Annual Report of Research Activities and Major Results
For the period: April 2006 – March 2007
NSF Grant: ATM 0354545
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This report is restricted to the past 12 months (April 2006 – March 2007). Results and presentations prior to that time are not included here.

I. Here is a summary list of our activities:
A. Student Muhtar Osman completed his MS degree (June 2006)
B. Postdoctoral scholar Lin lin Pan was hired (August 2006)
C. completed testing and implementation of Branstator's stationary wave model (SWM); including solving vexing problems with: divergence forcing and topography.
D. used highest resolution of SWM (R12, 10L; limited by 2GB addressable storage on a 32-bit machine) so we began creating 64-bit computer to allow higher resolution
E. completed all initial 'forward calculation' (given the forcing, find the parts of the bias) runs of SWM
F. completed all initial 'backwards calculation' (given the bias, find the forcing that creates it) runs of SWM.
G. created a project website (http://atm.ucdavis.edu/~grotjahn/Arctic/) to facilitate communication between team members.
H. displayed the bias in 3-dimensional structure (see http://atm.ucdavis.edu/~lpan/doc/ or the project website)
I. identified the forcing structures in 3-dimensions for the 4 prognostic variables.
J. identified which parts of the Arctic region bias could be isolated (Beaufort high region) and which were linked (North Atlantic, Barents dipole).
K. began development of study to separate diabatic from transient forcing of the bias
L. attended 10th CCSM workshop: presented results & met with collaborators
M. attended AMWG meeting (January, 2007): presented results & met with collaborators
N. imported CAM3.1p and began running it locally (the TB of data with necessary time, space resolution not available elsewhere) for separating diabatic and transient forcing.
O. purchased new cluster computer to facilitate multi-year AMIP runs of CAM3.1 (goal: increase rate of annual simulations by factor of 10.)
P. revised 3 papers, two have been published.

II. Major research findings are these:
This study seeks to understand the causes of the SLP bias in NCAR climate models.
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A. We deduced the forcing field that creates the Arctic region bias from running Branstator's SWM 'backwards'. Symbolically, the SWM can be written as: $Ax = F$ where F is the forcing, x is the solution sought, and A is a very large square matrix dependent on the basic state (3-dimensional DJF fields of vorticity, divergence, temperature, and $\log_e$ of surface pressure). To run the SWM

'backwards' we specify x and find the F. By specifying the bias fields as x, then we obtained the following important SWM backwards results:

1) Local forcing dominates the Arctic region bias. Solutions in Arctic region unchanged whether forcing was allowed or zeroed out south of 30N. (This was useful to eliminate considering the large forcing and bias over Himalayas.) The bias and forcing was successfully partitioned geographically: various portions of the bias field (e.g. the Beaufort negative bias) could be isolated from other parts.

2) The Barents SLP bias (positive) is linked to the North Atlantic bias (negative) while the Beaufort bias (negative) is not to the North Pacific, Barents, or Atlantic in any strong way.

3) The North Atlantic/Barents dipole bias is baroclinic for T and equivalent barotropic for vorticity. The associated forcing is baroclinic T forcing and equivalent barotropic vorticity forcing. For T the largest forcing tended to be at the surface and in the upper model levels. For vorticity the largest values tended to be in the middle or upper troposphere. See figs. 1 and 2.

4) The Beaufort region bias is mainly in the stratosphere for T (warm) and equivalent barotropic for vorticity. The associated forcing is equivalent barotropic for T and baroclinic for vorticity; both forcing fields have larger values in the upper troposphere.

5) Thus the forcing is very different for these two regions of the Arctic bias field.

B. We used the SWM to see the response of isolated forcing by individual fields.

1) Inspection of the low level T bias field suggests multiple monopoles in T forcing tendency. When a limited number of those T forcing centers are used to force the SWM, one obtains a solution field similar to the SLP bias over the Arctic. See Fig. 5.

2) A subset of T tendency monopoles (mainly N. Siberia >0 tendency, and Sahara-Arabia deserts <0 T tendency) appear to be the main forcing for Beaufort high <0 bias and Barents >0 bias.

