Global seismology and the need for seismology services

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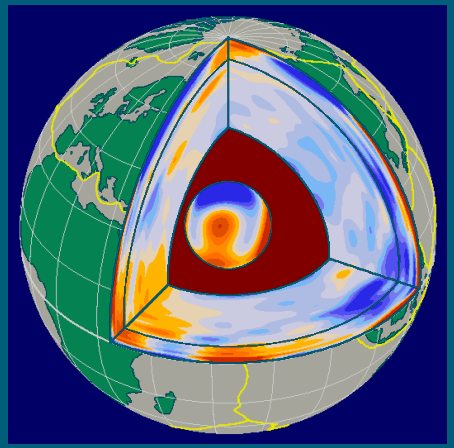
UCL Seismolab

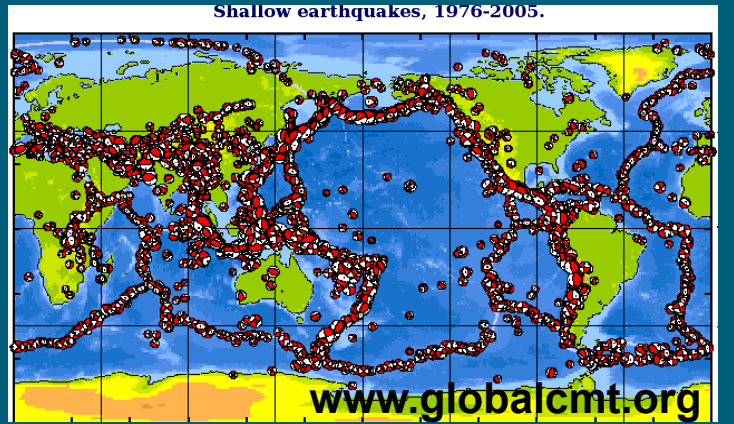
Global seismology

- Global imaging of the Earth's deep interior: **seismic tomography** – (an)isotropic structure, attenuation, density, …



Ritsema et al., 2011

- **Characterisation of global earthquakes** – locations, point and finite source models, source time functions, …



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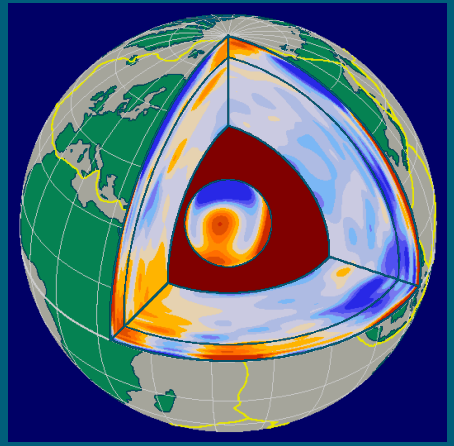

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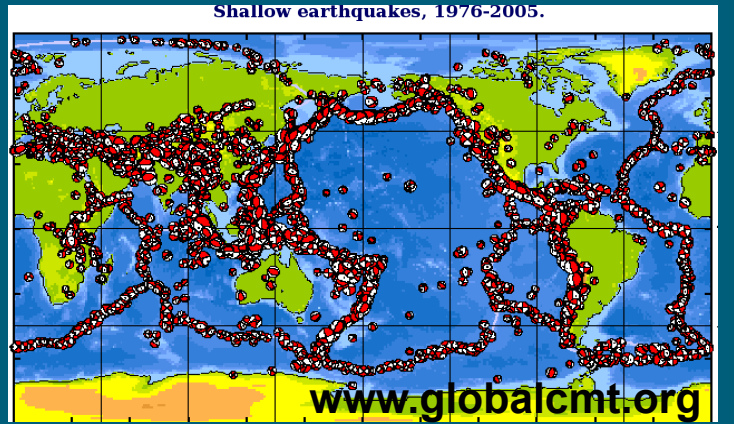

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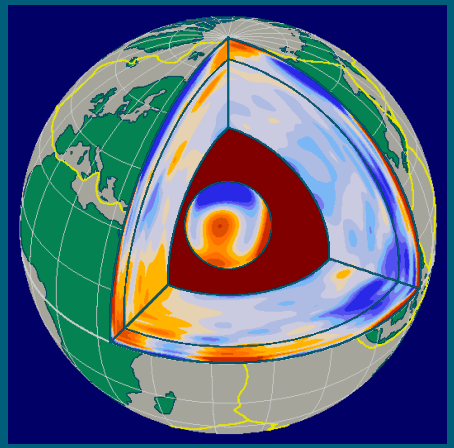

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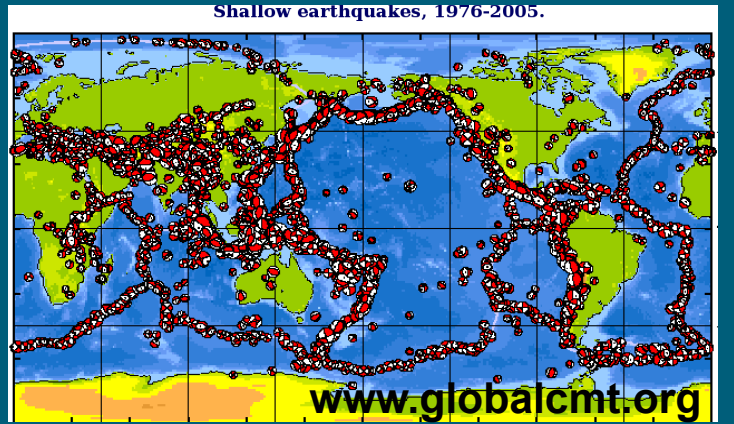


Views of the Earth's interior

Dramatic progress in the past 40 yrs

… 1-D ⇒ 3-D

… massive new data sets (e.g., GSN, IRIS, Orfeus, EIDA)

… new theoretical developments

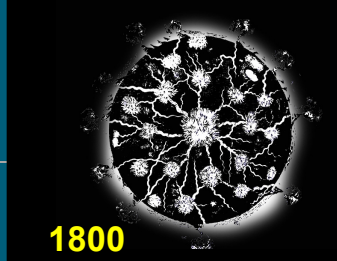
… new computational developments

Global 3-D tomography helps addressing fundamental questions

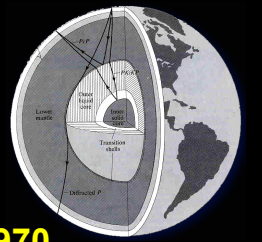
… what is the fate of subducted slabs?

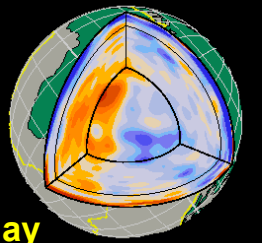
… what is the nature of mantle plumes?

… what is the nature and scale of heterogeneity?

