Met Office

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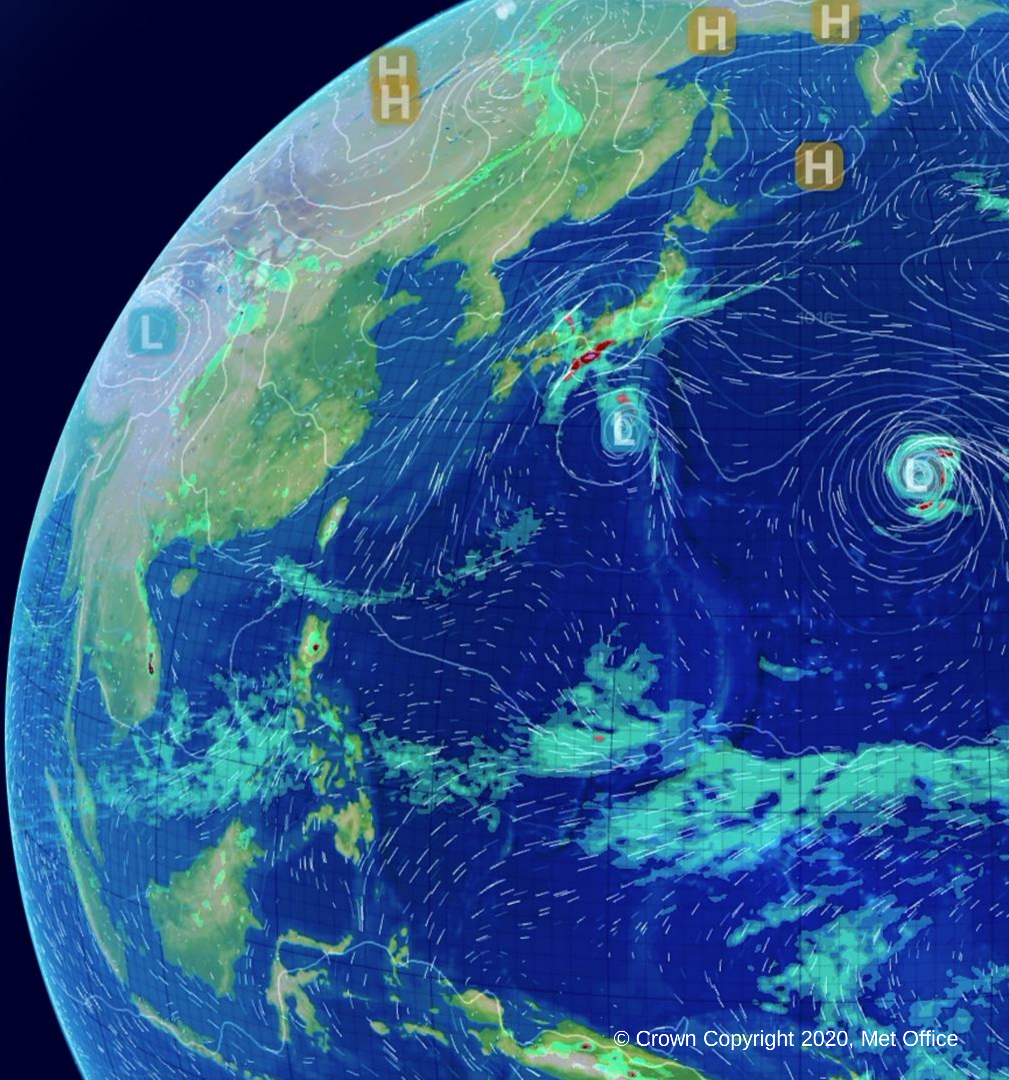
Advanced prediction in polar regions and beyond

Impacts of regional Arctic sea ice loss
and the role of QBO

Rosie Eade, Doug Smith, Leon Hermanson, Nick Dunstone, Jeff Knight, Andy Clark, Martin Andrews. Met Office, UK.

Climate Dynamics Workshop, 29.06.20



European Union Horizon 2020 research and innovation program, Grant Number 727862

Motivation

- Arctic Sea Ice Loss → easterly wind response
- Response uncertainty, Model inconsistency
- Government question (BEIS and Defra): *How might response counteract climate change?*

→ PAMIP: Polar Amplification Model Inter-comparison Project

Led by Met Office – Doug Smith.

