

# **Antarctic Sea Ice and Global Climate**

**Dr. V. Lytle, CReSIS**  
**With thanks to Ryan Bowman for his input**



**Do one Brave thing a Day**

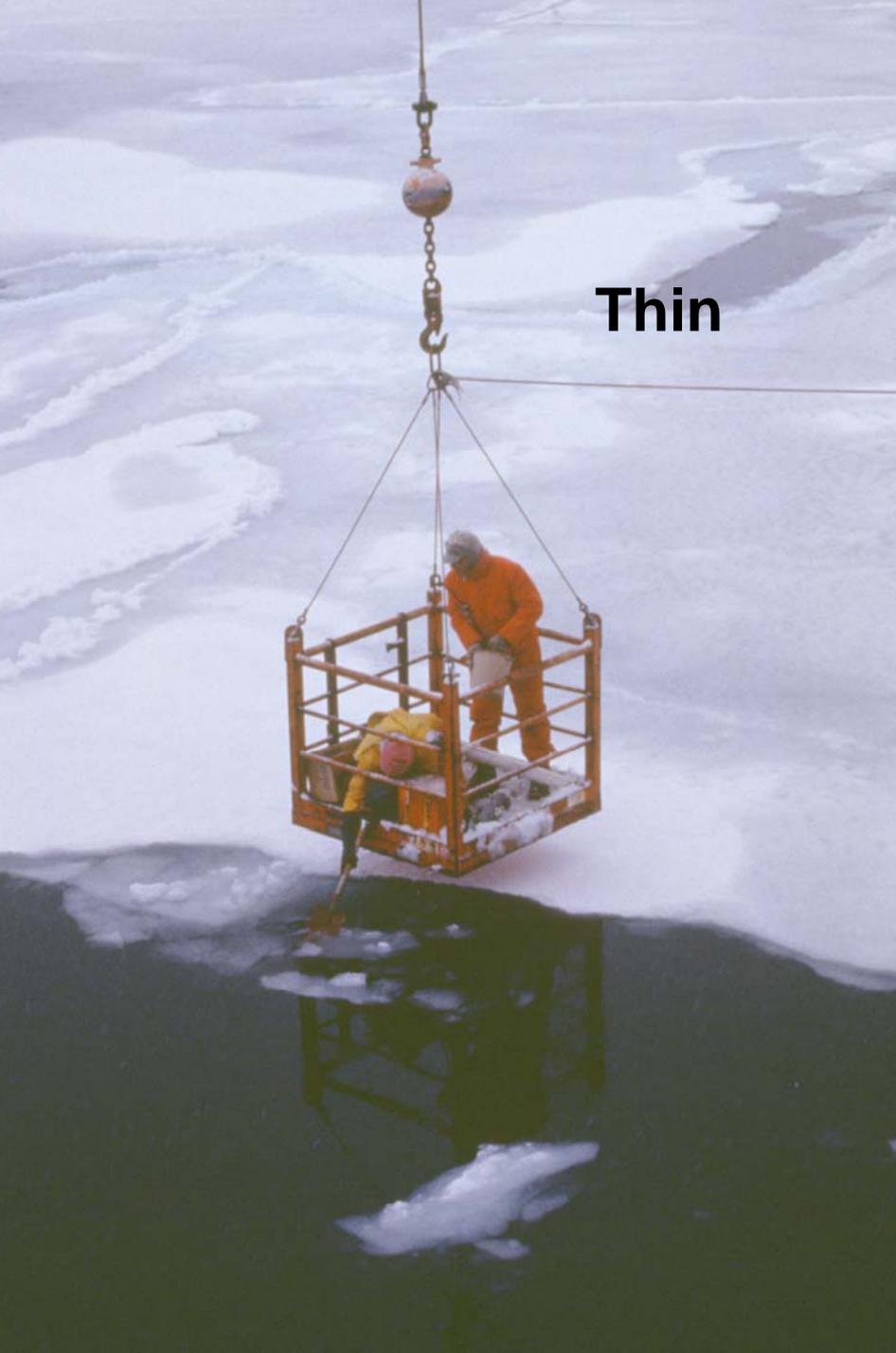
# Today's Presentation

- What does sea ice look like?
- Sea Ice Extent trends, predictions
- Ocean/Atmosphere heat flux
- Small Scale – Physics of sea ice formation
- Ocean Circulation/Ice Shelves

## **Not** Going to talk about

- Surface properties of sea ice – melt ponds, snow cover
- Polynyas
- Ecosystems and Biology in sea ice regions
- Shipping, Logistical issues
- Icebergs
- Indigenous/local populations and sea ice
- .....





