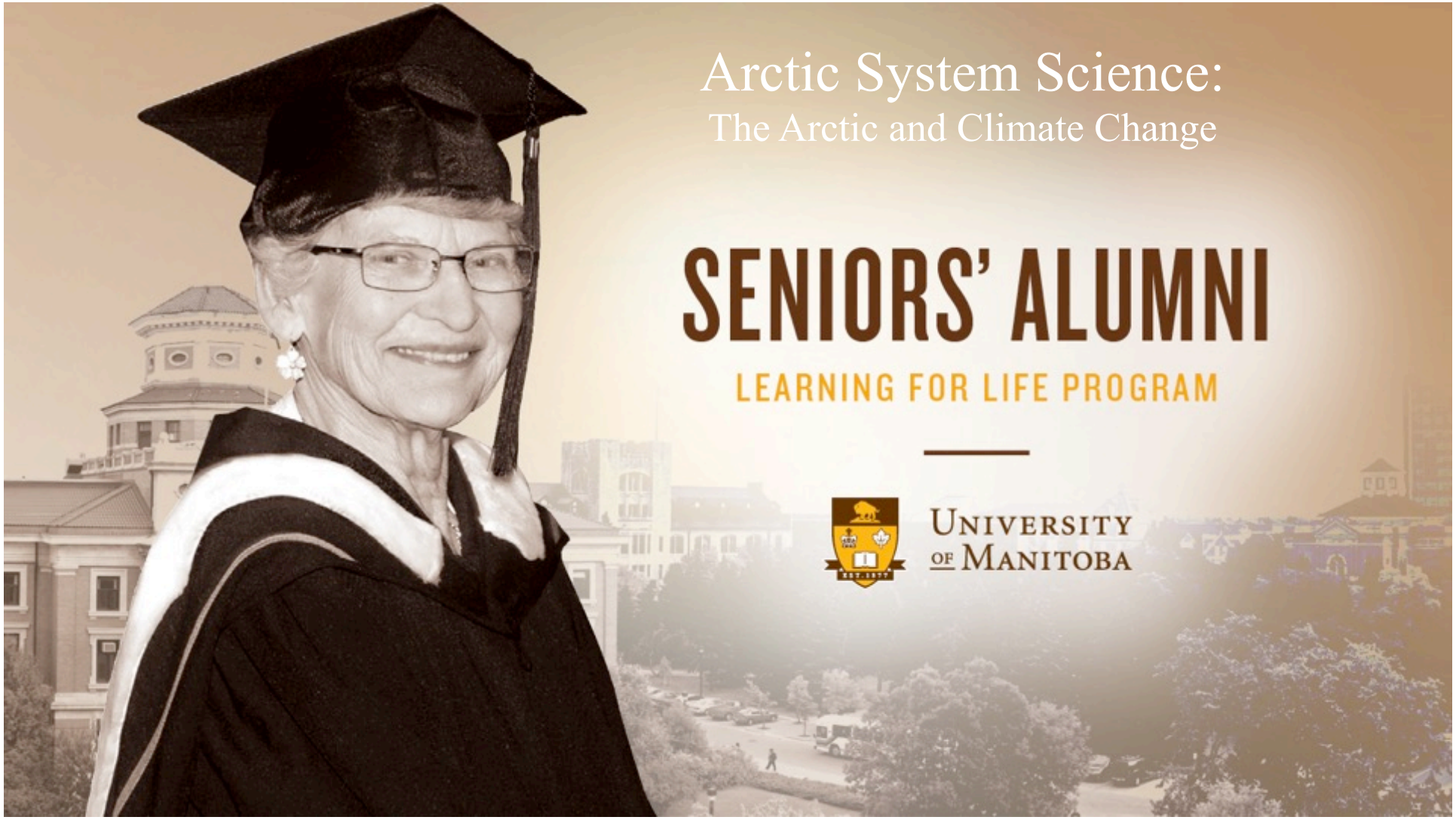


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Professor David G. Barber
Canada Research Chair in Arctic System Science
Associate Dean, Research, Faculty of Environment
University of Manitoba.

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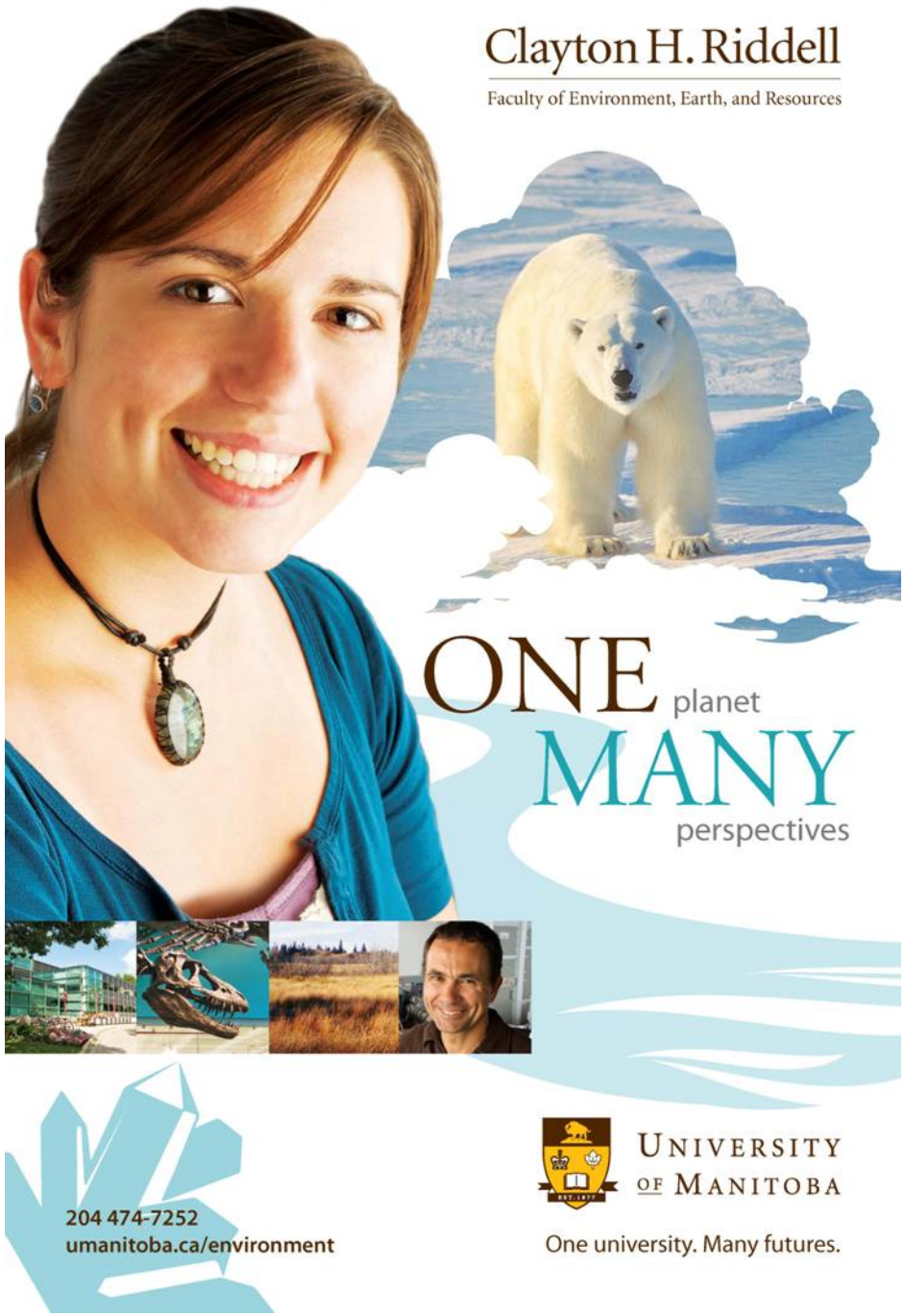
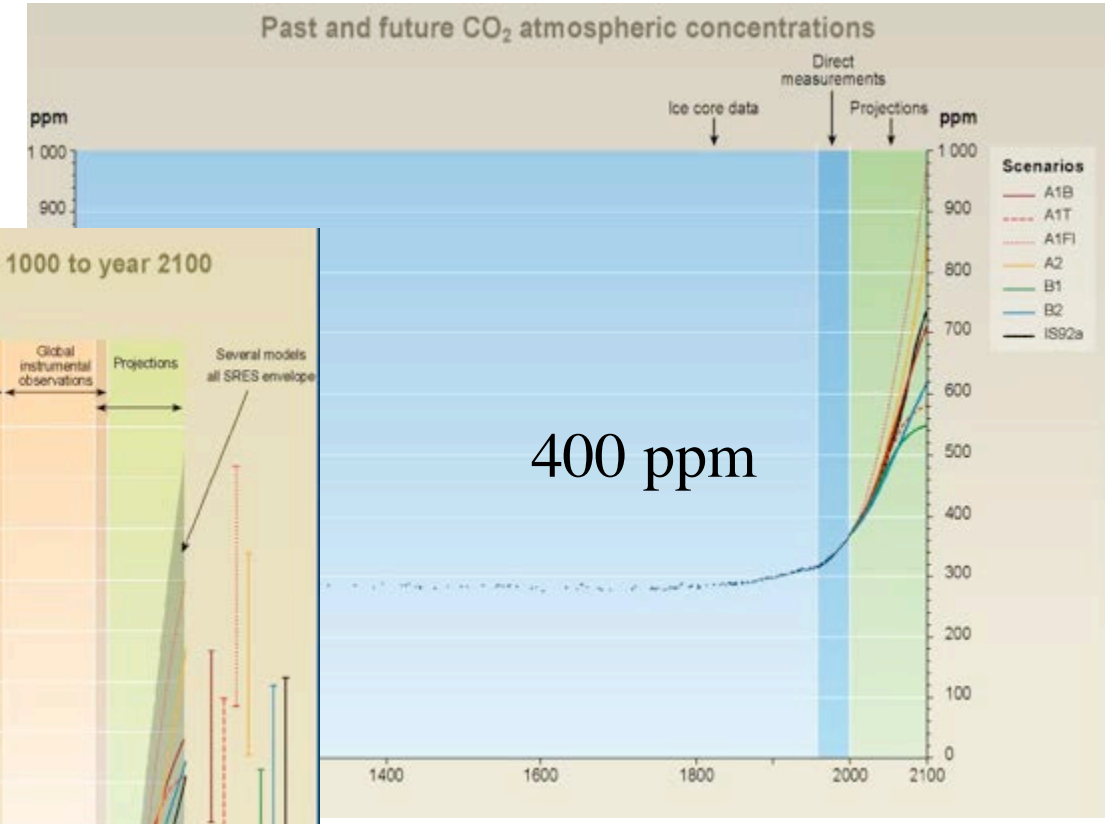


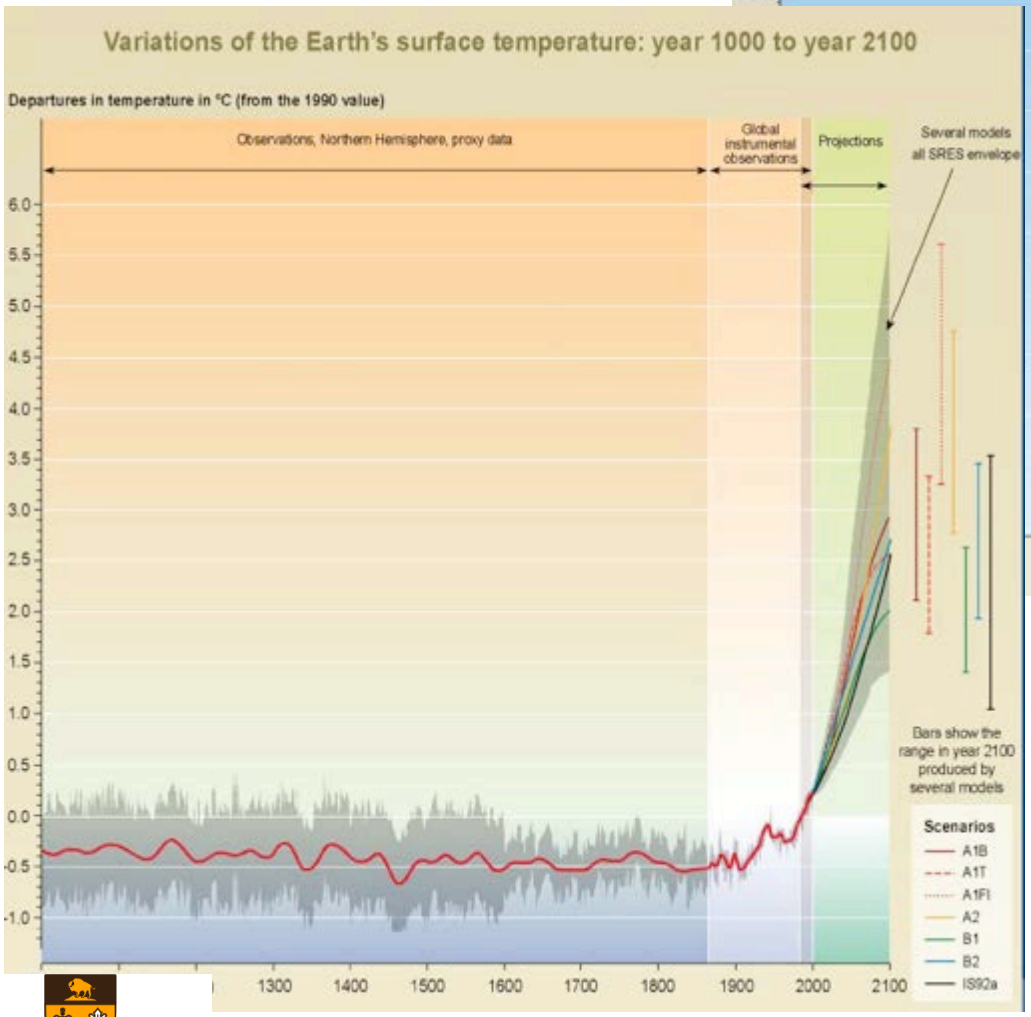

# Outline

- Some context.
- What can history tell us?
- What can the Arctic tell us?
- How we do our work.
- There are surprises.
- Why should you care?

# Intergovernmental Panel on Climate Change




$CO_2$ concentrations




Temperature

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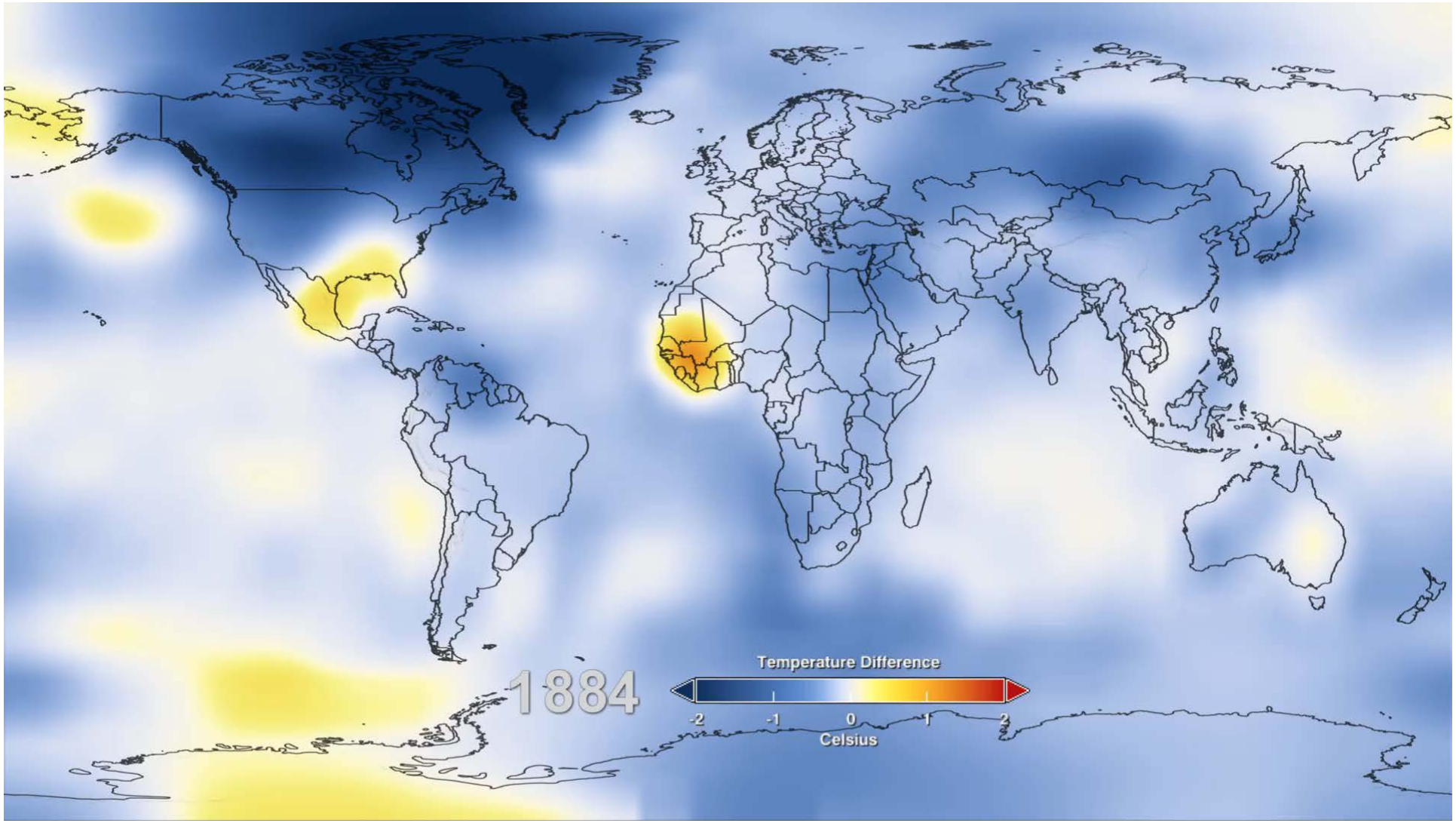
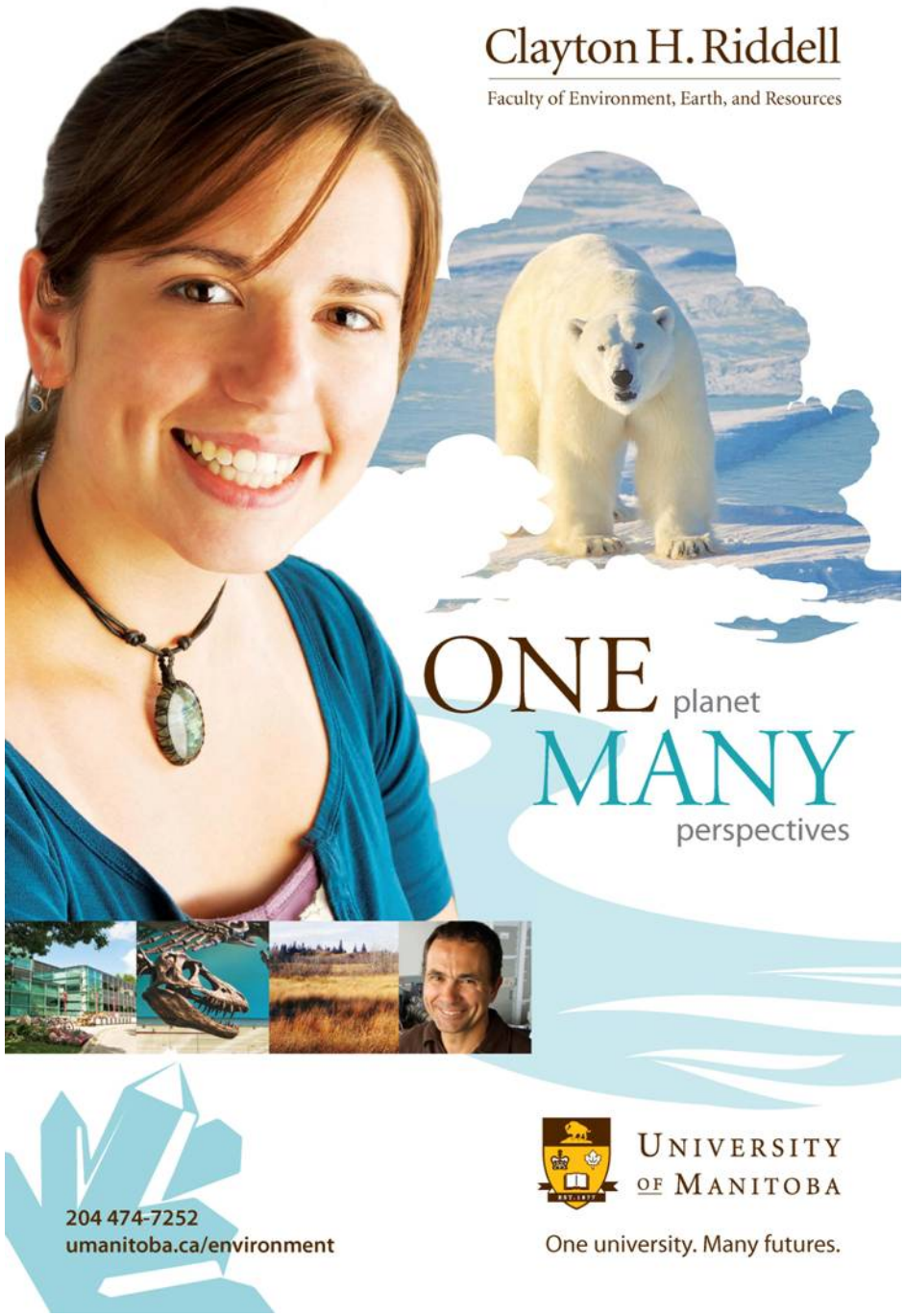



Observations - Five year running average (corrected)

NASA, 2012




**What can history tell us?**

# Calendar of Earth History

In the beginning:

Oxygen revolution (2.2 bya)

$O_2$

Earliest known life (3.5 bya)

Schopf et al., 2002, Nature

**January**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |

**February**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | | | | | |

**March**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | 31 | | |

**April**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |

**May**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

**June**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

**July**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |

**August**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | 31 | | | |

**September**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | |

**October**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |

**November**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | | | |

**December**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

20:45
Homo erectus (1.8 mya)

23:42
Homo sapiens (0.2 mya)

23:52
Out of Africa (70 ka)

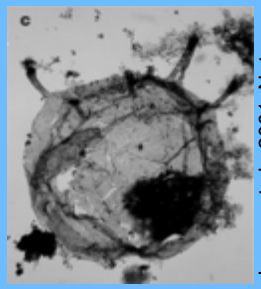
23:56:34
Reaching N.A. (30 ka)

23:58:51
Agriculture (10 ka)

23:59:46
Julius Caesar

23:59:58
Industrial revolution

Earliest known eukaryotes (1.5 bya)

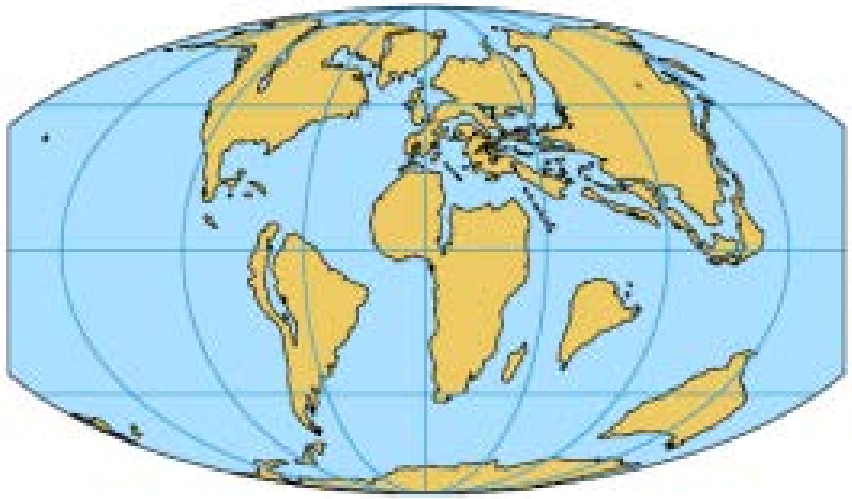


Javaux et al., 2001, Nature

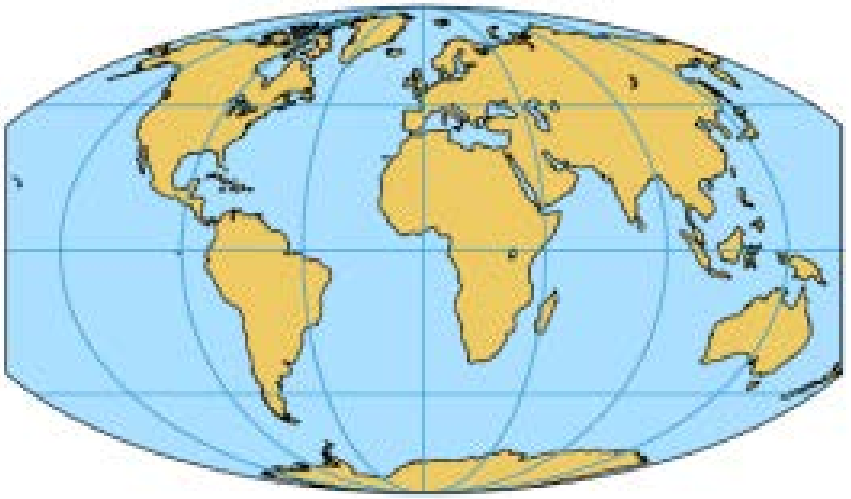
Dinosaurs stopped by and roared hello (230-65 mya)

