BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

BC3-UPV/EHU Summer School 2017
Climate Change in an Era of Uncertainty
Donostia - San Sebastián, 5-7 July 2017

A Tale of Climate Change: The Caged Bird and the Golden Bull

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BC3 - Basque Centre for Climate Change, Leioa, Spain

[2] Adjoint Presidential Professor
Nagaoka University of Technology, Nagaoka, Japan

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INGURUMEN, LURRALDE PLANGINTZA, NEKAZARITZA ETA ARRANTZA SAILA
DEPARTAMENTO DE MEDIO AMBIENTE, PLANIFICACIÓN TERRITORIAL, AGRICULTURA Y PESCA

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A Parallel Narrative

Reality	Metaphor
Climate Change	The Tale
Arctic sea ice	The Caged Bird
The natural environment	The coal mine
Greenhouse gases	Hazardous gases
Geoengineering	Mine ventilation system
Abrupt climate change	Coal mine accident
etc.	etc.

Should I use my car or my shoes?

1937 Morgan Super Sports Tricycle V-twin Matchless 1000
Woolwich, London, England, GB
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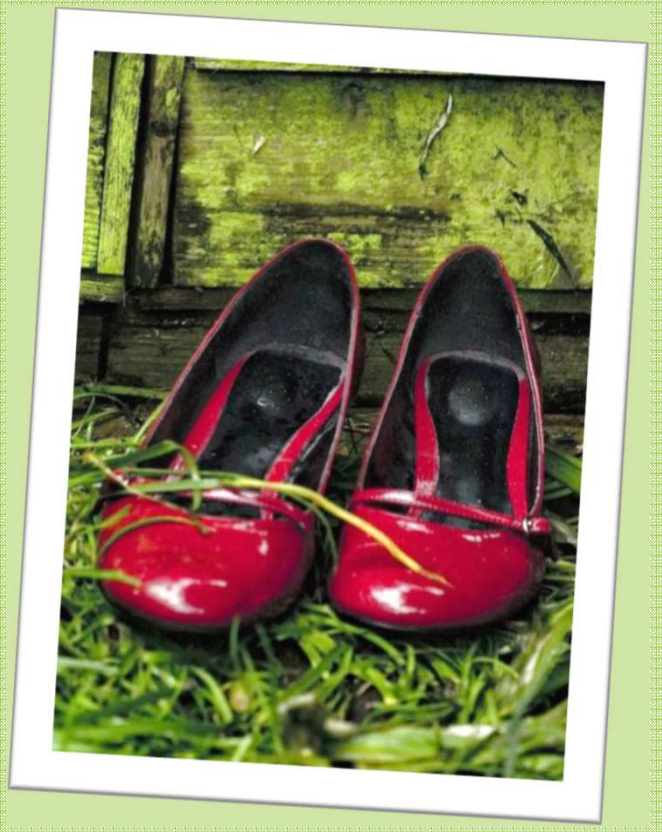
July 4, 2010
http://www.flickr.com/photos/kenjonbro/with/4762601826/



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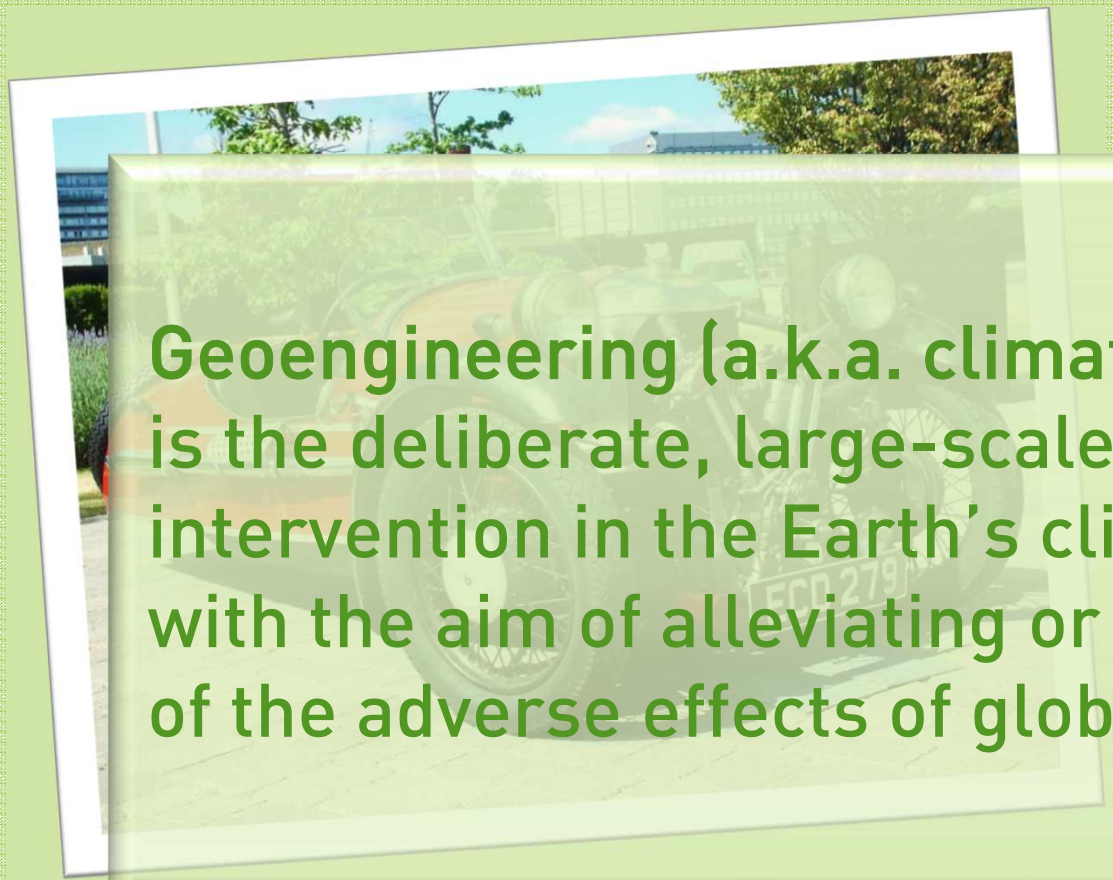
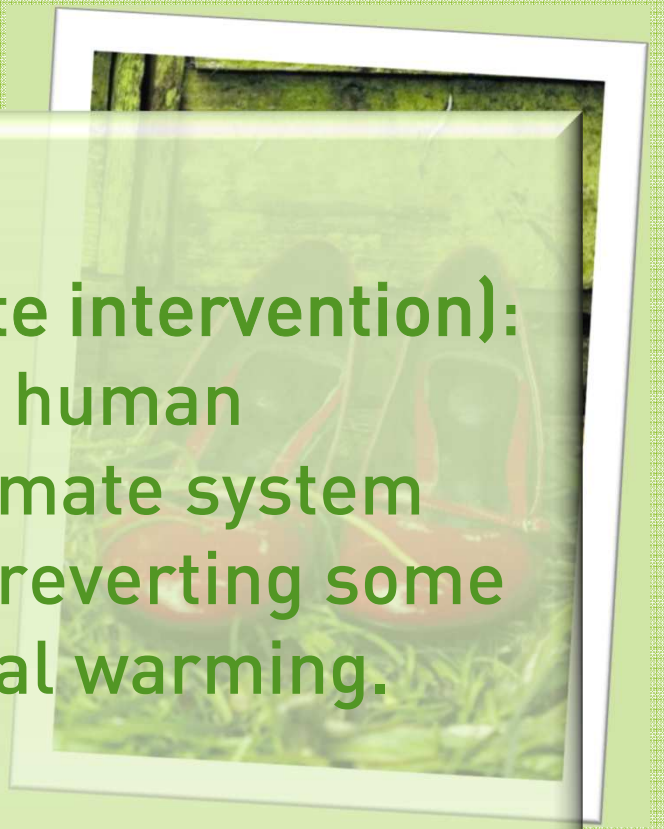
Should I use my car or my shoes?





Geoengineering (a.k.a. climate intervention): is the deliberate, large-scale human intervention in the Earth's climate system with the aim of alleviating or reverting some of the adverse effects of global warming.

1937 Morgan Super Sports Tricycle V-twin Matchless 1000
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http://www.flickr.com/photos/kenjonbro/with/4762601826/

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Is this geoengineering?

The Red Stiletto
By Michael Sauers (CC lic.)
June 13, 2006

http://www.flickr.com/photos/travelinlibrarian/with/166514354/

Sea Ice and Icebergs

Sea ice and icebergs. By M. Hambrey, http://www.swisseduc.ch/glaciers/

A Climate Change Tale:

The Caged Bird and the Golden Bull

By Sérgio H. Faria ©2017

Village in Ticino, Switzerland. Author unknown (CC lic.)
http://maxpixel.freegreatpicture.com/Ticino-Stone-House-Bergdorf-Switzerland-Alpine-113508

The Village

The Golden Bull

Bullock cart in Sogndal. **By Nils Olsen Reppen (1856–1925), Sogn og Fjordane County Archives (CC lic.)**
https://commons.wikimedia.org/wiki/File:Bullock_cart,_Sogndal,_ca._1898-1900..jpg

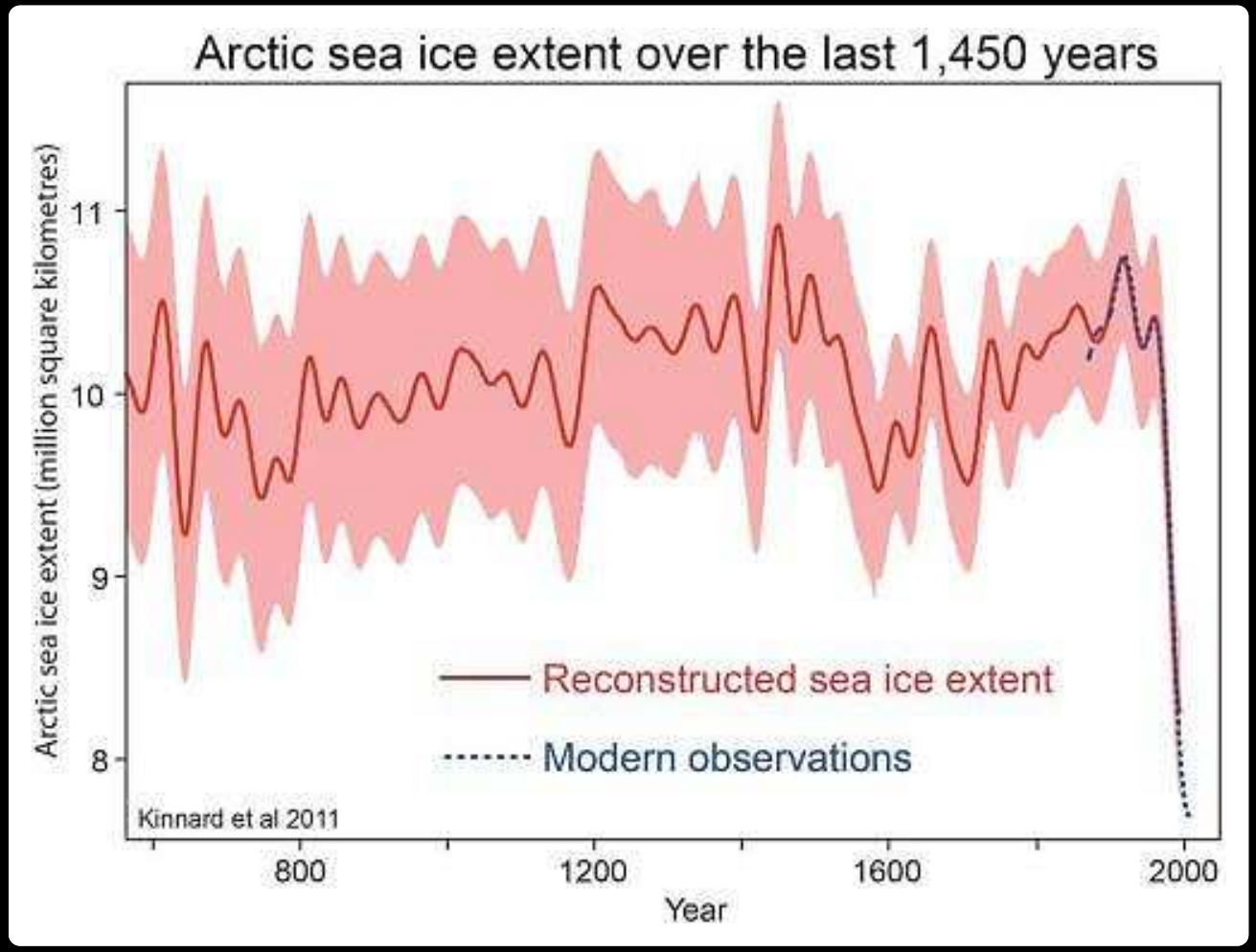
The Caged Bird

John Scott Holding a Canary Cage Used in Mines Rescue Training. **Courtesy of the Museum of Cannock Chase, Staffordshire, England (copyright unknown)**
http://www.cannockchasedc.gov.uk/site/custom_scripts/HeritageTrail/museum_cannock.html

The Arctic

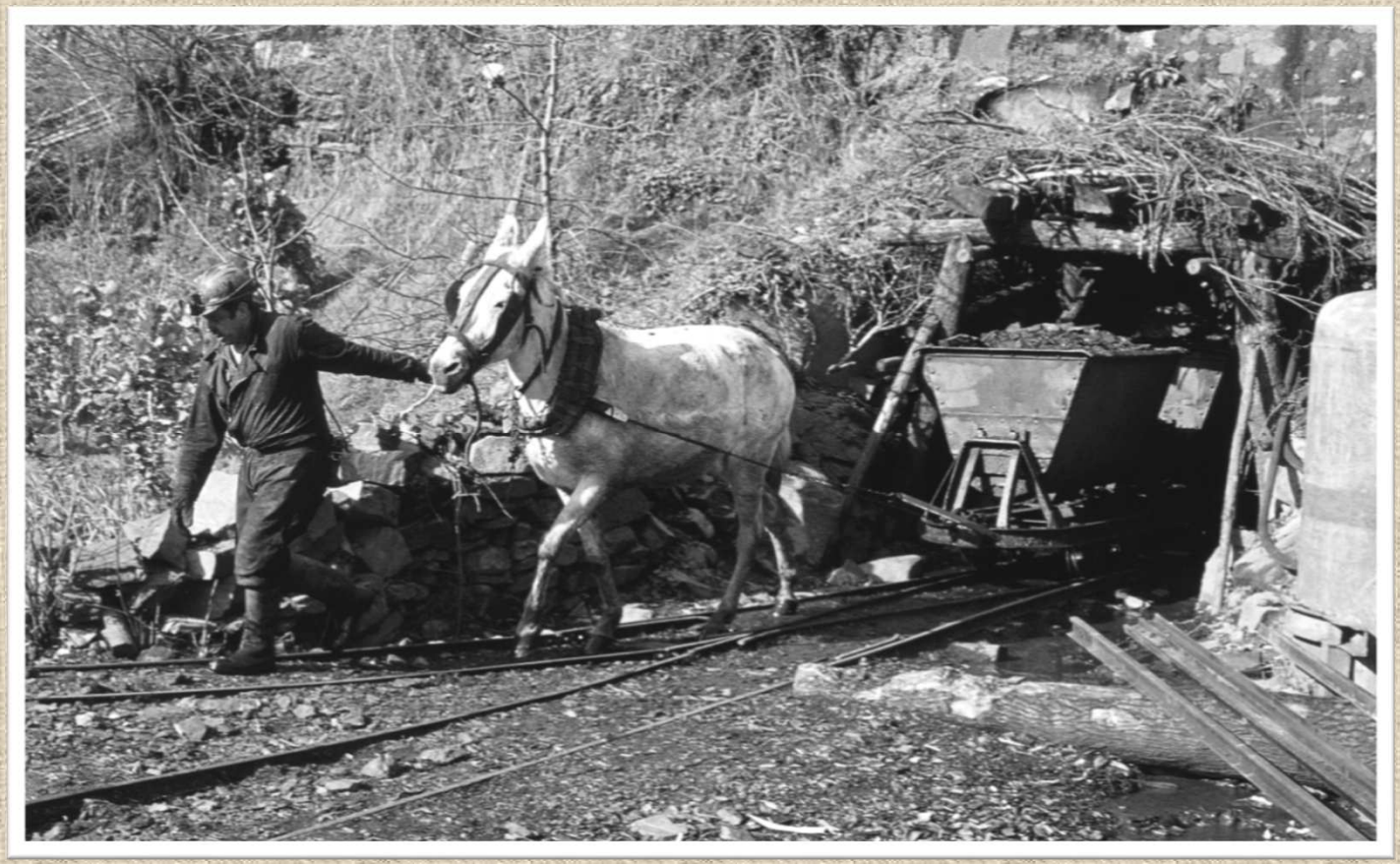
NASA/Goddard Space Flight Center Scientific Visualization Studio

Arctic Sea Ice Melting



Kinnard et al. (2011) *Nature* 479: 509-513

The Coal Mine



Une petite exploitation minière vers Matarrosa del Sil. By Didier Duforest (CC lic.)
https://commons.wikimedia.org/wiki/File:Mine_charbon_Matarrosa_del_Sil_avril_1984-a.jpg

The Coal Mine

Grinkle mine culvert collapse. By Philld (CC lic.)
http://www.geograph.org.uk/photo/1546942

Changing Habits

https://pixabay.com/en/mill-waterwheel-watermill-old-2078376/

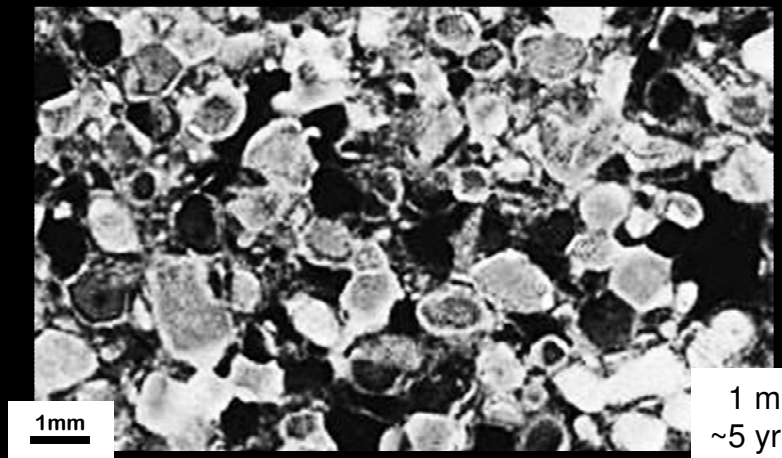
https://pixabay.com/p-2196532/?no_redirect

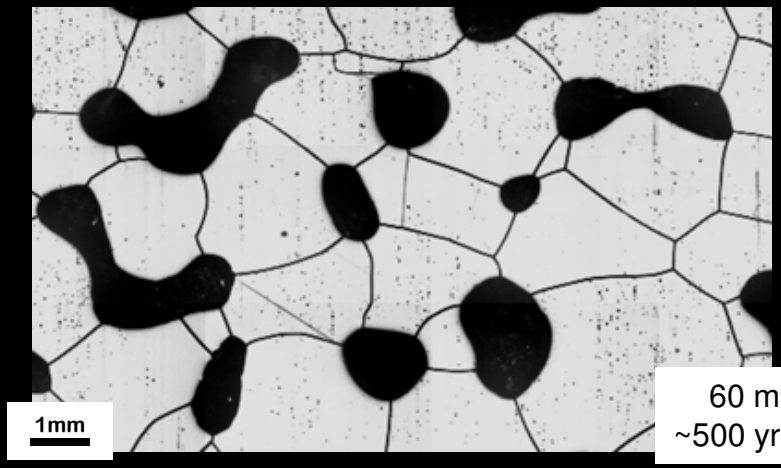
Paleoclimate Records

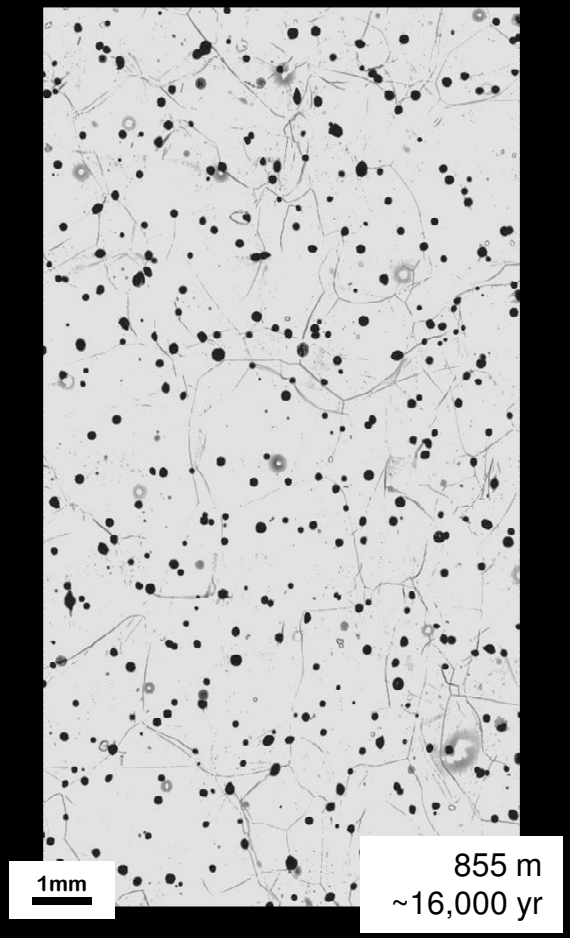
The EDML Deep Ice Core, total depth 2774.15 m

