FLARECAST

THE FLARECAST PROJECT AND WHAT LIES BEYOND

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FLARECAST (EC/H2020 grant No. 640216): flarecast.eu

EGU GENERAL ASSEMBLY 2016

Vienna, Austria, April 17 - 22, 2016

OUTLINE

FLARECAST

★ **The problem:** predicting space weather (in general) & solar flares (in particular)

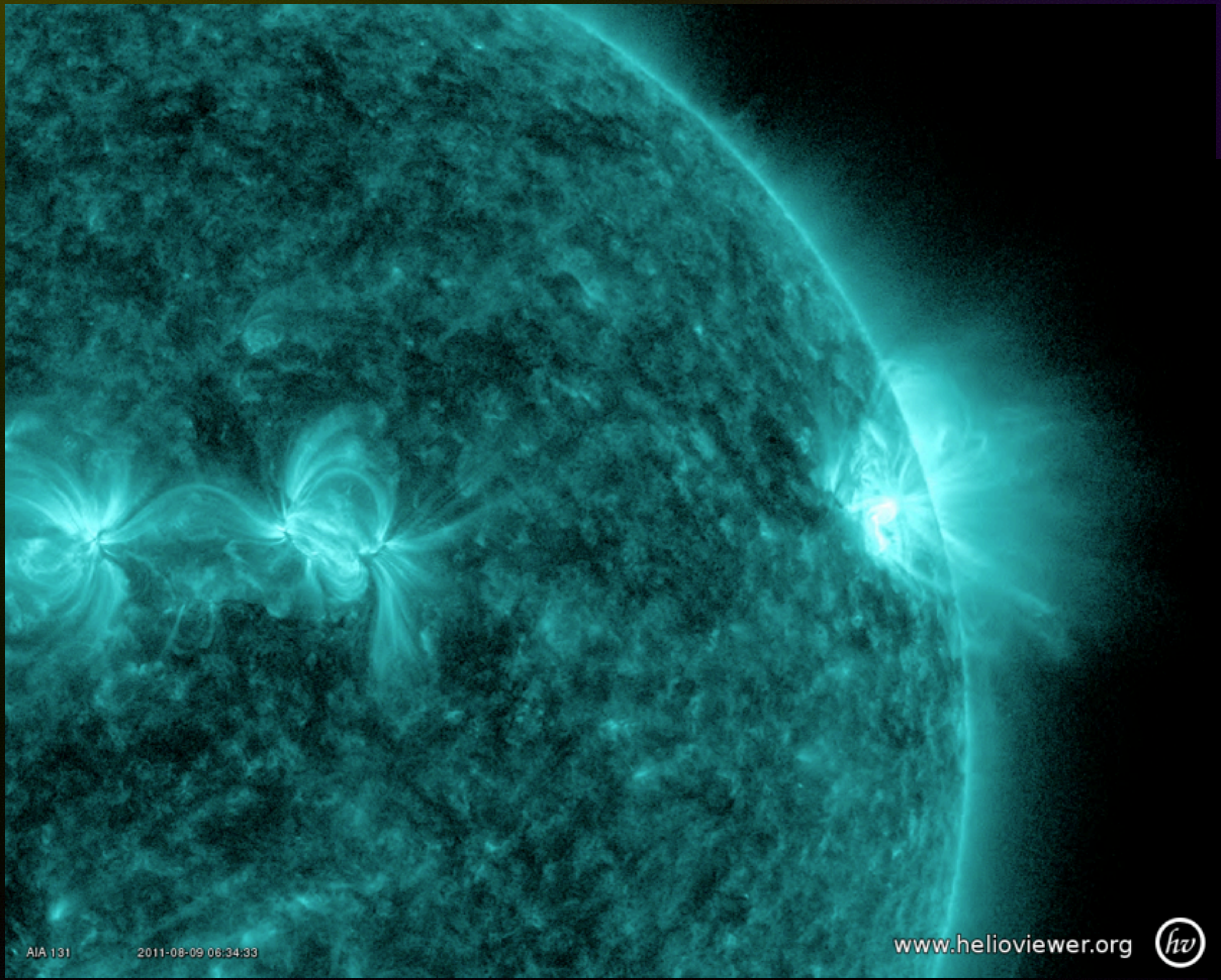
★ **The approach:** FLARECAST

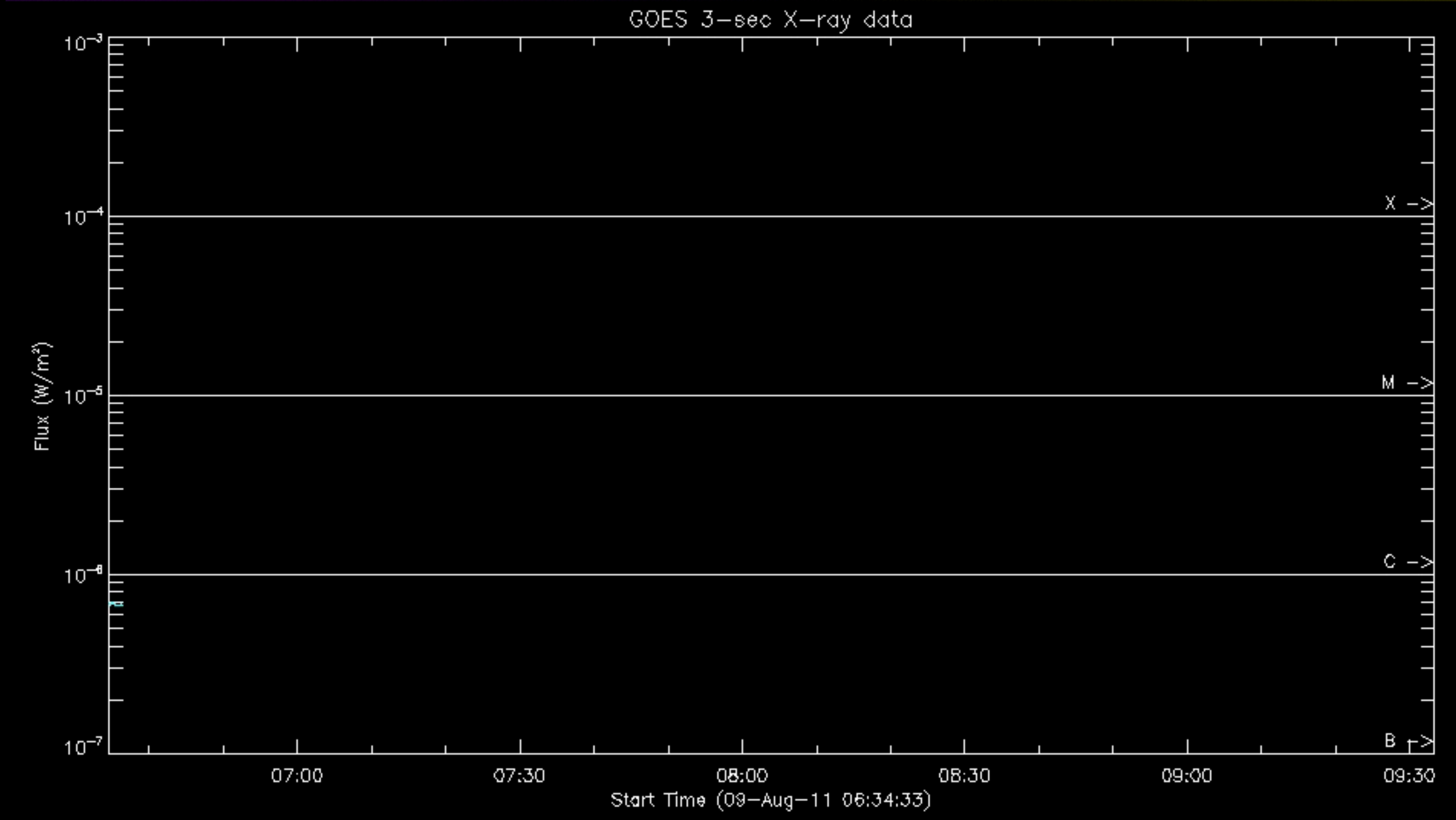
- *Science*
- *Architecture*
- *Expected results*