North Atlantic Local Bias Forcing

Q=ln(Ps)

- Bias subregion from 100W – 80E, 30N – pole → forcing → solution
- Forcing fields:
  - Equivalent barotropic in vorticity,
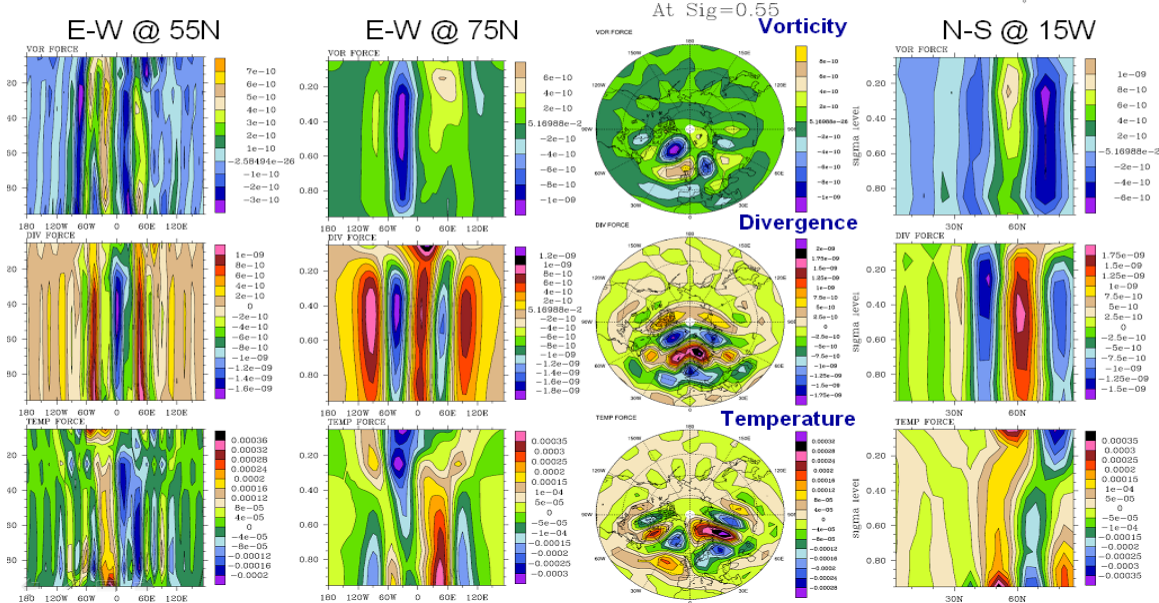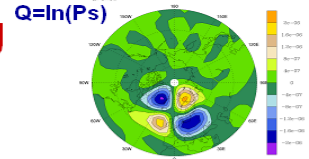 - Baroclinic (N-S and E-W) in temperature

At Sig=0.55

E-W @ 55N   E-W @ 75N   Vorticity   N-S @ 15W

Divergence

Temperature

Fig. 1: Vertical and horizontal structure of forcing in SWM for North Atlantic & Barents region bias.

North Atlantic Local Bias Solution

Q=ln(Ps)

- Bias subregion from 100W – 80E, 30N – pole → forcing → solution
- Bias-like solutions:
  - Equivalent barotropic in vorticity,
  - Baroclinic in temperature

