



Met Office

# Carrington – an Operational Space Weather Mission

2016 Space Weather Workshop

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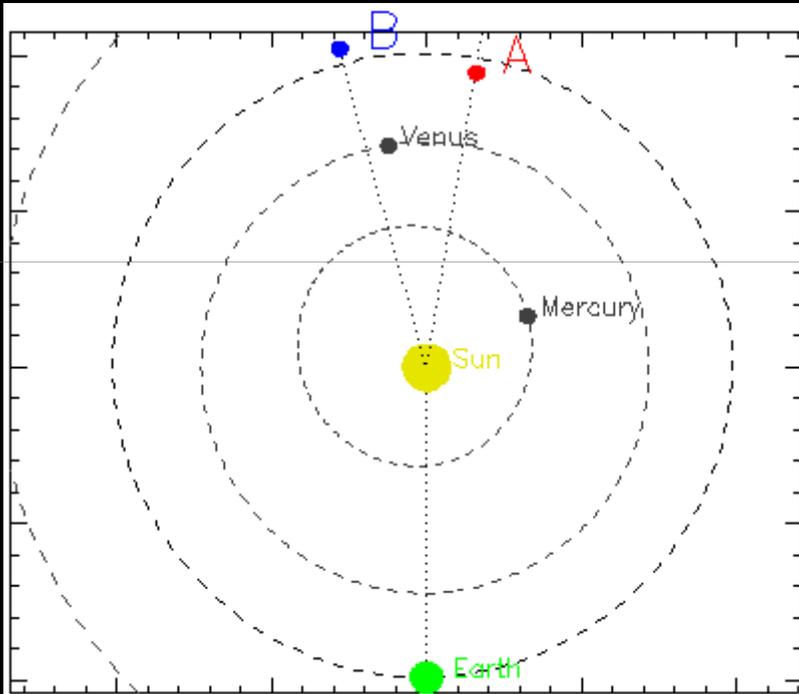


# UK interest in space weather?

- 2011 Space weather became a medium high risk on the UK NRR
- Vulnerability increasing with technology
- Extreme events don't necessarily cluster around solar max
- Royal Academy of Engineering report



