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An Open-source Solar Wind Prediction Tool Based on MHD Simulations

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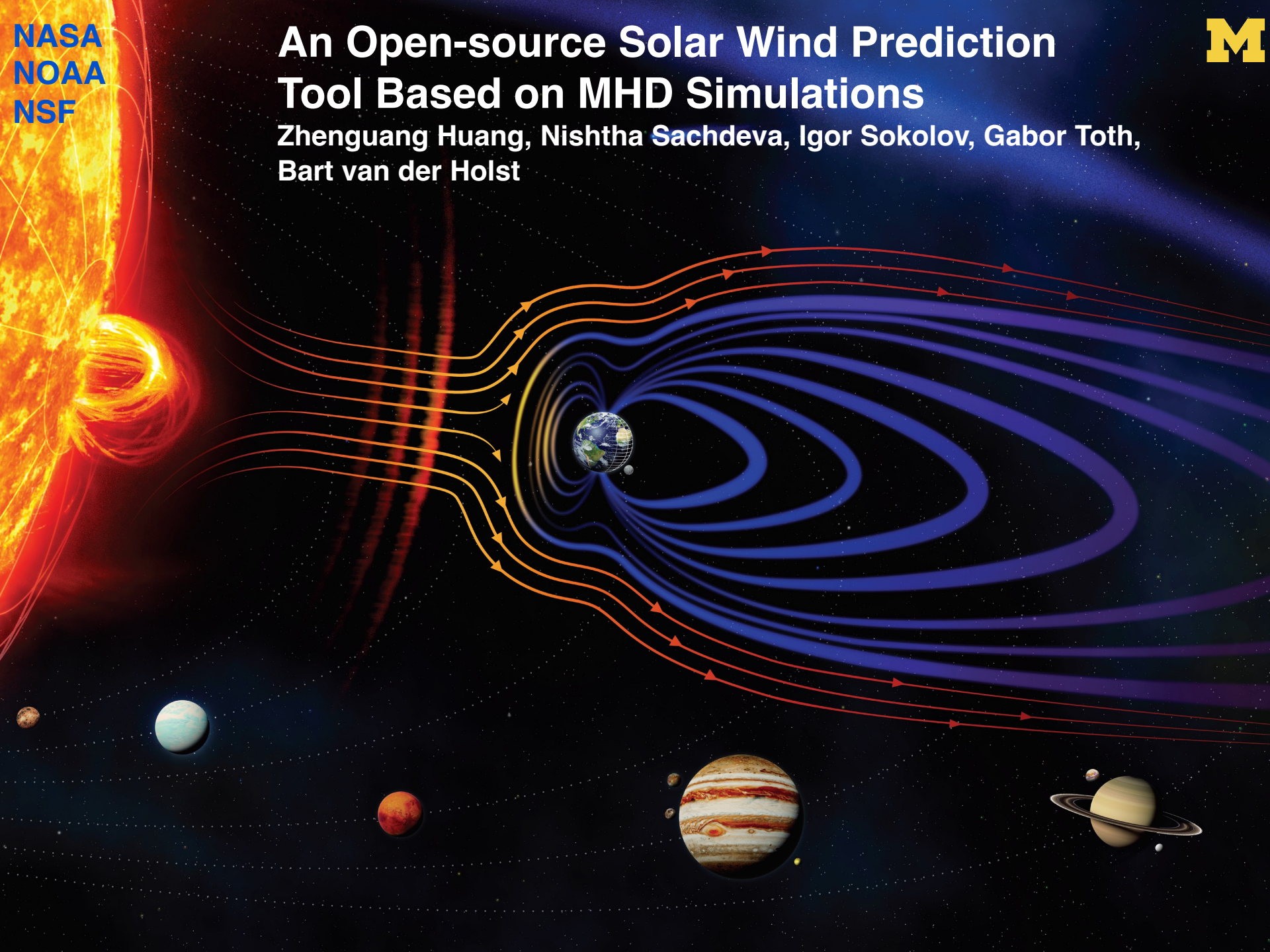


Real-time Solar Wind Predictions

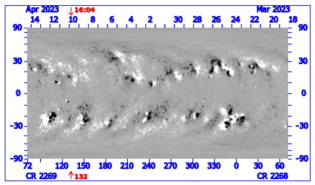
One of the core components in space weather

