Solar wind modelling at the Met Office – towards exploitation of L5 data

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RAS Discussion Meeting: Transitioning Research and Instrument Expertise in Heliophysics into Space Weather Monitoring Capabilities at L1 and L5

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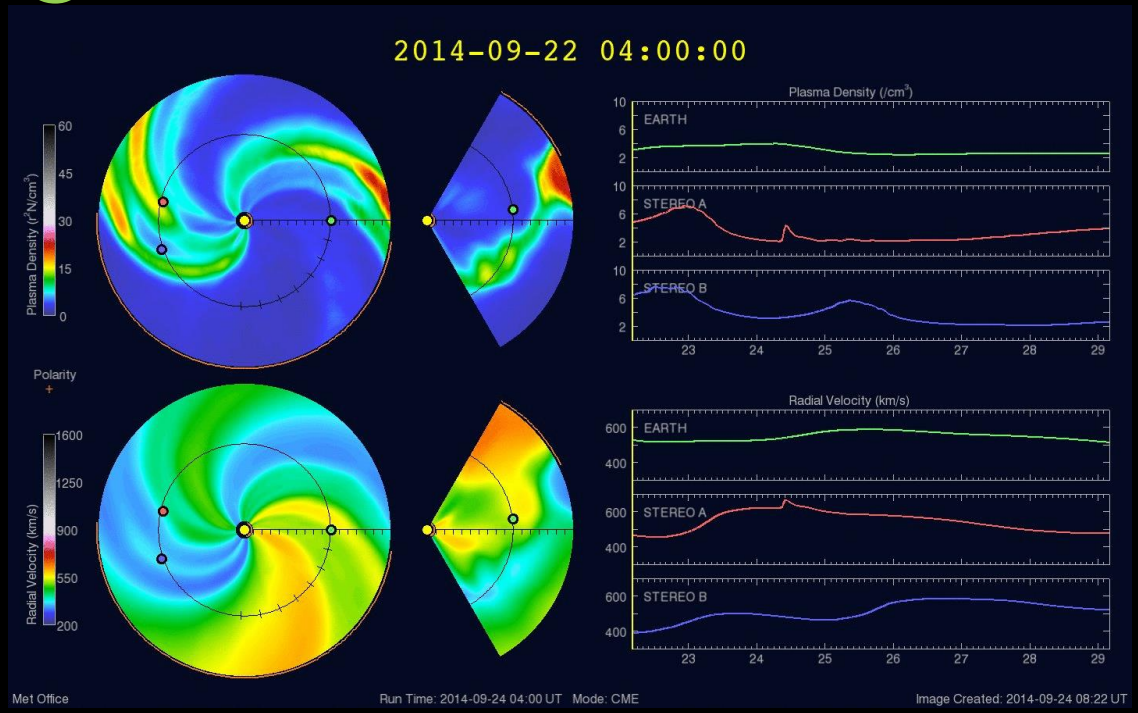
- 4 x L5 examples
  - Persistence modelling with STEREO – value of L5 in-situ observations
  - CME analysis tool (CAT) – value of L5 coronagraph and HI observations
  - Magnetofrictional model – potential value of L5 magnetograms; DuMFric Enlil producing results.
  - Assimilating in-situ solar wind data to improve the representation of the heliosphere. Large potential for assimilating L5 data into Enlil