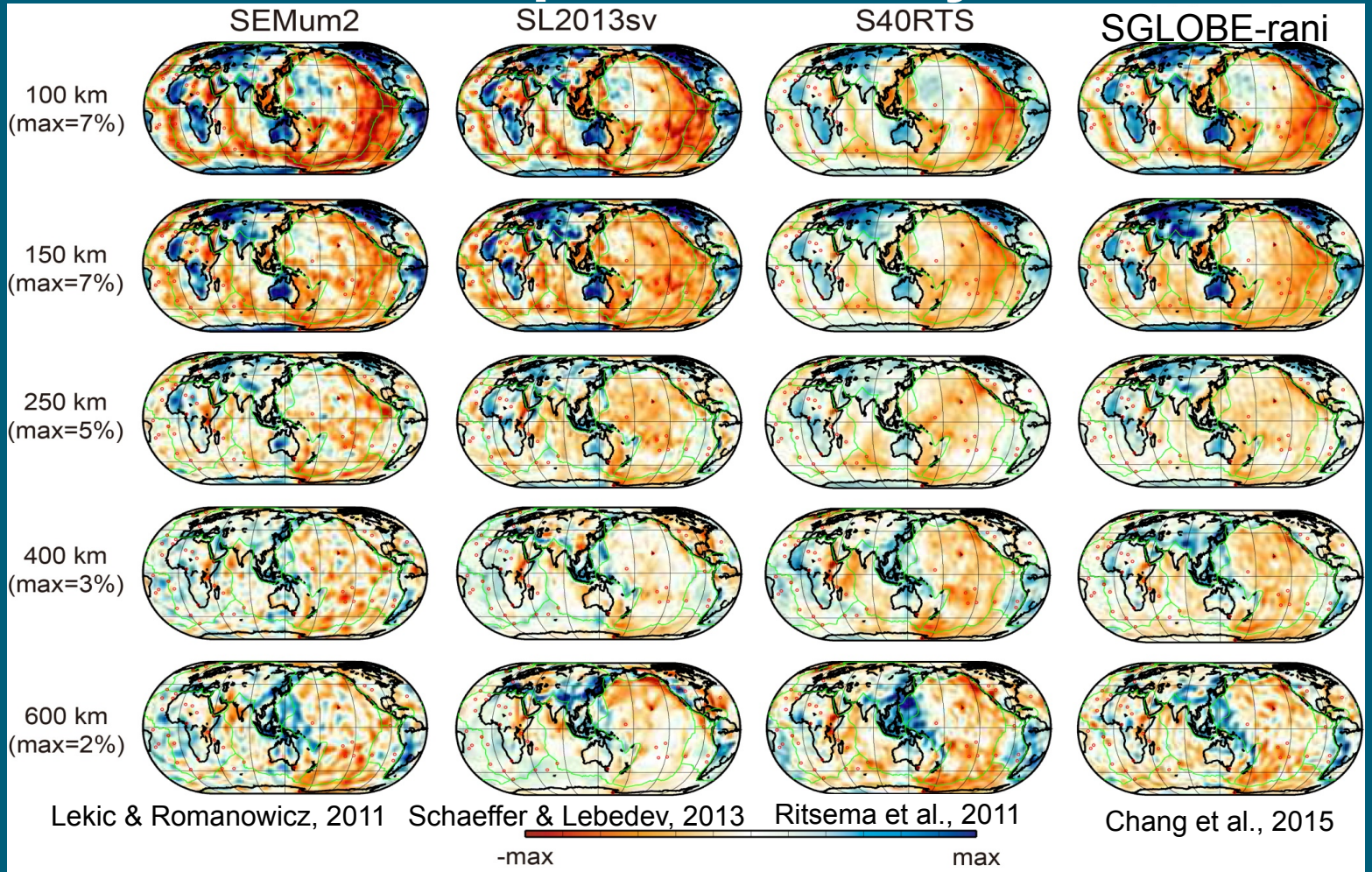

1800

1900

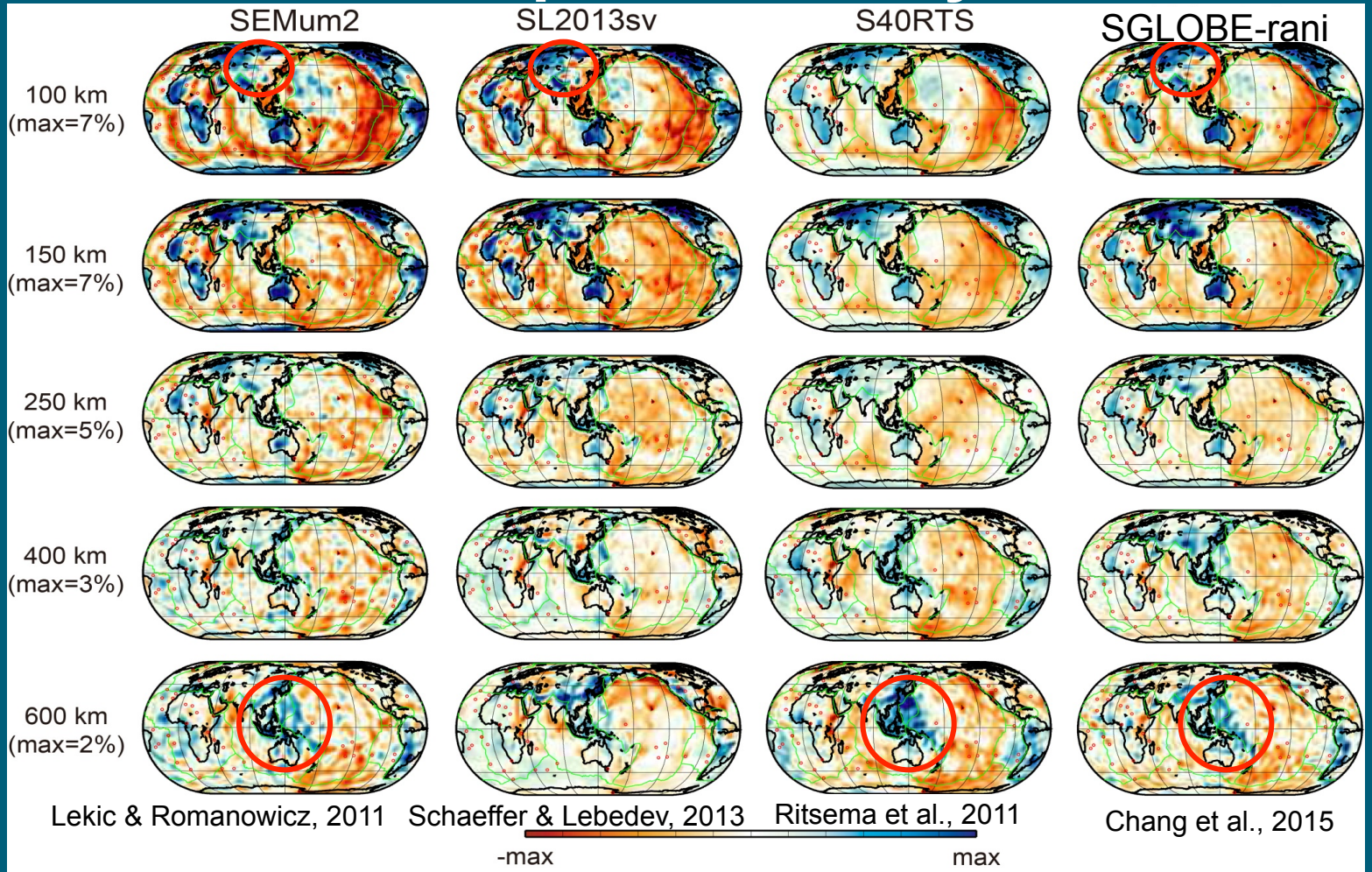

1970


Today

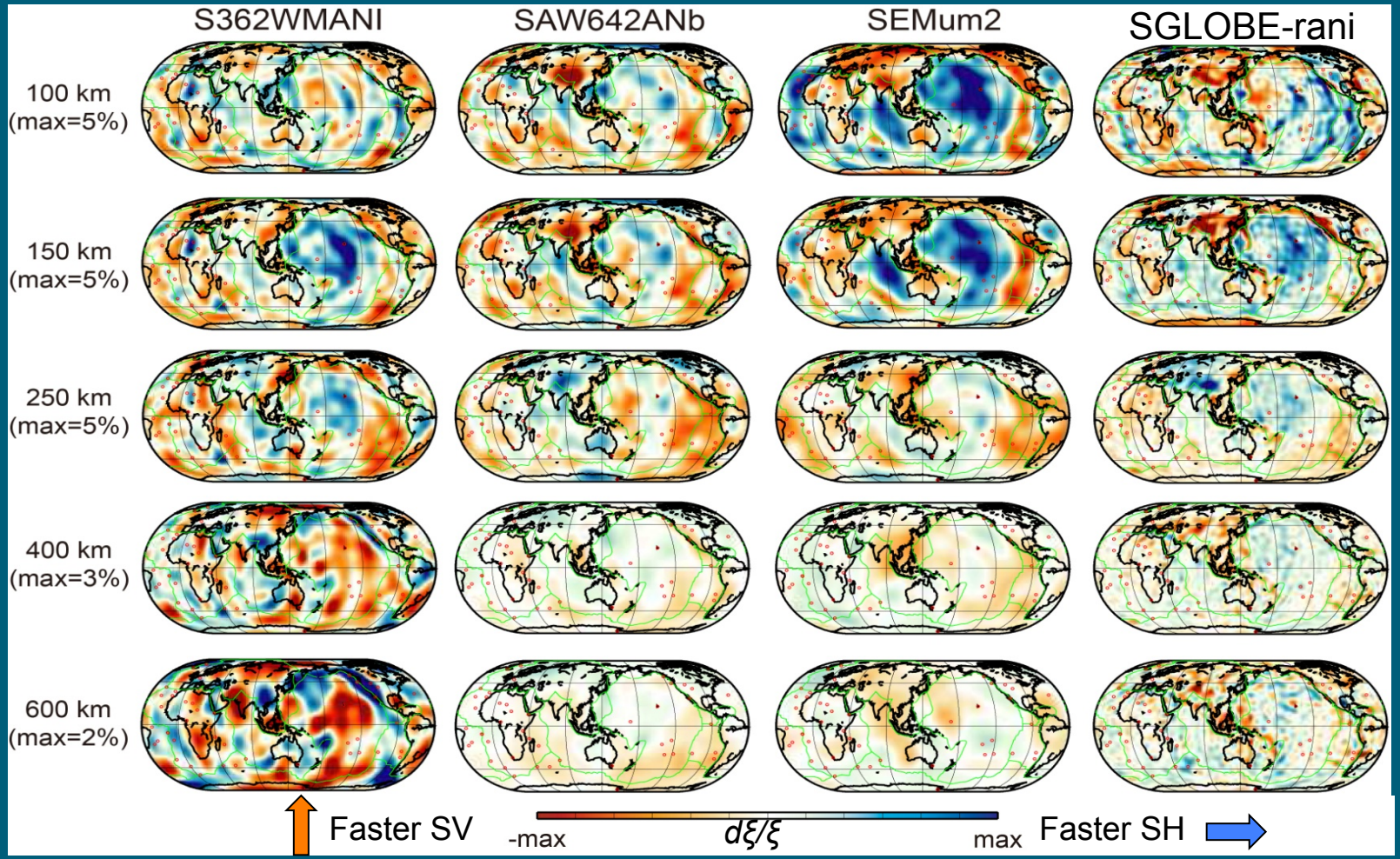
Isotropic S-velocity