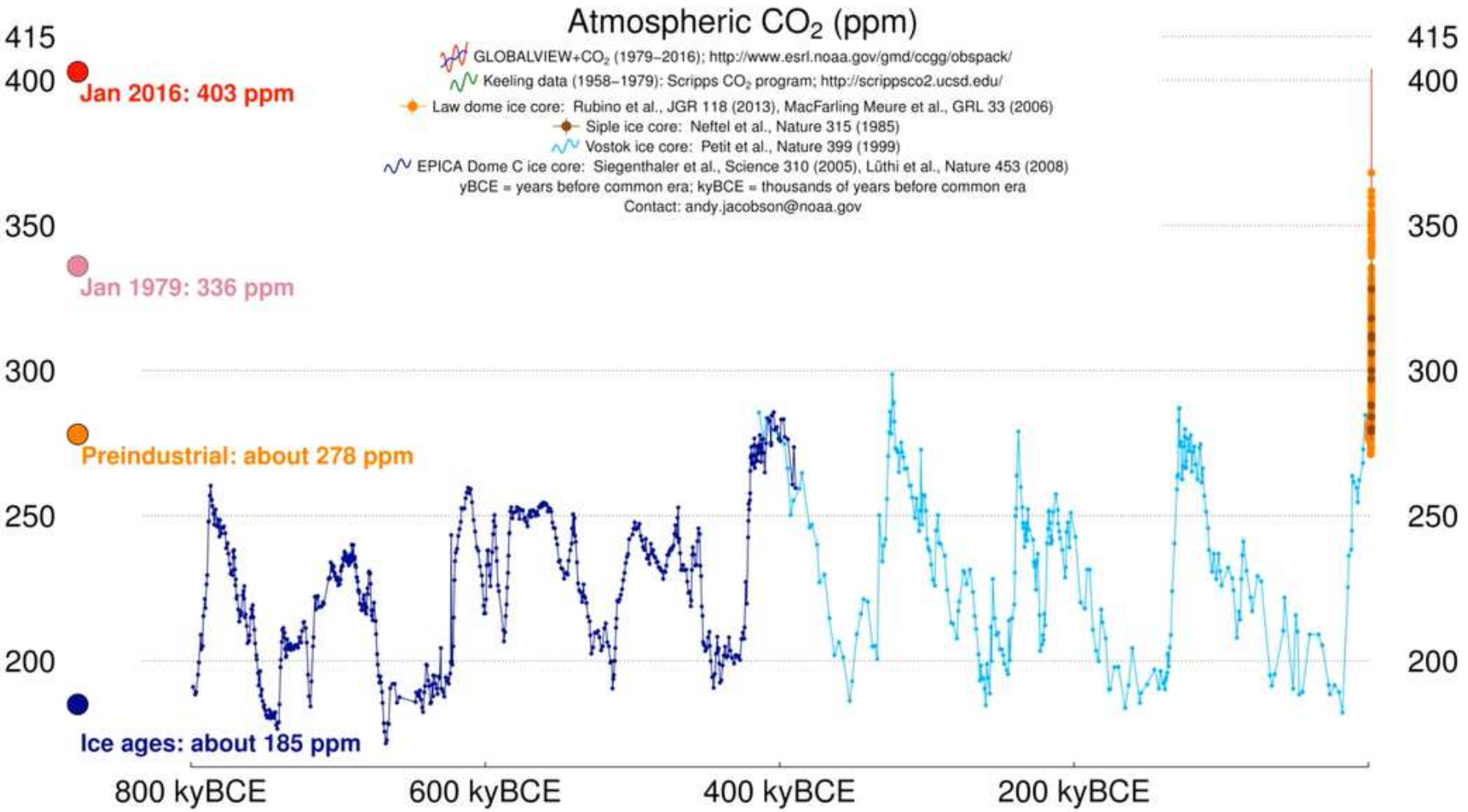
Paleoclimate Records

The EDML Deep Ice Core, from snow to firn and bubbly ice









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Epilogue

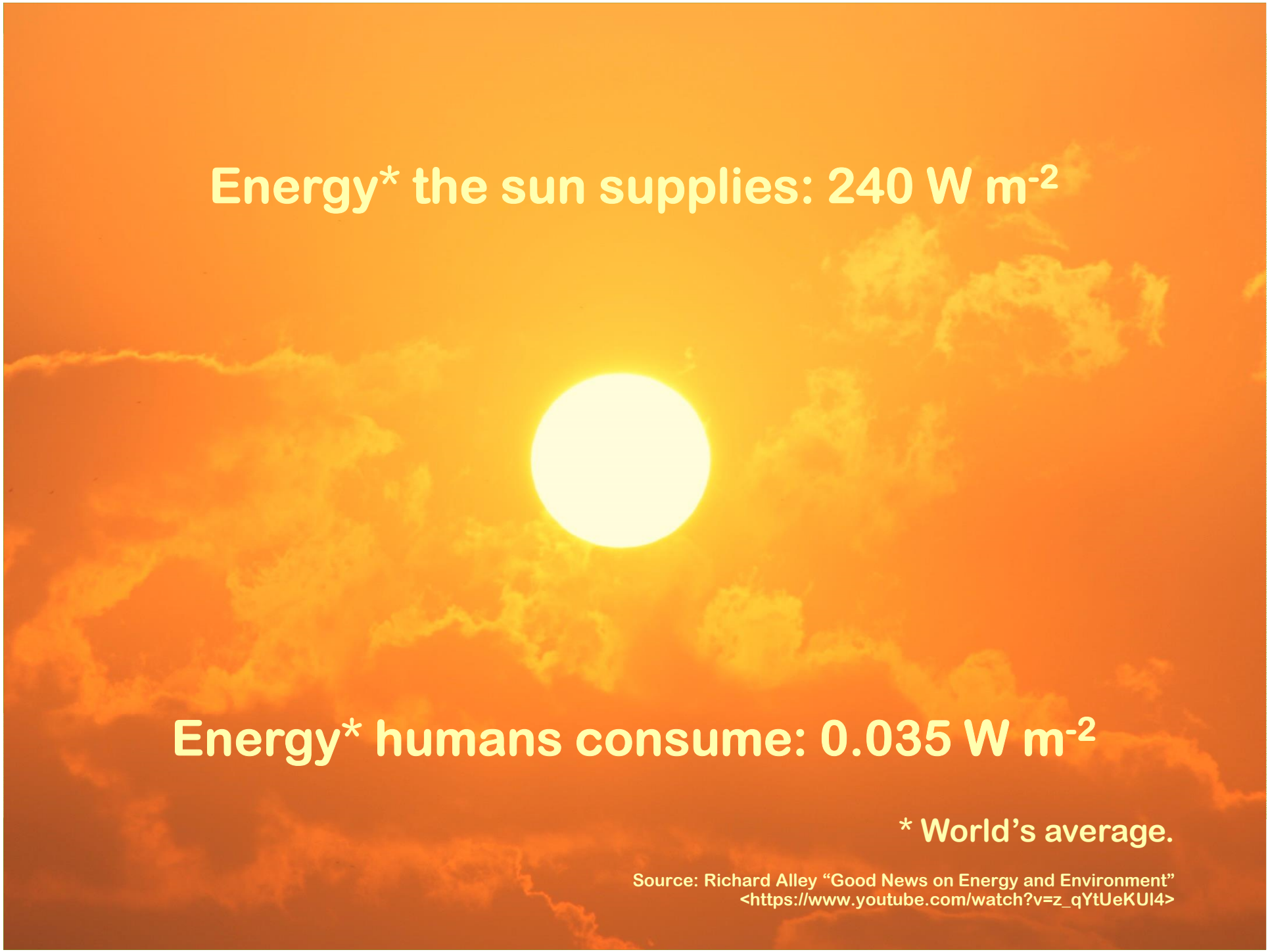
Excerpt from "Caged Bird"

by Maya Angelou (1928-2014)

Maya Angelou at President Clinton's inauguration in 1993.
Courtesy of William J. Clinton Presidential Library
https://commons.wikimedia.org/wiki/File:Angelou_at_Clinton_inauguration.jpg

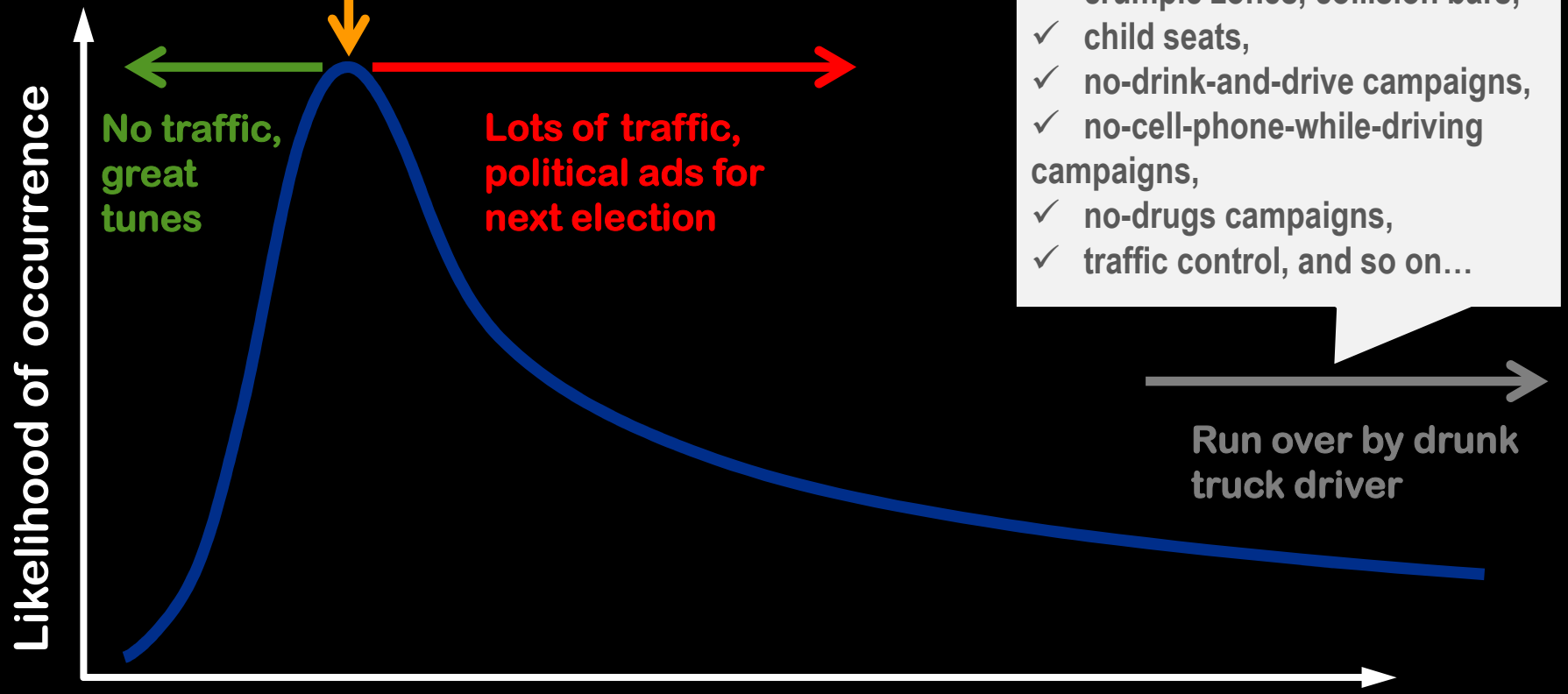
The caged bird sings
with a fearful trill
of things unknown
but longed for still
and his tune is heard
on the distant hill
for the caged bird
sings of freedom.

Angelou, M. (1983) *Shaker, Why Don't You Sing?*
New York: Random House.


Energy* the sun supplies: 240 W m-2
Energy* humans consume: 0.035 W m-2
* World's average.
Source: Richard Alley "Good News on Energy and Environment"
<https://www.youtube.com/watch?v=z_qYtUeKUI4>

The "Fat Tail" Distribution

The Commuter Problem

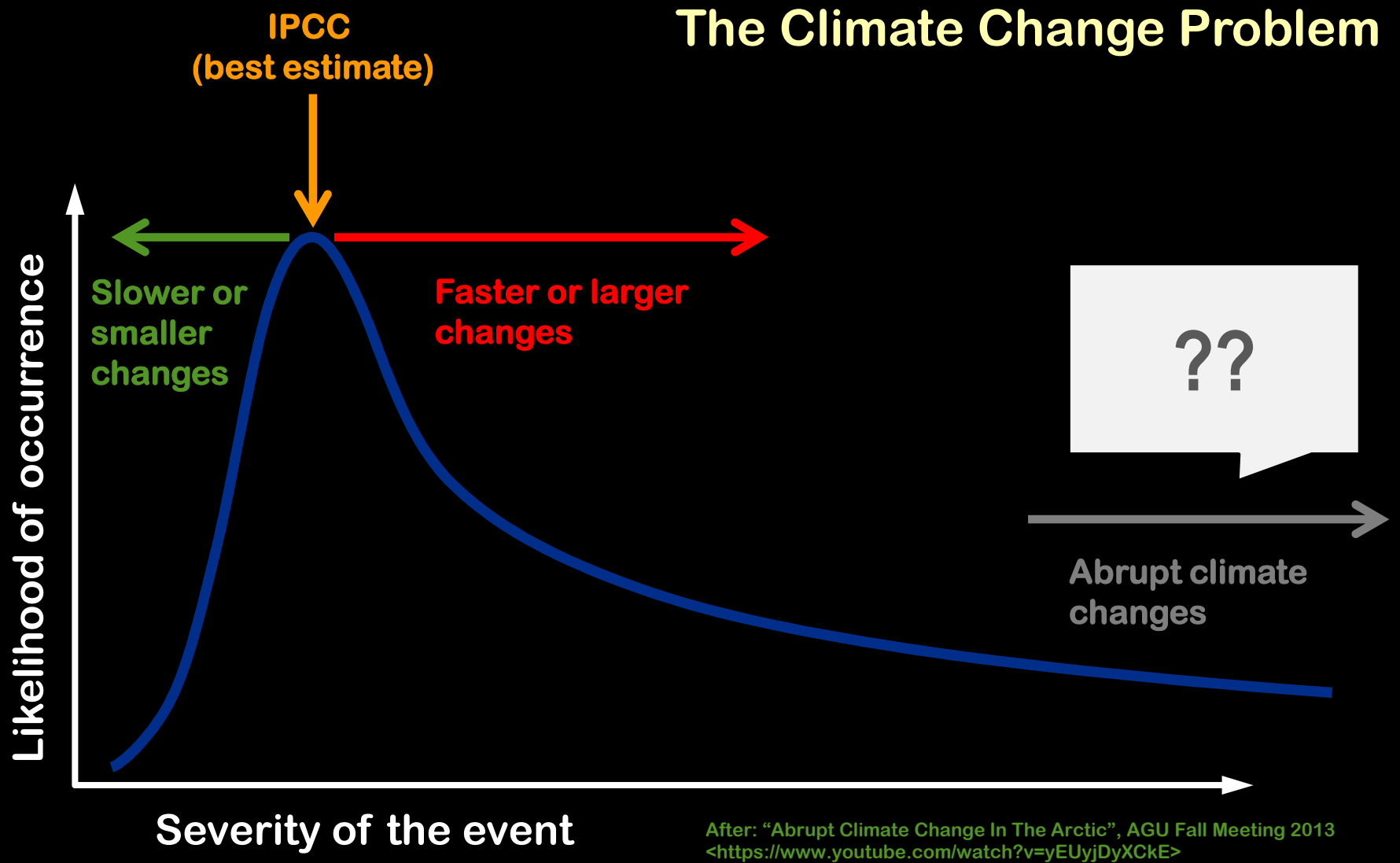


- ✓ Air bags, ABS, ESC, RSC,…
- ✓ crumple zones, collision bars,
- ✓ child seats,
- ✓ no-drink-and-drive campaigns,
- ✓ no-cell-phone-while-driving campaigns,
- ✓ no-drugs campaigns,
- ✓ traffic control, and so on…

Run over by drunk truck driver

After: "Abrupt Climate Change In The Arctic", AGU Fall Meeting 2013 <https://www.youtube.com/watch?v=yEUyjDyXCkE> with modifications

The Climate Change Problem



After: "Abrupt Climate Change In The Arctic", AGU Fall Meeting 2013
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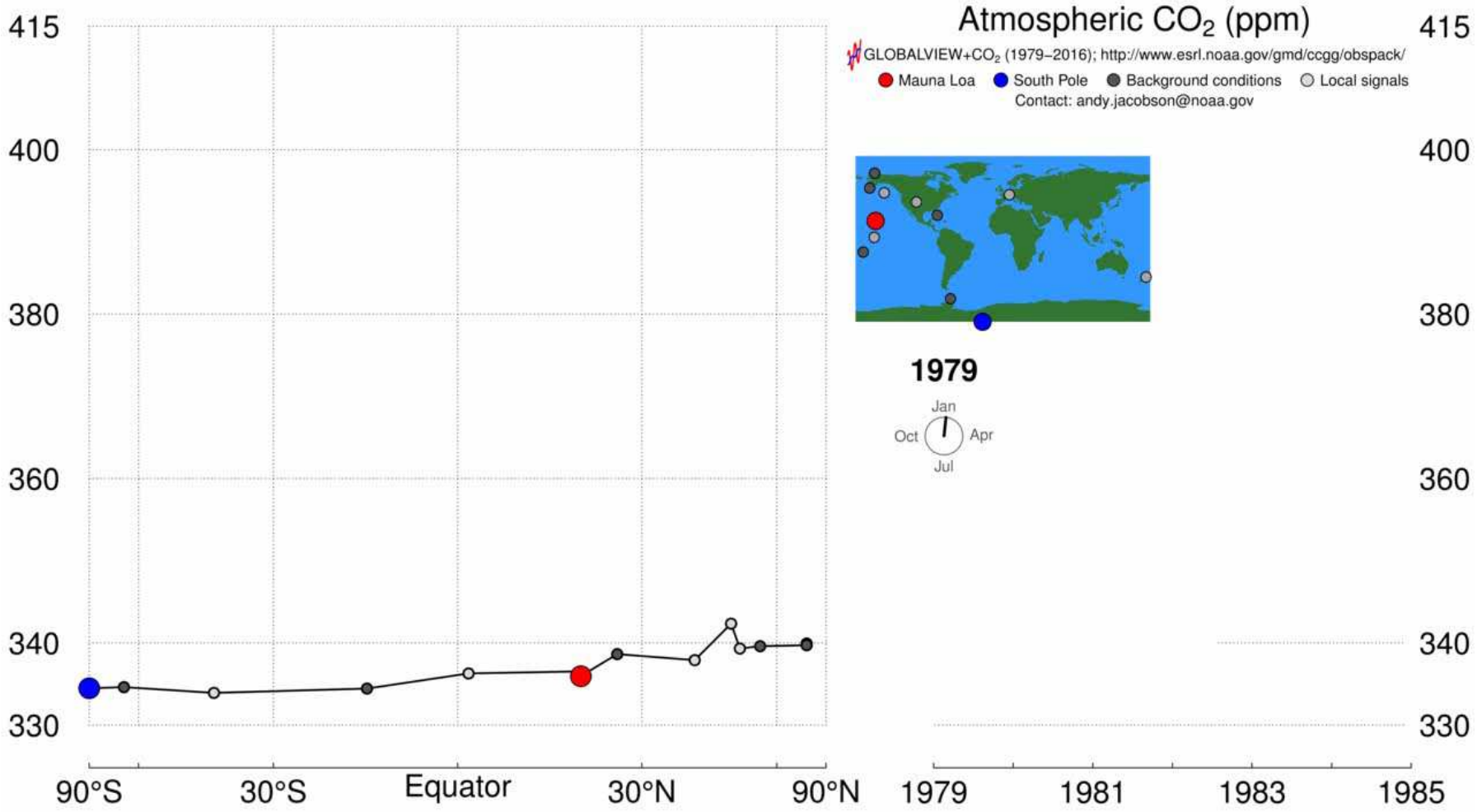
with modifications



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Final thoughts: a common dilemma…

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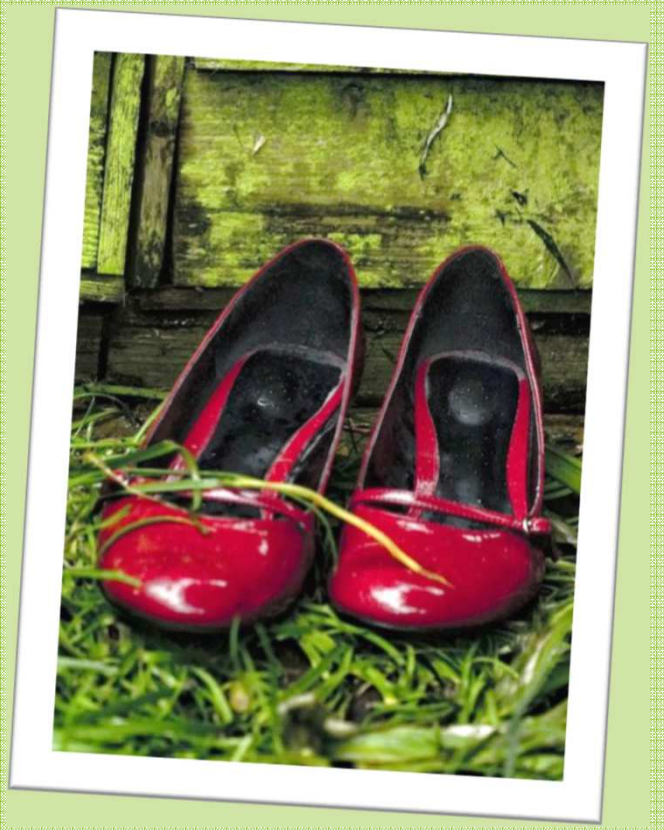

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Why not switching to renewables?

By Michael Carruth (CC lic.)
July 4, 2007
http://www.flickr.com/photos/michaelcarruth/with/871146589/

bc³

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Thank you!

By Lee (CC lic.), April 24, 2009,
http://www.flickr.com/photos/64663706@N00/with/3472630396/

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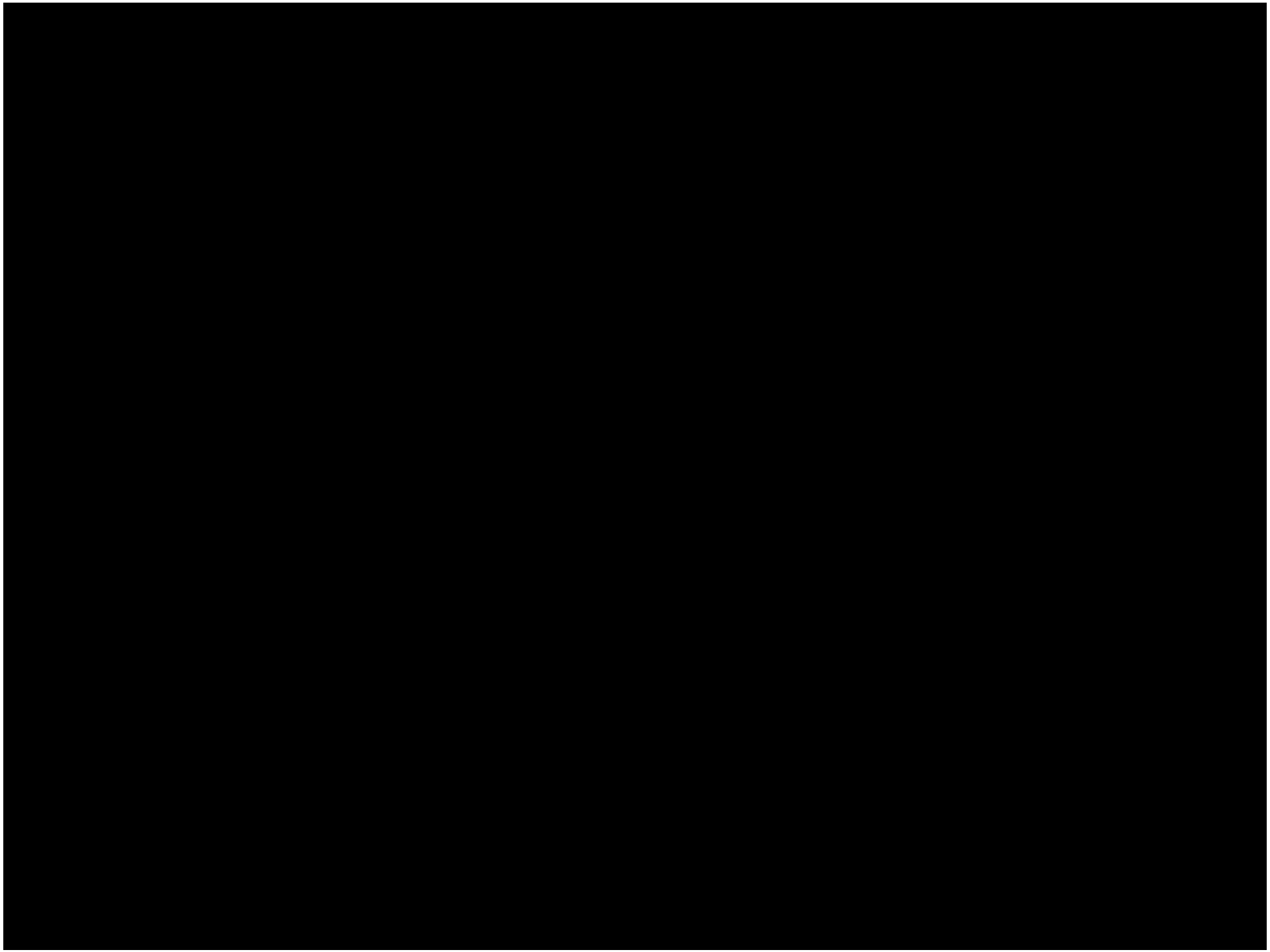
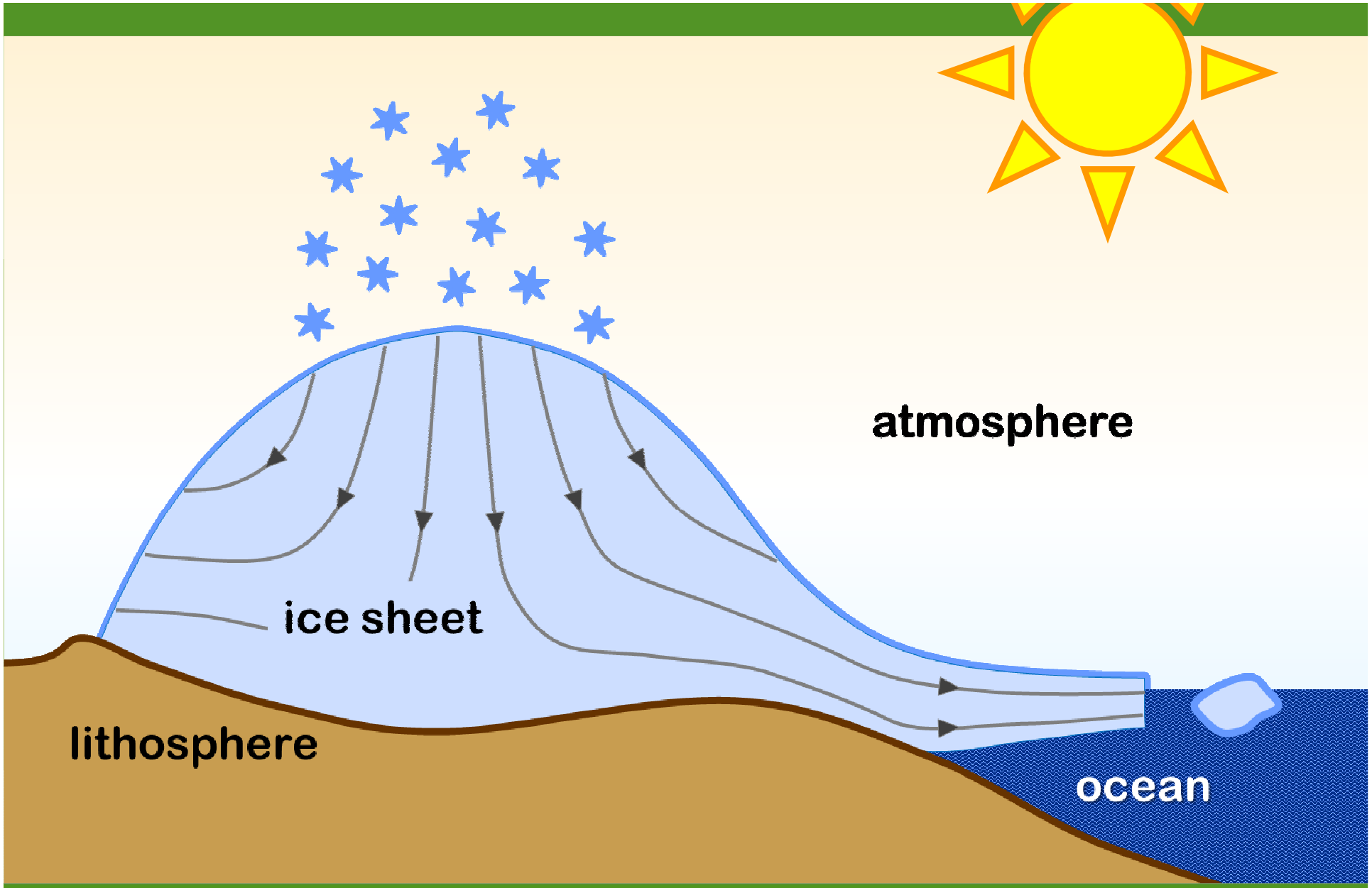


