

## SEA-LEVEL OBSERVING ACTIVITIES IN ITALY

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### Introduction

Sea level measurements started in Italy in 1871 by means the first instruments installed and operated at Trieste (1859) by Istituto Talassografico (ITS), at Venezia (1872), Rimini (1867), Genova by the Navy Hydrographic Institute (IIM) (1883). Afterwards, from 1896 to 1897, the sea level stations of Imperia, Livorno, Civitavecchia, Napoli (Arsenale e Mandracchio), Messina, Palermo, Catania, Ancona, Ravenna Porto Corsini, Cagliari, and La Maddalena started working. Then, in 1920 the stations of Reggio Calabria and Vieste started and, under the management of the National Marine Service, the Italian sea level stations begun to have the characteristics of a real network distributed on the territory.

The regular tidal observations made in Venice are among the oldest and most reliable in Italy and in the Mediterranean in general. Systematic observations of sea level in Venice started in 1872 with the installation of the first tide gauge by the Military Geographic Institute and afterwards run by the Hydrographic Office of Venice. The latter has been a special technical and fact-finding body operating in the Lagoon since 1907 to 1989 within the *Magistrato alle Acque*, Water Authority for river basins and marine districts in the North-Eastern Peninsula.

Its responsibilities included:

- Systematic observation of tide levels and parameters influencing meteo-marine phenomena in the lagoon and along the north Adriatic coast;
- Analyses of historical time series for tide data, also in relation to subsidence and eustatism in the northern Adriatic region;
- Measurement of current parameters at the inlets in relation to lagoon-sea exchanges under different tide conditions.

In the 1960s, the Hydrographic Office established a correlation between the tide levels recorded at Punta della Salute, instituted in 1923 in the historic centre of the city of Venice, and levels recorded in Venice in the preceding decades. The result was to put together a continuous string of data that dates back to 1872. The reference benchmark, called "Zero

*Mareografico di Punta della Salute*" (ZMPS) corresponds to this day to the mean sea level recorded in 1897.

At the end of the 80s 2 tide gauge governmental network were operating in Italy:

1. The National Tide Gauge network (NTG) constituted by 28 stations located along the Italian coastline;
2. The Venetian and Northern-Adriatic Tide Gauge network (VNATG) constituted by 40 stations located into the lagoons and along the coastline;

From 1986 to 1998, the NTG has been reorganized, and the attention to the continuity of the reference level, which was the characteristic of mechanical instruments, was not as good as it was before, due to poor maintenance procedure and many gaps or jump of the reference level which were detectable in the data analysis, compromising the continuity of the time series of sea level measurements for some stations.

It is worth remembering that continuous time series of tidal observations starting from the last decades of the XIX century are available only for a few Italian stations, mainly for Trieste, Venezia, and Genova.

## ITALIAN SYSTEM FOR SEA LEVEL MEASUREMENTS

ISPRA is the Italian Governmental Organization which manages the NTG and the VNATG. The NTG is now constituted by 26 stations, scattered within harbour inlets and along the Italian coastline as follows: Trieste, Venezia Lido, Ancona, Ravenna, Pescara, Ortona, Isole Tremiti, Vieste, Bari, Otranto, Taranto, Crotone, Reggio Calabria, Messina, Catania, Porto Empedocle, Lampedusa, Palermo, Palinuro, Salerno, Napoli, Cagliari, Carloforte, Porto Torres, Civitavecchia, Livorno, Genova, and Imperia (figure 1).

The stations which constitute the NTG, are now all equipped with two different tide gauges: a main electronic ultrasound instrument, with tubular guide and temperature compensation, and a secondary floating mechanic gauge with paper recording, used for a good data control, for the analysis of important events or phenomena and in case of occasional instrument failure as data recovery. Tide gauges are referred to a geographic fixed points (benchmarks) found by high-accuracy levelling, verified with reference to the nearest Military Geographic Institute (IGM) benchmark. Stations are also provided with an anemometric sensor (wind speed and wind direction at 10 meters height), a barometric sensor, an air temperature sensor and a water temperature sensor. All the stations are equipped with a local system of data management/storage and with a real-time transmission device connected with the ISPRA Central unit in Rome. Since the new tide gauge network has been fully operating, the ISPRA provides updated information concerning historical series, real-time observations, astronomical tide forecasts, and data analyses for both planning and scientific purposes. Tide gauge data and updated local tide constants are published on the annual bulletin. Moreover, ISPRA has carried out a recovery of the historical data collected by the pre-existing set of stations, both in paper and digital form, in order to add historical observations to the new National Network archive ([www.apat.it](http://www.apat.it)). ISPRA has inherited the duties of the Hydrographic Office concerning the lagoon of Venice and manages the VNATG. The VNATG is now constituted by a 52 Tidal Gauge system network distributed in the lagoon basin and along the north Adriatic coastline. 25 of these stations are equipped for real time data transmission the processing centre of ISPRA –Venice lagoon Service. Correct functioning of this system is fundamental for warning and prediction of exceptional or atypical tides (flooding) and for the management of the lagoon hydraulic system

