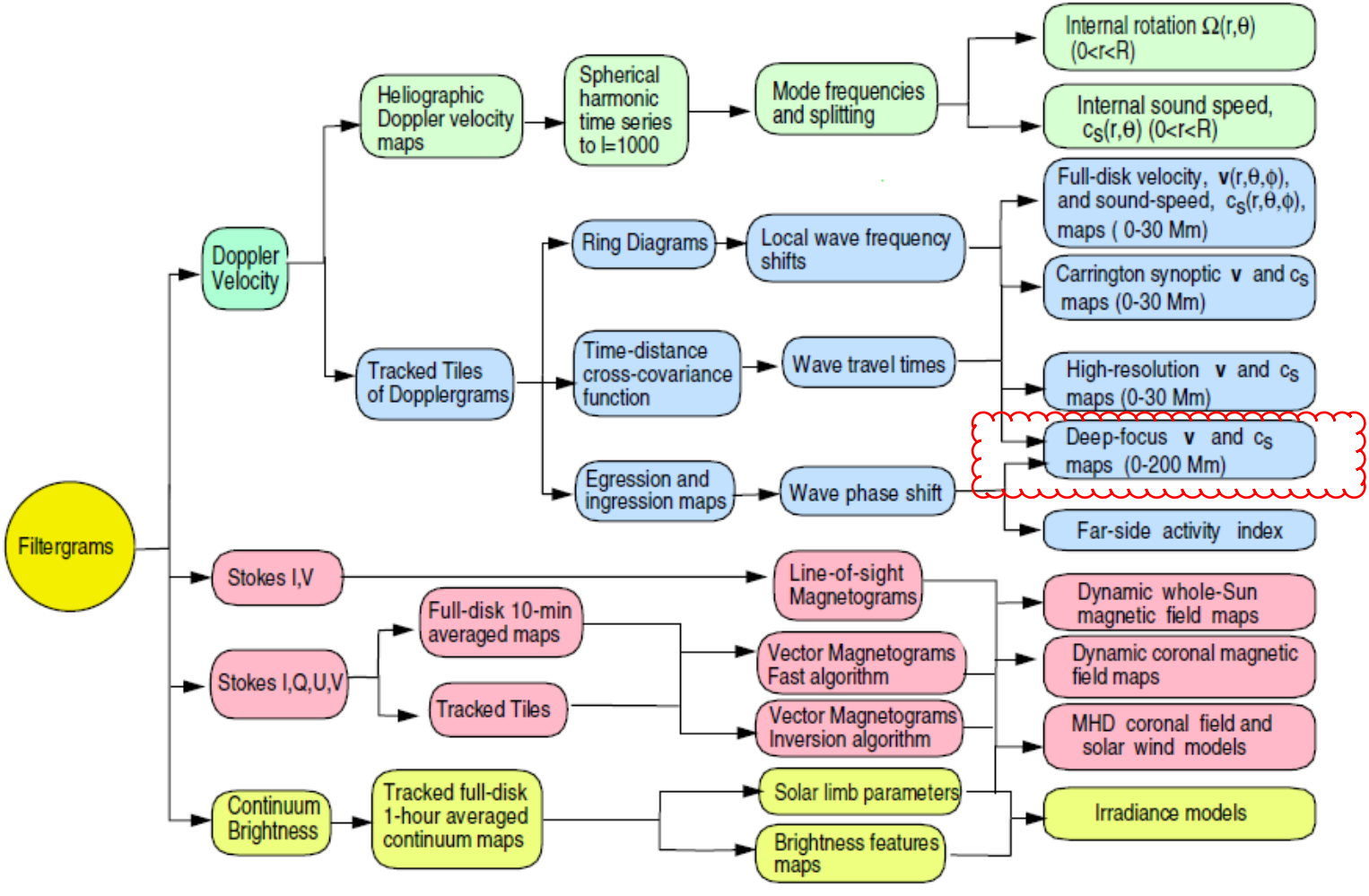
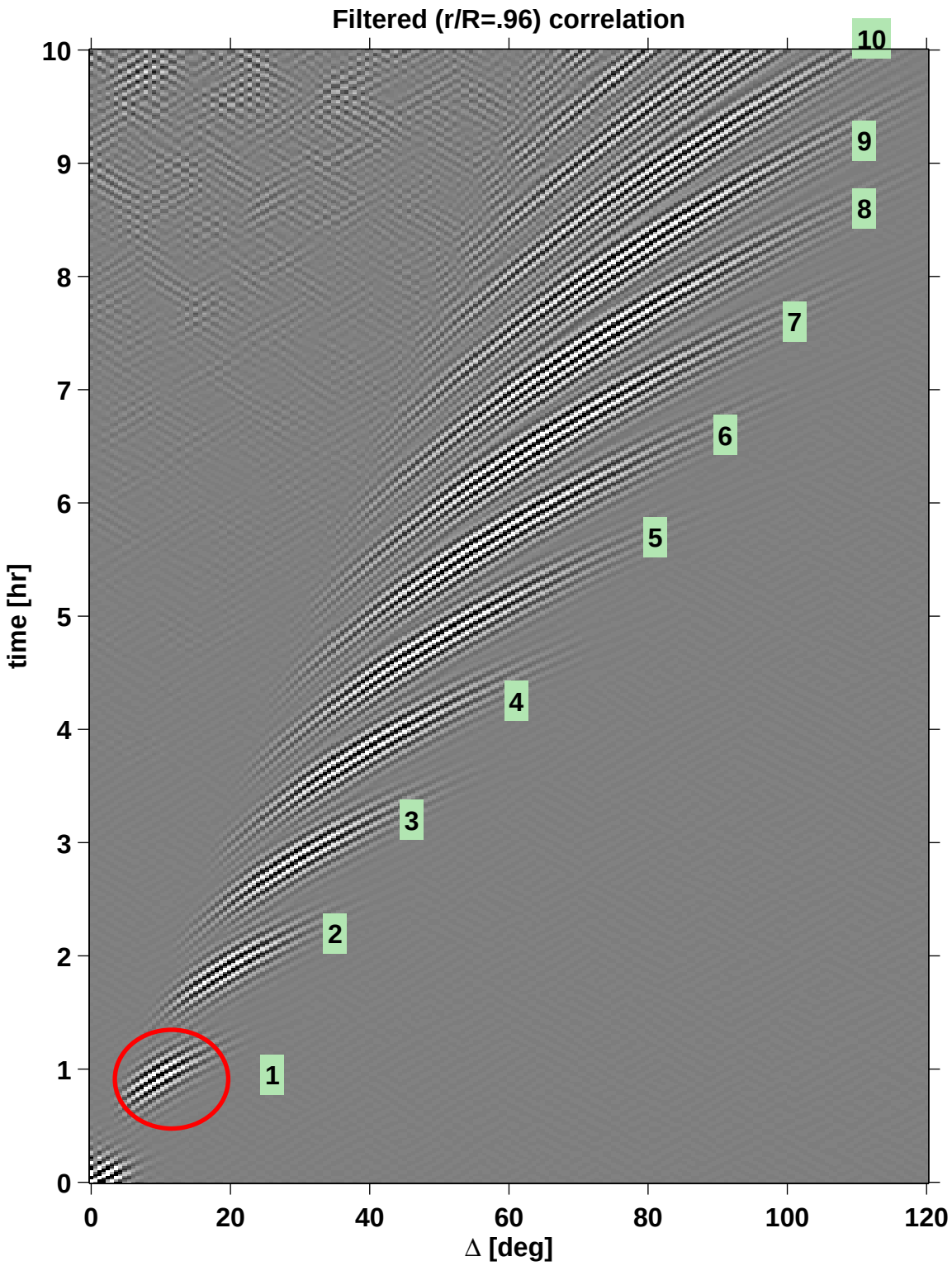
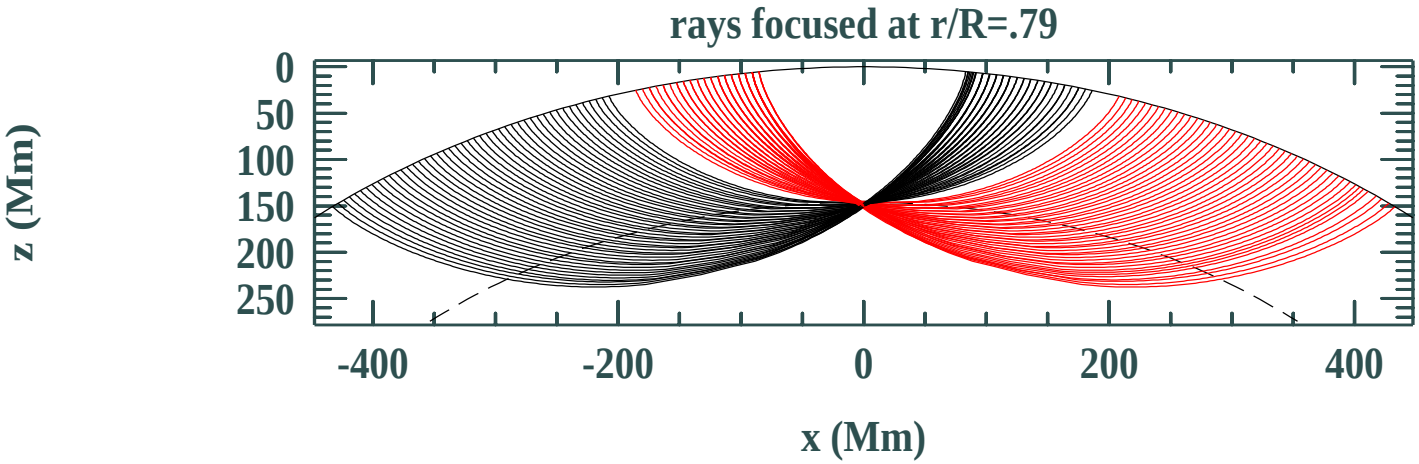
What good are multiple bounces, anyway?