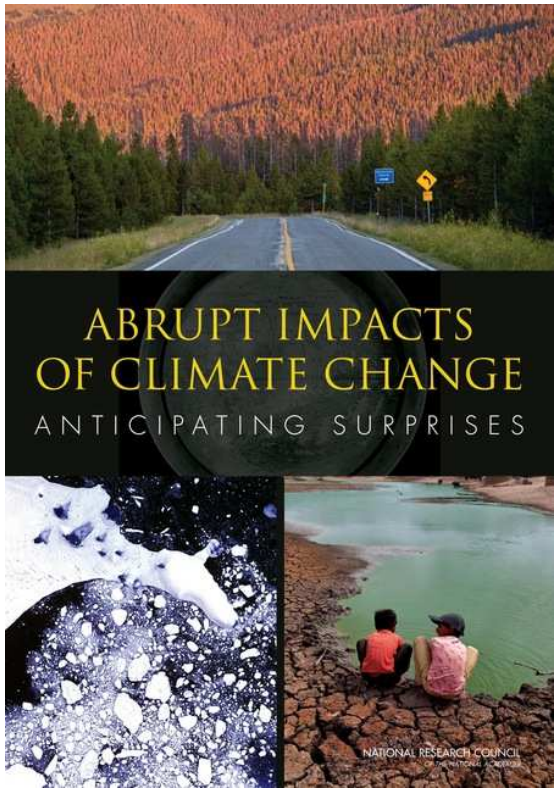

atmosphere
ice sheet
lithosphere
ocean

The “Fat Tail” Distribution (of Doom?)

Prof. Richard Alley
Penn State University

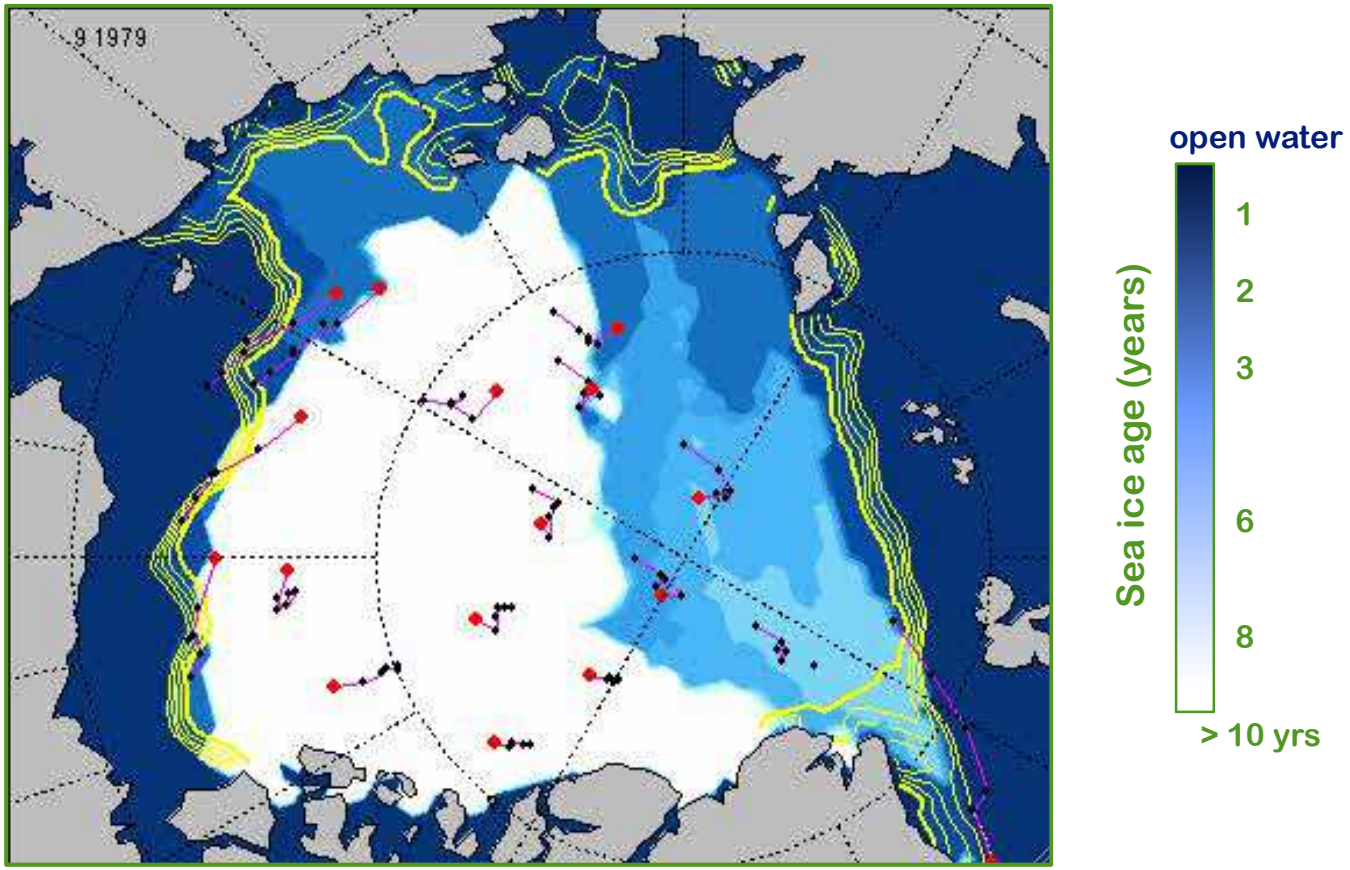
“Slip Slidin’ Away: Ice Sheets and Sea Level in a Warming World”
Stanford University, October 2012
<https://www.youtube.com/watch?v=jt4QLcocveE>

“Abrupt Climate Change In The Arctic”
AGU Fall Meeting 2013
<https://www.youtube.com/watch?v=yEUyjDyXCkE>



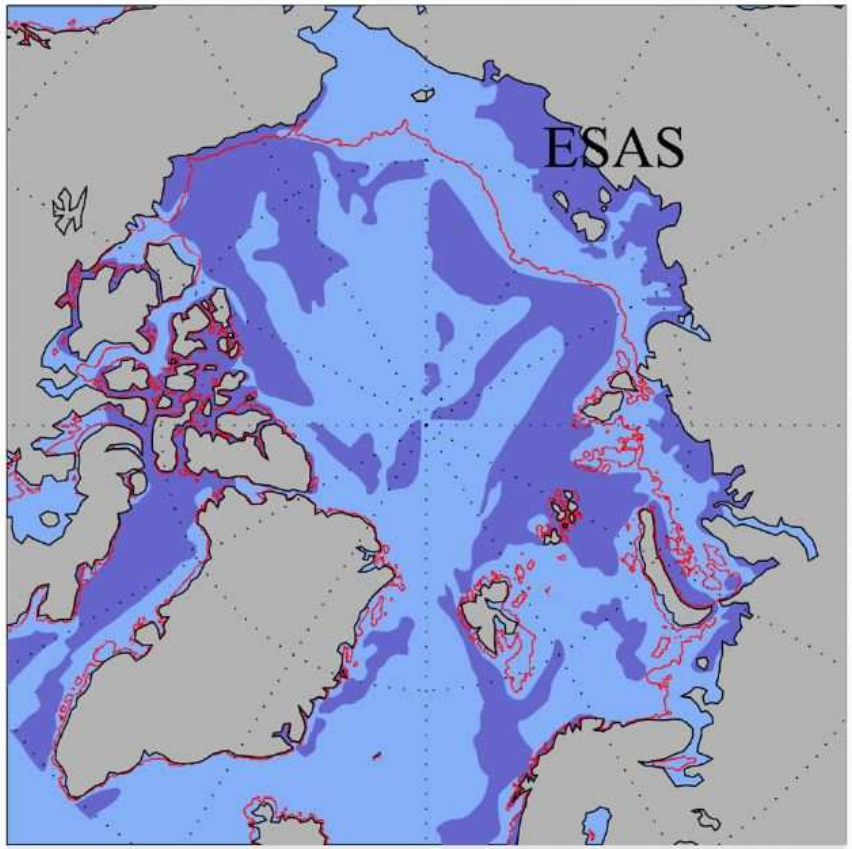
White, J. et al. (2013) Abrupt Impacts of Climate Change: Anticipating Surprises. Washington DC: National Academies Press.

Arctic Sea Ice Extension, Thickness, and Drift
Sep 1979 – Aug 2007

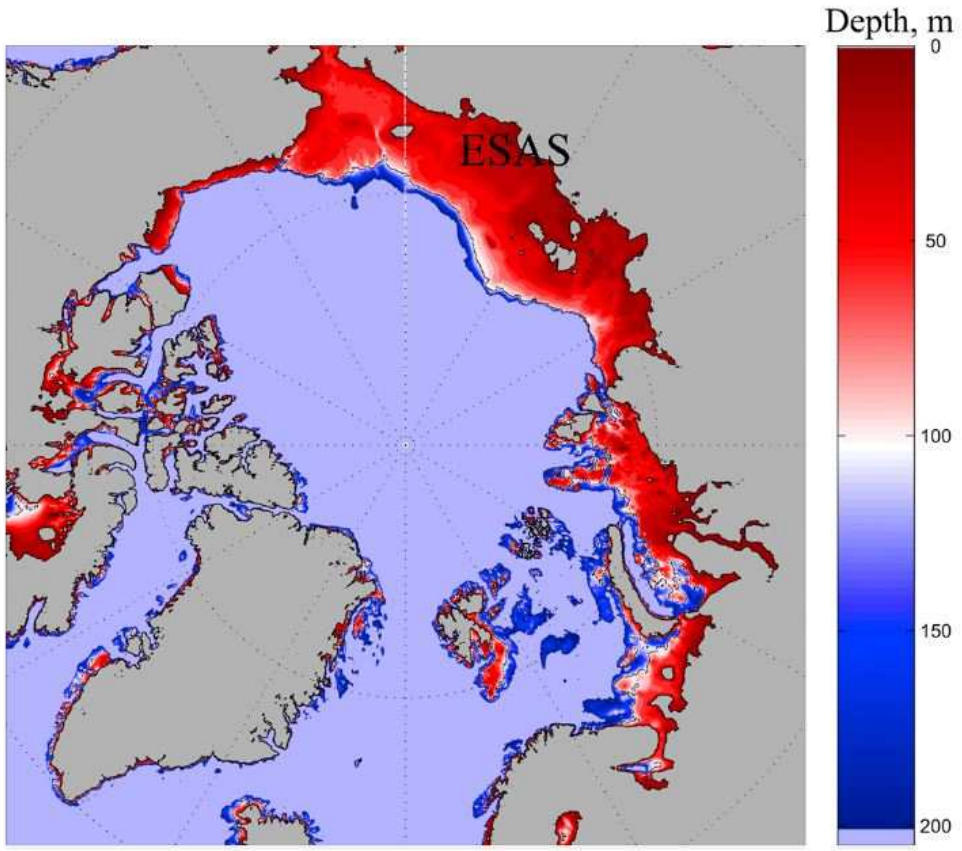


By Ignatius Rigor and John M. Wallace. International Arctic Buoy Program.
http://iabp.apl.washington.edu/research_seaiceageextent.html

Methane Hydrates in Shallow Arctic Shelves



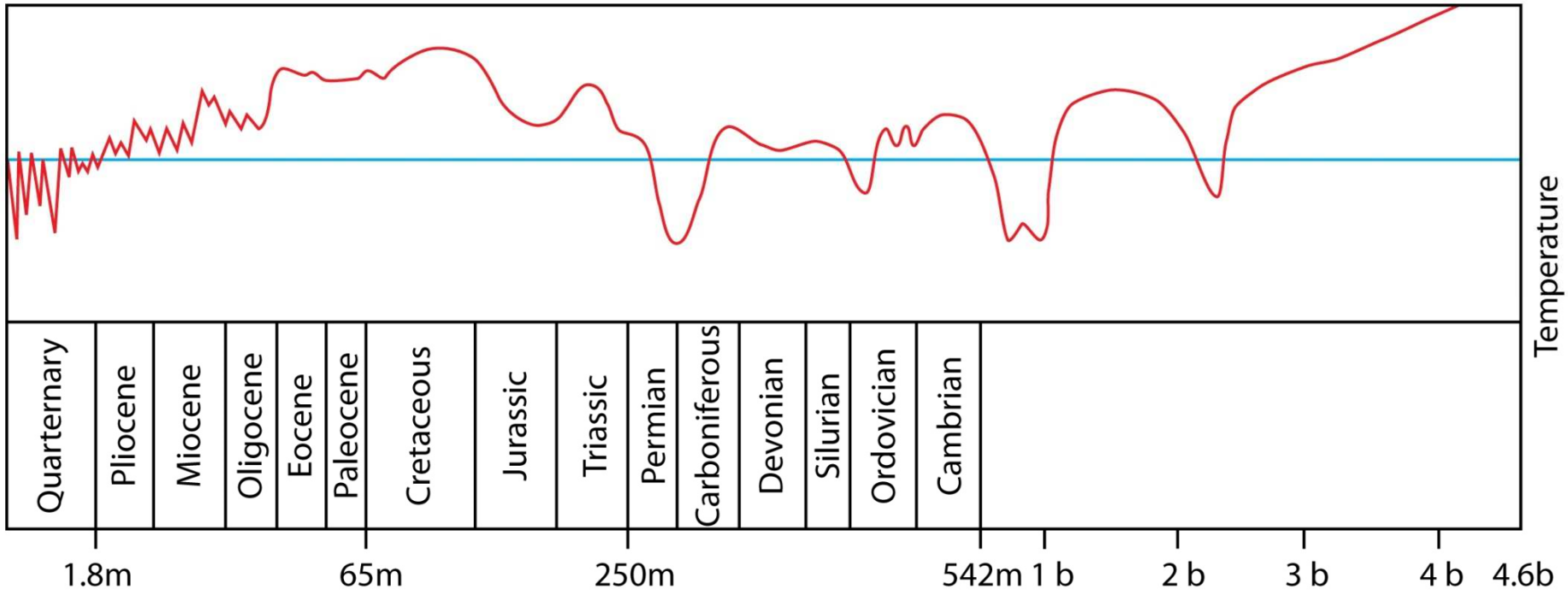
Predicted deposits of shallow methane hydrates (purple) over the Arctic Ocean. Red line marks the 50 m isobath.



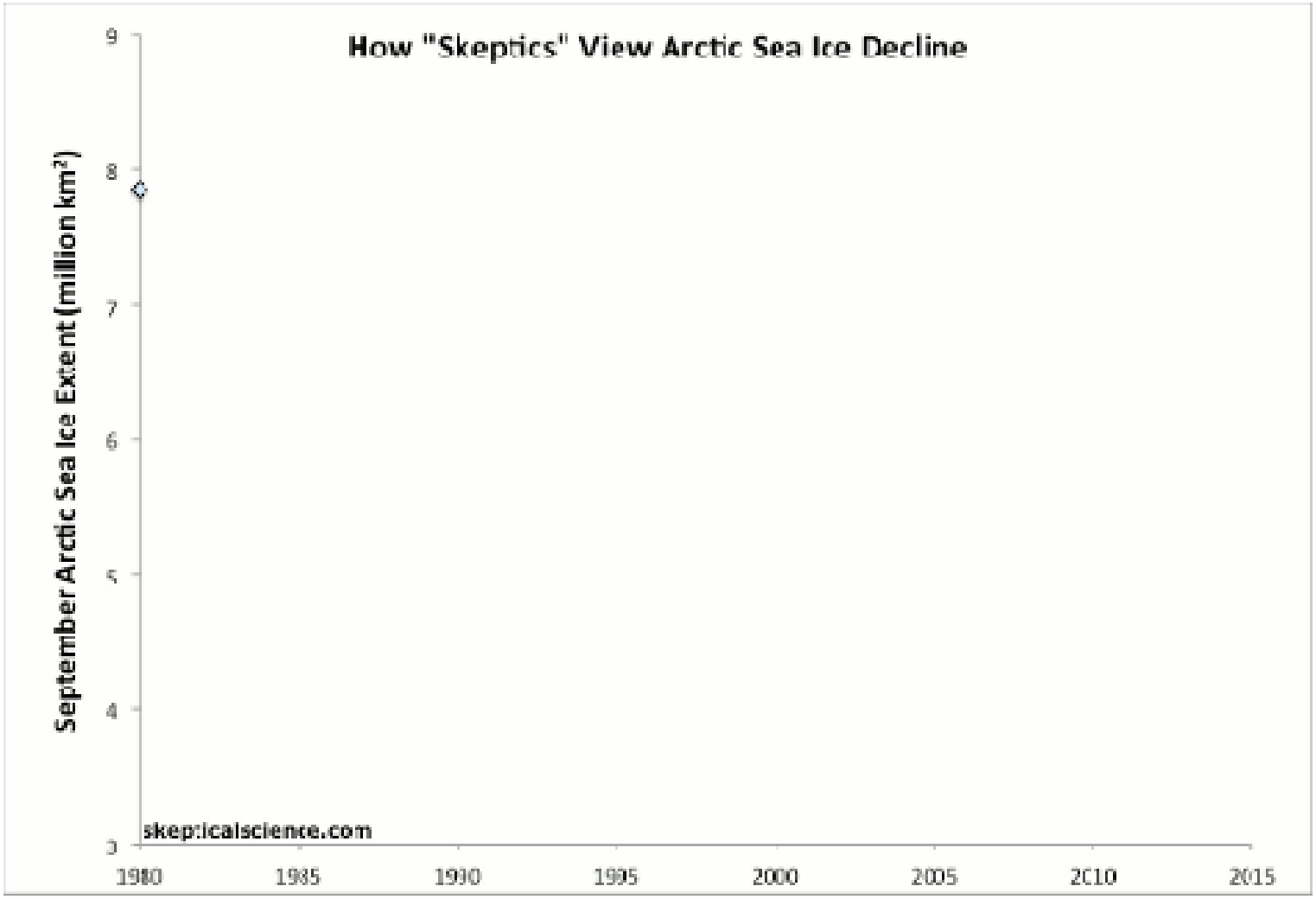
Distribution of subsea permafrost.
ESAS = East Siberian Arctic Shelf

Shakhova et al. (2010) Geochemical and geophysical evidence of methane release over the East Siberian Arctic Shelf. *JGR* **115**:C08007.

Earth's temperature history in the last 4.6 billion years

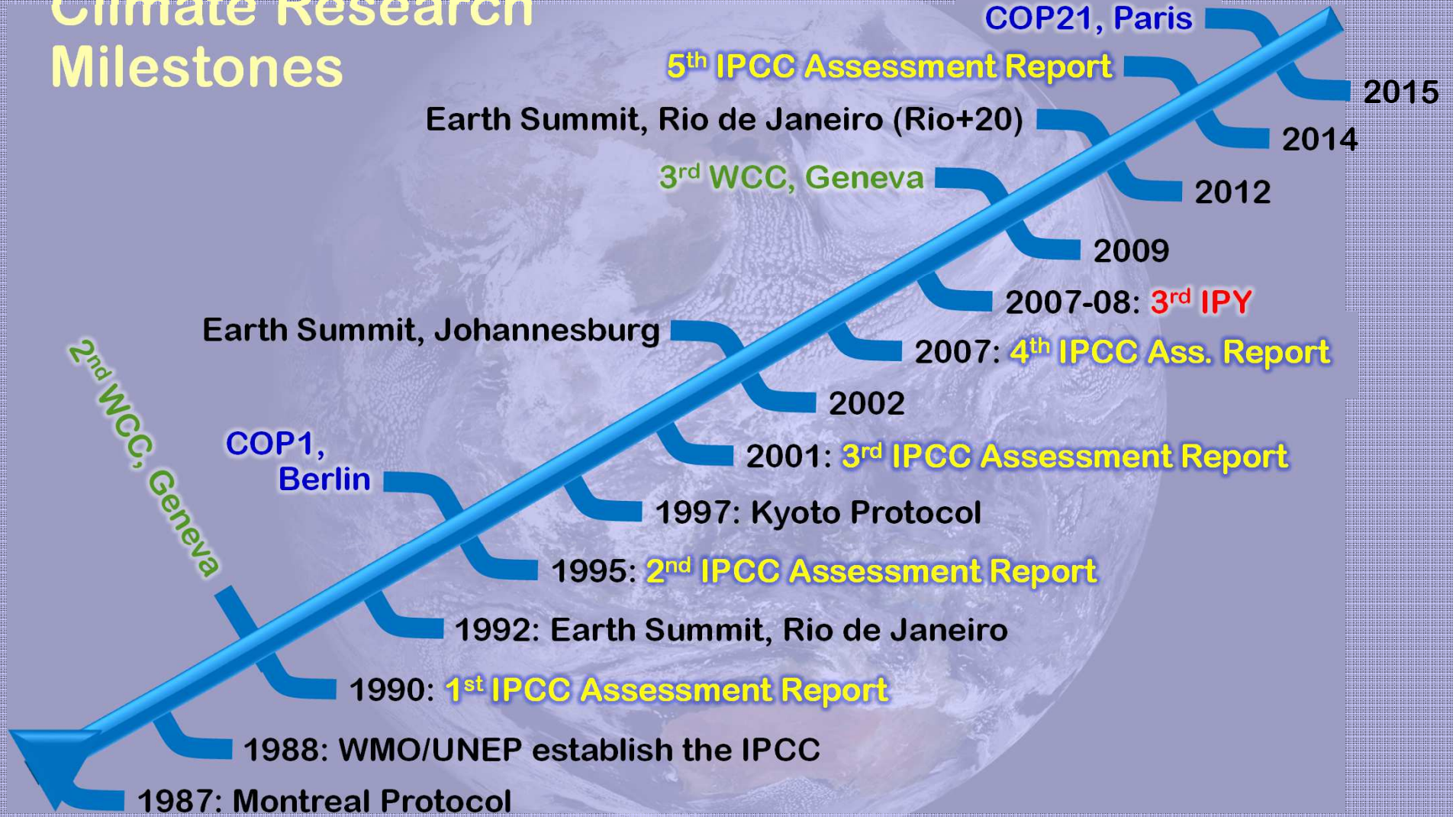


Saltzman, B. (2002) Dynamical Paleoclimatology. New York: Academic Press.

