How changing of source surface height parameter in EUHFORIA affect solar wind simulations

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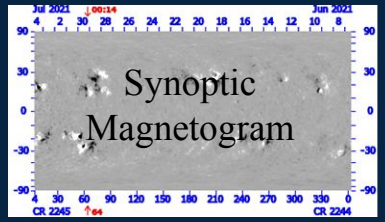
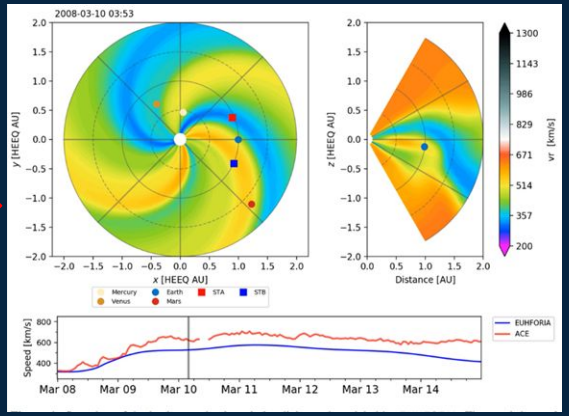
Motivation & model introduction:

- Accurate modelling of fast solar wind → more accurate modelling of CMEs
  → better forecasting of the CME arrival time!
- EUHFORIA (EUropean Heliospheric FORecasting Information Asset; Pomoell & Poedts, 2018) is a 3D MHD model of solar wind and CMEs in the inner heliosphere.



Coronal model
PFSS + SCS model
(upto 0.1 au)

Heliosphere model
Time-dependent
3D MHD

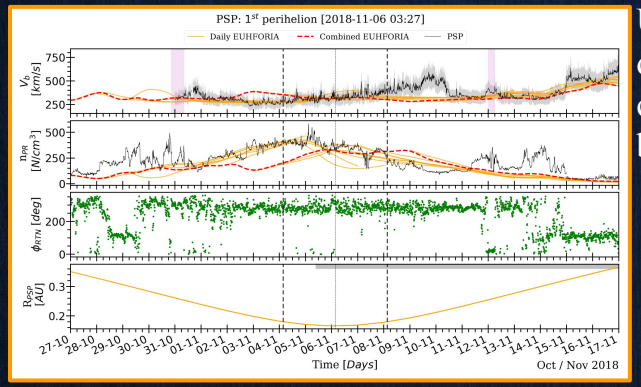


- Modelling of solar wind at 1 au with EUHFORIA (Hinterreiter et al., 2019; Samara et al., 2021).
  - Validation of the solar wind modeling at close to Sun distances is now possible with the novel Parker Solar Probe (PSP).

EUHFORIA simulated solar wind during 10 perihelions of PSP:

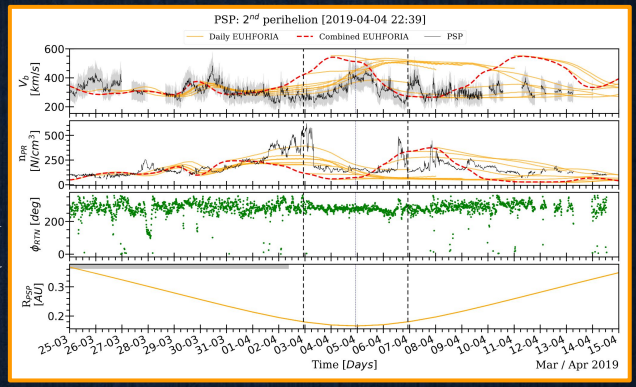
EUHFORIA modeled solar wind (default model parameters) diverge from the PSP observations due to:

1) Old magnetogram:



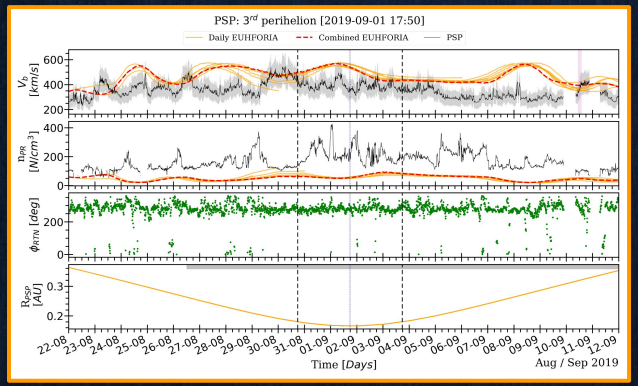
Under/overestimates depending on the size of coronal hole at "old" (Sun's back-side) magnetogram.

2) Close to inner boundary of EUHFORIA:

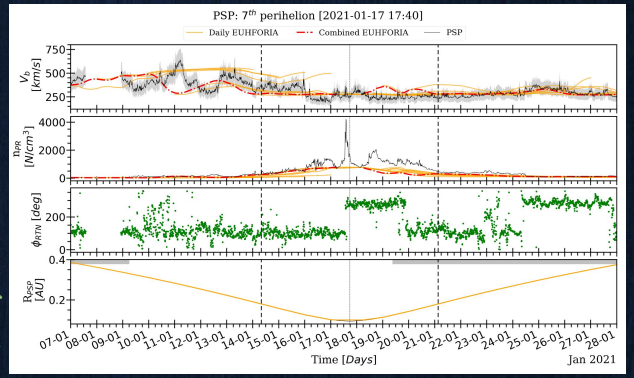


Effects often remain unclear near 0.1 au boundary ⇒ both over/underestimated velocities.

3) *Large extension of polar coronal hole*:



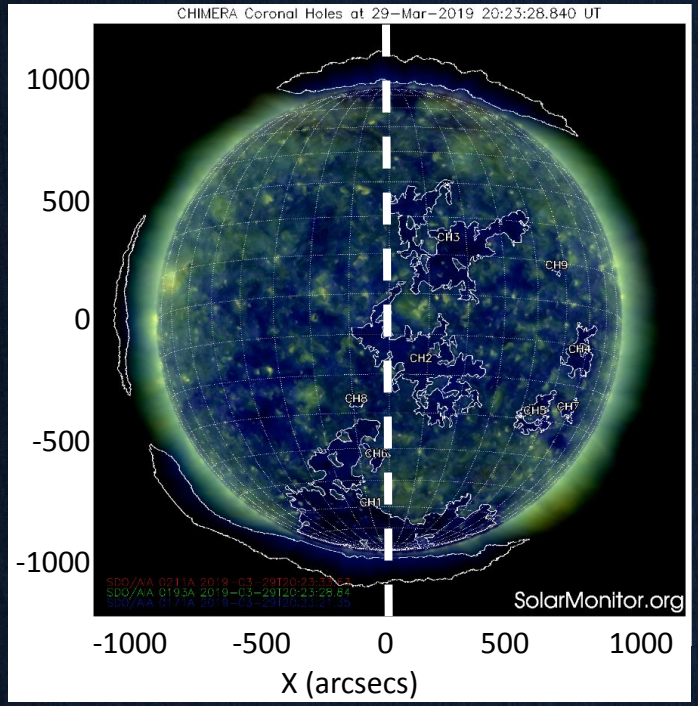
EUHFORIA "merges" polar coronal hole and its lower latitude extensions ⇒ broader flows and overestimation of velocity.