Tom Duvall

1.L - HMI Data Products




Filtered (r/R=.96) correlation
time [hr]
Δ [deg]
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120


rays focused at r/R=.79
z (Mm)
0
50
100
150
200
250
-400
-200
0
200
400
x (Mm)

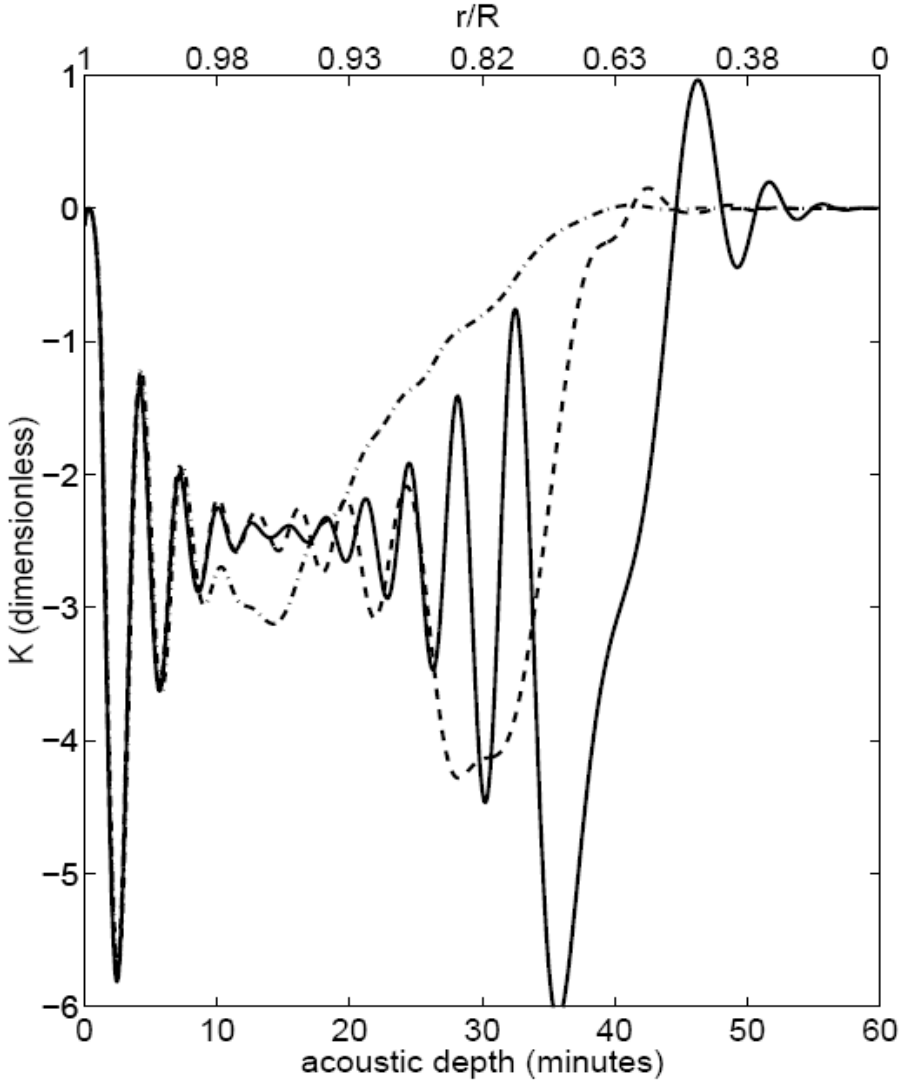


Figure 4.13: Deep-focusing travel-time kernels, $\tilde{K}$, for sound speed. The solid line is for a focus depth of $0.65R_\odot$(39 min), the dashed line is for $0.8R_\odot$(31 min), and the dot-dashed line is for $0.975R_\odot$(13 min). The lower horizontal axis is acoustic depth, in minutes. The upper horizontal axis is fractional radius. An acoustic depth of 60 min corresponds to the center of the Sun and 0 to the solar surface. Notice that all three of the kernels are similar near the surface (small acoustic depth). The kernels are mostly negative, i.e. an increase in sound speed leads to decreased travel time. Also notice that the kernel for the deepest focus depth (solid line) has weight at greater depth than the other two.

