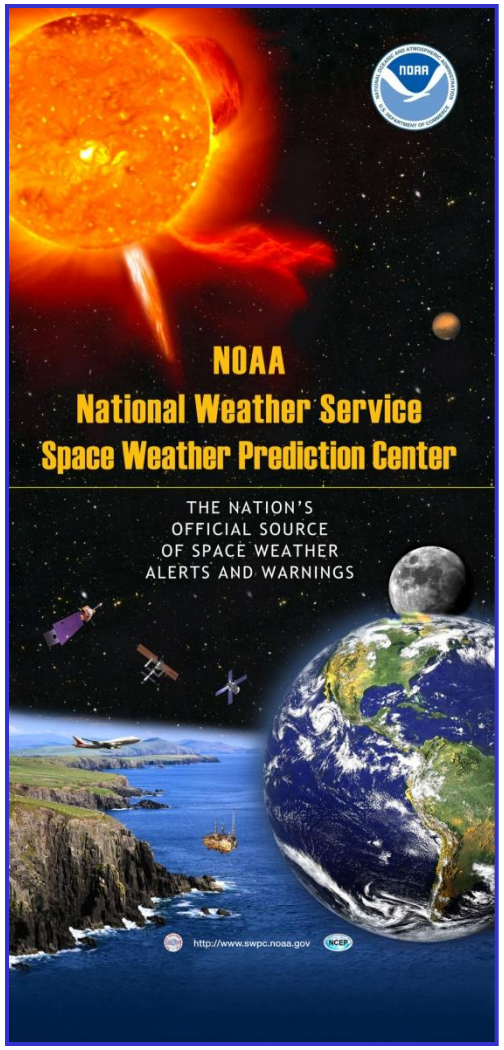
"...and why we care from both science and operational interests"



In Session on Model Predictions, their validity, and why do we care

Outline:

- Historical Lessons and Who Cares
- Space Weather Models in use and planned for SWPC
- Opportunity for CEDAR-GEM Collaboration

Acknowledgments: Evans, Fuller-Rowell, Kunches, Matsuo, Murtagh, Onsager

Howard J. Singer, NOAA Space Weather Prediction Center
CEDAR-GEM Workshop, Boulder, CO, June 23, 2013

Safeguarding Our Nation's Advanced Technologies

Space Weather: Societal and Economic Impact

- March 25, 1940
- Large Geomagnetic Storm
- Western Union set up emergency circuits to re-route messages as regular lines went dead.
- Telegraph lines went haywire.
- Geospace models in operations will help to protect similar, but modern, vital service

Life Magazine, vol 8, no 15, page 38, April 8, 1940. Brought to my attention by D. Evans

SUNSPOTS GREW TO THIS SIZE BY MARCH 25

MARCH 26. SPOTS MOVE SLOWLY ACROSS THE SUN'S FACE

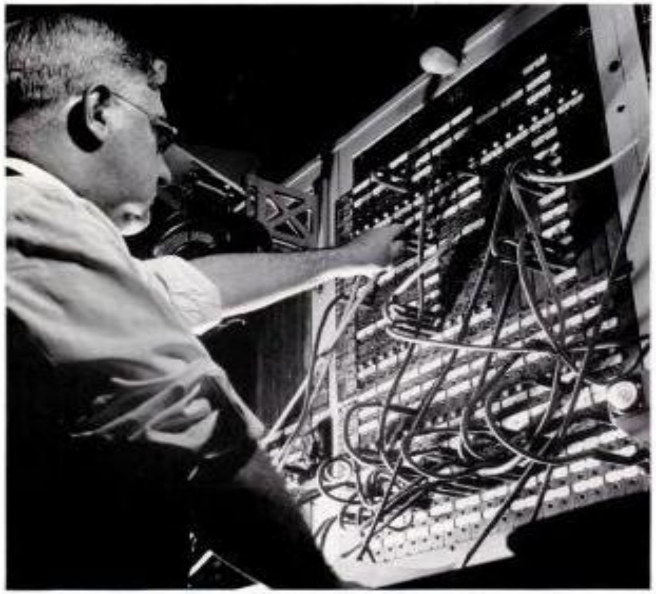
MARCH 27. BIGGEST GROUP IS 13,000 MILES ACROSS

SPOTS ON THE FACE OF THE SUN MESS UP EARTH'S COMMUNICATIONS

Last week the earth's magnetic field had a bad attack of spring fever. Well-behaved landlines of A. T. and T. turned taciturn. The ionosphere, the super-stratospheric layer of the earth's atmosphere, which radio companies use for a cushion to bounce their signals like billiard balls across the ocean, suddenly went porous. Wirephotos showed black streaks and teletype machines went to work on their own to click off analphabetic rhapsodies like the one below.

