A Virtual Guide:

An Adaptive Prediction System for Specifying Solar Wind Speed near the Sun

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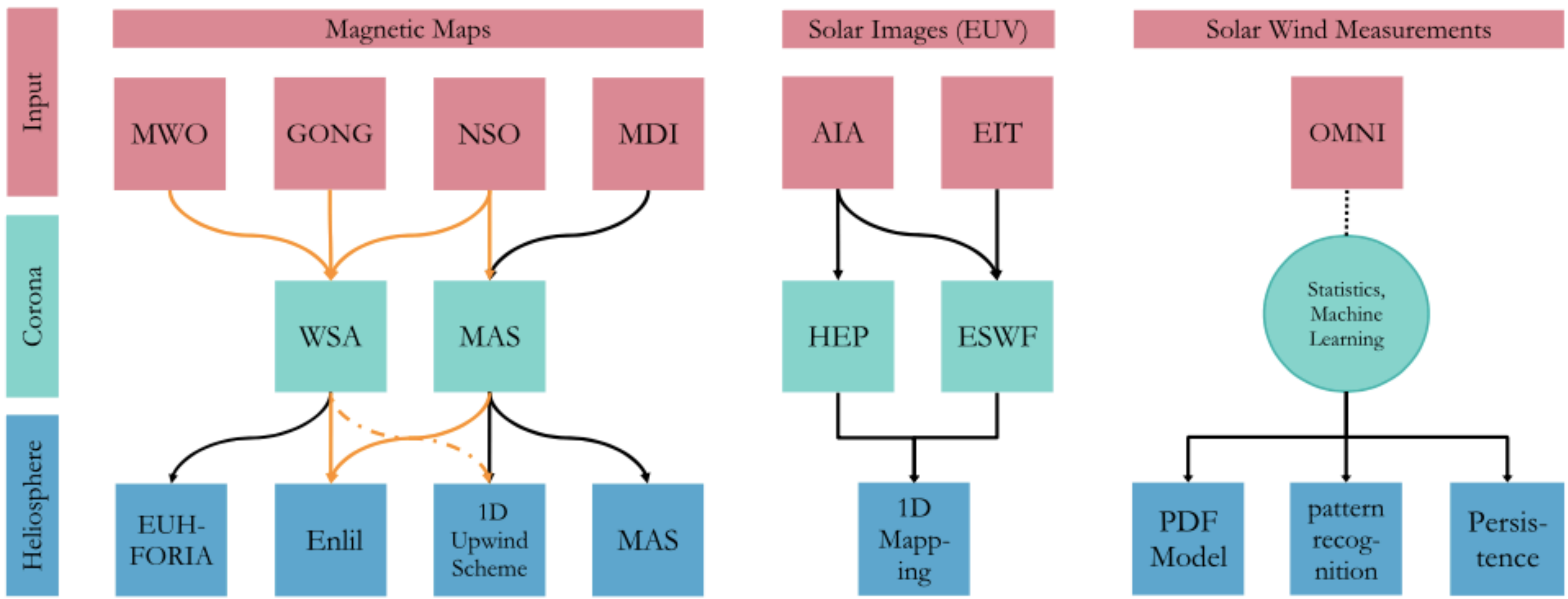
Accurate modeling of the evolving ambient solar wind flow is of crucial importance, because

- The evolving ambient solar wind flow ***determines key properties in interplanetary space*** such as the solar wind bulk speed, magnetic field strength, and field orientation.

- The solar wind state in the interplanetary medium affects the ***dynamical evolution of coronal mass ejections***.

- ***High-speed solar wind streams*** contribute about 70% of geomagnetic activity outside of solar maximum and about 30% at solar maximum (Richardson et al., 2000).

Solar wind frameworks couple models of the corona with those of the inner heliosphere.



Reiss et al. (2019)

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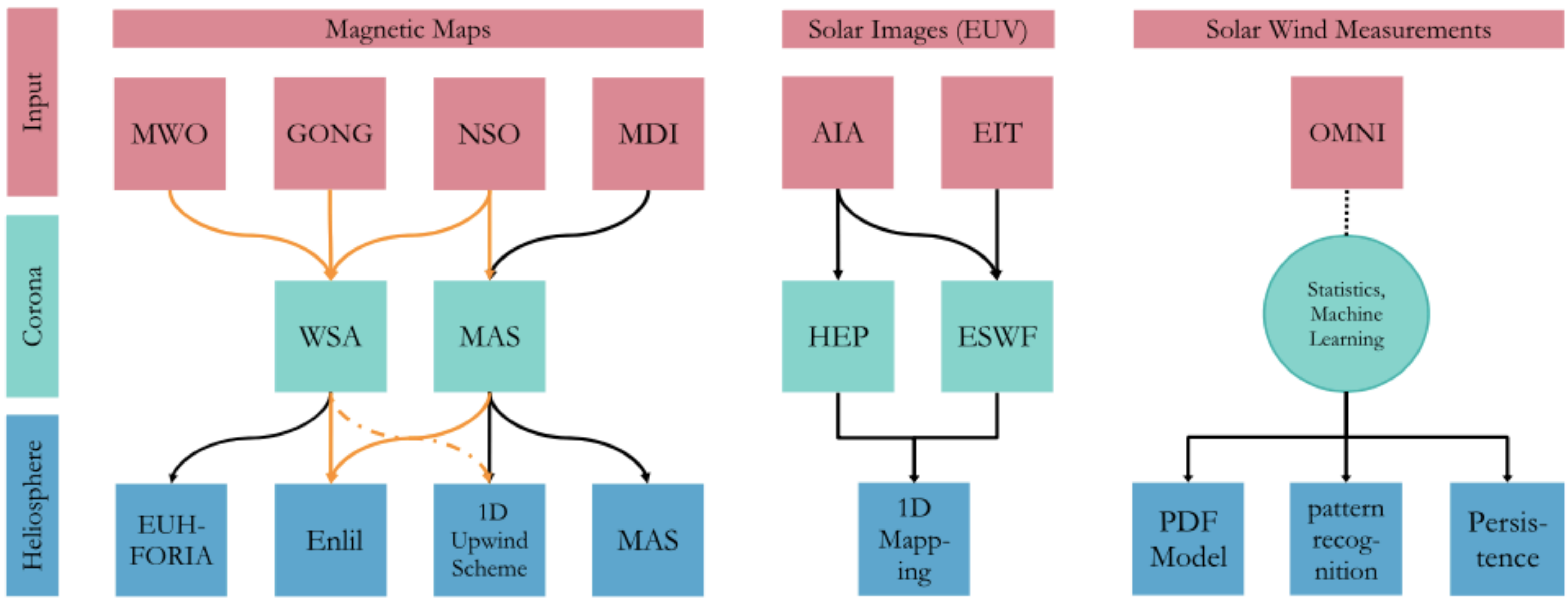

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- Recent studies show that the ***predictive abilities*** of solar wind models are, if at all, only slightly better than a ***model of persistence*** (e.g., Jian et al. 2011, Riley et al. 2015).

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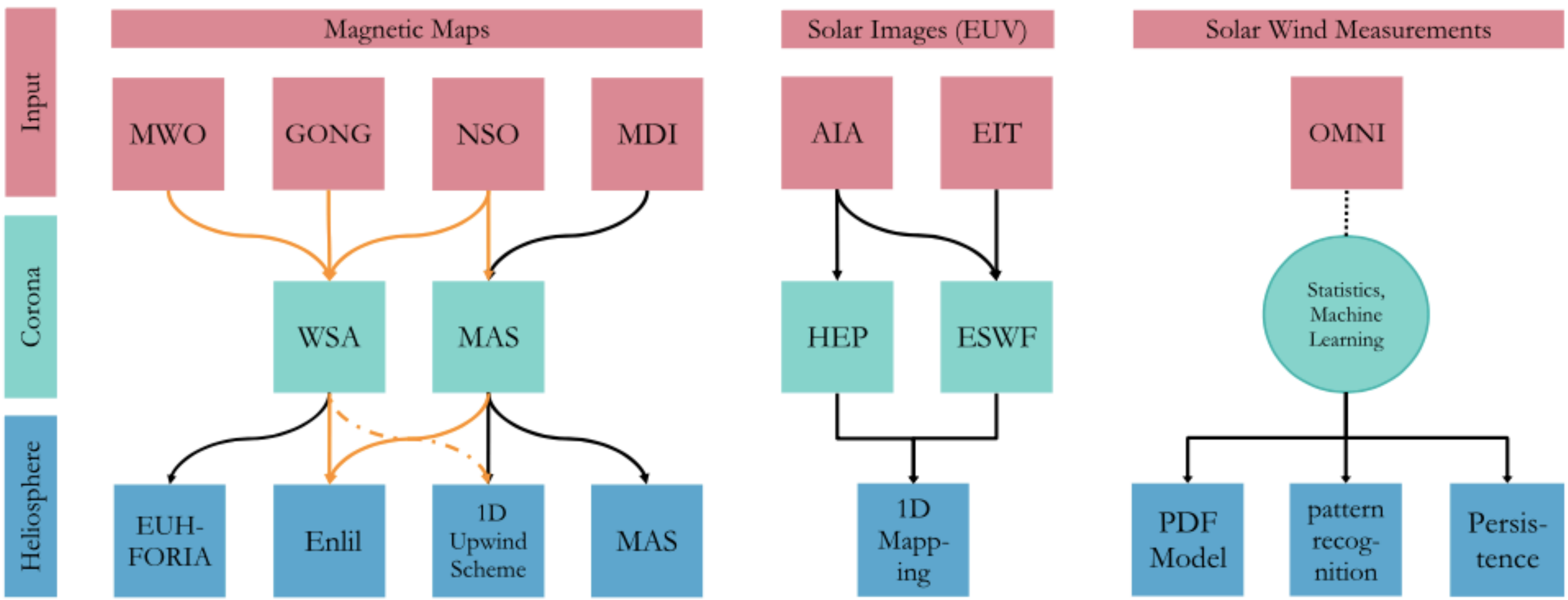

