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CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

A crustal *P*-wave velocity model for Israel to improve IMS capabilities in the Middle East

L. Schardong[1], Y. Ben Horin[2], A. Ziv[1], S.C. Myers[3],
H. Wust-Bloch[1], M.L. Begnaud[4], B. Young[5] and Y. Radzyner[2]

Talk O1.2-412

1 (IL) TEL AVIV UNIVERSITY אוניברסיטת תל אביב
2 (IL) SOREQ Soreq Nuclear Research Center
3 (US) Lawrence Livermore National Laboratory
4 (US) Los Alamos NATIONAL LABORATORY
5 (US) Sandia National Laboratories

Outline

- Introduction
- The Israeli seismic bulletin
- Revision of the Israeli seismic bulletin
- Tomographic inversions with *FMTOMO*
- Tomographic inversions with *LOTOS*
- Conclusions

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Introduction

Wetzler & Kurzon (2016) reported large uncertainties in event locations listed in the Israeli seismic bulletin, which can be due to:

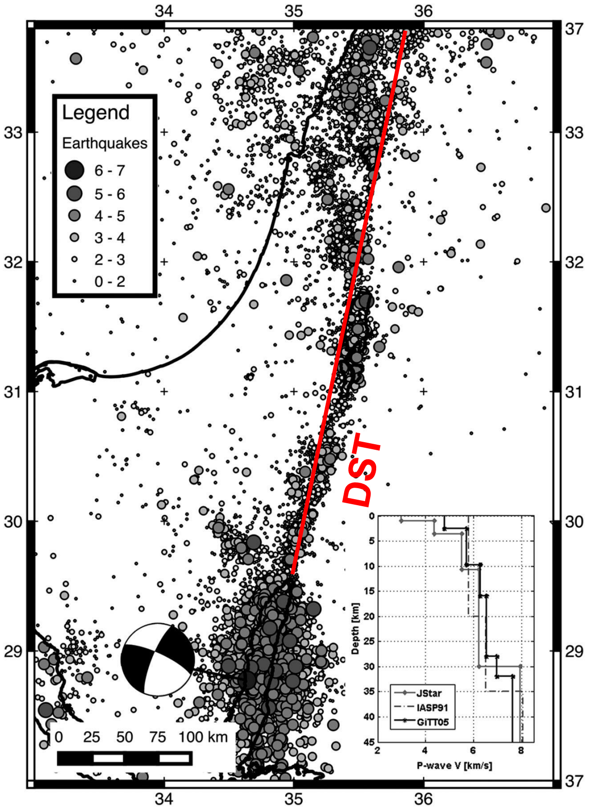
- lack of consensus on local velocity model
- numerous ISN upgrades over the years
- network coverage (*e.g.*, on either side of **DST**)

Table 1
Median Values of Locations and Relocations Misfits

Distribution Type	Location (JStar)				Relocation (IASP91)				Relocation (GITT05)			
	Events	Error *x* (km)	Error *y* (km)	Error *z* (km)	Events	Error *x* (km)	Error *y* (km)	Error *z* (km)	Events	Error *x* (km)	Error *y* (km)	Error *z* (km)
All	15,856	8.4	4.0	6.0	15,150	0.77	1.05	1.30	15,181	0.72	1.00	1.26
In-Network*	6576	2.3	1.3	2.2	5909	0.44	0.56	0.78	6223	0.43	0.55	0.76
Off-Network-N	1447	[illegible]	[illegible]	[illegible]	1783	[illegible]	[illegible]	1.14	1528	0.78	[illegible]	1.31
Off-Network-S	7833	135.0	17.0	30.0	7454	1.47	1.83	2.35	7430	1.39	1.74	2.27

CURRENT GLOBAL LOCAL

Median values of locations and relocation misfits calculated for (a) the initial locations and for the Antelope relocations using (b) IASP91 global velocity model, and (c) GITT05 local velocity model (Gitterman *et al.*, 2005).
*The area of the In-Network events is presented by the rectangle in Figure 3.



