

LA-UR-16-25214

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Title: Improvements in Earthquake Location from Joint Inversion of Seismic and Gravity Observations – Application to the Iran Region

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Intended for: EIVR meeting

Issued: 2016-07-19

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Improvements in Earthquake Location from Joint Inversion of Seismic and Gravity Observations – Application to the Iran Region

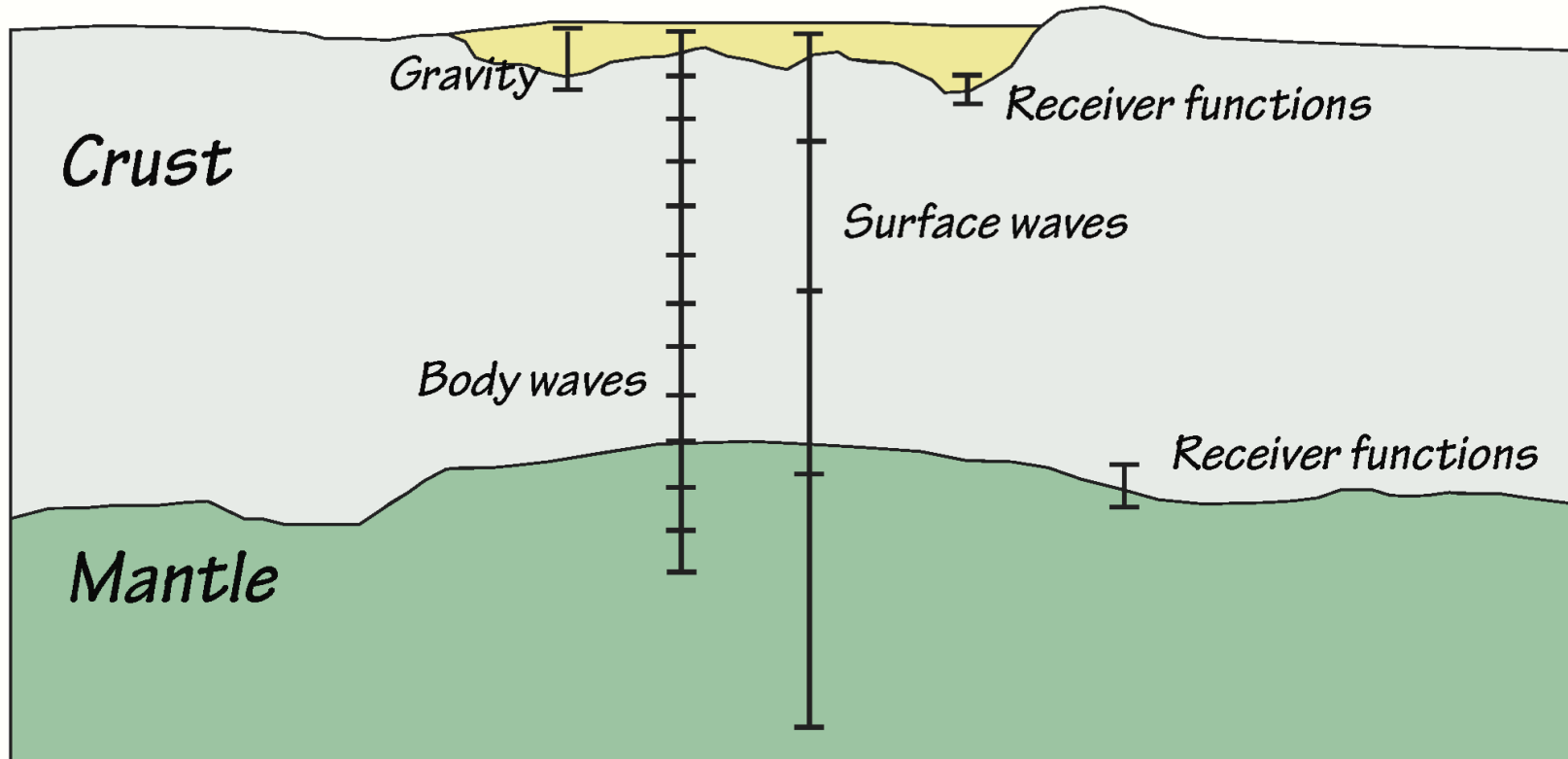
Ellen Syracuse, Monica Maceira, Scott
Phillips, Mike Begnaud, Stuart Nippres,
Eric Bergman, Haijiang Zhang

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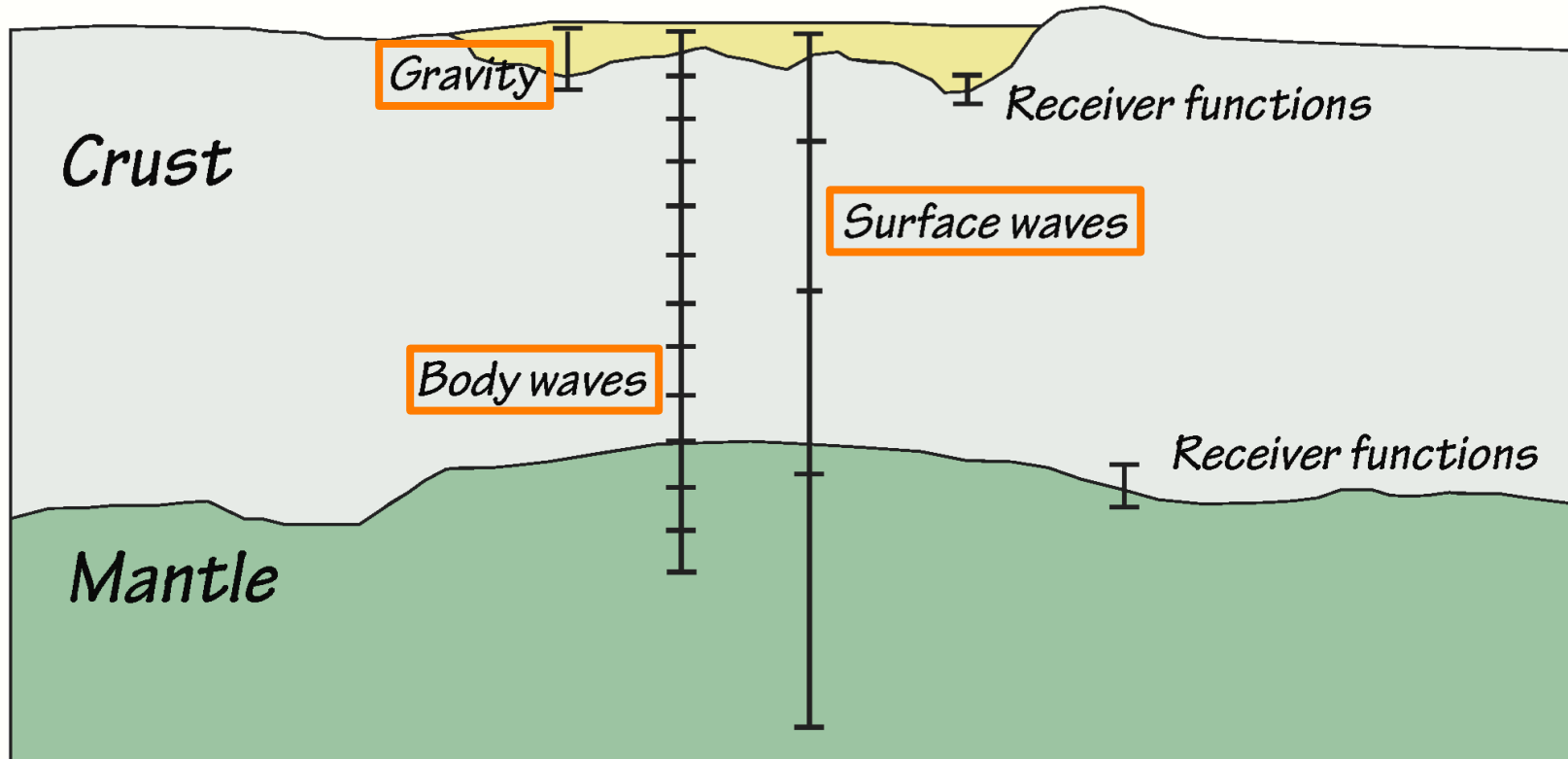


