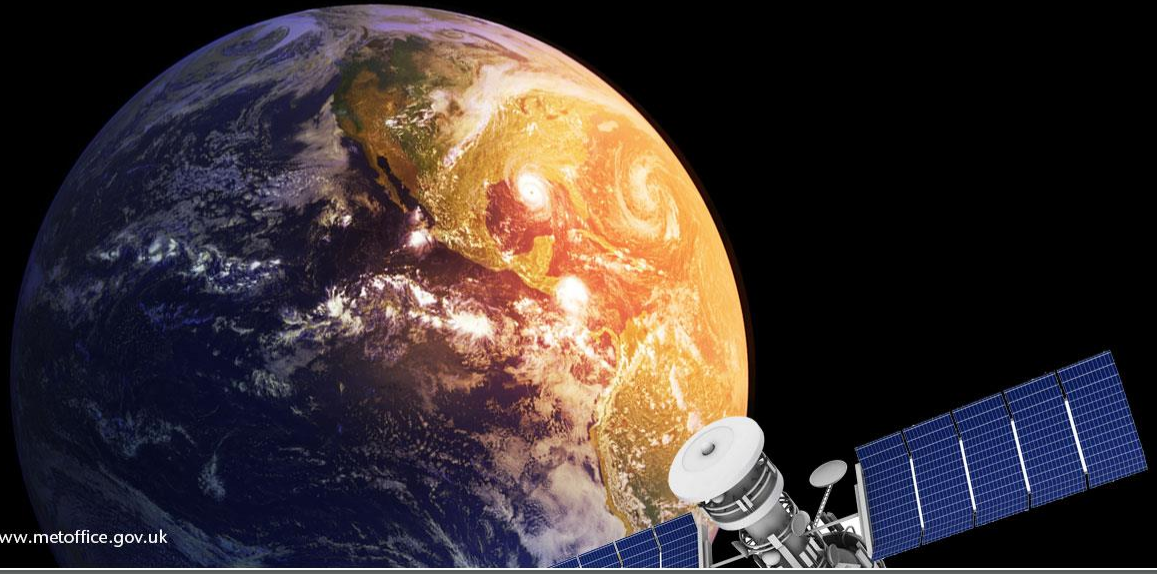
Solar and Heliospheric Physics

L5 measurements

Mark Gibbs, Head of Space Weather, UK Met Office



National Academy of Sciences
Space Weather Operations & Research Infrastructure
Workshop 1, 16-17 June 2020

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- Issues & challenges
- Why L5?
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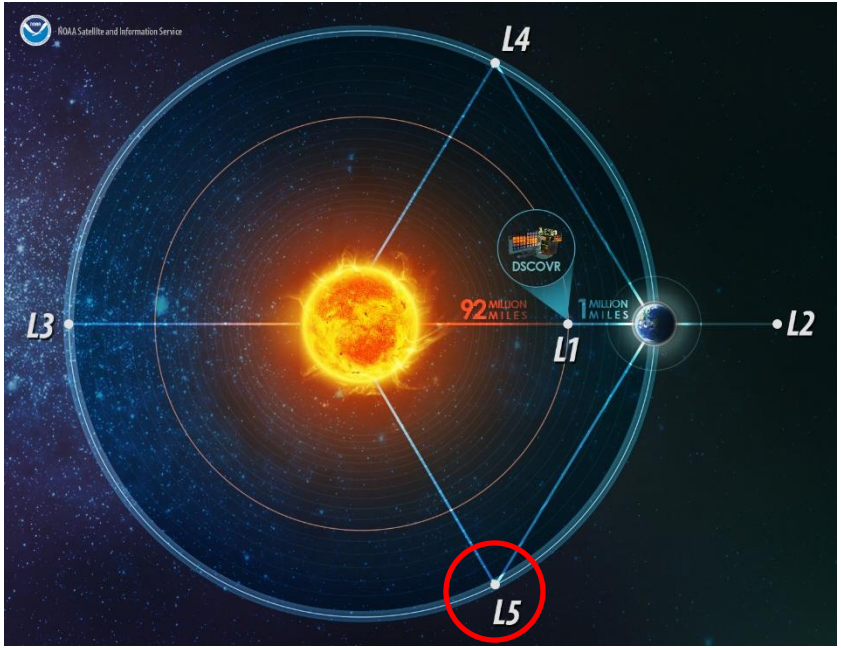
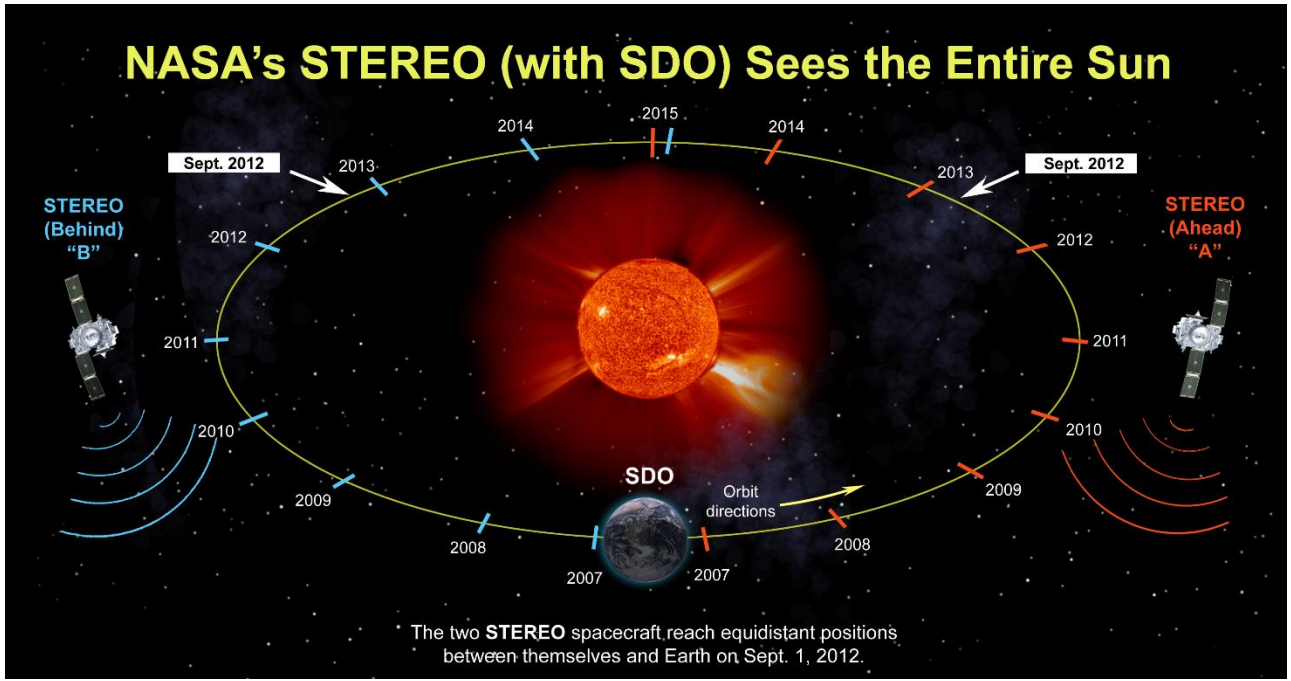
- How to use the information?