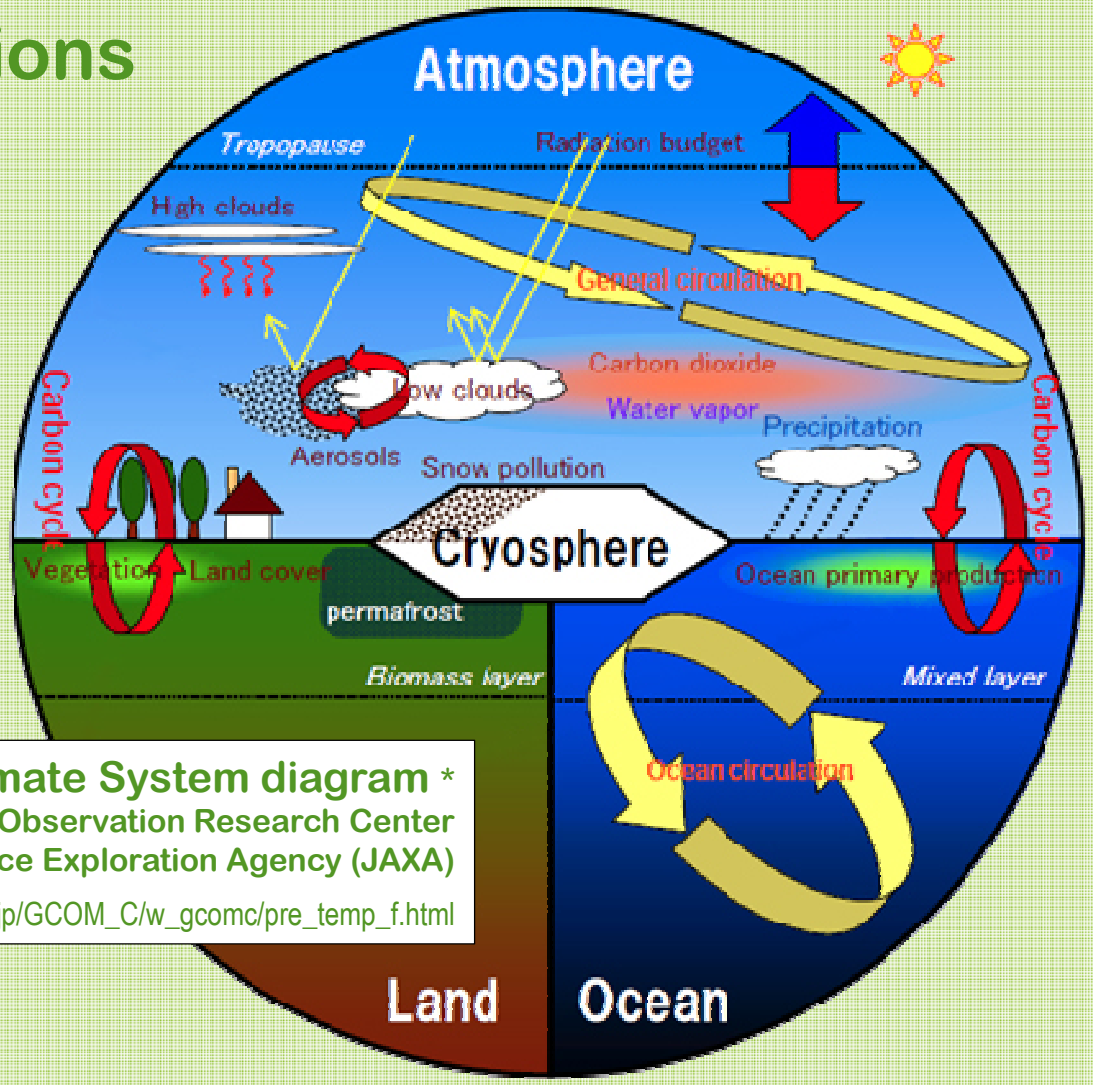

How "Skeptics" View Arctic Sea Ice Decline
September Arctic Sea Ice Extent (million km²)
9
8
7
6
5
4
3
skepticalscience.com
1980
1985
1990
1995
2000
2005
2010
2015

Climate Research Milestones

Climate Research Milestones



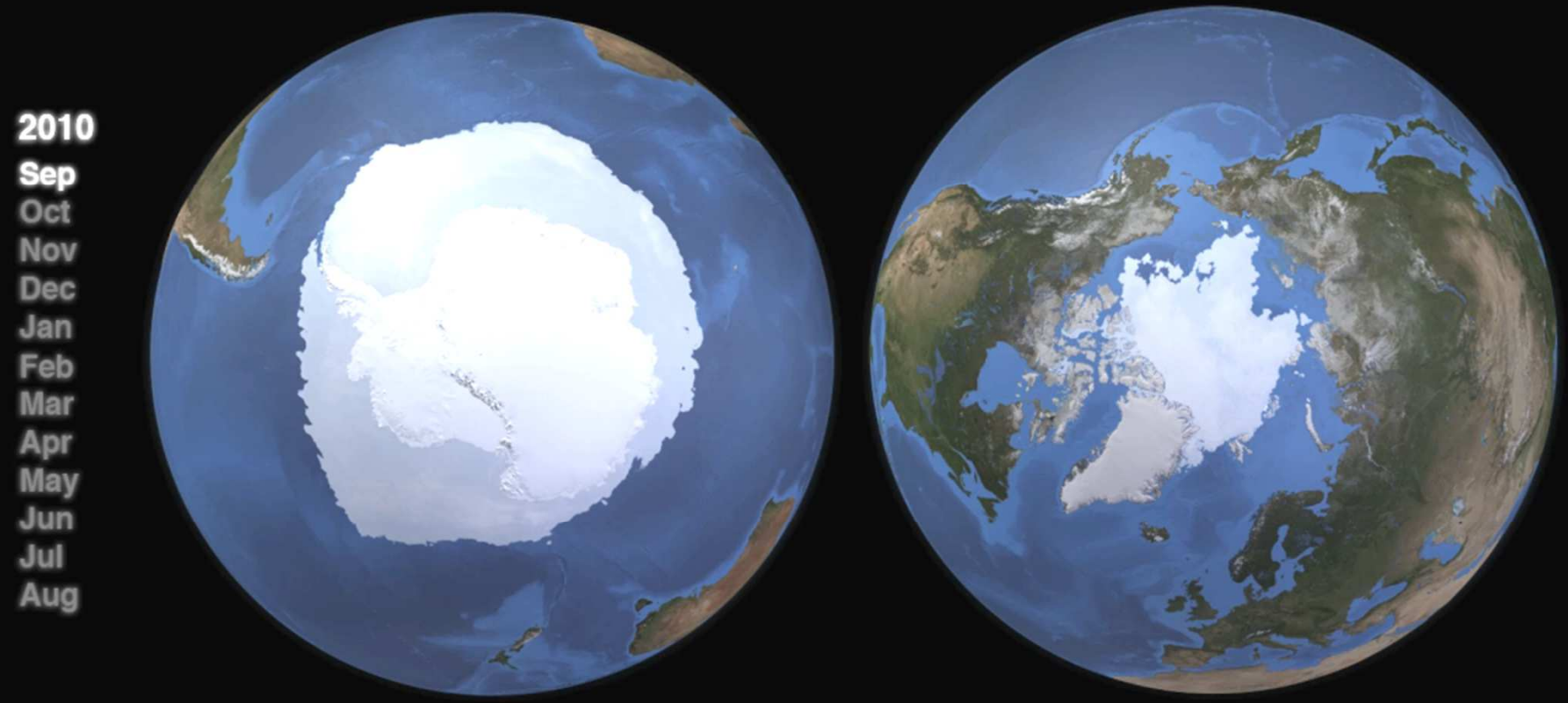
1st: Polar regions are essential components of the global climate system



Climate System diagram *
Earth Observation Research Center
Japan Aerospace Exploration Agency (JAXA)
http://suzaku.eorc.jaxa.jp/GCOM_C/w_gcomc/pre_temp_f.html

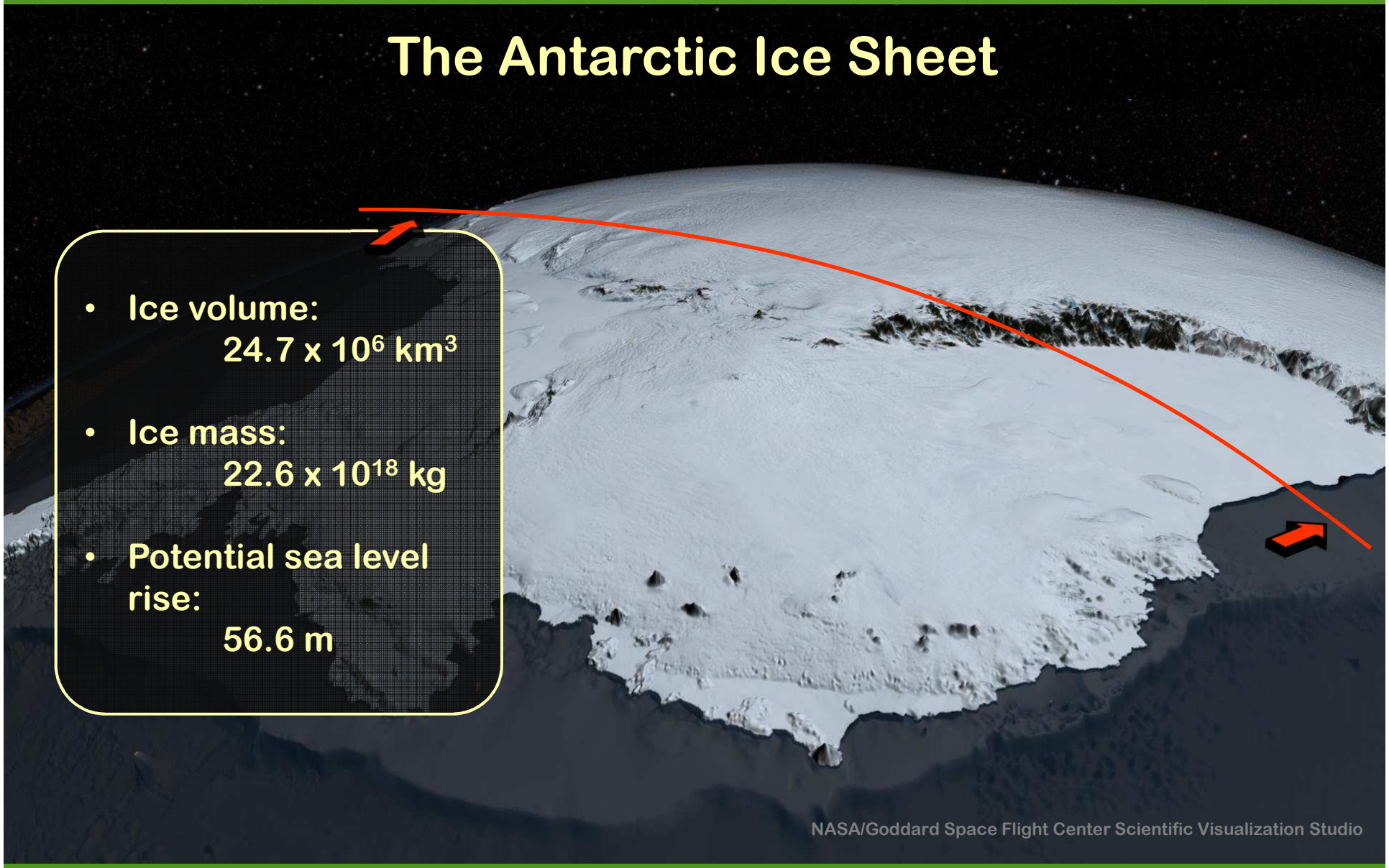
* with minor modifications

Seasonal cycles in polar regions



NASA/Goddard Space Flight Center Scientific Visualization Studio

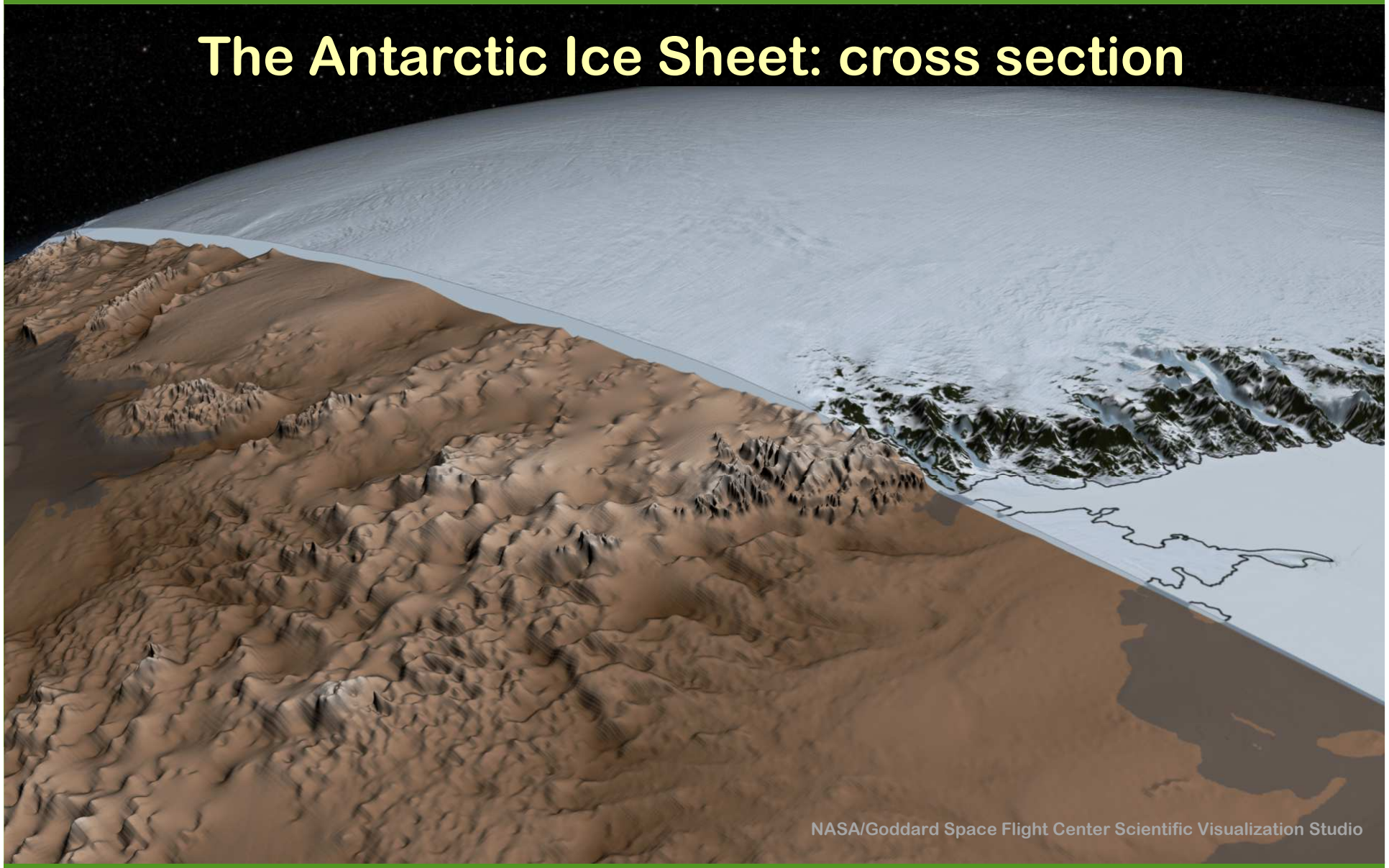
The Antarctic Ice Sheet



- Ice volume:
  24.7×10^6 km^3
- Ice mass:
  22.6×10^{18} kg
- Potential sea level rise:
  56.6 m

NASA/Goddard Space Flight Center Scientific Visualization Studio

The Antarctic Ice Sheet: cross section



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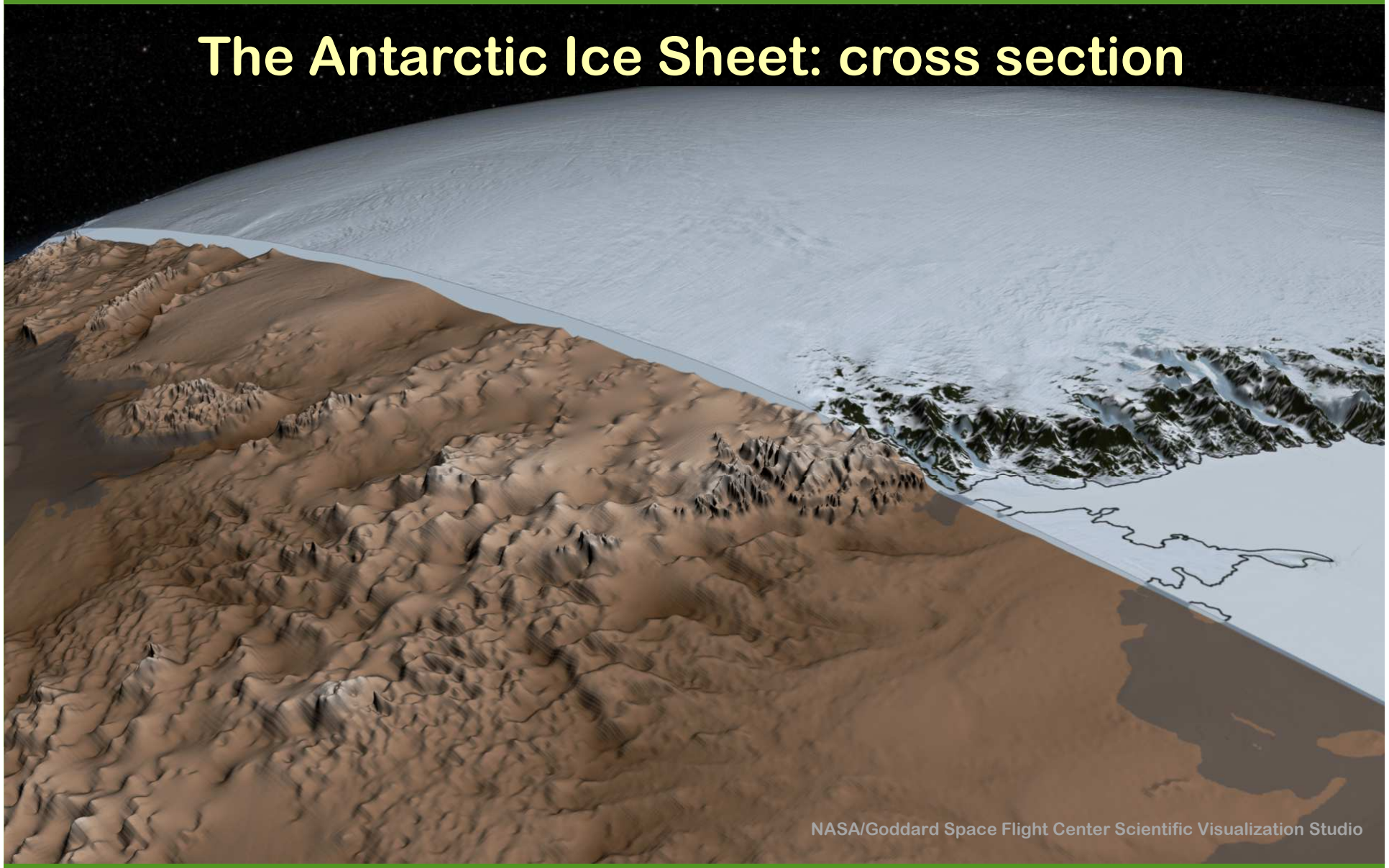
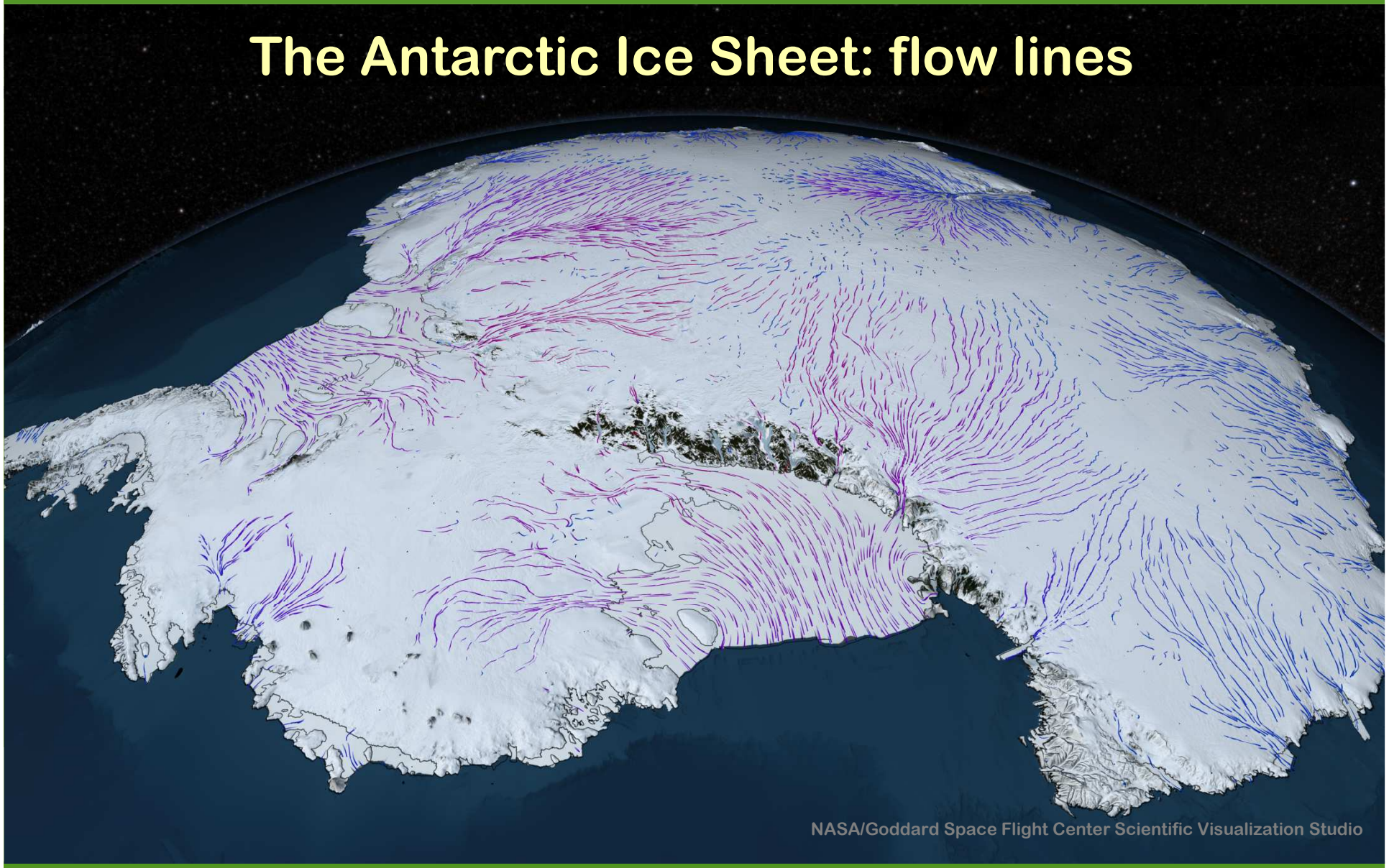
Antarctic Ice Sheet Velocities
1
3
10
30
100
300
1000
3000
meters per year

