P-wave tomographic model from local bulletin data for improved seismic location in and around Israel

Session SM4.3: Imaging, modeling and inversion to explore the Earth’s lithosphere

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משרד העלייה והקליטה
Ministry of Aliyah and Integration

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Motivations

Hofstetter *et al.* (2012)
Pinsky *et al.* (2013)

- No reliable **3-D velocity model** for Israel

  source locations using various 1-D regional & local models

- Required for local **Earthquake Early Warning System**

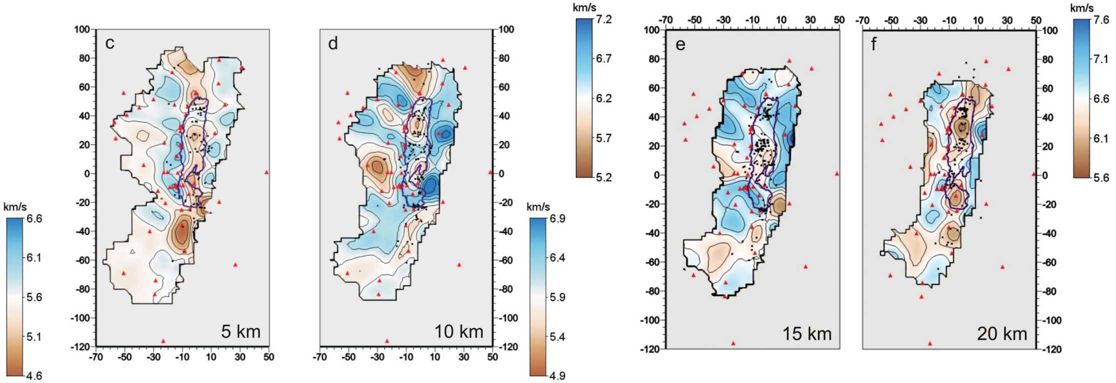
  Dead Sea fault and network geometry, topography in Dead Sea Basin and Sea of Galilee

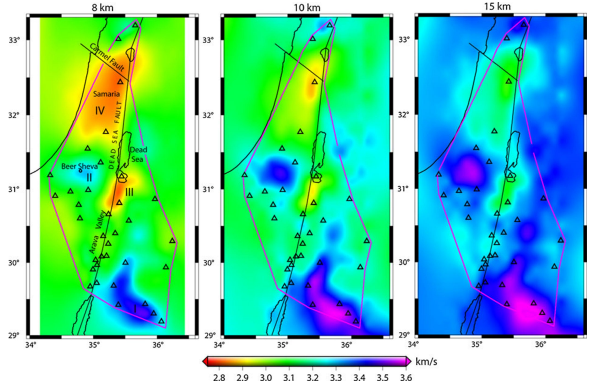
- Necessary to improve **CTBT monitoring**

  integration into a regional model for the Eastern Mediterranean and Middle East region (EMME)

EEWS

CTBT





Research plan

- Building of **local travel time database**
  revision of existing bulletin data, collection of unpublished data
- **Identification** of events with high **ground-truth** (GT) accuracy
  GT0 (known location) explosions, GT5 (location error < 5 km) earthquakes and explosions
- Joint relocation of **different types of seismic sources**
  explosion data for better coverage, GT locations used as references

Schardong *et al.* (to be submitted)

- Assembling of a **starting model** for Israel
  compilation of geophysical data, crustal structure, etc.
- **Tomographic** inversion for a **crustal model** of Israel
  FMTOMO, P-wave earthquake and explosion data
- Using the crustal model as starting point for **regional model**
  RSTT method (CTBT), designed to allow real-time travel-time calculations

Future work

Israeli seismic bulletin

[GII](#)