Rosie - PhD with Exeter University on decadal variability of the NAO and potential drivers such as Arctic sea ice.

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Climate change

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Met Office: Arctic sea-ice loss linked to colder, drier UK winters

Decreasing amounts of ice in the far north is contributing to colder winters and drought, chief scientist Julia Slingo tells MPs

Adam Vaughan
@adamvaughan_uk
Wed 14 Mar 2012 16.59 GMT

Sea ice

This article is more than 7 years old

Arctic sea ice melt 'may bring harsh winter to Europe'

The unprecedented loss of polar sea ice may lead to 'wild extremes' in the UK and northern Europe, say researchers

Stephen Leahy in Uxbridge, Canada
Fri 14 Sep 2012 11.52 BST

Sea ice

This article is more than 6 years old

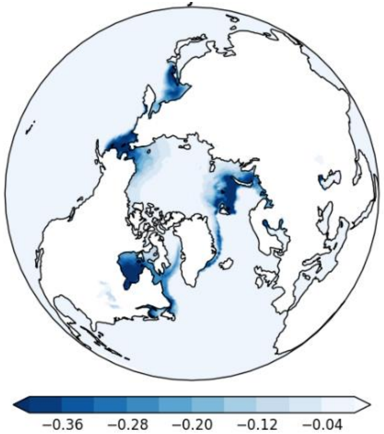
Scientists link frozen spring to dramatic Arctic sea ice loss

Melting sea ice, exposing huge parts of the ocean to the atmosphere, explains extreme weather both hot and cold

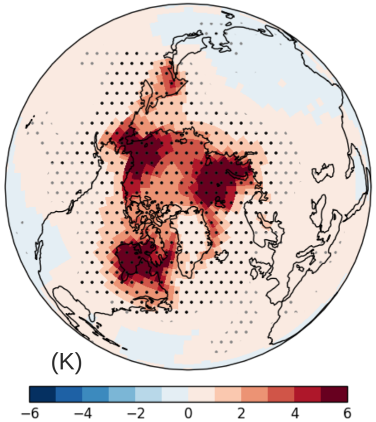
John Vidal, *environment editor*
Mon 25 Mar 2013

Response to future Arctic sea ice loss

Future Sea Ice loss



Surface temperature

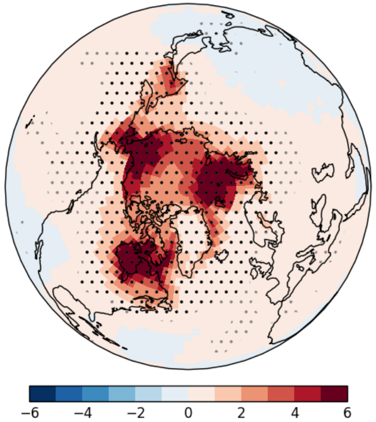


- Winter (DJF): ice loss around edges
- Warming “hotspots” over ice loss regions
- Warming spreads across Arctic and to lower latitudes
- No significant Eurasian cooling

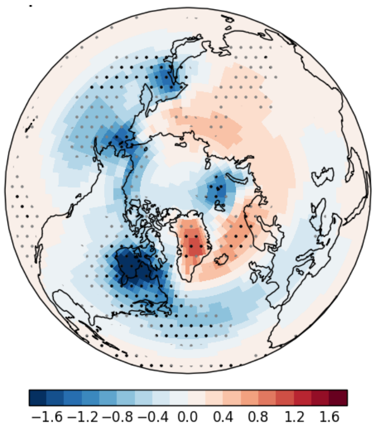
- Multi-Model International Collaboration
- Atmosphere only models
- 18 models
- 100+ ensemble members per model
- **Stippled where 90% (black) or 80% (grey) of models agree on sign of response**