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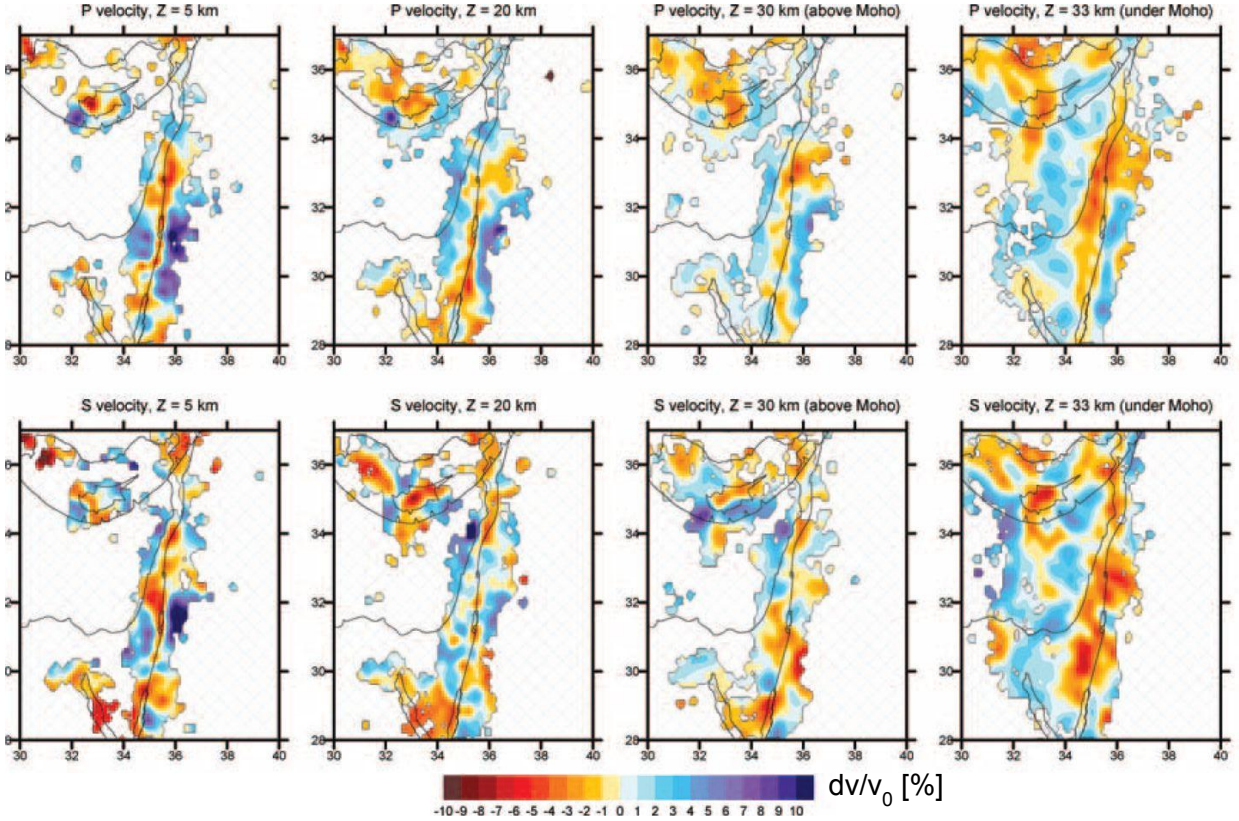
Introduction

Koulakov & Sobolev (2006) produced the latest maps of seismic velocities in and around Israel

