Article

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More frequent atmospheric rivers slow the seasonal recovery of Arctic sea ice

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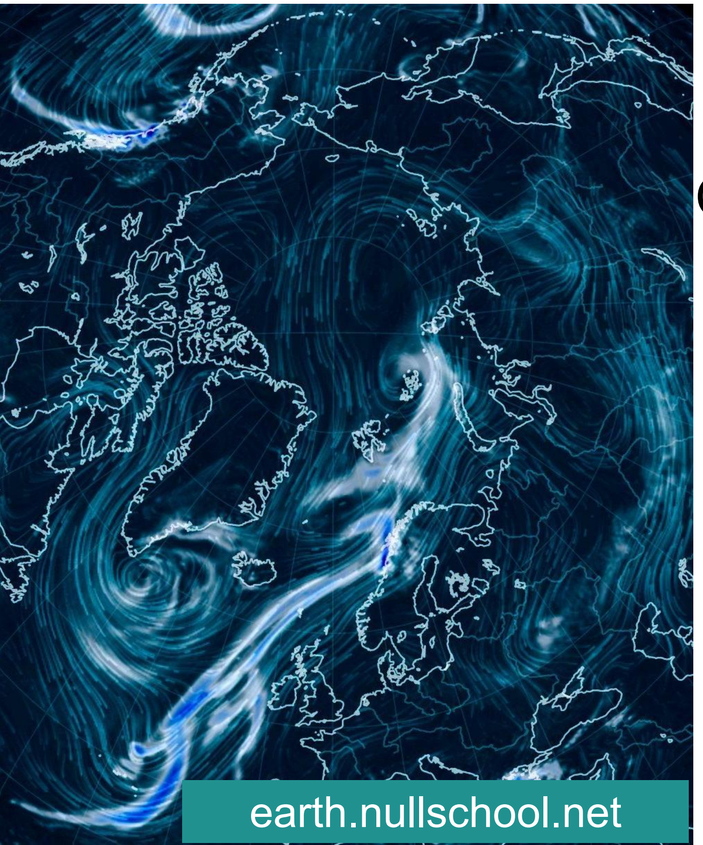
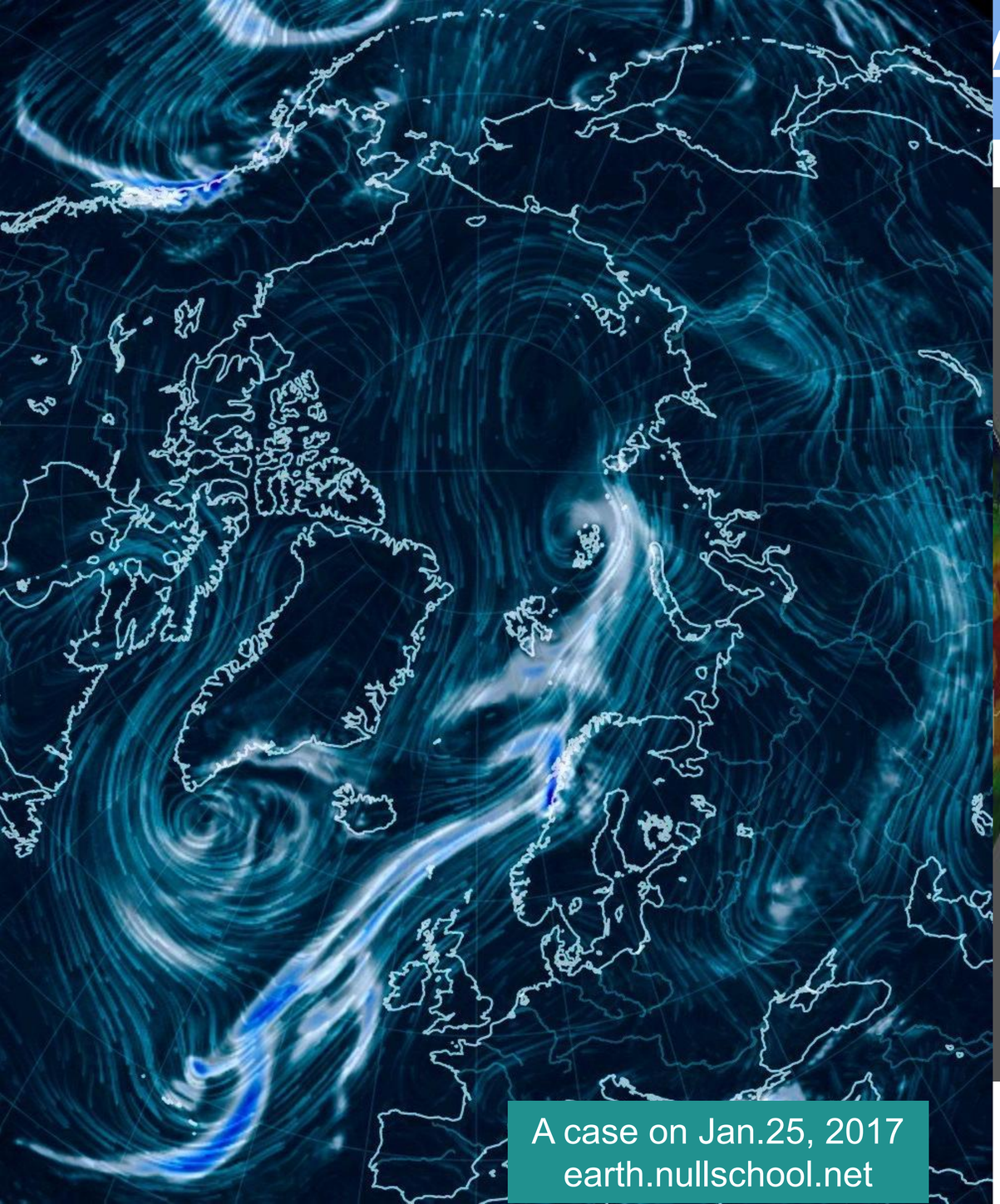