- Published by the **Geophysical Institute of Israel**

Figure 1:
Local M>1.5 seismicity; explosions

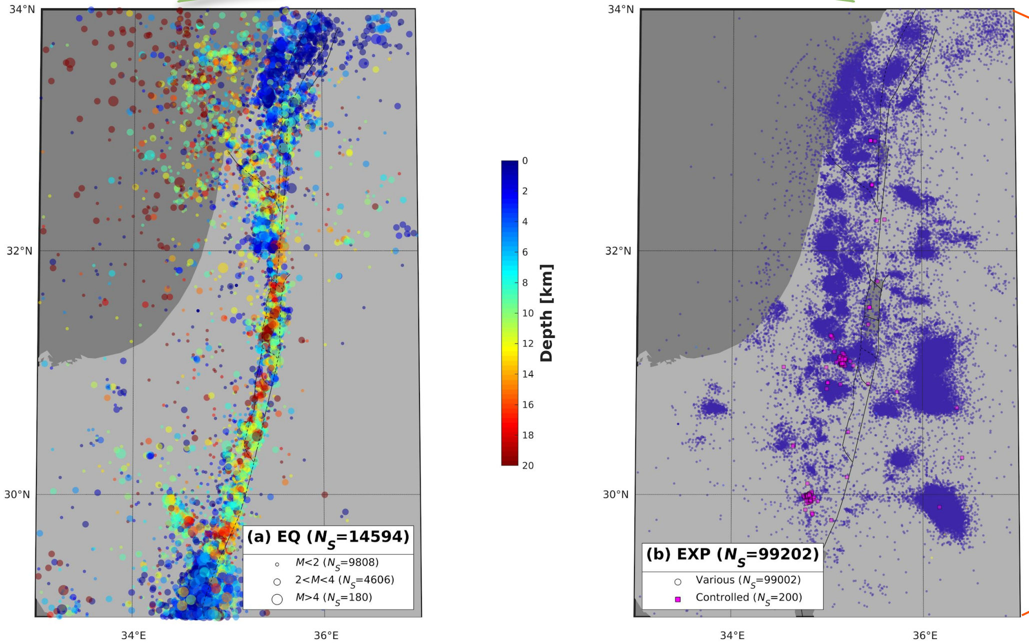
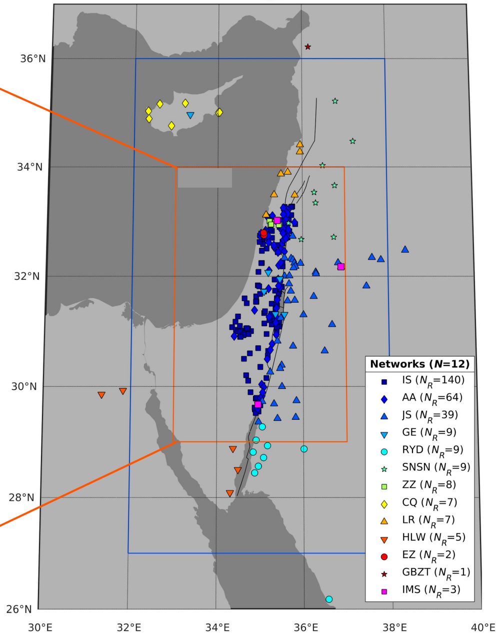


