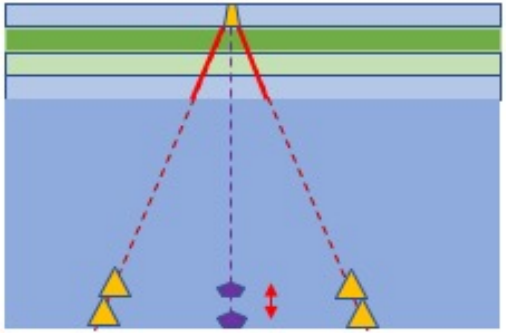
Quantifying vertical deformation of the seafloor

Why a different method for the vertical component?



Variable upper layers

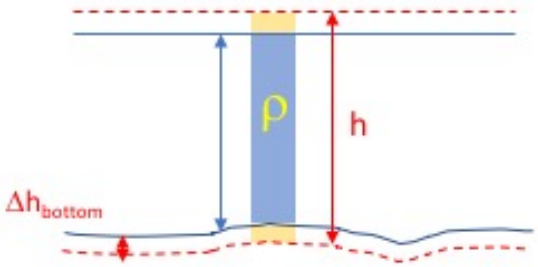
Similarities with GNSS:

- measurement platforms (or satellites) are all above the points to locate.
- Crossing of a variable layer (cf troposphere)

Direct correlation between sound velocity error and vertical position.

Using pressure :

Seafloor Pressure = $P_{atm} + P_{water} = P_{atm} + \rho gh$

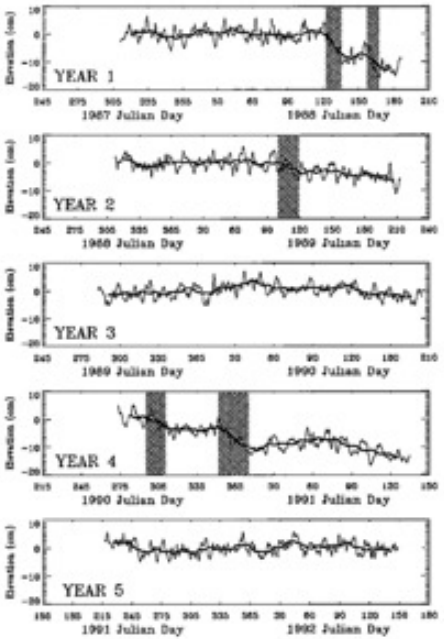


Simple concept

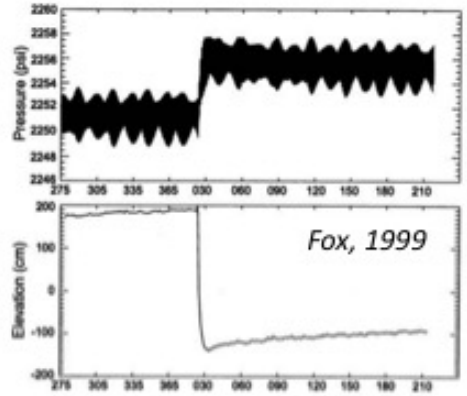
1 cm ~1 mbar

The challenge is to detect/identify Δh_{bottom} in the signal.

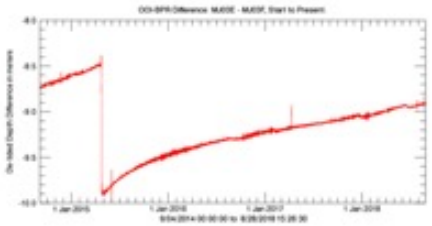
First measurements on Axial volcano *(Fox, 1990, 1993, 1999)*
Evidence of episodes of slow deformation (few cm in few days)
Evidence of a 3m subsidence related to the 1998 eruption
Today, measurements are continued (4 sites) as **part of the NSF Ocean Observatory Initiative (OOI) cabled observatory**.

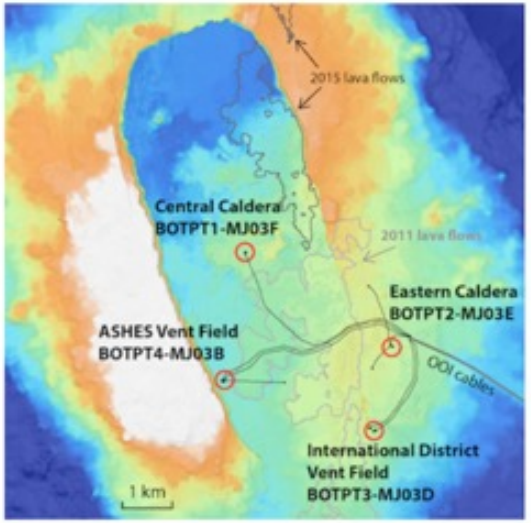


Fox, 1993

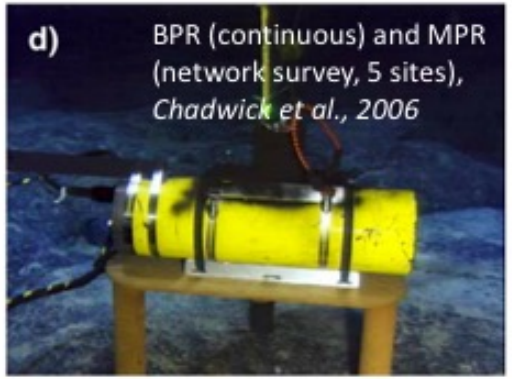


Depth-difference (MJ03E-MJ03F), Start to Present





Map of Axial caldera with OOI cables (black lines), recent lava flows (grey outlines), and locations of BOTPT instruments (red circles).



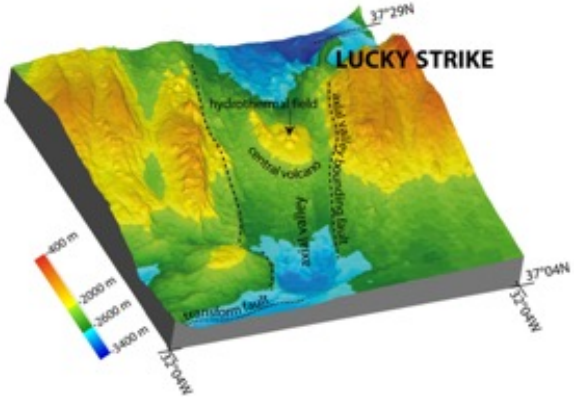
Vertical seafloor deformation studies in France

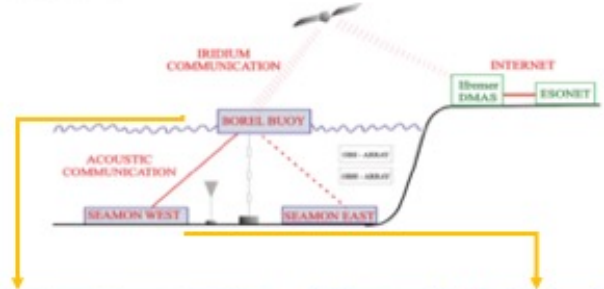
- On the Mid-Atlantic Ridge, in the framework of EMSO (European Multidisciplinary Seafloor and water column Observatory). On-going.
- On the Santorini volcanoe: fast response to an increasing volcanic activity and on-land deformation. Continuous (>1year) and small network. Terminated
- In Vanuatu, as part of a land and sea geodesy project. Continuous recording at 2 sites. Interrupted but should resume.

