The 22-years of the PSLNET RI, involving Patras-Prague joint stations - a significant progress in the source studies of Greece earthquakes

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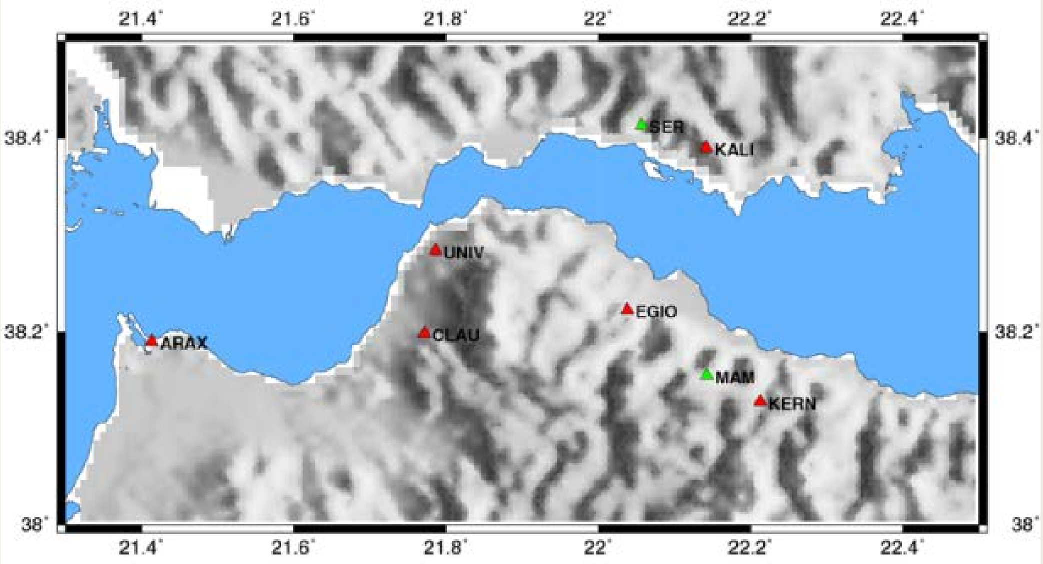
History

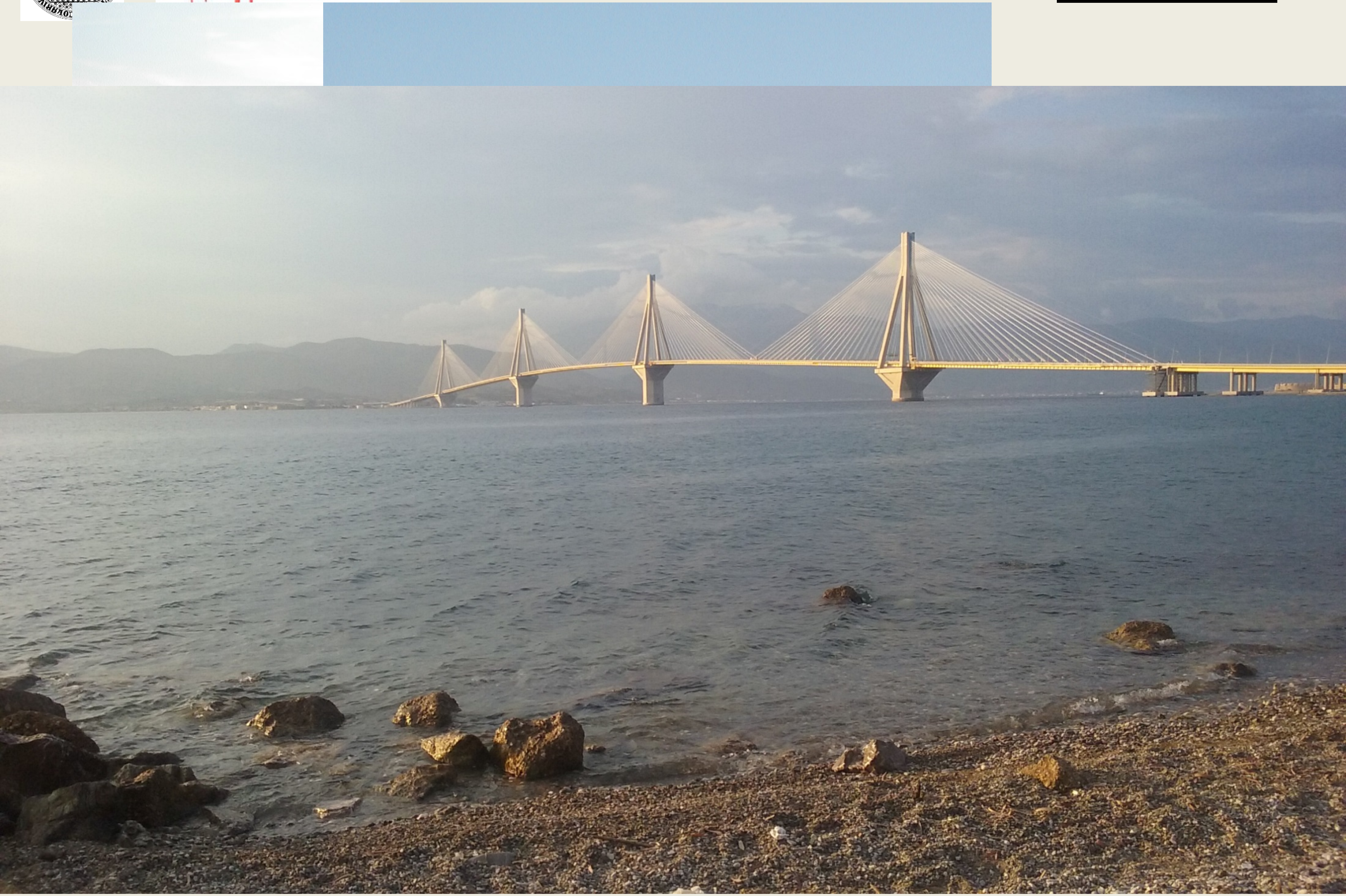
- **Charles University and Patras University have started to collaborate in the middle of the nineties.**

- **The first Broad Band (BB) stations (Guralp CMG-3T sensors, DM-24 digitizers, SAM data equisition units) were installed in 1997 as stand alone systems.**



