Climate impacts on terrestrial hydrology and hydrometeorology in Alaska and Yukon River Basin: a modeling effort guided by Indigenous Knowledge

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Challenges Faced by Indigenous Alaskans

Climate Change

The Arctic is experiencing rapid change across all Earth system components including Arctic hydrology. The hydrologic changes comprise abrupt increases in permafrost degradation and increasing active layer depth, earlier snow melt, lengthening of the snow-free season, reduced river ice, frozen soil warming, and related shifts in the fluvial freshwater seasonality

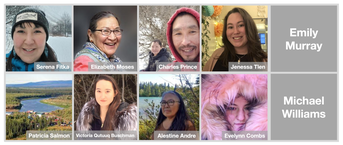
Socioeconomic Stressors

Arctic environment change has led to historically King and Chum salmon runs over the past two years. Corresponding bans on subsistence fishing greatly imperils the livelihood and cultural heritage of Indigenous communities in the Yukon River Basin. Unprecedented inflation causing surging grocery and fuel prices further negatively impacts the quality of life for many Indigenous community members.

Objective

As the foundation of capturing a trustworthy climate sensitivity of the freshwater cycle, we aim to develop a high-fidelity, process-based representation of climate and land surface processes for Alaska and the Yukon River Basin

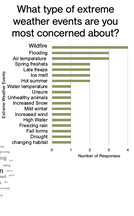
Indigenous Guidance



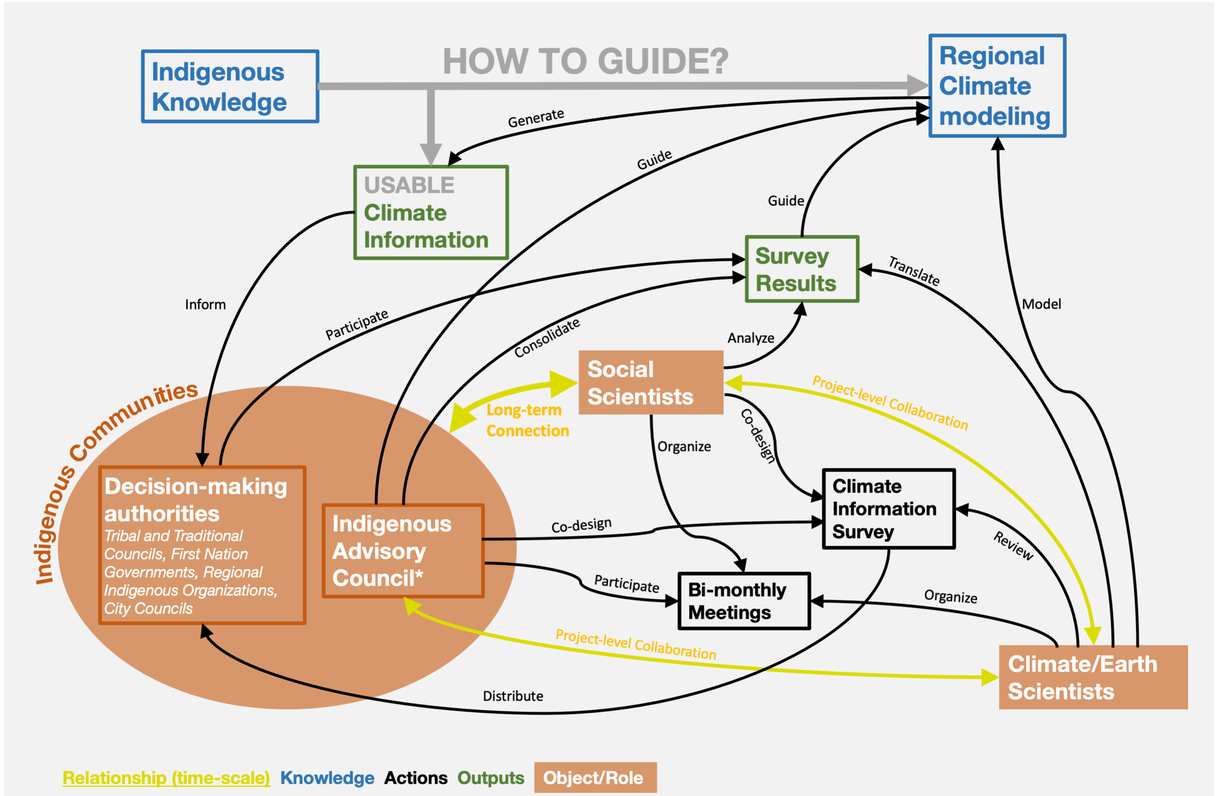
Strong collaboration with Indigenous communities and community-based science networks: Co-production of knowledge

