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Summer drying under enhanced greenhouse gas warming

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Present day climate and future climate projections from the latest version of the Max Planck Institute GCM, ECHAM5, at T106 resolution are used to investigate changes in the near-surface climate, focusing on summer in Europe. For the control climate, ECHAM5 has been integrated over the period 1961 to 1990, using sea surface temperature (SST) and sea ice cover (SIC) provided by the EU project PRUDENCE. Projections of future climate are based on the SRES scenario A2 from 2071-2100. SST and SIC were inferred from a coupled transient experiment carried out at the Hadley Centre with HadCM3. The comparison of simulated and observed soil moisture data showed that ECHAM5 strongly overestimates the soil moisture depletion during the summer months (May-September). In the future climate integration, summer precipitation decreases over most of continental Europe excluding Northern Scandinavia. This leads to a distinct decrease in soil moisture, with maximum absolute changes in Central Europe and Northern Spain. The highest negative signal in evaporation is found over Southern Europe where water is already limited under present-day climate conditions. This feature is closely related to the strong decrease of the water stress factor south of approximately 46N. The Bowen ratio will decline by more than 3 during the pronounced summer drying in Southern Spain, South Italy and Greece, implying a reduced evaporative cooling and thus a strong warming. In contrast, water hardly becomes a limiting factor in Central and Northern Europe in summer. The variability of summer temperatures generally increases slightly over Central Europe. Additionally, the widening of the statistical distribution exceeds 20% in major parts in Southern Europe since these areas are more often affected by summer droughts. For precipitation, the coefficient of variance (the standard deviation divided by its mean)

increases by more than 100% over major parts of the Iberian Peninsula, indicating that the normalized precipitation variability significantly increases over the strongly water-limited region. In winter, ECHAM5 simulates a water-limited climate only in a minor part of Southern Europe, while in the major part of Europe precipitation is sufficient to allow for unlimited water supply. In the scenario run, the water-limited climate slightly extends to the north, up to approximately 40N. In addition to Southern Europe, the water stress factor in the scenario run (in JJA) declines by more than 0.1 in the following regions: Southwest Africa (Namibia, Botswana) as well as extended parts in Brazil and Australia. These predominantly semi-arid regions will thus be more often affected by droughts in the future, pointing out the high vulnerability of semi-arid land to enhanced greenhouse gas warming.