Natural variability of the atmosphere and ocean are important processes to understand and quantify in order to accurately detect and predict anthropogenic climate change. In order to investigate and quantify natural variability, multiple global climate models (GCMs) are utilized along with observational data. These methods are used to investigate the multi-decadal natural variability of three processes:

First, the natural variability of the Southern Annular Mode (SAM) and Southern Hemisphere westerly jet strength and position are quantified using 14 different GCMs. The magnitude of the natural variability of these quantities is compared with recent observational trends that have been attributed to ozone depletion. While in the literature these three quantities are assumed to have similar variability, the results in this thesis show there are distinct differences between them. In addition, comparison of the modeled natural variability with the observed trends suggest that the observed trends in these three metrics are not decisively outside of the natural variability.

Next, the relationship between oceanic heat and carbon content is examined in a suite of coupled climate model simulations that use different parameterization settings for mesoscale mixing. The different parameterizations result in different multi-decadal variability, especially in the Weddell Sea where the characteristics of deep convection are changed. While there are differences in the variability, there is a robust anti-correlation between global heat and carbon content in all simulations. Global carbon content variability is primarily driven by Southern Ocean carbon variability. This contrasts with global heat content variability, which is primarily driven by variability in the southern mid-latitudes and tropics.

Finally, we explore the relationship between age and oxygen and find that in both observations and a model, the assumed negative linear relationship between age and oxygen is not found both within and directly below the ventilated thermocline at the end of Line W. While observations along Line W shows a decoupling of the biologically-driven age-oxygen relationship, our model analysis indicates that this phenomenon is relatively localized to Line W due to the combination of relatively weak horizontal gradients in age and oxygen resulting reduced along-isopycnal variability and vertical heave acting on a depth offset between age and oxygen extrema.