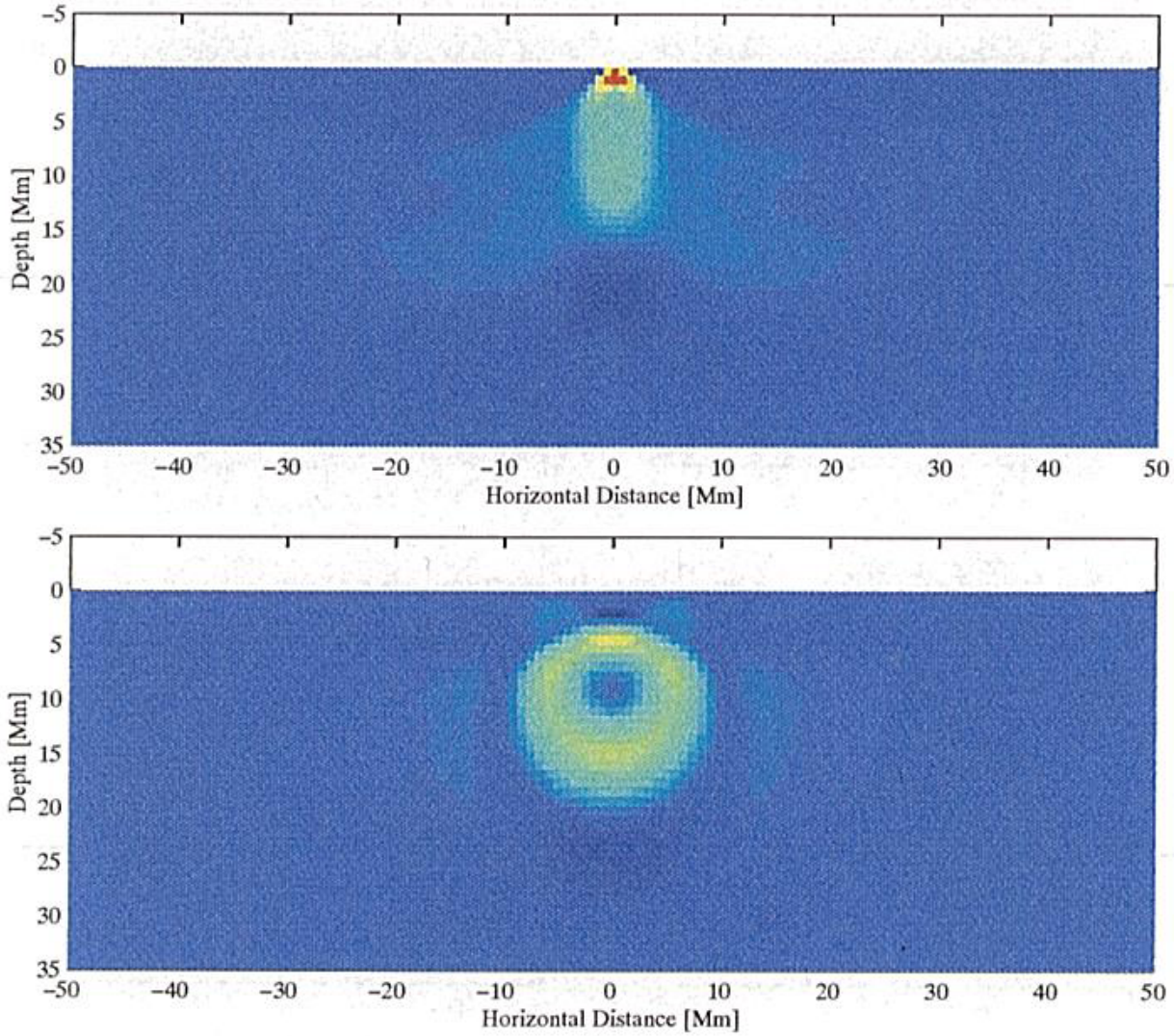
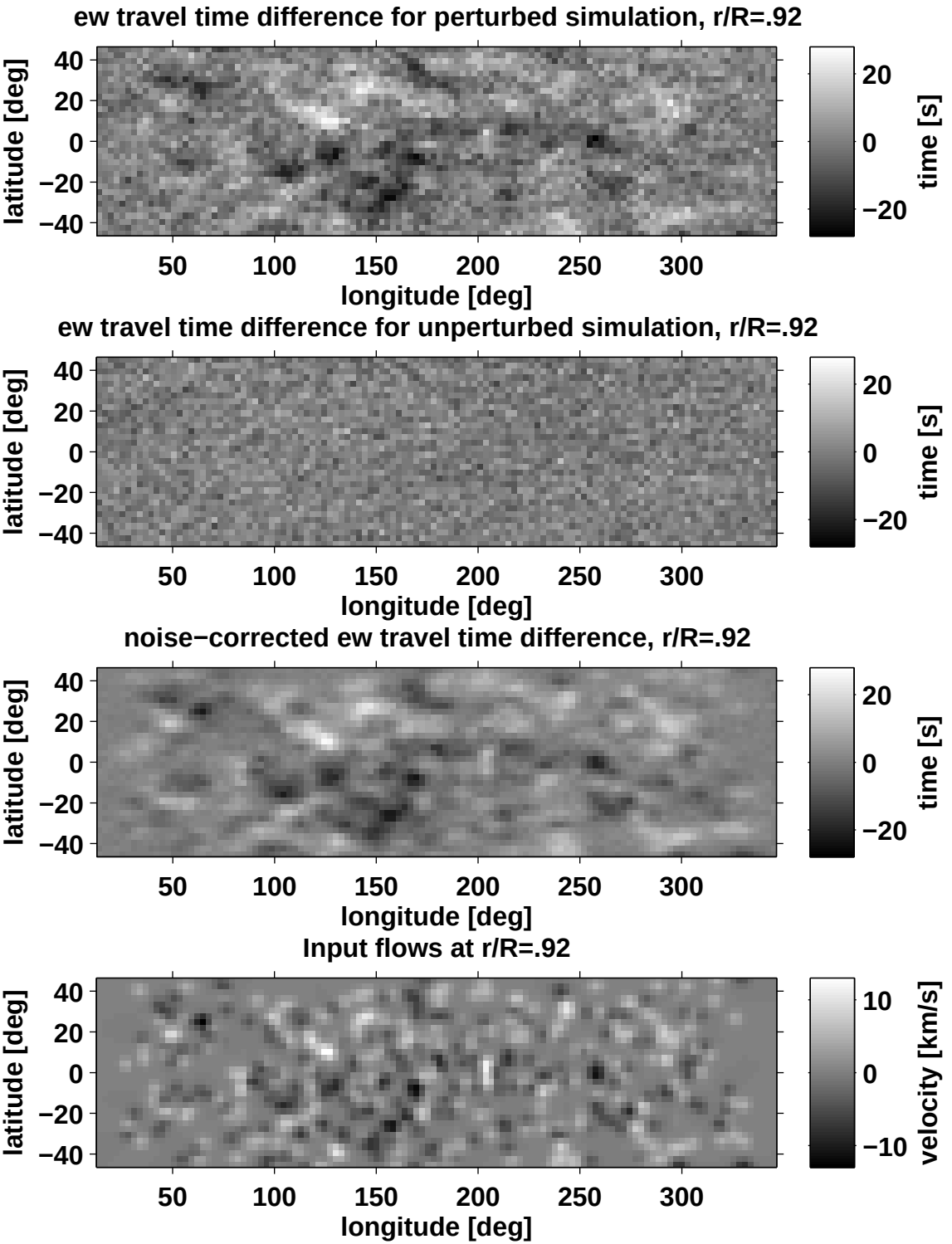
