ARCTIC SEA ICE LOSS, ARCTIC AMPLIFICATION & LINKAGES TO MID-LATITUDES

Present vs Future

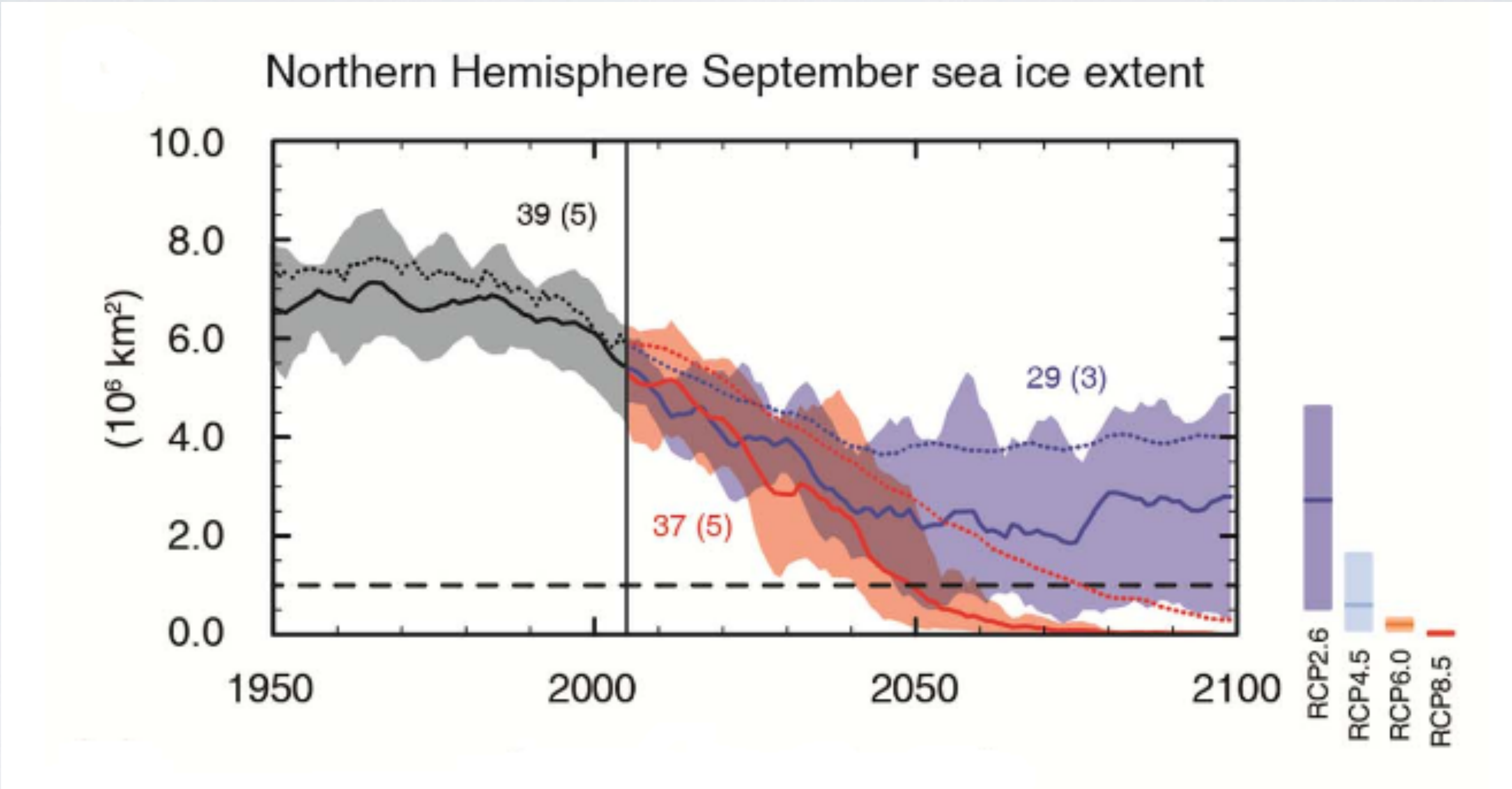
James Screen, University of Exeter

OUTLINE

- What aspects of present-day Arctic change are expected to **continue in the future**?
- How might Arctic change be **different in the future**?
- What are the **implications for lower latitudes**?

(Arctic change = sea-ice loss and Arctic amplification)

