

3D Sun Loop Trace: A Tool for Stereoscopy of Coronal Loops for STEREO

Paulett Liewer

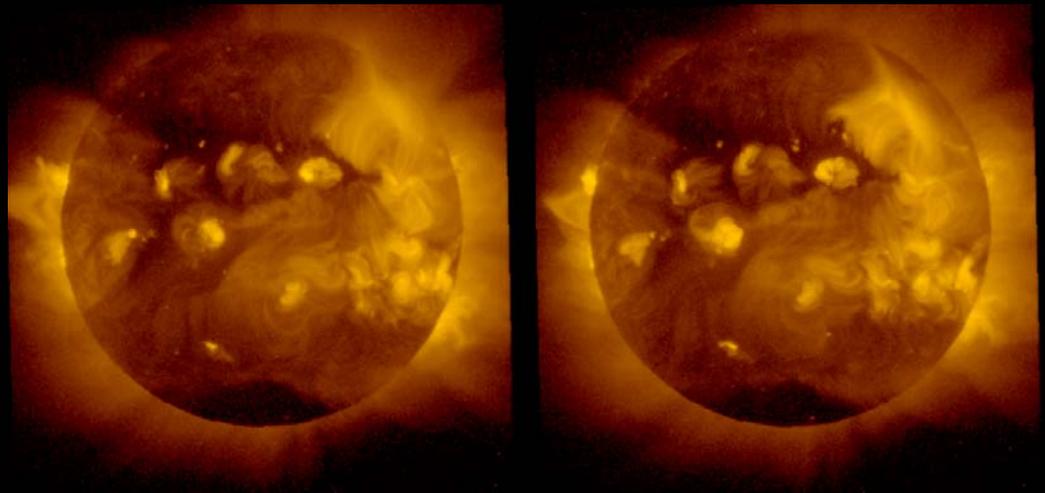
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Abstract

Stereoscopy and triangulation can be used to determine the three-dimensional geometry of coronal loops seen in simultaneous images from the two STEREO spacecraft. Here we demonstrate a new tool, 3D Sun Loop Tracer (3DSLTL), which uses stereoscopy to determine the 3D structure of a loop that can be identified in both images. SLT proceeds in several stages. First, the user "seeds" the tool by selecting the same loop in the two images of a stereoscopic pair. Next, the tool uses loop tracing algorithms and triangulation techniques to obtain the three-dimensional (x,y,z) coordinates of points on the loop. The tool has been developed and tested using a physics-based synthetic 3D coronal model (K. Schrijver, private communication). The tool has been shown to produce accurate results for loop reconstruction over a wide range of stereoscopic (separation) angles. The goal is to use this tool to analyze the evolution and stored magnetic energy in loops observed by the EUV instruments on the STEREO spacecraft. Once the loops have been reconstructed in 3D, they can be compared to non-potential magnetic field line extrapolations. In the future, we plan to incorporate a magnetogram-based magnetic field model and implement a procedure for adjusting the parameters of the extrapolation to match the reconstructed loops. In this way, the evolution of the stored magnetic energy can be determined.

Synthetic Corona Data Set

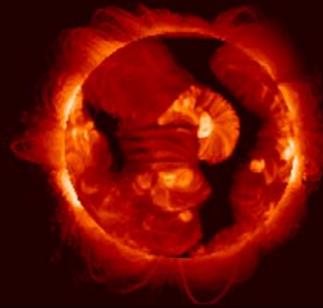
Used synthetic corona data from *Schrijver et al*
(*Ap J* 2004)

