The role of the air-sea water fluxes and of the lateral salinity influence in the bimodal circulation variability of the Northern Ionian Gyre (NIG) in the period 1988-2020.

by
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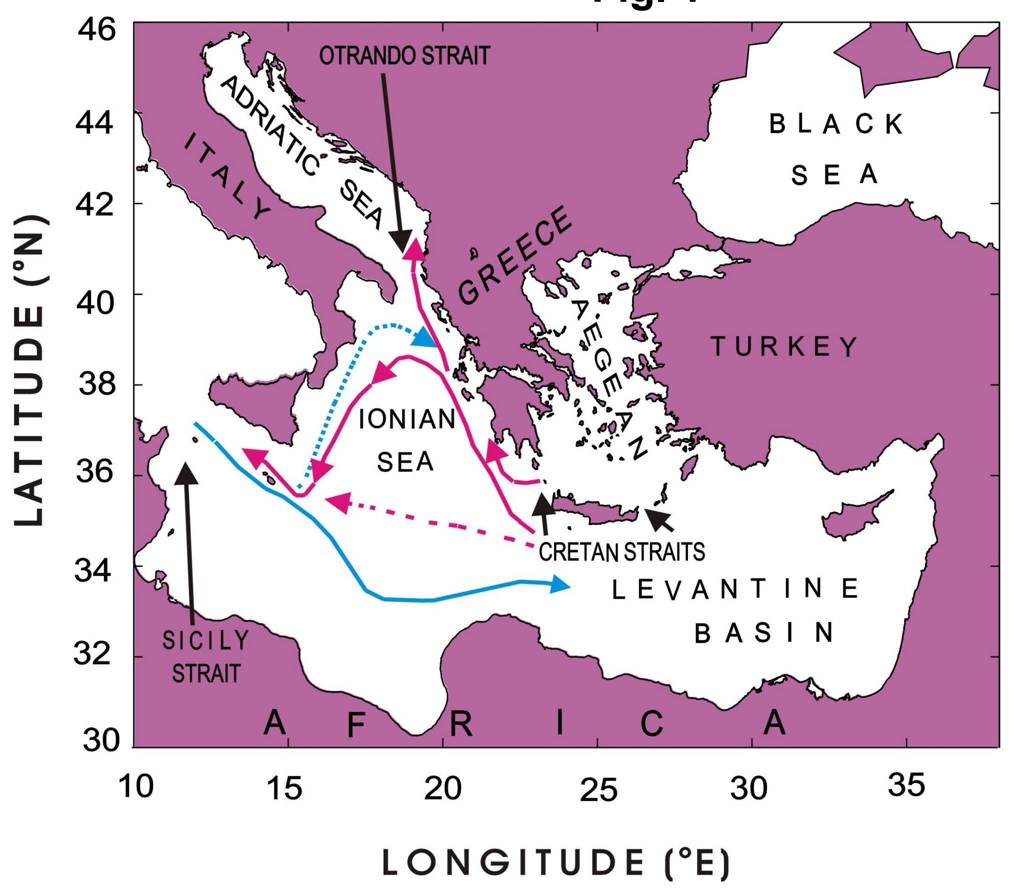
1. **Introduction:** The circulation in the upper layer (~0-400 m) of the Ionian Sea is characterized by an alternation in the routes (solid vs dashed curves, Fig. 1) along which the lower-salinity Modified Atlantic Water (MAW) propagates to the east and the higher-salinity Levantine Intermediate Water (LIW) propagates to the west.

Fig. 1



Blue: Transport routes of low salinity MAW (Modified Atlantic Water)

Red: Transport routes of higher salinity LIW (Levantine Intermediate Water)

NIG is in the North-West Ionian Sea

In the Ionian Sea, the role of the air-sea water fluxes in shaping the upper-layer salinity, which is linked to the appearance of a cyclone/anticyclone in periods characterized by higher/lower densities in the upper-layer, **has not been considered** in the so-far bibliography on the circulation variability in the NIG.

WE USE DYNAMIC HEIGHTS TO INVESTIGATE THE CIRCULATION VARIABILITY BASED ON T,S OF COPERNICUS MONTHLY REANALYSIS during 1988-2020

2. Results: Figures 2, 4 show results from previous studies based on absolute dynamic topography data, while Figures 3, 5 show corresponding present results based on Copernicus data. THE PRESENT RESULTS AGREE TO THE PREVIOUS ONES. The year-mean circulation during 1996, 1998, 2005, 2007, 2010, 2016, 2018 (common in Figs. 2,3) is in agreement. Maximum circulation variability (Figs. 4, 5) on the NIG is also in agreement. Maximum variability of density and salinity is also on the NIG (Fig. 6). Within the NIG, salinity is the dominant factor determining the density (Fig. 7, Fig. 8).