The Antarctic Ice Sheet: cross section



NASA/Goddard Space Flight Center Scientific Visualization Studio

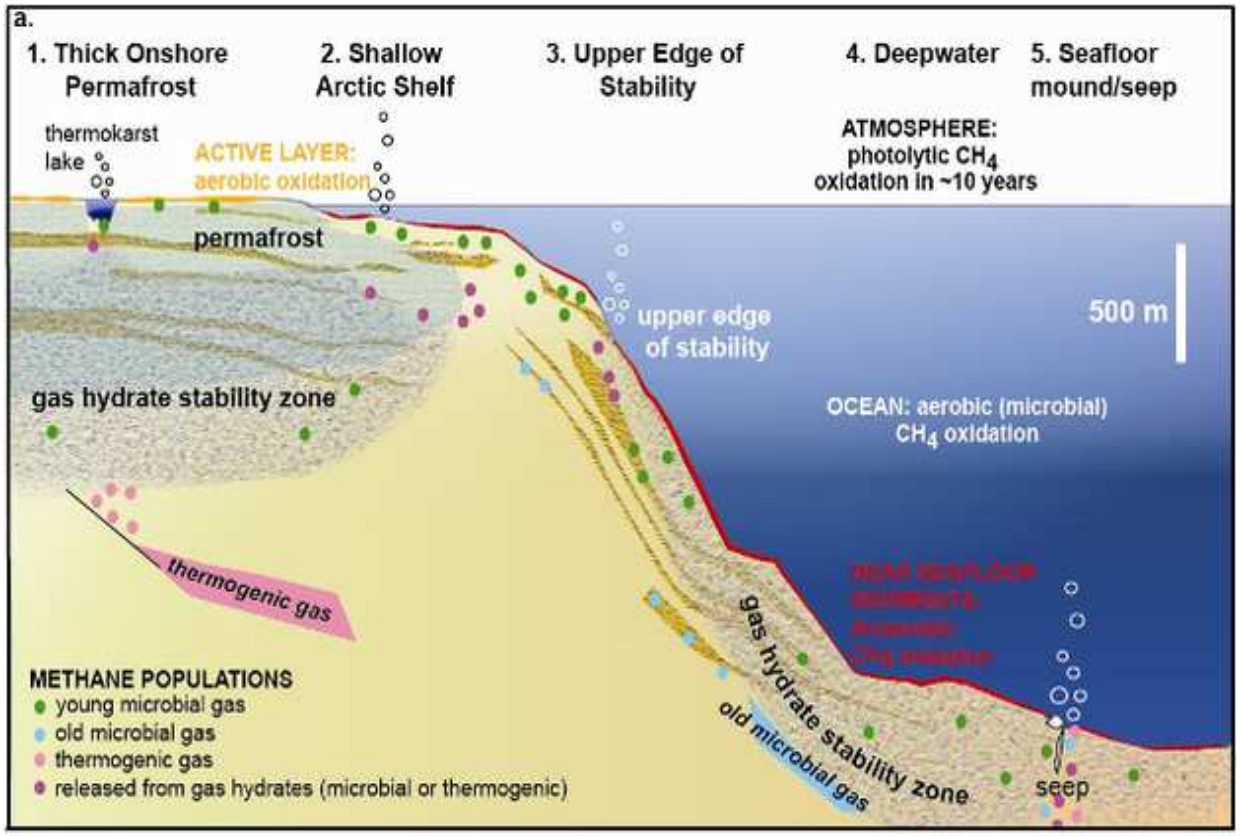
The Antarctic Ice Sheet: flow lines



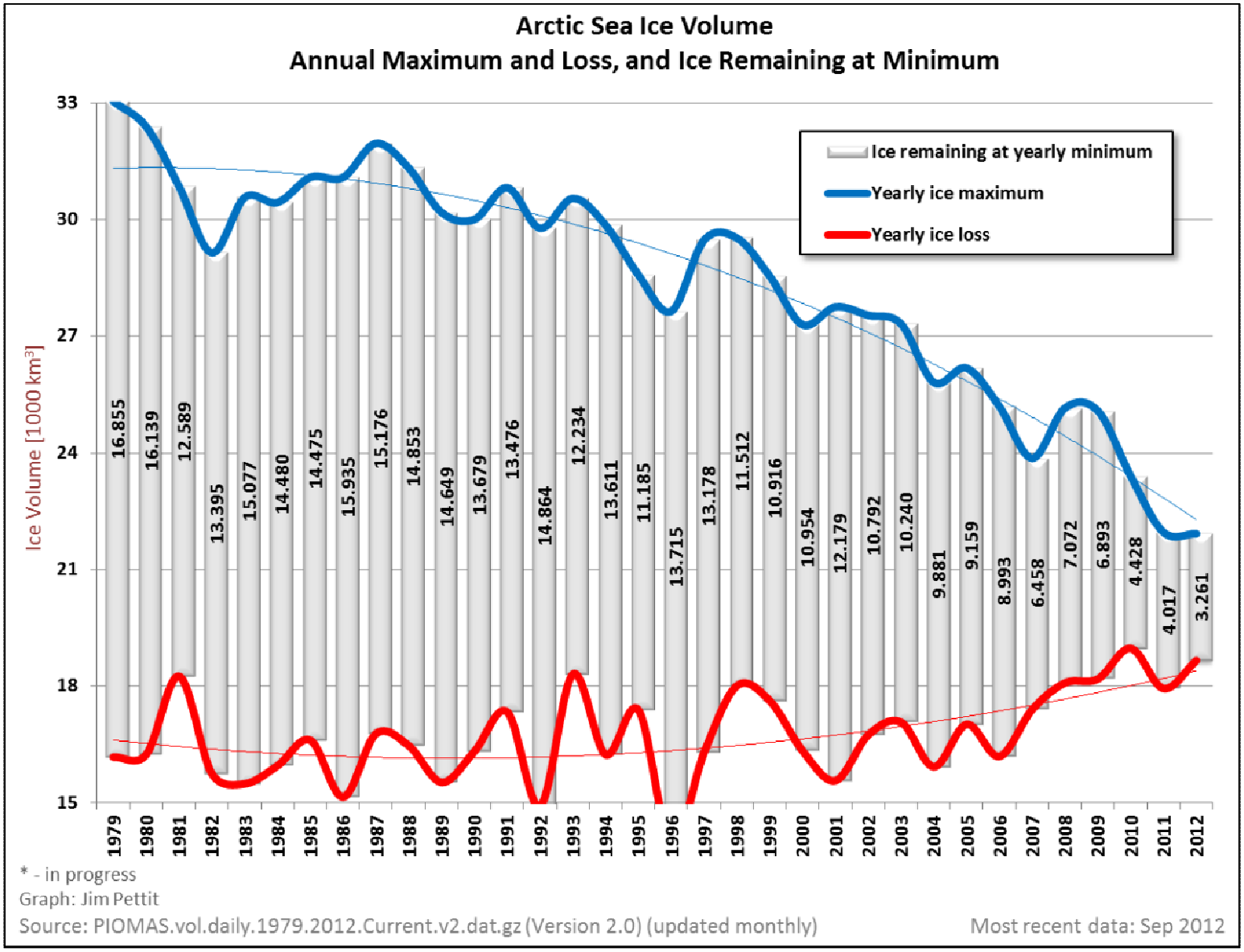
NASA/Goddard Space Flight Center Scientific Visualization Studio

Methane Hydrates Deposits in Shallow Arctic Shelves

By Ignatius Rigor and John M. Wallace. International Arctic Buoy Program. http://iabp.apl.washington.edu/research_seaiceageextent.html



Ruppel, Nature Knowledge, Hydrates/Climate, April 2011


Arctic Sea Ice Volume
Annual Maximum and Loss, and Ice Remaining at Minimum
Ice Volume [1000 km³]
33
30
27
24
21
18
15
Ice remaining at yearly minimum
Yearly ice maximum
Yearly ice loss
16.855
16.139
12.589
13.395
15.077
14.480
14.475
15.935
15.176
14.853
14.649
13.679
13.476
14.864
12.234
13.611
11.185
13.715
13.178
11.512
10.916
10.954
12.179
10.792
10.240
9.881
9.159
8.993
6.458
7.072
6.893
4.428
4.017
3.261
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
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1995
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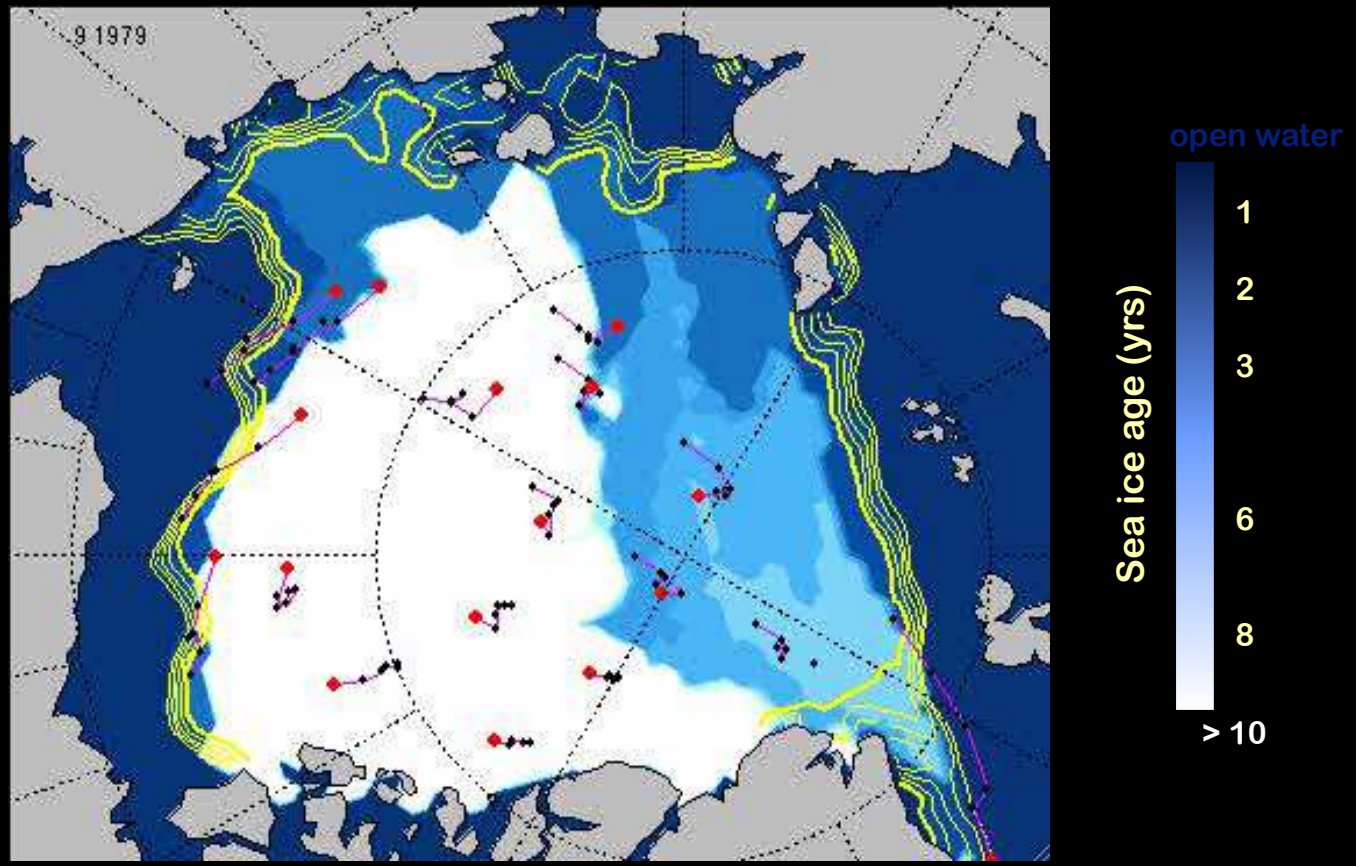
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
* - in progress
Graph: Jim Pettit
Source: PIOMAS.vol.daily.1979.2012.Current.v2.dat.gz (Version 2.0) (updated monthly)
Most recent data: Sep 2012

Arctic Sea Ice Extension, Thickness, and Drift
Sep 1979 – Aug 2007



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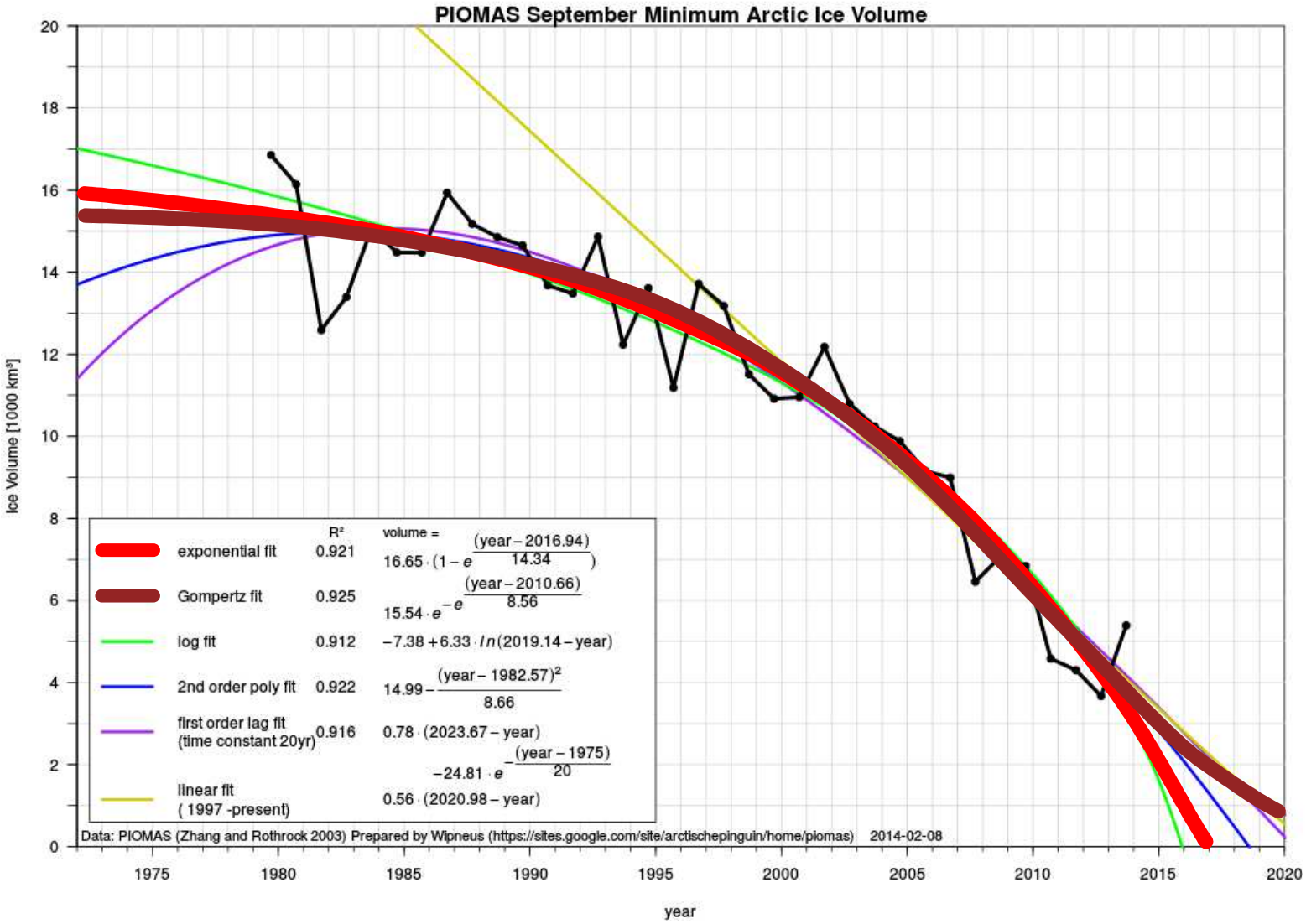
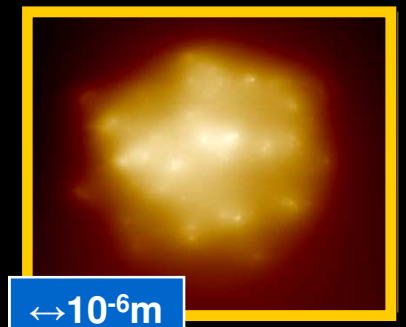
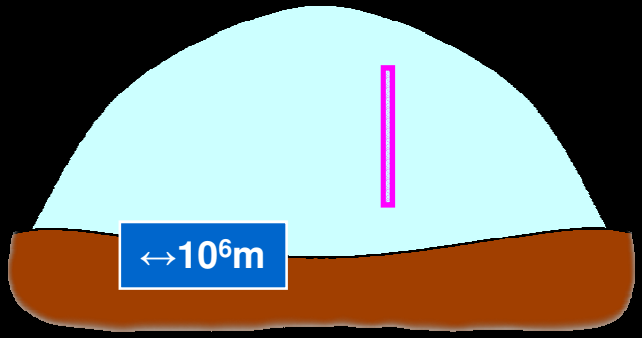

PIOMAS September Minimum Arctic Ice Volume
Ice Volume [1000 km³]
year
20
18
16
14
12
10
8
6
4
2
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
R²
volume =
exponential fit 0.921 16.65 · (1 − e^(−(year − 2016.94)/14.34))
Gompertz fit 0.925 15.54 · e^(−e^(−(year − 2010.66)/8.56))
log fit 0.912 −7.38 + 6.33 · ln(2019.14 − year)
2nd order poly fit 0.922 14.99 − (year − 1982.57)²/8.66
first order lag fit (time constant 20yr) 0.916 0.78 · (2023.67 − year) − 24.81 · e^(−(year − 1975)/20)
linear fit (1997 -present) 0.56 · (2020.98 − year)
Data: PIOMAS (Zhang and Rothrock 2003) Prepared by Wipneus (https://sites.google.com/site/arctischepinguin/home/piomas) 2014-02-08

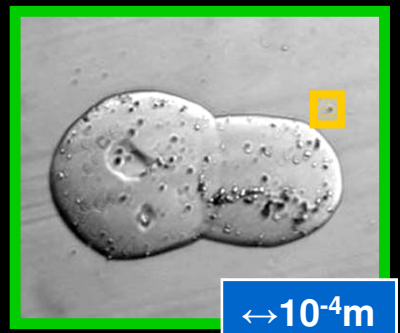
Multiscale Structures in Ice Sheets



↔10^{-6}m



↔10^{6}m



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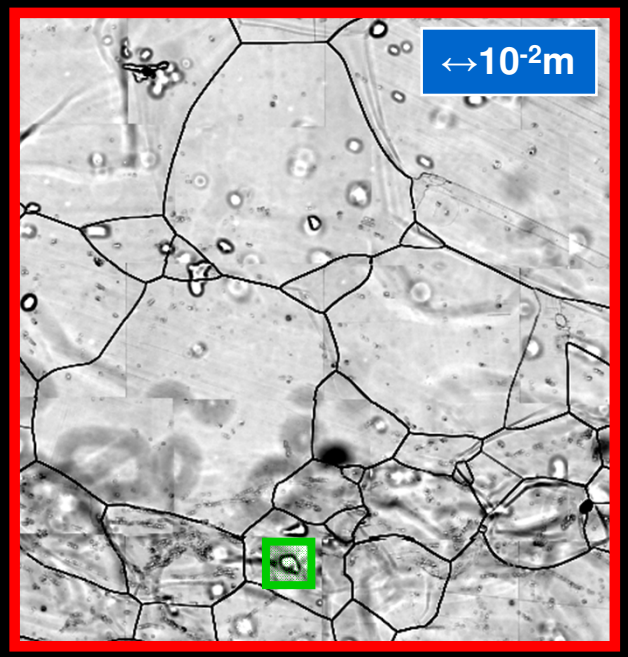
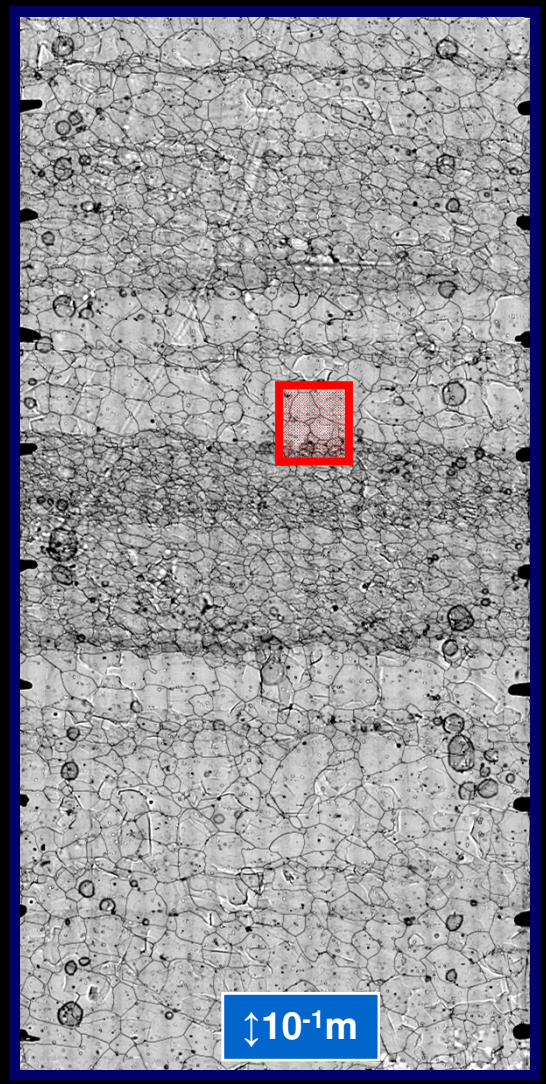
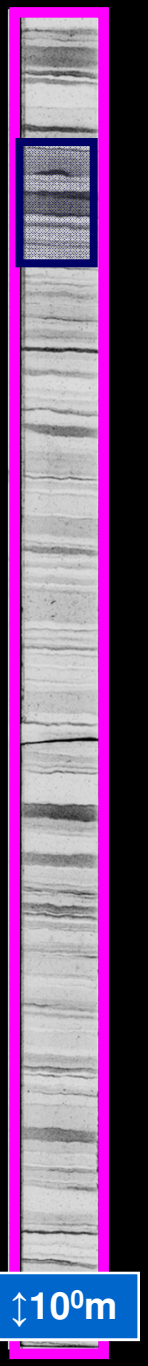