# Finding a historical analog

## The Cenozoic Era



End of Cretaceous (65 My BP)



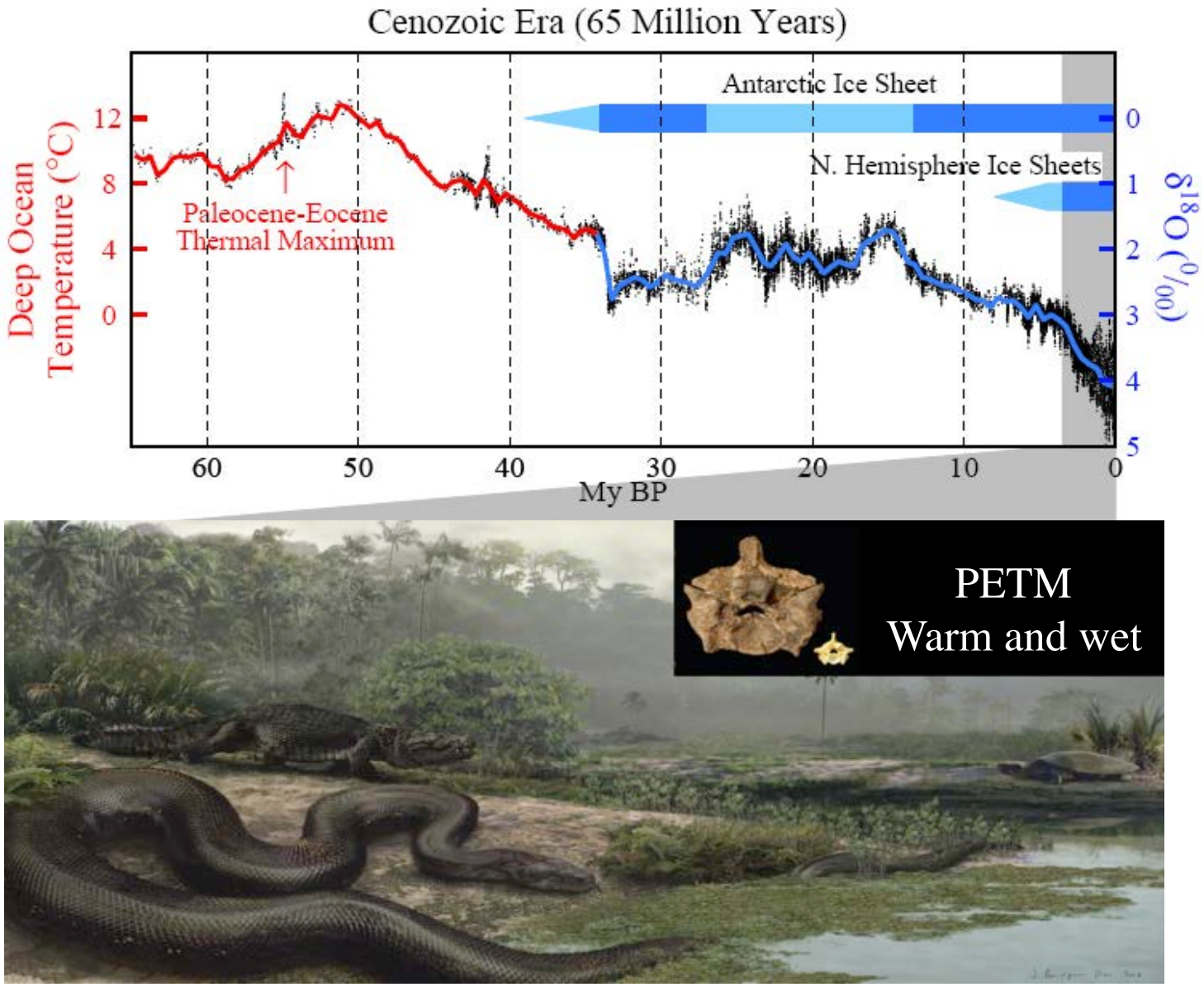
Present Day

**Global Climate Forcings**

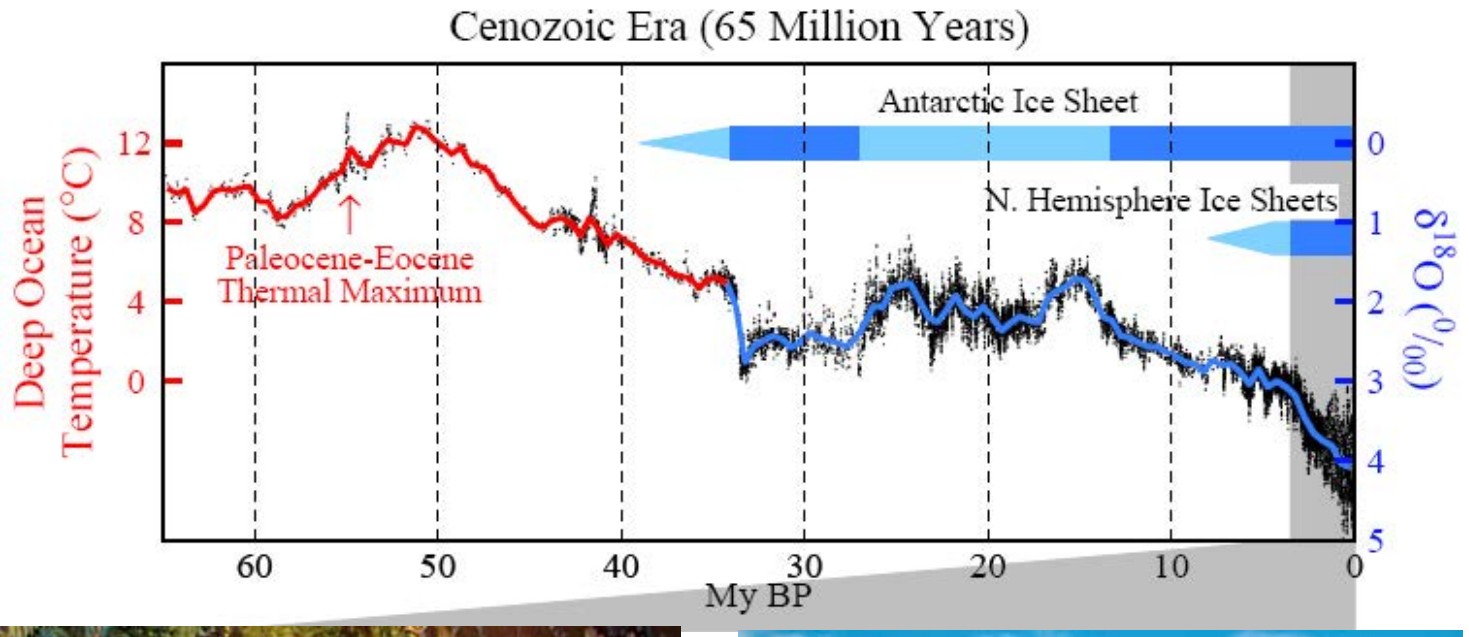
External (solar irradiance): +1 $W/m^2$

Surface (continent locations): ~1 $W/m^2$

Atmosphere ($CO_2$ changes): > 10 $W/m^2$

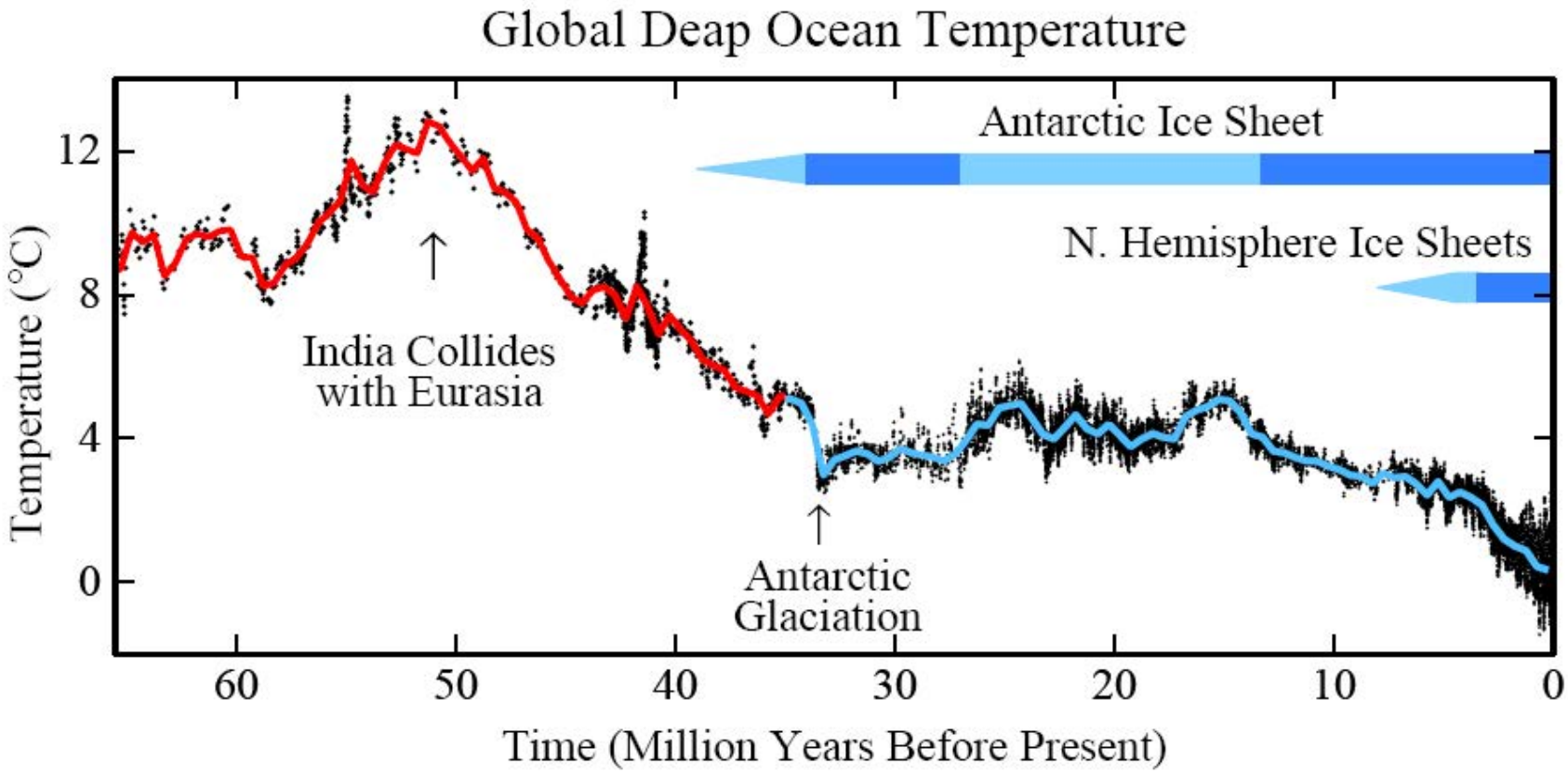

Cenozoic Era (65 Million Years)
Deep Ocean Temperature (°C)
12
8
4
0
Paleocene-Eocene Thermal Maximum
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
δ18O (‰)
0
1
2
3
4
5
60
50
40
30
20
10
0
My BP
PETM
Warm and wet

Canadian Museum of Nature (Marianne Douglas et al)




PETM – Ellesmere Island

Today– Ellesmere Island




- Continents stabilize close to present position
- $CO_2$ rapidly drops
- < 450ppm Antarctic icesheet forms

# Summary: Cenozoic Era

## 1. Dominant Forcing: Natural $\Delta CO_2$

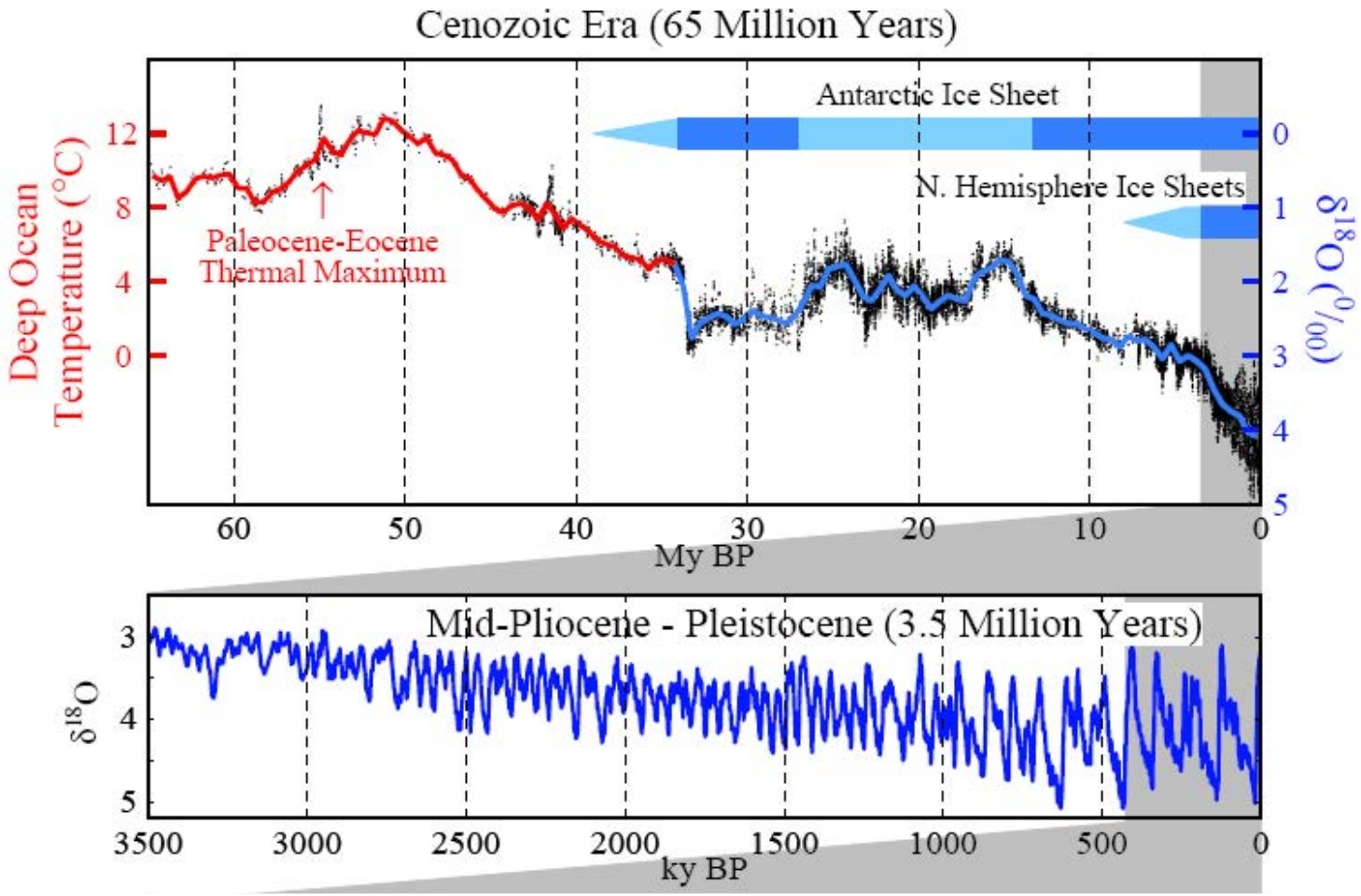
- Rate ~100 ppm/My (0.0001 ppm/year)
- Human-made rate today: ~2 ppm/year

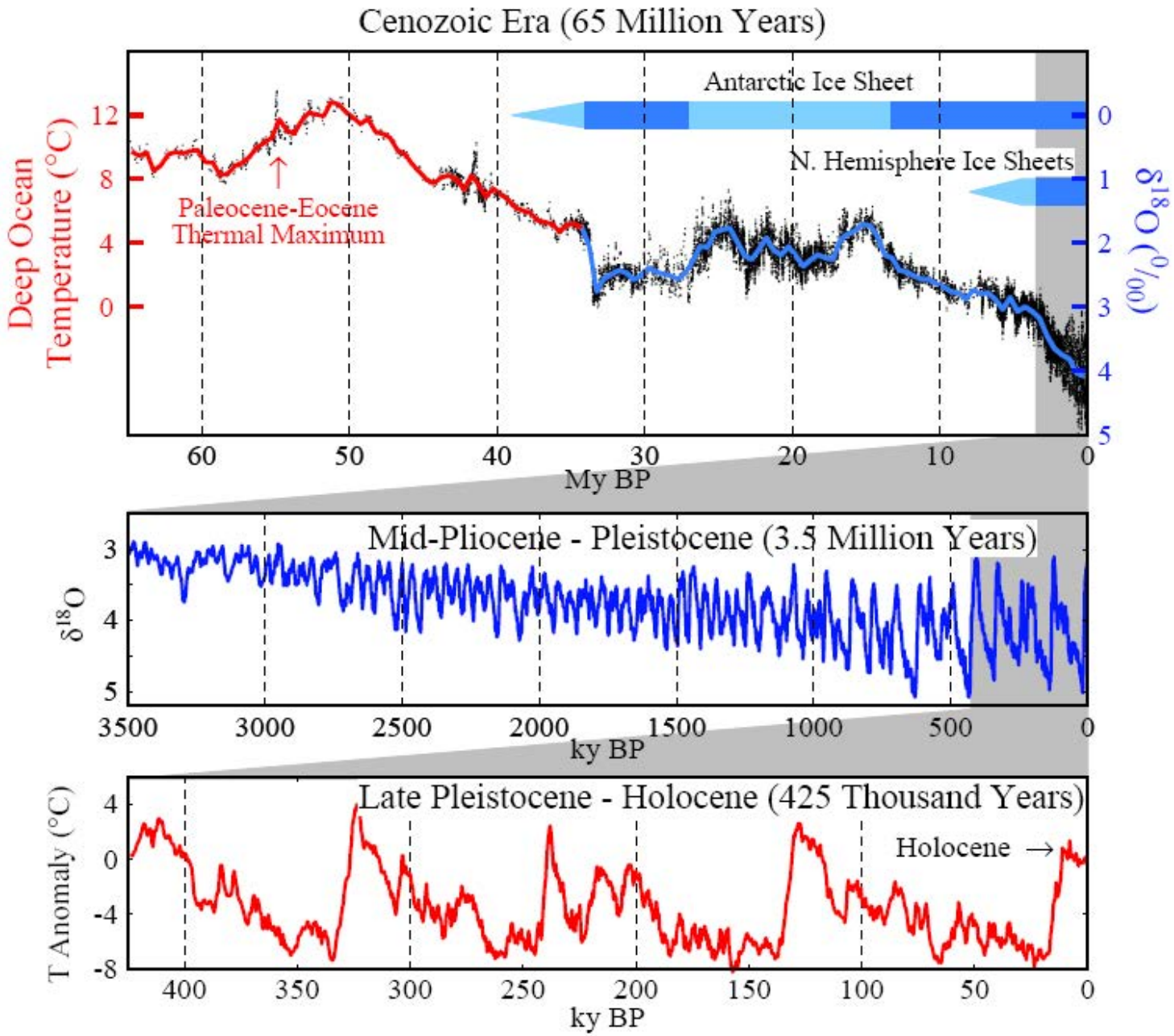
**Humans Overwhelm Slow Geologic Changes**

## 2. Climate Sensitivity High

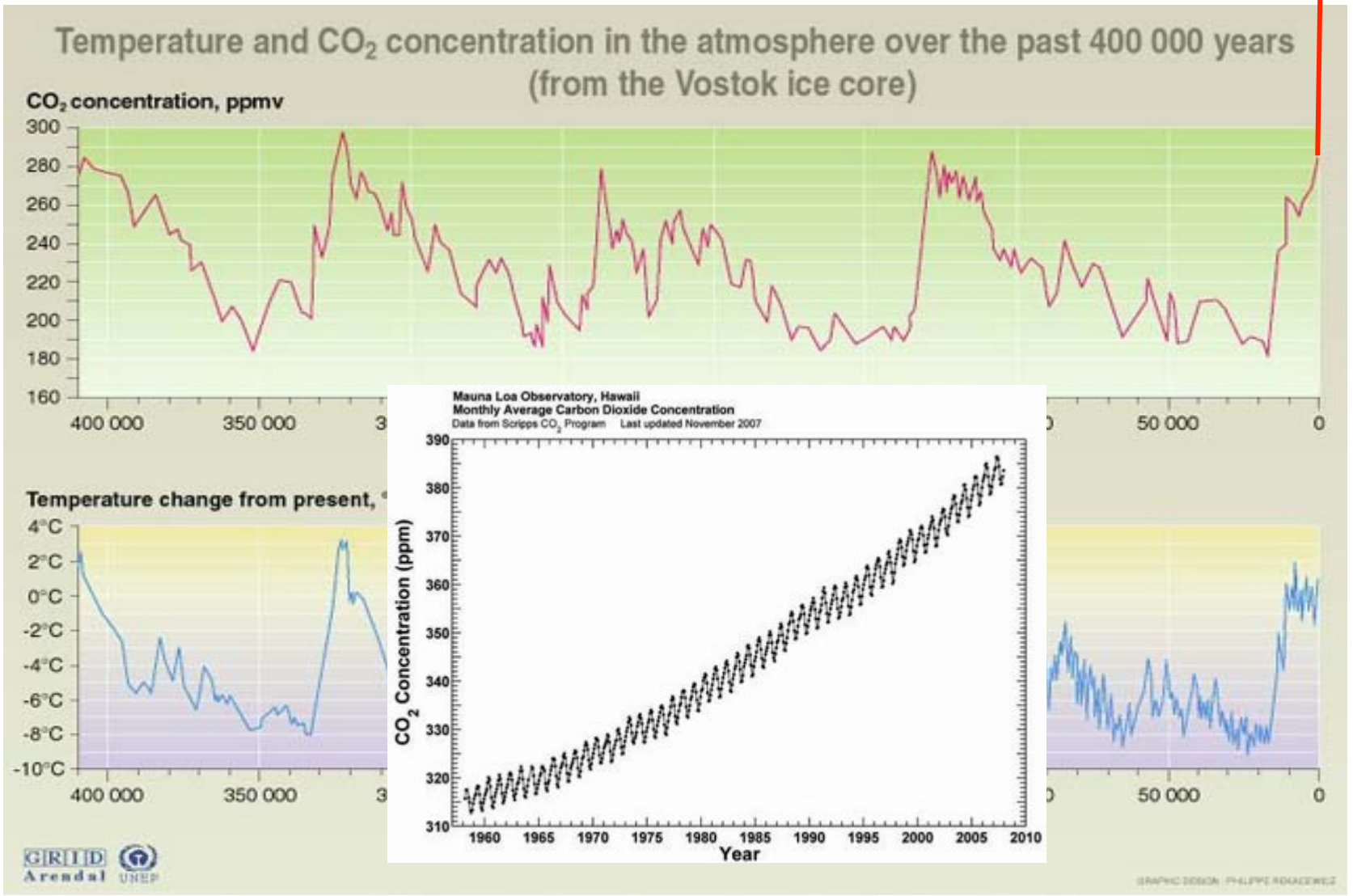
- Antarctic ice forms if $CO_2$ < ~450 ppm
- Ice sheet formation reversible

**Humans Could Produce "A Different Planet"**


Cenozoic Era (65 Million Years)
Deep Ocean Temperature (°C)
12
8
4
0
Paleocene-Eocene Thermal Maximum
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
δ18O (‰)
0
1
2
3
4
5
60
50
40
30
20
10
0
My BP
Mid-Pliocene - Pleistocene (3.5 Million Years)
δ18O
3
4
5
3500
3000
2500
2000
1500
1000
500
0
ky BP


Cenozoic Era (65 Million Years)
Deep Ocean Temperature (°C)
12
8
4
0
Paleocene-Eocene Thermal Maximum
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
δ18O (‰)
0
1
2
3
4
5
60
50
40
30
20
10
0
My BP
Mid-Pliocene - Pleistocene (3.5 Million Years)
δ18O
3
4
5
3500
3000
2500
2000
1500
1000
500
0
ky BP
Late Pleistocene - Holocene (425 Thousand Years)
T Anomaly (°C)
4
0
-4
-8
Holocene →
400
350
300
250
200
150
100
50
0
ky BP

