Developing fast solar wind modeling with EUHFORIA

Evangelia Samara[1,2]

in collaboration with

J. Magdalenic[1], L. Rodriguez[1], S. Poedts[2]
S. G. Heinemann[3], J. Hinterreiter[3]

[1]Royal Observatory of Belgium
[2]CmPA, KU Leuven
[3]Institute of Physics, University of Graz

ESWW16
Liege, Belgium
Nov. 18, 2019

Outline

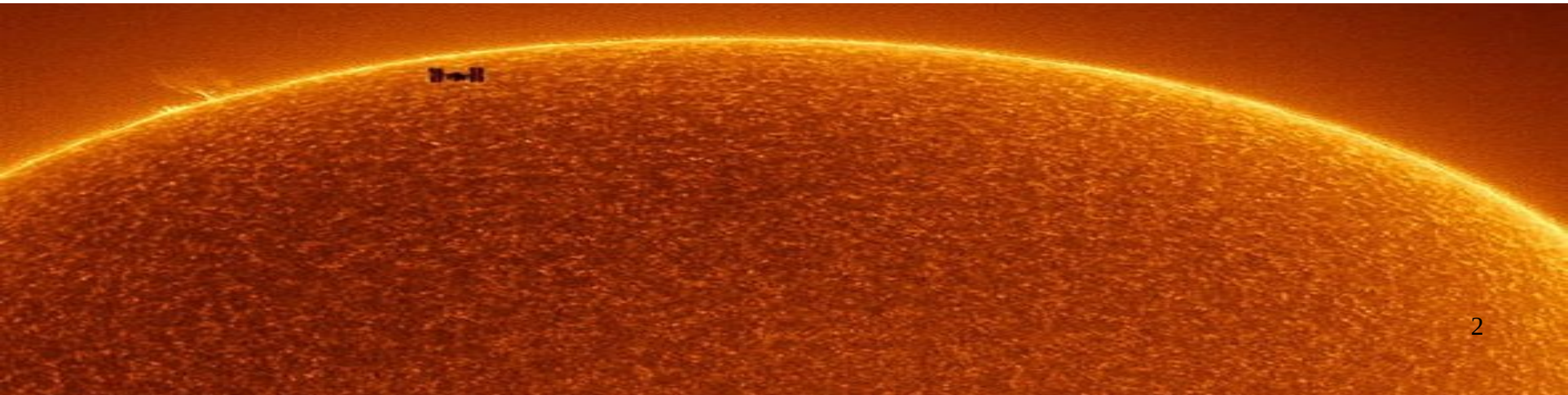
- Dealing with the problem of fast solar wind modeling in EUHFORIA

    1. Virtual Spacecraft & 3D structure of the HSSs
        → Correlation with coronal holes (CHs) on the Sun

    2. Changing EUHFORIA's default parameters
        → (e.g., PFSS height, SCS inner boundary)

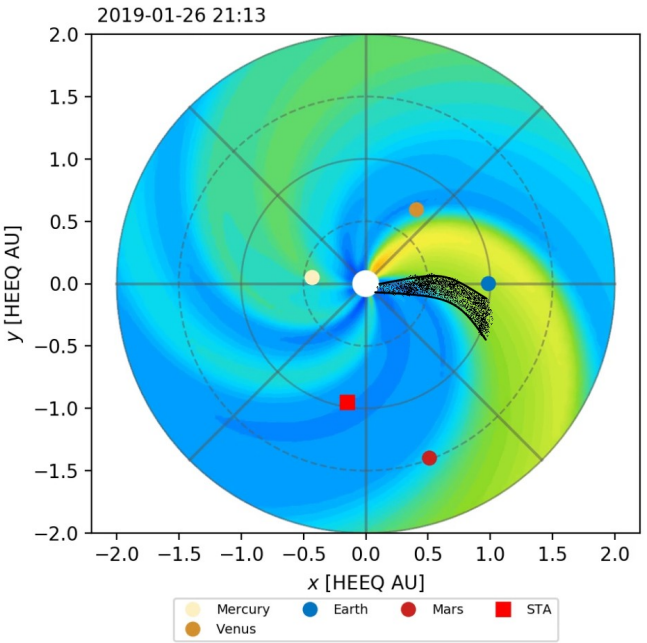
    3. Application of different magnetograms

