Preliminary Results: Inflows in the Solar Corona

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Mapping Regions of Inflows over Long Time Periods:

A suitable method of mapping positions of inflows over long time periods was to find the position and extent of inflows, over a period of 3 months from 3 different years that coincided with Solar Maximum and Minimum (for comparative purposes), or as near to as possible. The years selected are 2000 and 2013. The images used to detect the inflows and catalogue them, are from Dr Huw Morgan's recent research and can be seen in figure 1.4.

Position Angle and extent (Minimum and Maximum) are calculated from these images in an anti-clockwise direction with 0^o being taken in the vertical.

This was carried out in an attempt to find whether the events being observed were persistent features (Sourced on the surface) and not just sporadic events that lead on from spontaneous conditions within the corona. It was suspected that the former was more likely and analysis of the data confirms this.

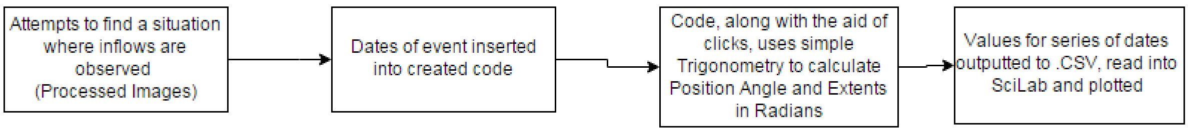

Figure 1.1 – Flow chart outlining the method of obtaining Figure 1.2.

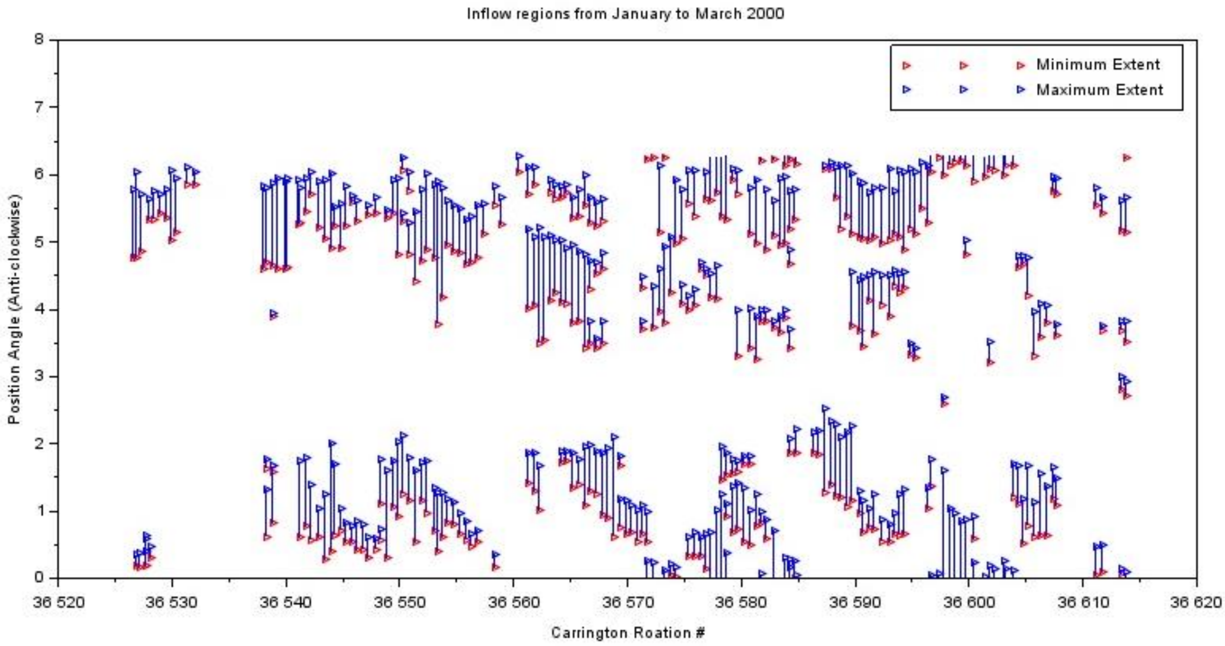

Figure 1.2 – Example map of the results for year 2000, months Jan to Mar. Note the repeated pattern between the pair of Carrington Rotations 36560 and 36570 and the next pair 36585 and 36595 on the western limb (3 < Position angle < 6). The upper feature (average position angle ≅ 5.5) grows over the course of a solar rotation and the lower feature (average position angle ≅ 4.4) shrinks / dissipates.

