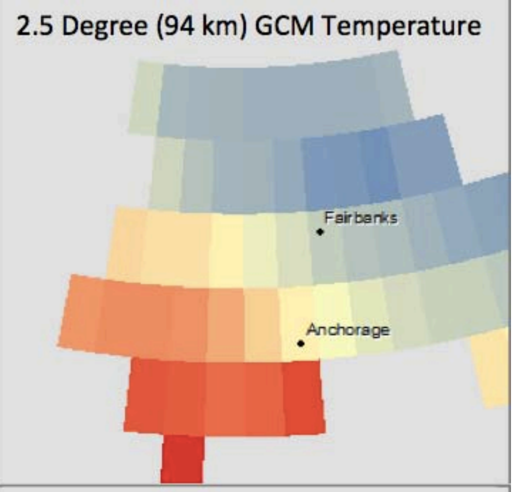
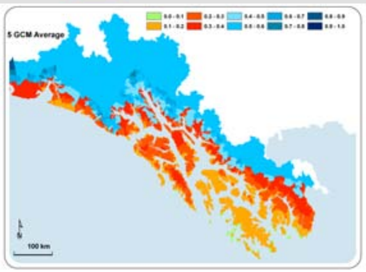




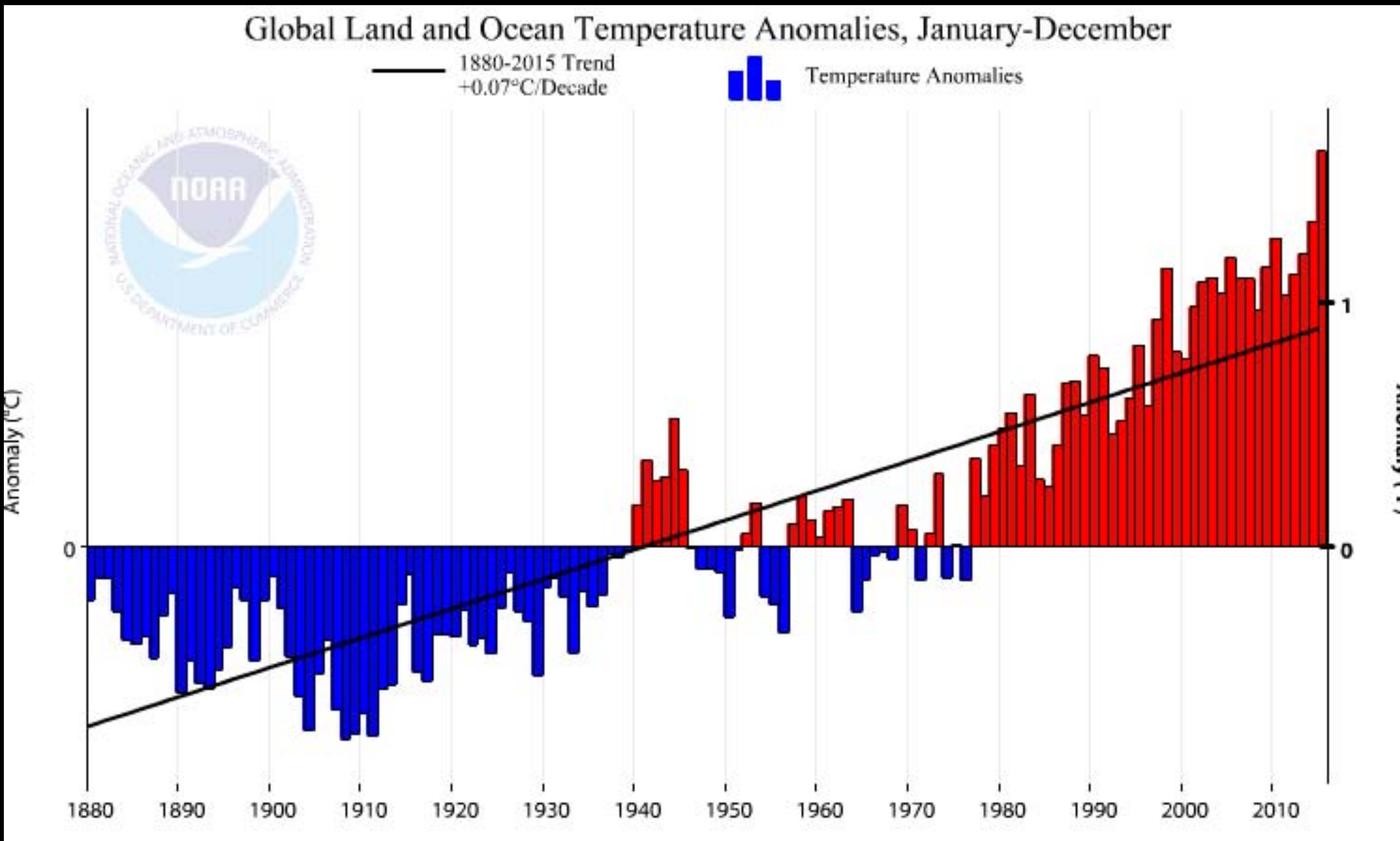
Downscaled climate projections for southeast Alaska

and considerations for use in modeling, management, and planning

Jeremy Littell
Alaska Climate Science Center

AK CSC
Alaska Climate Science Center

The planet is warming.



2015	0.87°C
2014	0.73°C
2010	0.72°C
2005	0.66°C
2013	0.66°C
1998	0.63°C
2009	0.63°C
2012	0.63°C
2007	0.62°C
2002	0.61°C
2003	0.60°C
2006	0.60°C
2004	0.58°C
2011	0.57°C
2001	0.55°C
2008	0.54°C
1997	0.50°C
1995	0.46°C
1990	0.43°C
1999	0.43°C
2000	0.43°C
1991	0.41°C
1988	0.37°C
1987	0.35°C

+0.16°F / decade, 1925-2015; +0.31°F / decade 1970-2015

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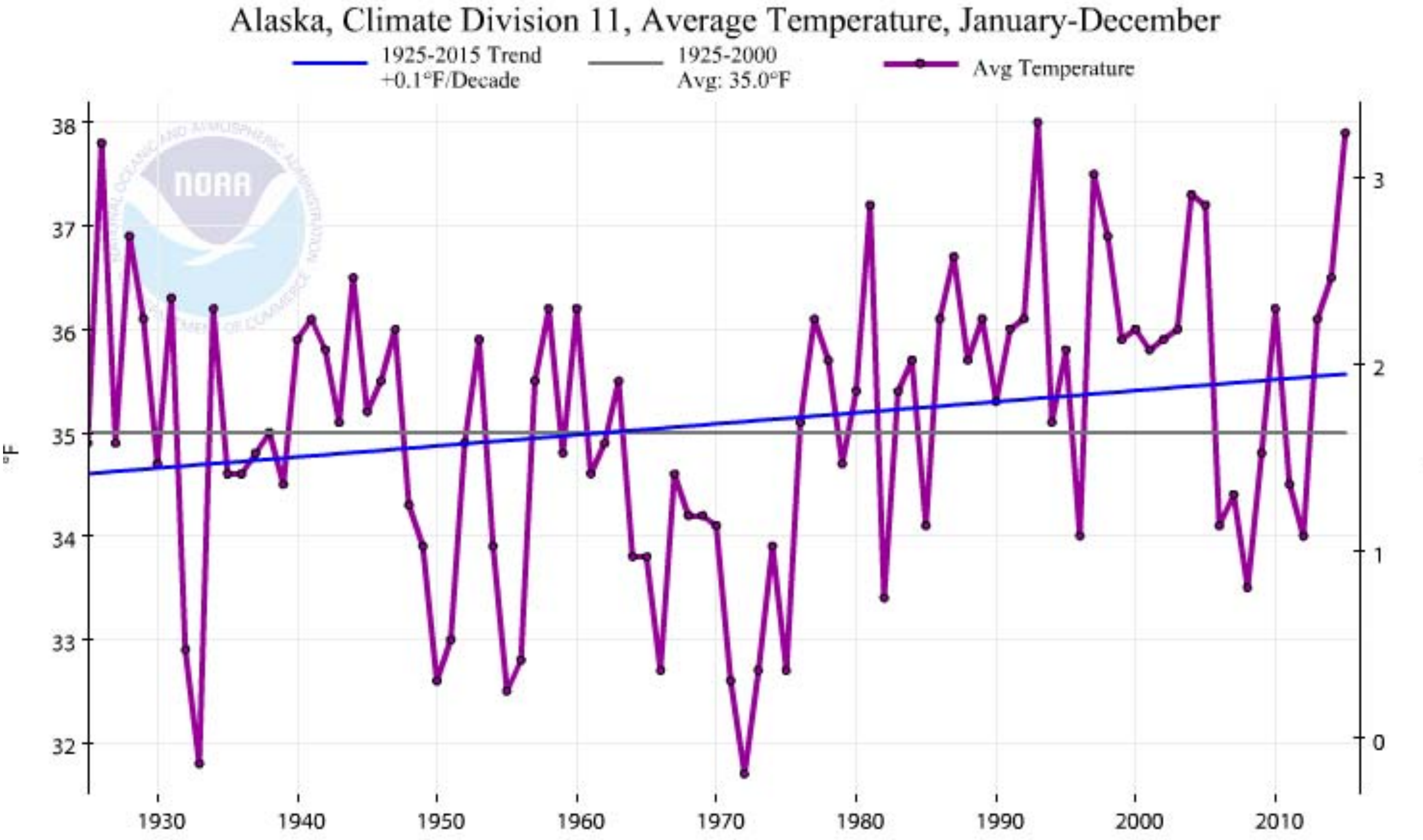

