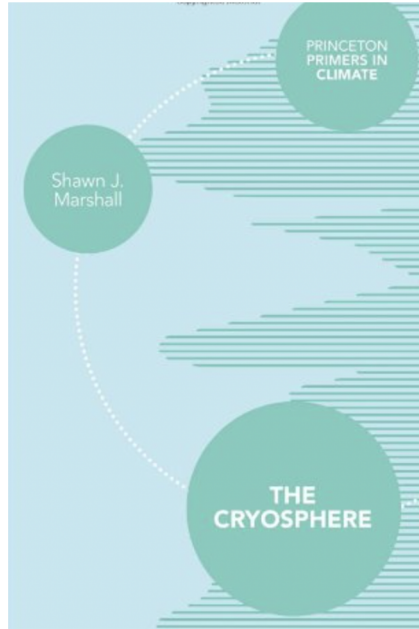


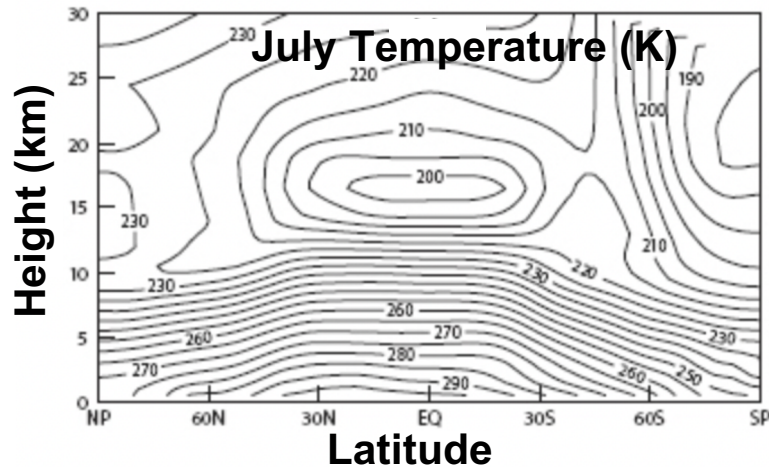
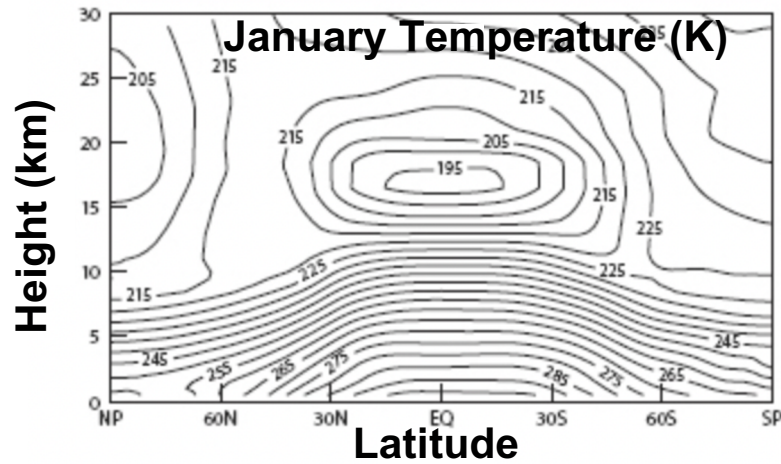
Seasonal snow and Sea Ice



Natalia Roldán-Henao
November 22, 2022

Learning Outcomes for today

- How ice crystals form and grow in the atmosphere
- How snow behaves and evolves once it is deposited in the ground
- The seasonal cycle of sea ice
- Differences between the Arctic and the Antarctic
- Dynamics of sea ice

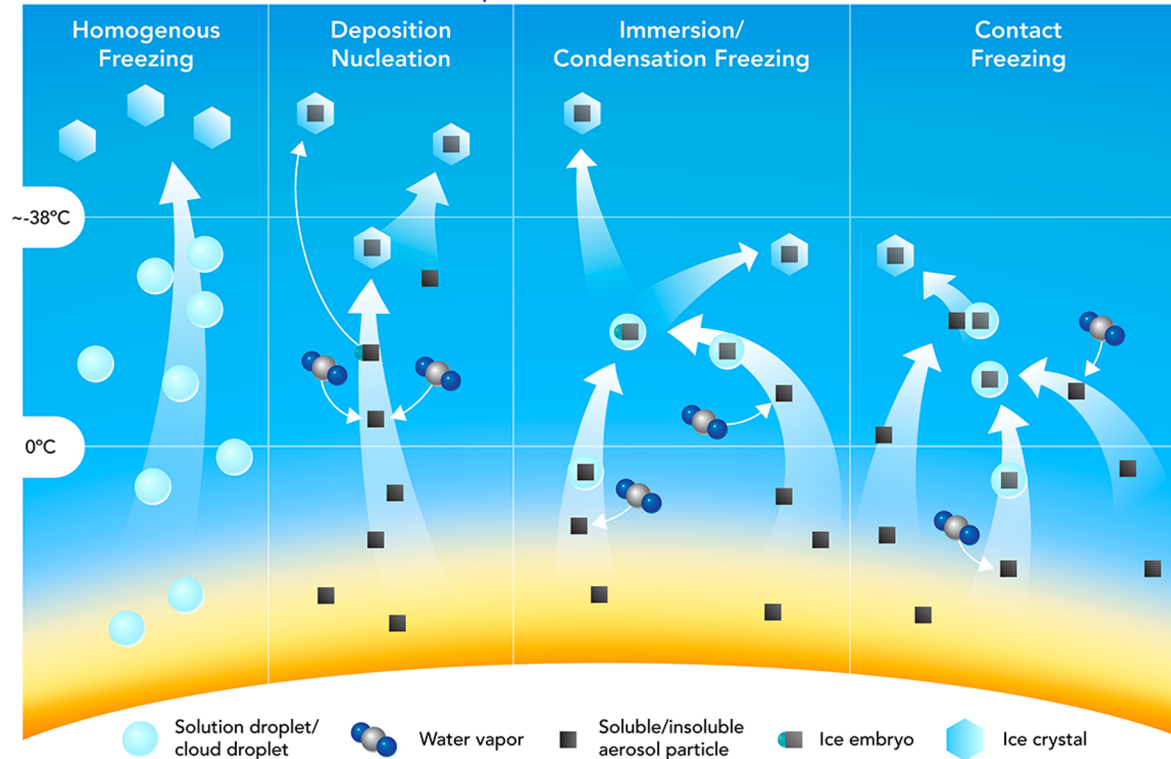


- Ice crystals are form by**
1. Homogeneous nucleation
 2. Heterogeneous nucleation
 - a. Deposition nucleation
 - b. Immersion freezing
 - c. Contact freezing

