Detection of tsunami induced ionospheric perturbation with shipbased GNSS measurements: 2010 Maule tsunami case study

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Outline

1 **Introduction**

2 **The VARION algorithm**
- VARION fundamentals

3 **2010 Maule earthquake and tsunami**

4 **Conclusions and prospects**

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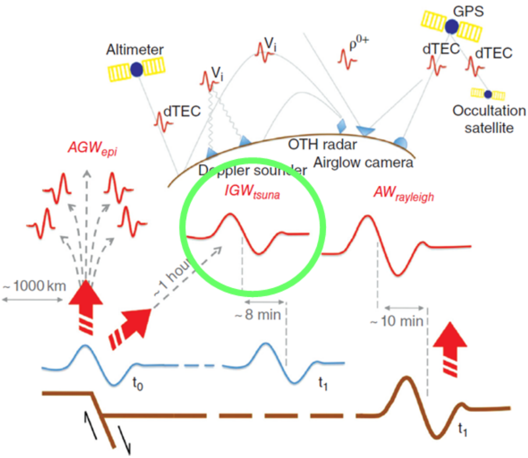
Travelling Ionospheric Disturbances (TIDs)



(*Figure from Occhipinti et al., 2015*)

Travelling Ionospheric Disturbances (TIDs)

TIDs related to gravity waves

- atmosphere as **low-pass filter**: only waves with **frequency lower than buoyancy frequency** (about 3.3 mHz at sea level) reach the ionosphere
- **strong amplification** during the upward propagation (density decreasing, momentum conservation)
- ionosphere **perturbations detectable with GNSS**

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VARION fundamentals

Variometric **A**pproach for **R**eal-time **IO**nosphere Observatio**N**

Features

- derived from **VADASE (real-time ground velocity and displacement)**
- **sTEC variation** estimation from the observations of a **stand-alone GNSS receiver** (single station approach) in **real time**
- advantages: no infrastructure, no post-processing, no initialization needed

Realization

- designed in 2015 at **Sapienza University of Rome**
- developed and validated in 2016 in collaboration with the **Jet Propulsion Laboratory, Ionospheric and Atmospheric Remote Sensing Group**

Reference

Savastano, G.; et al. Real-Time Detection of Tsunami Ionospheric Disturbances with a Stand-Alone GNSS Receiver: A Preliminary Feasibility Demonstration. Sci. Rep. 2017, 7, 46607. DOI: 10.1038/srep46607.

VARION fundamentals

Methodology

$$\underbrace{L_{4R}^{S}(t+1) - L_{4R}^{S}(t) =}_{\text{time single difference} \quad \textbf{geometry-free observation}}$$

$$\underbrace{\frac{f_1^2 - f_2^2}{f_2^2}\left[I_{1R}^{S}(t+1) - I_{1R}^{S}(t)\right]}_{\text{unknown term, sTEC variation}} + \underbrace{\Delta m_R^S + \Delta \epsilon_R^S}_{\textit{noise}}$$

Ship-based GNSS receiver application

the receiver motion does not affect the sTEC estimation process

VARION fundamentals

Methodology

- **epoch-to-epoch sTEC variations**

$$\delta sTEC(t+1,t) = \frac{{f_1}^2 {f_2}^2}{A({f_1}^2 - {f_2}^2)} \left[L_{4R}^{S}(t+1) - L_{4R}^{S}(t) \right] \quad (1)$$

note: this is a **total space-time variation**

- sTEC time series

$$\Delta sTEC(t_f, t_0) = \int_{t_0}^{t_f} dTEC(t) \quad (2)$$

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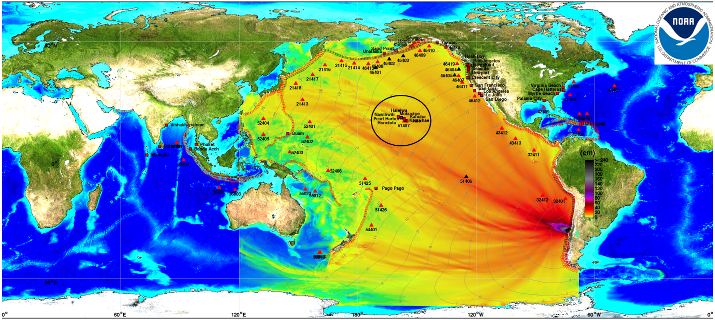
2010 Maule earthquake and tsunami

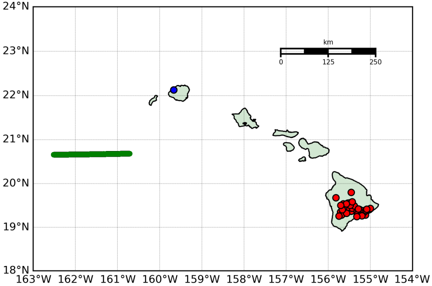
Aim of the work

- Feasibility study on the possibility to use data from ship-based GNSS receiver to detect TIDs
- application to 2010, M_W 8.8 Chilean (Maule) earthquake and tsunami



2010 Maule earthquake and tsunami

- **two GNSS** receivers installed on a **ship** (green track) moving near Kauai Island in the Hawaiian archipelago
- one GNSS permanent station (**KOKB**) placed on Kauai (blue point)



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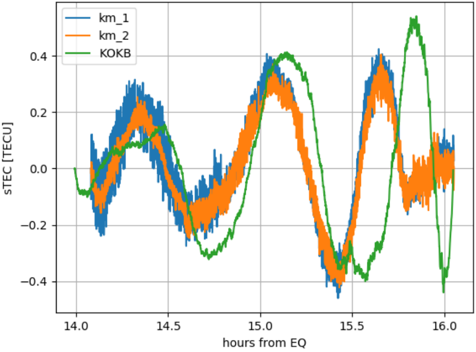

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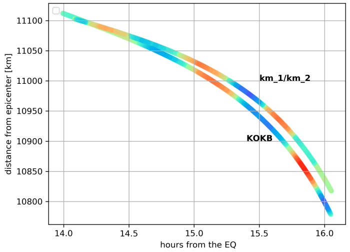

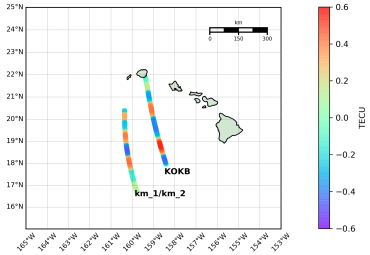

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Conclusions and perspectives

Summarizing

Ship-based GNSS data for TIDs detection

- if the same satellite is considered, the detected TIDs is the same
- **cost-effective** tool
- densification of **ionosphere monitoring**

Outlook

real-time detection of TIDs for enhancing tsunami early warning system

Thanks for your kind attention!

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