The Frequency-Domain Characterization of Cosmic Ray Intensity Variations Before Forbush Decreases Associated with Geomagnetic Storms

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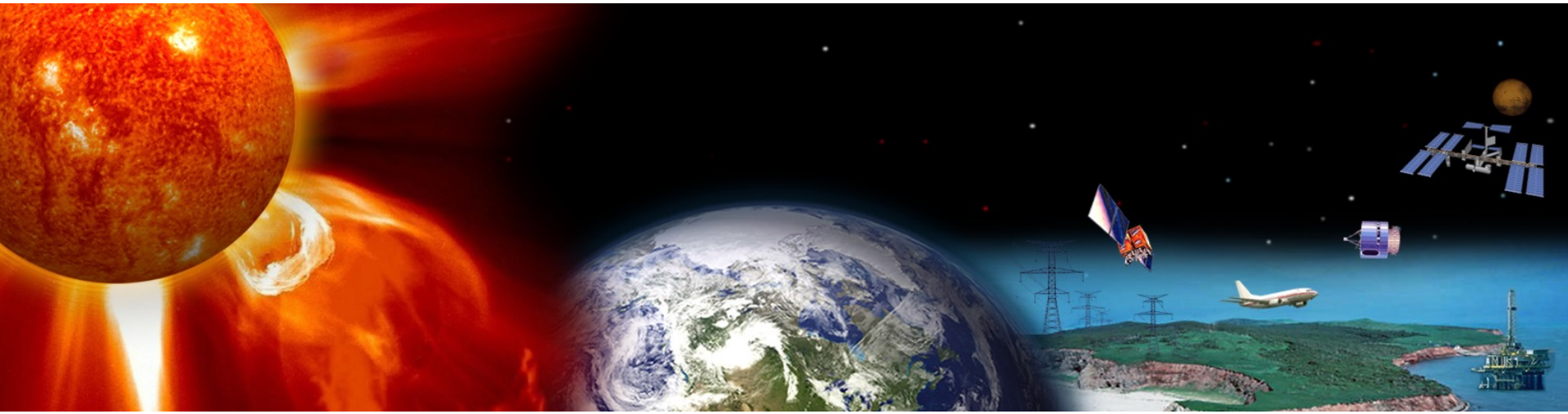

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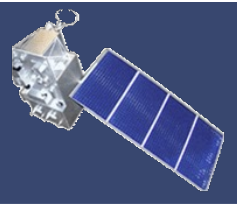
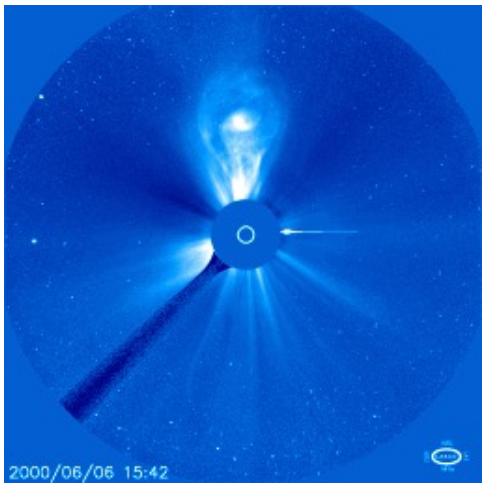
Outline



1. Motivation: forecast ICMEs-driven geomagnetic storms
2. Method: how to quantify variations
3. Results: validate prediction performance
4. Summary

Motivation



Interplanetary Coronal Mass Ejections (ICMEs)