Response to future Arctic sea ice loss

Surface temperature

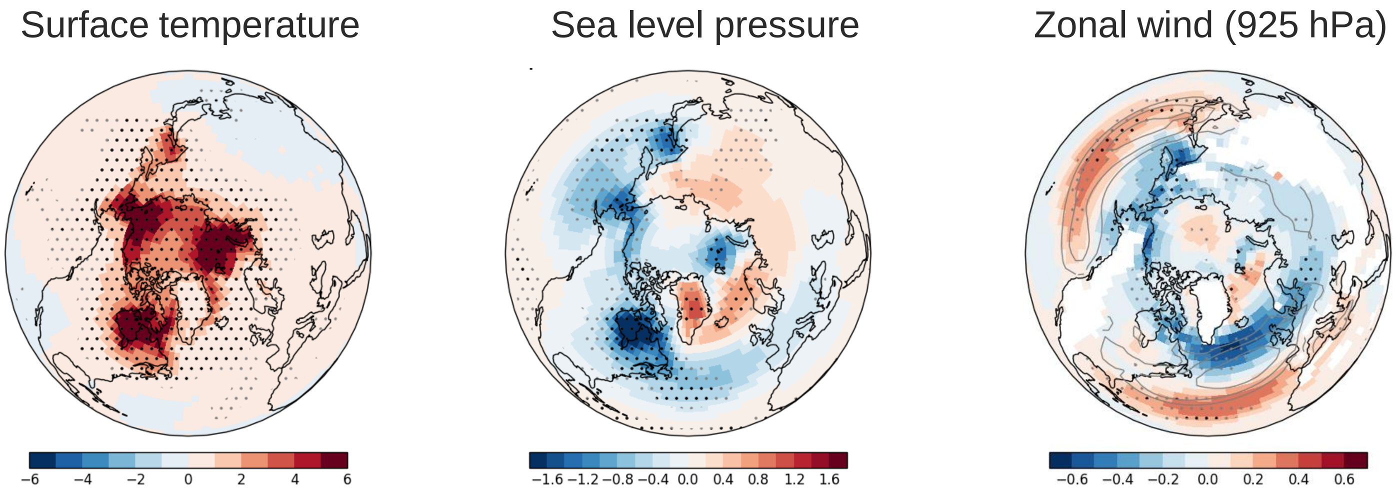


Sea level pressure



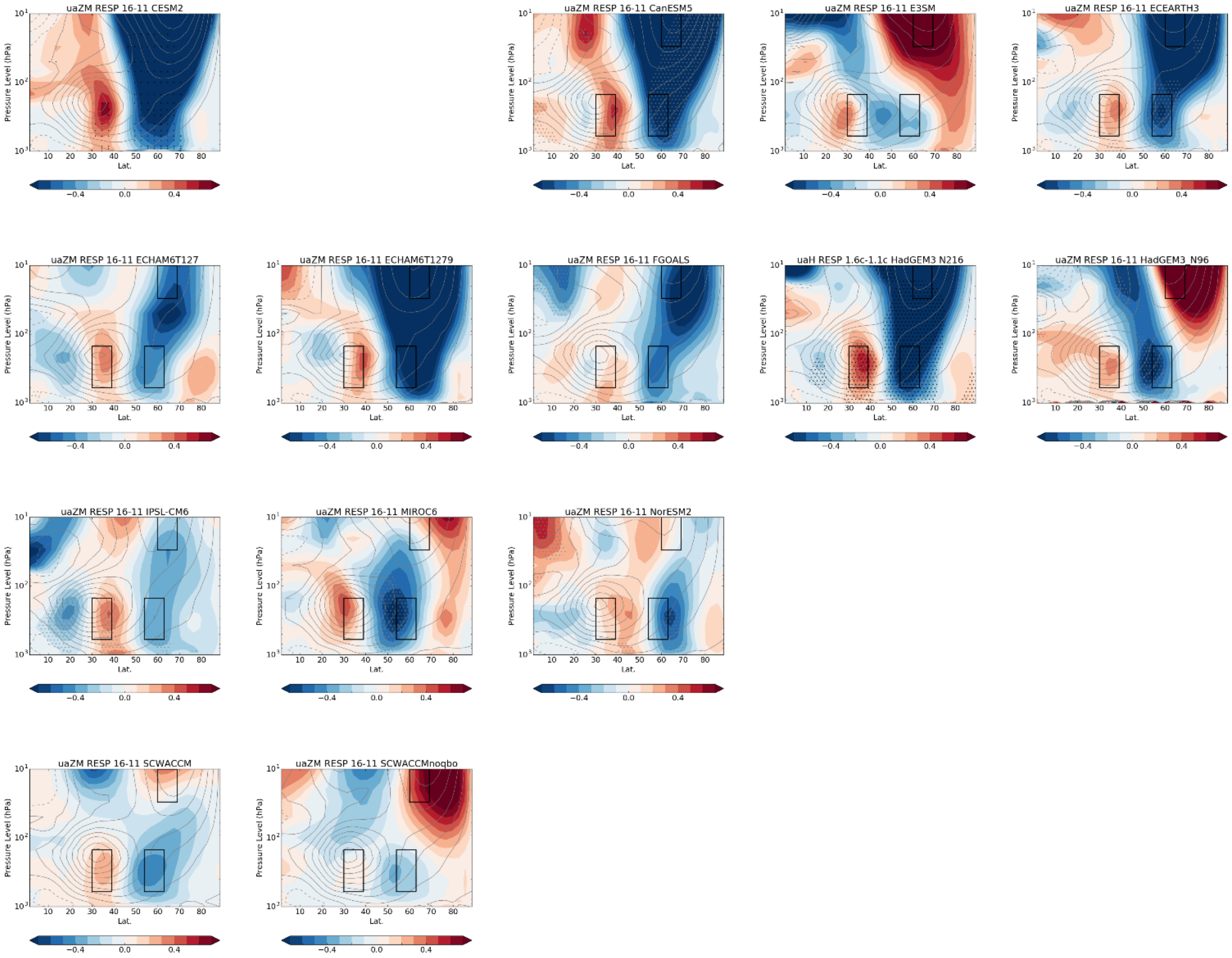
- Low pressure over warming “hotspots” → thermodynamic “heat low”
- High pressure Greenland to Siberia → dynamical response

