

*Progress Report of WG5 (and related) activities:
The Bs Challenge*

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**ISEST 2018 WORKSHOP
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The Bs challenge: Statement of the WG

(from ISEST description)

The presence of **southward** magnetic fields in ICMEs are the most important factor in producing **geomagnetic storms**.

WG5 aims to **understand** and **reconstruct** the possible flux rope **magnetic structure** of **CMEs/ICMEs** from observations and models. It also aims to **predict** the **intensity** and the duration of the **Bs** in **ICMEs** upon arriving at the Earth.

DIFFICULTIES

State of the Art

Radio diagnostics of CME coronal & IP magnetic field by Faraday rotation (e.g., Bird et al. 1985; Jensen & Russel 2008, Liu+ 2007, Jensen+2010; Liu+ 2007; Bisi+ 2016; Kooi+ 2017) & gyrosynchrotron emission (e.g., Bastian+2001; Tun & Vourlidas 2013; Carley+2017) are **difficult & rare**

Advent of **methods** to **infer** the **CME magnetic field in the corona/IP**

Emergence of **magnetized CME heliospheric propagation models** for space-weather predictions (EUHFORIA, COIN-TVD, ENLIL, SUNSANOO); **constraints by coronal CME b-field inferences**

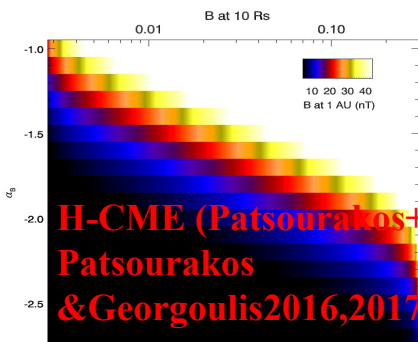
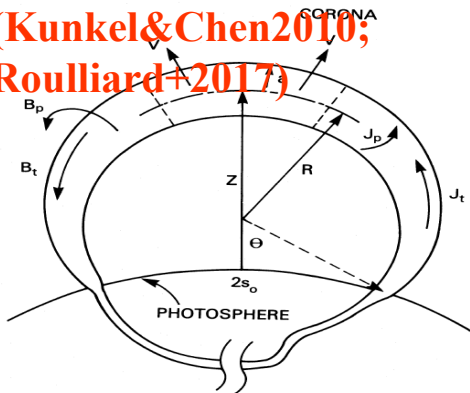
Sun-to-Earth CME simulations (AWSOM, MAS thermodynamic): genesis & propagation

Development of **statistical framework** to compare Bz-predictions with observations

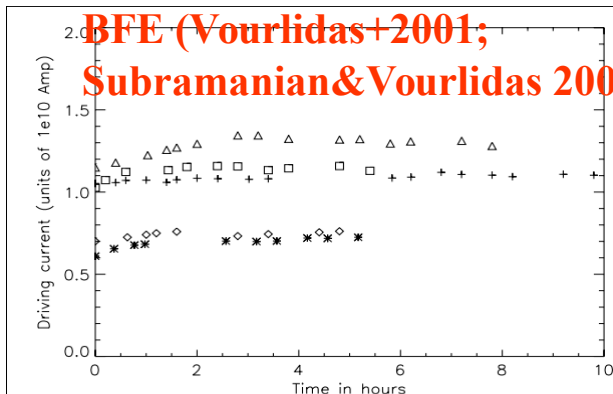
Many Models of CME Magnetic Field Inference

HELIO-XM

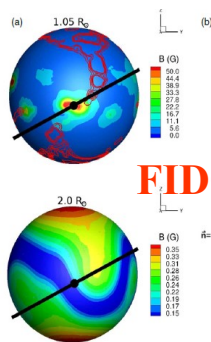
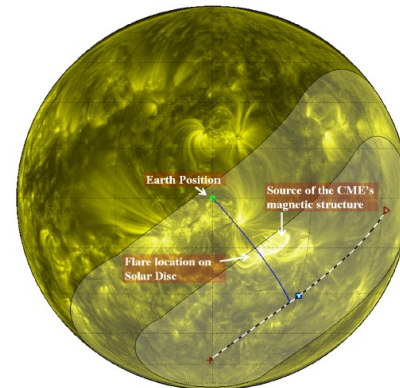
(Kunkel&Chen2010;
Roulliard+2017)



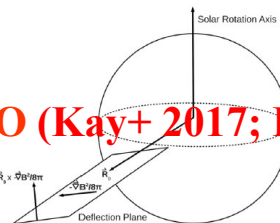
**BFE (Vourlidas+2001;
Subramanian&Vourlidas 2009)**



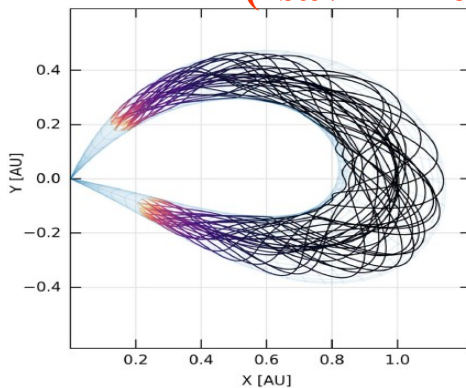
BZ4CAST (Savani+ 2015, 2016)



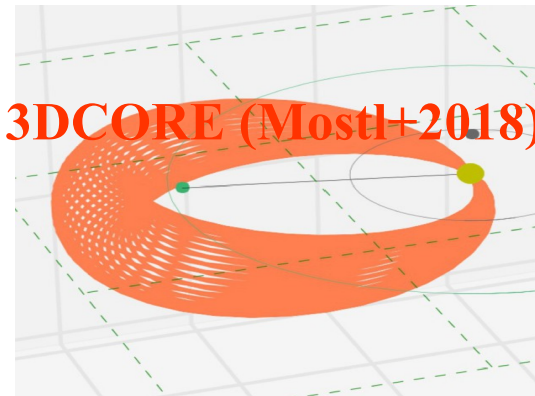
FIDO (Kay+ 2017; Kay&Gopal 2017b)



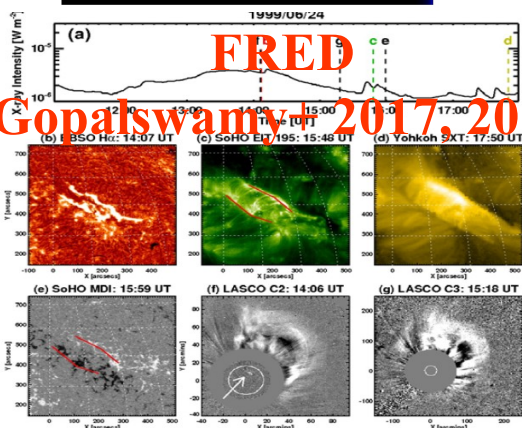
FriED (Isavnin 2016)



3DCORE (Mostl+2018)