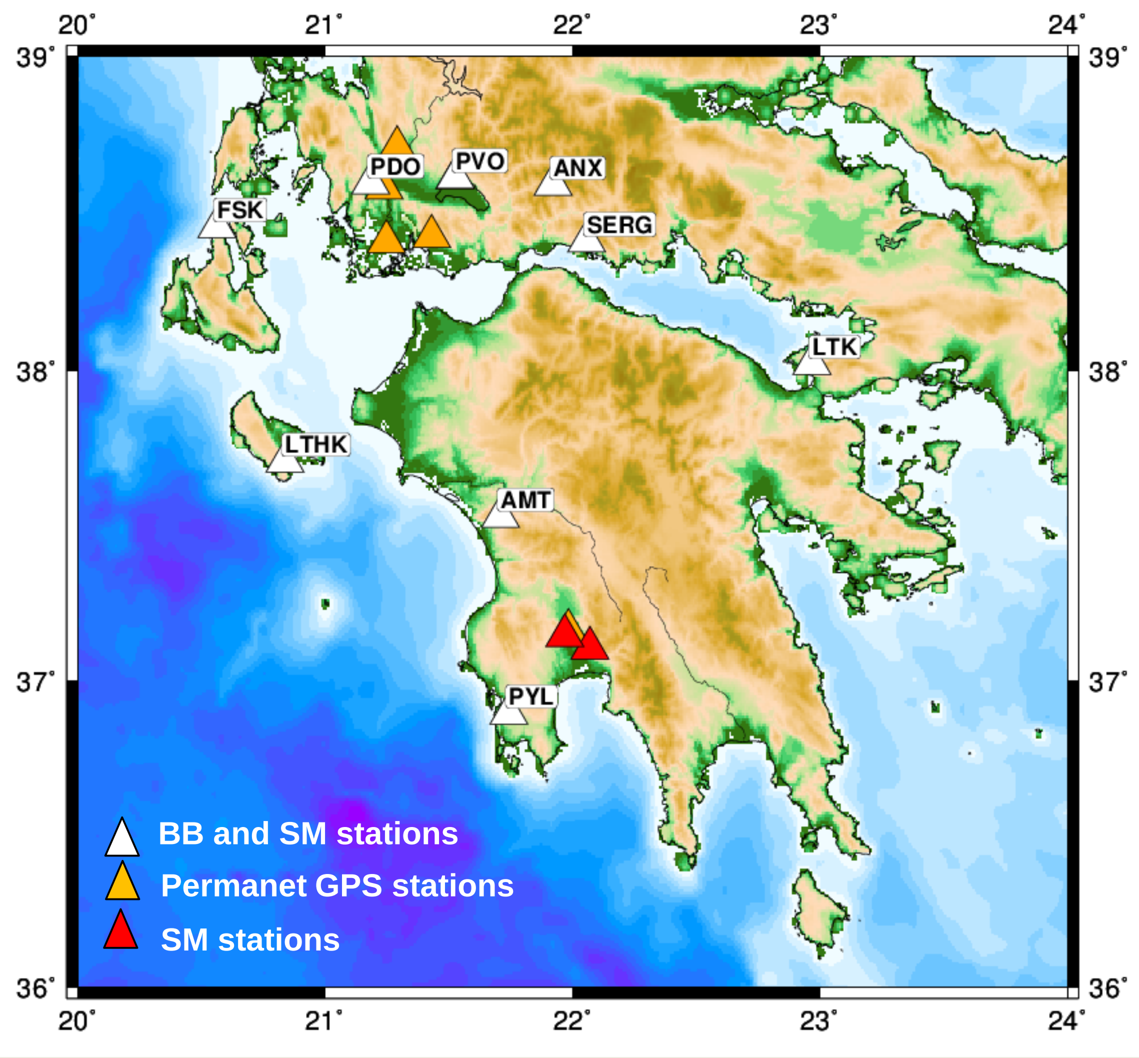
From the beginning we have concentrated on area of Corinth and Patras gulf. The map shows all station positions tested since 1997.

History



Present

- The network was expanded by permanent GNSS (PPGNet) and strong motion stations.



In the present time the network contains 9 BB, 11 SM and 6 GNSS stations.

The seismic data are available through NOA EIDA Data Archives.
http://eida.gein.noa.gr/webdc3/

Part of Hellenic Unified Seismic Network (H.U.S.N.)
CRL – Corint Rift Laboratory
Near fault Observatory/EPOS

Cooperation

- University of Patras, *Greece*
- Athens University , *Greece*
- Aristotle University of Thessaloniki, *Greece*
- Institute of geodynamics (G.I.) , National Observatory of Athens, *Greece*

- Geology Laboratory of Ecole Normale Supérieure, Paris – ENS, *France*
- Institut de Physique du Globe de Paris *France*

- The Research Institute of Geodesy, Topography and Cartography, Geodetic Observatory Pecny, *CR*

Projects and Publications

- **International projects (8)**

  NATO, GR-COAL project, Inco-Copernicus ISMOD project, EC project PRESAP, EC project 3HAZ-CORINTH, EC FP6 project MAGMA, MOBILITY (Using space geodesy to investigate the mechanics of earthquake ruptures)

- **National projects (6)**

  Hybrid kinematic modeling of earthquake strong ground motions, *GAUK*
  Sensor of rotational movement around vertical axis for seismic measurements, *GACR*
  Probabilistic modeling of seismic hazard due to aftershocks of large earthquakes, *GACR*
  Quick Extended Source Solution, *GACR*
  Improving physical insight into the Mediterranean earthquakes, *GACR*
  Multiscale spatial-temporal complexity of tectonic earthquake sources, *GACR*

- **2010-2015: CzechGeo, Distributed System of Permanent Observatory Measurements and Temporary Monitoring of Geophysical Fields in the Czech Republic**

- **2016-2019: CzechGeo, Distributed System of Permanent Observatory Measurements and Temporary Monitoring of Geophysical Fields.**

- **More than 40 publications of our team in reviewed journals related to PSLNET RI**

List of significant publications

- E. Sokos, Gallovič, F., Evangelidis, C.P., Serpetsidaki, A., Plicka, V., Kostelecký, J., Zahradník, J. (2020). **The 2018 Mw 6.8 Zakynthos**, Greece, earthquake - Dominant strike-slip faulting near subducting slab, Seism. Res. Lett., in press.
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- Křížová, D., J. Zahradník, and A. Kiratzi (2013). Resolvability of isotropic component in regional seismic moment tensor inversion. *Bull. Seism. Soc. Am.* 103, 2460-2473.
- Sokos, E. and J. Zahradník (2013). Evaluating centroid moment tensor uncertainty in new version of ISOLA software. *Seismol. Res. Letters* 84, 656-665.