Joint Inversion



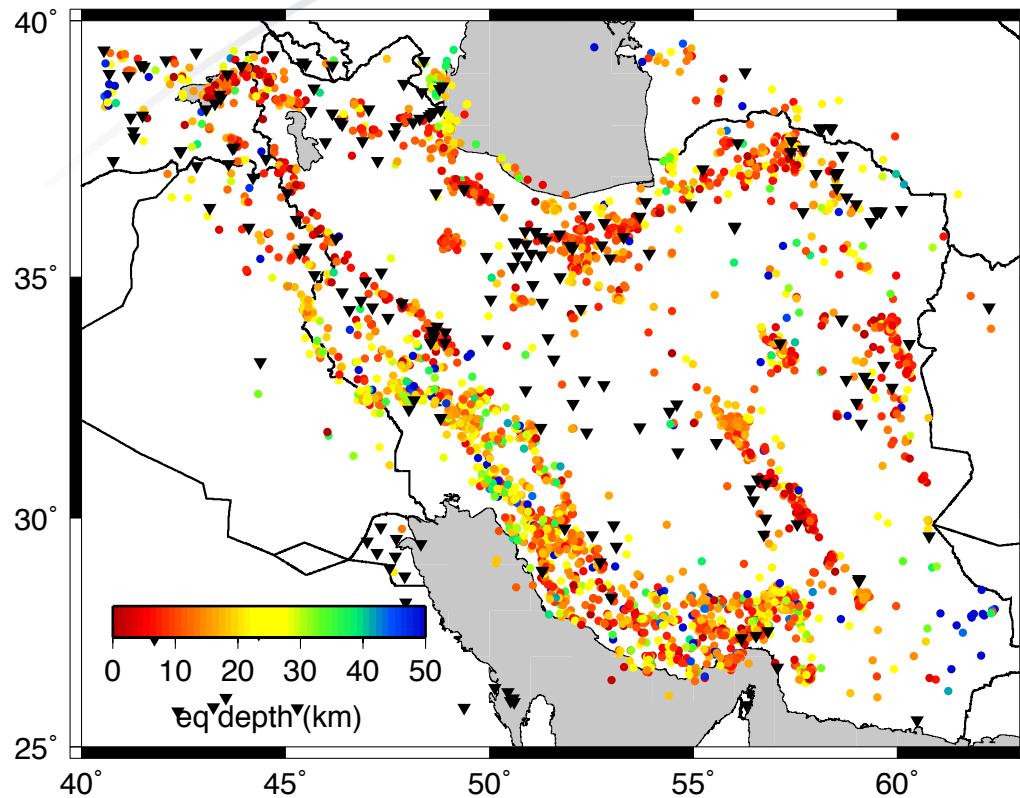
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Joint Inversion



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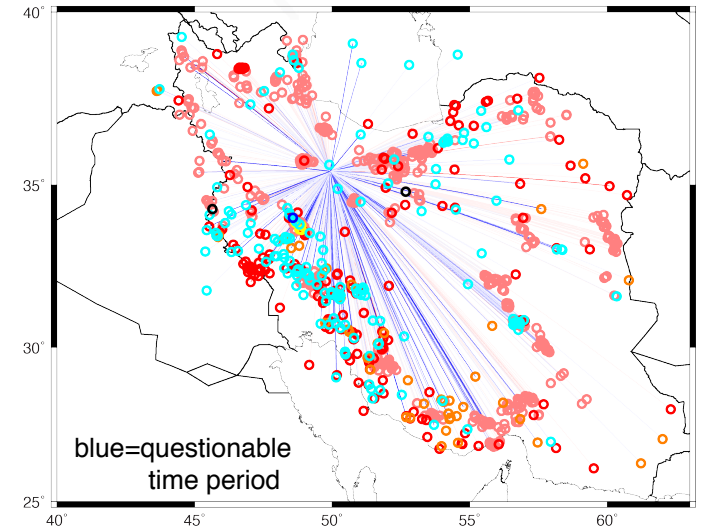
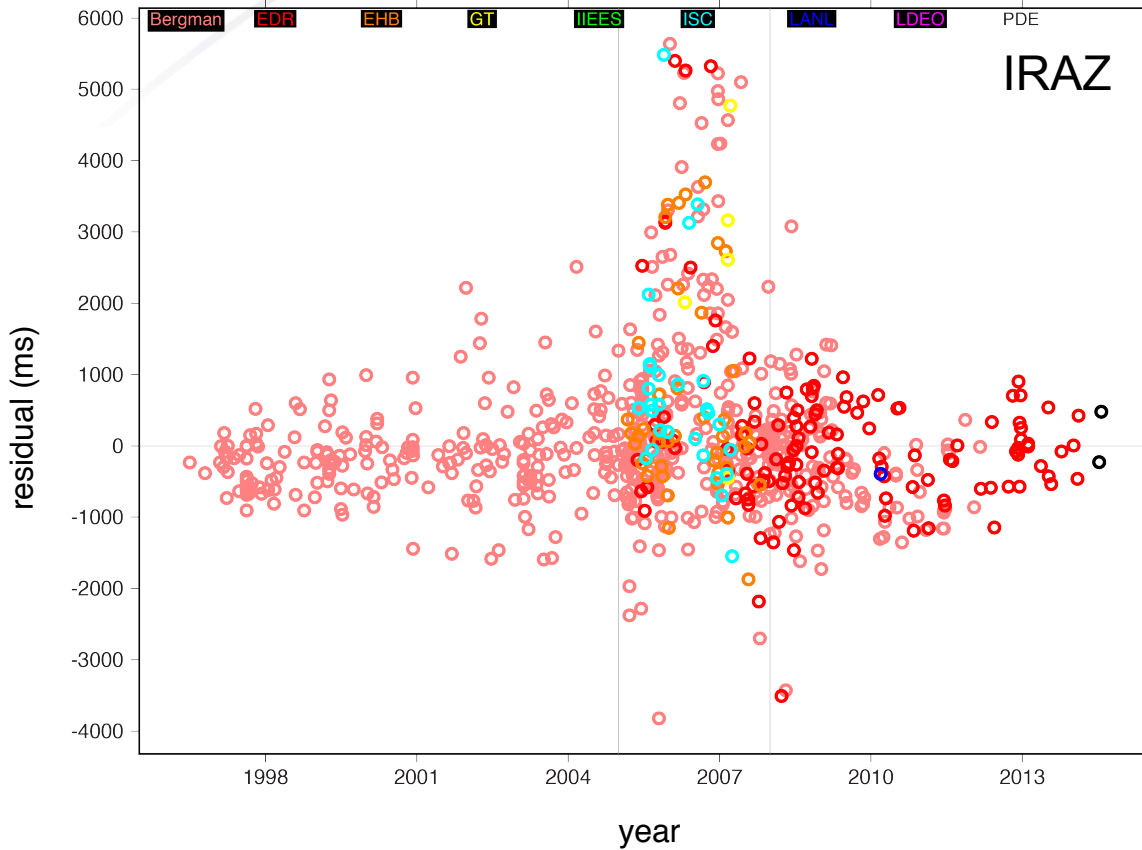
Body-wave dataset