Fig 4.5 Atmosphere, clouds, and climate

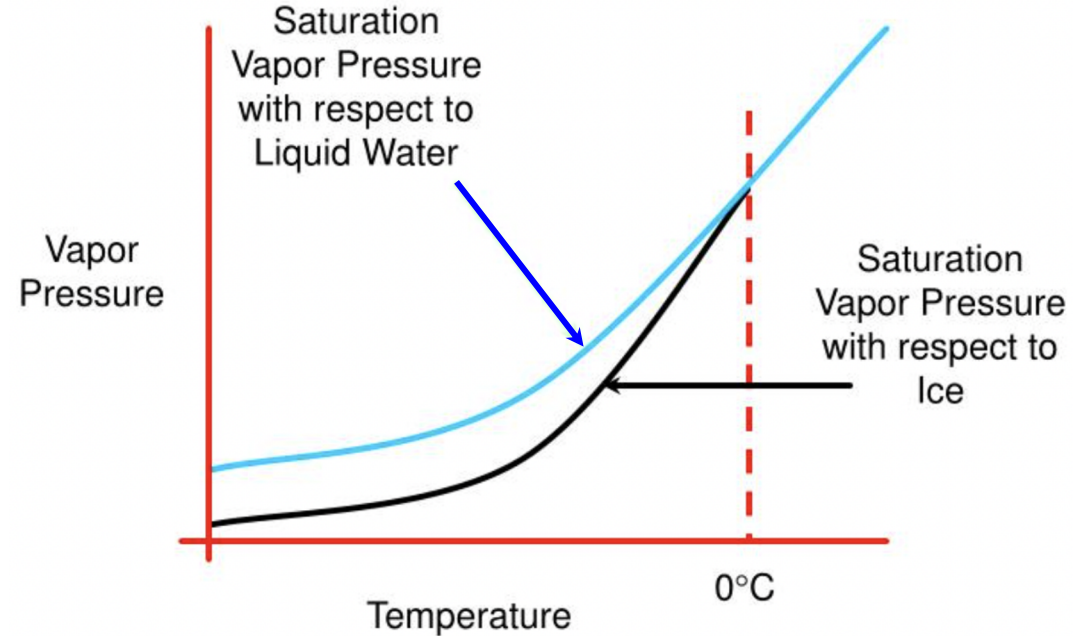
Snow in the atmosphere: How crystals form?

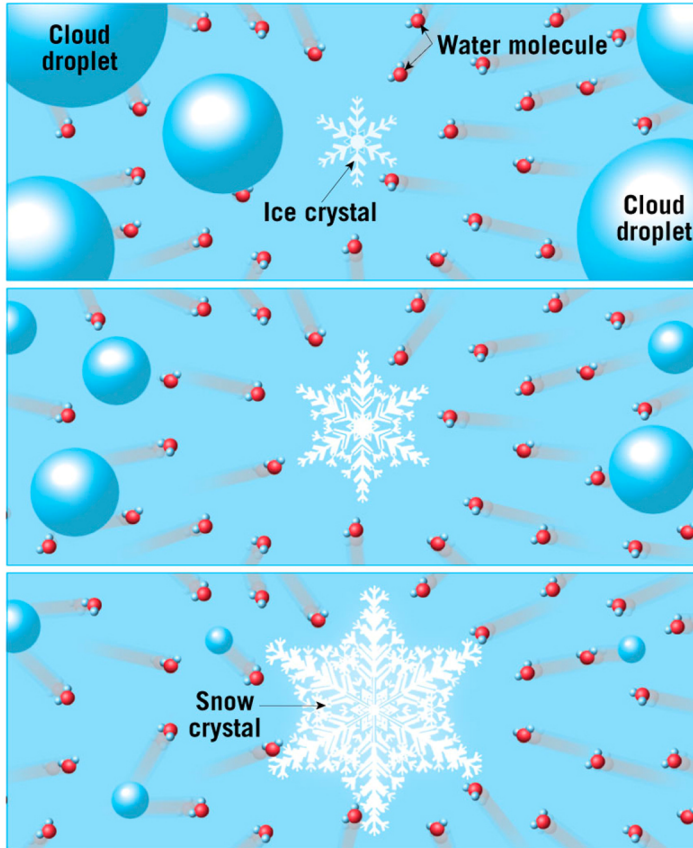
Ice Nucleation Mechanisms in the Atmosphere



Growth of crystals: Bergeron Process

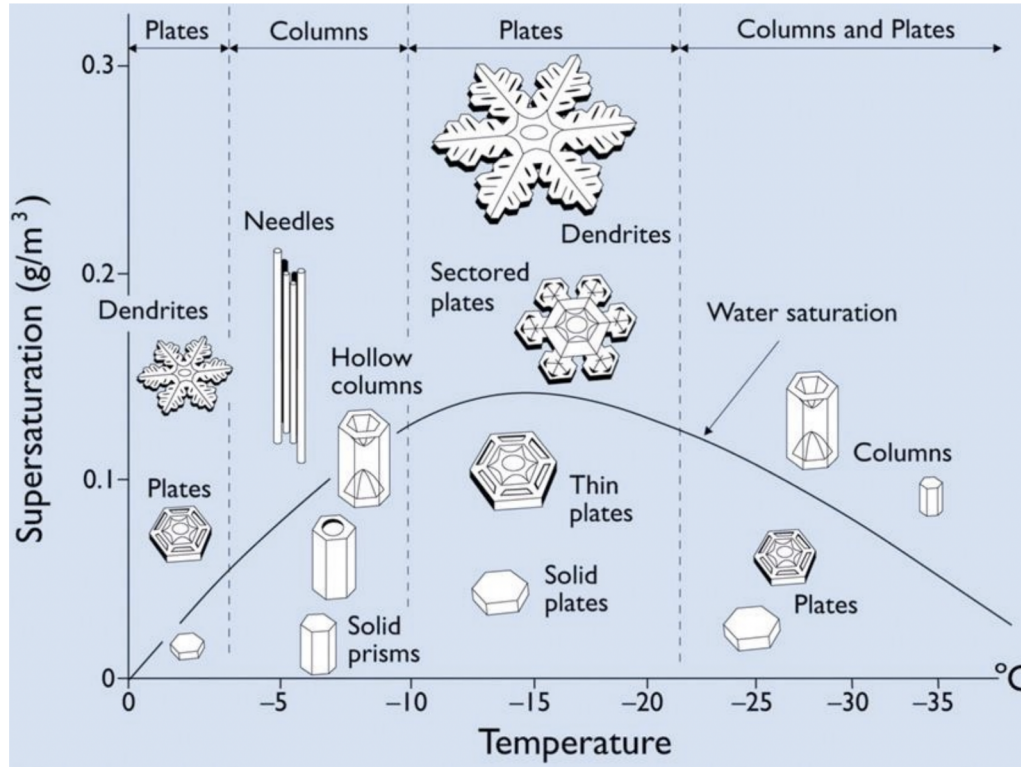
What are the three components of clouds?