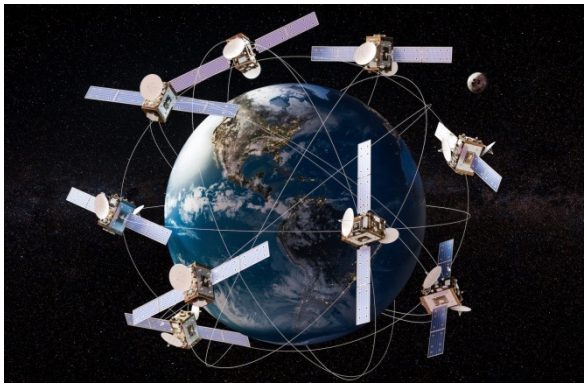
strong geomagnetic storms

Effects

random

hard to forecast

Aurora

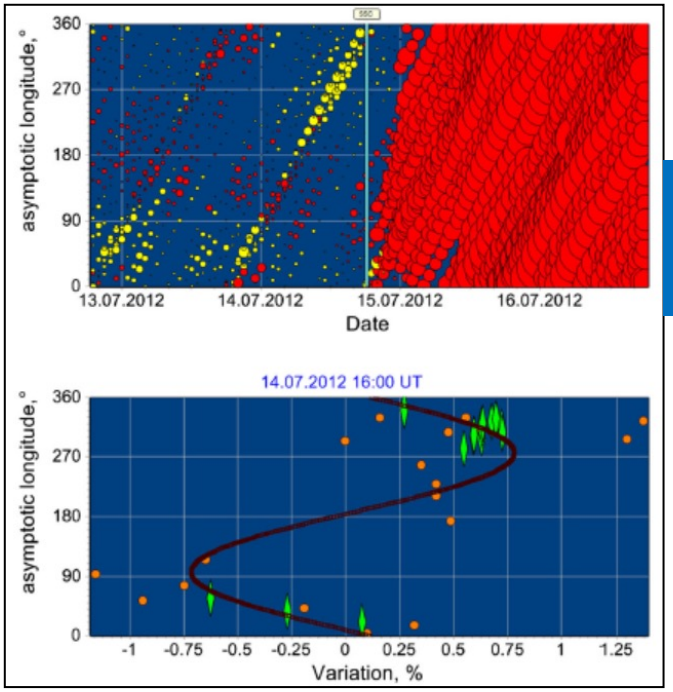


Global Navigation Satellite System (GNSS) disruption

Geomagnetically Induced Currents (GICs)

Motivation

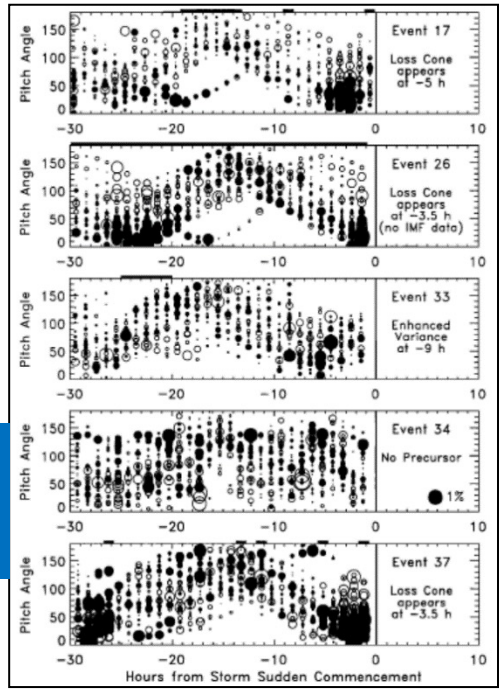
- ICME shocks cause **Cosmic Ray Intensity (CRI) variations** (pre-increase, pre-decrease, anisotropy)



[Lingri et al., 2019]

