FLARECAST: Flare Likelihood and Region Eruption Forecasting : a space weather H2020 project

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for the FLARECAST project (PC. M. Georgoulis3 ; PS. S. Bloomfield 4)

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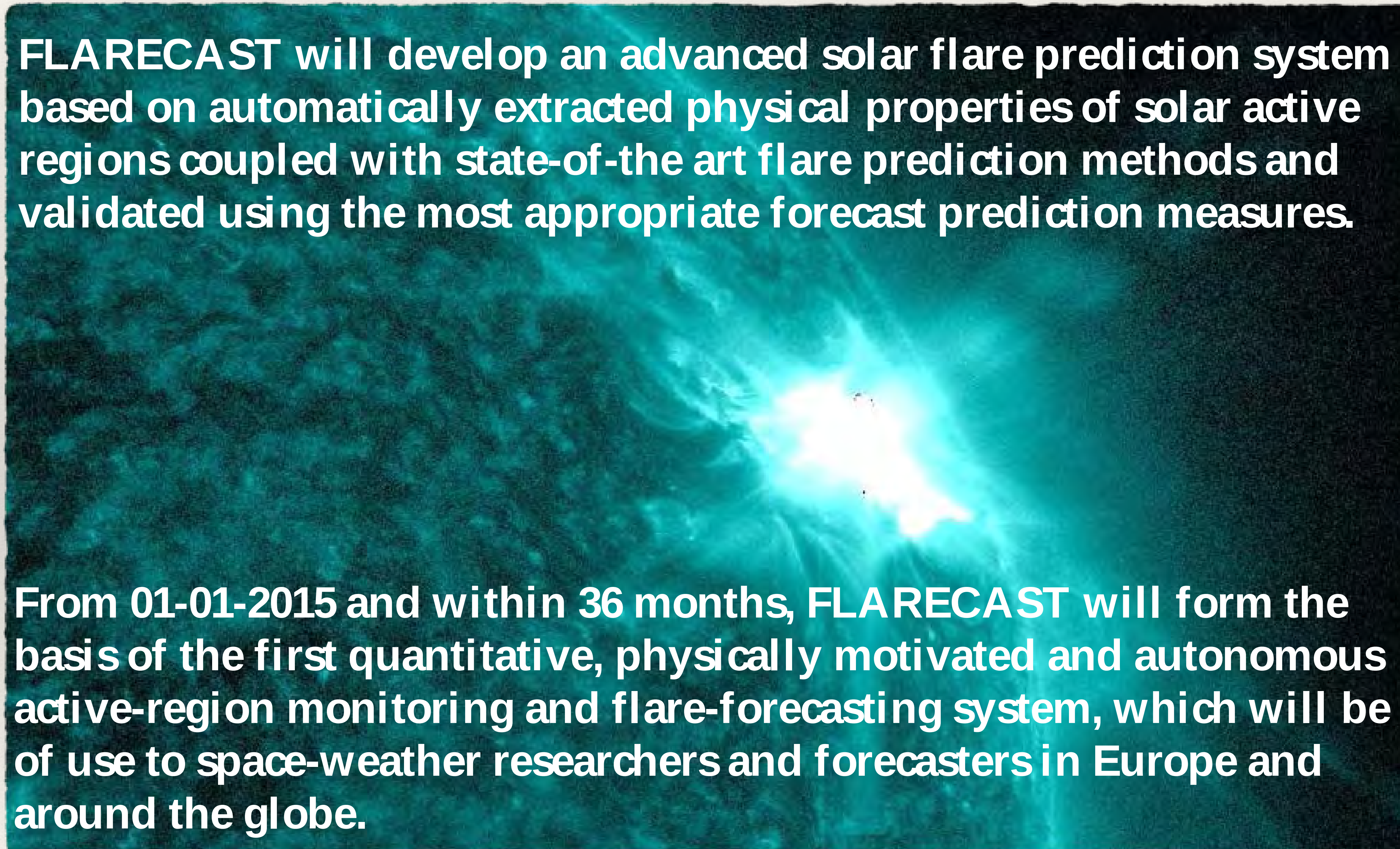
FLARECAST

PROTEC-1-2014 Space weather

Atelier ESTERS: Météorologie de l'atmosphère à l'espace

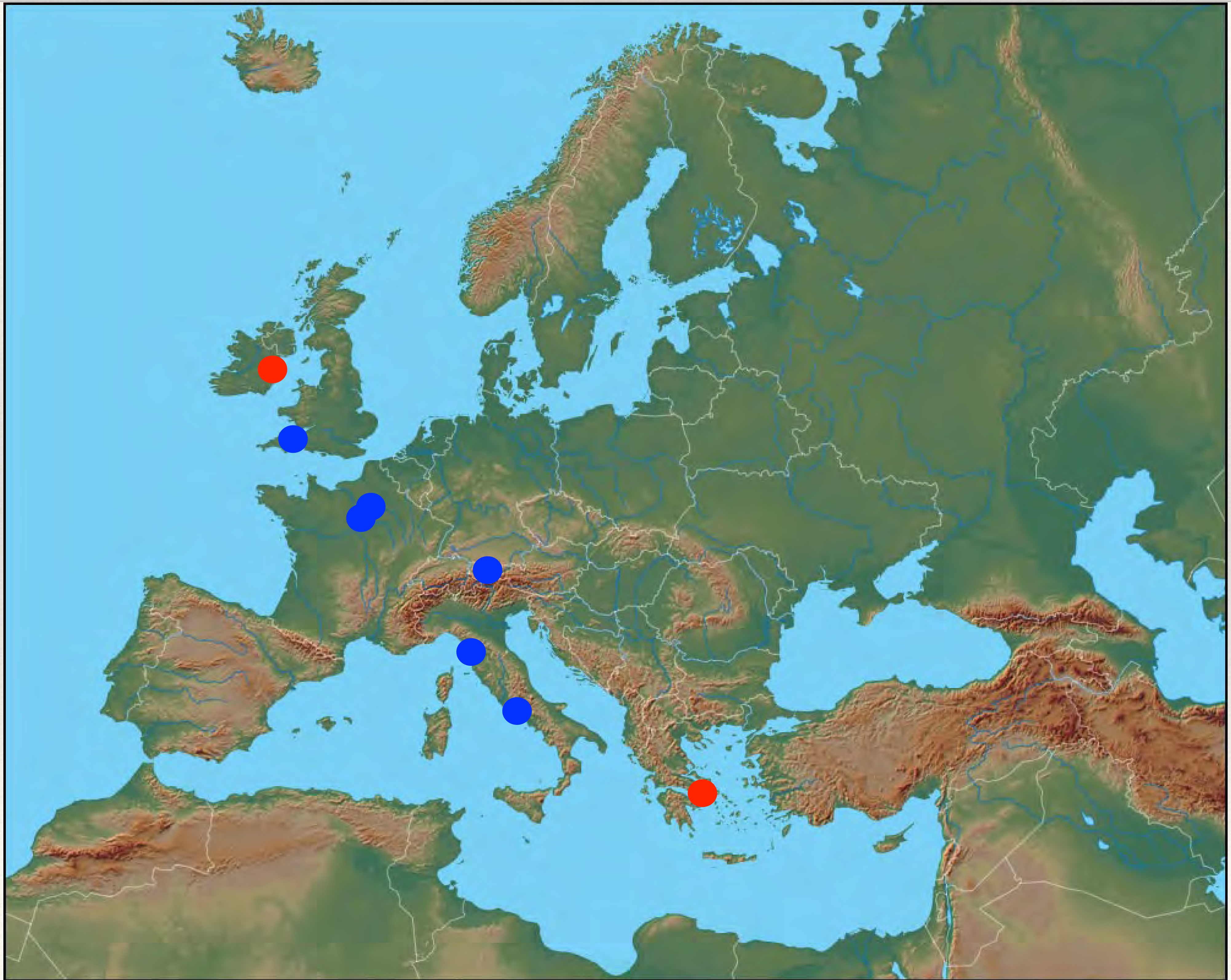
What is FLARECAST?



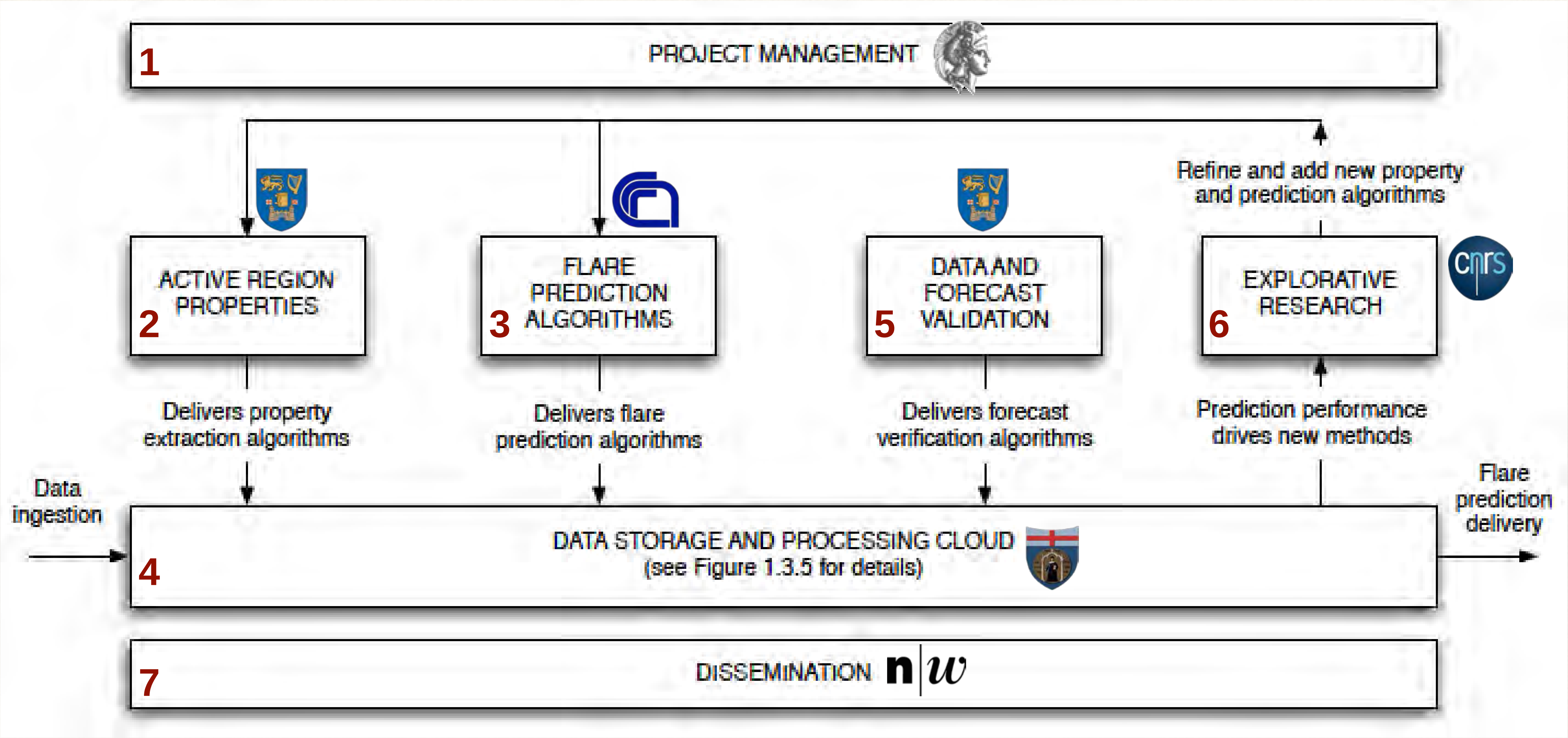
FLARECAST will develop an advanced solar flare prediction system based on automatically extracted physical properties of solar active regions coupled with state-of-the art flare prediction methods and validated using the most appropriate forecast prediction measures.

