Reconstruction of the 3D distribution of physical parameters in the northern part of Lake Iseo

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1. EFFECT OF EARTH ROTATION ON LAKE ISEO INFLOW

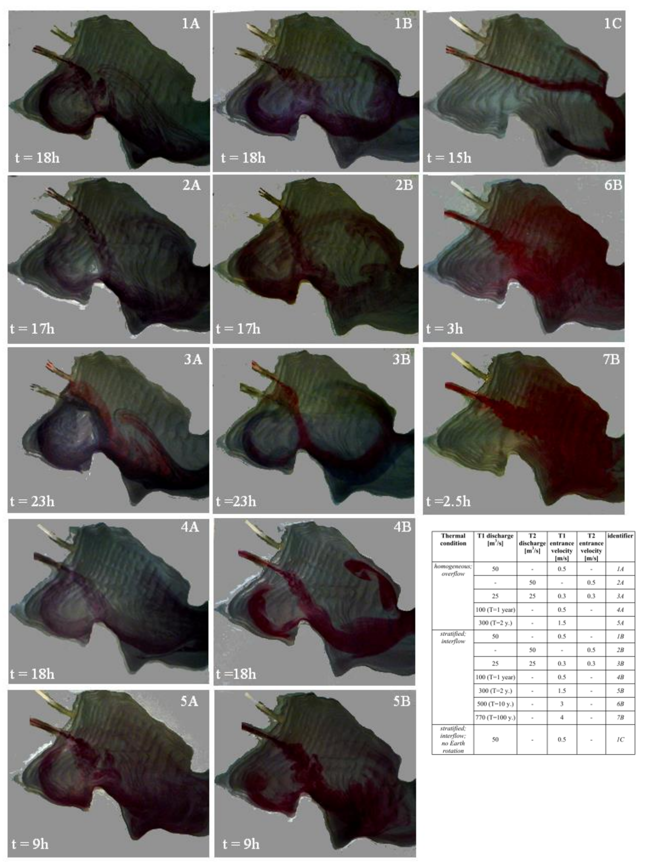

Figure 1 – Comparison between flow fields in thermally homogeneous (A), stratified (B) and no rotation (C) conditions. The table details the prototype conditions simulated with the model. The T letter within round brackets shows the return period

In order to study the area of influence of the two major tributary rivers in Iseo Lake, a rotating vertically distorted physical model of the northern part of this lake was prepared and used, respecting both Froude and Rossby similarity. The model showed the occurrence of dynamical effects related to the Earth's rotation on the plume of the two tributaries which enter the northern part of the lake. Under ordinary flow conditions, the model shows a systematic deflection of the tributary waters towards the western shore of the lake, triggering a clockwise gyre within the Lovere bay and a slow counter-clockwise gyre that returns water towards the river mouth moving along the eastern shore. For discharges with higher return period, the effect of the Earth's rotation weakens in the entrance zone and the plume has a more rectilinear pattern. On the basis of these results one could expect that the north-western part of the lake between Castro and Lovere, although disaligned with respect to the tributaries axis, is more sensitive to accumulation effects related to river-borne pollution. The results have been recently confirmed by SENTINEL-2 satellite observations and were tested during a detailed monitoring campaign

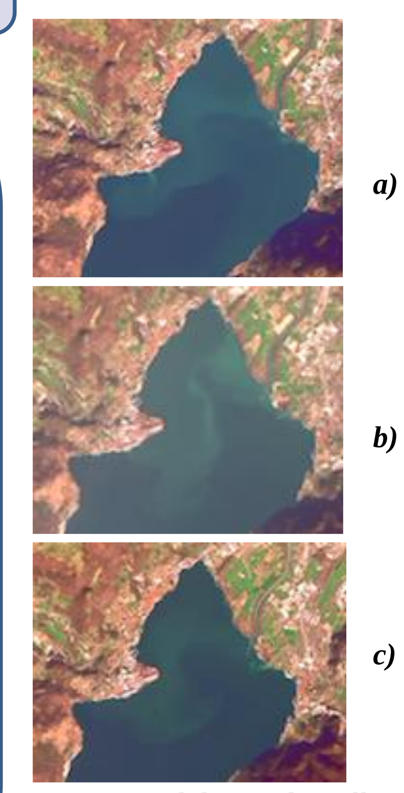

Figure 2: Elaborated satellite images of tributary inflow to Lake Iseo, evidencing strong westward drift of currents in thermally unstratified period (a, b: 3/2014; c: 3/2016)

