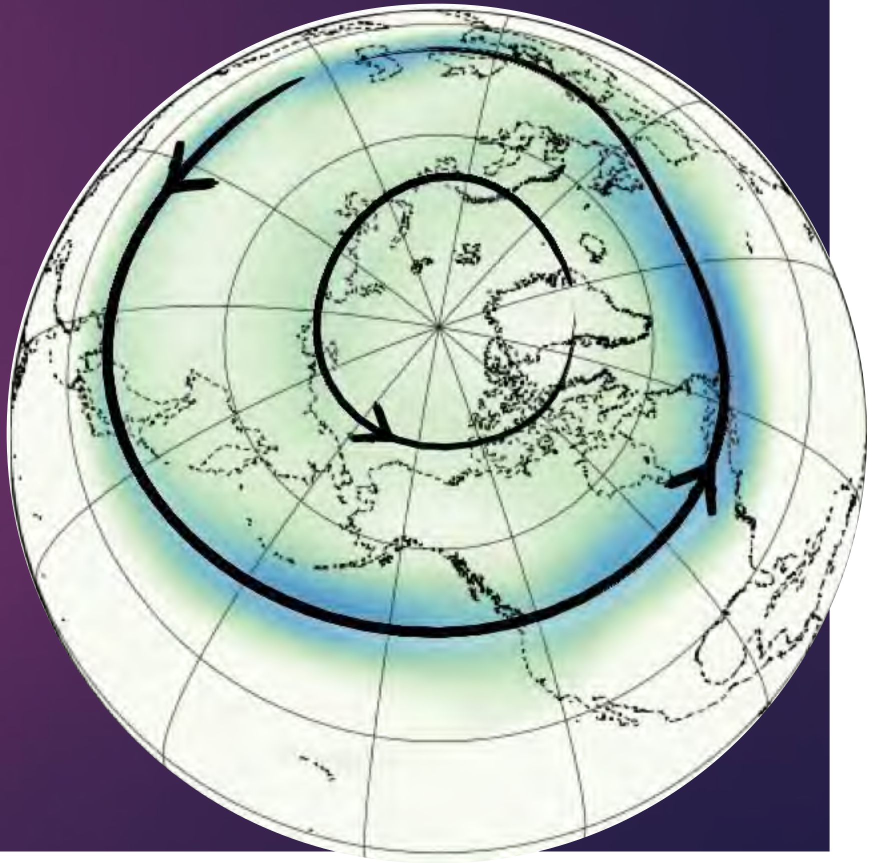
Arctic-Midlatitude Interactions

LATEST DEVELOPMENTS

Muyin Wang & Simon Wang



Arctic Midlatitude Working Group

The US CLIVAR Working Group on Arctic Change and Possible Influence on Mid-latitude Climate and Weather was formed in May 2015. The intent of the working group is to further the understanding of the coupling between Arctic variability and mid-latitude climate and weather by synthesizing ongoing efforts, coordinating research to fill out key gaps, and providing specific recommendations for accelerating scientific progress.

Update from the Arctic-Midlatitude WG

Arctic Midlatitude Working Group

US CLIVAR
Climate Variability & Predictability

ARCTIC CHANGE AND POSSIBLE INFLUENCE ON MID-LATITUDE CLIMATE AND WEATHER

A US CLIVAR White Paper

March 2018

Meetings

February 1–3, 2017 – Arctic Change and Its Influence on Mid-Latitude Climate and Weather

Table of Contents

White Paper

March 2018

PAMIP (Polar Amplification MIP)

June 2018

Geoscientific Model Development
An interactive open-access journal of the European Geosciences Union

White Paper

The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: investigating the causes and consequences of polar amplification

Doug M. Smith[1], James A. Screen[2], Clara Deser[3], Judah Cohen[4], John C. Fyfe[5], Javier García-Serrano[6,7], Thomas Jung[8,9], Vladimir Kattsov[10], Daniela Matei[11], Rym Msadek[12], Yannick Peings[13], Michael Sigmond[5], Jinro Ukita[14], Jin-Ho Yoon[15], and Xiangdong Zhang[16]

[1]Met Office Hadley Centre, Exeter EX1 3PB, UK

Review status

This discussion paper is a preprint. It is a manuscript under review for the journal Geoscientific Model Development (GMD).

White Paper

March 2018

nature climate change

Submitted

July 2018

Divergent consensus on the influence of Arctic Amplification on mid-latitude severe winter weather

J. Cohen[1,2], X. Zhang[3], J. Francis[4], T. Jung[5], R. Kwok[6], J. Overland[7], T. Ballinger[8], U.S. Bhatt[3], H. W. Chen[9], D. Coumou[10,11], S. Feldstein[9], D. Handorf[5], G. Henderson[12], M. Ionita[5], M. Kretschmer[10], F. Laliberte[13], S. Lee[9], H. W. Linderholm[14], W. Maslowski[15], Y. Peings[16], K. Pfeiffer[1], I. Rigor[17], T. Semmler[5], J. Stroeve[18], P.C. Taylor[19], S. Vavrus[20], T. Vihma[21], S. Wang[22], M. Wendisch[23], Y. Wu[24], J. Yoon[25]

[1]Atmospheric and Environmental Research, Inc. [2]Massachusetts Institute of Technology. [3]University of Alaska Fairbanks. [4]Rutgers University. [5]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research. [6]Jet Propulsion Laboratory. [7]NOAA/PMEL. [8]Department of Geography, Texas State University. [9]Pennsylvania State University. [10]Potsdam Institute for Climate Impact Research. [11]VU Amsterdam. [12]United States Naval Academy. [13]Environment and Climate Change Canada. [14]University of Gothenburg. [15]Naval Postgraduate School. [16]University of California, Irvine. [17]University of Washington. [18]University College London. [19]NASA Langley Research Center. [20]University of Wisconsin, Madison. [21]Finnish Meteorological Institute. [22]Utah Climate Center/Dept. PSC/Utah State Univ. [23]University of Leipzig. [24]Lamont-Doherty Earth Observatory, Columbia University. [25]Gwangju Institute of Science and Technology.