Distance – Time Analysis:

After compiling a catalogue of promising events, at this point it was necessary to ensure the events viewed were not an illusion of the eye, given the nature of these inflows being very faint and easily indistinguishable in the background plasma motions.

Wang and Sheeley previously used Distance – Time Analysis to bring out the motions of the plasma in regions close to the inner FOV of LASCO C2, A near exact method to this has been used to create tracking of inflows further out than before yet still works for lower coronal events.

This method is completed through the use of both short and long time scales. Taking user defined points, a written IDL code cycled through a specified time period and recorded the pixel values of the post-interpolated chosen points (8 initial then interpolated to 100 points) through each image within the specified time frame. The pixel values are then stacked with increasing time to provide crude motion tracking of the plasma along the chosen 8 points.

"Streaks" that move to the left or to the right of the image are movements of plasma either in the direction of the inner FoV (movements to the left) or vice versa.

As can be seen in the sample image in Fig 1.4, at least 3 inflows can be clearly seen. It is now clear that the inflows are physical phenomena and not just illusions caused by the eye.

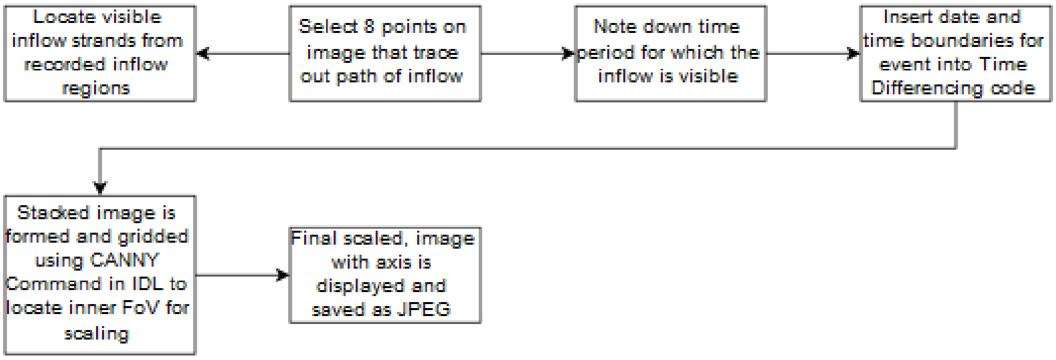

Figure 1.3 – Flow chart for coding method for Time Difference Images.

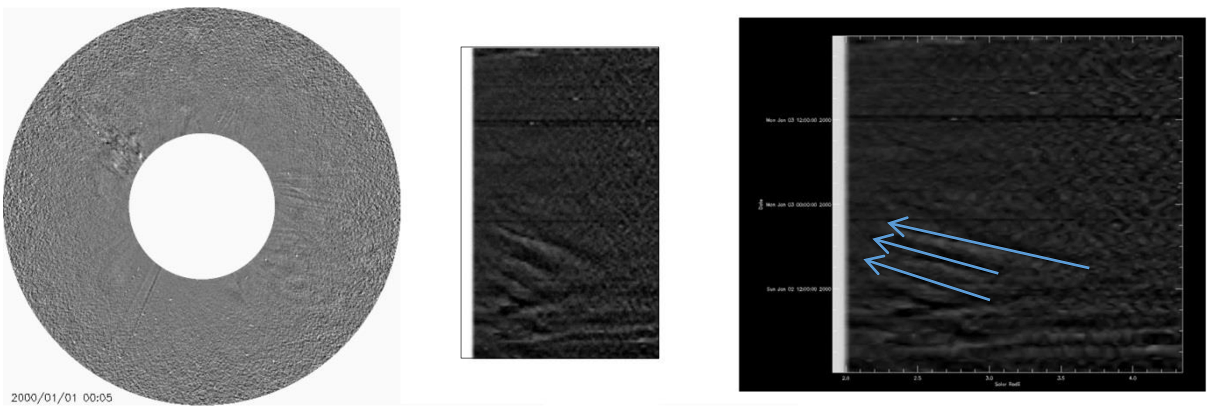

Figure 1.4 – Typical input and output of the code used for Time Differencing. (Left) Starting image on which inflows are seen and recorded post image processing carried out by Dr Huw Morgan. (Middle) Output of first part of code, CANNY is carried out on this image to locate inner FoV. CANNY draws a skeletal image based on high sudden changes in pixel value (between black and white). (Right) Final output image scaled to Solar Radii and Days. Inflows have been highlighted in the right hand image for ease of identification.

