

SUPPLEMENTARY DOCUMENT

Cold Intermediate Water Formation in the Black Sea Triggered by March 2022 Cold Intrusions

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Tracks of 12 ARGO floats analyzed between February and May 2022.

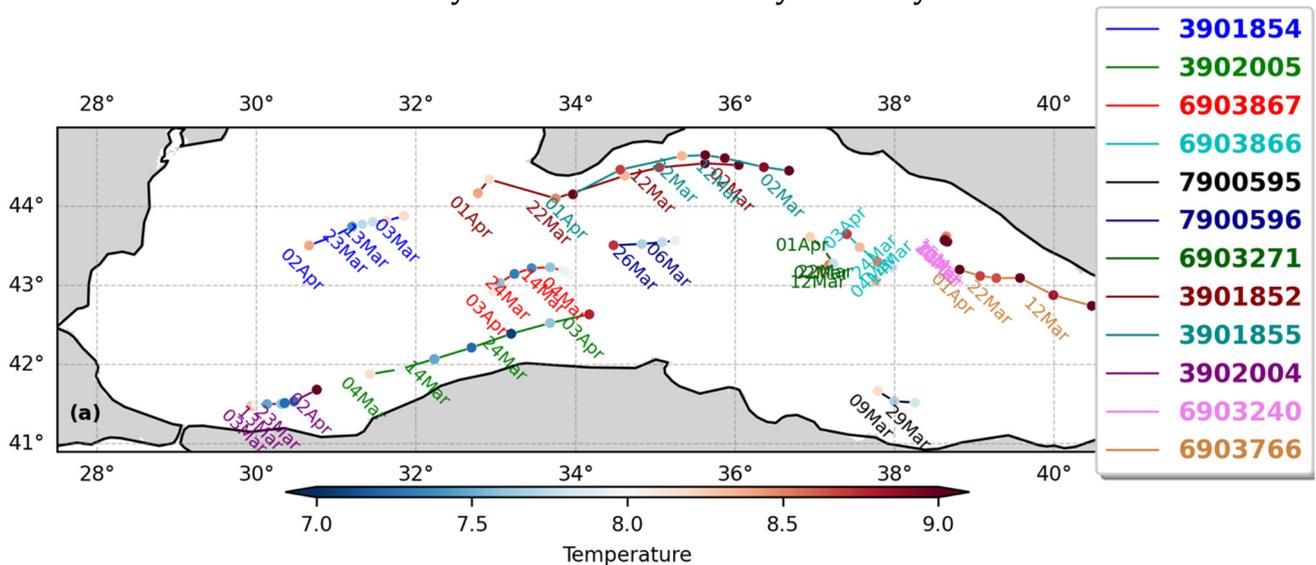


Figure S1. Tracks of 12 ARGO floats analyzed between February and May 2022. Colors of the circular position markers show the ARGO sea surface temperatures.

CIL Criterion with ($<8.35\text{ }^{\circ}\text{C}$)

By adopting the warm CIL criterion ($<8.35\text{ }^{\circ}\text{C}$) proposed by Capet et al., [5], it was observed that additional cycles met the criterion in 2020 and 2021 (shown in Supplementary Materials: Figure S2). Out of 744 Argo cycles in 2020, 29 cold water formations with temperatures below $8.35\text{ }^{\circ}\text{C}$ were observed on the northern continental slope and the western cyclone, while none were detected in the rest of the cycles in the eastern and southern Black Sea. The CIL formations detected in mid-February and early March were reduced to a thin layer by the onset of seasonal warming in mid-March, with no further detections by the end of March. In 2021, the warm criterion by Capet revealed a slight increase, with 34 CIL formations out of 790 cycles (Figure 8). Surface layers warmed as a result of the seasonal thermocline formed in mid-March, and a thin layer of CIL remained. However, even considering the warm CIL requirements, only a few weak CIL formations were found, which quickly warmed up and disappeared by early April. Floats did not visit the western Black Sea in 2021, but CIL formation in a comparably warmer part of the eastern cyclonic area in February suggests formations in the western cyclonic area as well. After April, neither the warm nor the classical CIL definitions detected further CIL formation, though both identified winter cold water formations exclusively on the northwestern continental slope and cyclonic gyres.

The application of the warm CIL criterion to the 2022 measurements resulted in detections across a substantial portion of the basin-wide observations made by Argo floats. The number of CIL detections increased 3.5 times, rising from 133 to 481 out of 785 cycles. The use of Capet's warm criterion led to a significant rise in CIL detections, starting with the initiation of seasonal warming in April and continuing through the end of the year (Supplementary Materials: Figure S2).