List of significant publications

- Sokos, E., J. Zahradník, A. Kiratzi, J. Janský, F. Gallovič, O. Novotný, J. Kostelecký, A. Serpetsidaki, and G-A. Tselentis (2012). The January **2010 Efpalio earthquake sequence** in the western Corinth Gulf (Greece). *Tectonophysics*, 530-531, 299-309.
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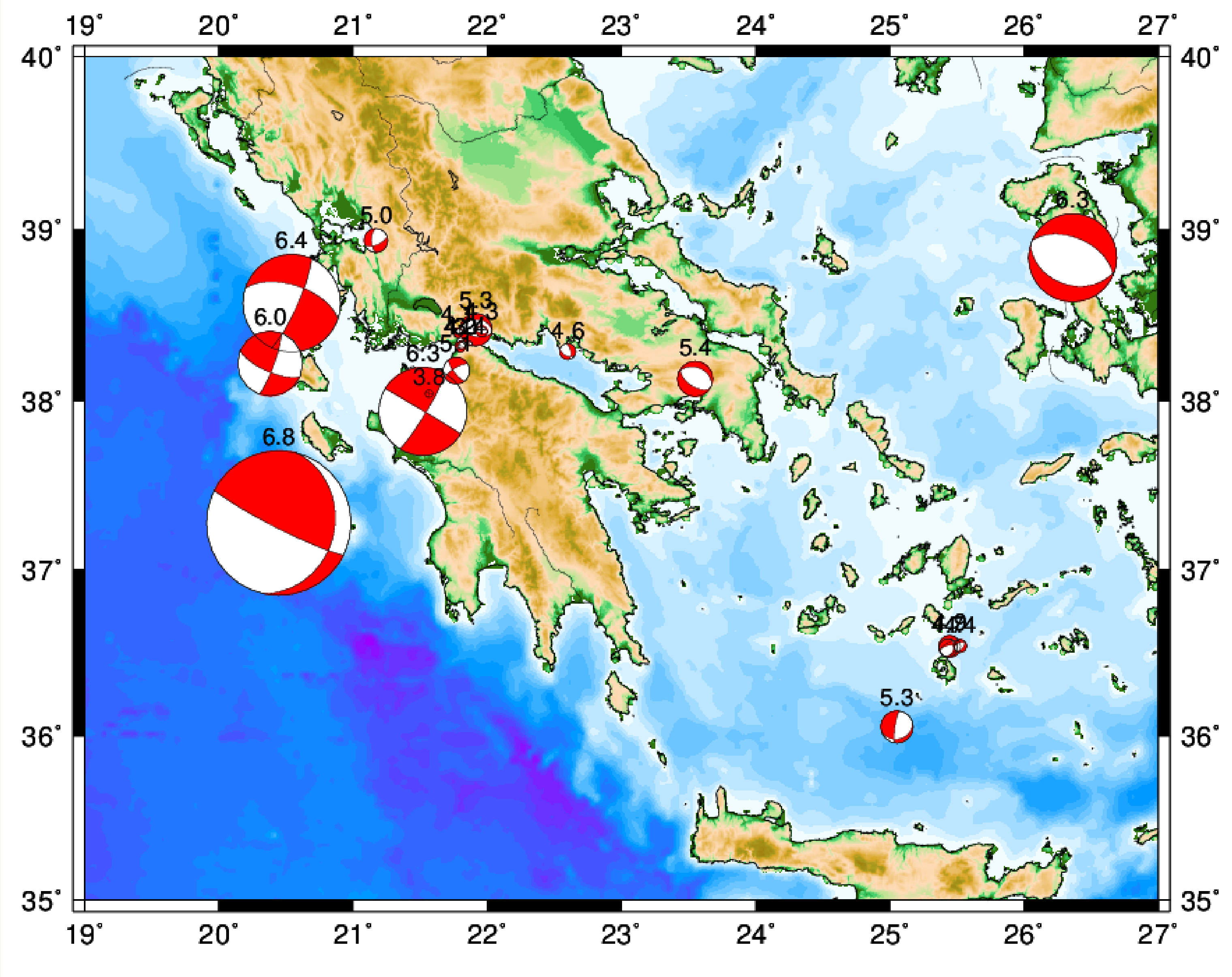
Map of significant earthquakes



Software development

- **ISOLA:** moment tensor retrieval software. It is based on multiple-point source representation and iterative deconvolution
- **ISOLA-ObsPy:** Python/ObsPy module for automated moment tensor inversion
- **MuFEx:** multiple finite-extent source model
- **SlipGen:** k^{-2} hybrid slip generator
- **LinSlipInv:** Suite of codes for linear slip inversions and resolution analysis.
- **RIKsrf:** Codes for strong ground motion simulations using an advanced kinematic source model
- **PATCHEs**, Imaging of seismic rupture process by two dominant slip patches.
- **FUWEI:** Inverting full waveforms into 1D seismic velocity model
- **EGF** method using Non negative least square method
- **EMPIRE:** empirical greens tensor derivatives

Asperity break after 12years: The Mw6.4 2015 Lefkada (Greece) earthquake

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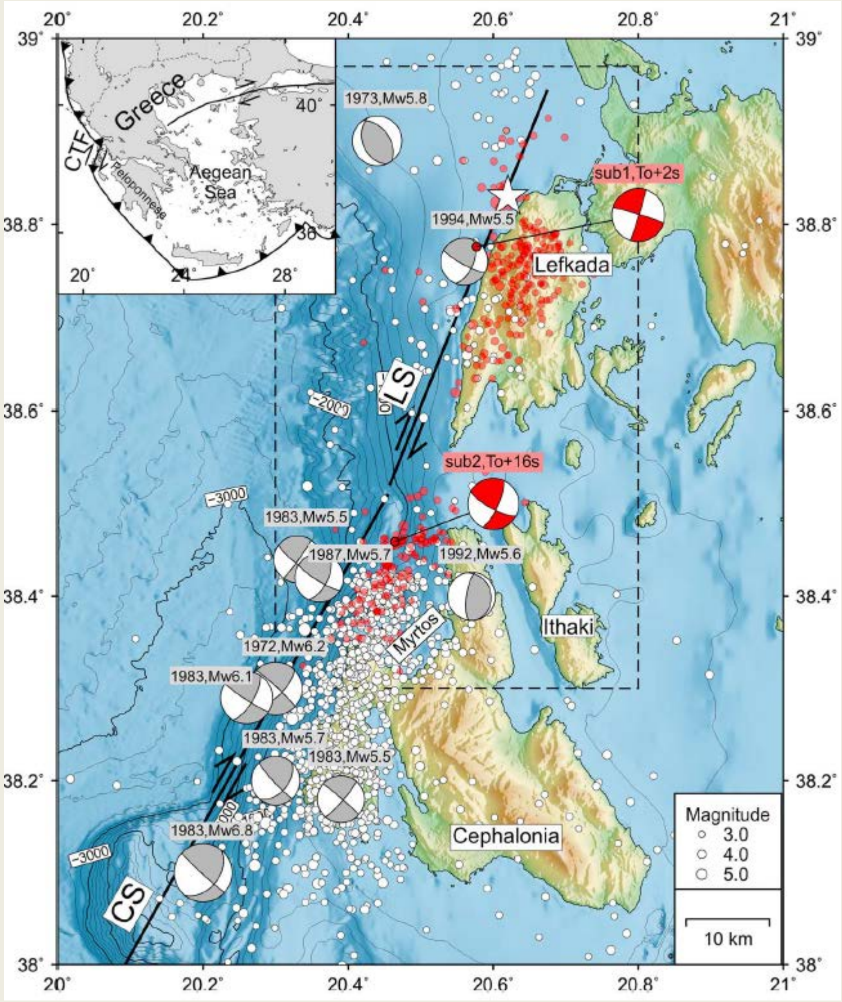
[2]Faculty of Mathematics and Physics, Charles University in Prague, Prague, Czech Republic,
[3]Department of Geophysics, Aristotle University of Thessaloniki, Thessaloniki, Greece



17 November 2015 earthquake ruptured the southern part of the Lefkada Segment (LS) of the Cephalonia Transform Fault (CTF) zone.

