SnT 2019

The 2017 North Korean Nuclear Test – A Comprehensive Multi-Technology Analysis

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GFZ, German Research Centre for Geosciences
KIT, Karlsruhe Institute of Technology

The 2017 North Korean Nuclear Test - A Comprehensive Multi-Technology Analysis

- September 3rd 2017: Sixth nuclear test conducted by North Korea
- Test takes an outstanding place in the sequence of North Korean nuclear test explosions
  - Estimated body wave magnitude of 6.2
  - Calculated explosive yield of several hundred kt TNT equivalent
  - Strong surface and tectonic activity observed in the aftermath of the test
  - Possible observations of radionuclides related to the test

- Involvement of the German National Data Center
  - Provide an independent and advanced evaluation of the 2017 test
  - Collaboration with experts from federal or scientific institutions (BfS, GFZ, KIT)
  - Application of several different geophysical methods:
    - Seismology
    - Infrasound
    - Remote Sensing
    - Radionuclide Monitoring and Atmospheric Transport Modeling
  - Utilization of national technical means and additional non-IMS data

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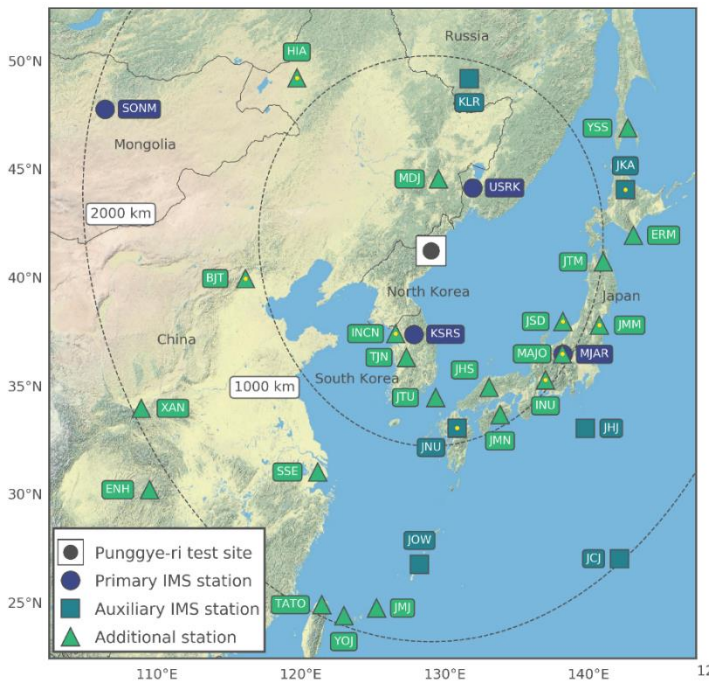
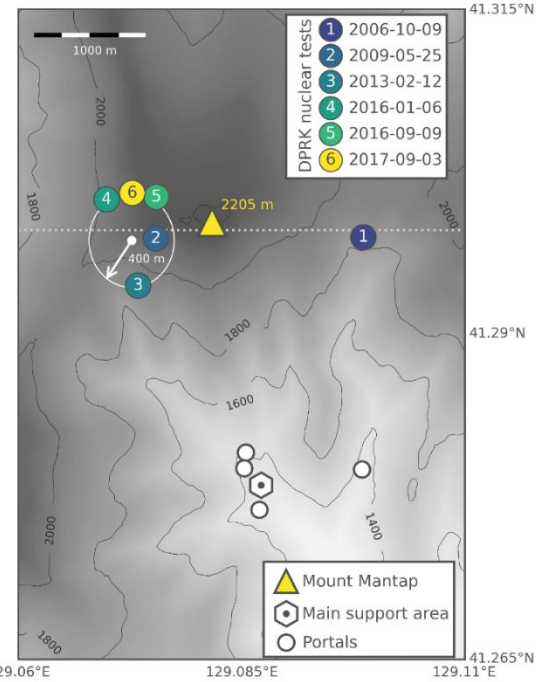
Seismology – Relative hypocenter localization

- Hypocenter from high-precision relative location methods based on seismogram cross-correlation
- January 2016 DPRK event as ground truth
- Relative location error of 100 m
- Events 2009 to 2017 are located within a radius of 400 m

