Exploring and exploiting the ISC arrivals database: station corrections for rapid and reliable earthquake location

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For effective earthquake and tsunami early-warning it is crucial that key earthquake parameters are determined as rapidly and reliably as possible.

**EarlyEst (EE):** Rapid earthquake analysis module at INGV CAT tsunami alert center:

Realtime display OT+8min
M7.5 Papua New Guinea
Station corrections not just for better locations, but also for stable, robust and reliable rapid locations.

Example: False events

M3.5 Greece
FALSE: M6 Mali
FALSE: M6 South Atlantic Ocean
M7 Mid-Atlantic Ridge

Causes:
- Poor station distribution
- 3D structure but 1D velocity model
- Poor pick/travel-time error model
- Incorrect phases association

Station corrections can help avoid this problem.
Average station P residuals ISC 2008-2012 reflect large-scale tectonics

Average station P residuals
ISC revised catalog, EE stations 2008-2012 M≥5 Δ0-100°
Average station P residuals for distant events show lithosphere / upper mantle tectonic most clearly.
Average station P residuals for regional events differ, reflect shallower structure.

 ISC revised catalog, EE stations 2008-2012 M≥5 $\Delta$0-30º

$\Delta$0-30º

Residual (sec)

- 1
- 2
- 3
- 4
- 5

Red dots: pos (late/slow)
Blue dots: neg (early/fast)
Average station P residuals for Early-est similar, but not identical: larger than ISC, local differences → use EE for EE!

Average station P residuals Early-est 2014-2015 $\Delta0$-100º
Event P residuals at single stations, fit with constant and polynomial functions

**ISC revised 2008-2012 M≥5**

- Station WRAB
  - Blue – deeper events
  - $3^{rd}$ order polynomial

- Station AAK

**Early-est 2014-2015**

- Station WRAB
  - $3^{rd}$ order polynomial

- Station AAK
Question: Why always large variance in residual at ~constant distance (same source region)?

- Depth-Origin-Time trade-off?
- Different station sets used? (sta availability, magnitude)
- ... combined with 1D velocity model
- Mis-identified phases?
- ???

 ISC rev 2008-2012 M≥5

 ISC EHB 2006-2008 M≥5

 Early-est 2014-2015 M≥5
Early-est locations: Station corrections should give more associations and better absolute hypocenters.

Without corrections:

- Region: Galapagos Islands Region
- Origin Time: 2015.06.11-08:29:08.92 UTC
- Hypocenter: lat: 1.51° lon: -91.03° [±/18km] depth: 20km [±/16km]
- Location stdErr: 2.6s assocPhases: 14 usedPhases: 13

With P corrections:

- Region: Galapagos Islands Region
- Origin Time: 2015.06.11-08:29:09.13 UTC
- Hypocenter: lat: 1.61° lon: -90.77° [±/18km] depth: 20km [±/16km]
- Location stdErr: 2.5s assocPhases: 26 usedPhases: 20

Early-est P corrections, 4th order polynomial fit
Early-est: P corrections + more picks help avoid false events

Helps, but more needed:
Intelligence & statistics for rapid & robust earthquake detection, association and location,
Lomax et al., S01e Real-Time Seismology and Early Warning, Wed, July 1, 08:30
Empirical station corrections give more associations, lower errors; can give more accurate absolute locations.

Corrections should be developed and used on the same analysis system.

Polynomial fit of residuals vs distance works well.

Why is there a large variance in residuals at each distance?
Which is better: empirical corrections or travel-time in 3D models?

More needed: Intelligence & statistics for rapid & robust earthquake detection, association and location, Lomax et al., S01e Real-Time Seismology and Early Warning, Wed, July 1, 08:30

Support: Centro Nazionale Terremoti, INGV
Data: ingv.it, geofon.gfz-potsdam.de, geosbud.ipgp.fr, resif.fr, ird.nc, iris.washington.edu, usgs.gov
Analysis Software: R statistics and graphics language; Python: pandas.pydata.org, matplotlib.org

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