The 52 tide gauge station, the data processing Centres and the Radio Relay Network constitute the Real Time Tidal Gauge System of the Lagoon of Venice. This system is a fundamental part of the weather and marine monitoring system of Italian Seas, controlled by ISPRA including the National Tide gauge Network and National Sea Waves Measuring Network. In addition , the ISPRA –Venice Lagoon Service has the capability to exchange data measured in real time between the networks of the Environmental Operating Centres of the North-Eastern regions of Italy (Veneto, Friuli Venezia Giulia and Trentino-Alto Adige). The real-time operability of this network is aimed at several ends, among which are: issuing the Daily Tide Bulletin, signalling and forecasting exceptional high tides and warning civil protection bodies, assisting pilots of the Port of Venice cruising to the harbour inlets and along the big inner canals, starting hydraulic defences in the nearby lagoon inland, etc.

Each of these stations is equipped with a floating tool that gauges and records the tide level electronically. The sampling frequency is adjusted on data every 10 minutes . The gauging reliability in each station is ensured by a second, also floating, mechanic tool, recording on a paper diagram the locally measured tide curve.

Some of the stations, according to their location, are also equipped with tools to gauge such meteorological parameters as atmospheric pressure, rain, wind direction/speed within the Venice lagoon, as well as wind direction and speed along the Northern Adriatic coastline.

The data so-collected are then checked and validated according to the protocols set by subsequently disseminated through specific reports by ISPRA international scientific organizations (IOC, 1985; IOC, 1994; IOC, 2001; WMO) and yet, tide gauge observations, dating back to the 90's, are not yet available in the electronic format. ISPRA updates systematically the processing of the sea level annual mean value estimated for some of the VNATG stations providing the longest observation series. In 2004, ISPRA Trieste and Venice stations have been equipped with new different sensor: a floating electro-mechanic gauge with "code grey" digital output. At the moment, with this sensor is possible to have the same accuracy of the floating mechanic gauge but the data storage is made locally on a electronic support like the ultrasonic instrument. The sampling rate is one minute and so is possible to have a better resolution to measure the "anomalous" waves. Since 2005, the station in Punta della Salute has been equipped with a co-located suitable GPS. A three years time series of GPS data have been elaborated in order to detect the effect of land subsidence in the sea level measurements. At the beginnings of the current year two new co-located GPS devices have been installed at the tide gauge stations of Venezia - Lido Diga Sud and Grado along the north Adriatic coastline. ISPRA, with at least 5 of its sea-level measurement stations, is directly involved in the implementation of a sea level coastal stations network in order to develop the NEAMTWS monitoring system of tsunami warning system in the Mediterranean Sea. Nevertheless, starting from the end of 2009, the Italian tide gauge network (NTG) will be upgraded: 10 new stations will be installed (Pescara, Isole Tremiti, Pantelleria, Stromboli, Bosa, Arbatax, Gaeta, Ponza, Anzio and Portoferraio). All the stations of the NTG will be equipped with new two different tide gauges: a main electronic microwave instrument and a floating electronic gauge with "code grey" digital output; the theoretical measurement accuracy will be 1 mm and the sampling rate till 15 sec for all stations. Hence the NTG will be composed of 37 stations connected, if required, through a real-time transmission with the ISPRA Central unit in Rome with a great improvement in accuracy, frequency of sampling rate and data availability. Other Organizations are involved in sea-level measurement in Italy:

- i) Navy Hydrographic Institute - Genova
- ii) Institute for Marine Sciences – Trieste - (ISMAR\_TS).
- iii) Istituzione Centro Previsioni e Segnalazioni Maree - Municipality of Venice;

- iv) Calabria Region;
- v) Abruzzo Region;
- vi) Puglia Region.

The Marine Hydrographic Institute of Italy is located in Genova since 1872. Its main task is to survey Italian seas and coasts and to report in form of charts and nautical publications for navigation safety.

