Hydrological Fluxes during Past and Future Greenhouse Climates

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During the Phanerozoic the Earth's climate has alternated between two states, one with polar ice and a large meridional temperature gradient, "icehouse," and the other lacking ice except at high elevations and with reduced temperature gradients, "greenhouse". About 20-25% of the present land surface was flooded by seas. The polar regions had no permanent ice cover and the mean annual temperature of polar surface waters was as high as 15°C. Today, it is around -1.7°C at the North Pole. Greenhouse conditions are thought to have been the result of atmospheric CO_2 levels 3-12 times that of the pre-industrial era, amplified by the water vapor greenhouse effect. Because of the non-linear relation between water, vapor and temperature, the hydrologic cycle varies with different global climatic states; enhanced during greenhouse and suppressed during icehouse times.

Previous numerical simulations have demonstrated that during warm times the role of the hydrologic cycle in global climate was greater than today. Here, we present the results of simulations by GENESIS 2.0 Earth System Model to show that the land-related parts of the hydrological cycle operated differently from today, substantially affecting weathering and sedimentation processes. Surface runoff was reduced in the Cretaceous to the benefit of subsurface runoff, which increased by 65% compared to today. Intense spring storms and for the Cretaceous arguably snowmelt are responsible for the timing of surface runoff maxima in both the present day and Cretaceous simulations. Enhanced subsurface runoff would introduce time delays in supplying water to rivers, resulting in less seasonal variability in flow. Broader implications of stronger hydrological cycling and shifts in the ratio of surface/subsurface runoff include changes in rain water chemistry and more intense continental weathering. This in turn would amplify nutrient leaching and carbon turnover in terrestrial soils and subsequent export to the oceans.