Evaluating the Skill of Forecasts of the Near-Earth Solar Wind using a Space Weather Monitor at L5

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L5 in tandem with L1 **09 March 2017**

Motivation

Many important space weather effects at Earth are driven by the solar wind.

Predictions of those effects require advance knowledge of solar wind speed, density and temperature, and the interplanetary magnetic field vector.

e.g. Solar wind dynamic pressure depends on speed and density

e.g. An important driver of radiation belt relativistic electron flux enhancements is solar wind > 500 km/s

e.g. Solar wind power input to the magnetosphere/unit area:

$$P = V_{sw} B_{IMF}^2 \mu_0 \sin^4(\theta /2)$$

Perreault and Akasofu 1978

How much improvement in forecasting capability can be expected when solar wind measurements at L5 are available?

How well does this compare to a simple 28 day persistence forecast?

Model

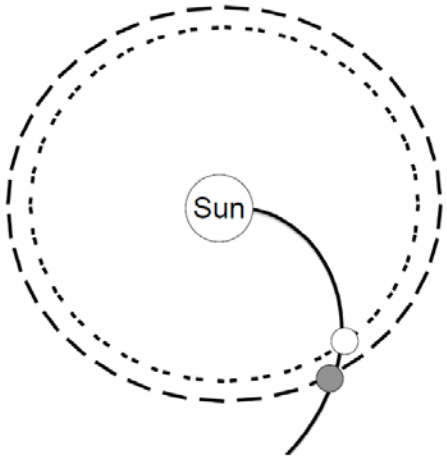
Solar wind measurements at L5 can be used to predict future conditions at L1/Earth if the solar source of the wind that is measured at L5 is

- stable on the time scale of a few days
- is at a sufficiently similar helio-latitude to the source that produces solar wind that reaches L1/Earth

To make a forecast we take measured parameters at “L5” and propagate them to “L1/Earth”

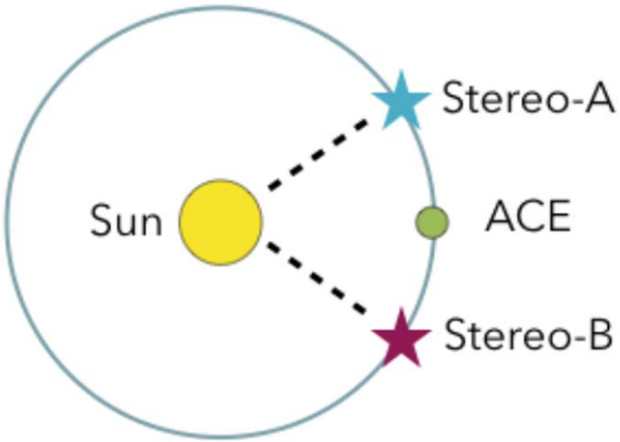
$$\Phi_{Carr\_expected} = \Phi_{Carr\_B} - \frac{\Omega_{Sun}(R_B - R_A)}{V_{SW\_B}}$$