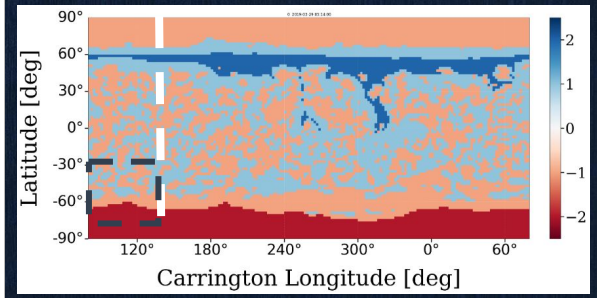
EUHFORIA models the solar wind well (except for 1 input magnetogram) ⇒ importance of input magnetogram (Hinterreiter et al., 2019)

Reconstruction of inner boundary magnetic field maps of EUHFORIA:

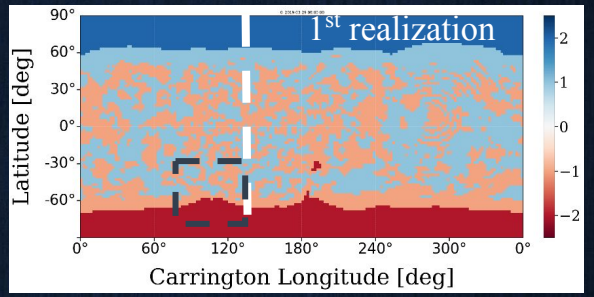
CHIMERA coronal holes at 2019-03-29T05:14

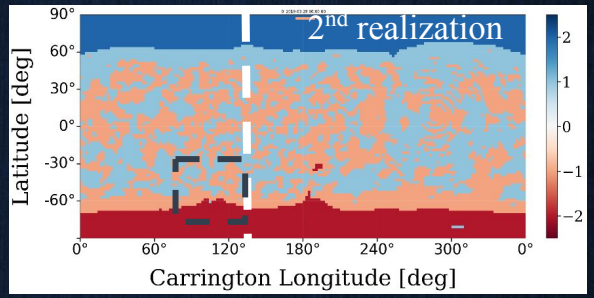


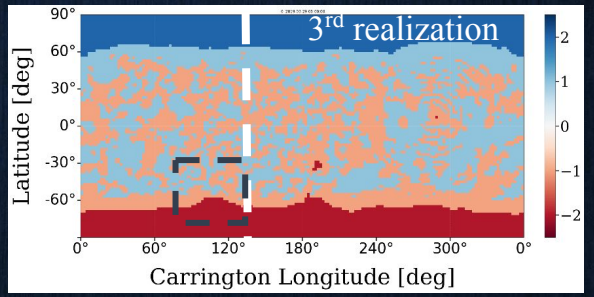
GONG synoptic map



GONG ADAPT (1–3) synoptic map





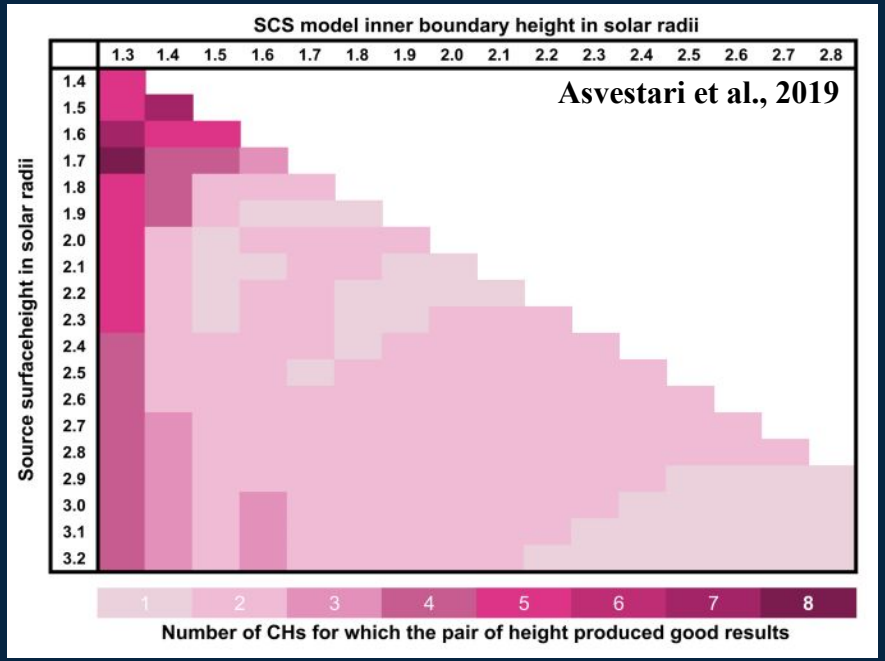


- "Coronal holes" at inner boundary maps are not reconstructed accurately using default parameters in EUHFORIA.

Preliminary parameter study of source surface height in EUHFORIA:

- In EUHFORIA's coronal model:

  SSH height (Source Surface Height) in the PFSS (Potential Field Source Surface) model, & the SCS height (Schatten Current Sheet)
  Play important role in modeling accuracy of coronal hole areas & open flux.