- 3500 earthquakes between 1960 and 2014, with GT estimated at 50 km or better
- 220 stations
- first-arrival P and S phases; 6+ P arrivals, 1+ S arrival

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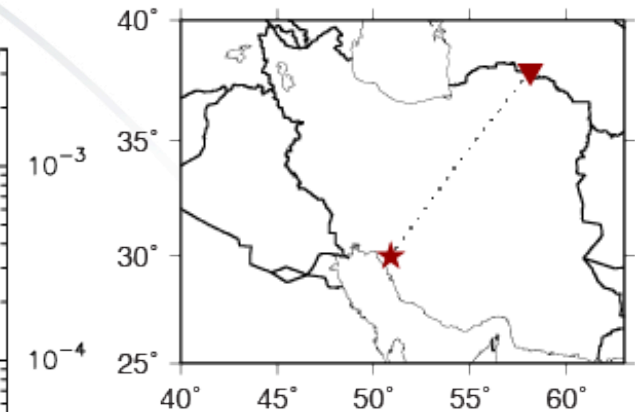
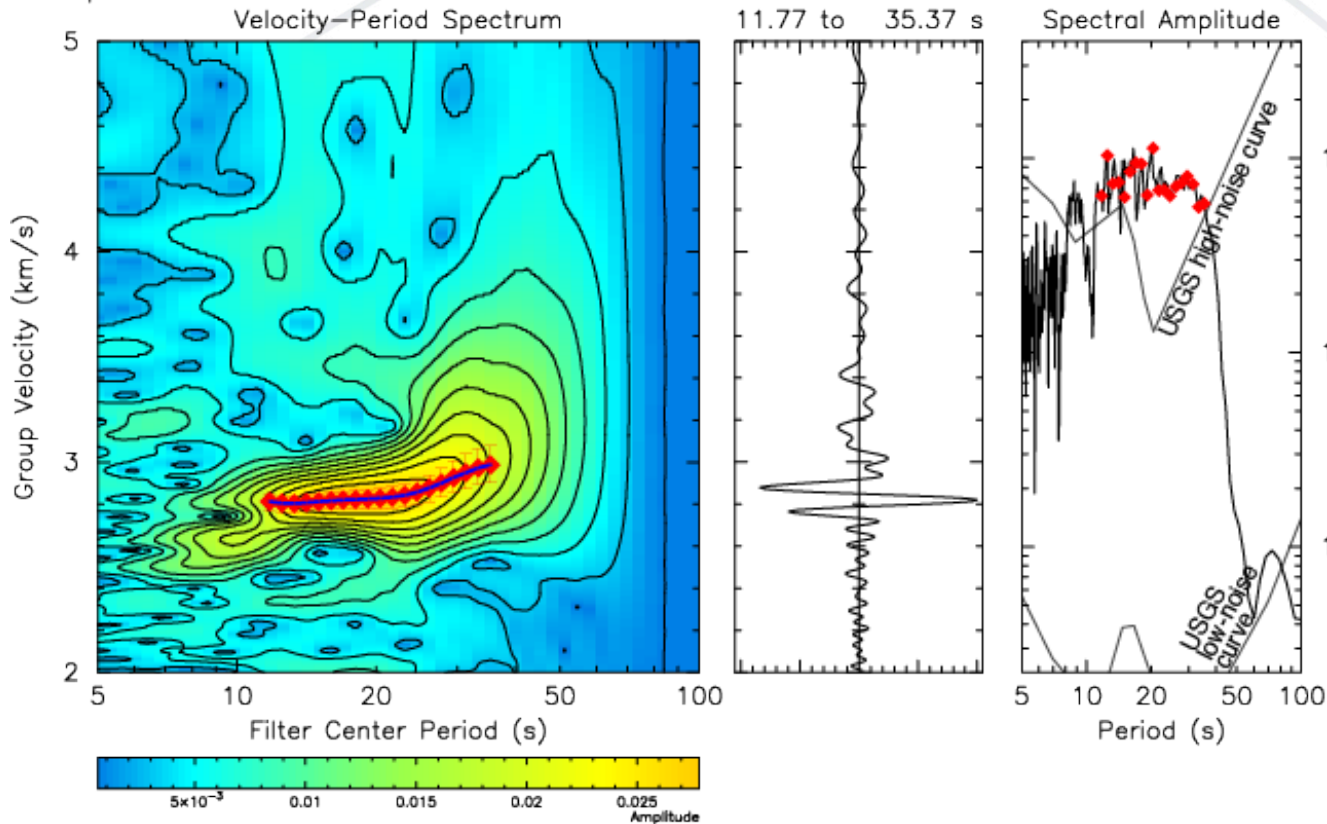
Body-wave dataset



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Surface-wave dataset

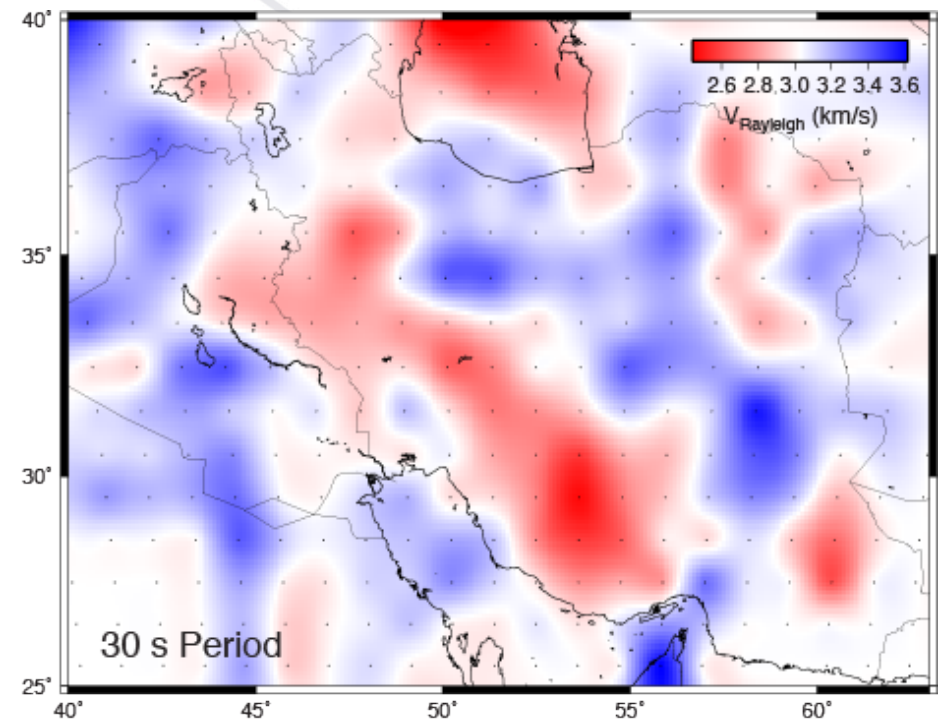
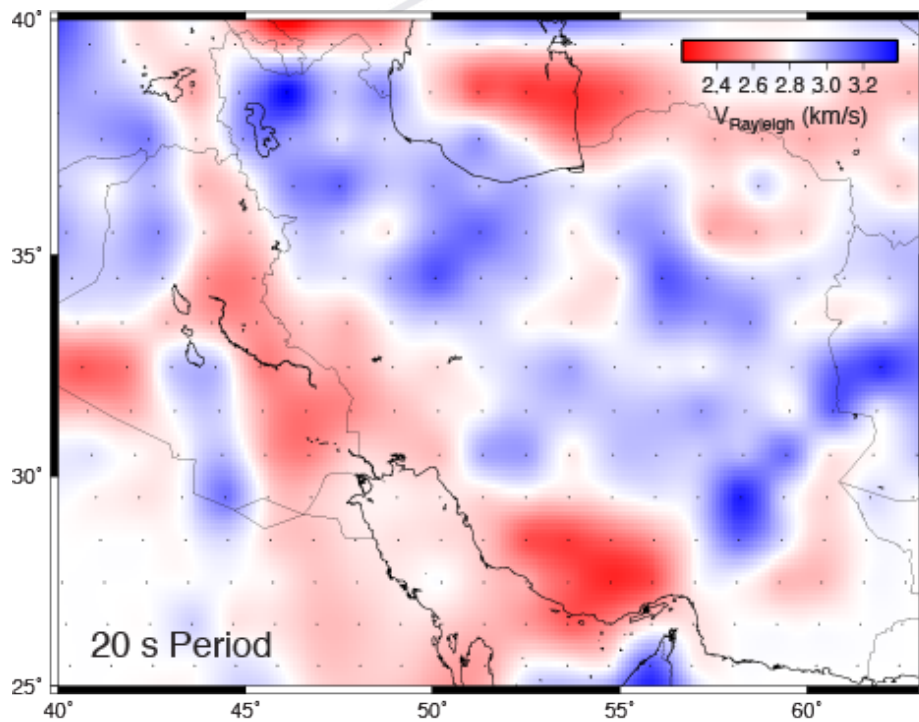
Station: ABKT Component: LHZ00 Date: 2002 06/16 (167) 22:30
Alpha=Variable Distance: 1110.5 Az: 35.1