Almost half of the ICMEs-driven storms during 2008-2016 have precursors

The precursor signal of CRI appeared 6-9 hours before storm sudden commencement

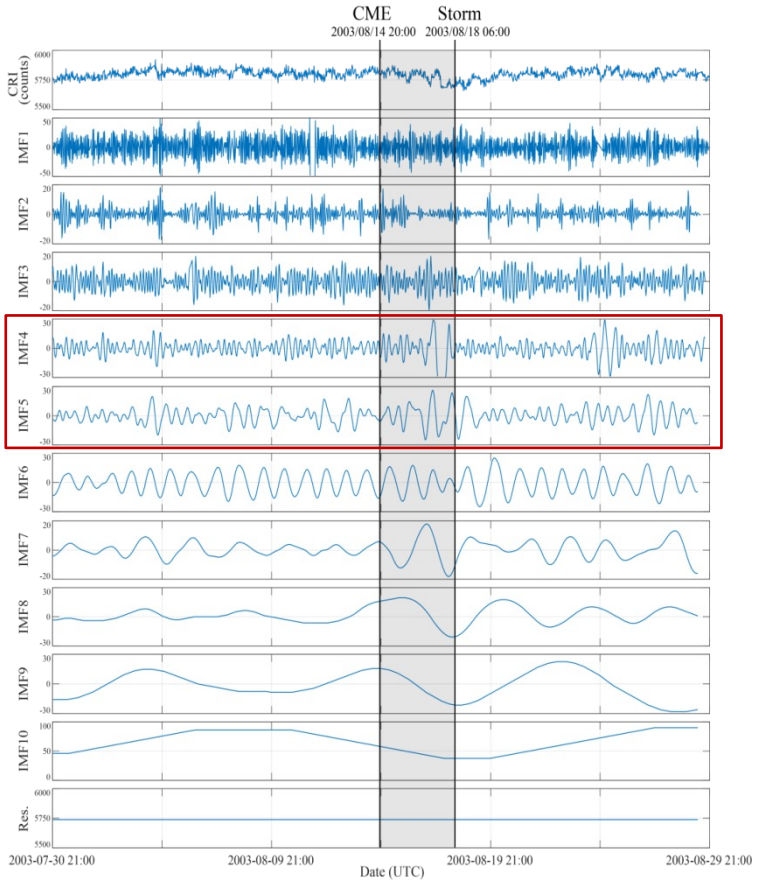


[Munakata et al., 2000]

- Such variations can be used as **precursors** of ICMEs-driven geomagnetic storms

Method

GOAL: quantify both amplitude and frequency variations in CRI



PROBLEM: CRI is a complex signal

- modulated by **many factors**, ICME is just one of them

Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN)

- a self-adaptive empirical signal decomposition tool
- decomposes a signal into several intrinsic mode functions **(IMFs)**, and a residual function **(Res.)** by a sifting process
- different IMFs have different oscillation frequencies

