Ensemble CME Modeling at CCMC

M. Leila Mays

A. Taktakishvili

Email: m.leila.mays@nasa.gov, aleksandre.taktakishvili-1@nasa.gov

Ensemble Modeling

Ensemble modeling is used in weather forecasting to quantify prediction uncertainties and determine forecast confidence

- Individual forecasts which constitute an ensemble forecast represent possible scenarios that approximate a probability distribution which reflects forecasting uncertainties.
- Uncertainties can be from initial conditions, observation error, and techniques and models.
- Different forecasts in the ensemble can start from different initial conditions and/or be based on different forecasting models/procedures.
- Provides a quantitative description of the forecast probability that an event will occur by giving event occurrence predictions as a percentage of ensemble size (probabilistic forecast).
- Conveys the level of uncertainty in a given forecast in contrast to a categorical yes/no forecast (with only two probabilities, zero and one).

Ensemble Modeling with WSA-ENLIL+Cone

The current version of real-time ensemble modeling at the CCMC/SWRC evaluates the sensitivity of CME arrival time predictions from the model to initial CME parameters.

- Measure a set of *n* CME input parameters. Typically *n*=36 to 48 provides an adequate spread of input parameters, and this number can be increased as needed.

- These are used as input to an ensemble of *n* WSA-ENLIL+Cone model runs.

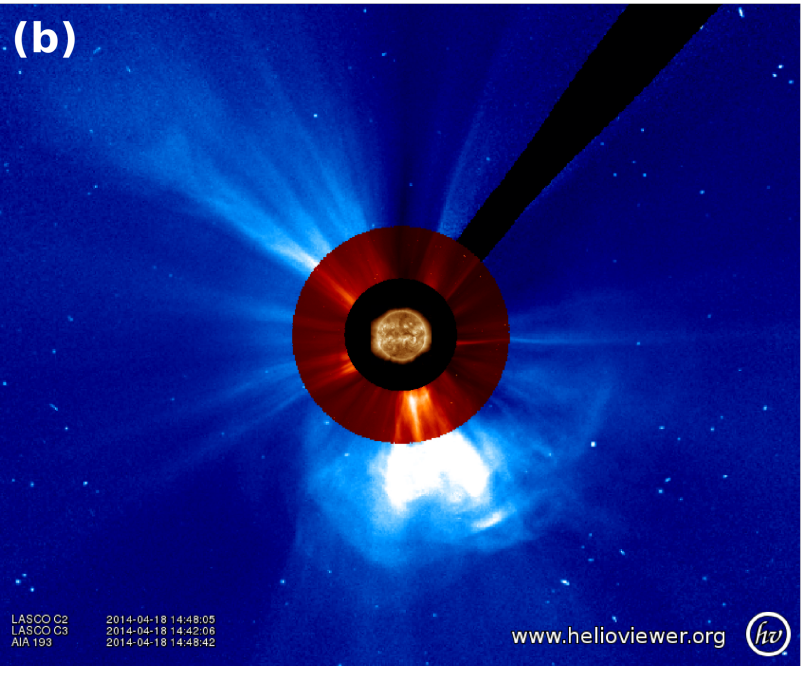
- This gives an ensemble of *n* profiles of MHD quantities and *n* CME arrival time predictions at locations of interest.