CIL Criterion with ($<8.35\text{ }^{\circ}\text{C}$)

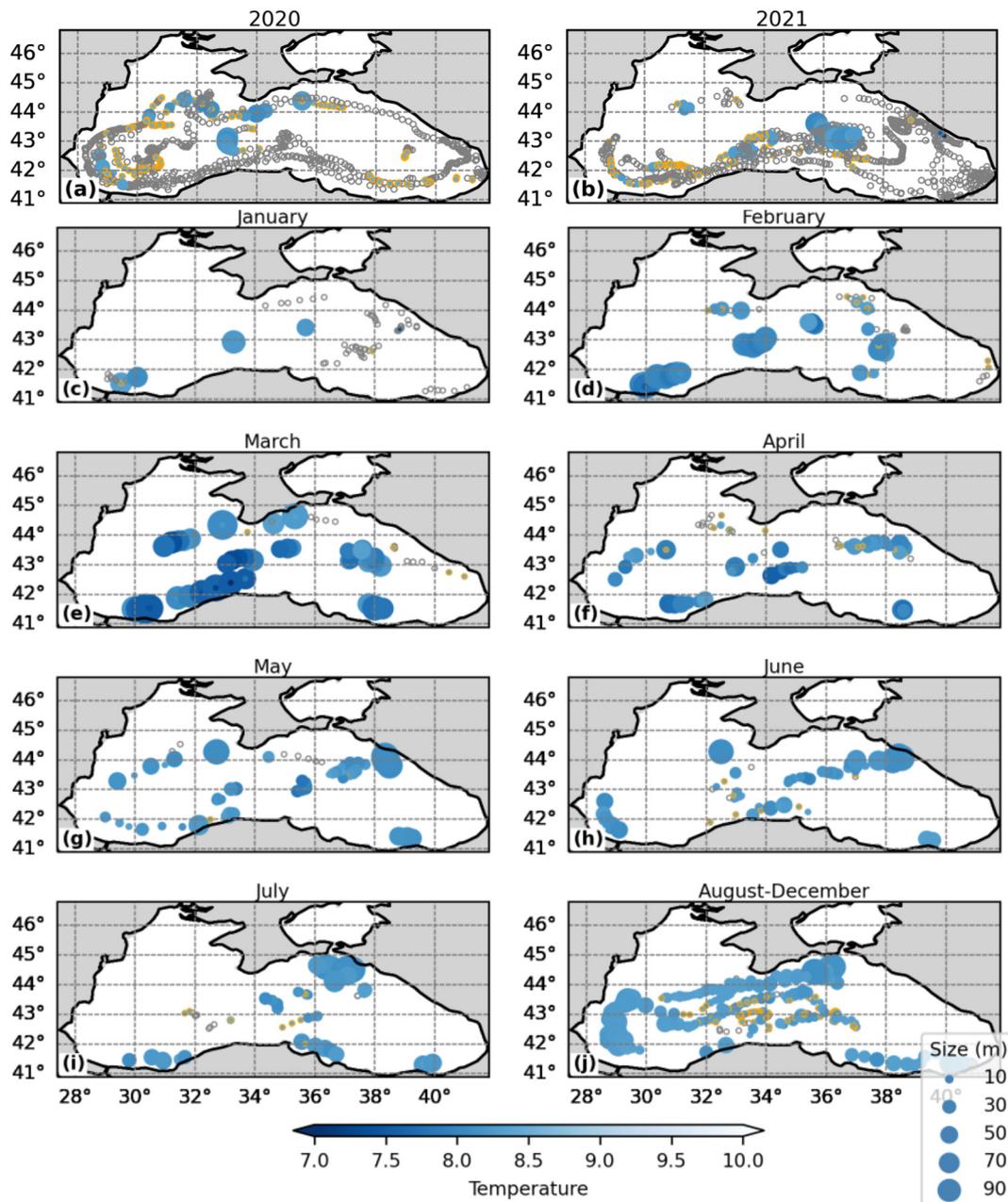


Figure S2. Float measurements: Mean of temperatures below $8.35\text{ }^{\circ}\text{C}$ temperatures are shown by blue circles. The sizes of blue circles show the thickness of the layer below $8.35\text{ }^{\circ}\text{C}$. The temperatures of water column slightly over ($8.35\text{ }^{\circ}\text{C} < \text{temperature} < 8.5\text{ }^{\circ}\text{C}$) are highlighted with orange circles without providing any thickness information. The gray circles depict if none of the two conditions were satisfied in the position of the float profile (a) during 2020 and (b) during 2021. The monthly compositions in 2022 are (c) January; (d) February; (e) March; (f) April; (g) May; (h) June; (i) July; and (j) August to December.