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Submitted

July 2018

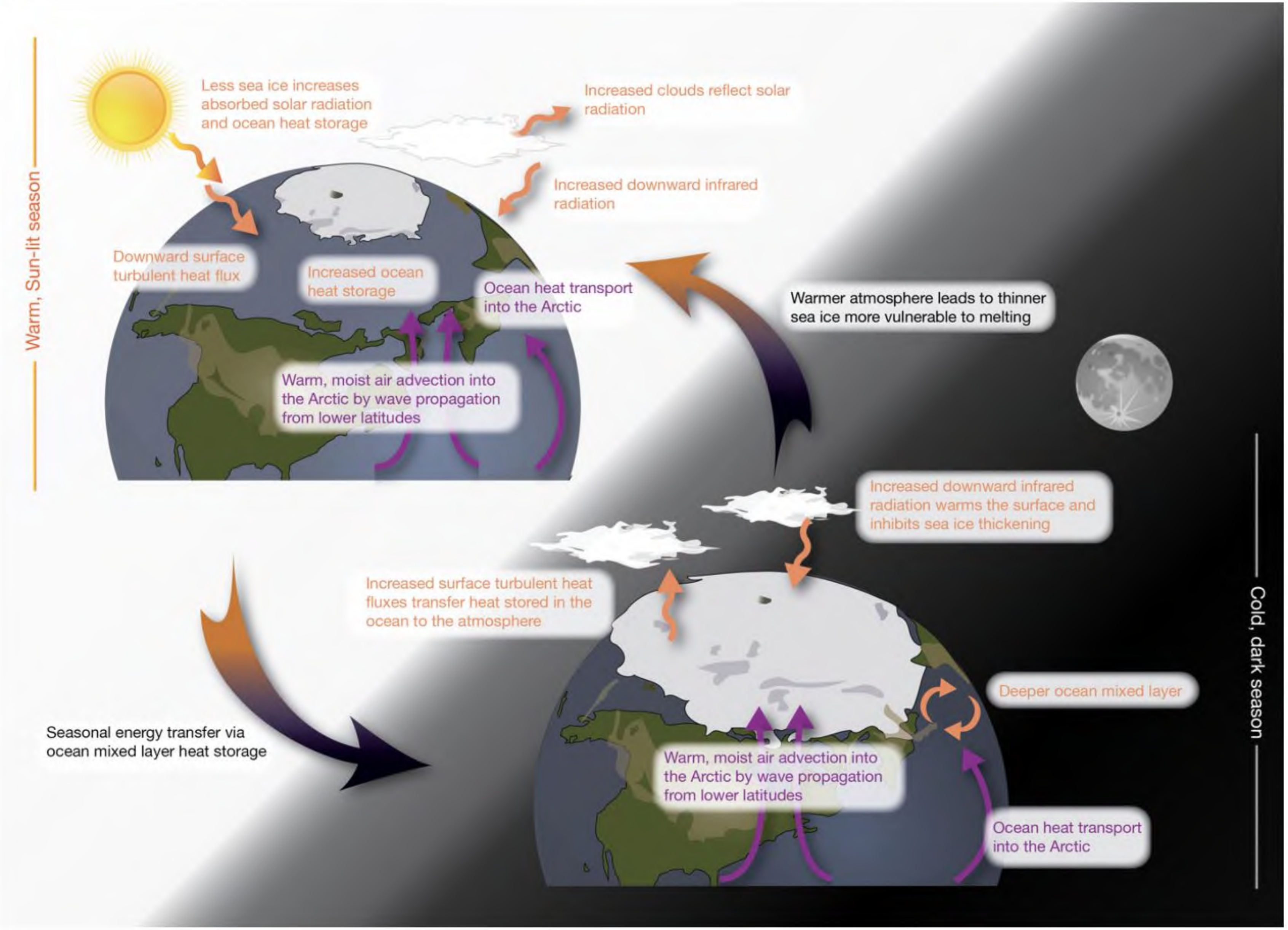


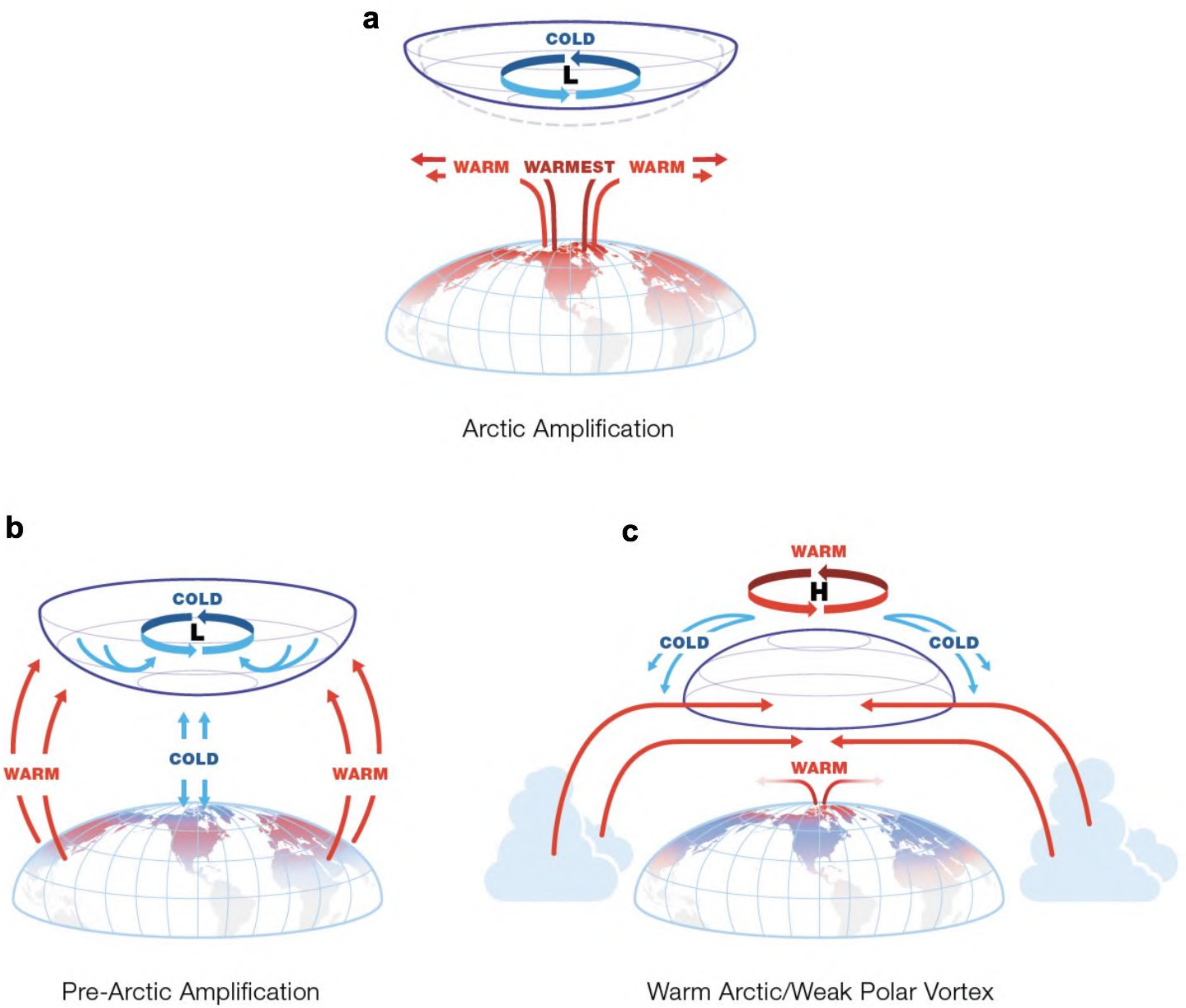
Figure 2. Mechanisms for Arctic amplification are complicated. Schematic illustrates the important processes and energy flows influencing Arctic amplification. Local processes, such as