- multi-filter analysis of Rayleigh wave group velocities

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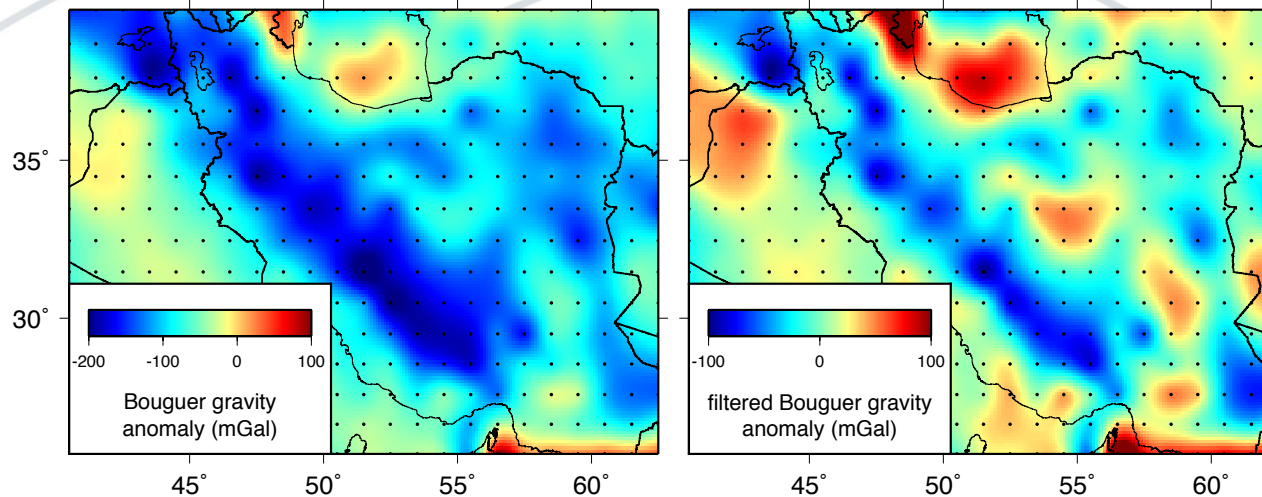
Surface-wave dataset



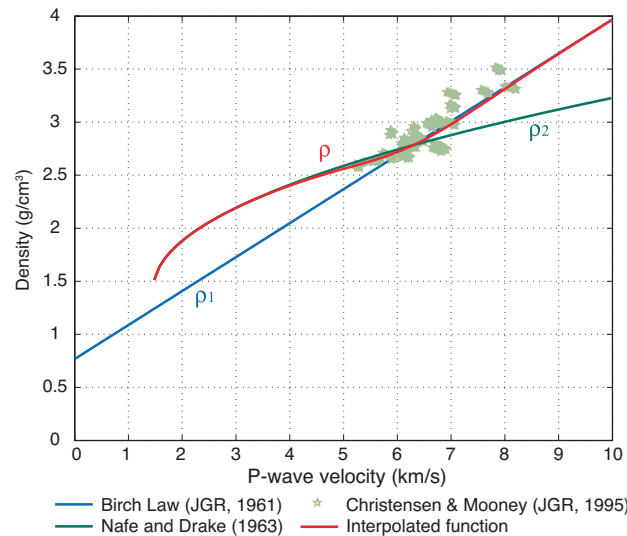
- invert for 2D period-dependent surface wave velocity maps, 10-34 second periods

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Gravity dataset



- filter satellite-based gravity data to remove long-period signals



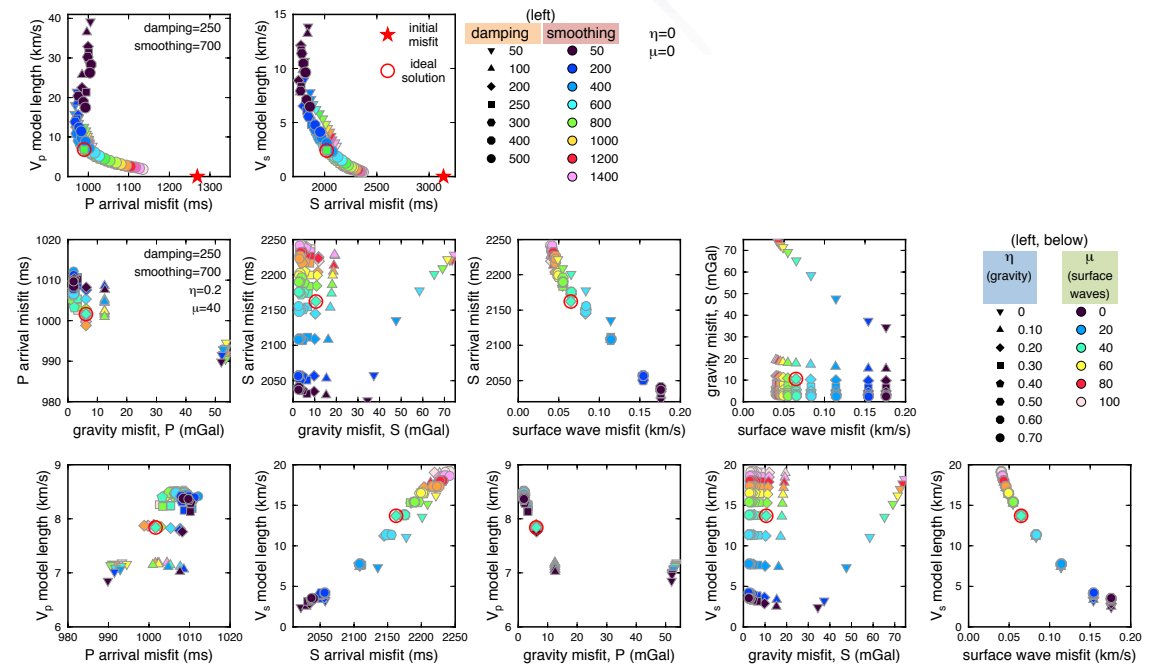
- relate gravity to velocity through empirical density-velocity relationships