# What sparked UK interest in L5?

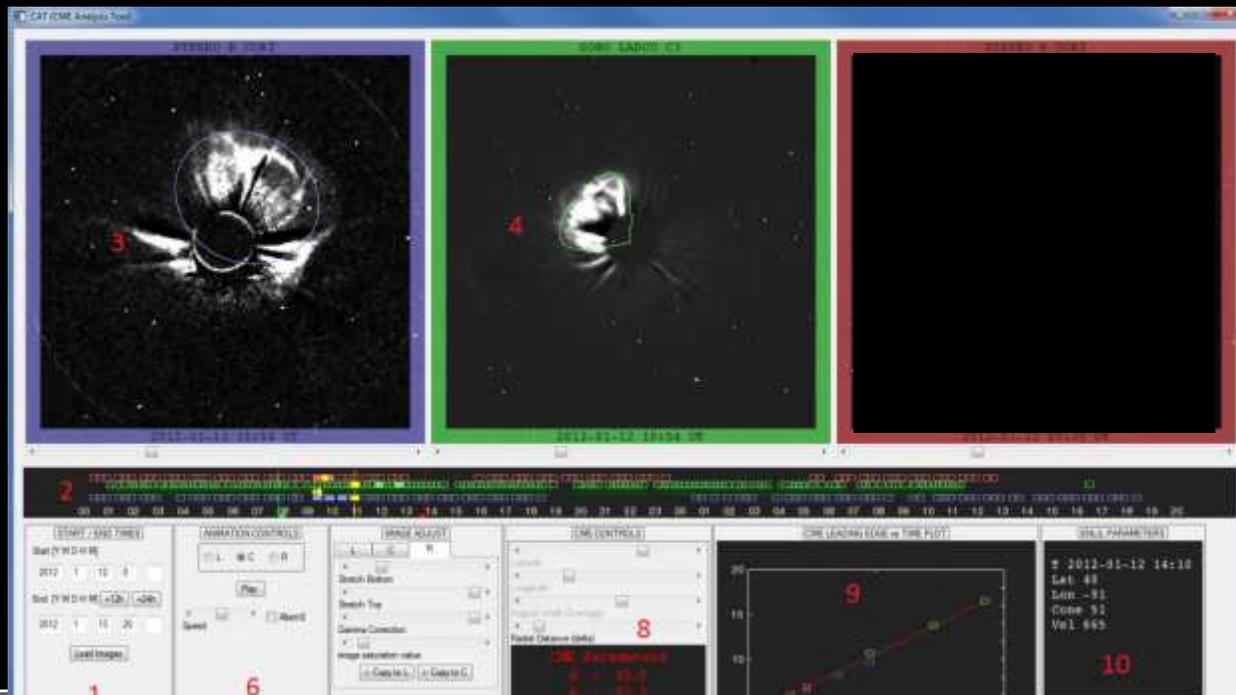


- Nov 2014
  - STEREO B out of operation
  - STEREO A going into conjunction
- Reduction in forecast skill
  - Briefing Note to Ministers
- Meeting with Ministers (Feb '15)
  - L5 concept discussed
  - Engage with international partners to share cost
  - Demonstrate economic benefit



# L1 and L5 in tandem

- L1 – maintain capability essential
  - In-situ IMF & solar wind
  - Solar imaging (Coronagraph, magnetograph, etc)
- L5 operating in tandem with L1





# Carrington mission concept

- Increase resilience of UK
  - Improve geomagnetic storm forecasting
- Primary objective: Provide at least 12 hours warning, with greater accuracy, of a significant CME hitting Earth thru'
  - Improved CME estimates of speed, direction and density
  - Improved background solar wind velocity and density fields (inc. representation of HSS & SIRs)
  - Real-time operational data flow will allow much quicker identification of fast Earth-bound CMEs
- Conceived as a UK National mission
  - Unrealistic but useful starting point

# Carrington mission concept

- Operational continuous 24/7/365 availability
  - 15m ground station antenna network
- Key instruments / observations
  - Coronagraph
  - Heliospheric imager
  - Magnetograph (inc white light images)
  - Bulk plasma
  - Vector IMF



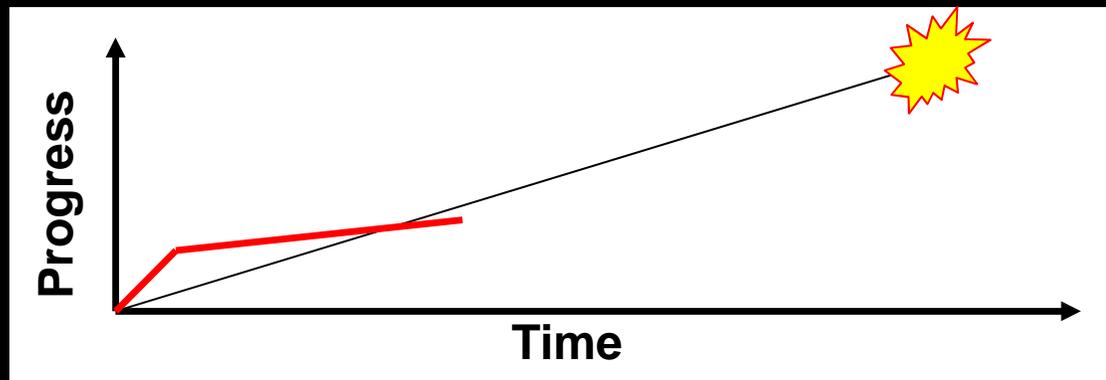


# Progress

- UK Space Agency funded study (due July'16)
  - Socio-economic study
  - Phase 0 study
  - Options Roadmap (UK, bilateral, ESA & EC)
  - Business case for UK Government
- 2 ESA funded studies (due Sept'16)
  - Phase 0 for L1 and L5
- Carrington mission & ESA mission have different needs & differences in instrument priority

# Progress

- By end of summer 2016
  - UK socio-economic study, phase 0 study, options roadmap & business case
  - 2 ESA Phase 0 studies
  - ESA Cost Benefit Analysis of SSA – near complete