Simunac et al. 2009

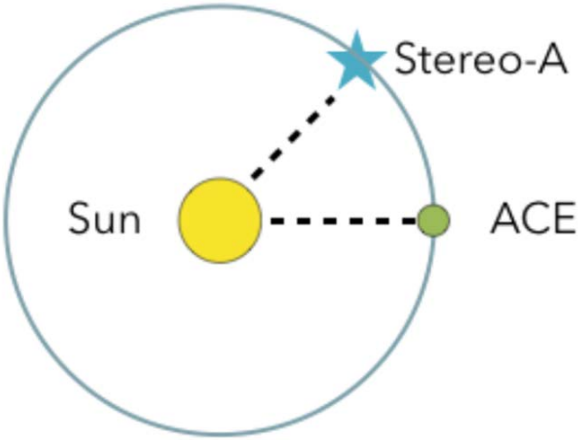


Relevant Time Intervals and Spacecraft Combinations

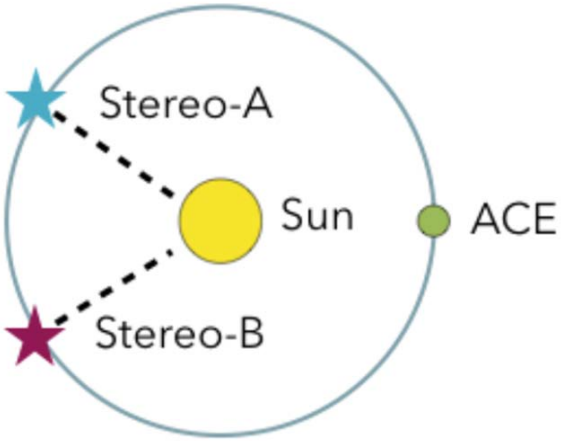
2008



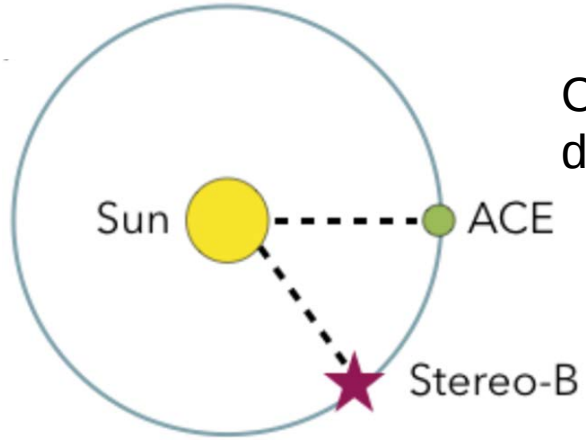
2009



2013/4



The 60° heliographic longitude separation geometry between L5 and L1/Earth has been reproduced several times by STEREO A, B and ACE



Combined duration of useful data intervals > 1 year

Some Previous Studies

Simunac et al., 2009:
studied StA/St-B data from July 2008, illustrated forecasting potential of L5

Turner et al., 2011:
studied St-B/ACE data between Aug 2008 – Aug 2009, explored using L5 data to enhance D_{st} predictions (geomagnetic storms)

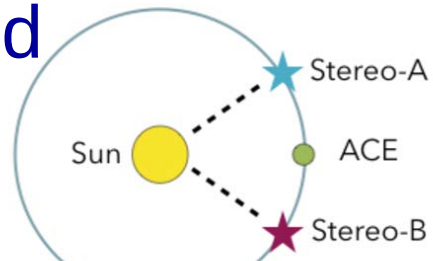
Owens et al, 2013:
evaluated skill score for 27-day persistence forecast

