Inversions for Deep Meridional Flow Inversions using Spherical Born Kernels and GONG Data

Vincent Böning, Markus Roth, Jason Jackiewicz, and Shukur Kholikov

ISSI team meeting

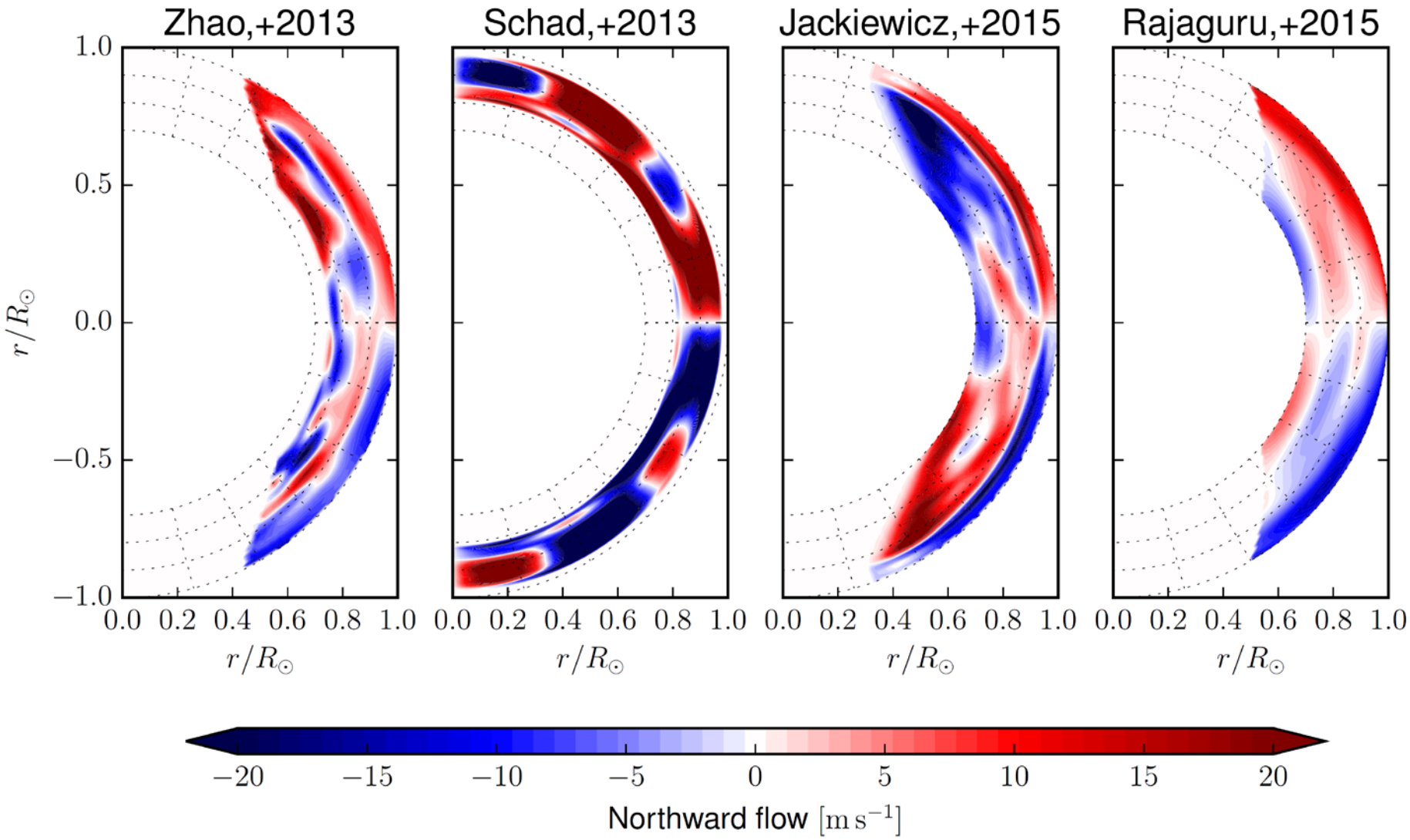
Bern, 03.07.2017

European Research Council
Established by the European Commission

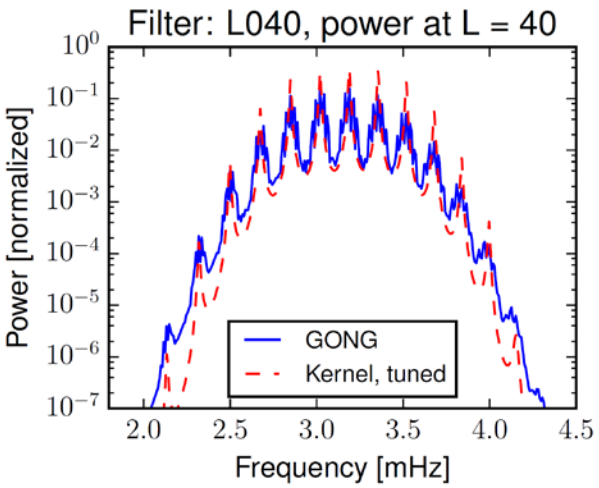
ISSI Team meeting „Studies of the Deep Solar Meridional Flow“