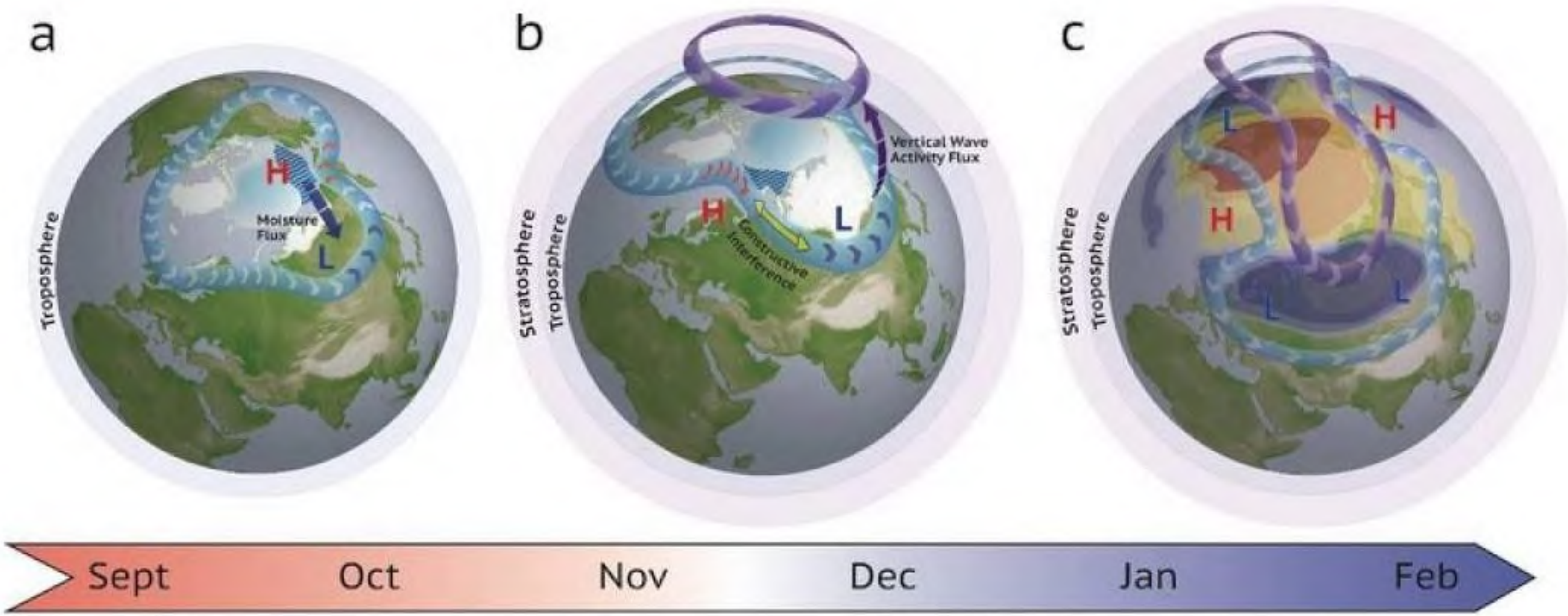
Observed and simulated temperature relationships to Arctic warming share similarities regionally.

Observed and simulated mid-latitude temperature trends are diverging.

Conceptual mechanisms shown derived from archived ensembles coordinated among modeling centers. **a** Most model experiments support that Arctic amplification disrupts the polar vortex but of weak amplitude. Any induced cooling due to changes in the polar vortex are overwhelmed by warming of the Arctic and transport of the milder Arctic air southward. **b** Same as Figure (a).

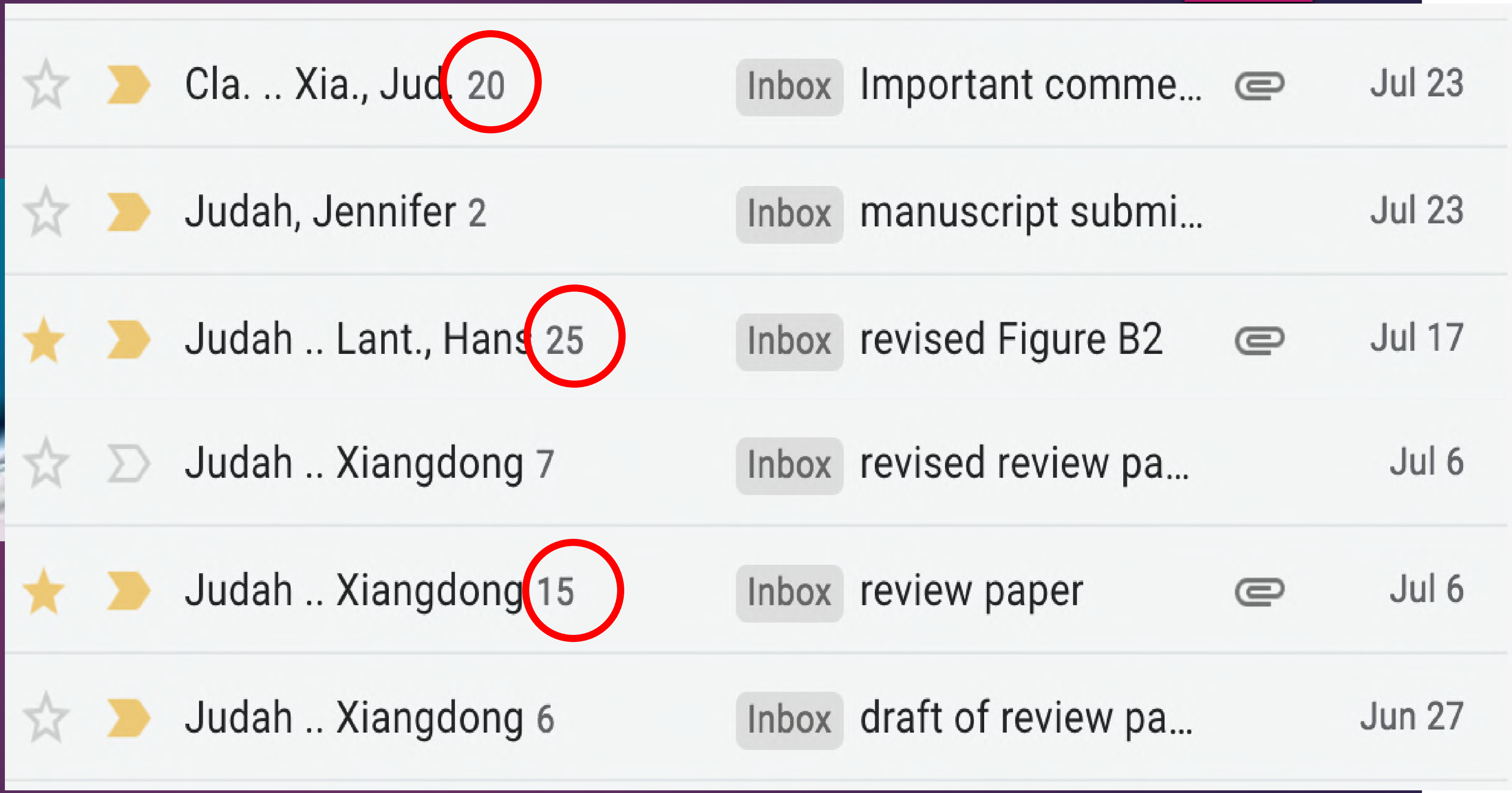
However, during the period of Arctic amplification, observed colder temperatures in the mid-latitudes is due to natural or internal variability. **c** For example, changes in tropical convection transports additional heat both into the Arctic, resulting in amplified Arctic warming, and into the polar stratosphere leading to a more amplified disruption of the polar vortex and displacement of cold air southwards to lower latitudes. Dynamic cooling offsets any thermodynamic warming forced by Arctic amplification.





warm arctic, cold continents

From Simon's email box



leading to withdrawal of certain authors due to disagreements on the model representation of natural vs. forced Arctic variability and midlatitude responses

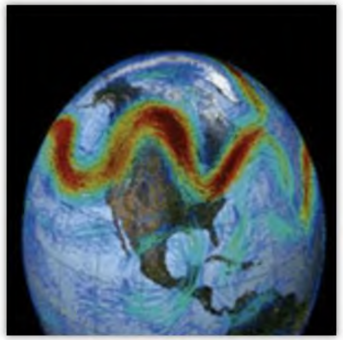
This GRL collection on linkages between the Arctic and the mid-latitudes brings together some of the most definitive papers in this rapidly evolving field of atmospheric research.

