
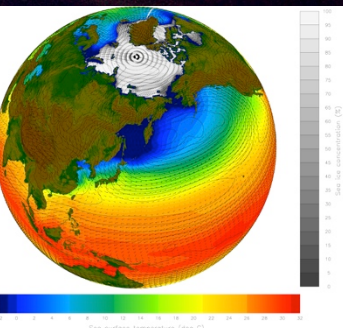
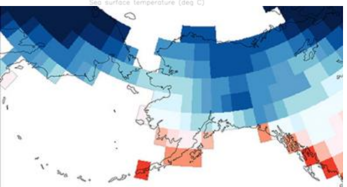
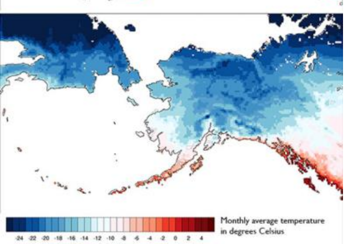

Climate model uncertainty

(with notes on where it comes from and what it means for using projections)

Jeremy Littell
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science for a changing world

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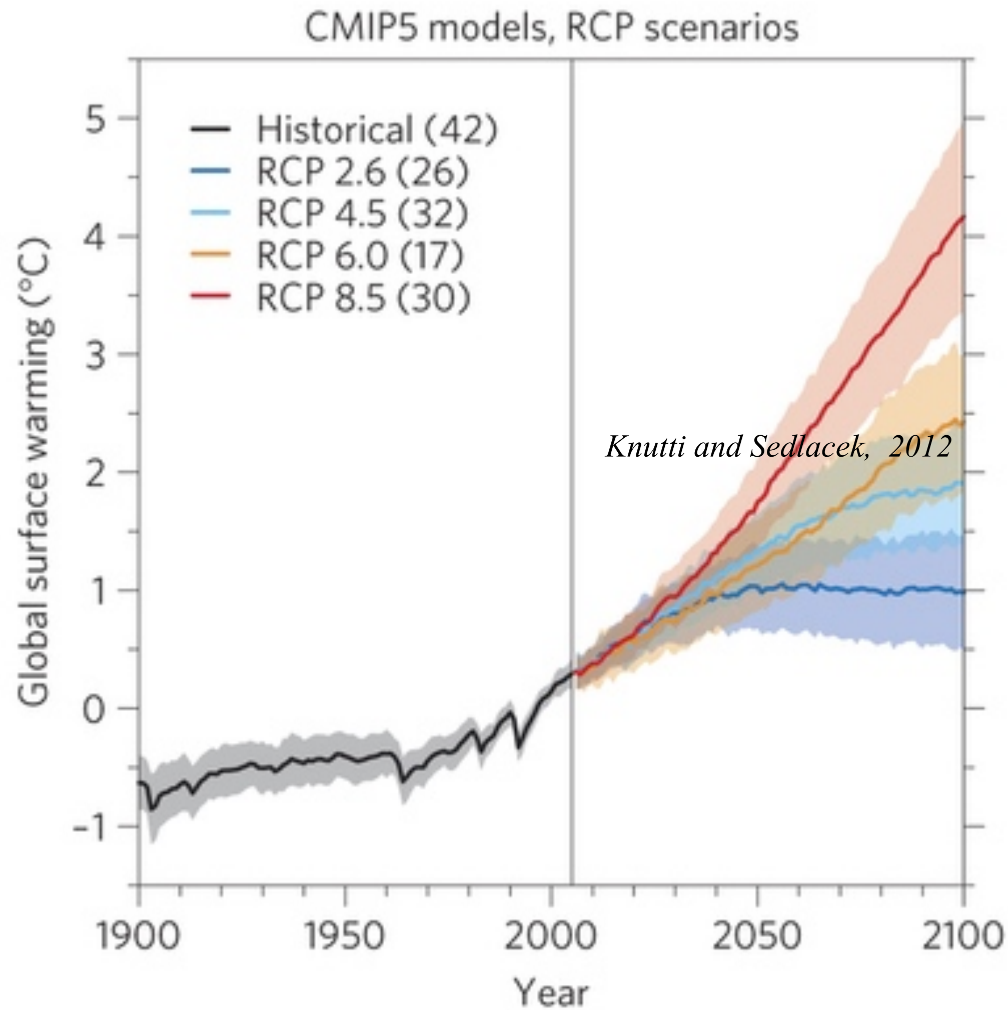
Climate model projections

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

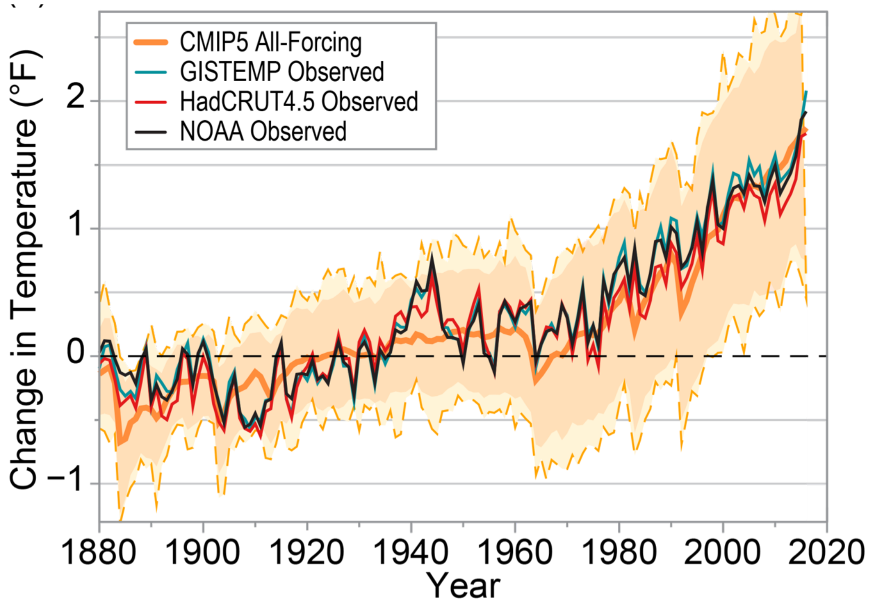
These models are run under common forcings – but not usually as short-term forecasts. They are run given the initial conditions and mechanics of the model.

They are therefore projections, not forecasts with probabilities.



Q: How do we know climate models are any good?

The average of 36 climate models with both human and natural climate drivers match observed records.

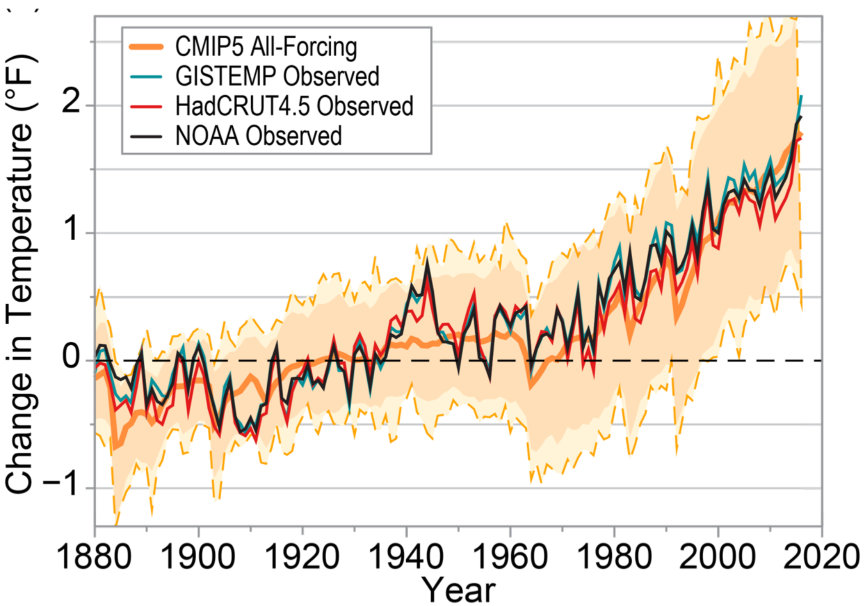


Source: IPCC AR5

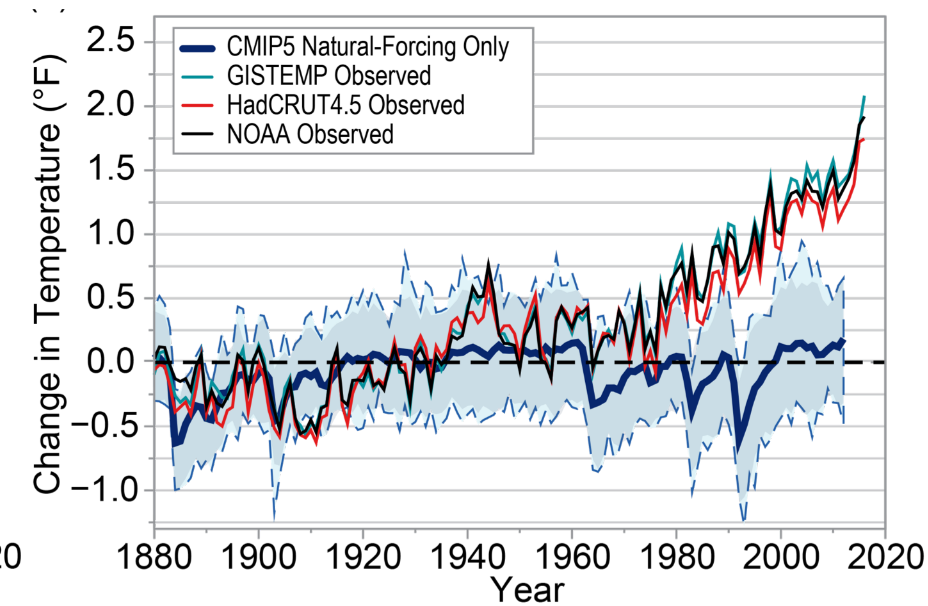
Q: How do we know climate models are any good?

A: Collectively, they give us back the history we know to have occurred. For temperature. For the planet.

The average of 36 climate models with both human and natural climate drivers match observed records.



The same models with just natural climate drivers do not match observed records.



