Effects of Spatial Resolution of Boundary Data on Coronal Magnetic Field Extrapolations

Marc L. DeRosa[(1)], Michael S. Wheatland[(2)], and the NLFFF Team*

[(1)] Lockheed Martin Solar and Astrophysics Laboratory (Palo Alto, CA, USA)

[(2)] School of Physics, University of Sydney (Sydney, NSW, Australia)

Motivation: *Previous investigations into the determination of nonlinear force-free field (NLFFF) models of the solar coronal magnetic field had uncovered several factors that affected the ability to obtain reliable results. Of these factors, the effects due to the spatial resolution of the photospheric vector magnetogram boundary data were hypothesized to be significant, due to the apparent fine-scale nature of vertical currents present in high-resolution vector data.*

The Experiment: *We test this hypothesis by performing extrapolations of the coronal magnetic field overlying AR10978 of December 2007, using high-resolution (normal-map) polarization spectra from the Hinode/SOT spectropolarimeter. These spectra have been rebinned by various factors (1, 2, 4, 8, 12, and 16) prior to being inverted into vector magnetograms, which are then in turn used as lower boundary conditions for the modeling (see* ***Figure 1****).*

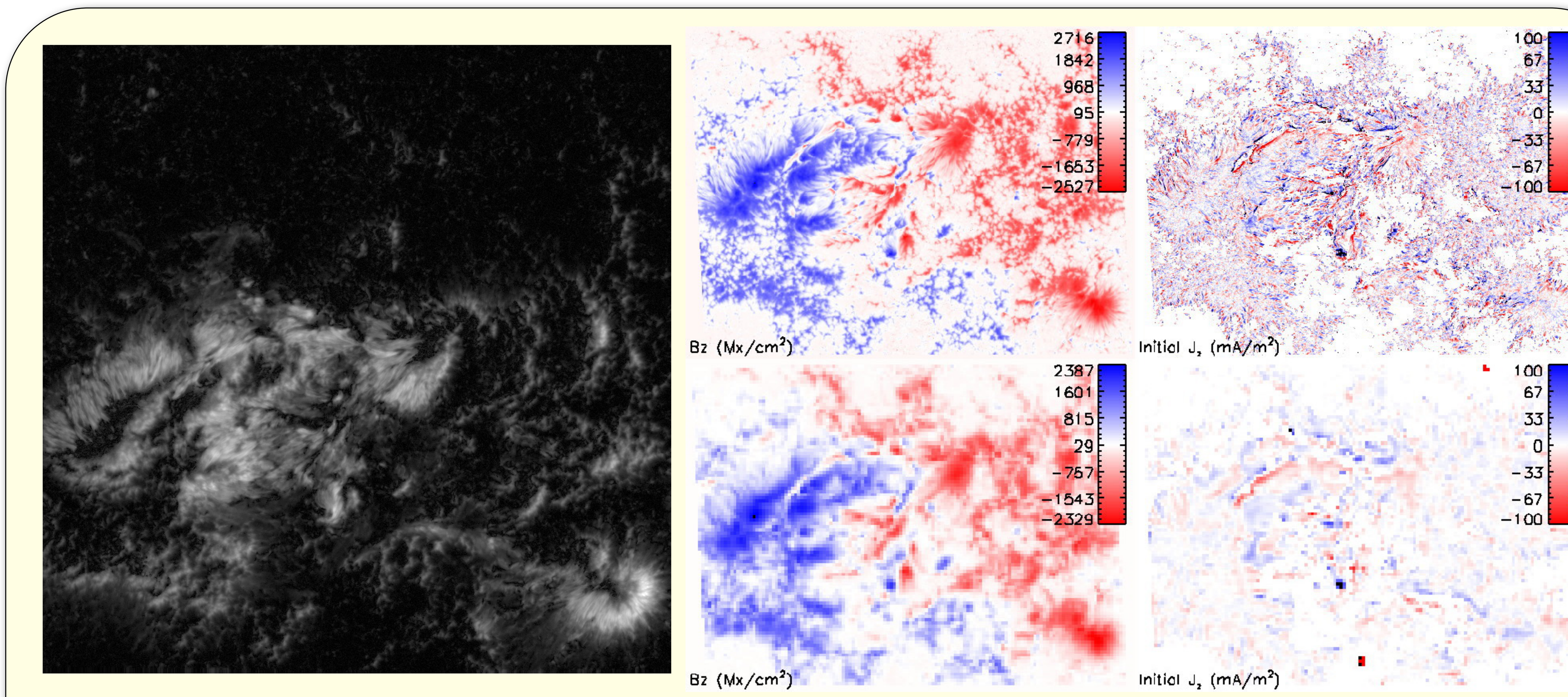

Figure 1: *Full-resolution image of the magnitude of the transverse magnetic field (left, grayscale image) from Hinode/SOT for AR10978. Maps of B_z and J_z (right, color images) as derived from vector magnetograms created from SOT-SP data at native resolution of 0.16" pixels (top) and binned by a factor of 8 (bottom). The maps of B_z and J_z are used as boundary conditions for the extrapolation modeling codes. The results of such modeling are summarized in* ***Figure 2*** *and in the table.*

Figure 2: *Plot of free energy ($E-E_0$) vs. bin factor for the series of extrapolations. Results from the five codes (CFIT, XTRAPOL, FEMQ, magnetofrictional, and optimization) are shown.*

Models calculated using Grad-Rubin methods (CFIT, XTRAPOL, and FEMQ) have markedly lower free energies than either magneto-frictional or optimization methods.

Models calculated using Grad-Rubin and optimization generally show increasing free energy for more highly resolved data. The magnetofrictional method mostly shows the inverse trend.