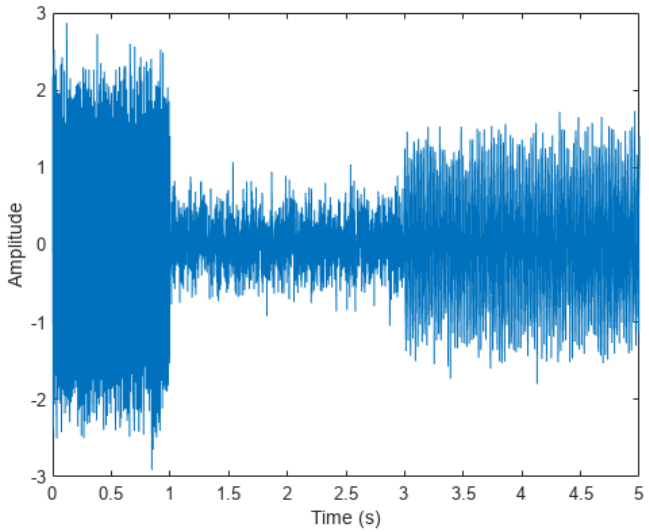
proxy signal = IMF4 + IMF5

Method

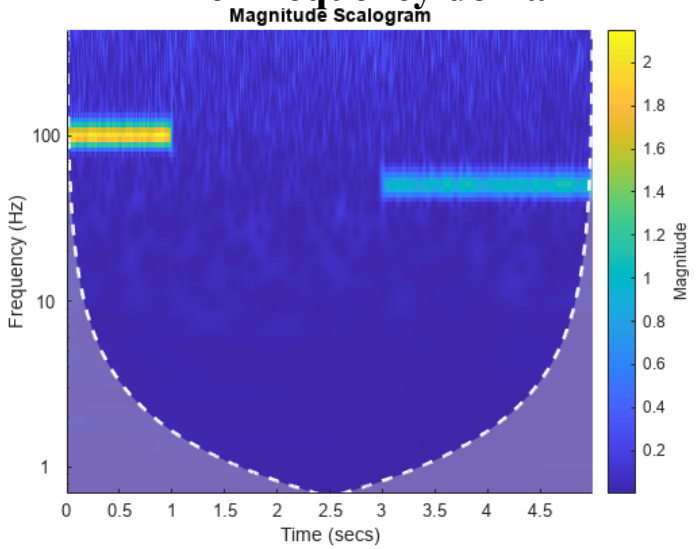
GOAL: quantify both amplitude and frequency variations in CRI

Continuous Wavelet Transforms (CWT)

