Sources of CAM3 Arctic Surface Bias from Parsing the Temperature Equation

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1. Background Information
Recent versions of NCAR climate models have consistent simulation errors in Arctic surface climate (e.g. sea level pressure and low-level wind). These errors have important consequences, such as unrealistic spatial distribution and thickness of Arctic sea ice. We have been studying the simulation errors by examining the remote mechanisms that affect the Arctic sea level pressure (SLP) in both observation and model output. We use uncoupled (CAM 3.0) model output, since the coupled runs introduce additional error brought by ocean model climate drift. Our primary focus is on the SLP bias, and that bias is similar in both CCSM and CAM3.0.

2. Data Used
Linear Stationary Wave (LSW) Model
The instantaneous temperature equation (P coord.):
\[ \frac{\partial}{\partial T} TTV + \nabla \cdot + \frac{\partial}{\partial t} = \frac{\nabla}{\partial T} \cdot \tau + \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta = \frac{\nabla}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta = \frac{\nabla}{\partial T} \cdot \kappa \]

The diabatic heating is a residual from this equation:
\[ \frac{\partial}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta \]

Define time average with overbar and use a prime for the deviation 'sigma' levels.

On the UCD cluster we ran a 20 year AMIP T42, 23 level, simulation of the CAM3 model bias in the Arctic and surrounding region.

A model of the linearized CAM3 dynamics (Branstator, 1990) with friction and heating to control nonlinear instability is used to deduce the forcing that creates the model bias as a stationary solution. The forcing needed to produce the structures and nearly all the amplitude of the Arctic region bias are either localized to the Arctic region or in the midlatitude storm tracks.

Previously we showed 3-D structure of the CAM3 model bias in the Arctic and surrounding region.

3. Parsing the Temperature Equation
The instantaneous temperature equation (P coord.):
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The diabatic heating is a residual from this equation:
\[ \frac{\partial}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta \]

For the time mean of the ERA-40 observational data we have:
\[ \frac{\partial}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta \]

Define a notation for the bias, for example:
\[ \frac{\partial}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta \]

The first 2 terms on the RHS are nonlinear terms in the bias. The group labeled THF are transient heat advection bias. Q^2 is the bias in diabatic heating.

The time mean temperature equation in the reverse configuration of the Branstator LSW looks like:
\[ \frac{\partial}{\partial T} = \frac{\nabla}{\partial T} \cdot \kappa + \Delta \Delta \]

7. Ongoing and Future work
• Fix F magnitude. Find & remove large eigenvalue modes from bias?
• Further parse the forcing by region, frequency range, and level
• Examine vorticity and q forcing from their respective equations

6. Discussion & Conclusions
A LSW model thermal bias forcing, F, eqn (4)

B. Forcing from model output and observations, eqn (3)

C. Forcing from model output and observations, eqn (3)

D. Forcing from model output and observations, eqn (3)

E. Forcing from model output and observations, eqn (3)

F. Forcing from model output and observations, eqn (3)

G. Forcing from model output and observations, eqn (3)

H. Forcing from model output and observations, eqn (3)

I. Forcing from model output and observations, eqn (3)

J. Forcing from model output and observations, eqn (3)

K. Forcing from model output and observations, eqn (3)

L. Forcing from model output and observations, eqn (3)

M. Forcing from model output and observations, eqn (3)

N. Forcing from model output and observations, eqn (3)

O. Forcing from model output and observations, eqn (3)

P. Forcing from model output and observations, eqn (3)

Q. Forcing from model output and observations, eqn (3)

R. Forcing from model output and observations, eqn (3)

S. Forcing from model output and observations, eqn (3)

T. Forcing from model output and observations, eqn (3)

U. Forcing from model output and observations, eqn (3)

V. Forcing from model output and observations, eqn (3)

W. Forcing from model output and observations, eqn (3)

X. Forcing from model output and observations, eqn (3)

Y. Forcing from model output and observations, eqn (3)

Z. Forcing from model output and observations, eqn (3)