Developing Actionable Regional Climate Models and Data for Communities and Decision-makers Across Alaska and Northwestern Canada

CESM Workshop, High-resolution cross-working group,
11 June 2025

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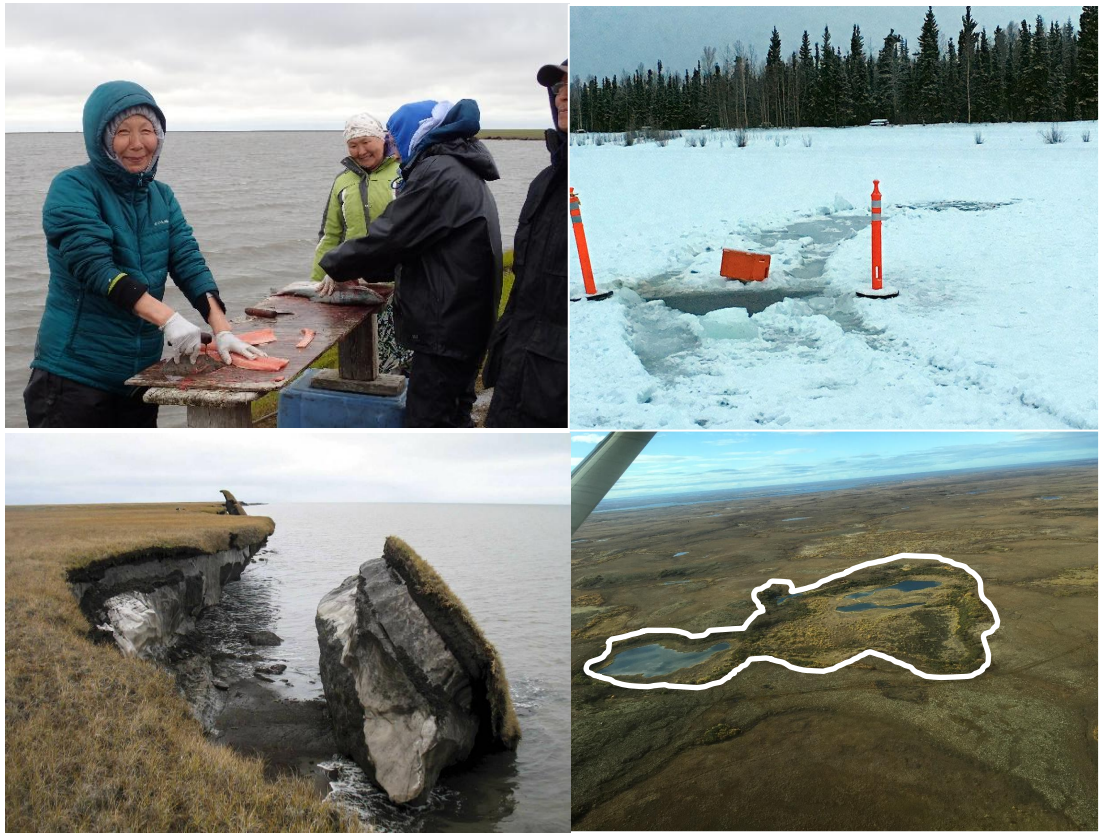
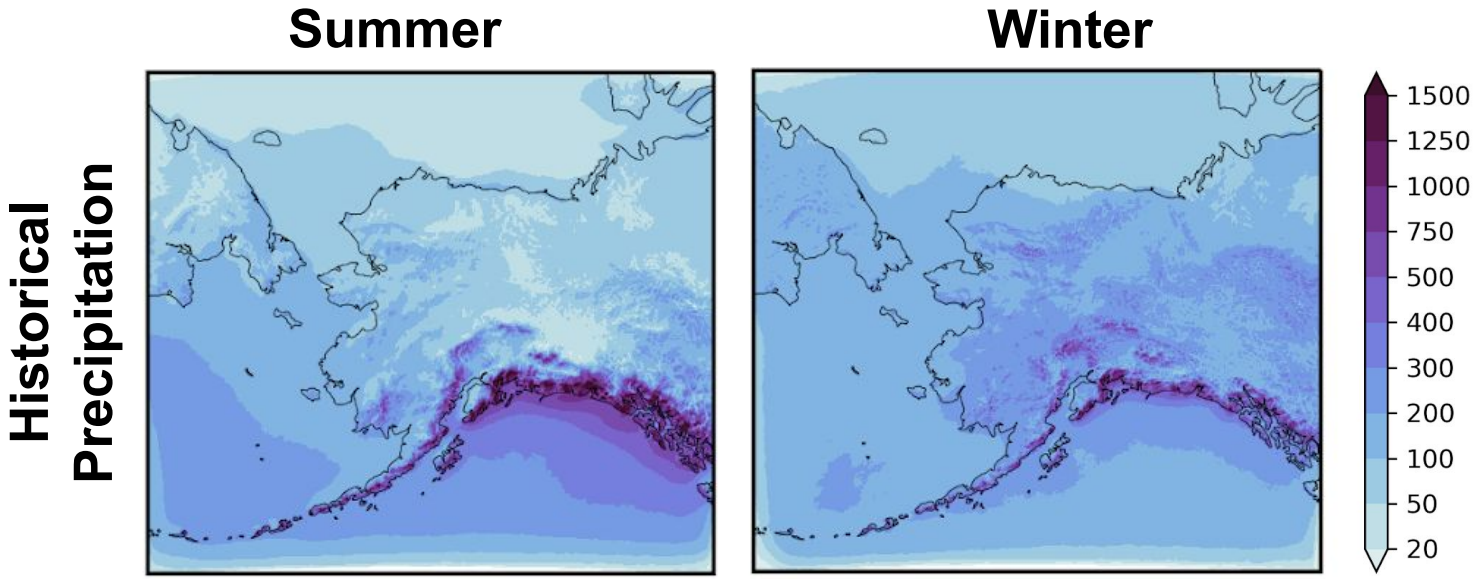
Overview