Geophysical Research Letters

AN AGU JOURNAL

Atmospheric Linkages Between the Arctic and the Mid-Latitudes

Atmospheric Science | First published: **Apr 28, 2017** | Last updated: **19 March 2018**



Summer: the missing link

Most studies analyzing Arctic links to mid-latitude weather focused on **winter**,

yet recent **summers** have seen robust changes in the mid-latitude circulation.

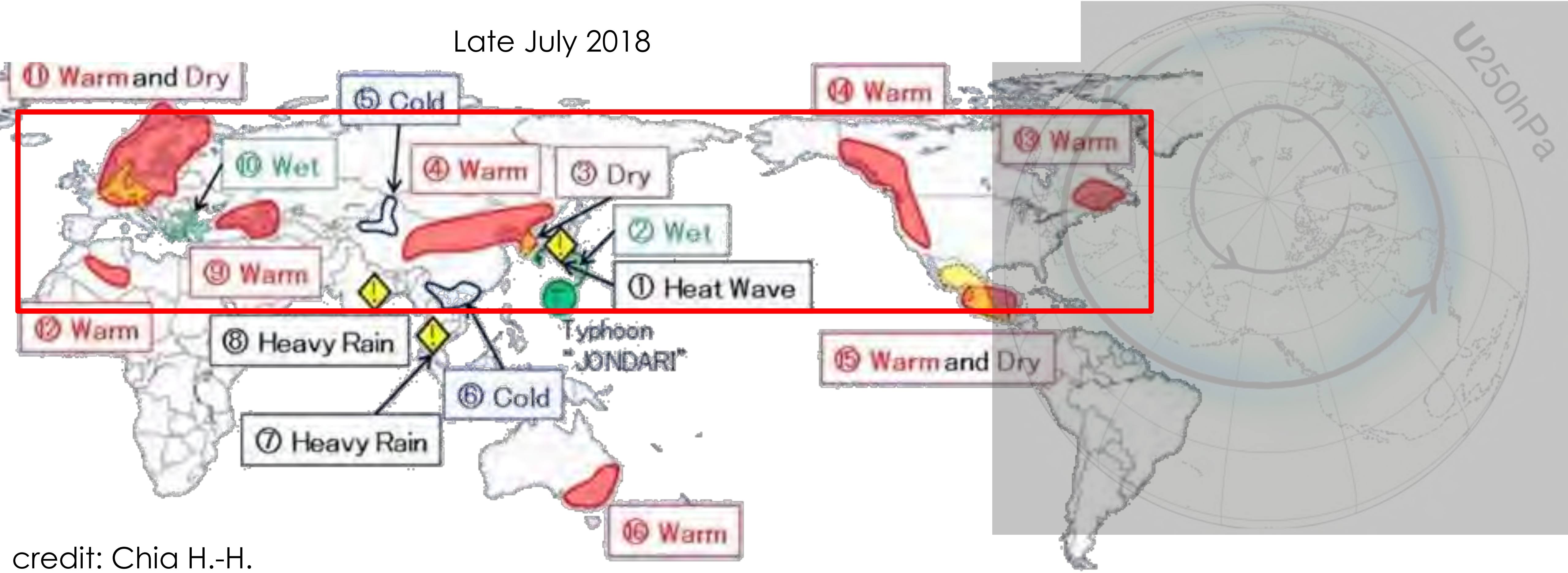
Summer: the missing link

The recent summers have seen

i) strong reductions in sea-ice extent and snow cover,
ii) a weakened equator-to-pole thermal gradient and
iii) associated weakening of the mid-latitude circulation.

Look at THIS summer: full of extremes!

Late July 2018



credit: Chia H.-H.

nature COMMUNICATIONS

REVIEW

DOI: 10.1038/s41467-018-05256-8 OPEN

The influence of Arctic amplification on mid-latitude summer circulation

D. Coumou[1,2], G. Di Capua[1,2], S. Vavrus[3], L. Wang[4], S. Wang[5]

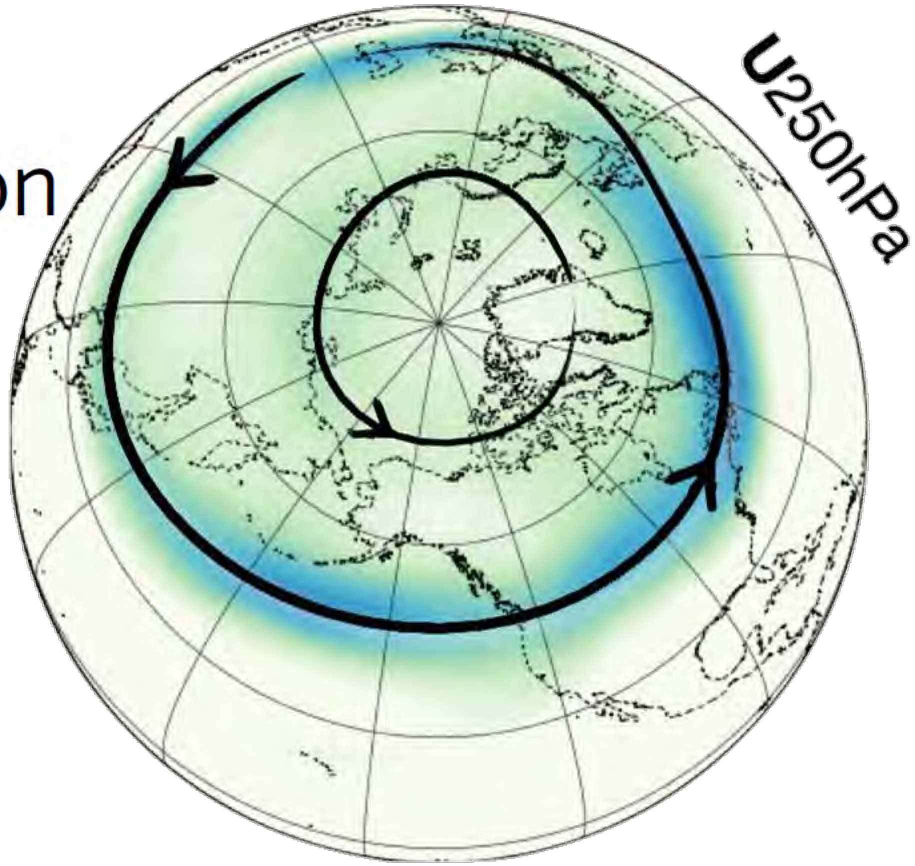
(1) Institute for Environmental Studies, Department of Water & Climate Risk, VU Amsterdam, Amsterdam, Netherlands

