An Update on Snowpack Projections for Alaska: Chugach Results

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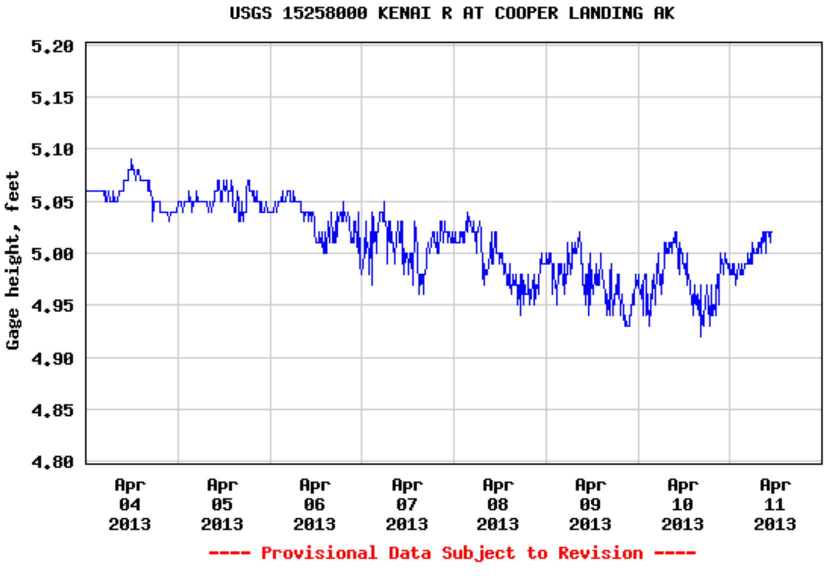
Why snow? That depends….

http://www.fs.usda.gov/detail/chugach/about-forest/districts/?cid=stelprdb5052473



http://waterdata.usgs.gov/ak/nwis/uv?site_no=15258000

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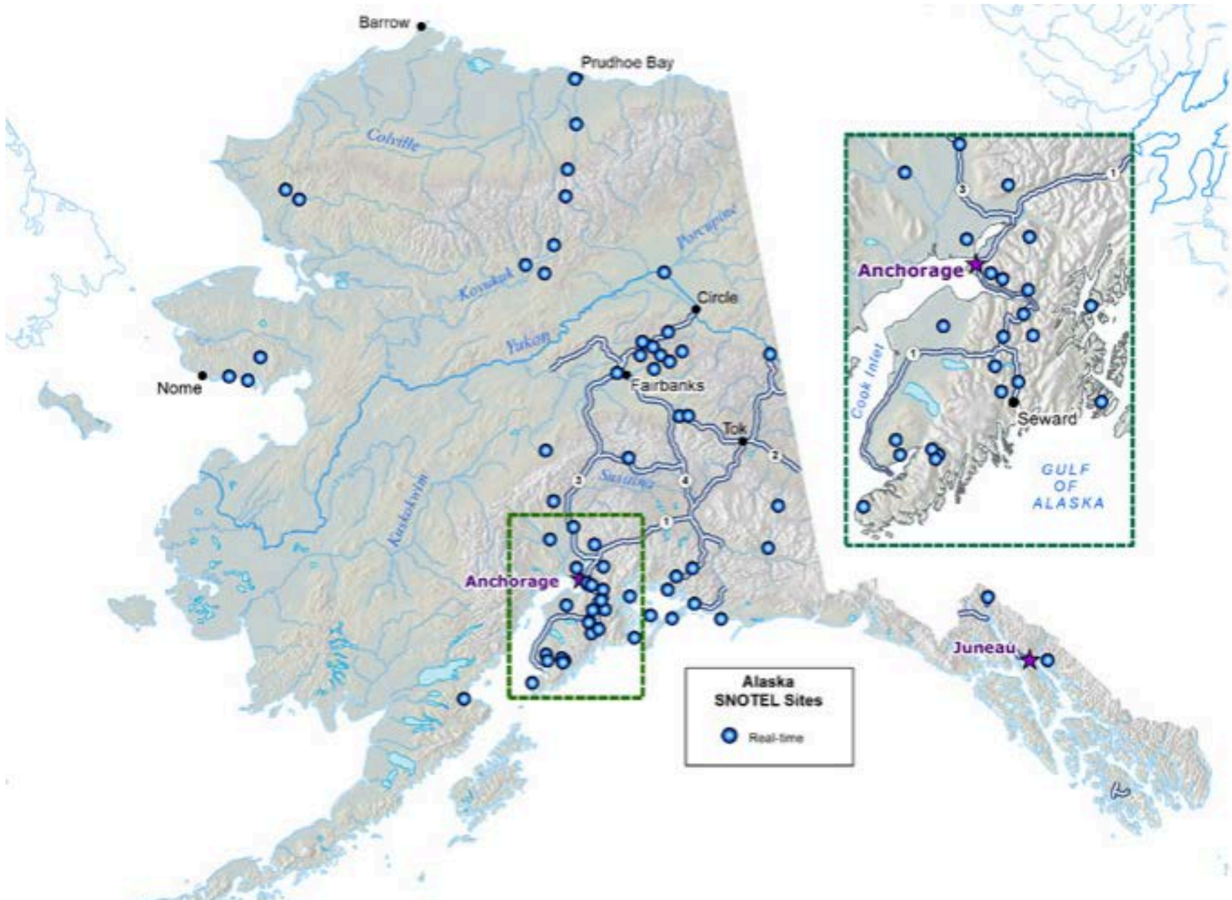
What do we know about historical snow pack?



http://www.wcc.nrcs.usda.gov/snotel/Alaska/alaska.html

SNOTEL (NRCS) data = paired temperature, precipitation, snow water and depth, but only back to 1980 in the best cases, more often 1990s or even 2000s, and limited distribution

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What do we know about historical snow pack?

Geographic Information Network of Alaska

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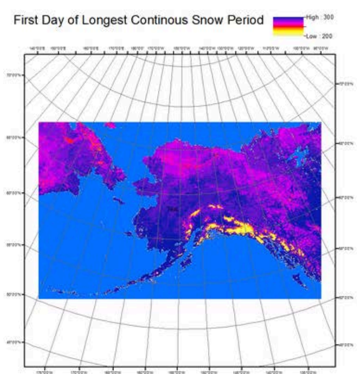
MODIS-derived Snow Metrics

Summary

The National Park Service and Geographic Information Network of Alaska (GINA) are developing an algorithm to derive snow cover climatology for Alaska using the MODIS snow cover daily product.

The algorithm is two-fold and involves both data processing and the derivation of snow cover metrics. Terra MODIS snow cover daily 500m grid data (MOD10A1) are processed to reduce cloud obscuration through iterations of cloud reduction methods that include spatial, temporal, and snow cycle filtering. A total of 12 metrics (e.g. date of first snow, date of persistent snow cover) for each pixel are calculated.



Data Sources

The MODIS Terra Snow Cover Daily L3 Global 500m Grid data (MOD10A1) from the National Snow and Ice Data center (NSIDC) is used to calculate the snow metrics.

The data files can be downloaded from ftp://n4ftl01u.ecs.nasa.gov/SAN/MOST/MOD10A1.005/

The MOD10A1 data contains snow cover, snow albedo, fractional snow cover, and Quality Assessment (QA) data along with corresponding metadata. It consists of 1200 km by 1200 km tiles of 500 m resolution data gridded in a sinusoidal map projection. For our purposes, we downloaded 24 tile files covering the Alaska region, created a mosaic, reprojected them into the Alaska

Product Details

Now 2001 to 2012 snow year metrics are provided through the WCS.

Snow metrics WCS URL: http://snow.proto.gina.alaska.edu/metrics?

Snow-metrics data file defines the following 12 snow metrics:

1. first_snow_day, first day of the full snow season (FSS start day)
2. last_snow_day, last day of the full snow season (FSS end day)
3. fss_range, last_snow_day-first_snow_day +1
4. longest_css_first_day, first day of the longest CSS segment (CSS start day)
5. longest_css_last_day, last day of the longest CSS segment (CSS end day)
6. longest_css_day_range, longest_css_last_day-longest_css_first_day +1
7. snow_days, the number of snow days
8. no_snow_days, the number of no snow days
9. css_segment_num, the number of CSS segments
10. mflag, pixel type (ocean, land, or lake/inland water) and type of snow (no snow, broken snow, or continuous snow)
11. cloud_days, number of cloud days
12. tot_css_days, total number of all days within CSS segments

http://www.gina.alaska.edu/projects/modis-derived-snow-metrics

Zhu (GINA) and Lindsay (NPS) et al. derived snow products from remotely sensed data: Wall to wall snow metrics for Alaska, but short duration (2001-2012).