➢ 41.300682 N
➢ 129.07276 E
➢ 1.1 km depth





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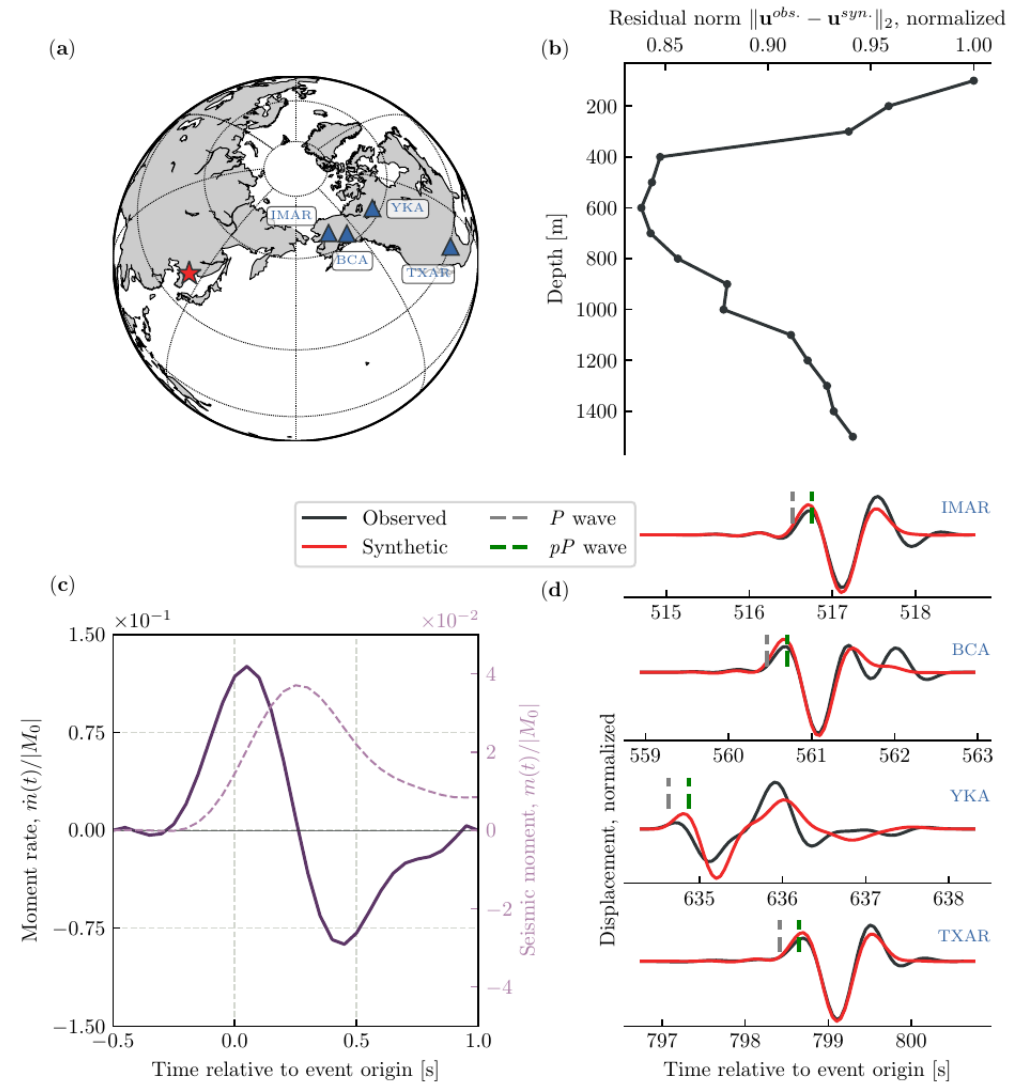
Seismology – Depth phase modeling

- Additional estimation of hypocenter depth using depth phase modeling
- High-frequency depth phases recorded in teleseismic distances
- Generation of waveform-beams at small-aperture arrays to enhance SNR
- Depth estimate of around 400-800 m
- Mw estimate of 5.5 – 5.97



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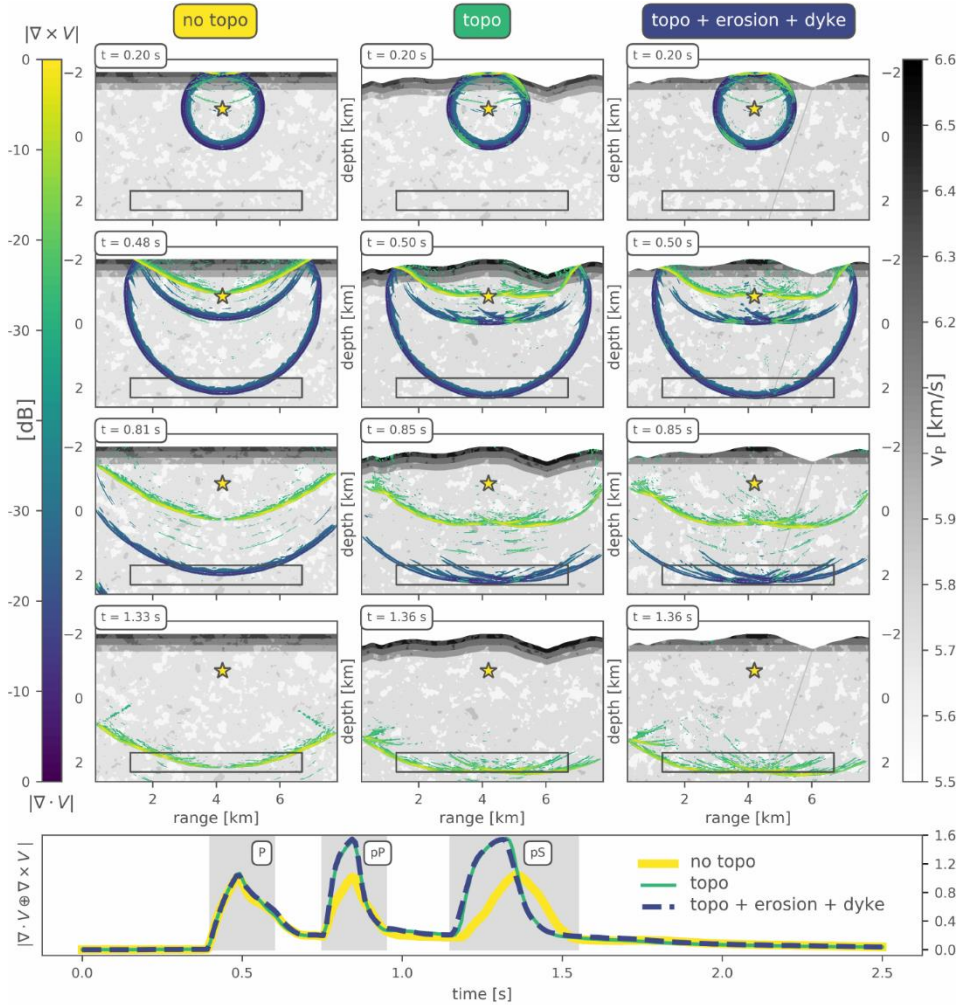
Seismology – Influence of topography

