# How does global warming threaten the polar bear?

An investigation of the present and likely future status of polar bears in a warming climate by the USGS and Collaborators

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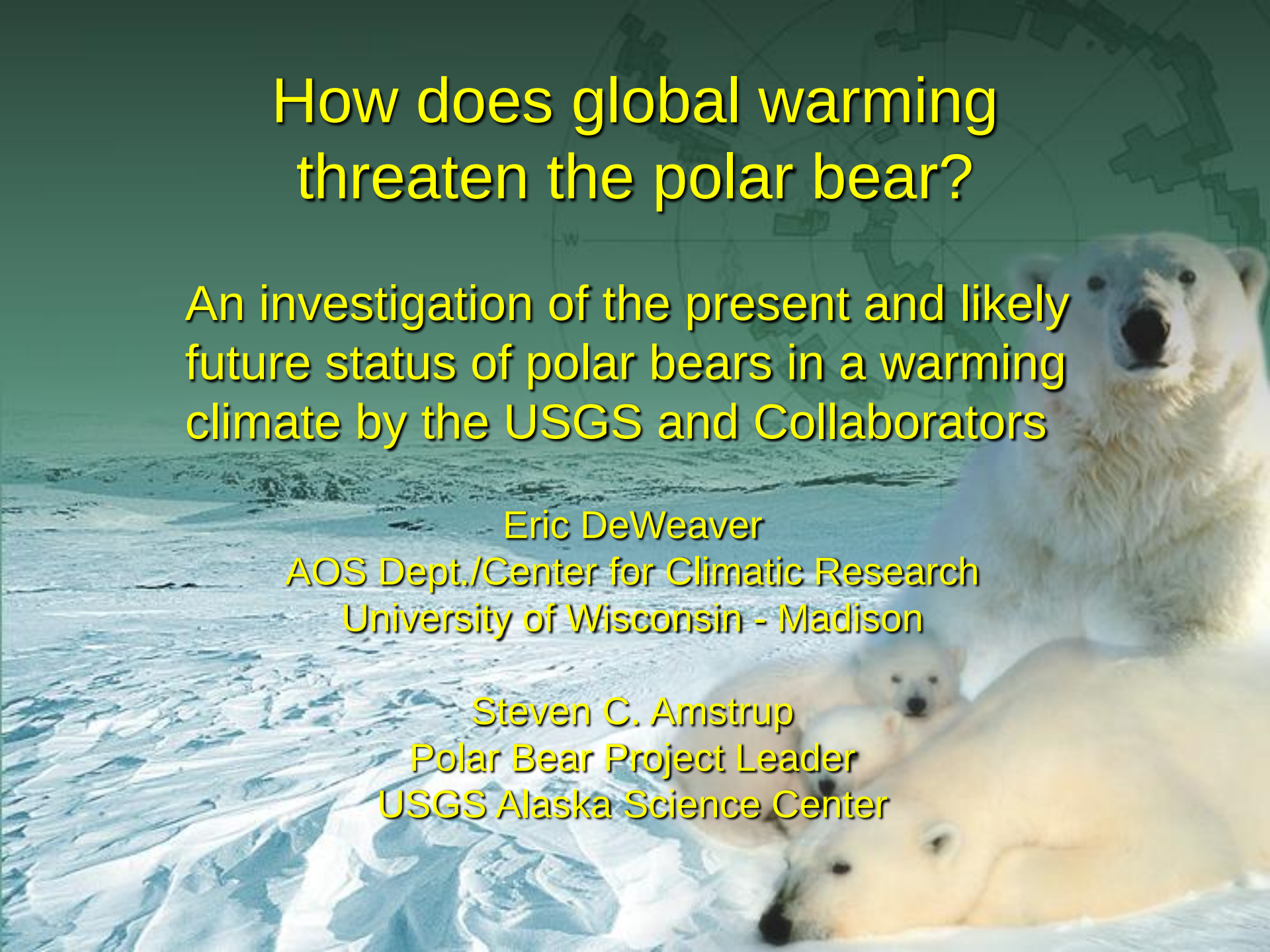

It’s official: the polar bear has (finally) been listed as a threatened species under the ESA. The listing is based on “best available science”, much of it provided by PCWG members:



(Kempthorne, 2008)

CBD complaint: he “turned a pit bull into a poodle”

The good news: it’s a policy issue, not a science issue

Obviously, global warming is bad for polar bears. But how do you make the connections (in strongest terms) between sea ice and polar bears? In January 2007 FWS commissioned USGS to conduct research on polar bears and their likely response to sea ice decline.

The USGS reports, released in September, combine fieldwork, radio telemetry, satellite observations, and climate model output to make projections of polar bear habitat and population in the middle and late 21st century (the designated ESA “foreseeable future”).

This talk gives an overview of the USGS findings, based on briefings conducted at USGS, FWS, and DOI.

# USGS Project Team

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

**Ian Stirling, Evan Richardson *Canadian Wildlife Service***

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**Bruce Marcot *U.S. Forest Service***

**Hal Caswell *Woods Hole Oceanogr***

**Christine Hunter *University of Alas***

**Eric DeWeaver *University of Wisco***

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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.

# Issues addressed in the reports:

**Climate issues:**

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

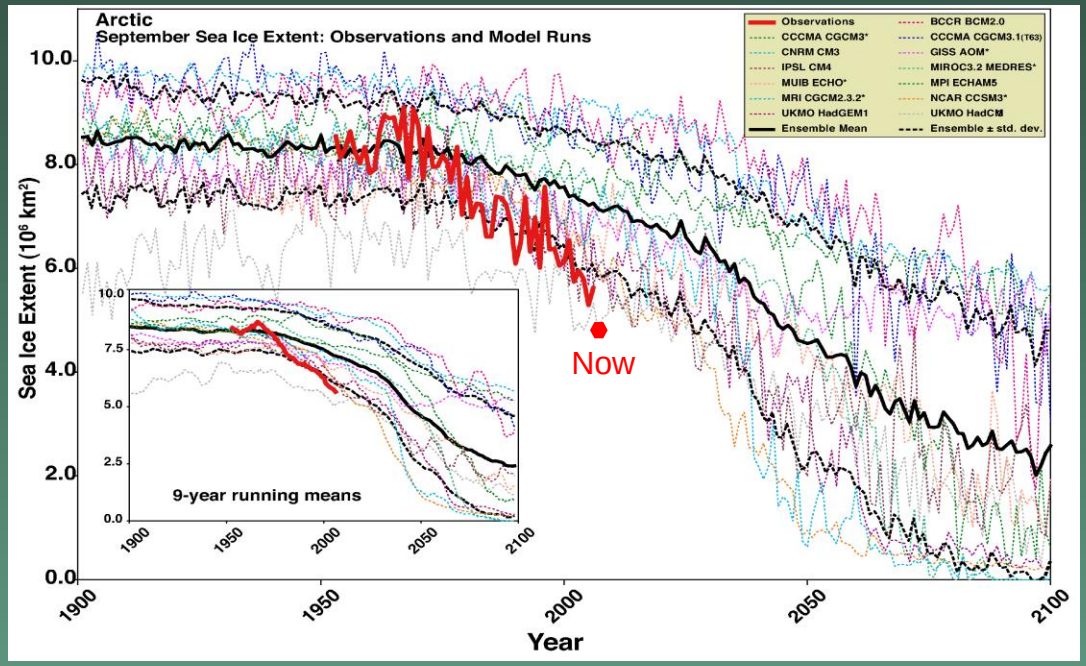
**Polar bear response:**

- 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
  - Bayesian Network model

- How does sea ice decline affect population growth?
  - Markov modeling based on fieldwork in SBS
  - Additional fieldwork in Hudson Bay

# 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.

# 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.

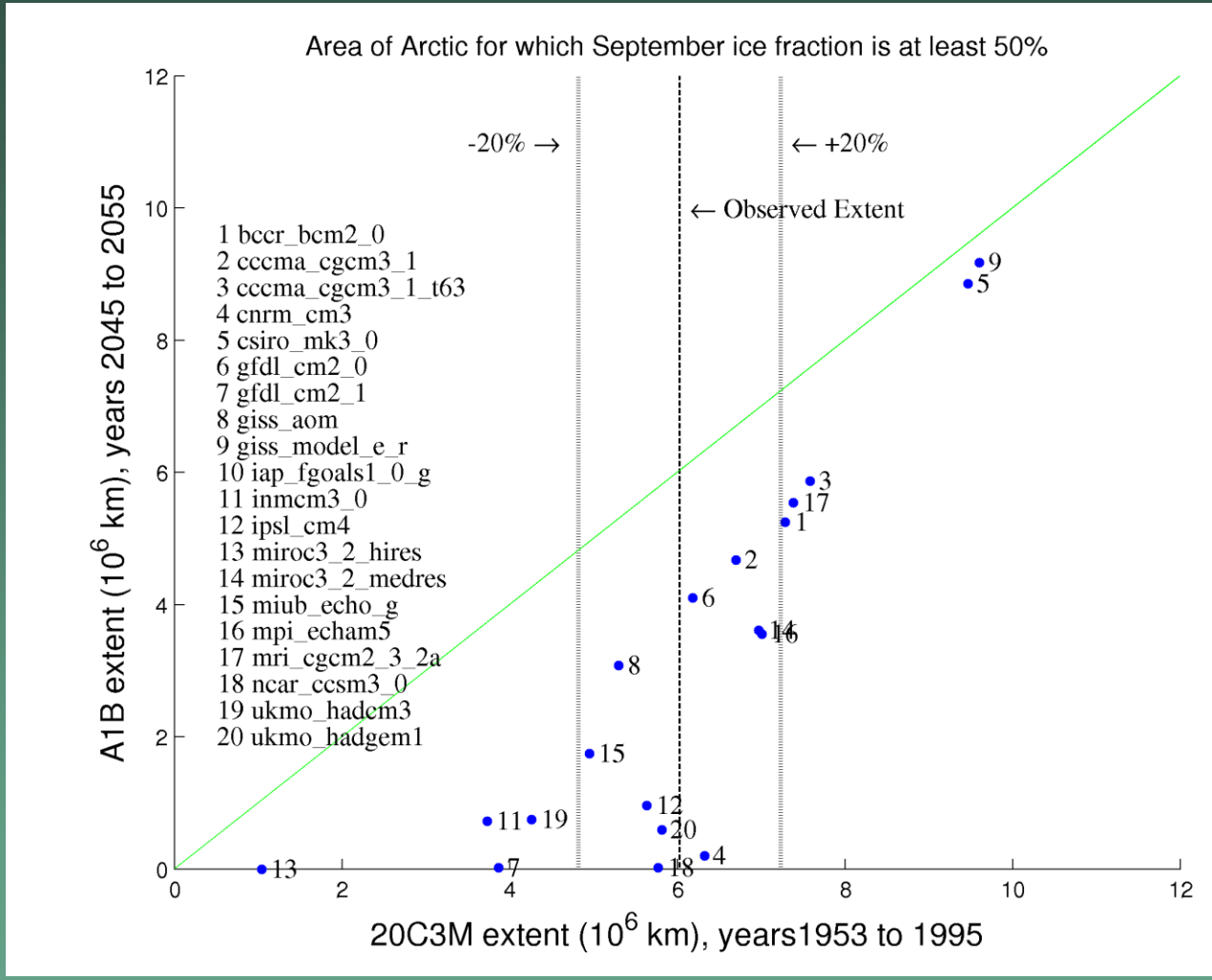
## Criterion:

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%.