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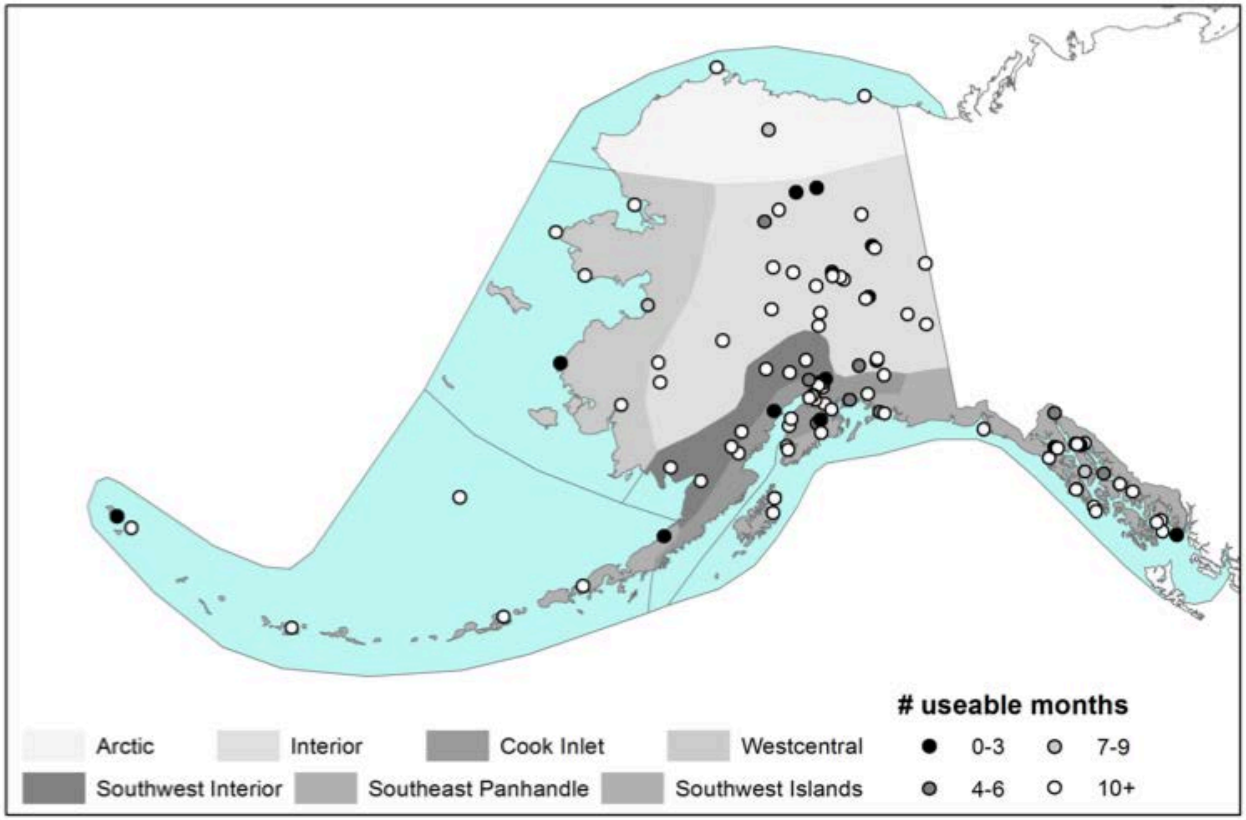
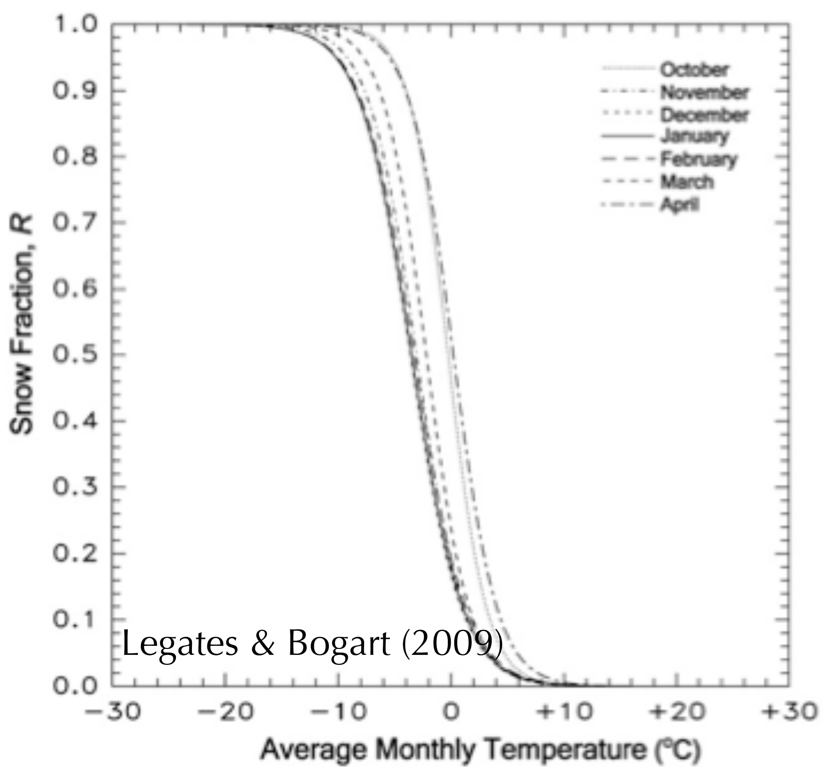
What do we know about historical snow pack?

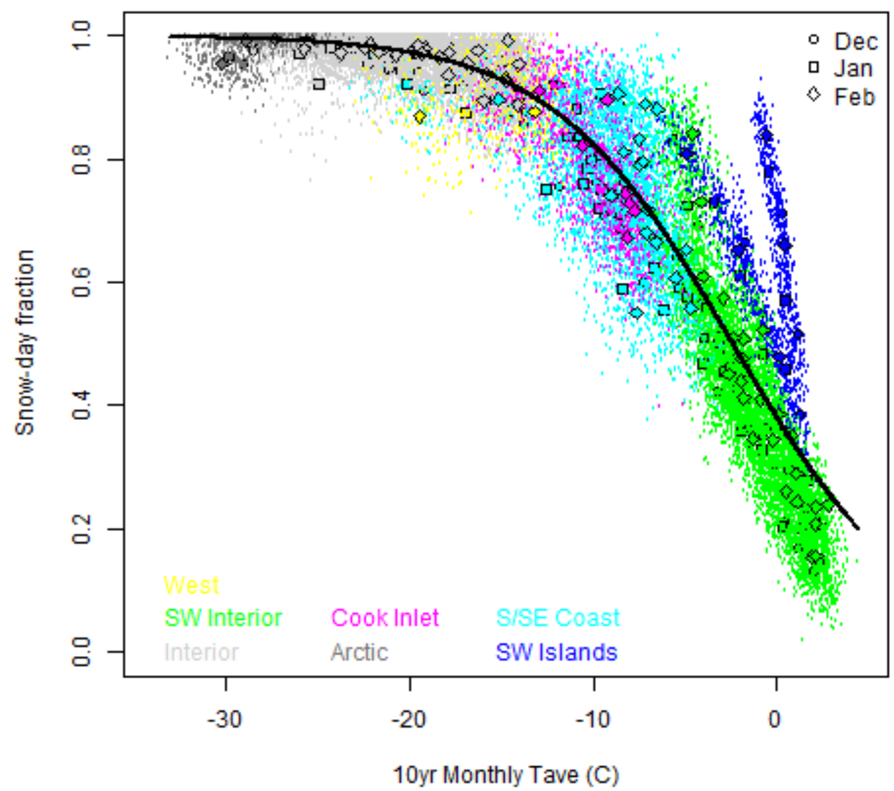


McAfee, Walsh, and Rupp. In press. STATISTICALLY DOWNSCALED PROJECTIONS OF SNOW/RAIN PARTITIONING FOR ALASKA.

