EGU General Assembly 2021
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The Sensitivity of Tsunami run-up to Earthquake Source Parameters and Manning Friction Coefficient in High-Resolution Inundation Simulations

Steven J. Gibbons, Stefano Lorito, Marc de la Asunción, Manuela Volpe, Jacopo Selva, Jorge Macías, Carlos Sánchez-Linares, Malte Vöge, Roberto Tonini, Piero Lanucara, Sylfest Glimsdal, Jan Christian Meyer, Fabrizio Romano, and Finn Løvholt

In session NH5.1 -Tsunamis :
from source processes to coastal hazard and warning
Tue, 27 Apr, 09:00–12:30 (CEST) overview 11:28–11:30
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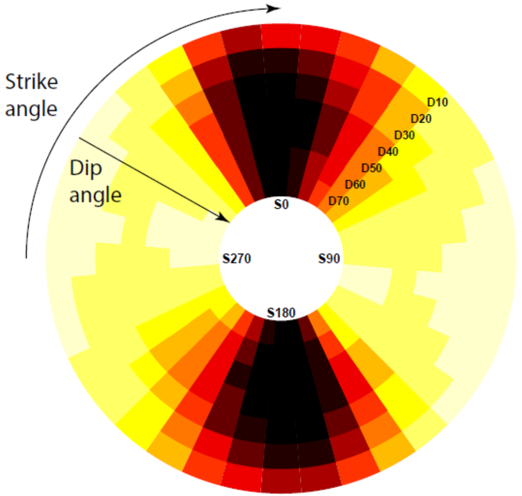
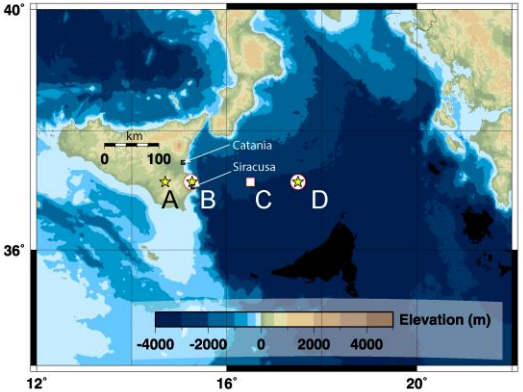
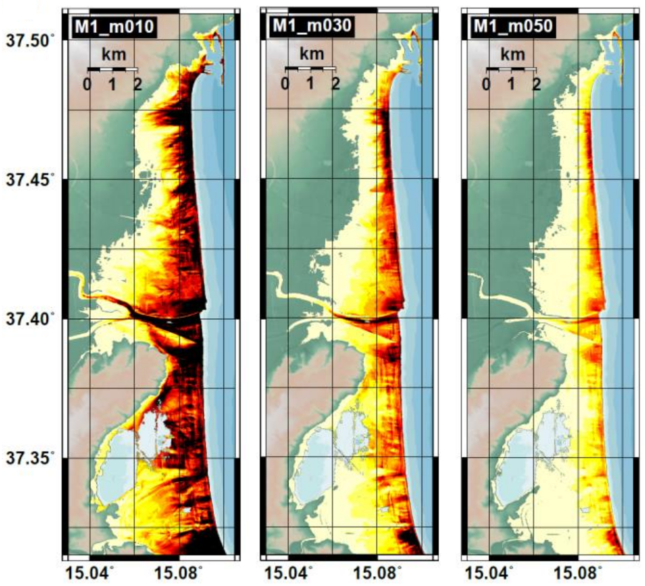
Tsunami-HySEA