- 2-D synthetic wave-field simulations using Chebyshev pseudo-spectral approach
- Considering an 8 km long East-West profile across Mt. Mantap and taking geology into account
- Topography has a strong impact on the surface reflected wave-field, both for pP- and pS- onsets
- Topography has an impact on infrasound, high yield, and non-isotropic moment tensor



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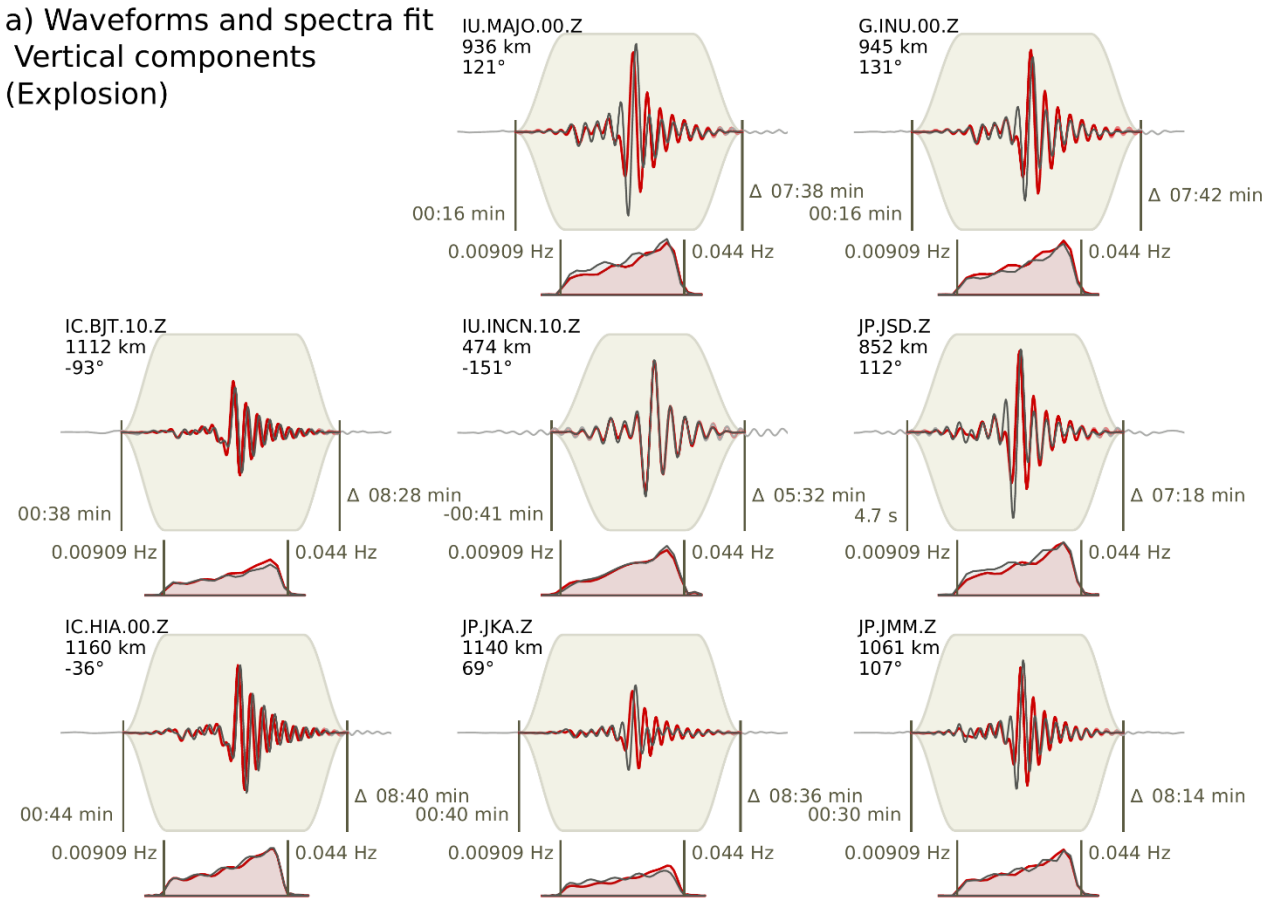
Seismology – Moment tensor inversion of the main event (1)

- Low frequency amplitude spectra (epicentral distances up to 1200 km)
- Full displacement waveforms (epicentral distances up to 600 km)
- Layered halfspace model (Ford et al., 2010)