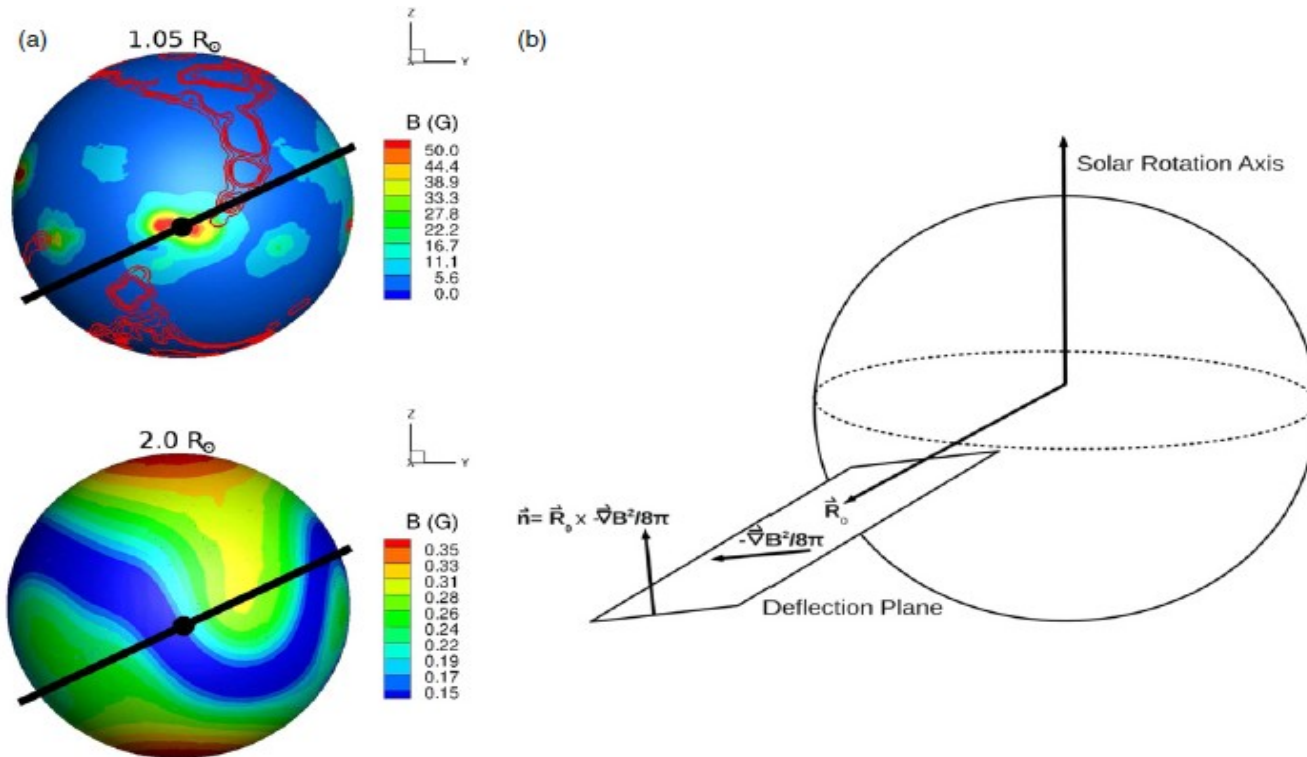
FRED (Gopalswamy+ 2017, 2018)



FIDO (Kay+2017; Kay&Gopalswamy 2017)

ForeCAT semi-analytical data-constrained model (Kay+2013,2014,2015)

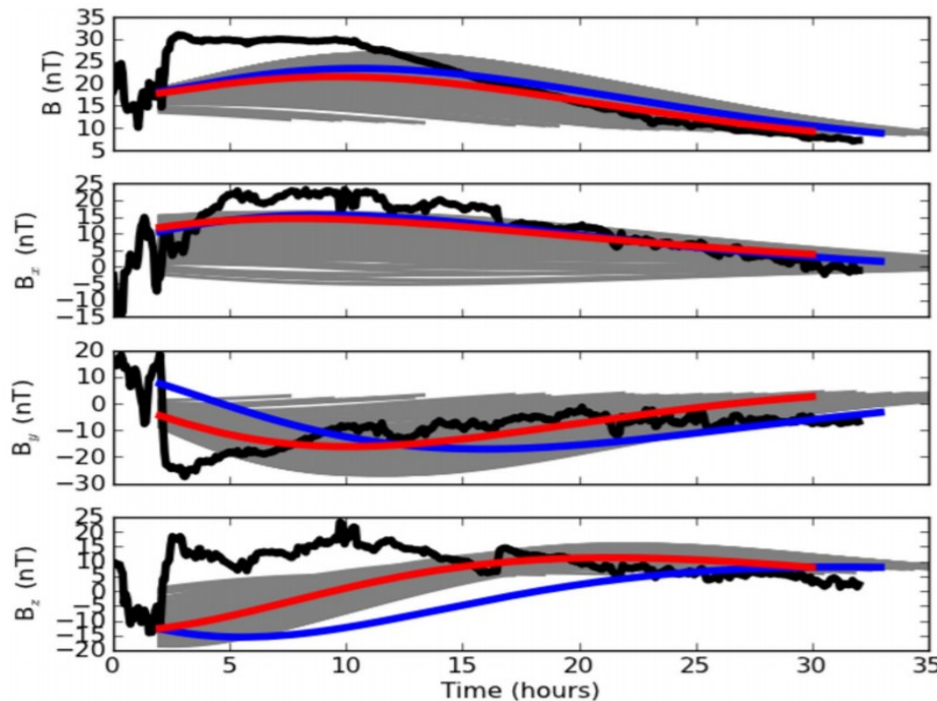
magnetic forces acting on CMEs --> near-Sun CME deflection + rotation



LFF cylindrical model + flux conservation --> B CME @ 1 AU

FIDO (Kay+2017; Kay&Gopalswamy 2017)

