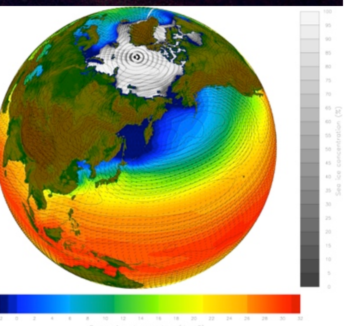

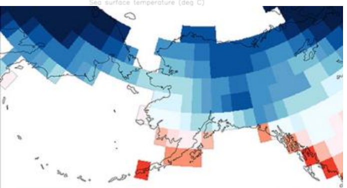

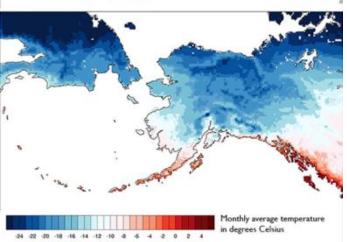

Practical Notes on Using Climate Projections in Alaska

Jeremy Littell
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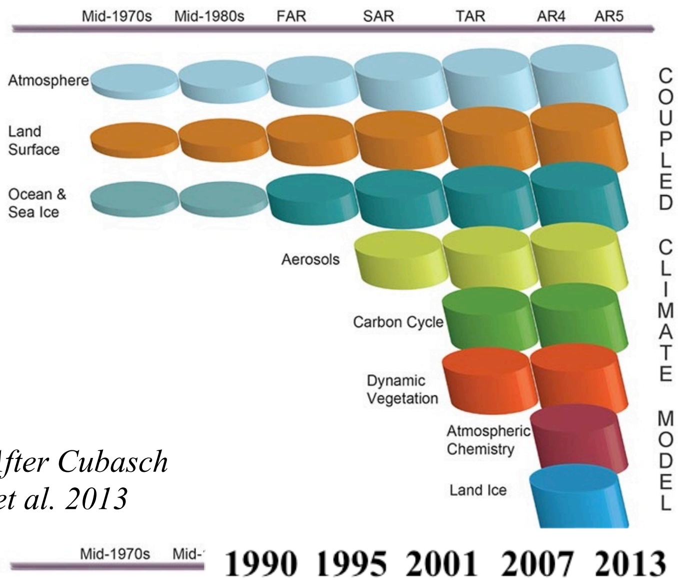
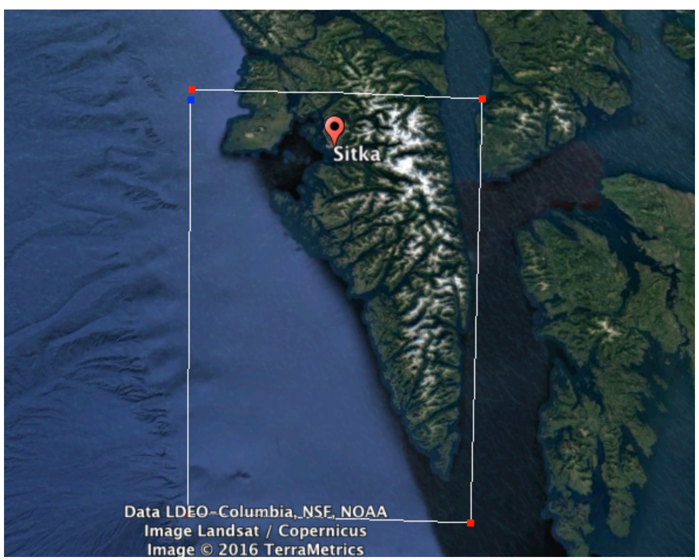
Thinking like a climate model



After Cubasch et al. 2013



Climate models simulate the processes that affect climate.

The complexity of the processes simulated, their integration, and resolution have steadily increased.

They use grids that cover the planet, with many (dozens) of layers in the ocean and atmosphere.

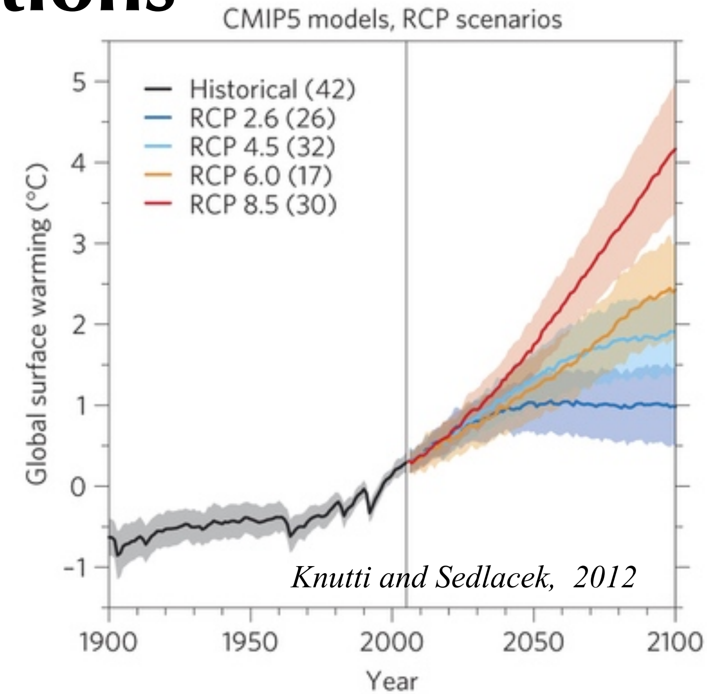
CMIP5 climate model resolution varies but is commonly about 100km – not unlike Baranof Island.

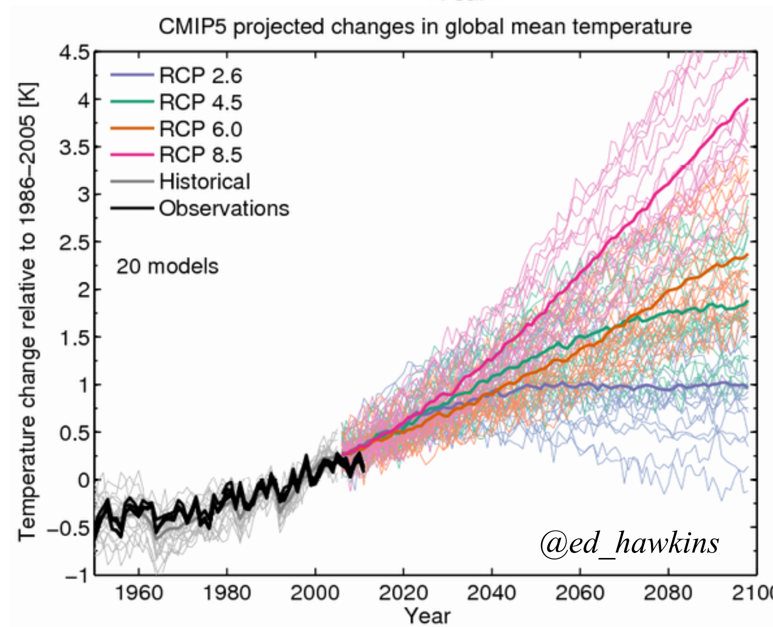
Climate model projections

Climate model output for global (IPCC) and national (NCA) assessments comes from dozens of modeling groups around the world.

These models are run under common forcings – but not usually as short-term forecasts. They are run given the initial conditions and mechanics of the model.

They are therefore projections, not forecasts with probabilities.