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Regularization & data weights

$$\begin{bmatrix}
 \mathbf{G}_H^{T_p} & \mathbf{G}_{V_p}^{T_p} & 0 \\
 \mathbf{G}_H^{T_s} & 0 & \mathbf{G}_{V_s}^{T_s} \\
 0 & 0 & \mu \mathbf{G}_{V_s}^{SW} \\
 0 & \eta \mathbf{G}_{V_p}^{B_p} & 0 \\
 0 & 0 & \eta \mathbf{G}_{V_s}^{B_s} \\
 0 & \mathbf{wL}_{V_p} & 0 \\
 0 & 0 & \mathbf{wL}_{V_s} \\
 \lambda \mathbf{I} & 0 & 0 \\
 0 & \lambda \mathbf{I} & 0 \\
 0 & 0 & \lambda \mathbf{I}
 \end{bmatrix}
 \begin{bmatrix}
 \Delta \mathbf{H} \\
 \Delta \mathbf{m}_p \\
 \Delta \mathbf{m}_s
 \end{bmatrix}
 =
 \begin{bmatrix}
 \mathbf{d}^{T_p} \\
 \mathbf{d}^{T_s} \\
 \mu \mathbf{d}^{SW} \\
 \eta \mathbf{d}^{B_p} \\
 \eta \mathbf{d}^{B_s} \\
 0 \\
 0 \\
 0 \\
 0 \\
 0
 \end{bmatrix}$$

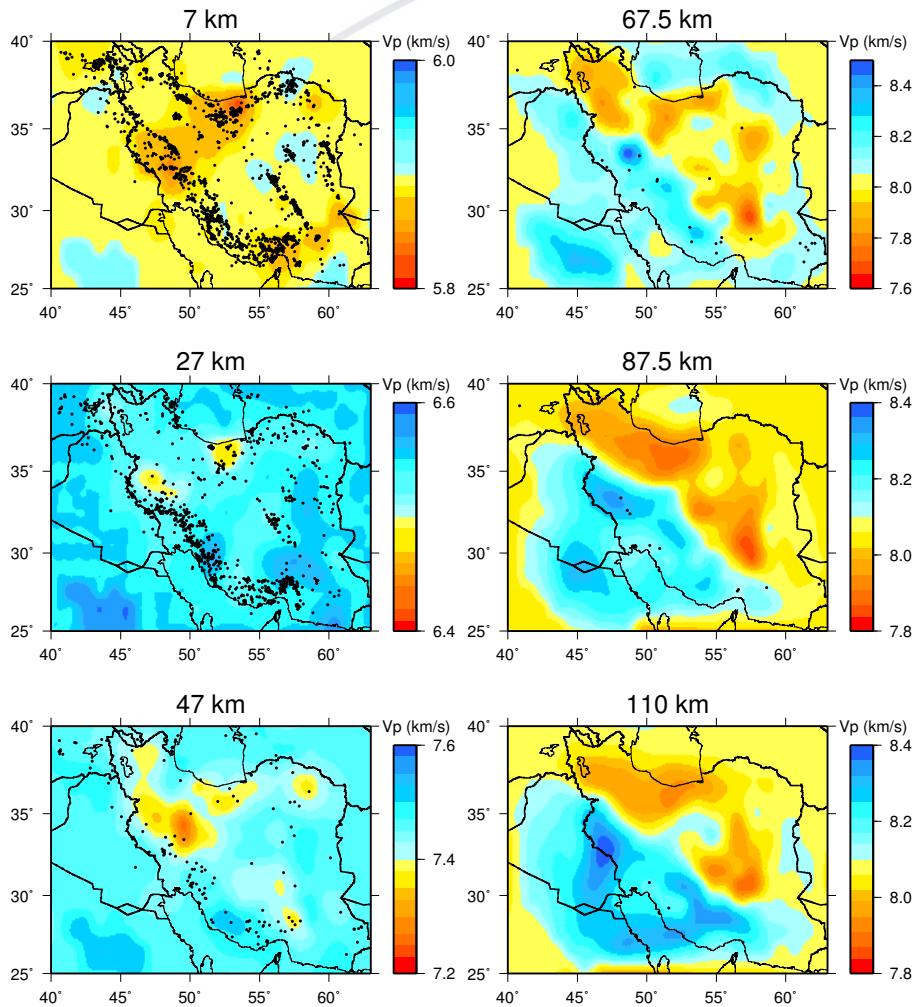
· explore a full range of regularization and data weights



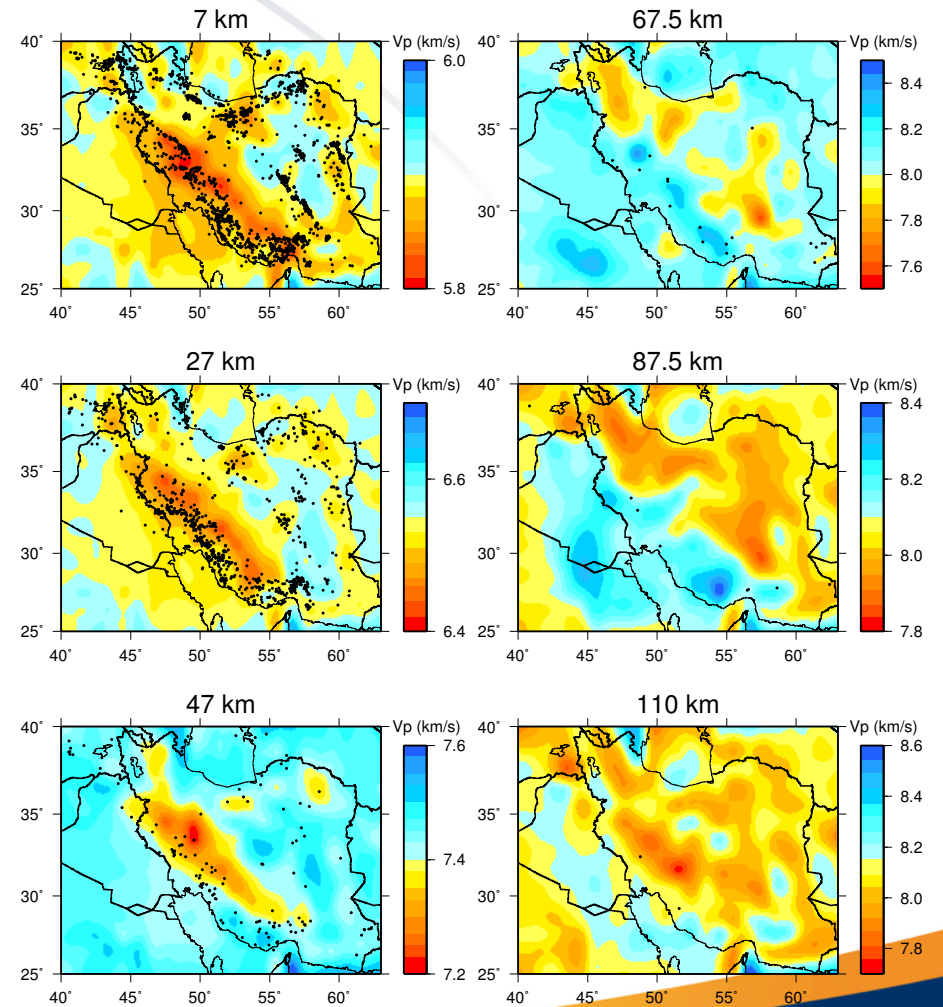
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P-wave velocities

