HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

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GEOMAR

Marine Geohazards (non-seismic)

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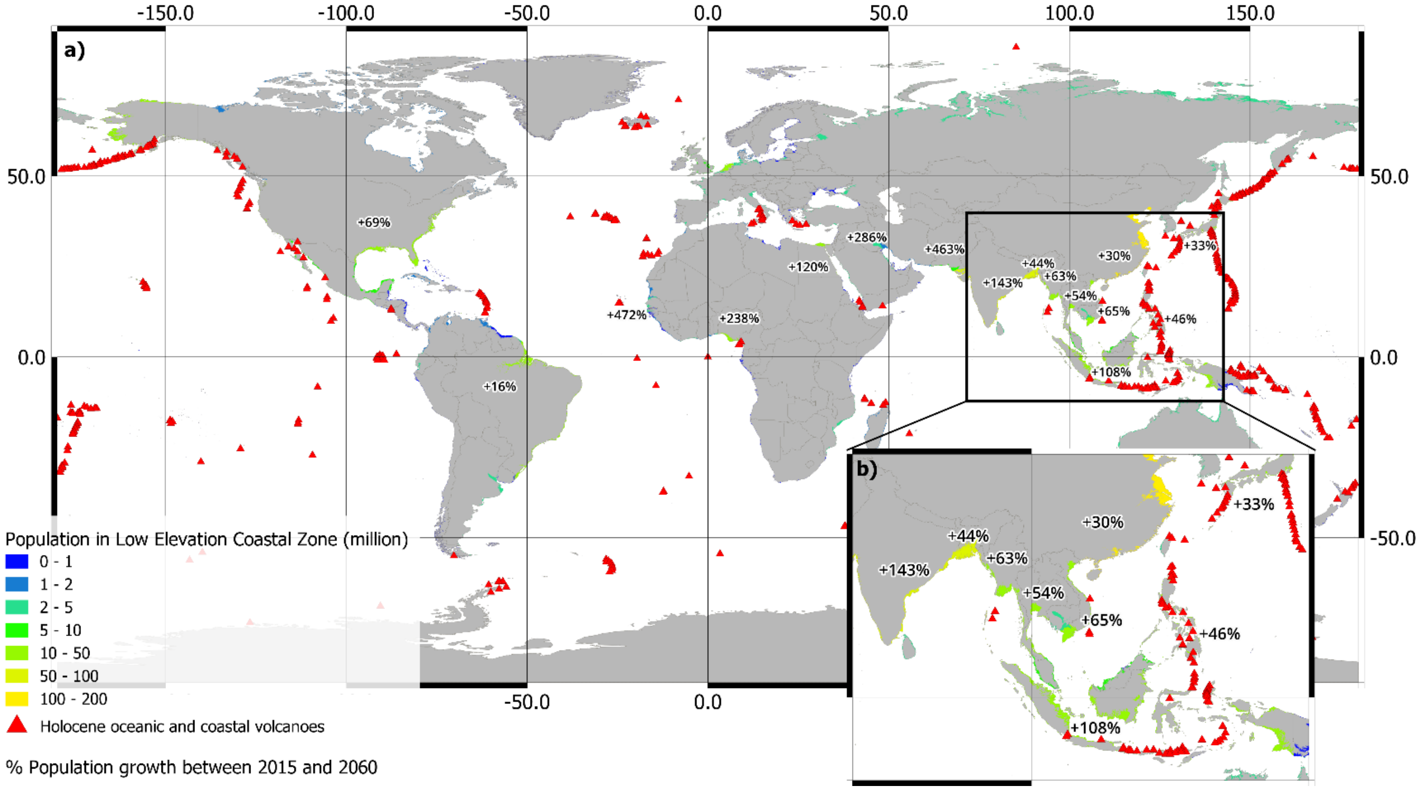
Workshop on the future of Scientific Ocean Drilling with MSP and Chikyu

