Hydrology: The Influence of Climate Change and/or Land Cover/Use Change

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Global Climate Change

The earth is warming, in part due to human influences, including the emissions of various atmospheric pollutants (CO_2, etc.). This warming is causing increased rates of melt near the poles (Antarctica, Greenland), and disequilibrium in other areas, such as a net loss of the Arctic sea ice and many glaciers. Some mountain glaciers are and even have disappeared. However, this warming is not ubiquitous; some of the world's glaciers are actually growing.

Precipitation is also changing. Accompanied by an increase in the occurrence and severity of storms (e.g., hurricanes and tornados), precipitation rates and quantities are increasing in various regions. In other areas, the rates and amounts are decreasing. The timing of when precipitation occurs in the year is also changing. This, together with temperature changes, is altering the phase of precipitation between rain and snow.

Precipitation and temperature are the main drivers of hydrological systems, which influence water availability. In the environmental context, global ecosystems are dependent on the same climate drivers. Changes in precipitation and temperature directly and indirectly cause changes in other hydroclimate system variables, including evaporation rates and streamflow. Similarly the climatic changes that alter precipitation yield differing amounts of cloud-cover which changes short-wave and long-wave radiation fluxes onto the earth's surface.

The climate is changing in many parts of the world. The instrument record is long enough in enough locations to begin assessing climate trends over space. Trend assessment and forecasting assumes stationarity – the variability in past observations resembles the expected future variability and with a consistent long term average. Recently the issue of non-stationarity has arisen. For example, in various locations there has been a warming trend that has been due to an increase in minimum temperatures, while the variability in those temperatures has decreased.

Hydrologic changes are occurring due to a changing climate. For snow dominate environments, snowmelt streamflows are starting earlier with peak flows occurring earlier. This is due to decreased snow accumulation, warmer temperatures, and land cover changes. Other hydrologic changes are occurring due to shifting precipitation characteristics and/or temperature variations.

Potential future changes are being simulated using global climate (general circulation) models (GCMs) based on future scenarios that have been developed by the Intergovernmental Panel on Climate Change (IPCC). Some of these scenarios are based on CO_2 emissions in the atmosphere. Due to differences in model configuration, data requirements, and process representations (process physics), current analyses are using the output from multiple GCMs to present an ensemble of future possibilities. In general, most models agree that northern environments, in particular, Canada, Scandinavia, many of the former Soviet republics, Russia and Mongolia, will see an increase in runoff. Mid-latitude regions, such as the Southwest US, Europe, Mediterranean Africa, and the Middle-East, are expected to see a significant drying.

Rangeland Hydrology

Large portions of the earth's surface receive limited amounts of precipitation, have low humidity, and experience large daily temperature fluctuations. These arid (desert) and semi-arid (steppe) regions have varying soil characteristics covered with a variety of grasses and shrubs. Cold winter temperatures in some of these arid and semi-arid regions yield snow that accumulates and usually redistributes from strong winds.

The vegetation is not continuous in rangelands, which creates large scale variations in hydrologic properties, including soil moisture and snow cover. Snow cover is especially crucial due to its higher reflectivity (albedo) compared to the reflectivity of vegetation and soil. These reflectivity differences, together with accumulation and scour of snow in and around vegetation, create local energy balance variations. Also, since snow is an insulator, the accumulation patterns dictate soil freezing and water availability for soil moisture.

Modelling Tools

We can assess data to identify trends and to develop predictions; we can use computer models to understand the sensitivity of processes, to assess data quality, and to simulate future possibilities from climate scenarios. To identify trends, data must be compiled and their quality must be assessed. The significance of trends can be computed using tests such as Mann-Kendall, with rates of change with confidence intervals computed by Sen's slope.

Hydrological models use soils and topography data to derive static parameters for the desired modelling spatial resolution. While often also used to derive static parameters, land cover and canopy density data help formulate vegetative based parameters. Most parameters are calibrated to improve modelling results. For index-type semi-physical models, precipitation and temperature data are the meteorological drivers. For physically-based models that simulate the mass and energy balance, short-wave and long-wave radiation, wind speed and direction, humidity, and station pressure are additional drivers. Within both model types, various state variables, such as snowpack properties and soil moisture, are simulated. Model output is typically streamflow which, together with the state variables, is used for parameter calibration and verification.