Monitoring polar climate change from space

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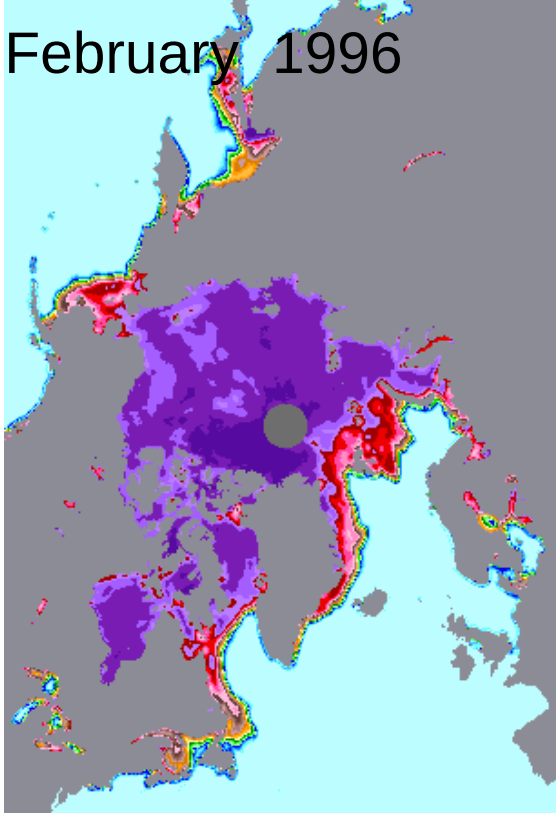
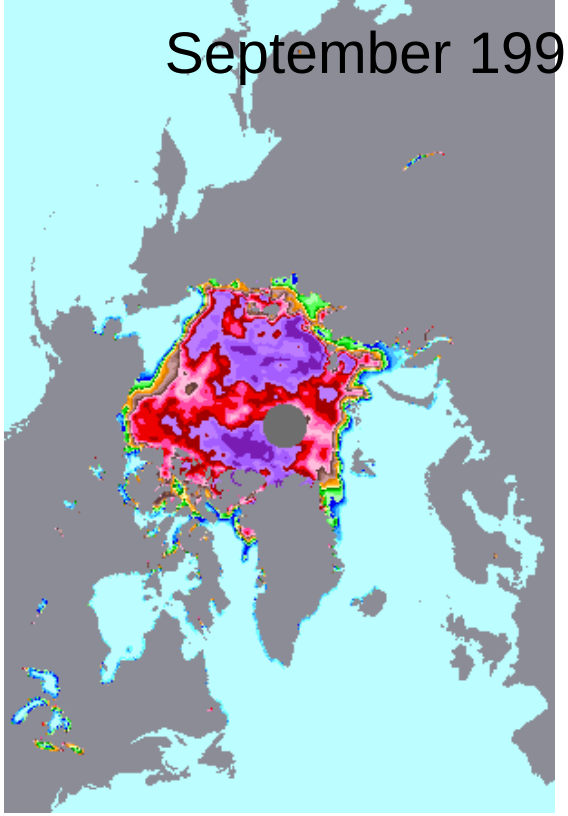
Greenbelt, MD 20771

February 1996



September 1996



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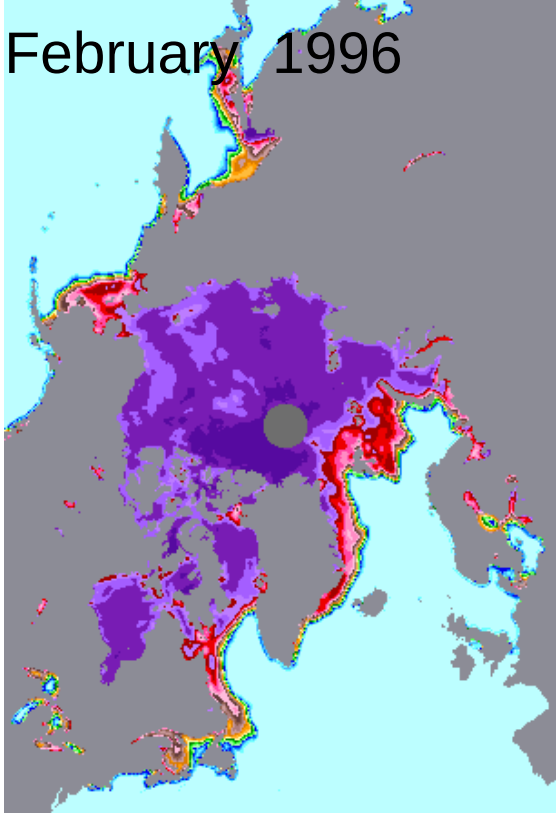

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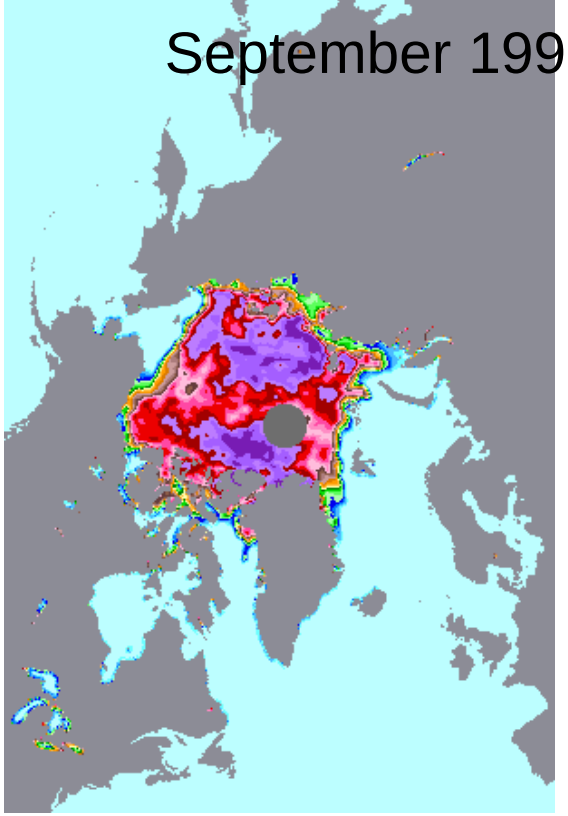

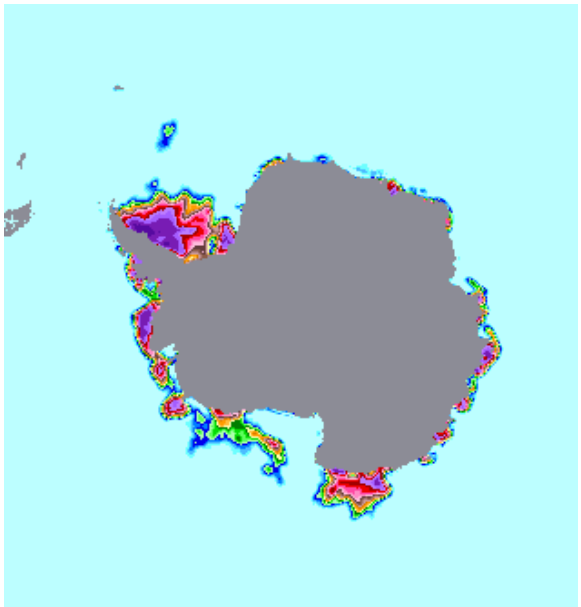

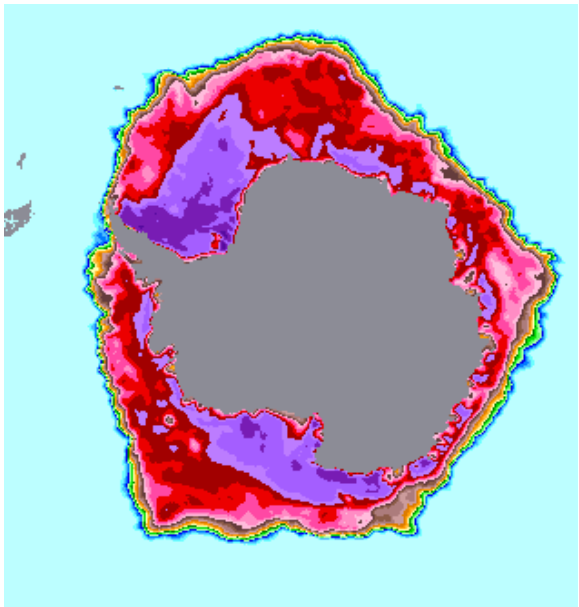

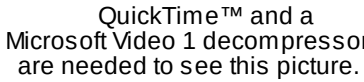
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Microsoft Video 1 decompressor
are needed to see this picture.


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Space-borne Capabilities:

- Visible (Passive: Photography; Active: Laser backscattering)

- Thermal infrared (Passive: Temperature)

- Microwave (Passive: Emission; Active: Radar backscattering)

Space-borne Capabilities:

- Visible (Passive: Photography; Active: Laser backscattering
  - Very high spatial resolution (up to 15 m (Landsat))
  - No measurements during night or under cloudy conditions

- Thermal infrared (Passive: Temperature)
  - Very high spatial resolution
  - No measurements under cloudy conditions

- Microwave (Passive: Emission; Active: Radar backscattering)
  - Passive: Coarse spatial resolution (6.25 - 50 km)
  - Active: High spatial resolution (30 m SAR)
  - No dependence on solar illumination
  - Penetration through clouds (“more or less”)
  - Passive: Daily to twice-daily global coverage
  - Capability to retrieve sub-surface information

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The length of microwave observations and their continuous coverage make them the primary data source for climate studies of sea ice

Some microwave fundamentals:

Every body (and everybody) is emitting radiation at a frequency spectrum depending on its temperature (blackbody radiation)