Isotropic S-velocity



Radial anisotropy $\xi = V_{SH}^2 / V_{SV}^2$



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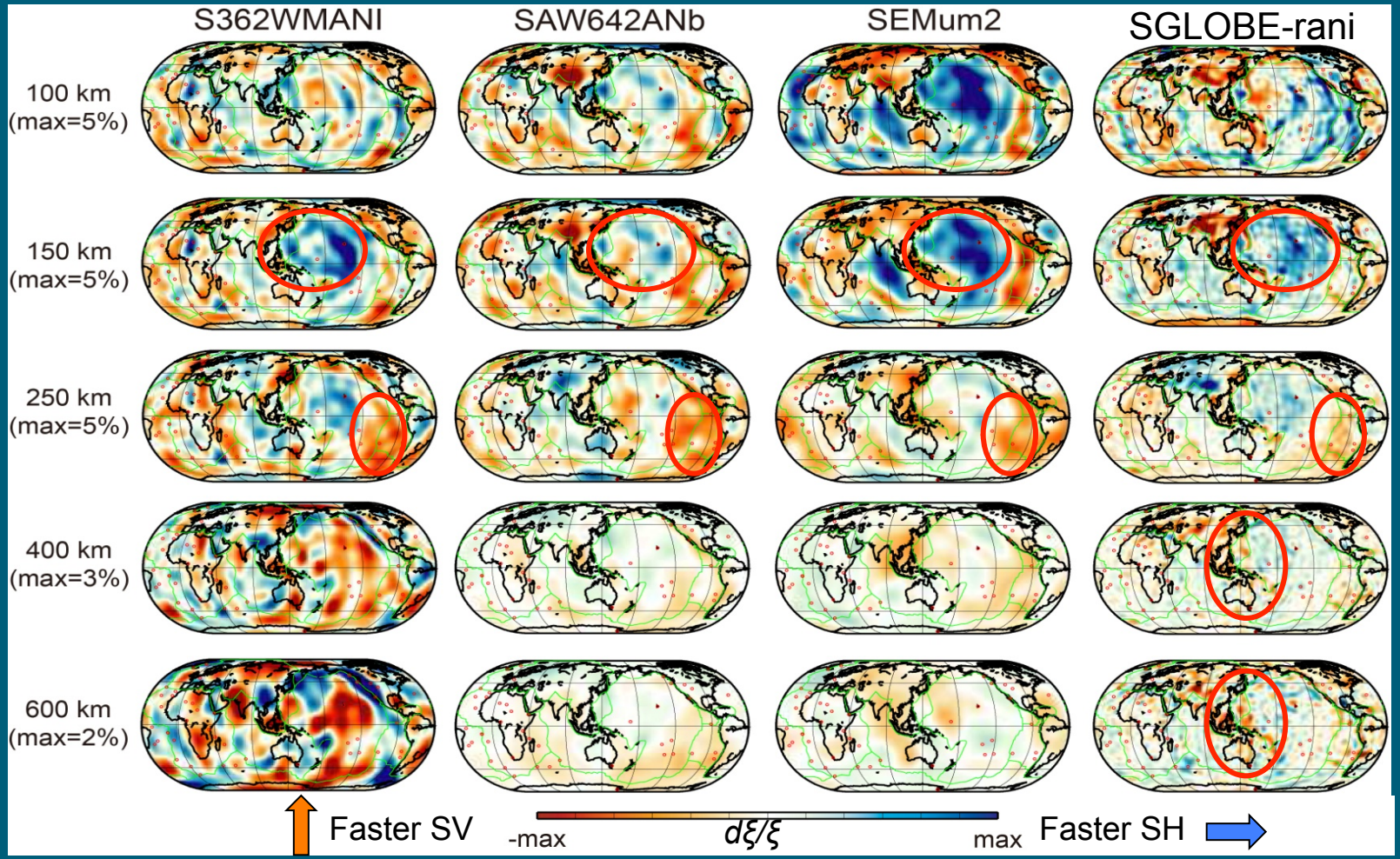
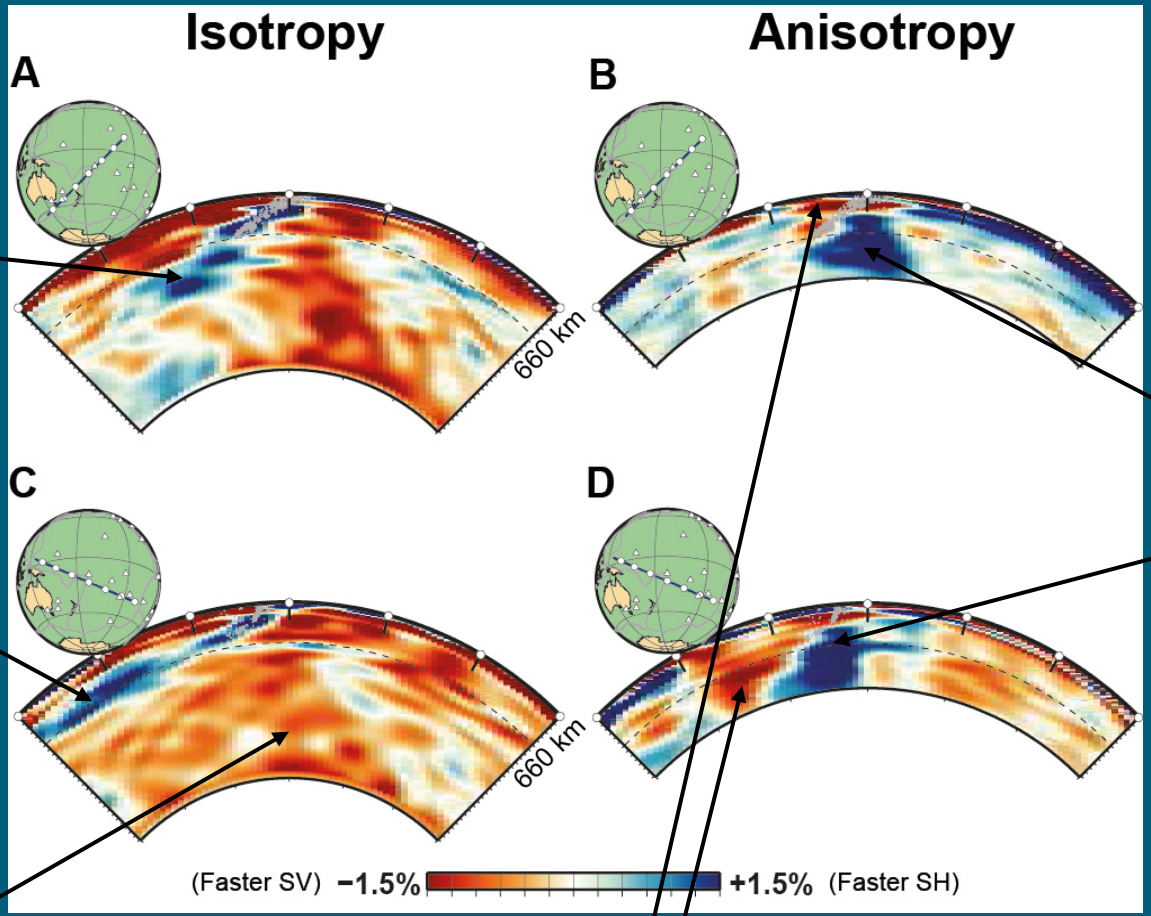