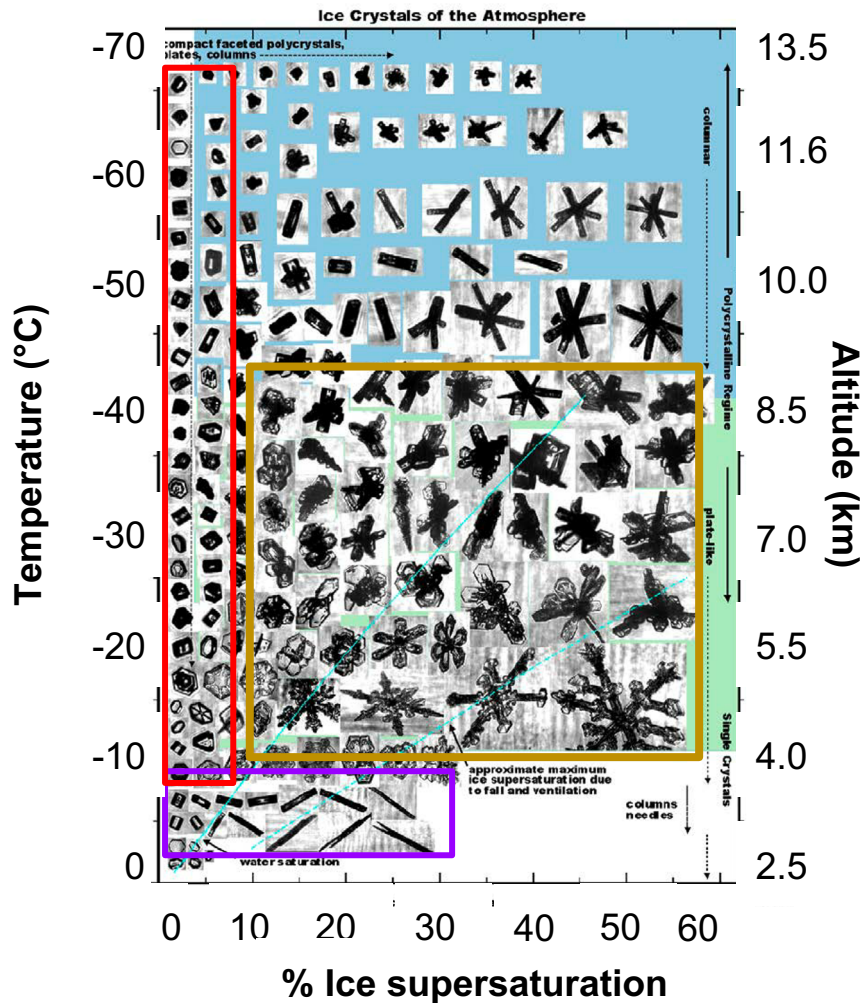
<https://biology-forums.com/index.php?action=gallery;sa=view;id=31161>

Structural form of snowflakes



The form changes back and forth between columns and plates as T changes.

Increasing S increases the surface area to volume ratio of the crystal.

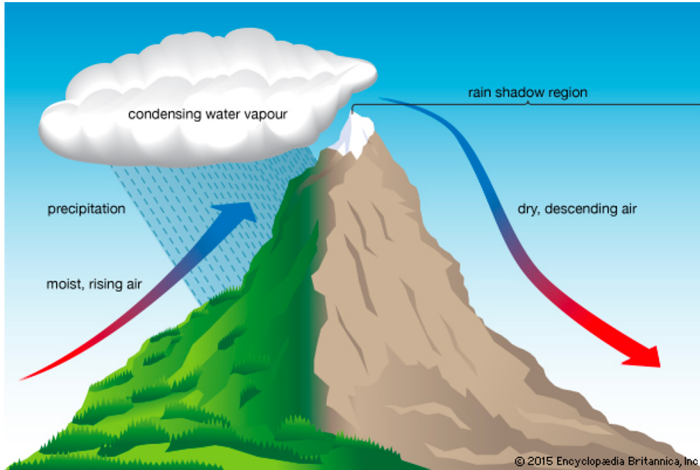


What kind of behavior can you see in this Figure?

Source: Mitchell (2011). Planet Earth 2011 - Global Warming Challenges and Opportunities

What are the two mechanisms of precipitation associated with snowfall?