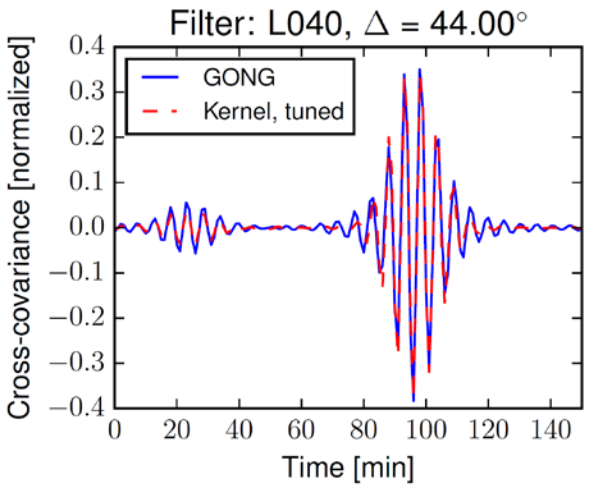
1 week, end of November 2016, Bern

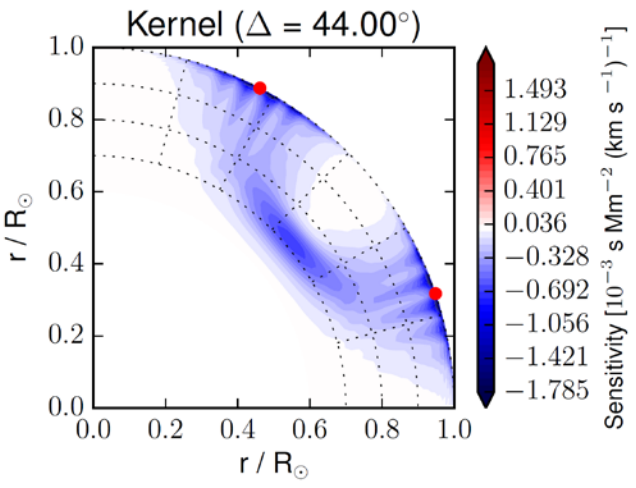
The starting point

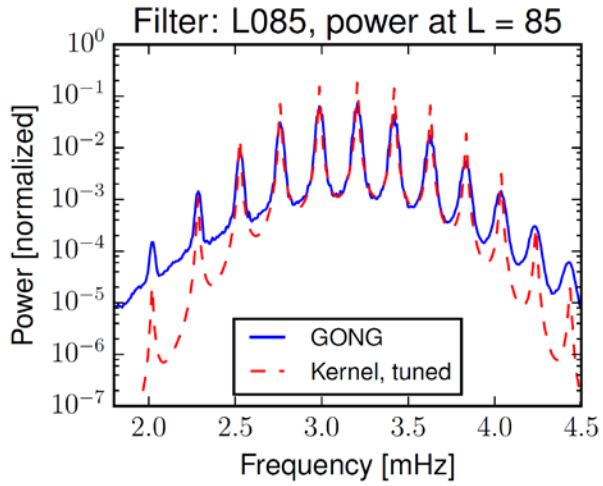


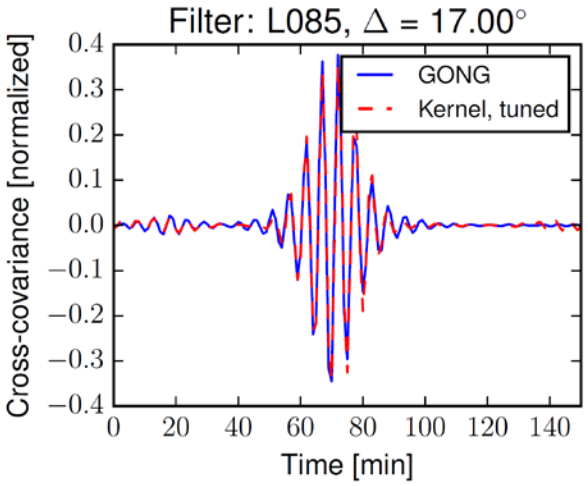
Born Approximation

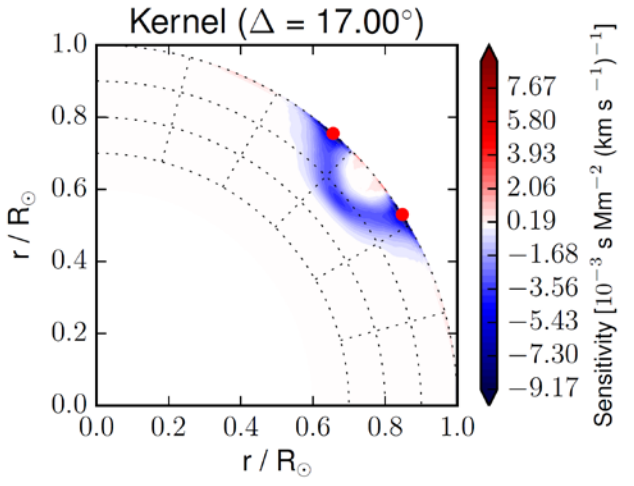




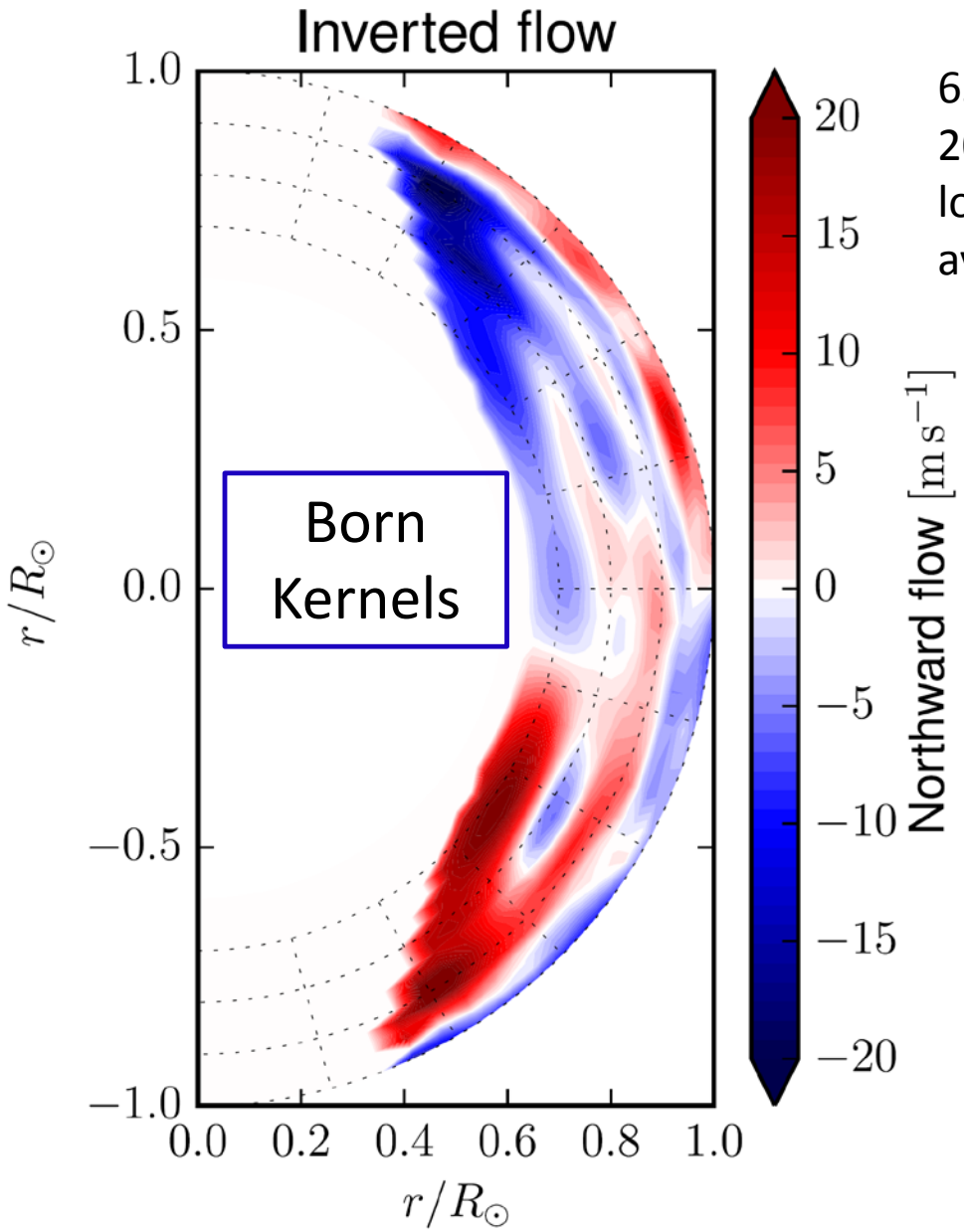




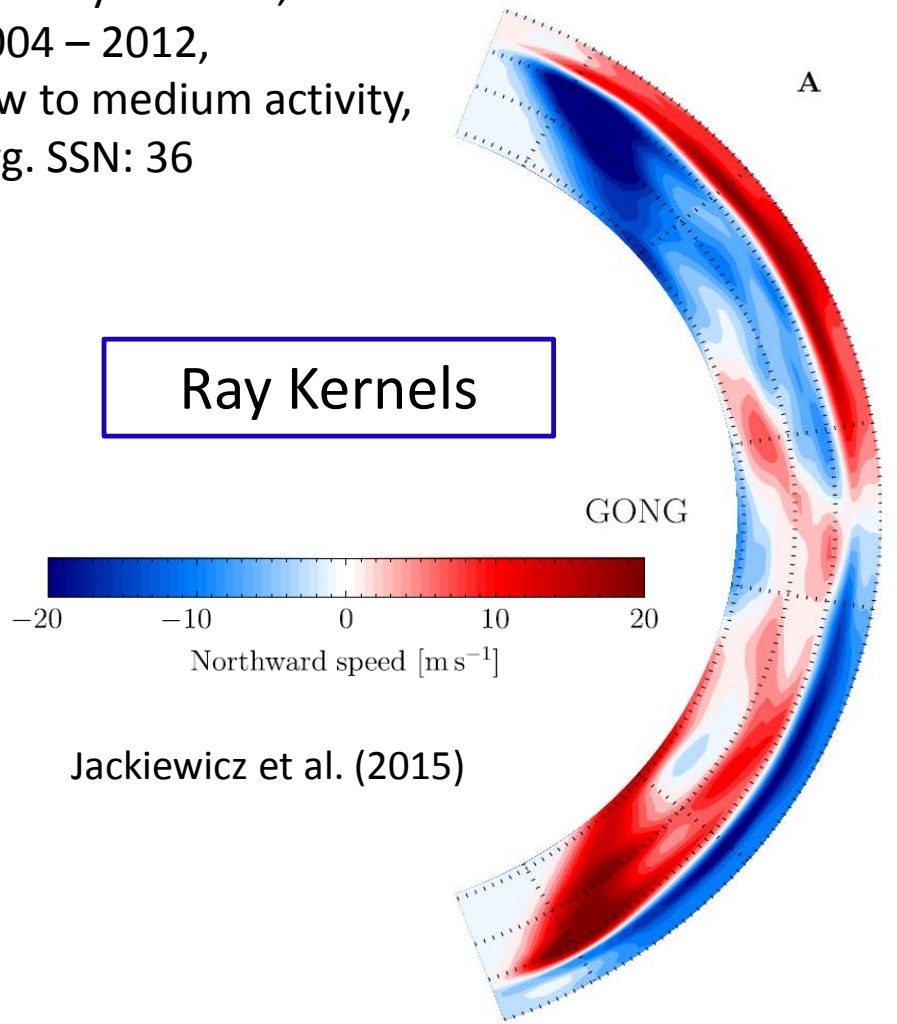




Inversions of GONG Data (1): Born instead of Ray Kernels

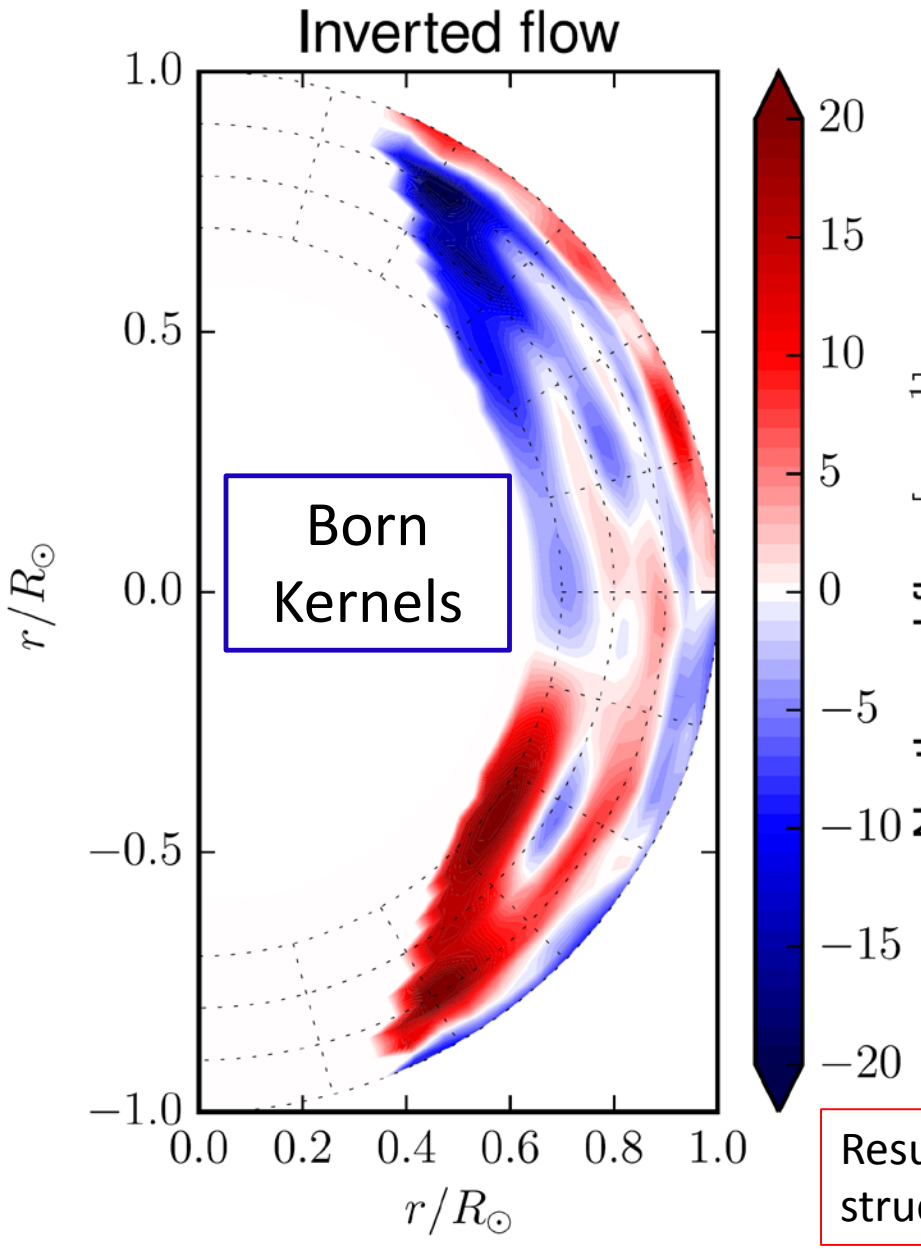


652 days of data,
2004 – 2012,
low to medium activity,
avg. SSN: 36

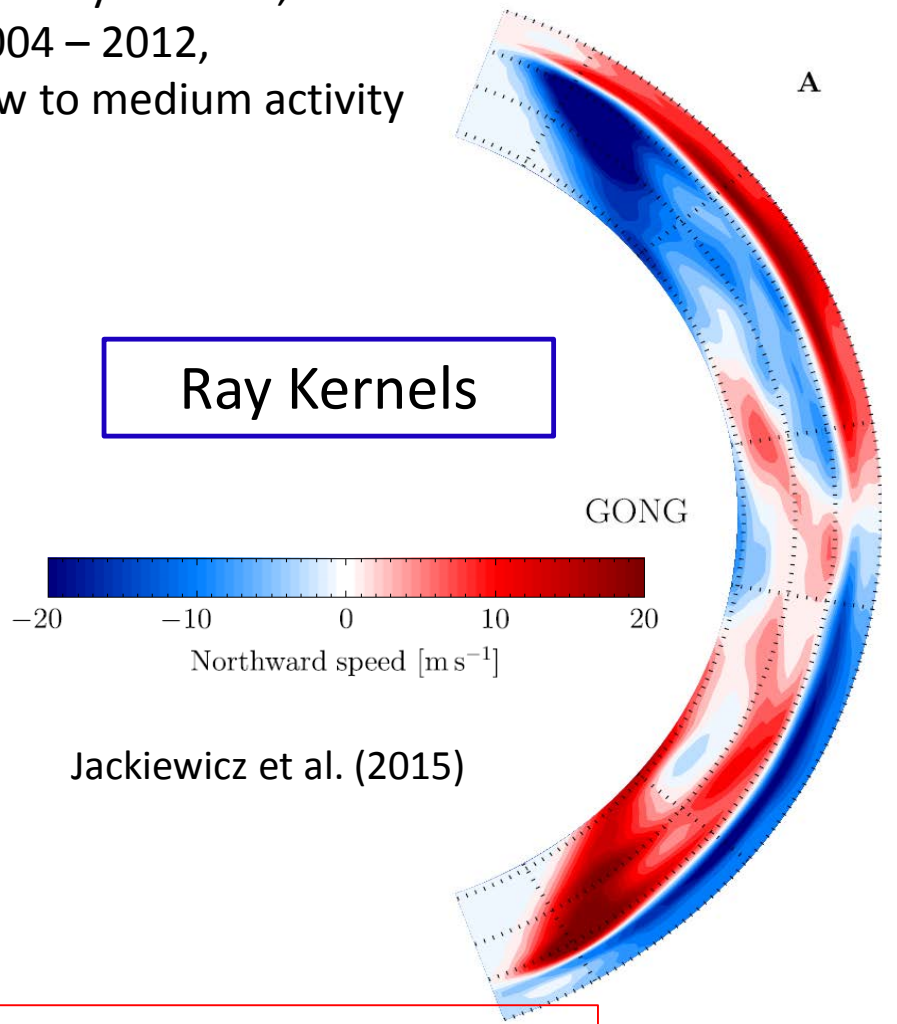


Jackiewicz et al. (2015)

Inversions of GONG Data (1): Born instead of Ray Kernels



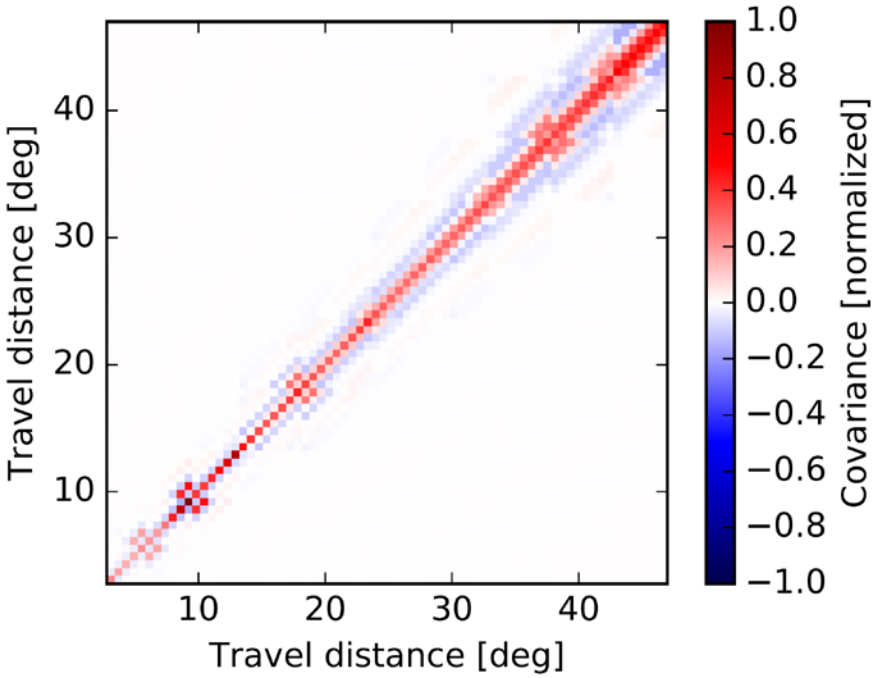
652 days of data,
2004 – 2012,
low to medium activity



