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Local and remote drivers of the observed thermohaline variability in the northern Adriatic shelf

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The northern Adriatic (NAd in the following), the northernmost embayment of the Mediterranean Sea, is a shallow shelf with maximum depths reaching 60 m only. Thermohaline variability of the NAd shelf is considered to be mostly driven by local rivers (mainly by the Po River), releasing a large freshwater load to the sea. Moreover, this embayment is surrounded with large mountain chains that play a role in shaping the wind regimes over the sea. For that reason, the NAd thermohaline variability has been considered to be driven mostly by local drivers: (i) heat fluxes, particularly heat losses peaking during severe wintertime bora that generate dense waters and trigger the Adriatic thermohaline circulation, and (ii) river discharges shaping both salinity and temperature in the area and maintaining strong stratification during the warm part of a year. To investigate this hypothesis, we correlated the temperature, salinity and potential density anomaly (PDA) data collected along the Po-Rovinj transect in the NAd for the period 1979-2016 with different local and remote drivers: ERA-Interim net heat flux and total precipitation averaged over the whole basin, Po River discharges, the BiOS (Adriatic-Ionian Bimodal Oscillating System) index, and different indices that describe hemispheric (North Atlantic Oscillation - NAO, East Atlantic - EA, East Atlantic/West Russia - EAWR, Scandinavian - SCA) and regional (Mediterranean Oscillation - MO) atmospheric circulation patterns. Correlation analyses between a thermohaline variable and a driver with the phase lag up to -12 months were performed separately for the winter (February), when the dense water formation (DWF) is occurring, and for the annual averages with the phase lag up to -5 years. Heat flux is the most relevant driver of the wintertime temperature variability, yet not during the DWF itself, but two months prior (December). The river discharges are only marginally affecting the wintertime temperature, but are quite important for the salinity variability. Precisely, large river discharges up to 4 months prior the DWF and during the previous summer are lowering the wintertime NAd salinity, and therefore the DWF intensity. The strongest correlation to the NAd salinity is achieved by the BiOS index. In average, the BiOS regime changes in the northern Ionian are affecting the NAd salinity after 2-3 years. As for the hemispheric and regional atmospheric circulation patterns, no significant connection of the NAd thermohaline variability was found with NAO and EAWR. EA is driving the temperature variability in the area (through the heat flux control), whilst processes described by the SCA and MO indices are presumably influencing the generation of the saline LIW in its source areas, which then takes a few years to travel to the NAd. Our findings are emphasizing the importance of remote oceanographic and atmospheric processes for driving thermohaline variability in semi-enclosed seas such as the NAd, presumably reflecting to its hydrography, biogeochemistry, biology and even fisheries.