Research Project
Genetics and species history of polar bears

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Polar bears: genetic issues

- Has the species been exposed to previous periods of reduced sea ice?
- Is there potential for inter-species hybridization with brown bears?
- Are there geographic population units?
- Fitness and genetic variation

Scientific collaborations

- USDA Agricultural Research Service Fort Keogh Livestock and Range Research Lab-Cattle genetics (Michael D. MacNeil)
- University of California Davis Department of Animal Science-Cattle genomics (Juan F. Medrano)
- Texas Tech University Department of Biology-Interspecies genetic relationships (Robert J. Baker)
- Pacific Identifications Inc.-Assessment of Paleo-climate and paleo sea ice environments (Susan J. Crockford)
- Other colleagues in genetics, systematics, taxonomy

Research Objectives

- Quantify the genetic relationships of polar bears and brown bears
- Estimate the time of divergence of the species
- Assess sea ice conditions in the Arctic in the past
- Assess polar bears past sea ice habitats

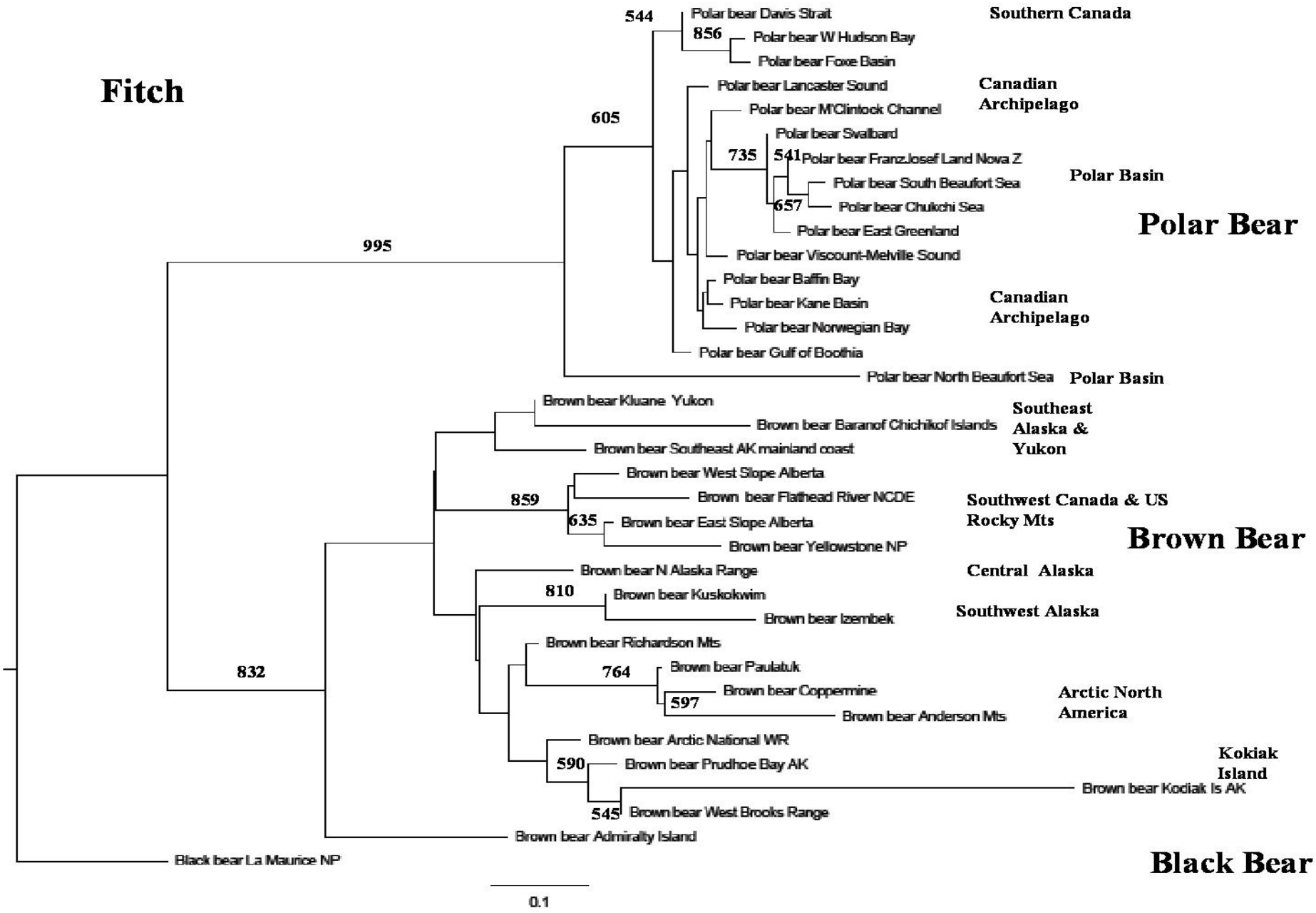
Methods

- Genomics
- DNA sequencing
- Genetic distances with AFLP and microsatellite DNA
- Review of paleo-climate and paleo-environment of the northeast Pacific ocean and Arctic

