Coastal storm hazards, extreme loads and threats from tsunami

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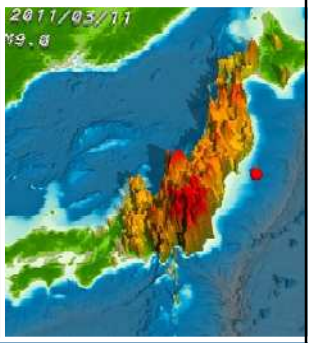
HR Wallingford

- A private company
- Research / consultancy
- Limited by guarantee, non profit distributing, independent
- Turnover £22 million
- £12 million in total assets
- Offices and agents world-wide - more than 50% income from overseas
- Over 250 staff including world leading experts

Summary

- Introduction
- Coastal hazards
- Wave loads
- Tsunami risks to UK and Ireland
- Tsunami analysis
- Implications of Tohuku
- Future?

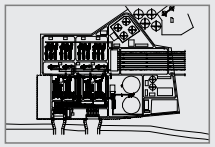


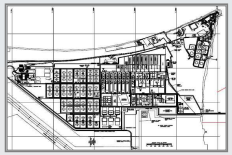
Coastal hazards – key processes

- Beach movement / coastal erosion;
- Wave overtopping / flooding;
- Wave disturbance in harbours / ship motion;
- Armouring of soft frontages and rubble mounds;
- Loads on walls / decks.

Image courtesy of HR Wallingford, Coasts & Estuaries group.

Coastal vulnerability – industry





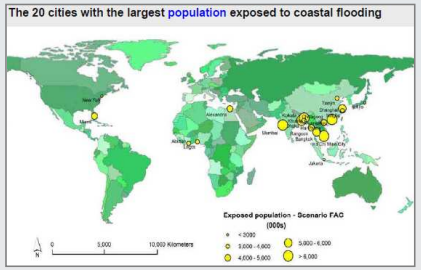
Images courtesy of HR Wallingford, Energy group.

Infrastructure plant design – requires co-operation between Mechanical / Chemical / Civil Engineering and Hazard specialists, examples: power stations, refineries, re-gas etc.

Coastal vulnerability – housing

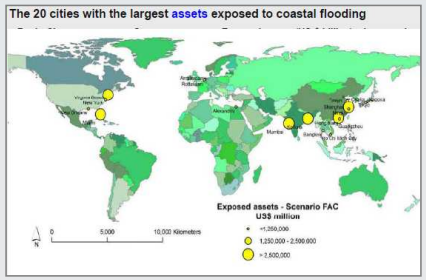
Images courtesy of HR Wallingford, Floods group.

Coastal vulnerability



Courtesy of Wolfgang Kron, Munich Re – presentation to ICCE 2008.

Coastal vulnerability



Courtesy of Wolfgang Kron, Munich Re – presentation to ICCE 2008.

Storm damage

Italian marina breakwater under storm attack.

Image courtesy of Prof Leo Franco.

Wave forces

Impulsive wave breaking against vertical or battered walls

⇒ high overtopping

+ high velocities

+ intense local pressures

Wave forces

Impulsive loads on vertical wall at Amlwch, small movements, about 1m at breakwater head.

Over-simple wave load formulae.

Ignored research on impulsive wave loadings.

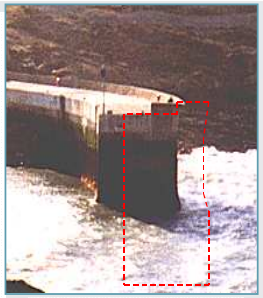


Image by Prof William Allsop.

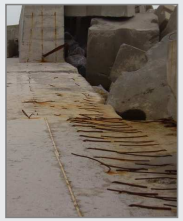
Storm damage

Structural failure of crown wall, Motril, Spain.

Images courtesy of Prof Vincente Negro Valecantandos.

Storm damage

Structural failure of crown wall, note limited size / length of rebar.



Images courtesy of Dr Keith Powell.

