Geomagnetic response to different solar wind drivers and the dependence on storm intensity

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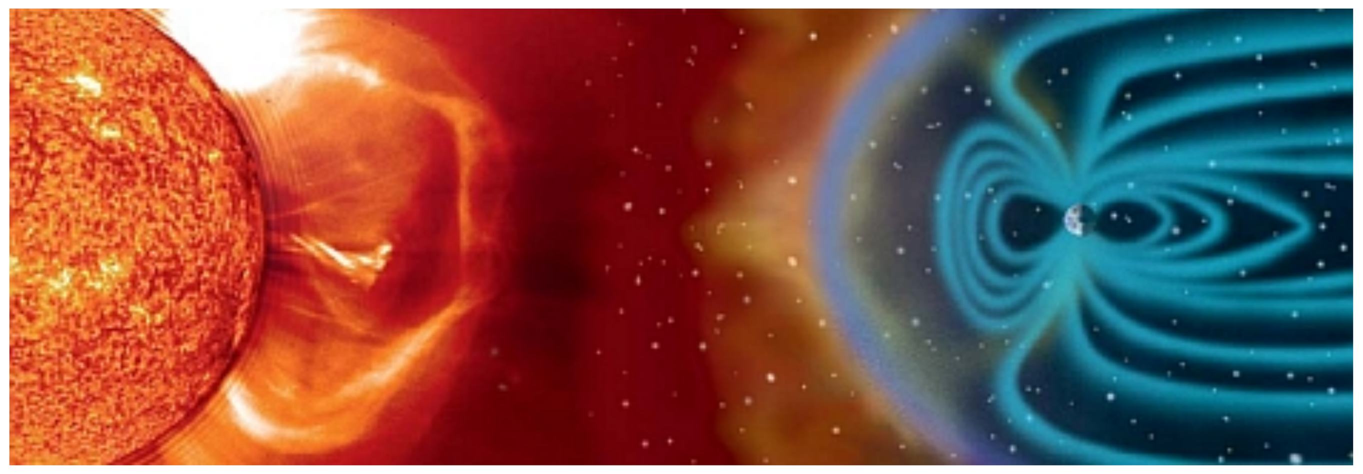
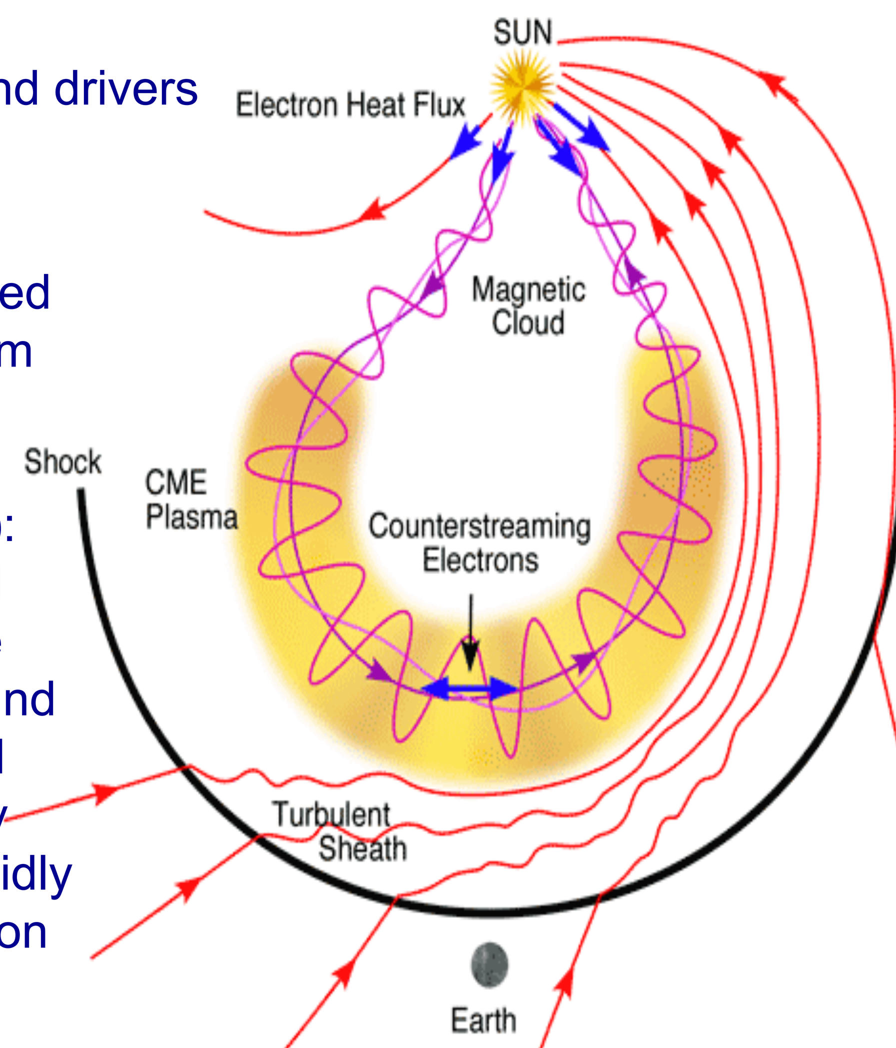
Introduction to Space Weather