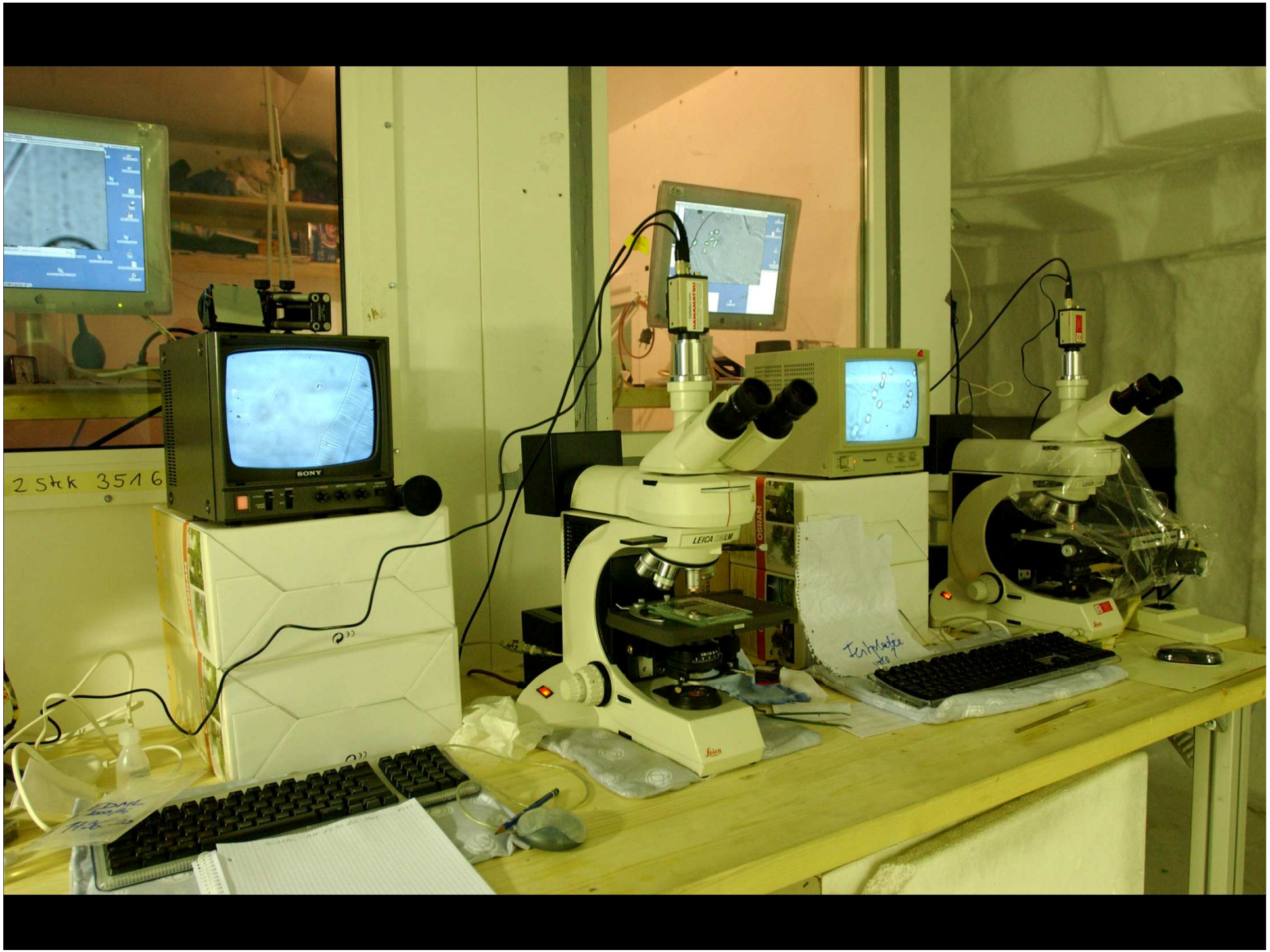
↔10^{-2}m



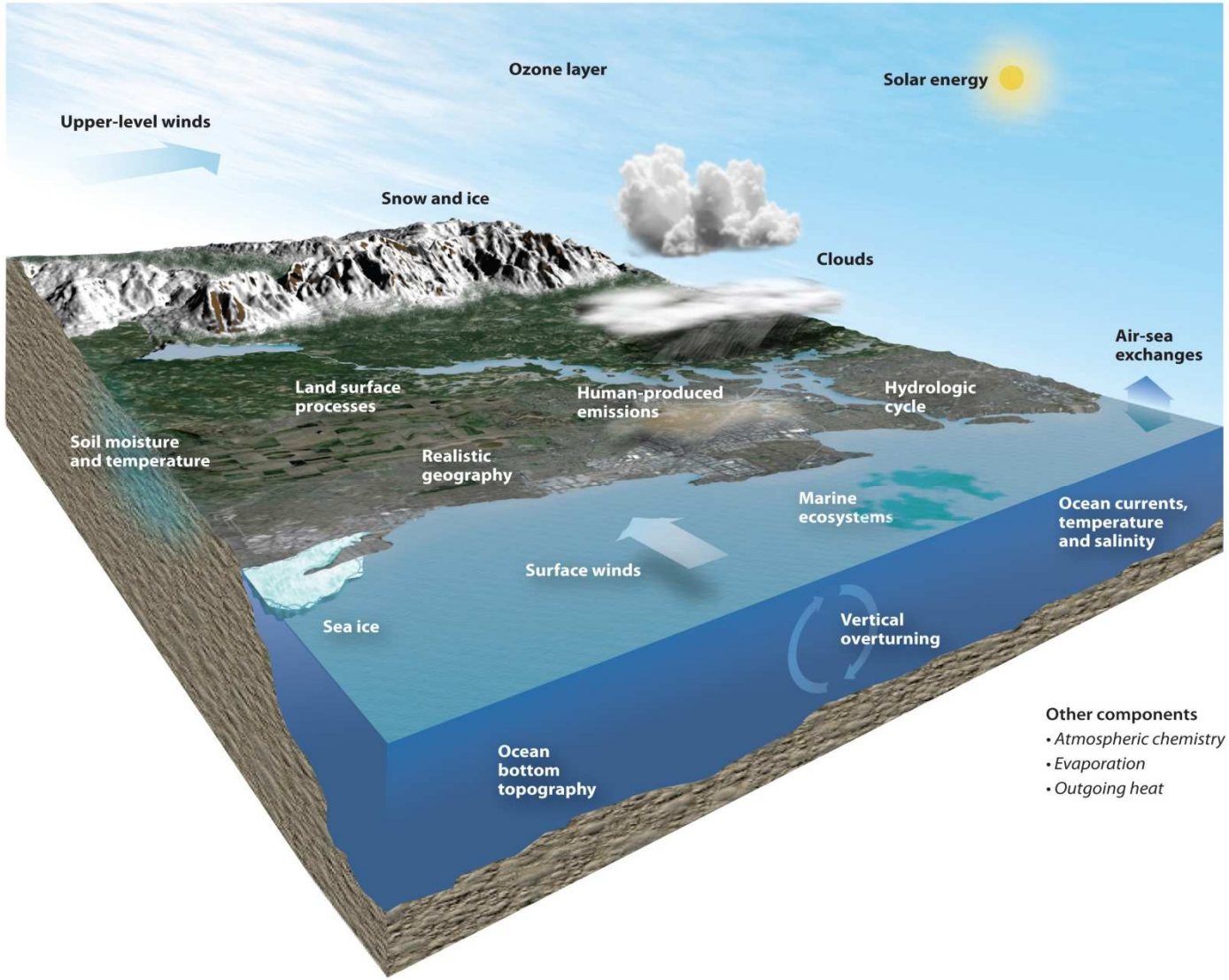
↕10^{-1}m



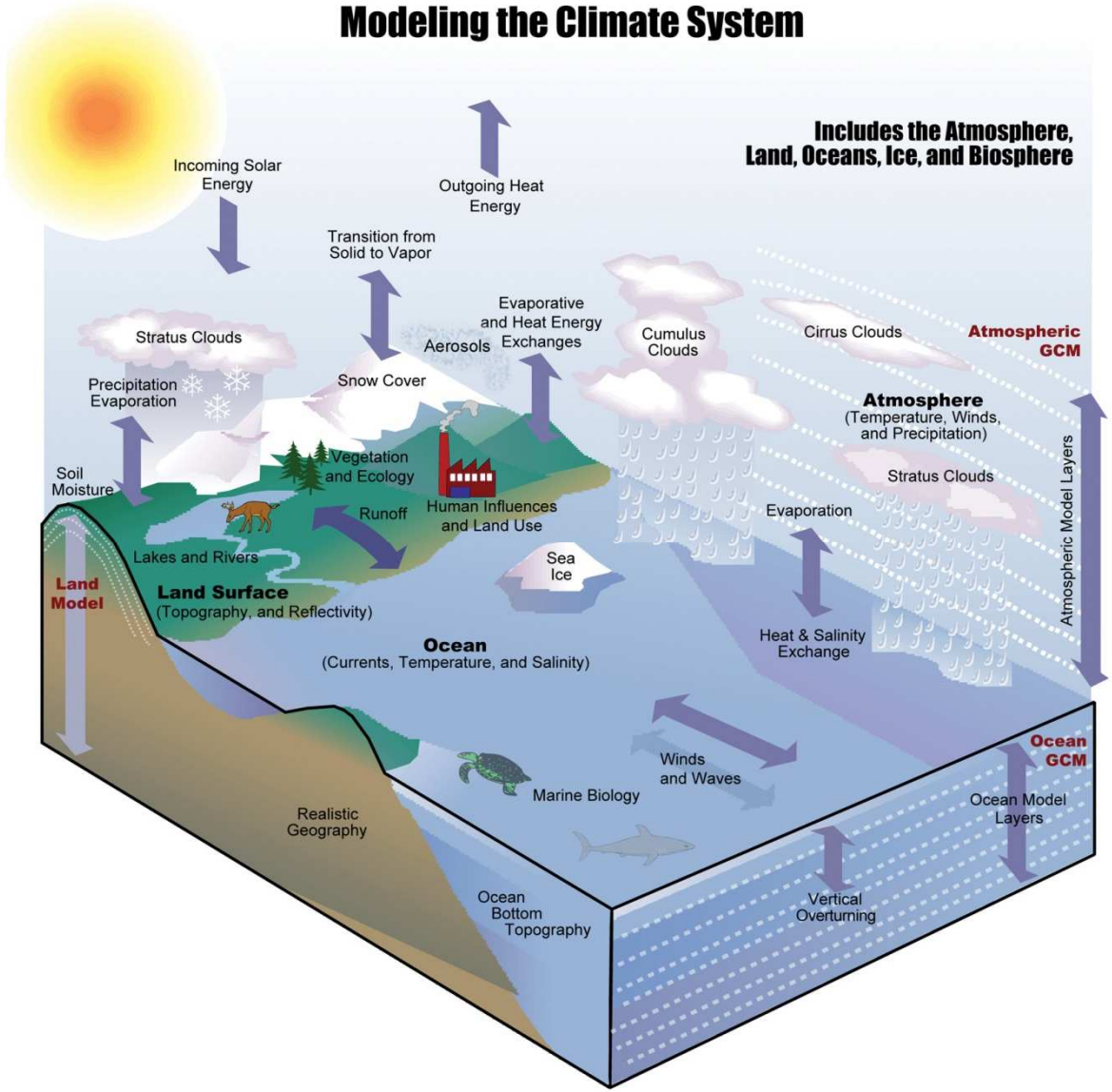
↕10^{0}m

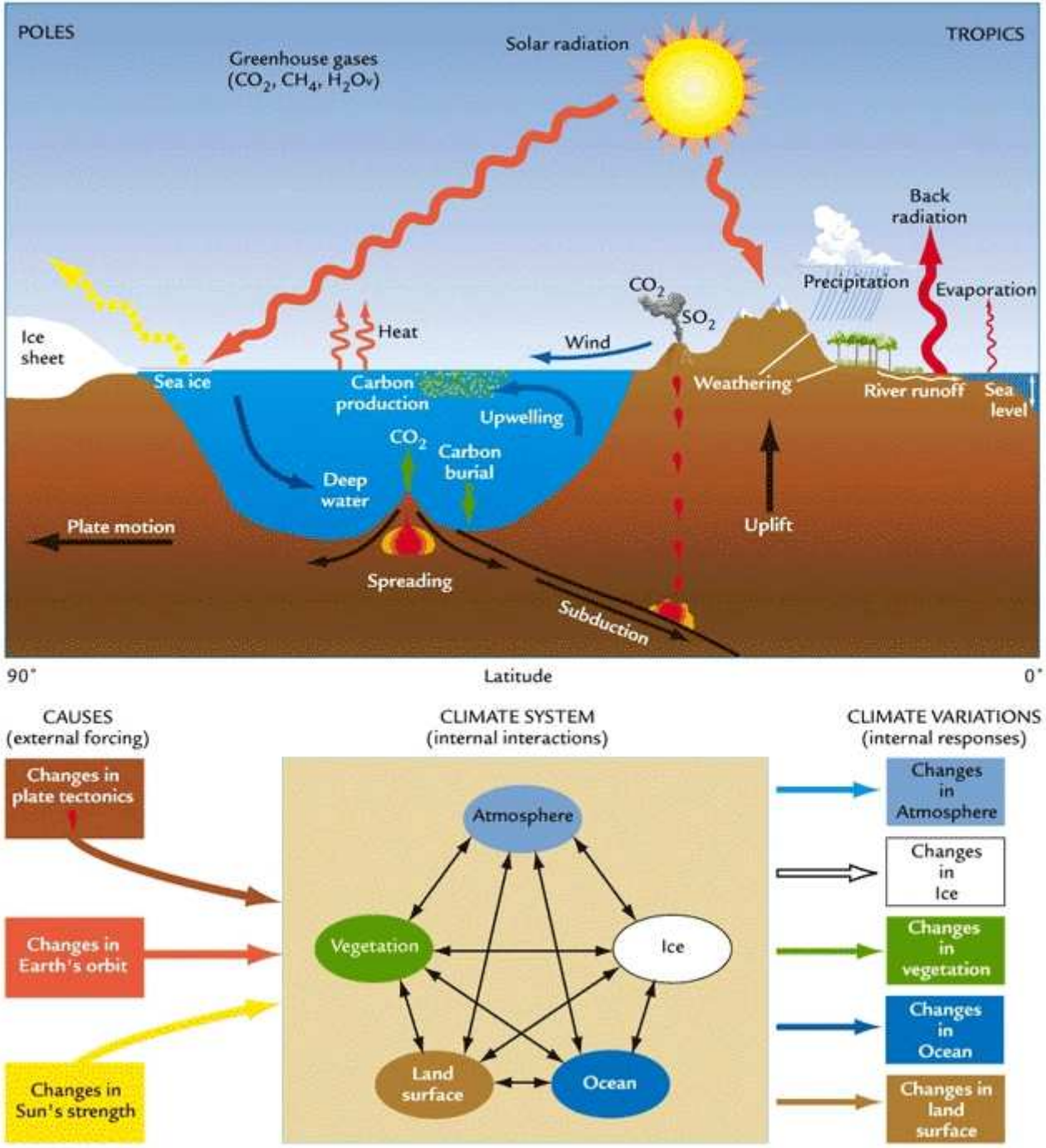

2 Stck 3516
SONY
LEICA DM
OSRAM

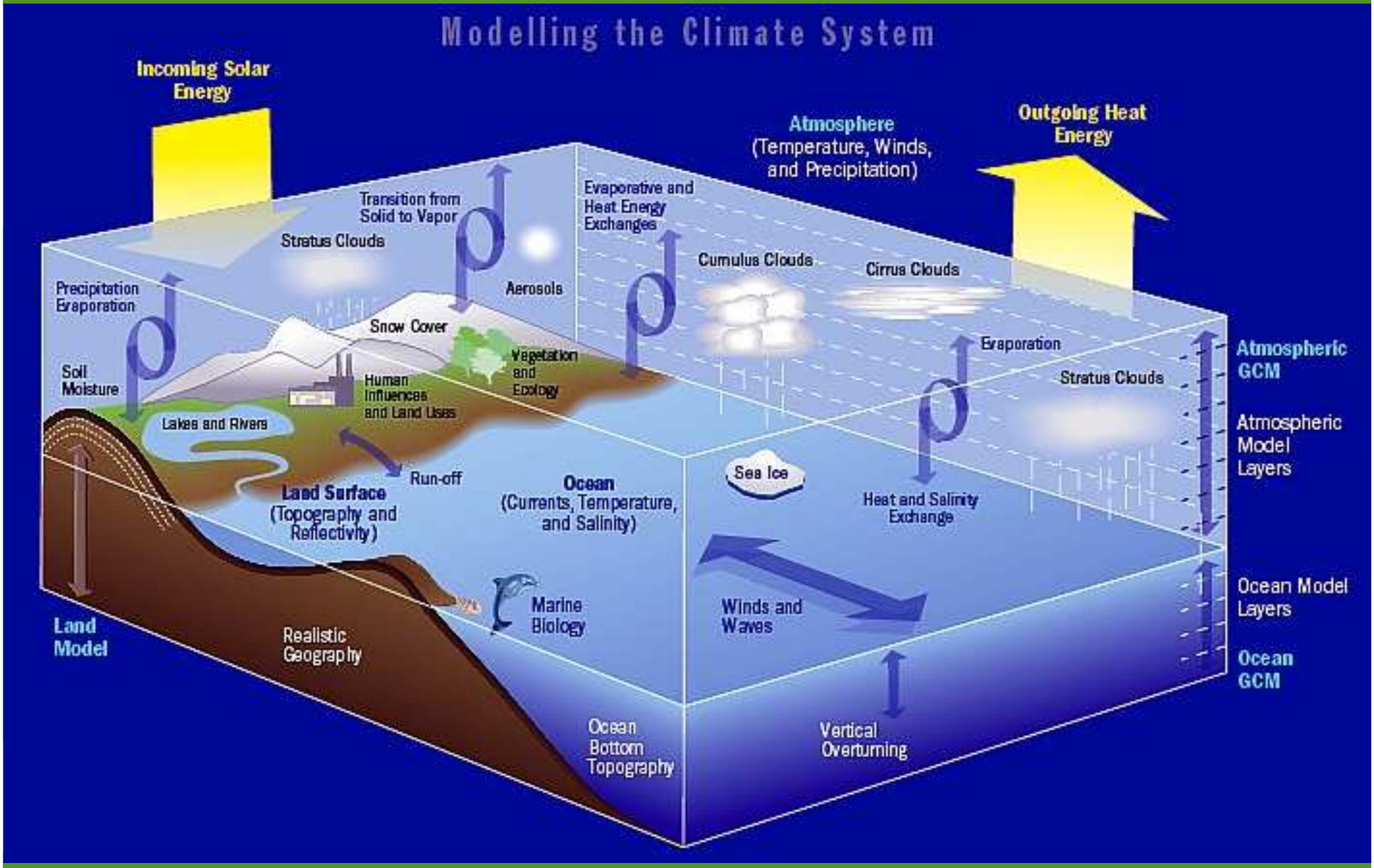
1 Statement of the Problem


Ozone layer
Solar energy
Upper-level winds
Snow and ice
Clouds
Air-sea exchanges
Land surface processes
Human-produced emissions
Hydrologic cycle
Soil moisture and temperature
Realistic geography
Marine ecosystems
Ocean currents, temperature and salinity
Surface winds
Sea ice
Vertical overturning
Ocean bottom topography
Other components
• Atmospheric chemistry
• Evaporation
• Outgoing heat

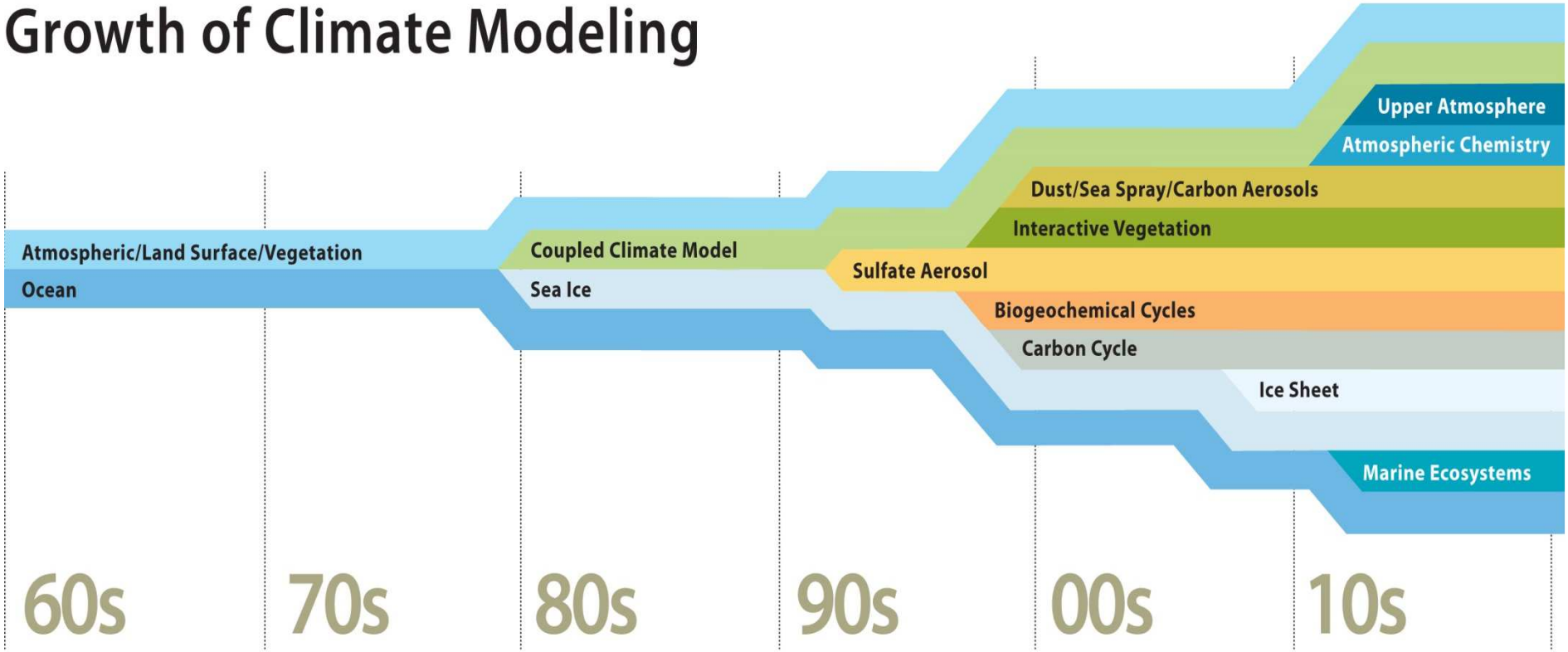
Modeling the Climate System

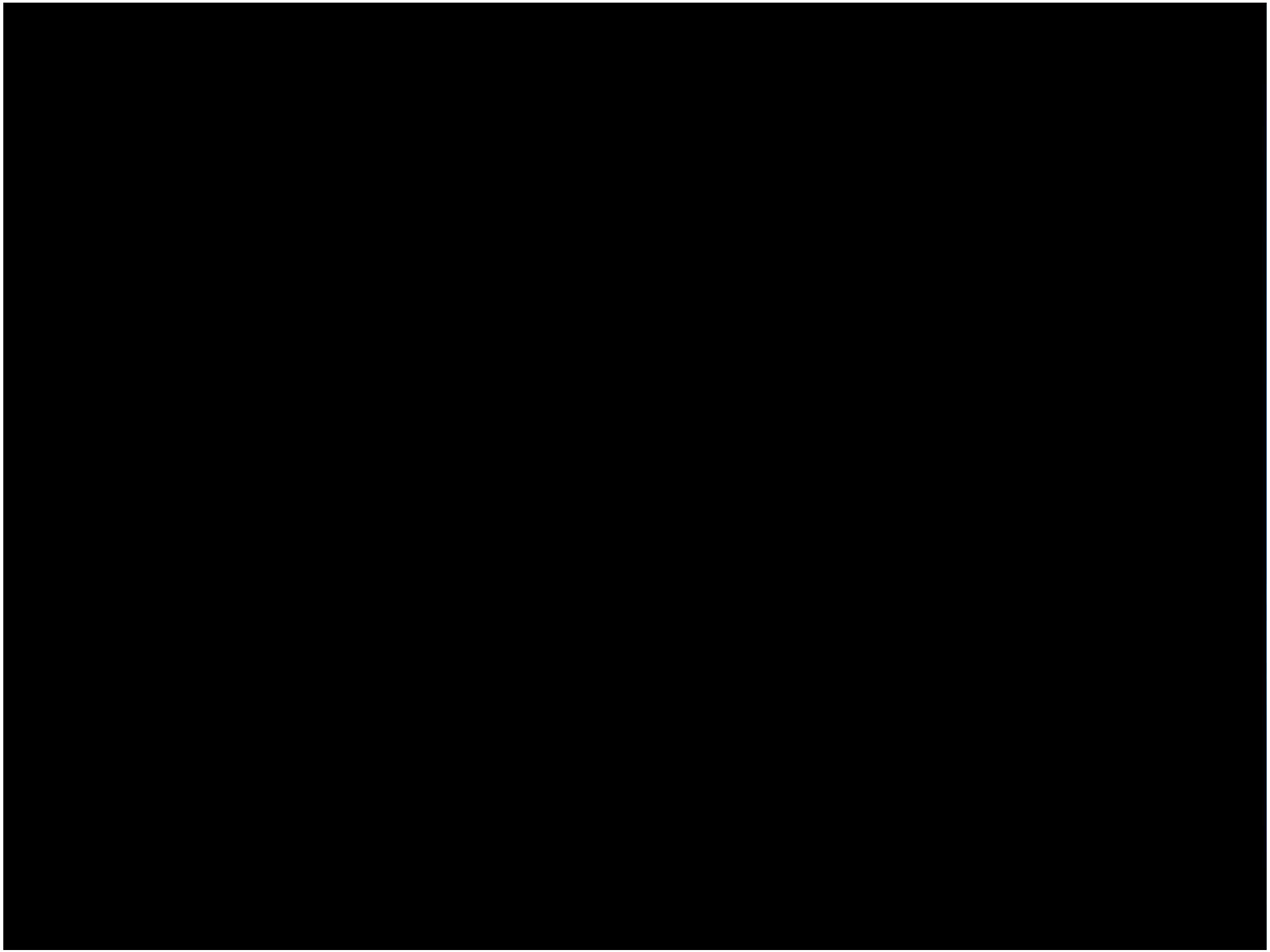



POLES
TROPICS
Greenhouse gases
(CO_2, CH_4, H_2O_v)
Solar radiation
Back radiation
Precipitation
Evaporation
CO_2
SO_2
Heat
Wind
Ice sheet
Sea ice
Carbon production
Upwelling
Weathering
River runoff
Sea level
CO_2
Carbon burial
Deep water
Plate motion
Uplift
Spreading
Subduction
90°
Latitude
0°
CAUSES
(external forcing)
CLIMATE SYSTEM
(internal interactions)
CLIMATE VARIATIONS
(internal responses)
Changes in plate tectonics
Changes in Earth's orbit
Changes in Sun's strength
Atmosphere
Vegetation
Ice
Land surface
Ocean
Changes in Atmosphere
Changes in Ice
Changes in vegetation
Changes in Ocean
Changes in land surface


