Sea Level and Climate Research Team

OBSERVATIONAL CHARACTERIZATION OF METEOTSUNAMI TRIGGERING IN THE BALEARIC ISLANDS FROM AN ULTRA-DENSE OBSERVATIONAL NETWORK

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VENOM

Abstract:

This presentation participates in **OSPP**

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Abstract:

Contents

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1. What is a meteotsunami?

Abstract:

Meteotsunamis are oceanic waves with oscillation periods that range from a few minutes to an hour. These waves can take energy from atmospheric perturbations through three resonant mechanisms (Monserrat et al., 2006)

Synoptic conditions

↓

Mesoscale pressure perturbation

↓

Atmosphere-Ocean energy transfer (Proudman Resonance)

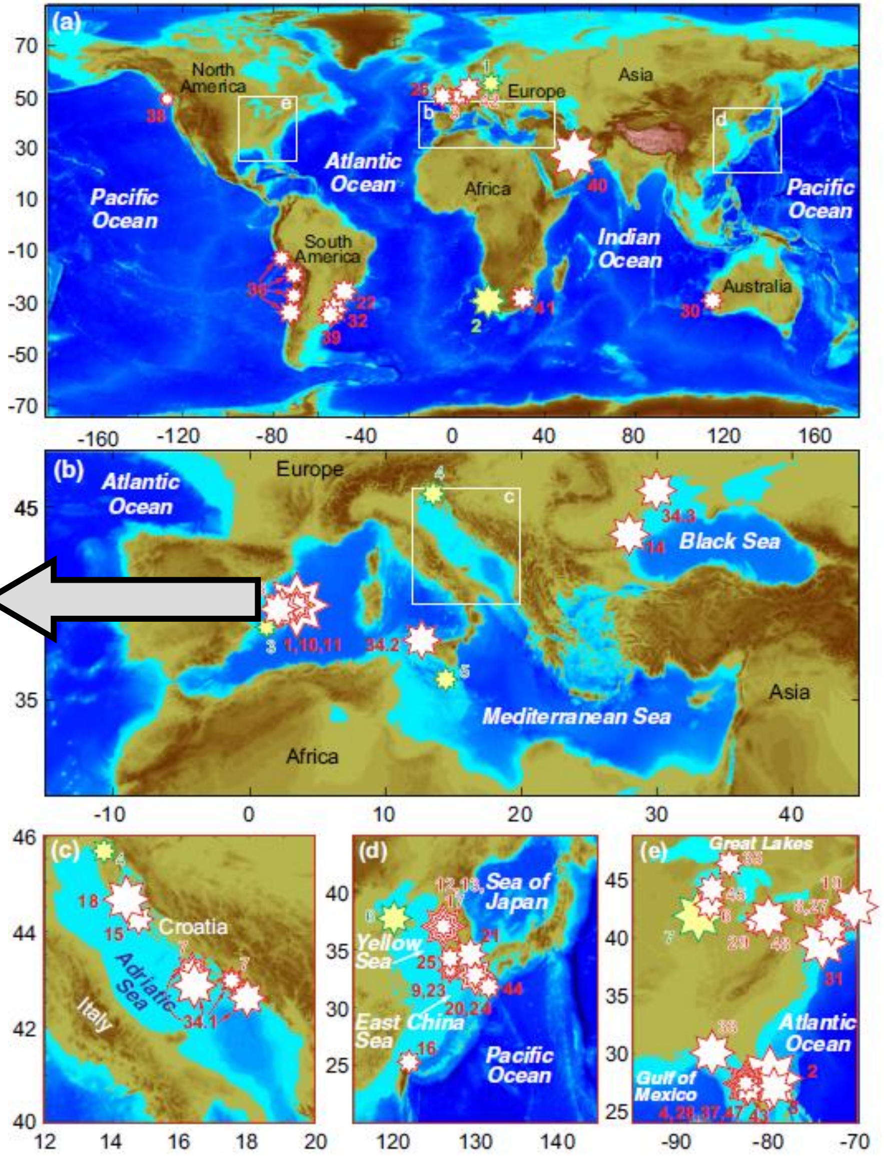
↓

Wave amplification Harbor resonance

Catastrophic consequences:

Ciutadella 15 June 2006

Source: Jansà et al., 2007



Source: Rabinovich, 2019

1. Generation mechanism

Abstract:

Numerous observational and numerical **studies have enabled to establish the basic understanding of the generation mechanism** that allows the transfer of energy from atmospheric pressure perturbations to large sea level oscillation.

Synoptic conditions

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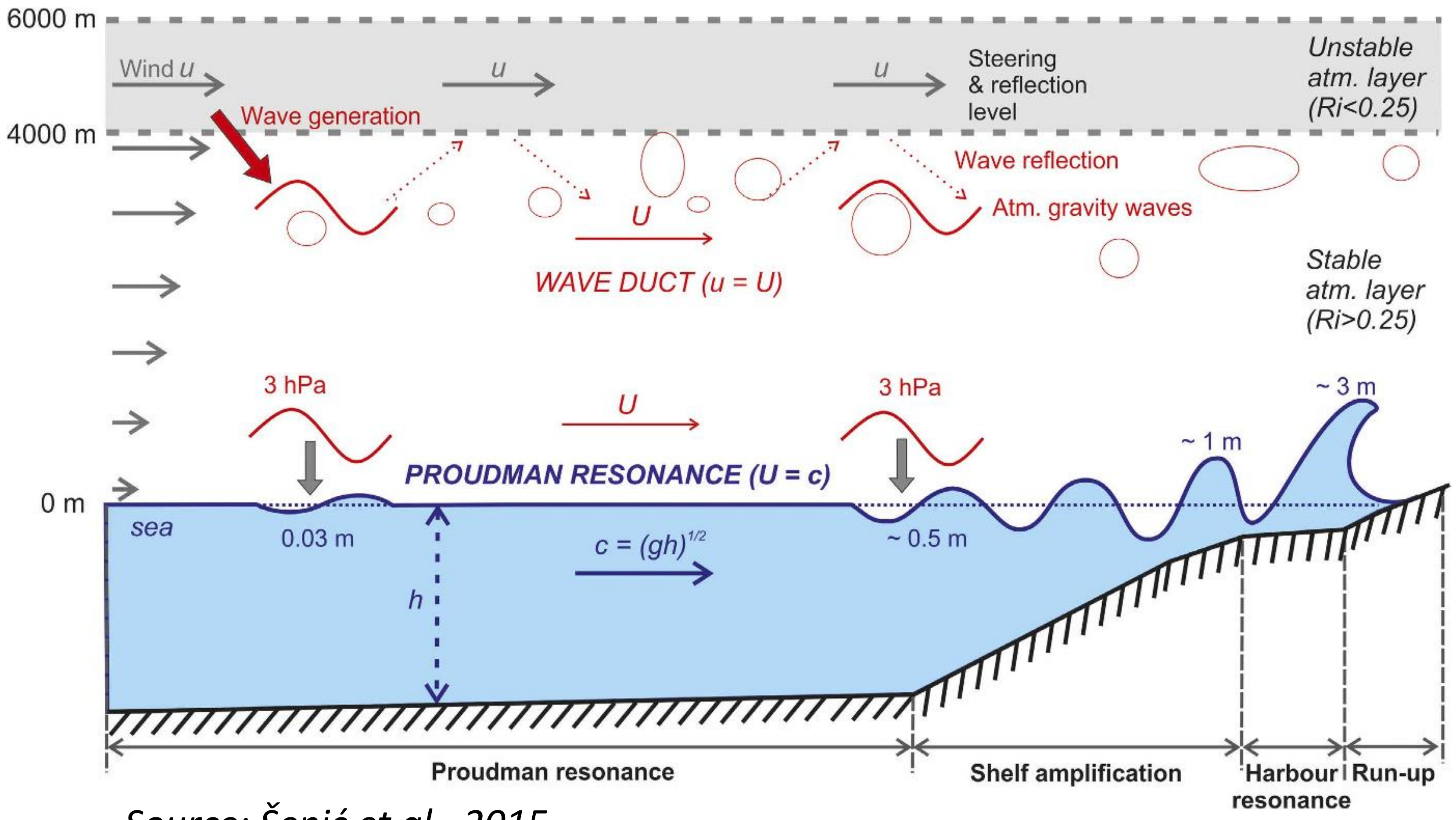
Mesoscale pressure perturbation

↓

Atmosphere-Ocean energy transfer

↓

Wave amplification
Harbor resonance



Source: Šepić et al., 2015

2. Motivation and goals

Abstract:

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Motivation:

There are unclear features in the physical processes that determine the magnitude and timing of the meteotsunamis. As a result of these uncertainties, the current warning and forecasting systems can still be improved.

A new, ultra-dense observation network is nowadays available, allowing the characterization of meteotsunami events with an unprecedented detail.