Seismicity along the Cephalonia Segment (CS) and the Lefkada Segment (LS) of the Cephalonia Transform Fault Zone (bold black lines). Large events are shown by grey beach balls. Red beach balls show two major subevents of the **14 August Mw6.2 2003** earthquake [Zahradník et al., 2005; Benetatos et al., 2007]. Text above the red beach balls depicts the timing of the subevents relative to its origin time To. Small red circles are aftershocks of the 2003 event, forming two well-separated clusters close to the subevents. White circles represent the seismicity after the 2003 event and before the 2015 event . Inset shows the position of CTF and the major tectonic elements in Greece.

Asperity break after 12years: The Mw6.4 2015 Lefkada (Greece) earthquake

The finite-fault modeling was performed using three independent methods:

1. the multiple point source (MPS) method using synthetic Green's functions

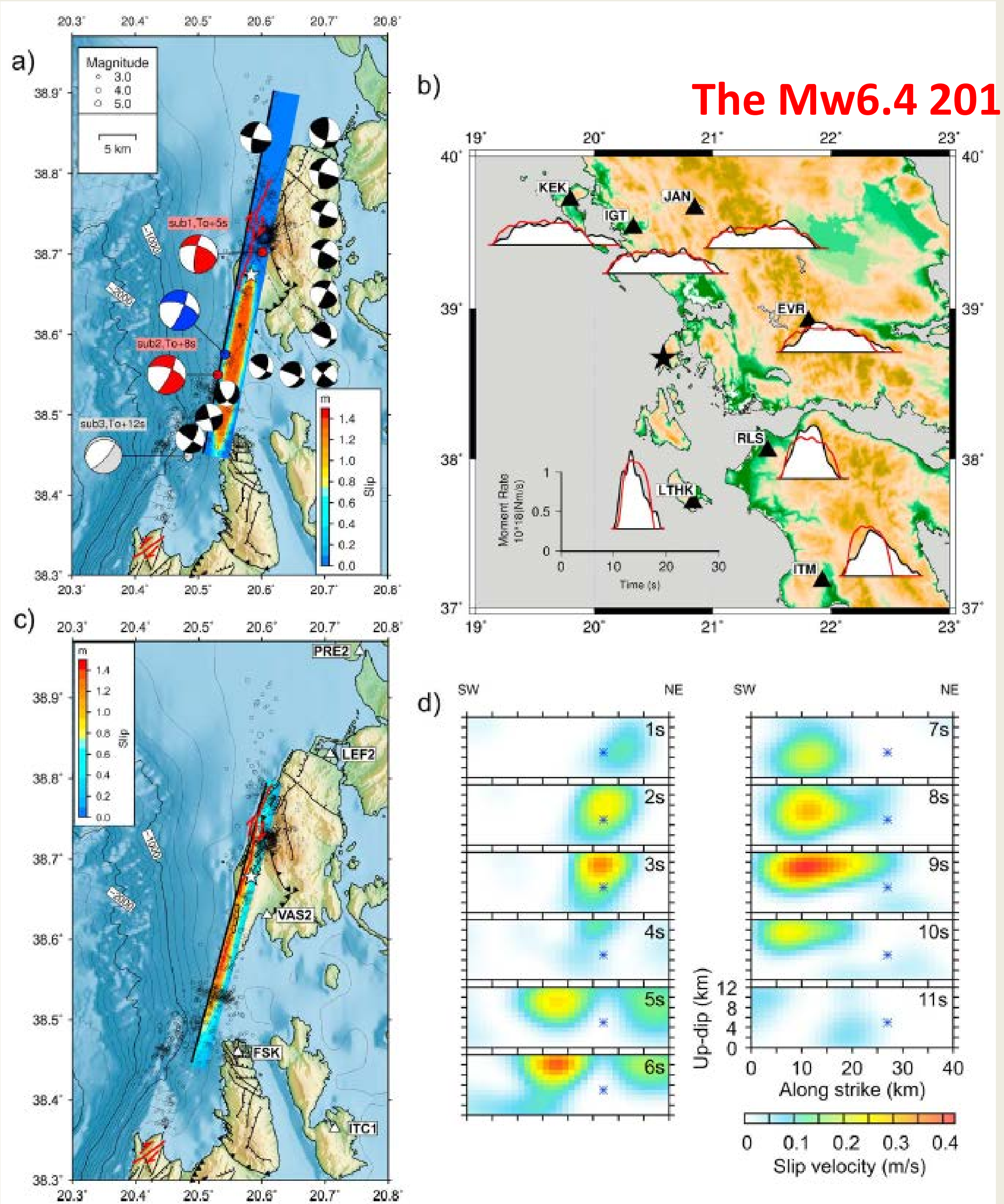
2. the patch method using empirical Green's functions (EGF)

Regional data

3. the linear slip inversion (LSI) using synthetic Green's functions.

Local strong motion recordings

Asperity break after 12years:
The Mw6.4 2015 Lefkada (Greece) earthquake



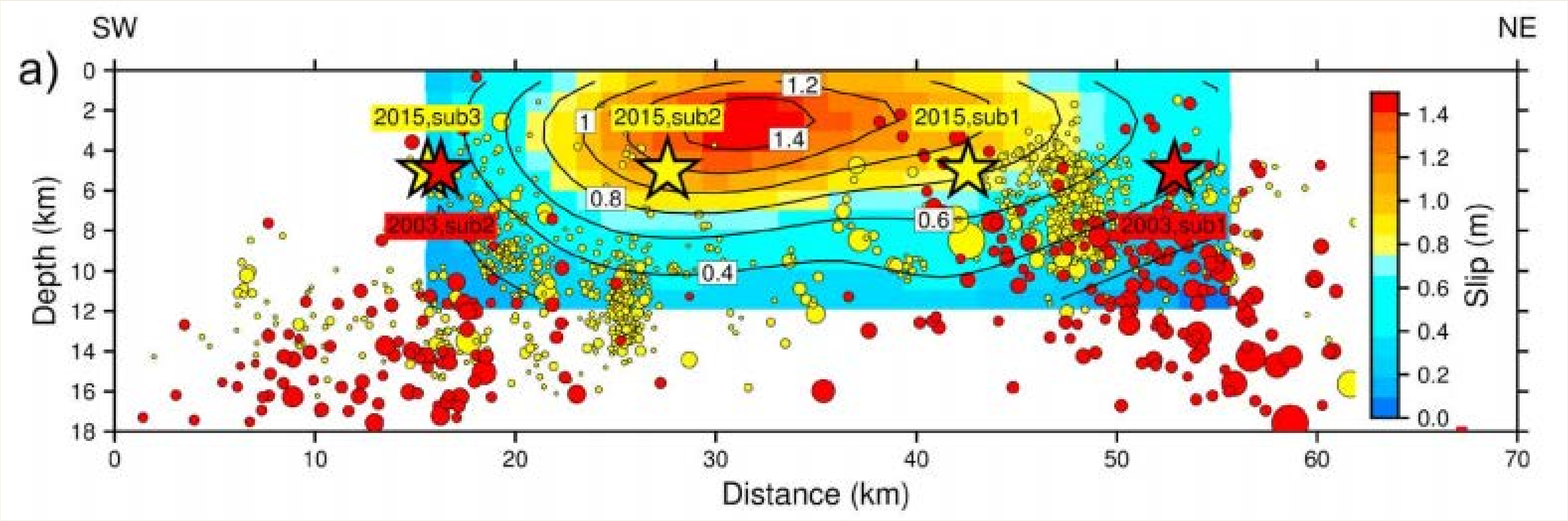
(a) Surface projection of the slip model obtained using the **empirical Green's function (EGF) approach**; it is calculated as a mean of 500 patch models well fitting the apparent source time functions (ASTF), shown in Figure b. Star denotes the epicenter; blue beach ball is the centroid moment tensor. Red beach balls are the two largest subevents of the multiple point source inversion with DC-constrained focal mechanism; the third subevent, whose mechanism is uncertain, is shown in gray.