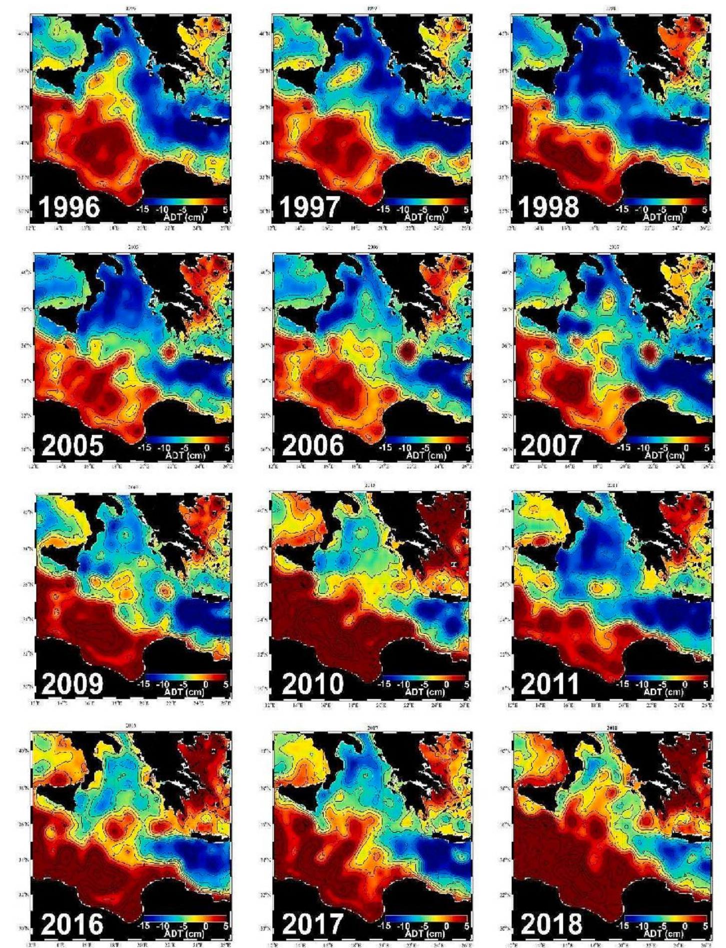


Fig. 2. Year-mean dynamic surface topography fields. From Civirarese et al. Progress in Oceanogr., 2023

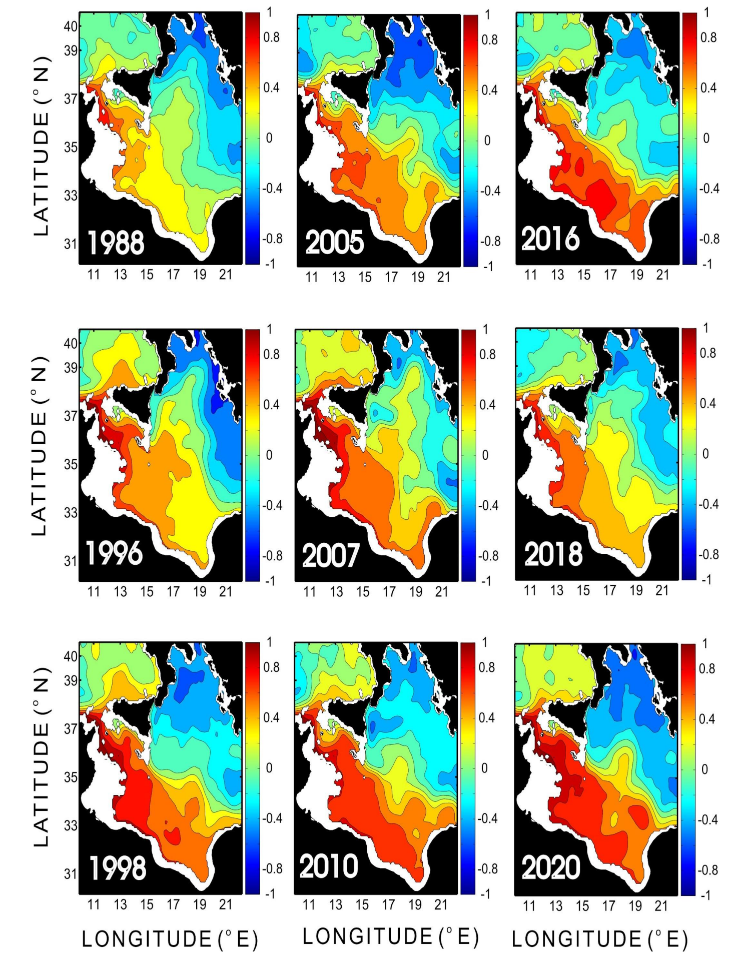


Fig. 3. Year-mean dynamic heights at the surface wrt 120 m (from the reanalysis of monthly mean temperature and salinity Copernicus data)