(2) Potsdam Institute for Climate Impact Research, Department of Earth System Analyses, Potsdam, Germany

(3) Nelson Institute Center for Climatic Research, University of Wisconsin-Madison, Madison, WI USA

(4) Harvard University, Department of Earth and Planetary Sciences, Cambridge, MA, USA

(5) Utah State University, Department of Plants, Soils and Climate, Logan, Utah, USA

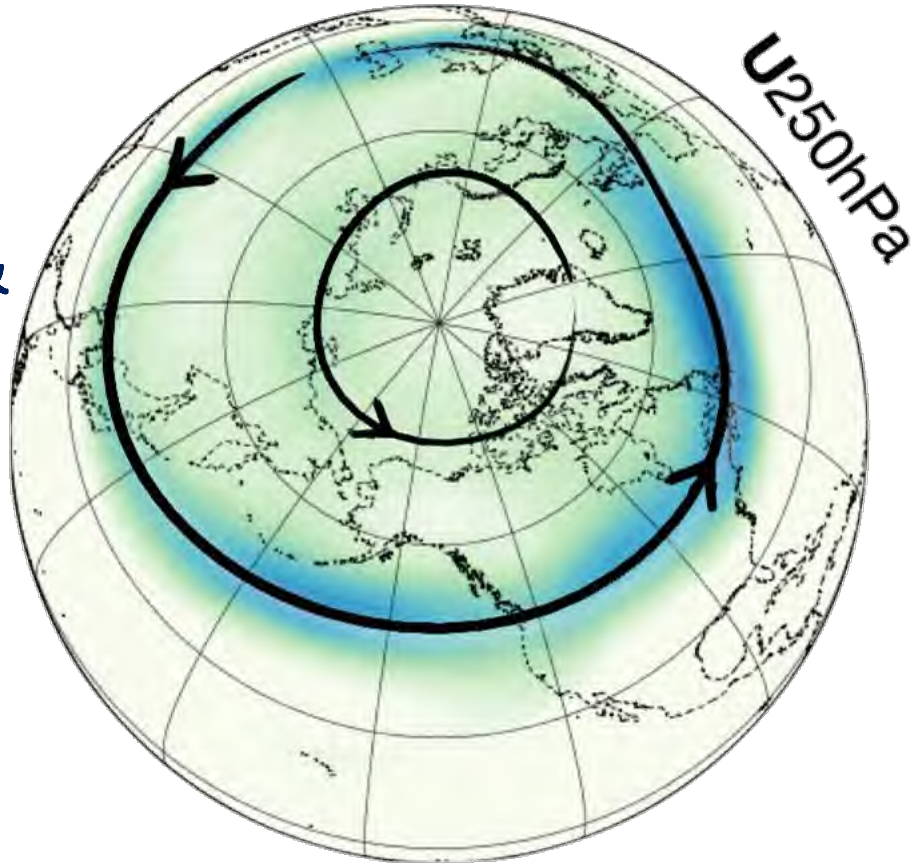


DOI: 10.1038/s41467-018-05256-8

OPEN

The influence of Arctic amplification on mid-latitude summer circulation

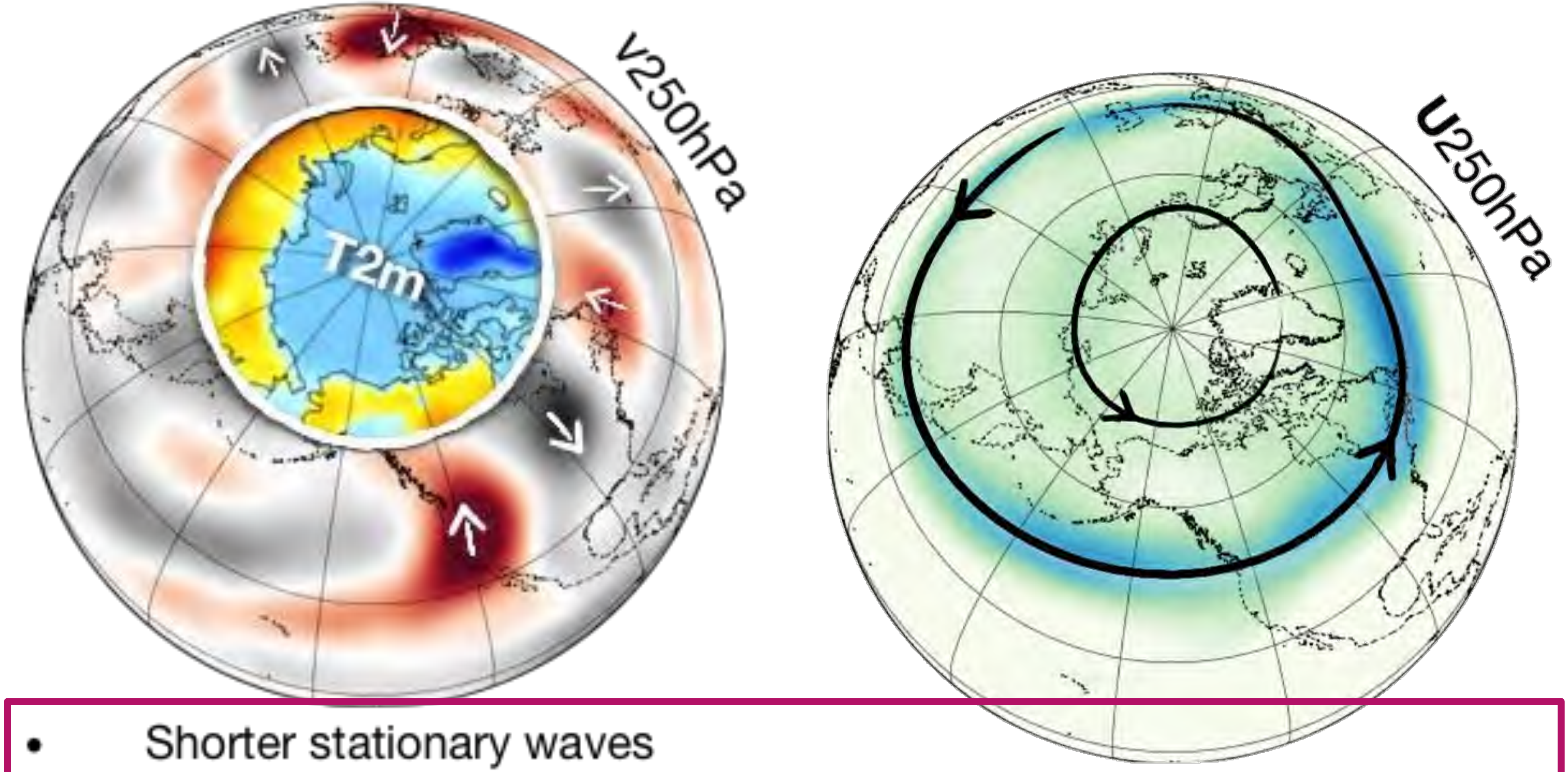
(They) review the scientific evidence behind three leading hypotheses on the influence of Arctic changes on mid-latitude summer weather: *Weakened storm tracks*, *shifted jet streams*, & *amplified quasi-stationary waves*.