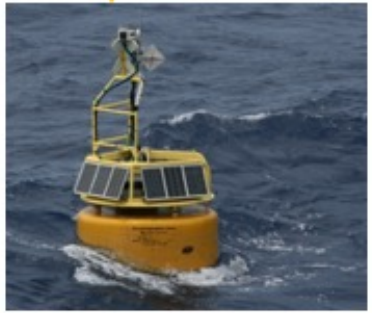
MoMAR : 2 folds geodesy experiment

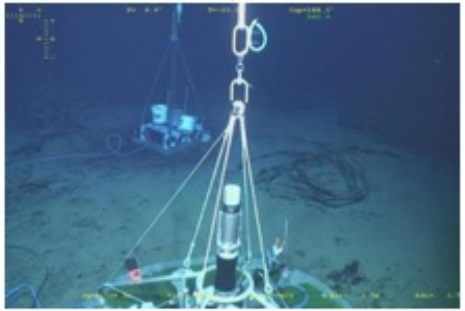
- campaign-style measurements: Graviluck cruise (2006)
- continuous recording: EMSO-Azores

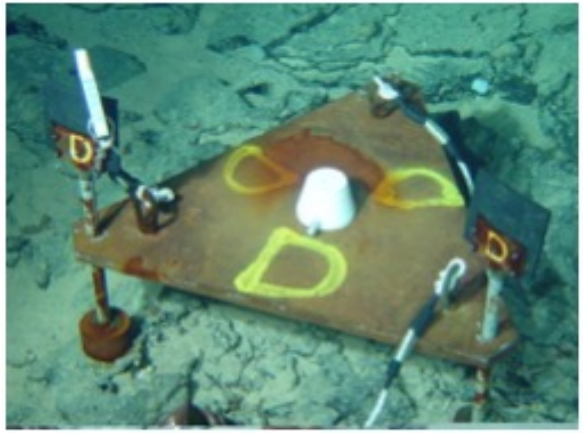
Repeated observation & continuous monitoring with data transmission to shore.

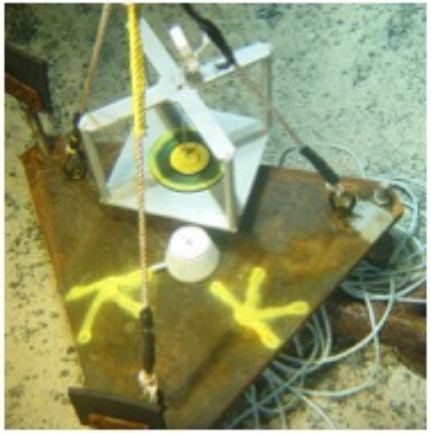


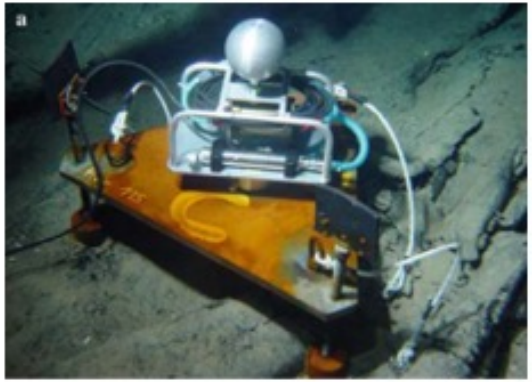


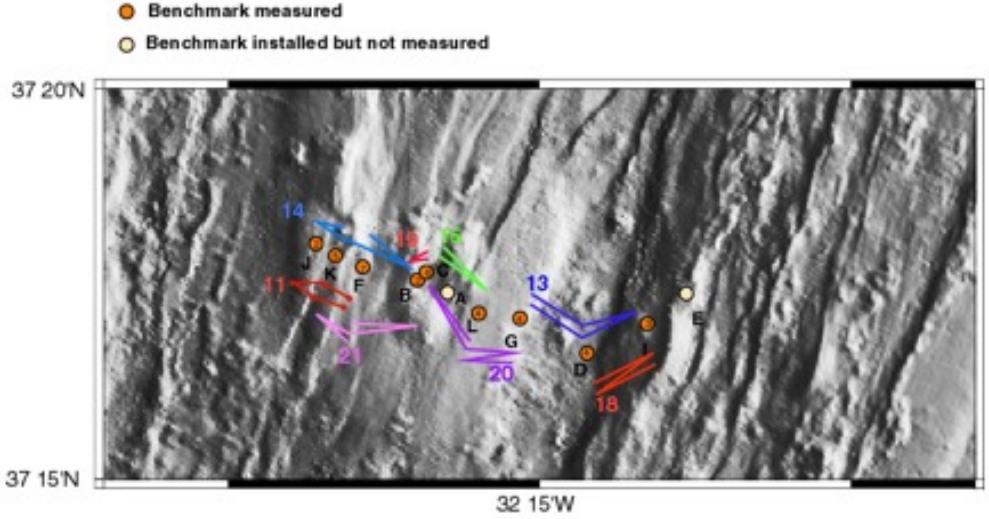






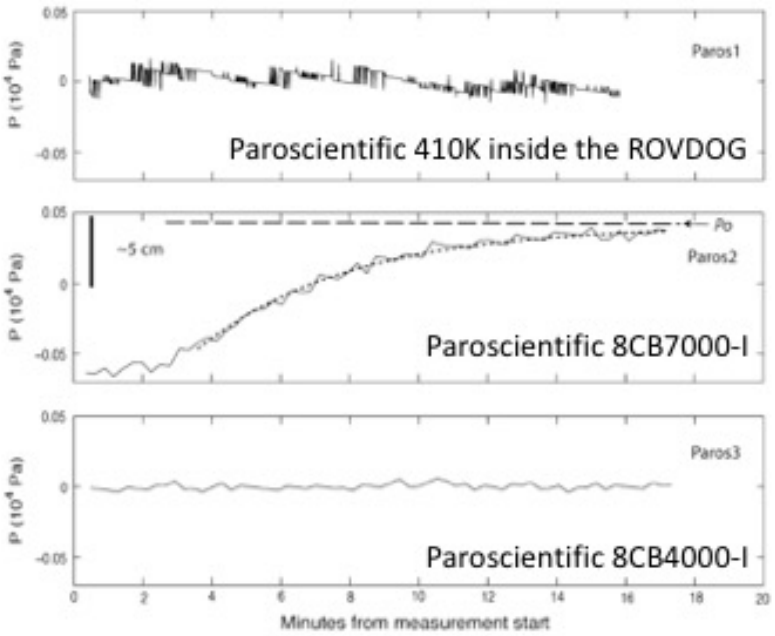






Graviluck: campaign-style measurements (9 sites)

