Exploring low-frequency sea level oscillations in the Mediterranean Sea: evidences from coastal observatories

Vesna Bertoncelj (1)*, Dušan Žagar (1), Davide Bonaldo (2), and Matjaž Ličer (3)

(1) Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia, (2) Institute of Marine Sciences, National Research Council, CNR-ISMAR, Venice, Italy, (3) National Institute of Biology, Marine Biology Station Piran, Slovenia

* contact: vesna.bertoncelj@gmail.com

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MOTIVATION

In low-lying coastal cities such as Venice (Italy) and Piran (Slovenia), only a few centimetres increase in sea level can contribute to incremental flooding, causing the damage of the private property and the cultural heritage.

In order to better understand the potential threats affecting coastal zones, **a thorough knowledge of all the factors controlling sea level is required** to properly design coastal defences, provide accurate forecasting and implement appropriate countermeasures.

With this urge in mind, we aim at characterising the extent, the timing and the amplitude of low-frequency sea surface height (SSH) oscillation throughout the Mediterranean basin in the present study.

IN SITU AND MODELING DATA ANALYSIS

Jesolo station (Venice, Northern Adriatic, Italy) - Current Meter AWAC

- 1 km from the coast, depth 7 m, sampling frequency 10 min, vertical resolution 50 cm
- Chosen event: intensive and long-lasting storm event on the North of the Adriatic Sea from the end of January till the beginning of February 2014
- Performed rotary spectral analysis

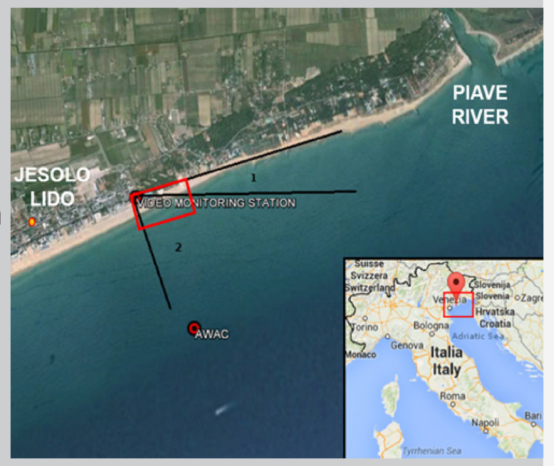

Figure 1: Location of a Current Meter in Jesolo (Venice, Northern Adriatic, Italy), (Archetti et al., 2016).

Tide gauge measurements at the other stations - obtained from EMODnet (European Marine Observation and Data Network) and The National Tidegauge Network (ISPRA)

- 62 stations along the Mediterranean coast (Italy, Spain and France)
- Performed spectral analysis and wavelet analysis

Figure 2: Locations of analysed stations in Spain (orange), France (purple) and Italy (blue), (GoogleMaps, 2018).

Modelling - obtained from Copernicus MEDSEA_ANALYSIS_FORECAST_PHY_006_013 ocean state product

Wavelet transform analysis was performed on multi-year timeseries to isolate events with maximum energy density in the subinertial part of the spectrum.

For the time windows of interest, modelled SSH was band-pass filtered over the entire Mediterranean basin. We used the 2nd order Butterworth filter with low cutoff frequency = 1/80 hours and high cutoff frequency = 1/60 hours.

2014 event in North Adriatic Sea

A signal of 0.3 c/d is evident in the analysis at the Jesolo station from both sea surface elevation (SSE) and current meter (Figure 3).

The peak at 3.3 days period appears only occasionally, while the rest of the signal is often a harmonic part of the continuum for frequencies between 0 and 0.5 c/d.