★ **The fusion:** FLARECAST & other FP7 & H2020 SWx projects

★ **Conclusion**

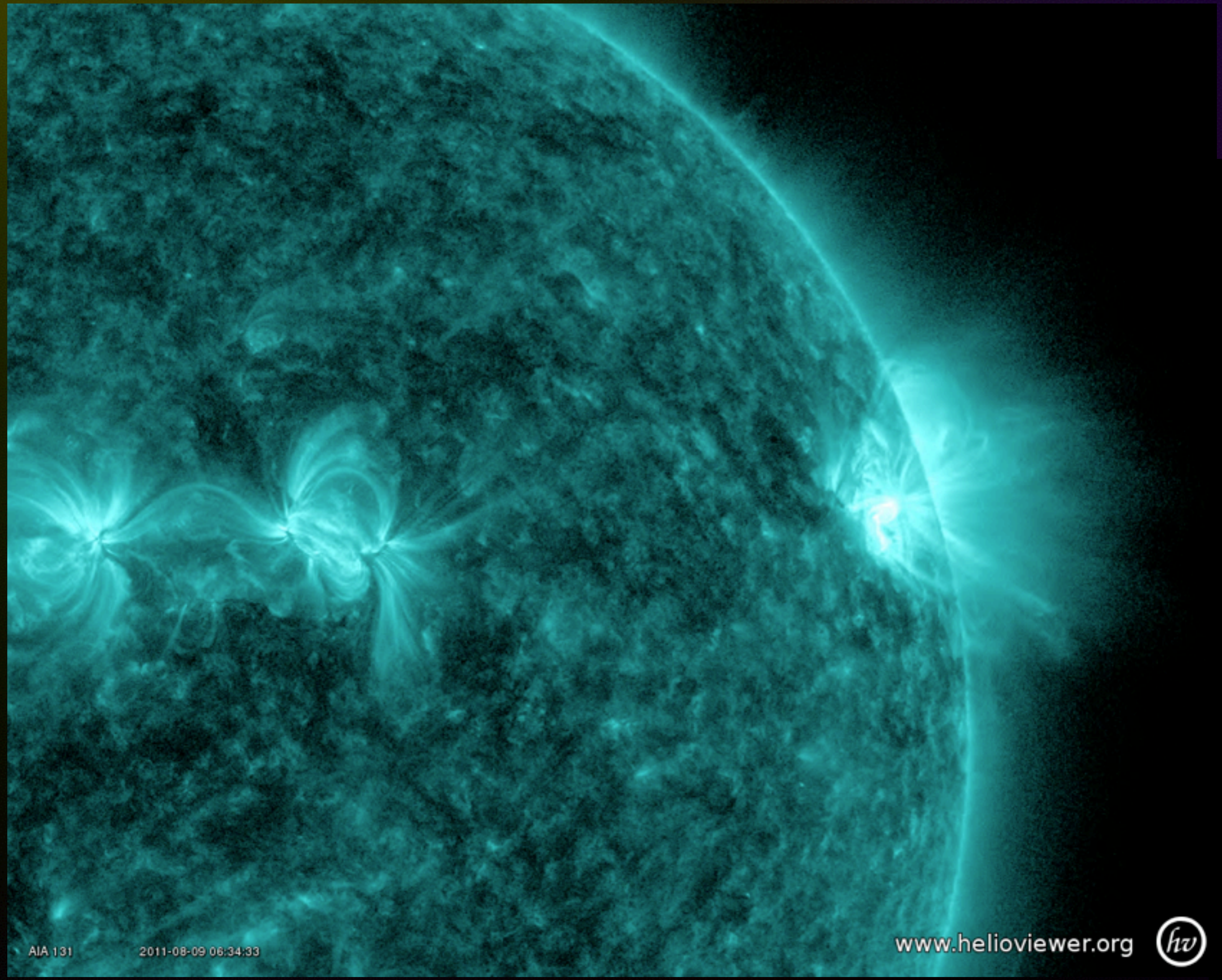
SOLAR FLARES: THE SINGLE …

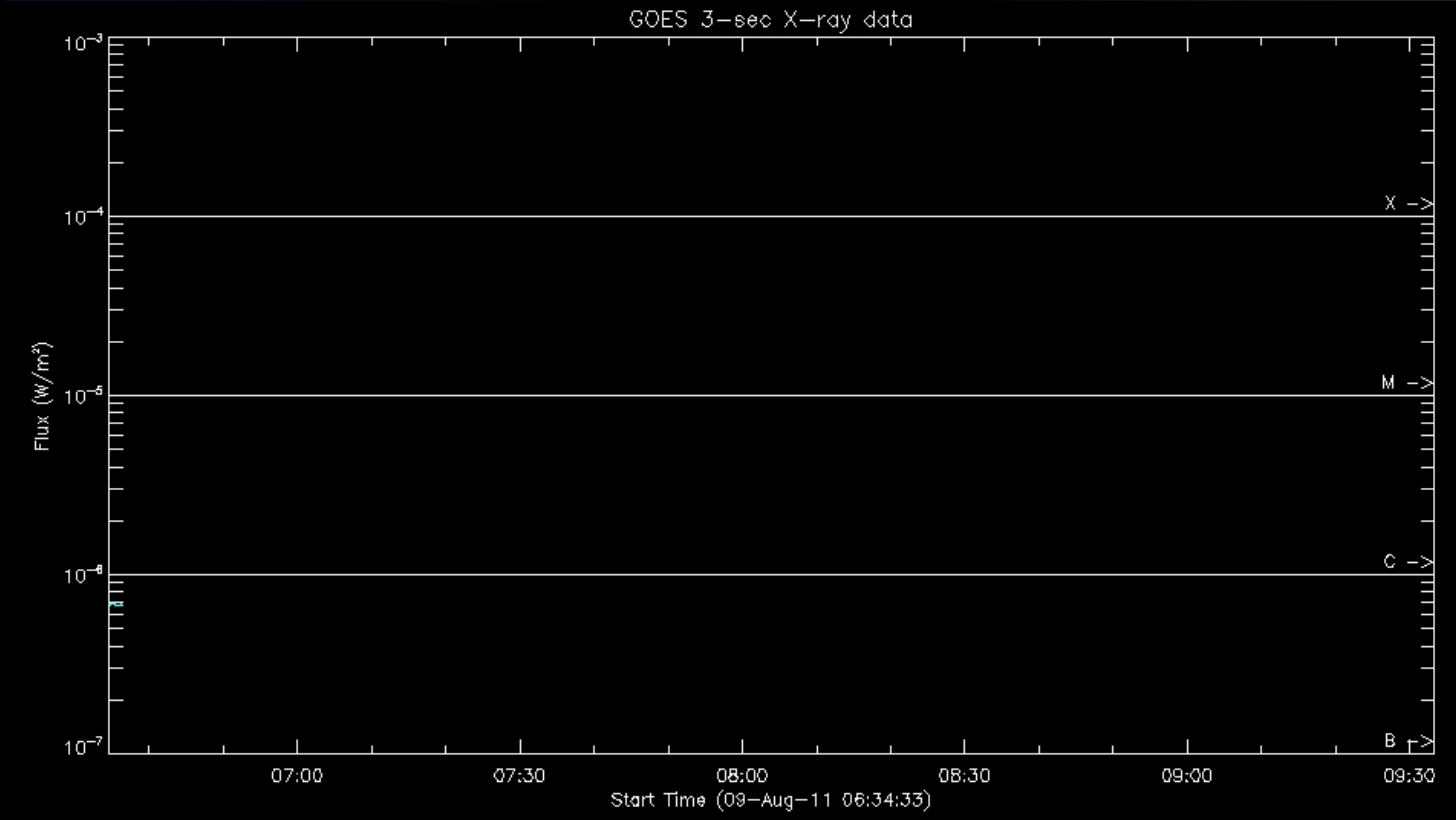




A sudden commencement of enhanced, localized electromagnetic emission extending over practically the entire range of the electromagnetic spectrum, from γ-ray to radio wavelengths

SOLAR FLARES: THE SINGLE …





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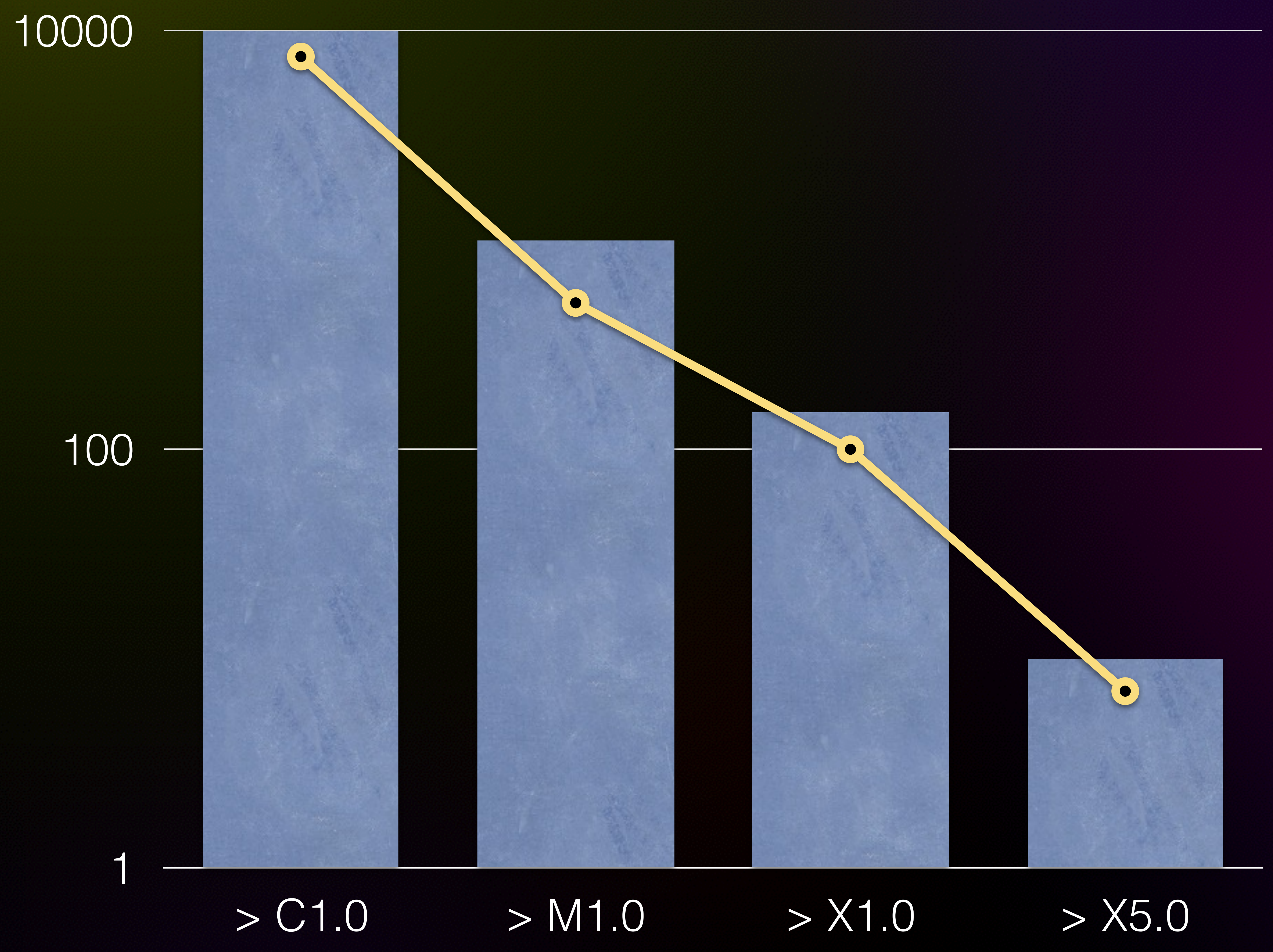
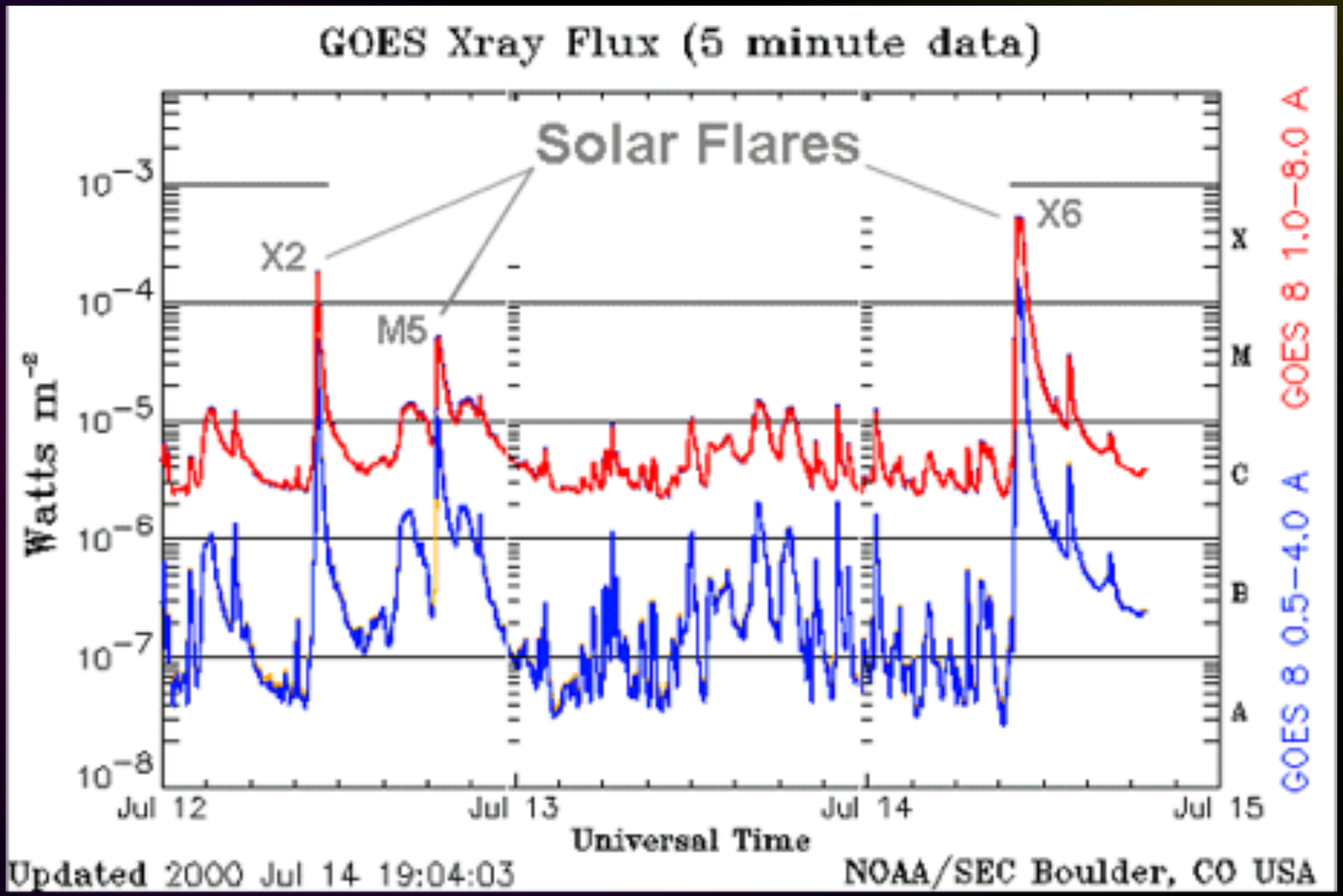
SOLAR FLARES: … AND THE PLENTY