Moving across the face of the sun could be seen the villains of the piece—a series of sunspots, volcanic whirlwinds of gas which so upset the earth's magnetic field that forces as high as 790 volts were induced in power and communications lines. Counting up at the end of the week, the world found a debit that no one cared to estimate in disrupted communications and fused wires. On the credit side were several spectacular displays of northern lights.

MAP OF U. S. AREAS WHERE "EARTH CURRENTS" WERE STRONGEST



WESTERN UNION SET UP EMERGENCY CIRCUITS TO RE-ROUTE MESSAGES AS REGULAR LINES WENT DEAD

AT THE HEIGHT OF THE MAGNETIC STORM, TELETYPE AND OTHER AUTOMATIC TELEGRAPH MACHINES WENT HAYWIRE, PRINTED OUT MESSAGES LIKE THIS ON THEIR OWN HOOK

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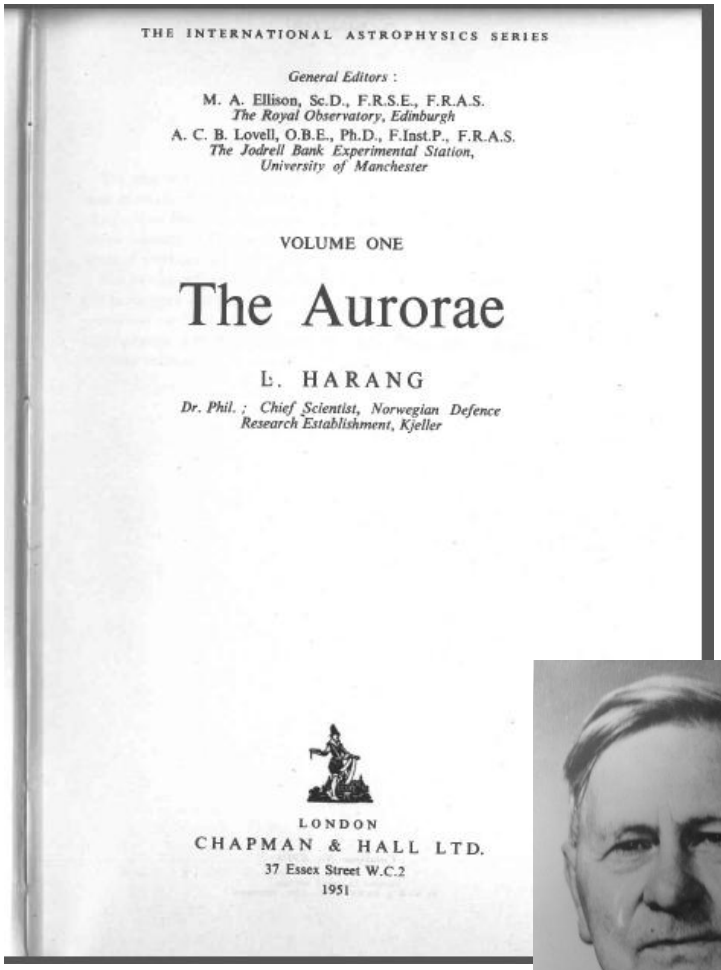
Space Weather: Societal and Economic Impact

"On the lines to Syltefjord and Makkaur all fuses (4 amp.) burnt through. Sparks and permanent arcs were formed in the coupling racks and watch had to be kept during the night to prevent fire from breaking out"

Log of the Vardø Station
Norwegian Telegraph Service
24 March, 1940


THE INTERNATIONAL ASTROPHYSICS SERIES

General Editors :

M. A. Ellison, Sc.D., F.R.S.E., F.R.A.S.
The Royal Observatory, Edinburgh
A. C. B. Lovell, O.B.E., Ph.D., F.Inst.P., F.R.A.S.
The Jodrell Bank Experimental Station, University of Manchester

VOLUME ONE

The Aurorae

L. HARANG

Dr. Phil. ; Chief Scientist, Norwegian Defence Research Establishment, Kjeller

LONDON
CHAPMAN & HALL LTD.
37 Essex Street W.C.2
1951

The Aurorea, Leiv Harang, 1951.