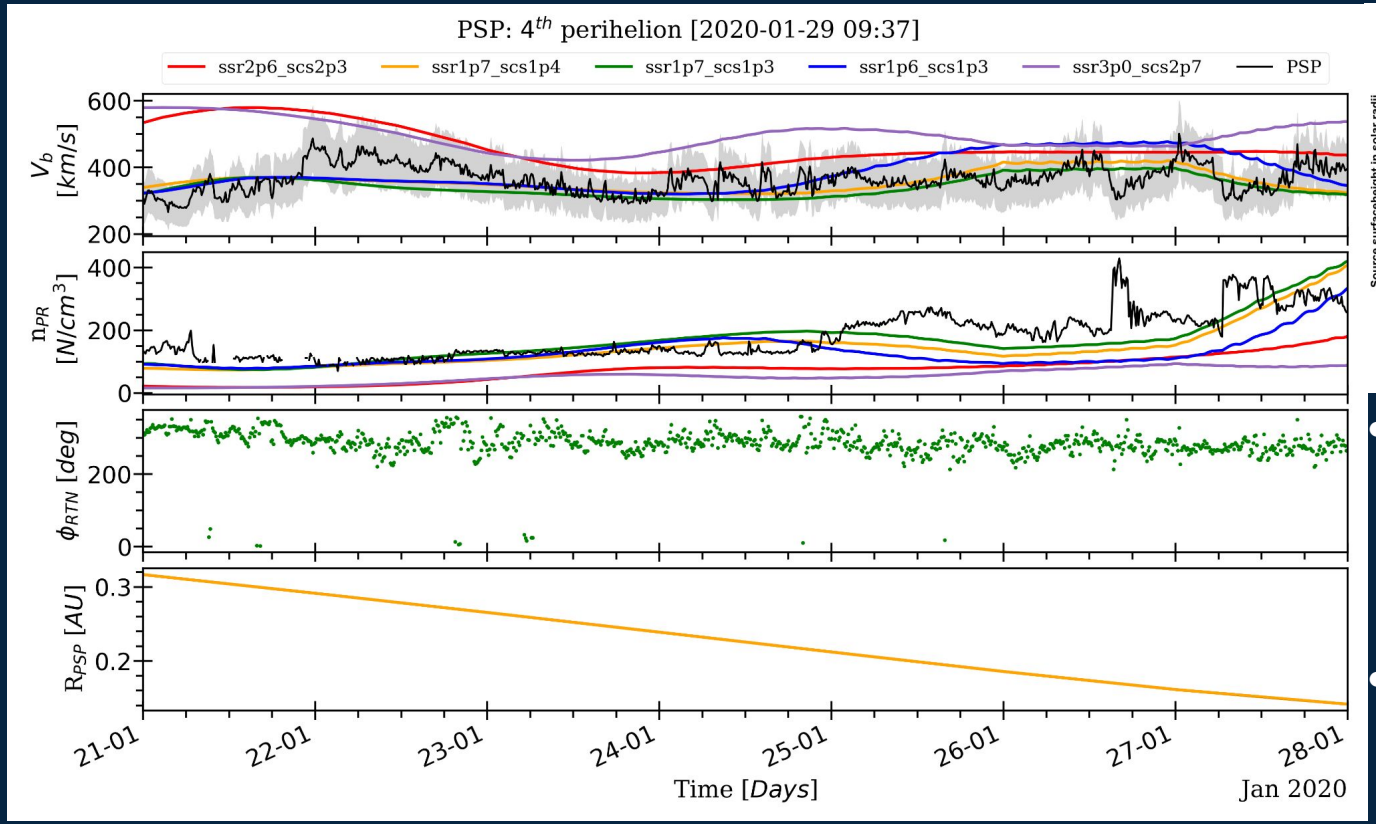


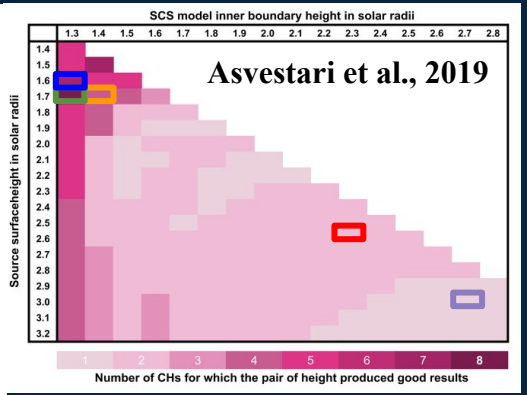
- Lower source surface height opens more flux.
- In general, amount of open flux $\propto$ area of modeled coronal hole.
- Asvestari et al. (2019):

  Tested 184 pairs of SSH & SCS to reconstruct coronal hole areas using EUHFORIA.

  Best modeling accuracy was obtained while using lower SSH than in EUHFORIA's default set-up (2.6 $R_{\odot}$).

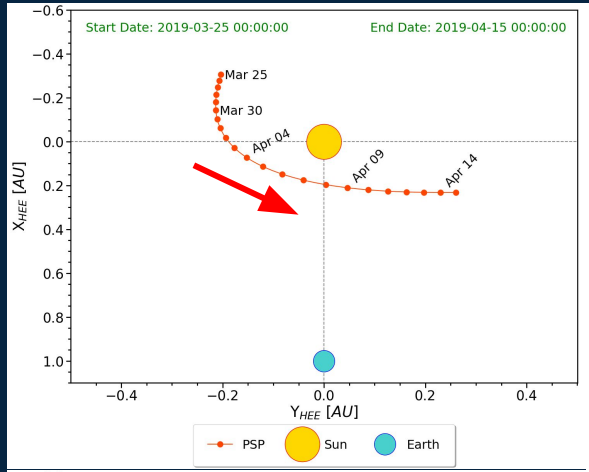
Parameter study of source surface height in EUHFORIA:

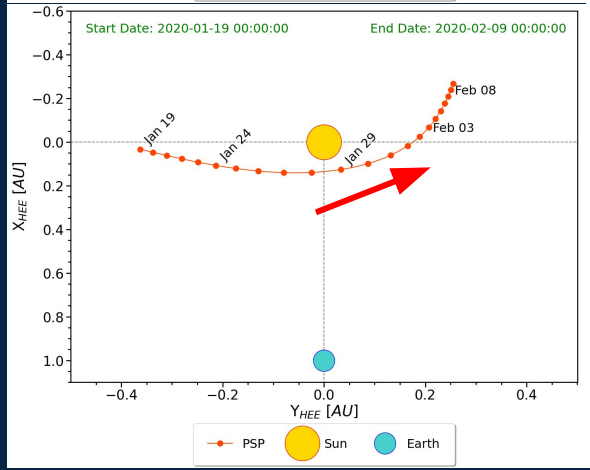




- SSH values of 1.7 $R_\odot$ & 1.6 $R_\odot$ result in better modelling of the solar wind parameters (in agreement with Asvestari et al., 2019).
- We carried out solar wind simulation for 21 days around first 10 PSP perihelions with reduced SSH & SCS heights of 1.7 and 1.4 $R_\odot$.

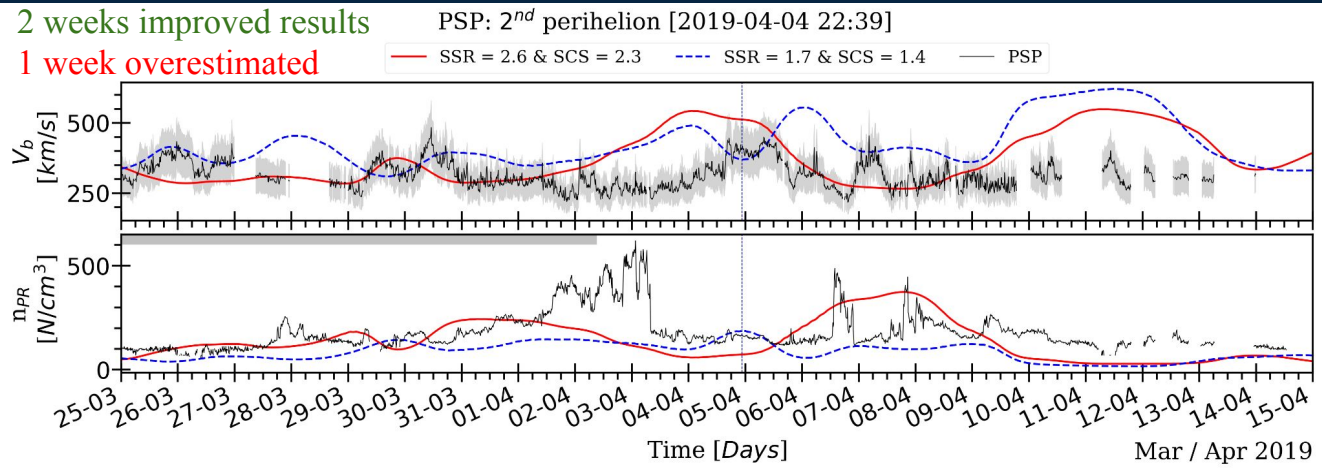
Example: Modelling of the solar wind with different SSH & SCS in EUHFORIA:





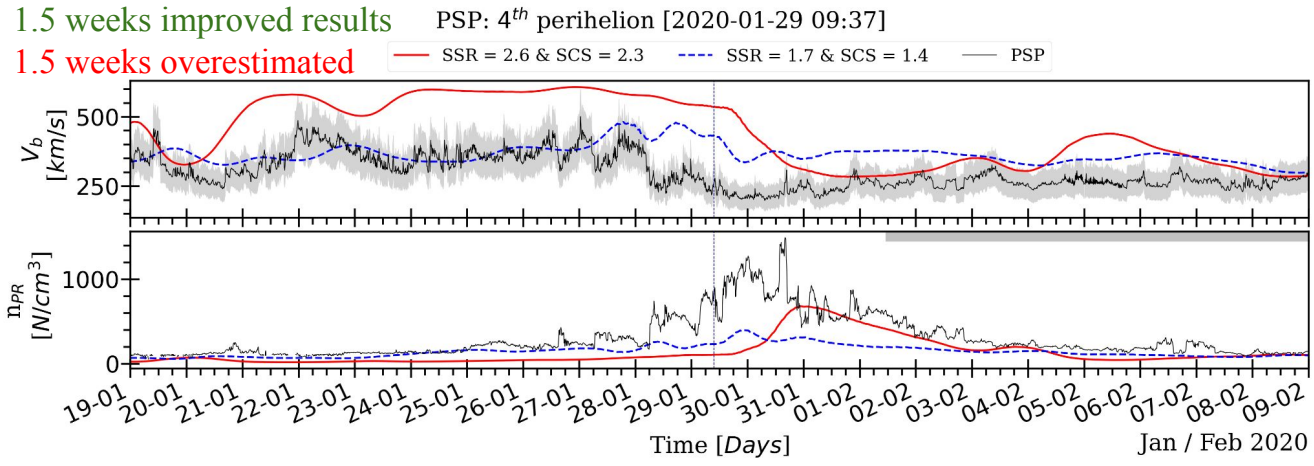
2 weeks improved results

1 week overestimated



1.5 weeks improved results

1.5 weeks overestimated



Comparative study of modelled data with different SSH in EUHFORIA:

Period	Total nb	Better modelling	Overestimation	Similar results
PSP position: Front + Back	29 weeks	13 weeks - 45 %	7 weeks - 24 %	8 weeks - 28%
PSP position: Front	15.5 weeks	8 weeks - 52 %	3 weeks - 19 %	4 weeks - 26 %

- Better modeled solar wind was obtained using the reduced SSH in EUHFORIA for **52 %** of the time period, on the front-side, and **45 %** of the changing (back to front or vice versa) position of PSP.

  ⇨ This justifies the change of the SSH & SCS heights from the default set up of EUHFORIA.

- As expected, in about 20% of the time the modelled solar wind velocity was overestimated.

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However, we found no systematic results indicating stronger influence of the 'old' back-side magnetograms.

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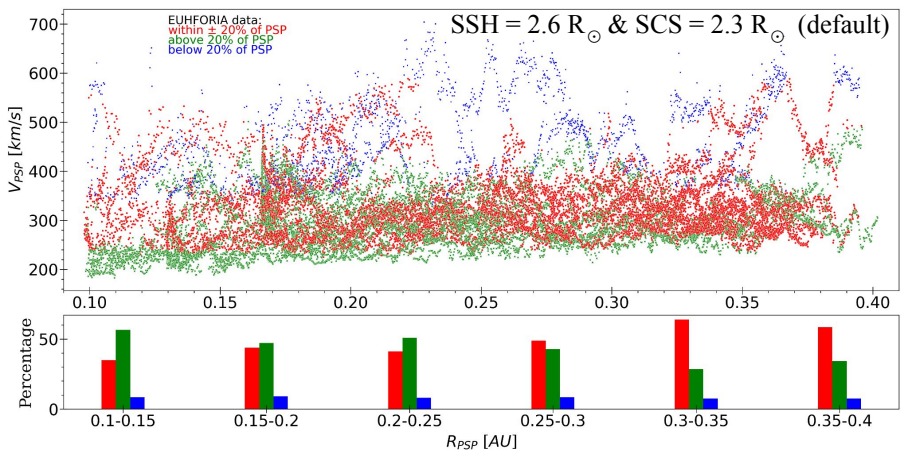
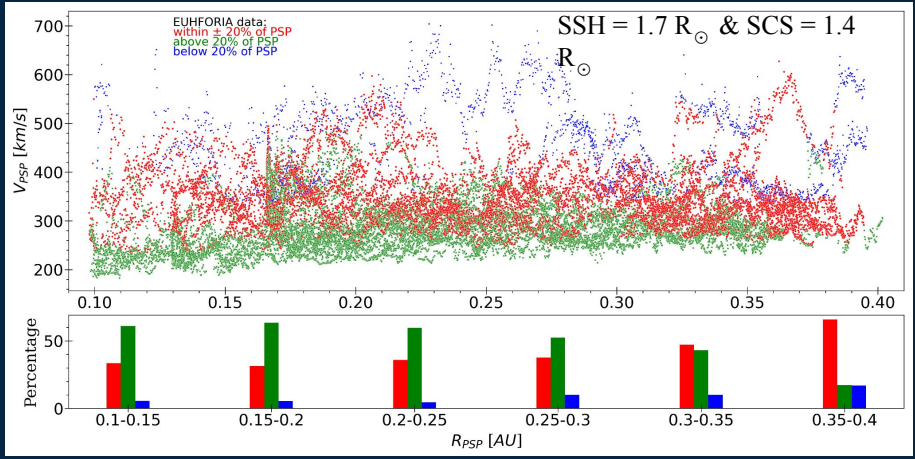
Systematic inspection of the EUV observations, aiming to understand the complexity of the solar magnetic field and its possible influence to the modelling accuracy, is ongoing!

Modelled solar wind speed over the different radial distance:





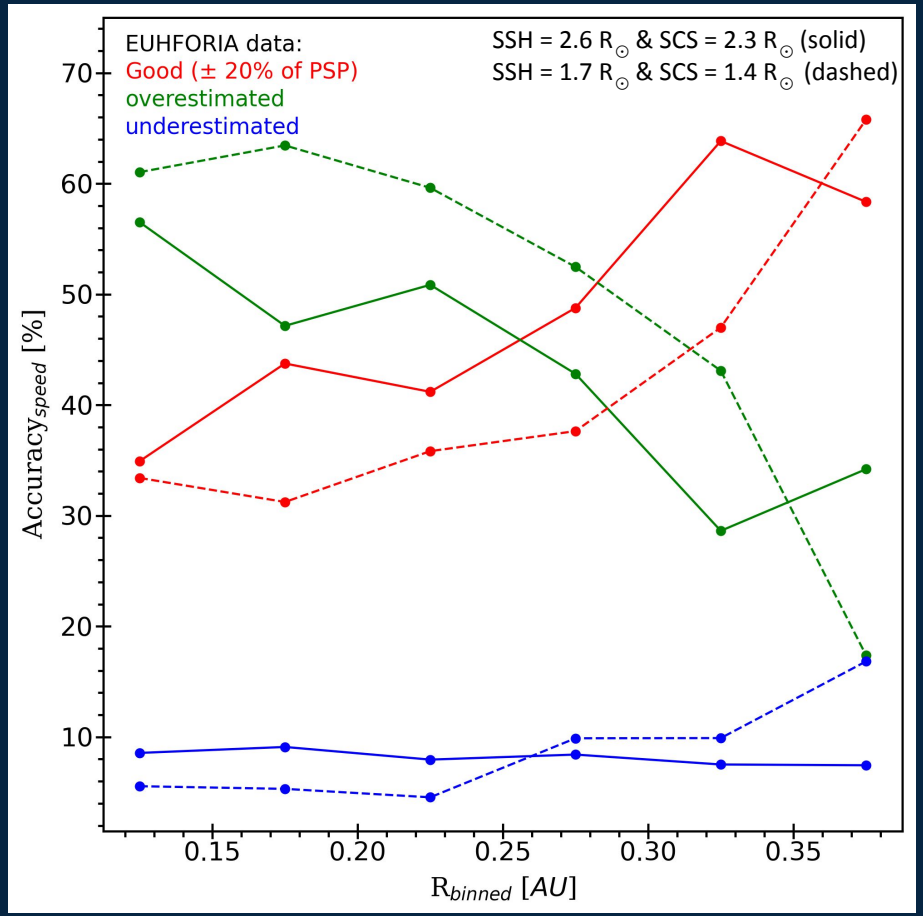
- Modelling accuracy improves with increasing distance from the Sun, but
  it is lower at Earth than at PSP distances.

- ***Default EUHFORIA set up***:
  Modelling accuracy increases with the distance from the Sun.
  Overestimation of the modelled solar wind velocity is systematically decreasing.
  ⇒ This indicates the over-expansion of the solar wind at close to the Sun distances.

