New Probabilistic Forecast Models of Solar Flares and CMEs

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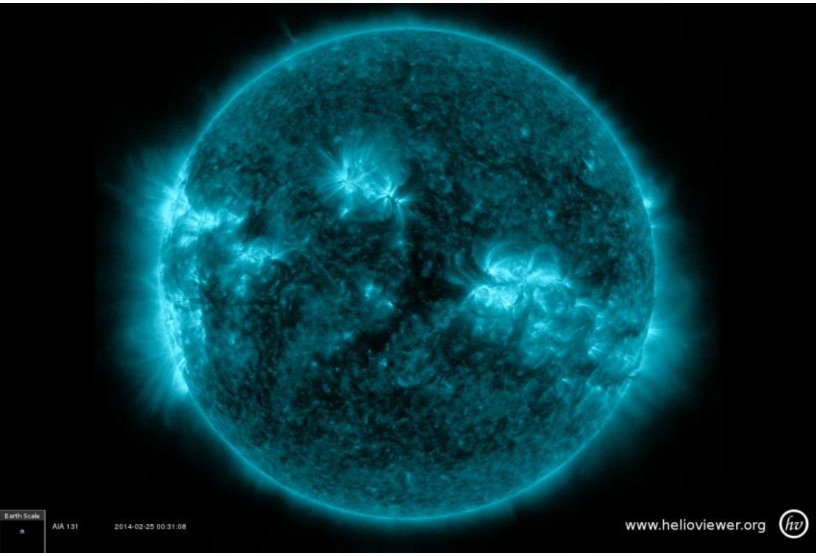
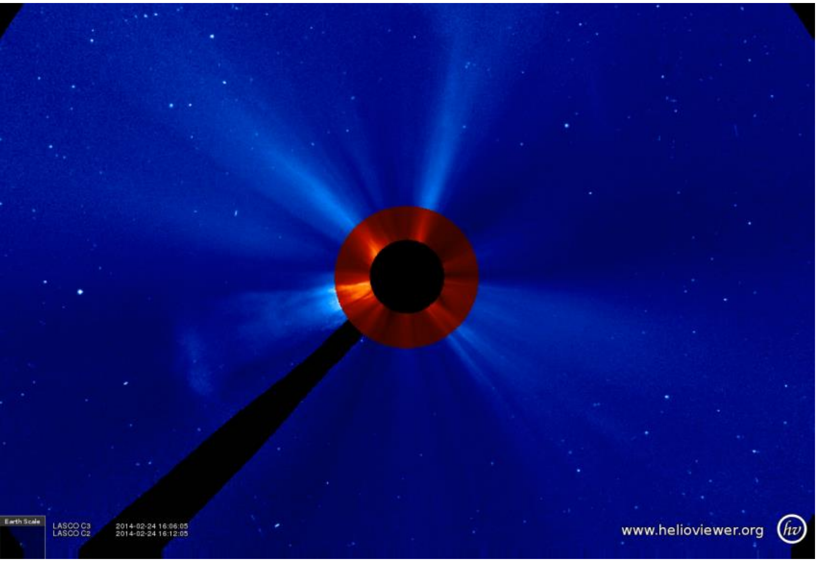
Introduction



