Unifying the Validation of Ambient Solar Wind Models

Martin A. Reiss
Austrian Academy of Sciences,
Space Research Institute, Graz, Austria

Karin Muglach
NASA GSFC

Richard Mullinix, Chiu Wiegand, Masha Kuznetsova
NASA GSFC/CCMC

and ISWAT Team Members from
IRAP Université de Toulouse
KU Leuven
Met Office UK
Predictive Science Inc.
Royal Observatory of Belgium
University of Reading

and many more, see www.iswat-cospar.org/H1-01
This talk presents a team effort for tying the community together for the unified validation of ambient solar wind models.

I. Why does ambient solar wind modeling matter?

II. What are the problems? How do we tackle these issues?

III. Where does our ISWAT team stand and what are our future steps?

more about ISWAT: www.iswat-cospar.org
Accurate models of the large-scale corona and heliosphere are a bottleneck in solar and heliospheric research

An (incomplete) „family portrait“:

**Magnetic Maps**
- GONG
- WSO
- MWO
- NSO SOLIS
- HMI

**Coronal Domain**
- CESE-HLLD: Li et al., 2018, 2020
- MAS: Linker et al., 1999
- MULTI-VP: Pinto and Rouillard, 2017
- PFSS: Altschuler and Newkirk, 1969
- AWSoM: Van der Holst et al., 2014
- WindPredict-AW: Reville et al., 2020

**Model Interface**
- DCHB Model: Riley et al., 2015
- WSA Model: Arge et al., 2003
- Adaptive-WSA Model: Reiss et al., 2020

**Heliospheric Domain**
- CESE-HLLD: Li et al., 2018, 2020
- Enlil: Odeschi et al., 2003
- EUHFORIA: Pomoell and Poedts, 2018
- Heliomas: Linker et al., 1999
- LFM-hello: Merkin et al., 2016
- HUX, THUX: Riley and Lionello, 2011
- HUXt: Owens et al., 2020
- SWMF: Tóth et al., 2005

*Note that an empirical model at the interface is not always needed.*

Flow of Models from the Sun into our Solar System

from Reiss et al., 2022 (published in ASR)
What are the problems with ambient solar wind model validation?

- keeping up with the ever-growing number of models, and different versions thereof. (Problem 1)
- no agreement on forecasting goals and metrics. (Problem 2)
- slow iterative process between model developers and end-users (see MacNeice et al., 2018). (Problem 3)
- increasingly versatile user needs. End-users have to rely on metrics selected by authors of validation studies. (Problem 4)
- challenging to trace the progress of models over time. (Problem 5)
Our vision is to develop an online validation platform in a bottom-up approach from the community

- Enables a fast online illustration of state-of-the-art solar wind model solutions. (Problem 1)
- Use metrics agreed on by the space weather community. (Problem 2)
- New model versions can be instantly made available online. (Problem 3)
- End-users can select metrics. (Problem 4)
- Trace our progress over time. (Problem 5)

A central platform for validation analysis can be leverage for innovation

Find out more at www.iswat-cospar.org/h1-01
Since the beginnings of this initiative, we have achieved our first milestones:

- "Building Bridges"
- Forecasting Goals
- Validation Metrics
- Metadata Architecture
- Prototype of Online Platform
- 1st Paper Publication

COSPAR ISWAT Working Meeting (Florida, USA) February 2020

June 2022

Find out more at www.iswat-cospar.org/h1-01
After collecting feedback from the community, we recommend testing the quality of community models in the online platform based on two forecasting goals:

1) The ability of the solar wind model to output the **temporal evolution of the solar wind speed**, as well as **abrupt changes from slow to fast solar wind**.