Wave forces

Courtesy Han Padron

Damage from wave forces under deck

Wave forces

Hurricane Wilma, Cozumel Island (Mexico) October 2005

Images courtesy of Dr Matteo Tirindelli.

Wave forces

Highway bridges, US90, Gulfport, after Katrina

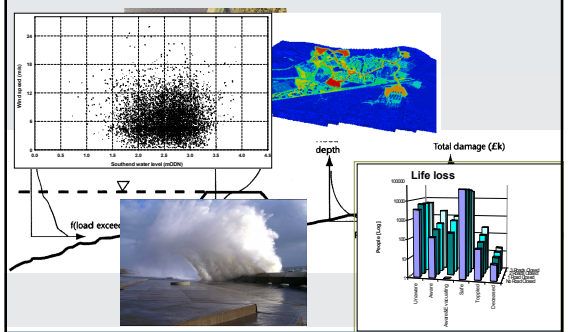
Image by Prof William Allsop.

Wave forces

Courtesy Scott Douglass, USA

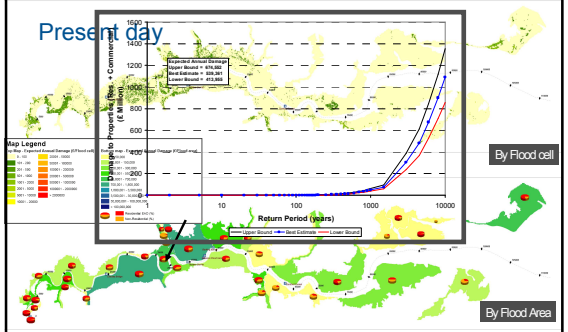
Highway bridges, I90, Biloxi, after Katrina

Sea defences / flooding



Sea defences / flooding

Present day



Encounter probabilities

Service conditions:

1:1 to 1:10 year returns.

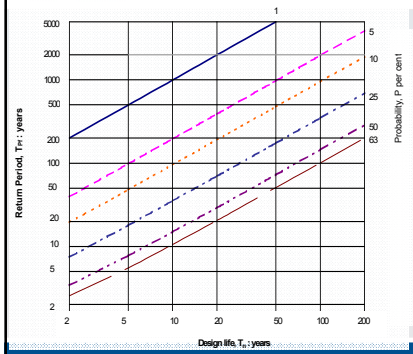
Design conditions:

1:50-1:500 year returns

Overload conditions:

1:1000 to 1:10,000 year returns.

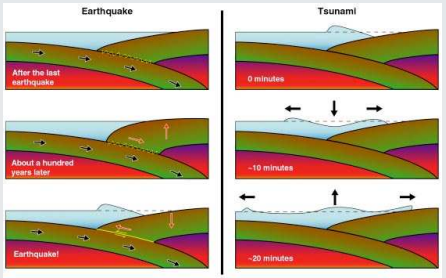
Encounter probabilities



Design life often 20, 30, 50 or 100 years.

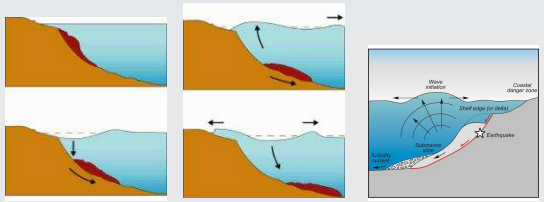
Acceptable probabilities of exceedance may be 40%, 25%, 10%, 5%, or less.