Goals:

- To review the **agreement between observational data** of meteotsunami events **and the established meteotsunami generation mechanisms**.
- To **estimate the atmospheric perturbation velocity** from the new dataset, which has an unprecedented spatial and temporal resolution.
- To identify the **key parameters of the atmospheric perturbation** that determine the meteotsunami amplitude.

The main part of this work was part of Joan Villalonga's Master Thesis, submitted in October 2021

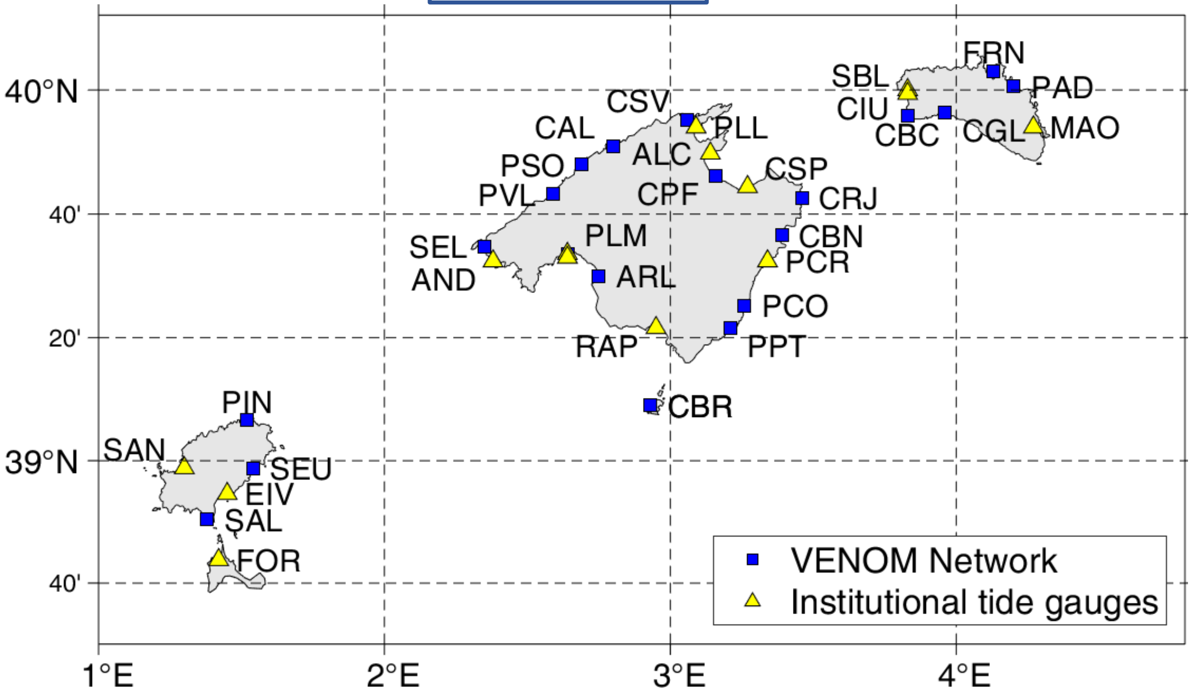
3. Observational data

Abstract:

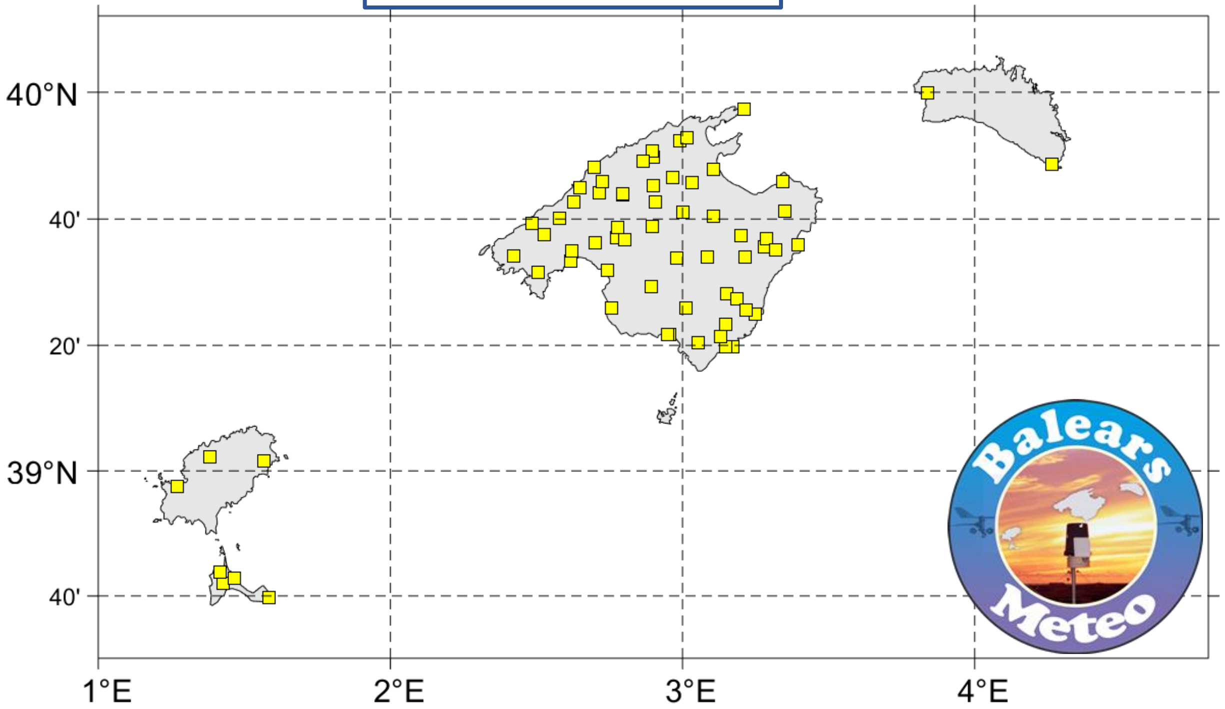
- The new VENOM low-cost tide gauge network.
- The BalearsMeteo high-resolution atmospheric data.

These two networks complements the existing sea level and atmospheric pressure networks.

Tide gauges



Microbarographs



Puertos del Estado

SOCIB Balearic Islands Coastal Observing and Forecasting System

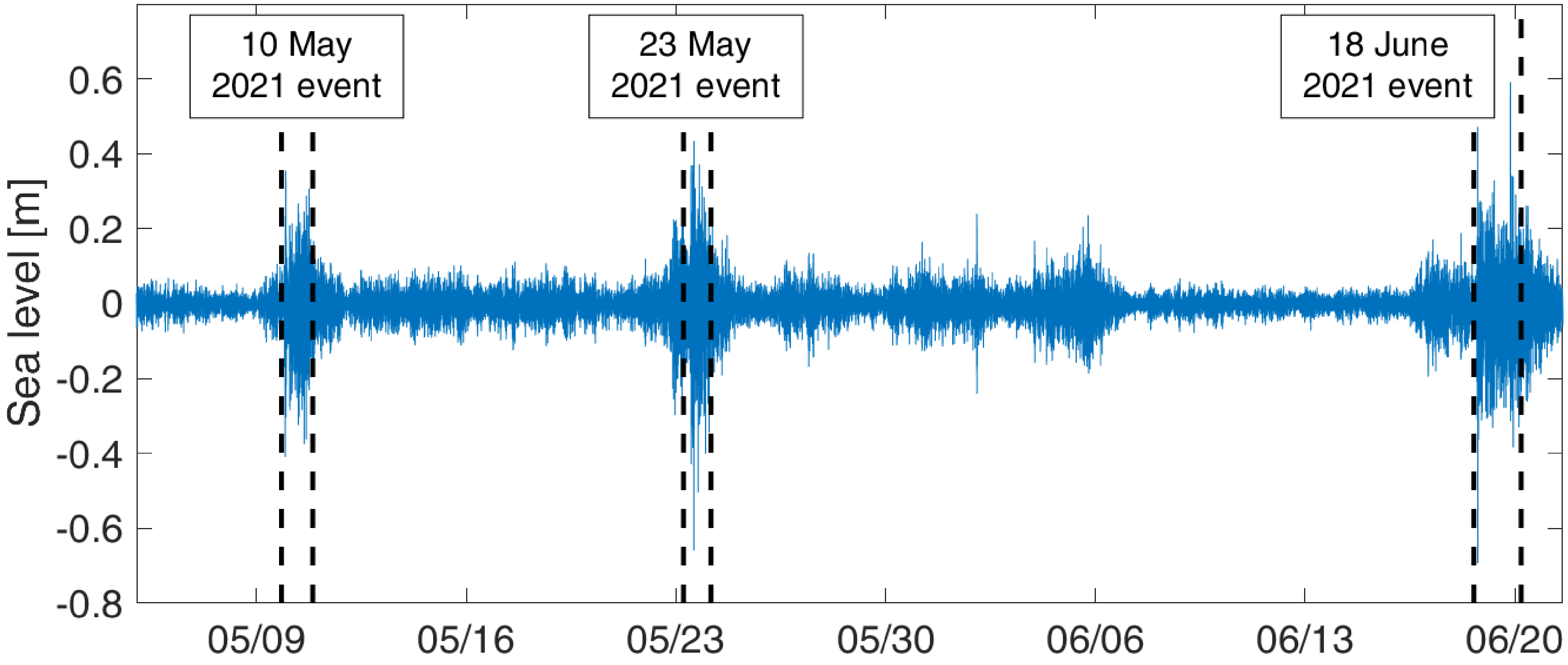
Ports IB Govern de les Illes Balears

4. Results

Abstract:

Here we analyse 3 meteotsunami events:

- 10 May 2021: 65 cm (Ciutadella).
- 23 May 2021: 109 cm (Ciutadella).
- 18 June 2021: 115 cm (Ciutadella).



