Transfer-Solar-GAN

Generation of Input Sources for Solar Wind Models with Deep Learning

Xiaoyue Li[1], Mark D. Butala[1], Senthamizh Pavai Valliappan[2], Jasmina Magdalenic[2],

Veronique Delouille[2], Luciano Rodriguez[2] and Daria Shukhobodskaia[2]

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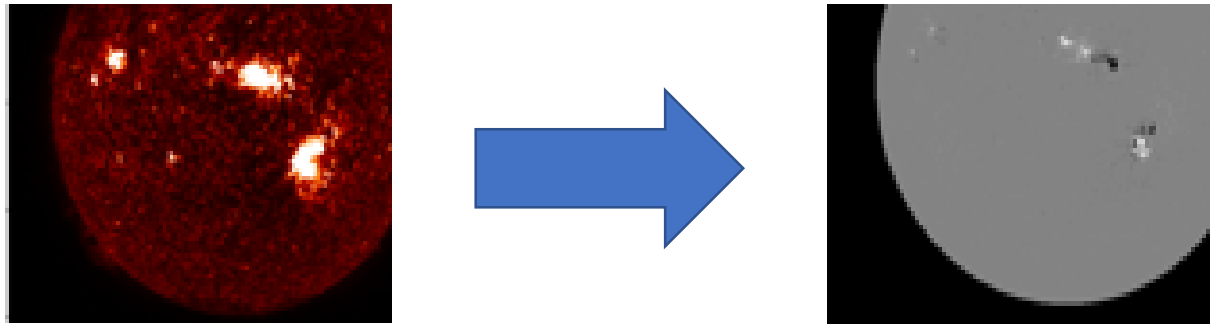
1 ZJU-UIUC Institute

Zhejiang University / University of Illinois at Urbana-Champaign Institute

2 Royal Observatory of Belgium



Contents

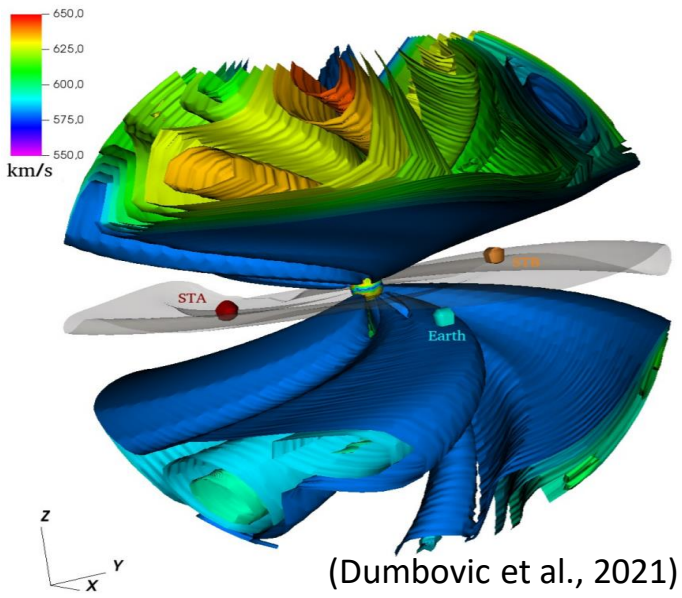
Motivation --- EUHFORIA model

- EUHFORIA : A physics-based, forecasting-targeted inner heliosphere model
  - Solar wind relaxation, CME insertion and forecast
- GONG synoptic line-of-sight magnetograms are used as boundary conditions
- **EUV imagers** are more numerous, but not used as input into physics-based models like EUHFORIA

  - More intensively used
  - More complex situations (CME modeling, farside points,…)
  - Timely, Solar Orbiter & Parker Solar Probe are available

Fundamental question: How to use numerous EUV images to produce boundary conditions for a solar wind model?