http://www.ncdc.noaa.gov/cag/time-series/us/

Central panhandle temperature

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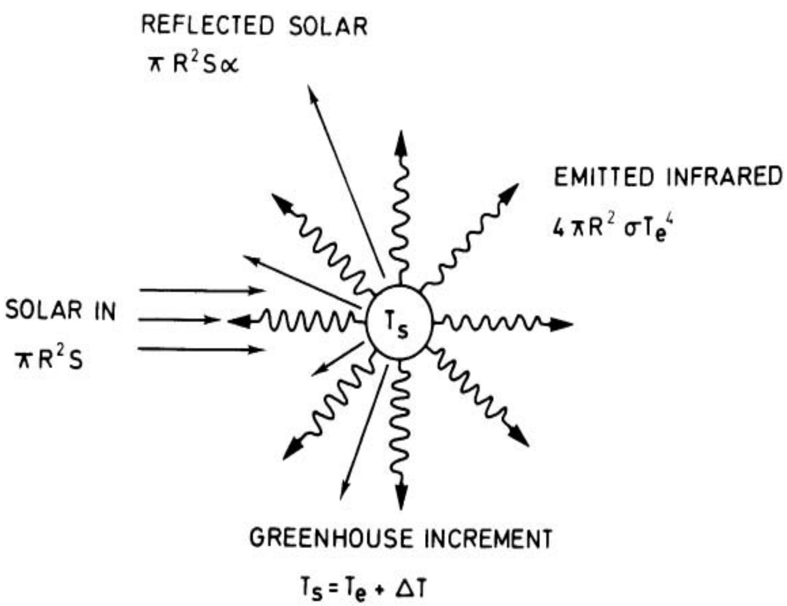
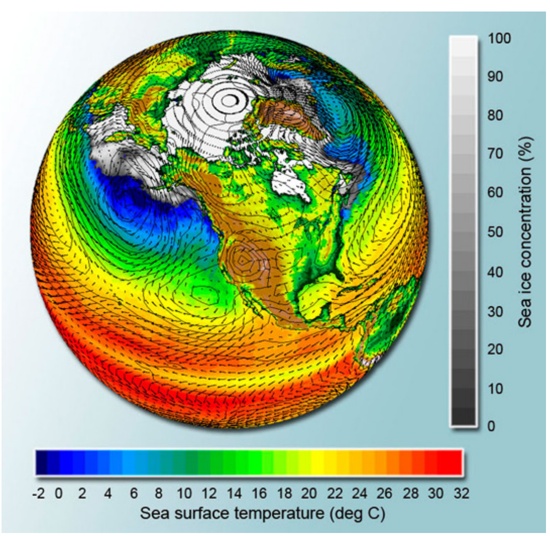
Climate models are simplifications



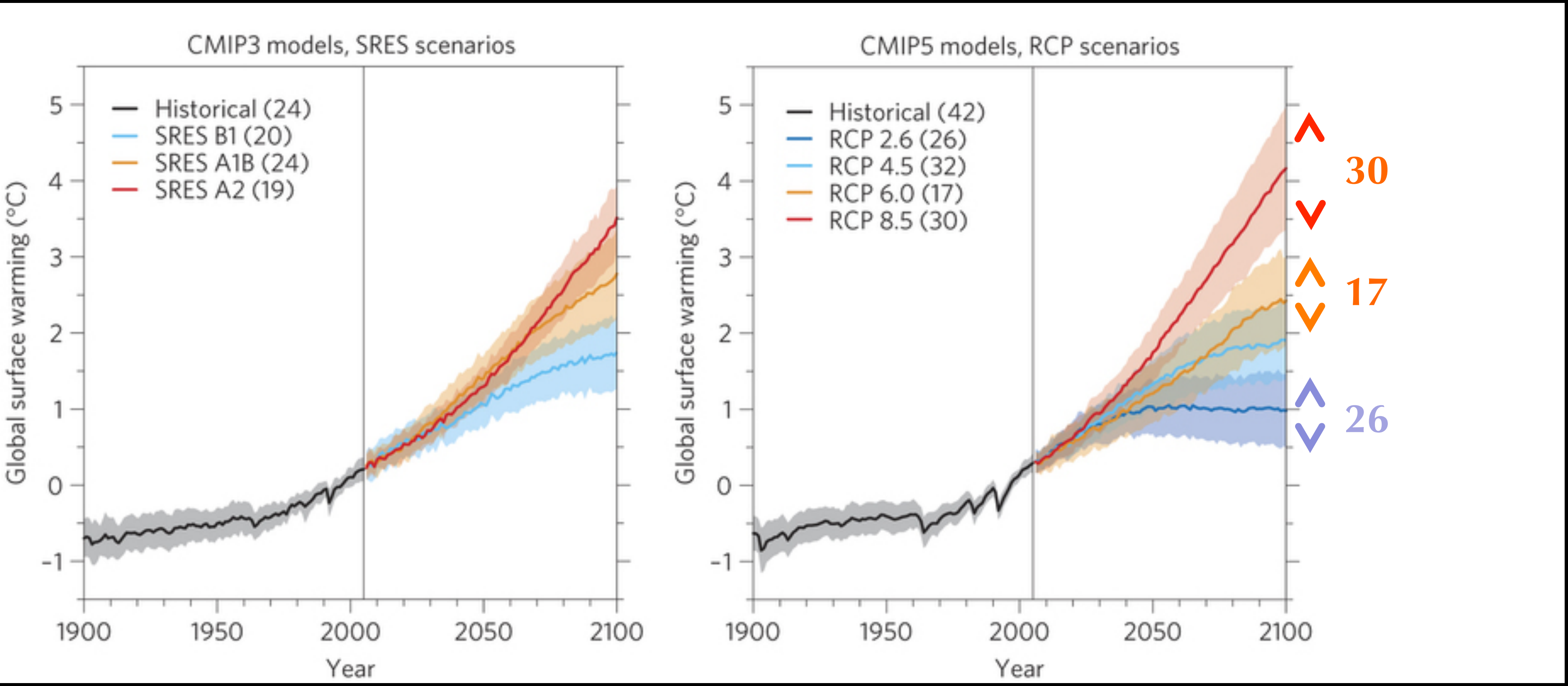
After Henderson-Sellers and McGuffie, 1987



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



Fourth IPCC Assessment (2007)

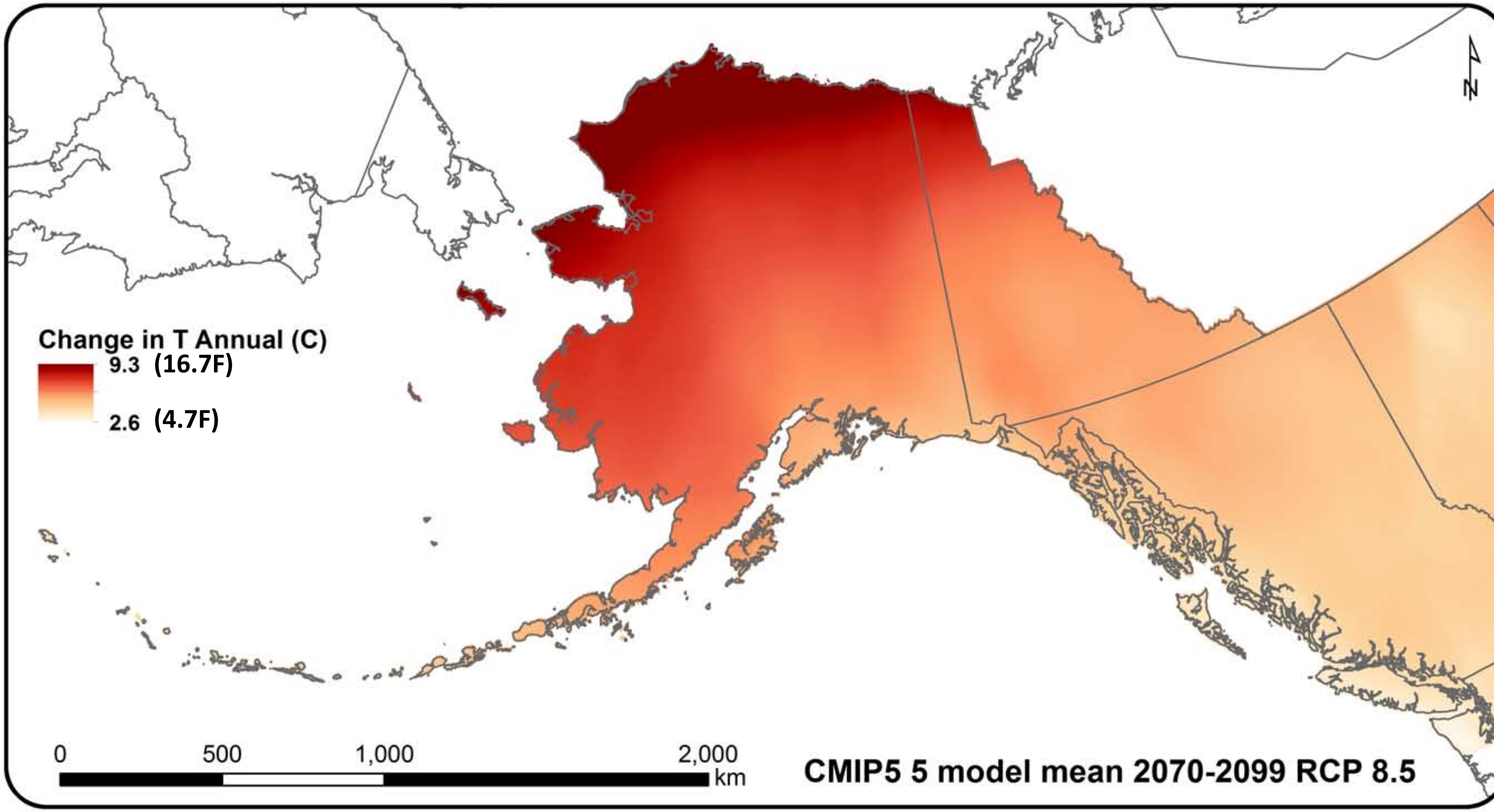
Fifth IPCC Assessment (2013)

Knutti and Sedlacek, Nature Climate Change 3, 369–373 (2013)

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



SNAP

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

Regional Deltas

RCP 8.5 (higher emissions)

	2020s		2040s		2080s	
	C°	(F°)	C°	(F°)	C°	(F°)
ANN	1.2	(2.2)	2.4	(4.3)	4.9	(8.8)
DJF	1.5	(2.7)	2.7	(4.9)	5.7	(10.3)
MAM	0.6	(1.1)	1.6	(2.9)	3.8	(6.8)
JJA	1.0	(1.8)	2.1	(3.8)	4.5	(8.1)
SON	1.8	(3.2)	3.0	(5.4)	5.7	(10.3)
Precipitation						
ANN	7.6%		11.4%		20.6%	
DJF	11.1%		14.1%		26.5%	
MAM	10.2%		15.8%		29.4%	
JJA	5.6%		8.9%		14.1%	
SON	6.5%		10.2%		19.9%	

Baseline: 1970-99. SNAP projections. Values are five-model CMIP 5 means (CCSM4, GFDL3, CGCM3, GISS2, IPSL5). 2020s – 2010-2039; 2040s – 2030-2059; 2080s – 2070-2099.

