Towards untangling uncertainties in future sea iceatmosphere interactions

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2011 Arctic sea ice minimum, Scientific Visualization Studio, NASA Goddard

some compelling correlations between observed ice loss and atmospheric changes





models suggest most robust signals are in the maritime Arctic and lower troposphere Sept-Dec; ocean-to-atmosphere heat loss, low level warming/moistening, increased lower tropospheric thickness (e.g., Screen et al. 2013)

lessons/warnings from modelling experiments

- natural variability matters for the atmospheric circulation response to ice loss (e.g., Screen et al. 2013)
- response is sensitive to model state and may exhibit non-linear behaviour (e.g., Petouhkov & Semenov 2010, Bader et al. 2011)
- uncoupled answer (response) is not necessarily the same as the coupled answer (two-way interaction)



uncoupled (response), coupled (interaction) c

surface heat flux variability: pattern, sign, relationship to ice and temperature





surface heat flux variability: pattern, sign, relationship to ice and temperature



future: adding uncertainties to coupled ice-atmosphere-ocean interactions

There are **3** categorical sources of uncertainty regarding the future evolution of climate:

- a) Amount of external (greenhouse gas) forcing applied
- b) Model-to-model (physical parameterization) uncertainty
- c) Coupled internal variability

(Tebaldi & Knutti, 2007; Hawkins & Sutton, 2009; Deser et al., 2012)

future: adding uncertainties

3 categorical sources of uncertainty in the future evolution of Arctic sea ice:

- a) Amount of external (greenhouse gas) forcing applied
- b) Model-to-model (physical parameterization) uncertainty
- c) Coupled internal variability



Different external forcing —> different Arctic sea ice (a)

- Substantial model-to-model uncertainty (b)
 compare across RCP8.5 & RCP2.6, "chosen" (3/5) vs. ensemble (29/37)
- Is internal variability (c) important?

future: adding uncertainties

3 categorical sources of uncertainty in the future evolution of Arctic sea ice:

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- Identical external forcing (BC's identical)
- 39 realizations from one (dated) fully-coupled model: CCSM3 at T42 resolution
- Only difference: initial condition in the atmosphere
 —> internal variability is important

future: adding uncertainties to complex atmosphere-ice interactions



future: adding uncertainties to complex atmosphere-ice interactions



even if we have a perfect model with perfect ice forcing, we would also need to consider:

- two-way interaction (O/I \rightarrow A & A \rightarrow O/I)
- natural variability in both sea ice and atmosphere
- uncertainty in external forcing