Asessing threats to wildlife from global warming: The polar bear test case

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Based on a USGS-led research effort in support of the polar bear listing decision

Acting on a petition from the Center for Biological Diversity, FWS proposed listing the polar bear as a threatened species under ESA in January 2007. If the polar bear is listed (by Jan. 9, 2008), it will be

- **First species officially threatened by global warming.**
- **First ESA listing informed by climate model simulations.**

It's been said that the polar bear listing decision will set a precedent for future warming-related decisions.

But: what does this precedent mean? How does it apply?

To address this question, I will outline some results of research that USGS did in support of the polar bear listing decision. Key points are

- **How uncertainty was incorporated.**
- **How model simulations and observations were combined.**
- **How expert judgement and synthesis were accomplished.**

The bulk of this talk comes from a briefing presented at DOI on the results of 9 reports developed by USGS and collaborators, at the behest of USFWS.

Issues addressed in the reports:

1. Climate assessments:

- How are real-world climate and sea ice changing?
- What do climate models project for the future of sea ice?
- How good are climate models, and what are their sources of uncertainty?

2. Impact assessments:

- What is optimal polar bear habitat, how is it changing now, and how would it change under climate model projections?
  - Resource Selection Functions
  - Carrying capacity models
- How does sea ice decline affect population growth?
  - Markov modeling based on fieldwork in SBS
  - Additional fieldwork in Hudson Bay

3. Expert judgement/synthesis: Bayesian Network Model

USGS Project Team

Steve Amstrup, Dave Douglas, George Durner, Michael Runge, Eric Regehr
U.S. Geological Survey

Ian Stirling, Evan Richardson *Canadian Wildlife Service*

Martyn Obbard, Eric Howe *Ontario Ministry of Natural Resources*

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Christine Hunter *University of Alas*

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Scott Bergen *Wildlife Conservatior*

Why polar bears are at risk from sea ice decline

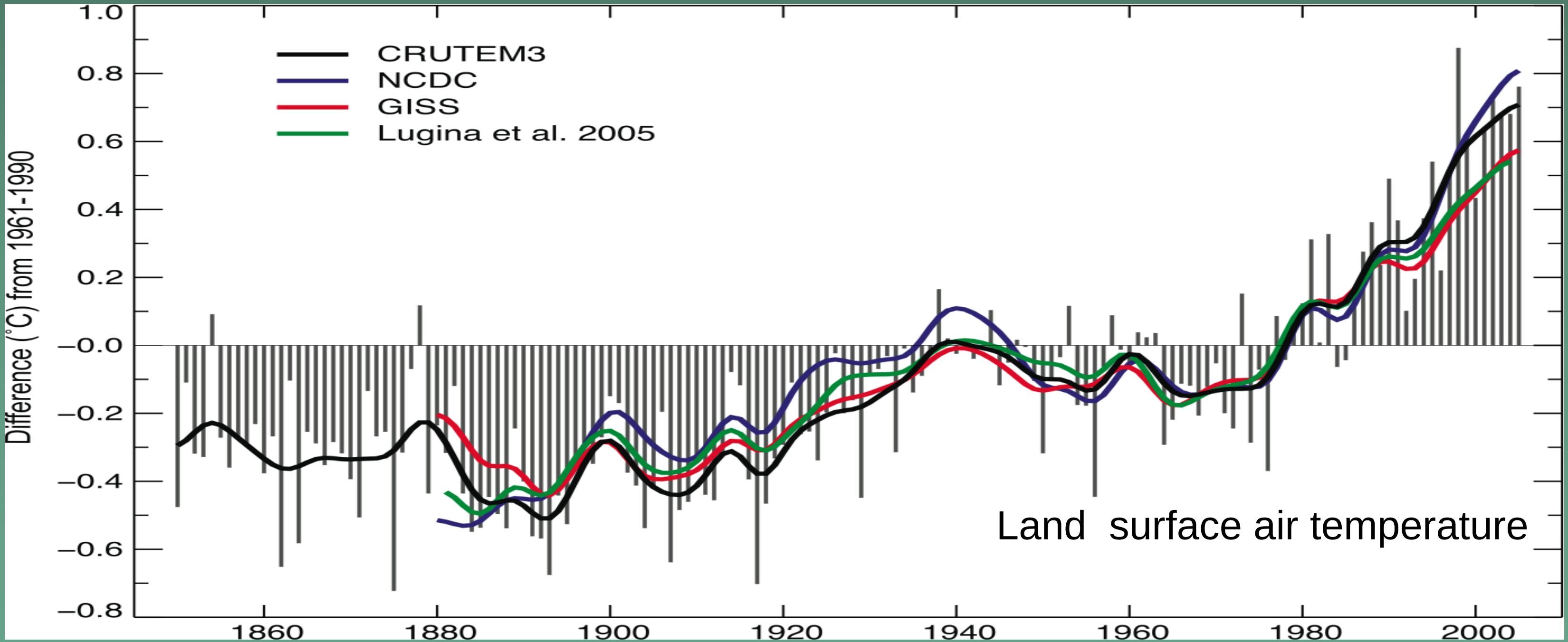
- Long lived – up to 30 yrs
- Low reproductive rates
- Forage almost exclusively from sea ice on seals
- Mother enters maternity den in November, cubs born January, nurse 3 months. 5 months of fasting, or more if the sea ice retreats.   8 months in more productive Hudson Bay. Important for seasonality of sea ice decline.
- Needs ice over continental shelves.

Polar bear populations projected to decline range-wide

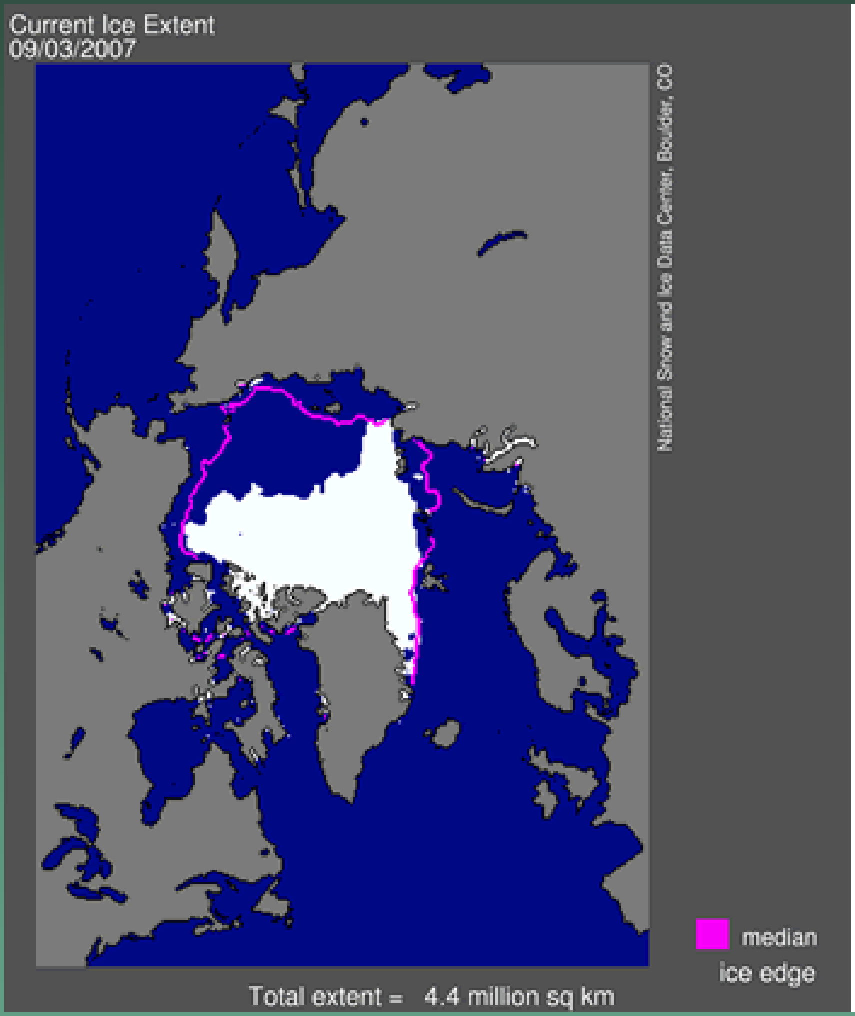
- Mid-century:
  - Probable extirpation in Divergent and Seasonal ice Ecoregions.
  - <u>These represent ~2/3 of the current range-wide population</u>
- Late century:
  - Probable extirpation in Polar Basin Convergent Ecoregion.
  - Probable remnant populations in Archipelagic Ecoregion

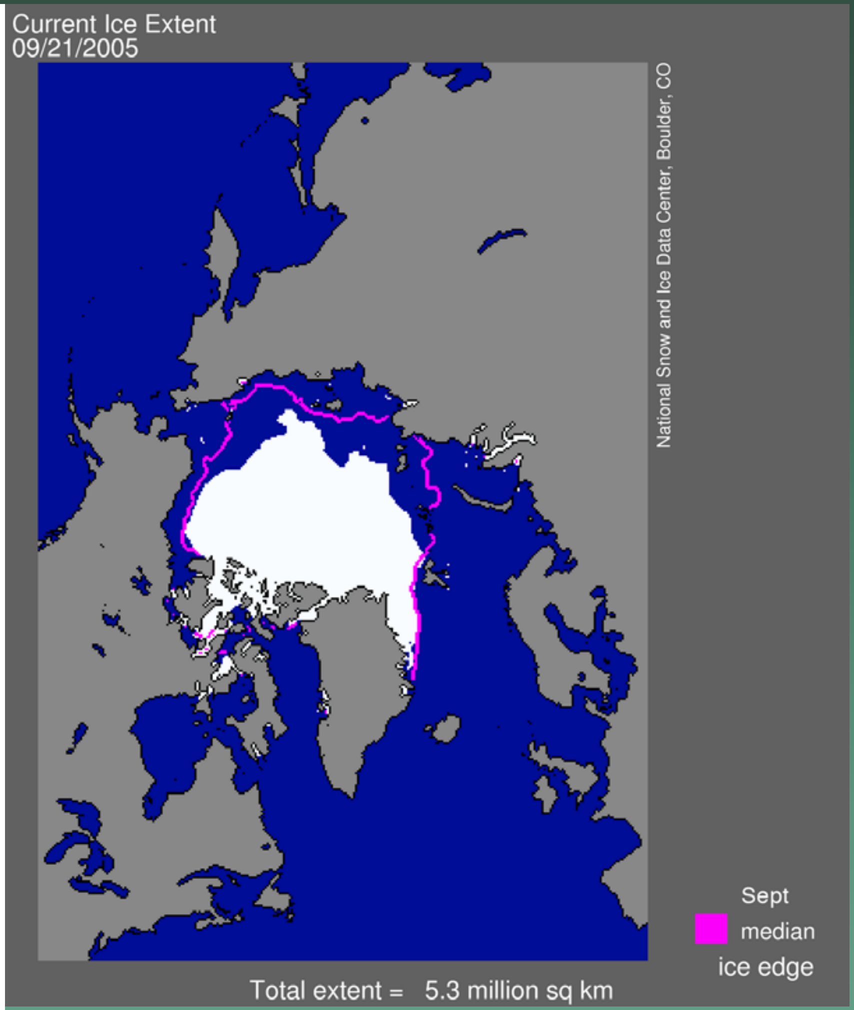
1. Climate Assessment: the world is warming: IPCC Fourth Assessment Report (AR4)

- "Warming of the climate system is unequivocal."
- Warming of the last 50 years is "very likely" (at least 90% probability) due to human activity.



