Considerations in the prediction of regional Arctic climate change

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WCRP Workshop on Polar Predictability

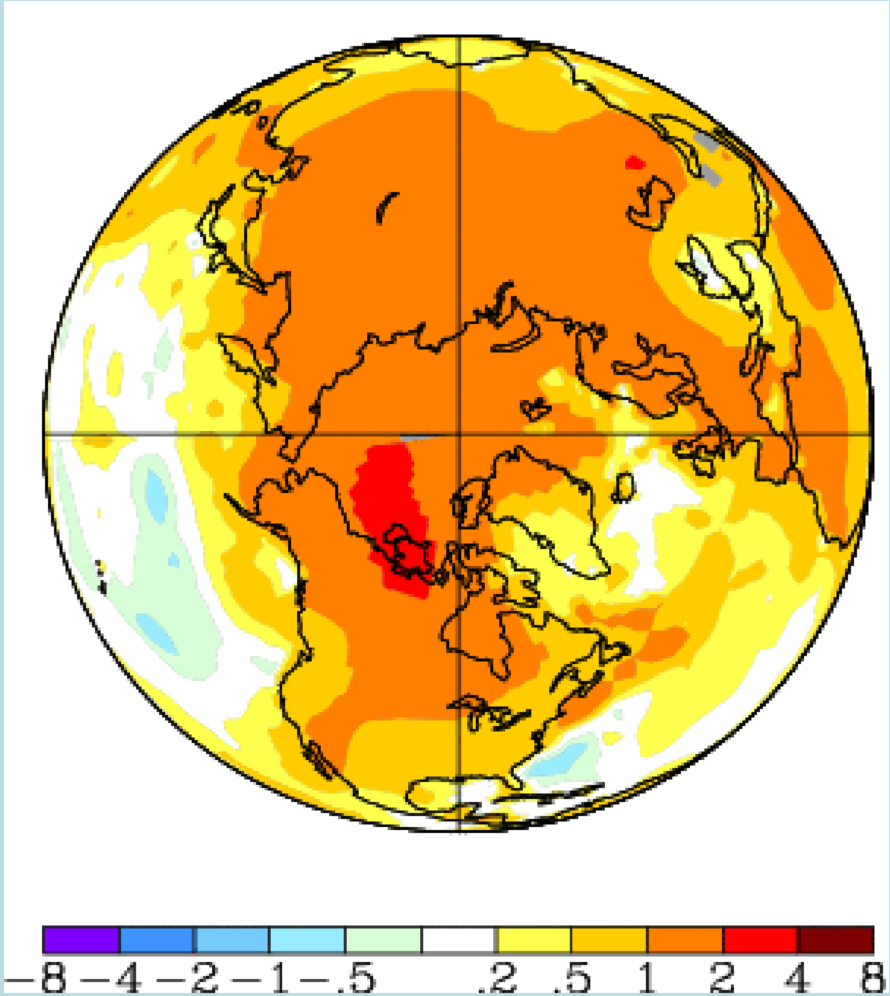
Bergen, Norway, October 2010

Outline

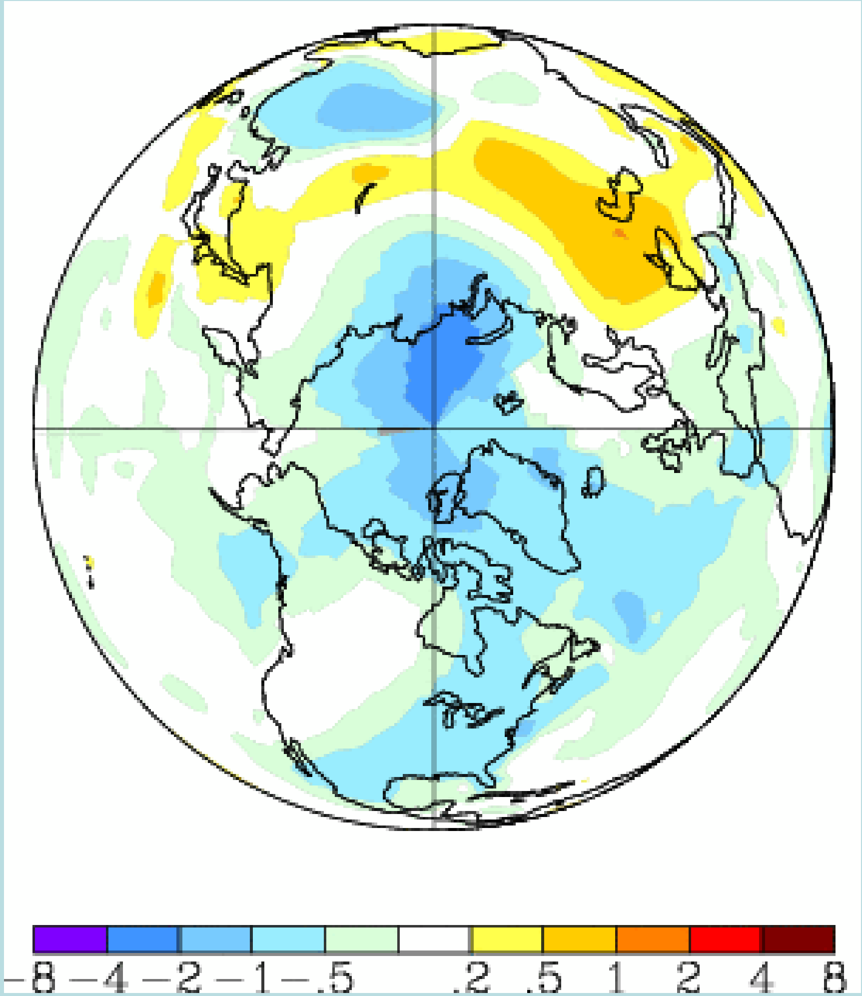
- Low-frequency variability in data and models
- Model evaluation and selection
- Empirical competition

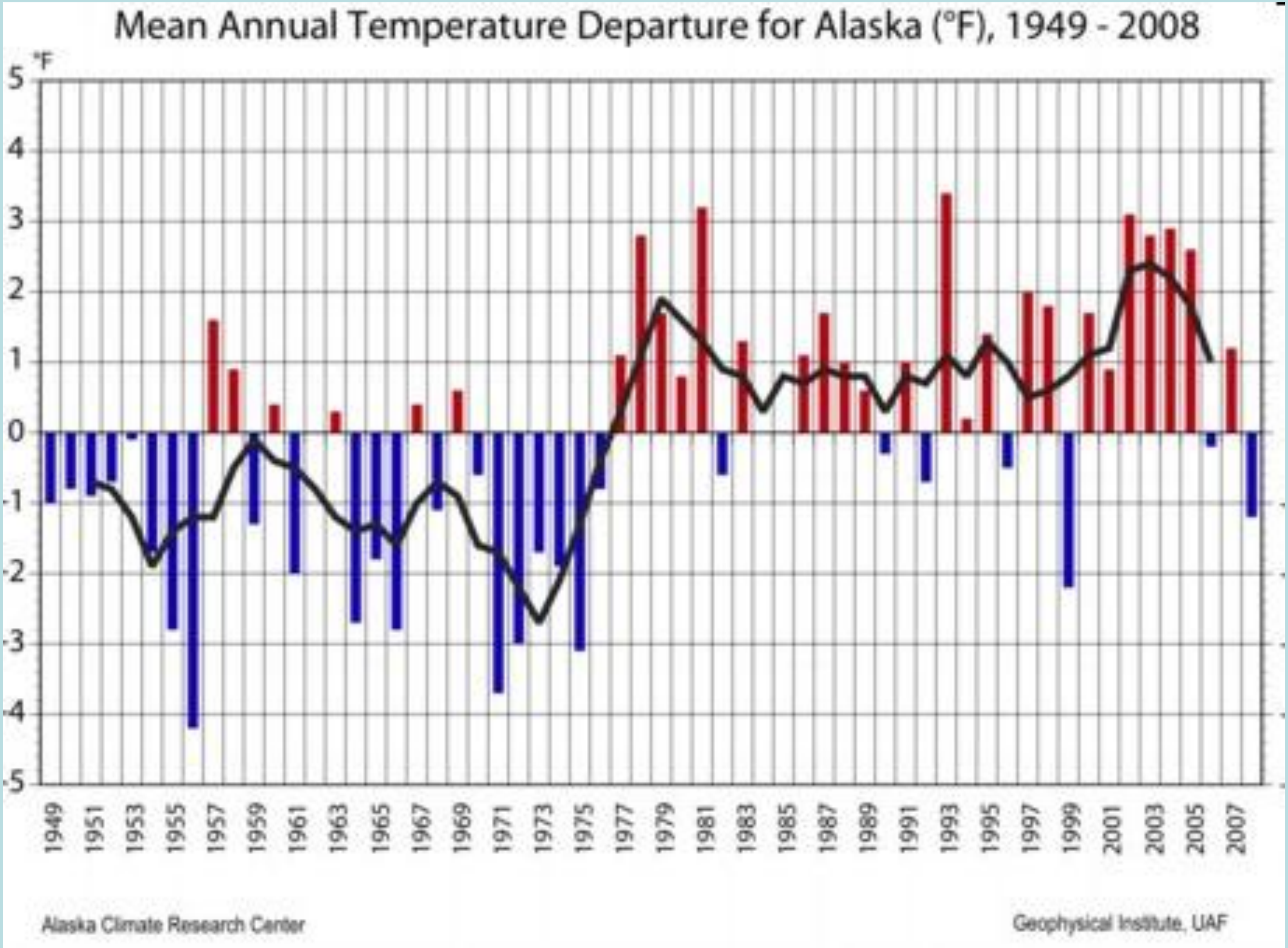
Change in surface air temperature (annual)