Applied to 49 events



black ---> observations
blue --> no deflection/rotation
red ---> model

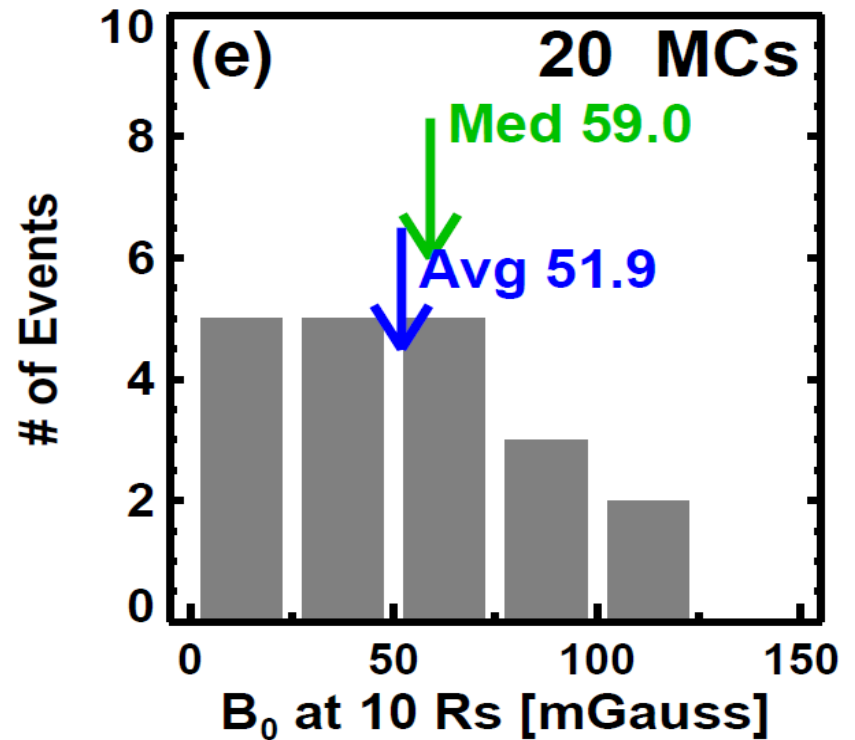
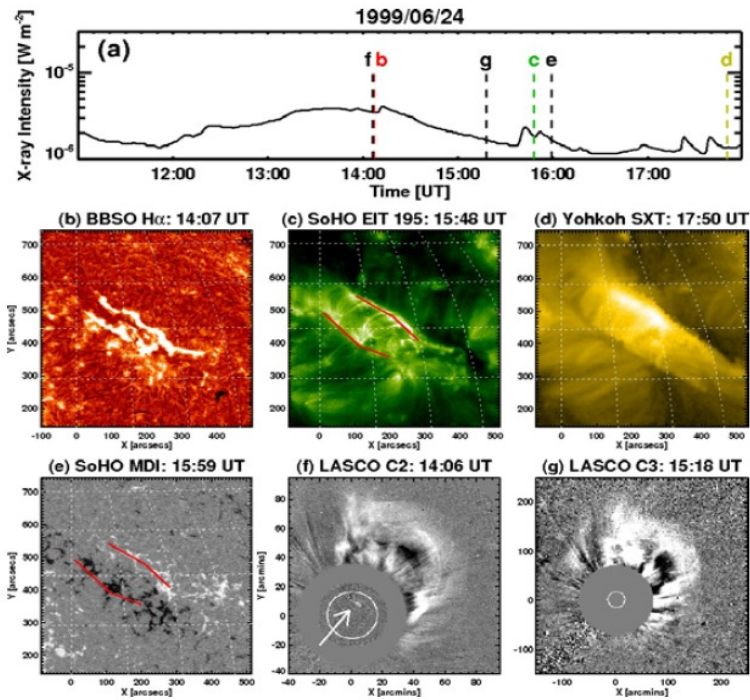
ballpark agreement

gray --> uncertainties
5 deg (lat); 10 deg (lon,tilt)

B sensitive to uncertainties of CME location/orientation
--> **C. Kay talk**

Uses in-situ observations @ 1 AU for near-Sun CME |B|

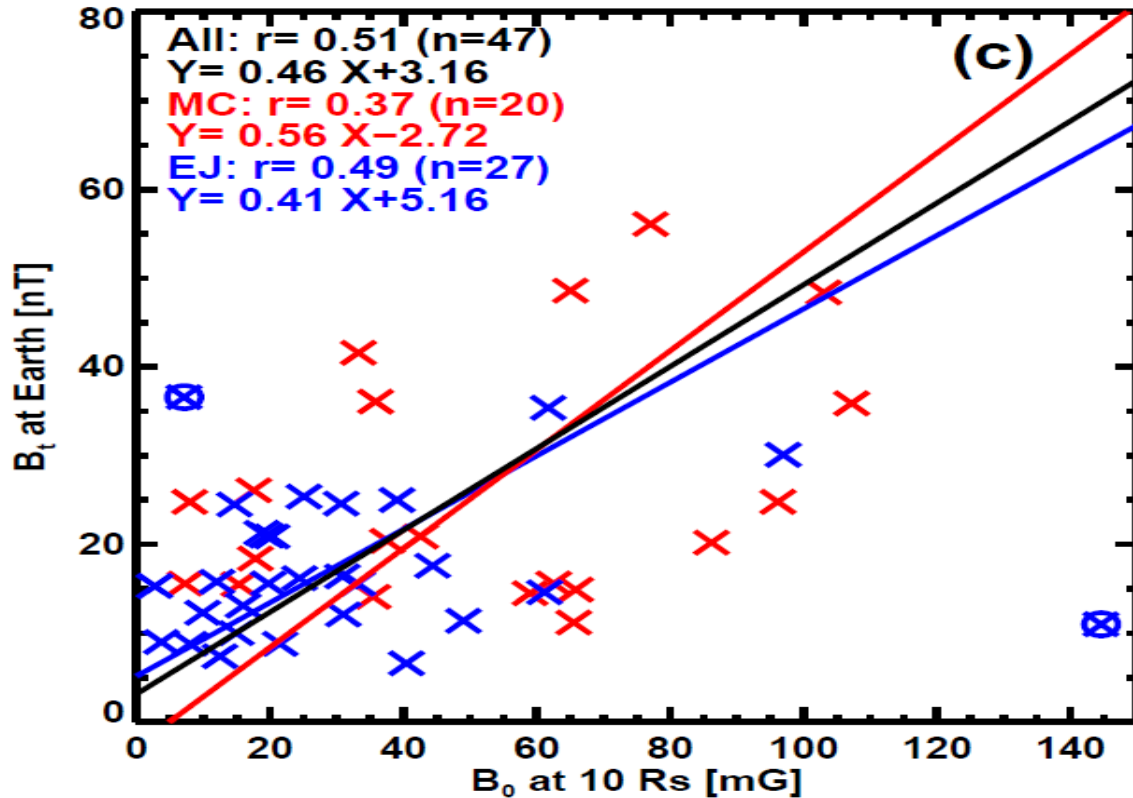
FRED (Gopalswamy+ 2017, 2018)



Calculate reconnected flux in post-eruption arcades + fit flux rope model to corresponding CMEs from LASCO observations of 54 CMEs

Apply constraints to cylindrical LFF model ---> CME magnetic field at 10 R_s ($>$ ambient)