2007 | 2005

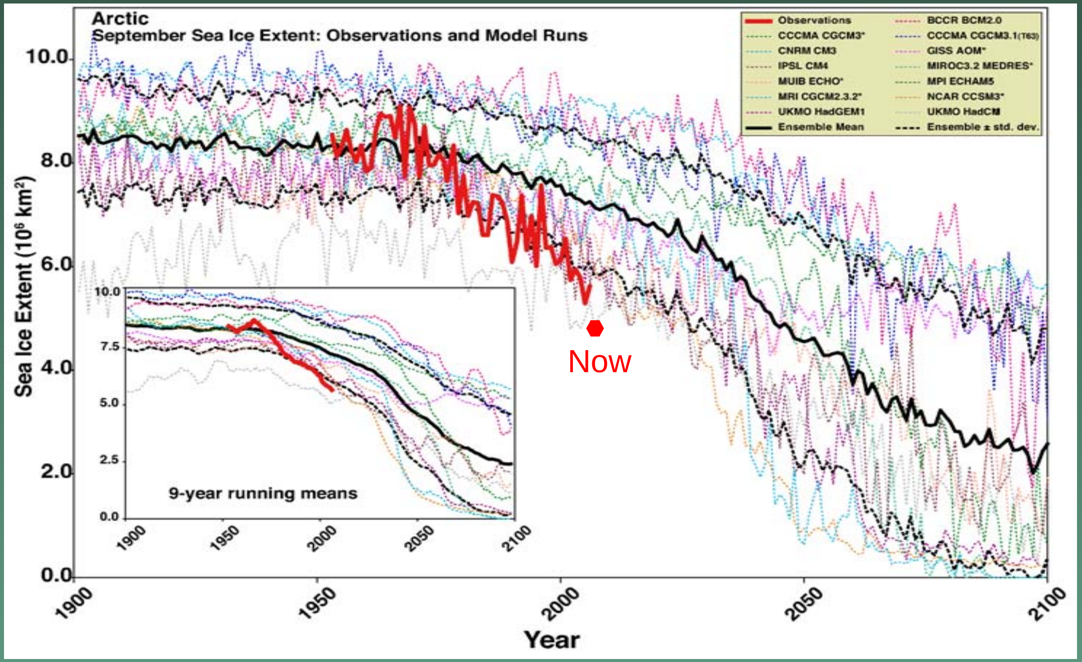




2007 shattered the 2005 record for minimum extent

Climate model assessment: sea ice simulations from climate models compared to decreasing trend found in observations.

The models are underestimating the dramatic downward trend in September sea ice extent (Stroeve et al. 2007).



1979 - 2006 September trend: -5.4% for models, -9.1% for observations (percent per decade)

This year's record low is consistent with the finding of underestimation.

Climate Models and their Uncertainties

- Climate models are built from atmosphere, ocean, land, and sea ice component models, in which laws of physics are encoded on global computational grids.

- Important small-scale processes like cloud formation and precipitation can only be approximately represented on global grids. Different climate models use different approximations and produce different simulations and projections.

- Climate models will always produce a range of estimates of the severity of global warming and sea ice loss.

Uncertainty due to unpredictable natural variability

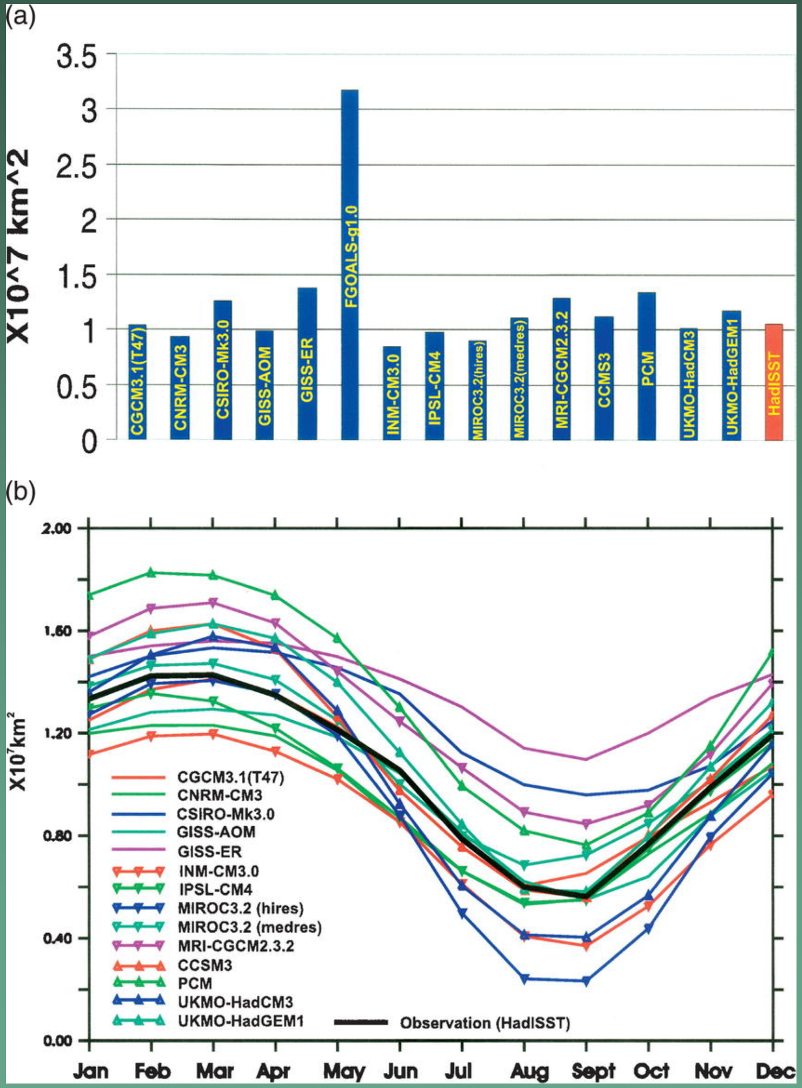
Arctic climate has a high degree of multi-decadal variability, particularly in the form of the Arctic Oscillation and warm Atlantic Water (AW) incursions.

Natural variability accounts for some of the recent sea ice decline and may lead to periods of rapid sea ice loss in the future.

Sea Ice Simulations from Climate Models: Mean and Seasonal Cycle of ice cover in 20th Century climate simulations (20C3M)

Zhang and Walsh (2006):

- Annual-mean area is within 20% of observations for 11 of 15 models.
- Seasonal cycle generally captured.
- Ensemble-mean area agrees well with observations.



Selection Criterion for Sea Ice Models Used in Polar Bear Analyses

We need an ensemble of models to represent the range of possible habitat outcomes.

We seek a balance between using only the best simulations and having the largest ensemble size to consider the range of outcomes.

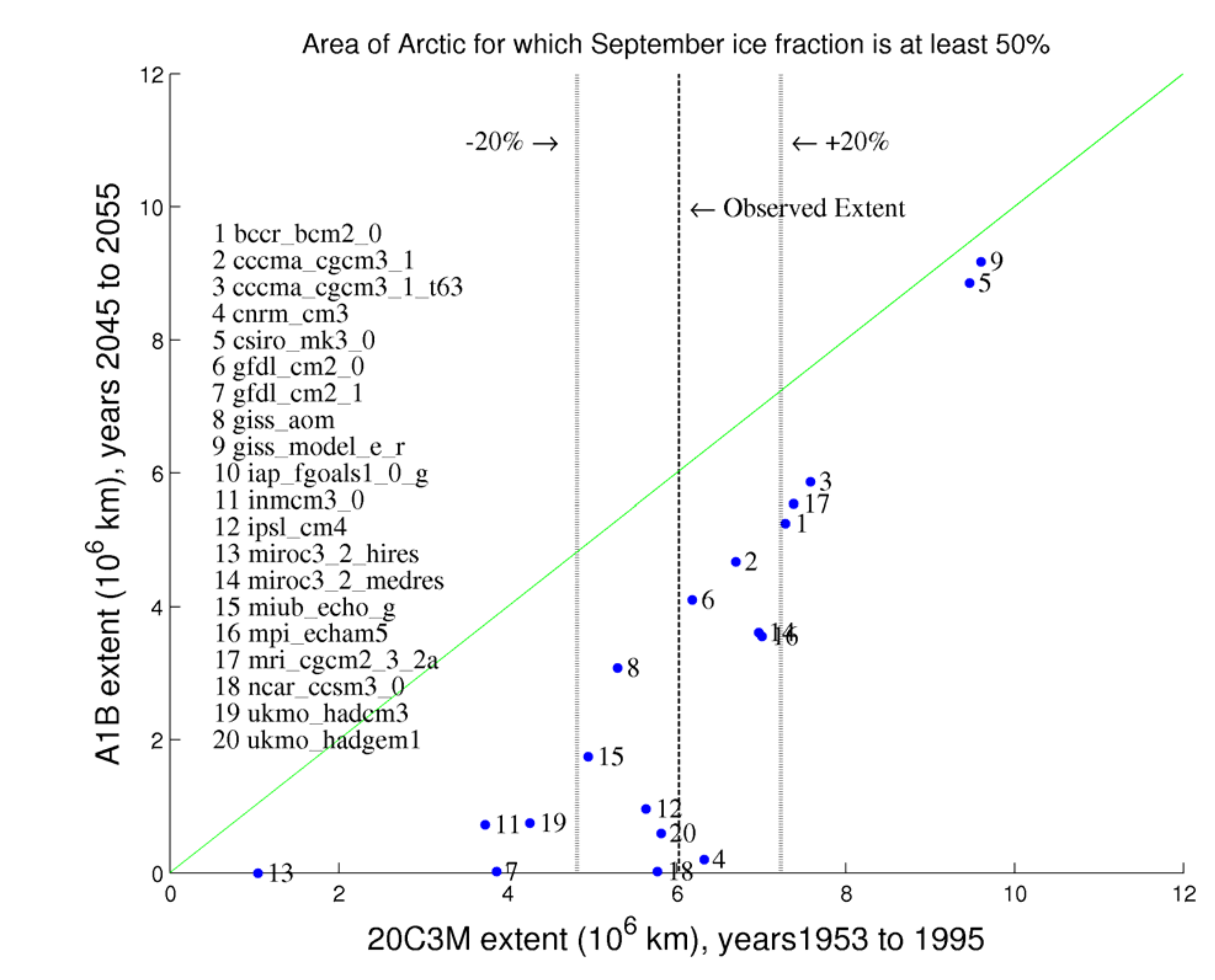
Criterion:

Use models which simulate September sea ice extent within 20% of observations for 1953 to 1995, where extent is the total Arctic area with at least 50% fractional ice cover.

This results in a sub-ensemble of 10 out of 20 models.

Selection of Sea Ice Models for Polar Bear Analyses

- x-axis is 20th century extent, y-axis is A1B mid-21st century.
- Models within the dashed lines are retained.
- Distance below green line represents ice loss.
- 4 models lose over 80% of their September ice, all lose at least 30%.