Rake angle = 90 degrees

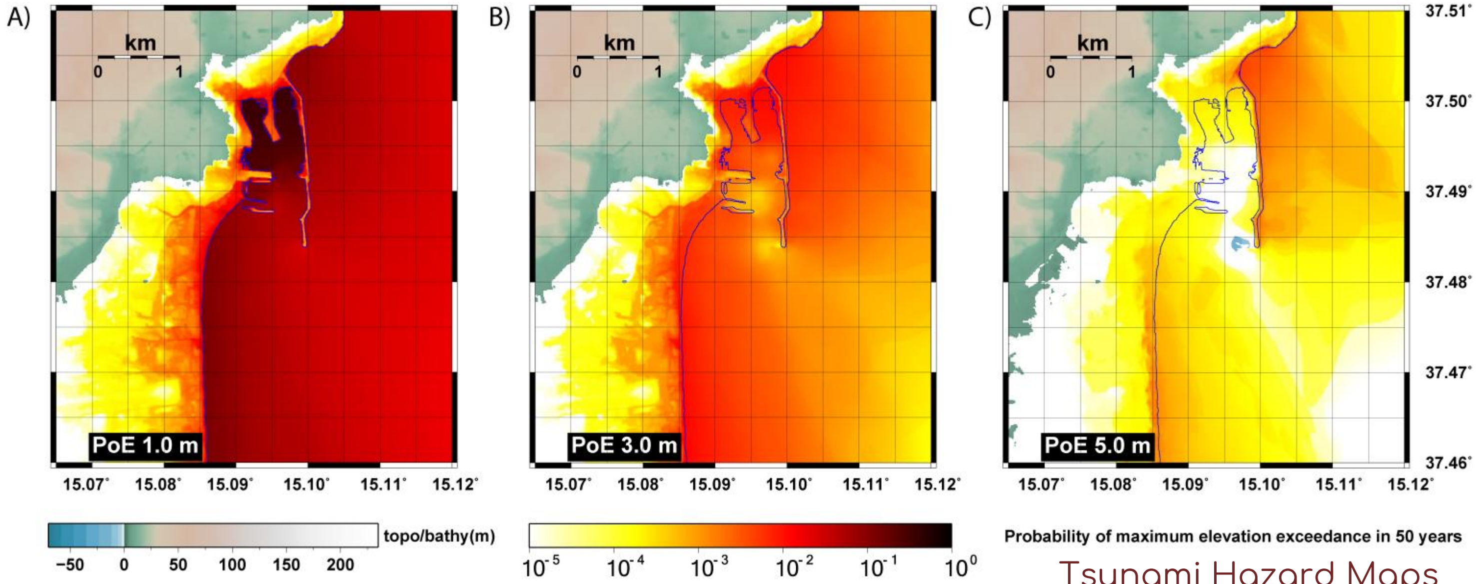
- GPU-optimized code and pre-exascale supercomputers allow us to perform thousands of high-resolution numerical tsunami simulations simultaneously
- In Probabilistic Tsunami Hazard Analysis for a given site, we need to simulate tens of thousands of earthquake scenarios
- How many scenarios is enough?
- We need to test the sensitivity of inundation to small changes in how earthquakes are specified (e.g. mag., location, strike, dip, rake, depth)
- Also need to test sensitivity to parameters of the numerical simulation (e.g. friction specification)
- Co-seismic deformation significant for near-field earthquakes. Many more local scenarios are needed.





Maximum Momentum Flux for different values of the Manning friction

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …



Tsunami Hazard Maps

Probabilistic Tsunami Hazard Analysis

PTHA estimates the probability of exceeding a given tsunami inundation metric at a given location in a given time interval.

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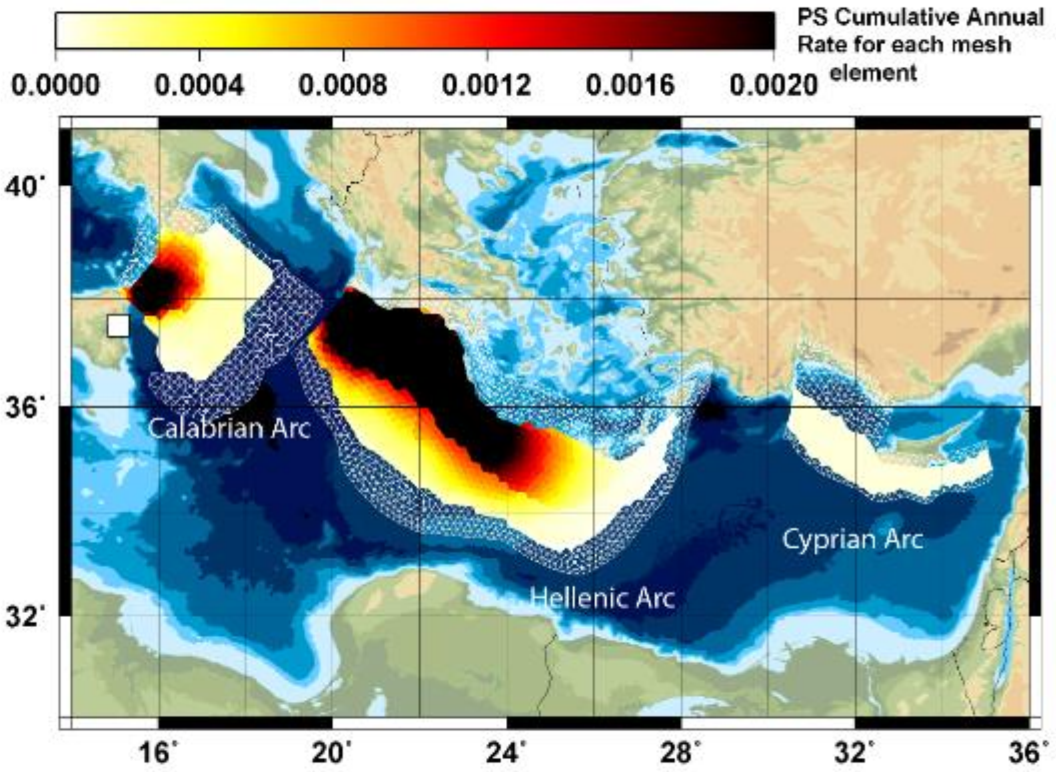
Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

In PTHA, in principle, we need to consider EVERY possible source of tsunami!