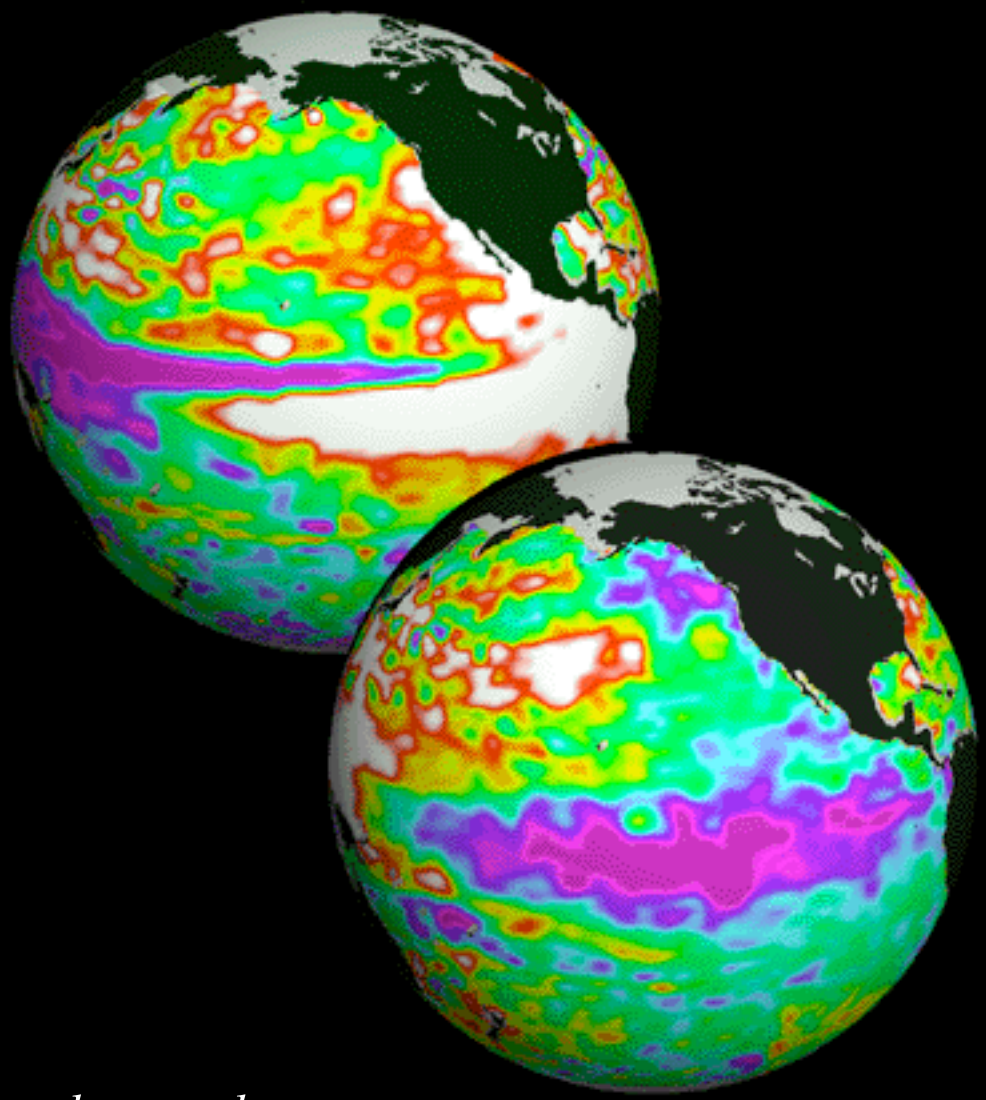
400ppm




Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

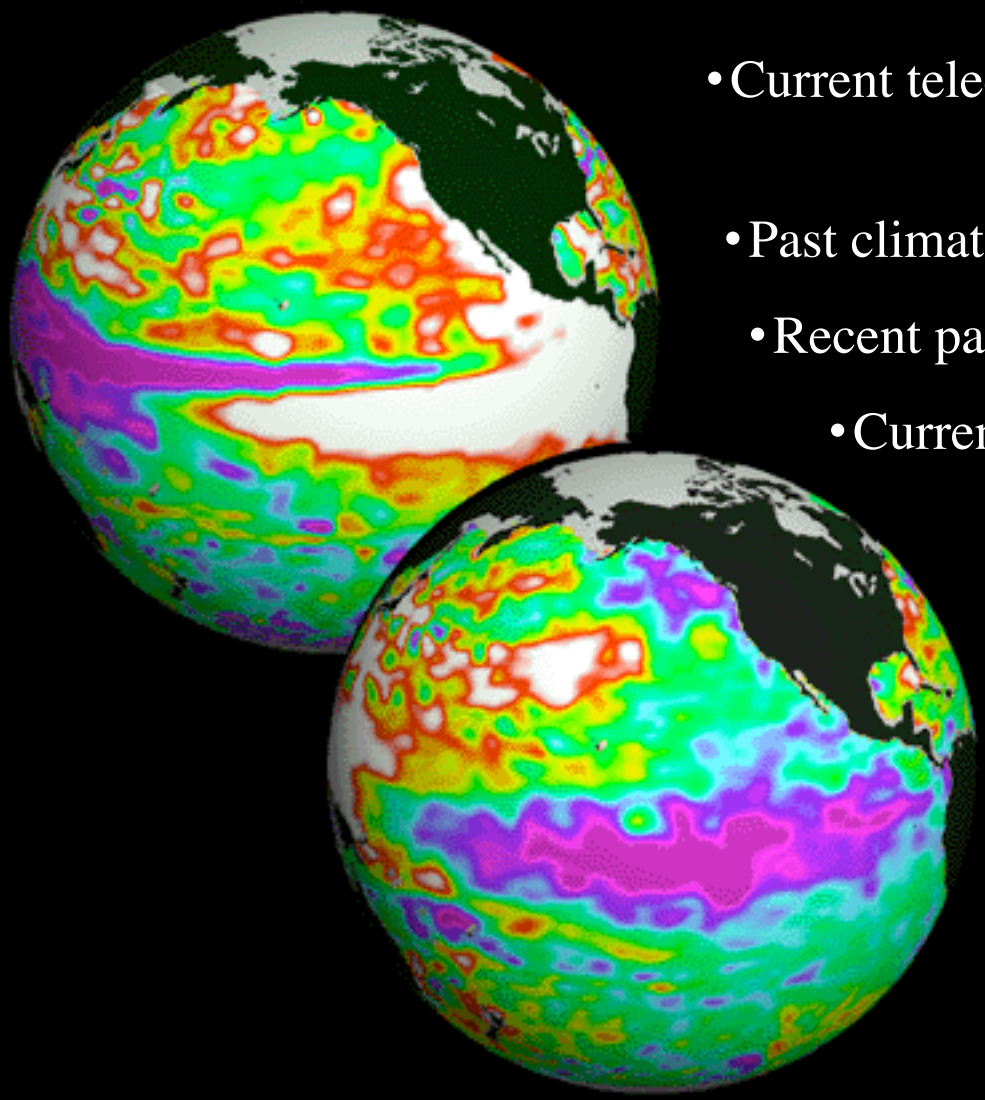
General Circulation Models

Validation
- -Paleoclimates
- -contemporary
- -hindcasting
- -ensemble runs
- -intercomparisons



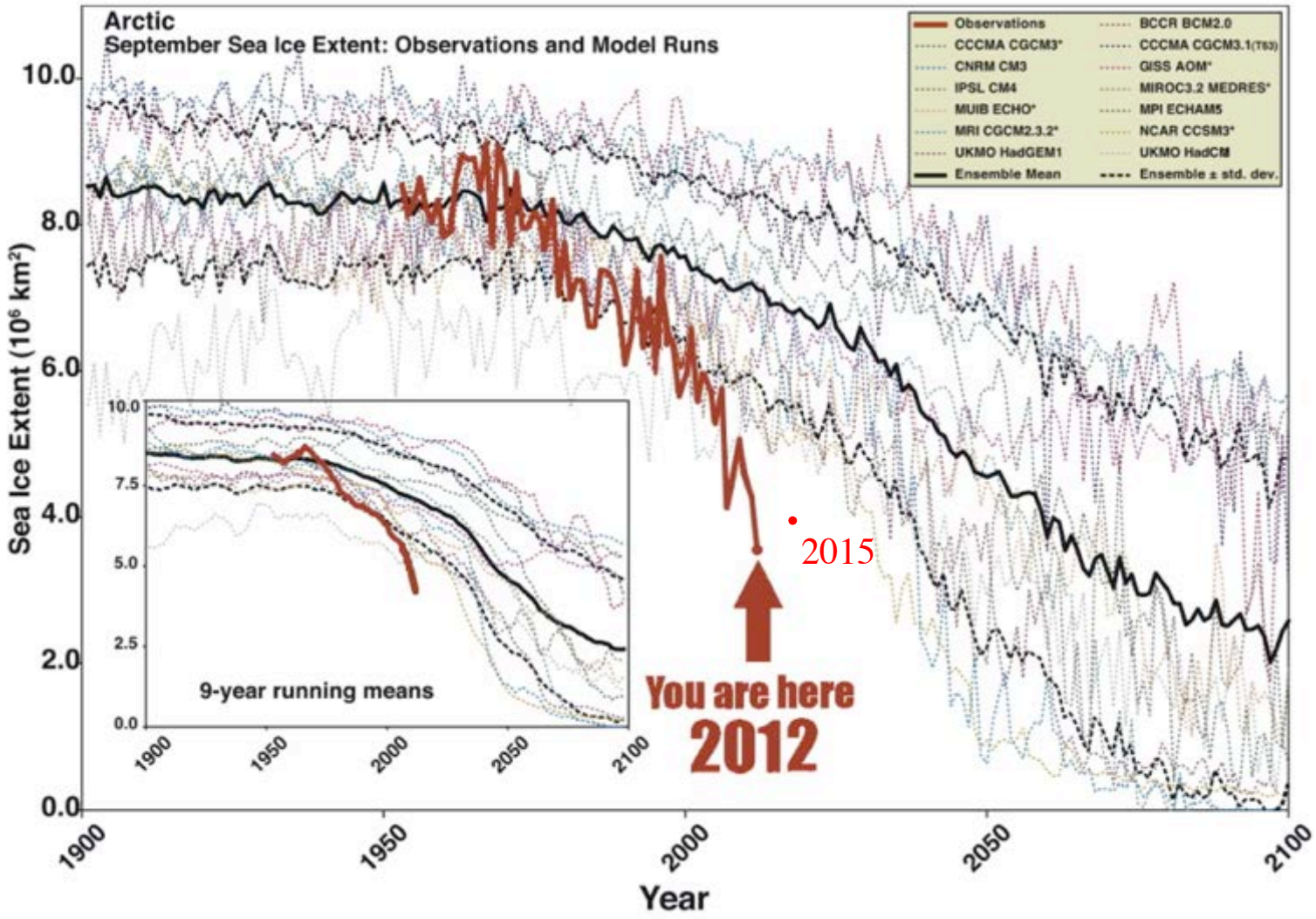
*Hah – they can't even predict the weather tomorrow*

## But they can predict:

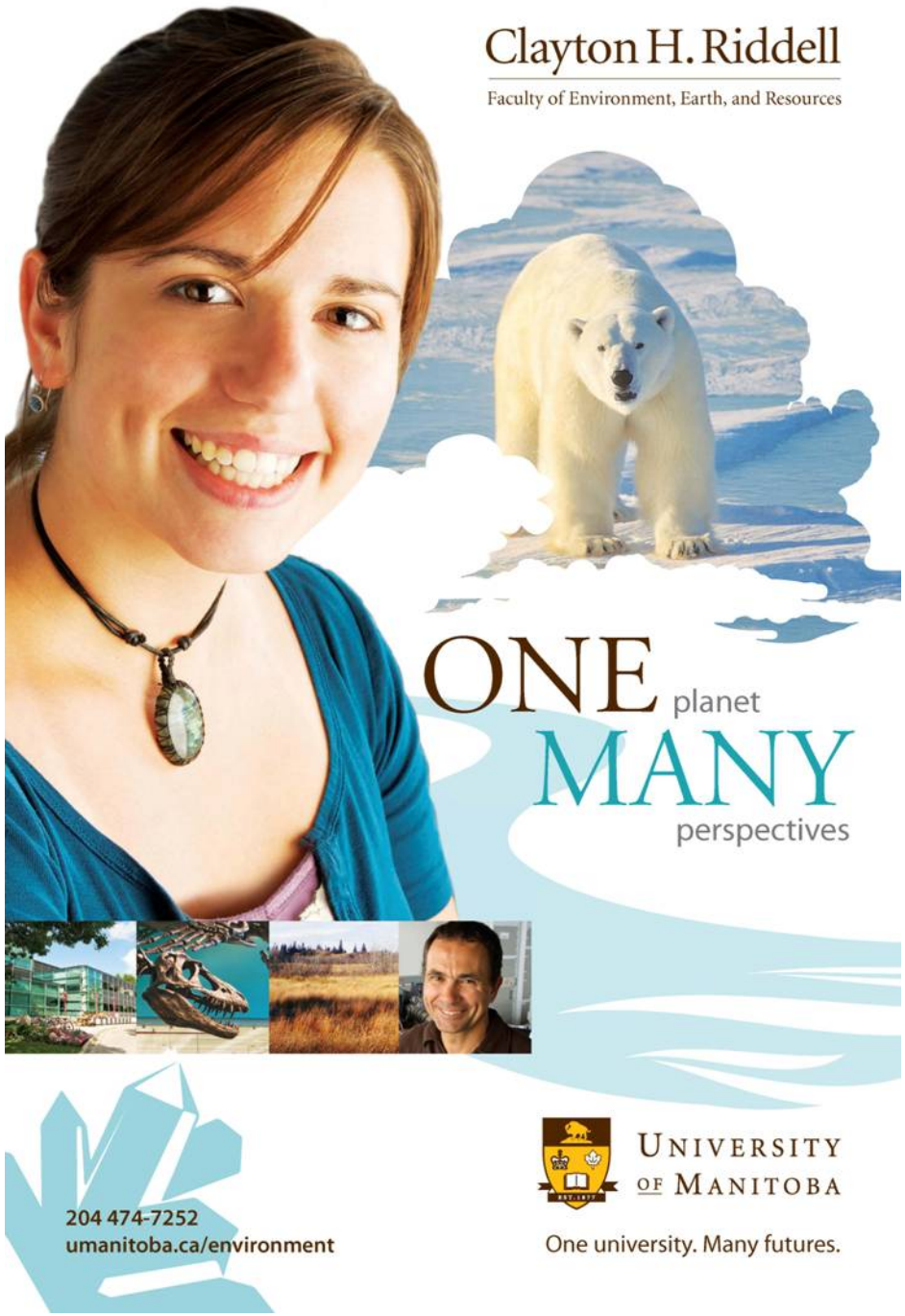


- Current teleconnection patterns (e.g., ENSO)
- Past climates (back 65My BP years)
- Recent past climates (1000's y BP)
- Current Global warming trends
- Current Arctic trends

*Model are actually conservative on most predictions relative to observations*




Sea ice minimum (Observed) relative to IPCC model estimates (CMIP3)




**What can the Arctic tell us?**

# Sea Ice and Climate Change

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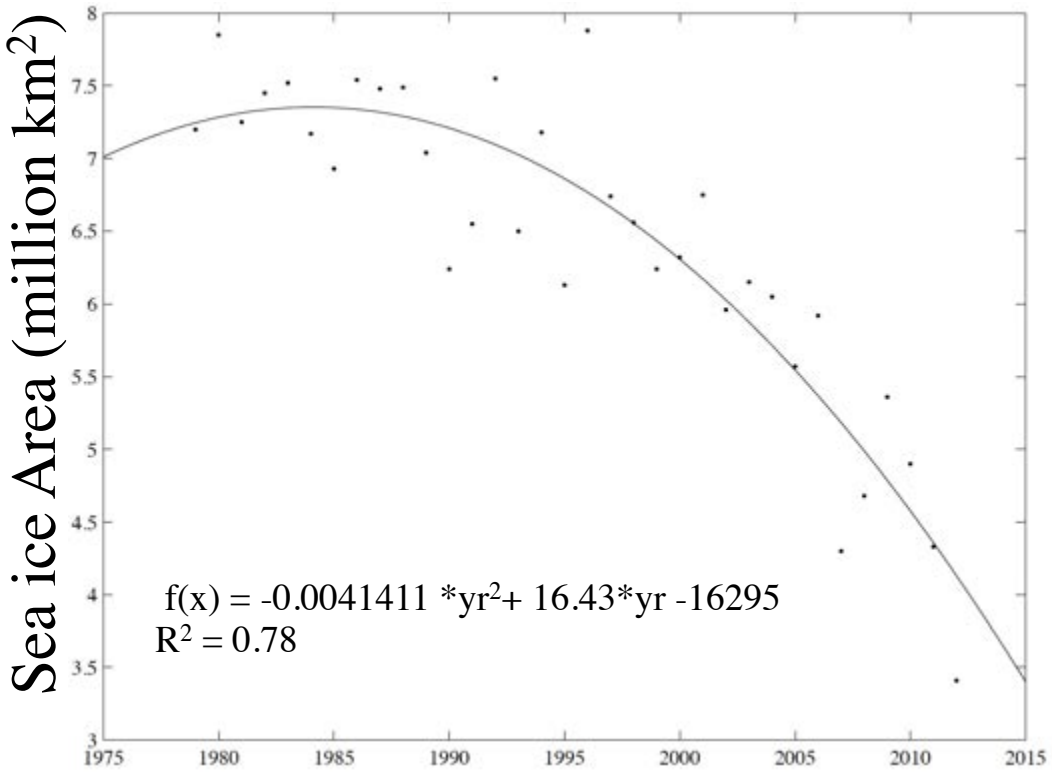
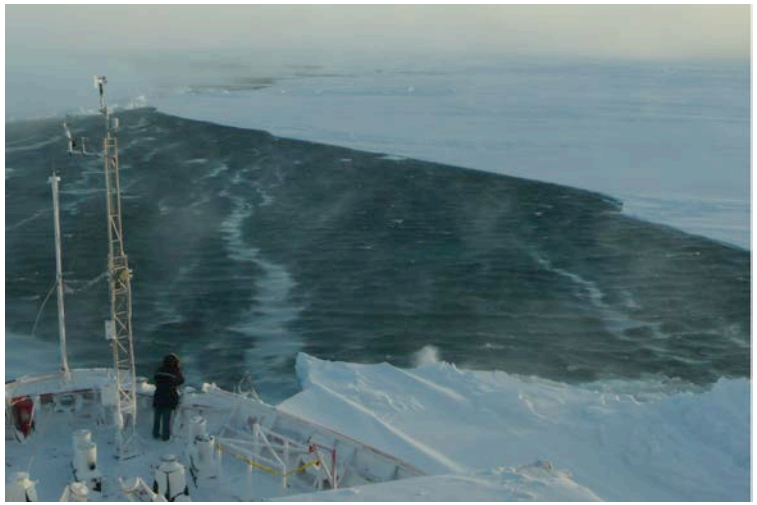
# Reduction in the Sea Ice summer minimum - winter?



January, 2008

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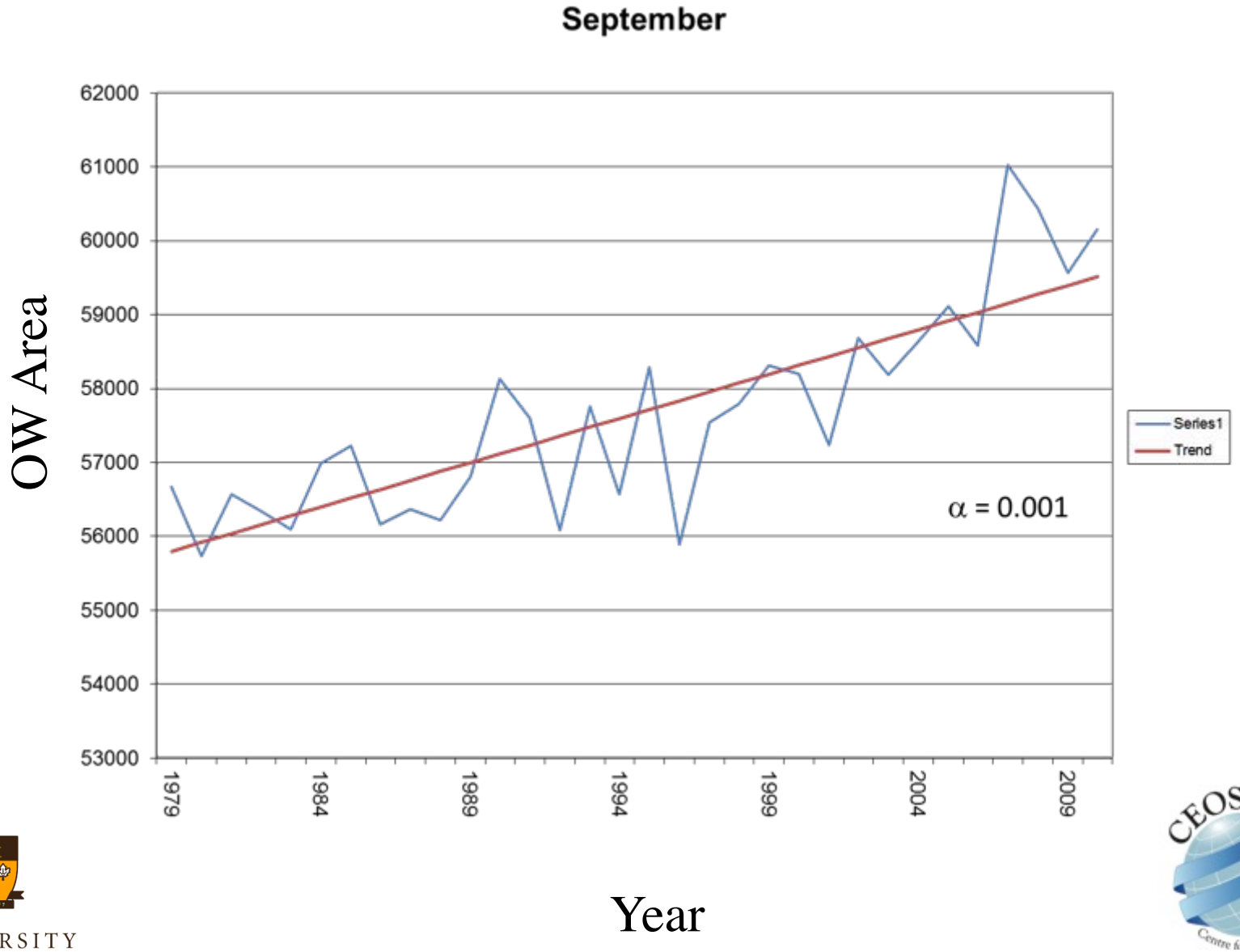
# Trend in Open Water by Month (1979 – 2010)

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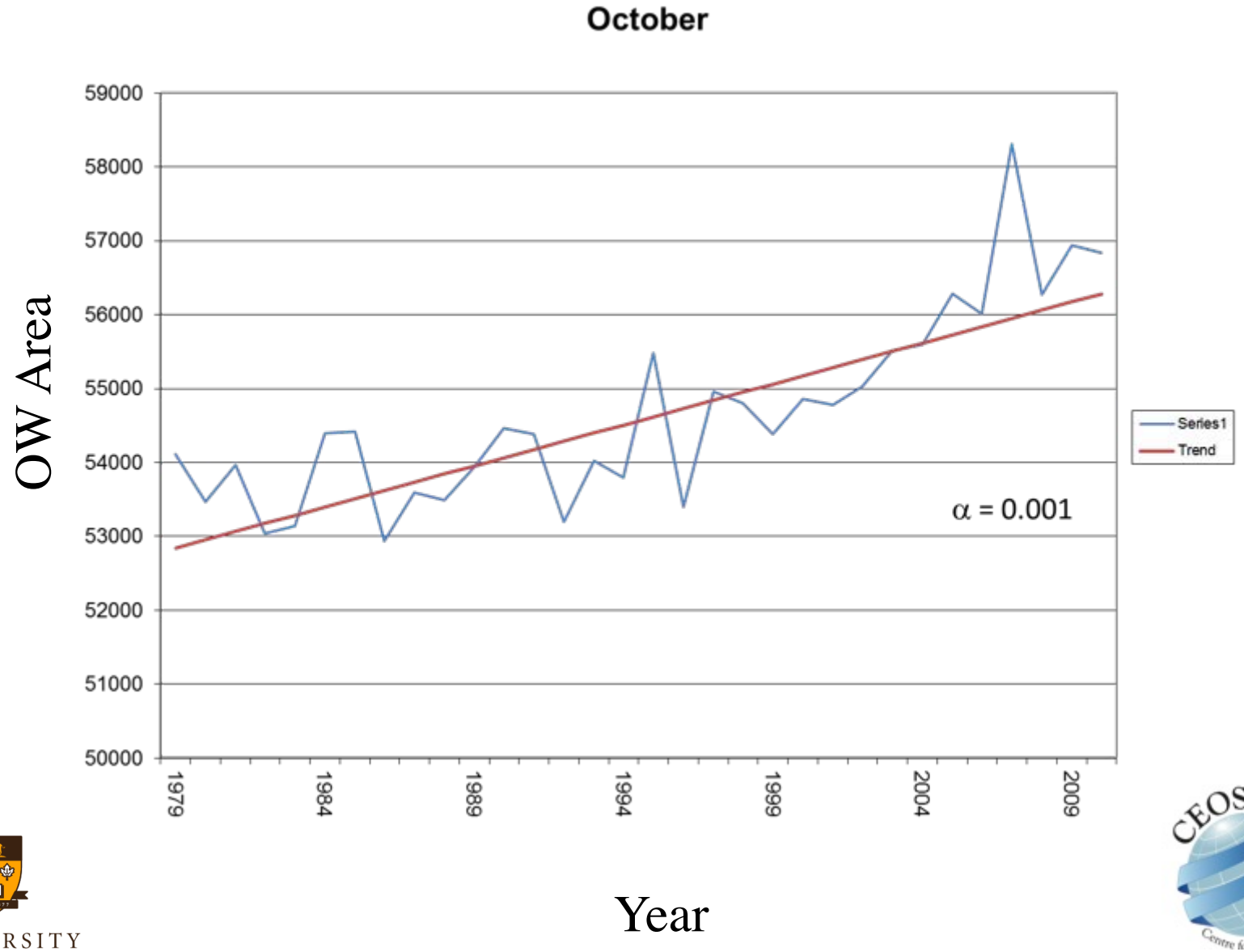