At Sig=0.55

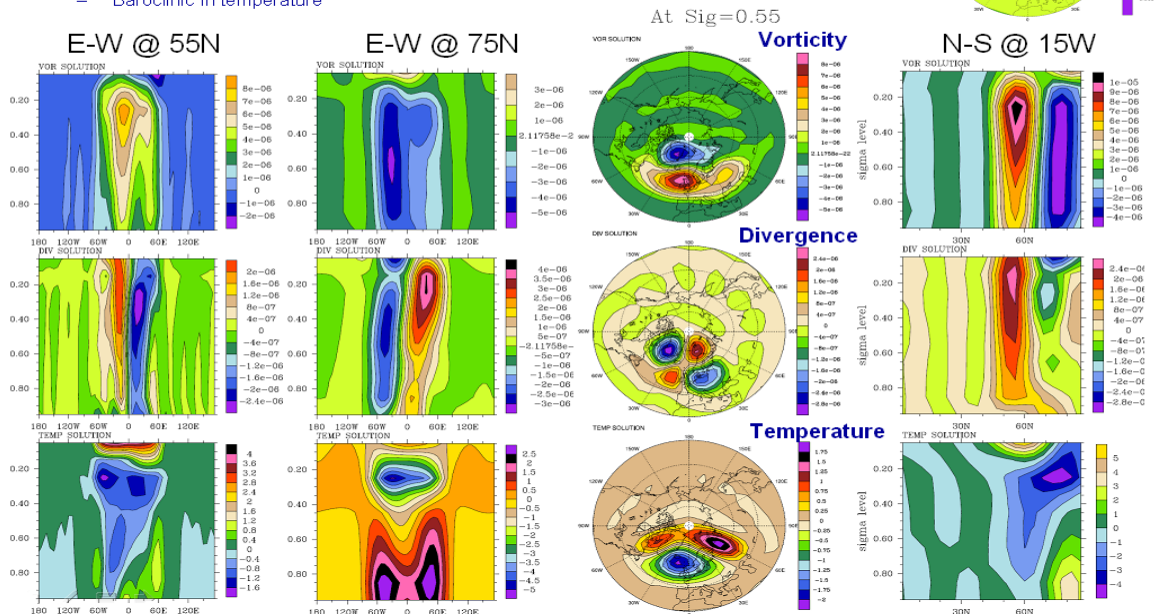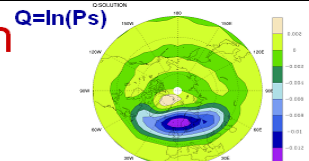E-W @ 55N   E-W @ 75N   Vorticity   N-S @ 15W

Divergence

Temperature

Fig. 2: Vertical and horizontal structure of SWM solution created by forcing in figure 1.

Beaufort Local Bias Forcing

- Bias subregion from 100W – 80E, 30N – pole → forcing → solution
- Forcing fields: (pattern 'opposite' to N. Atlantic cross sections)
  - Baroclinic (N-S and E-W) in vorticity,
  - Barotropic in temperature

Q=ln(Ps)