- The solar wind density
- The solar wind speed
- The interplanetary magnetic field, especially the Bz component
- Provides the plasma conditions for drivers (Coronal Mass Ejections (CMEs), Solar energetic particles (SEPs), etc.) of space weather events

Models used to predict the solar wind

- Empirical, semi-empirical or AI/ML models:
  - The Wang-Sheeley-Arge (WSA) model
  - Many others
- Fully first-principles based models:
  - AWSoM (Alfven-Wave driven Solar atmosphere Model) within the Space Weather Modeling Framework (SWMF)
  - The MHD-Around-a-Sphere (MAS) model
  - Many others

AWSoM as a Whitebox



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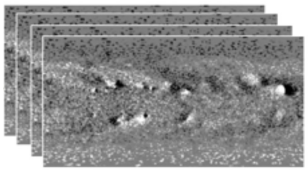
Or



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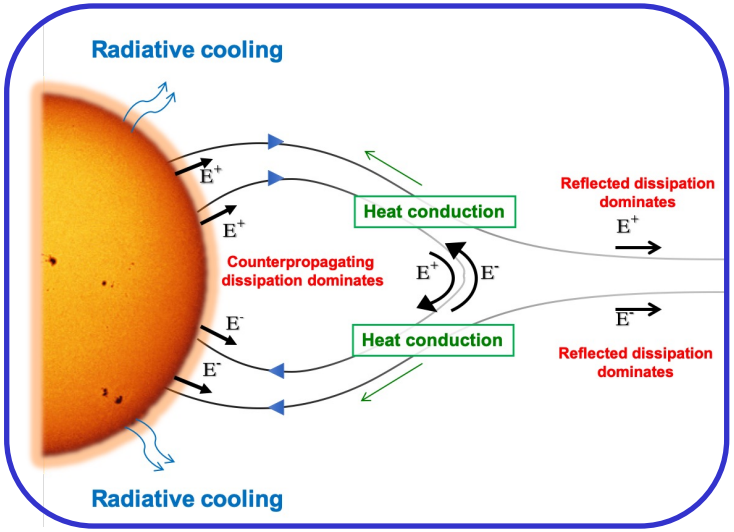
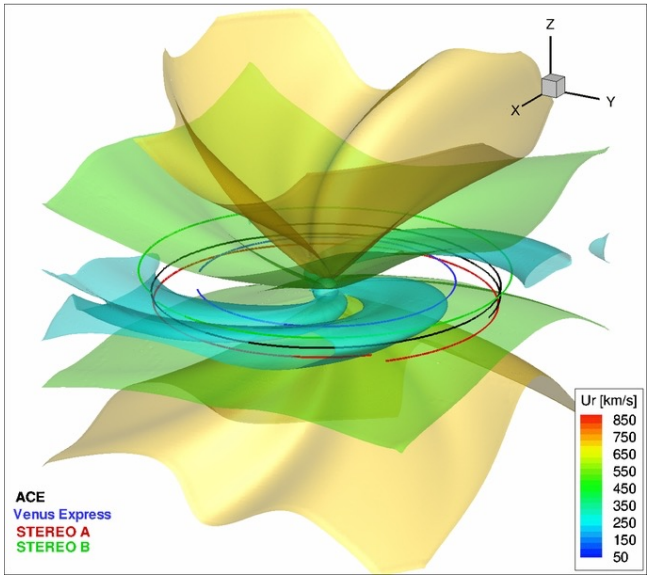
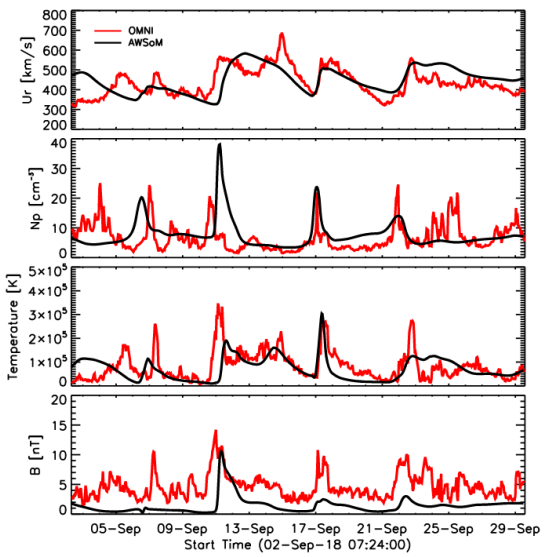
Or other magnetograms