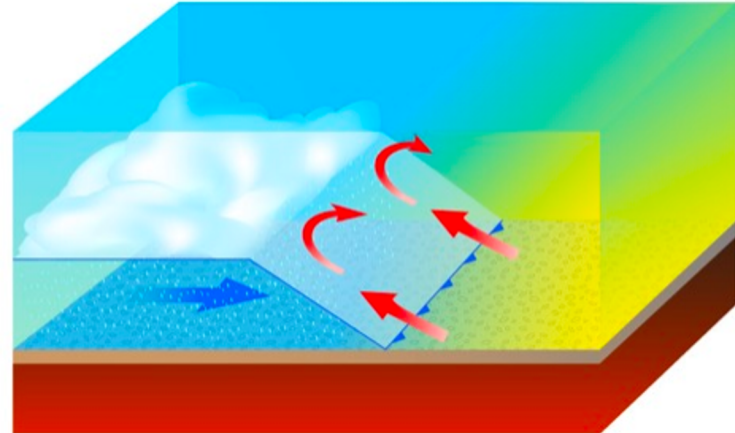
Orographic uplifts



Himalayas, New Zealand, Andes

<https://kids.britannica.com/students/article/microclimate/604042>

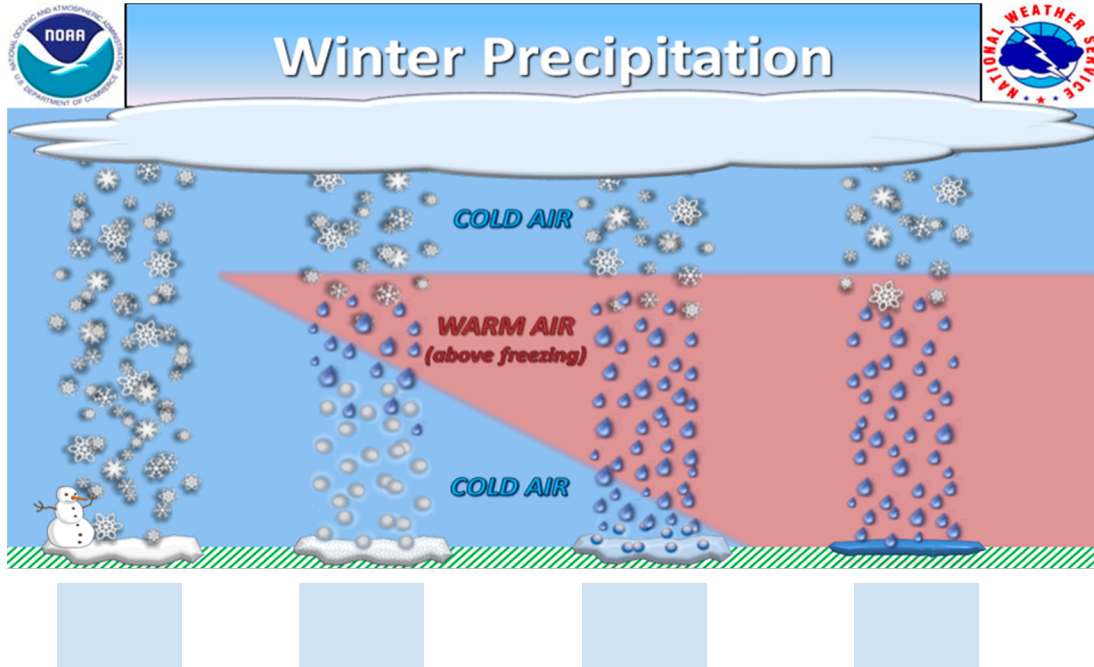
Air mass mixing/frontal precipitation



Winter storms at midlatitudes

<https://www.acurite.com/blog/cold-fronts.html>

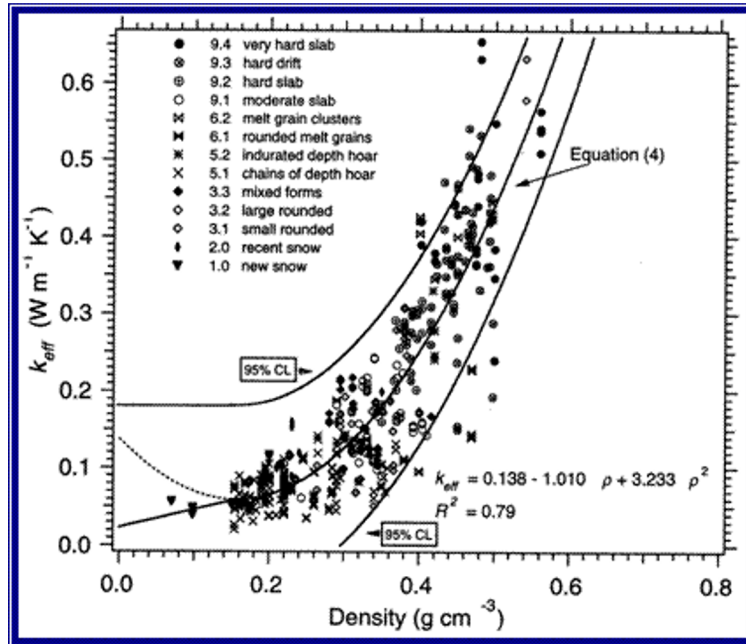
Types of Snow



1. Freezing rain
2. Snow
3. Rain
4. Sleet

Once in the ground ...

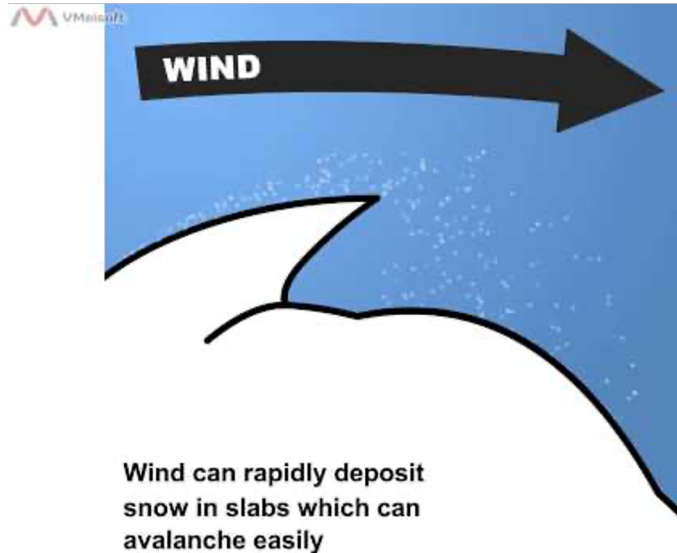
Once in the ground snow acts as an insulator with a typical density of 100 g/m³



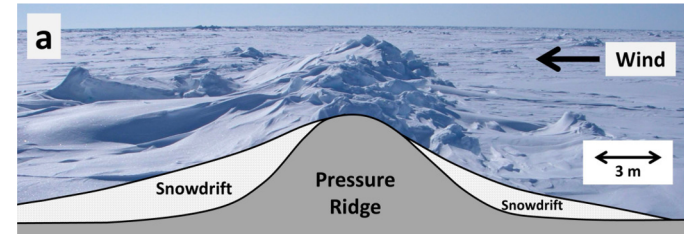
Wind, humidity, temperature play a strong role in the evolution and densification of the snowpack ...

The role of winds

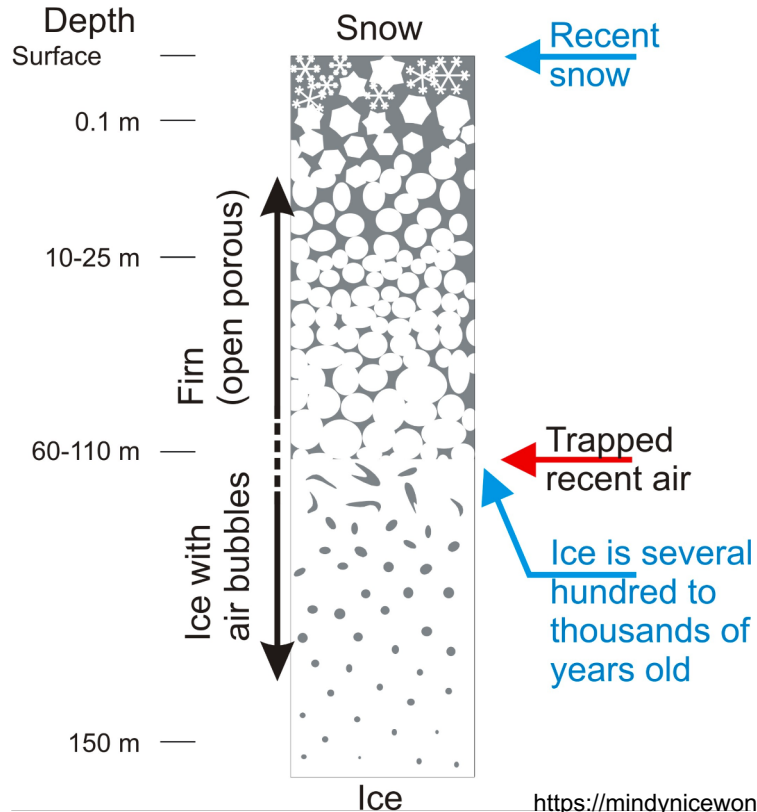
Persistent winds in **dry and cold** conditions: Wind slab (density 400 kg/m³)



Convergence zones: Snow accumulation



Snow age



Compacting buried snow results in gradual densification.