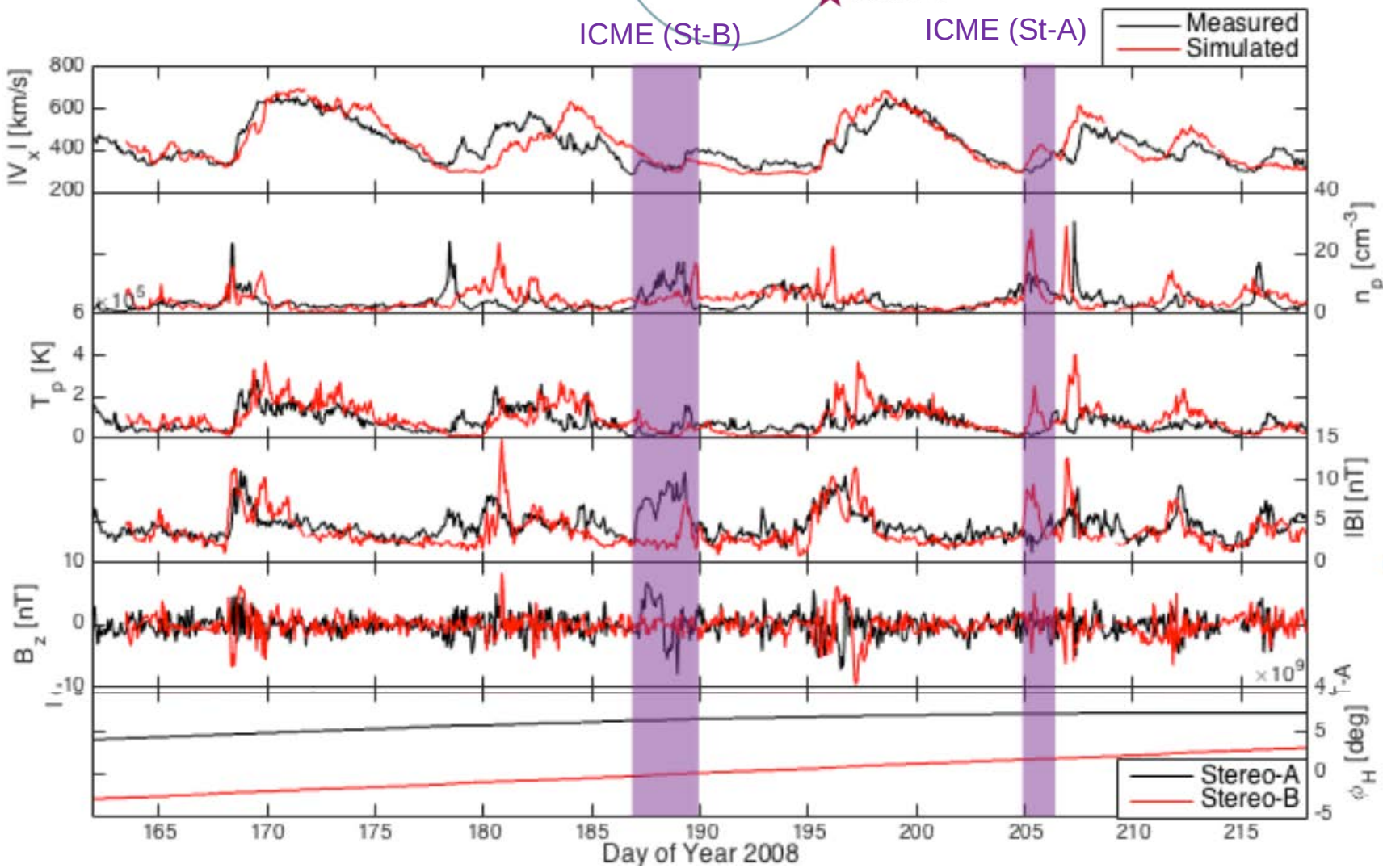
Kohotuva et al., 2016:
studied St-B/ACE data collected during summer 2009; skill scores for IMF B_z