Ballu et al., 2009

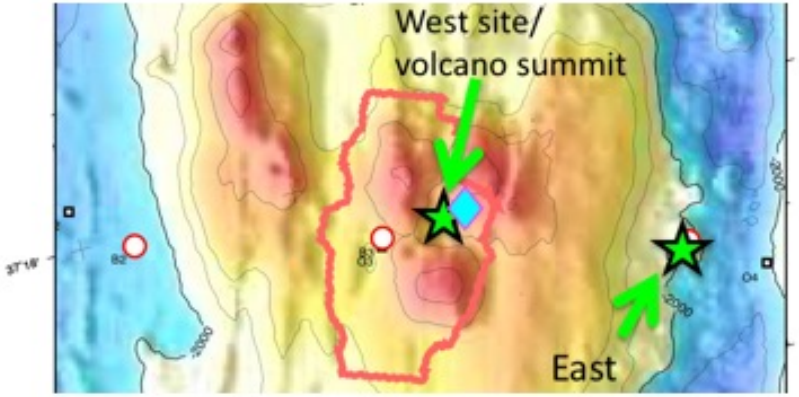


Final results after least square adjustment of the whole network, including 1 drift /day for each gauge.

Couple de repères	Dh en metres, calculés à partir des DP (1mBar ~ 1cm) 95% interval de confiance
I - D	430.374 +/- 0.005
D - G	-330.016 +/- 0.036
G - L	-50.681 +/- 0.008
L - C	50.996 +/- 0.006
C - B	-8.290 +/- 0.006
B - F	0.196 +/- 0.008
F - K	-35.295 +/- 0.011
K - J	0.755 +/- 0.013

The network should be able to detect **~1 cm deformation**

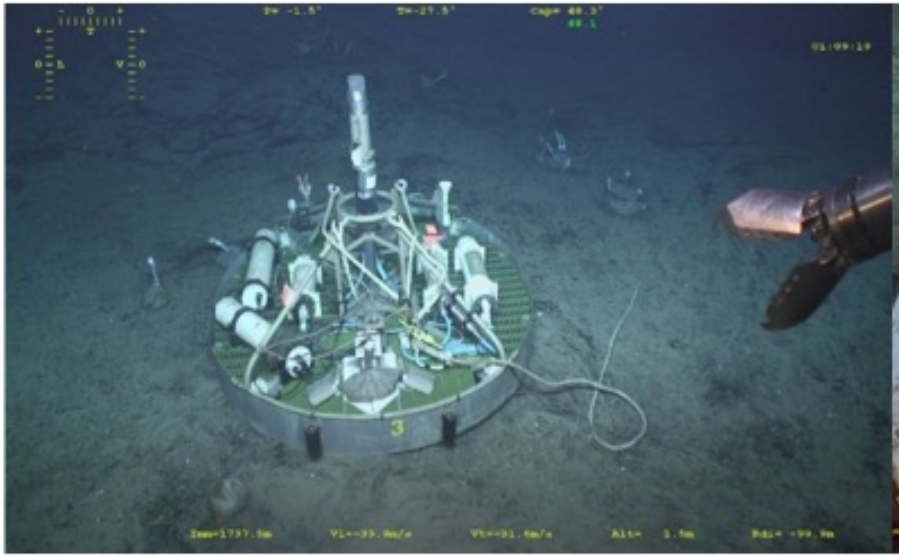
Ballu et al., 2009

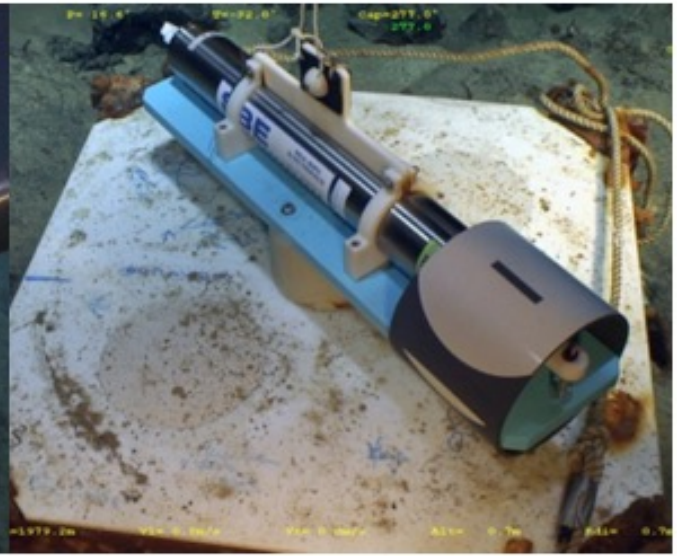


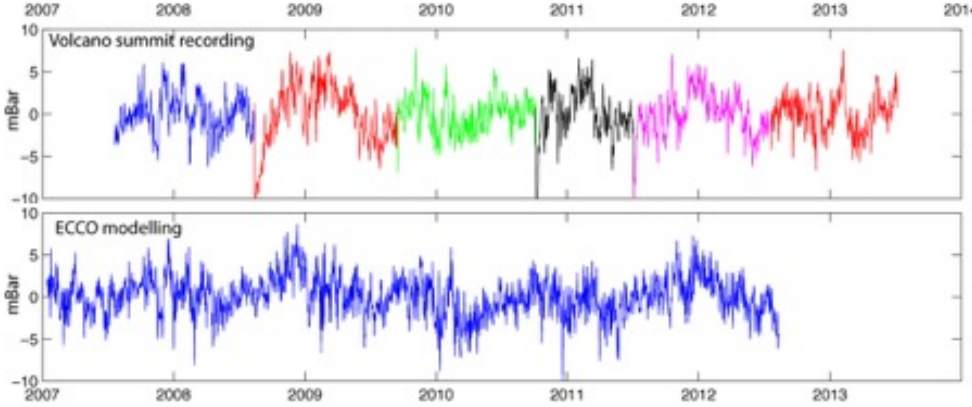
Continuous pressure recordings at Lucky Strike