In practice, this can't be done – we need to discretize possible sources and perform **hazard disaggregation** (find which sources matter most).

We consider Predominant Seismicity (well understood subduction earthquakes)

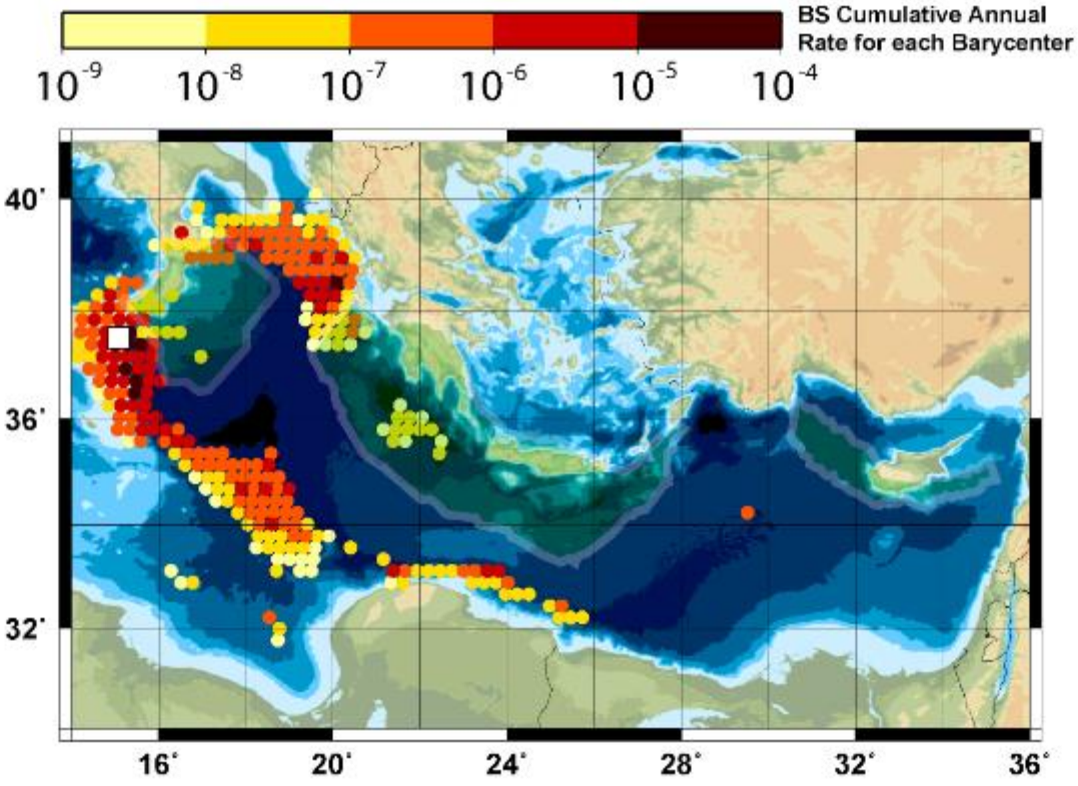


Sensitivity of Tsunami Run-up to Earthquake Source Parameters ...

We consider also **Background Seismicity** (crustal earthquakes in poorly understood tectonic settings)

How densely do we need to discretize the source space?