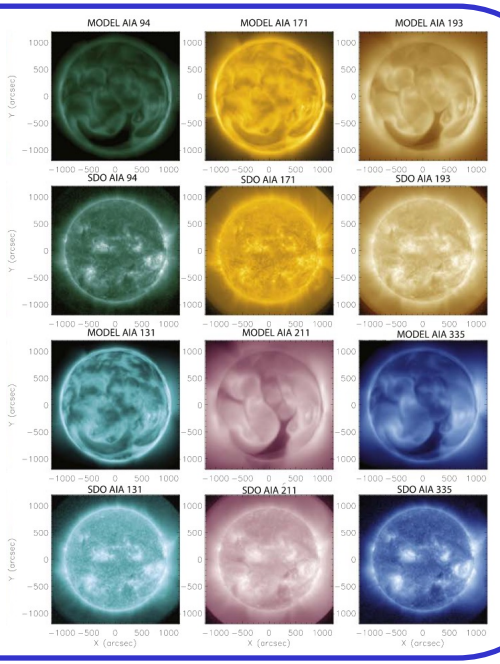


Parameters:

- Observations: density, temperature, Poynting flux, etc.
- Physical process: correlation length, amplitude and exponent of the stochastic heating profile, etc.



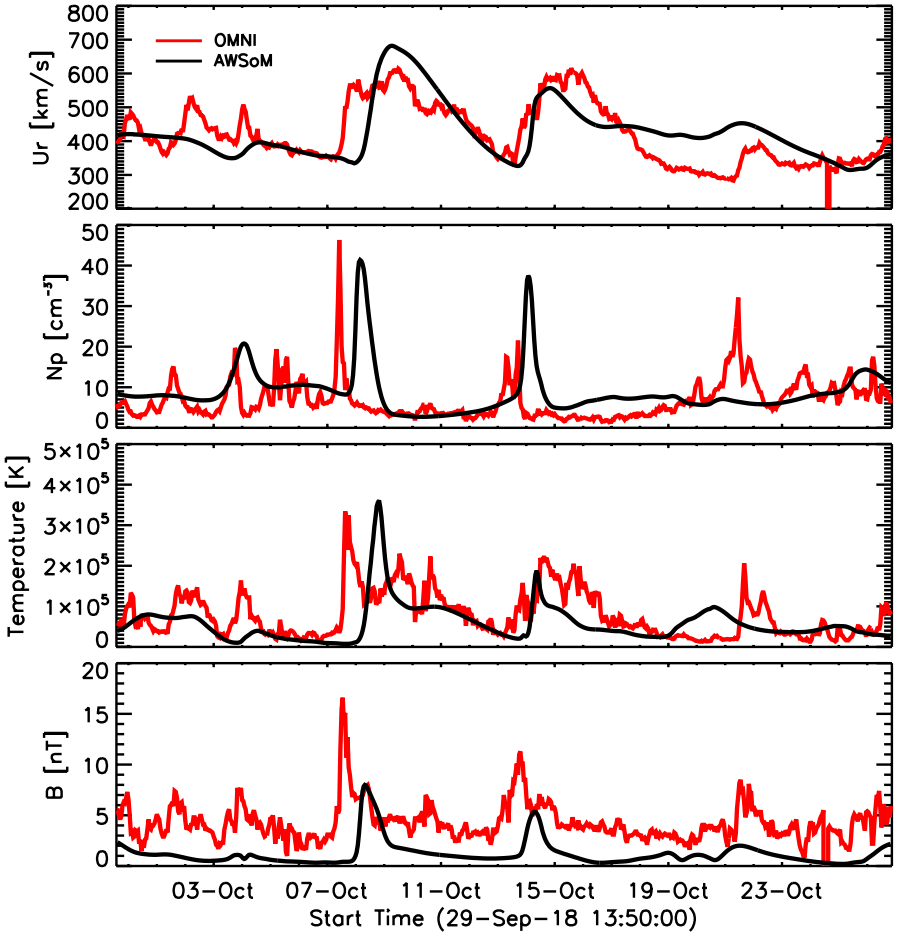




AWSoM Results for Solar Minimum and Maximum