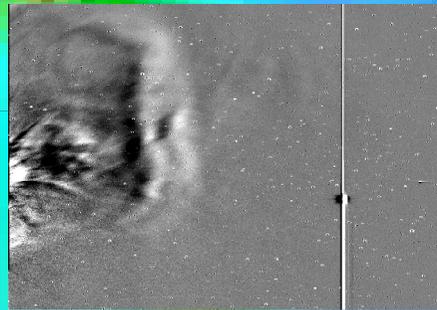
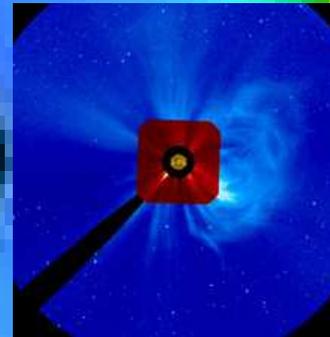


# The ideal World?

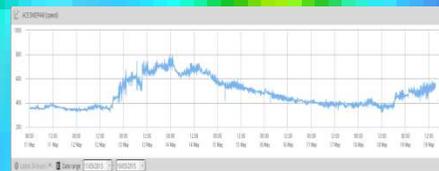
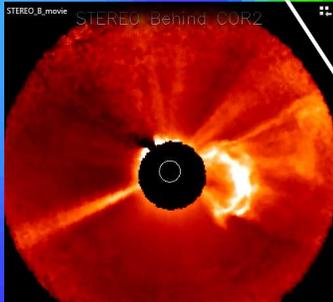


60°

L1



L5





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# Data Assimilation

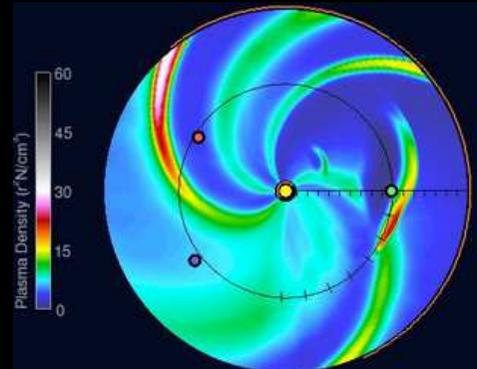
Developing in conjunction  
with University of Reading

Starting with in situ data  
(plasma, magnetic field)

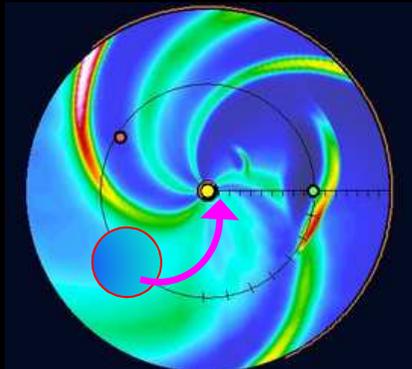
Other observations may be  
useful later

- e.g. HI data – increments  
more complex – 3D from 2D –  
yet coverage better – less of a  
point measurement

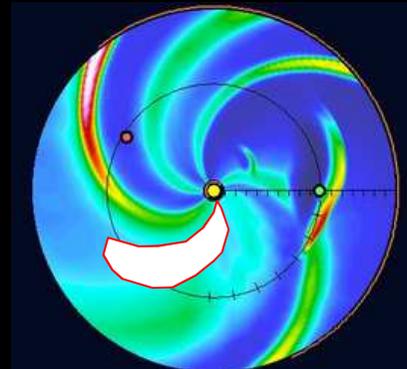
Will be doing this with STEREO  
data; proof of concept for L5



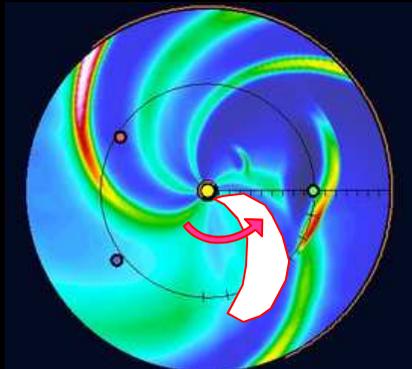
Compare ENLIL background  
solar wind & in situ data at  $T_0$   
(here data lower density)