Tsunami generation, subduction



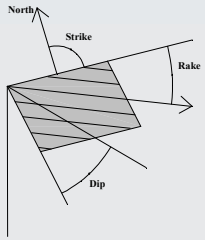
http://www.soest.hawaii.edu/tsunami/tsugen.html

Tsunami generation, slide



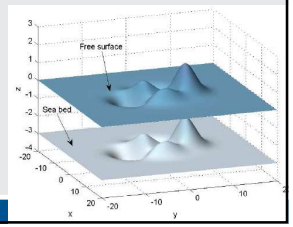
Earthquake Generated Tsunamis

Okada, 1985

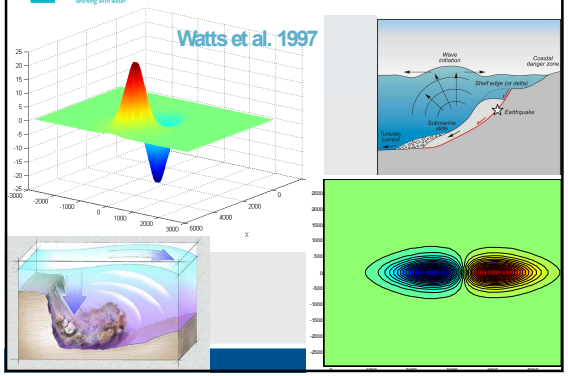


The displacement of the free-surface is equal to that at the sea bottom;

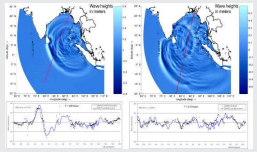
The bottom moves at the same time over the whole fault



Submarine Landslides/Slumps



Numerical Modelling of Tsunamis



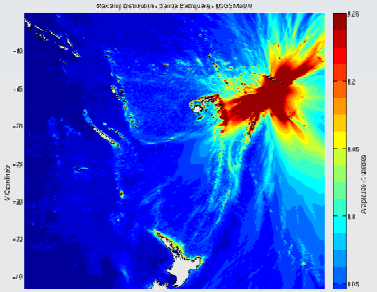
Generation

Vertical seafloor displacement (Okada)

Propagation

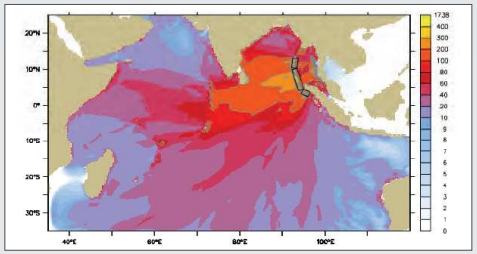
Most numerical studies: Shallow Water or Bousinesq models, reasonably well understood

Tsunami propagation



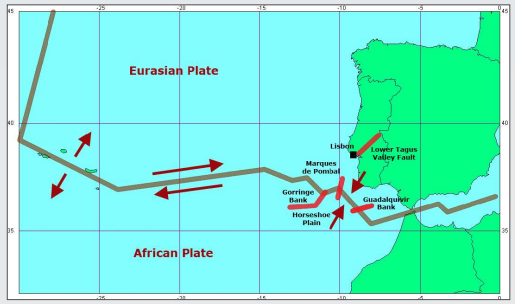
http://www.geonet.org.nz/news/article-sep-30-2009-samoa-islands-earthquake.html

Tsunami propagation

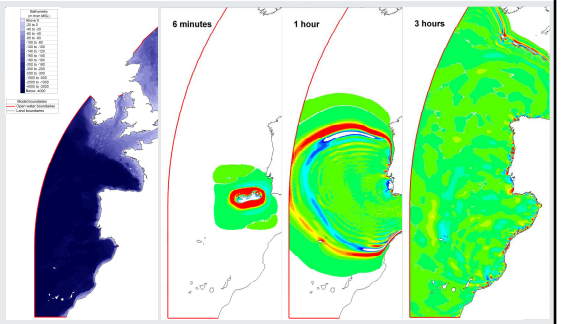


Maximum computed tsunami amplitudes (in cm) in the Indian Ocean - (NOAA Center for Tsunami Research, http://nctr.pmel.noaa.gov/indo_1204.html)