No. of flares per class over typical solar cycle

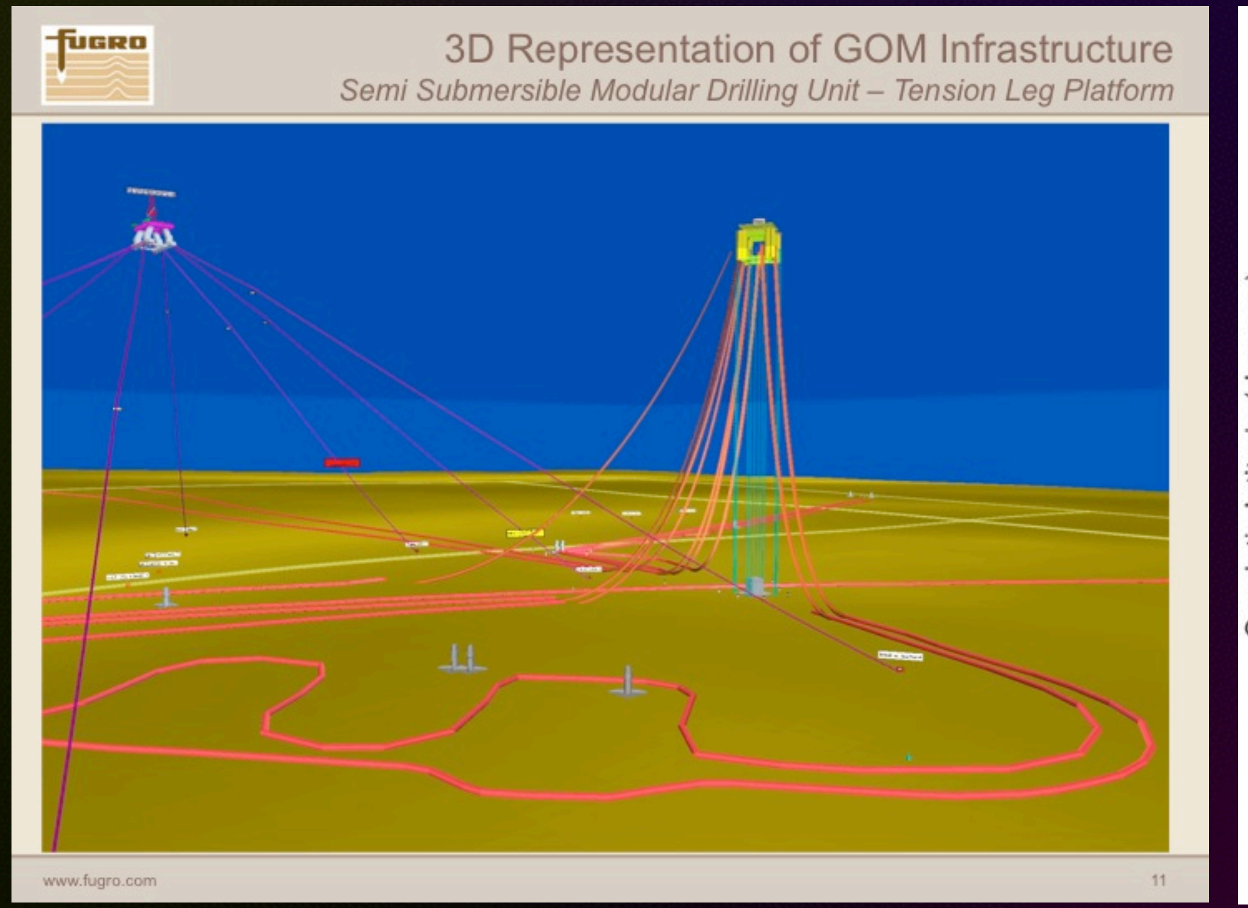


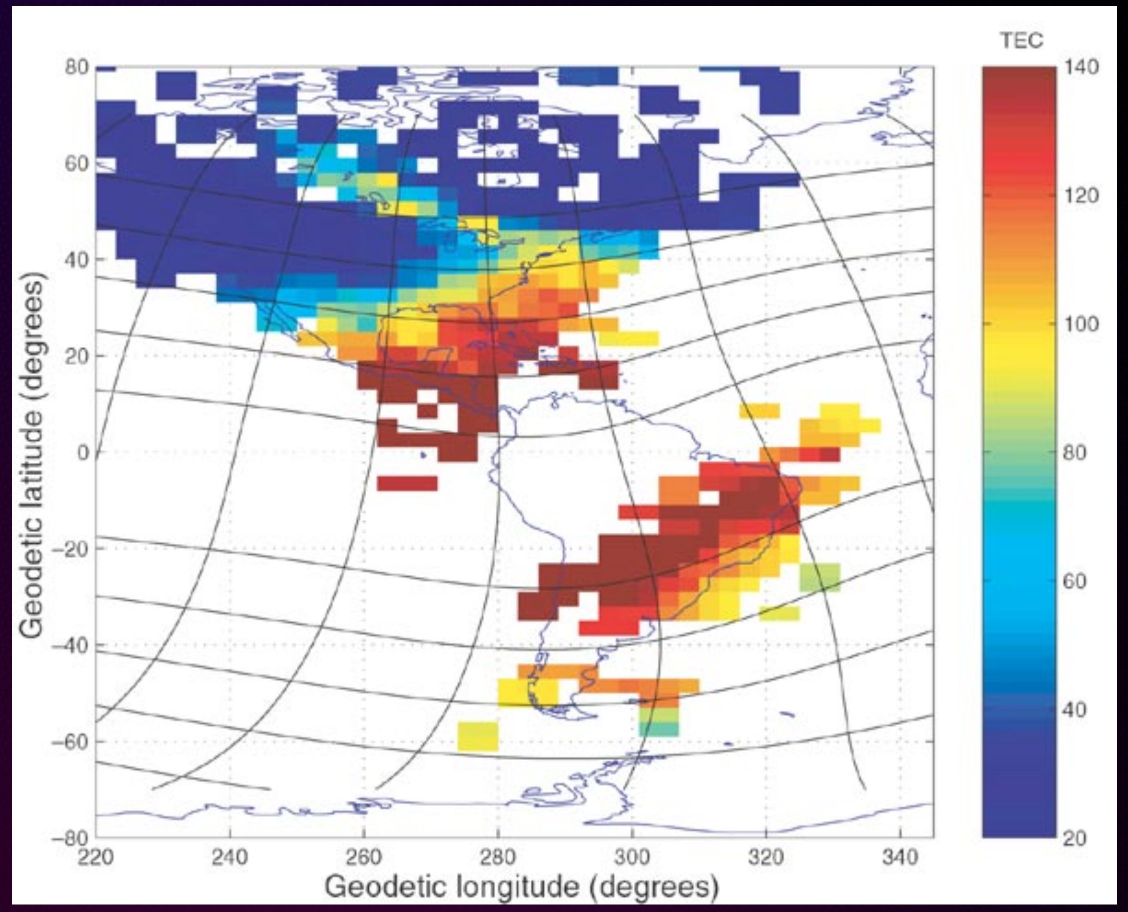


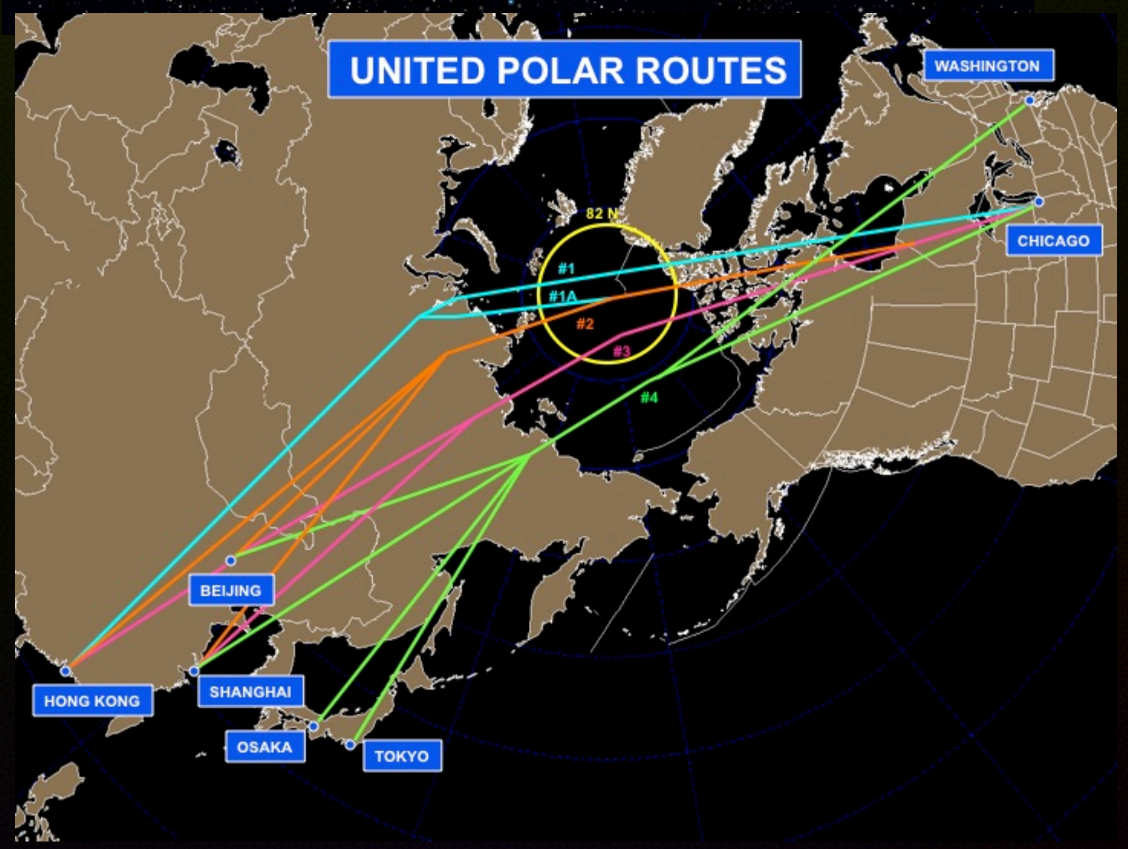
"Active" solar conditions over a 3-day period in July 2000