360 views of the synthetic corona - 1° spacing

0°



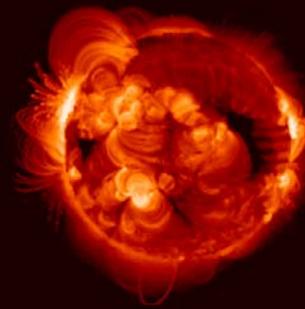
15°



45°



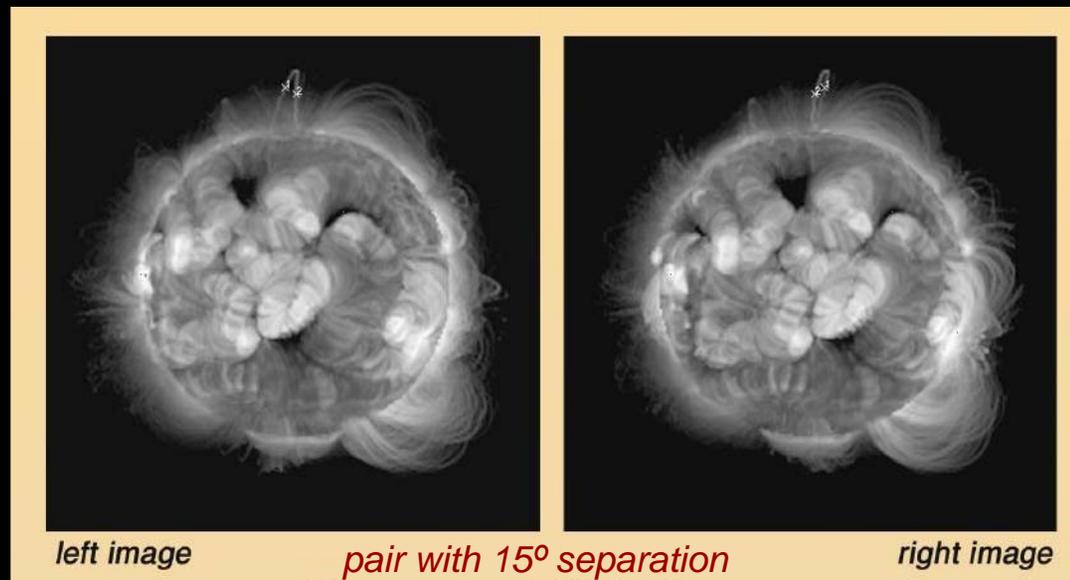
90°



Used different "pairs" to study reconstruction for
different stereo separation angles

Step 1: Select the loop in both images

User selects 'seed' points on the same loop in each image of the stereo pair using a cursor.



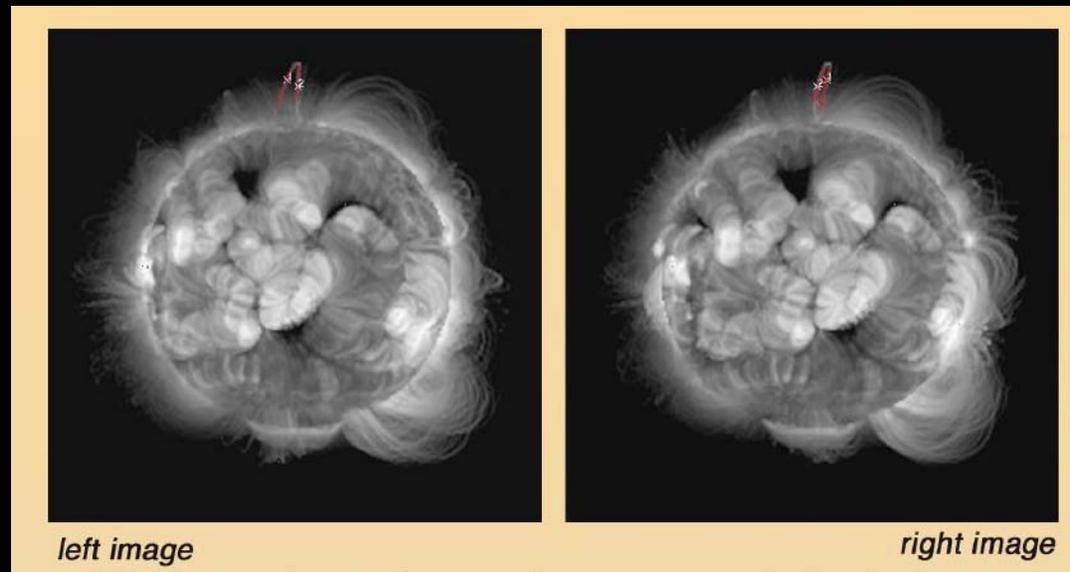
Seed points can be anywhere on same loop segment

Here we show 2 selected seed points - "up" and "down" segments of the loop selected separately

Step 2: Trace and Solve

Run the SUNLOOP algorithm to trace loop segments in each image and run XYZSUN to solve for 3D solar coordinates of points along the loop.

