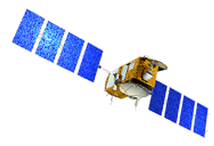
# Using radar altimetry, combined with bottom pressure data, to measure underwater vertical movements

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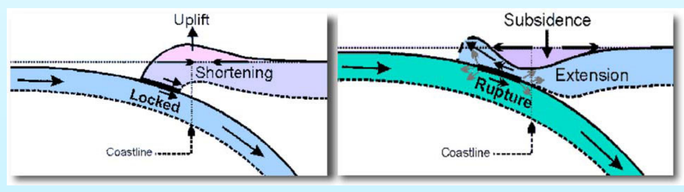
**Summary**:

*Subduction zones, when locked, have the potential of generating the most devastating events (earthquakes and tsunamis) on Earth. As subduction plate boundaries always lie underwater, measuring the deformation offshore is crucial for understanding the stress accumulation at these zones and thus for mitigating potential seismic risk.* ***Here, we combine altimetry and tide gauge data to obtain vertical deformation at two offshore sites in the New Hebrides subduction zone****. The two sites, Sabine and Wusi Banks, are located on both sides of the tectonic plate boundary, respectively on the subducting Australian plate and the over-riding Vanuatu Arc. The 1999-2010 water depth series derived from seafloor pressure are combined with altimetry data to determine movements in a global reference frame. Sabine Bank pressure data combined with EnviSat data show that the deformation rate on the subducting plate is close to zero (-0.1 +/- 1.2 mm/yr) and Wusi Bank pressure data combined with Jason-1 and EnviSat data show that the over-riding plate is subsiding at this site at a rate of several mm/yr. This subsidence (downward motion) indicates that the subduction is locked and that stress is accumulating in the area. This study demonstrates for the first time that combined altimetry and pressure data can be used to derive absolute vertical motion offshore and thus bring new insights on processes occurring at subduction zones.* ***It also illustrates the usefulness of continuous long-term high accuracy radar altimetry records, even at local scale****.*

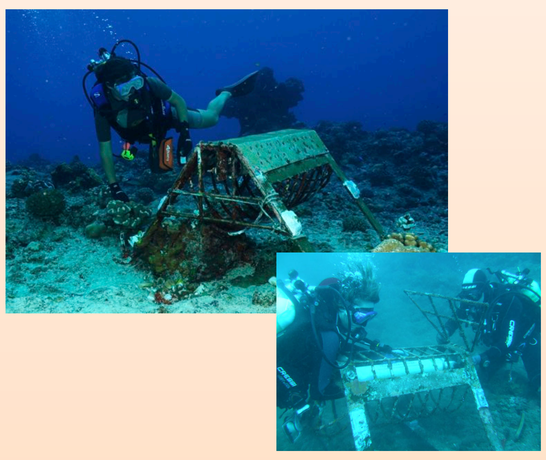

## Why developping new tools to monitor vertical deformation underwater?

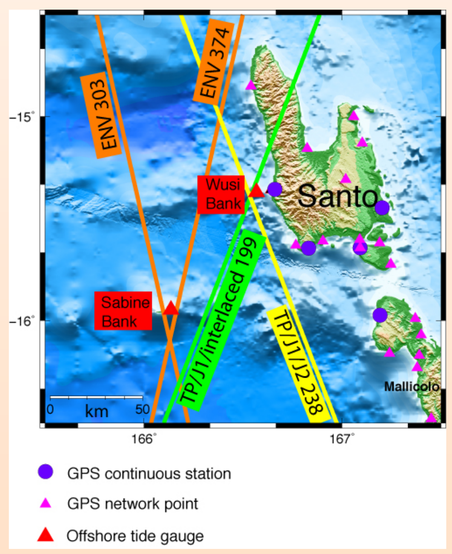
- Vertical deformation is a key indicator of stress accumulation (seismic coupling) and thus of seismic hazard.



