Data Assimilation in Solar MHD for Dummies

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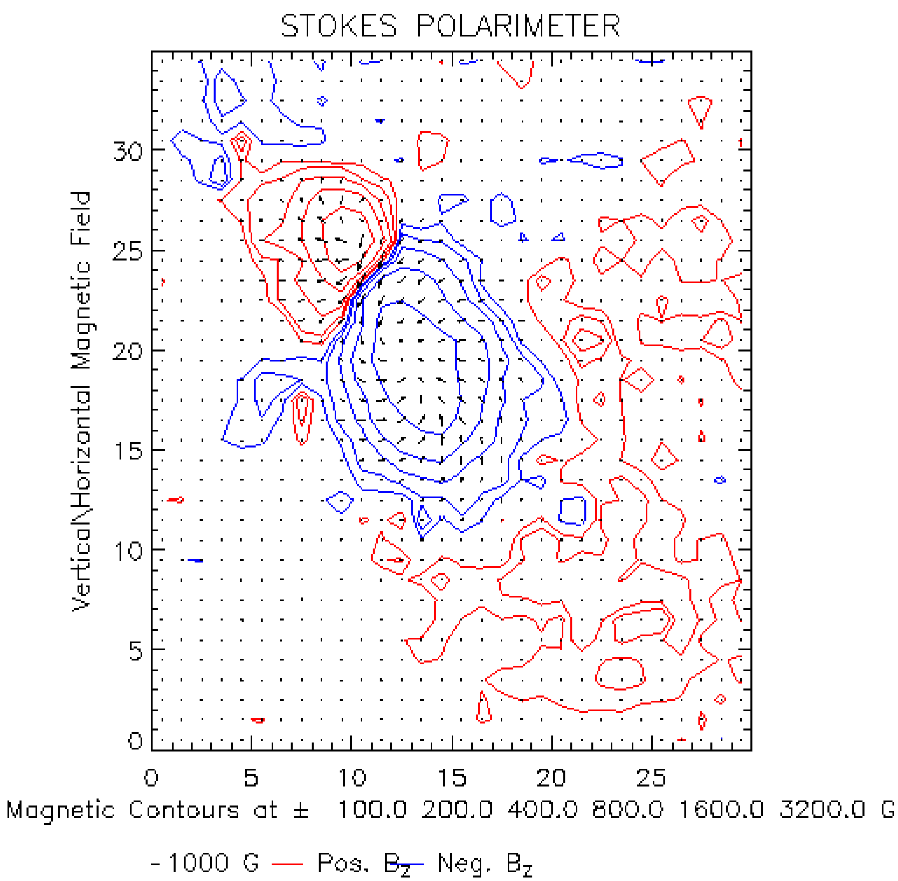
- Goal: Be able to understand magnetic field evolution well enough to predict the evolution of coronal structure from observed photospheric field evolution.

Issues

- Evolution of solar corona probably controlled by evolution of magnetic fields at and below the photosphere
- Must now find a way to incorporate vector magnetogram observations into time dependent MHD codes
- In future need to incorporate coronal magnetic field and X-ray data

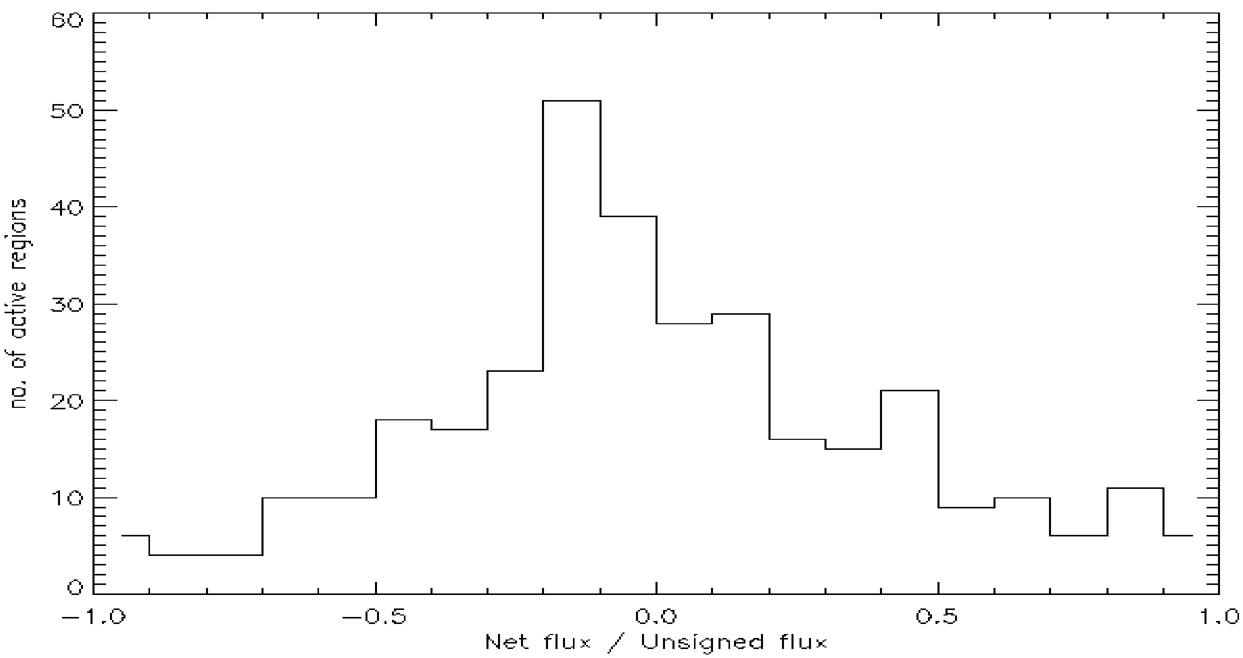
Example: vector magnetogram of a δ-spot active region



