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Future of the hydrological cycle over Europe - Lessons learned from a surrogate climate change scenario

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The hydrological cycle is known to be a very sensitive component of the climate system. It has been shown that the variability of the atmospheric moisture content in the mid-latitudes largely depends on temperature rather than relative humidity. Given the higher water holding capacity of the atmosphere in a warmer climate, global circulation models suggest an invigoration of the hydrological cycle in the future, resulting in an increase of global mean precipitation.

In this study, a surrogate climate change scenario is used to investigate the hydrological impact of a warming increment of 3 K imposed on the large-scale circulation. For this purpose, the regional climate model COSMO-CLM is applied at a horizontal resolution of 50 km over Greater Europe. It is driven by the ERA-interim reanalysis over the period from 1989 to 2009. The control simulation (CTRL) uses the original forcing of the reanalysis at its lateral boundaries, whereas the scenario (W3K) includes the aforementioned temperature increment. The latter is associated with an increase of the atmospheric moisture content in W3K according to the Clausius-Clapeyron relation (roughly +21%).

The large-scale warming leads to a substantial upward shift of the freezing level by about 400 m in winter over European land with an attendant reduction of ice, snow and graupel below 700 hPa. As a consequence, snowfall becomes less frequent in W3K. The ratio of snowfall to total precipitation declines by 10–30% over Central and Eastern Europe. The total amount of precipitation increases by about 15% on average. As a result of the reduced snowfall, the surface albedo decreases by more than 20% in large parts of Europe, leading to a strong snow-albedo feedback that amplifies the local warming beyond the imposed 3 K.

In summer, the effective warming near the surface is found to be below 2 K in Central and Eastern Europe. This can be attributed to an increased fraction of low clouds (+4–6%). This effect reduces the downward surface shortwave radiation by more than 10 W m^{-2} on average in summer. Furthermore, deep convective becomes more frequent, particularly in summer, leading to a higher cirrus cloud cover over large parts of Europe.