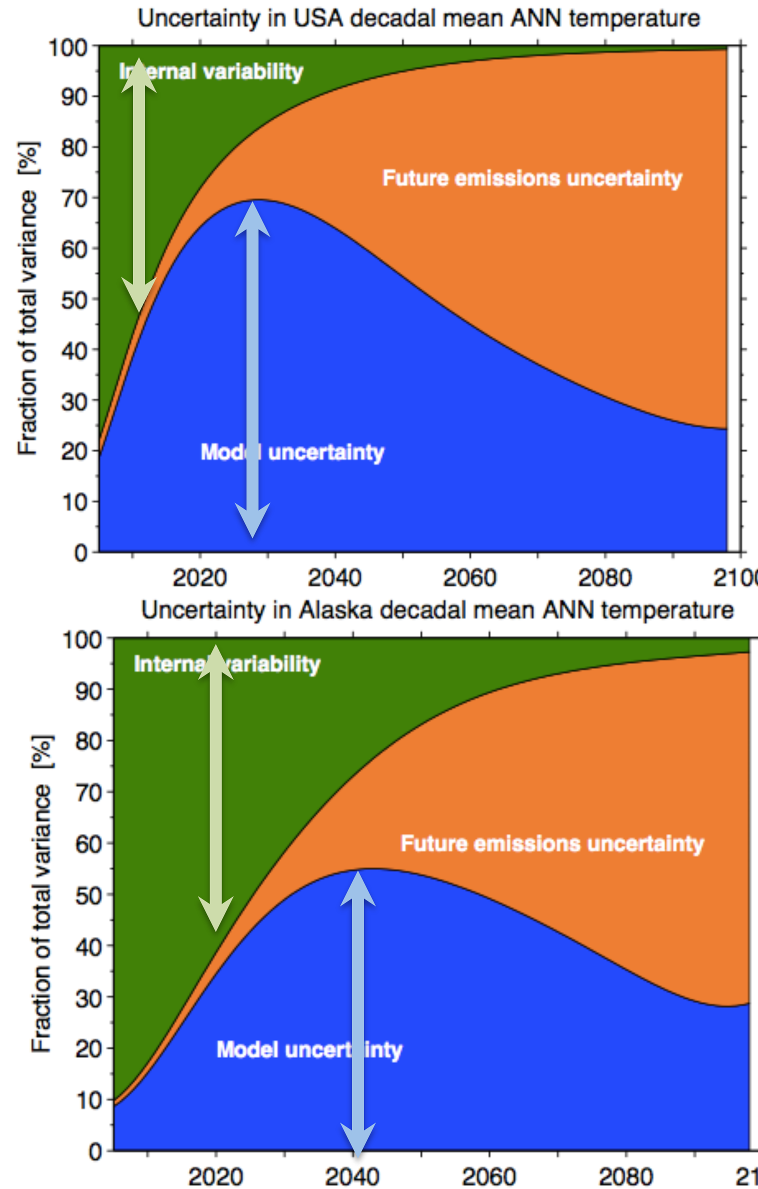
Climate model uncertainty

Uncertainty in climate projections comes from multiple sources and their ***relative**** contribution varies with time from the present.

Internal variability – like decadal climate variability – dominates early.

By mid-21st century, model uncertainty becomes more important.

By late-21st century, emissions become more important.



***TOTAL uncertainty increases with time!**

Draft CCSR, After Hawkins and Sutton, 2009, 2011.

Five useful facts

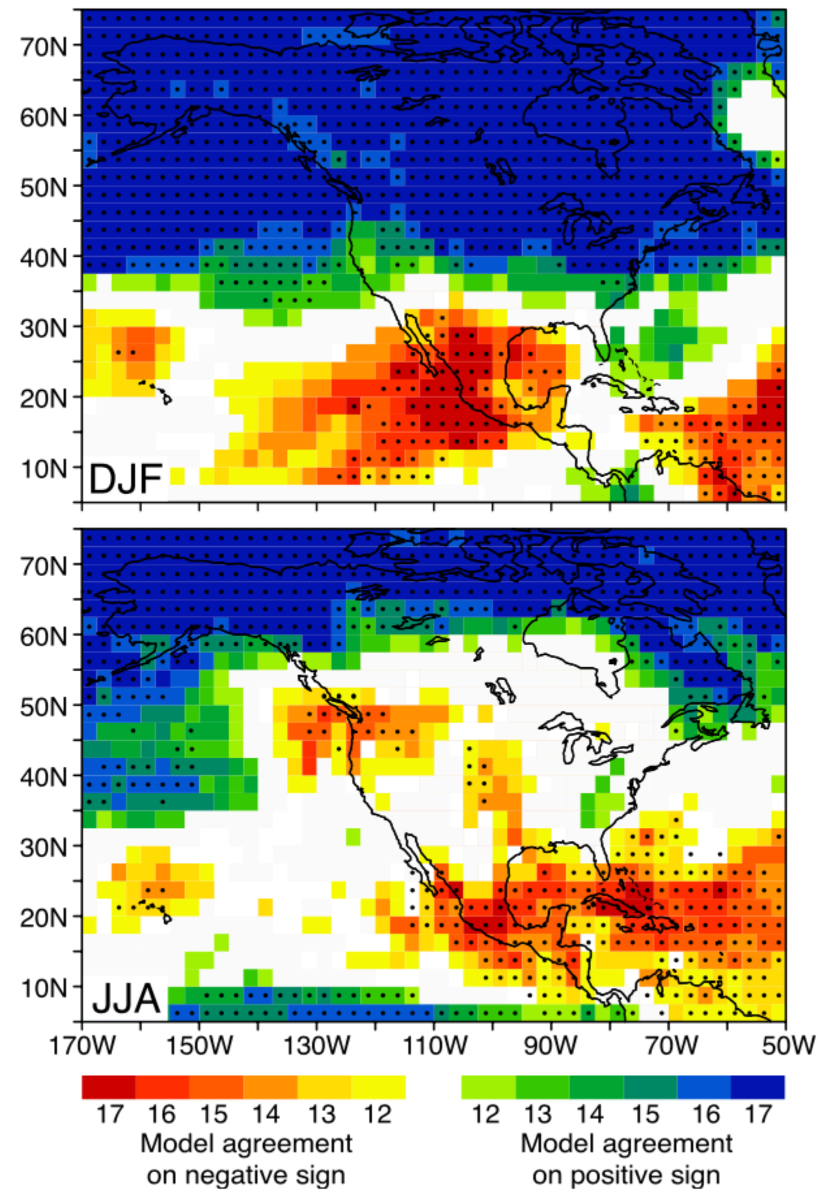
1. Model disagreement is higher for precipitation than temperature projections.