Example 1: directly measured

12 Jun 2008 – 08 Aug 2008 (58 days)

ST-A measured ST-B based prediction

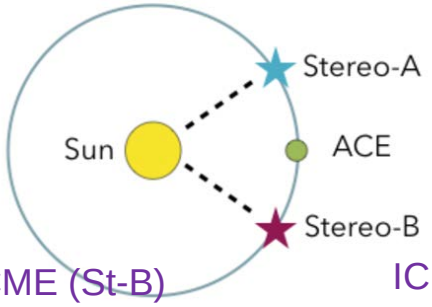


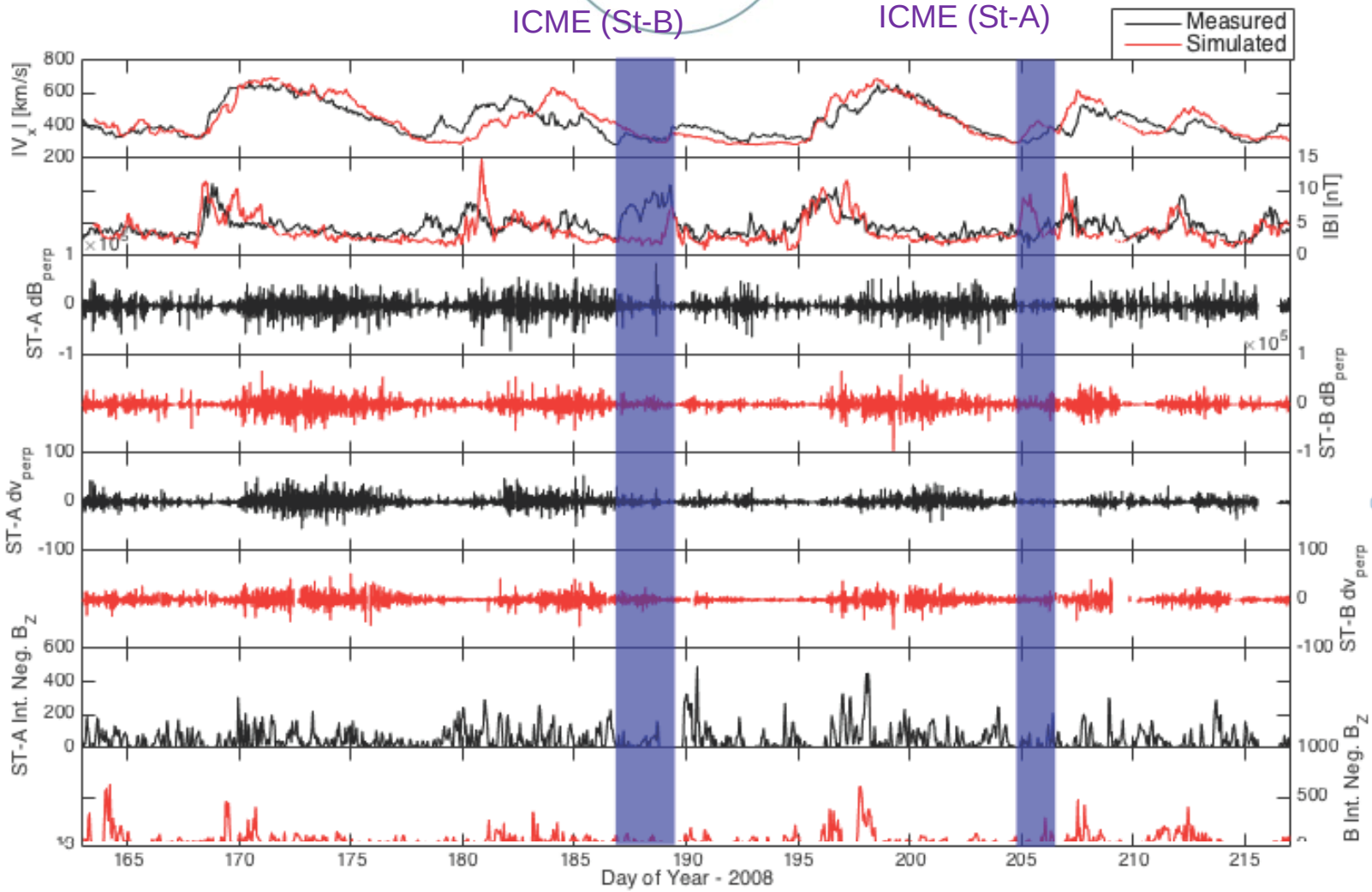


Example 1: value added

12 Jun 2008 – 08 Aug 2008 (58 days)

ST-A measured ST-B based prediction





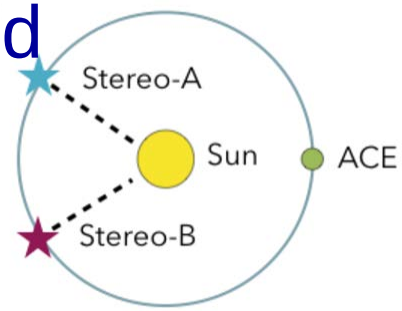
dB_{perp} and dV_{perp} are intended as proxies for Alfven wave activity

