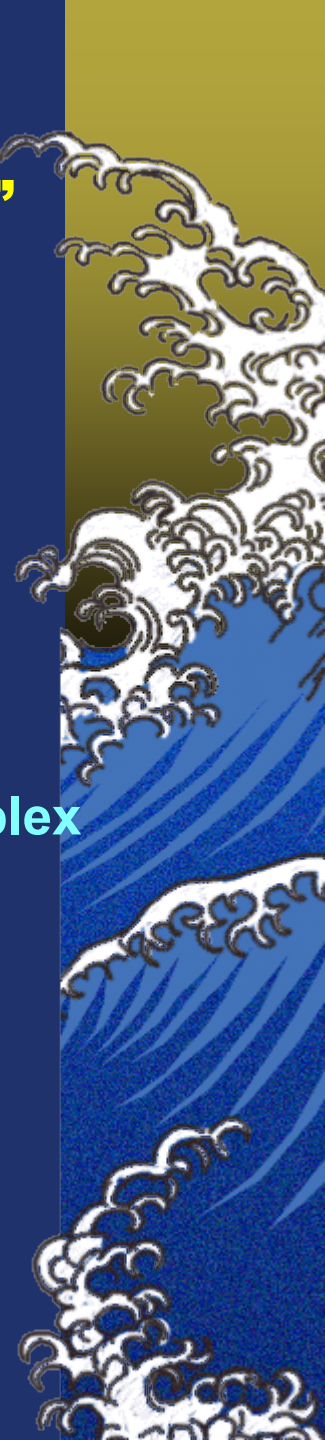
United Nations Ocean Decade 2021-30
Safe Ocean Laboratory Satellite Activity
"Further Challenges for Warnings of Tsunamis"

SESSION B
What do we know and need to know to warn for Tsunamis generated by non-seismic and complex sources ?

Keynote
What are the Tsunamis generated by non-seismic and complex sources and how do we warn for them ?

François Schindelé
(International Tsunami expert – CEA – France
Past Chair ICG/PTWS, ICG/NEAMTWS
UN Decade Tsunami Programme Scientific Committee)



“Further Challenges for Warnings of Tsunamis”

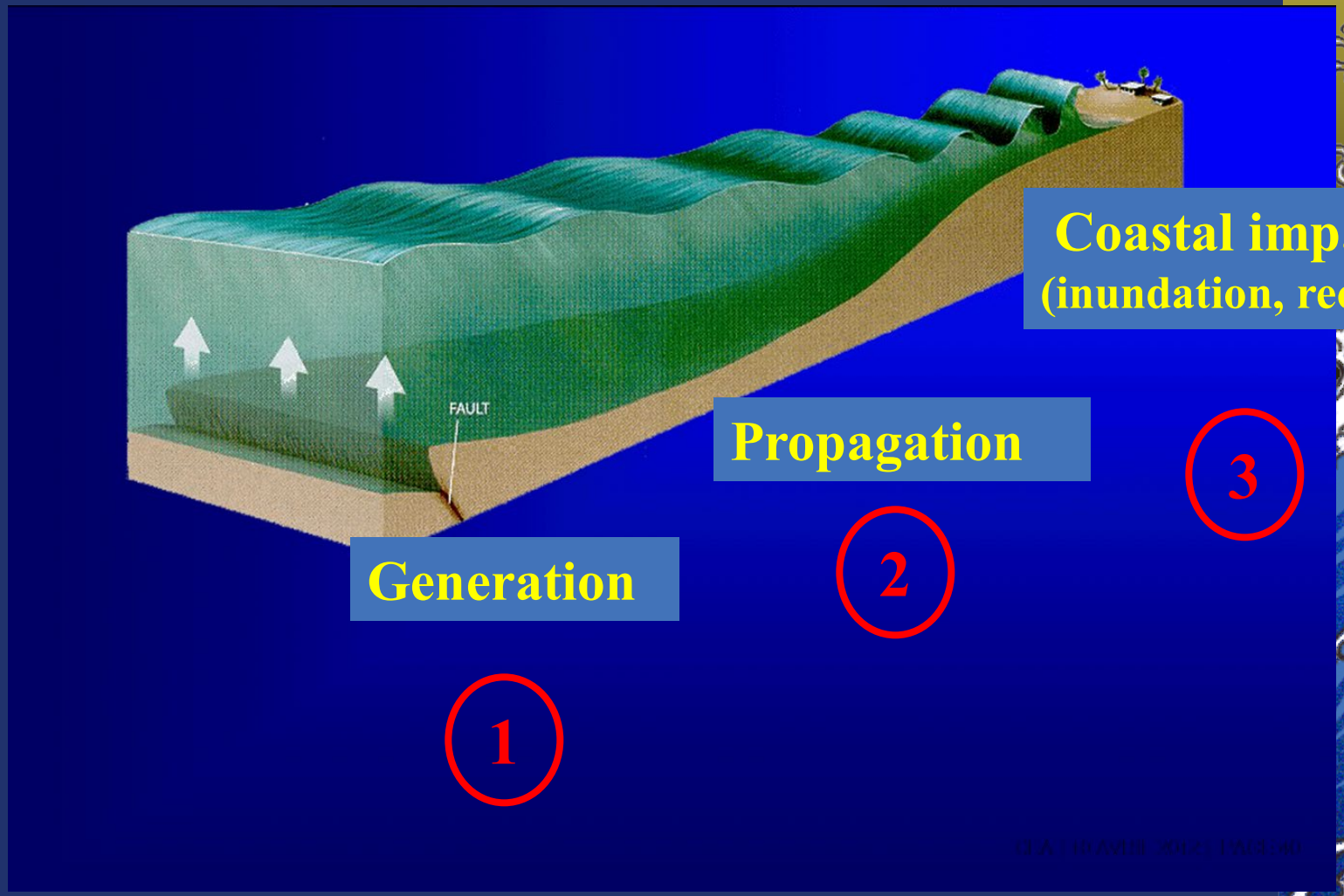
What are the Tsunamis generated by non-seismic and complex sources ?

- ***Three types of non-seismic sources :***
  - ***Landslides (Aerial , submarine, combined)***

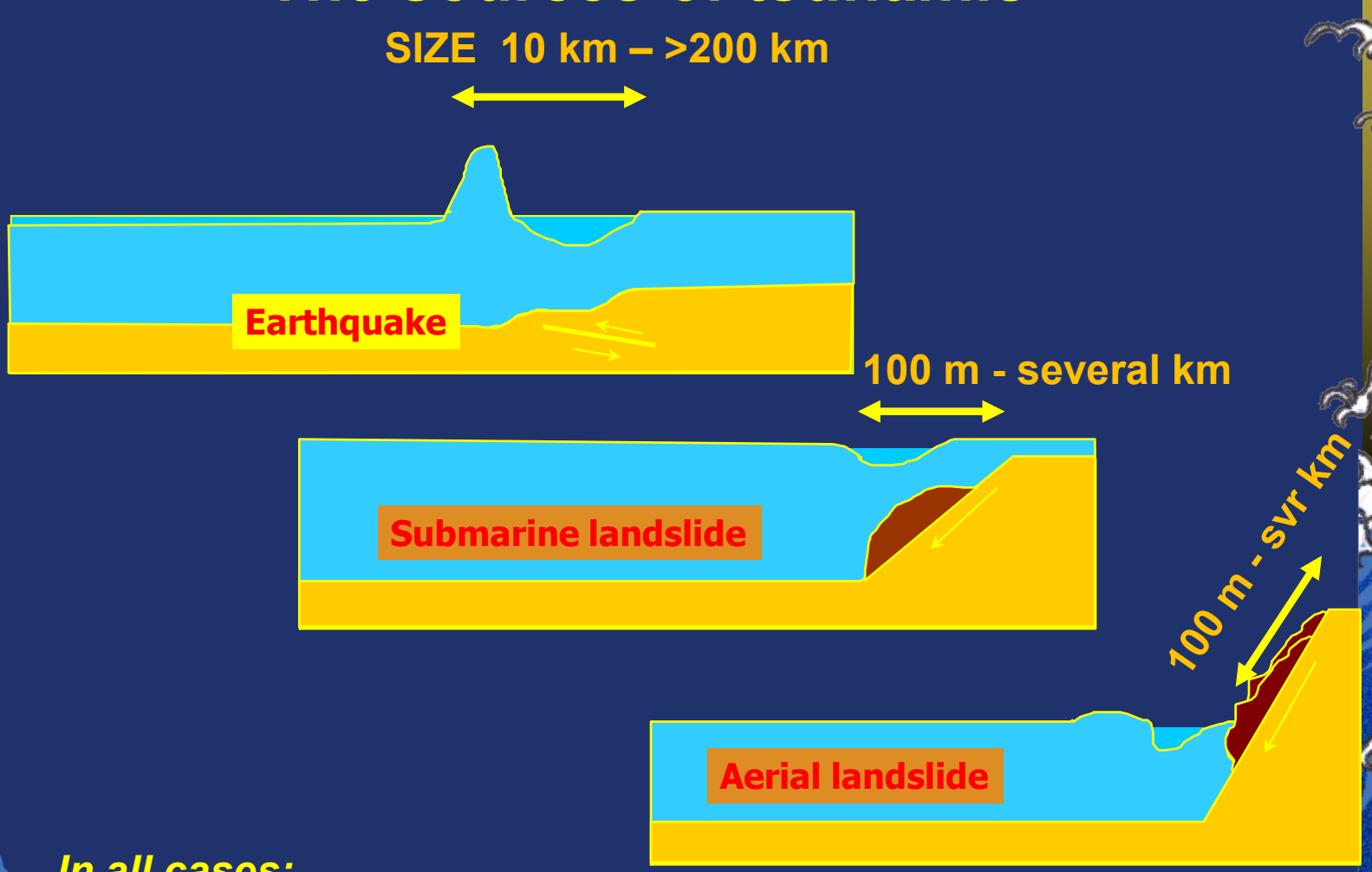
  - ***Volcano (seven types of sources – Item 4 by Raphaël Paris)***

