

Solar active longitude and active level estimation



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Outline

- **Solar Active Longitudes**
→ Where solar activity often occurs
- **Solar Activity Level Estimation**
→ How to estimate activity level of active regions
- **Summary**



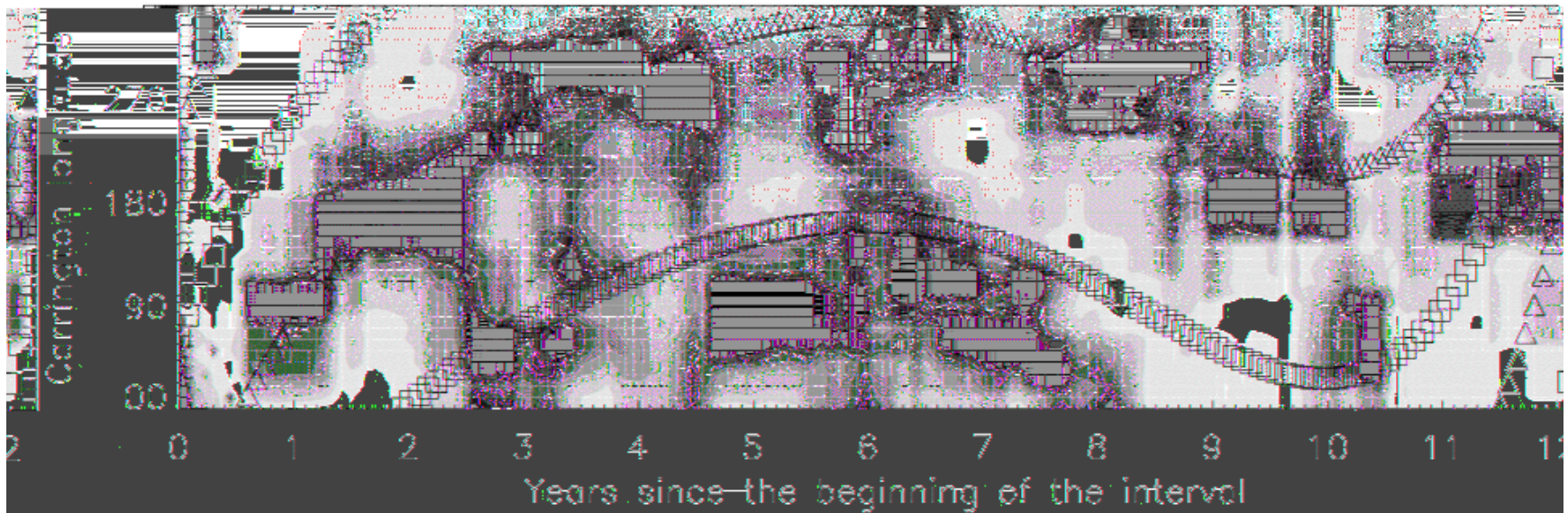
1. Solar Active Longitudes

(1) Two persistent active longitudes of sunspots (Usoskin, et al., 2005, A&A, 441, 347)

The distribution of sunspots is non-axisymmetric implies that the existence of two persistent (on century scale) active longitudes separated by 180 deg. These longitudes migrate with differential rotation and periodically alternate their activity levels showing a flip-flop cycle.

The longitudinal distribution of the sunspot area during cycle No. 19. (Usoskin, et al., 2005, A&A, 441, 347)

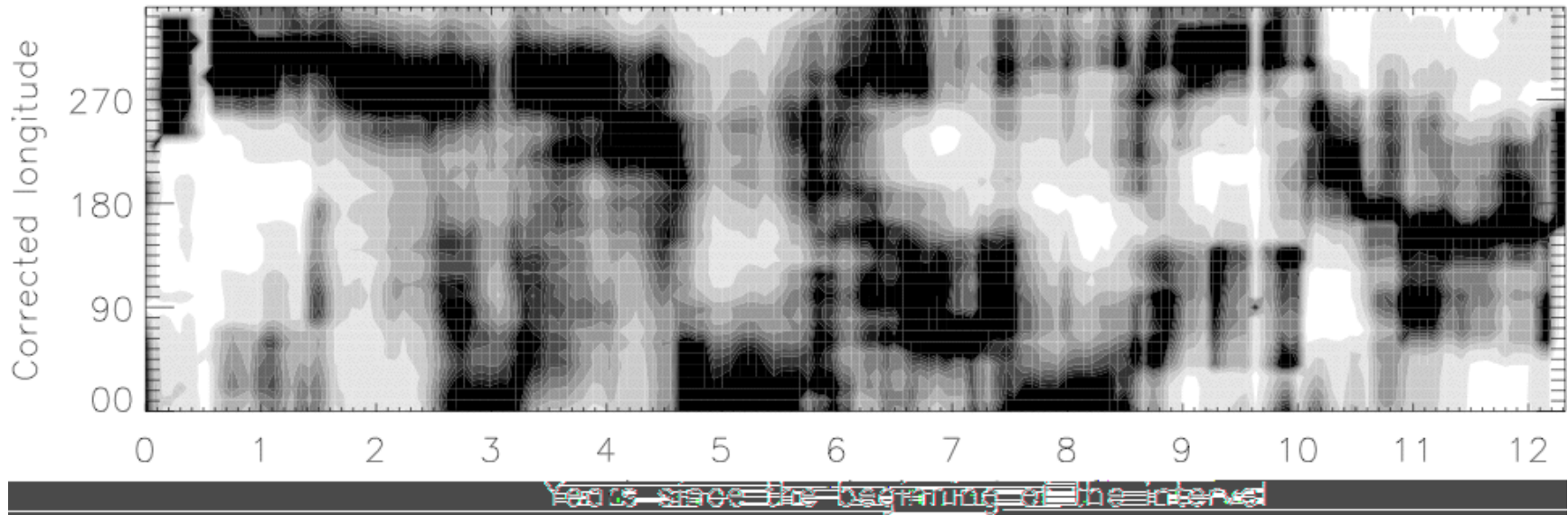
North 1954 – 1965



The expected migration path of the two active longitudes according to differential rotation law