**Thin**

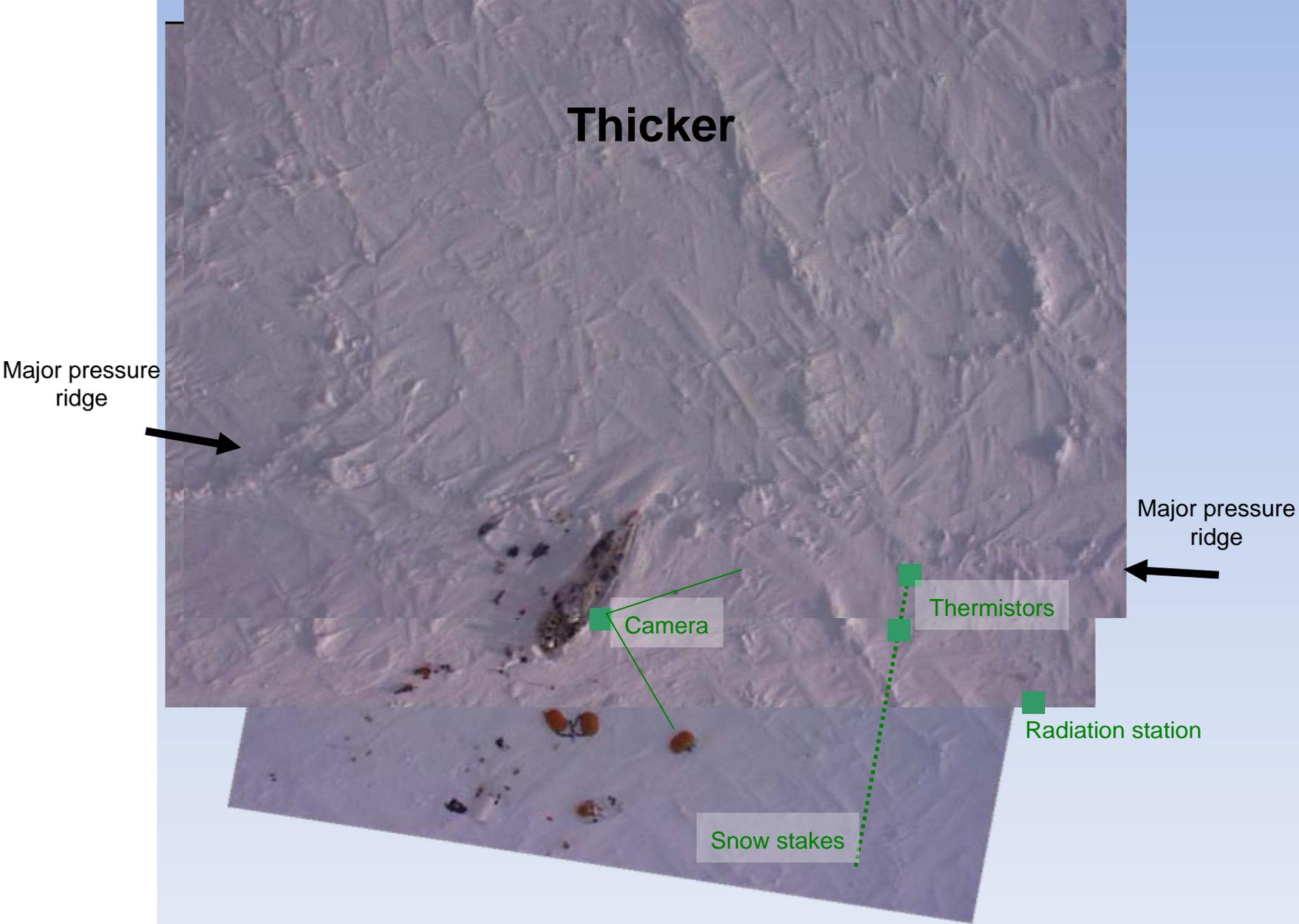


**Thicker**



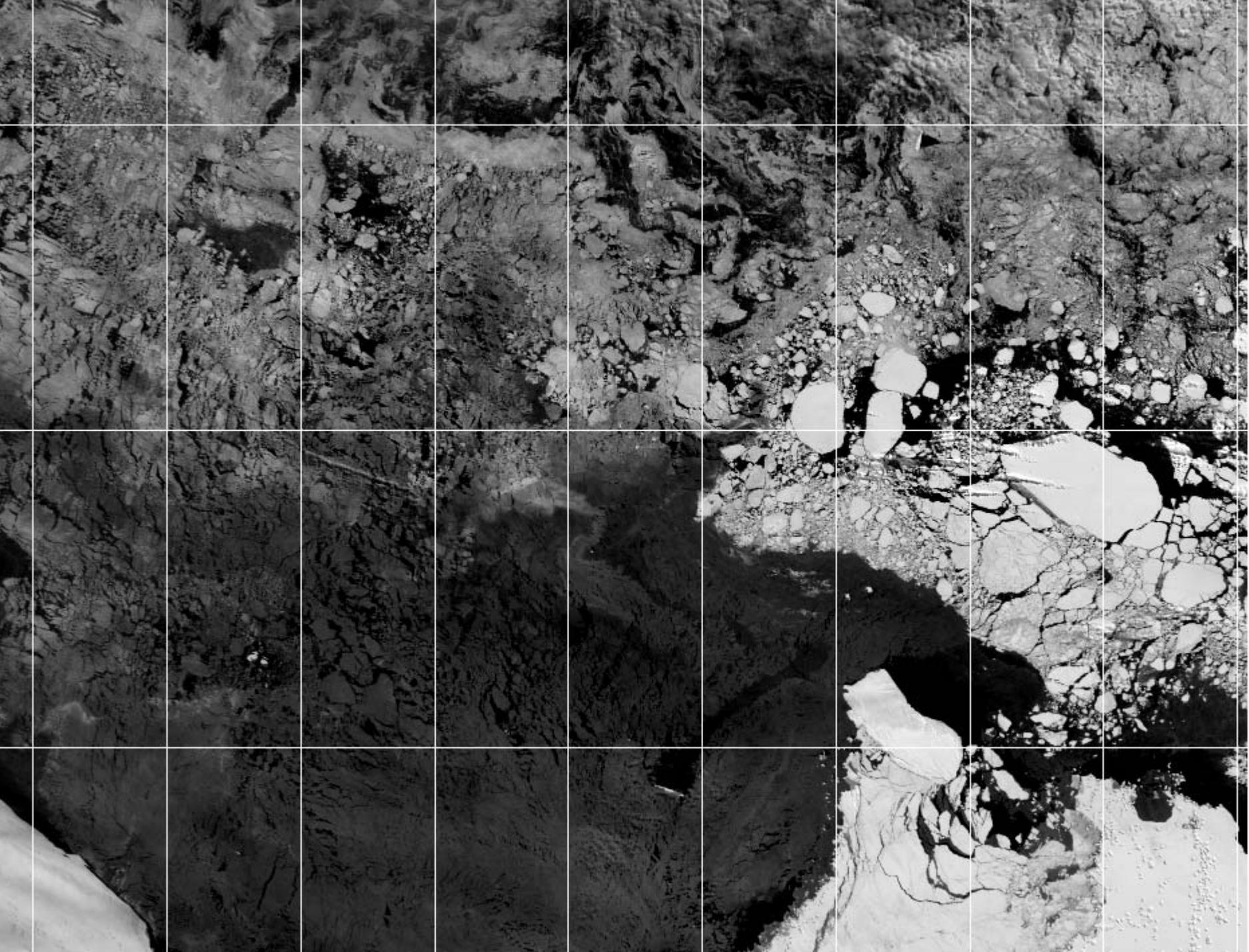
**Flat, relatively smooth**

# Aerial photograph (from approx. 200 m height)





**Rescue operation before ice deformation  
crushes instrument**



64°S

65°S

66°S

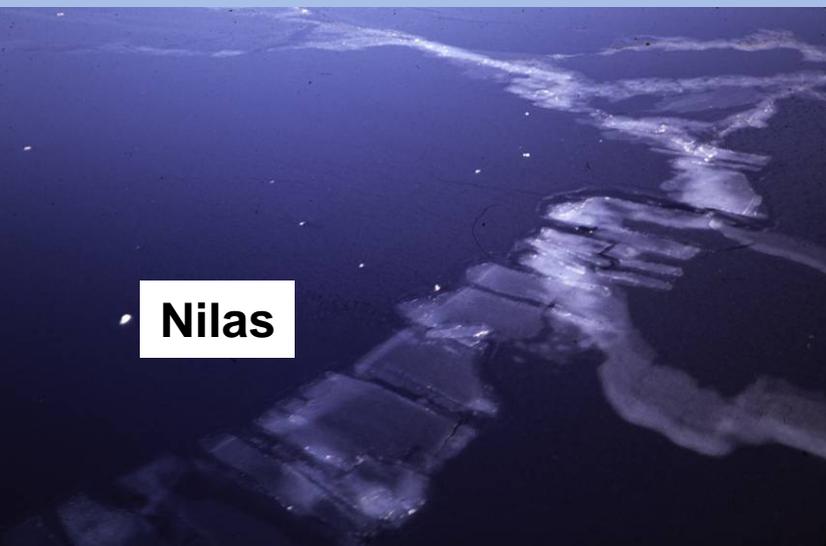
# Turbulent Conditions



# Grease Ice/ Frazil



# Calm Conditions



**Nilas**



**Finger Rafting**



**Frost Flowers**



# Thick Snow Covered Ice



## Arctic Sea Ice Gone in Summer Within Five Years?



### LATEST PHOTO NEWS

WEEK IN PHOTOS: Pagan Fire Fest, Fukang Meteorite, More



### LATEST VIDEO NEWS

Tornado Town Goes Green

### Most Viewed News

## Arctic ice shrinks to record low, melting faster than computers predicted

The Associated Press



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## Arctic Sea Ice Shrinks to Record Low

Scientists Say Arctic Sea Ice Levels Are at a Record Low and Still Dropping

By **RANDOLPH E. SCHMID** AP Science Writer  
WASHINGTON August 17, 2007 (AP)

There was less sea ice in the Arctic on Friday than ever before on record,

## 'Arctic is screaming,' say scientists seeing new data; worry over 'tipping point'

The Associated Press

## Arctic Sea Route Opens as Ice Melts - Space Agency

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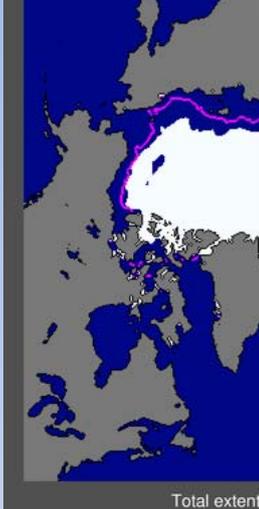
UK: September 17, 2007

**LONDON** - The Arctic's Northwest Passage has opened

FONT SIZE A A A

# 2006

## Record Low Arctic Sea Ice Extent in September 2007



National Snow and Ice Data Center

# 2008



Total extent = 4.3 million sq km

median  
ice edge

# Summer

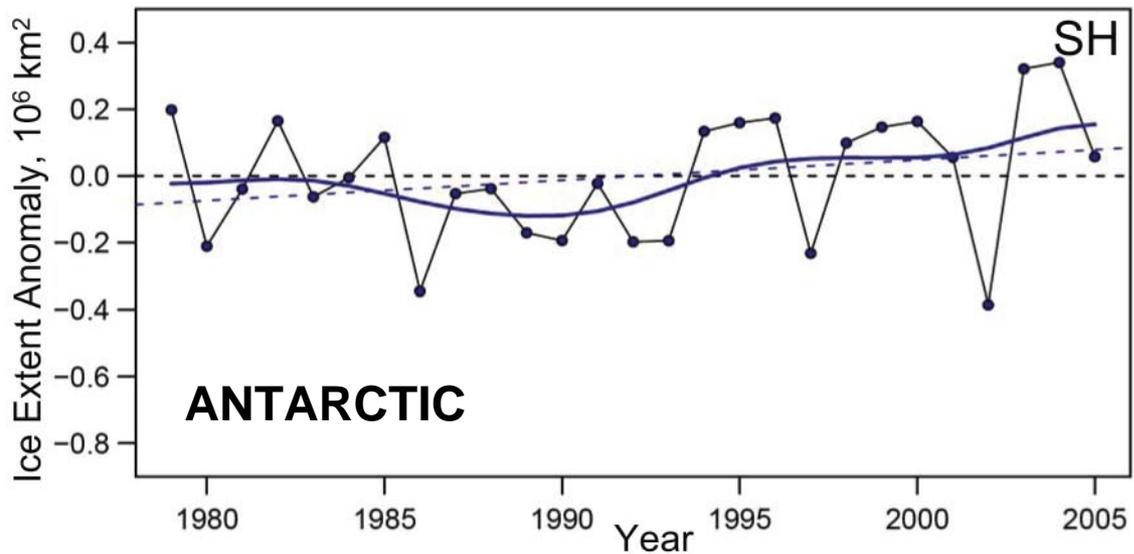
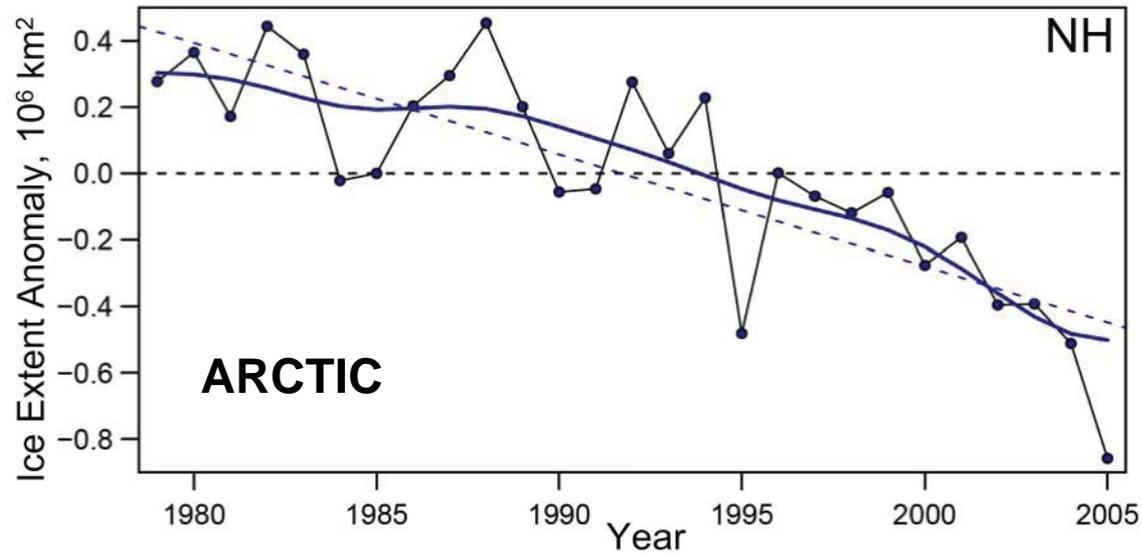
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# 2008