Brought to my attention by D. Evans

Executive Office of the President

Geomagnetically Induced Currents Interagency Working Group

- Formed by Office of Science and Technology Policy to address space weather threat.

- Membership includes NOAA, USGS, NASA, NSF, DoD, DOE, DHS, NRC, FERC

- White House wants action….gets updates during space weather outbreaks.

Precision Farming - optimize returns on inputs and preserve resources while reducing environmental risks

"I work with a John Deere Dealer group in North Dakota. We encounter many problems with our GPS Auto Steer etc. when K-Indexes are high and I have signed up for alerts from you. We are working to set up a mass text message system that will go out to all our customers warning them of when problems will arise. This would save us many problems, headaches, and probably 1000+ phone calls per day companywide with our GPS technicians."

- Apr 2012

NOAA SPACE WEATHER PREDICTION CENTER

Geomagnetic Storm Warning issued upon detection of CME at L1 on ACE

- 15-45 MIN forecast

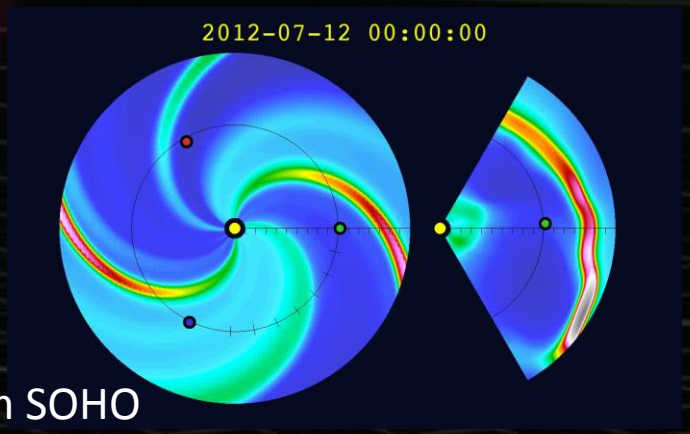
L1

Geomagnetic Storm Alert issued upon onset of geomagnetic storm using USGS magnetometers

- Current condition

Geomagnetic Storm Watch issued upon detection of Earth-directed coronal mass ejection (CME) on SOHO LASCO and STEREO coronagraphs

- 1-3 day forecast



CME measurements from SOHO and STEREO drive the Enlil model which predicts arrival time

Example of Evolving Customer Requirements

Electric Utilities			
Geoelectric Field Vector	6 hr. forecast, updated hourly	Various Power Companies	To know the key ingredient that plays into the GIC at selected points, is a critical parameter for the industry. To do this requires local dB/dt and geologic conductivities.
K-7 Geomagnetic Storm Warnings	Minutes to hours Operators want as much lead time as possible, but any lead time is considered useful	North America Electricity Reliability Corp. Midwest Independent System Operator Electricity Reliability Coordinators	The Midwest Independent System Operator receives the K-index forecast. If the index is K-7 or higher, MISO notifies all NERC reliability coordinators concerning the level and expected duration of the specific event. These forecasts are shared with all power system operating entities throughout North America so that those power systems that are particularly susceptible

SWPC Customer Requirements for Space Weather Services

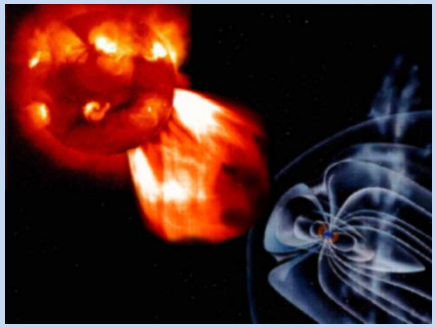
See: http://www.swpc.noaa.gov/Services/index.html

Potential New Geomagnetic Services Product Geospace Model

- Goal: Evaluate Geospace models (MHD and empirical) to determine which model(s) are ready for transition to operations
- Focus: Regional K and dB/dt (important to electric utilities)
- Partnership: Evaluation at NASA/Goddard CCMC working with SWPC, modelers and science community

Select Models and Events → Establish Metrics → Model-Data Comparisons → CCMC Reports to SWPC

