The Polar Amplification Asymmetry: Role of Antarctic Surface Height

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Polar Amplification Asymmetry

Local temperature change when $\Delta T_{glob} = 2^\circ C$ from the CMIP5 RCP8.5 experiment

Seneviratne et al., Nature 529, 477-483 (2016)
Role of antarctic land height

- use Community Earth System Model (CESM) v1.0.6, at low resolution (T31, gx3v7)
  1. base control run
  2. base 2xCO2 run
  3. flat Antarctica control run
  4. flat Antarctica 2xCO2 run
Role of antarctic land height

- mainly analyze years 80 to 109
- use partial radiative perturbation (PRP) method to compute forcing and feedbacks
  - lapse rate (LR)
  - Planck (PL)
  - surface albedo (ALB)
  - water vapor (WV)
  - cloud (CL)
- regions defined by polar circles
Top of atmosphere radiation budget

base control run

\[ F_{\text{TOA}} \text{ (W m}^{-2}\text{)} \]

- red: solar
- blue: terrestrial

latitude

90S 60S 30S 0 30N 60N 90N
Top of atmosphere radiation budget

![Graph showing top of atmosphere radiation budget](image)

- **NASA CERES**
- **F_{TOA} (W m^-2)**
- **Latitude**

- **Solar** line
- **Terrestrial** line
Top of atmosphere radiation budget

base and flat AAcontrol runs

F_{TOA} (W m^{-2})

90S 60S 30S 0 30N 60N 90N

latitude

solar base
terrestrial base
solar flat Antarctica
terrestrial flat Antarctica
Surface air temperature increase due to CO₂ doubling
Northward atmospheric heat transport

![Graph showing atmospheric heat transport](image-url)
Northward oceanic heat transport
Radiative forcing and feedbacks

\[ \text{FSU} = \text{LR} + \text{WV} + \text{ALB} + \text{CL} \]

- CO2 (mean: 2.4 W m\(^{-2}\))
- PL (mean: -5.4 W m\(^{-2}\))
- LR (mean: 0.9 W m\(^{-2}\))
- WV (mean: 1.9 W m\(^{-2}\))
- ALB (mean: 0.7 W m\(^{-2}\))
- CL (mean: 0.3 W m\(^{-2}\))
- FSU (mean: 3.8 W m\(^{-2}\))
- SUM (mean: 0.8 W m\(^{-2}\))
- RES (mean: 0.1 W m\(^{-2}\))
Difference (base - flat AA)

\(\Delta CO_2\) (mean: \(-0.0\) W m\(^{-2}\))
\(\Delta PL\) (mean: \(-0.4\) W m\(^{-2}\))
\(\Delta LR\) (mean: \(0.2\) W m\(^{-2}\))

\(\Delta WV\) (mean: \(0.1\) W m\(^{-2}\))
\(\Delta ALB\) (mean: \(0.2\) W m\(^{-2}\))
\(\Delta CL\) (mean: \(0.1\) W m\(^{-2}\))

\(\Delta FSU\) (mean: \(0.5\) W m\(^{-2}\))
\(\Delta SUM\) (mean: \(0.0\) W m\(^{-2}\))
\(\Delta RES\) (mean: \(0.0\) W m\(^{-2}\))
Compare local feedbacks

Arctic - Antarctic

ΔF (W m⁻²)

CO2
LR
PL
WV
ALB
FSU
RES

SUM

base
flat AA
Why this LR feedback difference?

Additional PRP sensitivity runs …

<table>
<thead>
<tr>
<th>label</th>
<th>variable(s) from flat AA model setup in base model setup</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRPLSens</td>
<td>surface air ($T_s$) and atmospheric ($T_a$) temperature</td>
</tr>
<tr>
<td>LRsens</td>
<td>atmospheric temperature $T_a$</td>
</tr>
<tr>
<td>PLSens</td>
<td>$T_s$ and control $T_a$ with added $\Delta T_s$ as in PL</td>
</tr>
</tbody>
</table>
Why this LR feedback difference?

... suggest that LR feedback mainly depends on surface
Attempt to analyze budgets

Arctic - Antarctic

$\Delta(\Delta F)$ (W m$^{-2}$)

-1.5
-1.0
-0.5
0.0
0.5
1.0

flat AA - base

CO2
PL+LR
ALB
CL
FSUP
OHT
AHT
HS
RES

HS: heat storage; FSUP = FSU + PL
Summary/Conclusions

- Antarctic surface height plays an important role for polar amplification asymmetry.

- Flat Antarctica allows for warm air advection from lower latitudes.
  - Once the ice shield is lost, warm air advection might make restoration of the ice shield more difficult.

- Local feedbacks and ocean heat transport play important roles as well.

- Other important factors investigated elsewhere.
thank you!


U.S. contributions:

- satellite data product: NASA CERES (EOS, Langley)
- model: CESM (CGD/NCAR, sponsored by NSF and DOE)
- analysis software: NCL (UCAR/NCAR/CISL/TDD)
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Temporal evolution
Air temperature profiles

Antarctic

Arctic
Regional Feedbacks