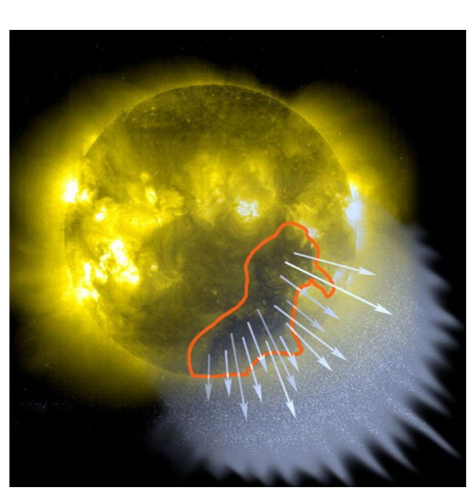


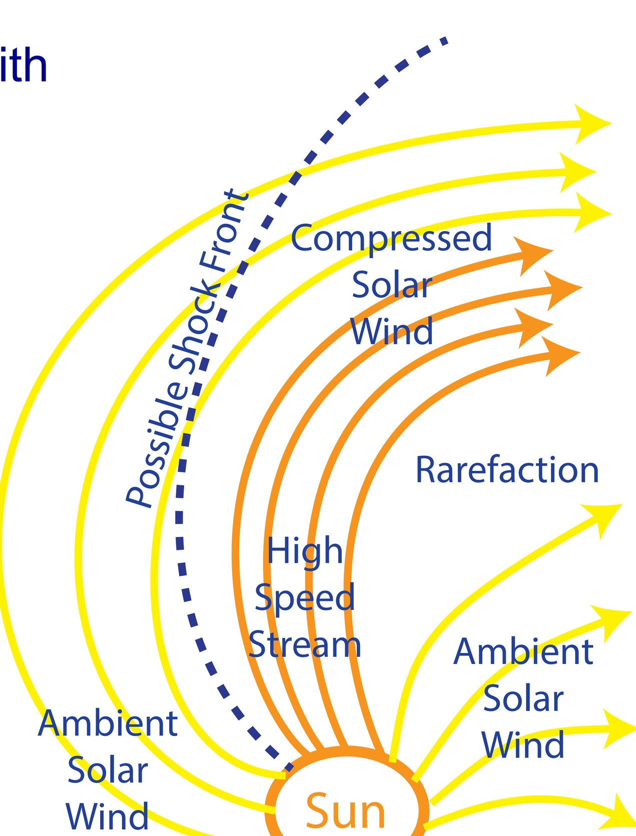
Geomagnetic storm: activity on the Sun causes plasma structures in the solar wind which produces a disturbance in near-Earth space