(Zhang et al NCC 2023)

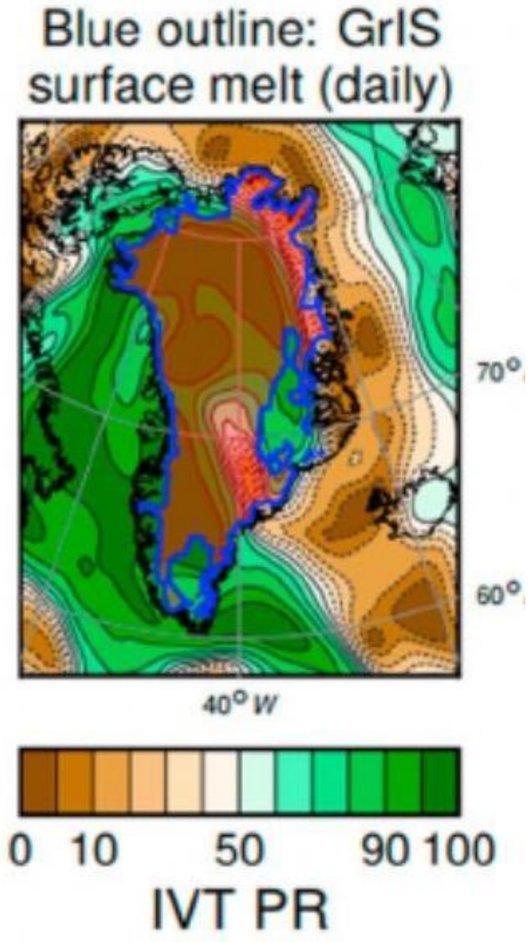
ARs)

