The LIWG’s “hottest” topic: meltwater

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Photo: Kelvin Trautman
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How well is CESM2 representing melt across the Antarctic Ice Sheet?

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Photo: Kelvin Trautman
Melt increases exponentially with temperature

\[ \text{Melt} = 1,183 \exp(0.4557 \, T_{2m}) \]

\[ r^2 = 0.86 \]

\[ \text{RMSE} = 60.9 \]

\[ \text{Observed DJF air temperature} \]

\[ \text{Surface melt and anomaly (s.d.)} \]

\[ \text{Year} \]

\[ \text{Surface meltwater production (mm w.e. yr}^{-1} \)]

\[ \text{RACMO2 (ERA-Interim)/QuikSCAT} \]

\[ \text{RACMO2 (EC-Earth) RCP4.5} \]

\[ \text{RACMO2 (EC-Earth) RCP8.5} \]

\[ \text{Historical melt evolution before ice shelf collapse.} \]

\[ \text{11-year centred moving averages. Dashed horizontal lines (in light blue) show average pre-collapse melt on Larsen A and B simulated by RACMO2.} \]

\[ \text{Amery Island ice cap JRI ice core melt} \]

\[ \text{Larsen A surface melt} \]

\[ \text{Larsen B surface melt} \]

\[ \text{Pine Island} \]

\[ \text{Ross Island ice cap} \]

\[ \text{Prince Gustav-Ackermann Ice Shelf} \]

\[ \text{Shackleton Ice Shelf} \]

\[ \text{Wilkins Ice Shelf} \]

\[ \text{Fimbul Ice Shelf} \]

\[ \text{Venable Ice Shelf} \]

\[ \text{Larsen C} \]

\[ \text{Larsen B} \]

\[ \text{Larsen A} \]

\[ \text{Abbot Ice Shelf} \]

\[ \text{Getz Ice Shelf} \]

\[ \text{Amery Ice Shelf} \]

\[ \text{Shackleton Ice Shelf} \]

\[ \text{George VI Ice Shelf} \]
Firn air depletion fueling ice shelf hydrofracture

Kuipers Munneke et al., 2014
Research Questions

What conditions are necessary for the Antarctic firn to become depleted of air?
Research Questions

What conditions are necessary for the Antarctic firn to become depleted of air?

When will these conditions be met across Antarctica?
How well is CESM2 doing? – Wind Speed

Dec-Jan-Feb
Bias = 0.15 m/s

Mar-Apr-May
Bias = 0.50 m/s

Jun-Jul-Aug
Bias = 0.23 m/s

Sep-Oct-Nov
Bias = 0.10 m/s
How well is CESM2 doing? – Wind Speed

Dec-Jan-Feb
Bias = 0.15 m/s

Mar-Apr-May
Bias = 0.50 m/s

Jun-Jul-Aug
Bias = 0.23 m/s

Sep-Oct-Nov
Bias = 0.10 m/s

Annual Bias = 0.27 m/s
How well is CESM2 doing? – Temperature

Dec-Jan-Feb
Bias = -1.09 K

Mar-Apr-May
Bias = -2.32 K

Jun-Jul-Aug
Bias = -3.48 K

Sep-Oct-Nov
Bias = -3.81 K
How well is CESM2 doing? – Temperature

Dec-Jan-Feb
Bias = -1.09 K

Mar-Apr-May
Bias = -2.32 K

Jun-Jul-Aug
Bias = -3.48 K

Sep-Oct-Nov
Bias = -3.81 K

Annual Bias = -2.69 K
How well is CESM2 doing? – Melt

Melt bias (model – obs)

-400 0 400

mm w.e/year
How well is CESM2 doing? – Melt

Annual Bias = 12.41 mm w.e./year
How well is CESM2 doing? – Melt

Melt bias (model – obs)

Annual Bias = 12.41 mm w.e/year

Snowfall bias (model – obs)

Annual Bias = 68.32 mm w.e/year
Surface melt: 150% to 800% increase

Credit: Jan Lenaerts
Snowfall increases only 10-25%

Credit: Jan Lenaerts
while rainfall increases strongly (100-700%)
Towards liquid water dominated ice shelves
Summary

• Wind – No significant bias
• Temperature – CESM2 is cold
• Melt - CESM2 has more melt on Peninsula
• Snowfall – CESM2 has more snowfall
• Trend towards more liquid production on ice shelves
Research Questions

What conditions are necessary for the Antarctic firn to become depleted of air?

When will these conditions be met across Antarctica?
How well is CESM2 doing? – Melt volume

Observations - CloudSat

CESM2

mm w.e/year

0

100

200

300

400

500
How well is CESM2 doing? – Snowfall

Observations - CloudSat

CESM2

mm w.e/year