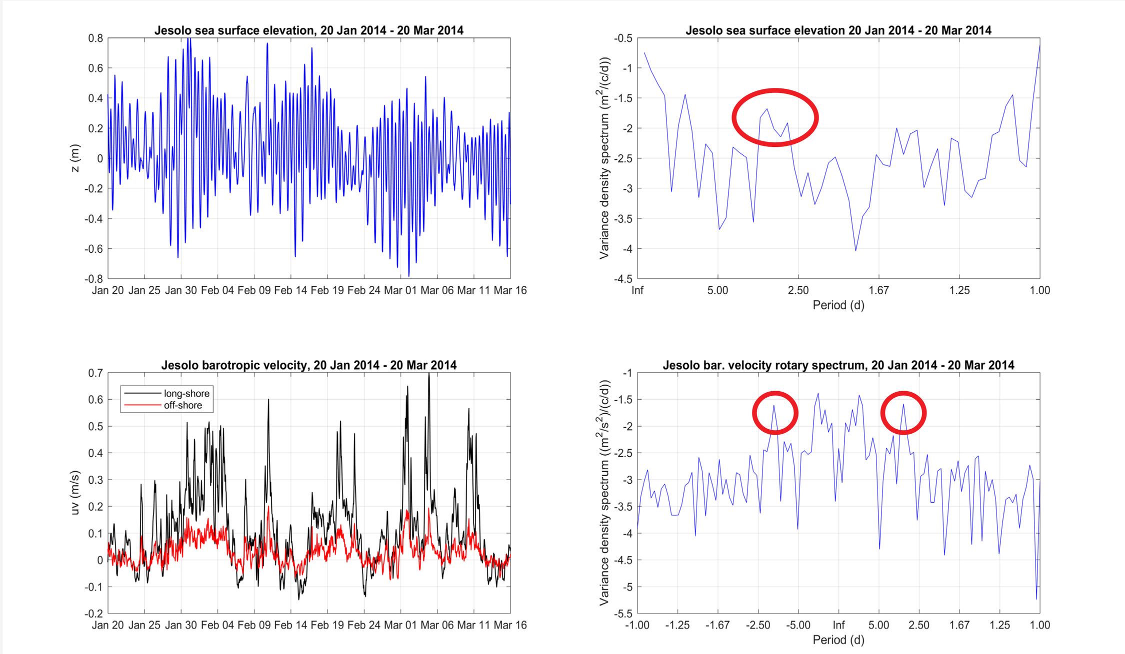

Figure 3: Rotary spectral analysis for Jesolo stationwith an evident peak at 3.3 days period.

Wavelet analysis and spectral analysis were performed at several stations along the Mediterranean coast to determine whether this signal is a part of a wider pattern. The results of wavelet and spectral analysis revealed a signal with the same 3.3 days period at the La Spezia station in Ligurian Sea, Italy (Figure 8), for the same event in 2014 as found in Jesolo (Figure 4).

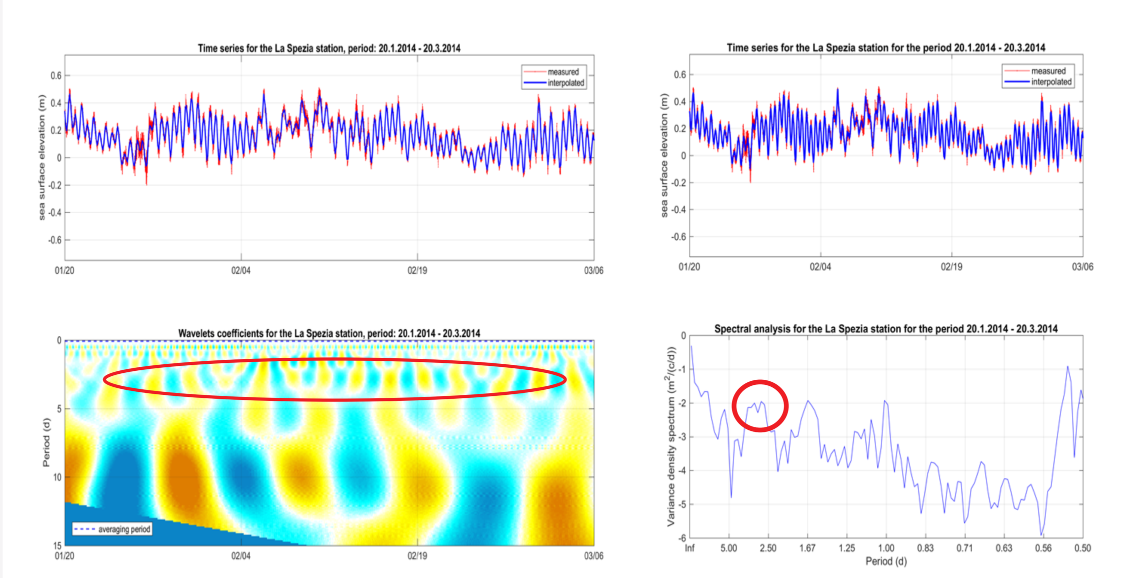
Figure 4: Wavelet analysis (left) and spectral analysis (right) for the La Spezia station (Italy) show the evidence of a 3.3 days signal.