# Predicting the Future Distribution of Polar Bear Habitat in the Polar Basin from Resource Selection Functions Applied to 21st Century General Circulation Model Projections of Sea Ice

U.S. Department of Interior
U.S. Geological Survey

USGS Report: Durner et al. 2007

# Purpose:

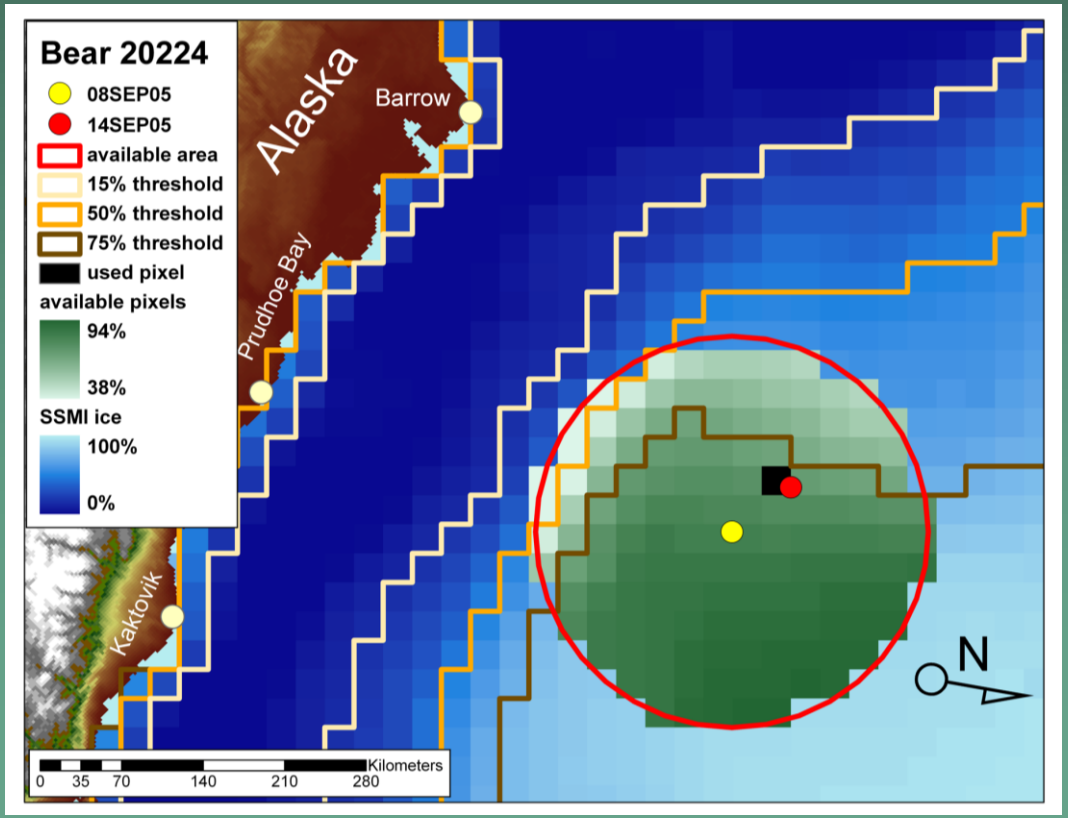
- Build habitat models from the observational record of sea ice extent and polar bear location data derived from satellite radio-telemetry, 1985-1995

- Extrapolate habitat models to general circulation model (GCM) projections of sea ice extent throughout the 21st century to estimate changes in polar bear habitat in the pelagic realm of the polar basin

# Resource Selection Functions (RSF)

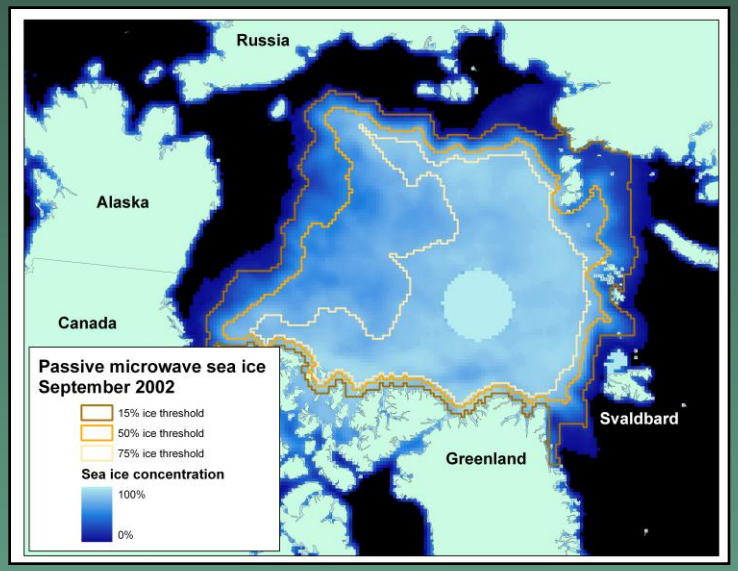
- A statistical model that estimates the probability of habitat use (Manly et al. 2002)
- RSFs are built with animal location data and measurements of habitat variables
- RSFs compare the habitat used to the habitat available (i.e., selection)

- 1 of >12,000 pairs of polar bear locations:



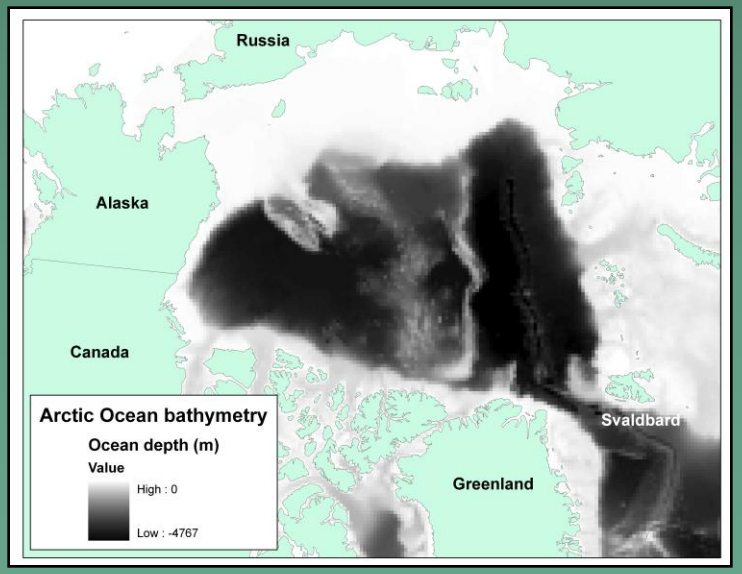
# Data sources:
# Building the RSF

- Satellite radio-collars deployed on female polar bears



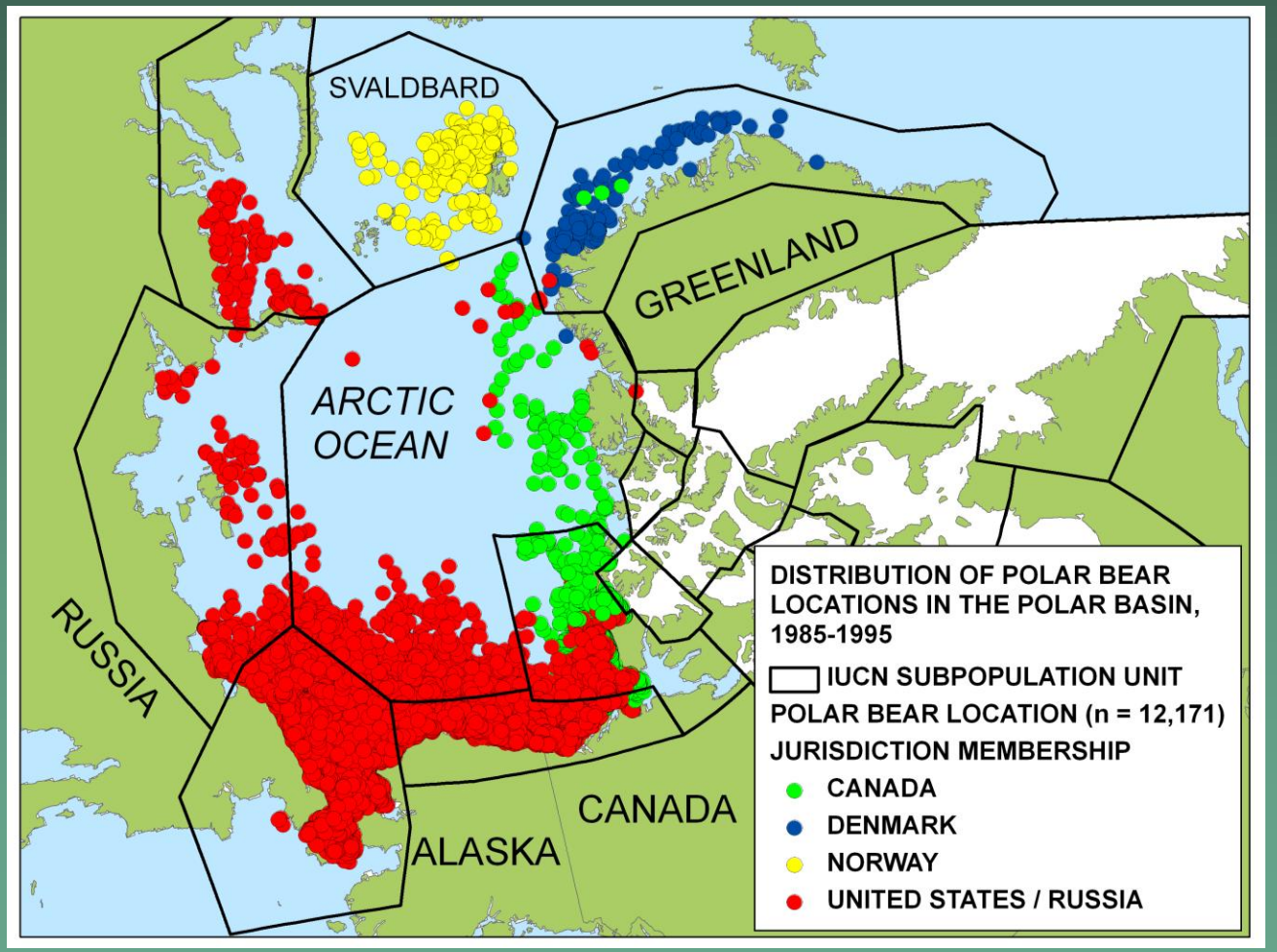

- Passive microwave sea ice concentration (NSIDC, Boulder)