- Summary & Future steps

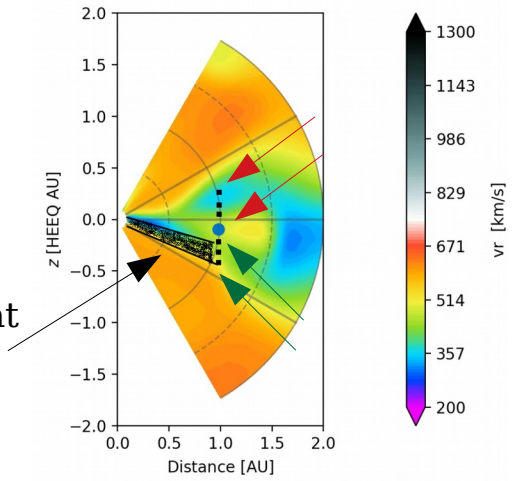


1. Virtual Spacecraft & 3D structure of the HSSs

Equatorial plane



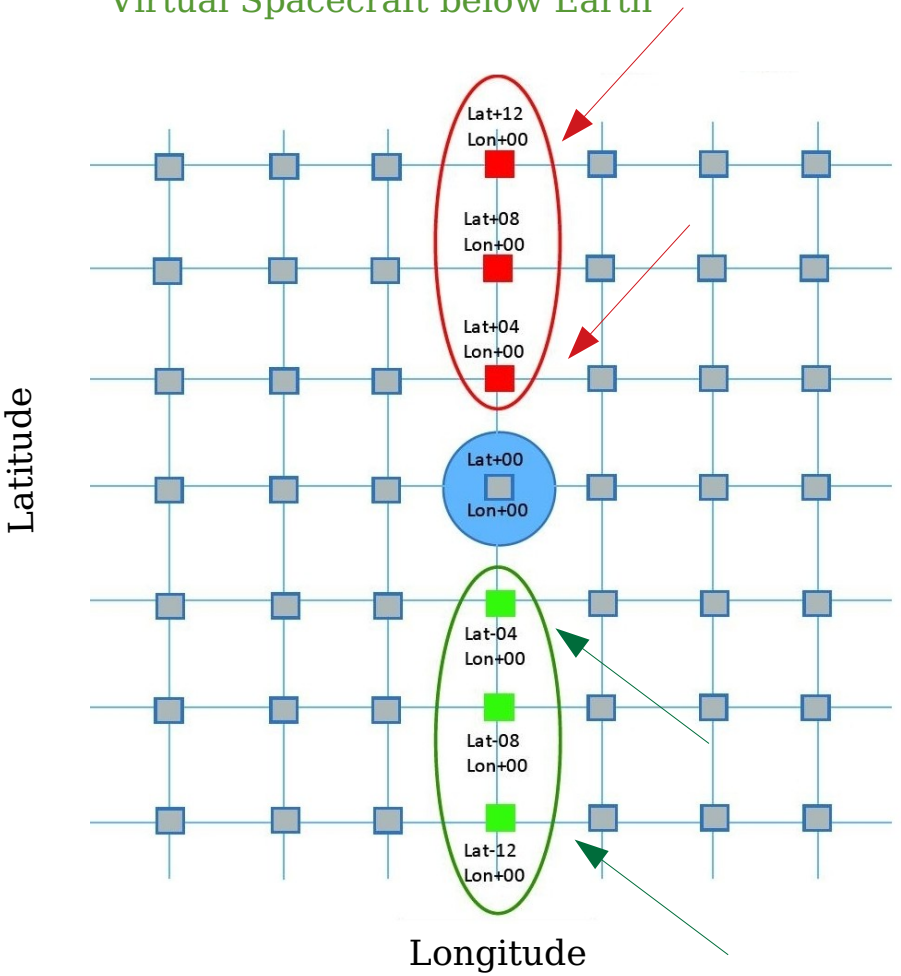
Meridional plane



Fast flow that surpassed Earth below

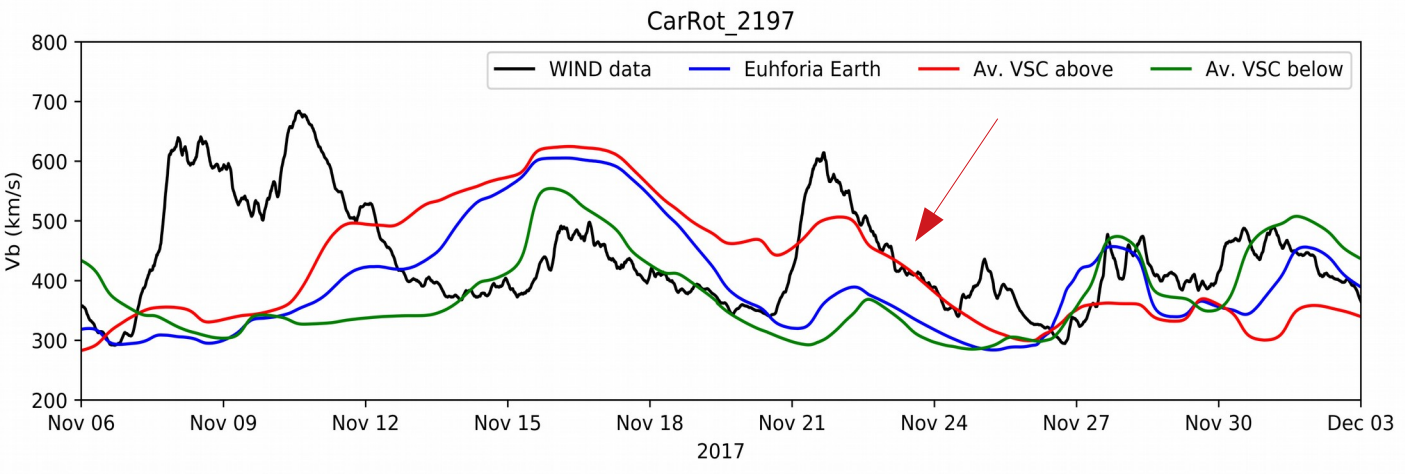
Virtual Spacecraft above Earth

Virtual Spacecraft below Earth

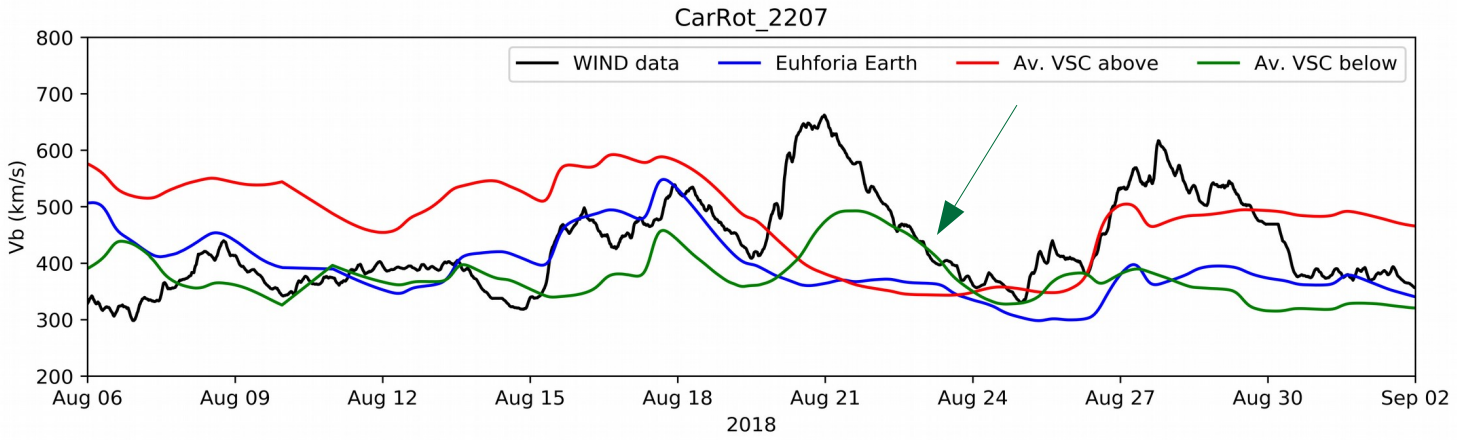


1. Virtual Spacecraft & 3D structure of the HSSs

Analysis of insitu data & modeling of EUHFORIA output
for ~2 years during solar minimum: Nov. 2017 – Sep. 2019



EUHFORIA output not only at Earth's position but also in latitudes above & below!

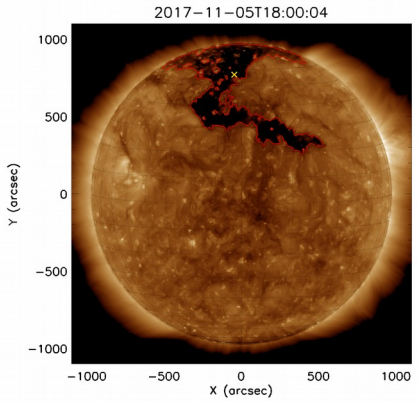


1. Virtual Spacecraft & 3D structure of the HSSs

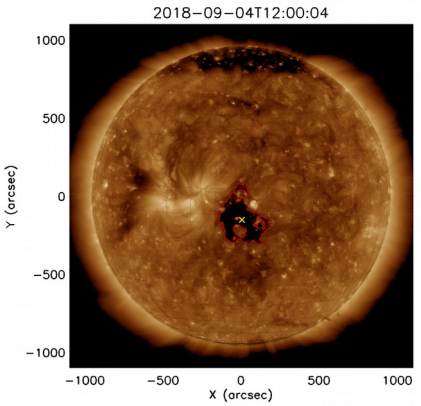
Correlations between CH topological characteristics and HSSs at Earth!

