Decadal Variability of the Eighteen Degree Water derived from the Northwest Atlantic Regional Climatology

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Abstract

Ocean heat analyses of the North Atlantic Ocean based on the new high-resolution Northwest Atlantic (NWA) Regional Climatology (RC) developed at the NOAA's National Centers for Environmental Information (NCEI) revealed decadal variability of the Eighteen Degree Water (EDW) depth that may be instrumental for understanding the localized heat accumulation in the NWA. The EDW is an important element of the Northwest Atlantic heat balance and an indicator of the ocean-atmosphere interaction in this region. The EDW deepening, or "heaving", on decadal timescales are most likely caused by increasing Ekman pumping due to changes in the wind stress curl pattern over the NWA. The NCEI's NWARC has also revealed that the highest rates of heat gain occur in the Sargasso Sea, southeast of the Gulf Stream path in the region occupied by the EDW. The volume of EDW depends on many factors, of which the most important are: Ekman pumping, heat fluxes at the air-sea surface, and heat advection within the Gulf Stream and the subtropical recirculation gyre. However, heat accumulation in several "pockets" southeast of the Gulf Stream and its extension seem to be most closely connected to EDW heaving. The depths of EDW for two independent ˜30-year periods and their differences were computed and analyzed in conjunction with the changes in the curl of wind stress. As the comparison between the EDW depths mapped on three different spatial grids with 1°x1°, 1/4°x1/4°, and 1/10°x1/10° resolutions illustrate, the grid resolution does matter for mapping EDW on decadal timescales. The 30-year climate shift of the EDW depths between 1985-2010 and 1955-1984 compares quite well with the climatic shift in Ekman vertical velocities derived from the changes in the wind stress curl over the same time period. Comparing the eddy-permitting EDW heaving inferred from the NCEI's NWARC and the ˜30-year shift of the curl of wind stress, and consequently Ekman pumping, confirms a strong resemblance of the eddy-permitting and eddy-resolving EDW heaving patterns with two tightly localized pockets of heat accumulation southeast of the Gulf Stream and its extension.

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The Eighteen Degree Water (EDW) is an important element of the Northwest Atlantic ocean heat balance and a reflection of the ocean-atmosphere interaction in this region. The analysis of the North Atlantic (NA) climate change based on the World Ocean Atlas [1] and high-resolution Northwest Atlantic Regional Climatology (NWARC) [2] allows us to assess the decadal variability of the EDW (Fig. 1) and its depth that may help us understand localized heat accumulation in the NWA and NA.

