Extreme Weather Whiplash:
Exploring Groundwater Responses to the 2021 Drought and Atmospheric River Events across British Columbia, Canada

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Background

The focus of hydrometeorological extremes often overlooks groundwater, yet, it is an integral component in controlling drought moderation and recovery. While droughts and atmospheric rivers (ARs) are not uncommon in British Columbia (BC), the co-occurrence of a heatwave-enhanced drought and severe successive ARs in 2021, was a first.

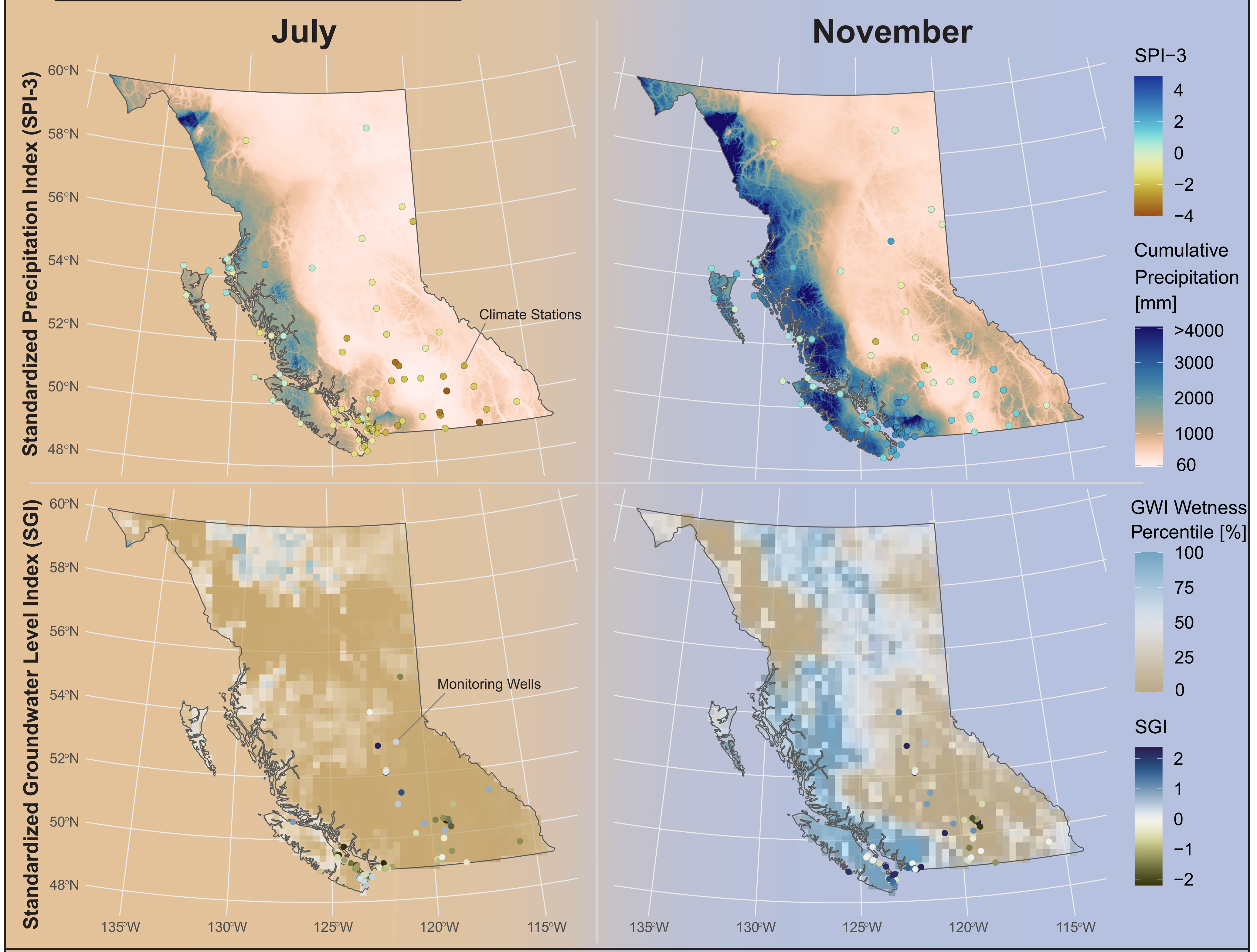
- **Meteorological Drought:** Over 50 days without precipitation (mid-June to early August).
- **Extreme Heatwave:** 13-day heatdome with temperatures exceeding 40°C to a max of 49.6°C (late June).
- **Extreme Precipitation:** Two major AR events shedding several hundred millimetres of precipitation, nearly a doubling over normal November precipitation (14/15 and 29/30, November).