Source: IPCC AR5

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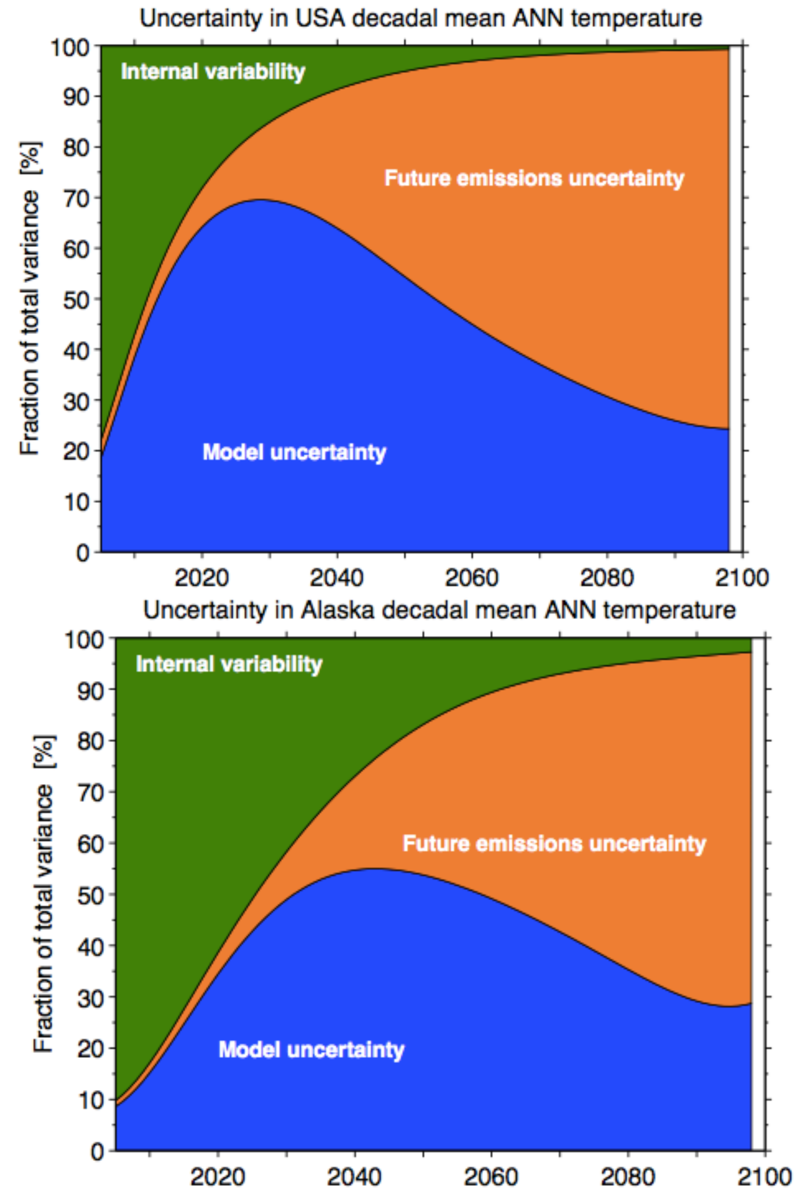
Climate model uncertainty

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!**

NCA4 Vol 1 CCSR, After Hawkins and Sutton, 2009, 2011.

Climate model uncertainty

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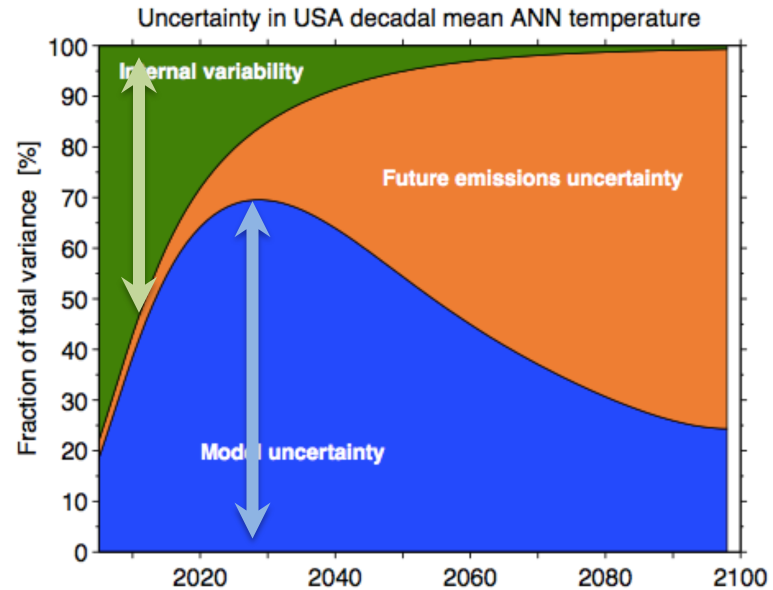

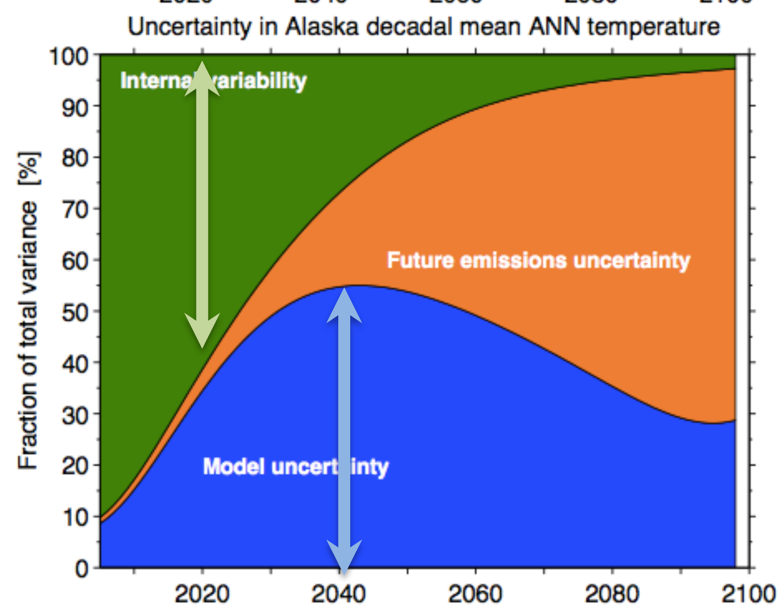

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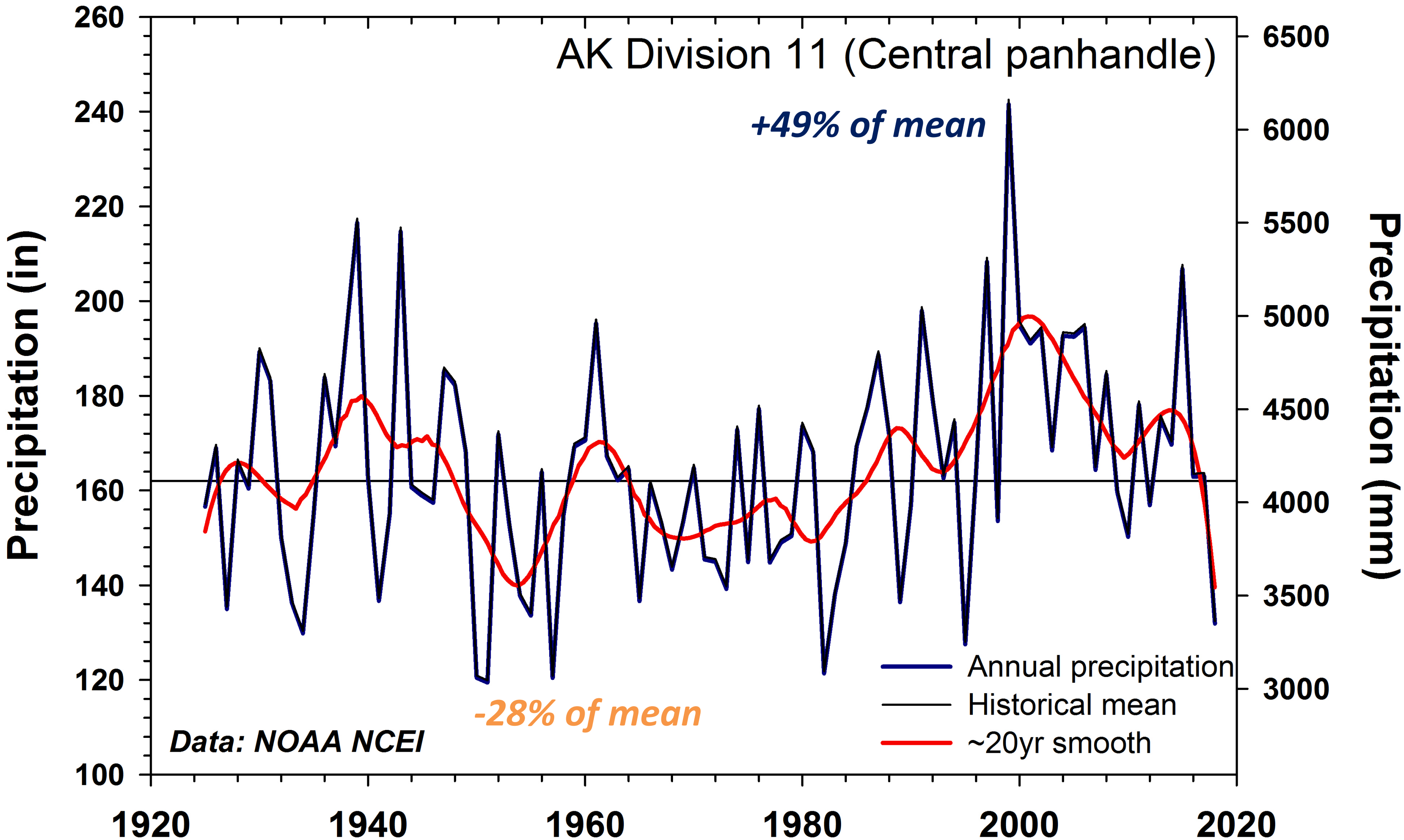
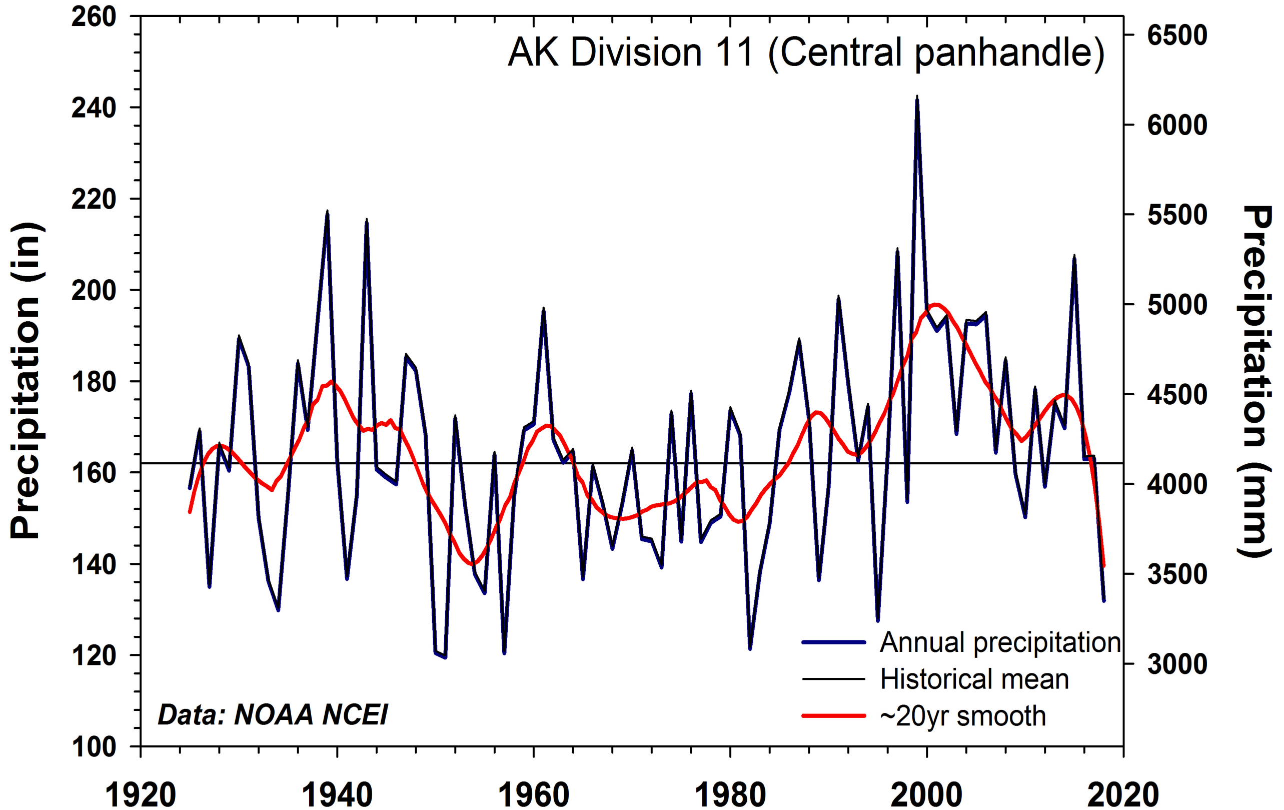
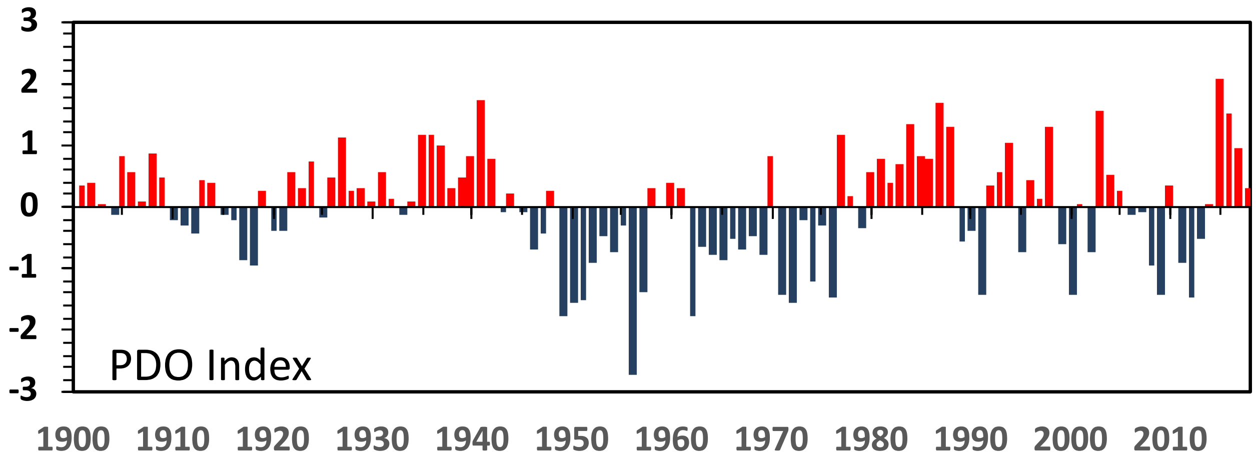