(b) The **ASTFs obtained from EGF method** (black) at regional stations and synthetic ASTFs calculated from the best slip-patch model (red). Note the short duration and large amplitude at the LTHK station, implying directivity toward south. In most stations the ASTFs also clearly show the multiple character of the source.

(c) Surface projection of the slip model obtained using the **linear slip inversion (LSI)** method employing strong motion waveforms from stations depicted on the map (triangles). **Note the consistency of the location of the major slip patch with the slip model in Figure a.**

(d) Space-time rupture evolution of the LSI model plotted in terms of slip velocity snapshots every 1 s. The blue asterisk denotes the vertical projection of the hypocenter on the fault (unused in the inversion). Note the initial up dip rupture propagation, which continued predominantly toward SSW (antistrike) and partly toward NNE.

Asperity break after 12years: The Mw6.4 2015 Lefkada (Greece) earthquake



Vertical cross section showing **collocation of slip distribution** inferred for the **2015 earthquake** by the LSI method (color and isolines), MPS solution (yellow stars), and the two subevents of the **2003 earthquake** (red stars). Yellow and red circles correspond to the aftershocks of the 2015 and 2003 events, respectively.

Asperity break after 12years: The Mw6.4 2015 Lefkada (Greece) earthquake

Conclusions

- All three methods provided **similar major features of the slip model**, such as **predominantly unilateral rupture propagation toward SSW**.

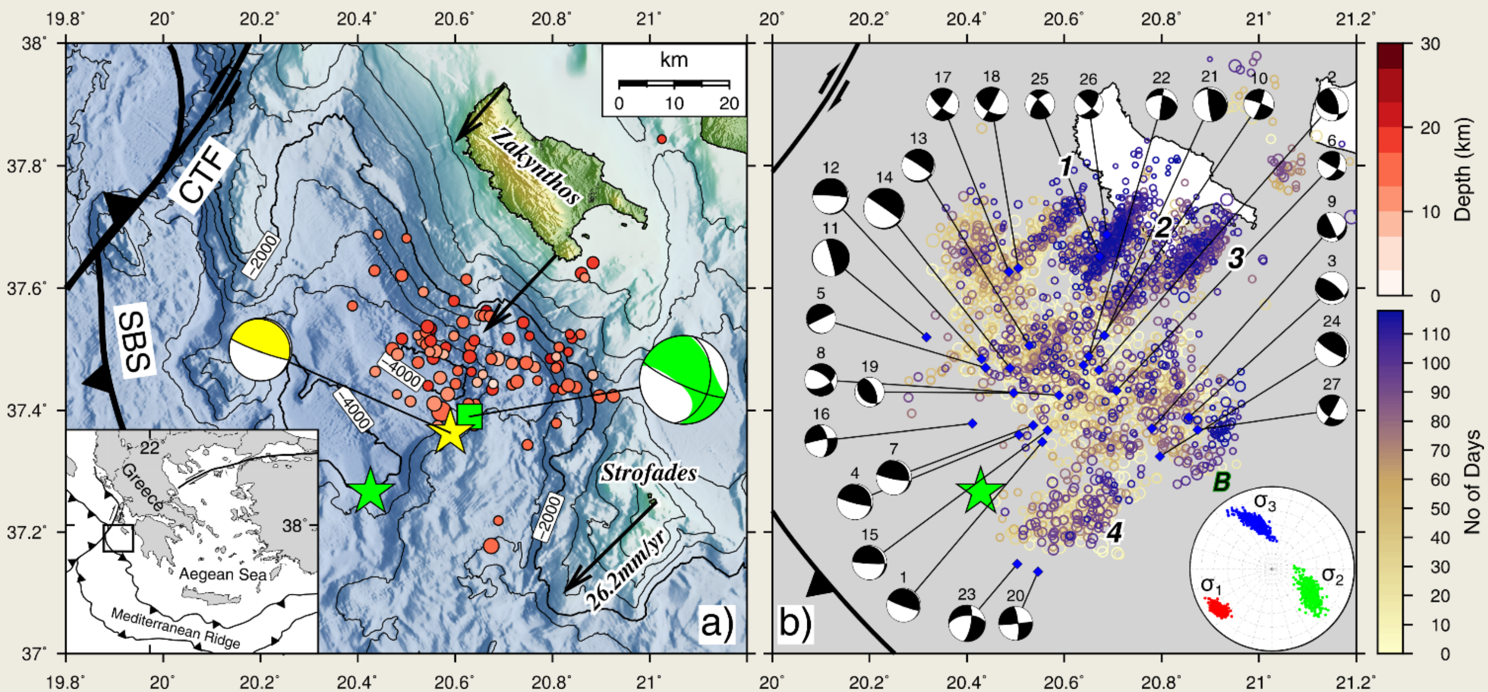
- Slip is mainly concentrated at the **central south part of the Lefkada Segment**, roughly 10 km south west of the epicenter along a ~15–20 km long fault. The **maximum slip of ~1.5 m** was situated predominantly at relatively shallow depths (from 3 to 7 km).

- **The rather light damage** distributed along the Lefkada and Cephalonia Islands supports the initial **minor slip above the hypocenter** and with the **major slip toward south**, partially offshore, i.e., away from populated areas.

- A large zone ~15–20 km long coinciding with the major slip episode, southwest of the main shock epicenter, remained almost free of aftershocks. The aftershock activity developed toward the edges of the rupture, only a few hours after the main shock, in the form of two major clusters.