2. Impact Asessments, including:

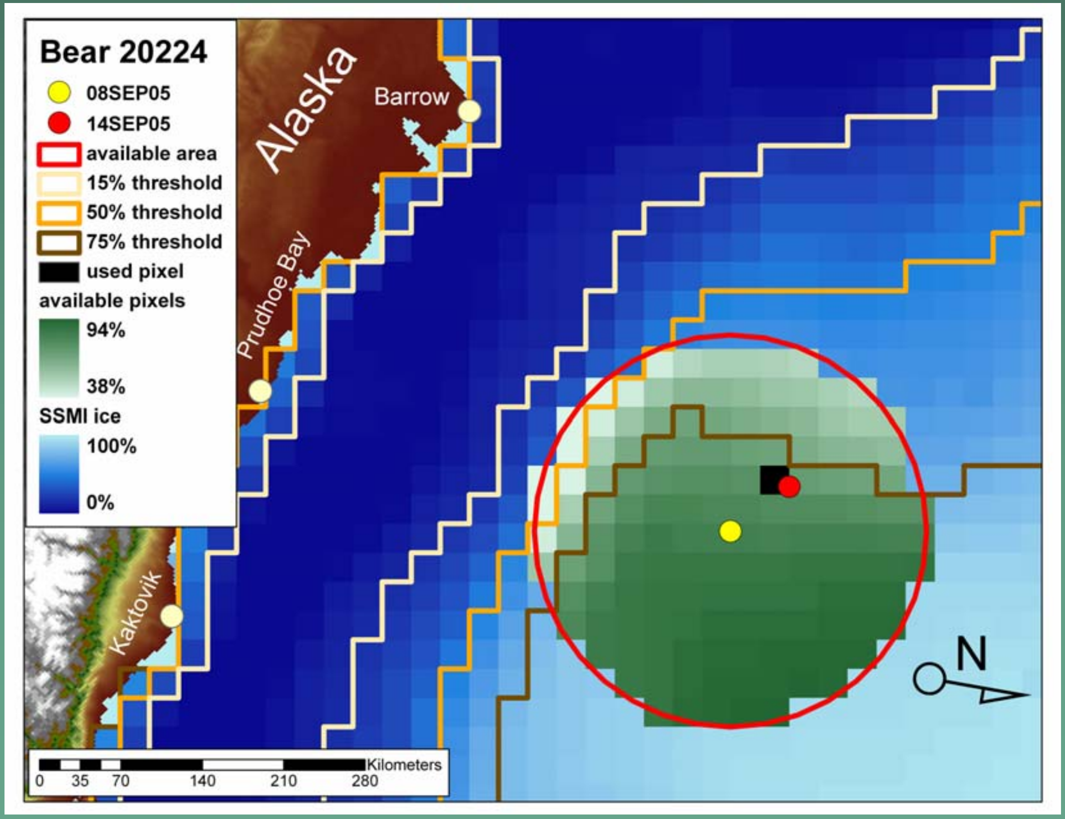
- Durner et al. 2007: Relate sea ice to polar bear habitat.

- Hunter et al. 2007: Relate sea ice to population growth rate in Southern Beaufort Sea.

Both studies find ways to combine real-world data and model output to assess impact of sea ice loss.

Resource Selection Functions (RSF)

- A statistical model that estimates the probability of habitat use (Manly et al. 2002)
- RSFs are built with animal location data and measurements of habitat variables
- RSFs compare the habitat used to the habitat available (i.e., selection)
- 1 of >12,000 pairs of polar bear locations:



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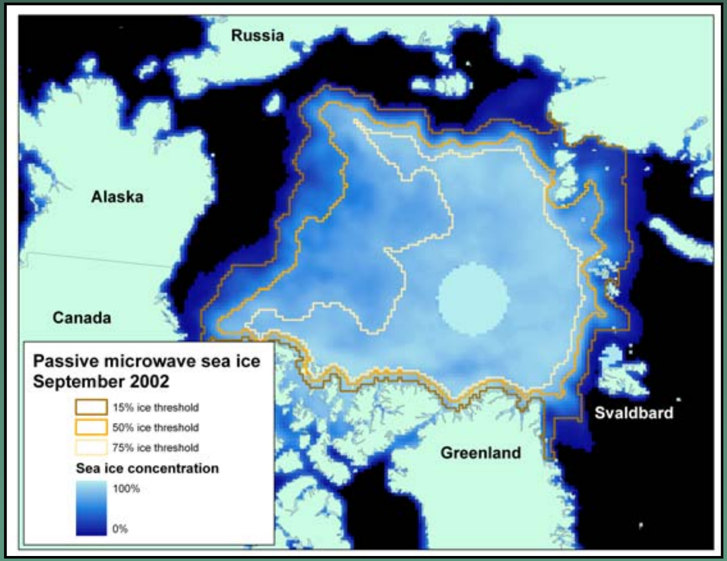
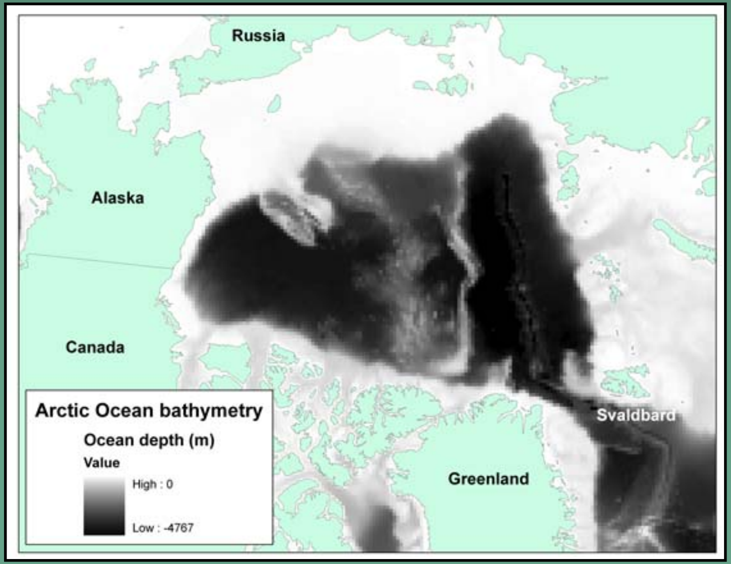
Data sources: Building the RSF

- Satellite radio-collars deployed on female polar bears



- Passive microwave sea ice concentration (NSIDC, Boulder)

- Ocean depth and distance to land



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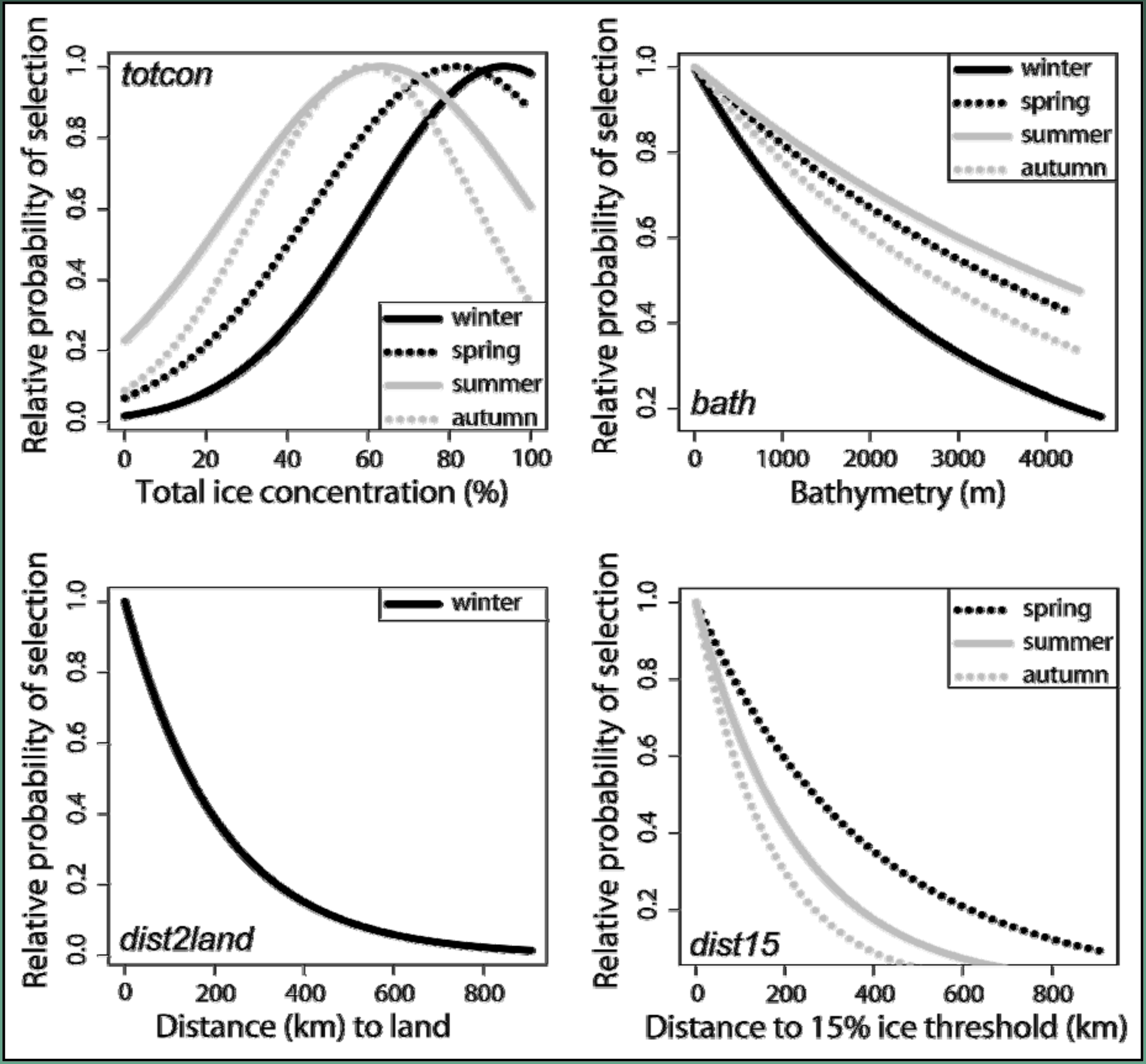
Final RSF model structure – Four seasonal RSFs
Response to covariates

- Medium to high ice concentration
- Shallow waters
- Near the 15% ice threshold
- near land (winter)



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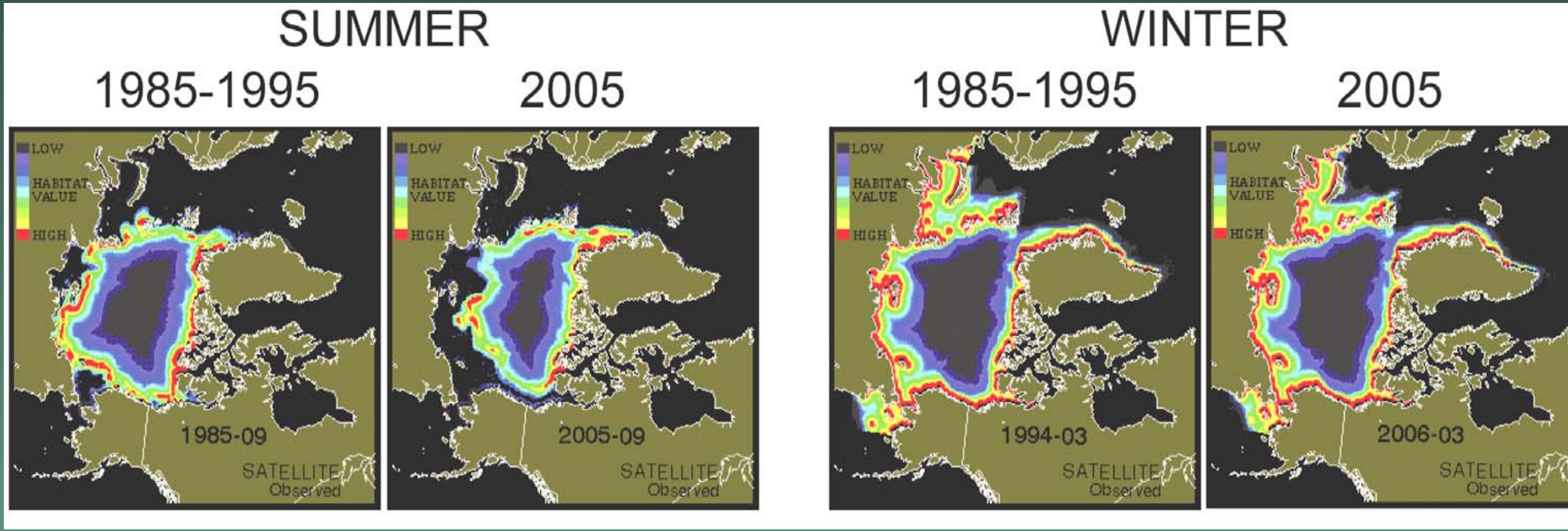
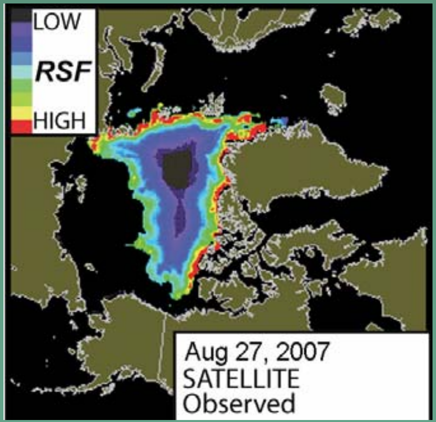
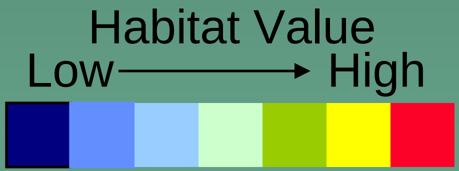
RSF models extrapolated to satellite-observed sea ice data