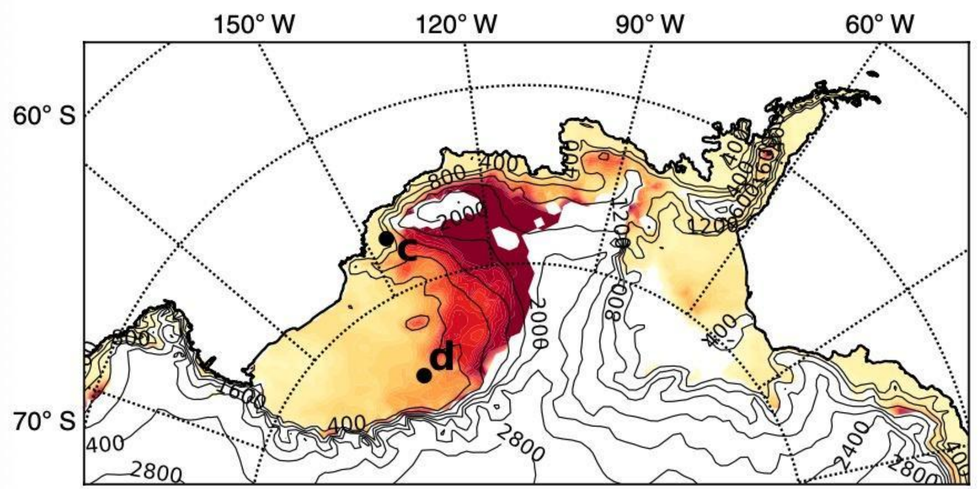


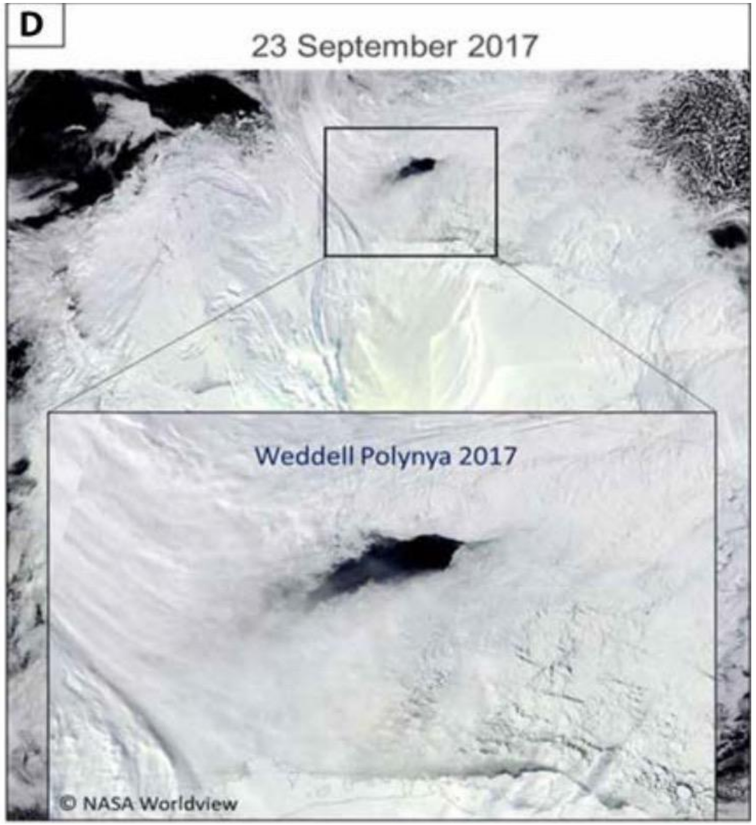
- Narrow, elongated synoptic jets of water vapor
- length>2000km; intensity > 85th percentile of IVT.
- Up to 90% poleward water vapor transport in midlatitude (Zhu and Newell 1998; Newman et al. 2012)

Polar ARs—Melting effect

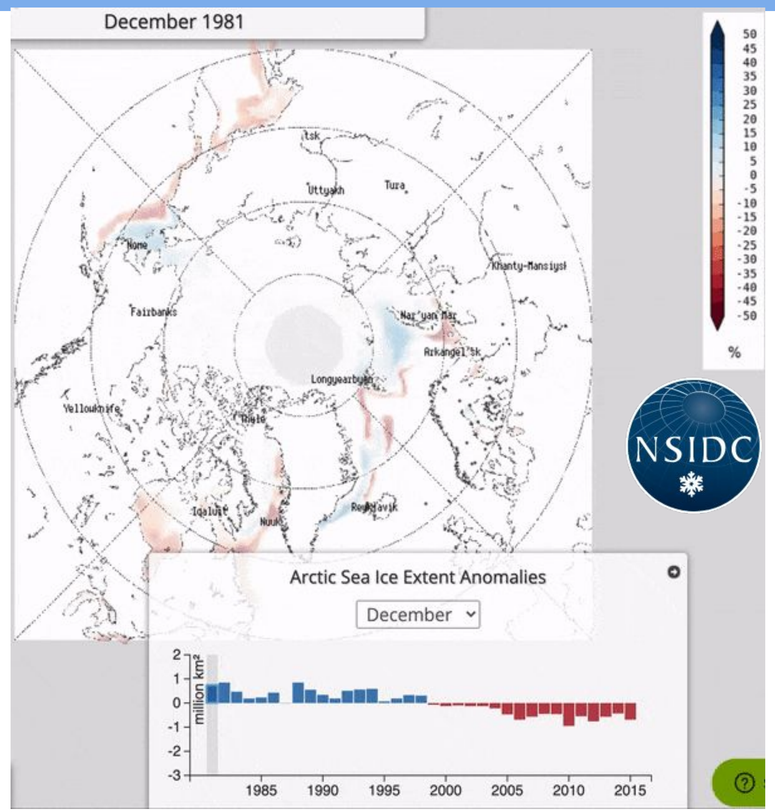
- Ice sheet melt in Greenland and West Antarctic, polynya events in the Weddell Sea, and 2016-17 record low winter Arctic sea ice (Hegyi and Taylor 2018; Mattingly et al. 2018, Wille et al. 2019, Francis et al. 2020)