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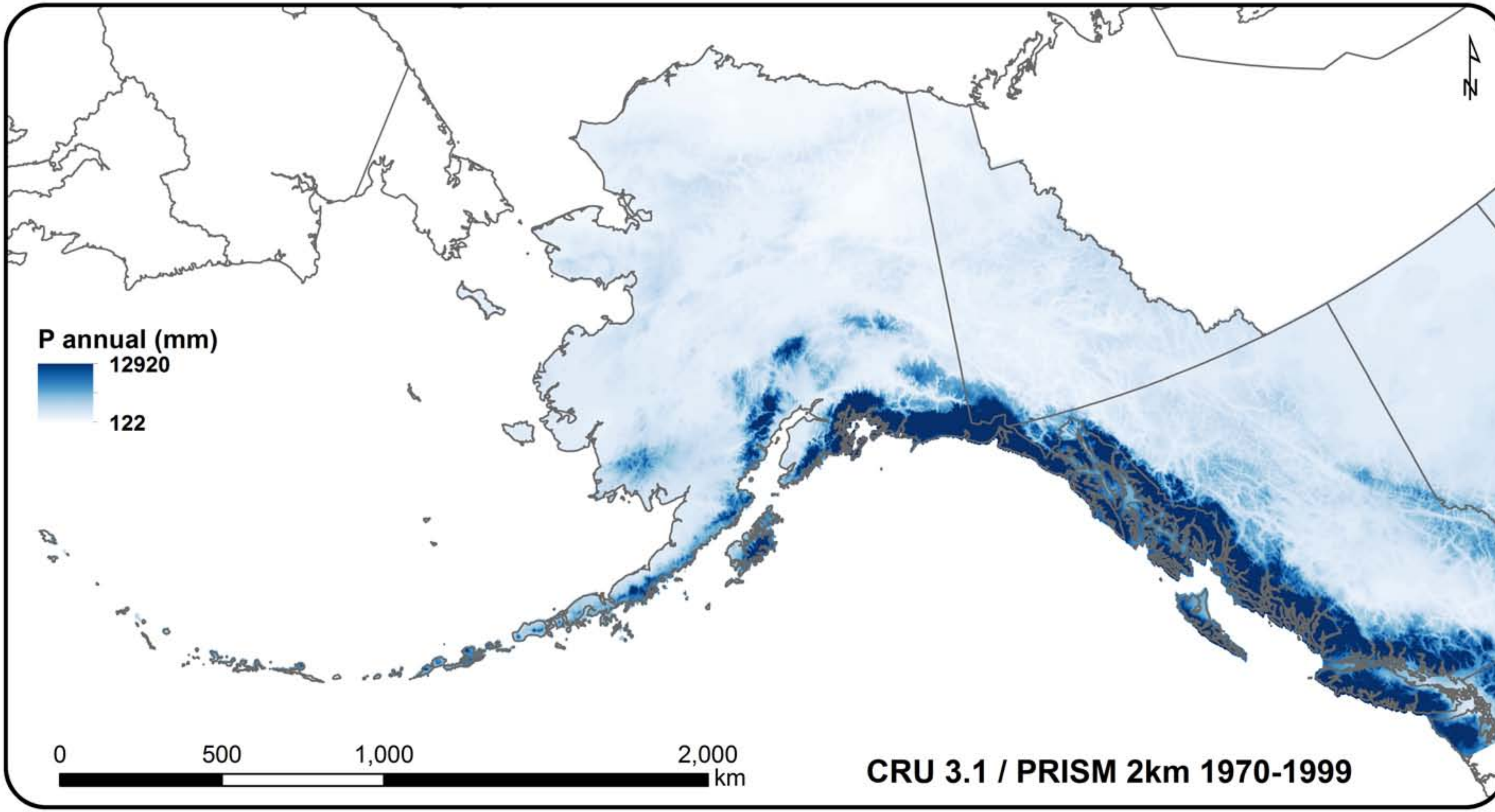
Historical annual precipitation: 1970-1999 (CRU 3.1 downscaled to PRISM)



SNAP

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

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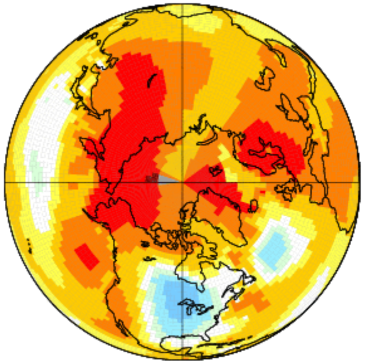
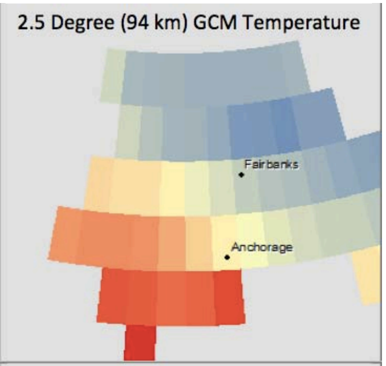
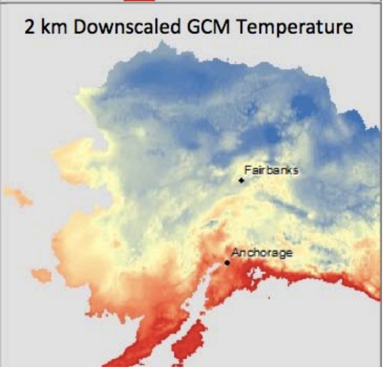
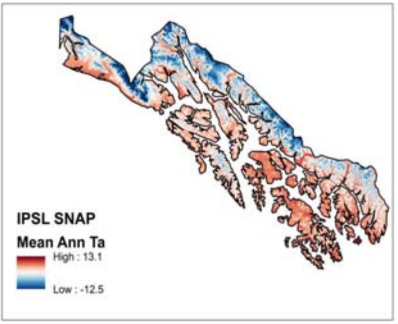
Downscaling









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.

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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	1971–2000 PRISM
Spatial Resolution	771m
Temporal Resolution	Monthly
Spatial Extent	Alaska

TEMPERATURE

Metadata: Projected Monthly Average Temperature 771m AR5

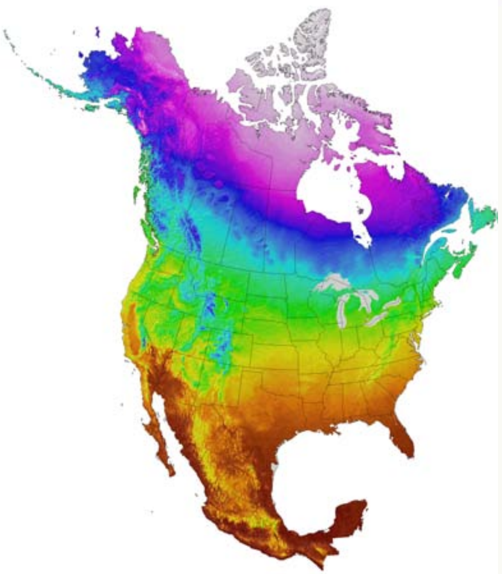
	Scenario		
Model	RCP 4.5	RCP 6.0	RCP 8.5
5-model Average	2006-2100 (4.7 GB)	2006-2100 (4.7 GB)	2006-2100 (4.8 GB)
CCSM4	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)
GFDL-CM3	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)
GISS-E2-R	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)
IPSL-CM5A-LR	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)
MRI-CGCM3	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)	2006-2100 (4.8 GB)