- Ocean depth and distance to land



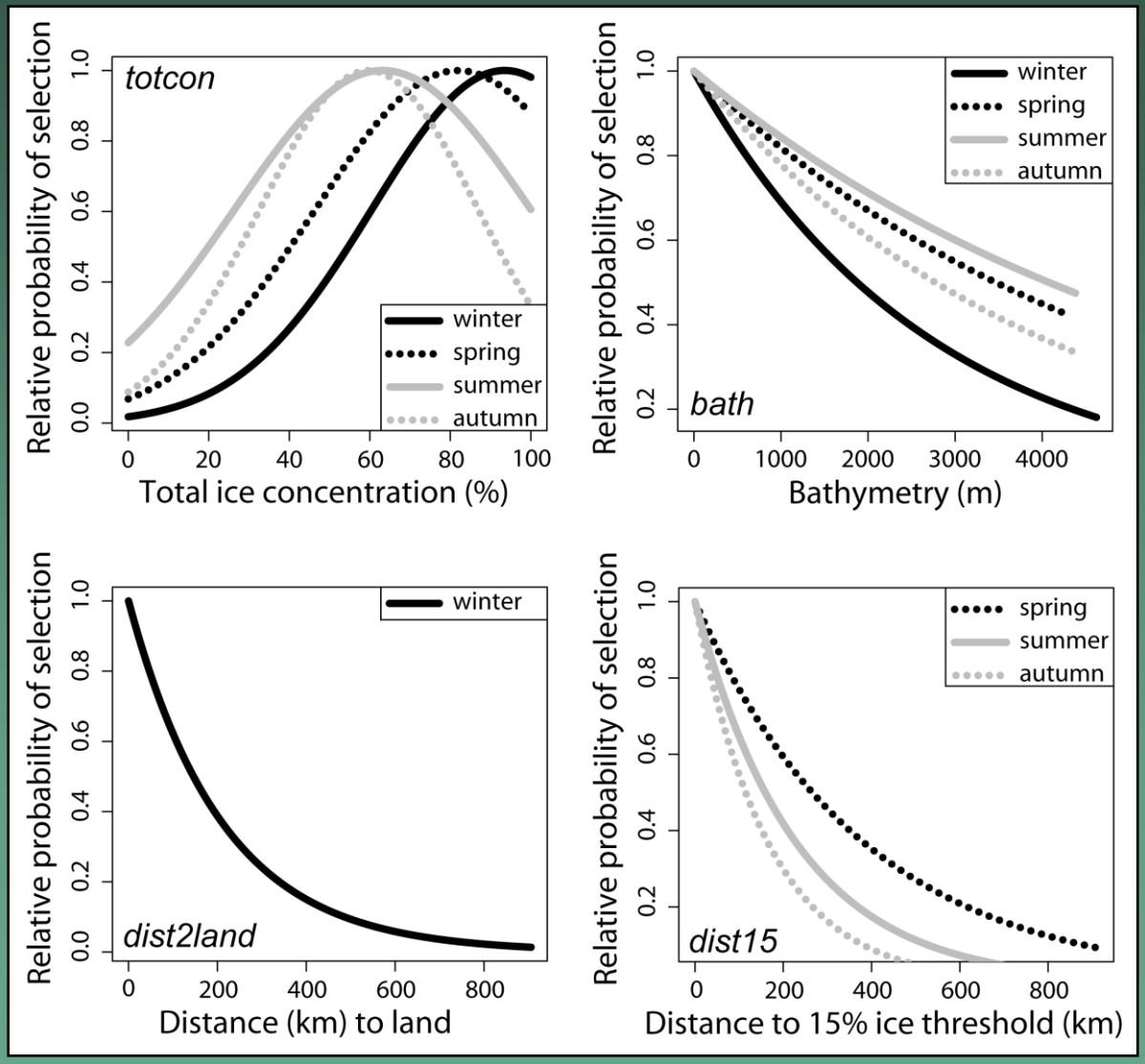
# Focus: the pelagic ecoregion of the Arctic Basin

- Divergent ice and convergent ice ecoregion
- 333 bears and 12,171 locations
- International contributions

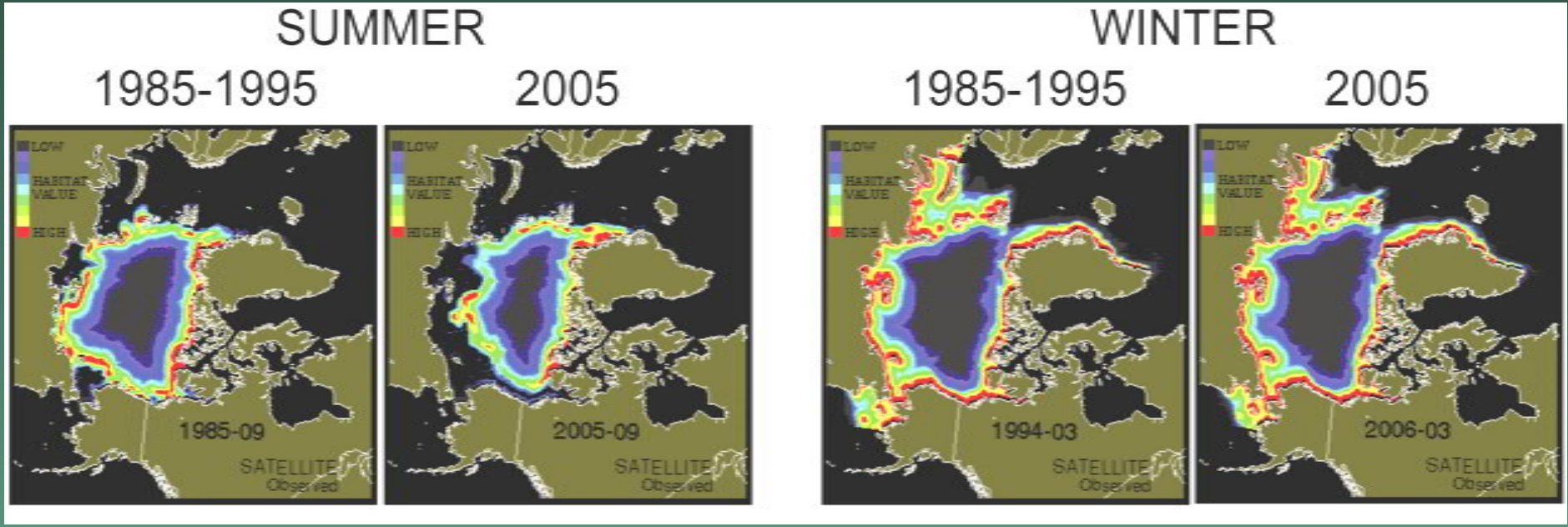


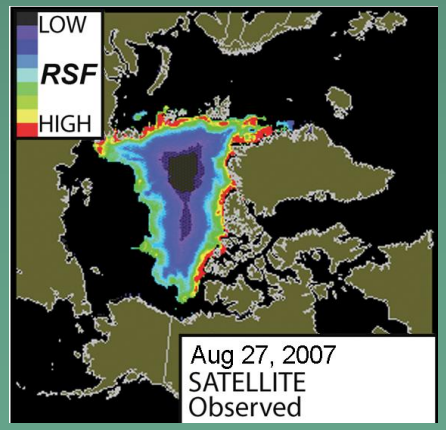
# Final RSF model structure – Four seasonal RSFs Response to covariates

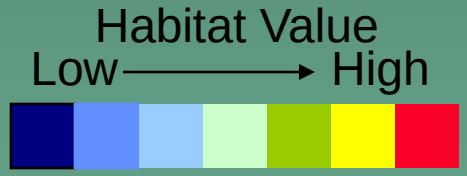
- Medium to high ice concentration
- Shallow waters
- Near the 15% ice threshold
- near land (winter)



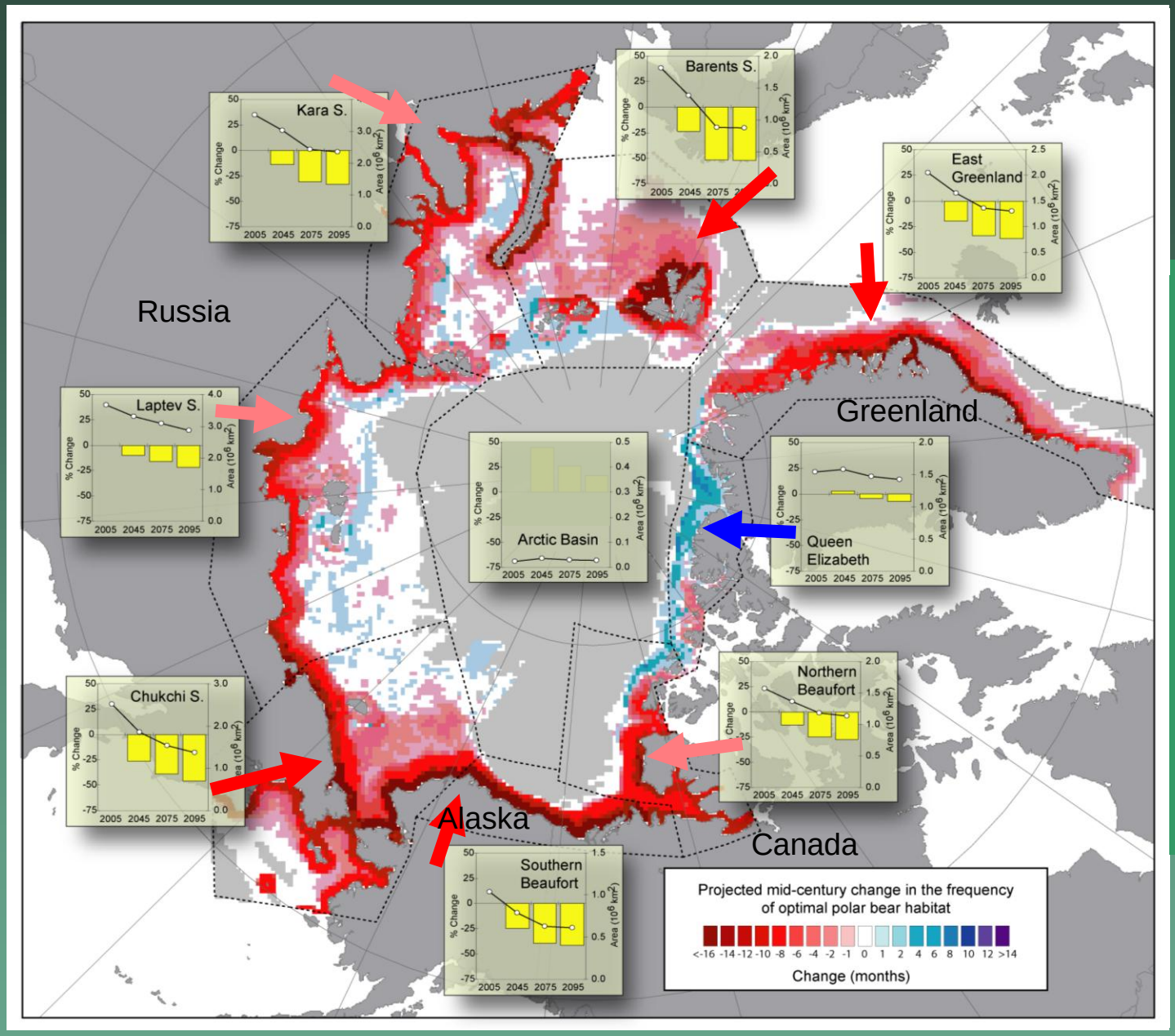
# RSF models extrapolated to satellite-observed sea ice data



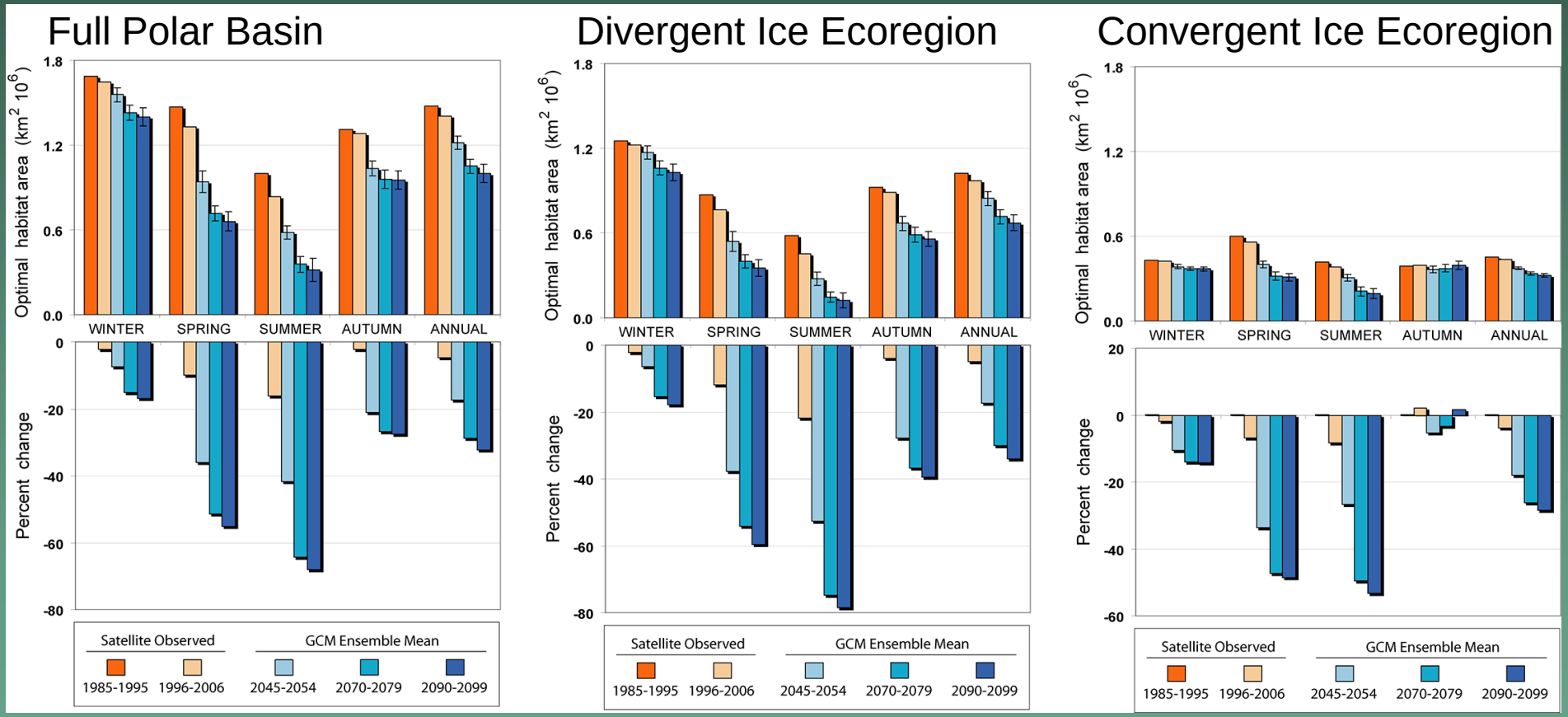

USGS Report: Durner et al. (2007)