Arctic sea ice decline in wintertime



Sea ice concentration anomalies (SICa) in Dec

- The concept that poleward moisture transport contributes to sea ice retreat is not novel (Park et a. 2015, Woods and Caballero 2016, Yang and Magnusdottir 2017 ……).
- To what extent the melting effect of ARs explain the rapid decline of Arctic sea ice ?

Contents

- What’s the melting effect of ARs on Arctic sea ice in winter?
- Is there a change in Arctic ARs? To what extent the AR changes contribute to the sea ice decline trend?
- To what extent human activities have contributed to Arctic AR changes ?

ARs' melting effect on the Arctic sea ice

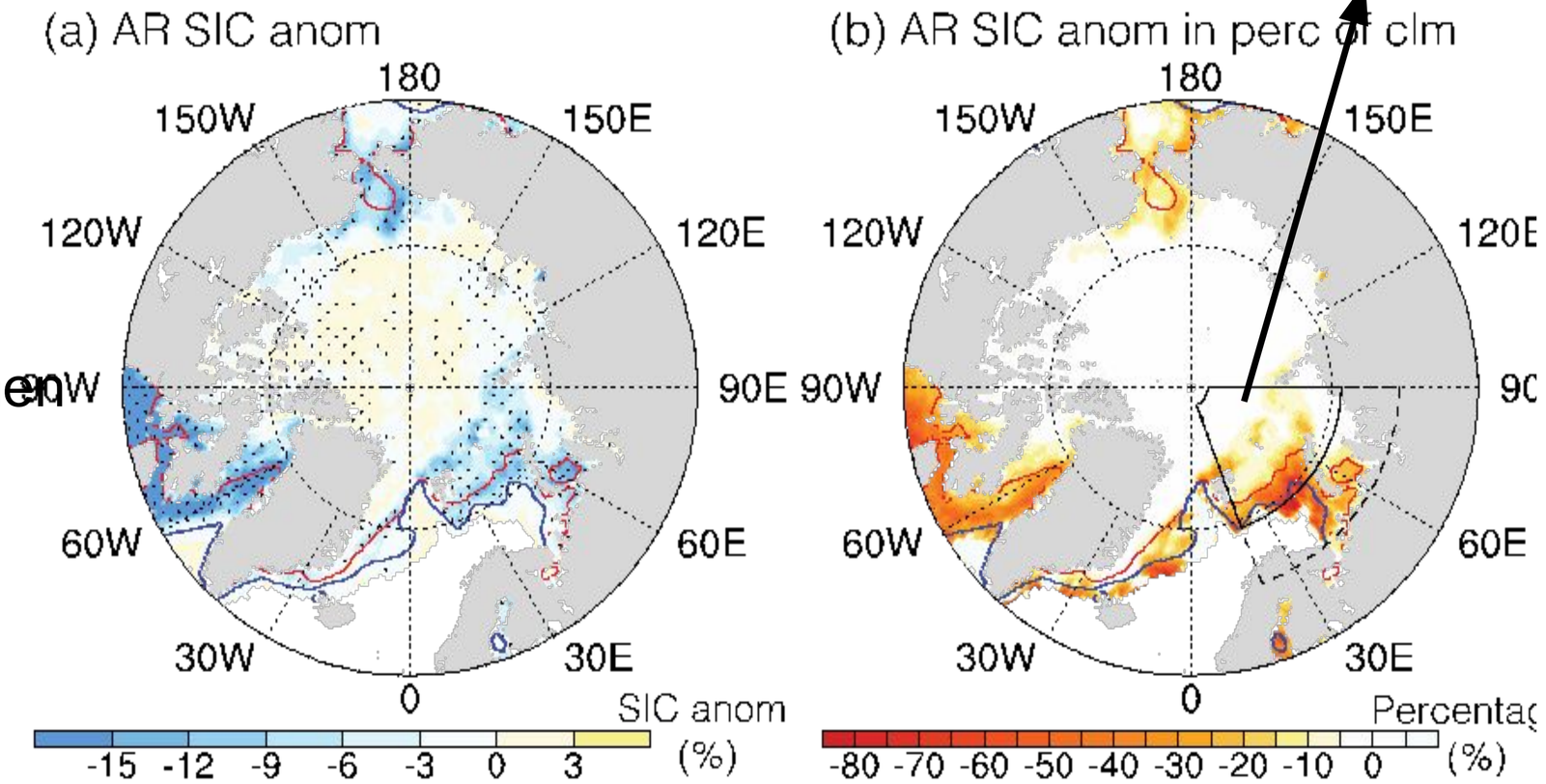
Composites in NDJ during 1979-2021

Red contour: clm ice edge on Oct.31
Blue contour: on Jan.31

- Significant ice reduction when ARs are deteched;
- especially on the newly formed ice cover, which is thinner, fragile.

Sea Ice Concentration anomalies associated with ARs

Barents-Kara and the central Arctic to the north
ABK



Data: ERA5, NSIDC (SIC)
AR algorithm: Guan and Wailser (2015) and Mattingly (2018)

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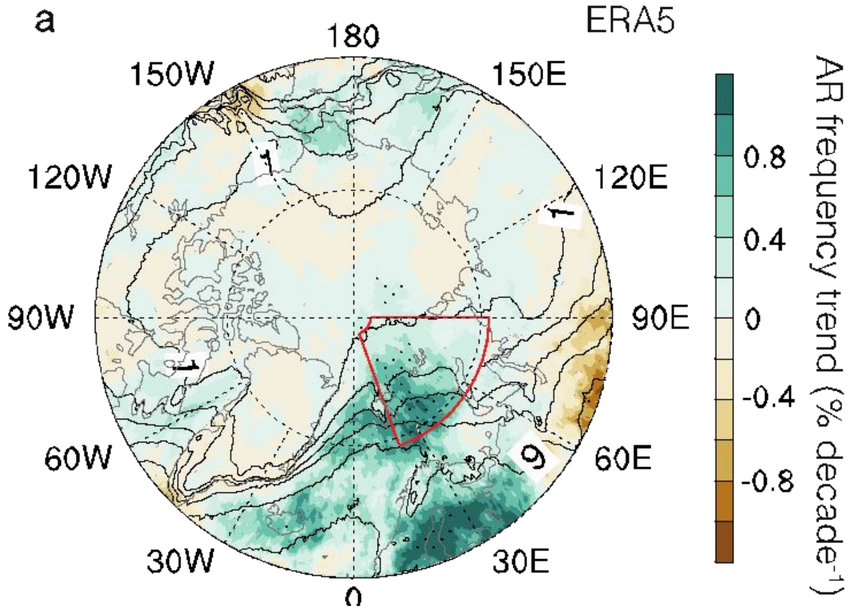
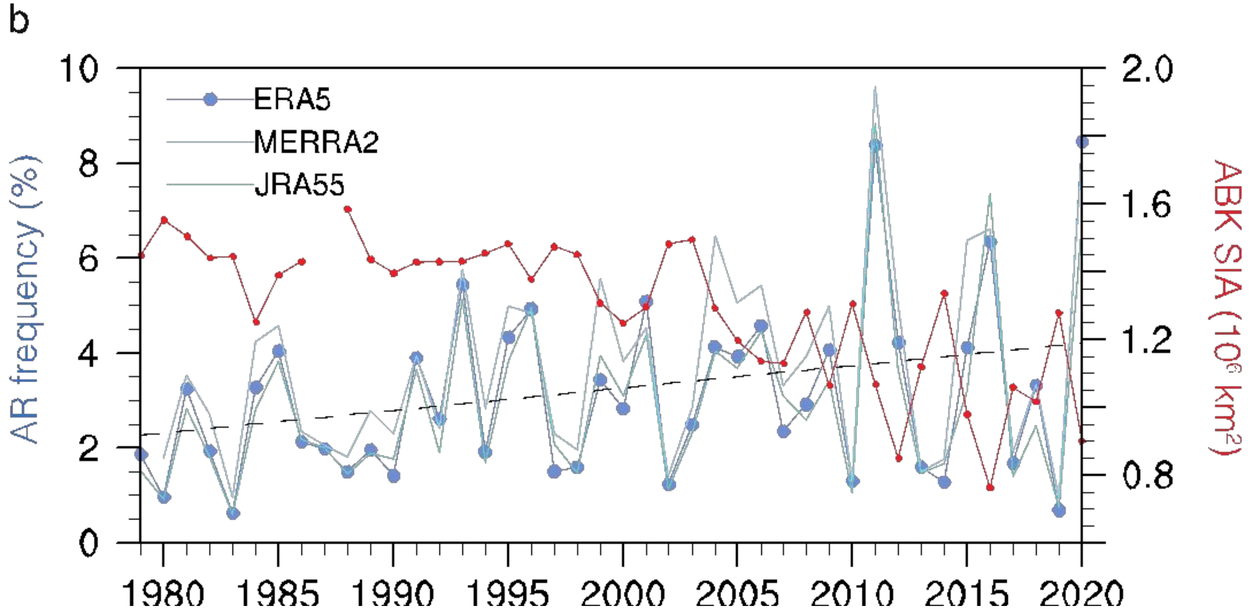
Increased AR penetration