1957-2006

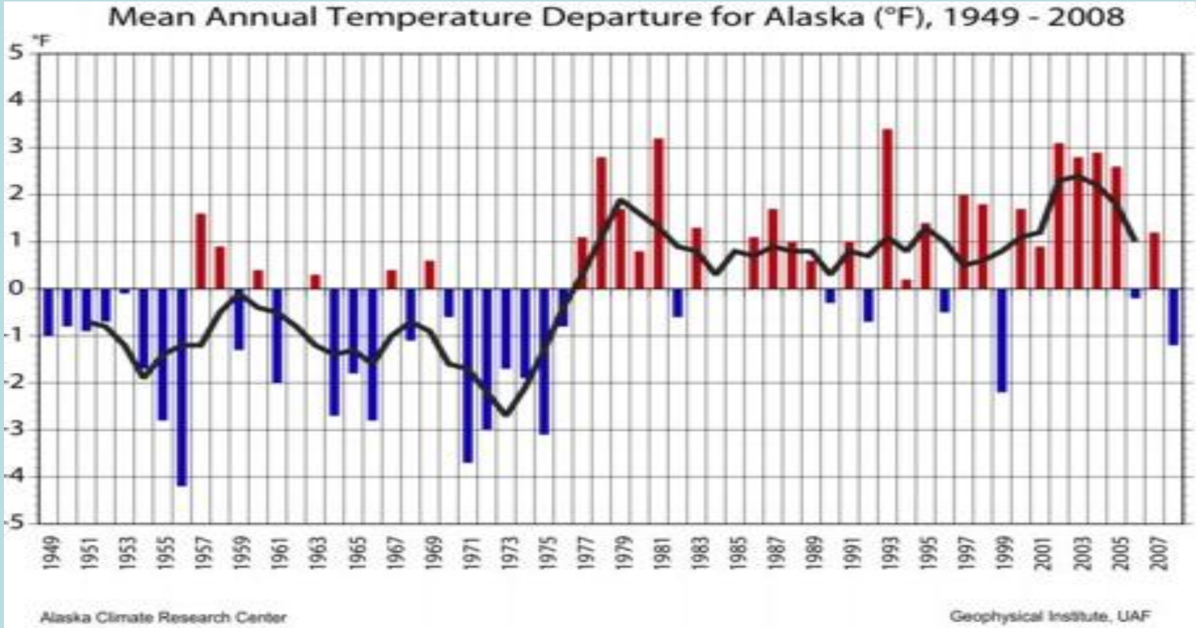


1941-1980

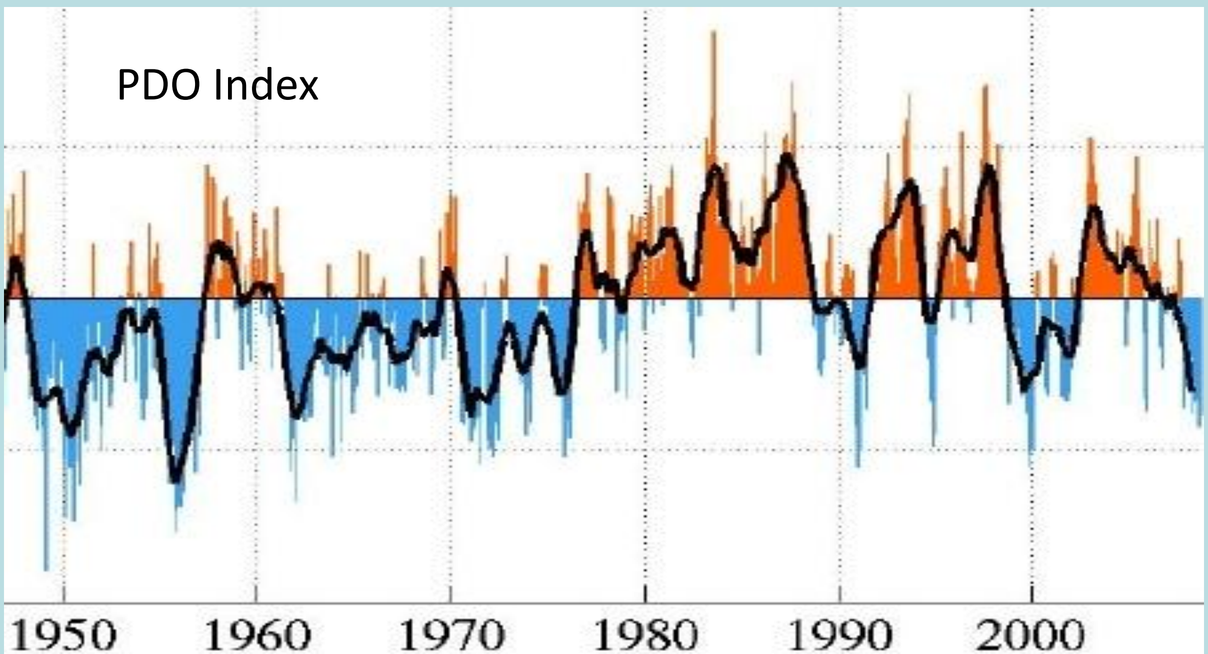




(from Alaska Climate Research Center)