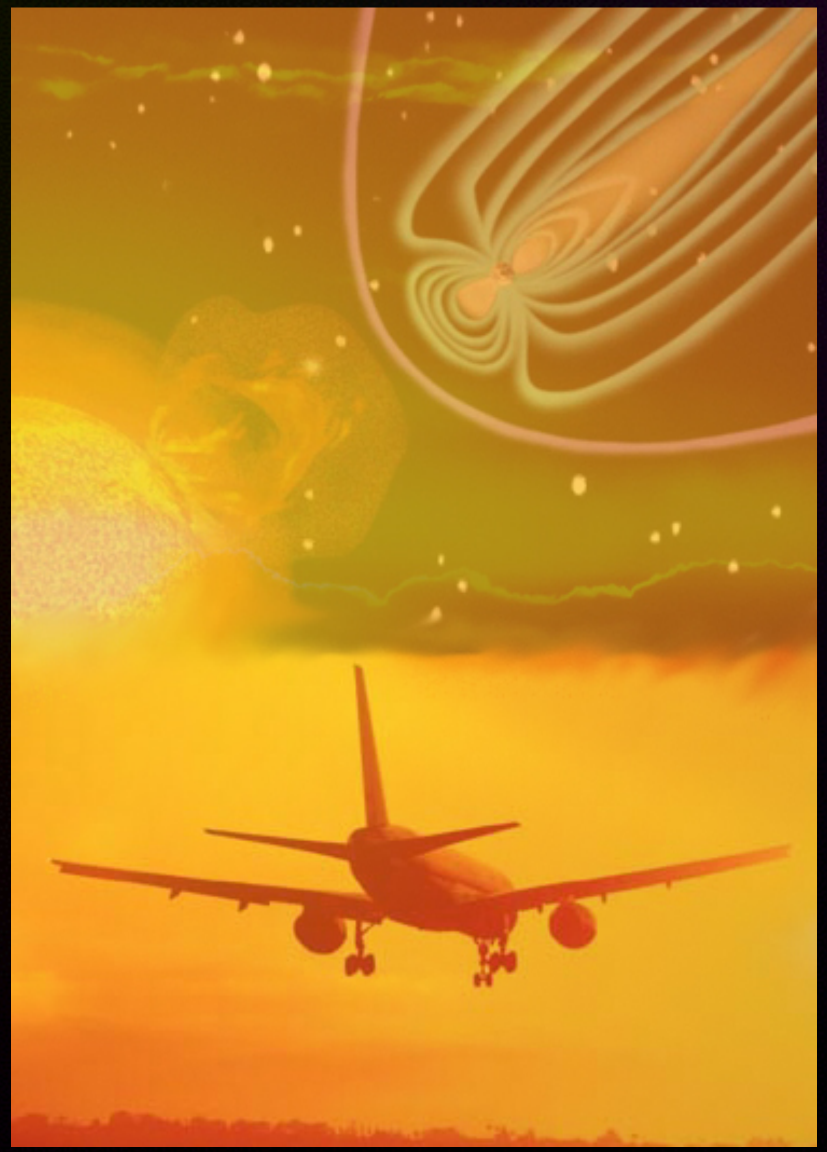
MAJOR FLARE REPERCUSSIONS: EVERYTHING UNDER THE SUN

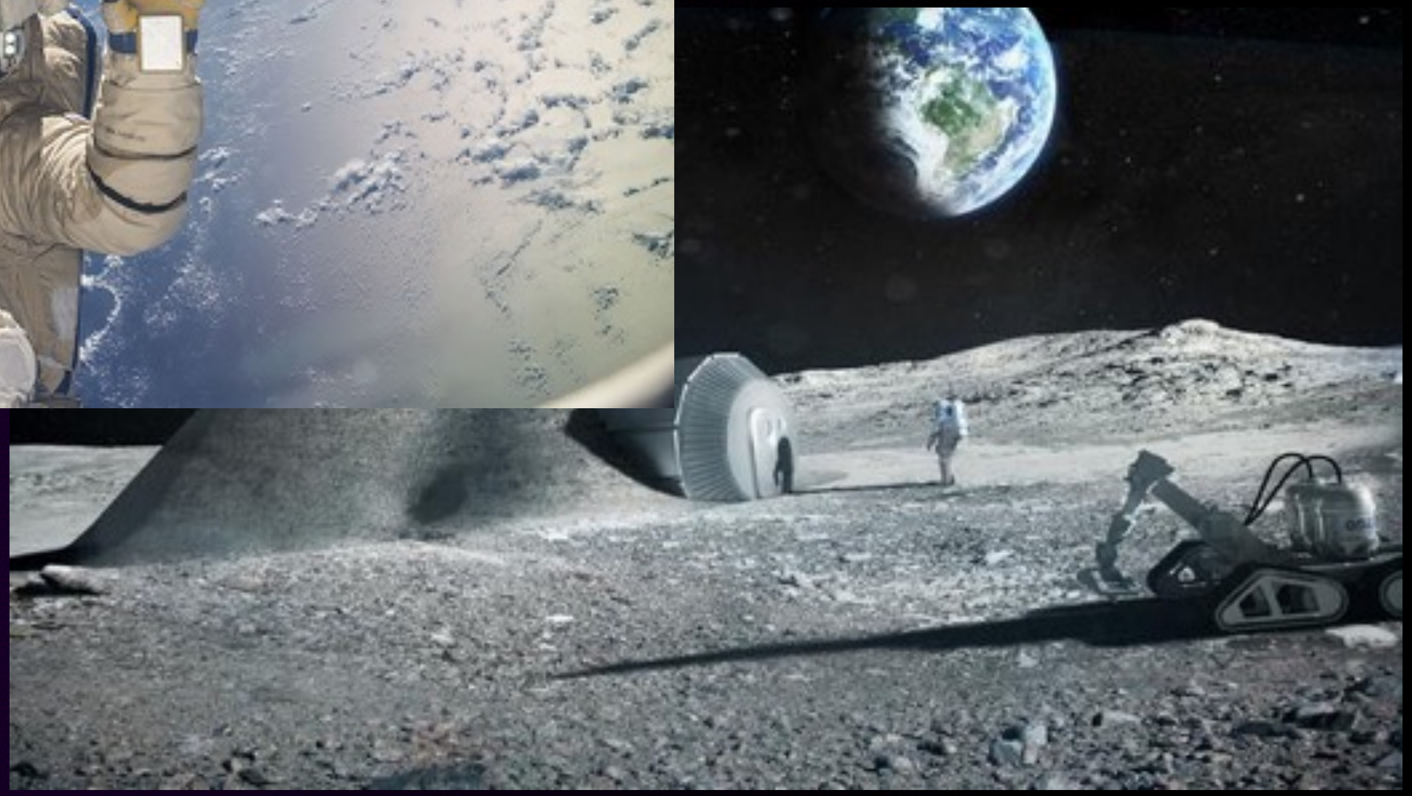
FLARECAST











THE CHALLENGE

Objective: predict solar flares from near real-time (NRT) observations of solar evolution

- Prediction typically incolves solar photospheric (LOS or vector) magnetic field measurements. SDO/HMI is the most prominent source of these data
- Predictive parameters are inferred locally
- Observational cadence:
  - — 45 s, for full-disk LOS data
  - — 720 s, for full-disk vector data

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THE APPROACH: FLARECAST / H2020 PROTEC-2014 PROJECT

FLARECAST

"Diverse expertise and ways of thinking … this is what FLARECAST is all about"
(FLARECAST 1st year press release)

