ICEARRAY and the M6.3 Ölfus earthquake on 29 May 2008 in South Iceland: Extreme near-fault strong-motion array recordings

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Plate tectonics of Iceland

- North American Plate
- Kolbeinseyjarhryggur
- North Transition Zone
- South Transition Zone
- SISZ
- EVZ
- WVZ
- TFZ
- European Plate

9.7 mm/year movement
ICEARRAY, the ICESMN and Strong Earthquakes in the SISZ

The town of Hveragerði

Western part of the SISZ

M6.5 2000
M6.4 2000
M~7 1912

Recording sites of the Icelandic Strong-motion Network in the South Iceland Seismic Zone

- Gray, thick north-south lines ➔ Faults of last three earthquakes of M>6 in SISZ
- Thin, black lines ➔ surface expressions of past earthquakes
ICEARRAY network in Hveragerði

- Purpose
  - monitoring of significant SISZ earthquakes
  - quantitative estimation of spatial-variability of ground motion
  - providing insight into earthquake source processes
  - applying array processing techniques (S/N gain ~ $\sqrt{N}$)

ICEARRAY Layout ($N=14$)
Mw6.3 Ölfus earthquake on 29 May 2008
Fault locations

- Red: aftershocks (based on IMO eq. locations)
- Green: GPS & InSAR inversion (Decriem et al., 2008)
- Black: InSAR (Halldorsson, Jonsson, Monelli, 2009; in progress)
Fault locations

- Ascending InSAR image
  - RED: Up/West
  - BLUE: Down/East

- Fault lines
  - **Cyan**: based on aftershock distribution (based on IMO eq. locations)
  - **Pink**: GPS & InSAR inversion (Decrem et al., 2008)
  - **Black**: InSAR (Halldorsson, Jonsson, Monelli, 2009; in progress)
Static slip distribution

- Available static slip distribution models (GPS and/or InSAR) show different results
- They give maximum slip
  - Ingolfsfjall fli: 1-2.3 m (!)
  - Kross fli: 1.8-2.4 m (!)

- Time dependence of slip only retrievable using strong-motion data
- **Caution:** Large uncertainties of fault parameters (Monelli et al., 2009)

Halldorsson, Jonsson, Monelli (2009, in progress)
Halldorsson & Sigbjornsson (2009, SDEE)
Acceleration – east-west

Max Acc. 1807.52 cm/s², Max Time 15.00 s
All traces: N080°E

Halldorsson & Sigbjornsson (2009, SDEE)
Geographical distribution of PGA within HVeragerði

- Peak horizontal acceleration
- Largest values in the east and west parts of the town
- Lowest values close to the centre
- Correlates well with observed damage
- Structural integrity of vast majority of structures was NOT compromised (fortunately)
Elastic Response Spectra

Halldorsson & Sigbjornsson (2009, SDEE)
Velocity – north-south

Max Vel. 131.94 cm/s. Max Time 15.00 s
All traces: N000°E

Halldorsson et al. (2009, in progress)
Halldorsson et al. (2009, in progress)
Coseismic displacement from three-component triggered acceleration data

- Processing the data using a new method based on wavelet decomposition (Chanerley, Alexander & Halldorsson, 2009, in-press)
- Reveals the details of the coseismic displacement at each ICEARRAY station during the earthquake
- GPS measurements show ~17 cm northwest, 3.5 cm up
  - *Play MATLAB plot here*
- Very interesting ground displacements – Further modeling required (studies are ongoing)
Time interval between faults

- **ICEARRAY**: $\Delta t \sim 1.6$-2.0 seconds
  - S-wave triggering
  - Points to largest S-waves coming from a major slip subevent in the southern part of Kross fault

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Halldorsson, Jonsson, Monelli (2009, in progress)
Conclusions

• ICEARRAY deployed in October 2007

• First small-aperture strong-motion array in Iceland ($N=14$, $D=1900$ m, $d=50$ m)
• Designed via optimization of Array Transfer Fcn.
• Resolves $f=1$-20 Hz and $\kappa=1.5$-24 rad/km

• Monitors significant earthquakes in the SISZ
• Establishes spatial coherency functions of seismic waves
• Useful for investigating earthquake source processes
Conclusions (cont’d)

• Magnitude 6.3 earthquake on 29 May 2008 recorded by the ICEARRAY, less than 2 km away
  – *Worldwide unique dataset*
  – Complex event, multiple causative faults
  – ICEARRAY near-fault data:
    • Mainshock: 11 stations x three-components of acceleration
    • Aftershocks: Over 600 recorded (~100 larger than M3)
  – High intensity ground motion, *PGA*=0.38g–0.88g
  – Short duration ~ 4-5 seconds
  – Near-fault velocity pulses, *PGV*=27-62 cm/s, *T*=1-1.2 s
  – Dynamic offset agrees with GPS measurements
  – Implications for earthquake resistant design in the near-fault region

• Data analysis and modeling continues......
Thanks!

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