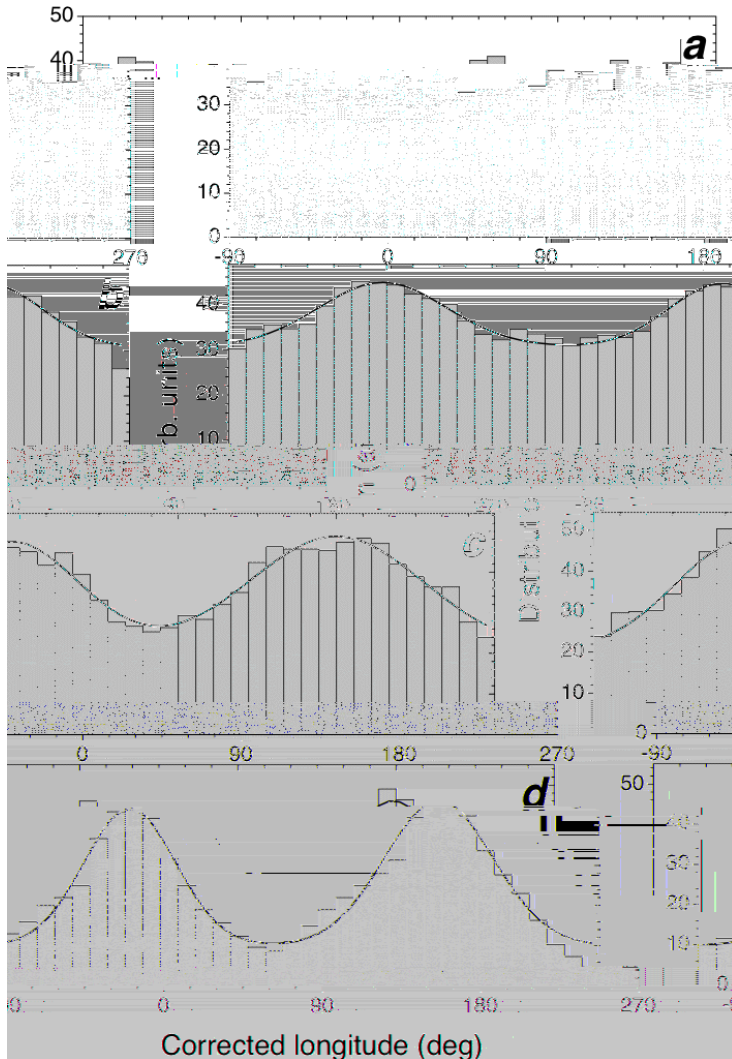
The corrected longitudinal distribution of the sunspot area during cycle No. 19. (Usoskin, et al., 2005, A&A, 441, 347)

North 1954 – 1965



The longitudinal distribution of the sunspot area is corrected with a dynamic reference frame based on differential rotation law

Longitudinal distributions of sunspot occurrence in the Northern hemisphere for the period 1878--1996.



- a) Actual sunspots (area weighted) in the Carrington frame. The distribution is nearly isotropic.
 - b) The same as panel a) but in the dynamic reference frame.
 - c) Only the position of one dominant spot for each Carrington rotation is considered.
 - d) The same as in panel c) but for 6-month averages.
- (Usoskin, et al , 2005, A&A, 441, 347)

(2) Two persistent active longitudes of solar X-ray flares

(Zhang, et al 2007, A&A, 471, 711)

When the Usoskins's method was employed for observational solar flare data, the same phenomenon was found in the longitudinal distribution of powerful X-ray flares.



a) Data

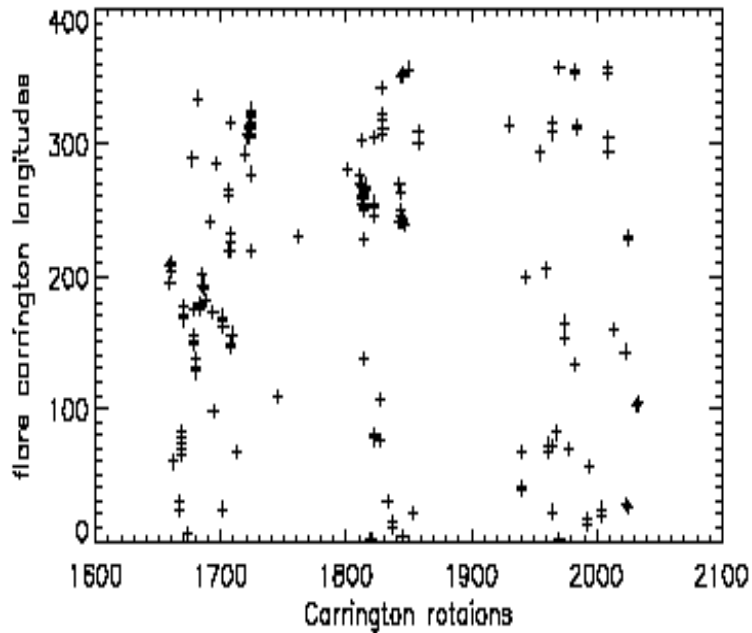
Optical flares associated with all the solar X-ray flares \geq C class observed by GOES during the period of 1975 to 2005;

Sunspots collected at the Royal Greenwich Observatory, the US Air Force, and NOAA for the same period as X-ray flares.