Modelling the Climate System
Incoming Solar Energy
Atmosphere (Temperature, Winds, and Precipitation)
Outgoing Heat Energy
Transition from Solid to Vapor
Evaporative and Heat Energy Exchanges
Stratus Clouds
Cumulus Clouds
Cirrus Clouds
Precipitation Evaporation
Aerosols
Snow Cover
Vegetation and Ecology
Evaporation
Soil Moisture
Human Influences and Land Uses
Stratus Clouds
Lakes and Rivers
Run-off
Sea Ice
Land Surface (Topography and Reflectivity)
Ocean (Currents, Temperature, and Salinity)
Heat and Salinity Exchange
Atmospheric GCM
Atmospheric Model Layers
Marine Biology
Winds and Waves
Land Model
Realistic Geography
Ocean Model Layers
Ocean GCM
Ocean Bottom Topography
Vertical Overturning

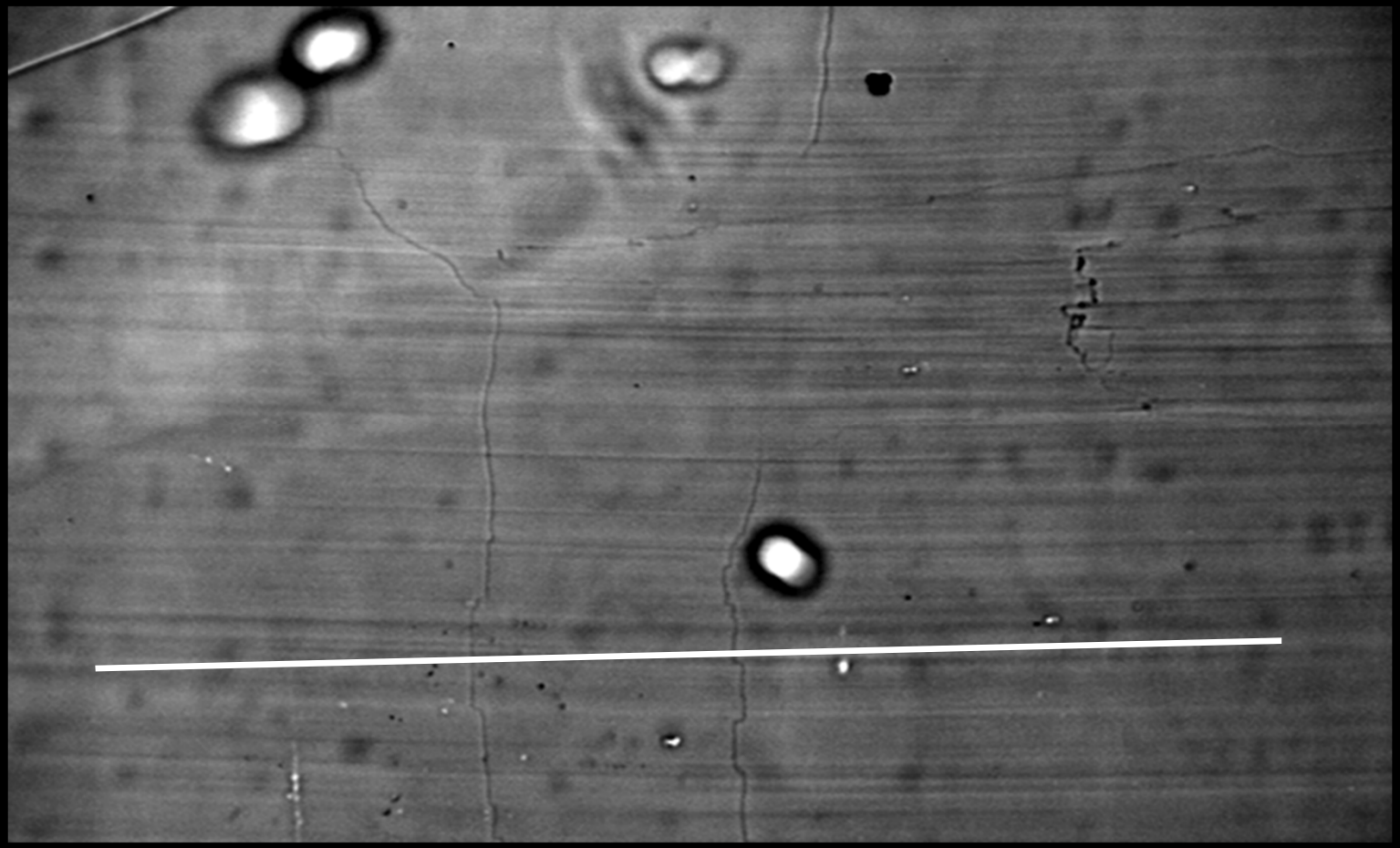
Growth of Climate Modeling



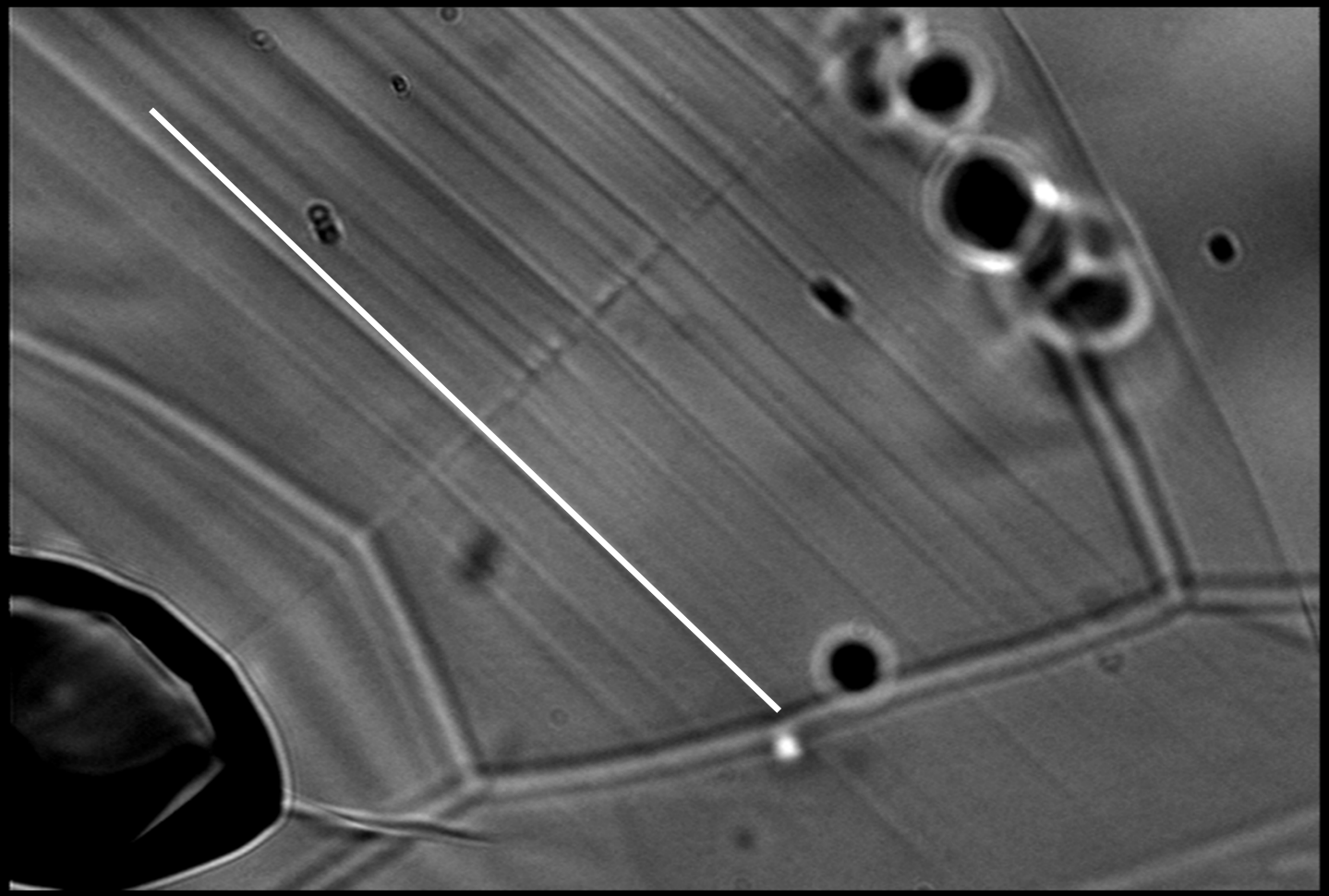


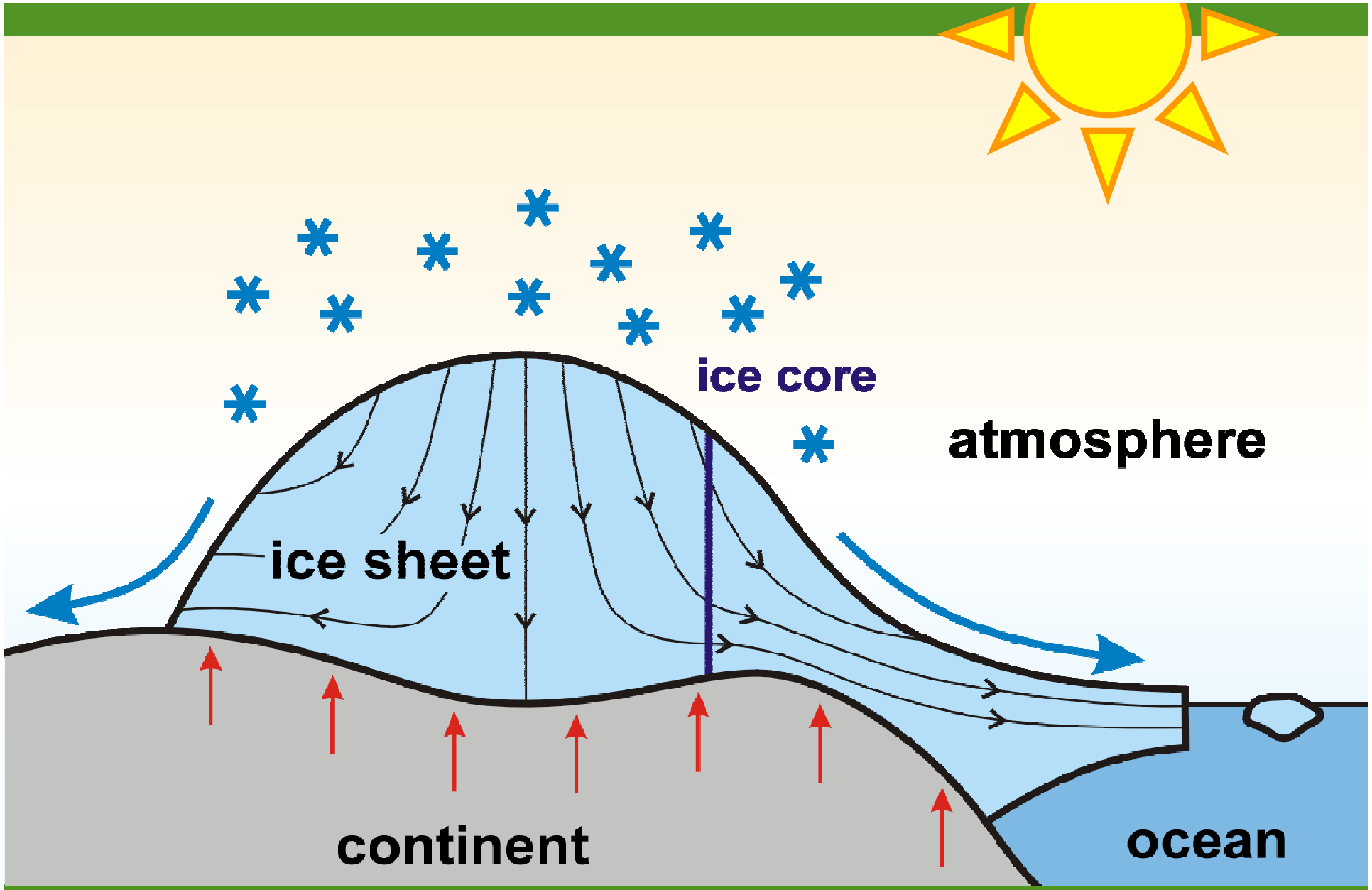
Dome C, 14 Jan 2000, 767m

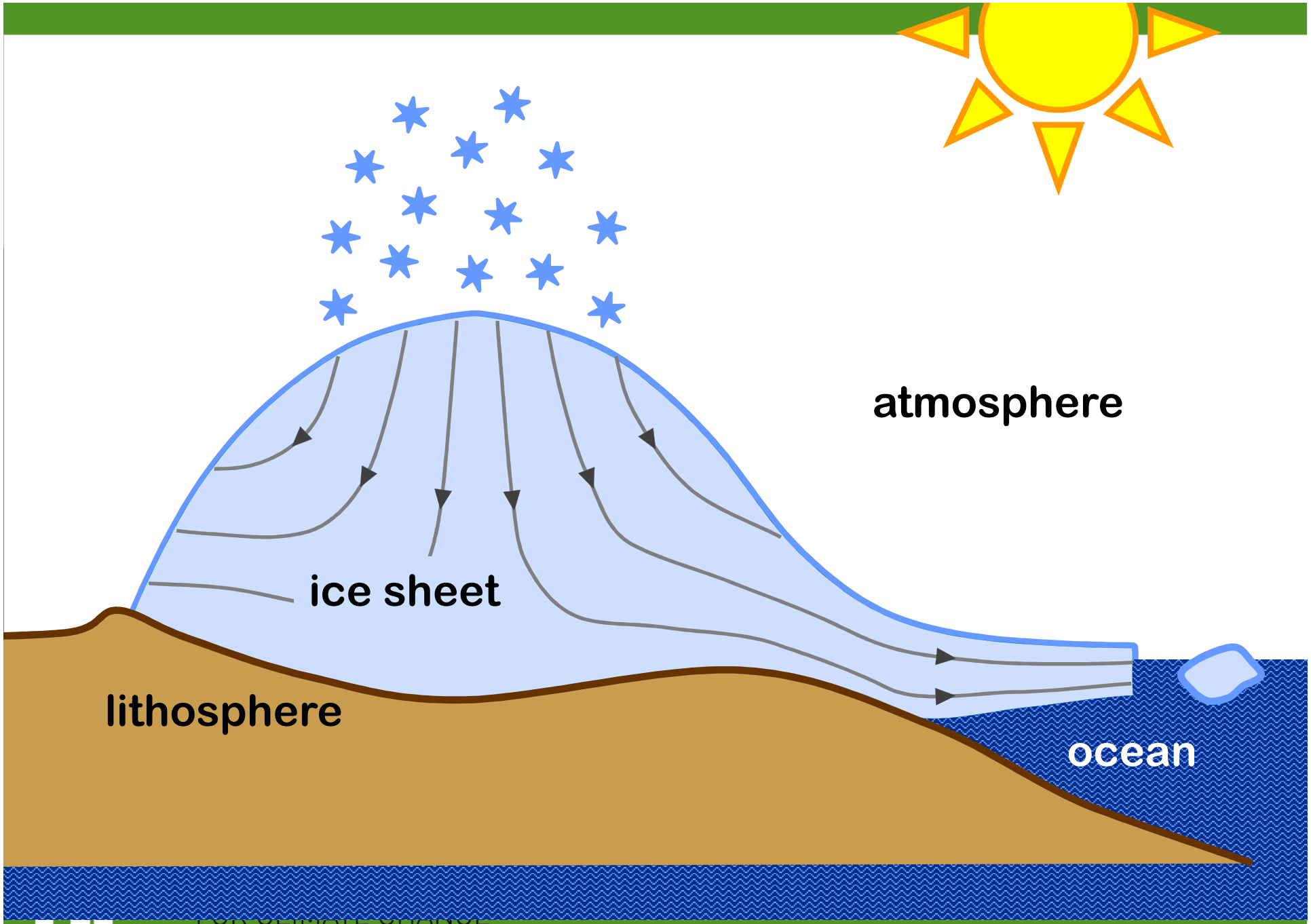
North GRIP, 2418 m

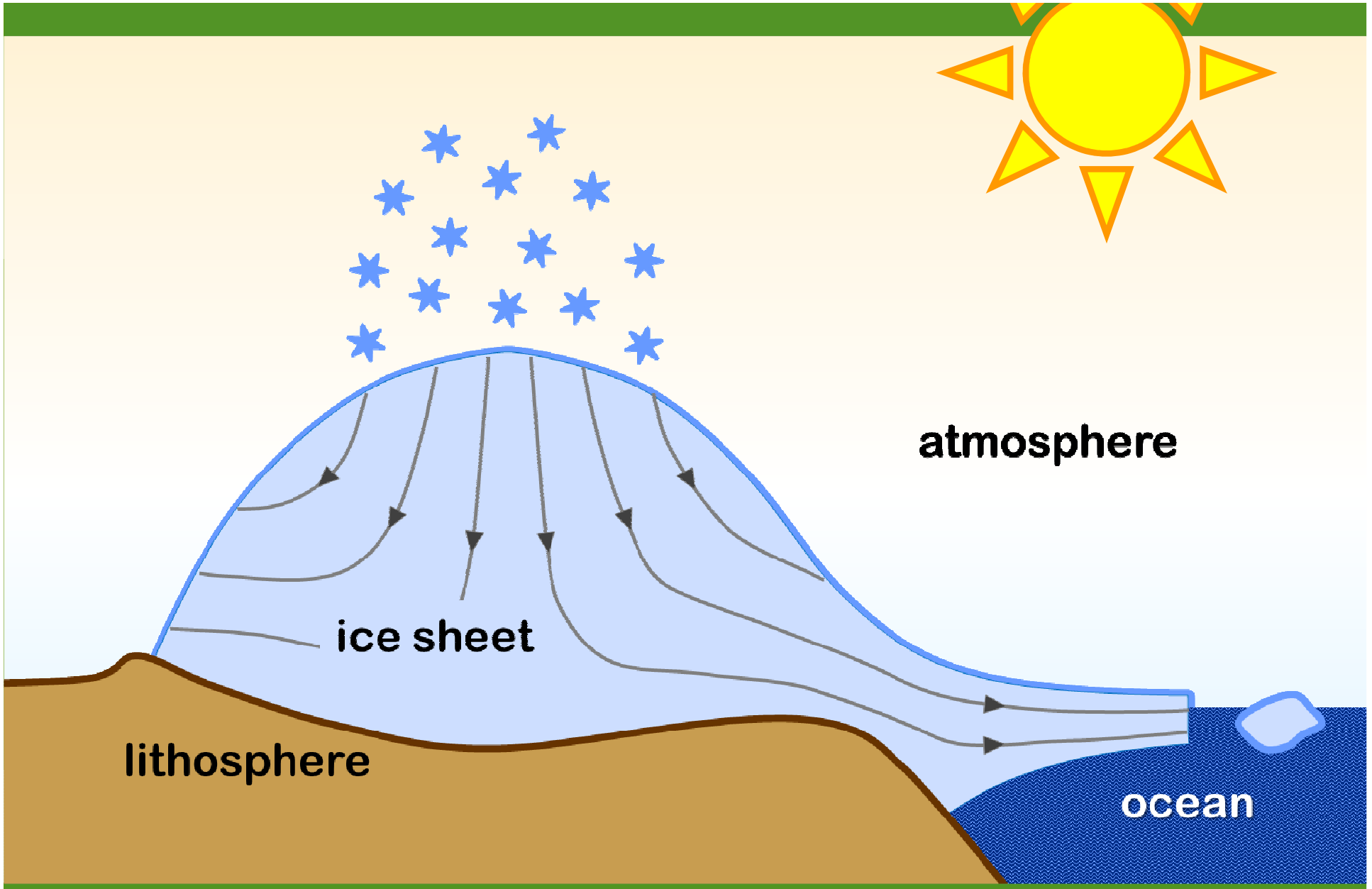


Dome C, 05 Jan 2000, 611m



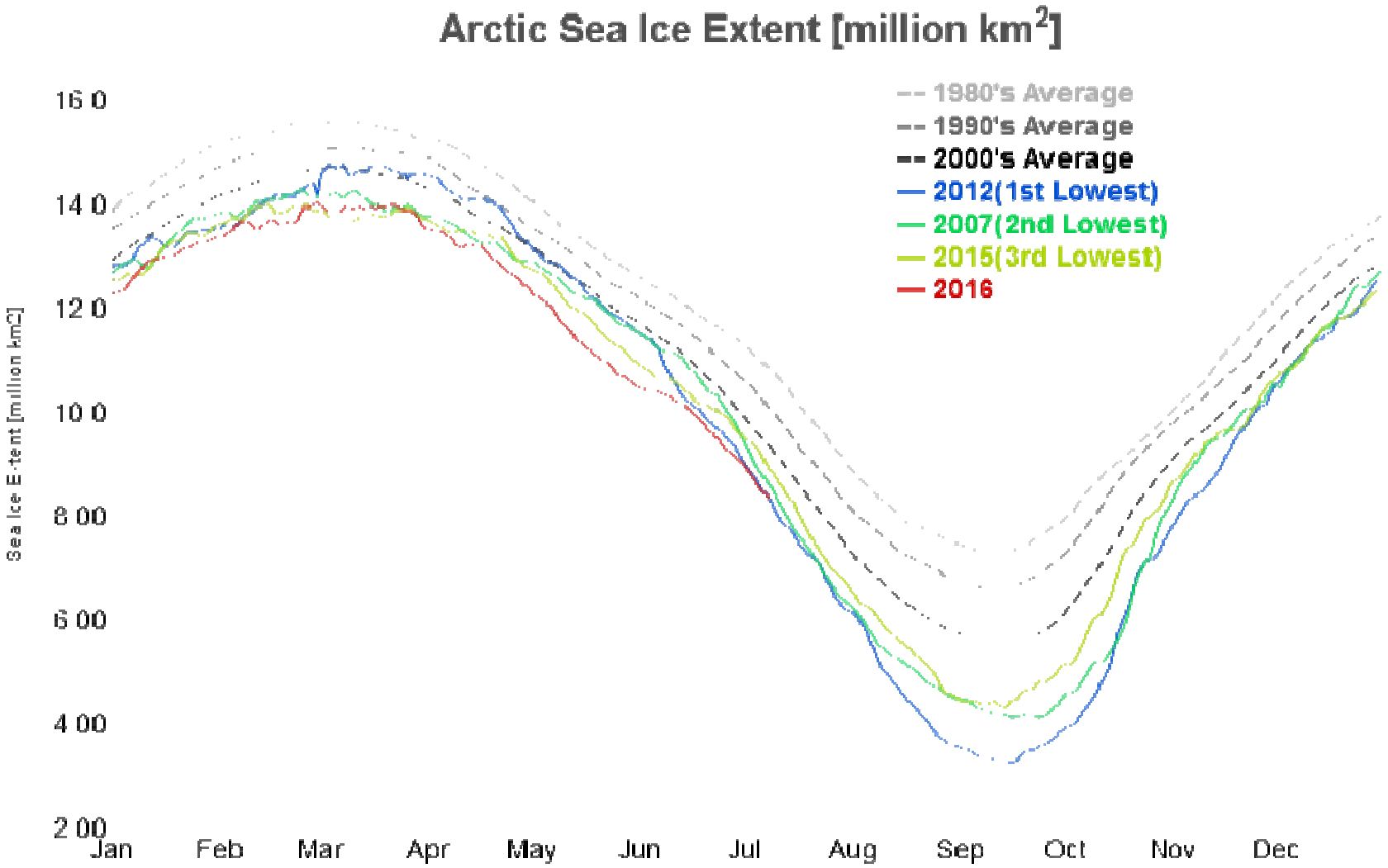

ice core
atmosphere
ice sheet
continent
ocean


atmosphere
ice sheet
lithosphere
ocean


atmosphere
ice sheet
lithosphere
ocean

1980
1990
2000
2010
Arctic Sea Ice Minimum Volume
PIOMAS Vol/1000km³
20
15
10
5
0
16855 km³
16855 km³
1979
1979
Source: http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/
Created by: Andy Lee Robinson http://youtube.com/ahaveland Oct 2014