Get local increment, & via e.g.  
variational technique the source  
increment at  $25 R_s$  at  $T_0 - \Delta T_1$



Apply source increment, run  
ENLIL forward to  $T_0 \rightarrow$  good  
analysis – model solar wind is  
balanced, yet closer to  
observations – more realistic

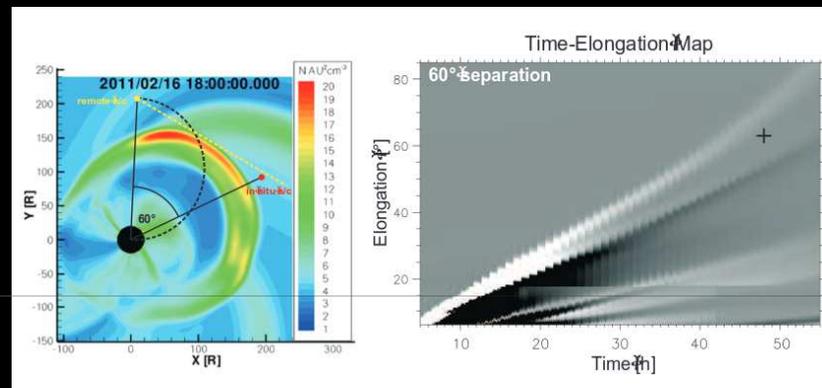
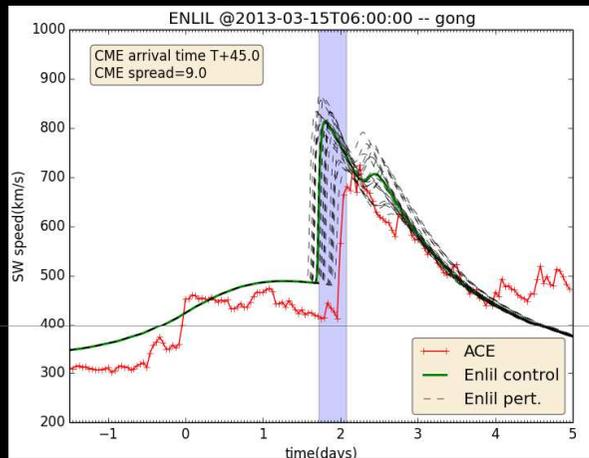


Persist source increment to  
 $T_0 + \Delta T_2 \rightarrow$  better solar wind  
forecasts at earth; better also  
between sun & earth  $\rightarrow$  more  
accurate CME arrival times

# Heliospheric imagers

## Pruning a CME ensemble forecast?

- Generate synthetic Jmaps for each member



Lugaz 2009,  
Rollett 2013

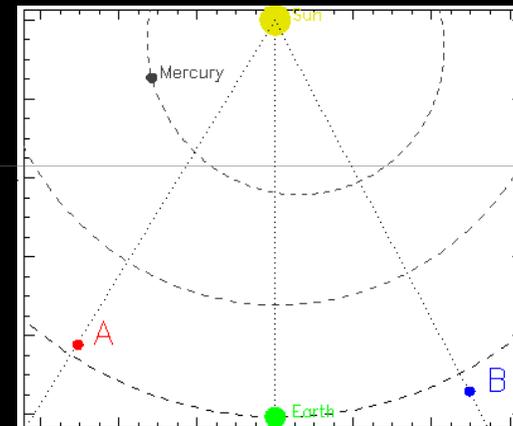
- Compare actual & model Jmaps (auto or manual)
  - Reject model members disagreeing with obs
- More realistic ensemble spread
- Intermediate step
  - Forecaster apply bias correction to ENLIL run subjectively



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# Summary

- Several L5 mission concepts being developed
- Economic and scientific evidence required
- No money committed yet
  - \$200m - \$250m
    - national mission & shared launch
- Need operations in 6 years



93 million

The journey of a thousand miles  
begins with one step

Lao Tzu



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Thank You  
Questions?