Solar wind modeled by EUHFORIA



(Dumbovic et al., 2021)

Related Work

- A Generative Adversarial Network (GANs) is a type of neural-network model that performs image-to-image translation

- Kim, et al. (Nature Astronomy, 2019) suggested generating solar farside magnetograms from STEREO/EUVI 304 Å observations using a deep learning model

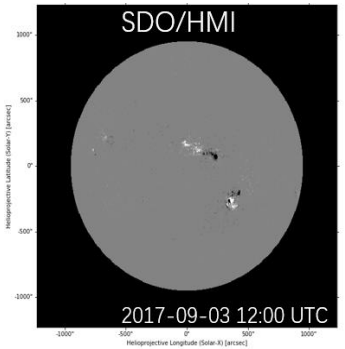
- Jeong et al. (in preparation) developed, pix2pixCC [1], which generates more realistic magnetic flux

[1] https://github.com/JeongHyunJin/pix2pixCC

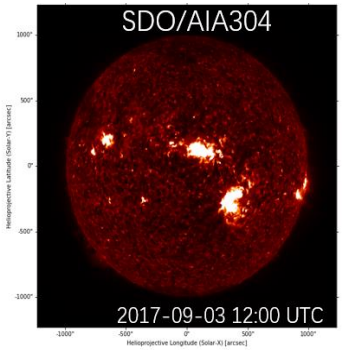
Problems

- **Limited number** of AIA sine synoptic maps which coincide with GONG synoptic maps
- Large, specially prepared dataset of AIA and HMI images exists for training the source model [2]
- Generating a daily updated, synoptic map dataset is **time-consuming**
- **Overexposed or underexposed strips** due to the camera exposure time or image quality key-factors

Pairs of full-disk images

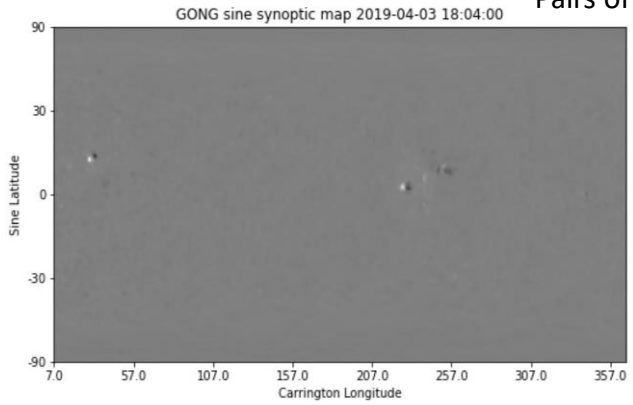


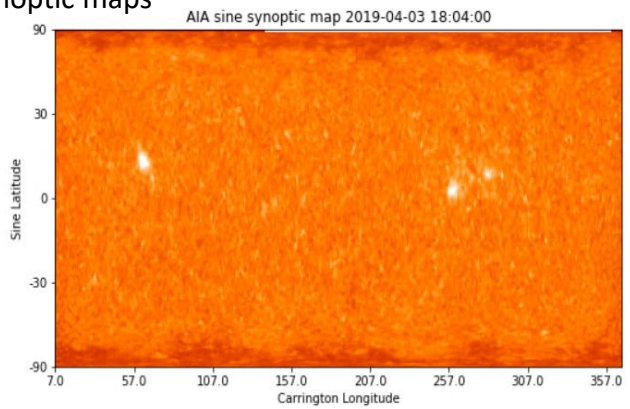
Magnetogram



EUV (Extreme ultraviolet) Imager

Pairs of synoptic maps





- **Transfer learning** is a good choice to solve limited data problem
- A simple yet effective scheme called **FreezD** has been used for transfer learning of GANs [3]

[2] R. Galvez et al. A machine learning dataset prepared from the NASA Solar Dynamics Observatory mission. The Astrophysical Journal Supplement, 242(1), 2019.
[3] Mo S , Cho M , Shin J . Freeze the Discriminator: a simple baseline for fine-tuning GANs. CVPR AI for Content Creation Workshop, 2020.