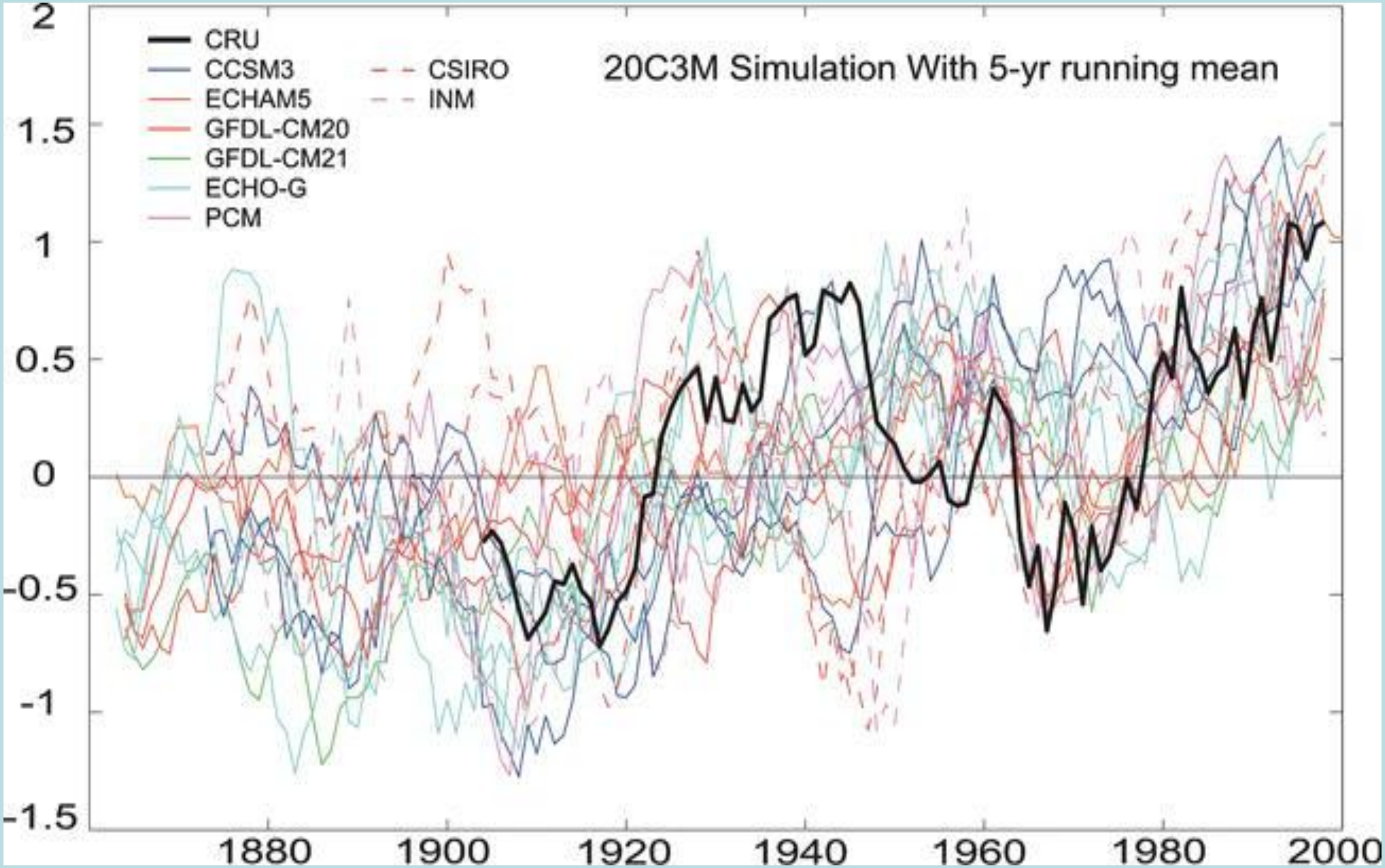
Alaska annual temperature anomalies

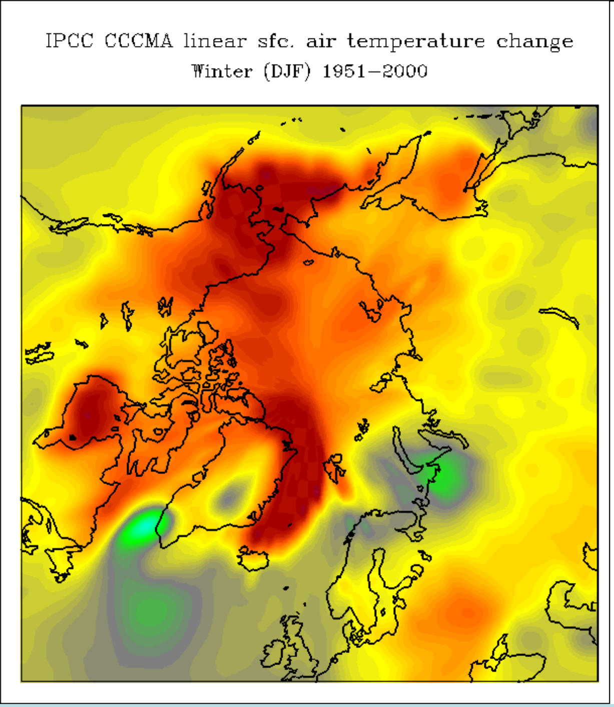


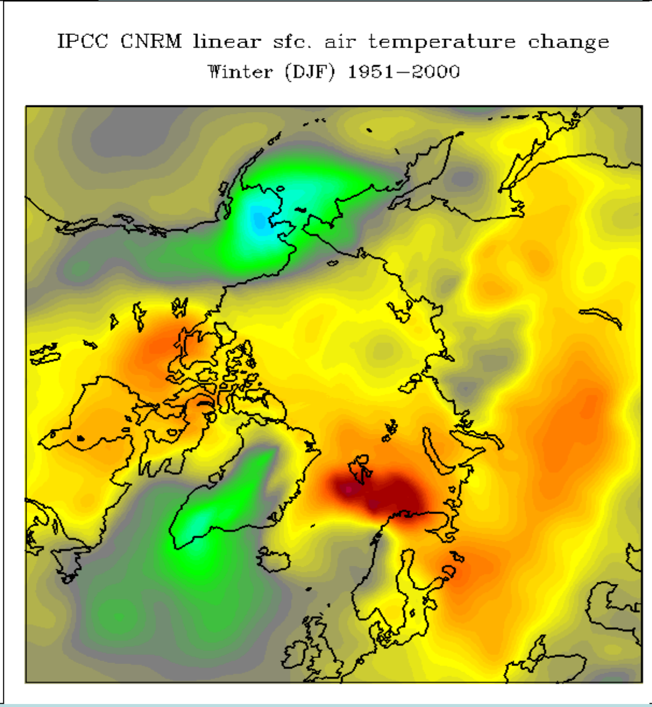
Pacific Decadal Oscillation Index

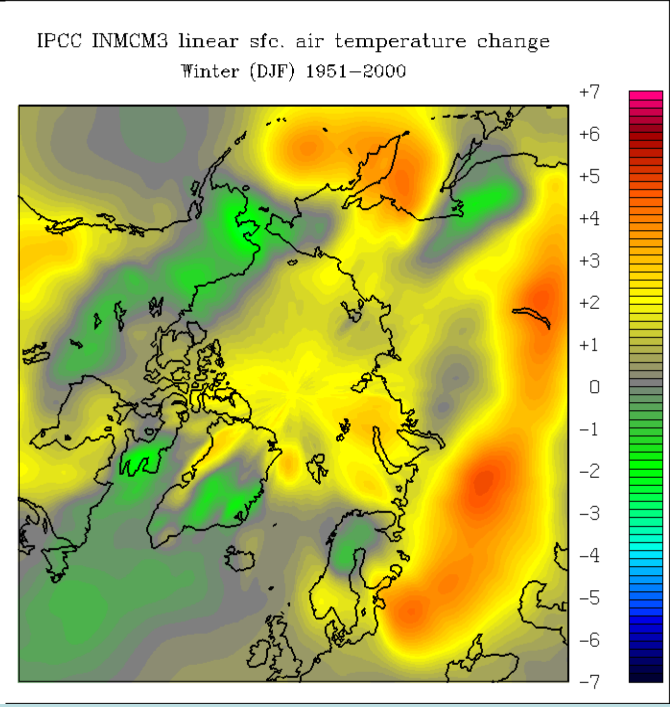
20th-century Arctic (60-90°N) temperatures simulated by individual IPCC models

[from M. Wang et al., 2007, J. Climate]





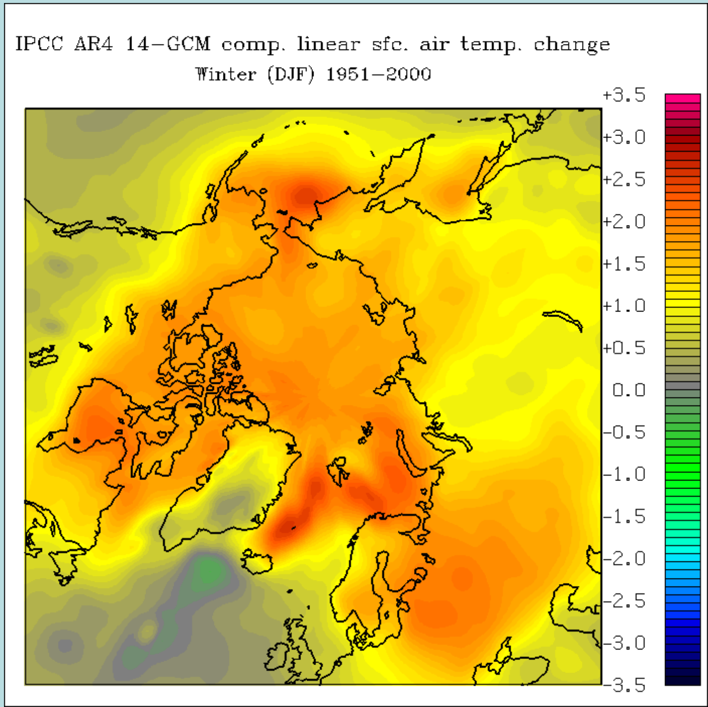