It produces the classified documentation and the nautical instrumentation to military vessels. (<http://www.marina.difesa.it/idro/index.htm>).

Its activity mainly deals with navigation, including chart production. It manages two sea-level gauges (IIM, 2000) at Genoa and Brindisi, equipped with mechanical float gauges. Data are continuously recorded on paper and subsequently digitized.

The Institute manages the tide gauge station in Genova, with a more than centennial time series of sea level, and the tide gauge station in Brindisi.

New data analysis of Genova time series have been performed in collaboration with ISPRA.

The Institute for Marine Sciences is a research institute belonging to the National Research Council (CNR). It manages one sea-level station in Trieste which is equipped with two float gauges. Analog records are made on paper, and digital records are stored on solid state memory. Atmospheric pressure, wind vector, air temperature and sea temperature are measured at two stations within 500 m from the sea-level gauge. Ferraro (1972) reports the details on the sea-level gauge, including the different zeroes adopted during the secular history of the station. Sea-level related activity includes sea-level modelling (Raicich et al., 1999b) and joint analysis of sea-level and atmospheric data time series on different time scales, namely from hourly/daily, as in the case of seiches and storm surges (Raicich et al., 1999a), to interannual/multidecadal, concerning mean sea level variability (Crisciani et al., 1994; Raicich and Crisciani, 1999). IST also publishes astronomic tide predictions for Trieste (Maselli and Raicich, 1999). CSPM is a Organization belonging to the municipality of Venice. Its activity includes sea-level monitoring at 14 sea-level gauges and sea-level prediction. It is also in charge of issuing warnings to Venice population when particularly high sea-level events are predicted. CSPM operates 14 sea-level gauges, all provided with real time data transmission, located inside the lagoon of Venice. In such events the *Istituzione Centro Previsione e segnalazione Maree* of the Municipality of Venice (CSPM) warns its citizens by the sound of sirens at various locations throughout the city. The Regional Administration of Calabria has been managing 3 sea level and meteomarine stations since three years at Cetraro, Corigliano and Roccella Ionica. The Regional Administration of Abruzzo has been managing a sea level and meteomarine station since 20 years at Pescara. The Regional Administration of Puglia, South Italy, also operates on sea-level measurements: since 2006, 4 new tide gauges have been installed at Ischitella, Manfredonia, Brindisi, Porto Cesareo. The measurement stations are able to automatically obtain the water level's value, calculate the averaged out values in a programmable time, to store average and extreme levels and transmit data to the main station through GSM system. The system includes an ultrasonic level gauge of high ranking precision and capacity of storage, able to ensure a high quality functioning. The data surveyed from the sensors are processed through an electronic station (Data Logger), installed nearby the sensors, and then transmitted to a Database Server at the Collection and Processing Data Center.