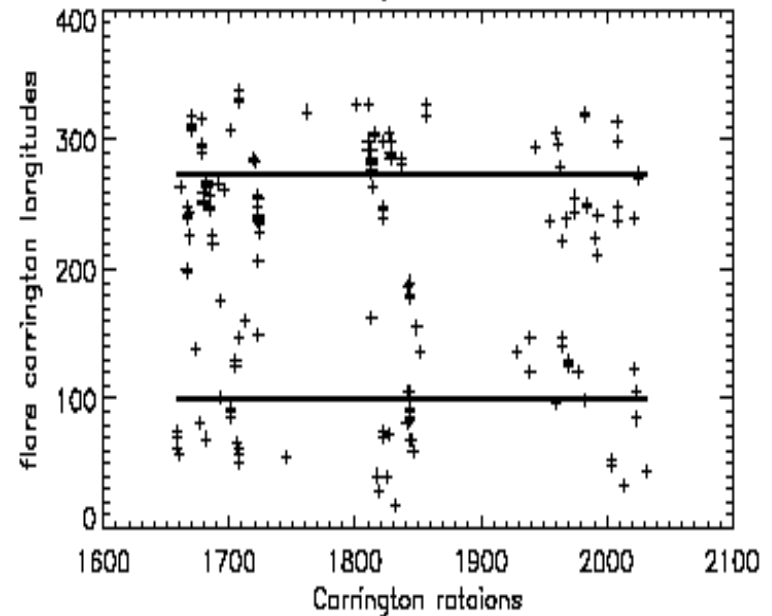
b) Analysis Method

The longitudinal distribution of the solar flares is corrected with a dynamic reference frame based on differential rotation law.

c) Result



The observed longitude distribution of X-Class flares in the Carrington frame for the period of 1975–2005

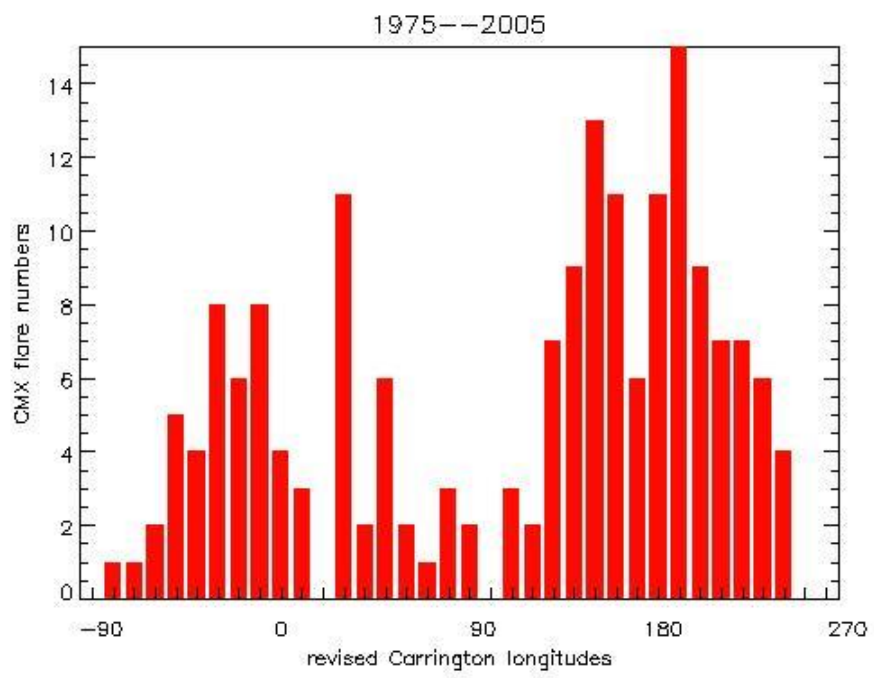
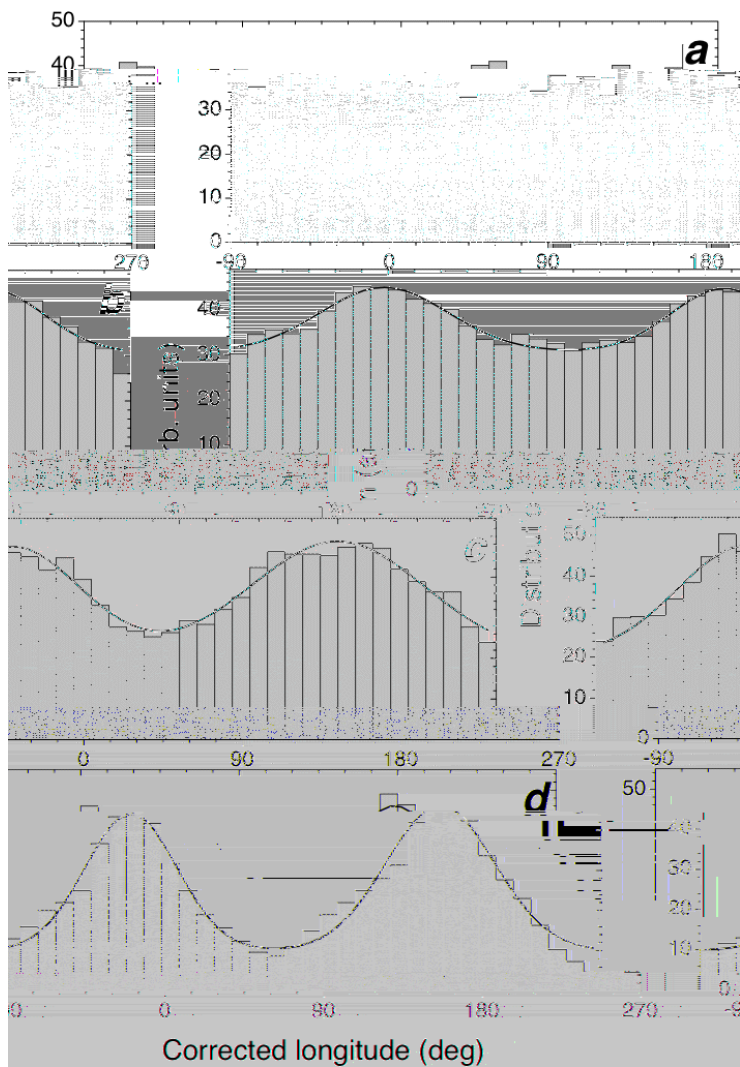