Measuring Kinematics of "blobs":

The next investigation revolved around ascertaining kinematic properties of the plasma that is seen falling towards the inner FoV. For this, the shapes of the inflow tracks underwent Bootstrapping interpolation to provide 2 equations of motion that were, in turn, used to isolate velocity and acceleration profiles of the "blobs".

Bootstrapping uses a logical test to reduce the distance between each point and a theoretical line of best fit through many iterations of the logical test. It works for as many degrees of freedom as are specified, of which for the context of this investigation were limited to 2 (Velocity) and 3 (Acceleration)

The results for velocity matched the values stated by Wang and Sheeley i.e. of the same order of magnitude. Interestingly, after measuring 42 events, it's clear to see from Figure 1.5 that there is a preferential speed of lower than $23kms^{-1}$.

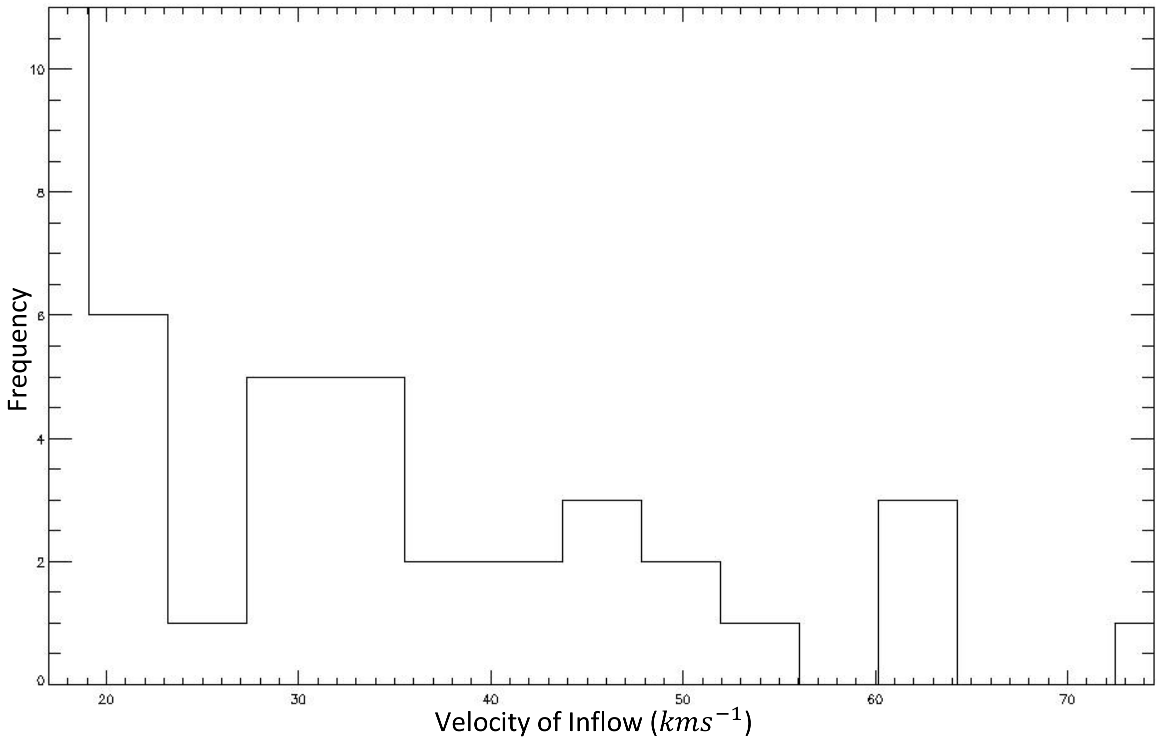

Figure 1.5 – Average velocity for the measured 42 inflow events. A clear preference can be seen here that the velocity of inflows are more likely to be below 35 kms^{-1} with the highest band being between 17 and 19 kms^{-1}, though it is likely that the sample size is still too small to draw this conclusion definitively at between 17 and 19 kms^{-1}.

The second subtask used the 3 degrees of freedom within the bootstrapping technique to isolate an average acceleration / deceleration for the inflows. These values differed slightly to the values that were stated by Wang and Sheeley ($\sim 6.5ms^{-2}$) though still of the same order of magnitude and can be seen in figure 1.6.