Depth hoar or sugar snow

What is depth hoar?

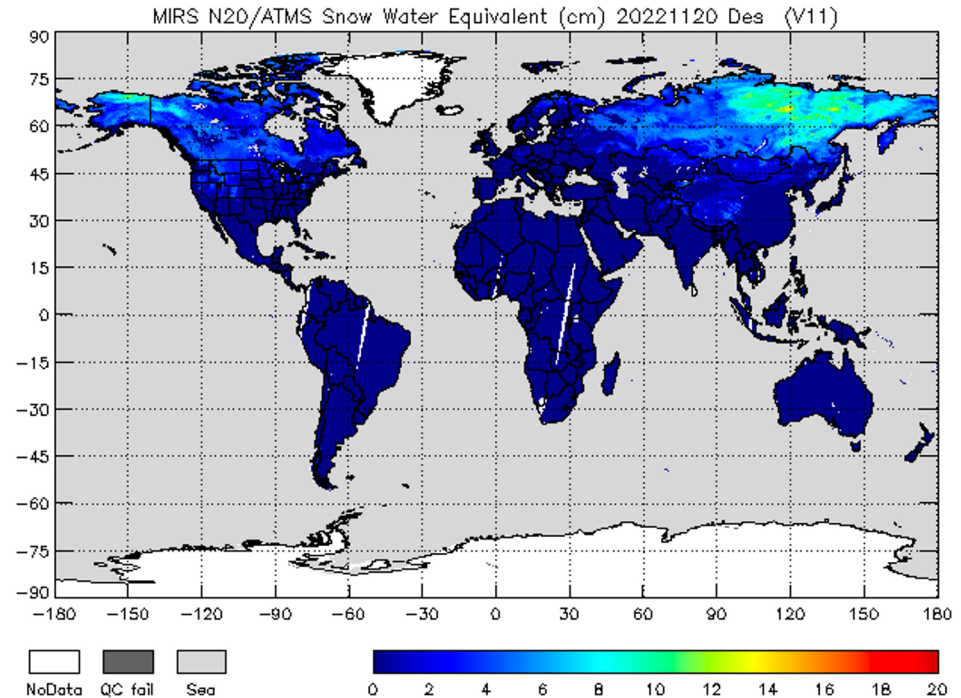
What is the main mechanism that drives the formation of depth hoar?



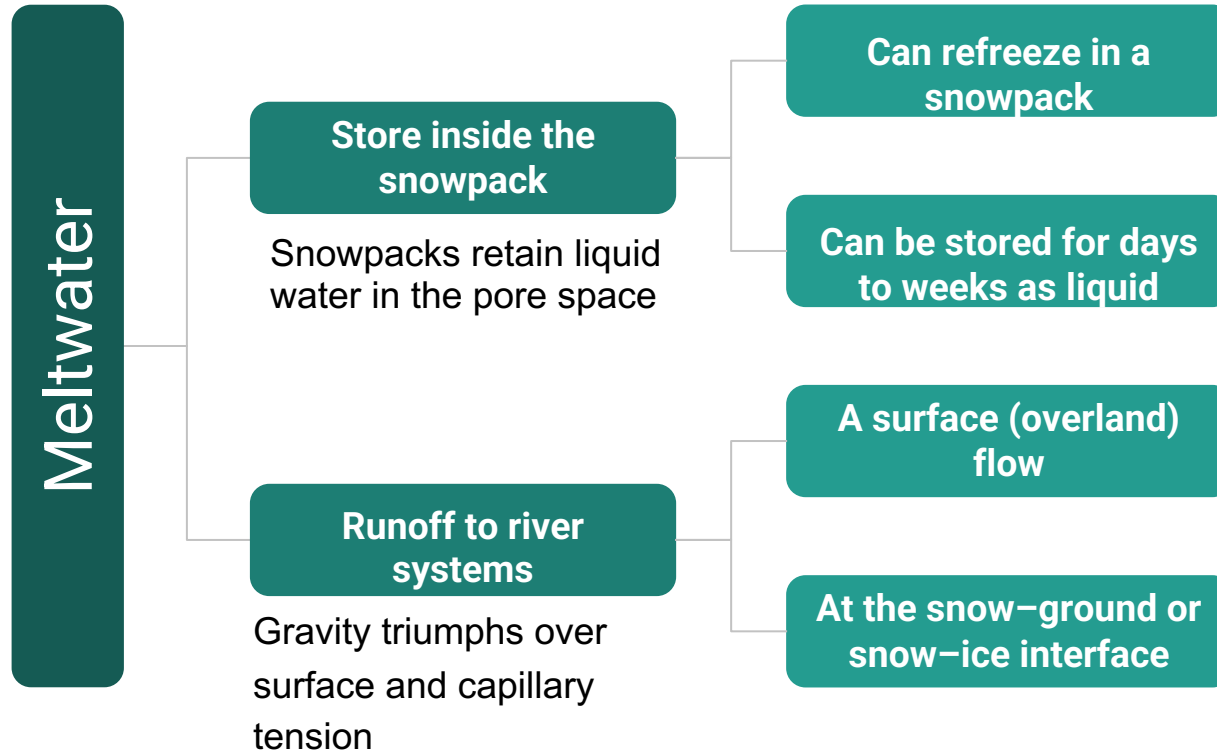
<https://www.youtube.com/watch?v=JjW2GnTogdo&t=1s>

Observations of seasonal snow

What is snow water equivalent (SWE) ?



Once snow melts ...