- ***Reduced SSH & SCS height***:
  Accuracy increases with the distance from the Sun.
  Percentage of overestimated velocity significantly decreases with increase of distance.

- The range of distances where modelling "efficiency" changes will be further inspected using PSP observations at further away from the Sun (on-going study).

Modelling accuracy over radial distance while using different SSH & SCS input:



- Modelling accuracy increases with distance from the Sun, both while using default SSH of 2.6 $R_{\odot}$ and a reduced SSH of 1.7 $R_{\odot}$.
- 10% - 15% difference between good and overestimated modelling results when using different EUHFORIA set-ups.
- The overexpansion of the solar wind modelled by EUHFORIA at close to the Sun distance increases with the increased amount of the open flux (lower SSH & SCS heights).

Summary:

- Solar wind simulations for 3 weeks around first 10 PSP perihelions performed with reduced SSH & SCS heights of 1.7 $R_{\odot}$ & 1.4 $R_{\odot}$.
- Better modeled solar wind was obtained using the reduced SSH in EUHFORIA for **52 %** of the time period, on the front-side, and **45 %** of the changing (back to front or vice versa) position of PSP.
  ⇒ no systematic results indicating stronger influence of the 'old' back-side magnetograms.

  ⇩

  Systematic inspection of the EUV observations, aiming to understand the complexity of the solar magnetic field, is ongoing!
- Modelling accuracy increases with increased distance from the Sun
  ⇒ over-expansion of the modelled solar wind at close to the Sun distances.
- The percentage of overestimated velocity decreases with increasing distance while using reduced SSH.

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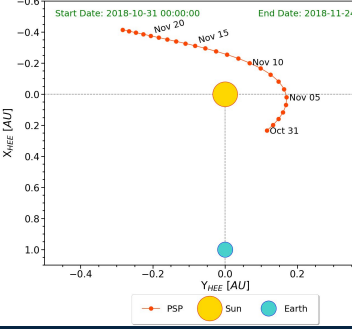
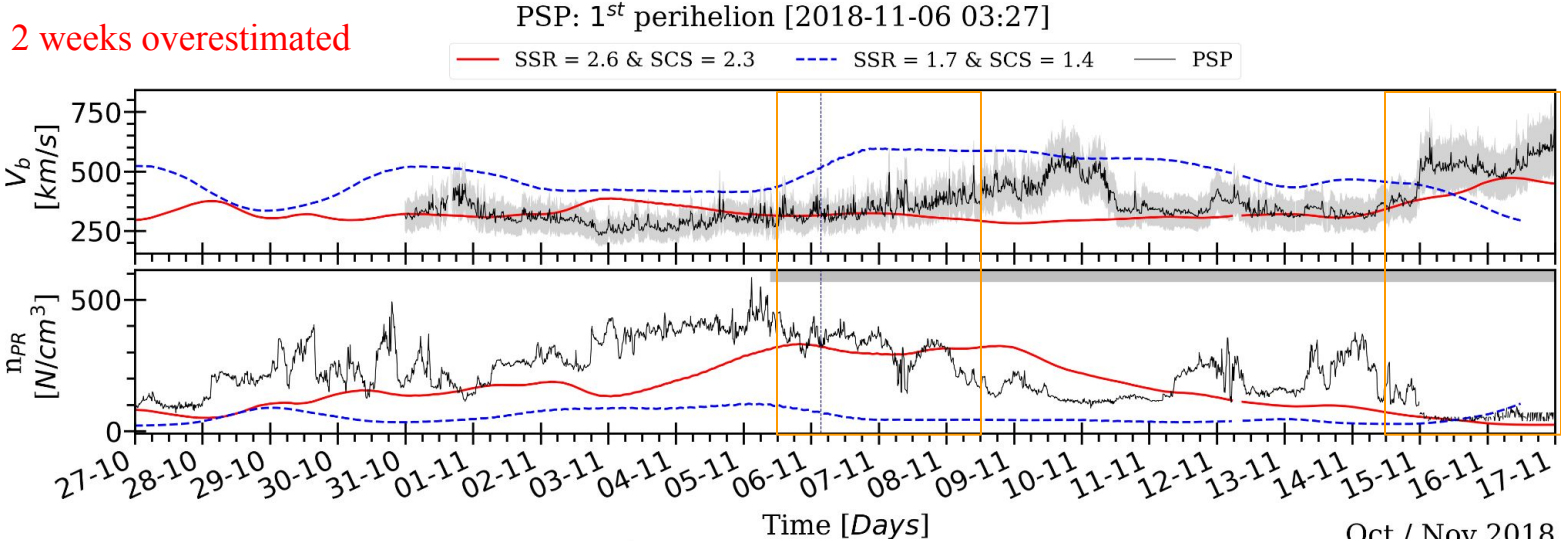
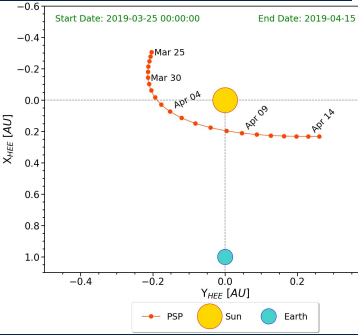
  The range of distances at which the "efficiency" of the modelling is changing to be studied considering not only the close encounters, but also PSP observations at distances further away from the Sun (on-going study).

Thank You!