- Categorization of CHs in groups based on their shape or latitude
- CH extraction (topological CH properties) by the **CATCH tool** (S. G. Heinemann et al., 2019)

Polar Extensions

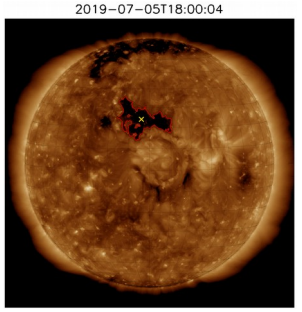


Individual CHs

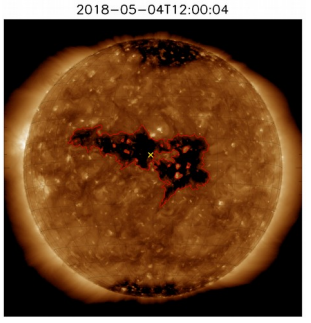


Aim: understand which input parameters to EUHFORIA will provide the best modeled result for HSSs originating from CHs of different properties!

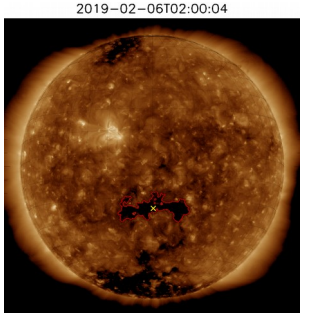