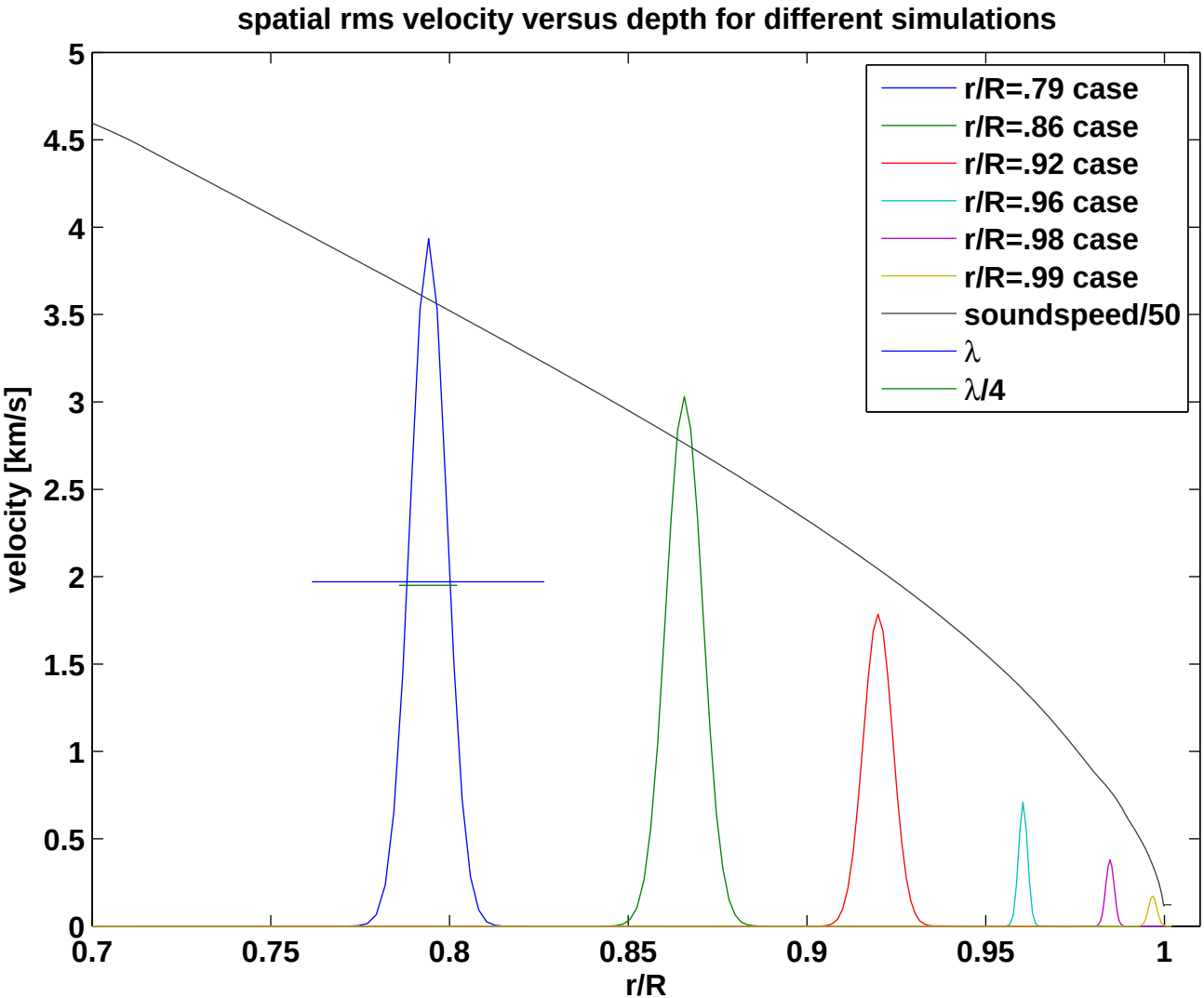
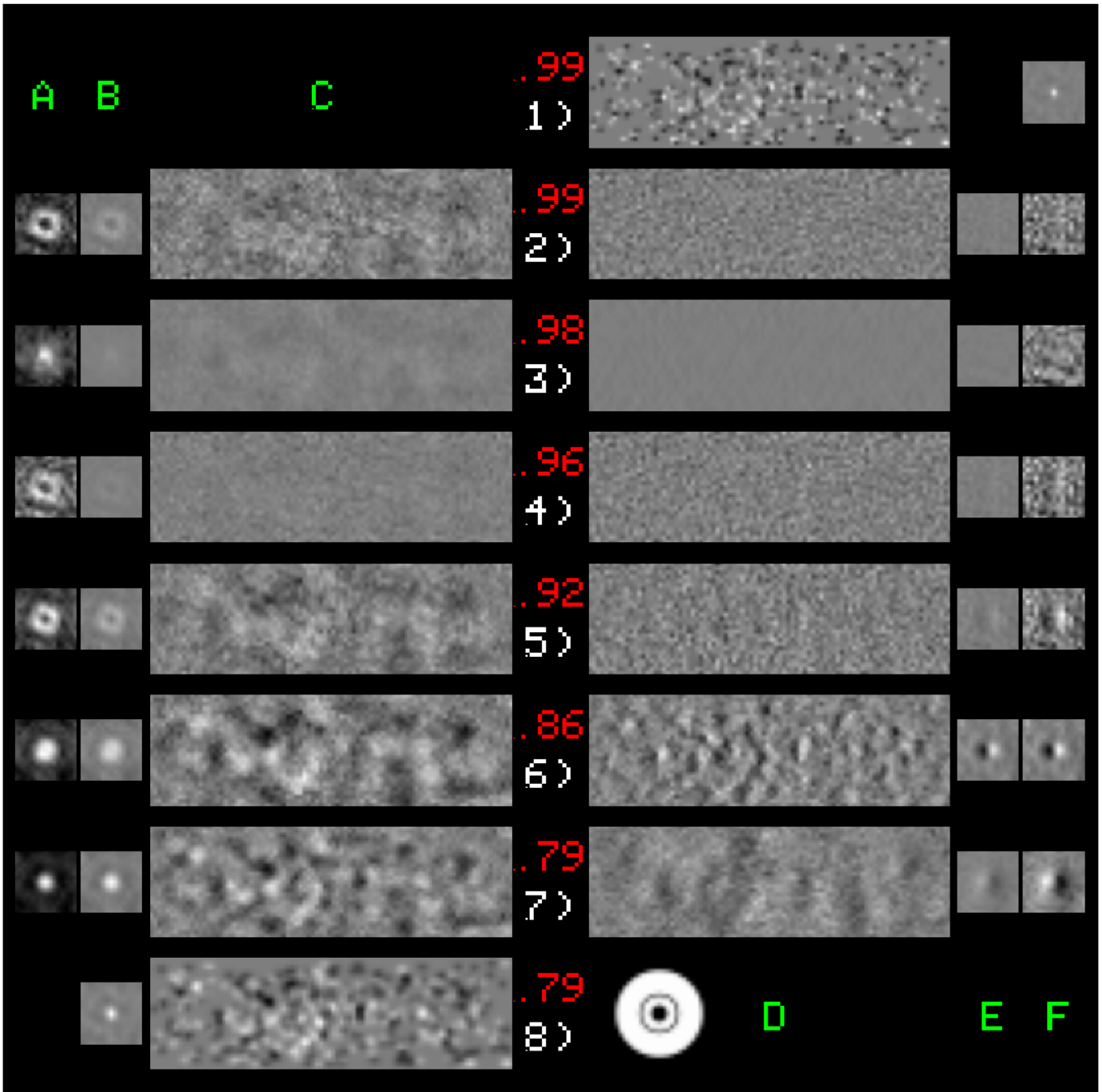