Datasets

Datasets used in this project

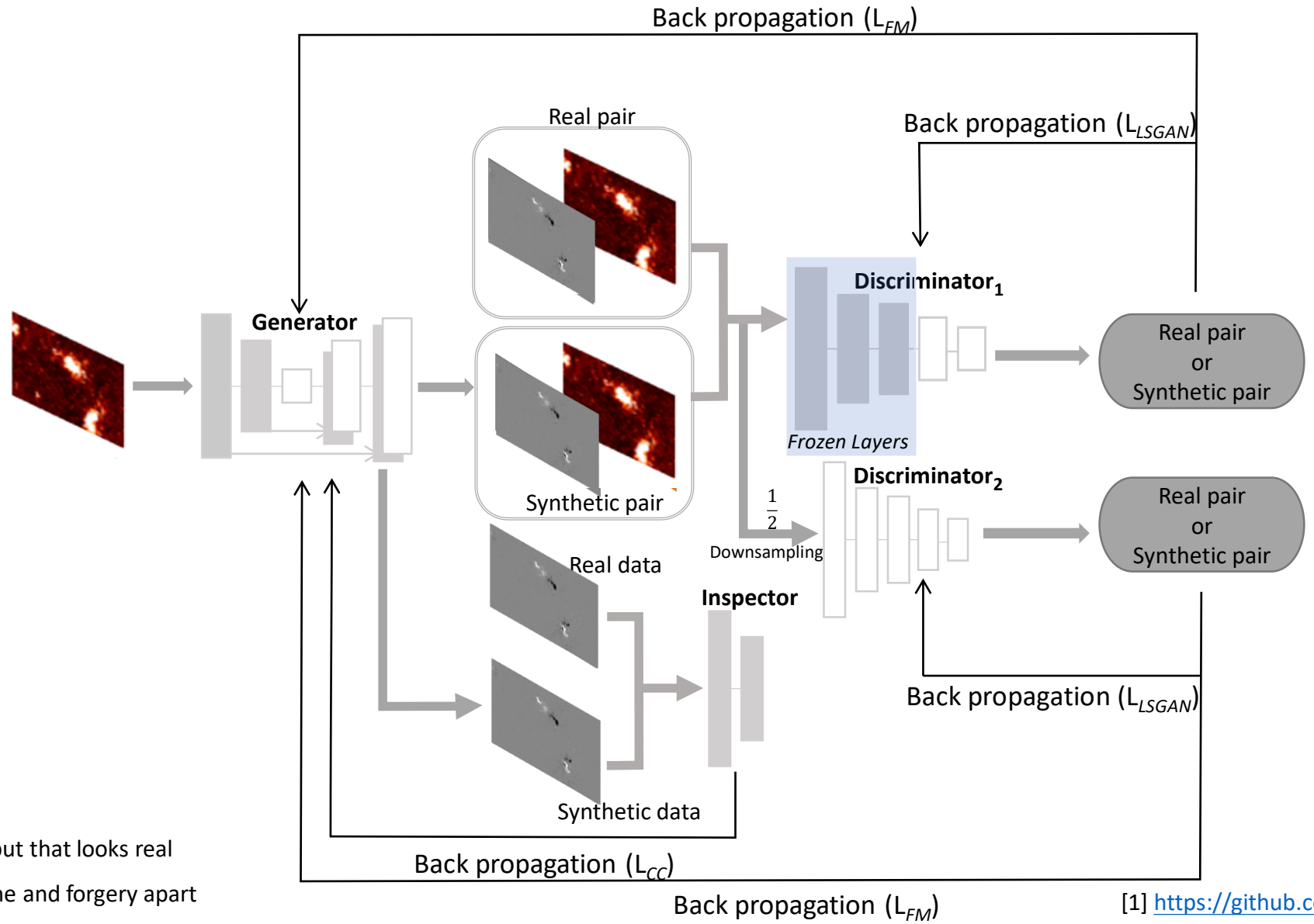
Dataset[4] for Source Model Time Frame: 6 hr cadenced from 2011 to 2018		**Dataset for Target Model** Time Frame: CR2097 to CR2251 with 1 Carrington rotation cadenced *	
Training Set	Test Set	Training Set	Test Set
8115	1005	135	10

*With data augmentation: flipping horizontally and vertically, with 180-degree rotation to increase the training dataset volume

[4] R. Galvez et al. A machine learning dataset prepared from the nasa solar dynamics observatory mission. The Astrophysical Journal Supplement, 242(1), 2019.