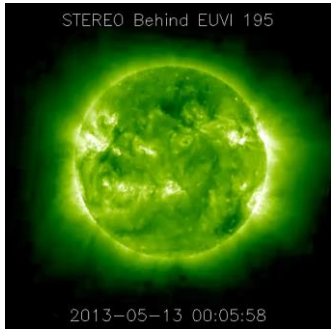
93 million miles from the Sun,
93 million miles from the Earth

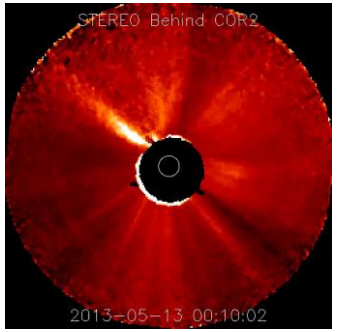
We've already been there!

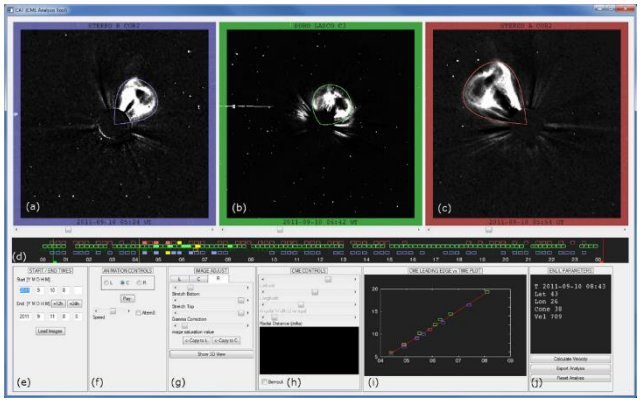
and will be again soon! (STEREO A ~70º)



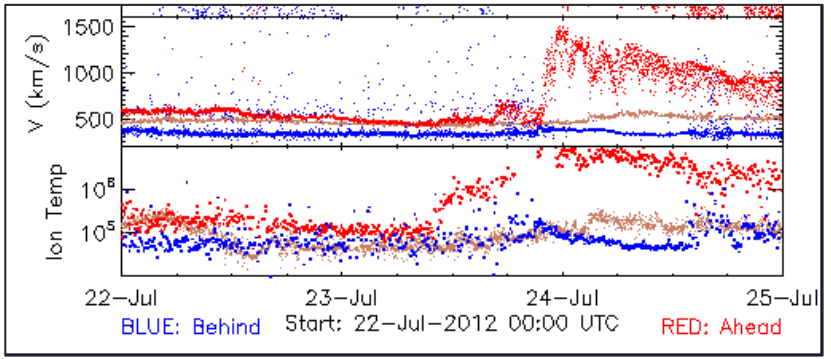
Use of STEREO imagery/data







Millward *et al.* (2013)



Operationally – only had beacon data

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Issues & challenges

- Clarify the requirement
  - Subtle differences between L5 for ‘Earth forecasting’ and exploration support
- Communication is difficult
  - Think carefully about resolution, cadence, latency & priority
  - ESA planning 30m+ dishes
- Takes fuel to stop
  - Do you stop at L5 or drift?
  - Multiple spacecraft - create a ‘string of pearls’

Met Office

Why L5?