The revised longitude distribution of X-class flares by differential rotation law

Non-axisymmetry comparison between flare and sunspot number

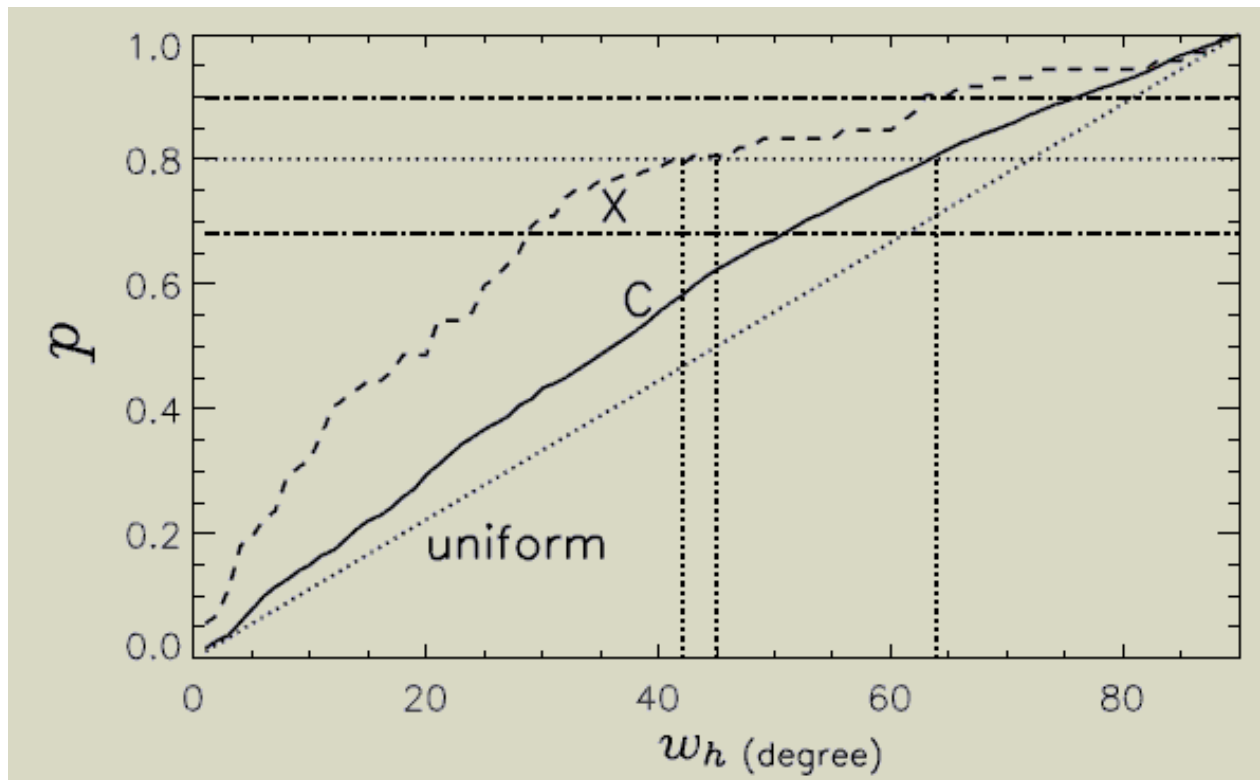
	Northern		Southern	
	Γ	$N_1/(N_1+N_2)$	Γ	$N_1/(N_1+N_2)$
Sunspots	0.06	0.53	0.05	0.53
C-flares	0.15	0.58	0.14	0.57
M-flares	0.27	0.63	0.20	0.60
X-flares	0.55	0.78	0.49	0.74

This fact means that active longitudes related to X-ray flare location are more outstanding than those related to sunspot location.



(3) Application: X-ray flares in 23rd solar cycle

- $p = N_f / N_t$
- N_f the number of flares occurred in longitudes with ω_h width
 - N_t the total number of all flares



2. Solar Activity Level Estimation

(1) Solar flare productivity

Solar active strength

GOES X-ray flux is employed as a quantitative parameter for describing solar active strength