Solar minimum: CR2209

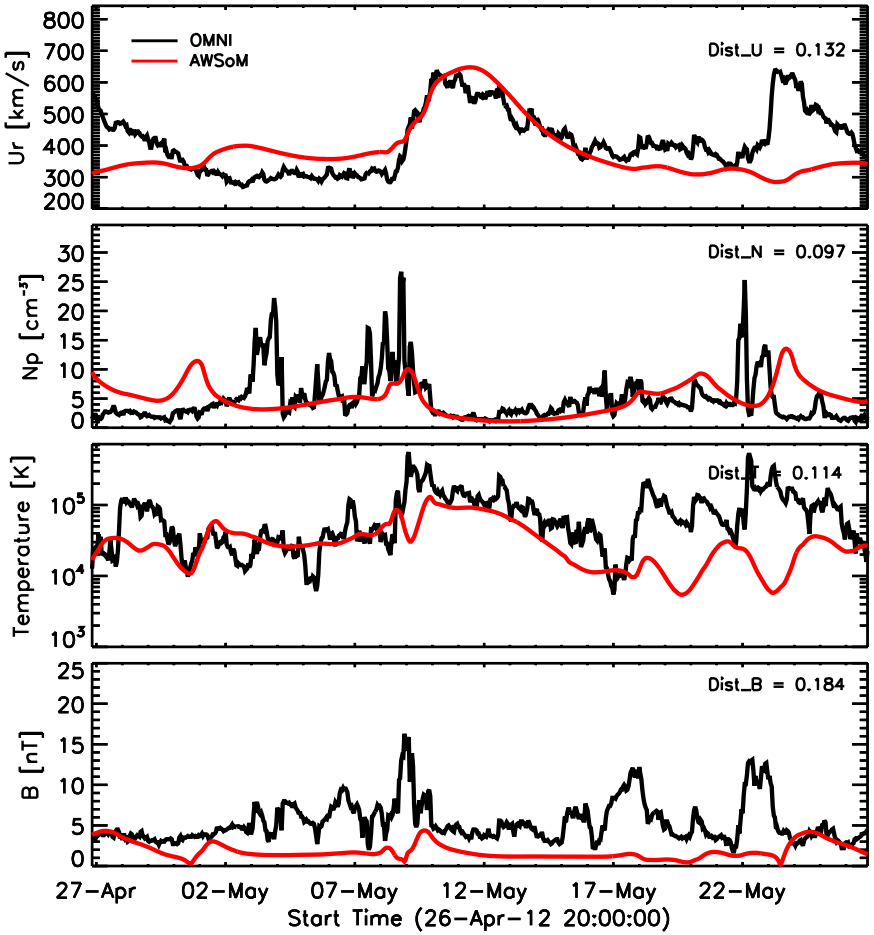
The Poynting flux parameter is set to 1.0 $MWm^{-2}T^{-1}$



Sachdeva et al. 2019, *ApJ*, 887, 83

Solar maximum: CR2152

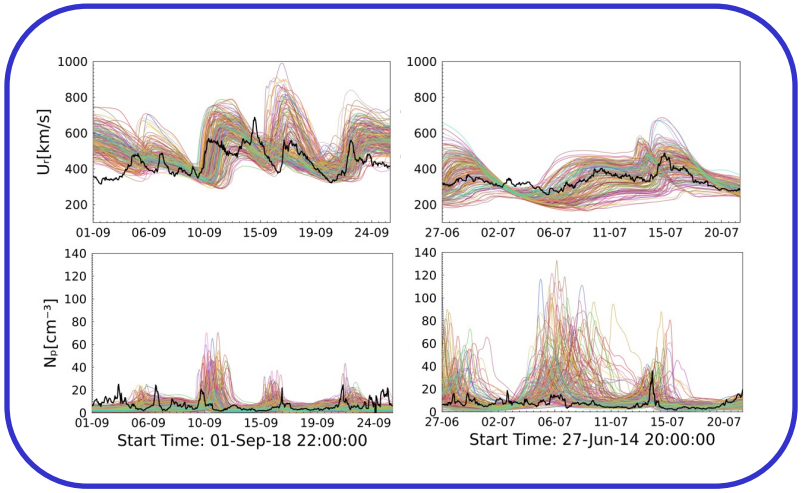
The Poynting flux parameter is set to 0.5 $MWm^{-2}T^{-1}$