- Provides critical side-on view of Sun-Earth line
  - Improves CME kinematics for model initiation (with L1)
  - HI allows observation of Sun-Earth line
- Extend visible disk by 60º - “up wind”
  - Image photosphere & solar corona
  - Earlier identification of Active regions
  - Continuous monitoring of AR evolution – additional 4 days
- Sampling solar wind ~ 4 days ahead
  - HSS stream identification

What to measure? Remote sensing

Measurement	Instrument	Use
Photospheric magnetic field	Magnetograph	• Identify magnetic emergence • Improve solar wind representation in models
Low solar corona (171 to 304 Å)	EUV Imager	• AR development • Flare location / detection • Monitoring coronal holes, prominences, etc
K-corona (CME identification)	Coronagraph	• Identify CMEs • Obtain CME kinematic properties
Imaging Sun-Earth line	Heliospheric Imager	• Identify CMEs • Obtain CME kinematic properties

What to measure? In-situ monitoring

Measurement	Instrument	Use
Solar wind (ion density, temperature & velocity)	Plasma Analyser	• Predicting future L1 solar wind • Identify solar wind features e.g. HSS, CME
Vector IMF	magnetometer	• Predicting future L1 IMF
Energetic particles Electrons (keV to MeV) Protons (1 MeV to 500 MeV) Ions & alpha particles	Radiation monitor	• Identify/measure SEP • Identify/classify solar wind features
X-Ray flux	X-ray flux monitor	• Flare detection

What use are these instruments?

Coronagraph use already well understood

Use of magnetograph

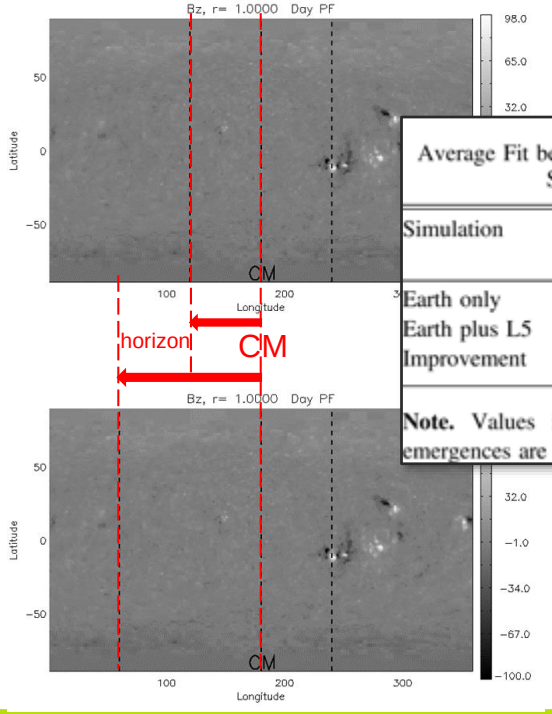
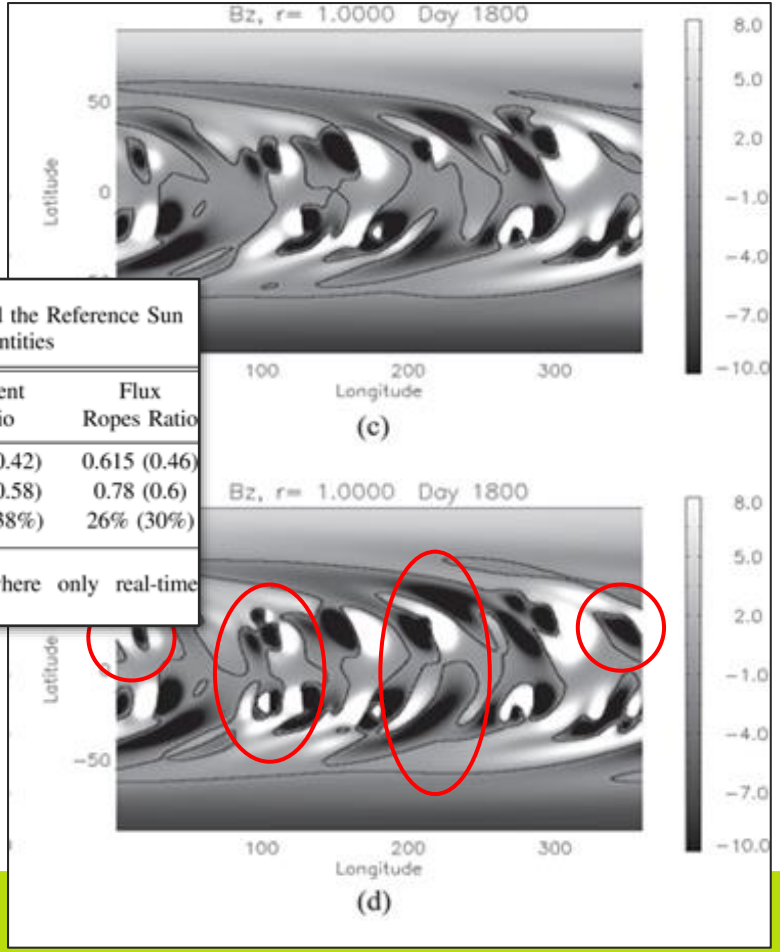