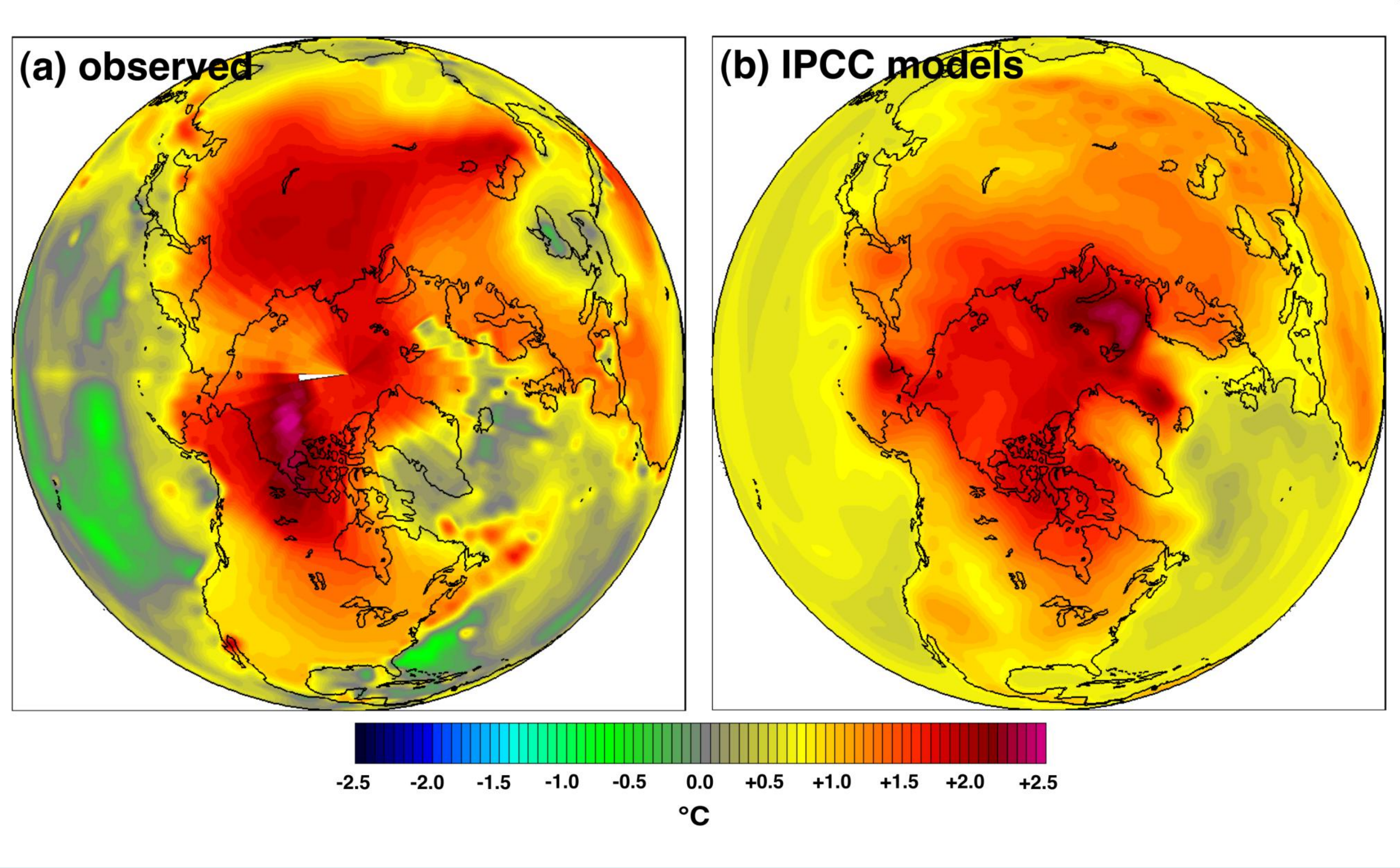
↑ **individual models** ↑

Winter temperature changes, 1951-2000

composite →



Change in *annual* surface air temperature, 1957-2006



Outline

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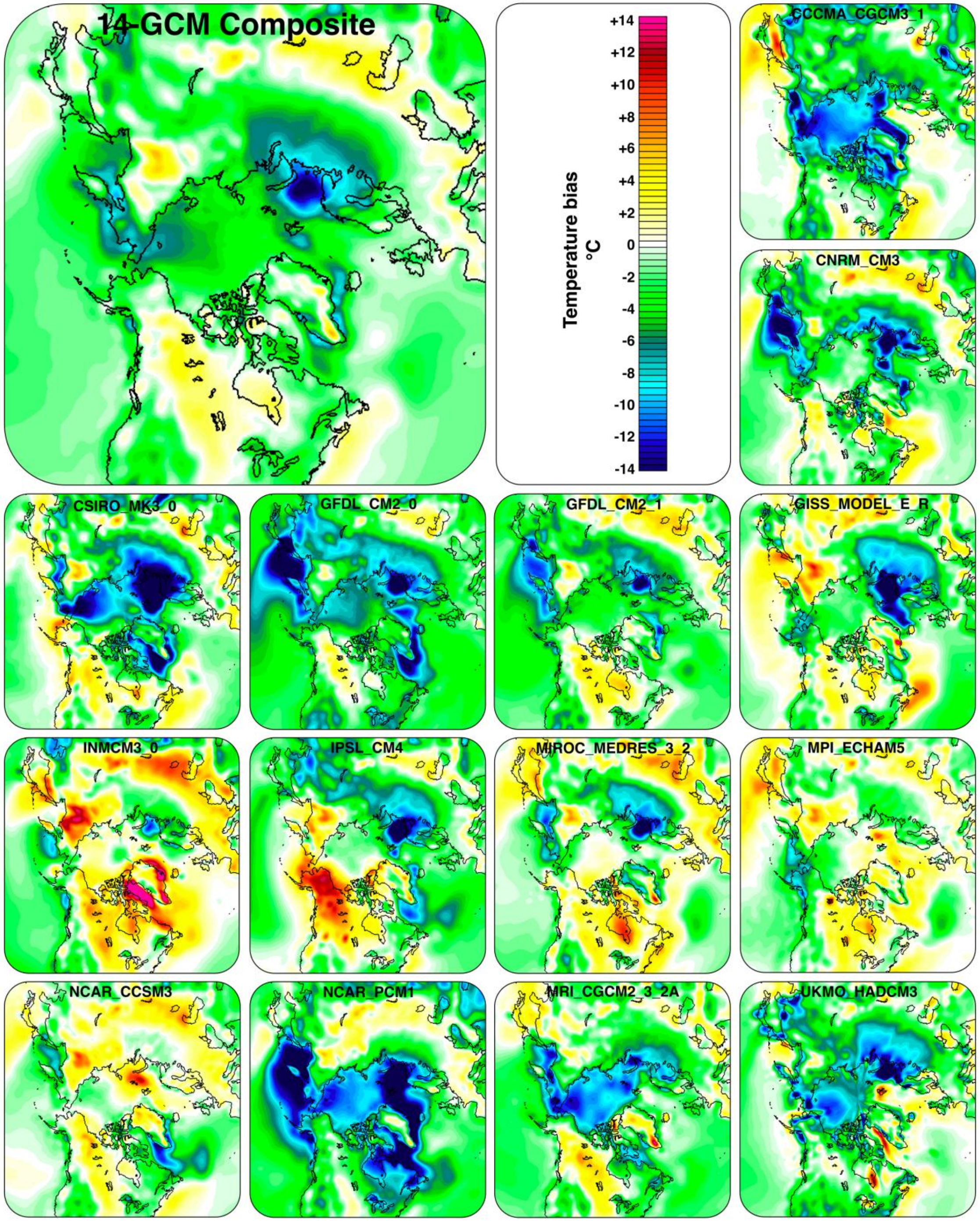
- **Can Arctic climate simulations be improved by the selection of a subset of global models?**

  -- Is the age of model democracy over?