Response to future Arctic sea ice loss



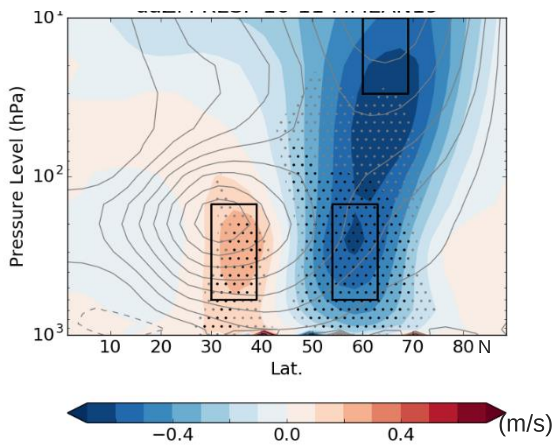
- Low pressure over warming “hotspots” → thermodynamic “heat low”
- High pressure Greenland to Siberia → dynamical response
- Equatorward shift of storm tracks (Atlantic and Pacific)

- Zonal mean winds
- Robust response in troposphere
- Not robust in stratosphere
- What is the physical mechanism?
- What causes the model spread?
- What is the real world response?

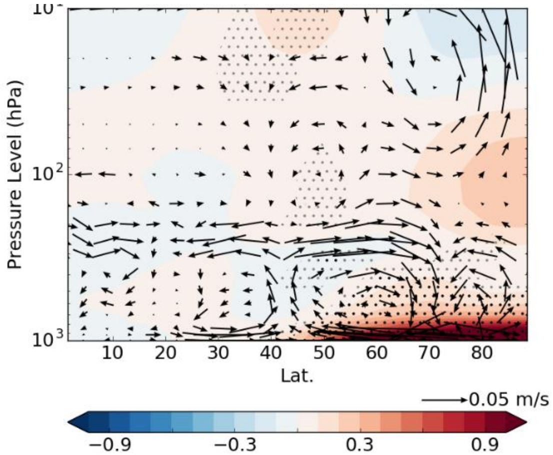


Response to future Arctic sea ice loss

Zonal wind



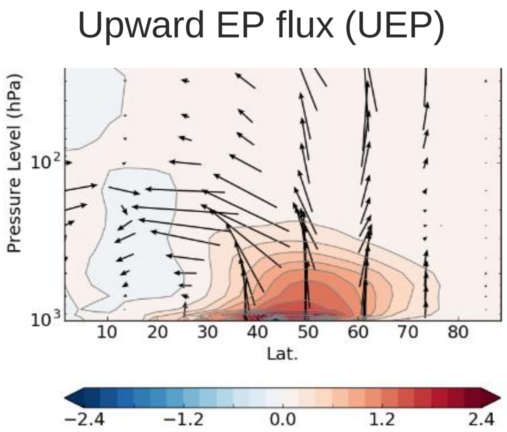
Temperature/winds

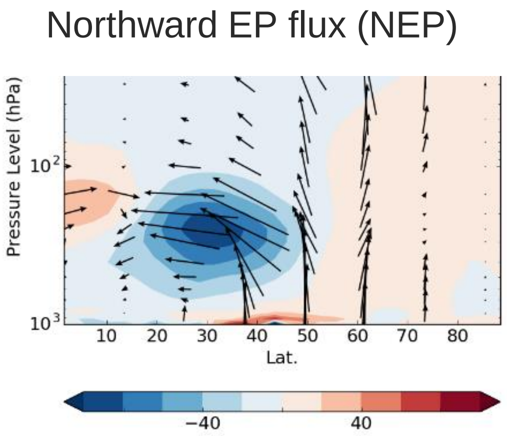


- Robust equatorward shift of tropospheric zonal winds
- Less robust in stratosphere → not crucial for the mechanism

- Arctic warming near surface