Hypothesis

Research Question: *How did the relatively rapid shift in weather extremes influence groundwater levels across the province, and what potential factors control persistence or recovery to these extremes?*

Examination of the 2021 extreme events at a site-scale (Otter Park) revealed clues about how shallow subsurface hydraulic properties (e.g. storage) are likely controls on the magnitude of groundwater response. This prompted us to explore groundwater levels at a province-wide scale, using data from the Provincial Groundwater Observation Well Network (PGOWN)[2]. We suspect that aquifer storage plays a large role in influencing groundwater memory.

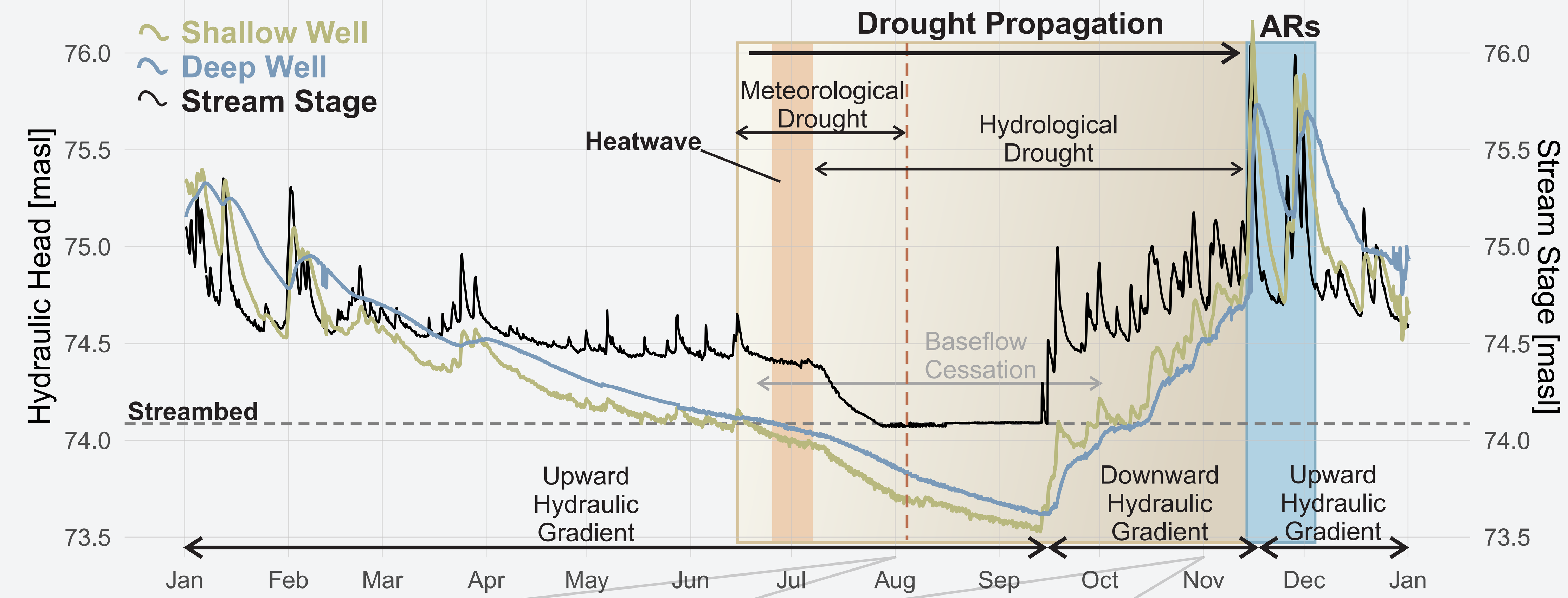
Provincial Response

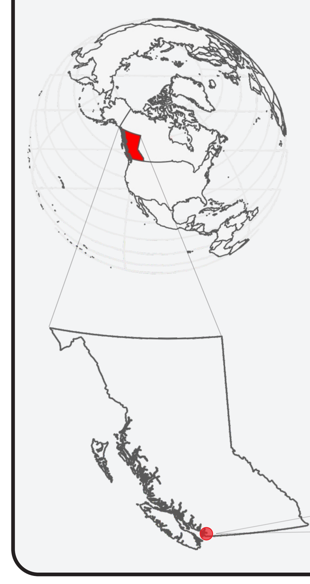


Method: The three-month Standardized Precipitation Index (SPI-3) from the North American Drought Monitor (NADM)[5] for 78 climate stations was used as an indicator of meteorological drought or deluge. The Standardized Groundwater Level Index (SGI)[2] was computed for 72 groundwater monitoring wells (>30 yrs data)[3] as an indicator of groundwater level departures from the mean (hydrological drought or surplus).