ECORD
EUROPEAN CONSORTIUM FOR OCEAN RESEARCH DRILLING

At risk: Coastal societies



At risk: Seafloor infrastructure

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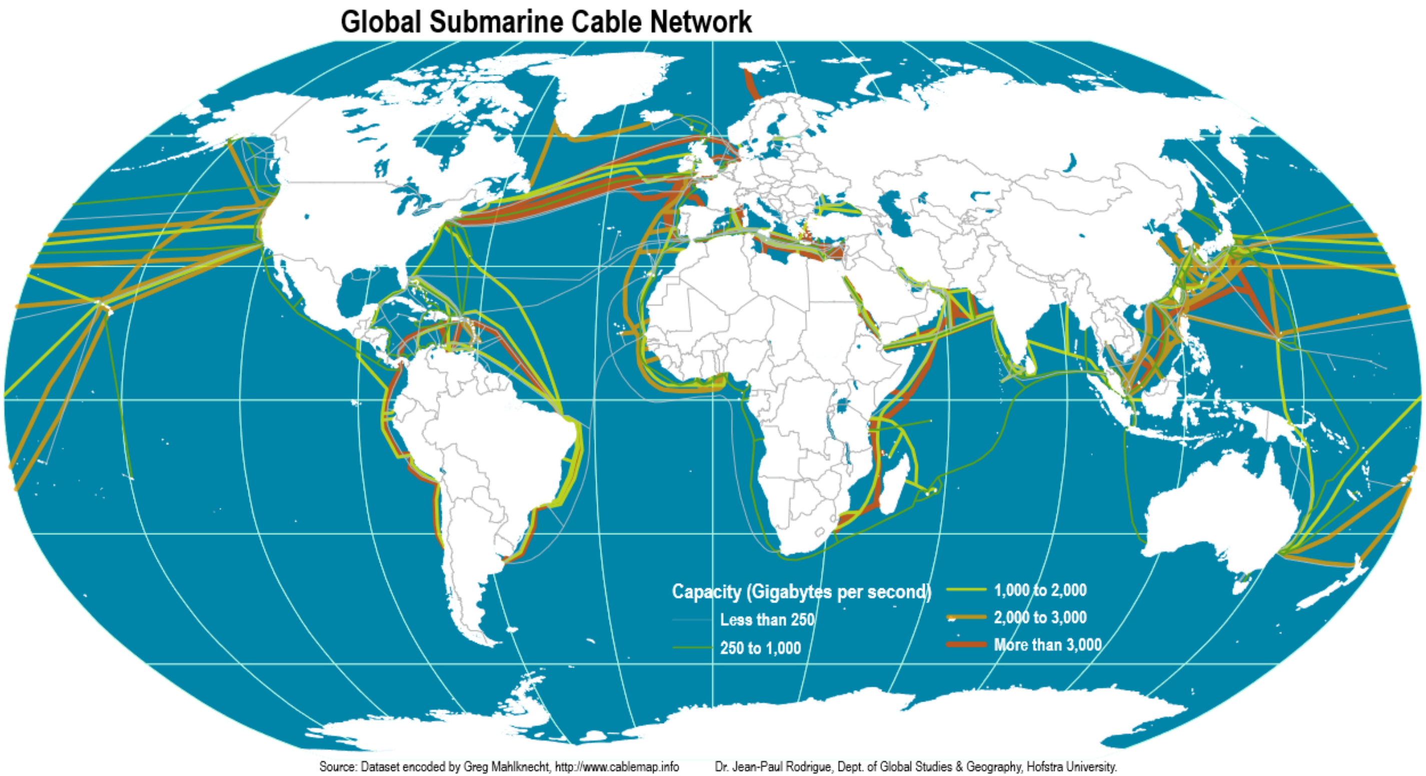

Warning, forecasting, mitigation?

Non-seismic marine geohazards are not included in warning systems

Anak Krakatau collapse, and tsunami (December 2018)

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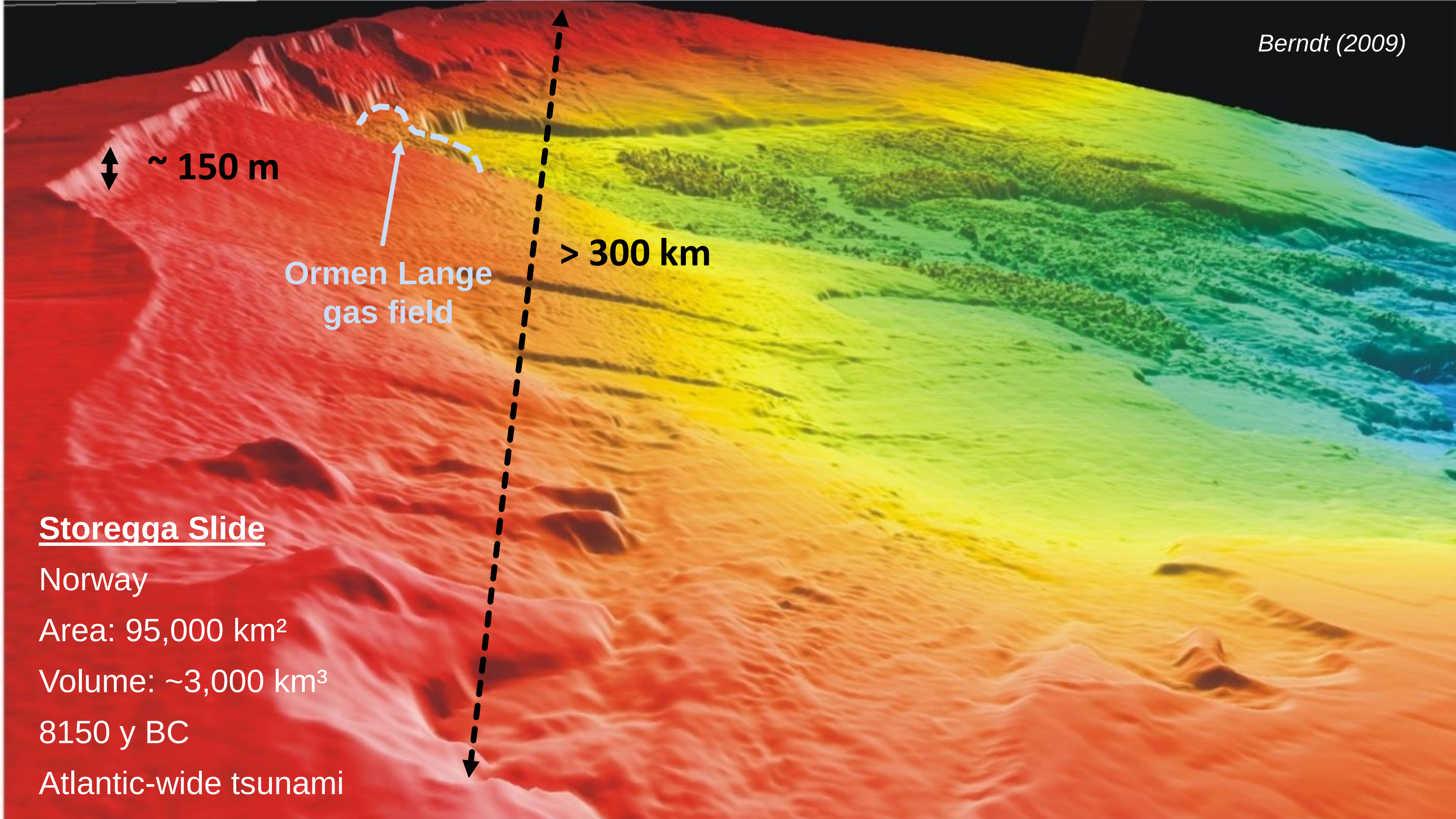
Non-seismic marine geohazards are not included in warning systems