Model(s) selection (FY13) by SWPC based on CCMC reports, internal and external advice, and following considerations:

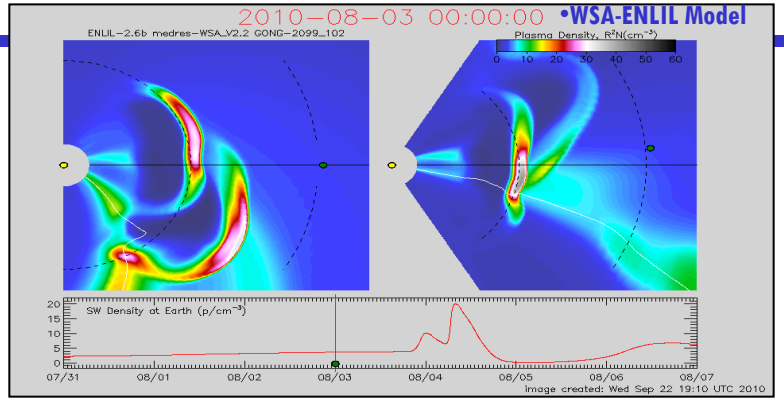


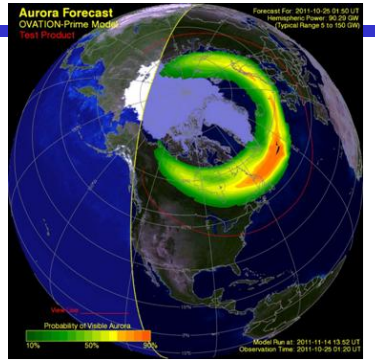
Solar Influences on Geospace Predicted with Geospace Models using Solar Wind Input

- Strategic Importance
- Operational Significance
- Implementation Readiness
- Cost to Operate, Maintain, and Improve

NOAA's commitment to improved operations
New Models and Products

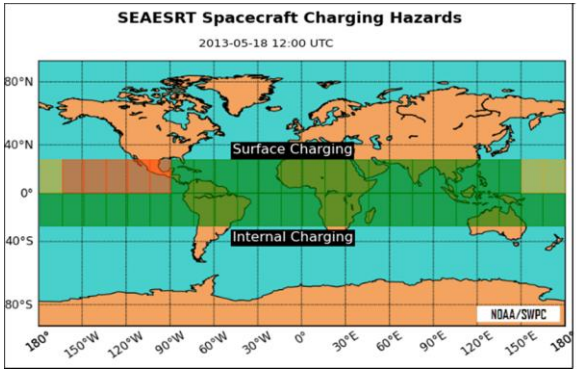
- **Model transition**
- WSA-Enlil
- OVATION (2012)
- SEAESRT (2013)





OVATION

- **Space Weather Prediction Testbed**
- Geospace Model (selection 2013)
- The Whole Atmosphere Model (ops 2017)



- **Upgrade operational product suite – critical new data sets**
- Geomagnetic Storm Products
- USGS and INTERMAGNET data
- International Partners – magnetometer data

Ensemble Modeling
Lessons from Solar-Helio Research

Ensemble Forecasting Definition

•Ensemble forecasting… is a method of prediction that relies on the use of a representative sample of possible future states to derive a prediction.” (Riley et al., JGR,118, 600, 2013)

Merits of this Method Include:

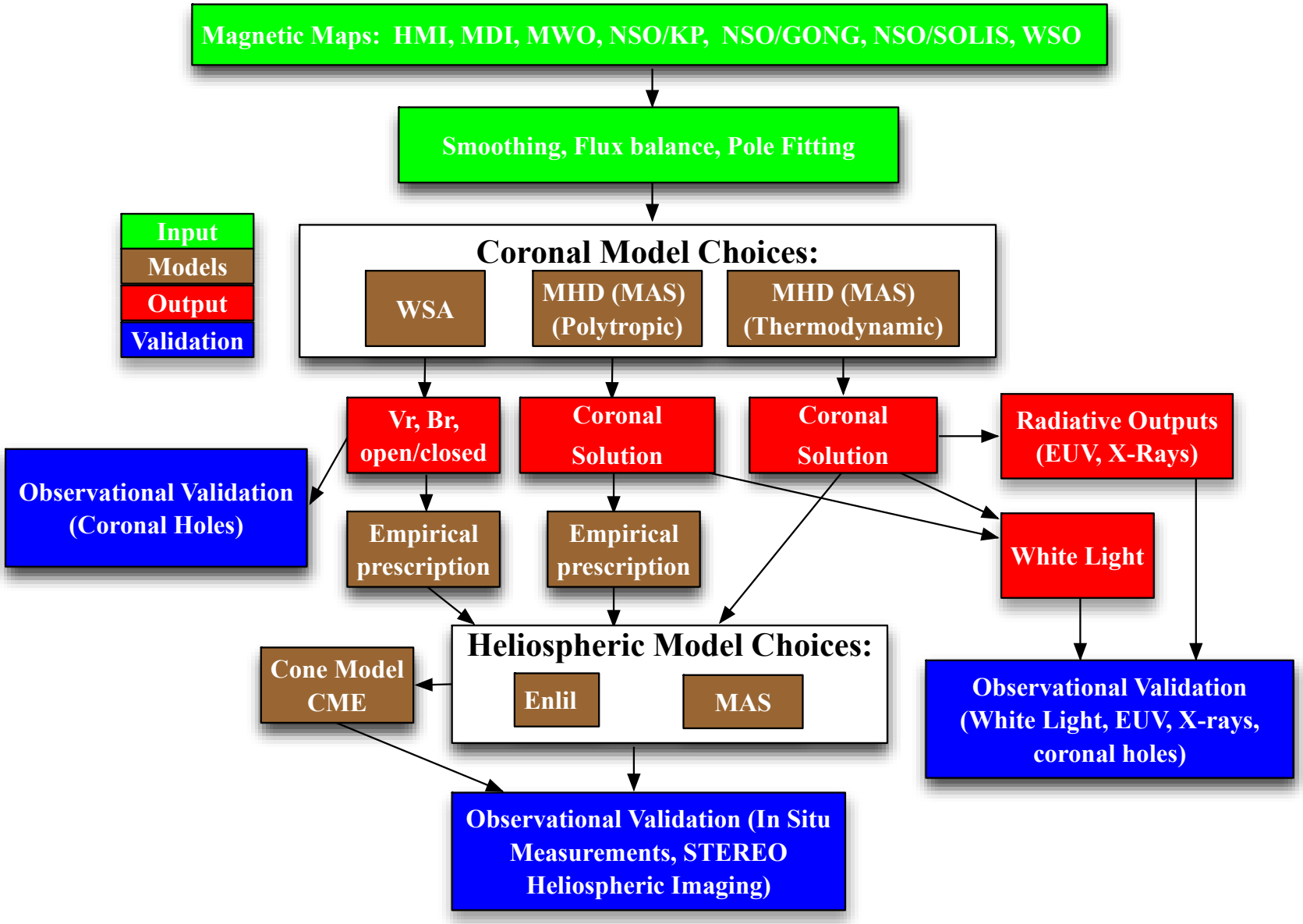
•Rigorous method for computing confidence bounds on the solution by estimating the uncertainty

•Ability to assess areas for physical model improvement

•Mean of the ensemble of forecasts is or should be more accurate than the forecast from any individual member