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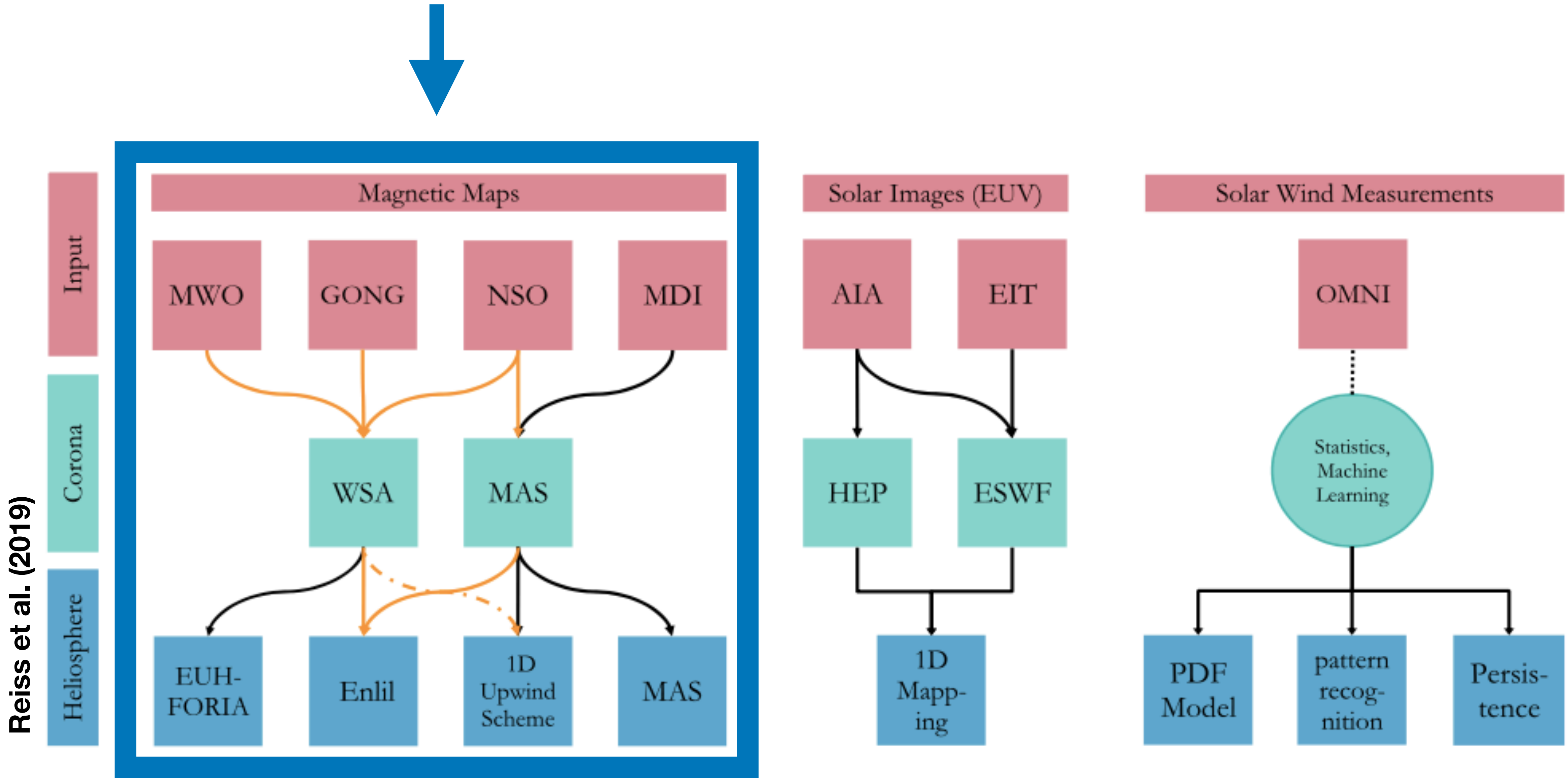
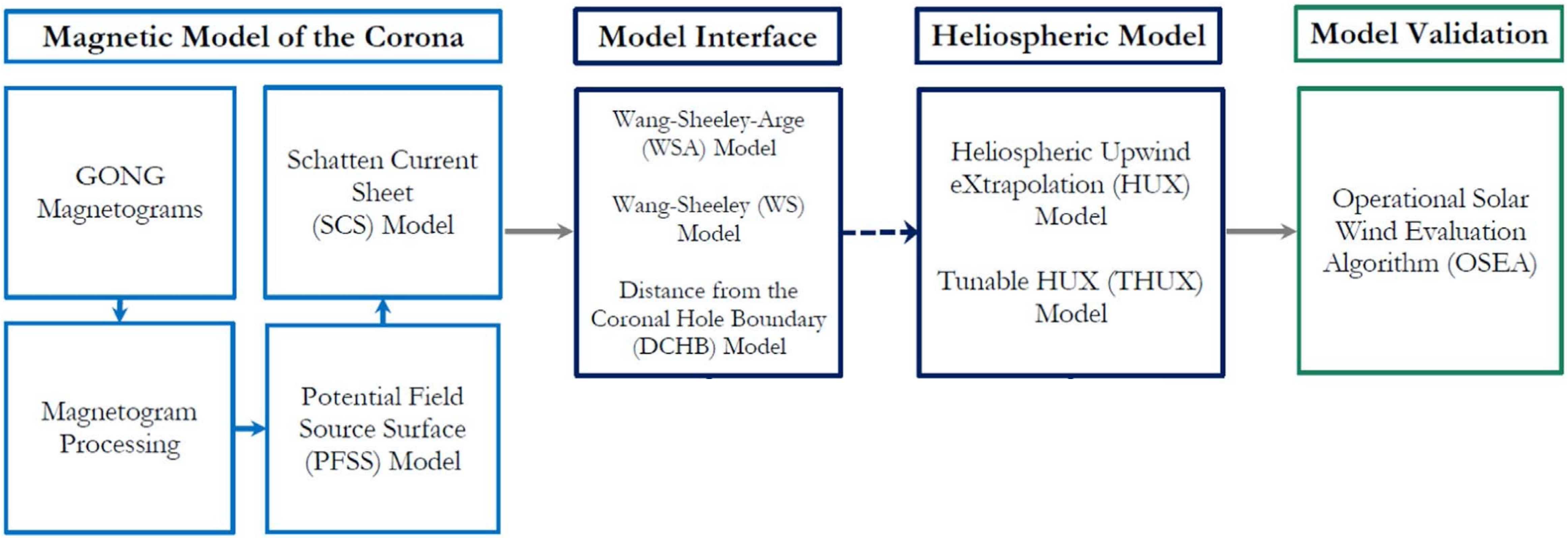
- Recent studies show that the ***predictive abilities*** of solar wind models are, if at all, only slightly better than a ***model of persistence*** (e.g., Jian et al. 2011, Riley et al. 2015).
- ***Continued efforts*** are therefore needed.



The state-of-the-art model approach relies on reconstructing the global coronal magnetic field from photospheric magnetic field measurements.

To seamlessly simulate the dynamics of the evolving ambient solar wind from the Sun to Earth, it is important to treat the photosphere, corona, and inner heliosphere as a coupled system.

In this study, we use the following solar wind framework as a starting point.



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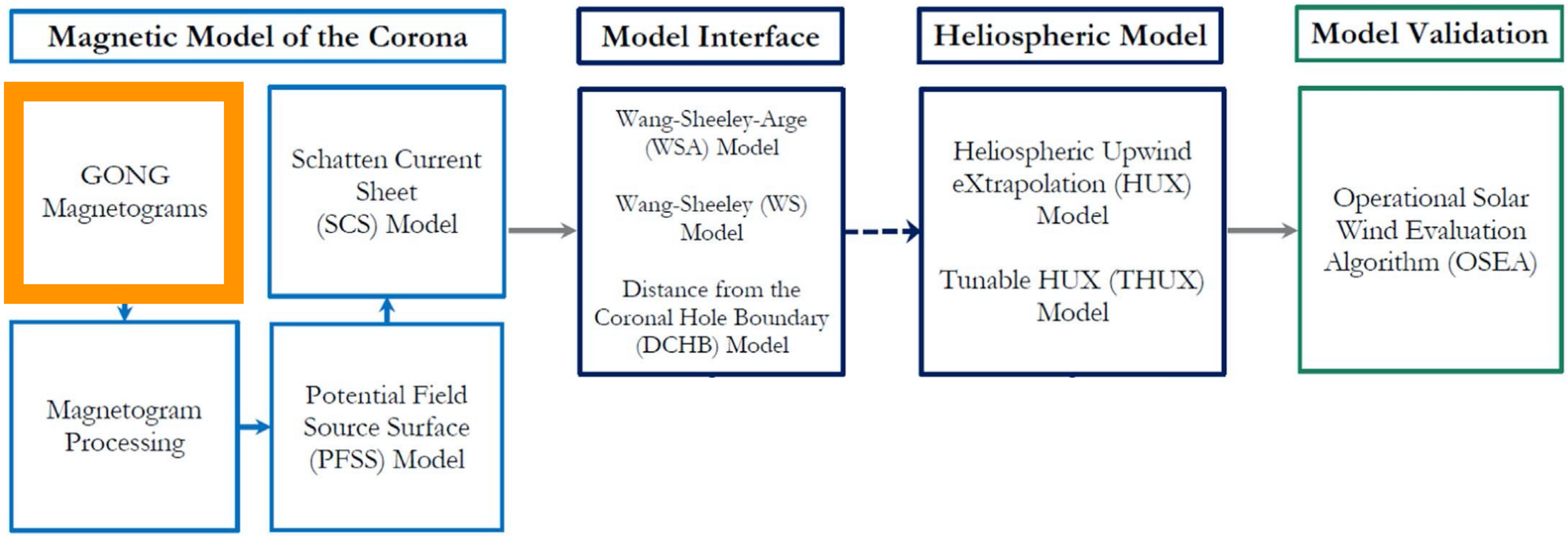

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We use photospheric magnetic field measurements as input for the magnetic model of the Sun.