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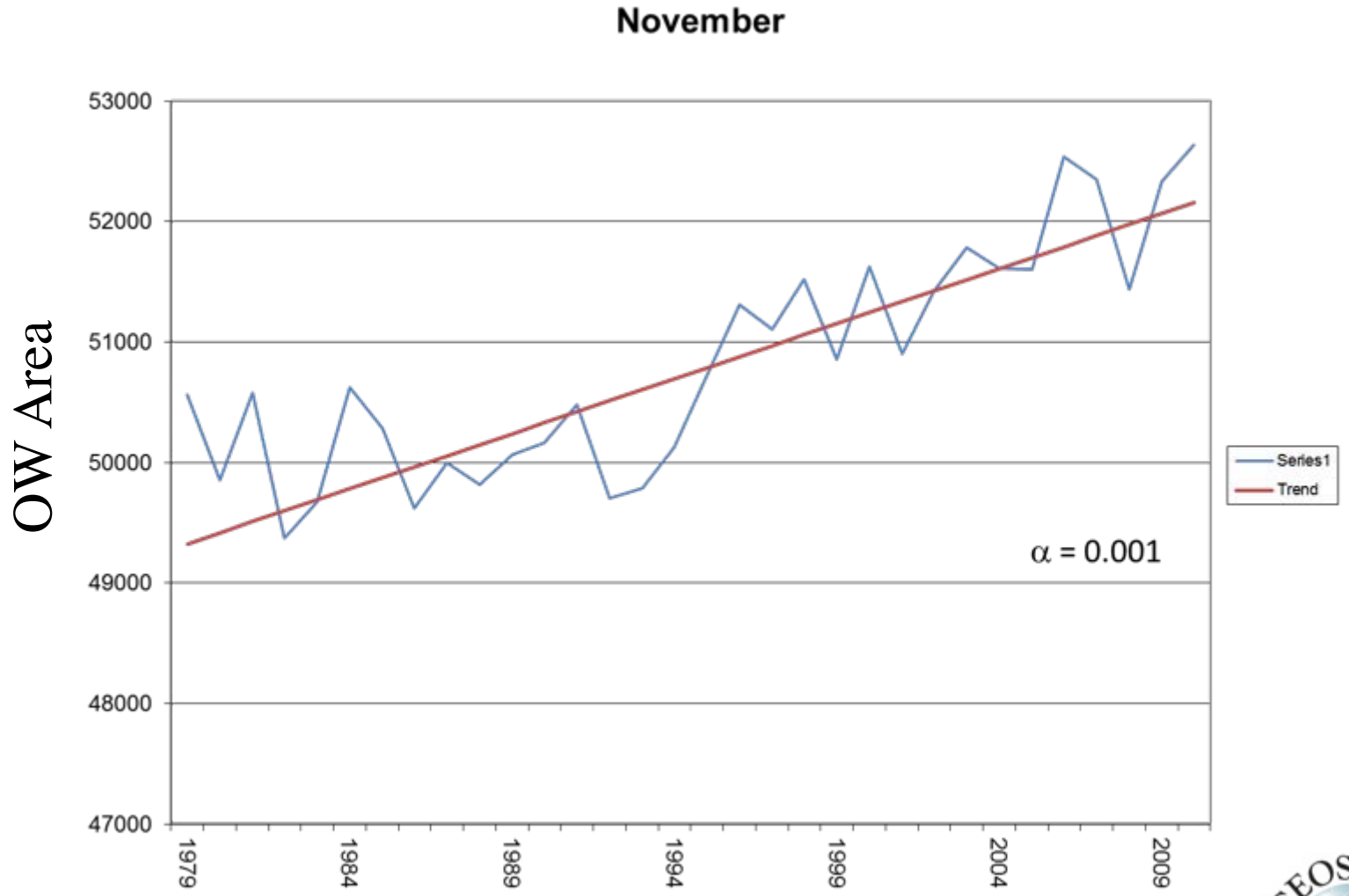


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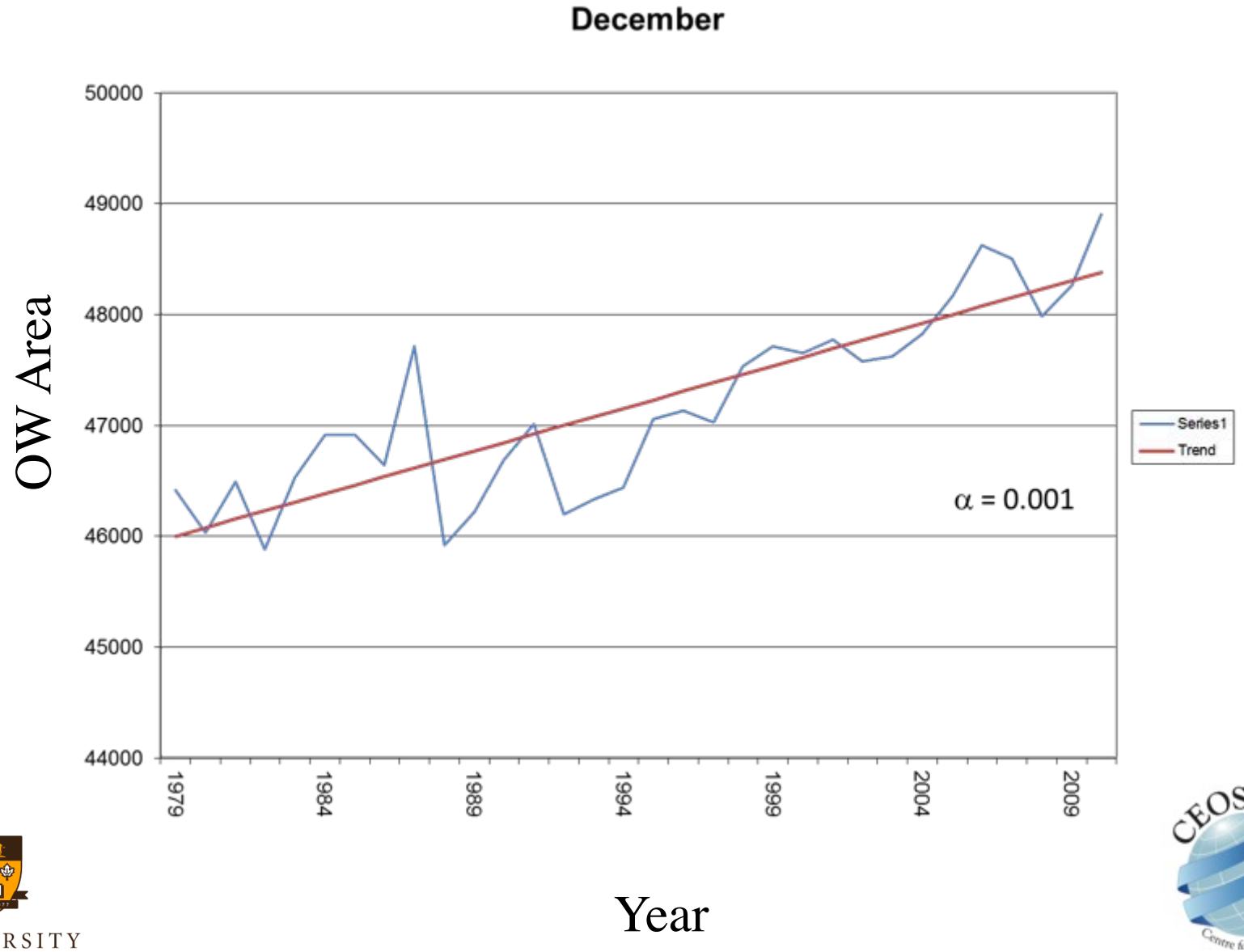


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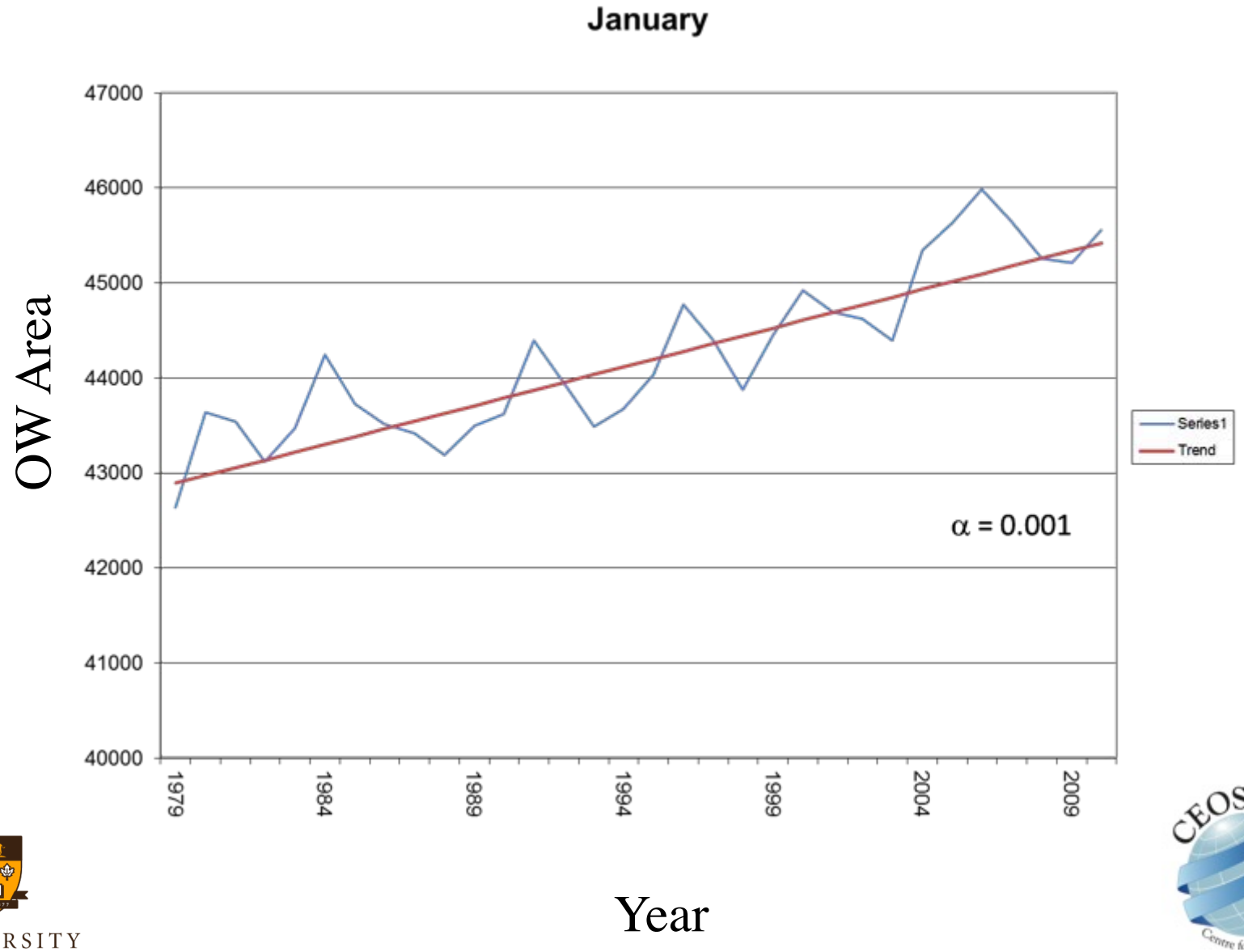


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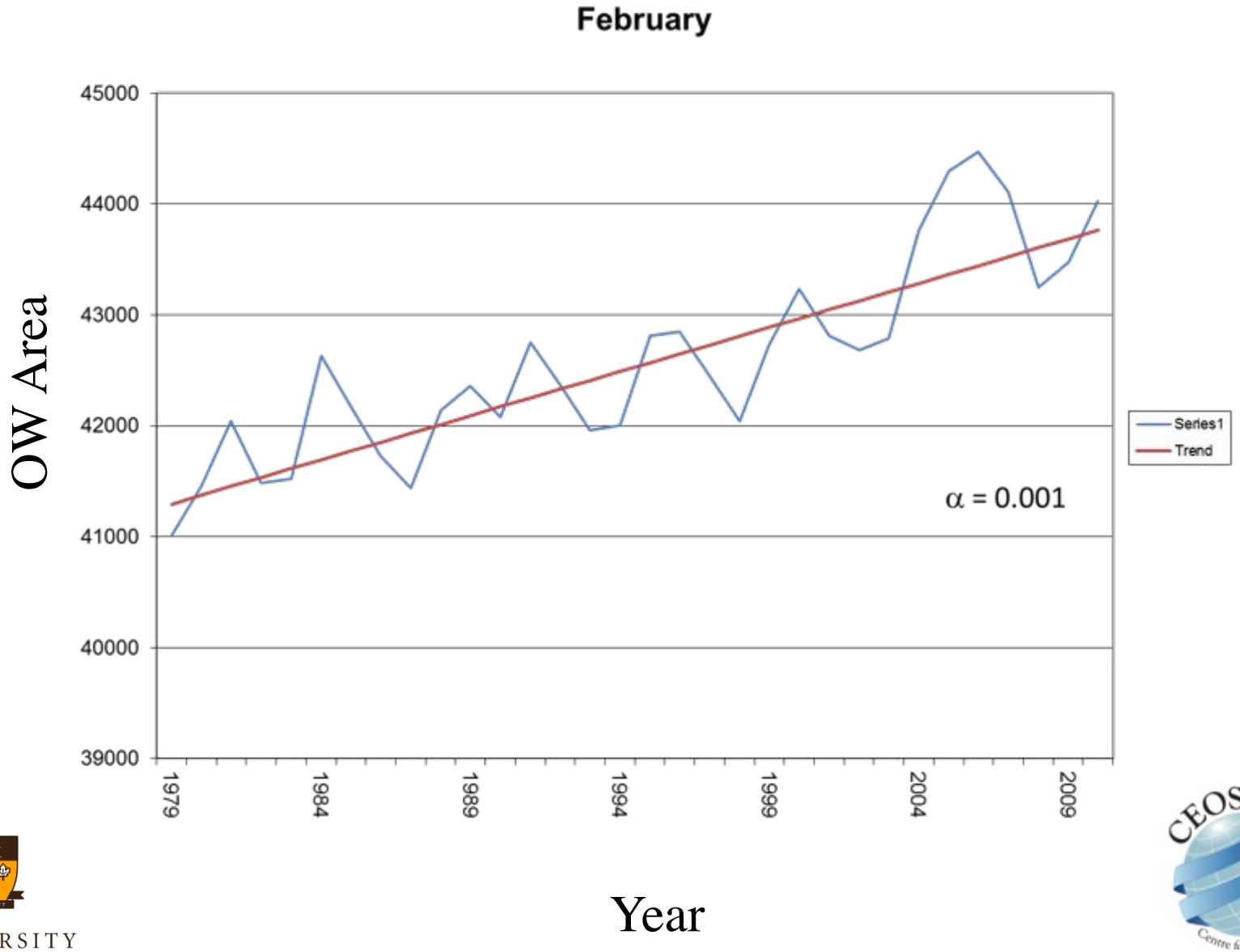


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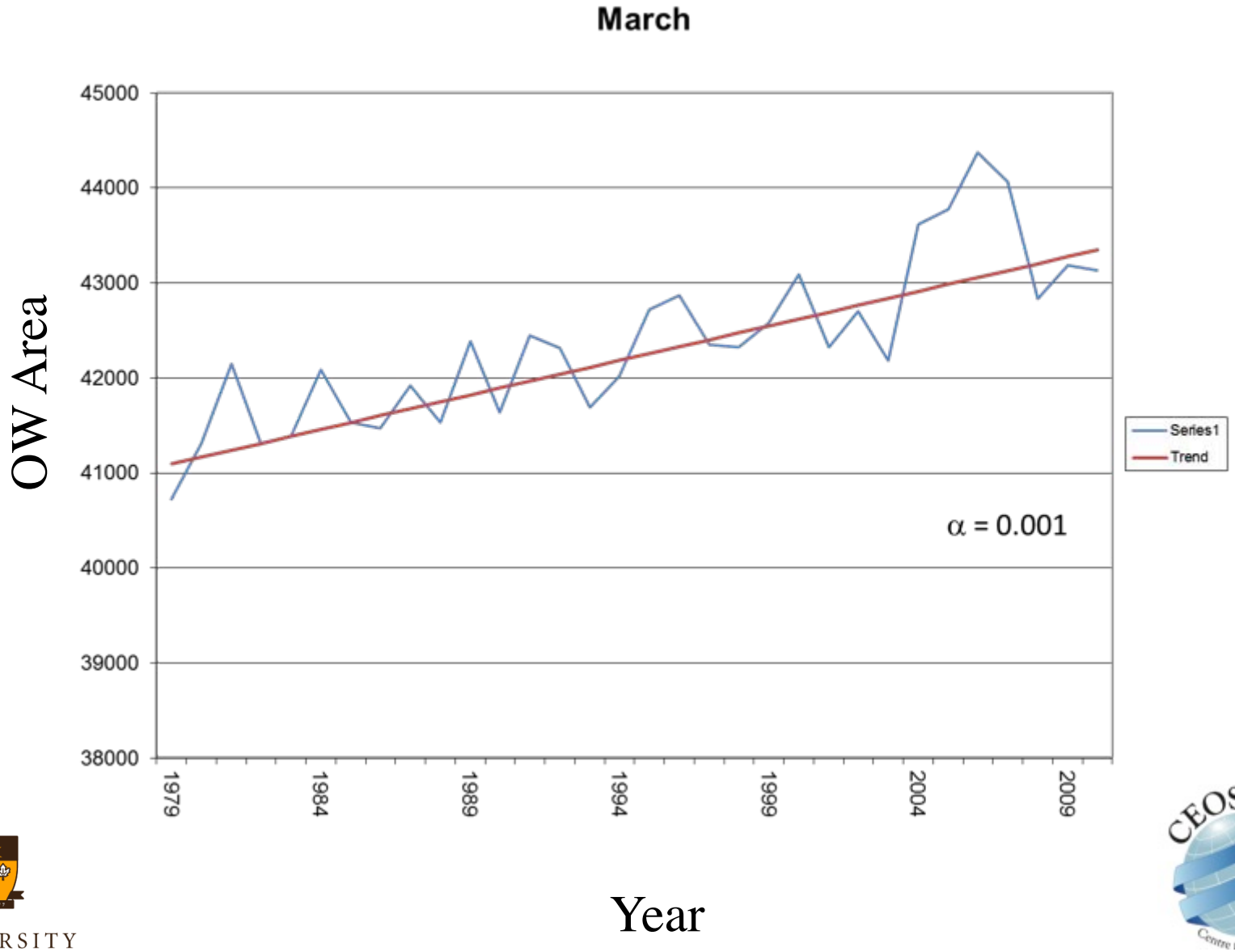


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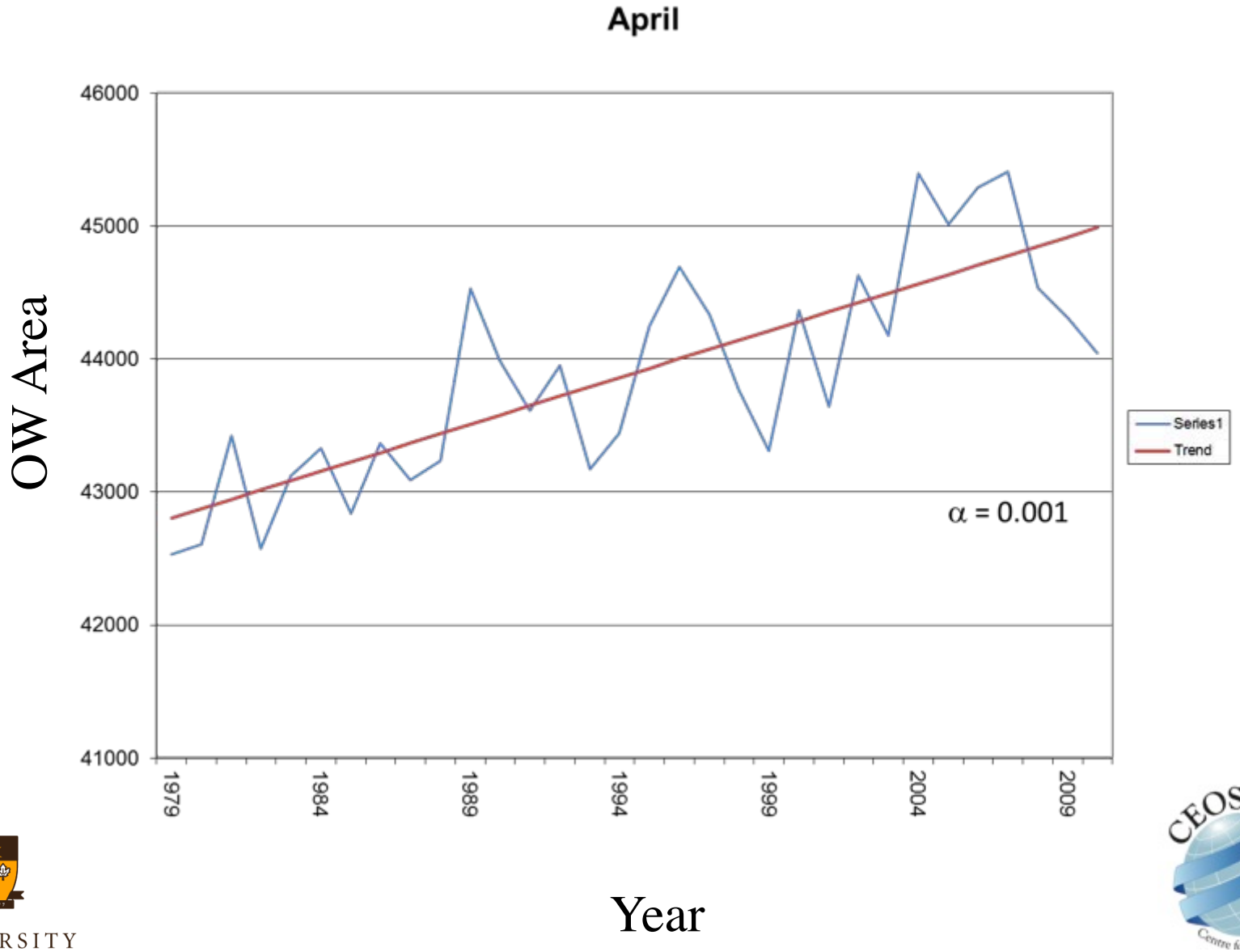