Projection of Habitat change

Decade 2001-2010 To Decade 2041-2050

# Projected changes in optimal habitat: Pronounced Seasonal Variability




Durner et al. (2007)

# Conclusions of RSF Study:

- Polar bears select habitats over shallow waters, so the loss of ice over the continental shelf results in large losses of habitat
- Habitat loss is highly seasonal, with greatest losses in spring and summer
- Optimal polar bear habitat will likely persist in high latitude regions near the Canadian archipelago
- Observed rates of habitat loss during 1985-2006 are greater than rates predicted during the 21$^{st}$ century, indicating that our models showing loss of polar bear habitat may be conservative.

# How will Polar Bear Populations Respond to Habitat Change: analyses from the Southern Beaufort Sea

U.S. Department of Interior
U.S. Geological Survey

USGS Report: Hunter et al.(2007) with model inputs from Regehr et al. 2007 and DeWeaver (2007) climate model selection

# Southern Beaufort Sea Population: Goals

- current population status
- future population changes
- matrix population model
  - population growth rate[s]
  - projection of population size for next 100 years
  - relation to sea ice conditions
  - response to climate model sea ice forecasts
- model based on polar bear life cycle

# Capture-recapture study 2001-2006

**Immobilization from helicopter.**

**Samples and measurements.**

**Application of ear tag.**

**Lip tattoo.**

**Tooth for age determination.**

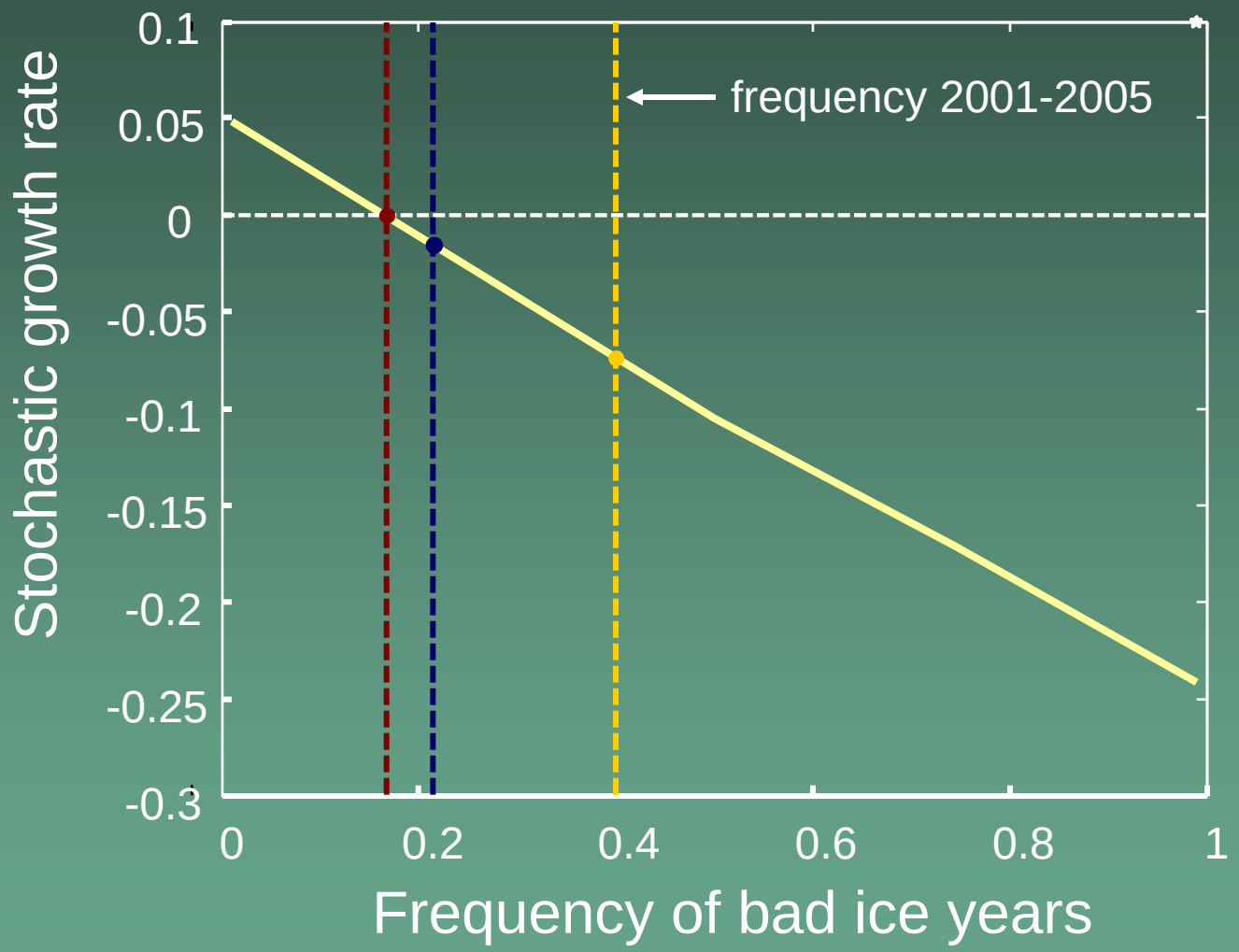
# Deterministic population growth rate

| 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 |

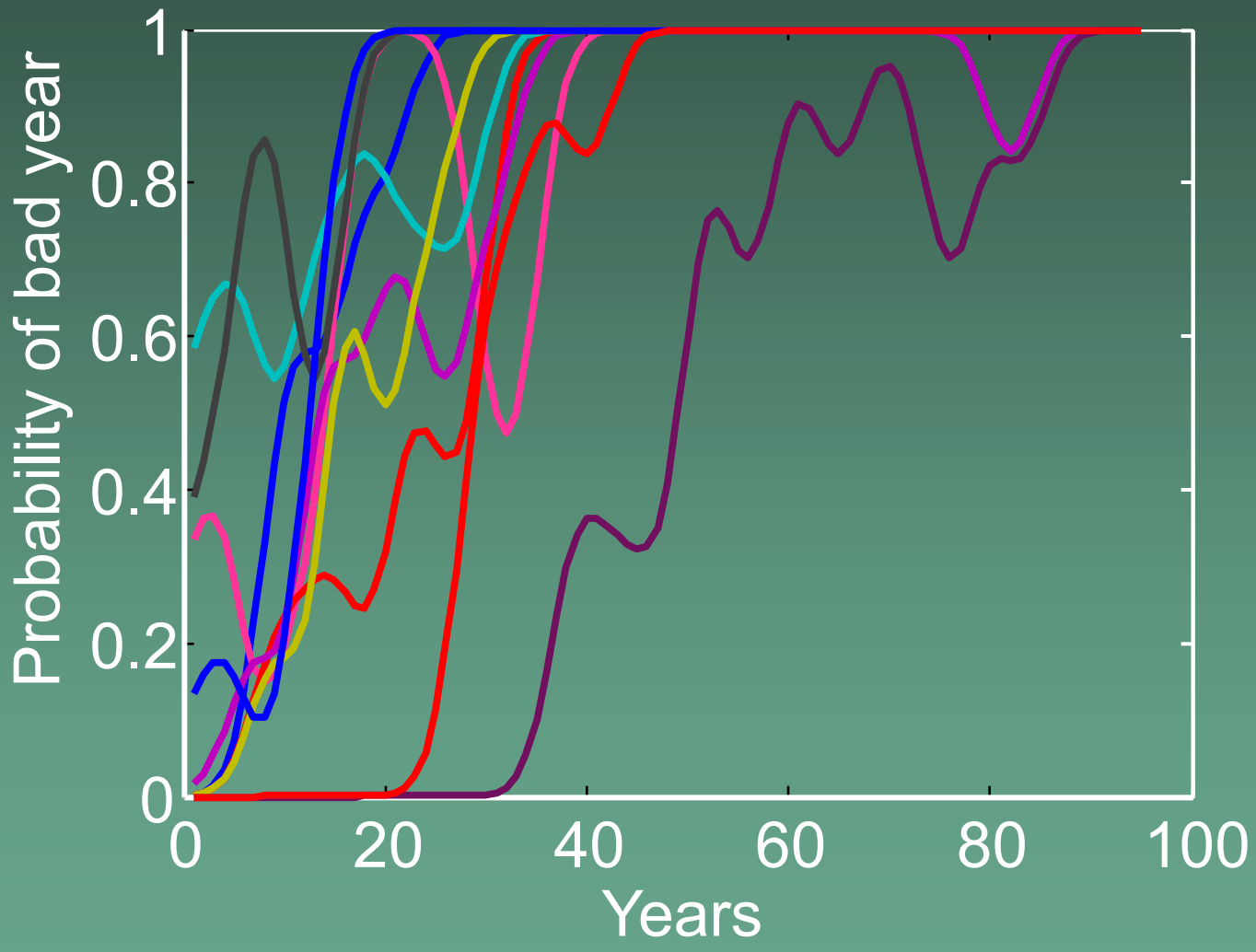
"good" years

"bad" years

# Growth rate versus frequency bad years



# Climate model projections of bad years



# Summary: Climate model scenarios

- If ice conditions follow the ensemble of 10 climate models, the population:
  - will probably decline to 1% of current size in 45 years
  - will probably decline to 0.1% of current size in 75 years
- high probability of extinction by 2100

## Polar bear populations projected to decline range-wide

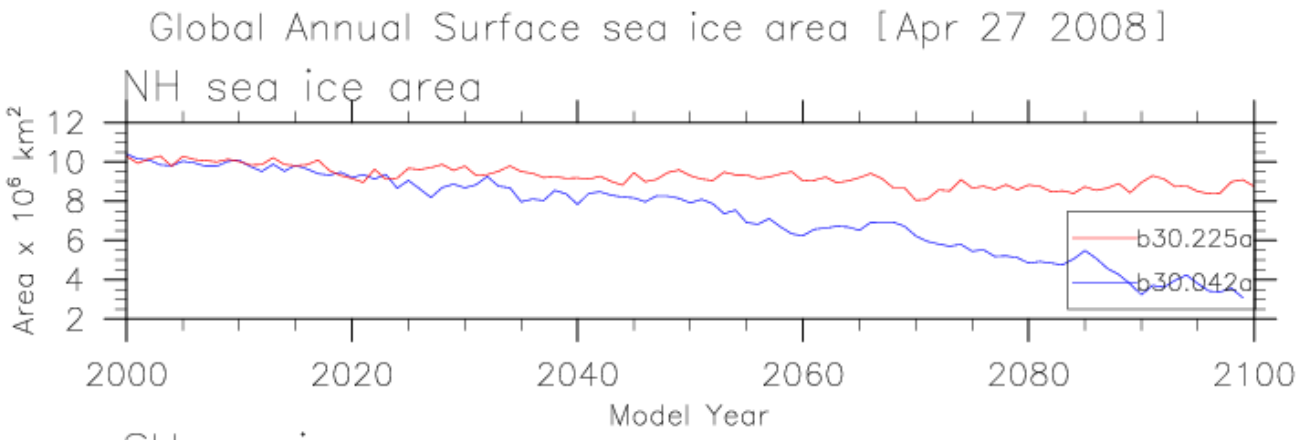
- Mid-century:
  - Probable extirpation in Divergent and Seasonal ice Ecoregions.
  - These represent ~2/3 of the current range-wide population
- Late century:
  - Probable extirpation in Polar Basin Convergent Ecoregion.
  - Probable remnant populations in Archipelagic Ecoregion