4. Atmospheric perturbation

Abstract:

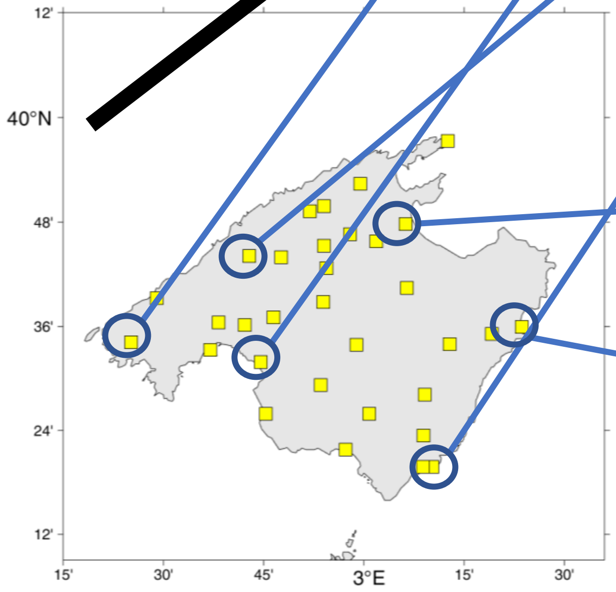
BalearsMeteo Data

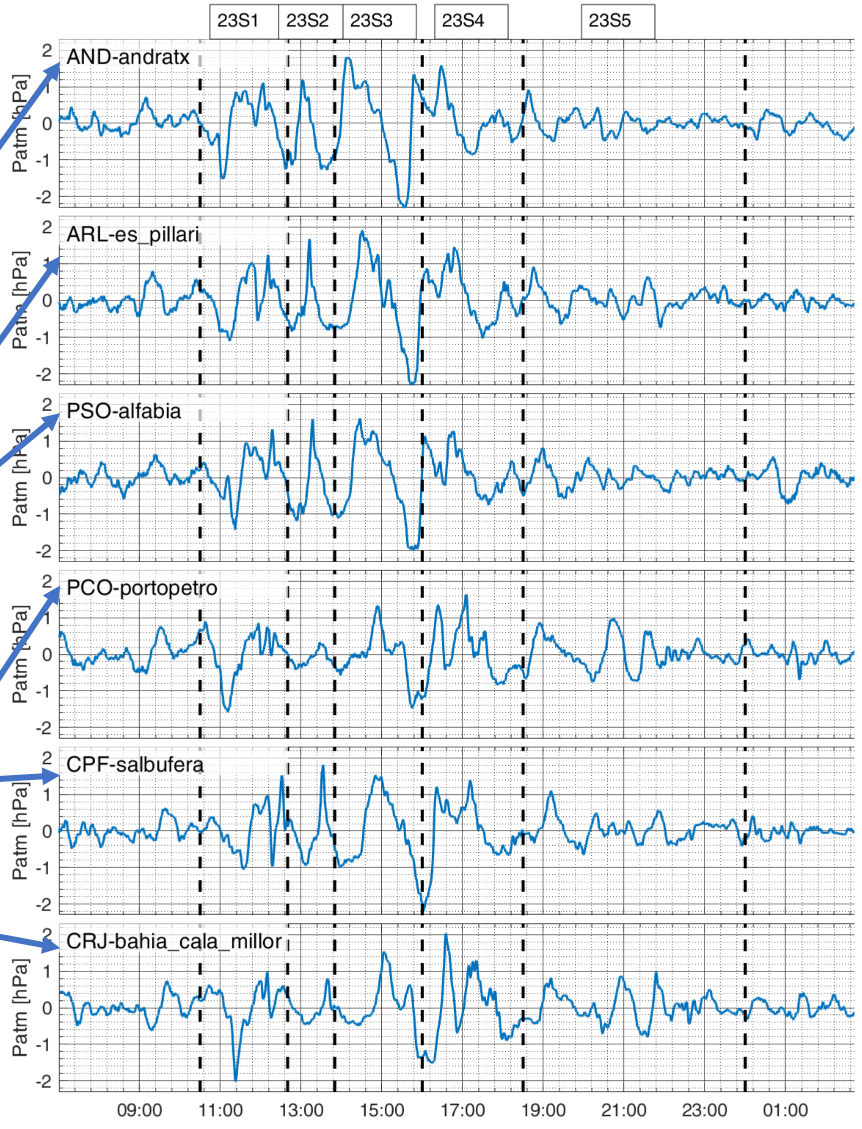
23 May 2021

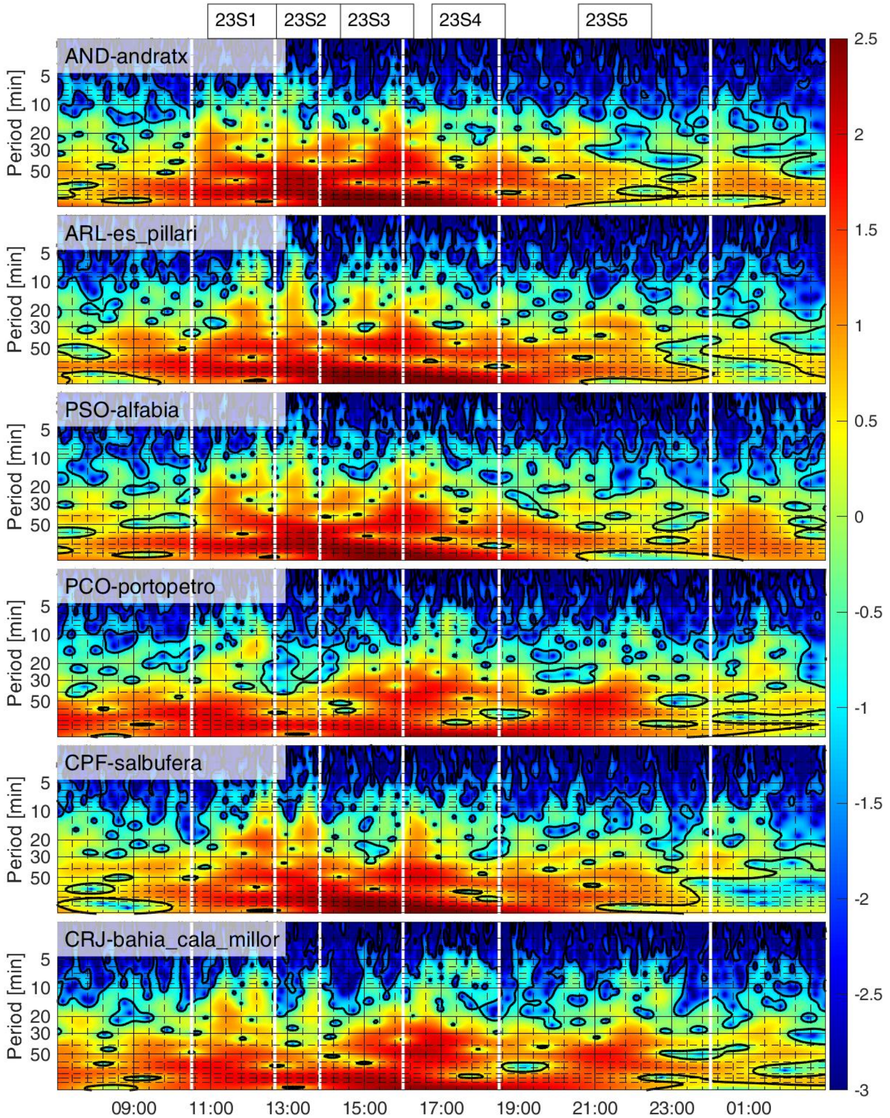
Main result:

The atmospheric perturbations are not homogeneous and evolve with time.

