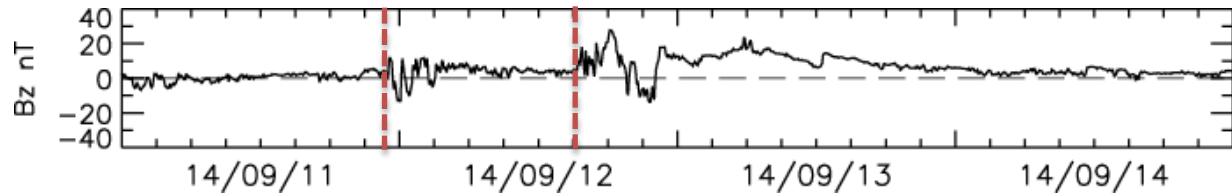
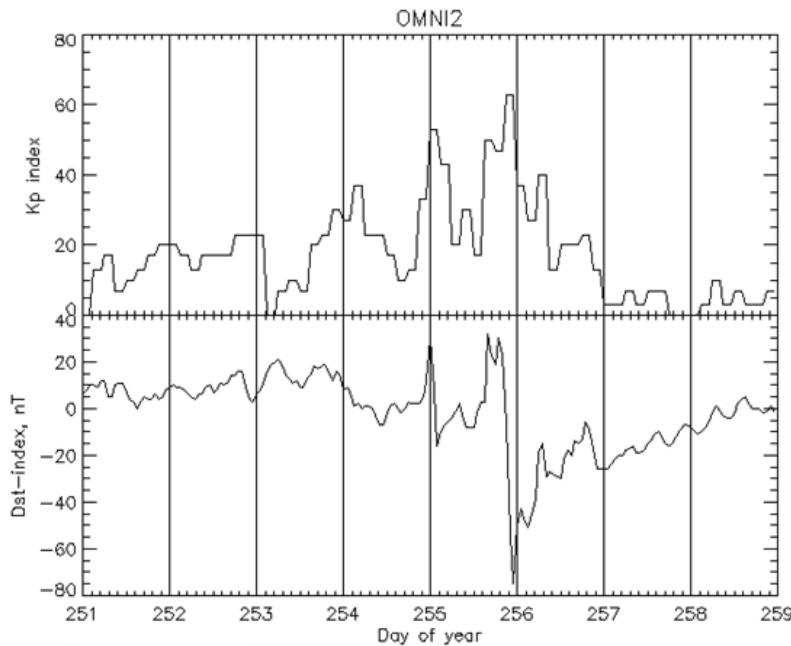
## 2. Effects

Solar and Space weather group

## ◆ ICME's arrival

- 1<sup>st</sup> : 09/11 ~23h UT
- 2<sup>nd</sup>: 09/12 ~ 16h UT
- Bz during two ICMEs looks positive (N)

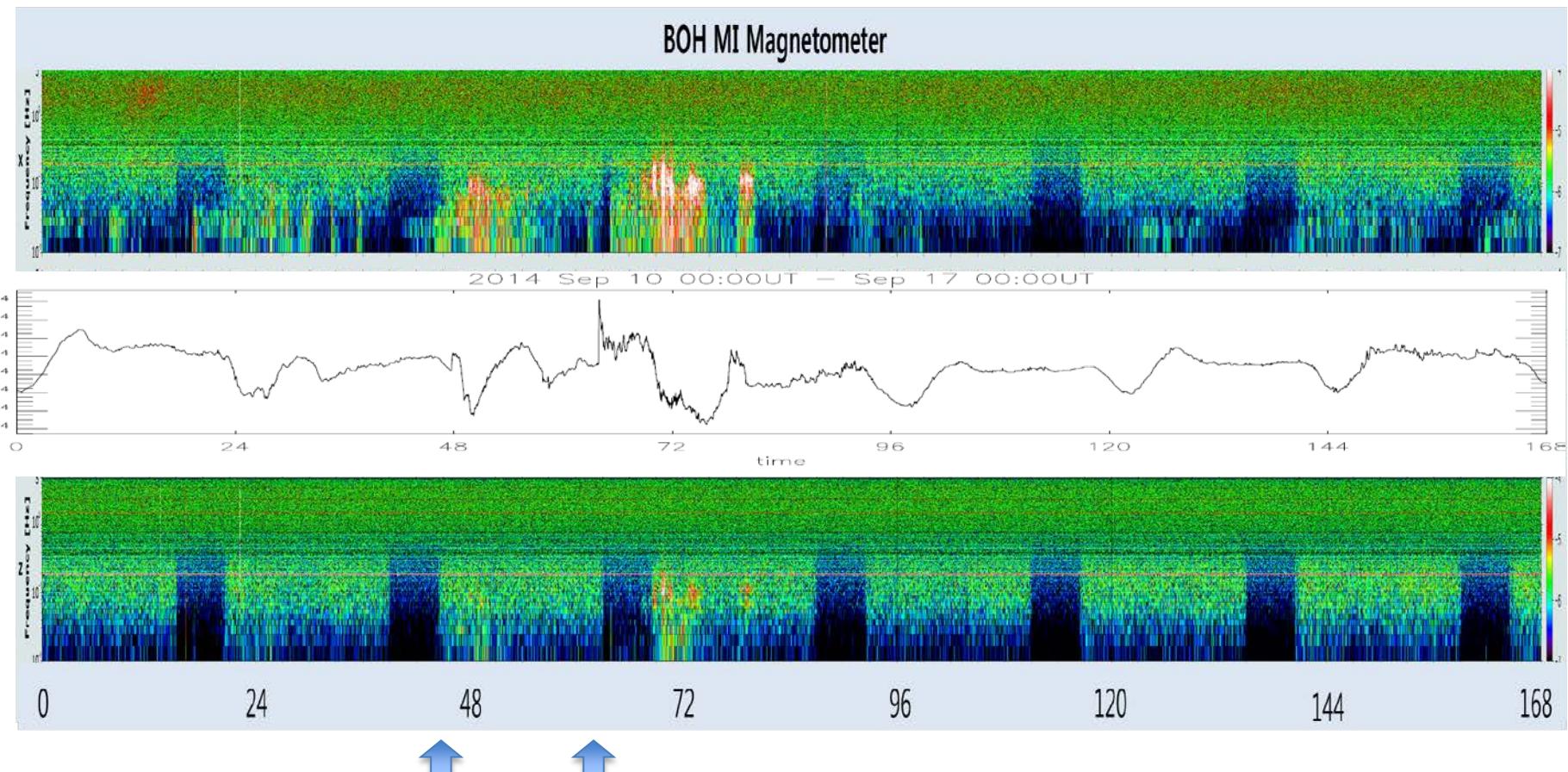
Plot omni2 data from 20140908 to 20140915



- 2 Geomagnetic Storms
  - 09/11 23h UT : Kp=5, Dst = -20 nT
  - 09/12 21h UT : Kp=6, Dst=-75 nT

# Ground observation at BOH ( $L = 1.35$ )

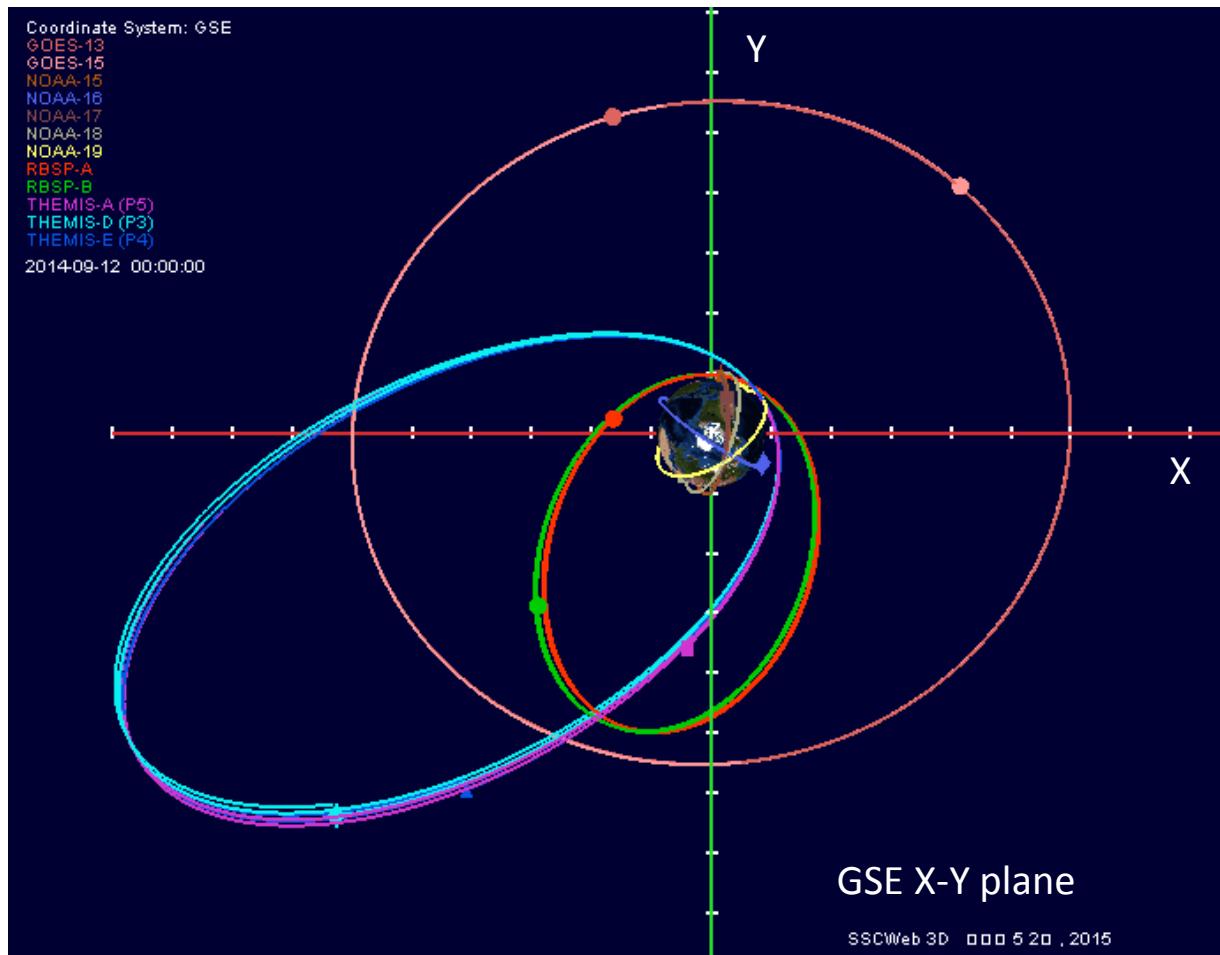
Fluxgate and Mageto-Impedance magnetometer