At Sig=0.55

Vorticity

Divergence

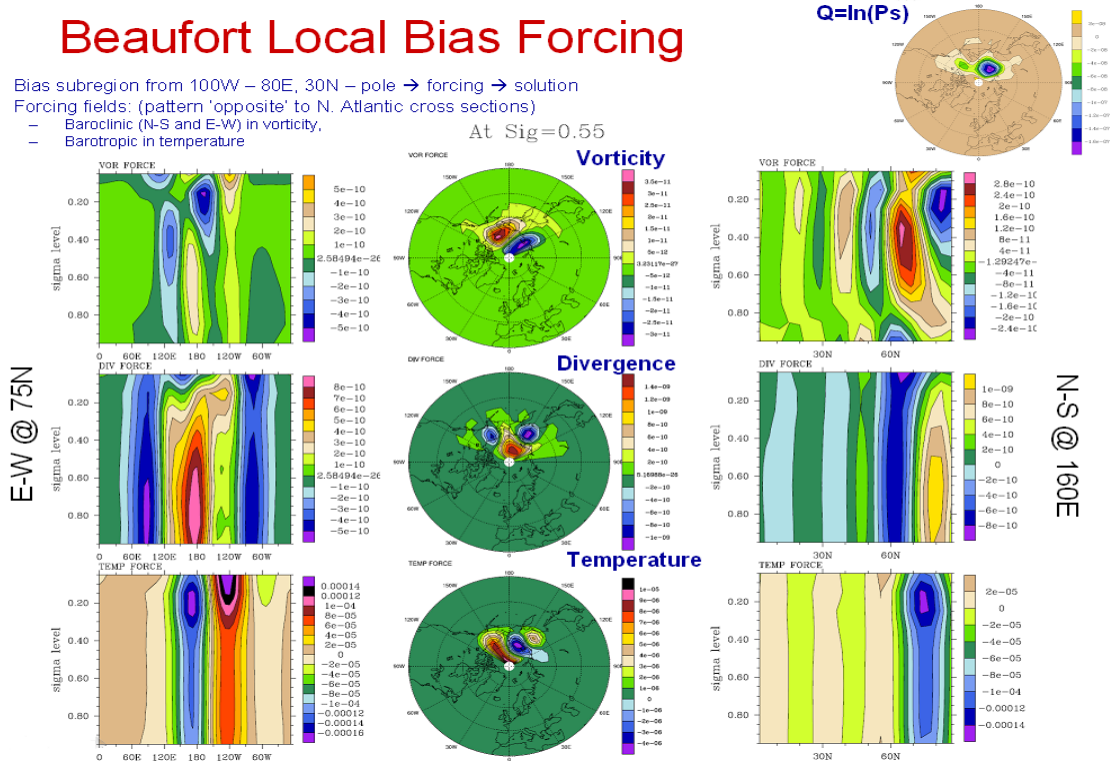Temperature

E-W @ 75N

N-S @ 160E

Fig. 3. Vertical and horizontal structure of forcing in SWM for Beaufort Sea region bias.

Beaufort Local Bias Solution

- Bias subregion from 100W – 80E, 30N – pole → forcing → solution
- Forcing fields: (pattern 'opposite' to N. Atlantic cross sections)
  - Equivalent barotropic in vorticity,
  - Stratosphere in temperature – model too warm

Q=ln(Ps)