Results
Microsatellite DNA

Reassess previously published data

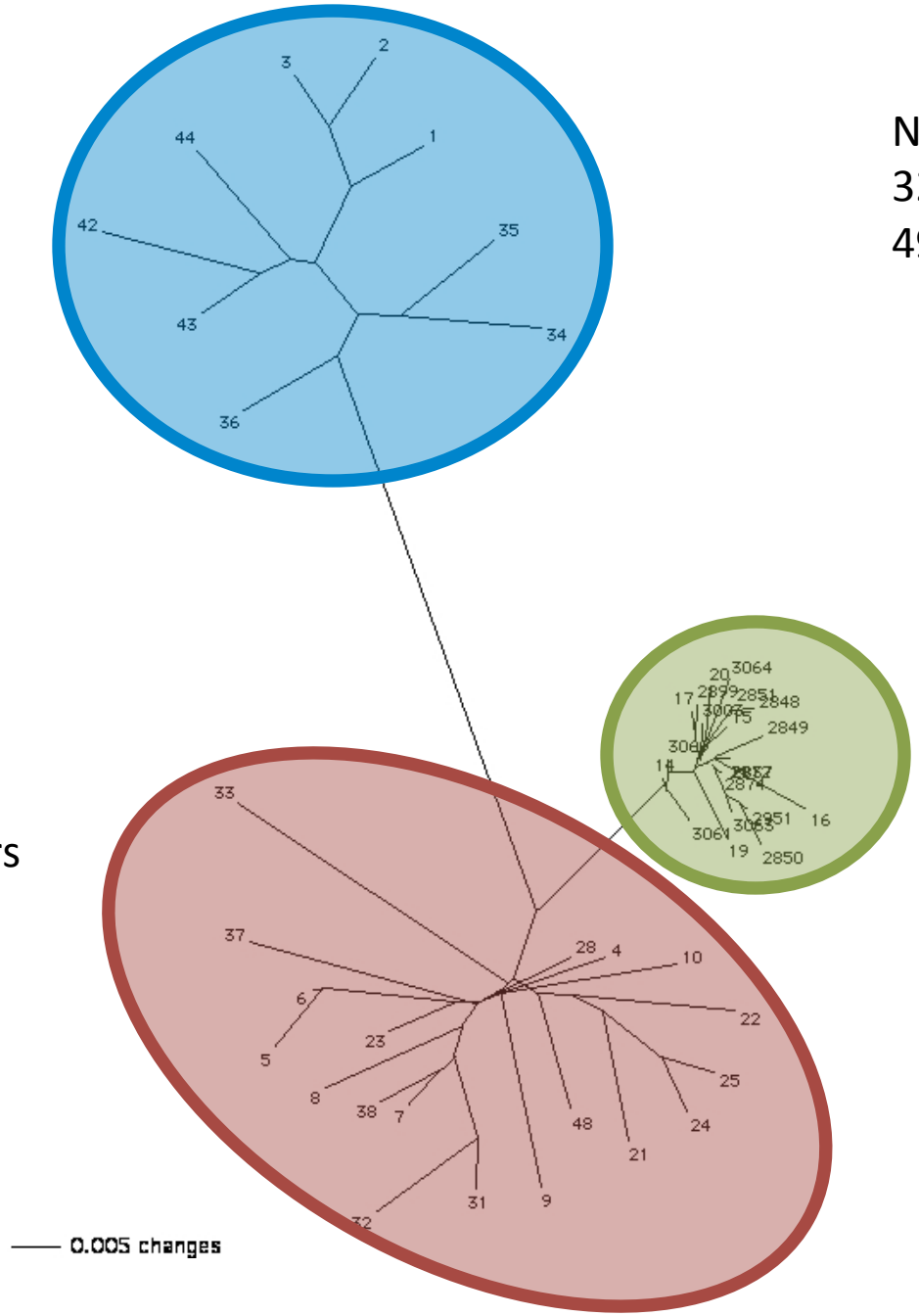

Arctic Ocean
CS
EG
NW
KB
WBR
PB
SBS
BB
VM
LS
FN
SV
ANWR
NAR
KK
RMt
AMt
NBS
IZ
KI
GB
MC
PK
FB
KL
CM
DS
MC
B&C
AI
WHB
North Atl
WS
ES
LM
FR
YNP


Fitch
544
Polar bear Davis Strait
856
Polar bear W Hudson Bay
Polar bear Foxe Basin
Southern Canada
Polar bear Lancaster Sound
Canadian Archipelago
605
Polar bear M'Clintock Channel
Polar bear Svalbard
735
541
Polar bear FranzJosef Land Nova Z
Polar bear South Beaufort Sea
Polar Basin
657
Polar bear Chukchi Sea
Polar bear East Greenland
Polar Bear
995
Polar bear Viscount-Melville Sound
Polar bear Baffin Bay
Polar bear Kane Basin
Canadian Archipelago
Polar bear Norwegian Bay
Polar bear Gulf of Boothia
Polar bear North Beaufort Sea
Polar Basin
Brown bear Kluane Yukon
Brown bear Baranof Chichikof Islands
Southeast Alaska & Yukon
Brown bear Southeast AK mainland coast
Brown bear West Slope Alberta
859
Brown bear Flathead River NCDE
Southwest Canada & US Rocky Mts
635
Brown bear East Slope Alberta
Brown bear Yellowstone NP
Brown Bear
Brown bear N Alaska Range
Central Alaska
810
Brown bear Kuskokwim
Brown bear Izembek
Southwest Alaska
Brown bear Richardson Mts
832
764
Brown bear Paulabuk
Brown bear Coppermine
597
Arctic North America
Brown bear Anderson Mts
Brown bear Arctic National WR
590
Brown bear Prudhoe Bay AK
Kokiak Island
Brown bear Kodiak Is AK
545
Brown bear West Brooks Range
Brown bear Admiralty Island
Black bear La Maurice NP
Black Bear
0.1