USGS Report: Durner et al. (2007)

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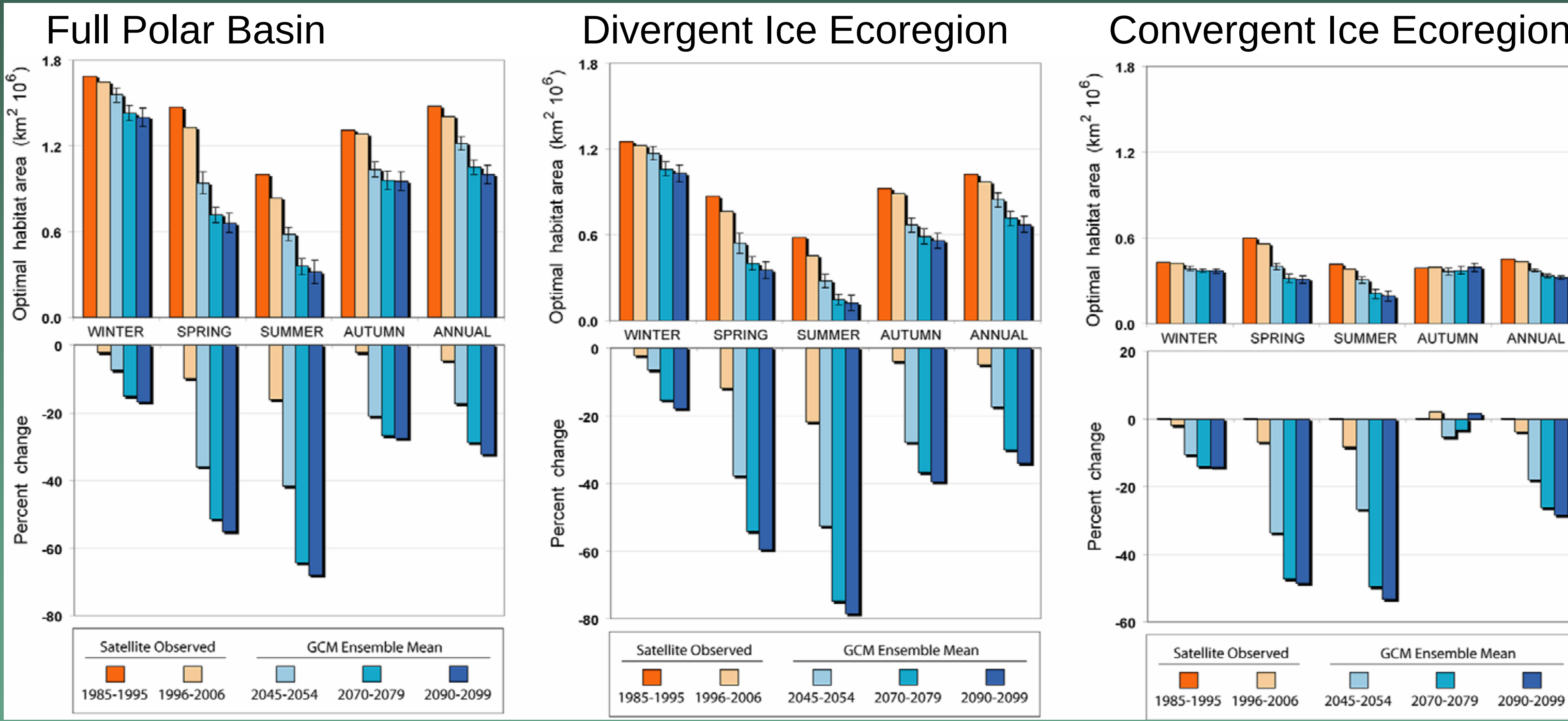
Projected changes in optimal habitat: Pronounced Seasonal Variability



USGS Report: Durner et al. (2007)

Hunter et al. report: Capture-recapture study, Southern Beaufort Sea 2001-2006

Immobilization from helicopter.

Samples and measurements.

Application of ear tag.

Lip tattoo.

Tooth for age determination.

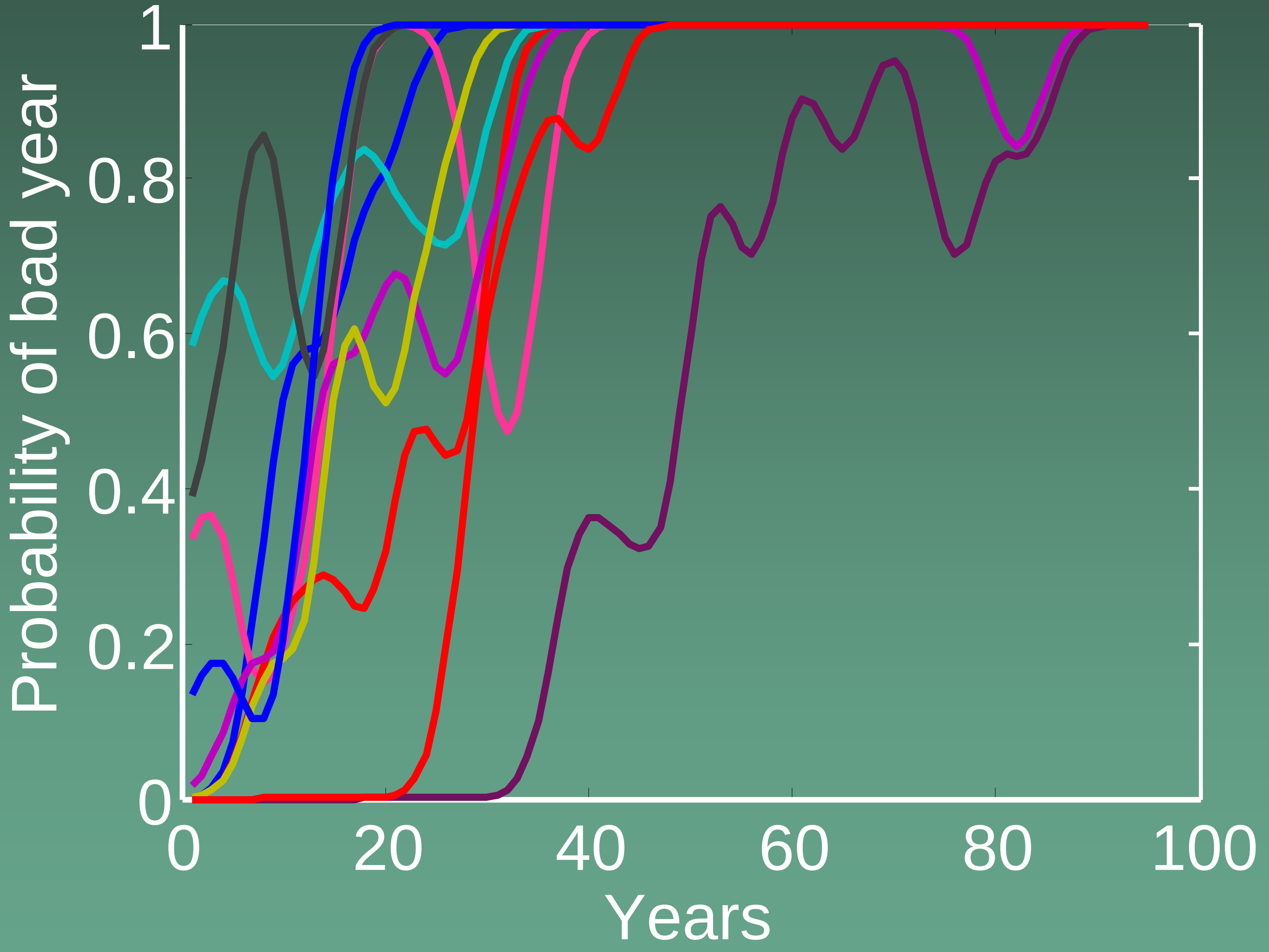
Deterministic population growth rate

Year	population growth rate	growth per year	# ice-free days
2001	1.06	+ 5.8%	90
2002	1.06	+5.8%	94
2003	1.04	+3.9%	119
2004	0.76	-27.0%	135
2005	0.80	-22.0%	134