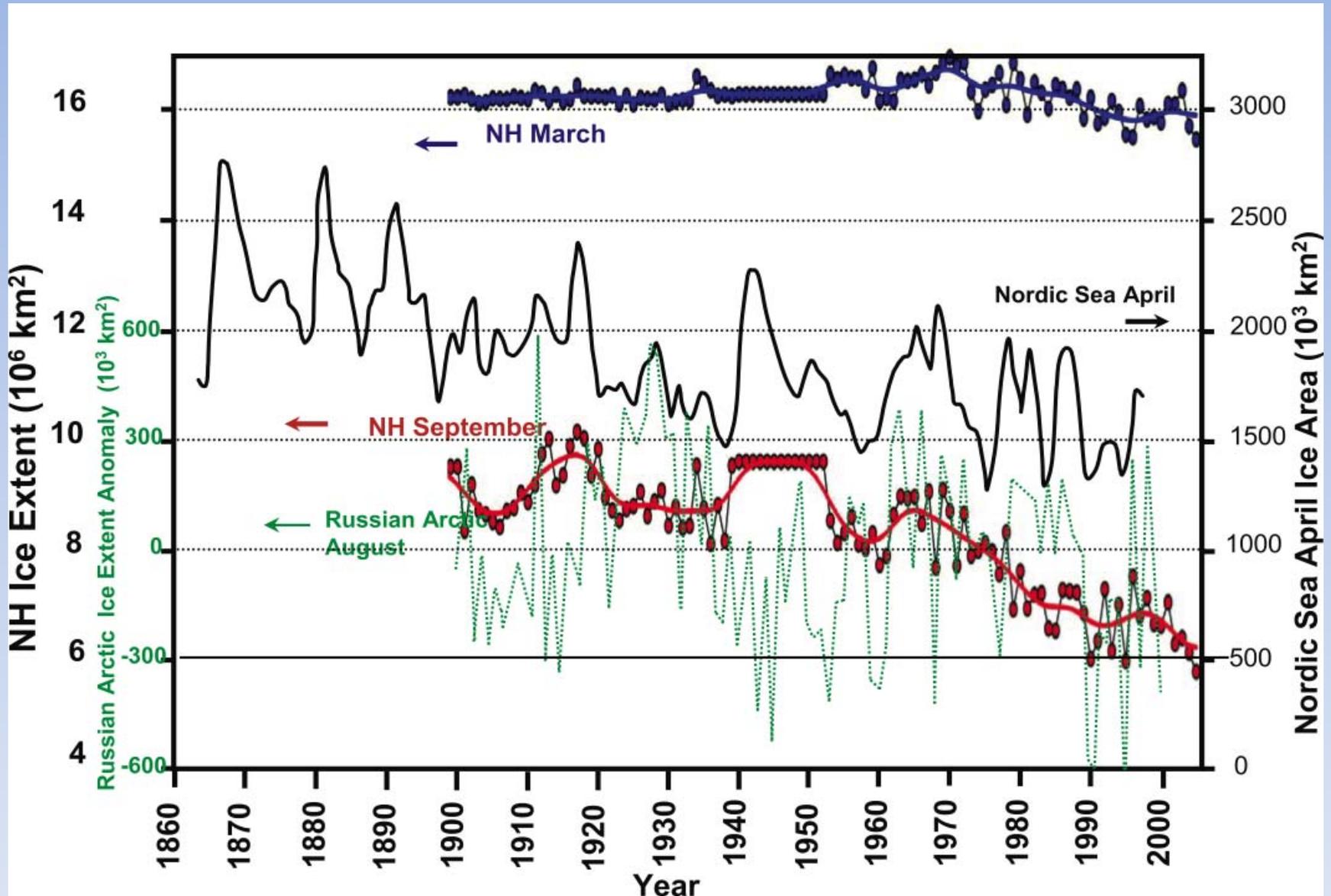


median  
ice edge

# Sea Ice Extent Anomalies

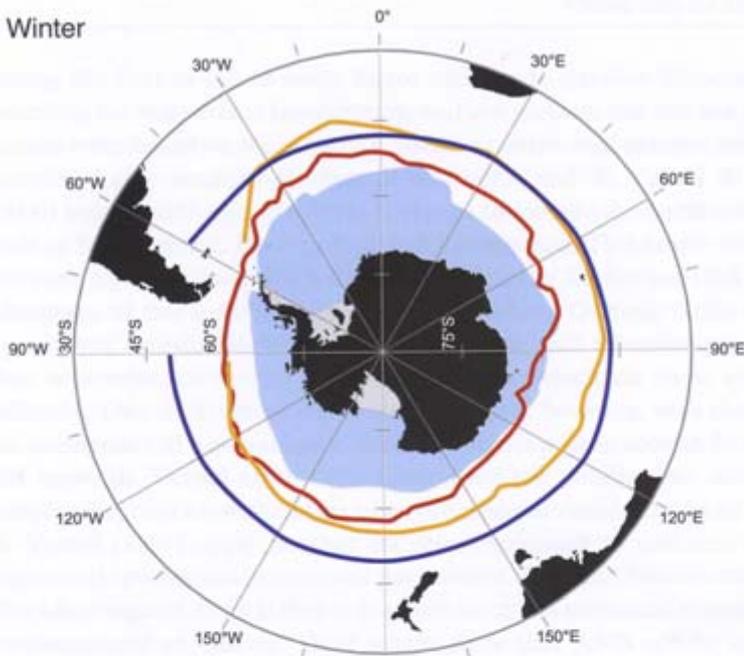


**But this is only 30 years....**

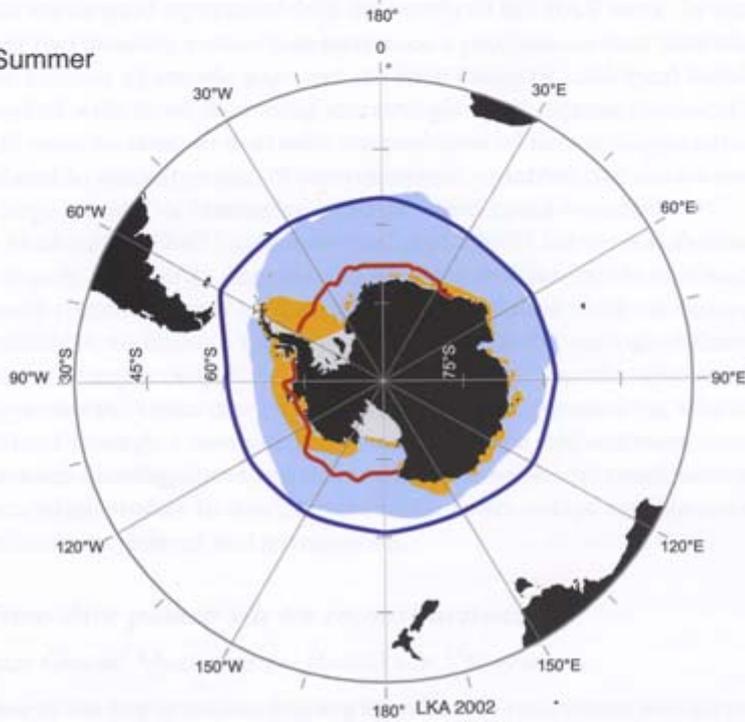


**Red Line is the estimated Minimum Arctic extent**

A. Winter



B. Summer



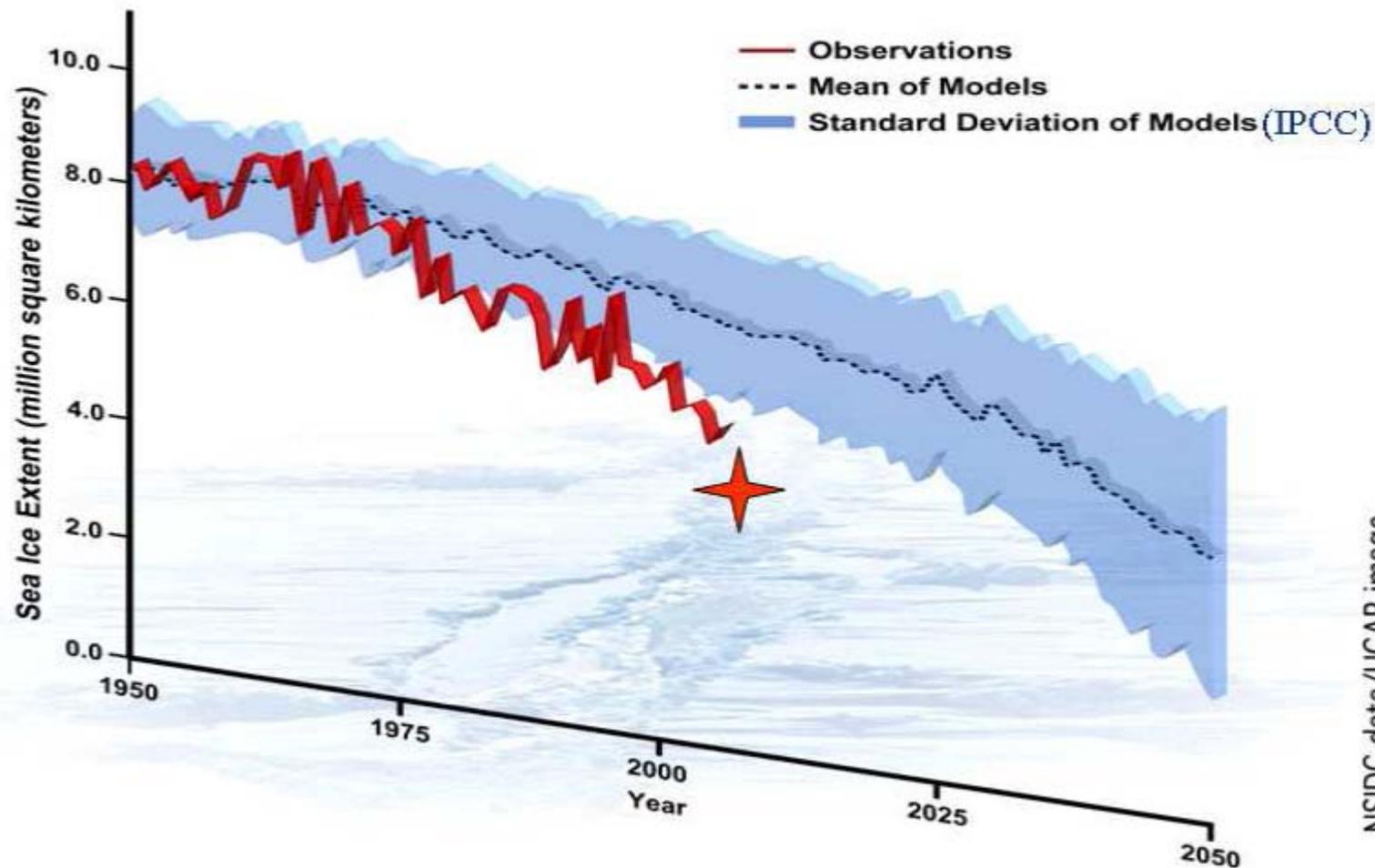
## Sea Ice Extent at Last Glacial Maximum Armand (2002)

- MODELLED Ganopolski et al. (1998)