For long term snow climatology, weather station data are still the best we have. Even those have data quality and length-of-record issues that need to be carefully evaluated. McAfee et al. have done that for purposes of a first-order snow product

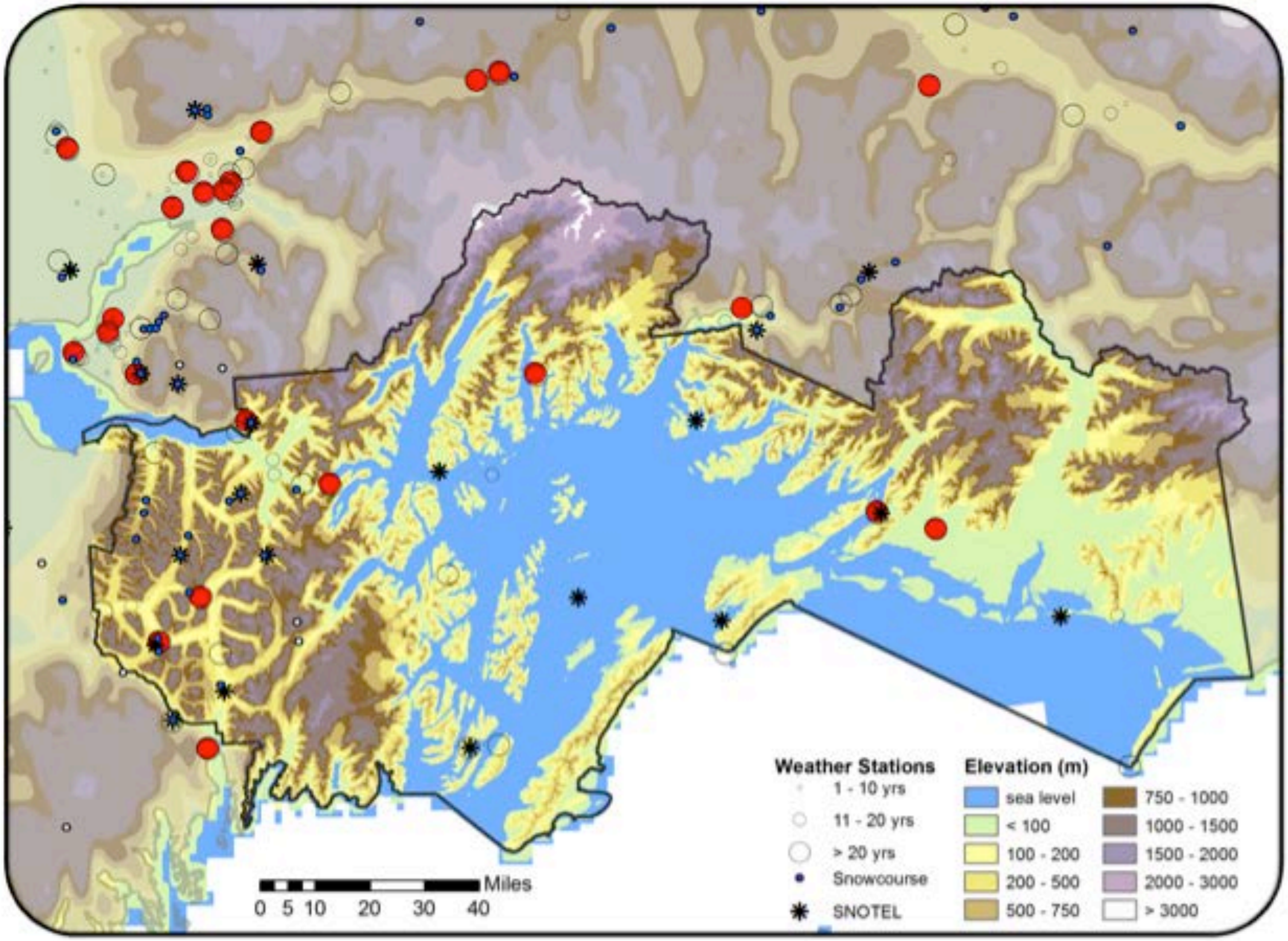
We use a statistical method relating decadal average snow fraction to decadal average monthly temperature.





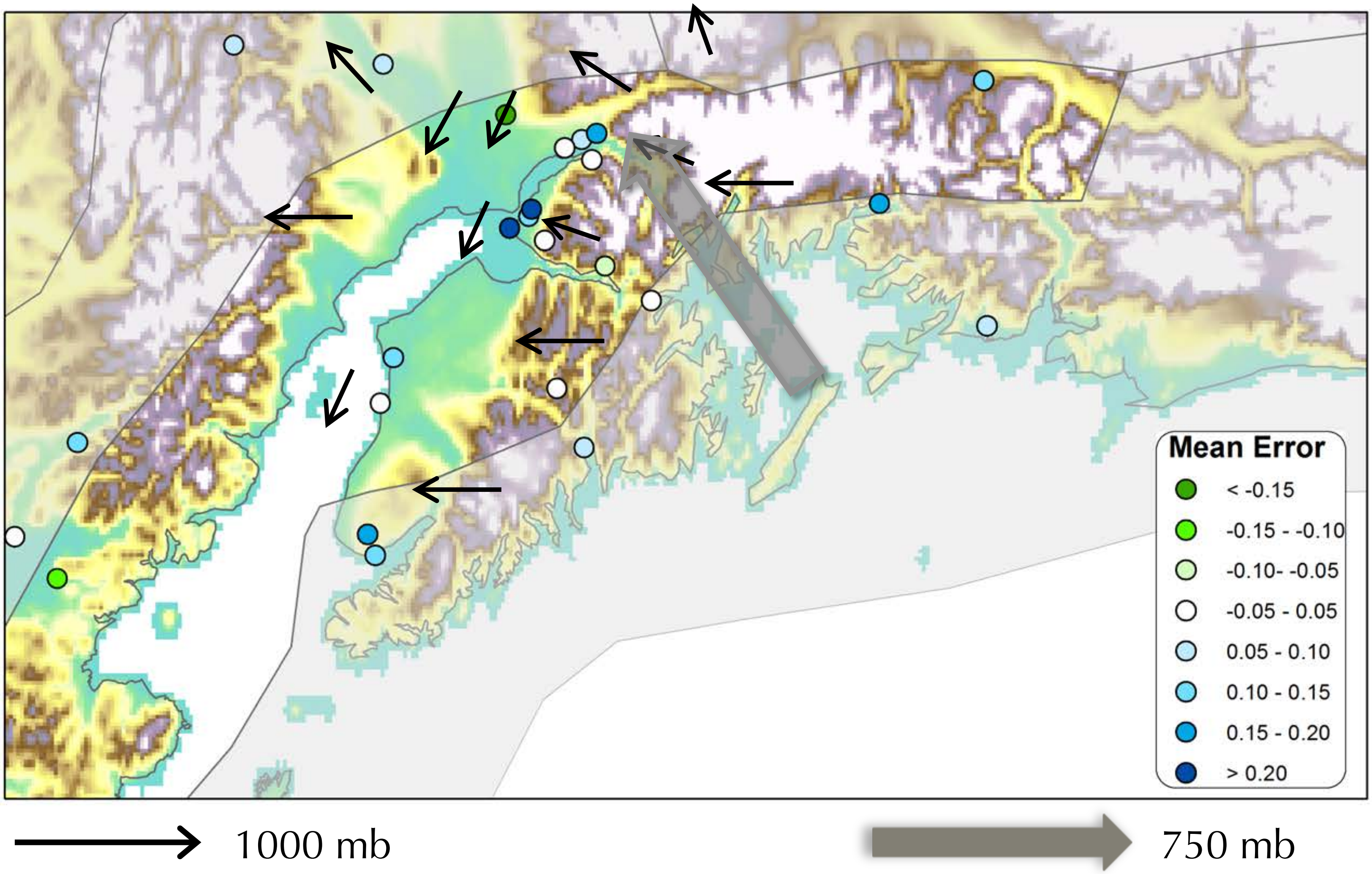
Slide: S. McAfee

Chugach stations



Map: S. McAfee

April – Cook Inlet



Slide: S. McAfee

Conclusions

- Decadal average monthly snow fraction.
  - 771-m. resolution
  - Historical (1900 – 2009)
  - A1B and A2 scenarios (2010 – 2099)
  - 5 models
- Suitable for scenario-planning exercises.
- Suggests increasing spring rain-on-snow events in western Alaska.
- Suggests that really understanding future snow in south-central and southeastern Alaska may require dynamical downscaling.

Slide: S. McAfee

SNAP

Historical Decadal Averages Of Monthly Snow-day Fraction 771m CRU TS 3.1

These snow-day fraction estimates were produced by applying equations relating decadal average monthly temperature to snow-day fraction to downscaled decadal average monthly temperature. Separate equations were used to model the relationship between decadal monthly average temperature and the fraction of wet days with snow for seven geographic regions in the state: Arctic, western Alaska, Interior, Cook Inlet, SW Islands, SW Interior, and the Gulf of Alaska coast.

Although the equations developed here provide a reasonable fit to the data, model evaluation demonstrated that some stations are consistently less well described by regional models than others. It is unclear why this occurs, but it is like related to localized climate conditions. Very few weather stations with long records are located above 500m elevation in Alaska, so the equations used here were developed primarily from low-elevation weather stations. It is not clear whether the equations will be completely appropriate in the mountains. Finally, these equations summarize a long-term monthly relationship between temperature and precipitation type that is the result of short-term weather variability. In using these equations to make projections of future snow, as assume that these relationships remain stable over time, and we do not know how accurate that assumption is.

Read the user's guide for this data set (PDF, 1.5MB) for information on methodology and validation.