Active sample

A sample with GOES X-ray flux is larger than a threshold is called active sample

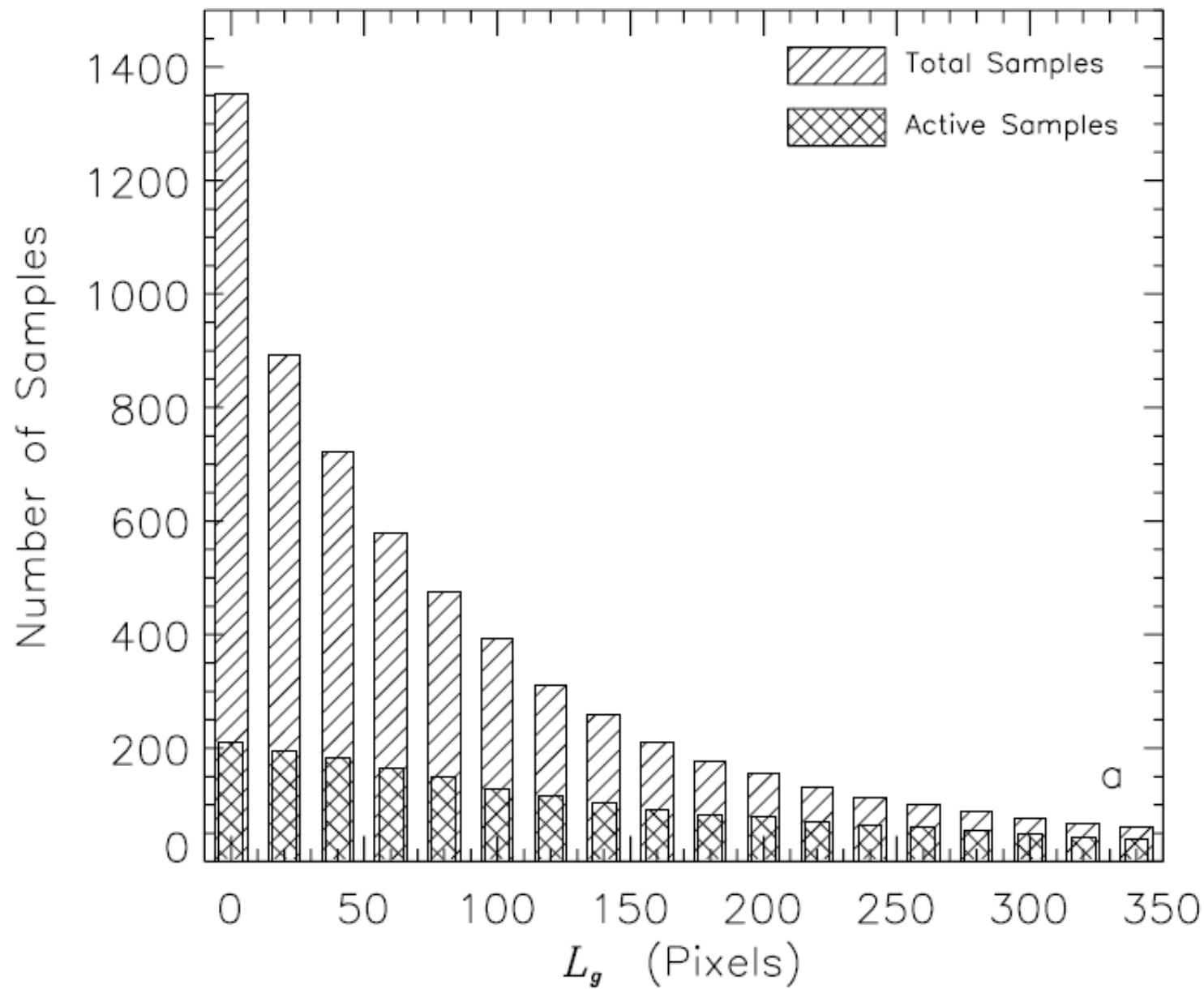
Forecasting time window

A forward looking period when a parameter is measured at a moment.

Flare productivity

$$P(x) = Sa(x)/St(x),$$

where X is a random value of measures describing magnetic properties, $Sa(X)$ and $St(X)$ are the number of the active samples and that of the total when values of these parameters are in the range $[X, \infty]$, respectively.





(2) Statistical analyses

Data (1996-2006)

MDI/SOHO magnetograms : 23990

related active regions : 839

HSOS vector magnetograms: 1353

related active regions : 554

near the central of solar disk($E30^{\circ}$ - $W30^{\circ}$).

Threshold for total soft X-ray flux:

to be equivalent to a M1 flare

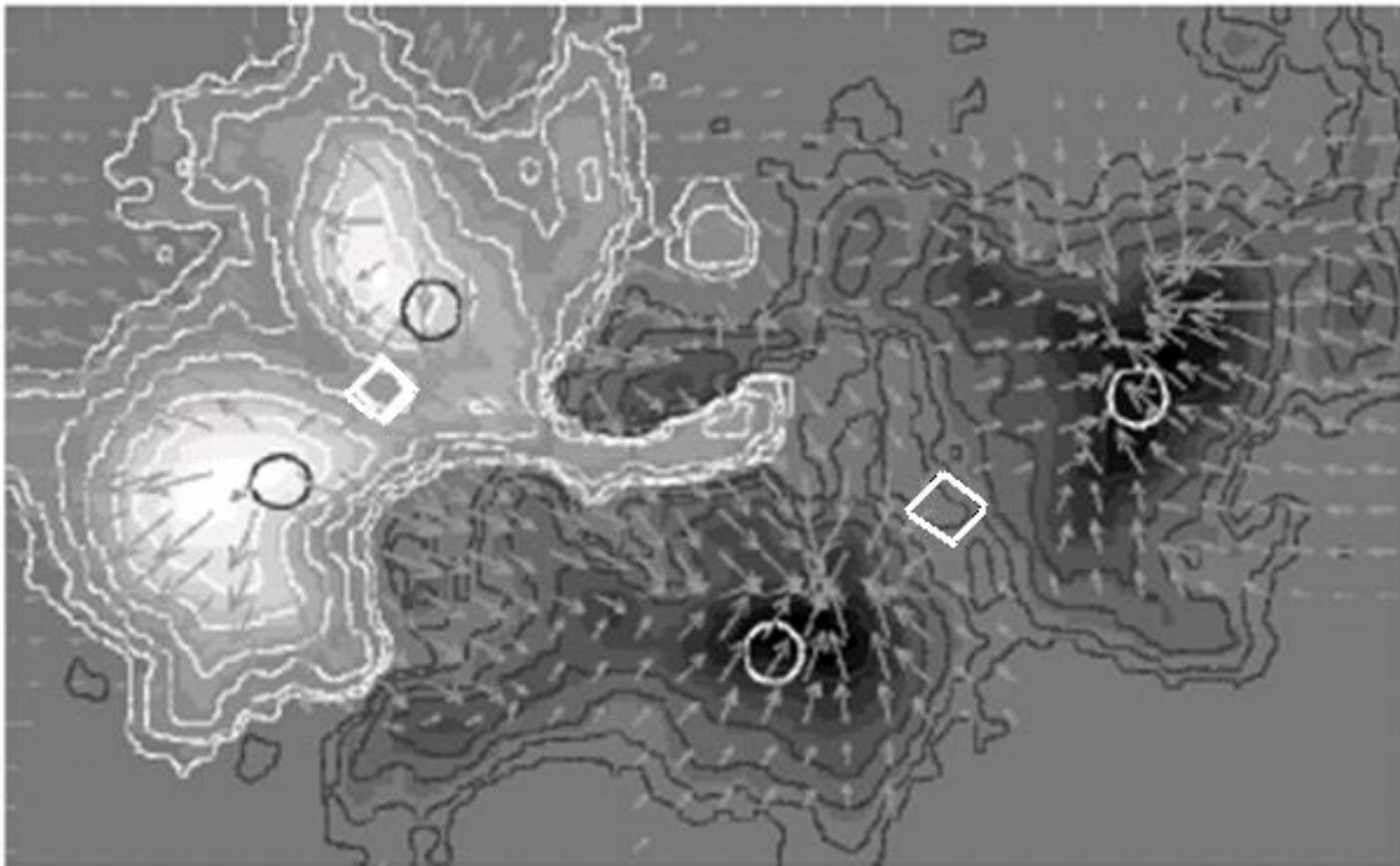
Selected parameters

Maximum of horizontal gradient in longitudinal field $|\nabla_h \mathbf{B}_z|_m$

length of neutral line with high horizontal gradient L

number of singular points in transverse field η

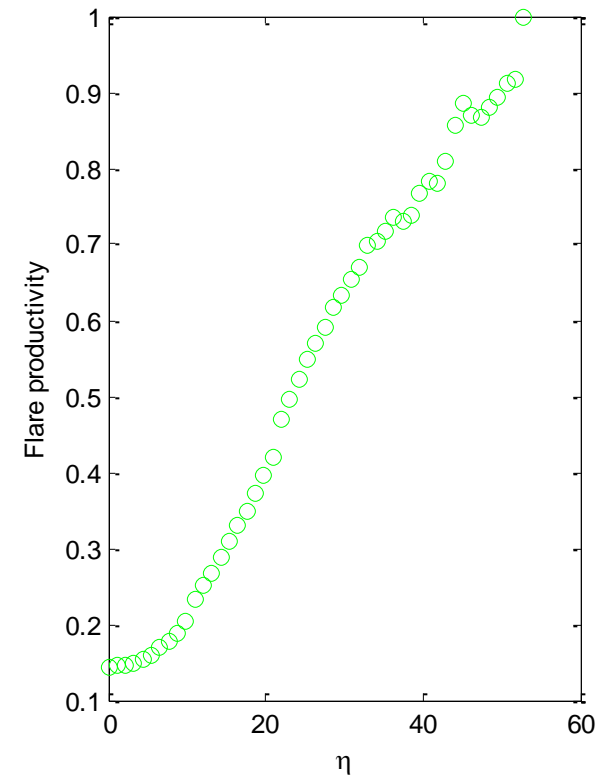
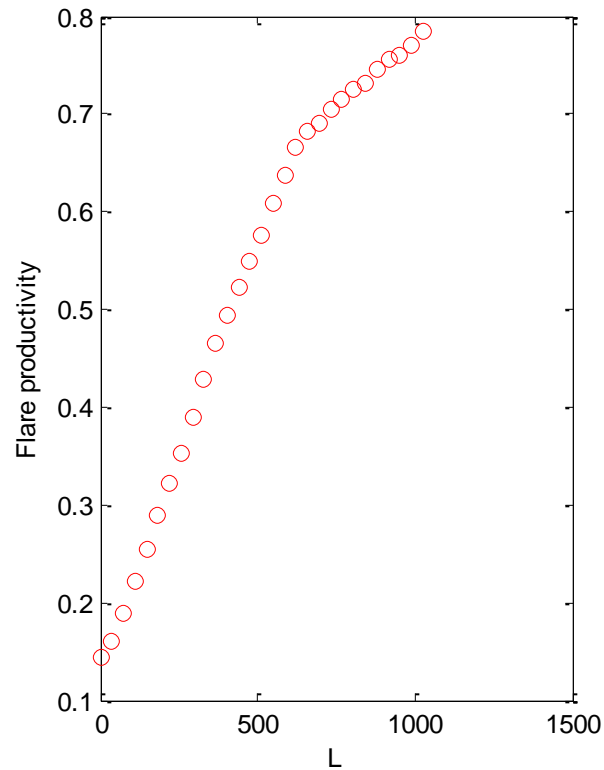
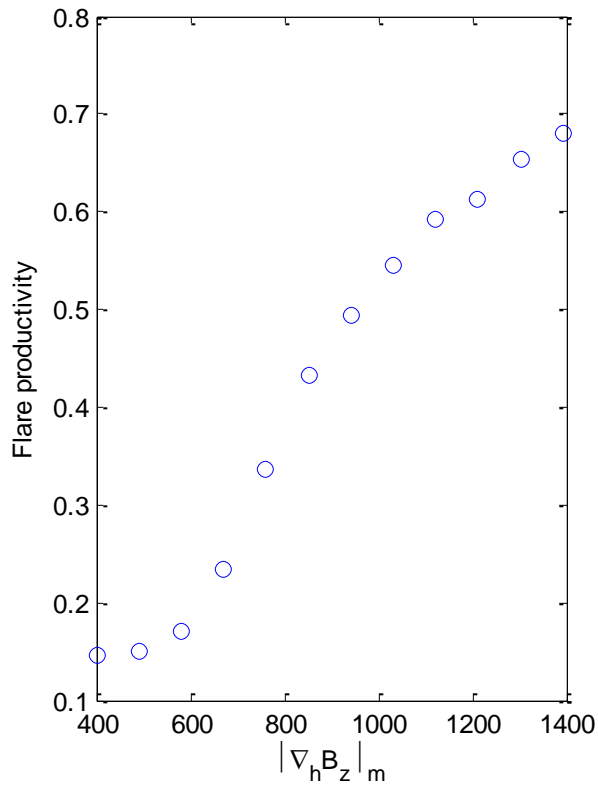
Singular points in transverse field