From 01-01-2015 and within 36 months, FLARECAST will form the basis of the first quantitative, physically motivated and autonomous active-region monitoring and flare-forecasting system, which will be of use to space-weather researchers and forecasters in Europe and around the globe.

Who Participates?

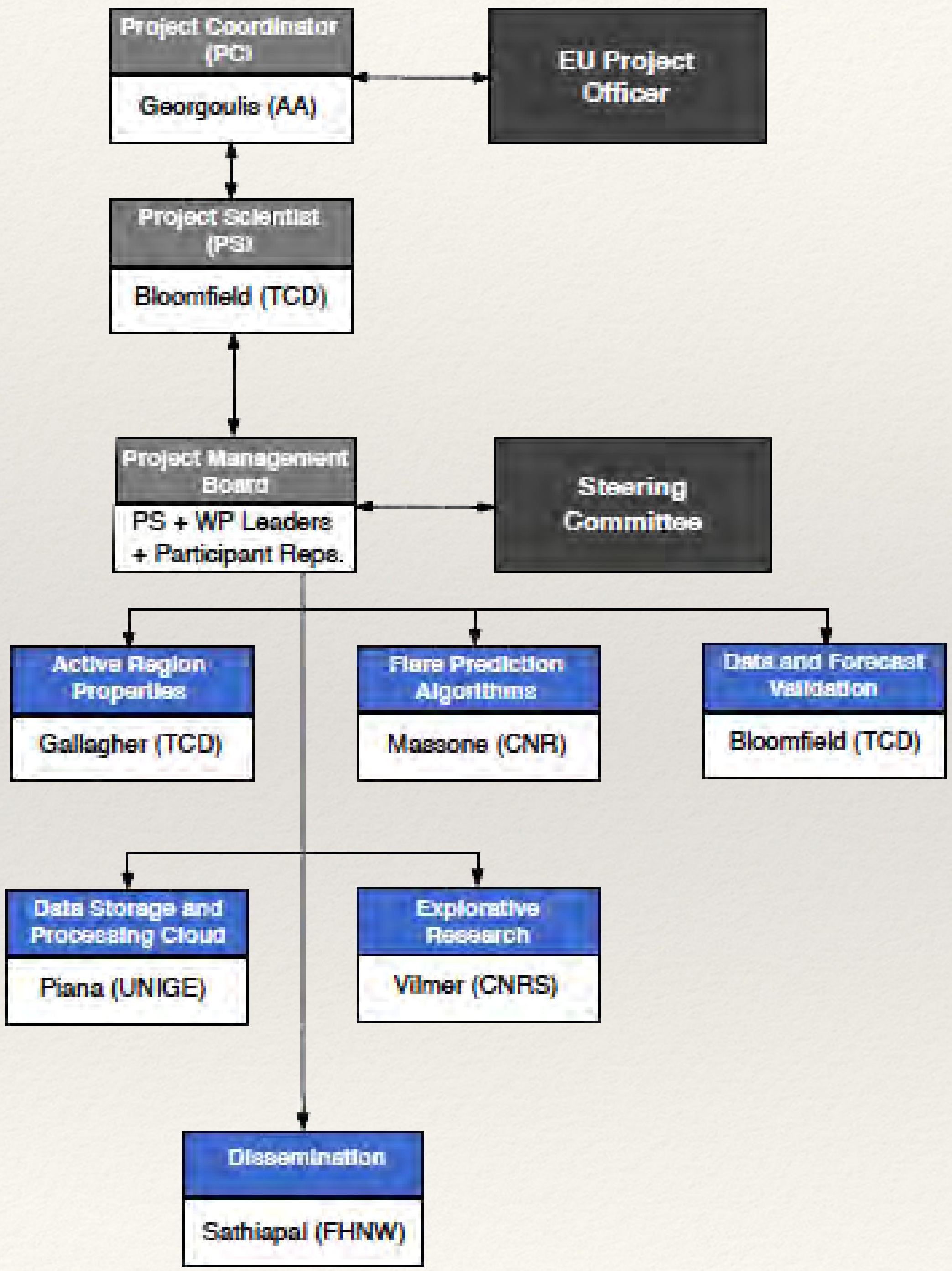


Overall Structure of Work Tasks



Automatic extraction of properties of active region coupled to flare prediction methods validated using forecast verification method

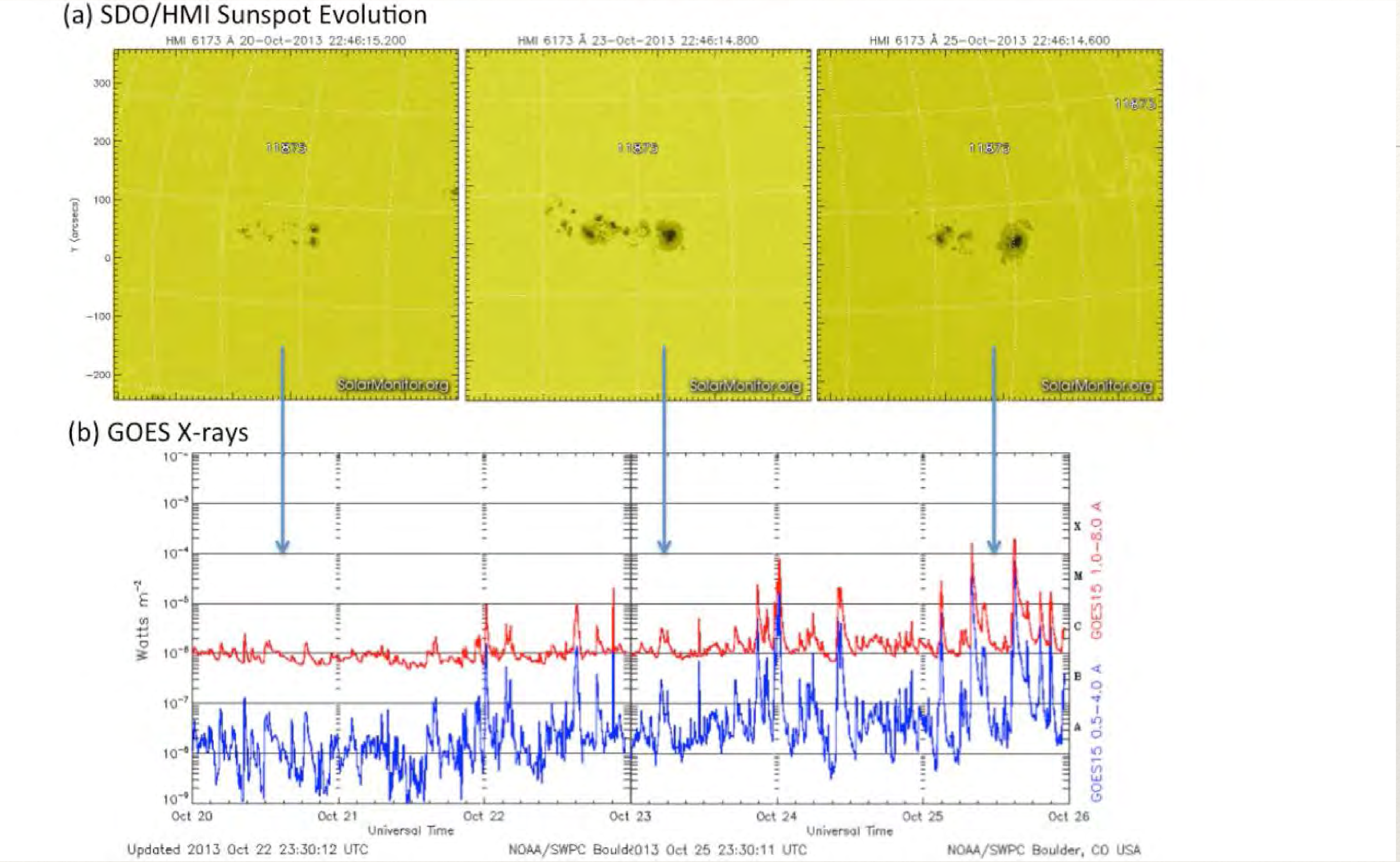
The FLARECAST team



Name	Affilliation	Role
* M. K. Georgoulis	AA	Project Coordinator
* D. S. Bloomfield	TCD	Project Scientist
* P. Gallagher	TCD	WT2 leader
* A. M. Massone	CNR	WT3 leader
* M. Piana	UNIGE	WT4 leader
* D. S. Bloomfield	TCD	WT5 leader
* N. Vilmer & * E. Pariat	CNRS	WT6 leader
* H. Sathiapal	FHNW	WT7 leader
* F. Baudin	UPSud	Local group leader
* A. Csillaghy	FHNW	Local group leader
* D. Jackson	MET OFFICE	Local group leader