Baseline Reference Climate	1971-2000 PRISM
Spatial Resolution	771m
Temporal Resolution	Monthly
Spatial Extent	Alaska

Data

1910-2009 (250MB)

Data

Model	Data
cccma_cgcm31	2010-2099 (479 MB)
gfdl_cm2_1	2010-2099 (491MB)
miroc3_2_medres	2010-2099 (461MB)
mpi_echam5	2010-2099 (476MB)
ukmo_hadcm3	2010-2099 (470MB)

Metadata by product

Metadata: Historical Decadal Averages Of Monthly Snow-day Fraction 771m CRUTS3.1

http://www.snap.uaf.edu/data.php#dataset=historical_monthly_snow_day_fraction_771m

http://www.snap.uaf.edu/files/data/snow_day_fraction/snow_fraction_data_users_guide.pdf

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Snow-day fraction to SWE

- For each month and each decade, snowday fraction x precipitation gives an upper bound for snow water equivalent. 771m cells.
- Does not account for melt, re-distribution, sublimation.
- Mid-century medium- to high-impact focus, so A1B emissions
- 30yr average to minimize effect of decadal variability
- Five GCM composite and multi-model bracketing to minimize effect of model error

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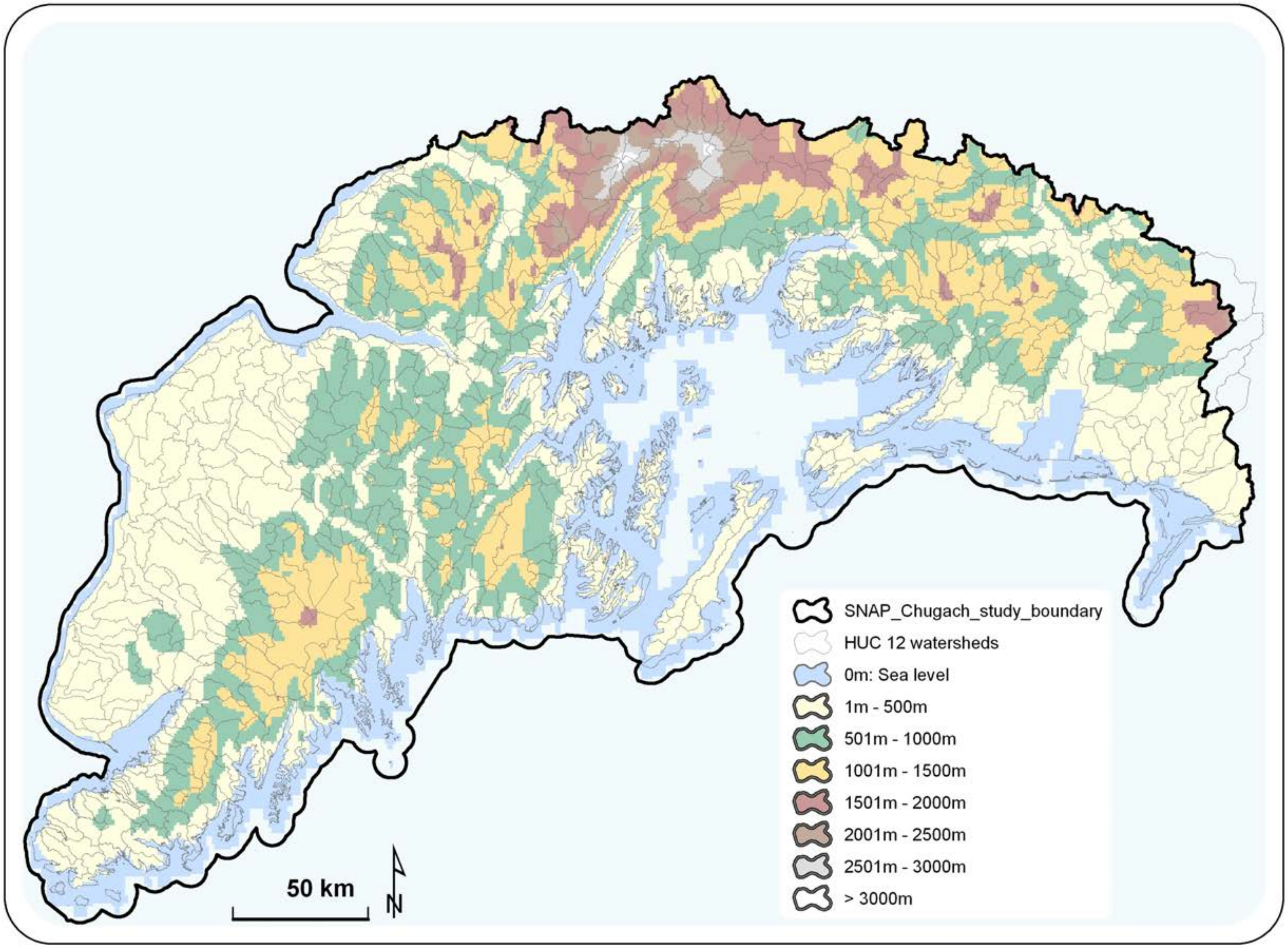
Chugach Results, but have run complete statewide data



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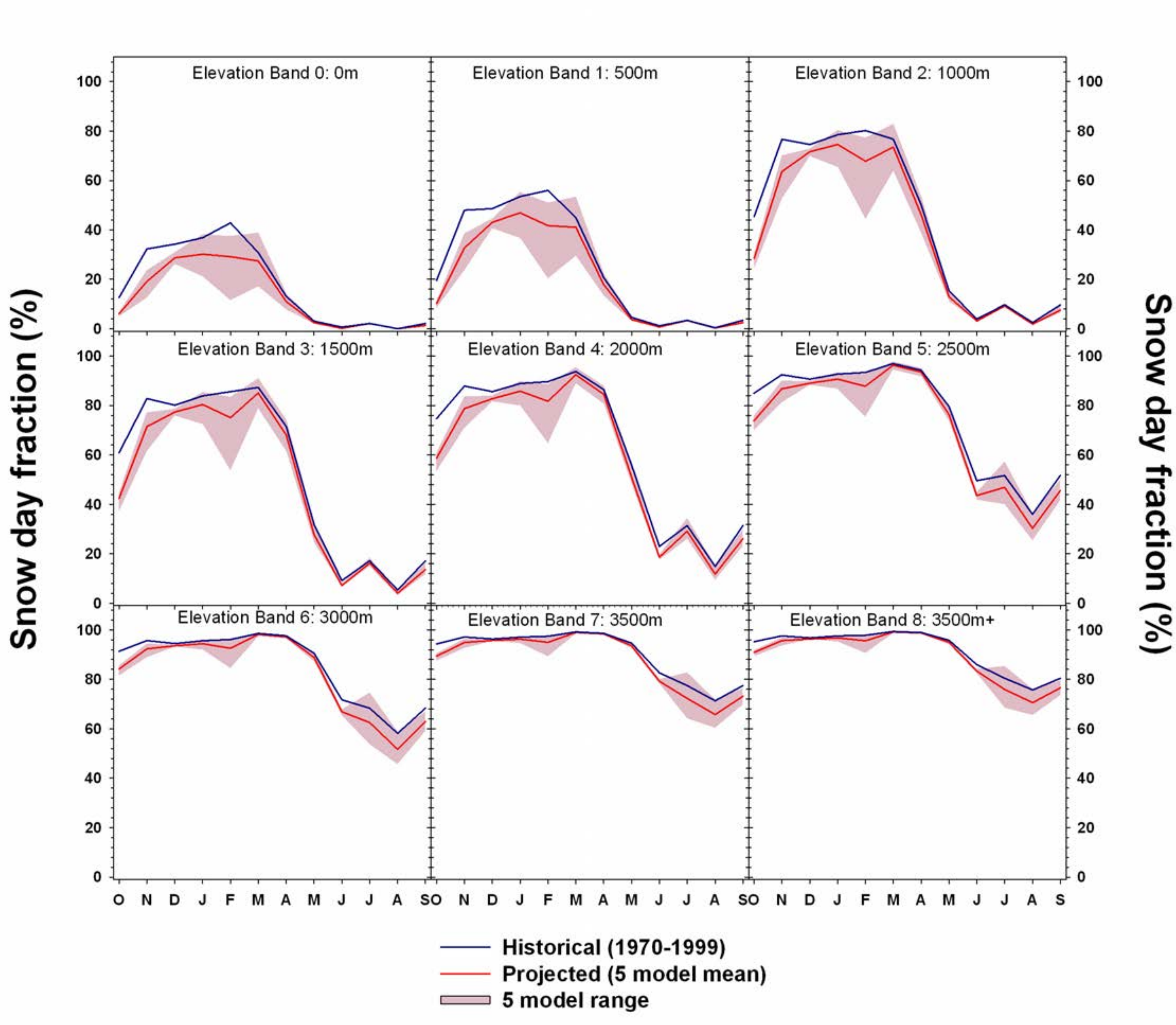
2040s changes in snow-day fraction: by elevation



Decreases at all elevations in Oct, Nov.