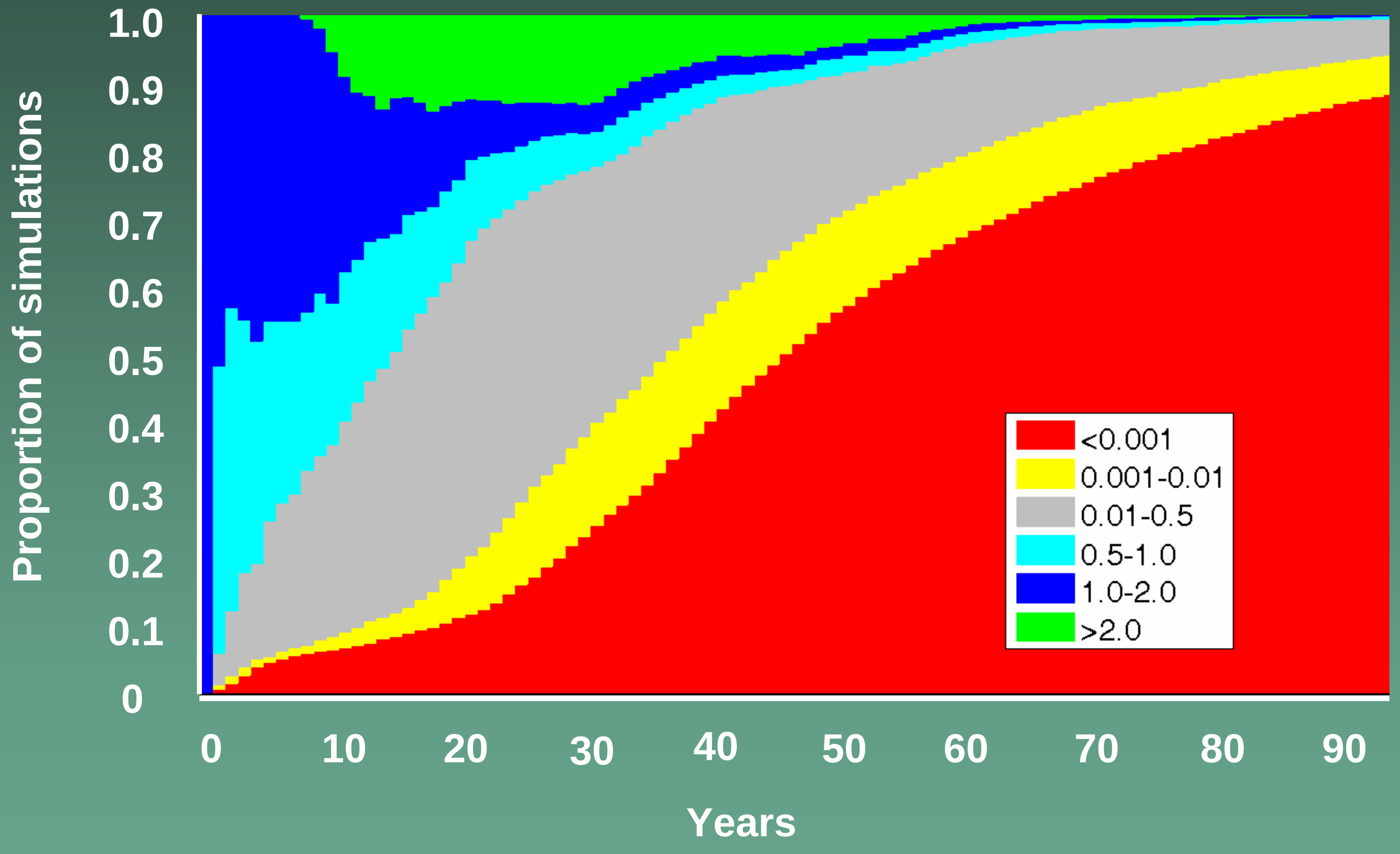
“good” years (2001–2003)

“bad” years (2004–2005)

Climate model projections

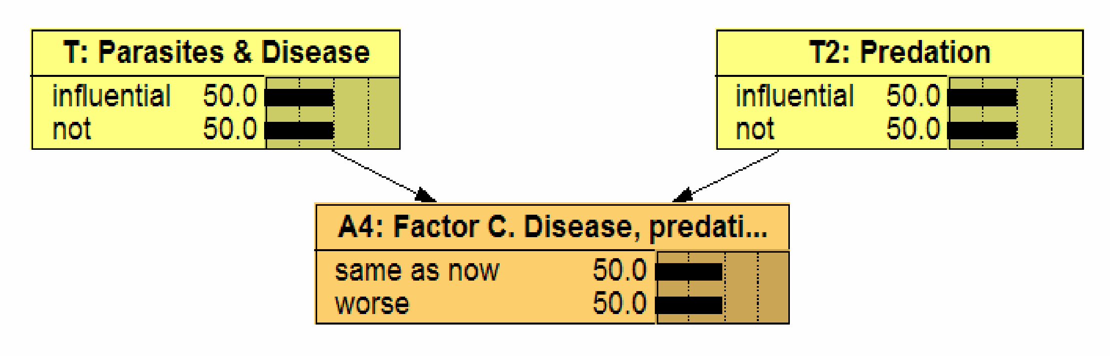


Climate model population projections



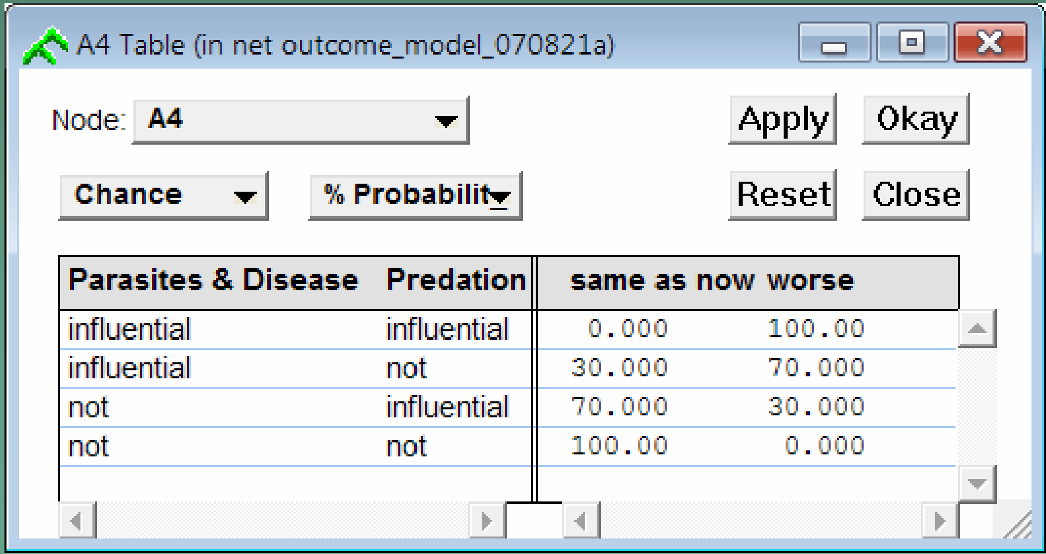
3. Synthesis and Incorporation of expert judgement:

Bayesian Network Model for polar bear populations stressors (Amstrup et al. 2007)



Allows sensitivity testing, “what if” scenarios, and transparency.

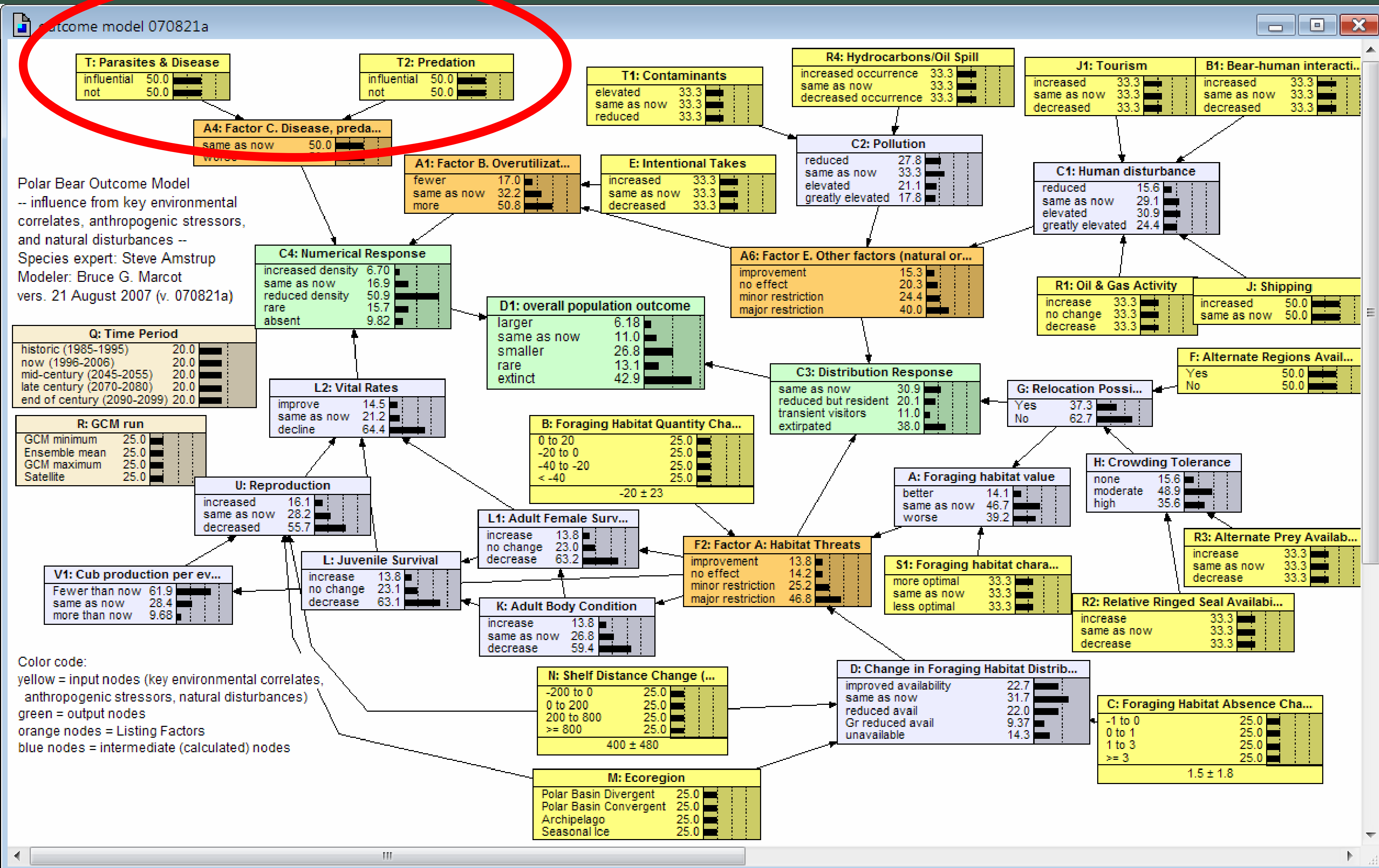
BNM incorporates expert judgement by defining key factors and calculating conditional probabilities based on multiple choices of multiple factors. Inputs can be quantitative data or expert judgements.



Parasites & Disease	Predation	same as now	worse
influential	influential	0.000	100.00
influential	not	30.000	70.000
not	influential	70.000	30.000
not	not	100.00	0.000

Conditional probability table

The full Bayesian network:



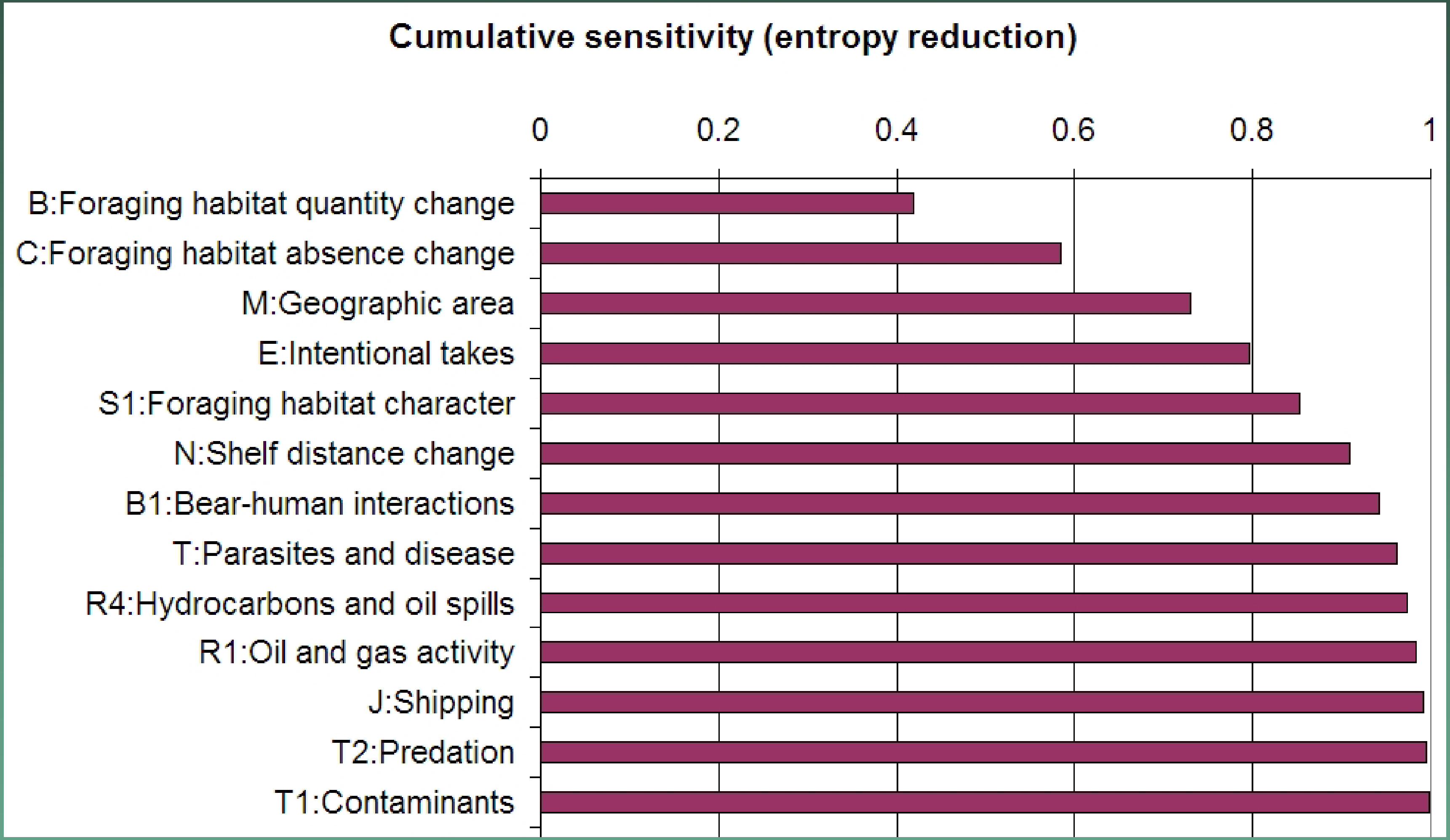
Bayesian Network Population Stressor Model