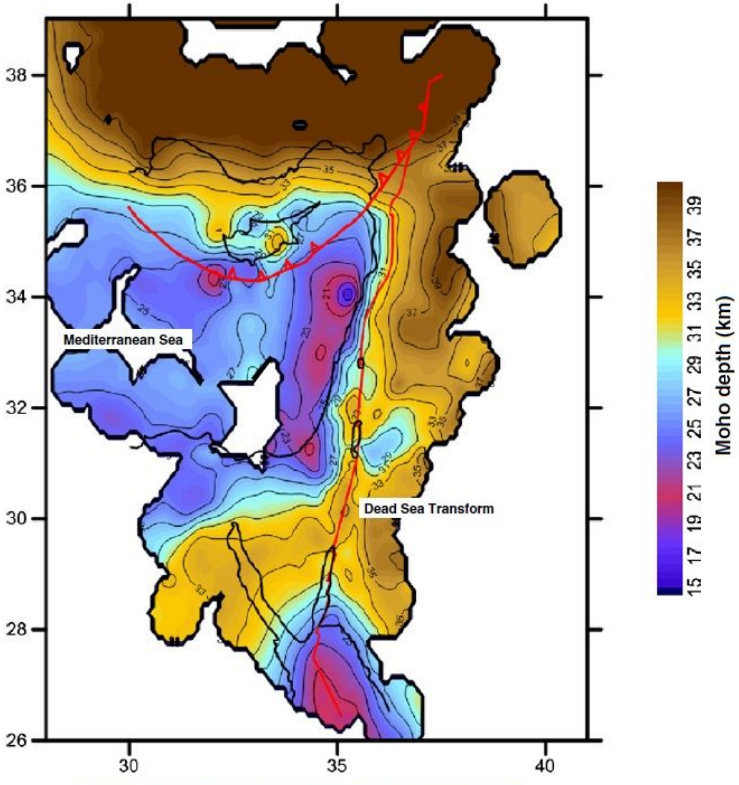
- low-velocity DST in the upper crust
- contrasts with lower crust and upper mantle



Introduction

Koulakov & Sobolev (2006) produced the latest maps of seismic velocities in and around Israel

- low-velocity DST in the upper crust
- contrasts with lower crust and upper mantle
- large variations in Moho depth across the area

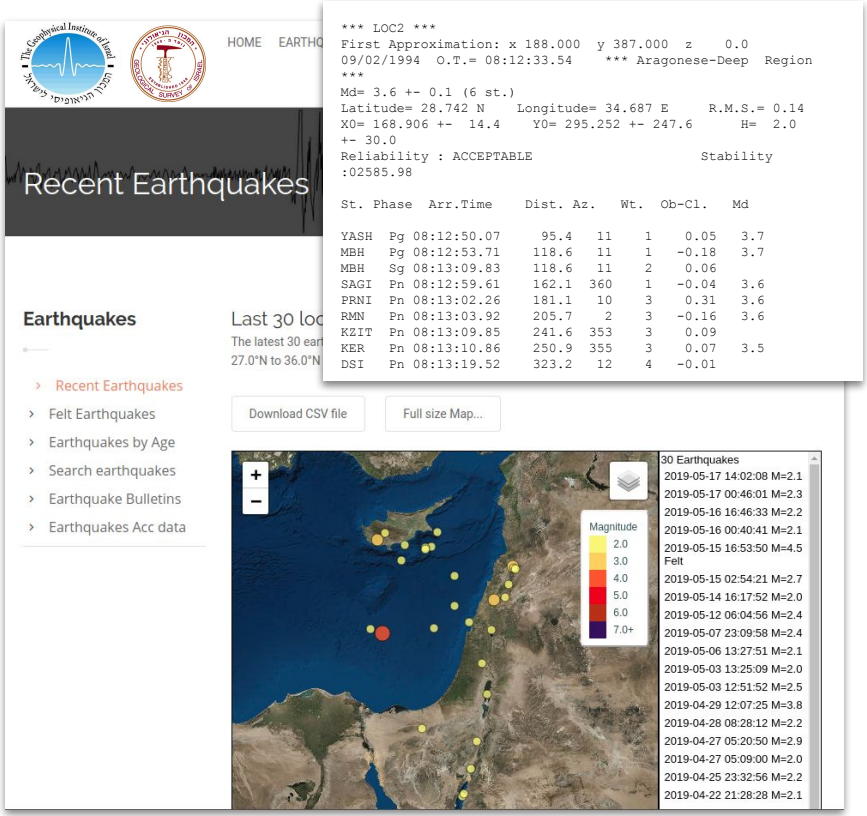


Introduction

- New 3-D velocity model necessary to improve EQ locations
  - homogeneous set of event locations
  - reduced event location errors
  - includes strong local effects
- CTBTO monitoring and local early warning system (EEWS)
  - current models in use are low-resolution or 1D
  - set of local 1D models can be designed from 3D model