1. CHs [20,60] deg



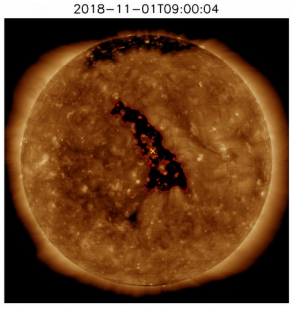
2. CHs [-20,20] deg



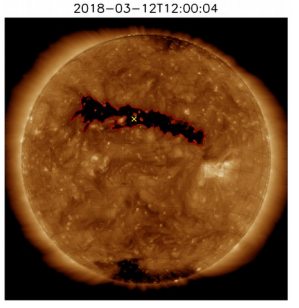
3. CHs [-60,-20] deg



4. Elongated in lat.

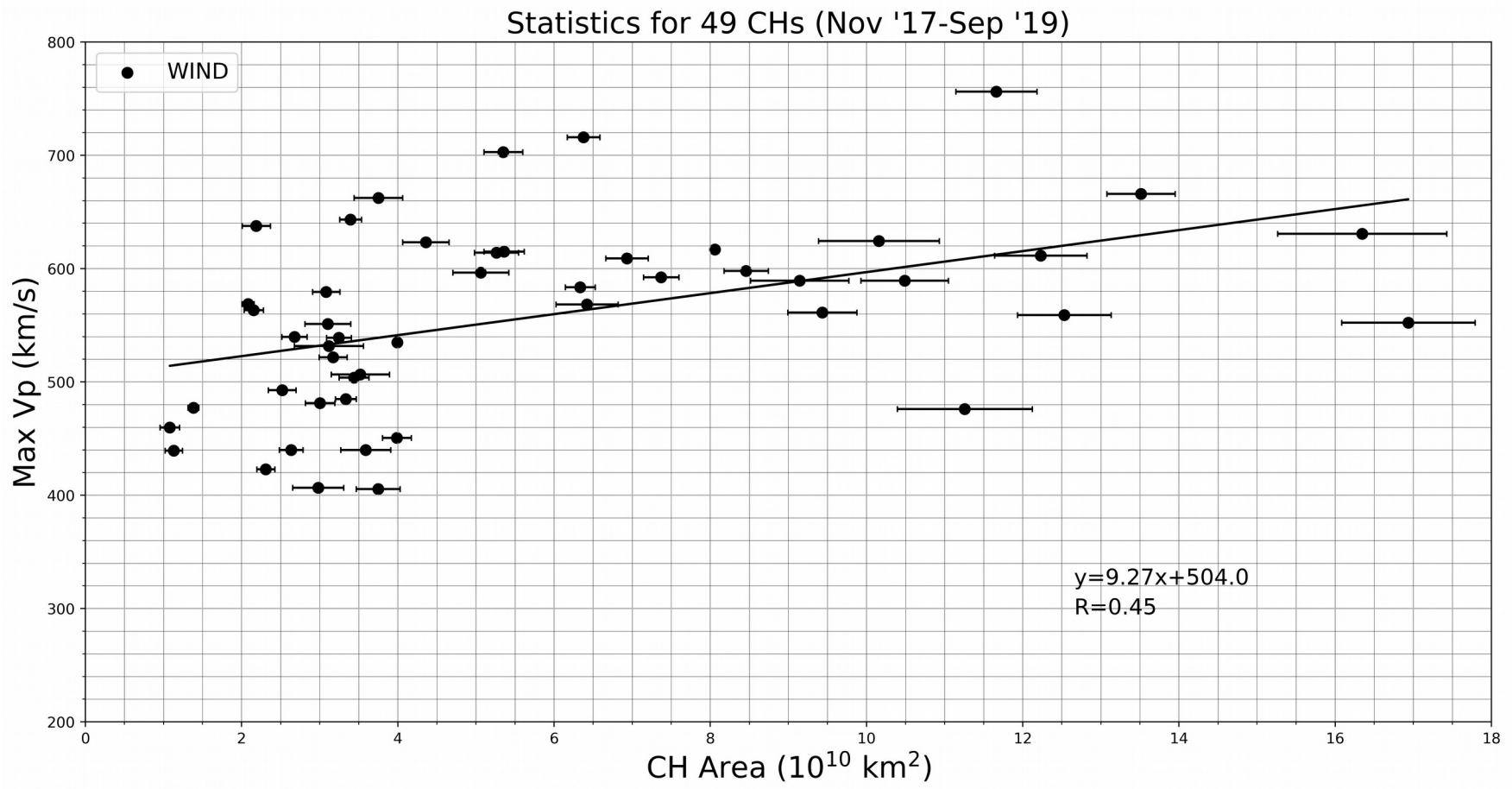


5. Elongated in long.



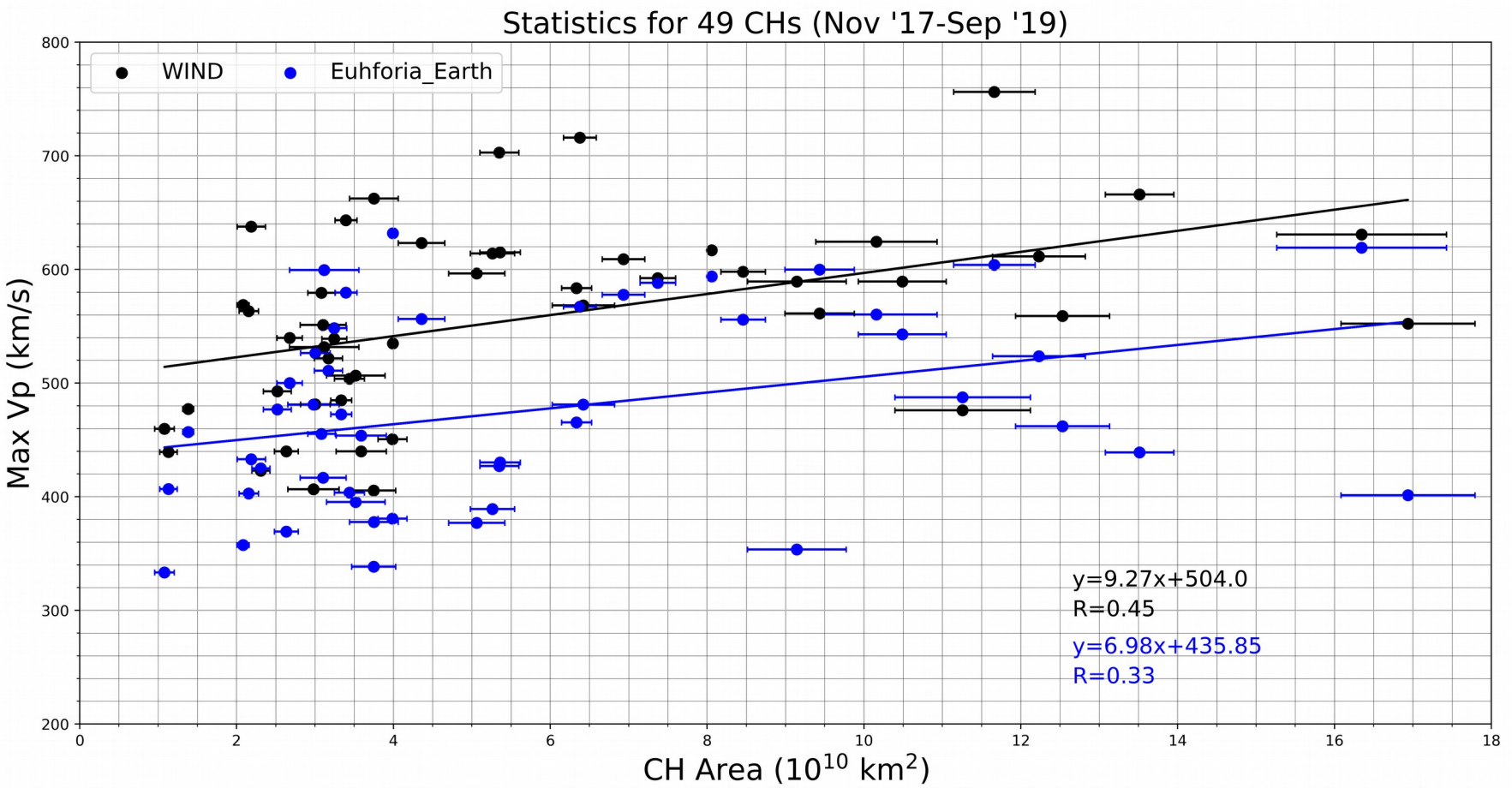
1. Virtual Spacecraft & 3D structure of the HSSs

All 49 individual CHs



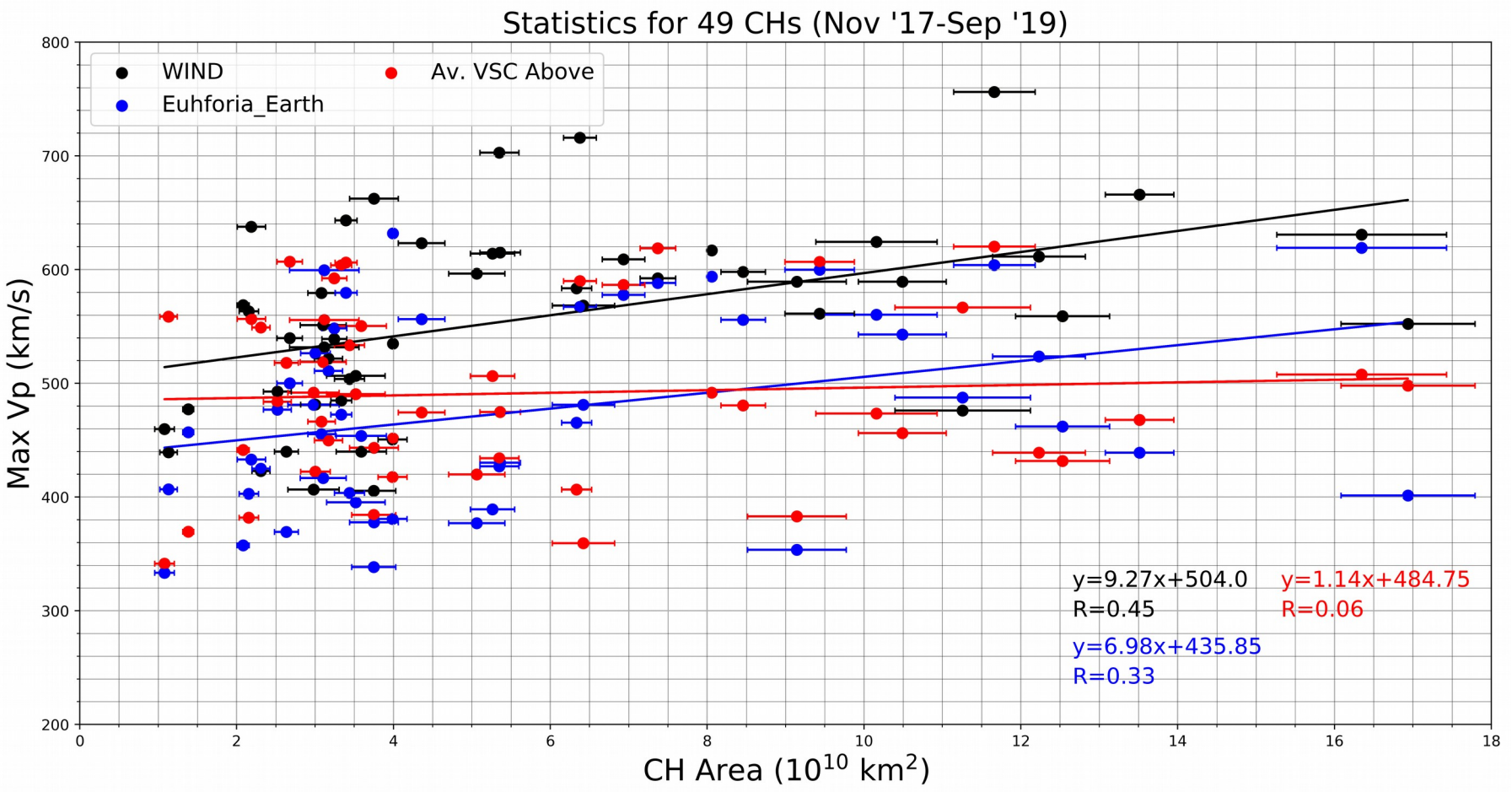
1. Virtual Spacecraft & 3D structure of the HSSs