Climate in SE Alaska, and Alaska in general, has characteristic interannual to decadal variability.


AK Division 11 (Central panhandle)
Precipitation (in)
Precipitation (mm)
Annual precipitation
Historical mean
~20yr smooth
Data: NOAA NCEI
260
240
220
200
180
160
140
120
100
6500
6000
5500
5000
4500
4000
3500
3000
1920
1940
1960
1980
2000
2020

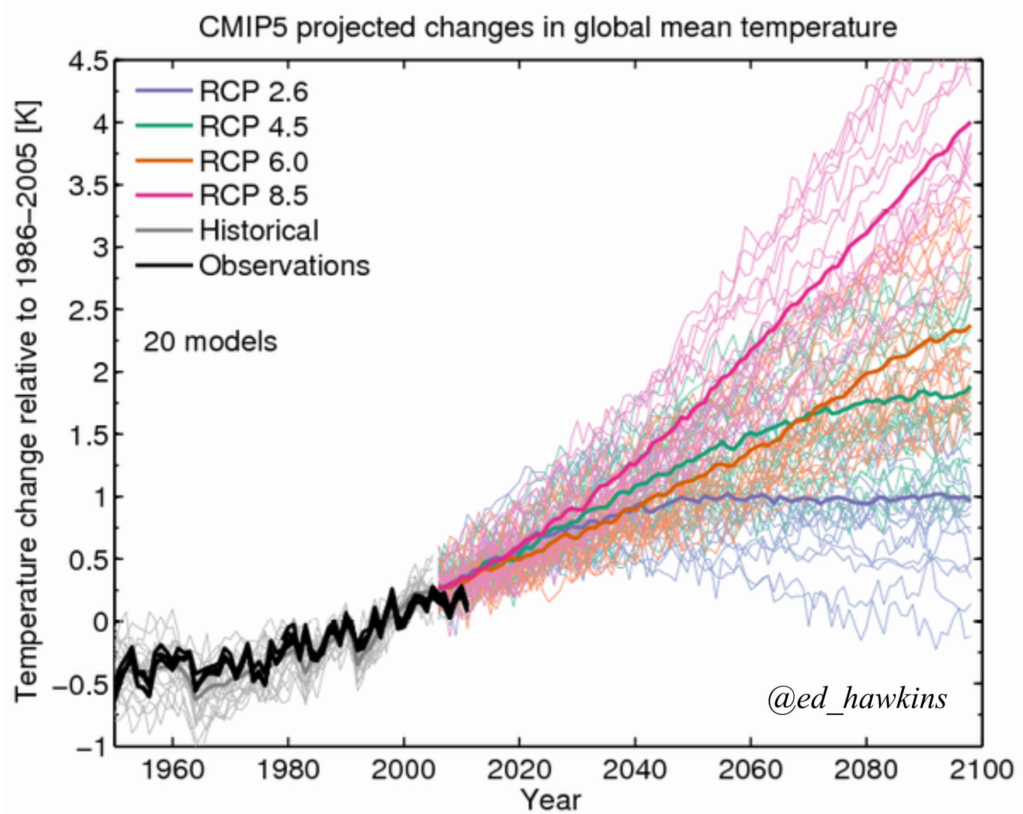

PDO Index
3
2
1
0
-1
-2
-3
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Uncertainty due to climate variability

The future we expect for a given emissions scenario is roughly sketched by ***averages across many climate models***.

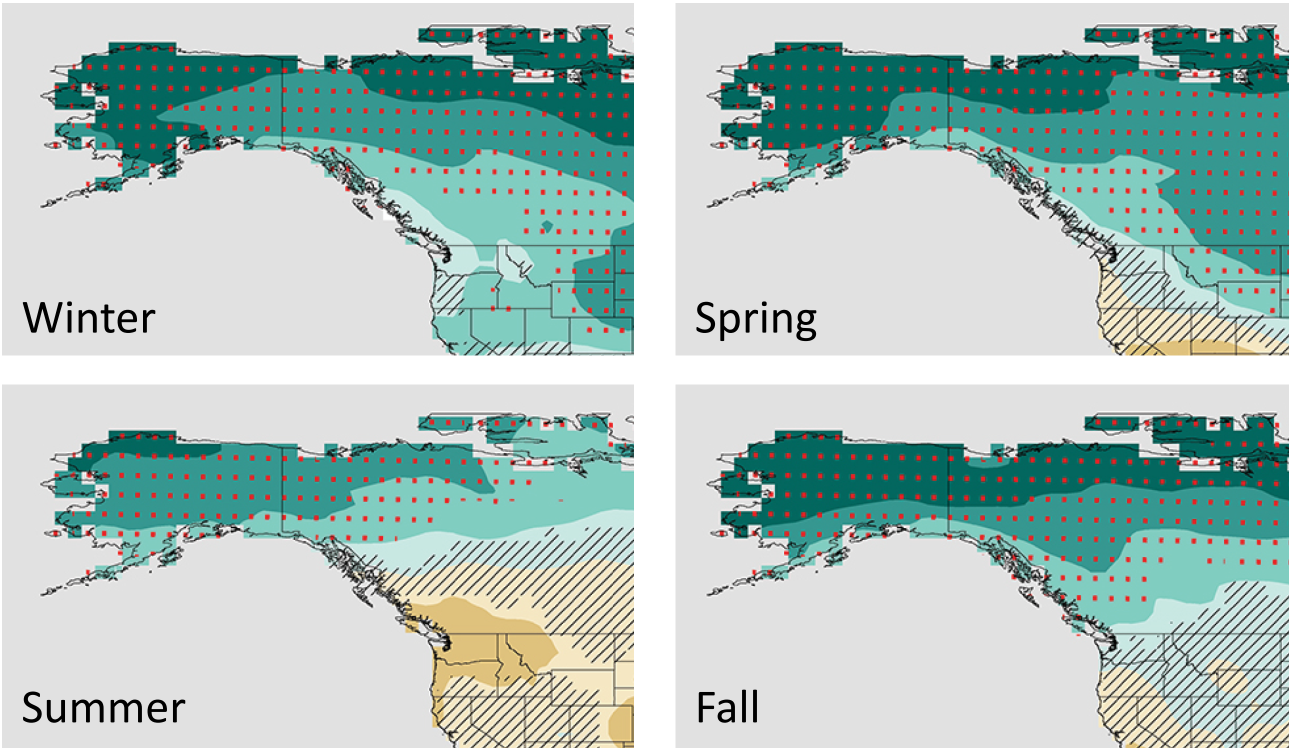
The future we actually experience will be as "bumpy" – perhaps bumpier – than the past we've experienced because climate variability is still going to occur!

The first thing to plan for is the combination of the expected trend ***and*** the variability we know* to characterize the regional climate.