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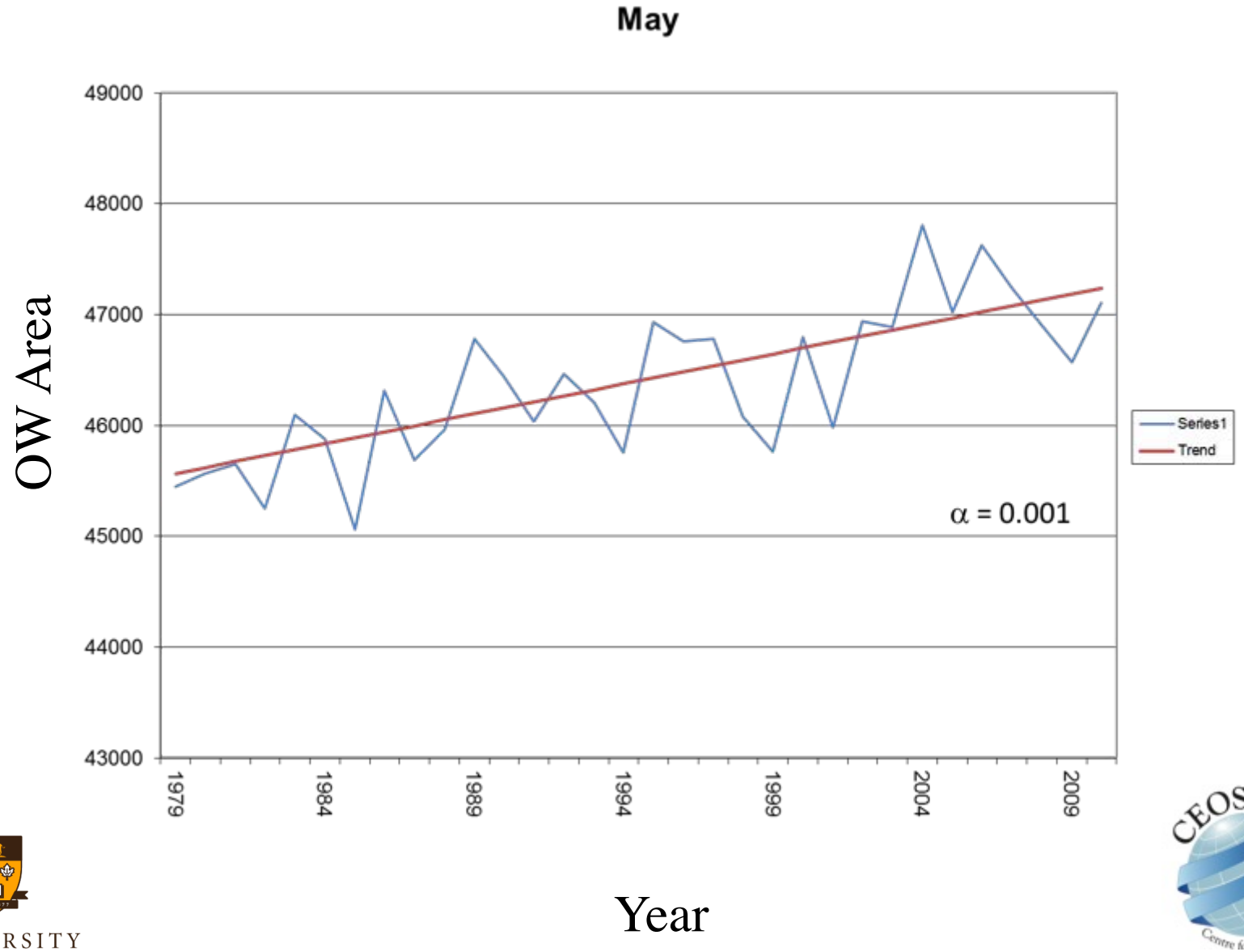


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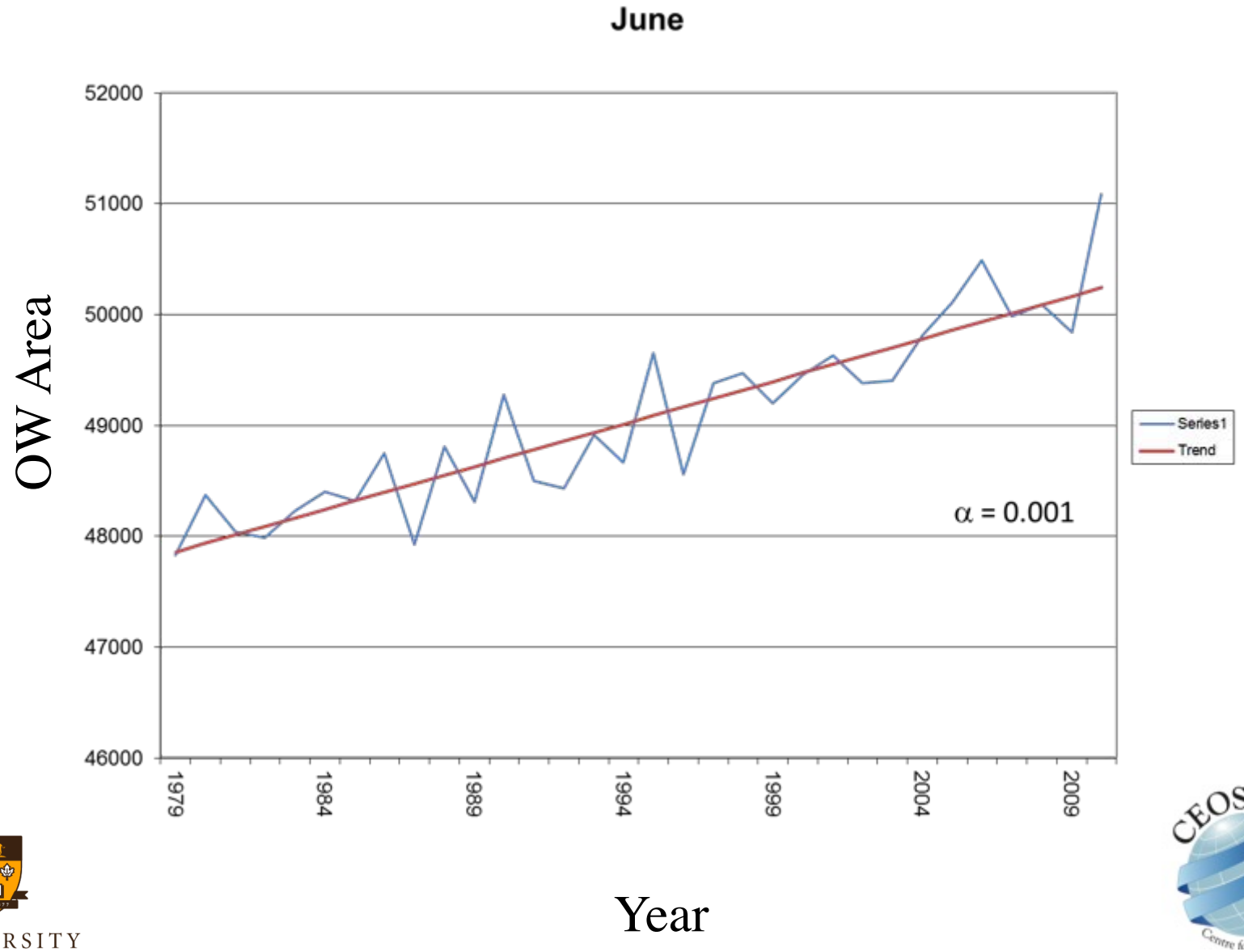


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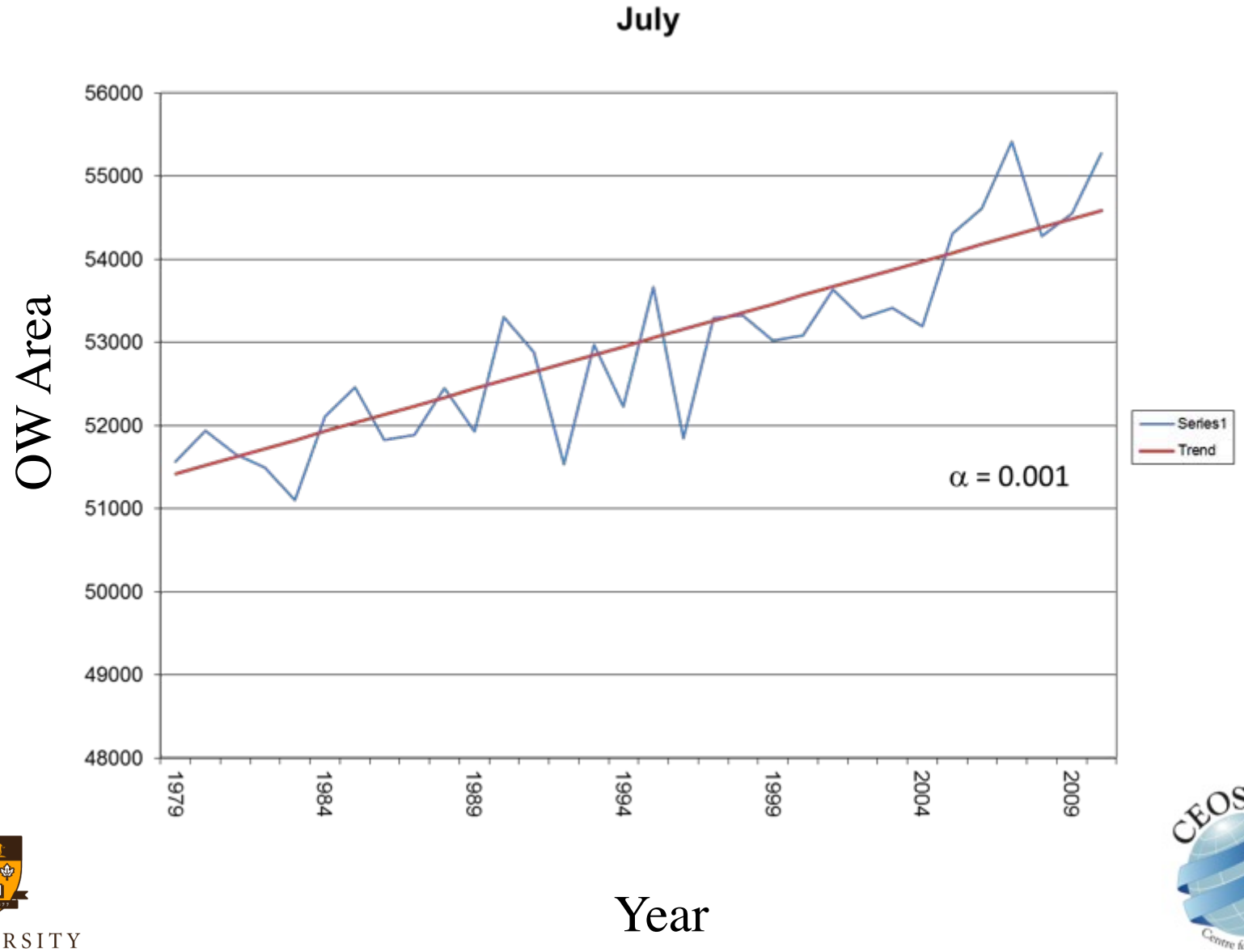


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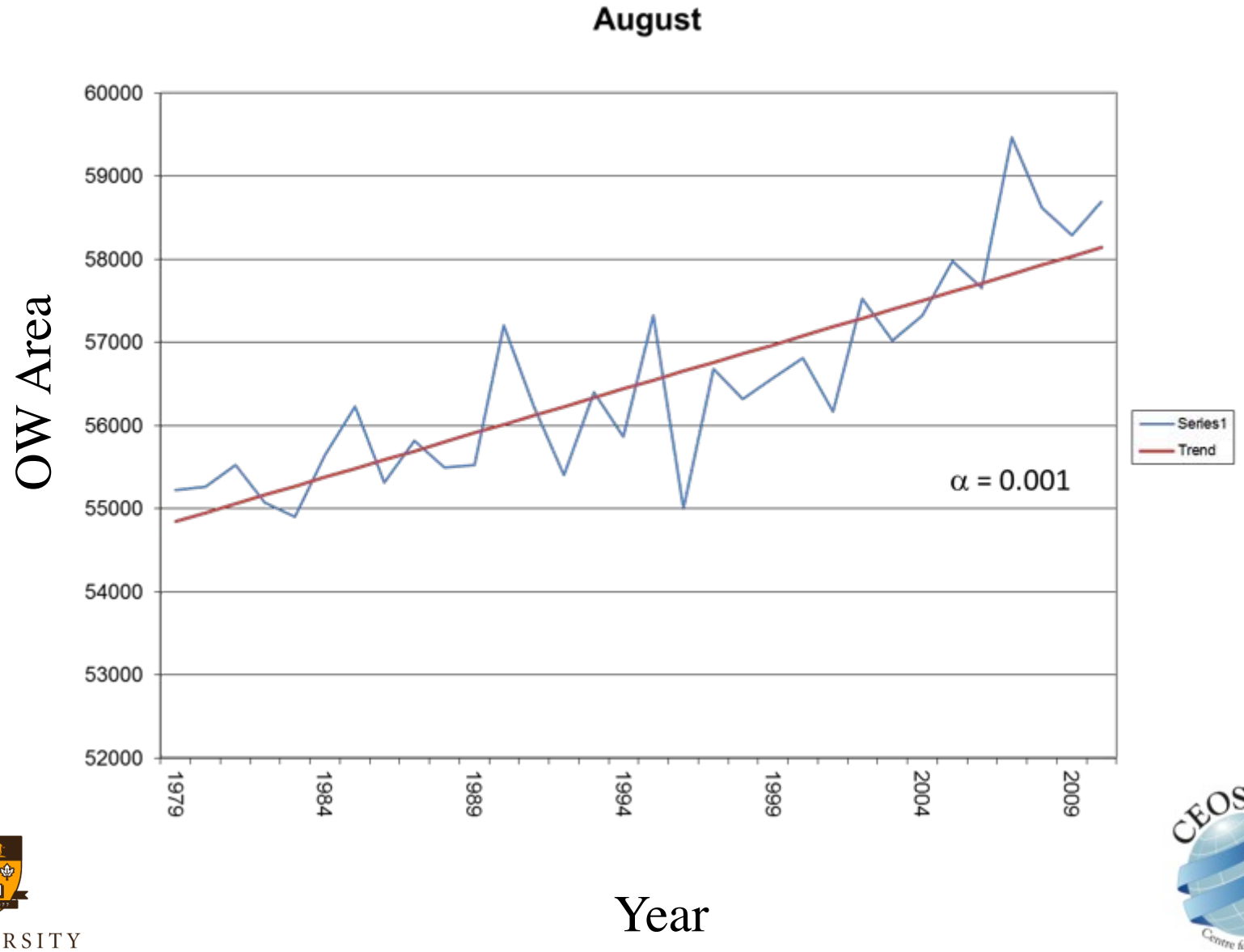


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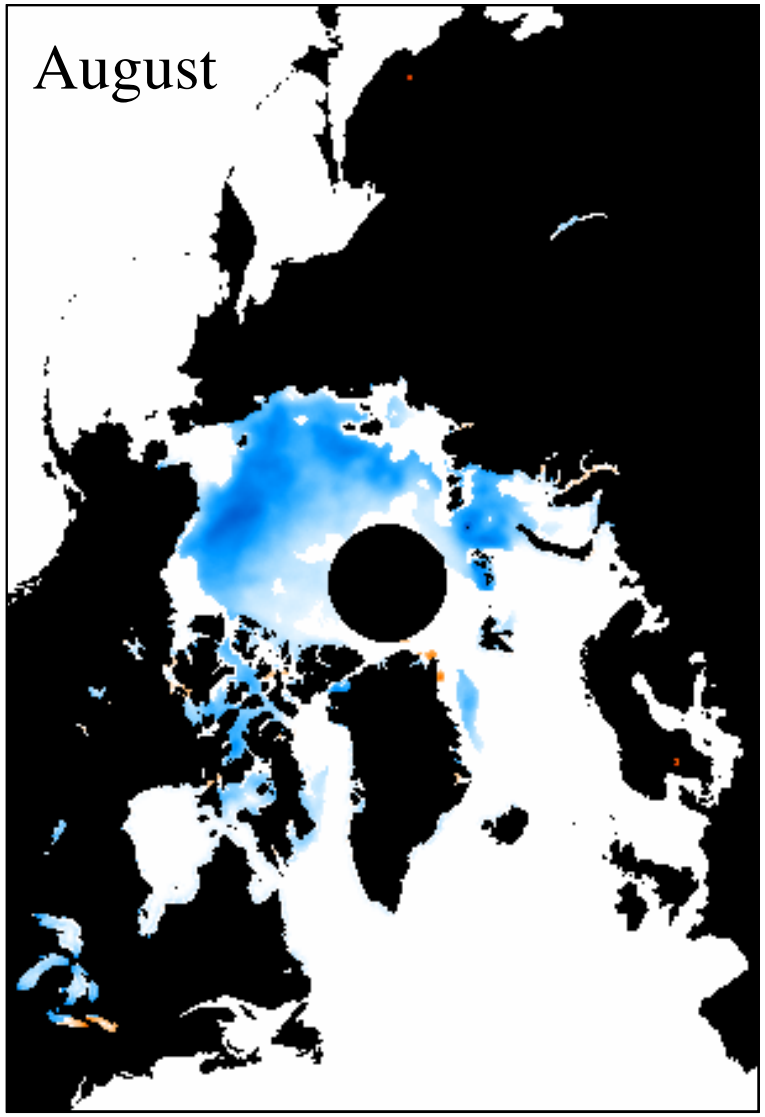
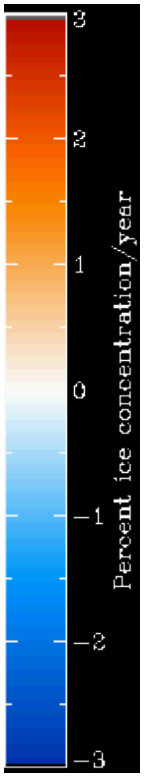
Trends in Percent change in SIC
$\alpha \leq 0.05$




Barber et al. 2015

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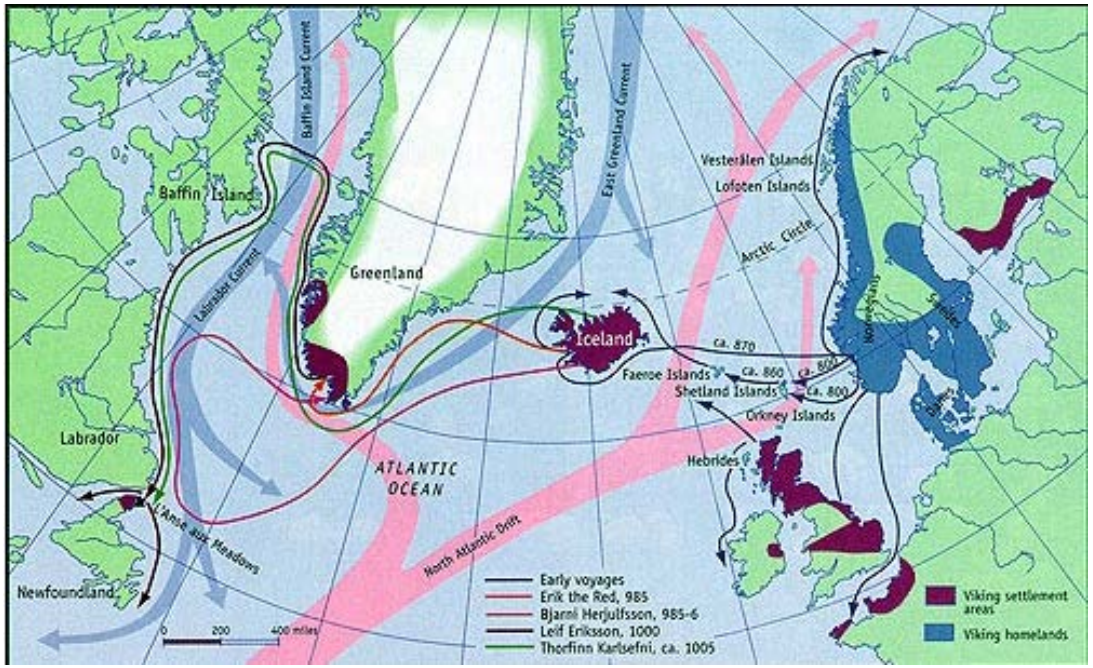
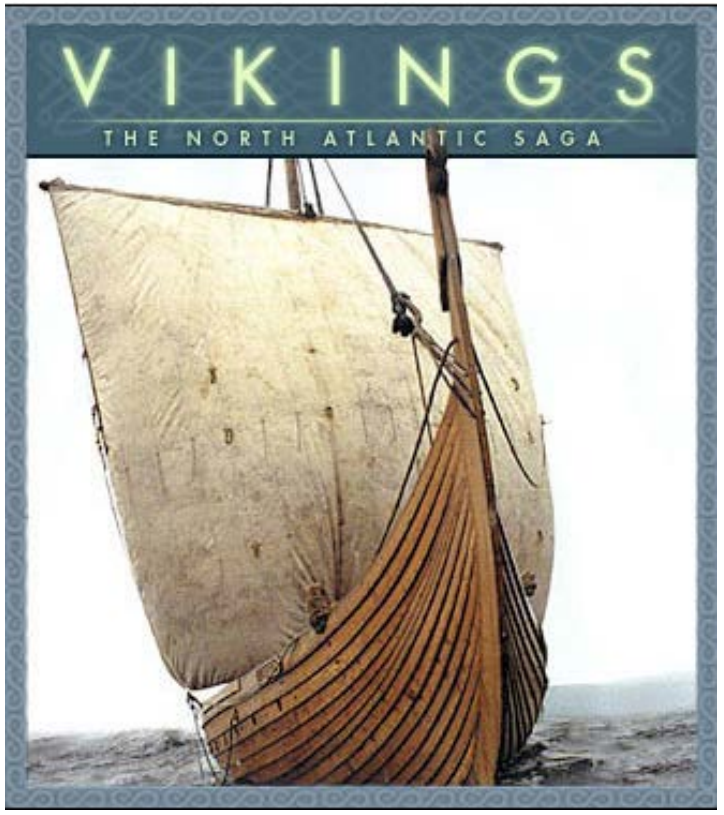
# So how significant is this change?




The Medieval Warm Period

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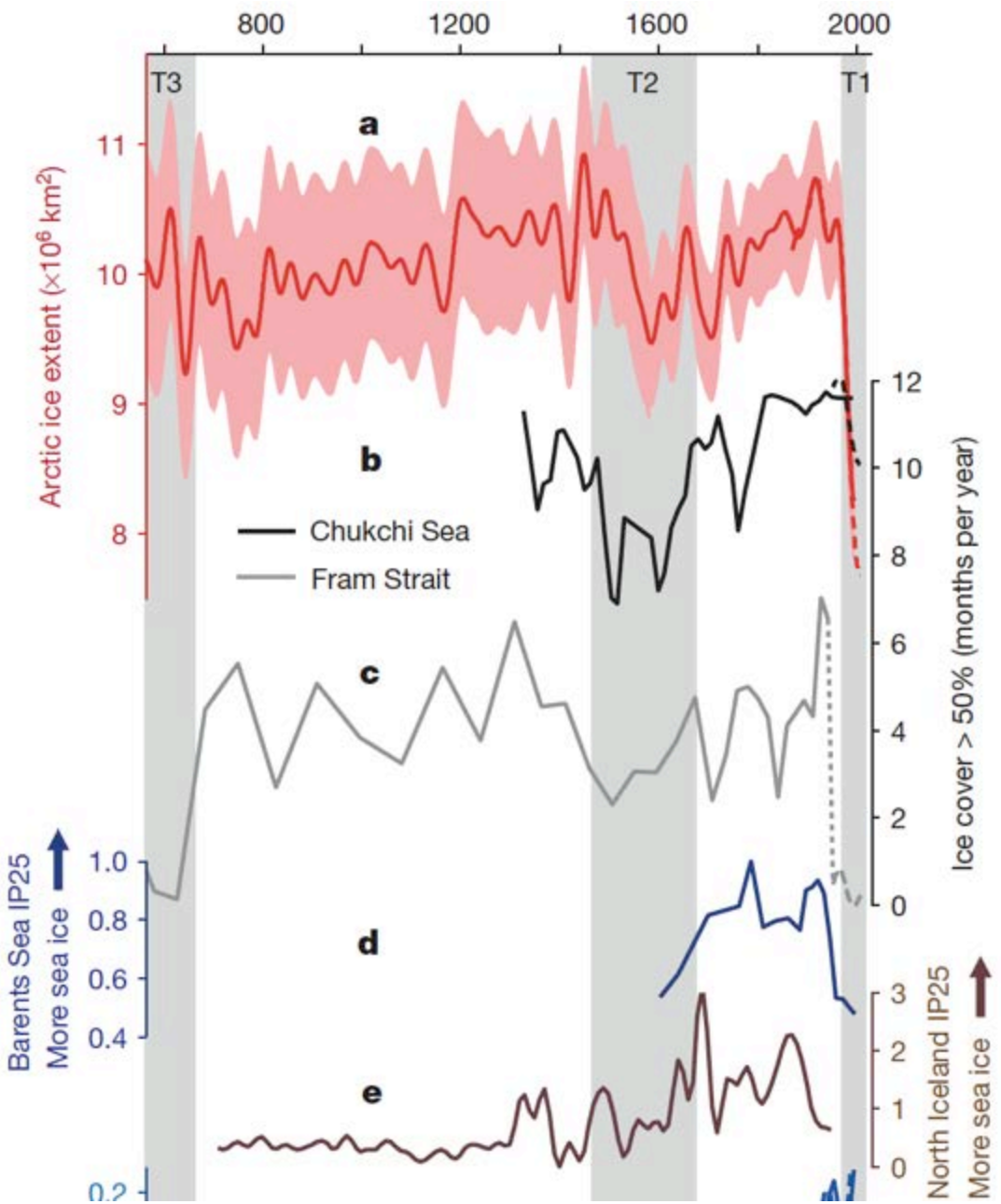


Kinnard et al. 2011

So how significant is this change?