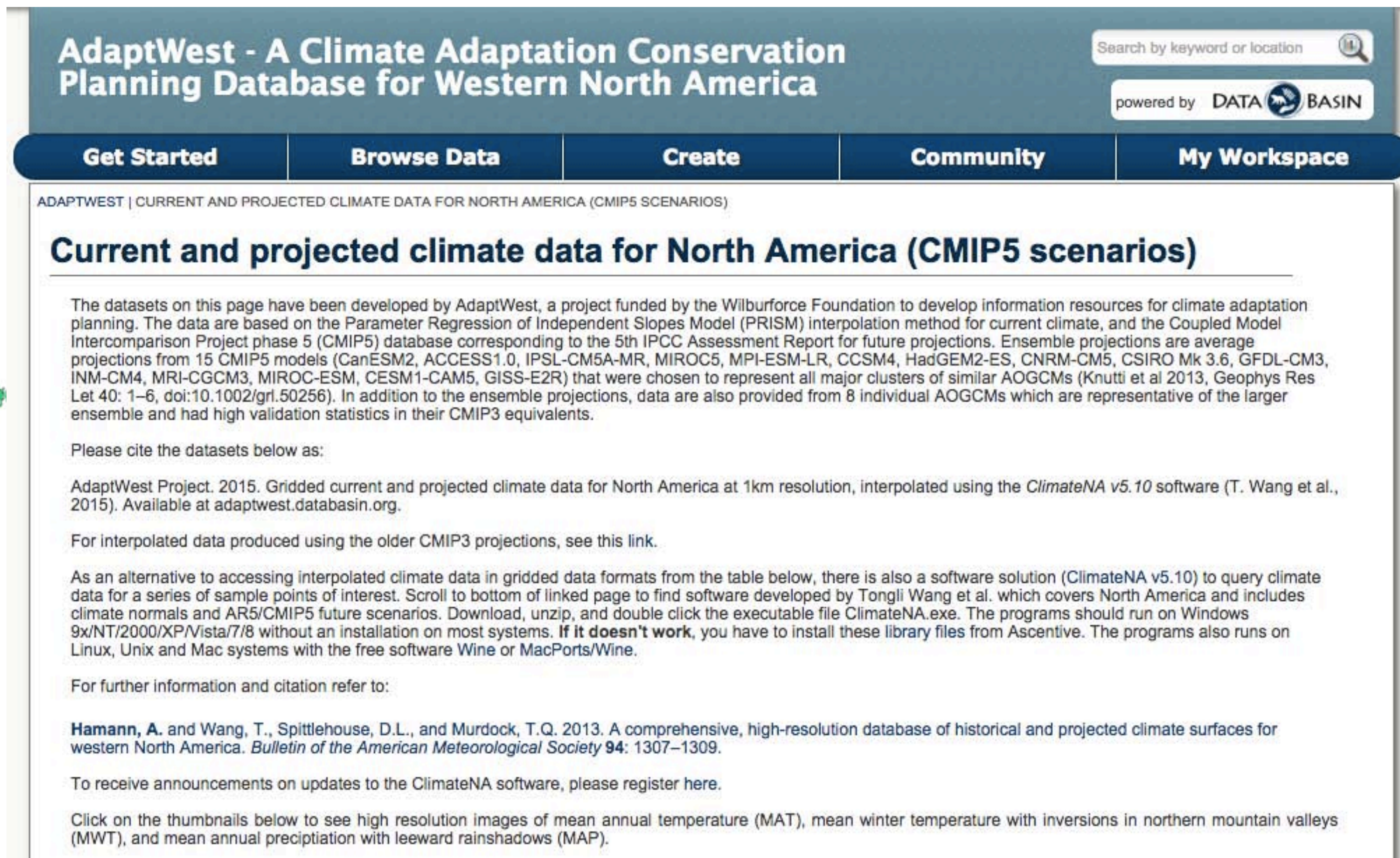
https://www.snap.uaf.edu/tools/data-downloads

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)





AdaptWest - A Climate Adaptation Conservation Planning Database for Western North America

Search by keyword or location

powered by DATA BASIN

Get Started | Browse Data | Create | Community | My Workspace

ADAPTWEST | CURRENT AND PROJECTED CLIMATE DATA FOR NORTH AMERICA (CMIP5 SCENARIOS)

Current and projected climate data for North America (CMIP5 scenarios)

The datasets on this page have been developed by AdaptWest, a project funded by the Wilburforce Foundation to develop information resources for climate adaptation planning. The data are based on the Parameter Regression of Independent Slopes Model (PRISM) interpolation method for current climate, and the Coupled Model Intercomparison Project phase 5 (CMIP5) database corresponding to the 5th IPCC Assessment Report for future projections. Ensemble projections are average projections from 15 CMIP5 models (CanESM2, ACCESS1.0, IPSL-CM5A-MR, MIROC5, MPI-ESM-LR, CCSM4, HadGEM2-ES, CNRM-CM5, CSIRO Mk 3.6, GFDL-CM3, INM-CM4, MRI-CGCM3, MIROC-ESM, CESM1-CAM5, GISS-E2R) that were chosen to represent all major clusters of similar AOGCMs (Knutti et al 2013, Geophys Res Let 40: 1–6, doi:10.1002/grl.50256). In addition to the ensemble projections, data are also provided from 8 individual AOGCMs which are representative of the larger ensemble and had high validation statistics in their CMIP3 equivalents.

Please cite the datasets below as:

AdaptWest Project. 2015. Gridded current and projected climate data for North America at 1km resolution, interpolated using the *ClimateNA v5.10* software (T. Wang et al., 2015). Available at adaptwest.databasin.org.

For interpolated data produced using the older CMIP3 projections, see this link.

As an alternative to accessing interpolated climate data in gridded data formats from the table below, there is also a software solution (ClimateNA v5.10) to query climate data for a series of sample points of interest. Scroll to bottom of linked page to find software developed by Tongli Wang et al. which covers North America and includes climate normals and AR5/CMIP5 future scenarios. Download, unzip, and double click the executable file ClimateNA.exe. The programs should run on Windows 9x/NT/2000/XP/Vista/7/8 without an installation on most systems. **If it doesn't work**, you have to install these library files from Ascentive. The programs also runs on Linux, Unix and Mac systems with the free software Wine or MacPorts/Wine.

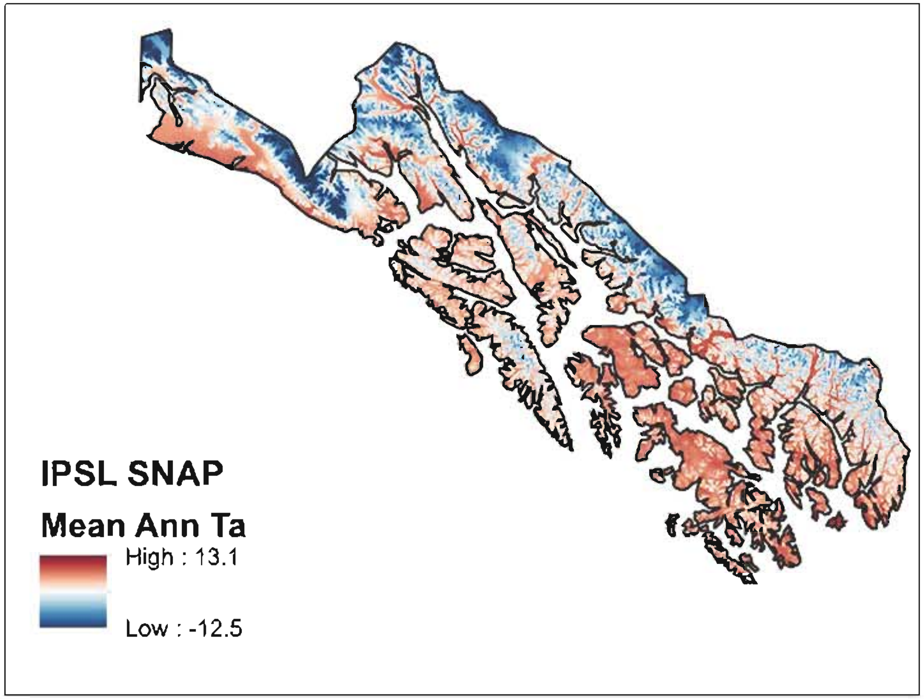
For further information and citation refer to:

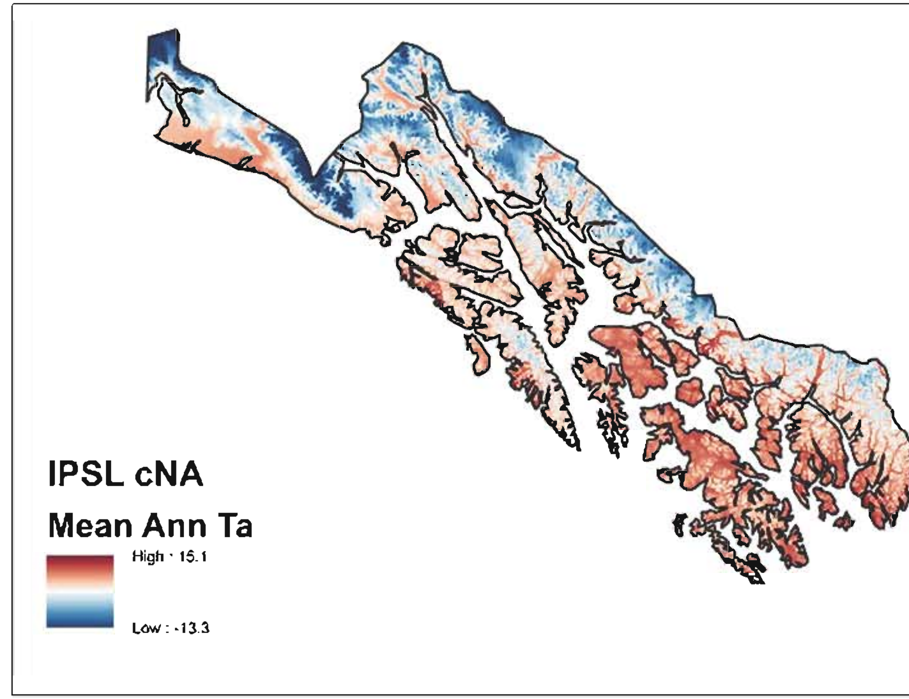
Hamann, A. and Wang, T., Spittlehouse, D.L., and Murdock, T.Q. 2013. A comprehensive, high-resolution database of historical and projected climate surfaces for western North America. *Bulletin of the American Meteorological Society* **94**: 1307–1309.

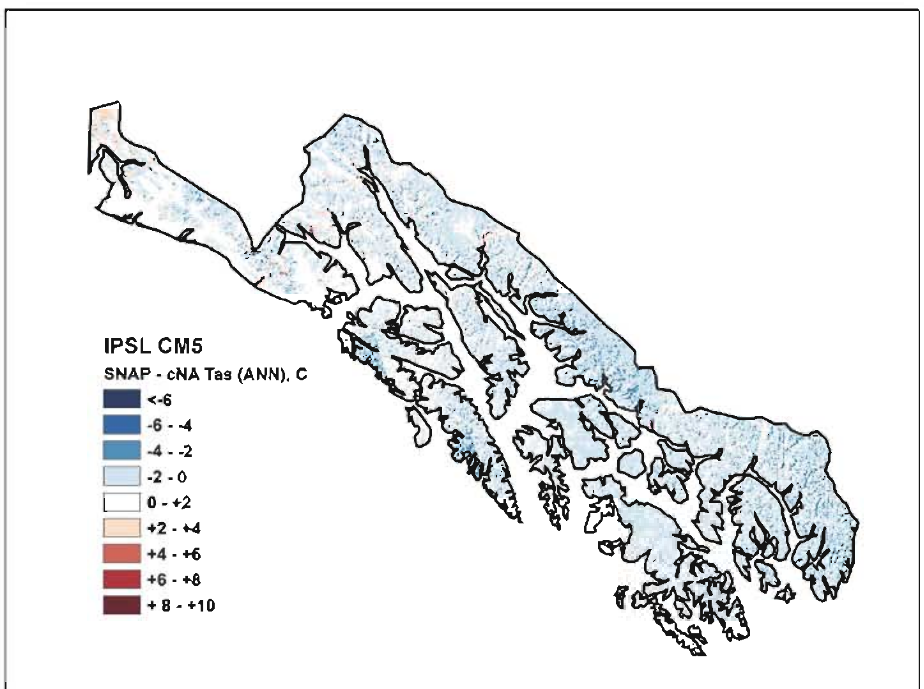
To receive announcements on updates to the ClimateNA software, please register here.