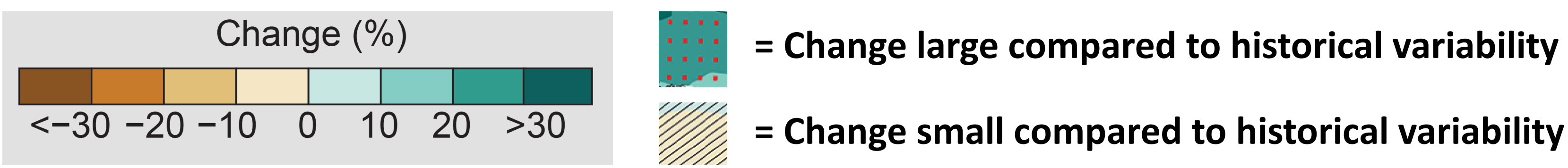
**What we "know" in Alaska is from a fairly limited time frame…..*

Future precipitation projections



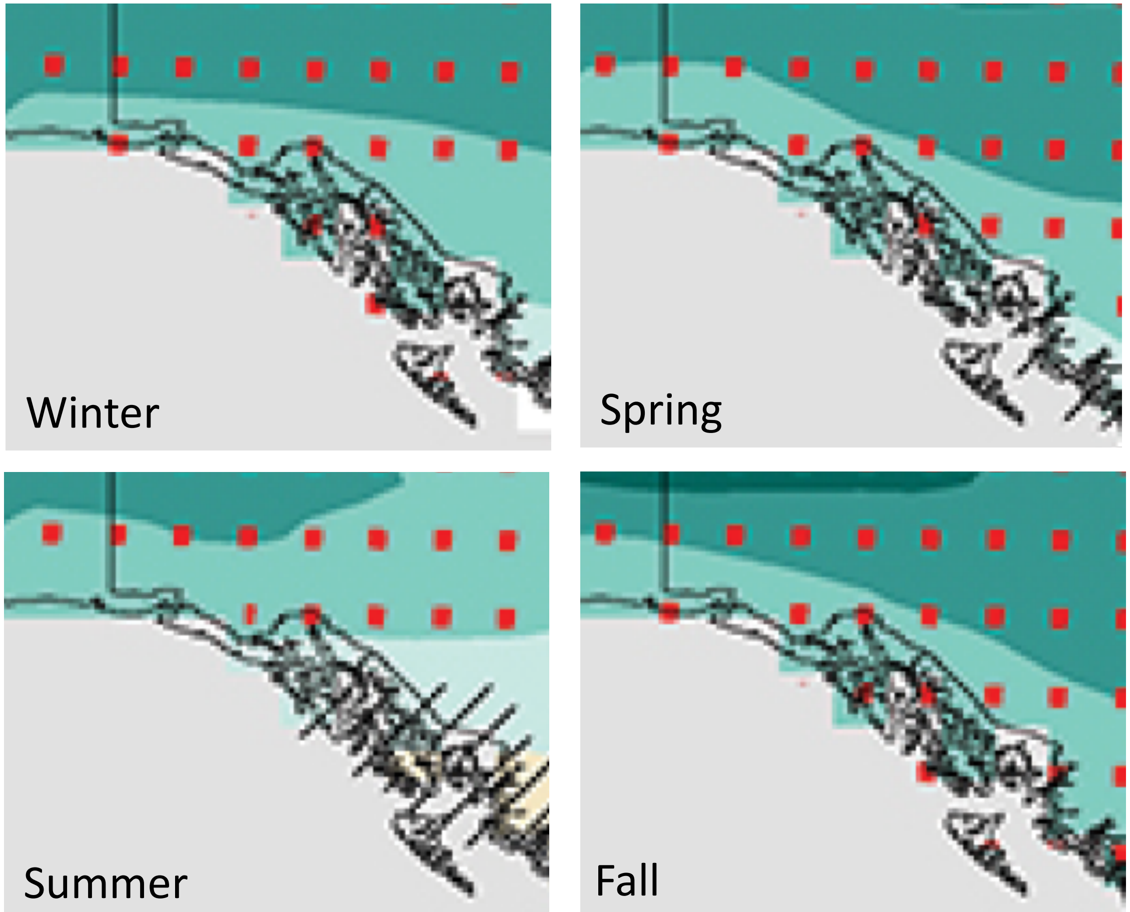
Over most of Alaska, mean precipitation is Projected to increase in all seasons.

The projected increases are large compared to historical variability



Projected change (%) in total seasonal precipitation from CMIP5 (RCP8.5) simulations for 2070–2099. Weighted multimodel means, baseline 1976–2005. Data source: World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project. (Original Figure source: NOAA NCEI).

Adapted from NCA4 Volume 1, CCSR, Chapter 7: Precipitation Change in the US. https://science2017.globalchange.gov/chapter/7/

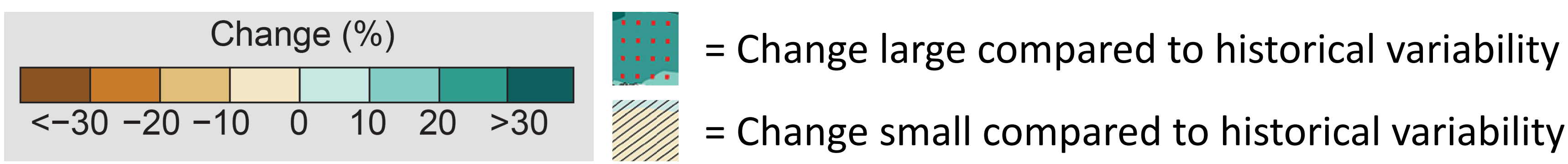


In Southeast Alaska, the same is true EXCEPT for summer.

The projected increases are small compared to historical variability.

These are averages across many climate models....

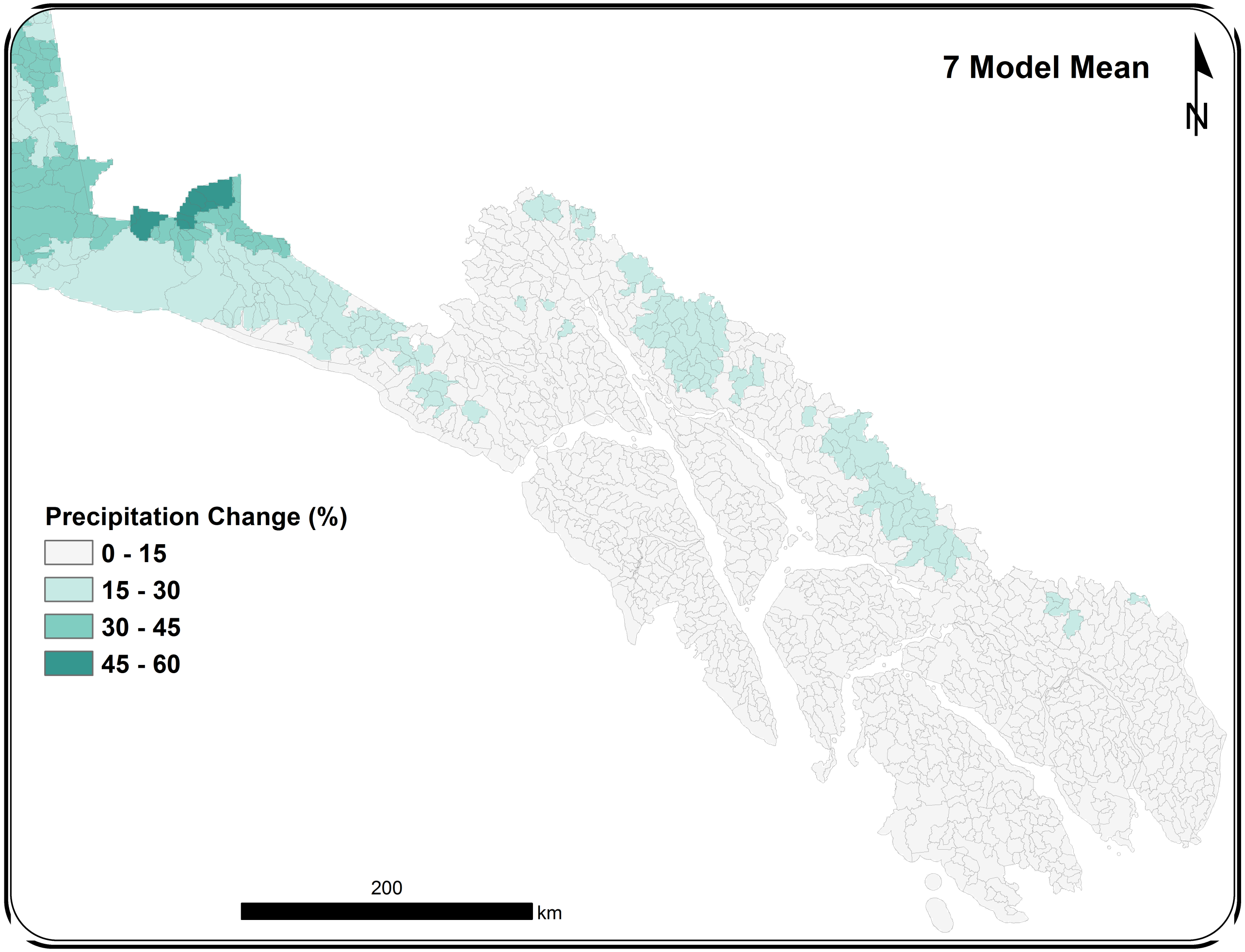
Let's use that to look at model uncertainty.



Projected change (%) in total seasonal precipitation from CMIP5 (RCP8.5) simulations for 2070–2099. Weighted multimodel means, baseline 1976–2005. Data source: World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project. (Original Figure source: NOAA NCEI).