+ EC Project Officer + Steering Committee +
+ local group members + students & post-docs

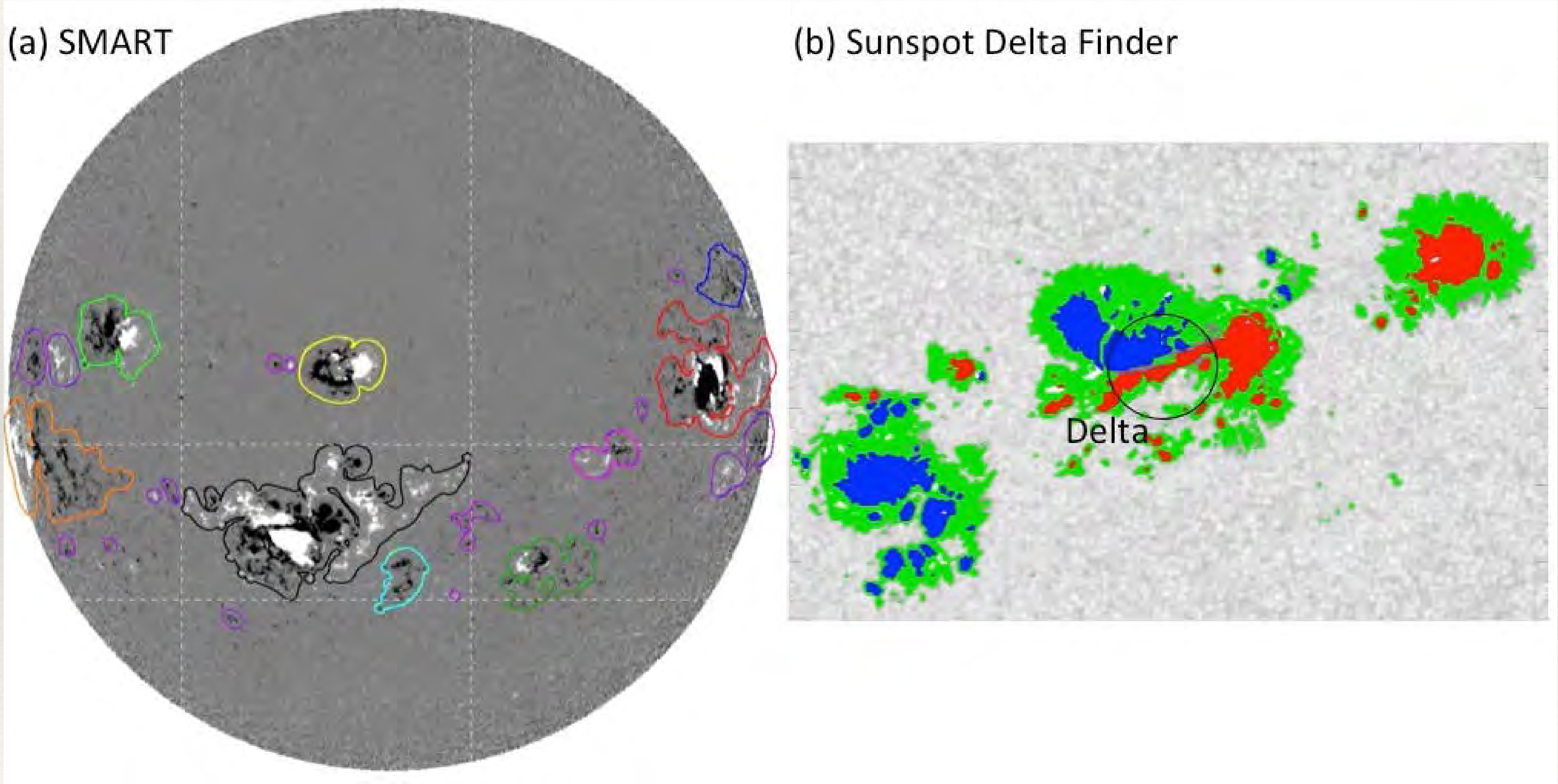
FLARECAST aim



Understanding the drivers of flare activity and improving flare prediction
Evolution of an AR over 6 days and GOES X-ray emissions
The AR is quiet for the first 2 days (small and simple)
Flaring activity increases after day 3 (strong magnetic flux emergence)

FLARECAST

WT2: Active Region Predictors of Flare Activity



Automatic extraction of active-region size, flux, morphology

Data mining of active region catalogue properties

Active Region Predictors of Flare Activity

SWPC catalogue properties

- Number of spots
- Total spot area
- Longitudinal length

- McIntosh class based on white light images

(sunspot size and separation, complexity…)

- Mt. Wilson class

Represents distribution of spot polarities in magnetographs

αunipolar

βbipolar

$\beta\gamma$ multipolar

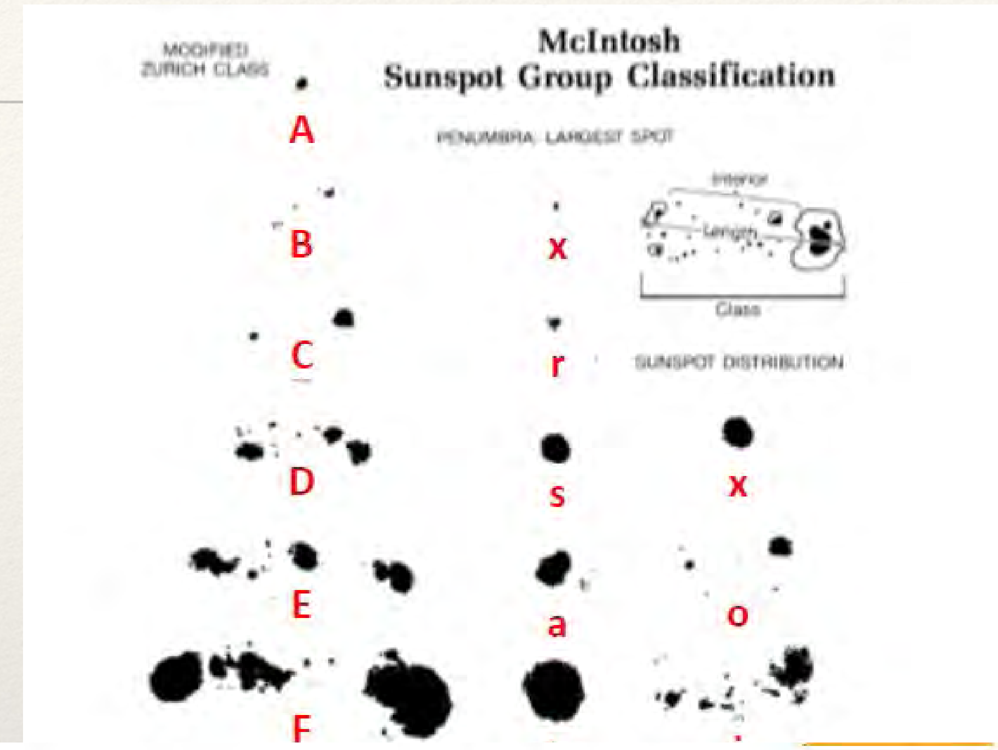
δ close opposite polarity

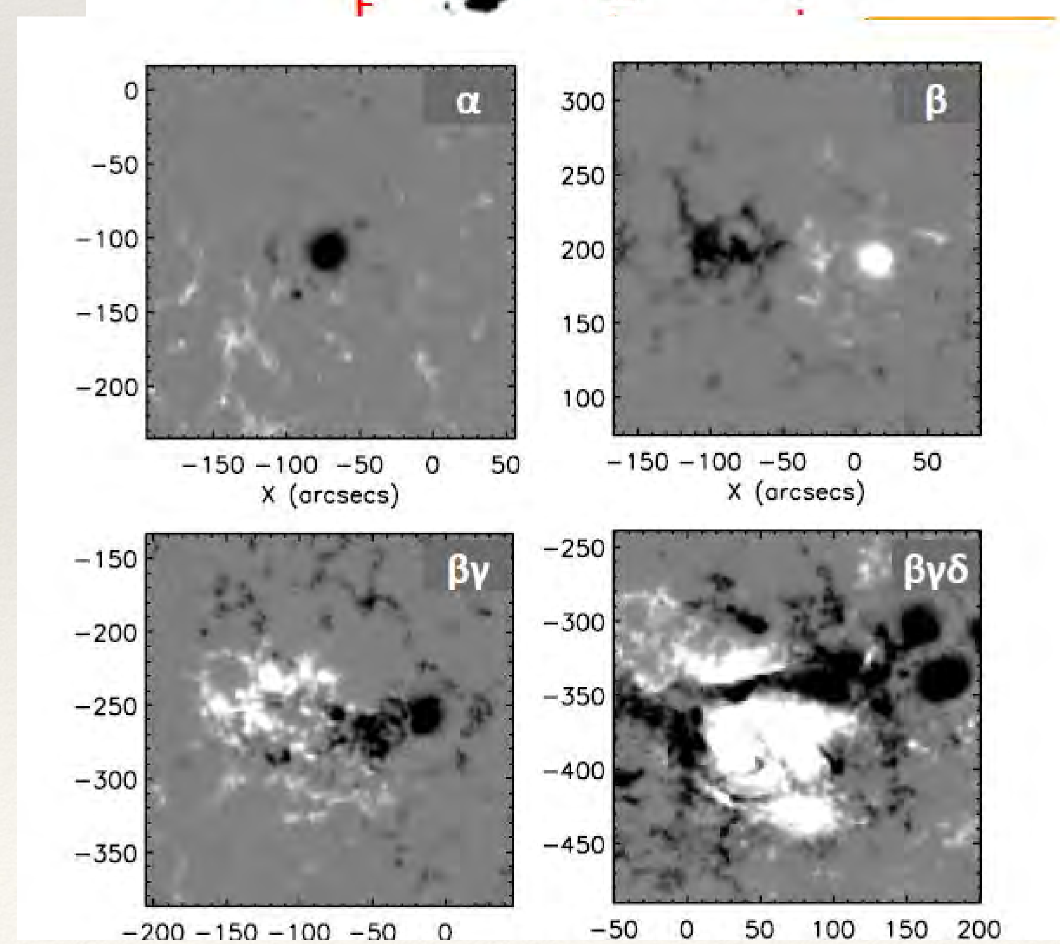
Sunspots are footprint of B field:

Complex structure$\rightarrow$ non potential B field$\rightarrow$ currents$\rightarrow$ free energy for flaring

Aim: look at the evolution in complexity, increase of spot area leading to higher flare rate

(Shaun Bloomfield TCD)





Existing prediction algorithms

Operational (i.e., same times daily)

- SWPC/Met Office
  - Poisson flaring rate (as starting point) THEN expert experience
- Solarmonitor.org
  - Poisson flaring rate

Psuedo-Operational (i.e., every day)

- Max Millennium Program
  - minimum observation criteria AND/OR expert experience

Poisson probabilities computed from historical flare rates from individual McIntosh classes (Bloomfield et al;, 2012)

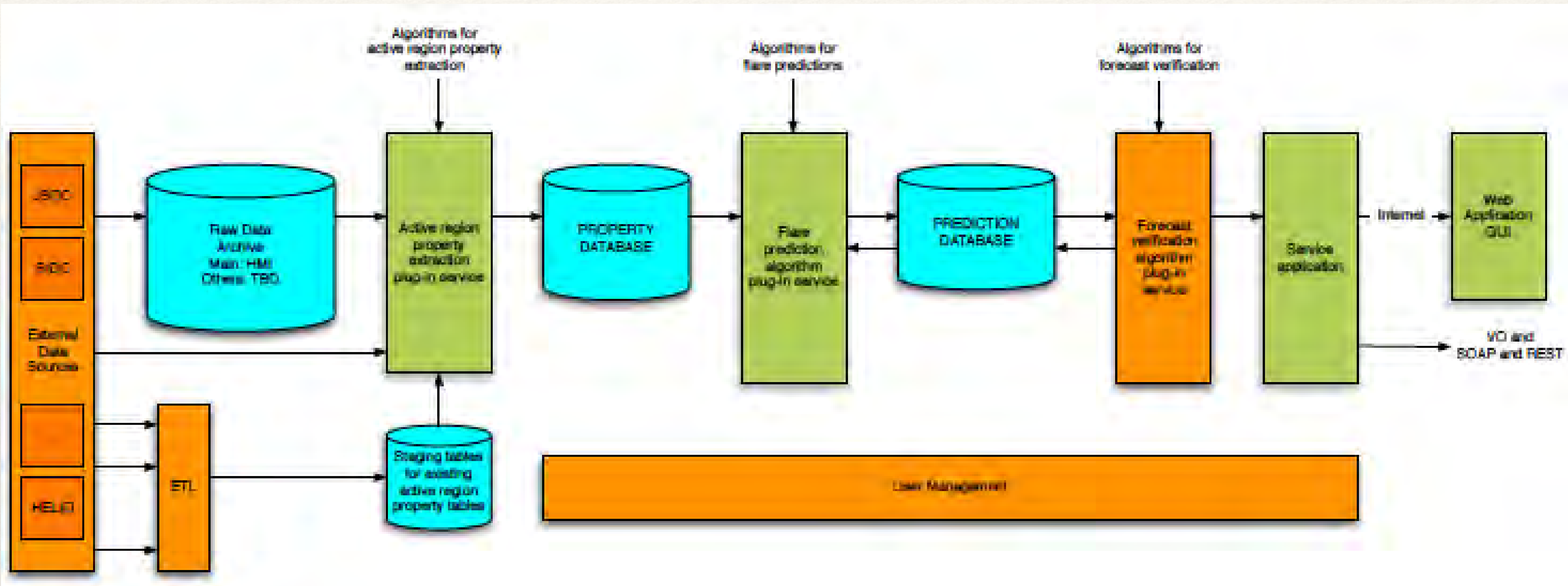
WT3: Flare Prediction Algorithms

FLARECAST will utilize the best published (scientific) flare prediction algorithms (aiming to see which of them, or which combinations of them, can notably improve our forecast capability

A.M. Massone CNR

WT4Data Storage and Processing Cloud

WT4: Data Storage and Processing Cloud F. Baudin, E. Buchlin MEDOC (IAS) Lead M. Piana (UNIGE)



Databases Flare data SDO/ HMI , others?
Active Region Properties **MEDOC**
Prediction data base

Services: algorithms for AR properties extraction, Flare prediction can be plugged in

WT5 Data and Forecast Validation

WT5: Data and Forecast Validation (D.S Bloomfield, TCD (leader) and D. Jackson (UK Met Office))

Dichotomous Forecasting (Yes/ No)

		Predicted		
		YES	NO	TOTAL
Observed	YES	F_{11} (hits)	F_{12} (misses)	N_{event}
	NO	F_{21} (false alarms)	F_{22} (correct negatives)	
	TOTAL	$N_{forecast}$		

(a)

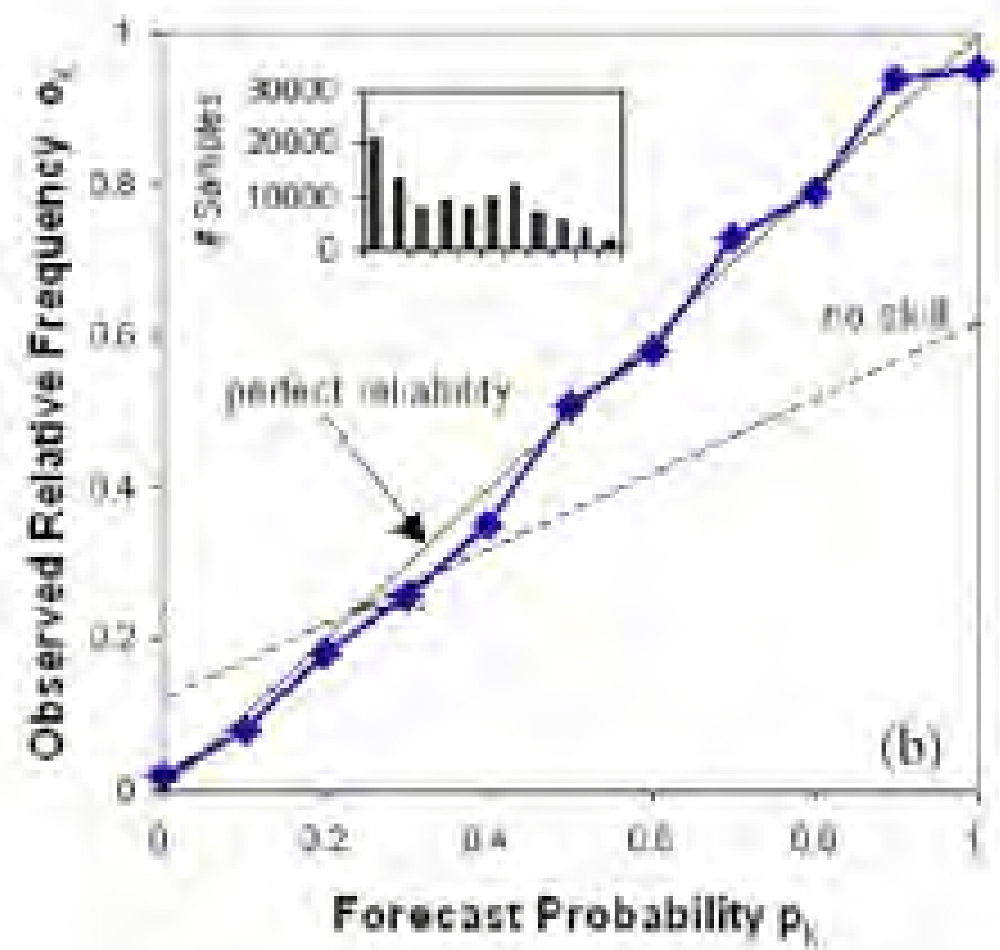
Source: World Climate Research Programme (WCRP)