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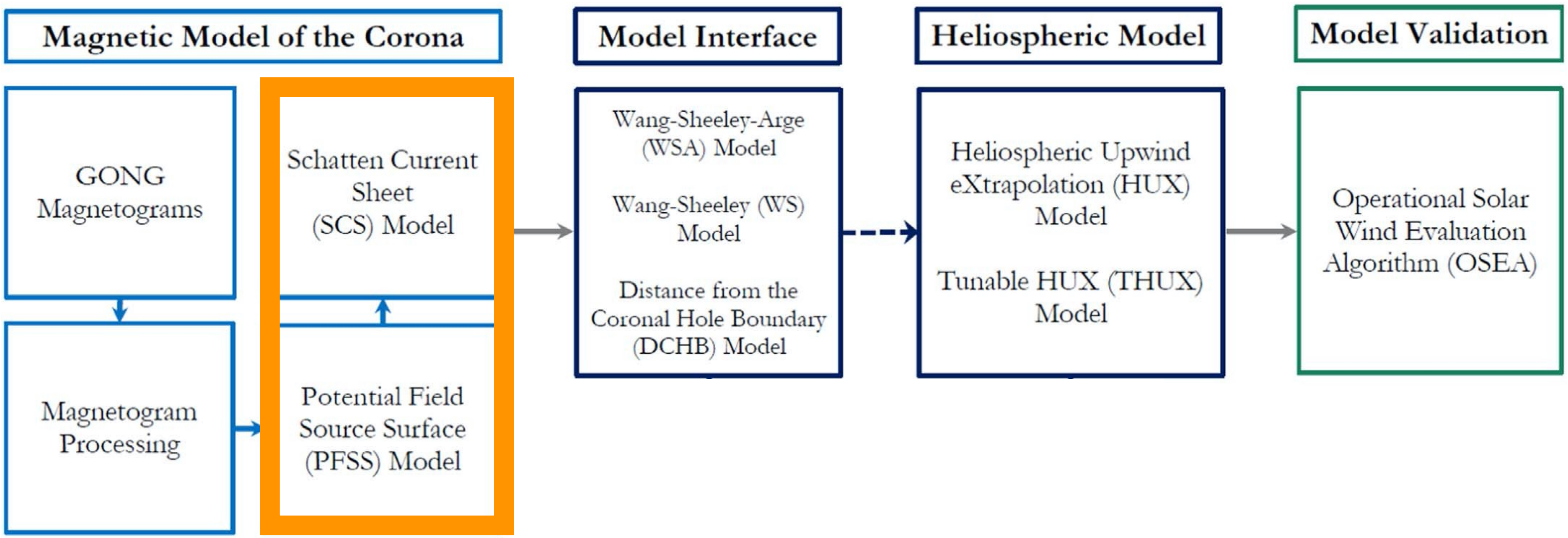

Reiss et al. (2019)

Specifically, use of a PFSS model in combination with a Schatten Current Sheet model for reconstructing the global coronal magnetic field.

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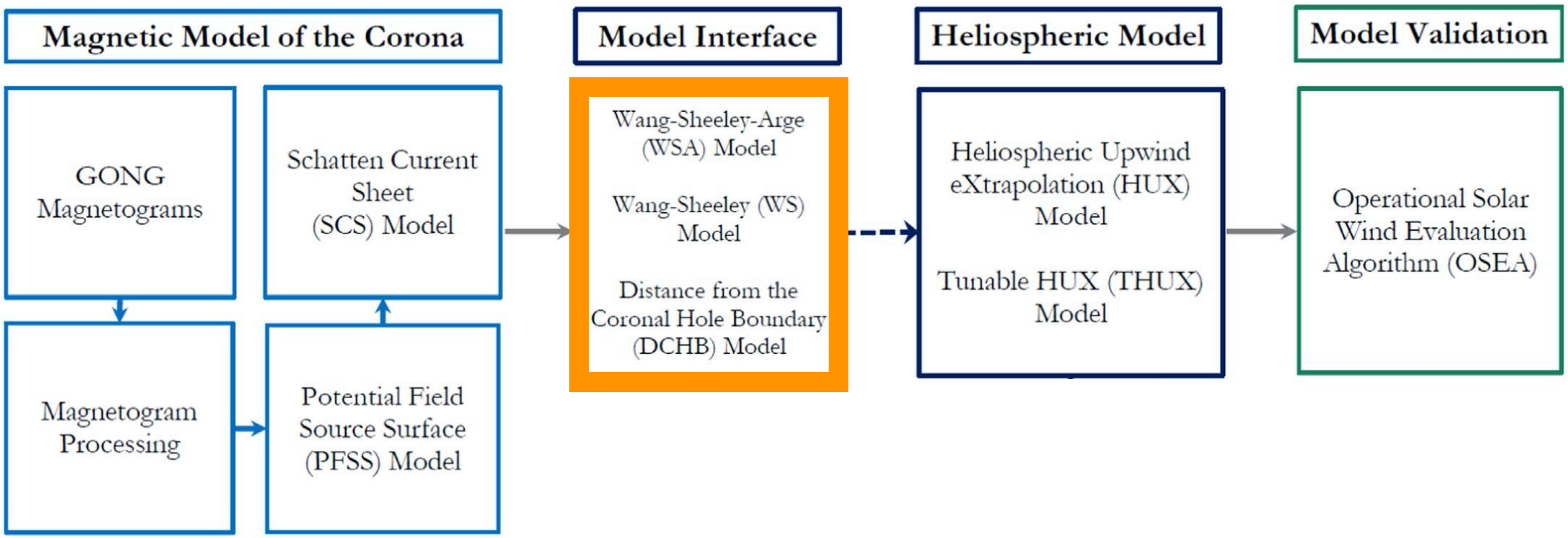

Reiss et al. (2019)

Next we study the WSA, WS, and DCHB model relations for specifying solar wind conditions at the inner boundary of heliospheric codes.

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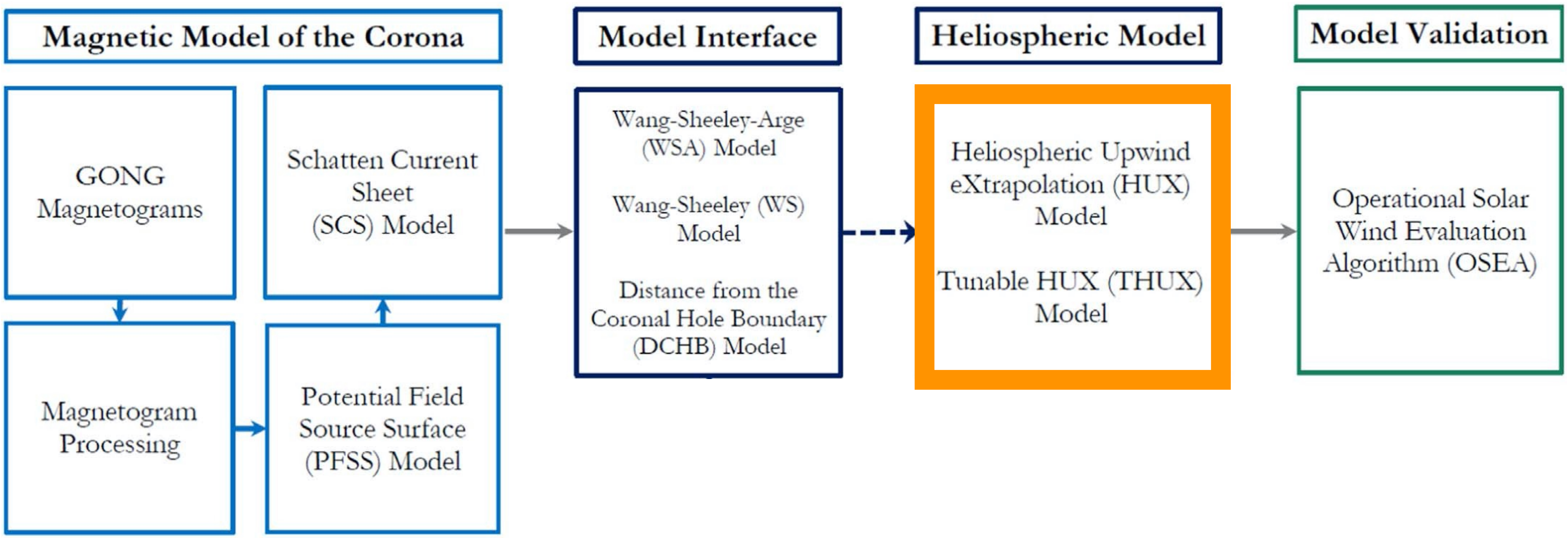