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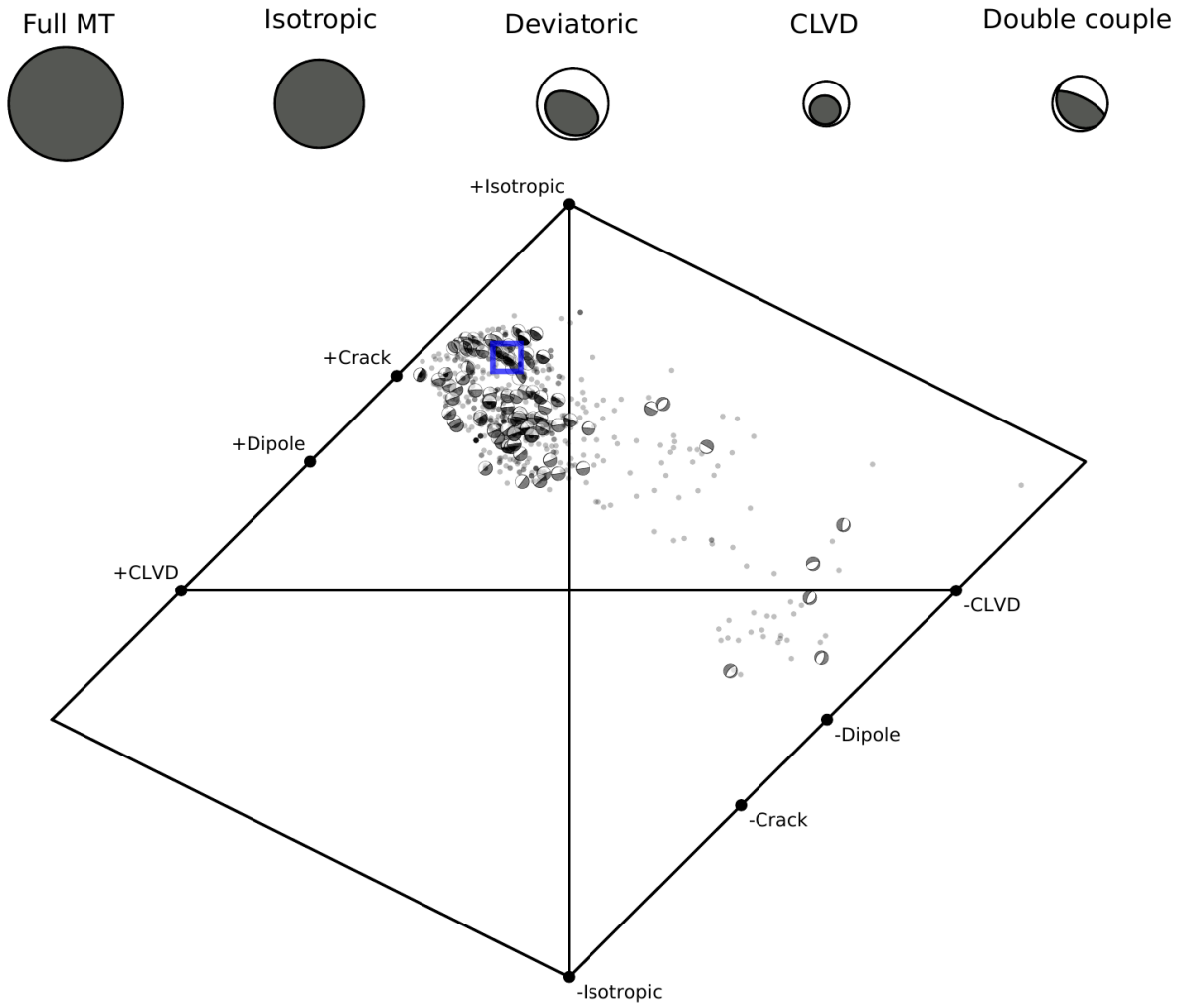
Seismology – Moment tensor inversion of the main event (2)

- Moment Tensor solution
  - ISO: 60% (positive)
  - DC: 24 %
  - CLVD: 16 %
  - Mw: 5.5

➢ Explosive source



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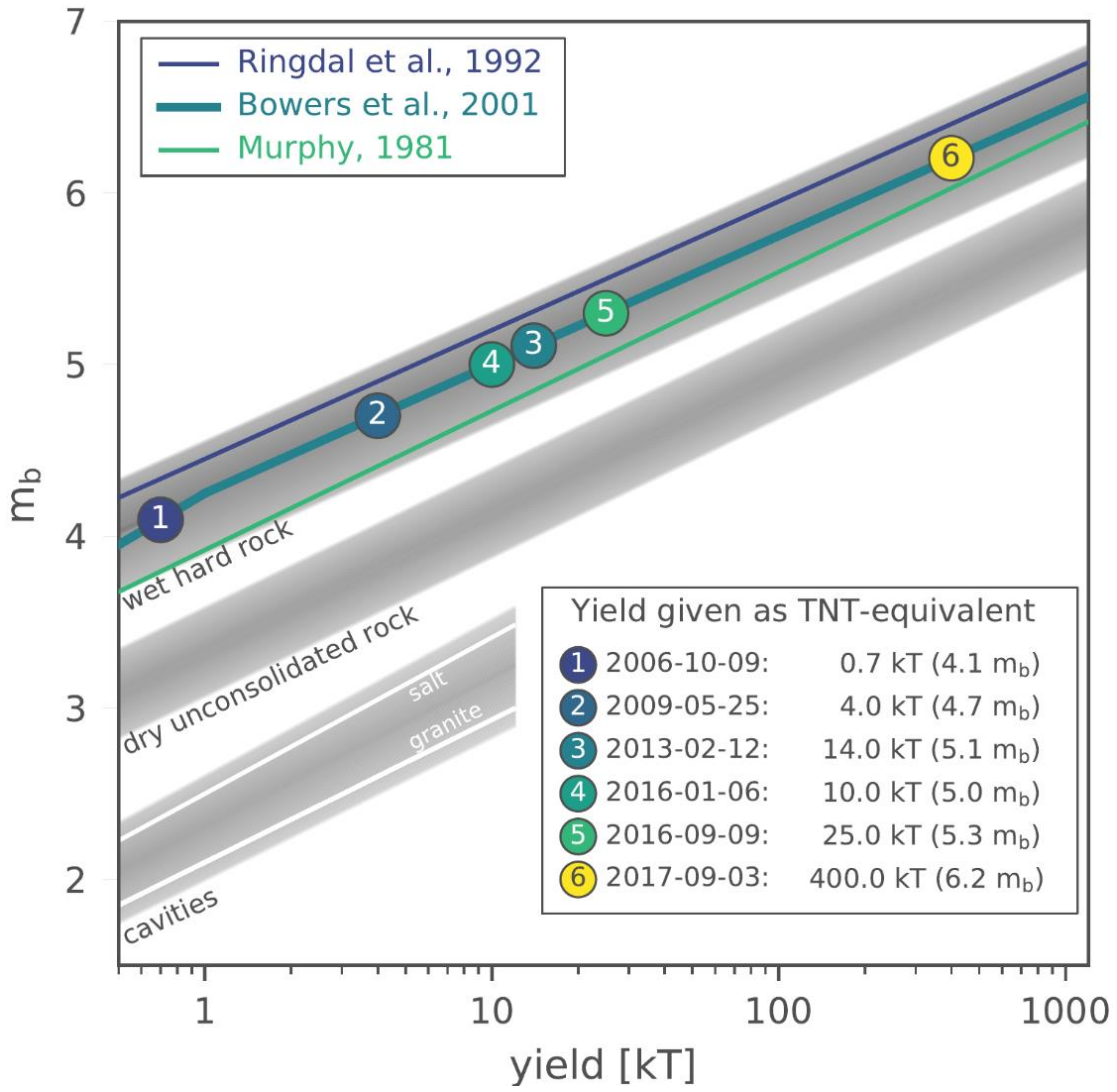
Seismology – Yield estimation