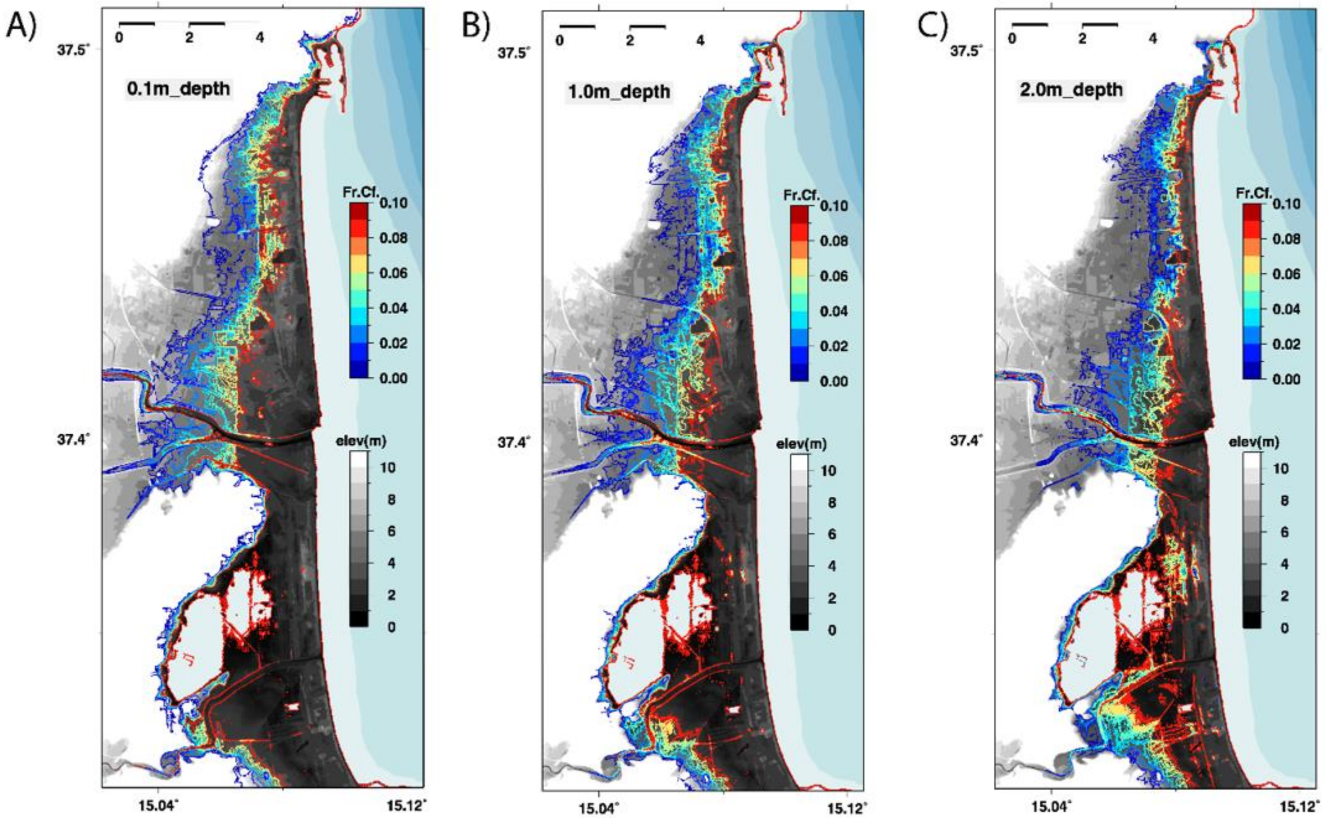
How sensitive is the tsunami inundation to changes in the specification of earthquake parameters?



Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

Sensitivity Studies also allow us to see how the severity of tsunami inundation changes with details of the numerical model.

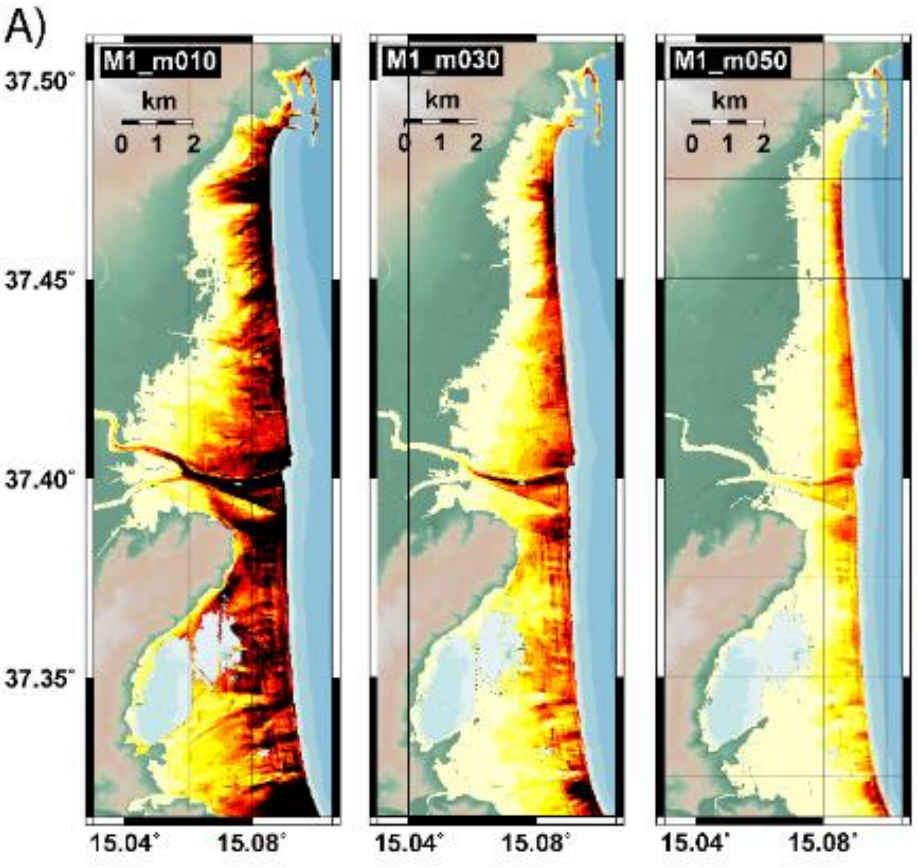
Here, different values of the friction lead to different extents of inundation.