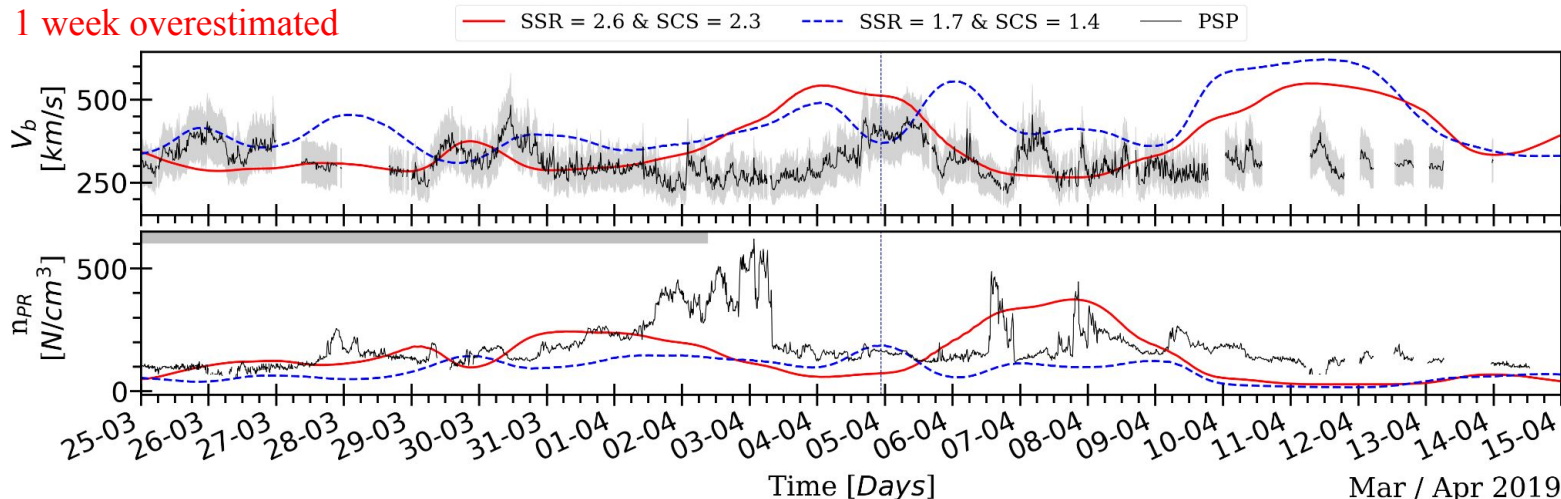
2 weeks overestimated

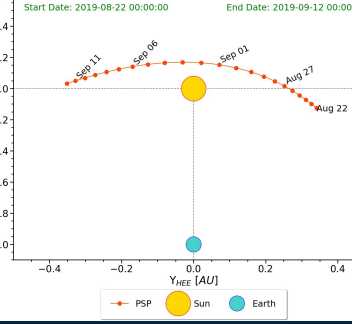




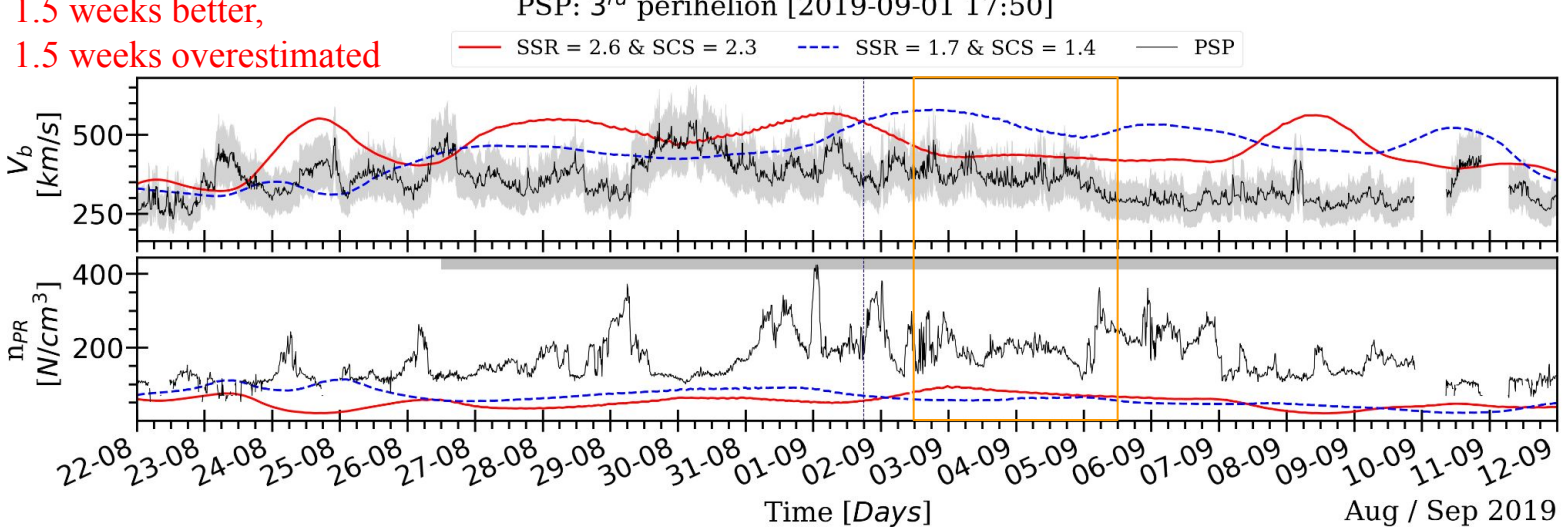
2 weeks better modelling result

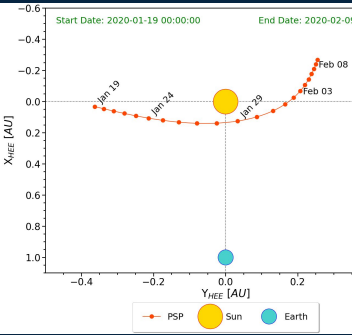
1 week overestimated





1.5 weeks better,
1.5 weeks overestimated





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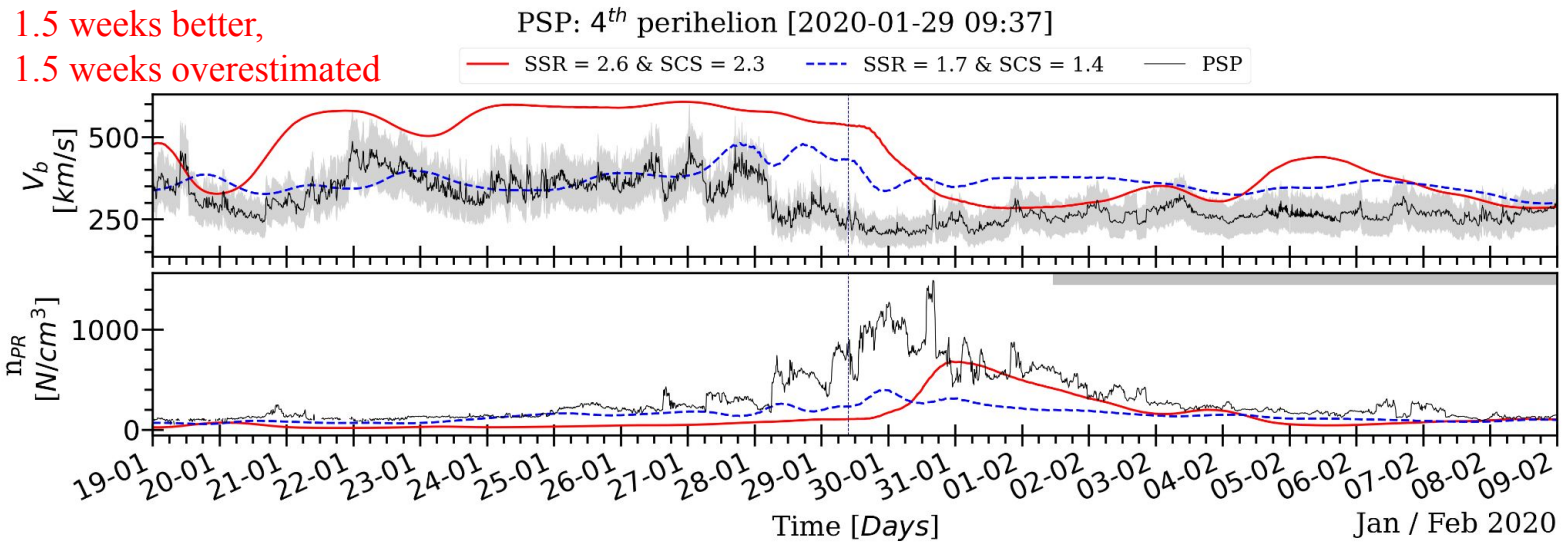
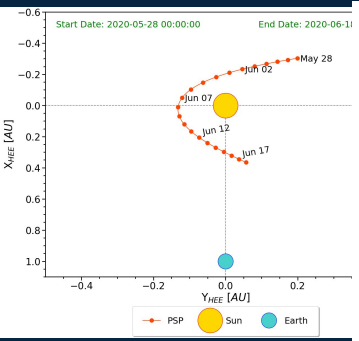
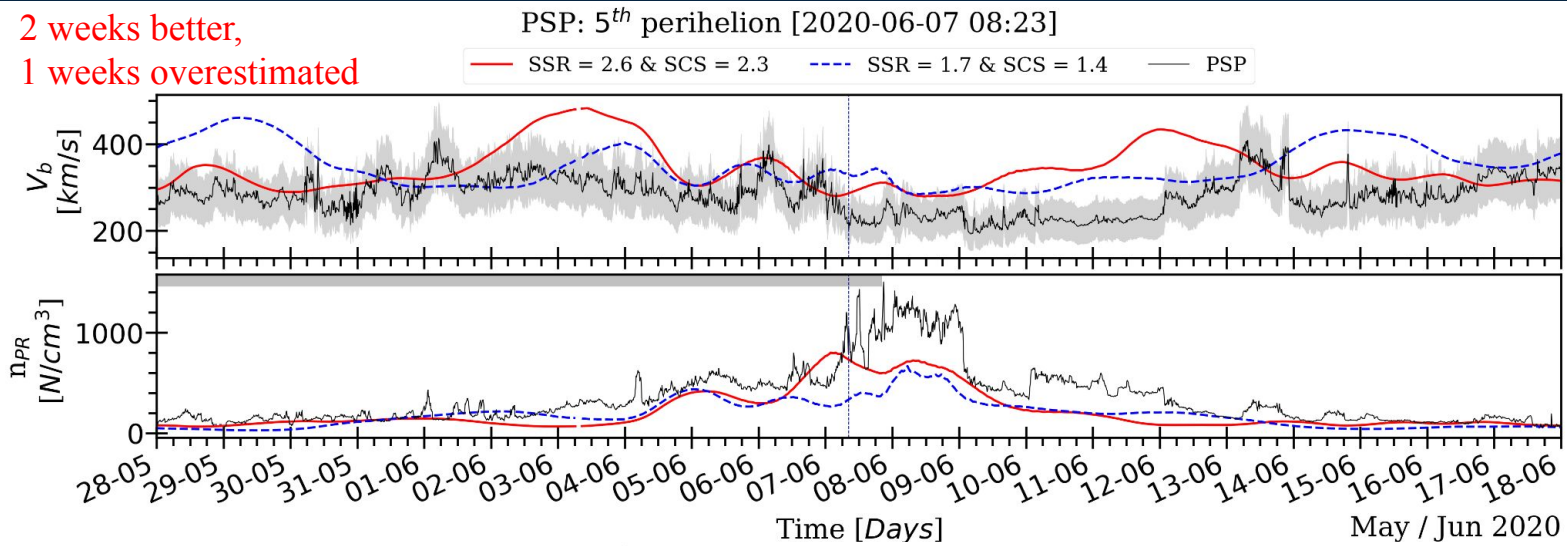
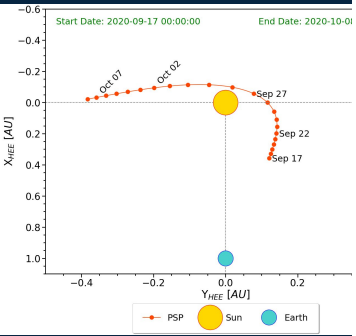