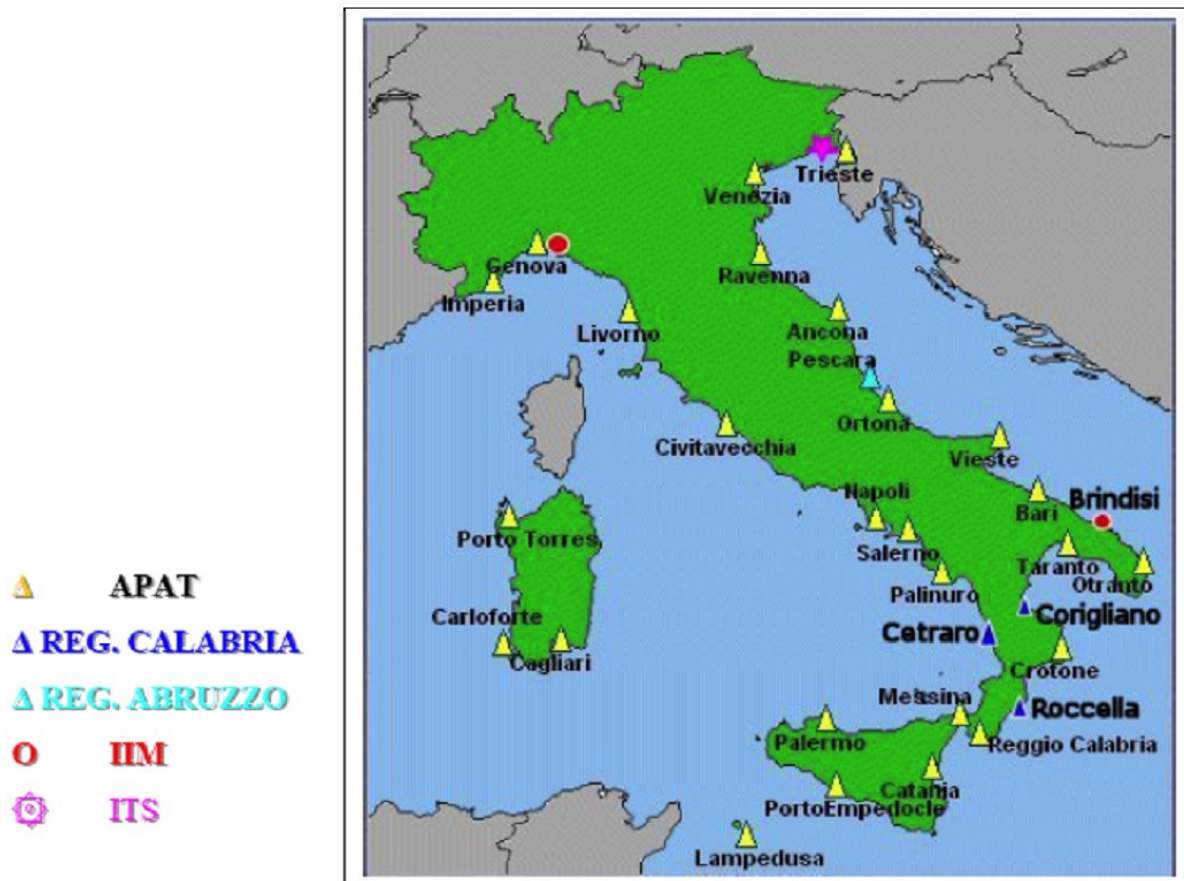


Fig. 1 – The Italian Sea Level Network

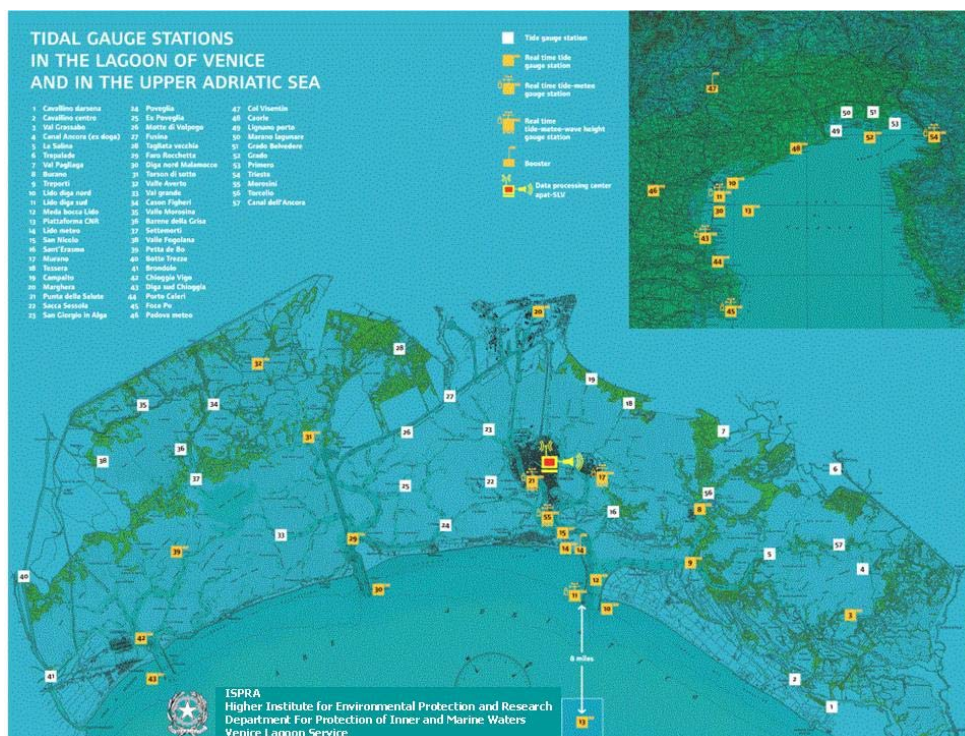


Fig. 2 – Tidal gauge stations in the lagoon of Venice and in the upper Adriatic sea.