Click on the thumbnails below to see high resolution images of mean annual temperature (MAT), mean winter temperature with inversions in northern mountain valleys (MWT), and mean annual precipitation with leeward rainshadows (MAP).

http://climatewna.com/







IPSL CM5

SNAP - cNA Tas (ANN), C

- <-6
- -6 - -4
- -4 - -2
- -2 - 0
- 0 - +2
- +2 - +4
- +4 - +6
- +6 - +8
- + 8 - +10

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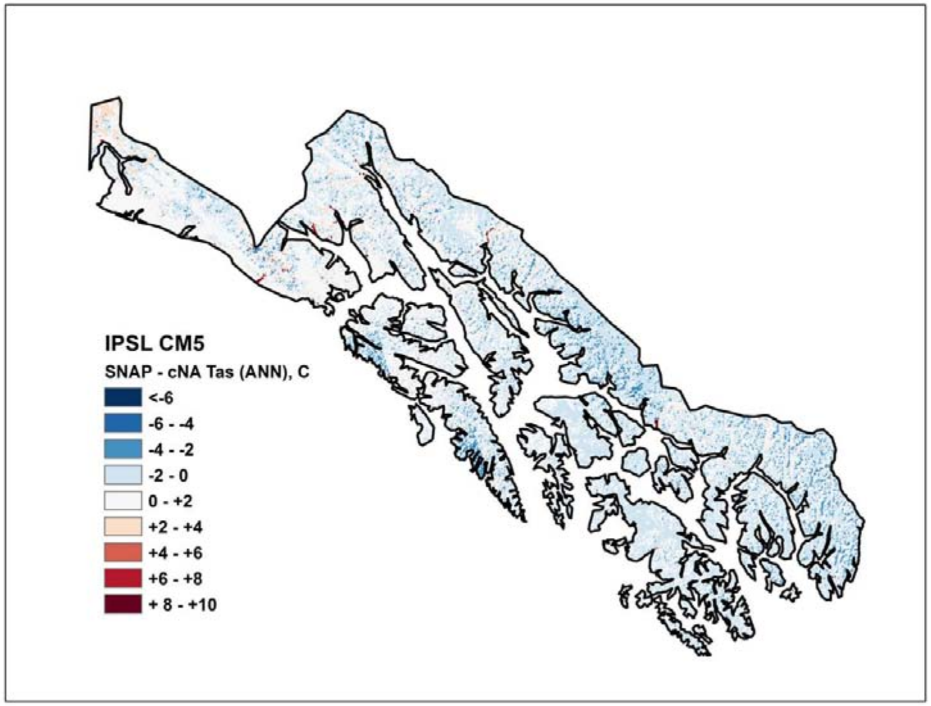

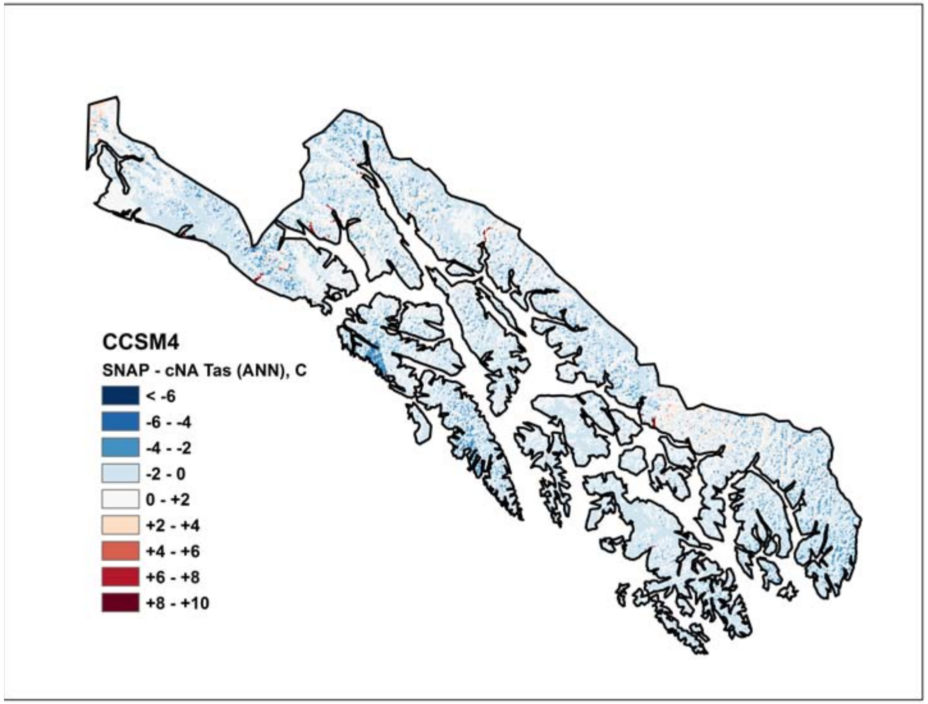

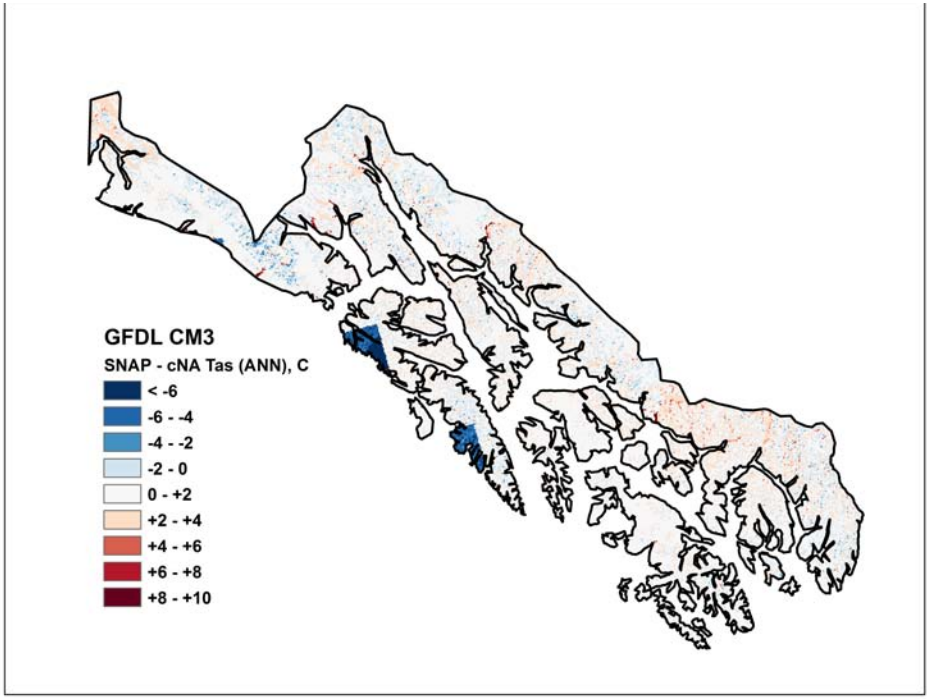

The differences aren't climatic – they're methodological!

But for decisions, characterizing those choices and what they mean for impacts is key.

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Scenarios for Impacts Assessment

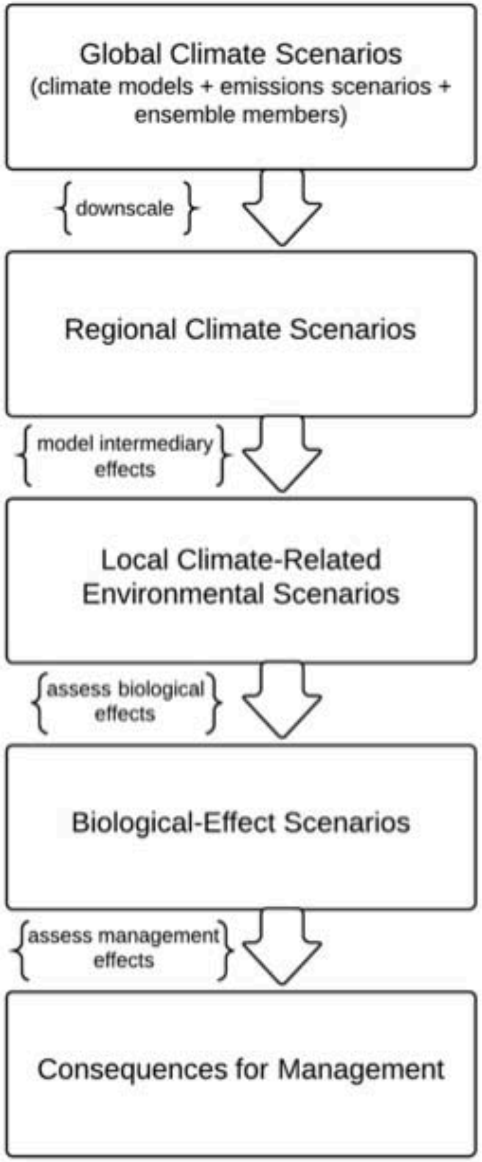

Figure 1. A common method of assessing the consequences of climate change for natural systems is a top-down impact assessment, which links, in turn, projections of global climate, regional climate, regional effects, biological effects, and responses.