The Israeli seismic bulletin

- Seismological Division monitors 200+ stations
  - 20+ stations from historical ISN
  - 100+ stations from TRUA'A (EEWS)
  - 2 stations from the CTBTO's IMS
  - 6 stations from the NDC's CNF
- Also collects data from nearby countries
  Cyprus, Lebanon, Syria, Turkey, Jordan, Saudi Arabia, Egypt
- Database starts in the 1980's
- Local, regional and teleseismic events
- Natural as well as man-made seismicity
  quarry blasts, calibration explosions




```
*** LOC2 ***
First Approximation: x 188.000  y 387.000  z    0.0
09/02/1994  O.T.= 08:12:33.54    *** Aragonese-Deep  Region
***
Md= 3.6 +- 0.1 (6 st.)
Latitude= 28.742 N    Longitude= 34.687 E     R.M.S.= 0.14
X0= 168.906 +-  14.4    Y0= 295.252 +- 247.6      H=  2.0
+- 30.0
Reliability : ACCEPTABLE                        Stability
:02585.98

St. Phase  Arr.Time    Dist. Az.   Wt.  Ob-Cl.   Md

YASH  Pg 08:12:50.07     95.4   11    1    0.05   3.7
MBH   Pg 08:12:53.71    118.6   11    1   -0.18   3.7
MBH   Sg 08:13:09.83    118.6   11    2    0.06
SAGI  Pn 08:12:59.61    162.1  360    1   -0.04   3.6
PRNI  Pn 08:13:02.26    181.1   10    3    0.31   3.6
RMN   Pn 08:13:03.92    205.7    2    3   -0.16   3.6
KZIT  Pn 08:13:09.85    241.6  353    3    0.09
KER   Pn 08:13:10.86    250.9  355    3    0.07   3.5
DSI   Pn 08:13:19.52    323.2   12    4   -0.01
```

Kurzon et al. (2020)

Revision of the Israeli seismic bulletin

- Revision of station metadata
  - identification of station inconsistencies
  - search in international station catalogues

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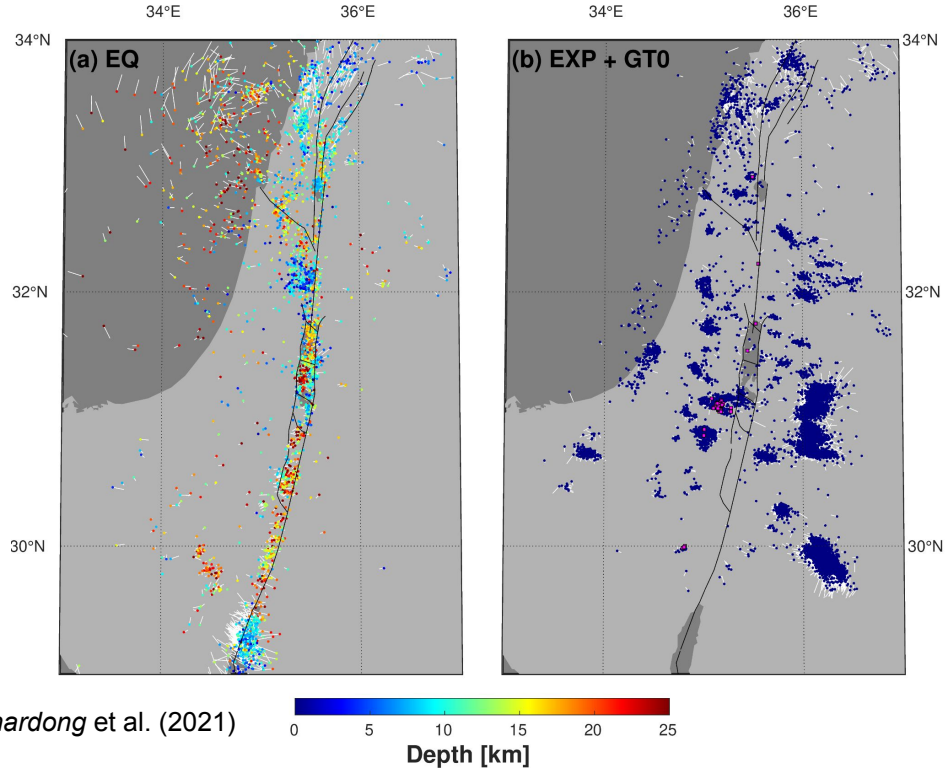
- Joint relocation of seismic events using *BayesLoc*