Loop coordinates are also written to an ascii file.

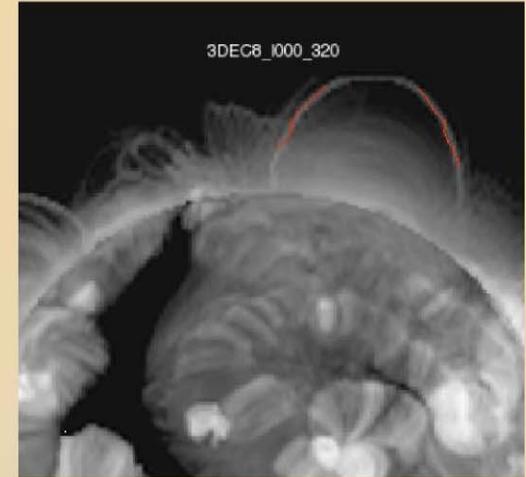
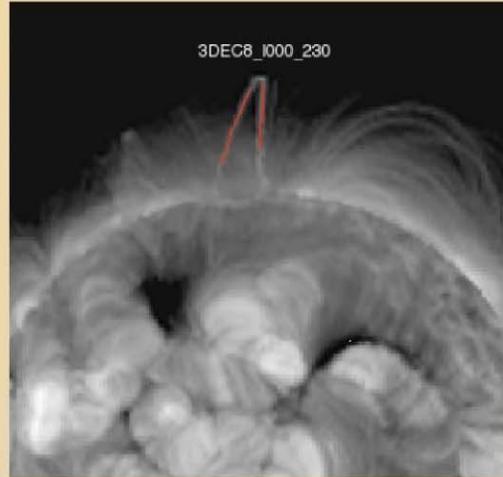


Red segments show reconstructed loop displayed on each image of the original stereo pair

Step 3: Verify Results



rotated -45 degrees



rotated +90 degrees

Display results from different viewpoints by rotating Sun in interactive viewer window (see demo). Red reconstructed loop segments are now compared to views not used in the reconstruction.

For -45° and 90 °, reconstructed loop segments lie on the actual loop, verifying the reconstruction.

Method for loop tracing

Sunloop uses triangulation to compute x, y, z coordinates (in the solar coordinate frame) and latitude & longitude information of a feature for a stereo image pair with known camera model.

The following steps are performed in tracing a loop:

1. Beginning with the user's seed points, the program searches a small area to locate the best quality point centered upon the loop. It prefers bright filaments but can also be configured to follow bright edges and other linear features.
2. Local direction (orientation) of the loop is calculated.
3. It then searches again in the direction of the loop for the best next quality point, and computes the new direction.
4. If that point passes the tests it is added to the segment. If not then growth stops in this direction.

