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Deep-mixing and deep-cooling events in Lake Garda: Simulation and Mechanisms

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A calibrated three-dimensional numerical model (Delft3D) and in-situ observations are used to study the relation between deep water temperature and mixing in Lake Garda (Italy). A model-observation comparison indicates that the model is able to adequately capture the production of turbulent kinetic energy in the surface layer and its vertical propagation during unstratified conditions. Here, the model is used as a support to identify the main processes causing deep water cooling and deep mixing in the lake. The analysis indicated that two processes cause mixing over the entire depth. The first process is thermocline tilting due to strong and persistent winds. This is found to generate a temporary disappearance of stratification followed by vertical mixing over the entire depth. The second process is turbulent cooling, which arises as a combination of negative-buoyancy produced by surface cooling and turbulence injection from strong winds. Turbulent cooling acts when vertical temperature gradients are absent over the whole depth and cools and mixes the lake over its entire vertical. The third identified process is associated to differential cooling between the shallow southern part and the deep northern trunk. This generates the advection of cold water from the southern, colder and well-mixed basin to the norther trunk along the sloping bottom of the lake. Such differential cooling is found to be a consequence of the turbulent cooling and is not associated with mixing over the entire depth in the northern trunk. Available observations indicate that the three processes identified from the model indeed occur in Lake Garda. Long- term simulations of deep water temperature and related deep mixing appear to be very sensitive to the atmospheric forcing, whose accurate reproduction is essential for the prediction of the future occurrence of deep mixing events.