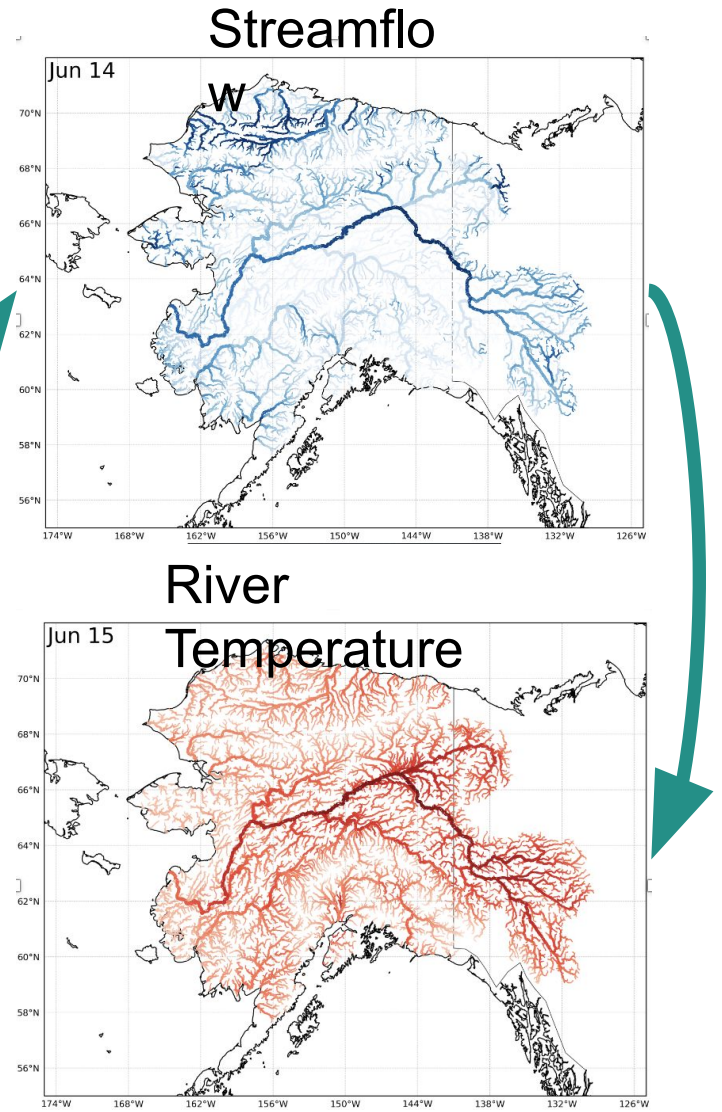


- The Arctic is rapidly changing:
  - Large increases in temperature and decreases in sea ice
  - Increases in annual precipitation and rain versus snow amounts
  - Changes in seasonal snowpack
- Inland river systems are essential for subsistence fishing as well as transporting fuels and supplies

