The intensity and extent of subtropical dry regions under global climate change: an idealized study

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Earth is characterized by strong subtropical zonal contrasts in precipitation during the summer season. Arid regions occupy a large part of the subtropics, and the magnitude and extent of these dry zones may change with global climate changes. Simulations of global warming scenarios for the 21st century using comprehensive general circulation models (GCMs) suggest that subtropical dry regions may become drier and wider as global-mean surface temperature increases. Enhanced dryness in the subtropics in a warmer world has often been attributed to changes in the strength and extent of the Hadley circulation, in particular its poleward extent. Yet drying trends can vary greatly across longitudes in GCM simulations of global warming scenarios, which suggests dryness at the surface is modulated at least as much by zonally asymmetric patterns as by the Hadley circulation.

The intensity and location of these zonally asymmetric patterns depend sensitively on the zonal- and time--mean state of the atmosphere. In particular, the locations and intensity of dynamical patterns associated with aridity at the surface, such as stationary subsidence in the troposphere, can be described as a linear response of the atmosphere around its mean state to diabatic heat sources (collocated with monsoonal precipitation maxima) and topography. Although a linear model of the subtropical troposphere seems quite successful at explaining the observed hydrologic contrast in present-day climate, application of this model to warmer climates is unexplored.

In this study we investigate the response of the atmosphere to local changes in surface properties in an idealized GCM with an active hydrologic cycle. We investigate how the zonally asymmetric patterns induced by these surface asymmetries affect the level of dryness in the subtropics, both regionally and in the zonal-mean, for different global warming and cooling scenarios. Results from these simulations are compared to a hierarchy of models, from the linear model of Gill (1980) to comprehensive GCMs.