Kermadec: down to LM

Tonga slab: stagnant in the TZ

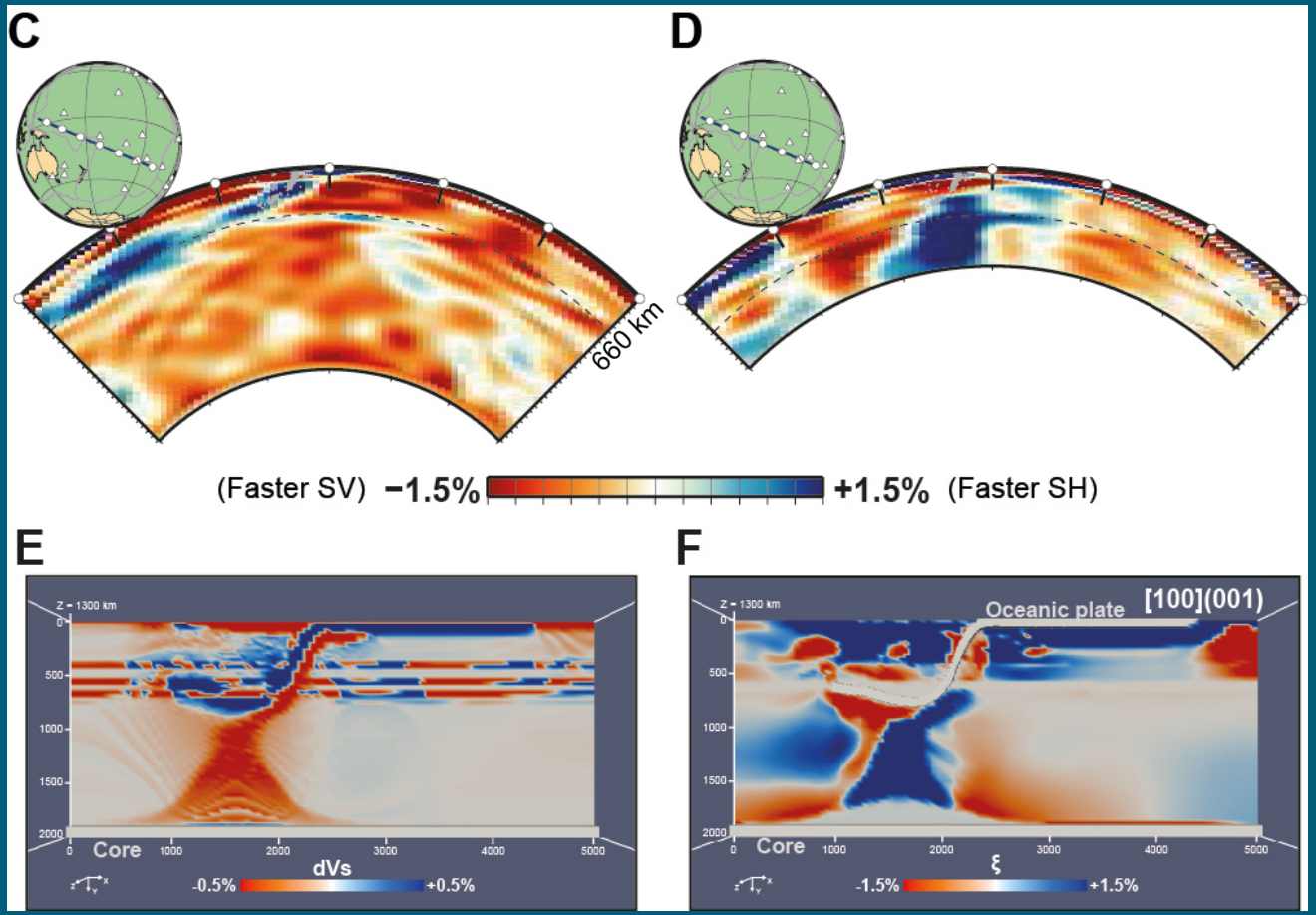
Large scale upwelling (Samoan plume) from mega-ULVZ in Pacific LLSVP