Regional Climate Model Development

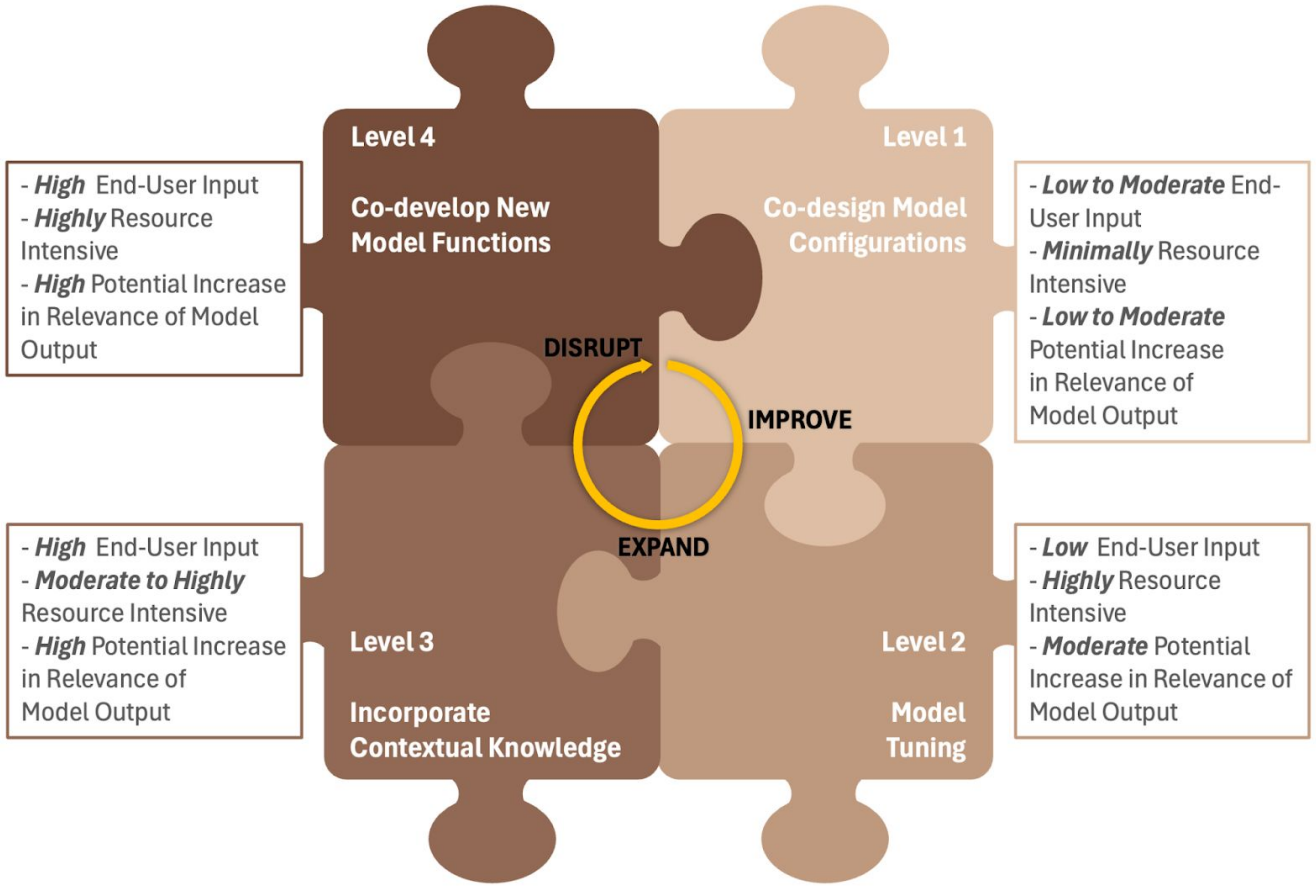
- NSF Navigating the New Arctic – Arctic Rivers project
  - Assessing the climate sensitivity of Alaskan & Yukon rivers and fish to support resilient communities
- Partnership with YRITWC informed the initial proposal motivation and conceptual approach