Science
- solar physics
- artificial intelligence
- validation
- exploration

Infrastructure
- hardware
- software buildup

Communication
- governments / end users
- public

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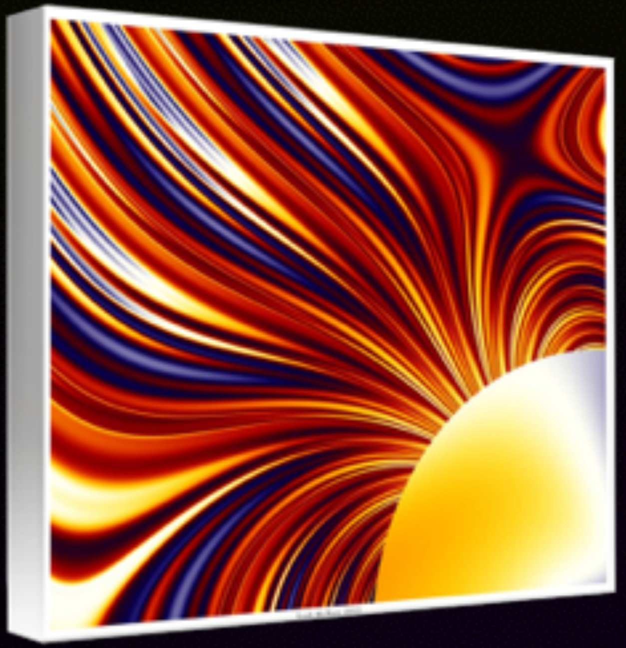
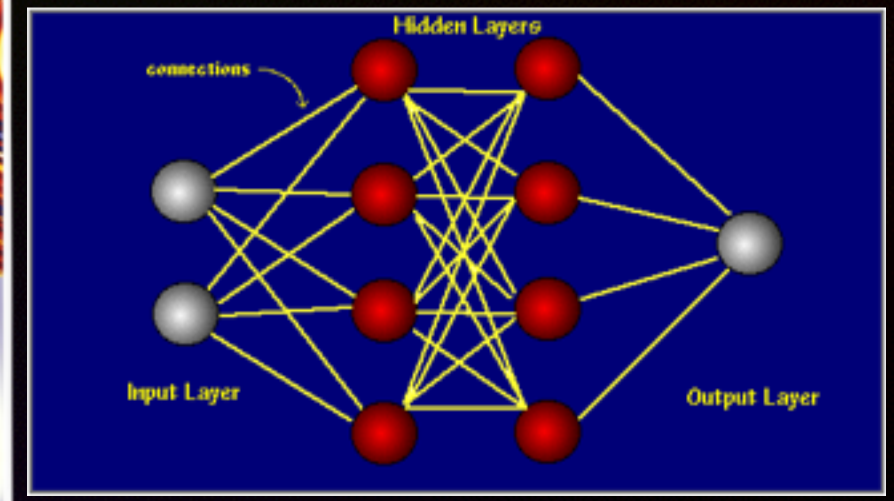
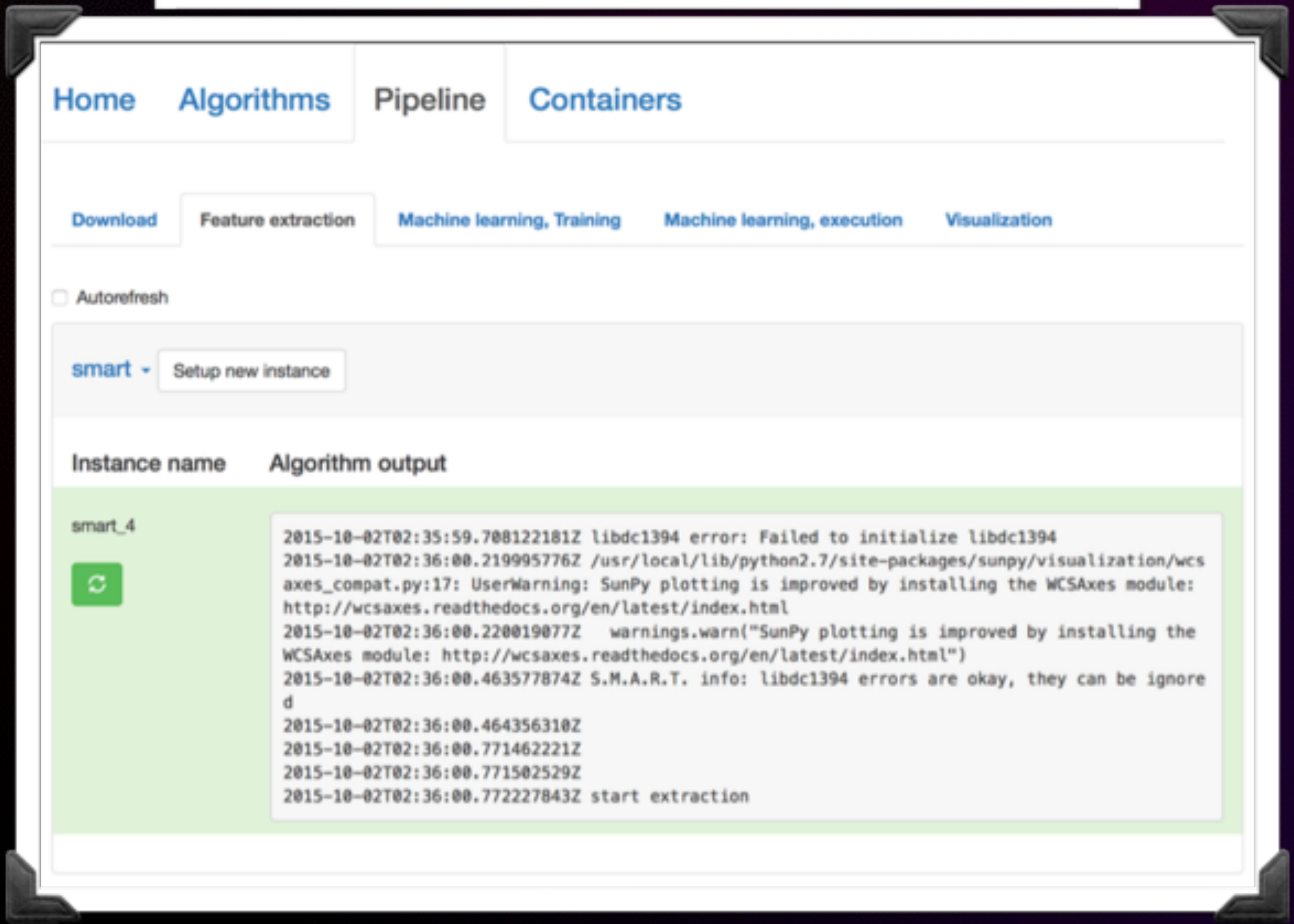




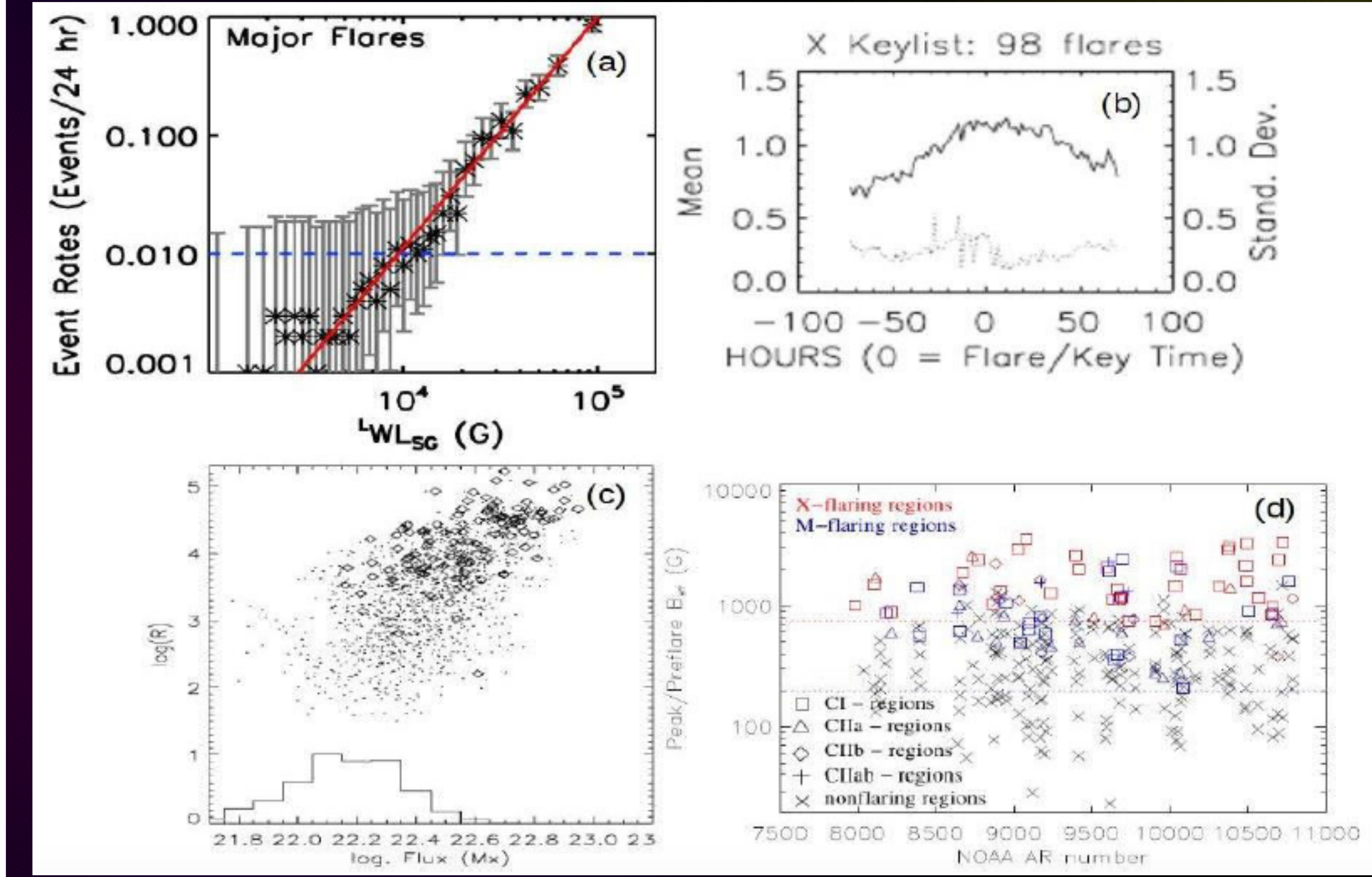
Credit: celestial dreams



FLARECAST SCIENCE: SOLAR FLARE PREDICTORS

FLARECAST

Keyword	Description	Formula	*F*-Score	Selection
TOTUSJH	Total unsigned current helicity	$H_{c_{\text{total}}} \propto \sum \lvert B_z \cdot J_z \rvert$	3560	Included
TOTBSQ	Total magnitude of Lorentz force	$F \propto \sum B^2$	3051	Included
TOTPOT	Total photospheric magnetic free energy density	$\rho_{\text{tot}} \propto \sum \left(\mathbf{B}^{\text{Obs}} - \mathbf{B}^{\text{Pot}}\right)^2 dA$	2996	Included
TOTUSJZ	Total unsigned vertical current	$J_{z_{\text{total}}} = \sum \lvert J_z \rvert dA$	2733	Included
ABSNJZH	Absolute value of the net current helicity	$H_{c_{\text{abs}}} \propto \lvert \sum B_z \cdot J_z \rvert$	2618	Included
SAVNCPP	Sum of the modulus of the net current per polarity	$J_{z_{\text{sum}}} \propto \left\lvert \sum^{B_z^+} J_z dA \right\rvert + \left\lvert \sum^{B_z^-} J_z dA \right\rvert$	2448	Included
USFLUX	Total unsigned flux	$\Phi = \sum \lvert B_z \rvert dA$	2437	Included
AREA_ACR	Area of strong field pixels in the active region	Area $= \sum$ Pixels	2047	Included
TOTFZ	Sum of *z*-component of Lorentz force	$F_z \propto \sum (B_x^2 + B_y^2 - B_z^2) dA$	1371	Included
MEANPOT	Mean photospheric magnetic free energy	$\overline{\rho} \propto \frac{1}{N} \sum \left(\mathbf{B}^{\text{Obs}} - \mathbf{B}^{\text{Pot}}\right)^2$	1064	Included
R_VALUE	Sum of flux near polarity inversion line	$\Phi = \sum \lvert B_{LoS} \rvert dA$ within R mask	1057	Included
EPSZ	Sum of *z*-component of normalized Lorentz force	$\delta F_z \propto \frac{\sum (B_x^2 + B_y^2 - B_z^2)}{\sum B^2}$	864.1	Included
SHRGT45	Fraction of Area with shear $> 45°$	Area with shear $> 45°$ / total area	740.8	Included
MEANSHR	Mean shear angle	$\overline{\Gamma} = \frac{1}{N} \sum \arccos\left(\frac{\mathbf{B}^{\text{Obs}} \cdot \mathbf{B}^{\text{Pot}}}{\lvert \mathbf{B}^{\text{Obs}} \rvert \lvert \mathbf{B}^{\text{Pot}} \rvert}\right)$	727.9	Discarded
MEANGAM	Mean angle of field from radial	$\overline{\gamma} = \frac{1}{N} \sum \arctan\left(\frac{B_h}{B_z}\right)$	573.3	Discarded
MEANGBT	Mean gradient of total field	$\overline{\lvert \nabla B_{\text{tot}} \rvert} = \frac{1}{N} \sum \sqrt{\left(\frac{\partial B}{\partial x}\right)^2 + \left(\frac{\partial B}{\partial y}\right)^2}$	192.3	Discarded
MEANGBZ	Mean gradient of vertical field	$\overline{\lvert \nabla B_z \rvert} = \frac{1}{N} \sum \sqrt{\left(\frac{\partial B_z}{\partial x}\right)^2 + \left(\frac{\partial B_z}{\partial y}\right)^2}$	88.40	Discarded
MEANGBH	Mean gradient of horizontal field	$\overline{\lvert \nabla B_h \rvert} = \frac{1}{N} \sum \sqrt{\left(\frac{\partial B_h}{\partial x}\right)^2 + \left(\frac{\partial B_h}{\partial y}\right)^2}$	79.40	Discarded
MEANJZH	Mean current helicity (B_z contribution)	$\overline{H_c} \propto \frac{1}{N} \sum B_z \cdot J_z$	46.73	Discarded
TOTFY	Sum of *y*-component of Lorentz force	$F_y \propto \sum B_y B_z dA$	28.92	Discarded
MEANJZD	Mean vertical current density	$\overline{J_z} \propto \frac{1}{N} \sum \left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y}\right)$	17.44	Discarded
MEANALP	Mean characteristic twist parameter, α	$\alpha_{\text{total}} \propto \frac{\sum J_z \cdot B_z}{\sum B_z^2}$	10.41	Discarded
TOTFX	Sum of *x*-component of Lorentz force	$F_x \propto -\sum B_x B_z dA$	6.147	Discarded
EPSY	Sum of *y*-component of normalized Lorentz force	$\delta F_y \propto \frac{-\sum B_y B_z}{\sum B^2}$	0.647	Discarded
EPSX	Sum of *x*-component of normalized Lorentz force	$\delta F_x \propto \frac{\sum B_x B_z}{\sum B^2}$	0.366	Discarded