Anak Krakatau collapse, and tsunami (December 2018)

- Remote detection difficult
- Seismic signature not well understood and networks not configured appropriately
- Highly site-specific (local topography, lithology, stress conditions, fluid systems, …)
- Comprehensive system understanding lacking

  - ➢ Science needed to understand processes, triggers and precursors
  - ➢ Warning systems need to be adapted to individual sites

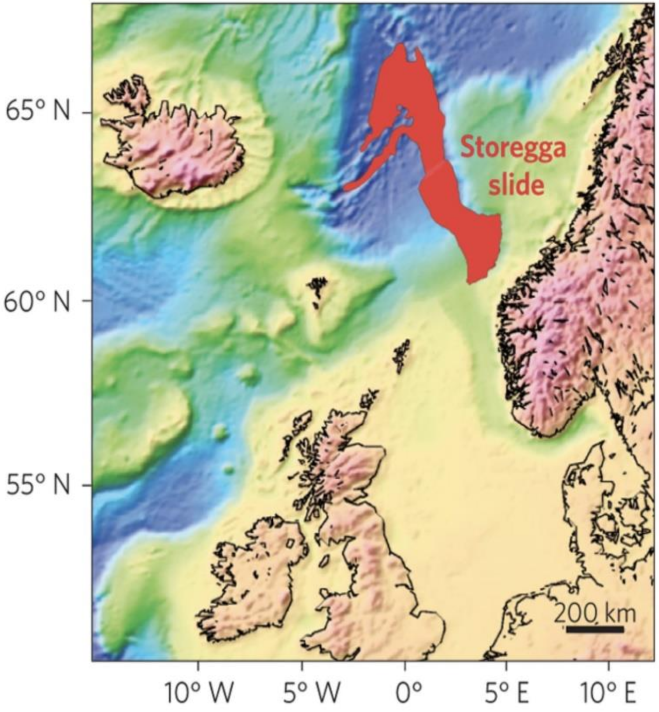

Berndt (2009)
~ 150 m
Ormen Lange
gas field
> 300 km
Storegga Slide
Norway
Area: 95,000 km²
Volume: ~3,000 km³
8150 y BC
Atlantic-wide tsunami

Storegga Slide (Norway)

The Ormen Lange Project (2000-2004)

- Aim: safe development of hydrocarbon field
- Extensive data set (bathymetry, seismics, wells, borings, pore pressure monitoring, geotechnics)
- Ongoing seabed monitoring (industry only)
- Best explanation: weak layer (marine clays) deposited during interglacial periods + excess pore pressures from rapid sedimentation during glacial periods
- Huge scientific impact!

Bondevik et al. (2005)

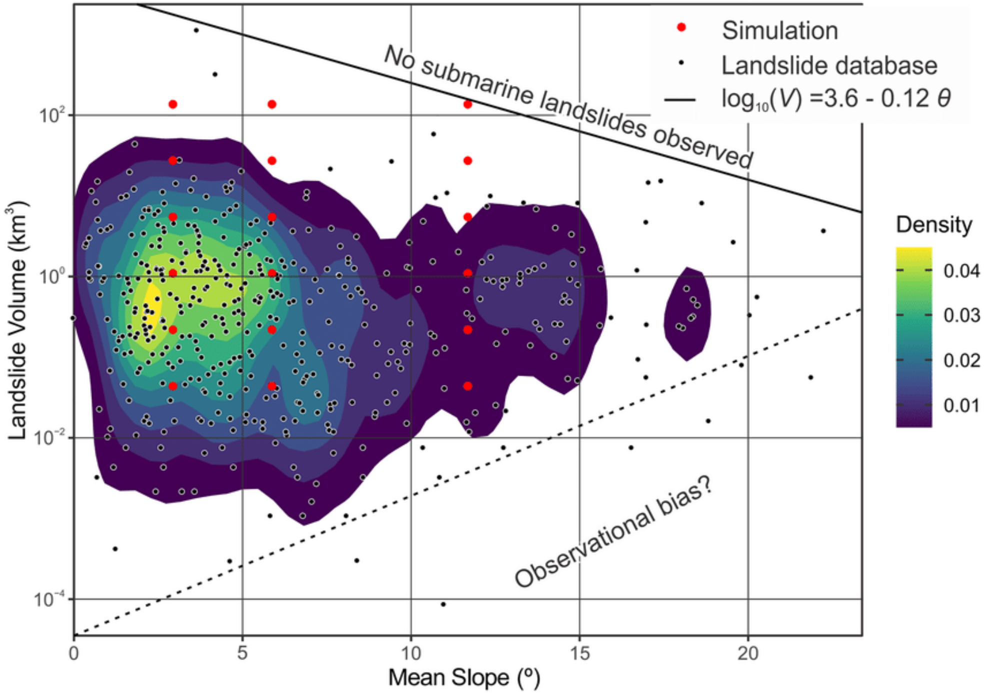


The 'weak layer' issue

- Largest landslides on low slope angles
- Drastically reduced shear strength

➢ Failure of distinct **'weak layers'** within sequences of otherwise stable sediments