Method

- pix2pixCC [1] is the foundation for this model



Generator : Try to generate the output that looks real

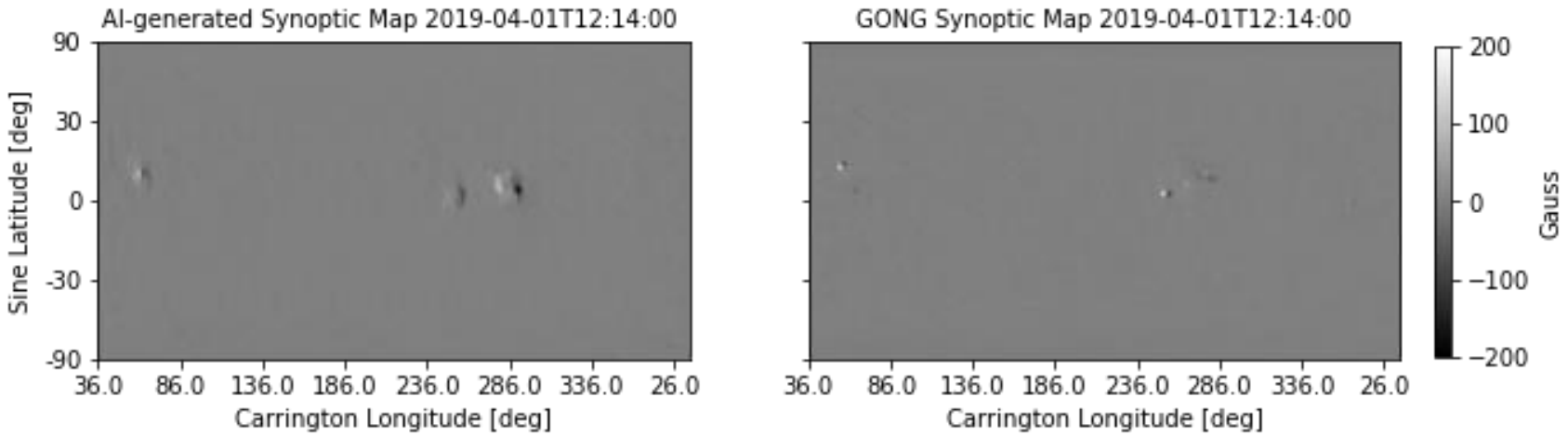
Discriminator: Aim to tell the real one and forgery apart

Inspector: Guide the generator to be well trained by computing correlation coefficient