- OBSERVATIONS Crosta et al. (1998)
- MODELLED Weaver et al. (1998)
- Modern winter maximum
- Modern summer minimum

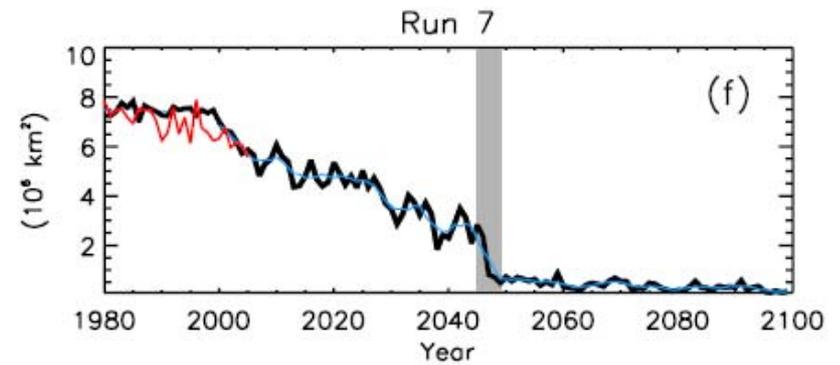
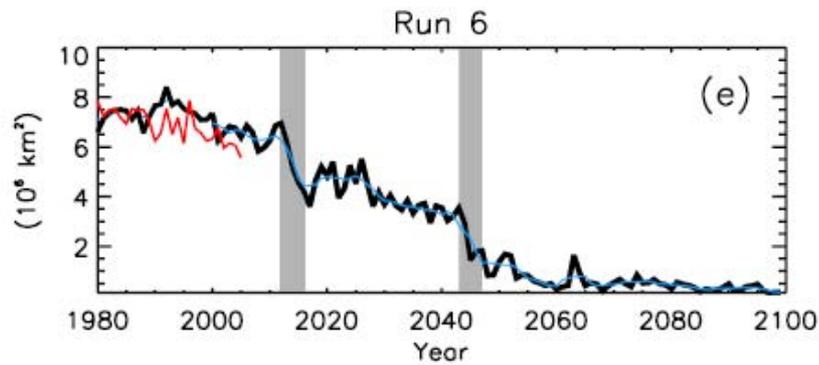
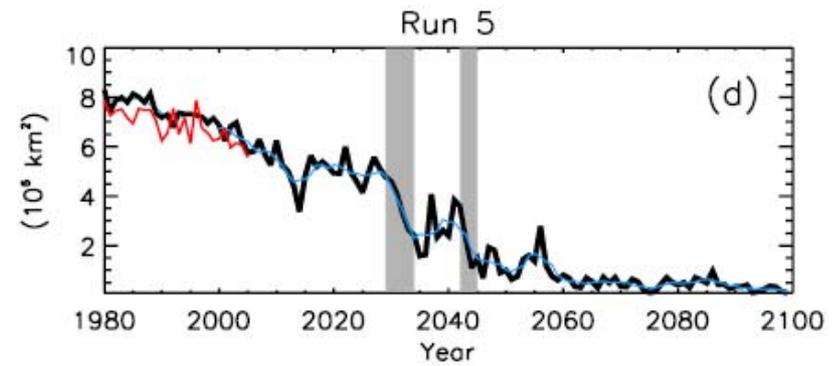
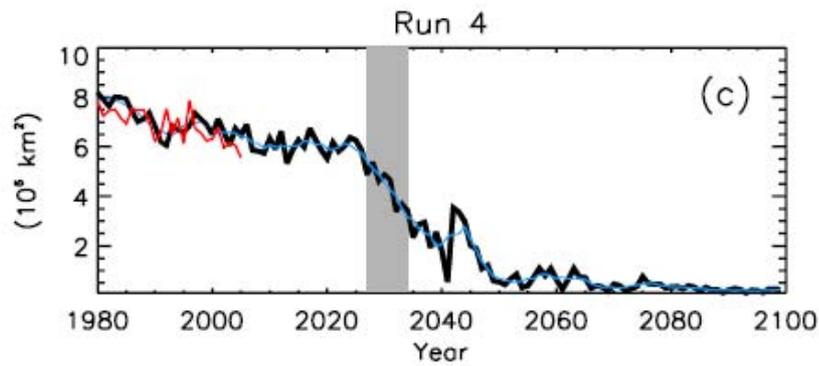
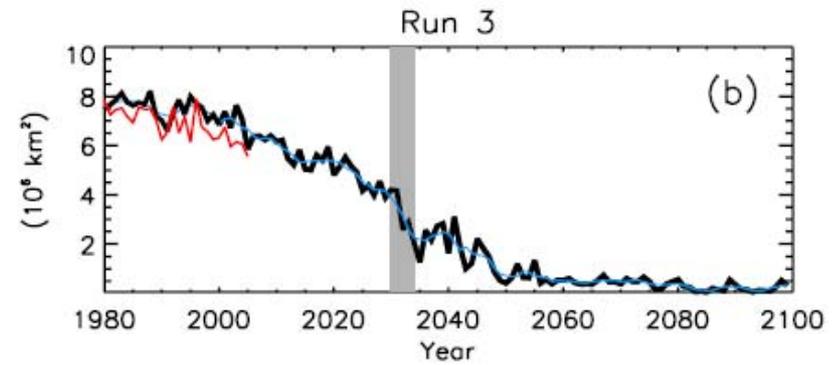
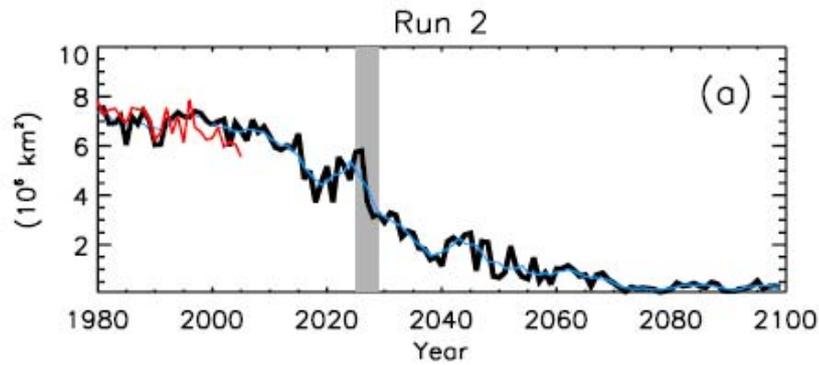
We THINK there was more  
sea ice in the past