2014. 2. 25. X4.9 flare

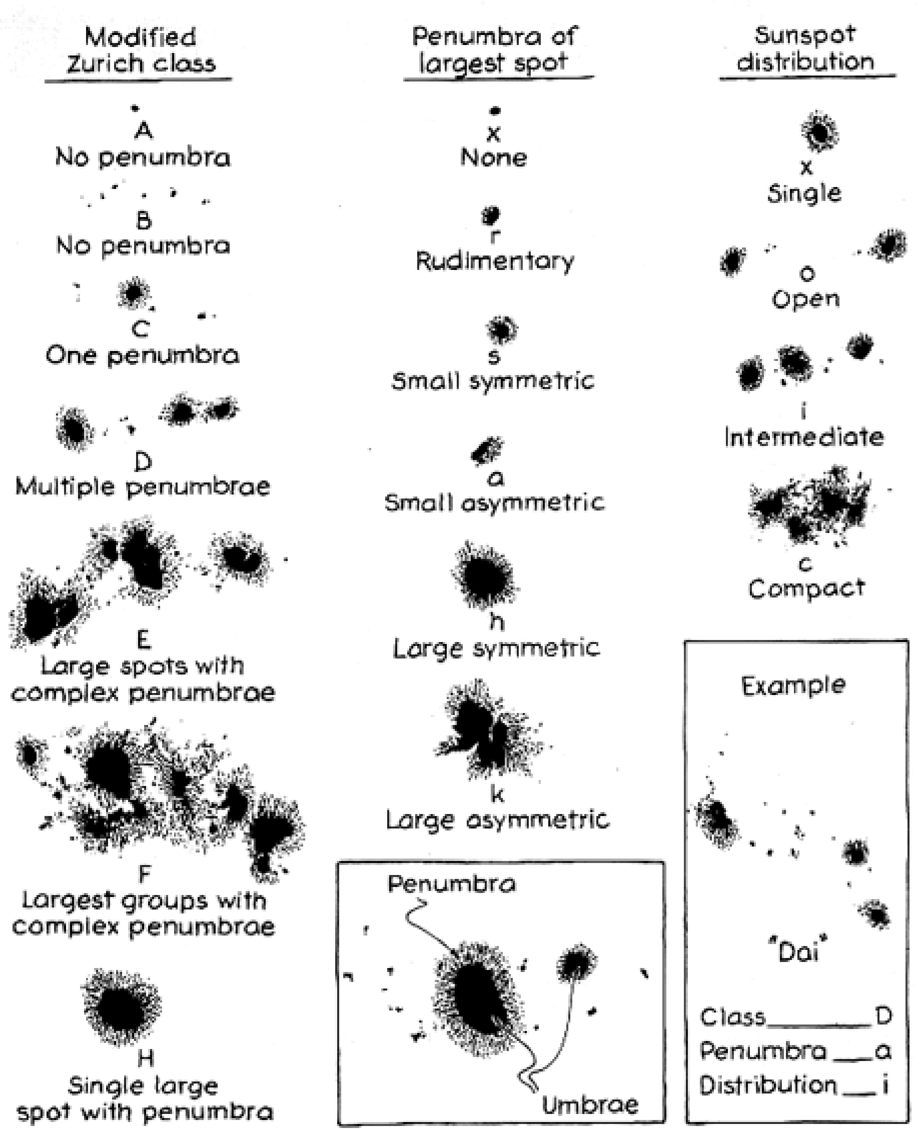


2014. 2. 25. CME

- The prediction of flares and CMEs is very important because they can cause space weather disasters.
- Flares and CMEs typically originate from active regions (ARs).
- "McIntosh sunspot group classification" has been widely used for the forecast of solar flares (e.g., NOAA/SWPC).
- There is no CME occurrence probability forecast model using McIntosh sunspot classes.

McIntosh sunspot group classification

McIntosh (1990)



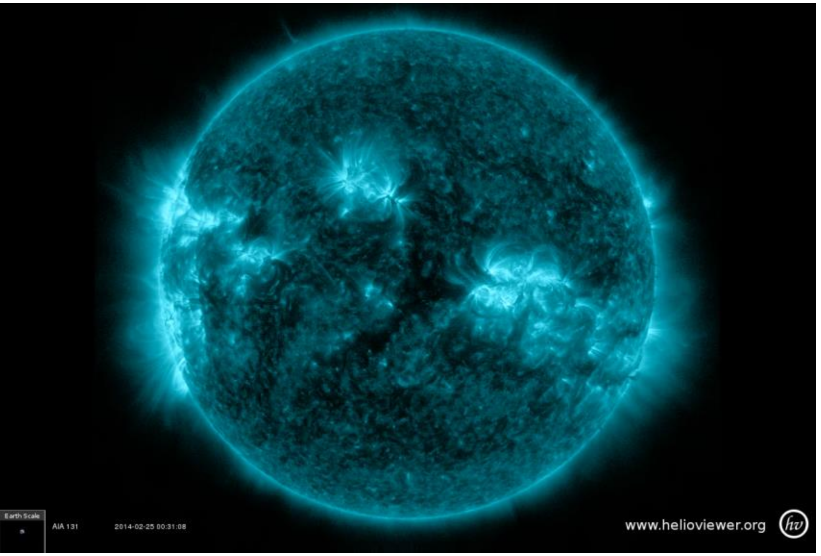
Z **p** **c**

Z is defined on the basis of whether penumbra is present, how penumbra is distributed, and by the length of the group.

p is the type of principal spot, primarily describing the penumbra.

c is the degree of compactness in the interior of the group.