~1000 km faster SH anomaly behind slab following the upwelling

Faster SV anomalies associated with slabs

Strong, deep plume-slab interaction?

Geodynamical interpretation – 3-D petrological-thermo-mechanical modelling



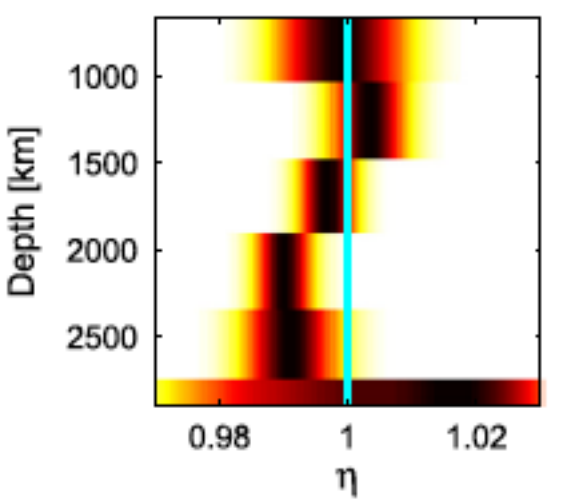
- The upwelling plume favors slab stagnancy in the TZ

- Identified possible dominant slip systems of Bridgmanite

Chang, Ferreira & Faccenda, Nature Comms., 2016

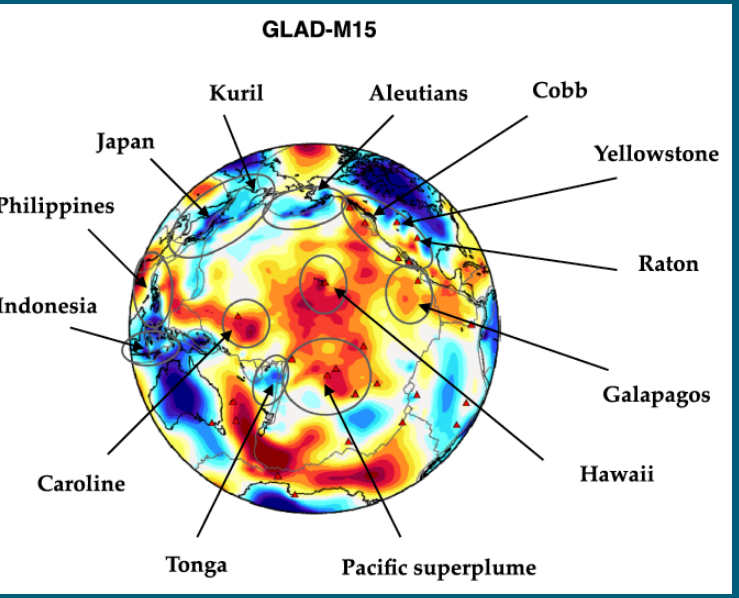
Other current research directions

Neural network inversions



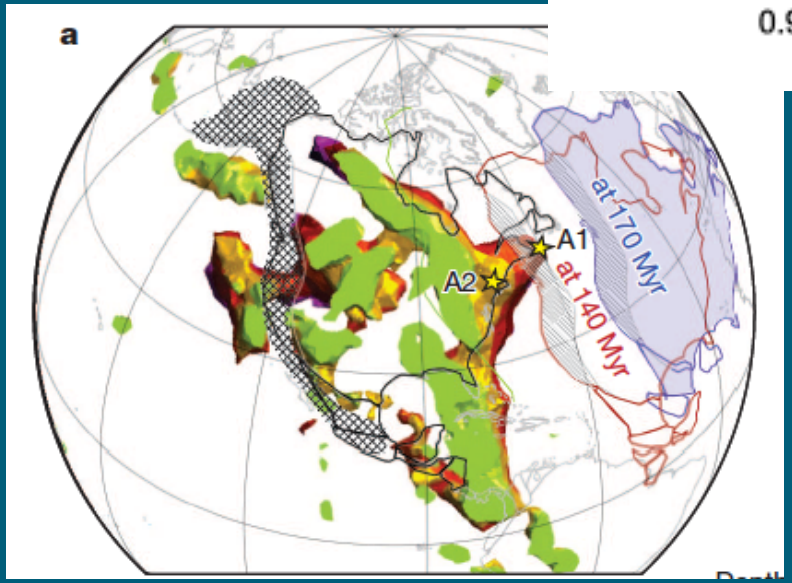
de Wit & Trampert, EPSL, 2015

Adjoint tomography



Bozdag et al., GJI, 2016

Finite frequency tomography



Sigloch & Mihalynuk, Nature, 2013

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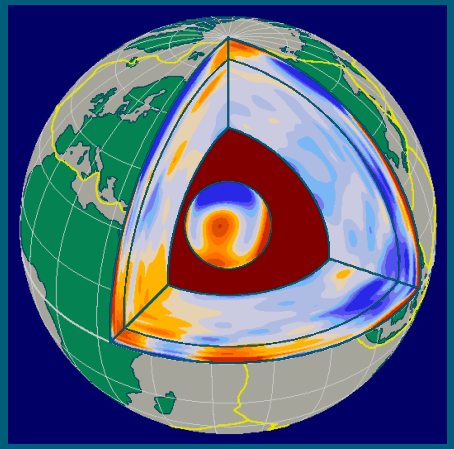

Ritsema et al., 2011

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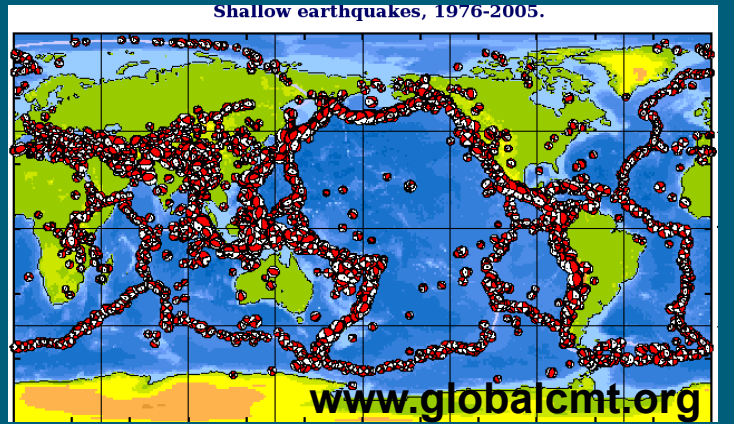