Jackiewicz et al. (2015)

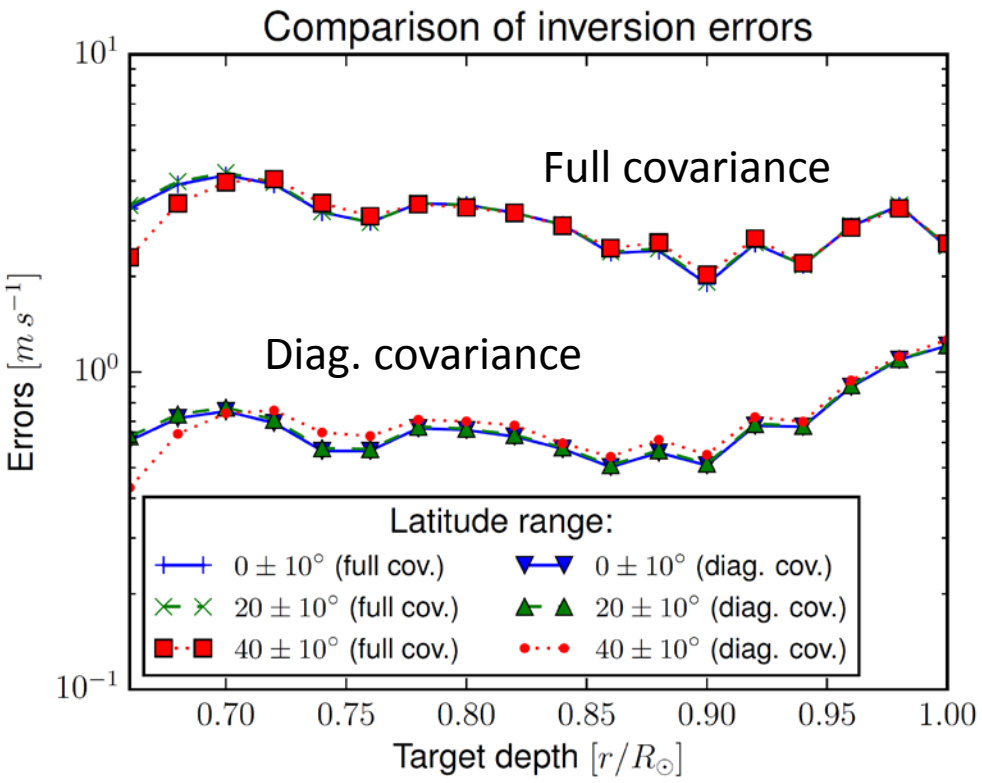
Results are quite similar! More fine structure with Born kernels.

Inversions of GONG Data: Diagonal vs. Full Covariance

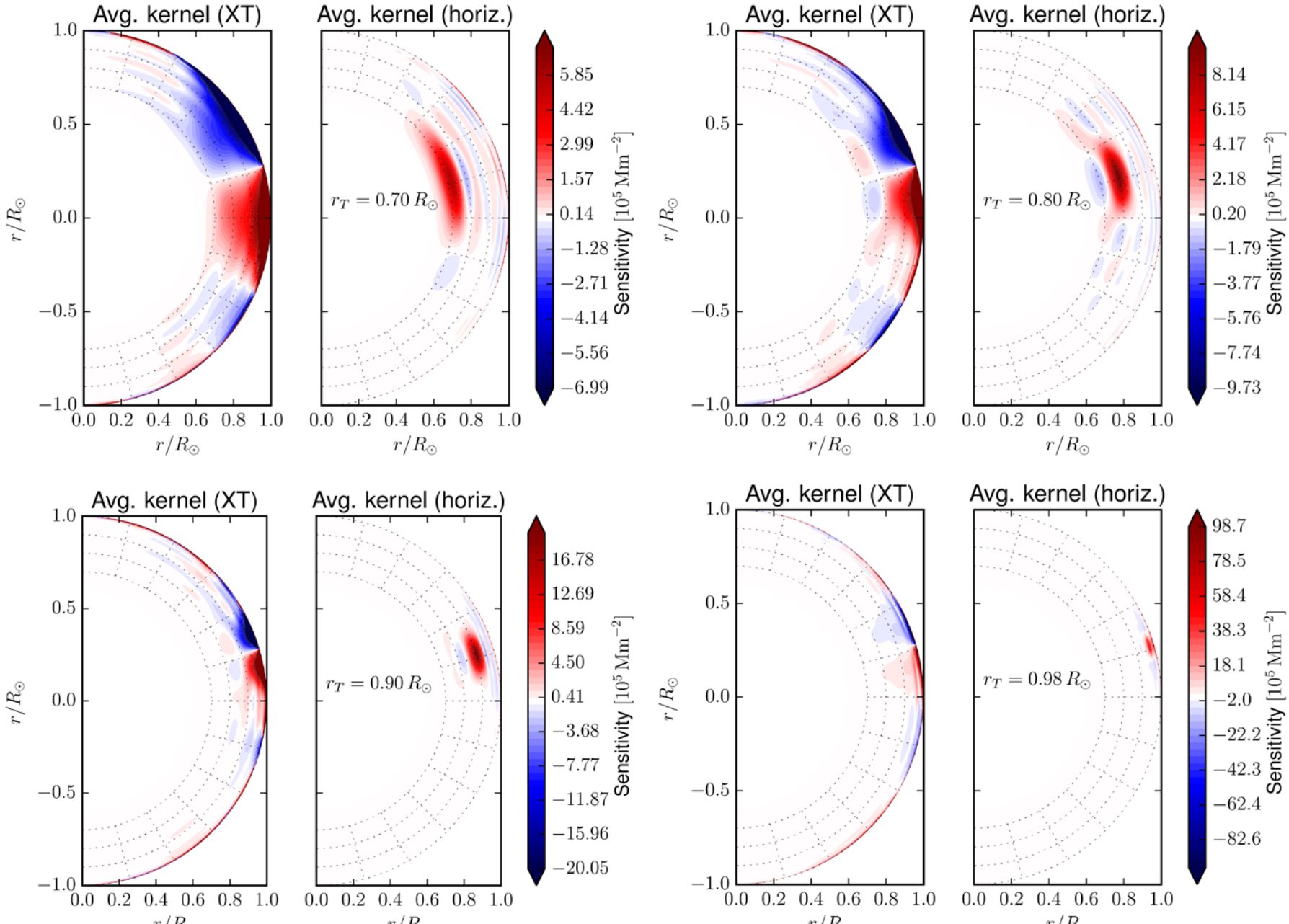


Model for covariance: see Gizon and Birch (2004), Fournier et al. (2014)

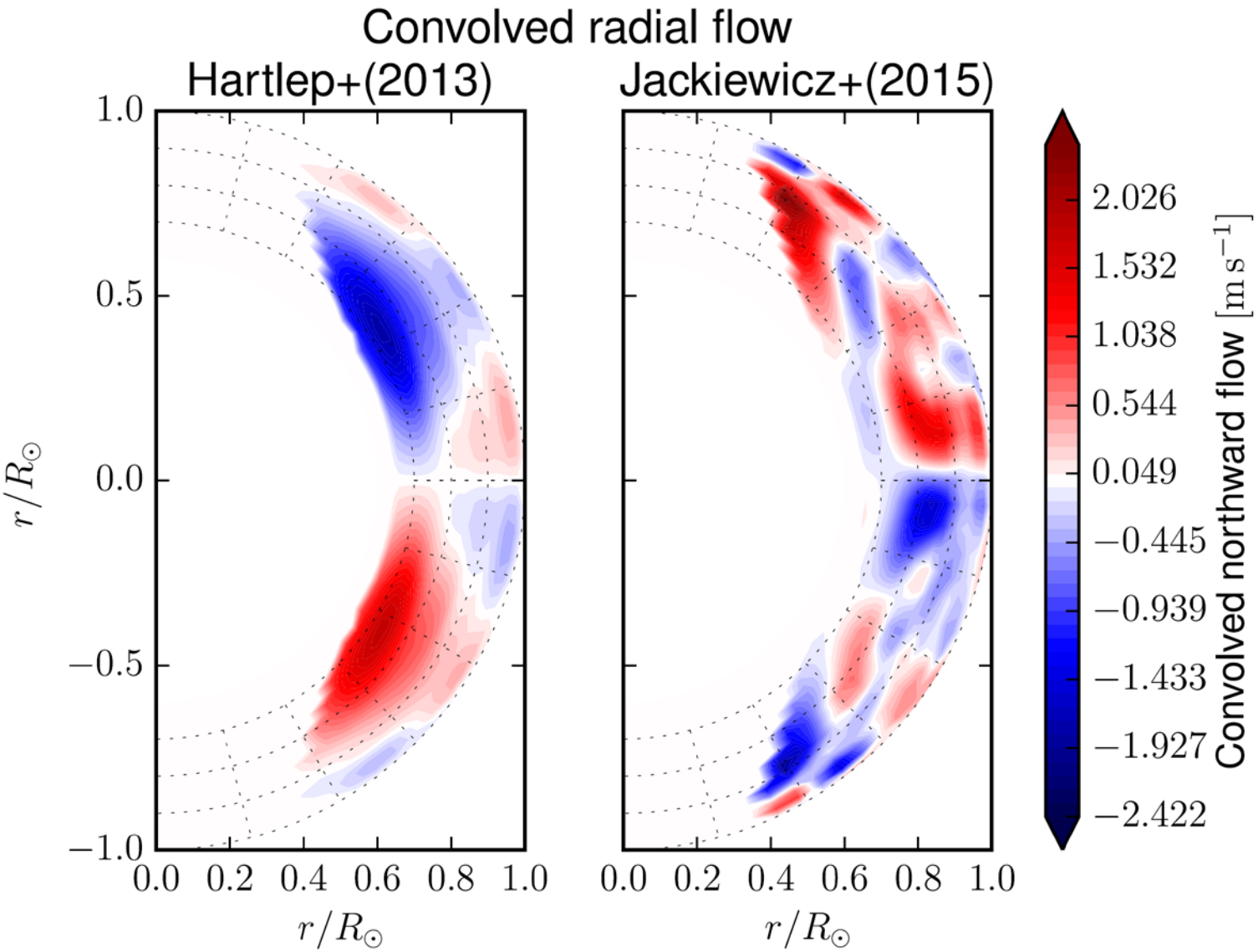
Errors with diagonal covariance are way smaller (factor 2-4) than with full covariance.