- **Indigenous Advisory Council** (*10 members from across the study region, compensated as contractors*)

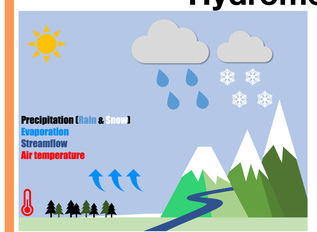
- **Climate Information Survey**
  - **23** responses were received from representatives across our study domain
  - Guiding modeling decisions
    - What future time horizon to model?
      - *2035-2065*
    - What Global Climate Models to use?
      - *We will choose two equally plausible but different GCM projections to downscale (Pseudo Global Warming)*



Collaborative mechanism to support co-production



Terrestrial Hydrology and Hydrometeorology



We conducted comprehensive evaluations on terrestrial hydrology & hydrometeorology

Precipitation
Precipitation was compared against observationally based probabilistic estimate of precipitation (Newman et al 2021). We included ensemble **mean**, **25th**, **50th**, and **75th** percentile in the plot.

Snow Fraction
Snow to precipitation ratio was compared against ERA5 dataset at seasonal level.

Streamflow
Streamflow was compared against **USGS flow observations** for 15 major river basins across Alaska. We also compared the flow simulation from **Coupled** modeling with standalone CTSM ($CTSM_{only}$)

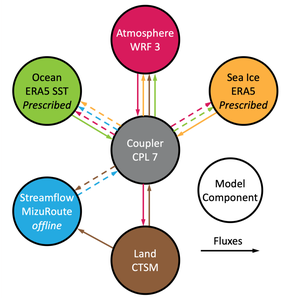
E/P ratio evaporation to precipitation ratio was compared against ERA5 dataset.

Air Temp air temperature was compared against over 500 onsite observations across Alaska

Main Takeaway

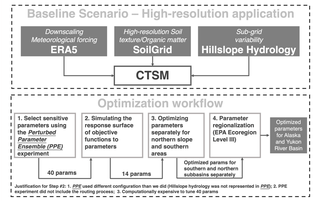
- **We actively engage Indigenous participation in this project to ensure that Indigenous Knowledge is included, valued and protected. Their knowledge also guided the study design and modeling decisions.**
- **A comprehensive evaluation for terrestrial hydrology and hydrometeorology was conducted for our historical simulation (1990-2018) and our coupled model simulation performs well (not shown).**
- **We will provide this coupled WRF-CTSM climate and hydrology dataset to the community with variables available from sub-daily to monthly from 1990 to 2021.**
- **Next Steps:**
  - **Finalize GCM selections and conduct PGW runs.**
  - **Initial results for historical runs will be presented in the coming Fall AGU.**

Regional Arctic Systems Model (RASM)



Coupled land-atmosphere model

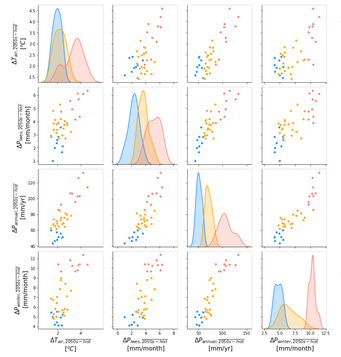
- Use prescribed SST and Sea Ice from ERA5
- Manually test coupled model
- Use an offline river routing model **mizuRoute**
- Update the land model in RASM by using the state-of-the-science land model (Community Terrestrial Systems Model, **CTSM**)
- Developed a framework for optimizing CTSM parameters
  - Step 1&2: Select sensitive parameters to arctic hydrology.
  - Step 3: Conducted an multi-objective optimization for streamflow and snow using an efficient optimization methodology.
  - Step 4: Parameter regionalization to account for spatial heterogeneity.



Pseudo Global Warming (Δ method)

Pseudo-global warming (**PGW**) refers to a simulation strategy in regional climate modeling. The strategy consists of directly imposing **large-scale changes in the climate system** on a control regional climate simulation (usually representing current conditions) by modifying the boundary conditions. Useful for developing 'what-if' future storylines

- We will conduct two PGW projections using two GCM groups.
  - **What is most likely to happen** (***Level of Change*** ranging between 25th and 75th percentile, orange dot below)
  - **Potential extreme cases** (***Level of Change*** larger than 75 percentile, red dot below)



- The selection of GCM groups are guided by the Climate Information Survey as the survey identified the events and variables of interest.
  - **Mean annual air temperature (T_{air})**
  - **Late winter to early spring precipitation (P_{lwes})**
  - **Mean annual precipitation (P_{annual})**
  - **Winter precipitation (P_{winter})**
- ***Level of Change*** integrated the projected changes across four variables above.

Acknowledgements

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