↑  
1<sup>st</sup> Shock      2<sup>nd</sup> Shock  
09/11            09/12  
23UT            16UT

Pi2 Pulsations (6-25 mHz)  
observed after the shocks

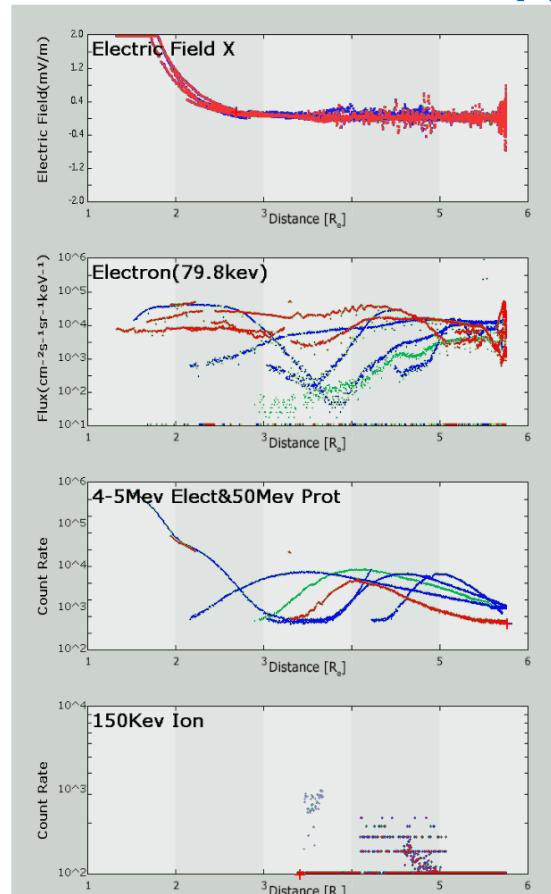
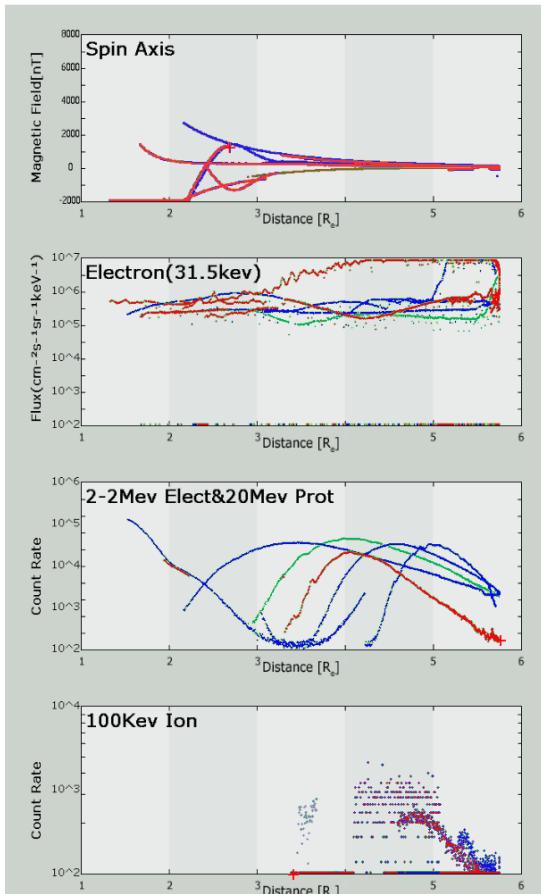
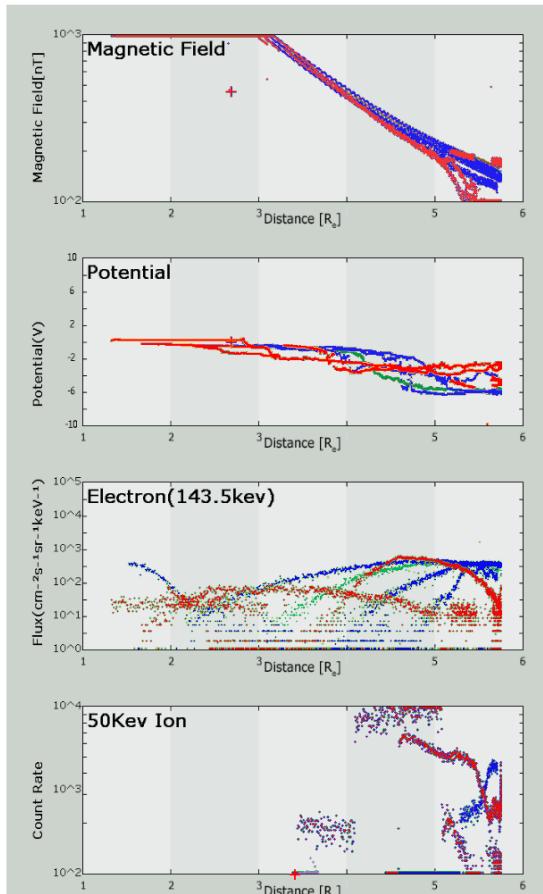
# Multipoint observations in the magnetosphere



# Van Allen Probes Space Weather Data

2014-09-13

[JHU/APL summary plot](#)



Korea Astronomy and Space Science Institute

— 9/11 (KST)

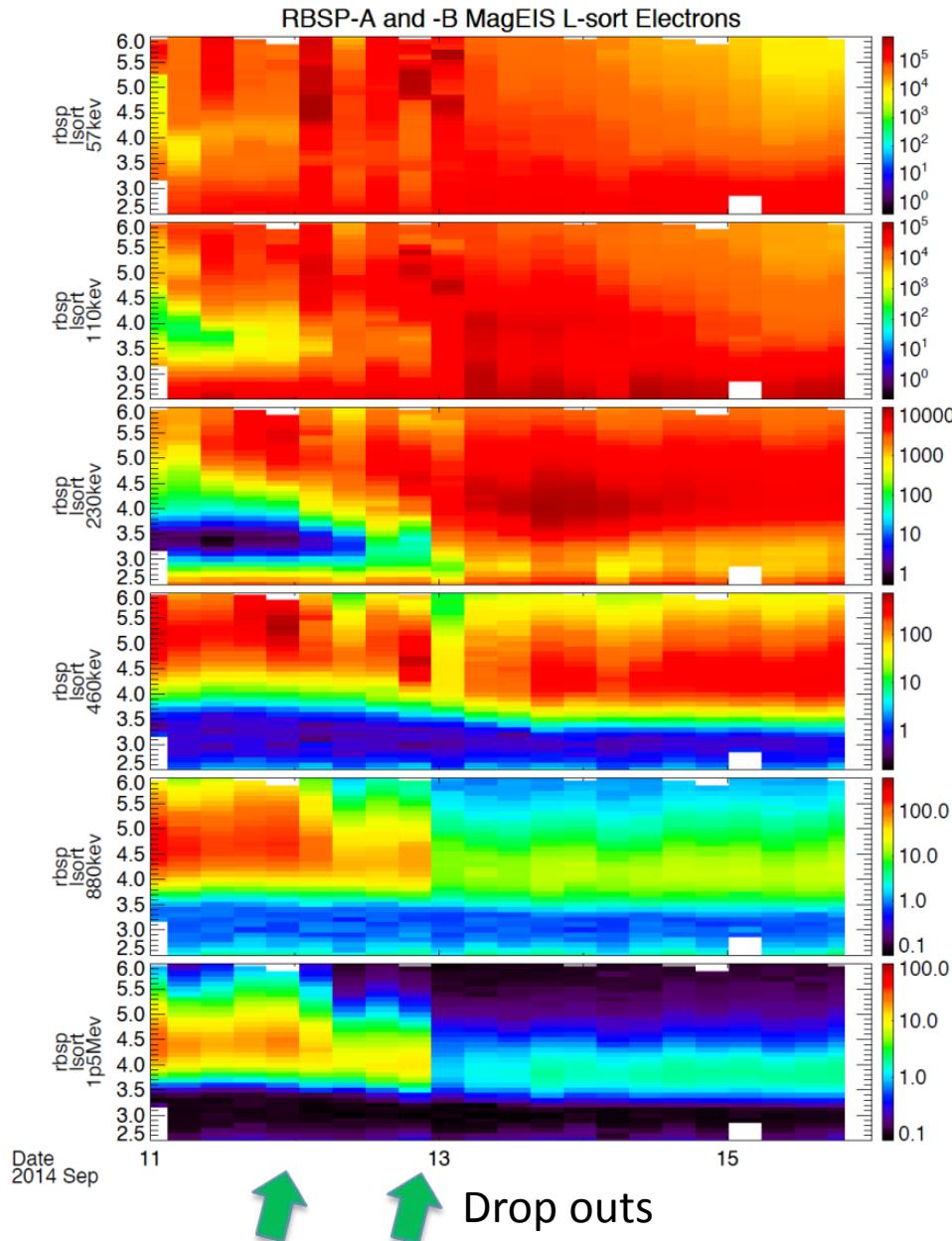
— 9/13 (KST)

— 9/12 (KST)

