Multiparametric analysis of Gulf of Pozzuoli

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1. Introduction

The Gulf of Pozzuoli is one of the more interesting areas for studies of several disciplines. It is a partially closed tiny basin that can be considered as the NW portion of Gulf of Naples, Italy. Its principal characteristic is the presence of volcanic caldera of Campi Flegrei, the most dangerous one in the world. At the same time, the Gulf of Pozzuoli is a natural laboratory for the study of sea behaviour in a semiclosed basin, above all for the circulation and particular oscillations (for example, seiches and Kelvin waves). These last ones are the reasons why the behaviour of this gulf is monitored by several instruments. Among these ones, there are the instruments of monitoring infrastructure M.E.D.U.S.A (acronym of Multiparametric Elastic-Beacon Devices and Underwater Sensors Acquisition system) belonging to Osservatorio Vesuviano, a research observatory situated in Naples. In this work, two physical parameters of Gulf of Pozzuoli have been analysed: temperature and velocity. The study has been realised using data acquired by a 3-D current meter placed in M.E.D.U.S.A buoy CFB3 at 40 m depth. The choice of this instrument has been made because it is equipped by several sensors, included temperature and velocity one. So, it is possible to develop an only acquisition system. But, apart this practical question, the most relevant aspect is that the instrument is placed in the internal part of Gulf of Pozzuoli, at 1,5 kilometers far away the coast. In this way, it is possible to obtain a double monitoring. First, the comparison of obtained temperature and velocity with those theoretical ones illustrated by previous works. Second, the eventual presence of a correlation between the sea behaviour and activity of volcanic caldera. To reach this goal, a spectral analysis has been implemeted and it has been obtained by means of a Continuous Wavelet Transform, performed by the specific Matlab function. The work is structured in following way: state of art of Gulf of Pozzuoli about circulation and temperature is briefly described in paragraph 2. In paragraph 3, there is a brief illustration of volcanic caldera of Campi Flegrei and of M.E.D.U.S.A infrastructure. Paragraph 4 is focused on description of data and methods used for the analysis. Finally, results and future perspectives are described in paragraph 5.

2. Study Area

The Gulf of Pozzuoli is a tiny body of water that represents the NW portion of Gulf of Naples. Its horizontal extension measures almost 9.5 km, considering distance between Capo Miseno and Capo Posillipo. It is a natural observatory for several scientific disciplines as biology, chemistry, physics. And volcanology and oceanography, too. Indeed, the Gulf of Pozzuoli is an integral part of volcanic caldera of Campi Flegrei. This latter is the most dangerous volcanic caldera in the world. This because it is situated in an area where there is a high exposure of people who live there (550,000 inhabitants ca.). With a diameter of 12-15 km, this volcanic caldera expands all the way both to land and to Gulf of Pozzuoli, so to sea. Actually, it is in quiescence and it is composed of craters, tiny volcanic cones and location of secondary volcanism, the bradyseism above all. Bradyseism is a typical phenomenon of Campi Flegrei and it represents an uplift and/or a descent of part of the ground surface placed on the top of magma chambers caused respectively by the filling or emptying of these ones or by hydrothermal activity.
Hydrologic structure of Gulf of Pozzuoli is composed of one substantially homogeneous layer, essentially made up of Atlantic water. Its maximum depth is 100 m, its density ranges from 1026.63 to 1028.65 kg/m^3, while salinity varies from 37.2 to 37.8 psu. Regarding to temperature, this last one ranges from 18°C in summer to 14°C in winter. In this season, temperature is almost constant because of continuous mixing of water column.
Regarding to circulation, regulated by equations of motion in shallow water, it is essentially due to large scale circulation forced by geostrophic and ageostrophic currents present along the lateral boundaries of the Gulf. In fact, the contribute of Ekman currents due to local winds is negligible. Drilling down, circulation in Gulf of Pozzuoli has essentially a zonal component and it has an interesting behaviour in autumn, when circulation is stronger (almost one order of magnitude) in left boundary, corresponding to Canale of Procida, than in right one. This because the particular conformation of Gulf of Pozzuoli inhibits in left part of basin that external currents could insinuate into it.