Figure 2:
ISN monitors most stations; other networks collected



Revision of the bulletin data

- **Irregularities** in the bulletin data

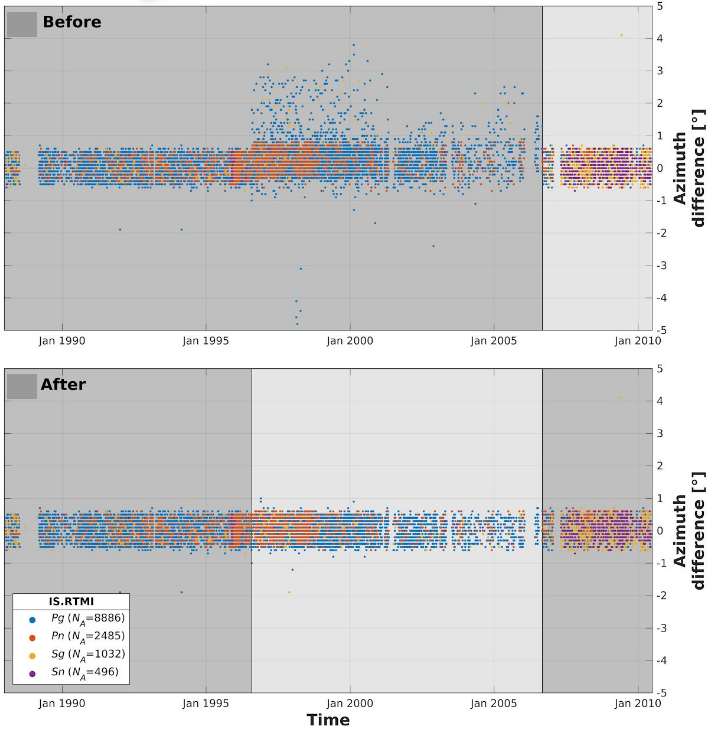
  clocking errors, missing station location history, etc.
- **Large uncertainties** on source locations

  various 1-D reference models, local or regional
- Review of **online station catalogues**

  [ISC](), [IRIS](), [FDSN](), [EMSC](), etc.
- Assembling of **new station catalogue**

  correction of station activity periods, locations, code names, etc.

Figure 3:
Event-to-station azimuth discrepancy before and after revision at RTMI for each **seismic phase**: ***Pg***, ***Pn***, ***Sg***, ***Sn***



Azimuth discrepancy is the difference between reported azimuth and recalculated azimuth based on available station catalogue

Numerical precision of azimuth in bulletin is 1°

Event classification

Bondár *et al.* (2004)

- **GT0**: explosions with **known location**

  calibration explosions, old ammunition detonations, etc.
- **GT5**: event with GT **accuracy greater than 5 km**

  based on network coverage parameters as defined by Bondár et al. *(2004)*

A seismic source is GT5 if:

more than 10 recording stations **within 250 km**

primary azimuthal gap (g_P) of **less than 110°**

secondary azimuthal gap (g_S) of **less than 160°**

at least one station within **30 km**

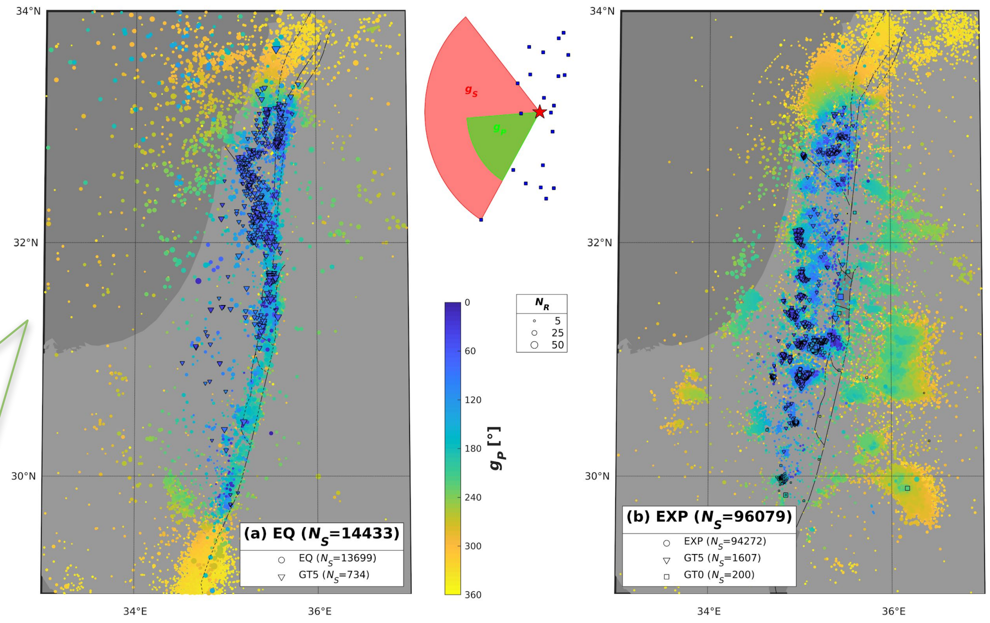


Figure 4: Station coverage of **(a)** earthquakes and **(b)** explosions. **Colour** gives primary azimuthal gap; **size** gives number of stations. **Symbols** depend on source type.