Temperature biases of IPCC AR4 models

Model selection

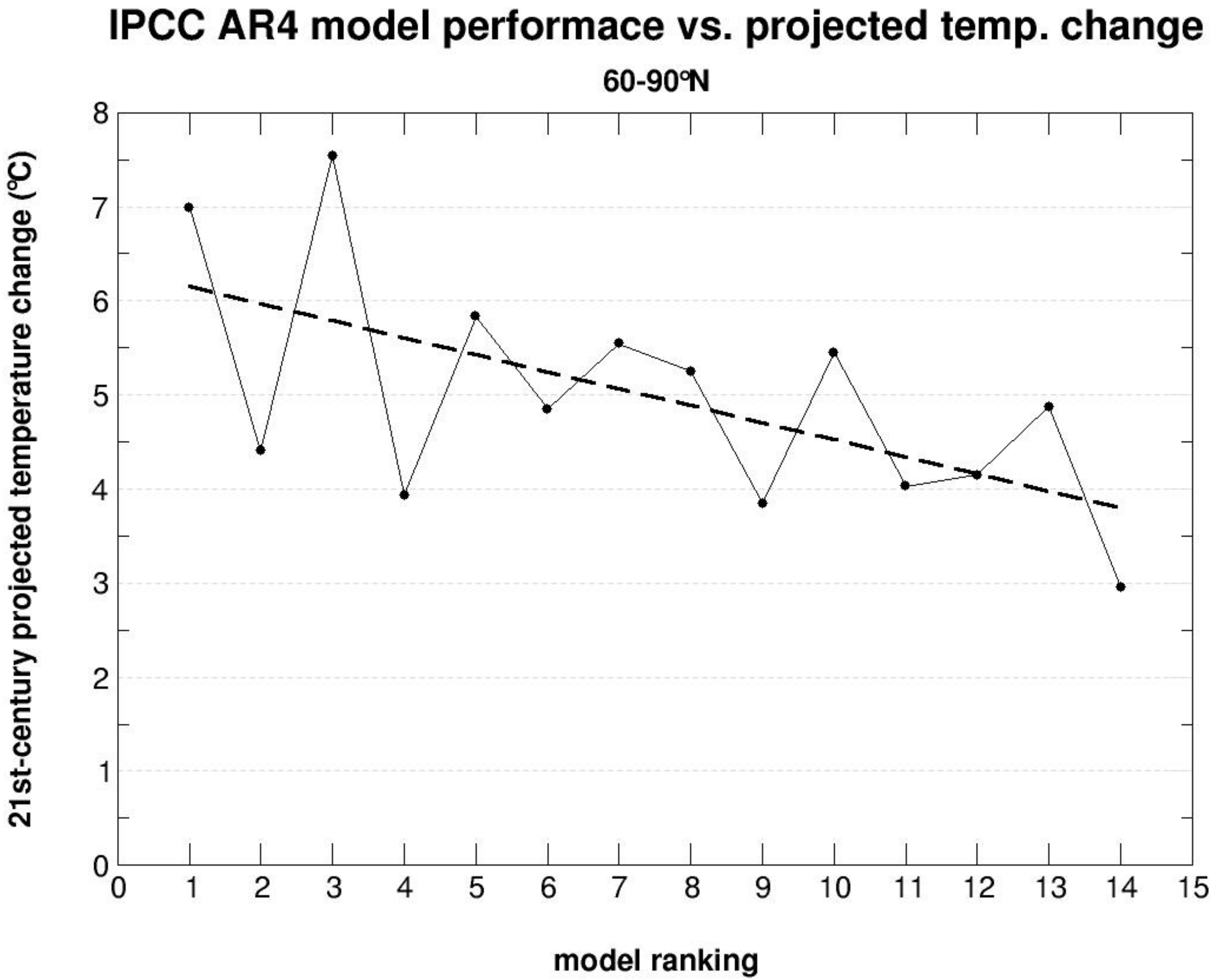
Basis:
Simulation of seasonal cycle of recent climate by 15 CMIP3 models

- **Period: 1981-2000; 1961-2000**
- **Validation: ERA-40 reanalysis**
- **Variables: Surface air temperature**
  Sea level pressure
  Precipitation
  [others]
- **Metric: Root-mean-square error, integrated over:**

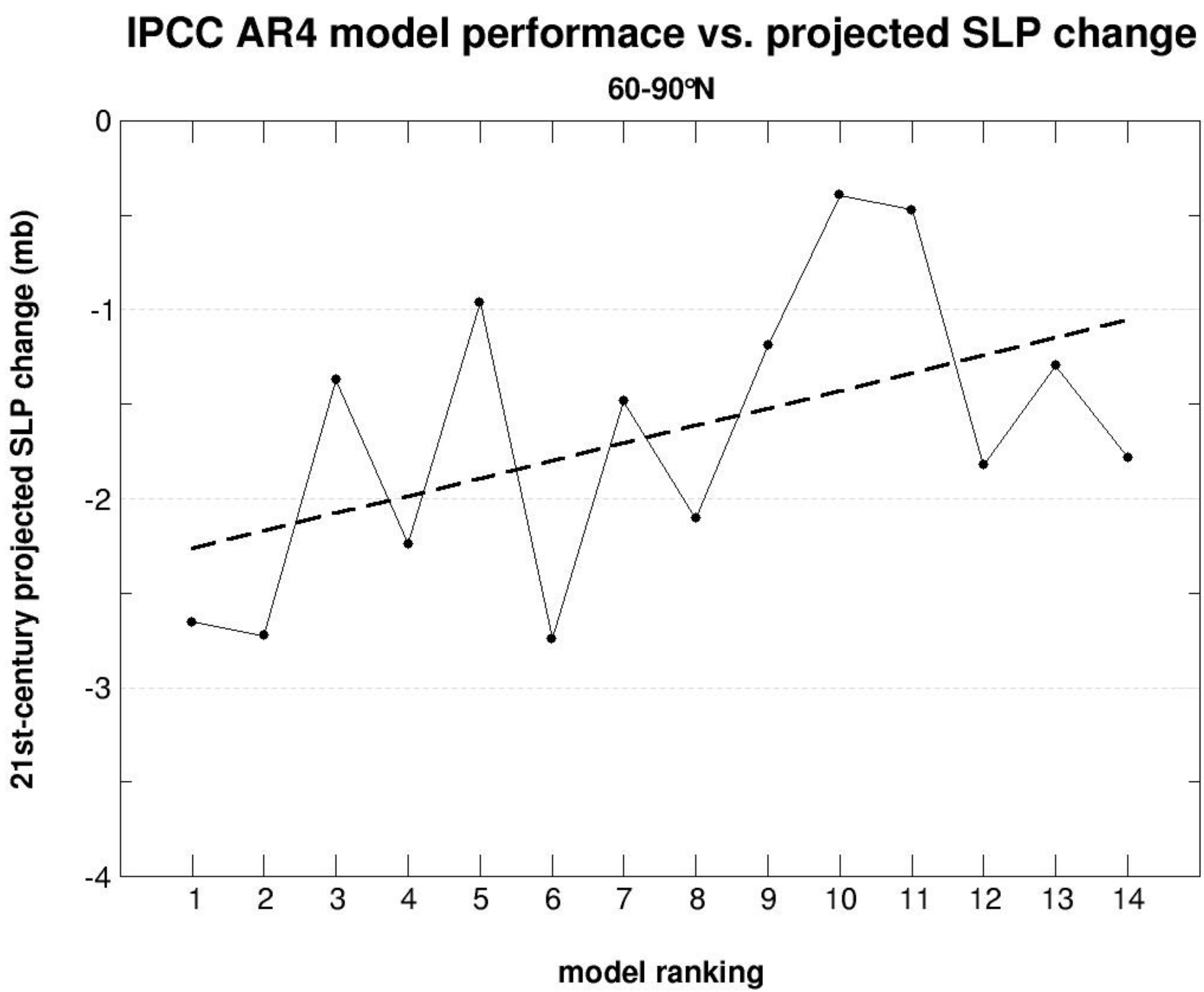
  1) seasonal cycle (12 calendar months)
  2) domains of interest: 20-90 N
  60-90 N
  Alaska
  Greenland

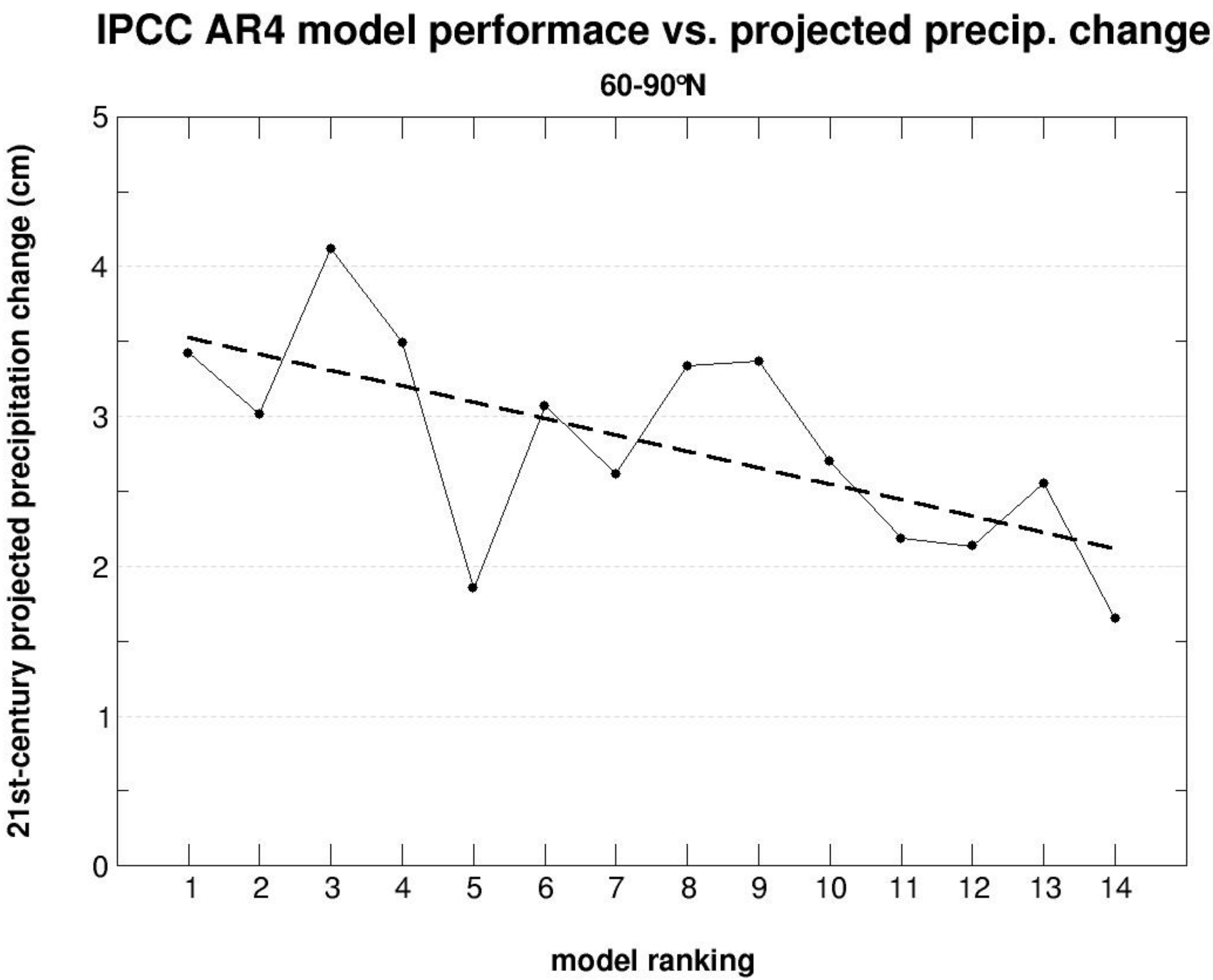
Ranking of CMIP3 models for various domains

