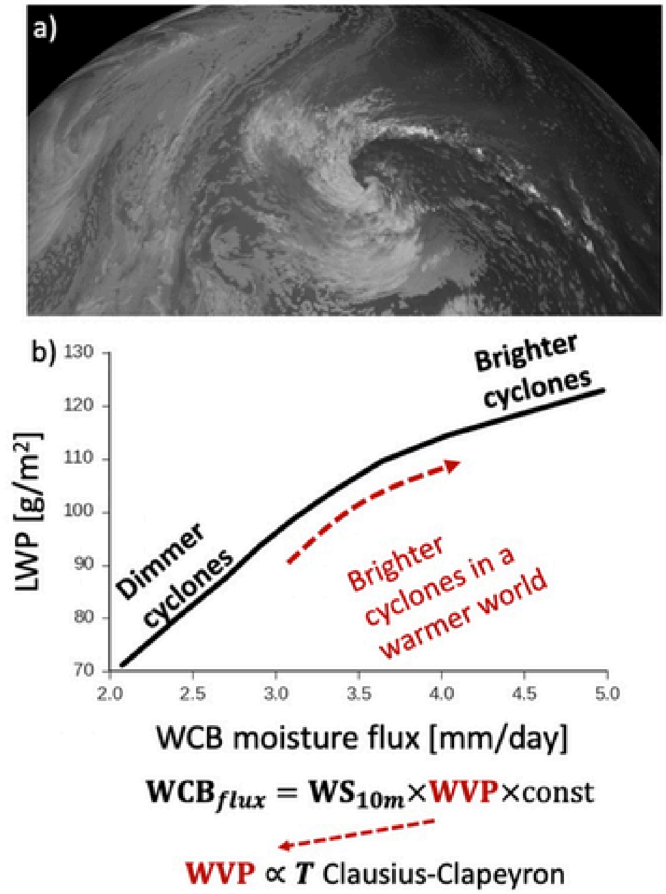
Extratropical cyclone processes as a key to understanding climate sensitivity

*Daniel McCoy[1], Paul Field[1,2], Alejandro Bodas-Salcedo[2], Gregory Elsaesser[3], Mark Zelinka[4]

1. University of Leeds, 2. UK Met Office, 3. Columbia University and NASA Goddard Institute for Space Studies, 4. Lawrence Livermore National Laboratory

Global climate models (GCMs) differ greatly in their shortwave cloud feedback. One feature that is consistent across GCMs is a positive shortwave cloud feedback in the subtropics, and a negative shortwave cloud feedback across the extratropics. Confidence has grown in the mechanisms that lead to, and the strength of, the subtropical shortwave cloud feedback, but the extratropical negative shortwave cloud feedback is not well-constrained or well-understood. It is critical to reduce uncertainty in extratropical shortwave cloud feedback. A more positive extratropical shortwave cloud feedback in the sixth coupled model intercomparison project (CMIP6) has been found to be one of the primary causes of the increased climate sensitivity of CMIP6 models relative to CMIP5. We show that changes in extratropical cyclones in future climates are the primary cause of the negative shortwave cloud feedback and are thus key to understanding the high climate sensitivity in the most recent GCMs. Warming-induced changes in cloud liquid water path in extratropical cyclones can almost entirely be explained by Clausius-Clapeyron increasing moisture convergence into cyclones. One concern with simulating extratropical cyclones is the lack of predictive skill at low resolution. A more realistic relationship between moisture flux and cyclone liquid content is found at high horizontal resolution (dx<25km), but the cloud feedback within cyclones can be explained by increased moisture convergence across low- and high-resolution models. Observations and models agree that the extratropical shortwave cloud feedback is moderated by precipitation processes in cyclones. This rules out a large contribution from ice-to-liquid transitions, as has been hypothesized in previous studies. Understanding and constraining these precipitation processes is crucial to constraining the response of extratropical cyclones to warming and by extension climate sensitivity.

Keywords: Cloud feedback, Extratropics, Climate sensitivity, Southern Ocean, Cyclone, Precipitation



(a) Convection-permitting simulations in the UK Met Office model of a cyclone. The moisture flux along the warm conveyor belt (WCB) of a cyclone plays a central role in determining cyclone cloud liquid water path (LWP) **(b)**. Because WCB scales with water vapor path (WVP) and surface wind speed, WCB moisture flux increases following Clausius-Clapeyron and predicts a negative extratropical cloud feedback.