Diagnosing anthropogenic nutrient enrichment in the Mediterranean Sea: 1950-2030

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Anthropogenic phosphorus (P) and nitrogen (N) loads to the Mediterranean Sea (MS) have increased significantly since the middle of the 20th century, because of rapid coastal population growth and on-going agricultural and industrial intensification. The aim of this study is to determine whether the large increases in anthropogenic reactive P and N inputs to the MS can be detected in measurements of nutrient concentrations, over and above variations caused by confounding factors, specifically the variability in thermohaline circulation (THC) in the MS. Nutrient loading trajectories for the time period 1950 to 2030 suggest that total land-derived reactive P and N inputs – from rivers, atmospheric deposition, direct wastewater discharges and submarine groundwater discharges – increased by factors of 3 and 2, relative to the corresponding 1950 inputs, for the Western MS (WMS) and Eastern MS (EMS), respectively. These inputs are imposed to a mass balance model of P and N cycling in the MS, together with a number of circulation scenarios. The latter simulate the likely range of inter-annual variability in THC. The results show that the magnitudes of changes in reactive P concentrations due to anthropogenic nutrient inputs are unlikely to be large enough to be observed over the noise caused by natural circulation variability. In contrast, anthropogenic N enrichment should be observable in time series data for dissolved organic N concentrations collected after the 1970s, and for nitrate concentrations after the 1990s. Anthropogenic nutrient enrichment signatures are also expected to be more clearly expressed in the EMS than WMS. The detection of anthropogenic nutrient concentration trends is difficult due to the unique nature of the MS. The largest nutrient input into the MS is from the Atlantic Ocean, which dilutes the anthropogenic nutrient inputs. In addition, the anti-estuarine circulation “cleans” the MS by removing P and N accumulating in deeper water layers, while variations in intermediate and deep water formation rates complicate the interpretation of temporal changes in reactive P and N water column concentrations.