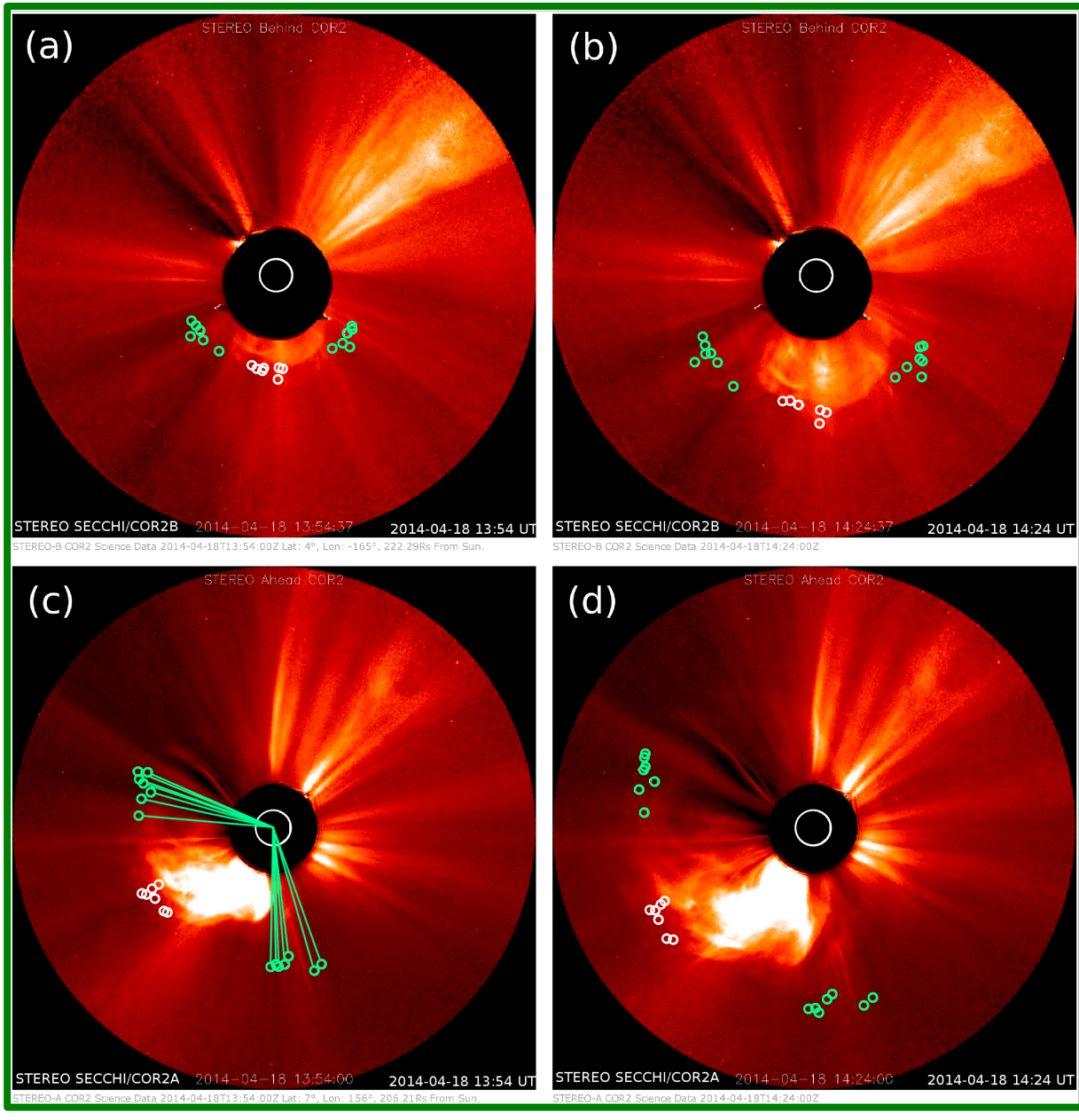
- At Earth, *n* Kp estimates are made using WSA-ENLIL+Cone model plasma parameters as input to the Newell *et al.* (2007) coupling function for three IMF clock angle scenarios (Θ_C=90°, 135°, and 180°).

- For *n*=48, an average run takes ~80 minutes on a cluster (using 128 processors).

