# The Arctic's Role in Changing Global Climate and Weather

Thomas Spengler| 08/10/2016

# About me

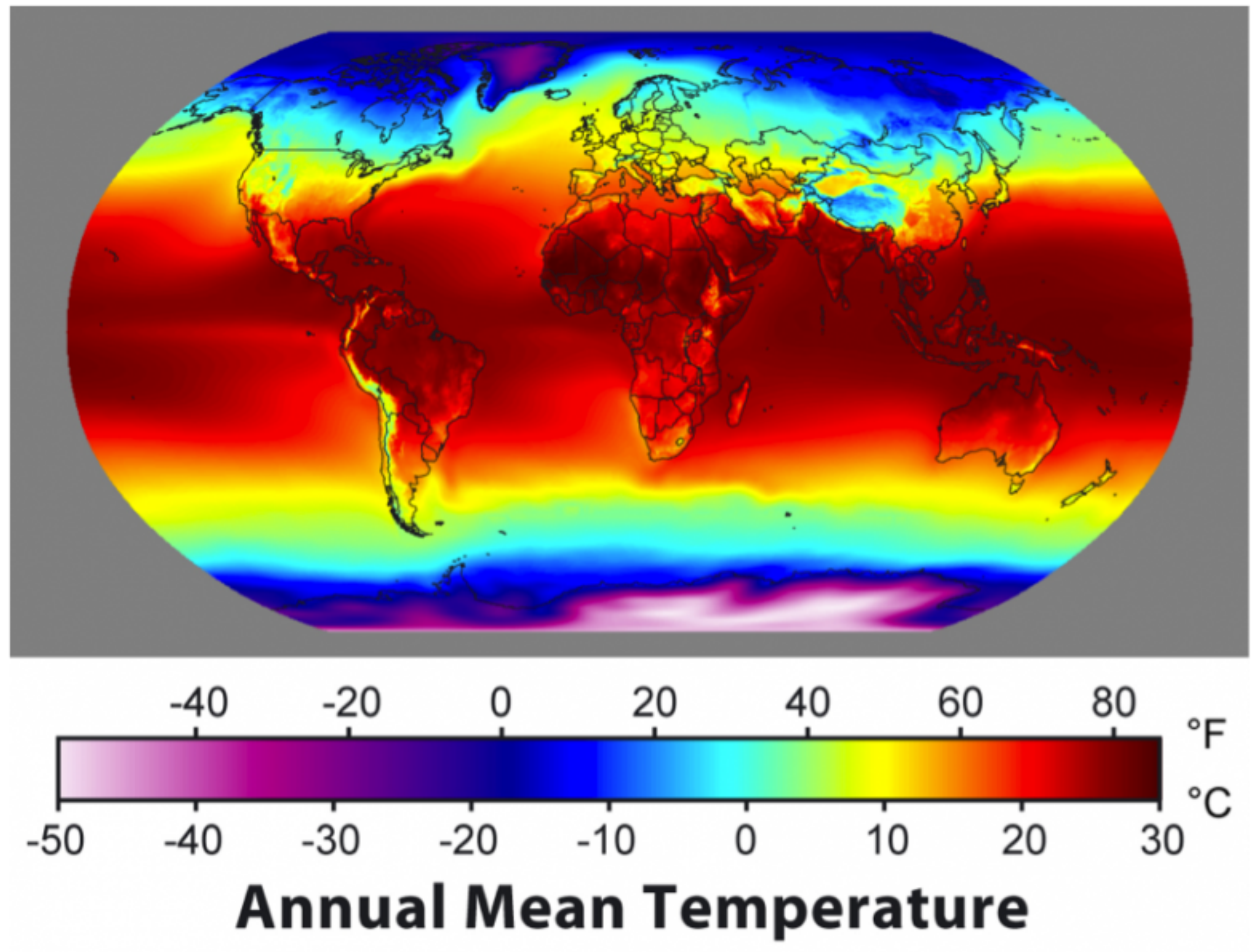
## Thomas Spengler

**Professor**

Director of the Norwegian Research School on Changing Climates in the Coupled Earth System (CHESS). Member of the International Commission for Dynamic Meteorology. Since 2015 elected chair of the Atmospheric Working Group of the International Arctic Science Committee (IASC).

## Experience

Meteorologist focusing on the combination of theory, observations, and modeling with specialization on a variety of scales ranging from meso, synoptic, to large-scale flow. My specific research interests are devoted to interaction processes between different space and time scales.