***Basemaps** *Top Row:* Daymet[6] cumulative annual precipitation. *Bottom Row:* NASA GRACE Groundwater Drought Index (GWI)[1,4] percentiles*

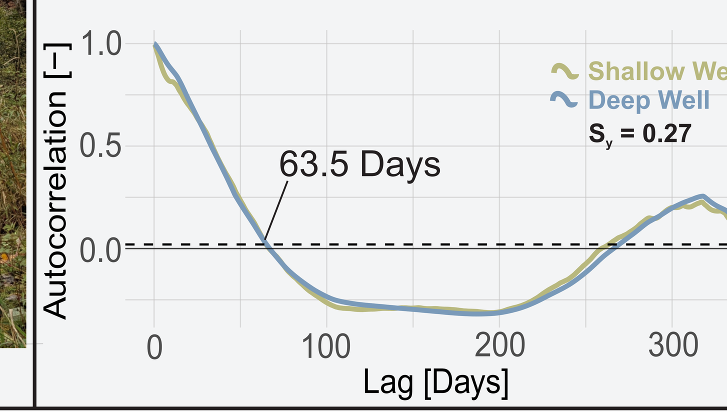
Changes in Groundwater Storage



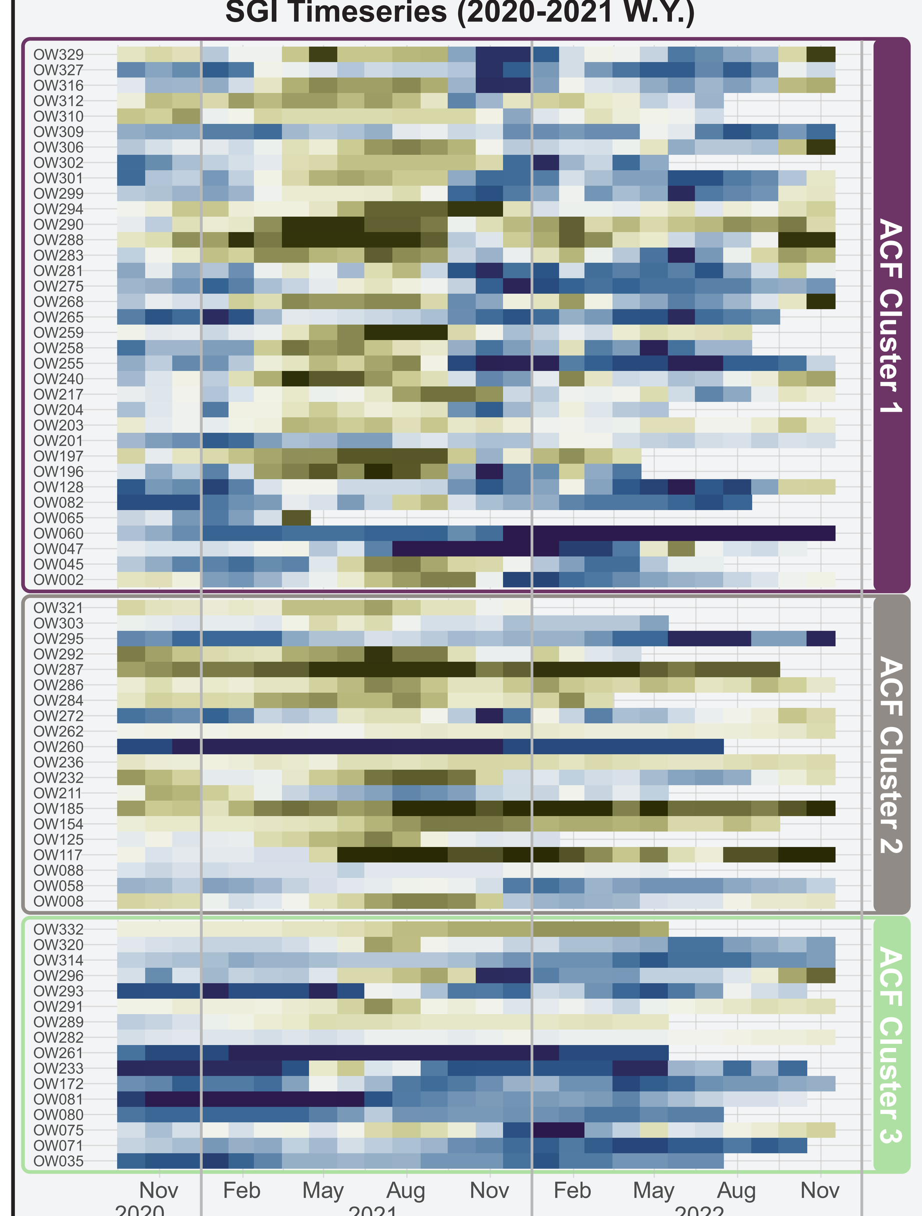


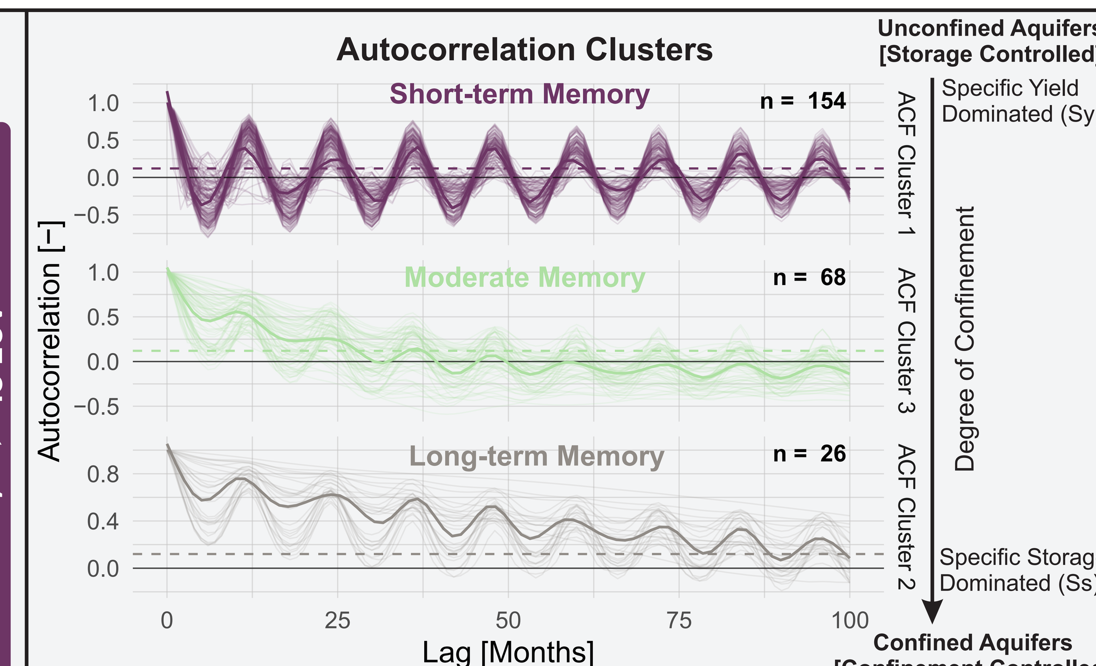
Bertrand Creek in 2021 at Otter Park, southwestern BC

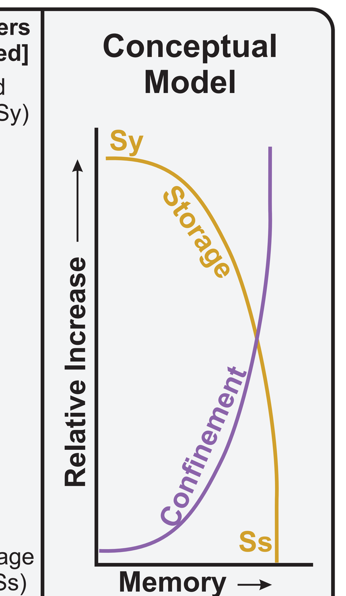
More Storage & Short-term Memory = Highly Responsive & Susceptible