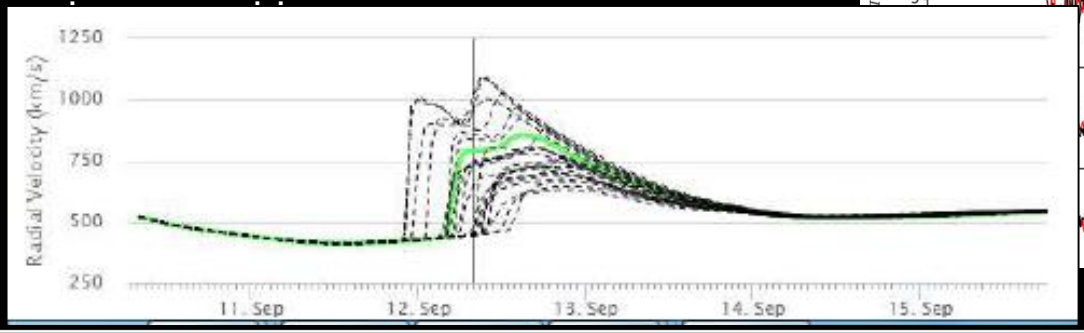
Solar wind & CME forecasting at MOSWOC

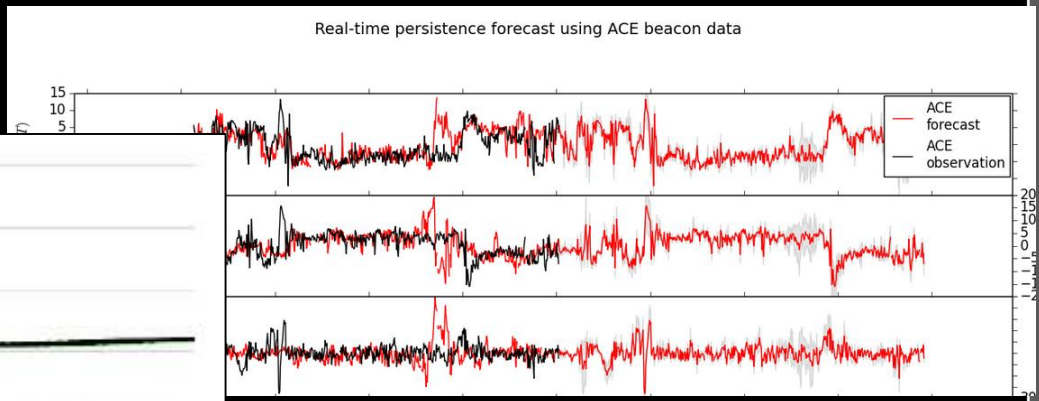
MOSWOC

- 24/7 Operations
- Forecasts of:
  - CMEs
  - Geomagnetic storms
  - Flares
  - Solar energetic particles (protons and electrons)



- Forecasters analyse images to identify CMEs and use **WSA Enlil & persistence model** to predict solar wind / CMEs
- CMEs can also be forecast





Solar Wind Persistence Model

Met Office

Driven by L1 or STEREO-B data

L1 f/cast 27 days ahead; STEREO-B around 4-5 days ahead (near L5) – benefit?

Operational at MOSWOC (ACE / DSCOVR)

Table 2. Skill Scores and Linear Correlation Coefficients for ACE and STEREO-B-Based Persistence Models for Various Solar Wind Parameters Over the Period March 2007 to March 2013[a]

	ACE		STEREO-B			
Parameter	Skill	r_L	Skill	Δ_S	r_L	Δ_r
B_x	29.1	0.50	40.9	**11.8**	0.56	**0.06**
B_y	20.7	0.42	30.4	**9.7**	0.45	**0.03**
B_z	4.3	0.14	21.4	**17.1**	0.18	**0.04**
$\|B\|$	16.6	0.24	24.8	**8.2**	0.33	**0.09**
N_p	54.2	0.41	23.2	−31.0	0.41	0.00
V_p	56.3	0.59	65.4	**9.1**	0.70	**0.11**
T_p	44.8	0.45	29.3	−15.5	0.48	**0.03**

[a]STEREO-B values show the difference in skill score Δ_S and correlation coefficient Δ_r relative to ACE values. Bold numbers show where these differences indicate the STEREO-B-based persistence forecast improves over the ACE-based persistence forecast.