3. Data and Method

The database used for the analysis is made up of data acquired by 3-D Dimensional current meter belonging to CFB3 buoy of MEDUSA infrastructure, situated at 40 m depth in Gulf of Pozzuoli (Fig. 2). More precisely, data consist of temperature and velocity acquired by the previously mentioned instrument in period January 2017 – May 2020. Data are sampled at frequency of 1 Hz, but, for obtaining a data compactness, they are averaged at 1 hour. In this way, 29184 temperature and velocity (regarding to this latter, data have been acquired both for zonal and meridional component) data have been sampled. Because of instrument's electronic problems, several sampled data have been missed, especially in first four months of acquisition (January – April 2017). So, original database is lightly reduced and it is made up of 26741 data for temperature and zonal velocity, while for meridional velocity new database is made up of 26699 data. In percentage, the reduction is approximately 8.4%. The process of data reduction has been occurred by means of specific MATLAB function "rmissing". Then, the work has been structured in following way. For temperature, entire time series has been plotted in a way to verify its seasonal tendency. After this, a Continuous Wavelet Transform (CWT) of time series has been performed. This specific typology of analysis has been made for two reasons. First, the CWT ensures the maintenance of time information when the passage from time dependence to frequency one happens. Second, CWT produces a better resolution compared to other similar methods that preserve both time and frequency information, as Short Time Fourier Transform (STFT). By means of CWT, the goal of verifying eventual prevalent frequencies and when these latter ones occur has reached. The entire procedure has been done again both for zonal and meridional velocity component, too. But, regarding to these latter, a more step in the procedure has been made. In fact, besides the treatment of the whole time series, a comparison between zonal and meridional velocity in autumn has been performed. This because the goal is the obtaining of a direct verify about circulation in Gulf of Pozzuoli in this determined season. This particular procedure has been made through time series of zonal and meridional velocity components acquired in November-December 2017 and November-December 2018. The analogous time series November-December 2019 has not been considered because of strong electric noise present. As for entire time series, for the two short time series previously mentioned, first a plot of comparison has been made and after CWT of them has been performed. Both plot and CWT of considered time series have been realised by means of opportune MATLAB functions, respectively "plot" and "cwt", this latter after having put sampling frequency equal to Hz.

Fig.1 - collocation and bathymetry of Gulf of Pozzuoli

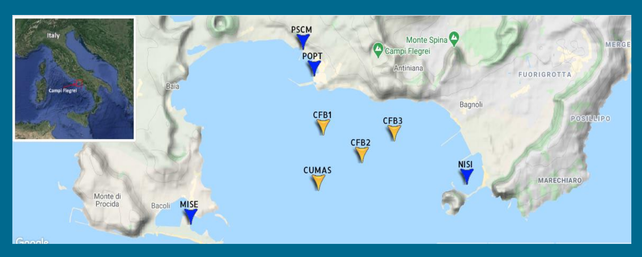


Fig. 2 – Ubication of the four buoys (in yellow) of M.E.D.U.S.A infrastructure in Gulf of Pozzuoli. In the circle, the buoy CFB3 where there is the 3-D dimensional current meter used for the analysis

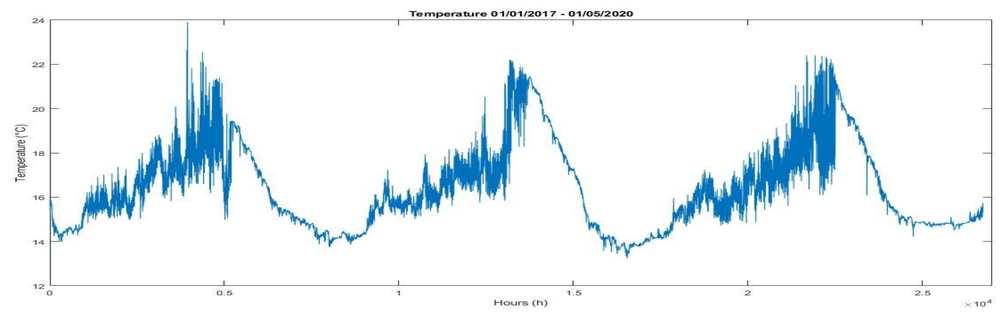
5. Further results and conclusions

In conclusion, data of temperature and velocity (zonal and meridional components) acquired in period January 2017 – May 2020 by a 3D-dimensional current meter belong to buoy CFB3, situated at 40 m of depth in right part of Gulf of Pozzuoli (see fig. 2) of infrastructure M.E.D.U.S.A performed by Osservarorio Vesuviano have been analyzed. Besides time series, CWT have been performed for verifying eventual interesting frequencies. For temperature, a seasonal variability is substantially confirmed and a peak of frequency of 22.3 μHz appears at maximum temperature. For zonal and meridional velocity component, there are two interesting results. First, the dominance of meridional velocity component as compared to zonal one in period November-December 2017. Second, the possible "contamination" of data velocity with earthquake swarms in Campi Flegrei. A result that could represent a future prospective, acquiring data from other current meters in other three M.E.D.U.S.A buoys and performing a direct comparison between these data and data obtained by other instruments of monitoring network of Campi Flegrei, as mareographs, seismometers and wind gauges.