Travel-times only



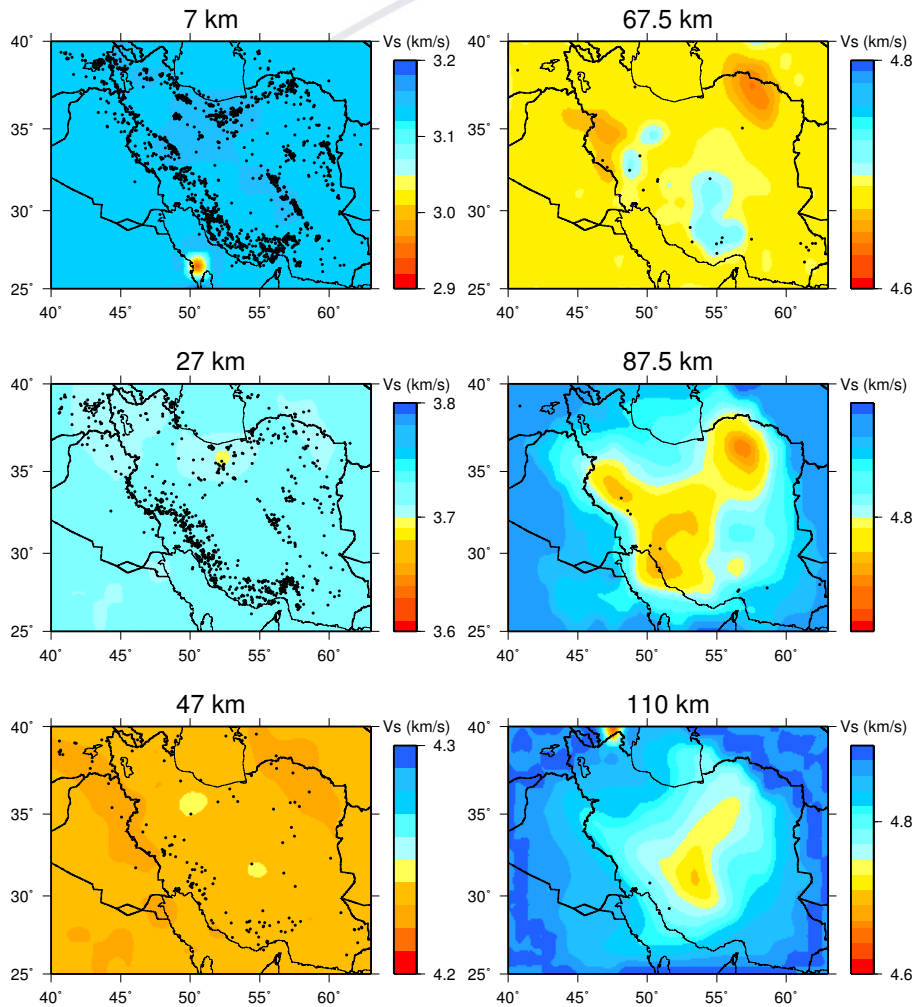
Joint inversion



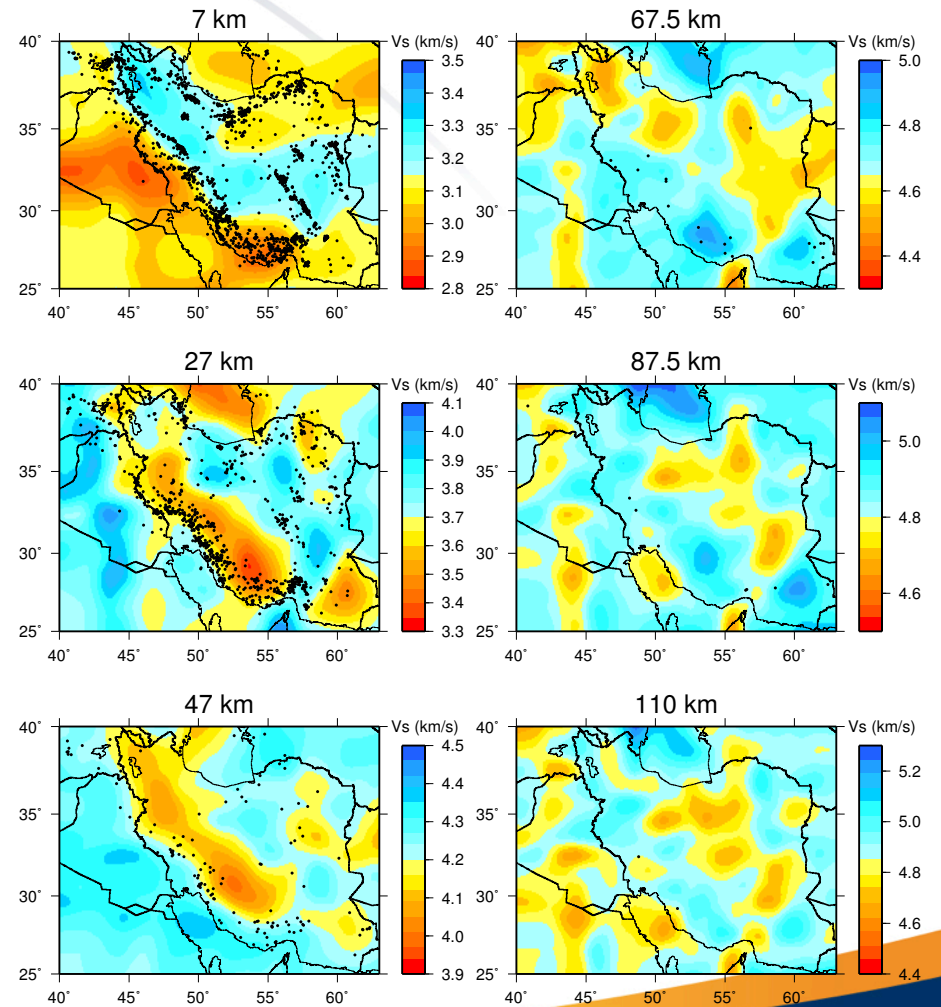
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S-wave velocities