Reiss et al. (2019)

We use the computationally efficient HUX model (Riley and Lionello, 2011) **for mapping the solar wind solutions from the near-Sun environment to the vicinity of Earth.**

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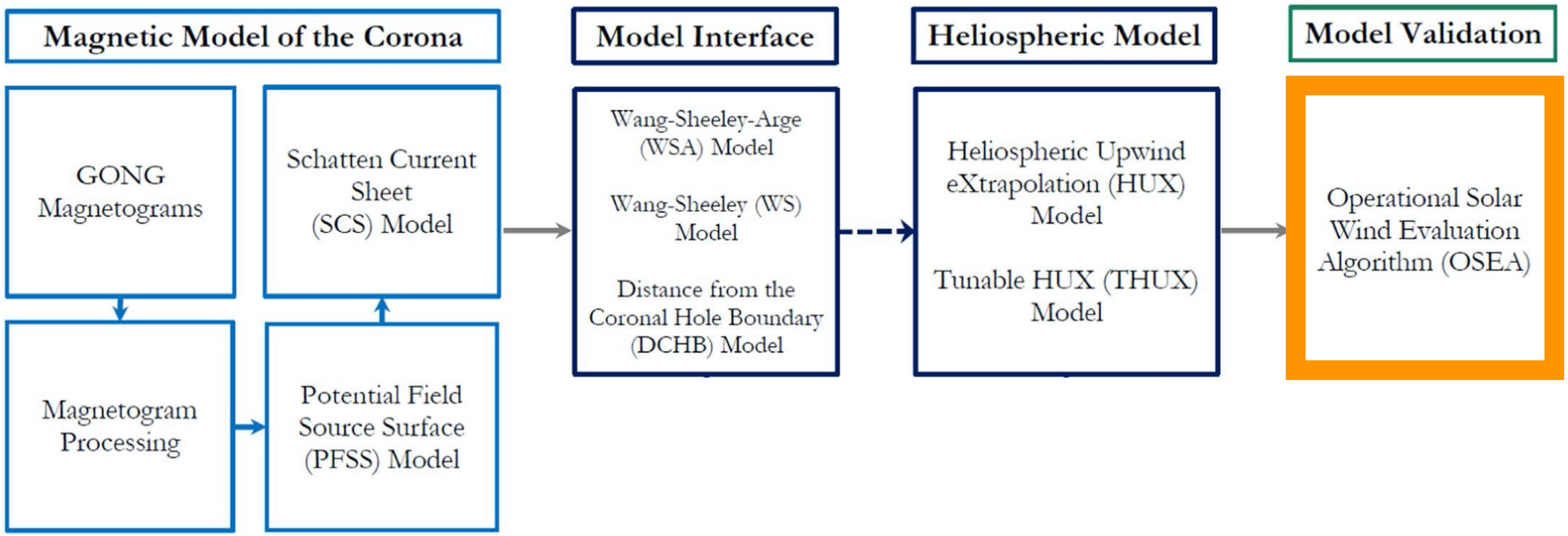

Reiss et al. (2019)

We use the Operational Solar Wind Evaluation Algorithm (OSEA) for validating solar wind predictions (Reiss et al., 2016).

https://github.com/starsarestrange

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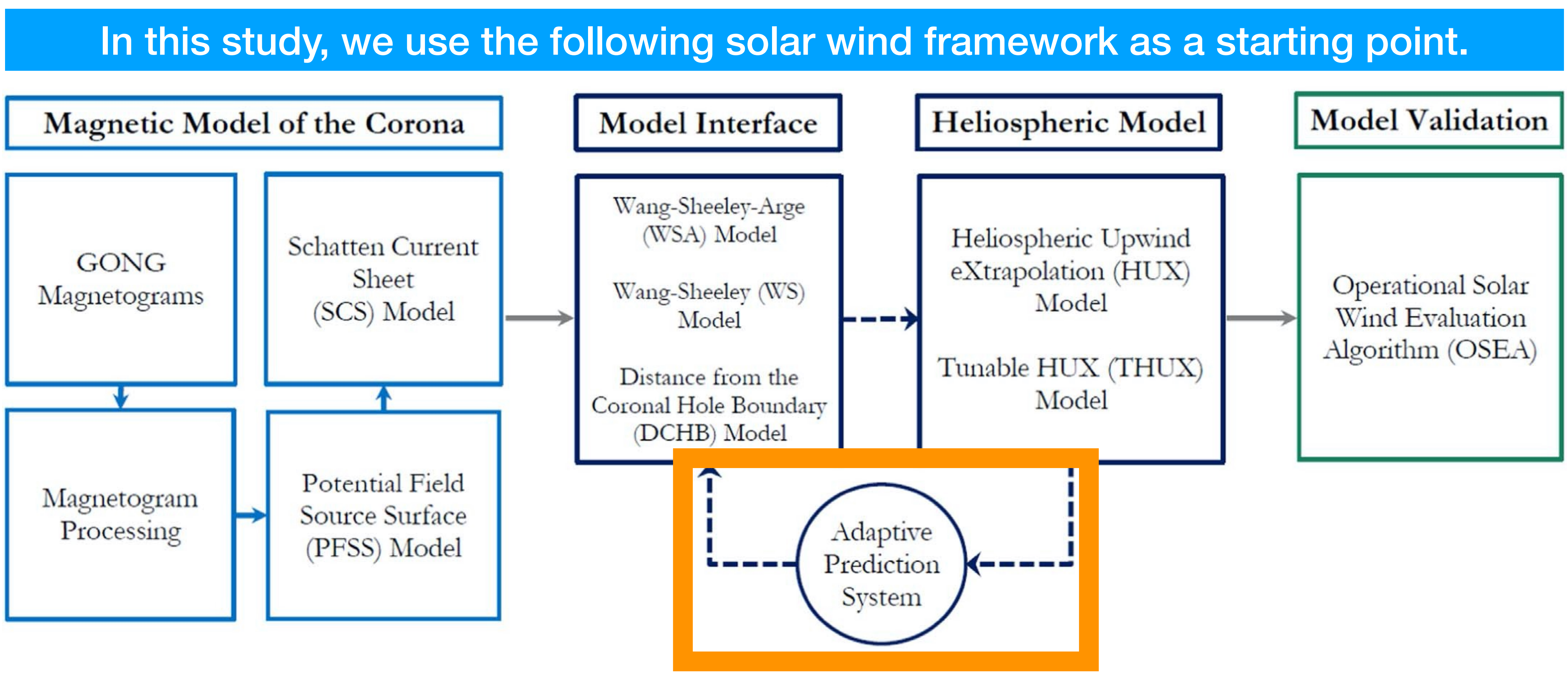
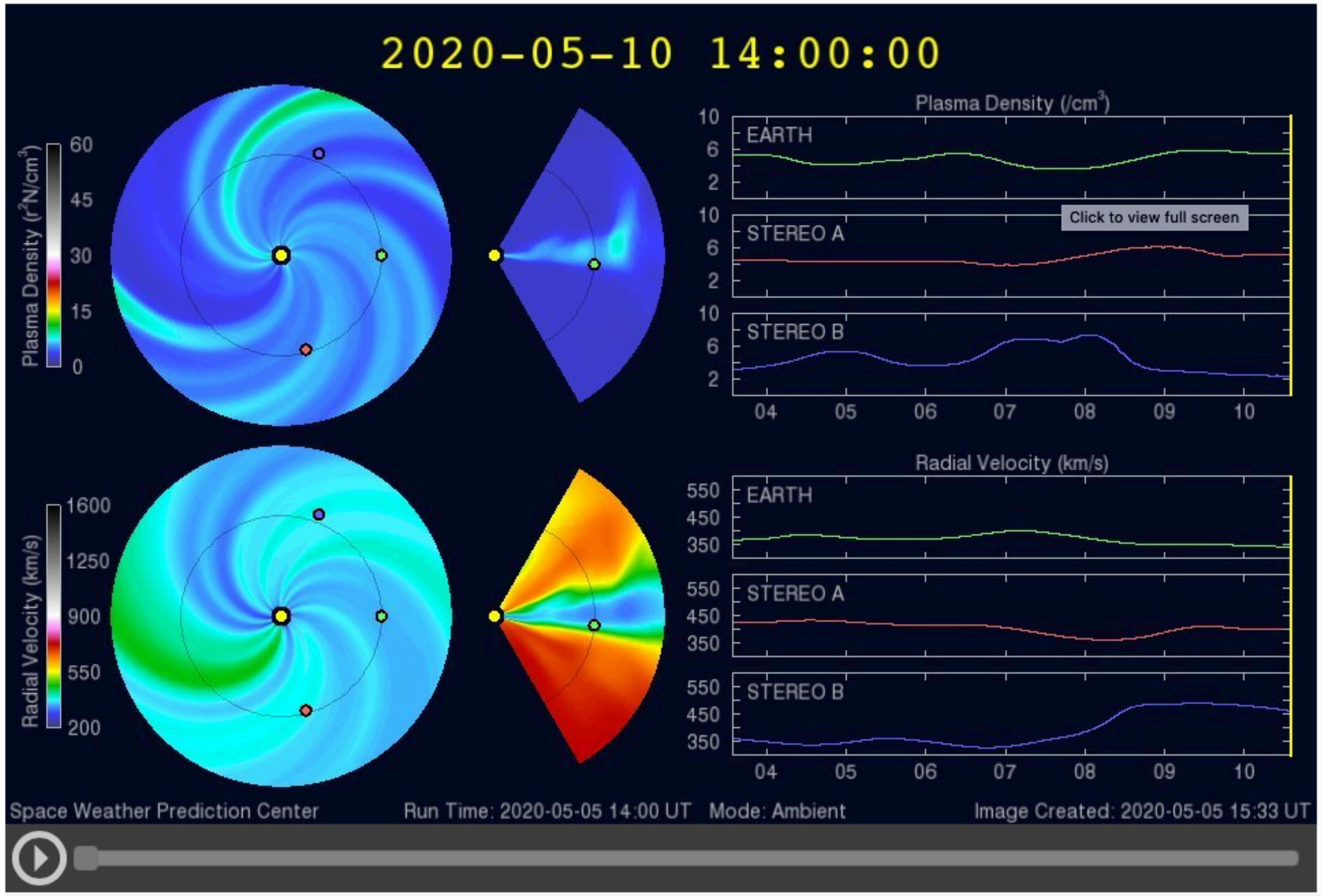