One Set of Population Outcomes for Seasonal Ice Ecoregion

Year	Larger	Same	Smaller	Rare	Extinct
-10	**94%**	**6%**	**<1%**	**<1%**	**0%**
0	**22%**	**44%**	**19%**	**8%**	**7%**
45	**1%**	**1%**	**10%**	**12%**	**77%**
75	**0%**	**<1%**	**3%**	**8%**	**88%**
100	**0%**	**<1%**	**3%**	**8%**	**88%**

S. Hudson Bay: declining body condition, lower survival in recent years, pattern similar to that in Western Hudson Bay of years ago. GCMs project a 2 month increase in ice-free conditions, bears already fasting for 10 months

What accounts for the uncertainty in overall outcomes?



Sea ice related factors account for 84% of the outcome variance.

Conclusions

All climate impact assessment efforts will have to

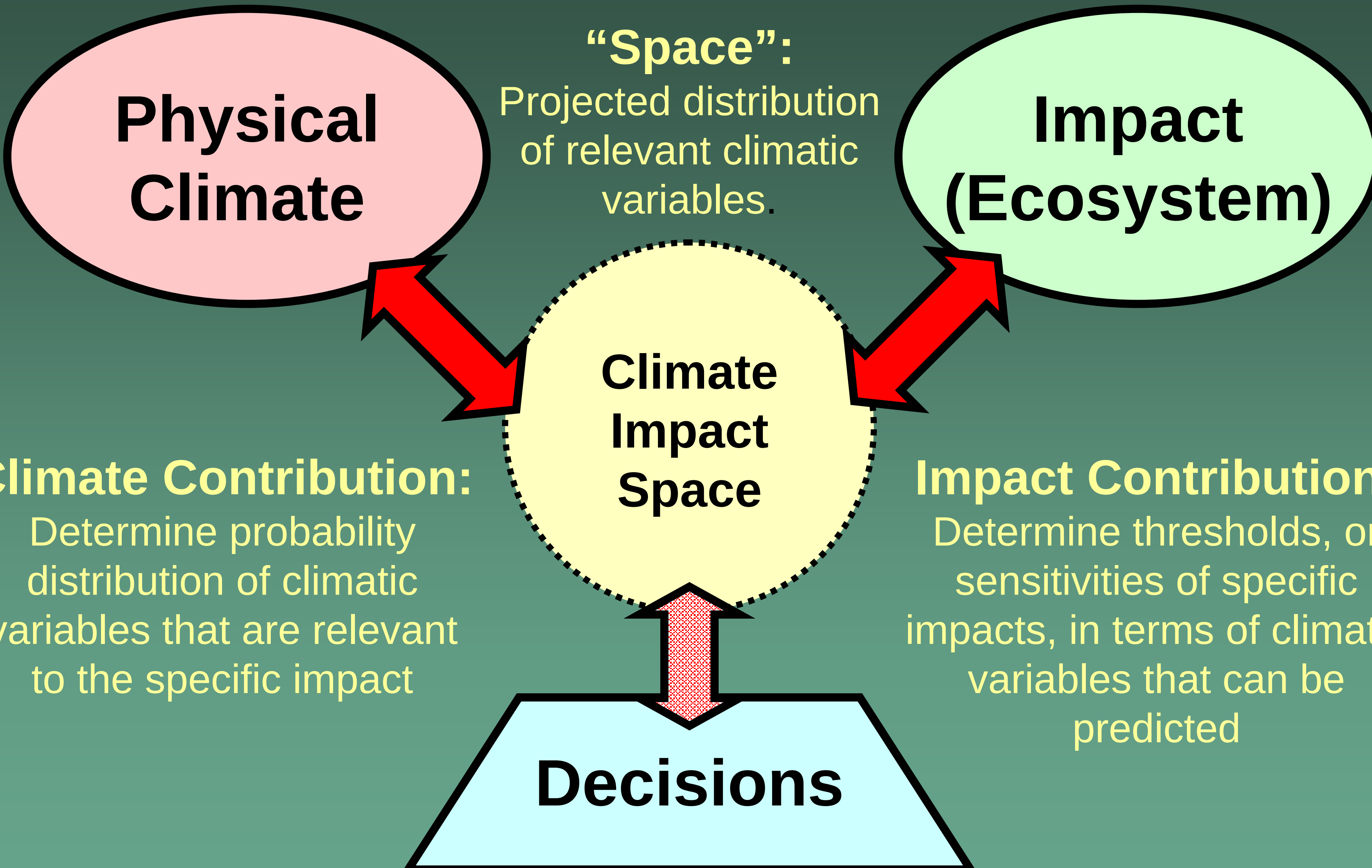
- **Content with large uncertainties.**
- **Find creative ways to combine model output with real-world data.**
- **Incorporate expert judgement and synthesis into the process.**

Communication is an essential ingredient:

climate models probably won't give you the information you want, expect to iterate back and forth between what you need and what models offer before identifying the most useful variables.

Impact Assessment Framework:

"Space":
Projected distribution of relevant climatic variables.



Climate Contribution:
Determine probability distribution of climatic variables that are relevant to the specific impact

Impact Contribution:
Determine thresholds, or sensitivities of specific impacts, in terms of climatic variables that can be predicted

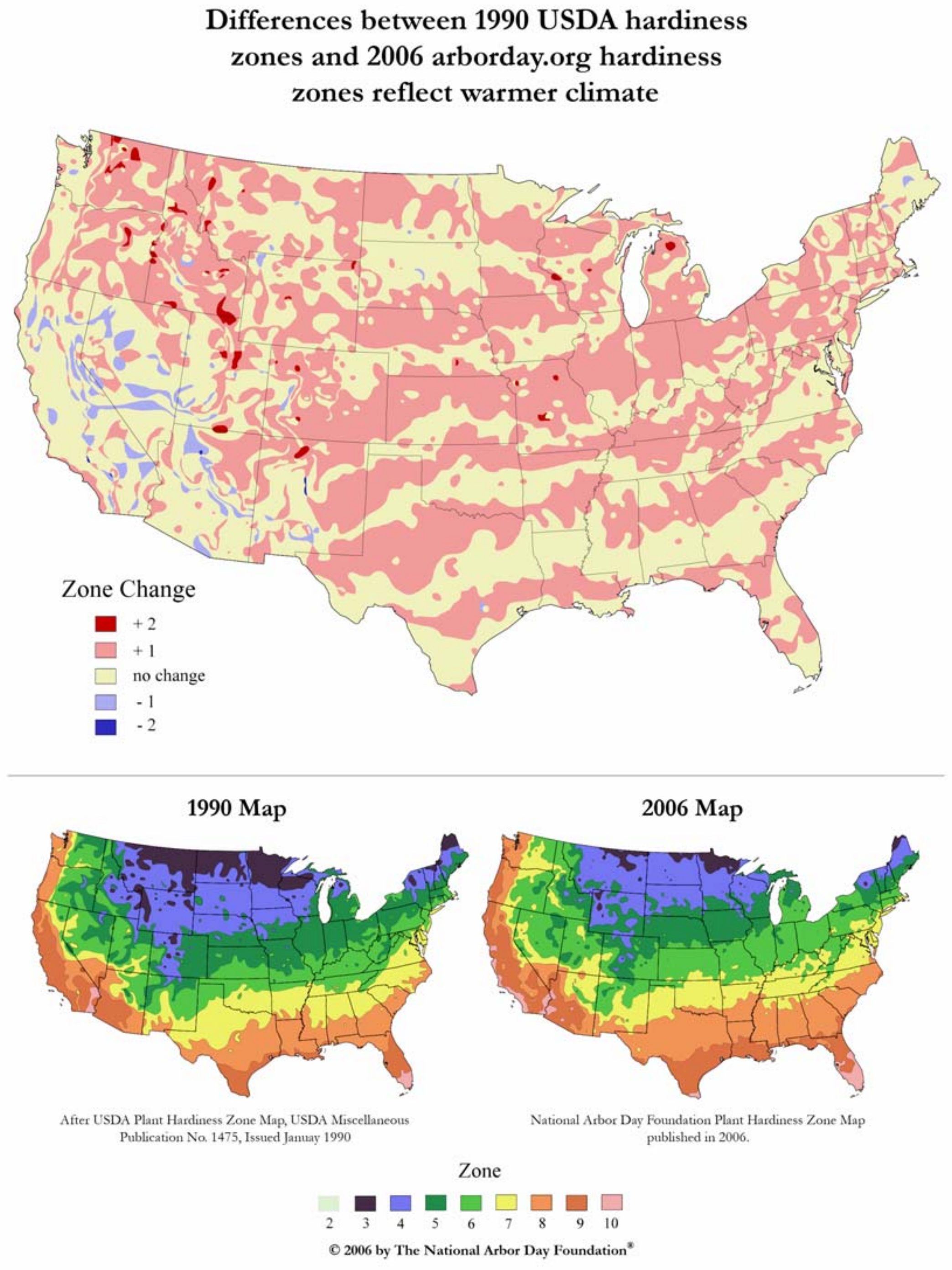
D. Vimont, CCR

Other closing thoughts

- Other stakeholders may not be so up-front about their uncertainties.
- Decisions can't wait for perfect knowledge.
- Climate change is a broad-scale phenomenon, so efforts should shared over as wide a region as possible. Wisconsin: WICCI should be announced shortly, hopefully interstate collaboration will follow shortly.

Questions?