Travel-times only



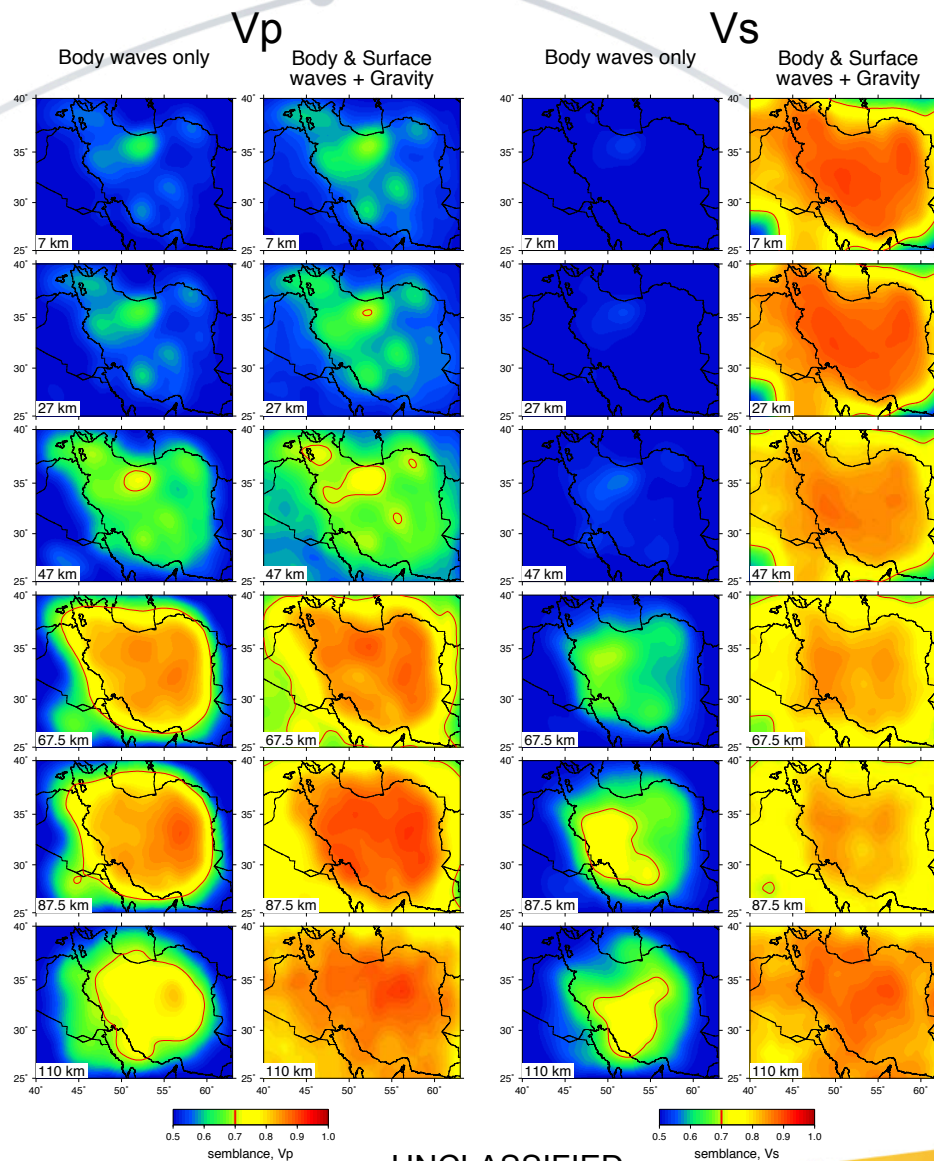
Joint inversion



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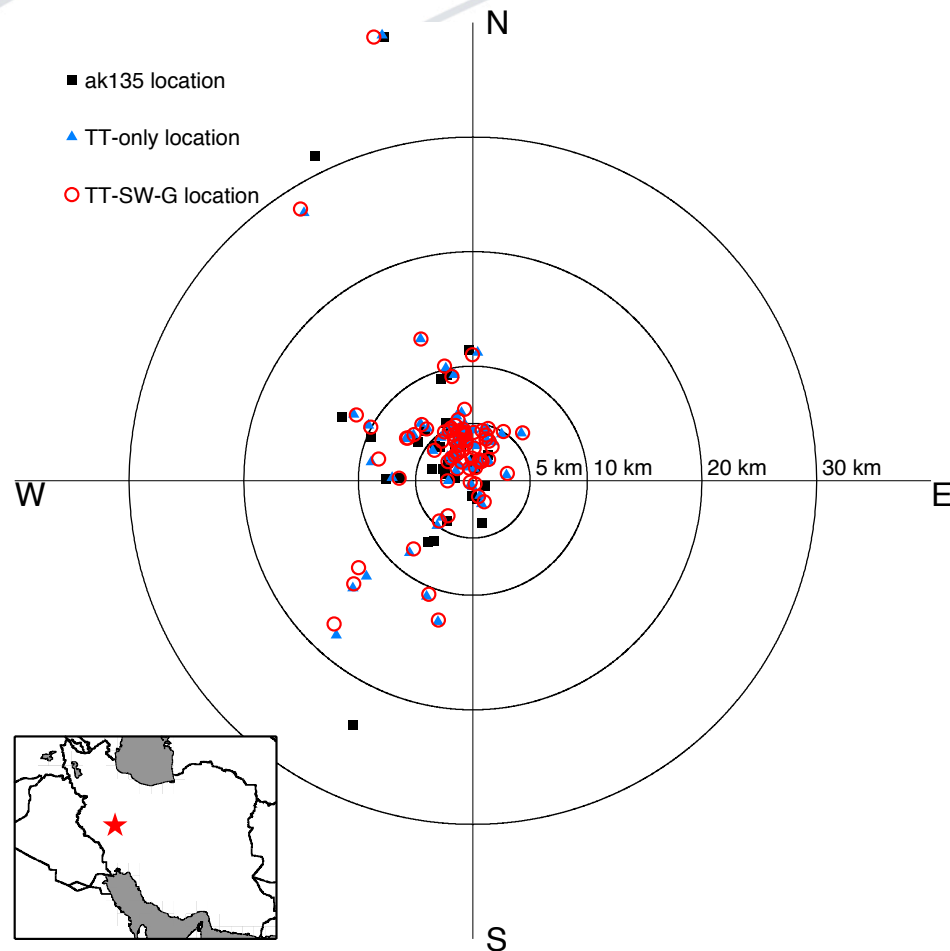
Velocity recovery

- semblance tests of the recovery of 100 randomly perturbed synthetic velocity models



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Effects on relocations



- multiple-event relocation of 2006 M6.1 Silahour Earthquake sequence by Ghods et al., 2013

- all earthquakes and events within 100 km of centroid are removed from 3D velocity inversion

- after relocation of target earthquakes, misfits are:

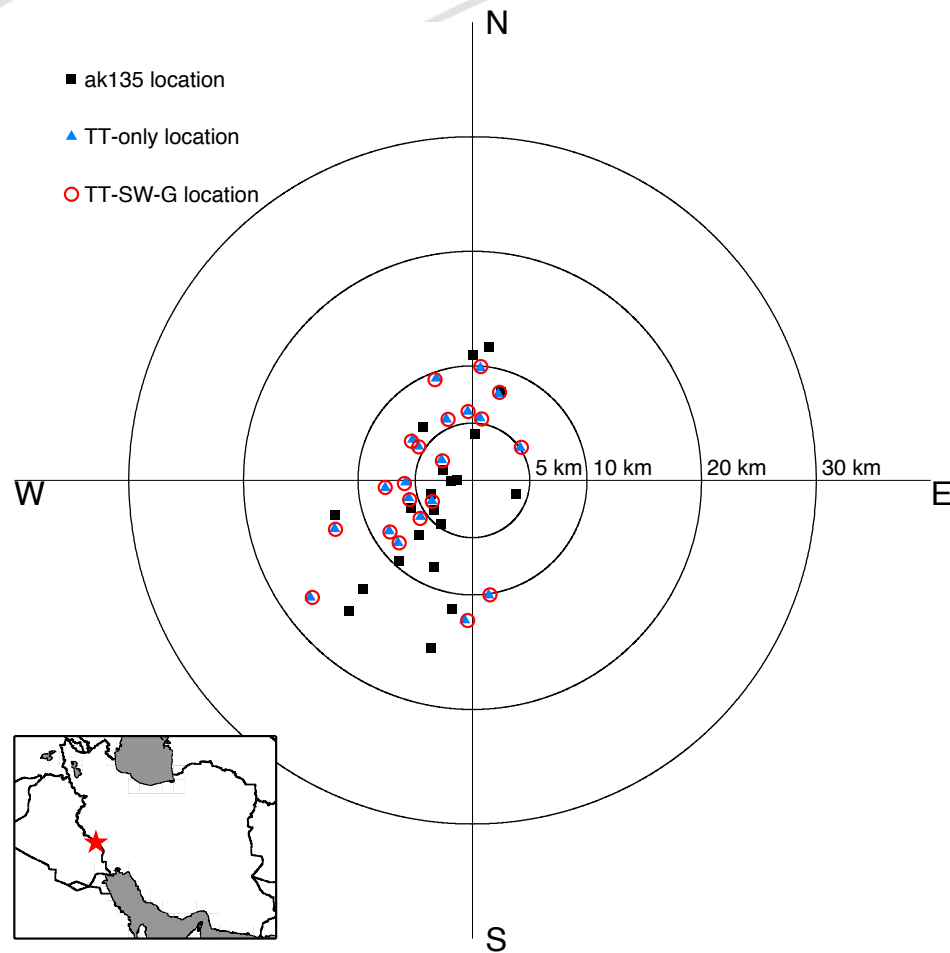
 - 7.12 km for ak135

 - 5.95 km for TT-only model

 - 5.85 km for joint model

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Effects on relocations



- joint analysis of seismic waveforms and InSAR constraints for 2008 & 2012 earthquake sequences by S. Nippress

- all earthquakes and events within 100 km of centroid are removed from 3D velocity inversion

- after relocation of target earthquakes, misfits are:

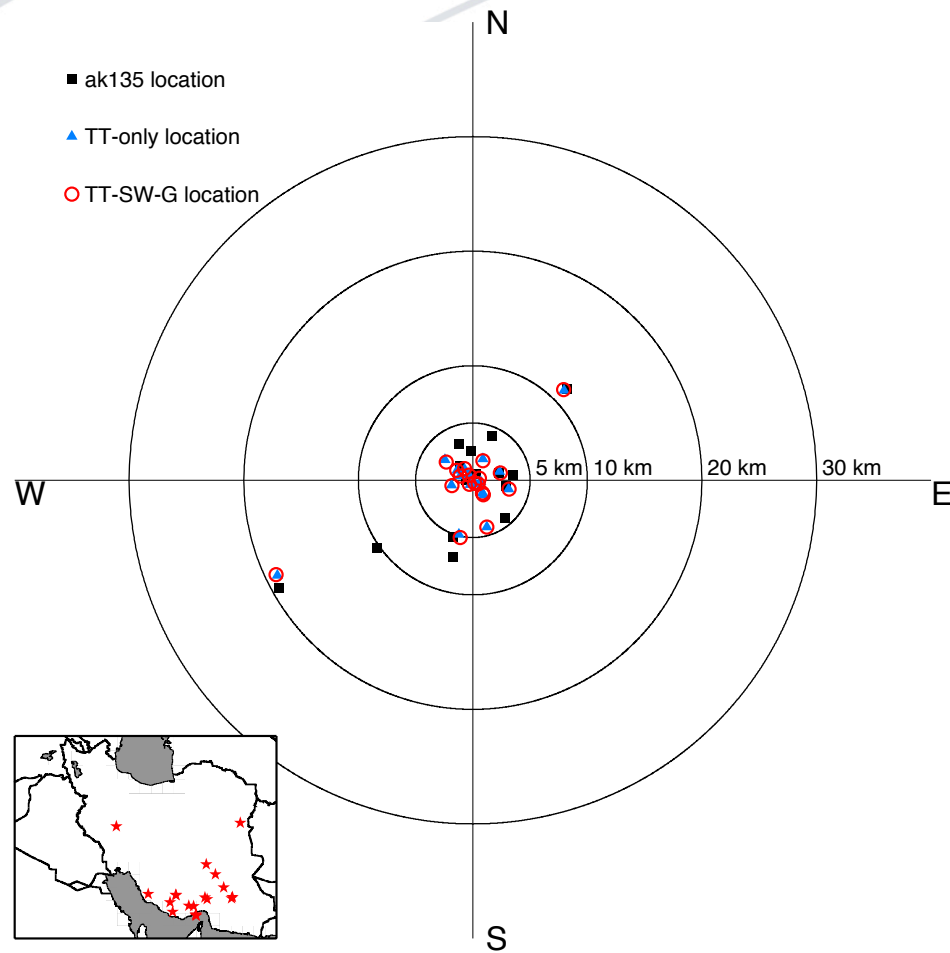
7.74 km for ak135

7.76 km for TT-only model

7.76 km for joint model

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Effects on relocations



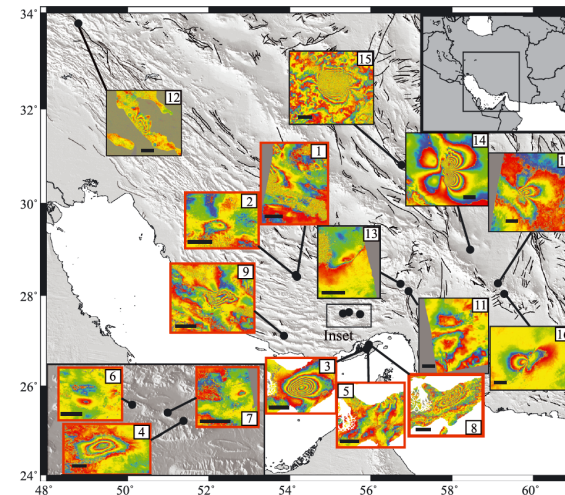
- compilation of InSAR constraints on fault geometries throughout Iran

- after relocation of target earthquakes, misfits are:

5.28 km for ak135

3.24 km for TT-only model

3.24 km for joint model



Barnhart et al., 2013

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Summary



- Joint inversion of multiple geophysical datasets improves recovery of velocity structures, particularly in Vs and in shallow parts of the model, in comparison to travel-time only models
- Resulting fits to travel time data are minimally degraded by joint inversions
- Correspondingly, fits to independent estimates of ground-truth locations are minimally affected by joint inversions
- Currently working on
 - expanding the boundaries of the model
 - testing ways of 'nicely' integrating the model into SALSA3D

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Joint Inversion

body-wave derivatives	$\mathbf{G}_H^{T_p}$	$\mathbf{G}_{V_p}^{T_p}$	0	$\begin{bmatrix} \Delta \mathbf{H} \\ \Delta \mathbf{m}_p \\ \Delta \mathbf{m}_s \end{bmatrix} =$	\mathbf{d}^{T_p}
	$\mathbf{G}_H^{T_s}$	0	$\mathbf{G}_{V_s}^{T_s}$		\mathbf{d}^{T_s}
surface-wave derivatives	0	0	$\mu \mathbf{G}_{V_s}^{SW}$		$\mu \mathbf{d}^{SW}$
	0	$\eta \mathbf{G}_{V_p}^{B_p}$	0		$\eta \mathbf{d}^{B_p}$
gravity derivatives	0	0	$\eta \mathbf{G}_{V_s}^{B_s}$		$\eta \mathbf{d}^{B_s}$
	0	$w \mathbf{L}_{V_p}$	0		0
	0	0	$w \mathbf{L}_{V_s}$		0
regularization	$\lambda \mathbf{I}$	0	0		0
	0	$\lambda \mathbf{I}$	0		0
	0	0	$\lambda \mathbf{I}$		0

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