ONGOING SEA-ICE LOSS



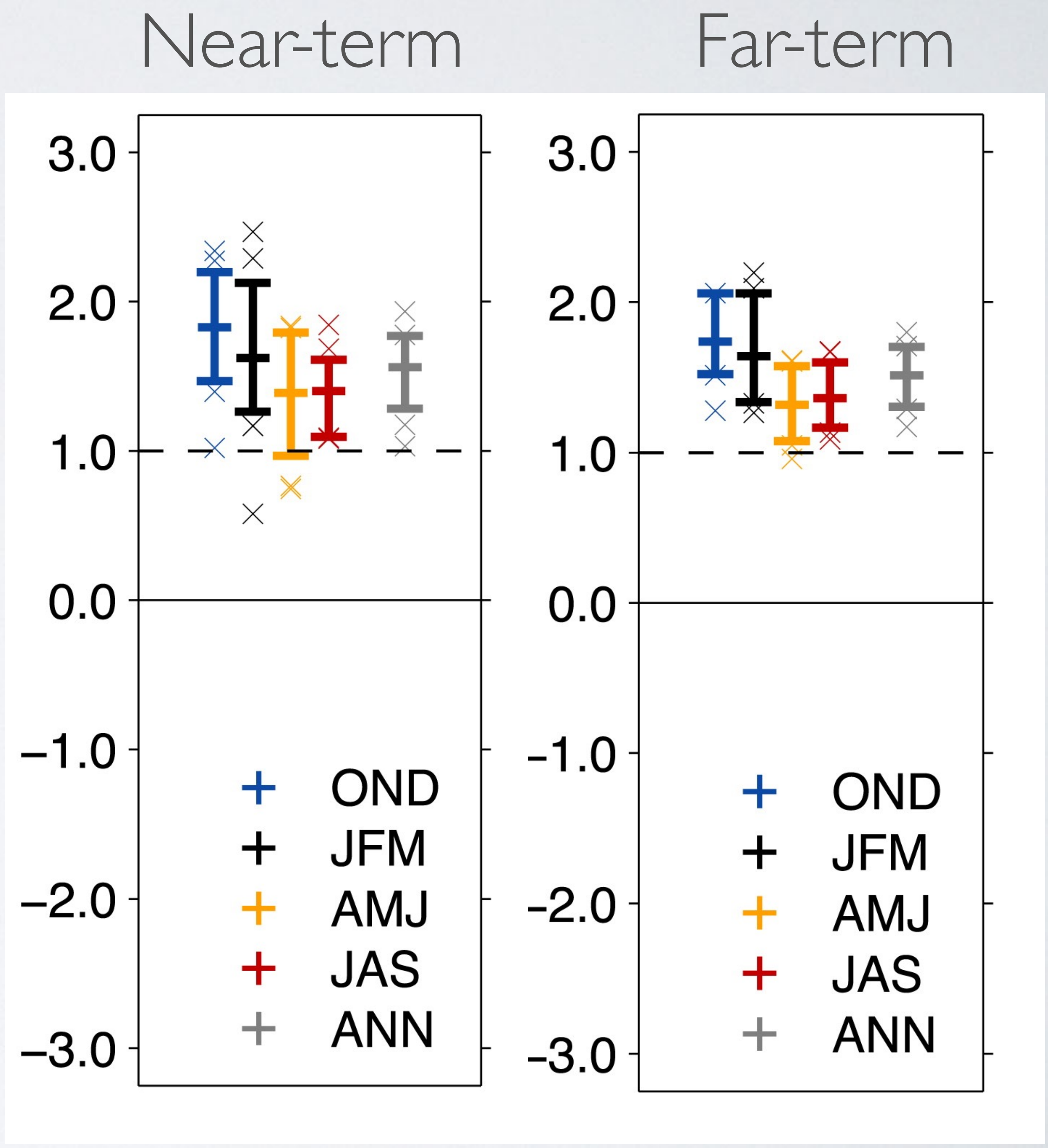
IPCC Fifth Assessment Report

- Even in lowest emissions scenario (RCP2.6), sea ice continues to decline under mid-century
- "Ice-free" summers likely this century in absence of mitigation

CONTINUED ARCTIC AMPLIFICATION

Barnes & Polvani 2015 (*J. Climate*)

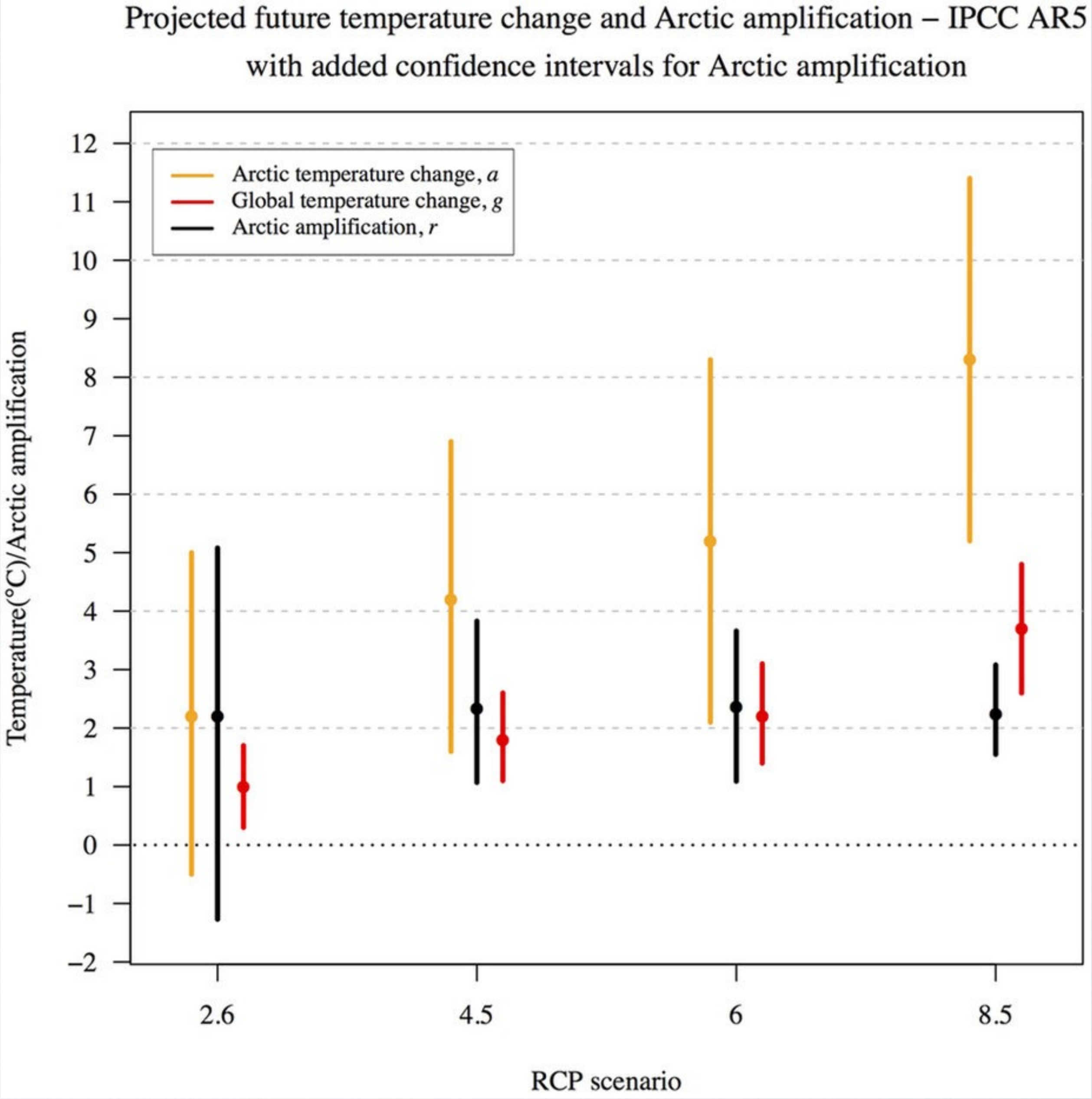
- CMIP5 models project continued AA in the near-term (left) and far-term (right)
- Robust feature of projected climate change
- AA continues to be largest in fall and winter