Zengaffinen et al., 2022



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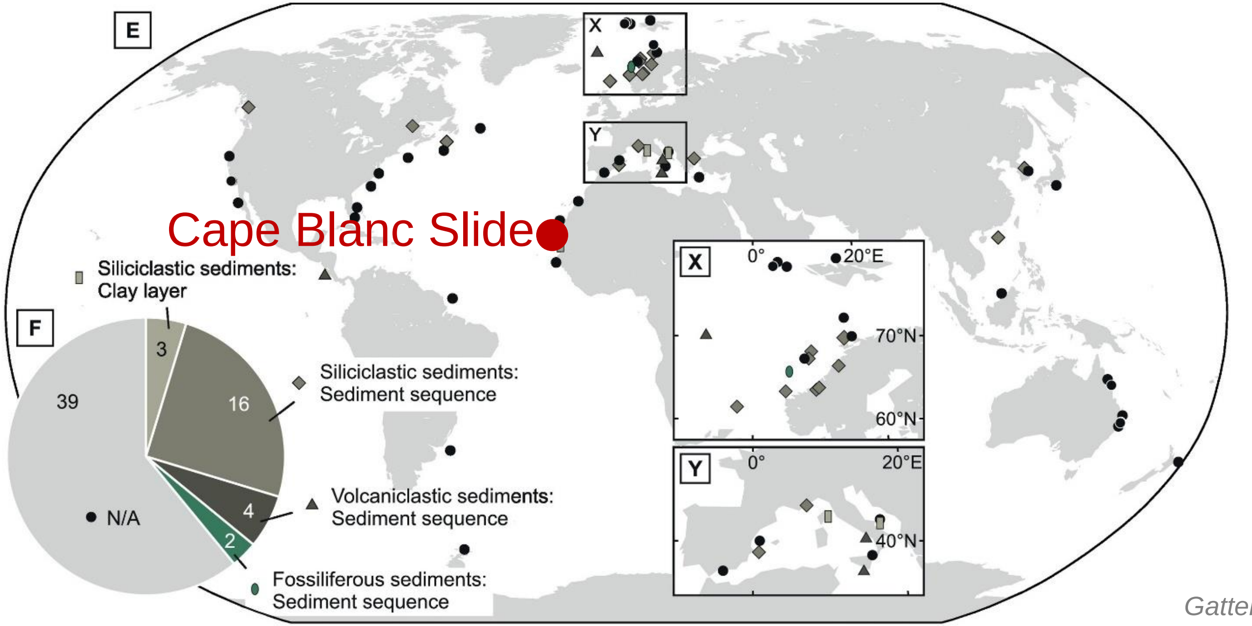
Occurrence of submarine landslides and lithologies associated with weak layers