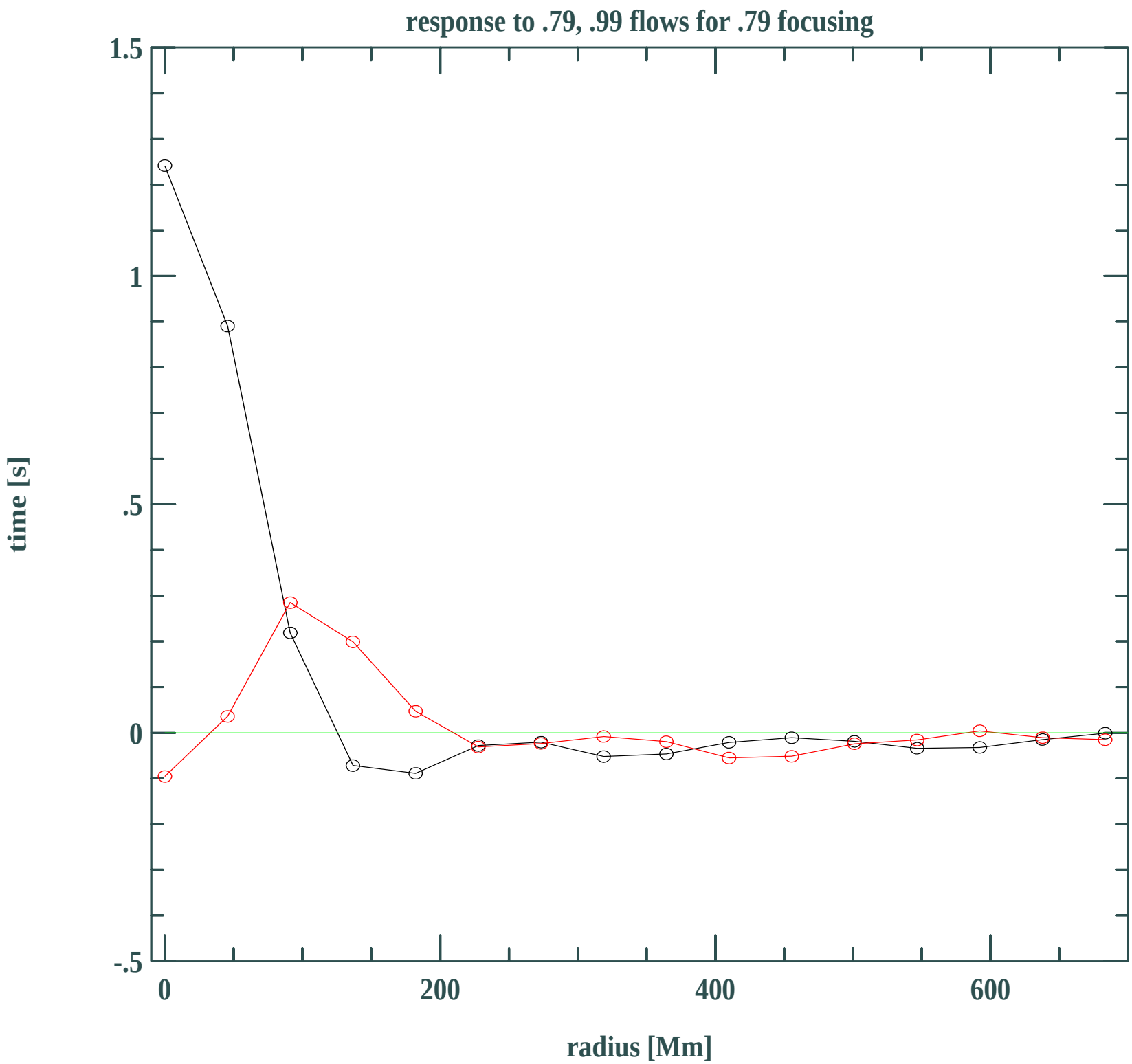
Figure 4: Wave theoretic sensitivity kernels for the ray configurations shown in figure 1. The top panel shows a kernel for surface focus data while the bottom panel shows one for deep focused data.

