Atmospheric response to Arctic sea ice: the importance of the background state

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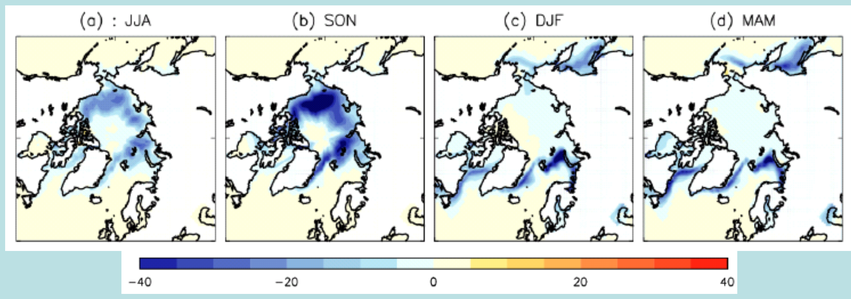
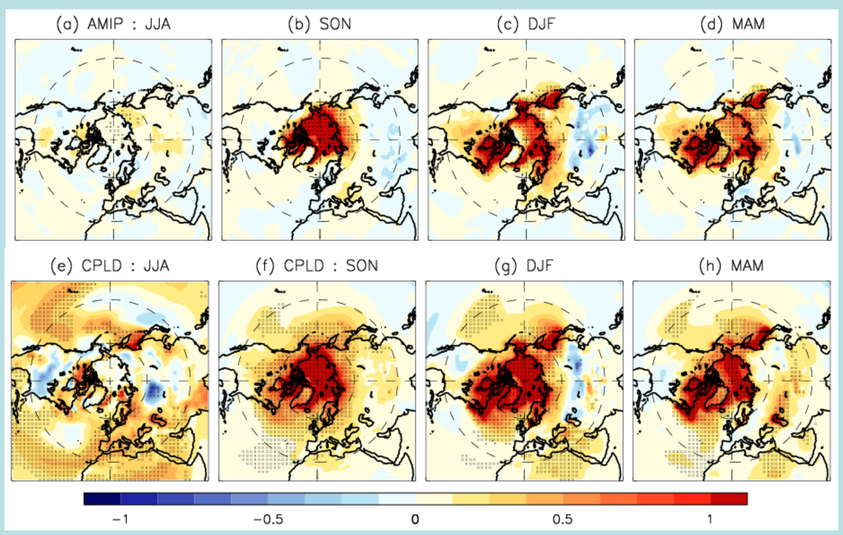
1. Experiments:
- 1979 to 2009 (30 years)
- Control: observed sea ice concentration
- Perturbed: reduced Arctic sea ice
- 10 ensemble members
- AMIP – observed SSTs
- CPLD – upper 200m of ocean free
- AMIP_CPLD – repeat AMIP but with CPLD SST bias

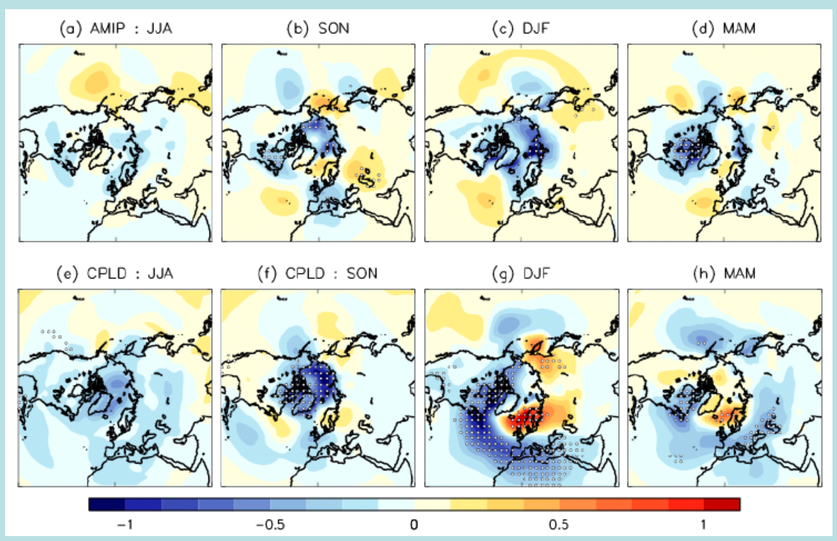


Imposed seasonal mean sea ice concentration difference (%)

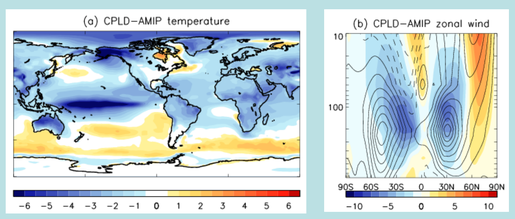
2. Temperature response:
- Larger response in CPLD
- Surrounding ocean warms
- Can reach the tropics