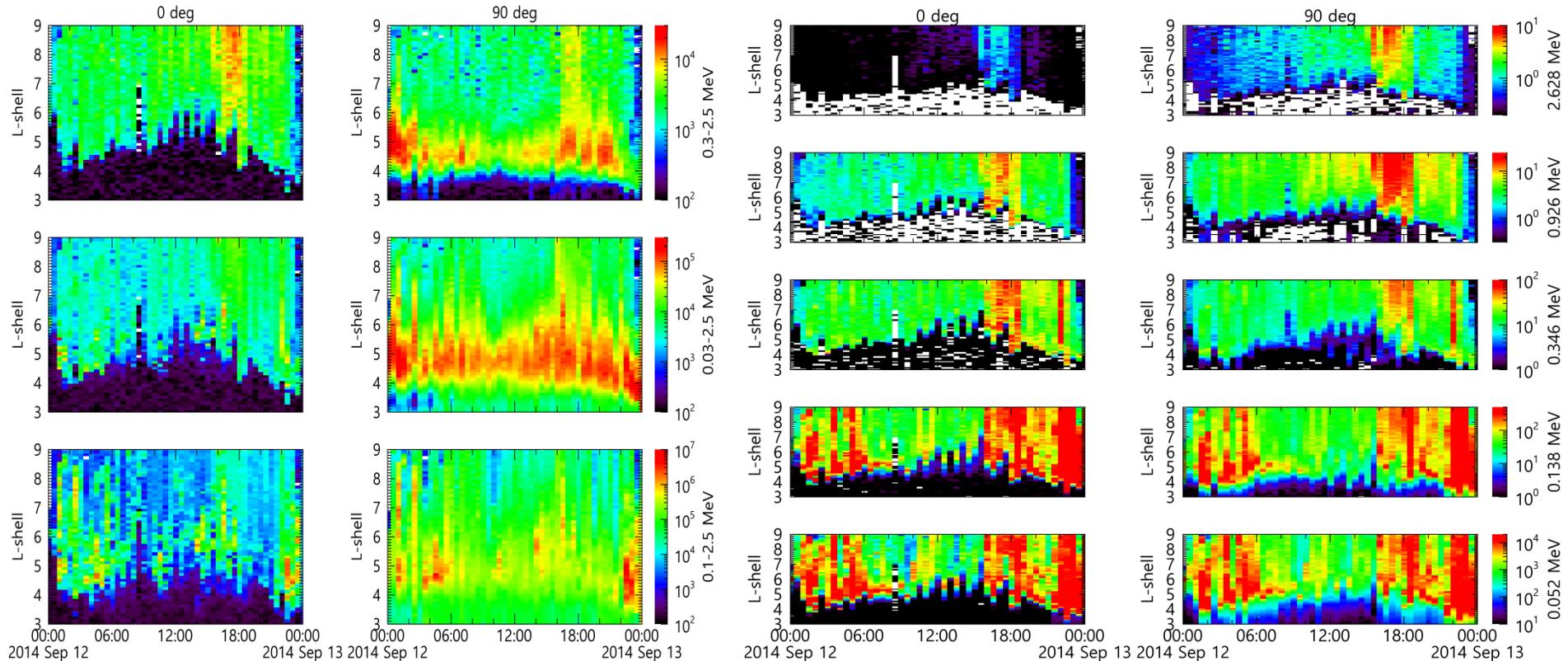
Space Weather Monitor

Space weather data

# RBSP/MagEIS observation



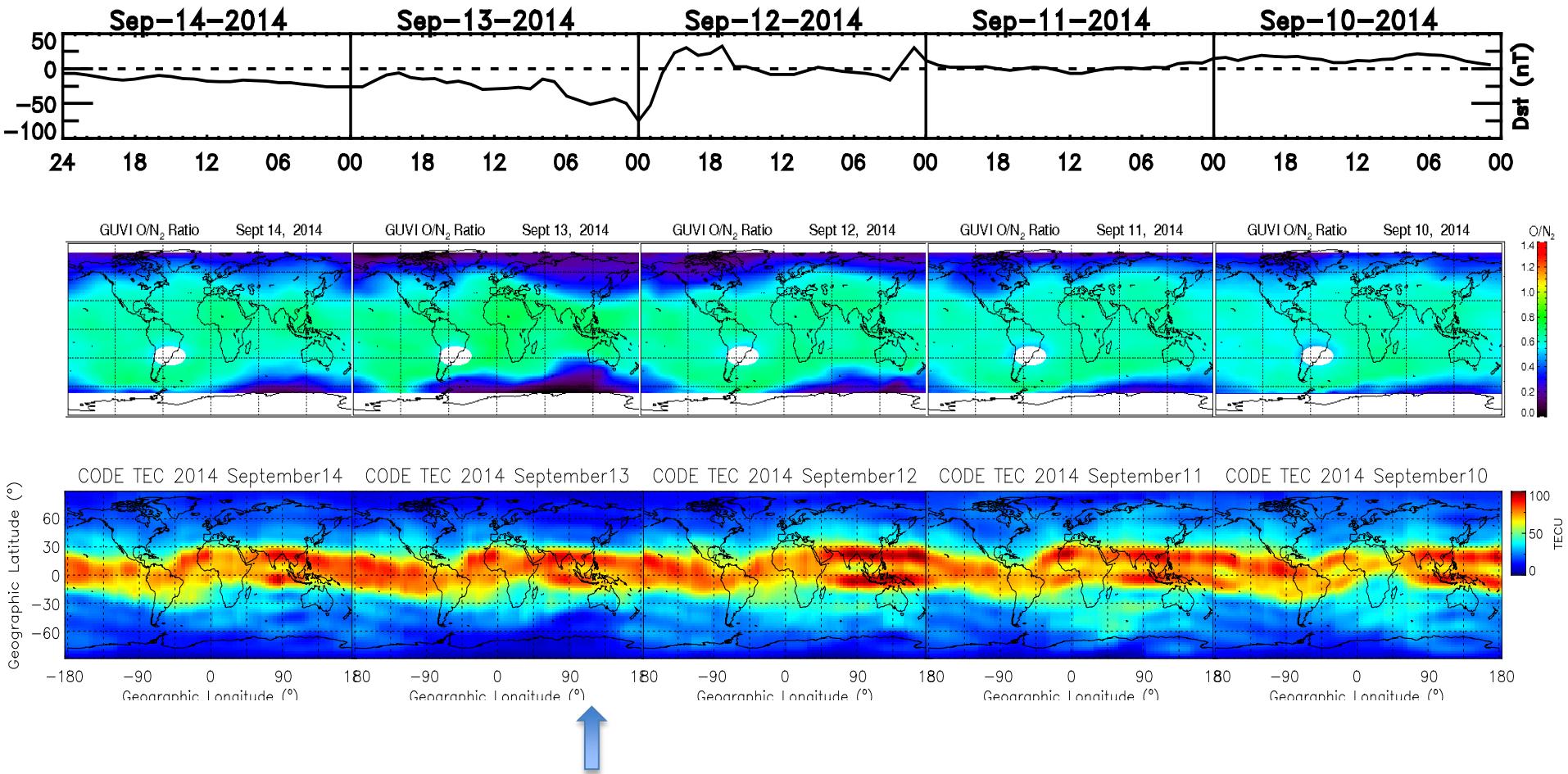
# NOAA POES observation



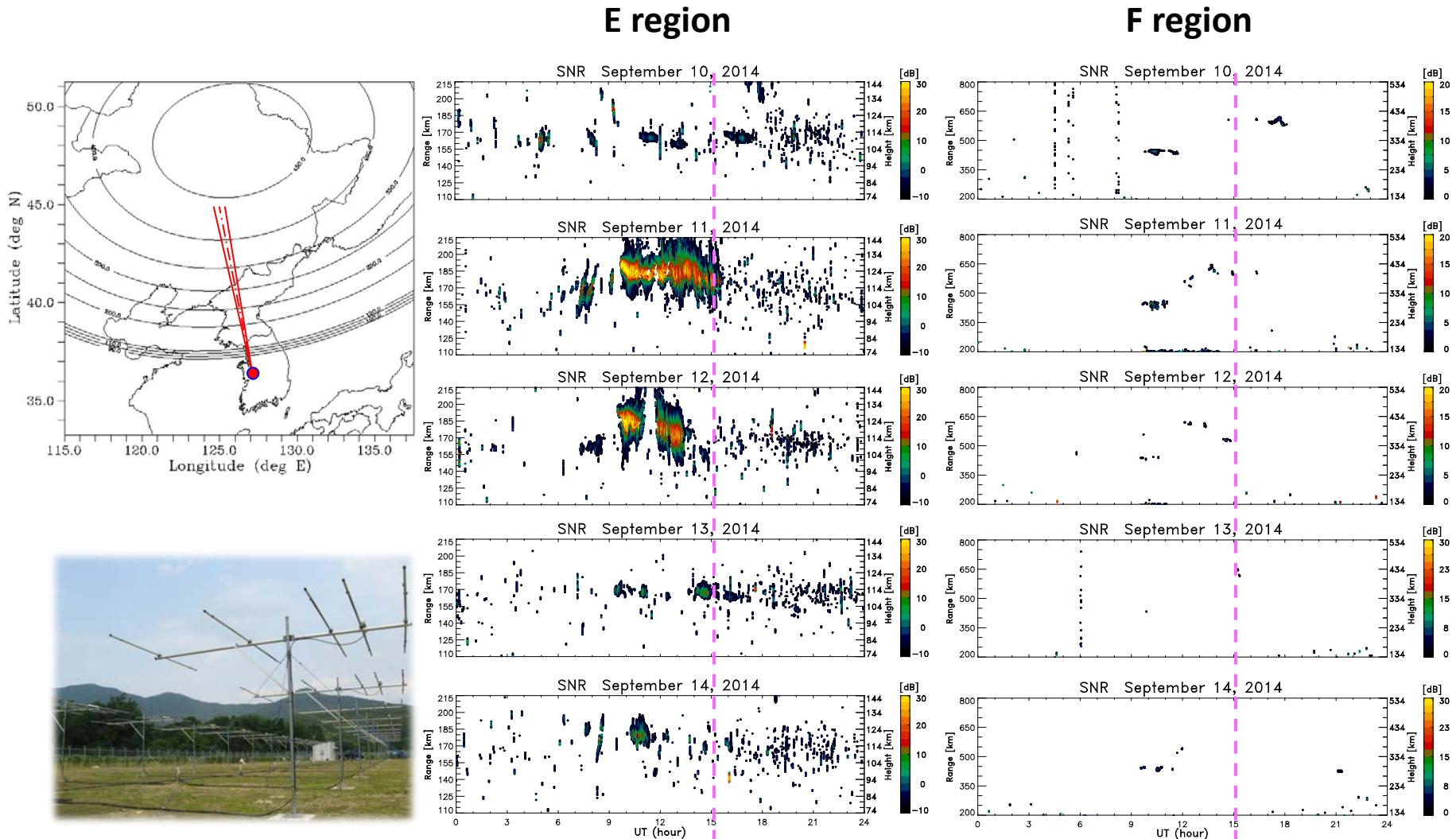
electron

proton

# Global Thermosphere/Ionosphere



# KASI VHF ionosphere observations

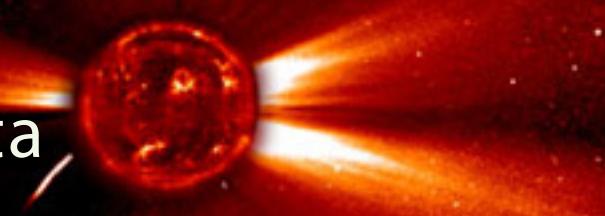


40.8MHz, KAF, CSR

### 3. Cause

Solar and Space weather group

# Empirical model for forecast of geoeffective CMEs using Solar Data



- Empirical storm prediction model (Kim et al., 2010, JGR)
  - We derived the empirical storm prediction formulas by using CME parameters.
    - ✓ Direction parameter has the best correlation with the storm strength.
    - ✓ Since the source locations of geoeffective CMEs are asymmetrical in longitude, we consider West 15° offset.
    - ✓ We divide CMEs into two groups according to their magnetic field orientation.

