Can we constrain preprocessing of vectormagnetograms with H_α images?

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on the NLFFF workshop 2006 and thereafter.

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1 Basics

- The idea is to add an additional term (say $\mu_5 L_5$) to the preprocessing program described in [WIS06].
- From the H_α images we will get vectors of the direction of the fields, say H_x and H_y.
- Let us rebin H_x and H_y to the same resolution as the vector magnetogram.
- In regions where we cannot see clear structures we set $H_x = H_y = 0$.
- The angle of the photospheric magnetic field with the H_α image is:

$$\sin(\xi) = \frac{\mathbf{B} \times \mathbf{H}}{|B||H|}$$

- We define the functional:

$$L_5 = \sum_p (B_x H_y - B_y H_x)^2$$

  One might weight this with the amplitude of B and H or not. We could add a weighting on how good H_x and H_y are measured or just absorb this weighting into H.

- We take the functional derivative of L_5

$$\frac{dL_5}{dt} = 2(B_x H_y - B_y H_x)\ (H_y \frac{dB_x}{dt} - H_x \frac{dB_y}{dt})$$

- For a sufficient small time step dt we get a decreasing L_5 with the iteration equations:

$$\frac{dB_x}{dt} = -2\mu_5 (B_x H_y - B_y H_x)\, H_y$$

$$\frac{dB_y}{dt} = 2\mu_5 (B_x H_y - B_y H_x)\, H_x$$

2 Tests

We test the method with the help of Aads model. We use Aads chromospheric magnetic field data as H_α images. Here we have directly the two vectors H_x and H_y. For real H_α we need to get H_x and H_y out of the image.

Aads chromospheric field is our reference field and Aads photospheric field the vector-magnetogram which we want to preprocess. We compare clasical preprocessing (as described in [WIS06]) and the new method described here. The only difference is that we have now the additional term L_5 as defined earlier in our functional L. We rate the quality of the preprocessing by:

1. Aly's force-free criteria. This is the sum of the force and torque-free parameter defined as: The force balance parameter $\epsilon_{\text{force}} =$

$$\frac{|\int_S B_x B_z \, dx\, dy| + |\int_S B_y B_z \, dx\, dy| + |\int_S (B_x^2 + B_y^2) - B_z^2 \, dx\, dy|}{\int_S (B_x^2 + B_y^2 + B_z^2) \, dx\, dy}$$

   The torque balance parameter $\epsilon_{\text{torque}} =$

$$\frac{|\int_S x((B_x^2 + B_y^2) - B_z^2) dx dy| + |\int_S y((B_x^2 + B_y^2) - B_z^2) \, dx dy| + |\int_S y B_x B_z - x B_y B_z dx dy|}{\int_S \sqrt{x^2 + y^2} \, (B_x^2 + B_y^2 + B_z^2) \, dx\, dy}$$

   Both parameter (and so the sum) should be small in order to find a force-free solution above the magnetogram. But for observed magnetograms and Aads photospheric data this is not the case and this is the reason why we do preprocessing. (See column two of the table)

2. The linear Pearson correlation coefficient between H_x, B_x and H_y, B_y in column three and four of the table, respectively.

3. The weighted average angle between $\mathbf{H}$ and $\mathbf{B}$ defined as:

$$\sin(\phi) = \left(\sum_i \frac{|\mathbf{H} \times \mathbf{B}|_i}{|\mathbf{B}_i|} \right) / \sum_i |\mathbf{H}_i|.$$

   in column five. (If you think that this formular looks familar, you are right. It is identical to Eq. 34 in our first NLFFF-paper. Just that J was replaced by H and that all vectors here are only 2D (x, y).)

References

[WIS06] T. Wiegelmann, B. Inhester, and T. Sakurai. Preprocessing of Vector Magnetograph Data for a Nonlinear Force-Free Magnetic Field Reconstruction. *Sol. Phys.*, 233:215–232, February 2006.