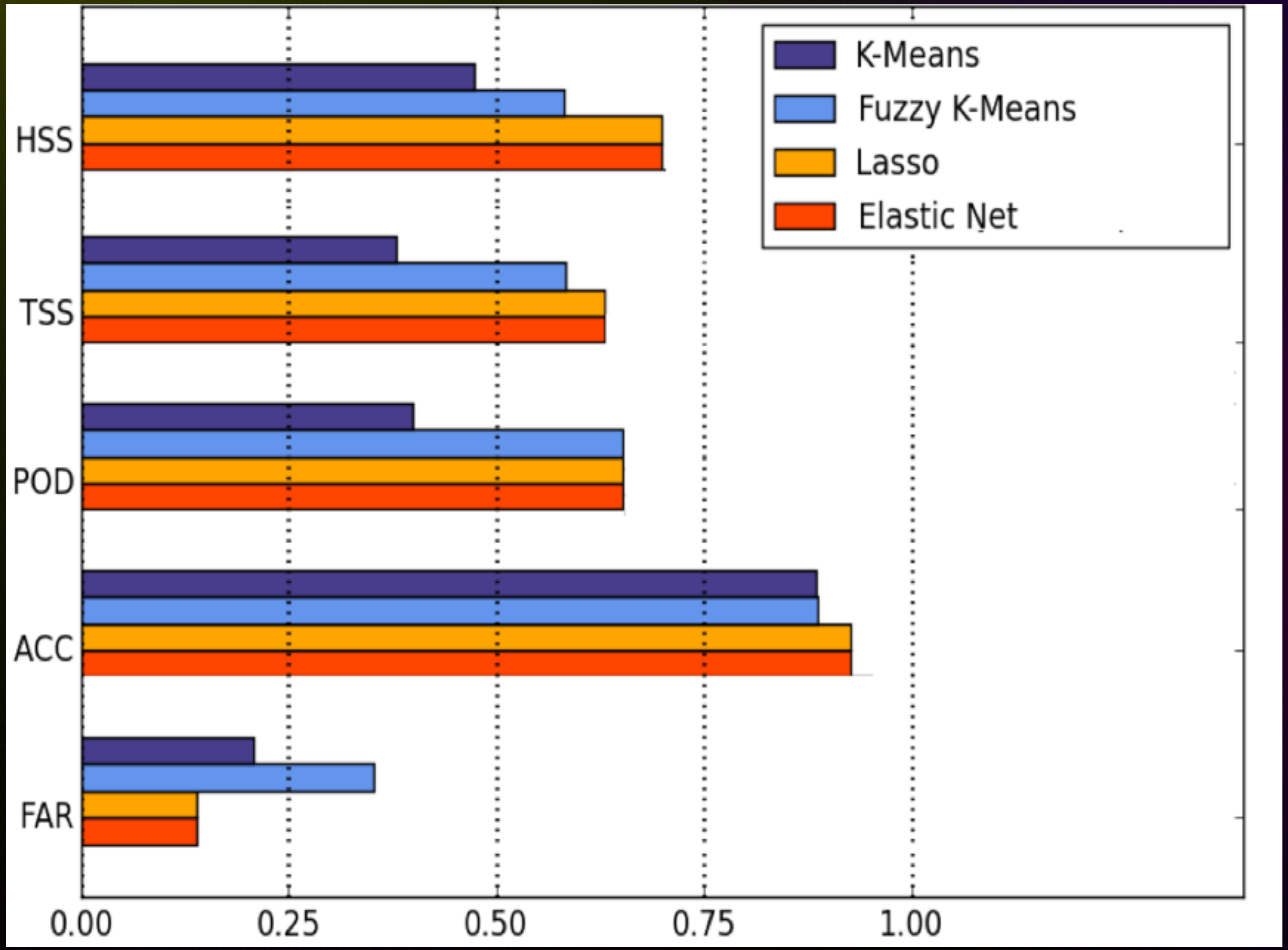


Bobra & Couvidat, ApJ, 2015

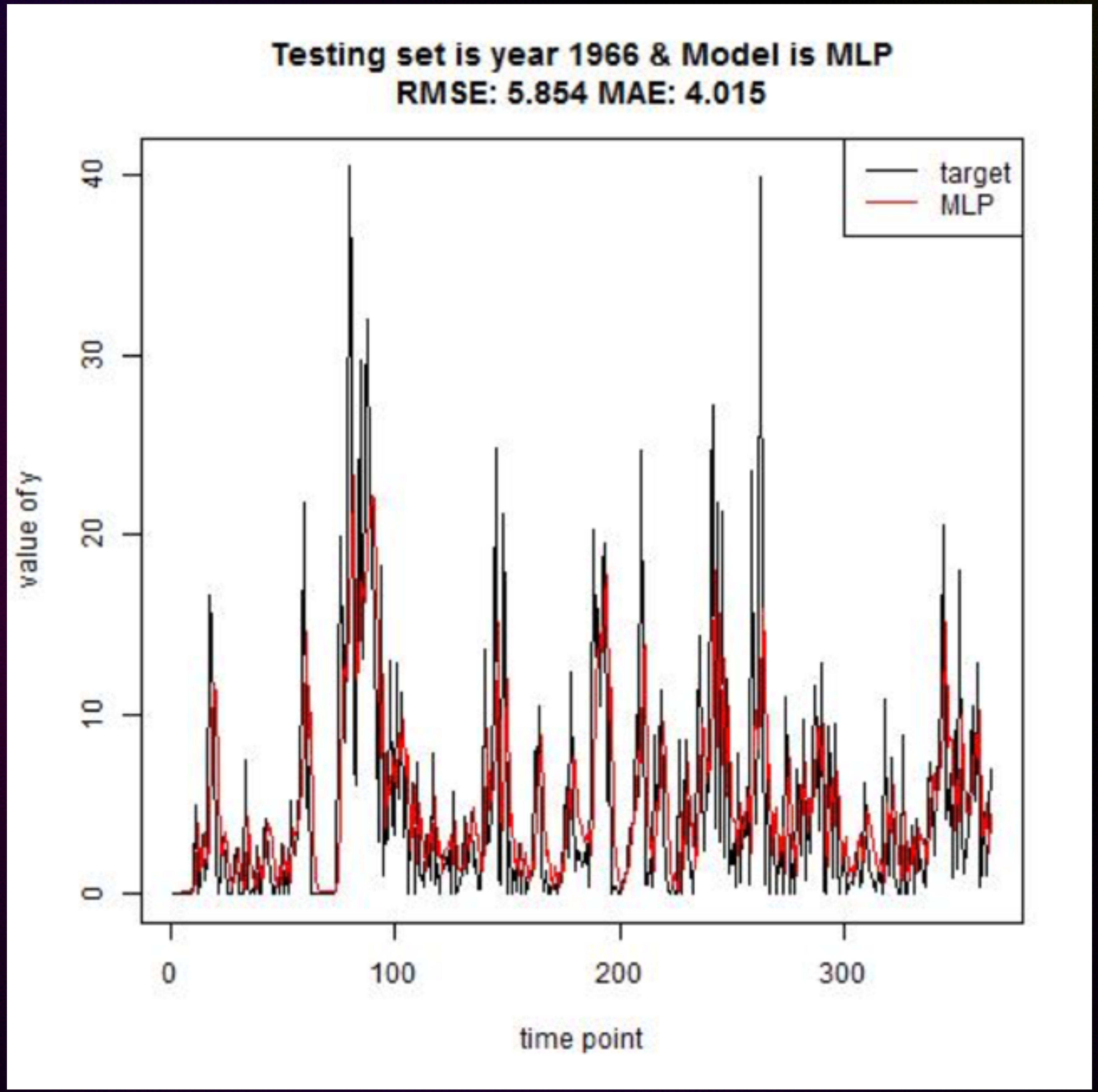
Utilize pretty much everything proposed in peer-reviewed literature

FLARECAST SCIENCE: PREDICTION ALGORITHMS

FLARECAST



Skill comparison between different machine-learning techniques applied to SDO/HMI data