Results

Amplified Fragment Length Polymorphism (AFLP)

Black bears



Neighbor-joining tree
329 bands
49 individuals

Polar bears

Brown bears

Results
Genomic sequencing

Research related to Alaskan Polar Bears, collaboration with U.C. Davis

University of Alaska Fairbanks
Matthew A. Cronin
University of California, Davis
Juan F. Medrano
Gonzalo Rincon
Alma Islas

Objectives and Deliverables at UCDavis:

1. Develop a draft assembly of the bear genome.

2. Develop a draft assembly of the mitochondrial genome.

3. Generate a large number of SNP in the bear genome that can be used to characterize and quantify genetic relationships among bears.

4. Develop a genotyping platform to characterize and quantify genetic relationships among bears. (SNP in candidate genes and target regions in the genome obtained from the bear genomic sequencing analysis will be used to develop a genotyping platform).

Sequencing Results

	Polar Bear	Brown Bear	Black Bear
Total DNA reads	410 million reads	490 million reads	80 million reads

Genomic assembly summary: 1 billion reads were used to perform the genome assembly

Two strategies:

De-novo assembly: all sequences were assembled de-novo to develop a draft bear genome assembly. 90,000 contigs were obtained including nuclear and mitochondrial DNA.

Reference assembly: all sequences were mapped to two annotated reference genome.

Using the Panda genome as a reference: 80% of the genomic reads were mapped

Using the Dog genome as a reference: 50% of the genomic reads were mapped.

SNP discovery provided more than **2.5** million SNP polymorphisms in the bear genome that are currently being analyzed and filtered.

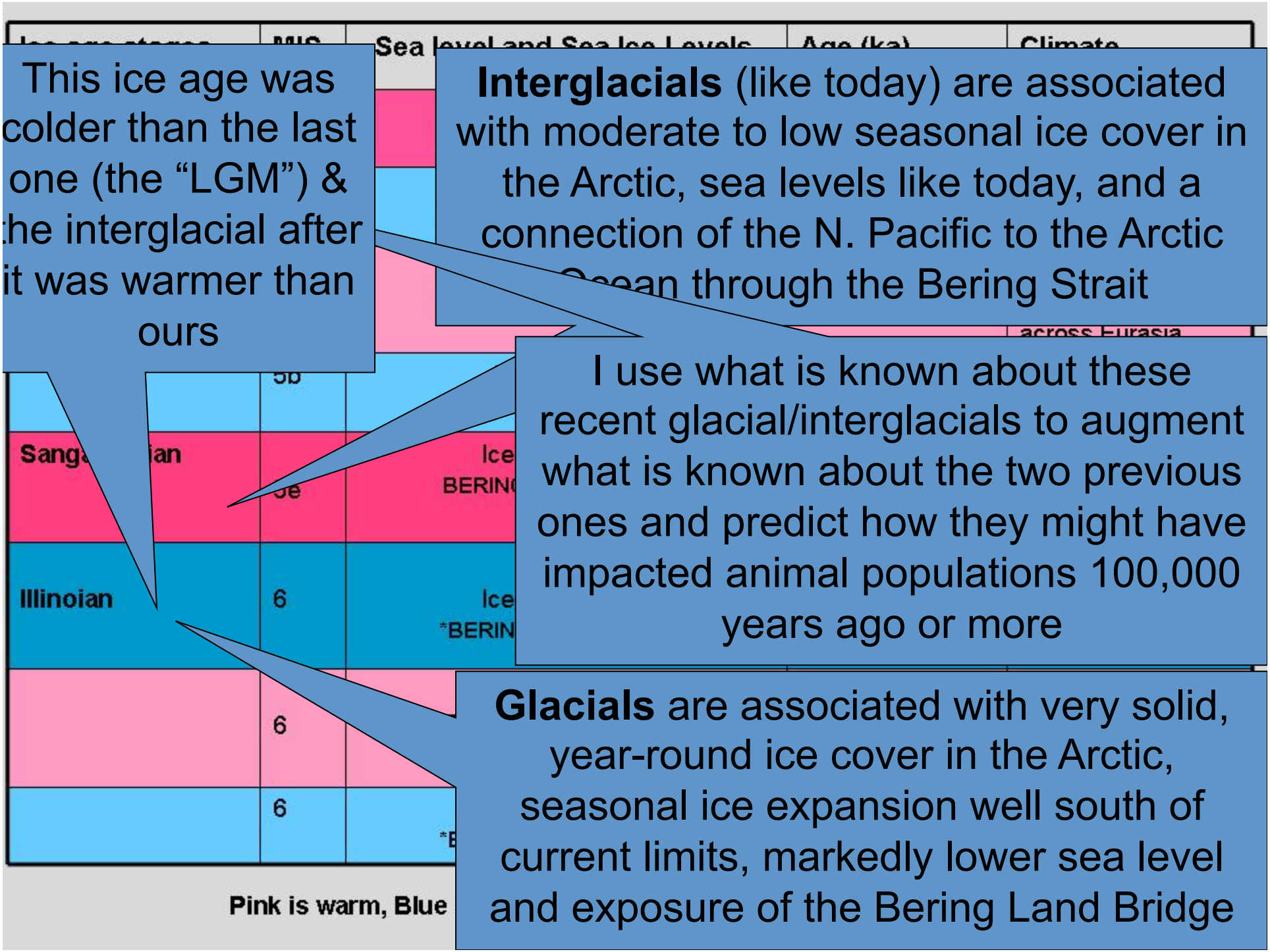
Results
Paleo-climate and Paleo-environments