$$\begin{aligned} \text{Dst (nT)} &= 160.87 - 32.94 \times L - 195.08 \times V - 329.40 \times D \text{ (South)} \\ \text{Dst (nT)} &= 52.47 - 44.58 \times L - 44.84 \times V - 205.18 \times D \text{ (North)} \end{aligned}$$

## □ Forecast Evaluation

- Model prediction gives us the PODy, PODn, FAR, and CSI as 0.93, 0.50, 0.26, and 0.70, respectively.

# Web-based empirical Model

- Inputs
  - CME time, AW, and F/B
  - CME source location, magnetic field orientation
  - CME propagation speed and direction (D)
- Outputs (forecast)
  - Storm time and Storm strength (Dst)
  - Probability of storm

http://sos.kasi.re.kr/a1/gsp\_input.aspx SOS Data Archive

## Geomagnetic Storm Forecast System

Use custom start/stop times  
Start: 2014 09 08  
Stop: 2014 09 12 12

Use latest times

Use specific event start/stop times  
2003/11/01 ~ 2003/11/07

Search

CME List

No.	Date	Time	dt0	PA	DA	Speed	dv	minv	maxv	halo?

Forecast Input

Start Time	Angular Width	Speed	F/B	Location	Direction Parameter	MFO	Action
2014/09/10 17:36	360	1600	Front	N15E02	0.65	South	+ADD

Shock Propagation Model - 우주환경 예보일지  
http://sos.kasi.re.kr/center/shock\_gui.php

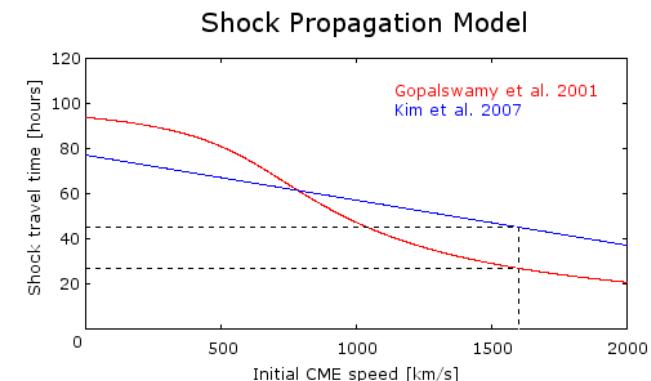
데이터입력

Date (YYYYMMDD)	20140910
Time (HHMM)	1736
CME Initial Speed (0 ~ 2000)	1600

Calculate Reset

계산결과값

Kim et al. 2007 Transit Time (Hour) Arrival Time (Date/Time)	44.86 2014-09-12 14:27
Gopalswamy et al. 2001 Transit Time (Hour) Arrival Time (Date/Time)	26.64530480827 2014-09-11 20:14



## ◆ CME speed: CMEs during Sep. 8~11, 2014

- LASCO/C2, C3 and CME lists
  - Cactus

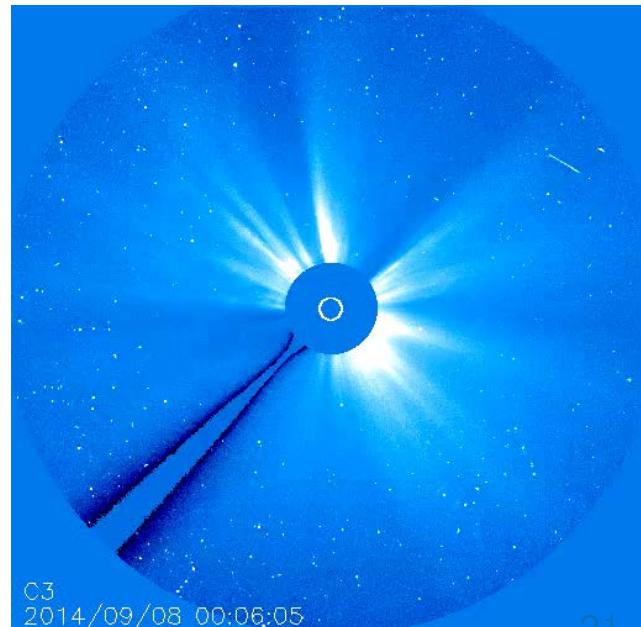
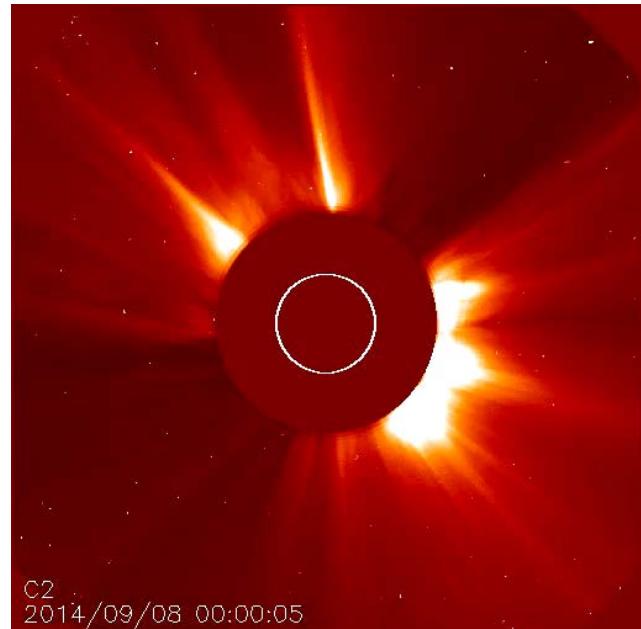
t0		dt0		pa		da		v		dv		minv		maxv	
2014/09/12	23:12		02		175		016		0398		0049		0332		0488
2014/09/12	20:00		01		056		010		0710		0111		0694		0919
2014/09/12	19:24		06		144		360		0844		0555		0176		1838
2014/09/12	18:48		04		024		022		0411		0163		0196		0762
2014/09/10	19:12		01		349		048		0322		0050		0242		0411
2014/09/10	18:48		01		263		024		1603		0442		0631		1834
2014/09/10	18:00		04		049		360		0637		0237		0206		1302
2014/09/10	17:48		02		318		050		0473		0131		0225		0762
2014/09/10	01:48		02		299		044		0355		0082		0223		0496
2014/09/09	16:36		01		038		010		0351		0069		0332		0480
2014/09/09	02:01		01		348		006		0142		0019		0108		0158
2014/09/09	00:58		01		048		030		0837		0372		0490		1627
2014/09/09	00:16		01		098		006		0958		0629		0294		1791
2014/09/09	00:16		01		118		046		0717		0310		0266		1490
2014/09/09	00:16		03		326		350		0715		0622		0190		1884
2014/09/08	16:13		01		288		030		0320		0057		0233		0372
2014/09/08	09:24		01		066		014		0391		0078		0260		0506
2014/09/08	02:24		01		079		012		0538		0020		0529		0577

### From Cactus

- : 2014/09/09 CME speed ~ 900 km/s
- : 2014/09/10 CME speed ~ 1600 km/s

- 2 strong flares

- 09/08 23:12 M4.6 (N14E31)
- 09/10 17:21 X1.6 (N11E05)



◆ Source Location and Magnetic field direction (AR 12158)  
: HMI magnetogram and AIA 304