Plant Hardiness Zones

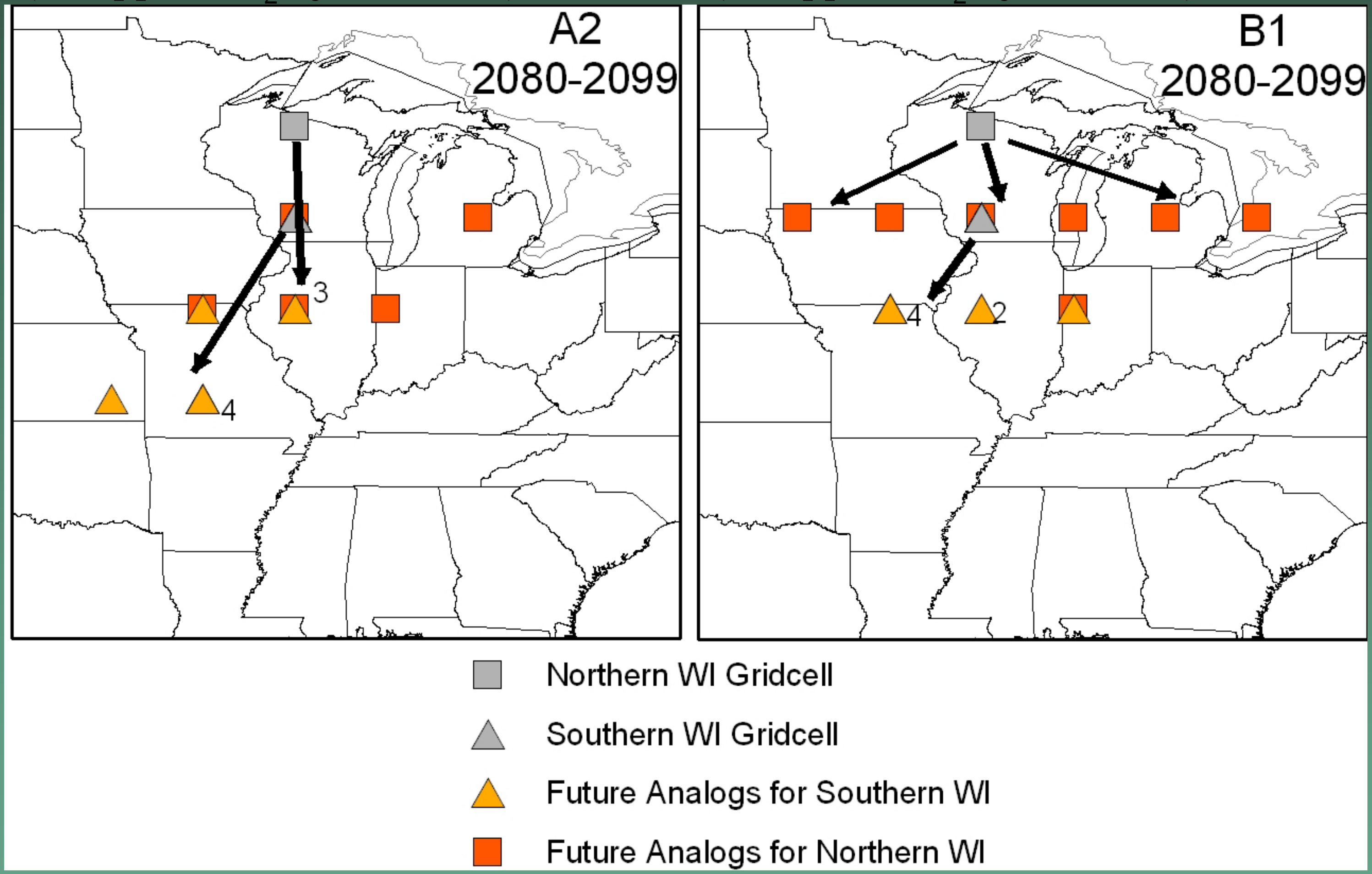


Source: National Arbor Day Foundation
www.arborday.org

What will Wisconsin climates look like by 2100 AD?

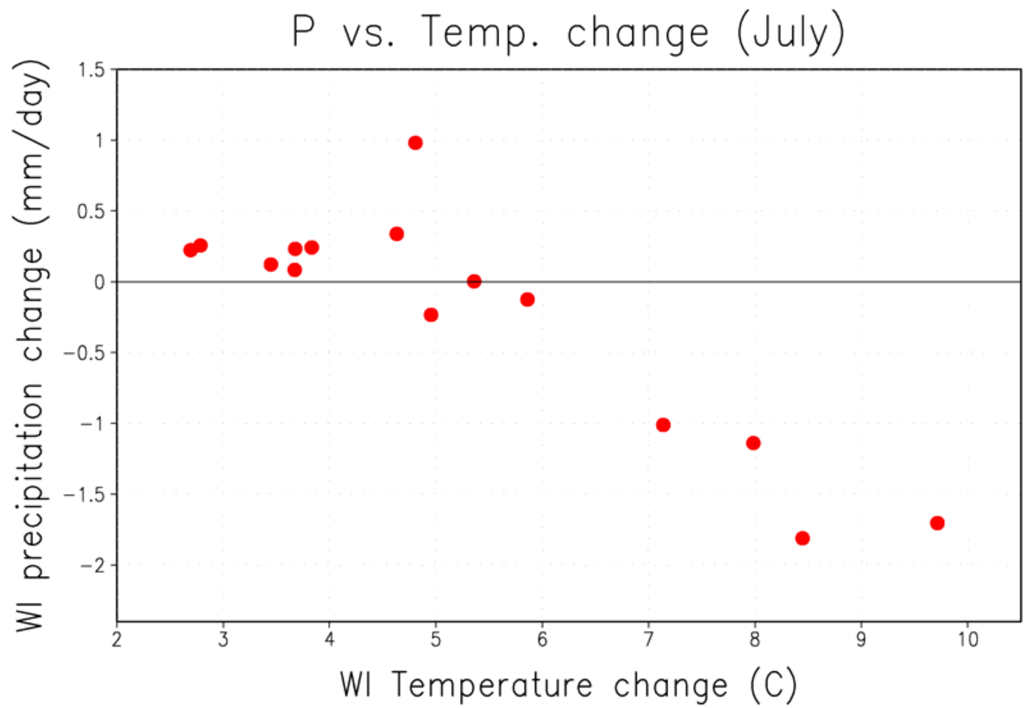
‘Business-as-usual’ scenario (850 ppm CO_2 by 2100 AD)

Mitigation scenario (550 ppm CO_2 by 2100AD)

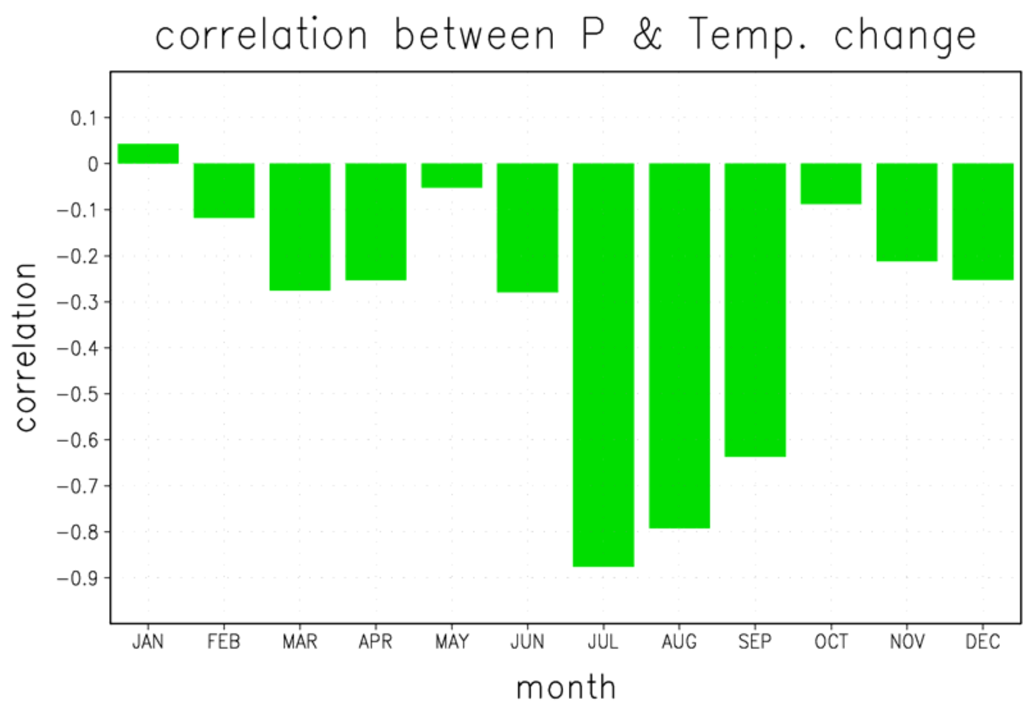


Source: J. Williams, UW Center for Climatic Research & Department of Geography

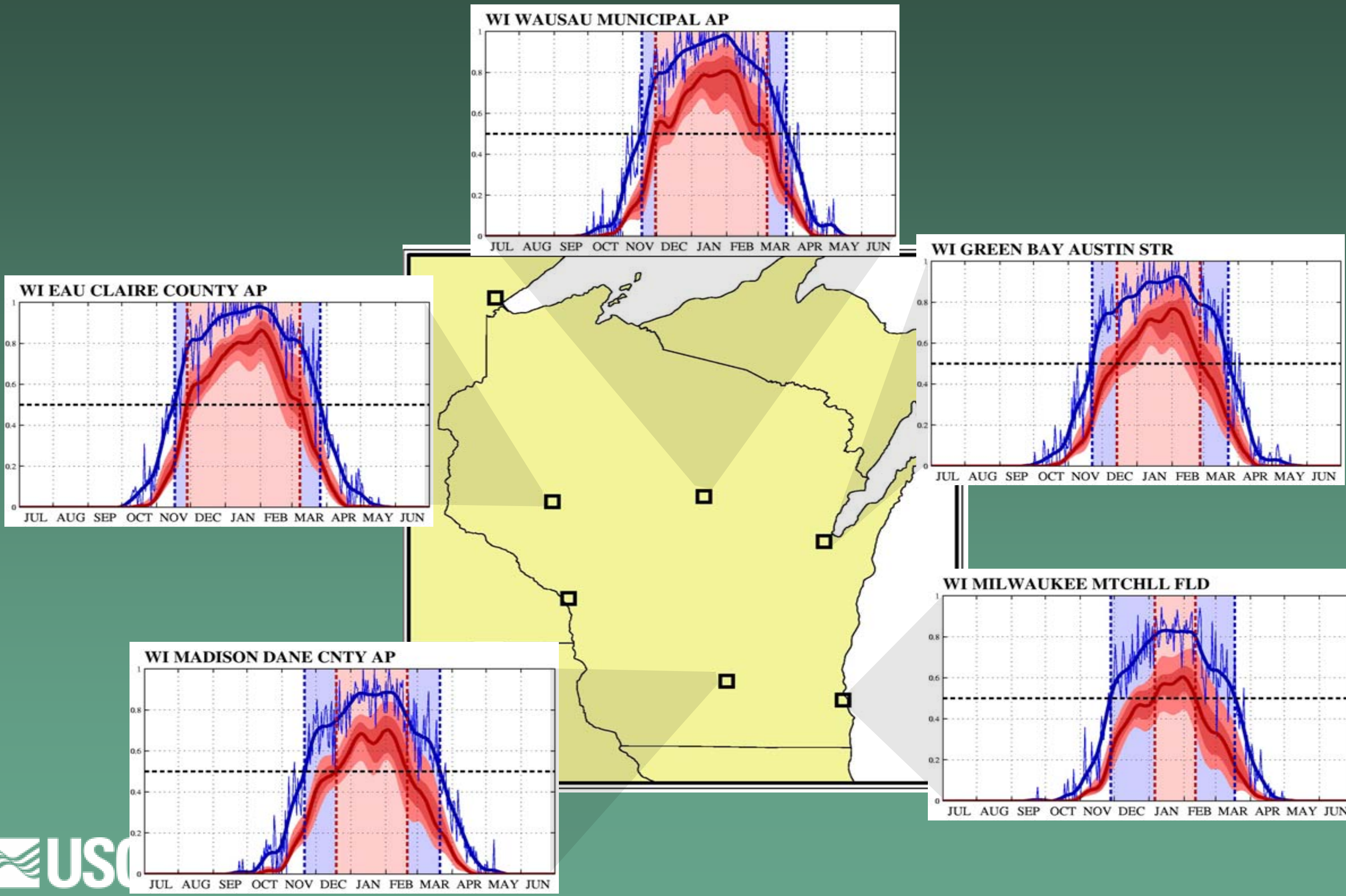
Change in Precipitation versus the change in Temperature in July for 15 IPCC models



Correlation between Change in Precipitation and the change in Temperature versus month.