Synoptic patterns of a signal

Subinertial oscillations of SSH are clearly resolved in the filtered results and seem to stem from synoptic variability in the Mean Sea Level Pressure (MSLP) over Mediterranean basin. To further back this assumption we performed band-pass filtering on ECMWF atmospheric MSLP fields over the Mediterranean. MSLP exhibits subinertial variability which is spatially and temporally consistent with the subinertial SSH signal.

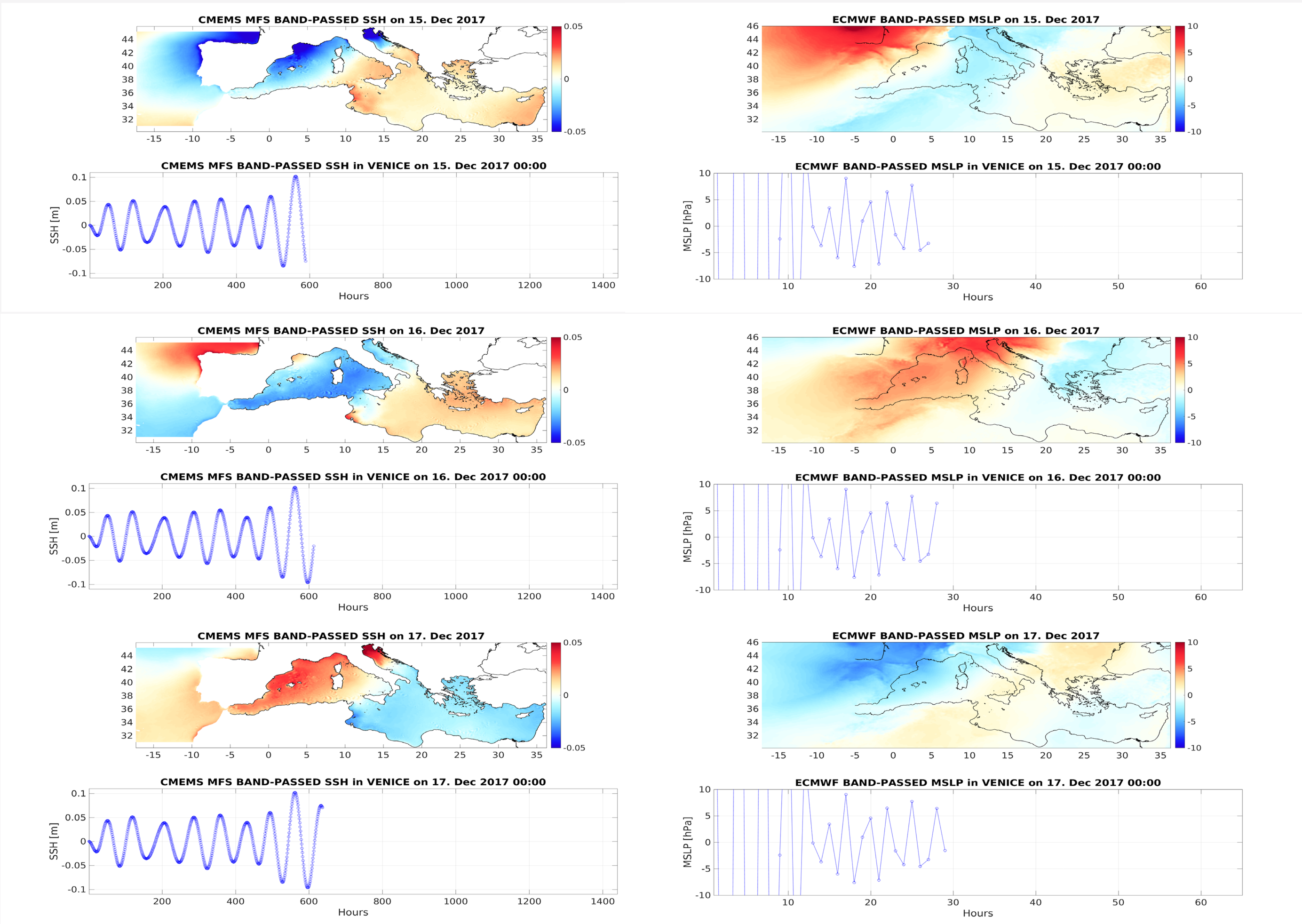

Figure 5: The evidence of the synoptic patterns of a signal. The Sea Surface Heights (left) and the atmospheric Mean Sea Level Pressure (right), both obtained for Venice (Italy), from 15th to 17th December 2017.

Seasonal occurrence and meteorological control of a signal