# Sea Ice Models – Too Conservative?

Arctic September Sea Ice Extent:  
Observations and Model Runs



NSIDC data/UCAR image



Holland *et al.*, 2006

- Grey bars represent an abrupt transition.

# Air-Sea Interactions

## Sea ice

- acts as a physical barrier to ocean-atmosphere heat and gas exchanges.
- increases surface albedo and reduces radiation absorption.

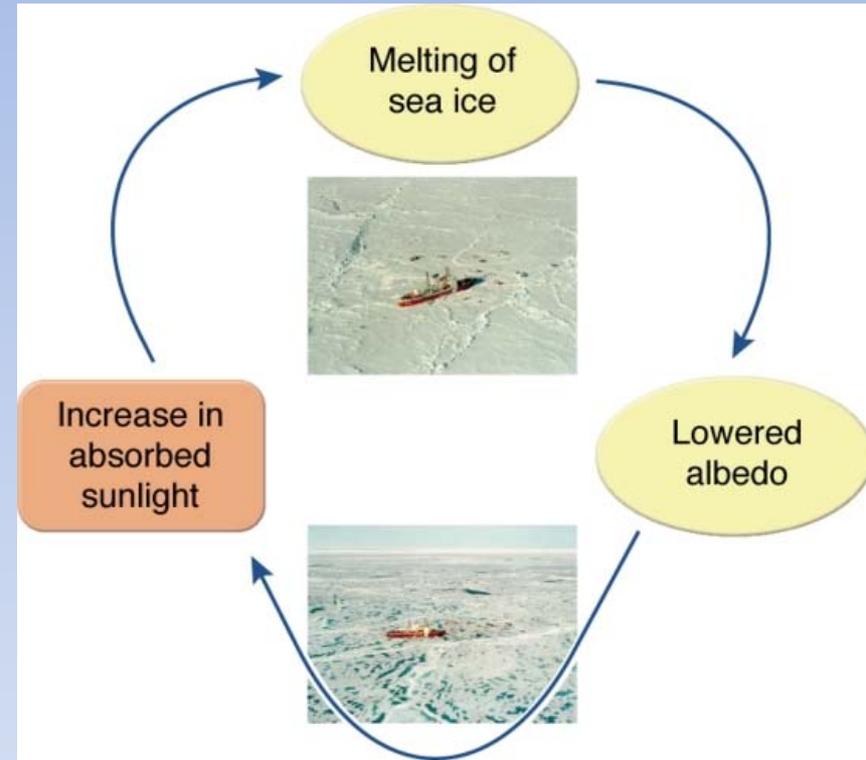
Summer –

More open water, more melt ponds absorb more solar radiation



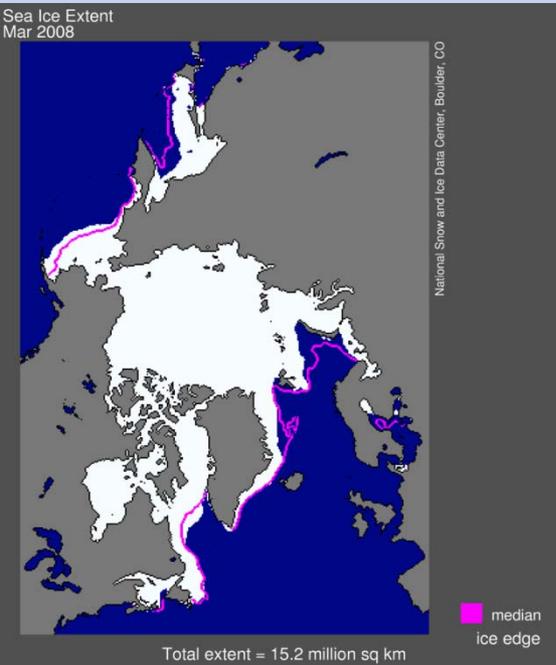
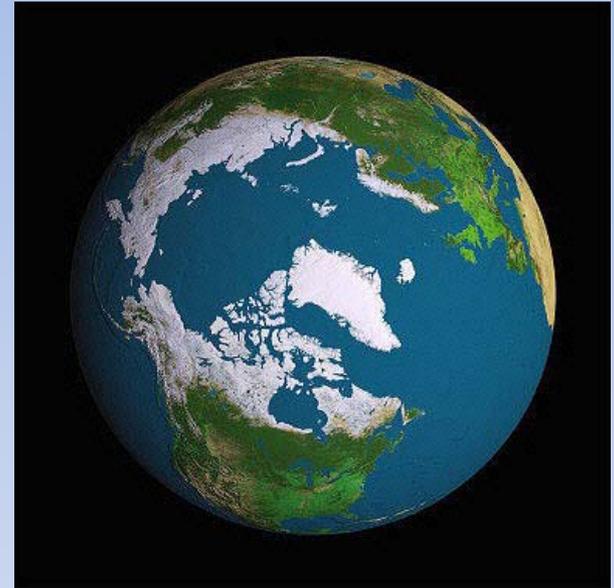
# Ice-Albedo Feedback

- Less ice and/or thinner ice
- More open water
- Lower albedo
- Increased absorption of short wave radiation
- More ice melts



# Predictions of future Arctic Sea Ice?

- We are likely to see an ice free arctic during the summer in our lifetime.

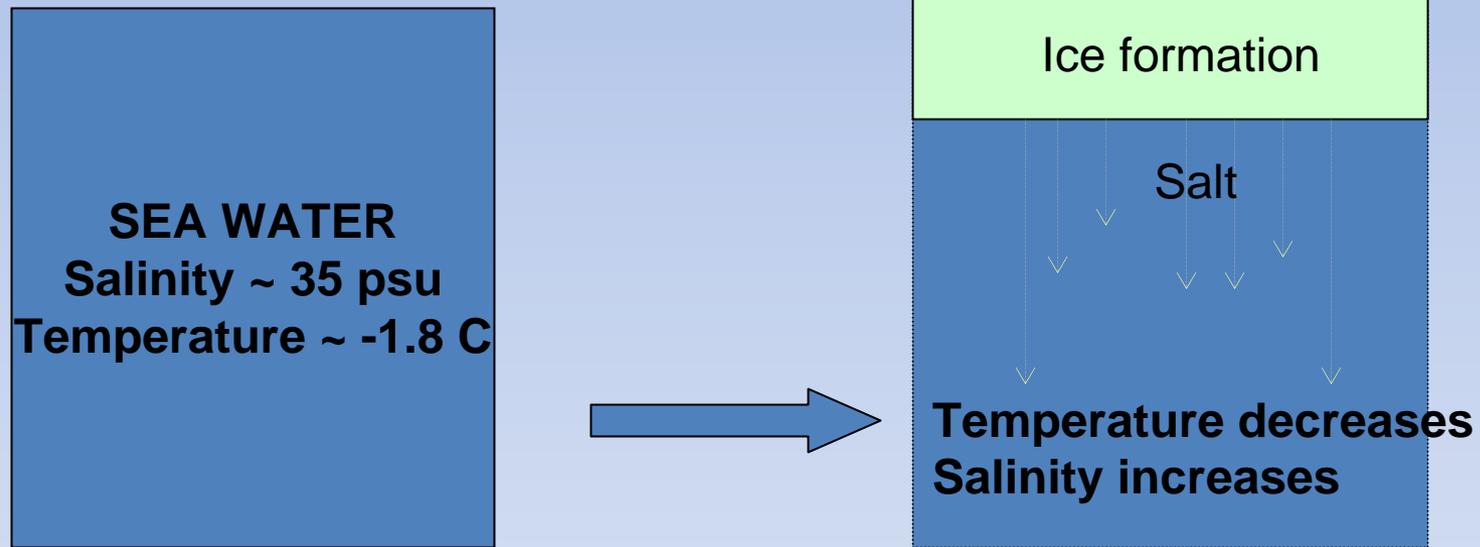


- But not in the winter – it's just too cold and dark.