Classifications of solar wind drivers



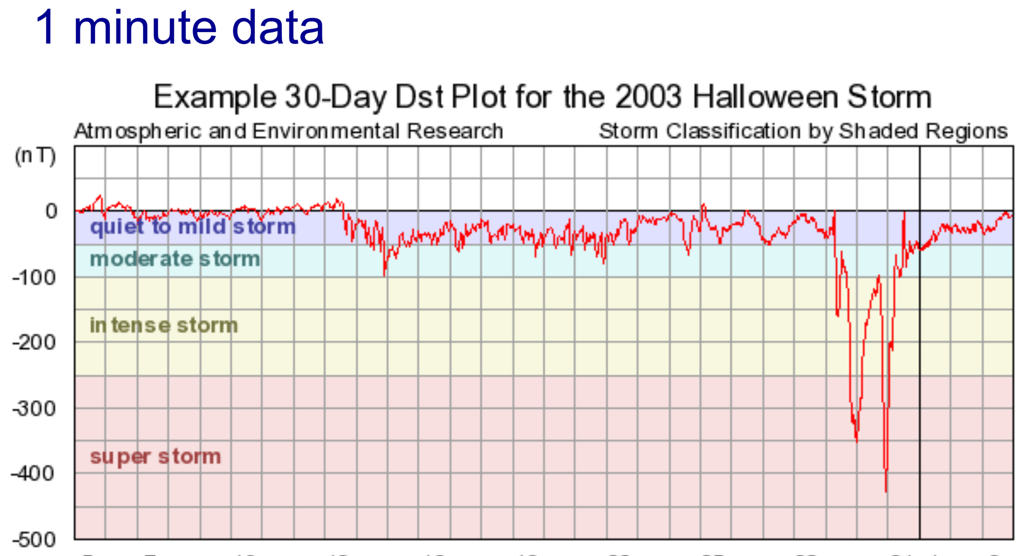
- Interplanetary coronal mass ejection (ICME): affiliated with compressed sheath fields, ejecta from the corona, or some combination
  - Magnetic Cloud (MC): Strong **B** field rotated through a large angle
  - Sheath (SH): solar wind plasma is heated and compressed, typically associated with a rapidly varying **B** field direction and high dynamic pressure
- Corotating interaction region (CIR): affiliated with high-speed stream originating from coronal holes





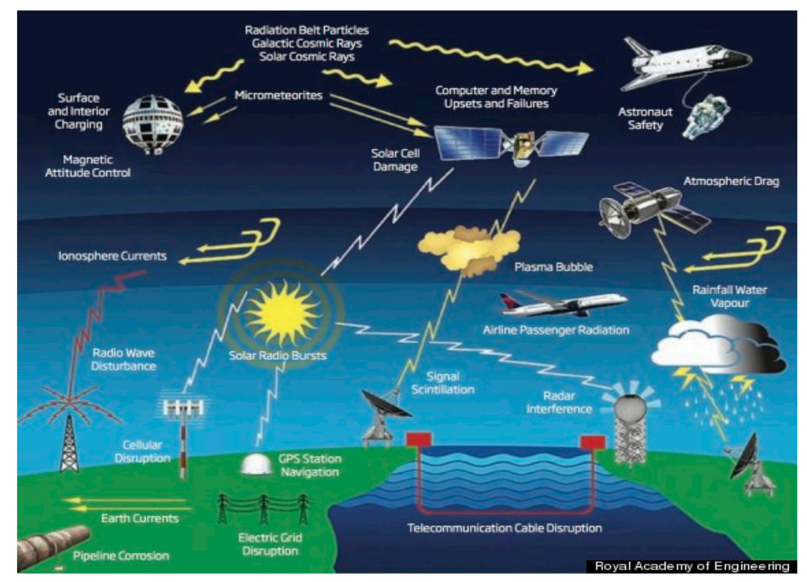
Geomagnetic Storms: progression and intensity is described using the Disturbance storm time index (Dst)

- Globally averaged low-latitude magnetic perturbation index
- Higher resolution versions of Dst include SYM-H & USGS
  - 1 minute data