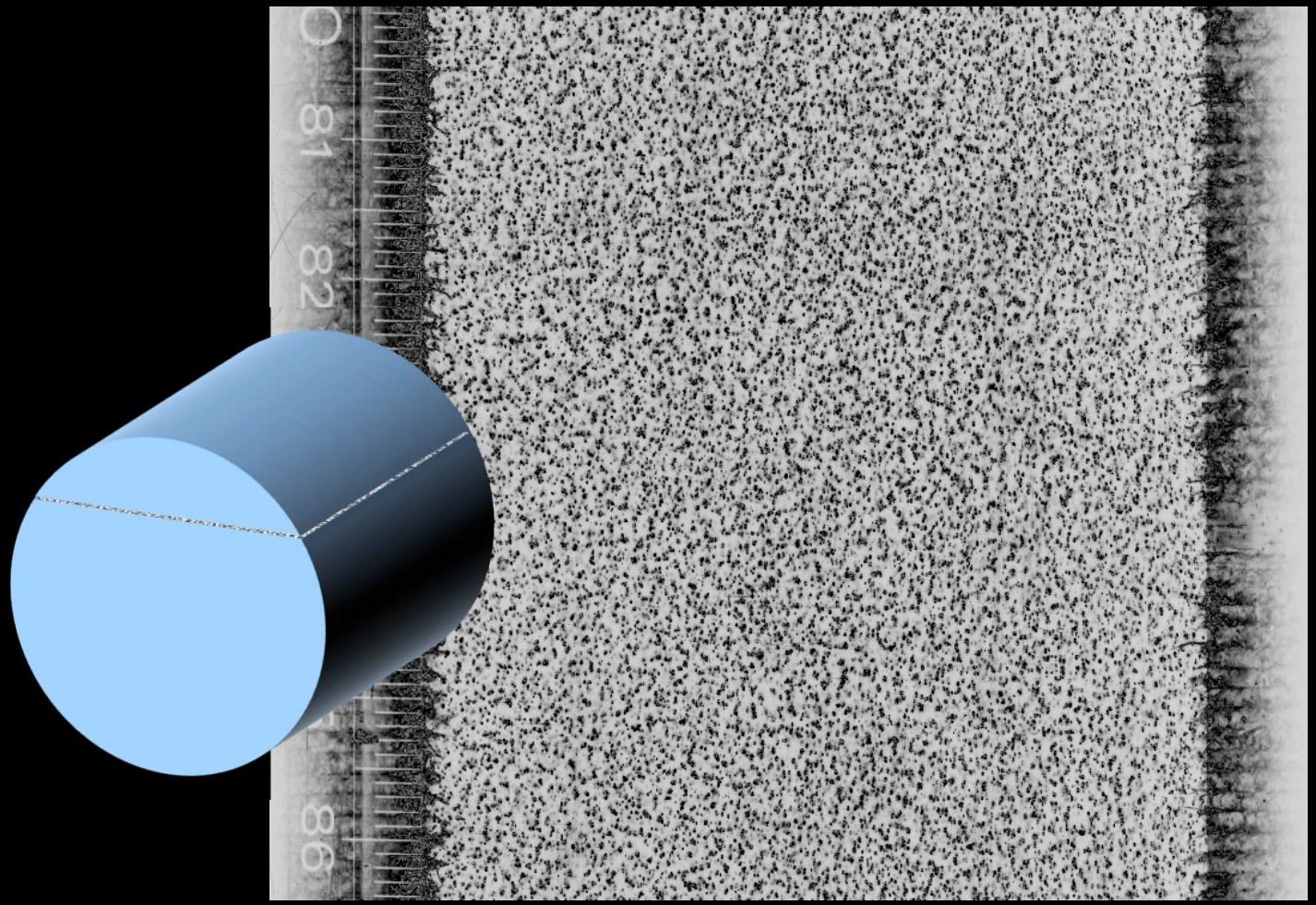
1980
1990
2000
2010
Arctic Sea Ice Minimum Volume
PIOMAS Vol/1000km³
20
15
10
5
0
16855
km³
6810
km³
1979
2014
Source: http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/
Created by: Andy Lee Robinson http://youtube.com/ahaveland Oct 2014



Courtesy NIPR, Arctic Data System
<https://ads.nipr.ac.jp/vishop/vishop-extent.html>

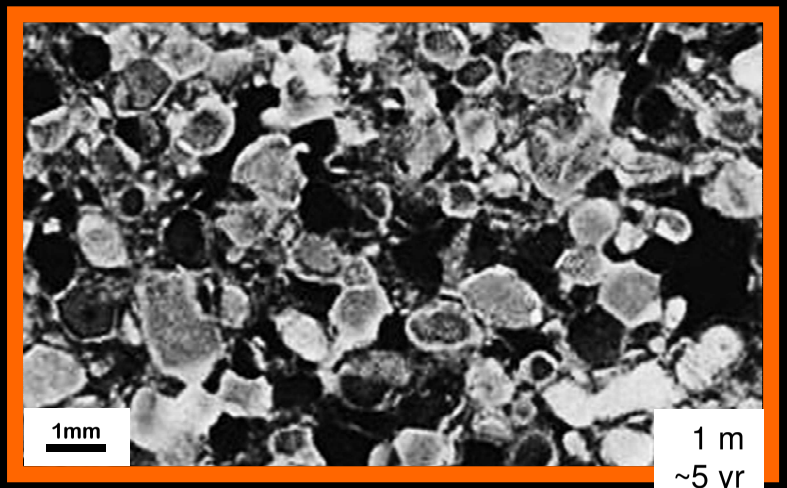
The EDML Deep Ice Core

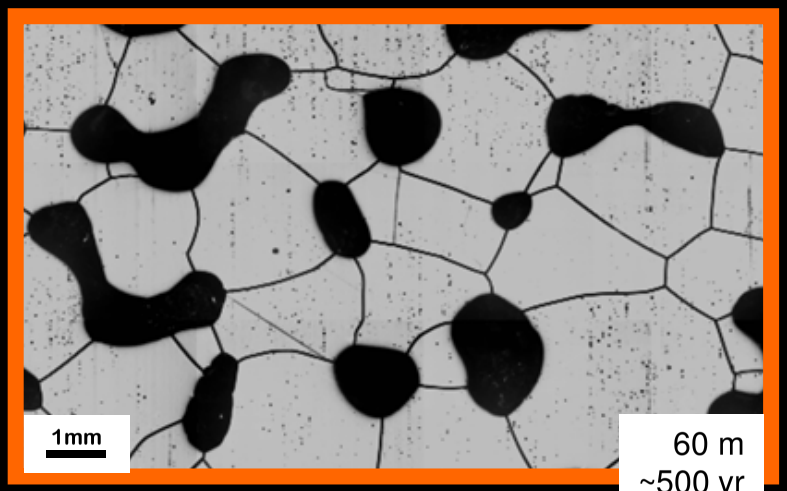
Air bubbles (EDML, 450 m depth)

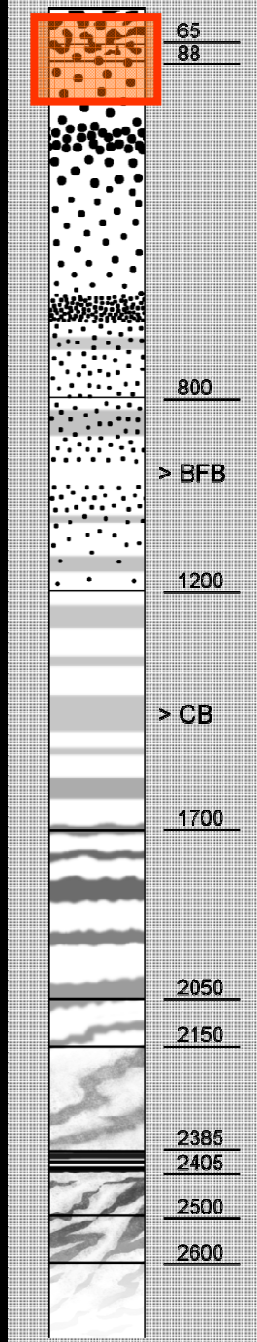


The EDML Deep Ice Core

From snow to bubbly ice and air hydrates



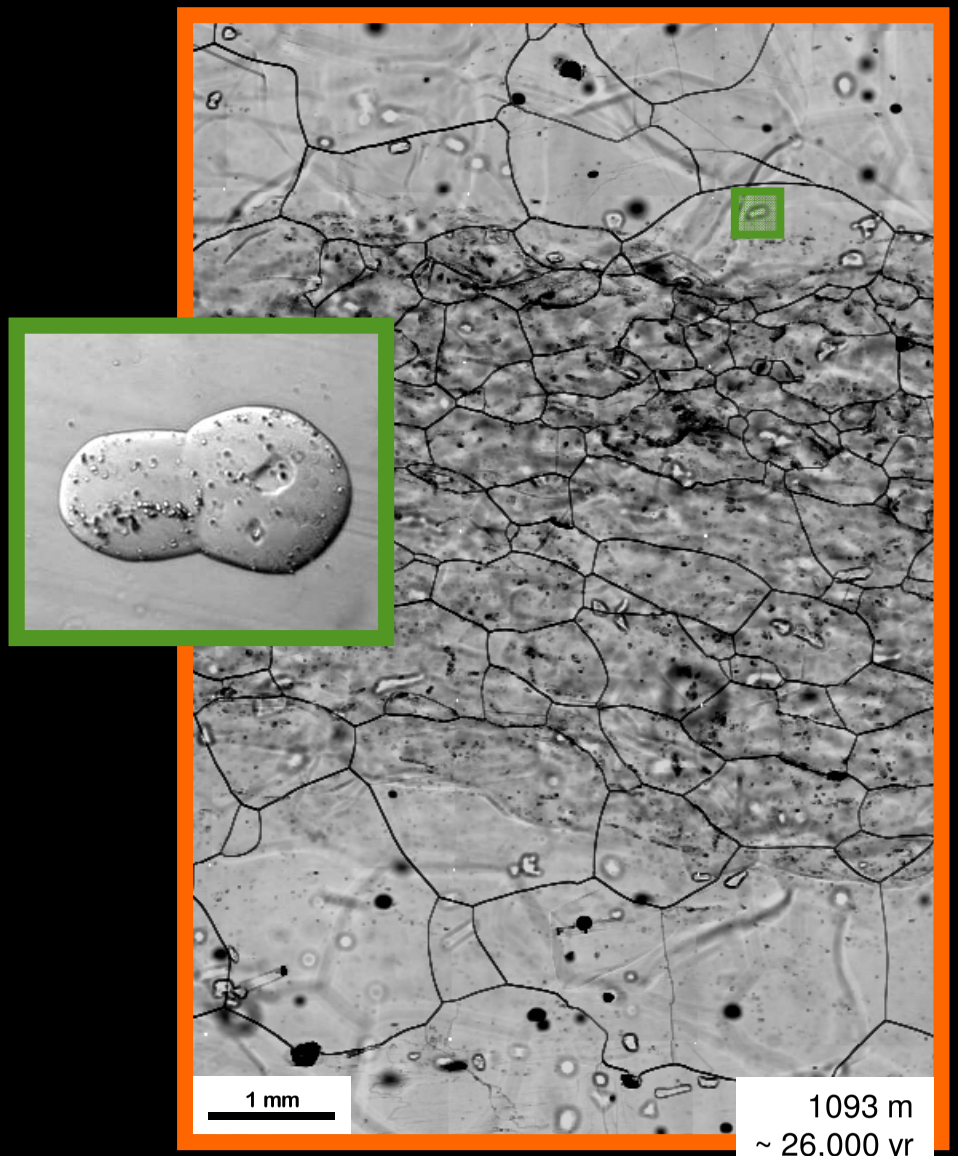


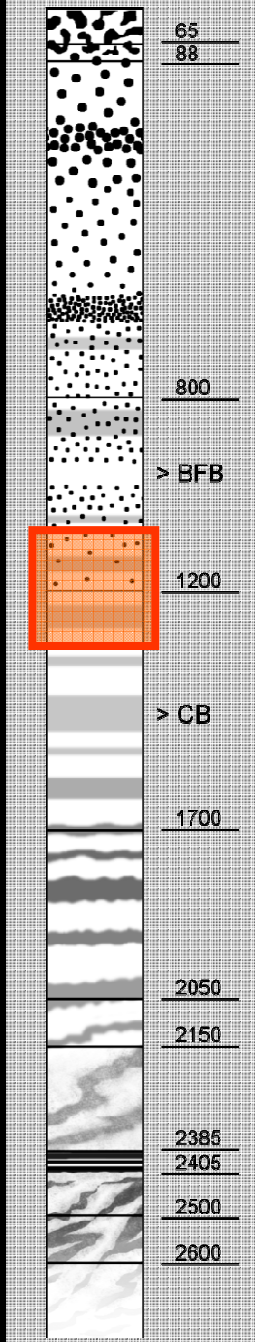


Faria et al. (2010) Polar ice structure and the integrity of ice-core paleoclimate records. *Quat. Sci. Rev.* **29**: 338-351.

The EDML Deep Ice Core

From snow to bubbly ice and air hydrates

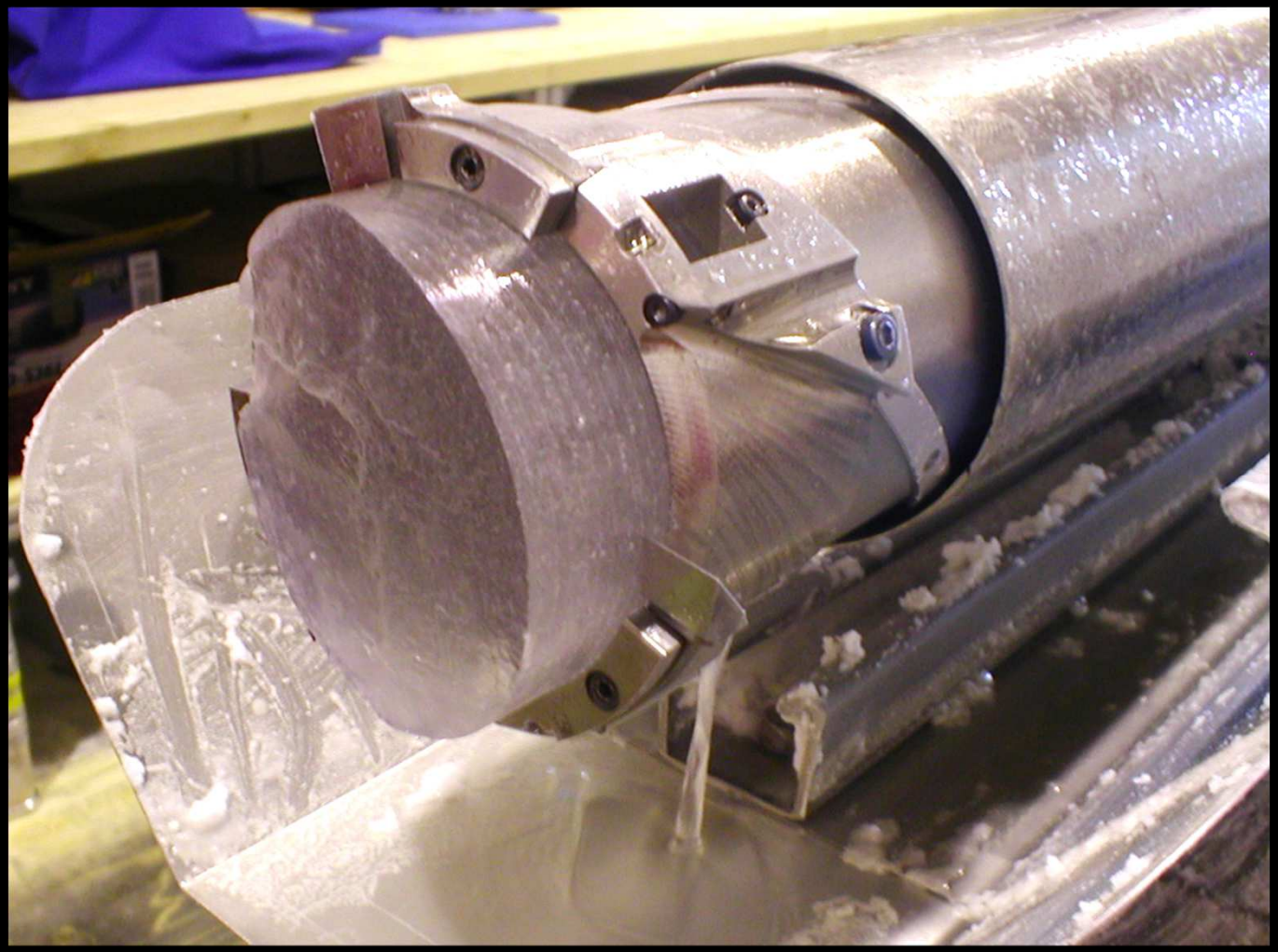




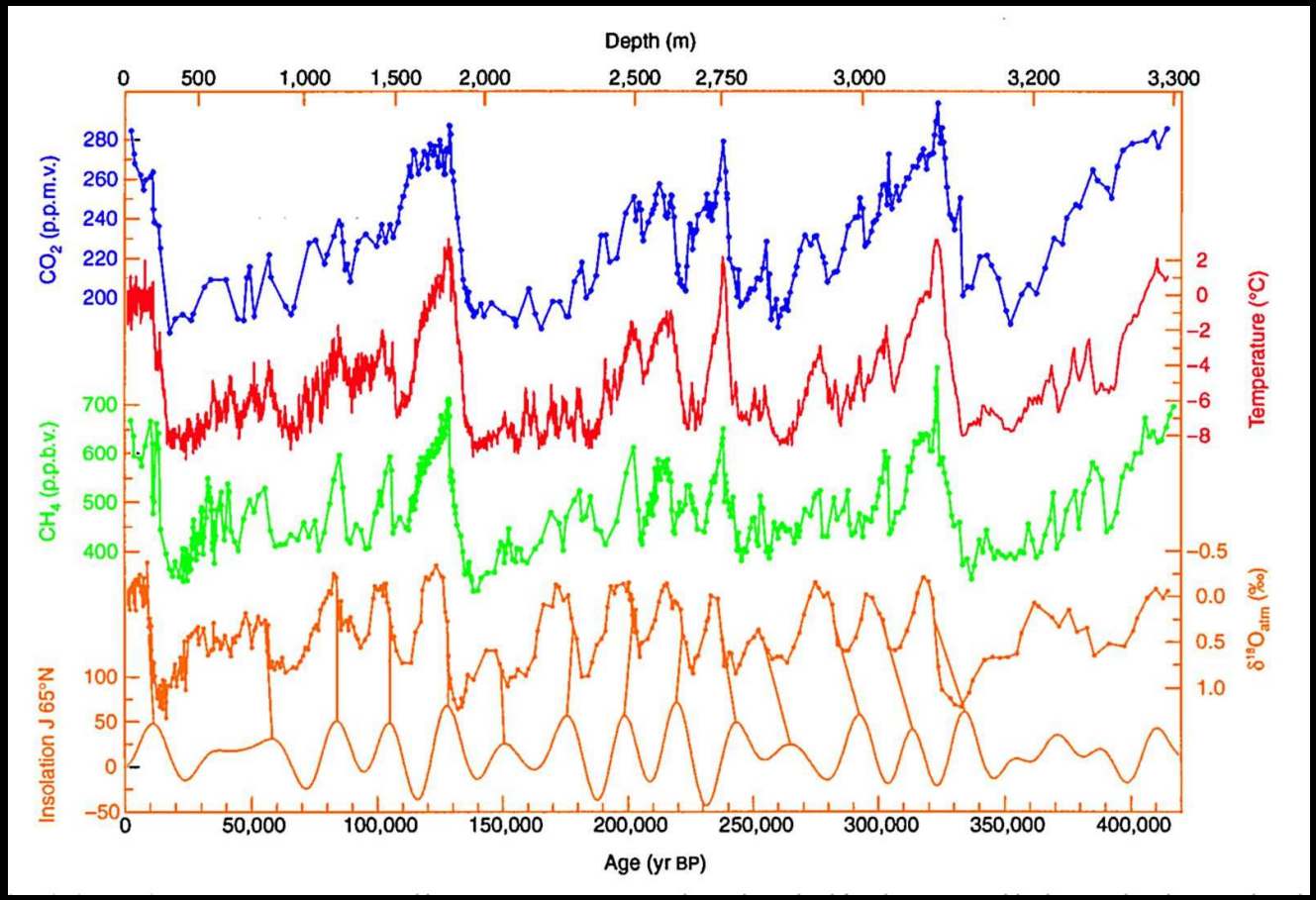
Faria et al. (2010) Polar ice structure and the integrity of ice-core paleoclimate records. *Quat. Sci. Rev.* **29**: 338-351.

The EDML Deep Ice Core

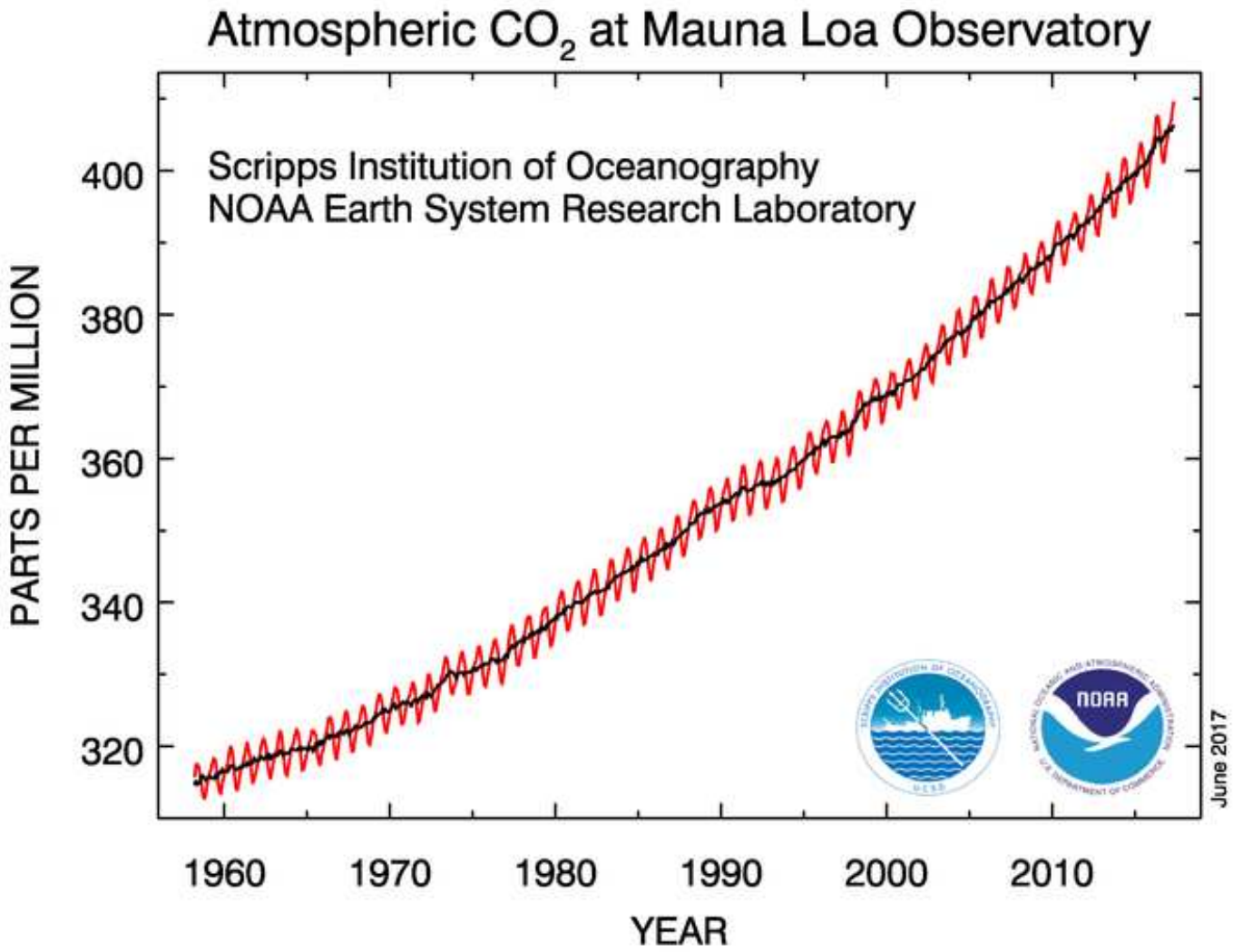
Total length 2774.15 m



3rd: Polar ice sheets are invaluable archives of Earth's past climate



Petit et al. (1999) Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399**:429-436.



May 2017

CO_2: 410 ppm

Trend: 406 ppm

Growth rate: 3 ppm/year