Table 2
Average Fit between the Limited Data Simulations and the Reference Sun Simulation for the Global Integrated Quantities

Simulation	Flux Ratio	Energy Ratio	Current Ratio	Flux Ropes Ratio
Earth only	0.55 (0.4)	0.46 (0.31)	0.57 (0.42)	0.615 (0.46)
Earth plus L5	0.75 (0.56)	0.65 (0.465)	0.74 (0.58)	0.78 (0.6)
Improvement	33% (40%)	41% (50%)	30% (38%)	26% (30%)

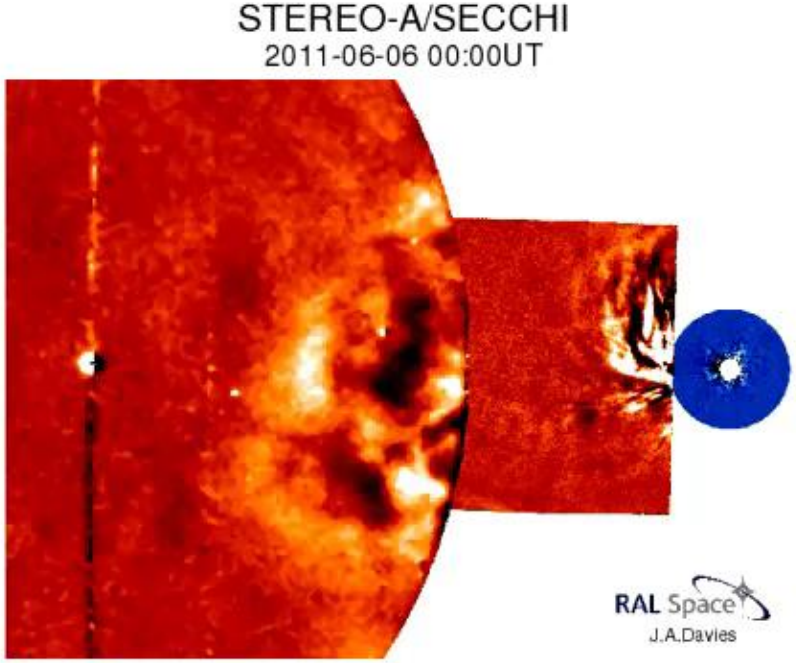
Note. Values in parentheses are for simulations where only real-time emergences are used.

Global non potential model day 1800

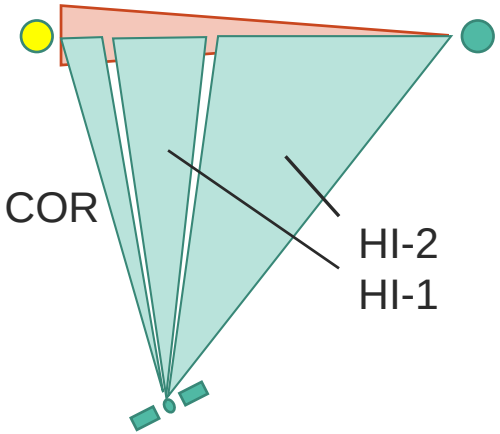


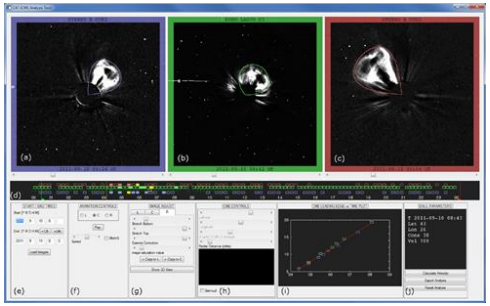
Mackay, *et al* (2016)

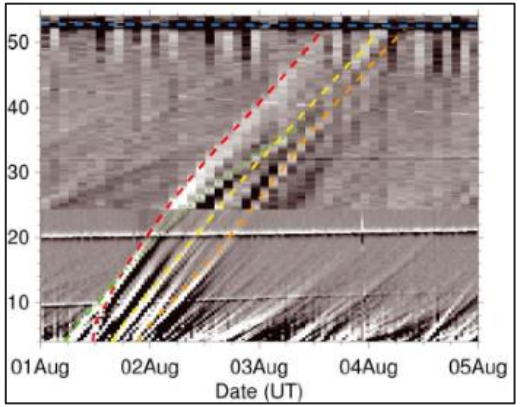
Heliospheric Imager (HI)