- Upper troposphere warming not robust
- Weakening of polar (thermally direct) and Ferrel (wave driven) cells

Eliassen-Palm fluxes: climatology

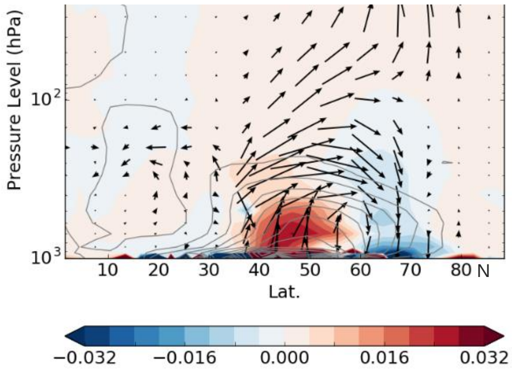




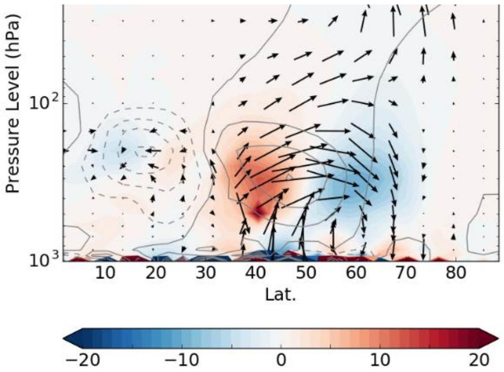
- Waves are generated at the surface by baroclinic eddies (positive upward EP flux)
- Propagate upward and refracted equatorward (negative northward EP flux)
- Flux momentum into source regions (divergence of EP flux)
- Drag the flow where they dissipate (convergence of EP flux)

Eliassen-Palm fluxes: response to sea ice loss

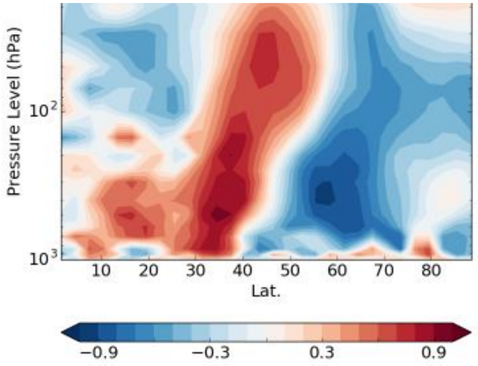
Upward EP flux



Northward EP flux divergence



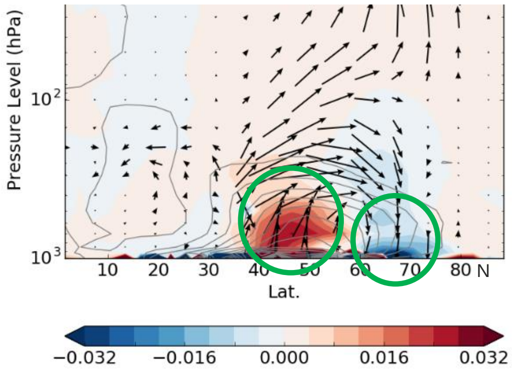
Correlation across models of zonal wind dipole response and divergence of NEP response