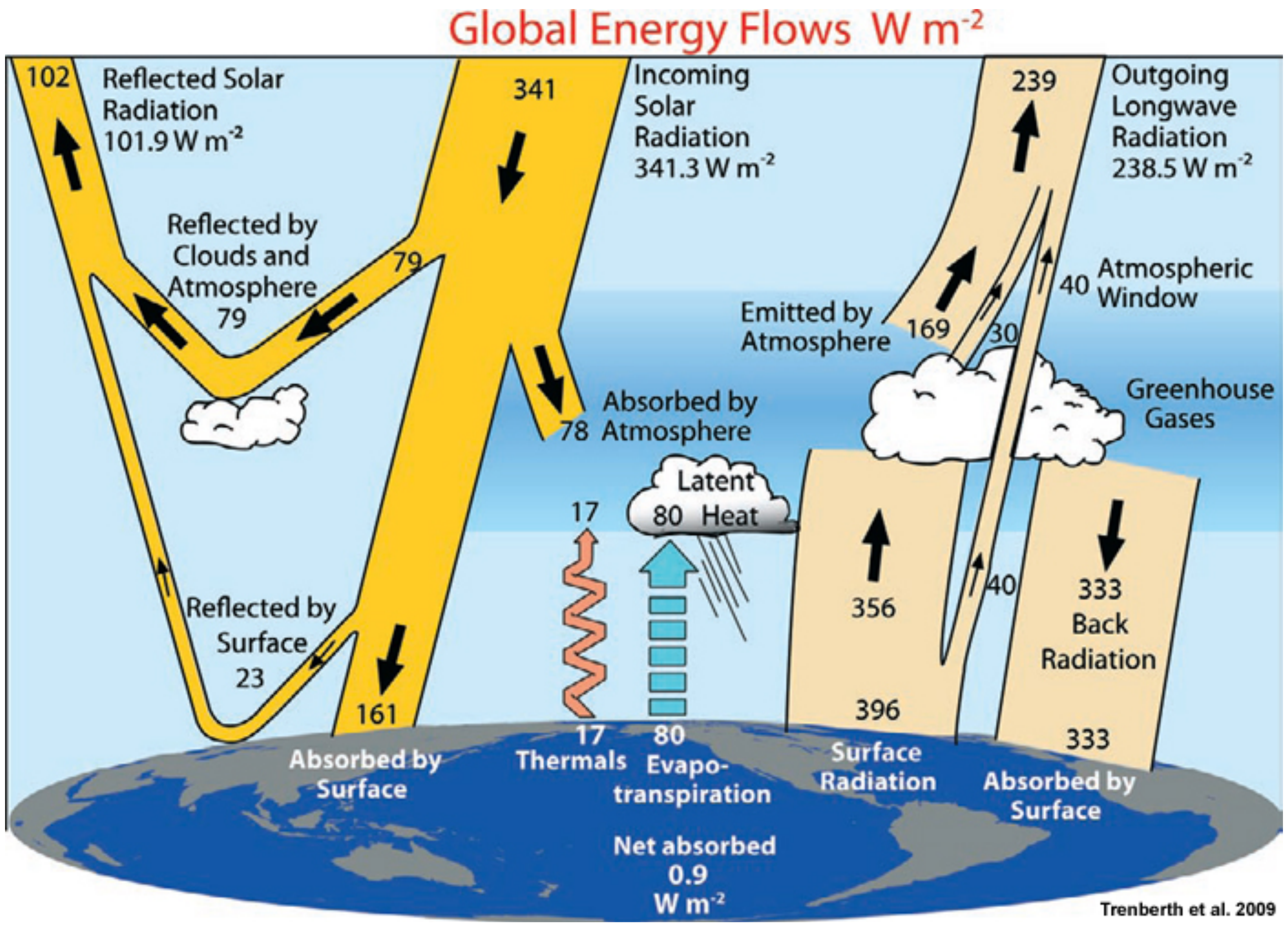


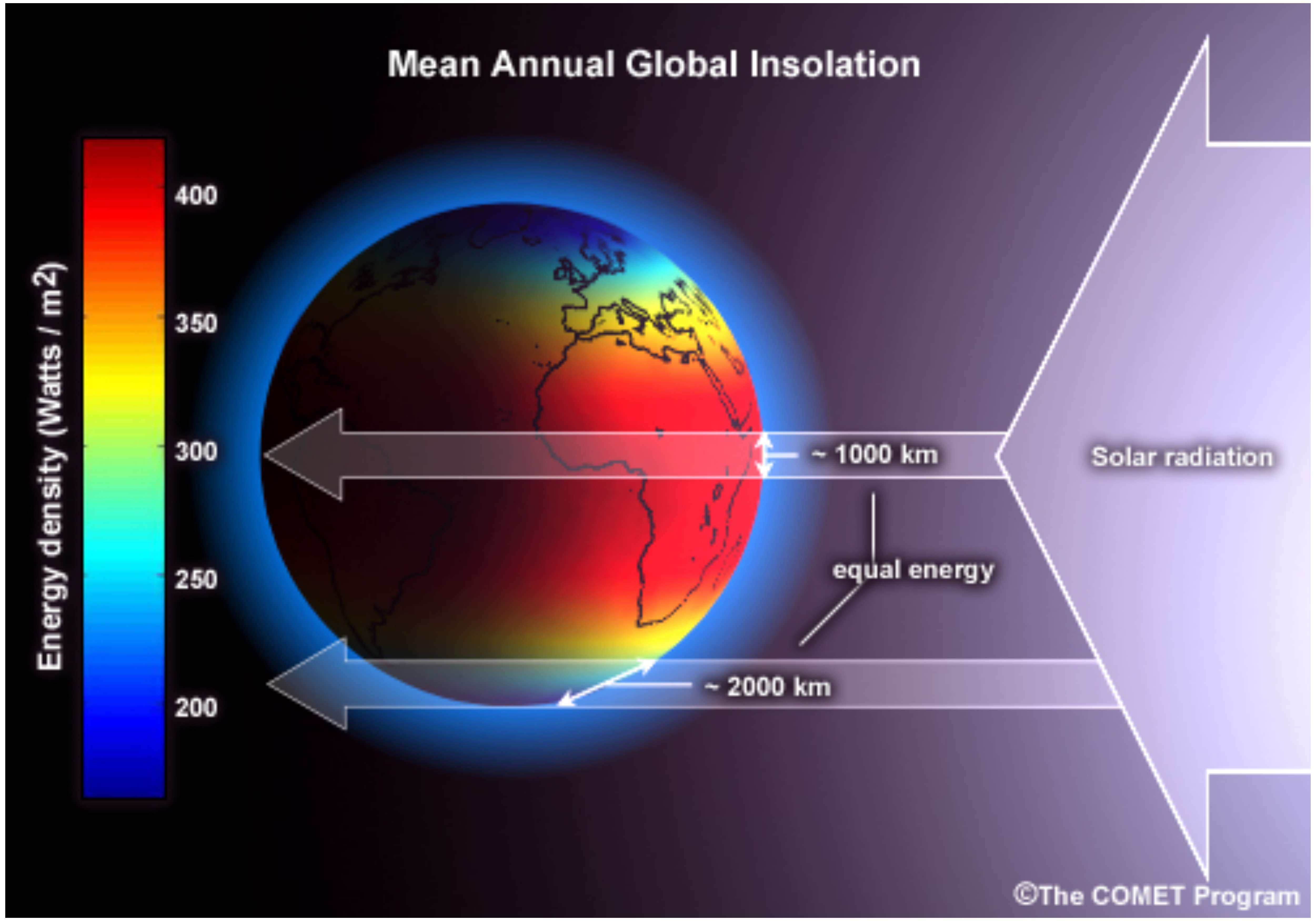

# Global Climate from Pole to Pole

## Earth's radiative Balance and Transport of Energy

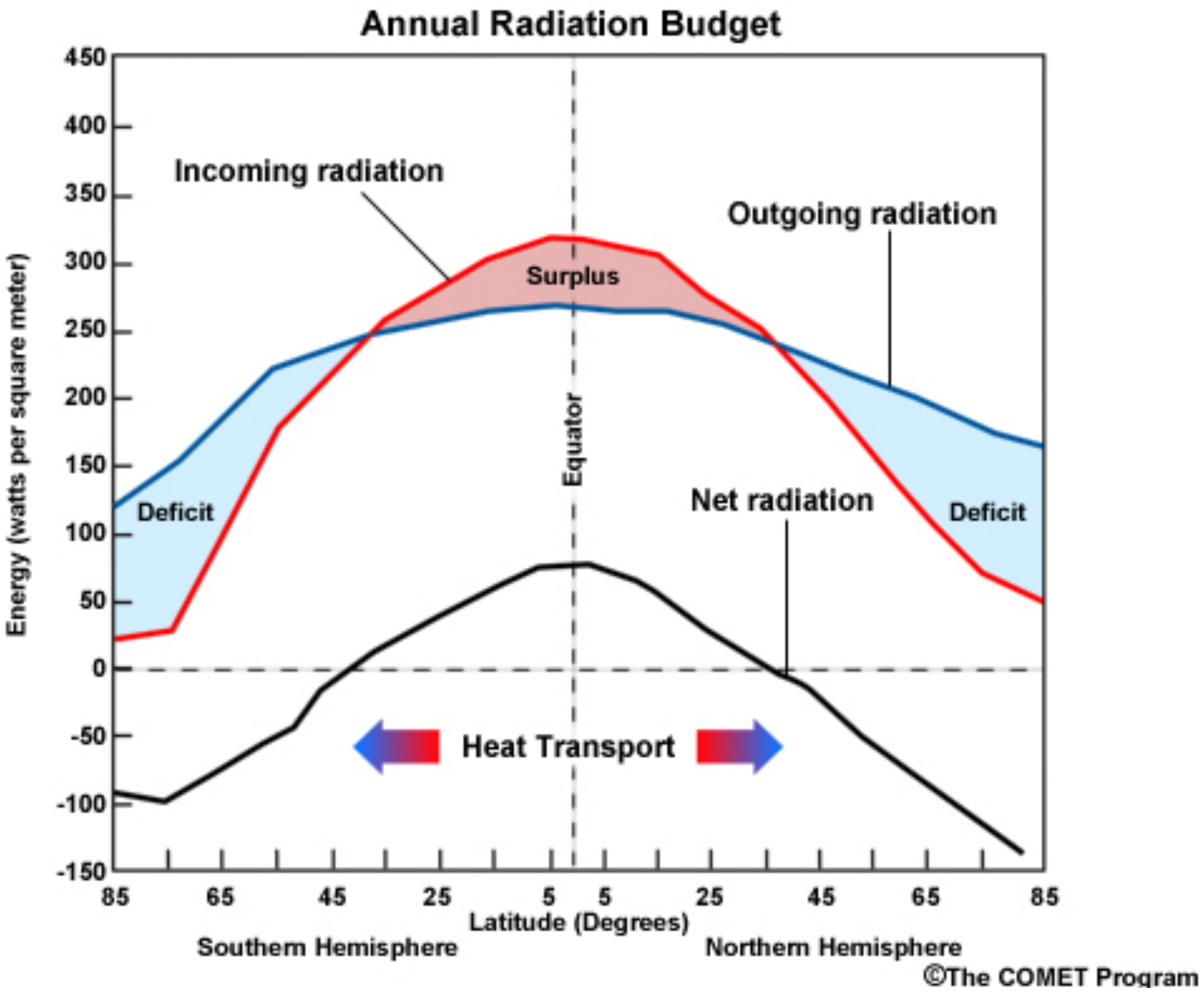
# Radiative balance

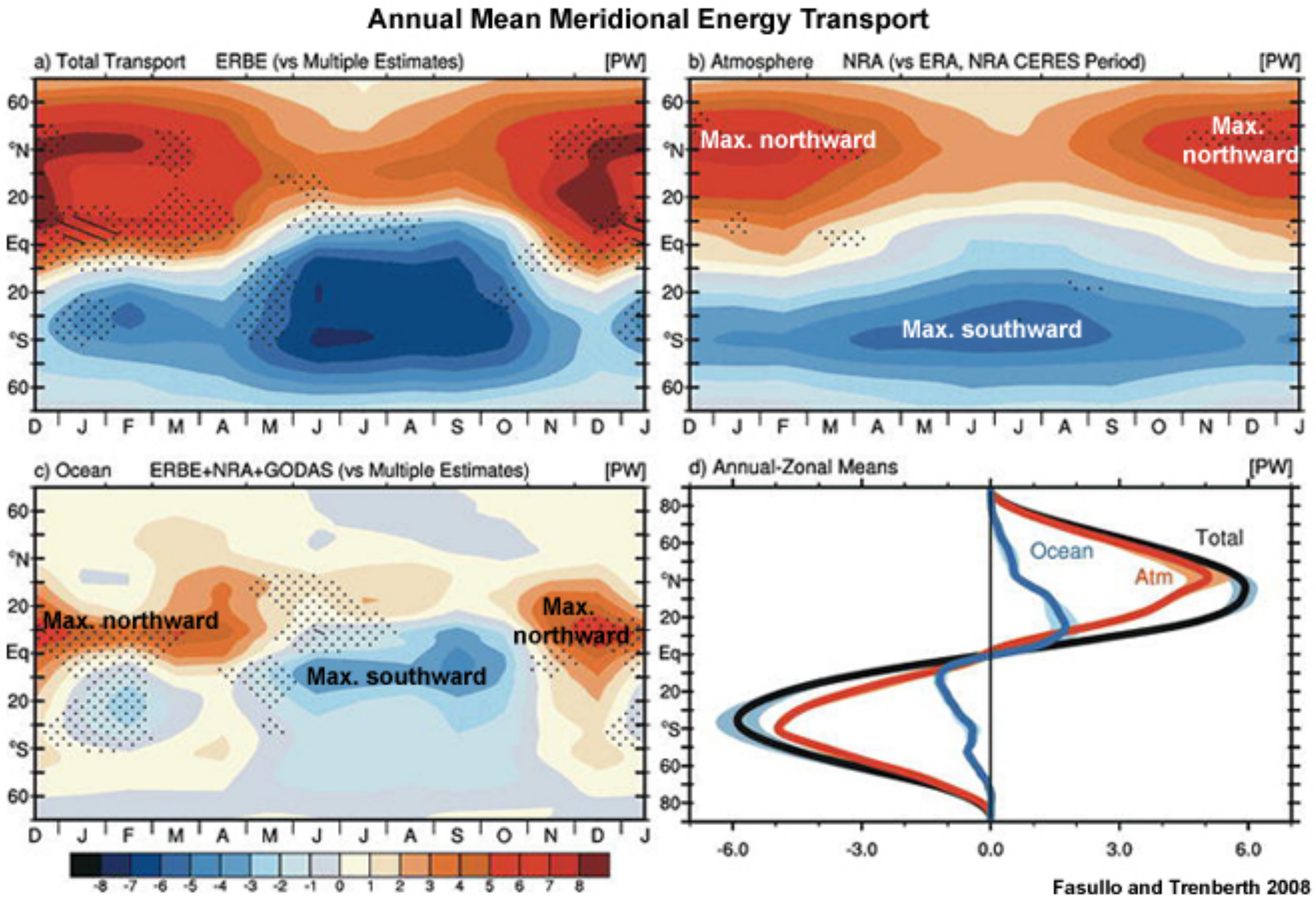
Global balance, but varying with latitude…