Polar bear evolution: genetics and climate change in the Late Pleistocene

Susan J. Crockford, Ph.D.
Pacific Identifications Inc.
Victoria, BC Canada

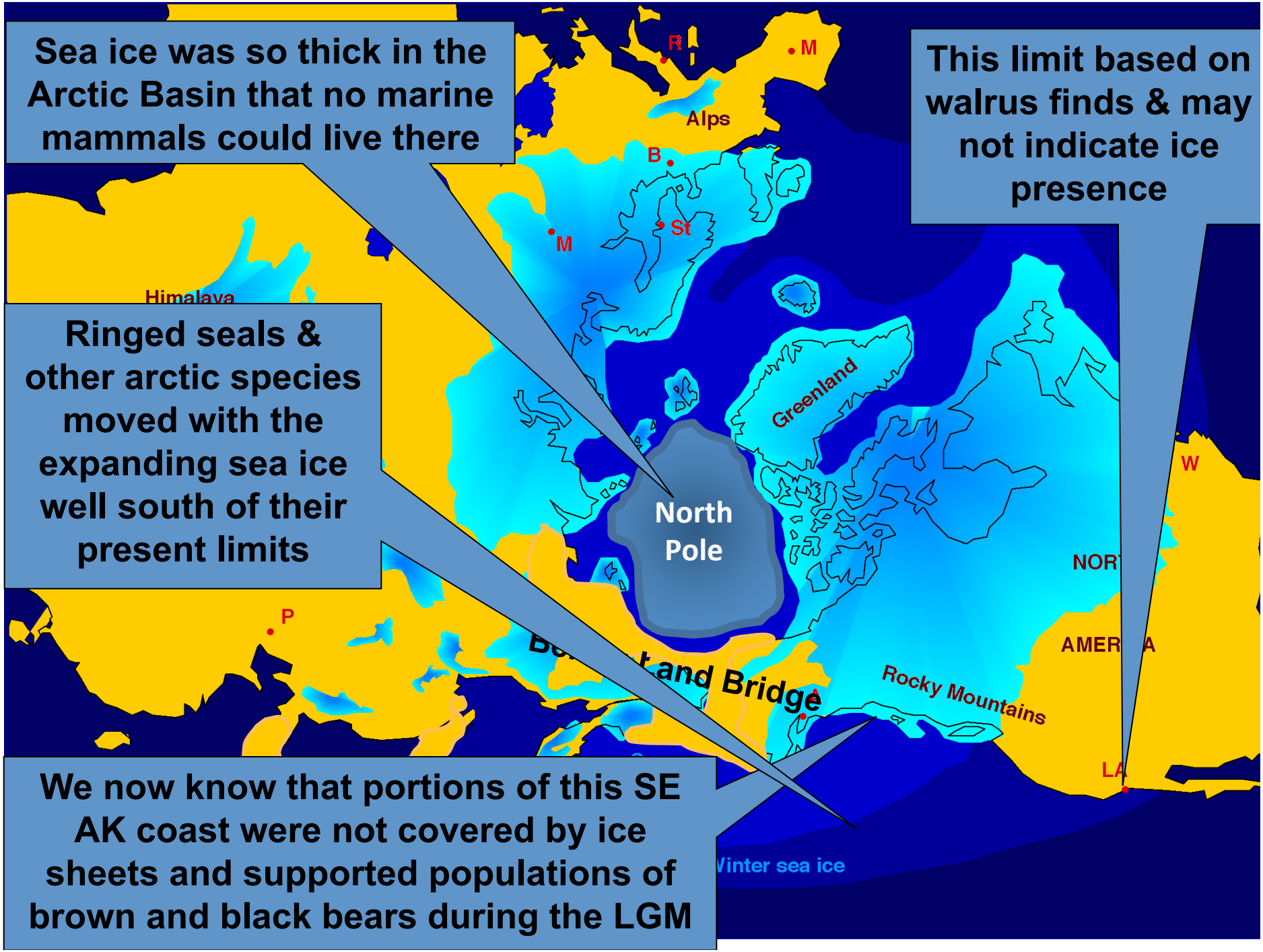
Ice age stages	MIS	Sea level and Sea Ice Levels	Age (ka)	Climate
Present Interglacial (V. Early Holocene)	2-1	Ice ↓↓↓ Sea↑↑↑ rapidly BERING STRAIT WATER	19-11.5	Very Warm, Like MIS 5e but short
Last Glacial Maximum, LGM	2	Ice ↑↑ Sea ↓↓ *BERING LAND BRIDGE*	ca. 30-19 (max at ca. 21)	Very Cold, short
	3	Ice ↓ Sea↑ BERING STRAIT WATER	ca. 50-30 (max. at 45-42)	Warm, long, AMHs expand across Eurasia
	5b	Ice ↑↑ Sea ↓↓ *BERING LAND BRIDGE*	ca. 90-80	Very Cold, short Like LGM? (MIS 2)
Sangamonian	5e	Ice ↓↓↓ Sea ↑↑↑ BERING STRAIT WATER	130-115 (max. at 120-125)	Very Warm, long Like (MIS 2-1) but much longer
Illinoian	6	Ice ↑↑↑ Sea ↓↓↓ *BERING LAND BRIDGE*	ca. 160-140 (max. at 150)	Very, very Cold, and long, colder than LGM (MIS 2)
	6	Ice ↓ Sea↑ ?BERING STRAIT WATER OR LAND BRIDGE REDUCED?	180-160	Warmer, long Like MIS 3?
	6	Ice ↑↑ Sea ↓↓ *BERING LAND BRIDGE*	190-180	Very Cold, short Like LGM? (MIS 2)