Sensitivity of Tsunami Run-up to Earthquake Source Parameters ...

Maybe the momentum flux is a more important metric of tsunami inundation?

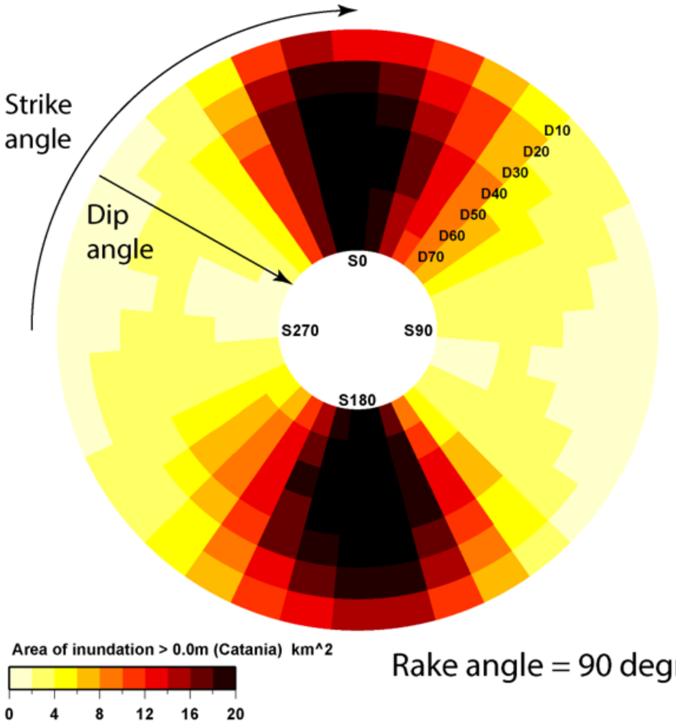
Plotting the maximum momentum flux as a function of location shows that friction reduces momentum flux more than inundation area.



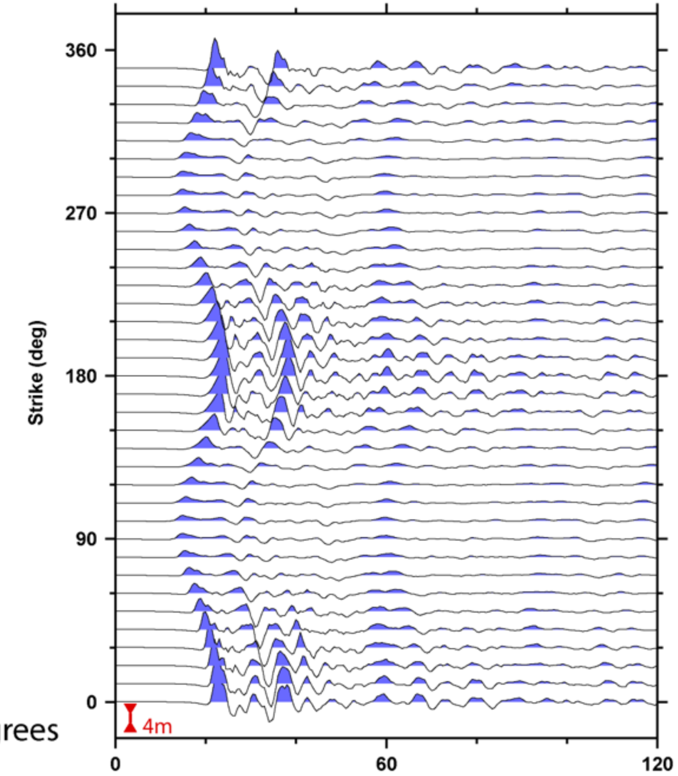
Sensitivity of Tsunami Run-up to Earthquake Source Parameters ...

Sensitivity Studies allow us to see how the severity of tsunami inundation changes with the earthquake parameters.

This guides our choice of earthquake scenarios for PTF and UrgentHPC.