Adapted from NCA4 Volume 1, CCSR, Chapter 7: Precipitation Change in the US.
https://science2017.globalchange.gov/chapter/7/

Model Uncertainty Example: JJA Precipitation



(CCSM4, GFDL3, CGCM3, GISSE2, IPSL5 + MPI ESM, CNRM5) 2040-2069, RCP 8.5. 2040-2069 HUC12 watershed changes relative to 1970-1999. Downscaled to <1km historical. Data: SNAP

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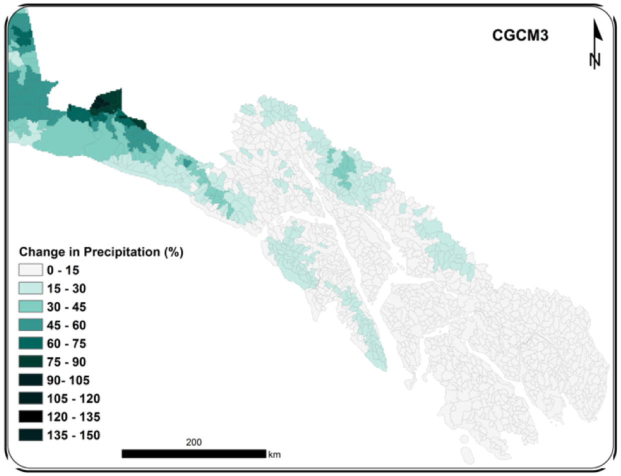
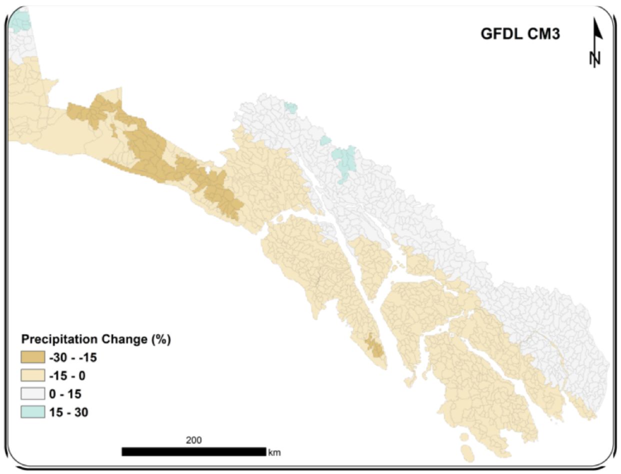
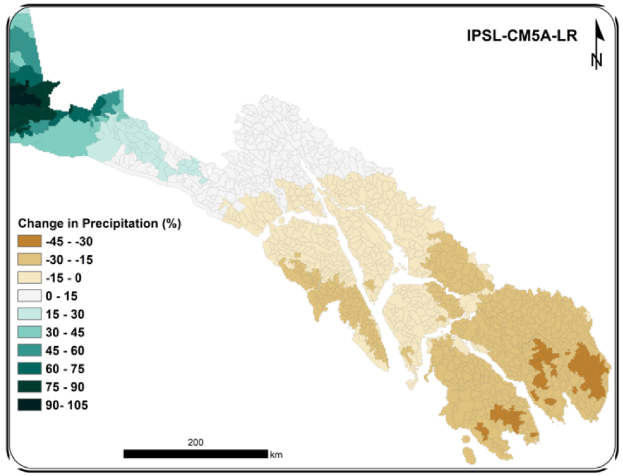
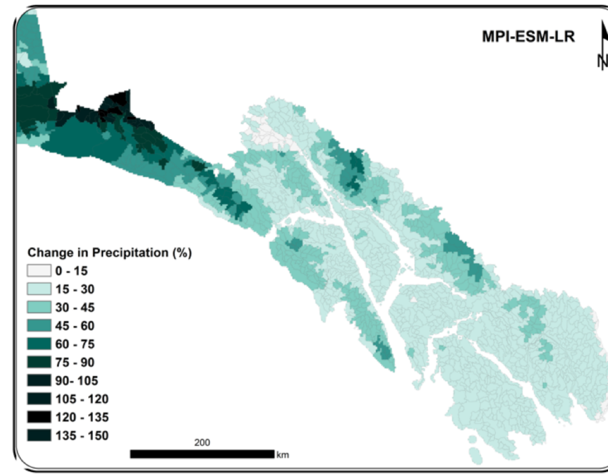
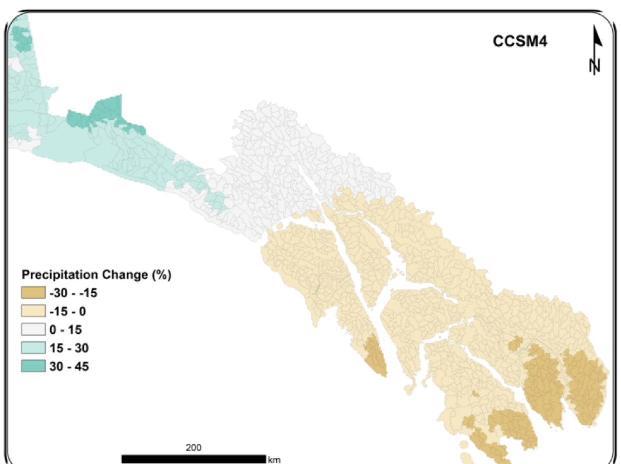


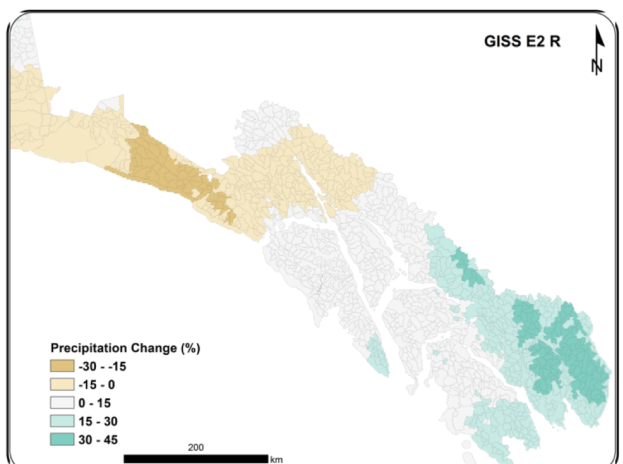
Summer precipitation changes from the 5 GCMs SNAP found to be good in Alaska vary. CGCM3 is much like the mean, but four others are drier in parts of SE AK. Two additional models provide wetter bracketing scenarios.

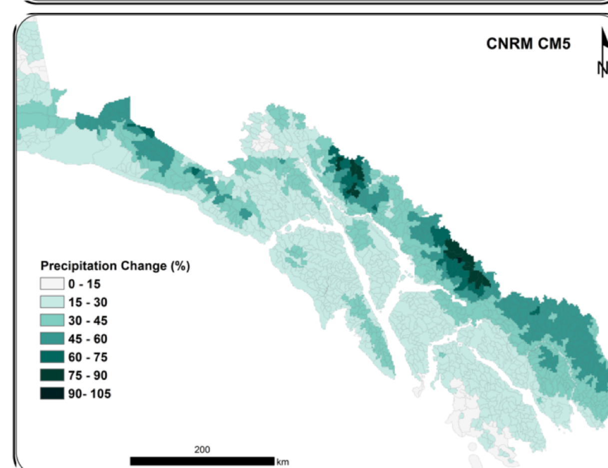










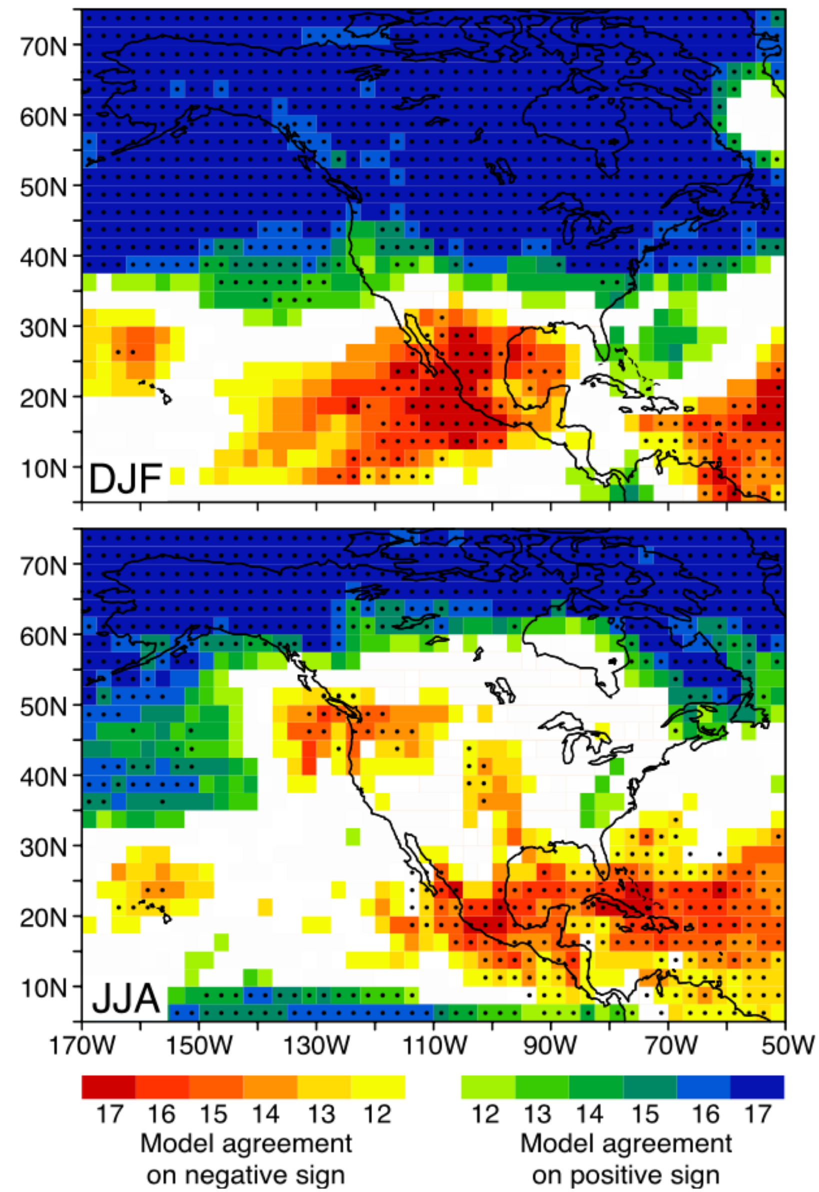


Precipitation (dis)agreement is not universal

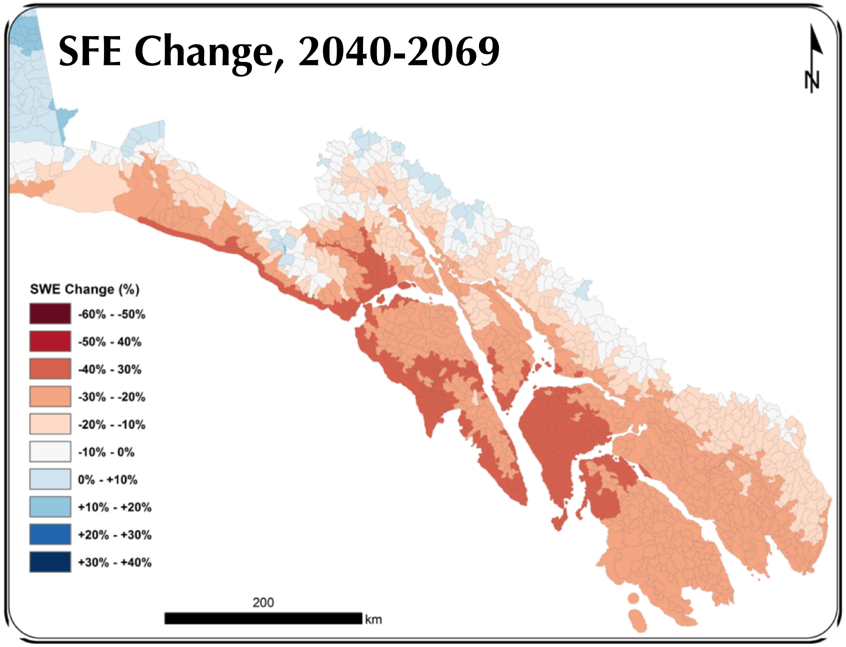
Models generally agree quite well on the sign and even magnitude of changes in characteristic geographical patterns: high latitudes, equator, and in parts of the mid latitudes between 10 and 30 N,S.