Introduction



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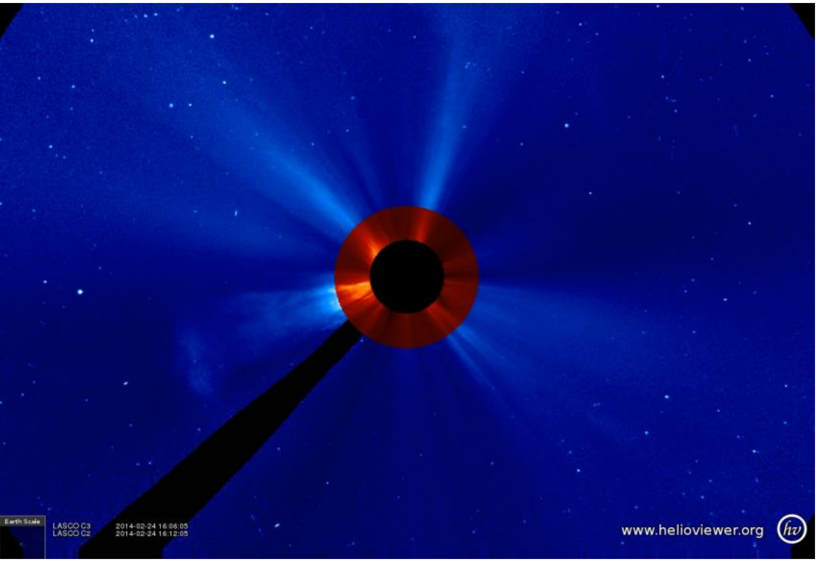

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- Flares and CMEs typically originate from active regions (ARs).
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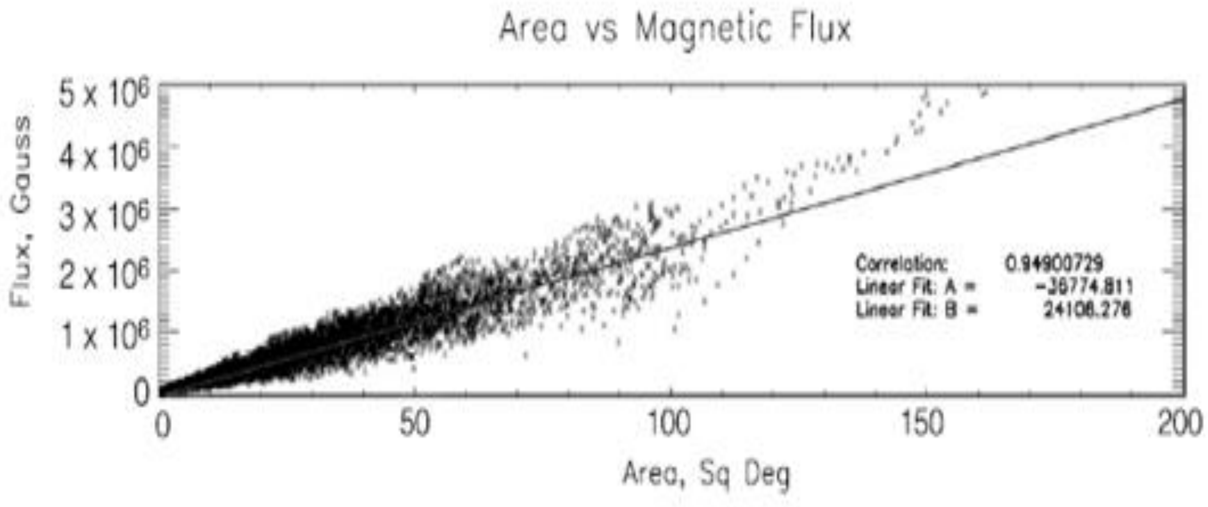
- There is no CME occurrence probability forecast model using McIntosh sunspot classes.

- We have developed the major flare (M and X-class) and Front-side halo CME (AW ≥ 120°) forecast models using McIntosh sunspot classes and their area changes.

- The AR area, which is corrected for the projection effect, and its change can be proxies of magnetic flux and its variation, respectively.