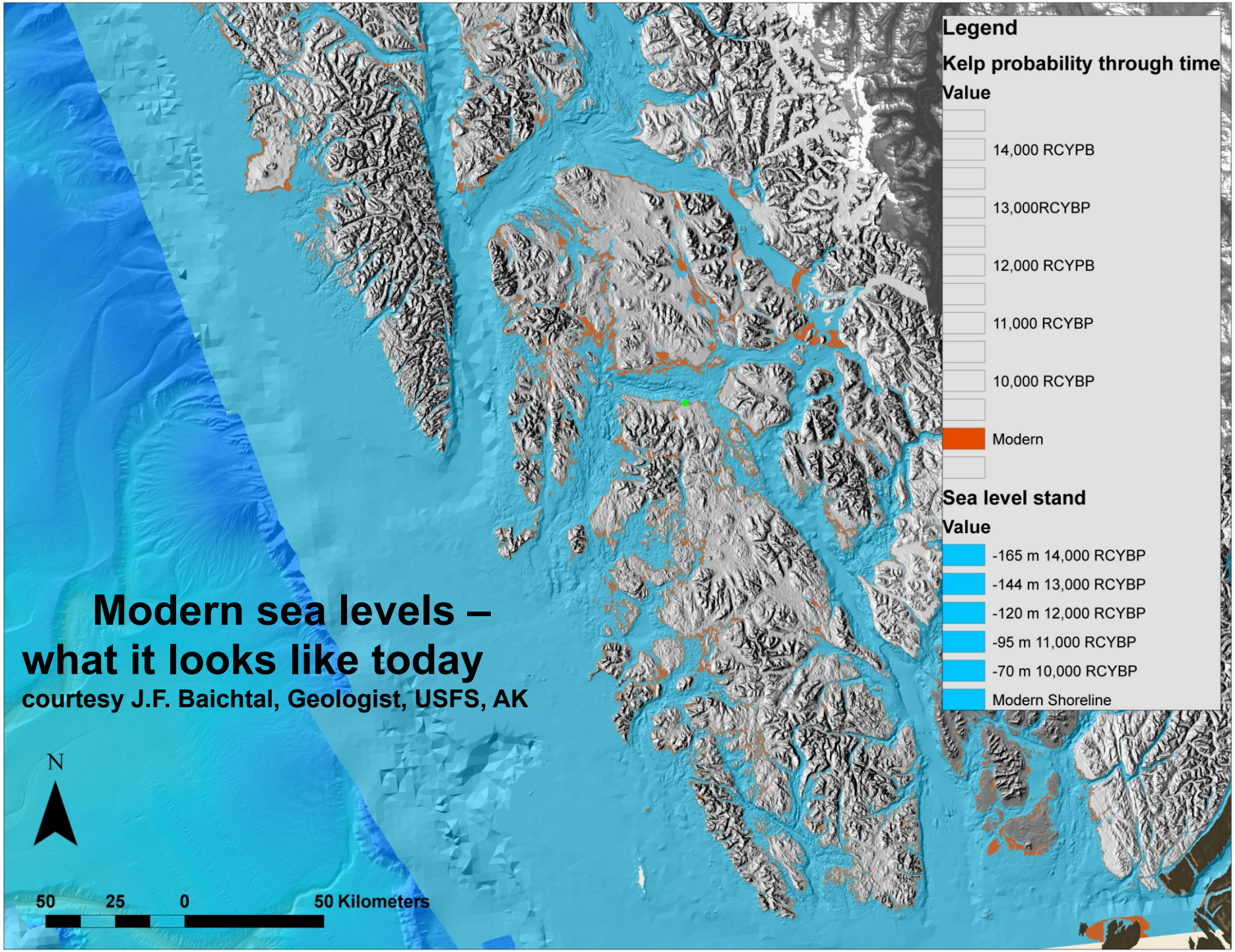
Pink is warm, Blue is cold: pale tones milder, dark tones more extreme