Instruments : Paroscientific 8CB400-I and Seabird SBE53

- SEAMON West node
- Pressure (West and East sites)
- Sismometers

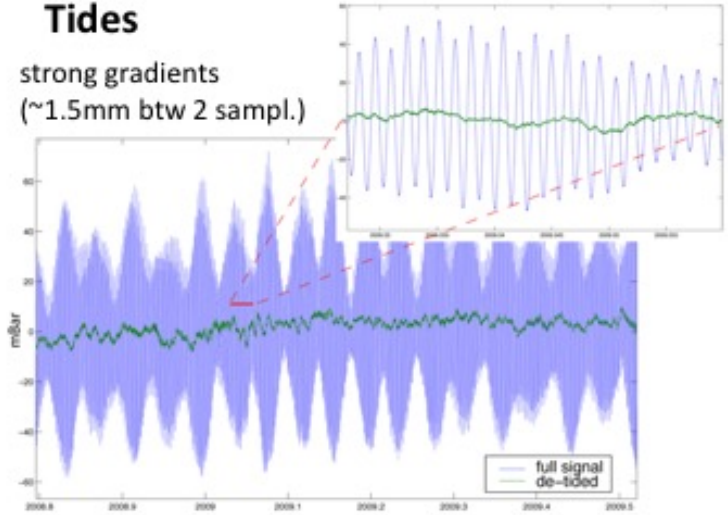




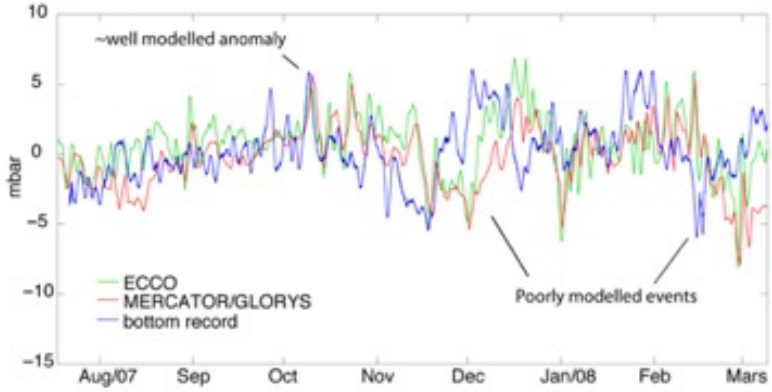


Tides

strong gradients
(~1.5mm btw 2 sampl.)

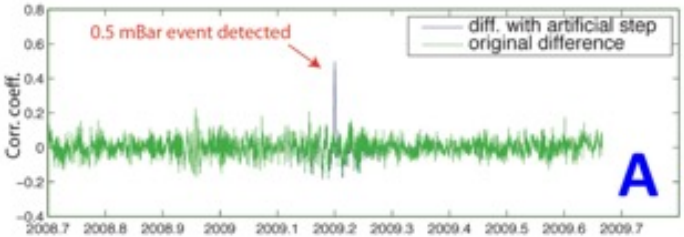


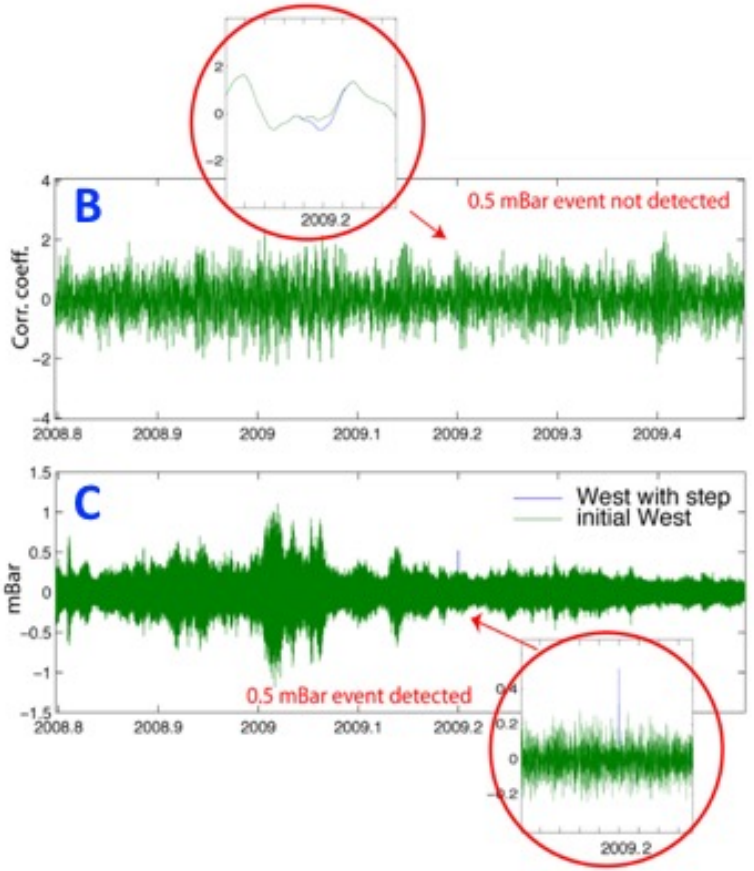
Oceanographic signal



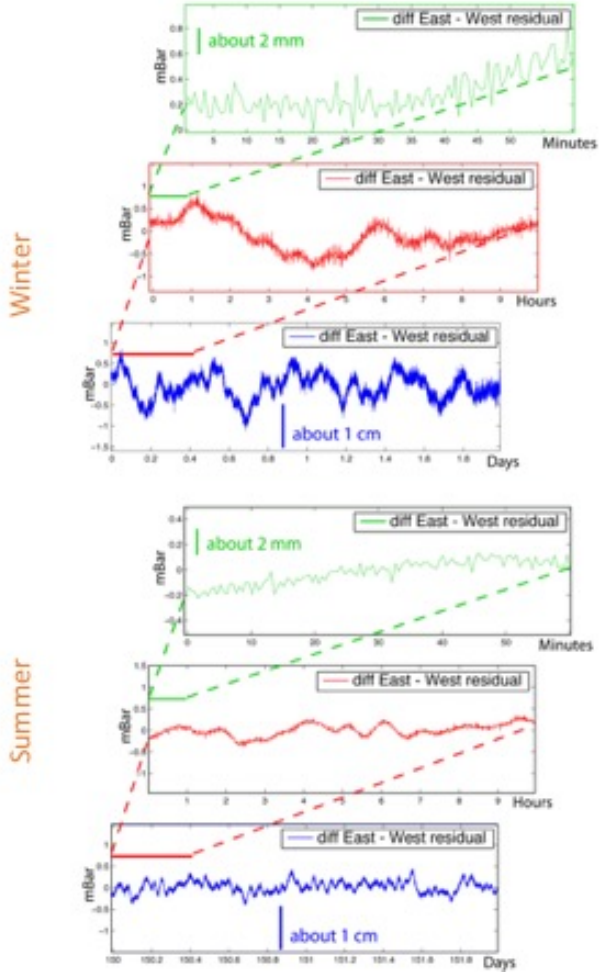
Detecting a 5 mm event?

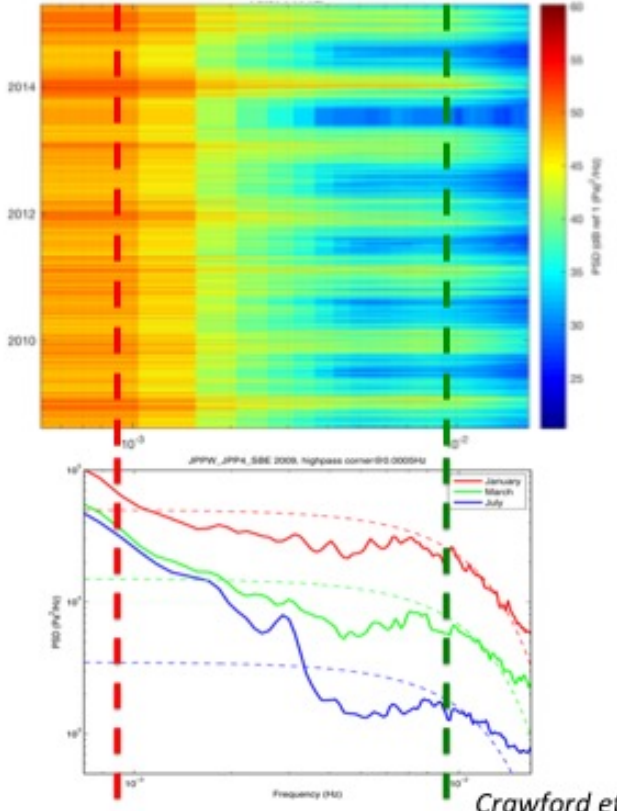
- By correlation between a time serie (TS) and a step function:
  - Easy recovery on the difference West/East (**A**)
  - 5 mm step is not recovered on a single TS (**B**)
- using timeseries gradients (P(n+1)-P(n))
  - 5 mm step can be recovered in calmer seasons (**C**).





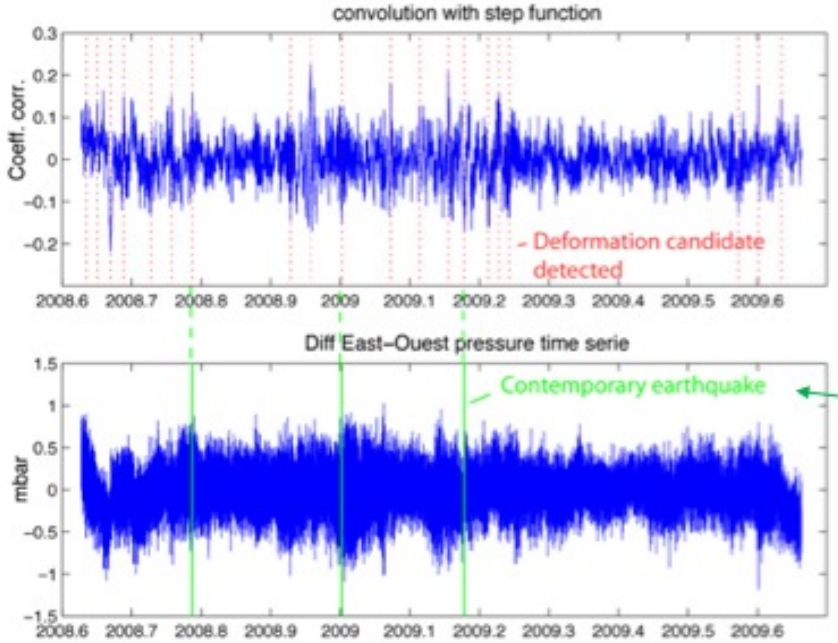
Noise on the seafloor : the role of infra-gravity waves





Crawford et al., 2015

Each peak in the correlation series is analyzed as a potential deformation candidate, and is associated to the closest earthquake in time (red dashed line). The green lines correspond to EQ happening less than 20 minutes from the event detected in the pressure series.

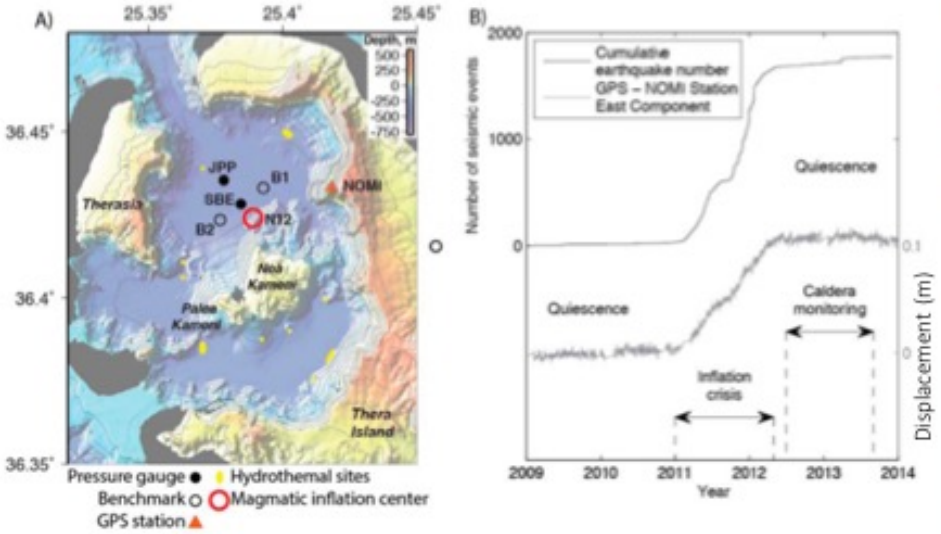


Seismicity catalog from OBSs

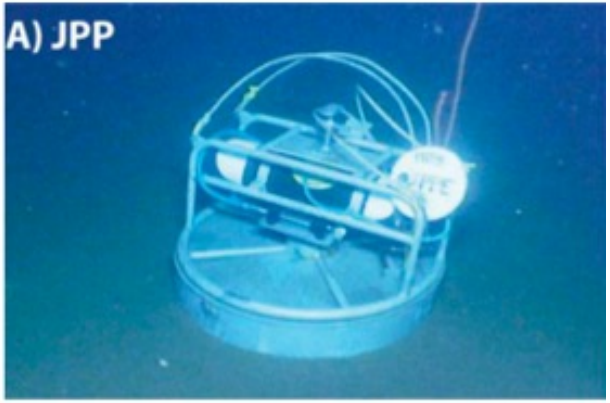
Crawford et al., 2013

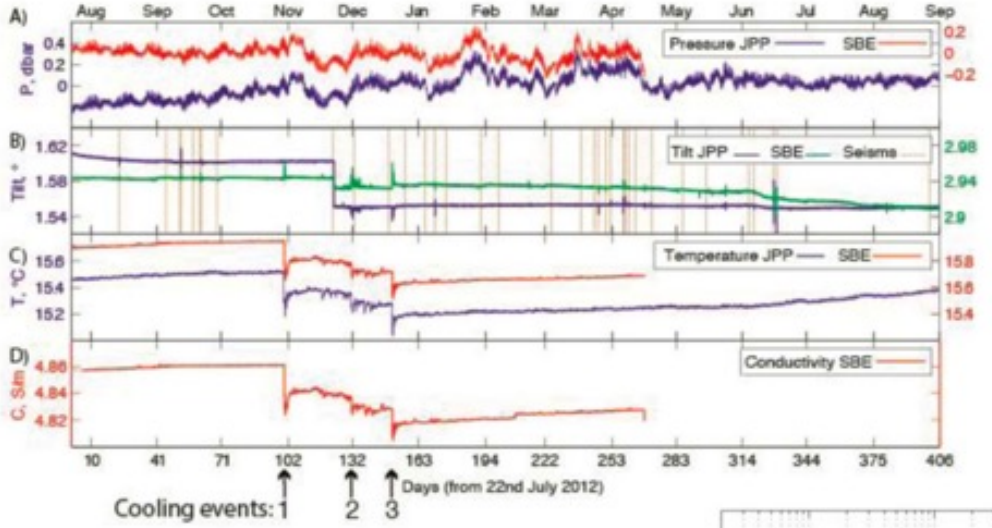
Up to now, no significant event has been detected.

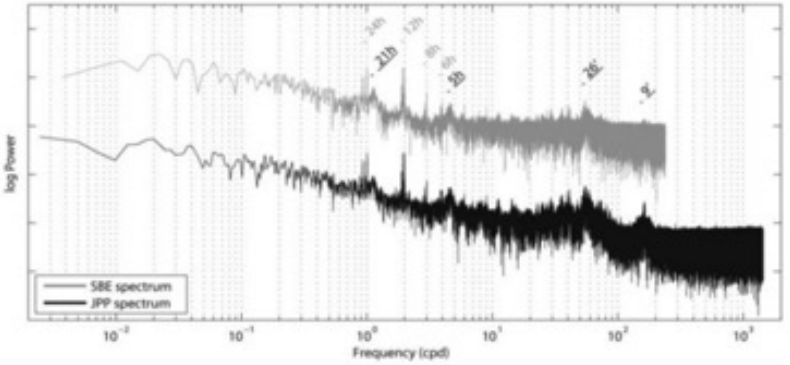
Santorini: a fast response experiment in the framework of Eurogoos fleet program.



Vilaseca et al., 2016







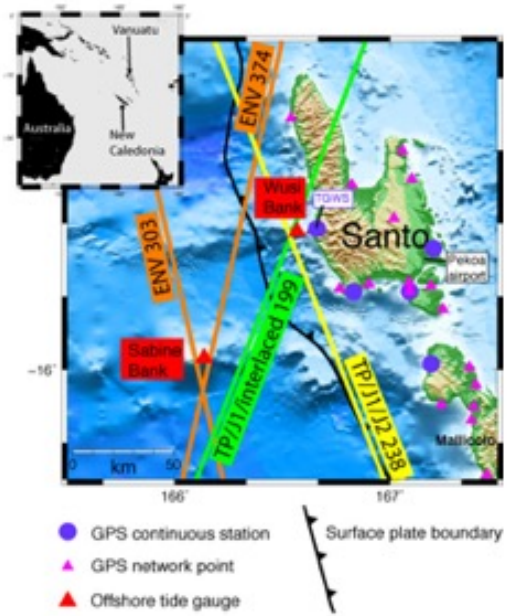
Vilaseca et al., 2016

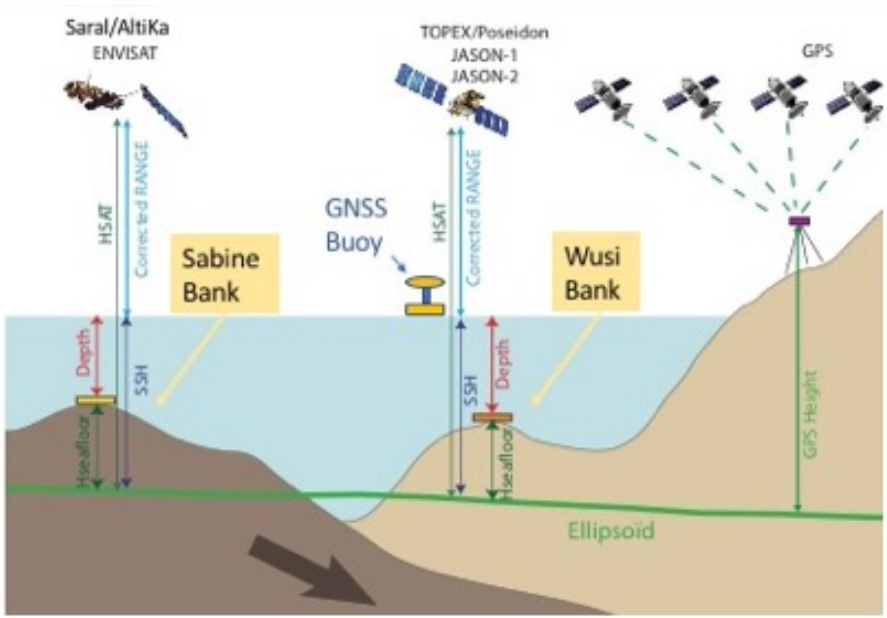
Grey : tidal frequencies / black: non tidal frequencies