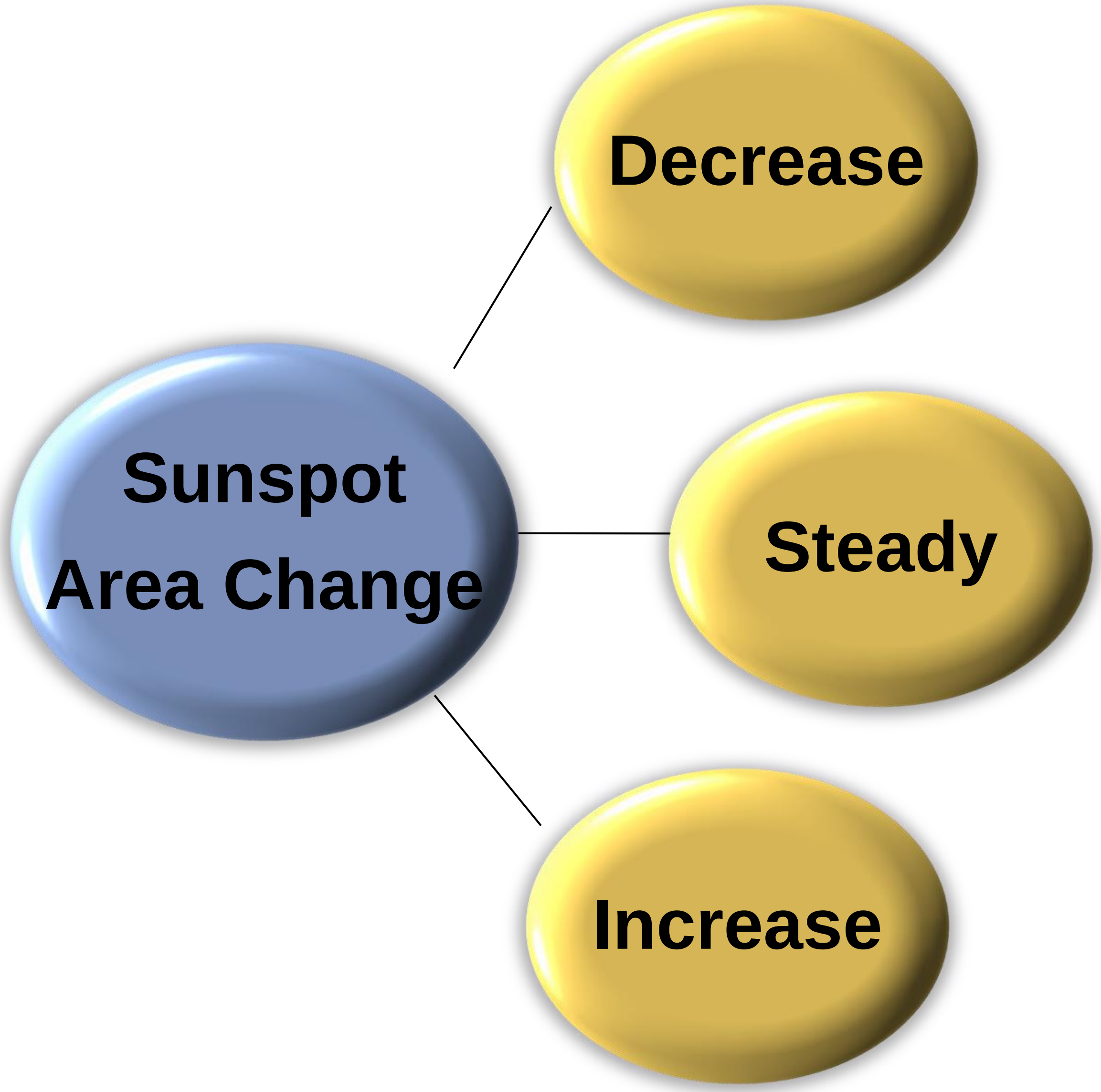


Zharkov and Zharkova (2006)

Data

- From 1996 to 2010
- SOHO LASCO CME catalog
  - Front-side Halo (partial + full) CMEs (FHCMEs)
- NGDC flare catalog (soft X-ray & AR number)
  - C, M, and X-class flares
- NOAA SWPC SRS data (for AR information)
  - AR area, AR number, and McIntosh class