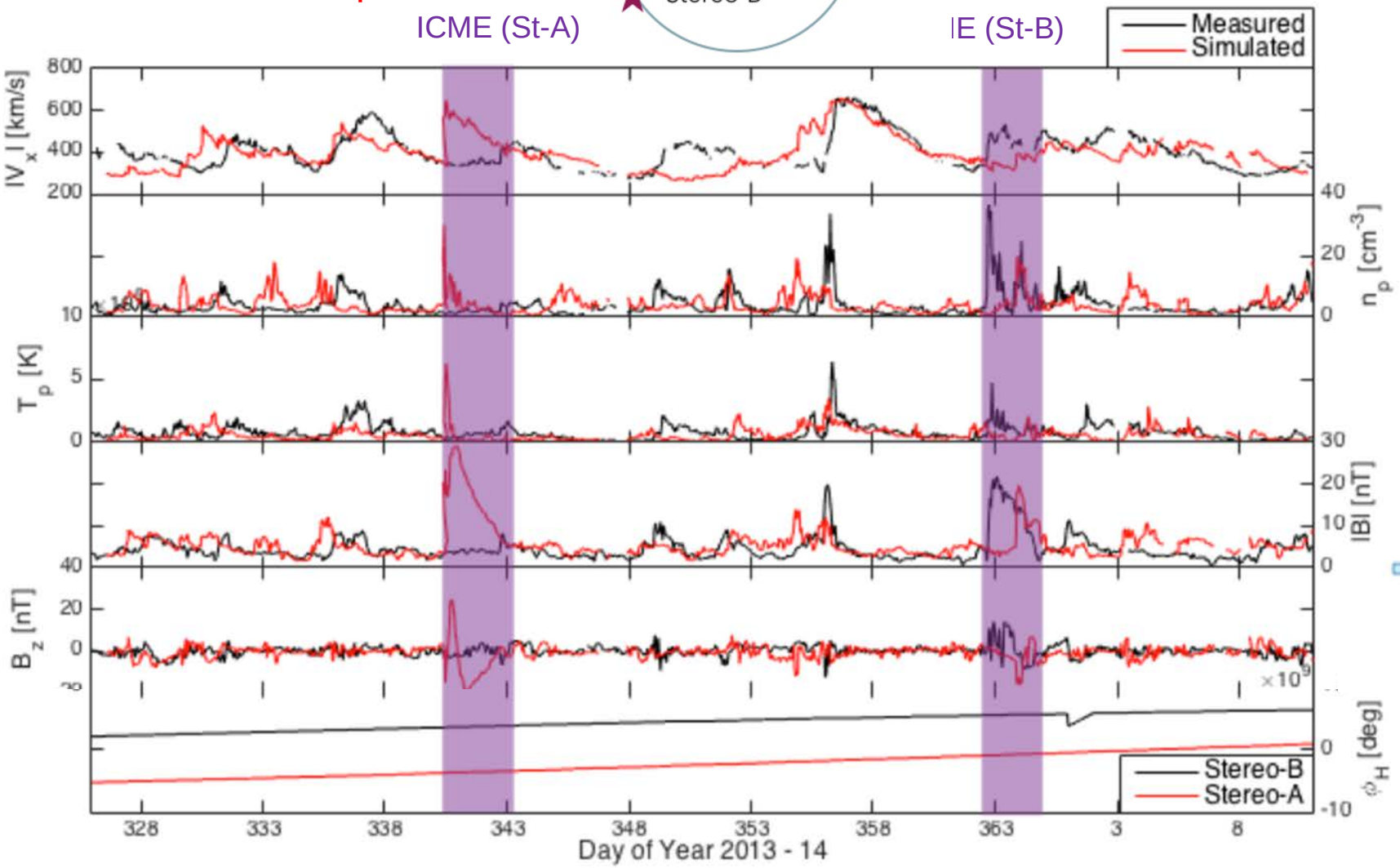
$\int (Bz < 0)dt$ as proxies for cumulatively geoeffective IMF orientation