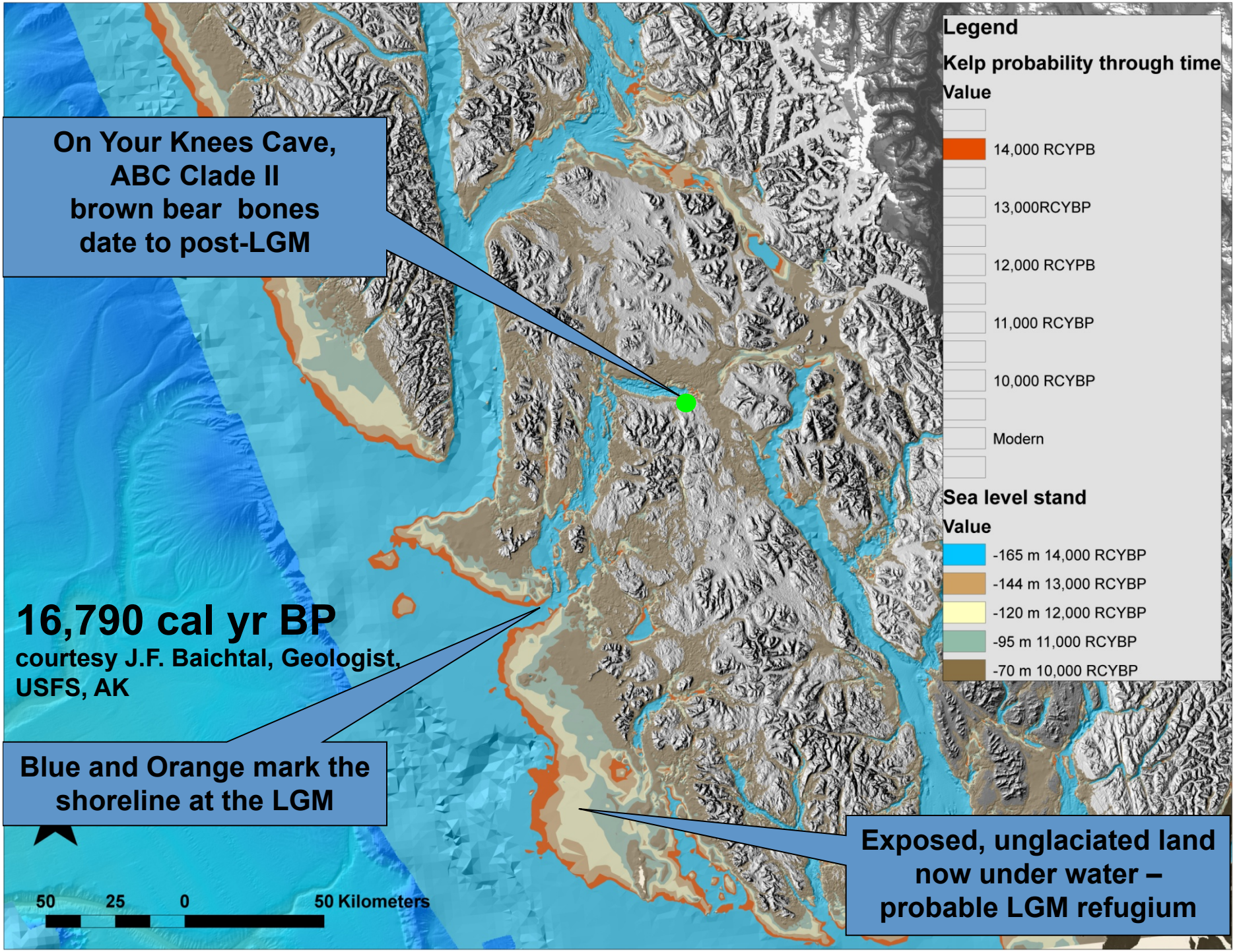

This ice age was colder than the last one (the “LGM”) & the interglacial after it was warmer than ours
Interglacials (like today) are associated with moderate to low seasonal ice cover in the Arctic, sea levels like today, and a connection of the N. Pacific to the Arctic Ocean through the Bering Strait
I use what is known about these recent glacial/interglacials to augment what is known about the two previous ones and predict how they might have impacted animal populations 100,000 years ago or more
Glacials are associated with very solid, year-round ice cover in the Arctic, seasonal ice expansion well south of current limits, markedly lower sea level and exposure of the Bering Land Bridge
Illinoian
6
Pink is warm, Blue