All 49 individual CHs



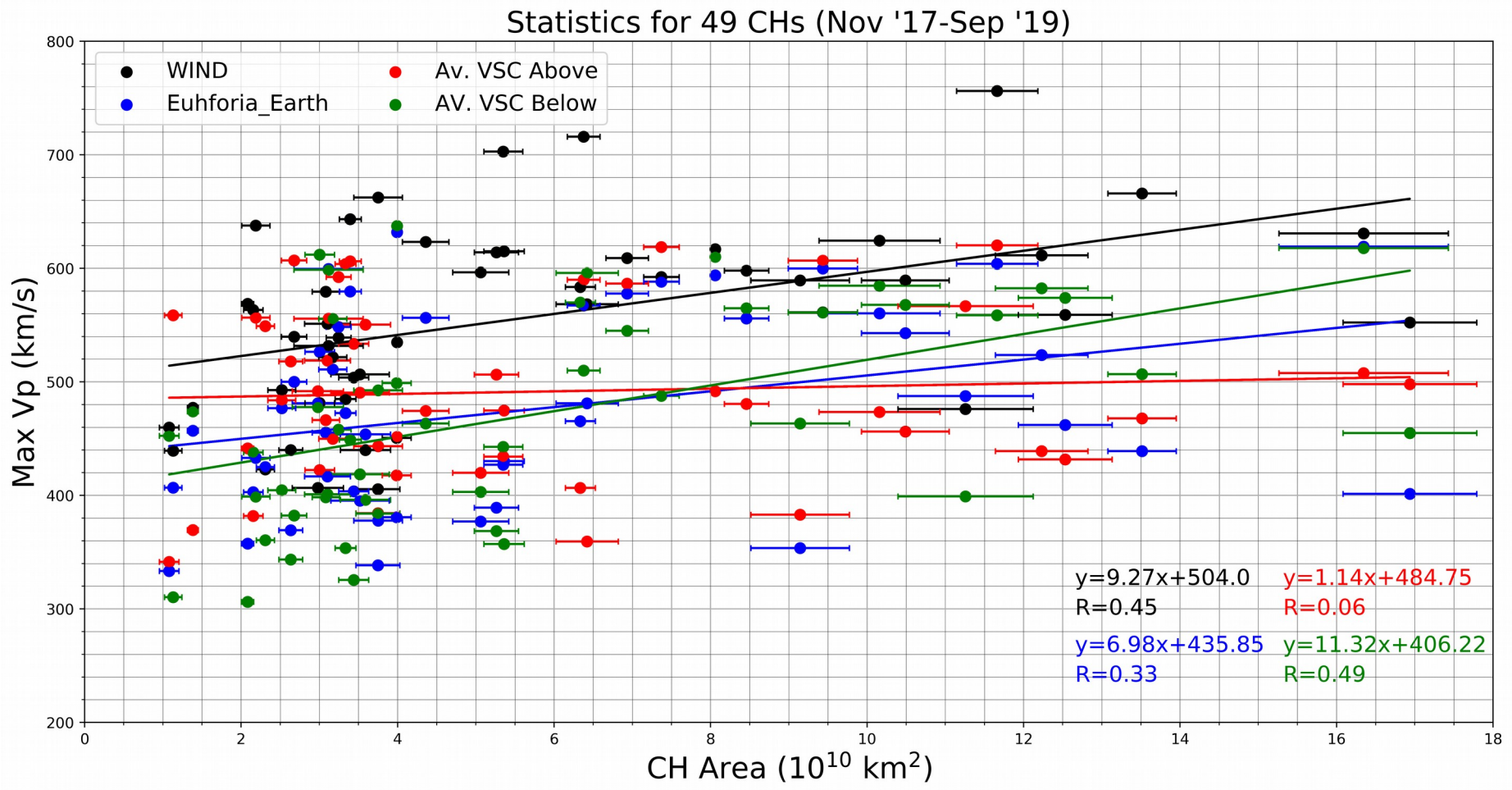
1. Virtual Spacecraft & 3D structure of the HSSs

