Arctic temperature inversions in the CESM- Large Ensemble

Line Bourdages [@mail.mcgill.ca]
PhD Candidate, McGill U.
CESM workshop, Breckenridge, June 2015
Inversion long recognized as a pervasive feature of Arctic climate, especially in winter.

**Recent studies:**
- Regulated by sea ice [Pavelsky et al (2011)]

Source: Pavelsky et al. (2011)

Inversion over polar oceans regulated by sea ice.
Background

Wintertime inversion

Inversion long recognized as a pervasive feature of Arctic climate, especially in winter

Recent studies:
- Regulated by sea ice [Pavelsky et al (2011)]
- Linked to Arctic Amplification [e.g Bintanja et al. (2011)]

Temperature change for 2 x CO2

Source: Bintanja, 2011: Arctic winter warming amplified by the thermal inversion [...]

Using EC-Earth Global coupled model
Background

Wintertime inversion

Inversion long recognized as a pervasive feature of Arctic climate, especially in winter

Recent studies:
- Regulated by sea ice [Pavelsky et al (2011)]
- Linked to Arctic Amplification [e.g Bintanja et al. (2011)]
- Large variability in GCM representation of inversions [Medeiros et al. (2011)]
Datasets

**CESM-LE** (Kay et al. 2014)
used to characterize natural variability of climate
Approx. 1 deg horizontal resolution

30 ensemble members
1920 – 2005 : historical forcing
2006 – 2100 : Representative Concentration Pathway (RCP) 8.5

**ERA-Interim** (Dee et al. 2011)
Global reanalysis
Approx 80km resolution
1979 – 2014

**Arctic System Reanalysis** (Bromwich et al. 2012)
Regional reanalysis with improved Arctic climate features and mesoscale circulation
30km resolution
2000-2010
Preliminary Results

Inversions in CESM-LE

Ocean (ice + open water)

Inversion definition:
$T_{850} - T_{\text{surface}}$

Arctic: Latitude > 64N

ERA-Interim
ASR (---)
REF Recent 1980-2005
REF 1920-2005
Inversions in CESM-LE

Preliminary Results

Ocean (ice + open water)

Arctic: Latitude > 64N

Inversion definition:
T (850mb) – T (surface)

ERA-Interim
ASR (- - -)
REF Recent 1980-2005
REF 1920-2005
FUT 2006-2080
FUT 2081-2100
Preliminary Results

Inversions in CESM-LE

-40            -20              0                20             40
Inv Delta T  ; Medeiros et al. 2011

ERA-Interim
ASR (-- --)
REF Recent 1980-2005
REF 1920-2005

Similar results to CAM3
ERA-Interim has biases and doesn't accurately represent low level inversions
Does ASR?

Pithan et al. 2014: model biases more important than reanalysis bias.
Preliminary Results

Inversions in CESM-LE

Ocean (ice + open water)

Inversion Strength [C ; T850-TREFHT]

Temperature at 850mb [C ]

Temperature at 2m [C ]

ERA-Interim
ASR (- - -)
REF Recent 1980-2005
REF 1920-2005
Preliminary Results

Inversions in CESM-LE

- **Ocean**
- **Ice**
- **Water**

**Main differences**
above the ice, near the surface

**ERA-Interim**
ASR (- - -)
REF Recent 1980-2005
REF 1920-2005
Preliminary Results

CESM-LE vs Reanalysis

- CESM-LE mean
  - $T(850\text{mb}) - T(\text{sfc})$
  - $T(\text{sfc})$

- ASR
  - ASR has reduced $T(\text{sfc})$
    - near the sea ice edge (storms?)
    - near Canadian Archipelago (sea ice thickness bias?)

- ERA-I
  - ERA-I has reduced $T(\text{sfc})$
    - Over sea ice

All plots in Celsius

2000 – 2010 DJF means
Preliminary Results

Recent past trends

T(850mb) - T(Surface)

T (surface)

T (850mb)

1970 - 2005

T850 increase can reduce trend in inversion strength

Strongest increase at surface co-located with sea ice loss pattern

Significant increase over sea ice

C/year
**Preliminary Results**

T(850mb)-T(Surface)  
Ice fraction

**Recent past trends**

1970 - 2005

T850 increase can reduce trend in inversion strength

Strongest increase at surface co-located w/ sea ice loss pattern

Significant increase over sea ice
Arctic temperature inversion strength is overestimated in CESM-LE

Bias is mostly near surface, but need to verify against observations instead of reanalysis

Bias linked to sea ice, possibly to mixing near sea ice edge

Inversion strength is projected to decrease, particularly over ice.

What are implications of inversion bias for projections of Arctic change?
What is the importance of different processes (mixing, transport, conduction)?
Thank You!

Questions/comments?
**Surface**
- LW deficit: equilibrium at low temperature
- Reduced mixing
- Turbulent fluxes and Winds can destroy inversions

**Inversion Layer**
- Upper layer cooling to space
- Heat input to maintain inversion
  (Overland & Guest, 1991)
- Subsidence: warming and drying
  (Curry, 1983)
Main Goal:

Characterize representation of inversion in CMIP5 models and understand impact of inversion on feedbacks related to the Arctic amplification phenomenon.

1) Inversion : processes and biases
   ➢ Quantify main inversion formation and strengthening processes
   ➢ Quantify differences between GCMs and reanalyses (and reanalyses vs obs)

2) Projected climate changes
   ➢ Develop climate scenarios of inversion change
   ➢ Which processes have the largest projected change?
   ➢ Implications of inversion biases for arctic amplification
Preliminary Results

Inversions in CESM-LE

Sea ice

ERA-Interim
ASR (---)
REF Recent 1980-2005
REF 1920-2005
FUT 2006-2080
FUT 2081-2100

Main differences above the ice, near the surface

Source:
Preliminary Results

Inversions in CESM-LE

Open water

Source:
Preliminary Results

Surface Radiation

1) Bias in cloud fraction in CAM5

Source: Kay et al. (2015). In prep.
See poster by Jen Kay
Preliminary Results

Surface Radiation

1) Bias in cloud fraction in CAM5
2) Bias in Downwelling LW radiation at surface

![Graph showing net LW at surface for Ocean, Ice, Water, and Land](image_url)
Preliminary Results

Surface Radiation

1) Bias in cloud fraction in CAM5
2) Bias in Downwelling LW radiation at surface
Preliminary Results

Surface Radiation

1) Bias in cloud fraction in CAM5
2) Bias in Downwelling LW radiation at surface

Since T850 is well represented, errors in cloud amounts, phase and/or height...
1) Bias in cloud fraction in CAM5
2) Bias in Downwelling LW radiation at surface

Are my labels wrong in the script plot_dist? Lwup looks like Lwd