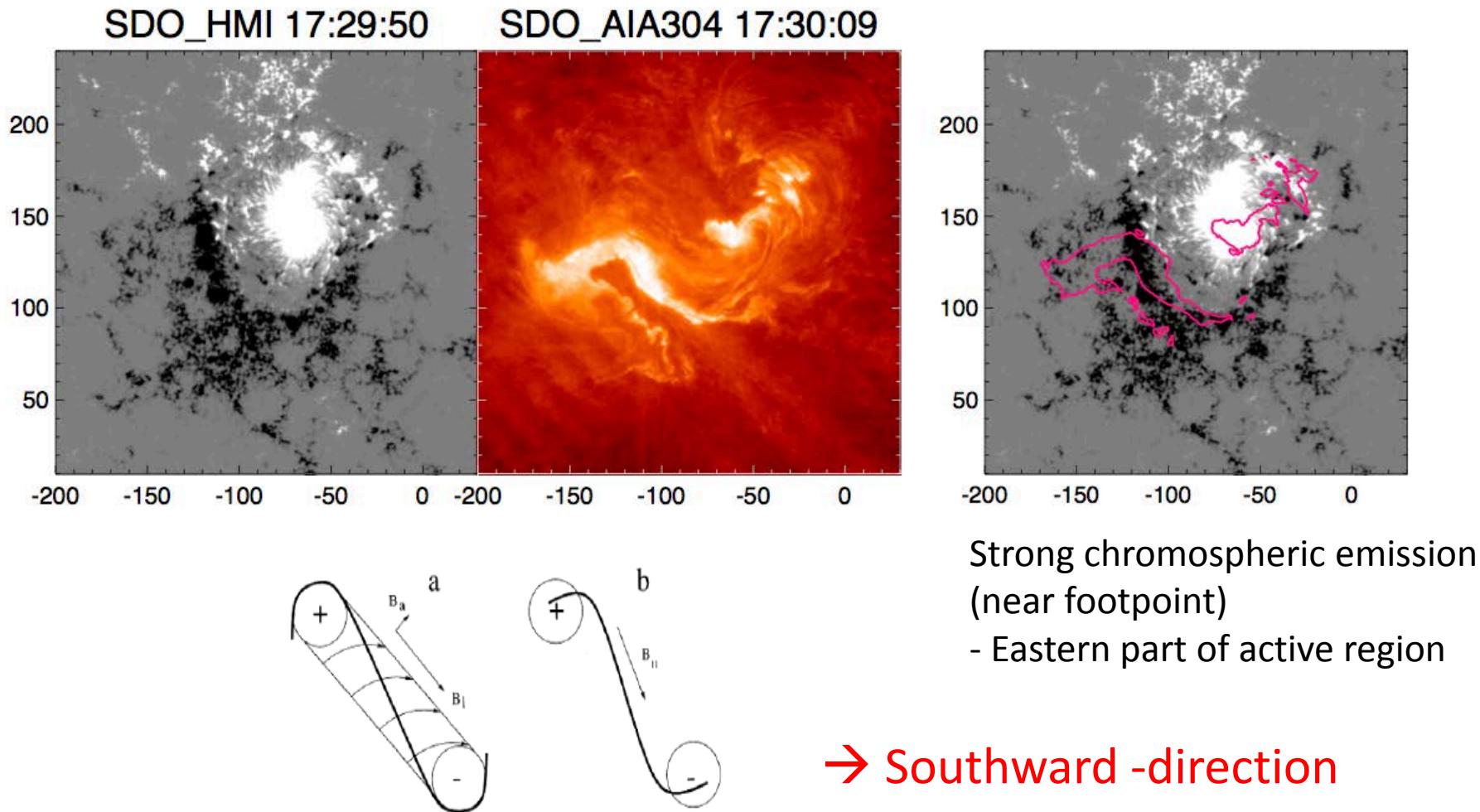
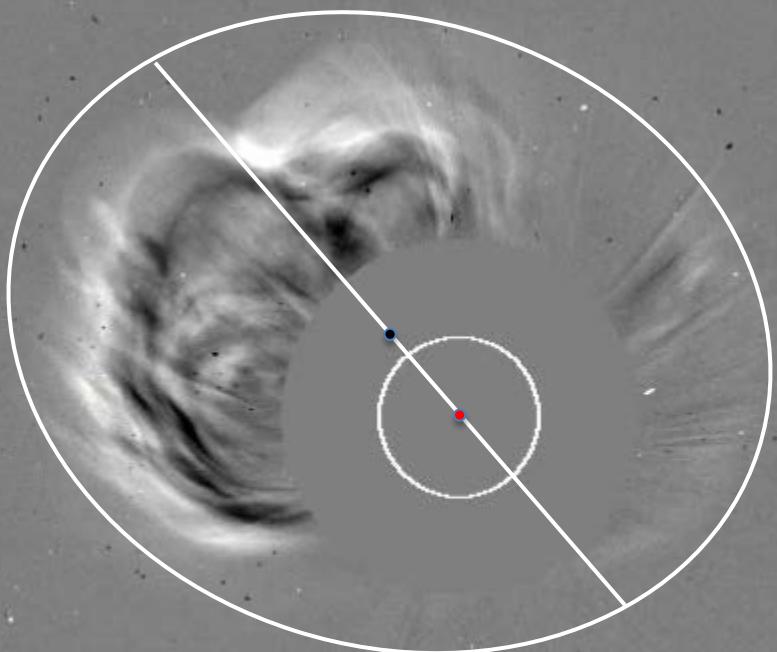


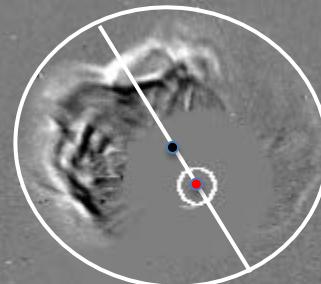
Figure 1. Field orientation of (a) the CFR and (b) the FFF model [Pevtsov and Canfield, 2001]. Circles

## ◆ Geomagnetic Storm Forecasts (M4.6 flare)

- 2014/09/09 00:16 CME
  - $V \sim 900$  km/s
  - $D=0.49$
- Forecast
  - Expected arrival: 09/11 05 ~ 11h UT
  - Expected Dst = -64 nT (if N=-46nT)
  - Arrival: 09/11 ~ 23h UT
  - Dst = -20nT



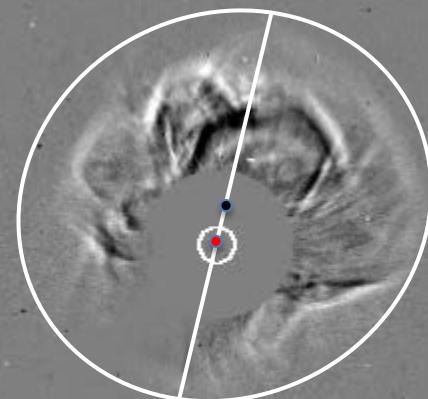
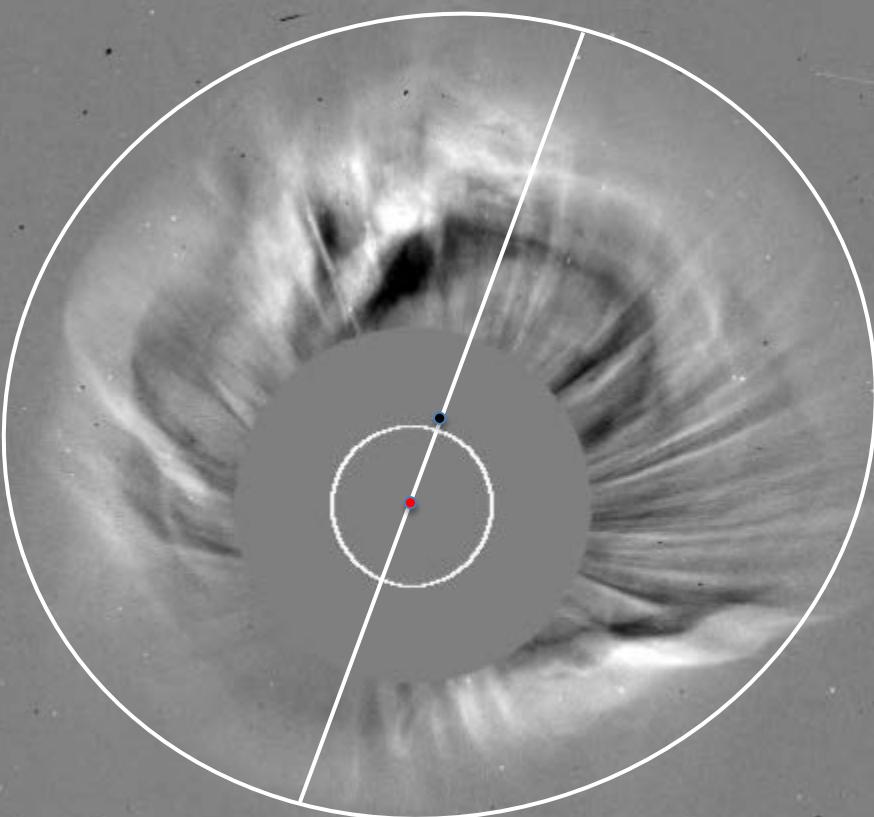
C2  
2014/09/09 00:48:23



