Sensitivity kernels for helioseismic travel times in spherical geometry

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Abstract

We present calculations of three-dimensional Frechet kernels in spherical geometry for use in time-distance helioseismology. These kernels give the linear sensitivity of travel times to localized flow perturbations.

Calculation of Kernels

The kernels are calculated following the general recipe given by Gizon & Birch (2002). Modes are excited as in Birch et al. (2004) by distributed stochastic sources. The mode damping rates were provided by J. Schou. The eigenfunctions and mode frequencies are derived from 'Model S' of Christensen-Dalsgaard (1996).

As a starting point, we have calculated sensitivity kernels for fixed values of the harmonic degree l and the radial order n, in order to validate the code. The flows only couple the azimuthal orders.

In the example we set l=30 and n=10. The effect of the projection of the wave velocity onto the line of sight is included in the calculation.

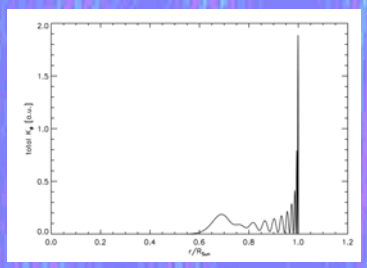

Fig. 2: Total integral over horizontal coordinates of Kϕ versus radius.

Results

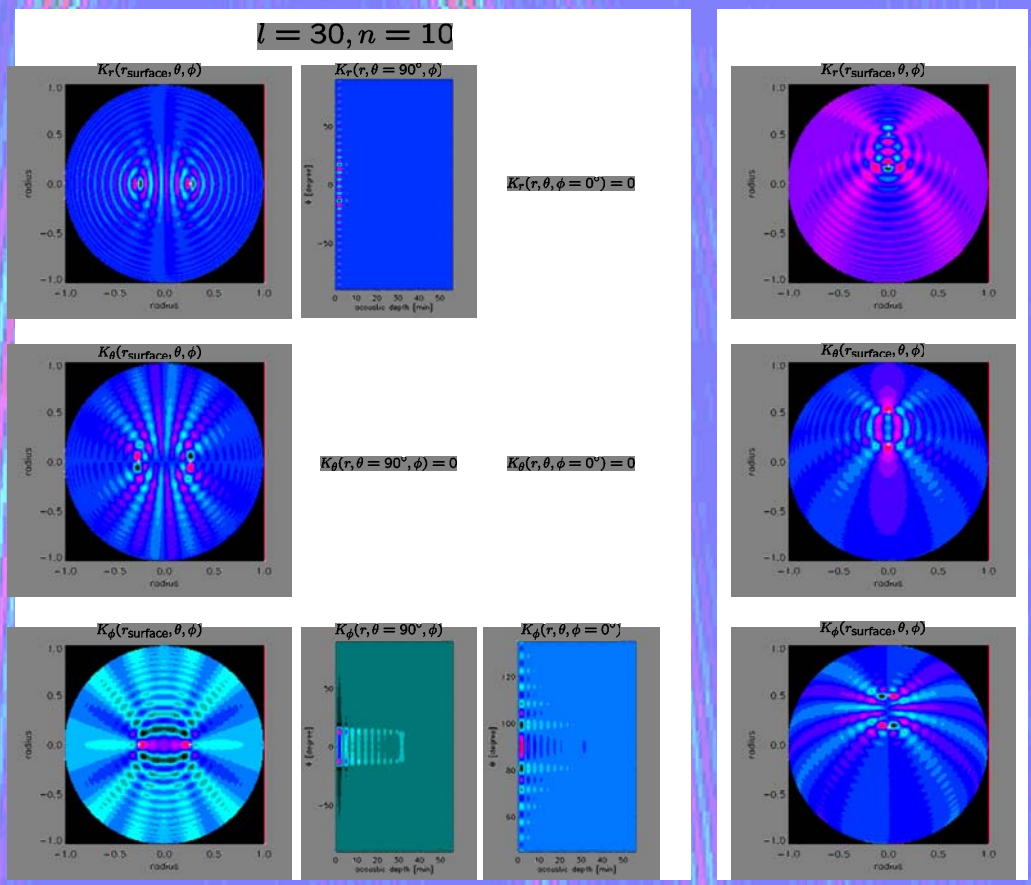

Fig. 1: Sensitivity kernels for flows in the r (top), θ (middle), and ϕ directions. *Left:* Cuts through the kernels at r=R_{Sun}. The positions of the observation points are (θ_1=90°,ϕ_1=-15°) and (θ_2=90°,ϕ_2=15°). The total integral over horizontal coordinates of Kϕ is close to the kinetic energy density of a mode with l=30, n=10 (Fig. 2).
Middle columns: Cuts at θ=90° or ϕ=0°, resp. with the same observation points as on the left.
Right: Same as on the left but for observation points at (θ_1=60°, ϕ_1=0°) and (θ_2=80°, ϕ_2=0°), away from the equator.

Future Work

- Extend the code to include all the modes that contribute to the cross-correlation
- Include all couplings between these modes
- Efficient implementation of the code for speeding up the calculation.

References

(1) Birch, A.C., Kosovichev, A.G., Duvall, T.L., Jr., 2004, ApJ 608, 580
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(3) Gizon, L., Birch, A.C., 2002, ApJ 571, 966
(4) Schou, J., private communications