2) The ability of the solar wind model to output the **magnetic polarity** and **magnetic sector boundary crossings**.
Reiss et al., 2022

"Building Bridges"

Forecasting Goals
Validation Metrics
Metadata Architecture
Prototype of Online Platform
1st Paper Publication

Model Chain

Observational Input

Data Preprocessing

Section 3.1: Observational Input
- Input type: Type of observations (e.g., magnetograms, etc.)
- Observatory: Name of the observatory
- Instrument: Instruments used for the observation
- Input description: Description of the model input
- Date and Time: Date of the observation
- Data Level: Level of data used for the observation
- Publications: List of publications
- Comments: Additional information on observational input

Section 3.3: Model Description
- Model name: Official model name
- Model domain: Description of the model domain (e.g., solar, etc.)
- Model type: Type of model (empirical, semi-empirical, full physics-based)
- Model description: Short description of the model
- Model version: Model version number
- Language: Programming language of the model
- Publications: List of publications
- Contacts: List of model developers and contacts
- Comments: Additional information on model description

Section 3.4: Model Settings
- Metadata link: Link to the model description metadata
- Model parameters: List of model parameters
- Grid parameters: List of grid parameters
- Other parameters: List of other parameters
- Ensemble: Description of ensemble approach
- Ensemble settings: List of parameters to create the ensemble run
- Ensemble output: Ensemble output (e.g., median value)
- Empirical relationships: Empirical relationships and parameter settings used to run the model
- Comments: Additional information on model settings

Section 3.5: Model Output
- Metadata link: Link to the model settings metadata
- Model output: Description of the model output
- Model output grid: Description of the model output grid (e.g., temporal and spatial resolution)
- Model output ensemble: Explanation of the output ensemble
- Post-processing: Description of the post-processing steps
- Publications: List of publications

Section 3.2: Data Preprocessing
- Model name: Official model name
- Model description: Description of the preprocessing steps
- Publications: List of publications
- Contacts: List of model developers and contacts

Section 3.6: Model Chain
- Metadata link: Link to the model settings metadata
- Model chain: Description of how the individual models are combined
- Boundary conditions: Description of the boundary conditions at the coronal and heliospheric model interface
- Publications: Related publications where this model combination is explained in detail
- Miscellaneous: Other comments

Section 3.7: Model Solution
- Model solutions: List of physical properties computed from the model chain
- Model solution grid: Description of the resolution used for the model.
  (For models that produce time-series only, the time cadence is required here.)
- Missions for validation: List of space missions that can test the model solutions.
1. Select time interval of interest

Thanks to Richard Mullinix, Chiu Wiegand, and the CCMC team!

L. Rastätter et al., 2019
1. Select time interval of interest

2. Select solar wind models
1. Select time interval of interest

2. Select solar wind models

3. Choose location
1. Select time interval of interest

2. Select solar wind models

3. Choose location

4. Select solar wind property
1. Select time interval of interest
2. Select solar wind models
3. Choose location
4. Select solar wind property
5. Display the model solutions
1. Select time interval of interest
2. Select solar wind models
3. Choose location
4. Select solar wind property
5. Display the model solutions
6. Run your validation analysis
Title
Unifying the validation of ambient solar wind models [Link]

Authors
Martin A. Reiss, Karin Muglach, and H1-01 team members.

Questions we discuss in the paper
- Why is ambient solar wind modeling important?
- What is the current state-of-the-art in solar wind forecasting at Earth?
- What are the problems in assessing solar wind models? How can we close these gaps?
- What advantages does the online platform bring?
- Why should model developers and end-users be interested in using the platform?
- What kind of metrics/metadata could be useful?
What are the next steps for 2022+?

Current Priorities
- Make metadata accessible via CAMEL
- Implement (all) the proposed metrics in CAMEL
- Release 1st version of the online platform
- Invite model developers to participate

Next Meeting
- Session during the COSPAR ISWAT Working Meeting in Coimbra, Portugal (September 2022)
- Collect feedback from team members and the community on what else is needed.
- Develop plan for the transition from historical validation to real-time validation.
- Develop concept of what could be included in an „Ambient Solar Wind Scoreboard“.

[www.iswat-cospar.org/wm2022]
Summary - Unifying the Validation of Ambient Solar Wind Models

The mission of our ISWAT team:

• Develop a comprehensive model metadata architecture including metrics agreed upon by the community.

• Implement an open online platform in collaboration with NASA’s CCMC to validate solar wind models with streamlined metrics.

• Quantitatively assess the state-of-the-art in forecasting the solar wind conditions at Earth and other planetary environments.

• Use our developed infrastructure to maintain up-to-date validation results in the future.

Useful Links
www.iswat-cospar.org
www.iswat-cospar.org/H1-01

Acknowledgements
P 34437
J 4160

Contact
martin.reiss@oeaw.ac.at
https://www.oeaw.ac.at/iwf/staff/martin-august-reiss