A large, white iceberg with a prominent hole in its center, floating in a dark blue ocean. The foreground is filled with a dense field of smaller, flat icebergs. The sky is a clear, pale blue.

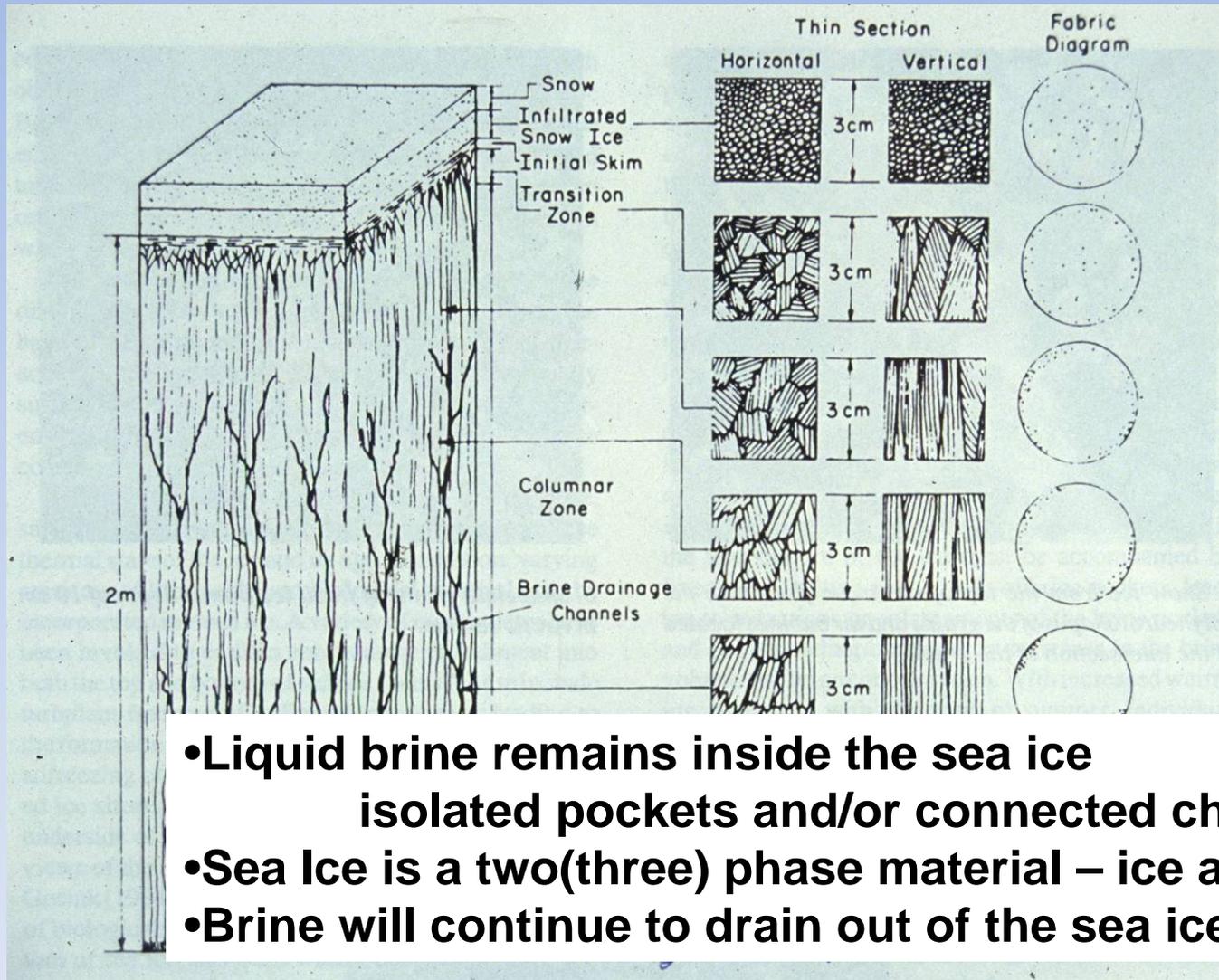
**What about the Ocean?**

# What happens when we freeze a bucket of sea water?

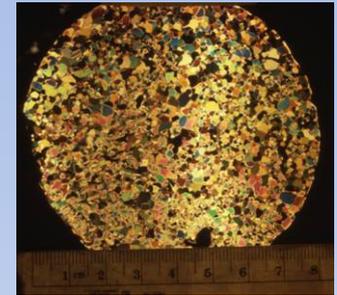


**As sea ice freezes it rejects salt**

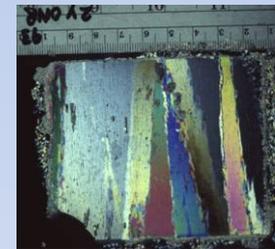
# Sea Ice Structure



Thin sections



Granular

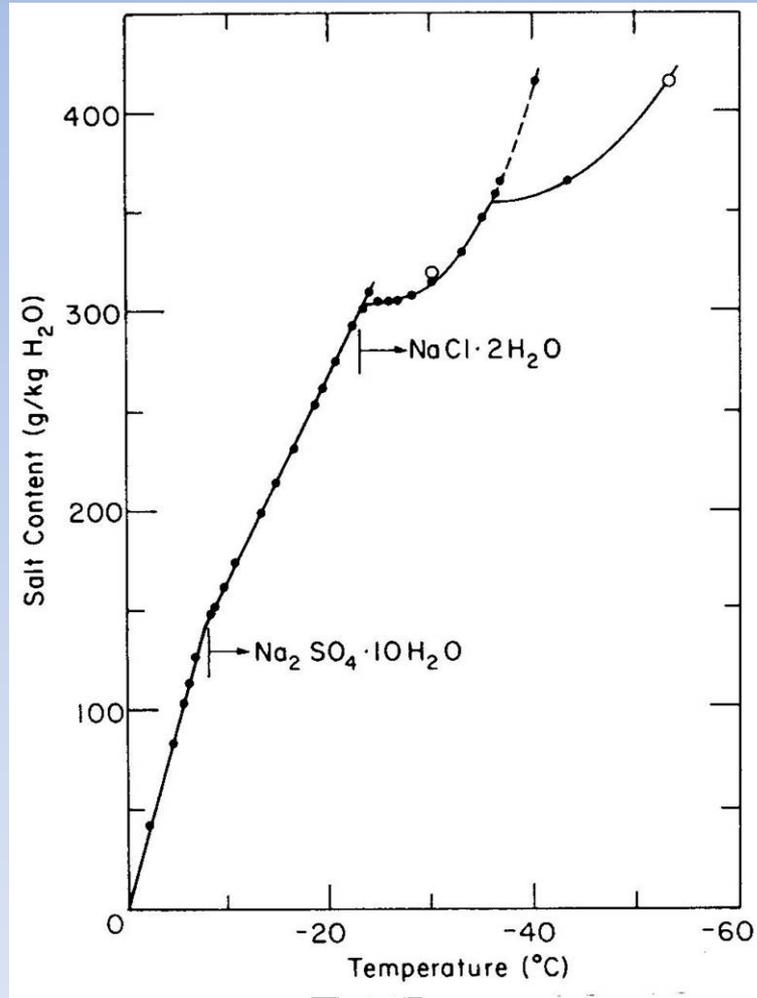


Columnar (Vertical)

- Liquid brine remains inside the sea ice isolated pockets and/or connected channels
- Sea Ice is a two(three) phase material – ice and brine (air)
- Brine will continue to drain out of the sea ice

Columnar (Horizontal)