- Estimation of mb using 15 IMS seismic stations
  - ➢ Mb 6.2
- Magnitude-yield relation by Bowers et al. (2001)
- Yield of around 400 kt TNT equivalent



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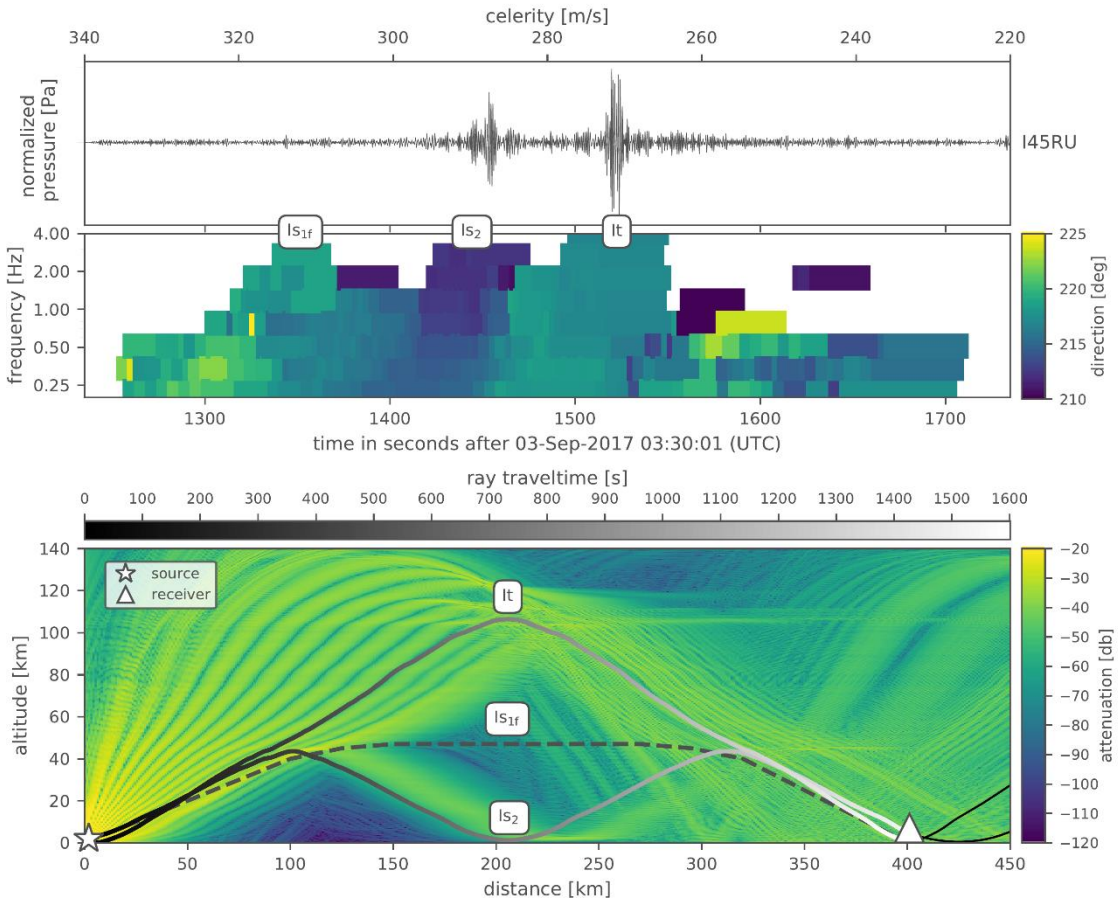
Infrasound observations

- Infrasound observations at the IMS station I45RU in a distance of around 400 km
- Observation of two clear waveform signals after travel times of 1450 and 1520 s (Is2, It)
- Association of preceding waveform activity to an infrasonic forerunner at 1350 s traveltime
- Backazimuth of 210 to 225 degrees