Example of multi-layer-perceptron reproduction of a given time series

FLARECAST SCIENCE: VALIDATION ON COMMON GROUNDS

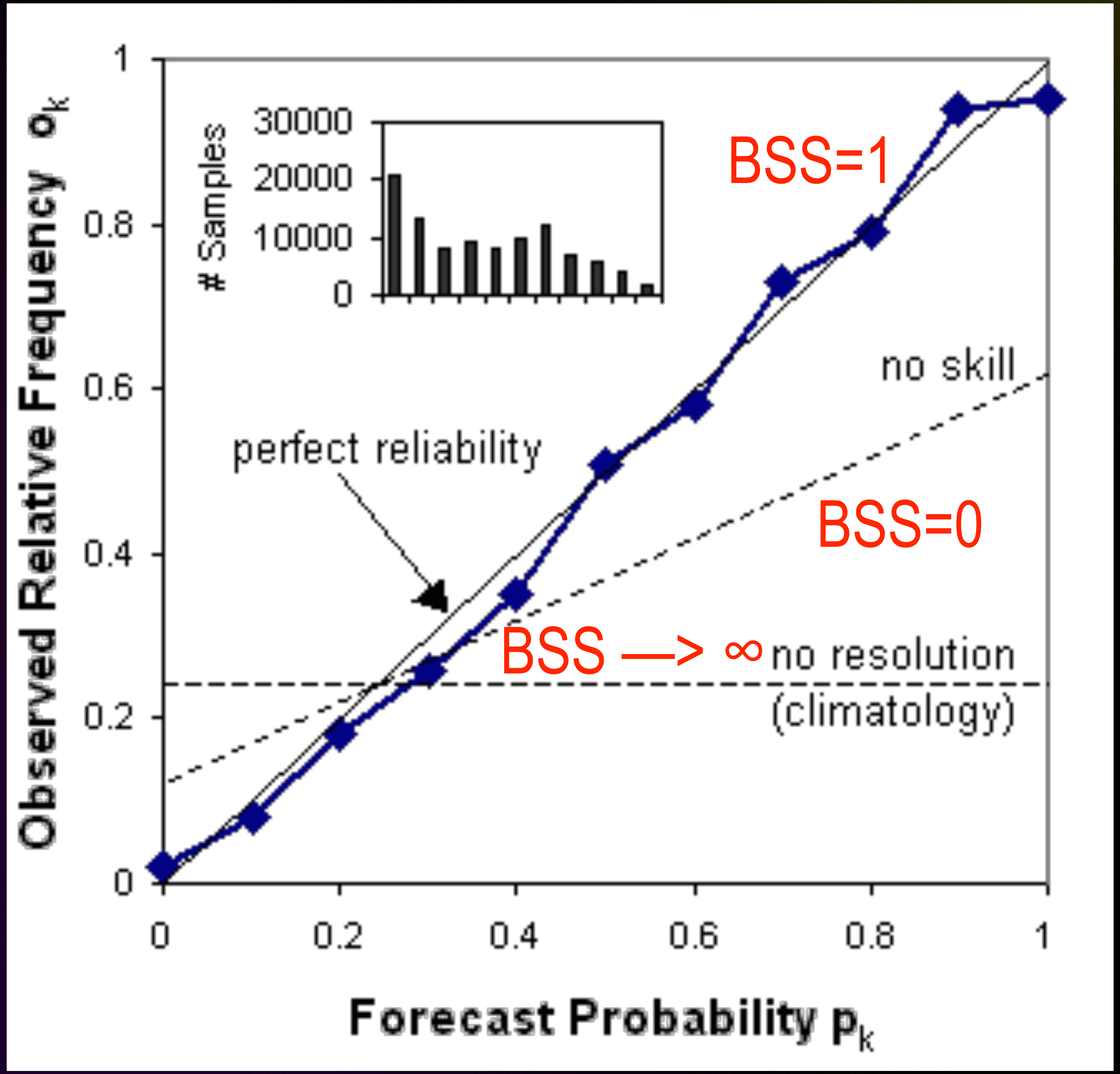
FLARECAST

Courtesy: Shaun Bloomfield

Metric Name	Short Name	Format	Worst Score	"No skill" Score	Perfect Score
Accuracy	ACC	(TP + TN) / N	0	...	1
Probability of detection	POD	TP / (TP + FN)	0	...	1
Probability of false detection (false alarm rate)	POFD	FP / (FP + TN)	1	...	0
False alarm ratio	FAR	FP / (TP + FP)	1	...	0
True skill statistic	TSS	POD - POFD	-1	0	1
Heidke skill score	HSS	(TP + TN - E_{random}) / (N - E_{random})	-1	0	1

Binary validation on categorical data

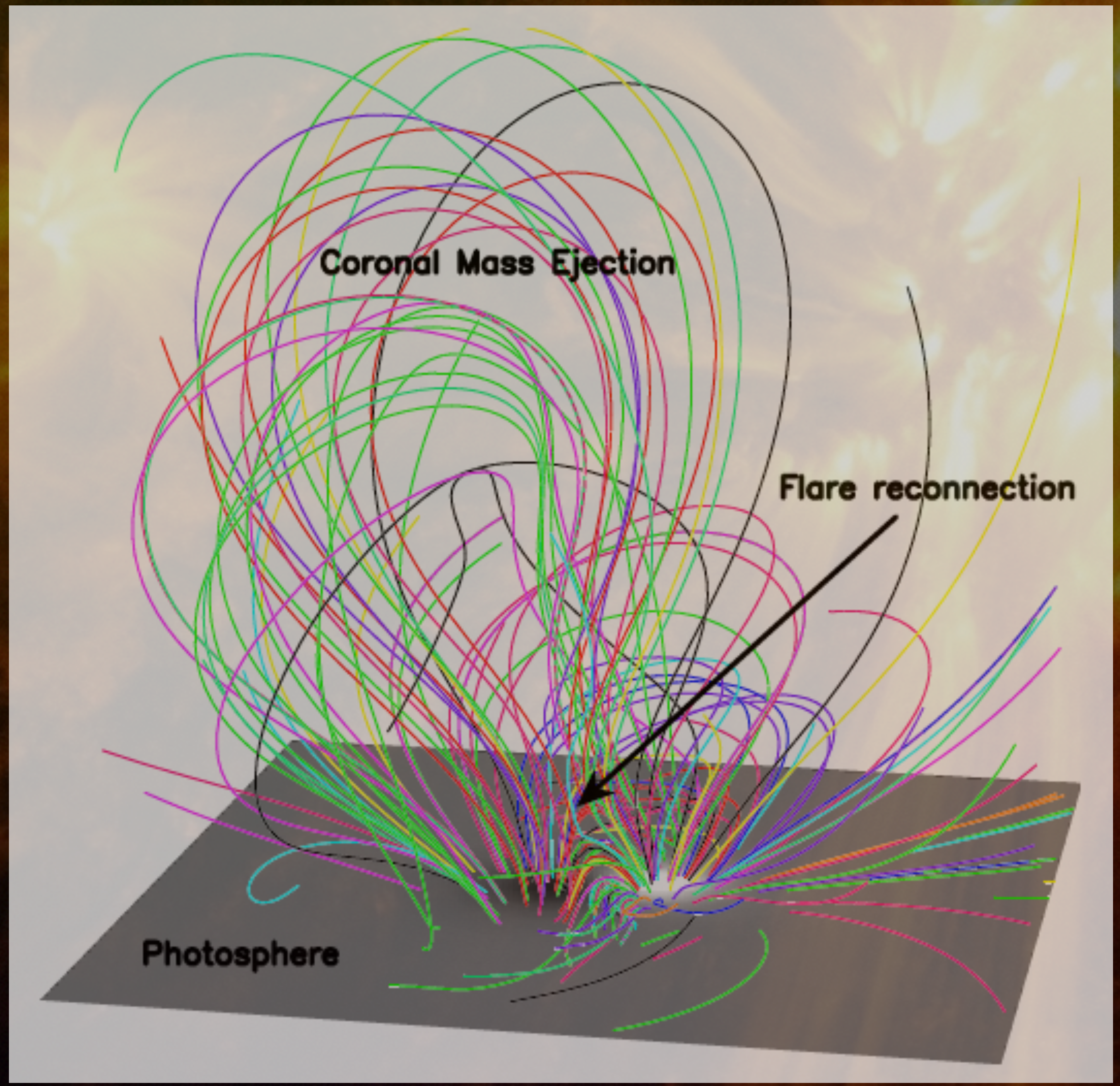
Source: WMO Forecast Verification



Probabilistic validation

FLARECAST SCIENCE: EXPLORATIVE RESEARCH

FLARECAST



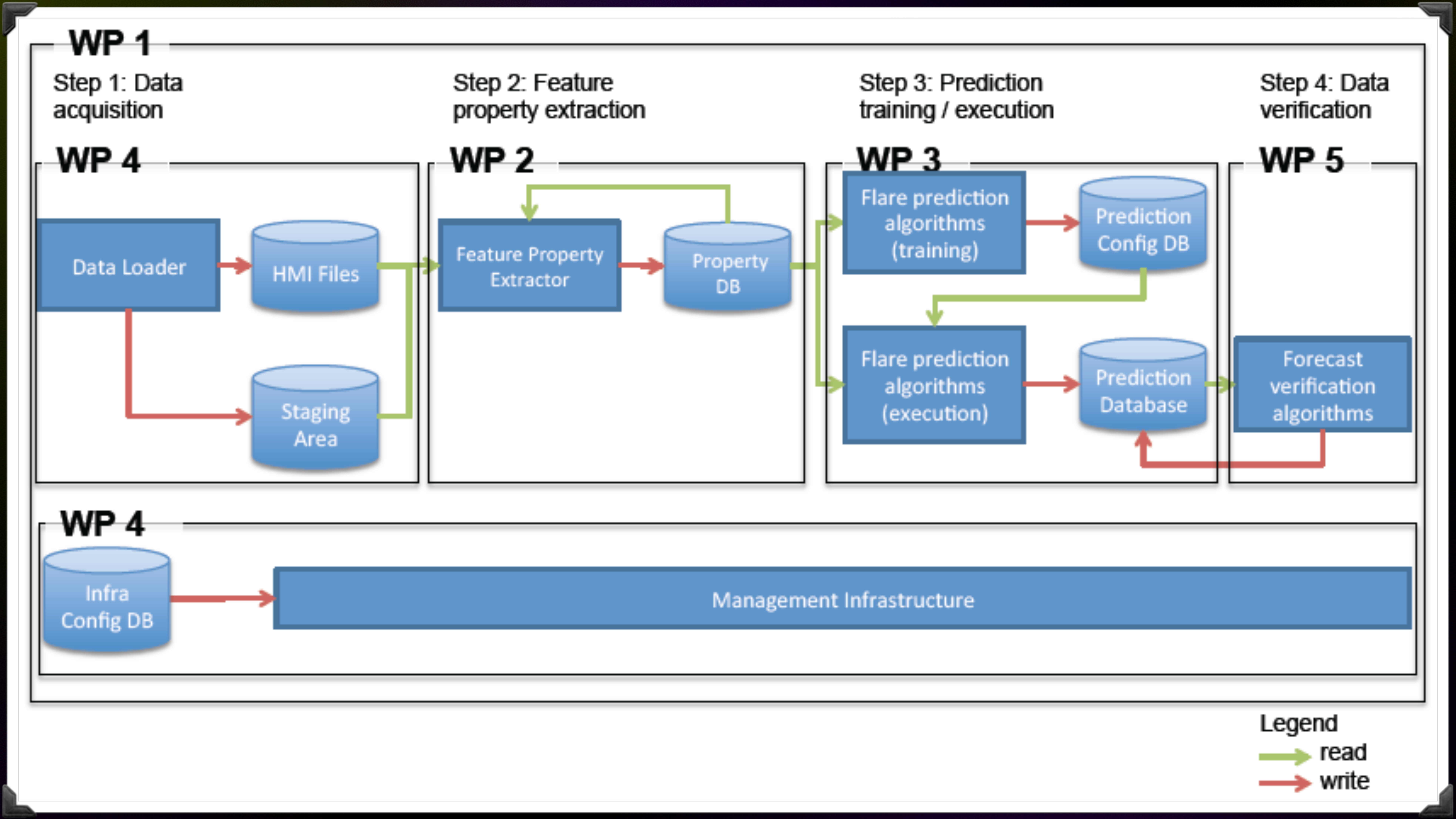
Aulanier et al., A&A, 2013

- Understand solar magnetic eruptions (flare-CME connection)
- Improve future flare prediction
- Investigate suitability of the flare forecasting window
- Advance CME prediction