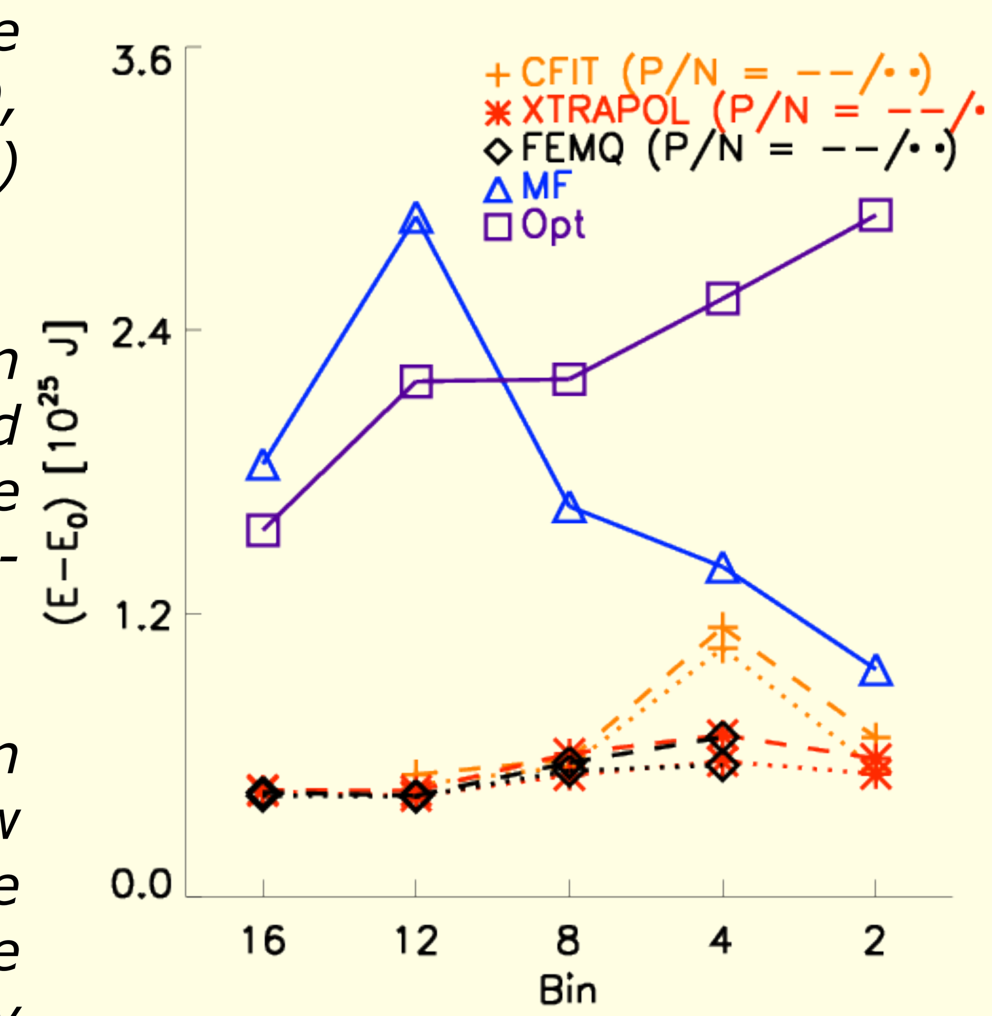

Table of Energy Statistics
for bin factor = 2 (0.32" pixels)

Code	Author(s)	E [10^{26} J]	E/E_0	H_m [10^{26} Wb^2]
CFIT −	Wheatland, Gilchrist	1.10	1.05	2.42
CFIT +		1.12	1.06	4.54
XTRAPOL −	Amari, Canou	1.27	1.04	3.19
XTRAPOL +		1.27	1.05	3.21
Optimization	Wiegelmann, Thalmann	1.50	1.24	−0.04
Magneto-frictional	Valori	1.08	1.10	1.88

Table of Energy Statistics
for bin factor = 8 (1.28" pixels)

Code	Author(s)	E [10^{26} J]	E/E_0	H_m
CFIT −	Wheatland, Gilchrist	1.12	1.05	4.66
CFIT +		1.12	1.05	3.35
XTRAPOL −	Amari, Canou	1.28	1.04	3.55
XTRAPOL +		1.28	1.05	3.81
Optimization	Wiegelmann, Thalmann	1.46	1.18	0.43
Magneto-frictional	Valori	1.28	1.15	5.17

E = energy of solution
E_0 = energy of potential field
H_m = relative magnetic helicity

Conclusions: *Considering all models and bin factors in the sample, the mean energy of the ensemble is 1.3×10^{26} J. The spread in free energies is larger, ranging from highly nonlinear cases with a lot of energy in currents to cases that are not too different than the potential field. The trends of energy vs. spatial resolution are mixed, with the optimization code showing an increasing trend and the others a decreasing trend. Details of the implementation of the Grad-Rubin methods matter less than the resolution in determining free energy. It is known that models that apply preprocessing to the lower boundary data tend to produce results having greater free energies, and this accounts for some of the discrepancy between the Grad-Rubin methods and the others.*

** The NLFFF Team consists of Tahar Amari, Graham Barnes, Aurélien Canou, Stuart Gilchrist, K.D. Leka, Anna Malanushenko, Stéphane Régnier, Karel Schrijver, Xudong Sun, Tilaye Tadesse, Julia Thalmann, Gherardo Valori and Thomas Wiegelmann.*

Acknowledgement: *This research benefited from discussions at the International Space Science Institute (ISSI) in Bern. We gratefully acknowledge the support provided by ISSI.*

Nov. 2013