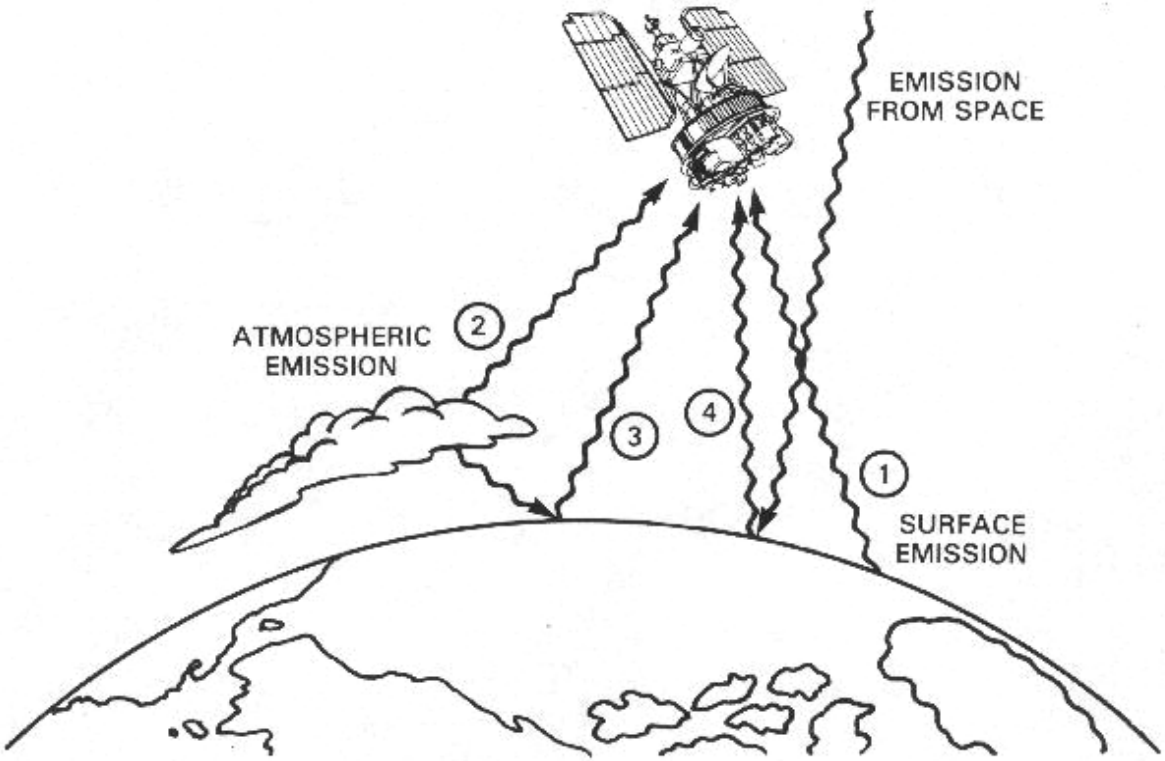
- Sun (T = 6000 K): peak in visible range
- Earth (T=280 K): peak in infrared range

Microwave range is in far end of the spectrum

Most objects are not perfect emitters (blackbodies)

→ Emissivity (between 0 and 1)

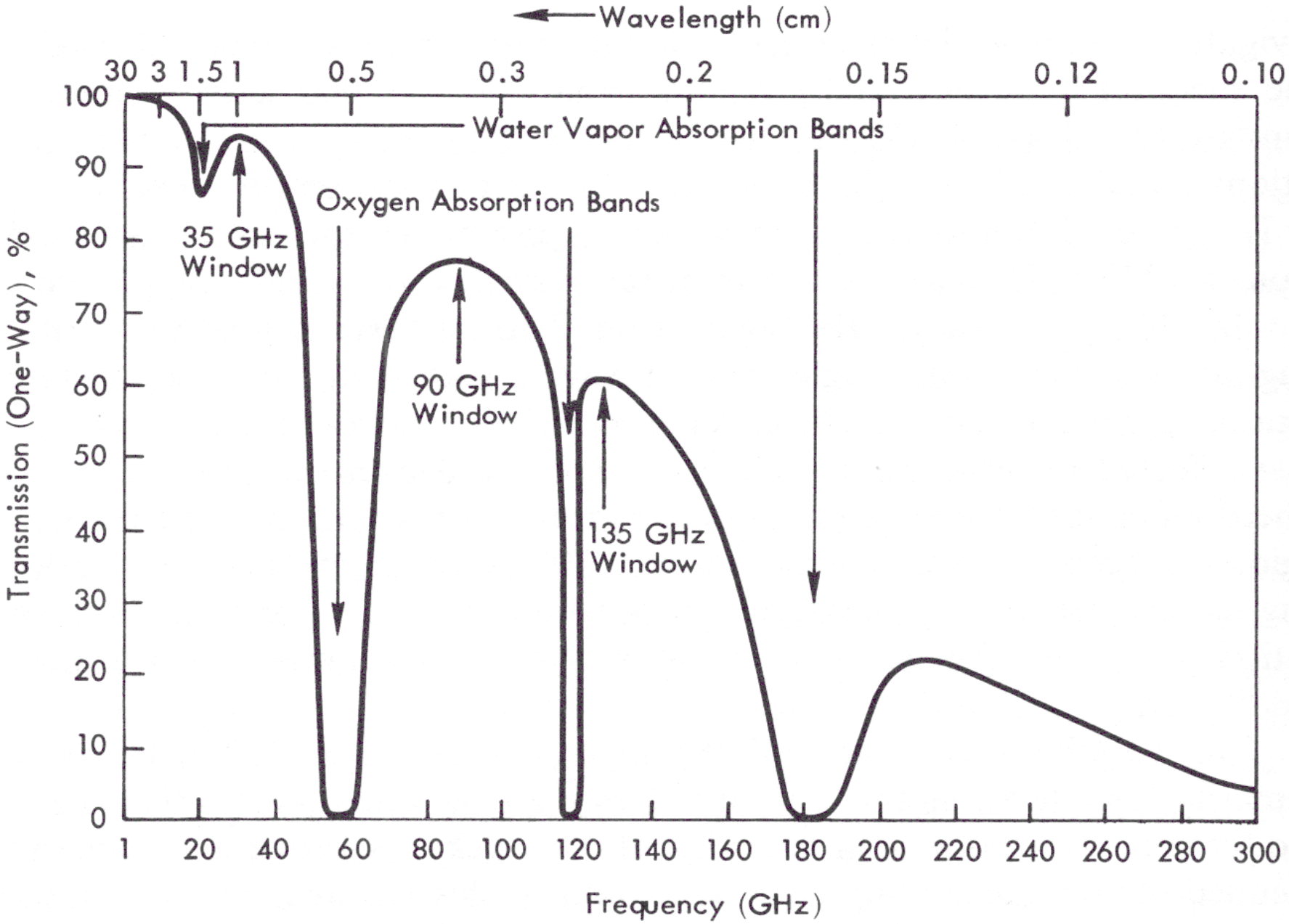
RADIATIVE TRANSFER EQUATION



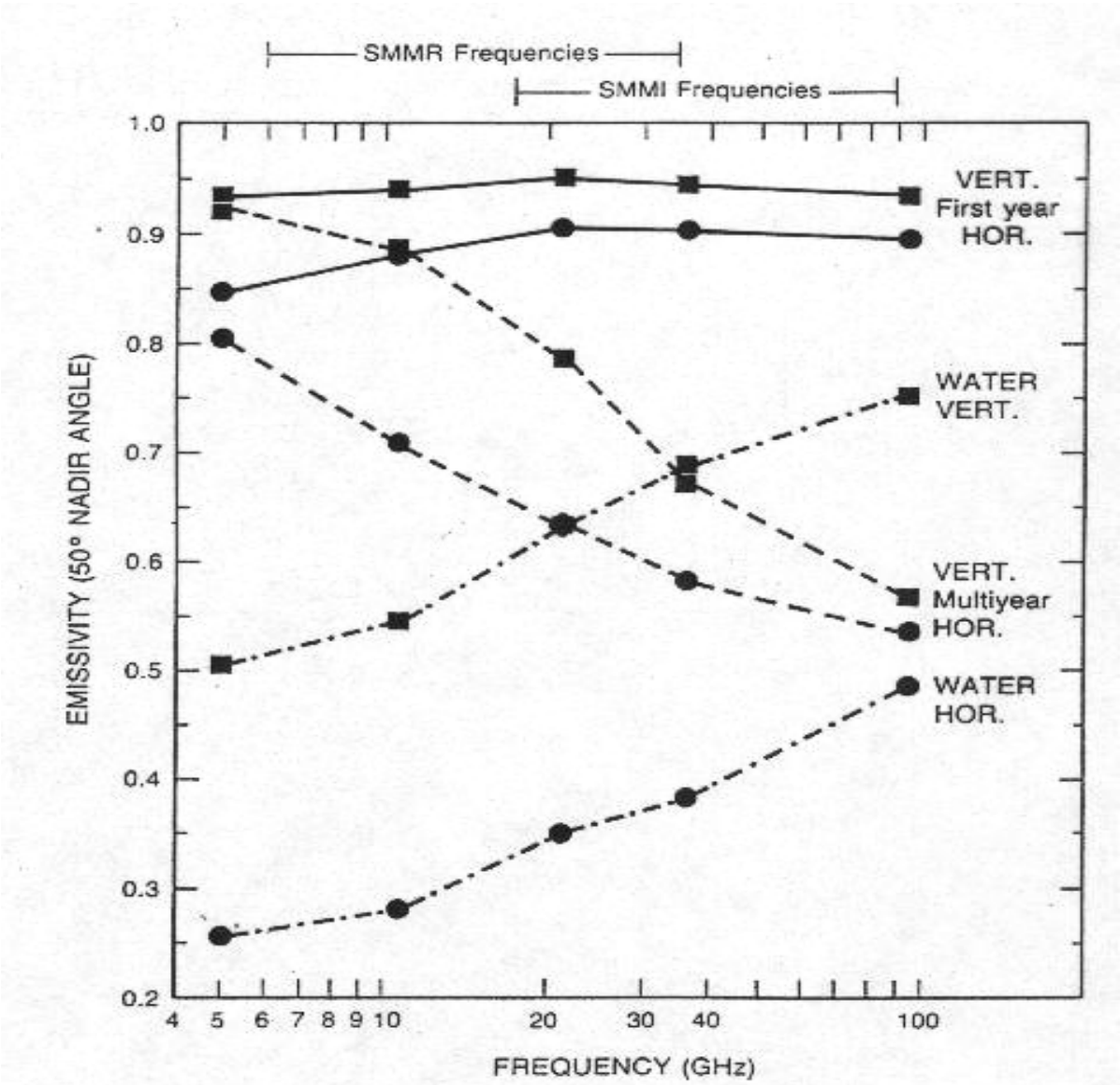
		①		②		③		④
BRIGHTNESS TEMPERATURE	=	(SURFACE EMISSIVITY) x x (PHYS. SURFACE TEMP) x (ATMOSPHERIC ABSORPTION)	+	(UPWELLING ATMOSPHERIC RADIATION)	+	(REFLECTED DOWNWELLING ATMOSPHERIC RADIATION) x x (ATMOSPHERIC ABSORPTION)	+	(REFLECTED SPACE RADIATION) x x (DOUBLE ATMOSPHERIC ABSORPTION)

$$T_B = \varepsilon T_S e^{-\tau} + \underbrace{T_{UP} + (1-\varepsilon) T_{DOWN} e^{-\tau} + (1-\varepsilon) T_{SP} e^{-2\tau}}_{\text{ATMOSPHERIC CORRECTION TERM}}$$