Inversions of GONG Data (1): (XT-) Averaging Kernels

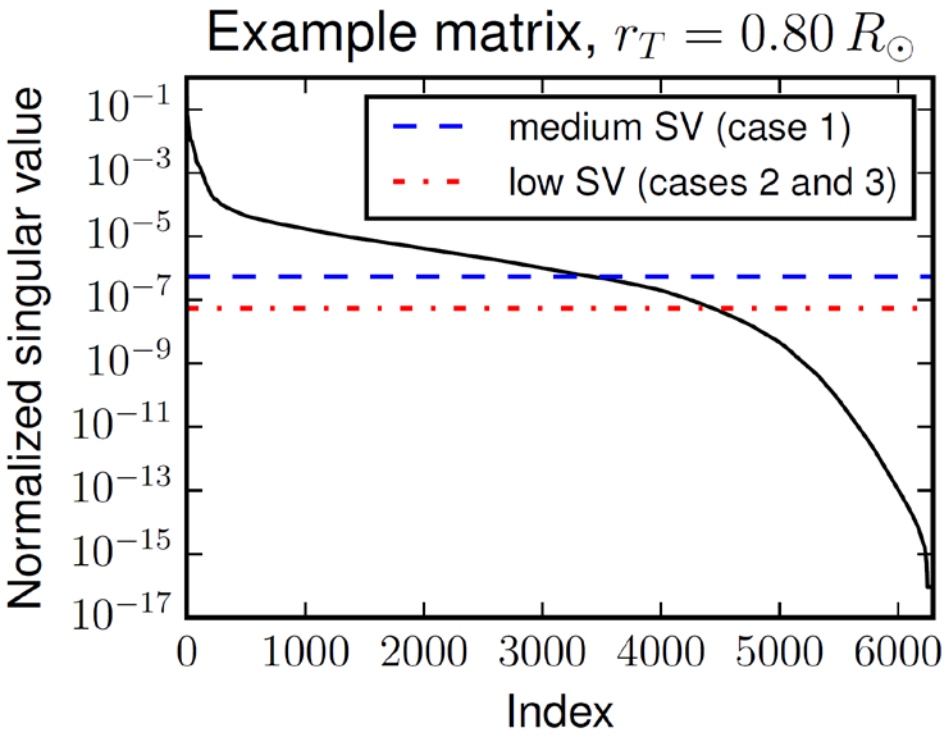


Inversions of GONG Data (1): Cross-talk for example flows

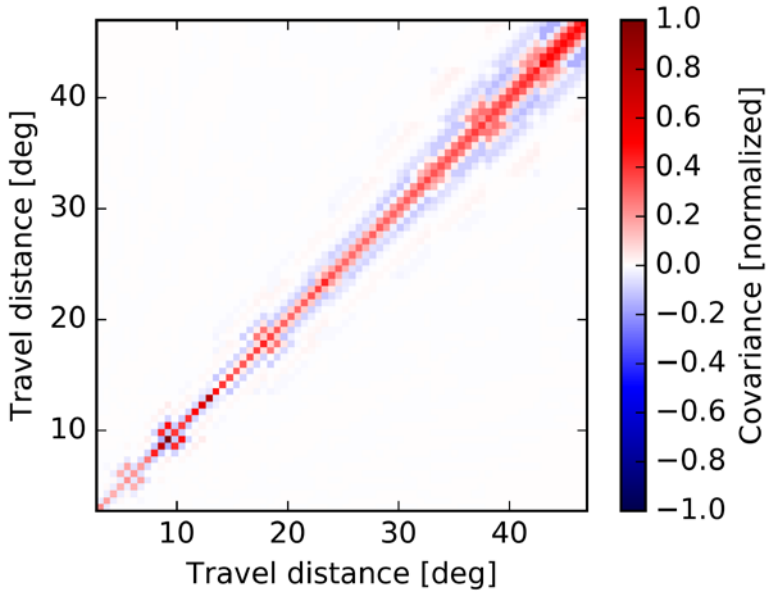


Inversions of GONG Data (2): Full Covariance + Cross-talk

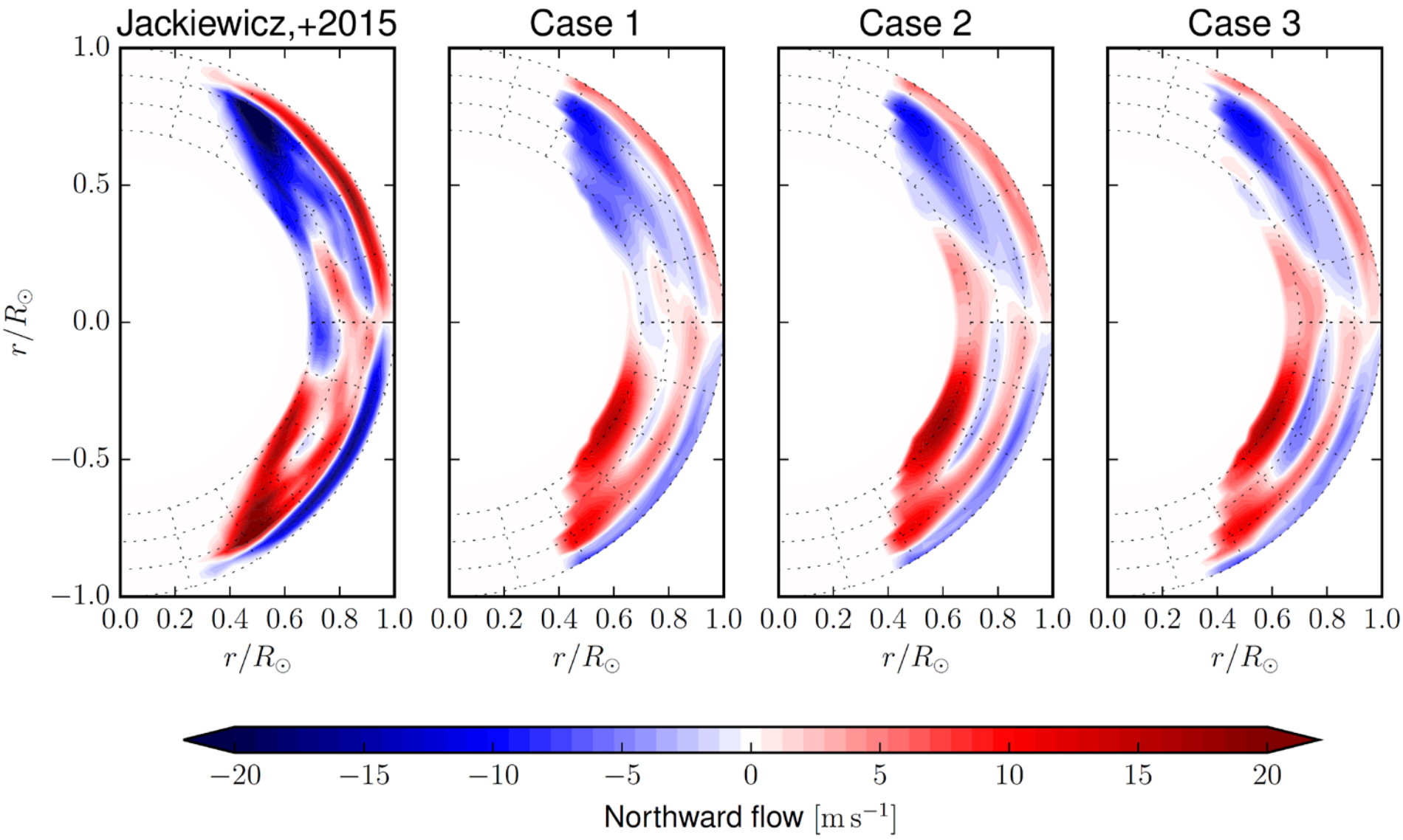
Inversions of GONG Data (2): Full Covariance + Cross-talk



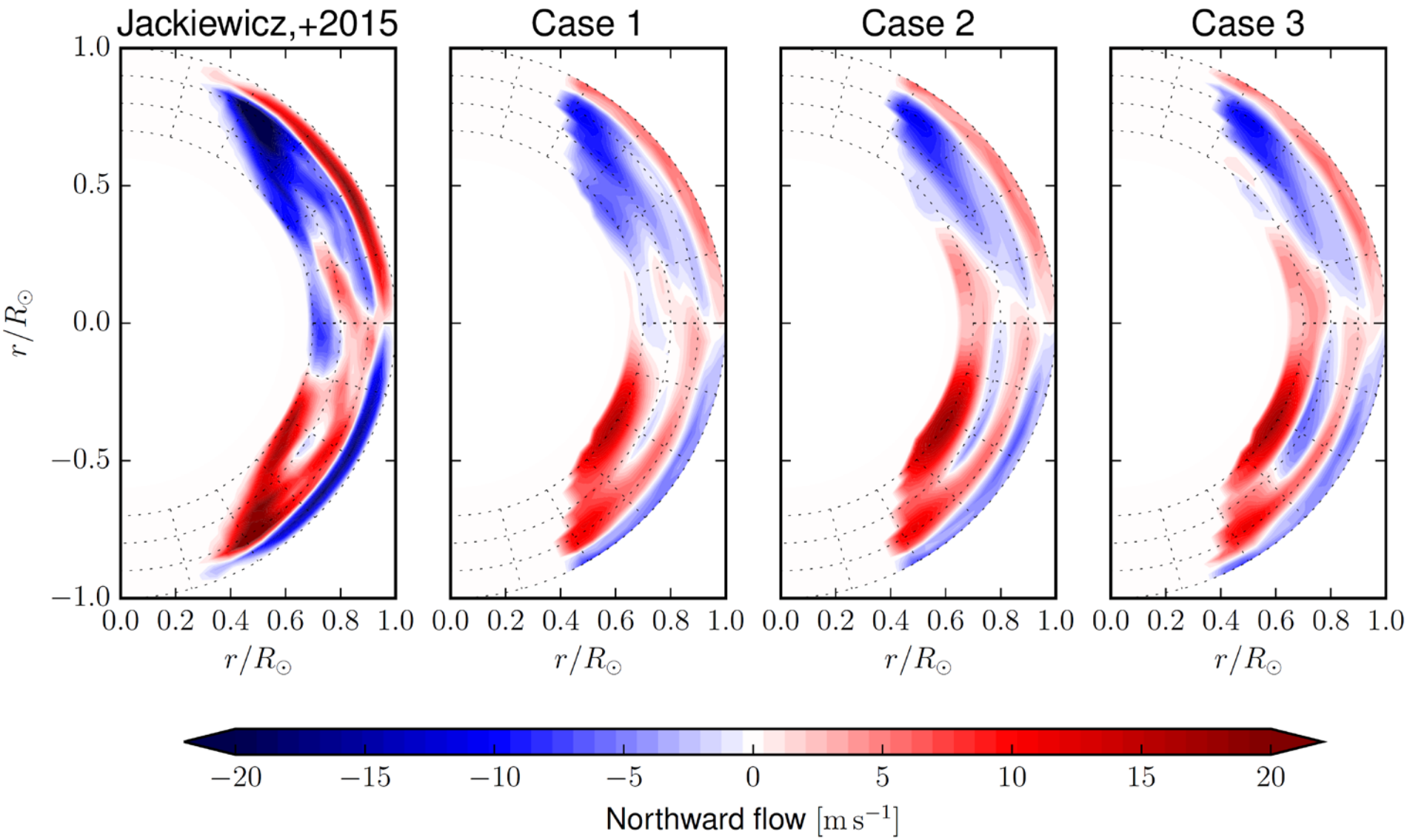
Inversion results depend on SV treshold used!



Inversions of GONG Data (2): Full Covariance + Cross-talk

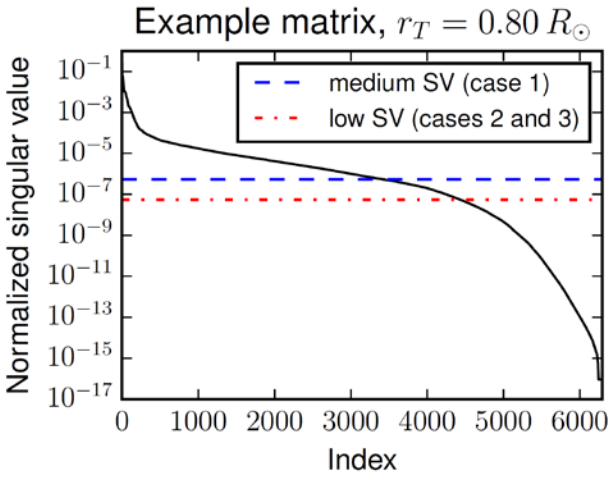


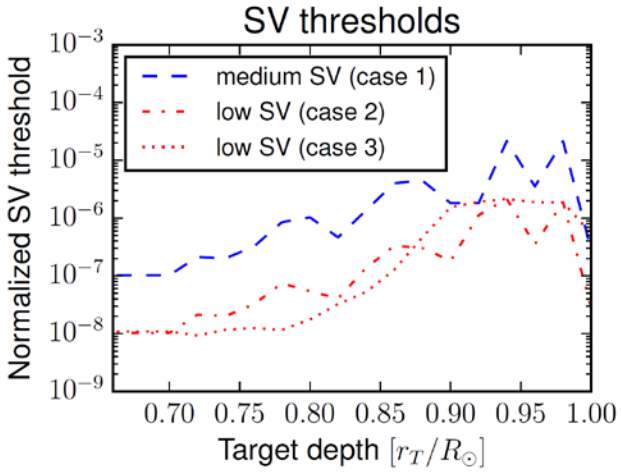
Inversions of GONG Data (2): Full Covariance + Cross-talk