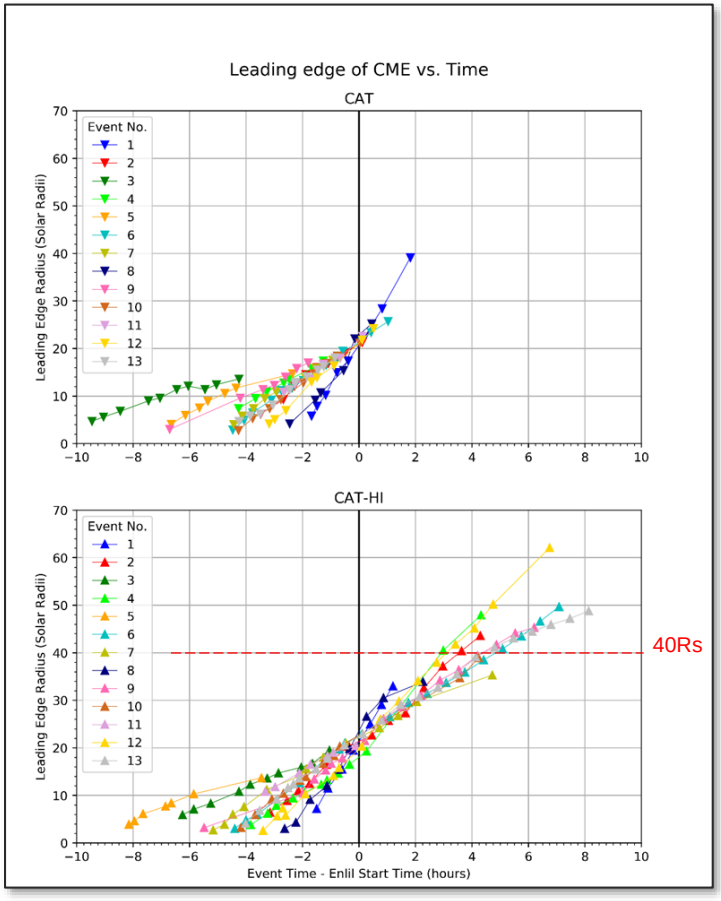


Use of HI





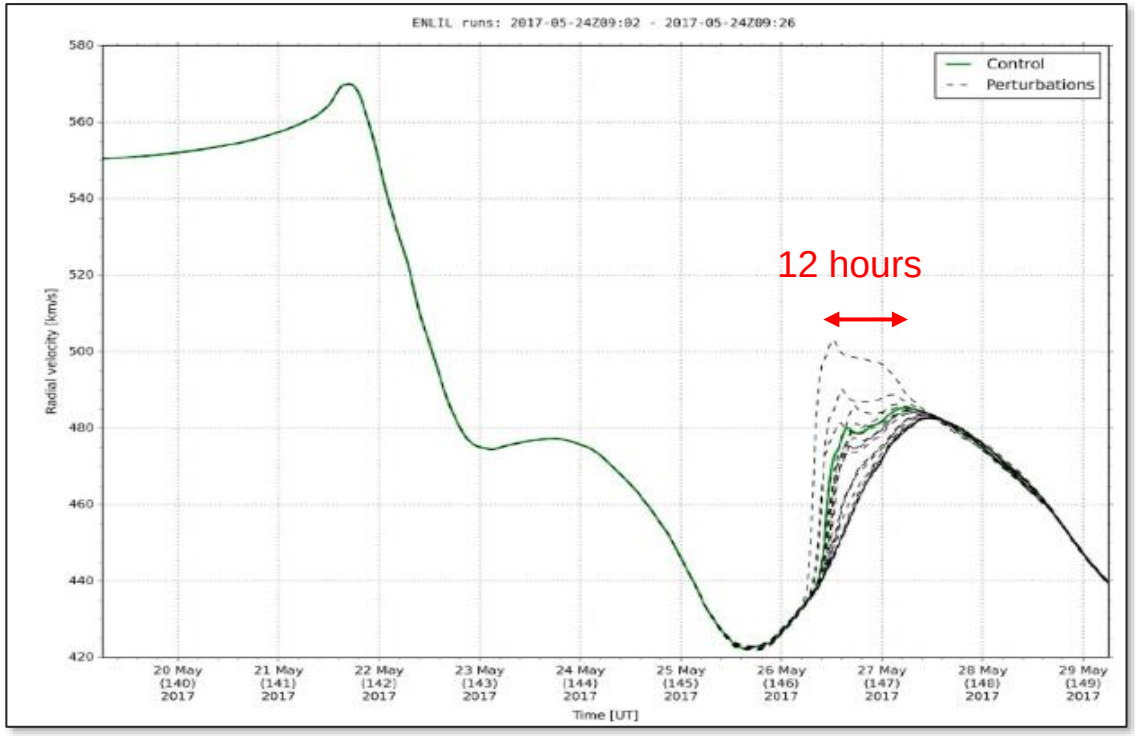




Wharton, *et al* (2019)

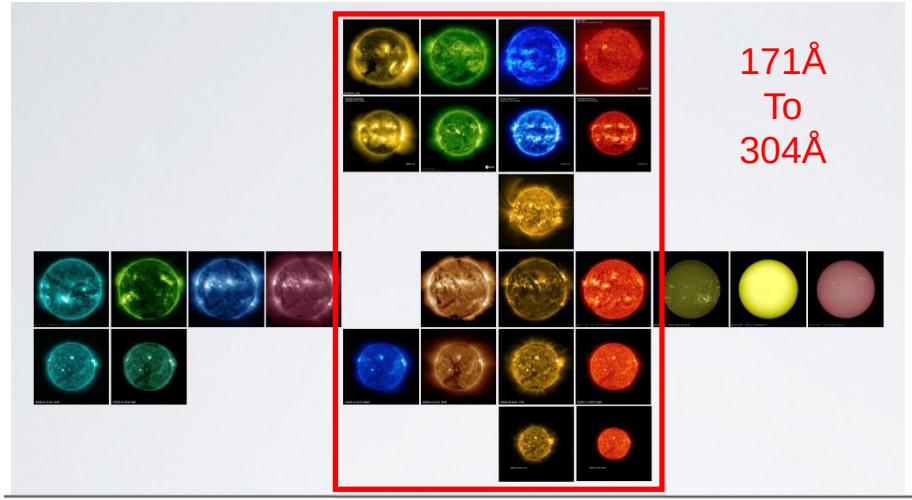
Use of HI

- ENLIL Ensemble
  - 24 member CME-only (UKMO) operational
- AFRL ADAPT
  - 12 member background field
- 24 x 12 large ensemble
- Prune out poor members



Harrison, *et al* (2017)

EUVI – what to choose?