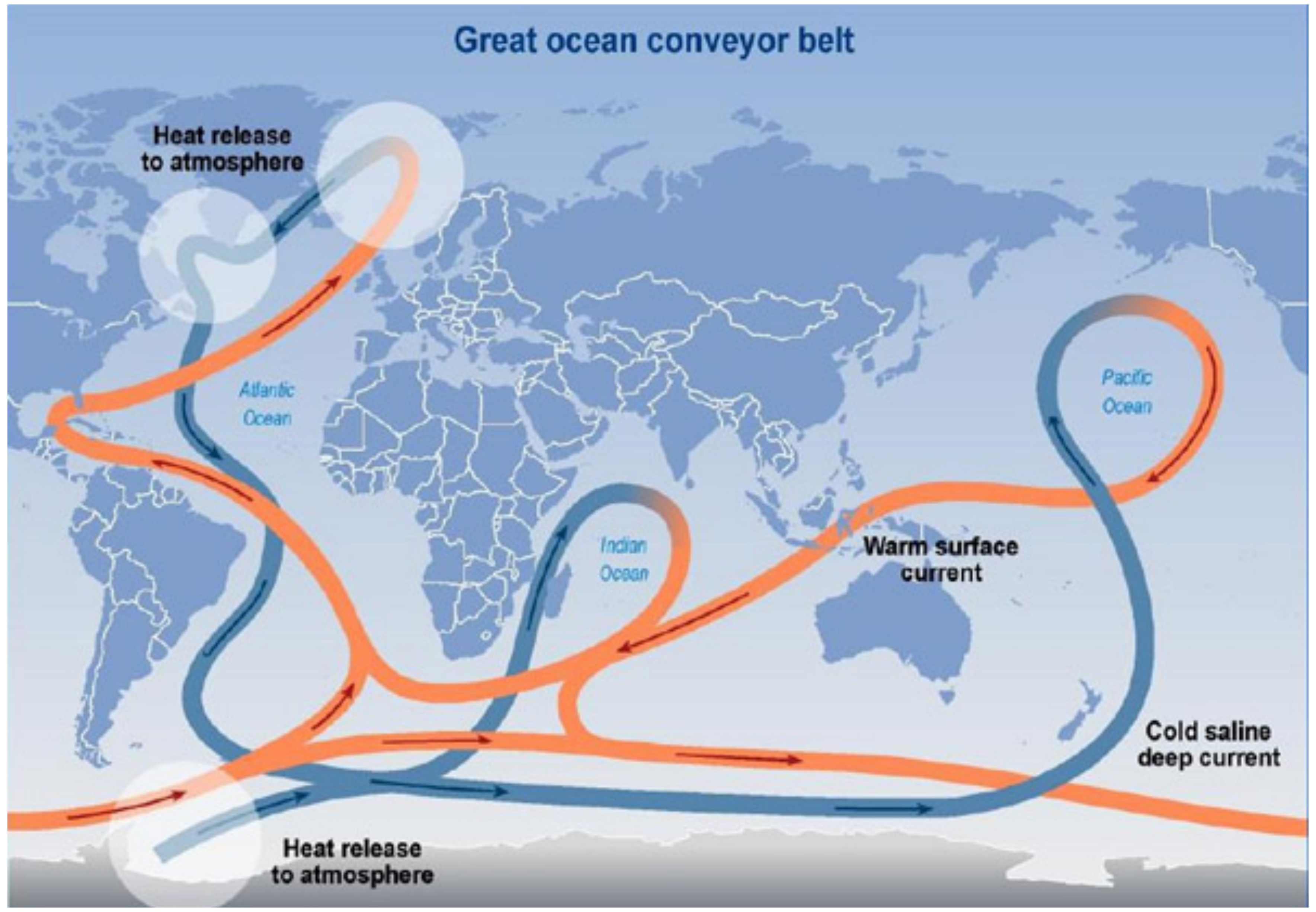
# Energy imbalance and transport

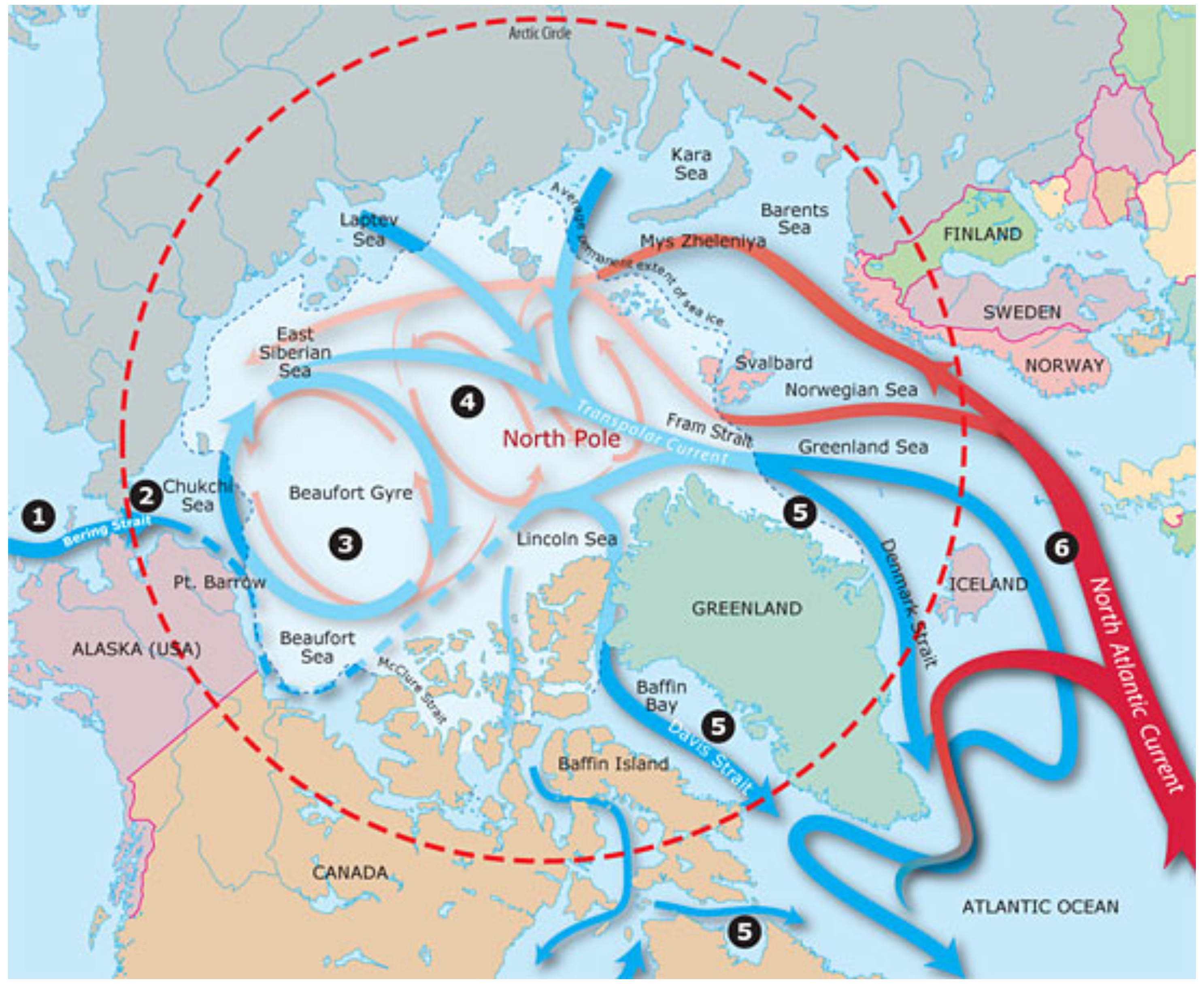


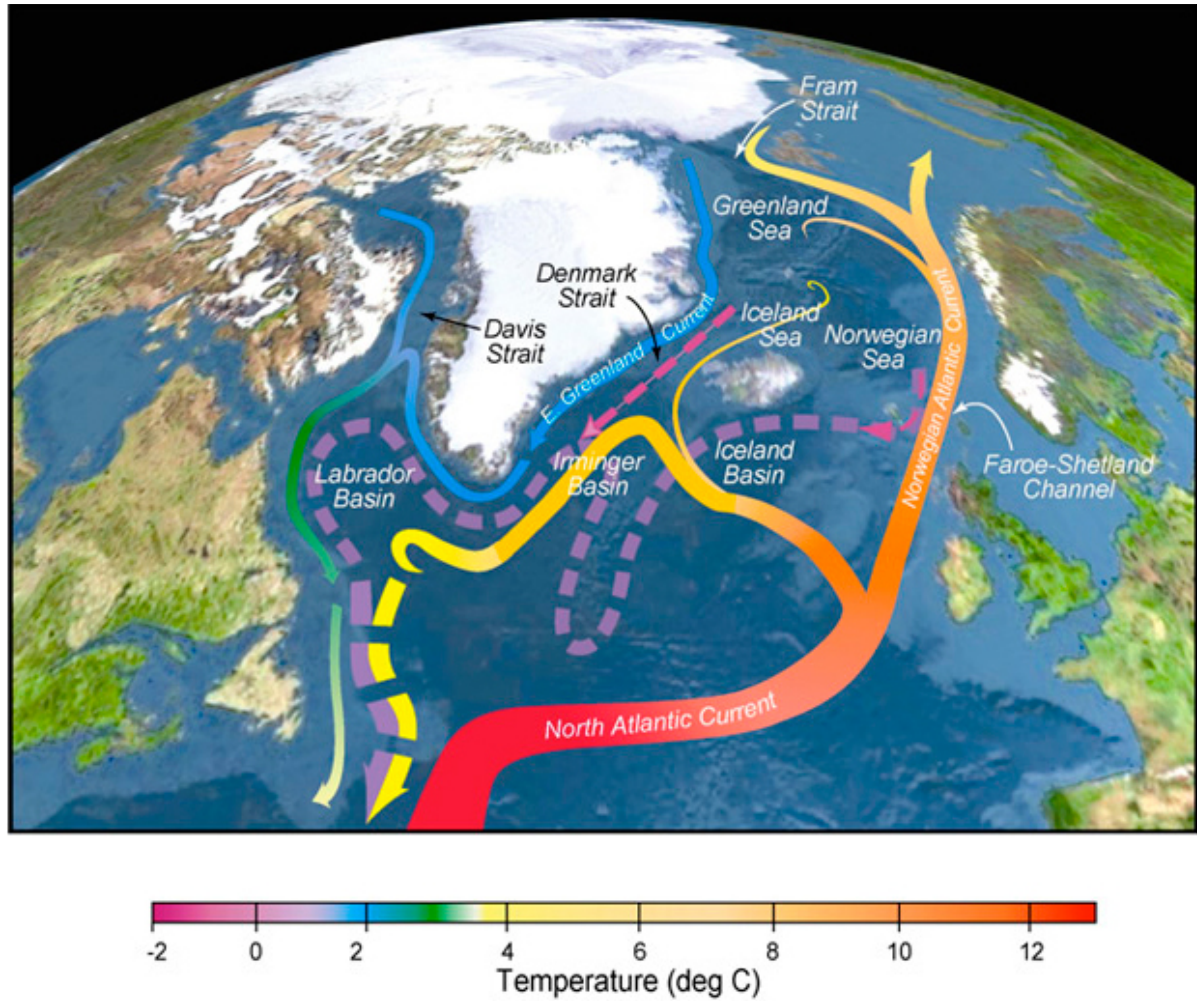




Net gain at lower latitudes and net loss at higher latitudes compensated by meridional energy transport in atmosphere and ocean.

# Energy transport globally connected

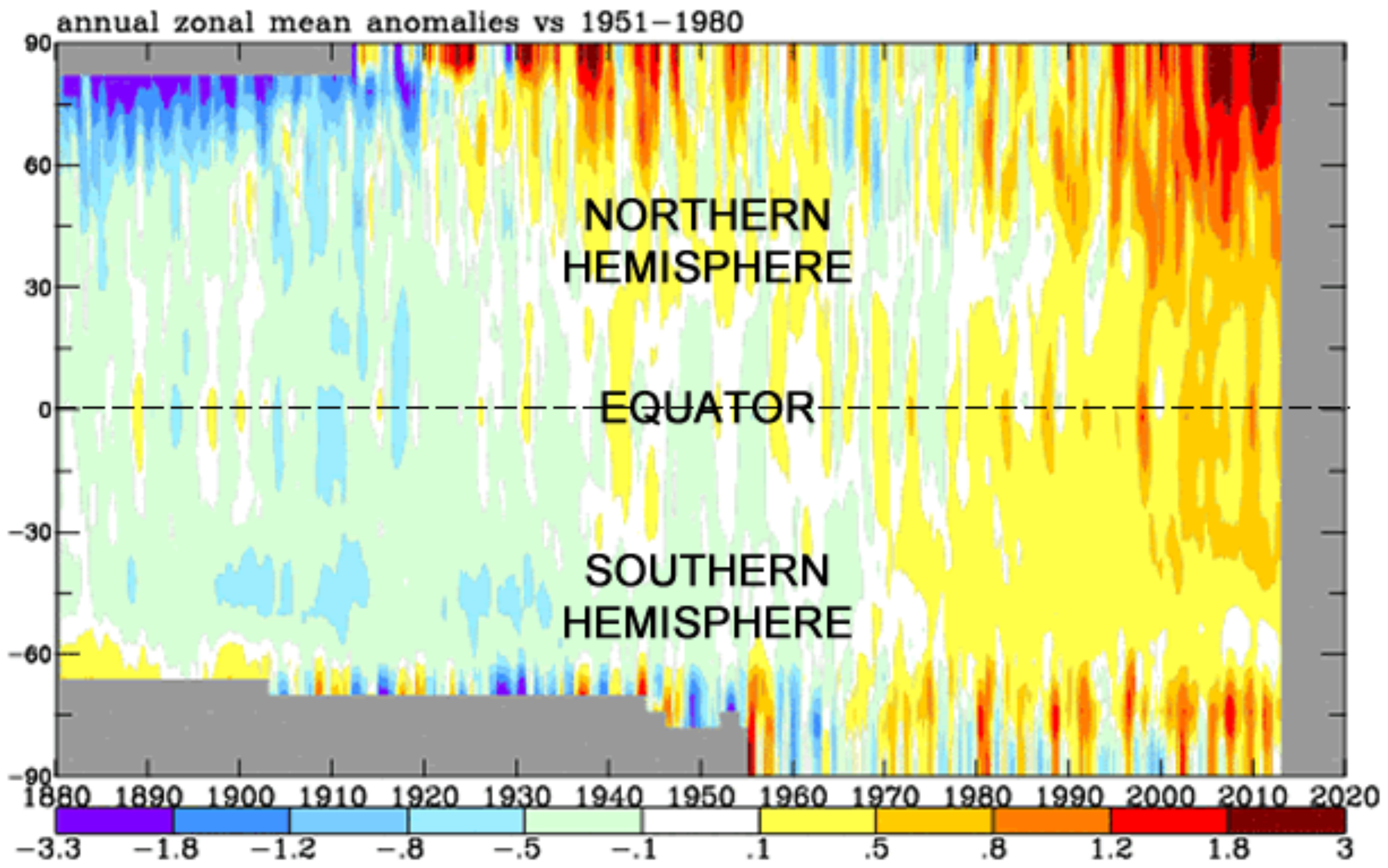


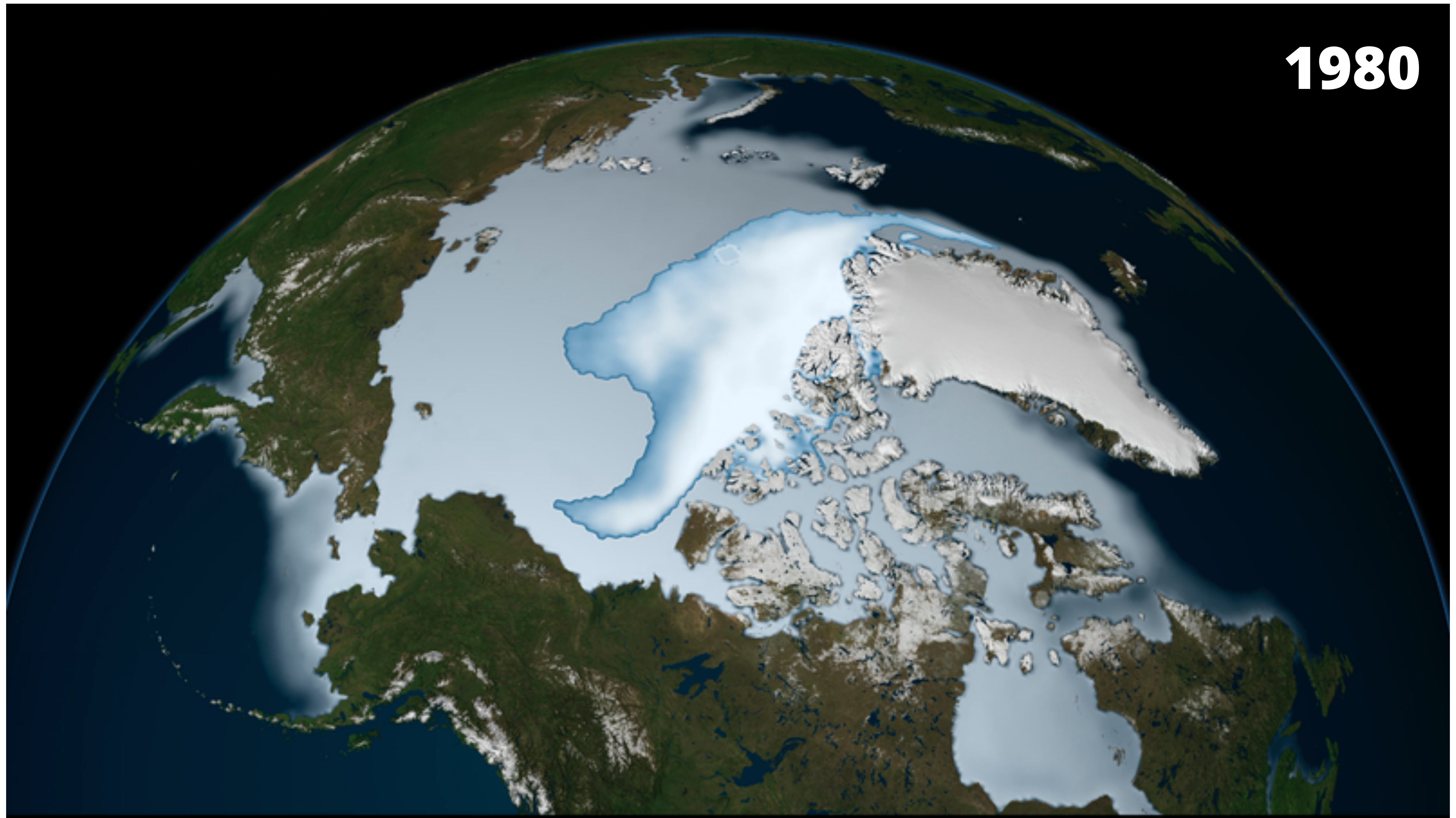

Net gain at lower latitudes and net loss at higher latitudes compensated by meridional energy transport in atmosphere and ocean.