FRED: Coronal and IP attributes (Gopalswamy+ 2017,2018)



correlation btw near-Sun BCME + MC axial field

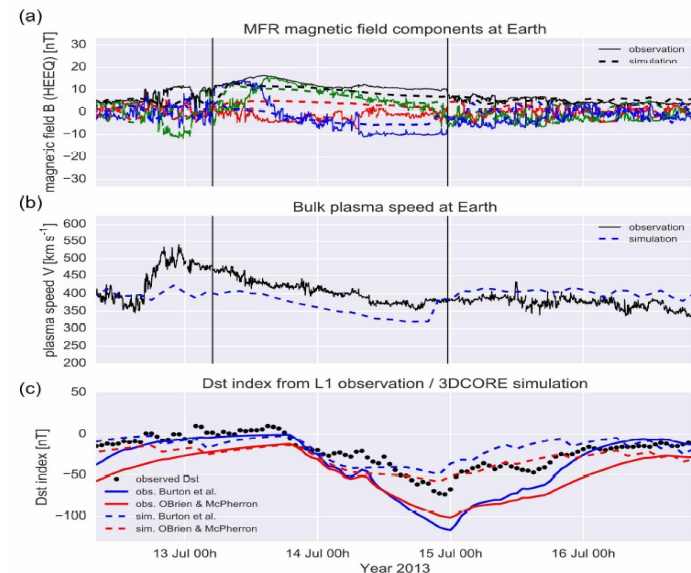
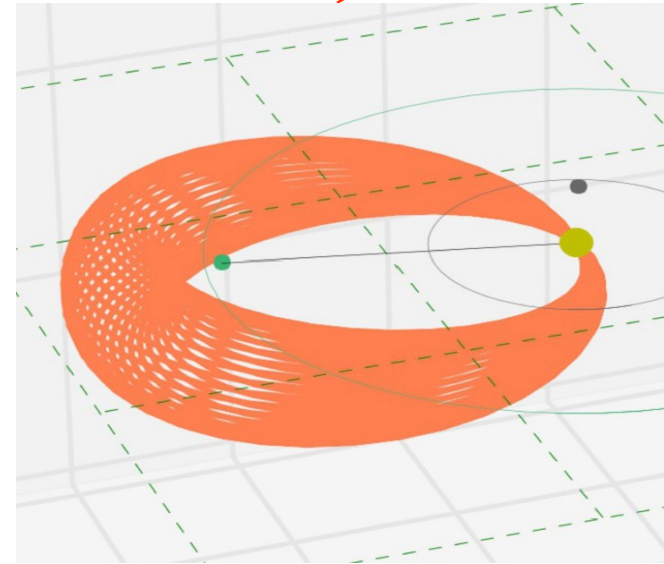
3DCORE (Mostl+2018)

Stack 2D Gold-Hoyle sections to a 3D tapered torus & flux conservation

drag-force model Vrsnak + 2013 --> kinematics

applied to a case study

Ballpark agreement + ToA



Uses in-situ observations @ Messenger to determine near-Sun CME [B]

H-CME (Patsourakos+2016)

For LFF cylindrical flux rope (Lundquist 1950) :
Dasso, Mandrini, Demoulin et al. 2003 →

$$B_0 = \sqrt{\frac{2.405 H_m}{4\pi LRJ}}$$

L, R → CME length+ radius from GCS
modeling of CMEs with STEREO (Thernisien et al 2009)

Hm → from photospheric magnetic/flow obs & extrapolations (e.g., Valori et al. 2017)
; conserved (e.g., Berger 1985)

Near-Sun CME magnetic field B_0

Extrapolation of coronal CME b-field to 1 AU

Use a power-law of the radial distance r:

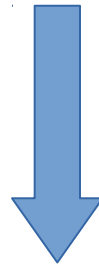
α_B → [-2.7, -1.0] from Demoulin & Dasso 2009

$$B_0(r) = B_* (r/r_*)^{\alpha_B}$$

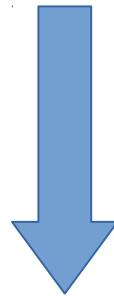
α_B is a free parameter used to match the in-situ observations

Parametric Studies of H-CME (Patsourakos & Georgoulis 2016, 2017)

Generate 10^4 synthetic CMEs by
by taking random samples from the observed AR Hm
(Tziotziou+ 2012) & CME geometrical parameter
(Thernisien+2009; Bosman+ 2012) distributions

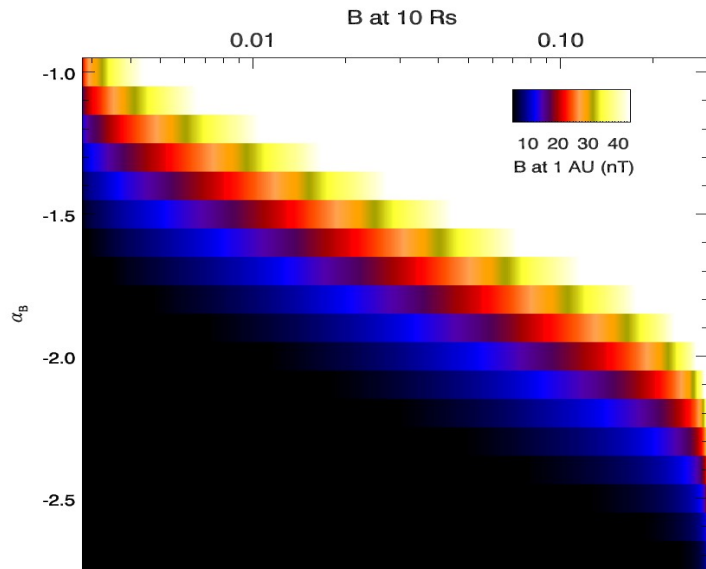


Determine near-Sun B^* for the 10^4 synthetic CMEs



Extrapolate CME b-field to 1 AU for different αB for the
 10^4 synthetic CMEs

Parametric Studies of H-CME (Patsourakos & Georgoulis 2016, 2017)

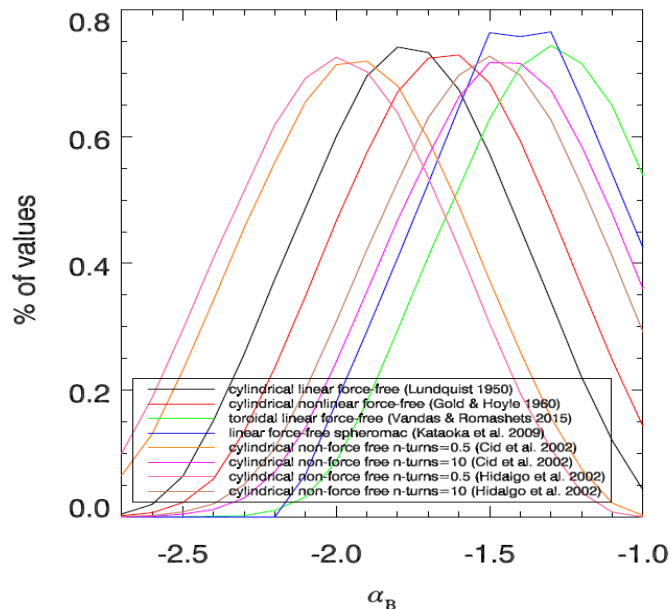


LFF cylindrical model

color --> extrapolated to 1 AU
CME magnetic field

black+white ---> outside range of MC
observations (Lynch+2003; Lepping+ 2006)

