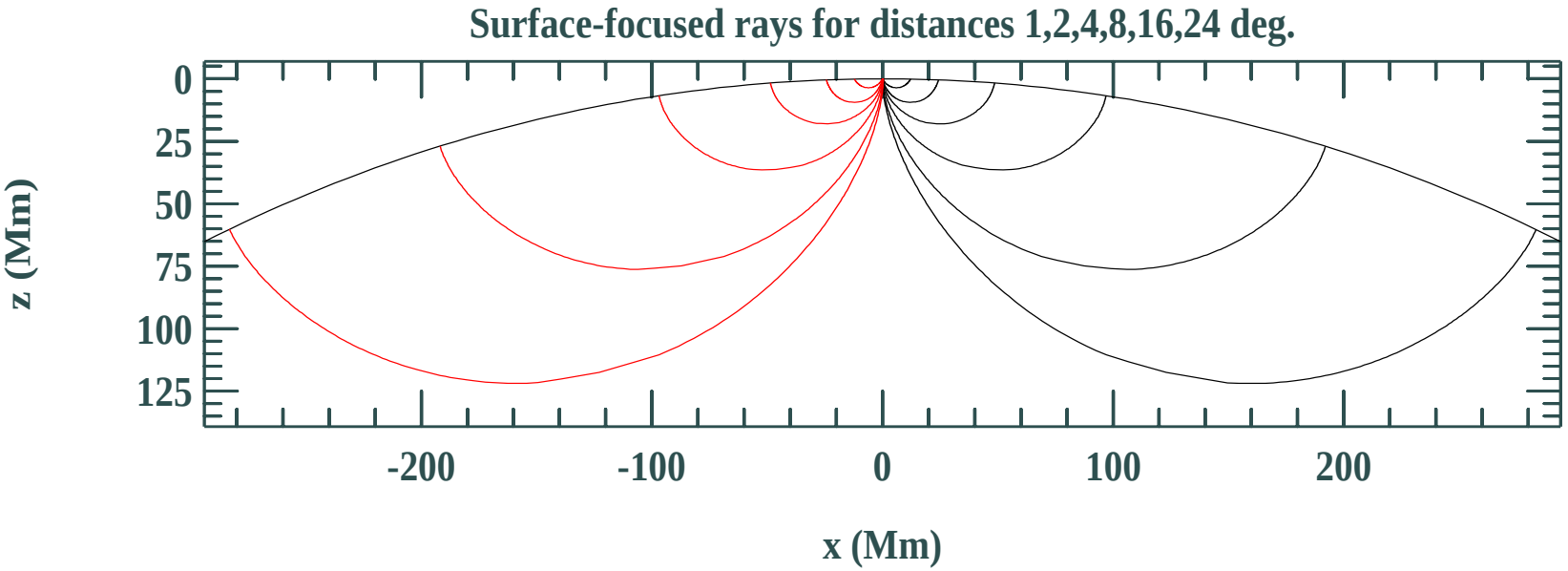
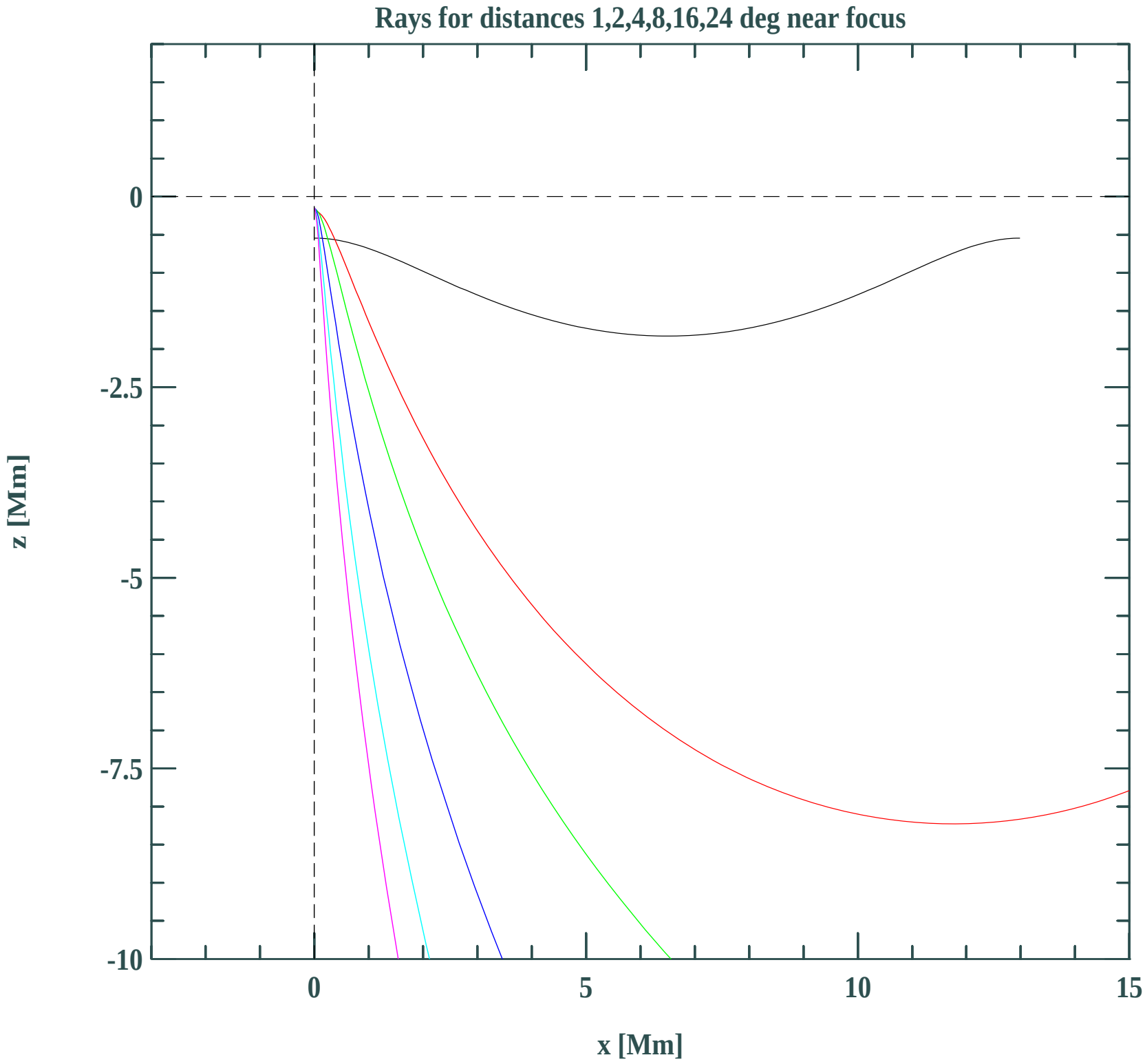
Subsurface Supergranular Vertical Flow Using Large-Distance Time-Distance Travel Times