Rake angle = 90 degrees



Offshore Earthquakes

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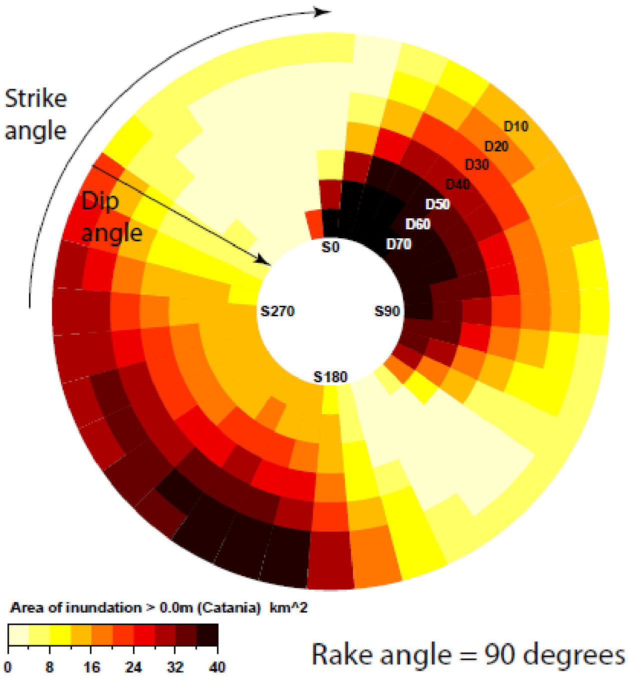
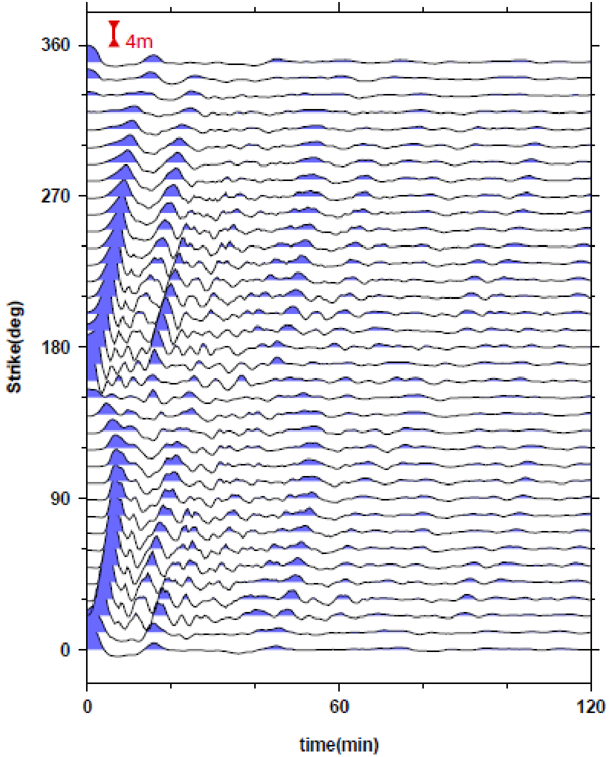


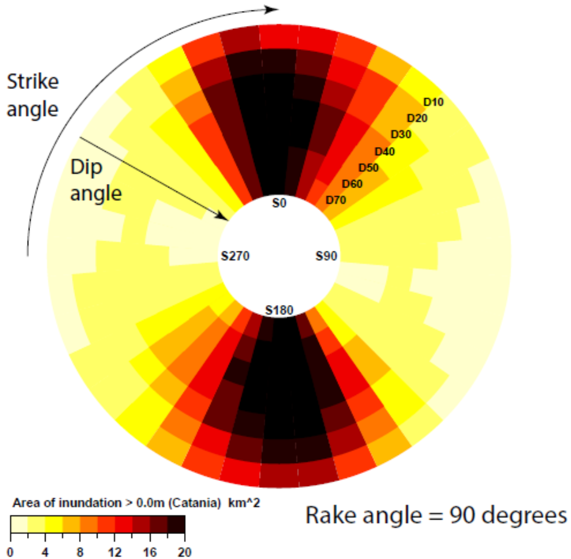


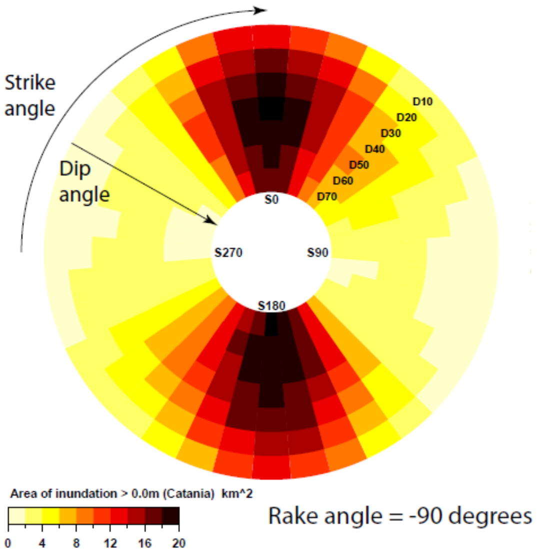
Near-Shore Earthquakes

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

The inundation experienced for large offshore earthquakes is most sensitive to the strike angle (maximum when parallel to the coast).