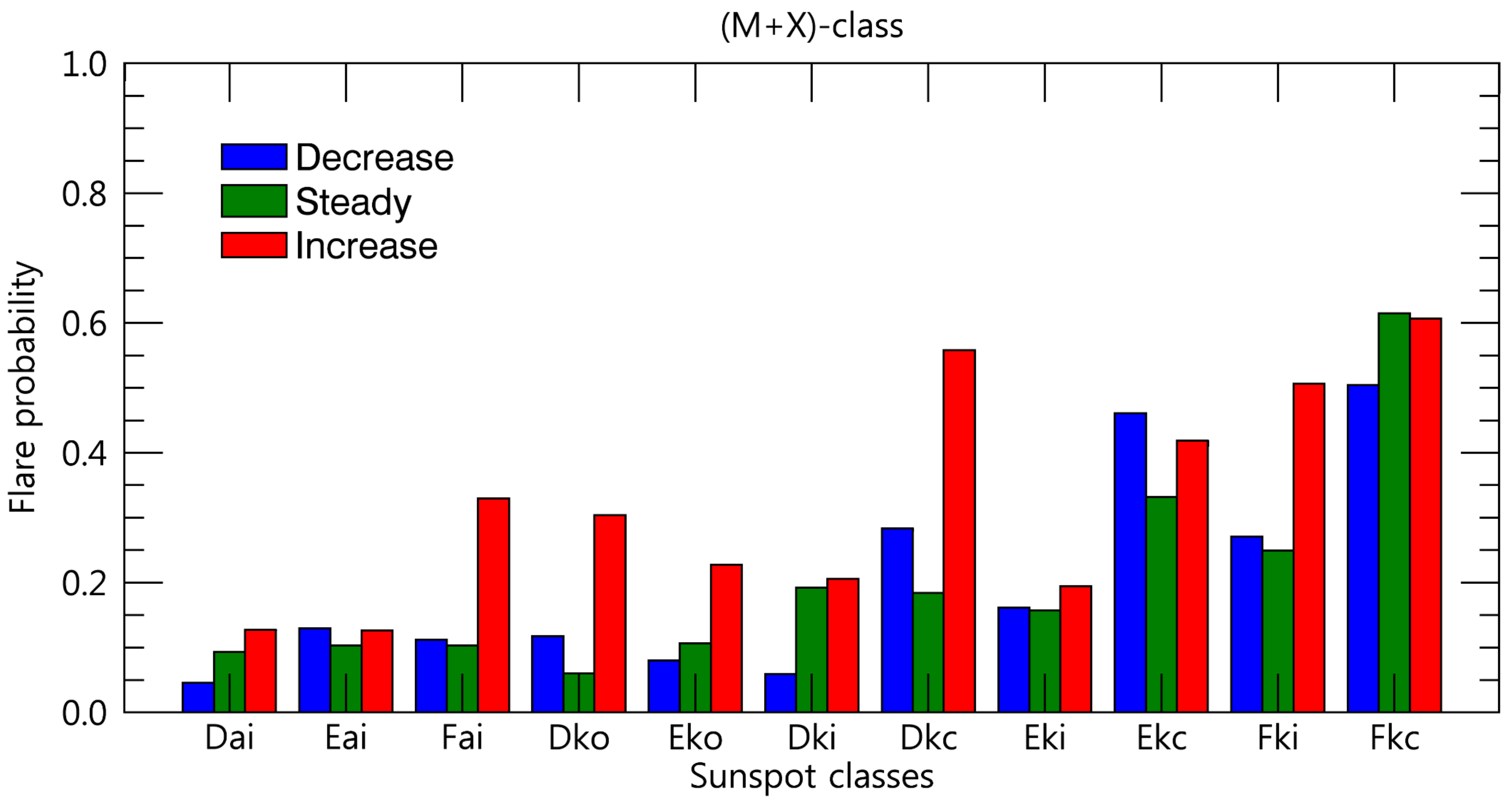
Analysis



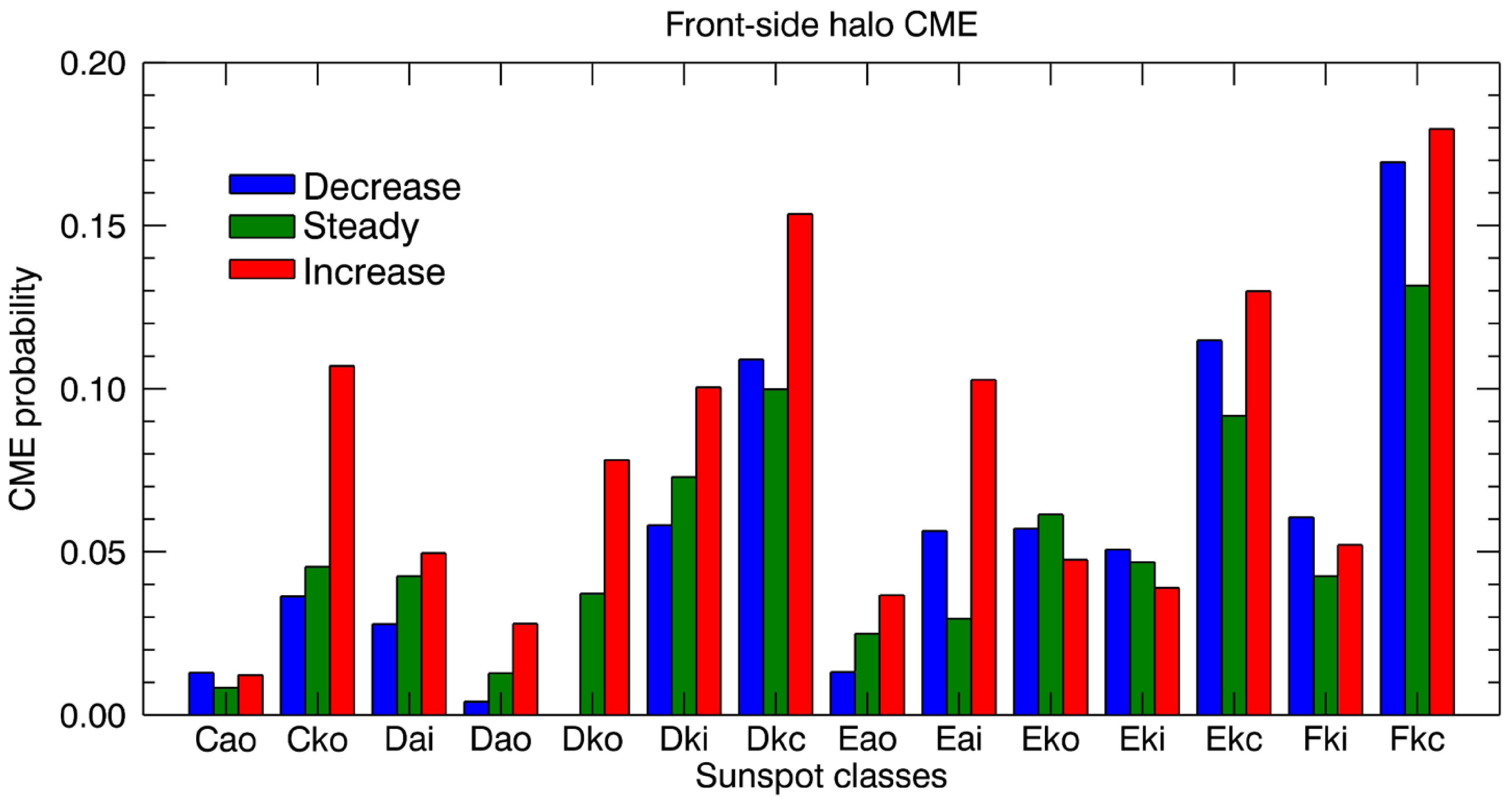
Calculating flare/CME occurrence rate (the number of flares/CME / the number of ARs for a given sunspot class)

