Seasonal hydrologic changes and their ecological consequences in headwater basins

We conducted two sessions that examined the causes and consequences of seasonal changes in water fluxes in headwater drainages. Analysis of long-term discharge records for several headwater basins has revealed seasonally specific changes in flow regimes regimes at two-dozen sites across the U.S. and Canada, which may be attributed to climate change and ecological responses to past disturbances (Jones et al. 2012). For example, polar/alpine sites are experiencing increased flows at the margins of the formerly frozen periods, whereas forested sites with snowpacks are experiencing changes in spring snowmelt timing. In contrast, vegetated sites without snow/ice are experiencing alterations in summer streamflow: both decreasing flows as would be expected from warmer temperatures and increased evapotranspiration, but also in some cases increasing flows associated with forest succession from past disturbances.

This working group addressed the question: How do these seasonal hydrologic changes affect ecological patterns and processes? We held an introductory session to provide an overview of the issue and the work plan. In session two, we divided into sub-groups to tackle specific ecological themes. Sub-groups focused on: (1) chemical responses to changing seasonality of flows; (2) evapotranspiration and woody plant responses; (3) organismal and community responses; (4) headwater ecosystems and engineered water systems of large river basins; (5) urban aquatic systems; (6) models. Sub-groups identified key research questions.

<u>Session 1: Overview of seasonal hydrologic changes</u>

- Hydrology – driver of change or responder to change?
- Direct link between climate and hydrology in some sites … e.g., NIWOT
- Indirect links in other sites (due to "filter" from vegetation)
- We need definitions: what are seasons? What are droughts and floods? What are extreme events?
- Can we quantify not only trends in averages, but trends in extremes?
- How important is the "switching" between extremes?

<u>Session 1, subgroup 1: Woody vegetation response to/influence on changing hydrology</u>
This subgroup addressed legacy effects of disturbance (insect, harvest); invasion of species (what are the drivers?); changing disturbance regimes.

<u>Summary Questions about seasonal changes in hydrology and woody plants</u>

- How do forest species (responsiveness of individual species to VPD through stomatal control, tree age, setting) determine hydrological outputs? Proposed approach: use measured relationship of sapflow to VPD to quantify elasticity, inelasticity of sapflow to changes in VPD, and check how this is reflected in water yields over time. See Ford et al. 2011, Williams et al 2012.
- Do forest community changes over course of success change trump climate change? Suggested by trends of increasing summer water yield 1950-2010at CWT, FER, HBR,

where forests undergoing succession after early 20th century disturbance, despite increasing temperature (Jones et al. 2012).
- What promotes woody plant invasions, and what are consequences for hydrology?

Given change in hydrology – what are the consequences to following:

Session 1, subgroup 2: Biogeochemical response to changing seasonal hydrology
Summary of points
- How do seasonal variations in flow influence nutrient export: are all trends explained simply by dilution or concentration of nutrients?
- In ice/snow/permafrost-dominated sites, old water is being melted … old water may be exported (e.g., NWT, Caine et al 2010)
- Biogeochemical responses depend on effects of climate on hydrological source areas to the stream and downstream surface waters (e.g., changes in wetlands, NTL, Sebestyen et al 2011)
- Centre of volume – common metric for monitoring change – look at changes in timing of mass of water and nutrients … disconnects emerge (e.g., HBR –Campbell pubs?)

Summary Questions
- How does climate influence hydrologic flow pathways/partitioning and their connectivity and what are the consequences to biogeochemistry? Concept is that portions of landscape are disconnected, but undergoing distinct biogeochemical processes; when these disconnected portions of the landscape are episodically connected, they produce altered biogeochemical signals. This provides a common framework for considering multiple sites. For example, materials can be held in frozen reservoirs, but also in isolated patches during droughts, which then become hydrologically connecting during floods (or wet periods). Could also explain different export signals both at seasonal dynamics and annual time scales (wet vs. dry years).
- Are low flows and high temperatures becoming coherent? And what are consequences to biogeochemical export? (e.g., Arismendi et al 2012)

Session 1, subgroup 3: Organism response to changing seasonal hydrology
Summary of points
- Timing of extreme flows and extreme temperature events may lead to “reset” of species

Summary Questions
- Are low flows and high temperatures becoming coherent? And what are consequences to organisms?
- What is the change in frequency/intensity of extreme events?
- How do change in flows and “extreme” events influence regime shifts? (e.g., Nancy Grimm)

Session 2, subgroup 4: headwater ecosystems and engineered water systems of large river basins

Summary Questions

- How do headwater ecosystems interact with downstream engineered water systems and human geography of large river basins (to alter propagated signal)
- What is the relevance of headwater systems to understanding effects of climate change on large river basins?
- Hypothesis: Large river basins not sensitive to certain types and directions of climate change because of the regulatory system
- Hypothesis: true for water quantity, but not water quality
- Further down the river continuum, are fluctuations being mitigated or amplified?

Session 2, subgroup 5: Urban aquatic ecosystems

Summary questions

- how do urban systems influence flow seasonality?
- How do urban systems influence groundwater-surface water connectivity?
- What are consequences of these physical processes for biogeochemistry/water quality?

Session 2, subgroup 6: seasonal hydrologic changes and hydrologic models

Summary questions

- What do we want from models? One size fits all, or customized ones?
- Conceptual models need first, then develop numerical models?
- Plant water transport – better representation a critical need in models

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