Overall Rank	Model	Alaska temperature	60-90° N temperature	20-90° N temperature	Alaska precipitation	60-90° N precipitation	20-90° N precipitation	Alaska sea level pressure	60-90° N sea level pressure	20-90° N sea level pressure	Integrated Rank Index
1	MPI ECHAM5	13	1	1	5	3	3	1	1	1	29
2	GFDL CM2.1	6	3	5	2	1	2	5	4	2	30
3	MIROC 3.2	2	4	3	7	6	8	10	3	5	48
4	UKMO HADCM3	11	8	6	3	2	9	4	6	7	56
5	CCCMA 3.1	12	11	10	4	8	2	8	2	4	61
6	GFDL CM2.0	6	9	14	1	10	6	4	8	4	62
7	MRI CGM2.3.2A	11	13	7	6	5	4	2	11	6	65
8	CNRM CM3	1	5	5	12	12	13	7	12	11	78
9	NCAR CCSM3	8	2	2	9	8	7	15	15	13	79
10	INMC 3.0	7	6	10	10	13	12	9	7	9	83
11	NCAR PCM1	14	13	14	8	5	10	6	5	12	87
12	CSIRO MK3.0	6	14	12	11	11	5	11	9	9	88
13	IPSL CM4	11	7	12	13	9	11	14	11	15	103
14	GISS E R	6	10	10	14	14	15	13	14	14	110
15	IAP_FGOALS1_0_G	15	15	15	15	15	14	12	13	10	124



IPCC AR4 model performace vs. projected temp. change
60-90°N
21st-century projected temperature change (°C)
model ranking
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


IPCC AR4 model performace vs. projected SLP change
60-90°N
21st-century projected SLP change (mb)
0
-1
-2
-3
-4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
model ranking

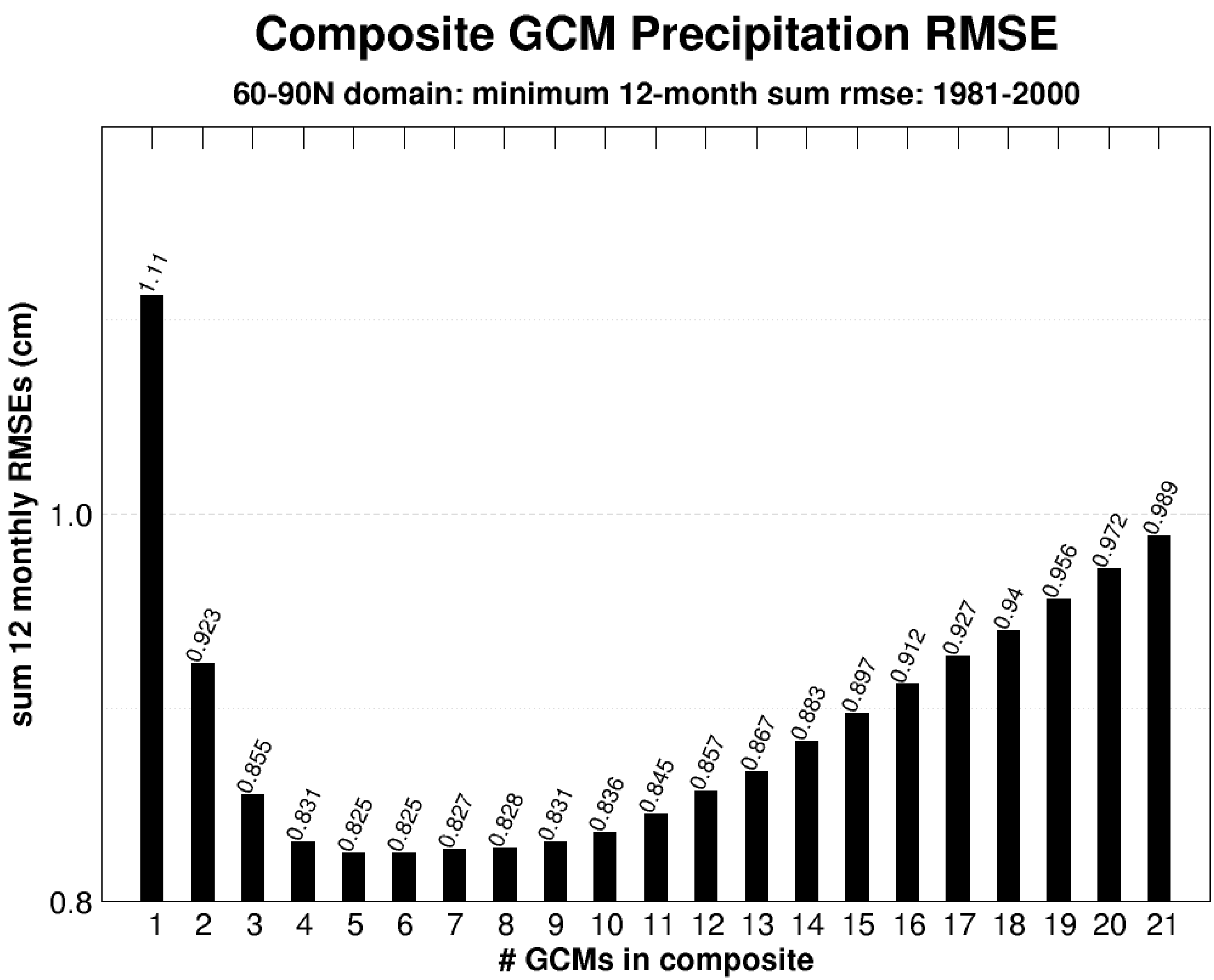


IPCC AR4 model performace vs. projected precip. change
60-90°N
21st-century projected precipitation change (cm)
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
model ranking

Given the differences of in the skill shown by different models, how many models should be used to optimize a simulation (and, ultimately, a projection) of Arctic climate?

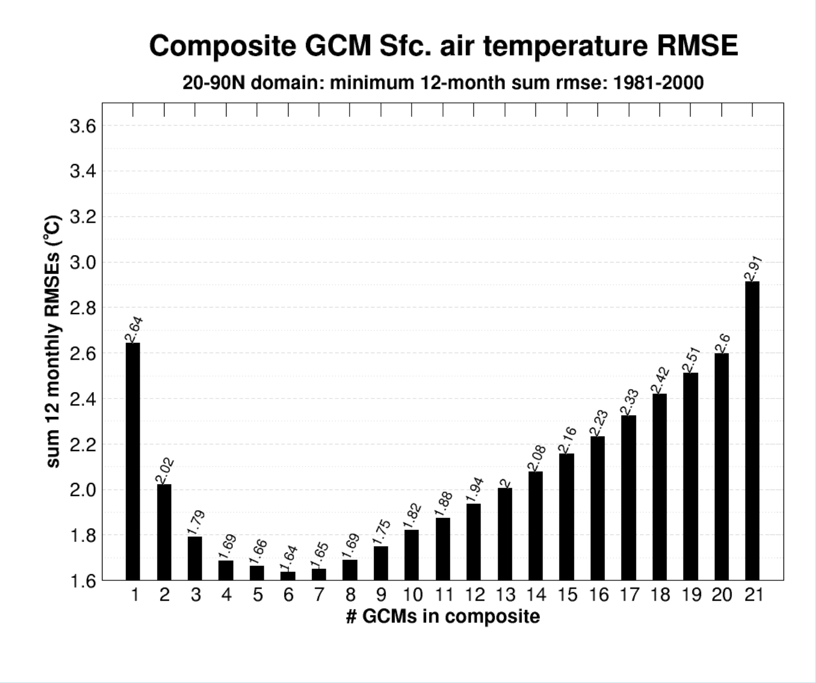
The "best" model only?

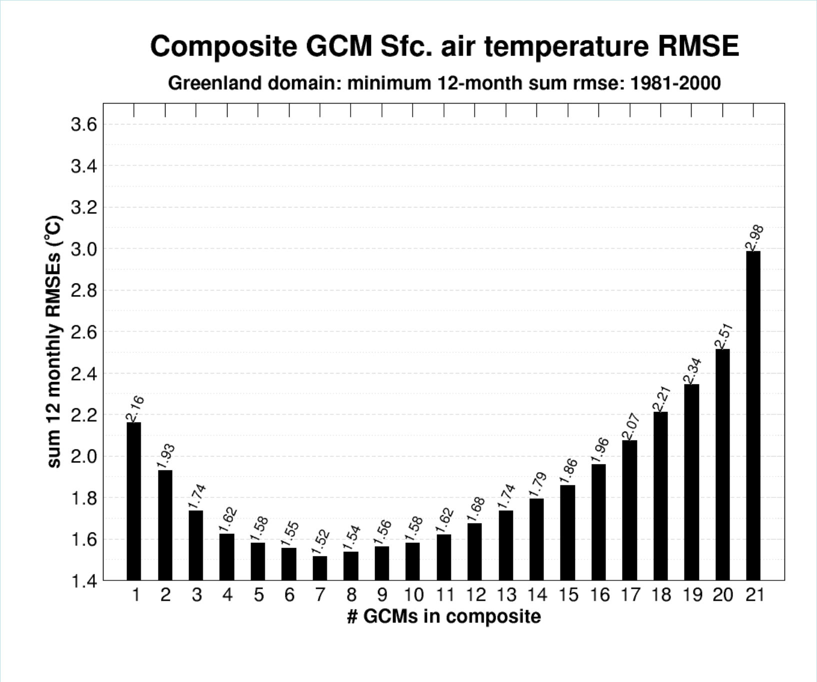
An average of all the models?