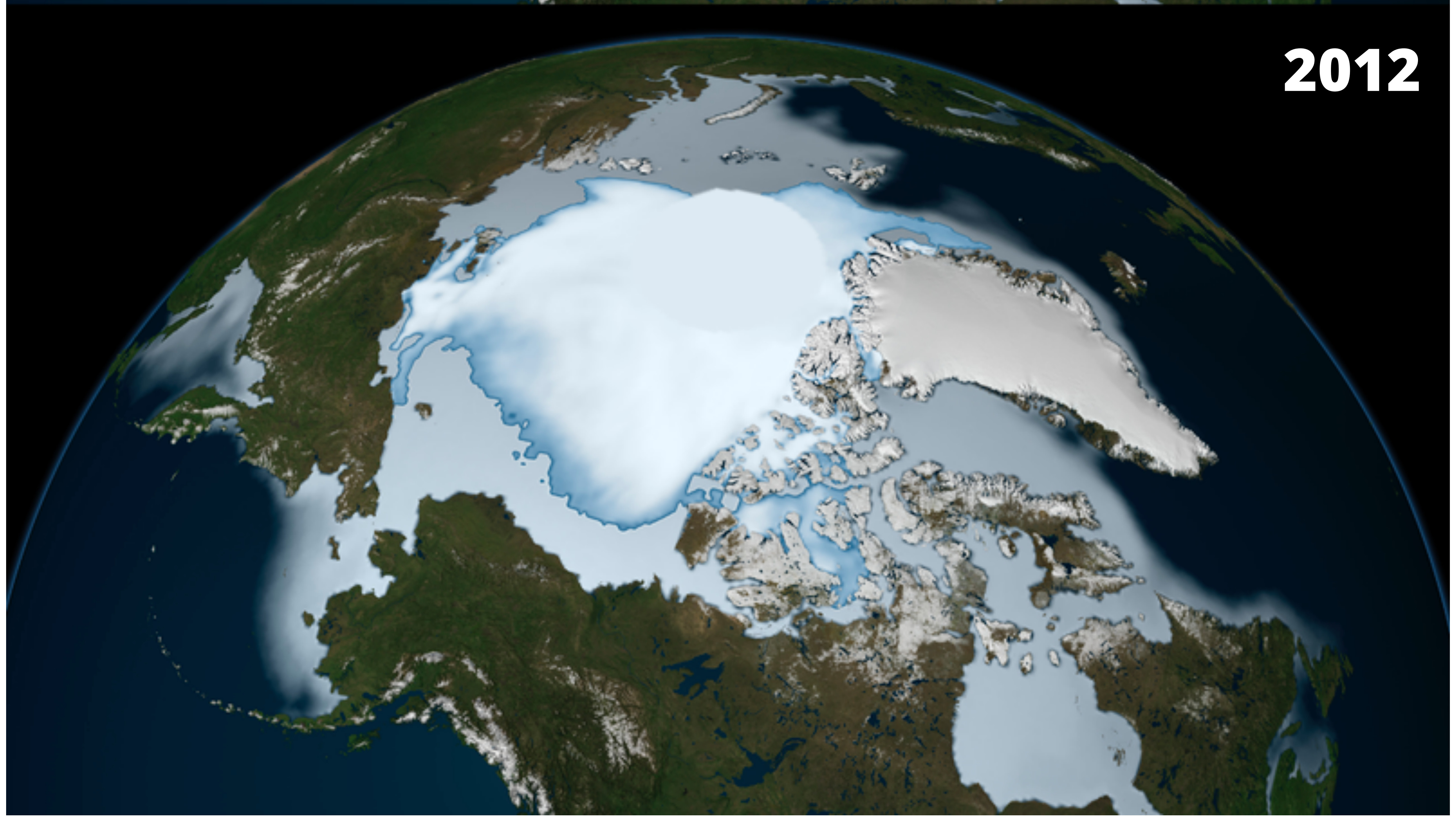
- Energy exchange, modes of energy transport, changes in energy transport with changing climate