It is believed that the reason for this difference in values is due to the results by Wang and Sheeley being consequence of a model that allows for a changing acceleration whereas the present model used here allows only for a constant (average) acceleration.

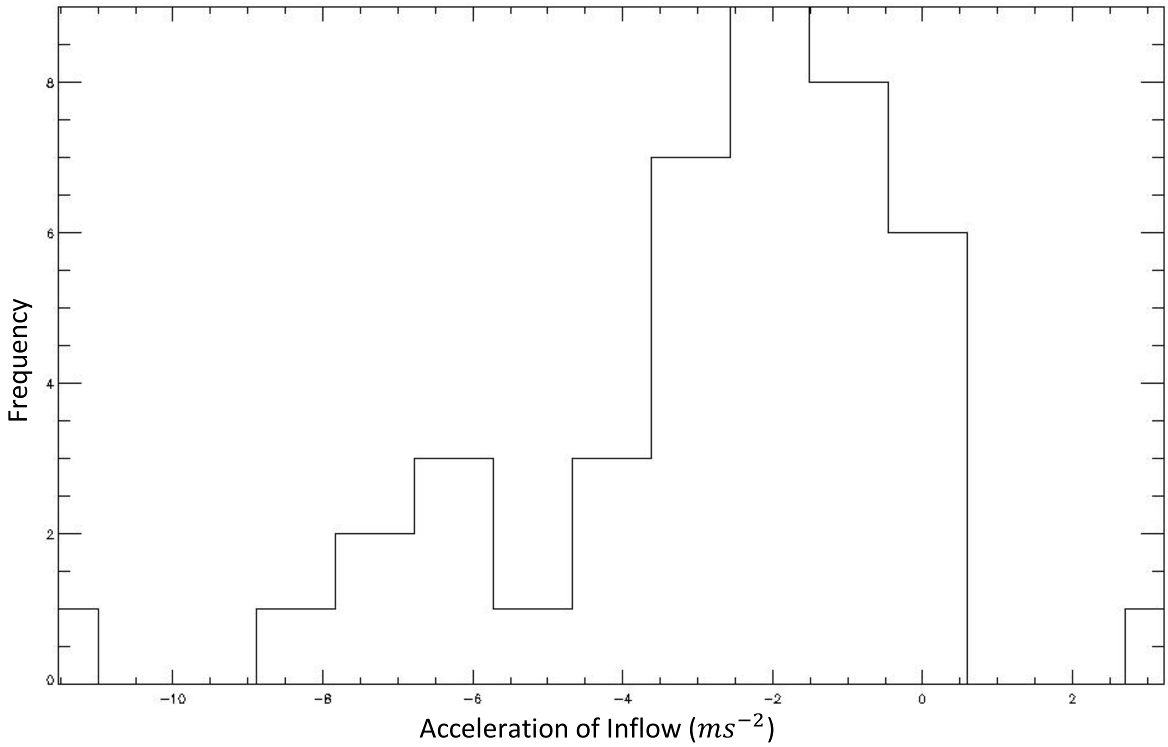

Figure 1.6 – Average acceleration profile for the 42 recorded inflow events. This trend takes account of inflows from multiple heights in the corona, this explains the large variance in the averages seen. A preference of between -0.5 and -2.5 ms^{-2}. The negative describes the deceleration as opposed to acceleration. It is interesting that accelerating inflows are being seen according to this model.

In conclusion, the results obtained so far match that of previous research, giving confidence that the methods used are adequate and suitable for further study. The results have been surprising concerning the trends shown. Only 42 events have been recorded using these new methods yet loose conclusions can be drawn on their observed behaviour.

Points for further study include the expansion of the acceleration model to include a further degree of freedom to study whether the inflow accelerations / decelerations change over time. Given their path in the time difference analysis, this is something that is to be expected. The next main task, however, will be to locate these inflows in instruments that have a higher spacial and temporal resolution for finer analysis of the properties outlined in this summary. This will enable a more comprehensive understanding of the nature of the inflows in the low corona environment.

Currently there is no craft that is capable of the high resolution that SDO has and also extends to $2.2R_{\odot}$. However the SWAP instrument aboard PROBA2 could enable some extended analysis of anything recorded in the SDO images due to the wider FoV ($2R_{\odot}$), though the spacial resolution may prove to be inadequate.