  [*Myers* et al. (2007, 2009)]
  - use of both EQ and EXP data
  - GT0 explosions used as reference
  - local 1D velocity model [*Feigin & Shapira*, 1994]

EQ: ~4,000
EXP: ~26,000
GT0: ~60



Schardong et al. (2021)

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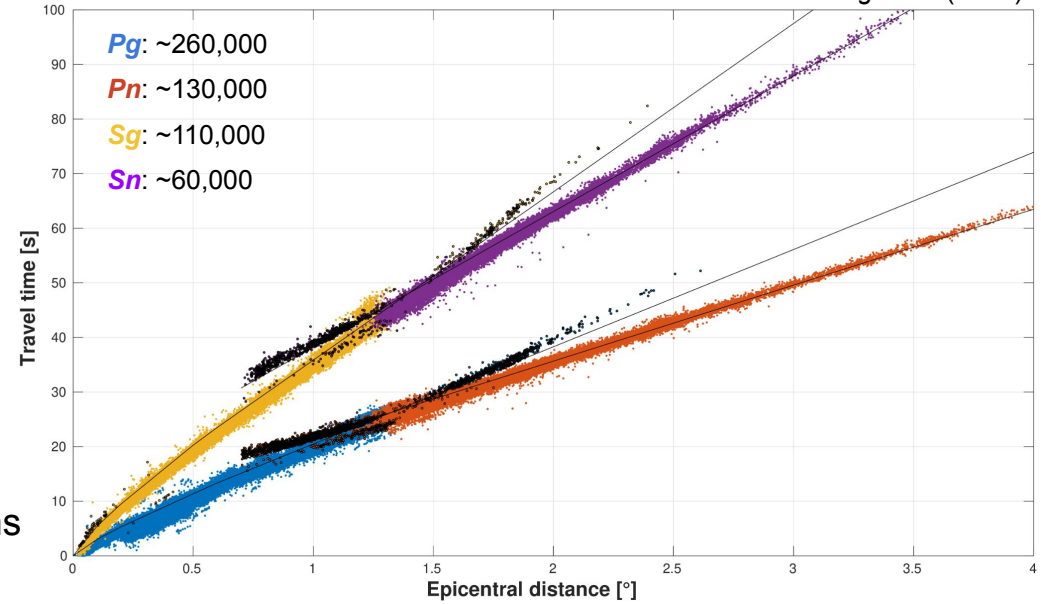
- Joint relocation of seismic events using *BayesLoc* [*Myers* et al. (2007, 2009)]
  - use of both EQ and EXP data
  - GT0 explosions used as reference
  - local 1D velocity model [*Feigin & Shapira*, 1994]
- Revised travel-time database
  - new set of coherent and accurate locations
  - set of phase, station and event statistics
  - original bulletin arrival times

Schardong et al. (2021)



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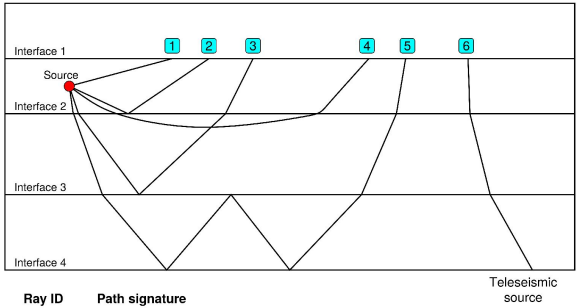
Soreq Nuclear Research Center