➢ Clear association of the observed signals to the 2017 North Korean event

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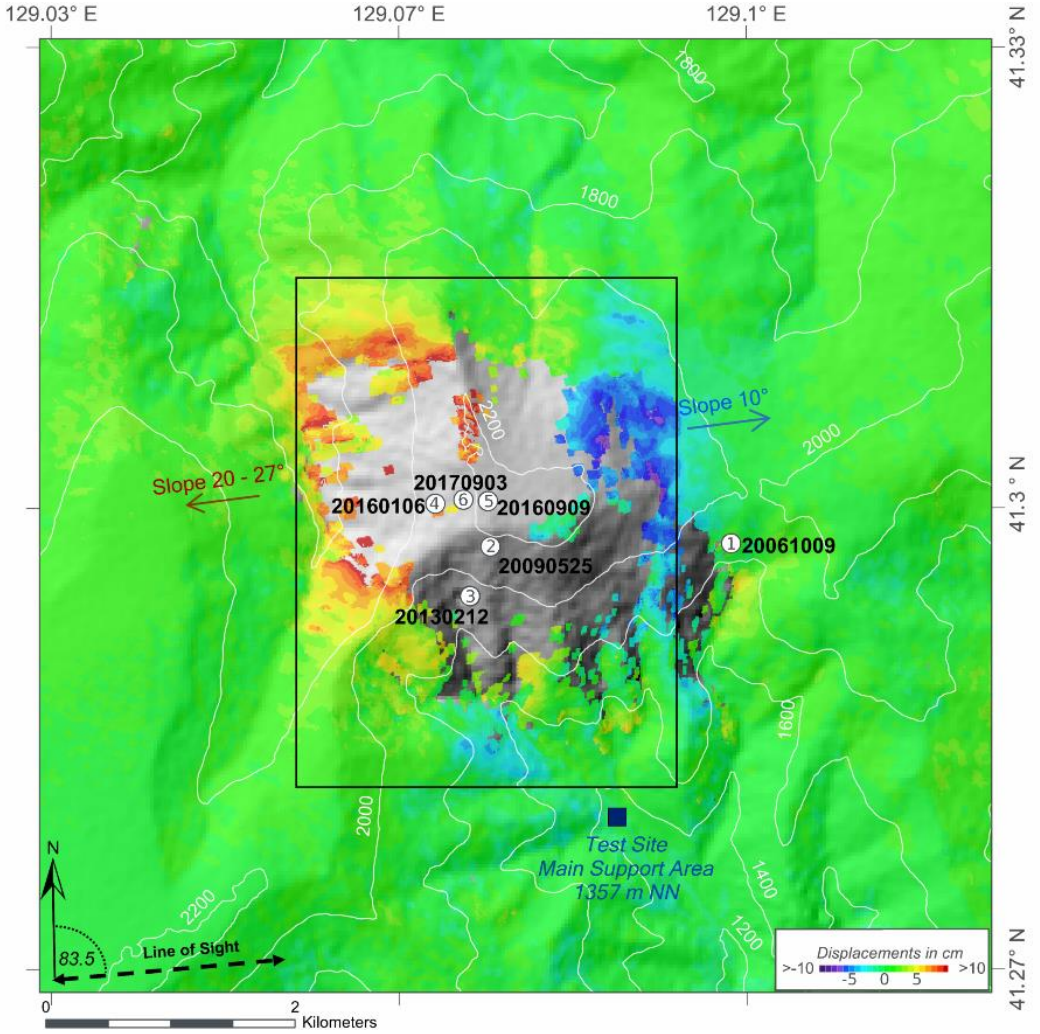
Remote Sensing – DInSAR results

- ALOS-2 satellite data from August 29th and September 12th 2017
- Analysis using DInSAR
- Mean coherence values of 0.6 for the investigated area
- Coherence values of 0.2 to 0.8 for areas with visible surface deformation

➢ Subsidence of up to 10 cm in the eastern part part of the Mt. Mantap massif
➢ Uplift of up to 10 cm in the western part of the Mt. Mantap massif



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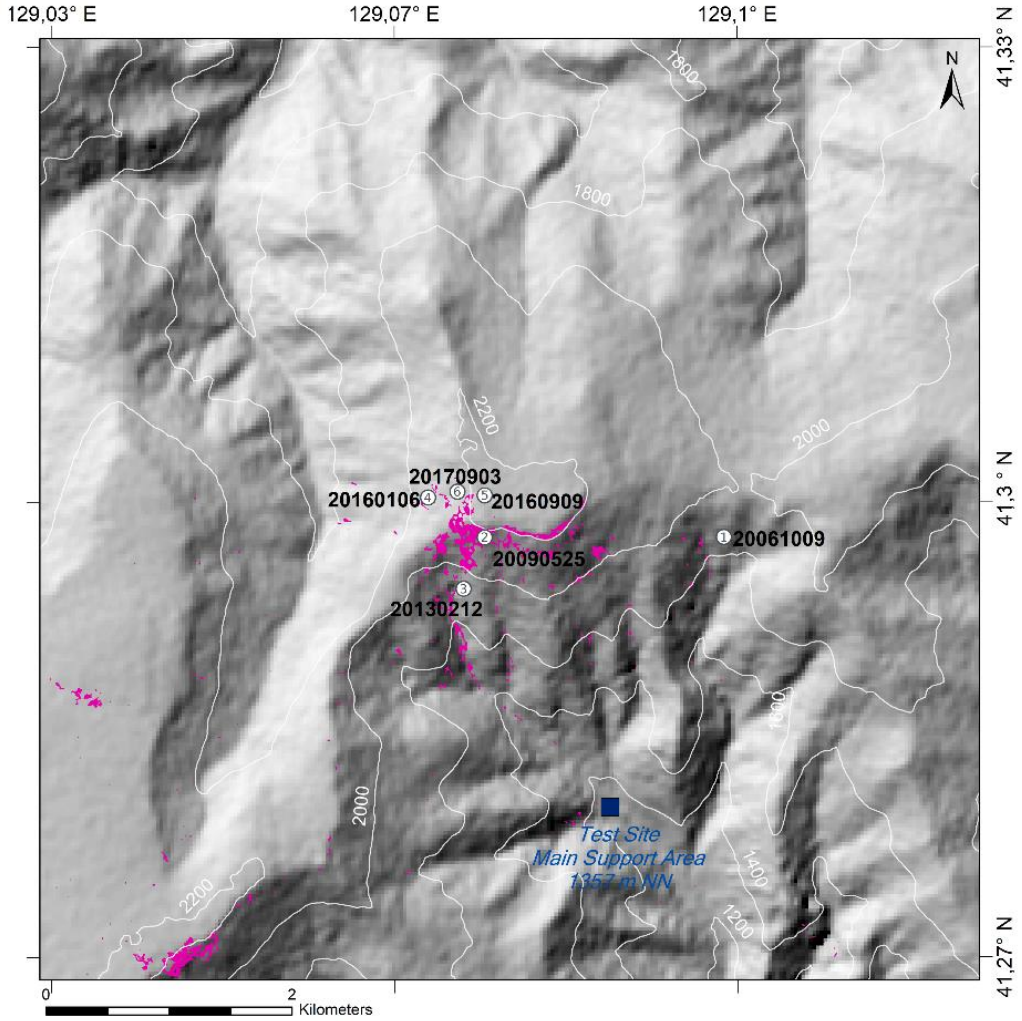
Remote Sensing – Results from Pleiades data