# Is it too late to save the Polar Bear?

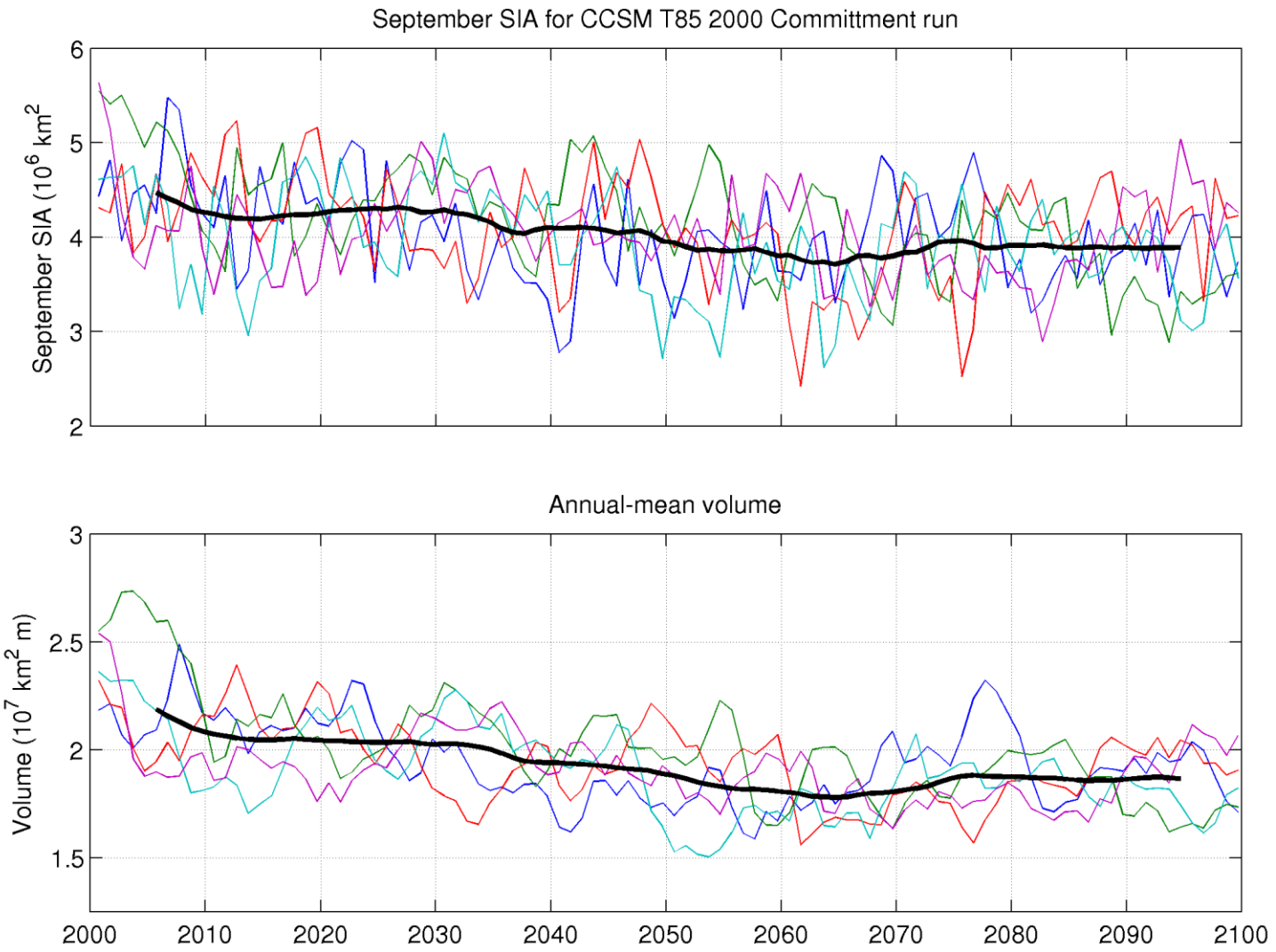
CBS News, 9/7/2007: “Scientists do not hold out much hope that the buildup of carbon dioxide and other gases can be turned around in time to help the polar bears anytime soon.
‘Despite any mitigation of greenhouse gases, we are going to see the same amount of energy in the system the next 20, 30 or 40 years,’ Mark Myers, the USGS director, said.”

## Next Step: polar bear habitat in mitigation scenarios

Hansen’s “Alternative Scenario” in CCSM3



# Questions?

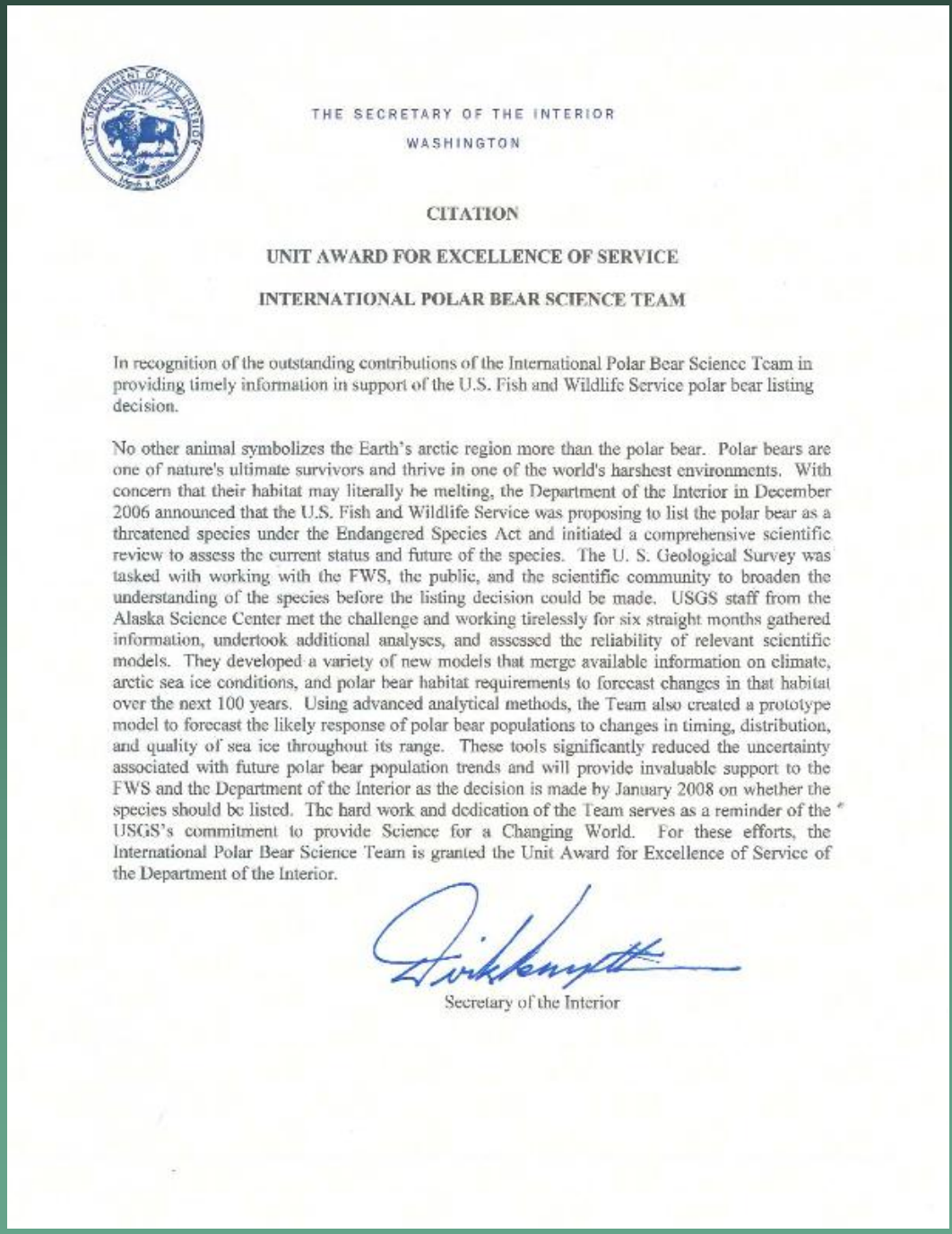

September SIA for CCSM T85 2000 Committment run
September SIA ($10^6$ km$^2$)
6
5
4
3
2
Annual-mean volume
Volume ($10^7$ km$^2$ m)
3
2.5
2
1.5
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

**Some good news:**

**Gov't has so far been receptive and appreciative of USGS research.**

**Next step:**

**Polar bears in the Alternative Scenario**



THE SECRETARY OF THE INTERIOR
WASHINGTON

**CITATION**

**UNIT AWARD FOR EXCELLENCE OF SERVICE**

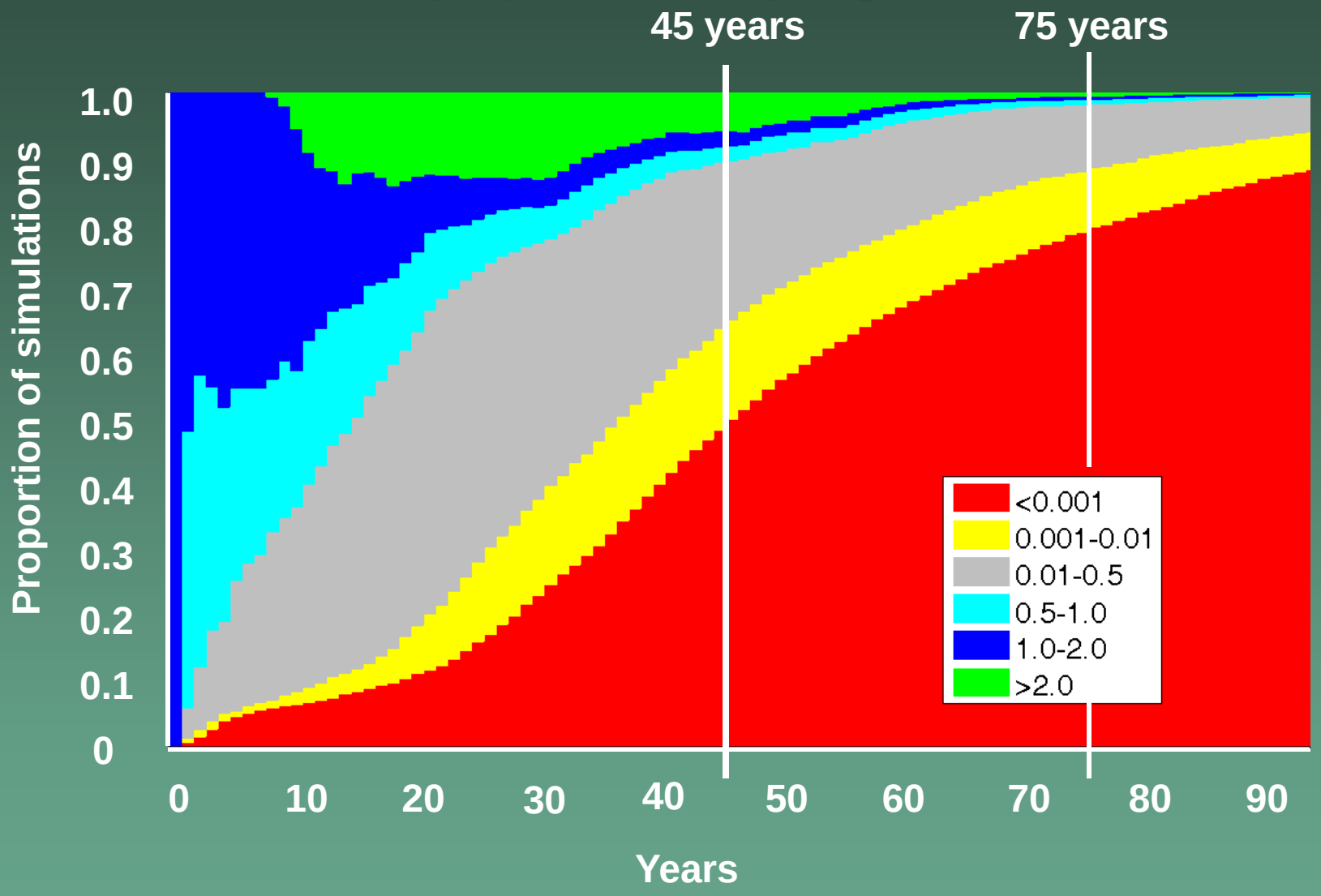
**INTERNATIONAL POLAR BEAR SCIENCE TEAM**

In recognition of the outstanding contributions of the International Polar Bear Science Team in providing timely information in support of the U.S. Fish and Wildlife Service polar bear listing decision.