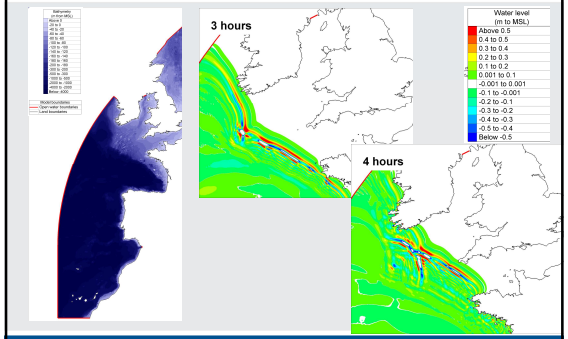
Threat to UK and Ireland



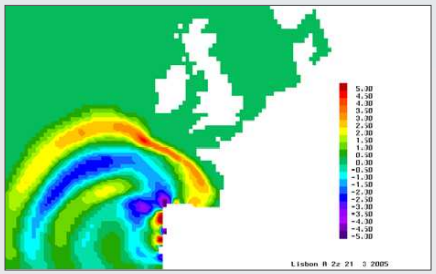
FAR-FIELD TSUNAMI MODELLING



FAR-FIELD TSUNAMI MODELLING

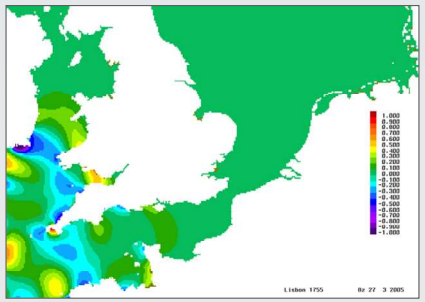


Threat to UK and Ireland

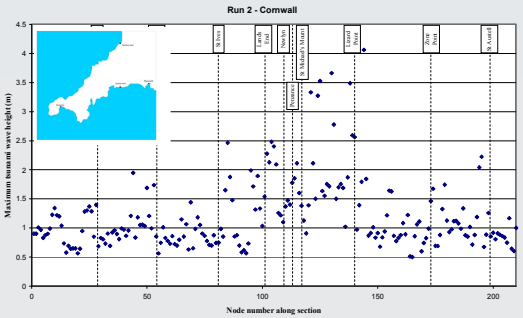


Courtesy POL

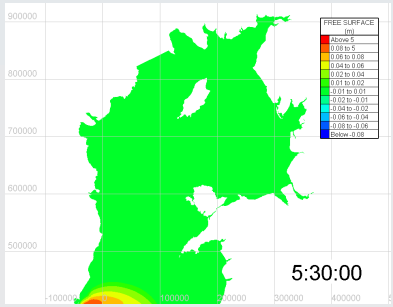
Threat to UK and Ireland



Max free surface at coast



FAR-FIELD TSUNAMI MODELLING



Threat to UK and Ireland

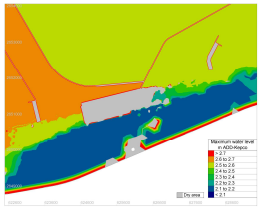
- > Arrival times are >4.5 hours
- > Water levels rise to approx 100 year event levels
- > Wave heights equivalent to severe winter storms
- > Significant shelter afforded by continental shelf

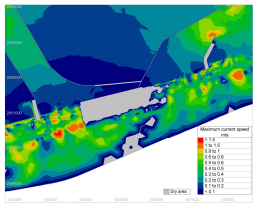
Details on
http://www.defra.gov.uk/environ/fcd/studies/tsunami/default.htm
"Impact of a Lisbon-type tsunami on the UK coastline, and the implications for tsunami propagation over broad continental shelves" in Jo. Geophysical Research

NEAR-FIELD TSUNAMI MODELLING

> Flow depth

> Flow velocity





Building to resist tsunami

Modelling tsunami threats

> Gaps in knowledge – nearshore propagation of tsunami waves, across shoreline and inland

> Complex flow interactions with beaches, sediment, coastal defences, and around buildings

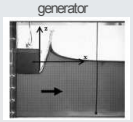
> Flow processes can be simulated in hydraulic models, but correct generation of the tsunami wave is essential:

- Multiple waves
- Preceding draw-down wave
- Realistic time series of wave heights and wavelengths

Tsunami modelling facilities

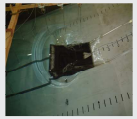
Maritime Structures Division of PARI , Japan

Scott Russell-type wave generator



NEES at Oregon State University, US

Wrigley Marine Science Center Catalina Island, California



Physical modelling of tsunami

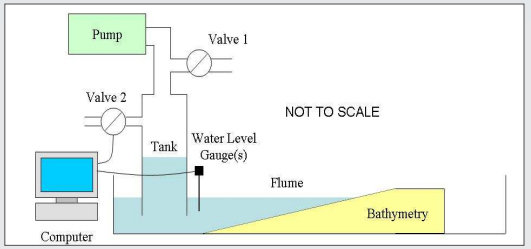
Since 1950s (Hall & Watts), flume experiments for the modelling of long waves on a sloping beach have been conducted

Paddle

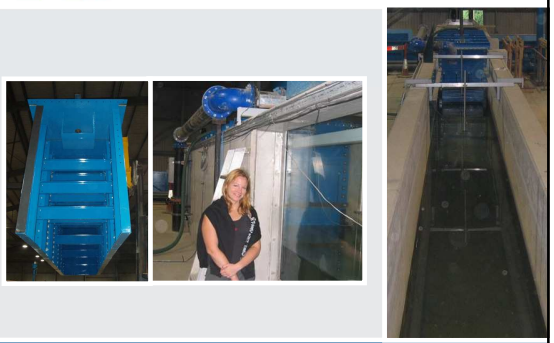
Wave run-up

HRW Tsunami generator

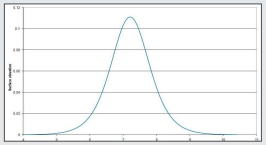
Conceptual design

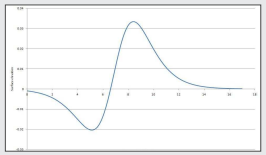


HRW Tsunami generator



How does it work?



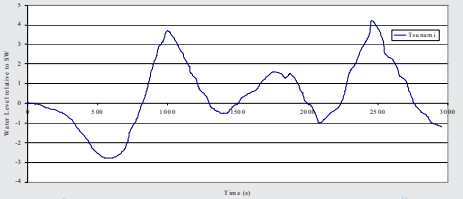


Theoretical waves often assumed to be representative of a tsunami

Solitary waves (Miles, 1980)

N-waves (Tadepalli & Synolakis, 1996)

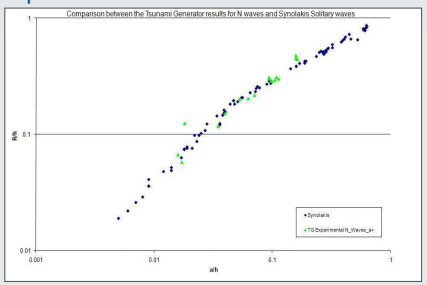
December 2004 tsunami



Record from depth-sounder on “Mercator”, approx 1 mile off Nai Ham beach, Phuket, Thailand. This record now inverted to give wave elevation.

HRW Tsunami generator

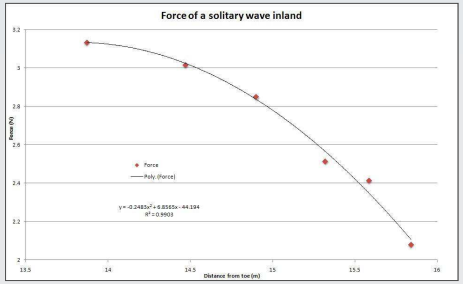
Example test results



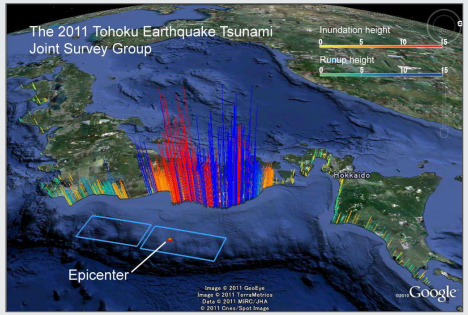
HRW Tsunami generator

Model building under test, Mercator time series.