Joint Working Group on Forecast Verification Research

2 x 2 Contingency Table

- Critical Success Index (CSI)
- Probability of false alarm (PFA)
- …

Probabilistic Forecasting



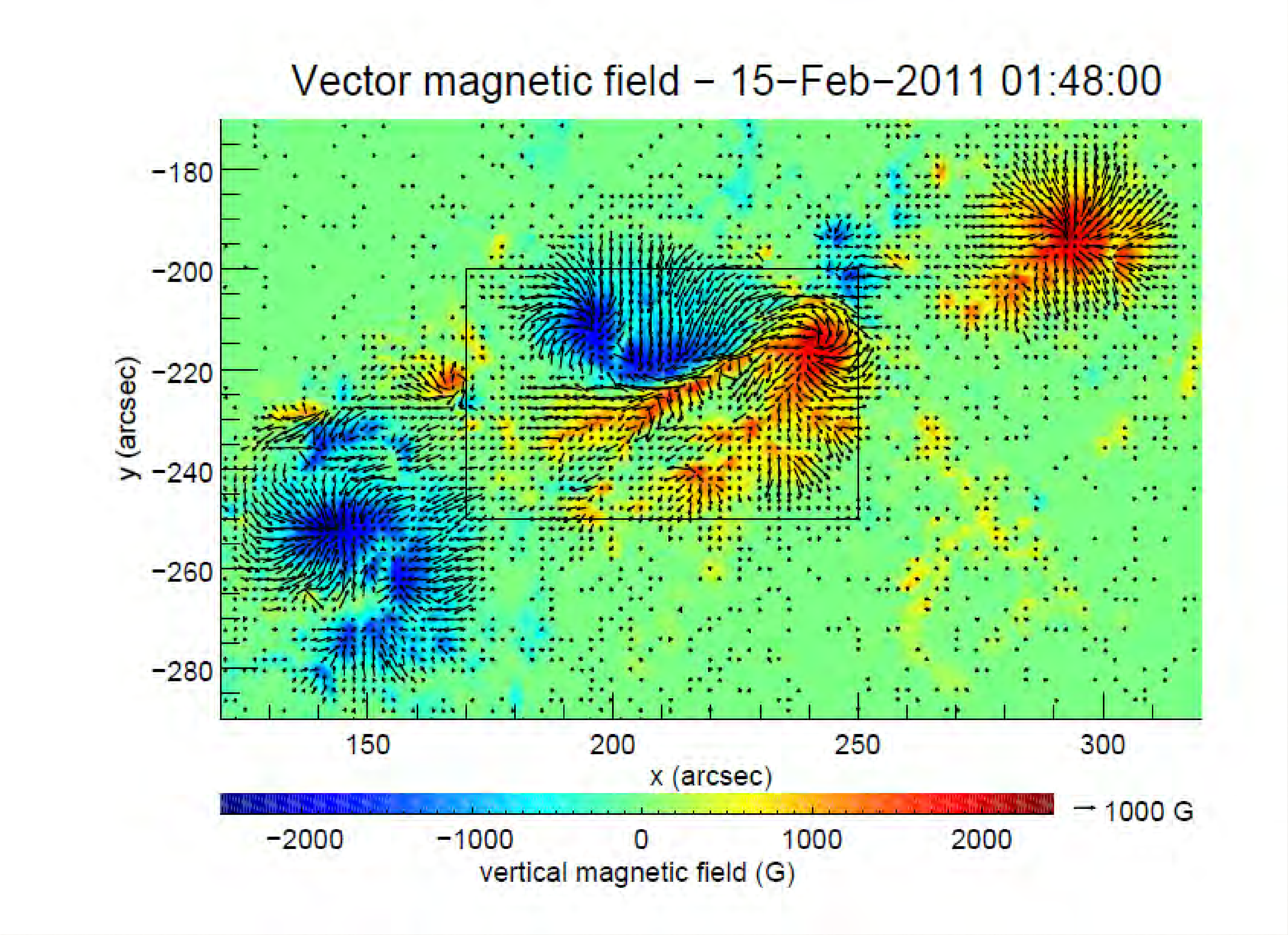
Reliability Diagram

Skill Score:

$$SS(p,o) = 1 - \frac{MSE(p,o)}{MSE(<o>,o)}$$

WT6 : Explorative Research

CNRS LESIA lead (E. Pariat, N. Vilmer, V. Bommier)
+TCD, UNIGE,AA,UK MetOffice



SDO/ HMI Observations
Investigate the use of vector magnetic field

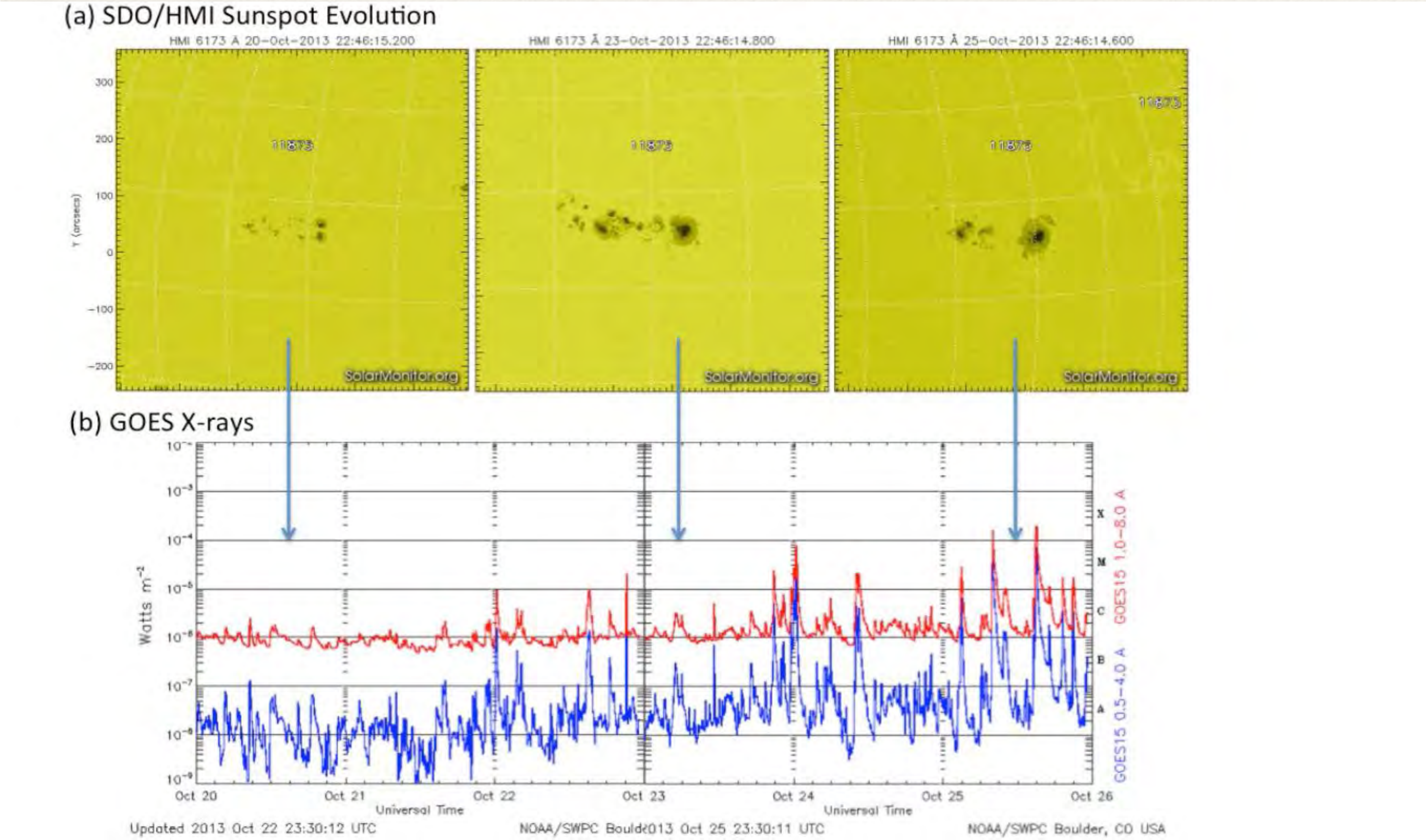
- Understand solar magnetic eruptions: Which are the dominant effects (properties of ARs and evolution which trigger the eruption of magnetic configurations)

Investigate new, and innovative flare predictors, their time series and combinations,evaluate their forecast performance and integrate them into existing or new prediction algorithms. In addition, extend the results of flare prediction into CME onset prediction and advance knowledge of CME properties

WT6 : Explorative Research

List of new quantities possessing high potential as improved flare predictors

Investigation of the evolution of active region properties leading to flare activity



Evolution of the active region after flux emergence

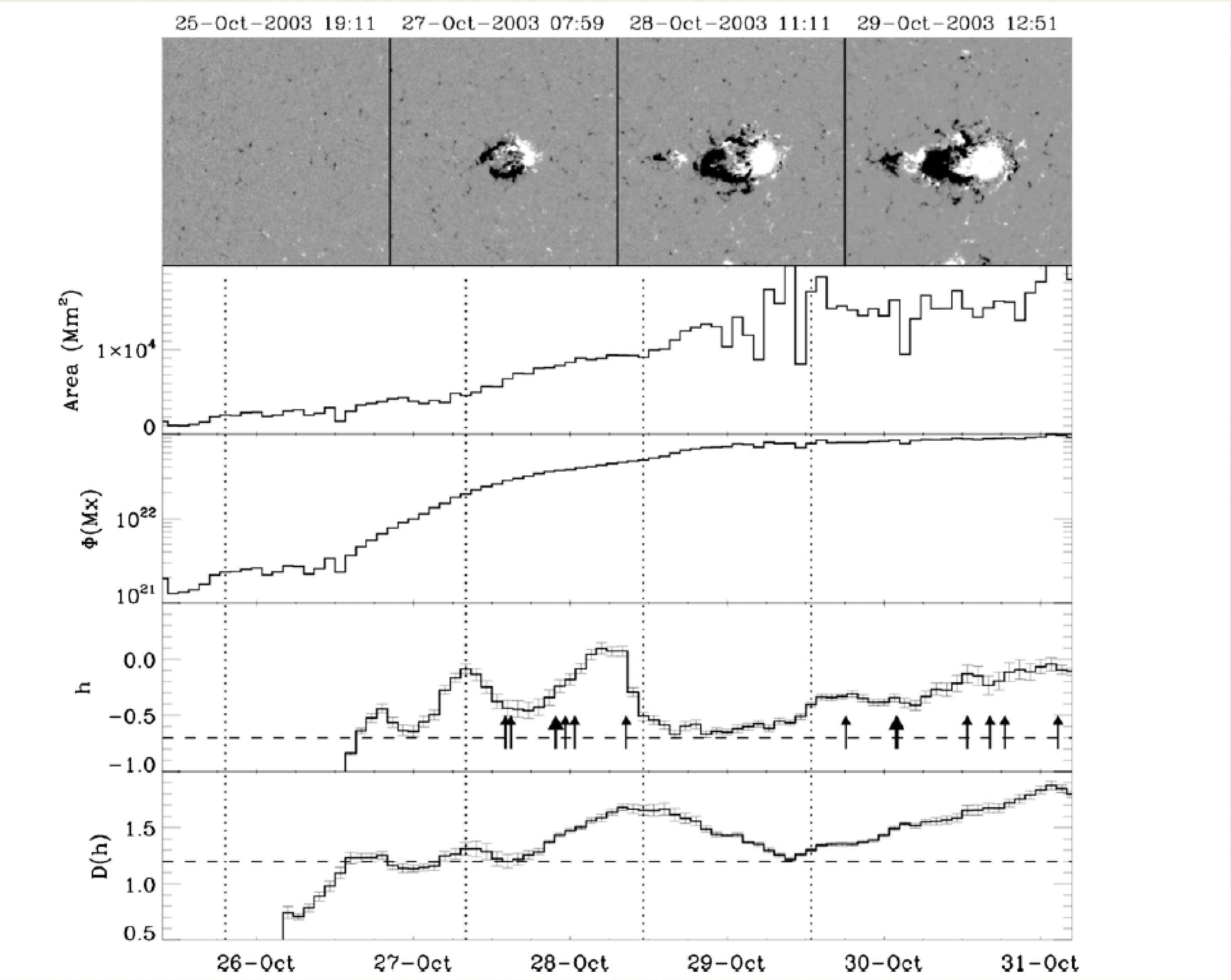
Evolution of other properties:
Magnetic fields?
Flows?
Vector magnetic fields?
Currents?