RATE OF CHANGE

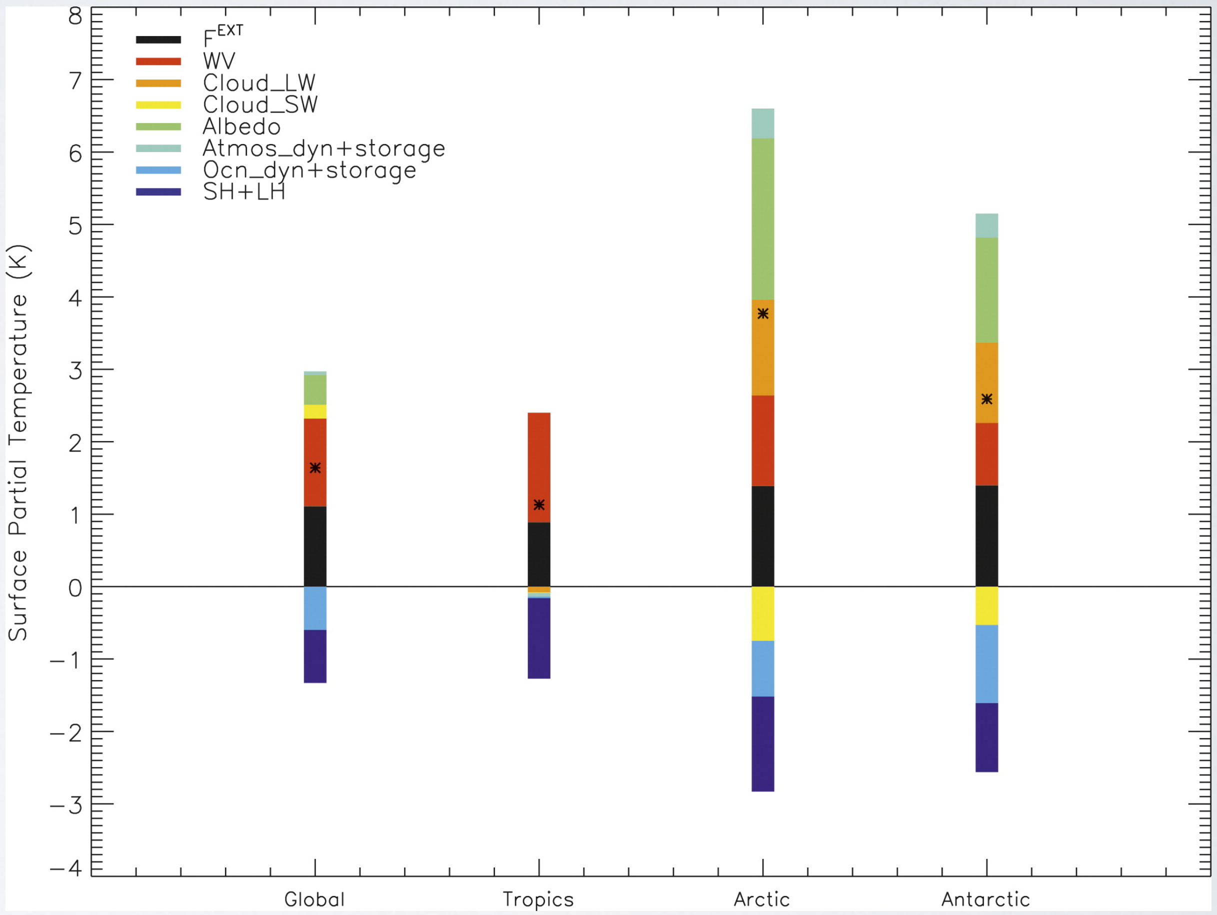
Hind et al 2016 (*Scientific Reports*)

- Magnitude of AA is dependent on future greenhouse gas emissions
- AA is > 1 (i.e.,. Arctic warms faster than global average) in RCP4.5, 6, 8.5
- Mitigation implies not just less global warming, but possibly less AA
- Under RCP2.6 (consistent with Paris Agreement) AA can be < 1 (i.e., Arctic warms slower than global average, or Arctic cools)



CHANGING ARCTIC FEEDBACKS

- Albedo feedback strength will change as Arctic transitions to seasonally ice-free
- Cloud cover feedbacks will also change, both through changes in cloud cover and in cloud radiative forcing
- Increased mechanical forcing by storms due to thinner, weaker ice pack
- AA will reduce poleward heat transport, but poleward moisture transport will increase



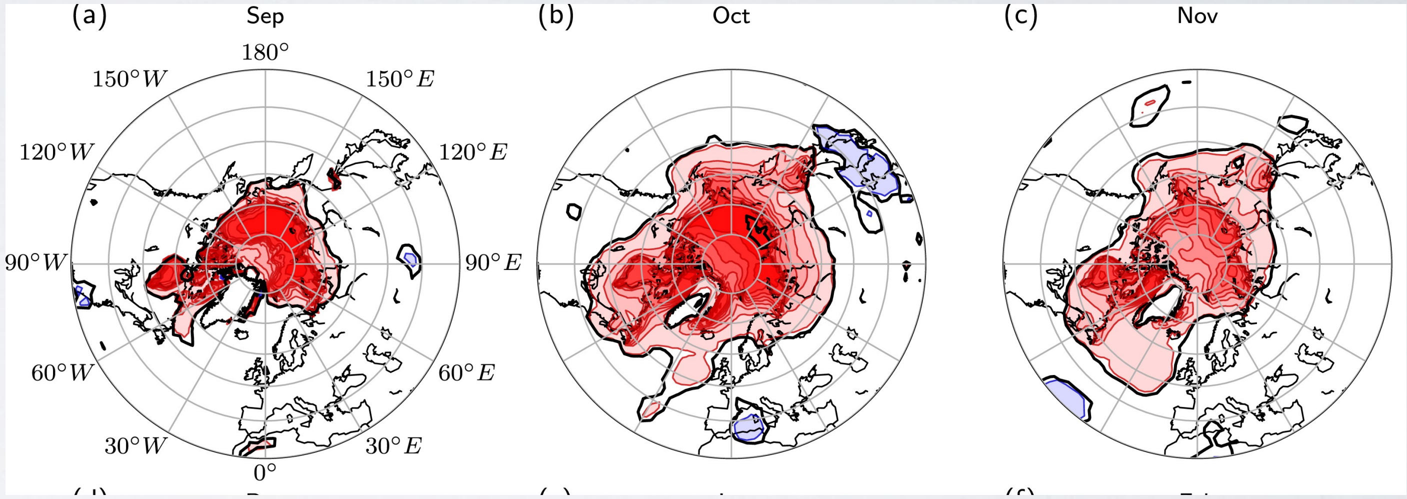
Taylor et al 2013 (*J. Climate*)