2. Model disagreement is higher in the mid-latitudes than at high latitudes.

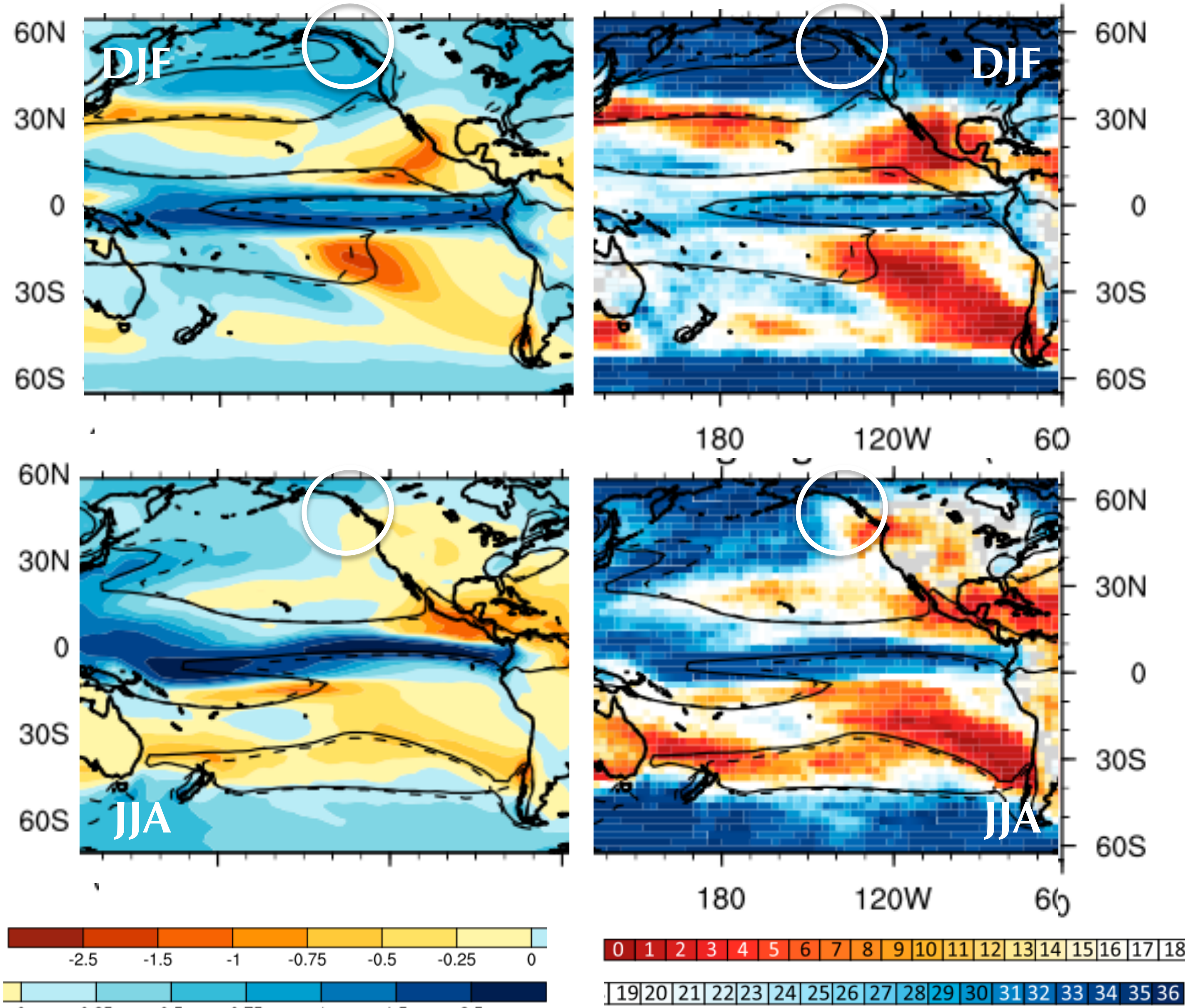
3. The range of future regional conditions simulated by one GCM driven using a range of initial conditions is a large fraction of the range of conditions across many GCMs.

4. The mean of a variable across multiple (~≥5-8) GCMs tends to approximate the observations of that variable historically.

5. The difference in skill between CMIP3/AR4 (~2007) and CMIP5/AR5 (~2013) is really not that big.



Maloney et al. 2014 JOC, 17 CMIP5 GCMs, RCP8.5



Mean 2070-2100 change in P (mm/day) relative to 1960-1990.

2070-2100 number of models agreeing that Precipitation will increase.

More models, same story.

In the SE AK region, models are in good agreement that precipitation will increase in DJF, but SE is in the geographic transition between increase and decrease for JJA.

Modified from Langenbrunner et al. 2015 JOC, 36 CMIP5 GCMs, RCP8.5

How are those facts useful?

1. Model disagreement is higher for precipitation than temperature projections.

   You can decide how many plausible future scenarios you need to consider.

2. Model disagreement is higher in the mid-latitudes than at high latitudes.

   You can use the position of your region along the equator-to-pole transect to inform thinking about diversity and timing of impacts.

3. The range of future regional conditions simulated by a single GCM driven by a wide range of initial conditions is a large fraction of the range of conditions across all GCMs.

   The climatic variability observed in the historical record is a good place to start; all models are a "right" model, and no model is the best model.

4. The mean of a variable across multiple (~≥5-8) GCMs tends to approximate the observations of that variable historically.

   Multi-model averages are better estimates of "the number", and the range is a good estimate of the plausible futures.

5. The difference in skill between CMIP3/AR4 (~2007) and CMIP5/AR5 (~2013) is really not that big.

   You do not have to start from scratch with new scenarios to have a good Impacts assessment.

A deliberate approach to uncertainty

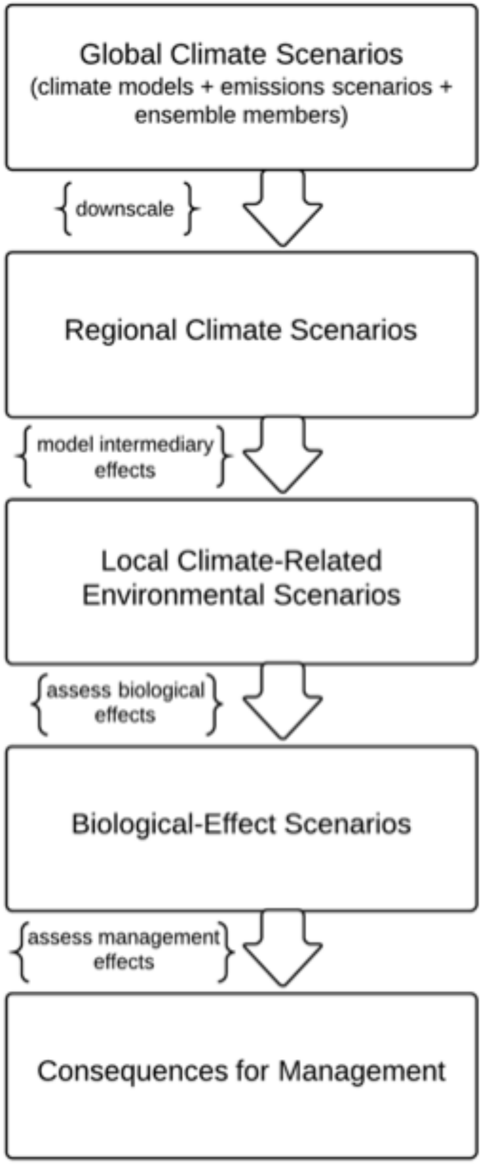


Figure 1. A common method of assessing the consequences of climate change for natural systems is a top-down impact assessment, which links, in turn, projections of global climate, regional climate, regional effects, biological effects, and responses.

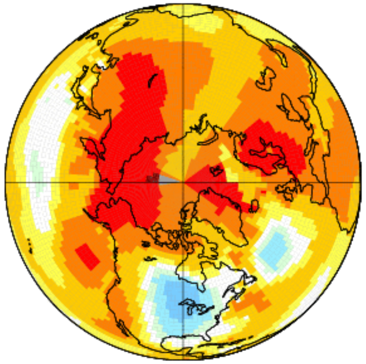
Snover et al. 2013, Conservation Biology

Use multiple models (as many as possible, but >3) and if you have to choose, bracket the range of variables that matter most to you.

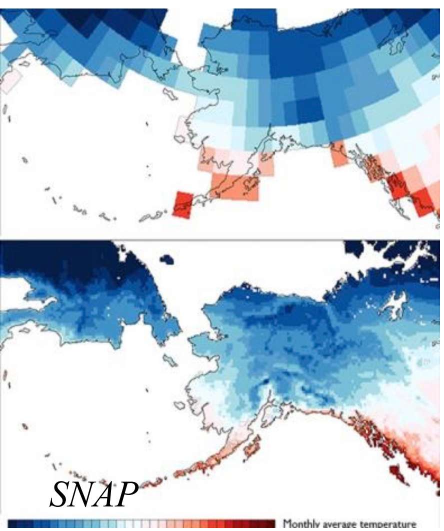
If you're in the far north, agreement is good. If not, look into whether models vary in the sign of the change expected or merely the timing.