To be investigated

How long in advance to follow the AR evolution?

WT6 : Explorative Research

List of new quantities possessing high potential as improved flare predictors:
e.g. fractal dimension
Investigation of the evolution of active region properties leading to flare activity



Combination of properties leading to large flares:
Not only complexity but also area and magnetic flux

Total area Mm^2

Total unsigned magnetic flux Mx

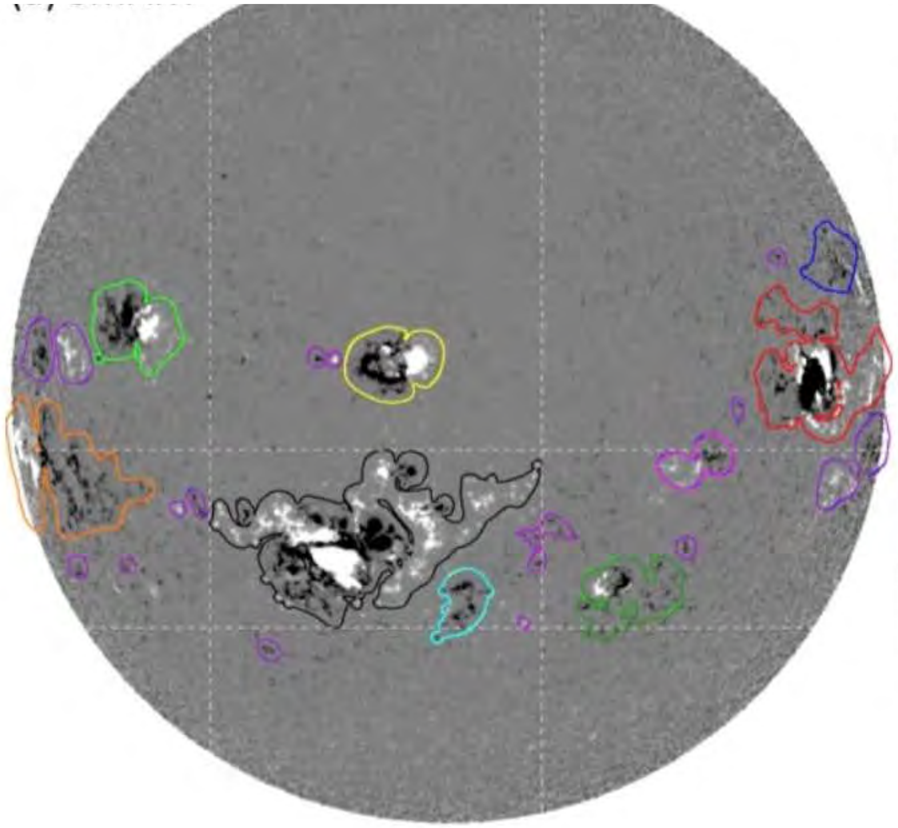
Hölder exponent: multifractal analysis
Reconfiguration of B fields

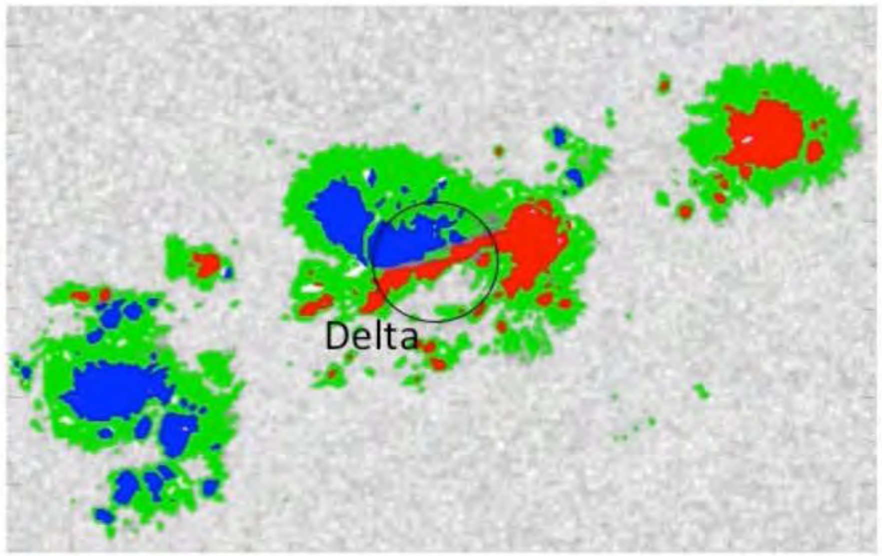
fractal dimension
McAteer , et al., 2005

Conlon et al., 2010

WT6 : Explorative Research

Active Region Properties	Data Sources	Algorithms
Area, number of spots, Hale class, McIntosh class	SWPC Solar Region Summary	N/A
Area, total flux, total negative/positive flux, flux imbalance, flux emergence rate, max/min field strength, PSL length, magnetic gradient, PSL gradient, Schrijver *R*, Falconer *WL*	Magnetograms	SMART [1] *R* [2]
Hale delta configuration	Magnetograms and white light images	Delta Finder [3]
Horizontal flow velocities, shear, gradients, vorticity	Magnetograms and white light images	FLCT [4]
Multiscale spectrum	Magnetograms	[5]
B_{eff} – Effective magnetic field strength	Magnetograms	[6]
Ising energy	Magnetograms	[7]
Fractal dimension	Magnetograms	[8]





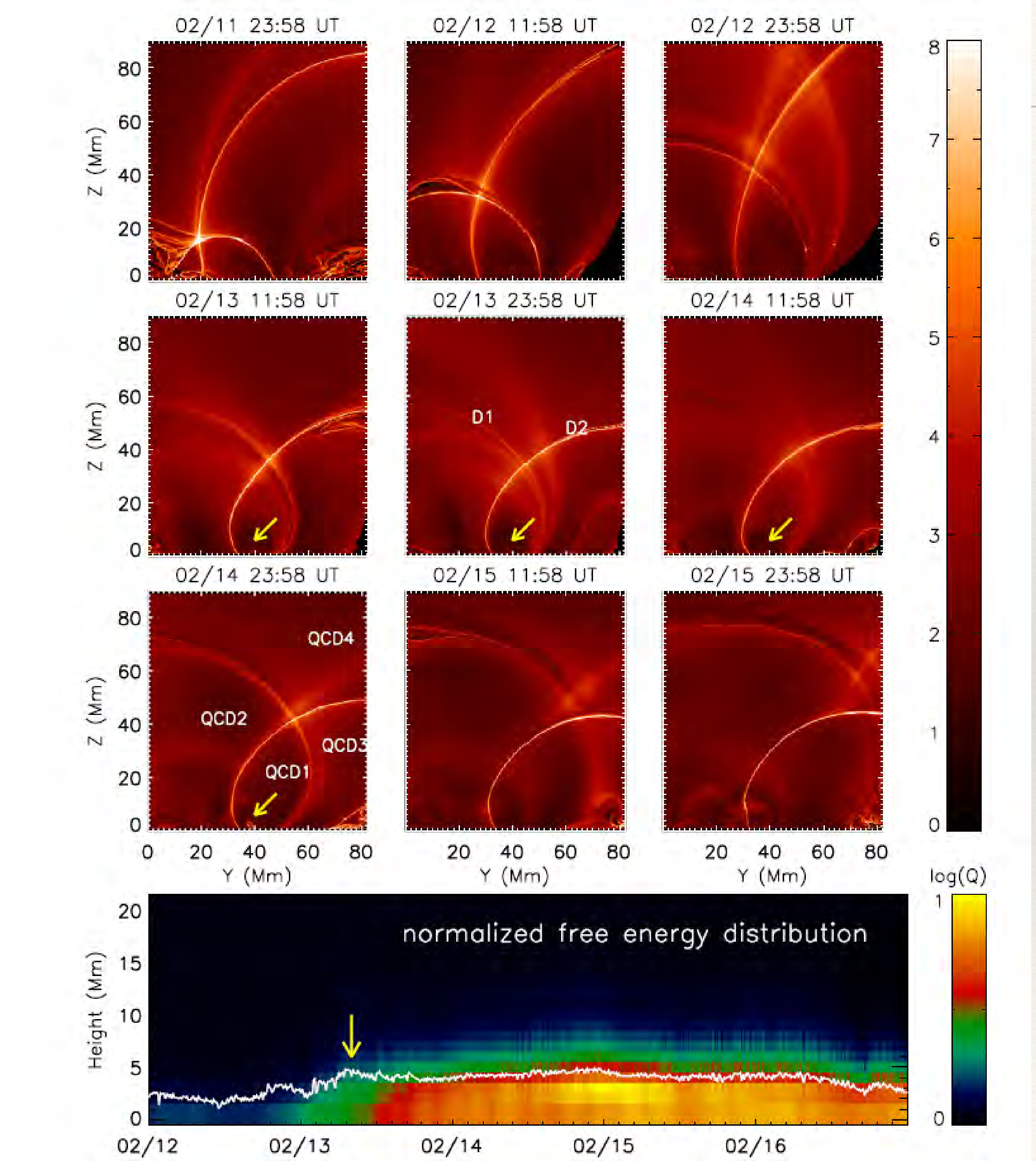
Investigate which ones of the properties or combinations are useful