DOI: 10.1038/s41467-018-05256-8
OPEN

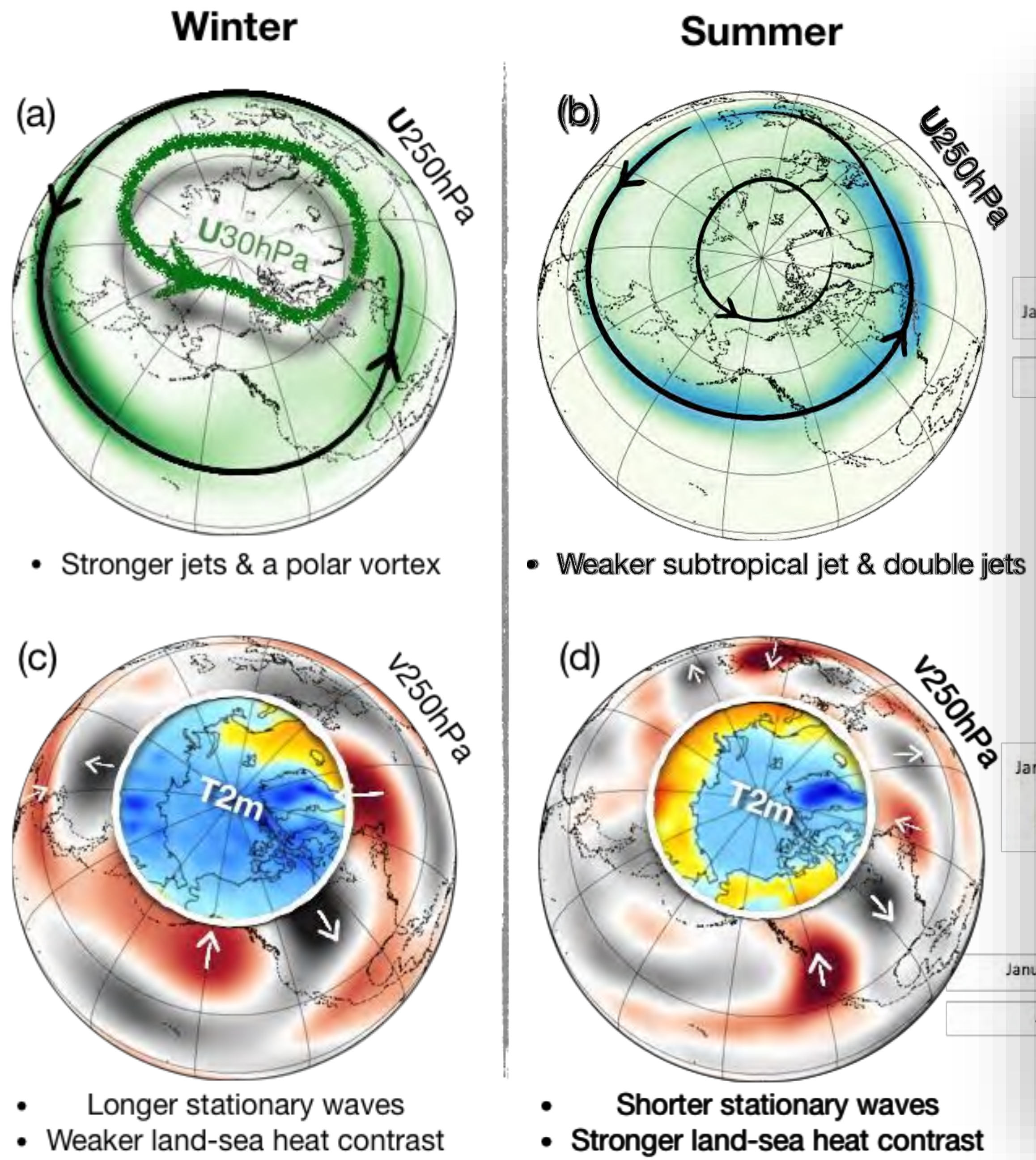
The influence of Arctic amplification on mid-latitude summer circulation

Summer



- Shorter stationary waves
- Stronger land-sea heat contrast
- Weaker subtropical jet & double jets

mid-latitude summer circulation



The seasonal differences in upper-level circulation between winter and summer. Top: 250-hPa wind speed illustrating the jet streams with black arrow lines. The wintertime stratospheric polar vortex is outlined with the thick green line. Bottom: the 250 hPa meridional wind depicting the stationary wave features associated with the jet streams.

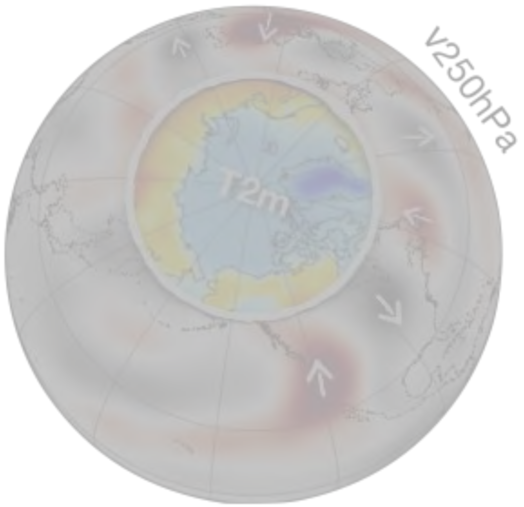
Summer differences (vs. winter) include shorter stationary waves, more northerly subtropical jet, absence of stratospheric polar vortex and an Arctic front jet forming <u>double jets</u>.

Data are 1970-2000 climatology of NCEP R1.

mid-latitude summer circulation

Summer circulation

Compared to winter, summer circulation in the mid-latitude is (1) weaker, more barotropic and the climatological jets are more zonally oriented, which promotes the formation of circumglobal wavetrains (CGWT), (2) less influenced by variability in tropical sea-surface temperatures (SST), and (3) more sensitive to land-atmosphere feedbacks involving soil-moisture or snow cover.