- Can measure vertical (contours) and horizontal (arrows) components of magnetic field in the photosphere

Problems with vector magnetogram data:

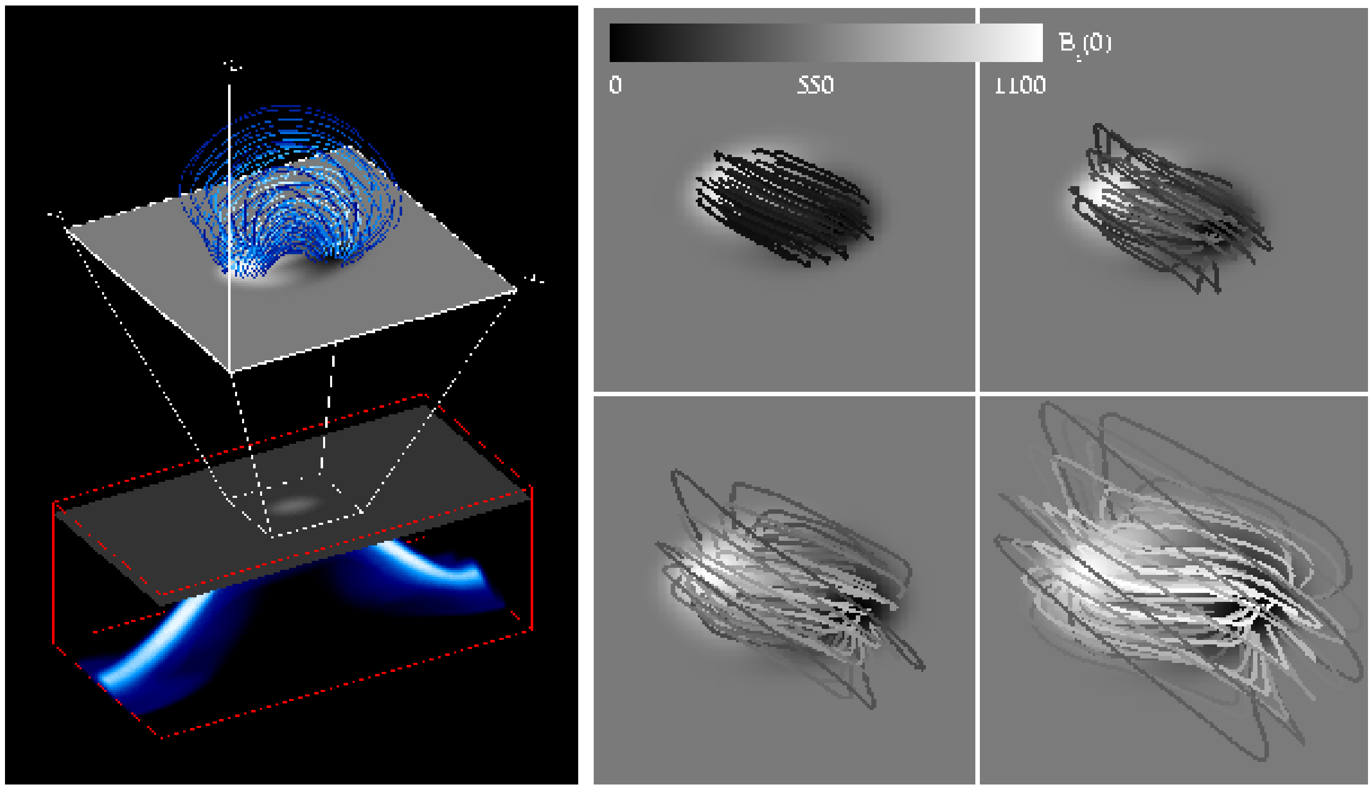
- Measurements of transverse field are noisy
- Hard to resolve the 180º ambiguity
- Coverage frequently incomplete in time, space



Problems with models:

- Don’t really understand physics at photosphere – is ideal MHD reasonable?
- Models require knowledge of depth gradients in magnetic, thermodynamic, and dynamic variables, but observations won’t give us this

One Difficulty: MHD solution requires **B** and **v** on lower boundary



But don’t generally get **v** from magnetograms.

Relationship between **B** and **v**:

$$\frac{\partial \mathbf{B}}{\partial t} = -\frac{1}{c}\nabla \times \mathbf{E}$$

$$\mathbf{E} = -\frac{\mathbf{v}}{c} \times \mathbf{B} + \eta \mathbf{J}$$

- Assume ideal MHD applies at photosphere:

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times \mathbf{v} \times \mathbf{B}$$

- Back out **v** from measurements of **B** and $\frac{\partial \mathbf{B}}{\partial t}$.

A trivial example - simple advection:

Assume that $\mathbf{v} = \mathbf{v}_h$ and that $\mathbf{B} = B_z\hat{\mathbf{z}}$.

Also assume that there are no gradients in the vertical direction, and that $\mathbf{v}_h$ is uniform. The ideal MHD induction equation then reduces to:

$$\frac{\partial B_z}{\partial t} + (\mathbf{v}_h \cdot \nabla) B_z = 0.$$

Here, $\mathbf{v}_h$ is over-determined.

From a time sequence of images of B_z, estimates for $B_z(x,y,t)$ can be obtained, allowing for e.g. a least squares solution for $\mathbf{v}_h$.

The full problem involving all 3 components of the magnetic field, and attempting to find the self-consistent velocity field, will be considerably more challenging.

A plan for MHD model tests with real data

- Get good series of vector magnetogram observations of isolated, emerging flux regions (simplest real, nontrivial physical system)
- Use vector magnetogram data to drive coronal MHD code
- Compare magnetic field evolution with EUV, X-ray evolution of corona in EFRs