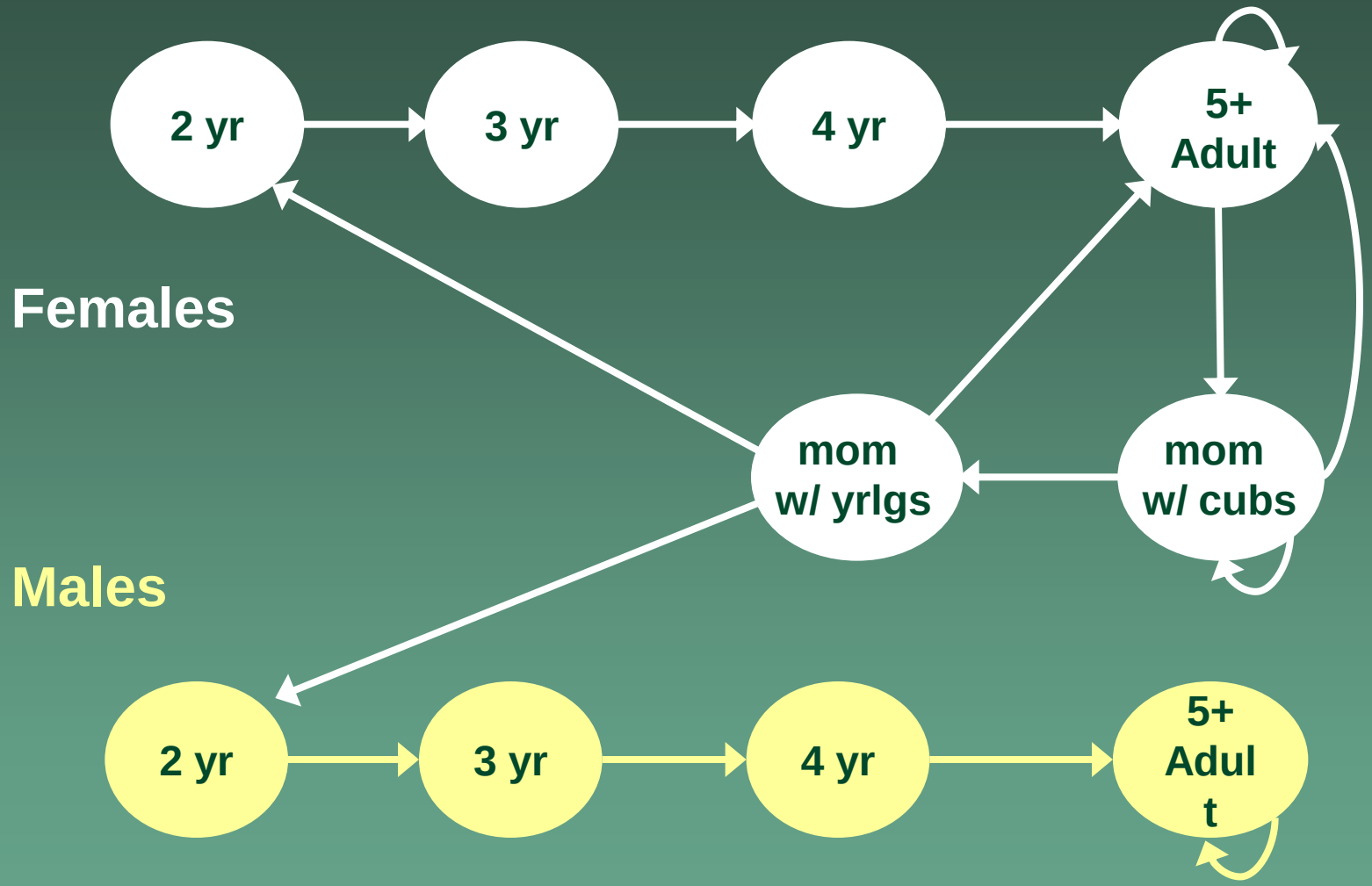
No other animal symbolizes the Earth's arctic region more than the polar bear. Polar bears are one of nature's ultimate survivors and thrive in one of the world's harshest environments. With concern that their habitat may literally he melting, the Department of the Interior in December 2006 announced that the U.S. Fish and Wildlife Service was proposing to list the polar bear as a threatened species under the Endangered Species Act and initiated a comprehensive scientific review to assess the current status and future of the species. The U. S. Geological Survey was tasked with working with the FWS, the public, and the scientific community to broaden the understanding of the species before the listing decision could be made. USGS staff from the Alaska Science Center met the challenge and working tirelessly for six straight months gathered information, undertook additional analyses, and assessed the reliability of relevant scientific models. They developed a variety of new models that merge available information on climate, arctic sea ice conditions, and polar bear habitat requirements to forecast changes in that habitat over the next 100 years. Using advanced analytical methods, the Team also created a prototype model to forecast the likely response of polar bear populations to changes in timing, distribution, and quality of sea ice throughout its range. These tools significantly reduced the uncertainty associated with future polar bear population trends and will provide invaluable support to the FWS and the Department of the Interior as the decision is made by January 2008 on whether the species should be listed. The hard work and dedication of the Team serves as a reminder of the USGS's commitment to provide Science for a Changing World. For these efforts, the International Polar Bear Science Team is granted the Unit Award for Excellence of Service of the Department of the Interior.

Secretary of the Interior

# Climate model population projections



# Southern Beaufort polar bear life cycle



# Conclusions

A combination of observations, climate model output, and expert judgement were used to project declines in

- Sea ice cover
- Optimal polar bear habitat
- Polar bear population
- Carrying Capacity

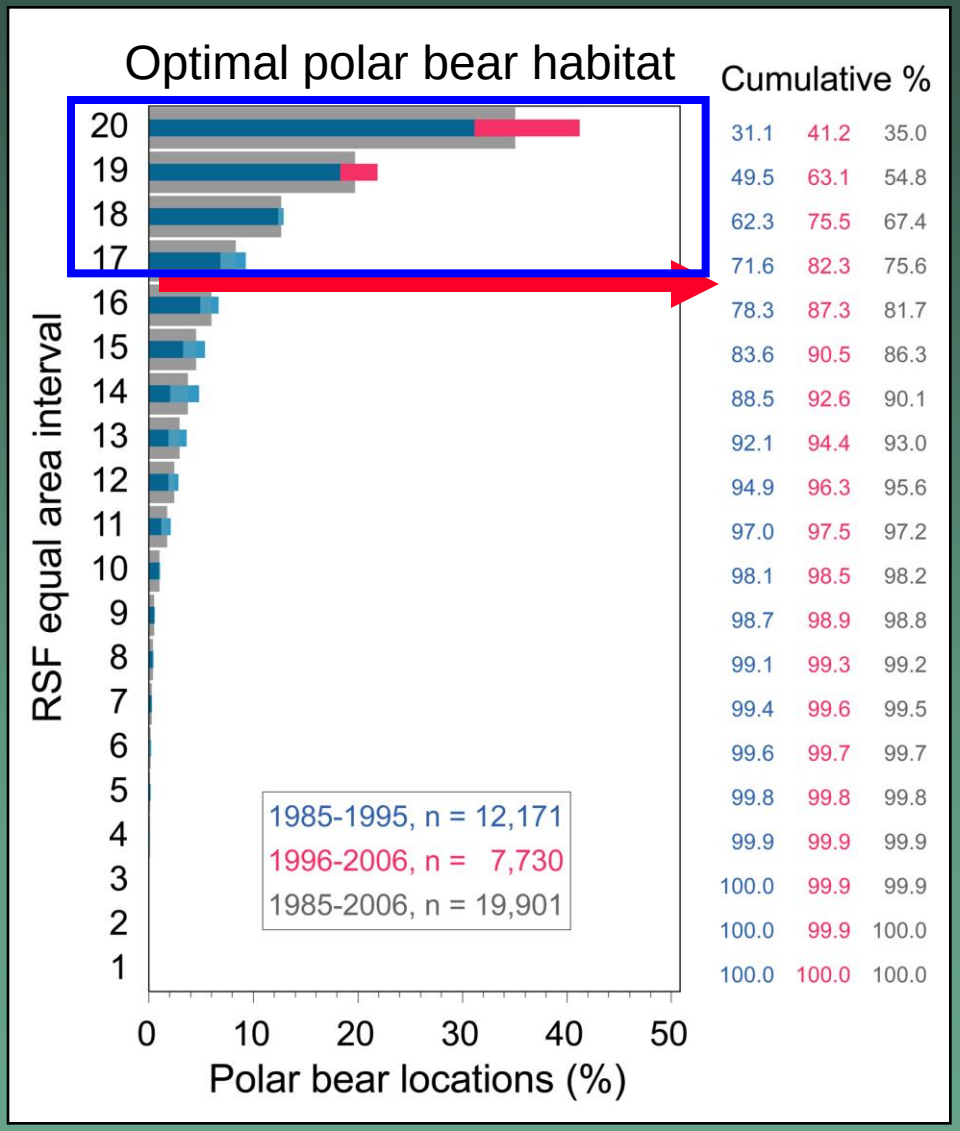
in the middle and late 21st century. Sea ice cover is the key variable in determining future polar bear status, especially summer sea ice cover.