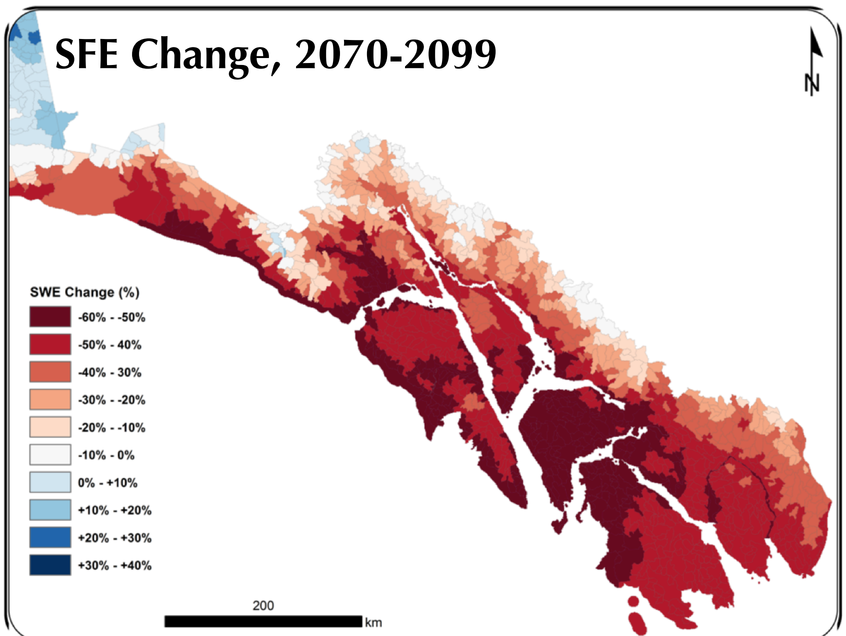
In between, there is considerable disagreement on sign and timing of changes

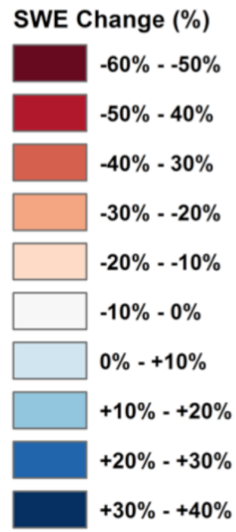
For summer, Southeast Alaska is on one of these transitions.



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







TWO kinds of snowdrought –

Less snow, more rain

-or-

Earlier melt

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)

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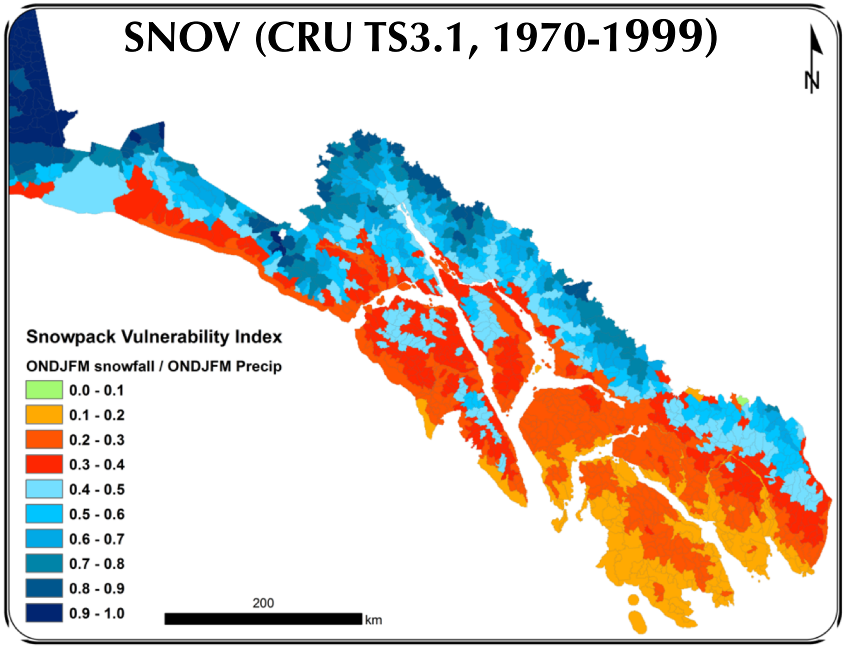
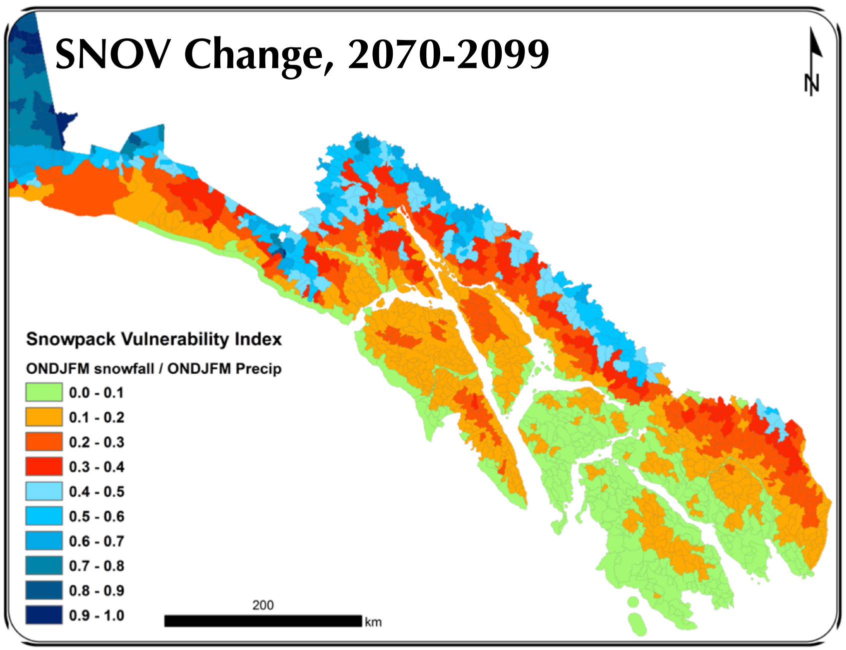
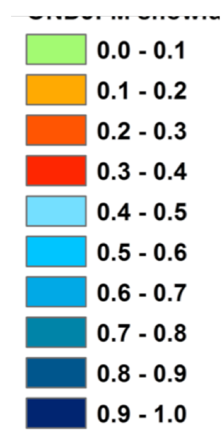
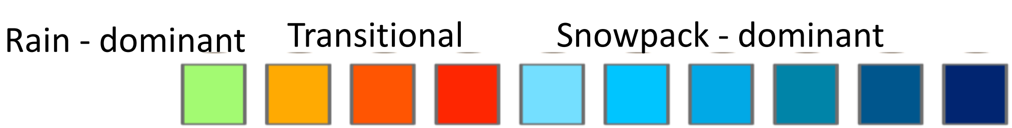
The amount of water in snowpack ~ April 1 has a lot to do with the seasonal timing of runoff.









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

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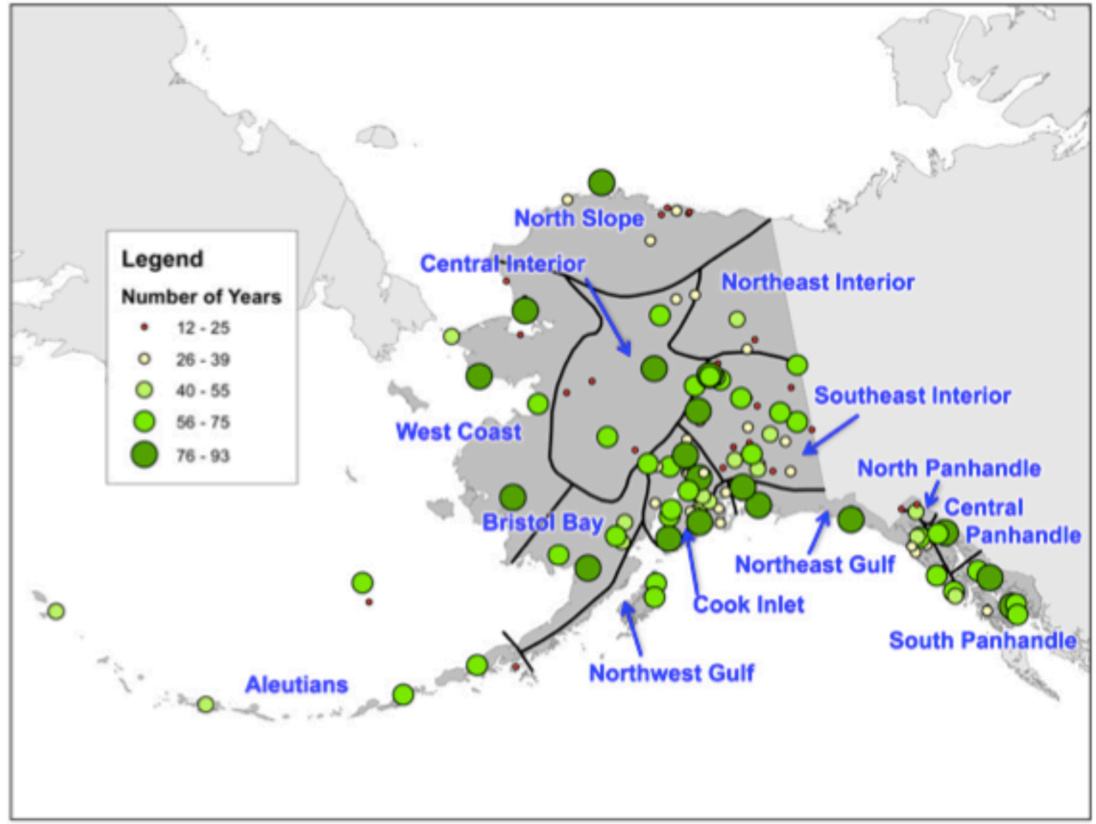
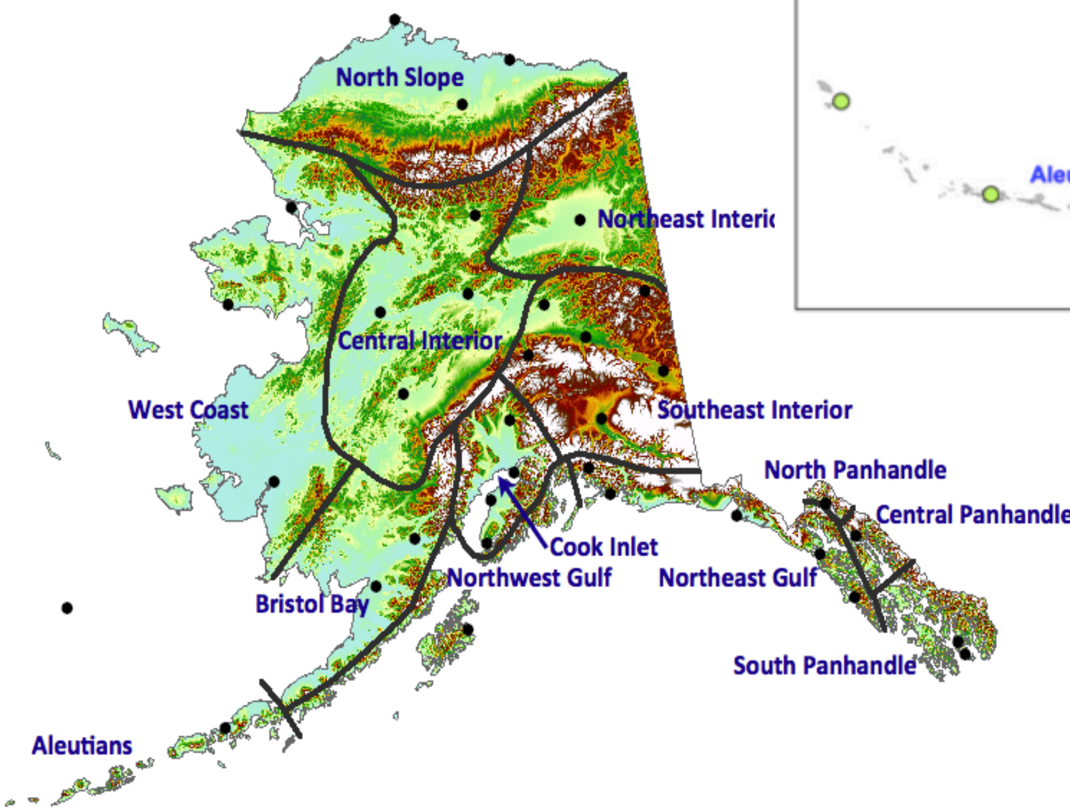
There are as many high quality weather stations in Alaska as in Michigan, but Alaska is about 7 times the size.