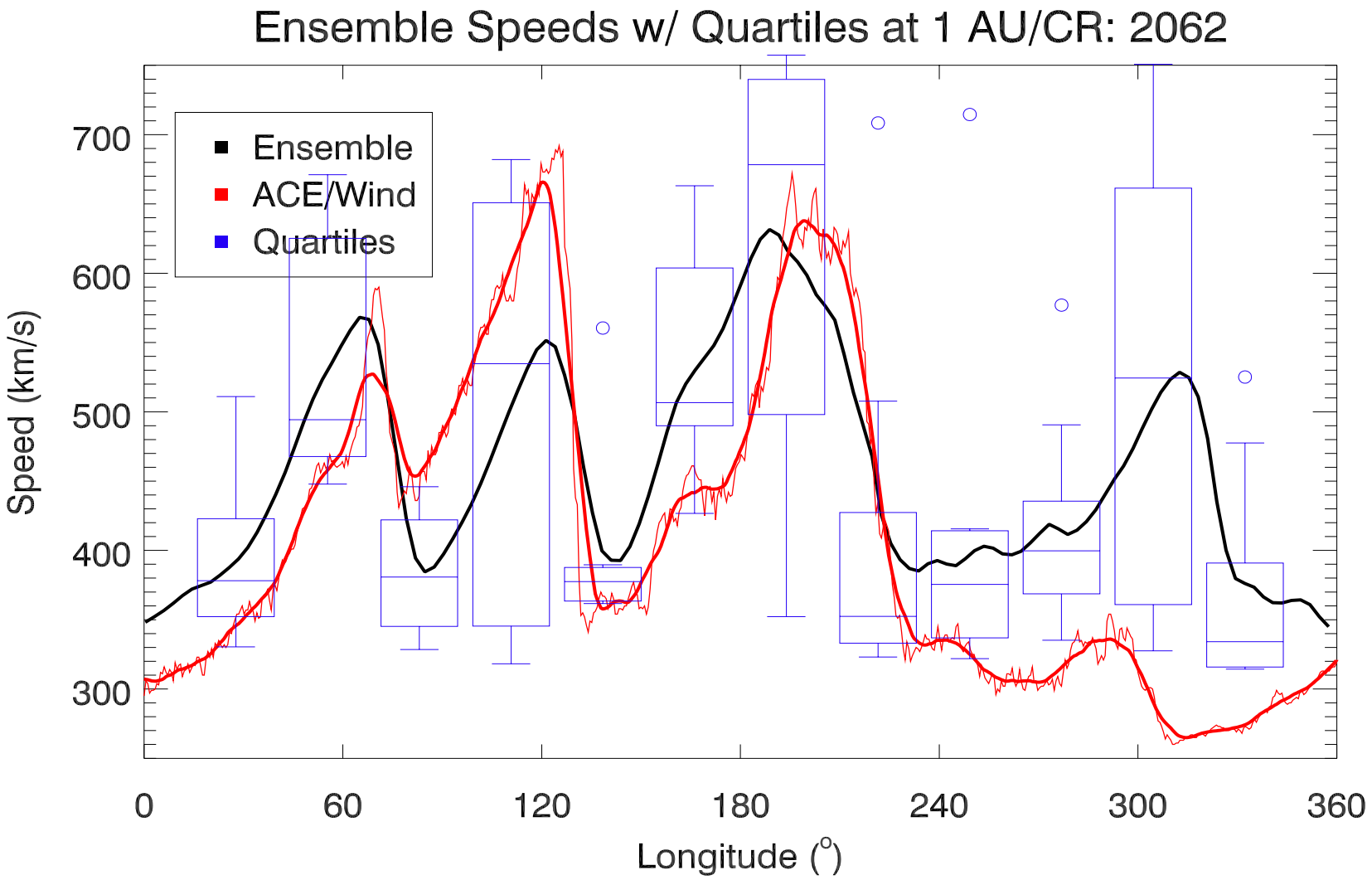
Comments

•Information in this figure and the next few slides are largely taken from Riley et al. where they utilize ensemble modeling to assess the uncertainty and limitations of ambient solar wind models. I want to acknowledge Pete Riley for discussions and sharing his figures.



A schematic illustrating how a typical global coronal/heliospheric ambient solution is constructed. Model inputs are shown in green, the models are shown in brown, the output from the models (which is, in some scenarios, also an input into the subsequent model) is shown in red, and the validation procedures are shown in blue.

Riley et al., JGR,118, 600, 2013



Comparison of ensemble model solution (black) with ACE in situ measurements (red; 1 h and 1 day averages). "Whiskers" summarize the variability of the realizations. The median value is indicated by the short horizontal line, while the tops and bottoms of the boxes mark the 25th and 75th quartiles. The tips of the "whiskers" mark the maximum and minimum values. When these maxima are more than three sigma from the median, they are marked with an open circle.

Riley et al., JGR,118, 600, 2013

Ensemble Modeling and Conclusions

- One other example of ensemble modeling, in the ionospheric community, is “An ionospheric multi-model ensemble prediction system by Xiaoqing Pi et al. (presented at The International Beacon Satellite Symposium, Bath 2013).
- Also, there are many examples that we can learn from in the meteorological community.
- However, the conclusion I would like to leave with you is that more can be achieved through CEDAR-GEM collaborations by utilizing the ensemble modeling approach illustrated by Riley et al. This will advance and improve coupled magnetosphere and ionosphere model capabilities, give insight into model uncertainties, and validate and prepare models for use in space weather operations.
- As a final note, it is important to convey to funding agencies that the value of supporting such work brings benefits to both science and operations.