SOHO-EIT

STEREO-EUVI

PROBA2-SWAP

SDO-AIA

GOES R-SUVI

SO-FSI

from West, *L5 in Tandem with L1 workshop* (2017)

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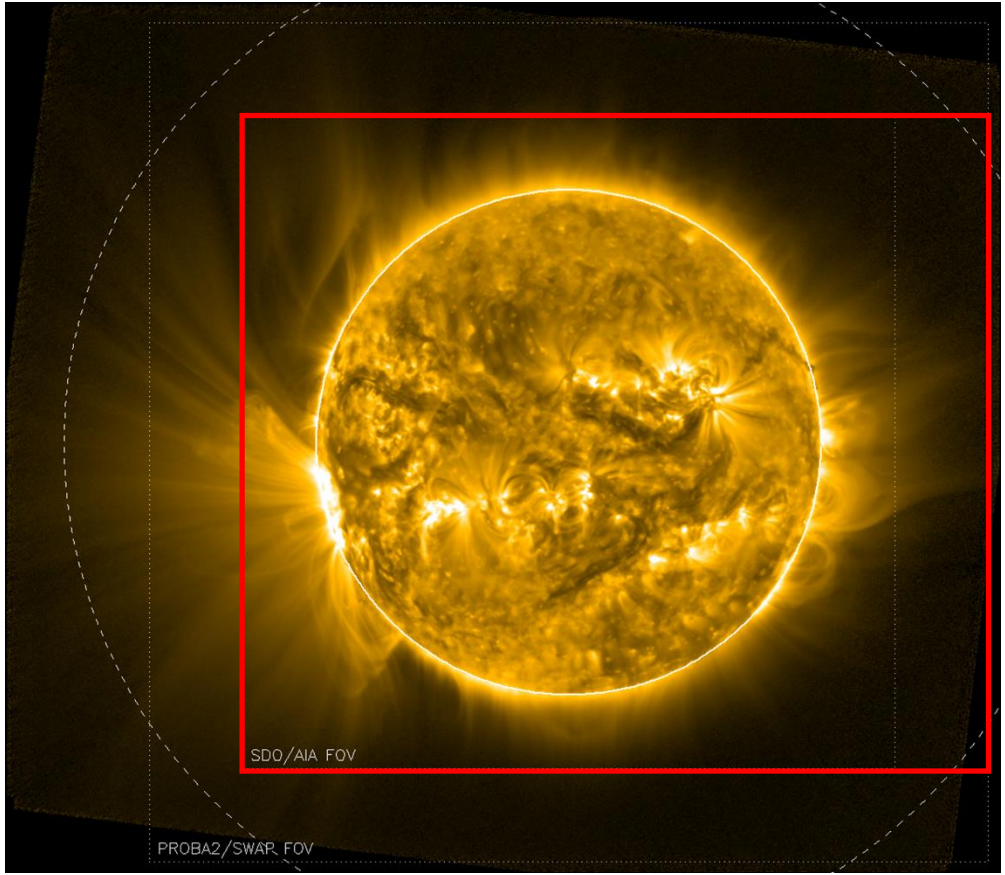
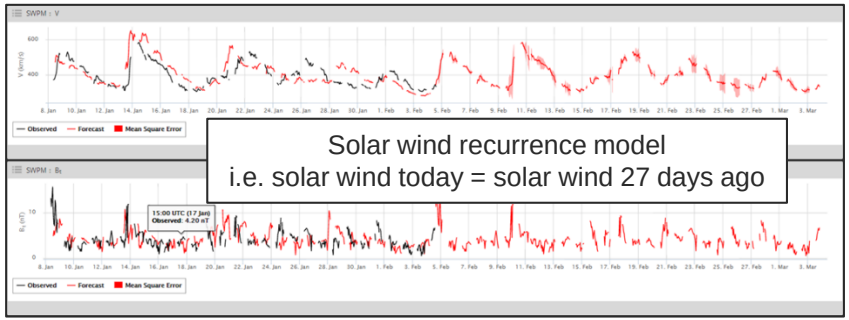
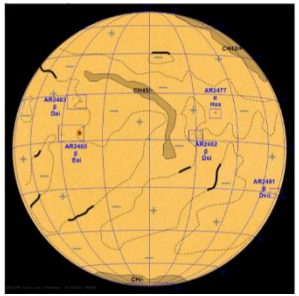
EUVI