  - ***Meteo tsunami***

3 steps of tsunami phenomena



The sources of tsunamis



- ***In all cases:***
  - *water column deformation (up-lift or/and down-lift)*
- ***Gravity wave propagation***

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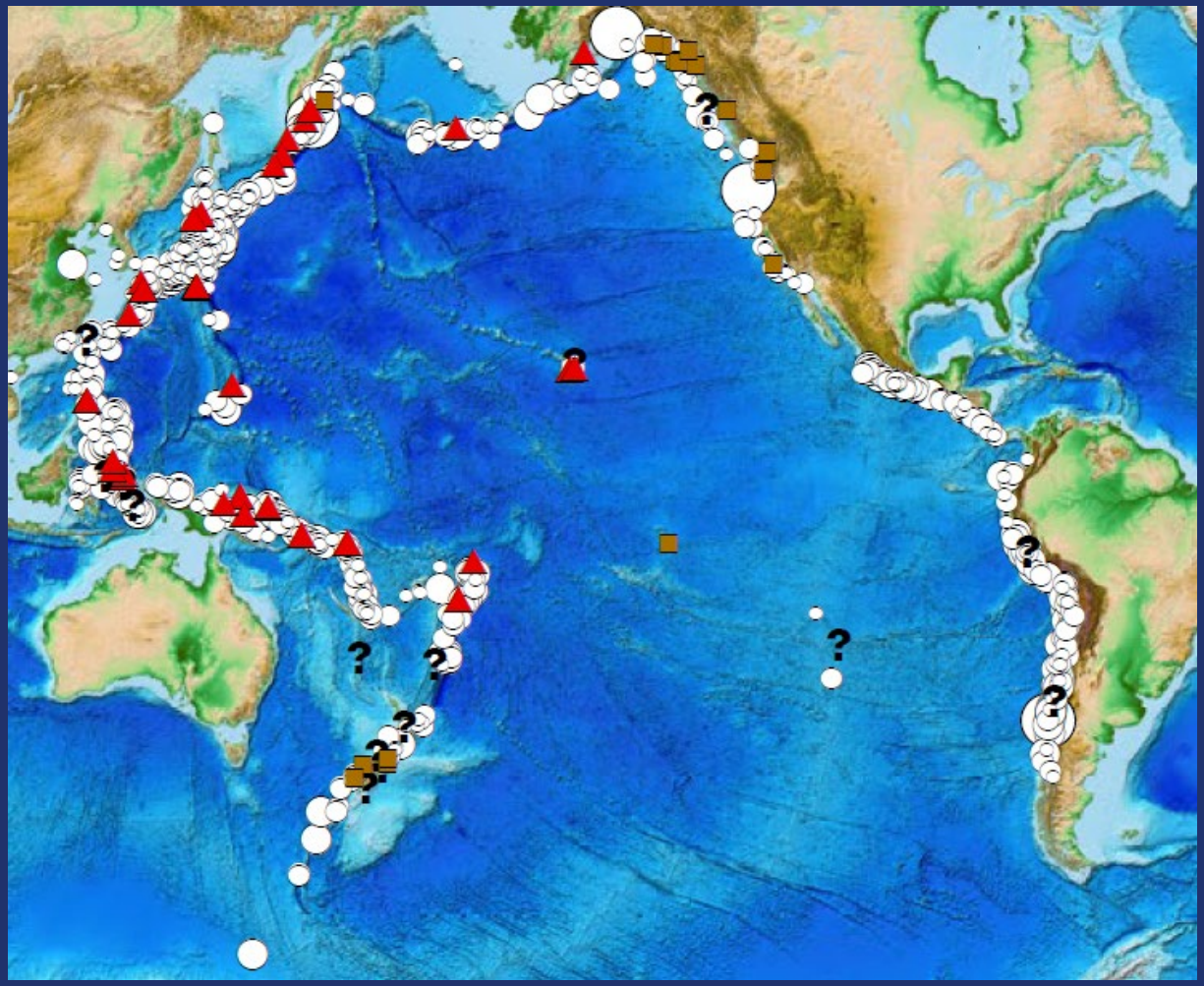
Pacific Tsunami Sources



Earthquake

Volcano

Landslide

IOC Tsunami Glossary

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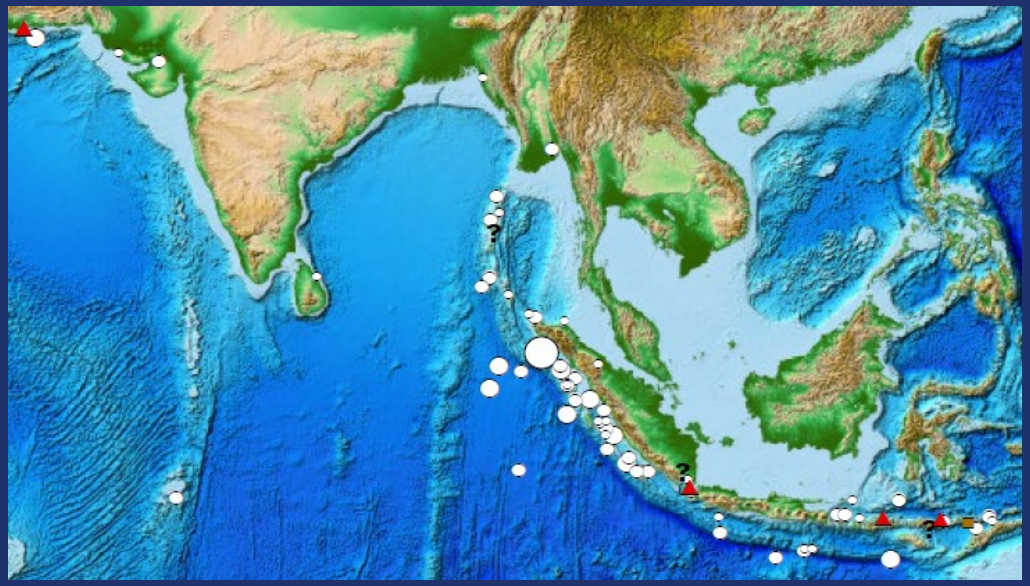
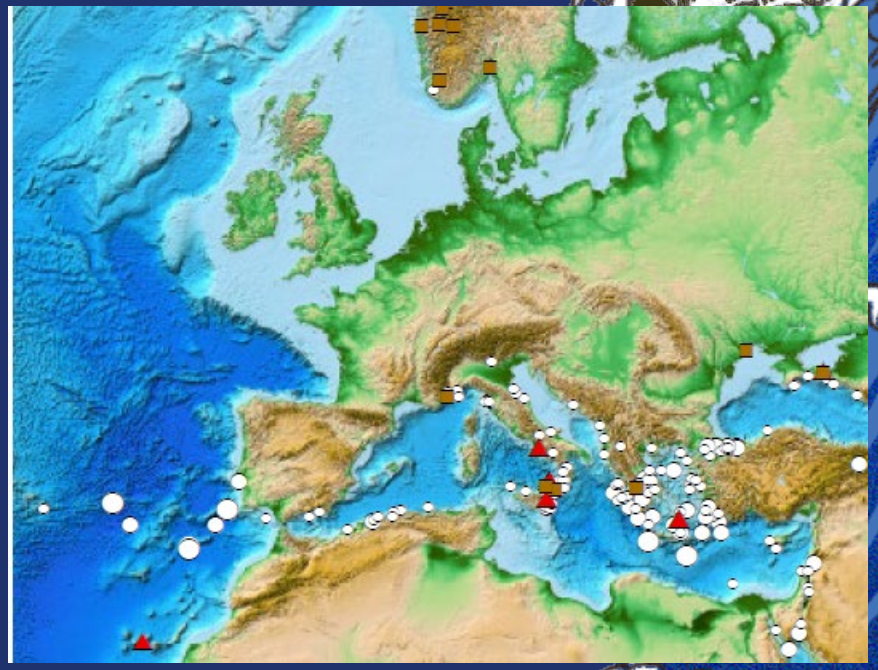
Indian Ocean –