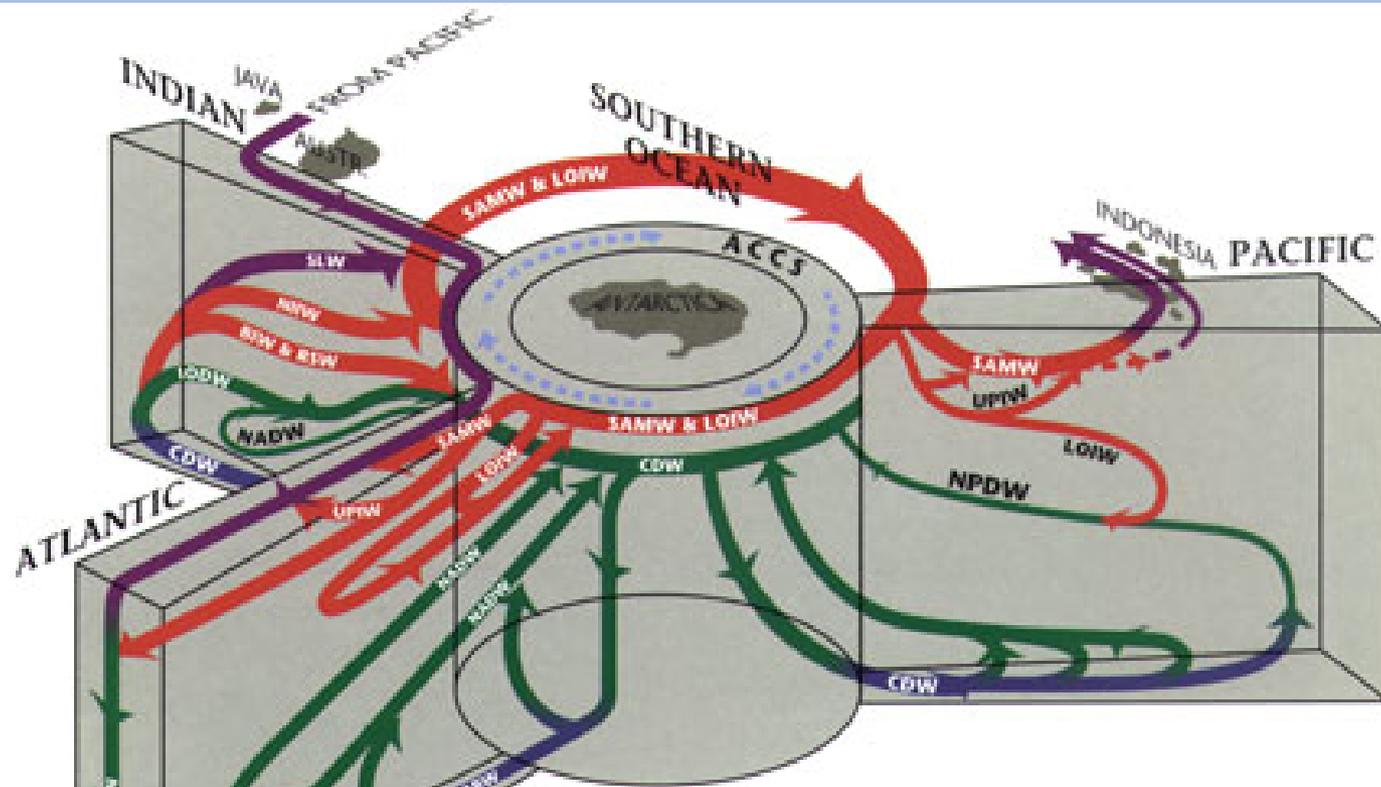
# Ice – brine equilibrium



Freezing point of brine as a function of the ratio of dissolved salts to pure water

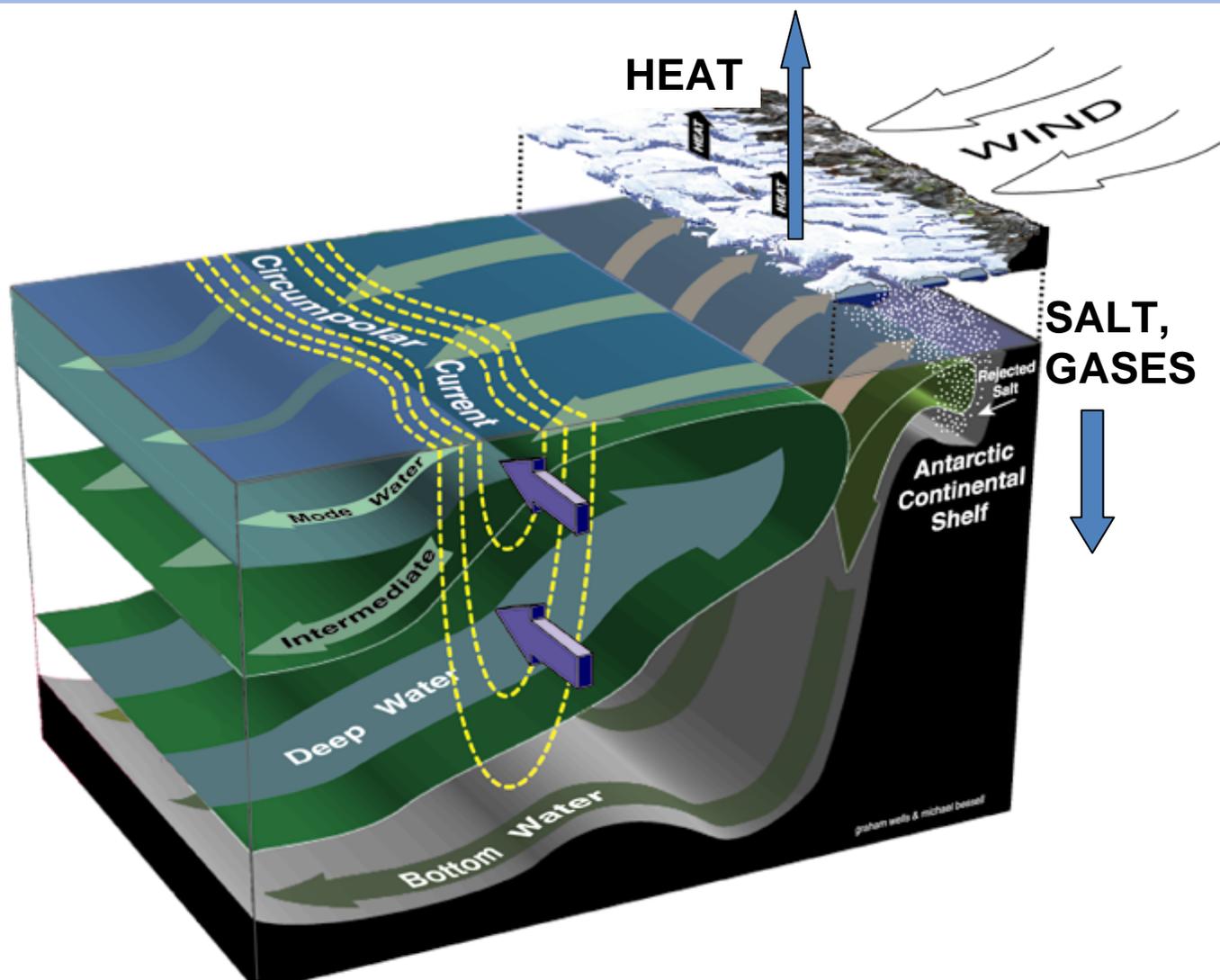
Changes in slope are caused by crystallisation of different salts