Earth to scale

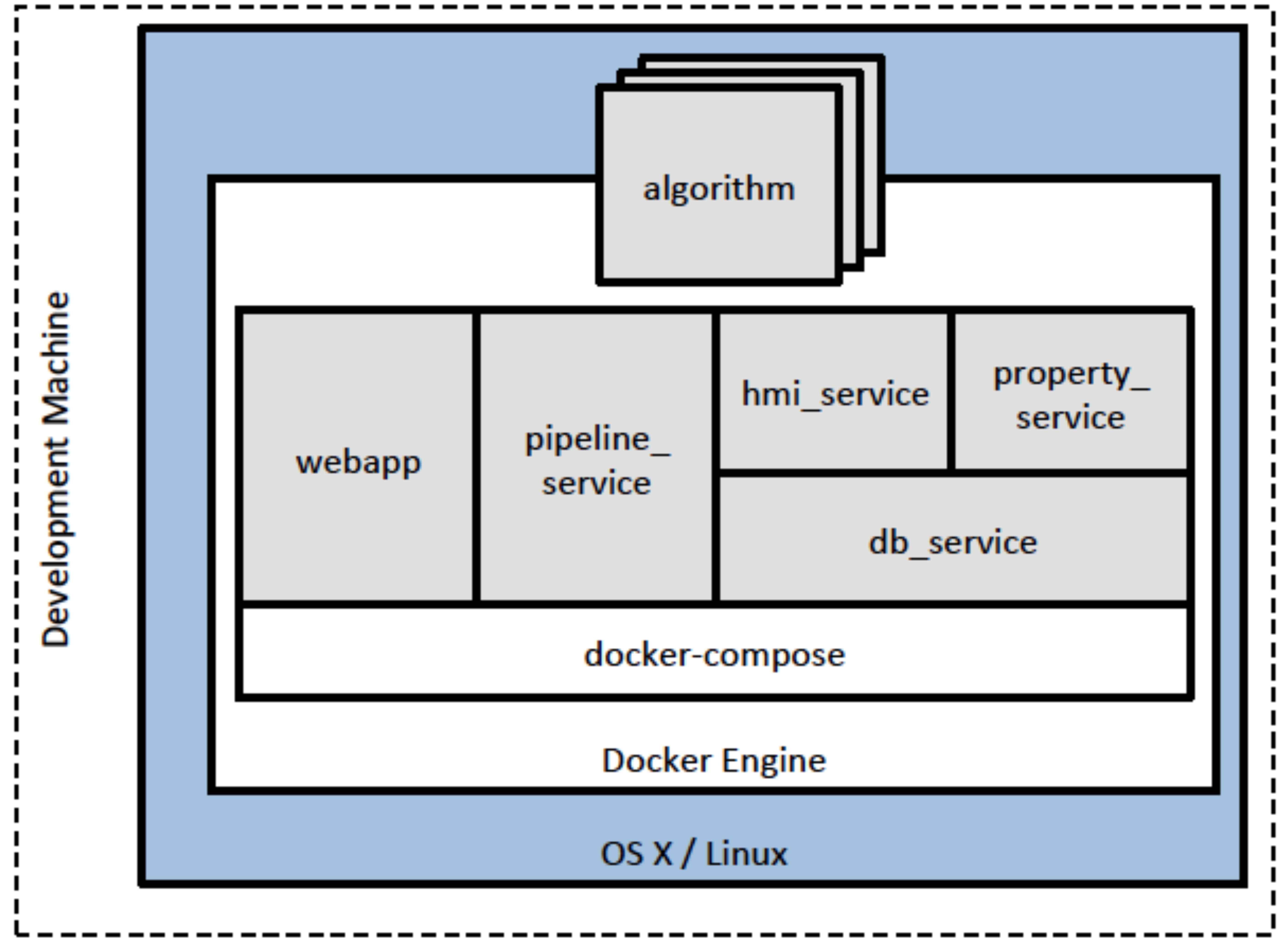
FLARECAST ARCHITECTURE

FLARECAST



EXPECTED RESULTS

FLARECAST



The FLARECAST forecasting system: openly accessible, featuring:

- fully automated flare forecasting based on our best (fully validated) results
- open-source software that will allow end users to perform their own tests.

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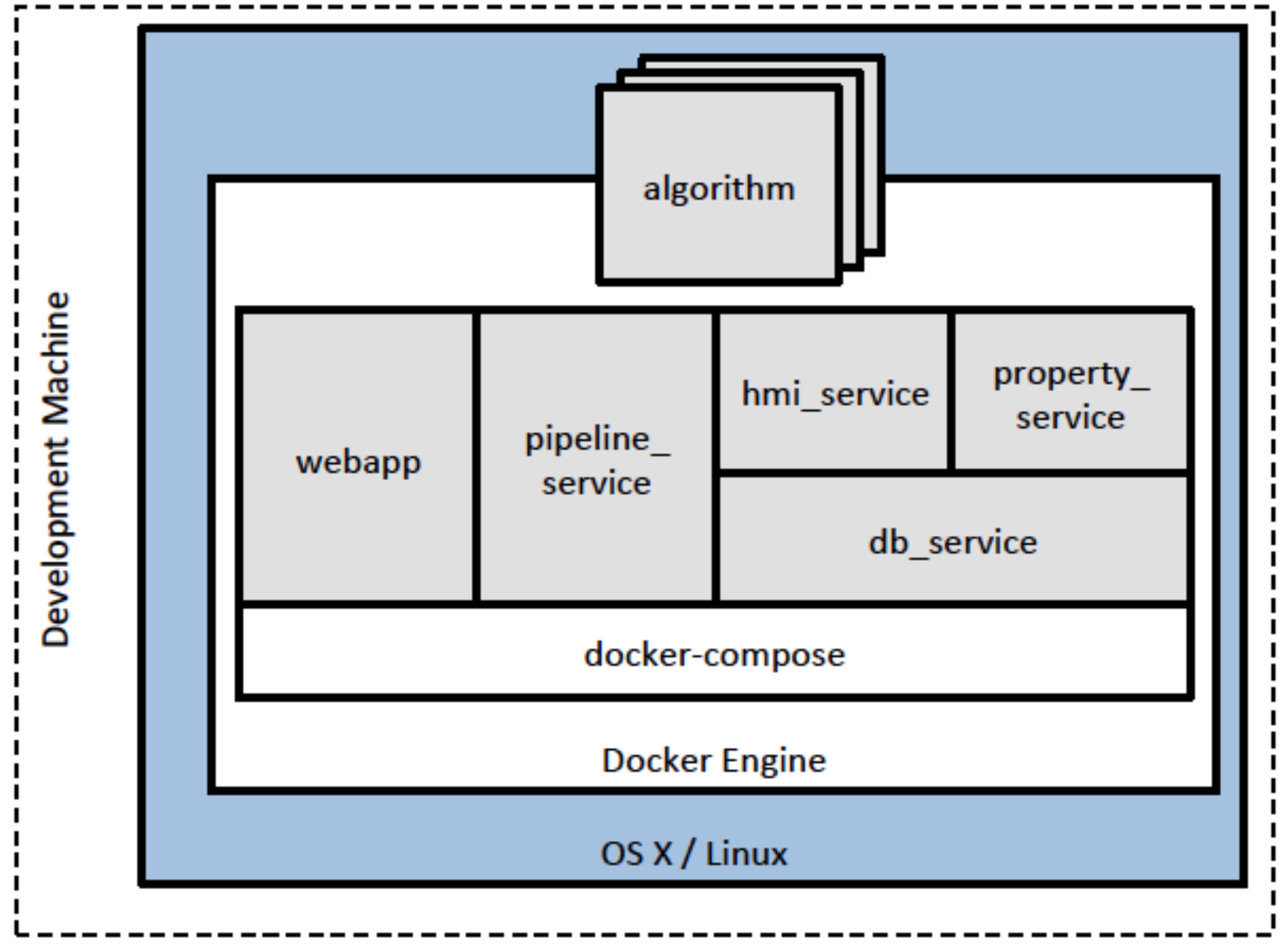

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FLARECAST will aim to both revamp solar flare prediction and contribute to a better understanding of the drivers of flare activity.

FUSION: FLARECAST & OTHER EC PROJECTS

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FLARECAST

FP7 SWx Projects

Ionospheric effects

AFFECTS – ionosphere, impact on communications
POPDAT – database of ionospheric waves catalogues

Data exploitation

ECLAT – magnetosphere, data mining & visualisation
HESPE – solar high-energy data analysis
eHeroes – DB&models for space exploration
SHOCK – plasma, kinetic modelling
SOLID – irradiance data & modelling

Atmospheric effects

ATMOP – thermosphere, better tracking of space objects in LEO

Effects on ground systems

EURISGIC – geomagnetically induced currents in power systems

Effects on space systems

SPACECAST – radiation belt, solar energetic particles, protection of space assets
SEPServer – SEP data and events
PLASMON – plasmasphere, radiation belt
COMESEP – coronal mass ejections, solar energetic particles, geomagnetic storms
MAARBLE – ULF/VLF database, radiation belt dynamics
SIDER – radiation shielding of composite enclosures

Global modelling

SWIFF – couplings at solar surface, in space and at Earth
SOTERIA – better databases of existing data & simulation models

P. Chiarini, SWSC, 2013

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H2020 SWx Projects:

PROGRESS

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H2020 SWx Projects:

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HESPERIA

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Can we consolidate the accumulated know-how and expertise toward a future integrated SWx prediction platform?

THE VEHICLE: THE EC CONTINUES TO SUPPORT SWx RESEARCH

FLARECAST

TOPIC : Space Weather

Topic identifier:	COMPET-5-2017		
Publication date:	14 October 2015		
Types of action:	RIA Research and Innovation action		
DeadlineModel:	single-stage		
Planned opening date:	08 November 2016	**Deadline:**	01 March 2017 17:00:00

Time Zone : (Brussels time)

Horizon 2020
Pillar: Industrial Leadership
Work Programme Year: H2020-2016-2017
Work Programme Part: Leadership in Enabling and Industrial Technologies - Space
Call : H2020-COMPET-2017

H2020 website

Call budget overview

COMPET-5-2017: "*Proposals are expected to improve the understanding of Space Weather phenomena and their impact on space systems and terrestrial infrastructure, and are also expected to analyse viable mitigation strategies, and to demonstrate how these add value compared to existing mitigation strategies*"

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Plausible ways to tackle such calls:

- Expand / extend existing projects (can a single project lead to an integrated solution, though?)
- Fuse between different projects (aiming at one step at a time)

CONCLUSION

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FLARECAST

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FLARE CAST

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- Synthesis in action: multi-level expertise, open-source infrastructure, "crowdsourcing" in terms of end-users performing new runs on new predictors
- Is this enough for a comprehensive SWx forecasting? **No!** - CMEs, SEPs
- EC / ESA : Utilize the collage of existing projects and expertise to expand on and aim toward a unified, expandable infrastructure along the lines of FLARECAST and other projects

BACKUP SLIDES