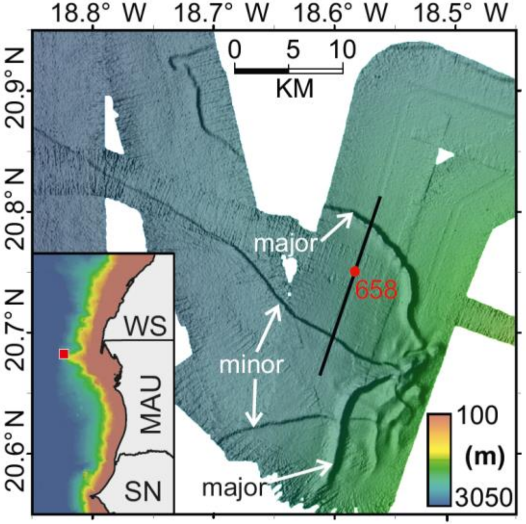


Gatter et al., 2021

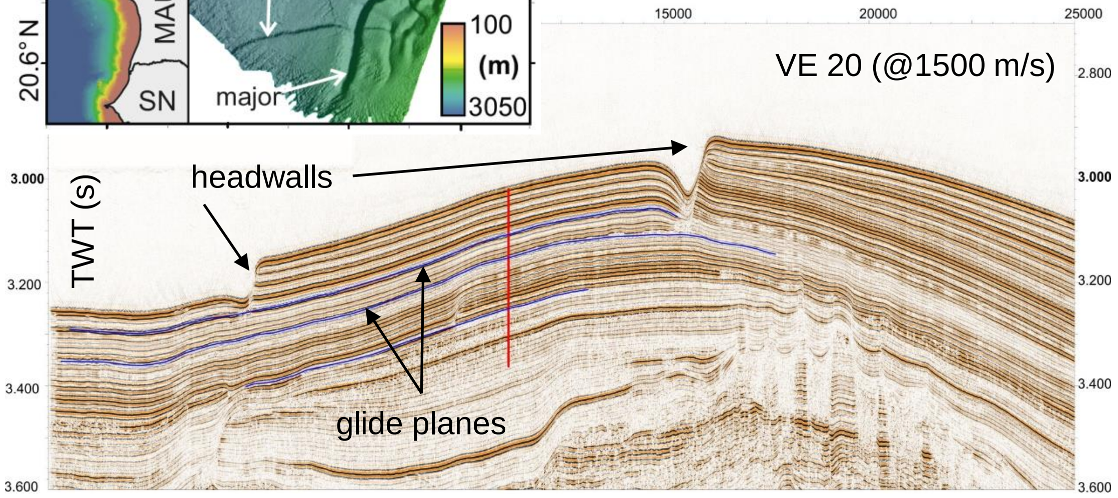
Submarine Landslides

The ‘weak layer’ issue

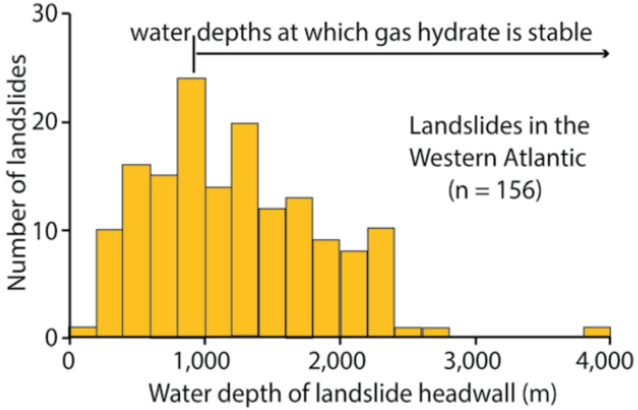
- Usually gone with the landslide
- Both intact and failed sequence needed
- Intact sequence not recovered with gravity coring



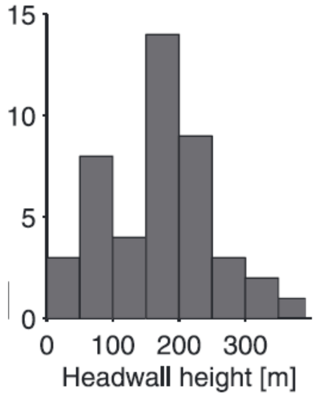
Cap Blanc Slide, NW Africa
Urlaub et al., 2018



Tackling the 'weak layer' issue with scientific ocean drilling



Talling et al. (2014)



Urlaub et al. (2015)

- Water depths <2500 m
- Glide plane depth <500 m
- Min 2 sites
- Undisturbed samples for geotechnical tests

➢ Achievable with scientific ocean drilling

➢ Enabling the identification of hazardous areas

The tip of the iceberg

- Catastrophic events:
  Hunga Tonga 2022, Anak Krakatau 2018, Stromboli 2002, Ritter Island 1888, Krakatau 1883, Unzen 1792, …
- Observatories in place (instrumentation on land only
- Typically >90% of volume submerged