Are you already invulnerable to the historical variations known to have occurred? Add the regional deltas to a historical record for a first approximation of what to expect.

CMIP3 ≈ CMIP5; don't worry too much about RCP 4.5, 6.0, 8.5 vs SRES B1, A1B, A2. Use risk tolerance to decide which, but we are closer to the 8.5/A1B/A2 future than the others.

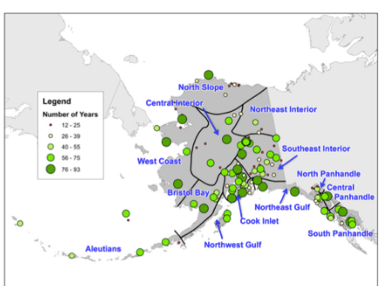


Downscaling:
A bridge between regional and local



Global climate models operate at scales (~100km / 62 miles or greater) that work for global-to-regional simulations, coarse changes and trends.

Historical climate observations and/or physical models can be used to "downscale" climate model projections to local scales where information is often (BUT NOT ALWAYS!) needed for decision making.



SNAP, Bieniek et al. 2012, 2014

In Alaska, the large gradients in temperature and precipitation and sub-regional terrain make downscaling very useful. But it also has limitations – there aren't as many weather stations in Alaska as the lower 48.

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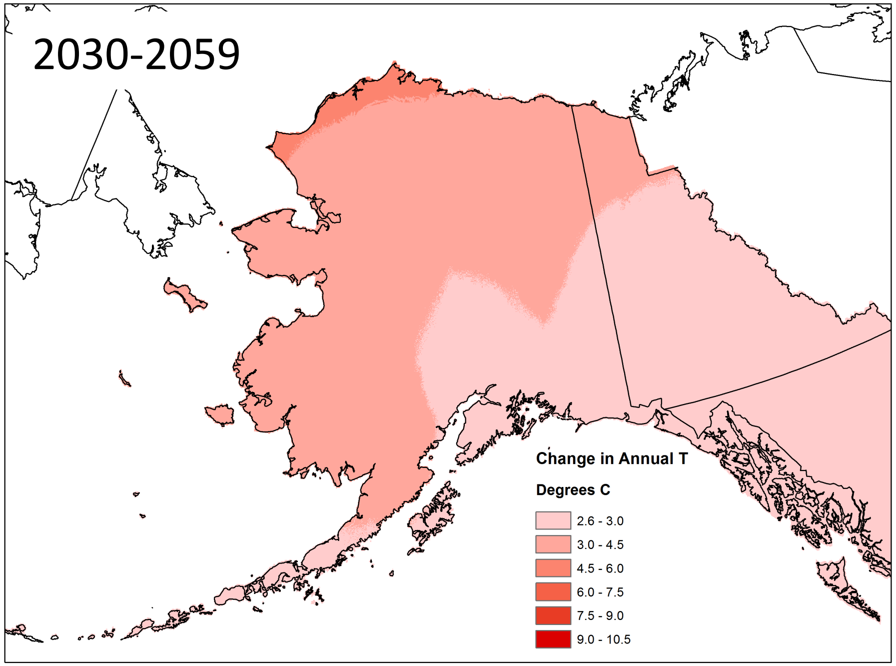
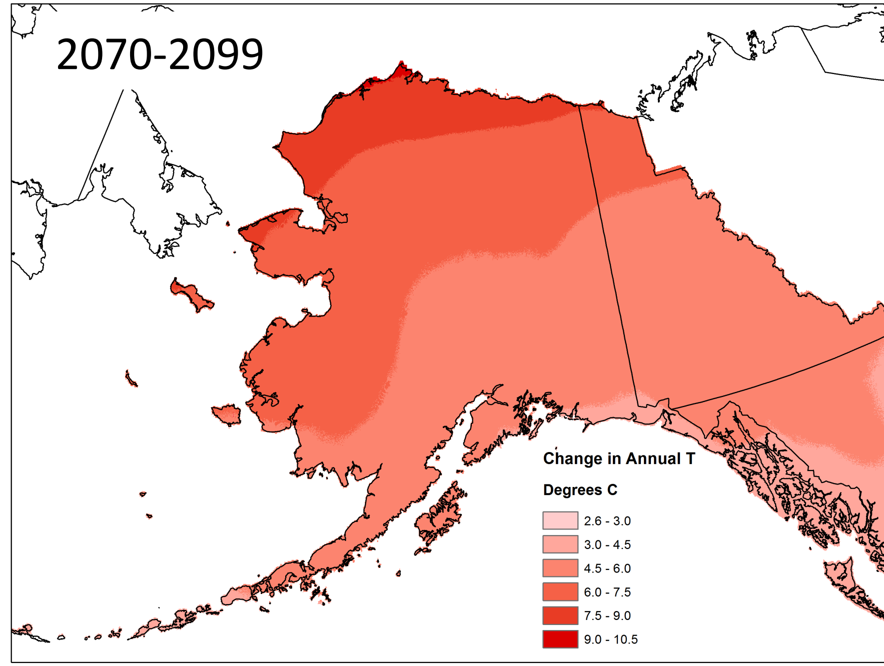
Alaska Climate Science Center

Climate projections: temperature





CMIP 5, RCP 8.5

Change, °F

4.7 - 5.4
5.4 - 8.1
8.1 - 10.8
10.8 - 13.5
13.5 - 16.2
16.2 - 18.9

Change in annual average temperature compared to 1970-1999. Average of 5 climate models.

For southeast Alaska, the projected changes in annual temperature are ~+3 to +5 °F by the 2040s, and ~+5 to +9 °F by the 2080s.