All 49 individual CHs



1. Virtual Spacecraft & 3D structure of the HSSs

All 49 individual CHs

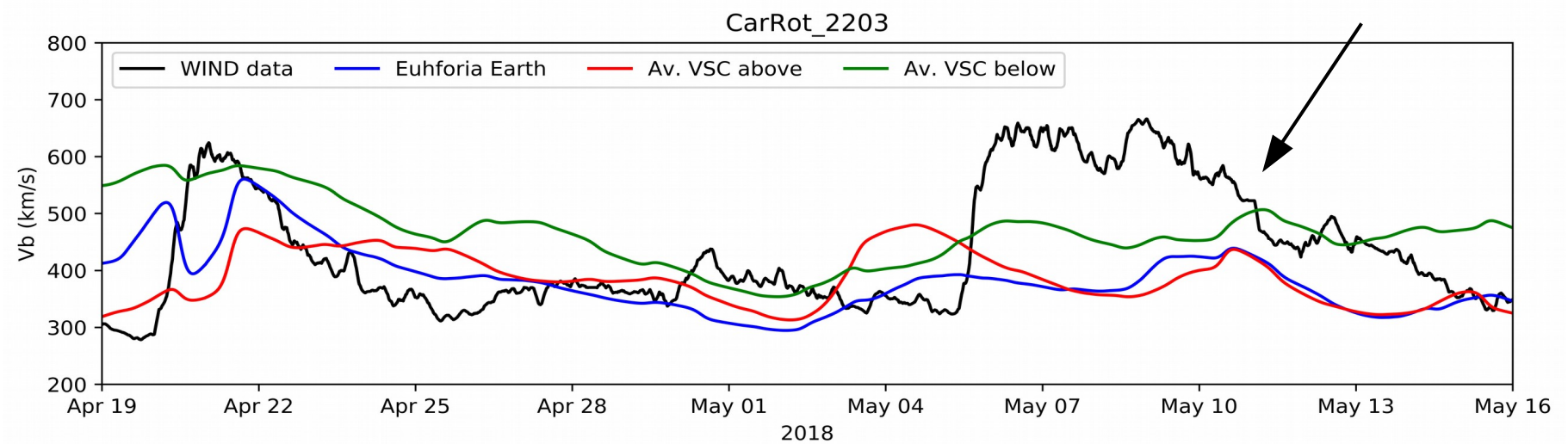


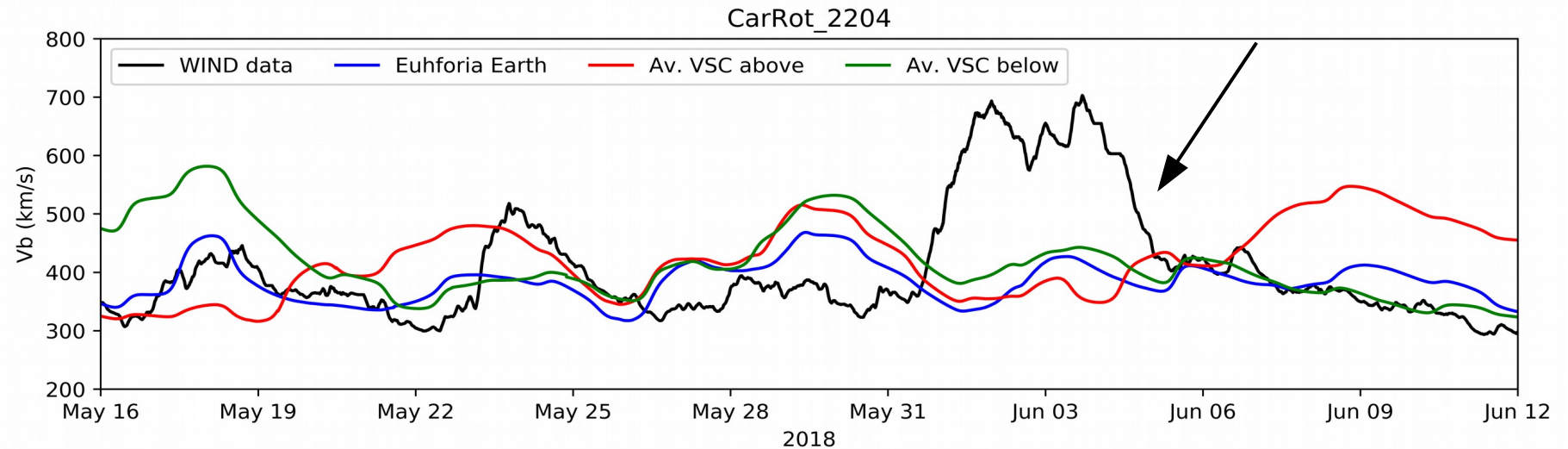
Conclusions (A)

- Statistics systematically indicate a much better correlation between the topological characteristics of the CHs and max. velocities of the HSSs as captured by VSC below Earth
- Comparing WIND & EUHFORIA speeds for different CH groups:
  - CHs between [20,60] deg: better captured by EUHFORIA at Earth
  - CHs between [-20,20] deg: better captured by VSC below
  - CHs between [-60,-20] deg: better captured by VSC below
- Significant dependence between the max HSS speed and the latitudinal extent of the CHs for all groups & categories

2. Changing EUHFORIA default parameters

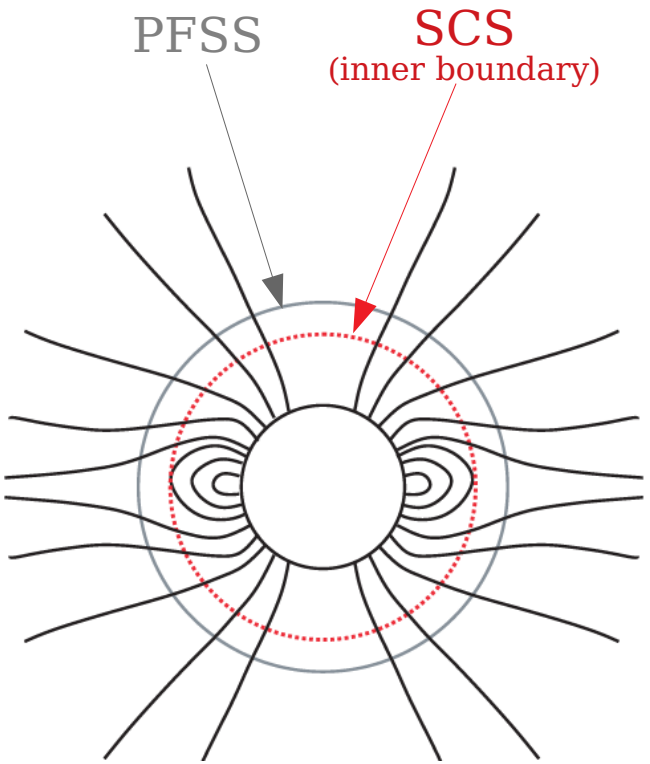
Cases for which EUHFORIA entirely missed the HSS





2. Changing EUHFORIA default parameters

For these cases, we lower down the values **[Rscs, Rpfss]**



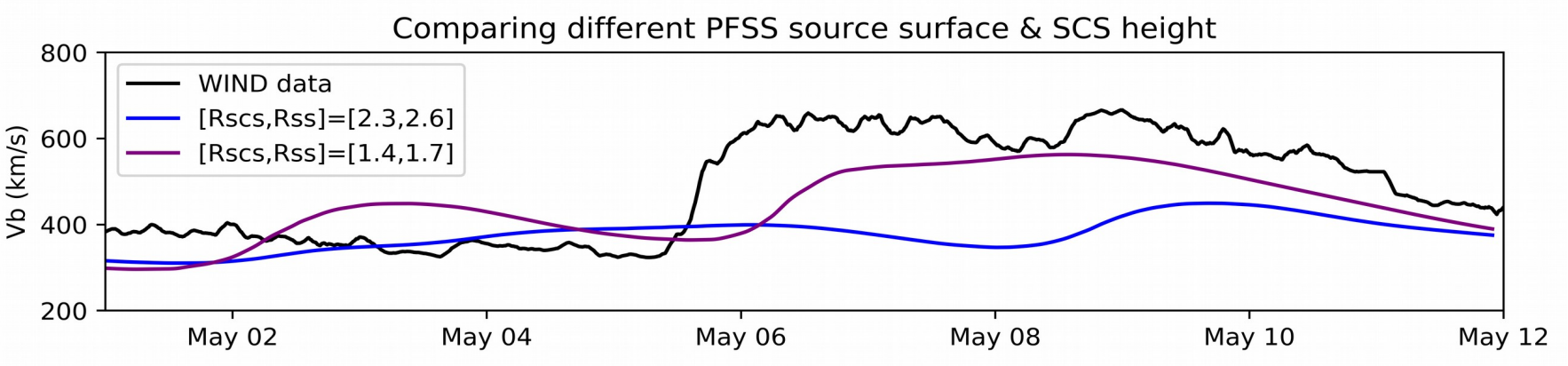
$$[\text{Rscs, Rpfss}]_{\text{default}} = \mathbf{[2.3, 2.6]}\ R_s$$