Below 1000m, declines in all cool season months, but also variable across models.

At highest elevations, declines in warm season, esp. late fall and summer.

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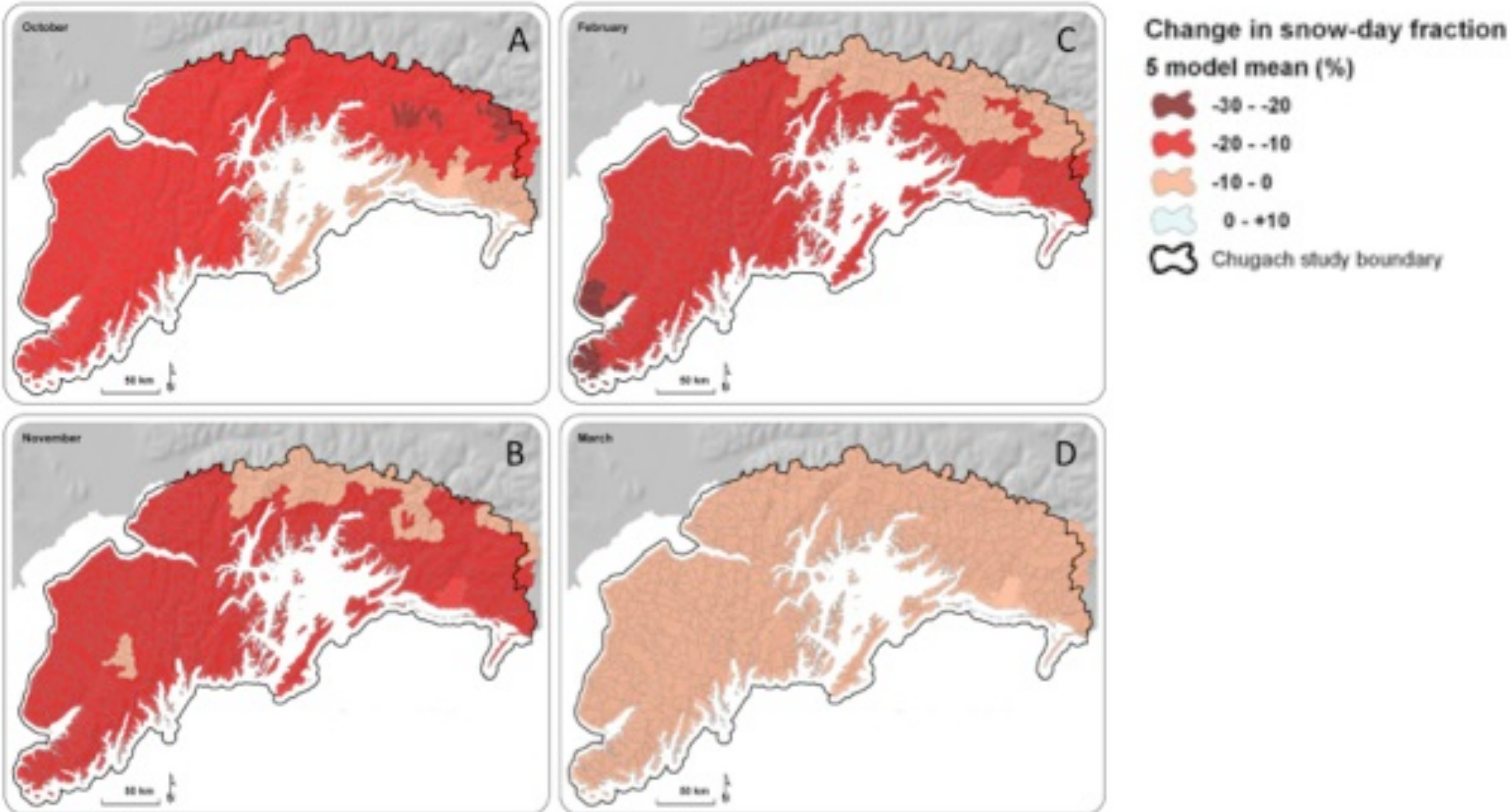
2040s changes in snow-day fraction: A1B composite



Decreases at all elevations (0 to 30%), but variable responses.
Most interesting changes: October, November, and February.
Different responses by elevation and proximity to open ocean.

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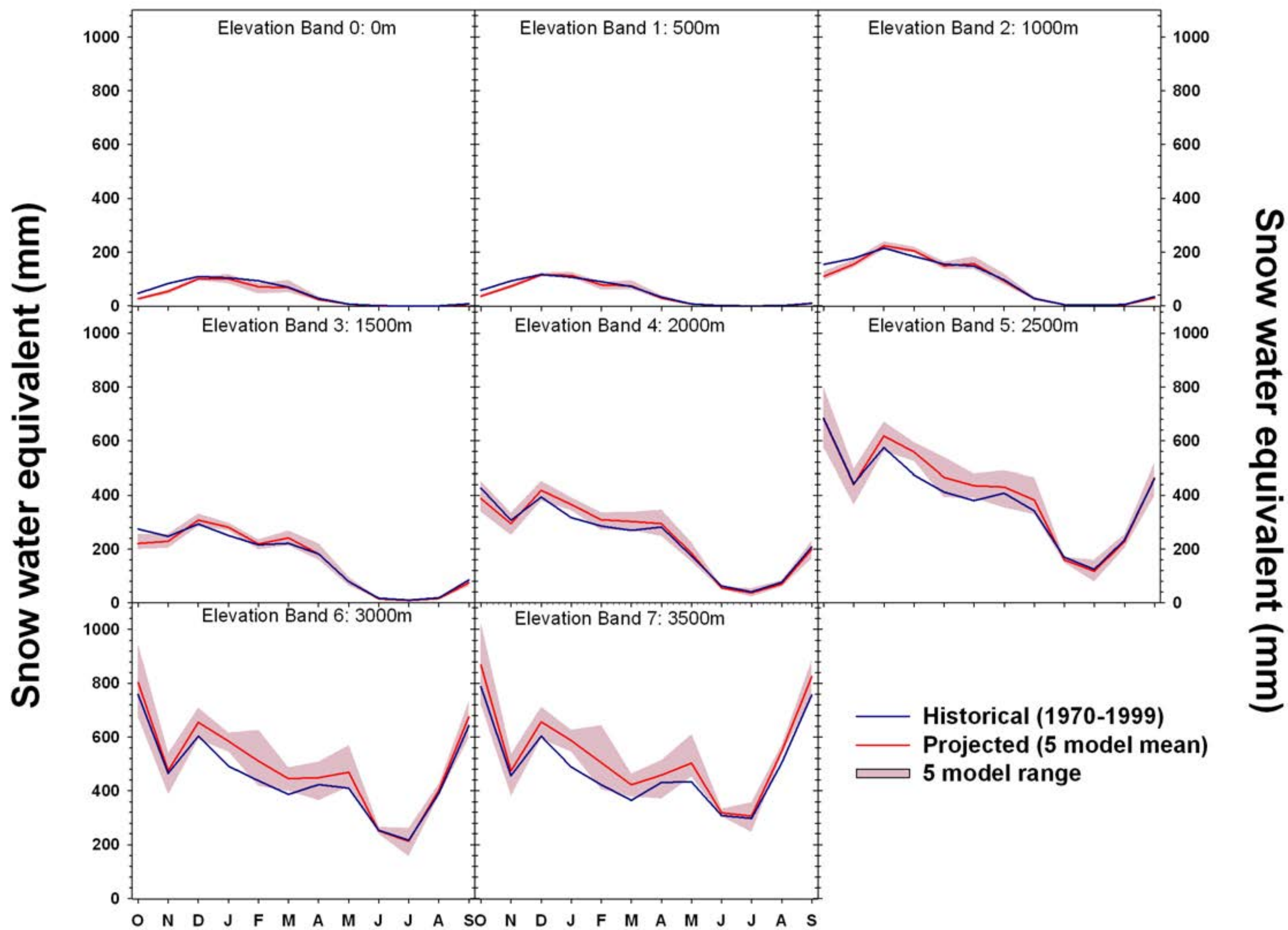
2040s changes in SWE: by elevation



Decreases at elevations <1000m in Oct, Nov.

