Downscaled climate projections for southeast Alaska and considerations for use in modeling, management, and planning

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The planet is warming.

+0.16°F / decade, 1925-2015; +0.31°F / decade 1970-2015
Alaska, Climate Division 11, Average Temperature, January-December

- 1925-2015 Trend: +0.1°F/Decade
- 1925-2000 Avg: 35.0°F
- Avg Temperature

Central panhandle temperature

http://www.ncdc.noaa.gov/cag/time-series/us/
Climate models are simplifications

Necessary processes and structure
to obtain sufficient skill, within the
limitations of computation and scientific understanding.

Dozens of models in continuous refinement, each with different treatment of fundamental sensitivity, feedbacks, structure, etc.
Future emissions and temperature scenarios

http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html

Deltas at regional scales look smooth

Example: Change in annual temperature, 1970-1990 to 2070-2099

Data: SNAP, https://www.snap.uaf.edu/
Regional Deltas

**RCP 8.5 (higher emissions)**

<table>
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**Precipitation**

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<td>19.9%</td>
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Historical annual precipitation: 1970-1999 (CRU 3.1 downscaled to PRISM)

Data: SNAP, https://www.snap.uaf.edu/
Downscaling

Global climate models operate at scales (~100km / 62 miles or greater) that work fine for regional simulations.

To translate those to finer scales, more information on local factors that affect local climate (topography, vegetation, glaciers, etc.) is required.

Historical observations of climate are used to “downscale” climate model projections to local scales and correct for any model bias.

In a place like Alaska, the sparse station network limits validation of the downscaling.
SNAP Downscaling

- CMIP3 and CMIP5 downscaled historical and bias-corrected projected temperature and precipitation and derived products.

- Five climate models, three GHG emissions scenarios, and are at 2km (AK and n. Canada) and 800m (AK) based on CRU and PRISM grids. Decadal averages by month and monthly time series.

Projected Monthly Temperature and Precipitation – 771m CMIP5/AR5

Projected (2006–2100: RCP 4.5, 6.0, 8.5 scenarios) monthly average temperature and total precipitation from 5 AR5 GCMs that perform best across Alaska and the Arctic, downscaled to 771m via the delta method. A 5-Model Average is also included.

Baseline Reference Climate
Spatial Resolution
Temporal Resolution
Spatial Extent

<table>
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<tr>
<th>Model</th>
<th>Baseline Reference Climate</th>
<th>Scenario RCP 4.5</th>
<th>Scenario RCP 6.0</th>
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https://www.snap.uaf.edu/tools/data-downloads
Climate WNA / BC / NA downscaling

- CMIP3 and CMIP5 downscaled historical and bias-corrected projected temperature and precipitation and derived bioclimatic products.

- Eight climate models, two GHG emissions scenarios, and are at 1km based on PRISM grids. Climatology averages (2020s, 2050s, 2080s)
The differences aren’t climatic – they’re methodological!

But for decisions, characterizing those choices and what they mean for impacts is key.
Increasingly, models built for purely scientific purposes are pressed into service for projecting future conditions relevant to resource management.

A prediction has clearly stated contingencies; a forecast has a probability.

But most climate scenarios (and ecosystem models) used for impacts assessment produce neither, especially in series.

These are projections.
Sources of uncertainty in climate projections

- Climate variability
- Emissions scenario uncertainty
- Climate model uncertainty

Hawkins and Sutton, BAMS 2009
Downscaling to what?

PRISM and reanalysis products are harder to verify in AK

- Lapse rates variable
- Strong decadal variation
- Larger topographic and precip gradients than rest of US combined

Bieniek et al. 2012, 2014
Downscaling in AK is available at 1km and can be made finer with topographic inferences.

But at some scale, other factors need to be incorporated to realistically downscale finer.

Arguably they should be physically simulated or, better, observations.

*Figure 1. Coverage of ClimateWNA and the distribution of the 3353 weather stations used to evaluate the output of this program.*
Hedges on uncertainty: Spatial, temporal, and multimodel averages

2040s changes in April 1SWE: A2 composite. Decreases at mid and lower elevations (0 to 30%), but increases (0 to +15%) at highest elevations.

Methods: Littell et al. in press
Precipitation extremes are clearly important, but the dynamics and physics are hard to simulate compared to average temperature.