Holocene Climate Changes

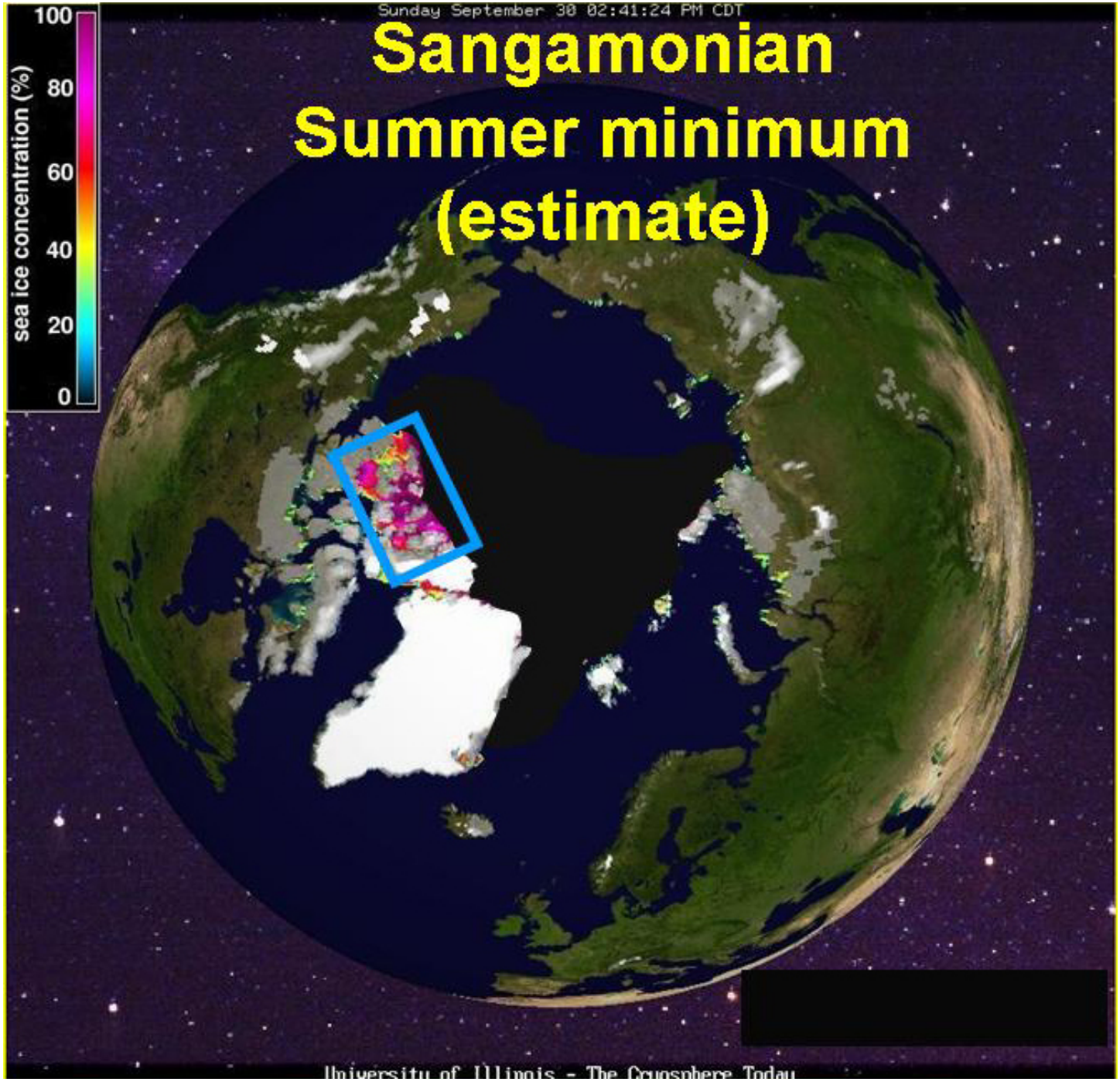
NA, N. Pacific	Ice + Sea levels	Climate	Calendar yrs
Modern Era ("today")	Ice ↓ Sea↑	**Warm (generally)**	AD 1880-2010
Little Ice Age (LIA)	Ice ↑ Sea ↓?	**Colder than today**	AD 1550-1880
Medieval Warm Period	Ice ↓↓ Sea ↑?	**Warmer than today**	AD 800-1500
Dark Ages Cold Period	Ice ↑ Sea?	**Colder than today**	AD 450-800
Roman Warm Period	Ice ↓ Sea?	**Warm, like today**	50 BC-AD 450
Mid-Holocene Neoglacial	Ice ↑↑ Sea ↓	**Colder than LIA**	3550-50 BC
Mid-Holocene Warm Period	Ice ↓ Sea?	**Warm, like today**	6050-3550 BC
Younger-Younger Dryas	Ice ↑? Sea ?	**Colder than today**	6550-6050 BC
Holocene Thermal Optimum	Ice ↓↓↓ Sea ↑↑↑	**Much warmer than today**	9550-6550 BC
Younger Dryas (end LGM)	Ice ↑↑ Sea ↓↓	**Much colder than today**	11050-9550 BC
Bolling Allerod (end LGM)	Ice ↓↓ Sea ↑↑	**Much warmer than today**	17050-11050 BC


Sea ice was so thick in the Arctic Basin that no marine mammals could live there
This limit based on walrus finds & may not indicate ice presence
Ringed seals & other arctic species moved with the expanding sea ice well south of their present limits
We now know that portions of this SE AK coast were not covered by ice sheets and supported populations of brown and black bears during the LGM
North Pole
Greenland
Alps
Himalaya
Rocky Mountains
Winter sea ice
R
M
B
St
M
P
W
LA