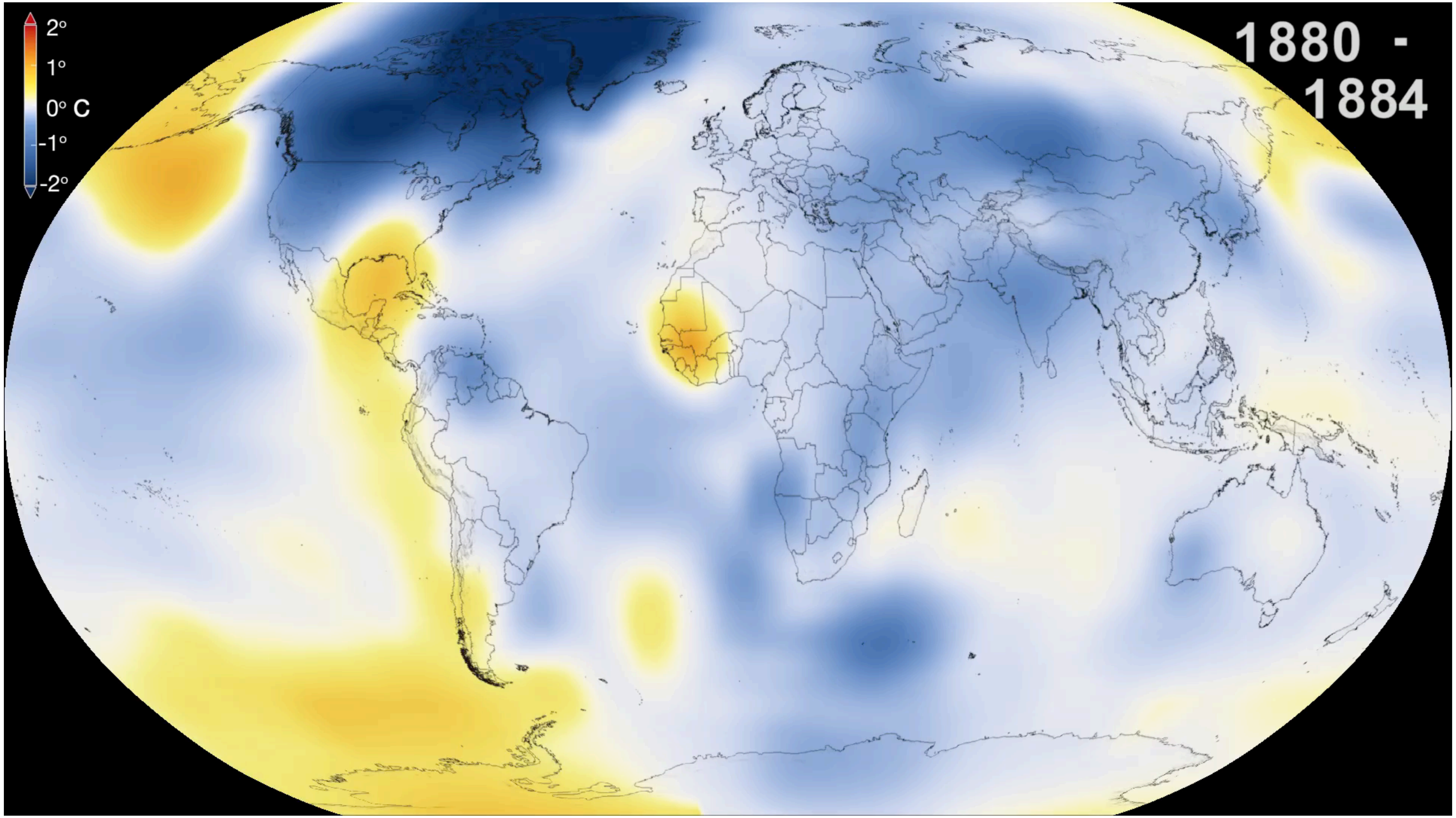

# Arctic Climate and Change

## Arctic Amplification



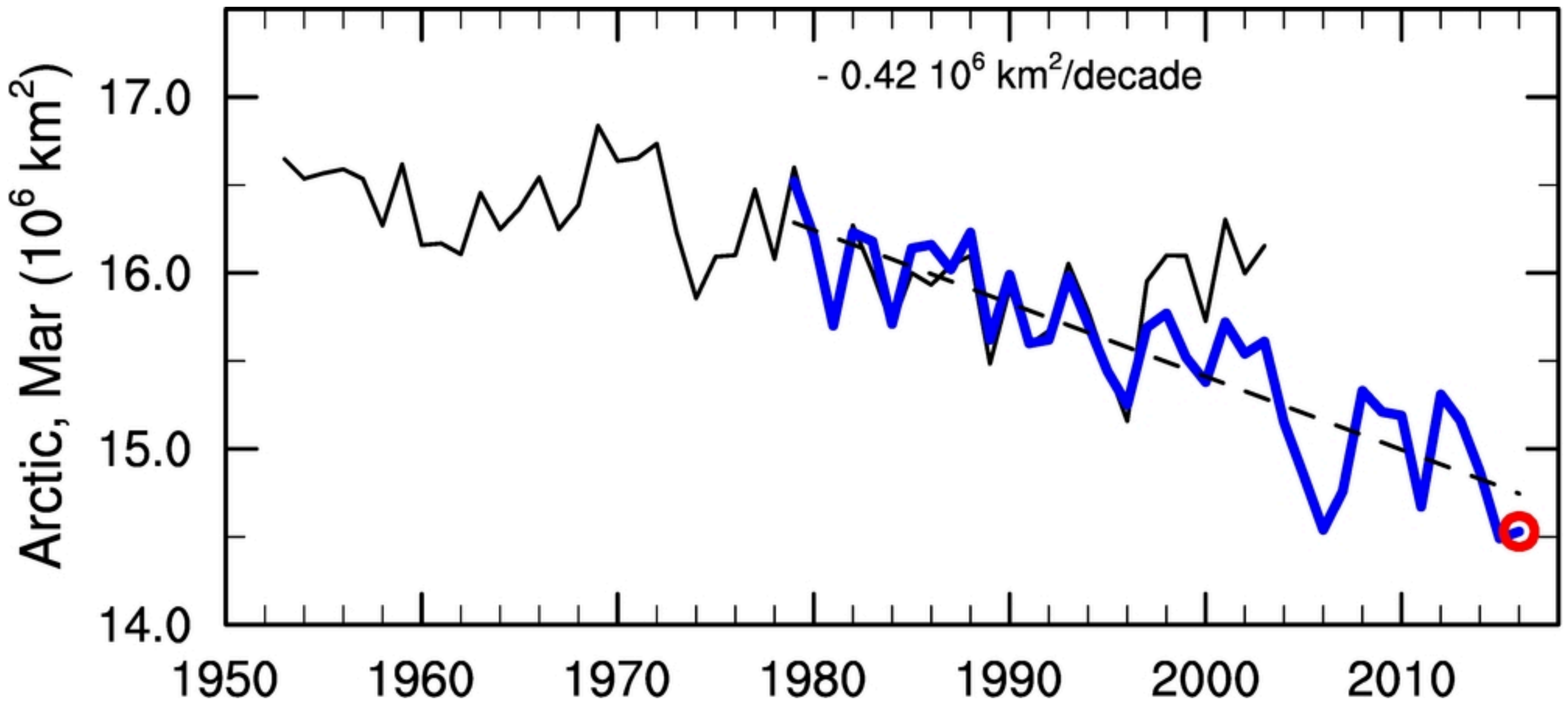



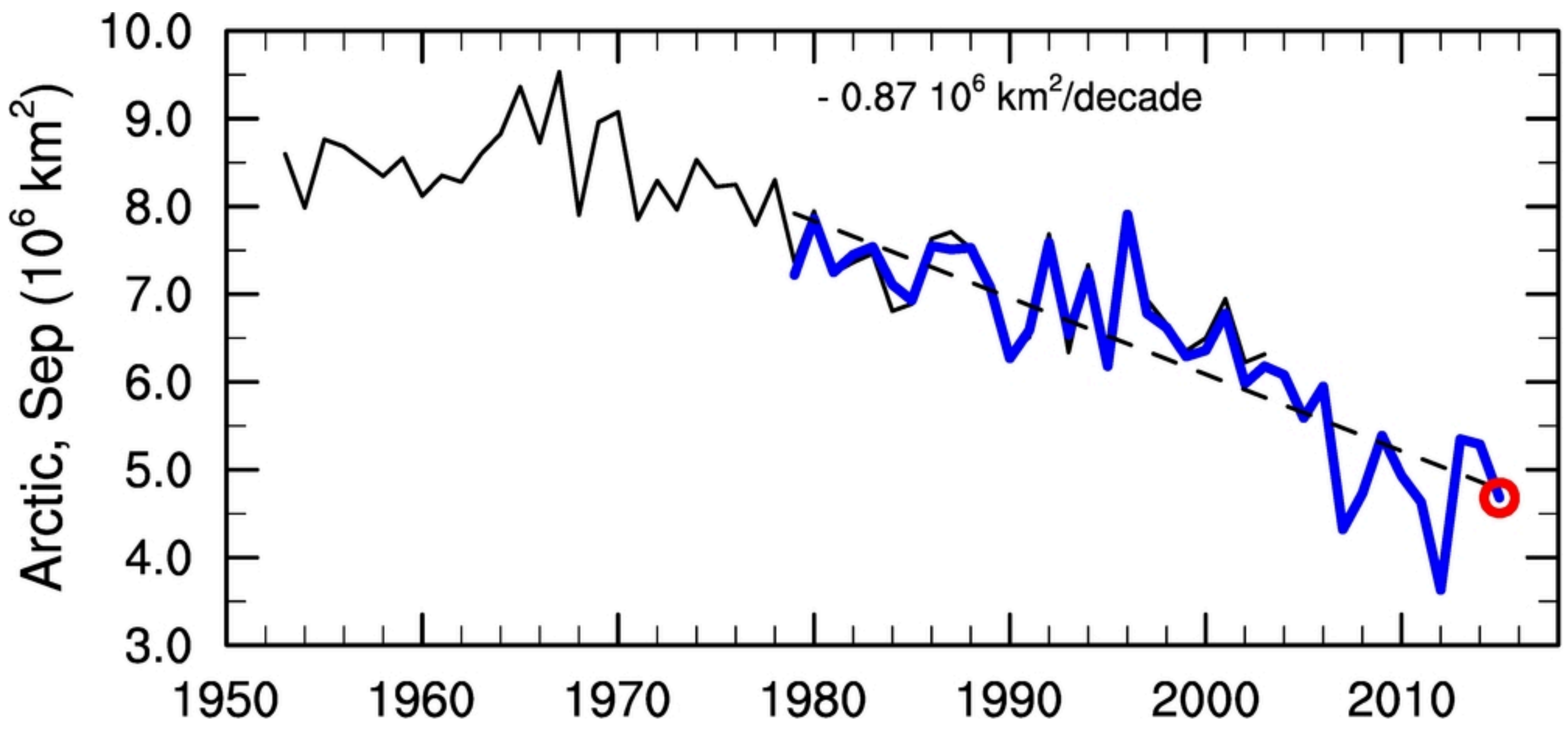
# Arctic Change in Global Comparison




- What determines the Arctic's Climate? The couple Air-Sea-Ice climate system. How is the aforementioned balance obtained, maintained, and changing?

# Sea Ice Extend

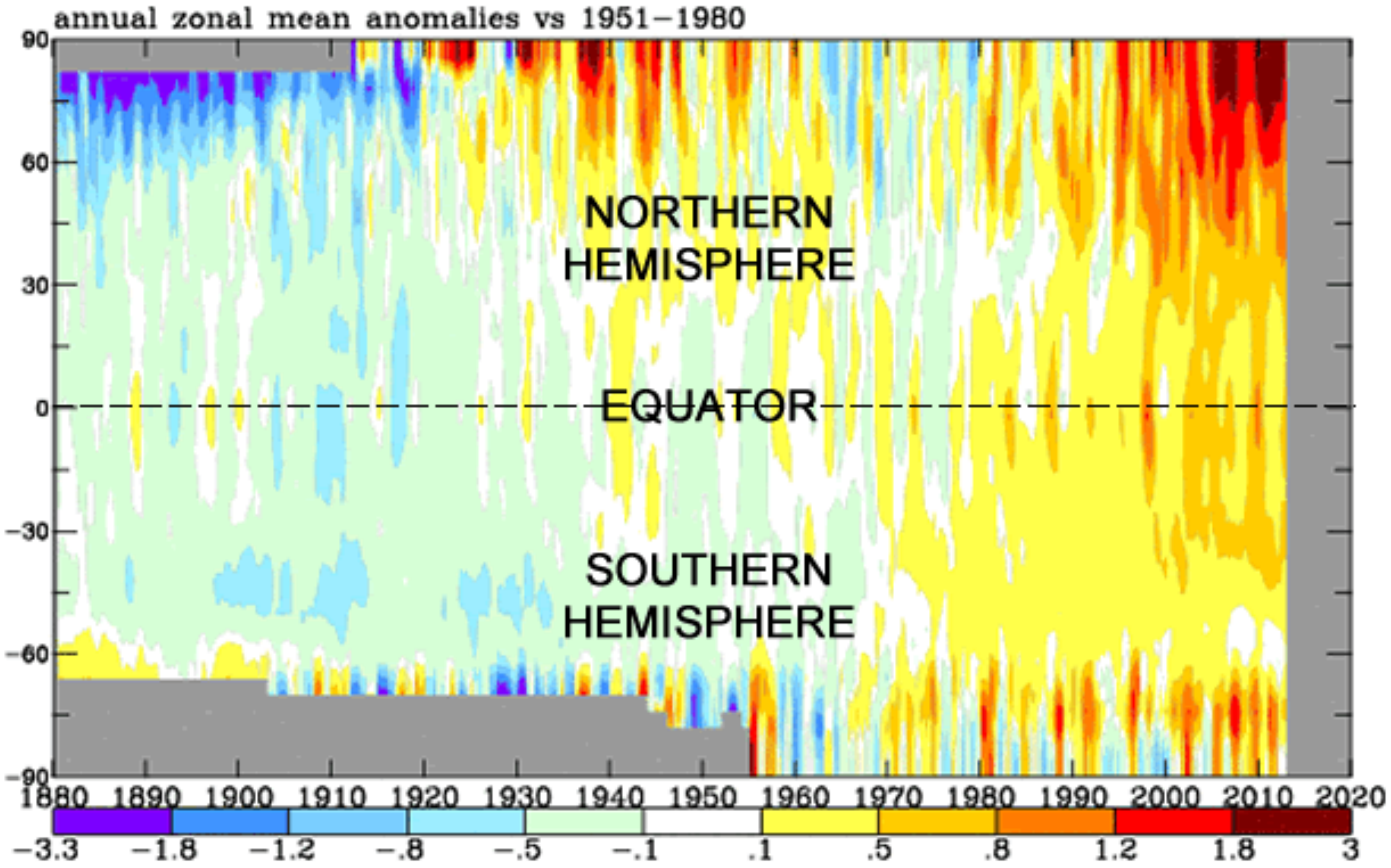



Albedo feedback: less ice, less albedo, warmer, less ice…

- Arctic's coupled air-sea-ice climate system inherently complex and we still lack understanding and modeling capabilities. Hence, uncertainties in weather predictions and climate projections.

# Arctic Amplification




NASA GISS

Arctic warms faster than the rest of the globe. Albedo feedback with sea ice and energy transport.

ARCUS rannís IASC ARCTIC CIRCLE

# Role of Moisture Transport

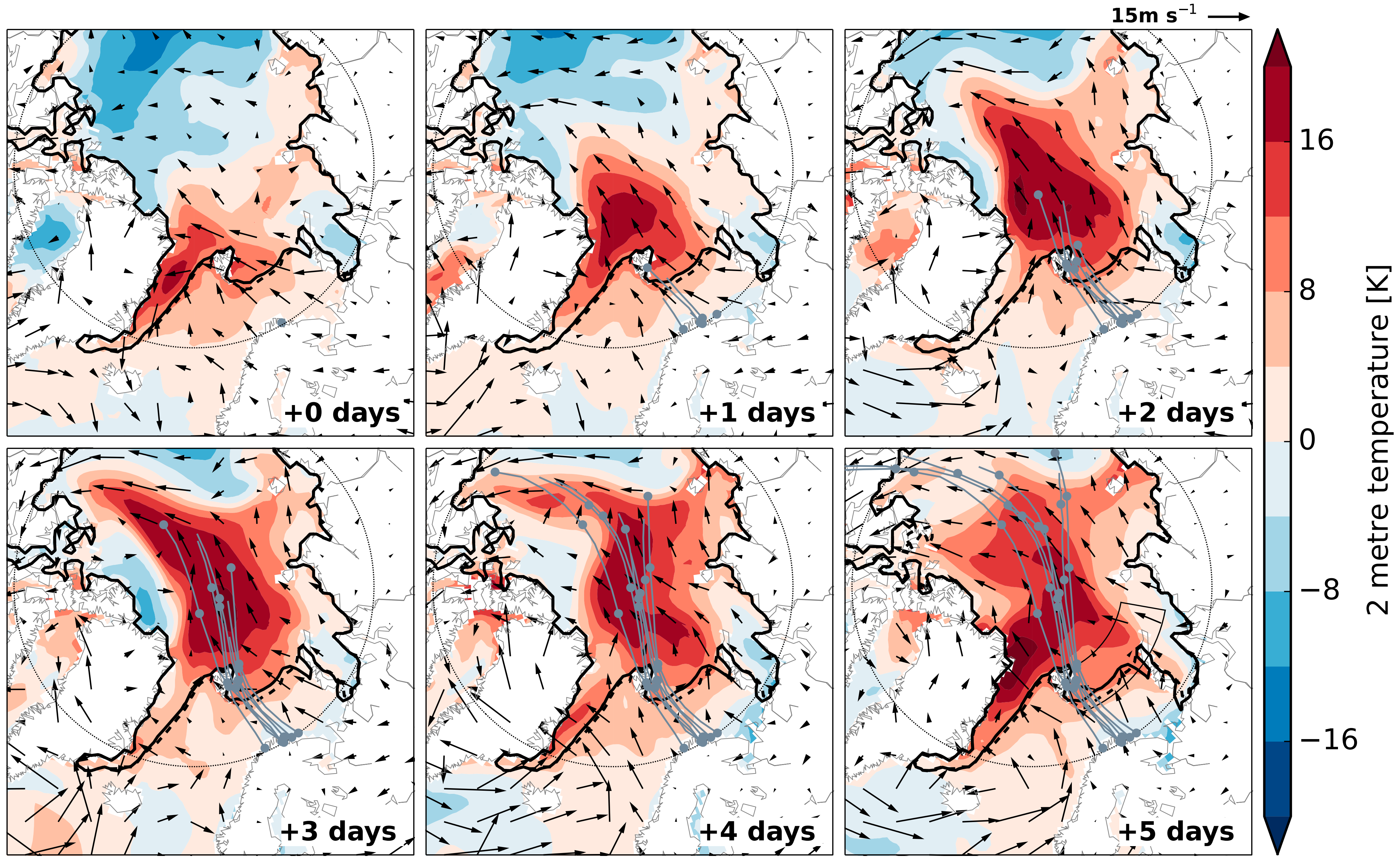



FIG. 2. Case study of an intrusion event beginning over northern Norway at 1800 UTC on 27 December 1999. Each panel shows a snapshot at a time relative to the beginning of the event as indicated in the lower-right corner. Gray lines show centroid trajectories with gray dots at 1-day intervals. Shading shows surface air temperature anomaly from a 6-hourly, smoothed seasonal cycle, arrows show 10-m wind, and the heavy black line shows the 15% SIC contour. As a reference, the dashed black line shows the 15% SIC contour 5 days before the beginning of the event. Dotted line is the 70°N latitude line. Thin black lines in the +5 days panel show the Barents Sea box.

