Determining properties of the solar atmosphere by inversion

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The Daniel K. Inouye Solar Telescope (DKIST) is the most advanced solar telescope in the world, and its observing time will need to be used efficiently. With better views of the solar spectrum available, inversion techniques, used to determine solar atmospheric properties from observed spectra, should be tailored to maximally exploit these new capabilities. Here we use the specific inversion code Stokes Inversion based on Response functions (SIR) to test whether a fine sampling of two spectral lines or a coarse sampling of five spectral lines is a more viable inversion approach. To this goal we generate theoretical spectra from two-dimensional model atmospheres, apply noise, and run them through SIR inversions to recover atmospheric parameters. We then determine the RMS differences between the model atmospheres and the SIR inversions to determine which method produced more accurate inversions. It was found that neither sampling method stood out as superior regarding RMSD values. In some situations the inversions from the fine sampling had lower RMSD values and in other situations it was the opposite. The inversions done on two spectral lines could be computed much faster so the fine sampling is a more efficient method in post-processing, but not necessarily in observing strategy.

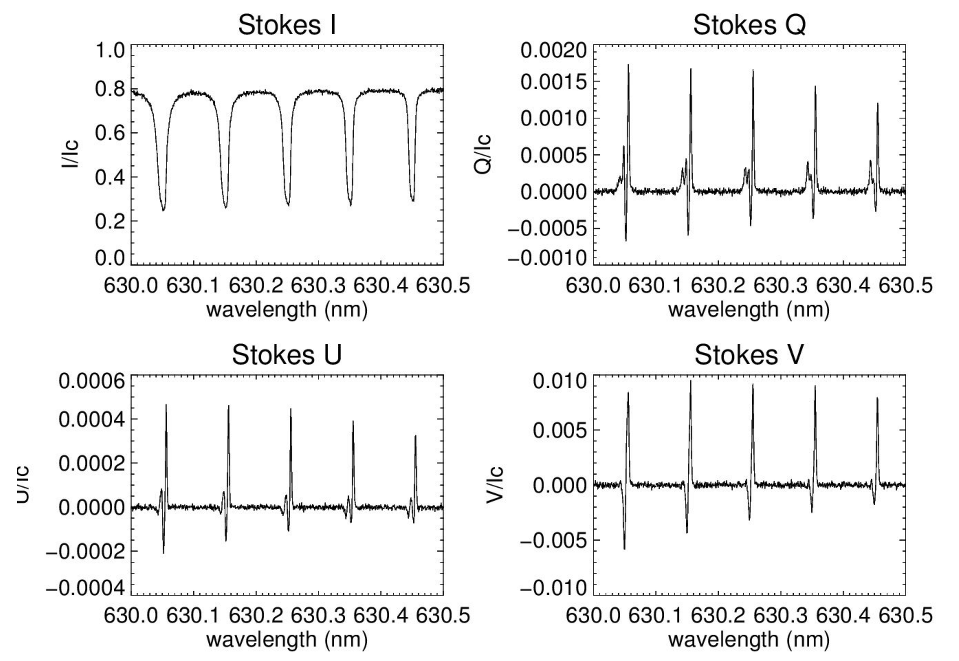
SIR code

Two modes:

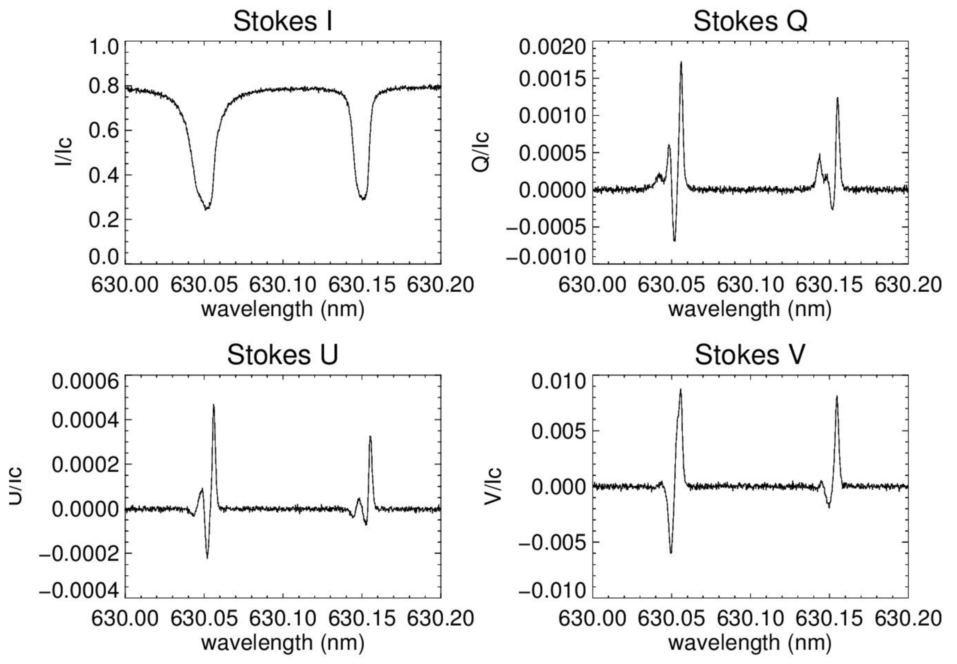
- Synthesis - this mode requires an atmosphere, spectral lines, and the desired grid of wavelength. It then uses radiative transfer equations to produce Stokes' profiles from the given atmosphere and spectral lines.
- Inversion - this mode requires an observed Stokes' profile, and a set number of cycles and nodes. From that it alters the guess model until it generates Stokes' profiles matching the observed ones over the chosen number of cycles. The altered guess model can then be compared to the original atmosphere.

(Bellot Rubio, L.R.) , (Ruiz Cobo, B., & del Toro Iniesta)

Spectral Lines

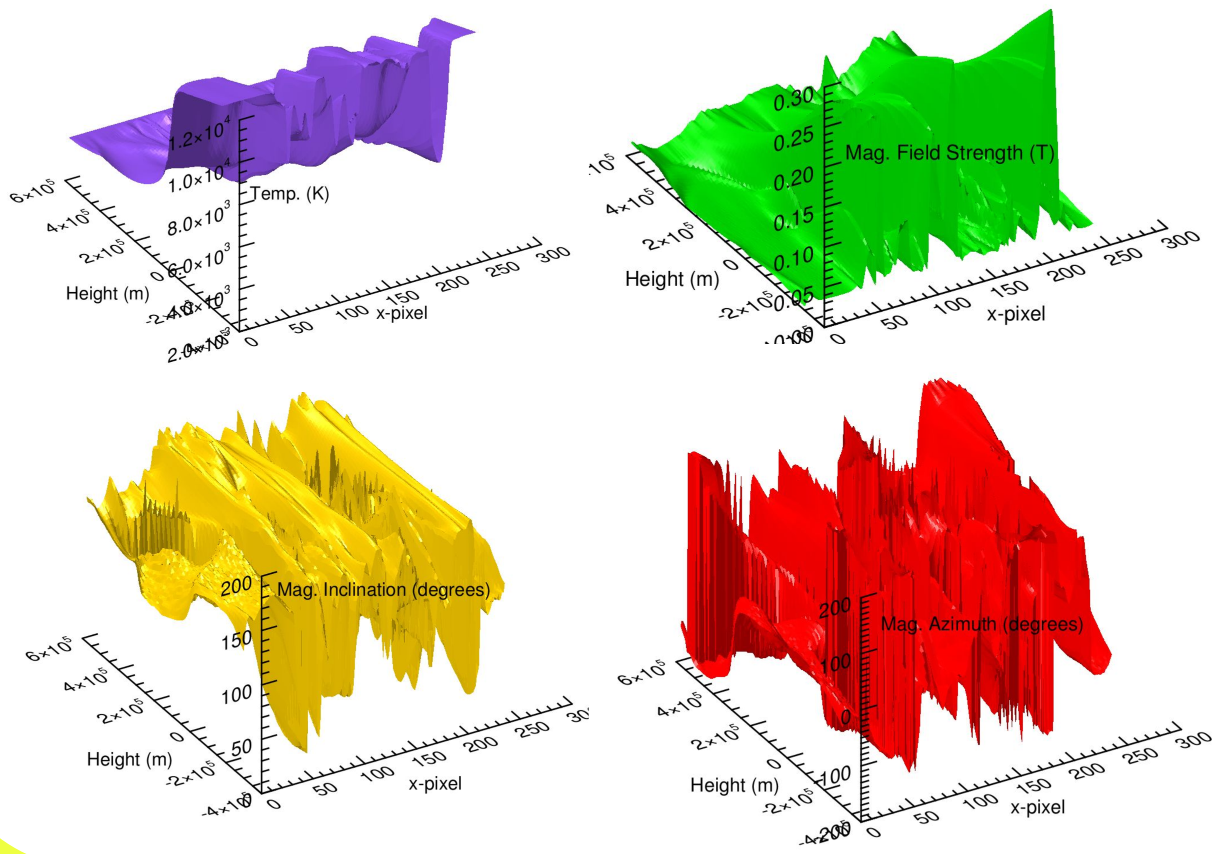


Example of a profile with coarse sampling. The spectral range is from 6300 Å to 6305 Å, sampled every 5 mÅ