Microwave spectrum



For example: Sea ice



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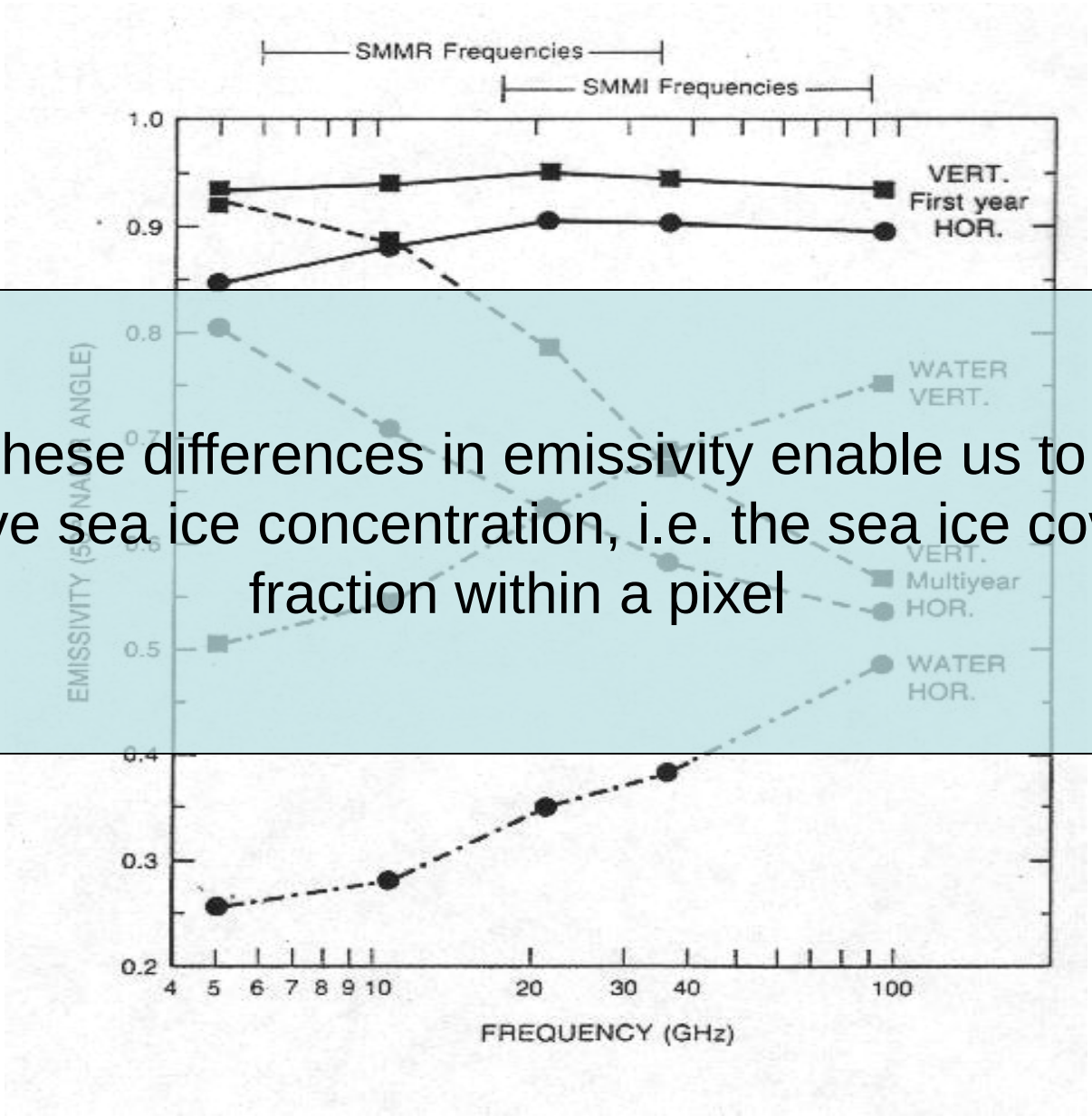
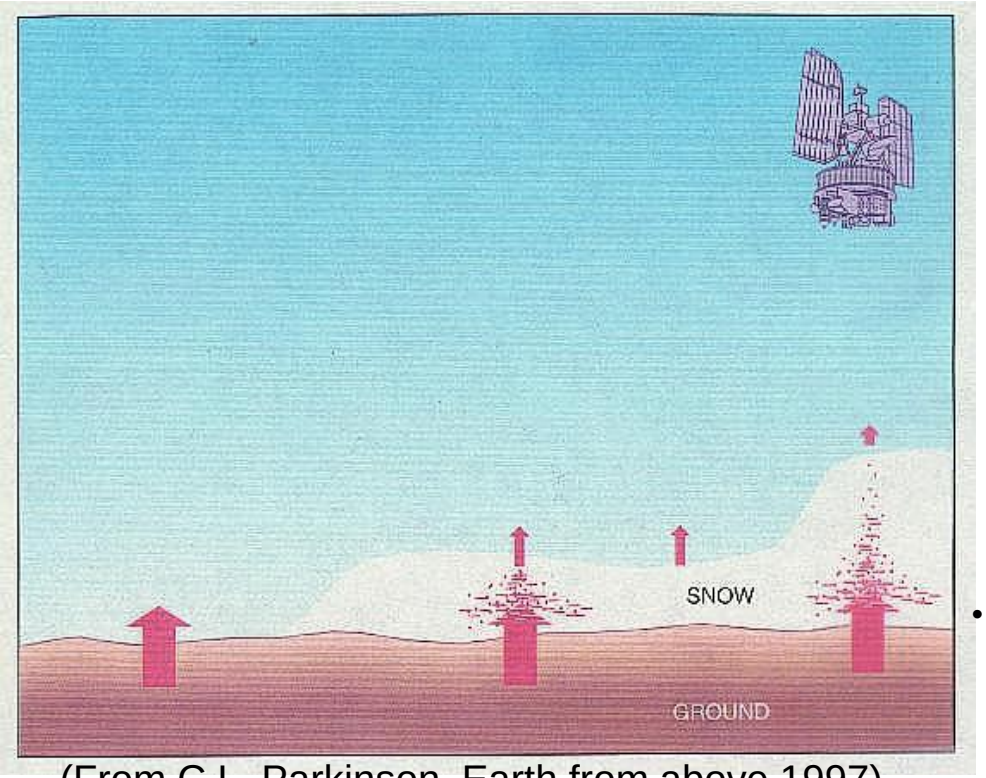


These differences in emissivity enable us to derive sea ice concentration, i.e. the sea ice cover fraction within a pixel

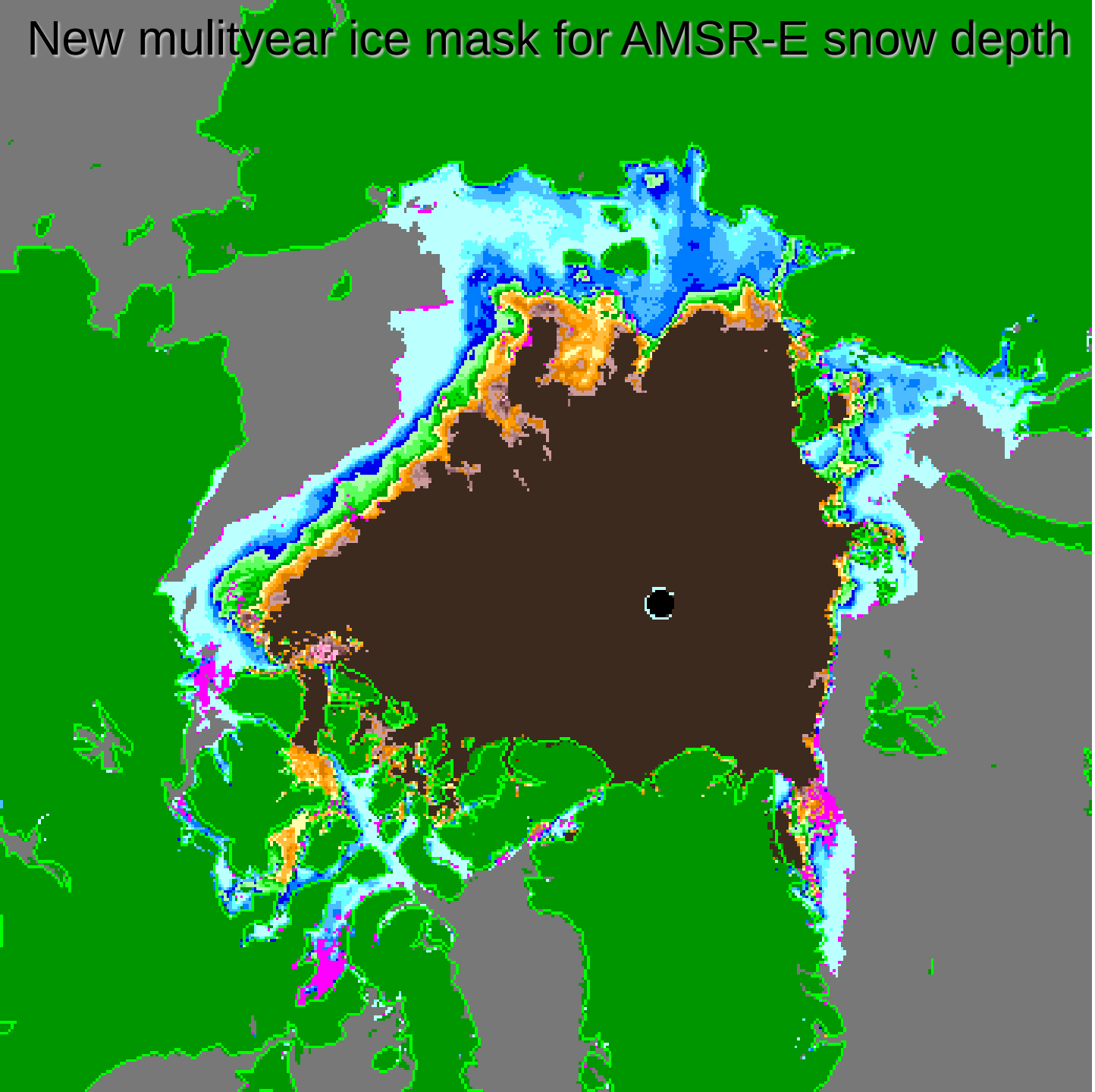
Snow depth on sea ice



(From C.L. Parkinson, Earth from above,1997)

- Idea:
  - Radiation from the ground is scattered by the snow cover.
  - The more snow the more scattering.
  - Scattering efficiency is frequency dependent.
  - $hs = c\,(T_{37GHz} - T_{19GHz})$
- Difficulties:
  - Different terrain forms
  - Scattering varies with snow physical properties (e.g., grain size, density, wetness)