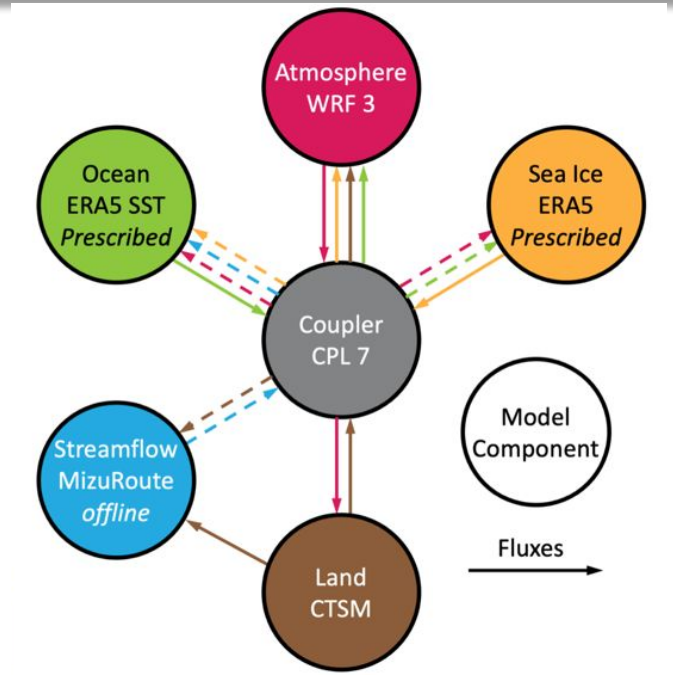
Regional Climate Model Development

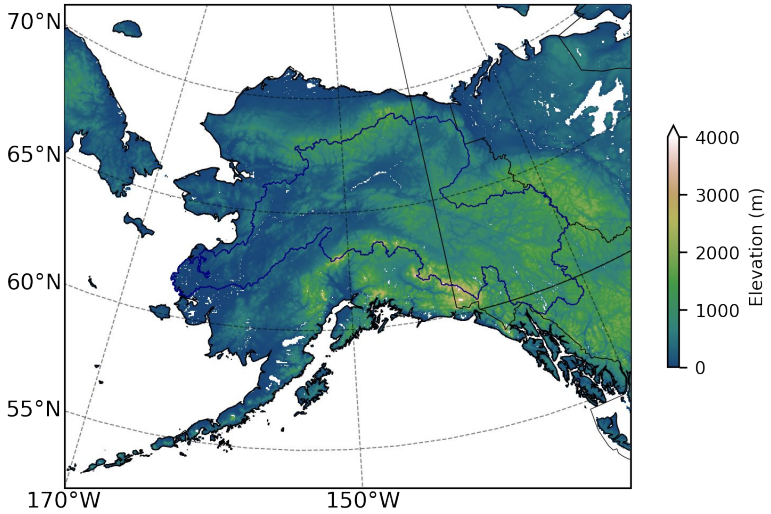
- Model (and projection) co-design is a spectrum ranging from none to very deep integration
- In our project, we worked across levels of co-design
  - Ranging from 2 (co-designing model configuration) to 3 (local knowledge informed model localization)
- Level of effort, skills, partner questions and capacity, other considerations all influence our research
  - Types of impact models
  - Probabilistic versus storylines



Cheng et al. 2025, in prep

Regional Climate Model Development



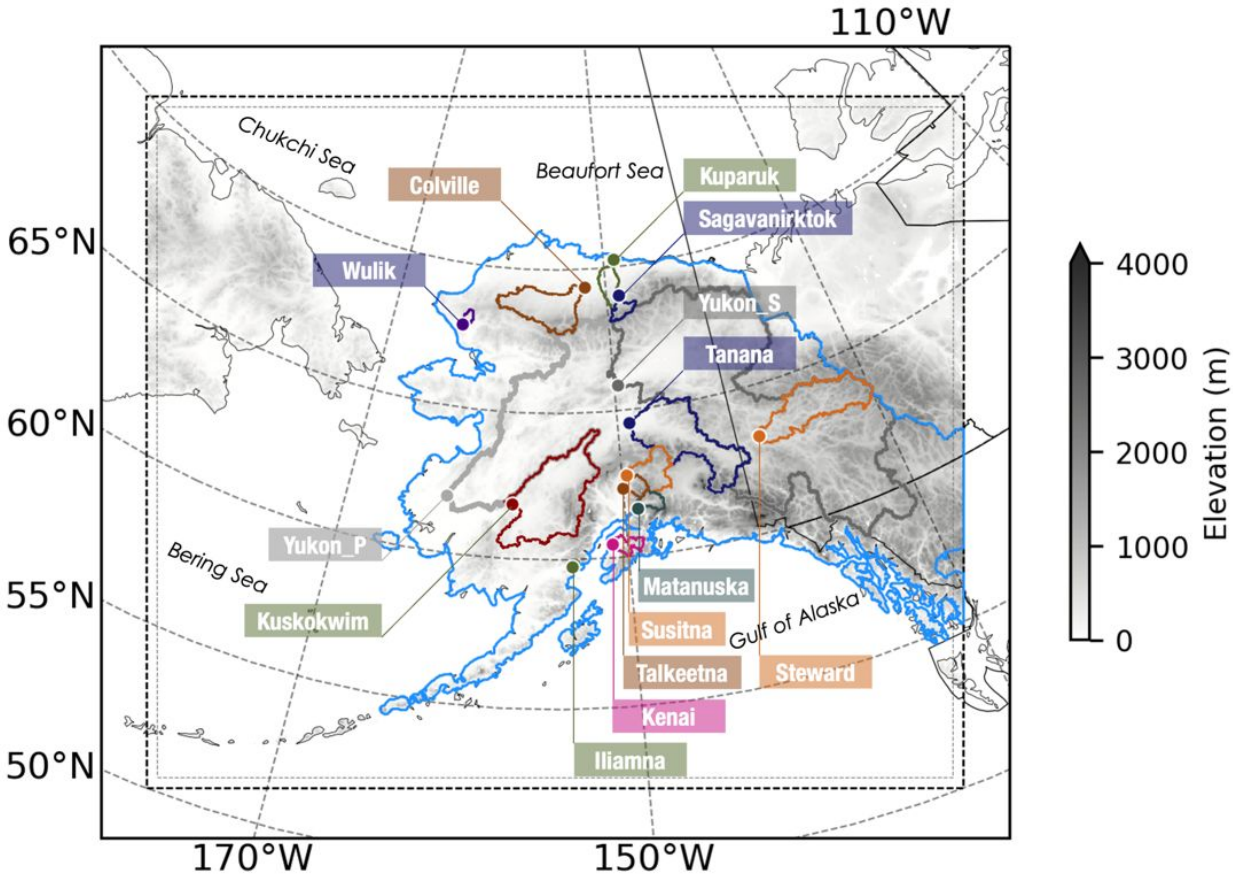


- **Co-design can help mitigate built-in assumption risk**
- Our model: Regional Arctic Systems Model (RASM)
  - A regional ocean-land-atmosphere-ice coupled model
    - WRFv3.7.1 atmospheric model
    - Community Terrestrial Systems Model (CTSM)
- All models have a world view (assumptions)
- What are the key limitations for your application?
  - Move to Community Terrestrial Systems Model (CTSM) in RASM, include hydrologic optimization
  - RASM and CTSM configurations
    - E.g. 4 km grid spacing, hillslope hydrology
  - Future climate experiments (number and time span)
  - Follow-on impact models, data dissemination

