Project for Solar-Terrestrial Environment Prediction (PSTEP) in Japan

Kanya Kusano

Institute for Space–Earth Environmental Research
Nagoya University
Outlook

1. Introduction to PSTEP, that is the nationwide project of space weather and space climate in Japan
2. The study for the physics-based prediction of solar eruption
PSTEP Network
Project for Solar–Terrestrial Environment Prediction

- 20 Institutes & 100 Researchers
【Objective 1】
To answer fundamental questions of solar-terrestrial environment:
- The onset mechanism of solar flares
- The mechanism of radiation belt dynamics
- The physical process whereby the sun affects climate

【Objective 2】
To build the base for next-generation space weather forecast system
- Useful prediction for each industrial activities
- Physics-based assessment of severe space weather disaster

Physics-based Prediction + Network Observation & HPC
System map of PSTEP models

Sun
inter-planetary
magnetosphere/ionosphere/atmosphere

Solar Dynamo

AR NLFF
Flare MHD
UFCORIN
PFSS
CME injector

Solar wind
SUSANOO

Solar wind injection
SEP transport

SEP

SEP dose warning system
WASAVIES

SEP injection
SEP transport

Global solar mag.

Magnetosphere
FAC, BBF

Ionosphere
stability

Plasma bubble
disturbance

Earth climate system

GIC
radio propagation simulator

Prediction of Solar Eruption

Flare MHD
UFCORIN
machine learning

T, rho

f(v)
History of Flare Prediction Skill

Perfect prediction

Forecast Skill

-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8


NOAA 2014, NOAA Space Weather Prediction Center, Boulder, CO, USA

http://www.swpc.noaa.gov/content/solar-activity-forecast-verification
What determines the onset of solar eruptions?

Observations

Simulations

Theory

AR1115 observed by Hinode
Ensemble Simulation Study of Trigger

Potential Field

Strong Shear

Weak Shear

Potential Field

Magnetic Shear Angle

Azimuth Angle of Small Magnetic Disturbance

Right Polarity

Opposite Polarity

Right Polarity

Normal Shear

Reversed Shear
Ensemble Simulation Study

Flare phase diagram (Kusano et al. 2012)

- Strong shear
- Weak shear
- Potential field

2-ribbon flares

No eruption

Eruption

No eruption

$\theta_0$ (degree)

$\varphi_e$ (degree)

Kinetic Energy

$E_K$ 0.5 1.0 1.5 2.0 2.5 (x$10^{-2}$)

Right Polarity

Opposite Polarity

Normal Shear

Reversed Shear
Two Types of Triggers

Opposite Polarity

Reversed Shear
Two ways to trigger eruptions

sigmoid

current sheet

Opposite Polarity

Reversed Shear
Observational Evidences


Opposite Polarity
Reversed Shear
What is the critical state?

Magnetic Reconnection

Eruptive Instability

Opposite Polarity

transferred from shear to twisted rope

Kusano et al. 2012

Feedback Cycle Model
Threshold of Instability

- Numerical experiments of solar eruption for the various duration of trigger field injection.

Injection of trigger flux

Point of no return

Critical state

OP field
Double Arc Instability


\[ \Phi_{\text{total}} = I \cdot \nabla \times B \]

\[ \Phi_{\text{rec}} \equiv \frac{T}{8\pi} \frac{\Phi_{\text{rec}}}{\Phi_{\text{total}}} > \frac{1}{8\pi} \]

Critical Parameter

magnetic twist

\[ T = \int \frac{B \cdot \nabla \times B}{B^2} dl \]

Normalized flux of tether-cutting reconnection

NLFFF

Inoue, Kusano, Hayashi 2016
Summary

- PSTEP is the new nation-wide Japanese project for developing the synergistic interaction b/w R-and-O.

- Some approach of physics-based prediction of solar eruption based on the numerical model.
  - A positive feedback b/w instability and reconnection must be the fundamental mechanism of solar eruption, and there are the two types of triggering processes.
  - We proposed Double-arc Instability as the key instability for the onset of solar eruptions, in which the critical state can be determined by $\kappa$-parameter.
  - NLFFF model may help us to develop a new physics-based prediction of solar eruptions.