Example 2: directly measured

22 Nov 2013 – 13 Jan 2014 (53 days)

ST-B measured ST-A based prediction

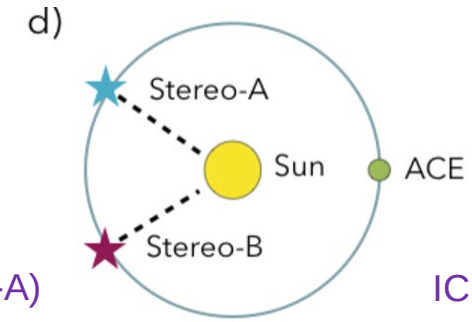


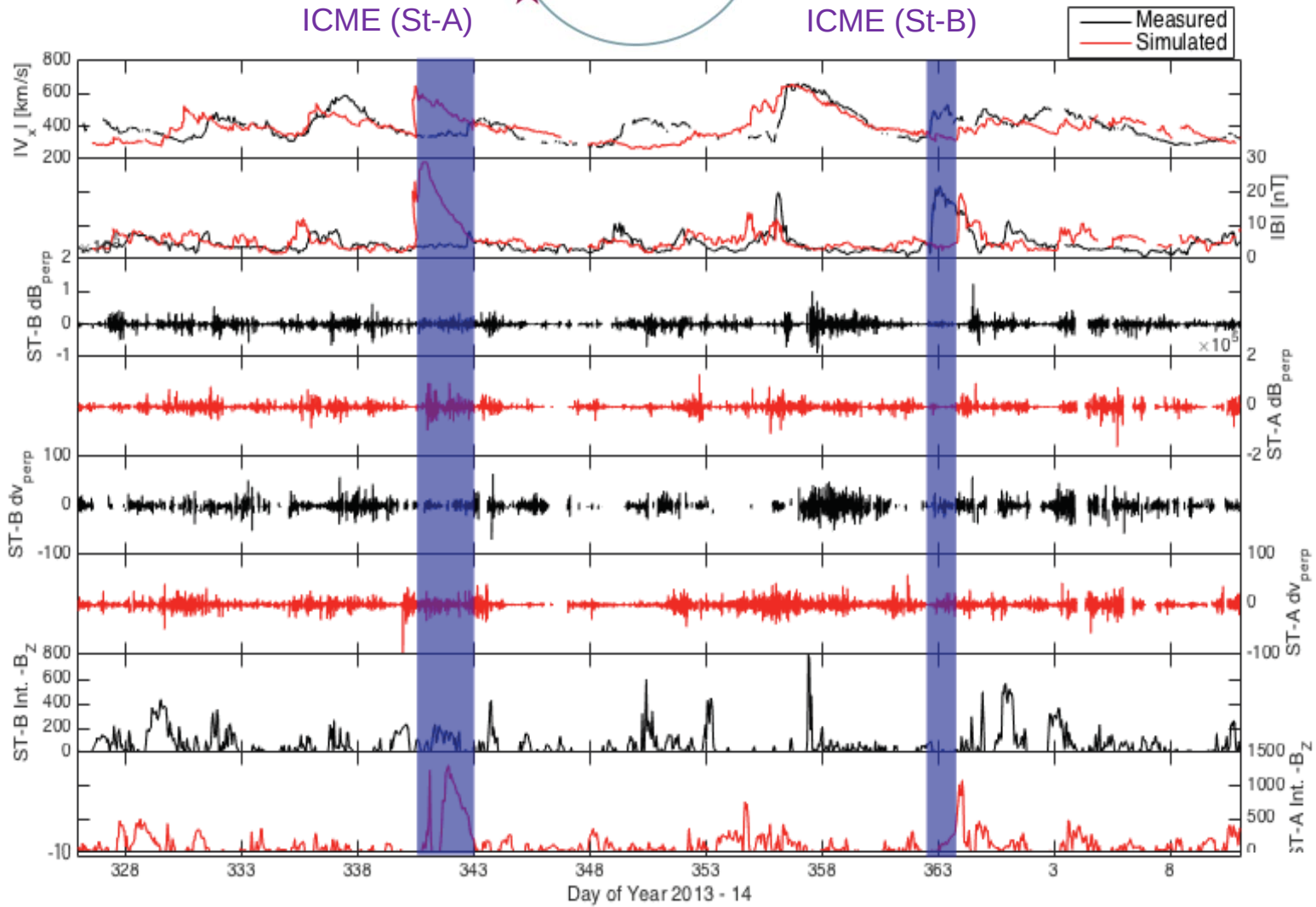


Example 2: valued added

22 Nov 2013 – 13 Jan 2014 (53 days)

ST-B measured ST-A based prediction





dB_{perp} and dV_{perp} are intended as proxies for Alfven wave activity

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Calculation and Interpretation of Skill Scores

The Skill Score is defined as follows, where MSE is the "mean square error" of the forecast with respect to the actual observations, model is the trial forecast and reference is a reference forecast

$$MSE = \frac{1}{N}\sum_{t=1}^{N}(X_{observation}(t) - X_{model}(t))^2$$

$$Skill = 100\left(1 - \frac{MSE_{model}}{MSE_{reference}}\right)$$

Skill Score	Interpretation
100	The model forecast is perfect
>0	The model forecast performs better than the reference
0	The model forecast performs as well as the reference
<0	The model forecast performs worse than the reference
<<0	The model forecast performs far worse than the reference

Results: Skill Scores (all data, includes ICMEs)

Our "reference forecast" is a 27 day persistence forecast

Parameter	St-B to ACE	ACE to St-A	St-B to St-A	St-A to St-B
$\lvert v_x \rvert$	+18.57	+34.91	+82.13	+56.08
n_p	+18.08	+15.07	+45.85	-22.65
T_p	+4.72	+17.00	+46.60	+23.71
$\lvert B \rvert$	-6.33	+20.72	+32.25	-40.59
B_z	-18.48	+7.44	-9.04	-39.39
$\int -ve\ Bz$	-9.07	+10.55	-11.70	-50.91

Plasma parameters give better skill than magnetic, broadly speaking

Results: Skill Scores (ICME events removed)

Our “reference forecast” is a 27 day persistence forecast

