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- M. N. Bouin
- S. Calmant

Valérie Ballu
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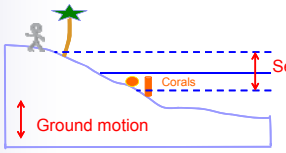
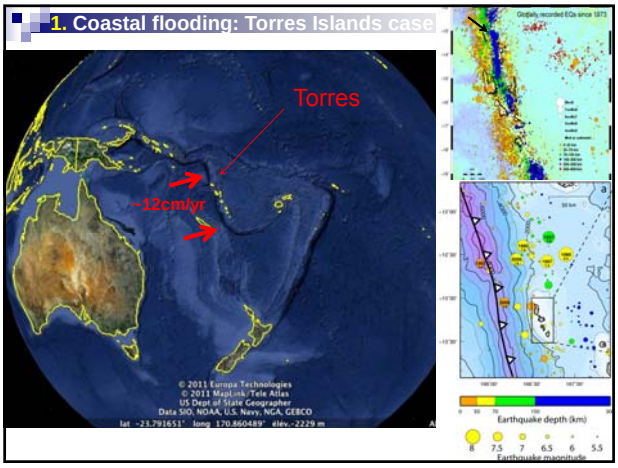
Apparent sea level rise and earthquakes



1. Coastal flooding: Torres Islands case

"possibly the world's first community to be formally moved out of harms way because of climate change" [2005 Climate Conference in Montreal, UNEP].

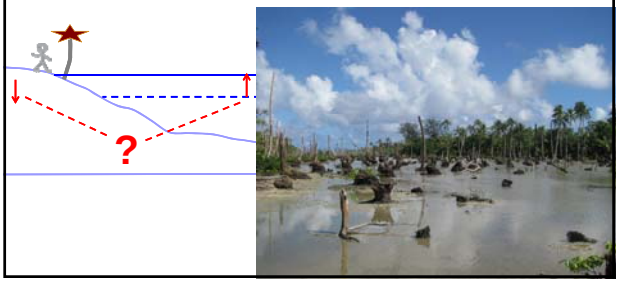
1. Coastal flooding: Torres Islands case



1. Coastal flooding: Torres Islands case

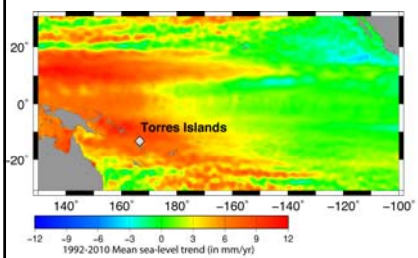
Coastal flooding in the Torrès:

- Climate related sea level rise?
- Tectonically induced subsidence?
- or a combined effect?



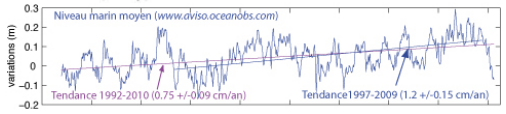
1. Coastal flooding: Torres Islands case

Sea surface height variations from satellites



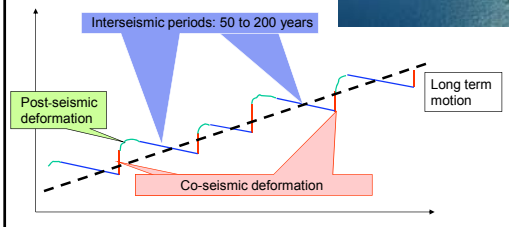
- Well above 2-3 mm/yr..
- Not linear
- Major rôle of El Niño/La Niña oscillation

Source: AVISO/CNES/CLS



1. Coastal flooding: Torres Islands case

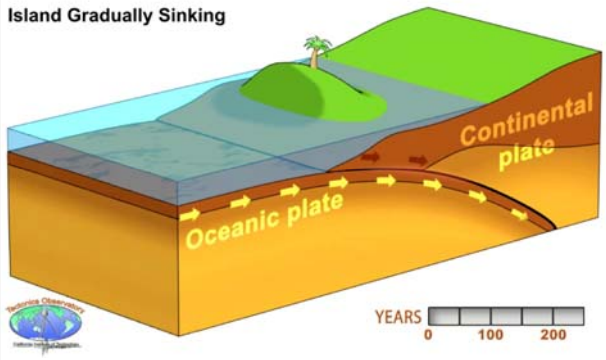
- Torres islands are rising by ~1mm/yr on the long term (Taylor et al. 1985).
  - Uplifted coral plateforms
- Long-term and short-term processes are superimposed



Typical seismic cycle in subduction zones

1. Coastal flooding: Torres Islands case

Island Gradually Sinking



1. Coastal flooding: Torres Islands case

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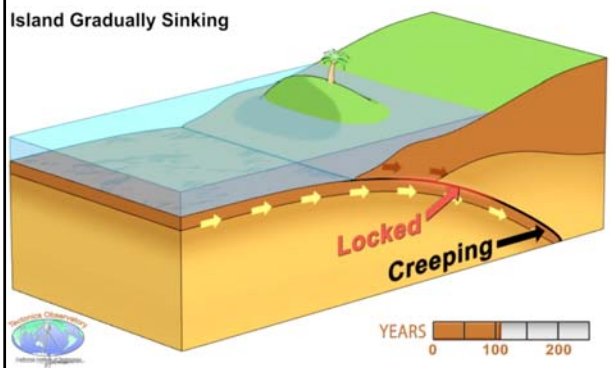

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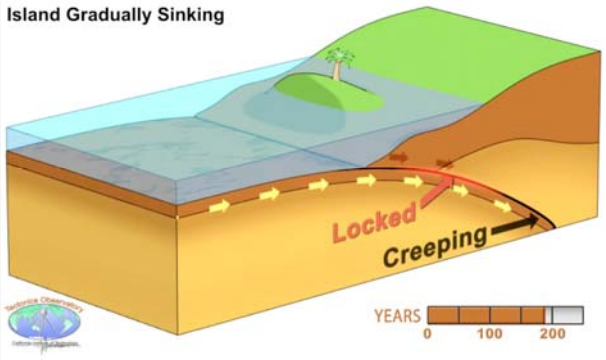
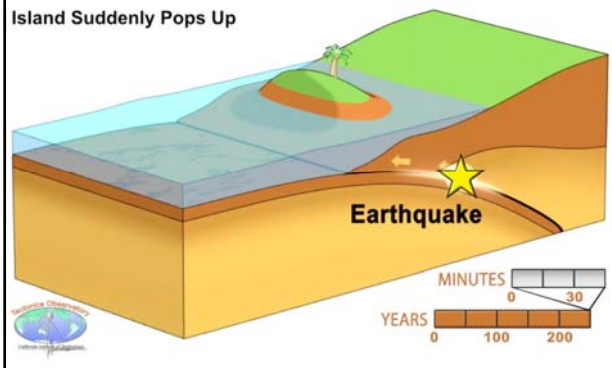
Island Gradually Sinking



1. Coastal flooding: Torres Islands case

Island Suddenly Pops Up



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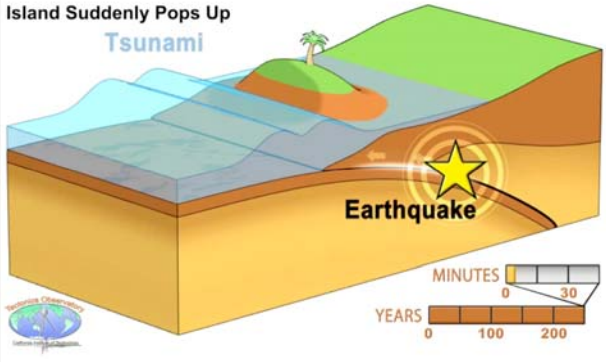
Island Suddenly Pops Up

Tsunami



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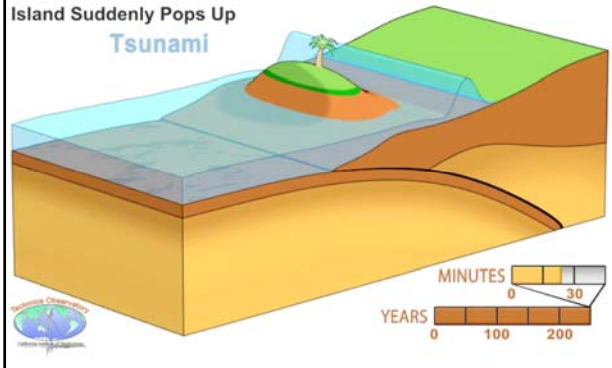

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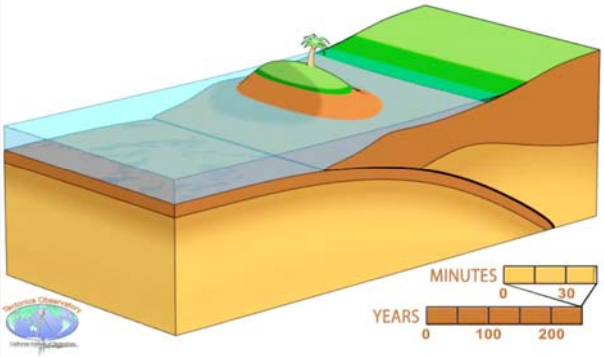

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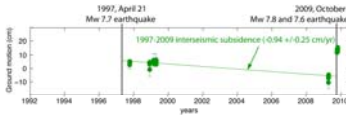
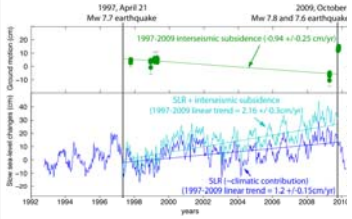


Ground motion
- Interseismic (~1cm/yr)
- Co-seismic

April 2009

2. Coastal flooding: Torrès Islands case



Ground motion
- Interseismic (~1cm/yr)
- Co-seismic

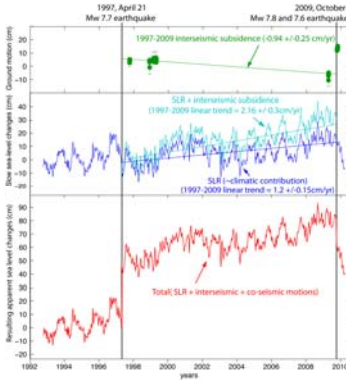
+

Sea level variations
- Seasonal + ENSO
- long term

=

Apparent sea level change

2. Coastal flooding: Torrès Islands case



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- Interseismic (~1cm/yr)
- Co-seismic

+

Sea level variations
- Seasonal + ENSO
- long term

=

Apparent sea level change

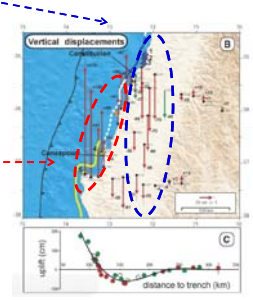
Ballu et al., PNAS 2011

2. Coastal flooding: Torrès Islands case

- The dominant factor, in this particular case, is not the global warming…
- Is it a problem to mis-identify the cause of the rise, as long as the village moved?
- Probably yes…They probably could have moved to a safer place, not exposed to future land motion or tsunami…

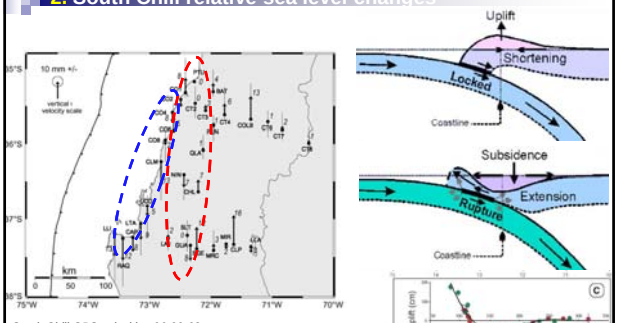
2. South Chili relative sea level changes

8.8 Maule megathrust earthquake, Feb. 27th 2010



Vigny et al. Science, 2011

2. South Chili relative sea level changes



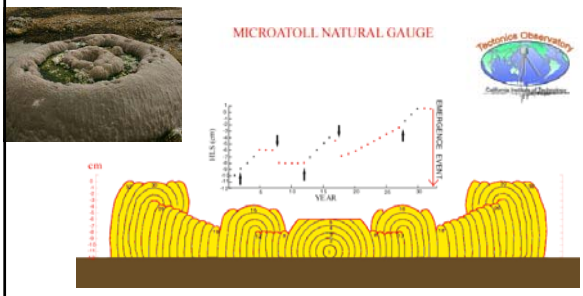
South Chili GPS velocities 96-99-02
Ruegg et al., PEPI, 2009

Vigny et al. Science, 2011

- Apparent sea level changes give insights on the locked zone geometry, the strain accumulation and thus seismic hazard
- Seismic cycles are long term processes… need for long records

3. Seismic cycle from coral sea level gauges

- Corals can record relative sea level variations
- Used to study earthquake cycles and infer earthquake hazard.
- E.g. Taylor et al., 1982, Sieh et al., 2008…



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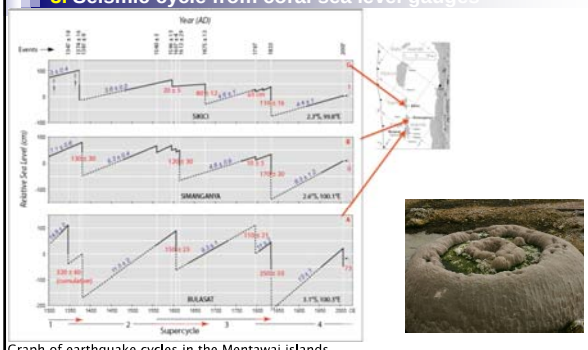
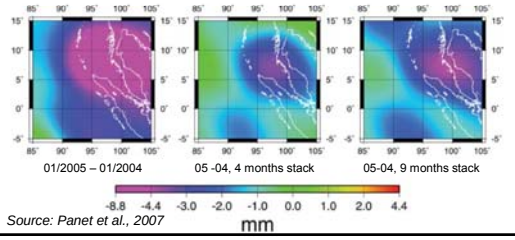


Graph of earthquake cycles in the Mentawai islands

Sieh et al., Science, 2008

4. Second order effect & geoid change

- As SL measurements accuracy increases, we may need to consider second order contribution to sea level changes.
- Melini et al. (GRL, 2004) evaluate that the global contribution of earthquakes to the long-term sealevel changes amounts to at least 0.1 mm/yr.
- Geoid variations induced by very large earthquakes can be detected in GRACE gravity data (e.g. Panet et al. 2007).



Source: Panet et al., 2007

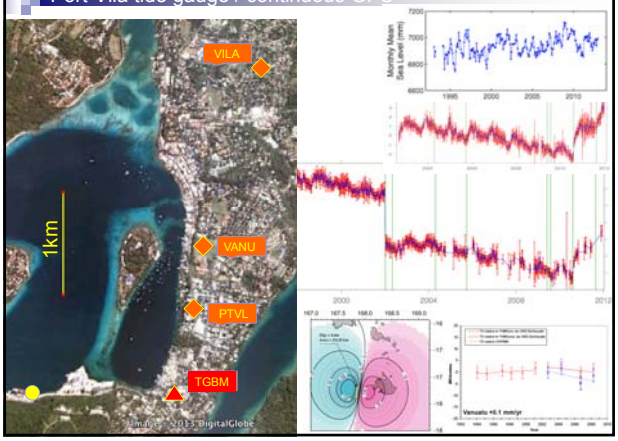
5. Concluding remarks

- By inducing static deformation of the Earth crust, earthquakes contribute to relative sea level changes
- The contribution of slow interseismic deformation may be significant but hard to identify in the apparent sea level changes, without independant data (mis-interpretation of the Torres « climatic » refugies).
- Relative sea level changes recorded by natural markers (such as coral) provide earthquake cycles records and may be key in seismic hazard assessment.
- The entire Pacific Ocean is bordered by active plate boundaries:
  - TG must be corrected for ground motion for proper global SLR assessment
  - Relative sea level changes may be used for geophysical purpose

5. Concluding remarks

Not many EQ free coastlines around the Pacific ocean

Port-Vila tide gauge / continuous GPS



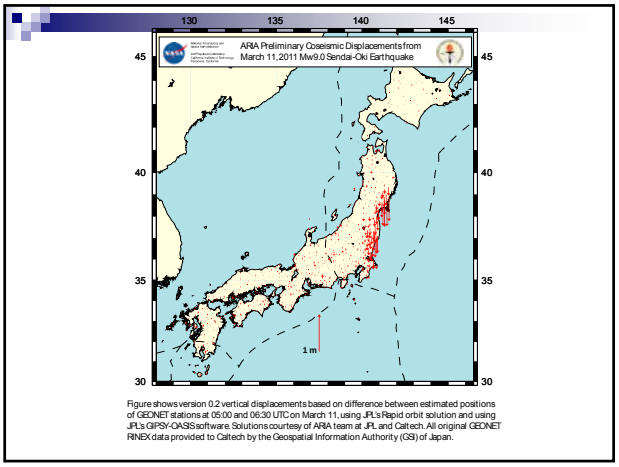
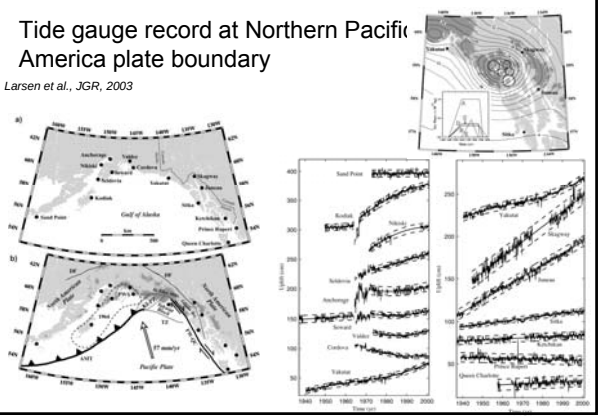


Figure shows version 0.2 vertical displacements based on difference between estimated positions of GEONET stations at 05:00 and 06:30 UTC on March 11, using JPL's Rapid orbit solution and using JPL's GIPSY-OASIS software. Solutions courtesy of ARIA team at JPL and Caltech. All original GEONET RINEX data provided to Caltech by the Geospatial Information Authority (GSI) of Japan.

Tide gauge record at Northern Pacific / North America plate boundary

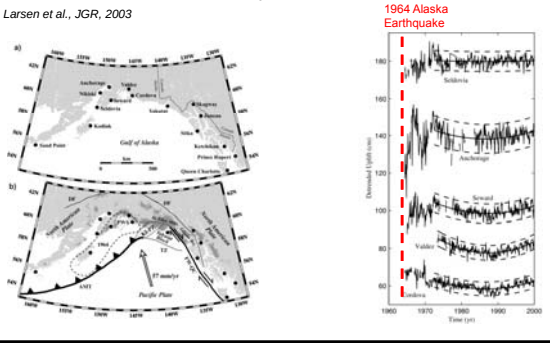
Larsen et al., JGR, 2003



Tide gauge record at Northern Pacific / North America plate boundary

Larsen et al., JGR, 2003

1964 Alaska Earthquake



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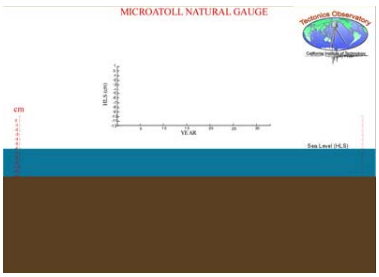
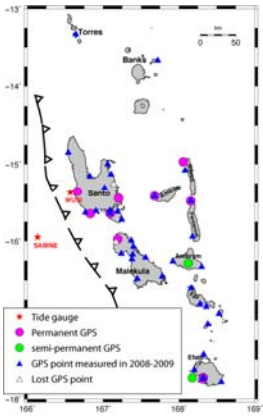
- Work from Taylor, Cabioch, Sieh…



2. Coastal flooding: Torrés Islands case

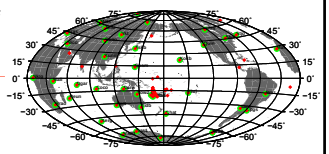
- Geodetic network installed in 90's (U. Texas, Orstom, ST, DGM)
- Periodic reoccupation

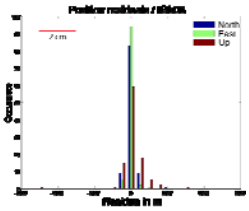
April 2009

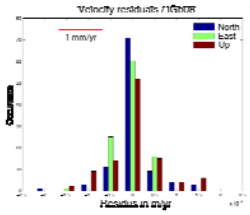


Strategy for vertical velocity estimate

- Stacking / alignment on IGb08 using CATREF (Altamimi et al., 2007)
- Global and homogeneous reference network (Woppelmann et al. 2004)







1. Introduction

Apparent or relative sea level change.