The global overturning circulation and the importance of non-equilibrium effects in ECCOv4r4 FIGURES

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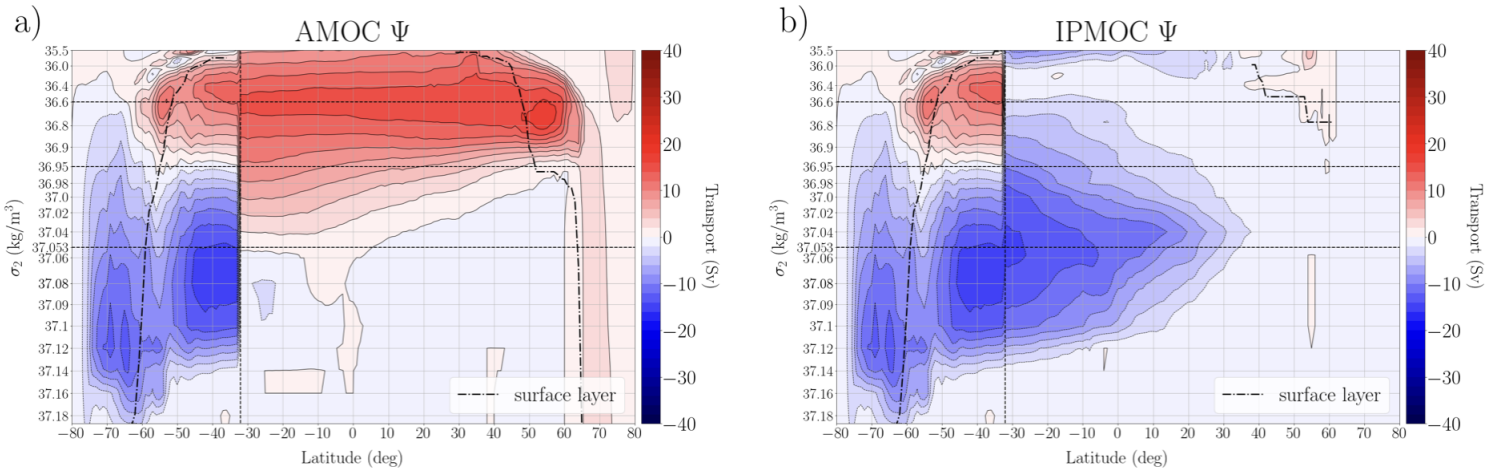

Figure 1. Atlantic, Indo-Pacific, and Southern Ocean stream functions in potential density space (referenced to 2000dbar), calculated from ECCOv4r4 and averaged over the full ECCO time period (1992-2017). (a) the Atlantic Meridional Overturning Circulation (AMOC) and (b) Indo-Pacific Meridional Overturning Circulation (IPMOC). The Southern Ocean Meridional Overturning Circulation is plotted in both (a) and (b) south of 32°S. Positive (red) denotes clockwise flow and negative (blue) denotes counterclockwise flow (CL=2Sv). The dash-dotted line indicates the bottom of the surface layer (see text). The vertical dashed line indicates the northern end of the Southern Ocean at 32°S. Horizontal dashed lines denote specific density surfaces of interest: the upper bound of southward-flowing NADW: σ_2=1036.6kg/m^3, the division between the upper and lower cells in the Southern Ocean: σ_2=1036.95kg/m^3, and the maximum density of NADW entering the SO: σ_2=1037.05kg/m^3. The density-axis is stretched to reflect the average isopycnal depth within the Atlantic for σ_2<1037.1kg/m^3 (the maximum density in the Atlantic) and is extended linearly to the highest densities in the Southern Ocean. The same density axis is used in subsequent plots.

