Model and state dependence of the atmospheric response to Arctic sea-ice loss

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PAMIP zonal mean zonal wind multi-model mean

Results from the currently available Polar Amplification Model Intercomparison Project (PAMIP) models illustrate a clear **weakening of the northern hemisphere mid-latitude jet** in response to Arctic sea ice loss. This is evident in the DJF zonal mean zonal wind anomaly between a future sea-ice loss case and a present day case (Fig. 1). Most models also show an **equatorward shift of the jet**.

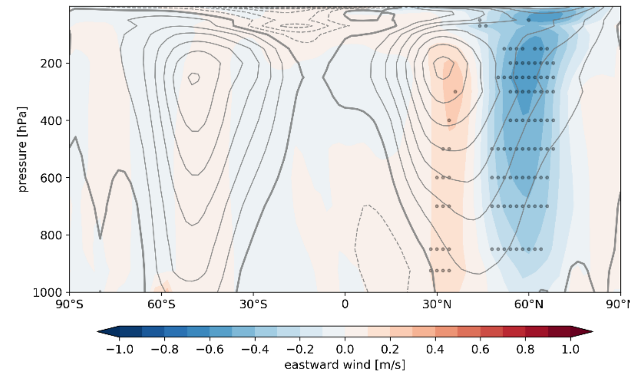

Fig. 1: **Zonal wind response to Arctic sea-ice loss.** DJF zonal mean zonal wind anomaly, pdSST-futArcSIC − pdSST-pdSIC (**16 model MMM**). Stippling marks regions where at least 14 models (87%) agree on sign of the anomaly.

Influence of model resolution on the response

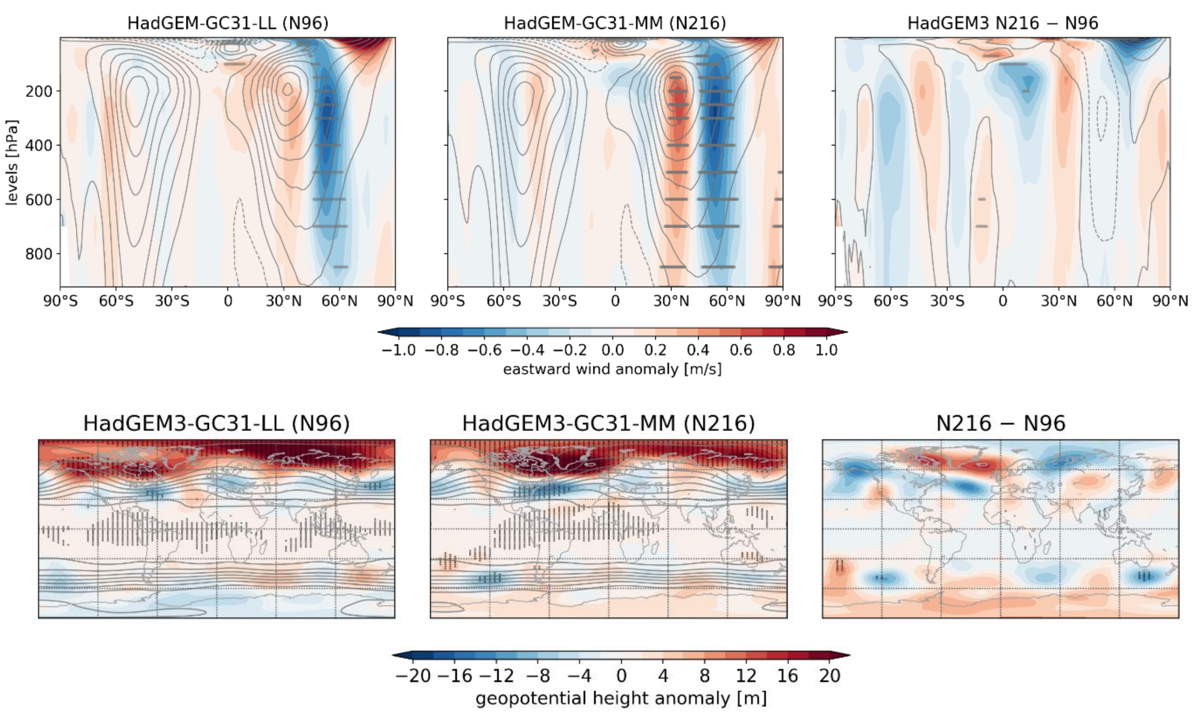

Fig. 2: **Zonal wind and geopotential height response at different resolutions**. DJF zonal mean zonal wind anomalies for HadGEM3 N96 and N216 (upper plots), and their difference, and DJF geopotential height anomalies for both resolutions and their difference (lower plots). The anomalies are calculated from the future Arctic sea-ice loss experiment minus present day experiment. Stippling marks regions which are significant at the 95% level.

Two model resolutions of HadGEM3 are compared (**N96** and **N216**). The **higher resolution** model shows evidence of a **more pronounced equatorward shift** of the mid-latitude jet, but this difference is not statistically significant (Fig. 2, upper panels). The magnitude of the jet weakening is similar for both resolutions. Differences in the geopotential height anomalies (Fig. 2, lower panels) show no statistical significance.

For the whole PAMIP ensemble, there is evidence that **model resolution contributes to a larger jet shift** (Fig. 3), although the p-value of the trend is moderately high (0.124).