Cheng et al. (2023, 2025)

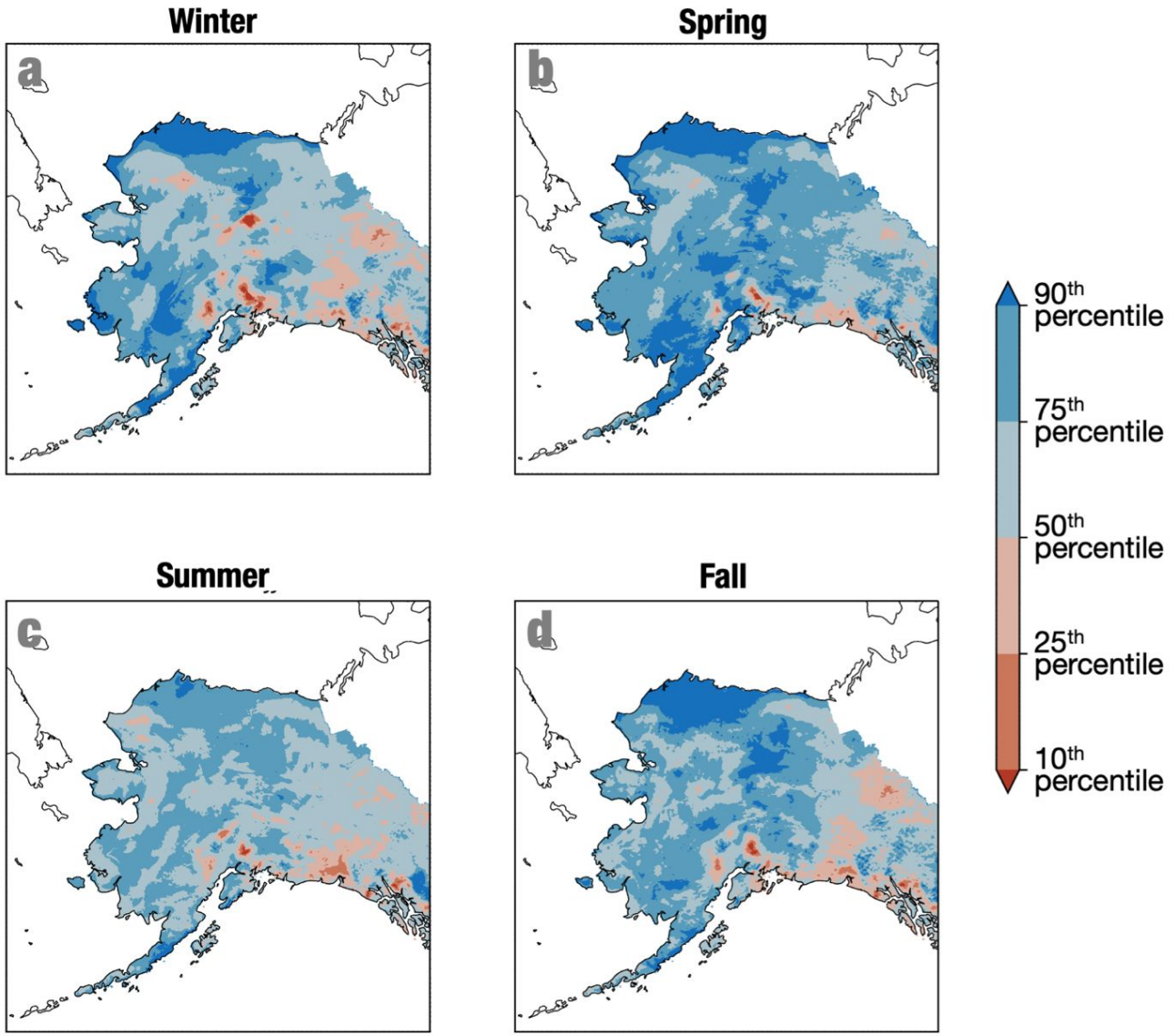
Experimental Overview

- Nearly all of Alaska, and all of the Yukon River basin
  - 4 km grid spacing
  - Formal optimization applied to CTSM, river routing, stream temp
- Simulations:
  - 30 year historical (ERA5 forced)
  - Two 30 year Pseudo Global Warming (PGW) (2035-2065)
  - Four CESM2-LE members
    - 30 historical and mid-century time slices matched to other runs



Cheng et al. (2025)

Historical Simulation Verification



- Use of performance benchmarks and other meaningful performance descriptors
- Observations have uncertainty, use it to guide validation
- Precipitation often falls within range of observational uncertainty (from Newman et al. 2020)
  - Arctic is challenging for quantitative validation
  - Few observations, complex spatial features
  - Consistent wet bias on north slope
  - Potential dry bias along SE AK