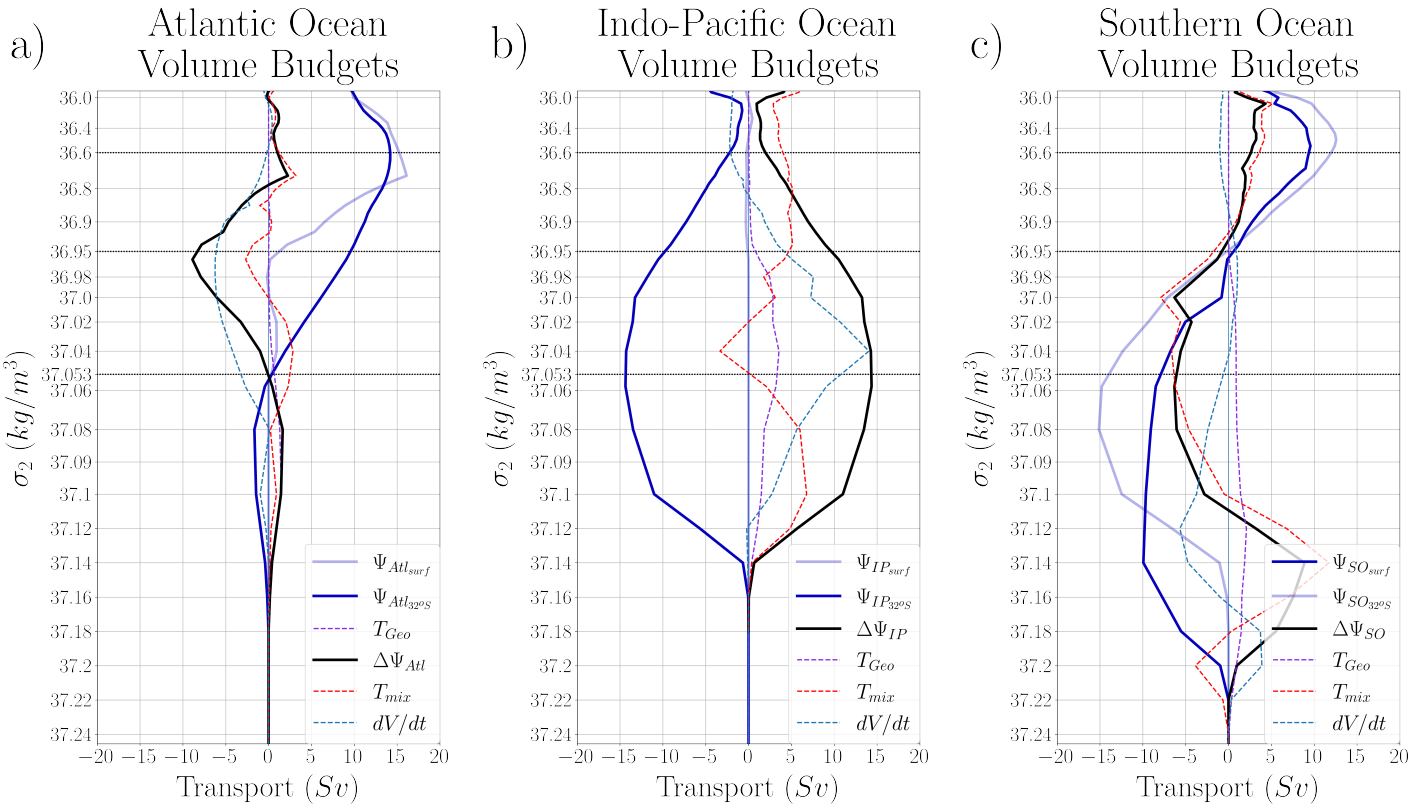

Figure 2. Volume budget decompositions across the Atlantic Ocean (**a**), Indo-Pacific Ocean (**b**), and Southern Ocean (**c**). Solid black lines denote net diapycnal transformation across density surfaces, inferred from the difference between $\Psi(\sigma_2)$ across each region's northern (light blue) and southern (dark blue) boundaries. The subscript $Surf$ refers to the stream function at the bottom of the surface layer, defined by the minimum surface density at a given latitude (Figure 1). The net diapycnal transport (solid black) is de-composed into contributions from: geothermal transformations (dashed purple), diffusive transformations (dashed red), and isopycnal volume change (dashed cyan).