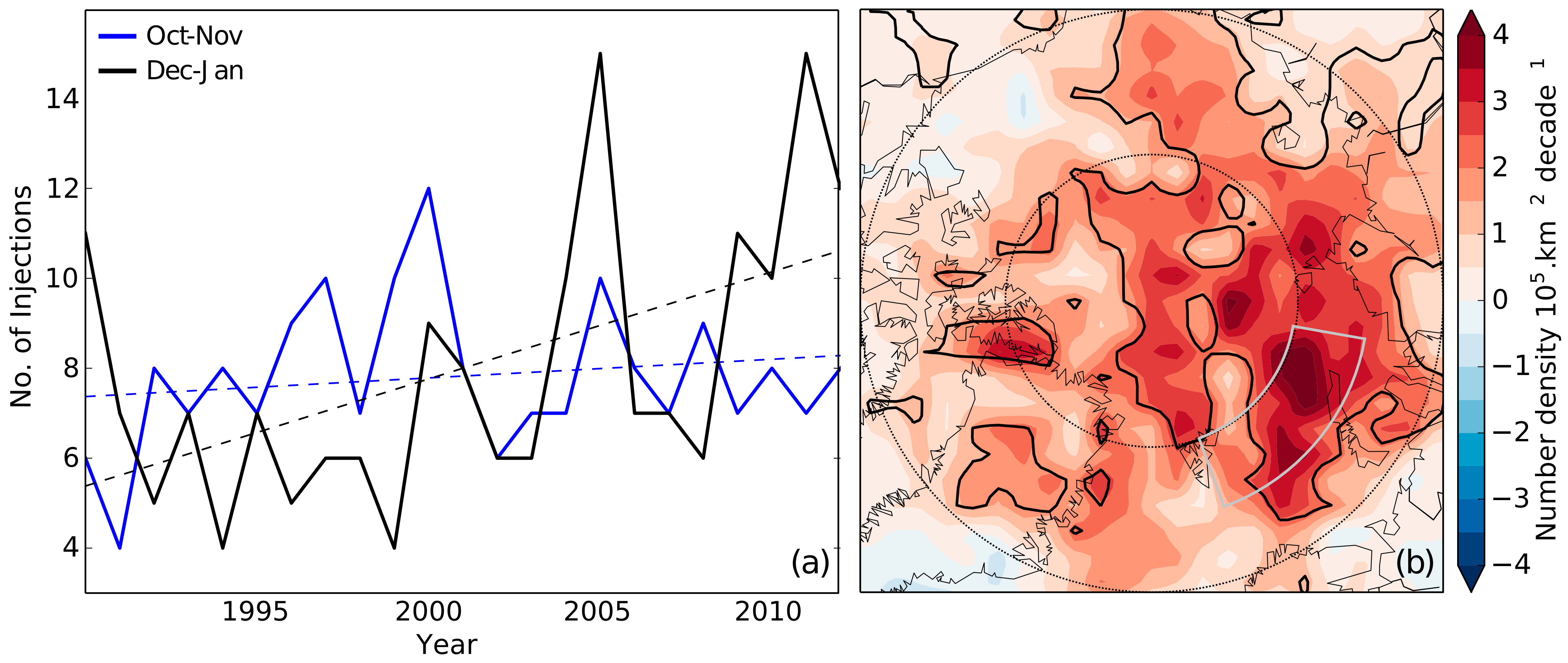


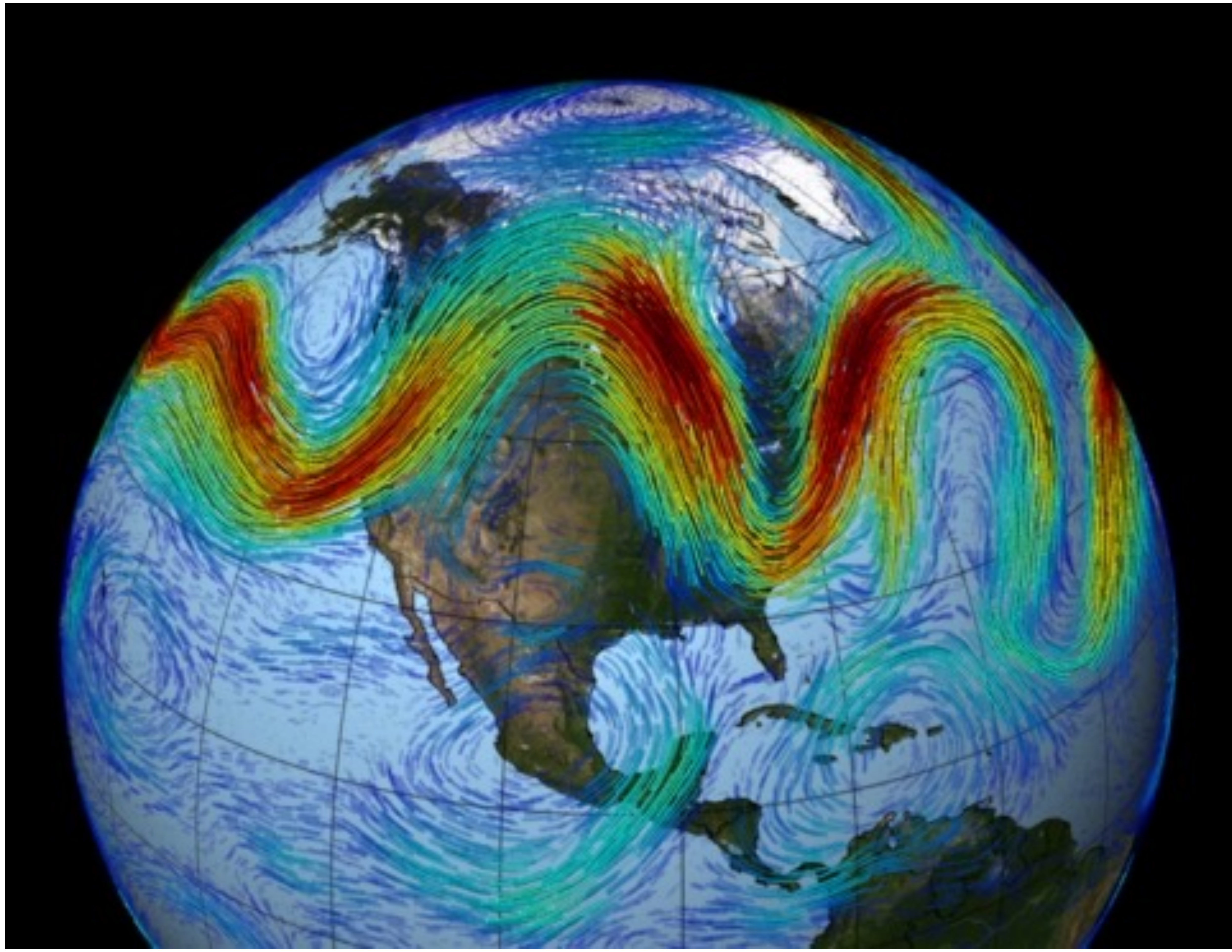

FIG. 8. (a) Total number of intrusion events during October–November (blue line) and December–January (black) for each year in the dataset. Dashed lines show linear fits. There is a significant trend in the number of intrusions during December–January of roughly 2.5 decade$^{-1}$ ($p = 0.005$). (b) Linear trends in intrusion density during December–January. Solid black lines enclose trends significant at the 5% level. Gray lines show the Barents Sea box. Dotted lines show the 70° and 80°N latitude lines.

Woods and Caballero (2016)

Latent heat transport contributes to warming and sea ice loss.

# The Role of the Arctic in the Global Climate System

## Feedbacks and Linkages



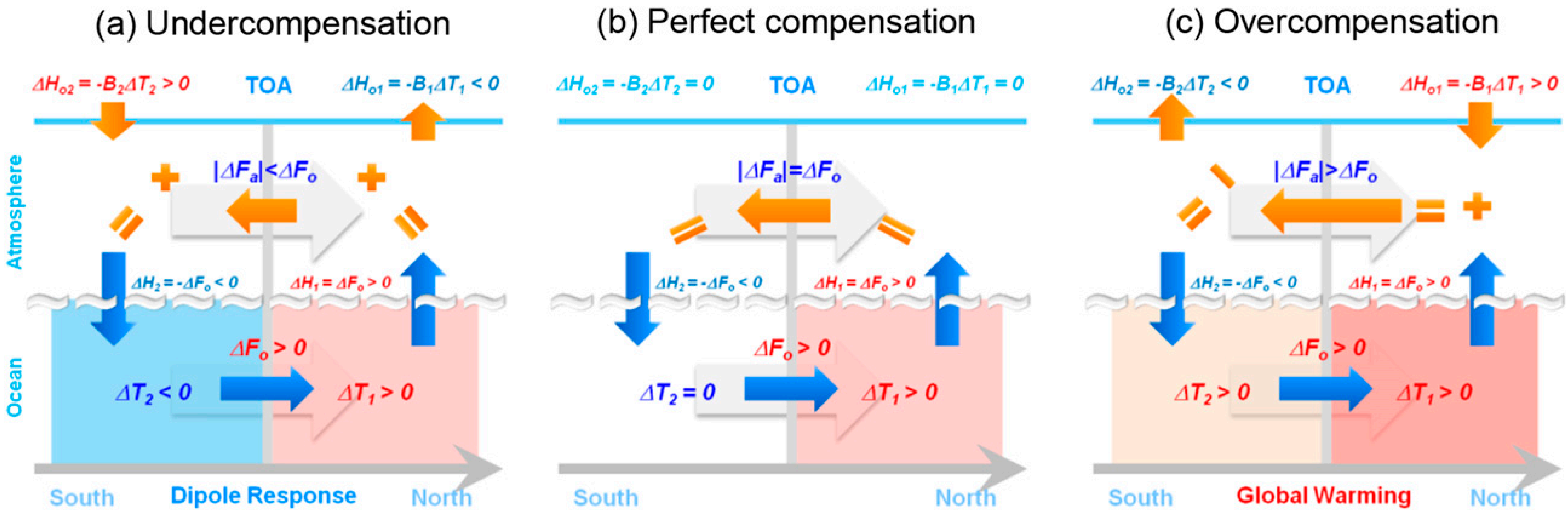
# The Role of the Arctic in the Global Climate System

- Energy exchange, modes of energy transport, changes in energy transport with changing climate

Arctic's role in the global climate rather clear via back of the envelope. However, we lack understanding of why transport ways for energy are as they are and how they will respond to climate change. In particular, we need a better process understanding, as it appears that a significant fraction of the transport is done by transient and short-lived phenomena and not climatological time-means