[1] https://github.com/JeongHyunJin/pix2pixCC

Results

2019-04-01T12:14:00



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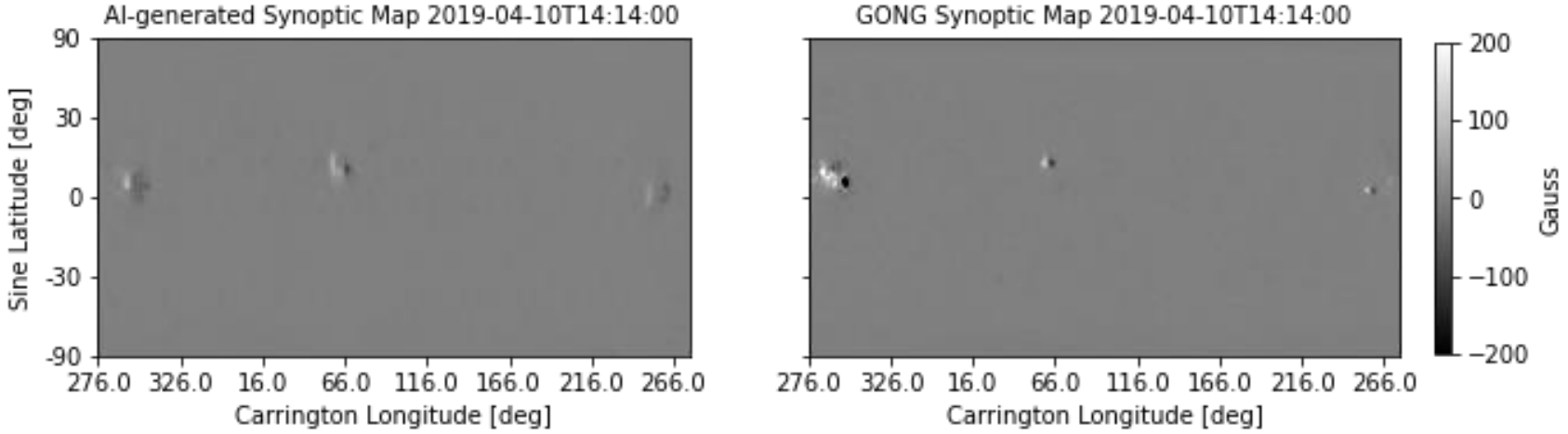
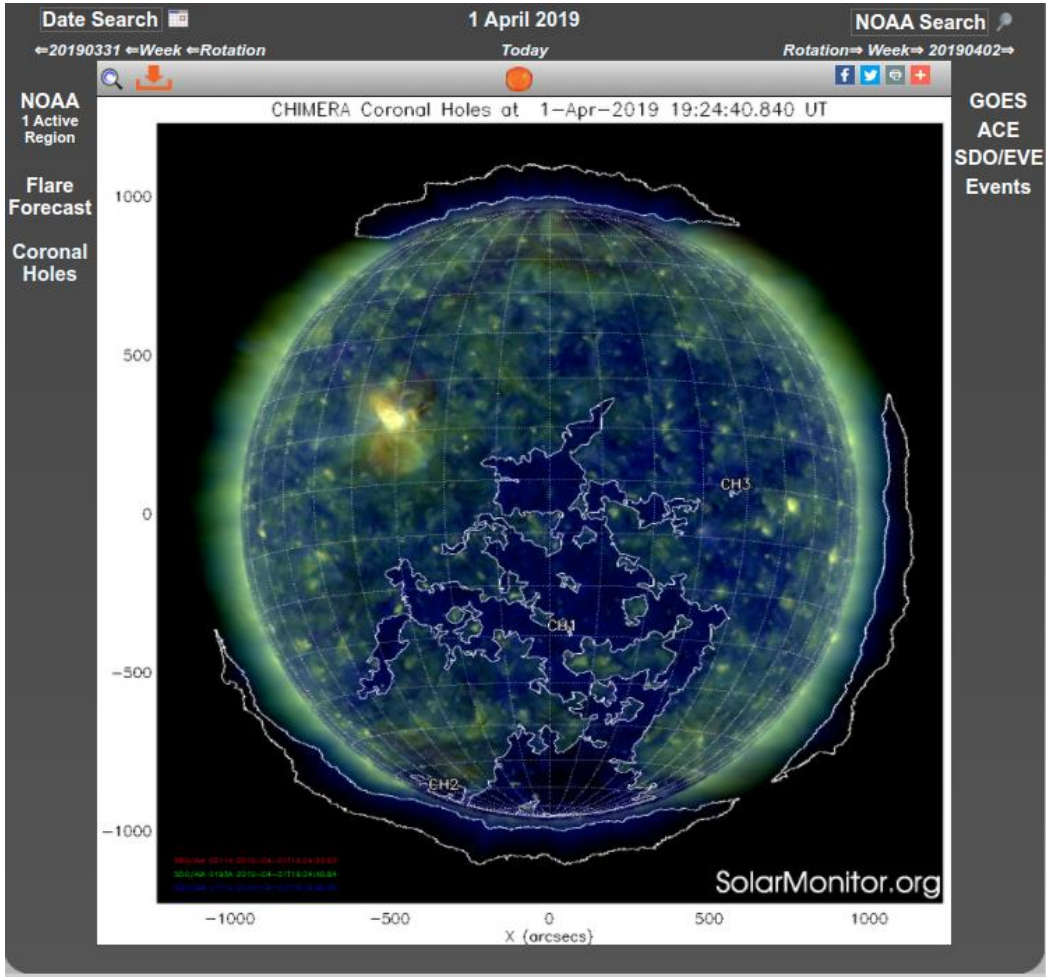