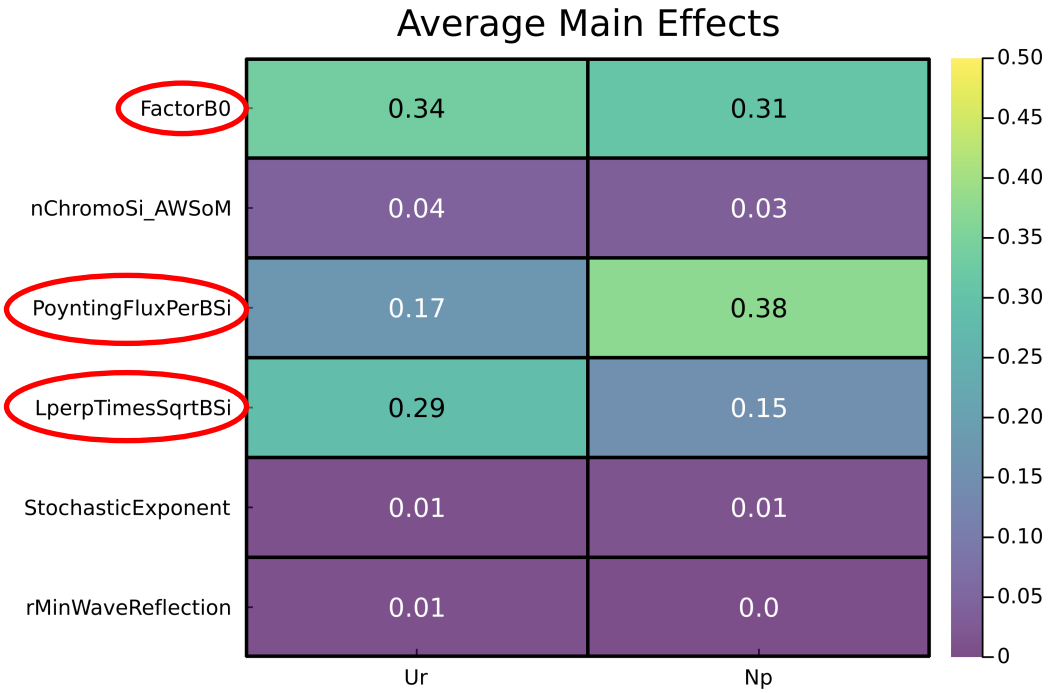


Sachdeva et al. 2021, *ApJ*, 923, 176

Prepare AWSoM for Real-time Operations

- **Considerations:**
  - Need to run faster than real-time ✓
  - Real-time observational inputs (magnetograms) ✓
  - How to prescribe the values of the parameters?