Reiss et al. (2019)

In this study, we present an adaptive prediction system that fuses information from in situ measurements to inform the Wang-Sheeley-Arge model.

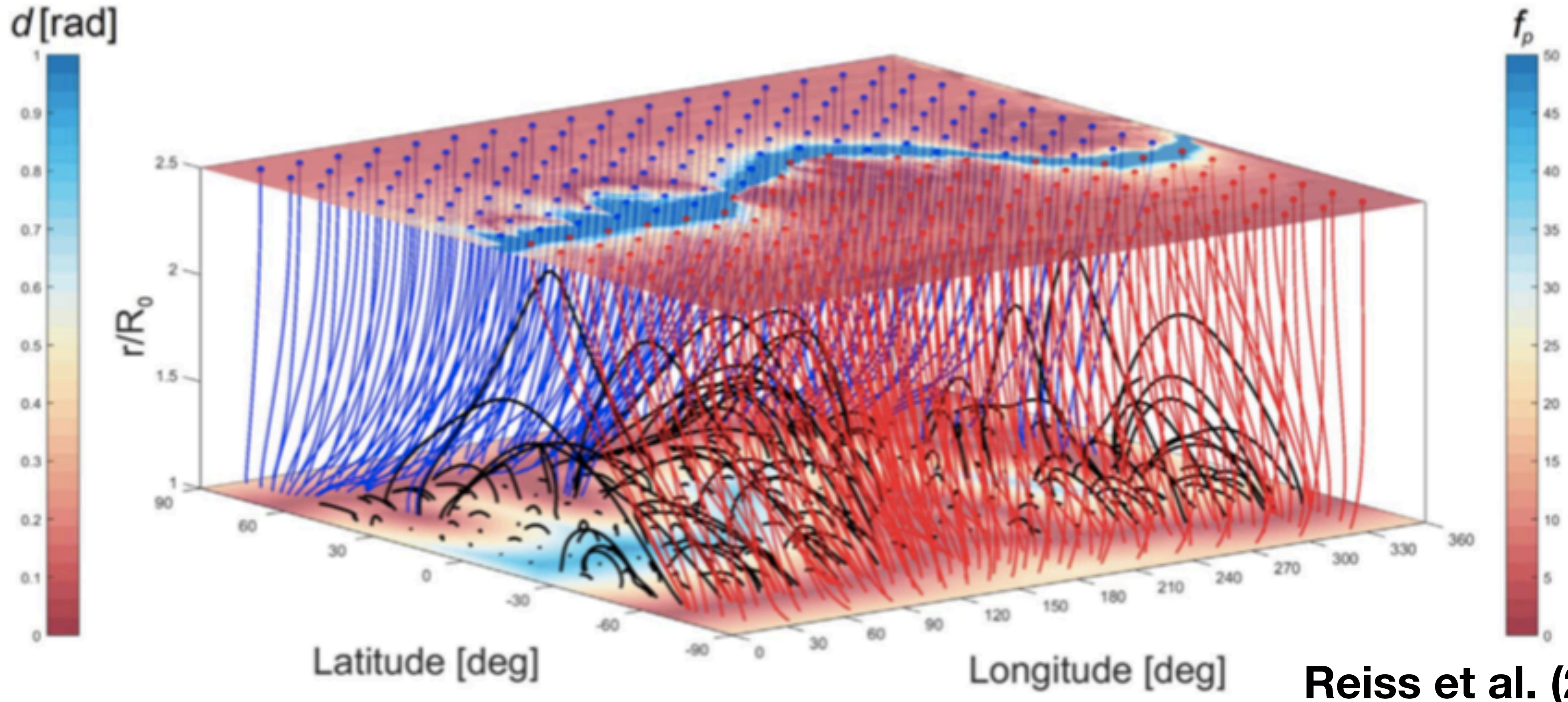
The Wang-Sheeley-Arge model has become one of the workhorse models in the space weather community.



https://www.swpc.noaa.gov/products/wsa-enlil-solar-wind-prediction

As an example, the coupled WSA/Enlil model is routinely used by NOAA and the Met Office.

CR2077:



Reiss et al. (2019)

Input WSA(fp, d)/Enlil:

$$v_{\mathrm{wsa}}(f_{\mathrm{p}}, d) = c_1 + \frac{c_2}{(1 + f_{\mathrm{p}})^{c_3}} \left\{ c_4 - c_5 \ \exp\left[- \left(\frac{d}{c_6} \right)^{c_7} \right] \right\}^{c_8}$$

The original WSA model relies on an empirical relationship based on the expansion factor *fp* (top layer) and the distance to the nearest coronal hole boundary *d* (bottom layer) for specifying solar wind speed near the Sun.

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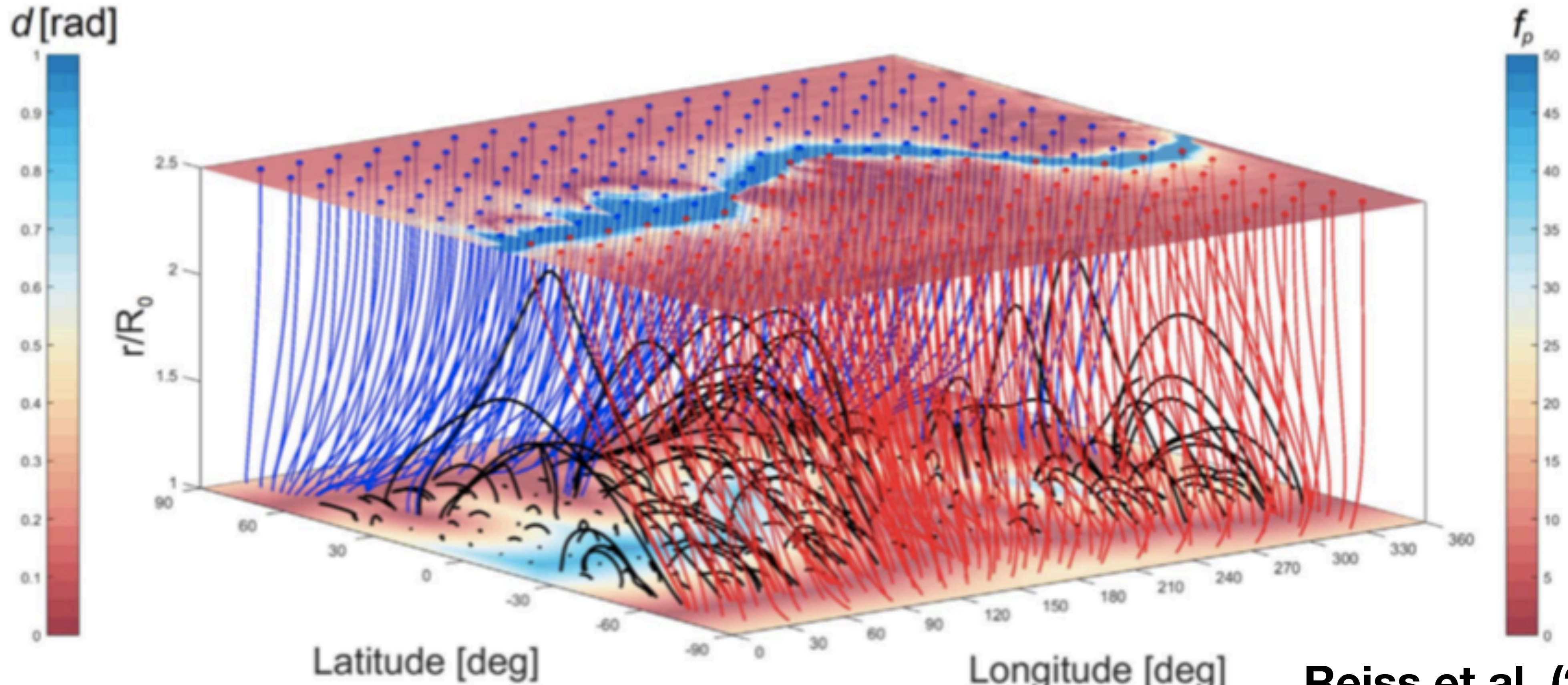

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Here we present an ***adaptive prediction system*** that fuses information from in situ measurements of the solar wind into numerical models to deduce the ***optimum WSA model coefficient settings*** c_i.