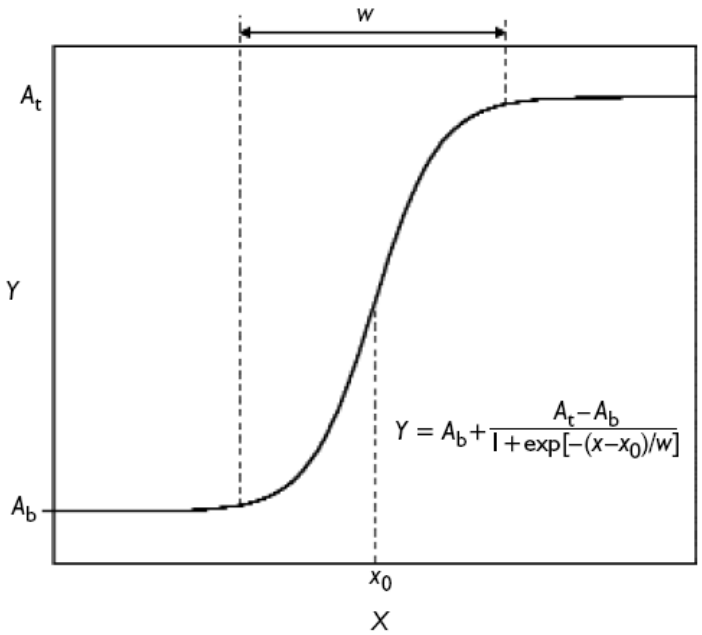




Solar flare productivity and magnetic measures

(Cui, Y. M. et al , 2006, 2007; Wang, H. N. et al, 2009; Yu D. R. et al, 2010)