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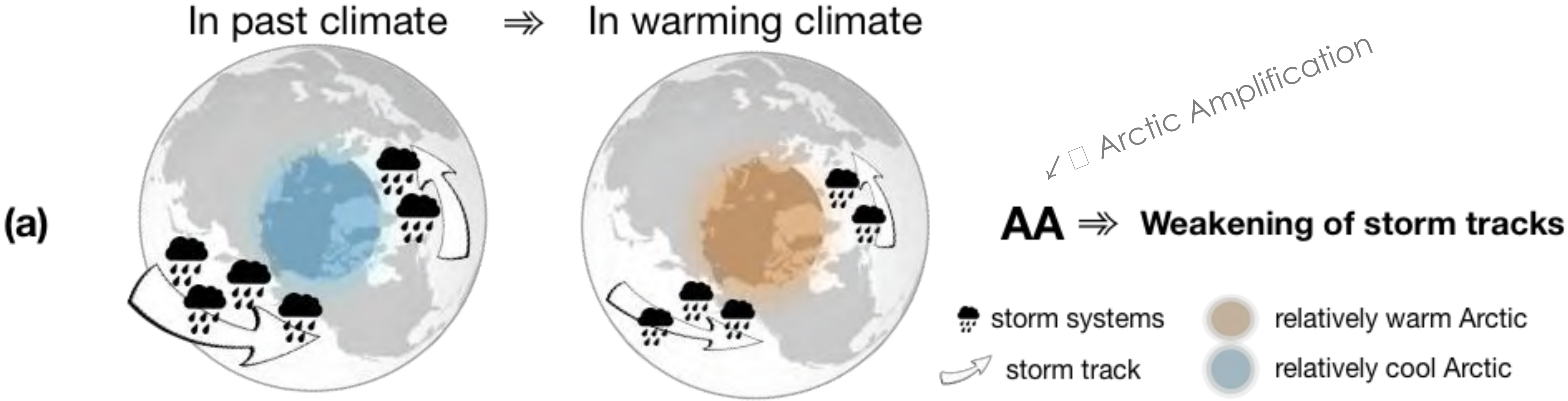
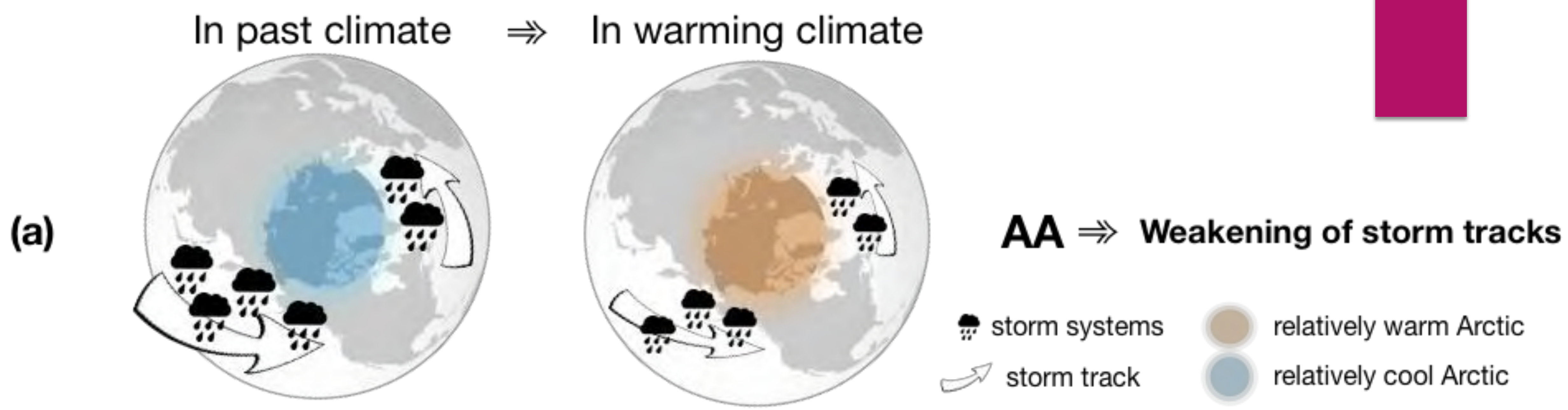
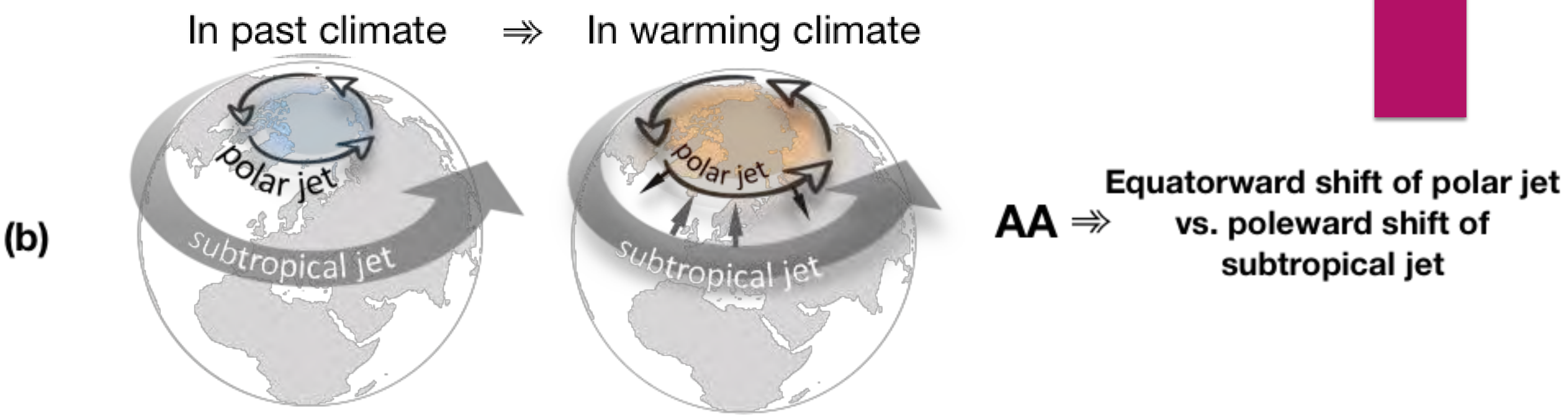
The proposed processes



Theoretical, observational and modeling evidence supports the hypothesis that summer storm tracks weaken with enhanced Arctic warming (Chang *et al* 2016, Coumou *et al* 2015, Petrie *et al* 2015).

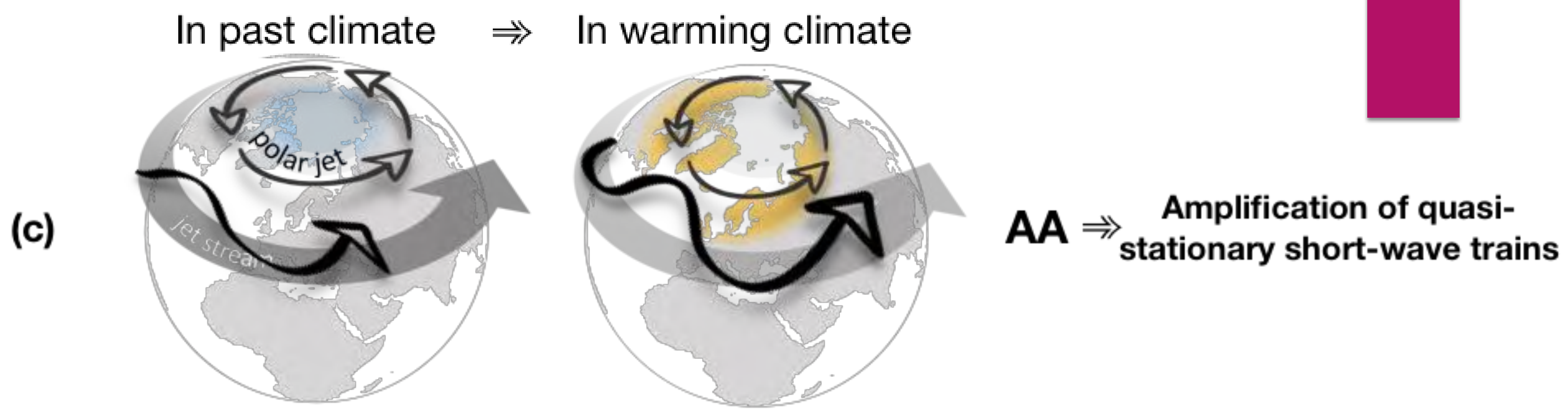


Theoretical, observational and modeling evidence supports the hypothesis that summer storm tracks weaken with enhanced Arctic warming (Chang *et al* 2016, Coumou *et al* 2015, Petrie *et al* 2015). The theoretical basis underlying AA and resultant weakening of the mid-latitude storm track is straight-forward: The thermal wind balance relates vertical shear in the westerly flow to the magnitude of the poleward temperature gradient. In the lower troposphere, a reduction in the temperature gradient equates to a similar reduction in the shear, weakening the thermally driven jet and reducing the low-level baroclinicity (Hoskins and Woollings 2015).