Propagation direction







4. Atmospheric perturbation velocity

Abstract:

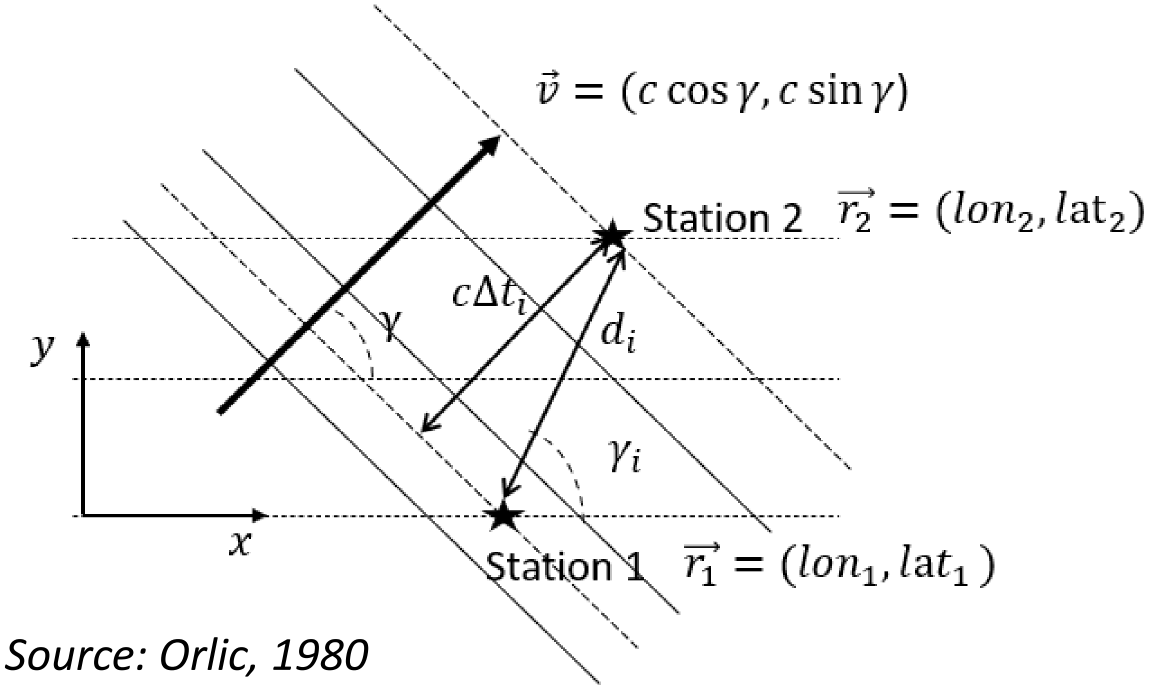
Perturbation velocity estimation algorithm

i. Compute the distance and the angle between stations.

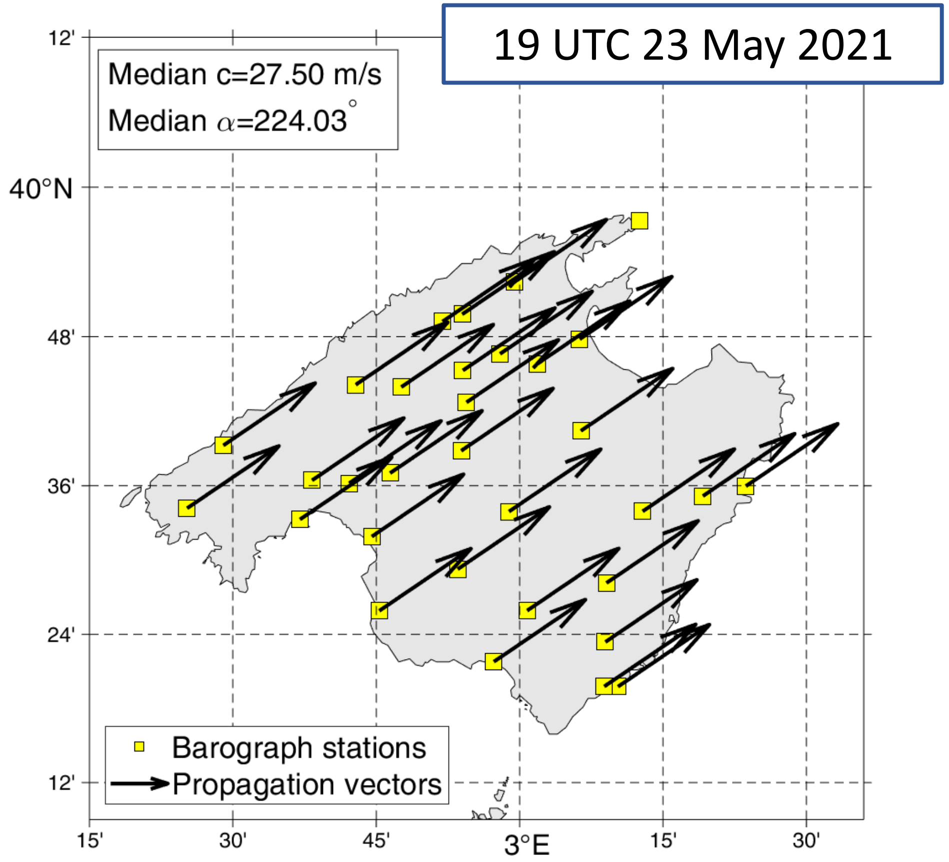
ii. Estimate the travel time of the perturbation using the correlation between time series.

iii. Minimize the following cost function to estimate the speed and the direction of the perturbation.

$$F(c,\gamma) = \sum_i A\left(d_i, C_i(\overline{\Delta t_i})\right)\left[\overline{\Delta t_i} - \frac{d_i \cos(\gamma - \gamma_i)}{c}\right]^2$$