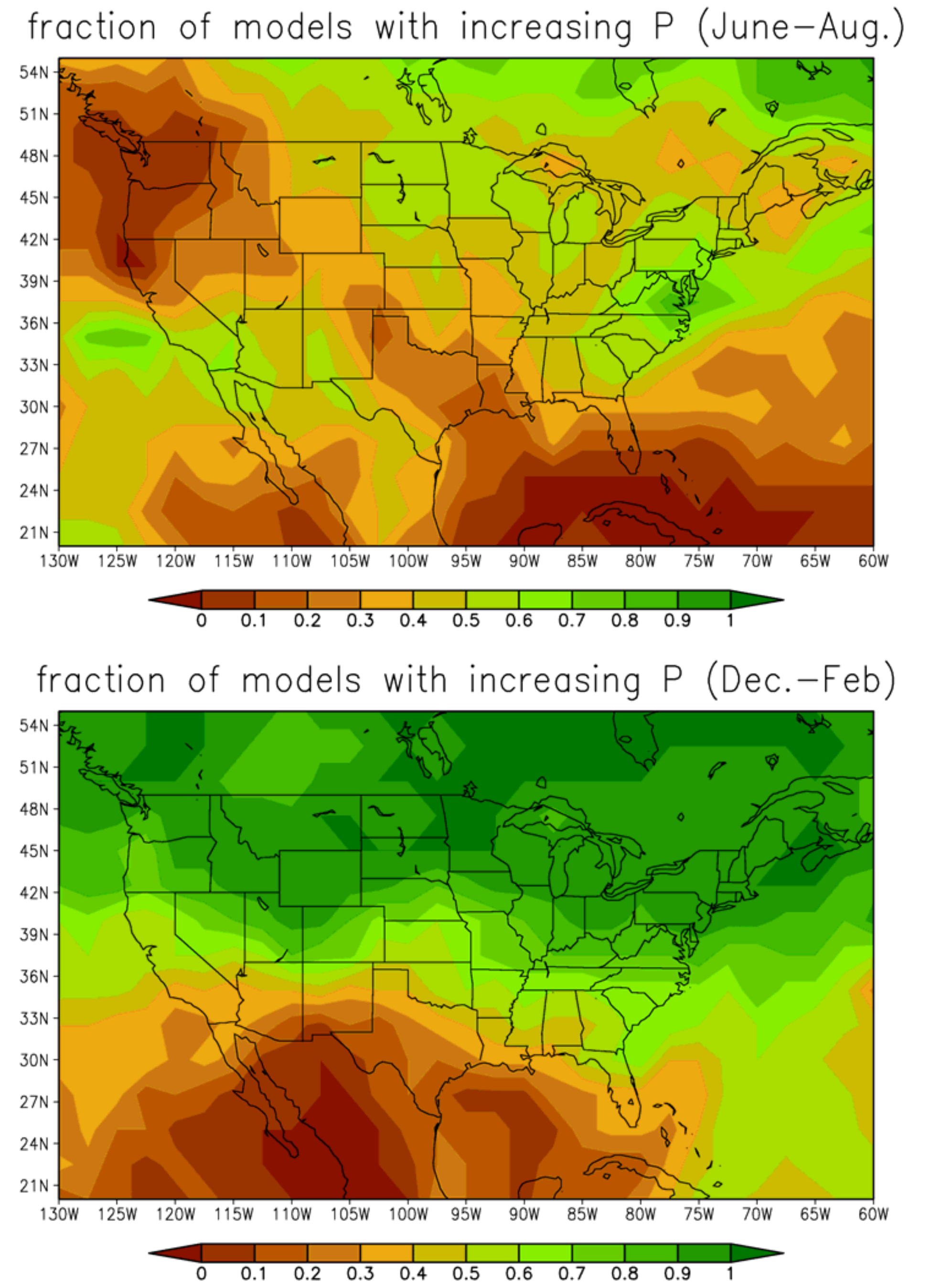


Probability of Snow vs. Rain



Precipitation change is more uncertain than the Temperature change:

Projected change in Precipitation (IPCC models)



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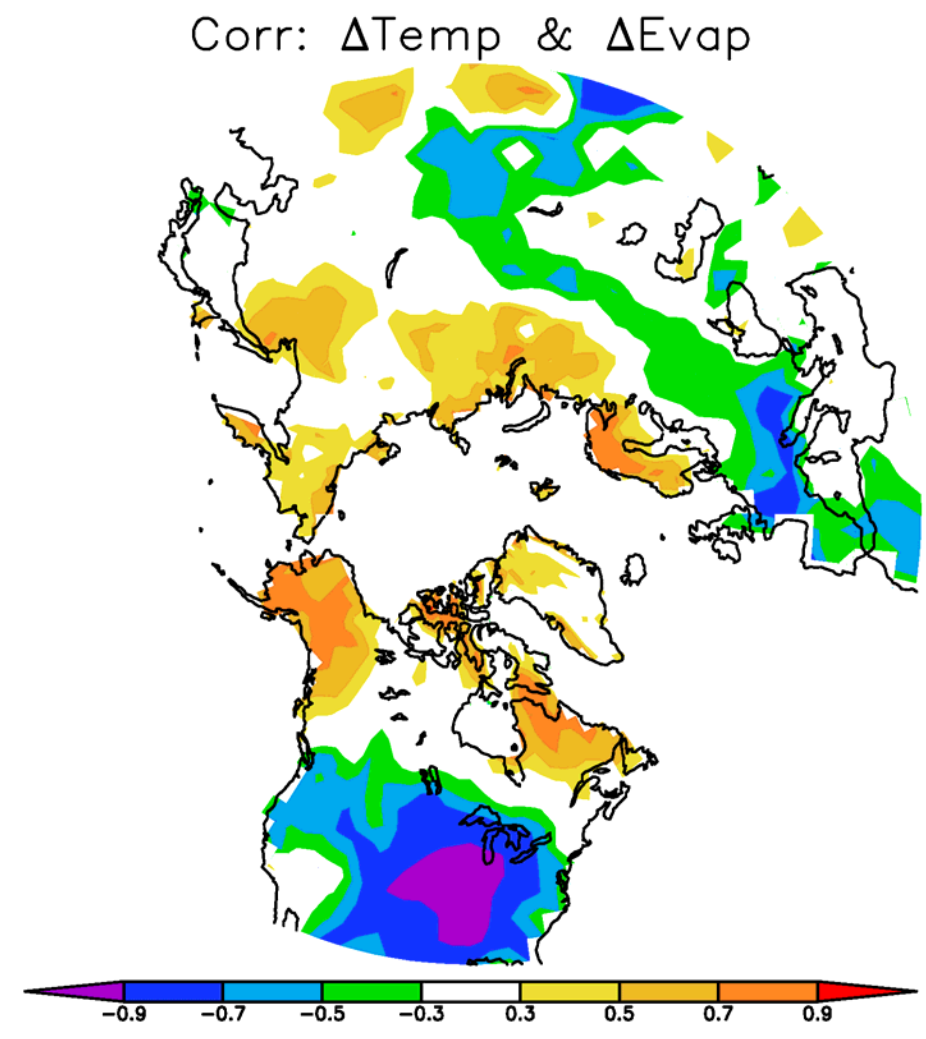
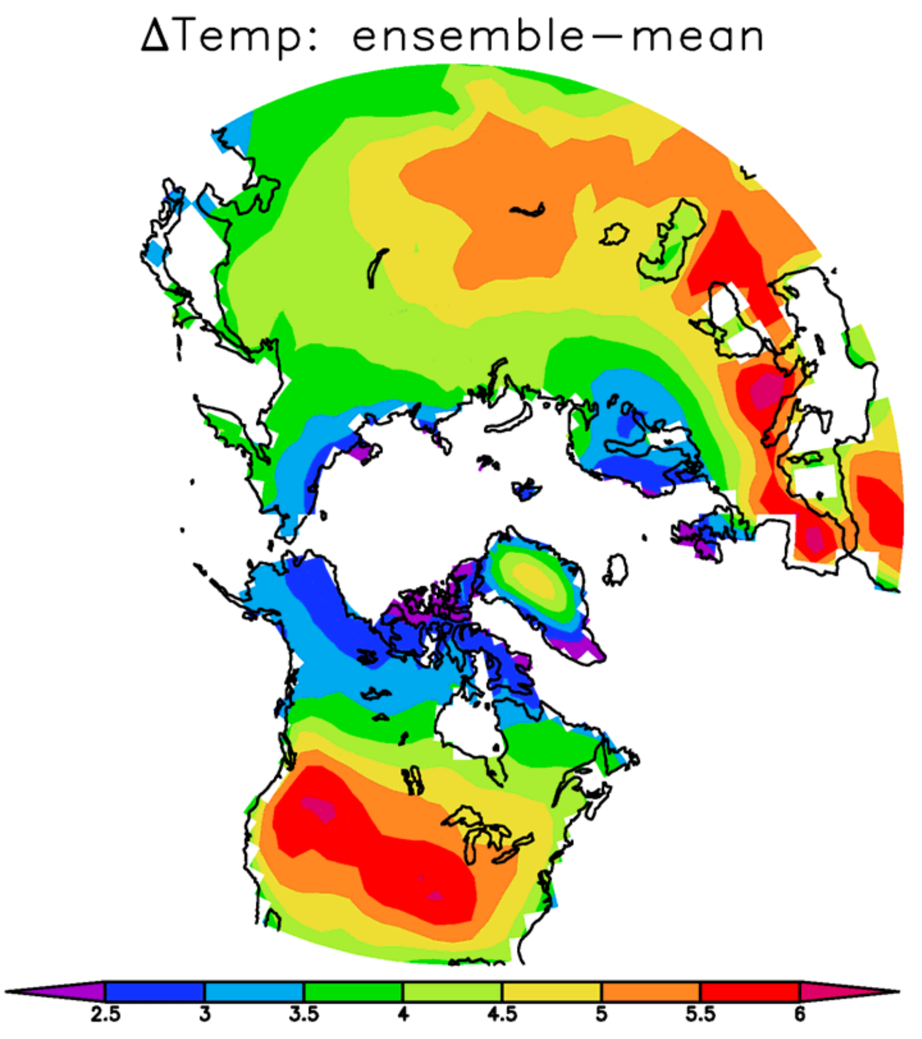
Temperature Change more strongly correlated with Evaporation Change:

Correlation between local Evaporation Change & local Temperature Change (July & August)





Look at changes in mid-latitude jets (i.e. zonal wind) to explain model-to-model variability in precipitation.

Maximum Covariance Analysis: Find coupled zonal wind and precipitation that explain the most variance between the two fields: