RÉPUBLIQUE FRANÇAISE
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Earthquake and Tsunami Risk Estimation by Ionospheric Sounding (ETREbis)

CNES CENTRE NATIONAL D'ÉTUDES SPATIALES

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Background

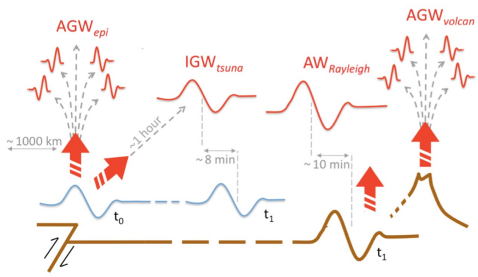
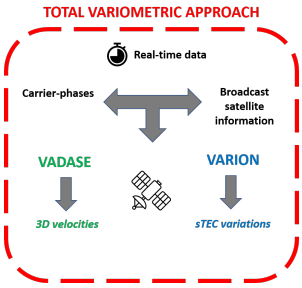


Figure adapted from Occhipinti, 2015

- Earthquakes, tsunamis and volcanic eruptions can produce **acoustic and gravity waves (AGWs)** that can perturb the ionospheric electron content generating ionospheric disturbances
- GNSS is routinely used to sound the ionosphere by estimating the ionospheric total electron content (**TEC**)
- **GNSS Ionospheric Seismology and Vulcanology** to detect the ionospheric perturbation produced by AGWs: AGW$_{epi}$, IGW$_{tsuna}$, Aw$_{Rayleigh}$, AGW$_{volcan}$

So, what's new?

- **VARION approach:** single time differences of geometry-free combination and for standalone GNSS receiver and standard GNSS broadcast products
- **Real-time application**



Ravanelli et al., 2021

Results

2022 Tonga volcanic eruption of January 15th affected the atmosphere and the oceans of all the world

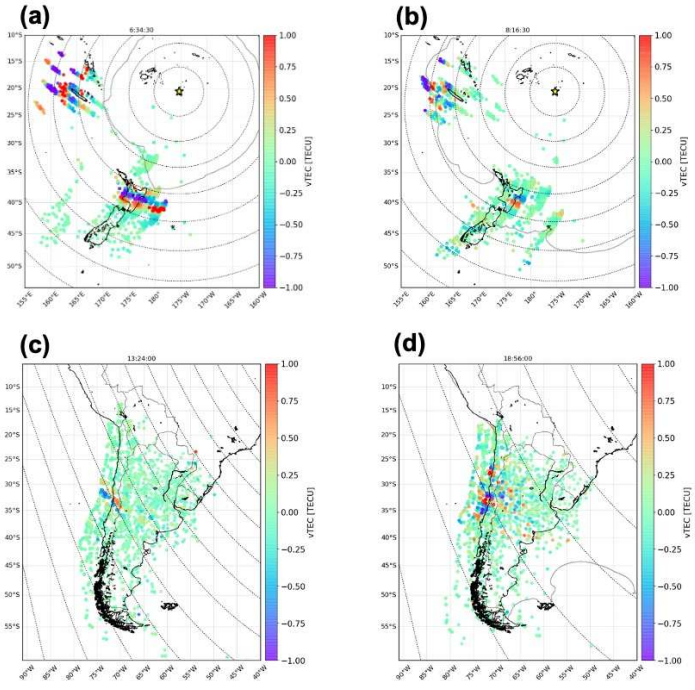
Asymmetrical response in the **oceans and in the ionosphere** in New Caledonia-New Zealand (near field) and Chile-Argentina (far field)

Detection of **Lamb waves** in the oceans and in the ionosphere:
- Lamb waves are atmospheric **pressure waves** that have a non-dispersive propagation into the Earth's atmosphere
- The propagation of Lamb waves is supposed to generate a variation in the sea level better known as **air-sea wave**: the pressure waves can lead to an energy transfer to the sea through resonance mechanism, causing a tsunami of atmospheric origin similar to a meteo-tsunami (Harkrider & Press, 1967)

At oceanic level, the Lamb induced air-sea wave is not followed by sea remarkable fluctuations, while the "regular" tsunami caused major variations in sea measurements (about 1m in the near field and almost 2m along the Chilean coastline)

At ionospheric heights, the situation is completely reversed: the Lamb wave induced CVID (peaking 1.1 TECU for both areas) was way more ample than the tsunami induced CVID (around 0.3 TECU)

Arrival of the Lamb wave in the ionosphere before that in the ocean in the far field, proving how GNSS ionospheric sounding can be helpful in **tsunami hazard assessment** and early warnings, notwithstanding the practical issues and further improvements



Ravanelli et al., *submitted to GRL, 2022*

Conclusions and Outlook

GNSS Ionospheric Sounding is fundamental:
- to **improve the reliability and accuracy of the tsunami warning systems in real-time**
- **to better understand natural hazards**

Outlook: **Real-time filtering** to highlight the earthquake/tsunami/volcanic eruption related perturbation and also a better localization of the perturbation

References

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- Harkrider, D., & Press, F. (1967). The krakatoa air—sea waves: An example of pulse propagation in coupled systems. *Geophysical Journal International*
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