MAGNITUDE OF CHANGE

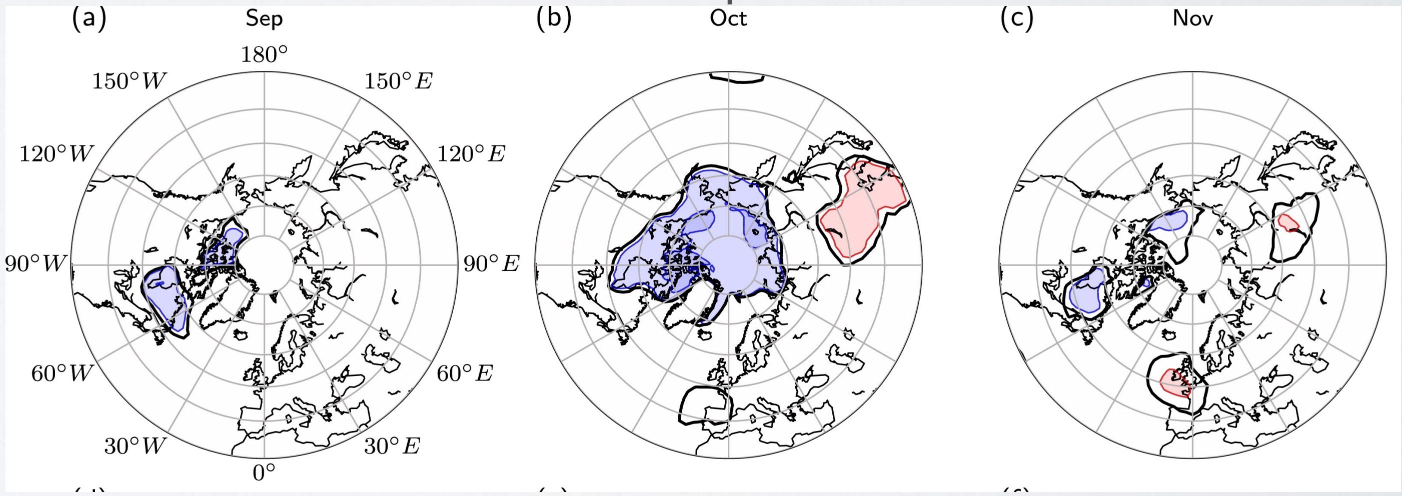
Chen et al 2016 (*J. Climate*)

- Larger loss of sea ice gives locally larger response
- Mid-latitude response is non-robust and not linearly related to the amount of sea-ice loss
- Cannot assume impacts scale linearly with forcing

Near-surface temperature



Sea level pressure

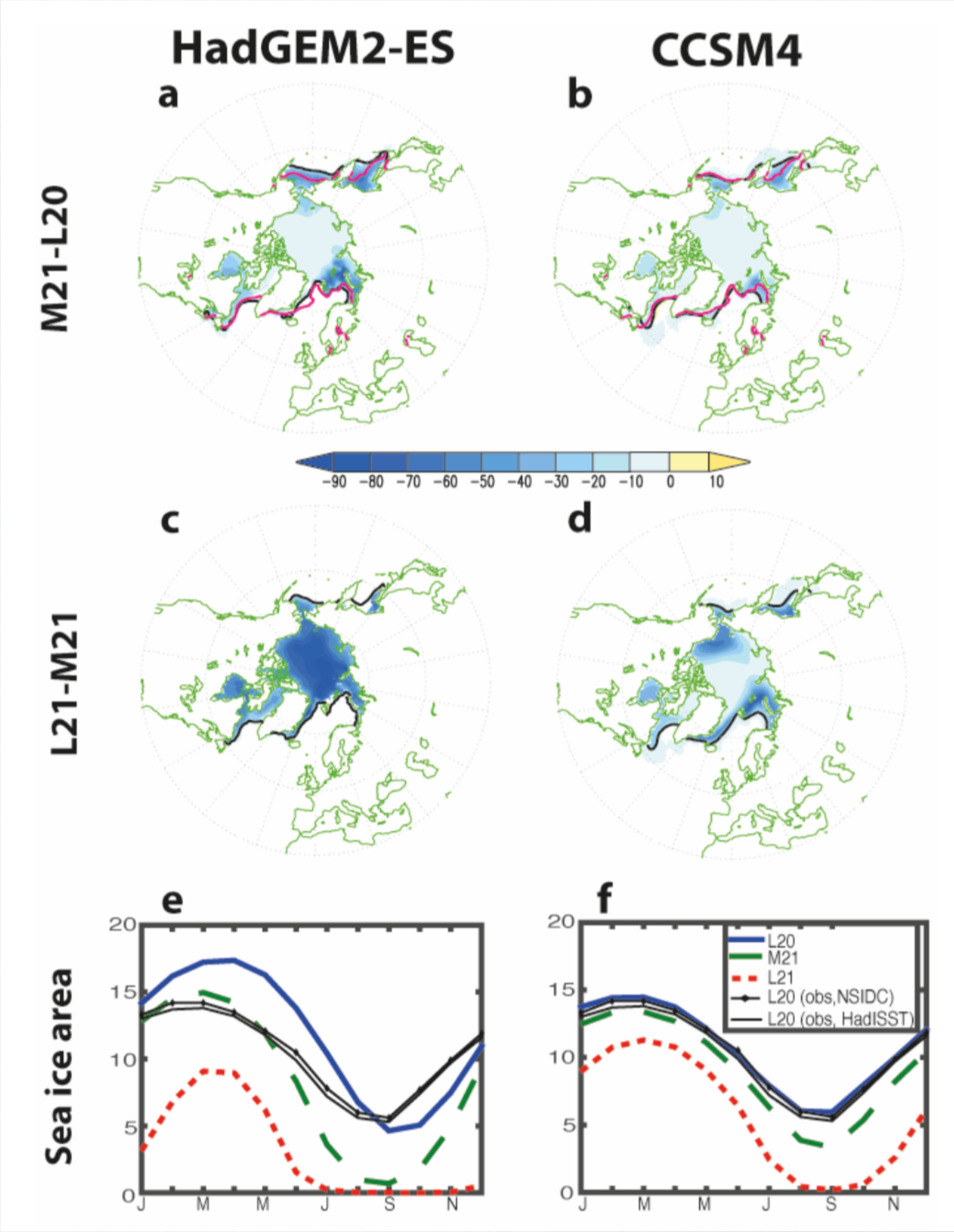


Correlation between forcing and response

SPATIAL PATTERN OF CHANGE

Ayarzaguena & Screen 2016 (*GRL*)