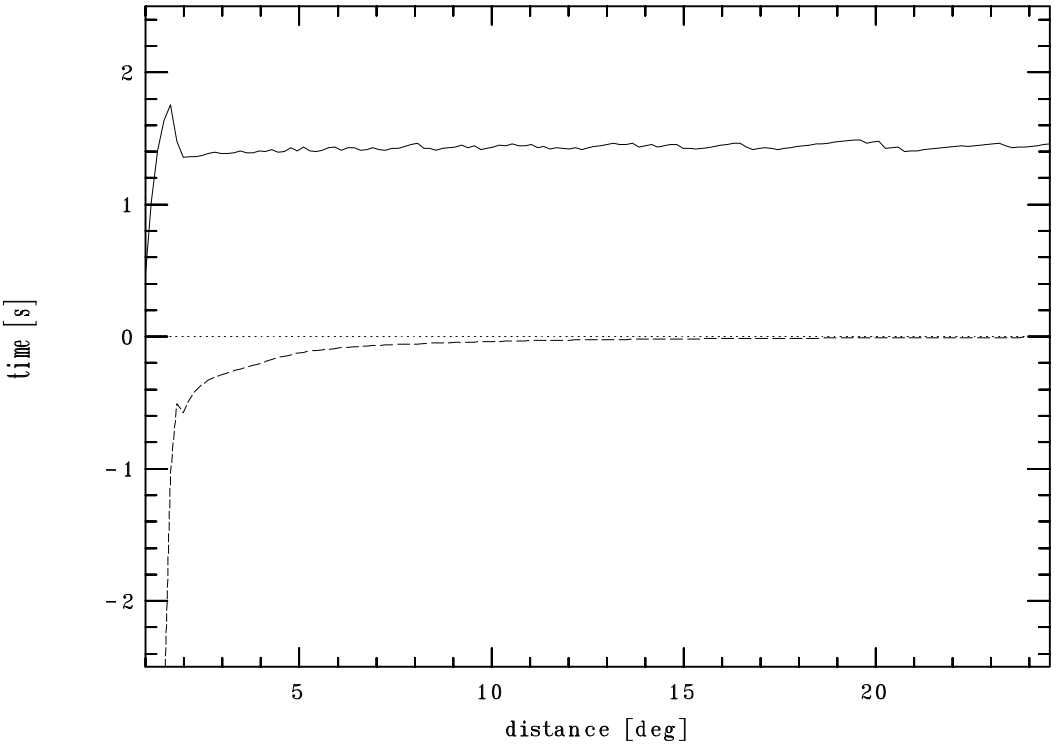
Tom Duvall
NASA/GSFC

- It might be useful to observationally separate the effects of vertical and horizontal supergranular flows. In principle this can be done using large-distance travel times as the rays for large distance are nearly vertical in the first few Mm below the surface.

Range of rays used in the analysis.