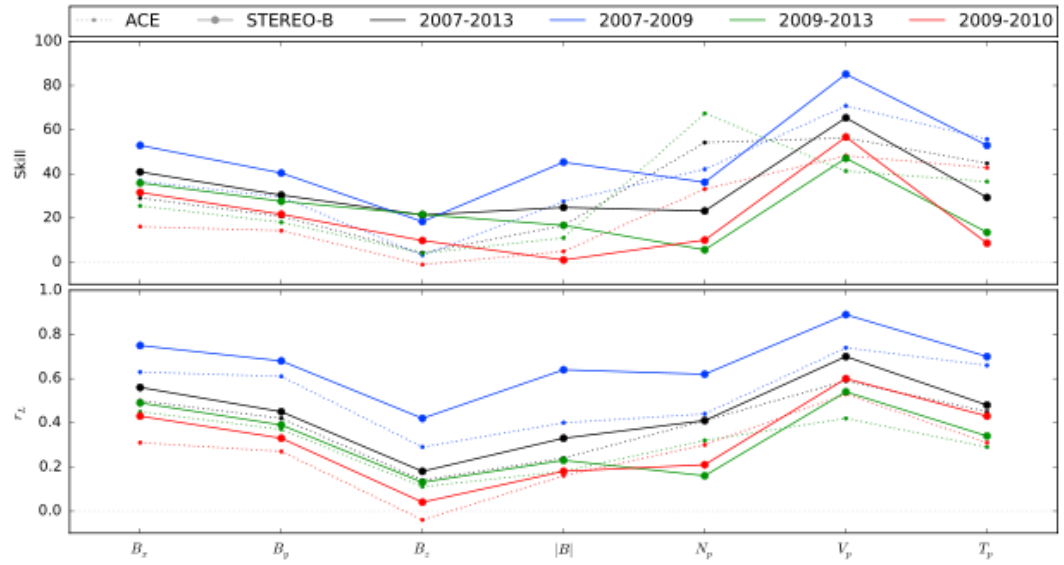


Figure 7. (top) Skill scores and (bottom) correlation coefficients for ACE (dashed lines) and STEREO-B (solid lines) evaluated over different periods. Years 2007–2013 (black line) show the entire period, corresponding to the results in Table 2, 2007–2009 (blue) show the period when the STEREO-B azimuthal angle Θ was < 50°, 2009–2013 (green) the period when Θ was > 50°, and 2009–2010 (red) the 6 month period (2 August 2009 to 29 January 2010) when 50° < Θ < 70°, i.e., the period roughly corresponding to the Θ = 60° values of an L5 mission.

Kohutova et al (2016) compared versions for 2007-2013

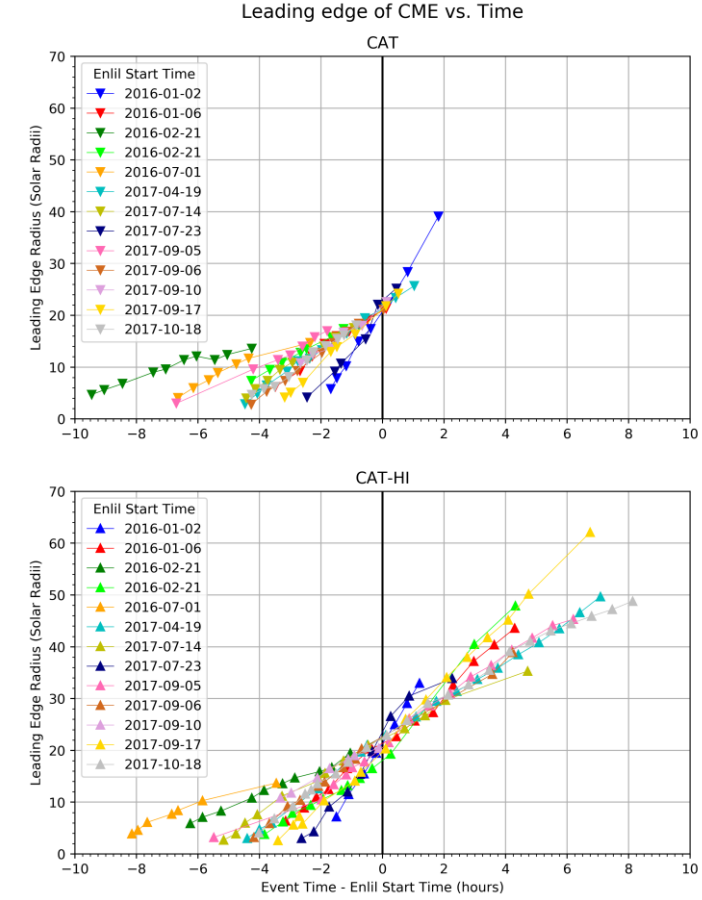
Generally positive impact on skill scores and correlation