North east Atlantic-Mediterranean



Earthquake

Volcano

Landslide

IOC Tsunami Glossary

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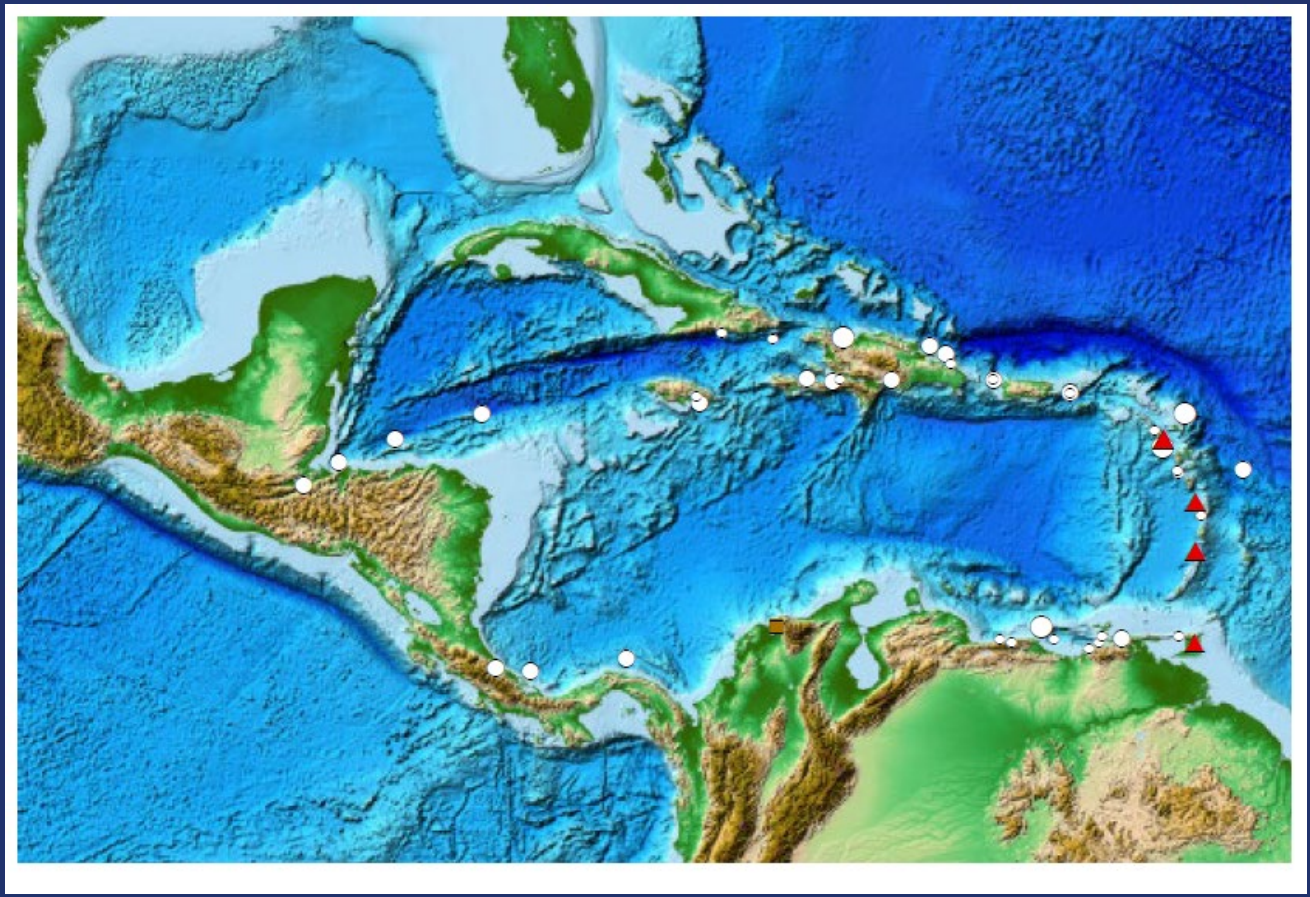
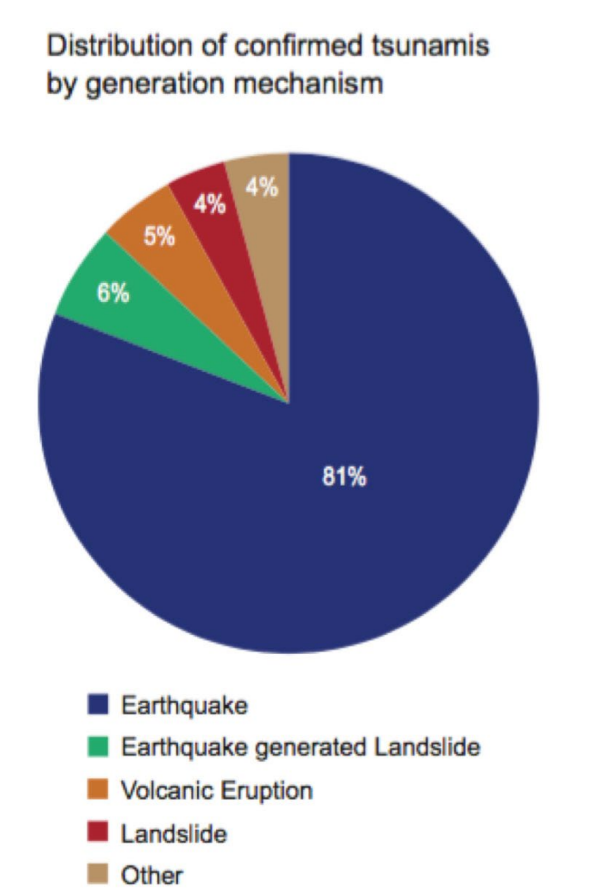
Caribbean Tsunami Sources