# Assessing the RSF and determining optimal polar bear habitat

- **1985-1995:**

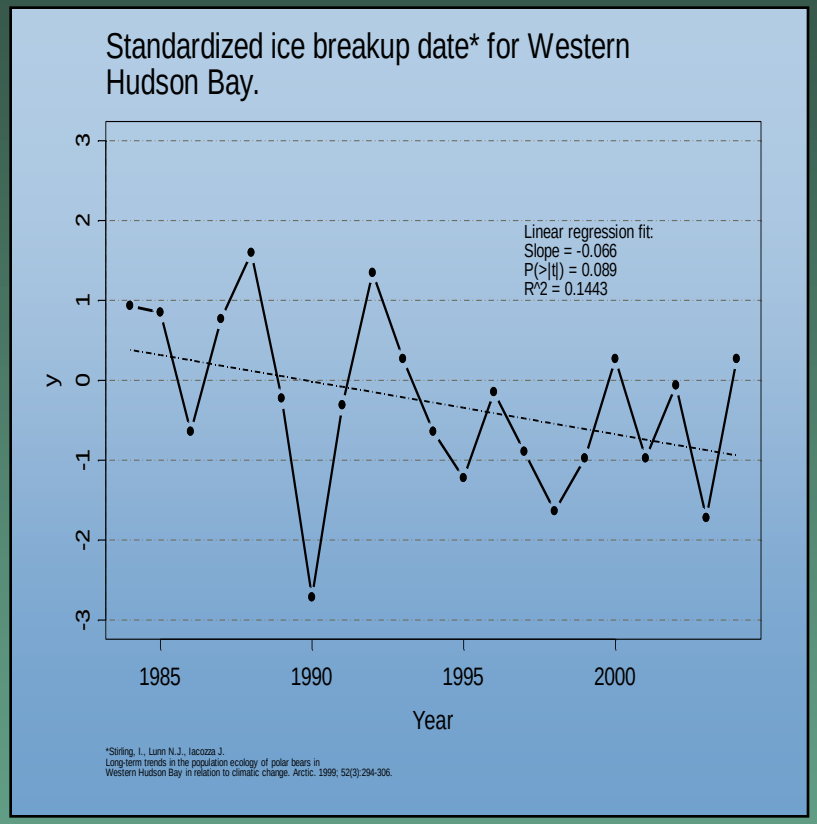
  **72% of locations in top 20% of RSF habitat**
- **1996-2006:**

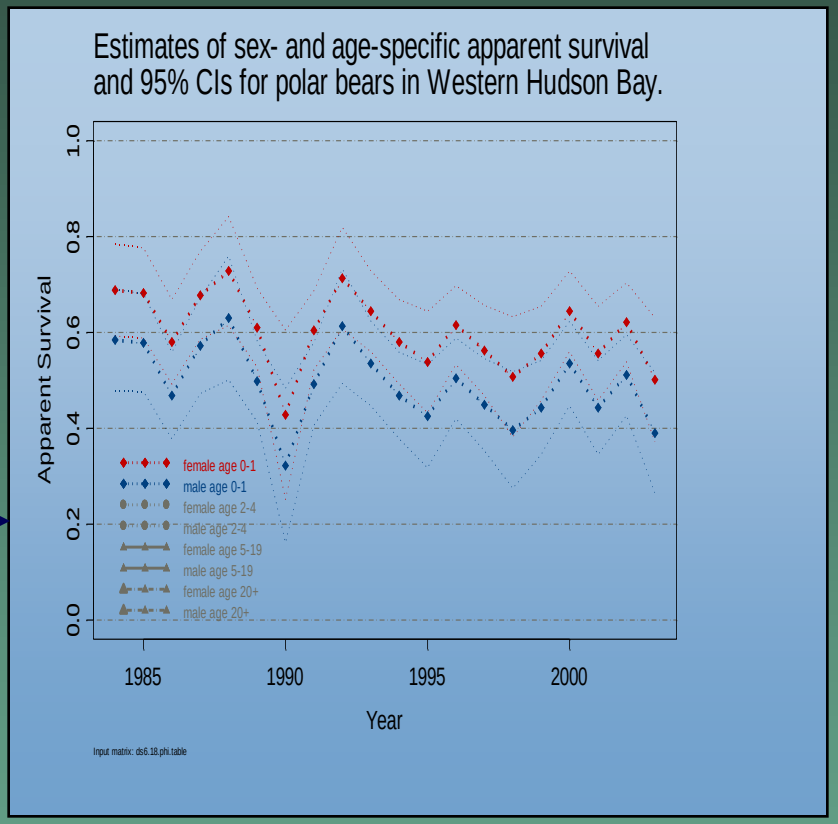
  **82% of locations in top 20% of RSF habitat**
- **The RSFs are robust to changes in sea ice**
- **The highest 20% of RSF pixels were considered "*optimal habitat*"**



# WHB population dynamics.

We found quantitative evidence for a correlation between the observed earlier spring ice breakup and decreased polar bear survival.



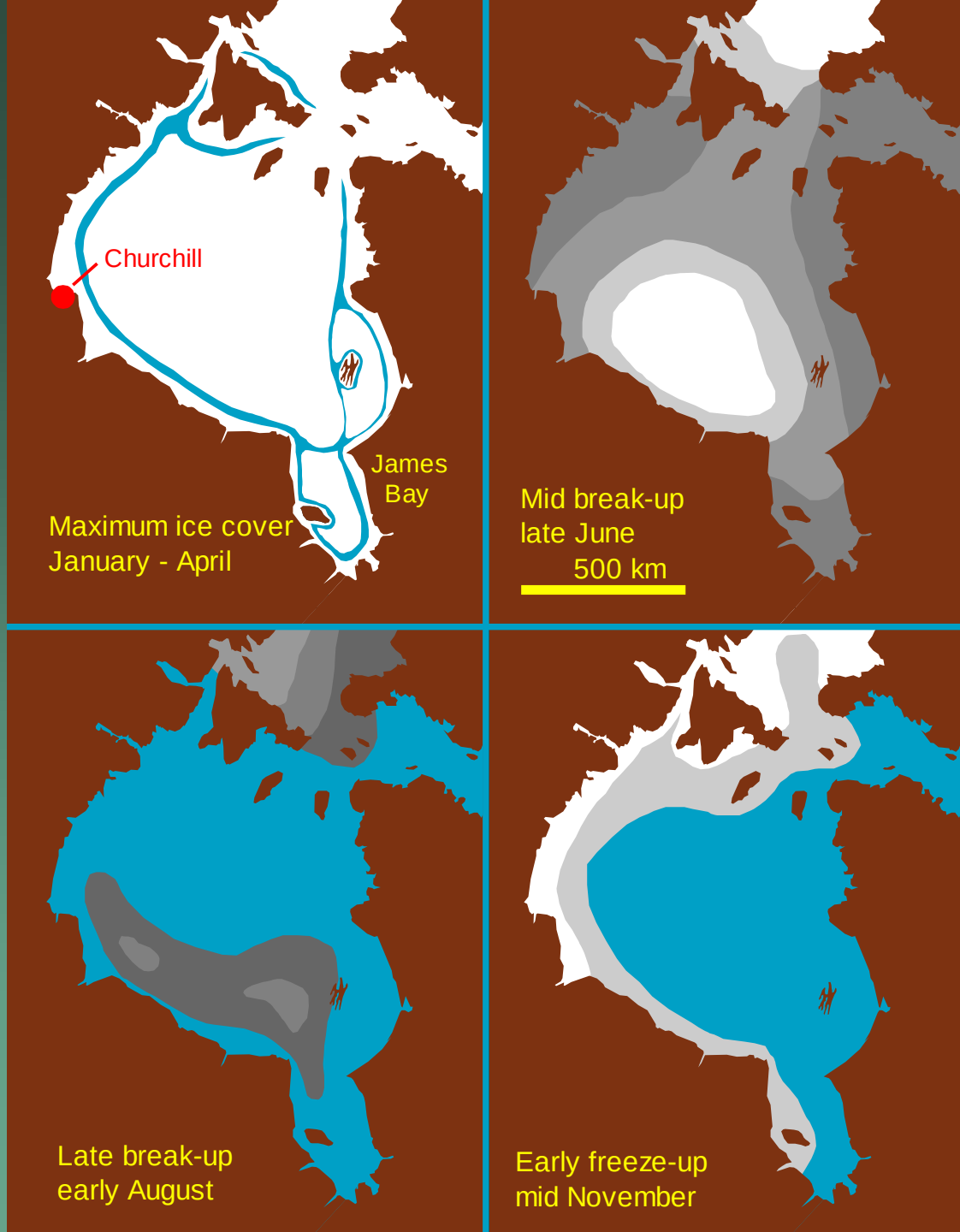




Breakup now occurs about 3 weeks earlier. Each week earlier breakup ≈ 3%-8% decrease in survival

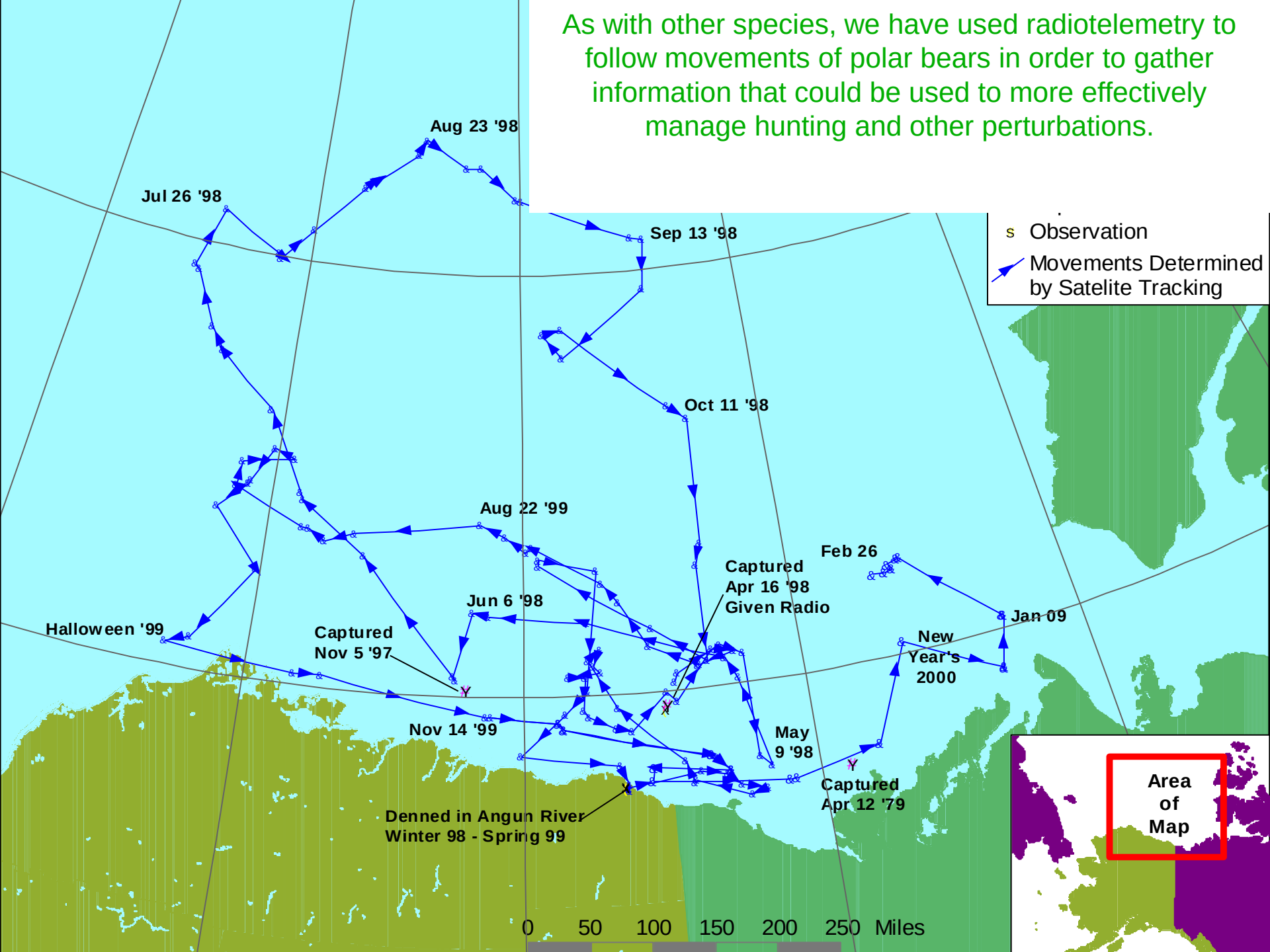
Like all members of the bear family, they start out small