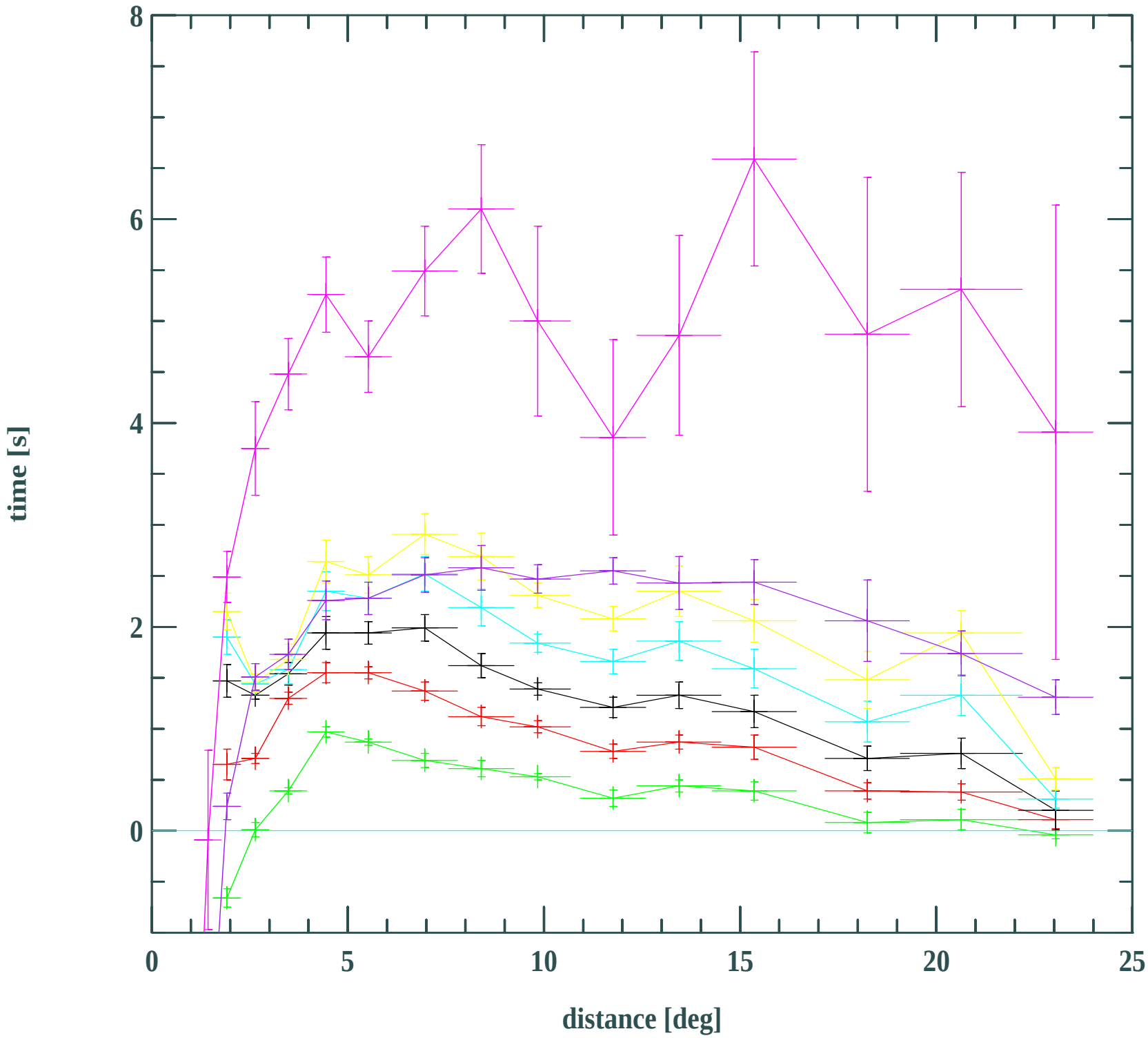


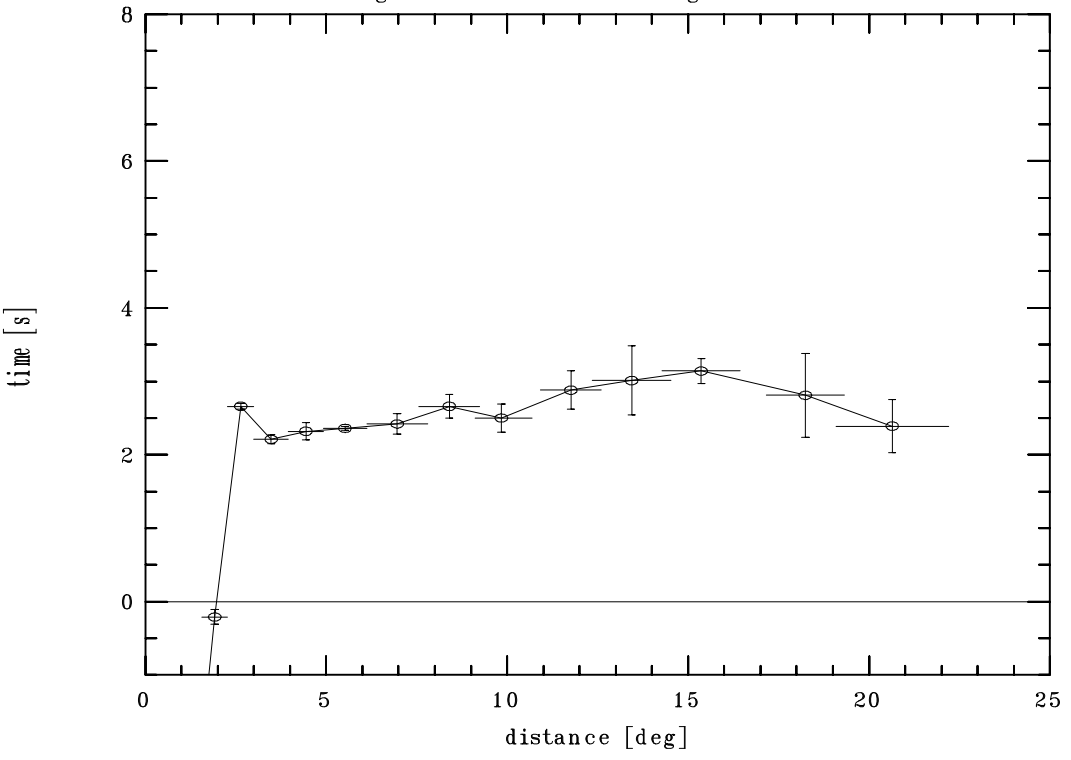

Rays for distances 1,2,4,8,16,24 deg near focus
0
-2.5
-5
-7.5
-10
z [Mm]
0
5
10
15
x [Mm]

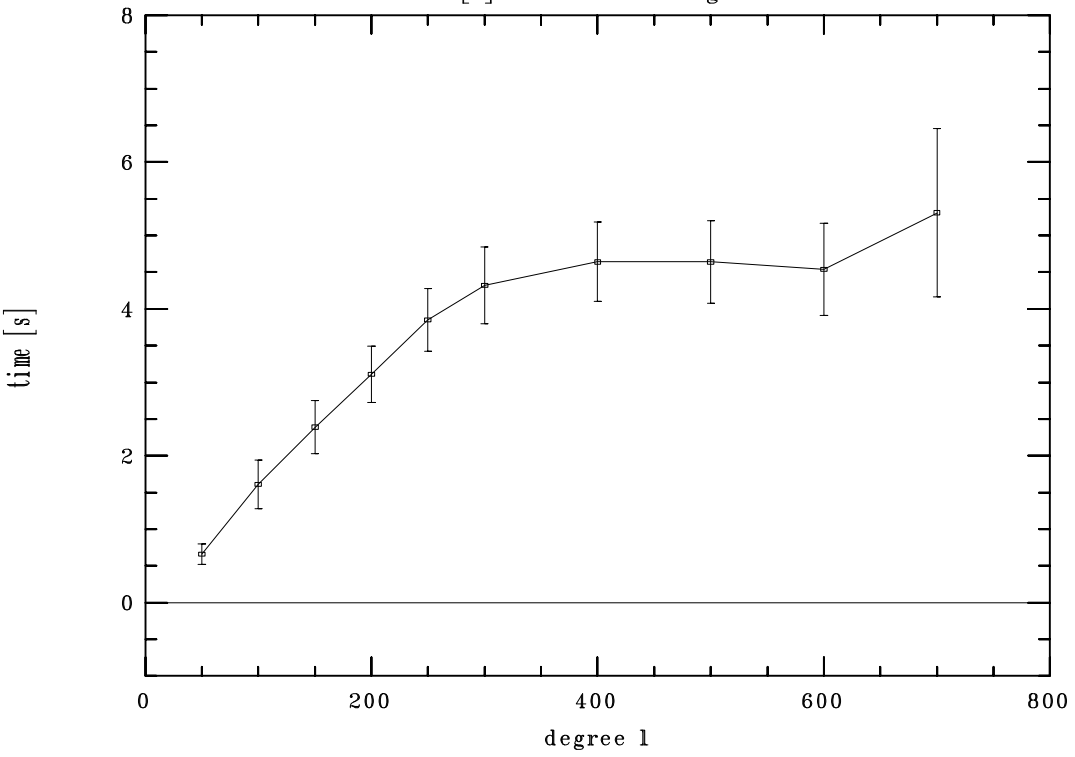

travel times for vertical(solid) and horizontal(dashed) models
time [s]
2
1
0
-1
-2
5
10
15
20
distance [deg]