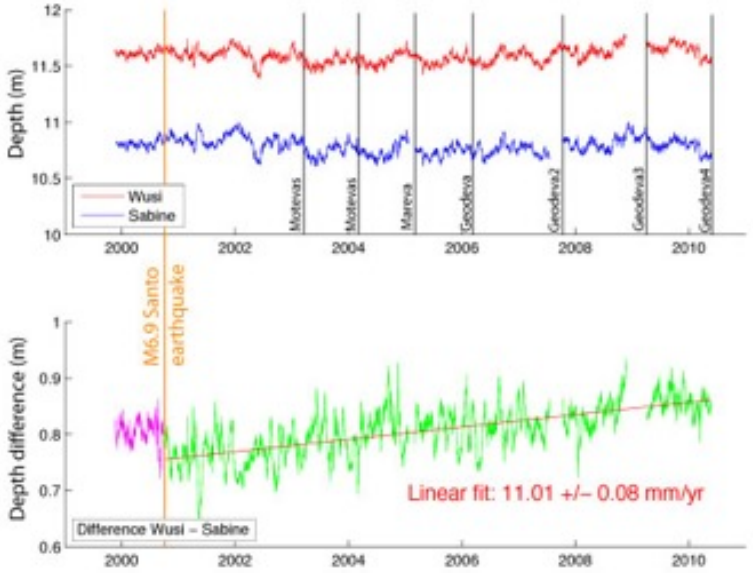
Monitoring subsidence in a subduction zone

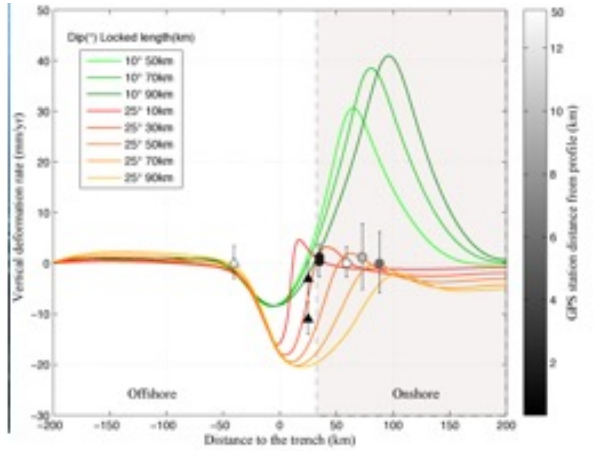
Why in Vanuatu?

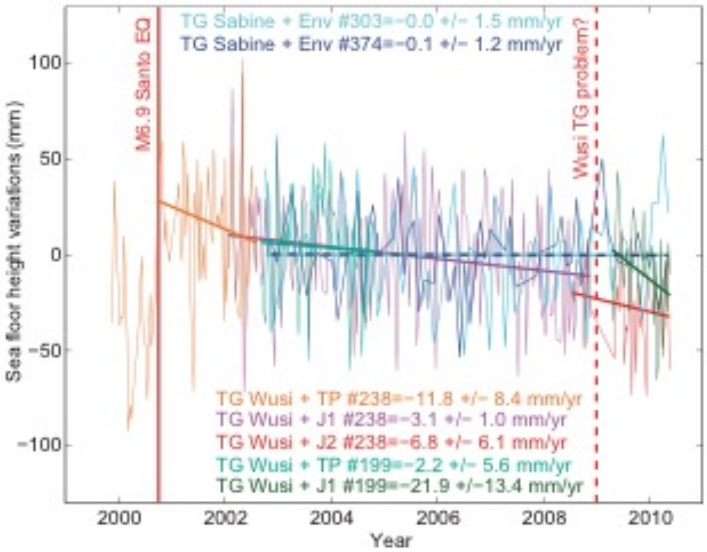
- Relatively fast subduction
- Known vertical motion, with spatial and temporal variability *(Taylor et al. 2005)*
- Propicious experimental setting with shallow seamounts and altimetry satellites











Differential motion: Wusi is subsiding with respect to Sabine Bank

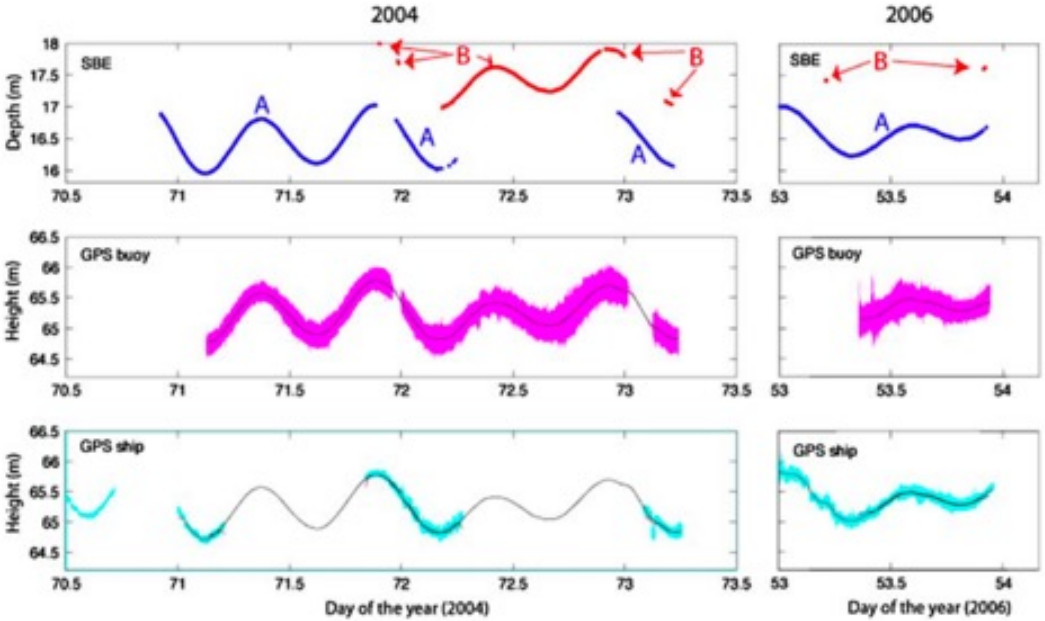
« Absolute » motion (Pressure + altimetry) in a geocentric reference frame:

- Sabine Bank (Australian plate) is stable,
- Wusi Bank (overriding plate) is subsiding.