SNAP

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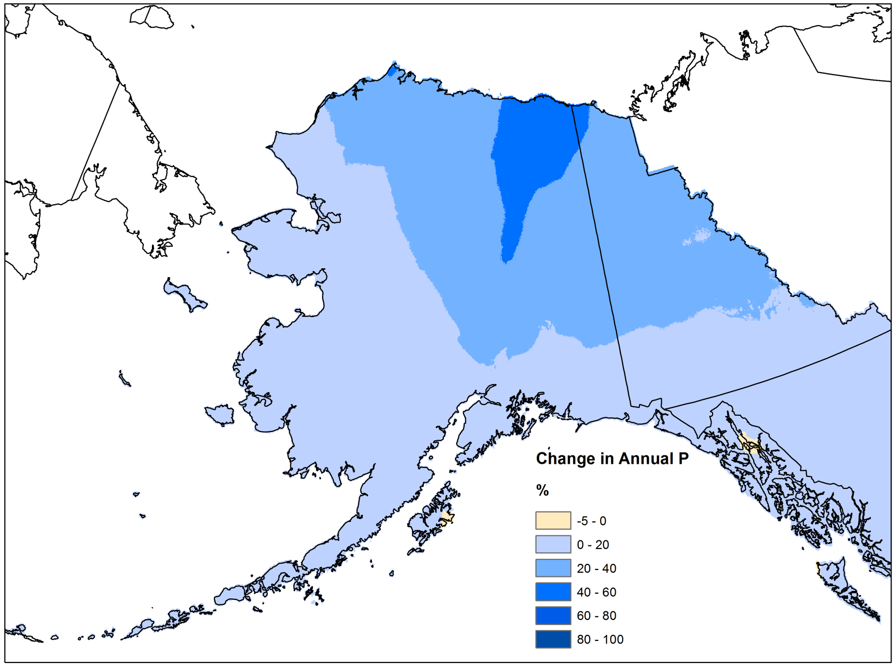
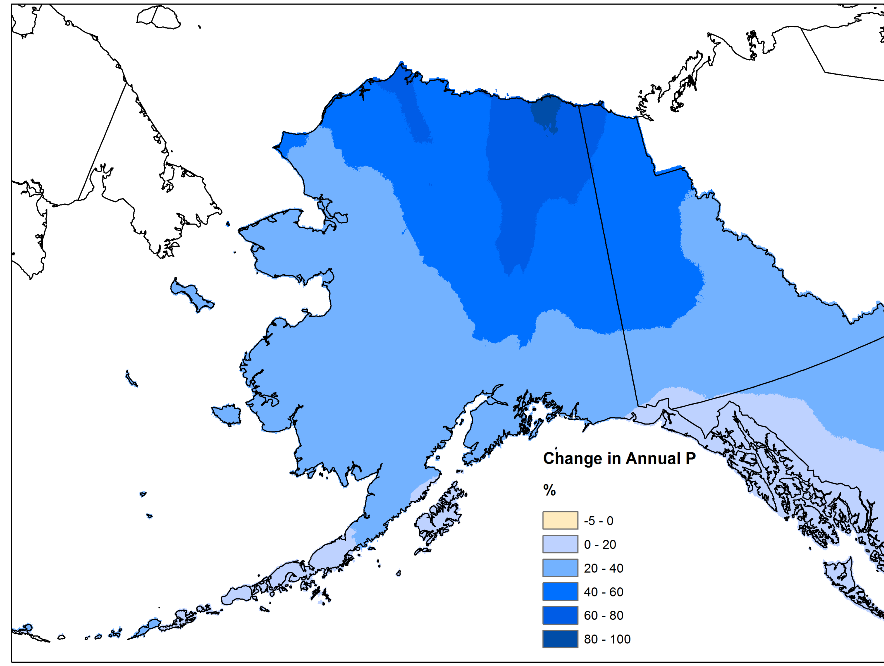
Alaska Climate Science Center

Climate projections: precipitation





CMIP 5, RCP 8.5

%

-5 - 0
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100

Change in annual total precipitation compared to 1970-1999. Average of 5 climate models.

For southeast Alaska, the projected annual changes are ~+10% to +12% by the 2040s, and ~+13% to +21% by the 2080s.

SNAP

AK CSC
Alaska Climate Science Center

For the Tongass region, seasonal differences are both important and evident. Compared to 1970-1999, average of 5 climate models suggests that:

- temperature will increase more in the cool season (fall and winter) than in the summer
- Precipitation will increase more in winter and spring

Under a lower emissions scenario, temperatures will increase about half what they are projected to under higher emissions.

Right: projected annual and seasonal deltas (1970-99 baseline) for temperature and precipitation in the Tongass region (SE AK) derived from SNAP projections. Values are five-model means (CCSM4, GFDL3, CGCM3, GISS2, IPSL5). 2020s – 2010-2039; 2040s – 2030-2059; 2080s – 2070-2099.

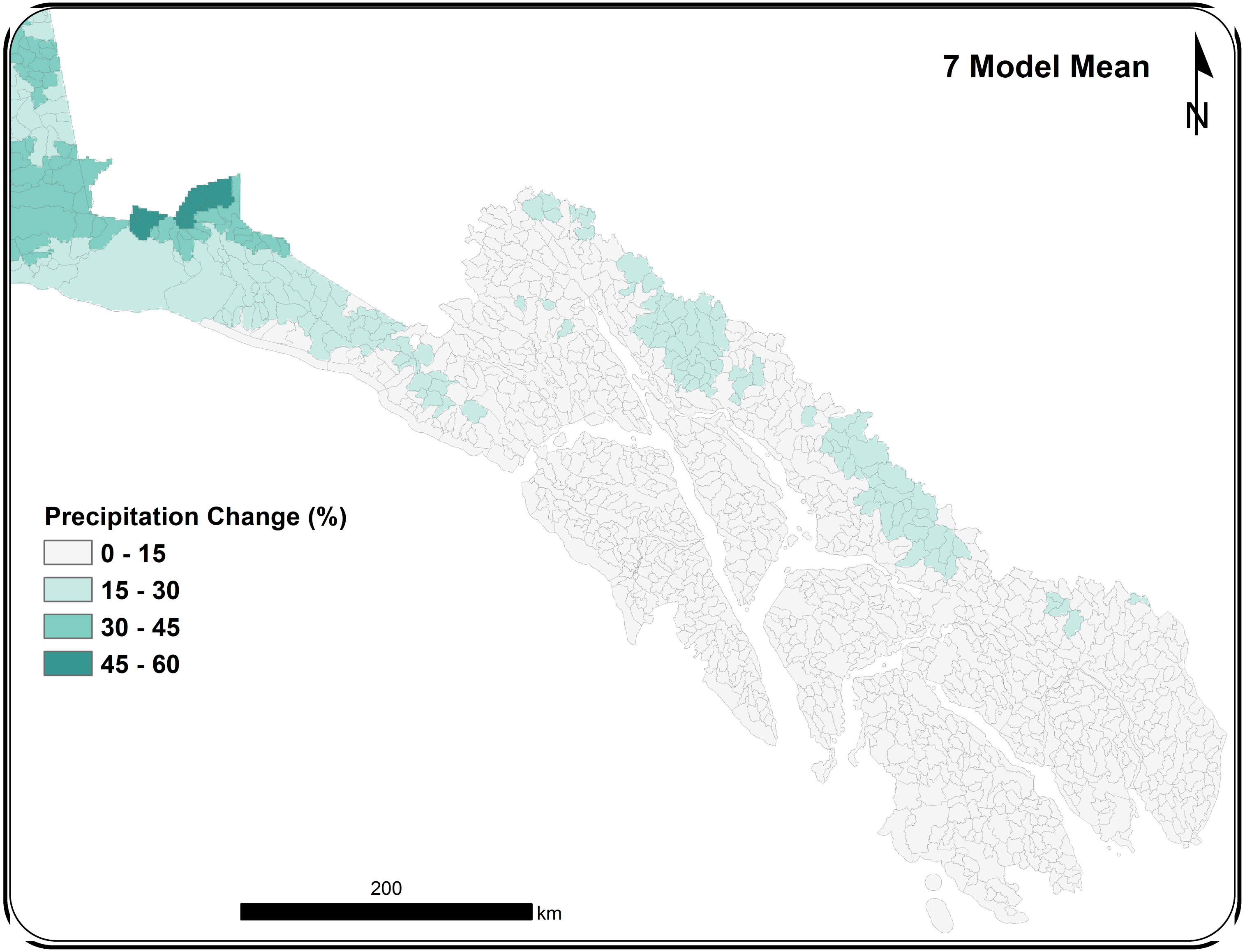
RCP 4.5 (low – mid emissions)

	2020s		2040s		2080s	
	C°	(F°)	C°	(F°)	C°	(F°)
ANN	1.0	(1.8)	1.9	(3.4)	2.7	(4.9)
DJF	1.0	(1.8)	2.1	(3.8)	3.0	(5.4)
MAM	0.5	(0.9)	1.3	(2.3)	2.0	(3.6)
JJA	0.9	(1.6)	1.6	(2.9)	2.4	(4.3)
SON	1.6	(2.9)	2.5	(4.5)	3.4	(6.1)
			Precipitation			
ANN	6.5%		10%		13.4%	
DJF	10.6%		14.5%		17.5%	
MAM	9.8%		14.7%		19.6%	
JJA	5.1%		7.9%		10.3%	
SON	4.4%		7.5%		11.6%	