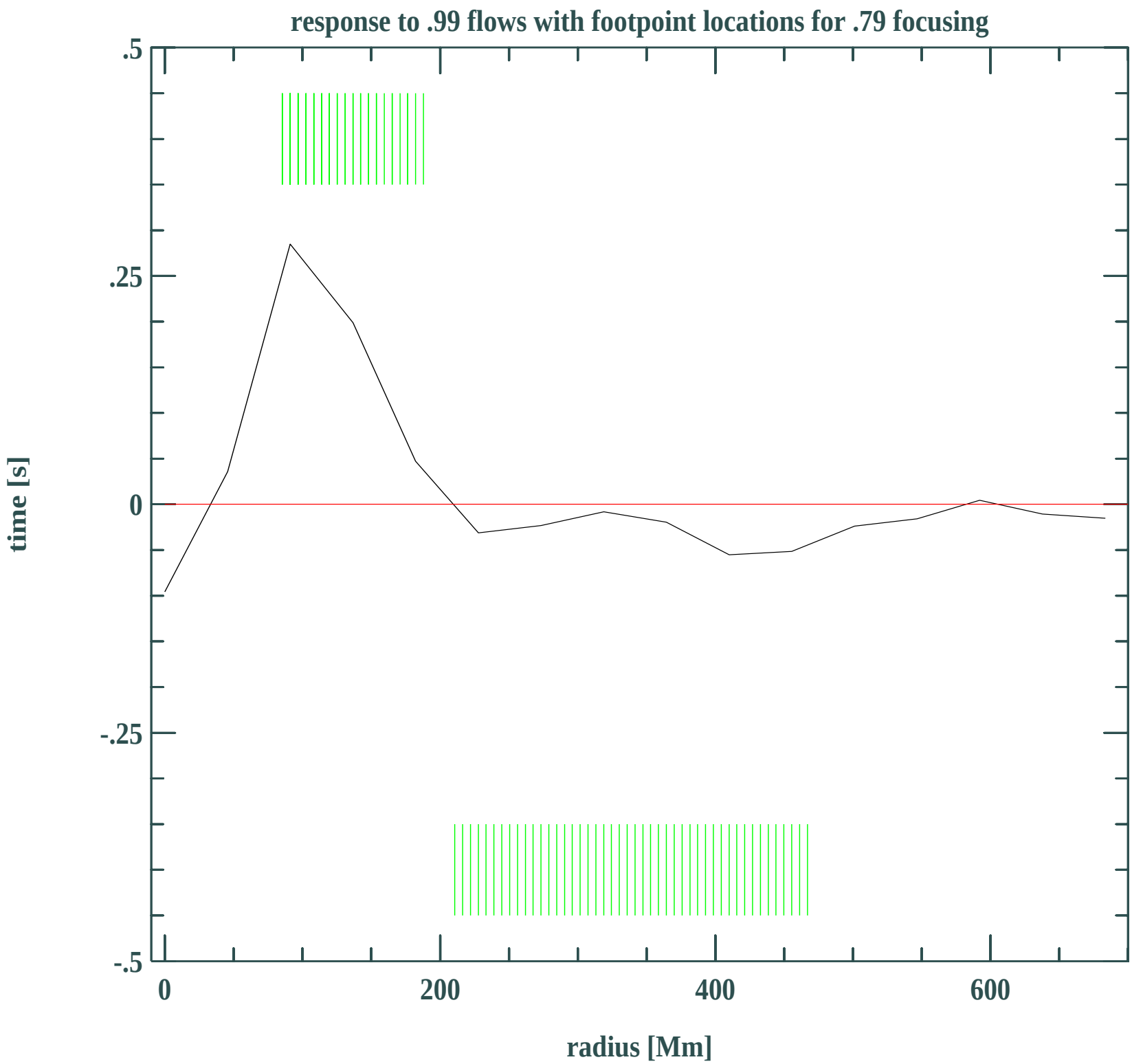

ew travel time difference for perturbed simulation, r/R=.92
latitude [deg]
40
20
0
−20
−40
50
100
150
200
250
300
longitude [deg]
20
0
−20
time [s]
ew travel time difference for unperturbed simulation, r/R=.92
latitude [deg]
40
20
0
−20
−40
50
100
150
200
250
300
longitude [deg]
20
0
−20
time [s]
noise−corrected ew travel time difference, r/R=.92
latitude [deg]
40
20
0
−20
−40
50
100
150
200
250
300
longitude [deg]
20
0
−20
time [s]
Input flows at r/R=.92
latitude [deg]
40
20
0
−20
−40
50
100
150
200
250
300
longitude [deg]
10
0
−10
velocity [km/s]

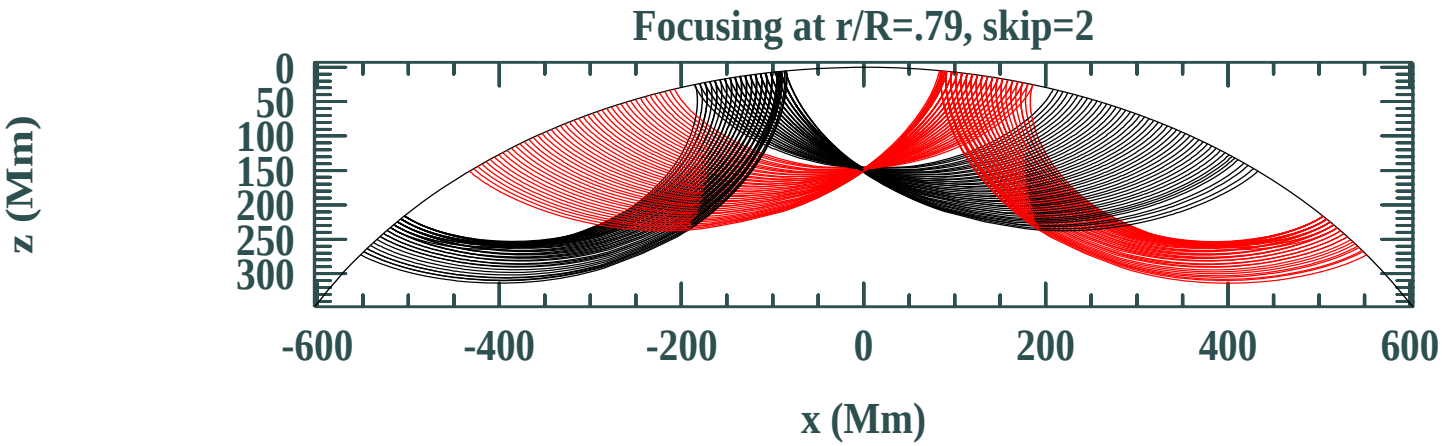

spatial rms velocity versus depth for different simulations
velocity [km/s]
r/R
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.7
0.75
0.8
0.85
0.9
0.95
1
r/R=.79 case
r/R=.86 case
r/R=.92 case
r/R=.96 case
r/R=.98 case
r/R=.99 case
soundspeed/50
λ
λ/4

