Inversión de los parámetros de Stokes mediante modelos de Inteligencia artificial

Juan Esteban Agudelo[1], Germain Nicolás Morales[1], Santiago Vargas[1] and Sergiy Shelyag[2]

Universidad Nacional de Colombia[1], Flinders University[2]

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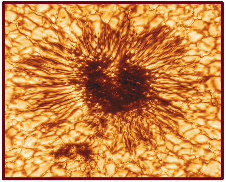
Motivation

New instruments ...

More complex

inversion codes...



Motivation

- **Computational demanding**

- **Carbon footprint**

- **Scientific time**

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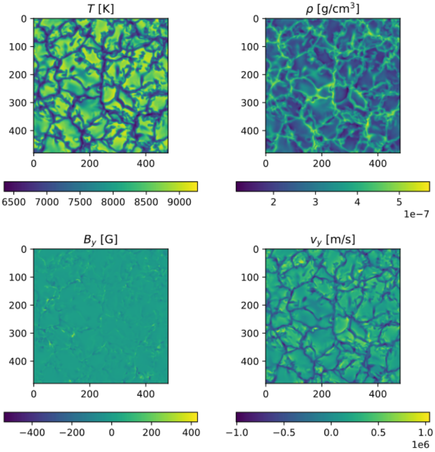
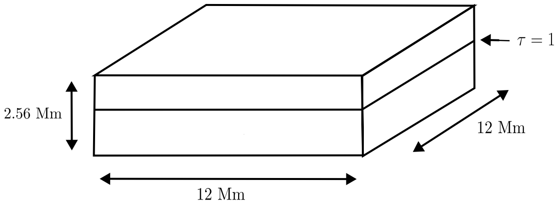
MHD - MURaM

A. Vögler et. al, (2004). Simulations of magneto-convection in the solar photosphere*. Equations, methods, and results of the MURaM code.



Spatial domain

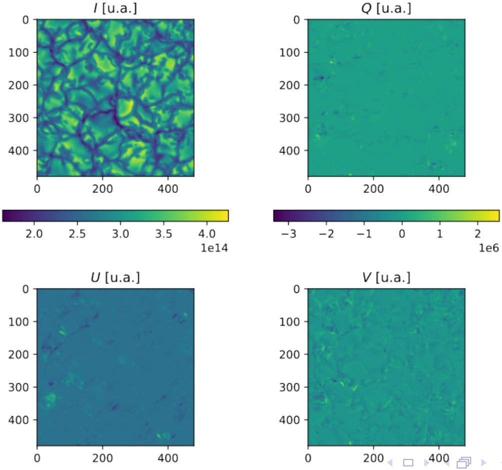
The simulation is developed around the photosphere and is treated as if in the center of the solar disk.



The domain in pixels is 480 x 480 pixels in the x and y axes, and 256 pixels in the z (geometrical height) axis.

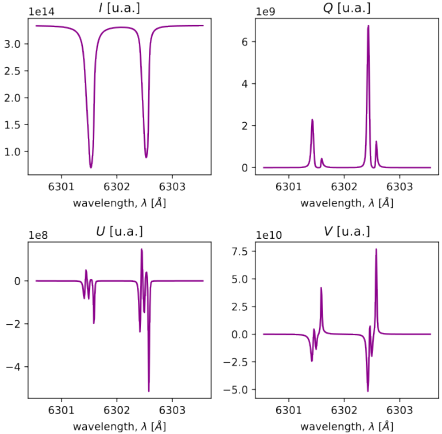
Stokes parameters

H. Socas-Navarro et. al, (2015). An open-source, massively parallel code for non-LTE synthesis and inversion of spectral lines and Zeeman-induced Stokes profiles*



Spectral domain

Using the NICOLE code for the Radiative Tranfer Equation (RTE) simulation parting from the MHD data, 300 spectral points are generated for the four parameters in order to include the Fe I absorption lines.



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Normalization

The Stokes vector and atmosphere magnitude values where normalized using general factors for each quantity according to the general observed magnitude order for each of them.