New mulityear ice mask for AMSR-E snow depth



Snow depth product
10/2004 - 9/2005

Land

Open ocean

Multiyear ice

Melt/freeze, Wx

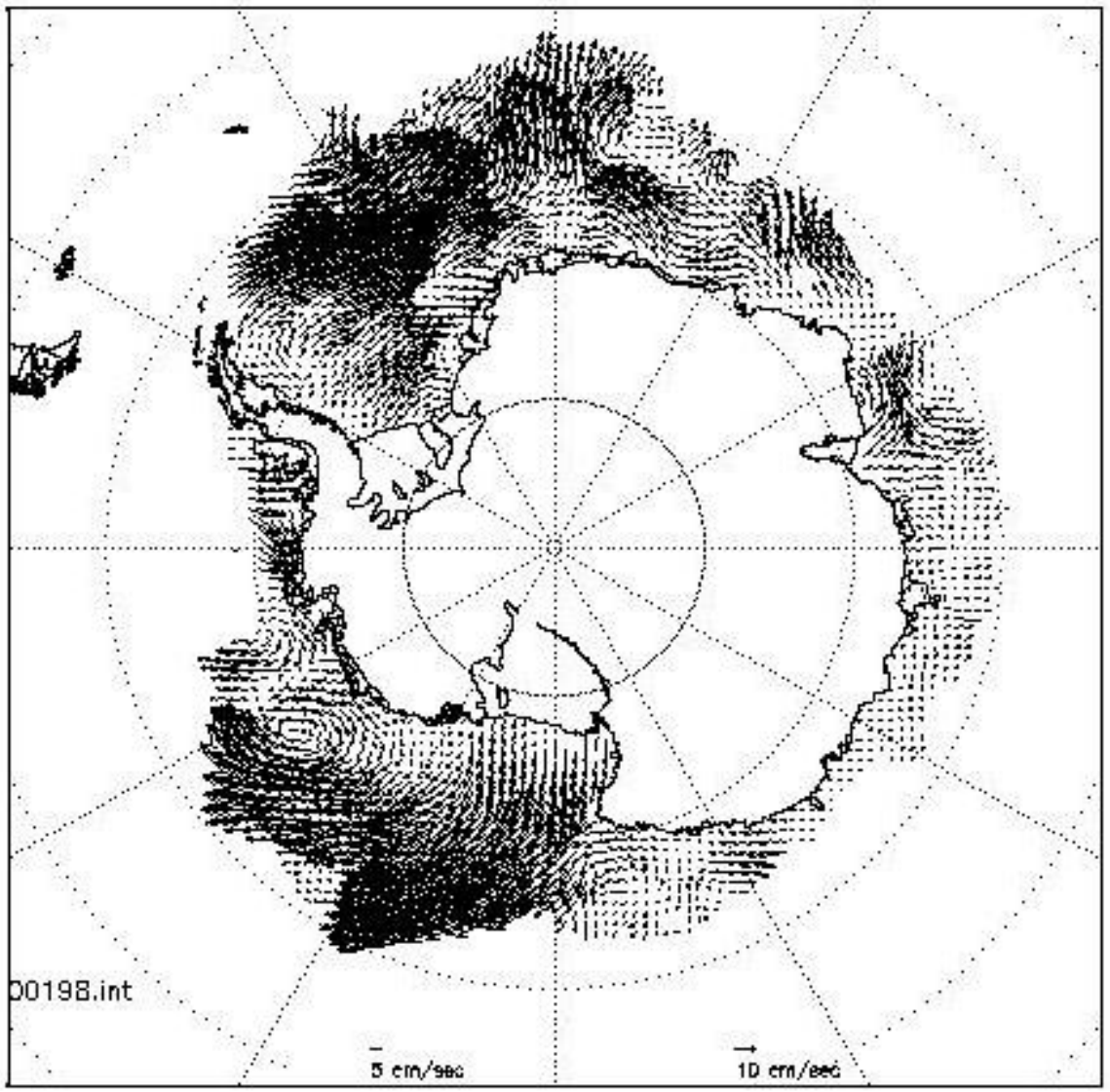
Summer melt

0 10 20 30 40 50

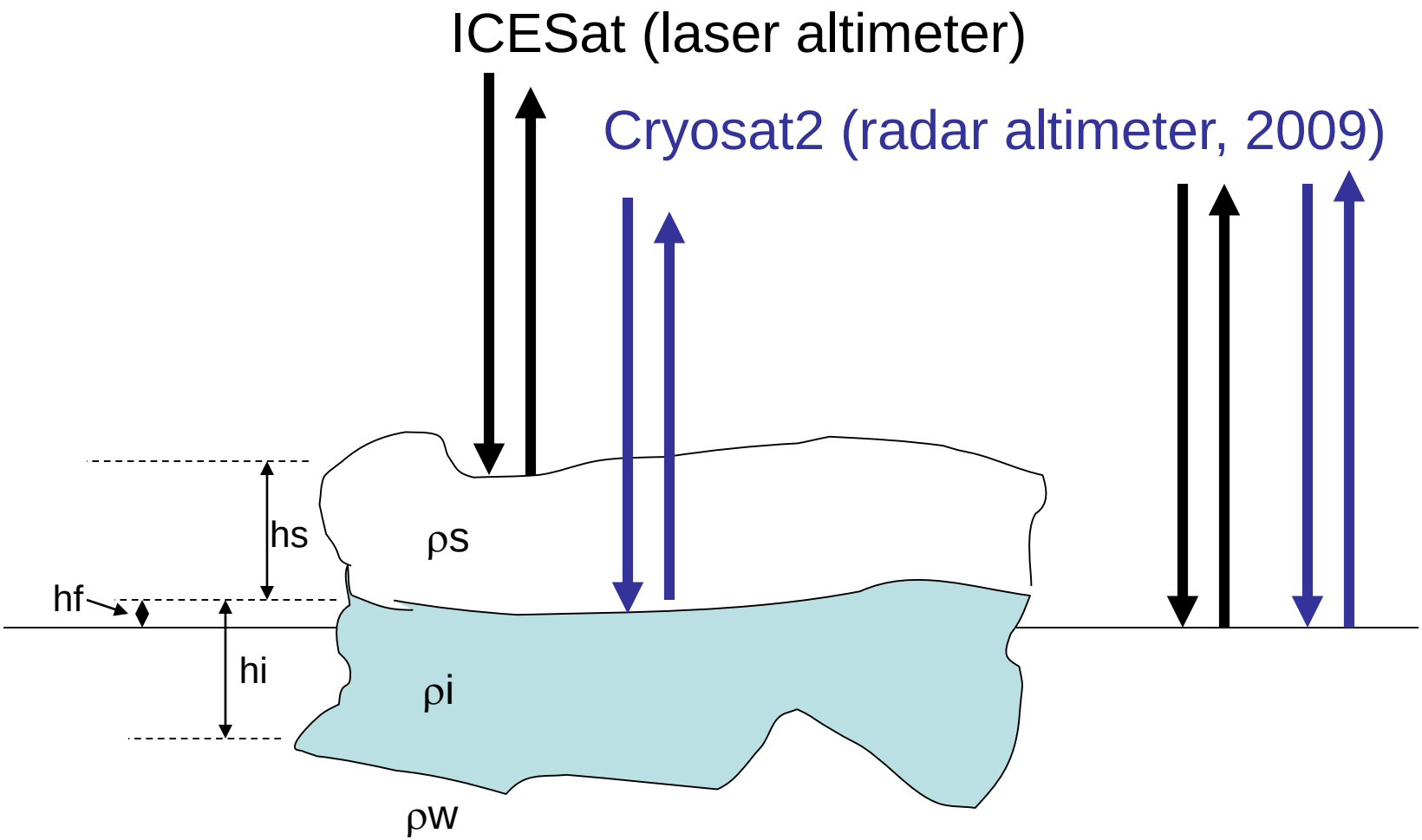
Snow depth [cm]

Other variables derivable from passive microwave data:

- Sea ice type
- Ice temperature
- Melt onset and end
- Sea ice drift

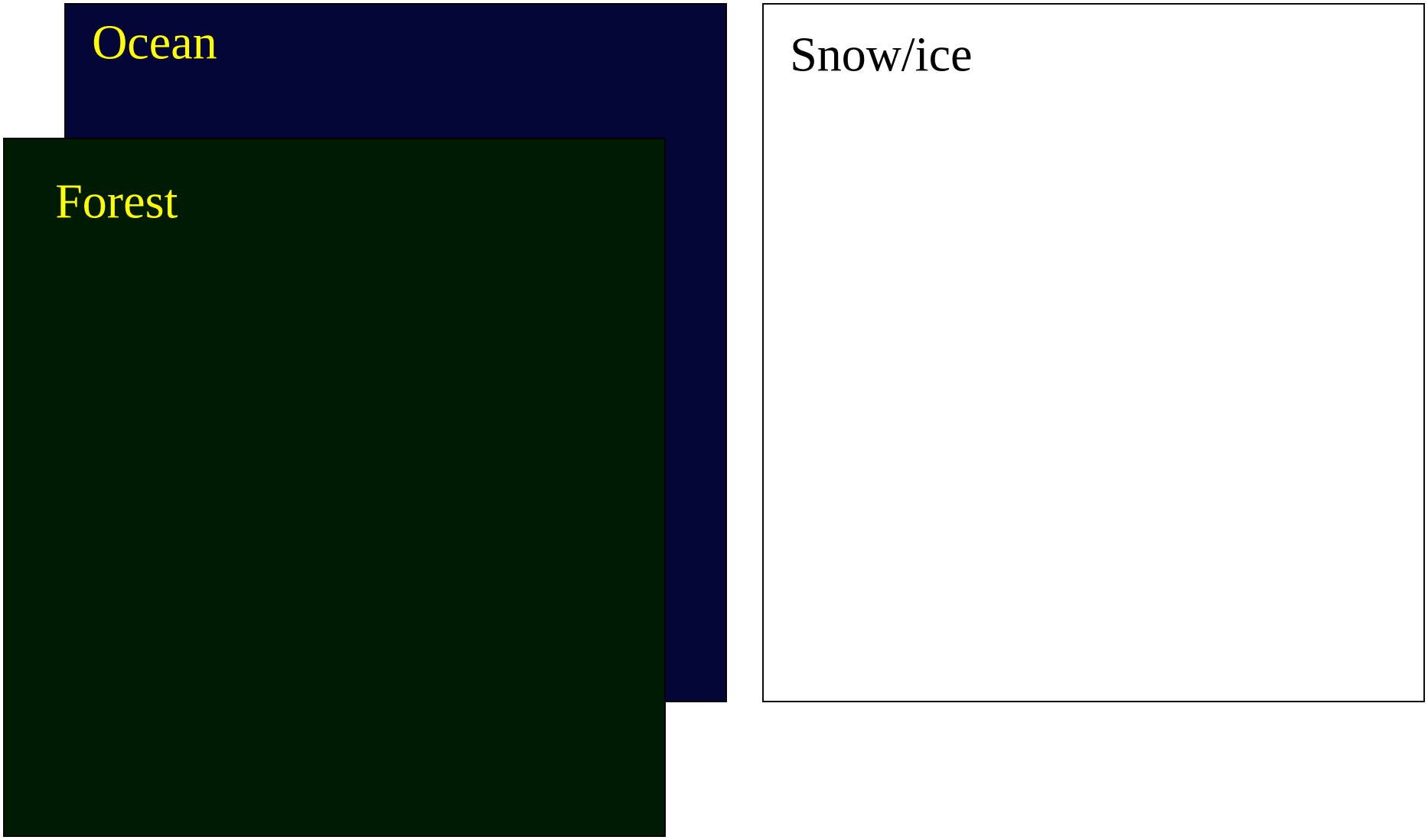


What is missing? The 3rd dimension!