At highest elevations, increases, especially in winter, some substantial in terms of total water

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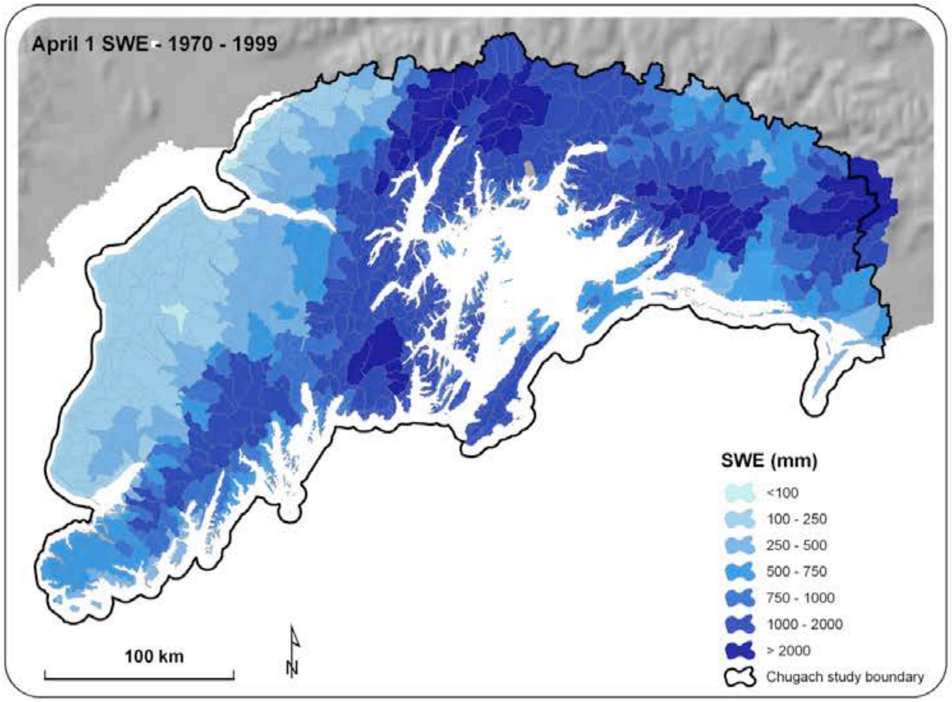
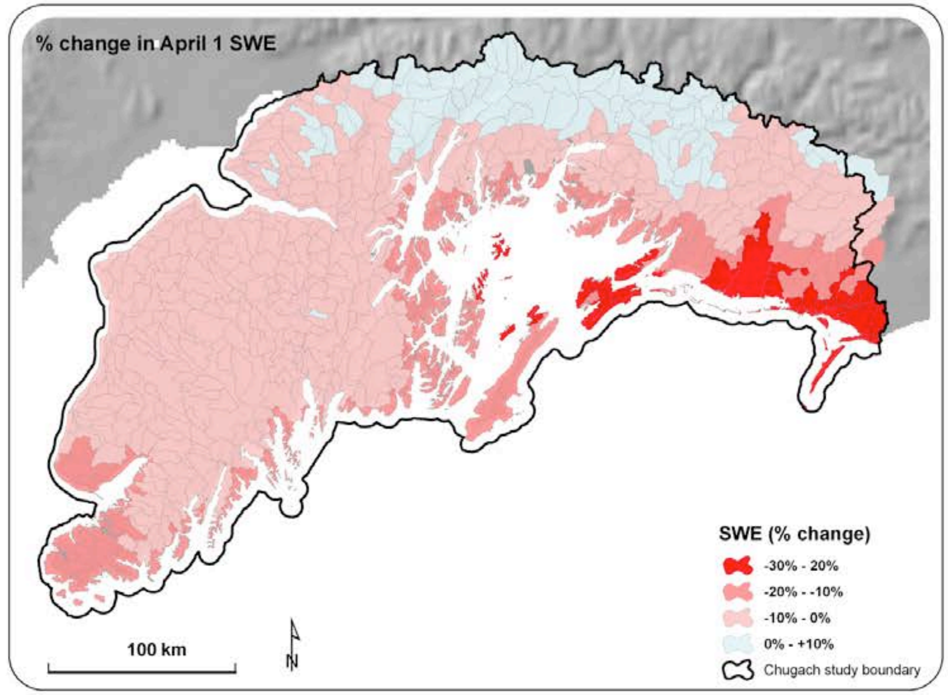
2040s changes in April 1SWE: A1B composite





Decreases at lower elevations (0 to 30%), but increases (0 to +10% at highest elevations.

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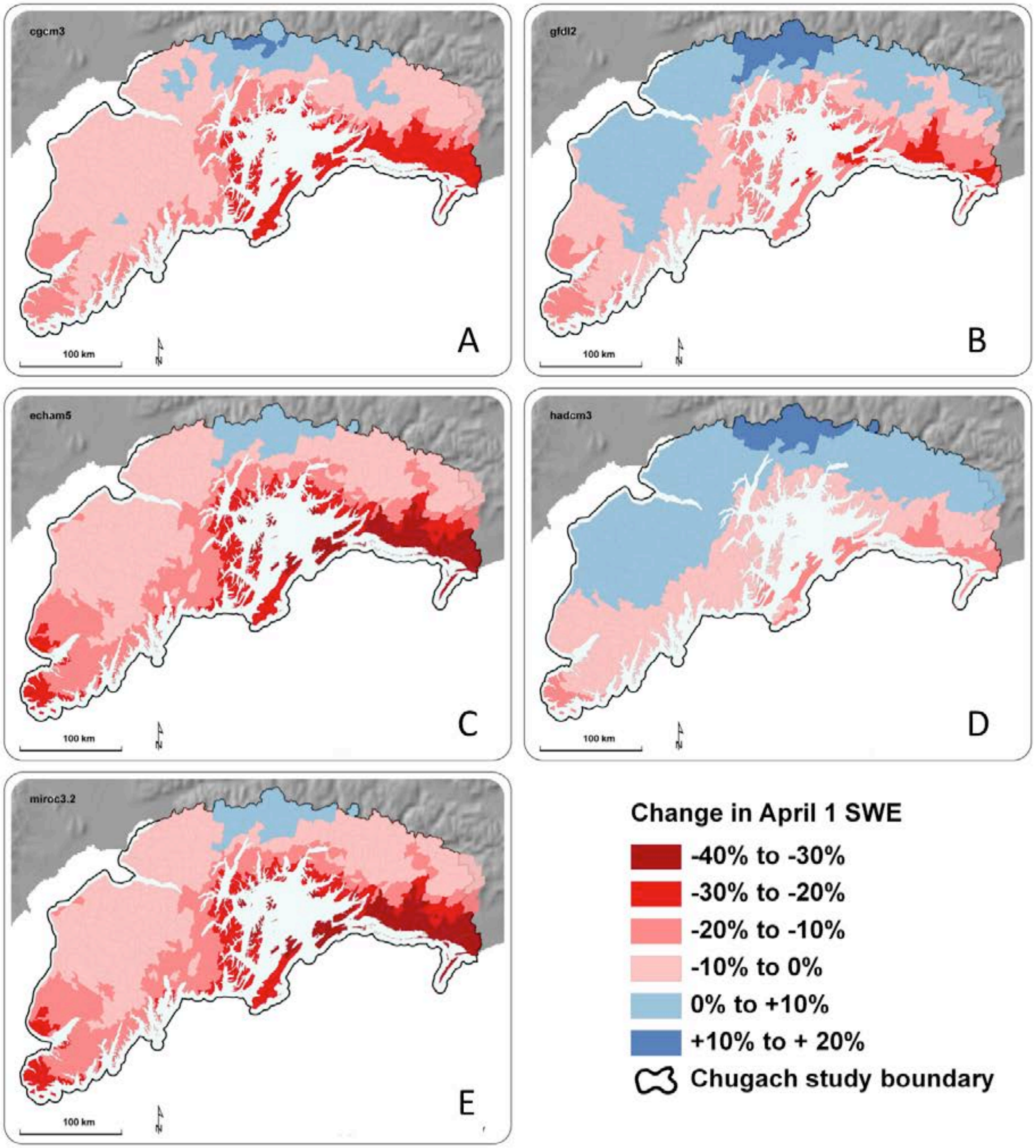
Model range of SWE changes



HadCM3 and GFDL2 (right) have similar patterns, as do CGCM3, ECHAM5, and MIROC3.2. Note that this ECHAM picture is not correct…

Models agree on general pattern of most SWE decrease and most SWE increase, but in range of 0-10%, they don't agree, particularly over the northwestern Kenai Peninsula.