AR freq trend in ERA5



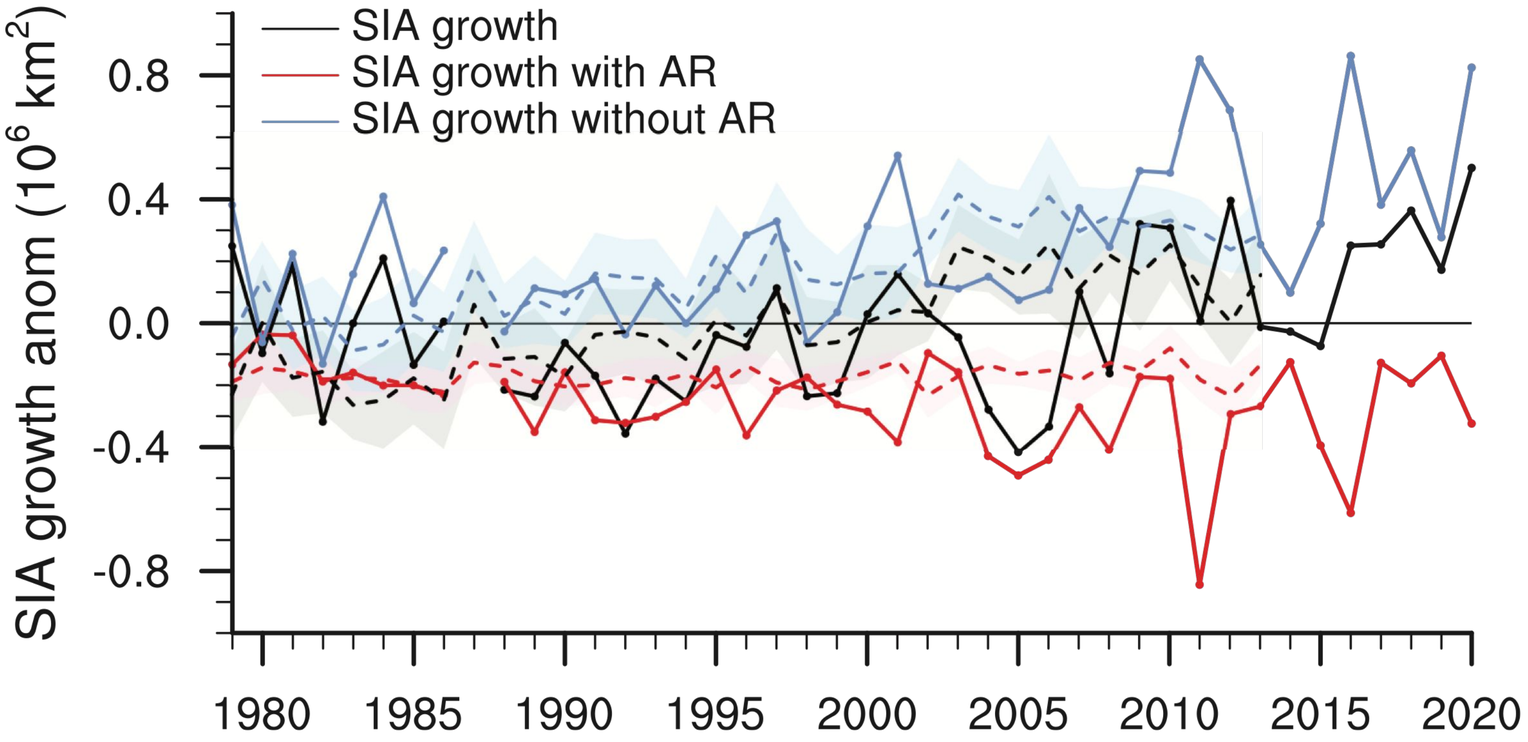
Three reanalysis datasets



- More frequent ARs in ABK in NDJ in 1979-2020
- AR increase trend coincides with local sea ice area decline