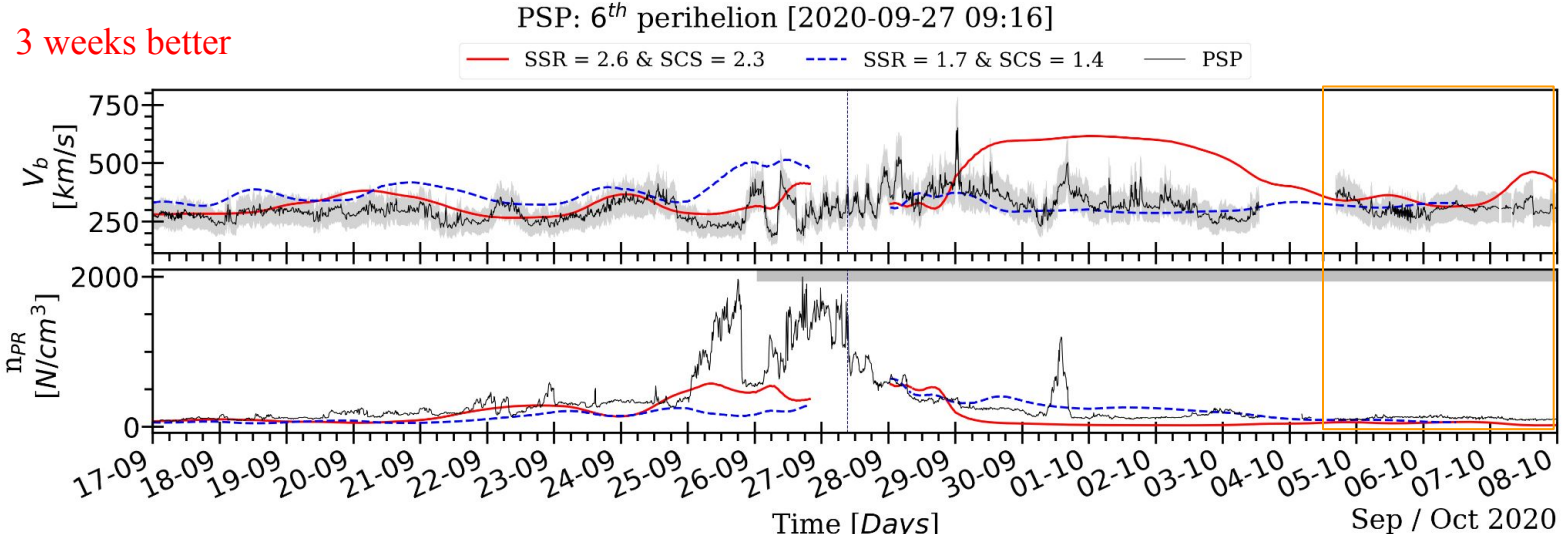


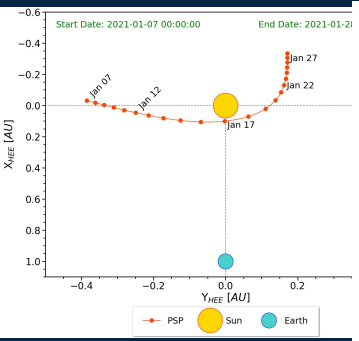
2 weeks better,
1 weeks overestimated



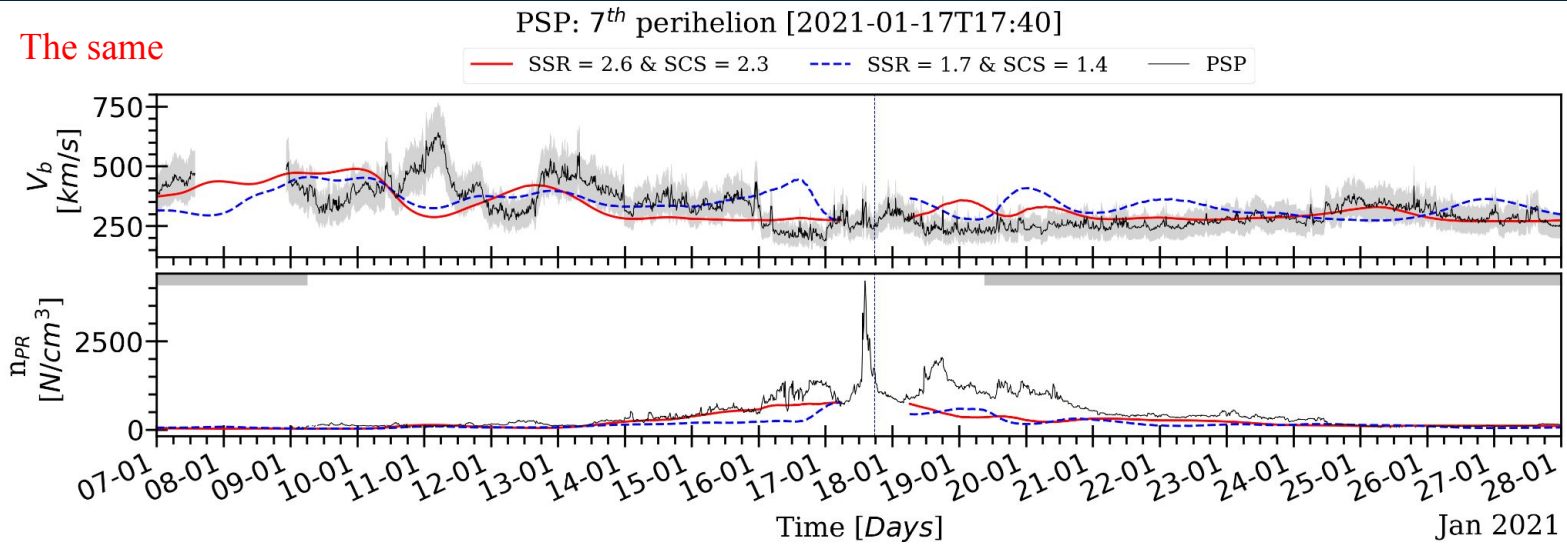


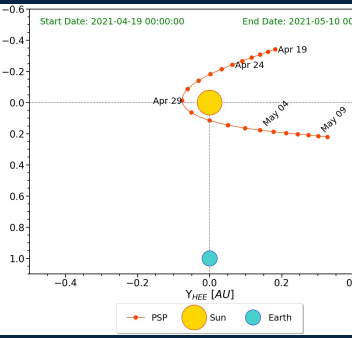
3 weeks better