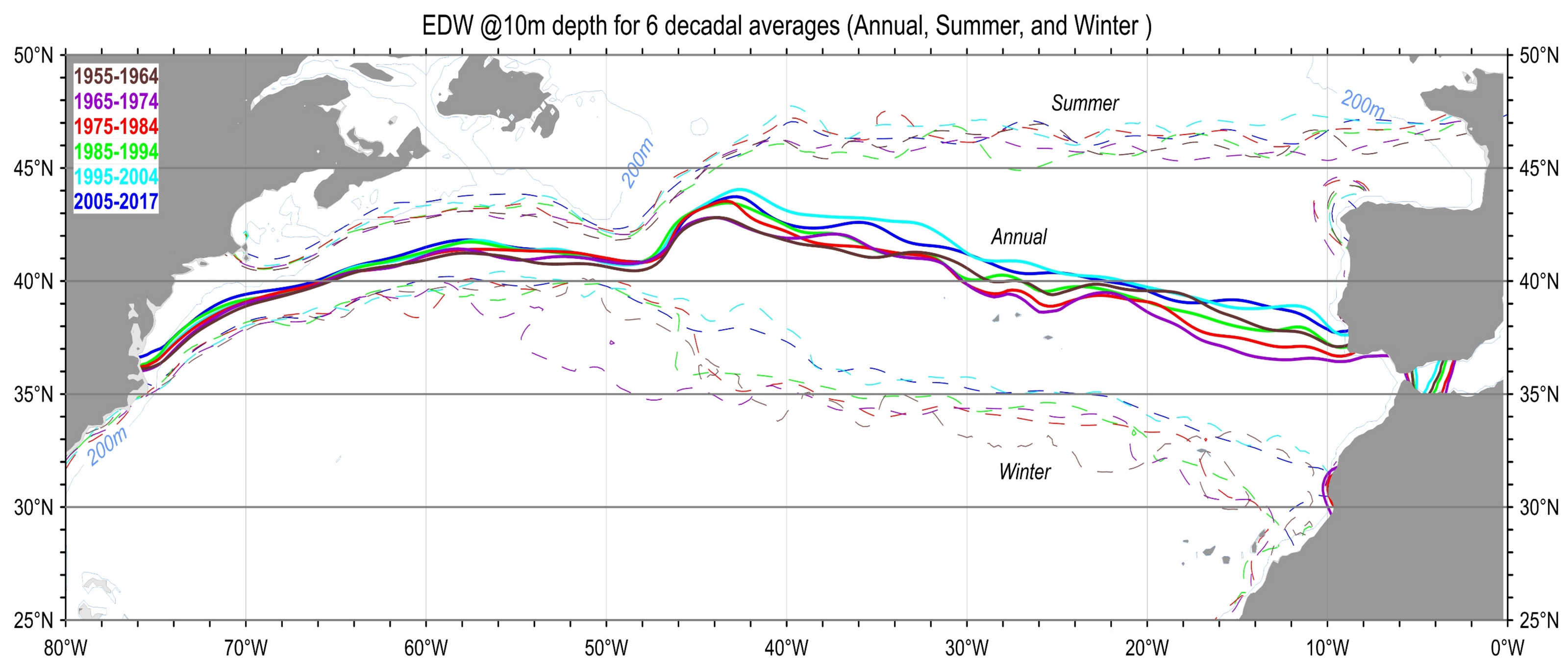

Figure 1. Mean annual and seasonal EDW positions at 10m depth for 6 decades (from 1955 to 2017) in the North Atlantic

NCEI's high-resolution NWARC has also shown that the highest rates of heat gain occur in the Sargasso Sea, southeast of the Gulf Stream path in the region occupied by the EDW [3]. The highest resolution analyses on a 0.1°x0.1°-degree latitude-longitude grid indicates that the EDW heaving is patchy and not as homogeneous as coarser resolution mapping [3,4]. The EDW deepening, or "heaving", on decadal timescales is most likely caused by increasing intensity of Ekman pumping [5].