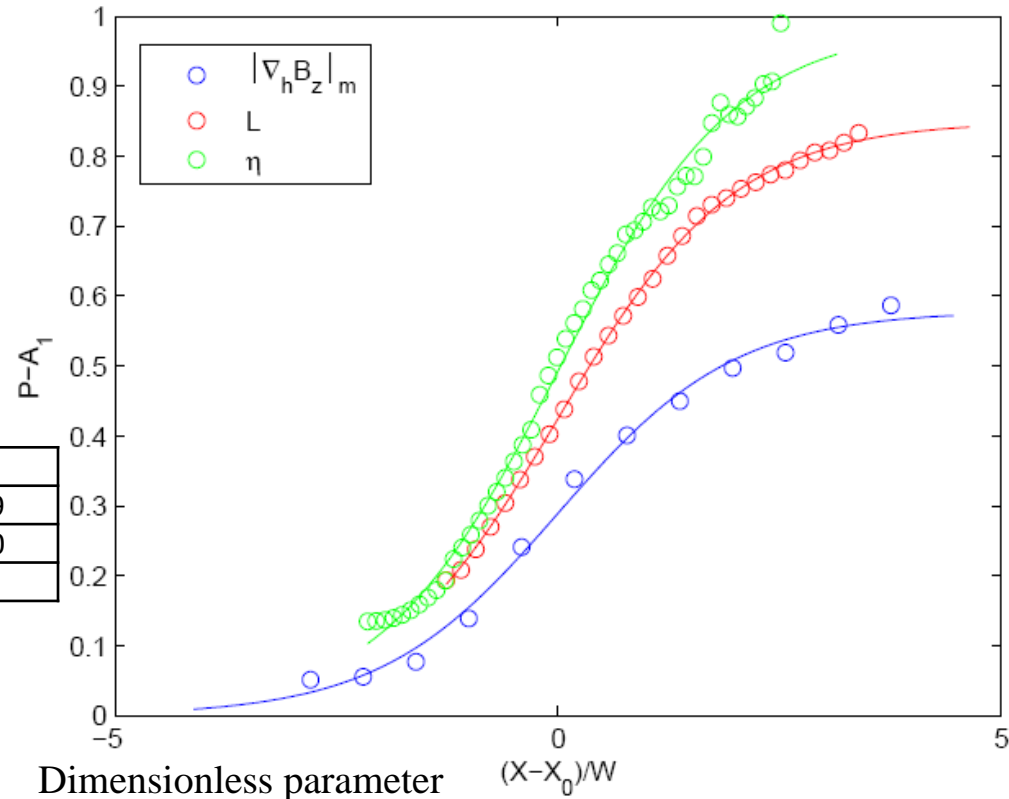




$$P = A_1 + \frac{A_2 - A_1}{1 + \exp[-(X - X_0)/W]}$$

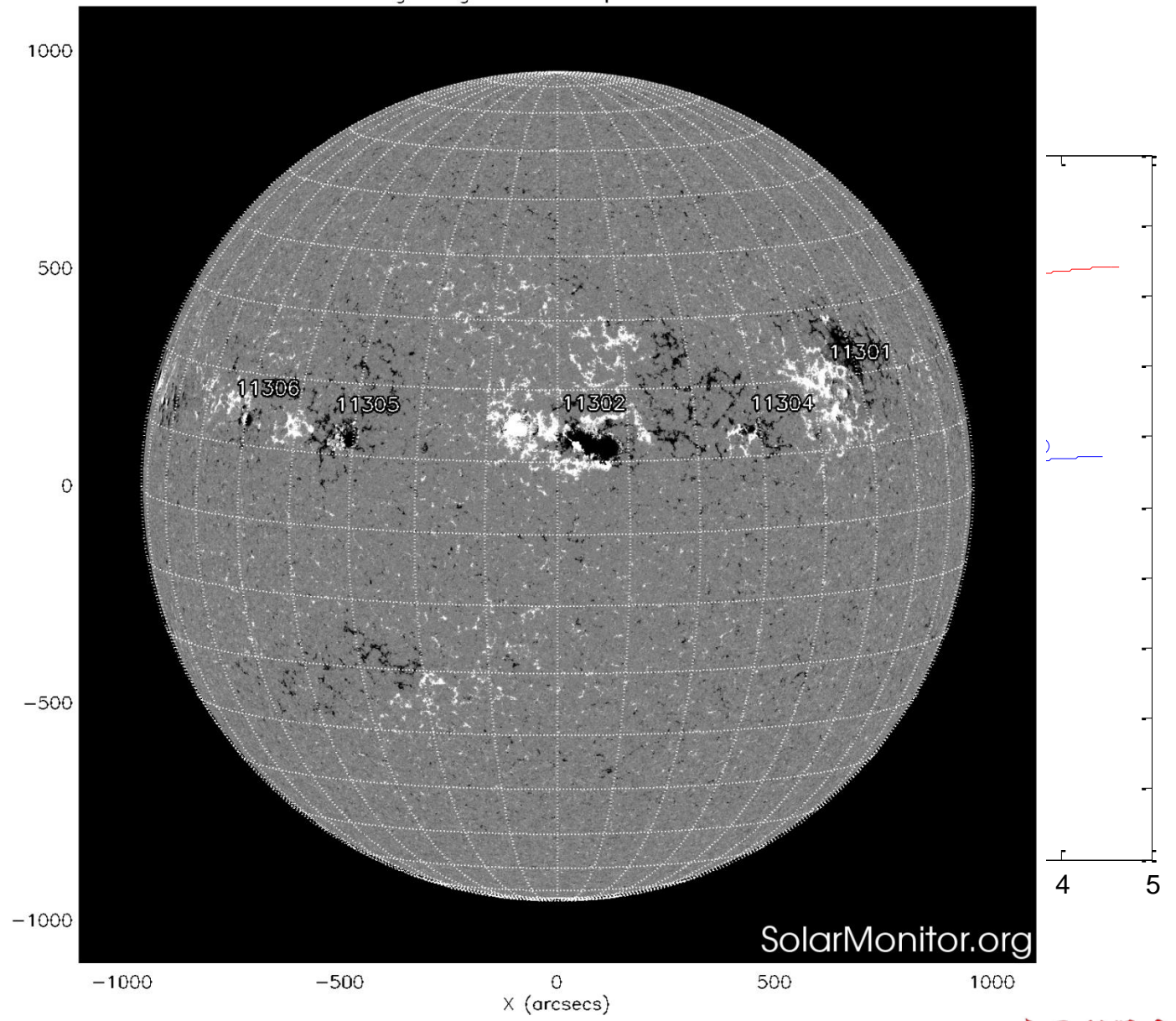
- A_1 and A_2 are two asymptotic values
- W is approximate width between these two asymptotic values
- X_0 is the center of W

	A_1	A_2	X_0	W
$ \nabla_h B_z _m$	0.0942	0.6732	823.4704	151.6299
L	-0.0488	0.8013	277.4077	220.3900
η	0.0096	0.9960	24.3303	11.3300





SDO HMI Magnetogram 28-Sep-2011 19:17:04.400



SolarMonitor.org

(3) Modeling and validation

Maximum horizontal gradient
of the longitudinal
magnetic field

Length of neutral line

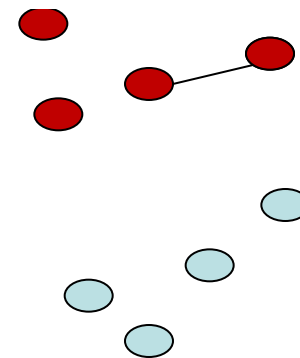
Number of singular point

Distance between center
of active longitude and
center of active region

Prediction
Model

Whether produce
solar flare within
the 48 hour

1-Nearest Neighbor
Model



Validation

	Predicted flaring samples	Predicted non-flaring samples
Actual flaring samples	Hit	Miss
Actual non-flaring samples	False alarm	

N_{CR}
 $N_{CR} + N_{FA}$

$$\text{Correct rejection rate} = \frac{N_{CR}}{N_{CR} + N_{FA}}$$

- Hit rate not considering active longitudes ~0.7
- correct rejection rate not considering active longitudes ~ 0.7
- Hit rate not considering active longitudes ~0.75
- correct rejection rate not considering active longitudes ~ 0.75

Summary

- Active longitude can be predicted by considering the solar surface differential rotation (Zhang, et al 2007, 2011)
- Activity level of active regions can be estimated by the dimensionless method (Wang, et al 2009)
- Combination between active longitudes and active level estimation will be beneficial to modeling for solar activity forecasting.

Thanks !

For all of these measures, we have sigmoid function fittings :

$$Y = A2 + \frac{A1 - A2}{1 + \exp[(X - X0)/W]}$$

where Y is the flare productivity, and X is the value of measures.

Init value: A1
Final value: A2
Center: X0
Width: W