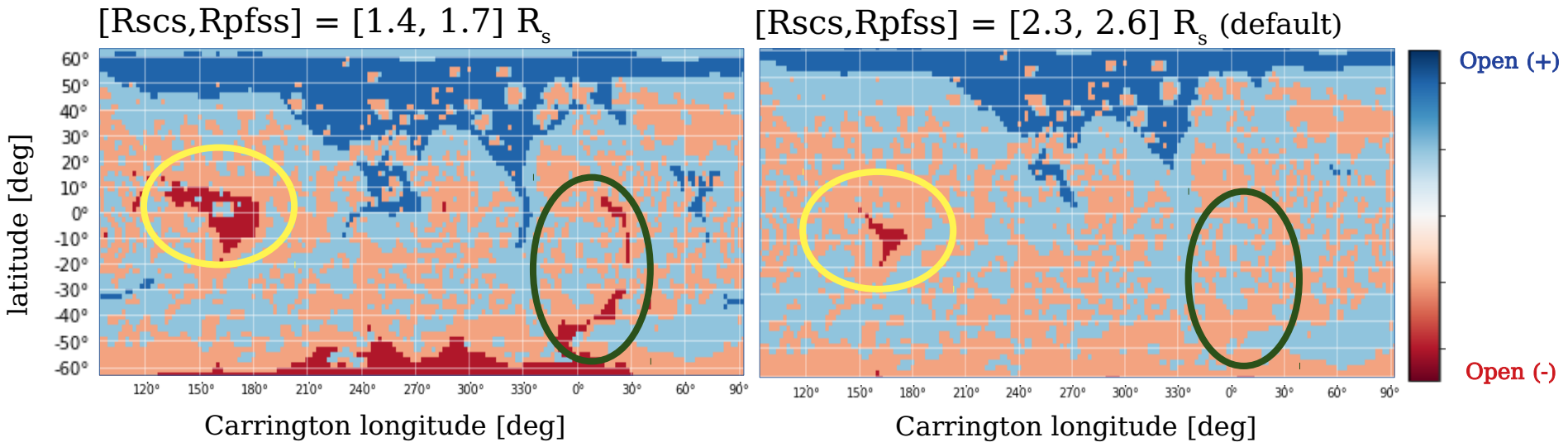
Changed to

$$[\text{Rscs, Rpfss}]_{\text{new}} = \mathbf{[1.4, 1.7]}\ R_s\ *$$

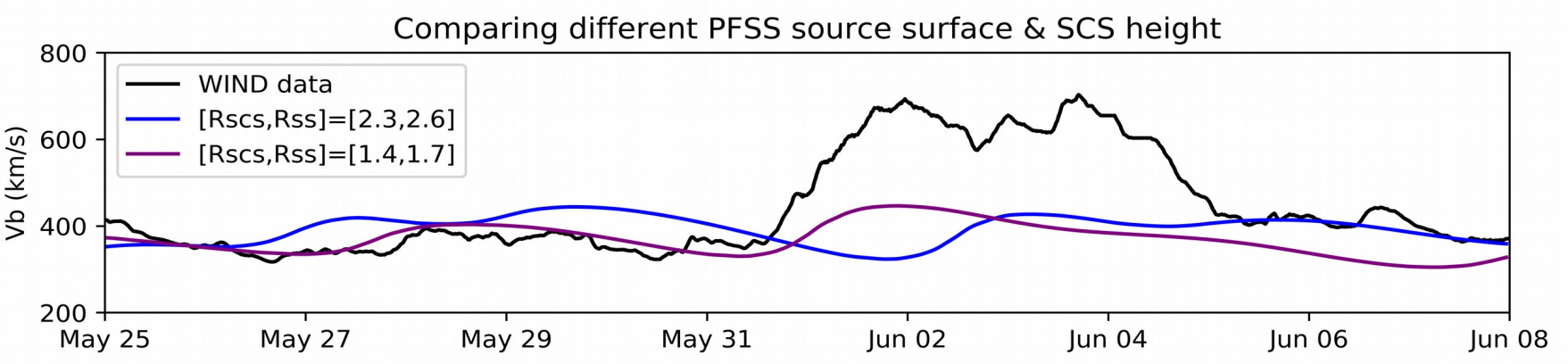
*one of the best [Rscs,Rpfss] values for EUHFORIA, as suggested by Asvestari et al., 2019
* image credits: Asvestari et al., 2019

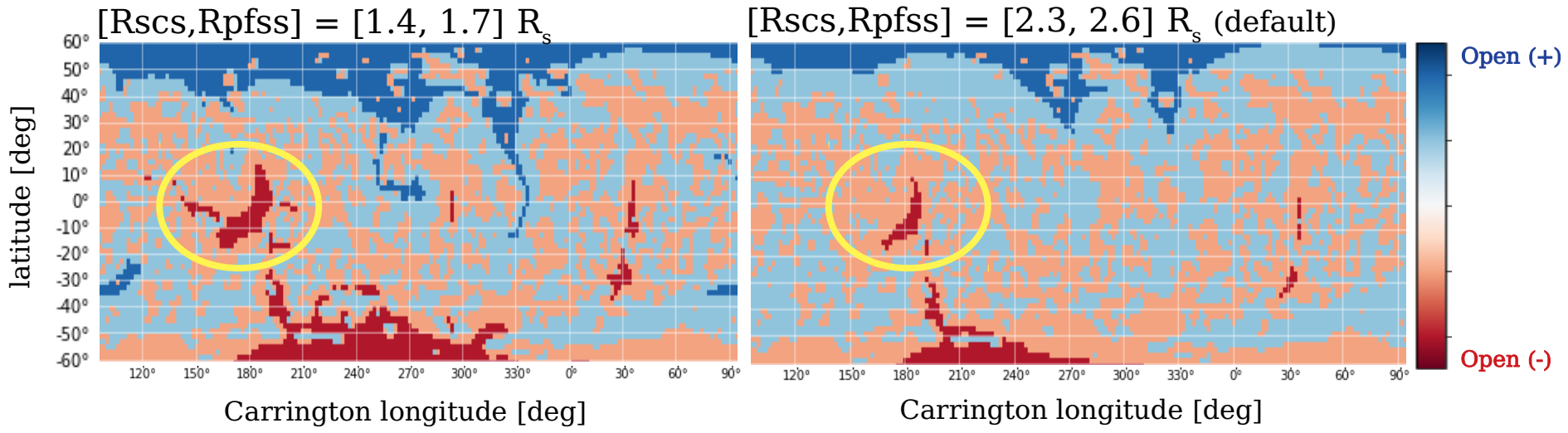
2. Changing EUHFORIA default parameters





2. Changing EUHFORIA default parameters





2. Changing EUHFORIA default parameters

Conclusions (B)