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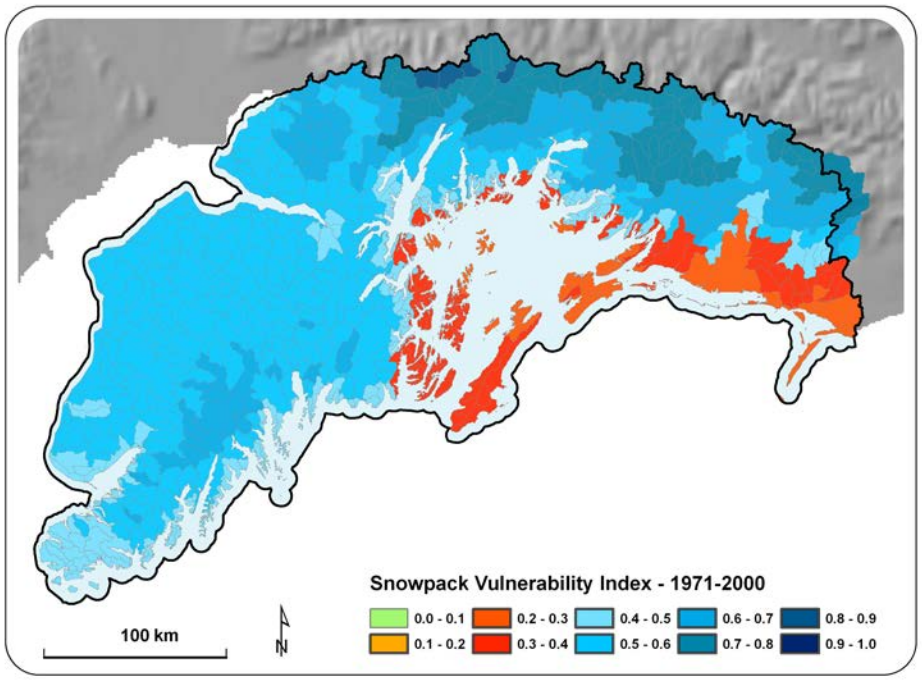
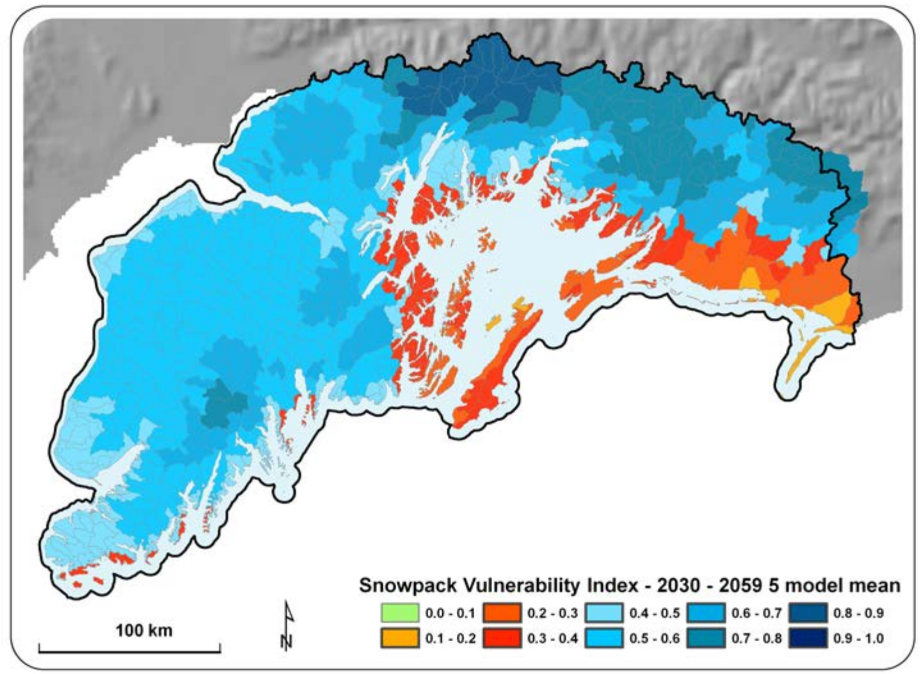
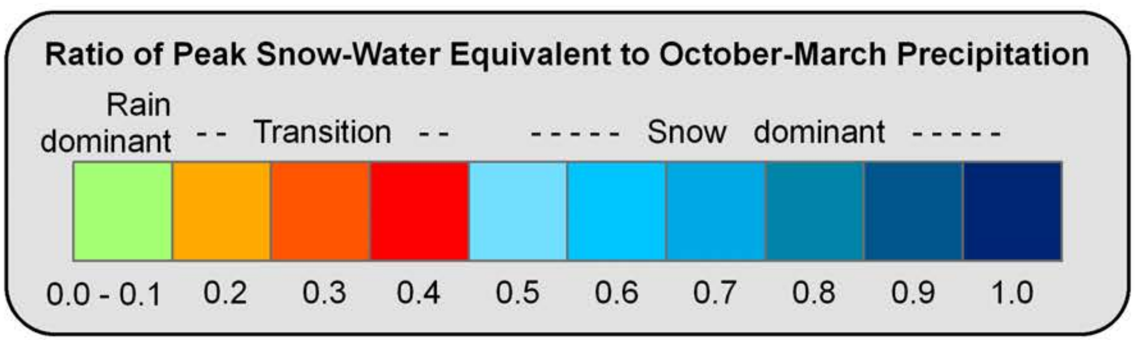
Snowpack vulnerability index

Fraction of October to March precipitation entrained in April 1 SWE (Hamlet et al. definition)







Legend: R. Norheim, Climate Impacts Group, University of Washington

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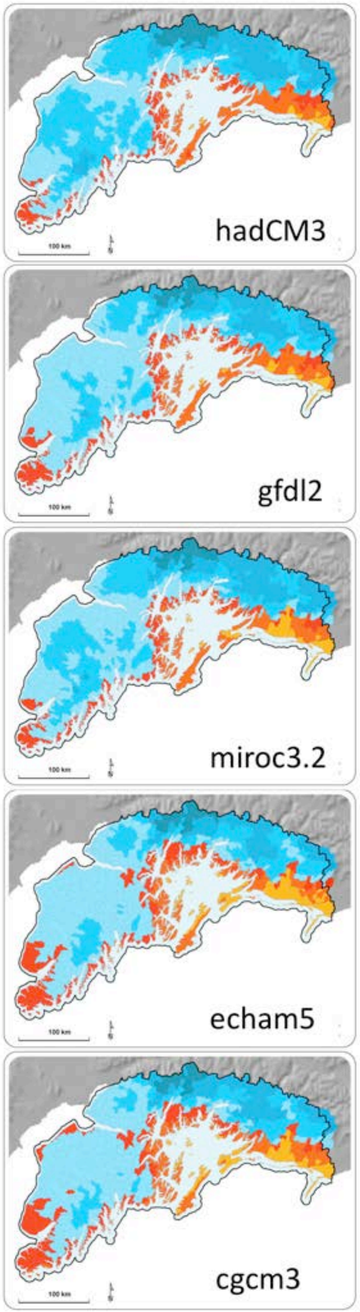
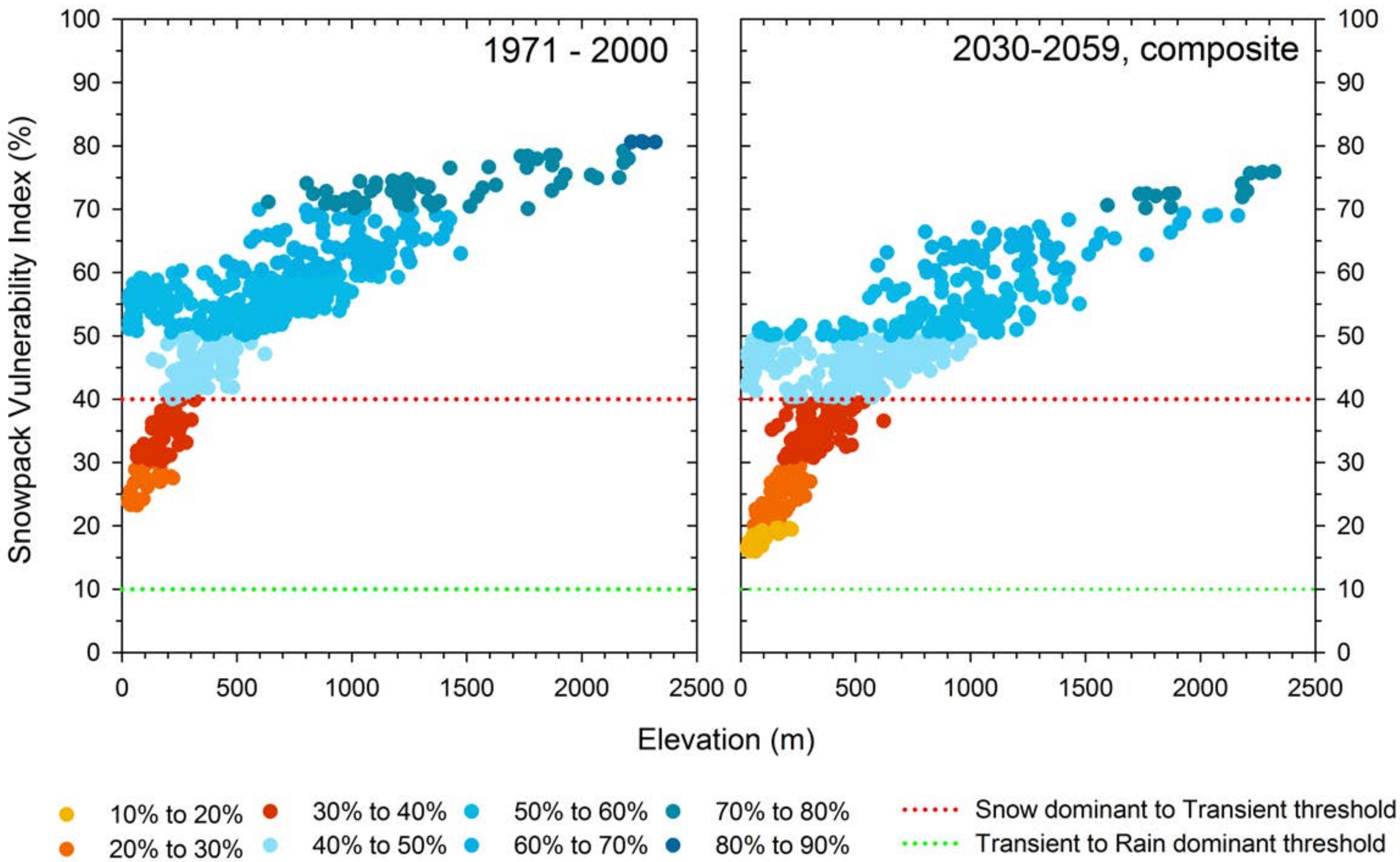
General agreement across climate models…..but timing of changes later will be key difference