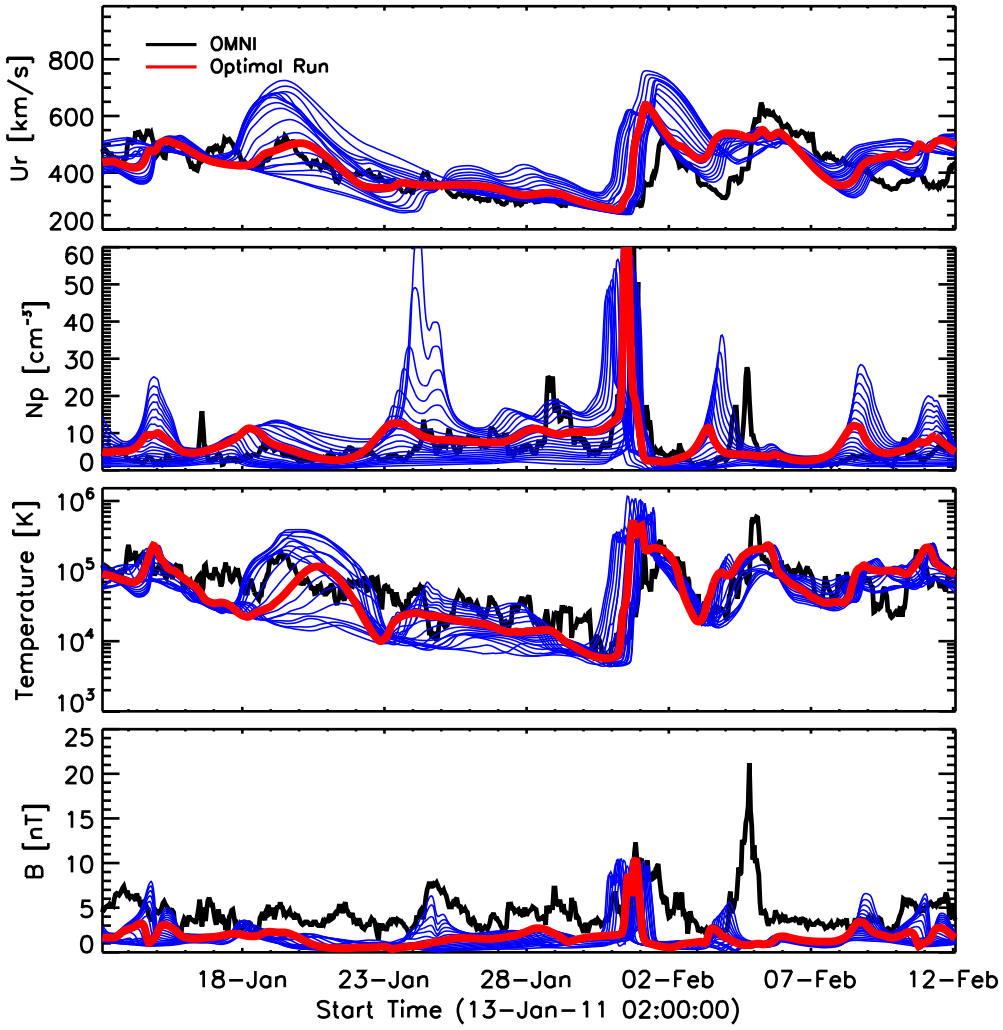




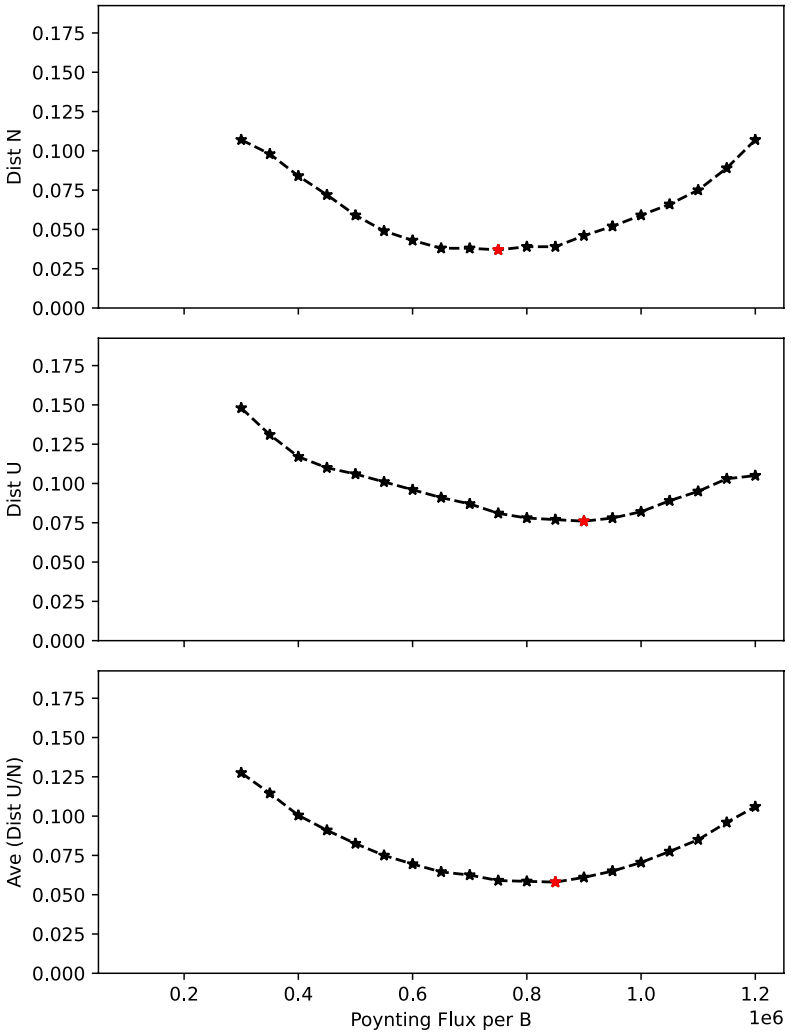
Jivani et al. 2023, *SpWea*, 21, e2022SW003262

The Poynting Flux Parameter of AWSoM

Simulated solar wind (in blue) with different values of the Poynting flux parameters