All 62 analysed stations in the Mediterranean coast show the evidence of a signal between December and April every year - this shows a strong wintry feature of a signal.

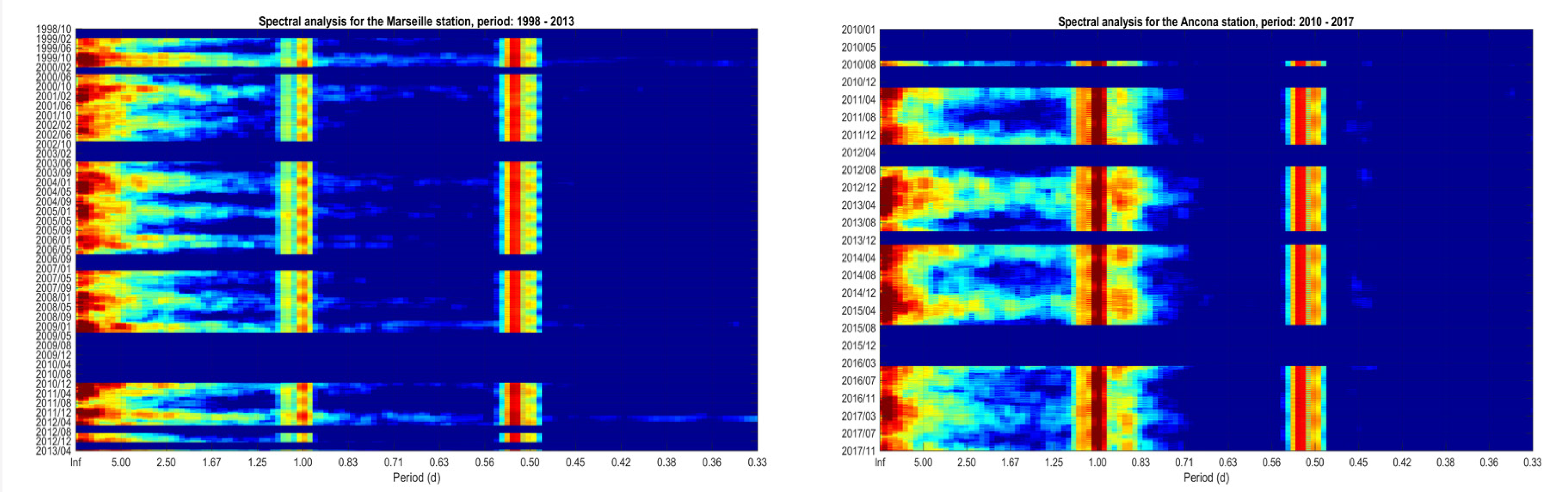
Figure 6: Spectral analysis of two stations: Ancona (North Adriatic Sea, Italy) and Marseille (Cote d'Azur, France) (Figure 8). Moving periodograms show the seasonal occurrence of the signal.

To see the connection of a signal with meteorological features, the atmospheric pressure spectra was performed for Porto Torres station (Figure 8). The spectral analysis shows the pattern which is similar to the seasonal pattern of the observed 3.3-day signal. The connection was already suggested in a paper by Candela and Lozano (1994).

