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A mechanistic view of how gyre-scale heat content anomalies form in the North Atlantic

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North Atlantic climate variability on decadal time scales is often characterised by basin-scale changes in sea surface temperature, which are generally attributed to coherent changes in the meridional overturning circulation. However, this view is inconsistent with striking gyre-scale contrasts in ocean heat content over the basin: the subtropics are often warm when the subpolar gyre is cool, and vice versa. We explore how the gyre-scale changes in heat content are mechanistically controlled using dynamical assimilations of historical temperature and salinity data over the last 60 years. There are different dynamical mechanisms at work over the basin. The heat content anomalies are usually associated with thermocline and overturning anomalies, a warmer heat content associated with a deeper thermocline and often with a weaker meridional overturning anomaly. The tendency of the subtropical heat content is primarily controlled by heat convergence, stronger Trade winds enhancing the influx of heat from the tropics, augmented by the poorly-known air-sea heat fluxes. The tendency of the subpolar heat content does not though directly link to the air-sea heat input integrated over the gyre. Instead the tendency of the subpolar heat content is controlled by the convergence in heat transport. The heat transport into the subpolar gyre is though affected by boundary density changes induced by atmospheric forcing: density increases along the Labrador Sea appear to lead to enhanced overturning at the subtropical/subpolar interface, which then drive a warming of the subpolar gyre. Hence, the heat content anomalies for each gyre are formed via different mechanisms, connecting in a different manner to the overlying atmospheric forcing.