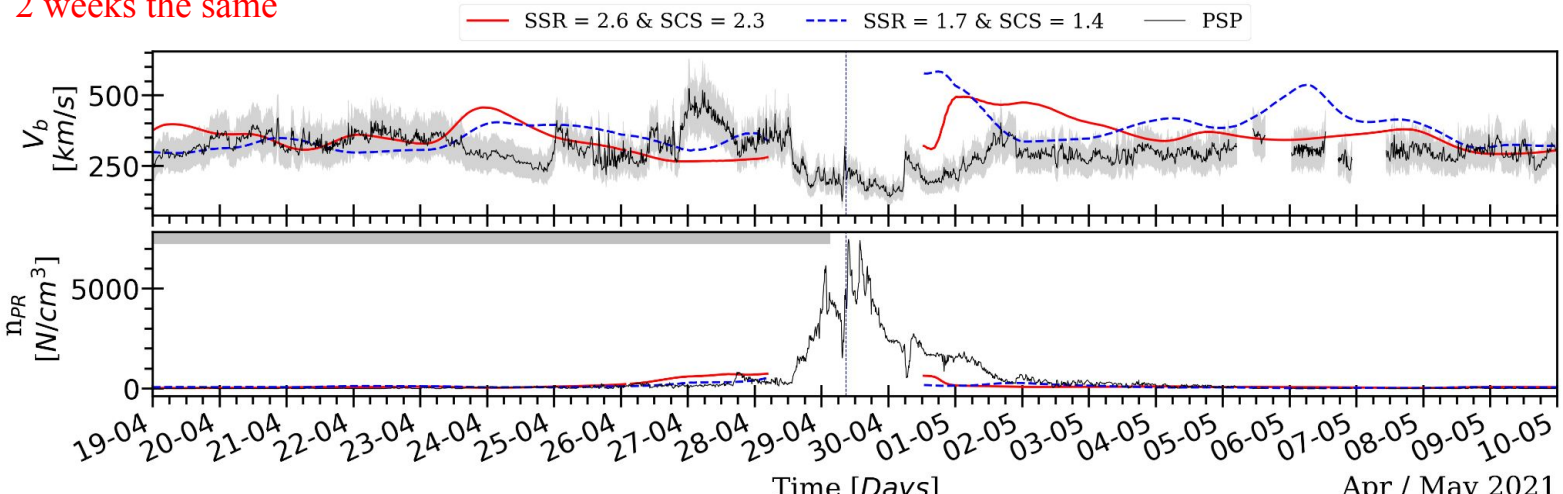


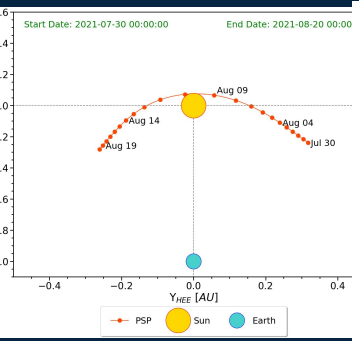
The same



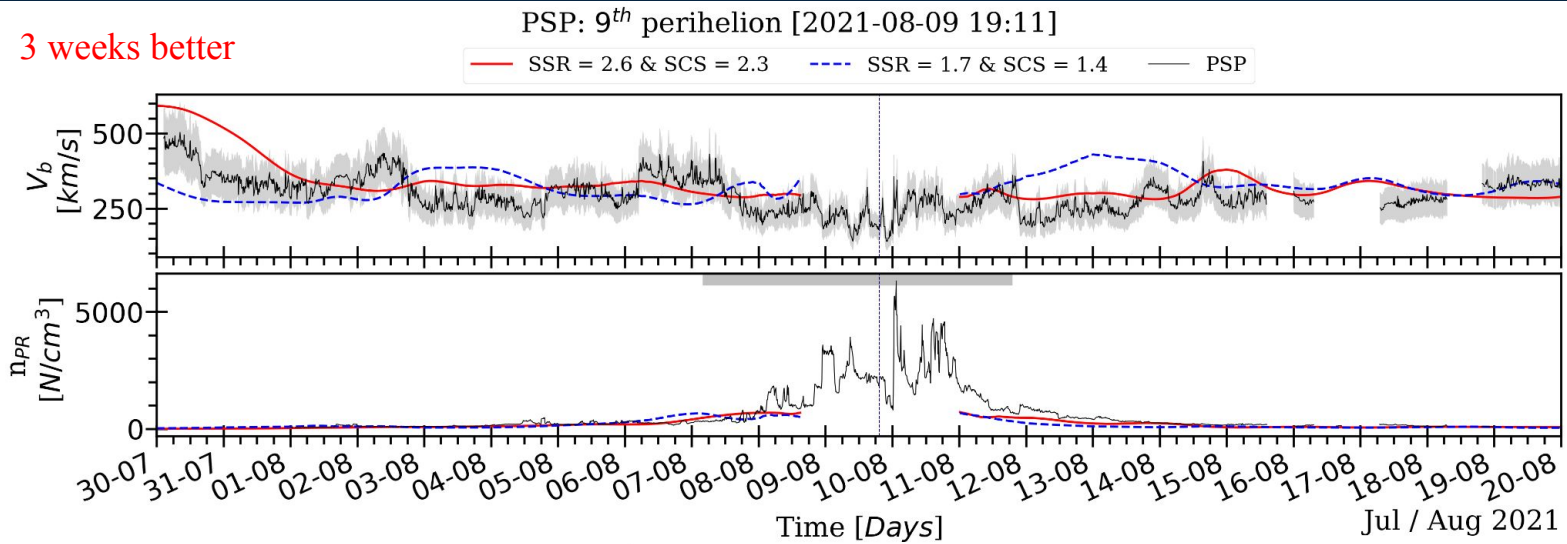


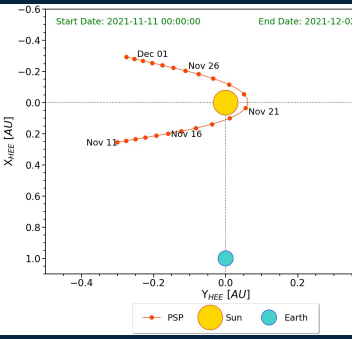
2 weeks the same





3 weeks better





3 weeks the same