IOC Tsunami Glossary

Distribution of confirmed tsunami by generation mechanism



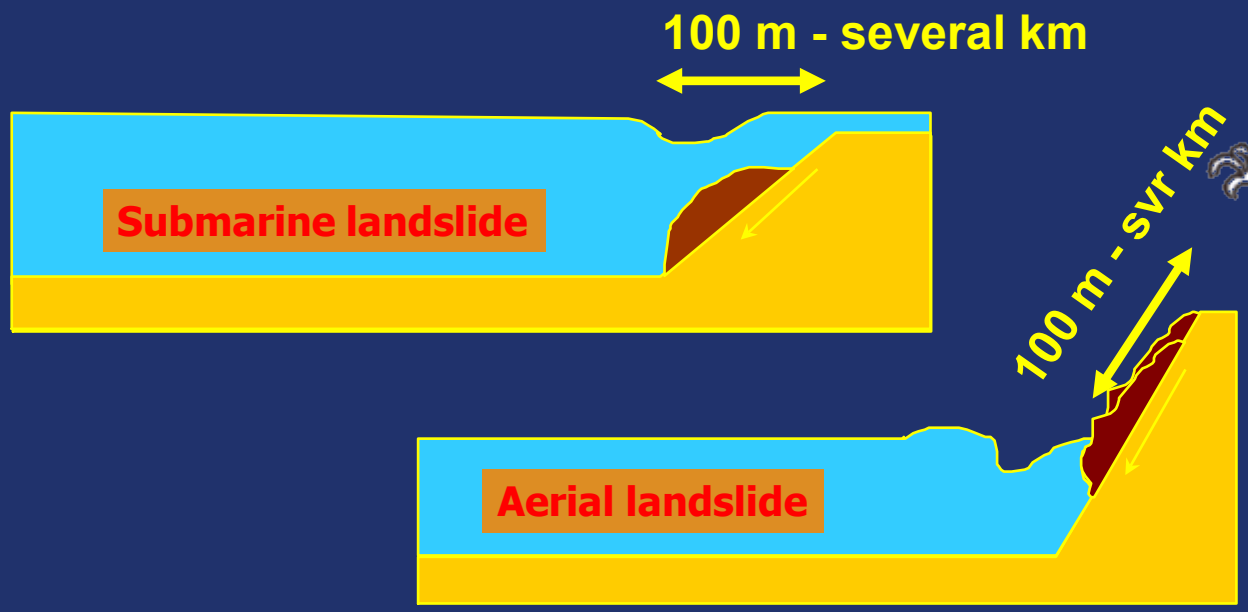
Distribution of transoceanic tsunamis (impact > 1000 km) by generation mechanism

3 **Volcanic** eruptions :
- Santorini -1650 BC
- Krakatau August 1883
- HungaTonga 15/01/2022

19 % tsunamis are generated by non-seismic or complex sources

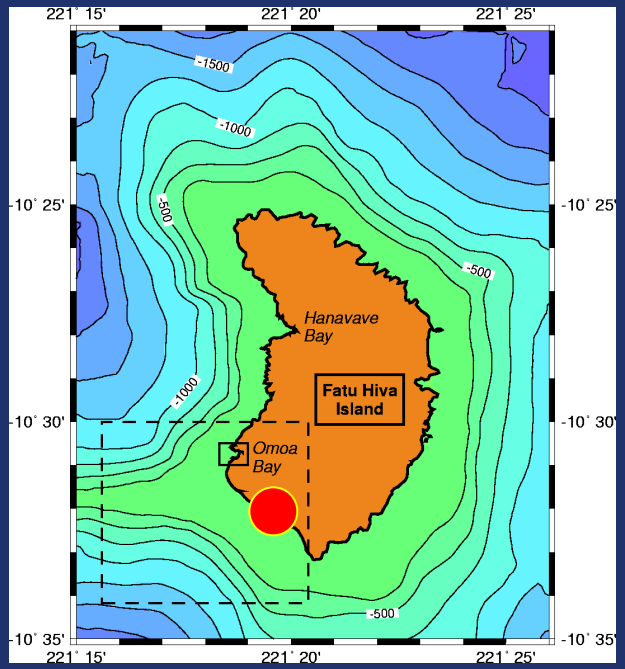
Landslides tsunamis
Problem of detection

- *Landslides generate earth surface deformation and seismic waves*

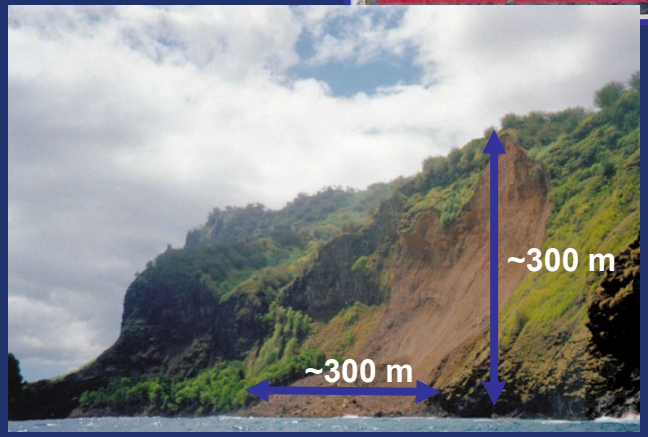


- *Small size of source => Seismic waves of small amplitude, in comparison to earthquake.*
- *Equivalent magnitude < 5,0 (most < 4,0)*
  - *No robust Automatic Discriminate method of earthquake and landslide*
  - *Implementation of local monitoring systems to detect landslide*

Fatu Hiva local tsunami (13 sept. 1999) French Polynesia



1996



E. Okal, 1999

Groendland 2017

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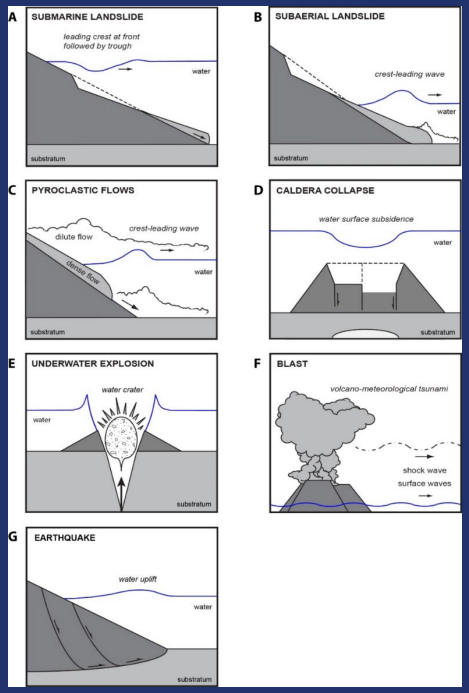
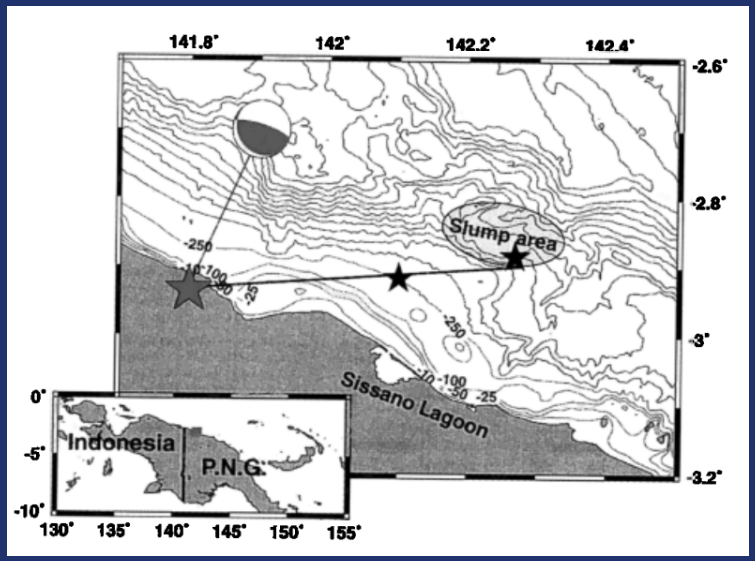
What are the Tsunamis generated by non-seismic and complex sources ?

- ***Complex sources :***
  - ***Earthquake and Landslide (Aerial , submarine, combined)***
  - ***Volcano (7 types of sources)***
    Item 4 by Raphael Paris