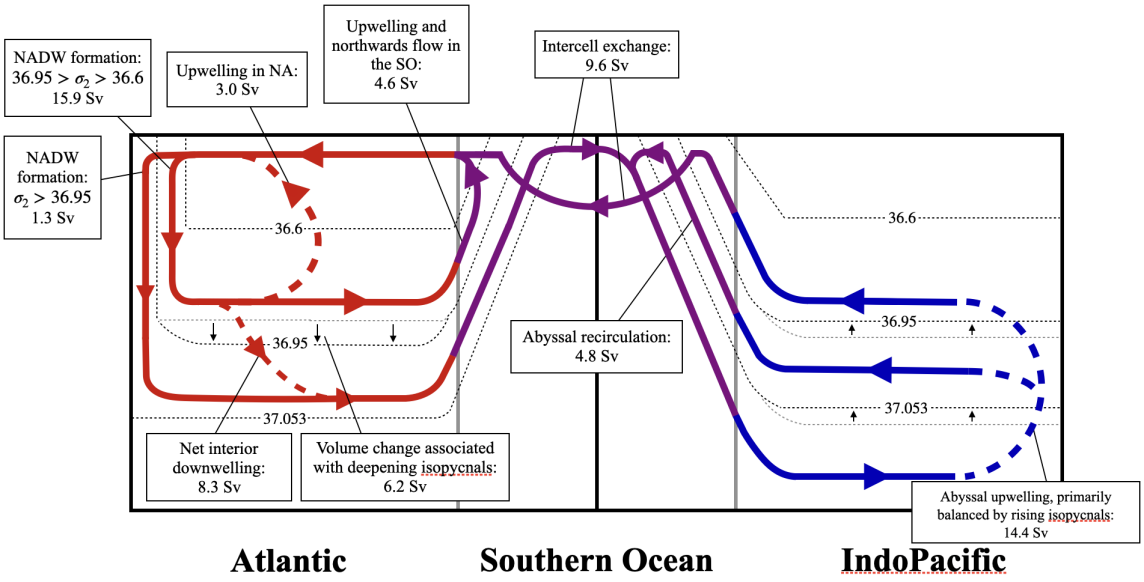

Figure 3. Schematic representation of the overturning, inferred from the stream function and volume budget decomposition (Figure 1, Figure 2). Net transport within the Atlantic Ocean (red arrows), Southern Ocean (purple arrows), and Indo-Pacific Ocean (blue arrows), are shown. Arrows denote direction of flow. Solid and dashed arrows below the surface denote primarily along- and across-isopycnal pathways, respectively. Dashed black lines denote the specific densities discussed in Figure 1, and isopycnal depth changes are indicated where they are the dominant contributor balancing up- and down-welling.

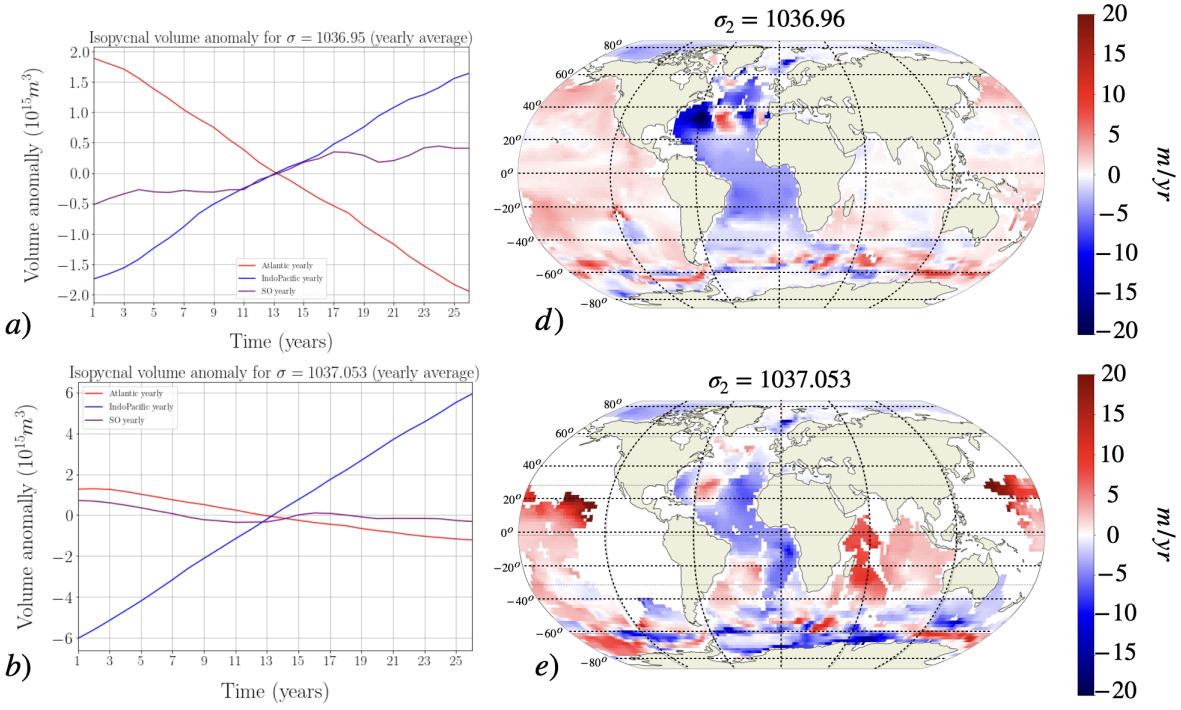

Figure 4. Trends in overall isopycnal volumes as calculated from yearly means and subdivided by basin (a, b), and spatial fields of time-averaged vertical isopycnal velocities, in meters per year, (d, e) for σ_2=1036.95kg/m^3 (top) and σ_2=1037.053kg/m^3 (bottom) over the ECCOv4r4 timespan (1992-2017). Striking linear trends are visible in the Atlantic and Indo-Pacific Oceans.