Increasing role of ARs in sea ice changes

Sea ice area growth (tendency) in NDJ



$$\sum_{Jan31} \left(\frac{A_{i+1} - A_{i-1}}{2} \right)$$

Solid: Obs (NSIDC)
Dashed: PAC

- Frequent ARs can prevent the sea ice from growing to the extent allowed by the freezing surface temperature.
- Enhancement of melting effect of ARs accounts for ~34% of the total SIA decline in NDJ.

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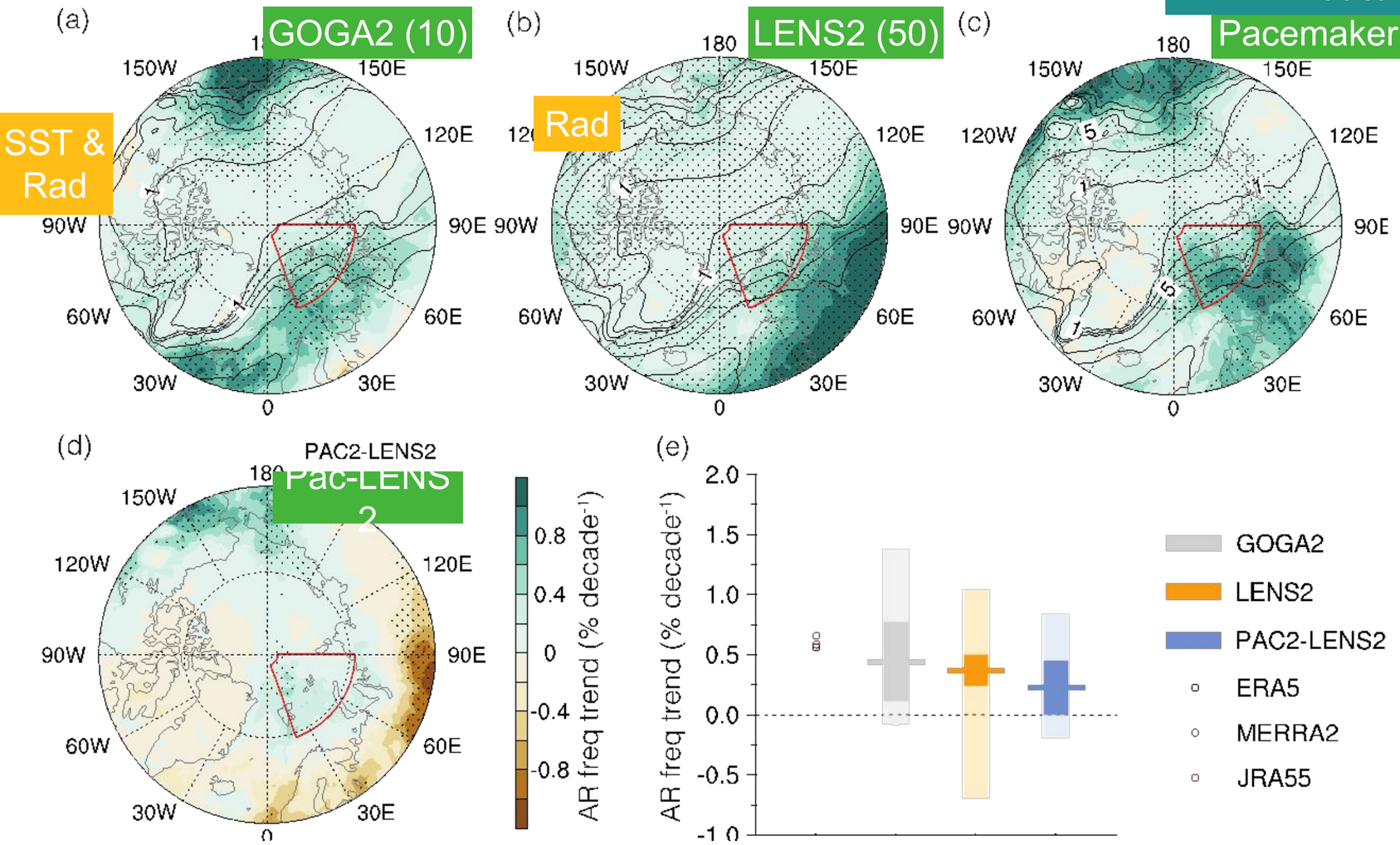
Drivers of increased AR frequency

Model experiments: CESM2 (CVCWG/NCAR)



- Tropical Pacific variability (Ding et al. 2014; Meehl et al .2018; et al.)
- By comparing AR changes across 3 ensembles, it becomes apparent that tropical Pacific variability cannot be ignored.

