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Tide propagation within Venice Lagoon: recent evolution trends

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Study area

Venice Lagoon lays in the North Western sandy shores of Adriatic Sea. It represents the largest Mediterranean lagoon with its area of 550 km^2. The surrounding coastline presents a large amount (~2400km^2) of areas below the mean sea level, consisting mainly of reclaimed land, which have experienced significant subsidence effects in the last century. Venice Lagoon is therefore increasingly exposed to the risk of flooding from both storm surge and sea level rise.

Morphological changes

The Lagoon has undergone many transformation processes over the past centuries, consisting in defences lines built to escape either from the risk of landfilling by rivers discharges within the Lagoon (the rivers diversion) or from flooding by the sea (the so called "Murazzi") (D'Alpaos, 2003 and 2010). Tide follows a counterclockwise path along the Northern Adriatic Sea (Polli, 1961) and enters Venice Lagoon through three inlets: Lido, Malamocco and Chioggia. During good weather conditions, the Lagoon can be virtually divided into three independent basins, each fed by a single inlet (Goldmann, 1975). Watershed lines can be identified as basin boundaries influenced by concurrent fluxes from two different inlets. These boundaries can somehow modify over the tidal time scale, given specific meteorological forcings. Anyhow, long term modifications are related to morphological changes occurred mainly during the XX century.

Astronomical tide

In order to determine the astronomical tide, Fourier analysis is commonly used. The astronomical tide amplitude at time *t* in any tide gauge station can therefore be expressed by a relationship of type: $H_t = H_0 + \Sigma A_i{*}\cos(\omega_i t-\varphi_i)$, where A_i is the tide amplitude in centimeters, ω is the angular velocity in degrees/hour, φ is the phase delay in degrees, while t indicates time in hours. Each of the functions $A_i{*}\cos(\omega_i t-\varphi_i)$ is called astronomical tide component, while the parameters A_i and φ_i represent the harmonic constants to be calculated starting from the tide gauge data (Shureman, 1971). In the Northern Adriatic sea, seven of such curves are enough to determine with acceptable approximation the astronomical tide amplitude. The components are named with abbreviations, related to their astronomical origin: 4 occur on semi-diurnal timescale (M2, S2, N2, K2), and the other ones (K1, O1, P1) on a diurnal timescale (Polli, 1960). Once the harmonic constants have been found, the astronomical tide range for each station can be easily calculated and the propagation delay, as compared with an arbitrary point/instant, can be determined.