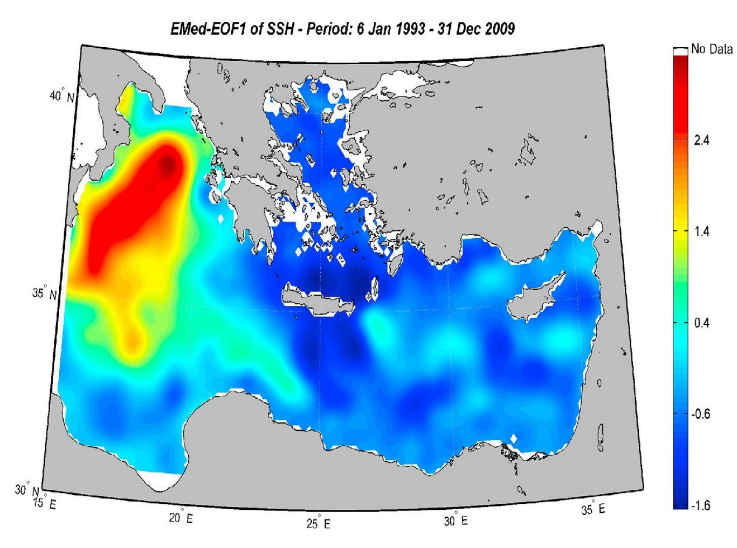


Fig. 4. 1st EOF amplitude of Sea Surface Height (surface dynamic topography) Period: Jan 1993 – Dec 2009. From Gacic et al., JGR, 2011

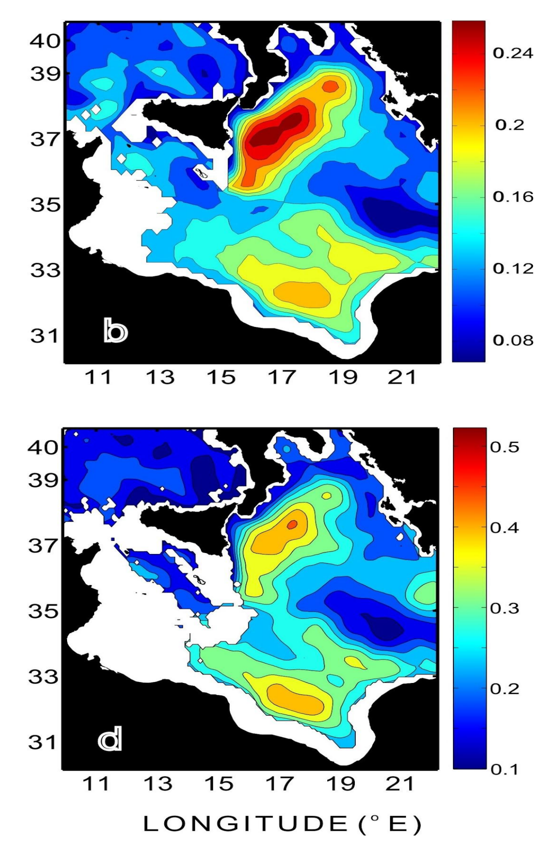


Fig. 5. Standard Deviation of Dynamic Heights (1988-2020) b: surface wrt 120 m, d: surface wrt 398 m.

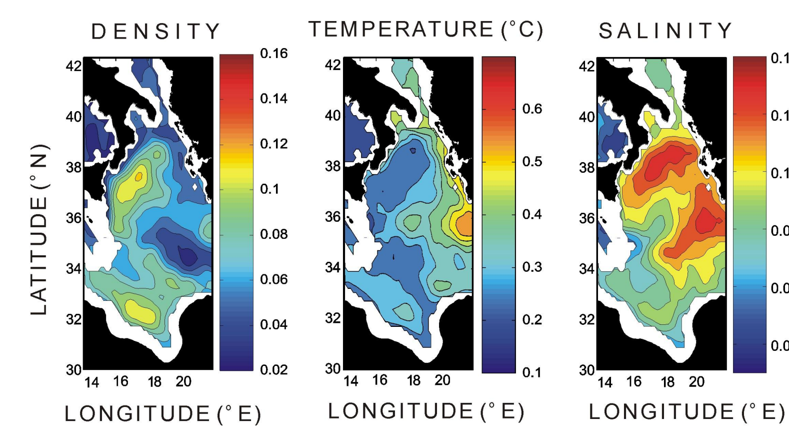


Fig. 6. Standard Deviation of mean Density, Temperature and Salinity (0-398 m)