The proposed Adaptive-WSA model is a new method that replaces the static empirical formulae in the WSA model by a more flexible approach, which updates after each Carrington rotation (CR).

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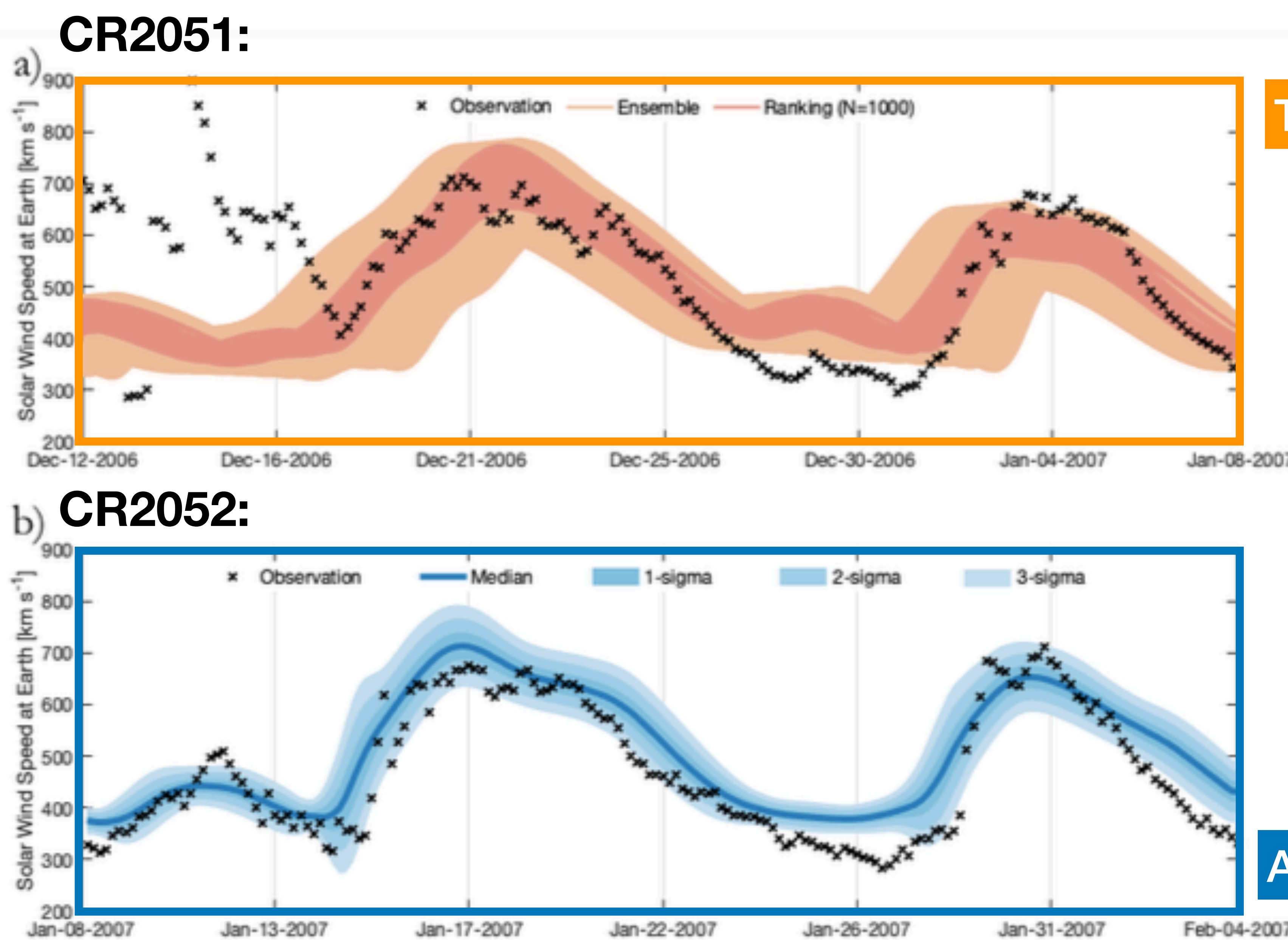
The adaptive WSA model uses information from in situ measurements of the ambient solar wind to train the model.



Training

Application

Reiss et al. (2020)

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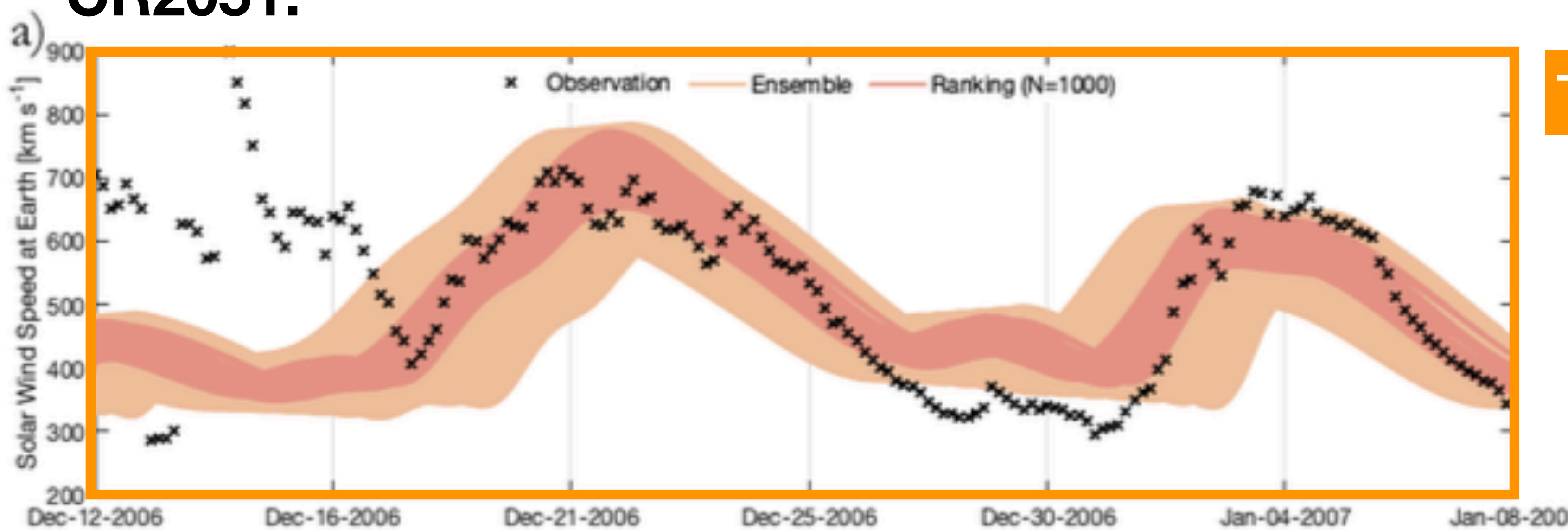
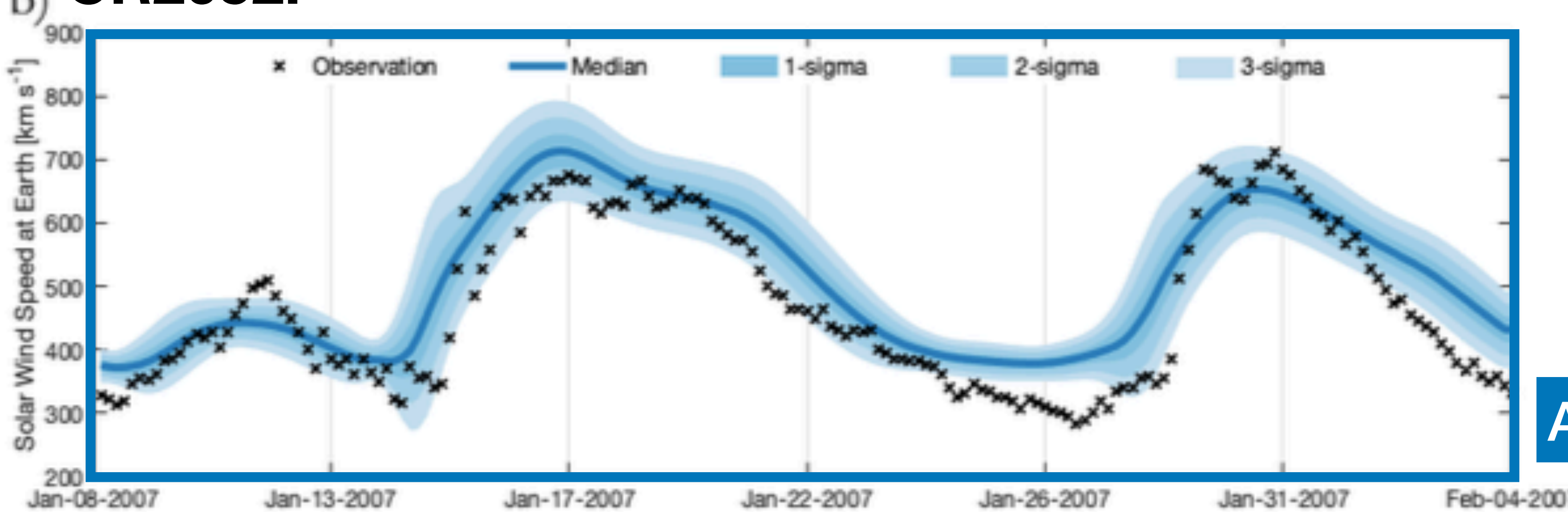
CR2051:



Training

This information is fed into the new model setting. Due to our efficient implementation, we can deduce error bounds and study thousands of settings within a matter of seconds.