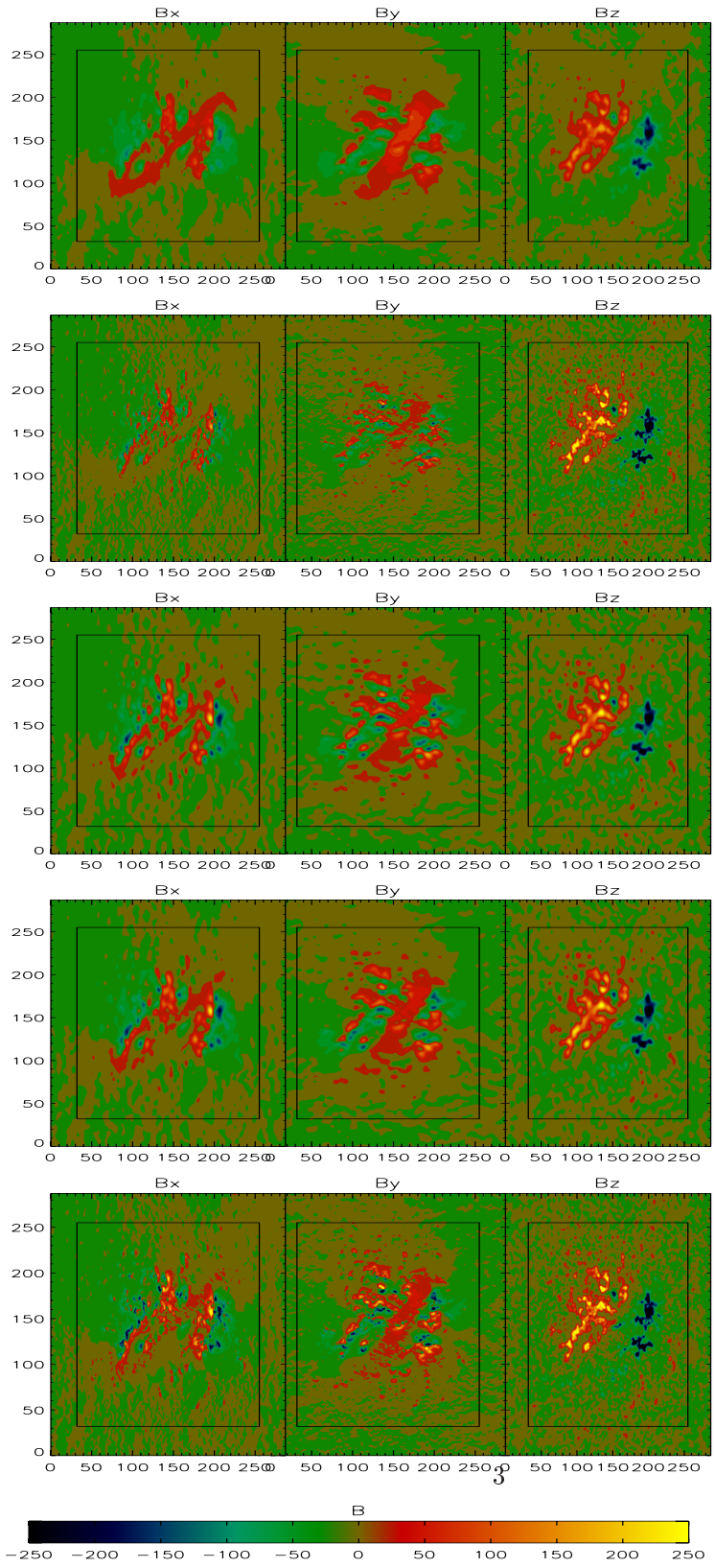

Figure 1: Top: Aads model chromosphere, 2. row: Aads model photosphere, 3. row: classical preprocessed, 4. row: preprocessed constraint with H_α image (or here: Aads chromosphere)including smoothing, bottom: H_α preprocessing without any smoothing.

Table 1: Column one names the used dataset and column two shows the sum of Aly' force and torque free condition. Aads chromosphere is the reference and used here as artificial H_α image and used as reference for the linear Pearson correlation in column three and four and the averaged weighted angle of magnetic field and H_α image in column 5. The last to columns are dedicated to the corresponding 3D-NLFFF computation. In column 6 and 7 we provide the well known vector correlation and magnetic energy in 3D, respectively. As reference we took the extrapolation from chromospheric Aads case. **Marc and Karel: Maybe you compute the values with Aads original model?**. Classic preprocessing was done with $\mu_3 = 0.001$, $\mu_4 = 0.01$ and $\mu_5 = 0$. The H_α preprocessing was done with $\mu_3 = 0.001$, $\mu_4 = 0.01$ and $\mu_5 = 0.01$. For H_α preprocessing without smoothing we used $\mu_3 = 0.001$, $\mu_4 = 0.00$ and $\mu_5 = 0.01$

Data	Force-free cond.	corr (H_x, B_x)	corr (H_y, B_y)	weighted angle	C_{vec} in 3D	Energy in 3D
Aad chrom.	0.039	1	1	0.0°	1	1
Aad photo.	0.998	0.76	0.75	17.9°	0.91	0.65
classic prepro.	0.0003	0.93	0.91	10.8°	0.97	0.97
H_α prepro.	0.0005	0.95	0.93	1.9°	0.97	1.006
H_α no smoothing	0.0002	0.84	0.81	3.6°	0.94	0.92