Time Domain



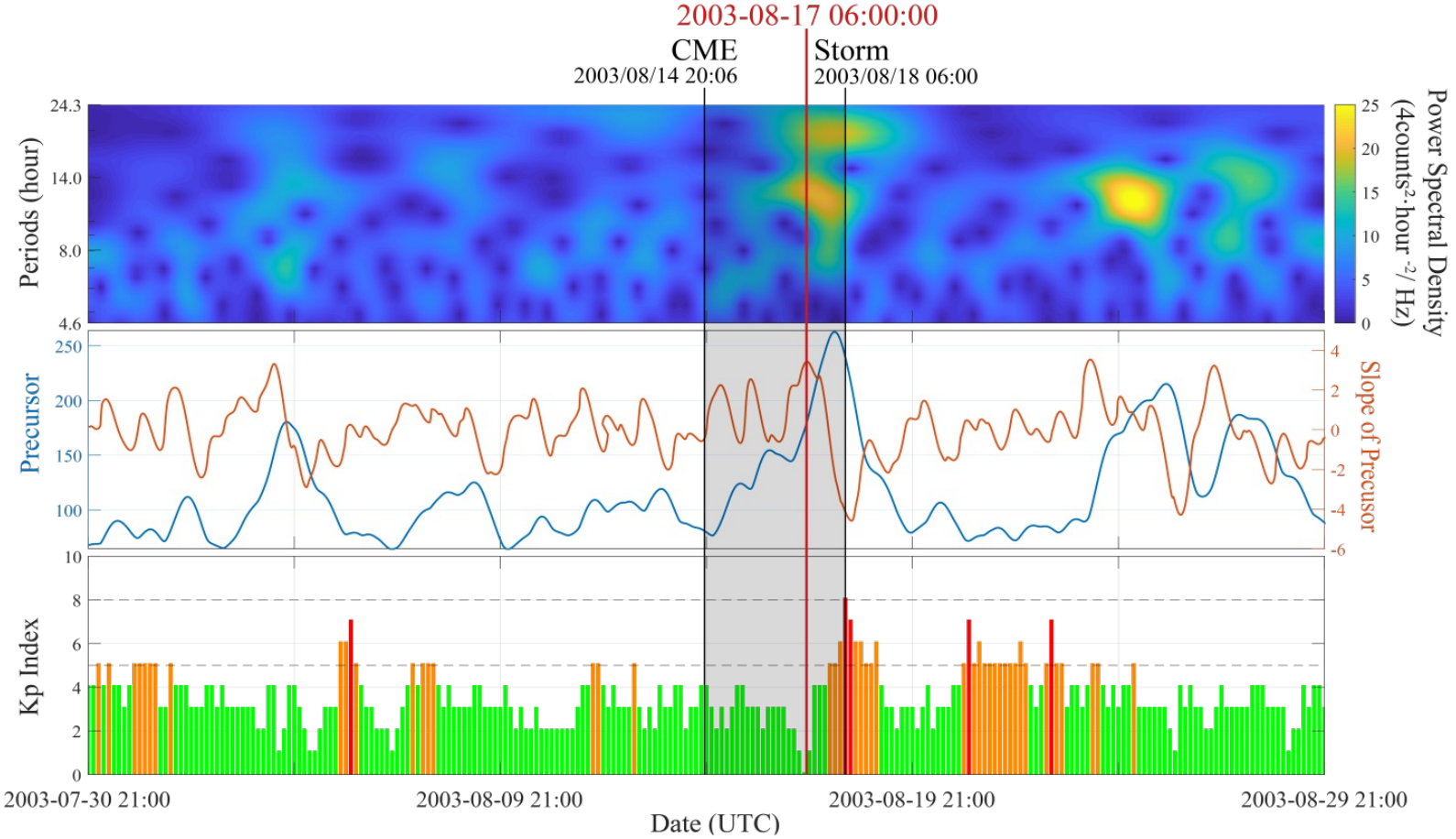
Time-Frequency domain



both Amplitude and Frequency variation

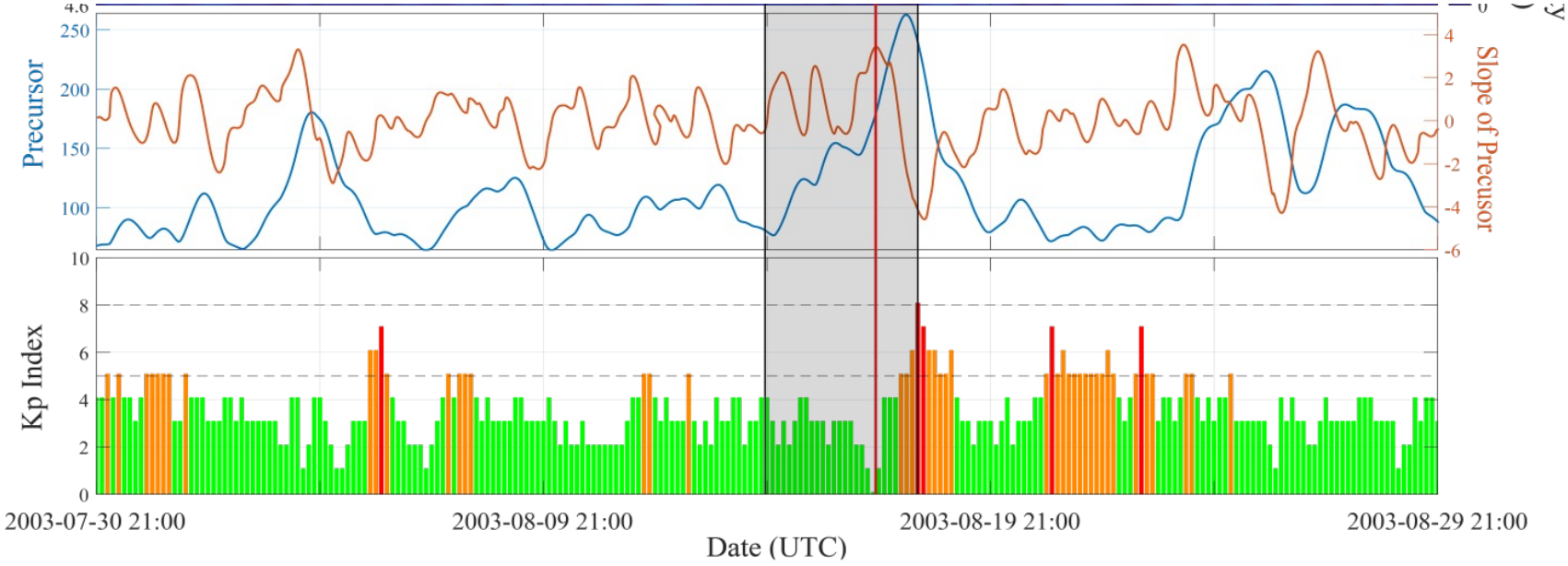
Method

GOAL: quantify both amplitude and frequency variations in CRI



Results

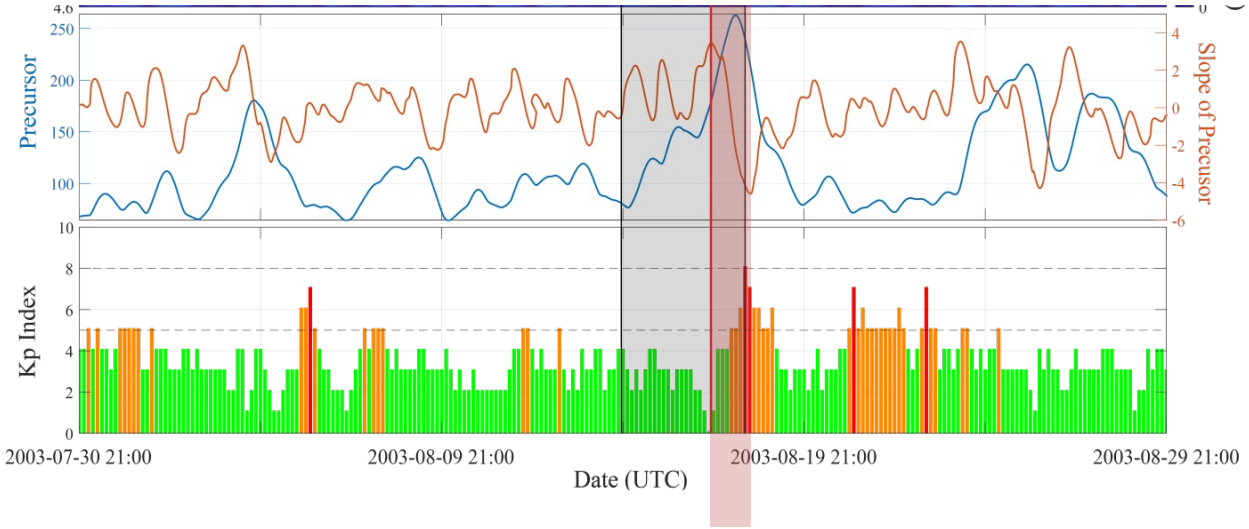
Prediction performance

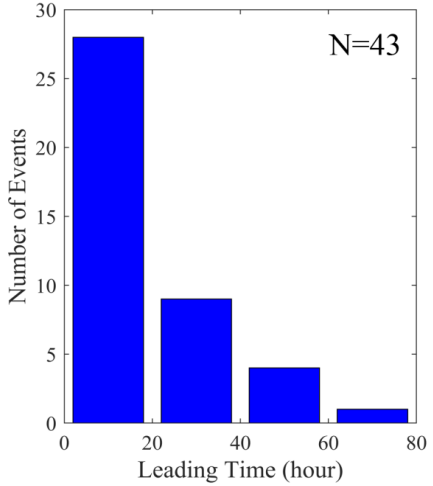


1. IF the slope of precursor reaches the local maximum