- 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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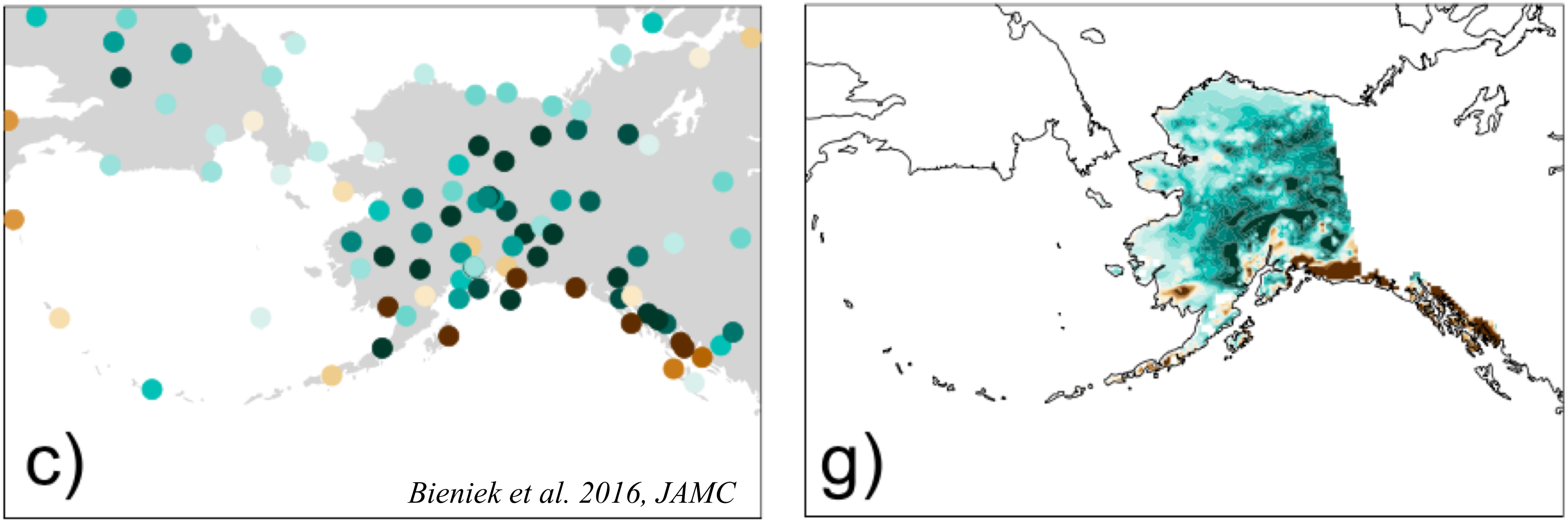
Dynamical downscaling

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.

Current work at 4km: ask Rick Lader!

Some strategies for USING climate projections

- Let the decisions and planning you need to do guide your use of projections, not the other way around.
- Don't wait for better projections – *you'll always be waiting*!
- Realize scenarios are not forecasts and we won't know exactly what the future will be until we get there!
- We know the future won't look exactly like any of the scenarios, but it ***will*** look a lot like some of them
- Plan for the projected conditions, but also plan for surprises, ***especially extremes***.

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jlittell@usgs.gov
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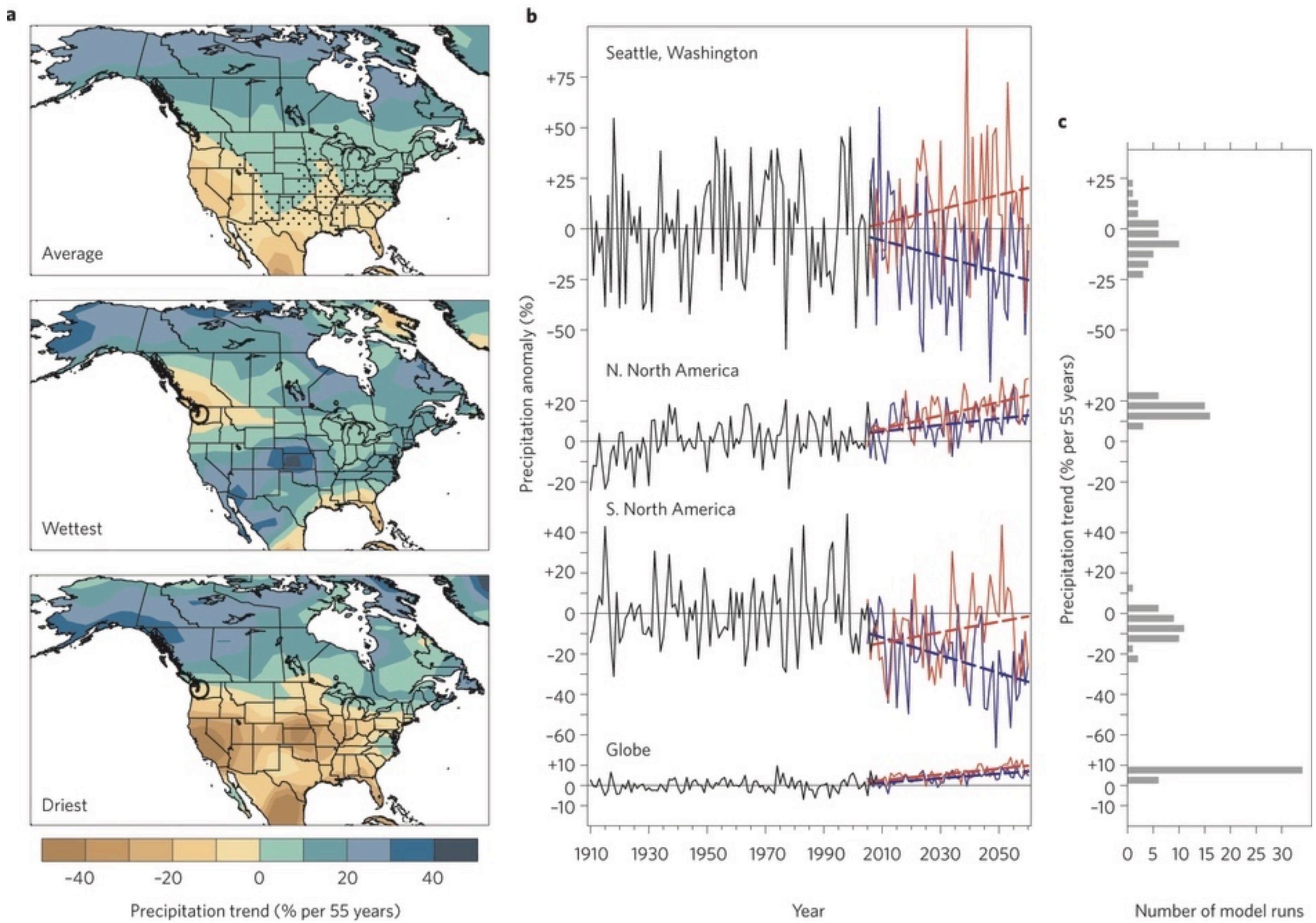
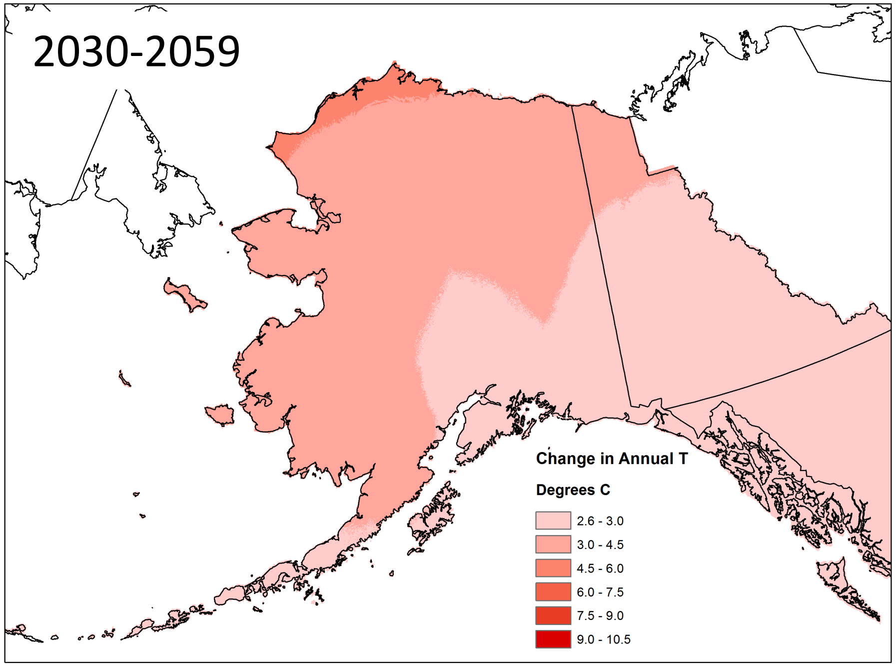
Model uncertainty and Internal variability