Complexe Source : EQ and submarine Landslide
Aitape PNG July 17 1998



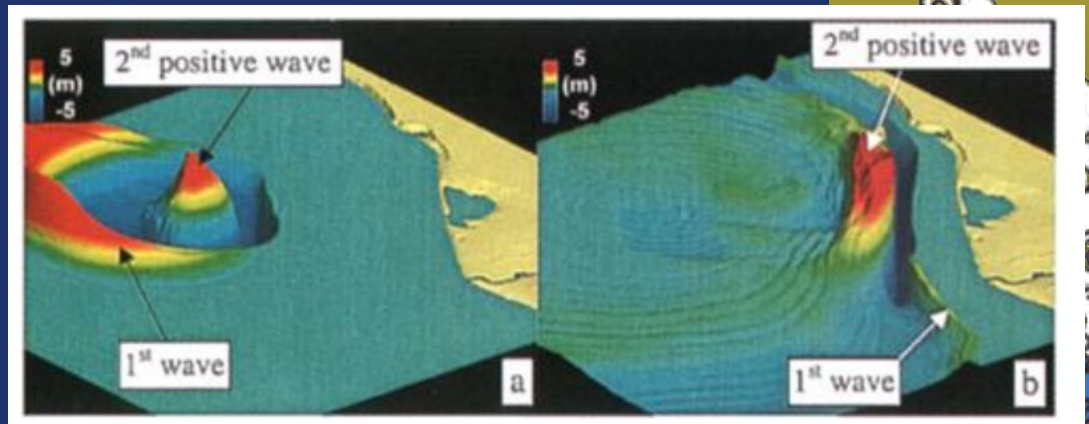
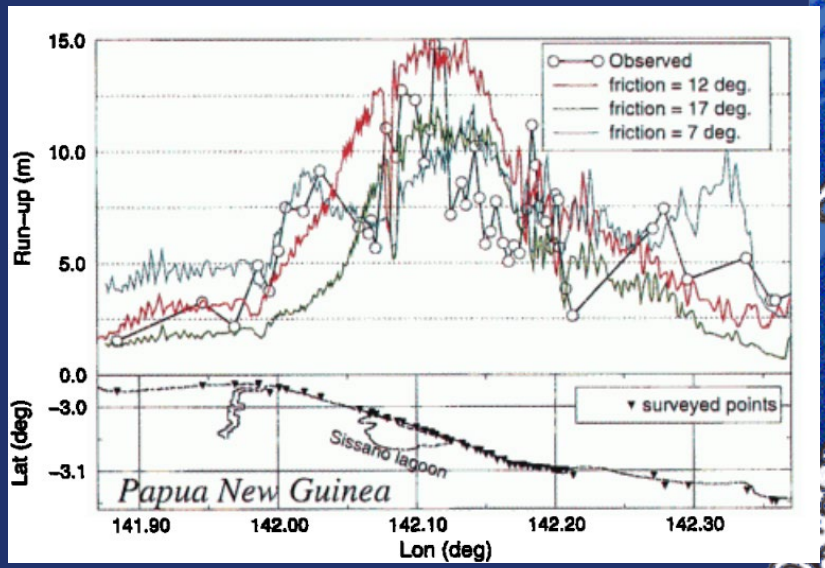


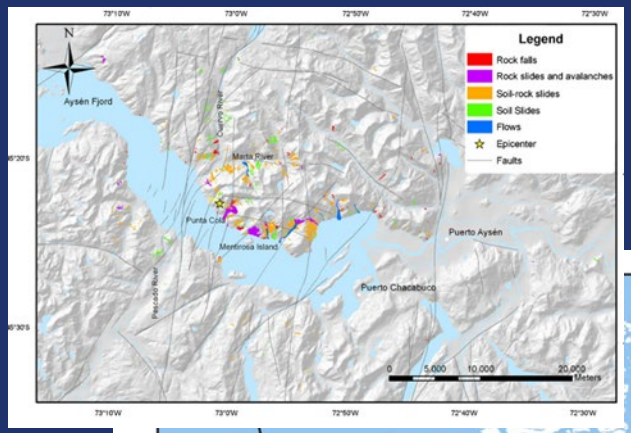
Figure 4. Snapshots of the computed water surface at $t=90$ s *(a)* and $t=360$ s *(b)* after the slide initiation. Same horizontal