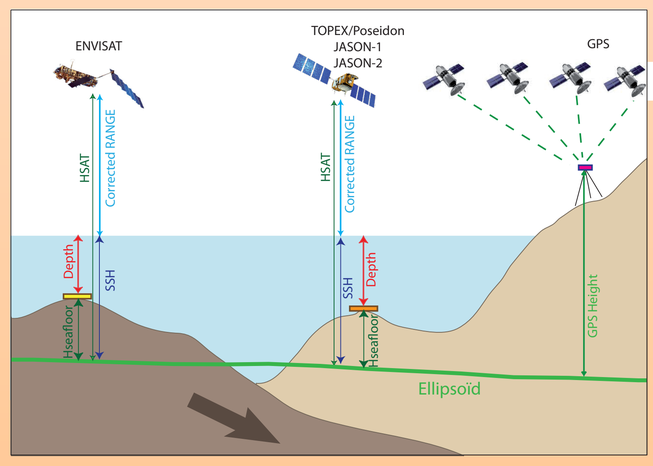

- In subduction zone, the surface interplate contact, where the expected vertical deformation is the strongest, lies underwater.
- For example, although densely collected, on-shore geodesy data were insufficient to fully understand stress accumulation before the Tohoku-Oki 2011. This illustrates how much offshore measurements are necessary both to monitor stress accumulation before the event (Sato et al., 2011a) and the stress release during the event (Ito et al., 2011; Sato et al., 2011b).

## Experimental configuration

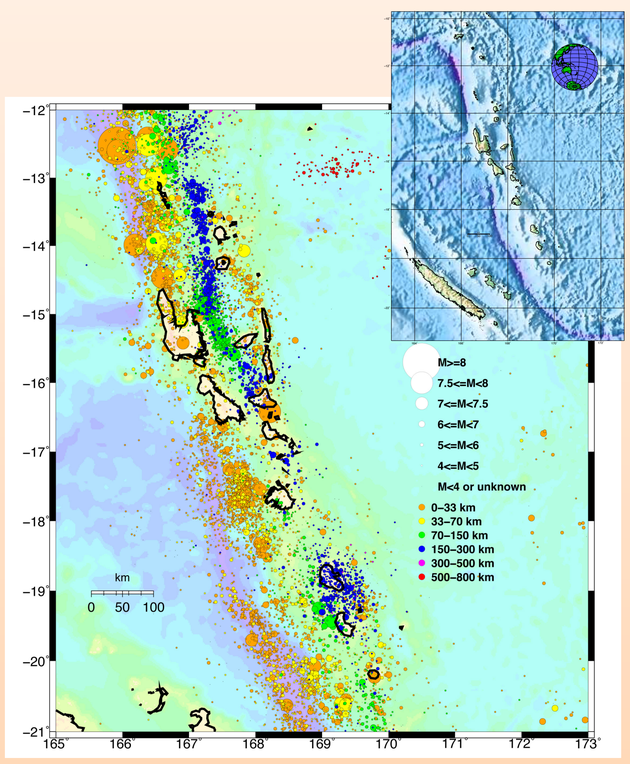





- Exceptionnal location for altimetry: 2 seamounts located beneath altimeter ground tracks crossover points for the nominal and interleaved missions of Topex-Poseidon, Jason1 and soon Jason2 and for the ERS/Envisat missions.
- Both seamounts are located on both sides of the plate interface, allowing the direct analysis of vertical motion close to plate limit, where vertical deformation is expected to be the strongest in case of seismic stress accumulation.




## Study area

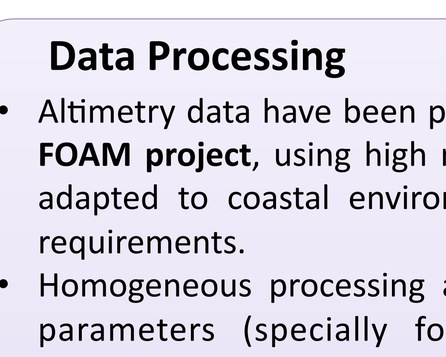



- The New Hebrides Subduction zone is part of Pacific Ring of Fire, one of the most active seismic zone. The Australian plate is diving under the North Fiji Basin, on the western border of the Pacific plate at a mean convergence rate of 12 cm/yr.
- About 1 M>7 EQ per year.
- Vertical motions happen at different time scales depending on their generating mechanism (interseismic, co-seismic, long term related for instance to isostasy…).