Similar for reverse and normal fault earthquakes.





Reverse Thrust Faulting

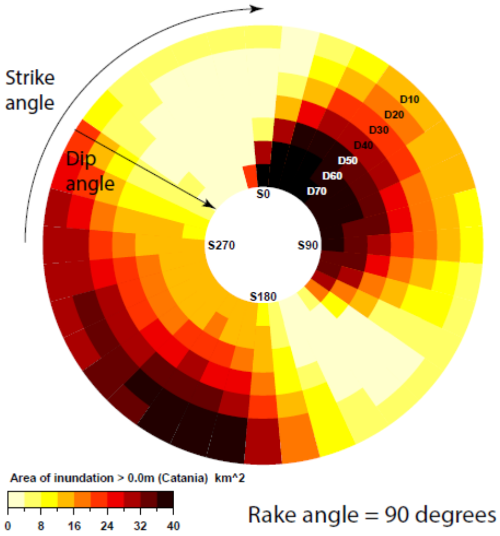
Normal Faulting

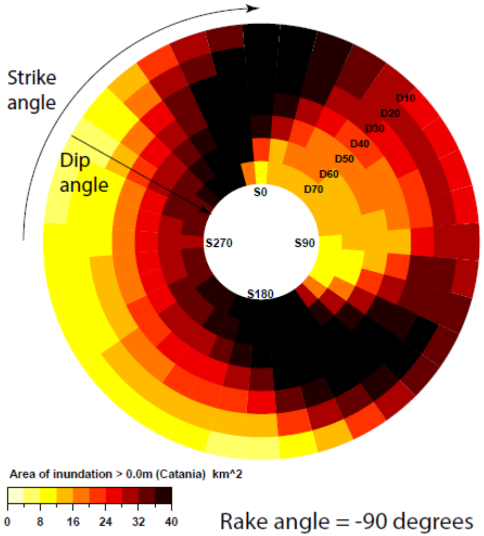
Offshore Earthquakes

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

When the earthquakes are close to shore and there is co-seismic displacement, this dominates the spatial pattern of inundation.

The angle of rake is crucial in determining the inundation when co-seismic displacement is significant.





Reverse Thrust Faulting

Normal Faulting

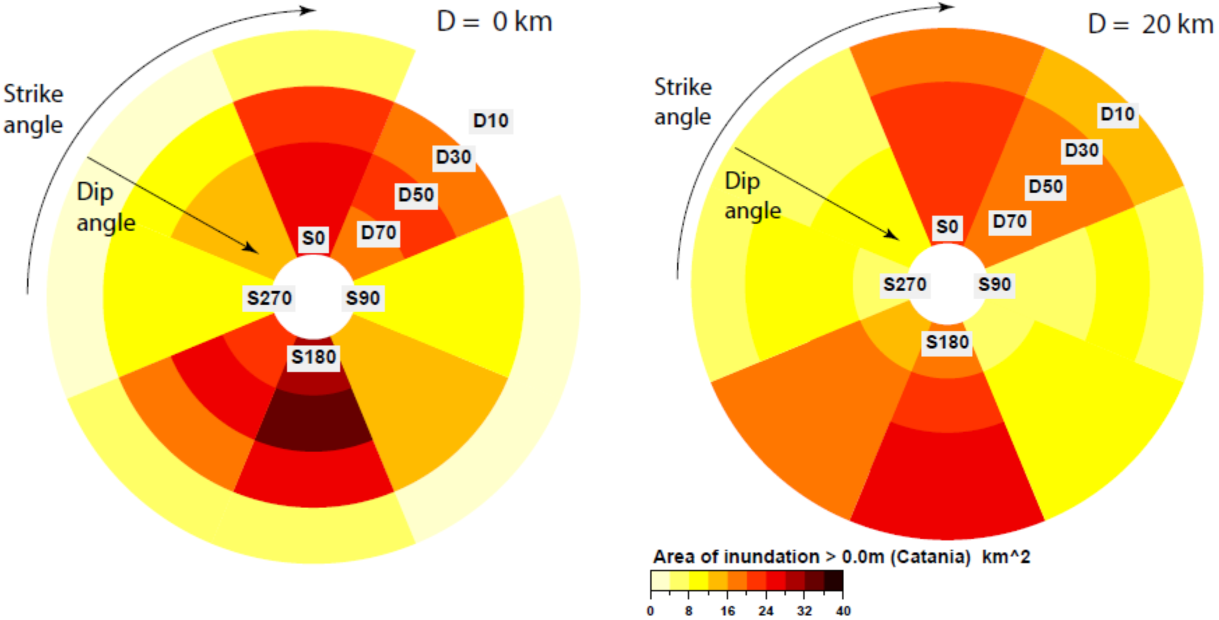
Near-Shore Earthquakes

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

We can explore the effect of depth.