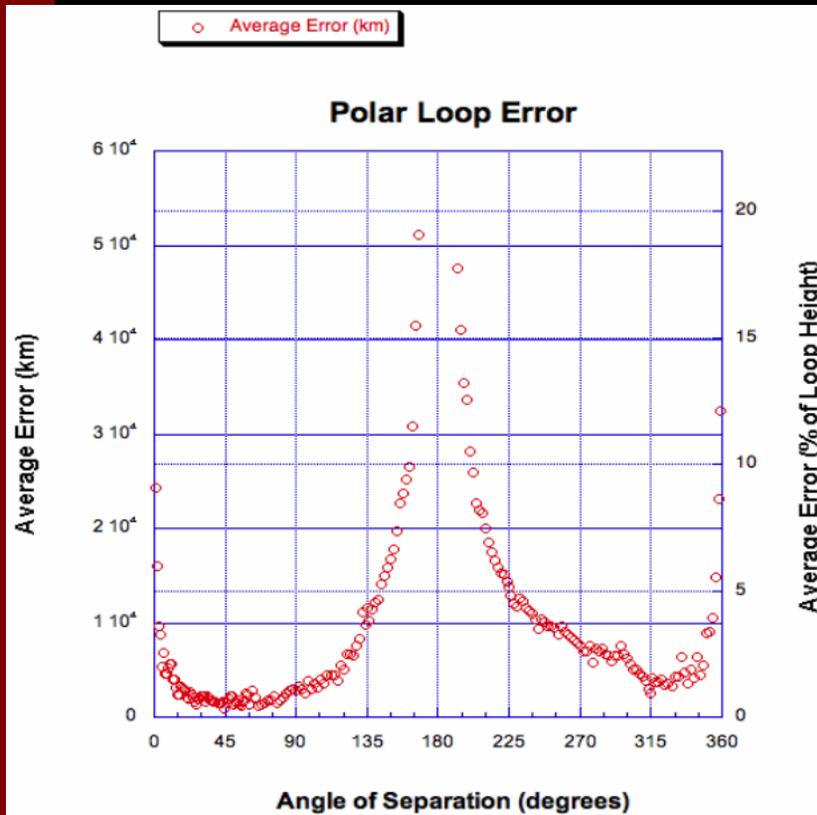
Method for finding 3D coordinates

The following steps are performed in determining the 3-d coordinates of points on the loop:

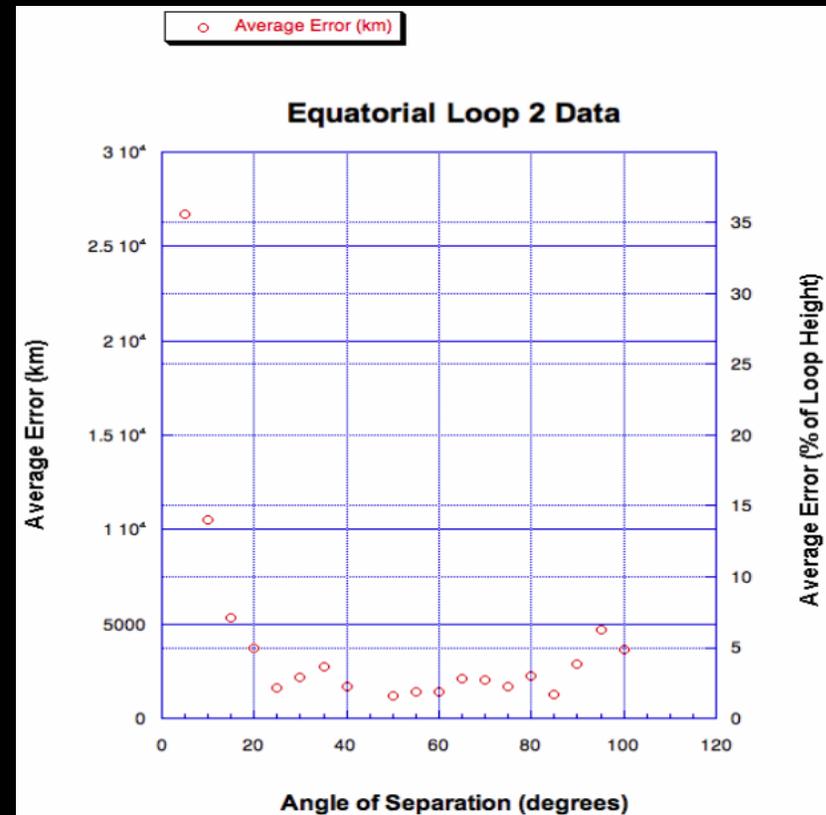
1. The ray vector for each point in the left profile is compared with the ray vector for every point in the right profile to generate an error (the miss distance of the two vectors).
2. The right point with the smallest error is, with its 2 neighbors, used to estimate the line where the vectors cross. We use a quadratic model which gives results good to about 1/10 pixel.
3. The sample value of this line is computed from a spline model of the right profile.
4. The left point and the new sub pixel right point construct vectors which cross at the solar xyz value of interest.
5. This cross point (the 3D location) is written to the output file.