region around $\alpha_B \sim -1.6$ fits reproduces the
bulk of MC observations

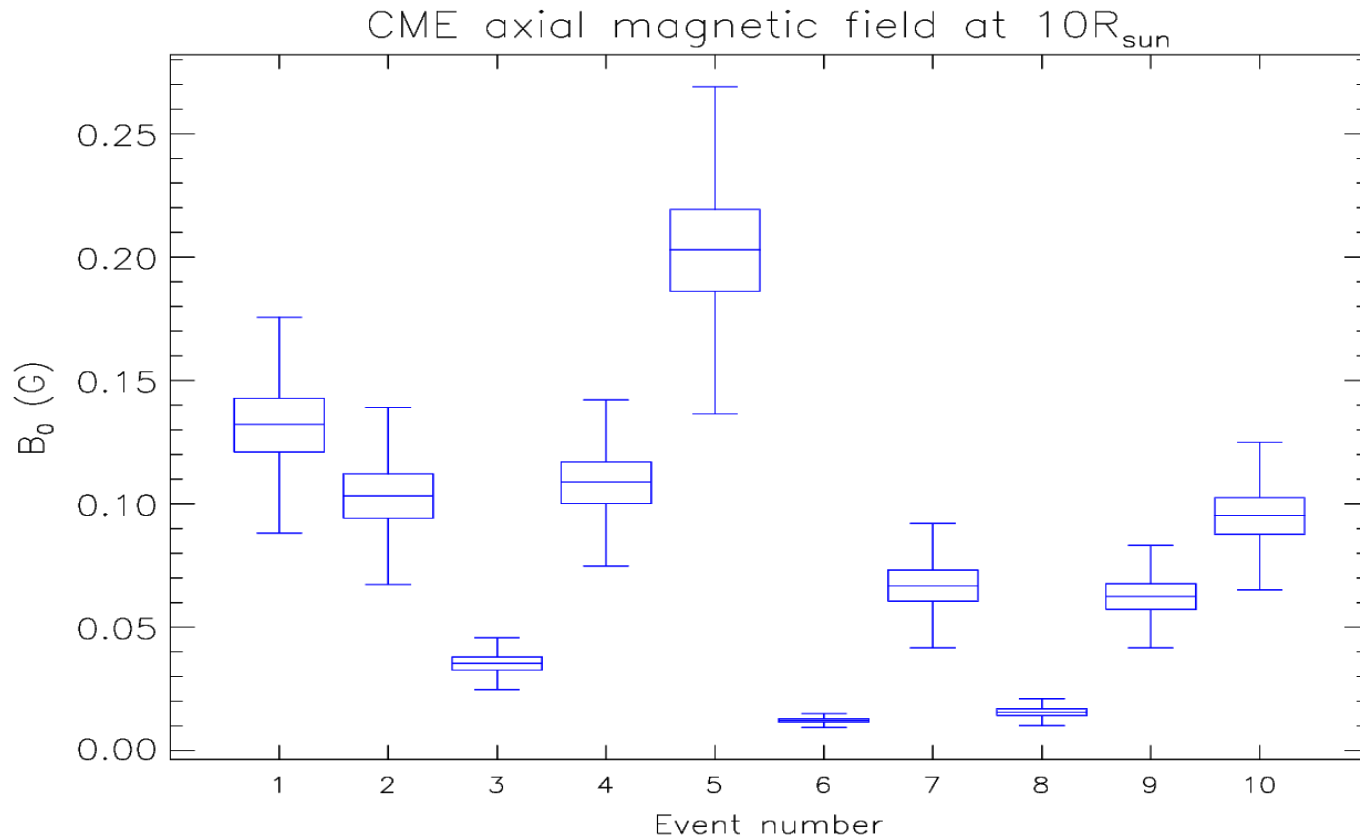


extension to various CME models
(e.g., non-force-free, spheromac etc)

% of predicted values within the range of
MC observations as a function of α_B

robustness of models for specific α_B -range
is used

H-CME application to 10 CMEs (Petroulea+2018)



ISEST event list 10 C-X class flares (Hess&Zhang 2017)

assess **uncertainties** in derived magnetic fields

x10 range in $|B|$; higher than ambient

Summary of CME b-field inference models (Vourlidas+2018)

Model	HELIO-XM	BFE	BZ4CAST	H-CME	FIDO	Fried	FRED	CORE3D
shape	torus	cylinder	cylinder	cylinder/torus/spheromac	torus	torus	torus	torus
principle	hoop force	CME energetics	hemispheric helicity rule & region of influence	magnetic helicity conservation	force balance	flux conservation along 3D torus	reconnected flux	populate 3D torus with 2D magnetic sections
Near-Sun magnetic field	non-force-free	force-free	force-free	force-free/non-force-free	force-free	force-free	force-free	force-free
B near-Sun	Y	Y	CCMC simul of sheath	Y	N	N	Y	N (@ Messenger)
near-Sun deflections	N	Y	Y	Y	Y	Y	N	Y
IP propagation	radial	radial	radial	radial	radial	radial	radial	radial
B IP evolution	force-balance	flux conservation	CCMC simulation	power-law with varying α_B	flux conservation	flux conservation	flux conservation	flux conservation
B vector	Y	N	Y	N	Y	Y	N	Y

HELIO-XM: [Kunkel & Chen \(2010\)](#); [Roulliard & Lavarra \(2017\)](#)

BFE: [Vourlidas et al. \(2001\)](#); [Vourlidas & Subrahmanian 2007](#)

BZ4CAST: [Savani et al. \(2015,2016\)](#)

H-CME: [Patsourakos et al. \(2016\)](#); [Patsourakos & Georgoulis \(2016,2017\)](#)

FIDO: [Kay et al. \(2017\)](#); [Kay & Gopalswamy \(2017\)](#)

Fried: [Isavnin \(2016\)](#)

FRED: [Gopalswamy et al. \(2017,2018\)](#)

CORE3D: [Mostl et al. \(2018\)](#)

no perfect model; pros + cons

Mostly “fit” in-situ

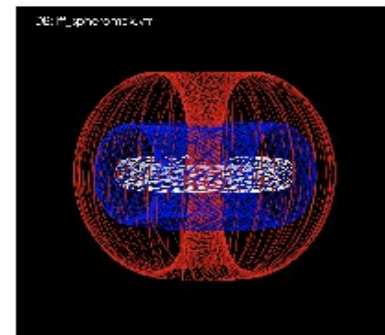
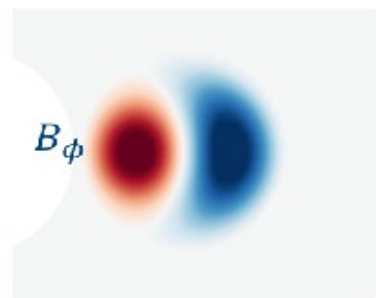
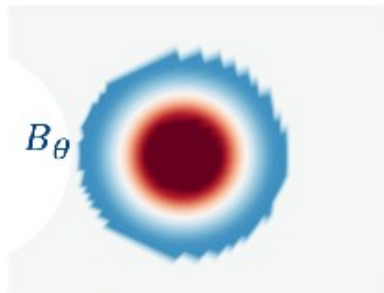
(|B| coronal from in-situ observations, radial fall-off of B parametrized to match in-situ, sheath-region, used instead of flux rope)

models **capture** the distribution of **B** in its components at **1 AU**

Empirically-Constrained Heliospheric CME Models

EUHFORIA: Spheromak CME

Flux rope modeled as Linear Force Free Spheromak



CME kinematics
Cone model



inner boundary @ 20 Rs

- Start time of CME
- Propagation velocity of CME
- Latitude of centre of CME source region
- Longitude of centre of CME source region
- Half-width of CME
- Density of CME
- Temperature of CME
- Title angle of the CME
- Helicity of the CME
- Total toroidal flux