Stokes vector factors

$$I \rightarrow (10^{14}, 0),\ Q \rightarrow (10^{14}, -10^{14}),\ U \rightarrow (10^{14}, -10^{14}),\ V(10^{14}, -10^{14})$$

Atmosphere magnitudes factors

$$T \rightarrow (10^{4}, 0),\ \log_{10}(\rho) \rightarrow (10^{-5}, -10^{-12}),\ B_{\mathsf{LOS}} \rightarrow (10^{3}, -10^{3}),\ v_{\mathsf{LOS}}(10^{6}, -10^{6})$$

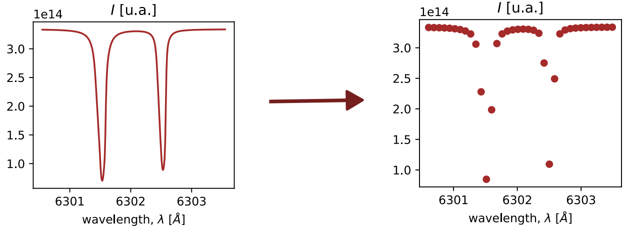
Optical depth stratification

A conversion between the geometrical height (scale used for the MuRAM simulation) to the optical depth as a measurement of height is done through the use of the Rossland opacity values.

S. Rose. The radiative opacity at the sun centre—a code comparison study. Journal of Quantitative Spectroscopy and Radiative Transfer, 71(2-6):635–638, 2001

Reduce wavelength resolution

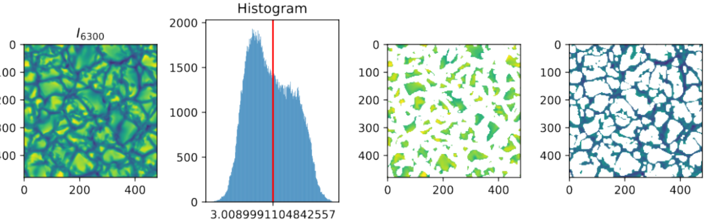
The original resolution of 300 spectral points is reduced to 36 spectral points to be closer to what real observations look like. This reduction is made by applying a gaussian kernel over 36 cen- tral points from the original 300 points.



Granular - intergranular balancing

Due to the usual imbalanced quantity of data between the granular and intergranular zones obtained from the simulations and observed in the actual sun, is necessary to balance their numbers. This is done by using the Otsu threshold

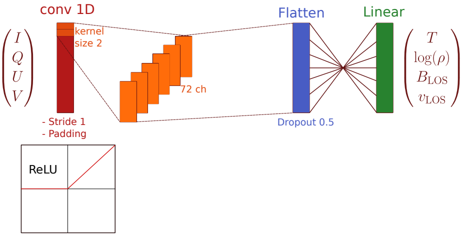
$$\sigma_\omega^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t)$$



Nobuyuki Otsu (1979). "A threshold selection method from gray-level histograms". IEEE Transactions on Systems, Man, and Cybernetics. 9 (1): 62–66. doi:10.1109/TSMC.1979.4310076. S2CID 15326934.

Train the neural network

Creating a simple convolutional arquitec- ture inspired in the integrals that are caracteristic of the radiative transfer for- mal solution, we intend to create a model that acts as a solver of the inversion pro- blem in the solar atmosphere using as in- puts the stokes parameters and as out- puts the Line-of-sight magnitudes of the solar atmosphere.



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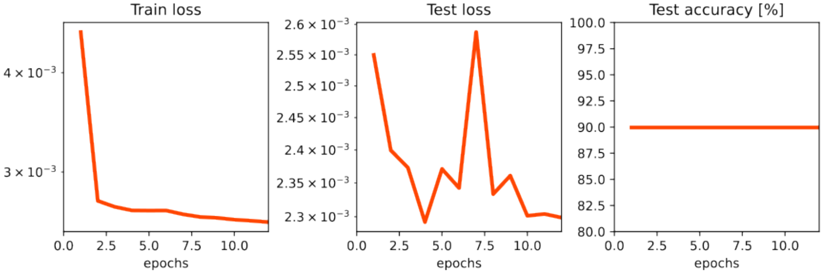
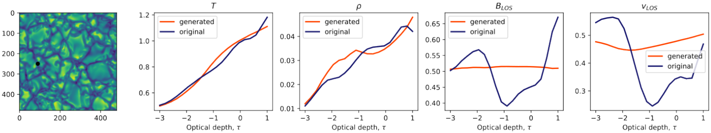
Metrics

