Cloud and water vapor Influences on ERA5, AMPS, and ModelE3 Surface Downwelling Longwave Radiation Biases in West Antarctica

Israel Silber, Hans Verlinde, Dave Bromwich, Sheng-Hung Wang, Ann Fridlind, Andy Ackerman, Ed Eloranta, Maria Cadeddu, Connor Flynn

E-mail: ixs34@psu.edu
• Polar clouds impact the surface energy budget, even when they optically thin.
• Polar clouds impact the surface energy budget, even when they optically thin.

• How well do models represent the surface LW↓, the main component controlled by overlying clouds?

• What is the contribution of Antarctic clouds (and their phase) to the model-observation differences?

• Comparison of observations with model output from:
  1. ECMWF ERA5 (reanalysis model).
  2. AMPS (forecast model).

Evaluation of the models in clear-sky periods, ice-cloud occurrences, and tenuous (LWP < 25 g/m²) and opaque (LWP ≥ 25 g/m²) liquid-bearing cloud occurrences (see Silber et al., 2018).
Modeled LW↓ Bias

Error = LW↓_{model} - LW↓_{obs}

ERA5, mean = -14.1 W/m², σ = 26.8 W/m²

AMPS, mean = -22.6 W/m², σ = 28.4 W/m²
Modeled LW↓ Bias

Underestimation of the total water vapor and/or deviations in the temperature-vapor profiles (especially in the lower kilometer).

Predominantly underestimation of LW↓ during clear-sky periods by ~5 W/m².
Modeled LW\downarrow Bias

Very large ice cloud spread, tendency for underestimation

Silber et al., *J. Clim.*, in revision

\begin{align*}
\text{Mean} &= -6.9 \text{ W/m}^2, \sigma = 21.0 \text{ W/m}^2 \\
\text{AMPS (polar WRF)} \quad \text{Mean} &= -21.0 \text{ W/m}^2, \sigma = 24.0 \text{ W/m}^2
\end{align*}
Modeled LW↓ Bias

LW↓ is consistently underestimated during Liquid-bearing cloud occurrence

Very large ice cloud spread, tendency for underestimation

**ERA5**

- clear sky
- ice clouds
- tenuous liquid
- opaque liquid

Mean = -29.4 W/m², σ = 27.7 W/m²

**AMPS (polar WRF)**

- clear sky
- ice clouds
- Tenuous liquid
- opaque liquid

Mean = -37.7 W/m², σ = 27.7 W/m²

Silber et al., *J. Clim.*, in revision
Modeled LW↓ Bias

LW↓ is consistently underestimated during Liquid-bearing cloud occurrence

Very large ice cloud spread, tendency for underestimation

Silber et al., *J. Clim.*, in revision
\( \text{RH}_{\text{ice}} \) Comparison (0-6 km)

**Obs:** the atmosphere is “starving” for ice nuclei \( \rightarrow \)
High ice supersaturation

Models: Highly efficient nucleation \( \rightarrow \)
\( \text{RH}_{\text{ice}} \) rarely exceeds 100% \( \rightarrow \) Quick desiccation of the atmosphere

Silber et al., *J. Clim.*, in revision
ModelE3 Climate Model

Silber et al., *J. Clim.*, submitted

2016 Specific humidity R² at 700 hPa

2016 Specific humidity mean and SD at 700 hPa
ModelE3 Climate Model

Silber et al., J. Clim., submitted

Solid – Obs
Dashed – Model

2016 Specific humidity $R^2$ at 700 hPa

2016 Specific humidity mean and SD at 700 hPa
Model E3 Climate Model

Silber et al., J. Clim., submitted

2016 Specific humidity $R^2$ at 700 hPa

Solid – Obs
Dashed – Model

2016 Specific humidity mean and SD at 700 hPa

Solid – McMurdo
Dashed – WAIS

PDF [$m^2/g$]

CDF

LWP [g/m²]

10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^1 10^2 10^3
ModelE3 Climate Model

Silber et al., J. Clim., submitted

2016 Specific humidity $R^2$ at 700 hPa

2016 Specific humidity mean and SD at 700 hPa

McMurdo Station

WAIS Divide

CDF

PDF [m$^2$ g$^{-1}$]

LWP [g m$^{-2}$]

Solid – McMurdo
Dashed – WAIS

Observations
ModelE3
AMPS
ERA5

80 100 120 140
80 100 120 140

RH$_{ice}$

$i_{ice}$

$H$
Conclusions and Summary

• Antarctic mixed-phase as well as ice clouds have a significant impact on the surface energy budget.

• Both ERA5 and AMPS, tend to underestimate the surface LW↓ relative to the observations.

• These deviations are significantly larger in the presence of liquid-bearing clouds.

• Excess production of ice is likely the culprit of the model LW↓ underestimation. The sources for this excess production of ice will be further investigated in future studies.

• Preliminary analysis of ModelE3 with nudged horizontal winds shows good results.

Poster #97 (feel free to visit #95 as well)