Source: Orlic, 1980



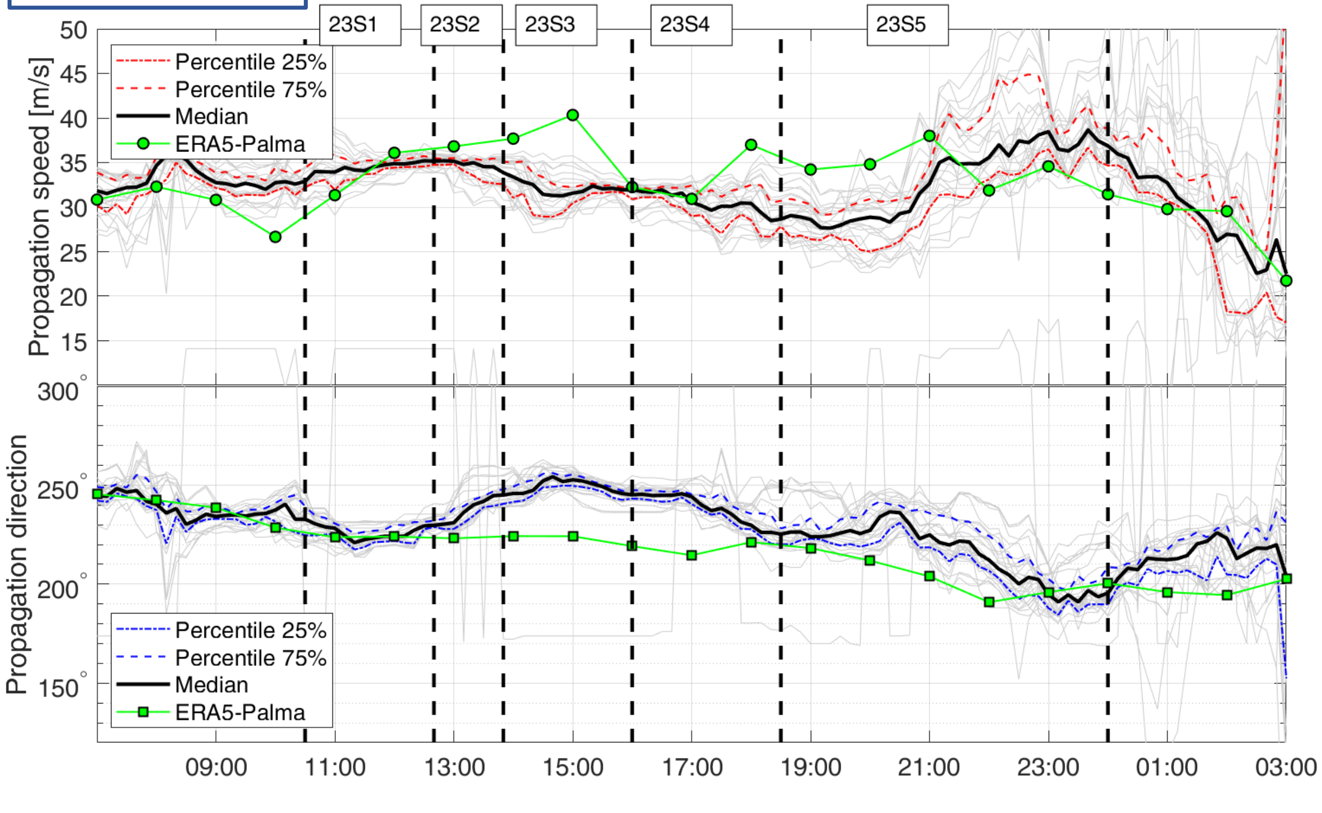
4. Atmospheric perturbation velocity

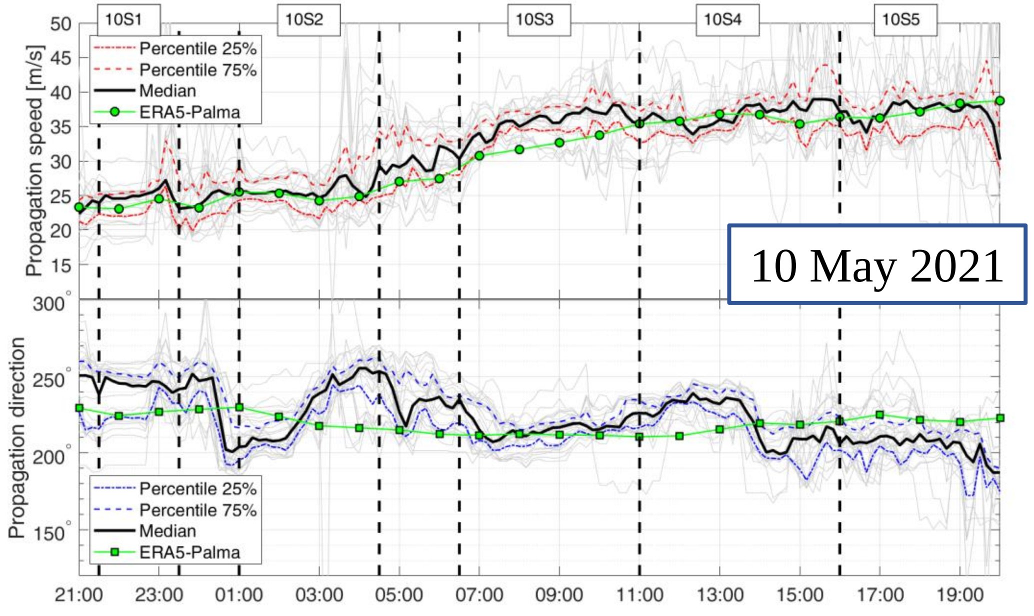
Abstract:

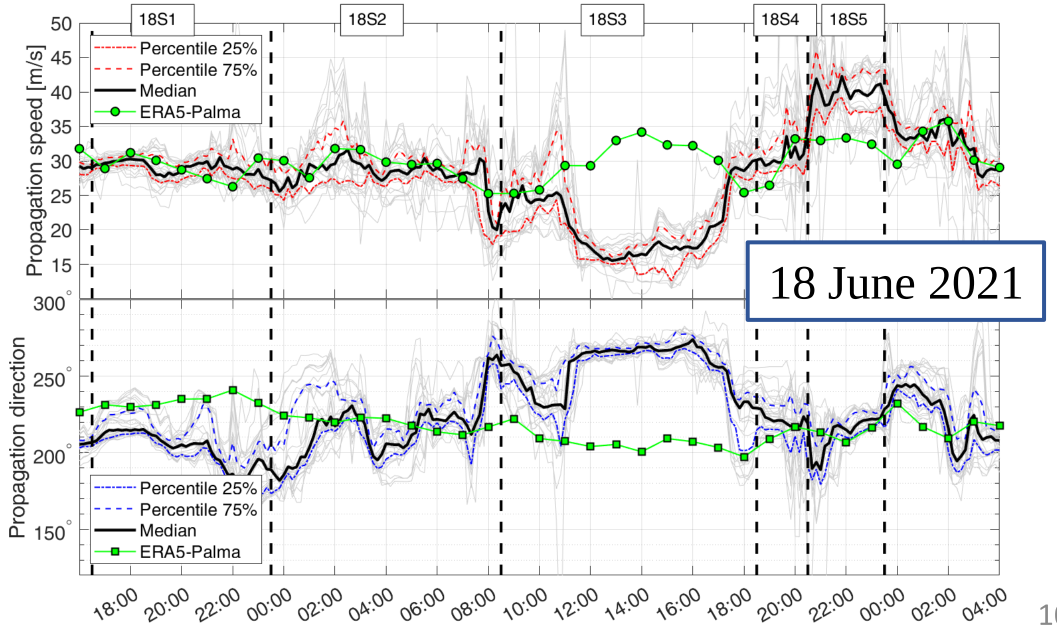
The time evolution of the perturbation speed and direction is estimated:

- Important variation in time and space are observed
- Good agreement between the estimated velocity and the wind velocity at 500 hPa is found.

23 May 2021

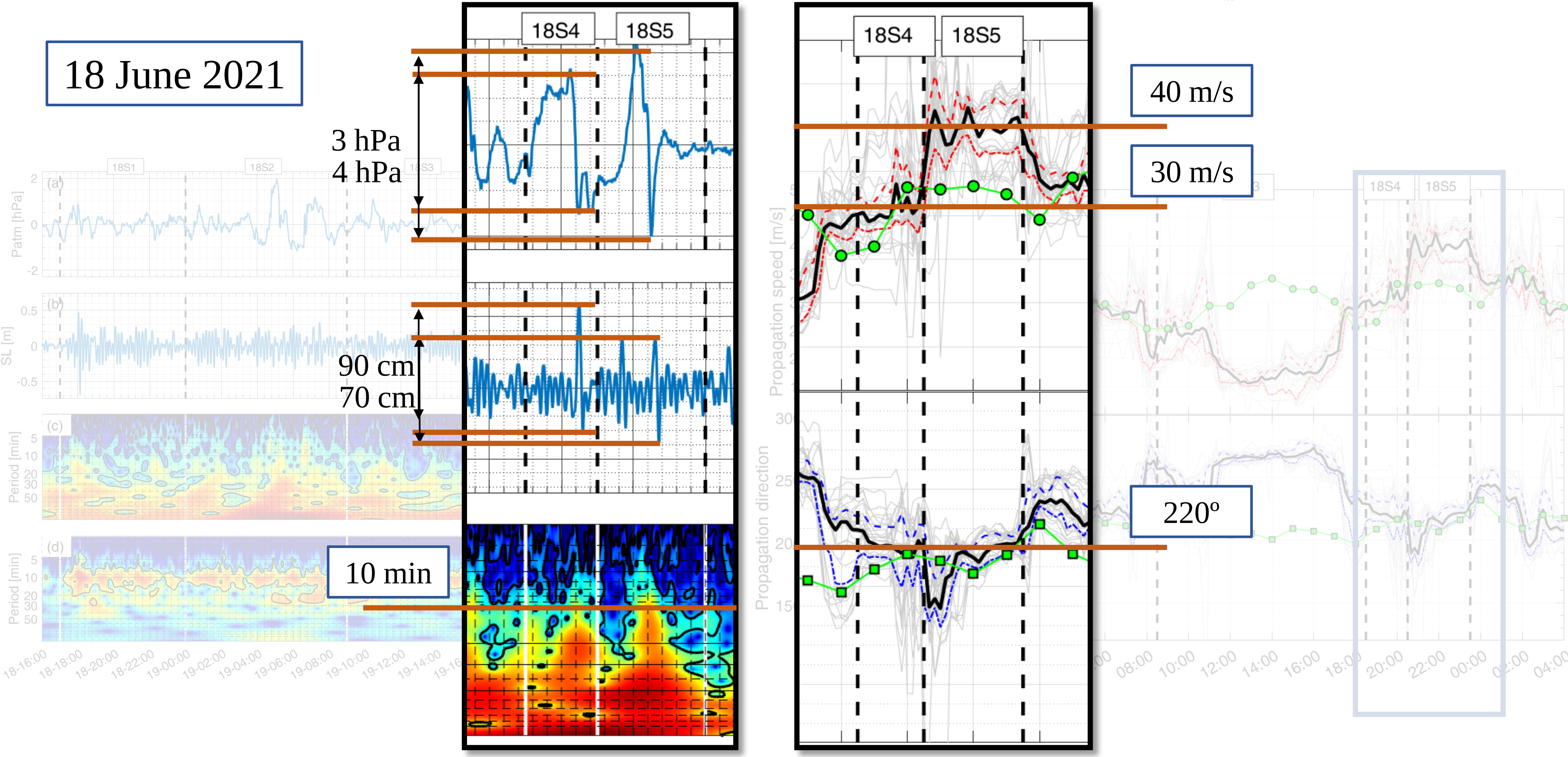






4. Atmospheric perturbation velocity

Abstract:



4. Atmospheric spectral energy

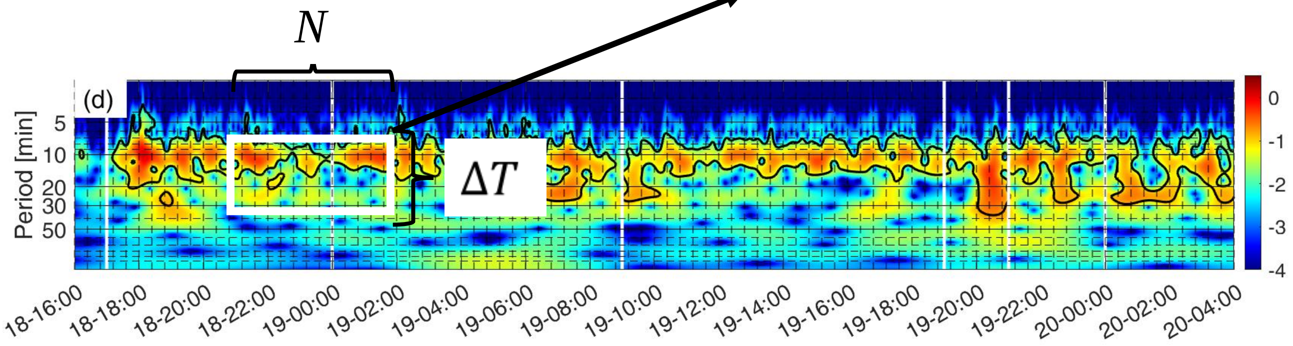
Abstract:

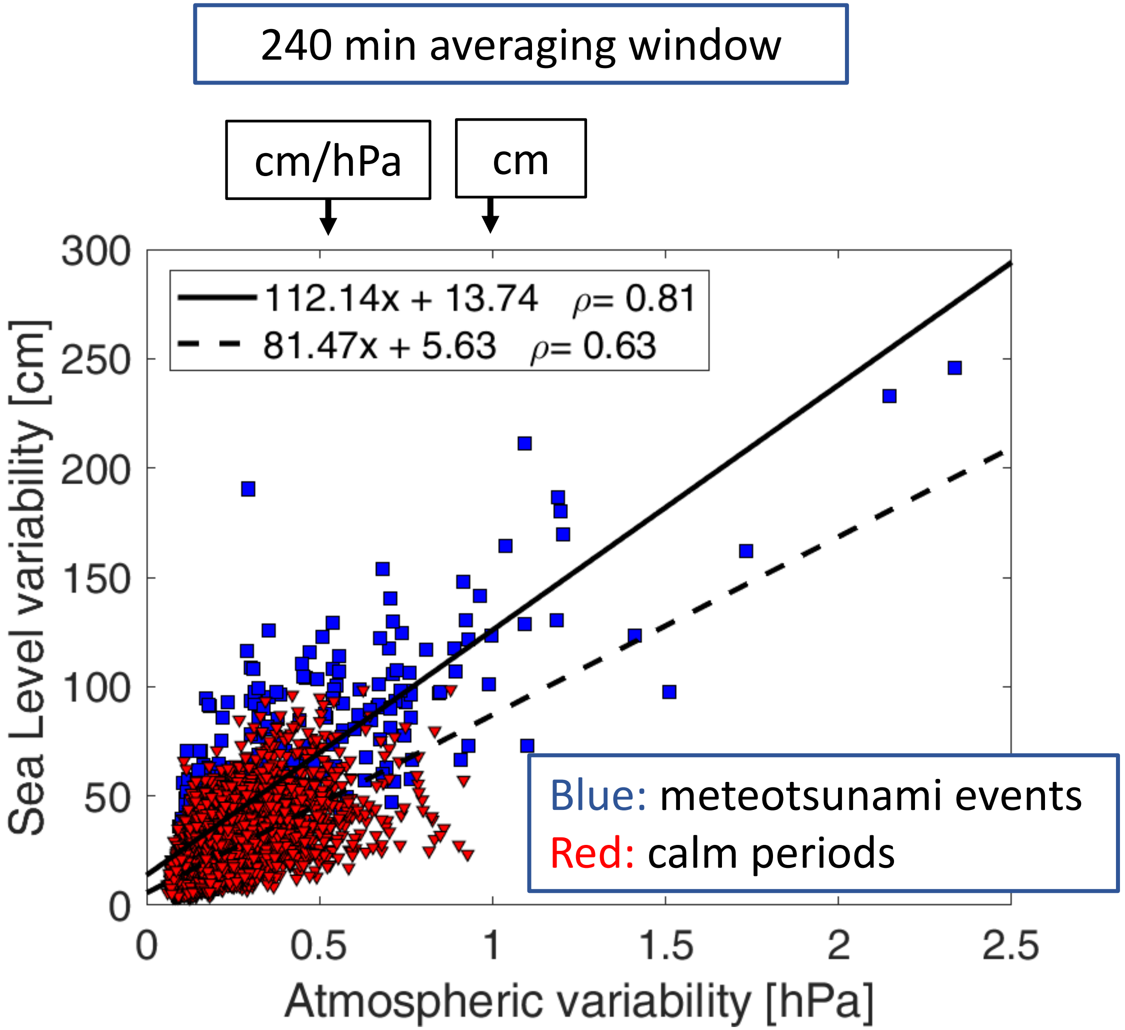
How does the spectral energy distribution affect the harbour amplification?

- Ciutadella Harbour amplifies perturbations with energy close to its 10.5 min normal period.
- Theoretically there should be a direct relation between the energy at 10.5 min period measured in the atmospheric series and in the sea level series of Ciutadella Harbour.

Variability computation:

$$\hat{\sigma}(t_k, T_n) = \left[\frac{1}{N} \sum_{i=k-N/2}^{k+N/2} \left(\sum_{T_j=T_n-\Delta T/2}^{T_n+\Delta T/2} |W(t_i, T_j)|^2 \right) \right]^{\frac{1}{2}}$$



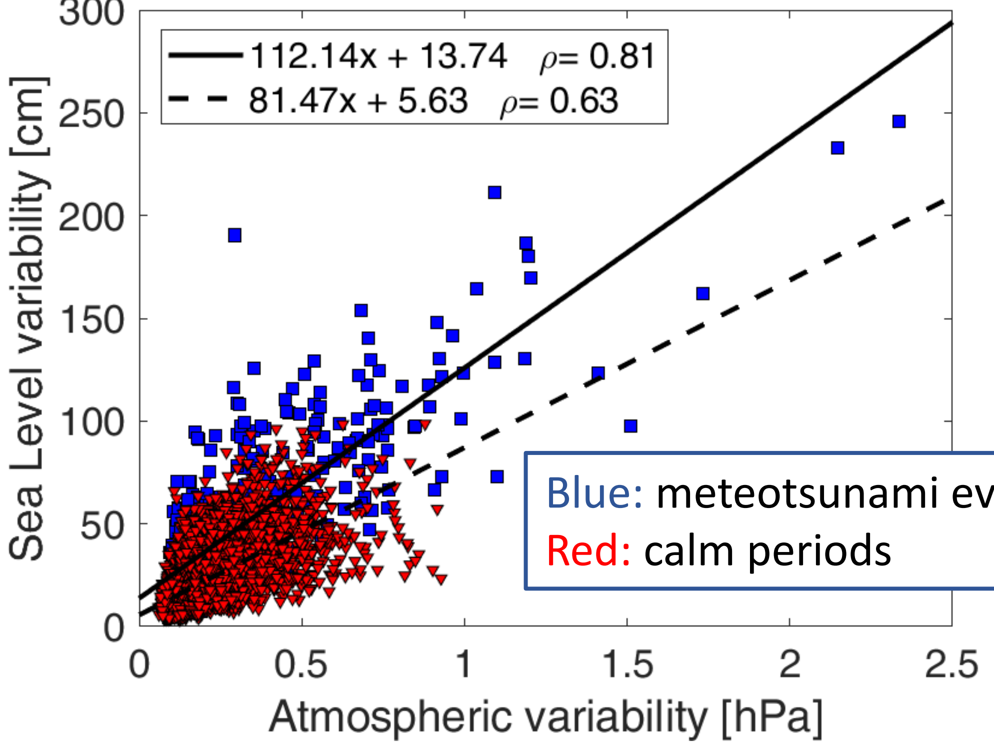


4. Atmospheric spectral energy

Abstract:

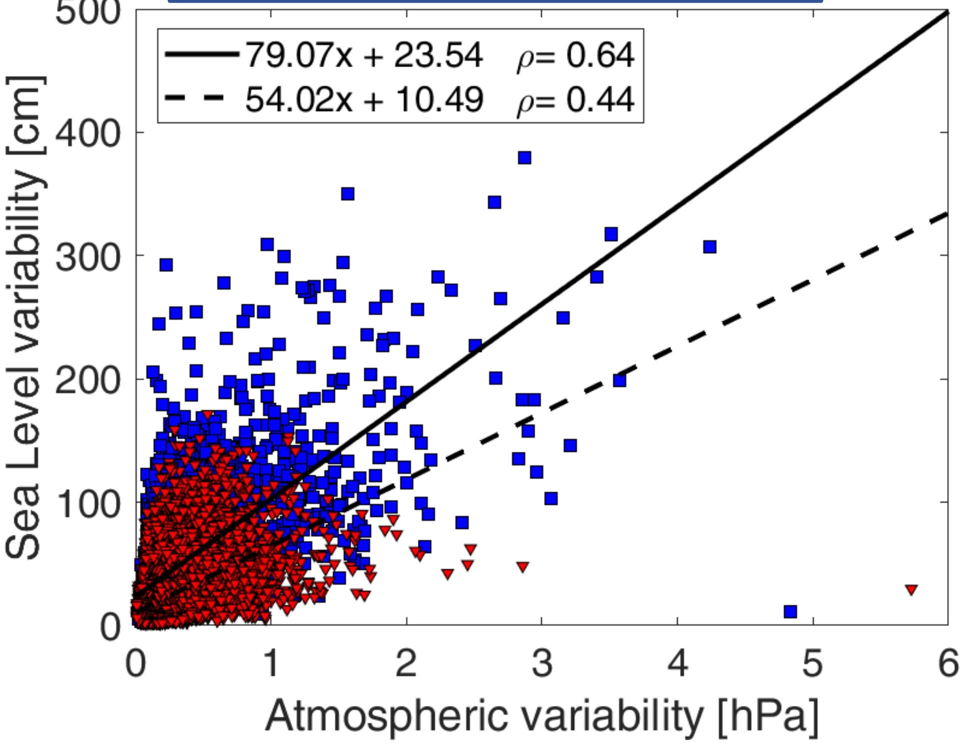
- High correlation (0.81-0.65) is found between atmospheric energy and sea level energy around 10.5 min period during meteotsunami events.
- The correlation and the regression accuracy are higher during meteotsunami events than during calm periods.
- The correlation is higher for larger averaging windows.
- There is no simultaneity, neither proportionality, between the high frequency perturbation and the sea level response.

240 min averaging window



Blue: meteotsunami events
Red: calm periods

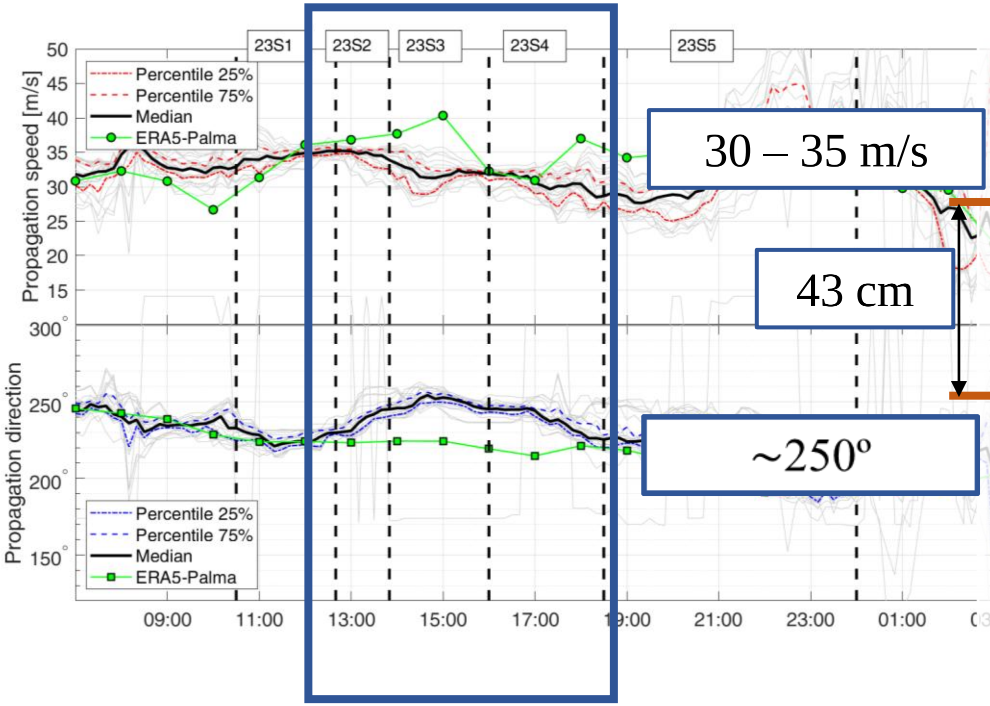
30 min averaging window

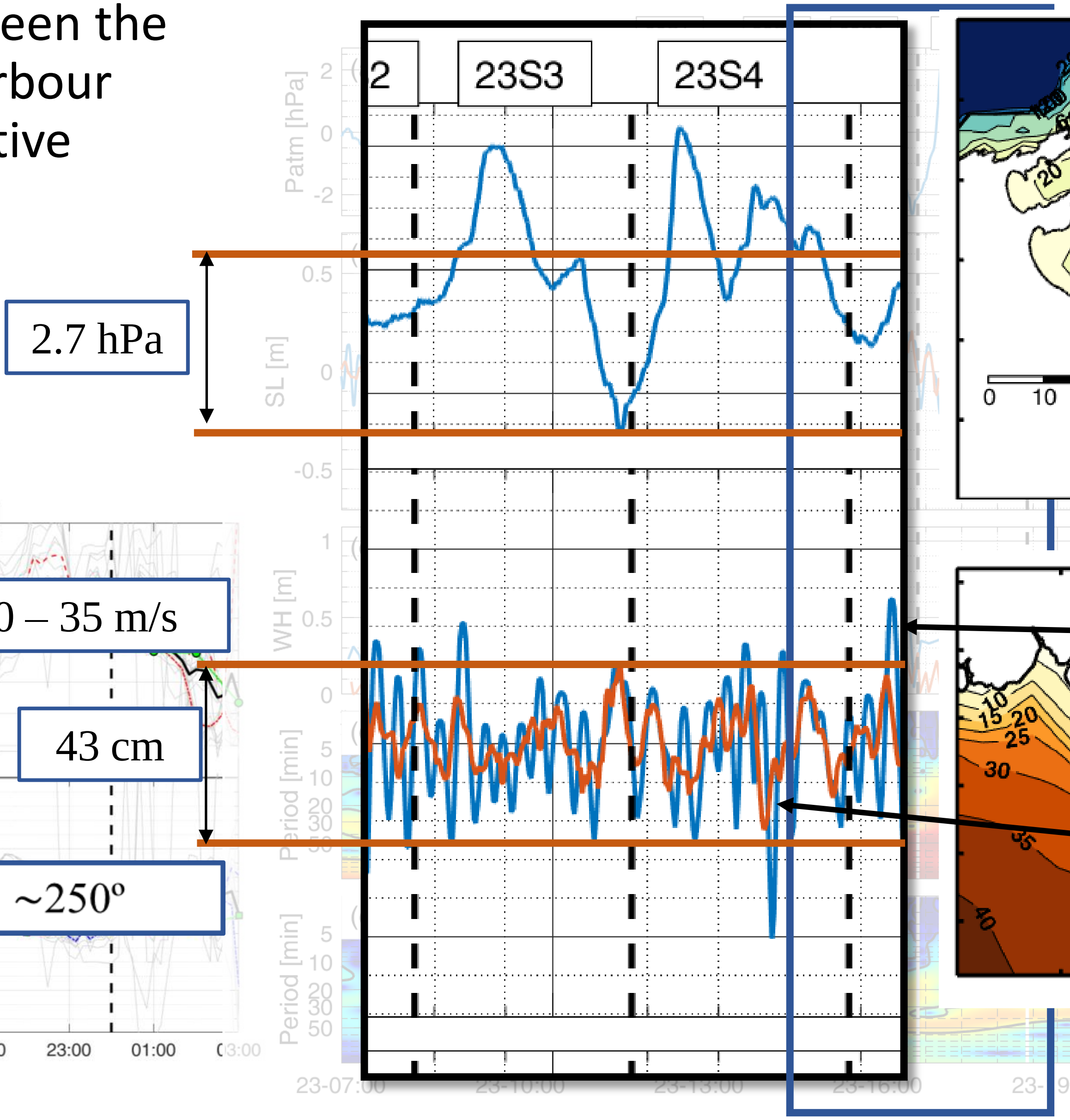


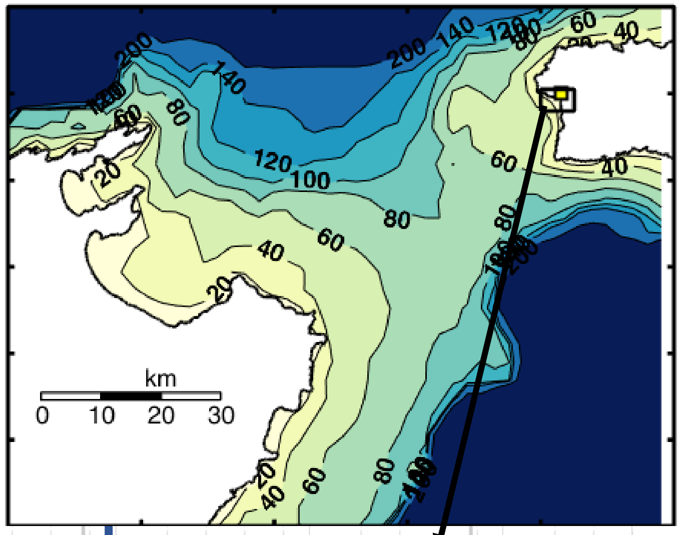
4. Results and discussion

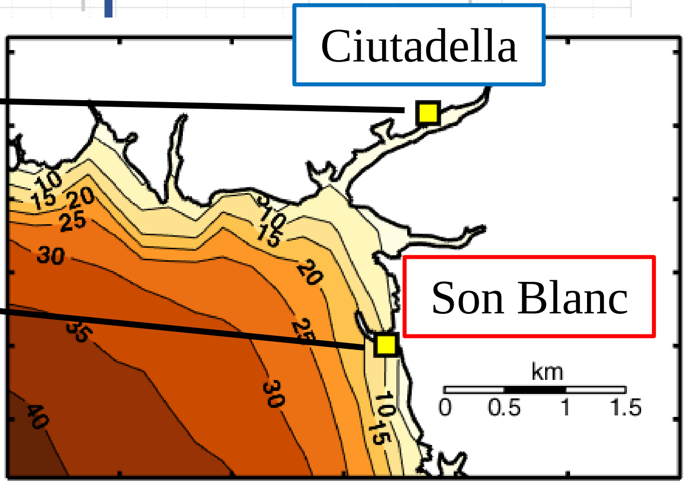
Abstract:

Is the phase difference between the forcing sea wave and the harbour oscillation causing a destructive interference?