# Ocean Circulation

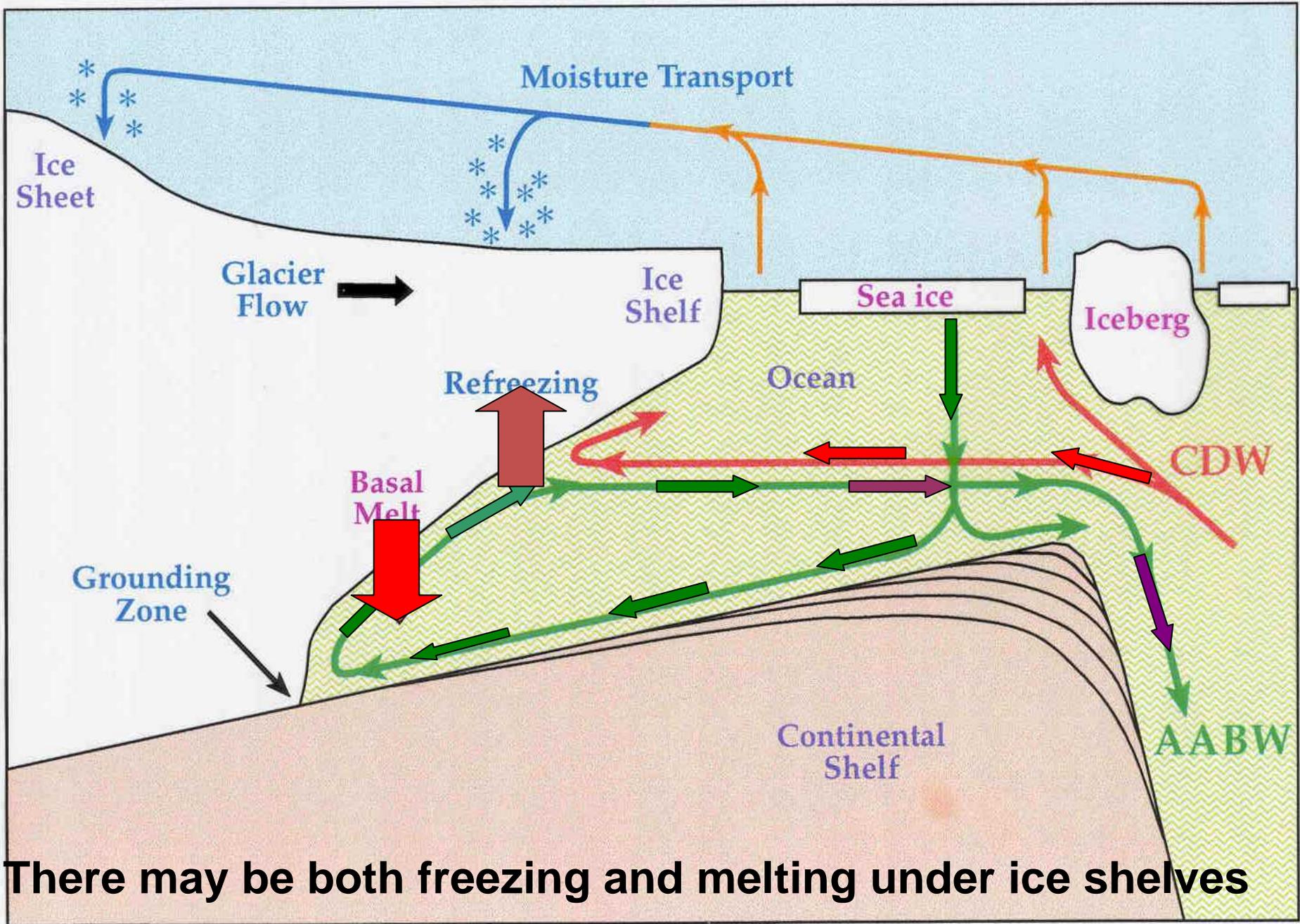


**SLW** Surface Layer Water  
**SAMW** Subantarctic Mode Water  
**RSW** Red Sea Water  
**AABW** Antarctic Bottom Water  
**NPDW** North Pacific Deep Water  
**ACCS** Antarctic Circumpolar Current System  
**CDW** Circumpolar Deep Water

**NADW** North Atlantic Deep Water  
**UPTW** Upper Intermediate Water,  $26.8 \leq \sigma_\theta \leq 27.2$   
**LOIW** Lower Intermediate Water,  $27.2 \leq \sigma_\theta \leq 27.5$   
**IODW** Indian Ocean Deep Water  
**BIW** Banda Intermediate Water  
**NIW** Northwest Indian Intermediate Water



**Antarctic Bottom Water is produced around the Antarctic Continent where sea ice formation rates are high**



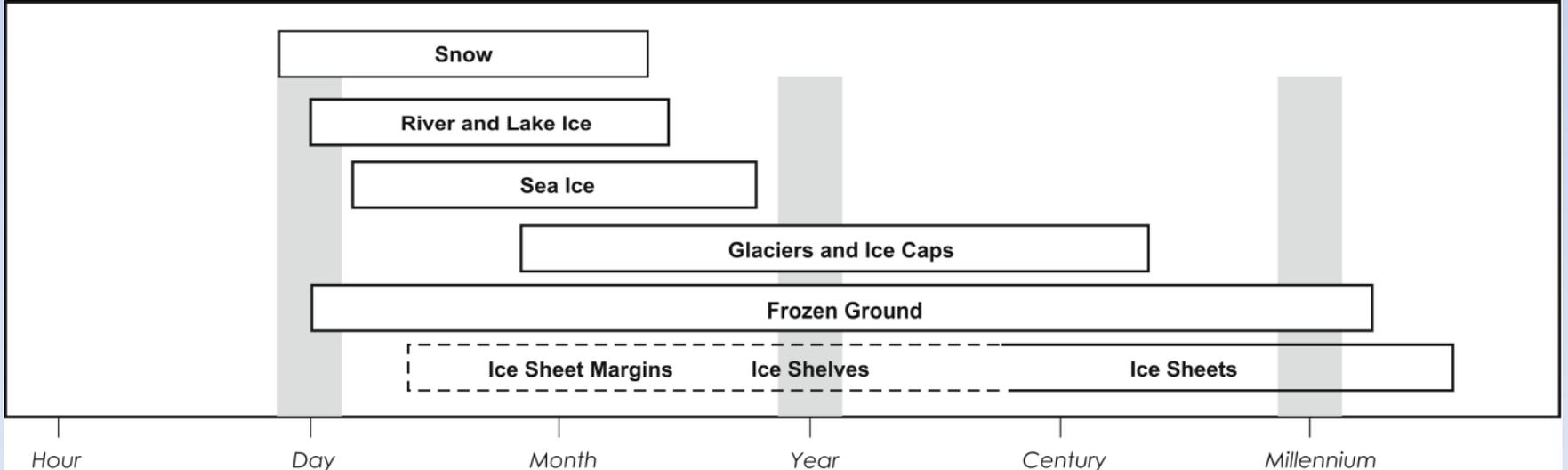
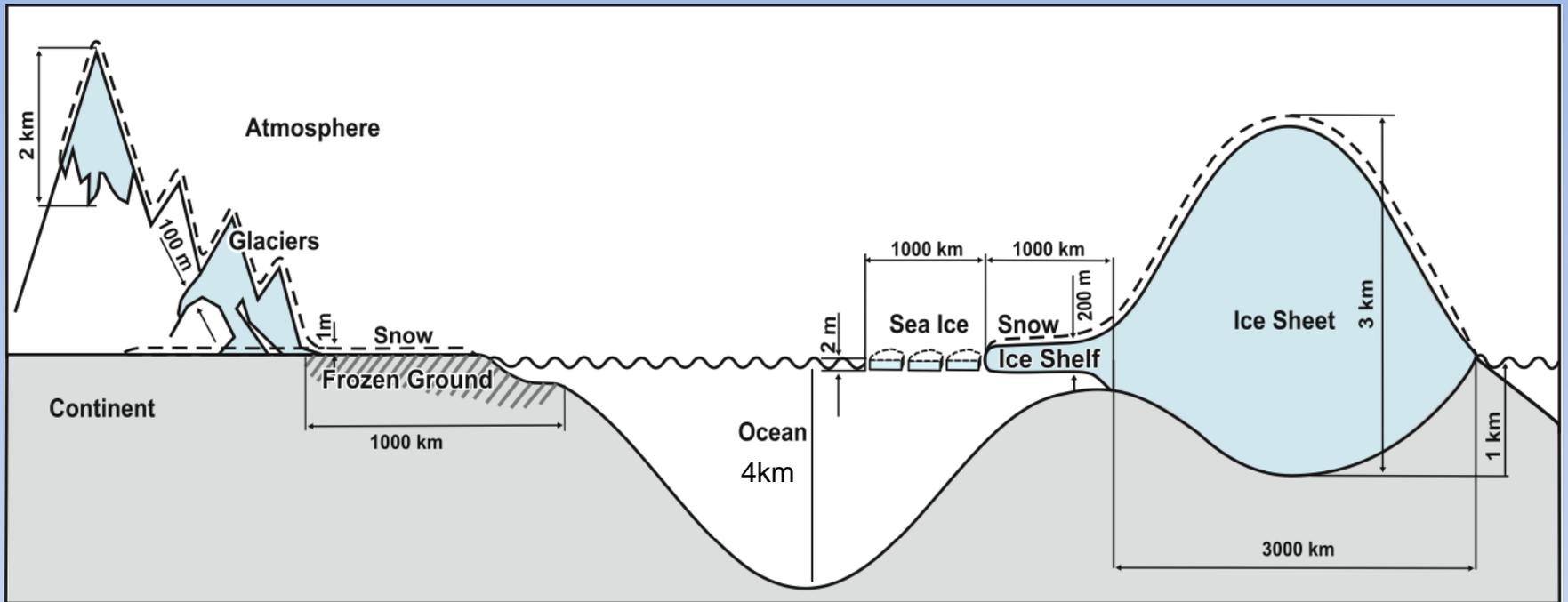
**There may be both freezing and melting under ice shelves**

# Ocean modification

Sea ice:

- Adds salt (fresh water) to the ocean during growth (melt).
- Transports net freshwater and negative heat equatorward.
- Without this heat transport, the poles would be much much colder, and the tropics would be much much warmer





Time Scale of Cryosphere components

# Sea Ice – Frozen Sea Water

- Average thickness is typically less than 1 metre (in Antarctica), less than 10 m (Arctic)
- Usually covered with snow
- Reflects much of the incoming solar radiation
- Maximum extent ~21 million km<sup>2</sup> in Antarctic, ~15 million km<sup>2</sup> in Arctic. (10 % of the ocean surface)
- Insulates the relatively warm (-1.8C) ocean from the cold atmosphere
- Rejects salt into the ocean – causing vertical circulation and modification of water masses