Example ensemble simulation: 18 April 2014 CME

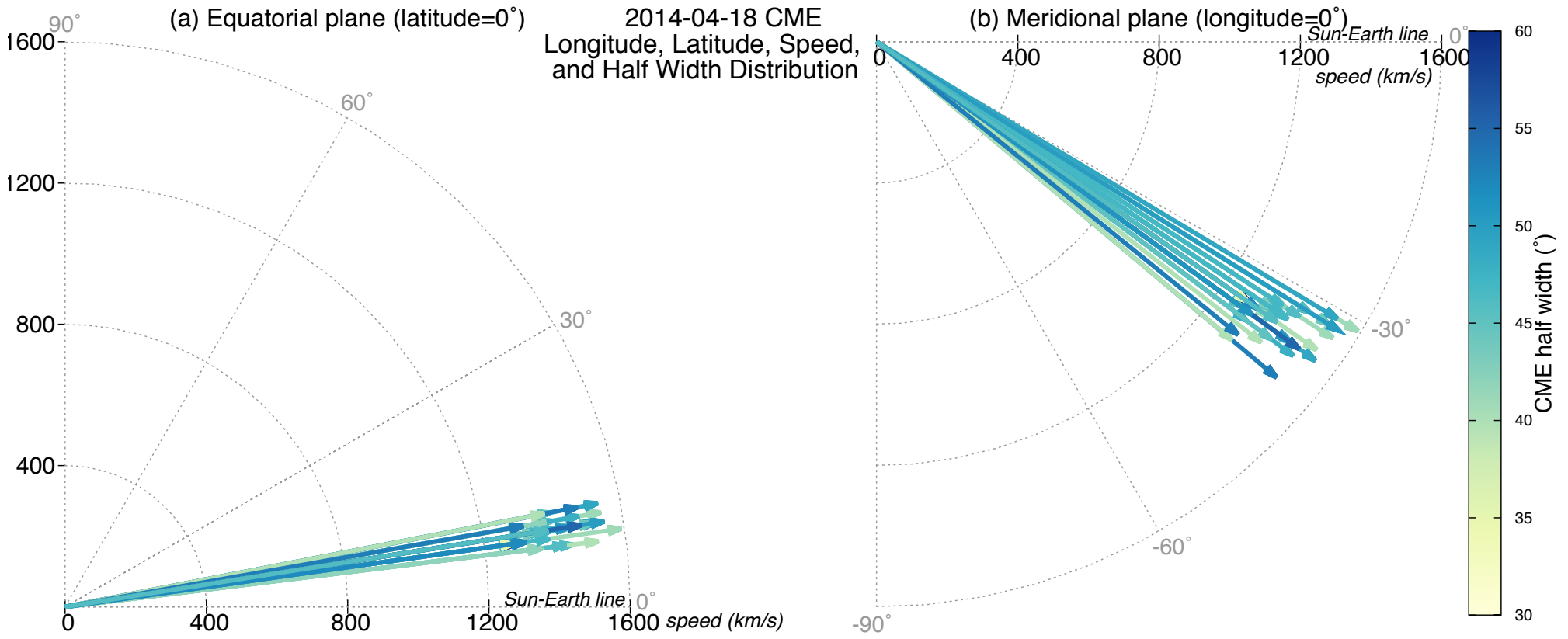
Halo CME associated with M7.3 flare, coronal wave visible south of the AR



