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Climate feedback efficiency and synergy

T. Mauritsen (1), R. G. Graversen (2), D. Klocke (3), P. L. Langen (4), B. Stevens (1), and L. Tomassini (1)

(1) Max Planck Institute for Meteorology, Atmospheric Department, Hamburg, Germany (thorsten.mauritsen@zmaw.de), (2) Stockholm University, (3) European Centre for Medium Range Weather Forecasts, (4) Copenhagen University

Earth's climate sensitivity to radiative forcing is determined by feedback mechanisms that either amplify or dampen the response. The major radiative feedback mechanisms involve changes in atmospheric water vapor, clouds and surface albedo in response to the changing temperatures. It is often assumed that the individual feedback mechanisms add linearly to form the total system feedback, and that the mechanisms act independently, responding only to the changing global mean surface temperature. Here we test these assumptions by systematically controlling, or locking, the radiative feedbacks in a state-of-the-art climate model. We find a close correspondence between feedback and surface temperature response for the water vapor and surface albedo feedbacks, while the cloud feedback is inefficient in causing surface temperature change. We suggest that cloud-induced warming in the upper tropical troposphere is responsible. On the other hand, we find a positive synergy between the water vapor feedback and the cloud feedback, meaning that the combined cloud- and water vapor feedback is greater than the sum of its parts. Negative synergies surround the surface albedo feedback, as associated cloud- and water vapor changes tend to dampen climate change. The negative synergies can be understood from the near-surface warming associated with the surface albedo feedback mechanism, and the atmospheric dynamical response to retreating snow and ice.