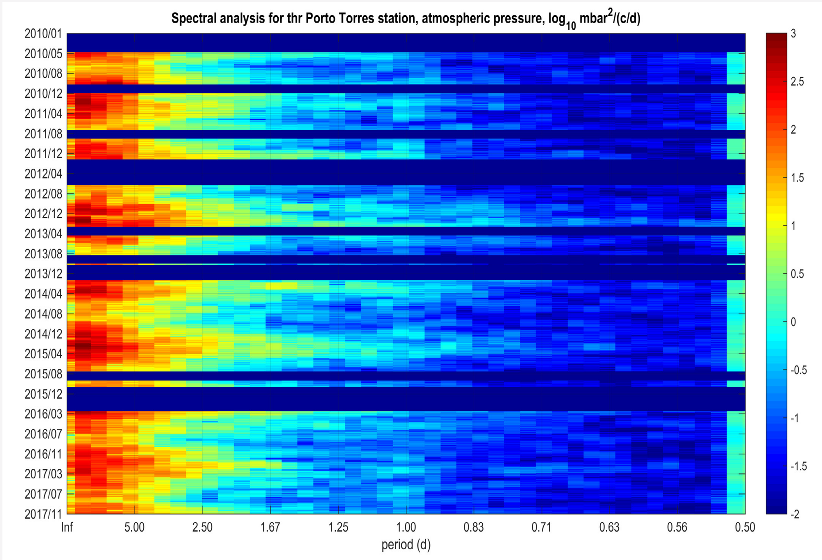
Figure 7: Atmospheric pressure spectra in Porto Torres (Sardinia, Italy).

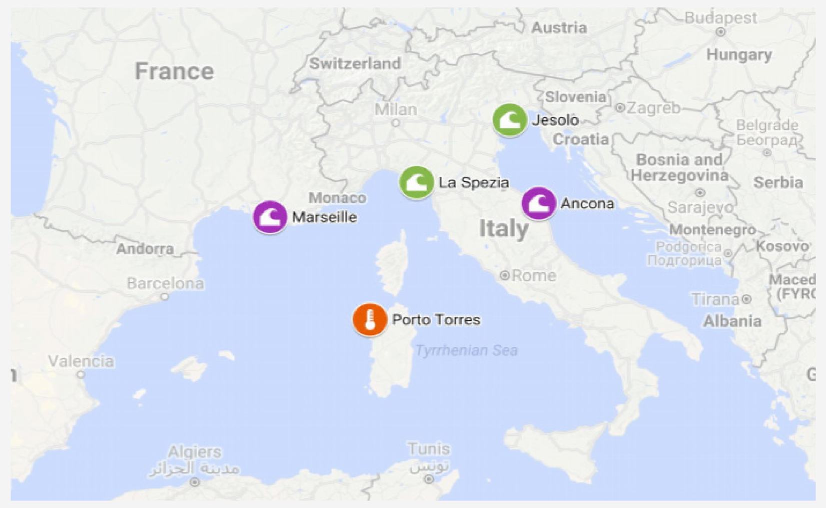

Figure 8: A map of stations in Marseille, Ancona, Porto Torres, La Spezia and Jesolo (GoogleMaps, 2018).

CONCLUSION AND FOLLOW-UP WORK

- There is an evidence of a strong low-frequency oscillation signal **along the Mediterranean coastline.**
- It is a **wintry feature** and is only occasionally peaked.
- There is an evidence of **a strong meteorological control** that is consistent with the paper by Candela and Lozano (1994).

Follow-up questions:

- In their research, Schwab and Rao (1983) find an evidence of free oscillation mode in the Mediterranean Sea for 38.5-hour period, which corresponds to half-period of the signal depicted in this study (3.3 days). Is there a presence of a free mode oscillation in the observed signal?

Follow-up work:

- Mediterranean-scale barotropic hydrodynamic model – we shall search for the evidences of free oscillation modes triggered by synoptic scale atmospheric processes
- A deeper investigation of the signal propagation throughout the basin
- Characterisation of the large scale metocean forcings triggering the process
- Investigation of possible climate change influence on sea level oscillations

References

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