Evaluation from EUHFORIA

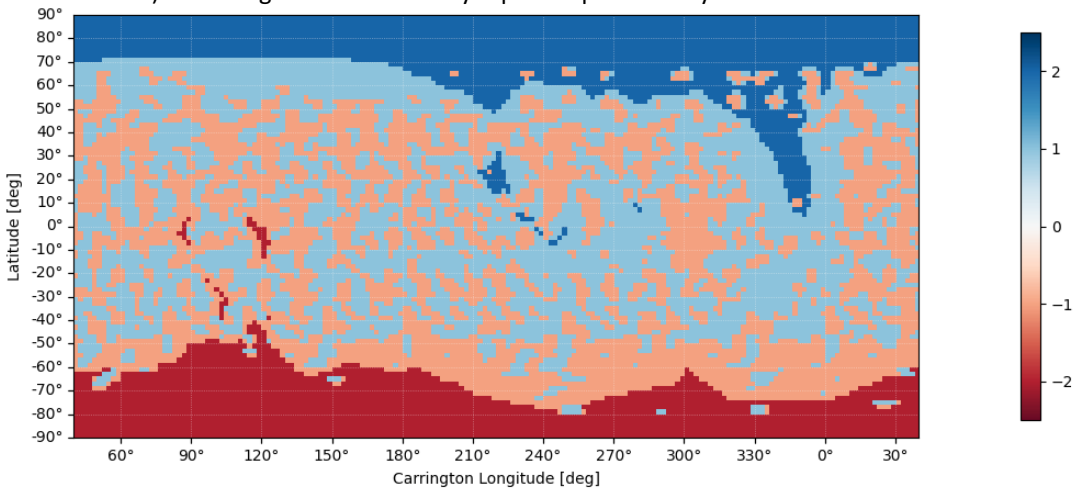


Today's Coronal Hole Properties

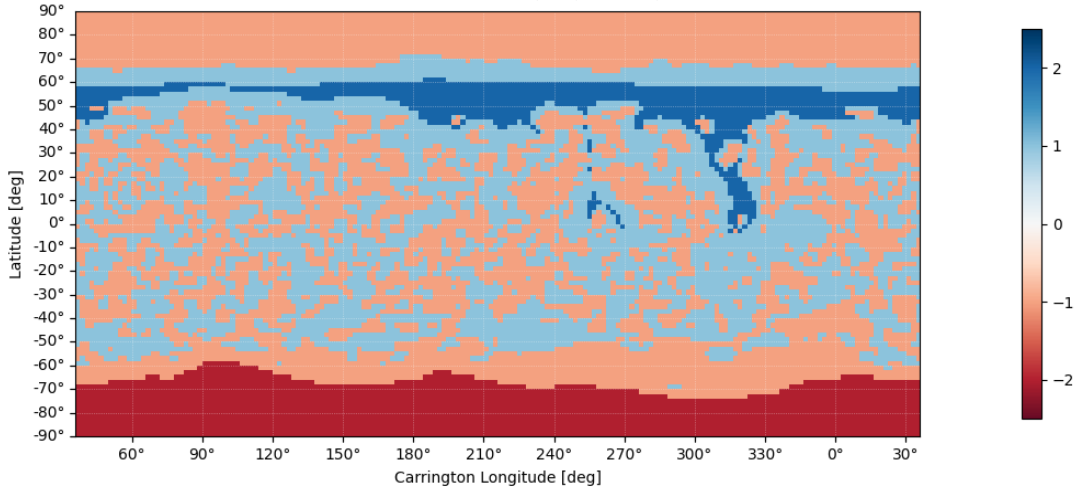
CHIMERA Number	Centroid [Heliocentric]	Width [°]	Area [%]	< B > [G]	< Φ > [Mx]
1	W05S42 (66",-565")	E54-W41 (95)	18.9	-0.5	-3.8e21
2	E67S68 (-332",-869")	E74-E50 (24)	0.2	-0.3	-2.7e20
3	W37S01 (583",70")	W36-W39 (3)	0.0	-0.9	-1.3e19