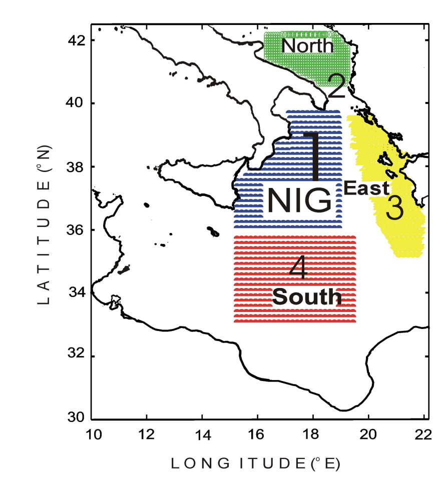


Fig.7. NIG and neighboring areas in which yearly spatially-mean upper-layer records of T, S, Density are constructed for 1988-2020

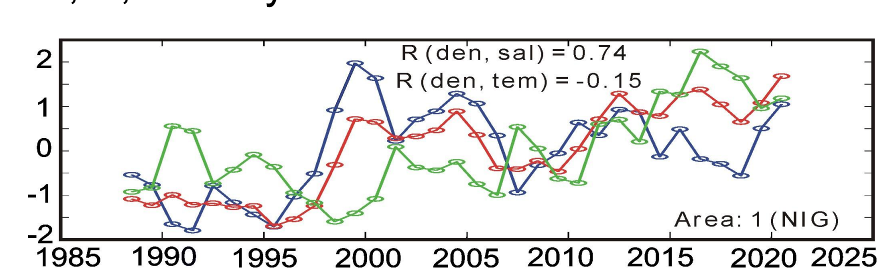


Fig. 8. Normalized anomalies of yearly mean T (green), S (red) and Density (blue) throughout the upper 398 m of the NIG. 'R' is correlation coefficient.

(Results continued) Of all the Ionian areas and the southern Adriatic (Fig. 7), it is only the NIG in which the salinity has the highest correlation to the (local) density (Fig. 8). In addition, the area to the southeast of NIG has a high correlation in salinity (R=0.8) with the NIG area. Since 'dyn. height ~ 1/density', the mean density throughout the upper NIG (e.g. ~1-400 m) can be used as an indicator of the all circulation changes within the NIG (Fig. 9), while the 5-point running- average of the normalized mean-density anomaly record (smooth blue curve with crosses) depicts the (three) major circulation regimes with duration of 8-10 each.

In the distributions of the standard deviation of the evaporation (E), precipitation (P) and E-P (Fig.10a, b, c) there is a tongue-like structure of maximum variability in P and E-P in the northwest Ionian, over the NIG area, where the standard deviations in the upper layer (1-398 m) of the spatially averaged salinities show maxima as well. The variability in E-P is mainly determined by P. E-P increases after the mid 2000s.

Therefore, and as it turns out, the NIG salinity, which determines the density, i.e., the dynamics, is correlated to the E-P. Specifically, for the time scales of the major circulation regimes with duration 8-10 years, the 5-point-running-average records of E-P, over the area of the southern-to-northern Ionian, and the corresponding yearly records of smoothed salinity in the upper 398 m of the NIG have statistically significant correlations with correlation coefficient (R) increasing from 0.62 for the period 1990-2018, to 0.74 for the period 1997-2018. After ~2009, while having a continuing increase of E-P and salinity, the correlation between these two parameters for the NIG increases further (R=0.98).

3. SUMMARY-CONCLUSIONS. The NIG salinity is the primary factor determining the NIG density, i.e., the NIG circulation dynamics. The NIG salinity is highly influenced by the area to the southeast (area 3, Fig. 7) and the Ionian E-P fluxes, particularly after the end of the E. Med. Transient (late 1990s) and even more during the increasing trend of the E-P, i.e. from ~2005 to the end of the current time series. *(This could be also associated with a weakening in the deep water formation in the E. Med (not shown here)).*