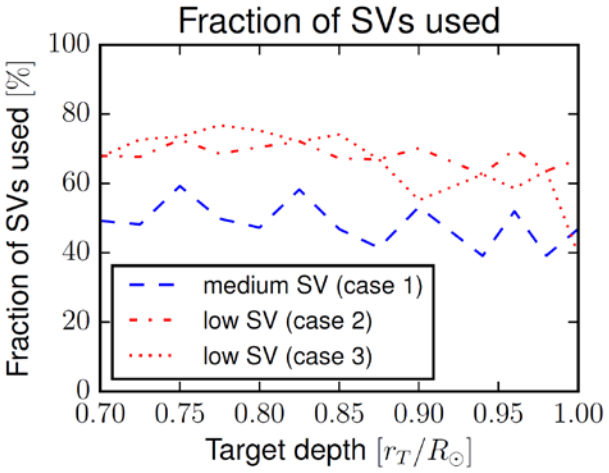


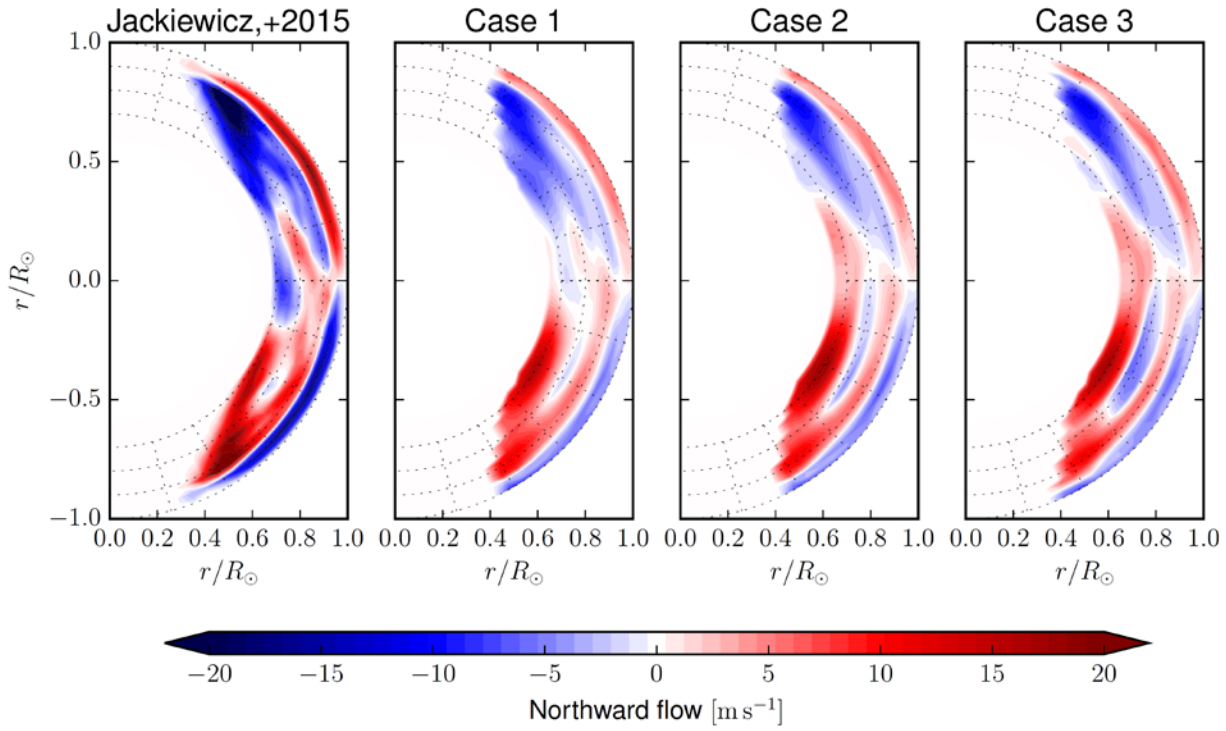
Results confirm Jackiewicz et al. (2015) until about 0.85 rSun, especially shallow return flow.

Inversions of GONG Data (2): Full Covariance + Cross-talk

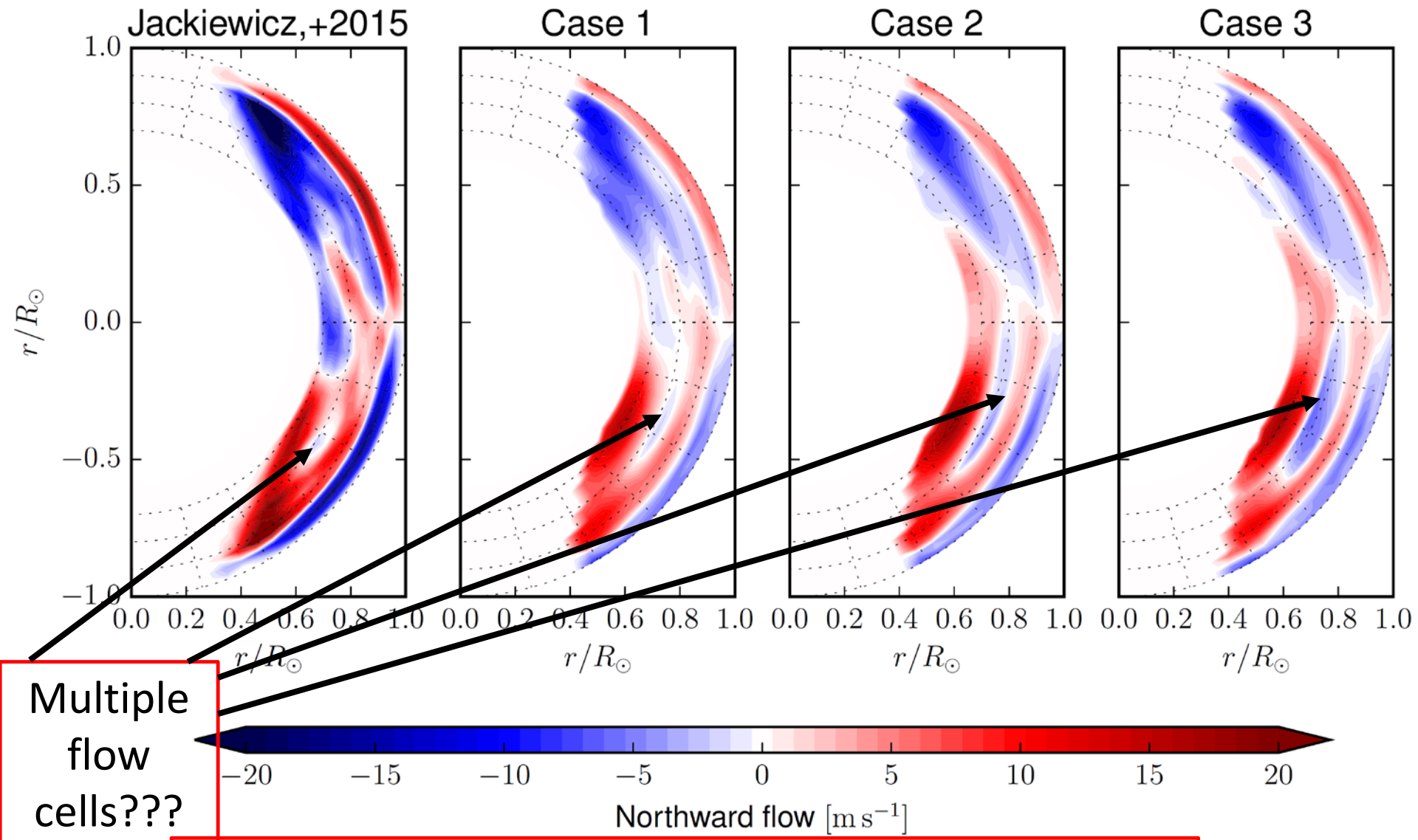








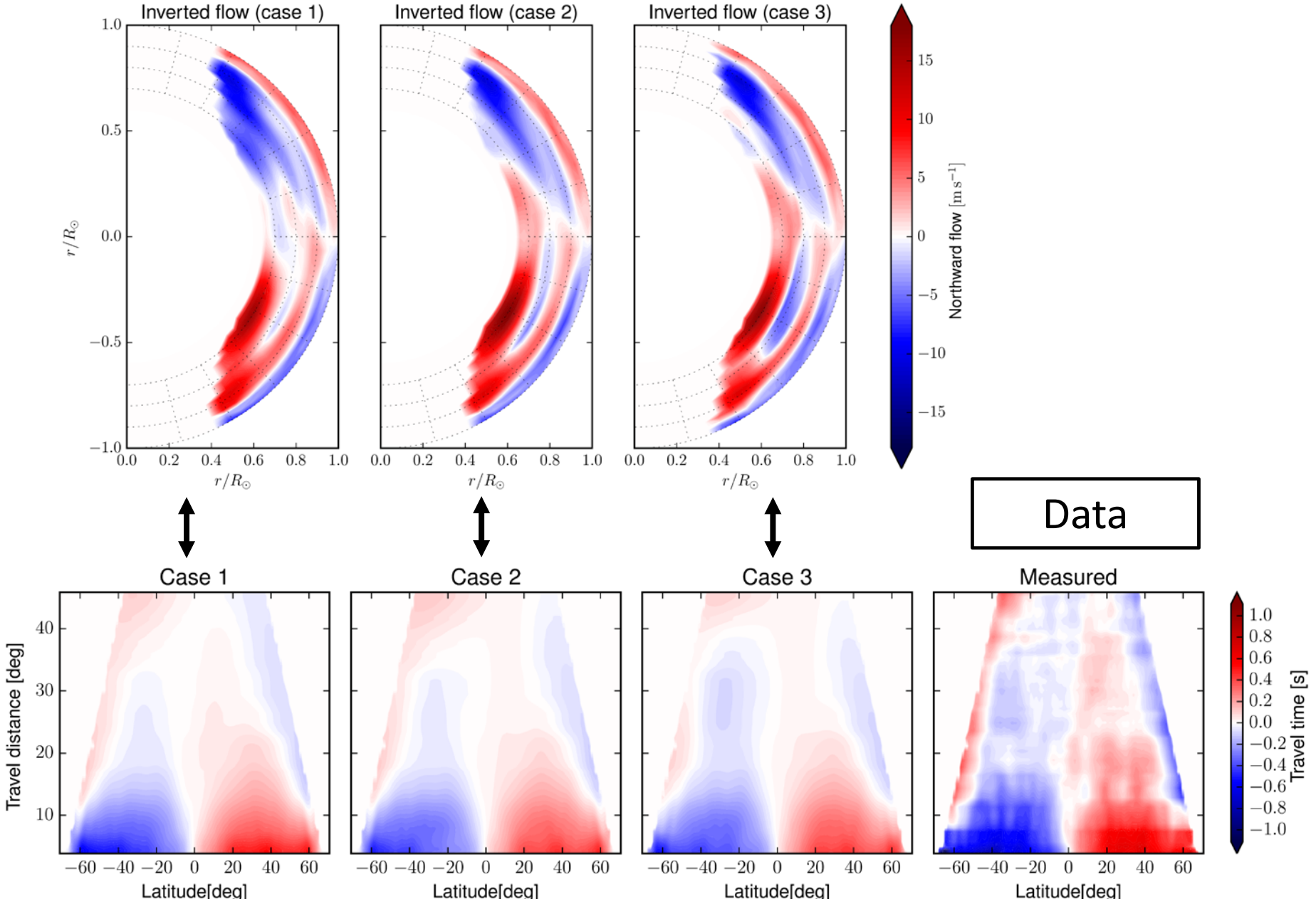
Inversions of GONG Data (2): Full Covariance + Cross-talk



