Summary

Hydrological functions summarize the hydrological cycle as collection, storage, and discharge. These functions describe the action of a basin on the water entering its control volume (Black, 1997; Wagener, Sivapalan, Troch, & Woods, 2007) as the collection of water from precipitation through different flowpaths onto different storage components (soil moisture, snow, lakes, etc.), and the final release or discharge as evaporation or runoff. The release function, especially the amount released as runoff, is of utmost importance for water managers, as it indicates the water availability. The storage function can have a pivotal role in mediating the partition of collected water into the different releases; however, this link is rather unclear. The objective of this thesis is twofold: First, it will try to determine the current state of hydrological functions; second, it will try to evaluate the effect of climatic changes on these functions. The function of basins is dependent on many factors, including topography, climate, and geology among many others, which is why this study is based in a comparative approach. A global data set of modeled outputs from the EUWATCH project is used, focusing on the 35 largest river basins in the world. The first objective is pursued following the hypothesis that the temporal patterns of each variable can be indicators of how the hydrologic functions work in a basin. This refers to how water is transferred from precipitation (collection function) into storage (storage function) to evaporation and discharge (release function). To study the temporal pattern of hydrological variables, a measure to quantify the degree of similarity in intra-annual variations is introduced under the term of *recurrence* is defined as the degree to which a monthly hydrological variable returns to the same state in subsequent years. The degree of recurrence in runoff is important not only for the management of water resources but also for the understanding of hydrologic processes, especially in terms of how the variables of precipitation, evaporation, and storage determine the recurrence in runoff. By analyzing these temporal characteristics, a simple

hydrologic classification framework applicable to large basins at global scale is proposed. The overview of recurrence patterns at global grid scale suggested that precipitation is recurrent mainly in the humid tropics, Asian monsoon area, and part of higher latitudes with a moisture source from the tropics due to oceanic currents. Recurrence in evaporation was mainly dependent on the seasonality of energy availability, typically high in the tropics, temperate, and subarctic regions. Recurrence in storage at higher latitudes depends on energy/water balances and snow, while that in runoff is mostly affected by the different combinations of these precipitation, evaporation and runoff. Regarding the basin scale classification, in the humid tropic region, the basins belong to a class with high recurrence in all the variables, while in the subtropical region; many of the river basins have low recurrence. In the temperate region, the energy limited or water limited in summer characterizes the recurrence in storage, but runoff exhibits generally low recurrence due to the low recurrence in precipitation. In the subarctic and arctic regions, the amount of snow also influences the classes; more snow yields higher recurrence in storage and runoff. The proposed framework follows a simple methodology that can aid in grouping river basins with similar characteristics of water, energy, and storage cycles. The framework is applicable at different scales with different data sets to provide useful insights into the understanding of hydrologic regimes based on the classification.

To analyze how the hydrologic functions of river basins are affected by climate change, future runoff projections using a Budyko- type equation with respect to projections by a global hydrological model (GHM) were compared. The comparison is made for the annual mean runoff projections for a future period (2060–-2100) after the Budyko parameter is set based on hydrologic model outputs at a present period (1960–-2000). By carrying out this comparison, it was possible to investigate the performance from the Budyko equation with respect to the hydrologic model at different climate regions and explore the effects of including a hydrologic-function perspective. According to the

comparison, the projections by the two approaches agreed well (R^2 = 0.983), in particular in humid tropic region (R^2 = 0.986) but with consistent underestimation of future runoff (ME = -0.042) by the Budyko equation. In subarctic region the performance of the Budyko equation was low (R^2 = 0.599) due to the overestimation of future runoff (ME = 0.110). The results in the dry and temperate regions also showed some discrepancy (R^2 = 0.931 and 0.724) without apparent patterns in the errors. The paper discusses possible reasons for the errors with respect to water and energy seasonality and changes in storage component contributions.