Dynamical downscaling and/or quantile mapping applied to historical hourlies are needed.
Characterization of Extremes

Quantile-mapped temperature and wind events at common GCM gridscale

Juneau-Sitka 1970 – 2100
DEC days below 0°C(32°F), RCP 6.0

GFDL
IPSL
CGCM3

SNAP

AK CSC
Alaska Climate Science Center
Opportunities / Needs

• Characterization of projection uncertainty
  – How do 5 selected models compare to the rest of CMIP5 (skill, extremes, sensitivity, etc.)
  – For limited impacts / vulnerability assessments, how to interpret “risk” given climate scenarios vs. other model output available?

• The opportunity to use dynamically downscaled climate is big:
  – Huge coastal relief, huge gradients
  – Station-sparse, high latitude and elevation: interpolation vs. physics
  – Feedbacks: snow, sea ice, North Pacific vs. Arctic, land surface
Opportunities / Needs

• From gridded climatology $\rightarrow$ time series
  – Realistic interannual-decadal variability (time to emergence questions, range of plausible conditions, sequences of events)

• Better understanding of extremes and impacts-relevant variables
  – (PET and AET, RH, runoff, snow, streamflow, stream temperature, permafrost hydrology)

• Cryosphere, cryosphere, cryosphere – snow, glaciers, sea ice, and permafrost
On the horizon

• NCAR / USACE work
  – Probabilistic assessment of bias in gridded observed climatology
  – Statistical downscaling + dynamical where it counts
  – Hyrdologic modeling with estimates of uncertainty

• NCA
  – Next generation NCA products (late 2016)
## Data Sources

### CRU

The Climate Research Unit at the University of East Anglia in England is a leading climate research group that also provides climate data.

**Source:** thousands of monthly temperature stations over land and marine waters

**SNAP uses:** CRU TS and CL high resolution (0.5° x 0.5°) gridded data

[Downscaling method](#)

### GCM

Research groups worldwide develop General Circulation Models (GCMs), which are used in periodic climate assessment reports published the United Nations [IPCC](#). GCM outputs help form the basis for many interpretations of future climate. The [IPCC Fifth Assessment Report (AR5)](#) was published in January 2014.

**Source:** Lawrence Livermore National Laboratory [Program for Climate Model Diagnosis and Intercomparison](#) data portal

**SNAP uses:**
- CMIP3 model outputs from the IPCC’s Fourth Assessment Report (AR4)
  - the first ensemble model run
  - Scenarios: A20, B1, A1B, A2
- CMIP5 model outputs from the IPCC Fifth Assessment Report (AR5)

### PRISM

PRISM data are some of the highest resolution spatial climate data currently available across large extents.

**Sources:** temperature and precipitation data from the North and other regions

**SNAP uses:**
- temperature and precipitation data from the 30-year (1961–1990) monthly climatology at 2 km spatial resolution covering Alaska and regions of Canada
- 771 m spatial resolution from 1971–2000 covering only Alaska
- other PRISM datasets such as the Pacific Islands for specific projects
Assessed the community needs for and decision uses of downscaled climate information. ACCAP (Alaska Center for Climate Assessment and Policy) survey had 20 respondents from: USDA FS, BLM, USFWS and LCCs, ADF&G, AOOS, ADEC/AQ, USGS, AK DGGS.

1. Higher-resolution climate projections including coastal/marine
2. Greater availability
3. Better characterization of changes in extreme events
4. Production of derived climate indices for Alaska
5. Readily available dynamically downscaled climate projections
The AK-CSC Mission

- Address critical climate science needs and knowledge gaps
- Add value to existing/emerging research, information, and – sometimes - monitoring efforts
- Ultimate goal is to address DOI management issues, while also recognizing other needs in the region
- Providing climate information useful for planning and decision making
This talk

- Introduction to climate models, projections, and downscaling
- Sources of downscaled climate projections for Alaska
  - SNAP
  - Climate WNA/Climate BC
  - Others
- Sources of uncertainty in climate projections for Alaska
  - Historical climate assumptions
  - Future projection methodologies and climate modeling assumptions
  - Downscaling methods
- What’s new under the sun, anyway?
  - Some new things on the horizon…