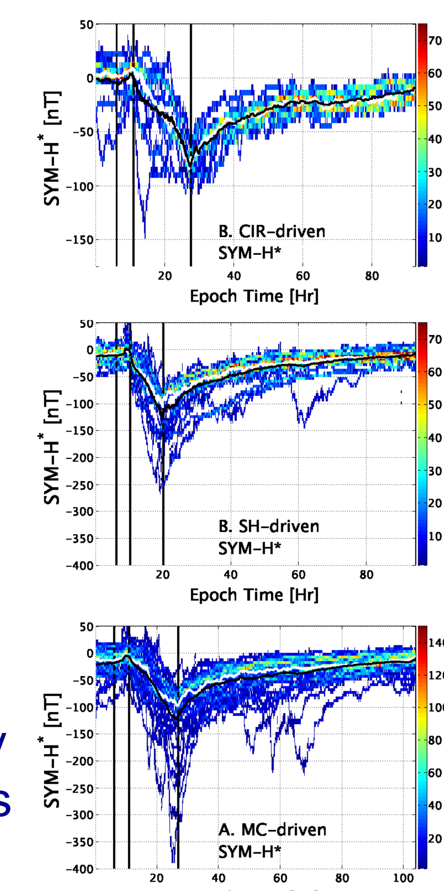
Motivation

- How do solar wind driving condition effect storm-time inner magnetospheric dynamics?
- Does this result depend on the storm phase or intensity?



Storms

- Solar cycle 23: 1996 – 2005
- Intense storms: Dst_{min}<-100 nT
- Storm Classifications
- Solar wind driver
- Intensity bins:
- All or Minimum Dst > -150 nT
- Y-axis = SYM-H* [nT]
- X-axis = normalized timeline
- Black vertical lines = start phase
- Color = superposed data density
- Bin size = 10 minutes X 100 bins
- Black & white = mean & median



HEIDI Model

- Hot Electron and Ion Drift Integrator
- Solves the gyration and bounce averaged kinetic equation for phase space density of hot ions from 2 to 6.5 R_E
- Assumes a static dipole magnetic field
- Coupled models
  - The dynamic global core plasma model
  - Rairden neutral hydrogen density model
- Electric field: Specified or self-consistent
- Boundary Condition: Nightside plasma data

	LANL Data	LANL Reanalysis
Volland-Stern **E**	1	3
Self-Consistent **E**	2	4

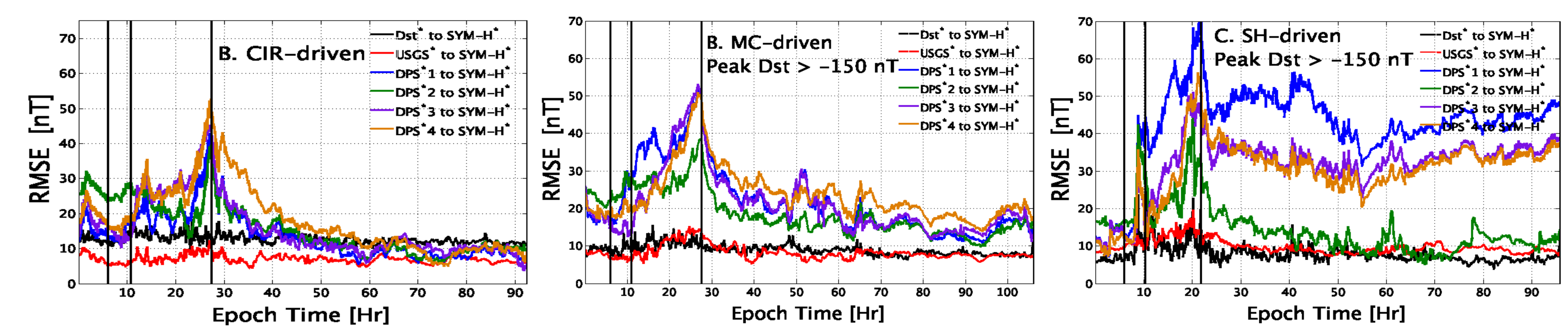
Summary

- The self-consistent electric field better reproduces CMEs
- The Volland-Stern electric field better reproduces CIRs
- This result is independent of the storm magnitude
- Modeled CIR peak magnitude is always less than expected values
- The model does not recovery quickly enough for magnetic cloud-driven events
- Sheath-driven events are not similar to CIR-driven events