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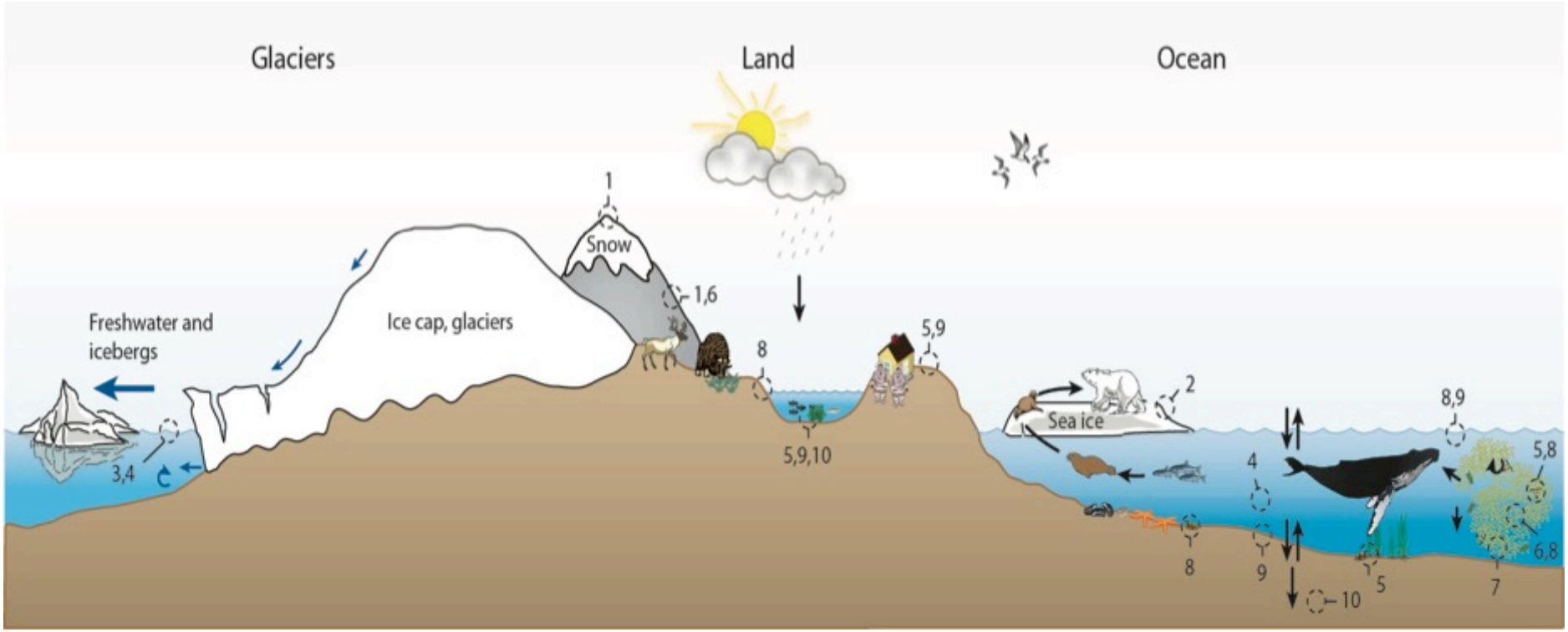
# Glacial freshwater fluxes

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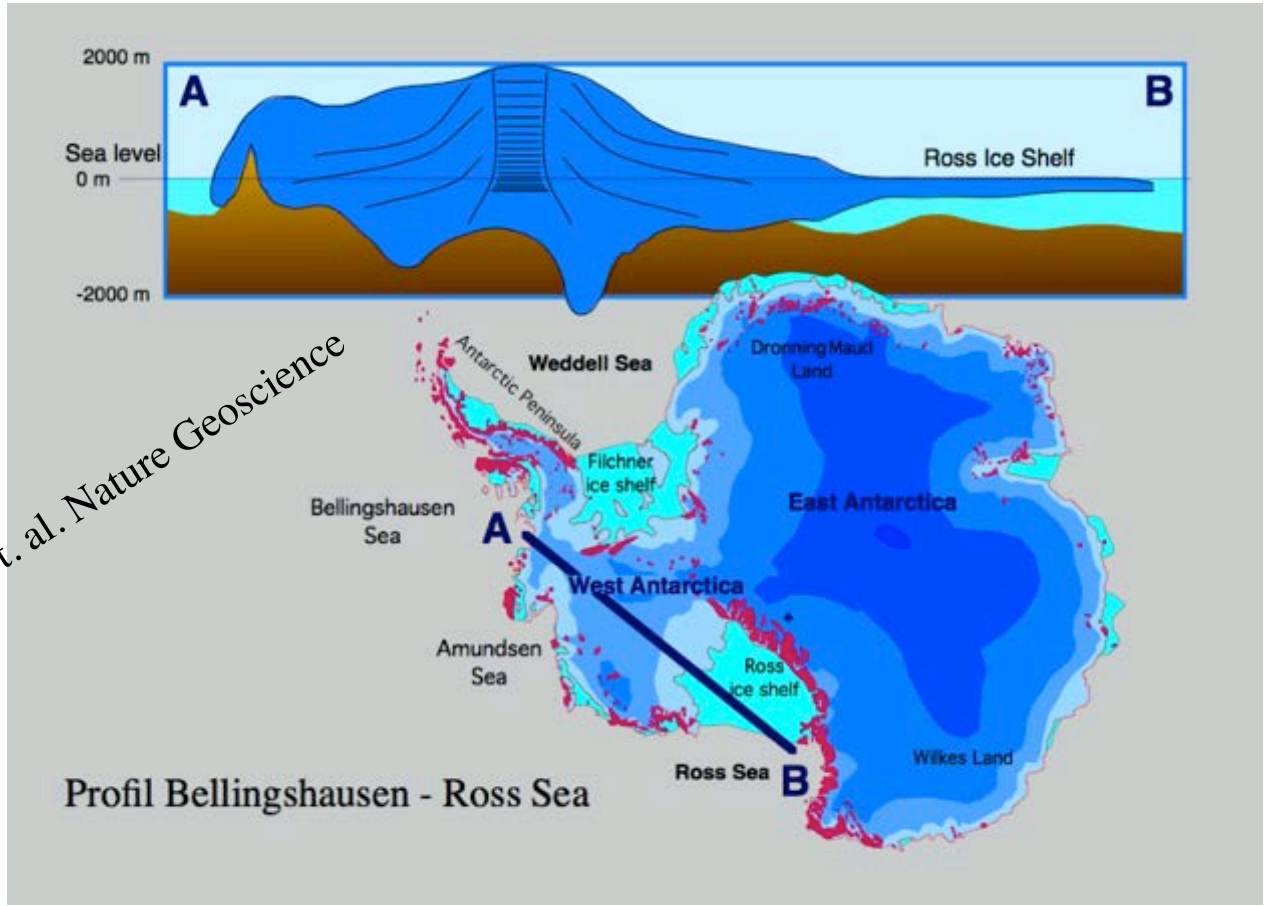
Centre for Earth Observation Science

# Glacial freshwater fluxes




Weber et. al. Nature Geoscience

Inevitable collapse of the West Antarctic Ice Shelves (Joughin et al 2014; and Rignot et al. 2014)

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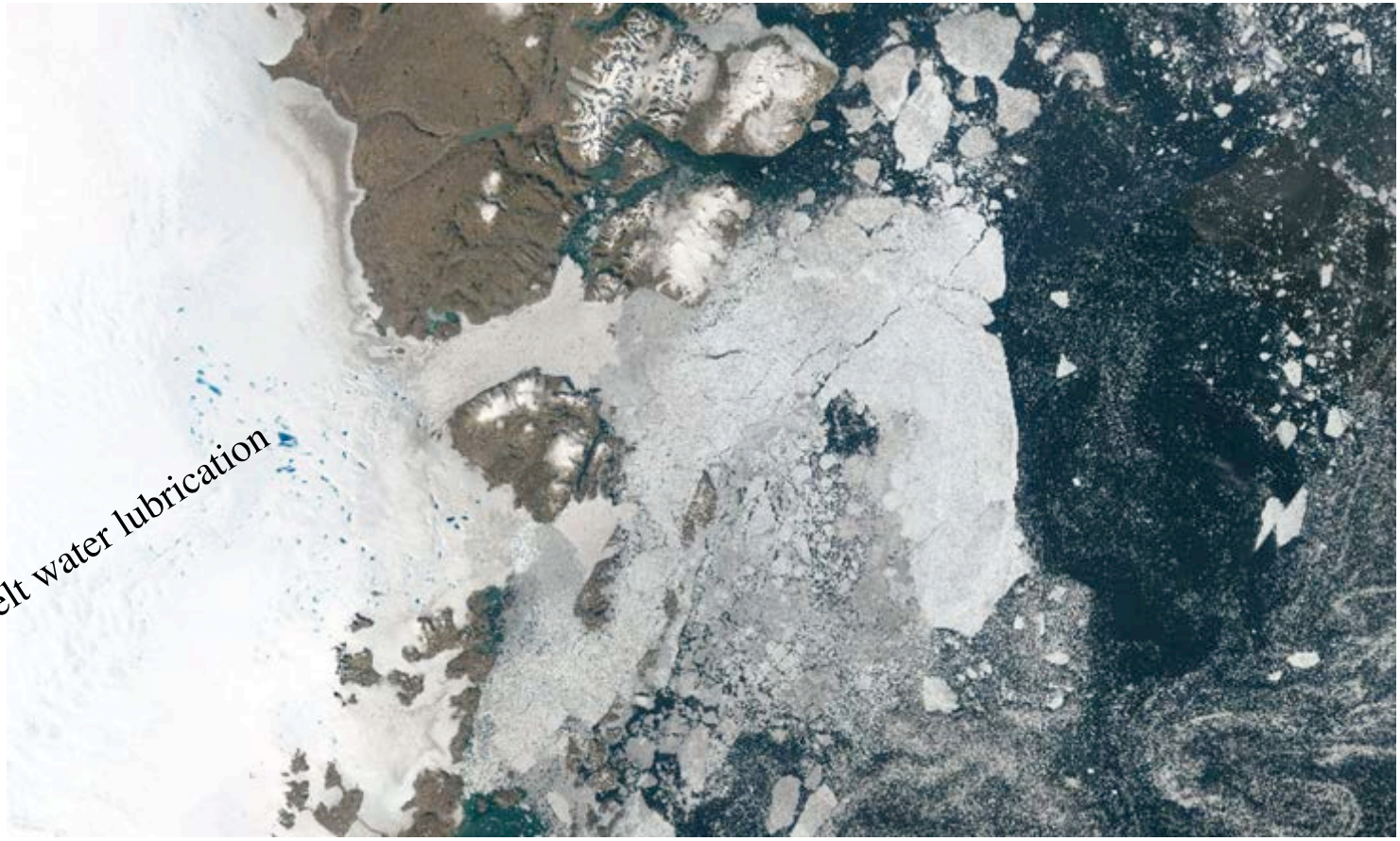
# Glacial freshwater fluxes




Zachariae Isstrom (NE Greenland) glacier enters period of rapid retreat contributing 0.5M of sea level rise equivalent

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# Glacial freshwater fluxes

Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

*Source: Roger Braithwaite, University of Manchester (UK)*

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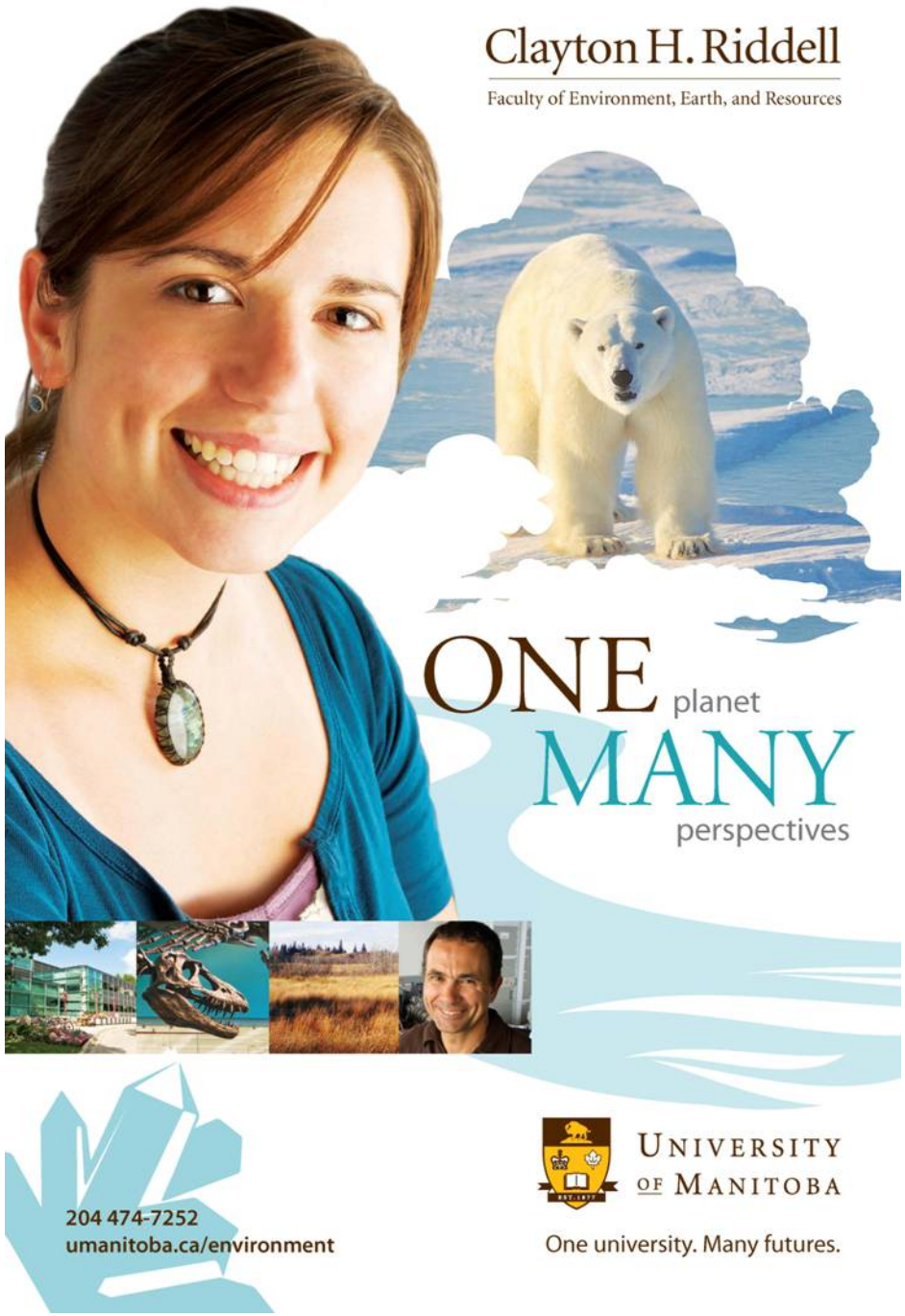
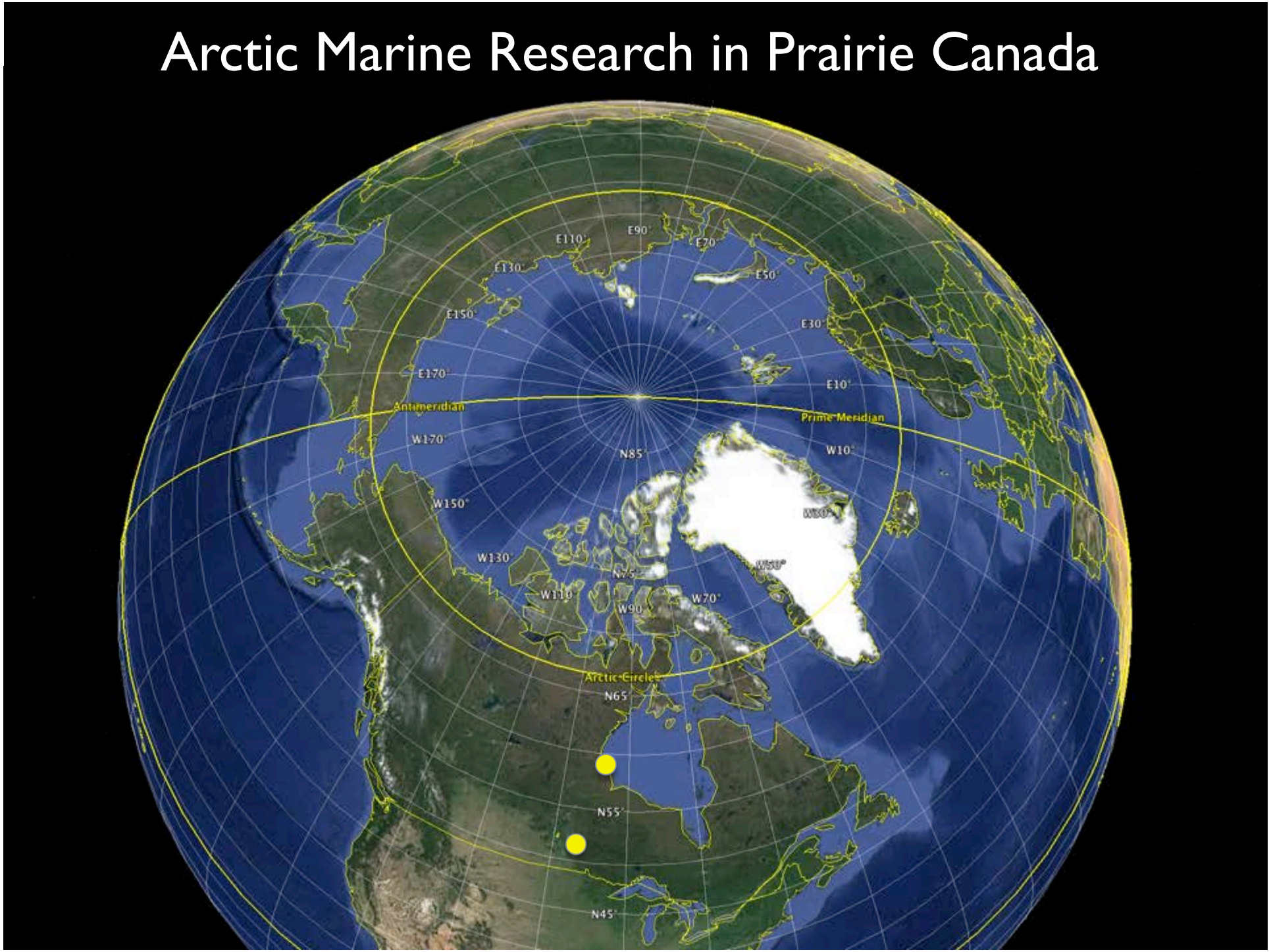



# How we do our work

# Arctic Marine Research in Prairie Canada



## Tenure Track Faculty (18)

Barber, David *(CRC)*
Rysgaard, Soeren *(CERC)*
Wang, Feiyue (CRC*)
Stern, Gary
Lot Shafi (CRC)
Puyan Majobi
Mundy, C.J.
Kuzyk Zou. Zou.
Ehn, Jens. E.
Hanesiak, John
Papakyriakou, Tim
Halden, Norman
Iacozza, John
Hansen, Mark
Stewart, Ron
*3 new faculty*

## Research Faculty (9)

Dmitrenko, Igor
Galley, Ryan
Lui, George
Lukovich, Jennifer
McCullough, Greg
Raddatz, Rick
Hubert, Casey
Ogi, Masayo
Puko, Monika

## Adjunct Faculty (8)

MacDonald, Robbie
Michel, Christine
Ferguson, Steve
Prinsenberg, Simon
Loseto, Lisa
Miller, Lisa
Hammill, Mike
Gosselin, Michel

35 MSc, 30 PhD, 17 PDF, 28 Tech/admin = 135 staff

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Totally Integrated Academic and Research Programs!

# First ASP planning meeting in Gimli - Canada

# ArcticNet

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One of 21 Networks of Centres of Excellence (NCE) jointly funded by the 3 Research Councils of Canada.

Funded for 7 years (2004-2011)
with possibility of 14 years (2004-2018)
$CDN 6.4 Million from NCE per year

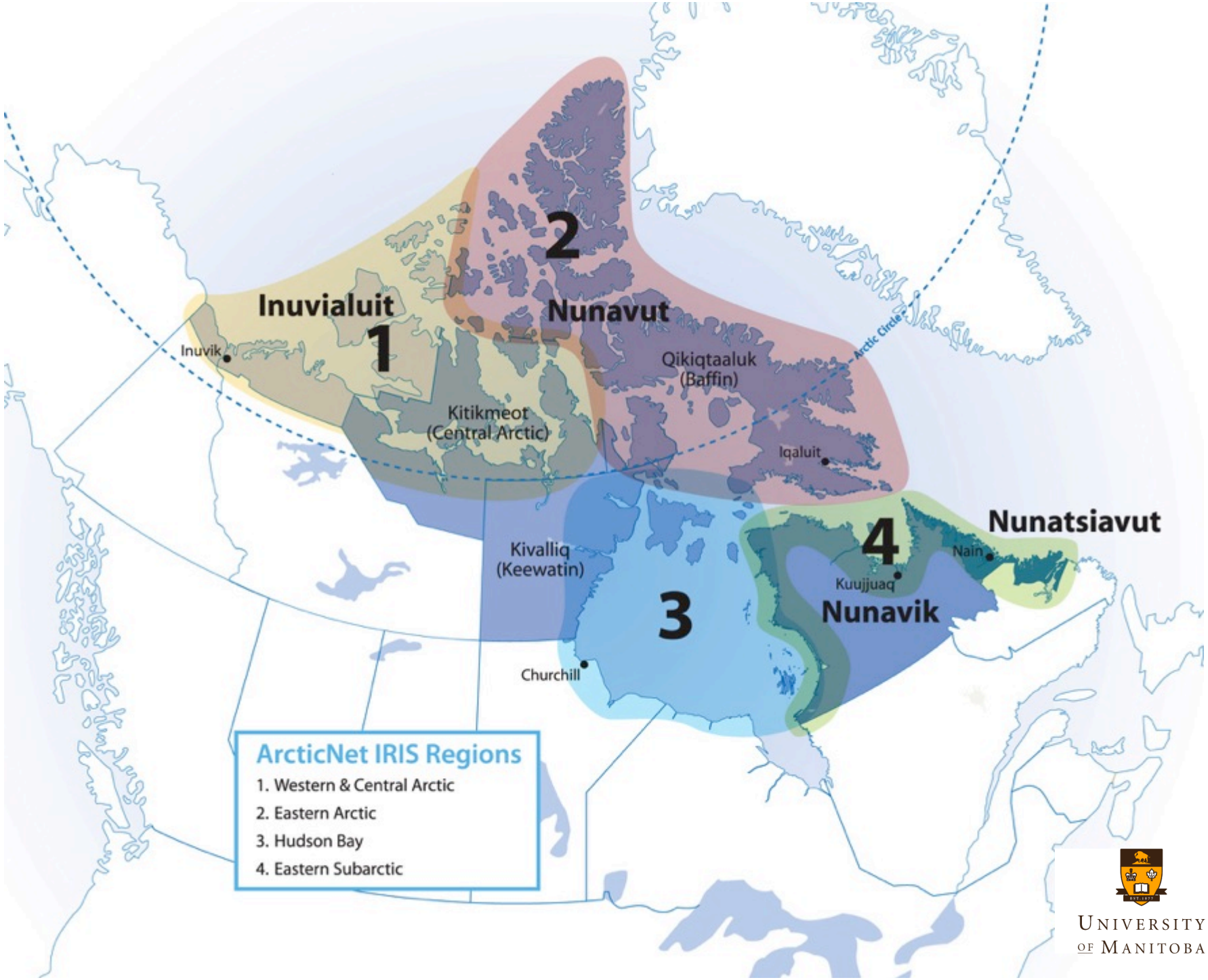
$CDN 9.2M from NCE per year (2011-2018)