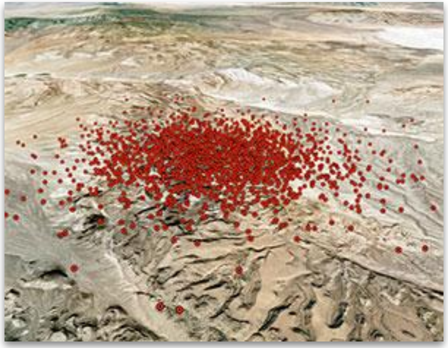
Event relocation

- **Multiple-event** seismic locator ***BayesLoc***

  apply TT correction to account for systematic errors, check phase labels
- **Origin priors** depending on source **location accuracy**

  GT0 locations fixed, little variations around GT5 locations
- **Selection** of sources with **best network coverage**

  >5 recording stations, primary azimuthal gap <90°



LLNL

Table 1: Number of **sources** (N_S) and **arrivals** (N_A) for each **source type**

Source type	N_S	N_A
EQ	369	4,784
EXP	2,150	19,878
GT5	1,412	27,677
GT0	200	2,873
Total	**4,131**	**55,212**

Table 2: **Origin priors** for each **source type**

	EQ	EXP	GT5	GT0
Epicentre [km]	10	10	2.5	0.01
Depth [km]	10	0.1	2	0.01
Origin time [s]	15	–	10	0.25

Crotwell *et al.* (1999)
Kennett *et al.* (1995)

- **Arrival-time** variance **reduction** of 50-80%

  elimination of outliers and mislabelled phases

- **TT corrections** eliminate systematic **errors**

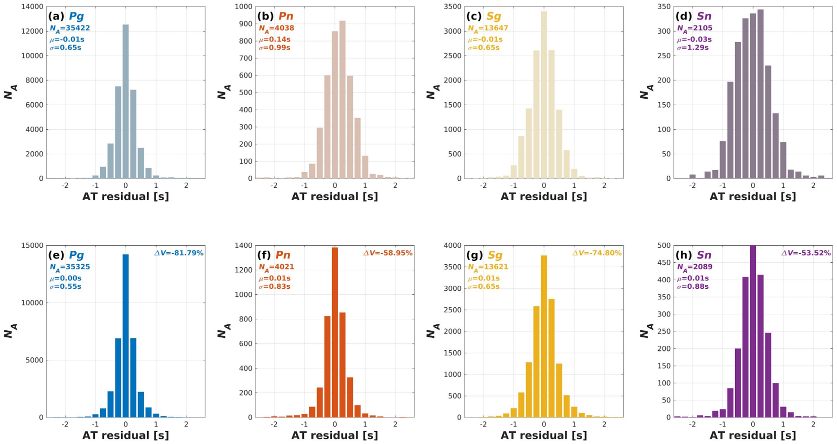
  arrivals align with theoretical curves (TauP *with* ak135)