2. MONITORING CAMPAIGN IN THE NORTHERN PART OF THE LAKE

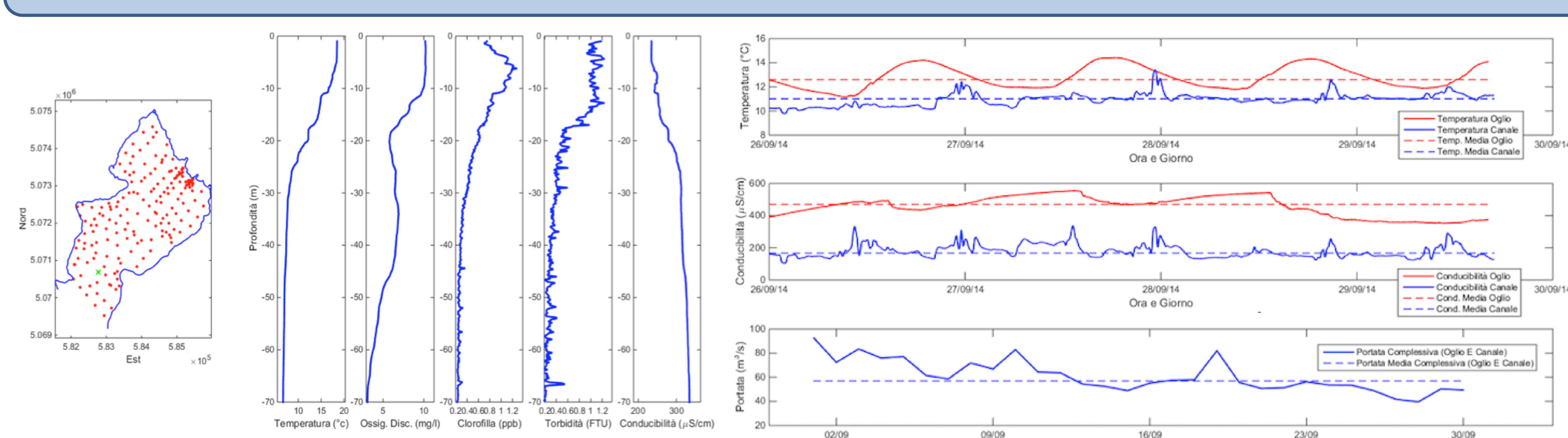

Figure 3: Sampling points and typical pattern of the investigated variables between 0 and 70 m, as measured at the station marked with a green cross green on the left panel. On the right, the temperature, conductivity and discharge variations of the 2 tributaries during the experimental campaign are shown

On 29 and 30 September 2014 an extensive experimental campaign was carried out in the northern part of Lake Iseo, Italy. 179 vertical profiles of temperature, conductivity, dissolved oxygen, chlorophyll A and turbidity were measured between 0 and 60 m of depth, at an average horizontal distance of about 350 m and a vertical resolution of 0.2 m. In the experimental period, the two main inflows conveyed 40-80 m^3/s in the lake The wide measured data set was used to test the capability of some interpolations methods in representing the spatial distribution of the variables.

3. 3D SPACE INTERPOLATION OF THE VOLUMETRIC DISTRIBUTION OF VARIABLES

Although in several cases kriging provides a superior interpolation, the fundamental assumption that mean and variance of the data are invariant with translation, i.e. stationarity of the investigated parameters, does not seem warranted. Inverse Distance Weighting method (IDW) was finally selected (e.g, Bahner 2006) because of its efficiency and ease of implementation within MATLAB environment. The succesful 3D interpolation through IDW was accomplished with optimal exponent of 3 for temperature, 2 for turbidity and 1 for the other variables. In order to deal with the strong vertical anisotropy determined by the thermal stratification, the vertical coordinate z was stretched by a vertical amplification factor 〈 , mapping the data from the xyz space to a xy$\underline{z}$ grid space, where $\underline{z}$ = 〈 z. To this purpose also the use of the Brunt-Vaisala frequency was tested, in order to reduce the uncertainty associated with the methodology.