Open & closed field regions at inner boundary 2019-04-01T12:14:00

a) From AI-generated GONG synoptic map with fuzzy features



b) From real GONG synoptic map



Field connectivity information is coded as:

+/- 2 : open field with positive/negative polarity at footpoint

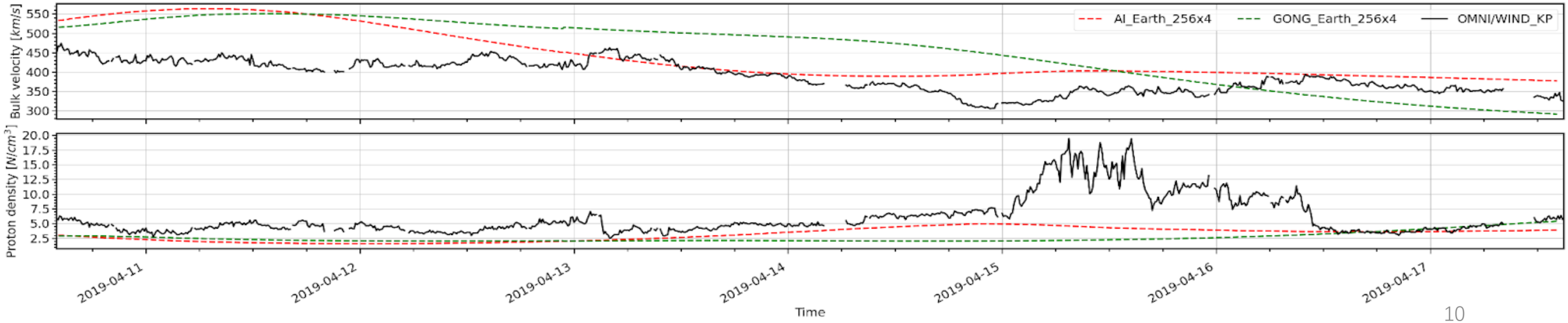
+/- 1 : closed field with positive/negative polarity at footpoint