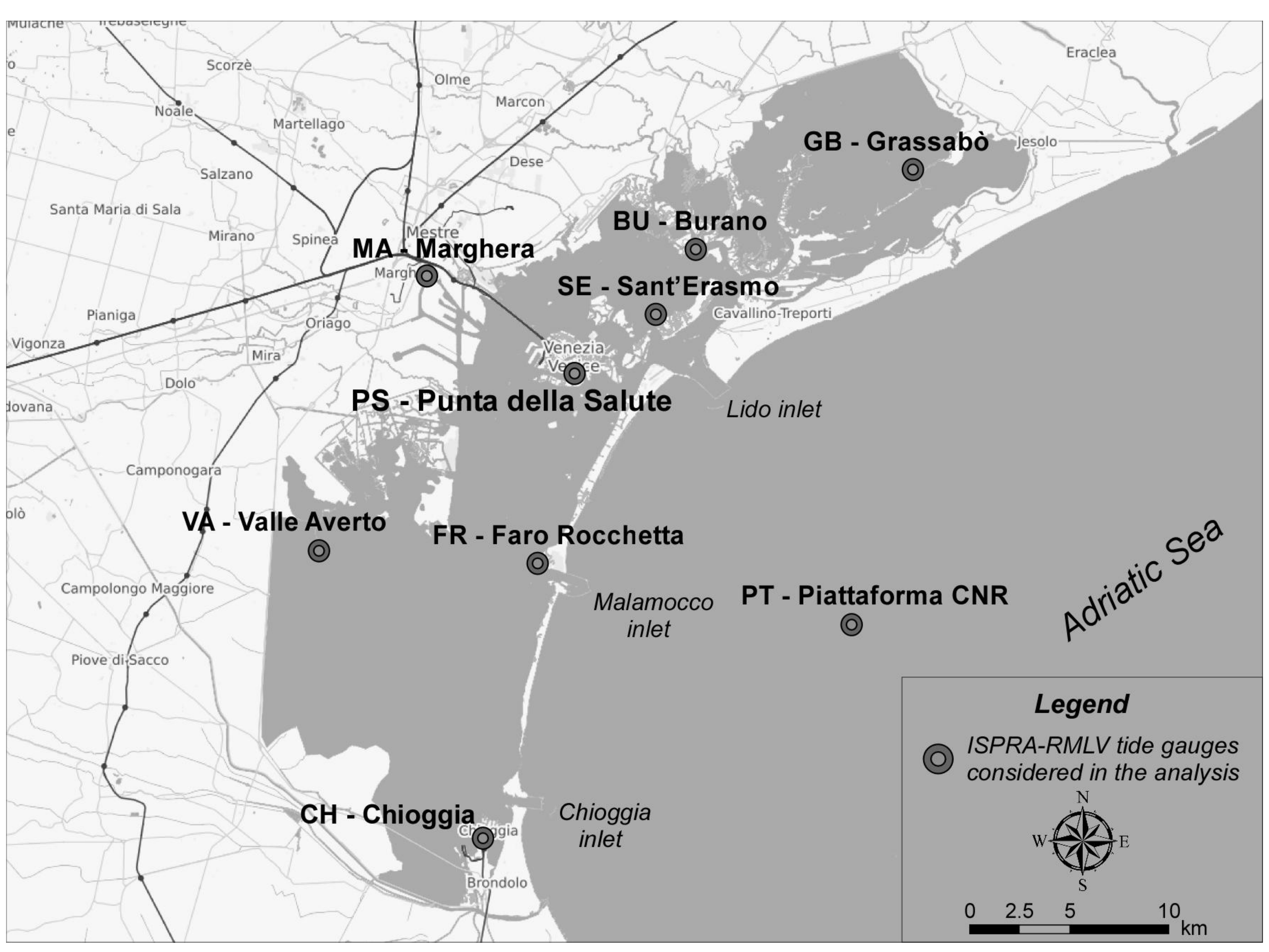

Fig. 1 – ISPRA – RMLV selected tide gauges

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Results

To ensure a proper coverage of the whole Venice Lagoon, 8 tide gauge stations have been selected for the aim of the present analysis. Piattaforma Acqua Alta, located 8 nautical miles off the venetian coastlines, has also been considered as reference station, being not influenced by any changes occurred inside the Lagoon (Fig.1). As regards tide amplitudes within the lagoon, they appear to be substantially stable until the years 2003/2004, which is the period when works of the Mo.S.E. project at the three inlets started. Instead, in the following years, all stations registered a notable fall of tide amplitude. The response of the Venice Lagoon appears not to be homogeneous: Northern Lagoon stations show a minor decrease in amplitude in comparison with Central and Southern Lagoon. Observed changes involve not only tidal amplitude but also phase delays with respect to the sea. Changes of this magnitude are very likely to be related with the modifications occurred at the three inlets for the construction of the movable gates system, which resulted in a reduction of the inlets width.

Conclusions

Such modifications suggest that the lagoon hydrodynamics have changed significantly in the last years. It may be presumed that the limits of the areas subject to the influence of each sea inlet (watershed) have moved. In particular, Lido inlet may have expanded its area of influence while the watershed related to Malamocco inlet could have decreased. This would imply changes in tidal currents paths, resulting in a reinforcement of the currents in areas close to Lido inlet with respect to the central part of the lagoon. Finally, a different hydrodynamic regime related to tide propagation changes would also imply direct consequences in residence time and water quality, not to mention the effects on suspended solid transport with possible impacts on the Venice Lagoon sediment budget.