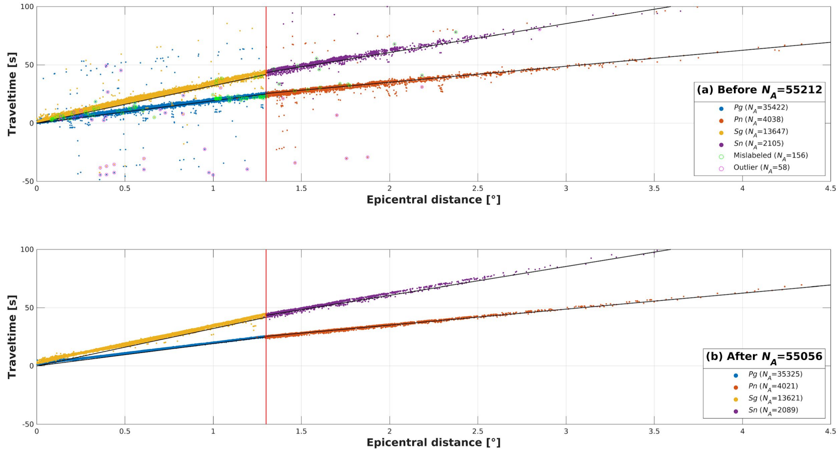
Figure 5:
Arrival-time residuals before (GII) and after relocation for each **seismic phase**: *Pg*, *Pn*, *Sg*, *Sn*

Figure 6:
Travel time as a function of **distance** before (GII) and after relocation for each **phase arrival**: *Pg*, *Pn*, *Sg*, *Sn*

Before

After





Before

After

New source locations

- **Most sources** relocated **<5 km** from initial location

  GT5 source locations vary much less than allowed

- **96-99%** of non-GT5 sources have **uncertainty <5 km**

  new GT5's can be used to improve even less accurately-located sources

Figure 7:
Distance from initial locations for each **source type**

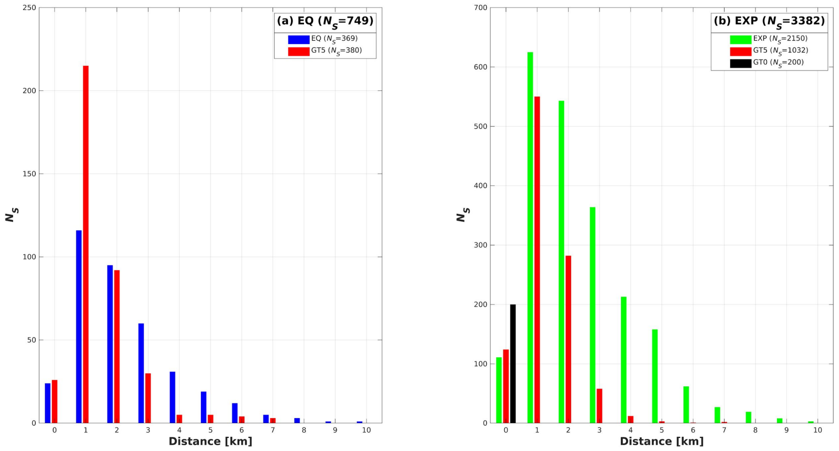
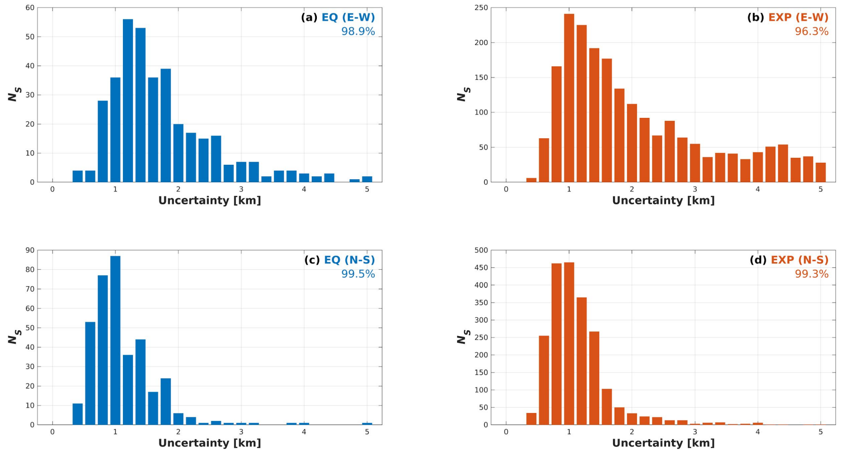


Figure 8:
Location uncertainties for non-GT5 earthquakes and explosions in the **east-west** and **north-south** directions