CR2052:



Application

Reiss et al. (2020)

Comprehensive validation analysis shows that the proposed prediction scheme ***improves all the investigated coronal/ heliospheric model combinations*** and produces better estimates of the solar wind state at Earth than established solar wind models.

1. WSA
2. Adaptive-WSA (ED)
3. Adaptive-WSA (S0)
4. WS
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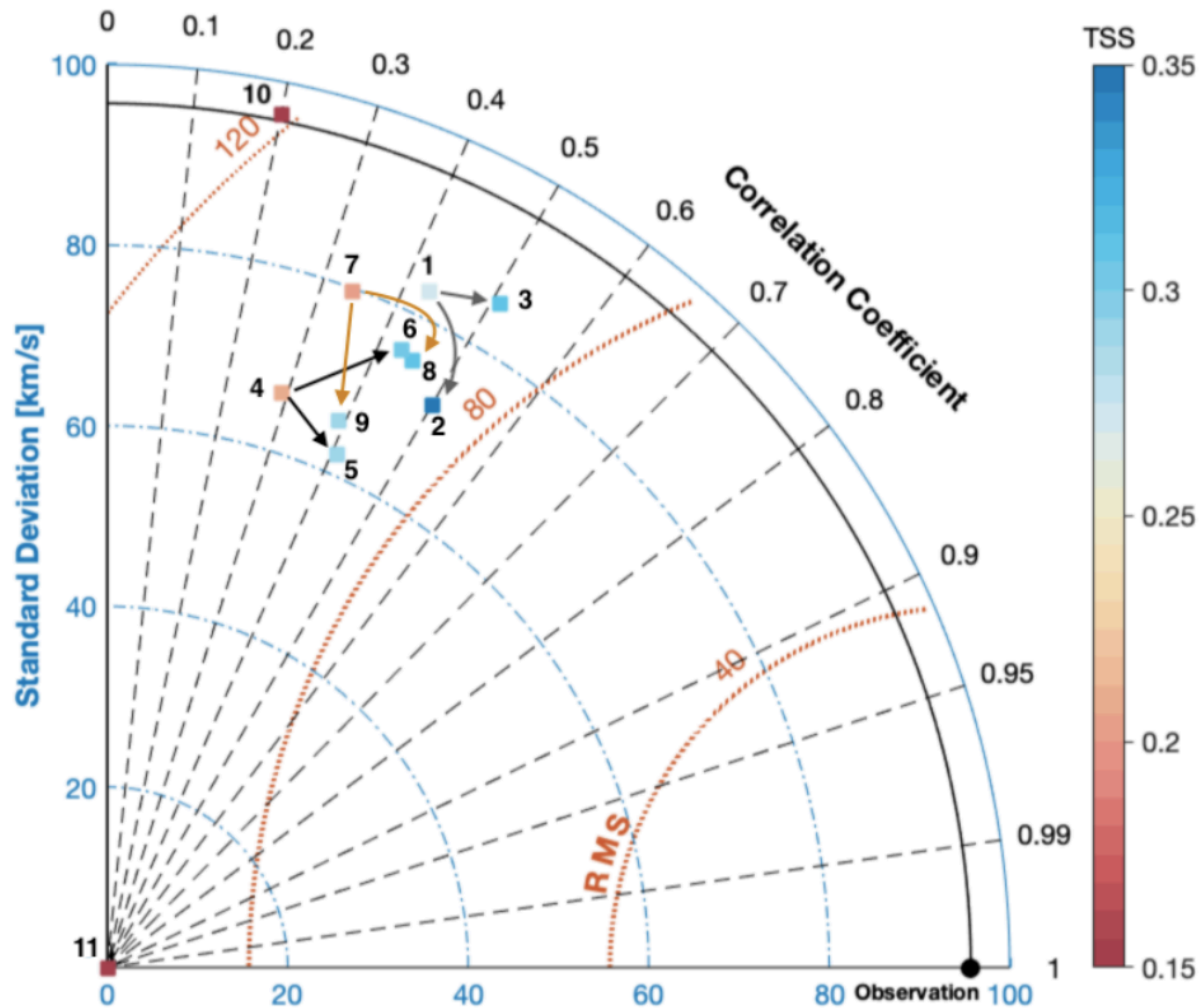
9. Adaptive-DCHB (S0)
10. Persistence (27-days)
11. Climatological Mean



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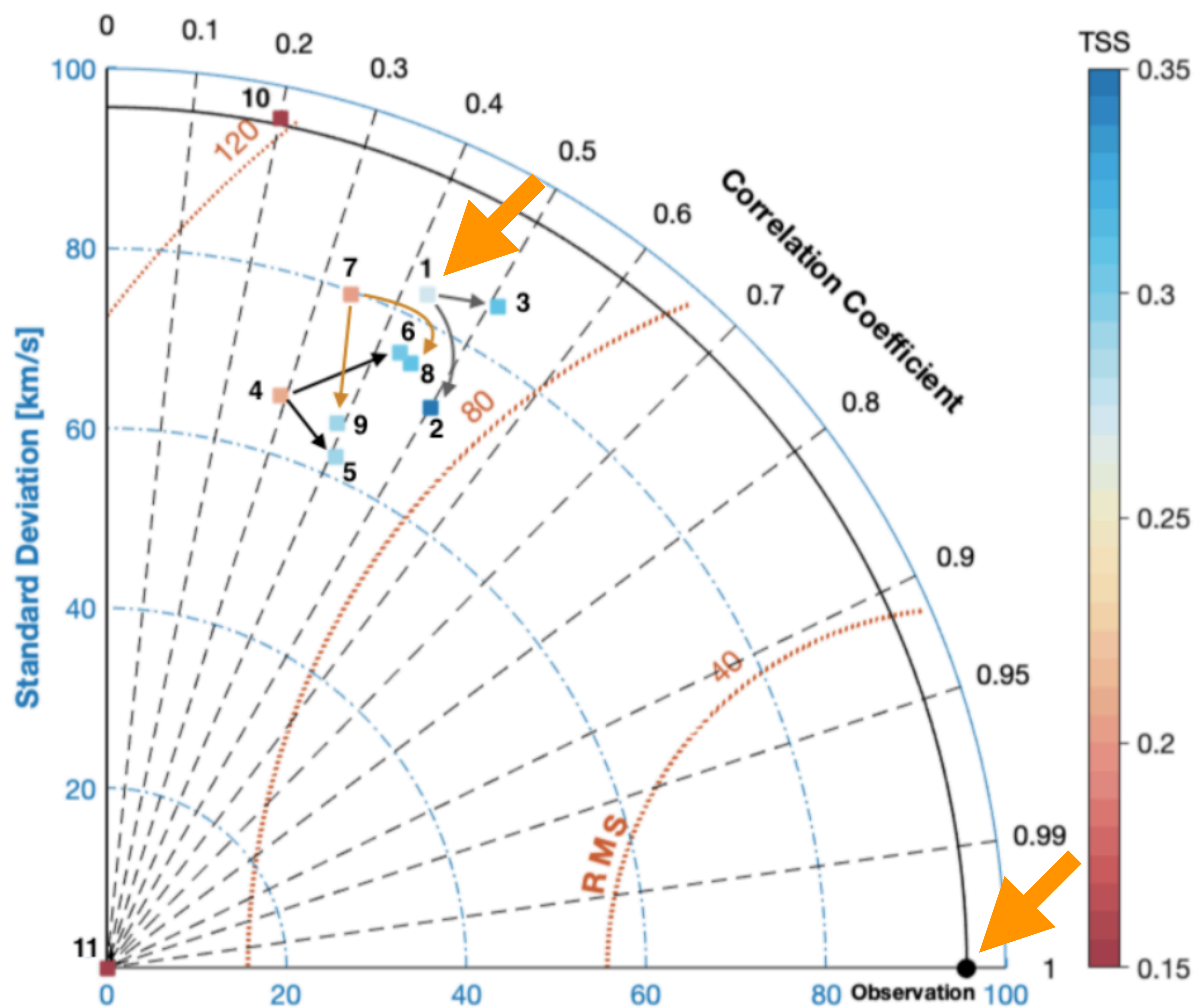

The distance the model solution has from the „observation“ on the x-axis correlates with its overall skill in terms of point-to-point measures.