HRW Tsunami generator

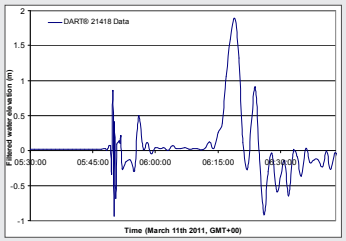


Tohoku tsunami, 11 March 2011

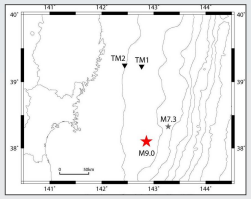


Tohoku tsunami, 2011

Data from DART 21418, on Pacific side of rupture zone, tide removed

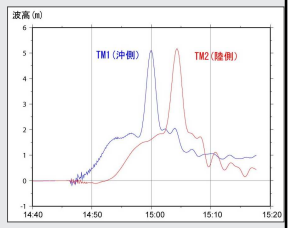


Tohoku tsunami, 2011



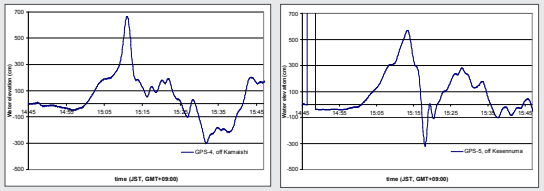
Location of bottom mounted gauges TM1 and TM2

Water level signals fromTM1 and TM2. Note absence of trough-led, and 2-part nature of the time series

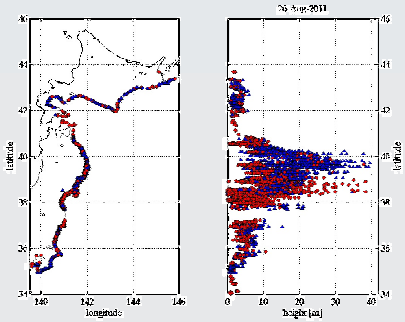


Tohoku tsunami, 2011

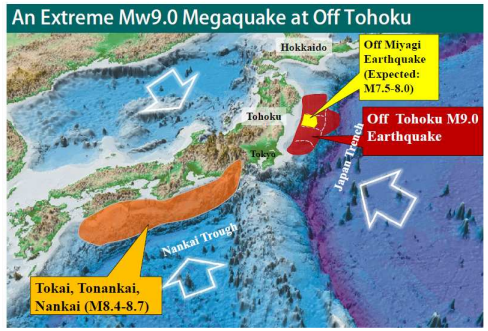
GPS buoy data, off Kamishi (left) and Kesennum (right)



Tohoku tsunami, 2011



Tohoku tsunami, 2011



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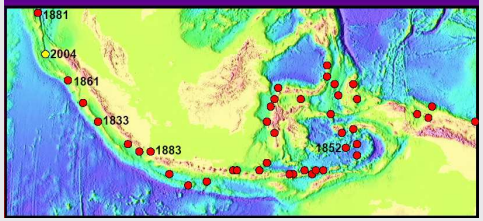
Working with water

Conclusions

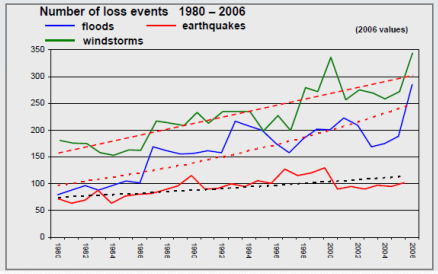
The Next Tsunami Source?



Can future seismic displacements be predicted?

HR Wallingford
Working with water

Conclusions



Courtesy of Wolfgang Kron, Munich Re – presentation to ICCE 2008.

HR Wallingford
Working with water

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