Climate change in a column

Can a single column model capture a GCM’s climate response?

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Searching for a column analog

\[
V \cdot \nabla \theta \\
V \cdot \nabla q
\]

26 levels

2.5°

“control climate”

“perturbed climate”

SST, CO₂, etc.

CAM (v3.1)

Single-column CAM (v3.1)
Replication (success)
Replication (caveat)
Removing constraints -- advection & sfc fluxes

Temperature & Cloud Amount

Specific Humidity & Liquid Water

Days

3.00  6.00  9.00  12.00  15.00  18.00

GCM

Single-column Model

270  275  280  285  290  295  300

0  3  6  9  12  15  18
Prototype

Forcing from GCM runs.

- Aquaplanets
- NCAR CAM (v.3.1)
- “SCAM”

Does SCAM reproduce CAM when forced by CAM output?

- Each SCM run should be statistically similar (because of aquaplanet)
- Is result sensitive to details? (Mix up initialization/forcing).
The forcing

Time averages from individual points.

Ensemble average
The forcing

Time averages from individual points.

Ensemble average

+2 profiles
Cloud forcing response

**Net Cloud Forcing (W/m²)**

- **Control SST**
- **SST+2K**

**Sampling**
- **SCM**: 30 days × 16 runs = 480 days
- **GCM**: 36 months at 128 longitudes

**ΔCRF**
- **SCM**: -12 (-11) W/m²
- **GCM**: -8 W/m²
Thermodynamic structure

Control SST

SST + 2K

Difference

Approx. Pressure

Potential Temperature [K]

Specific Humidity [kg/kg]

SCM instance
SCM ensemble
GCM latitude

Difference

Cloud structure

Control SST

SST + 2K

Difference

Approx. Pressure

Liquid Condensate [g/kg]

Cloud Amount

Approx. Pressure

Liquid Condensate [g/kg]

Cloud Amount

Approx. Pressure

Liquid Condensate [g/kg]

Cloud Amount

Approx. Pressure

Liquid Condensate [g/kg]

Cloud Amount

SCM instance
SCM ensemble
GCM latitude

Difference
Results suggest a small ensemble of SCM runs can reproduce the climate response from a larger sample of GCM points.

✱ Can forcing be simplified without sacrificing the fidelity to the GCM result?
  ‣ Building test cases for comparison with simulations/observations.

Change SCM forcing/physics to predict the GCM response.
  ‣ Parameterization development.

Isolating regimes mores carefully. Systematically investigate response of prevalent cloud regimes.
  ‣ Deconstructing GCM response.
Sensitivity to mean value

\[ x_{\text{new}} = x_o - \overline{x_o} + \langle x_i \rangle \]
Sensitivity to variance

\[ x_{\text{new}} = \bar{x}_o + \frac{\langle x'_i \rangle}{x'_o} x'_o \]
Impose mean & variance

\[ x_{\text{new}} = \langle x_i \rangle + \frac{\langle x'_i \rangle}{x'_o} x'_o \]