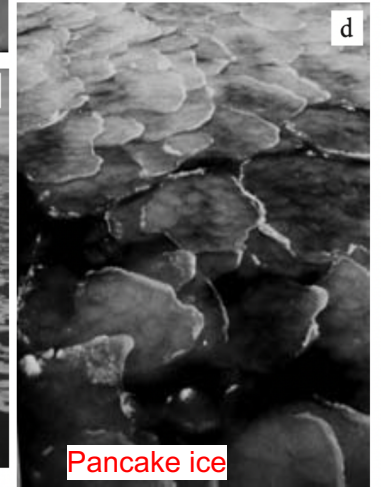
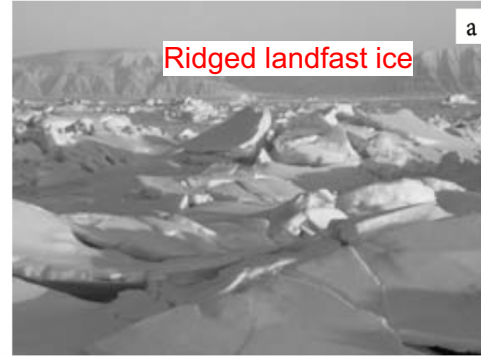


SEA ICE

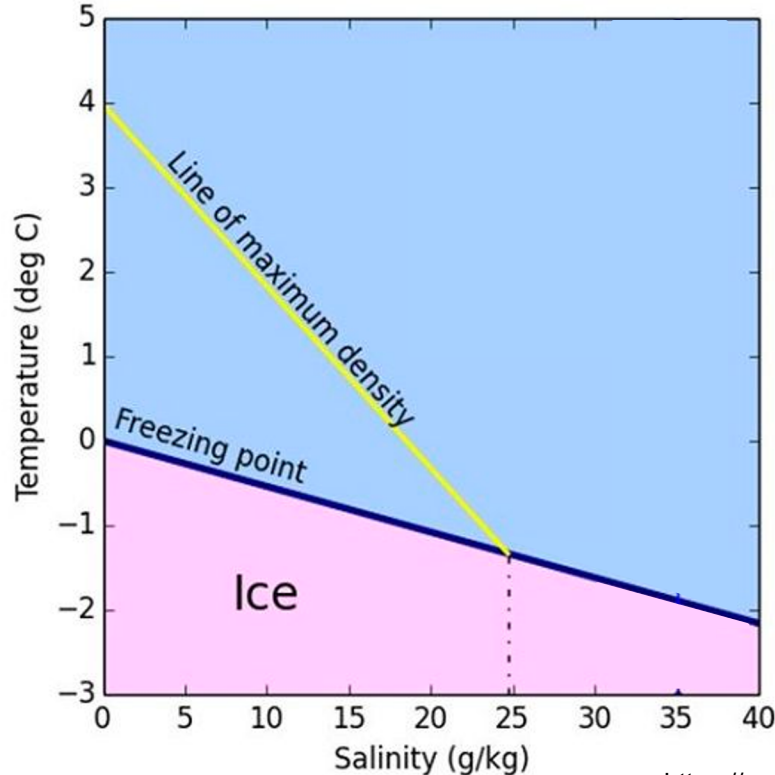
Sea ice is frozen seawater which floats on the surface of the ocean.

The chaotic looking of sea ice is from the way in which seawater freezes

What is the primary difference?



Freezing temperature vs salinity



What is the average salinity of seawater?

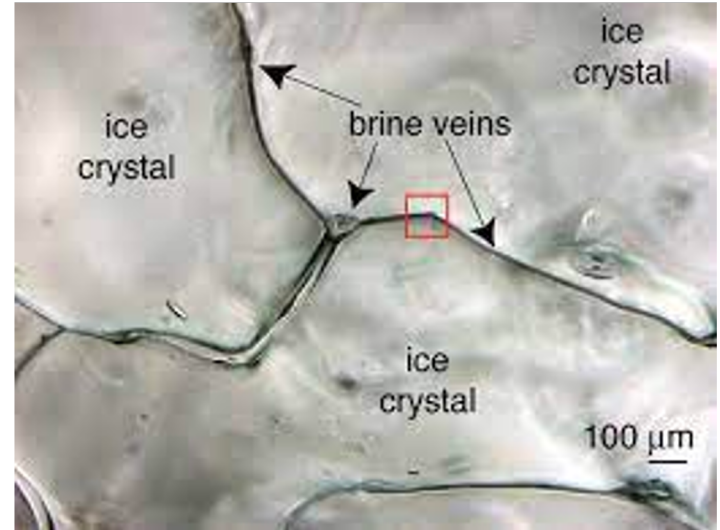
When seawater cooled from above, it continues to cause convection right down to the freezing point.

What is sea ice made of?

A mixture of brine, ice crystals, air, solid salts

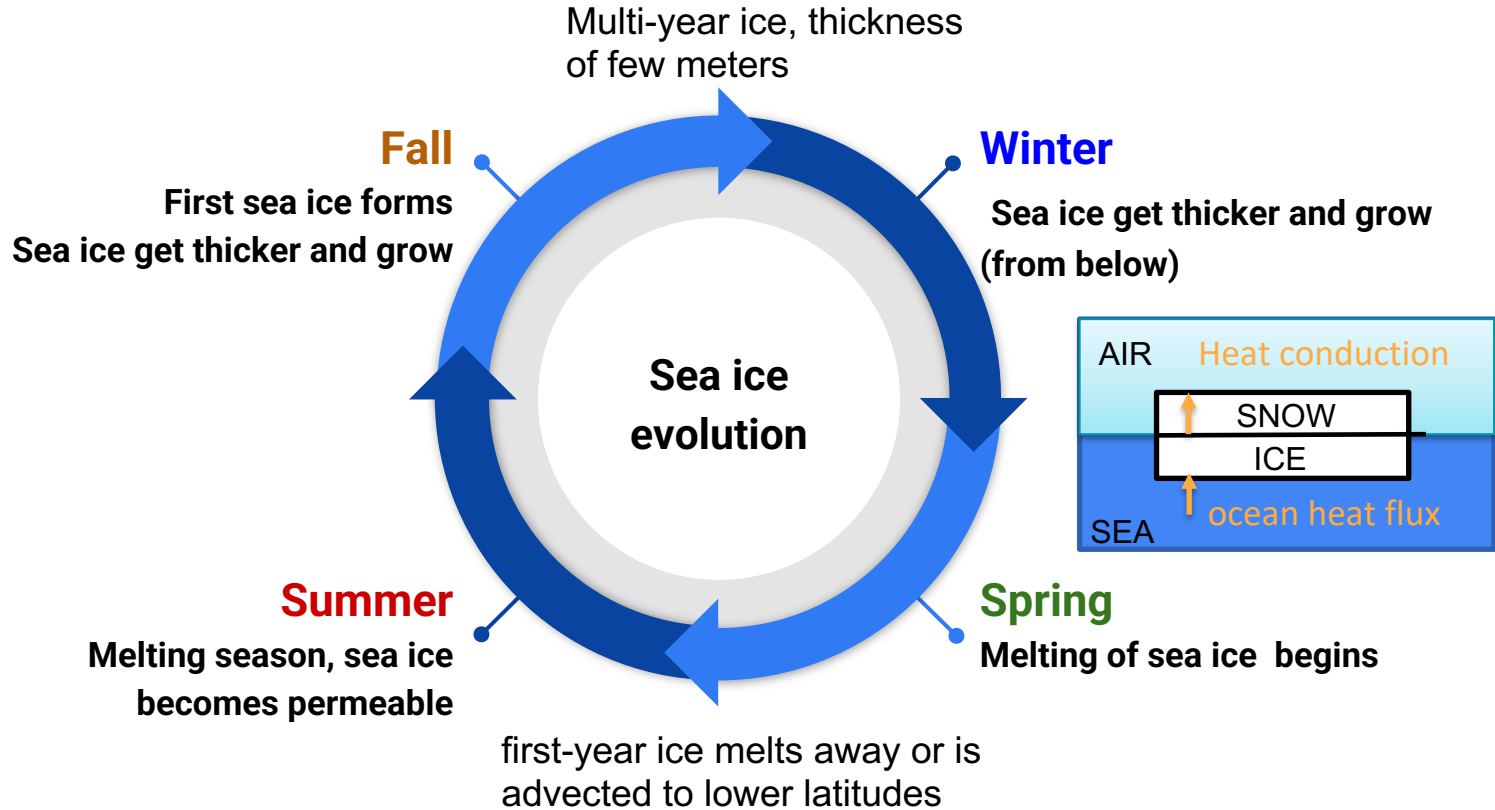
When sea ice forms, small spaces remain between the ice crystals and are filled with a salty liquid, known as brines.