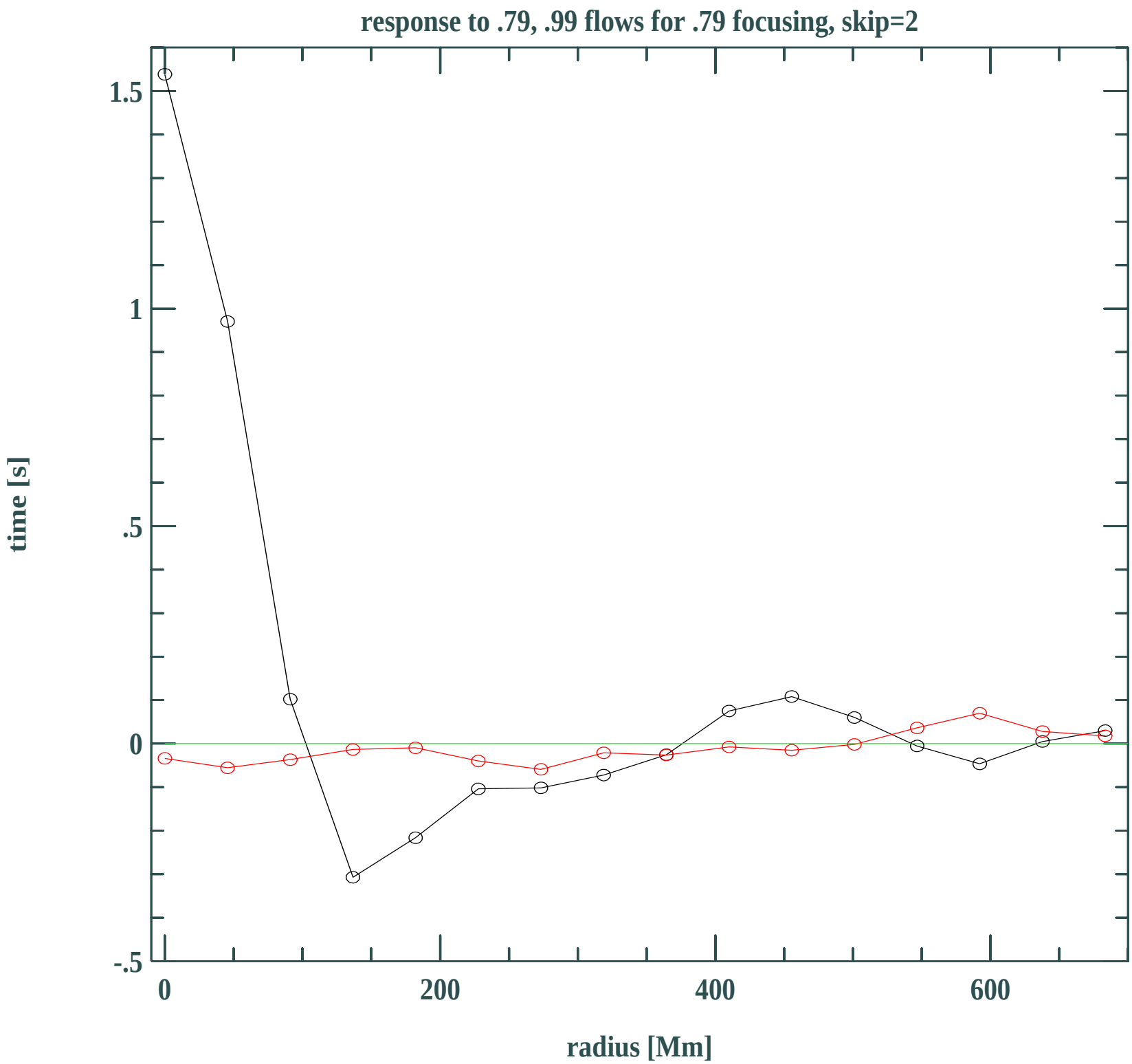

A
B
C
.99
1)
.99
2)
.98
3)
.96
4)
.92
5)
.86
6)
.79
7)
.79
8)
D
E
F

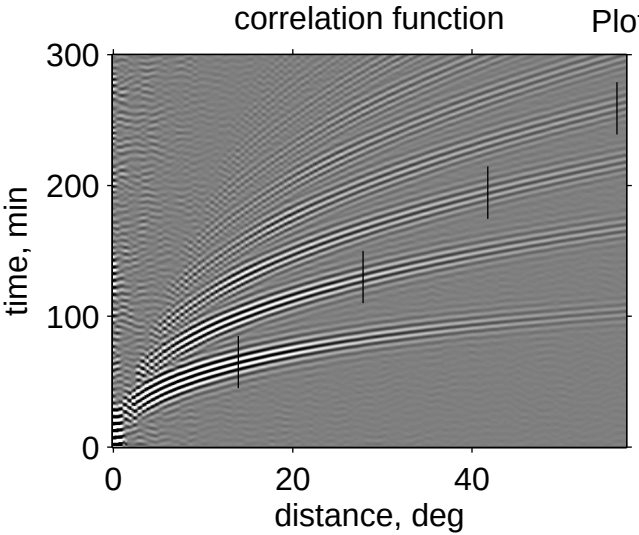

20
40
60
80
100
120
140
160
180
200

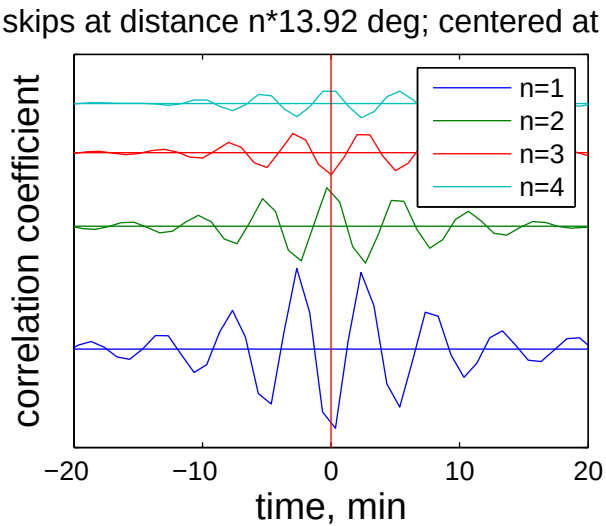

response to .79, .99 flows for .79 focusing
1.5
1
.5
0
-.5
time [s]
0
200
400
600
radius [Mm]

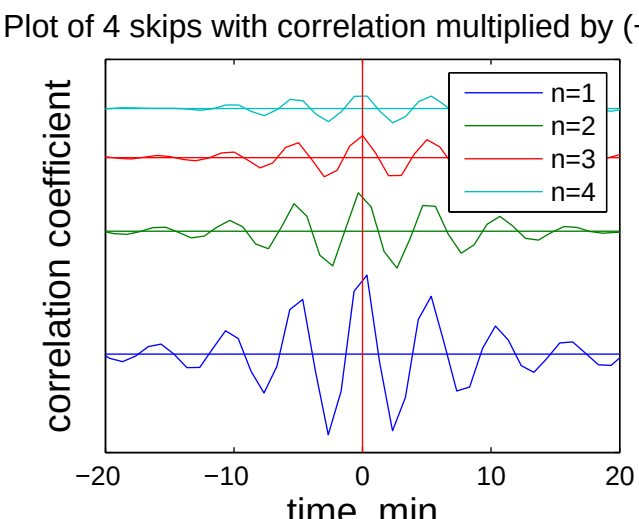

response to .99 flows with footpoint locations for .79 focusing
.5
.25
0
-.25
-.5
time [s]
0
200
400
600
radius [Mm]

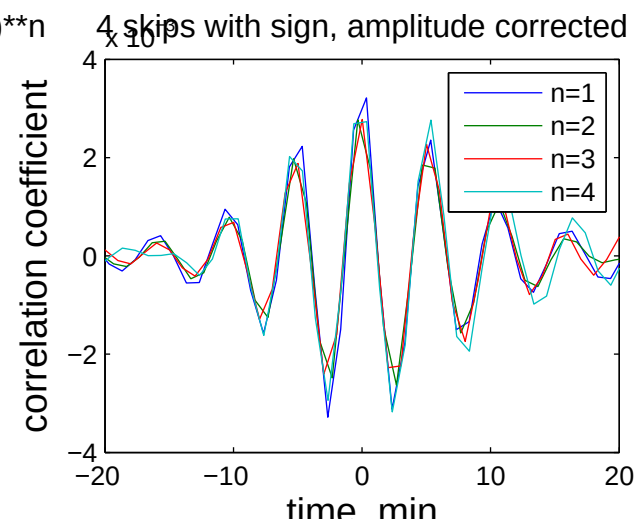

Focusing at r/R=.79, skip=2
z (Mm)
0
50
100
150
200
250
300
-600
-400
-200
0
200
400
600
x (Mm)