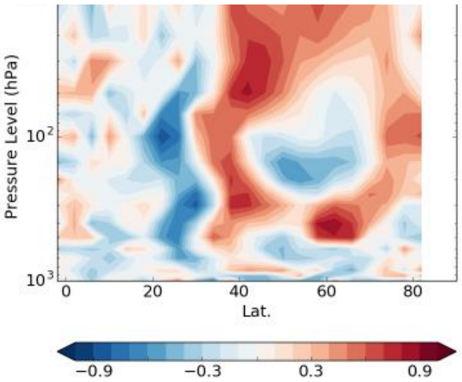
- Upward EP flux reduced at 60-70ºN, increased at 40-50ºN
- Northward EP flux increased at 40-60ºN in mid to upper troposphere
- Divergence (convergence) of northward EP flux at 30-45ºN (50-70ºN)
- Drives equatorward shift of zonal winds
- Divergence of NEP response explains model spread in zonal wind response

Eliassen-Palm fluxes: response to sea ice loss

Upward EP flux



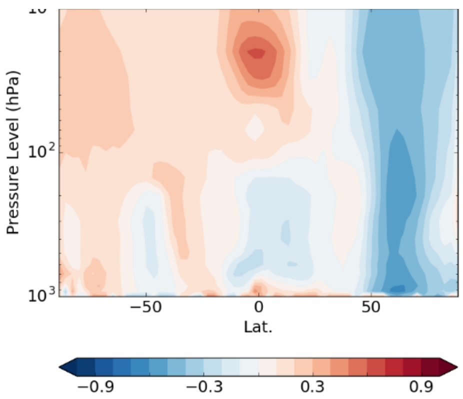
Correlation across models of zonal wind dipole response and refractive index response



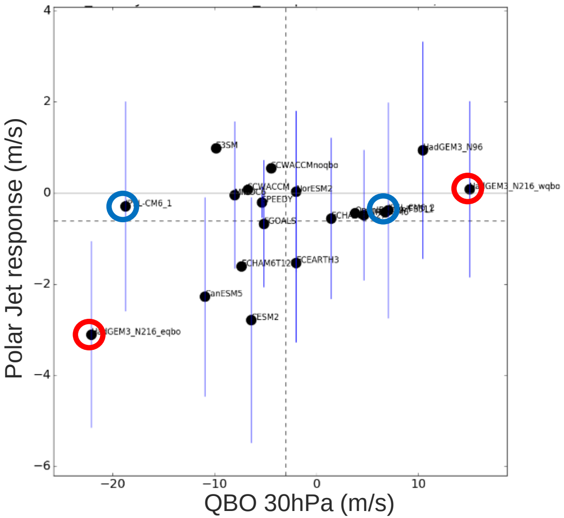
- Arctic warming → reduced equator to pole T gradient → weaker storm track → upward EP flux reduced at 60-70ºN
- Increased upward EP at 40-50ºN is a feedback:
  - Storm track (wave source) shifts equatorward
  - Reinforced by refractive index response at ~40ºN

Stratosphere response to sea ice loss

Correlation across models of stratospheric jet response and background zonal wind

