



Groundwater shifts and critical thresholds in the changing hydro-climate

Georgia Destouni

Department of Physical Geography, Bolin Center for Climate Research and Navarino Environmental Observatory,
Stockholm University, Stockholm, Sweden (georgia.destouni@natgeo.su.se)

This paper synthesizes recent data-driven advances in our understanding of hydro-climatic variability and change, and explores their implications for groundwater-related shifts and critical thresholds. As a starting point in this exploration, large-scale warm-season co-variability patterns between temperature and hydrology over Europe, from 850 CE to present, show negative association, i.e., drier conditions in terms of precipitation and soil moisture under warming for hydro-climatically vulnerable southern parts of Europe. While warming thereby decreases regional water inputs and water availability for vegetation and groundwater recharge, other recent studies show that common irrigation and flow regulation developments for enhanced food and energy supply over the last century have increased evapotranspiration and associated water outputs from the landscape back to the atmosphere in many parts of the world. Particularly under decreasing precipitation, such human-driven enhancement of water availability for plants and crops, as reflected in the observed evapotranspiration increases, has been achieved at the cost of even greater than the precipitation-driven decreases in groundwater recharge and runoff, and thus in water availability for other uses; data for multiple hydrological catchments around the world reveal such decreases over the last half century to present time. Groundwater mining with associated groundwater table lowering (i.e., decreased subsurface storage of water) may also feed the evapotranspiration increases associated with agricultural expansion, intensification and irrigation. For example, long-term hydro-climatic data time series (including also groundwater data) for multiple catchments across Iran show systematic groundwater depletion feeding such evapotranspiration increases to levels well beyond those sustainable by the annually renewable water inputs through precipitation. Moreover, long-term time series of calculated soil moisture and groundwater table variation and change indicate high drought risk enhancement also in humid parts of the world, such as the Swedish Stockholm County region, after major agricultural expansion and intensification with related increases in evapotranspiration as well as in short-term soil moisture and runoff variability, while average soil moisture and runoff have decreased over the last century. For coastal regions, the groundwater recharge, table, and flow lowering associated with such human-driven (and possible additional climate-driven) decreases in soil moisture and runoff may combine with expected sea level rise in driving increasingly larger (nonlinear) responses of seawater intrusion towards different critical limits for fresh coastal groundwater. These limits include that of intruded seawater reaching key locations of pumping for water supply, and the tipping point of complete seawater intrusion up to the prevailing

groundwater divide of a coastal aquifer. Recent investigation of prominent aquifers in the eastern Mediterranean region shows human-driven modifications of hydrologic regimes and associated salinization histories towards various current levels of proximity to these critical limits for essential groundwater resources.