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Towards an Assessment of Atmospheric Forcing on Chlorophyll-a and Turbidity in an Oligotrophic Lake: Lake Bolsena Case Study

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Chlorophyll-a (Chl-a) is commonly used as an indicator of phytoplankton biomass and eutrophication in inland waters, as it reflects changes in primary productivity and nutrient availability. Turbidity describes the optical effect of suspended particles in the water column and, in oligotrophic lakes, is typically low but highly responsive to external factors such as wind-induced mixing and precipitation. Analyzing Chl-a and turbidity together in relation to atmospheric conditions is therefore crucial for evaluating water quality and identifying potential pressures on aquatic ecosystems.
In this study, Lake Bolsena was investigated as a representative oligotrophic system to evaluate how atmospheric conditions influence Chl-a concentration and turbidity. The analysis was conducted over the lake surface and an additional surrounding land buffer of approximately 15 km, selected to account for meteorological and atmospheric processes that are not confined to the water body itself but can indirectly affect its optical and biological properties.
Chl-a and turbidity were derived from the data set (version 2.1) of the ESA Lakes_cci project based on the processing of OLCI images for the period 2016-2022. Meteorological variables considered include wind speed at 10m, 2-m air temperature, surface pressure, boundary layer height, precipitation, and solar radiation, all derived from the ERA5 reanalysis dataset (Hersbach et al., 2020). In oligotrophic lakes, wind speed regulates water column mixing and sediment resuspension, while air temperature and solar radiation influence thermal stratification and the energy available for phytoplankton growth; precipitation contributes to suspended material modifying surface optical properties. Boundary layer height and surface pressure provide additional information on atmospheric stability and mixing conditions that modulate air–water exchanges.
Aerosol Optical Depth (AOD) retrieved using the MAIAC algorithm was also included, although it is not available directly over the lake surface but only in the surrounding area (Lyapustin et al., 2018). AOD was used as a proxy for regional aerosol loading to investigate its potential indirect effects on the lake through dry and wet deposition of particulate matter and nutrients, which may alter water transparency and, over time, phytoplankton dynamics even under oligotrophic conditions.
Correlation analysis revealed significant seasonal variability throughout the studied period. Chl-a is particularly influenced by multiple atmospheric forces in autumn, while turbidity is primarily

driven by meteorological factors in summer. Both water quality parameters exhibit variable but significant dependencies in spring; on the other hand, atmospheric influence is less relevant in winter.

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