Example of a profile with coarse sampling. The spectral range is from 6300 Å to 6302 Å, sampled every 2 mÅ

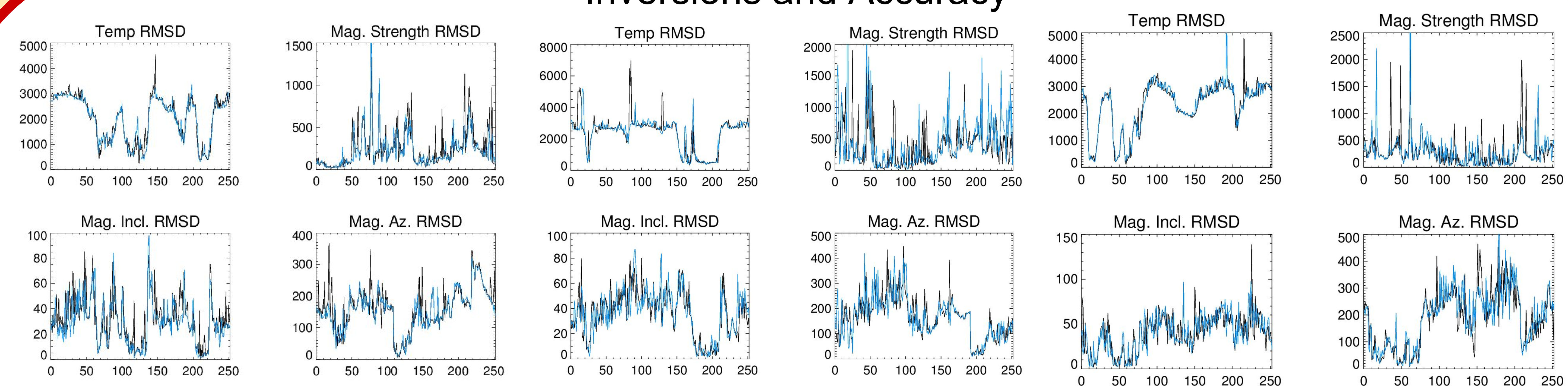
Atmosphere



2D model atmospheres used were created in the STAGGER code. They represent a plage area of the Sun, with an average vertical magnetic field of 250 G. These model atmospheres were used to synthesize Stokes' profiles rather than using observations so the accuracy of the inversions could be tested.

(Stein, R. F. & Nordlund, A.)

Inversions and Accuracy



In black are the RMSD values for the fine sample, in blue are the values for the coarse sample.

Parameter	% Diff	Coarse or Fine?
T	1.62	Coarse
B	9.03	Coarse
γ	10.2	Coarse
ϕ	4.32	Coarse

Inversion 1: atmosphere 1, guess mod. 1, 3 cycles

Parameter	% Diff	Coarse or Fine?
T	0.28	Neither
B	0.74	Neither
γ	0.98	Neither
ϕ	1.33	Coarse

Inversion 5: atmosphere 2, guess mod. 1, 4 cycles

Parameter	% Diff	Coarse or Fine?
T	0.58	Neither
B	6.85	Coarse
γ	2.49	Fine
ϕ	0.86	Neither

Inversion 8: atmosphere 3, guess mod. 1, 4 cycles

There is not a clear distinction between spectral samples. In some situations a fine sampling will be superior and in others a coarse sampling will be better, but there is not yet a way to predict which situations those are. While the coarse sample is more accurate in a greater number of trials, there are not enough trials to indicate absolute superiority. Additionally in most cases the differences between the inversions of fine versus coarse are not significant enough that they should factor into observations. There is no evidence sample type should be chosen based on SIR's ability to invert the profile.

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References

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Stein, R. F. & Nordlund, A. 1998, ApJ, 499, 914. <http://comp.astro.ku.dk/Twiki/view/CompAstro/StaggerCode>