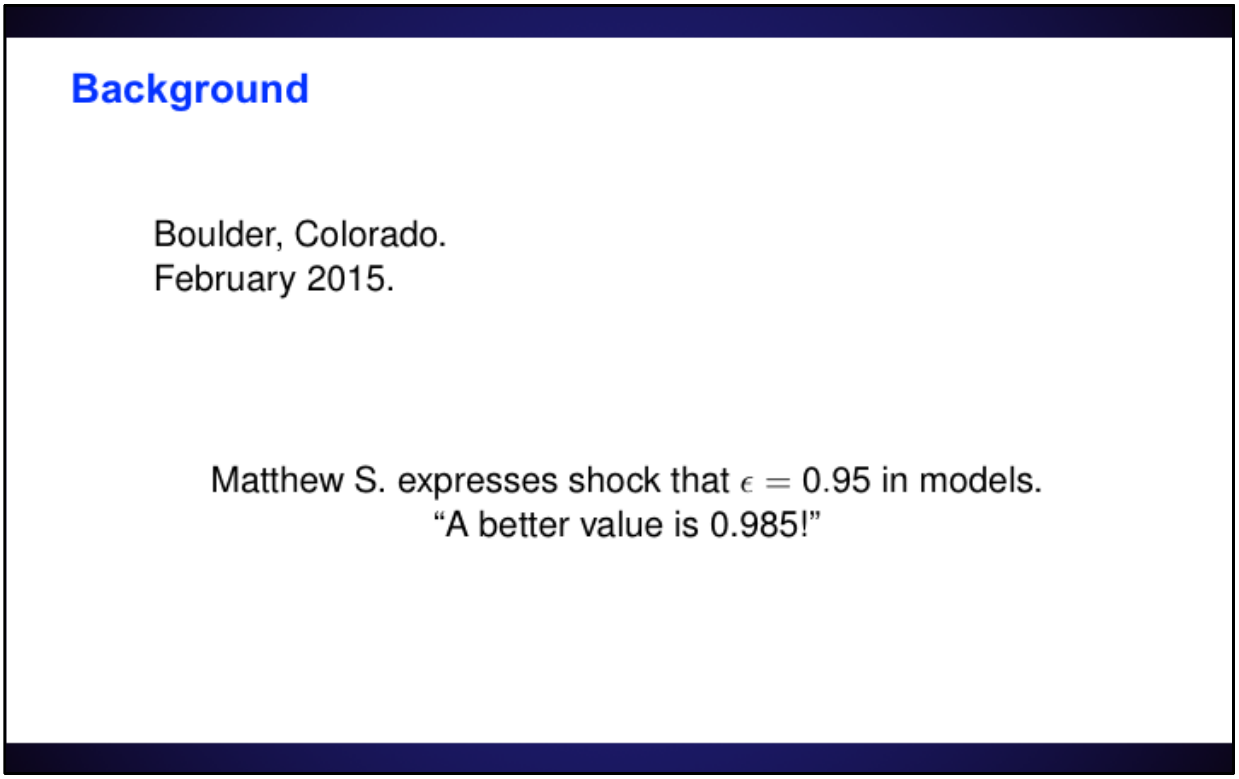
Model Sensitivity to
Emissivity

A Cautionary Tale

Emissivity reduces outgoing longwave radiation:

$$
\begin{aligned}
F_{LWUP} &= -\epsilon\sigma T_s^4 \\
0 \leq &\ \epsilon \leq 1
\end{aligned}
$$

This is an example in which added complexity can lead you astray. The emissivity is a model parameter that scales the amount of outgoing longwave radiation from the surface.



At a snow workshop in Boulder a couple of years ago, Matthew Sturm was shocked at the value that we use in the model, which has been 0.95 for many years. He said it should be 0.985.

Quiz

If ϵ is changed from 0.95 to 0.985 in a climate model, does the sea ice get thinner or thicker?

Why?

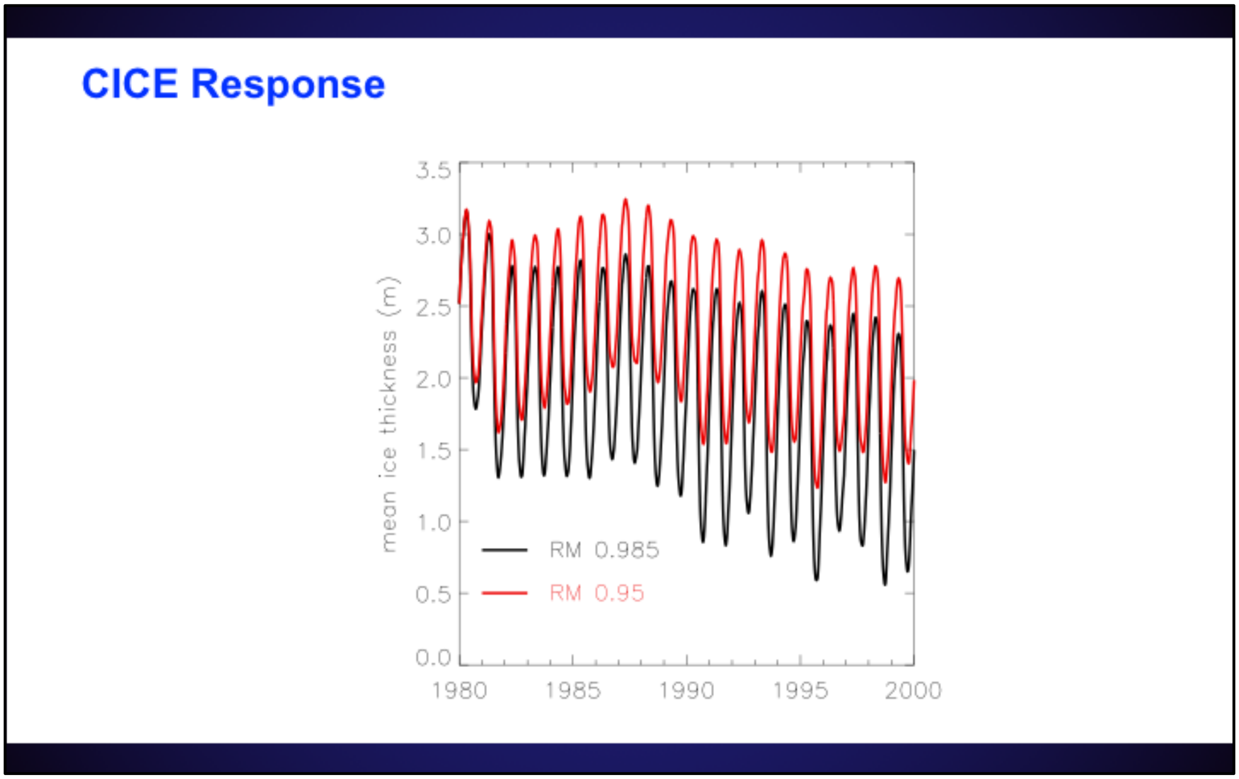
Tell me what you think will happen if we change this parameter value.

Sea Ice Model Sensitivity

Jorge Urrego-Blanco tests ϵ in CICE sensitivity studies.

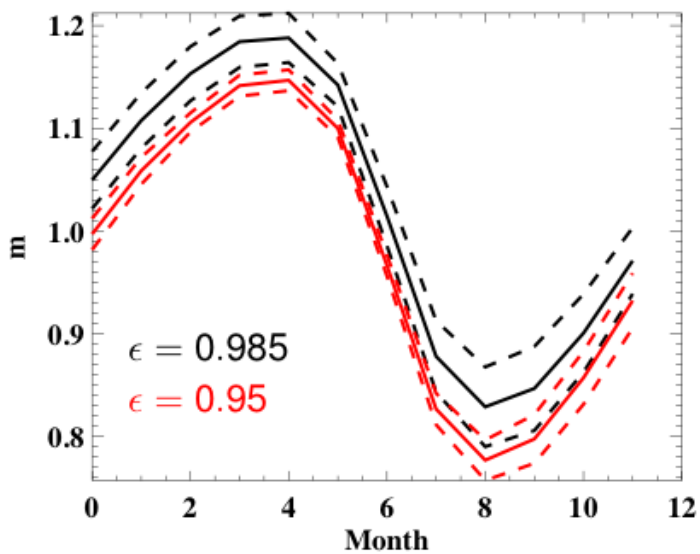
ϵ almost (but not quite) tops the list of parameters to which sea ice area and volume are sensitive, in both hemispheres, year-round, in CICE.

My postdoc Jorge did an extensive sensitivity test of CICE parameters, testing 40 of them in a stand-alone sea ice model configuration. The model is quite sensitive to the emissivity.

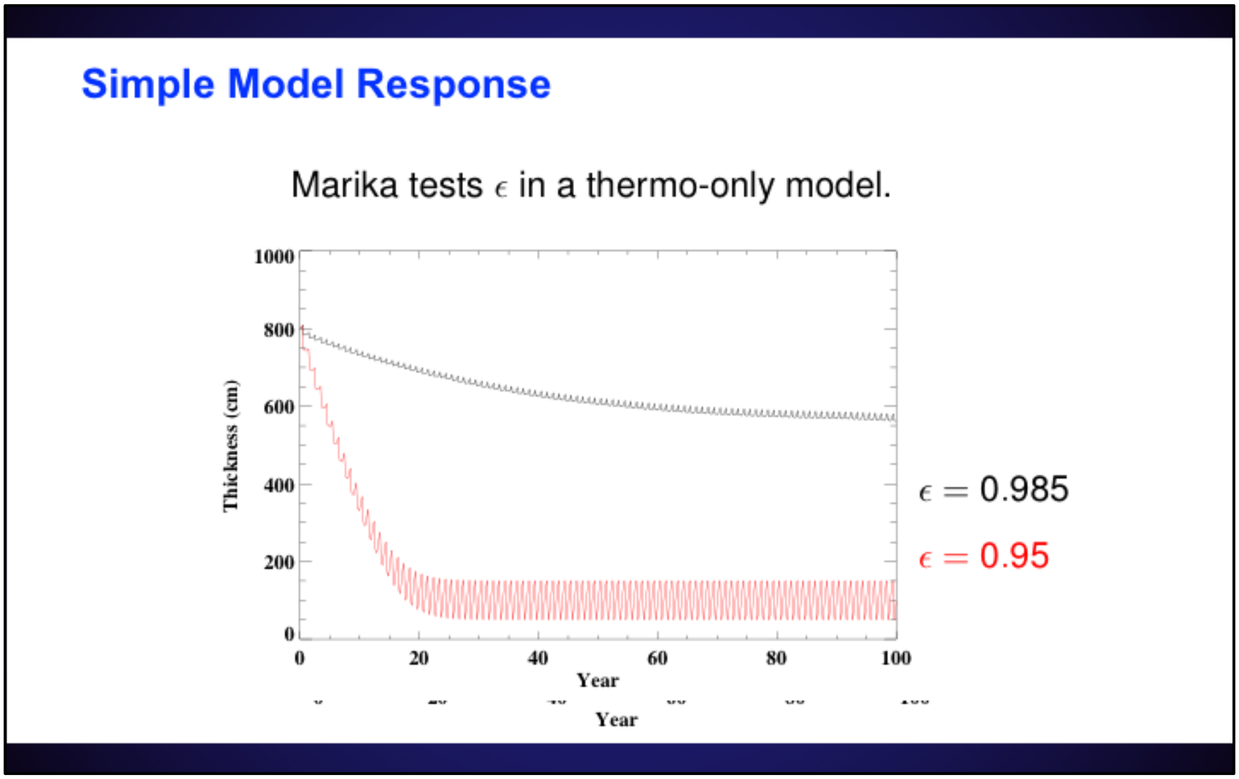


In his tests, increasing the emissivity decreases the ice volume and thickness in the Arctic.

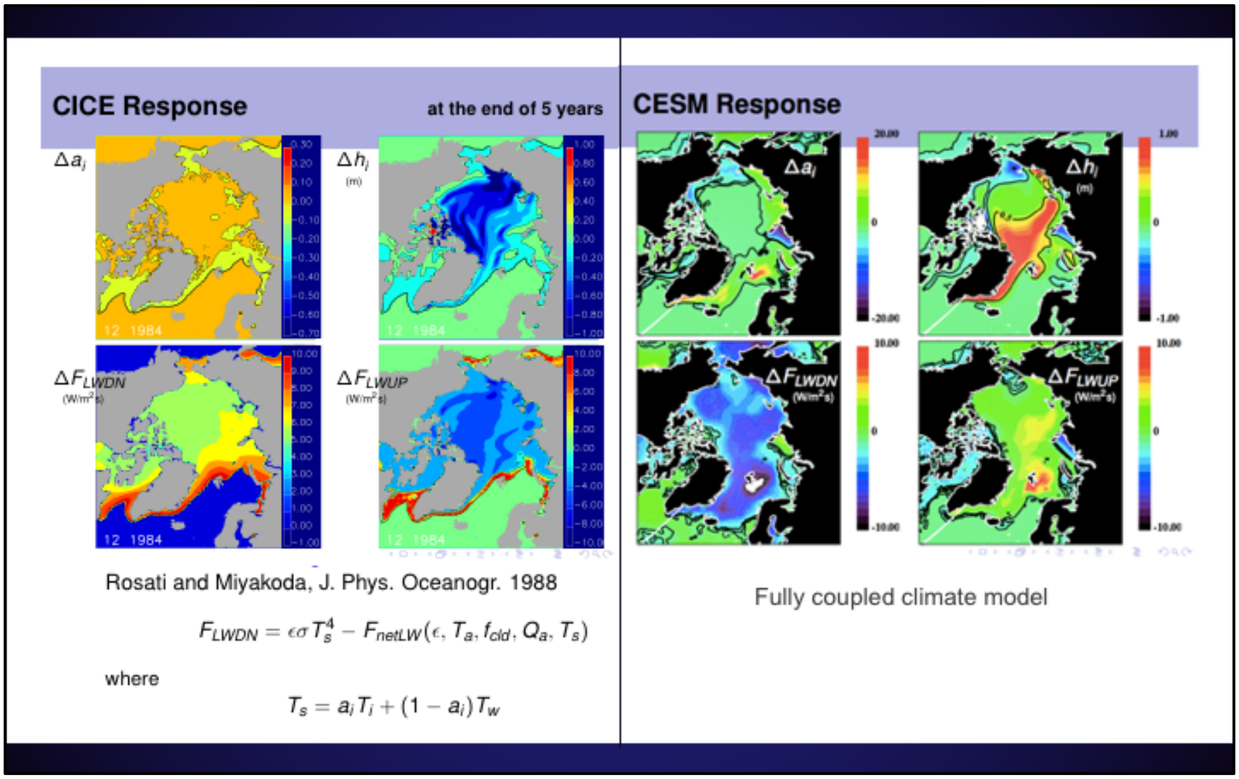
CESM Response



However, Marika Holland also tested this in the fully coupled CESM model, and it increased ice thickness.



That was curious, so she got out a simple, 1D thermodynamic model from years ago, and it also indicated that the ice thickness would increase. So what's wrong with the CICE model?



We traced it back to the form of the longwave forcing. Using the standard formula, the change in lwdn is positive and the thickness change is negative. In CESM, the change in lwdn is negative.

CICE Downward Longwave Forcing

Standard CICE forcing:
Rosati and Miyakoda, J. Phys. Oceanogr. 1988

$$F_{LWDN} = \epsilon \sigma T_s^4 - F_{netLW}(\epsilon, T_a, f_{cld}, Q_a, T_s)$$

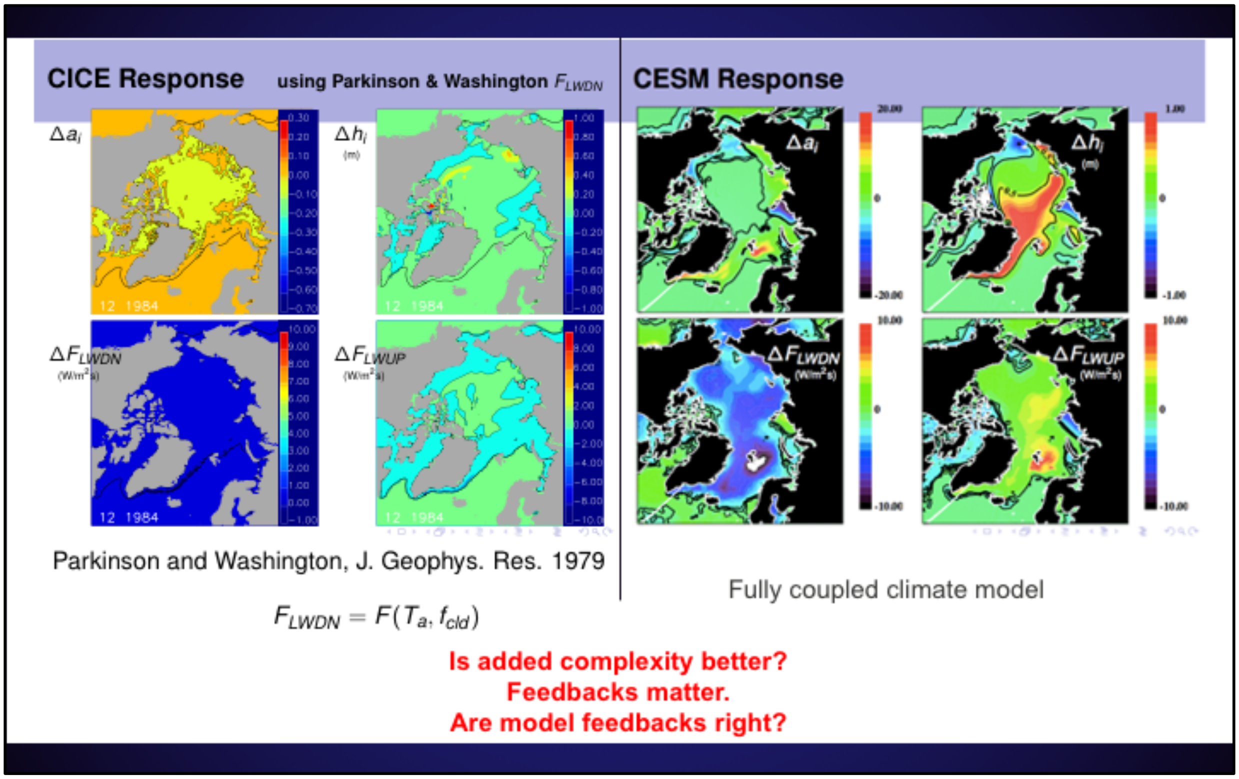
where

$$T_s = a_i T_i + (1 - a_i) T_w$$

Alternative CICE forcing:
Parkinson and Washington, J. Geophys. Res. 1979

$$F_{LWDN} = F(T_a, f_{cld})$$

In CICE, we use a longwave formula that depends on the emissivity, air temperature, cloud fraction, specific humidity and the surface temperature, which is an area-weighted average of ice temperature and SST. Since the ice model calculates the surface temperature, this includes a feedback between longwave and Ts. There is another option for calculating the longwave, using an older formula that only depends on air temperature and cloud fraction.



With that formula, the changes aren't spatially that similar to CESM, but at least they are of the same sign. Rosati and Miyakoda longwave formula is more complex but makes the simulation worse. Adding that feedback in the longwave is questionable. We aren't sure that the CESM is right, either, but I'm inclined to think it is.