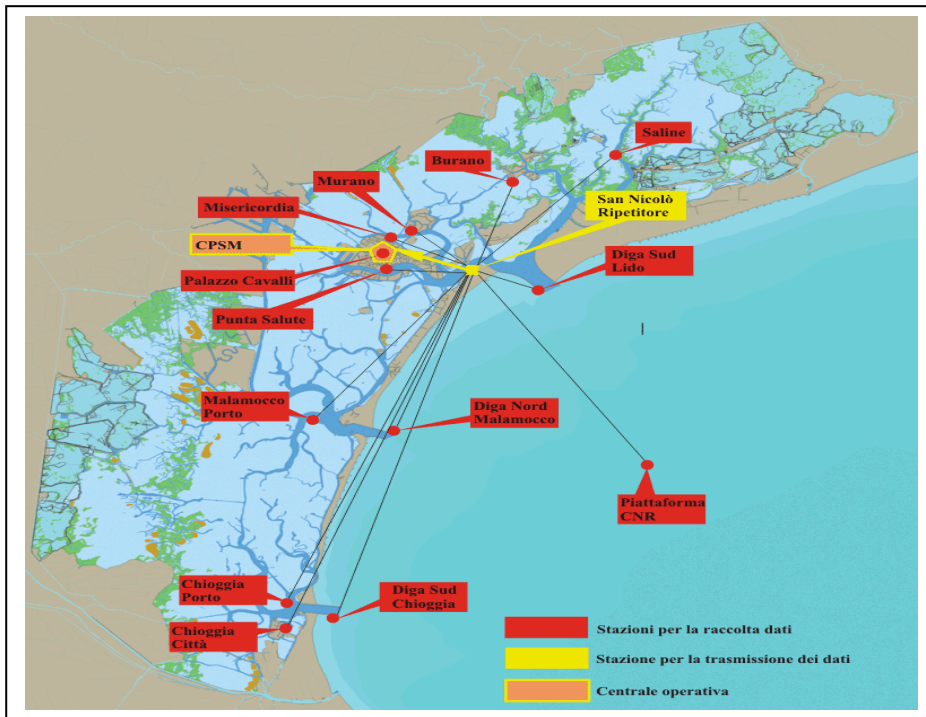


Fig. 3 – CSPM sea level network in the Venice lagoon.

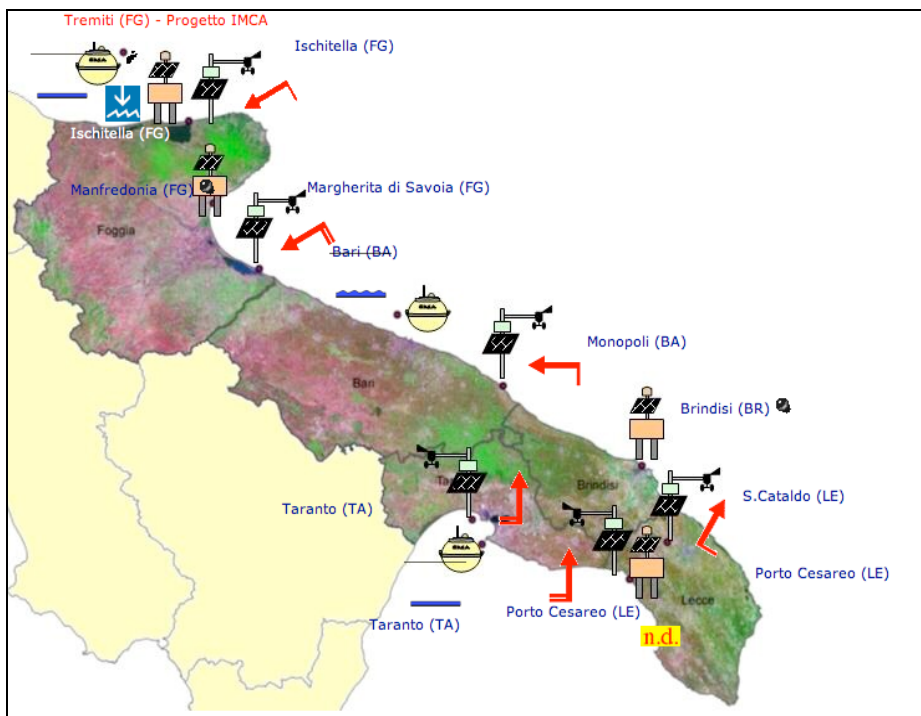


Fig. 4 – Sea level network in the Puglia Region

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