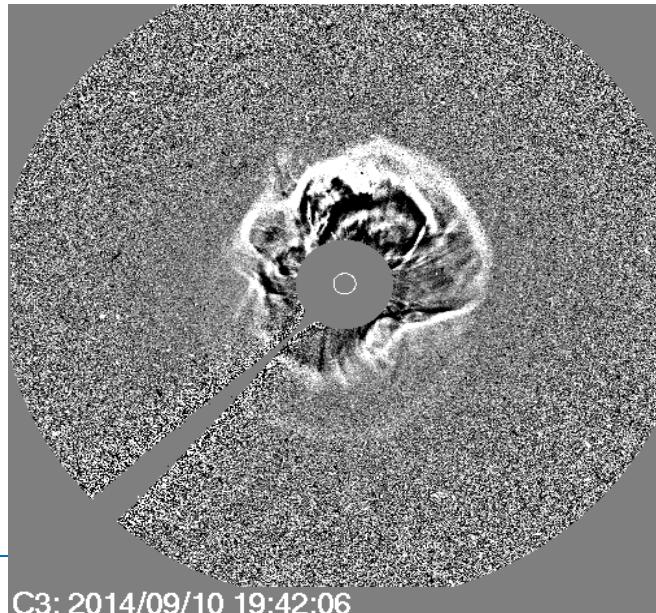
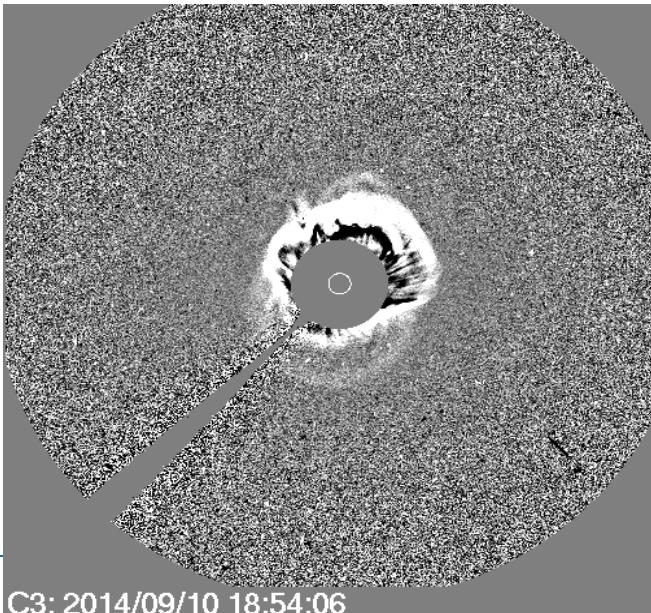
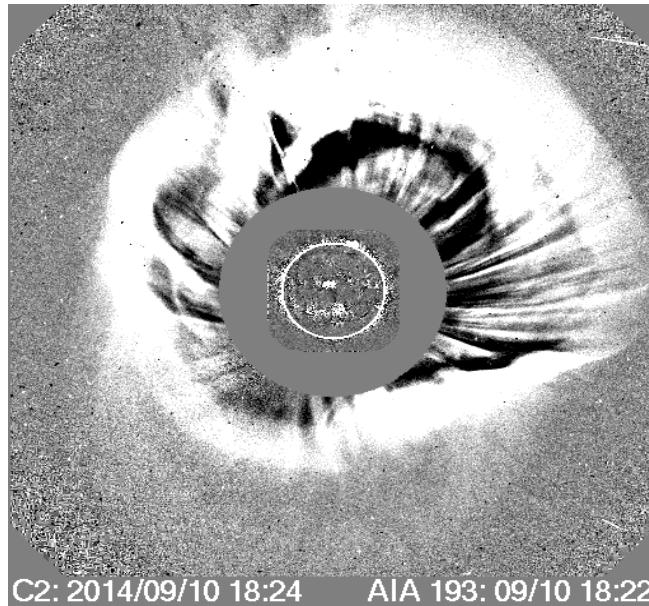
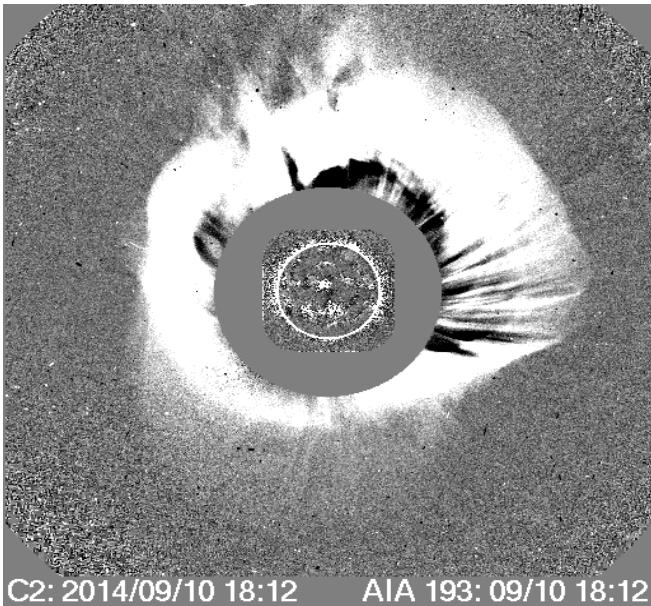
C3  
2014/09/09 01:55:59

## ◆ Geomagnetic Storm Forecasts (X1.6 flare)

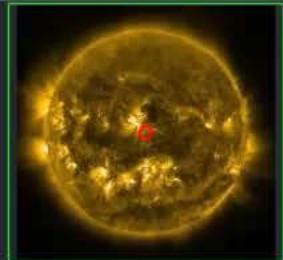
- 2014/09/10 17:36 CME
  - $V \sim 1600$  km/s
  - $D = 0.65$
- Forecast
  - Expected arrival: 09/12 11~17h UT
  - Expected Dst = -174 nT (if N=-104nT)
  - Minor Storm: 09/12, 16h UT
  - Dst= -75 nT



# Two CMEs (?) erupted by the X1.6 flare



## OVERVIEW



## DATE / TIME

Start	2014-09-10 17:00:00	<input type="button" value=""/>
End	2014-09-10 18:00:00	<input type="button" value=""/>
Step	0	<input type="button" value="getall"/> <input type="button" value=""/>
<input type="button" value="Apply"/>		

AIA 171A  + ADD

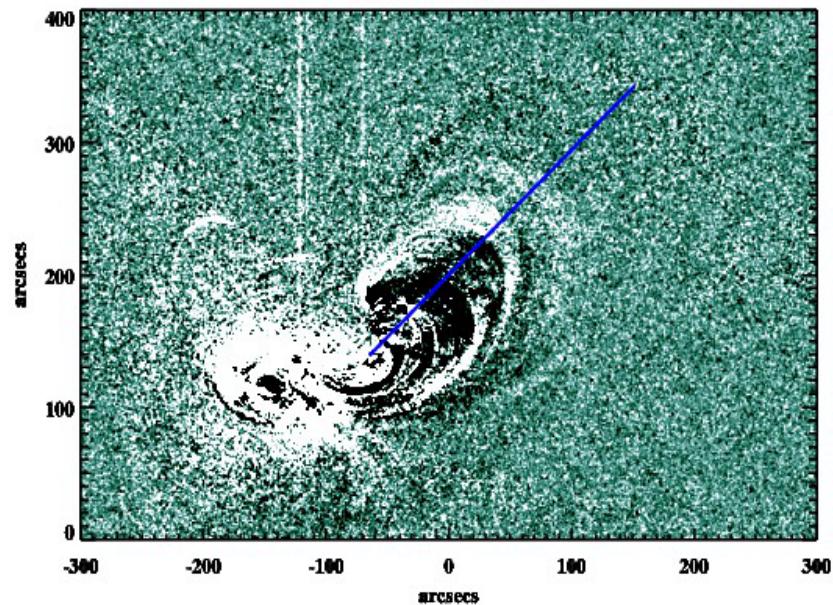
## FITS

## ADJUSTMENT

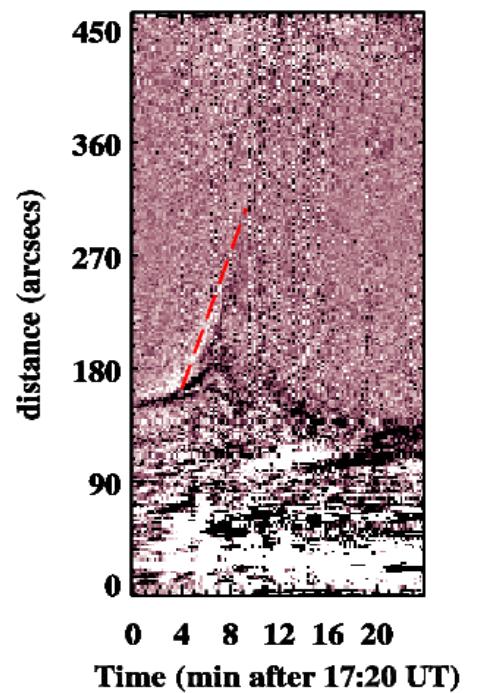
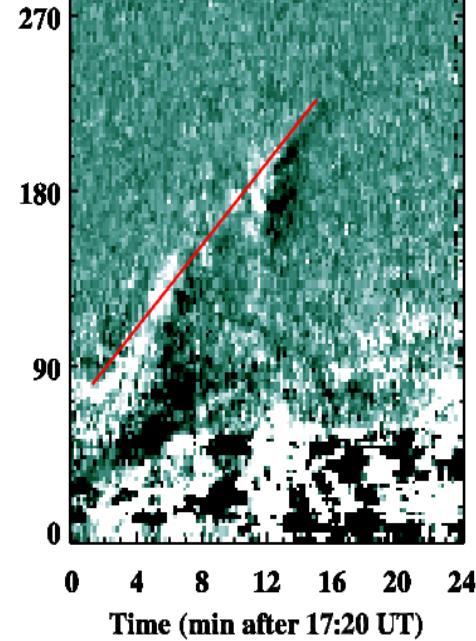
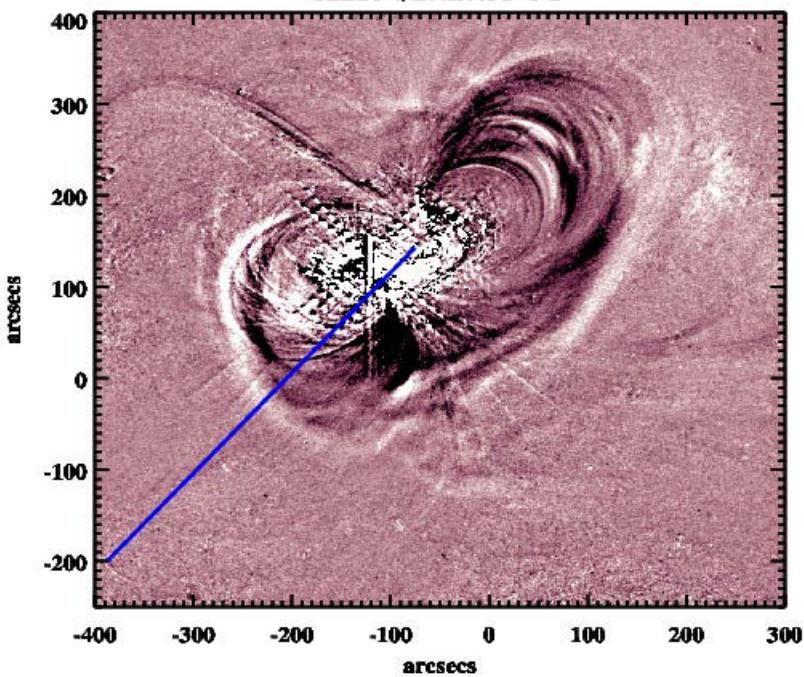
Selected layer	Opacity
AIA 171	100%
Sharpen	0
Gamma	0
Contrast	0
Difference	30
Color	SDO-AIA 171 A
Channels	<input checked="" type="checkbox"/> Red <input checked="" type="checkbox"/> Green <input checked="" type="checkbox"/> Blue

