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Towards understanding the climate change response of the subtropical atmosphere: An alternate framework

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Based on a synthesis of the existing literature, the character of the circulation of the subtropics is explored within the context of the mean meridional circulation (MMC). An idealized model of the MMC is described based on the results of (dry) isentropic streamfunction analysis. The picture of the MMC derived from this analysis yields a picture of the flow with many similarities to the standard 'three-cell model', but also significant differences. The isentropic MMC within a hemisphere depicts a single overturning cell, with each cell comprised of two prominent circulation 'lobes'. The tropical lobe is very similar to the classic Hadley circulation described by the three cell model, with a strong diabatically-driven circulation from the release of latent heat by convection and radiative cooling. An extratropical lobe, with quasi-isentropic flow is also present, and is associated with the mid-latitude baroclinic waves and the eddy-driven jet stream. This circulation -- the Polar Front -- is considerably more vigorous than the polar and Ferrel cells given by the three-cell model. The subtropical regions provide the 'bridge' to unify the hemispheric flow. Tropical-extratropical interactions, often manifest by Rossby wave-breaking, are crucial to the flow here. Both radiatively-driven tropical subsidence and extratropical baroclinic eddies are important drivers of the circulation in the subtropics. This model of the MMC varies temporally on seasonal and interannual time scales. Considerable longitudinal spatial variability is also observed, driven by the heterogeneity of the underlying surface. This model of the MMC does not represent a 'top-down' driver of the circulation; rather its characteristics represent the cumulative effects of myriad smaller-scale weather processes within the atmosphere, in turn modulated by the larger-scale environment. Emerging evidence indicates that climate change in the subtropics will be a complex mixture of tropical and extratropical factors. Both the widely-reported 'widening of the tropics' and changes to the extratropical portion of the circulation (e.g. annular mode increase) are likely to be significant in this area. The response of the subtropics is also likely to be influenced by the underlying geography and regional differences in the circulation. These factors are all interrelated, and this model of the MMC provides a framework to consolidate our understanding of their relative roles in producing both the observed and modelled responses of climate change within the subtropics.