Distribution of T-S for the years 2020, 2021, and 2022

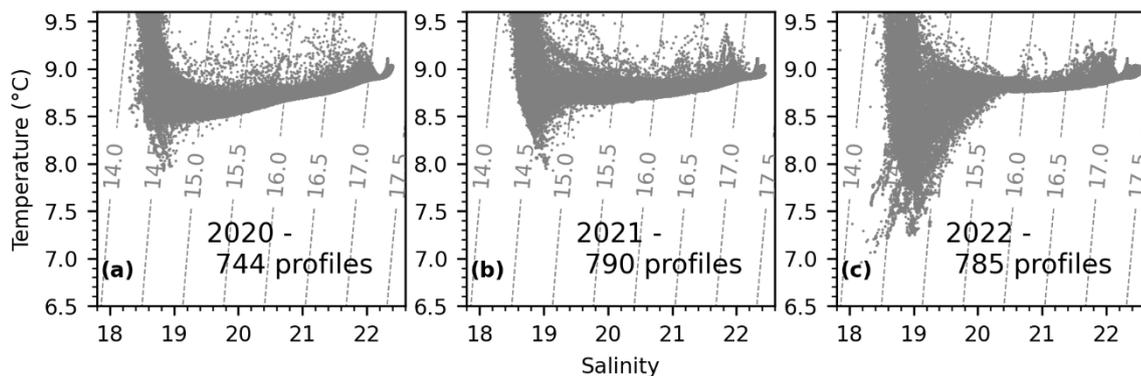


Figure S3. Distribution of T-S for the years 2020, 2021, and 2022. Multiple cycles of the float on the same day are represented by a single full profile of the float.

Surface monthly mean SST values for 2020

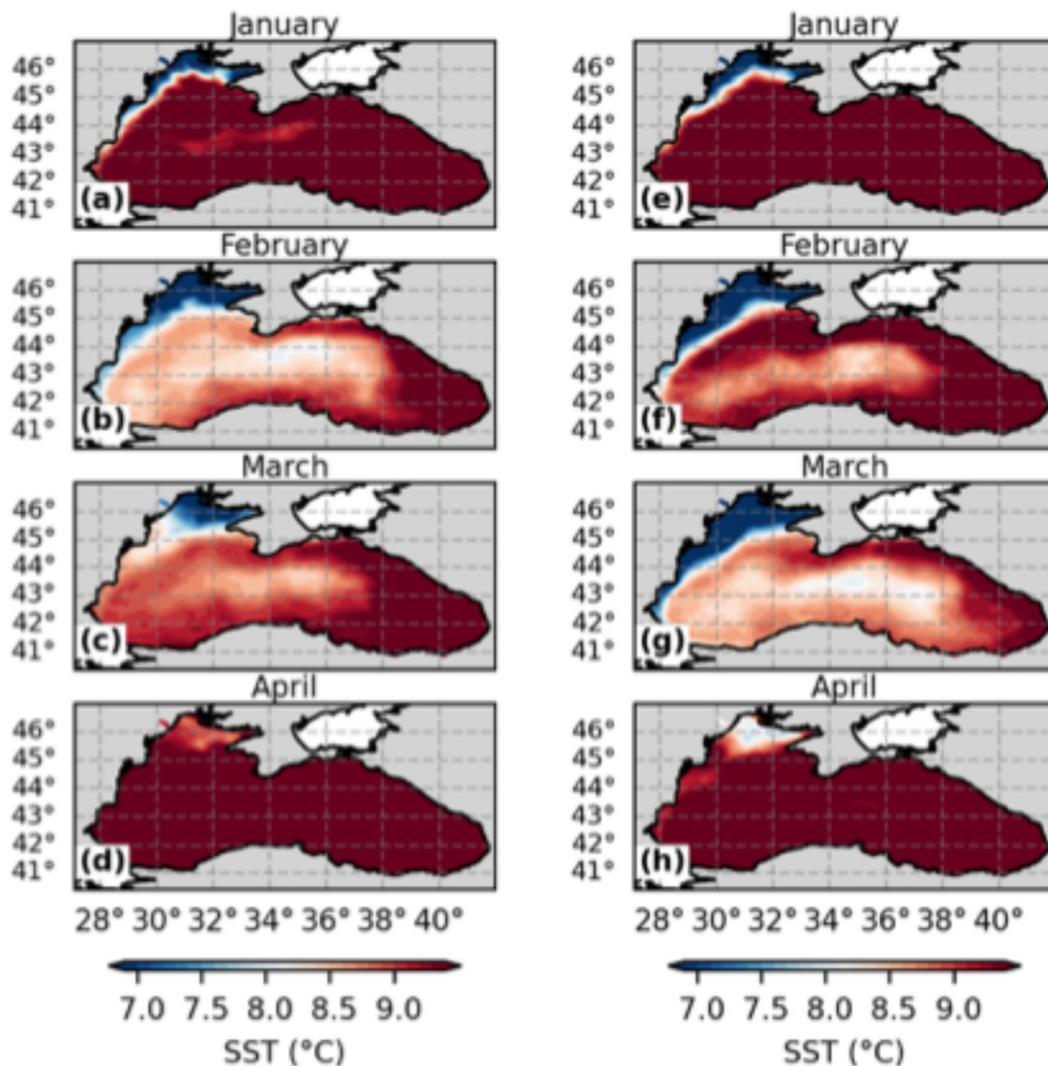


Figure S4. Surface monthly mean SST values for 2020 (a-d) and 2021 (e-h) for January to April were obtained from the Copernicus CMEMS gridded SST product.