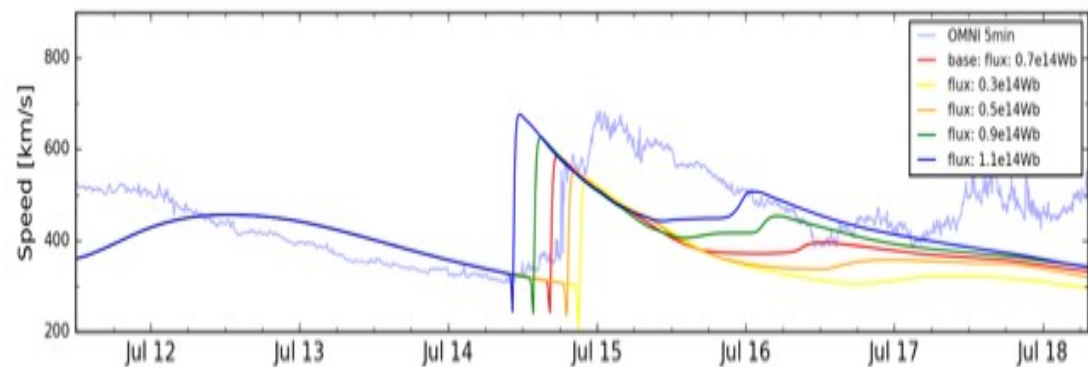
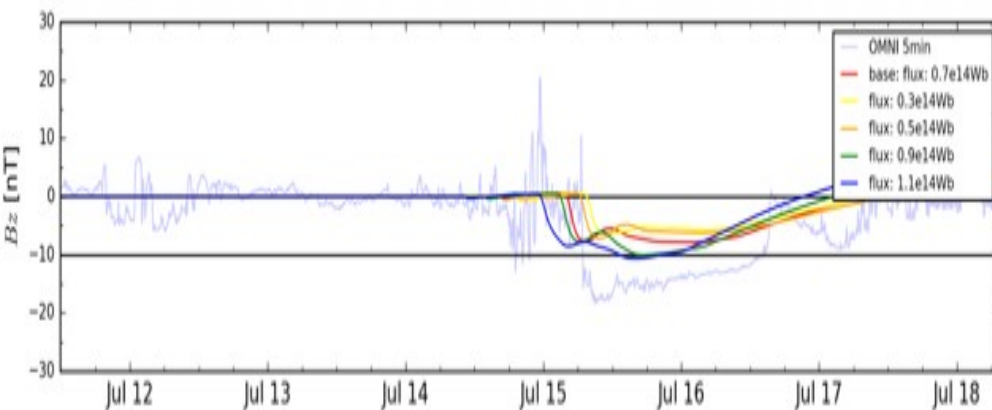
Flux rope
parameters



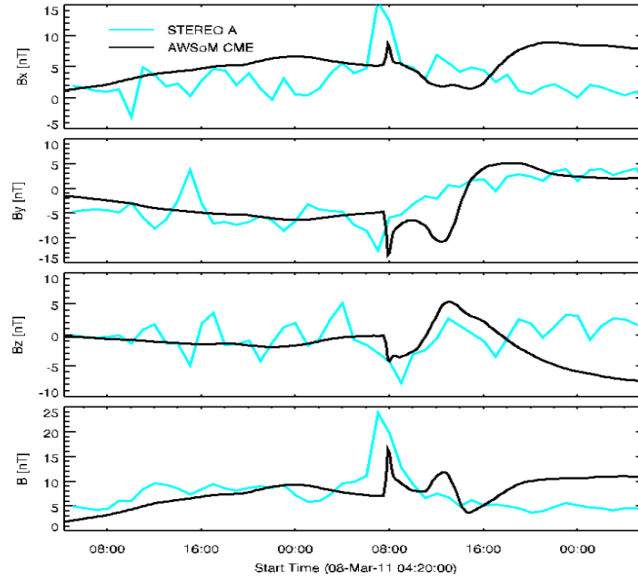
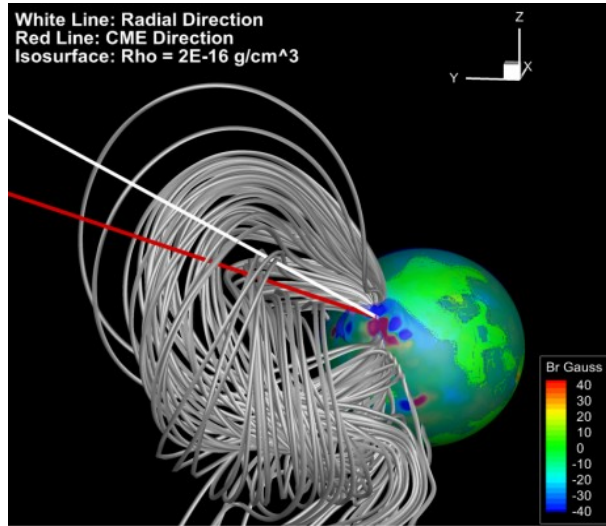
Parameter study using EUHFORIA (Verbeke+2018)

Use **FRED coronal magnetic field** to initialize the model for the major CME of 12 July 2012

change the CME axial flux by a factor ~ 7 --> **significant changes in B at 1 AU & ToA**