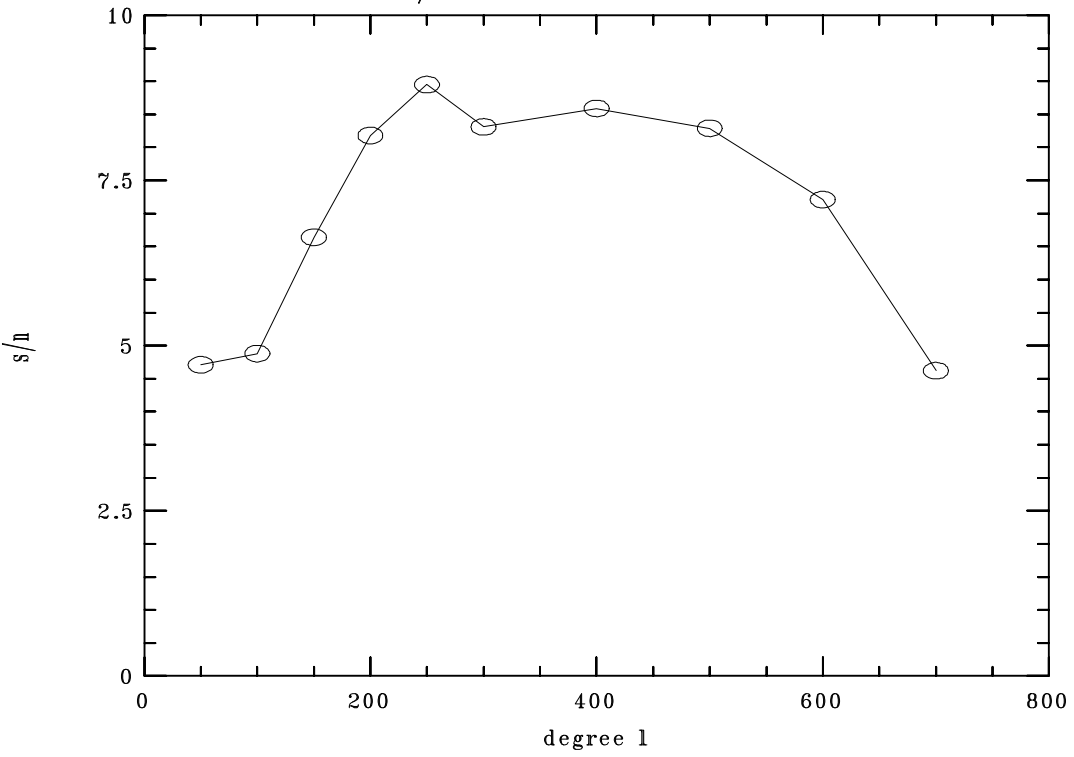
Analysis

- Tracking: HMI Doppler images interpolated onto a .03 deg latitude-longitude grid using linear interpolation. These 4800x4800 images are Fourier-filtered with a 2-d cosine bell (in k space) to kill power above the nyquist degree of 1500 (the nyquist for MDI full-disk data). After the Fourier filter, the images are binned 4x4 to .12 deg per pixel. At a later stage, the images are binned again 2x2 to .24 deg per pixel. Most of the large-distance analysis was done with the .24 deg sampled data.
- Supergranule location: First an f-mode analysis is done to 'find' the supergranules. Maps of the travel time difference between the inward-going waves and outward-going waves from a central point to an annulus yield a signal proportional to the horizontal divergence. Local peaks in this signal define the location of the centers of the supergranular cells. Six 12-hour intervals were analyzed yielding 3500 supergranules to use.
- Flow measurement: Various filters are applied to the data cubes and travel times are measured for the 'divergence' signal for point-annulus separations of 1-24 heliocentric degrees. The average signal at the centers of the 3500 supergranules is measured.


8
6
4
2
0
time [s]
0
5
10
15
20
25
distance [deg]


oi signal vs. distance for degree fwhm=150
time [s]
distance [deg]
8
6
4
2
0
0
5
10
15
20
25


oi travel time [s] at dist=20.64deg vs. filter fwhm
time [s]
degree l
0
2
4
6
8
0
200
400
600
800


s/n ratio vs. l fwhm of filter
10
7.5
5
2.5
0
s/n
0
200
400
600
800
degree l

Conclusions

- Using large distances is an effective way to separate the vertical and horizontal supergranular signals.
- The standard phase-speed filters are NOT useful in the measurement of these flow signals.
- The amount of supergranular vertical signal measured at different distances and with different filters depends on the l-width of the filter (a hypothesis that needs to be demonstrated).
- The 4-5 [s] travel time difference signal measured for the vertical signal with very little filtering is larger than we might have expected from the photospheric ratio of horizontal to vertical flow.
- We might need to rethink how flow measurements are made. As it stands now, the different filters have different responses to flows which I don't believe is taken into account by ray theory inversions.