Brines give first-year sea ice a salinity value between 5–15 ppt

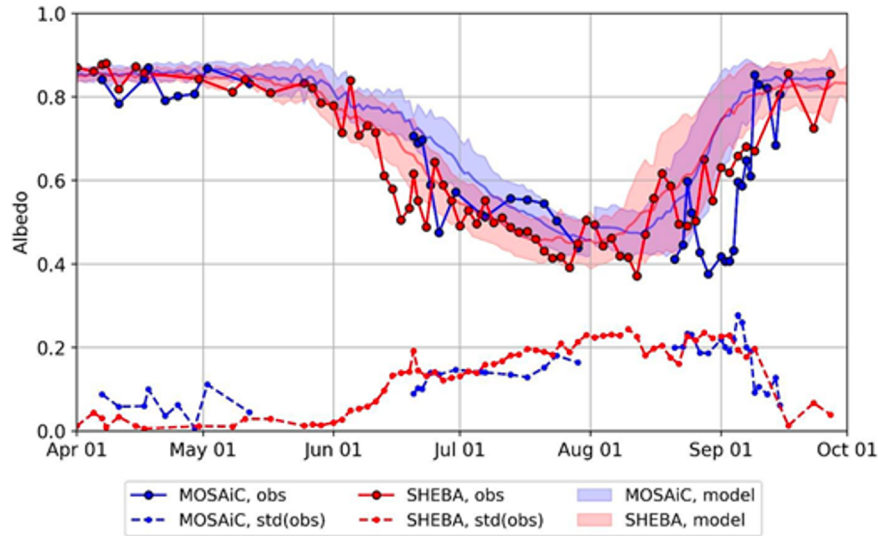


<http://greenedge-expeditions.com/brine-channels-micro-habitat-for-ice-algae/>

Sea ice during the Seasons



During summer, atmospheric heat flux drives sea-ice melt.



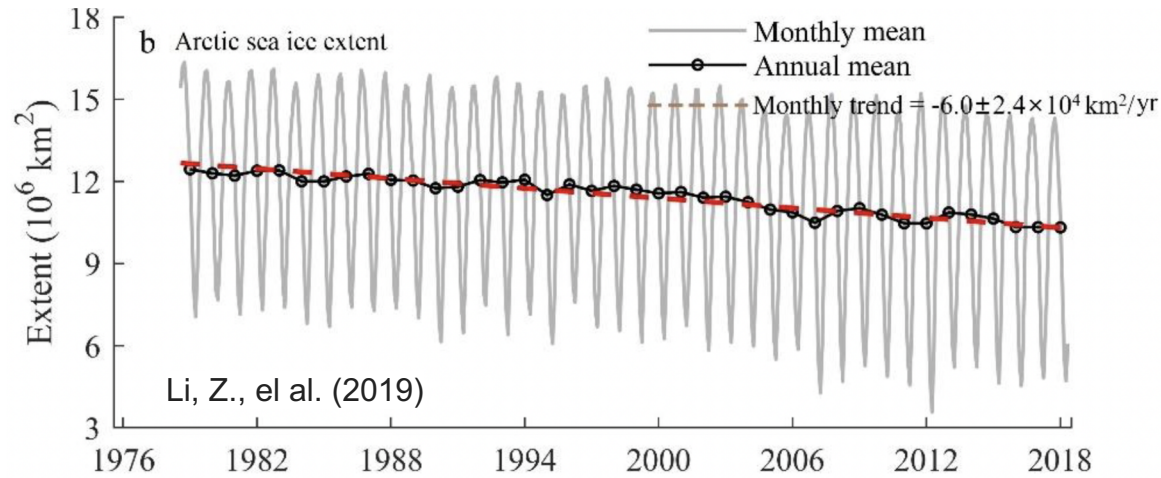
Light, B. et al (2022). *Elem Sci Anth*,