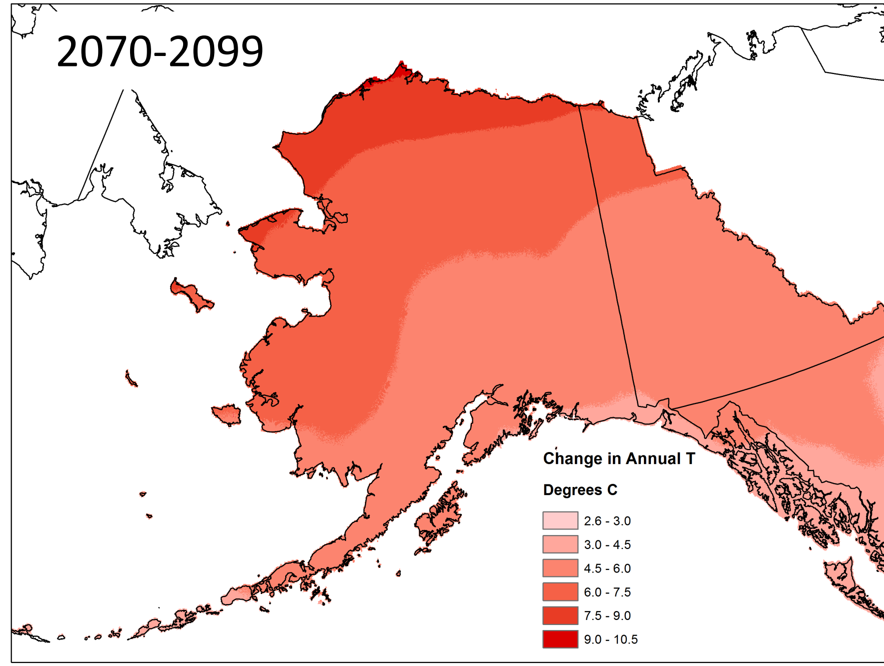


40 simulations of the same GCM (CCSM3, A1B), with same initial ocean, land and sea ice but different atmospheric conditgions sampled from 20th century model run, Dec1999-Jan2000

Deser et al. 2012, Nature Climate Change

Climate projections: temperature





CMIP 5, RCP 8.5

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.

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

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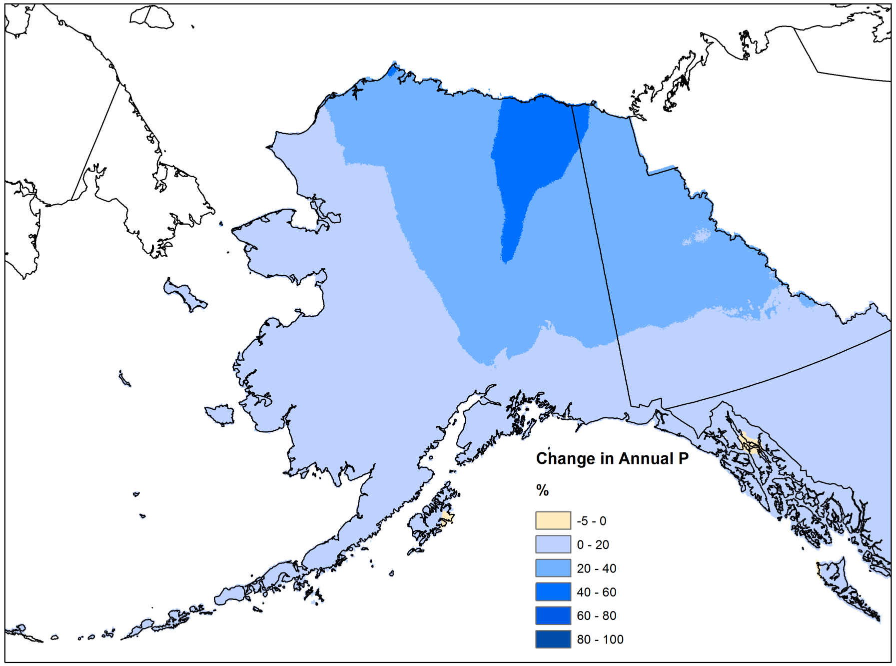
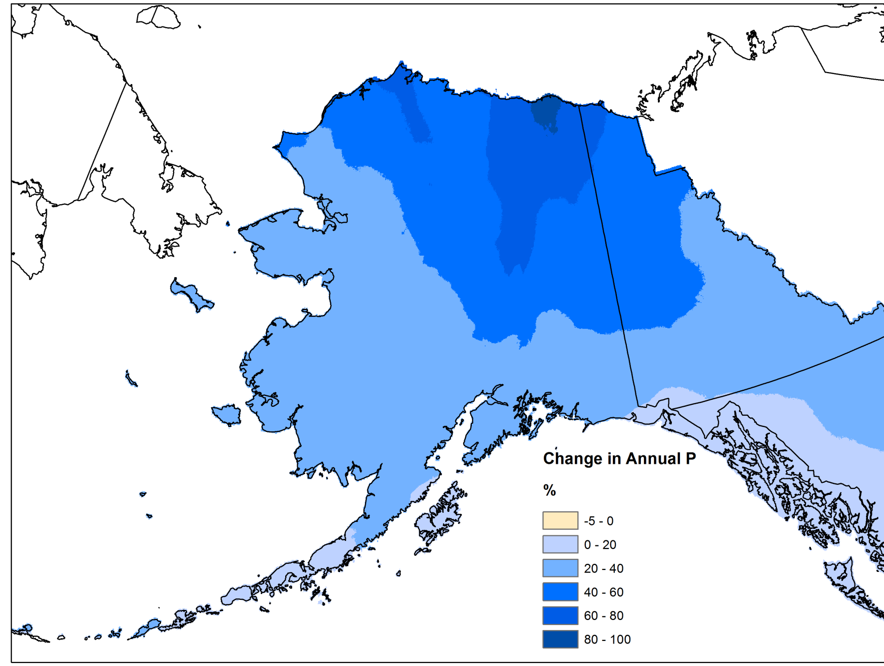
Climate projections: precipitation





CMIP 5, RCP 8.5

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.

%

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

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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.

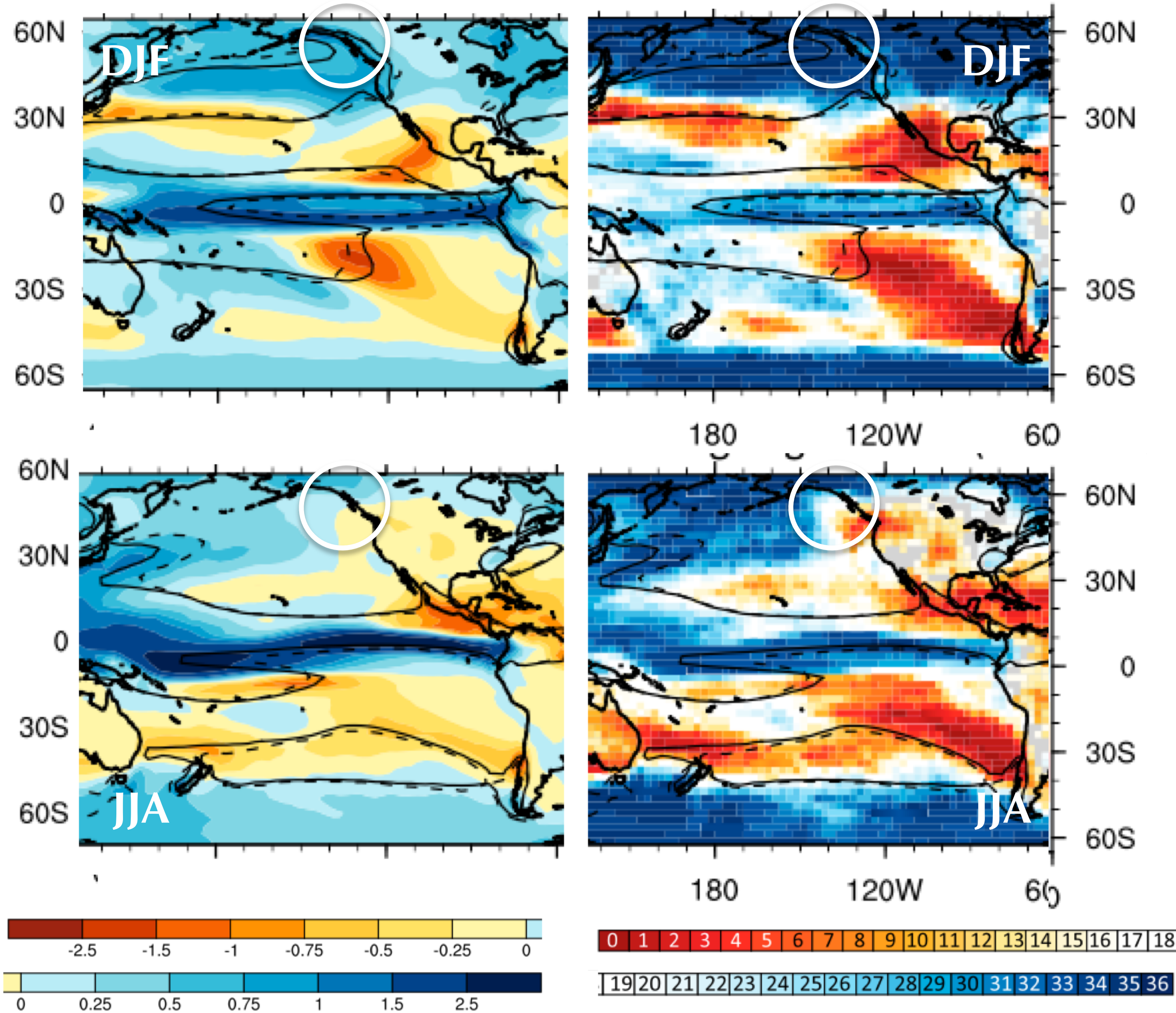
Right: projected annual and seasonal deltas (1970-99 baseline) for temperature and precipitation in the Tongass region (SE AK) derived from SNAP projections. Values are five-model means (CCSM4, GFDL3, CGCM3, GISS2, IPSL5). 2020s – 2010-2039; 2040s – 2030-2059; 2080s – 2070-2099.

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%	



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