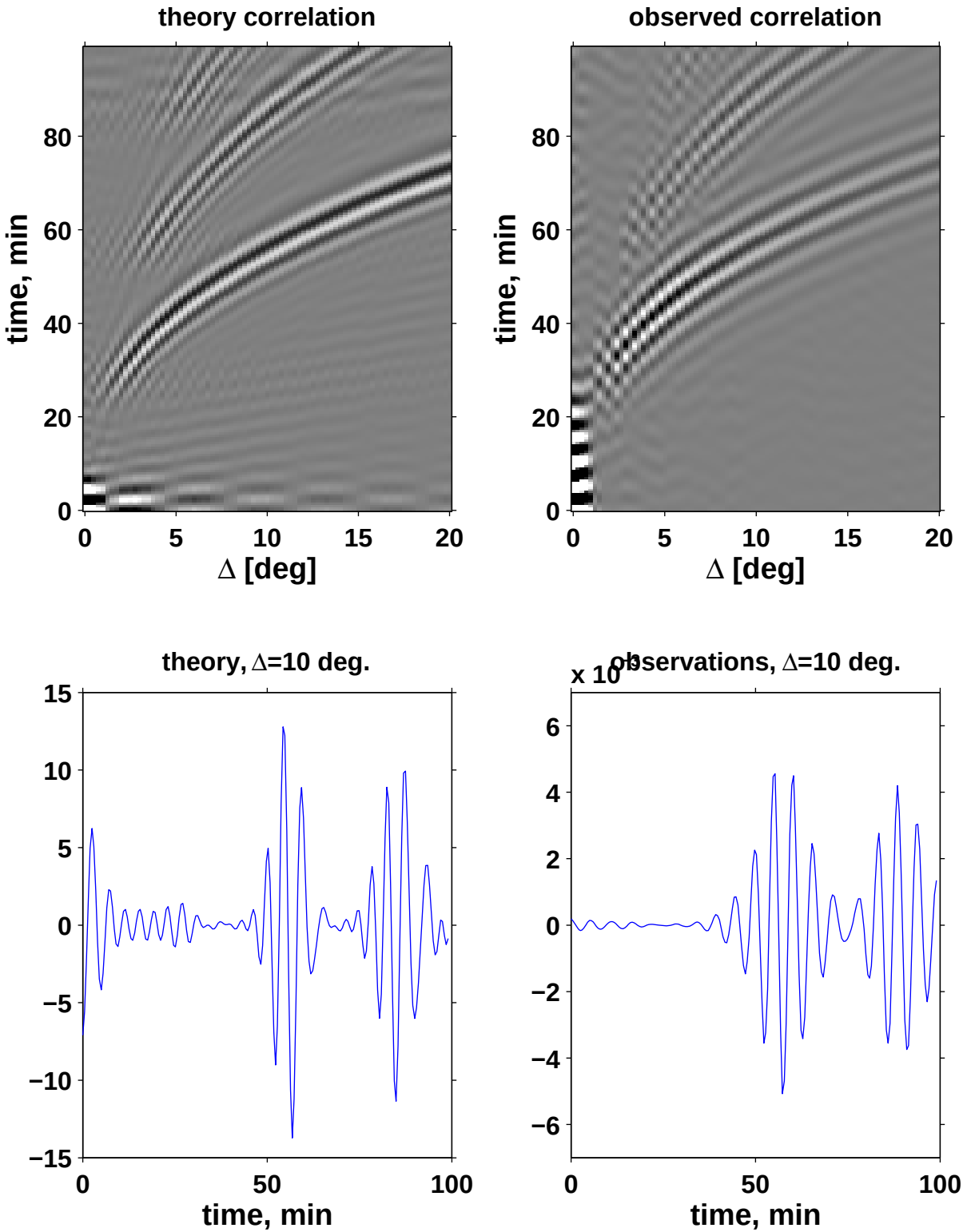

response to .79, .99 flows for .79 focusing, skip=2
1.5
1
.5
0
-.5
time [s]
0
200
400
600
radius [Mm]

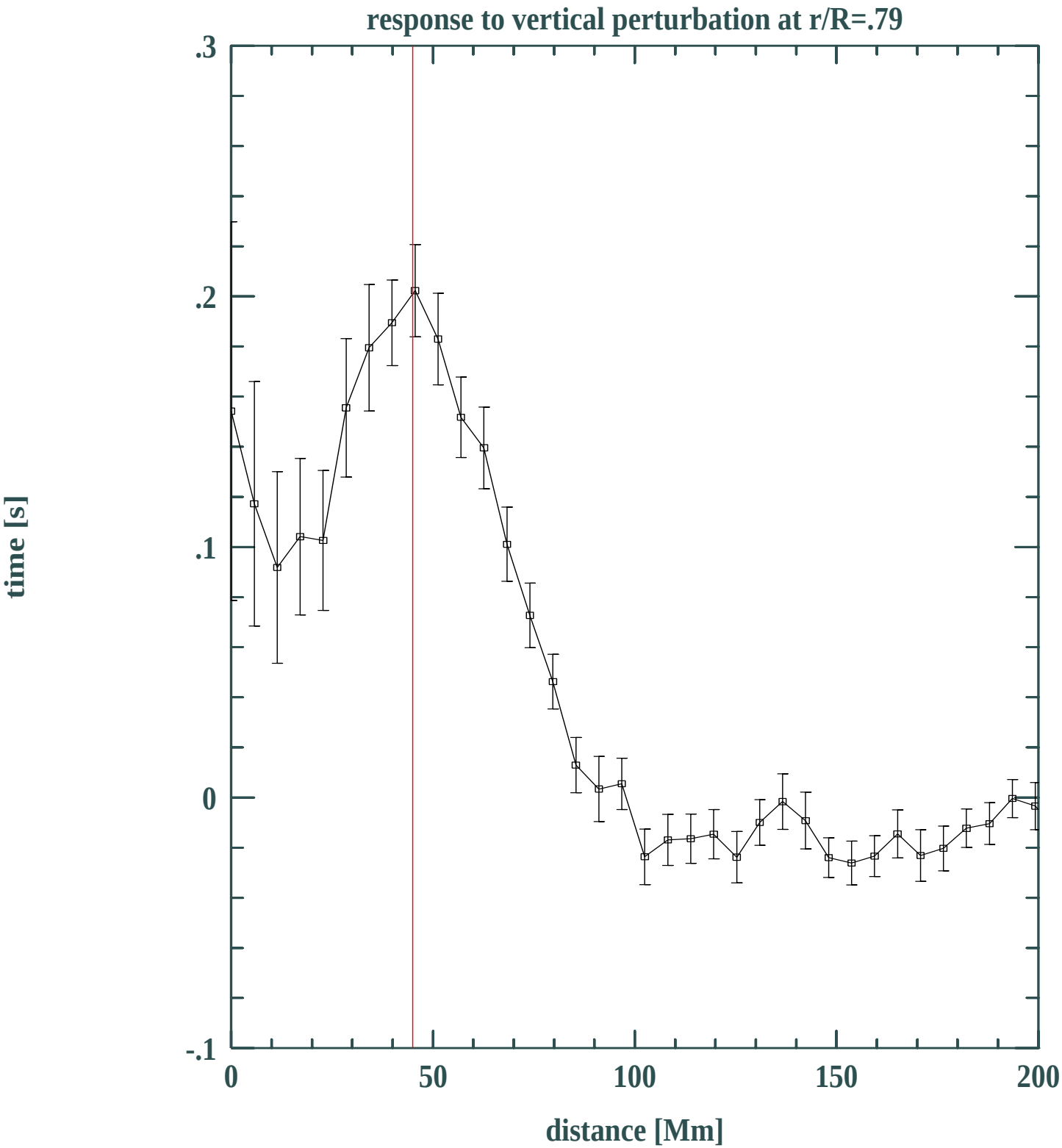

correlation function
time, min
distance, deg
300
200
100
0
0
20
40


Plot of 4 skips at distance n*13.92 deg; centered at n*64.66 m
correlation coefficient
time, min
n=1
n=2
n=3
n=4
−20
−10
0
10
20


Plot of 4 skips with correlation multiplied by (−1)**n
correlation coefficient
time, min
n=1
n=2
n=3
n=4
−20
−10
0
10
20


4 skips with sign, amplitude corrected
x 10^-3
correlation coefficient
time, min
n=1
n=2
n=3
n=4
4
2
0
−2
−4
−20
−10
0
10
20


theory correlation
observed correlation
time, min
Δ [deg]
theory, Δ=10 deg.
observations, Δ=10 deg.
x 10^-3
time, min


response to vertical perturbation at r/R=.79
.3
.2
.1
0
-.1
time [s]
0
50
100
150
200
distance [Mm]