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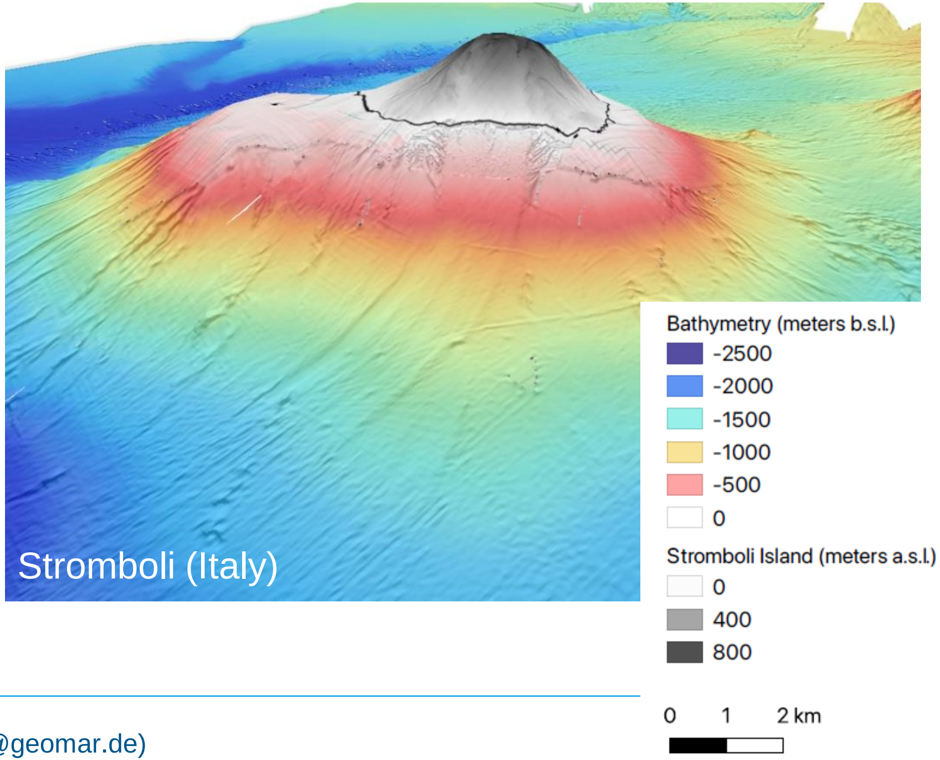
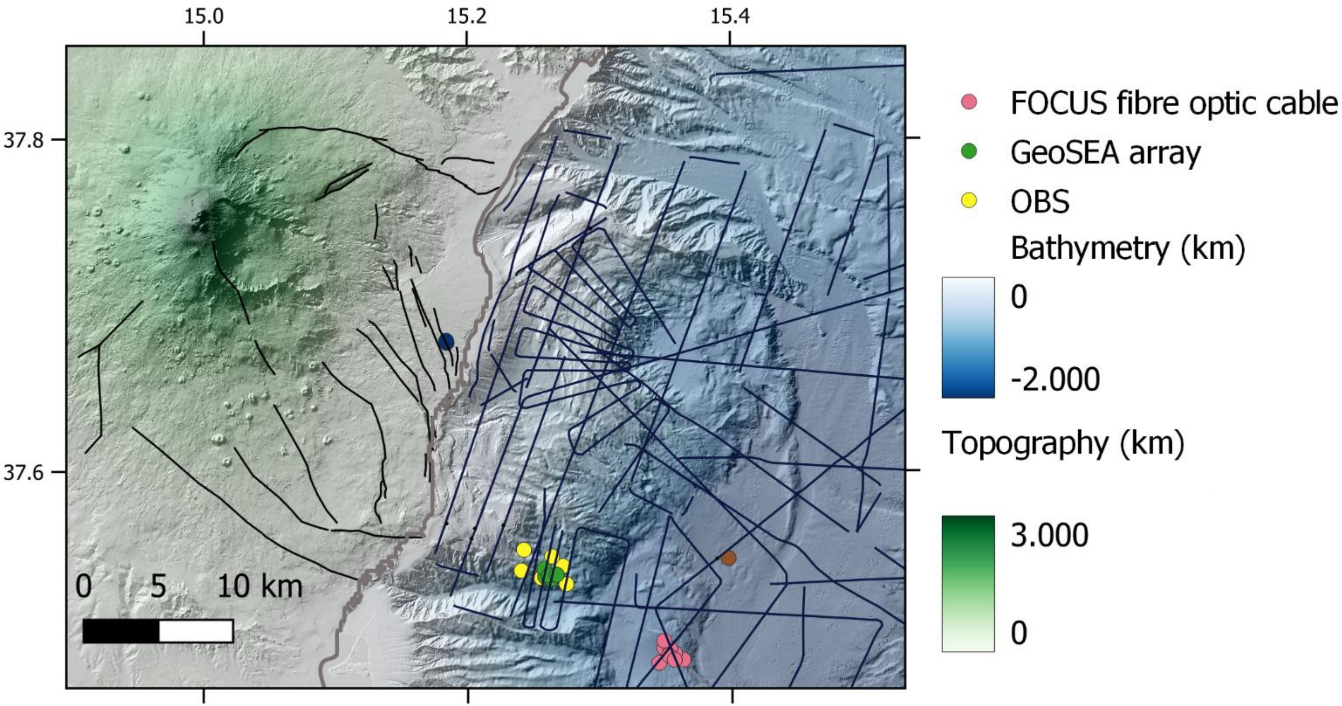
➢ System understanding and modelling requires information on entire edifice



Mount Etna flank instability

- SE flank moves seawards with ~3 cm/yr
- Bound by fault systems
- Ground deformation from InSAR, GNSS, seafloor geodesy

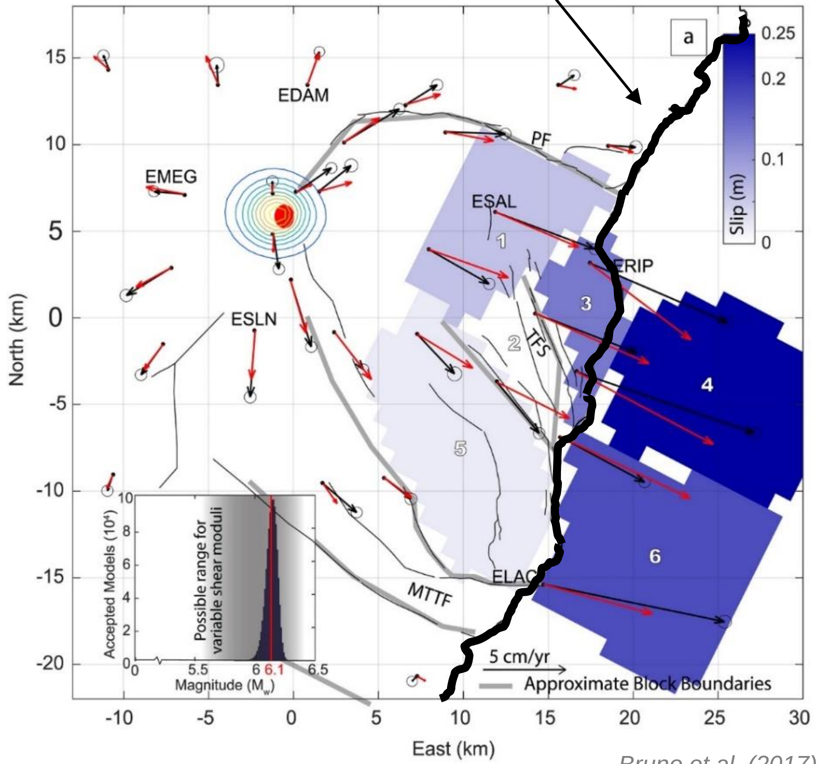


Mount Etna flank instability

- Kinematic models predict largest slip offshore
- Slip pattern governed by basement morphology (pre-Etnean clays)

➢ Offshore ground deformation & basement morphology (*detachment*) are crucial for kinematic models!

