Met Office Hadley Centre

Drivers of Arctic sea ice decline in the HadGEM1 model

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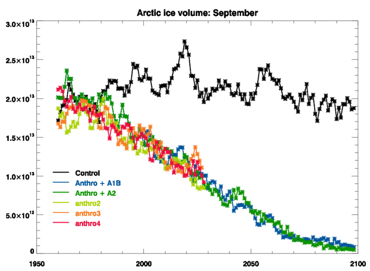
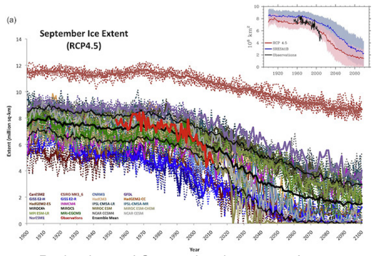
1) Introduction and motivation

- The Arctic sea ice extent and volume have been declining for a number of years.
- Models submitted to the CMIP3 and CMIP5 intercomparisons show a wide range of rates of decline, with a number projecting a slower decline than observed
- There is a large spread of estimates of the date at which the Arctic will first become seasonally ice-free



HadGEM1 – projections of ice volume



Projections of September ice extent from AR5 models (Streove et al, 2012)

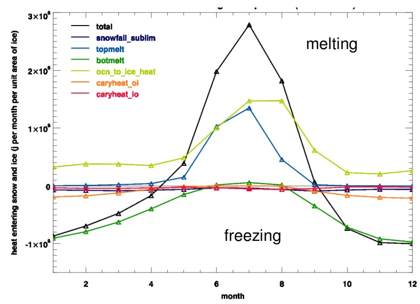
- Global coupled models remain our best tool for predicting future climate change, hence it is important to understand WHY model projections differ
- Here we use the heat budget of the sea ice as a tool to understand the factors driving the decline in one (CMIP3) model: HadGEM1
- We use an ensemble of projections, forced with observed time varying anthropogenic forcing to 2000, and the A1B or A2 scenario thereafter

2) Heat budget: mean seasonal cycle

Dominant components:

Summer melting:
- Melting at the top surface of the ice during June and July
- Basal melting due to ocean to ice heat flux, extending into Autumn

Winter freezing
- Diffusive heat flux through ice to the atmosphere
- Frazil ice formation
- Offset by some basal melting



Components of the heat budget of the sea ice and overlying snow, for the HadGEM1 control integration, expressed in terms of an equivalent amount of heat entering or leaving the ice (per unit area of ice)

3) Changes in components of the heat budget

The decline in ice volume is due to extra melting during the summer, rather than reduced freezing during the winter:

More surface melting during June and (initially) July

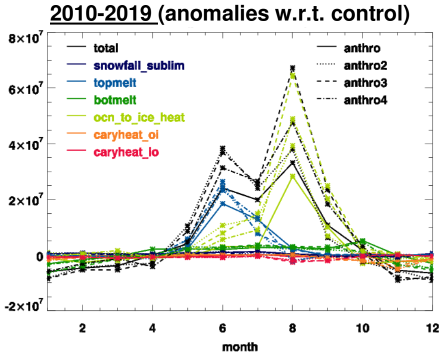
In HadGEM1 the ice albedo is a function of surface temperature.

Warmer surface temperatures in June lead to reduced albedo and extra melting

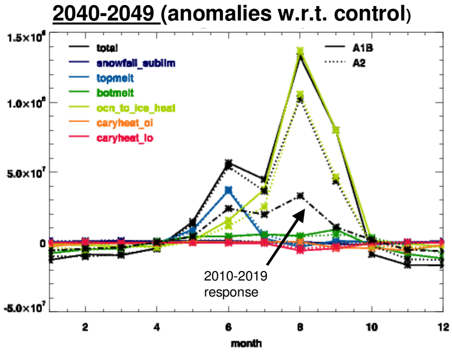
This effect is less evident in July, as in the control integration the surface temperature is already close to the melting temperature

Other changes (eg cloud) under investigation

2010-2019 (anomalies w.r.t. control)



2040-2049 (anomalies w.r.t. control)



Changes in components of the heat budget of the sea ice and overlying snow, for the HadGEM1, expressed in terms of an equivalent amount of heat entering or leaving the ice (per unit area of ice)

More melting at the sides and base of the ice during August and (later) September

It is likely that the extra heating is due to in-situ warming of the ocean surface as the ice cover retreats:
- the extra melting is confined to the summer months
- spatially the increases in o2i heat flux are correlated with decreases in ice concentration

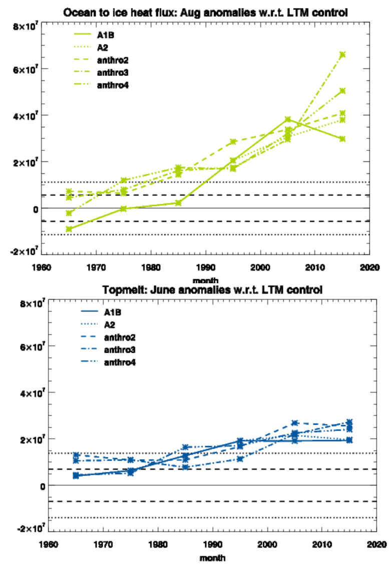
Analysis of the heat budget of the upper ocean is required to confirm this.

In both cases, the ice albedo feedback is important in determining which months have extra melting – highlighting the importance of a physically realistic representation of albedo in models used to make projections of future climate change.

4) A robust signal?

Ocean to ice heat flux anomalies (August)

Surface melting anomalies (June)



Evolution of anomalies, compared with control variability (+/- 1 and 2 standard deviations)

5) Summary and future work

- Initial analysis of changes in the components of the sea ice heat budget shows the main drivers of ice decline in the HadGEM1 model
- Analysis will continue to confirm conclusions and link the flux changes to wider model processes
- Should be a useful approach for inter-comparing the factors driving the decline in sea ice in a range of models.
- Combined with other work to compare model budgets with observations (West et al, in preparation), can aid the assessment of model strengths and weaknesses.

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