Investigate use of <u>vector magnetic field</u> from SDO/HMI

Higgins et al., 2011
Padinhatteeri et al., 2014

More than 25 properties of ARs automatically tracked

WT6 Explorative Research



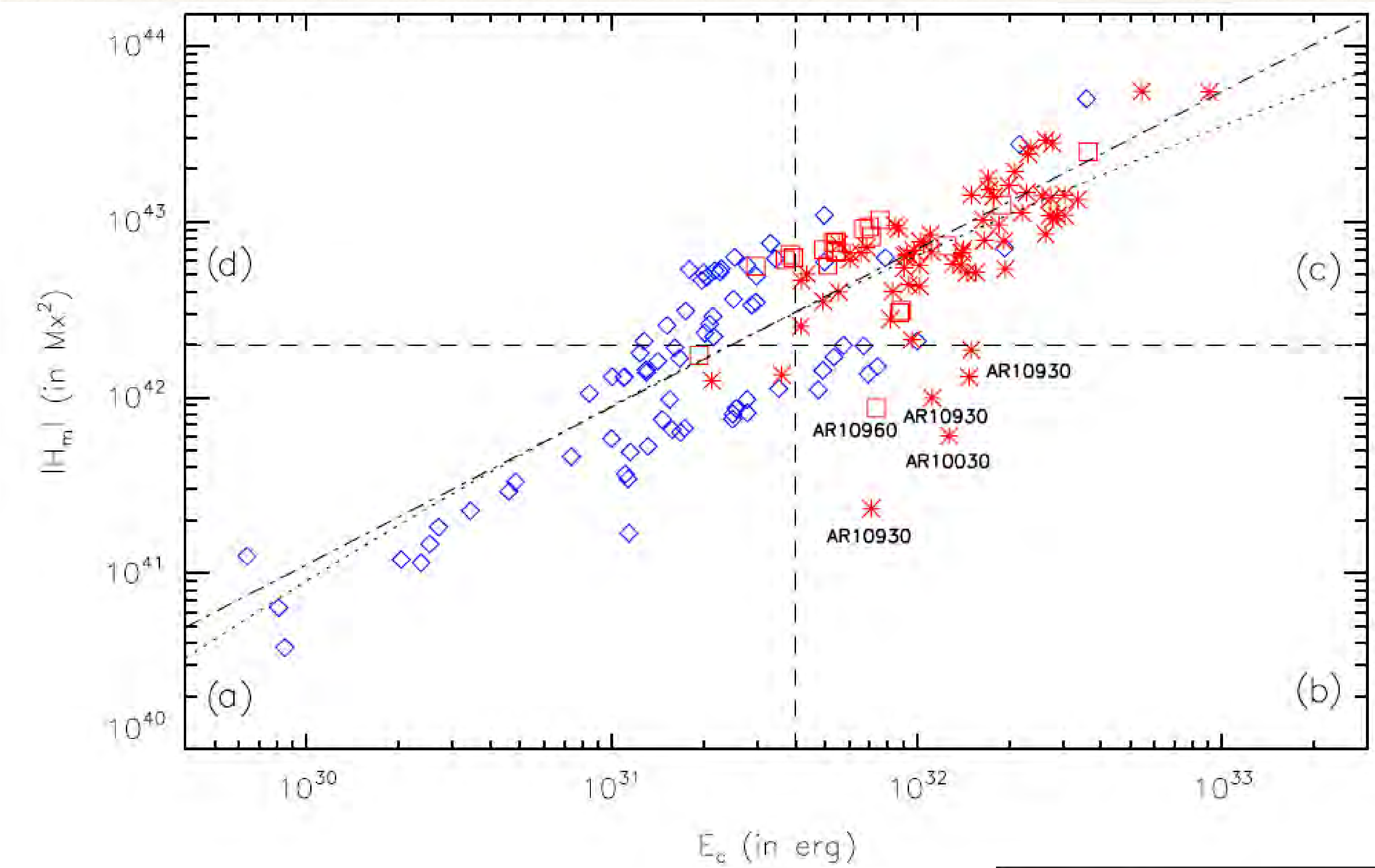
Investigation of the use of
Vector magnetic fields

NLFF magnetic extrapolation based on
SDO/HMI observations of
vector magnetograms

Evolution of Q maps:
Quasi separatrix Layers

Evolution of the normalized free energy
as a function of height and time
in AR 11158
before the X class flare of 15/12/01
(Zhao, Li, Pariat et al;, 2014)

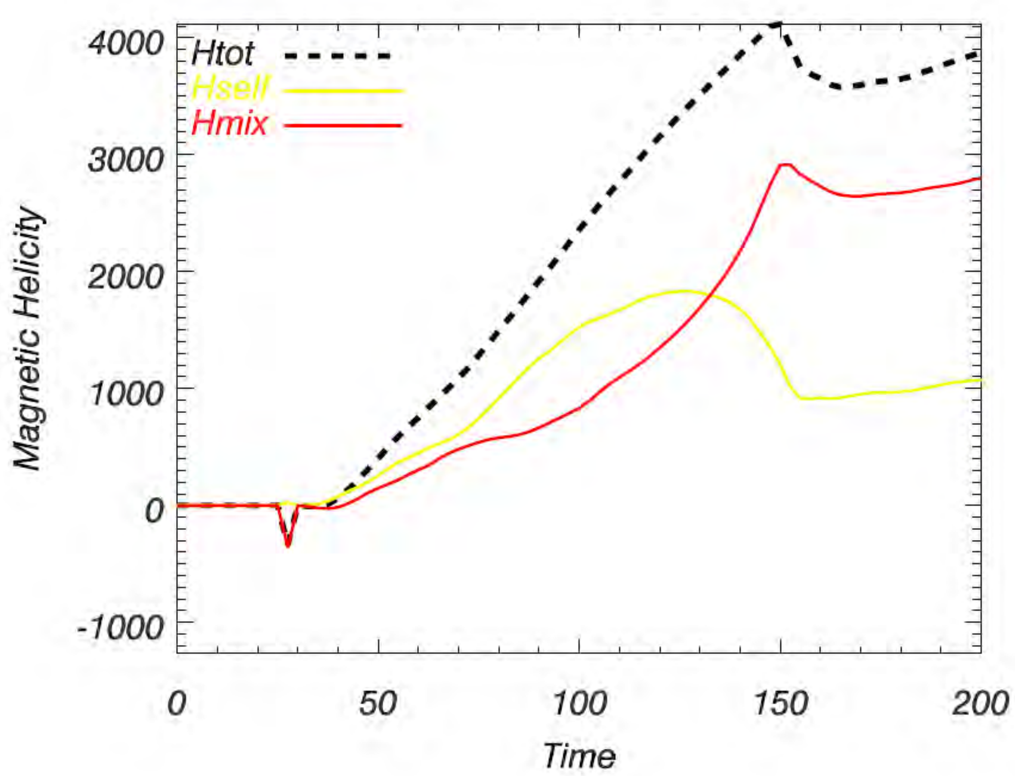
WT6 : Explorative Research

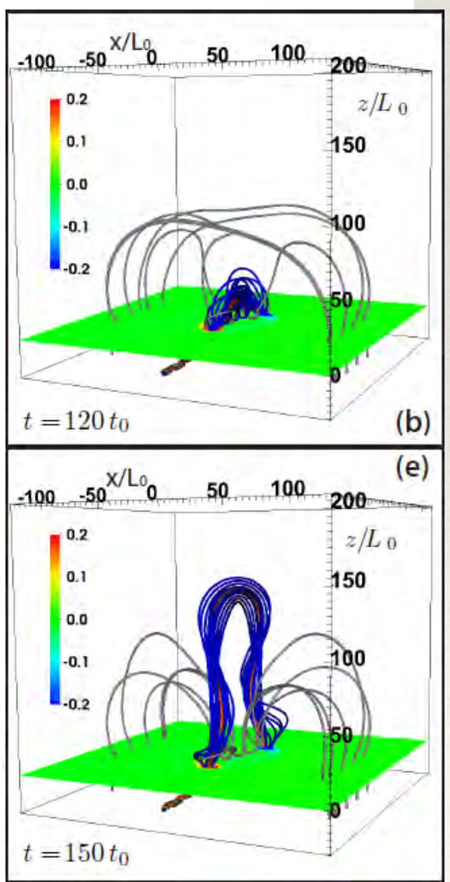


Investigate one of the few invariant of MHD : magnetic helicity

Helicity conservation plays role in:
-dynamo
- magnetic reconnection
- CME ejection

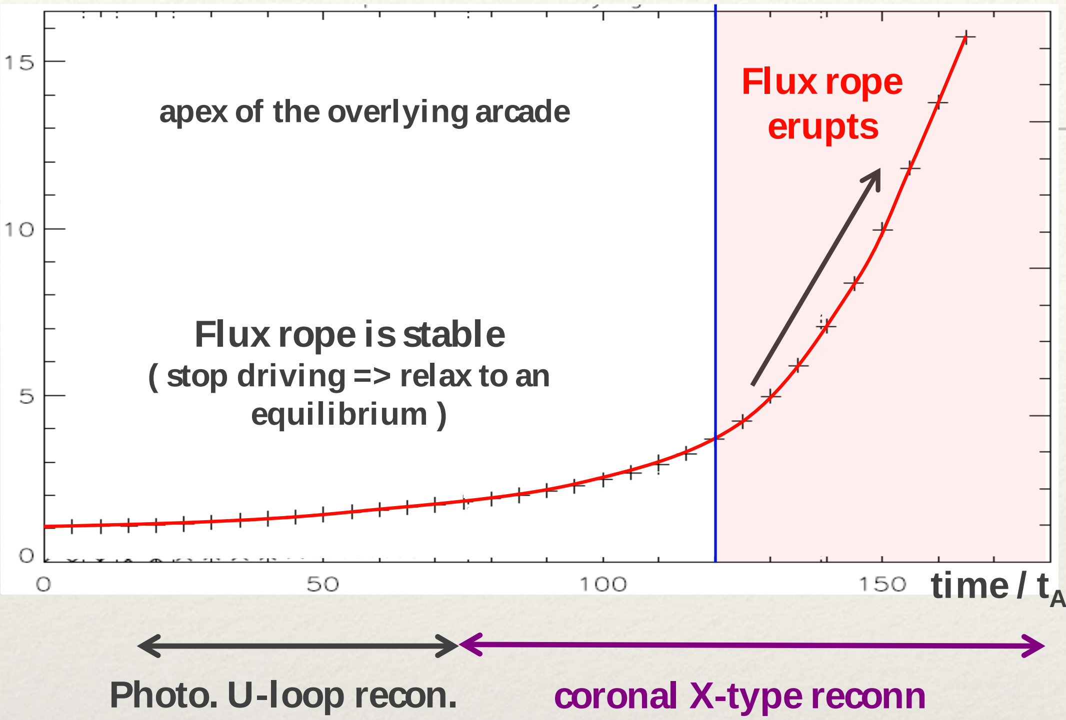
Methods of measures recently developed:
Georgoulis et al. 08, 12, Valori et al. 12, Moraitis et al. 14