hs = snow depth
hi = ice thickness
hf = freeboard

Importance of sea ice (1):
Global energy balance; Ice/snow albedo feedback

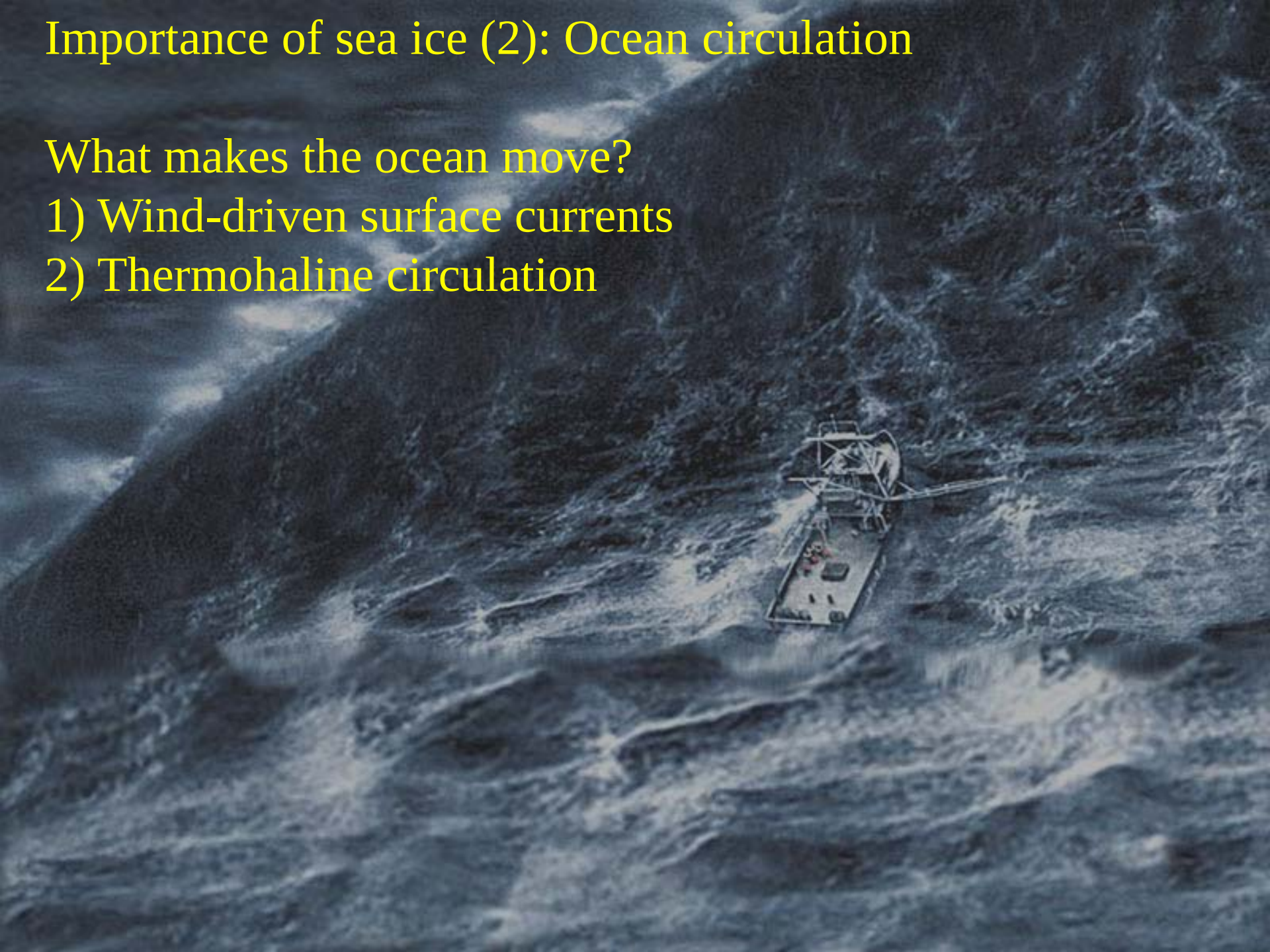


Importance of sea ice (2): Ocean circulation

What makes the ocean move?