# The Role of the Arctic in the Global Climate System

Bjerknes Compensation: Ocean and Atmosphere Energy Transport not independent

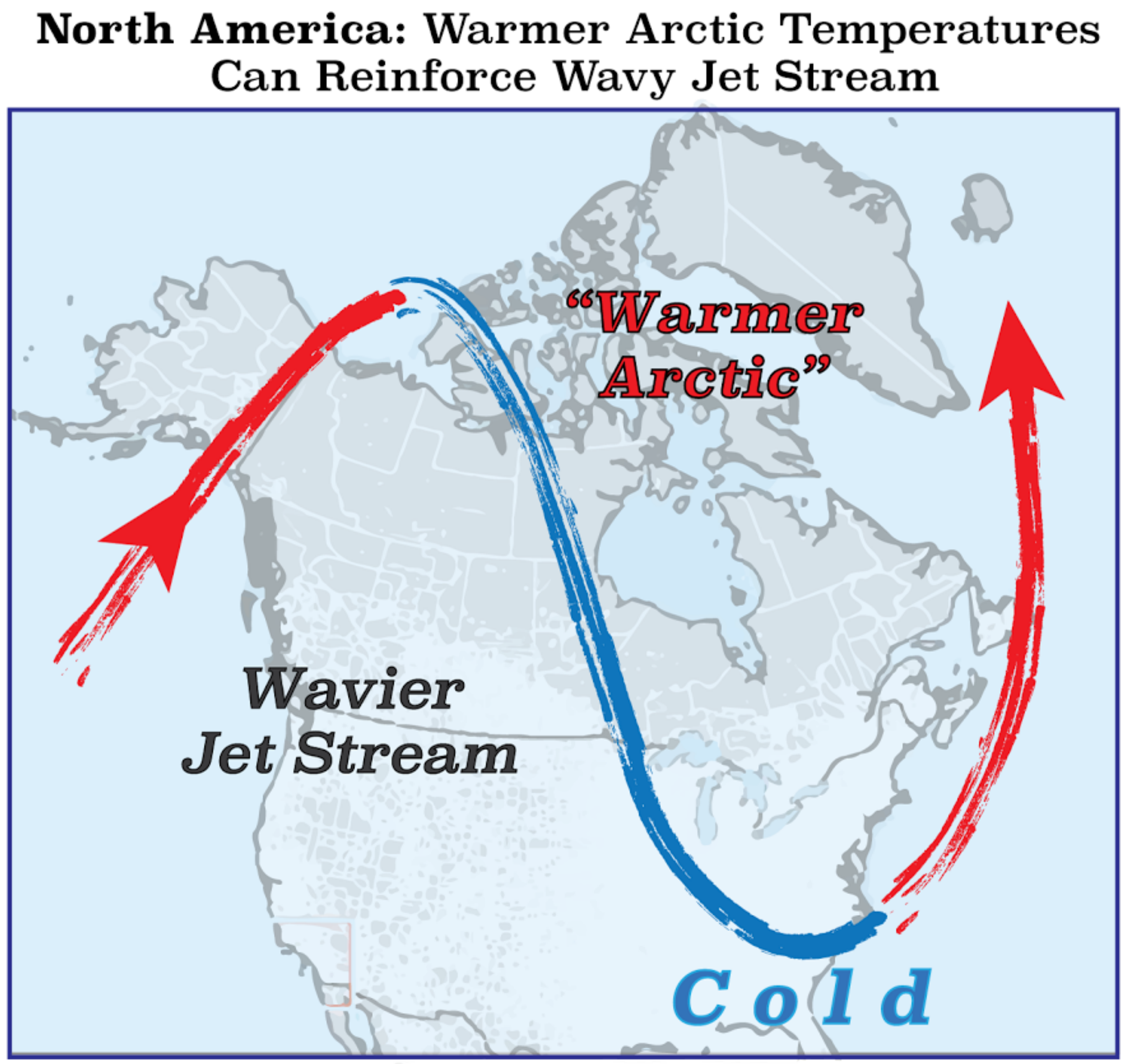



Yang et al. (2016)

FIG. 4. Schematic diagram showing the BJC mechanism. (a) Under negative feedbacks in both extratropical and tropical boxes ($B_1B_2 > 0$), the anomalous AHT undercompensates the anomalous OHT to keep the energy conserved in both tropical and extratropical boxes. Large gray arrows denote mean heat transports. (b) Under a zero feedback in the extratropical box ($-B_1 = 0$, $B_2 \neq 0$), the anomalous AHT compensates the anomalous OHT perfectly. (c) Under a weak positive feedback in the extratropical box ($-B_1 > 0$, $B_1B_2 < 0$), the anomalous AHT has to overcompensate the anomalous OHT.

# Arctic Amplification and its role for mid latitudes Weather and Extremes

- Linkages between Arctic Amplification and jet stream and extremes in mid-latitudes: Hypotheses, Debates, Controversies



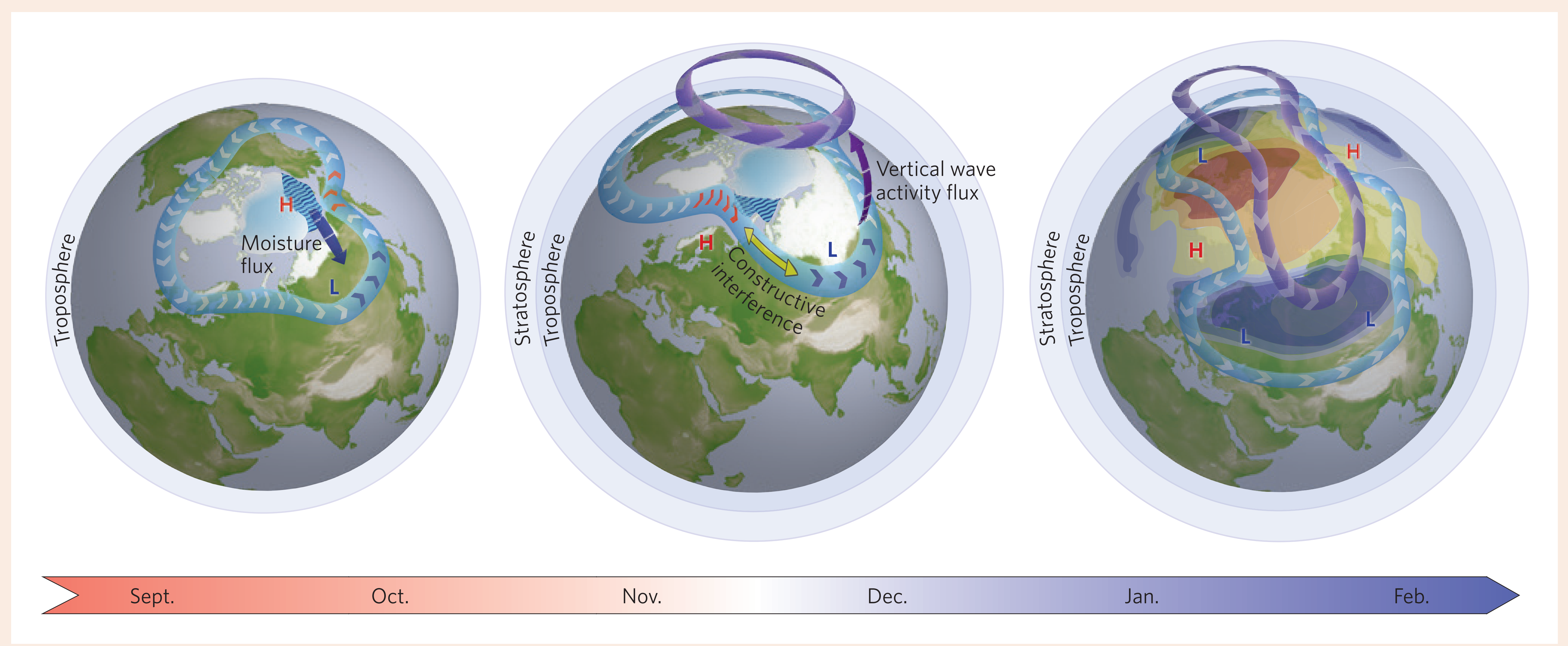




**Figure B2 | Synthesis of proposed cryospheric forcings.** The schematic highlights a proposed way in which Arctic sea-ice loss in late summer through early winter may work in concert with extensive Eurasian snow cover in the autumn to force the negative phase of the NAO/AO in winter. Snow is shown in white, sea ice in white tinged with blue, sea-ice melt with blue waves, high and low geopotential heights with red 'H' (red represents anomalous warmth) and blue 'L' (blue represents anomalous cold) respectively, tropospheric jet stream in light blue with arrows, and stratospheric jet or polar vortex shown in purple with arrows. On the right globe, cold (warm) surface temperature anomalies associated with the negative phase of the winter NAO/AO are shown in blue (brown). See Box text for detailed explanation.

Cohen et al. (2014), Francis and Skific (2015)

Overland et al. (2015)

# Arctic Amplification and its role for mid latitudes Weather and Extremes

- Linkages between Arctic Amplification and jet stream and extremes in mid-latitudes: Hypotheses, Debates, Controversies

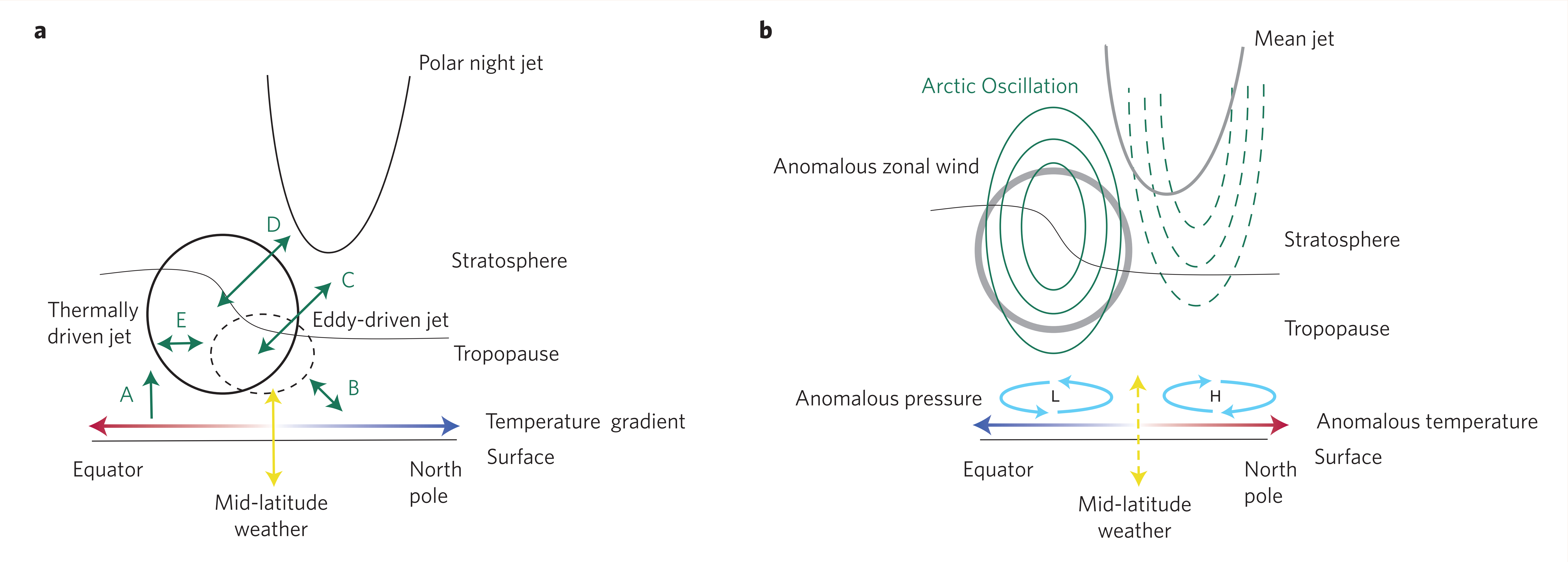



**Figure B1 | Schematic view of jet-related and negative North Atlantic Oscillation/Arctic Oscillation dynamics. a**, Here, the tropospheric jet is divided into two parts, a thermally driven part and an eddy-driven part. **b**, Changes in the atmospheric circulation associated with the negative phase of the North Atlantic Oscillation/Arctic Oscillation. See Box text for detailed explanation.