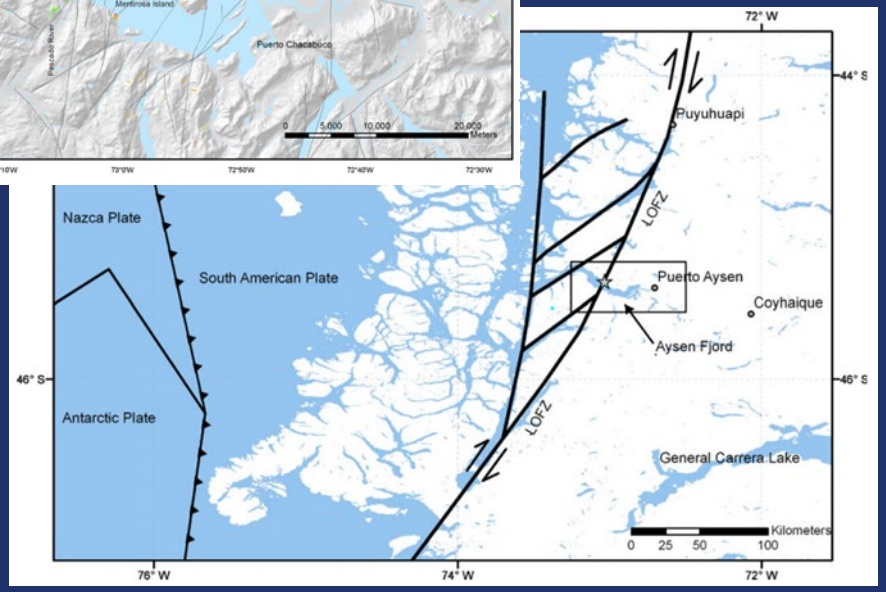


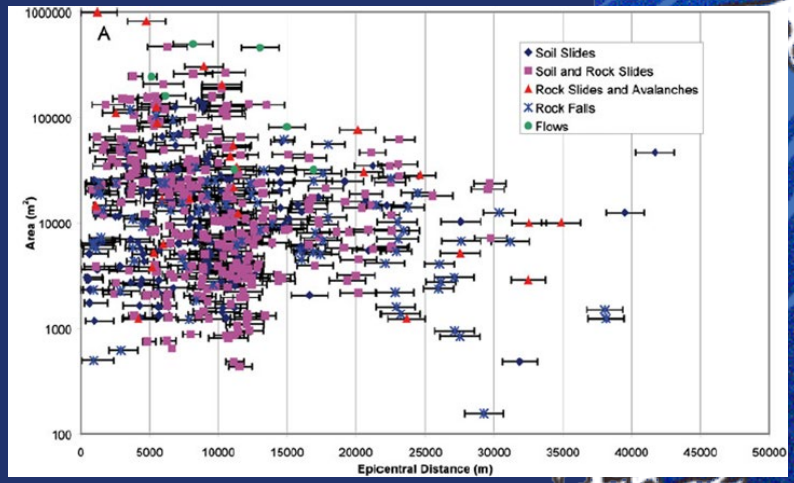
Heinrich et al. GRL, 2000

Complexe Source : Earthquake and 500 aerial landslides

Chile April 21 2007 Aysen Fjord M 6,2







Sepulveda et al. Landslides , 2010

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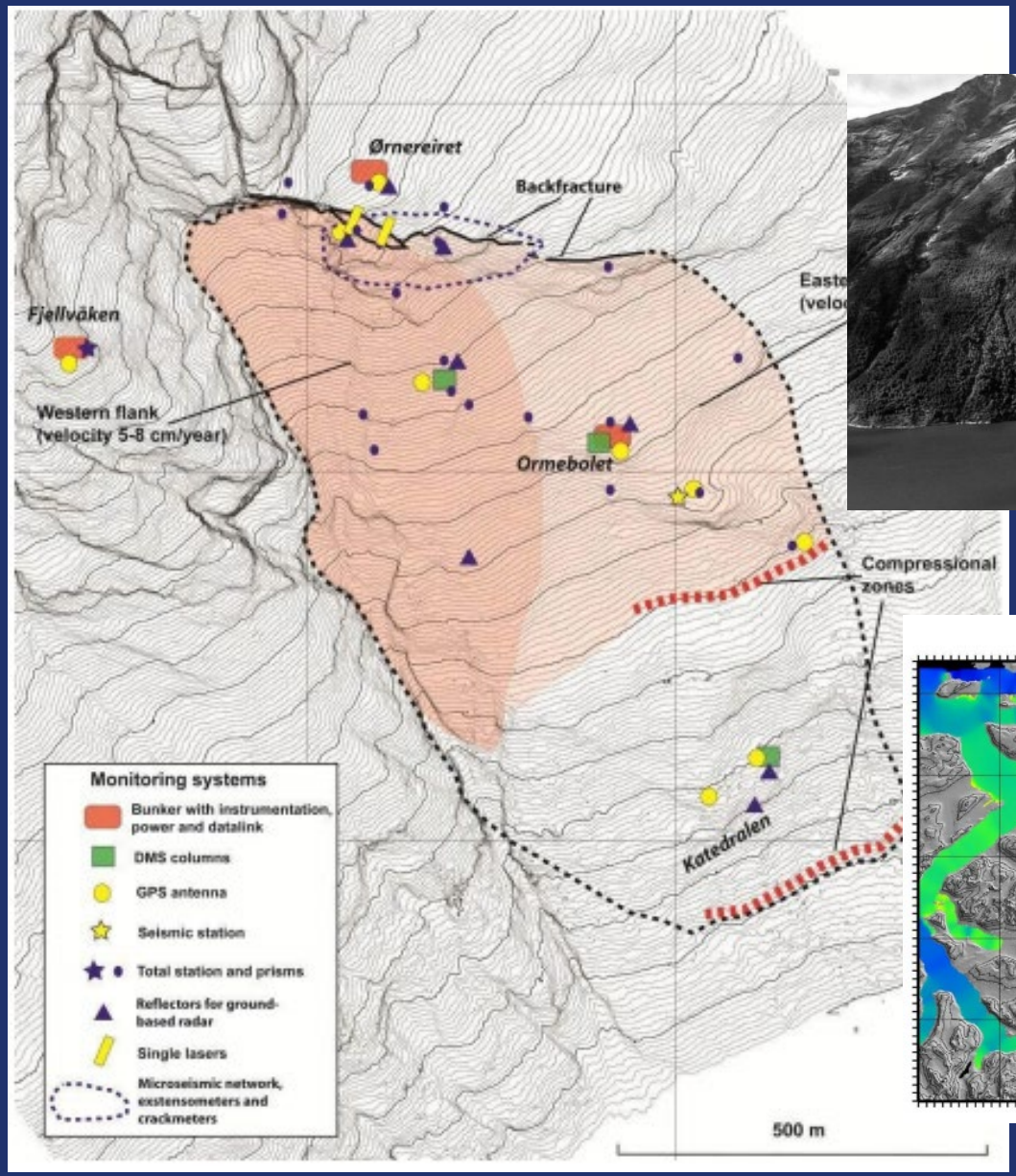
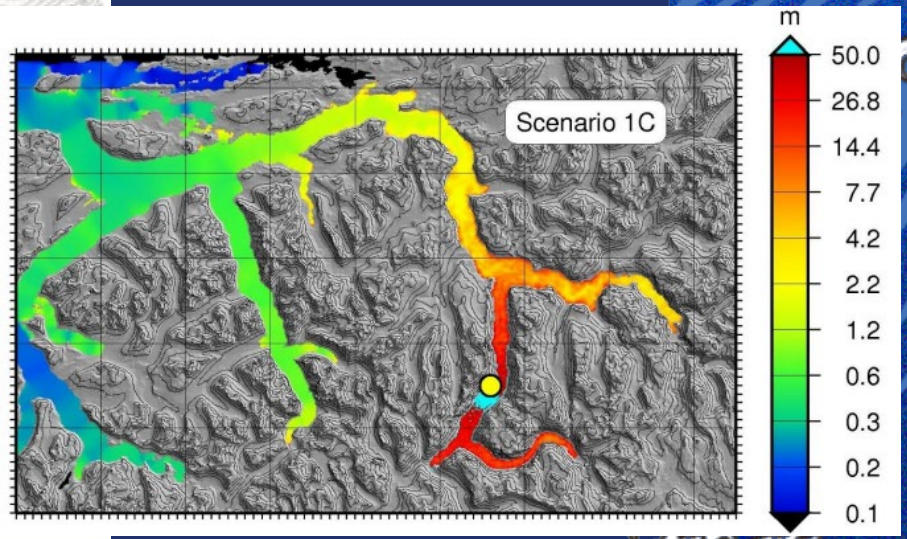
Aknes (Norway) Rockslide monitoring and warning system