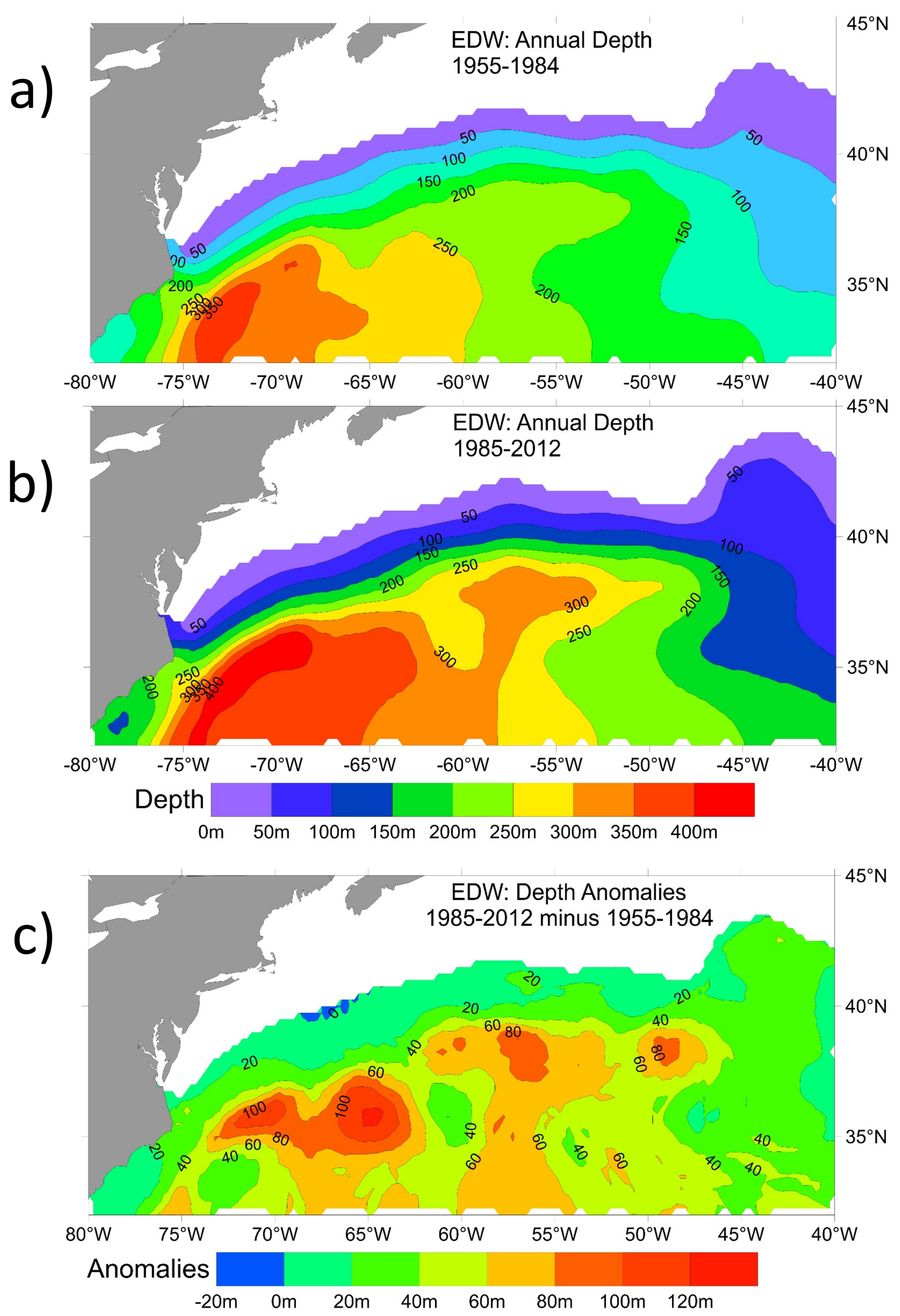

Figure 2. Mean annual EDW depth for: (a) 1955-1984, b) 1985-2012 periods, (c) EDW depth anomalies (1985-2012 minus 1955-1984)