Evaluation from EUHFORIA

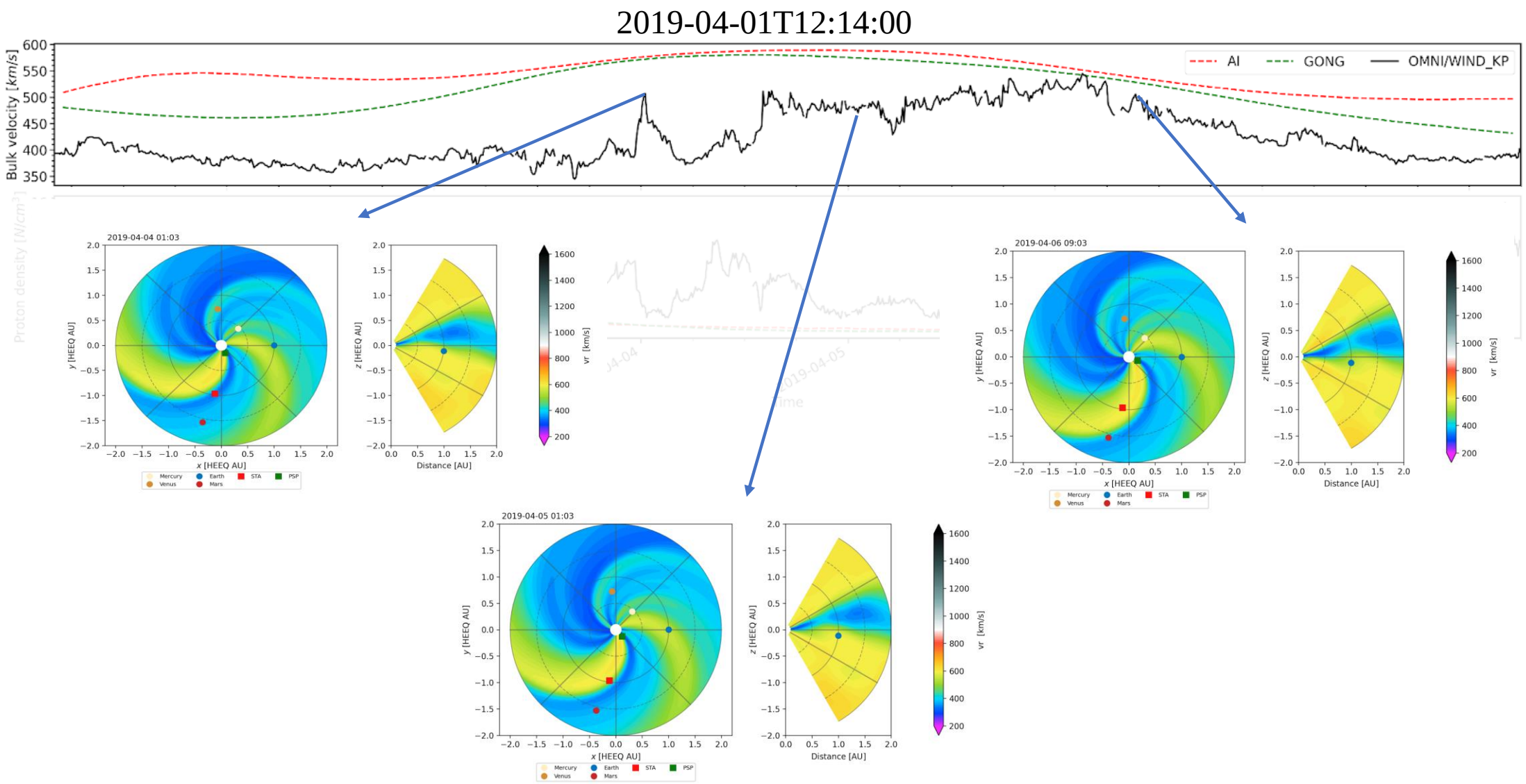
Radial speed and proton density at the position of Earth as a function of time

2019-04-01T12:14:00

2019-04-10T14:14:00



Evaluation from EUHFORIA



Summary and Conclusion

- Image-to-image translation (pix2pixCC)
- Transfer learning (FreezD) to solve limited shot image-generated problem
- Analysis of EUHFORIA model error introduced by the AI-generated magnetogram
- Next steps:
  - How to improve the quality of AI-generated magnetograms, with focus on coronal hole regions?
    - Data Input: Multi-channel preprocessed input data, selecting proper weighting factor for synoptic map generation
    - Network Structure : Multi-header, self-attention GAN which can focus more attention to coronal holes region / structure

Acknowledgements

- We thank Jeong et al. for sharing the pix2pixCC code (https://github.com/JeongHyunJin/pix2pixCC)

- We thank Galvez et al. to share their well-prepared machine learning dataset including AIA and HMI full-disk images from 2011 to 2018. The data are available through the Stanford Digital Repository (https://purl.Stanford.edu)

- We thank all the team members of the SDO mission, STEREO mission, GONG mission and acknowledge efforts devoted to the open-source solar data analysis Python packages: sunpy, astropy and aiapy

- GONG maps are available from National Solar Observatory (https://gong.nso.edu/data/magmap/QR/bq1/)

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Thank you for joining!