Tomographic inversions with *FMTOMO*

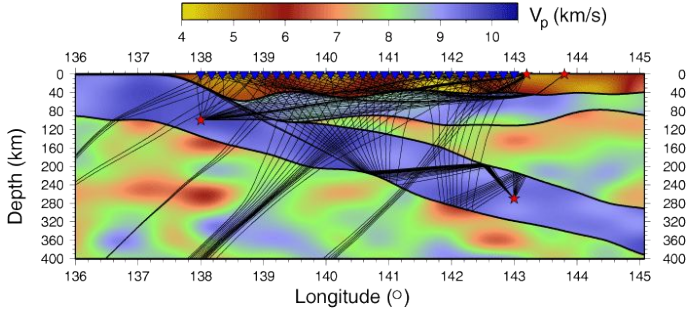
[*Rawlinson & Urvoy*, 2006]

- Forward modelling
  - many types of seismic data
  - local or teleseismic sources
- Model parameterisation
  - various model geometries possible
  - 1D or 3D starting model
- Crustal model for Israel and its surroundings
  - Two layers separated by Moho
  - Current horizontal spacing ~0.1°
  - Current radial spacing 5 km



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

The fast-marching method *Sethian* (1996)



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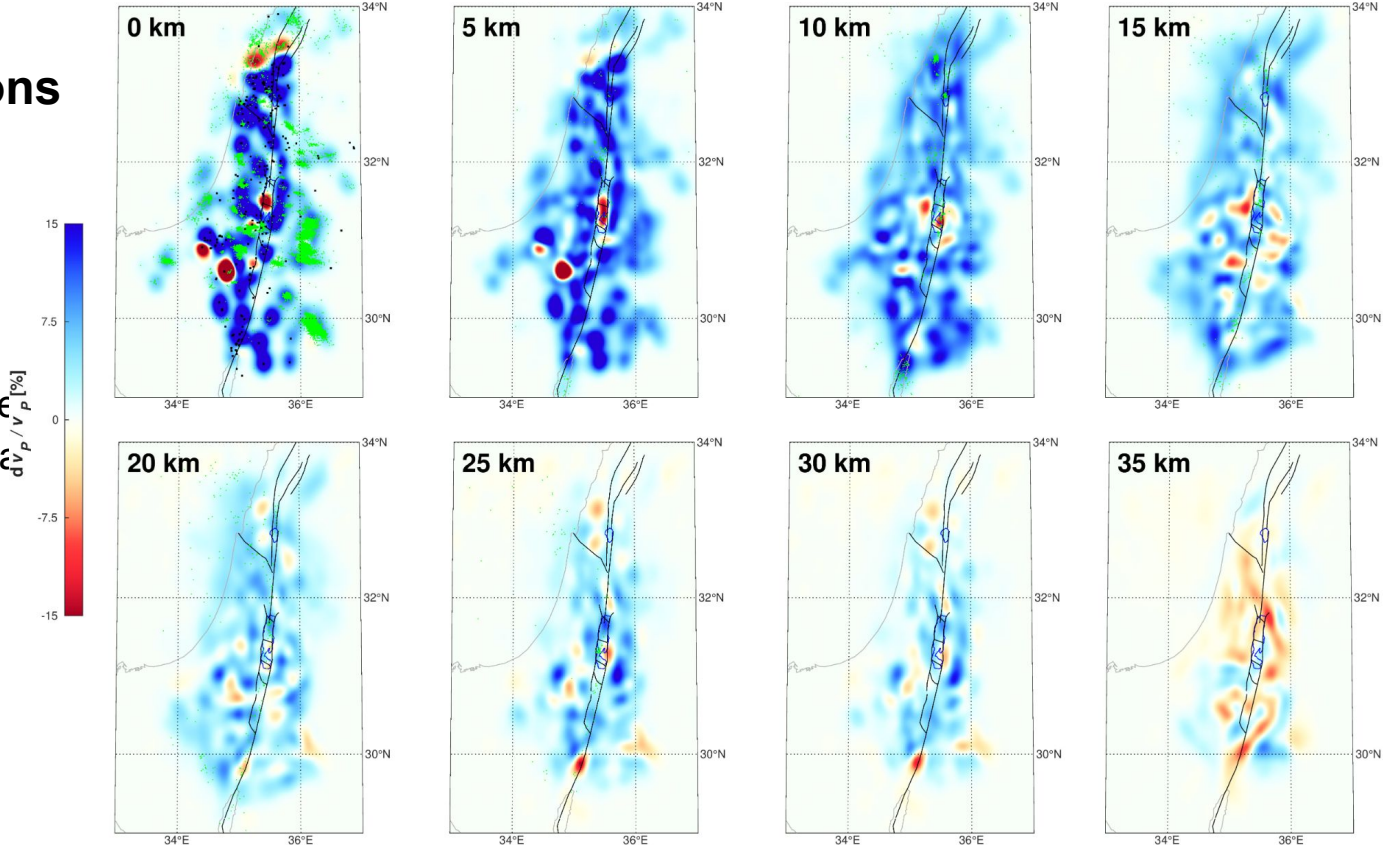
Tomographic inversions with *FMTOMO*