The 2018 Mw 6.8 Zakynthos, Greece earthquake – Dominant strike-slip faulting near subducting slab

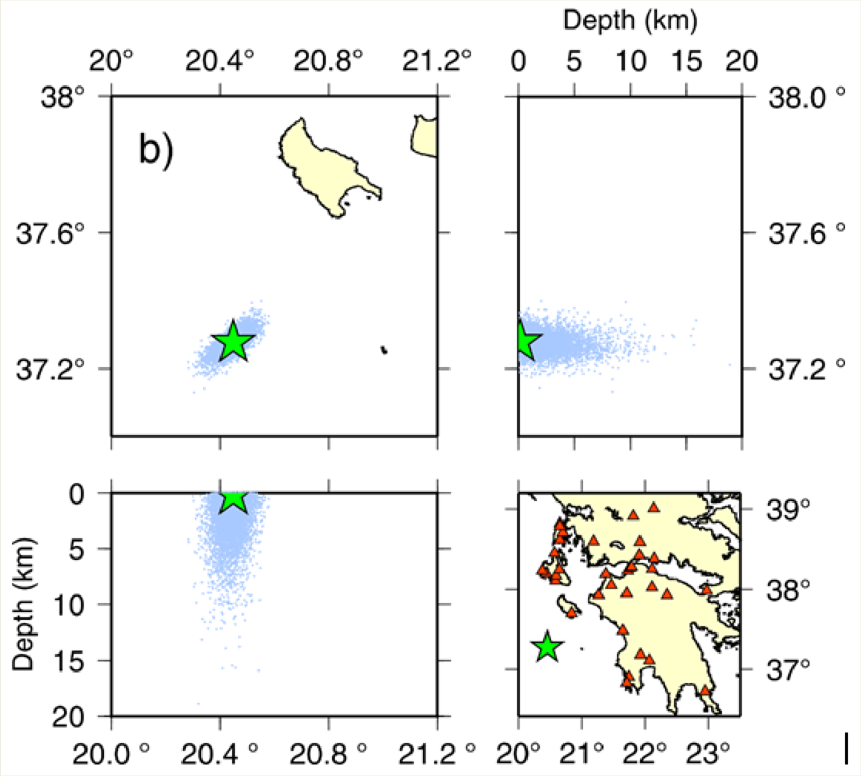
E. Sokos, F. Gallovič, C.P. Evangelidis, A. Serpetsidaki, V. Plicka, J. Kostelecký and , J. Zahradník

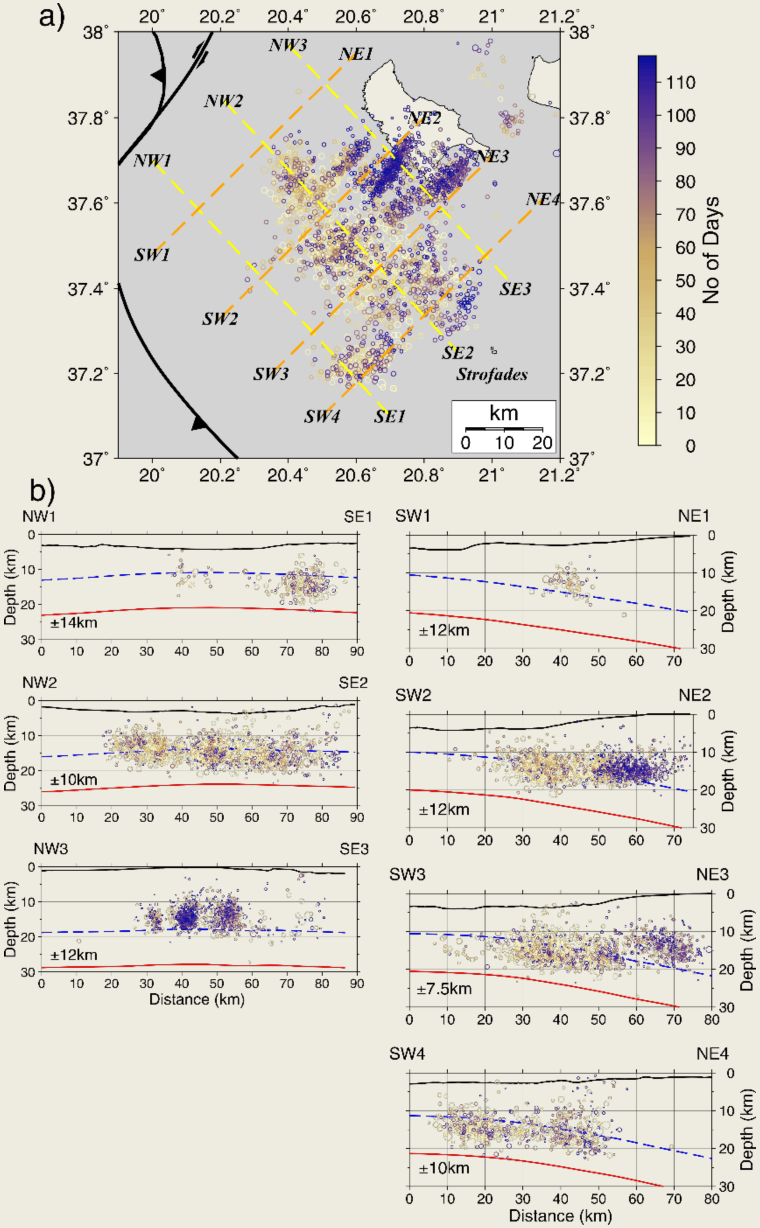


The source process of the 2018 mainshock and aftershocks was analyzed using regional broadband, accelerometric and GNSS data, considering also the 2011-2018 seismicity of the region. **We interpret the mainshock in terms of a segmented source model, possibly related to trench-orthogonal fractures in the subducting plate and reactivated faults in the upper plate.**

The 2018 Mw 6.8 Zakynthos, Greece earthquake – Dominant strike-slip faulting near subducting slab