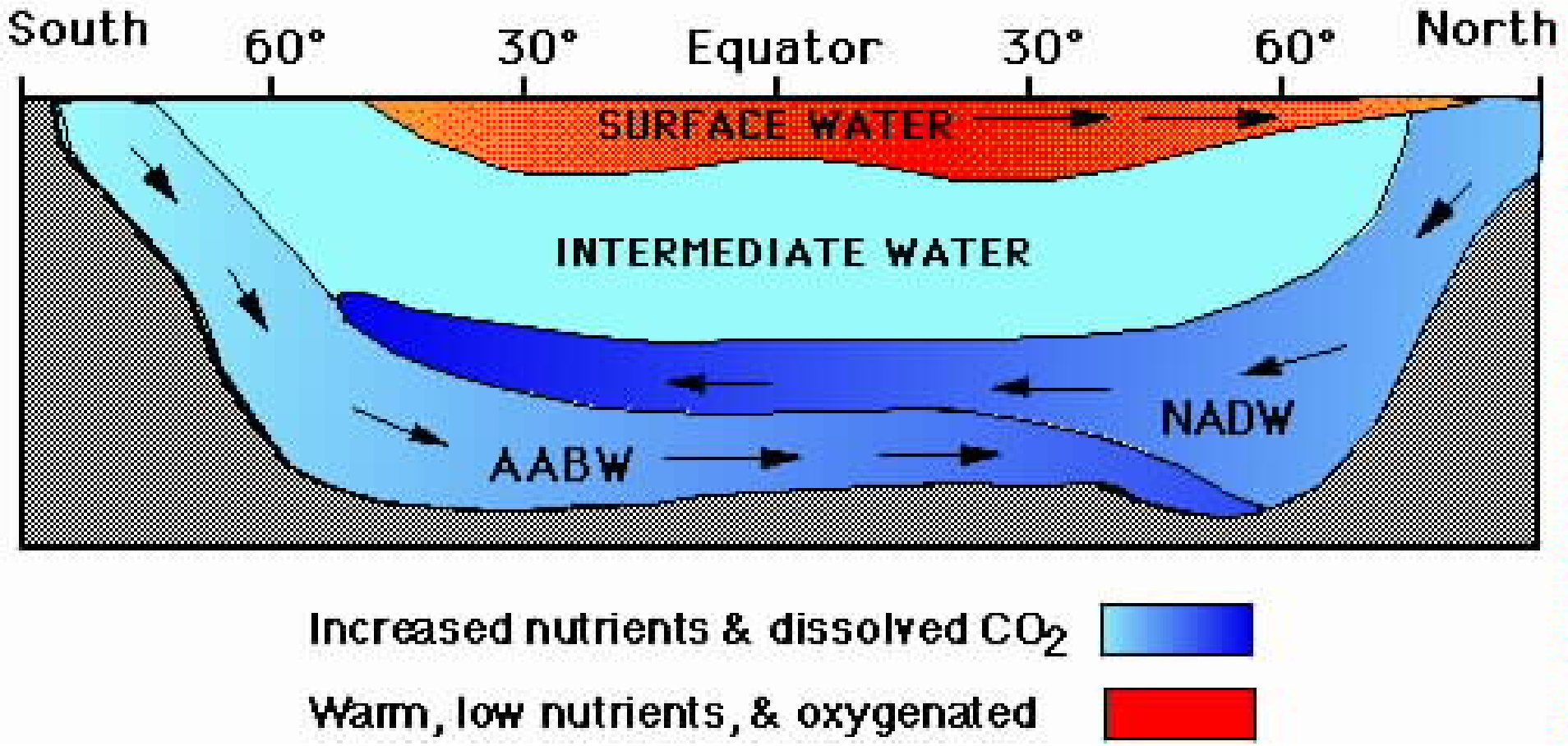
1) Wind-driven surface currents

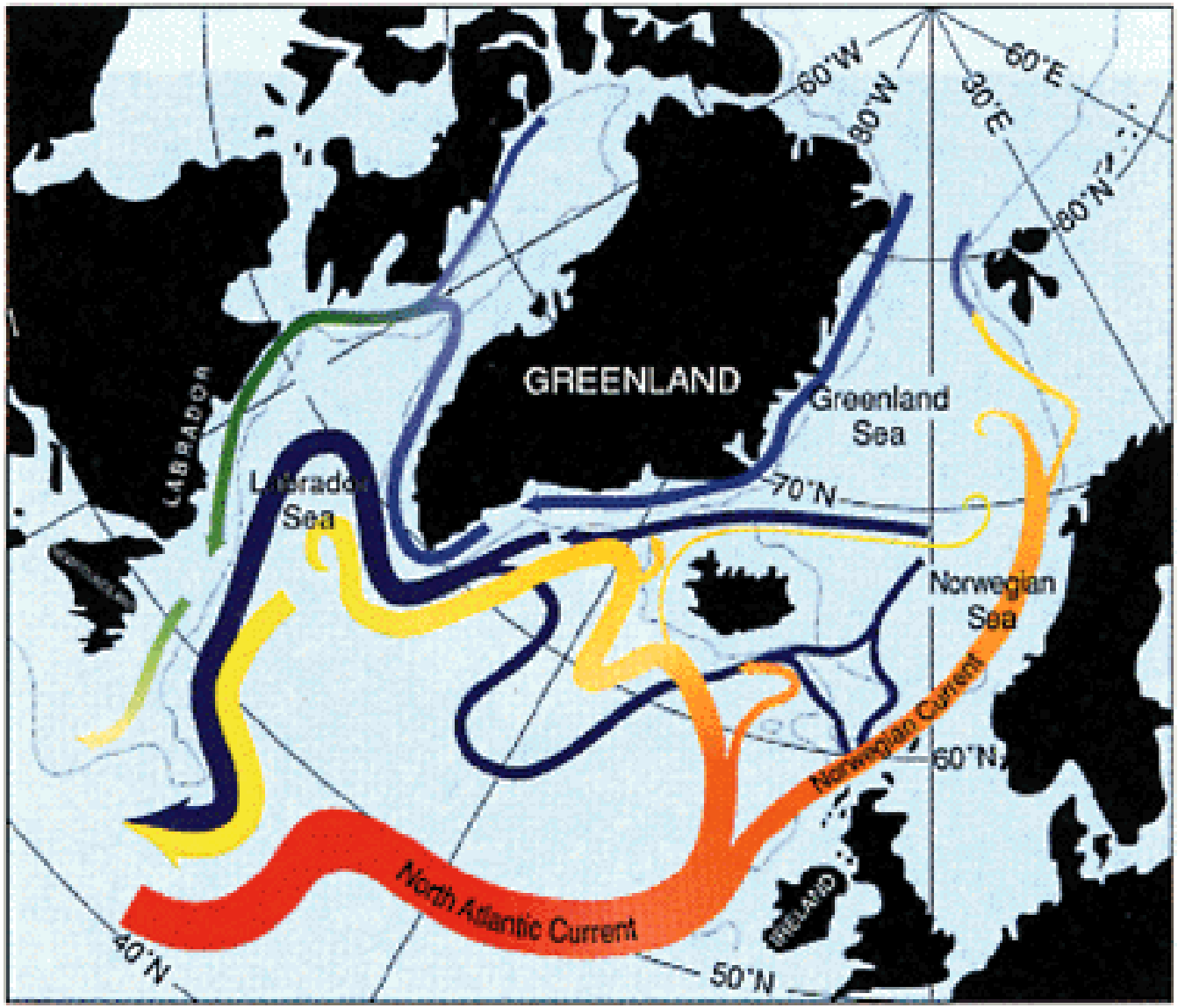
2) Thermohaline circulation



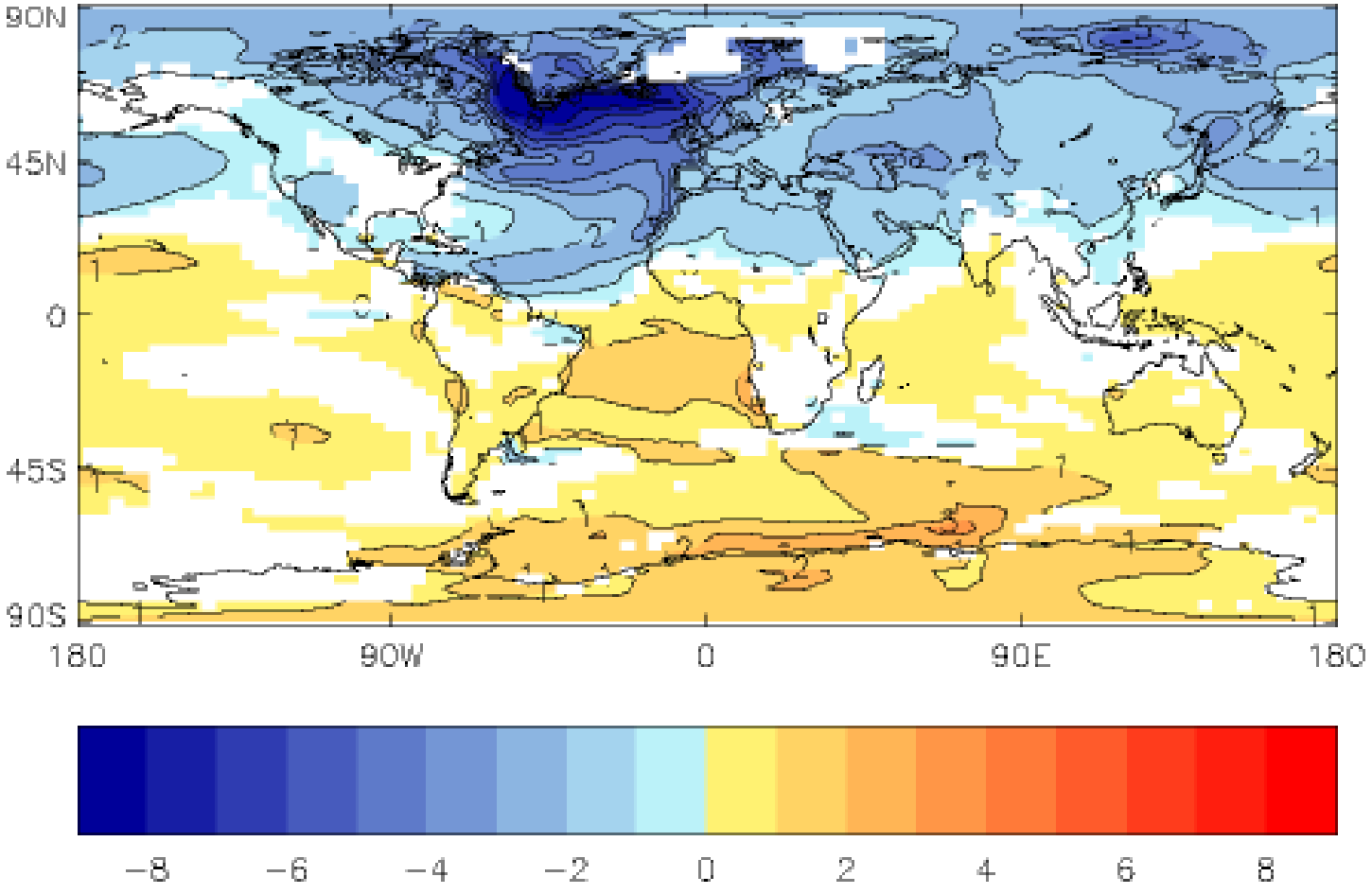
Importance of sea ice (3): Ecology, e.g. polar bears

Atlantic Ocean Thermohaline Circulation

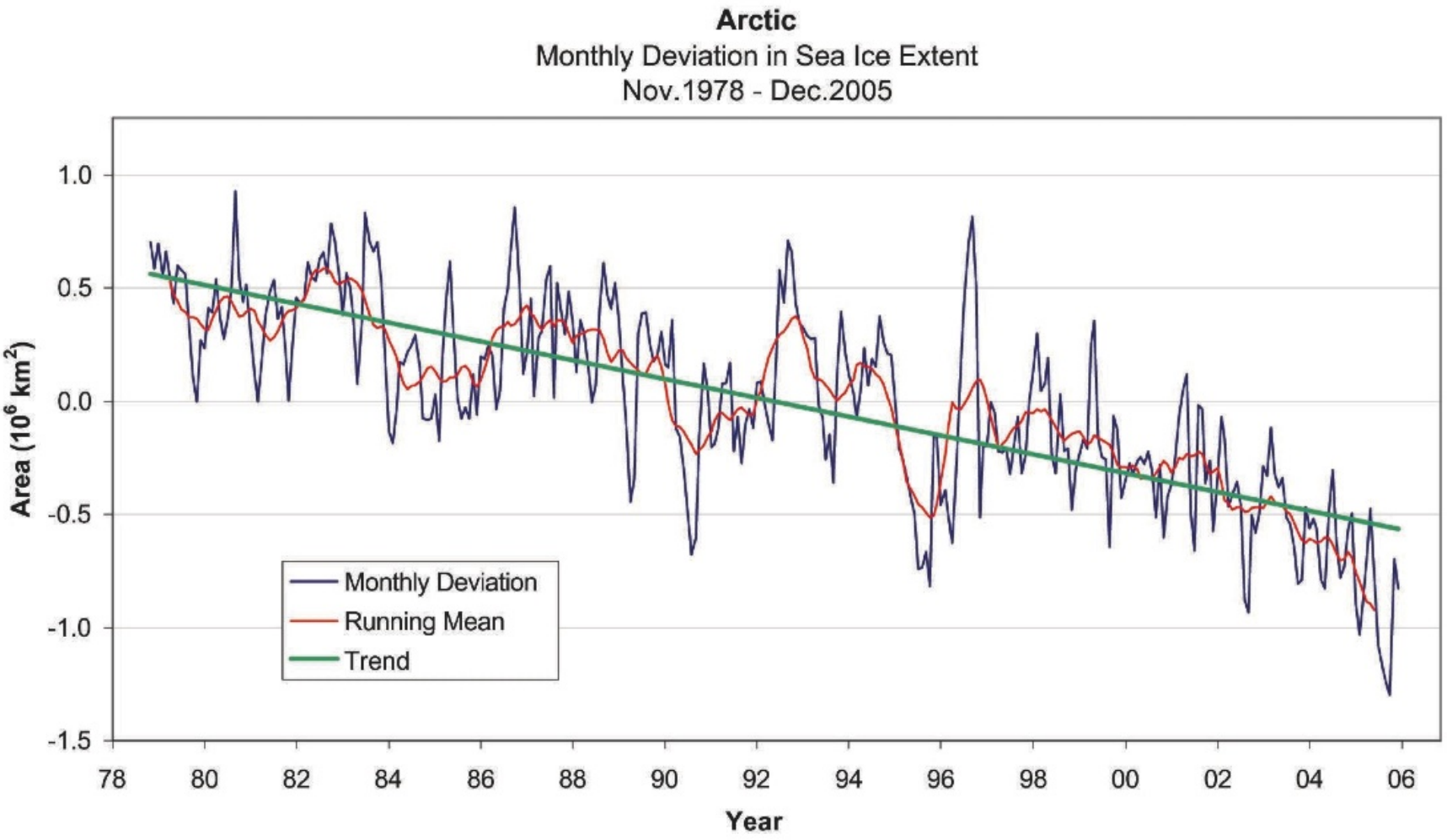


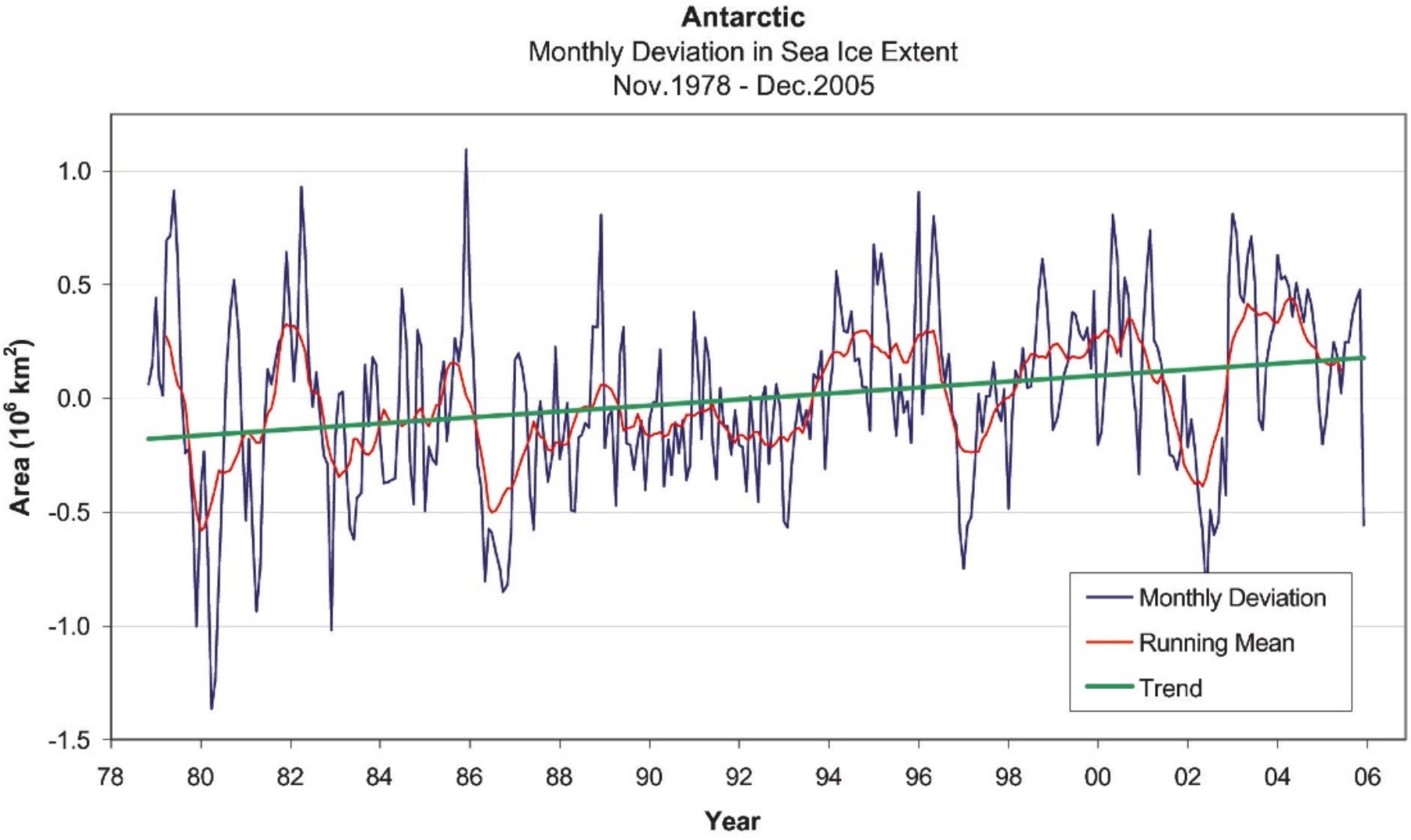

GREENLAND
Greenland Sea
Labrador Sea
Norwegian Sea
Norwegian Current
North Atlantic Current
ICELAND
60°W
80°W
60°E
30°E
80°N
70°N
60°N
50°N
40°N
WOODS HOLE OCEANOGRAPHIC INSTITUTION