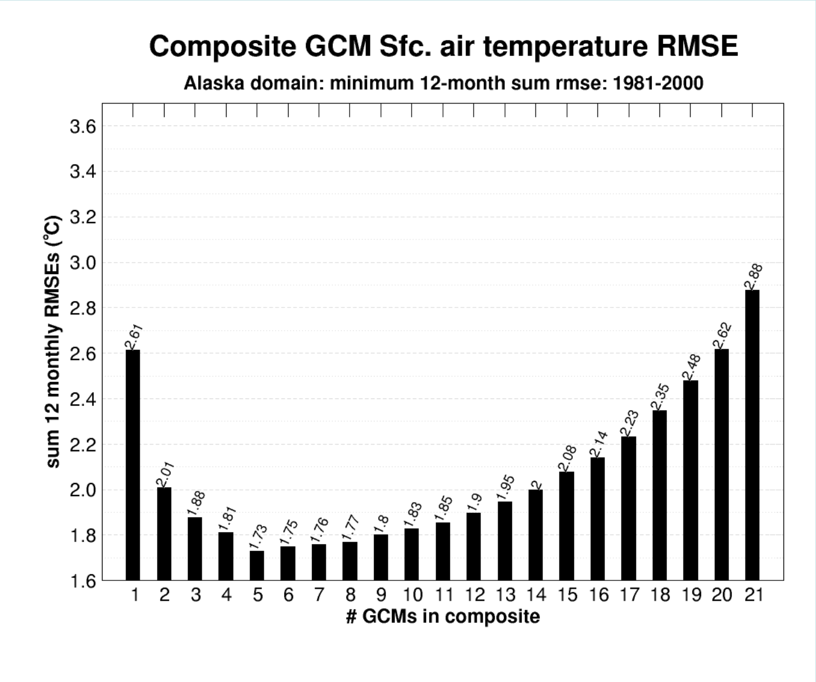


Composite GCM Precipitation RMSE
60-90N domain: minimum 12-month sum rmse: 1981-2000
sum 12 monthly RMSEs (cm)
1.0
0.8
1.11
0.923
0.855
0.831
0.825
0.825
0.827
0.828
0.831
0.836
0.845
0.857
0.867
0.883
0.897
0.912
0.927
0.94
0.956
0.972
0.989
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
GCMs in composite

5-8 GCM composite optimum: robust across domains







Conclusions (Part 2)

- **Models that perform best in the Arctic tend to show greater sensitivity to greenhouse forcing**

- **Different metrics of model skill produce *generally* consistent rankings of Arctic performance**

- **For the compositing of CMIP3 model simulations of the Arctic, the optimum number of models appears to be about half the total number**

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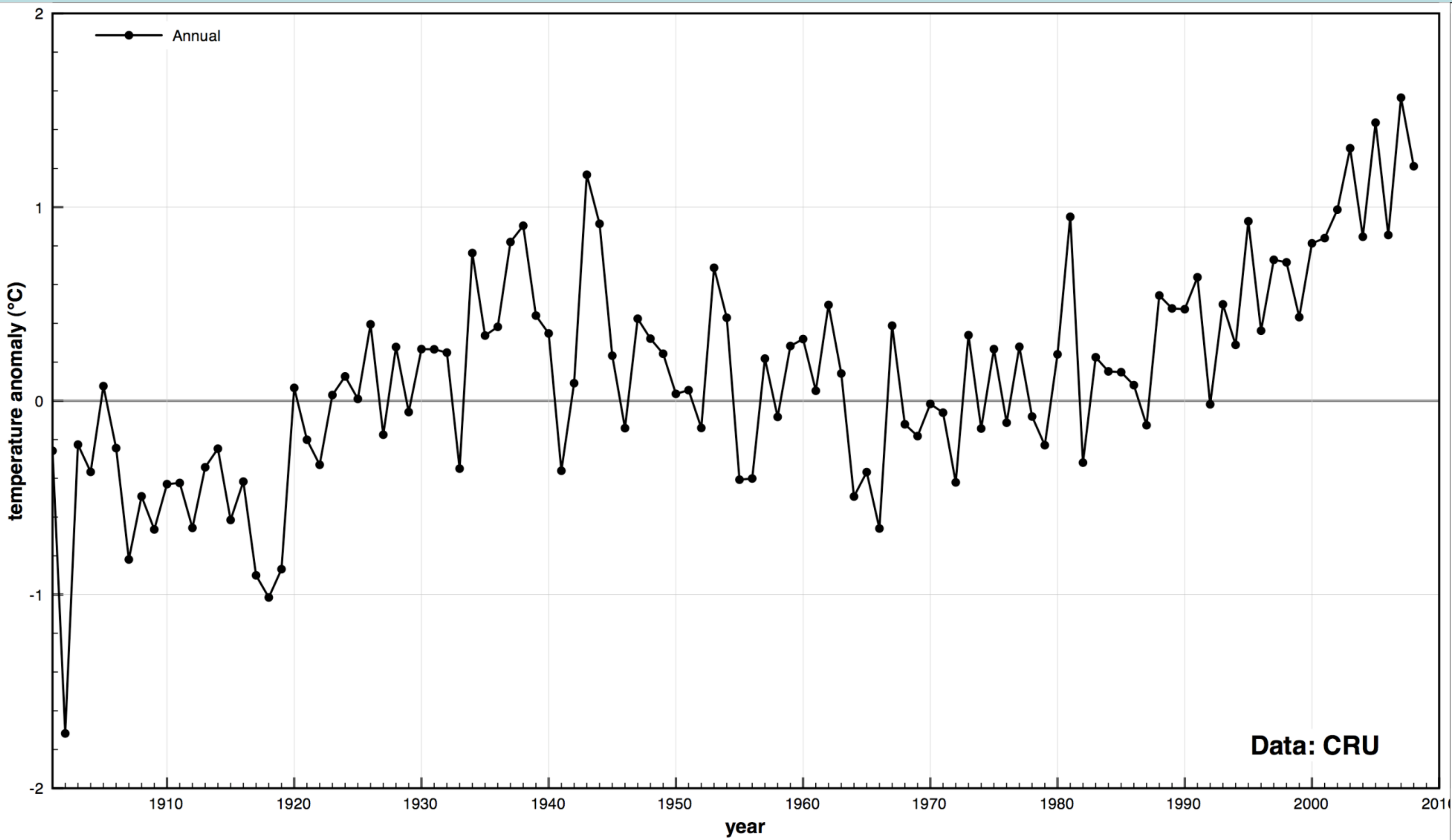
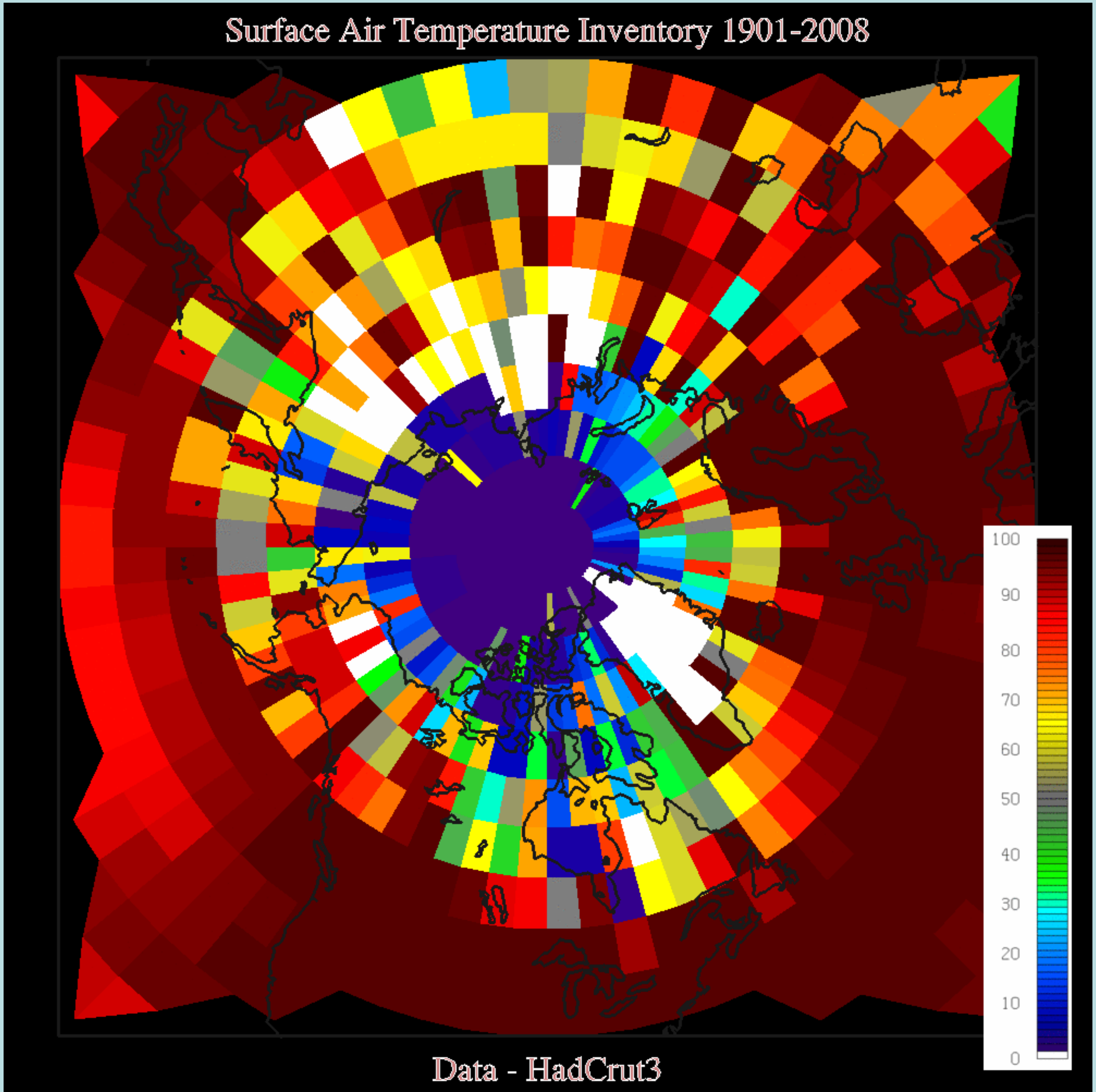
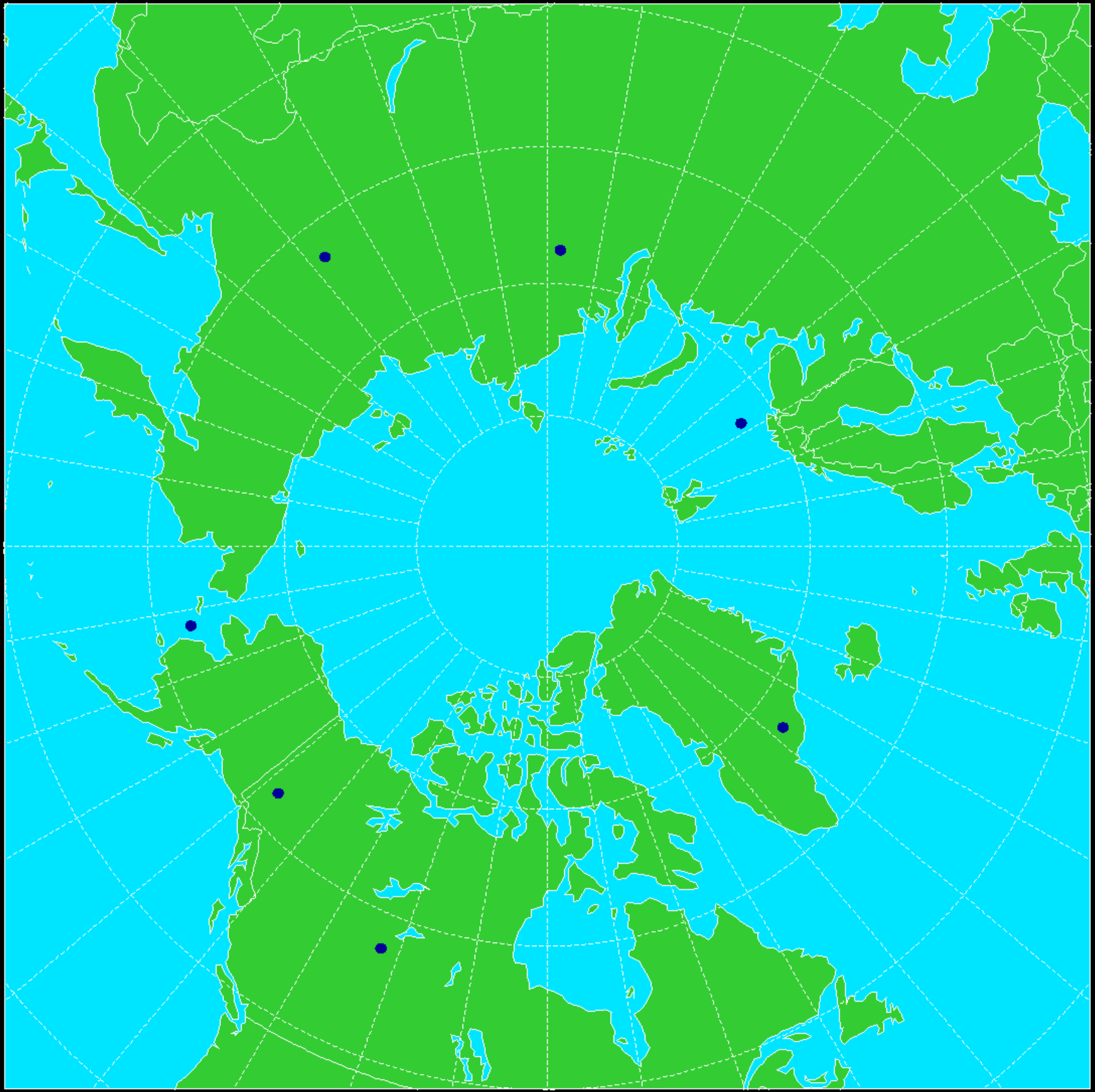
Can we capitalize upon the observational record to assess predictability?