Snover et al. 2013, Conservation Biology

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.

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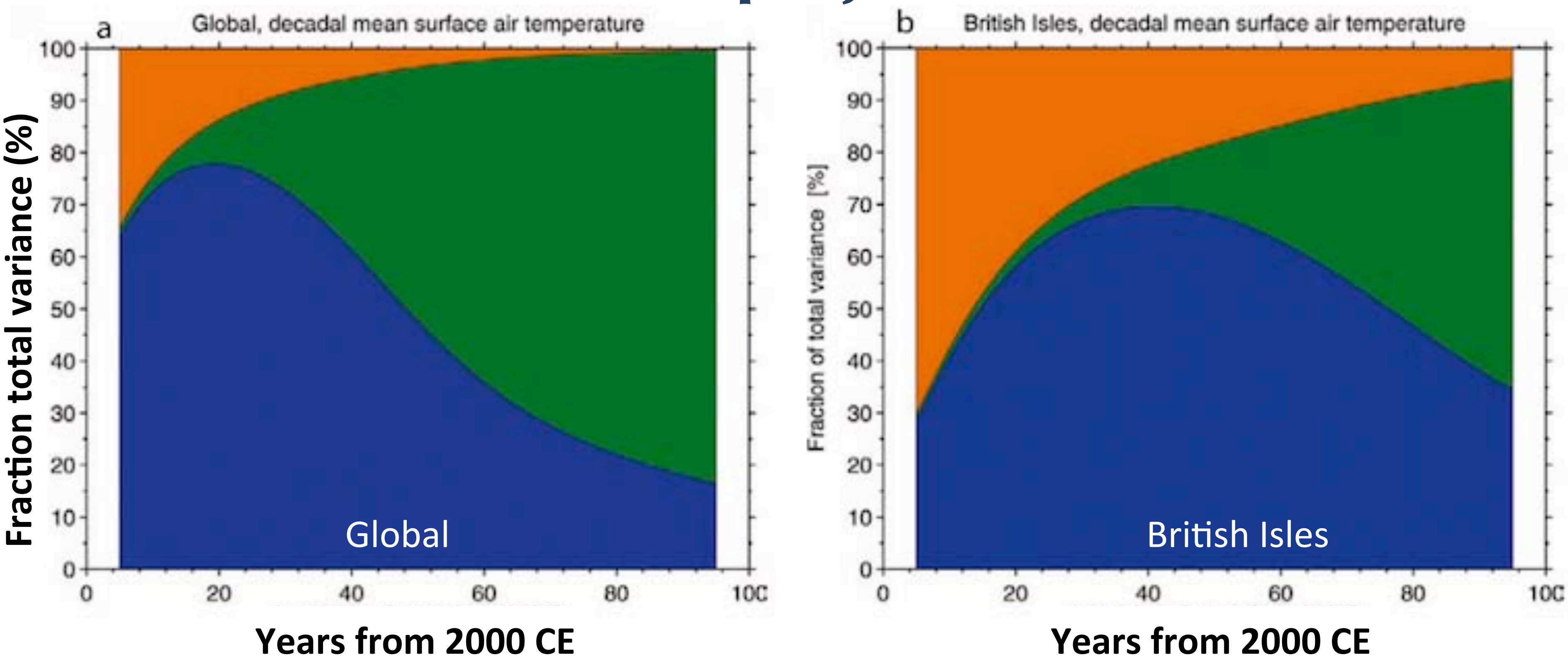
Sources of uncertainty in climate projections



Climate variability

Emissions scenario uncertainty

Climate model uncertainty

Hawkins and Sutton, BAMS 2009

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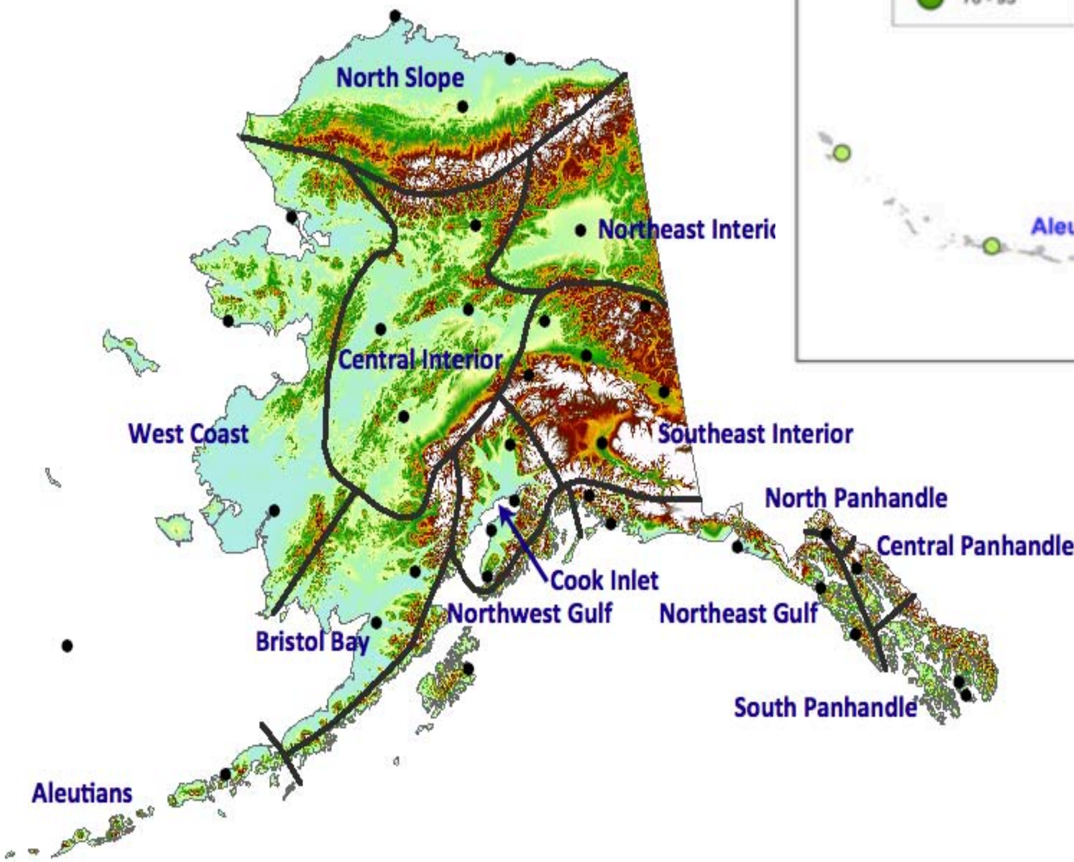
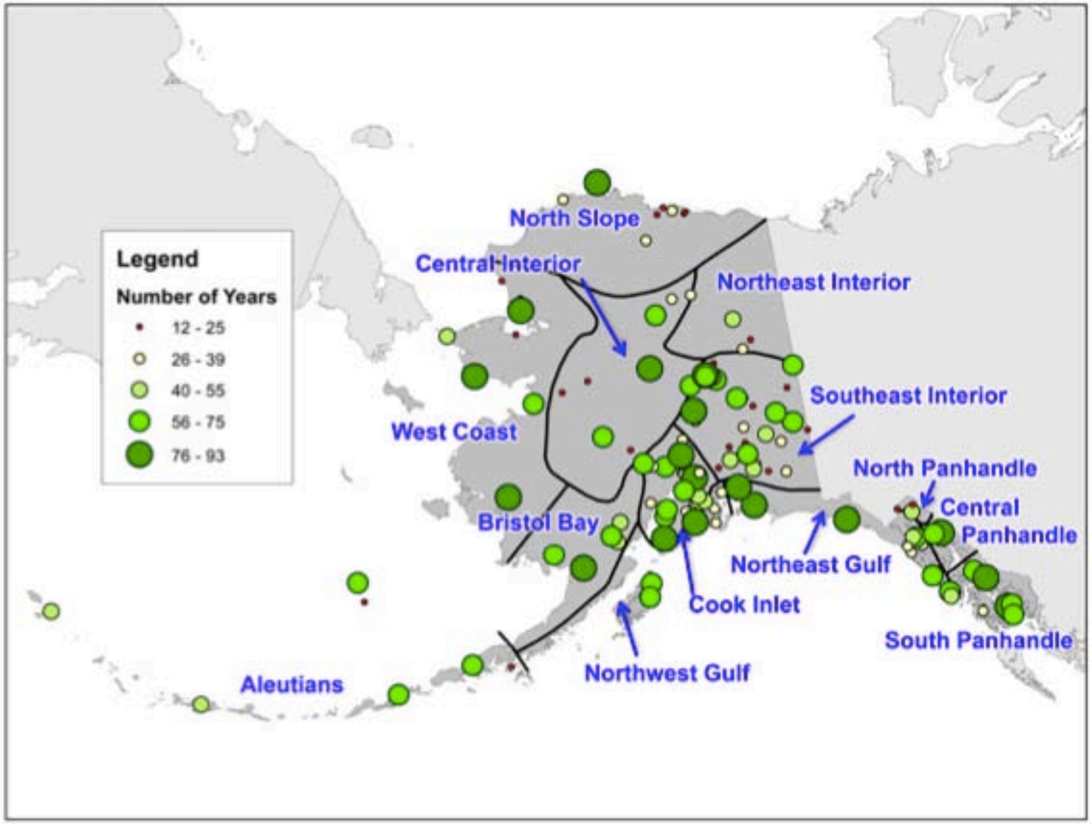
Downscaling to what?

