Abstract: Uncertainties about how clouds and particularly low clouds respond to climate change are principally behind the uncertainties in climate change projections. If low cloud cover increases as the climate warms, the increased planetary albedo implies a damping feedback on climate changes; if low cloud cover decreases as the climate warms, the reduced albedo implies an amplifying feedback. Existing theories and climate models do not even agree on the sign of low cloud cover changes as the climate warms, much less their magnitude. But now is the time to make fundamental progress: We are in a golden age of data on clouds from field studies and space-based observations, and advances in computational fluid dynamics (large-eddy simulations) now allow us to simulate cloud dynamics faithfully with resolutions of O(1 m) in domains with horizontal size O(100 km)---the size of a typical climate model grid box. To constrain and understand cloud feedbacks, we are developing a hierarchical modeling framework in which high-resolution simulations, validated with data for the present climate, are driven on the large scale by environmental conditions derived from coarser climate model simulations. Insights gained from such climatically relevant high-resolution simulations are then used to derive a unified representation of turbulent cloud and boundary-layer processes in climate models. I will present results from this approach that constrain the magnitude of how marine boundary layer clouds change with climate and provide insight into the physical processes controlling these changes.