Thomas et al (2018) found similar results

Shows value of L5 in-situ observations

CAT-HI

- CME analysis tool (CAT) uses SOHO + STEREO c/graphs to estimate CME speed, location, width
- Absence of STEREO degraded MOSWOC CAT estimates
- CAT-HI uses STEREO HI in addition to c/graphs
- PoC study (Wharton et al, submitted) - benefit in pruning ensembles rather than improved CME forecasts
- Further work on CAT assumptions – fixed speed, circular, etc…

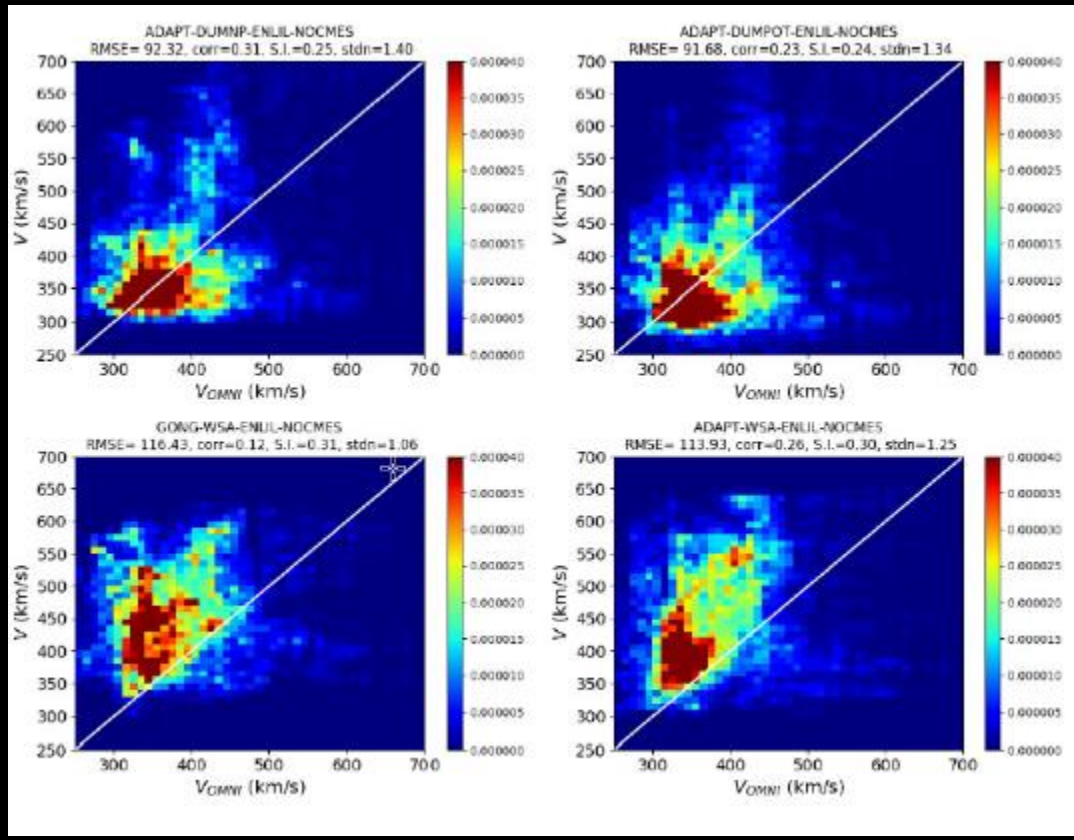


Samuel Wharton (Leicester)

Shows value of L5 coronagraph and HI observations

DuMFRic

- NLFFF magnetofrictional approach better represents evolution of coronal magnetic field
- Mackay et al (2016) – simulate L5 and Earth magnetograms – show 26-40% improvement in global integrated quantities (eg flux rope ratio, current ratio)
- DuMFric Enlil (using Earth m/grams) show promising results – ready to be exploited…