Parameter	St-B to ACE	ACE to St-A	St-B to St-A	St-A to St-B
$\lvert v_x \rvert$	+19.62	+36.38	+81.96	+70.10
n_p	+14.15	+15.29	+44.79	-11.65
T_p	+8.78	+20.01	+45.85	+7.06
$\lvert B \rvert$	+10.47	+20.74	+41.88	+46.77
B_z	-6.23	+6.97	-12.64	+15.14
$\int -ve\ Bz$	-8.72	+10.07	-7.15	-49.99

Some improvements as expected

Conclusions

We investigated 4 intervals (total duration 409 days, 1.1 years) with pairs of spacecraft separated in heliocentric latitude by ~ 60°

Skill scores for a forecast of solar wind plasma conditions at L1, using L5 data, are significantly improved (compared to a 27-day persistence forecast).

Forecasts of magnetic compression are improved, but magnetic field orientation less so.

Removal of ICMEs produced significant improvements in skill scores

We are considering whether a more sophisticated analysis tailored to the geoeffectiveness of large amplitude Alfvén waves in the fast wind may show better skill.

Thomas et al. (2017) in preparation

Also…

MSSL Space Plasma Instrument Heritage

MSSL has been building space plasma analysers since 1980s

Some notable examples include

- *Giotto JPA* (solar wind and cometary ions)
- *AMPTE UKS JPA* (solar wind and magnetospheric ions)
- *Cluster PEACE* (solar wind and magnetospheric electrons, 8 sensors each operational after > 16 years)
- *Solar Orbiter SWA* (solar wind analyser suite, flight instruments near delivery)

Recent work on solar wind analysers/missions in space weather context

- *Kuafu-A SWAN* (some UK funding for development work)
- *Sunjammer SWAN* (low resource variant some UK funding)

- *Carrington*
- *ESA SWE-X*

By the way…

If interested please contact
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