For shallow offshore earthquakes, inundation depends strongly on both strike and dip.

For deeper earthquakes the dependency on dip diminishes.



Shallow earthquakes

Deep earthquakes

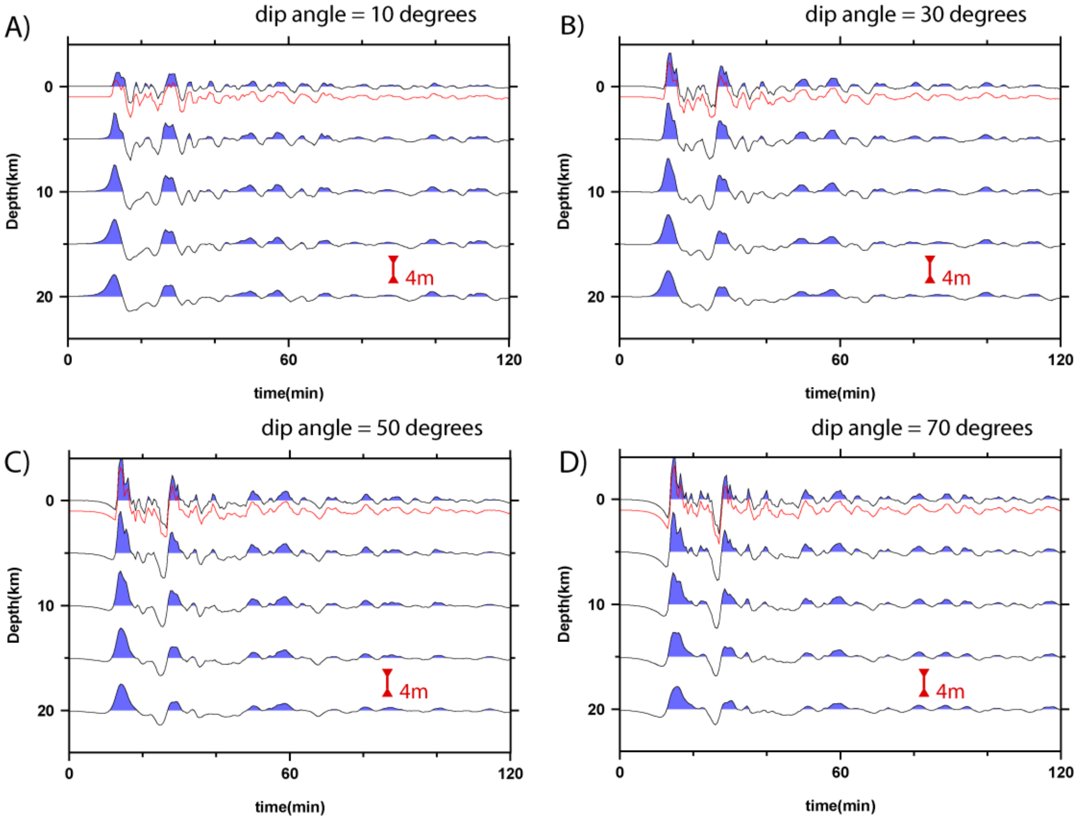
Offshore Earthquakes

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

We examine both onshore inundation and the nature of offshore waveheights.

Here we see how shallow earthquakes generate shorter period tsunami waves, and the wave height varies greatly with the dip angle.

Deep earthquakes generate longer period waves, and are less sensitive to dip.



Offshore Earthquakes

Sensitivity of Tsunami Run-up to Earthquake Source Parameters …

Conclusions

- HPC now allows us to perform many thousands of tsunami simulations with inundation modelled at high resolution.
- PTHA demands a discretization of earthquake sources. Sensitivity studies inform us of how many sources we need: how dense this discretization must be.
- Near-shore earthquakes demand a finer resolution than offshore earthquakes.
- Sensitivity to parameters of the numerical simulation (e.g. bathymetry, friction) needs to be understood to quantify the uncertainty.

Further Reading …

- **Probabilistic Tsunami Hazard Analysis: High Performance Computing for Massive Scale Inundation Simulations,**
  Gibbons et al., Front. Earth Sci., 2020
  https://doi.org/10.3389/feart.2020.591549

- **Testing Tsunami Inundation Maps for Evacuation Planning in Italy,**
  Tonini et al., Front. Earth Sci., 2021
  https://doi.org/10.3389/feart.2021.628061

- **The Making of the NEAM Tsunami Hazard Model 2018 (NEAMTHM18),**
  Basili et al., Front. Earth Sci., 2021
  https://doi.org/10.3389/feart.2020.616594