$$P\mu(N) = \frac{\mu^N}{N!}\exp(-\mu)$$

Calculating flare/CME probability (By Poisson's distribution)



In the majority case of "Increase" sub-groups, the flare occurrence probabilities are higher than those of other sub-groups.



For several halo CME-productive sunspot classes, the changes (flux emergence or cancellation) of sunspot area enhance remarkably the halo CME probabilities.

Forecasting system algorithm

Input parameters

- SRS (Solar Region Summary) data for two days

Process

Calculating AR area change for a given AR,
$\Delta A = A_T - A_P$
(the day – preceding day)

Classifying AR into the following groups: Increase, Steady, Decrease

Applying the historical flare/CME probability

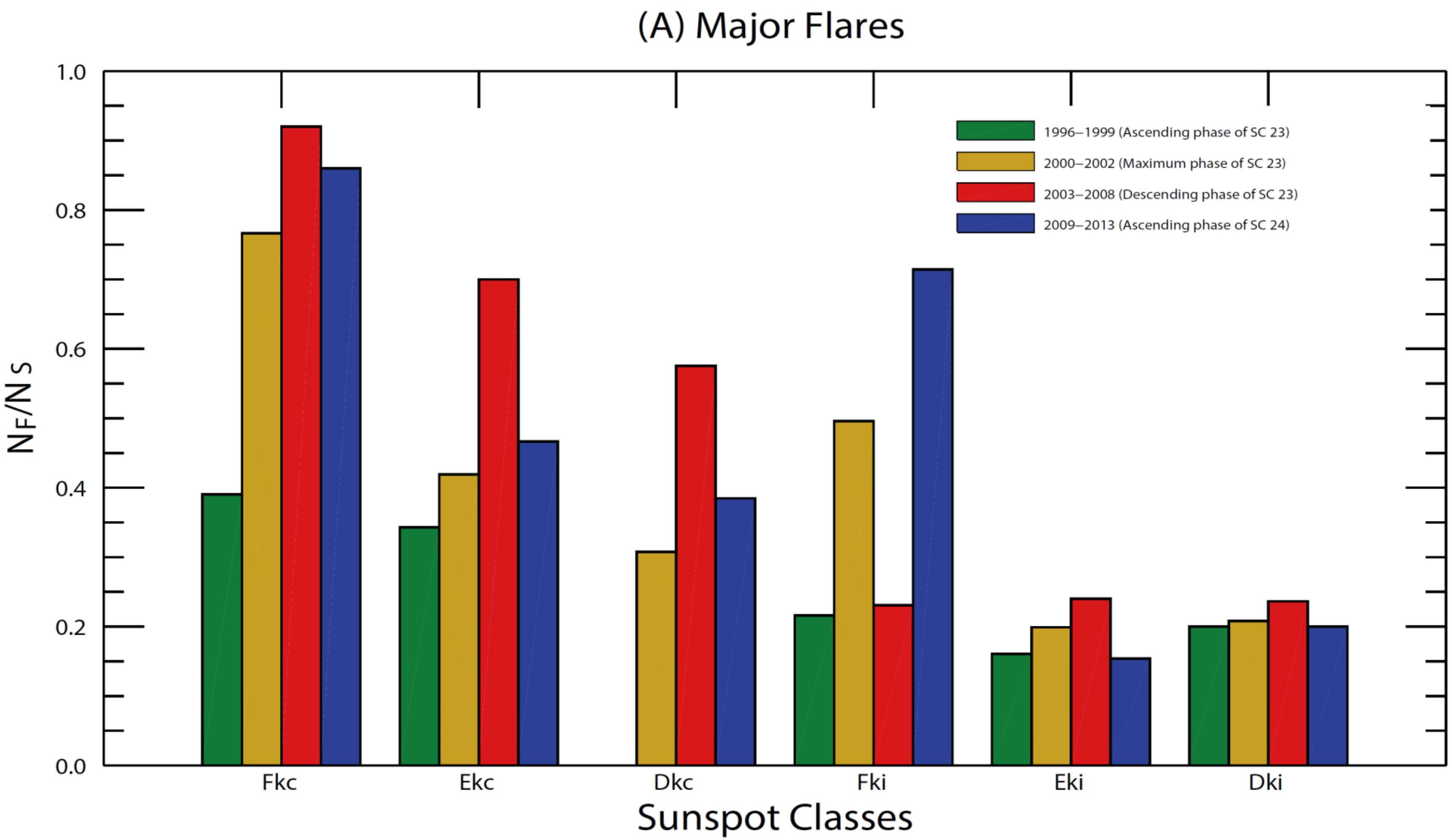
Output parameters

- For each AR,

  C-class prob.
  M-class prob.
  X-class prob.
  FHCME prob.

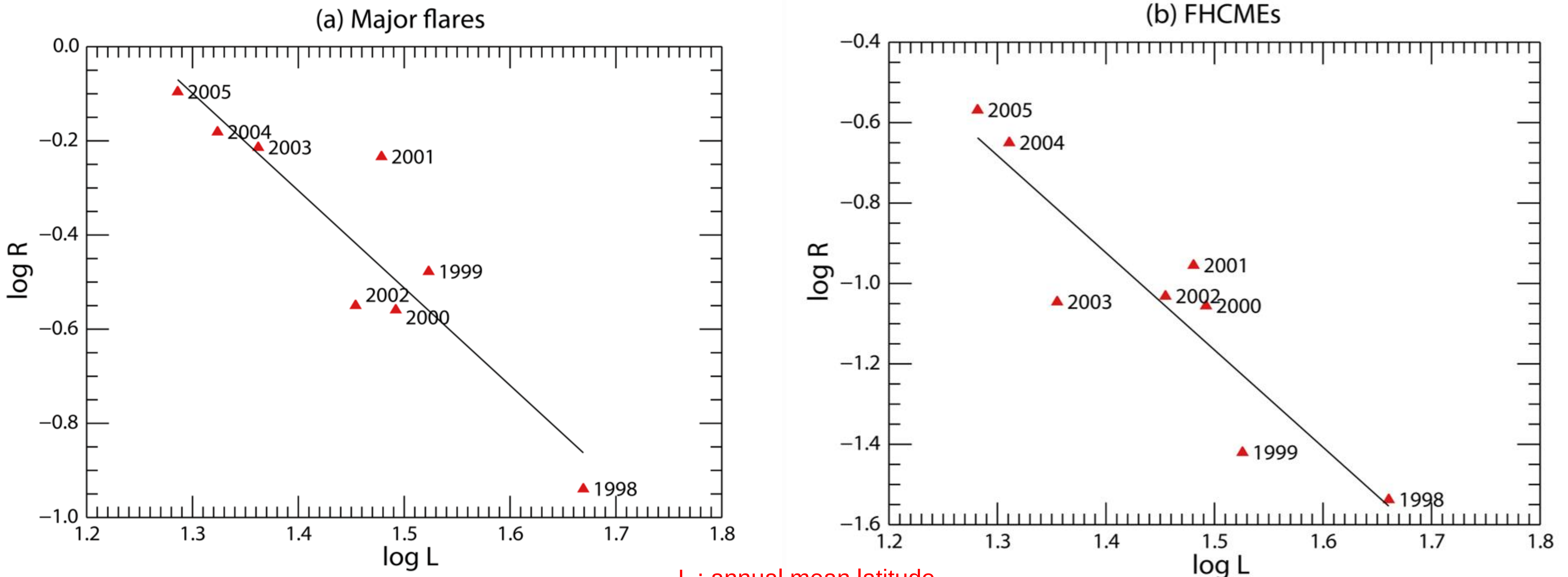
- Total C, M, X-class, and FHCME prob. on solar disk