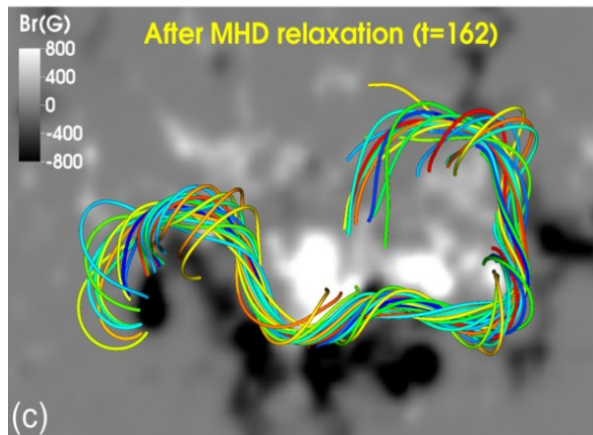
Sun-to-Earth MHD CME simulations



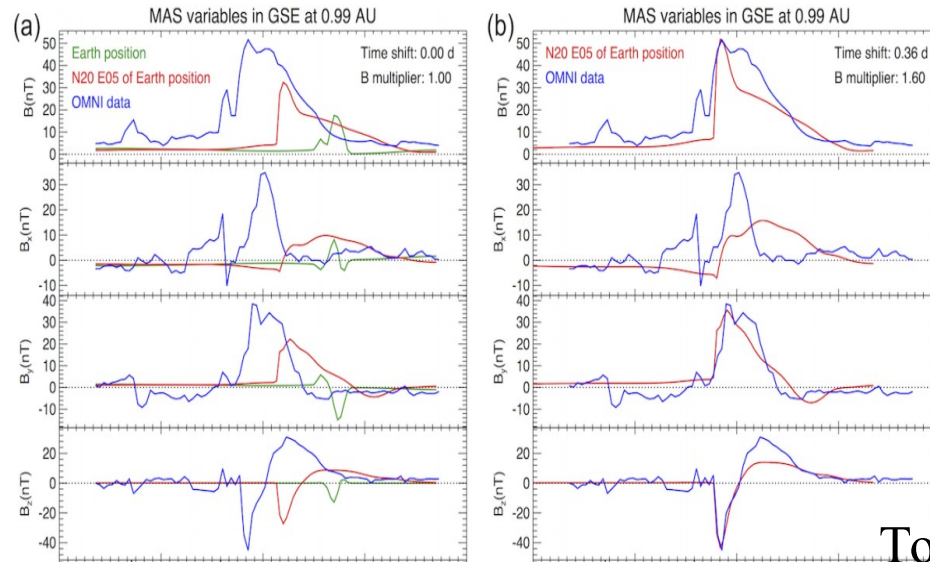
recovers
shock structure

Jin+2017a,2017b
talk by M. Jin

unstable flux rope



energize stable flux rope
w/ boundary flows



Torok+2018

$x1.6 |\mathbf{B}| + \text{shift by } 20 \text{ deg N to match in-situ}$

Standardizing Bz forecasting models

Build a common framework to compare Bz models with observations (e.g., various skill scores, ROC curves etc; widely used in weather & flare forecasting)

COMPLEXITY COORDINATED MODELING CENTER

Related Links | Frequently Asked Questions | Community Feedback | Downloads | Startup

About | Models at CCMC | Request A Run | View Results | Instant Run | Metrics and Validation | Education | R2O Support | Mission Support | Community Support | Tools

Real-time Forecasting Methods Validation: IMF Bz Scoreboard

CCMC is in the design and implementation phase of the "Bz Scoreboard" together with the international research community. The Bz scoreboard is designed as an automated system to evaluate skills for any predictions of the magnetic characteristics observed at LL.

The scoreboard will provide all international scientists and forecasters a single location where the community can test and prototype a variety of models than span the regime between fully operational to initial research ideas.

IMF Bz Scoreboard planning group:
Leads: Neil Savani (IMSC/NASA GSFC), Pete Riley (Predictive Science)
CCMC Facilitator: Lella Mays (NASA GSFC)

Please email Neil Savani, Pete Riley, or Lella Mays to get involved.

Latest News:

- The IMF Bz scoreboard is part of the IMF Bz Working Team in the Community-wide International Forum for Space Weather Modeling Capabilities Assessment.
- The first working group report to the workshop can be seen here.
- Summary of the findings and discussions from the Florida meeting can be seen here.

Currently registered models:
The models below are involved in assessing the appropriate strategy for skill evaluations. They are each at different stages of development:

Data driven
Bz4Cast model (N. Savani)
Helicity-CME (H-CME) model (Patsourakos, Georgoulis)
A. Kovalik model
PSI Pattern Recognition model (Riley et al. 2016; real-time forecast page; source code)

Numerical simulation
SUSANNO (D. Shota)
EUPHORIA (J. Pomori, S. Pfoetz)
EGG (S. W. Lee, J. Ugoi, S. Kovalik, Bart van der Holst, Meng Jin (now at Lockheed Martin), Ward Manchester, Gabor Toth and Tamas Gombosi)

IMF Bz Scoreboard Mock-up
TBD.

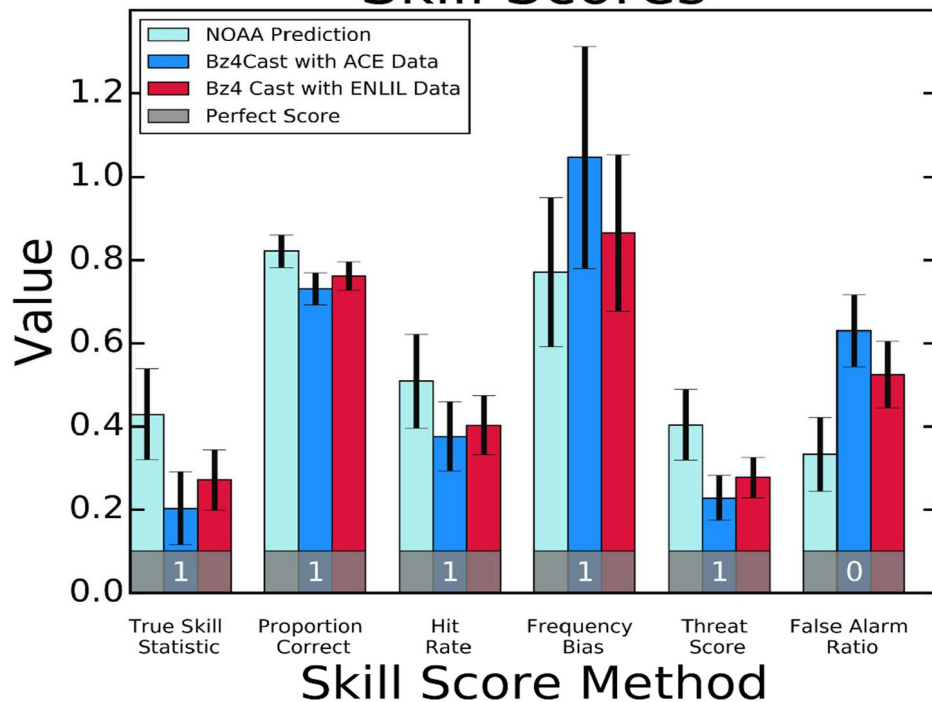
Initial ideas for the forecasts are to provide a clear visual of ROC curves to evaluate the skill of the magnetic vectors. And then to provide additional links and information via an interactive iSWA display of forecast data streams. Suggestions welcome!

Proposed forecast submission:
Developers Models/methods upload their predictions automatically to an anonymous ftp (under construction) which will be parsed by the system.