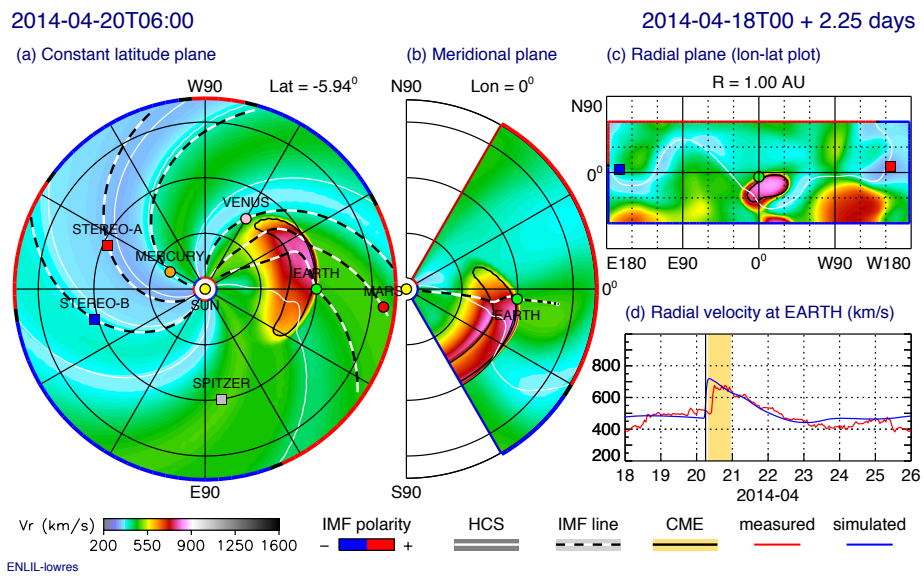


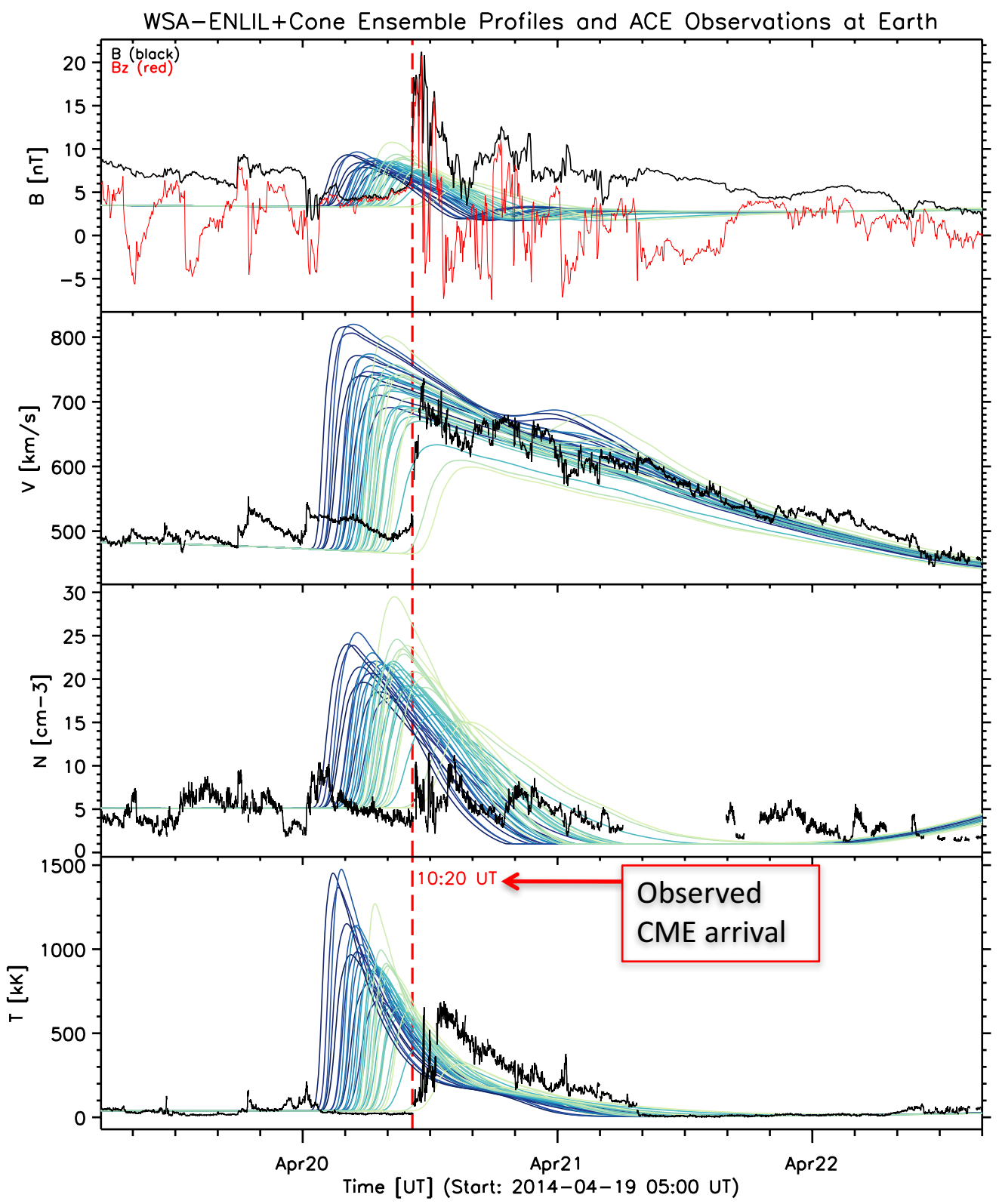
Ensemble of input CME parameters obtained by measuring the same feature using StereoCAT, which employs geometric triangulation techniques.

Distribution of the 18 April 2014 CME input parameters



Median CME parameters:
speed of 1394 km/s,
9° longitude,
-35° latitude,
46° half-width.