Cohen et al. (2014)

# Arctic Amplification and its role for mid latitudes Weather and Extremes

- Linkages between Arctic Amplification and jet stream and extremes in mid-latitudes: Hypotheses, Debates, Controversies

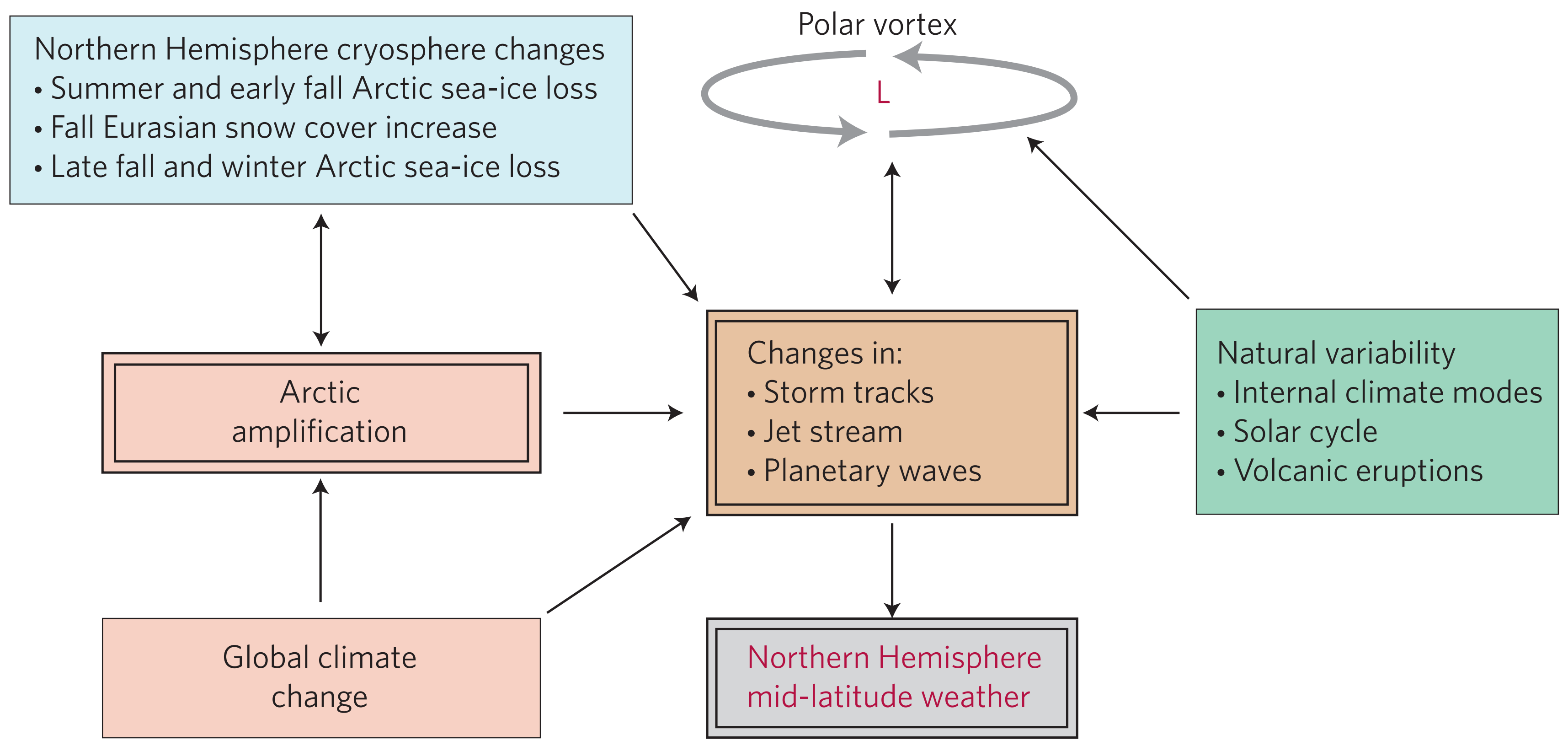



**Figure 4 | Schematic of ways to influence Northern Hemisphere mid-latitude weather.** Three major dynamical features for changing Northern Hemisphere mid-latitude weather — changes in the storm tracks, the position and structure of the jet stream, and planetary wave activity — can be altered in several ways. The pathway on the left and highlighted by double boxes is reviewed in this manuscript. Arctic amplification directly (by changing the meridional temperature gradient) and/or indirectly (through feedbacks with changes in the cryosphere) alters tropospheric wave activity and the jet stream in the mid- and high latitudes. Two other causes of changes in the storm tracks, jet stream and wave activity that do not involve Arctic amplification are also presented: (1) natural modes of variability and (2) the direct influence of global climate change (that is, including influences outside the Arctic) on the general circulation. The last two causes together present the current null hypothesis in the state of the science against which the influence of Arctic amplification on mid-latitude weather is tested in both observational and modelling studies. Bidirectional arrows in the figure denote feedbacks (positive or negative) between adjacent elements. Stratospheric polar vortex is represented by 'L' with anticlockwise flow.

Cohen et al. (2014)

Opinion

**The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?**

Barnes and Screen (2015)

The Jury is still out...

# Sea Level Rise?

Not quite sure if I should include it... maybe better covered by Julienne?

# The Arctic's Role: Open Questions

## Fully Coupled System

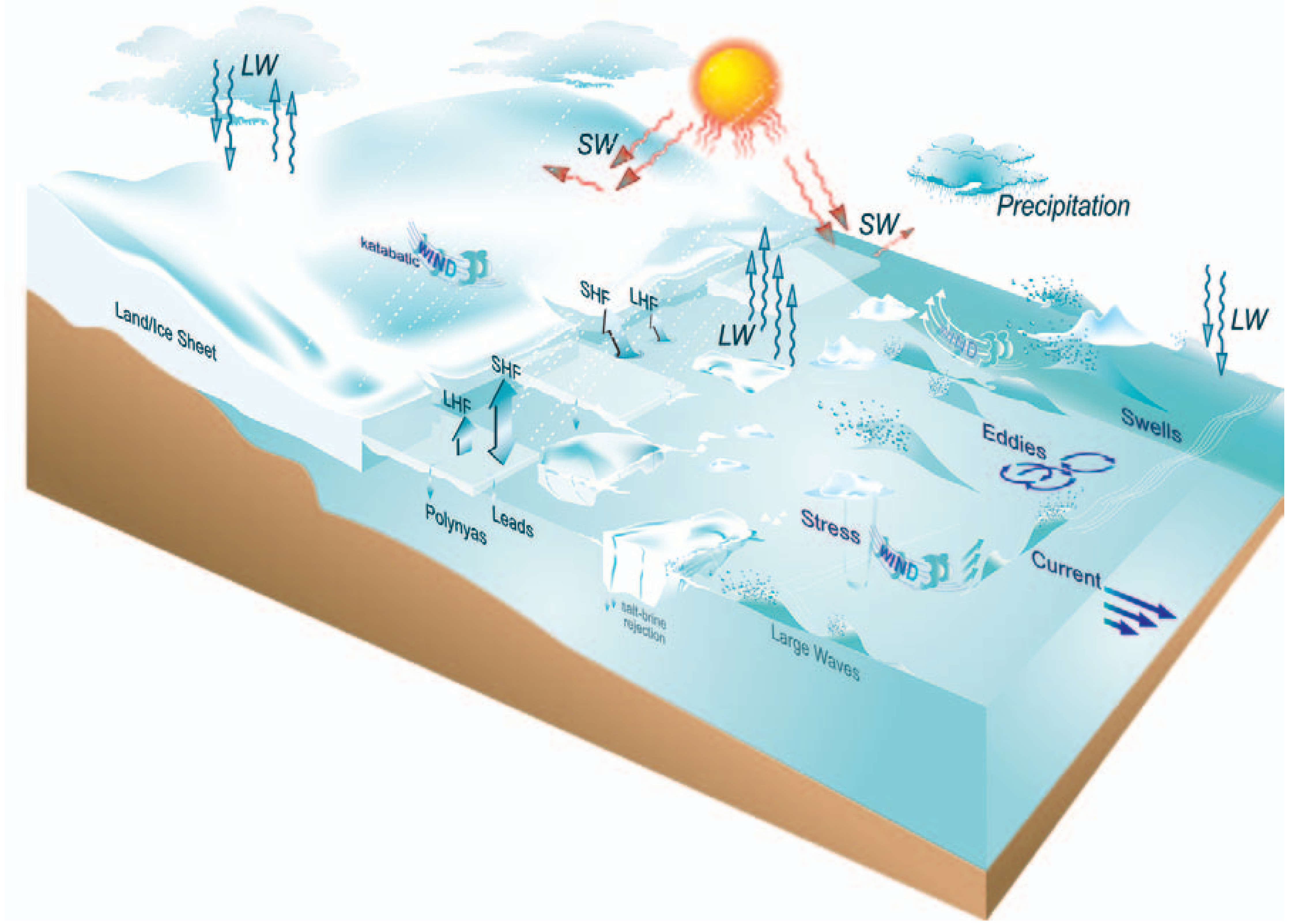



**FIG. 1. Schematic of surface fluxes and related processes for high latitudes. Radiative fluxes are both SW and LW. Surface turbulent fluxes are stress, SHF, and LHF. Ocean surface moisture fluxes are *P* and *E* (proportional to LHF). Processes specific to high-latitude regimes can strongly modulate fluxes. These include strong katabatic winds, effects due to ice cover and small-scale open patches of water associated with leads and polynyas, air–sea temperature differences that vary on the scale of eddies and fronts (i.e., on the scale of the oceanic Rossby radius, which can be short at high latitudes), deep and bottom water formation, and enhanced freshwater input associated with blowing snow.**

Bourassa et al. (2013)

# The Arctic's Role: Open Questions

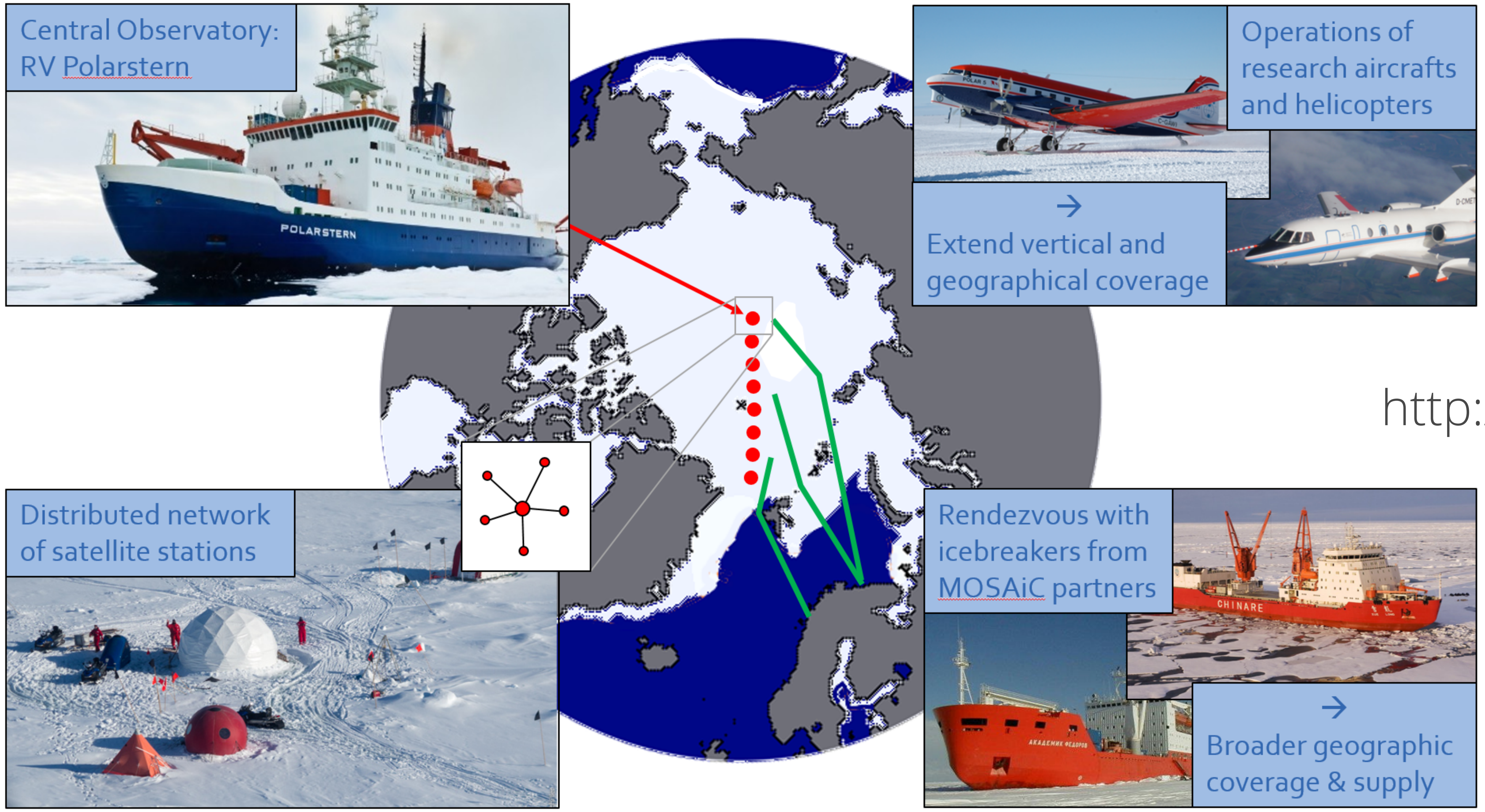
- Linkages: need to sort out dynamics behind
- Arctic Amplification: Role of sensible and latent heat transports
- See level rise

- The way forward is to think coupled and linked, i.e., not individual spheres (air, sea, or ice) in separation and not separate the polar climate from the rest of the planet's climate. The latter is based on the fact that the system is non-linear, hence one-way causal chains are difficult to establish and defend and it appears that the Arctic is more influenced by the mid-latitudes then the other way around.

# The fully Coupled System

MOSAiC

The International Arctic Drift Expedition


http://mosaicobservatory.org/