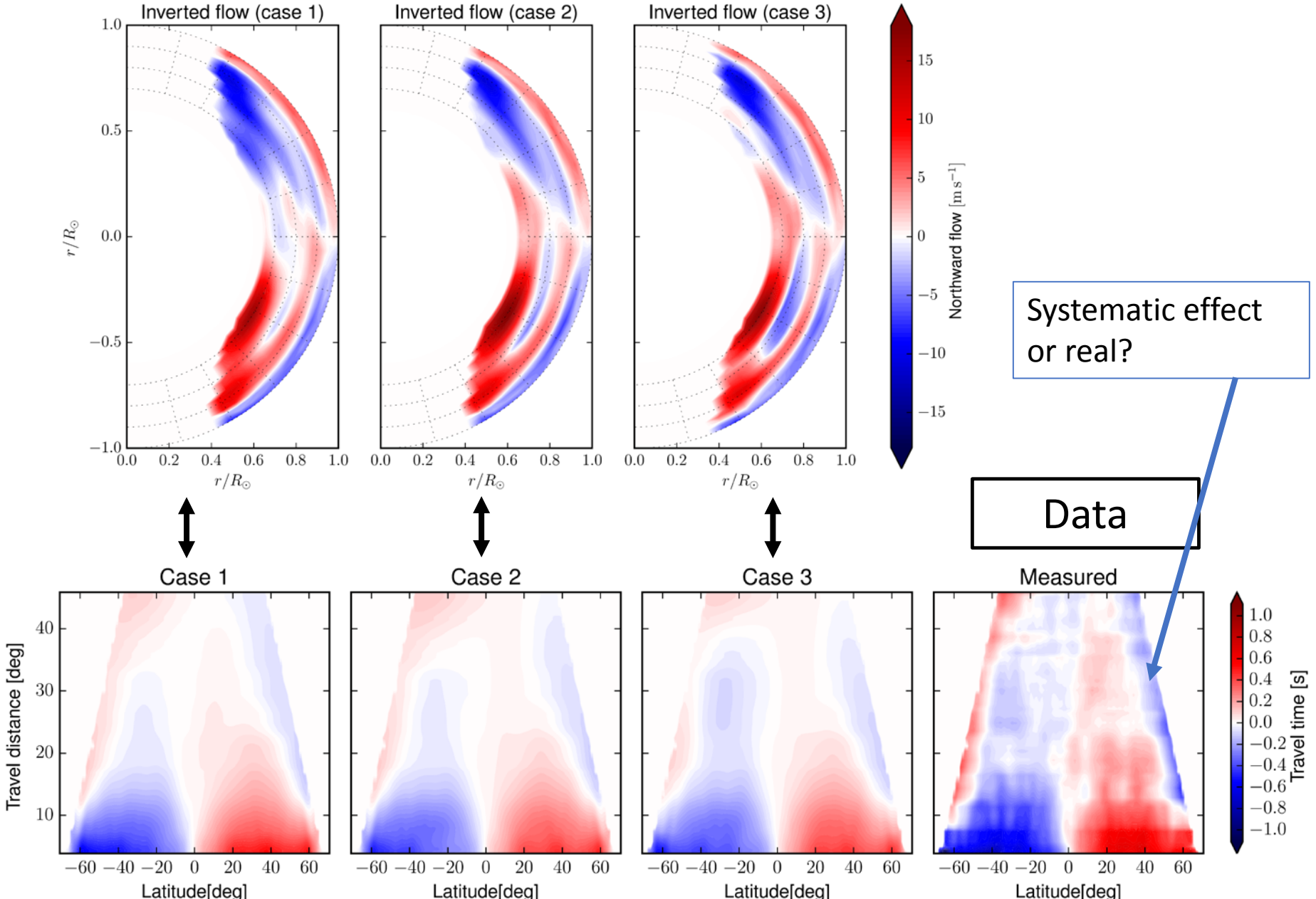
Multiple flow cells???

2 or 3 cells, depending on radial flow profile !?