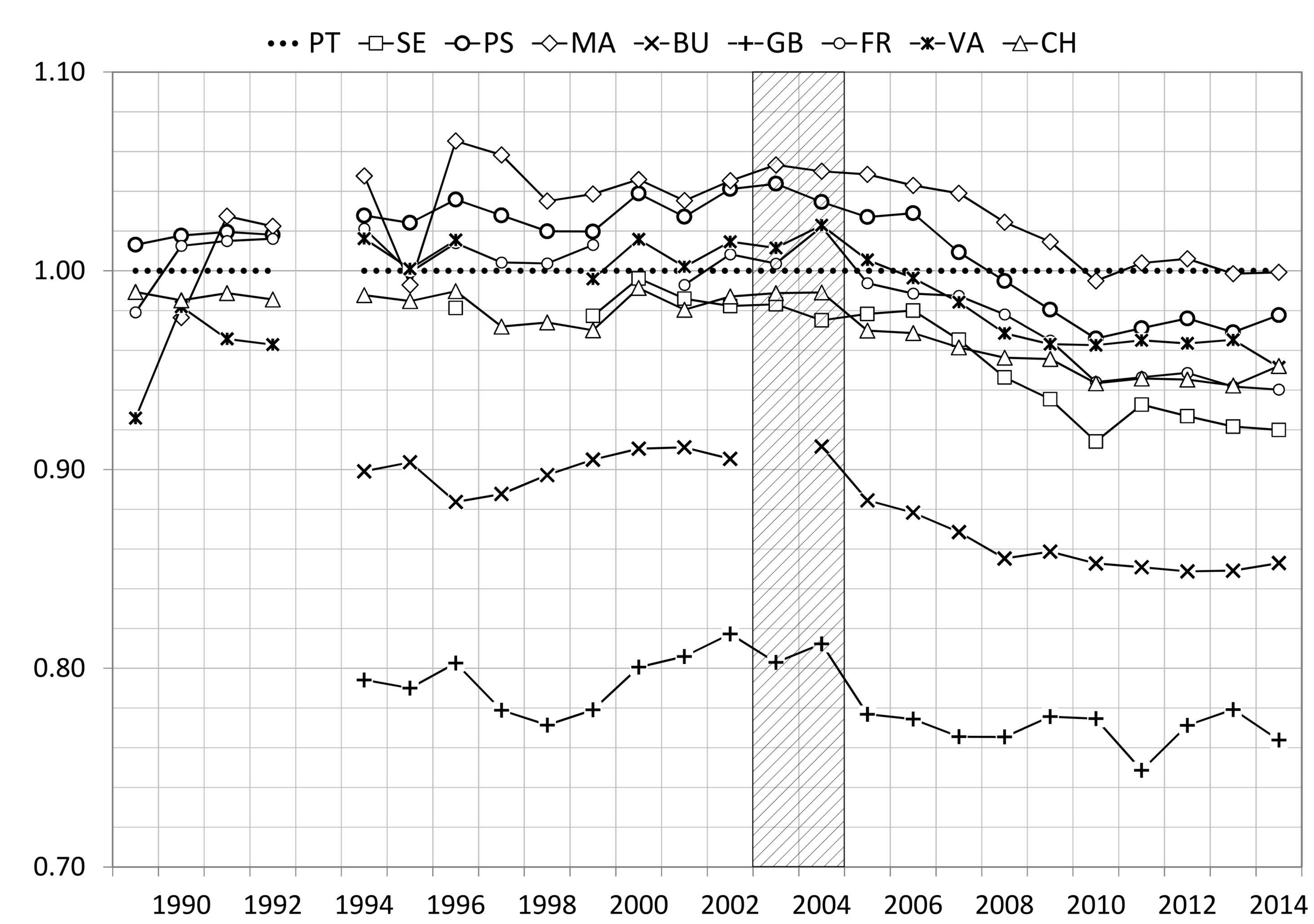

Fig. 2 – Amplitude reduction index within Venice Lagoon in comparison with Northern Adriatic Sea. The vertical bar highlights the beginning of amplitude changes.