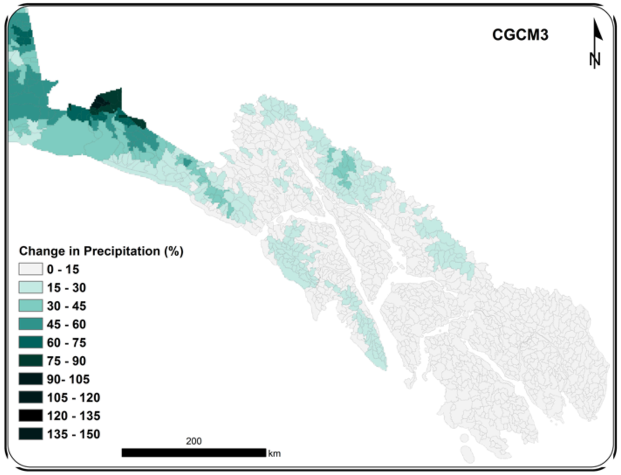
RCP 8.5 (higher emissions)

	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%	

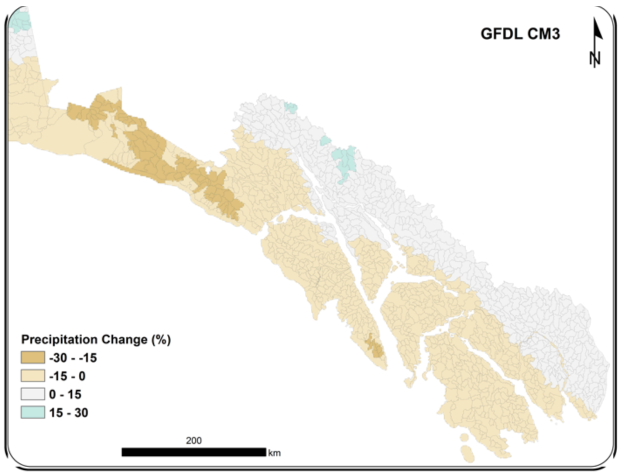
Example: JJA Precipitation

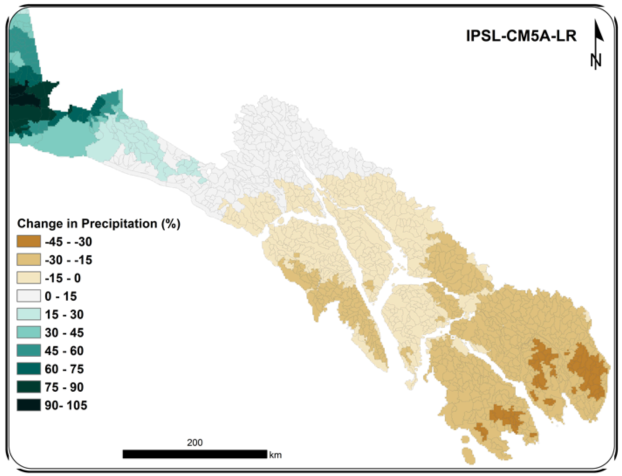


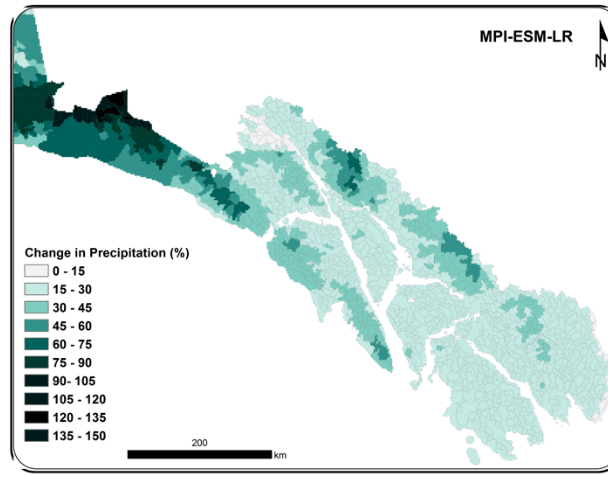
(CCSM4, GFDL3, CGCM3, GISSE2, IPSL5 + MPI ESM, CNRM5) 2040-2069, RCP 8.5

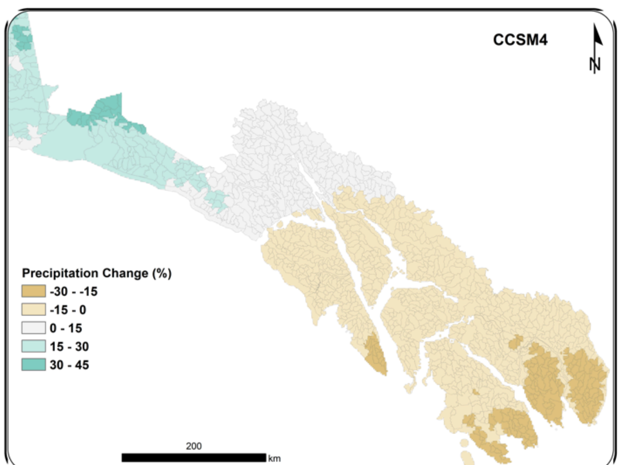


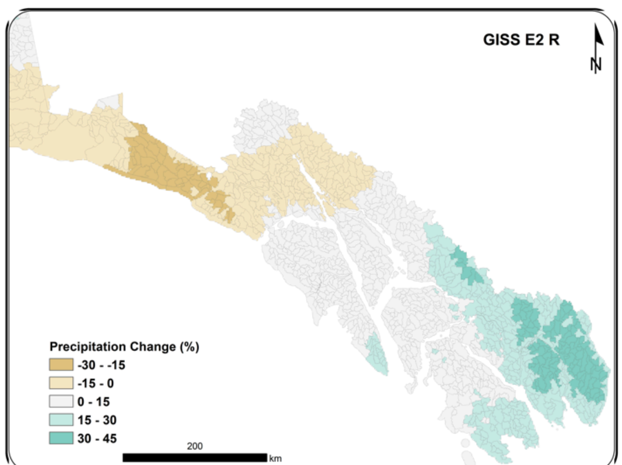
Summer precipitation from the 5 GCMs SNAP found to be good in Alaska vary. CGCM3 is much like the Mean, but four others are drier in parts of SE AK. Two additional models provide wetter bracketing scenarios.