Canada

UNIVERSITÉ LAVAL

UNIVERSITY OF MANITOBA

Networks of Centres of Excellence
Réseaux de centres d'excellence

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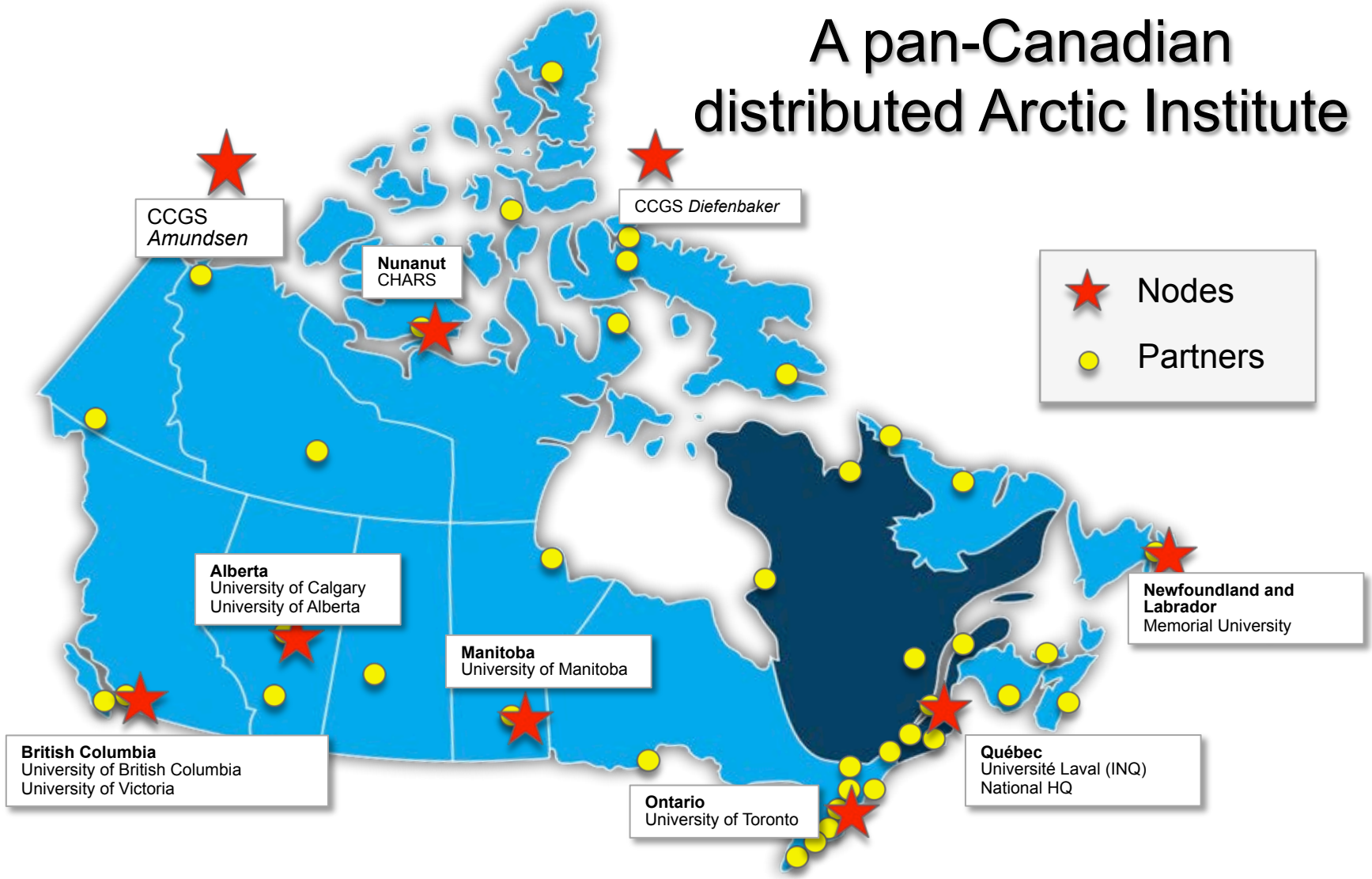
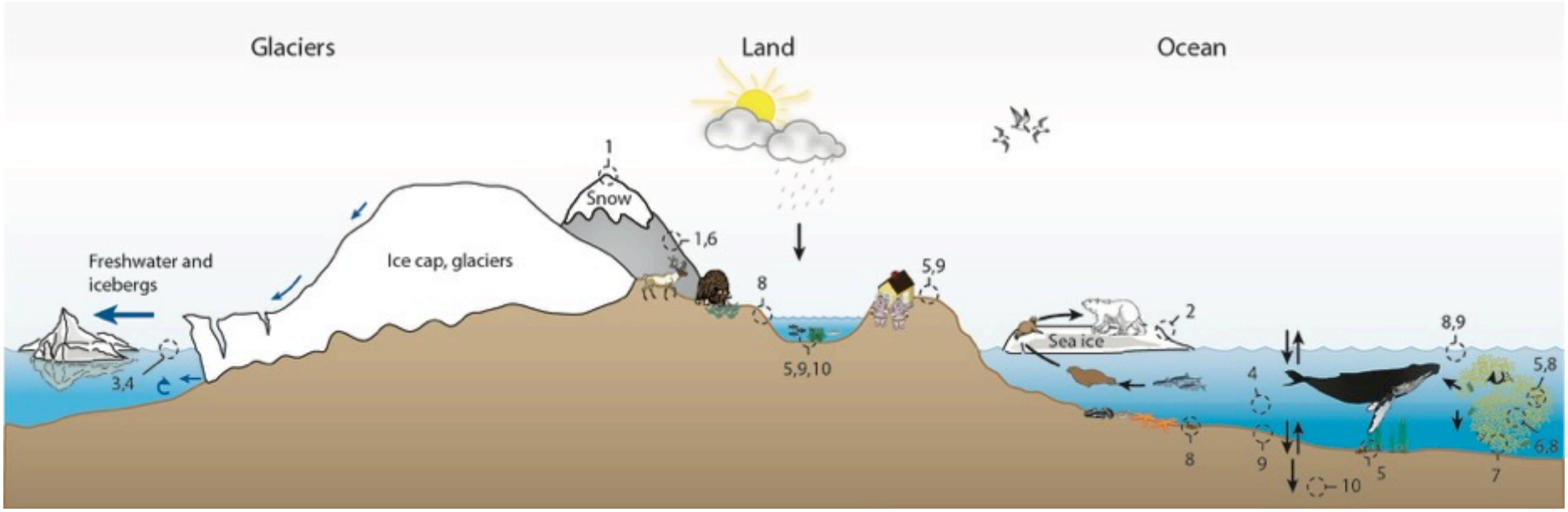
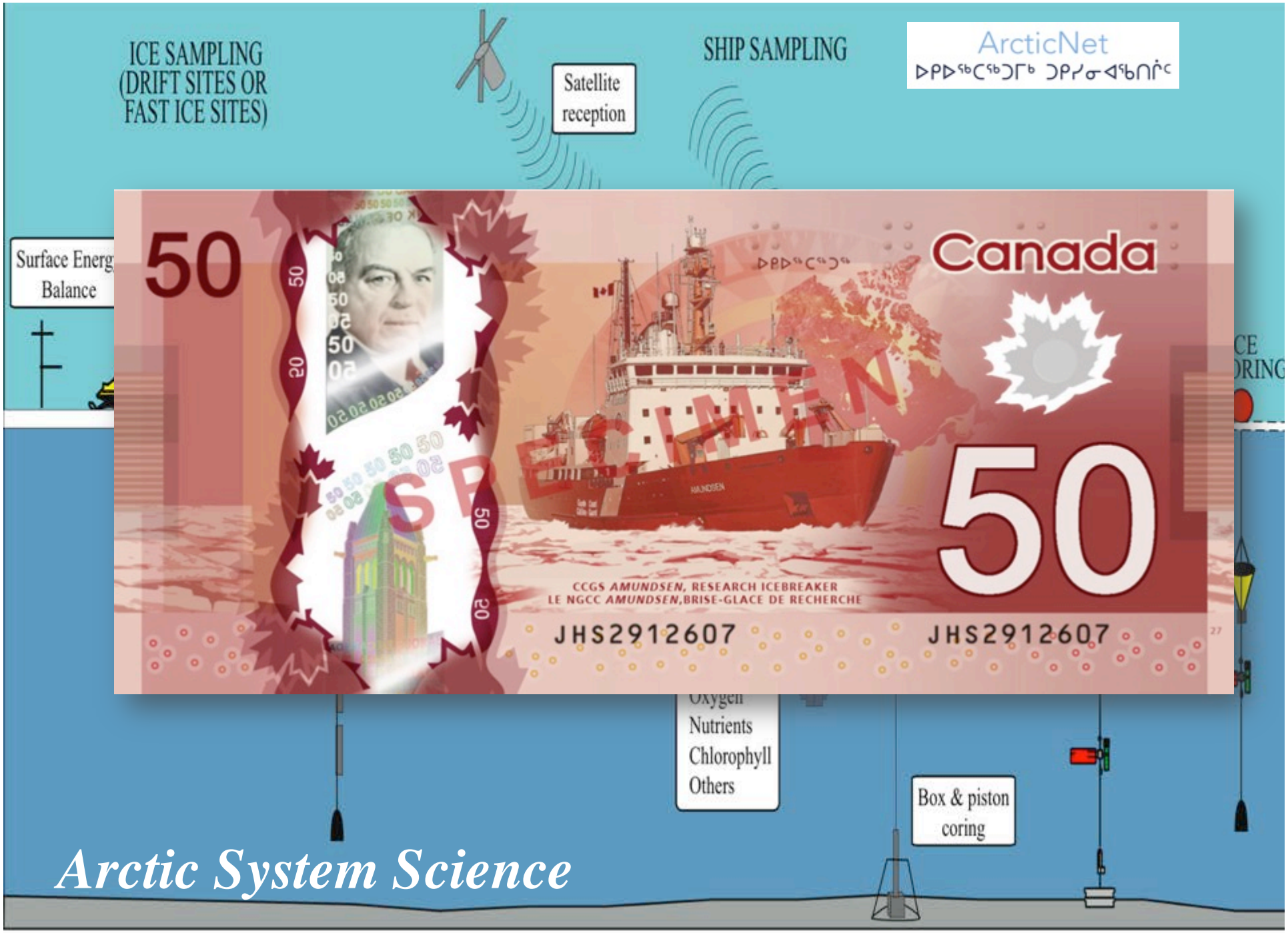
# A pan-Canadian distributed Arctic Institute

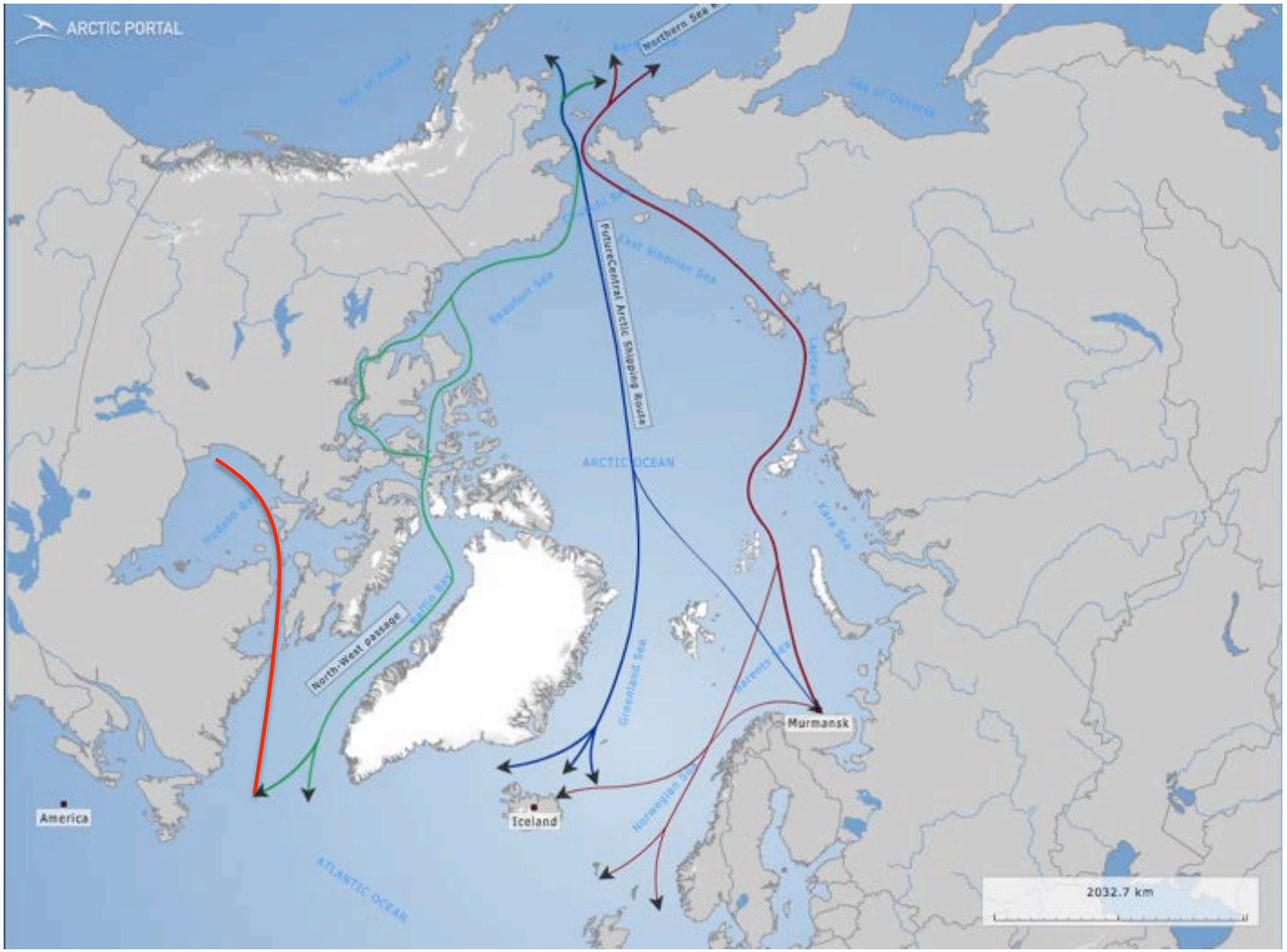





- Sea Ice physics
- Meteorology
- Climate Change
- Paleo science
- Biogeochemistry
- Carbon fluxes
- Ecosystems
- Shelf-ice
- Land-ice
- Techniques


ICE SAMPLING
(DRIFT SITES OR
FAST ICE SITES)
Satellite
reception
SHIP SAMPLING
ArcticNet
Surface Energ
Balance
50
Canada
SPECIMEN
50
CCGS AMUNDSEN, RESEARCH ICEBREAKER
LE NGCC AMUNDSEN, BRISE-GLACE DE RECHERCHE
JHS2912607
JHS2912607
Nutrients
Chlorophyll
Others
Box & piston
coring
Arctic System Science

# Opening of the Arctic



# Work with Industry

# Work with Industry

Manitoba Hydro

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᑦ ᑐᑭᓯᓂᐊᖅᑎᑦ

$14.7M


Hydro Québec

OURANOS

University of Manitoba

Université Laval

UQAR Université du Québec à Rimouski

University of Calgary

UNBC

Trent University

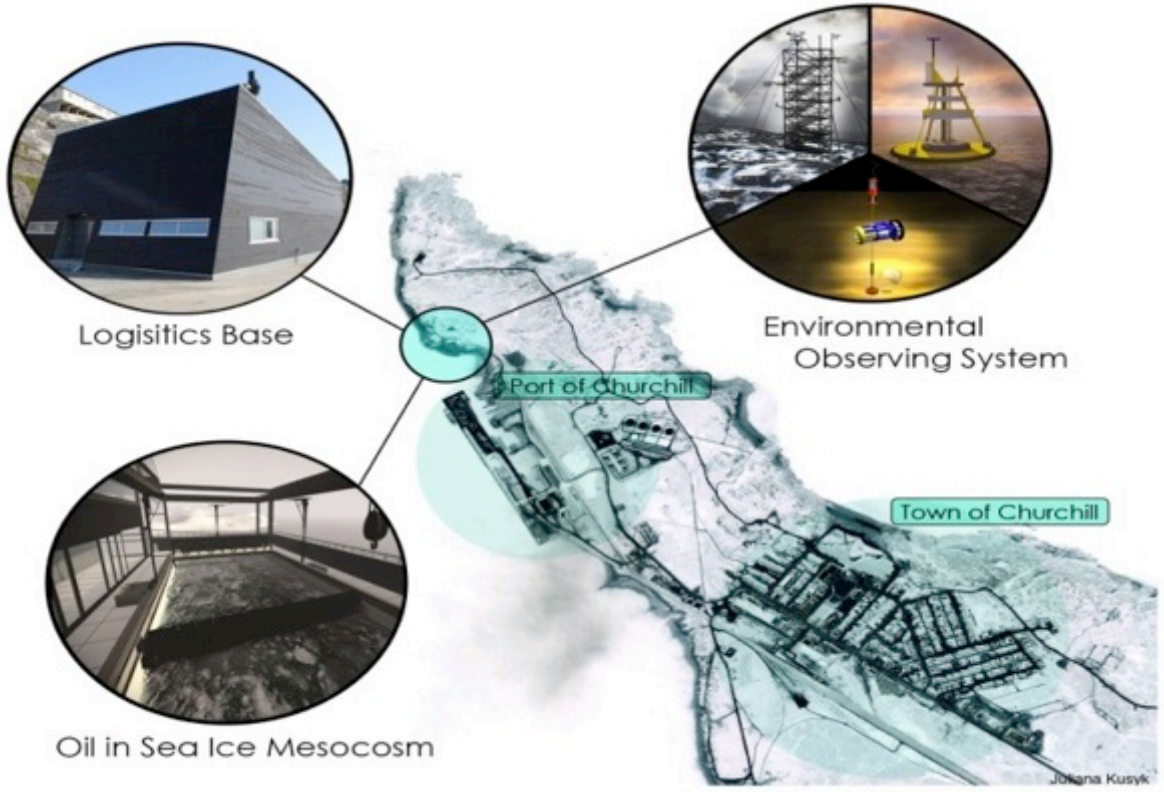
# Work with Industry






# The Churchill Marine Observatory (CMO)

*Science and Technology*
*In support of Arctic Sustainable Development*




University of Manitoba

$31.8M capital and $18M operating

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

# The Churchill Marine Observatory (CMO)





University of Manitoba

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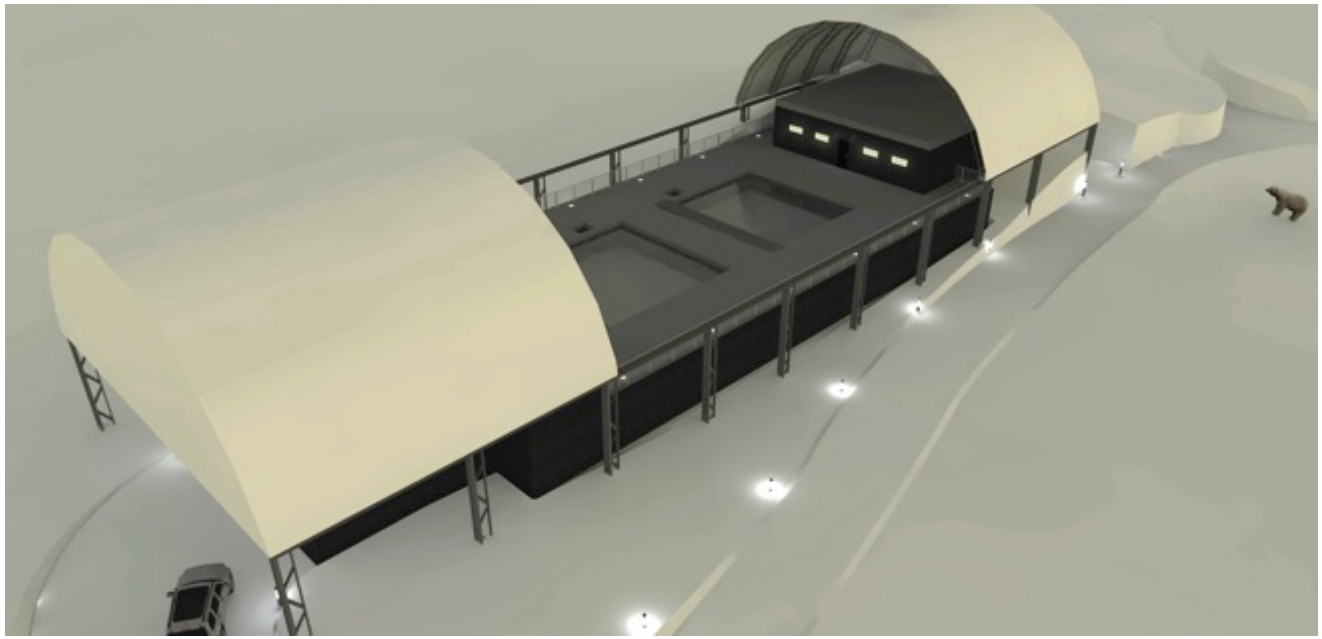
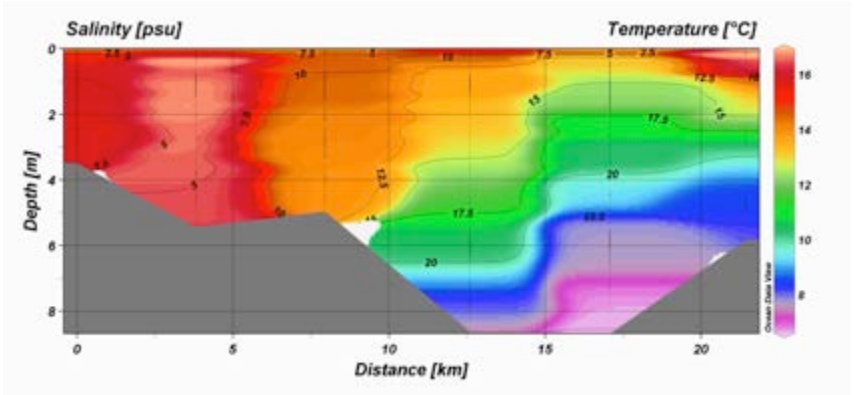
# Oil in Sea Ice Mesocosm - OSIM



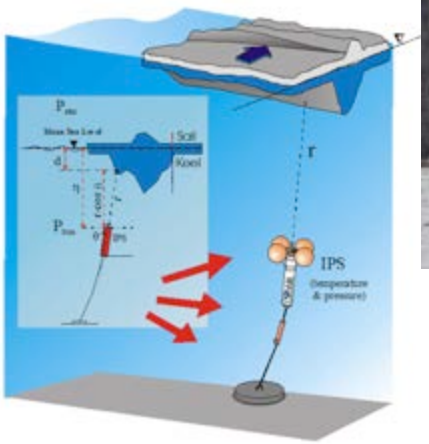
- A concept to allow controlled testing of the ocean, sea ice system response to oil, LNG, and contaminants.
- Science would concentrate on
  - **Detection** (of oil in sea ice)
  - **Impacts** (of oil spills on marine ecosystems)
  - **Mitigation** (of oil spills in sea ice using both genomics-enhanced bioremediation technologies and conventional techniques)

# Environmental Observatories (EOs)

- Estuary
- Ocean
- Atmosphere

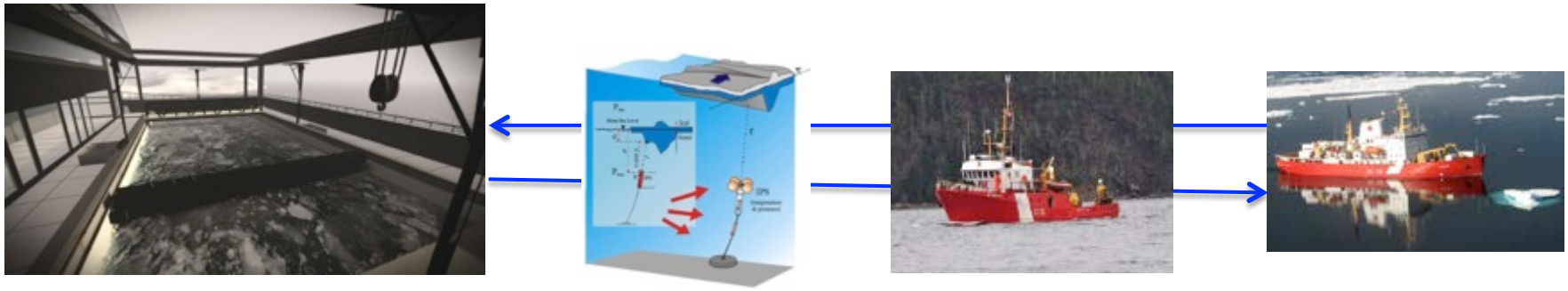




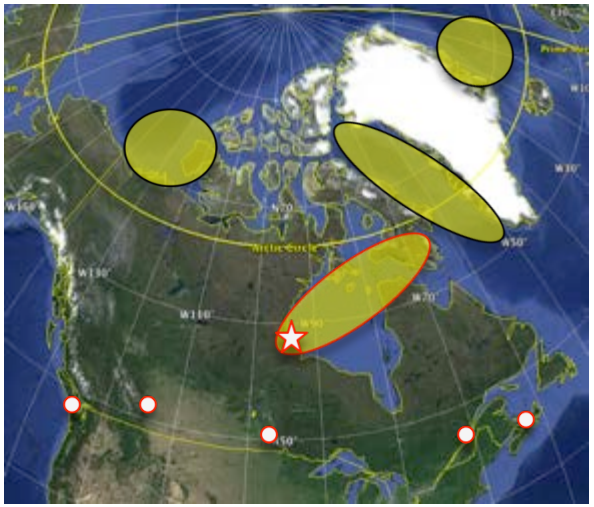



# The Churchill Marine Observatory (CMO)

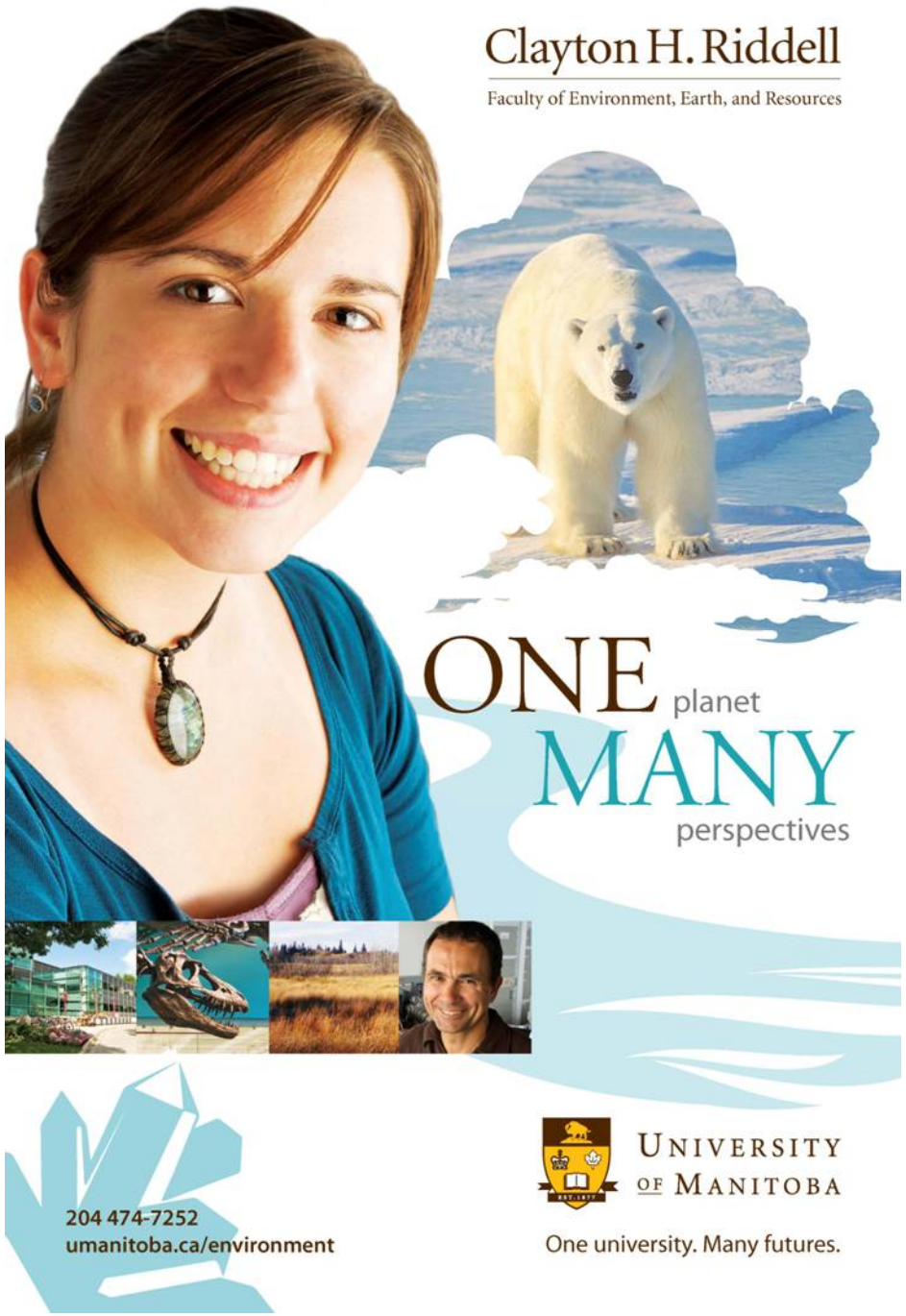
*A national centre with an international mandate.*