Change in temperature 30 years after collapse of the thermohaline circulation



Michael Vellinga, Hadley Centre


Arctic
Monthly Deviation in Sea Ice Extent
Nov.1978 - Dec.2005
Area (10^6 km^2)
1.0
0.5
0.0
-0.5
-1.0
-1.5
78
80
82
84
86
88
90
92
94
96
98
00
02
04
06
Year
Monthly Deviation
Running Mean
Trend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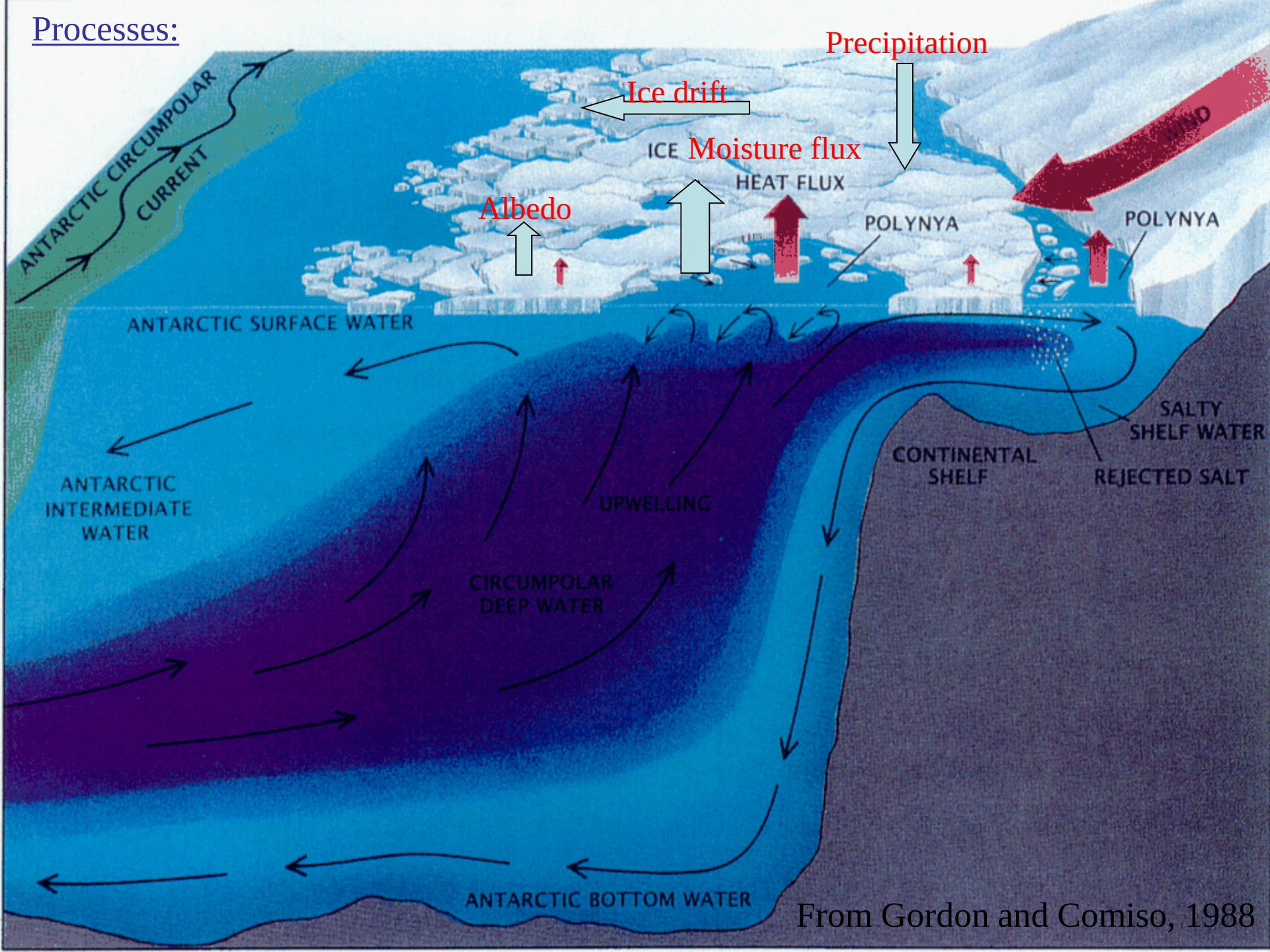
Processes:



From Gordon and Comiso, 1988

Antarctic sea ice increase with global warming?