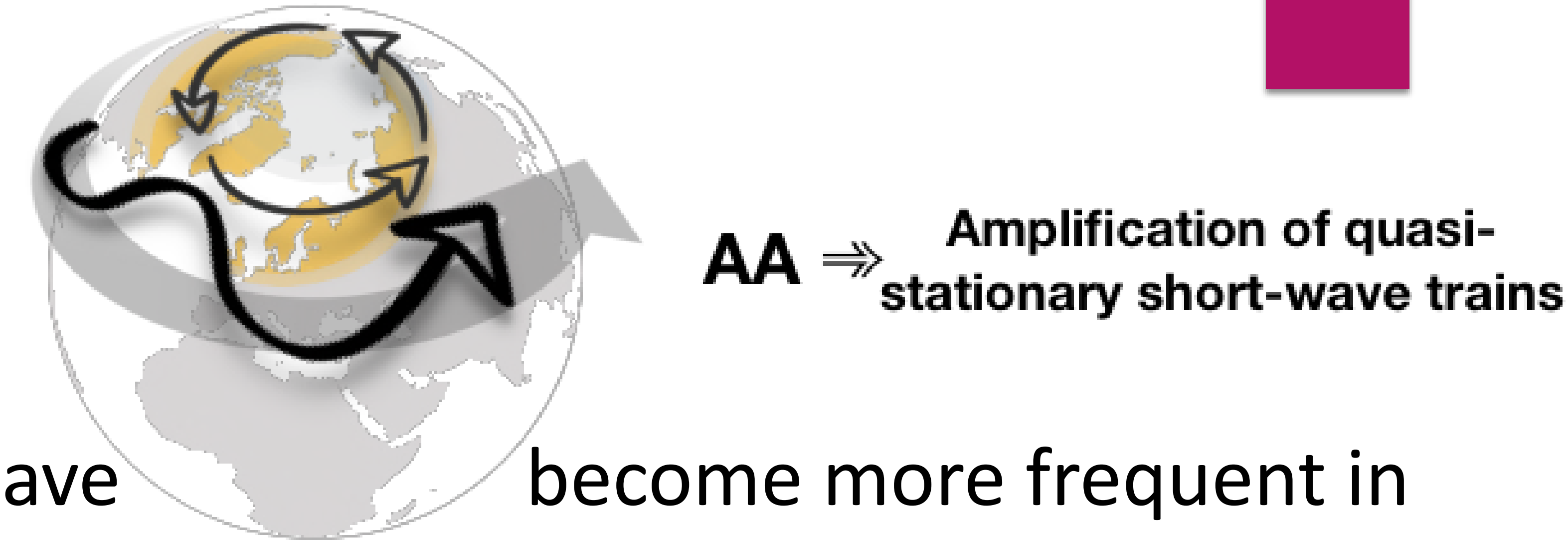
Theoretically, AA should cause a southward shift in the mid-latitude jet stream. Despite the process linking AA to a more equatorward (polar) jet, the mean jet is projected to migrate <u>poleward</u> by about 1° by the end of 21th century under a high emission scenario (Barnes and Polvani 2013, Vallis et al 2015).

Thus in the long run, the tropics likely dominate the tug-of-war, at least in models.



Limited evidence suggests that AA may amplify synoptic-scale, quasi-stationary waves embedded in the summer jet. The dry atmosphere dynamics suggests that a lower troposphere diabatic heating source in the mid-latitudes will have a larger stationary-wave response when the background baroclinicity and zonal winds are reduced, as a direct response of AA (Hoskins and Woollings 2015)…

Some observational evidence suggests that the quasi-stationary component of mid-latitude summer circulation has become wavier since the 1980s.



Such double jet regimes have become more frequent in recent years due to high-latitude land warming, partly attributable to anthropogenic greenhouse gas forcing (Mann *et al* 2017).

Double-jets favor waveguide formation and wave-resonance (Kornhuber *et al* 2017b, 2017a).

Though there is a solid theoretical basis underlying wave-resonances, their exact significance in causing extreme weather events is debated (Horton *et al* 2016).

Ways forward

DOI: 10.1038/s41467-018-05256-8

- Central challenge: quantify the interactions between Arctic teleconnections and other teleconnections and regional processes
- Require large ensembles and well-coordinated experiments with a range of different models (ongoing from WG)
- A so-called storyline approach can be insightful. This avoids quantifying probabilities associated with dynamical changes altogether and, instead, creates a set of physically plausible scenarios (i.e. storylines) of future changes (Zappa and Shepherd 2017, Hazeleger *et al* 2015).

Ways forward

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Relevant to PPAI: teleconnections in S2S

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Ways forward

Session **Synoptic-Dynamic and Quantitative Attribution for Extreme Weather and Climate Events**

PPAI members cochairing

Submitters:

Shih-Yu (Simon) Wang, Utah State Univ., Utah Climate Center / Plants, Soil & Climate, Logan, UT; Emily Becker, NOAA, CPC, College Park, MD; Christopher Castro, University or Arizona, Atmospheric Sciences, Tucson, AZ and Jinho Yoon, Gwangju Institute of Science and Technology, School or Earth

- A so-called storyline approach can be insightful. This avoids quantifying probabilities associated with dynamical changes altogether and, instead, creates a set of physically plausible scenarios (i.e. storylines) of future changes (Zappa and Shepherd 2017, Hazeleger *et al* 2015).

Ways forward

Continued…

- To overcome model biases, <u>novel machine learning approaches</u> should be considered in order to better integrate information from observations in climate models, e.g. in the representation of summer Rossby waves and ocean-atmosphere feedbacks in the presence of sea-ice.

- The mid-Holocene provides a possible paleo analog with enhanced high-latitude warming (interestingly, this period was also characterized by enhanced drought conditions in the mid-latitudes)

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REVIEW

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The influence of Arctic amplification on mid-latitude summer circulation

In summary, this review shows that AA is likely to have substantial impacts on mid-latitude summer circulation. The societal impacts can be severe due to tail risks arrising from radiatively forced mean summer warming combined with local and remote processes that favor more-persistent summer weather. A coordinated research agenda focusing on summer circulation, its drivers and extremes is needed to resolve the key knowledge gaps.