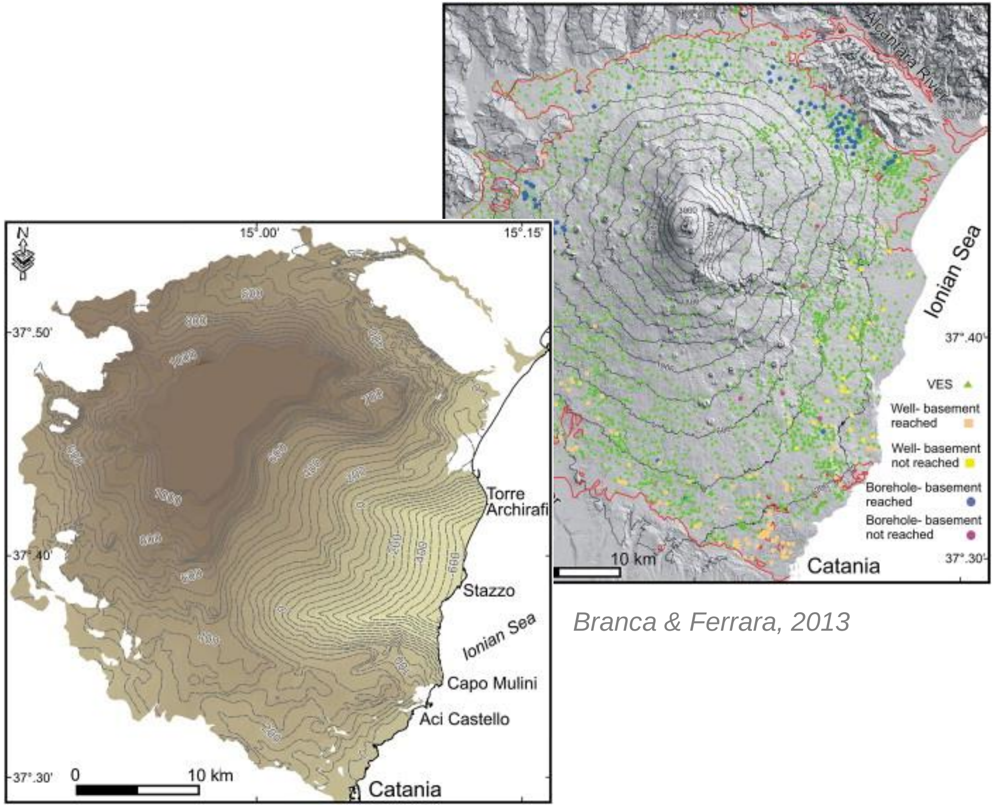
Inflation period & SSE
05/2015 – 09/2016



Bruno et al. (2017)