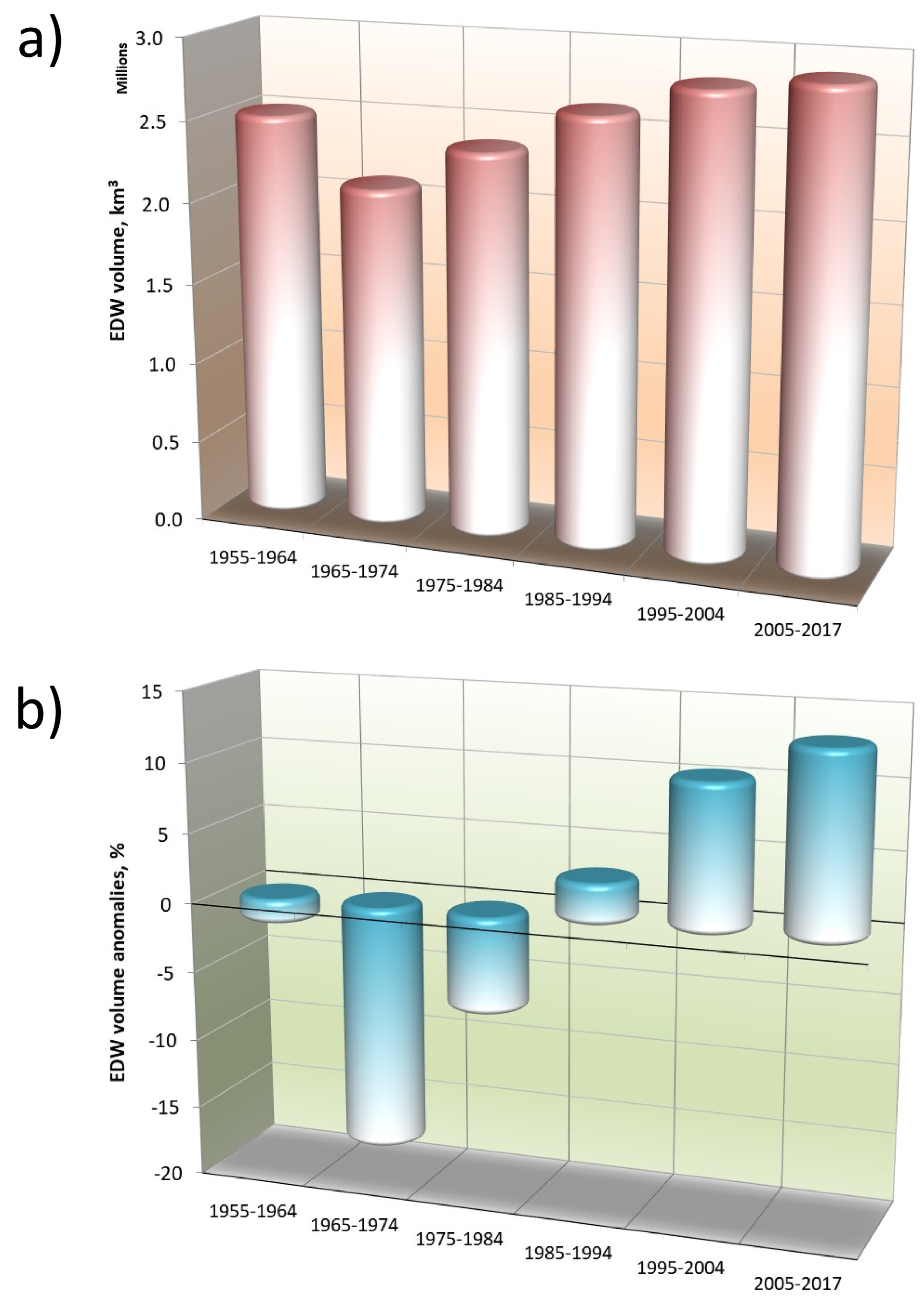

Figure 3. (a) Decadal EWD volumes (km^3) and (b) EDW anomalies as % of mean EWD volume over 1955-2017 period