Cheng et al. (2025)

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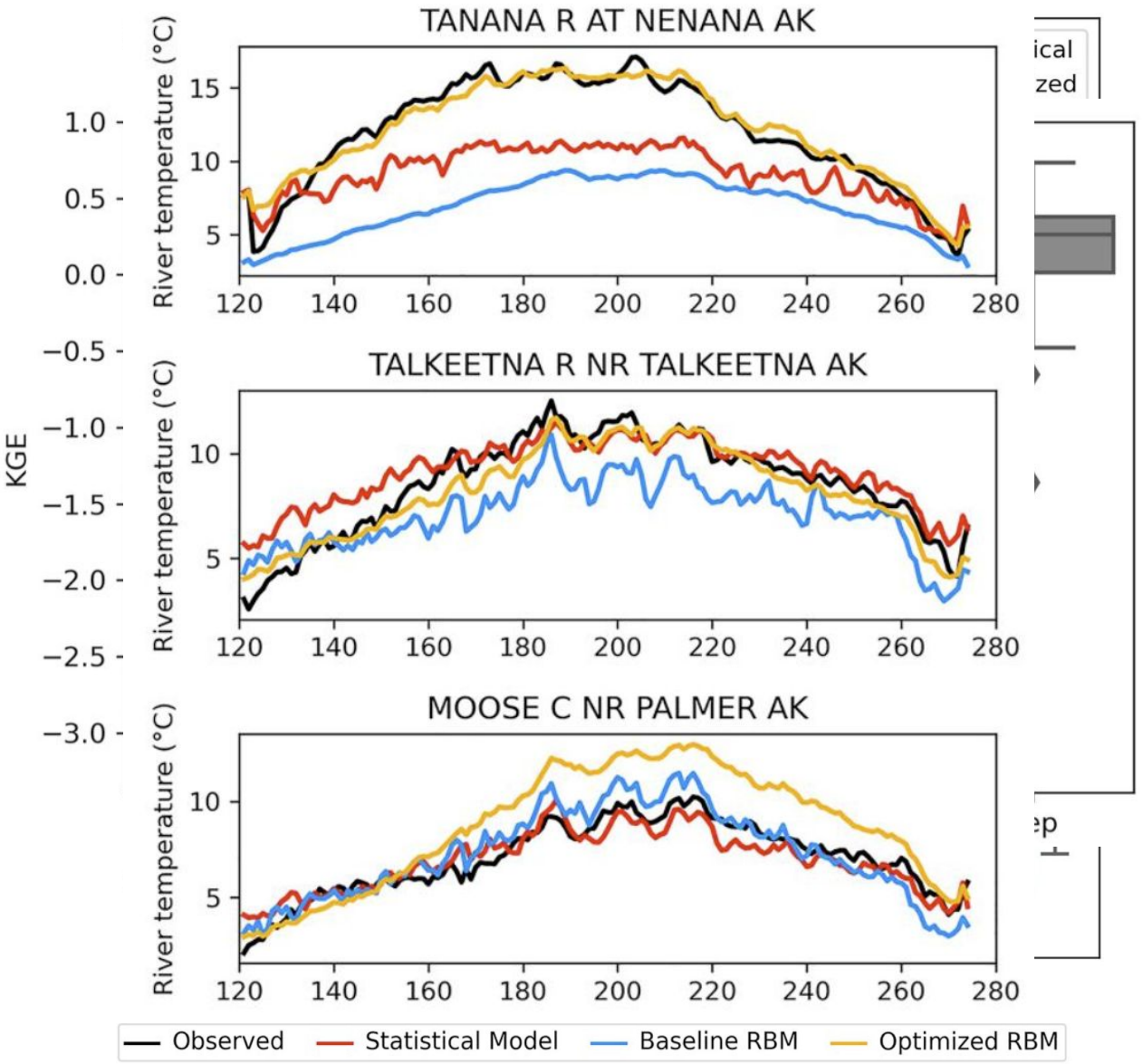
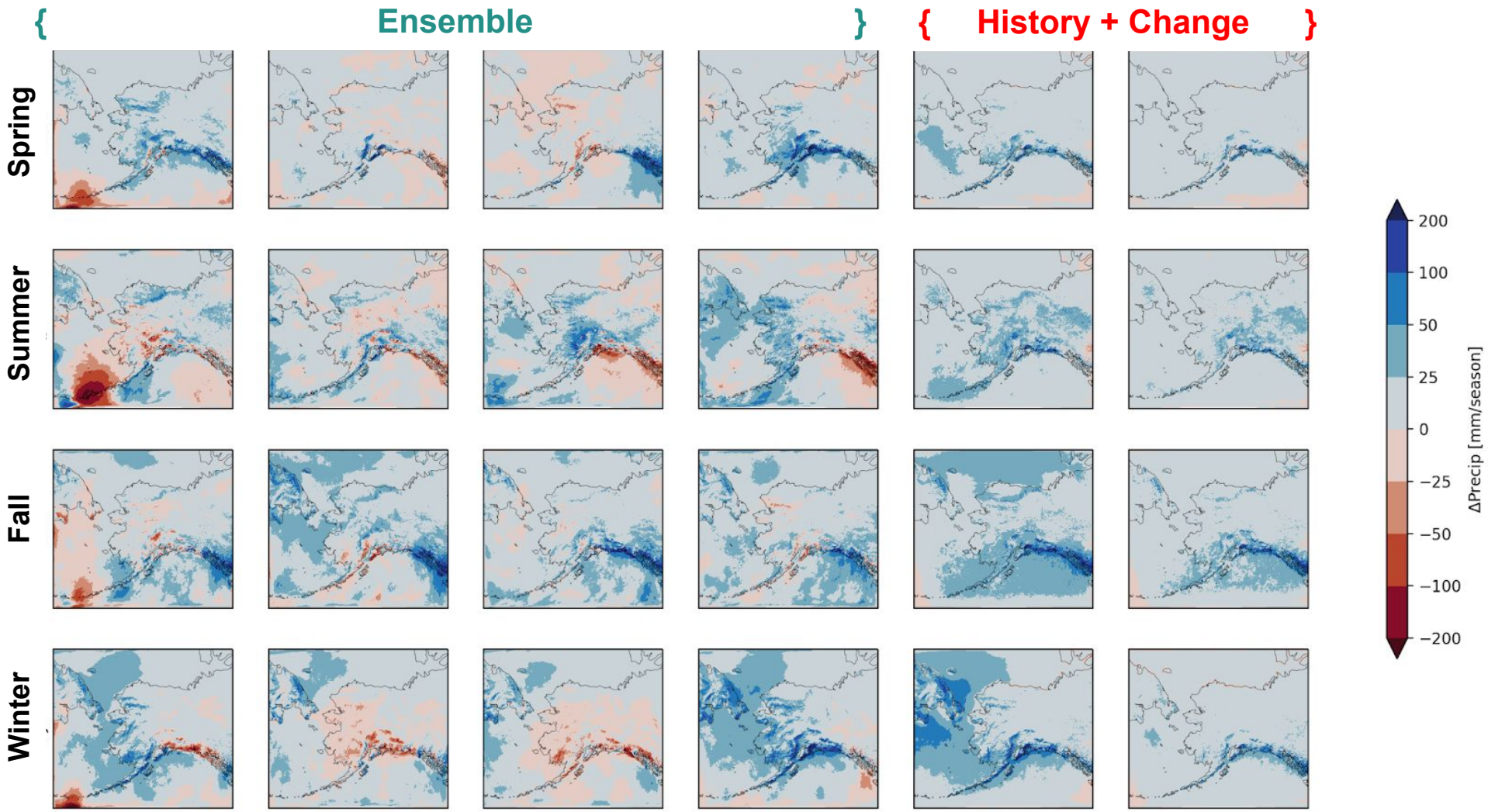