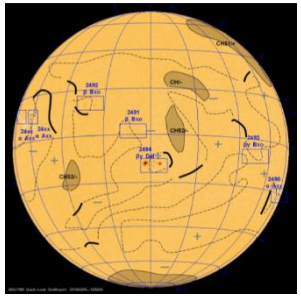


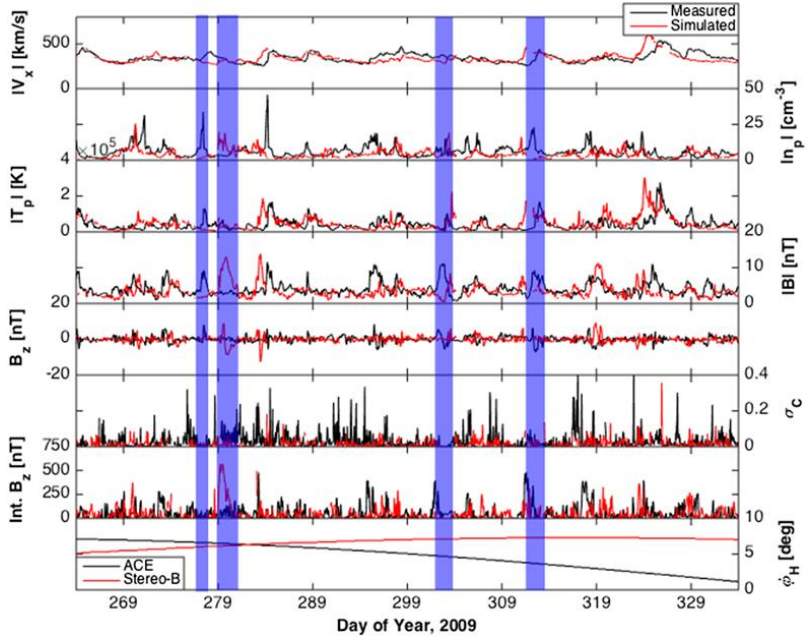
- Off point towards Earth
- EUVI outer Fov = COR inner Fov
- COR outer Fov = HI inner Fov

In-situ: solar wind prediction



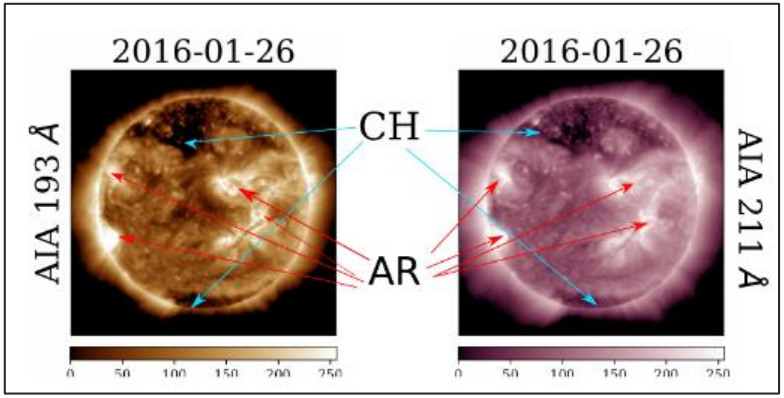




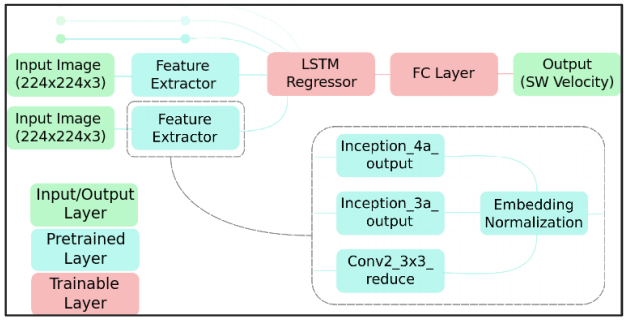


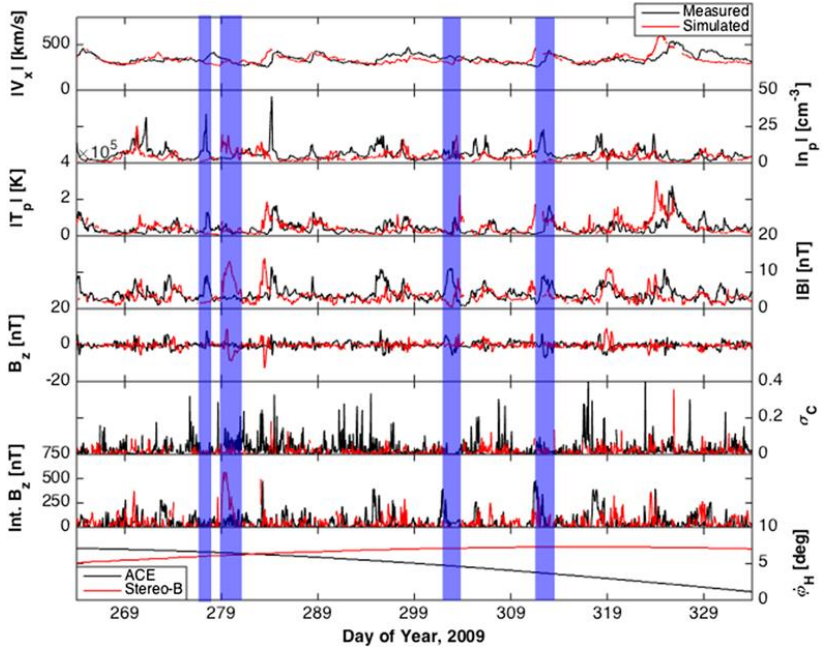
Thomas *et al* (2018)