The volumetric representation of the data shows that the Coriolis force manifests itself in a different average distribution of the parameters in the west side of this lake. From the environmental point of view the most important is the Oxygen concentration that reflects the stronger BOD related to the nutrient rich waters of the tributaries. This has also strong implications on swimming restrictions in recreational water during wet periods.

The analysis of the temperature data evidences strong spatial and temporal dishomogeneitis that, in reality, are an artifact of the highly transient field of internal waves. Accordingly, in order to reconstruct detailed maps of T distribution a detailed modelling of the lake hydrodynamics is of help in the interpretation of the measurements. We used the 3D *ELCOM* model to simulate the internal wave field in the period 26/09/2014 – 30/09/2014 on the basis of the wind field on the lake, interpolated between 2 land stations and a nearby LDS station.

On the other hand, the comparison between the measured data and the results of an the model prove that a correct reproduction of the internal waves at a local scale demands a very detailed reconstruction of the wind flow field. However, even a state of the art simulation of the distributed pattern of wind on the lake surface can't reproduce some fine structures that emerge from the experimental campaign.

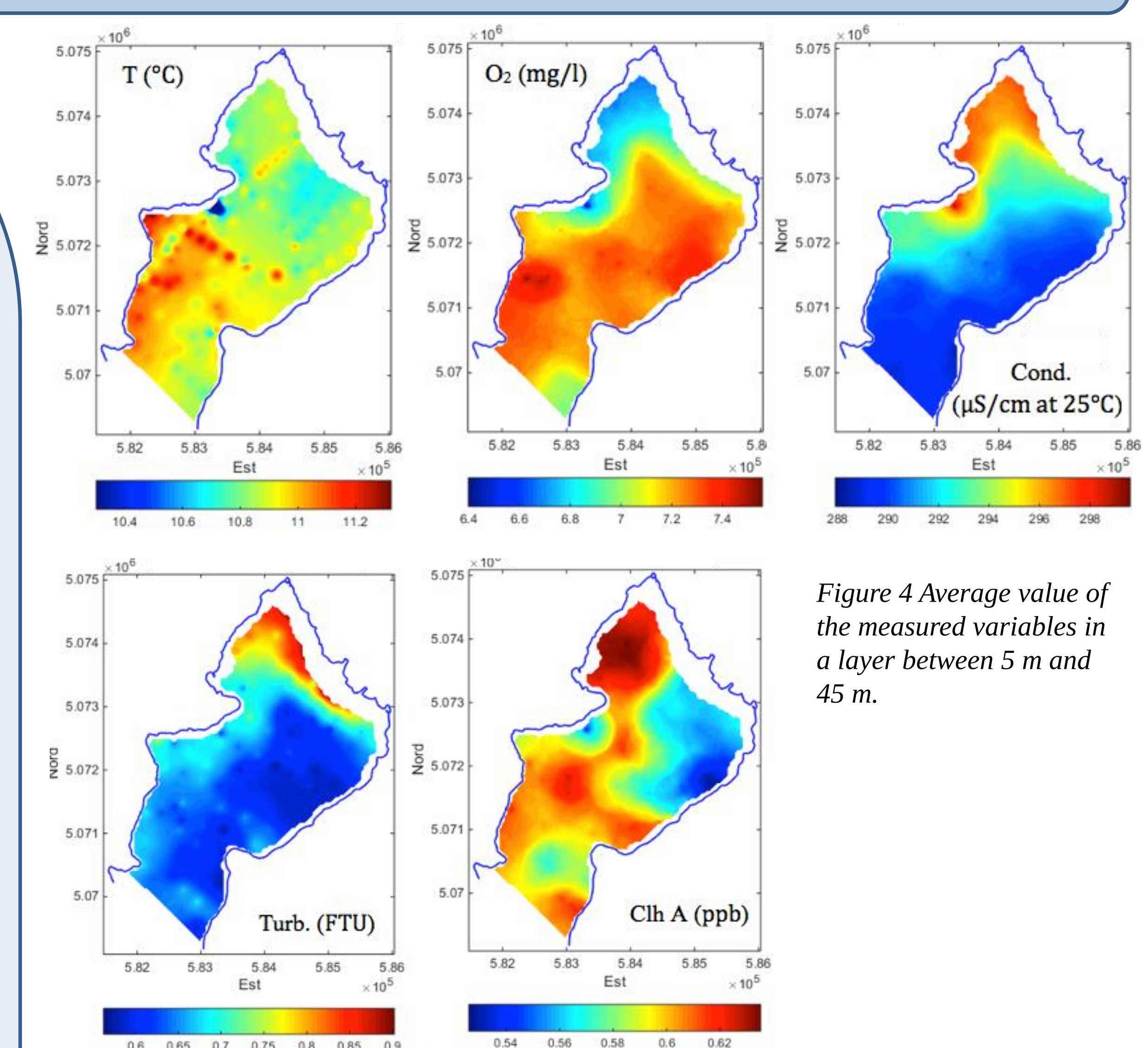

Figure 4 Average value of the measured variables in a layer between 5 m and 45 m.

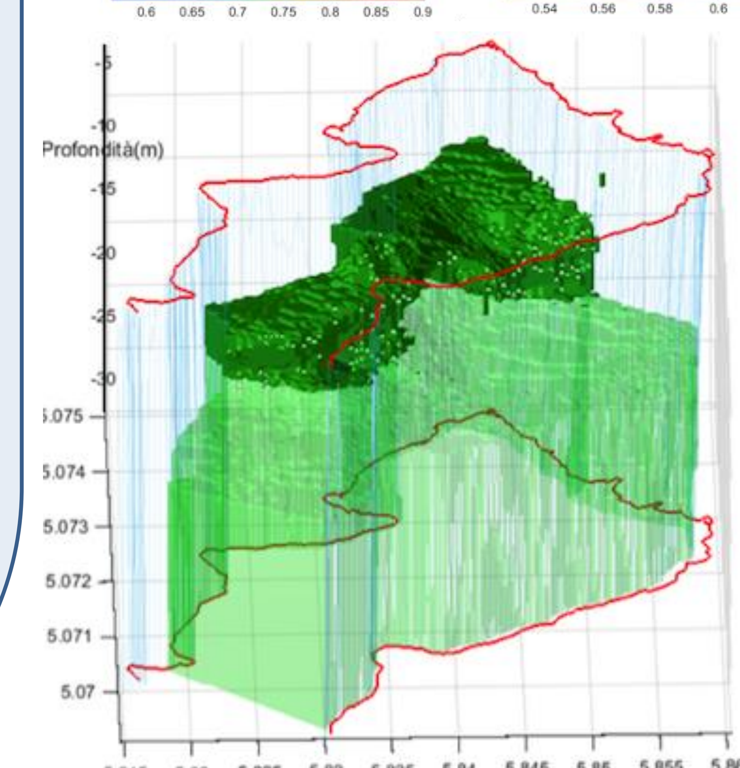

Figure 5 3D voxels visualization of normalised conductivity > 255 μS/cm