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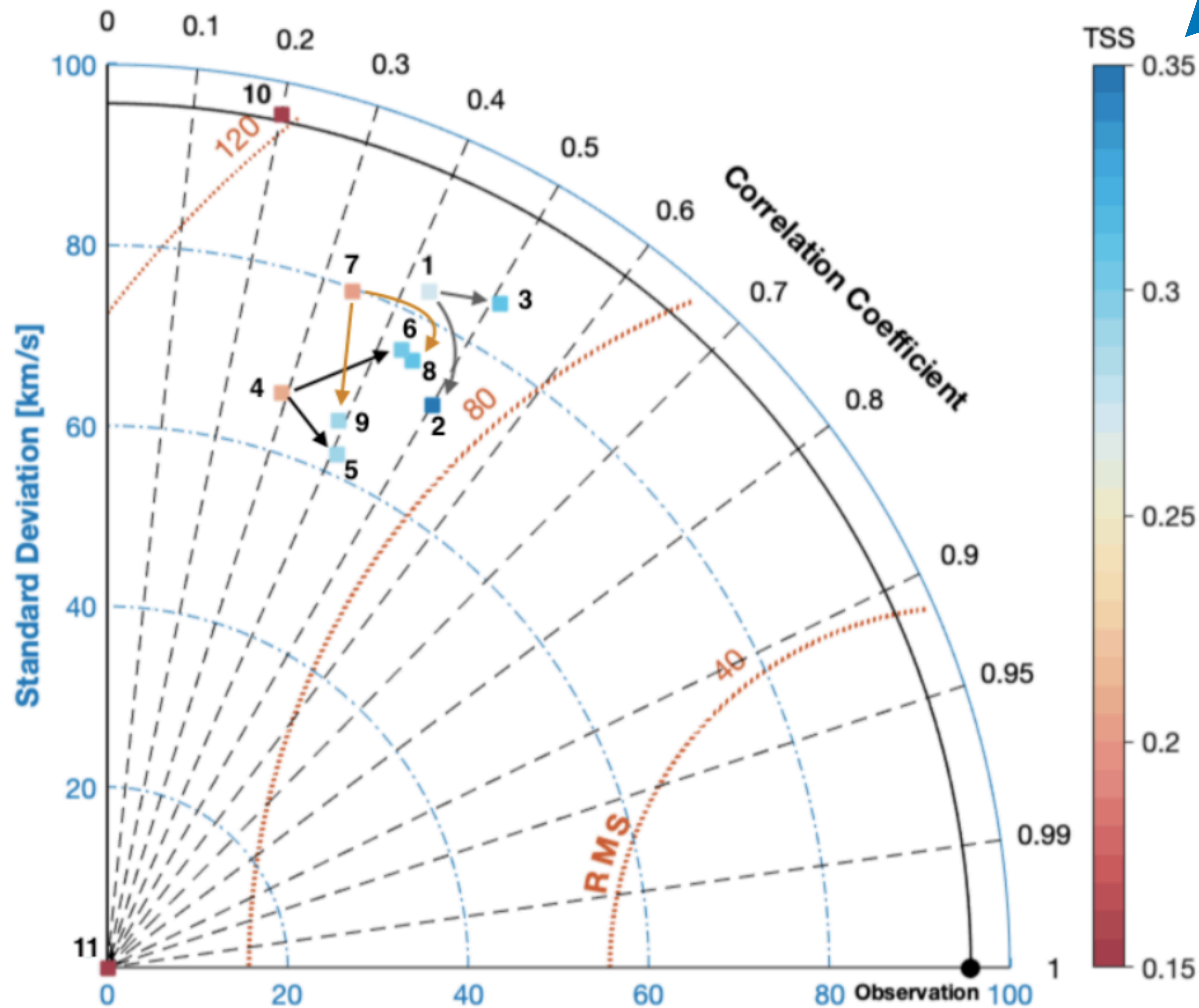

The color of each datapoint indicates the skill of each model in terms of an event-based validation analysis.

Reiss et al. (2020)

Summary:

An Adaptive Prediction System for Specifying Solar Wind Speed near the Sun

1. We present an ***adaptive prediction system*** that fuses information from in situ measurements of the solar wind into numerical models to better match the global solar wind model solutions near the Sun with prevailing physical conditions in the vicinity of Earth.

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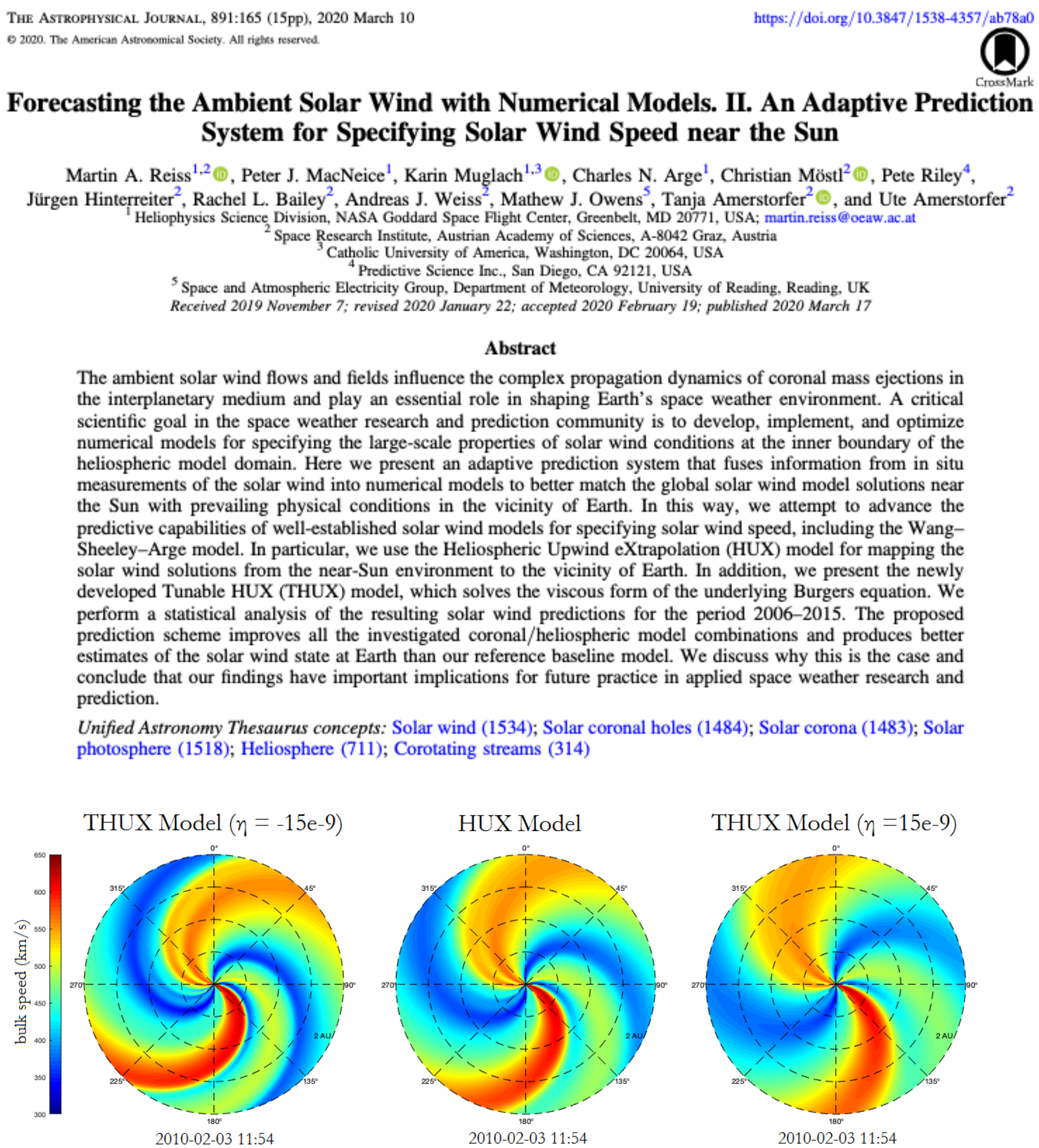
2. We perform a ***comprehensive validation analysis*** based on simple point-to-point error measures and event-based measures for the years 2006 to 2015.
3. We find that proposed prediction scheme ***improves all the investigated coronal/heliospheric model combinations*** and produces better estimates of the solar wind state at Earth than established solar wind models.

For more details on this study, we would like to refer to Reiss et al., 2020.



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CrossMark

Forecasting the Ambient Solar Wind with Numerical Models. II. An Adaptive Prediction System for Specifying Solar Wind Speed near the Sun

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Abstract

The ambient solar wind flows and fields influence the complex propagation dynamics of coronal mass ejections in the interplanetary medium and play an essential role in shaping Earth's space weather environment. A critical scientific goal in the space weather research and prediction community is to develop, implement, and optimize numerical models for specifying the large-scale properties of solar wind conditions at the inner boundary of the heliospheric model domain. Here we present an adaptive prediction system that fuses information from in situ measurements of the solar wind into numerical models to better match the global solar wind model solutions near the Sun with prevailing physical conditions in the vicinity of Earth. In this way, we attempt to advance the predictive capabilities of well-established solar wind models for specifying solar wind speed, including the Wang–Sheeley–Arge model. In particular, we use the Heliospheric Upwind eXtrapolation (HUX) model for mapping the solar wind solutions from the near-Sun environment to the vicinity of Earth. In addition, we present the newly developed Tunable HUX (THUX) model, which solves the viscous form of the underlying Burgers equation. We perform a statistical analysis of the resulting solar wind predictions for the period 2006–2015. The proposed prediction scheme improves all the investigated coronal/heliospheric model combinations and produces better estimates of the solar wind state at Earth than our reference baseline model. We discuss why this is the case and conclude that our findings have important implications for future practice in applied space weather research and prediction.

Unified Astronomy Thesaurus concepts: Solar wind (1534); Solar coronal holes (1484); Solar corona (1483); Solar photosphere (1518); Heliosphere (711); Corotating streams (314)

https://ui.adsabs.harvard.edu/abs/2020ApJ...891..165R/abstract

This study also includes:

- detailed description of the adaptive modeling approach,
- description of an efficient model for propagating the solar wind solutions near the Sun to Earth (Tunable HUX),
- sensitivity analysis of established solar wind modeling approach, and
- a detailed description of a comprehensive validation analysis for ambient solar wind models.

If you have any questions, please contact martin.reiss@oeaw.ac.at