The team will initially use the templates developed by the Flare Scoreboard - which will be accepting results via three avenues (click each for proposed template):
(1) XML schema, template, full example
(2) Plain text
(3) manual form input

Curator: Anna Chubik | NASA Official: Dr. Masha Kuznetsov | Privacy, Security Notices

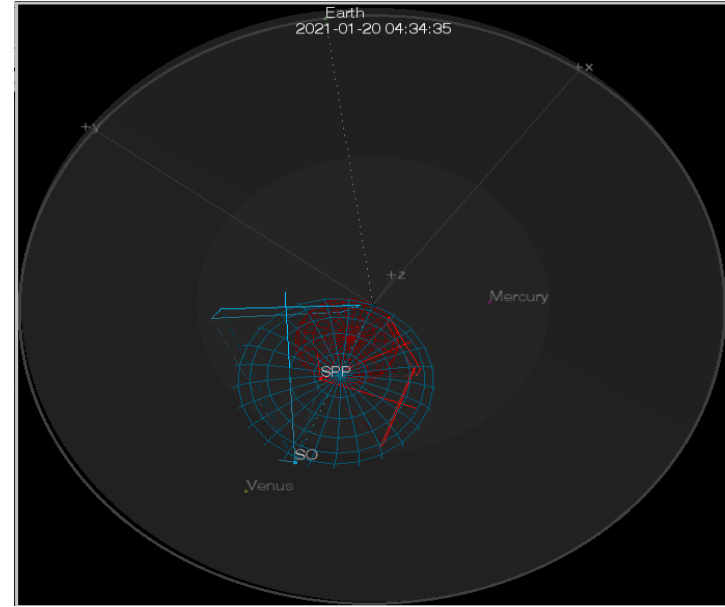
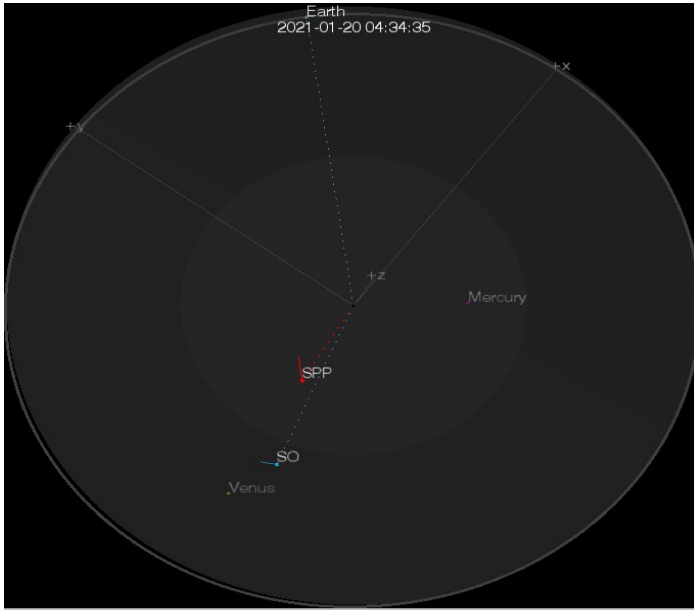
Skill Scores



B4CAST model (Savani+2015;2016) achieves similar scores as NOAA forecasters (Austin& Savani 2018)

IMF Bz scoreboard @ CCMC
Savani, Riley, Mays

Coming up soon: PSP & SoLO observations



track CMEs along the SC line with:

remote sensing from both SoLO (METIS&SoLO HI) & PSP (WISPR)

+ source region from PHI+SPICE+EUI(HRI)

& in-situ

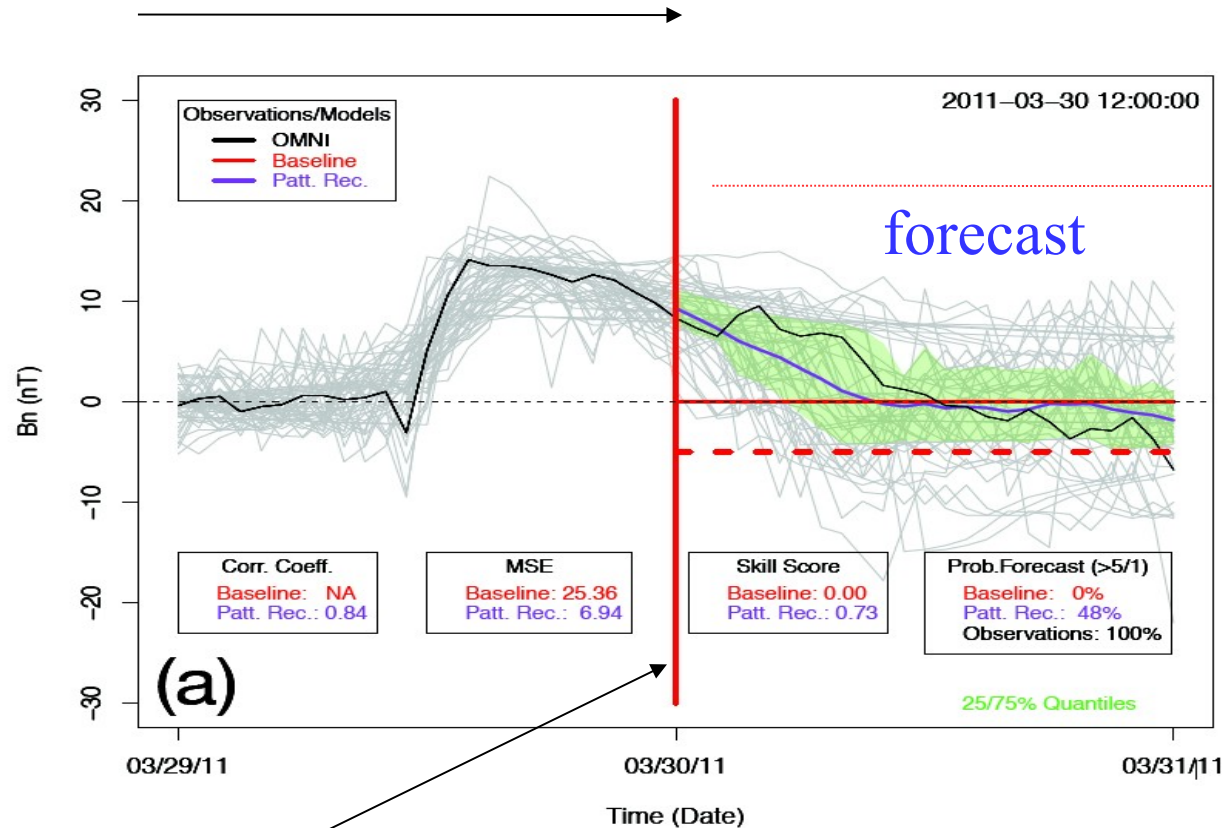
validate near-Sun CME B-field inferences & determine its nature (LFF?, NLFF?)

Nieves-Chinchilla talk on ICME models)

determine radial fall-off of B from corona to IP

better understand & characterize background solar wind

Bz prediction w/ pattern recognition (Riley+ 2017)



Set reference time & define window dt in past

Search 10 years of in-situ data for 50 best dt -long intervals & use their next dt for forecast

Good match between forecast + observations

Part of the MC should be already observed

Outlook

Test various existing models on the same events & exploit any radio available

Assess uncertainties of observational inferences & impact on heliospheric simulations

Come up with hybrid schemes

Consider complex set-ups (e.g., multiple CMEs, shocks)

Exploit the PSP & SoLO data-stream

Major element of ISEST follow-up