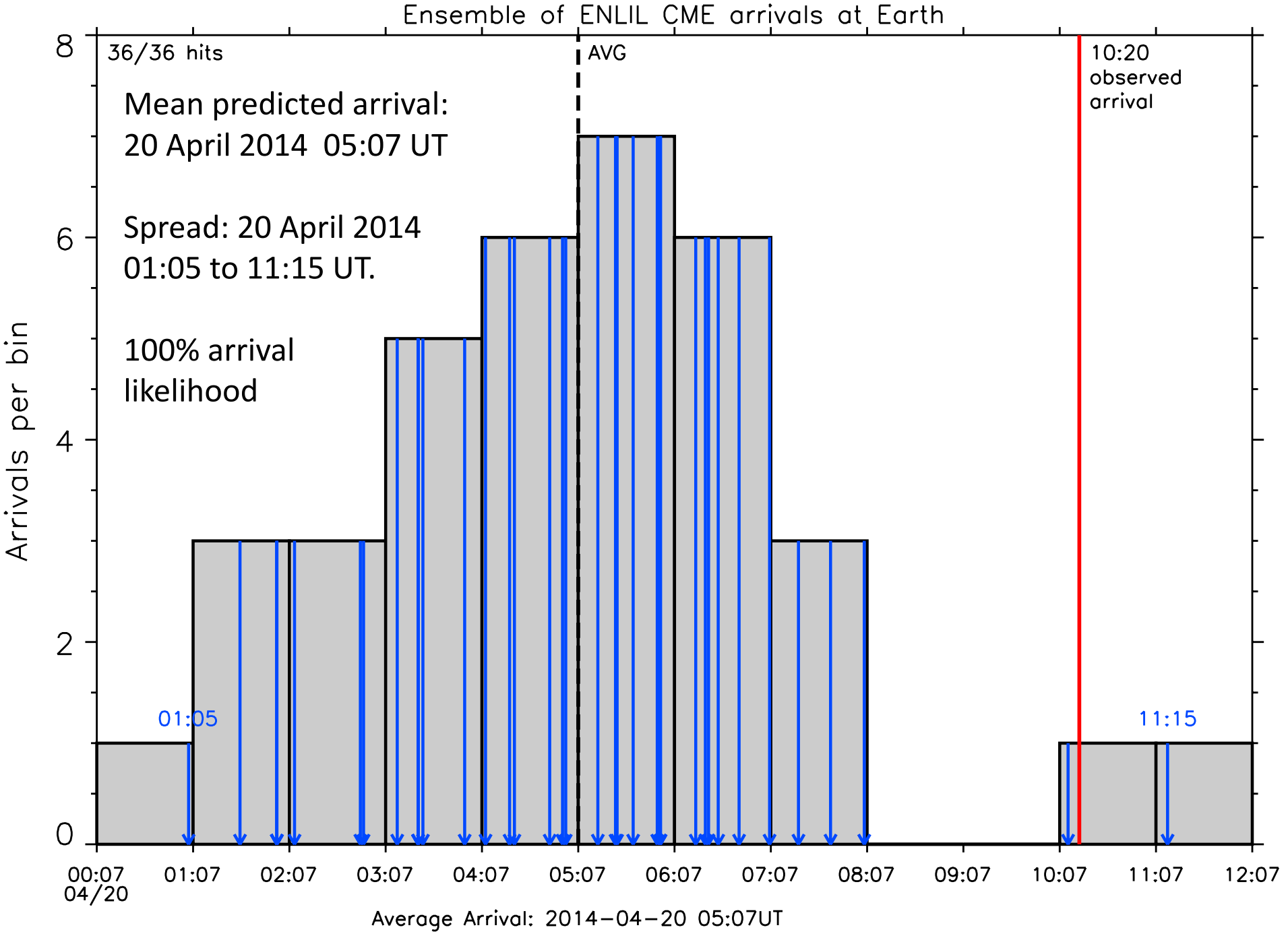




18 April 2014 CME: WSA-ENLIL+Cone modeled magnetic field, velocity, density, and temperature profiles at Earth for 36 ensemble.