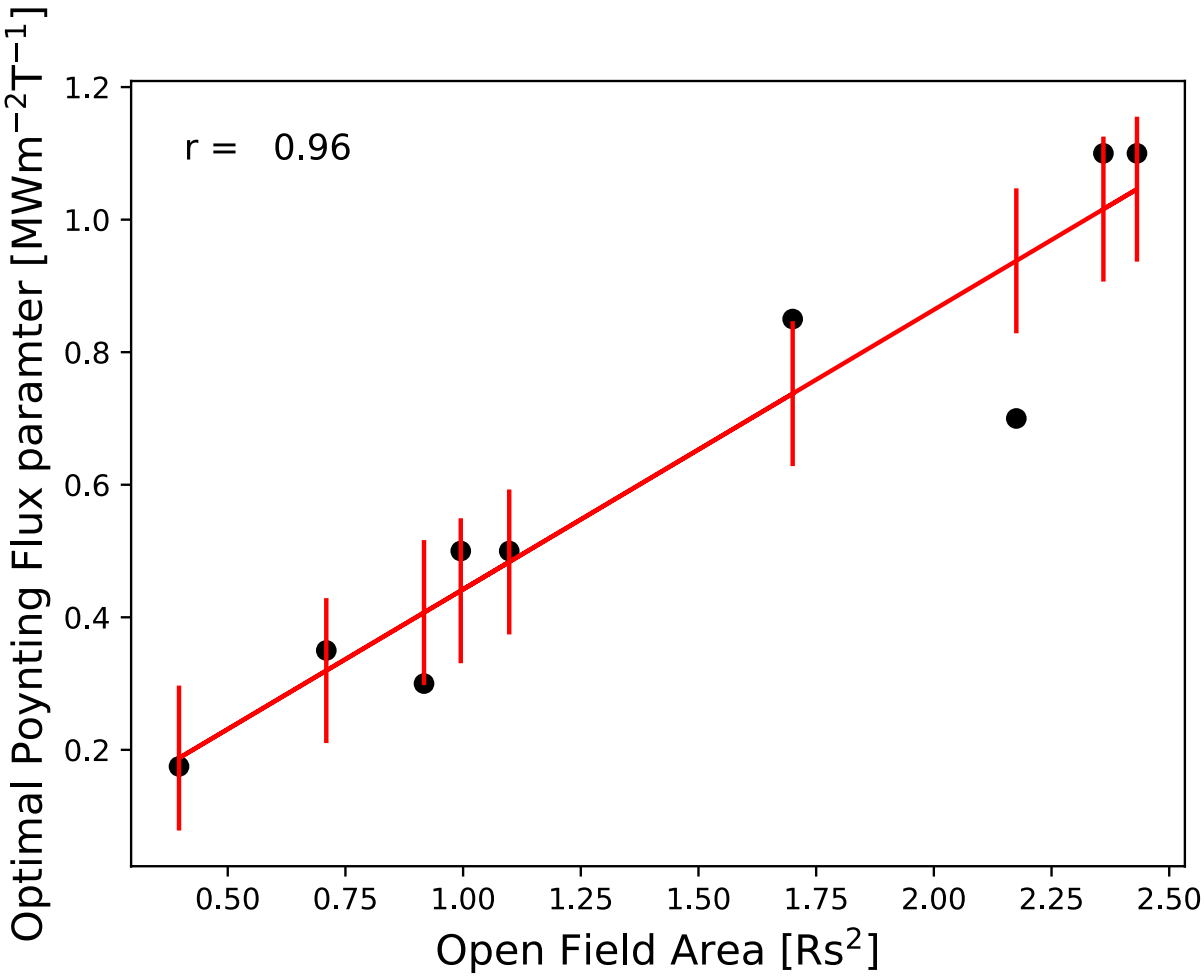


The distance values between the simulated and observed solar wind



Huang et al. 2023, *ApJL*, 946, L47

Empirical Formula for the Poynting Flux Parameter



Empirical formula between the optimal value of the Poynting flux parameter and the area of the open field regions:

$$P = 0.42 \cdot A + 0.02 \pm 0.11$$

Huang et al. 2023, *ApJL*, 946, L47

Summary & Future Directions

- **AWSoM is a first-principles based model and fully validated in solar minimum and maximum**
- **Used the Variance-based sensitivity analysis (Sobol indices) to determine what parameters are important**
- **Determined an empirical formula for the Poynting flux parameter**
- **Work in progress:**
  - More parameters and/or magnetograms
  - Transition the results to CCMC
  - RL6 verification in a near real-time environment
  - Build an open-source solar wind prediction tool