Views on earthquake source processes

Dramatic progress in the past 40 yrs

… massive new data sets

… new theoretical developments

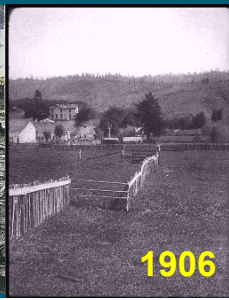
… new computational developments

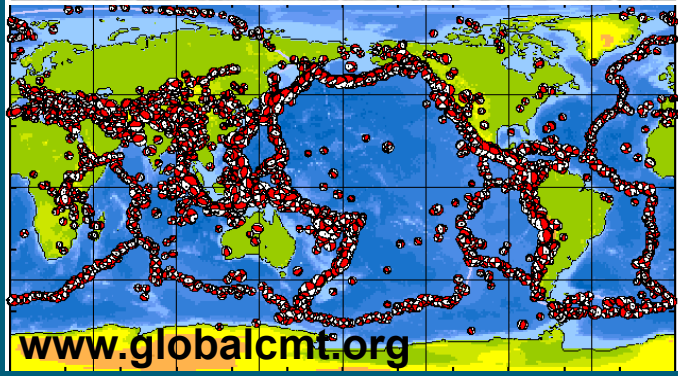
Earthquake models help addressing fundamental and practical questions

… how do faults slip?

… what are the geometrical properties of faults?

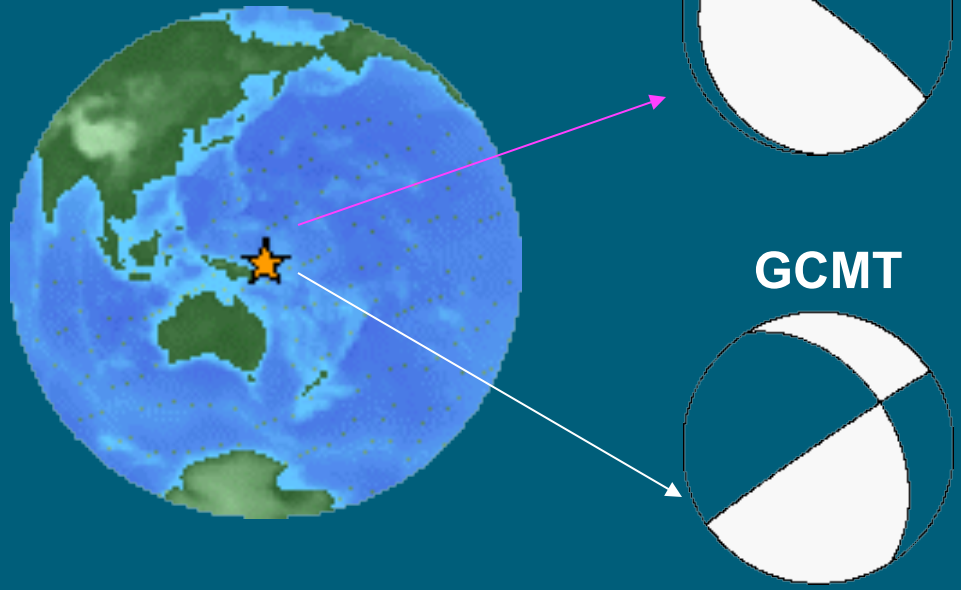
… how quickly can the size of an earthquake be estimated and reliable tsunami warnings issued?





Global earthquake source models

16 November 2000 New Ireland earthquake



Mw: 7.6
Mo: 3.30×10^{20} Nm
Depth: 13 km
Strike: 306°
Dip: 82°
Rake: 79°

Mw: 8.0
Mo: 1.24×10^{21} Nm
Depth: 24 km
Strike: 328°
Dip: 43°
Rake: 3°

Global earthquake source models

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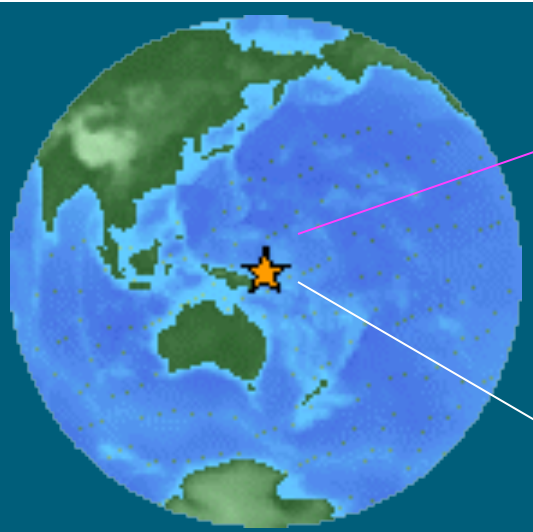
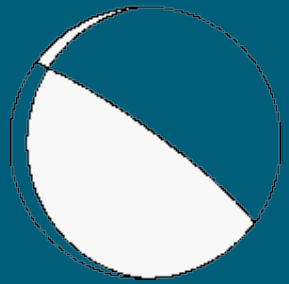
Uncertainties?
Data, modelling (approximations, Earth model…)



USGS



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GCMT

Mw: 8.0
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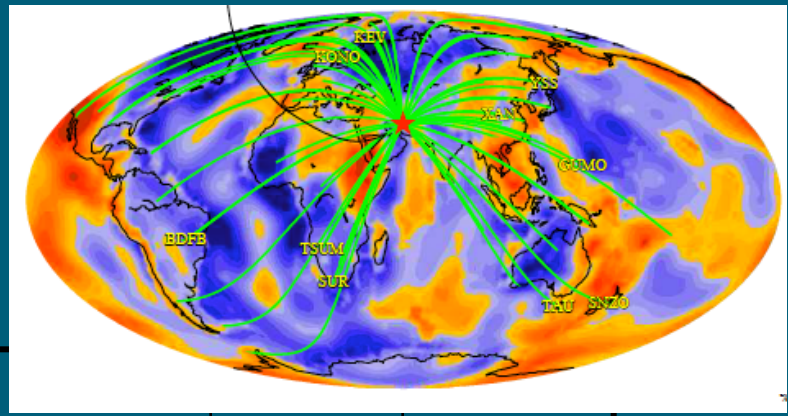
The 1998 Mw 6.6 Fandoqa, Iran earthquake