2. IF the maximum of the precursor surpass benchmark

Results

Prediction performance





Leading time

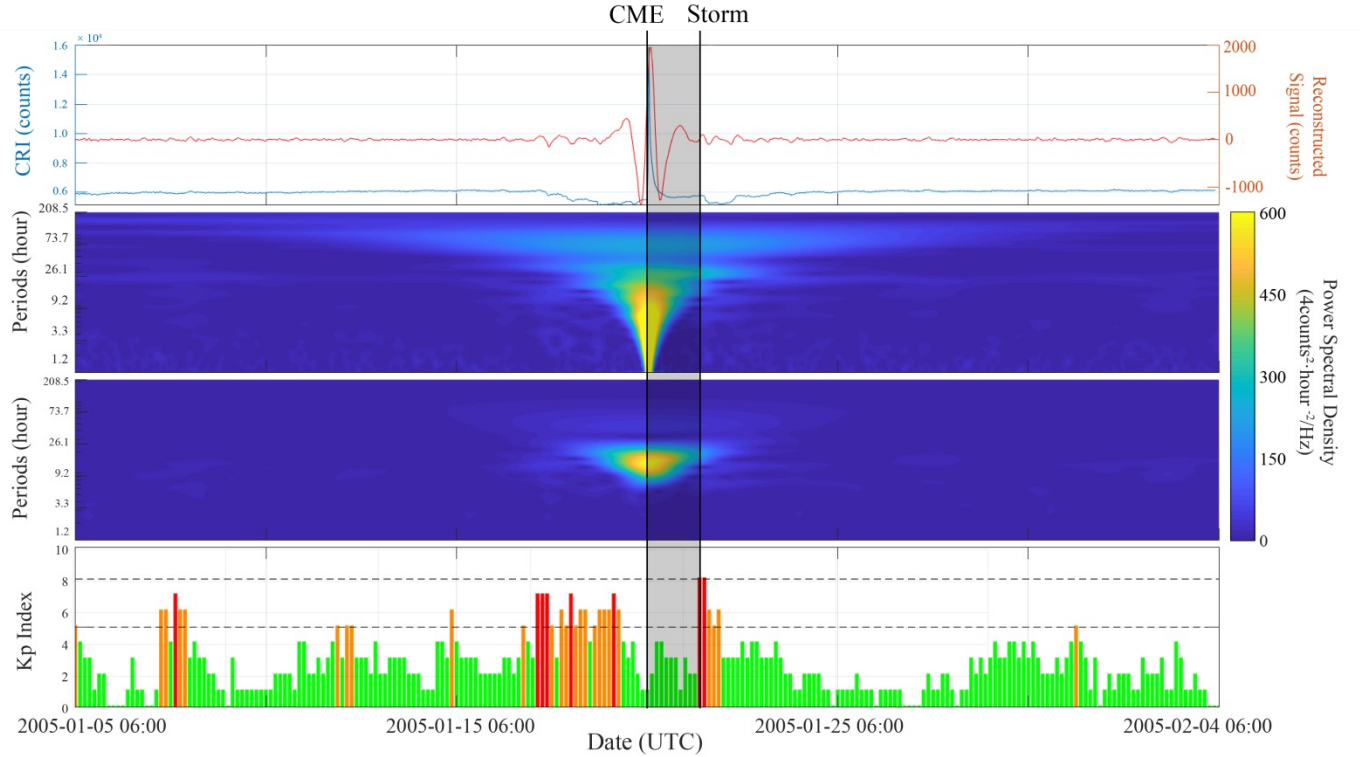
= T(storm's onset) - T(slope reach the maximum)

43 in 65 events (66%) are successfully predicted.

Leading time: concentrates on **0-20 hours** with an **average of 22.2 hours**

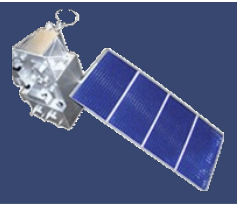
Results

Ground Level Enhancement (GLE)



GLE excluded: **43 in 45 events (96%)** are successfully predicted.

Summary



1. Cosmic Ray Intensity is a potential precursor of ICMEs-driven geomagnetic storm

2. The successful prediction ratio of our method is 66%, and if exclude events accompanied by GLE, the ratio rises to 96%.

3. In all successfully predicted cases, the leading time concentrates on 0-20 hours with an average of 22.2 hours.

Thanks for your attention.

Question?