Results for Reconstruction Error

Good stereoscopic reconstruction is possible over a wide range of separation angles

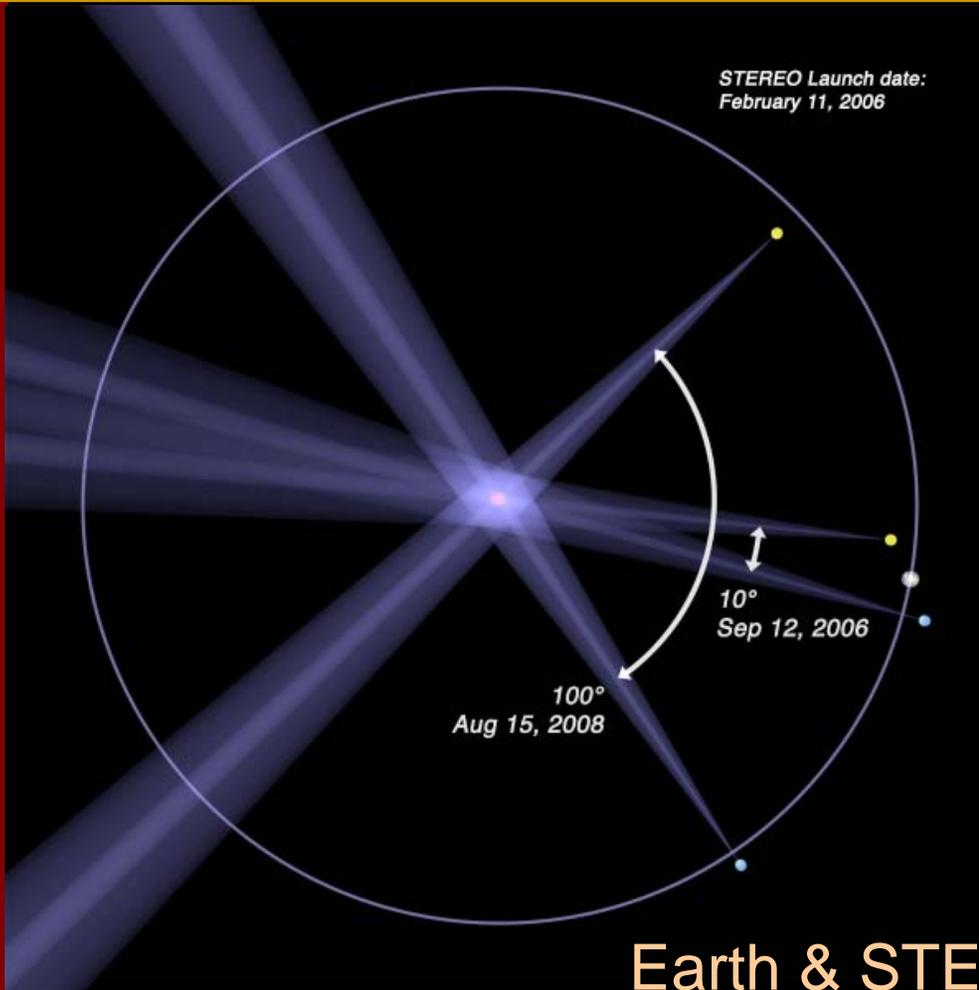


Error vs. stereo angle for polar loop (shown)



Error vs. stereo angle for an equatorial loop (not shown)

STEREO Angular Separation



Earth & STEREO spacecraft for separations of 10° and 100°

Summary

- Developed tool for 3D reconstruction of loops from STEREO / SECCHI pairs
 - Uses automatic feature tracking to trace loop segments in each image
 - Limited to cases where the same loop can be identified in both images
 - Limited to vertically oriented features due to horizontal stereo ambiguity
- Tested on SXT Virtual Corona dataset, courtesy K. Schrijver et al.
 - We find that it works over a broad range of separation angles of about 10 to 100 deg.
- Plan to make program available in IDL/SSW for the STEREO mission