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

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Downscaling uncertainty

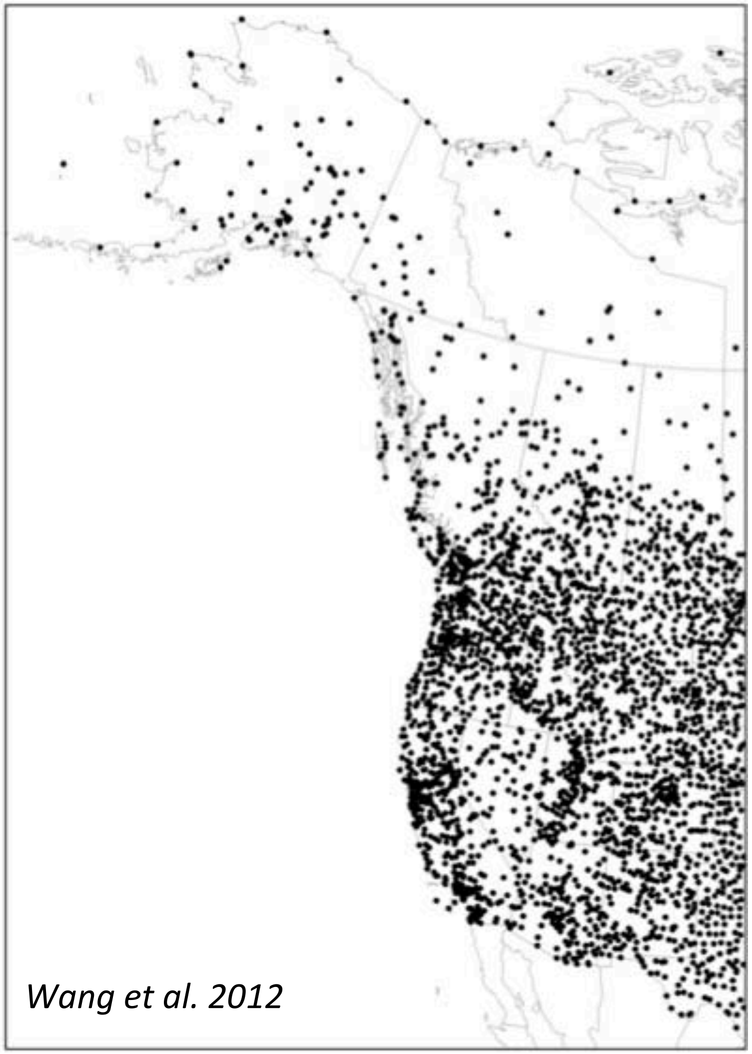
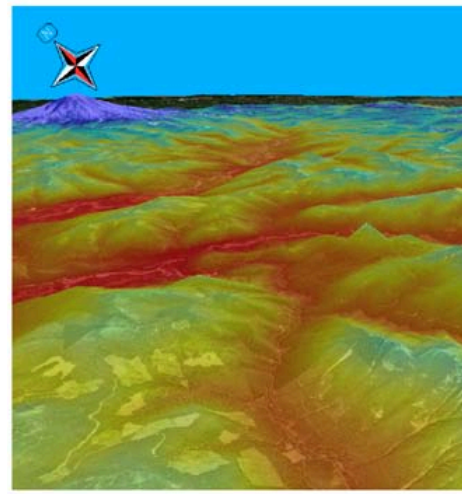
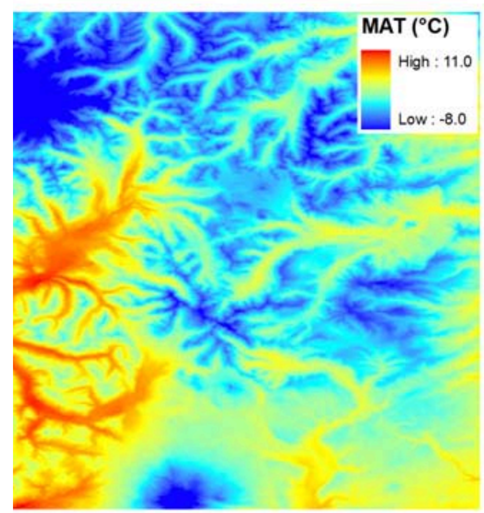


FIG. 1. Coverage of ClimateWNA and the distribution of the 3353 weather stations used to evaluate the output of this program.





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 down-scale finer.

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

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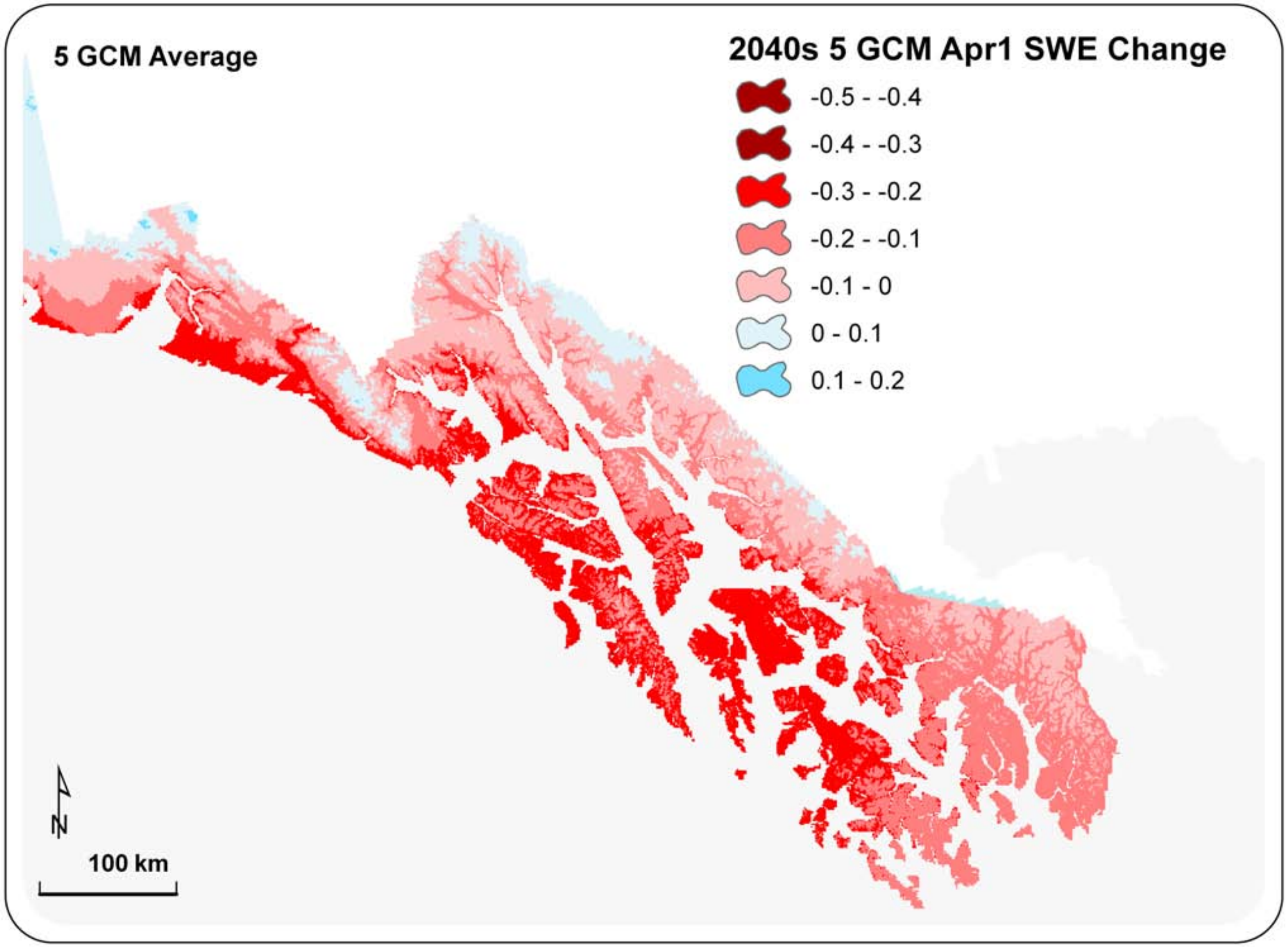
Hedges on uncertainty: Spatial, temporal, and multimodel averages



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

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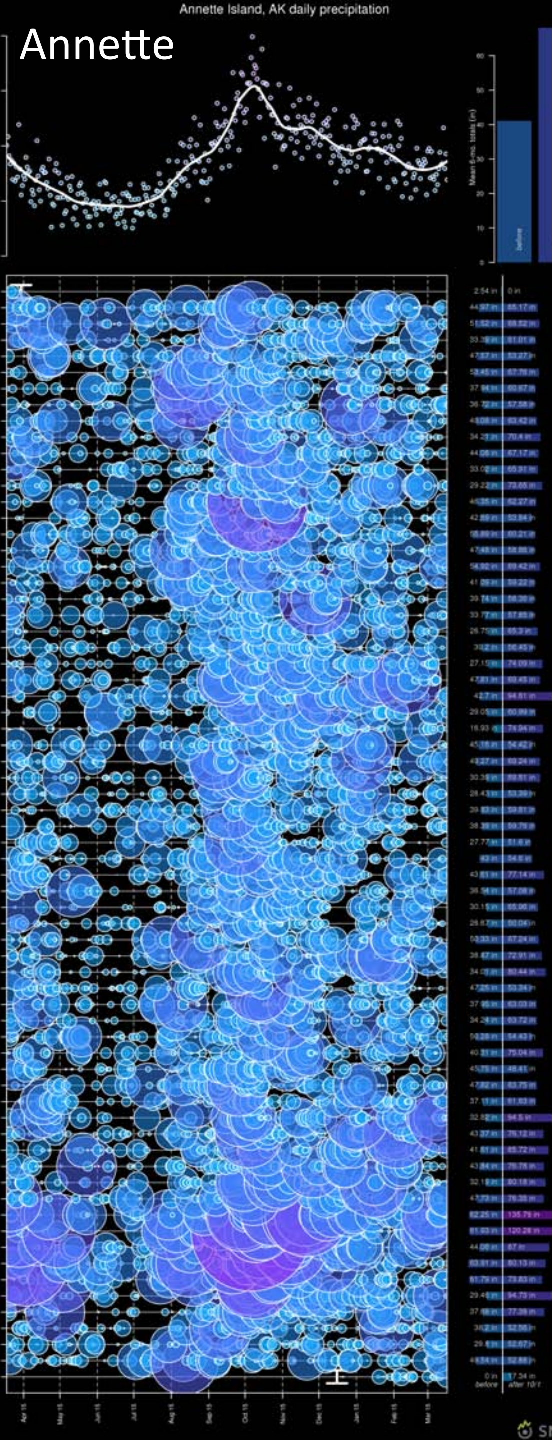