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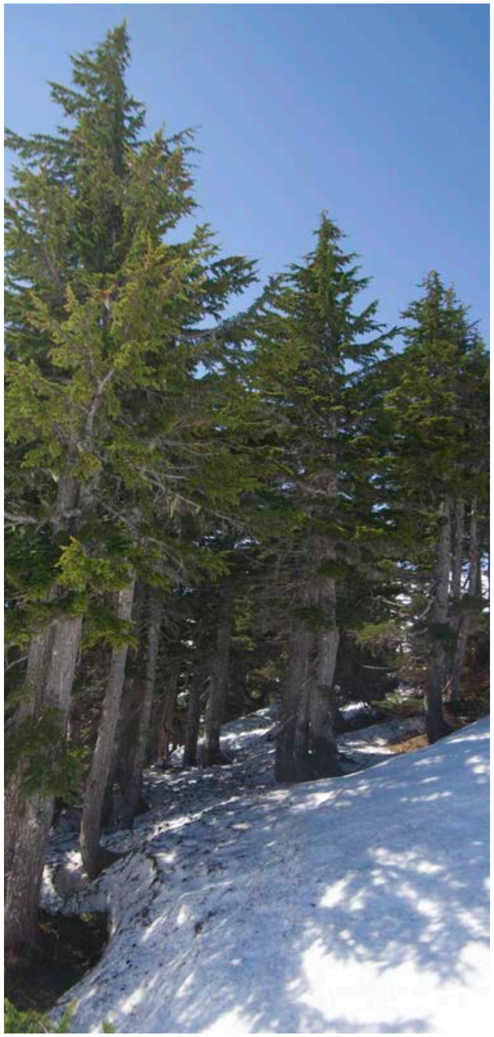
Conclusions

- From October to March and between sea level and 500m, the five GCM mean projects a **23% decrease from historical in the number of precipitation days that fall as snow.**
- SWE is projected to decline most in the autumn (October and November) and at lower elevations (less than 1500m), an average of -26% for the 2030-2059 period compared to 1971-2000.
- Compared to 1971-2000, in all future scenarios, there is a decrease in the percentage of the landscape that is snow dominant and, for the 2040s, an increase from 27% to 37% that is transient. Most of this change is at lower elevations.



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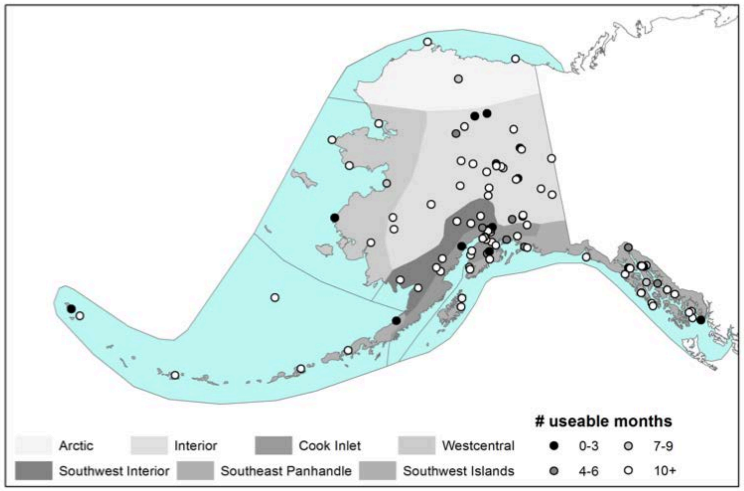
Some caveats and limitations



- Modeling based on snow fraction given temperature, and is assumed stationary in the future.
- Station data for modeling almost all from <500m, so higher elevation relationships may or may be different.
- PRISM, extreme coastal topography
- Inherits uncertainties of global climate models: climate variability, model error, and GHG forcing.

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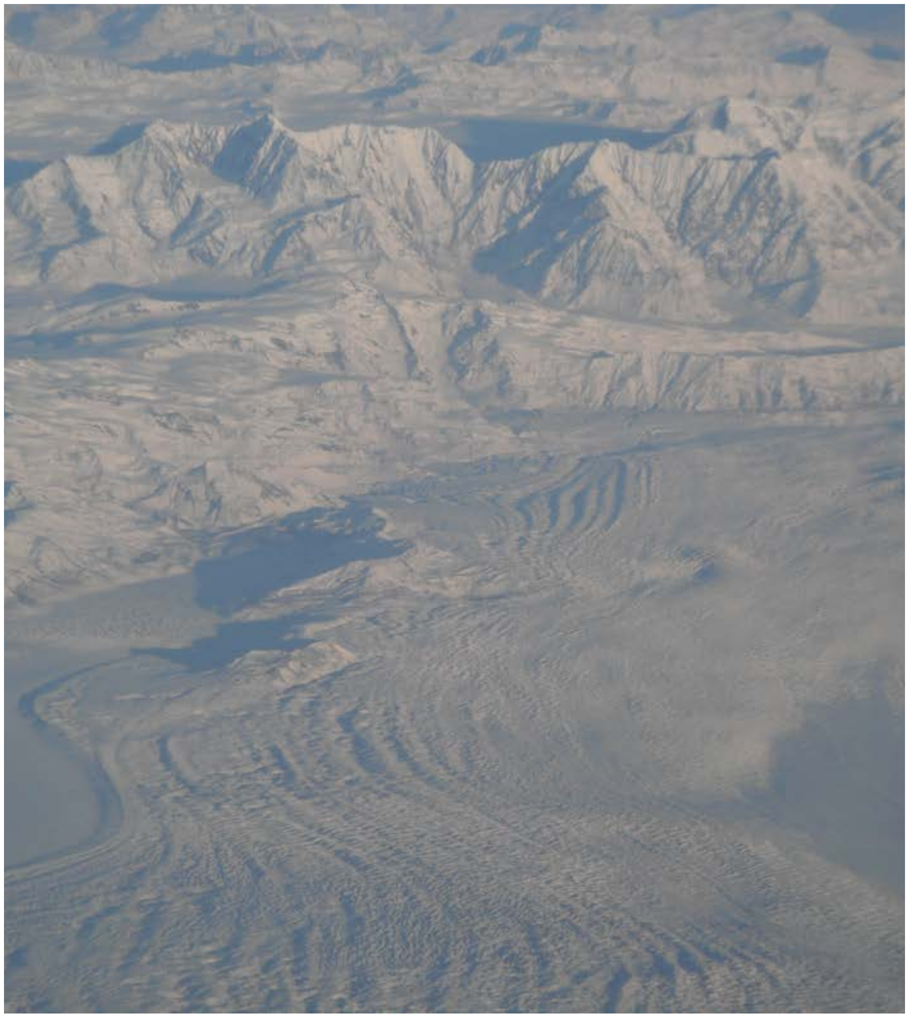
Next steps



- Validation of historical SWE and snowpack vulnerability index with independent data: SNOTEL
- Output generated for all of Alaska for A1B to 2100, but not yet summarized outside of Chugach for 2030-2059 or for A2
- CMIP5 / RCP possibilities through SNAP
- Regional climate modeling

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