Starting model for Israel

- **Moho depth** variations

  extracted from new compilation of crustal thickness maps in the EMME

- Starting **velocity model**

  compilation of geological and geophysical data from the Geological Survey of Israel

GSI

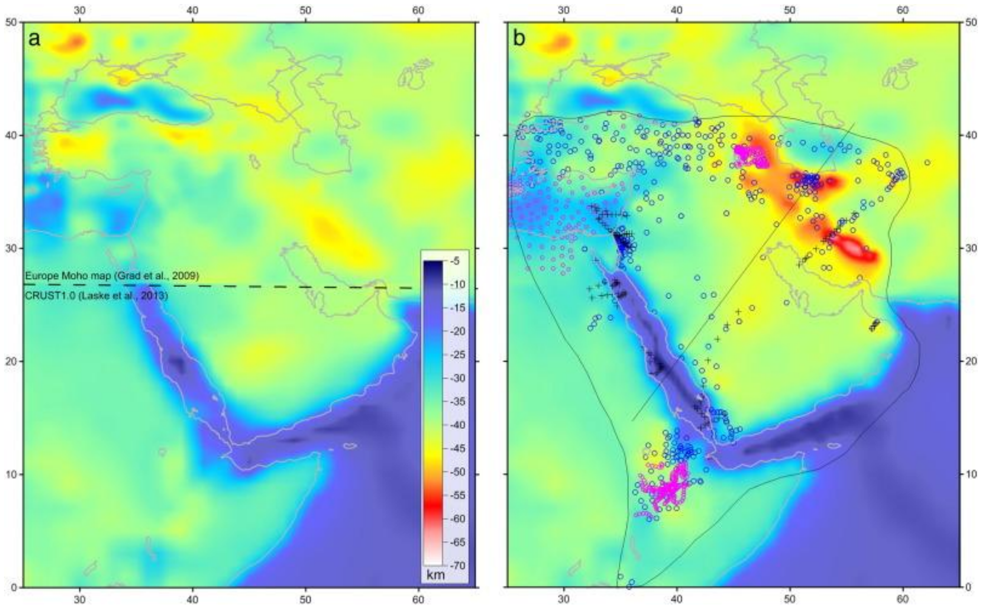


Figure 9: Moho depth maps in the EMME region. **(a) Pre-existing** Moho map **(b) New** Moho map of Gvirtzman *et al.* (2016).

Crustal velocity model for Israel

Rawlinson *et al.* (2006)

- Forward modelling uses **Fast Marching Method (FFM)**

  simplified ray tracing at any scale

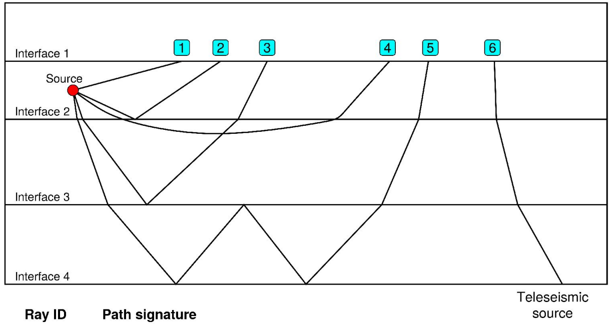
- Wide variety of input **data types** and **seismic phases**

  possibility to combine local and teleseismic data

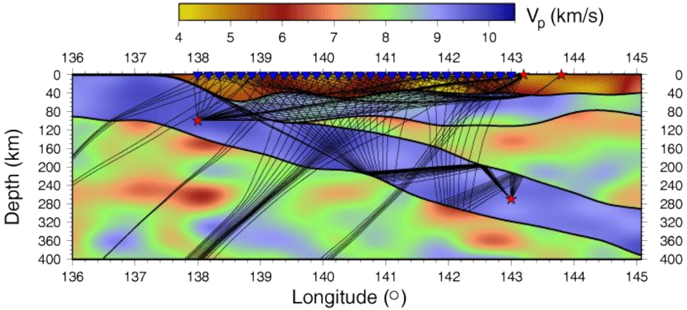
- Model parameterisation allows **complex structures**