In-situ: solar wind prediction



Machine learning



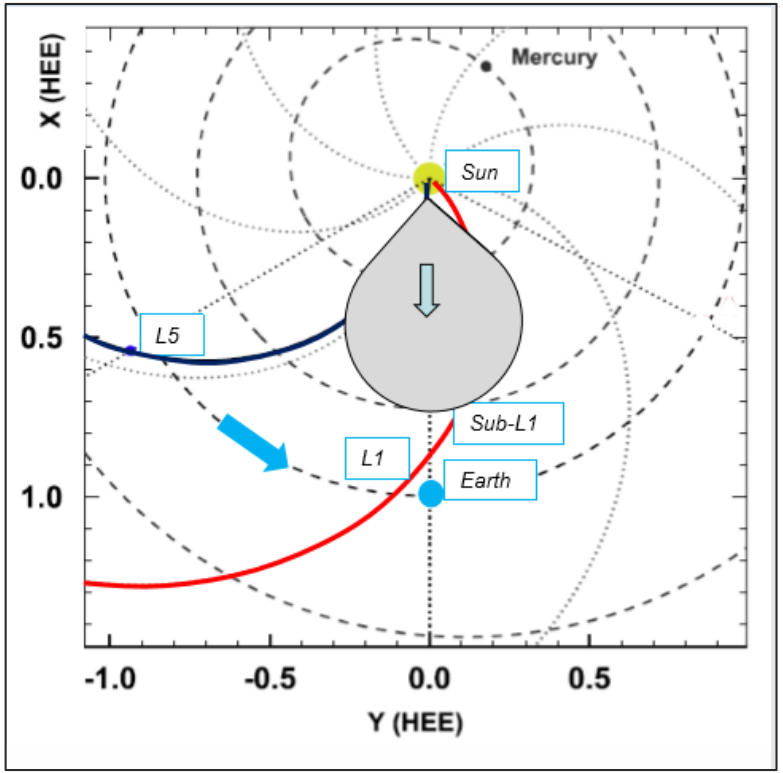


Upendran *et al* (submitted)

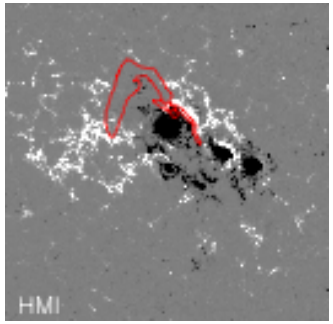
Thomas *et al* (2018)

In-Situ SEP

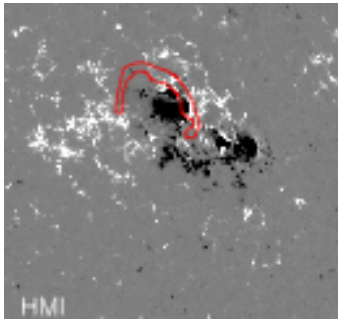
- More from L4 talk
- Fast Earth directed CME
  - L5 is a beacon for SEPs
  - Spacecraft challenge



Finally

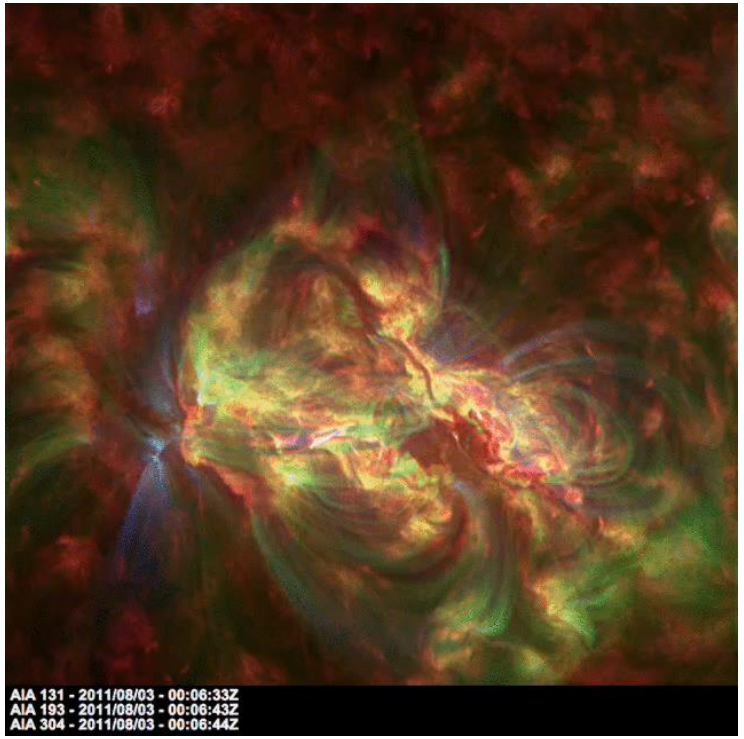


Before the flare



After the flare

- Stereoscopic view near L5 limb
- Enabling flux rope parameterisations?



Zuccarello *et al* (2014)

Met Office

Thank you