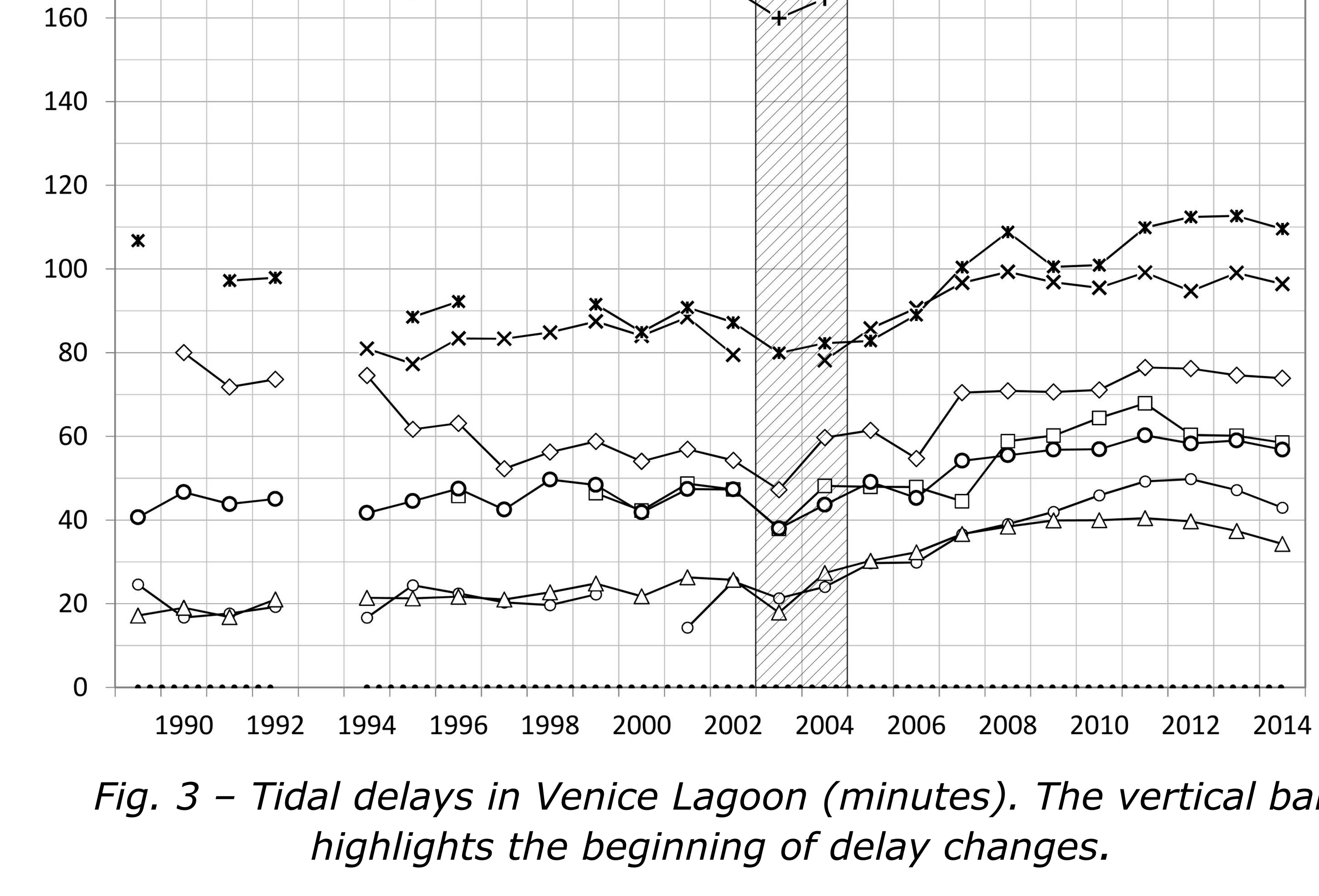

Fig. 3 – Tidal delays in Venice Lagoon (minutes). The vertical bar highlights the beginning of delay changes.

Source
Piattaforma CNR: Centro Previsioni e Segnalazioni Maree – Comune di Venezia.
All other tide gauges: ISPRA – RMLV (Venice Lagoon Tide Gauge Network)
Data processing: ISPRA