## HEK EVENTS

AIA 94/17:27:25 UT

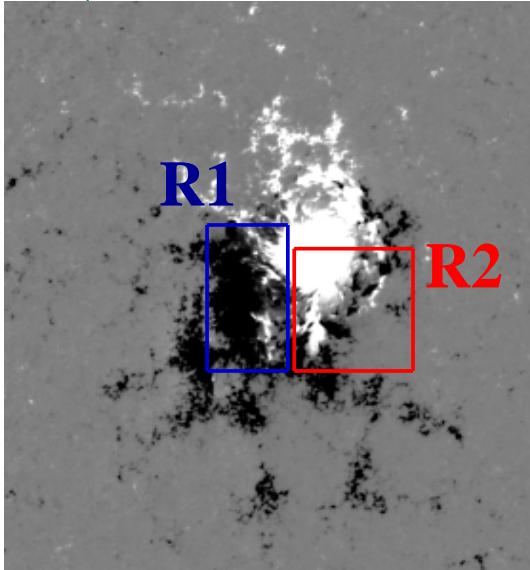


AIA 94/17:27:35 UT

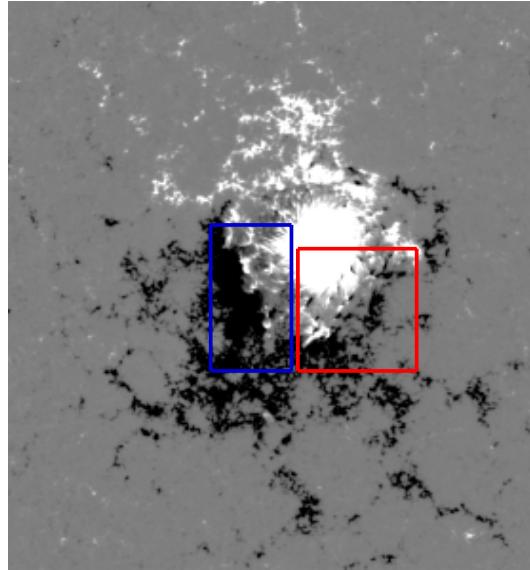


# Magnetic field in the source region (AR 12158)

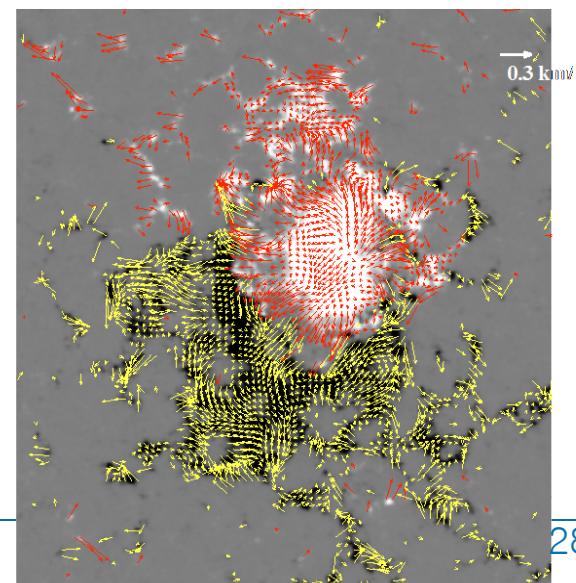
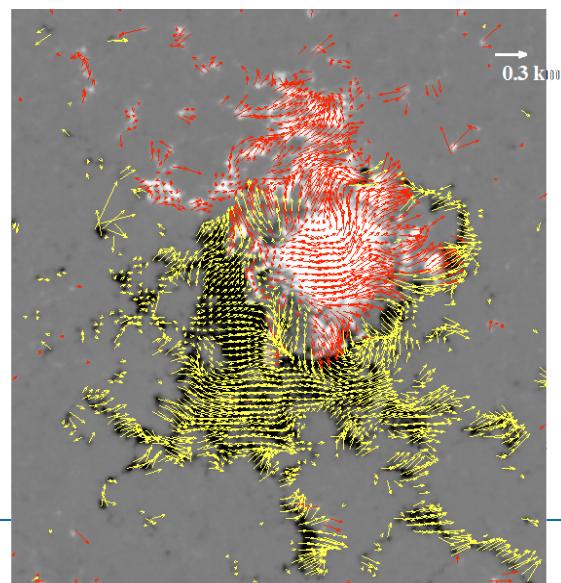
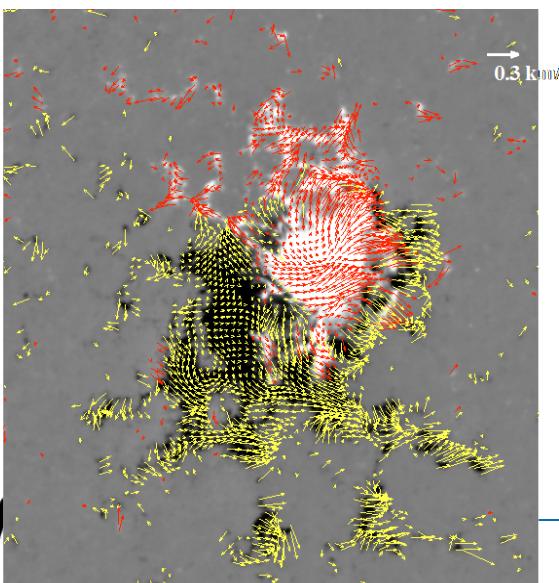
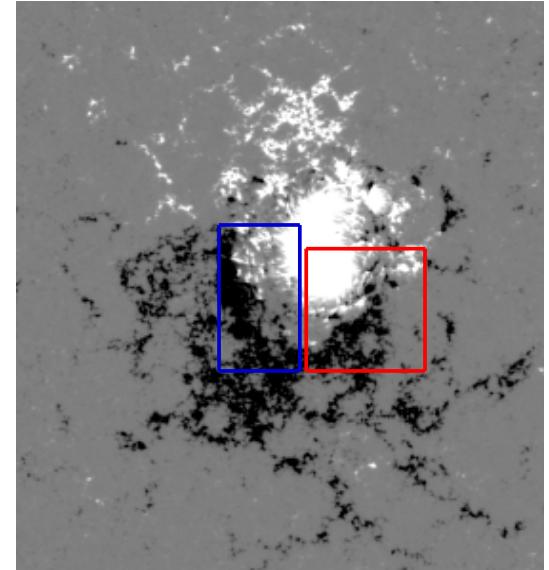
2014/09/09 00:00 UT