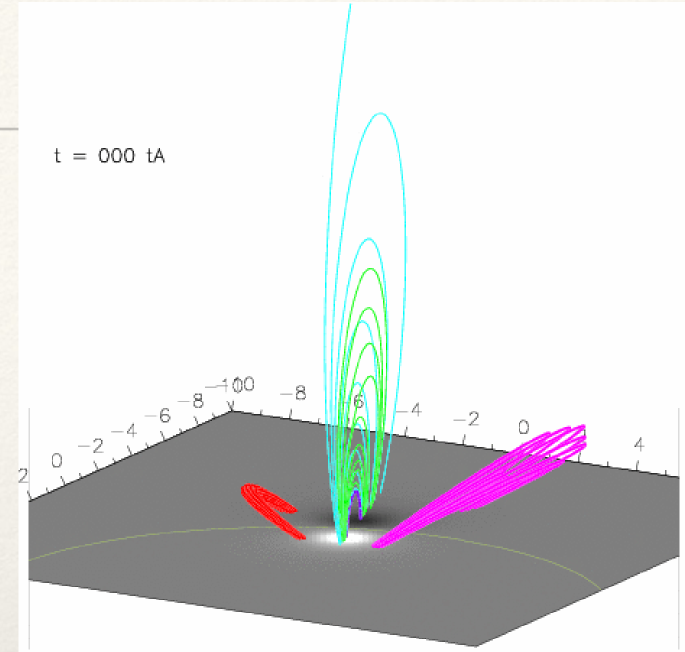




Study and determine the role of magnetic helicity
- MHD simulations
-observational data

WT6 : Explorative Research

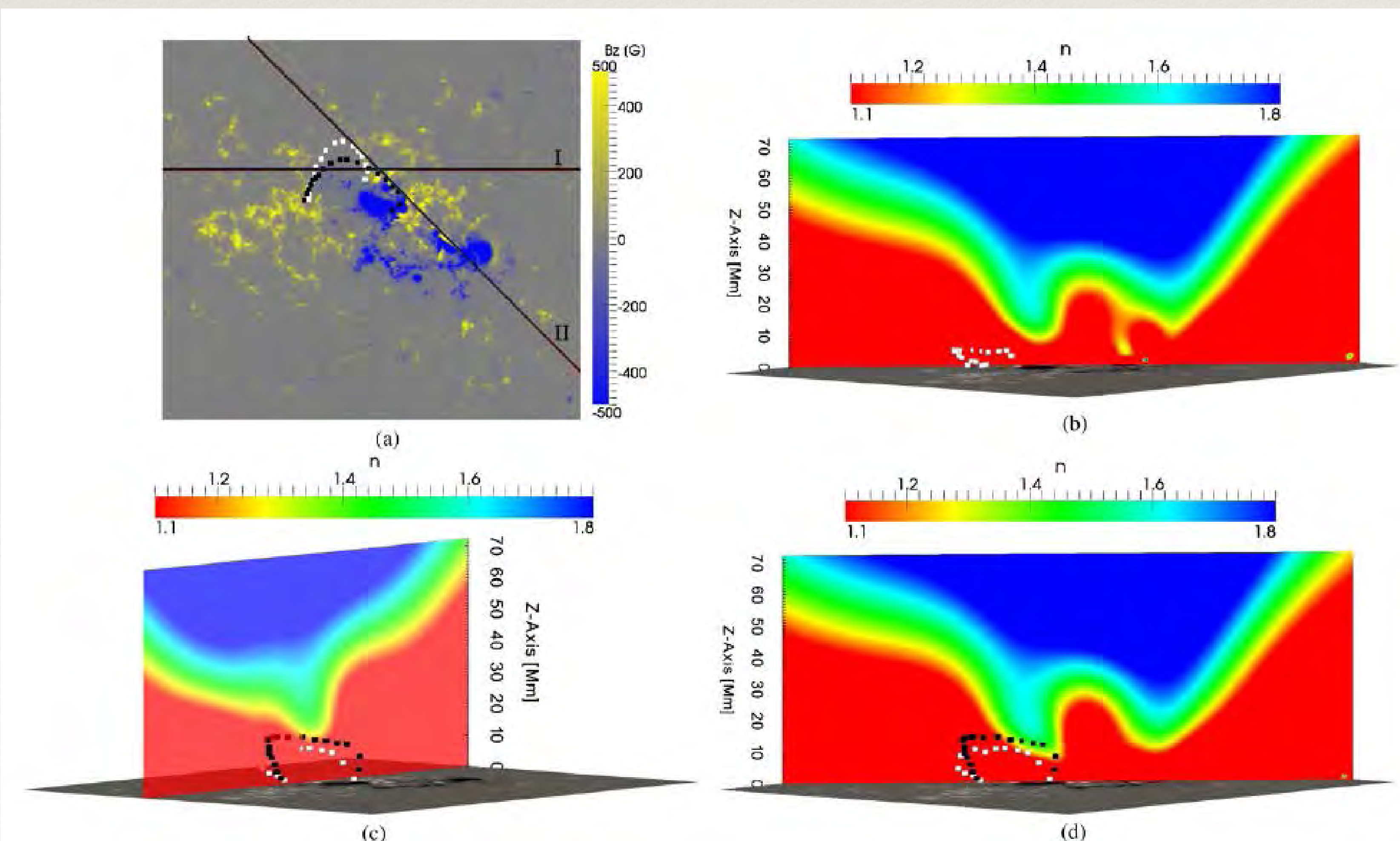




Study the trigger of CMEs:
Rôle of the Torus instability

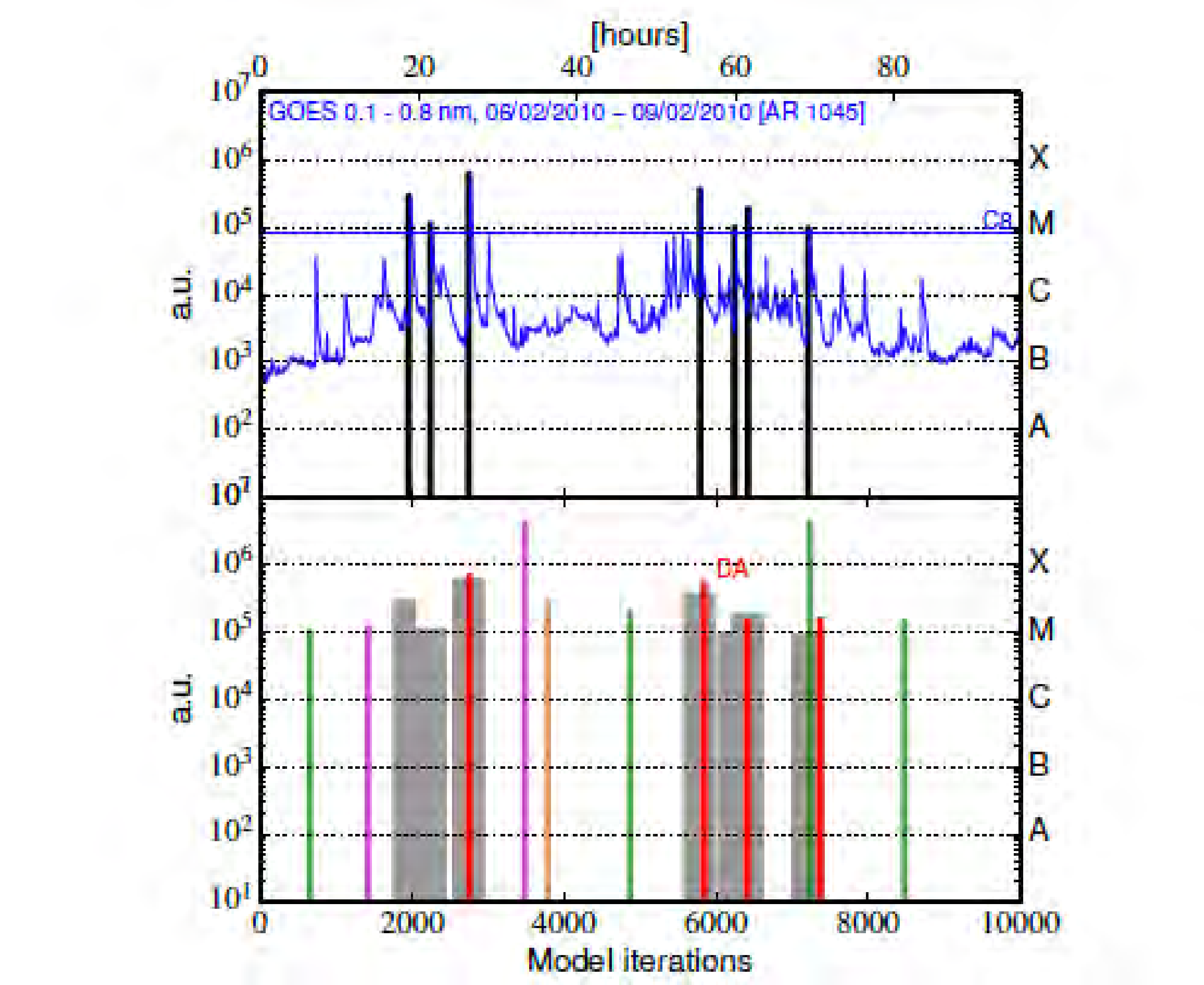
Theoretical studies indicating dominent role of Torus instability : Aulanier et al. 10,12; Savcheva et al. 12; Zuccarello et al. 14

Study and determine whether the ‘‘decay index, n’’ can be used as a CME trigger predictor



(a) (b) (c) (d)

WT6 Explorative Research



nvestigation of time series of flare predictors

If a flare has occurred, more will occur

(e.g. Wheatland, 2005;
Strugarek& Charboneau; 2014)

**Example of a run using data assimilation for the GOES flux in the 1–8 *A*˙ range during the flaring events of the active region 1045 between February 6 and February 9, 2010. The top panel show the GOES flux (blue)
The bottom panel shows the GOES signal (grey boxes) used in the data assimilation run. The assimilated sequence (DA) is shown in red along with three random realizations of the model in orange, green and magenta.
(Strugarek & Charboneau; 2014)**

FLARECAST

web page
http://flarecast.eu

WT7 : dissemination
H. Sathiapal FHNW

Still under construction