4. Main results

Figure 3

a



b

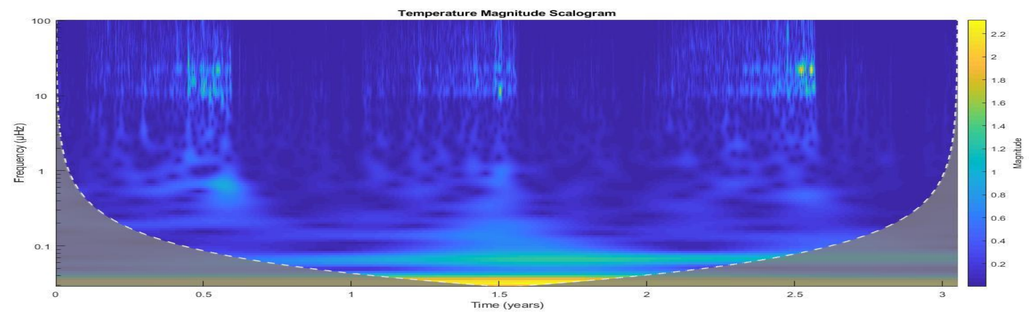
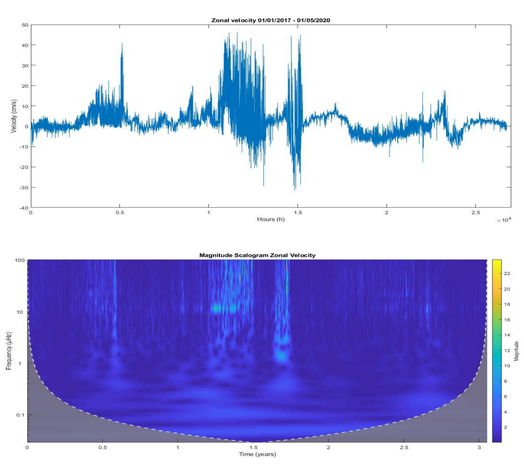


Fig. 3 – (a), time series of temperature in period January 2017 – May 2020 with its «wave» behaviour; (b) – CWT of time series where peaks at frequency of 22.3 μHz corresponding at maximum temperature appear

Figure 4

a



b

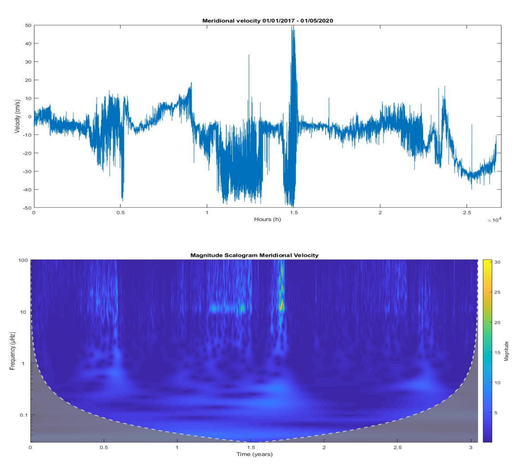


Fig. 4a – Time series of zonal velocity in period January 2017 – May 2020 (up) and its CWT (down); fig. 4b – Time series of meridional velocity in period January 2017 – May 2020 (up) and its CWT (down). In both time series, as is possible to observe, strong anomalies appear in period [1200 hrs, 1400 hrs], corresponding to March-April 2018 and in period [1500 hrs, 1700 hrs], corresponding to September-October 2018. These anomalies could be explained by means of two reasons: possible strong electronic noise or correlation with earthquake swarms happened in area of Campi Flegrei in those periods. An observation corroborated by two CWTs, where there peaks at 10 μHz, that is frequencies proximate to seismic ones.

Figure 5

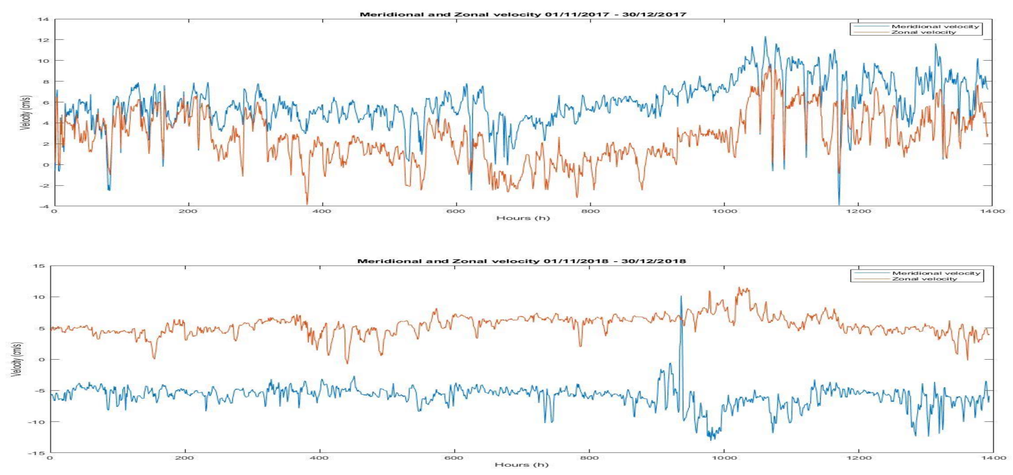


Fig. 5 a – Time series of meridional (blue) and zonal (red) velocity in period November-December 2017; Fig. 5b – same characteristics in period November-December 2018. It is possible to observe as, instead of theoretical previsions, meridional velocity is stronger than zonal component one in Nov-Dec 2017. «Regular» situation comes back in Nov-Dec 2018.

6. References

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