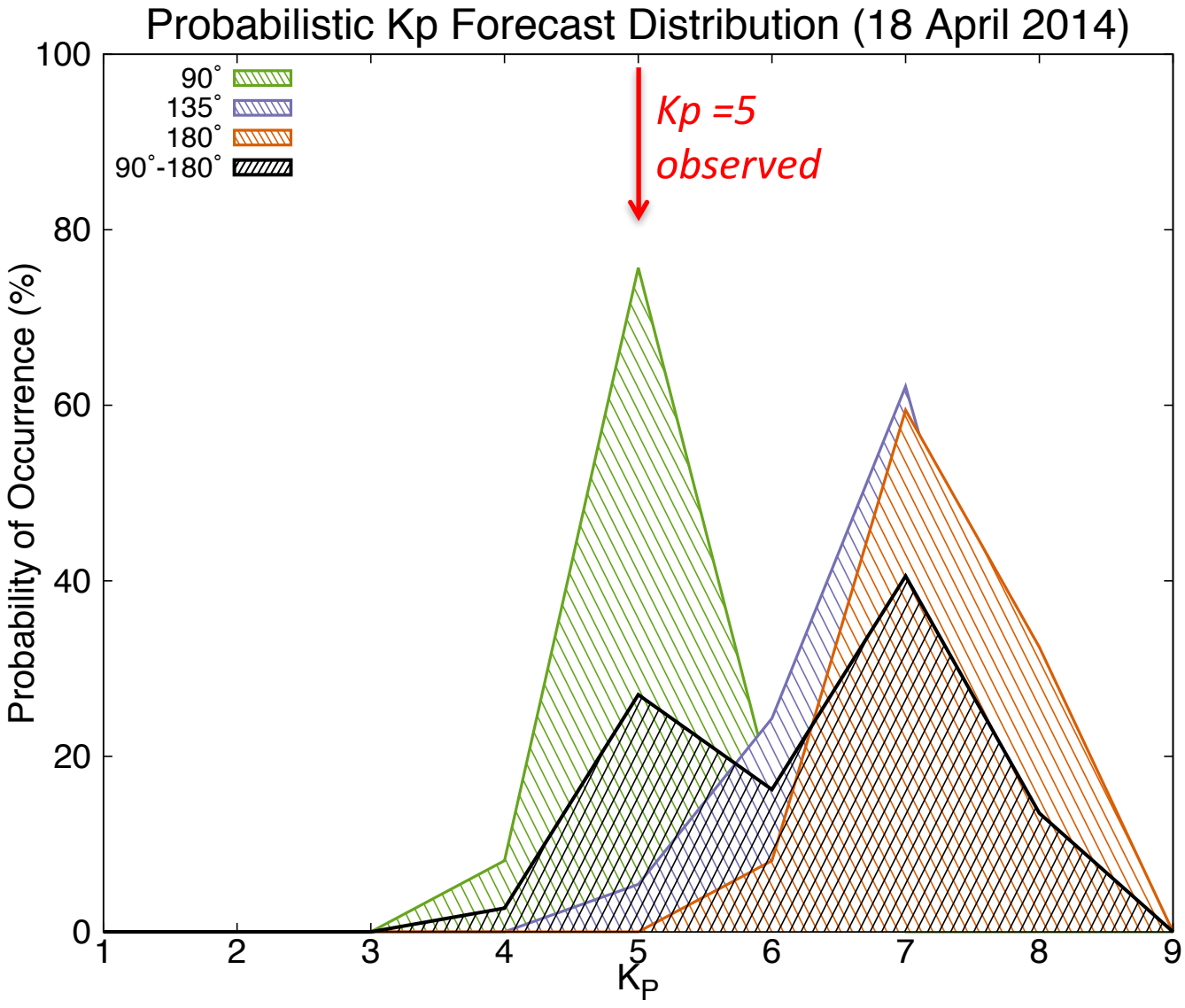
Clear ICME arrival with enhanced post-shock temperatures, enhanced magnetic field with rotations in direction, and declining solar wind speed.

18 April 2014 CME: Histogram distribution of arrival time predictions at Earth



-5.2 hours prediction error for average predicted CME arrival

18 April 2014 CME: Distribution of Kp probability forecast



Kp is forecast using ENLIL predicted solar wind quantities at Earth as input to the Newell et al. (2007) coupling function for three clock angle scenarios (Θ_C=90°, 135°, and 180°) and all three angles combined, assuming equal likelihood.

- Observed Kp: 5 during period 12:00-15:00 UT on 20 April.
- 84% of the forecasts fall between Kp = 5 to 7. The most likely forecast is for Kp=7 at 41%, followed by Kp=5 at 27% and Kp=6 at 16% likelihood of occurrence.
- Using the mean Kp forecast of Kp=6, the prediction error is $Kp_{error} = Kp_{predicted} - Kp_{observed} = 1$ (overprediction)