Root Mean Square Error

RMSE	Storms	DPS* 1	DPS* 2	DPS* 3	DPS* 4	Dst*	USGS*
All Storms	90	35.4 nT	25.1 nT	31.4 nT	28.4 nT	10.7 nT	8.6 nT
CME-Driven	79	37.5 nT	26.1 nT	32.8 nT	29.4 nT	10.3 nT	8.8 nT
CIR-Driven	11	15.6 nT	17.8 nT	18.5 nT	21.4 nT	12.7 nT	7.0 nT
CME-Driven, Dst > -150 nT	49	29.9 nT	18.4 nT	25.3 nT	25.7 nT	8.9 nT	8.6 nT
CME with MC-Driven	32	31.1 nT	28.5 nT	31.7 nT	29.7 nT	10.9 nT	9.2 nT
CME with Sheath-Driven	19	56.3 nT	29.3 nT	43.1 nT	34.9 nT	9.6 nT	9.7 nT
MC-Driven, Dst > -150 nT	23	24.9 nT	20.2 nT	23.7 nT	25.3 nT	9.0 nT	8.38 nT
Sheath-Driven, Dst > -150 nT	12	43.9 nT	16.4 nT	32.3 nT	30.9 nT	9.2 nT	9.9 nT

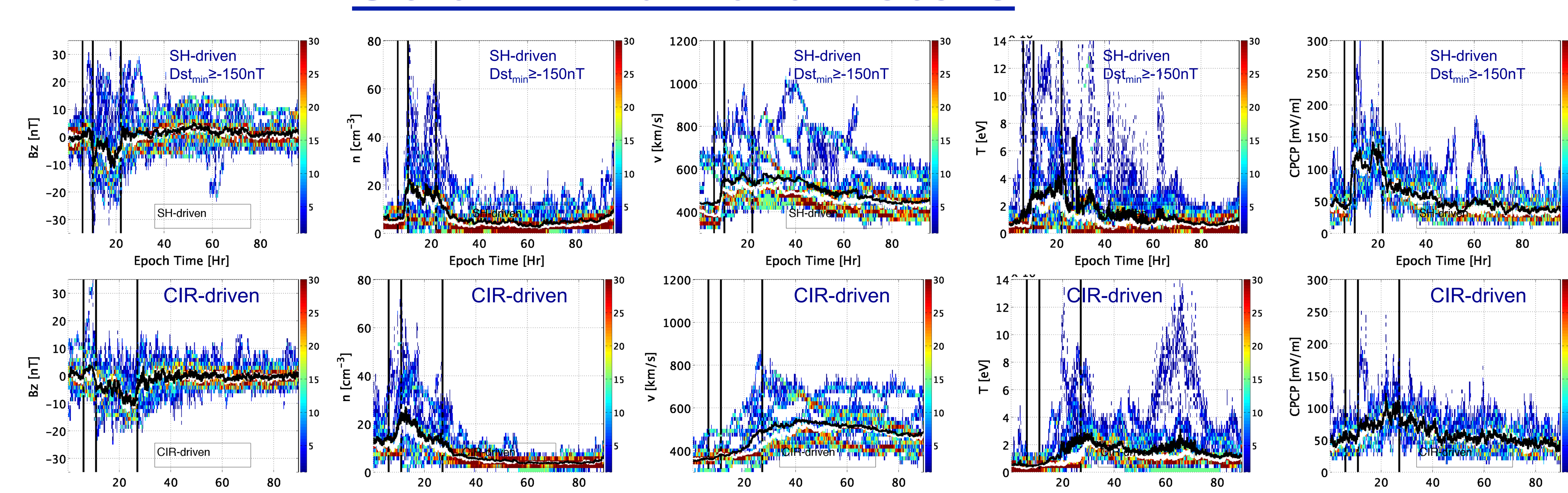
- The number of events included in each storm classification and the RMSE to SYM-H*



The RMSE of each run set or index to SYM-H* for each solar wind classification with -100 nT ≤ Dst_{min} ≤ -150 nT along the normalized epoch timeline

- The RMSE always increases approaching storm peak
- The RMSE is larger for ICME-driven events than CIR-driven events
- For ICME-driven storms the RMSE is lowest for run set 2
  - Self-consistent **E** & event based LANL data
- For CIR-driven storms the RMSE is lowest for run set 1
  - Volland-Stern **E** & event based LANL data
- Sheath-driven storms have a large RMSE in the recovery phase

Solar Wind Parameters



- Solar wind parameters for CIR and sheath-driven events
- Bz: larger magnitude fluctuations in sheath-driven events than CIR-driven event
- Density: sharper density gradient in sheath-driven events than CIR-driven event
- Velocity: larger velocity in sheath-driven events than CIR-driven event
- Energy: larger temperatures in sheath-driven events than CIR-driven event
- CPCP: greater activity in the main phase