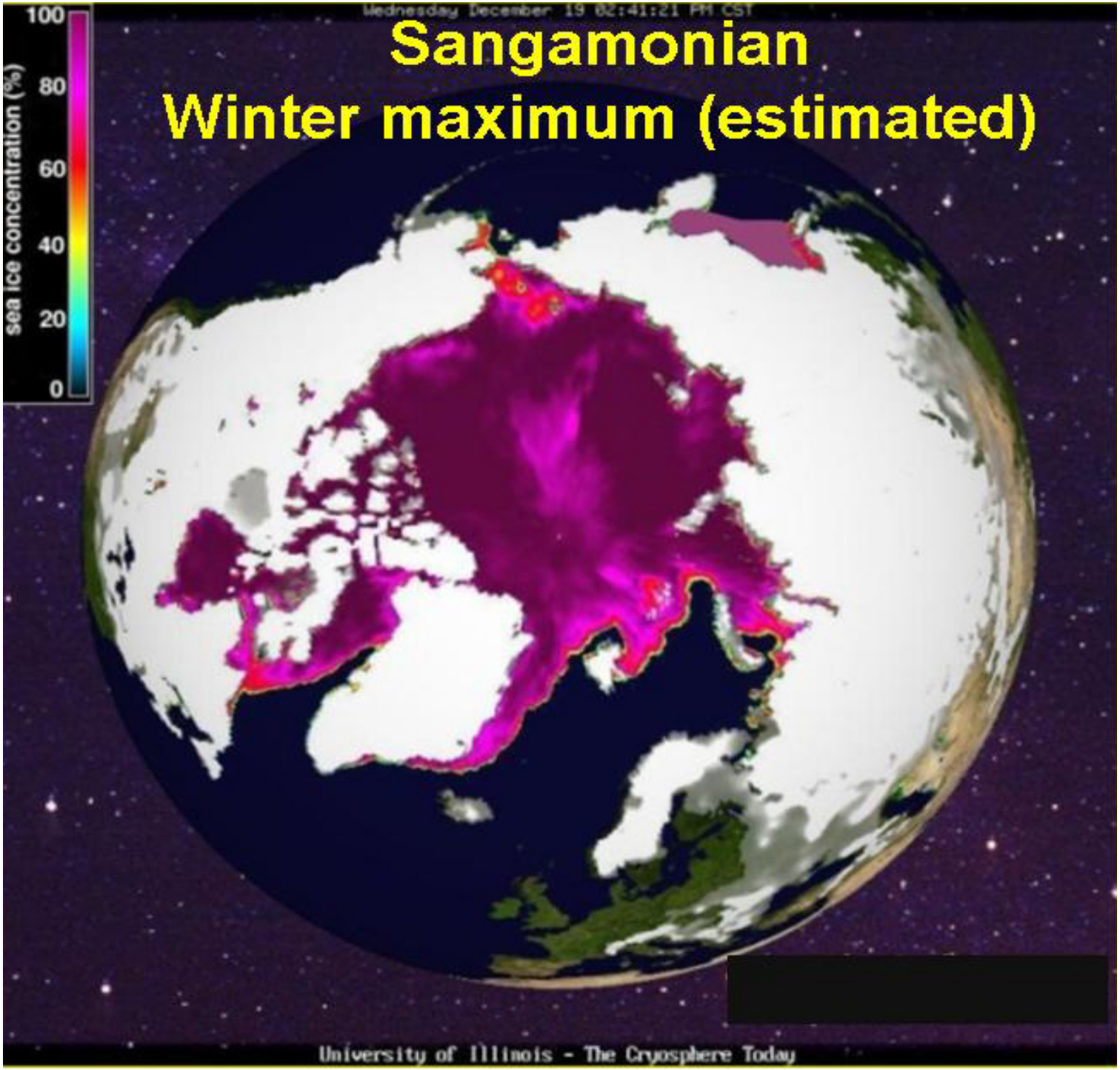

Legend
Kelp probability through time
Value
14,000 RCYPB
13,000RCYBP
12,000 RCYPB
11,000 RCYBP
10,000 RCYBP
Modern
Sea level stand
Value
-165 m 14,000 RCYBP
-144 m 13,000 RCYBP
-120 m 12,000 RCYBP
-95 m 11,000 RCYBP
-70 m 10,000 RCYBP
Modern Shoreline
Modern sea levels –
what it looks like today
courtesy J.F. Baichtal, Geologist, USFS, AK
N
50 25 0 50 Kilometers


On Your Knees Cave,
ABC Clade II
brown bear bones
date to post-LGM
16,790 cal yr BP
courtesy J.F. Baichtal, Geologist,
USFS, AK
Blue and Orange mark the
shoreline at the LGM
Exposed, unglaciated land
now under water –
probable LGM refugium
50 25 0 50 Kilometers
Legend
Kelp probability through time
Value
14,000 RCYPB
13,000RCYBP
12,000 RCYPB
11,000 RCYBP
10,000 RCYBP
Modern
Sea level stand
Value
-165 m 14,000 RCYBP
-144 m 13,000 RCYBP
-120 m 12,000 RCYBP
-95 m 11,000 RCYBP
-70 m 10,000 RCYBP

Polar bear sea ice habitat during the last Interglacial, 130-115 kya


Sunday September 30 02:41:24 PM CDT
Sangamonian
Summer minimum
(estimate)
sea ice concentration (%)
100
80
60
40
20
0
University of Illinois - The Cryosphere Today


Sunday September 30 02:41:24 PM CDT
Sept. 2007
Summer minimum
sea ice concentration (%)
100
80
60
40
20
0
09/30/2007
University of Illinois - The Cryosphere Today


Wednesday December 19 02:41:21 PM CST
Sangamonian
Winter maximum (estimated)
sea ice concentration (%)
100
80
60
40
20
0
University of Illinois - The Cryosphere Today

UAF

- Kramm GHG
- Zhang more winter ice with less summer ice

Federal Court deference to Federal Agency

- Page 4 of 116: "Although plaintiffs have proposed many alternative conclusions that the agency could have drawn with respect to the status of the polar bear**, the Court cannot substitute either the plaintiffs' or its own judgment for that of the agency. Instead, this Court is bound to uphold the agency's determination that the polar bear is a threatened species as long as it is reasonable, regardless of whether there may be other reasonable, or even more reasonable, views**. That is particularly true where, as here, the agency is operating at the frontiers of science."

Checks and balances

- Federal Judiciary defers to Federal Executive Branch Agency
- Congress is only potential check and balance of Federal power with regard to the ESA