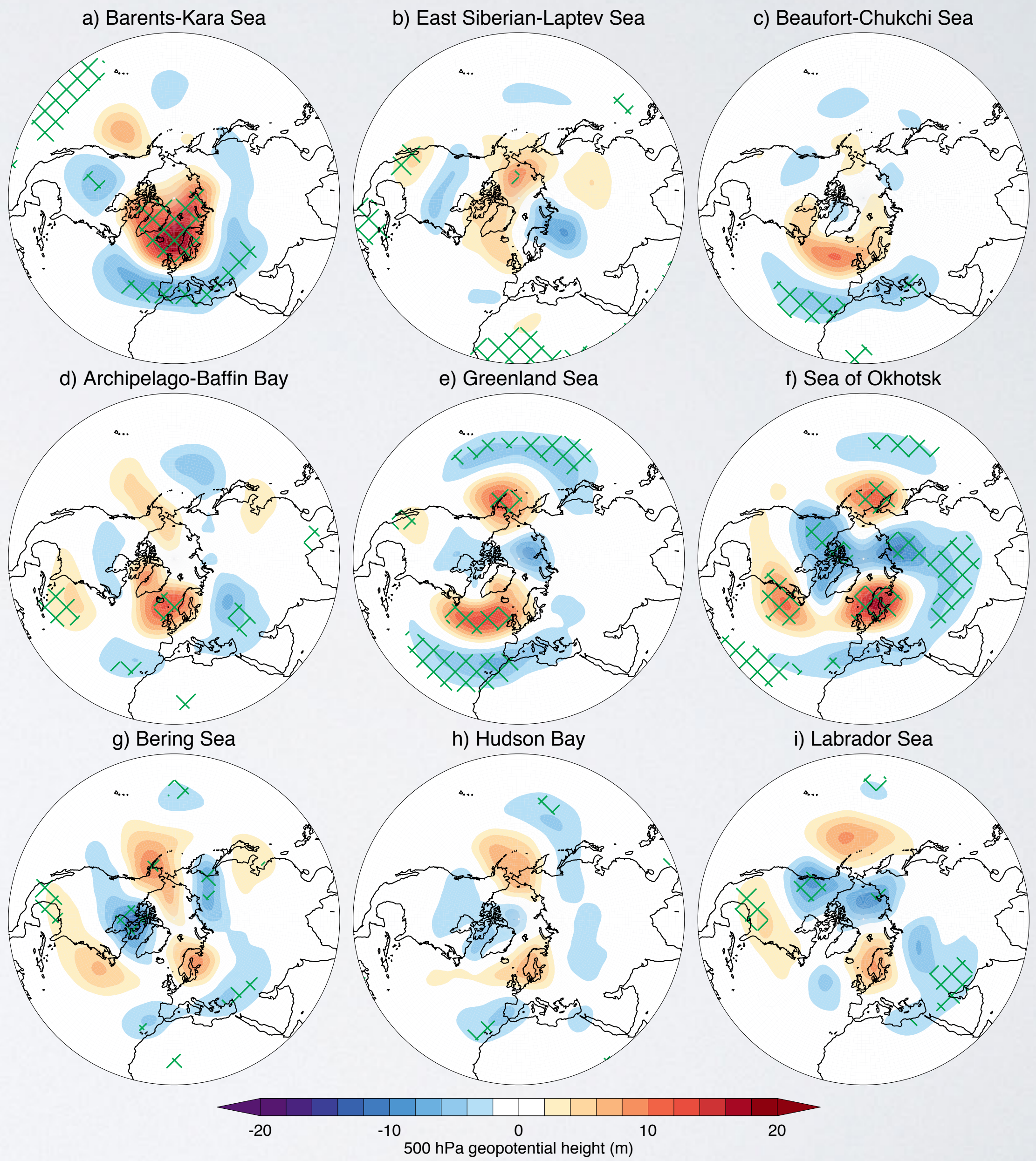
- Location of sea ice loss will change - from marginal seas to central Arctic
- Seasonal cycle of sea ice loss will change - from largest in summer to winter



DISTINCT ATMOSPHERIC RESPONSE TO REGIONAL SEA-ICE LOSS

Screen 2017 (*J. Climate*)

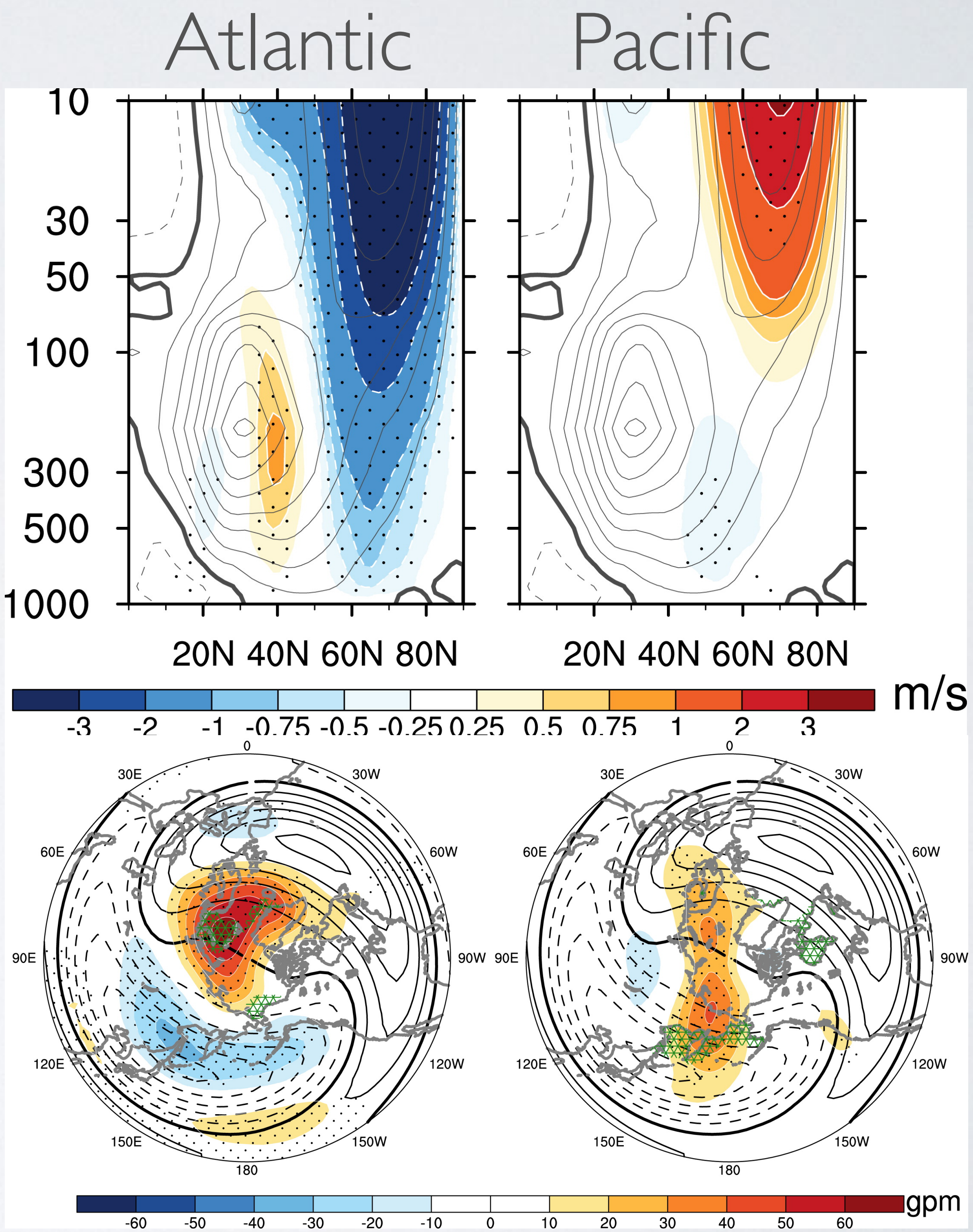
- Very different circulation responses to regional sea-ice loss
- NAO- response to Barents-Kara Sea ice loss only
- Wave-train response to Sea of Okhotsk ice loss
- Responses are non-additive (i.e., sum of responses to regional ice loss not equal to response to pan-Arctic response; see my poster)