- Multispectral optical data from the Pleiades satellite
- Change detection analysis
- ➢ Numerous landslides activated during the main event and the aftershocks



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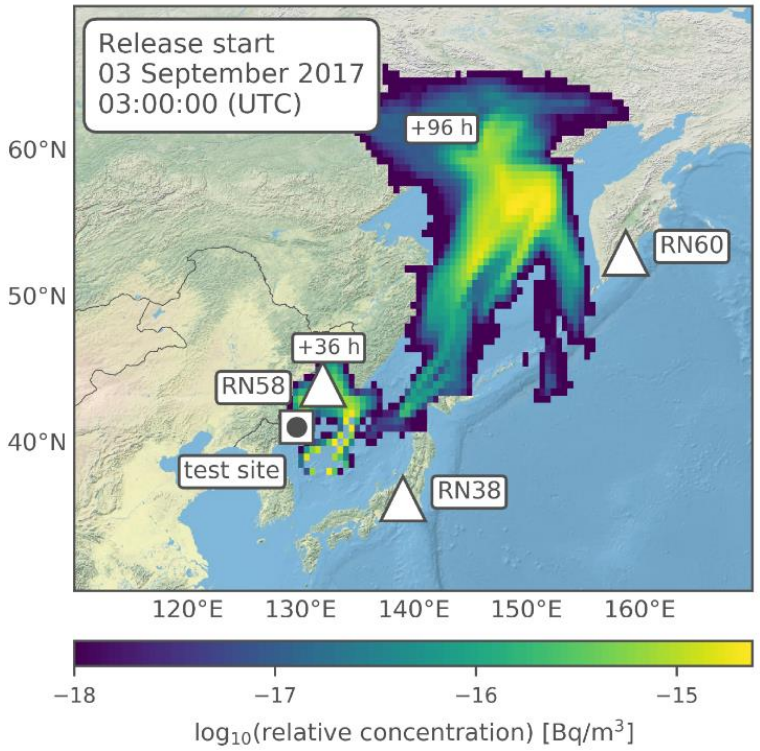
Radionuclides + ATM – September 2017 Detections

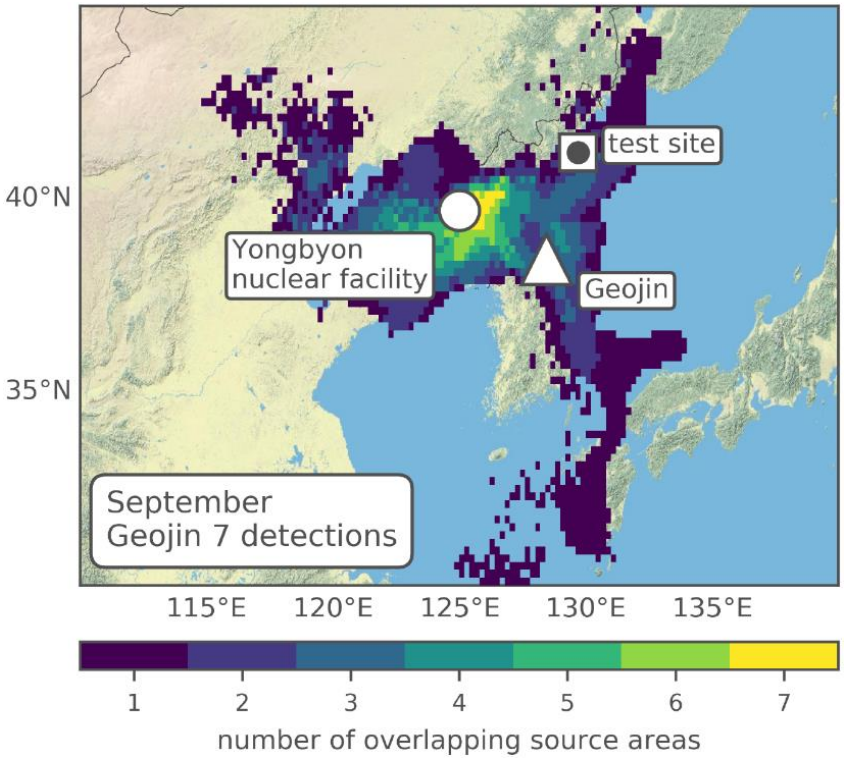
Forward simulations

- Immediate release after the explosion
- RN58 affected (no data available)
- RN38 missed



Backward simulations

- Additive overlay of the source regions of samples with elevated 133Xe
- ➢ Yongbyon area as likely coincident source