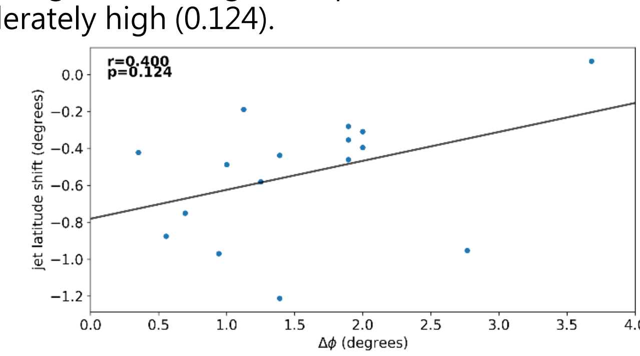

Fig. 3: Jet latitude shift with resolution. Comparison of DJF jet latitude shift against model horizontal resolution. Correlation coefficient = 0.4 and p value = 0.124.

Arctic sea-ice loss response dependence on QBO phase

The Arctic sea-ice response is modulated by the quasi-biennial oscillation (QBO) phase:

- QBO phase influences the zonal wind response, particularly in the stratosphere (Fig. 4), although the stratosphere difference is not statistically significant.
- For HadGEM3 N96, **QBO-E shows a stronger jet weakening** compared to QBO-W.

Polar cap height response to sea-ice loss is QBO phase dependent:

- Geopotential height anomalies for 60-90N (polar cap height) indicate that QBO-E results in a weakening of the polar vortex in November, which descends to the surface by January (Fig. 5).
- QBO-W polar cap height shows no indication of this weakening.
- This is evidence that the **QBO phase modulates the ice-loss response**, or that the QBO is itself modulated by the sea-ice decline.

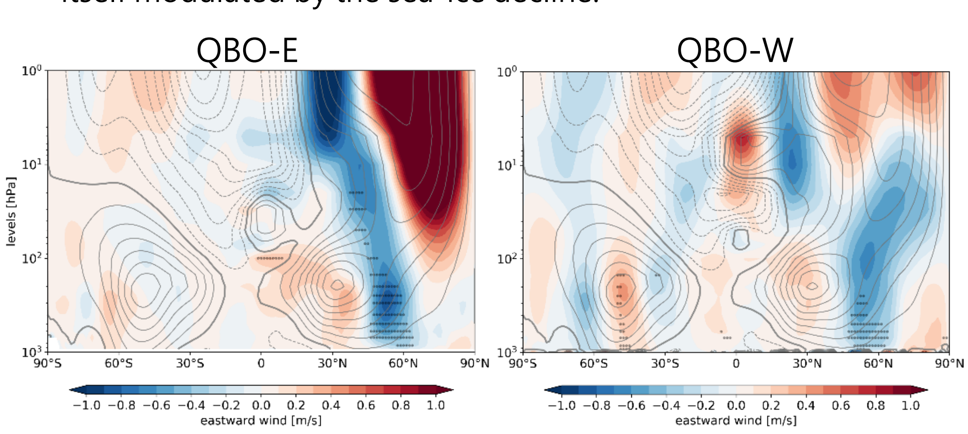

Fig 4: **QBO phase zonal wind response.** QBO DJF zonal mean zonal wind response to future Arctic sea-ice loss compared to present day for QBO-E and QBO-W separately. Stippling indicates significance at the 95% level.

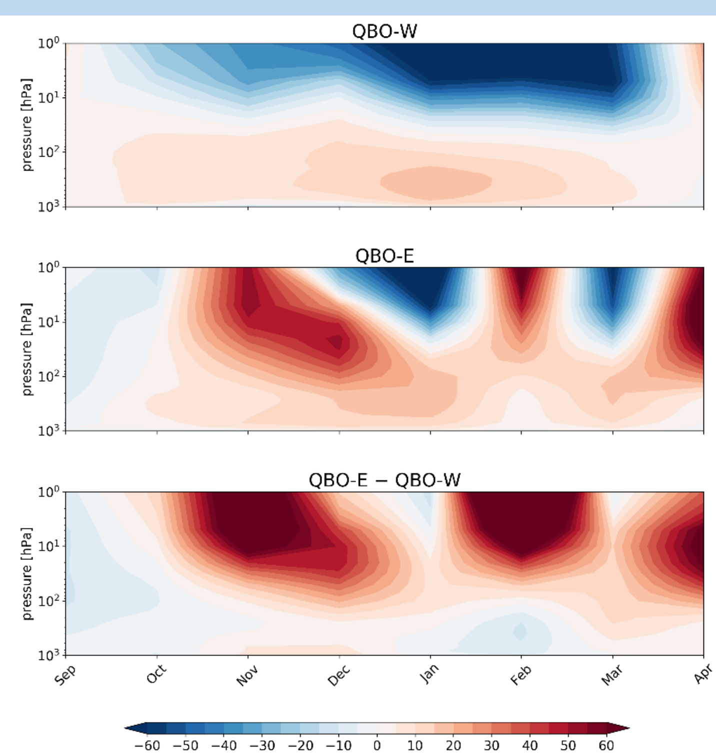

Fig. 5: Polar cap height response to sea-ice loss and QBO phase. Time evolution of the polar geopotential height anomaly (polar cap height). This is shown for QBO-W (top), QBO-E (middle), and their difference (bottom).