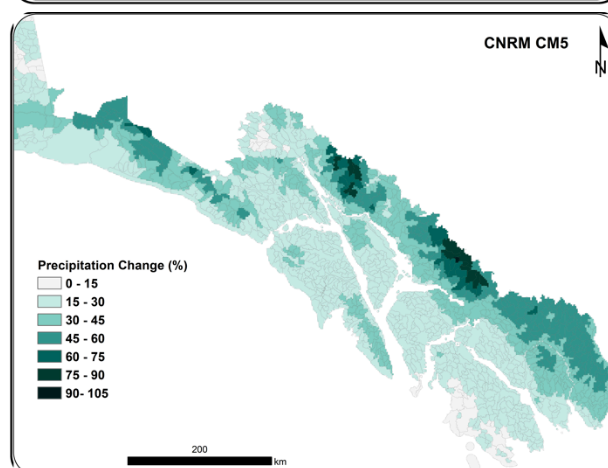


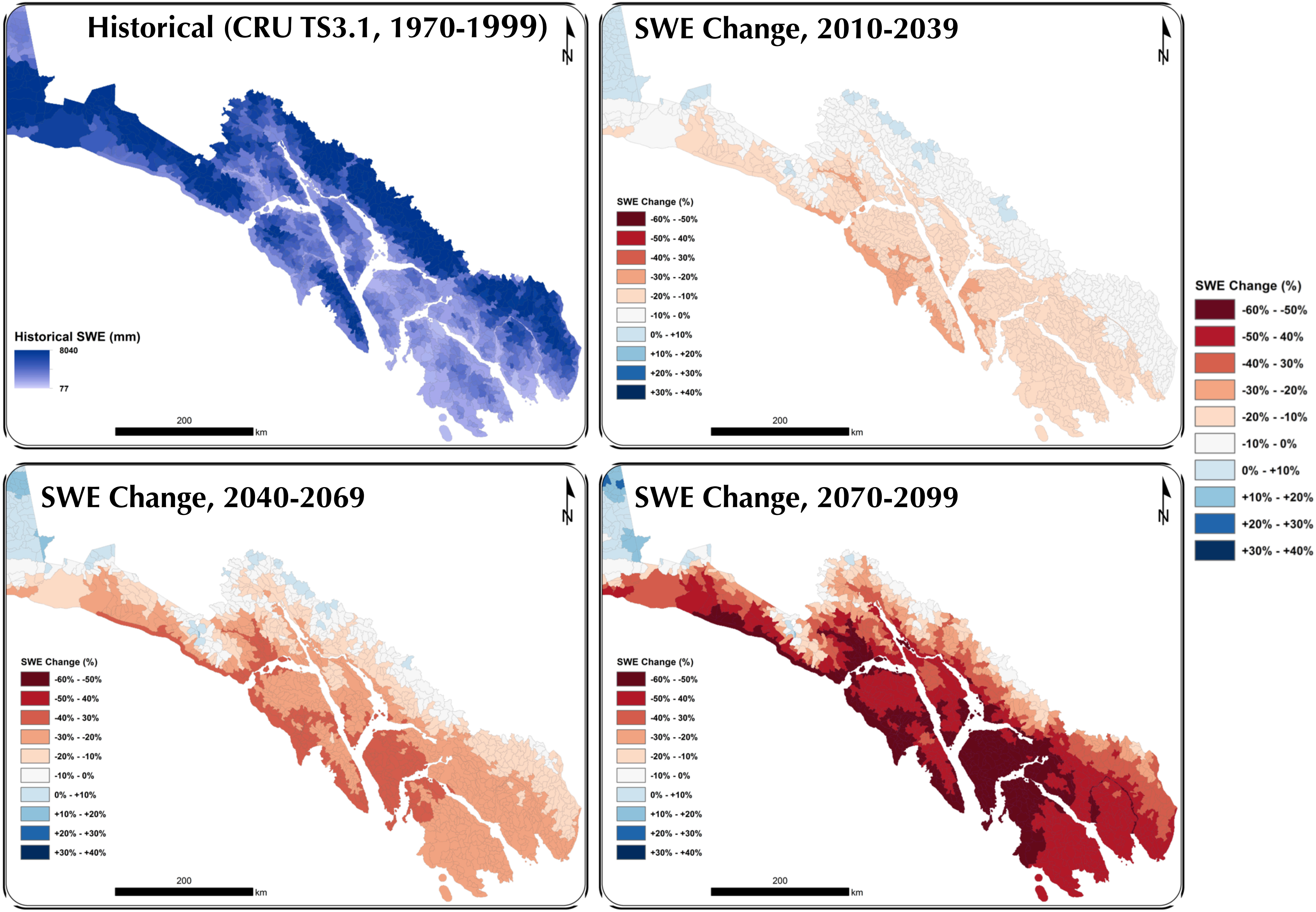






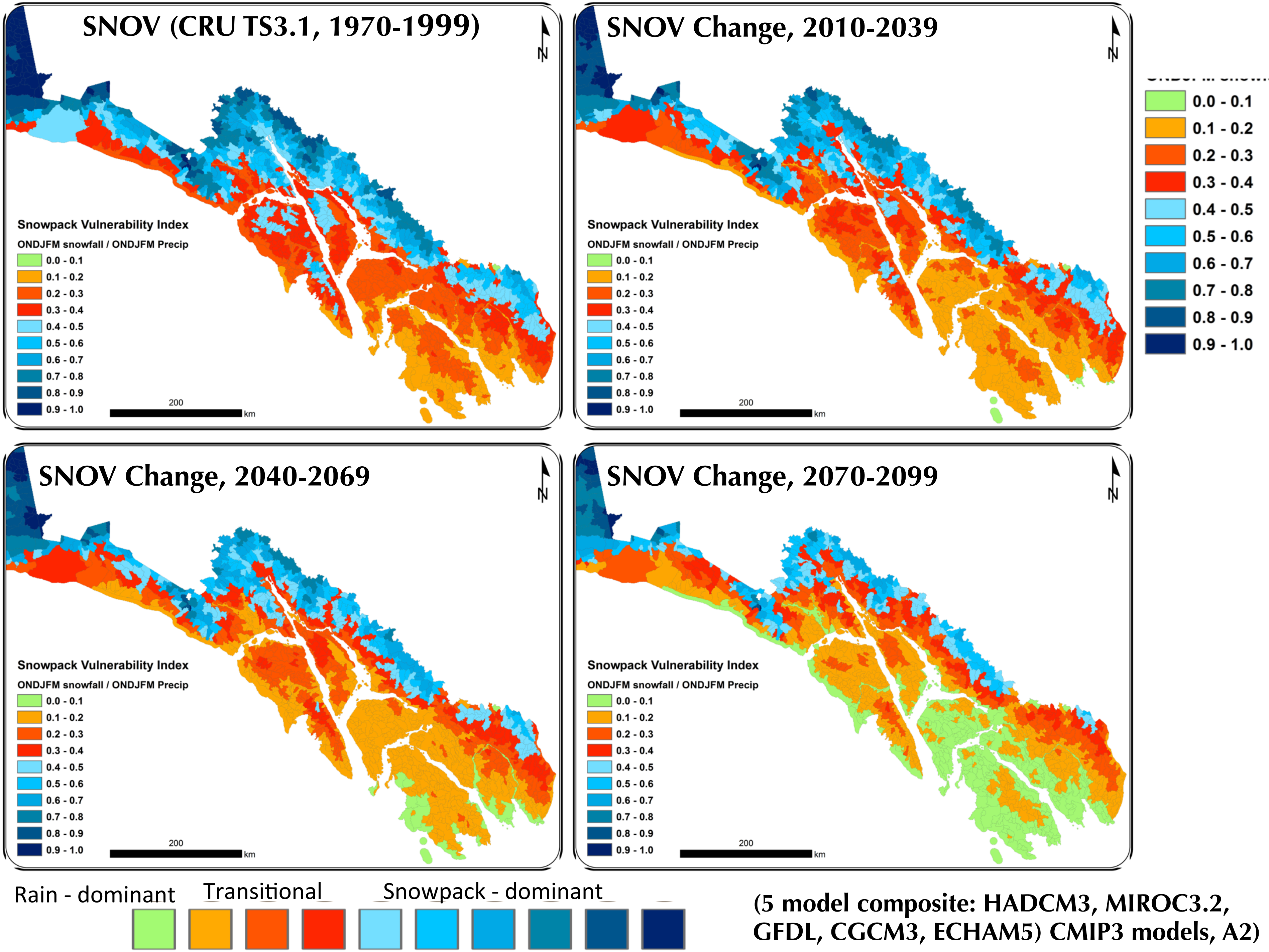






Snow-day fraction and precipitation can be used to estimate maximum snow water content.