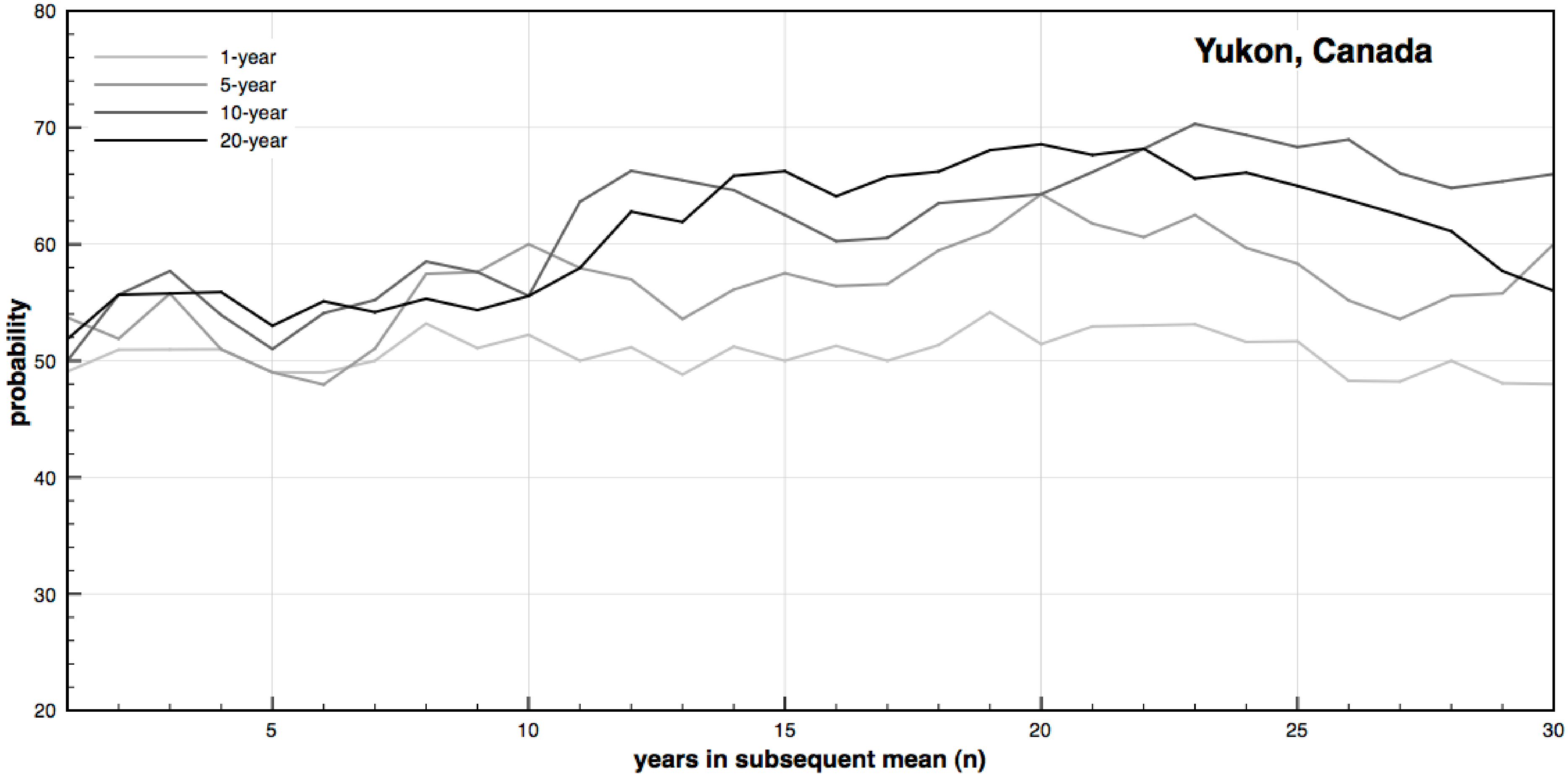


Completeness (%) of CRU temperature record, 1901-2008

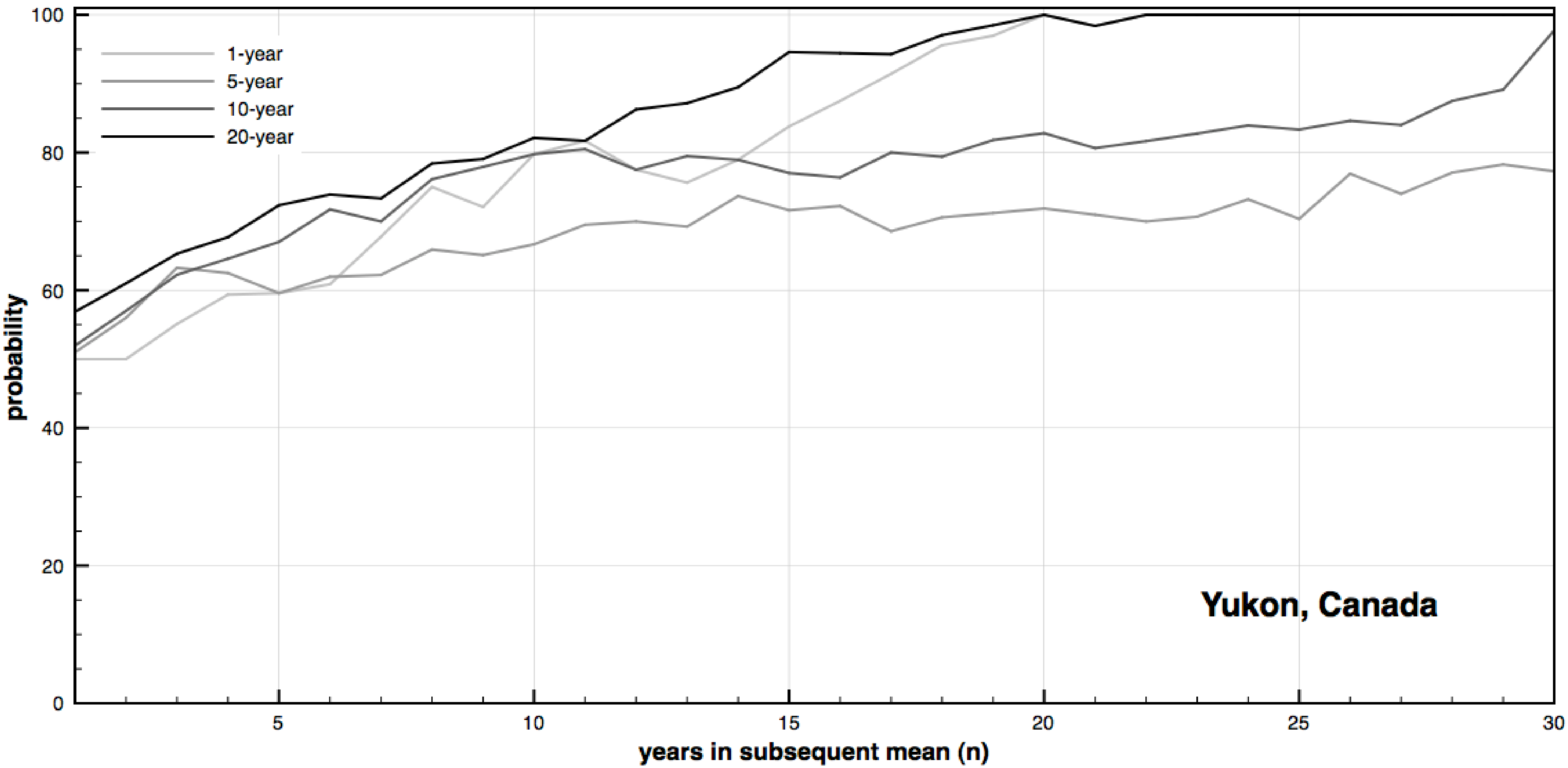




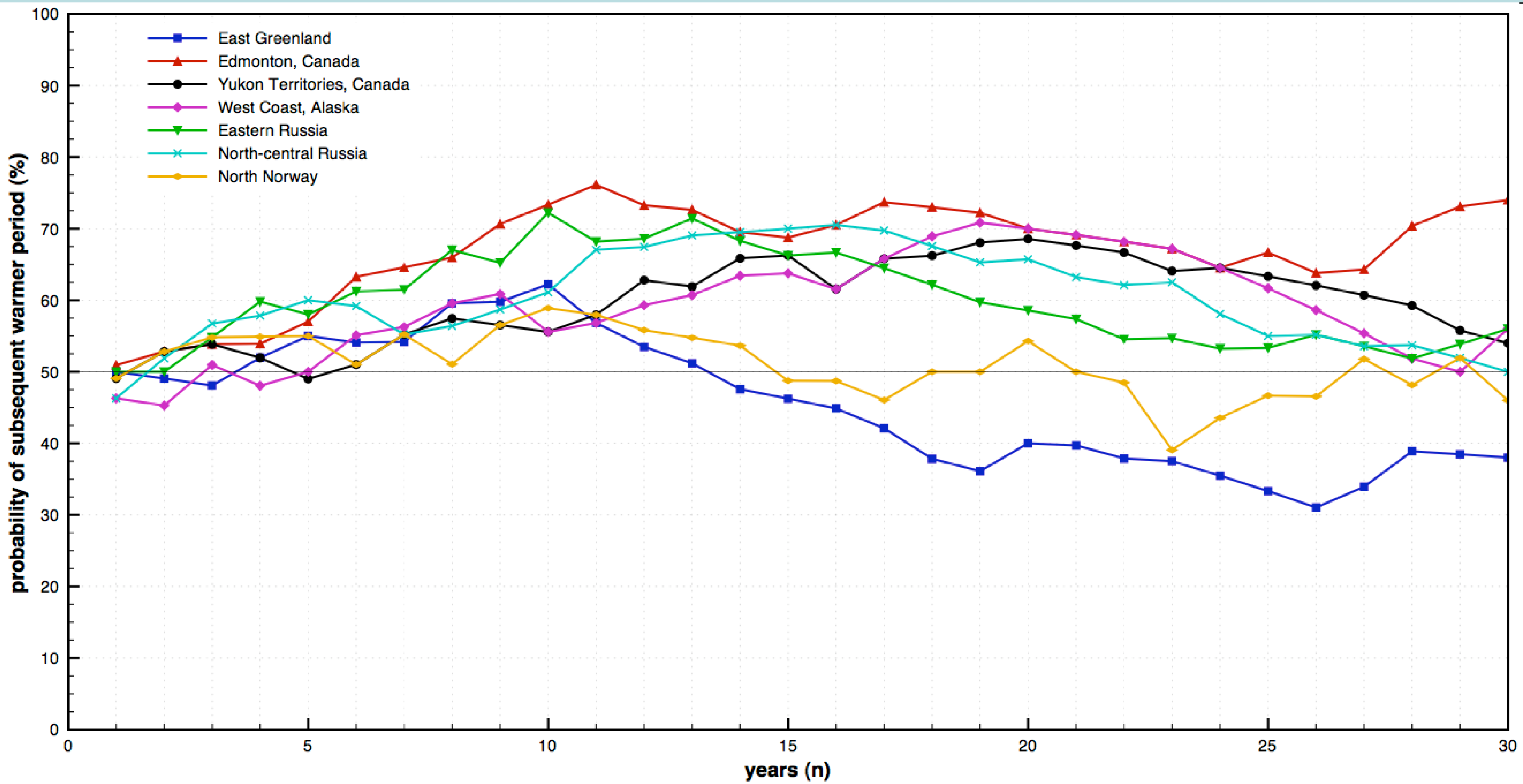
What is the probability that the subsequent n-year period will be warmer than the preceding 1, 5, 10…years – based on the observational record?



What is the probability that the subsequent n-year period will be warmer than the preceding 1, 5, 10…years – based on CCSM3 model output?



What is the probability that the subsequent n-year period will be warmer than the preceding n years – based on observational data?



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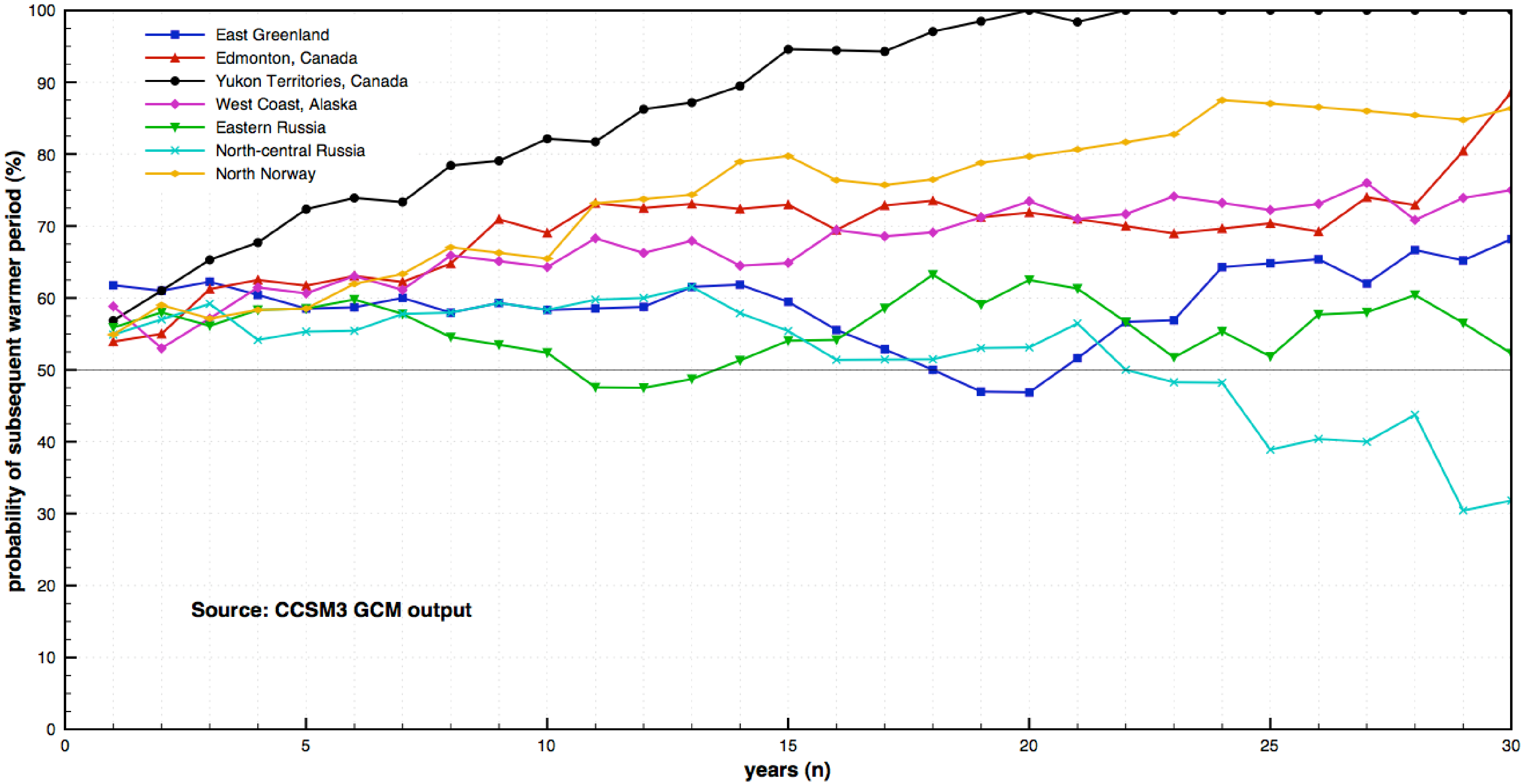

Analog forecasts based on antecedent n-year means: Correlations between predicted and observed

location	n=1	n=3	n=5	n=10
East Greenland	+0.445	+0.372	+0.248	-0.237
West-Central Canada	+0.181	+0.206	+0.156	-0.151
Yukon, Canada	+0.059	+0.202	+0.175	+0.090
West-Coast Alaska	+0.046	-0.001	-0.156	-0.183
East Russia	+0.020	+0.268	+0.503	+0.326
North Russia	-0.021	+0.085	+0.048	-0.125
North Norway	+0.031	-0.099	+0.122	-0.019
7-location mean	+0.109	+0.148	+0.157	-0.043

Analog forecasts based on antecedent n-year means: Correlations between predicted and simulated (CCSM3)

Analog forecast correlations: CCSM3 sfc. air temps.

location	n=1	n=3	n=5	n=10
East Greenland	+0.220	+0.420	+0.371	+0.244
West-Central Canada	+0.037	+0.333	+0.404	+0.093
Yukon, Canada	+0.221	+0.454	+0.663	+0.635
West-Coast Alaska	-0.011	+0.275	+0.262	+0.198
East Russia	+0.136	+0.287	+0.187	+0.019
North Russia	+0.166	+0.001	+0.154	-0.189
North Norway	+0.449	+0.453	+0.302	+0.732
7-location mean	+0.174	+0.319	+0.335	+0.247

Conclusions

- **Low-frequency variability in the observational record can be a source of modest predictability in the Arctic**

- **Corresponding predictability appears to be greater in model output than in observational data; caveats include**
  -- single model (CCSM3)
  -- short observational record

Needed: **Systematic *across-model* assessment of spectrum of variability, relative to observational variability**