At Sig=0.55

Vorticity

Divergence
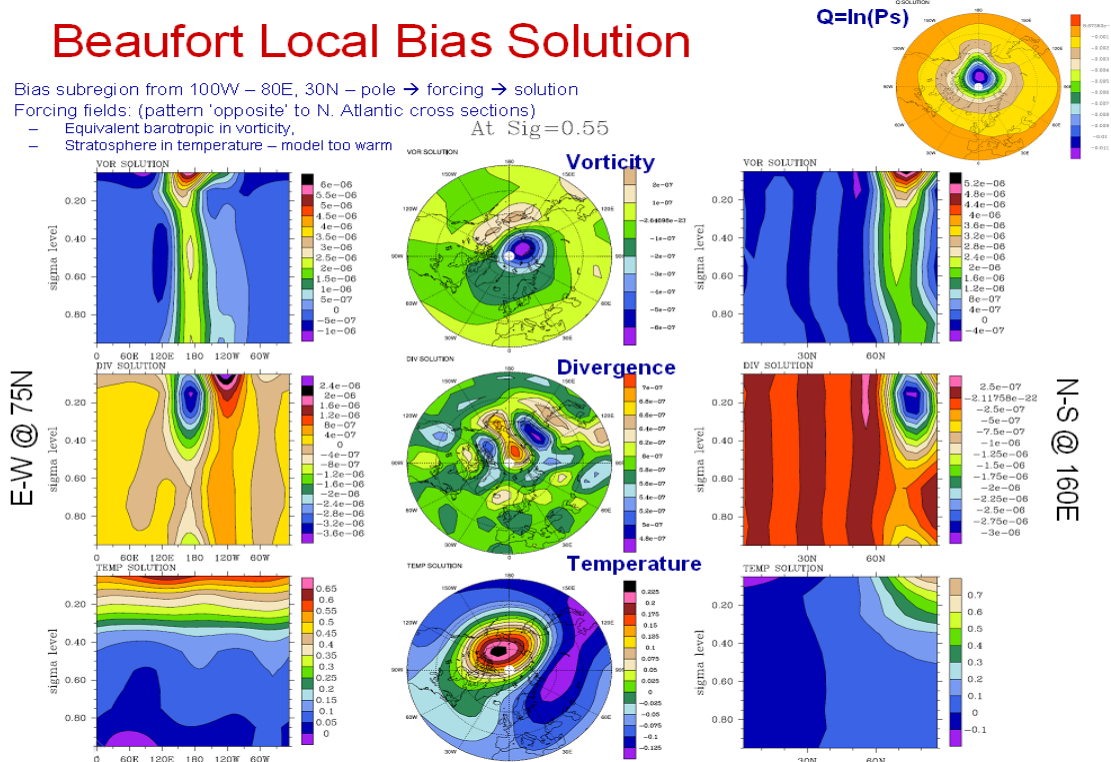
Temperature

E-W @ 75N

N-S @ 160E

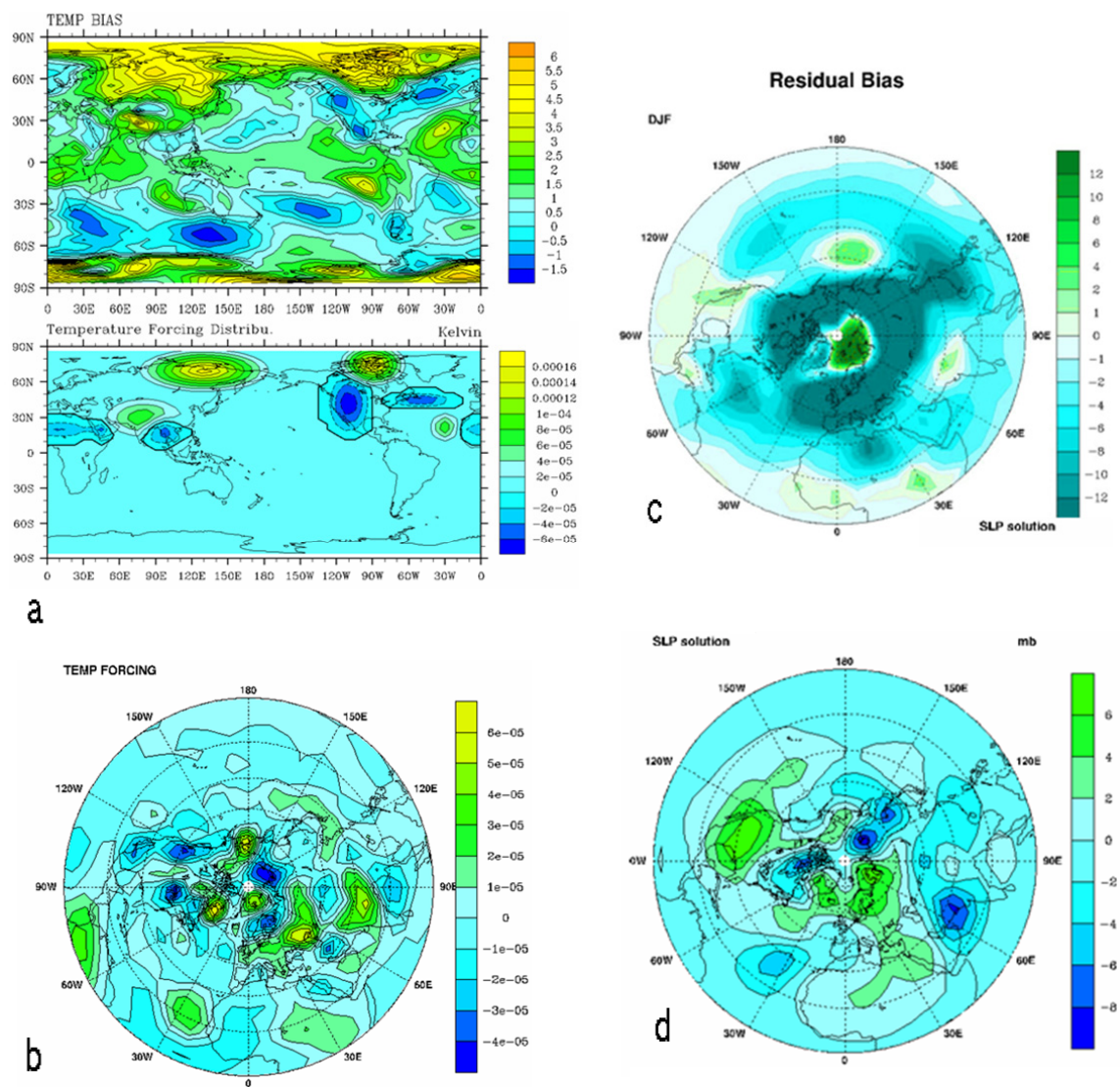Fig. 4: Vertical and horizontal structure of SWM solution created by forcing in figure 3.

Fig. 5. SWM solutions for function-specified monopole temperature forcing. a) Temperature (T) bias at σ = 0.991 and 9 monopoles of temperature forcing inspired by that T bias. b) Actual temperature forcing from bias field. c) Actual SLP (residual) bias after subtracting the dominant EOF of the CAM model. d) SLP solution from the 9 monopoles in T forcing. Notice how the SLP solution captures most features of the residual bias.