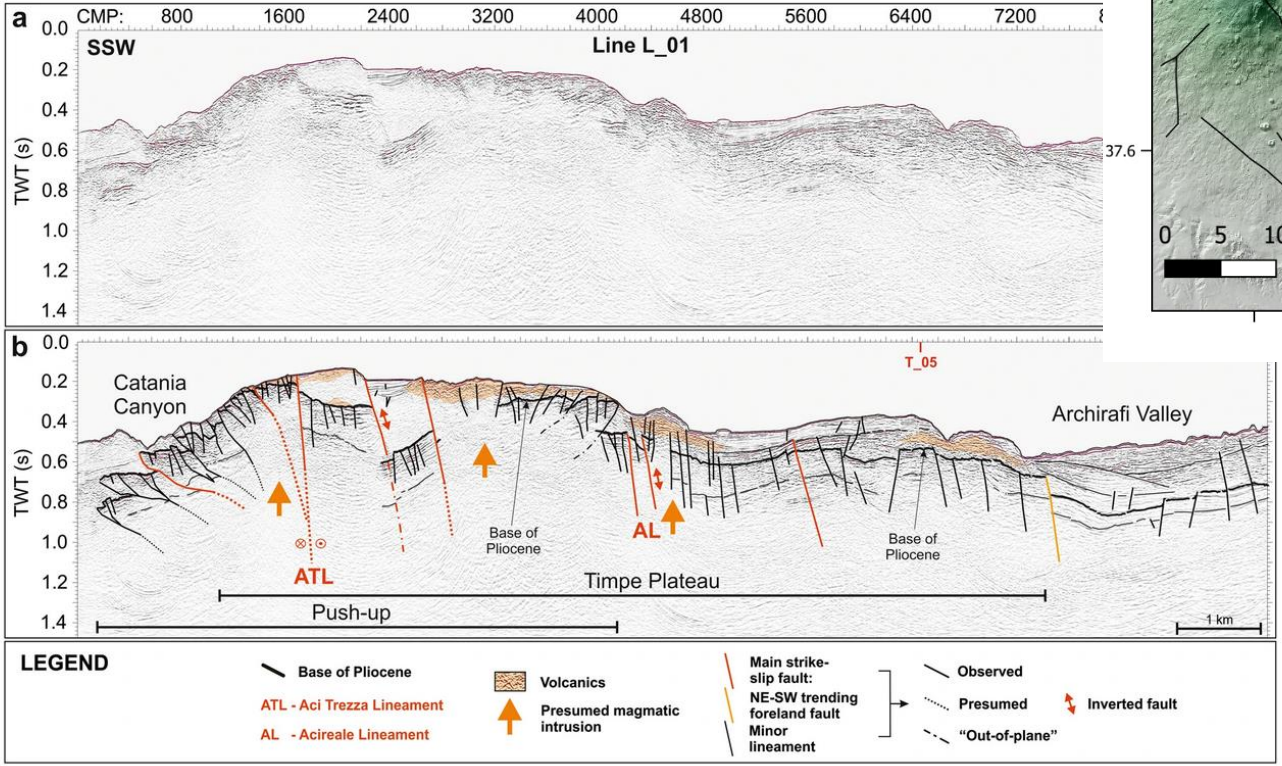
Mount Etna detachment

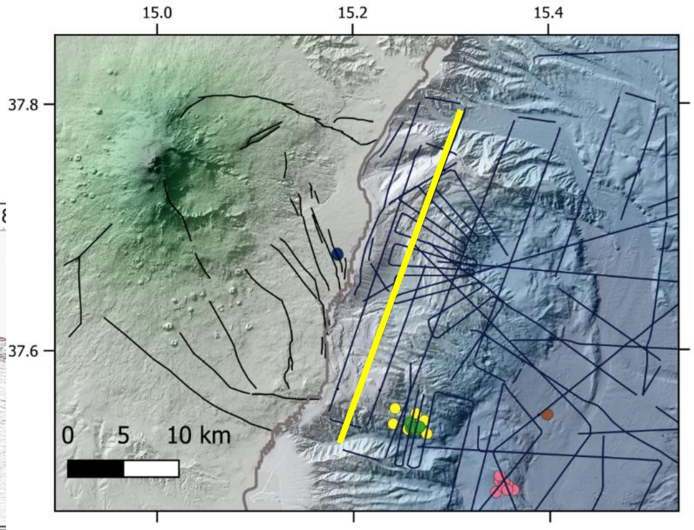
- Onshore: detachment depth and morphology well known from geoelectrics and boreholes
- Offshore: geophysical imaging proves difficult
- Outcrop at the seafloor unknown



Branca & Ferrara, 2013

Mount Etna detachment

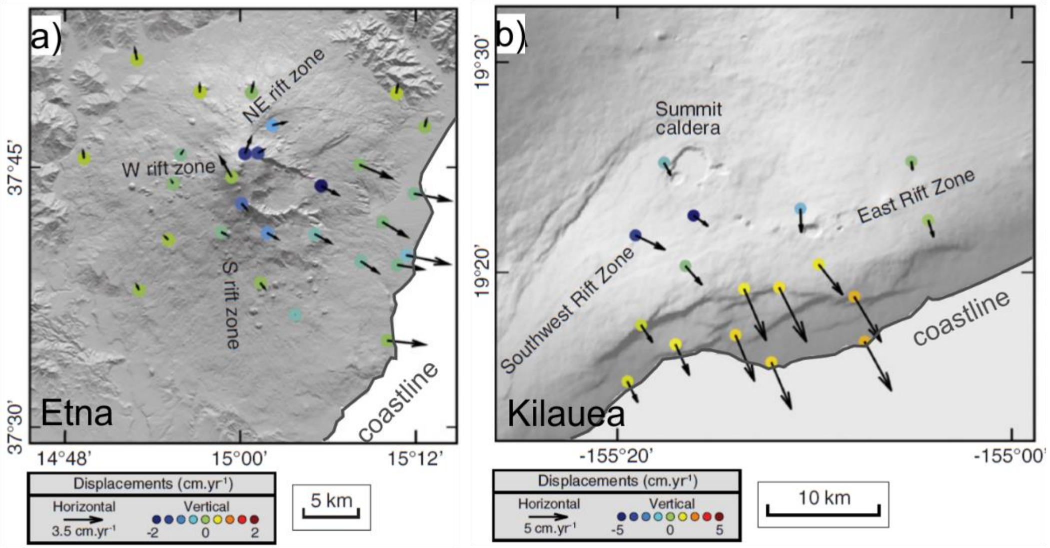




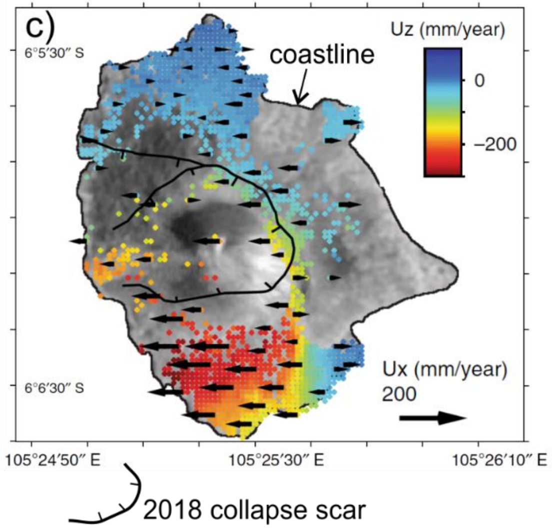
Carlino et al. (2019)

Flank instability at island volcanoes

Modified after Poland et al. (2017)



Walter et al. (2019)



- Slip rates highest at coasts
- Kinematic models predict largest slip offshore
- Volcanotectonics and dynamics unconstrained

➢ Water depths 0-4000 m
➢ Detachment depth < 1000 m
➢ 5-10 sites
➢ In-situ monitoring

Summary

- Improportional population increase in LECZ
- Future use of seafloor will be intense (infrastructure)

- Improve understanding of what landslides are moving on (weak layer / detachment) to identify hazardous areas and model ground deformation

- Few cores in many different locations
- High quality samples for geotechnical testing needed
- Boreholes for monitoring in hazardous areas

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