Ballu et al., 2013

Pilot experiment in Sarami Bay

Seafloor height in a geocentric frame: Combining pressure and seasurface height from GNSS data

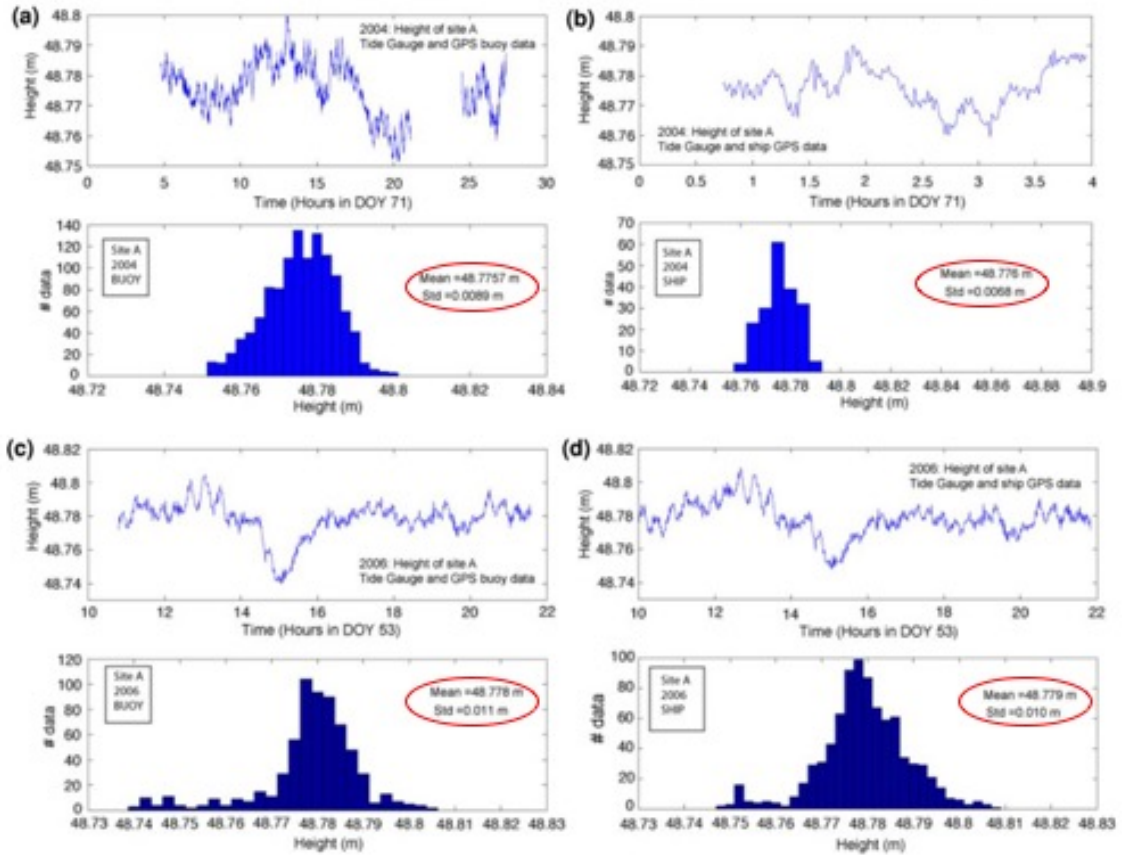


(Ballu et al., 2010)

Pilot experiment in Sarami Bay

« Absolute » height determination : ~ **1cm accuracy**

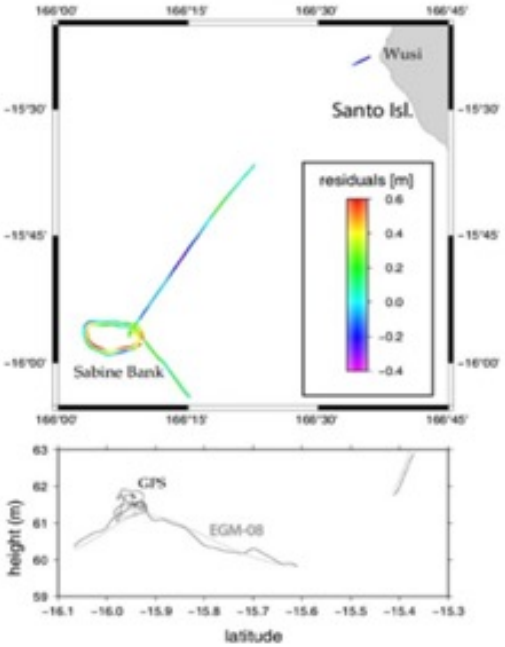
(Ballu et al., 2010)



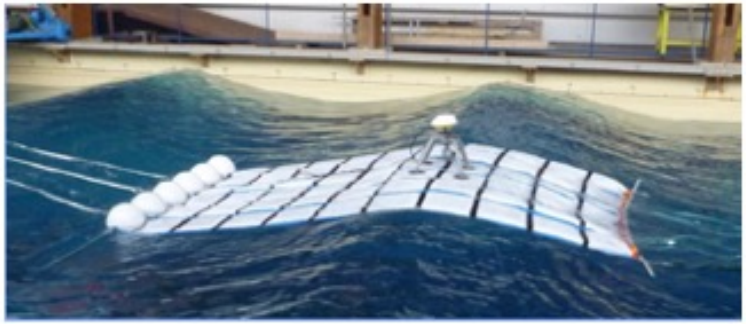
Perspectives

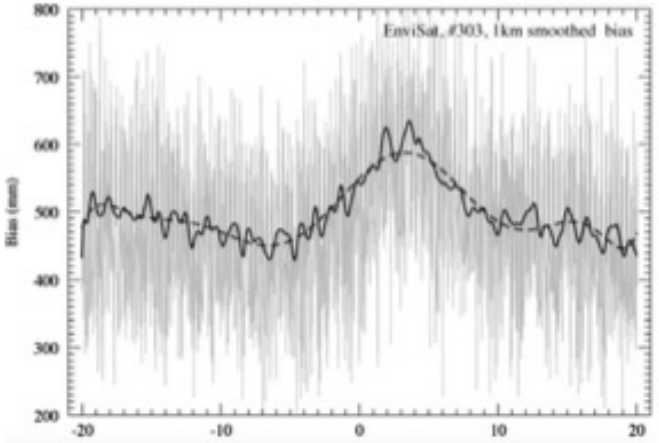
- New GNSS measurements above the Wusi and Sabine banks
- Improve altimetry processing with a better knowledge of small scale geoid.

=> **GEODEVA cruise June 2019**



From Bouin et al. 2009





From Ballu et al. 2013