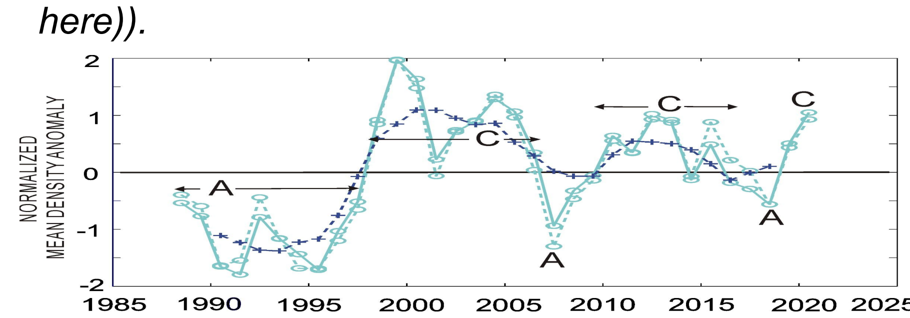


Fig. 9. Normalized yearly mean density anomalies throughout the NIG (solid / dashed cyan for the upper 398/120 m). Bleu smooth curve is the 5-point running average of the solid cyan. 'A'/'C' is for anticyclonic / cyclonic circulation.

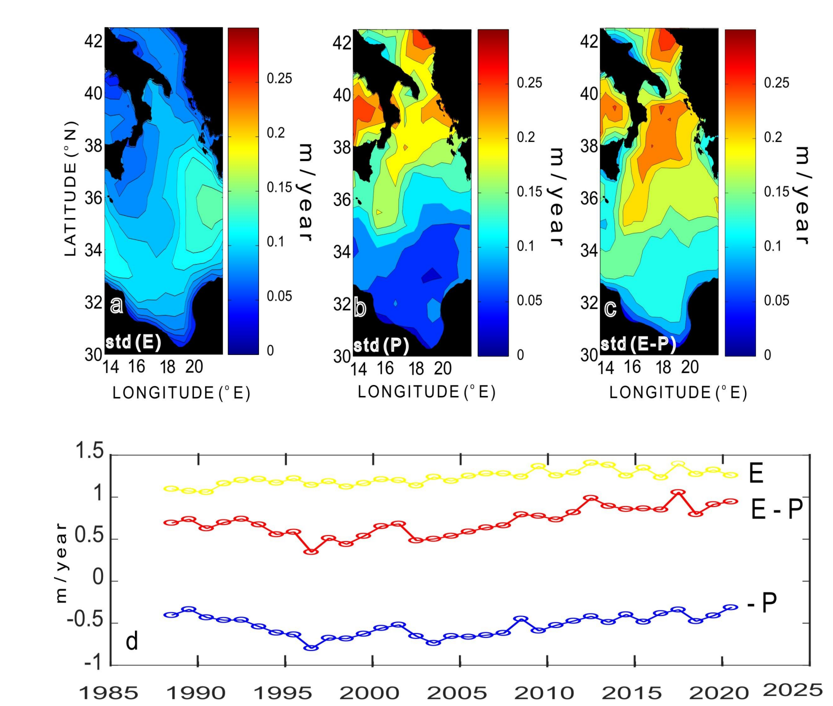


Fig. 10. a-to-c: Standard deviation (std) fields for evaporation (E), precipitation (P) and evaporation-minus-precipitation (E-P) during the period 1988-2020. **d:** Yearly mean values of E,-P and E-P during the period 1988-2020 averaged over the Ionian in the box of latitudes between 35-40 deg N and longitudes between 16-20 deg E. (The P and E fluxes are from monthly mean MERRA-2 data)

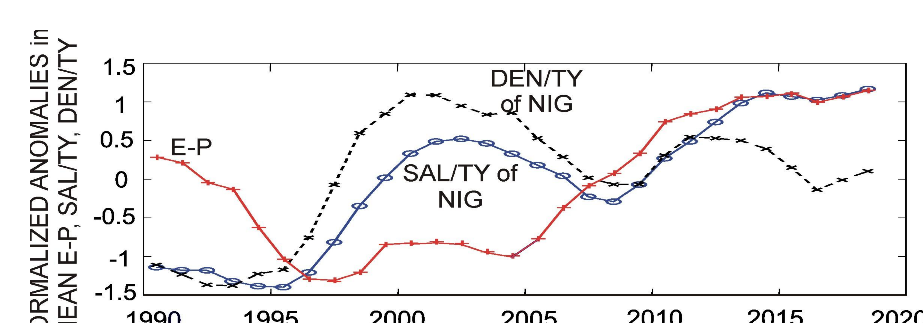


Fig. 11. Normalized anomalies of E-P over central to northern Ionian (33-39.5 N) normalized salinity (blue) and density (black dashed) of NIG (as in Fig. 9 blue curve). All time series are smoothed records through a 5-year running average.