Surface climate trends and variability around Antarctica over the past four decades: What does this tell us about model biases and errors?

Matthew England  UNSW Australia
The Future of Earth System Modeling: Polar Climates
November 28-30, 2018
Caltech, Keck Center
Observed surface T trends...
Global surface climate trends progressing largely as expected

Annual-mean temperature change predicted for ~2030 in the GFDL coupled climate model experiment.

Stouffer et al., 1989
Observations

Model

Arctic sea-ice trends has outpaced expectations.....

Average sea-ice 1979–2006 and then in 2007
Marked trend contrast across the hemispheres

Average sea-ice 1979–2006 and then in 2007

Annual SIC trends 1979–2013

Purich et al. 2016
Annual trends: 1979–2013

Schlosser et al. (2018)
Antarctic surface climate trends go against “expectations”

Southern Ocean warming delayed by circumpolar upwelling and equatorward transport

Kyle C. Armour¹*, John Marshall², Jeffery R. Scott²³, Aaron Donohoe⁴ and Emily R. Newsom⁵
Recent surface forcing trends over the Southern Ocean


500 hPa geopotential height

Winds and Air Temp

IPCC 2007

Multi-model SAM index (Nov-Feb)

GHG + O₃

GHG
Ocean-atmosphere imprint of the Southern Annular Mode

Surface fluxes, Ekman transport and MLD changes act in concert to produce SST response. Eddy heat fluxes act in the opposite sense.

Thompson, England, et al. (2011)
Nature Geosciences

Multi-model SAM index (Nov-Feb)
CMIP5 MODELS WESTERLY WINDS
But model mean does not match OBS transient cooling

Models should resolve these basic ocean physics......
So why don’t models capture this transient cooling?

Nature Comms
So why don’t models capture this transient cooling?

So why don’t models capture this transient cooling?

We can only observe one planet but we can simulate 100’s..

Models

- Single models
- CMIP5, CMIP6...

Purich, England et al. 2018
We can only observe one planet but we can simulate 100’s.....

Models

- Single models
- CMIP5, CMIP6...

Purich, England et al. 2018
So, variability appears to be playing a role....

(a) Observed trend (% decade$^{-1}$)  
(b) Observed ENSO composite (%)  

Journal of Climate
Pacemaker experiments help us understand how....

SST and MSLP trends over 1979–2013.

- (b) IPO trend = -0.26°C decade⁻¹, p = 0.03
- (c) Nino 3.4 trend = -0.11°C decade⁻¹, p = 0.38
- (d) Amundsen Sea Low trend = -0.64 hPa decade⁻¹, p = 0.14

- (e) Ross Sea trend = 1.72% decade⁻¹, p < 0.01
- (f) Bellingshausen Sea trend = -1.20% decade⁻¹, p = 0.01

Journal of Climate
Pacemaker experiments

(d) CESM1-eqPAC minus HIST
(e) CanESM2-TROP minus CLIM

Journal of Climate

SIC trend (% decade$^{-1}$)
MSLP contours from -2 (dashed) to 2 (solid) by 0.2 hPa decade$^{-1}$
Volume loss from Antarctic ice shelves 1994 – 2012

Paolo et al. 2015

Volume change (km$^3$) West East All
-1500 0 +1500

Rate of thickness change (m/decade)
-25 -10 0 10

% - Thickness change 1994-2012
loss 5%
gain 5%
Salinity trends 1950-2000

Durack and Wijffels (2010)
Salinity trends 1950-2000

Durack and Wijffels (2010)
SSS trends over 1950–2000

(a) Durack and Wijffels (2010)
SSS trends over 1950–2000

(a) Durack and Wijffels (2010)
SSS trends over 1950–2000

(a) Durack and Wijffels (2010)
“Pacemaker” experiments with SO SSS restored to OBS

**OBSERVED**

**MODEL**

(e) NSIDC Bootstrap SIC trends (% (10 y)^{-1})

(f) ACCESS1.0 SIC trends (% (10 y)^{-1})
Ocean-atmosphere imprint of the Southern Annular Mode

Regional & seasonal differences in sea-ice response

Reduced cloud cover

Increased eastward wind/current

Increased westward wind/current

Heat Fluxes

Eddy response

Surface fluxes, Ekman transport and MLD changes act in concert to produce SST response. Eddy heat fluxes act in the opposite sense.

Rising air

Subsiding air

Rising air

Antarctica

Enhanced upwelling of carbon-rich deep water

Barotropic flow

Weak return flow

Deep ocean

Thompson, England, et al. (2011)

Nature Geosciences

The **Southern Annular Mode** has made a major contribution to recent high-latitude cooling.
• The **Southern Annular Mode** has made a major contribution to recent high-latitude cooling.

• Yet almost all **climate models** fail to capture this cooling trend and ice growth despite generally capturing a trend in the mid-latitude jet.
Why do models “miss” the cooling?

1. **Model biases** in the midlatitude jet and interior temperature structure
Why do models “miss” the cooling?

1. **Model biases** in the midlatitude jet and interior temperature structure

2. **Missing freshening** over the surface Southern Ocean – perhaps due to cloud / precipitation biases...?
1. **Model biases** in the midlatitude jet and interior temperature structure

2. **Missing freshening** over the surface Southern Ocean – perhaps due to cloud / precipitation biases…?

3. **Interannual – decadal variability** is also a significant player, via the IPO / ENSO / Atlantic
Workshop Questions:

• How should we design a climate model to obtain better predictions of polar climates on timescales of decades?
  - Difficult bars keep getting set!
  - Mean state biases – OGCM, AGCM, sea-ice
  - Diversity remains critical
  - Tropical teleconnections also critical
  - SAM predictability so poor

....apart from forced signal?
Workshop Questions:

• How can we integrate observations better with models?
  - For large-scale interannual – decadal processes and predictions, evaluate models against key metrics and ‘predictable’ events

• What additional observations would help improving models?

---

Monthly SIE anomaly time series

Schlosser et al. (2018)
Surface climate trends and variability around Antarctica over the past four decades: What does this tell us about model biases and errors?

Matthew England    UNSW Australia
The Future of Earth System Modeling: Polar Climates
November 28-30, 2018
Caltech, Keck Center
Marked geometry contrast across the hemispheres

North Pole: Ocean + sea-ice
Surrounded by land

South Pole: Land mass + Land ice
Surrounded by oceans
Marked geometry contrast across the hemispheres

North Pole:
Ocean + sea-ice
Surrounded by land

South Pole:
Land mass + Land ice
Surrounded by oceans