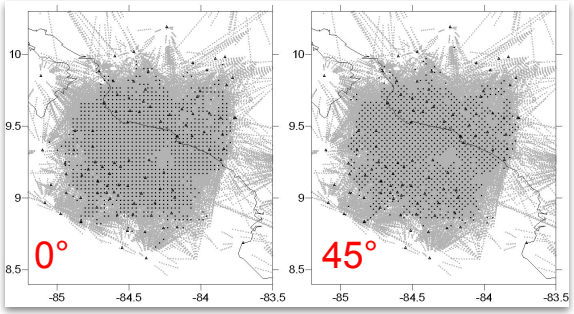
- Striking large-amplitude velocity anomalies below some of the stations
- Unsatisfactory synthetic te
  push us to try other softwa

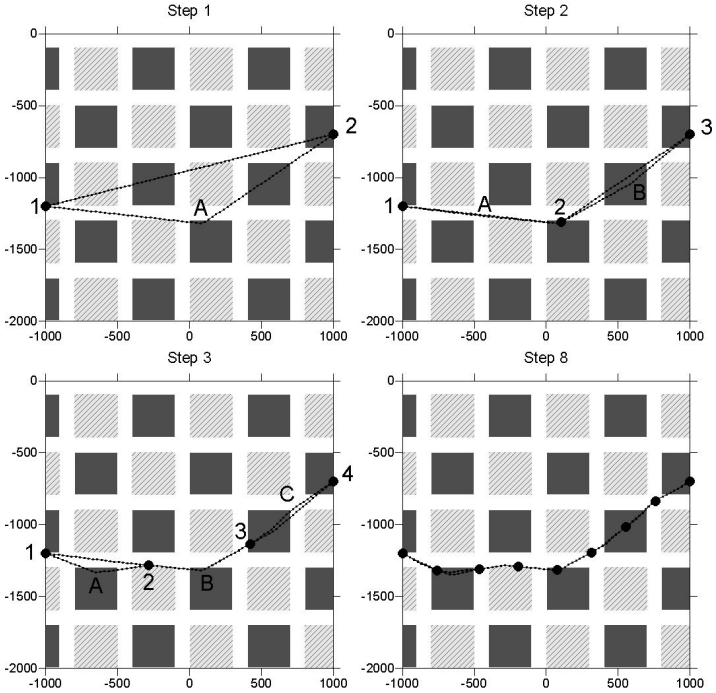


Tomographic inversions with *LOTOS*

[*Koulakov*, 2009]

- Main differences with *FMTOMO*
  - forward modelling with ray bending
  - considers both *P*- and *S*-wave velocities
  - parameterisation depends on ray density
  - inversions with different cell orientations
  - starting model optimisation





The ray-bending method
Um & Thurber (1987)