- Offline (not shown) and coupled streamflow improved over baseline
  - Offline model has NSE > 0.5 in majority of validation basins (usefulness metric)
  - Coupled model daily streamflow median KGE of 0.47
- Daily stream temperature estimates also improved
  - Compared to default and simple statistical model (benchmark)
  - Site to site variance

Blaskey et al. (2024)

Future Change Signals

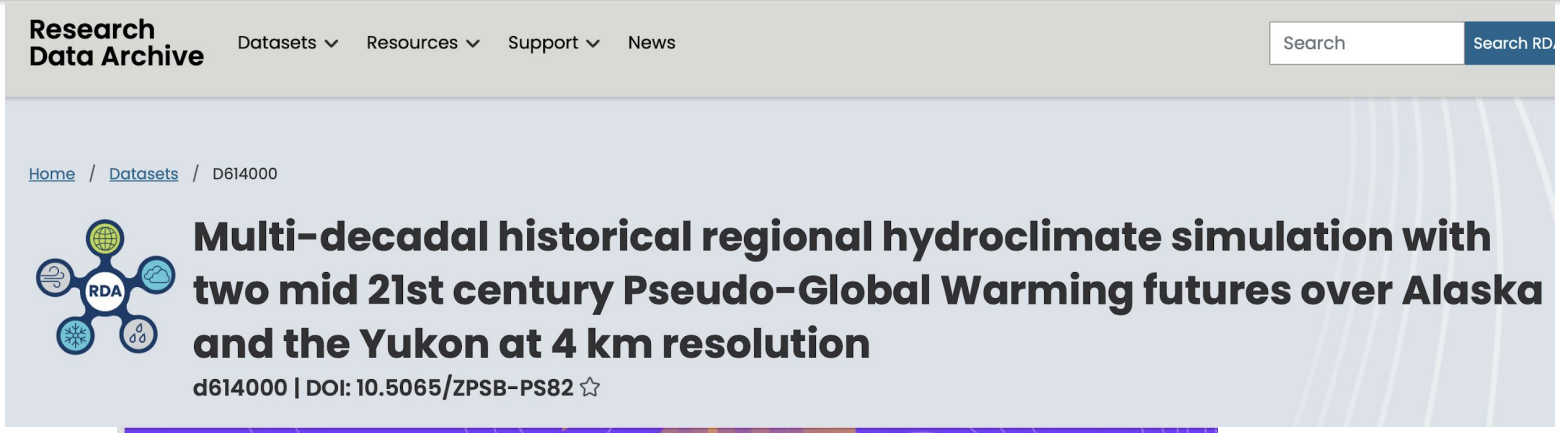
- Seasonal precipitation – long-term circulation changes matter in Alaska