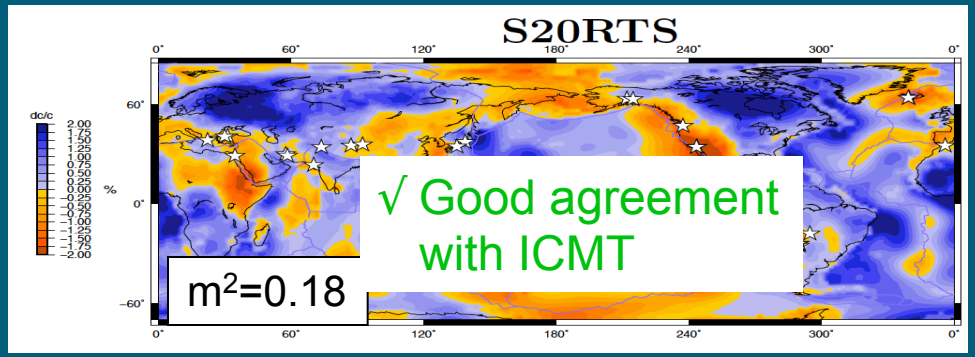
	Lat/Lon	M_0 (x10^{28}dyne-cm)	Strike/Dip/Rake	m^2	BB
1D - PREM	30.4/57.4	25.50	229/86/285	0.28	
3D - S20RTS	30.1/57.5	8.60	156/68/191	0.17	
3D - TW95	30.1/57.5	11.90	151/40/189	0.23	
Berberian et al. 2001	30.1/57.6	9.09	156/54/195	----	

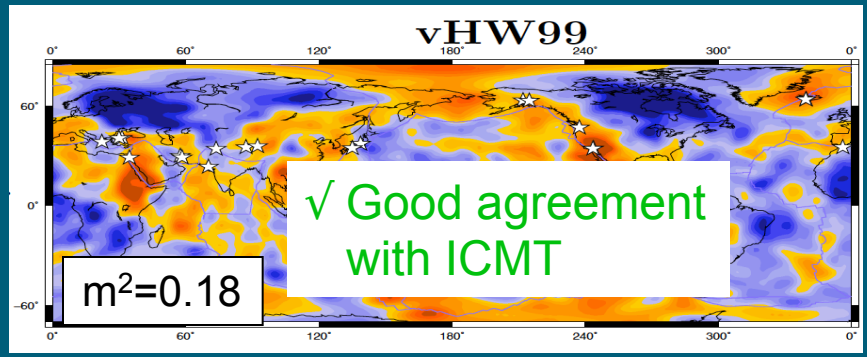
Ferreira & Woodhouse, GJI, 2006

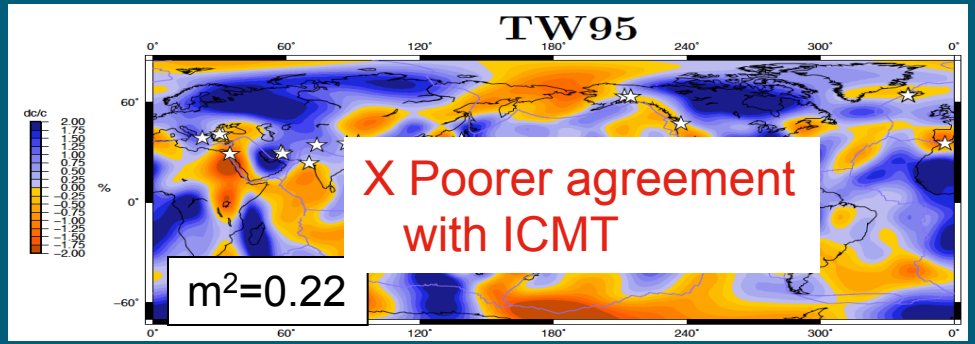
3D Earth structure helps constraining the seismic source