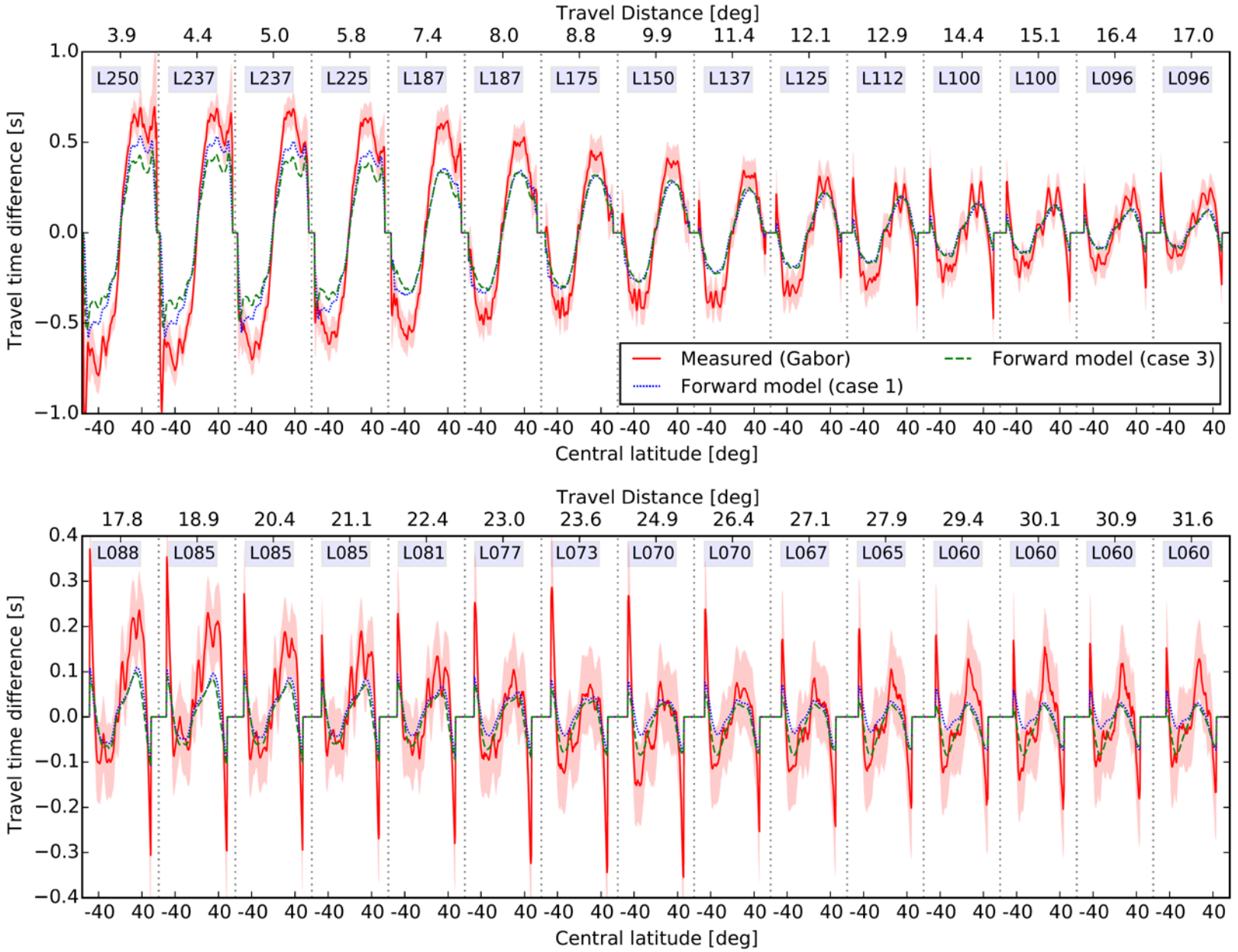
Born kernel inversion results vs. data



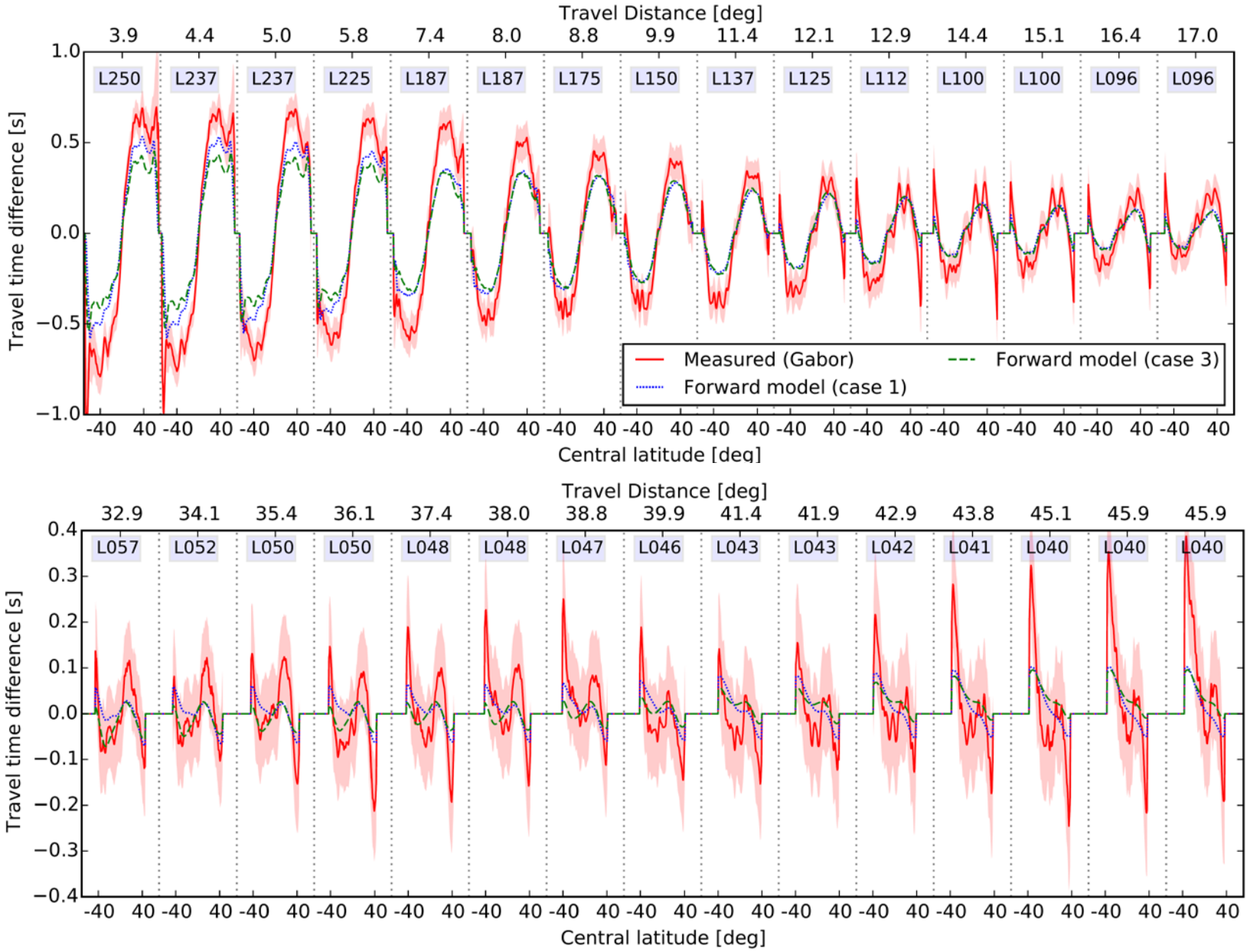
Born kernel inversion results vs. data



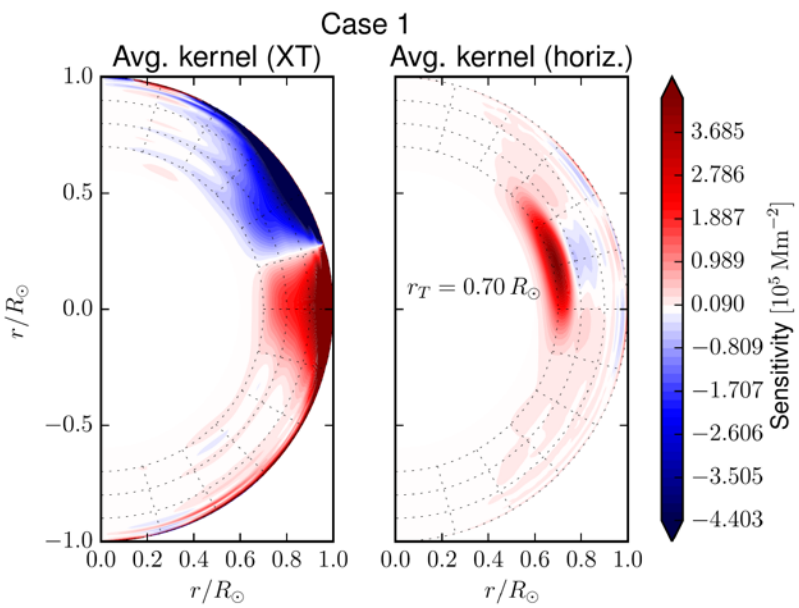
Born kernel inversion results vs. data

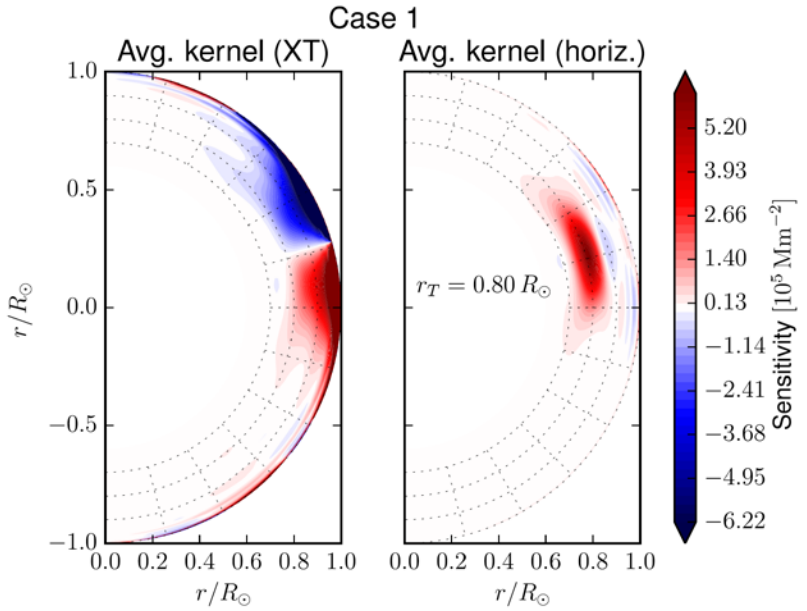


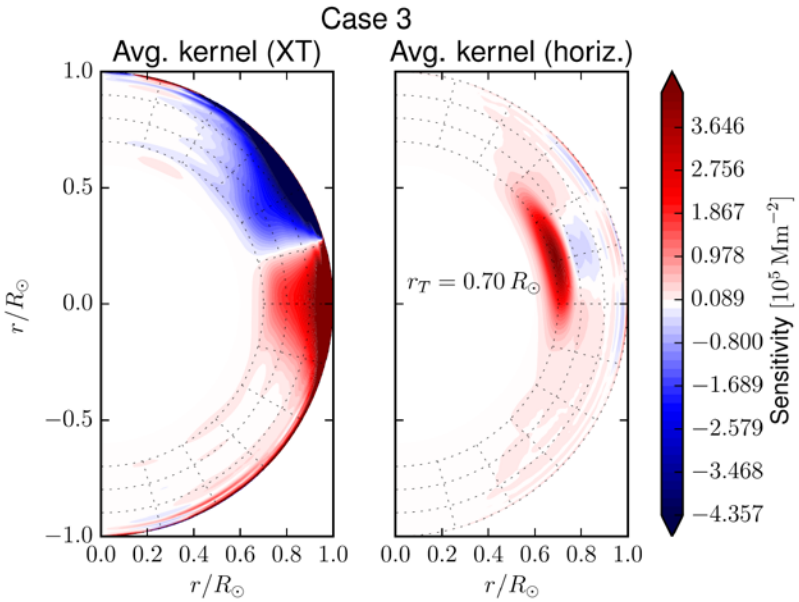
Born kernel inversion results vs. data

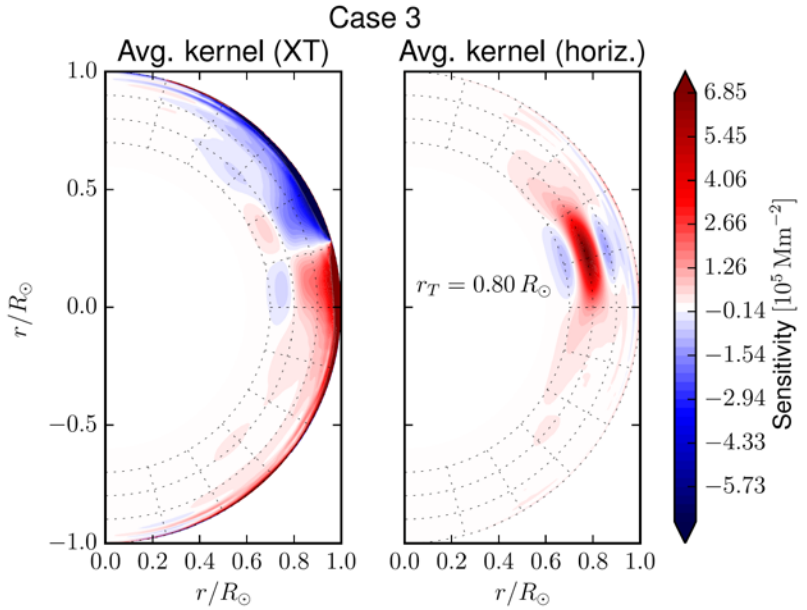


Born kernel inversion results (2): avg. Kernels





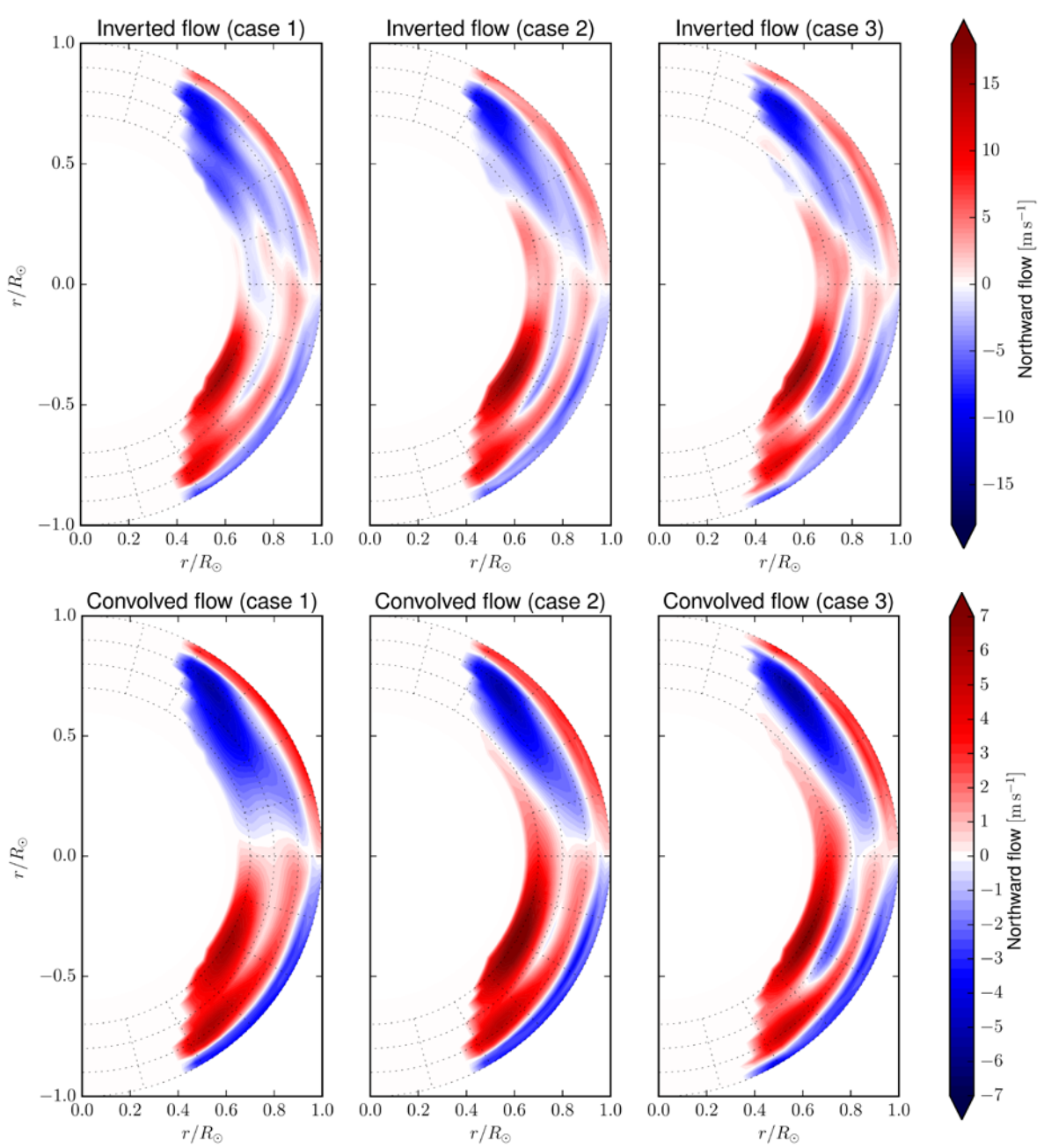




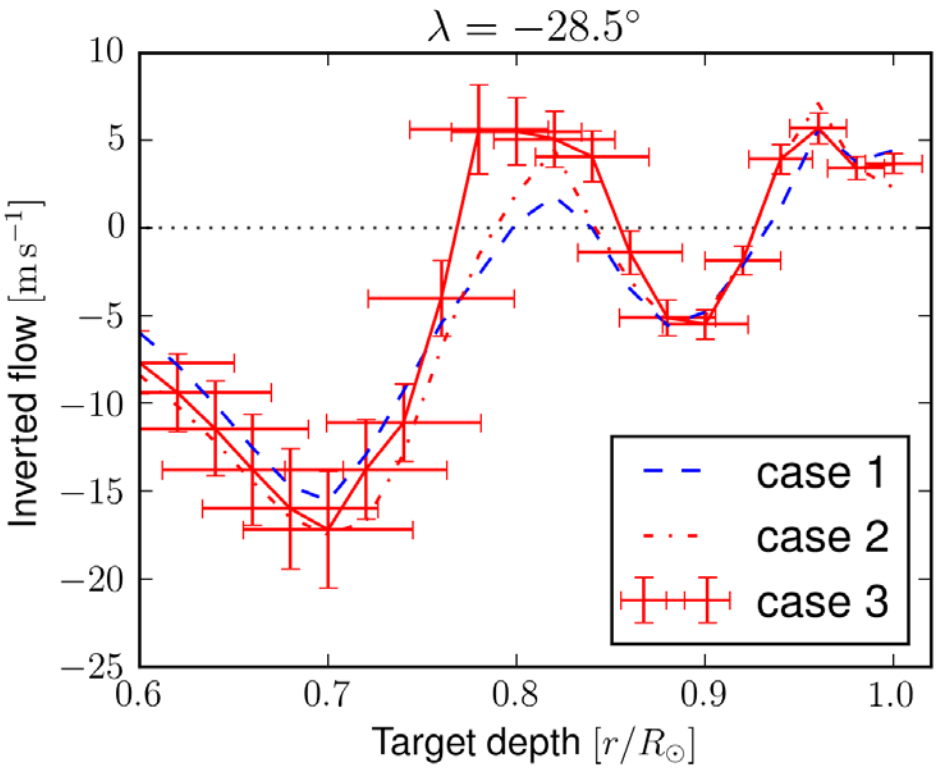
Born kernel inversion results convolved with avg. Kernels

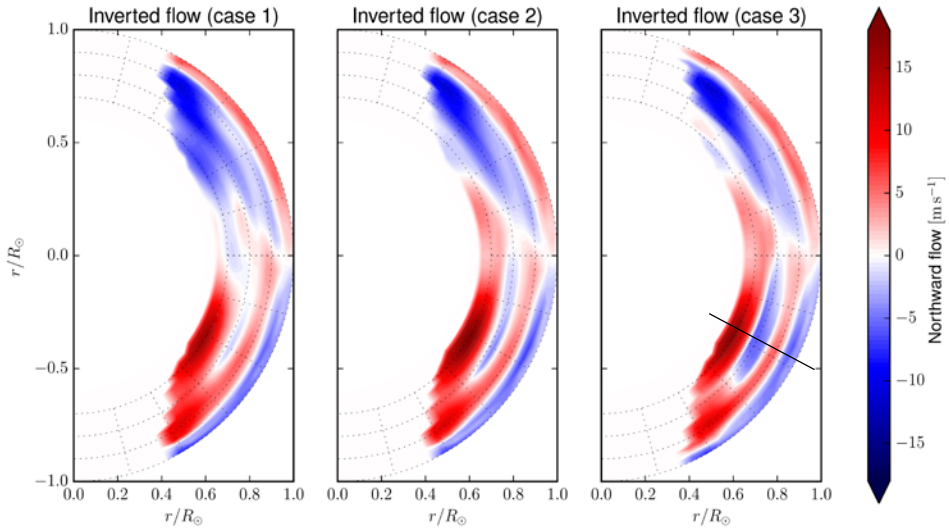
- Convolved flow shows how avg. Kernels change flows.
- Have a guess, how original flow looks like!

- Case 3 looks self-similar, just with reduction of speed.
- Original may be like case 3, with higher velocity.