DISTINCT ATMOSPHERIC RESPONSE TO REGIONAL SEA-ICE LOSS

Sun et al 2015 (*J. Climate*)

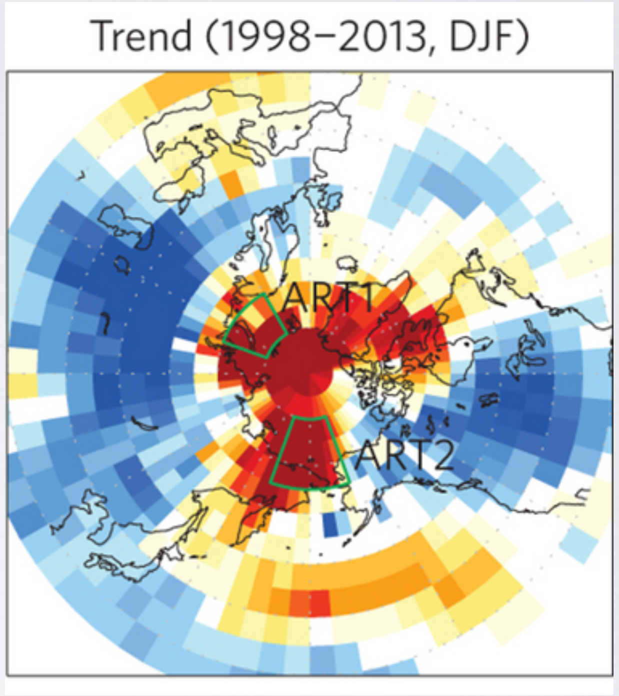
- Atlantic sector sea-ice loss causes a weakened polar vortex and polar jet
- Pacific sector sea-ice loss causes a strengthened polar vortex
- Together the two roughly cancel each other.

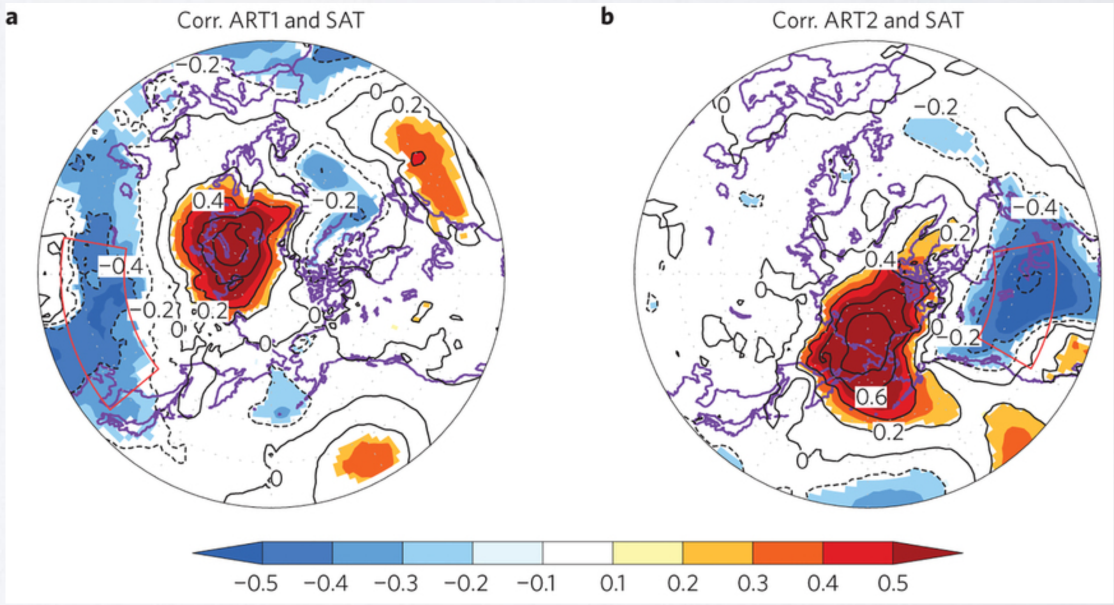


DISTINCT ATMOSPHERIC RESPONSE TO REGIONAL SEA-ICE LOSS

Kug et al 2015 (*Nature Geoscience*)

- Barents-Kara warmth (ART1) correlated with cold Eurasia
- Beaufort-Chukchi warmth (ART2) correlated with cold North America
- Causality not tested or clear