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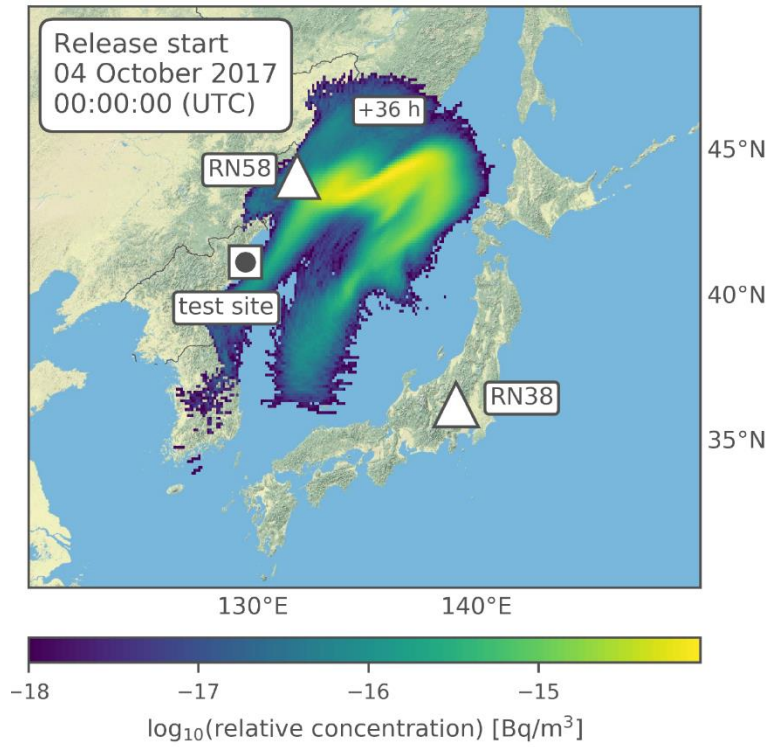
Radionuclides + ATM – October 2017 Detections

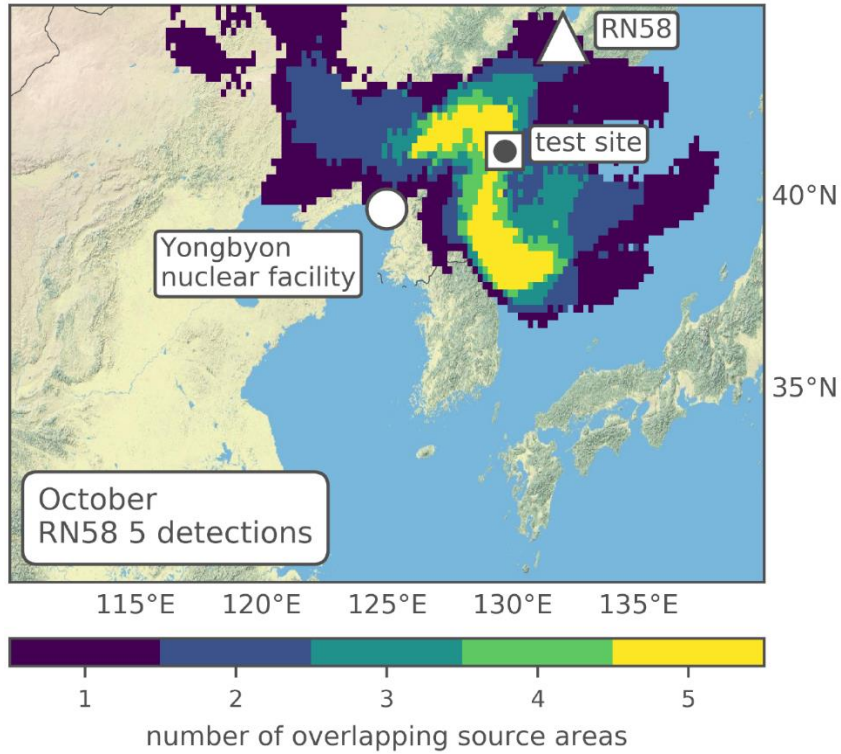
Forward simulations

- Release on October 4th 2017
- RN58 affected (data available)
- RN38 missed



Backward simulations

- Additive overlay of the source regions of samples with elevated 133Xe
- ➢ Test site as possible coincident source



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- Clear explosive character of the September 2017 event is confirmed by MTI analysis.
- The yield of the event is estimated to be around 400 kt TNT equivalent, which is must be considered as an upper limit value.
- Strong surface and tectonic activity was observable in the form of surface deformation, tectonic aftershocks and landslides in the aftermath of the test.
- Infrasound signals measured at the station I45RU can clearly be related to the 2017 event.
- No immediate measurements of radionuclides related to the test in September were observable, but there are indications for a delayed leakage of radionuclides from the test site in October.
- The estimated explosive yield is still compatible with a fission only device.

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SnT Contributions related to the 2017 test

- Gaebler et al.
  Seismological Investigations of the 2017 North Korean Nuclear Test
  Poster presentation T2.1-P24
- Pilger and Koch
  Analysis and modeling of the infrasound signals from the 2017 DPRK nuclear explosion at IMS station IS45
  Poster presentation T2.3-P3
- Ross, Gaebler and Ceranna
  Atmospheric Transport Modelling for dispersion conditions after the DPRK 2017 nuclear test and the origin of regional xenon detections
  Poster presentation T2.4-P13
- Frei and Grünberg
  Space Borne Optical and Radar Data to characterize North Korean Nuclear Test 2017
  Poster presentation T2.1-P27

- Comprehensive analysis in Gaebler et al. (2019):
  A multi-technology analysis of the 2017 North Korean nuclear test
  EGU Solid Earth, 10, 59-78, 10.5194/se-10-59-2019