Darker color bar: 2.5-97.5% confidence interval

Conclusion remarks

- ARs exert a pronounced melting effect on Arctic sea ice.
- More frequent ARs has been observed in Arctic in recent decades.
- The increase in AR frequency accounts for 34% of the sea ice area decline trend.
- Tropical Pacific variability is essential for generating the observed spatial pattern of AR changes

Thanks for your attention!

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AR's melting effect on the Arctic sea ice

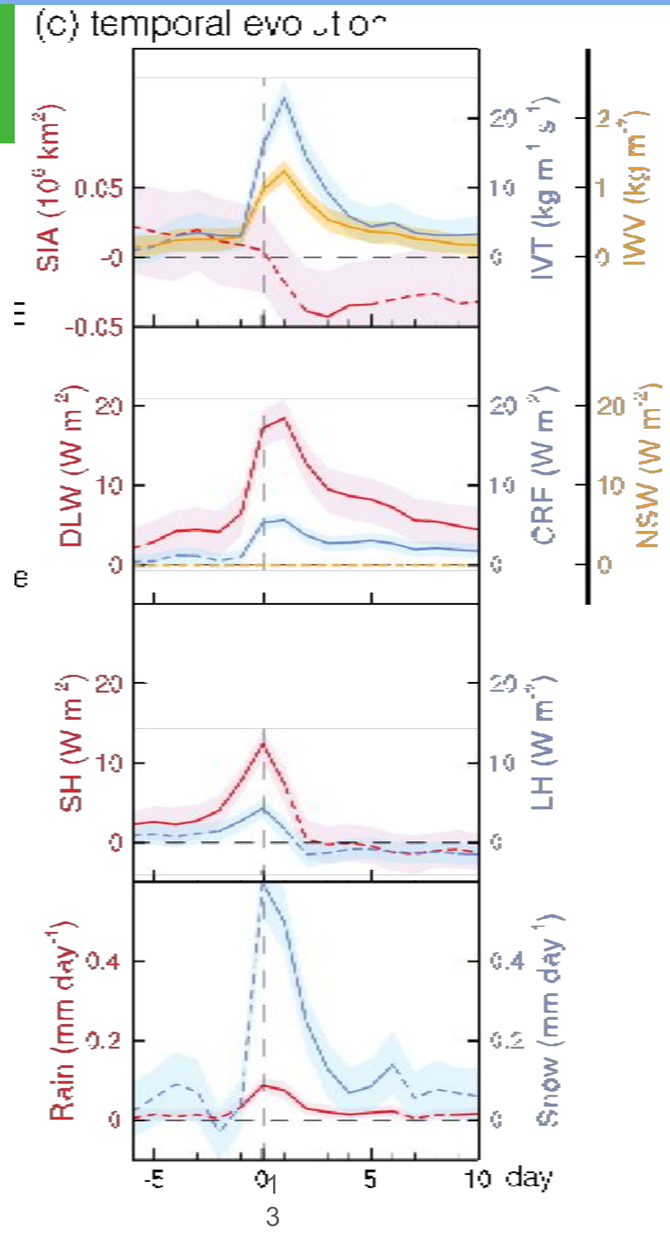
Temporal evolution when ARs make landfall on the ice cover in ABK region

Sea ice area in ABK
vertical integral water vapor transport (IVT)
vertical integral water vapor (IWV)

DLW
Cloud radiative effect in DLW
Net short wave radiation

Surface sensible heating flux
Surface latent heating flux

Liquid rainfall
Snowfall



- SH and LH decay fast;
- Snow's insulation effect could inhibit ice growth throughout the winter(Merkouriadi et al 2020).
- Two factors, DLW enhanced by cloud radiative effect and liquid rainfall, dominate the melting effect at synoptic time scale.

Mechanisms of Arctic AR change

$$\overrightarrow{IVT} = -\frac{1}{g}\int_{sfc}^{200hPa} \vec{V}\, q dp$$

- Amplified Arctic warming facilitates the penetration of ARs further north