  3-D starting model for velocity and crustal thickness

- **Vertical** grid spacing of 5 km (-35 to +5 km)
- **Horizontal** grid spacing of 0.25° (7.5°x6.5°)



Ray ID	Path signature
1	0 1
2	0 2 2 1
3	0 2 2 3 3 2 2 1
4	0 2 2 3 2 1
5	0 2 2 3 3 4 4 3 3 4 4 3 3 2 2 1
6	4 3 3 2 2 1



Regional tomographic model of the EMME

- ***RSTT***: software and **regional model**

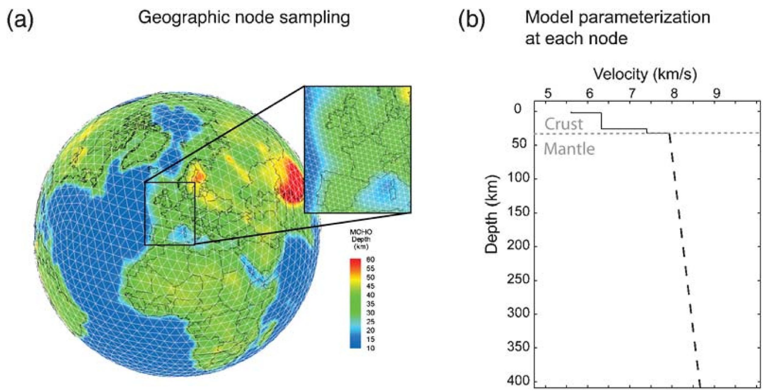
  designed for real-time travel time calculations

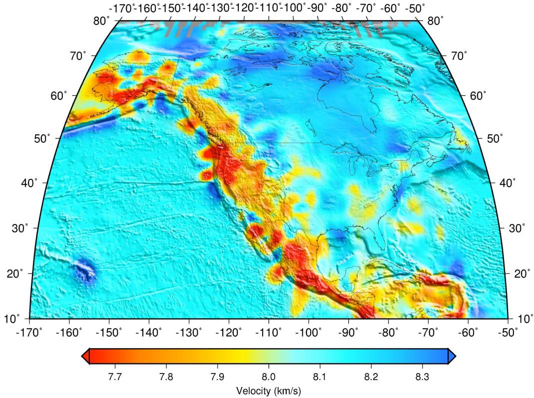
- **Global** tessellation of nodes every **1°**

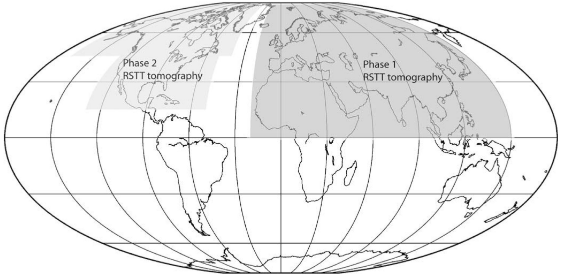
  1-D profiles interpolated to build 3-D model of crust and upper mantle

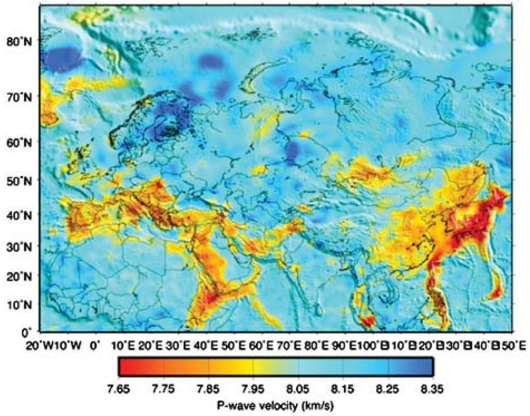
- Ultimate goal is **global model** to predict **regional phases**

  studies already conducted in Eurasia and North America









THANKS!

Any questions?

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