1.The persistent role of Coriolis force is evident in a different average distribution of the oxygen in the west side of this lakeand a systematic temperature differences in east-west transects.

2. A detailed monitoring campaign must be followed by a detailed modelling of the lake hydrodynamics that helps in the interpretation of the measurements. Without this type of support, the analysis of the data would evidence spatial and temporal dishomogeneitis that, in reality, are an effect of the highly transient field of internal waves.

3. The correct reproduction of the internal wave at a local scale demands a very detailed reconstruction of the wind flow field. However, even a state of the art simulation of the distributed pattern of wind on the lake surface, can't reproduce some fine structures that emerge from the experimental campaign. Accordingly, it seems that in presence of internal waves, the reconstruction of space distribution of relevant variables can be accomplished only through a suitable space and time averaging.

REFERENCES:

Pilotti, M., Valerio, G., Gregorini, L., Milanesi L. and Hogg C. (2014a), Study of tributary inflows in Lake Iseo with a rotating physical model , *J. Limnol.*, Vol 73, No 1, doi: 10.4081/jlimnol.2014.772.

Pilotti, M., Simoncelli, S., Valerio, G. (2014b), A simple approach to the evaluation of the actual water renewal time of natural stratified lakes, *Water Resources Research*, VOL. 50, Issue 4, pages 2830–2849, doi:10.1002/2013WR014471.

Valerio, G., M. Pilotti, C.L. Marti, C.L. and J. Imberger (2012), The structure of basin scale internal waves in a stratified lake in response to lake bathymetry and wind spatial and temporal distribution: Lake Iseo, Italy, *Limnol. Oceanogr.*, 57(3), 772-786.

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