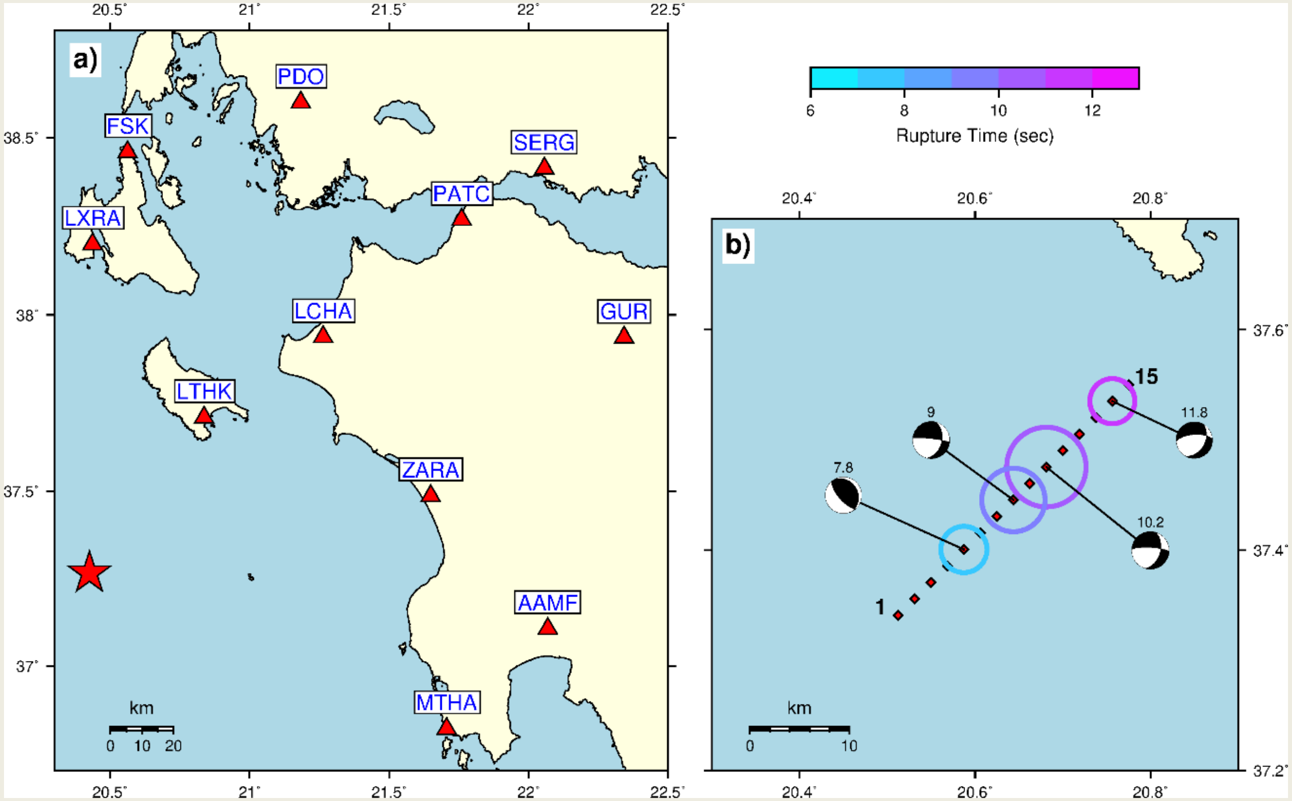
Location: NlinLoc, Hypoinverse, HypoDD





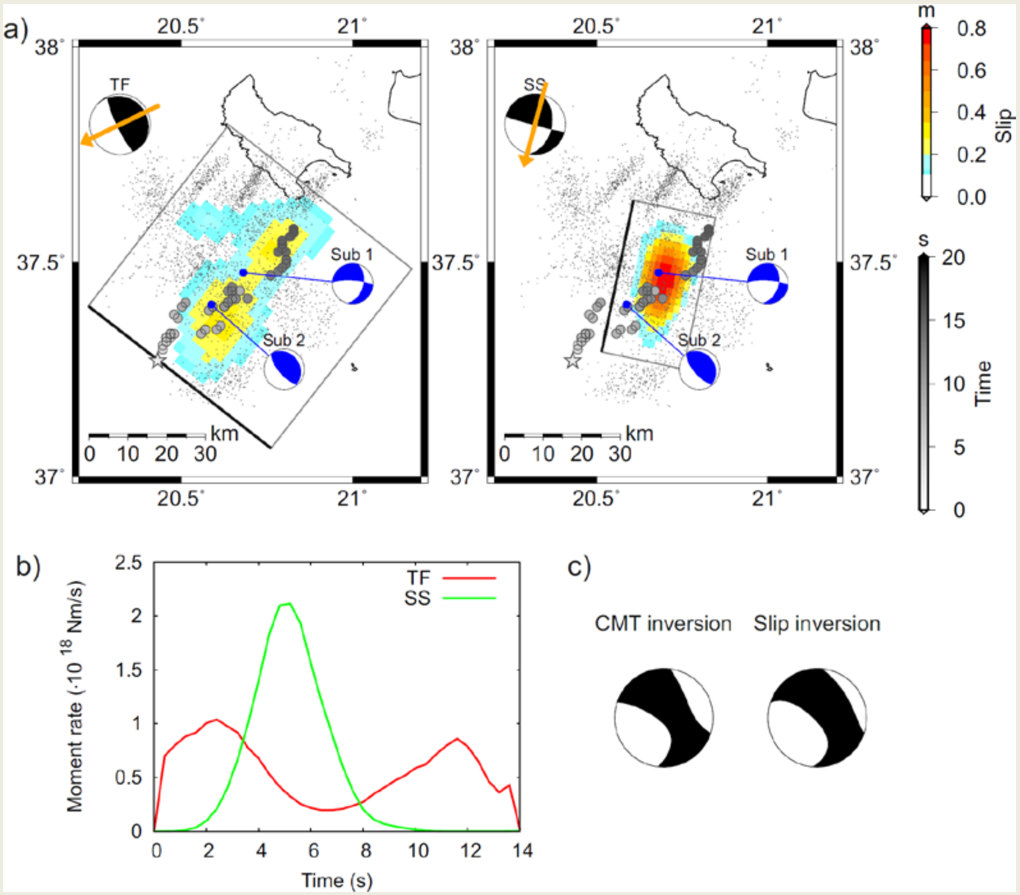
The 2018 Mw 6.8 Zakynthos, Greece earthquake – Dominant strike-slip faulting near subducting slab