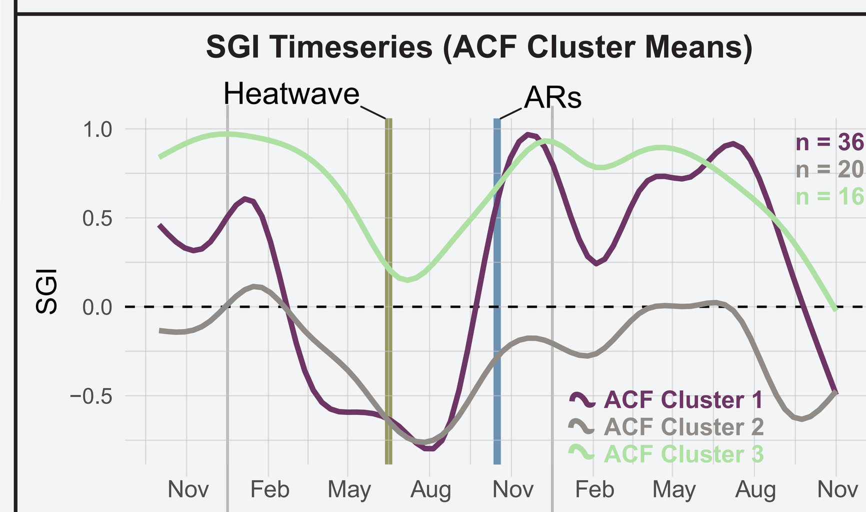
Memory Mechanism





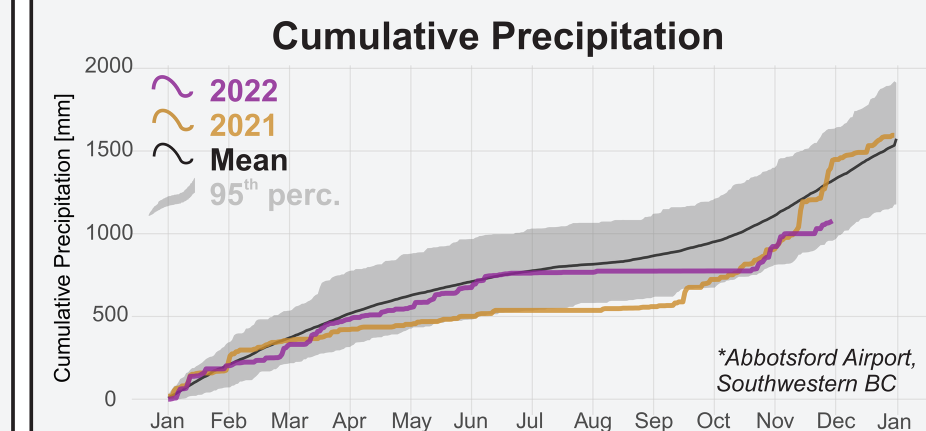


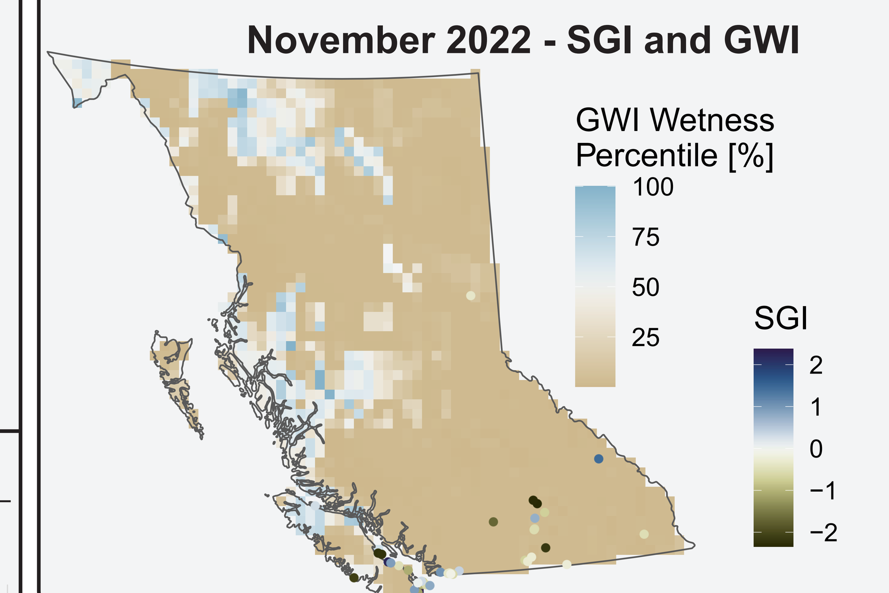
Water released from unconfined aquifer storage is faster (shorter memory) than release from confined aquifer storage (longer memory)



Method: Aquifer memory is inferred from autocorrelation function (ACF) structures, using 248 groundwater monitoring well records (>2 yrs data). ACFs were clustered into three groups using agglomerative hierarchical clustering by euclidean distance dissimilarity (Ward linkage).

Current Conditions





Main Findings

► Nearly all wells responded to both extremes, but the response magnitude is dependent on the degree of aquifer memory, which is a function of storage

► The ARs did allow drought-stricken aquifers to recover, specifically in the South Coast Region

► Drought propagation reduces shallow aquifer storage allowing hydrological drought to persist, even in the absence of meteorological drought

► Short-term memory in aquifers is likely controlled by storage while long term memory is controlled by the degree of aquifer confinement (aquitard thickness)

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Supplemental Information