2014/09/10 00:00 UT

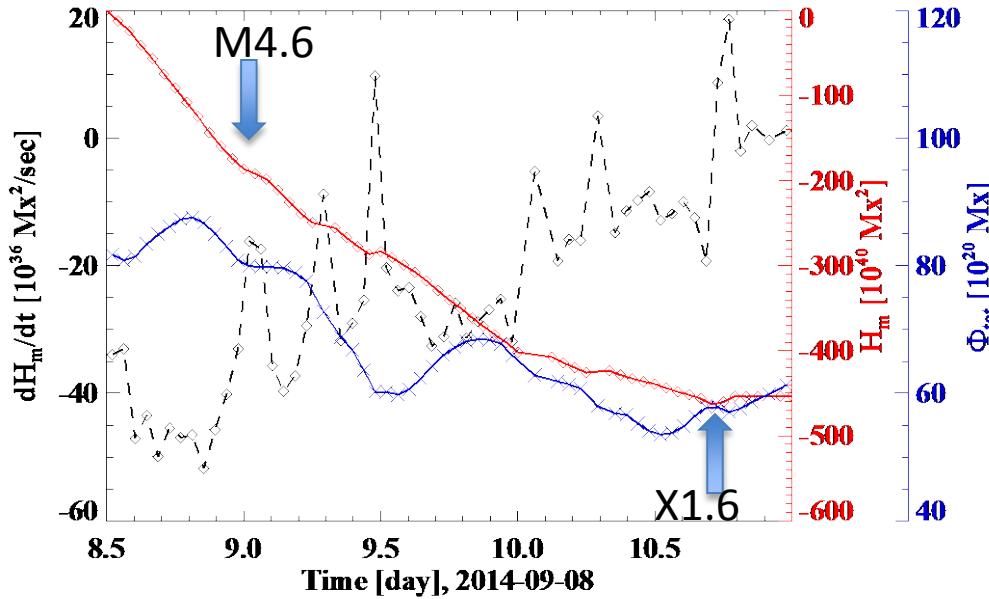


2014/09/11 00:00 UT

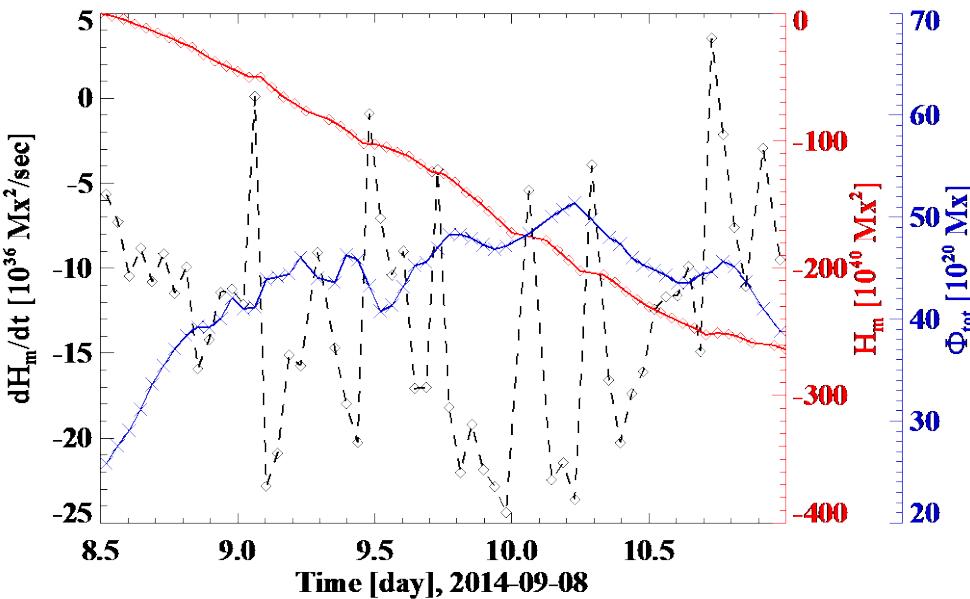


# Helicity Injection through the Local Regions

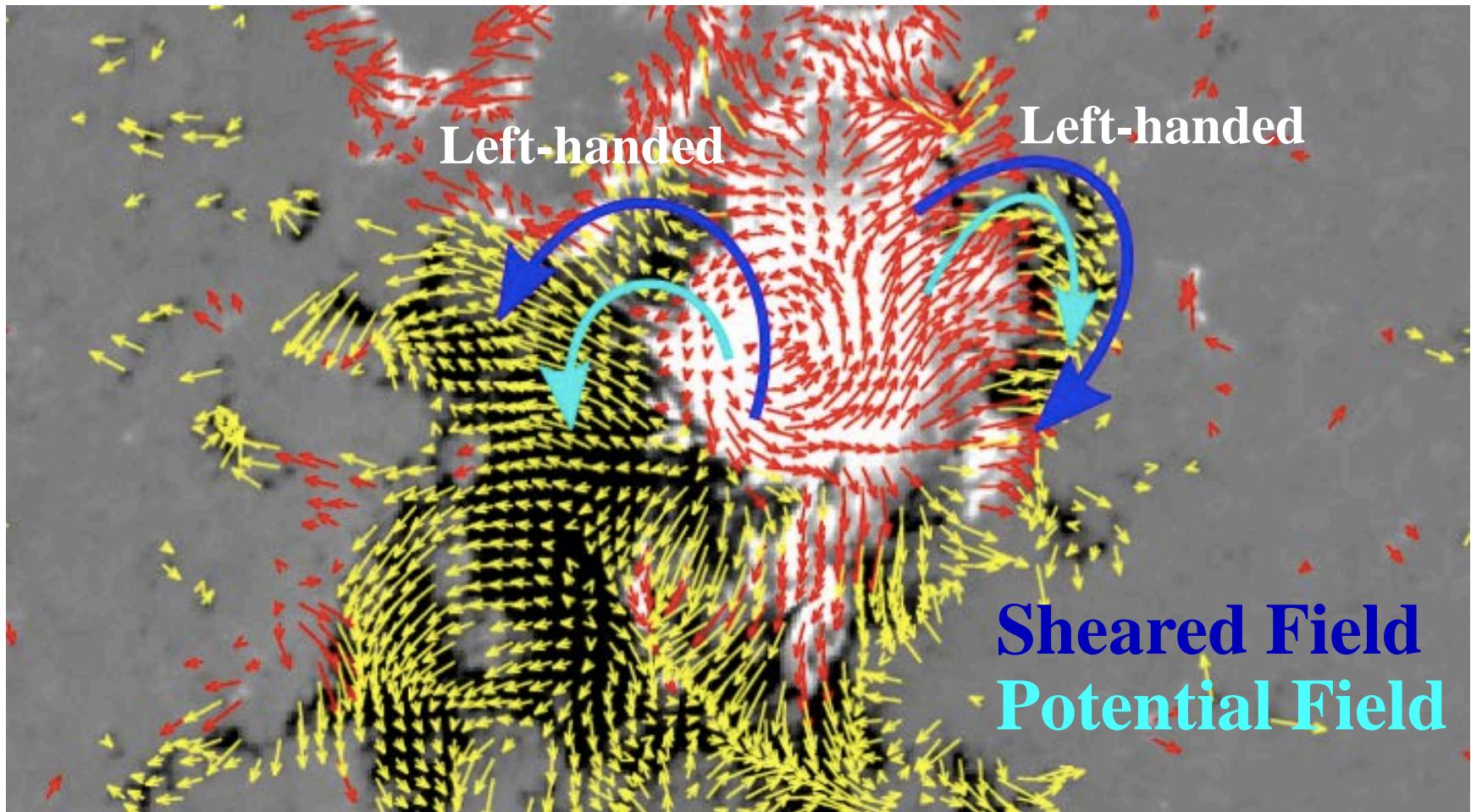
R1



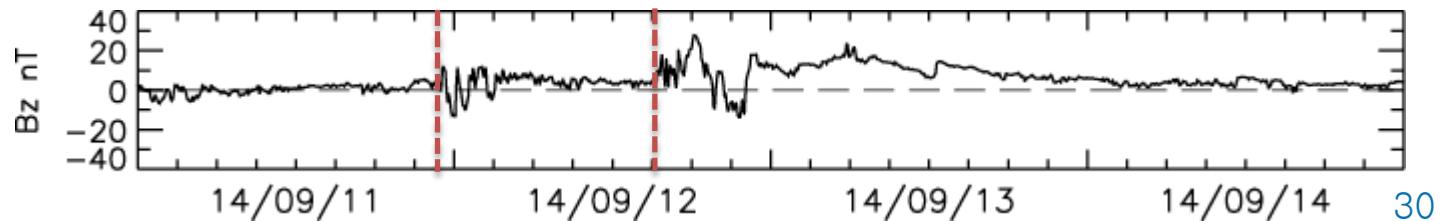
R2



# Estimation of Field Line Direction from Helicity



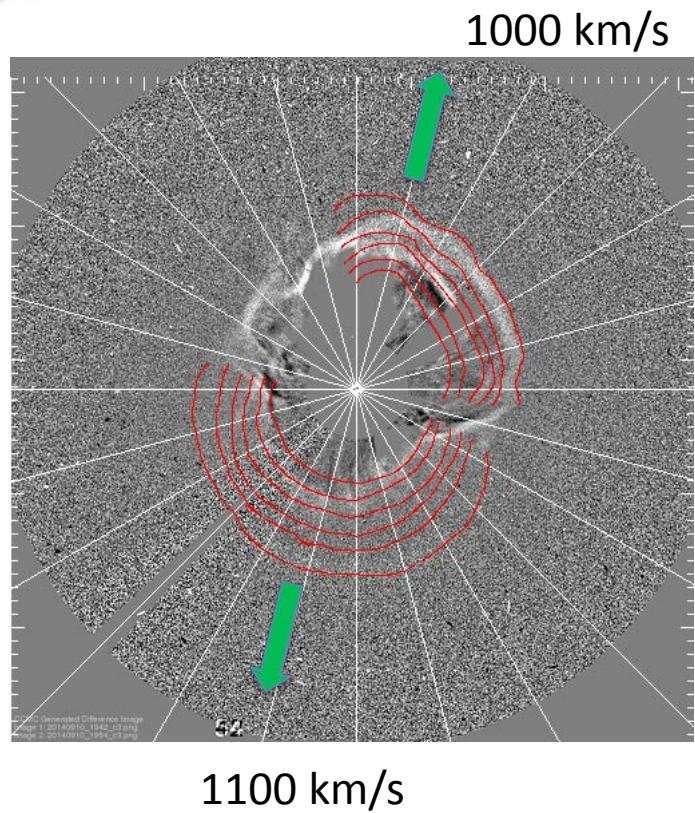
Solar wind  
Northward B<sub>z</sub>



## ◆ Geomagnetic Storm Forecasts

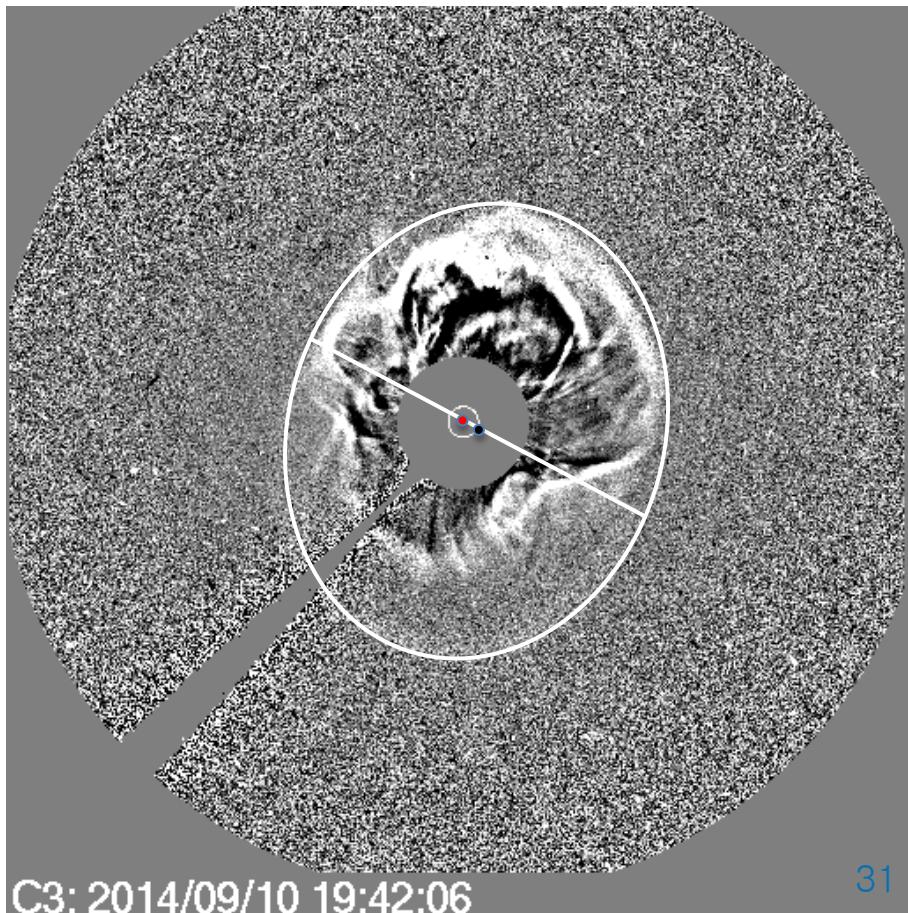
- 2014/09/10 17:36 CME

- $V \sim 1100 \text{ km/s}$
- $D = 0.81$
- $M = \text{North}$



- Forecast

- Expected arrival: 09/12 11 ~ 09/13 00h UT
- Expected Dst = -127nT
- Storm: 09/12 ~ 16h UT
- Dst=-75 nT (13 0h)



# Summary

- **Cause**

- There were two geomagnetic storms on Sep. 11<sup>th</sup> and Sep. 12<sup>th</sup> , 2014.
- The first weak storm was driven by the CME related to M4.6 flare and the second minor storms was driven by one of the CMEs related to X1.6 flare.
- The second storm was not strong because it was caused by the fast CME originated from the eastern part of the AR 12158 with northward magnetic field.

- **Effect**

- Electron flux in radiation belt increases in low energy channel while decreases in High energy channel (VAP observation)
- Electron and proton precipitation were observed by POES satellite
- TEC and O/N2 show a decrease in the polar region.

# Thank you

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