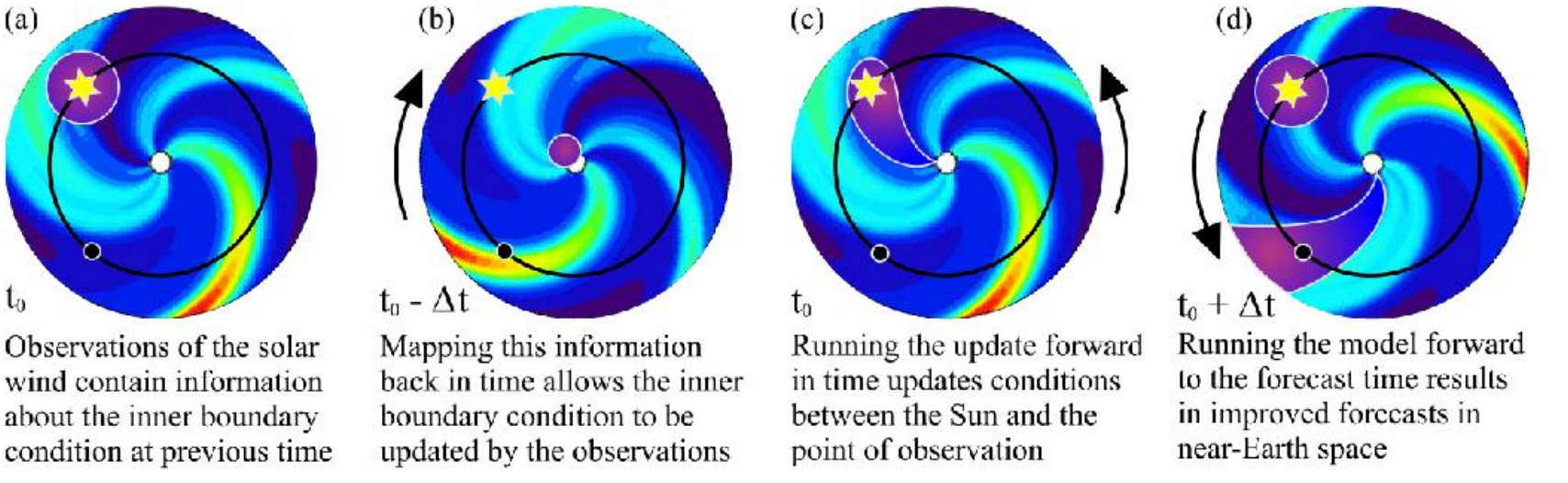


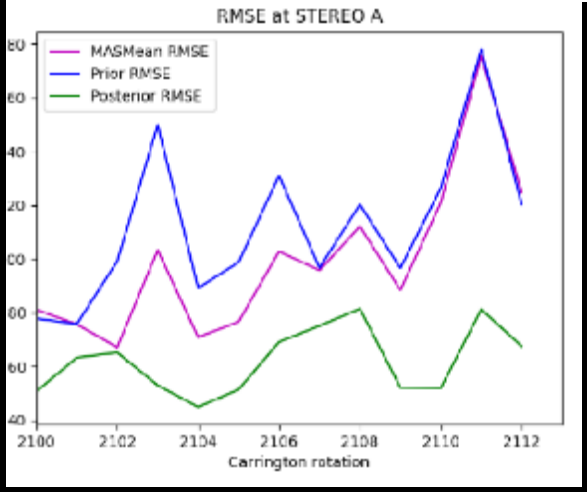
Gonzi et al (in prep.)

Shows value of L5 magnetograms

Heliospheric DA

Matt Lang (Paris), Matt Owens (Reading)





RMSE in near-Earth solar wind speed Blue = prior state, from the MAS ensemble. Green = posterior state, from DA of STEREO A and B

- **Need data ahead of Earth to improve forecasts at Earth**
- **But need to run model back in time to update inner boundary – otherwise information gets swept out beyond 1 AU by solar wind**
- **Lang et al (2017) showed that EnKF can't work with Enlil for this reason**
- **Applying 4D-Var to 2D solar wind model (Riley & Lionello) much more successful (Lang et al, 2018) since adjoint updates previous model state**
- **Window = 27 days. Simple linear model (NWP = 6 hrs). What about for an MHD model?**

May show value of L5 in-situ (and, later, HI) obs

Summary

- MOSWOC solar wind forecasts currently use Earth-based magnetograms, L1+STEREO c/graphs (WSA Enlil), L1 in-situ data (persistence)
- Further exploitation of STEREO and associated research shows potential benefits of L5 observations, notably:
  - In-situ (speed, density, magnetic field)
  - Heliospheric Imager
  - Coronagraph
  - Magnetograms
- New models (eg DuMFric) and analysis methods (eg DA) will maximise the benefit of these new observations

Extra slides