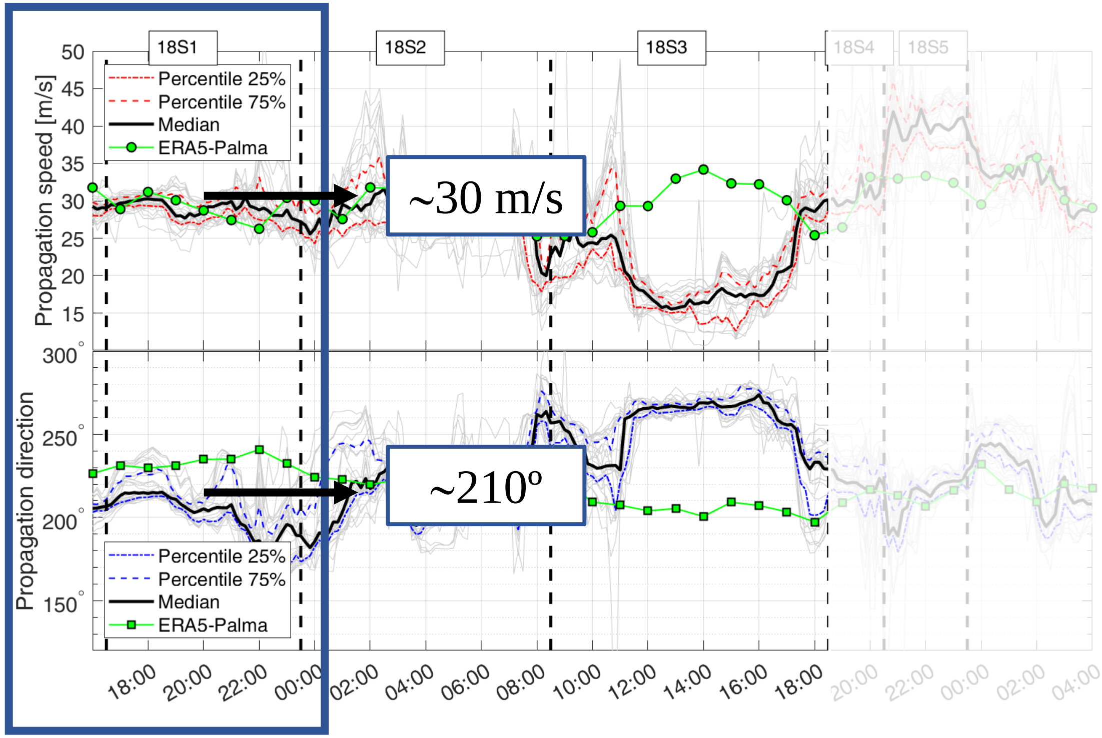


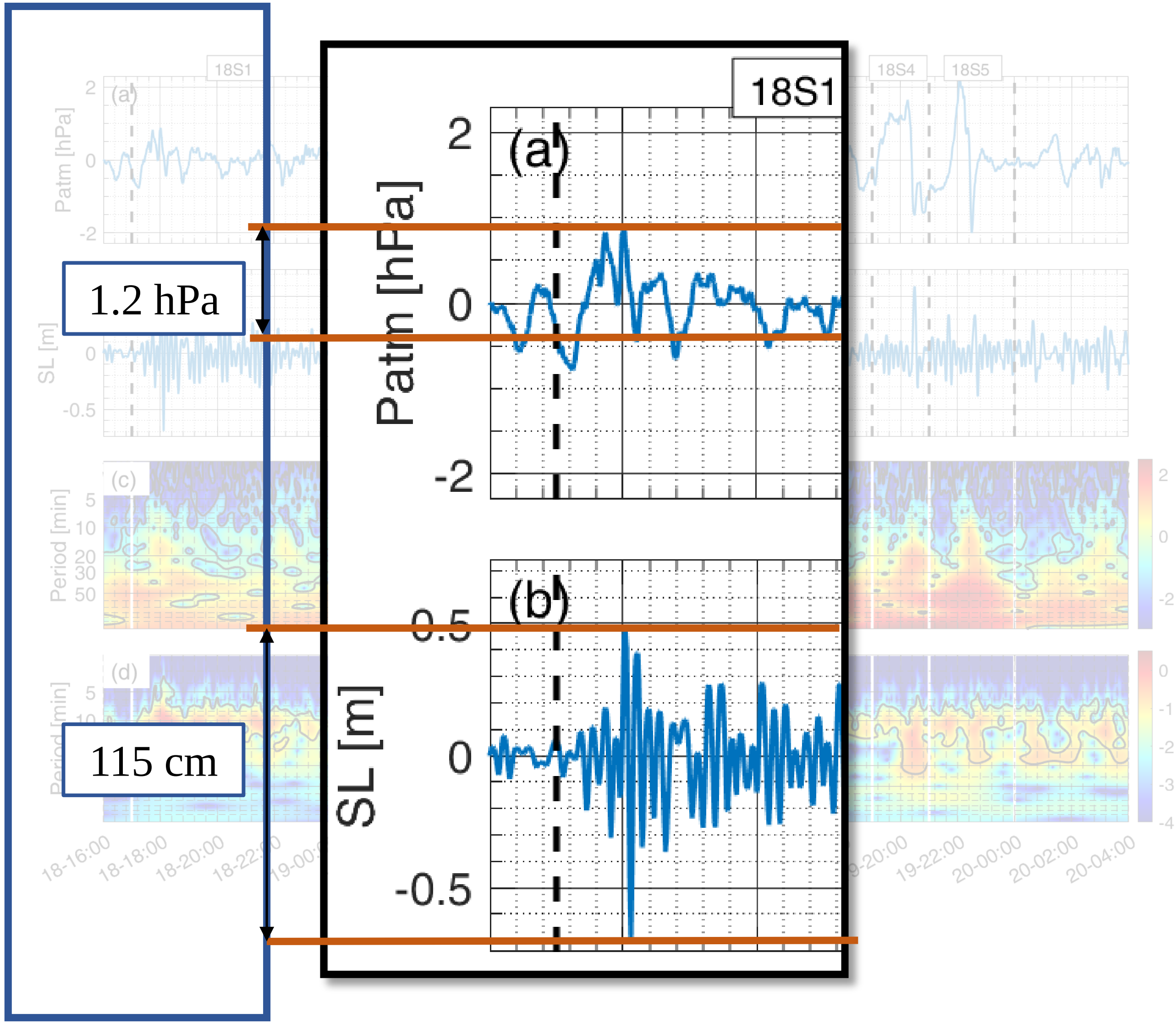
4. Results and discussion

Abstract:

How important is the perturbation duration?

The largest observed sea level oscillation is caused by a 1.2 h hPa perturbation.





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Abstract:

5. Conclusions

From the analysis of three meteotsunami events we have obtained the following results:

- **The atmospheric perturbations have been characterized,** estimating the speed and direction of propagation.
    - A **high spatial and temporal heterogeneity** has been found.
- The **most determinant parameters** of the atmospheric perturbation have been identified:
    - **Speed and direction of propagation.**
    - **Spectral energy contents**.
    - **Phase difference** between the forcing sea wave and the harbour oscillations.
    - **Duration**.

Further research

- Use of numerical simulations to **quantify the effects of: i) the spatial heterogeneity** of the atmospheric perturbations, and ii) **the duration of the atmospheric perturbation and the phase difference** between the forcing and the harbour oscillation, on the meteotsunami amplitude.
- Explore the proposed hypothesis with a **larger meteotsunami dataset**.
- Developing **an index that combines the listed parameters to relate them to the meteotsunami amplitude**, using a larger meteotsunami dataset.

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