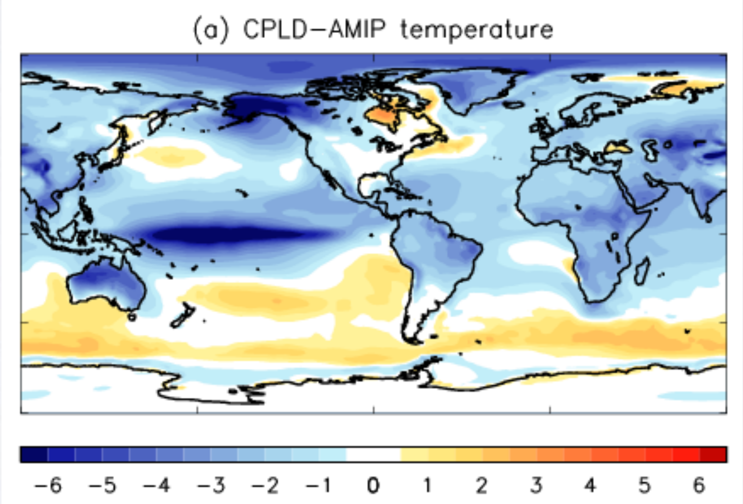


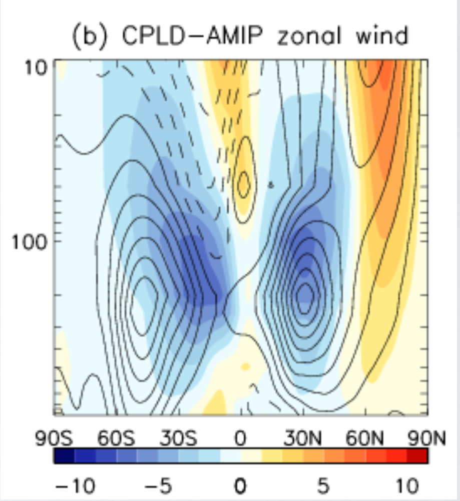
CHANGING BACKGROUND STATE

Smith et al submitted (*J. Climate*)

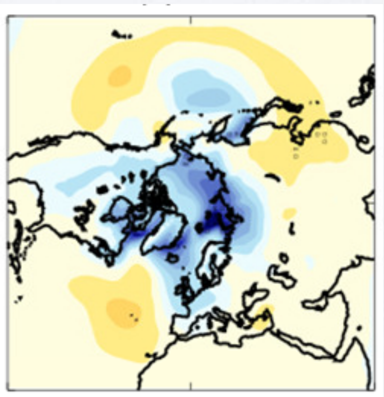
- Found contrasting responses in coupled and uncoupled simulations
- Differences appear to relate primarily to different mean states (SST biases in coupled model) not to ocean coupling
- Response to sea-ice loss dependent on mean state (e.g., jet latitude)

Coupled model SST and wind bias

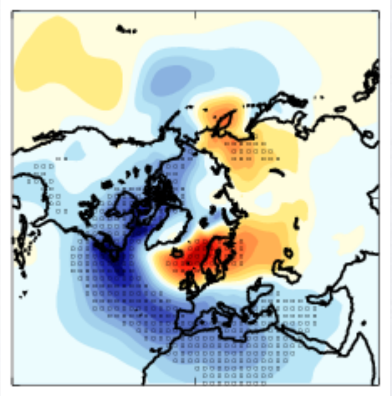




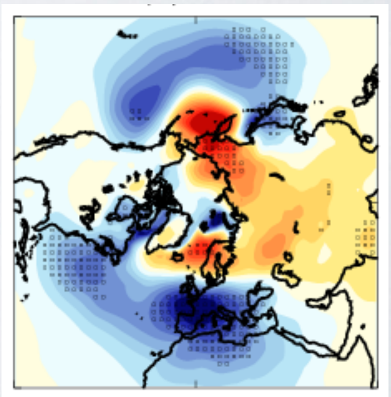
Uncoupled



Coupled



Uncoupled



No SST bias

SENSITIVITY TO BACKGROUND STATE

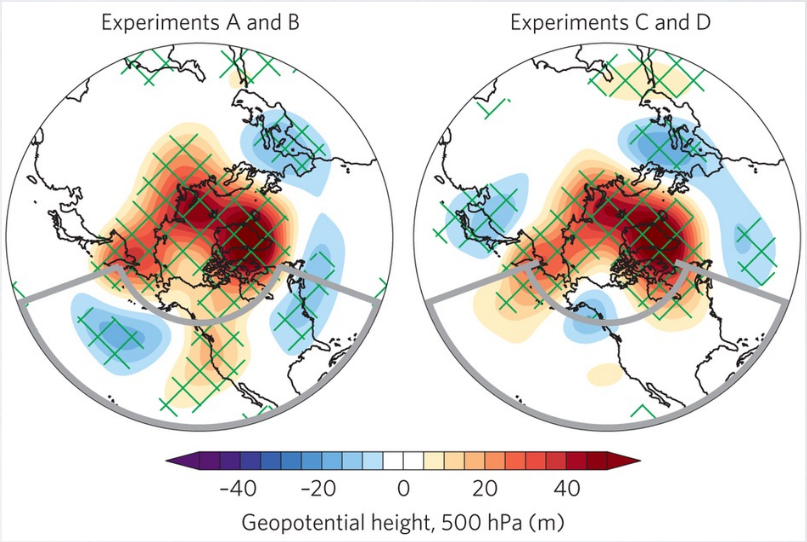
Osborne et al 2017 (*J. Climate*)

- Mid-latitude circulation response to sea-ice loss is sensitive to AMO-related SST anomalies
- Larger North American response when AMO+

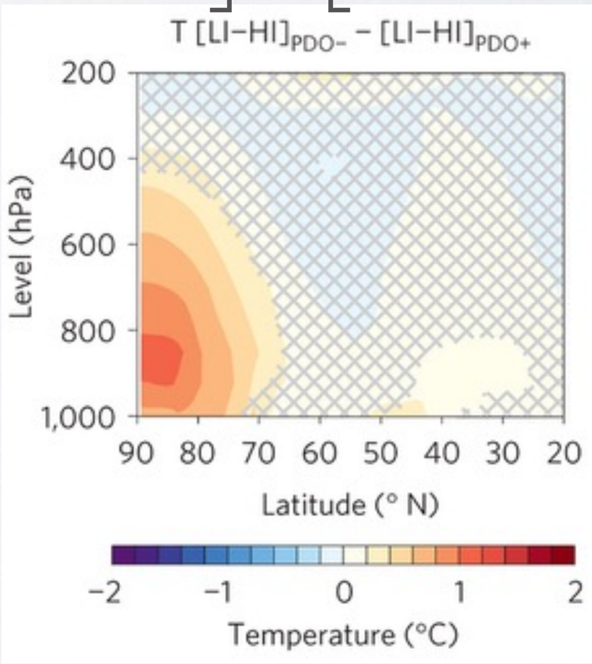
Screen & Francis 2016 (*Nature Climate Change*)

- Arctic warming response to sea-ice loss is sensitive to PDO-related SST anomalies
- Larger warming when PDO-