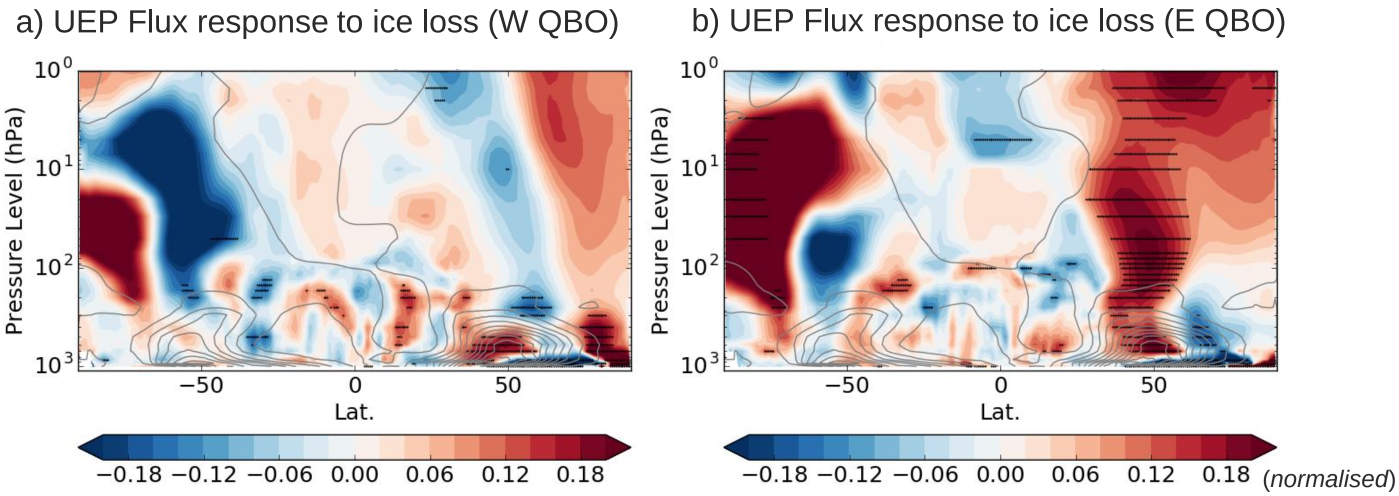


Polar jet response vs QBO (r=0.45)



- Stratospheric jet response appears to depend on background QBO
- Clear in HadGEM3 but not in IPSL

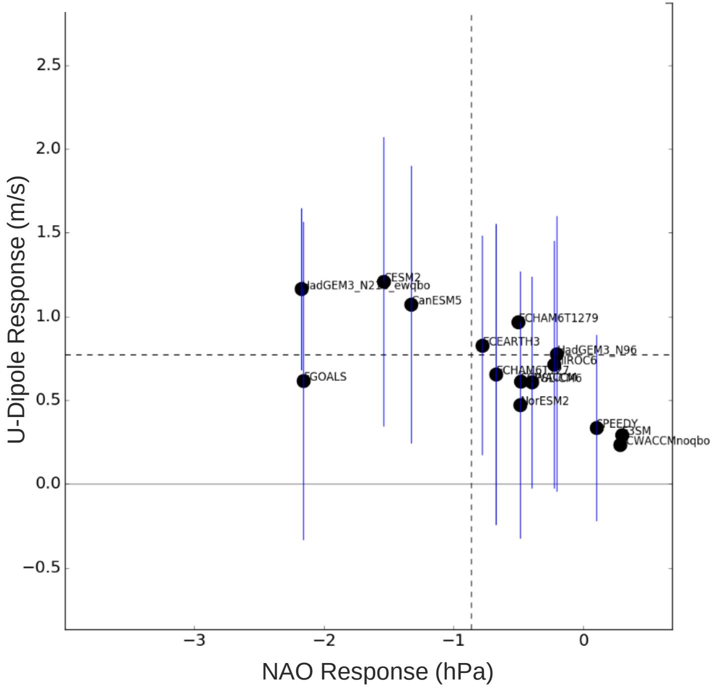
Stratosphere response to sea ice loss



- Increased upward EP flux when QBO easterly
- Consistent with Labe et al 2019
- Mechanism to be explored…

Real world response to sea ice loss?

Zonal wind and NAO responses



- Model response is weak relative to interannual variability
- Mean NAO response ~0.1 σ
- Max NAO response ~ 0.5 σ
- But models may underestimate true response (signal-to-noise paradox)
- Need an "emergent constraint"
- Difficult due to large uncertainties

Conclusions

- **Robust tropospheric response to future Arctic sea ice loss**
    - Equatorward shift of jet, negative NAO
- Weakening of polar (thermally direct) and Ferrel (wave driven) cells
- Stratospheric response appears to depend on QBO
- Weak signal relative to internal variability
- Large model spread (0.1 to 0.5 σ)
- Large uncertainties → diagnosing real world response is challenging