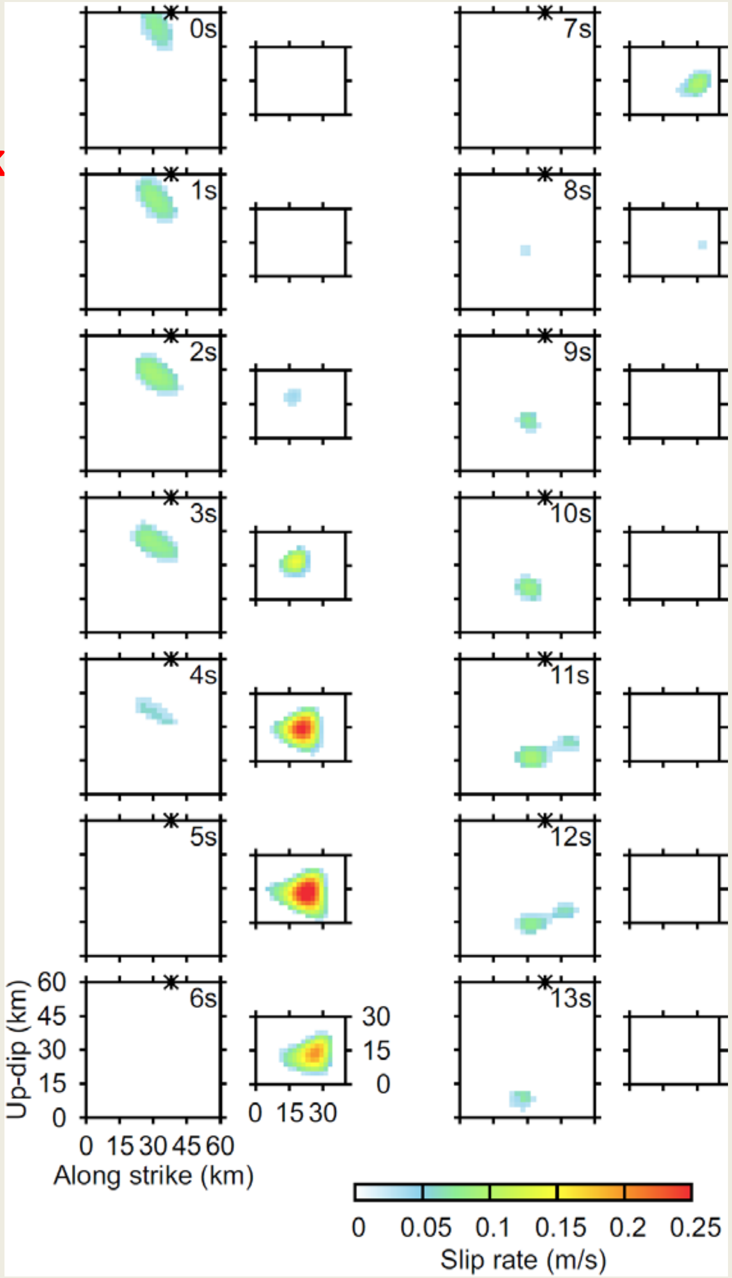
Multiple point source modeling in a DC-constrained mode
moderately-dipping strike-slip mechanism (SS) s/d/r ~ 10°/40°/180°
low-dip Thrust-fault mechanism (TF), s/d/r ~ 300°/10°/60°



The 2018 Mw 6.8 Zakynthos, Greece earthquak faulting near subducting slab

Segmented fault model of the mainshock

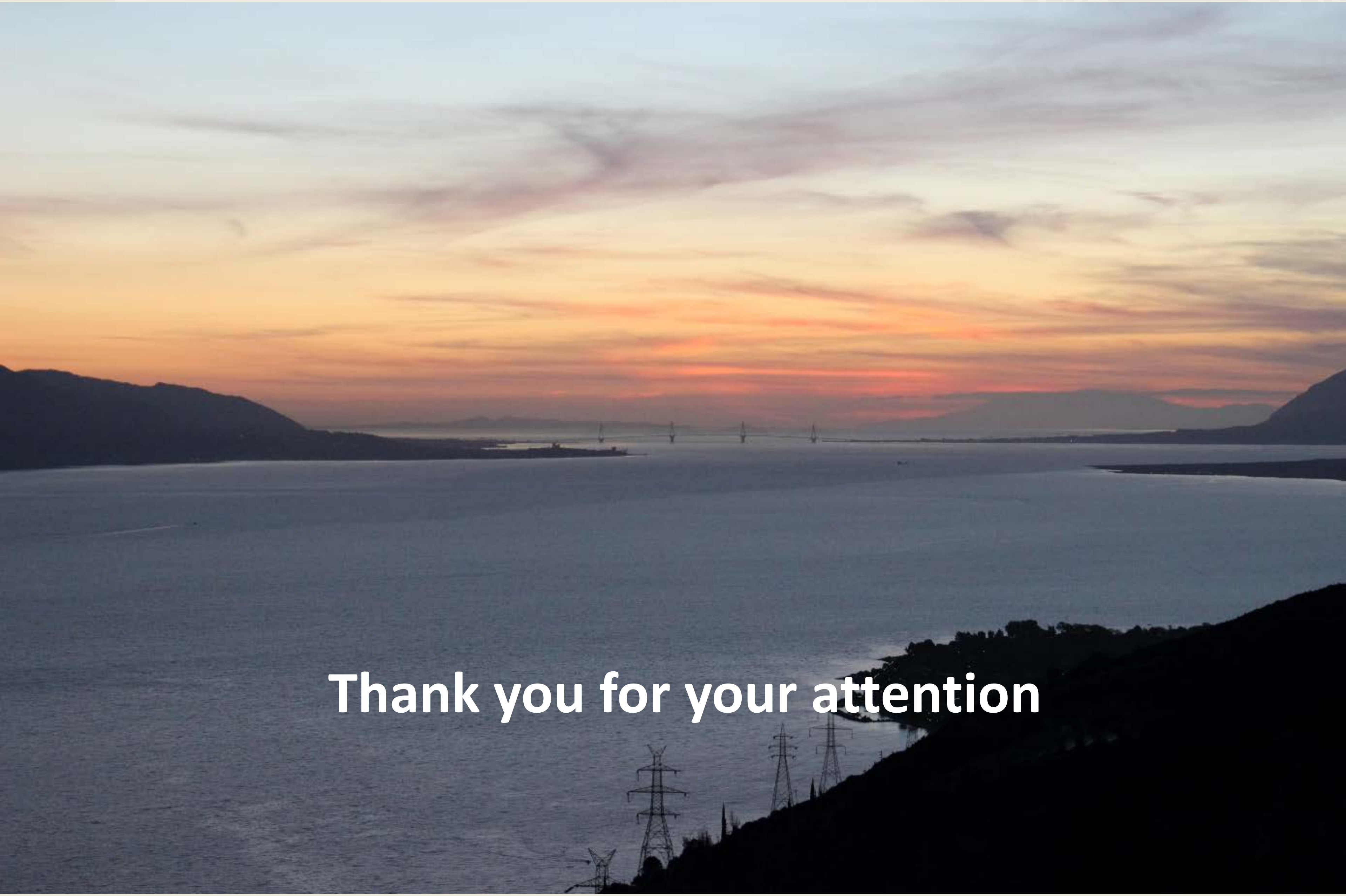




The 2018 Mw 6.8 Zakynthos, Greece earthquake – Dominant strike-slip faulting near subducting slab

Conclusions

- The Mw 6.8 event in 2018 was of a mixed TF(dip ~10°)+ right-lateral SS (dip ~40°, strike ~10°) type, as was also the whole aftershock sequence
- Both slip vectors have the same SW-orientation, consistent with the GNSS-derived major plate motion.
- The two-segment fault model explains the observed non-double-couple radiation.
- The low dip of the TF segment suggests the inter-plate origin.
- Relatively distant aftershocks (seemingly occurring off the mainshock fault) mapped several SW-NE streaks, or faults.
- As a whole, the mainshock progressed also in the SW-NE direction. This direction closely follows the trench orthogonal fractures related to differential slab motions.
- The 10°-striking SS segment of the mainshock could be a fault bend connecting such off-shore structures, or it could be explained by reactivation of ~N-S trending fault relay zone in the upper plate.
- Although the 2018 sequence involved a thrust fault, the strike-slip faulting was dominating the mainshock


Thank you for your attention