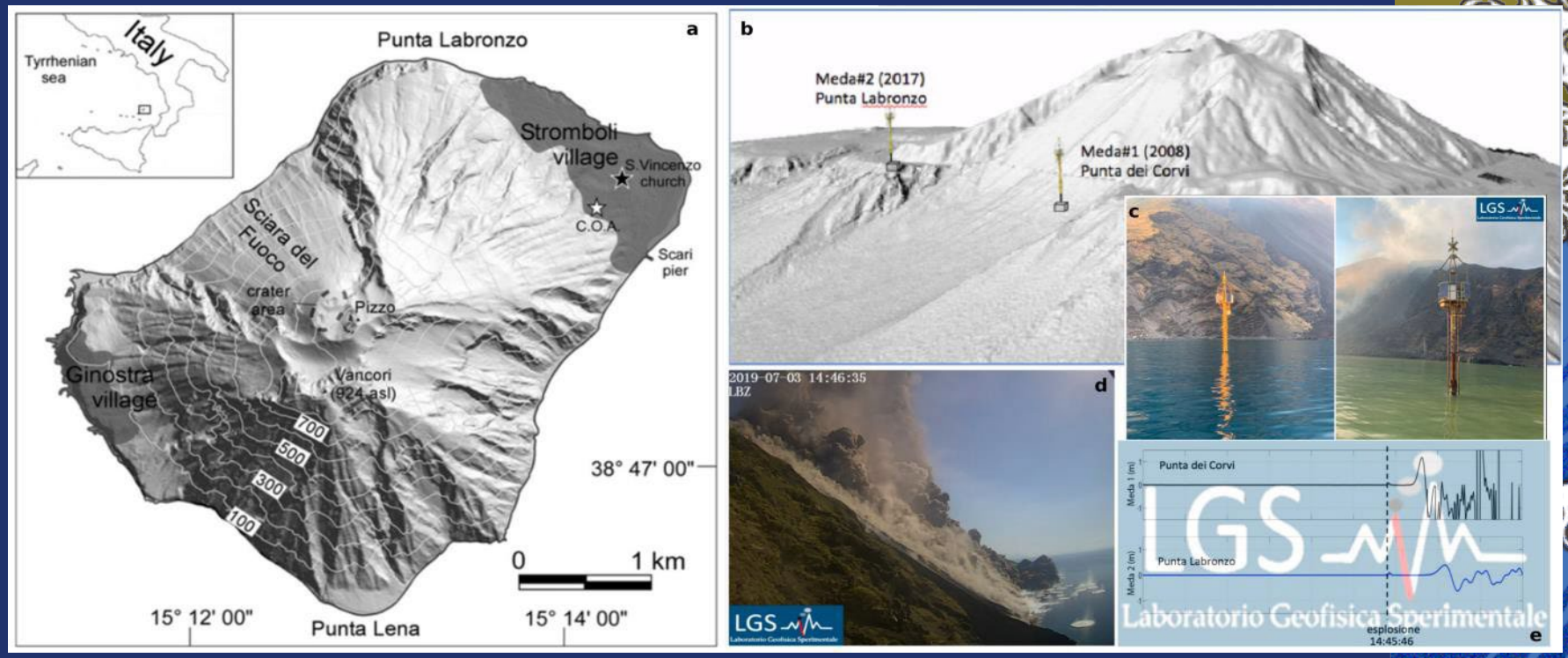




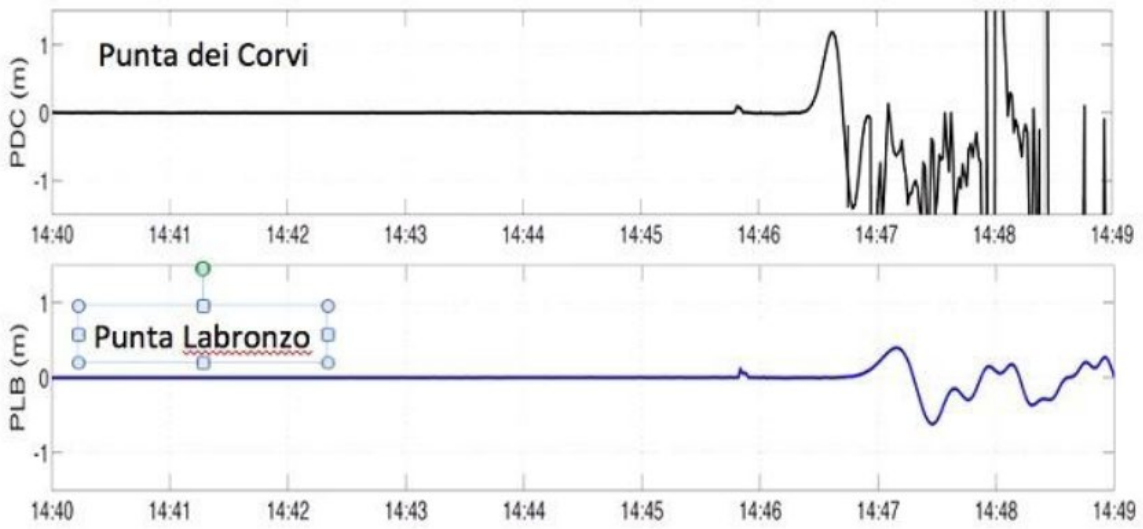
Aknes (Norway) warning system

Geologisk situasjon	Farenivå	Beredskapsnivå og -tiltak
Stabil bevegelse med sesongvariasjoner	Lav fare	**Grønn beredskap:** • Overvåking • Planlegging • Øving
Økt bevegelse, utover sesongvariasjon	Moderat fare	**Gul beredskap:** • Intensivert overvåking • Gjennomgang av planverk • Aktivering av samordningsfora • Forberede komplekse tiltak • Informasjonstiltak
Akselererende bevegelse	Høy fare	**Oransje beredskap:** • Intensivert beredskap • Flytting av sårbare objekt • Reduksjon av aktivitet og ferdsel
Skred nært forestående	Ekstrem fare	**Rød beredskap:** • Evakuering • Redning
Skred har gått, kan gå igjen		**Rød beredskap:** • Opprettholdelse av evakuering • Reetablering av overvåking

Stromboli (Italy) Tsunami Warning system

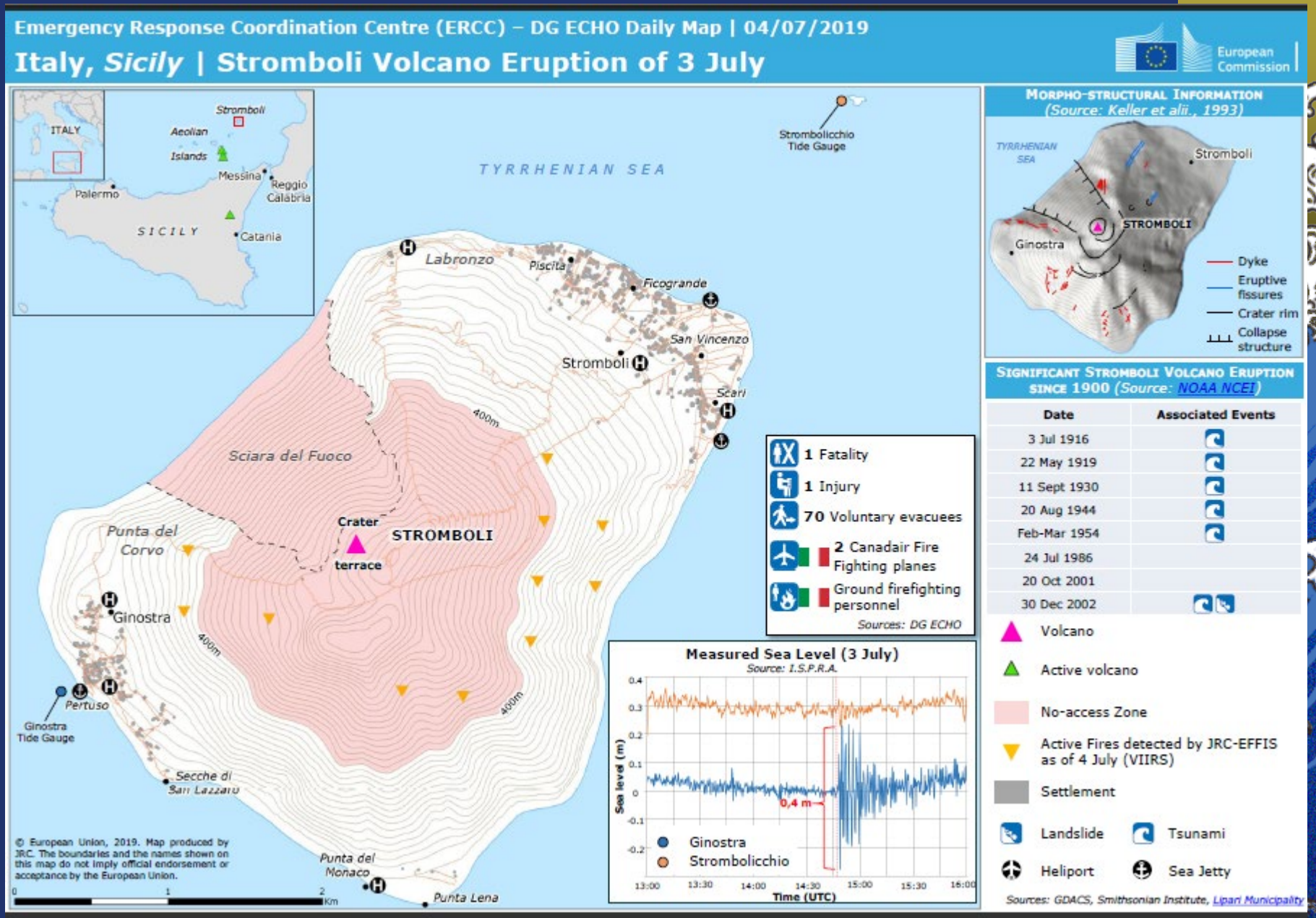


Stromboli 2019



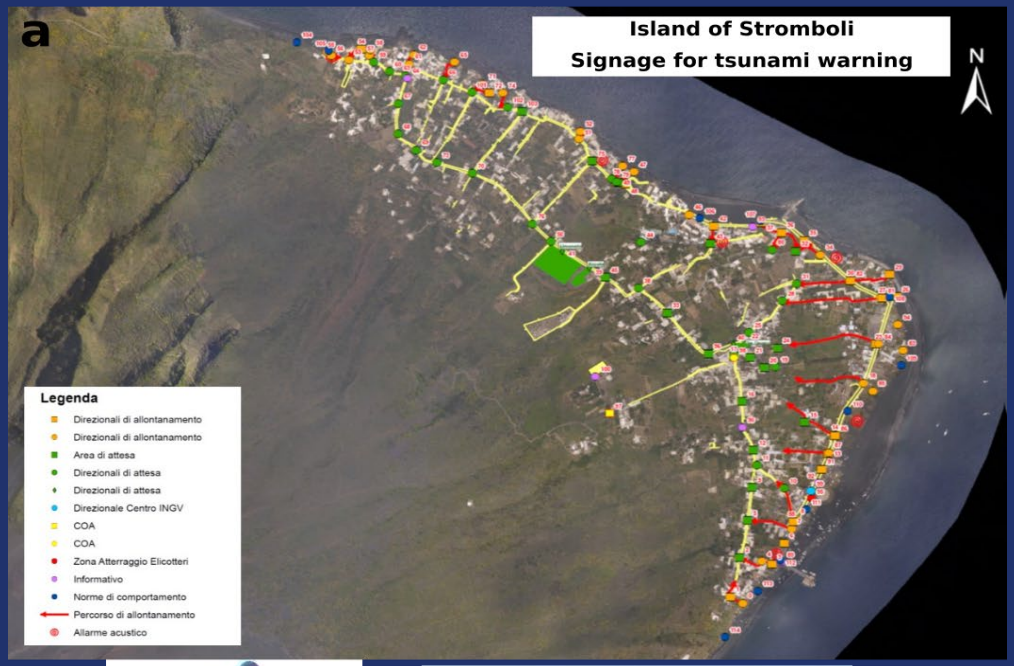
Sea level signals from the University of Florence

Stromboli 2019



Stromboli (Italy) Tsunami Warning system

a

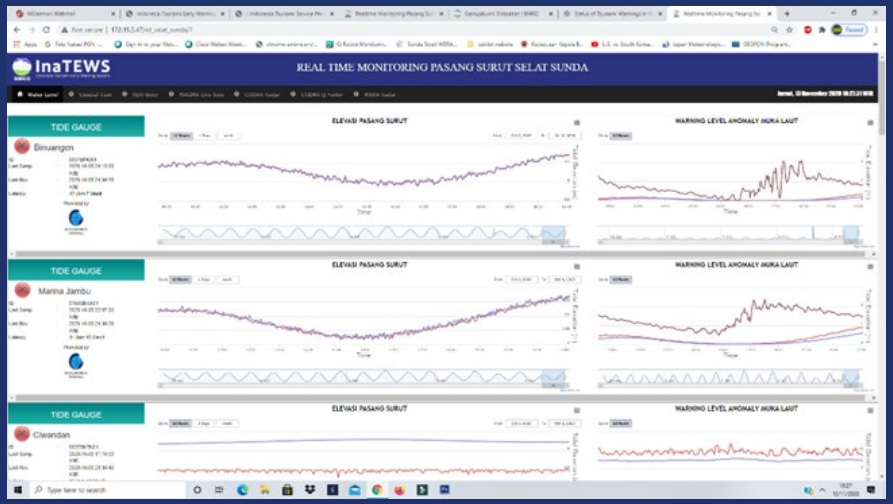


b

(photos curtesy of Dipartimento della protezione civile)

Krakatau (Indonesia) monitoring system

Krakatau monitoring system



Sea level

Monitoring

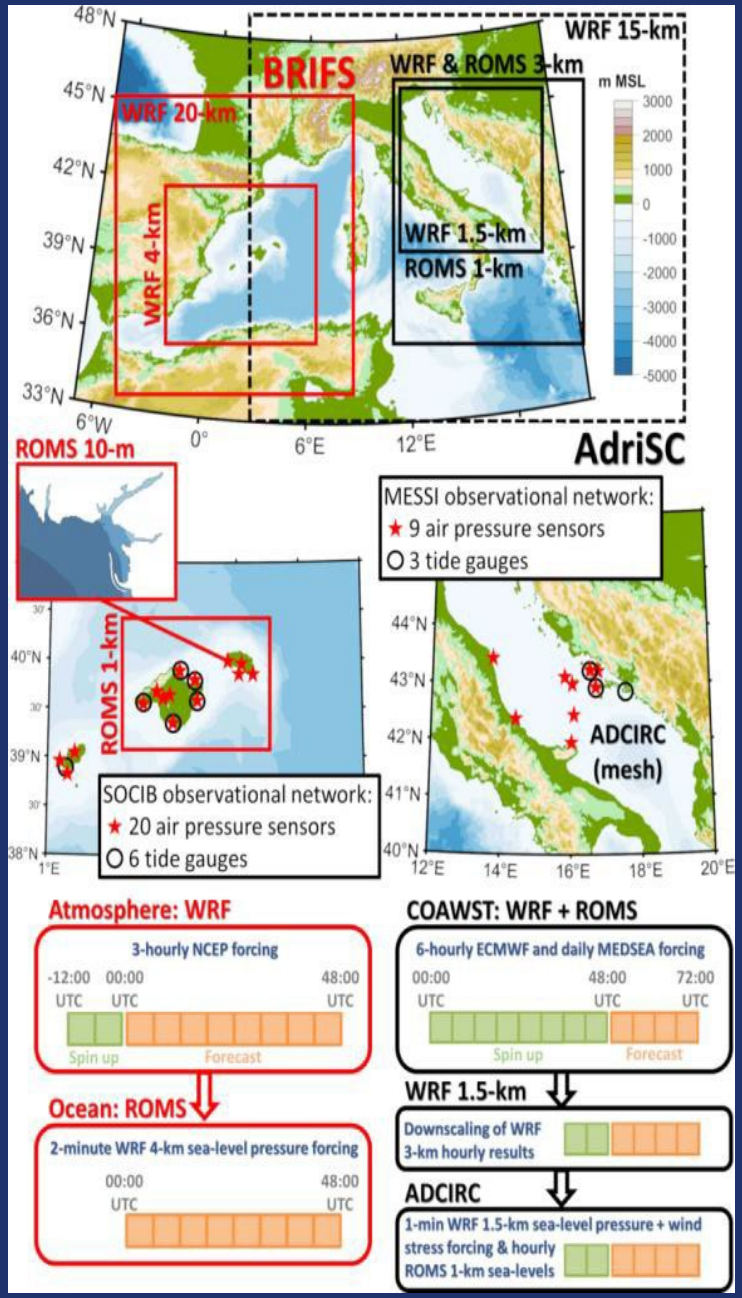
WERA Radar

Monitoring

Meteo-tsunami Warning systems

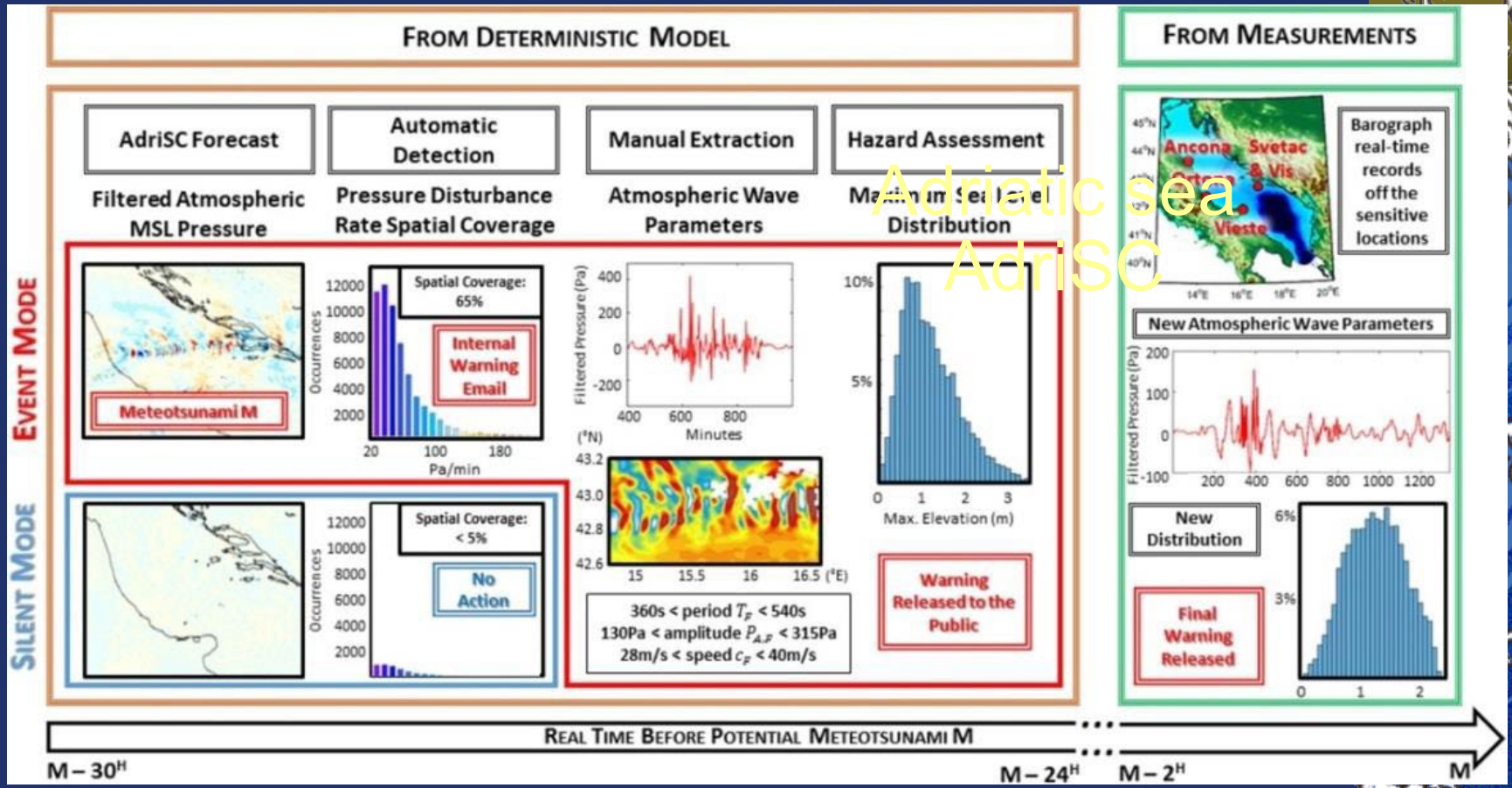
Balearic Islands BRIFS (Spain)

Adriatic sea AdriSC (Croatia)



Meteo-tsunami Warning systems

Adriatic sea
AdriSC



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- ***Complex sources :***
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  - ***Volcano (7 types of sources)***

- ***A very few number warning systems are in place :***
  - ***Landslides (Norway, Alaska, ?)***
  - ***Volcano (Stromboli (Italy), Krakatau (Indonesia), ?)***
  - ***Meteo tsunami (Balearic, Adriatic, ?)***