Inversions of GONG Data (2): Cut at southern hemisphere



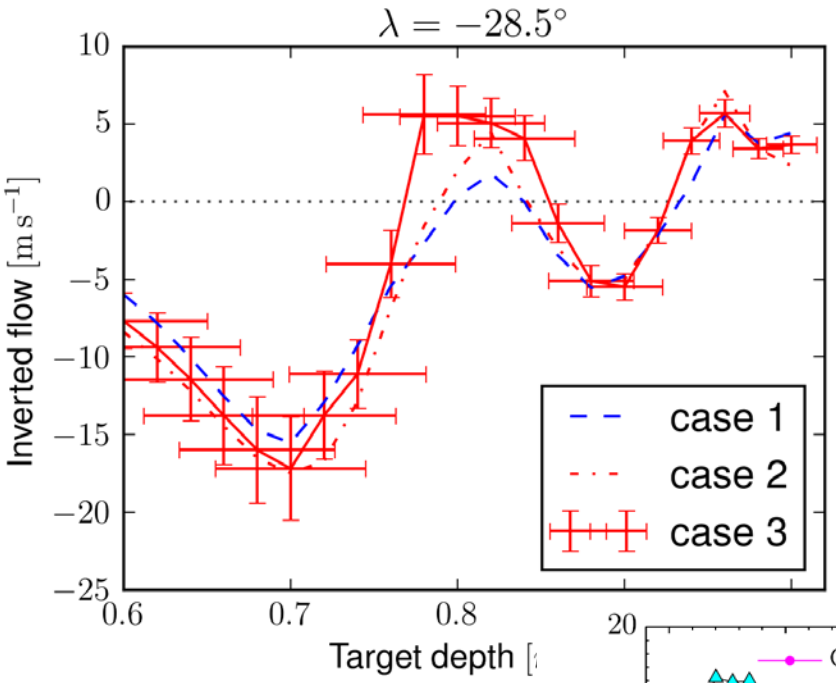


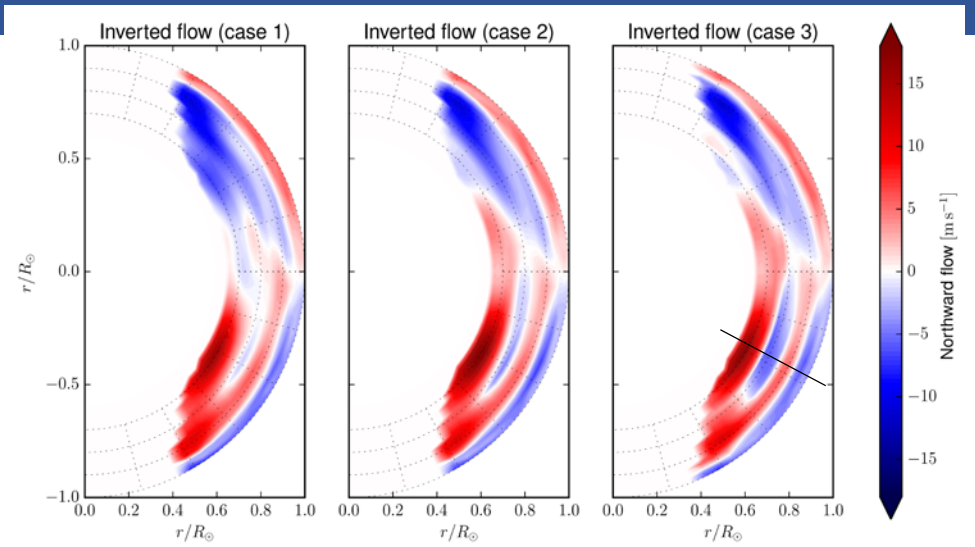
Amplitude of flows:

- Surface: Smaller amplitude: 5 m/s
- BCZ: up to 15 m/s (!?)

→ Problems for mass conservation?

Inversions of GONG Data (2): Cut at southern hemisphere





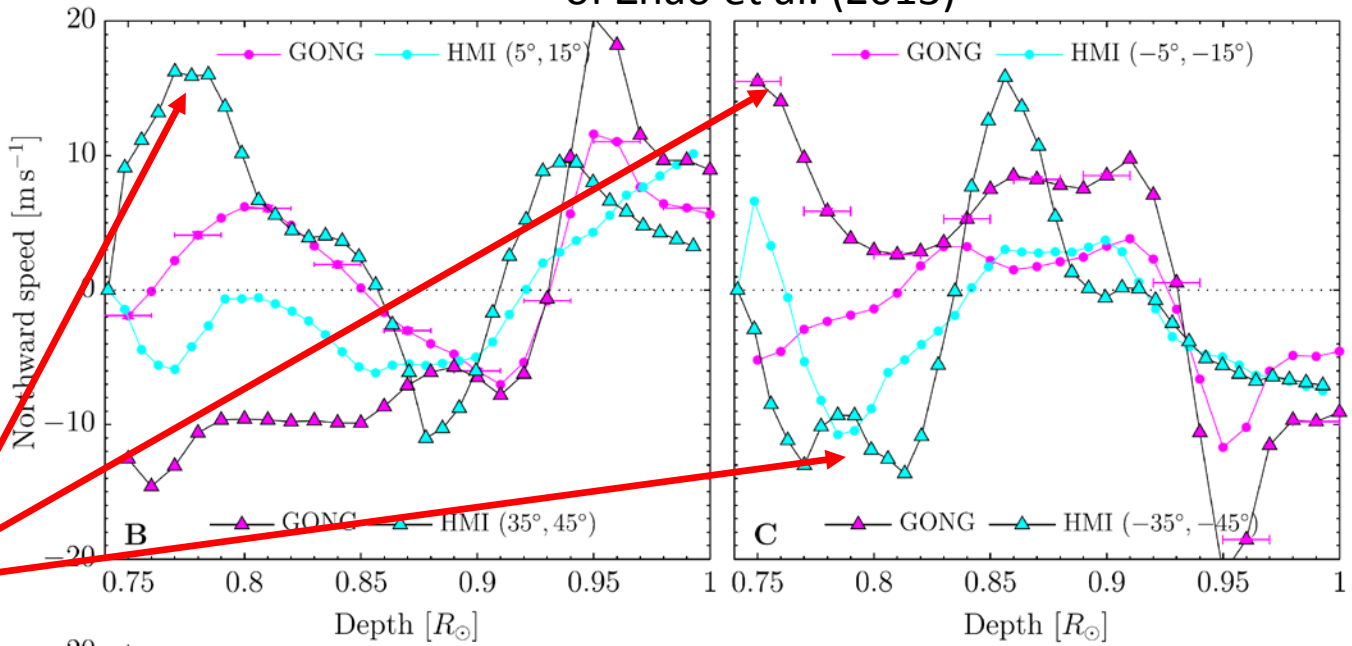
Jackiewicz et al. (2015) including results of Zhao et al. (2013)

Amplitude of flows:

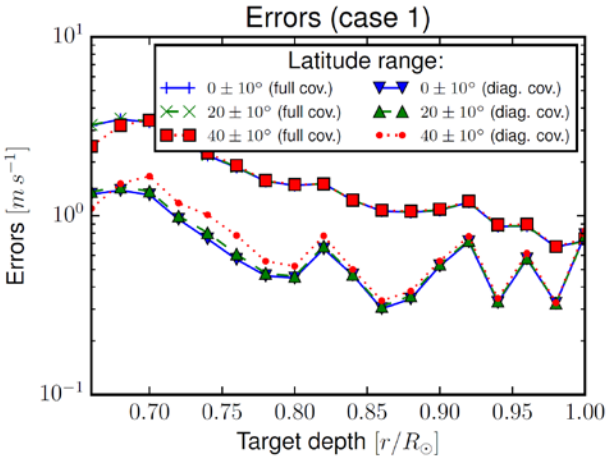
- Surface: Smaller amplitude: 5 m/s
- BCZ: up to 15 m/s (!?)

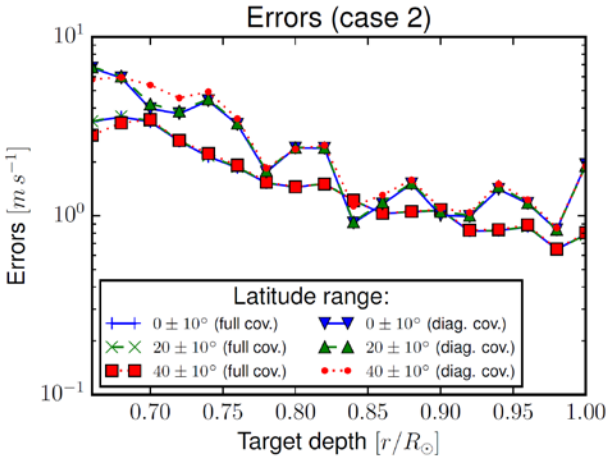
→ Problems for mass conservation?

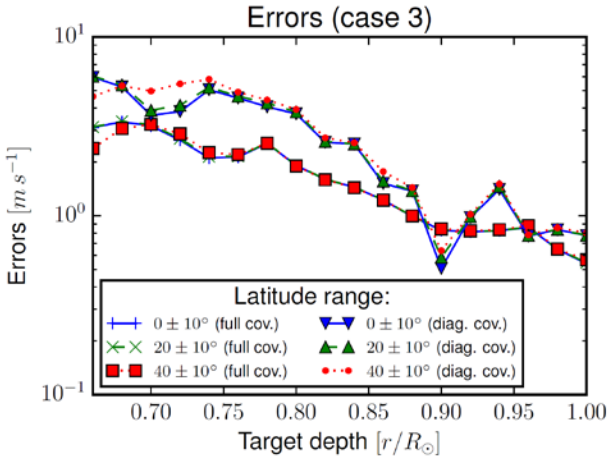
→ 15 m/s at BCZ also in other non-mass conserved results



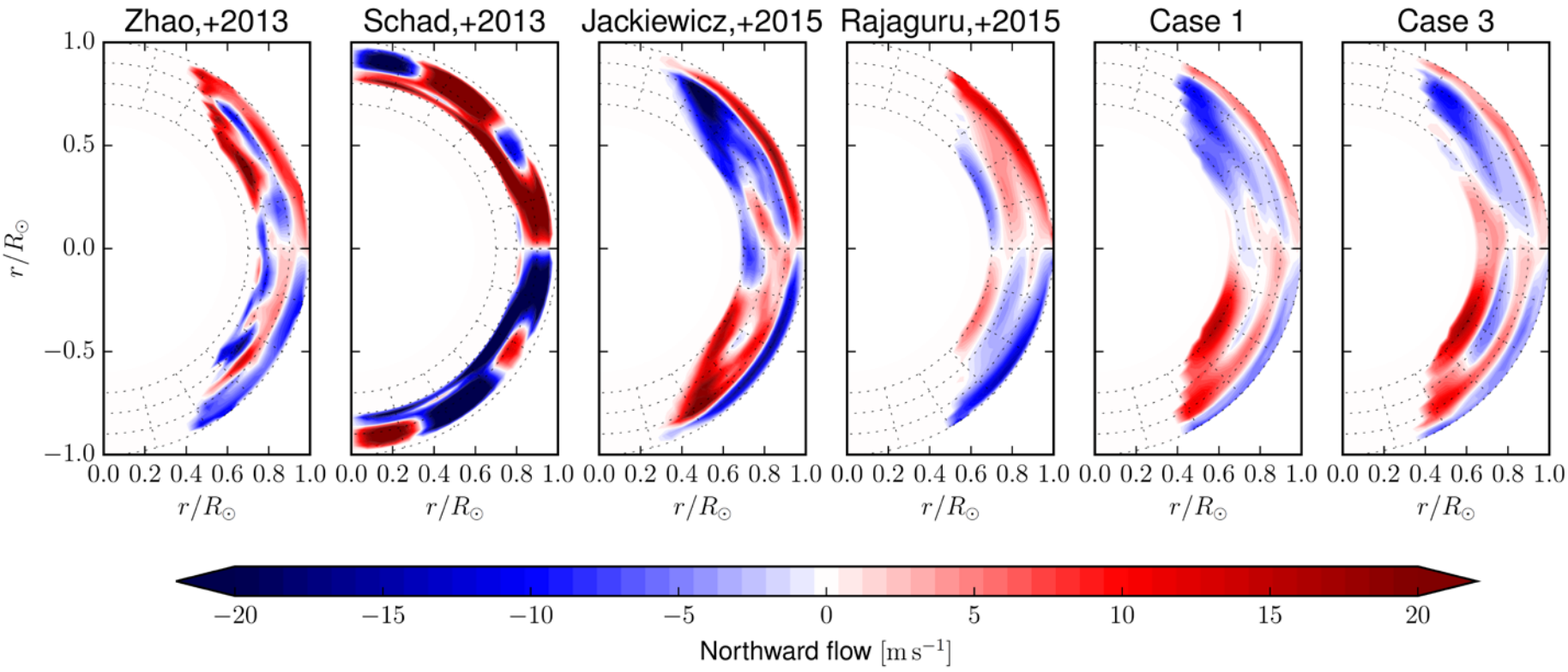
Born kernel inversion results (2): errors







Summary: Inversions with Born Kernels



- Pick your profile!
- Born vs. ray kernels doesnt seem to have a great difference for phase-speed filtered data
- Full covariance has an impact!
- Confirmation above 0.85 rSun
- Especially shallow return flow confirmed

Below 0.85 rSun:

- Result depends on SV threshold
- Single or multiple cells possible
- Errors not small enough to conclude (maybe better for HMI?)
- see also Braun and Birch (2008,2009)


Thank you very much!

Acknowledgements

This work was supported by the SOLARNET project (www.solarnet-east.eu), funded by the European Commission's FP7 Capacities Programme under the Grant Agreement 312495.

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013) / ERC Grant Agreement n. 307117. J.J. acknowledges support from the National Science Foundation under Grant Number 1351311. S.K. was supported by NASAs Heliophysics Grand Challenges Research grant 13-GCR1-2-0036.

How did I choose region to plot the results?