Solar Cycle Phase Effect



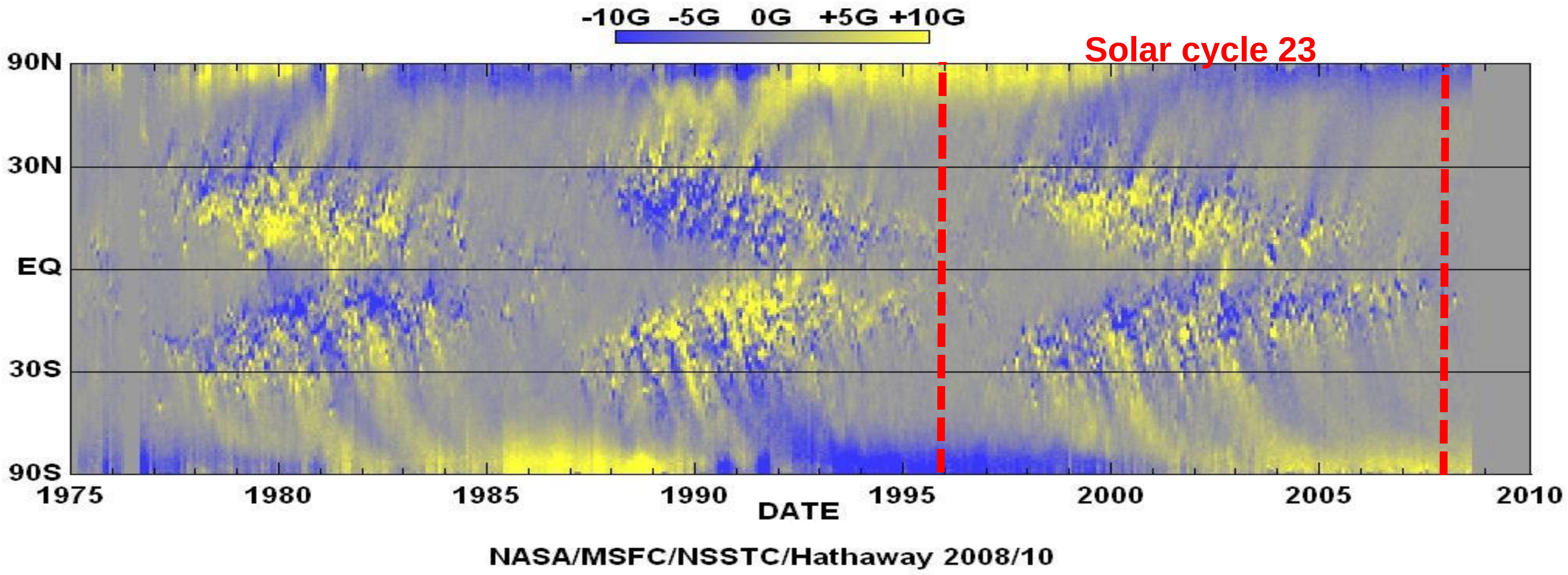
For the most major flare- and FHCME-productive sunspot classes (Fkc, Ekc, and Dkc)
the occurrence rates of major flares and FHCMEs during the descending phase of SC 23 are higher than those during the other phases.

Occurrence rate of major flares/FHCMEs vs annual mean latitude of AR



L : annual mean latitude
R: occurrence rate

The occurrence rates of major flares and FHCMEs are anti-correlated with annual mean latitude.



Sunspots move towards the equator as a function of year. Trans-equatorial loops (TLs) can be more easily formed during the descending phase.

Summary

- In the majority case of "Increase" sub-groups, the flare occurrence probabilities are higher than those of other sub-groups.
- For several halo CME-productive sunspot classes, the changes (flux emergence or cancellation) of sunspot area enhance remarkably the halo CME probabilities.
- For the most major flare- and FHCME-productive sunspot classes (Fkc, Ekc, and Dkc), which are characterized by large, asymmetric, and compact sunspots, the occurrence rates of major flares and FHCMEs during the descending phase of SC 23 are higher than those during the other phases.
- The occurrence rates of major flares and FHCMEs are anti-correlated with annual average latitude.
- The important factors of major flares and front-side halo CMEs : Z(size), p(asymmetry), c (compactness), solar cycle phase (large-scale connectivity)