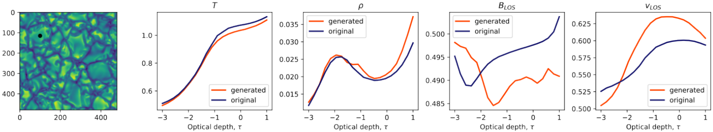

Train loss
4×10^{-3}
3×10^{-3}
0.0 2.5 5.0 7.5 10.0
epochs
Test loss
2.6×10^{-3}
2.55×10^{-3}
2.5×10^{-3}
2.45×10^{-3}
2.4×10^{-3}
2.35×10^{-3}
2.3×10^{-3}
0.0 2.5 5.0 7.5 10.0
epochs
Test accuracy [%]
100.0
97.5
95.0
92.5
90.0
87.5
85.0
82.5
80.0
0.0 2.5 5.0 7.5 10.0
epochs

Comparison granular - intergranular pixels

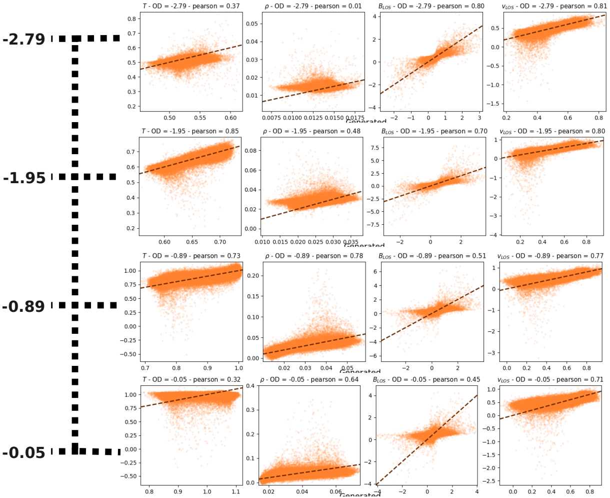
Integranular pixel



Granular pixel



Different OD correlations



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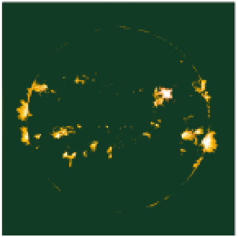
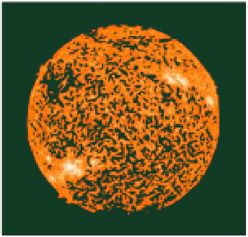
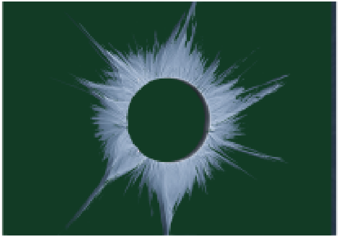
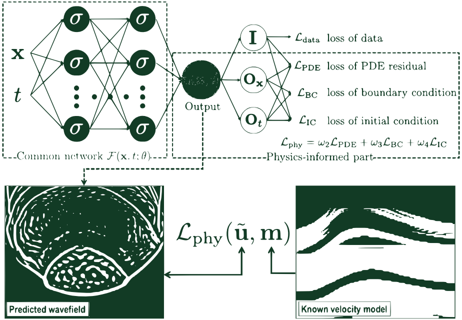
Physical analysis

Find physical constant behaviours to define physical criteriums to replace the statistical analysis made by correlation coefficients. This physical criterium may be defined by taking inspiration on inversion methods that are used specifically for the line-of-sight coefficients.

Apply Physics-assisted ML

Having well-stablished the physical criteriums for the verification of the correct physical behaviour generated by the neural network model, this criteriums could be added to the loss function as a physical constraint by knowing how to express this criteriums mathematically.



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Thank you!

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J. E. Agudelo: juagudeloo@unal.edu.co
G. N. Morales: gemoraless@unal.edu.co
S. Vargas: svargasd@unal.edu.co
S. Shelyag: sergiy.shelyag@deakin.edu.au