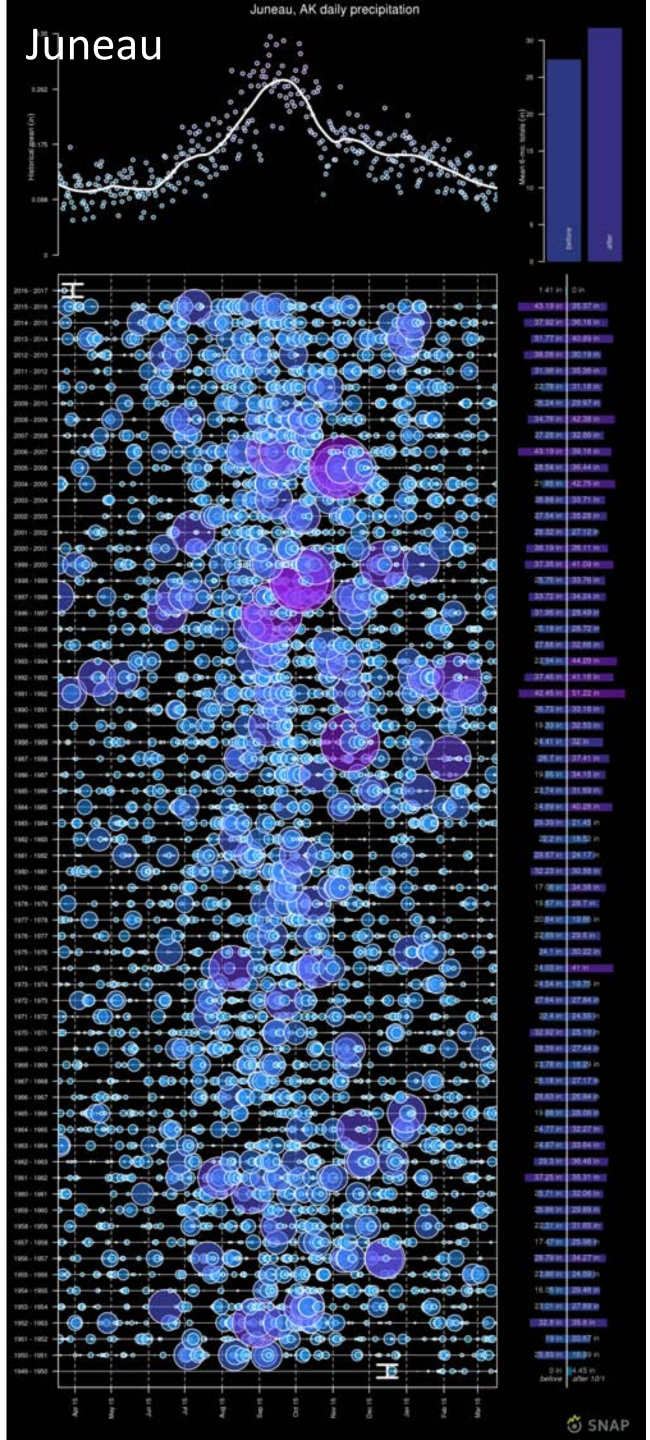

Extremes

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.

http://shiny.snap.uaf.edu/ak_daily_precipitation/

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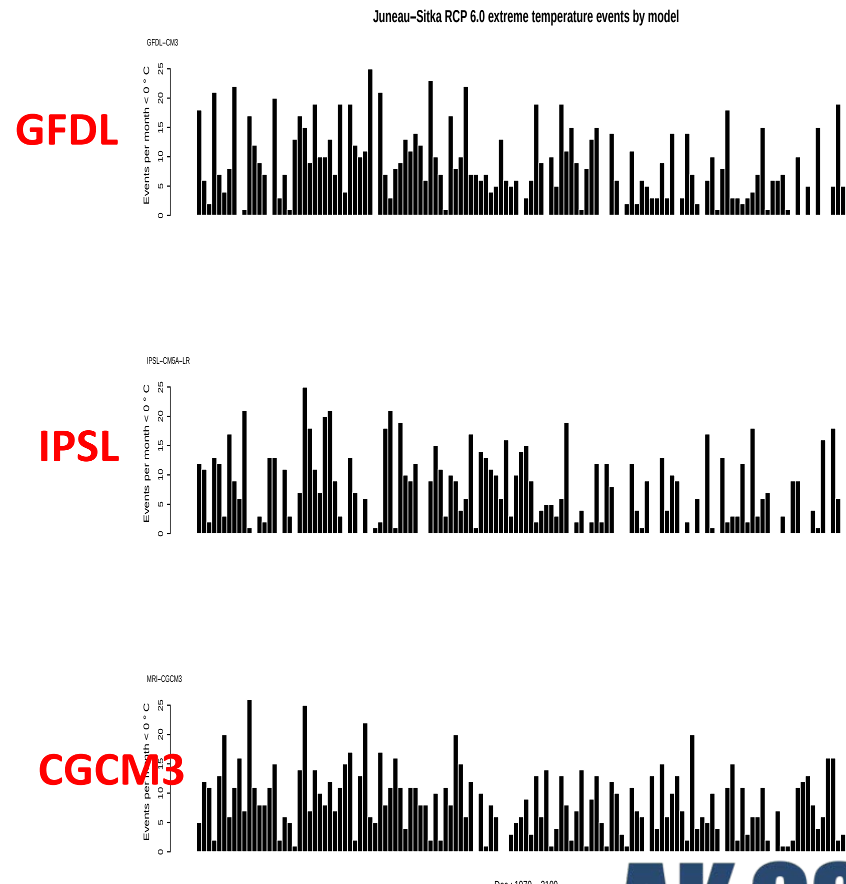
Characterization of Extremes

Quantile-mapped temperature and wind events at common GCM gridscale

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



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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

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Opportunities / Needs

- From gridded climatology → **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

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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)

jlittell@usgs.gov

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Raw Materials: Historical and Future Climate Data and Projections

SNAP

ABOUT ▾ EXPERTISE ▾ METHODS ▾ TOOLS + DATA ▾ PROJECTS

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: 20c3m, 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

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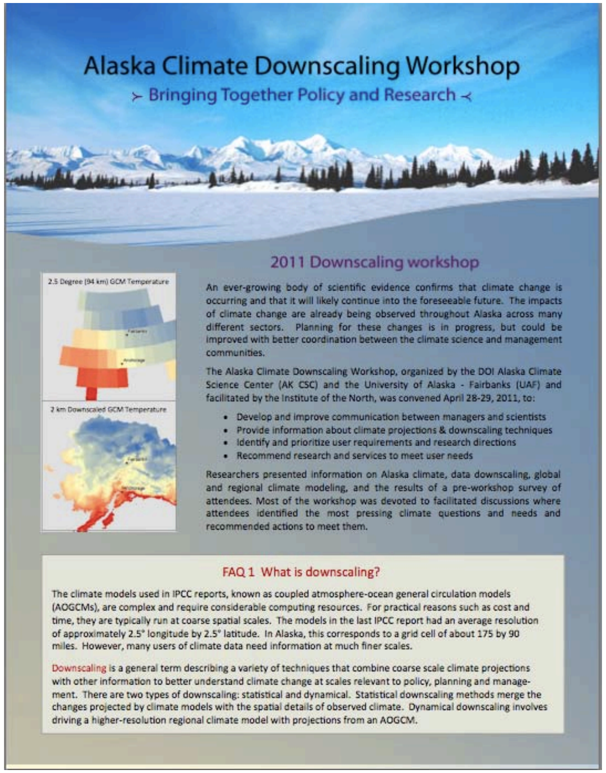
ell@usgs.gov


Alaska Climate Downscaling Workshop
➣ Bringing Together Policy and Research ➢

2011 Downscaling workshop

An ever-growing body of scientific evidence confirms that climate change is occurring and that it will likely continue into the foreseeable future. The impacts of climate change are already being observed throughout Alaska across many different sectors. Planning for these changes is in progress, but could be improved with better coordination between the climate science and management communities.

The Alaska Climate Downscaling Workshop, organized by the DOI Alaska Climate Science Center (AK CSC) and the University of Alaska - Fairbanks (UAF) and facilitated by the Institute of the North, was convened April 28-29, 2011, to:

- Develop and improve communication between managers and scientists
- Provide information about climate projections & downscaling techniques
- Identify and prioritize user requirements and research directions
- Recommend research and services to meet user needs

Researchers presented information on Alaska climate, data downscaling, global and regional climate modeling, and the results of a pre-workshop survey of attendees. Most of the workshop was devoted to facilitated discussions where attendees identified the most pressing climate questions and needs and recommended actions to meet them.

FAQ 1 What is downscaling?

The climate models used in IPCC reports, known as coupled atmosphere-ocean general circulation models (AOGCMs), are complex and require considerable computing resources. For practical reasons such as cost and time, they are typically run at coarse spatial scales. The models in the last IPCC report had an average resolution of approximately 2.5° longitude by 2.5° latitude. In Alaska, this corresponds to a grid cell of about 175 by 90 miles. However, many users of climate data need information at much finer scales.

Downscaling is a general term describing a variety of techniques that combine coarse scale climate projections with other information to better understand climate change at scales relevant to policy, planning and management. There are two types of downscaling: statistical and dynamical. Statistical downscaling methods merge the changes projected by climate models with the spatial details of observed climate. Dynamical downscaling involves driving a higher-resolution regional climate model with projections from an AOGCM.

ACCAP Alaska Center for Climate Assessment and Policy

SNAP

Downscaling Workshop, April 28-29, 2011

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

https://csc.alaska.edu/events/alaska-climate-downscaling-workshop

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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…