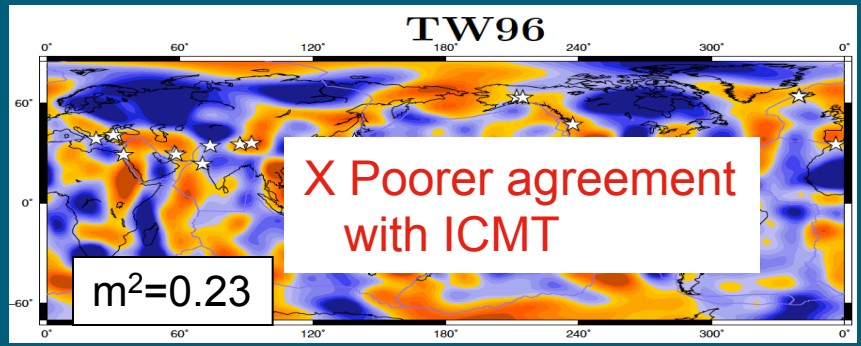
Assessing uncertainties

InSAR vs seismology



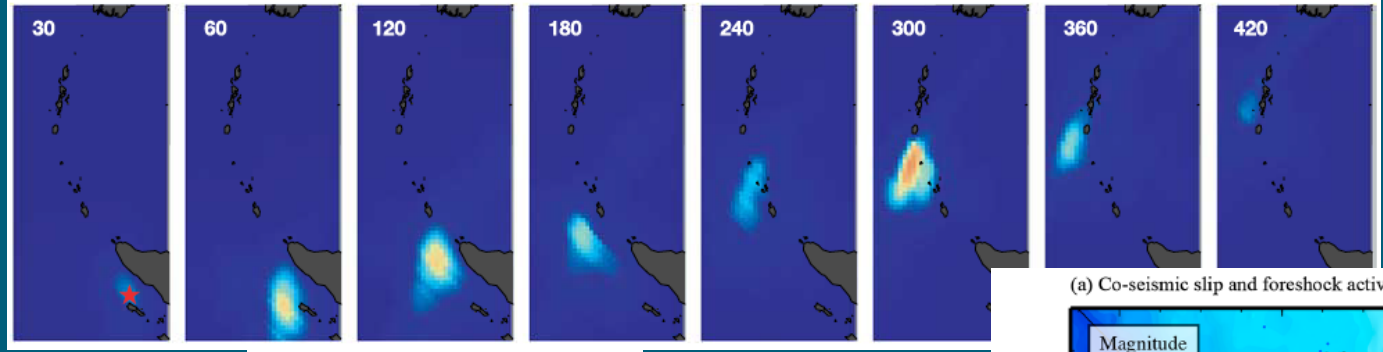






ICMT archive: novel tool to assess the quality of source and tomographic models

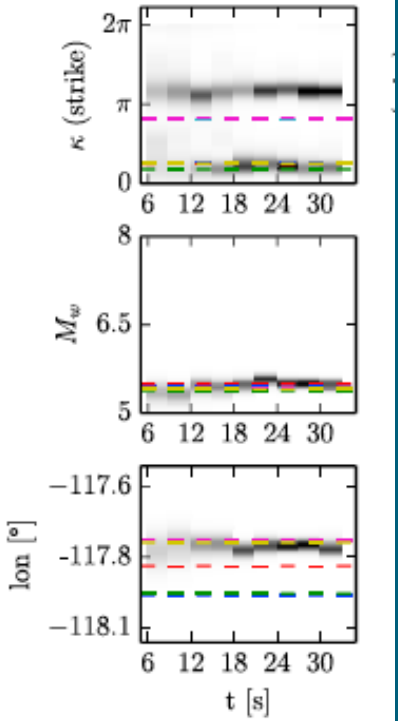
Ferreira et al., JGR, 2011



Back-projection

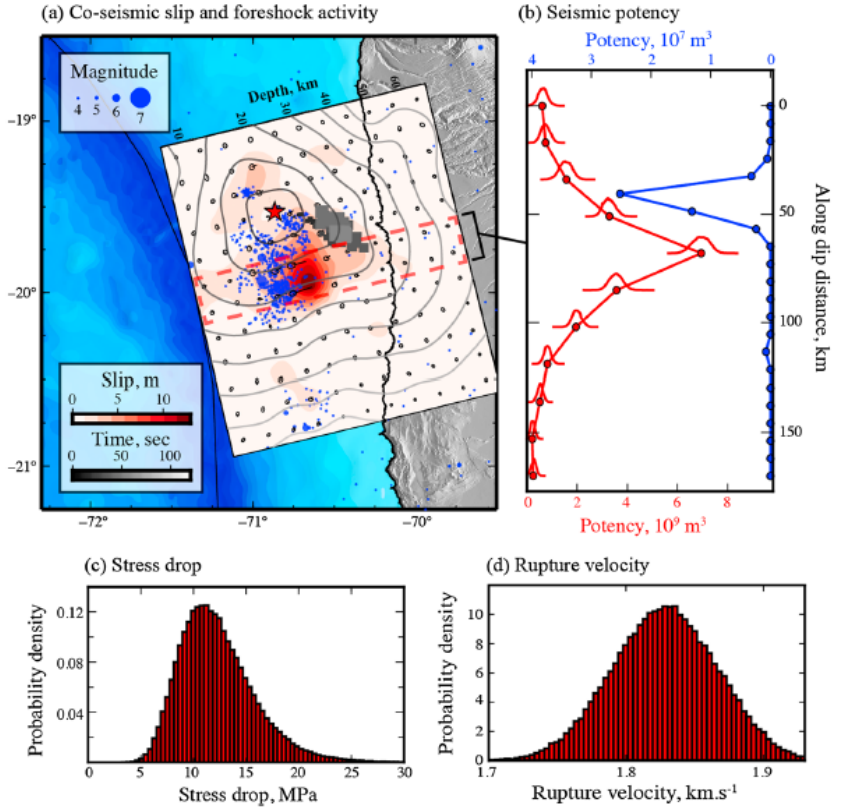
Ishii et al., Nature, 2005

Source inversions using pattern recognition



Kaufl et al., GRL, 2016

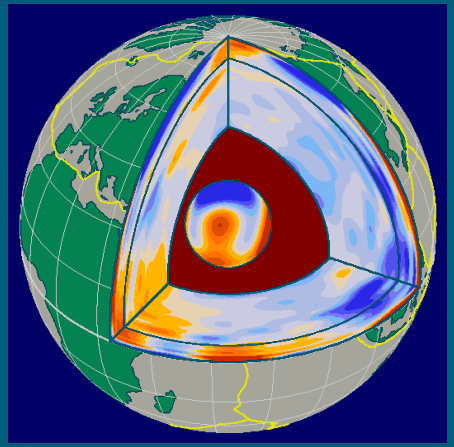
Bayesian source inversions of seismic, GPS, InSAR and tsunami data

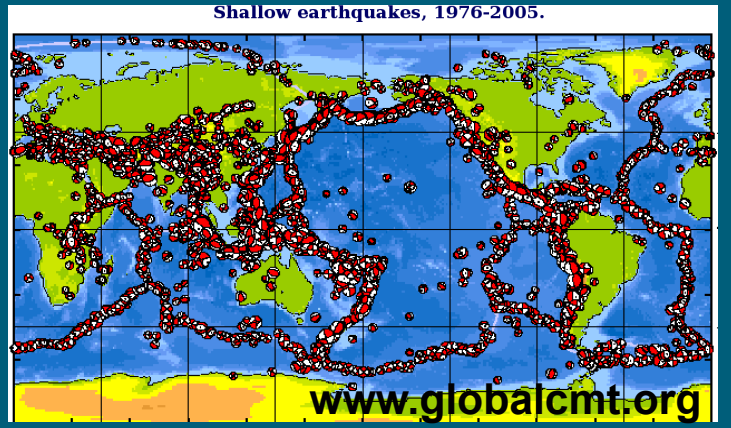


Duputel et al., GRL, 2015

Global seismology

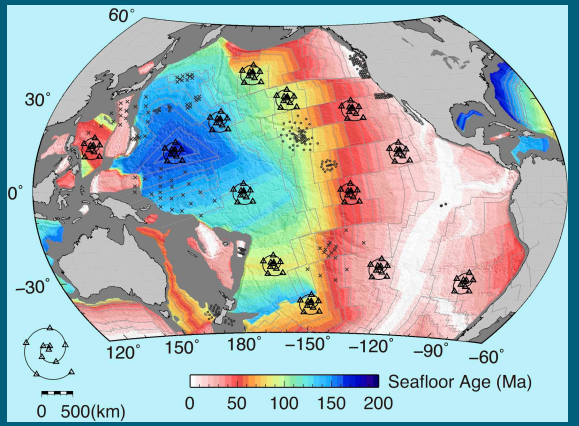
- Big data
- Full seismic wavefield calculations, extensive explorations of model space
- High Performance Computing
- Geological, geophysical knowledge and intuition





Wish list for seismological services

- Continue to collect and distribute **high-quality data:**
  - Cover the oceans, expand dense arrays
  - Explore other observables (e.g., amplitudes, rotations, strain)
  - Develop uniform data formats across the disciplines (e.g., geodesy)
  - Expand “data products” in data centres: tomography and source models and movies, uncertainties, …
  - Distribute multidisciplinary information (e.g., mineral and rock physics look-up tables, libraries of geodynamical simulations, etc etc)



Pacific array (courtesy H. Kawakatsu)

Wish list for seismological services

- **Good HPC facilities and support** for efficient full wavefield calculations accurate up to high frequencies (say 1 Hz) and full model space exploration:

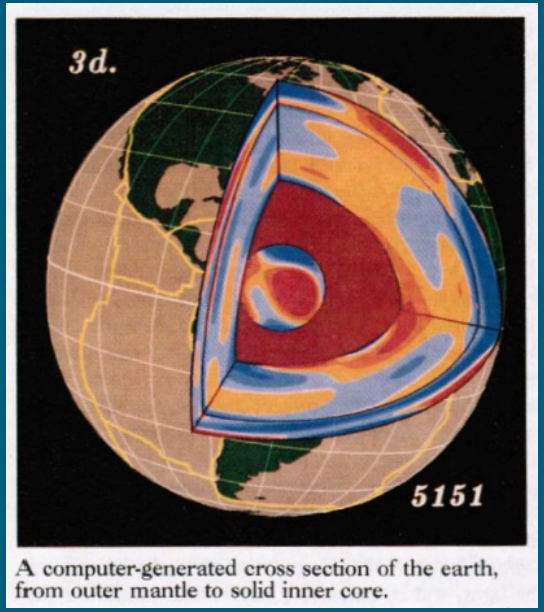
  – on demand synthetics calculations?
  – databases of synthetic waveforms?
  – blind tests/community validation exercises?
  – hands-on training activities

Wish list for seismological services

- **Better visualisation tools** (fast, easy to use):

- “Google deep Earth” ?

- Long-term, sustainable software engineering support – community efforts



A computer-generated cross section of the earth, from outer mantle to solid inner core.