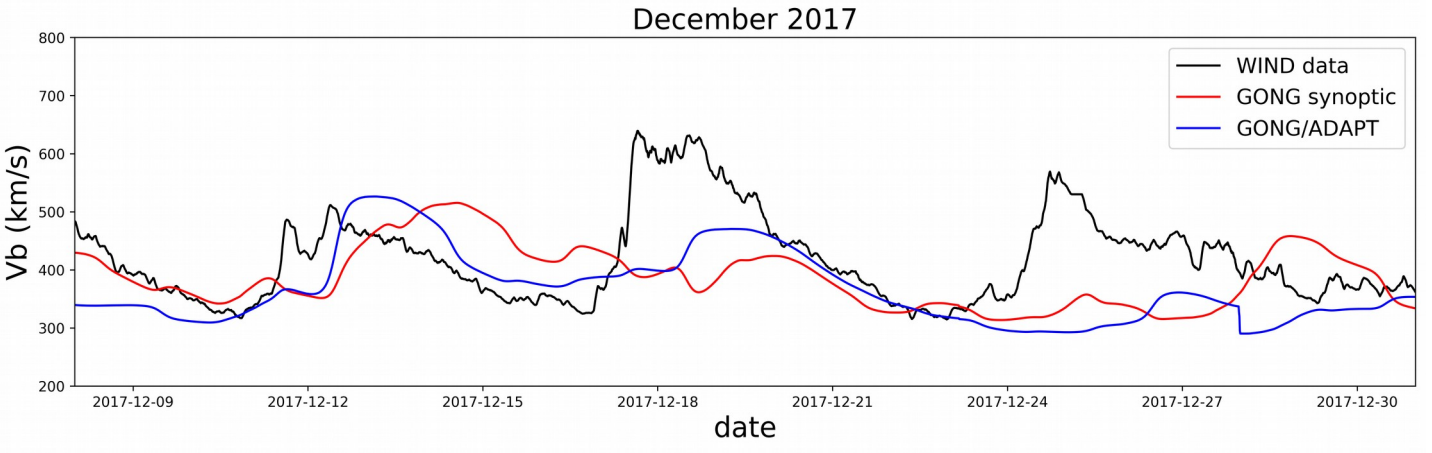
- Lowering down [Rscs,Rpfss] to a specific pair of values doesn’t always work for all CHs !
- Parametric study is ongoing for all CHs & HSSs in order to understand if we can find a pair of values that generally works better for all CHs, or maybe for CHs of specific properties
- Attention to excess flux!

3. Application of different magnetograms

$$\mathrm{MSE} = \frac{1}{N}\sum_{1}^{N}(X_t - X_{t'})$$

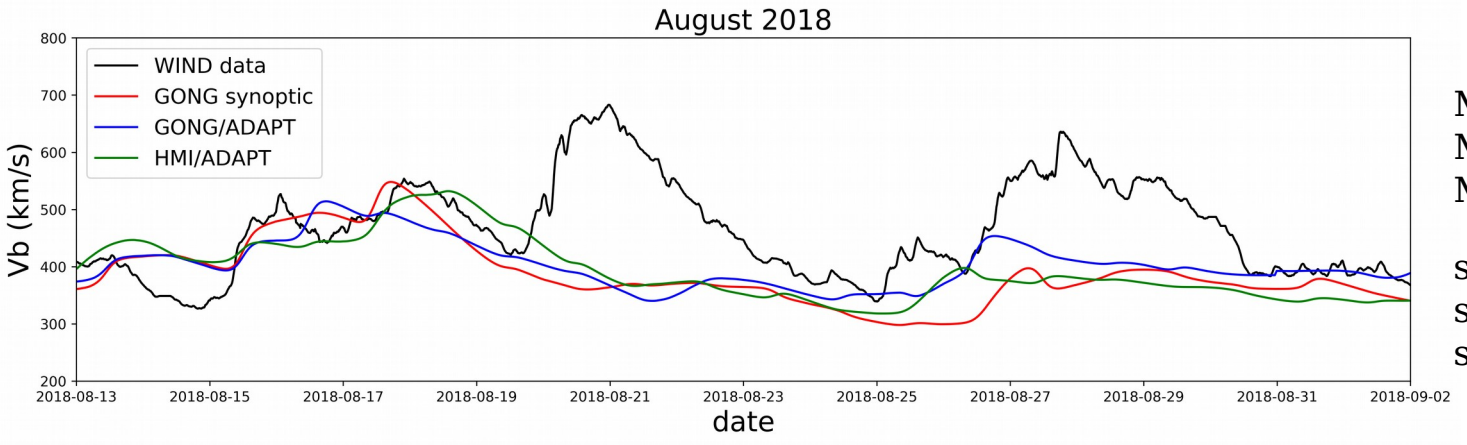
$$\mathrm{skill} = 100\left(1 - \frac{\mathrm{MSE}}{\mathrm{MSE}_{\mathrm{MeanModel}}}\right)$$

(Owens et al., 2008)
(MacNeice, 2009)



$MSE_{(gong\_syn)}$ = 9303
$MSE_{(gong/adapt)}$ = 8127

$skill_{(gong\_syn)}$ = -62
$skill_{(gong/adapt)}$ = -42



$MSE_{(gong\_syn)}$ = 13825
$MSE_{(gong/adapt)}$ = 11568
$MSE_{(HMI/adapt)}$ = 12786

$skill_{(gong\_syn)}$ = -86
$skill_{(gong/adapt)}$ =-55
$skill_{(hmi/adapt)}$ =-72

*HMI/ADAPT magnetograms provided by Carl Henney, AFRL

Summary & Future steps

- **Ultimate goal:** Improvement of (fast) solar wind modeling with EUHFORIA
  - not only for accurate HSSs predictions
  - but mostly for accurate CMEs modeling and forecasting

- **Overall summary:** A wide range of parameters that need to be tested
  - Robust correlations between HSSs velocities & topological properties of CHs?
  - Best initial values to be used for the coronal model in EUHFORIA?
  - Adoption of one type of magnetogram/provider?
  - Other coronal models?

- **Future steps:**
  - Parametric study for all CHs and all parameters of interest
  - Metrics and validation procedures for EUHFORIA

Thank you