Warmer temperatures

More moisture

More precipitation

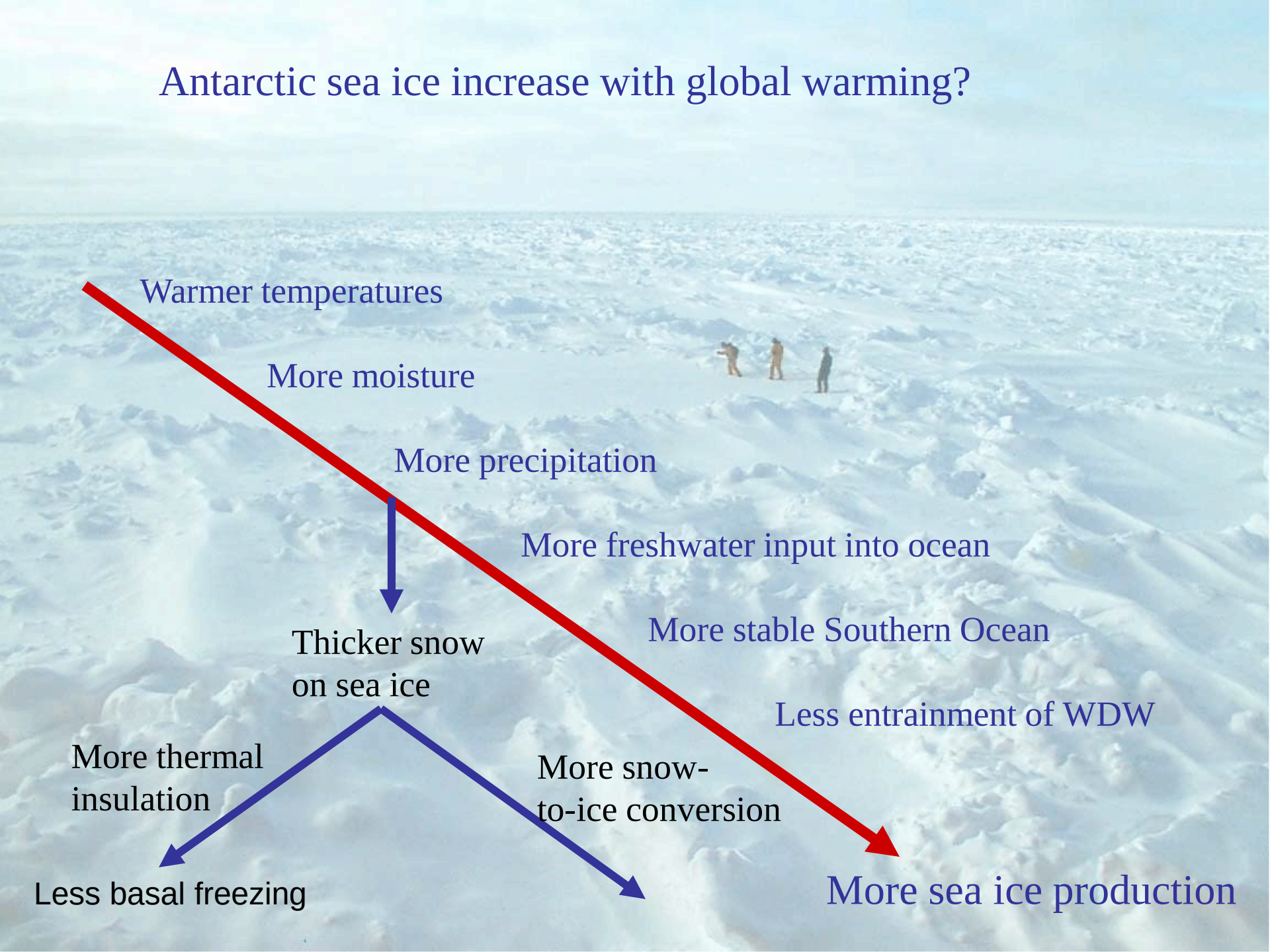
More freshwater input into ocean

More stable Southern Ocean

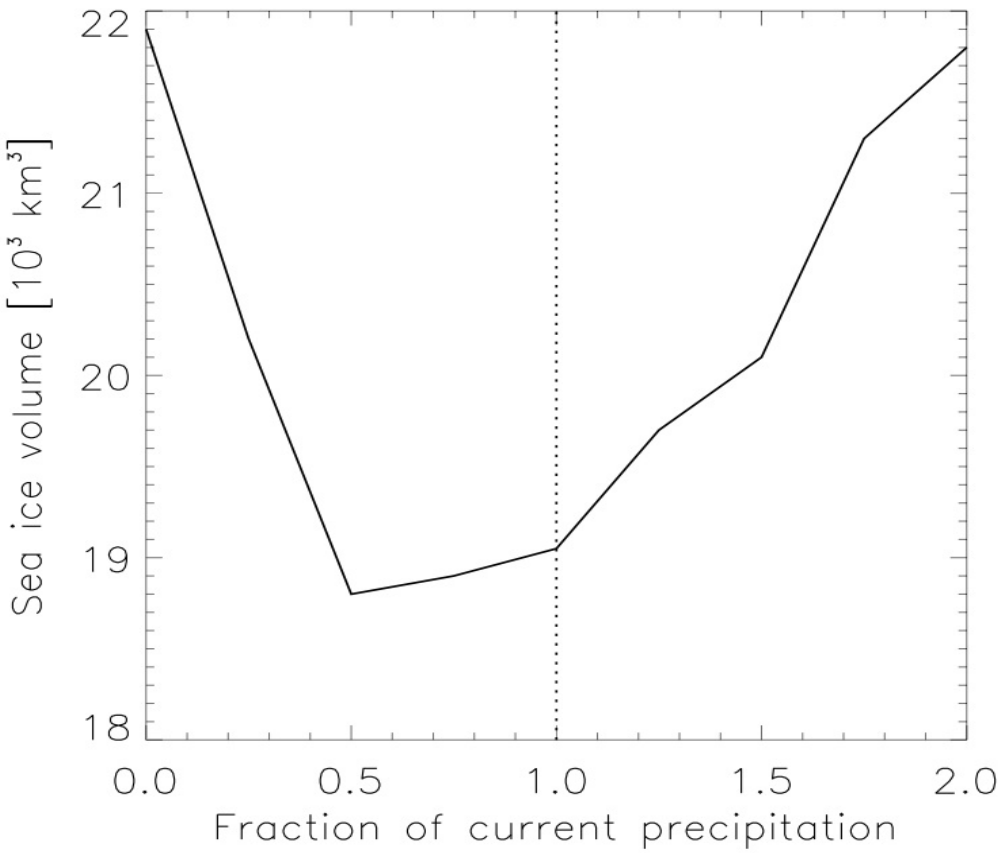
Less entrainment of WDW

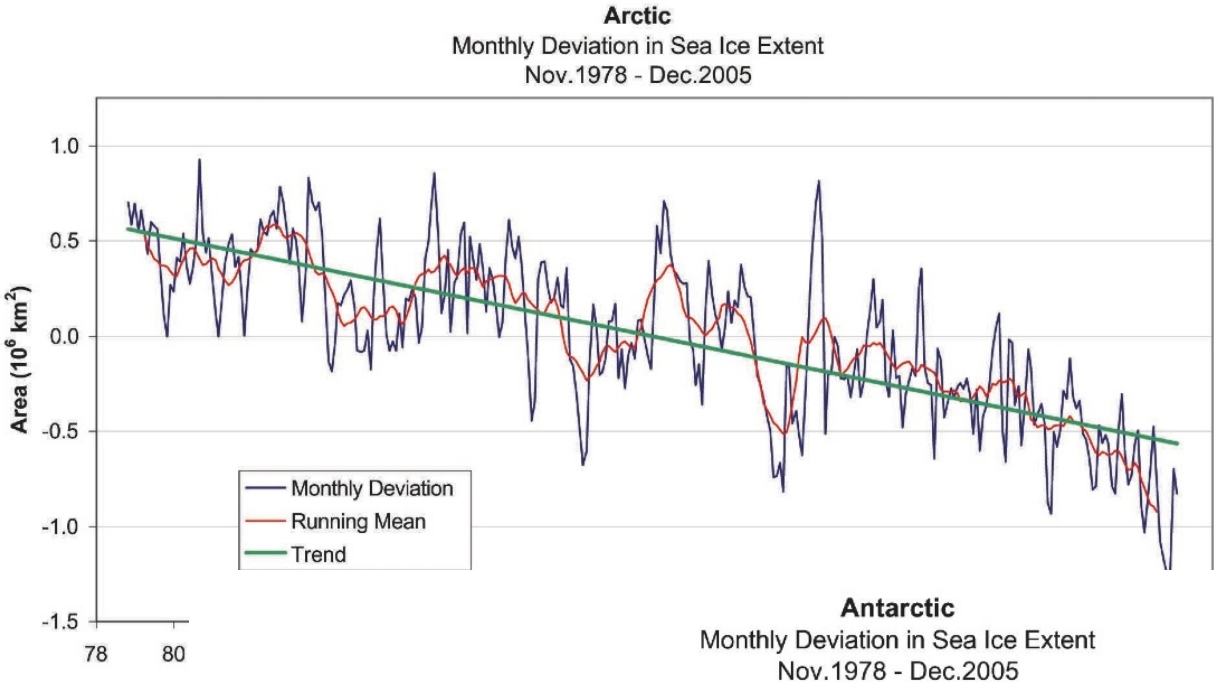
More sea ice production

Antarctic sea ice increase with global warming?



Change in sea ice volume as a function of precipitation
(Balance between thermal insulation and snow-to-ice conversion)

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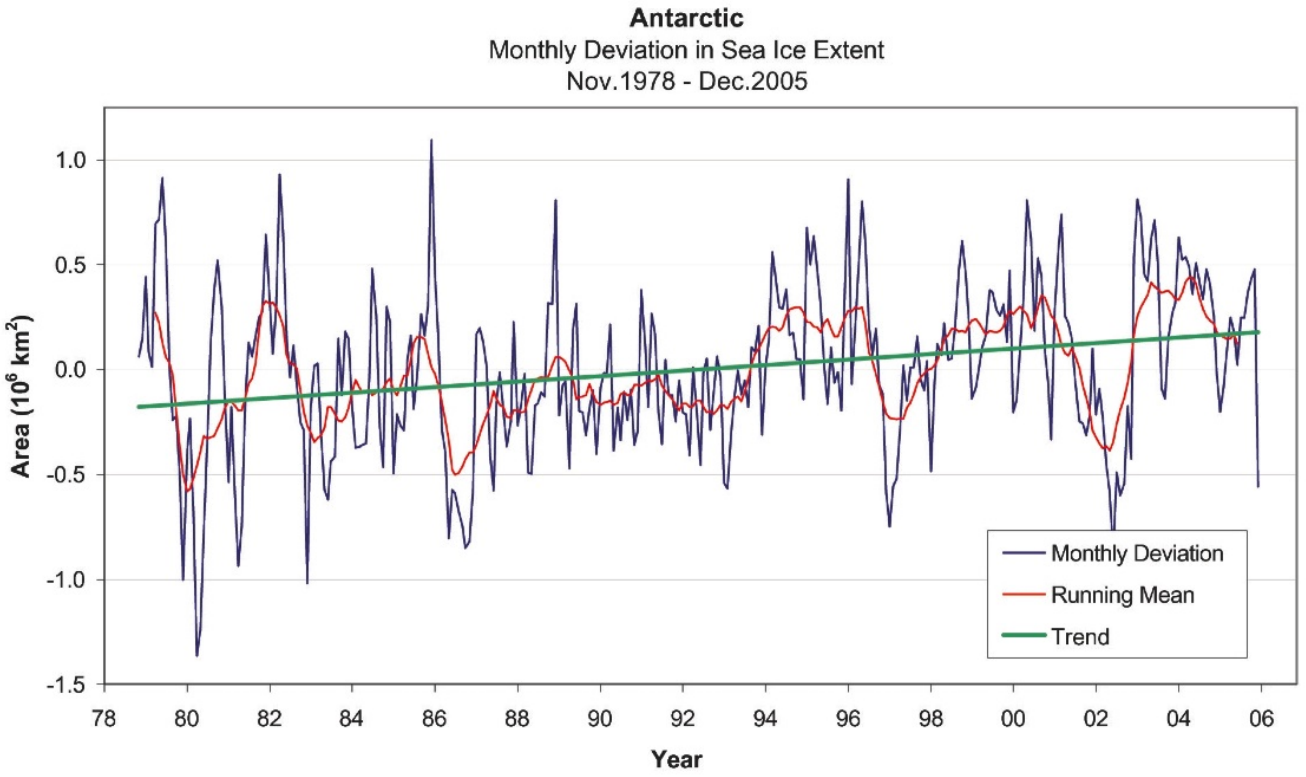
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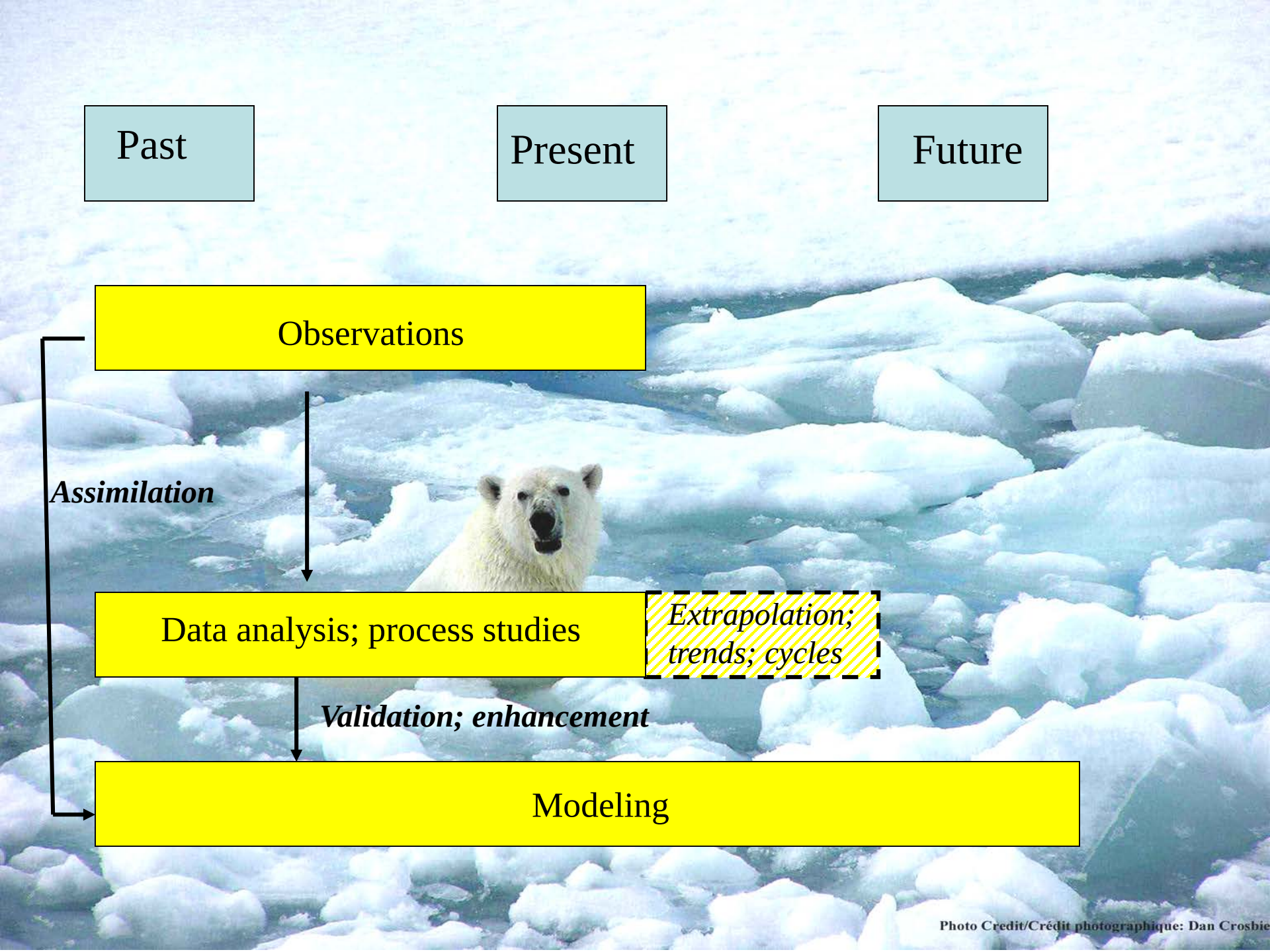
Past
Present
Future
Observations
Assimilation
Data analysis; process studies
Extrapolation; trends; cycles
Validation; enhancement
Modeling
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