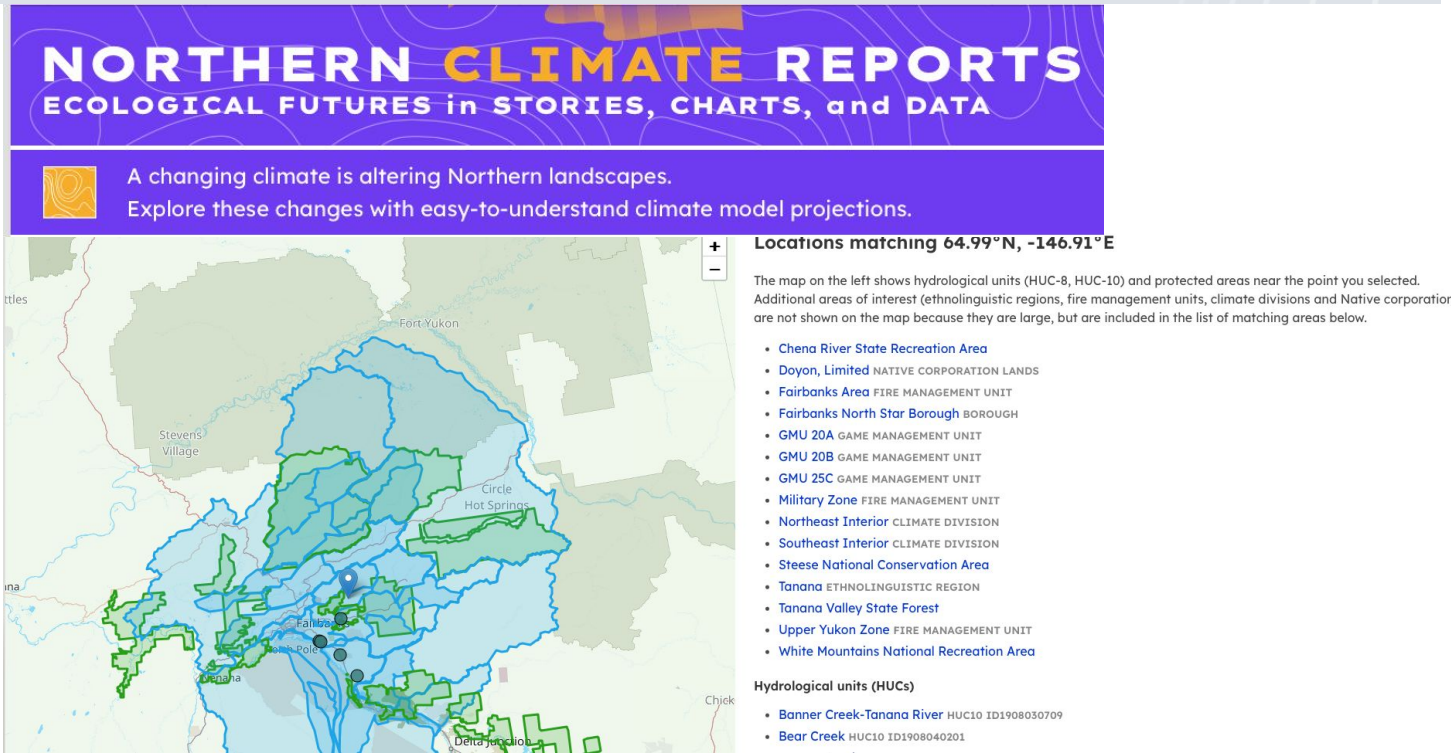


Newman et al. (2025), submitted to BAMS

Data Distribution and Post-processing

- Releasing datasets through traditional pathways
  - NSF NCAR Research Data Archive
  - NSF Arctic Data Center
  - Zenodo
- Archiving model code, namelists, restart files
- Also working on post-processed and interactive inquiry
  - Working with UAF, SNAP, and IARC
  - Northern Climate Reports
  - Rising Voices, Changing Coasts
  - Multiple spatial aggregations
  - Plain language summaries





Top: NSF NCAR RDA landing page

Bottom: northernclimatereports.org

Summary and Next Steps

- Successful initial co-design of a regional climate model
  - Lessons learned for future efforts
  - Data, models, and methods for applications and fundamental research
  - Future physical model improvements and process studies
- Information beginning to be used across communities and agencies
  - Focus of remaining project is on storylines and generation and dissemination of useful and usable data
- Much work remains to distill these massive, complex datasets
  - Initial data releases are not readily accessible by communities, so we are helping distill information