OSIM process studies  Scaling Arctic wide through EO system, CHARS, ARF, , and international field programs



- 170 researchers
- 6 CDN universities
- 10 gov. departments
- 10 private sector
- 4 NGO, co-management
- 50 HQP




# Unexpected Discoveries

Seven Surprises

1


Dieckmann et al., 2008

$CO_2$ exchange

Bromine – Ozone

Mercury Exchange

# Thinner and Saltier Ice Surfaces

2

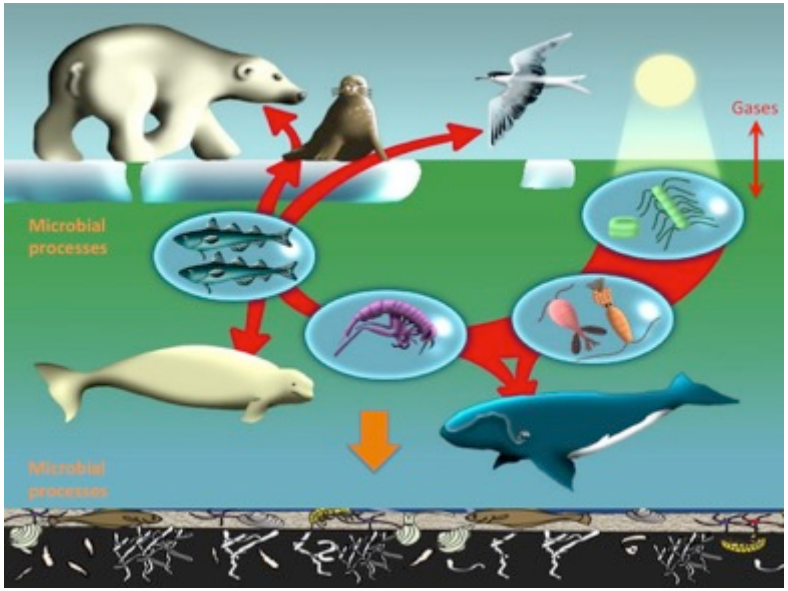
Snow on sea ice

3

Polar Bear and Seal Habitat

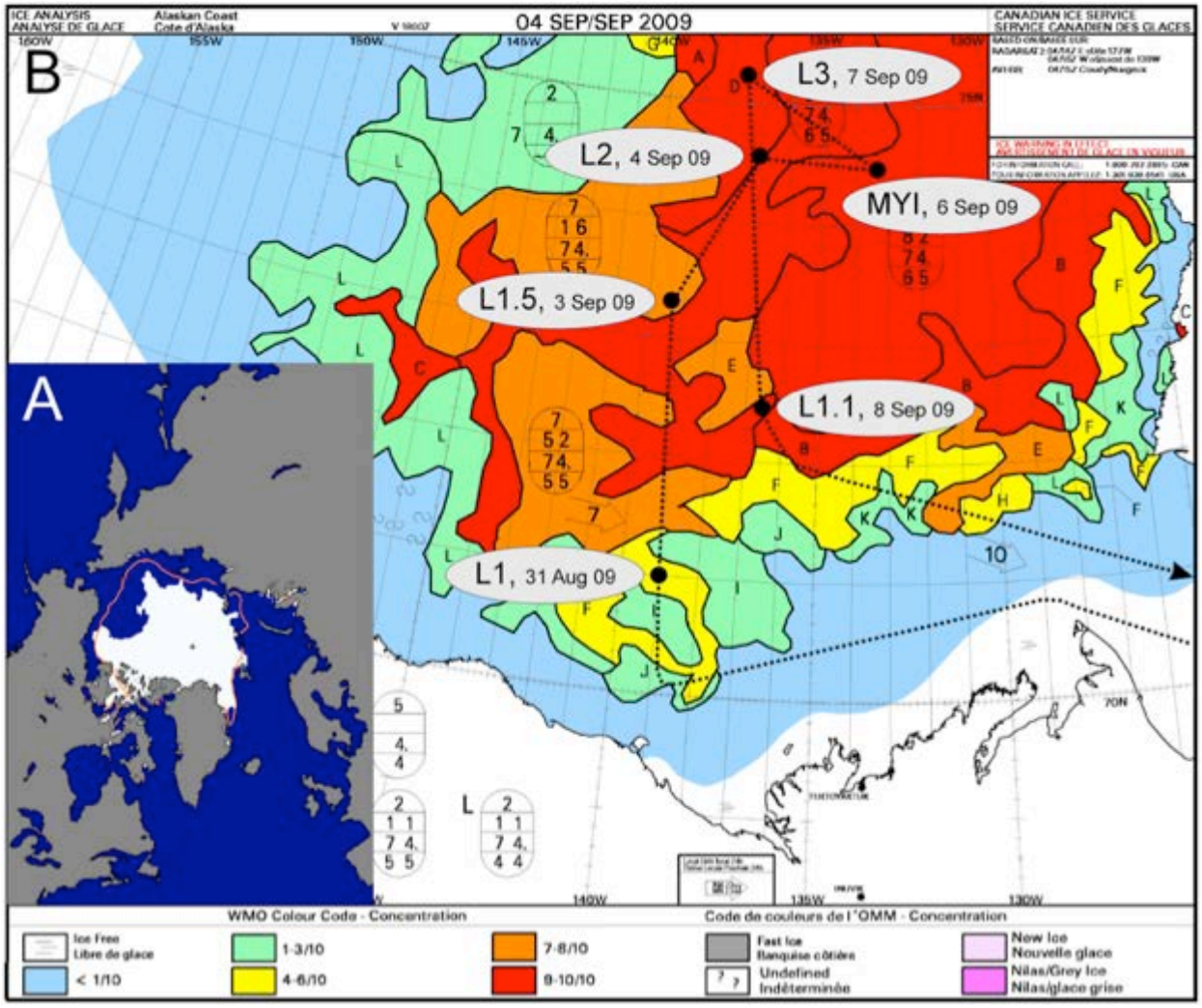
4

Sea Ice



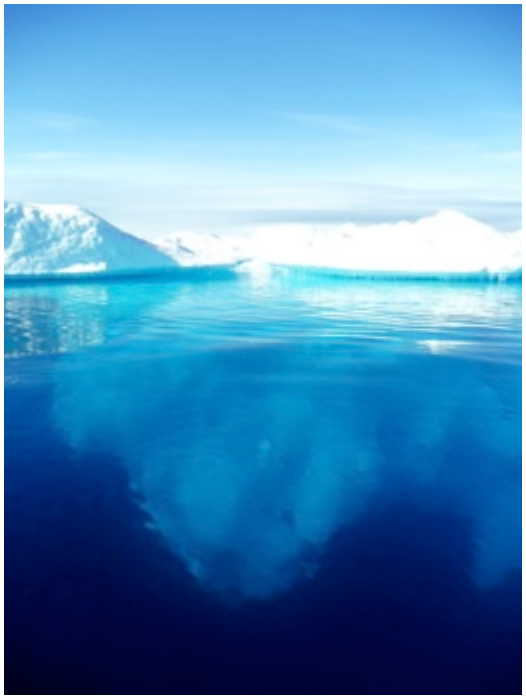

Tropical Rain Forest

5




The appearance of a ‘new’ type of summer sea ice (rotten ice).

6



Winds Faster Motion Glacial Ice Thick MY

# Increasing Ice Hazards?

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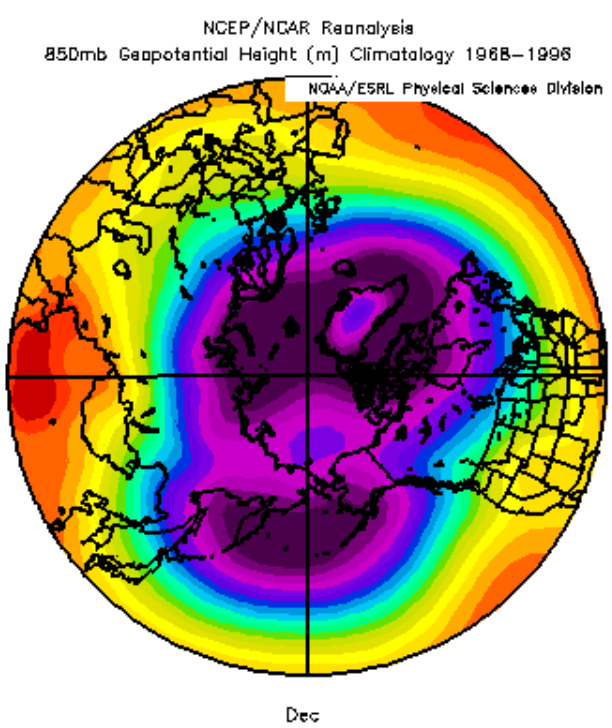
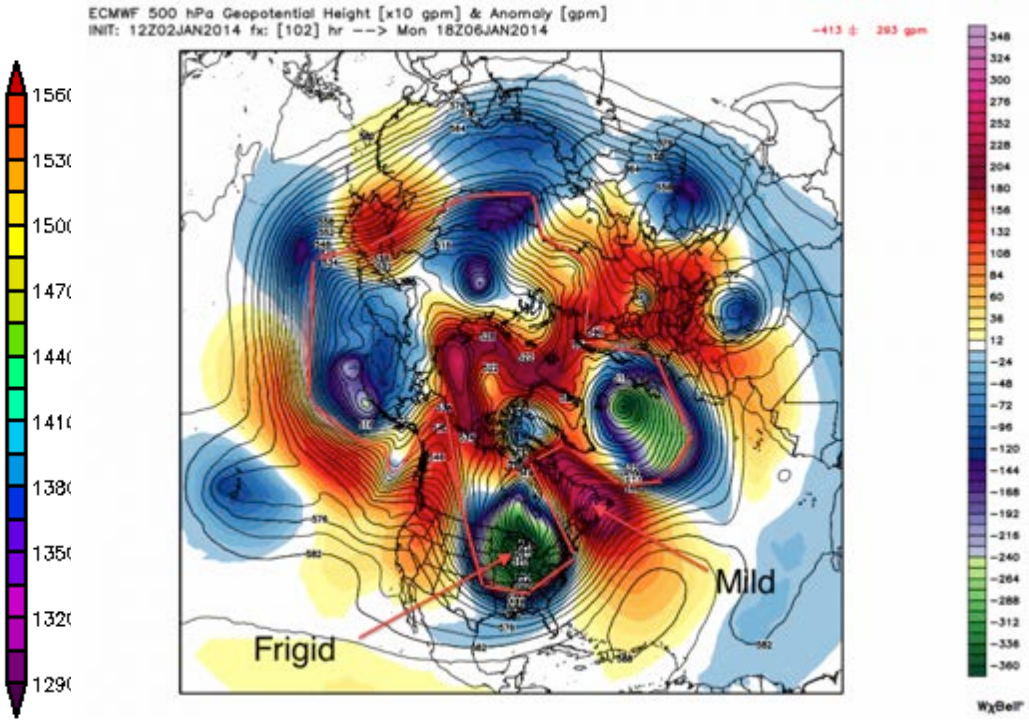
7

# Warm ocean cold continent hypothesis




Polar Vortex
Traps cold air in the Arctic

Polar Vortex breaks down
Increases cold outflows and persistence

Overland et al. , 2014

# In summary

1. A saltier ice surface increases exchange with atmosphere
2. Snow on sea ice causes decrease in MYI does not affect FYI
3. Polar bear habitat increasing in some areas decreasing in others
4. Whole ecosystem (virus – whales) affected (invasive species have arrived)

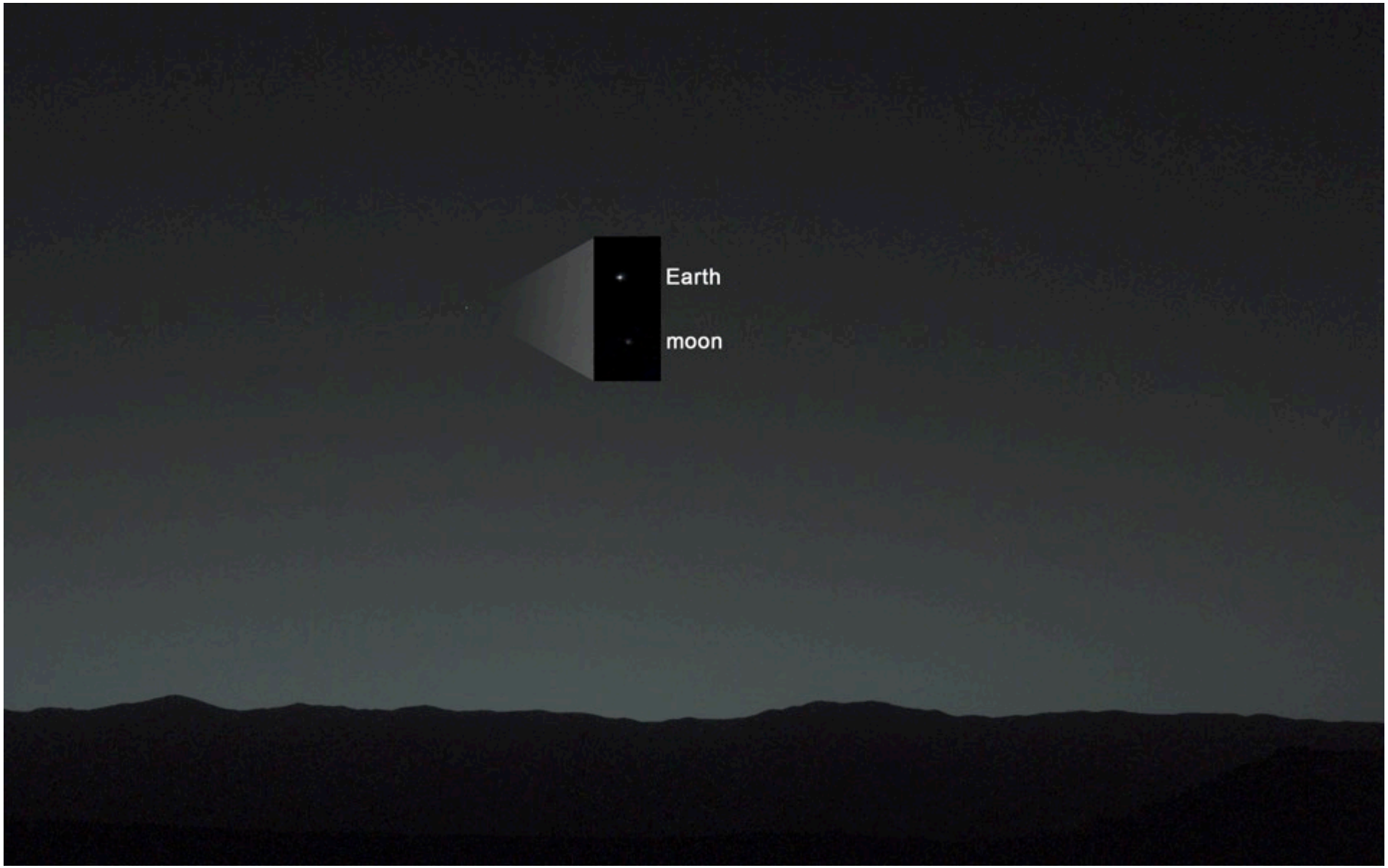
# In summary

5. Rotten sea ice is now common in the high Arctic – northern sea routes are opening
6. Paradoxically - Ice hazards are increasing
7. Polar Vortex appears to play a large role in cold air outbreaks and persistence of climate at lower latitudes

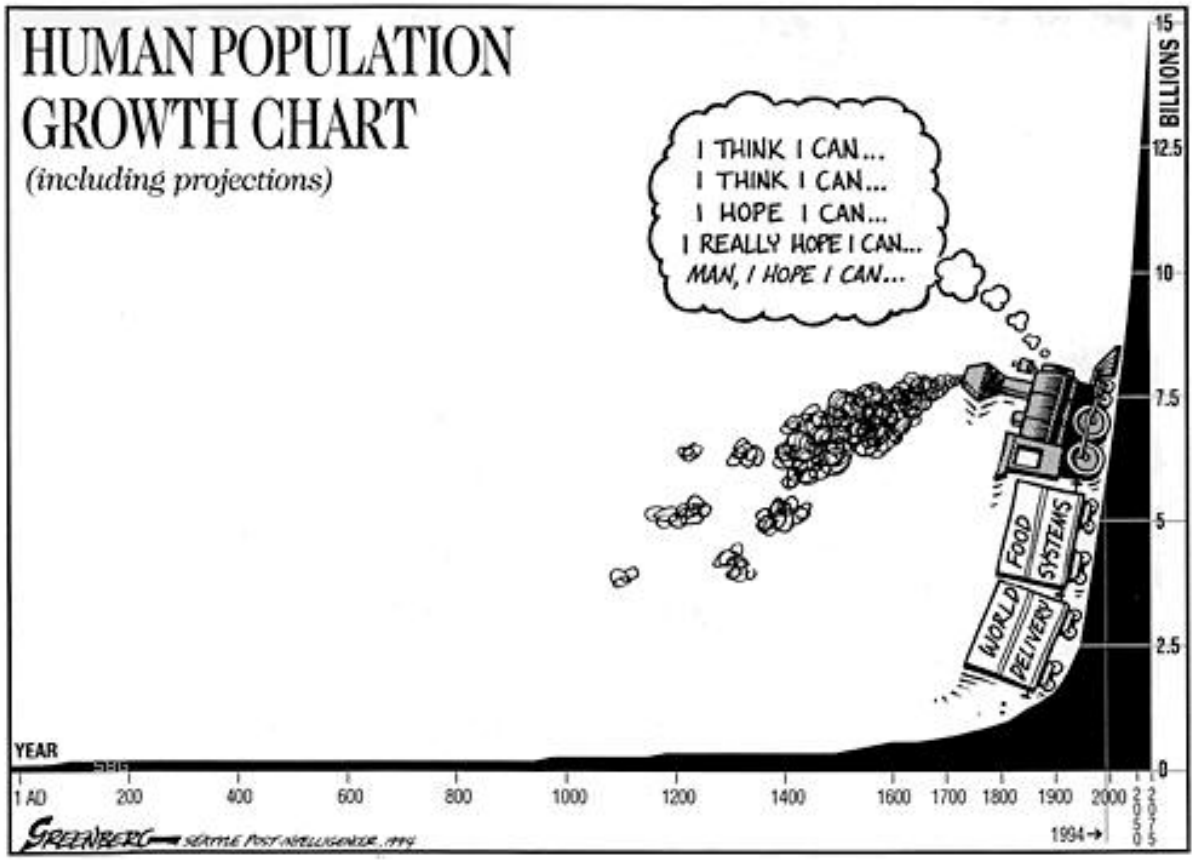
# Motivation

# Motivation

# Motivation

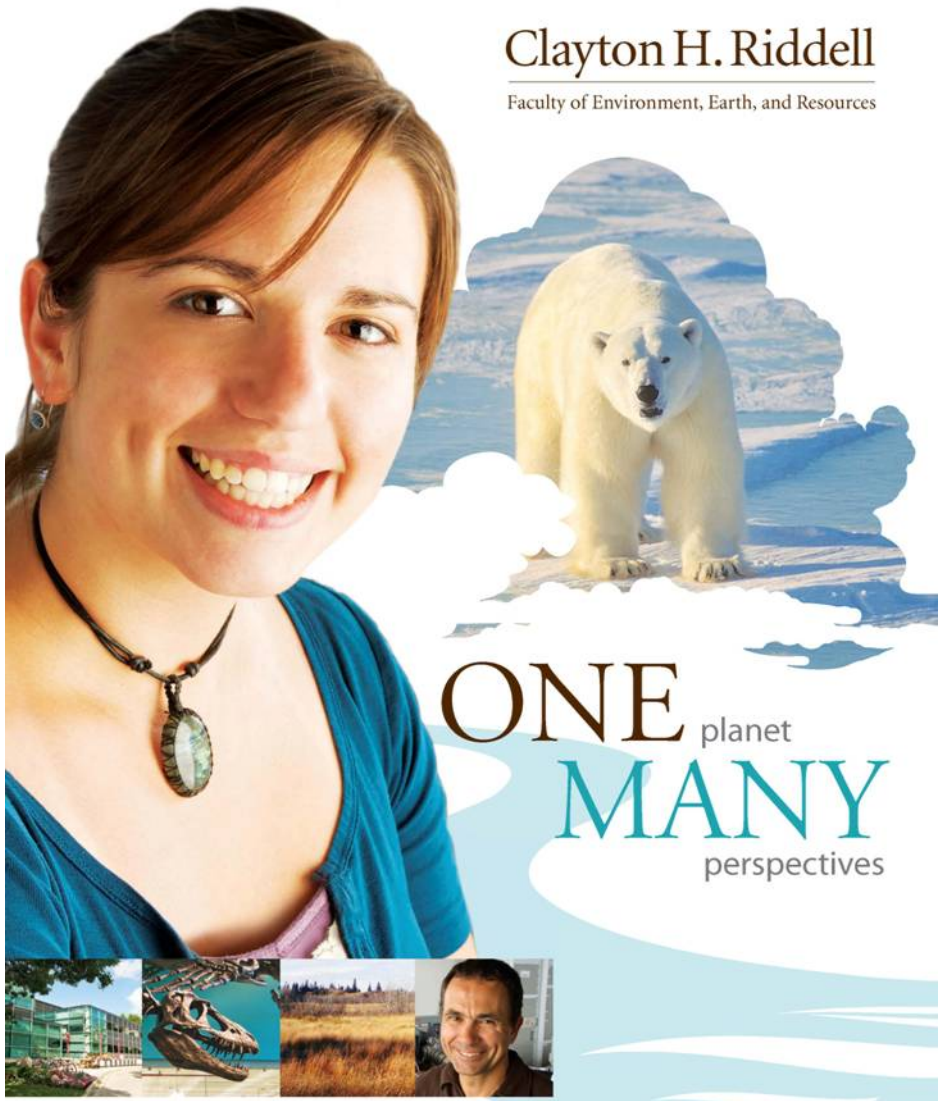


# Motivation




- 7000yrs – first billion;
- 130 yrs – second billion;
- 12-14yrs –third and onwards

# Motivation




# Thanks….

ArcticNet
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