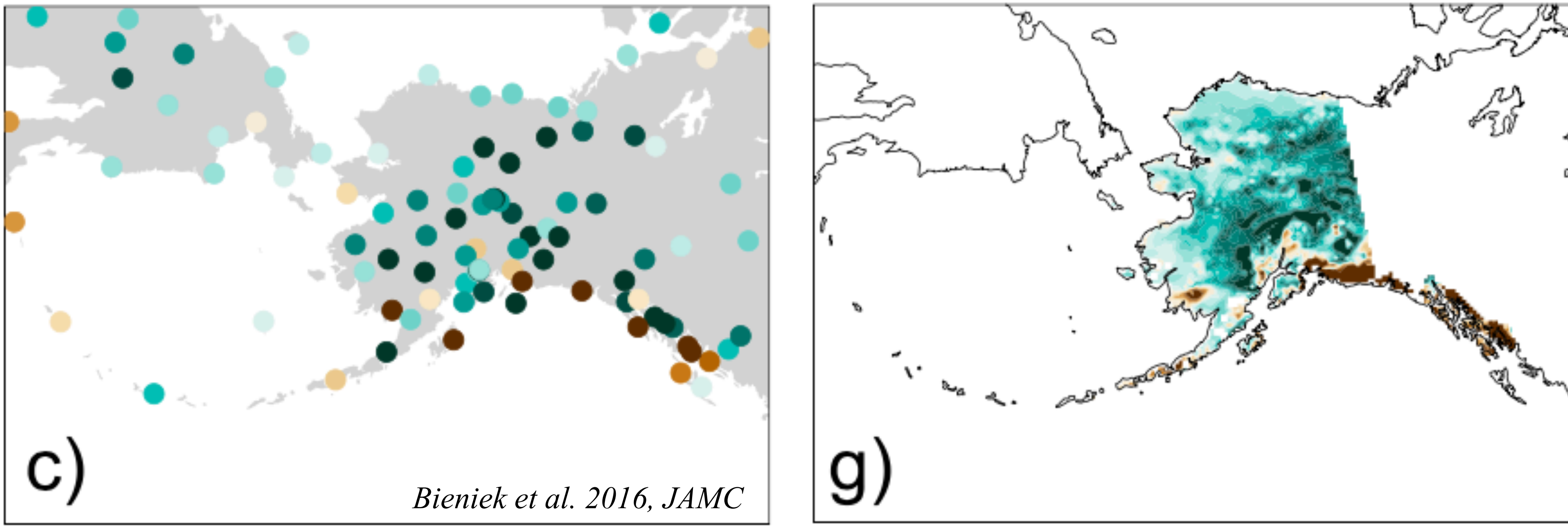
(5 model composite: HADCM3, MIROC3.2, GFDL, CGCM3, ECHAM5) CMIP3 models, A2 emissions)



(5 model composite: HADCM3, MIROC3.2, GFDL, CGCM3, ECHAM5) CMIP3 models, A2)

Dynamical downscaling

Dynamical downscaling uses a regional weather model to downscale global climate model output with physically-consistent processes rather than statistics. There are advantages and disadvantages, and the field is evolving.



Evaluation of dynamically downscaled historical JJA precipitation relative to (C) station Observations and (G) gridded observations. Southern SE AK dynamical downscaling has a dry bias, while northern SE AK has a wet bias. The authors attribute this to the topographical controls on SE precipitation which are likely not adequately captured at 20km resolution.

Some considerations

- The available products for evaluating how good projections are are limited now and into the foreseeable future
- Expect - but don't wait for - a better projection, or you'll always be waiting
- Use projections, but also use your knowledge of the system you work in
- The best available science vs. the best science we can imagine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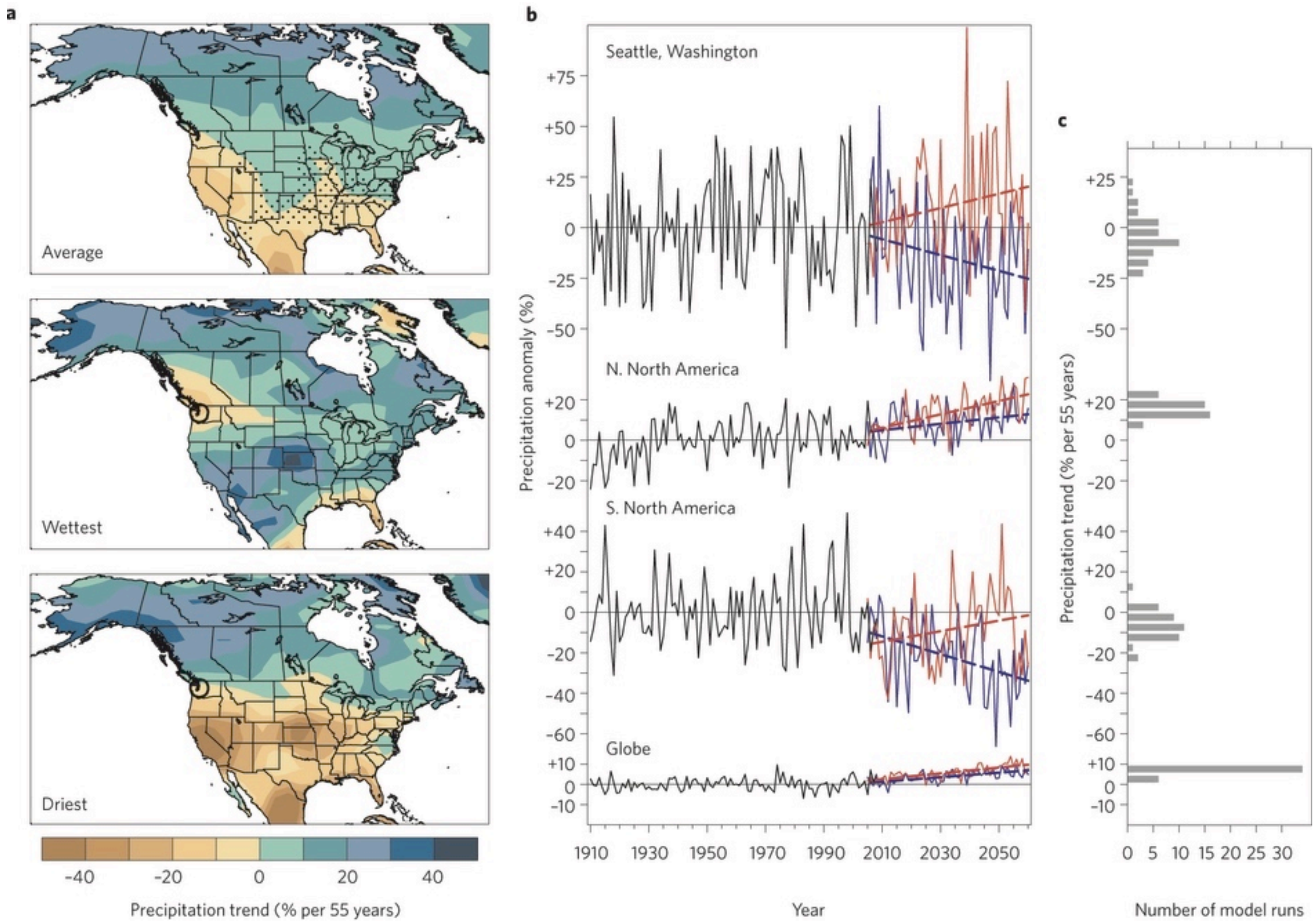
Model uncertainty and Internal variability



40 simulations of the same GCM (CCSM3, A1B), with same initial ocean, land and sea ice but different atmospheric conditgions sampled from 20th century model run, Dec1999-Jan2000

Deser et al. 2012, Nature Climate Change