AMO+ AMO-



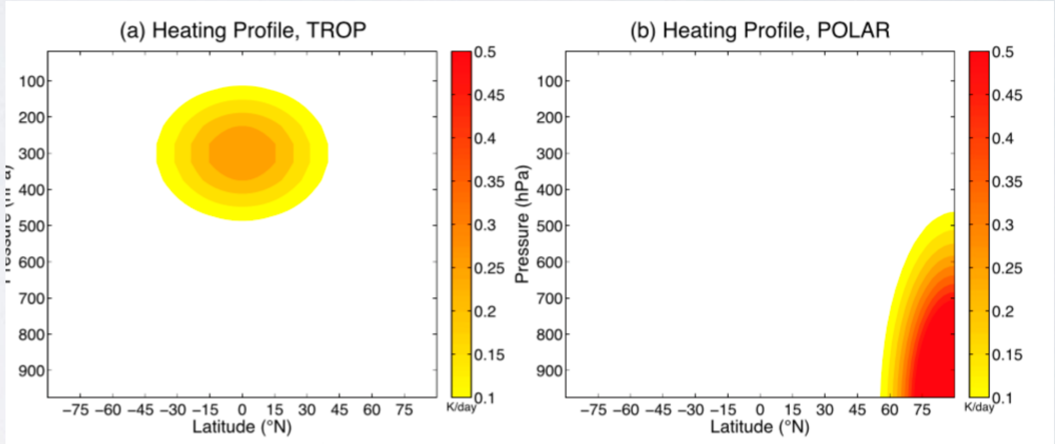
[PDO-] - [PDO+]



CHANGING BALANCE OF MULTIPLE INFLUENCES

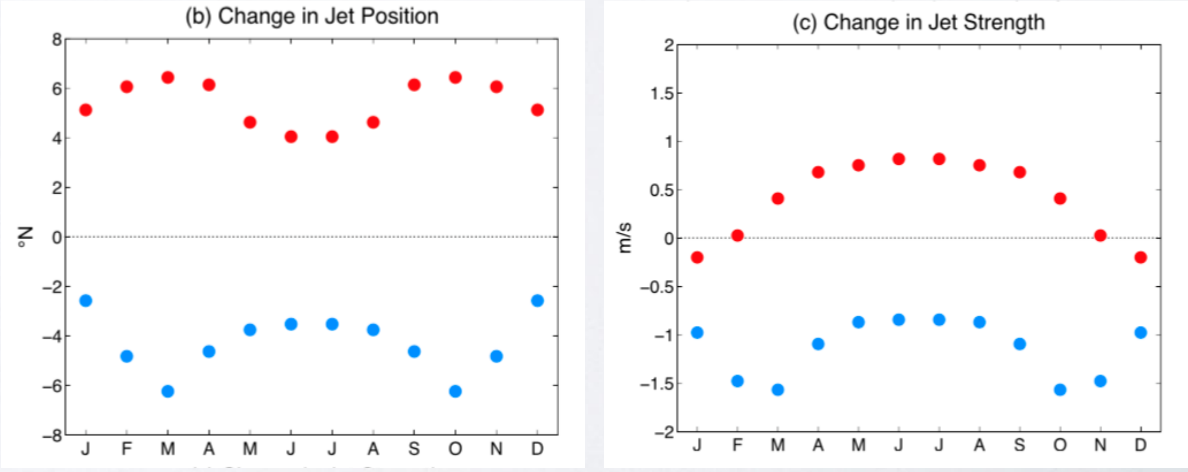
McCraw & Barnes 2016 (*J. Climate*)

- Tug-of-war between tropical and Arctic warming
- Tropical warming (red dots) pushes jet poleward; Arctic warming (blue dots) pushes jet equatorward
- Seasonal cycle of jet response suggests that whether or not the real world "sees" the effects of Arctic warming depends on delicate balance of multiple influences



Jet latitude

Jet strength



SUMMARY

- **Arctic sea-ice loss and AA will continue** and will remain potential drivers of mid-latitude climate
- The **magnitude, rate** and **spatial** pattern of **Arctic change will differ** in the future, **as will the background state** and importance of **other influences** on midlatitude weather and climate
- **Linkages to mid-latitudes are highly non-linear,** sensitive to both the nature of the forcing and the background state
- To the (limited) extent that simple causal Arctic-to-midlatitude pathways exist today (see Overland et al 2016), there are reasons to believe they may differ in the future. Or in other words, we should **expect surprises**!

FURTHER READING

Overland et al 2016 (*Nature Climate Change*)

- Discusses the non-linearity of Arctic-Midlatitude linkages
- Suggests we should be very cautious about seeking simple causal pathways
- Potentially helps explain some of the disparity in past studies
- Viewed through this lens, linkages are highly case-specific (regional, episodic)

nature climate change

Home | Current issue | News & comment | Research | Archive ▼ | Authors & referees ▼ | About the journal

home ▸ archive ▸ issue ▸ perspective ▸ full text

NATURE CLIMATE CHANGE | PERSPECTIVE

Nonlinear response of mid-latitude weather to the changing Arctic

James E. Overland, Klaus Dethloff, Jennifer A. Francis, Richard J. Hall, Edward Hanna, Seong-Joong Kim, James A. Screen, Theodore G. Shepherd & Timo Vihma

Affiliations | Contributions | Corresponding author

Nature Climate Change **6**, 992–999 (2016) | doi:10.1038/nclimate3121

Received 04 April 2016 | Accepted 03 August 2016 | Published online 26 October 2016

REFERENCES

- Barnes & Polvani 2015 http://dx.doi.org/10.1175/JCLI-D-14-00589.1
- Chen et al 2016 http://dx.doi.org/10.1175/JCLI-D-16-0167.1
- Hind et al 2016 http://dx.doi.org/10.1038/srep30469
- Kug et al 2015 http://dx.doi.org/10.1038/ngeo2517
- Osborne et al 2017 http://dx.doi.org/10.1175/JCLI-D-16-0531.1
- Overland et al 2016 http://dx.doi.org/10.1038/nclimate3121
- Screen & Francis 2016 http://dx.doi.org/10.1038/nclimate3011
- Screen 2017 http://dx.doi.org/10.1175/JCLI-D-16-0197.1
- Smith el al 2017, submitted (doug.smith@metoffice.gov.uk)
- Sun et al 2015 http://dx.doi.org/10.1175/JCLI-D-15-0169.1
- Taylor et al 2013 http://dx.doi.org/10.1175/JCLI-D-12-00696.1