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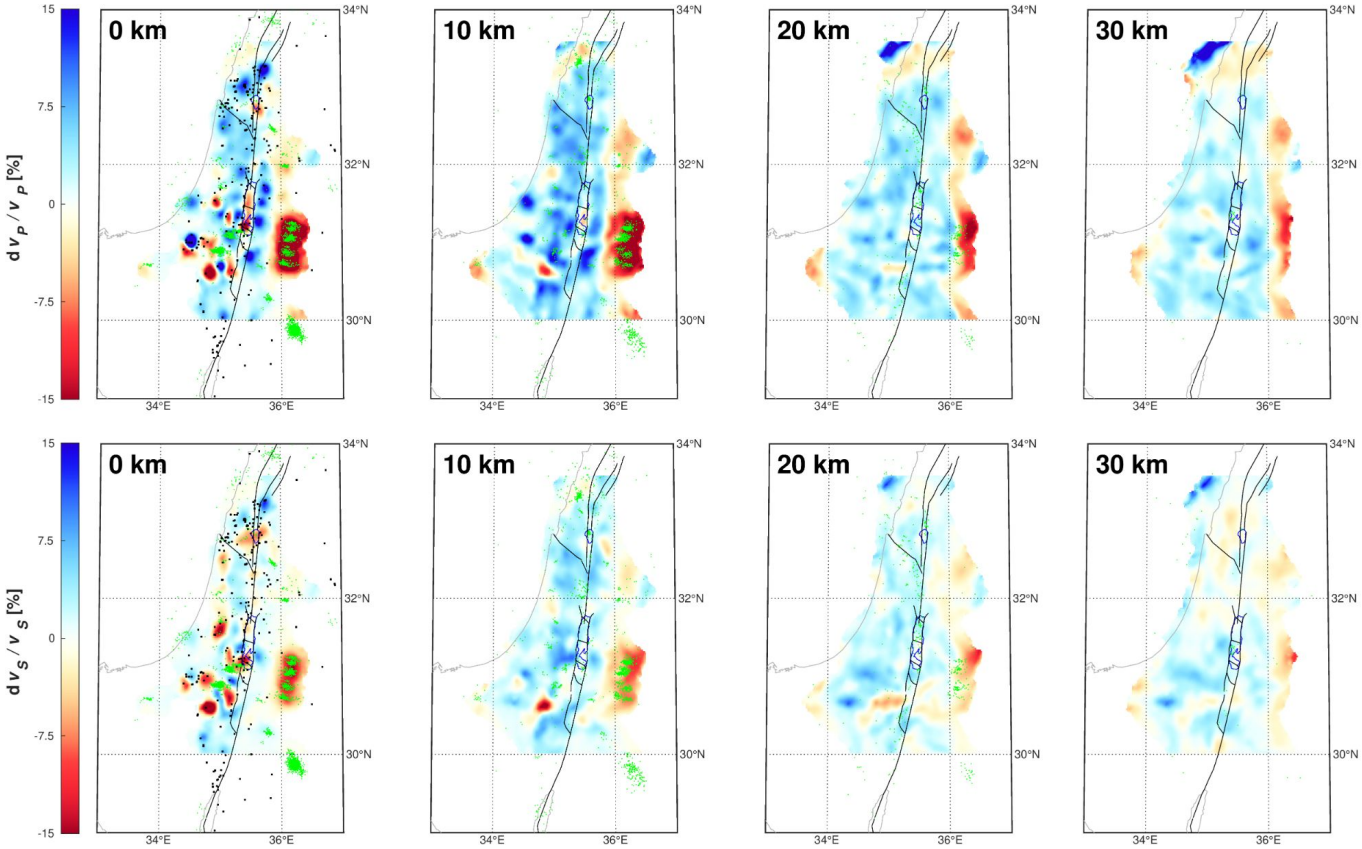
Tomographic inversions with *LOTOS*

- Initial test ran by code's author I. Koulakov
- Some visible improvements, more investigations needed



Conclusions and future prospects

- Tomographic inversion
  - finalise tomographic inversions
  - make results available to local and international communities
- Relocate seismicity using new 3D model (EEWS)
  - demonstrate this model improves location accuracy
  - design a workable approach to use the model
- Integrate model of Israel into global model (CTBTO)
  - finalise *RSTT* upgrade for local scale [*Philips* et al., 2007; *Myers* et al., 2010]
  - use 3D crustal model as starting point for the region

THANK YOU!

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