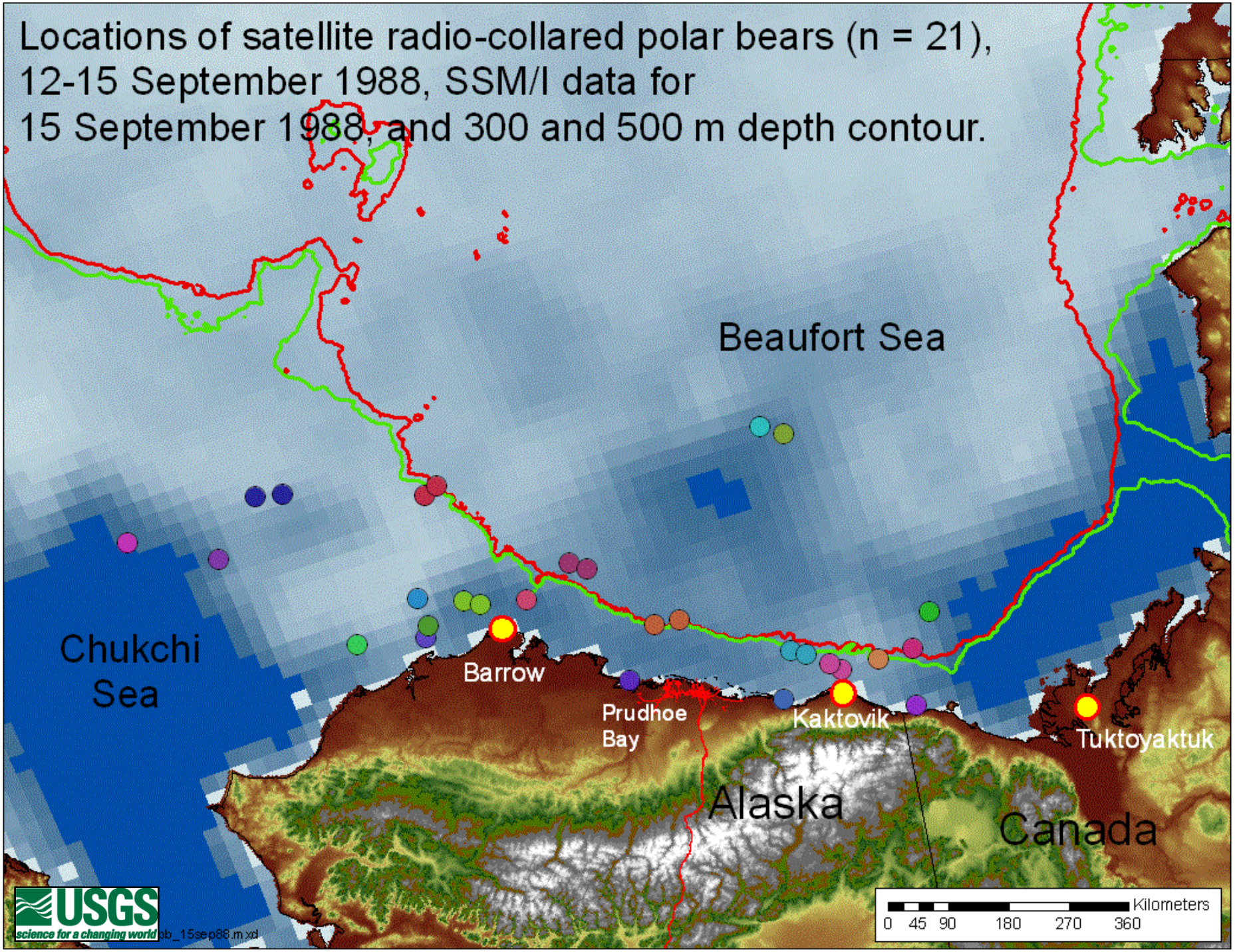
# Summary: Effects of earlier ice melt in Hudson Bay

- Bears come ashore earlier
- Reduced weights
- Poorer survival of young and old
- Declining population size



As with other species, we have used radiotelemetry to follow movements of polar bears in order to gather information that could be used to more effectively manage hunting and other perturbations.




Locations of satellite radio-collared polar bears (n = 21),
12-15 September 1988, SSM/I data for
15 September 1988, and 300 and 500 m depth contour.
Beaufort Sea
Chukchi
Sea
Barrow
Prudhoe
Bay
Kaktovik
Tuktoyaktuk
Alaska
Canada
USGS
science for a changing world
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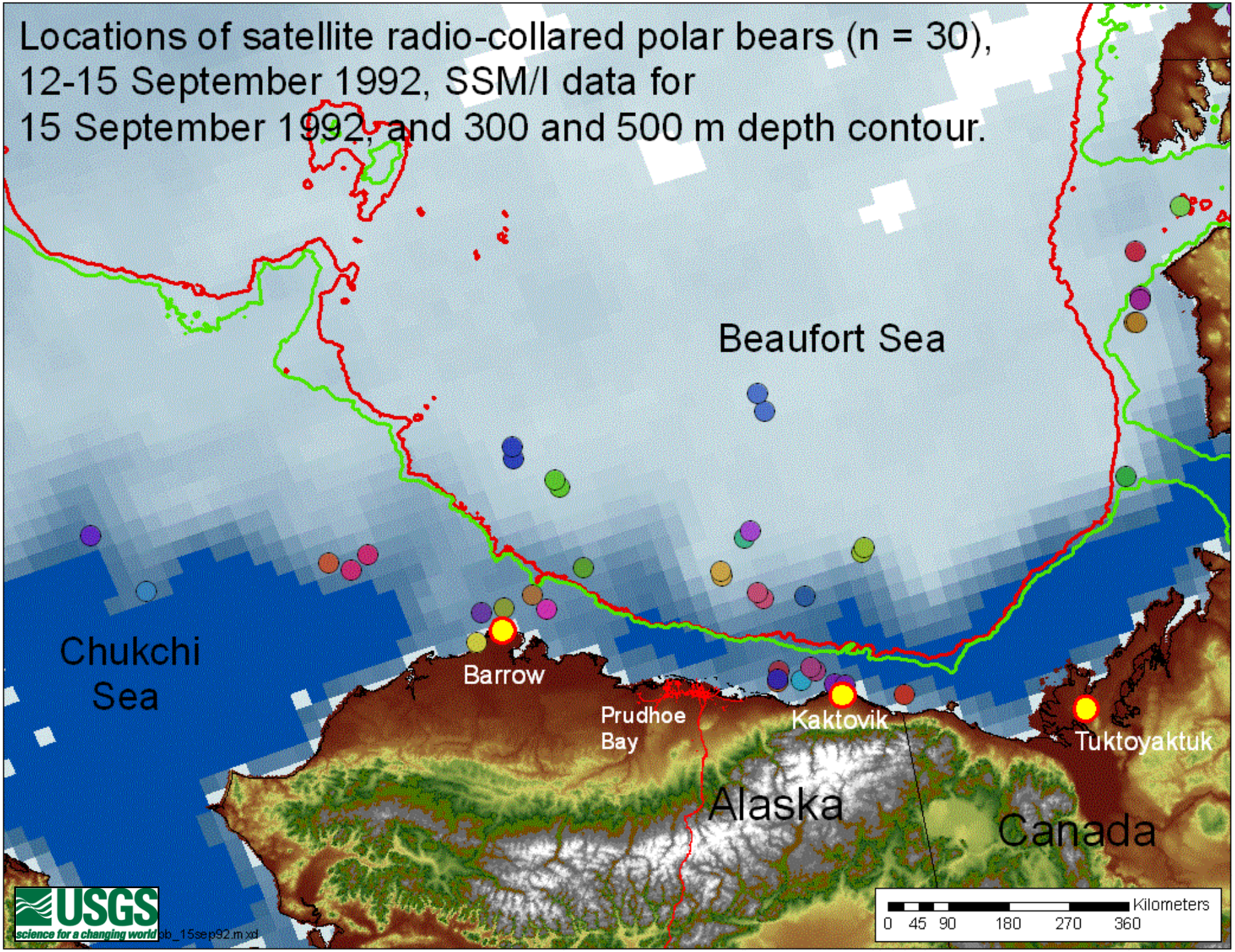
Kilometers
0 45 90 180 270 360


Locations of satellite radio-collared polar bears (n = 30),
12-15 September 1992, SSM/I data for
15 September 1992, and 300 and 500 m depth contour.
Beaufort Sea
Chukchi
Sea
Barrow
Prudhoe
Bay
Kaktovik
Tuktoyaktuk
Alaska
Canada
USGS
science for a changing world
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Kilometers
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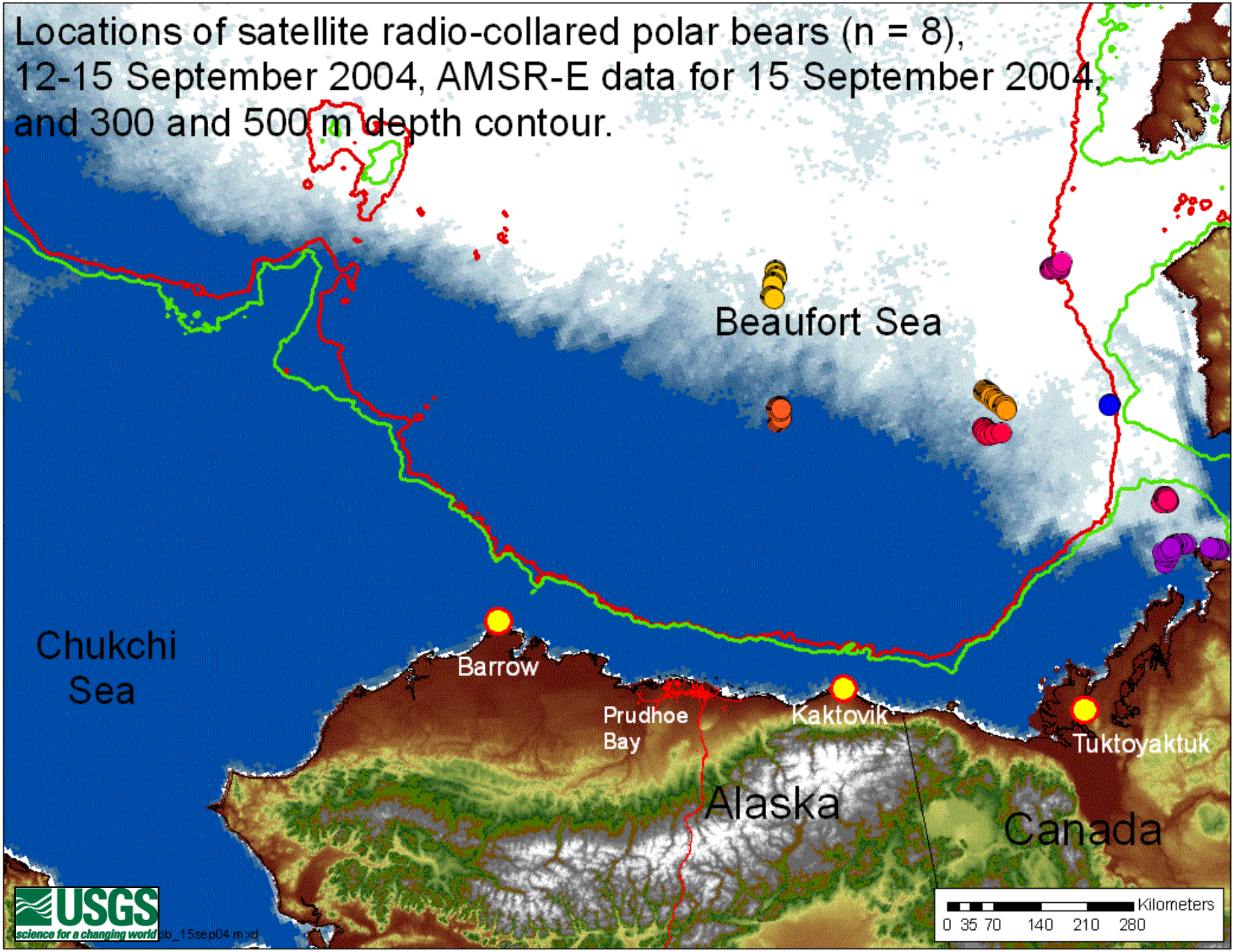
Locations of satellite radio-collared polar bears (n = 8), 12-15 September 2004, AMSR-E data for 15 September 2004, and 300 and 500 m depth contour.
Beaufort Sea
Chukchi Sea
Barrow
Prudhoe Bay
Kaktovik
Tuktoyaktuk
Alaska
Canada
USGS
science for a changing world
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Kilometers
0 35 70 140 210 280