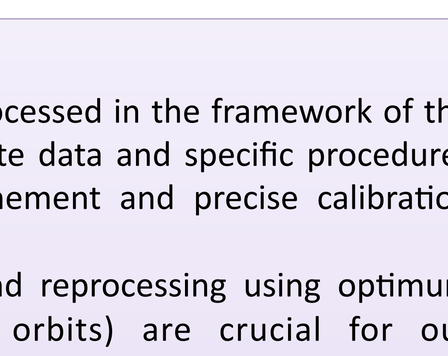
- Interseismic vertical deformation in some places is strong enough to be percevable by local people at decadal scale and had been mistaken for climate related sea-level change (for instance in the Torrès islands, Ballu et al. 2011).

## Data Processing

- Altimetry data have been processed in the framework of the **FOAM project**, using high rate data and specific procedures adapted to coastal environnement and precise calibration requirements.
- Homogeneous processing and reprocessing using optimum parameters (specially for orbits) are crucial for our application.
- In particular, we could not obtain coherent trends between ascending and descending tracks, before the reprocessing of ENVISAT data ➡ Need for reprocessed data (ERS?).
- In turn, applying calibration procedures on exotic data sets, may bring useful insigths for the altimetric community, thanks to the diversity of environmental parameters.

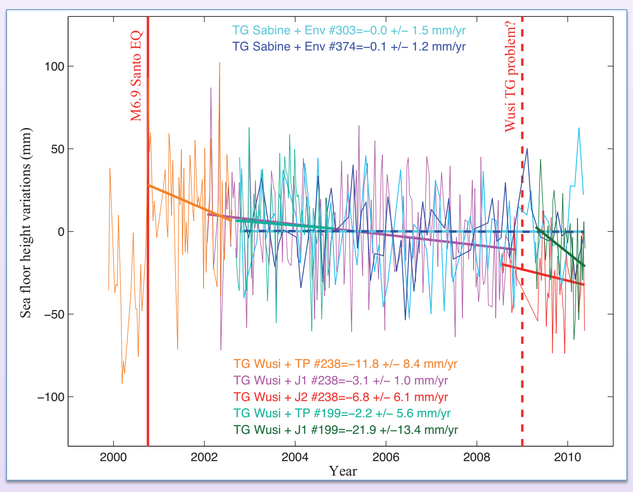



*Example of along-track geoid error estimation.*
*Along-track biaises variations (altimetry derived sea surface height minus tide gauge derived sea surface height). Raw differences in grey, running-averaged (1 km) ones in black.*

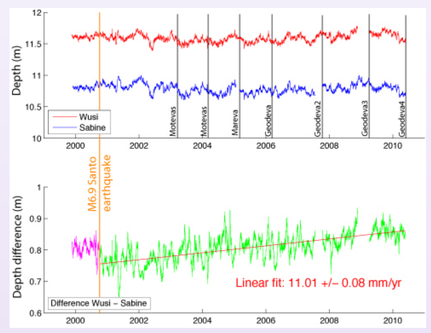



*Land contamination effect on the wet tropospheric correction. The plot shows differences between radiometer (GDR or decontaminated values) and modeled values averaged along the track on successive 5 km long windows. We used Brown (2010) decontamination algorithm (EPD).*

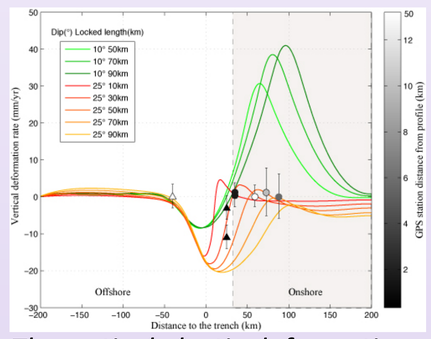
## Results




*Absolute motion derived from tide gauge and altimetry data. We can see a clear difference in trend between the two gauges (on 2 different tectonic plates).*




*Relative motion between both tide gauges, located on both sides of the plate boundary.*




*Modeling of the vertical deformation across the plate boundary, using both on-land and offshore data.*

*Theoretical elastic deformation profiles are computed using PyLith finite element code (Aagaard et al., 2008).*

- ***Subsidence of the over-ridding plate close to the plate limit***
- ***Evidence for locking of the subduction.***
- ***Requirement for precise and stable orbits, critical need of reprocessed data.***

**This study demonstrates for the first time that combined altimetry and pressure data can be used to derive the absolute vertical motion offshore and thus bring new insights on the stress accumulation in subduction zones.**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