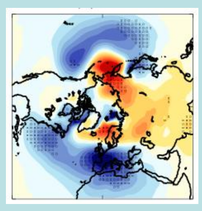
3. Mean sea level pressure response:
- AMIP: "heat low" in all seasons
- Positive NAO in DJF
- CPLD: negative NAO in DJF



4. AMIP_CPLD response:
- Add CPLD SST bias to AMIP
- Reproduces negative NAO
- Background state is key

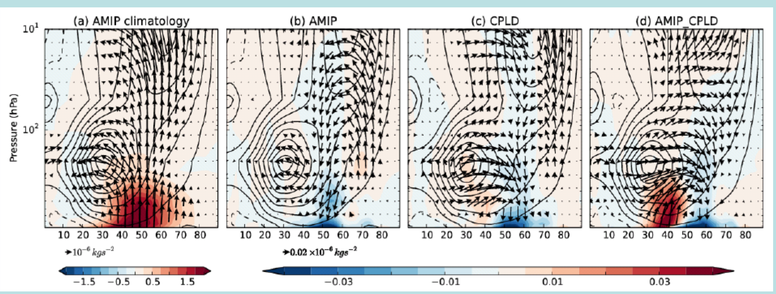


CPLD temperature and zonal wind biases

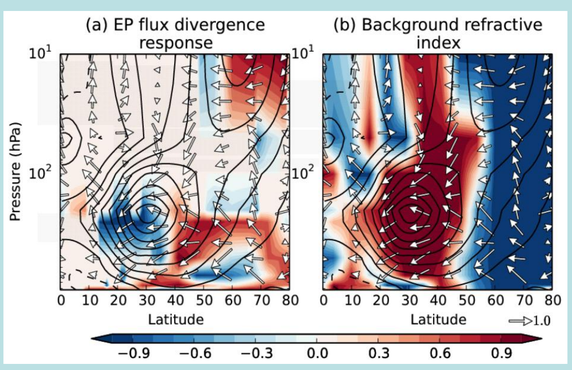


AMIP_CPLD DJF mslp response

5. Planetary waves:
- Decrease in upward EP flux at surface 50-60ºN in all experiments
- Consistent with reduced baroclinicity (weaker Equator to pole temperature gradient)



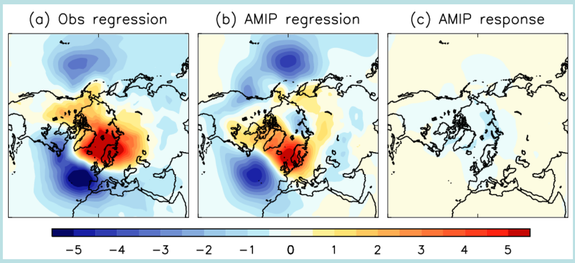
Shading: upward EP flux
Arrows: EP flux vectors



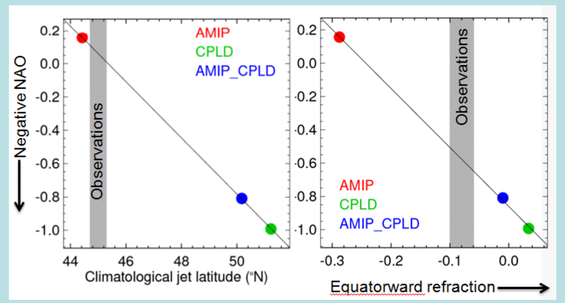
Correlation across AMIP, CPLD and AMIP_CPLD of response in Atlantic jet and
(a) EP flux divergence response
(b) Background refractive index
Arrows: correlation with EP flux vectors
NB: Sign reversed to represent increased Arctic sea ice (with increased upward EP flux)

6. Explanation:
- Easier to consider increased Arctic sea ice (increased upward EP flux)
- Response of Atlantic jet depends on propagation of EP fluxes
- More equatorward propagation leads to interaction with jet
- EP flux divergence/convergence on poleward/equatorward side of jet
- Jet shifts polewards (i.e. positive NAO for increased Arctic ice)
- Response depends on background refractive index

7. Real world response:
- Cannot be diagnosed from regression



- Possibility of "emergent constraint" but must be based on the underlying physical cause of model spread (i.e. the refractive index)



8. Summary:
- Sign of NAO response to Arctic sea ice depends on the background state
- Upward planetary waves from the surface are reduced when Arctic sea ice is reduced, consistent with reduced equator to pole temperature gradient and reduced baroclinicity
- NAO response depends on propagation of planetary waves, which is controlled by the refractive index of the background flow
- Real world response cannot be diagnosed from regression
- "Emergent constraint" might be possible
- Need coordinated multi-model experiments → please contact Doug Smith (doug.smith@metoffice.gov.uk) if you are interested in participating

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