The ocean’s global overturning circulation connects surface and abyssal waters and thus plays a prominent role in Earth’s climate through its regulation of heat and carbon storage. The overturning circulation also exists to deliver water from regions of buoyancy gain, largely at the low latitudes, to regions of buoyancy loss in polar regions. This characteristic, combined with the geometry of the ocean basins, places important constraints on the structure of the overturning circulation for given climate and surface forcing conditions. In this talk, I will discuss the physical mechanisms that control the transient adjustment of the ocean’s overturning circulation to surface forcing perturbations over decadal to multi-millennial time scales. Across all of these scales, the three dimensional nature of the circulation as well as dynamical differences between Atlantic, Indo-Pacific and Southern Oceans are key features of overturning transitions.