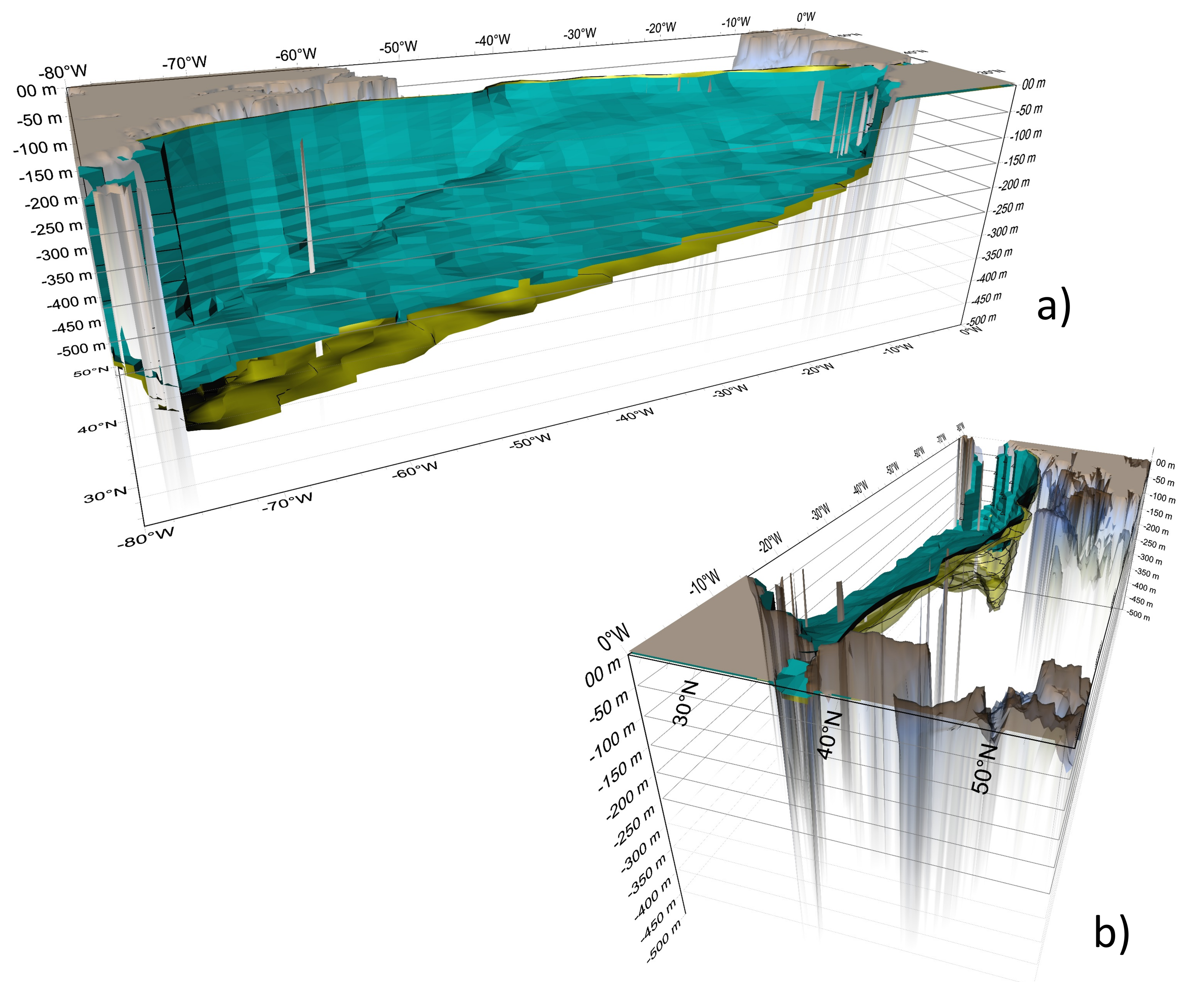

Figure 4. EDW shapes for coldest (1965-1974, blue) and warmest (2005-2017, dark-yellow) decades showing EDW heaving: a) Northeast view; b) Southwest view. (For better view - see animation)

The depths of EDW for two ~30-year intervals and their differences are shown in Fig. 2. The volume of EDW depends on many factors of which the most important are Ekman pumping, heat fluxes across the surface, and heat advection within the Gulf Stream and the subtropical recirculation gyre. However, heat accumulation in several "pockets" southeast of the Gulf Stream and its extension seems to be most closely connected to EDW heaving. Fig. 3 illustrates the variations in the EDW volume and its anomalies (in % comparing to the 60-year mean value) for 6 decades from 1955 to 2017. The difference in EDW 'heaving' is quite substantial – the volume of EDW has increased by ~790K km^3, which is equal to 35 volumes of all Great Lakes combined. Fig. 4 illustrates the EDW depths change from the coldest (1965-1974) to warmest (2005-2017) decade.

Comparing the eddy-permitting EDW heaving inferred from NCEI's NWARC and the ~30-year shift of the curl of wind-stress, and consequently Ekman pumping, confirms strong resemblance of the eddy-permitting and eddy-resolving EDW heaving patterns to two tightly localized pockets of heat accumulation southeast of the Gulf Stream and its extension [5].

References

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