Atmospheric and
ocean heat fluxes

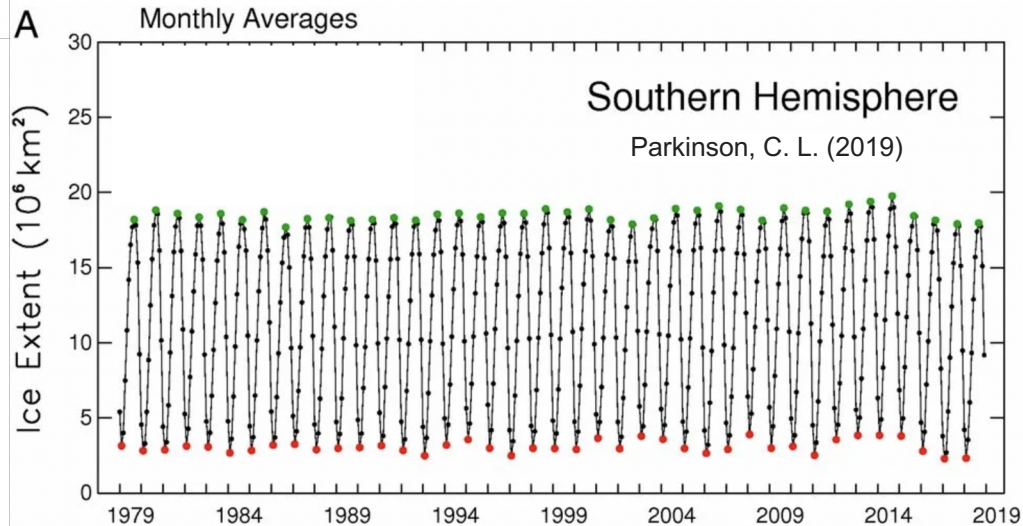
→ Sea ice warms and
melt

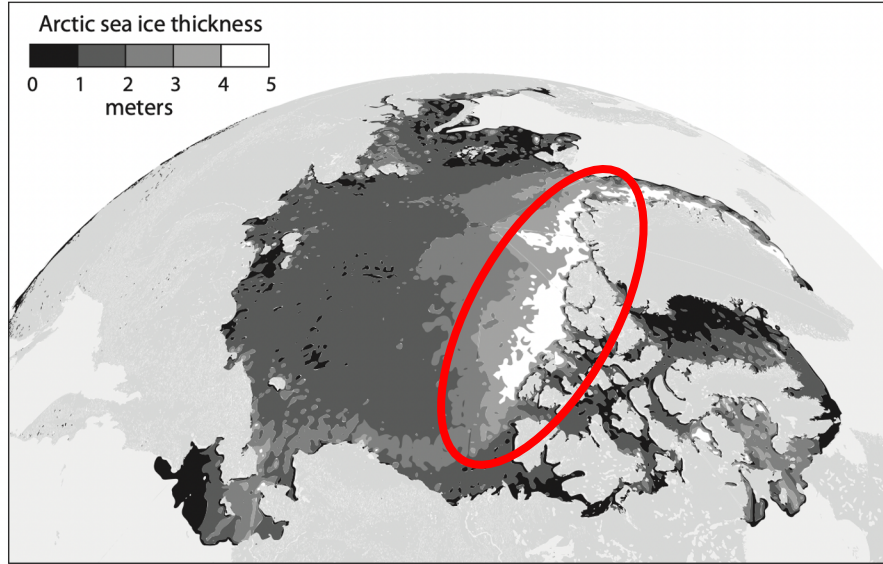
Albedo decreases
drastically and
melting increases

↓
← Melt ponds forms on
the ice surface

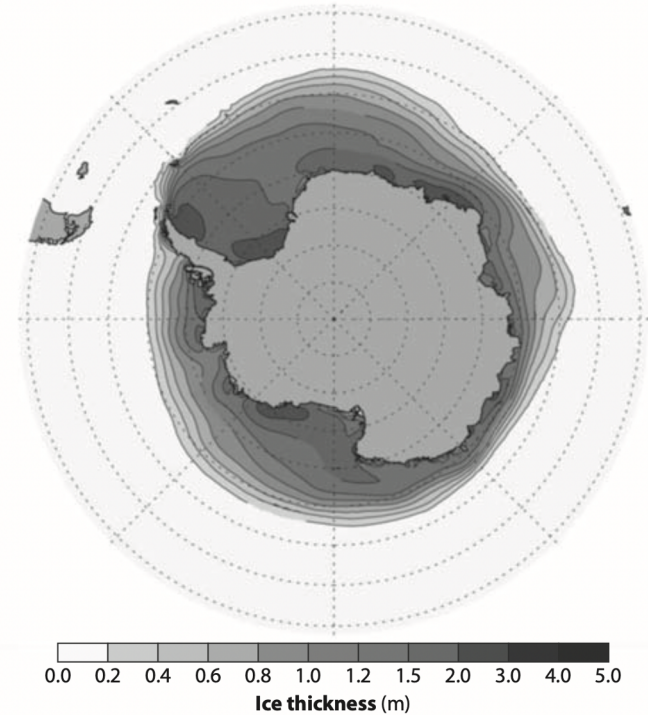


What are the main differences between Arctic and Antarctic?





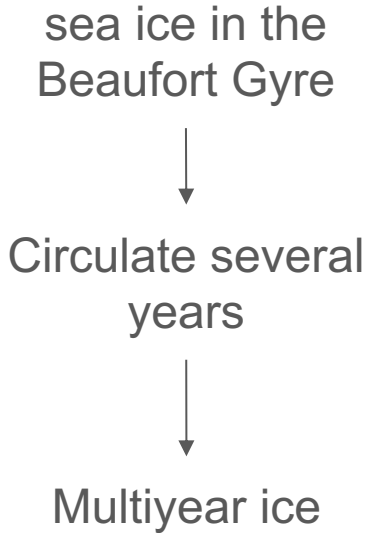
Why do we have multi-year sea ice over northern Greenland and the Canadian Arctic?



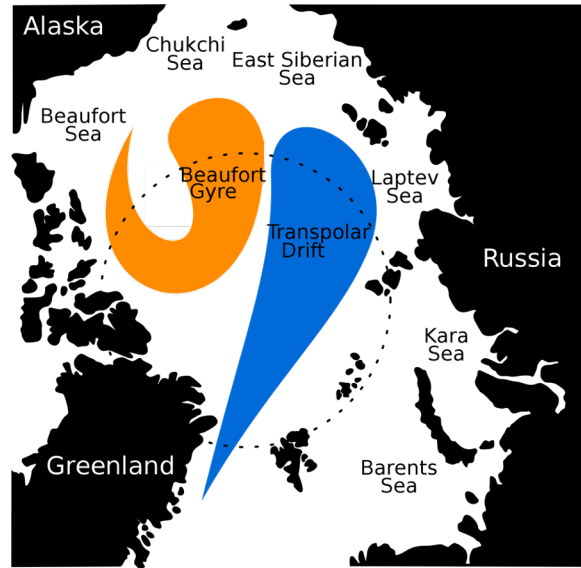
Why sea ice has a radial symmetry?

In the Arctic

Winter → The ice grows out



Summer → The ice contracts as it melts



In the Antarctica

Offshore winds from the continent push
ice northward



Divergent ice pack



Little multiyear ice

The differences between Arctic and Antarctic sea ice are explained by:

- The Arctic is an ocean surrounded by continent
- The Antarctic is land surrounded by ocean
- Convergence in the Arctic
- Divergence in the Antarctic

Interannual variability and climate change

Air temperature

Ocean Heat Fluxes

Ocean circulation

Winds



A change in any of
these variables could
lead to gain or loss of
sea ice

Sea-ice dynamics

$$\rho_{\text{si}} \left(\frac{\partial u}{\partial t} + u \cdot \nabla u \right) = - \rho_{\text{si}} f \times u + \tau_{\text{a}} + \tau_{\text{w}} - \rho_{\text{w}} g \nabla h_{\text{w}} + \nabla \cdot \sigma,$$

Overall

- Ice crystals are formed in the atmosphere by 4 different nucleation mechanisms. Once formed, ice crystals grow at the expense of supercooled water.
- Once in the ground, fresh snow has a lower density than old snow. This lower density makes fresh snow a good insulator.
- Sea ice grows during winter through basal accretion and melts during summer because of atmospheric heat fluxes.
- The differences between the Arctic and Antarctic sea ice are explained by their geographical location, winds and ocean currents, and the effects of climate change.