Air Parcel Trajectory Analysis to Identify the Effects of Low Cloud Formation on High-Latitude Cold Air Outbreaks in Warm Climates

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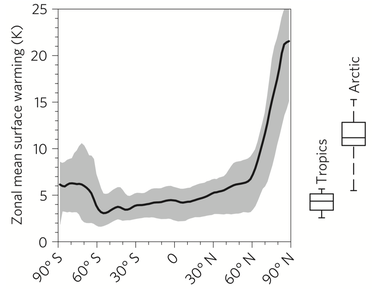
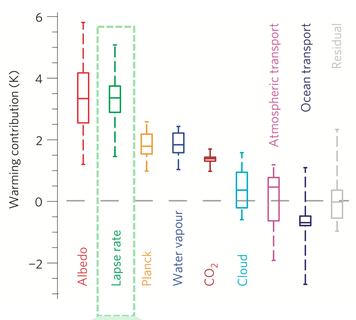
Arctic Amplification
is already underway and projected to increase but not fully understood



Zonal mean surface temperature change over the CMIP5 4xCO_2 experiment

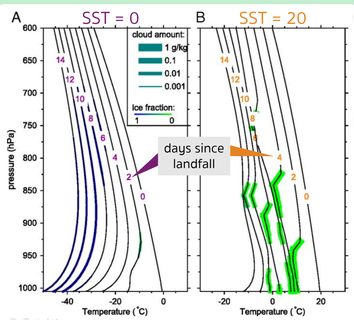
Figures: Pithan & Mauritsen 2014

Contributions to Arctic warming in CMIP5



Lapse Rate Feedback: warming is surface-amplified in Arctic
- major contributor to Arctic amplification, on par with ice-albedo
- no comprehensive explanation yet

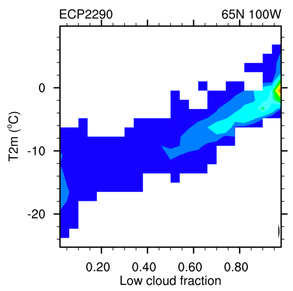
Previous Work
indicates low clouds may suppress cold air formation over Arctic continents



Figures: Cronin et al 2015
Hu et al 2018

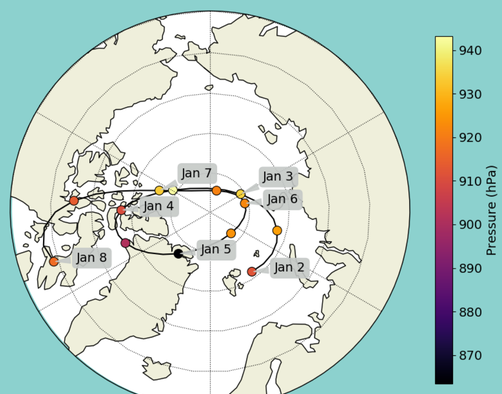
Lagrangian column model
SST=0 (left):
air mass cools rapidly over land
SST=20 (right):
low clouds (green bars) suppress cooling

Limitation: no air mass mixing



Eulerian GCM
in warmer climates (left, EPC8.5 in year 2281-2300), 2-meter temperature and low cloud fraction are correlated

Limitation: no causation, only correlation



Air parcel backtracking
is proposed to determine the effects of a warmer ocean on **low cloud formation** and **cold air suppression** over land during the Arctic winter.

MODEL warmer climates

Community Atmosphere Model (CAM4), coupled to land and sea ice

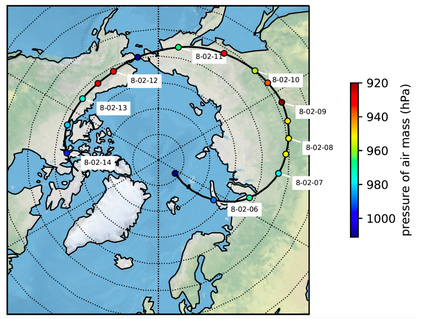
Four climate scenarios based on CMIP5 projections for comparison:
- Pre-industrial
- RCP8.5 2081-2100
- ECP8.5 2281-2300
- ECP8.5 with no sea ice, minimum SST=20

IDENTIFY cold air events

Compare 3-hourly surface temperatures to DJF climatology and identify the 20 coldest events over the model run period (~10 years)

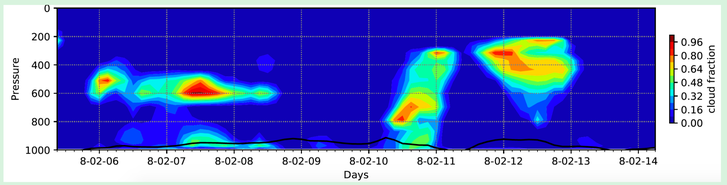
BACKTRACK corresponding air parcels

Using NOAA's HYSPLIT trajectory software, trace corresponding air columns back in time



ANALYZE cloudiness and radiative forcing

Create time series for air column along trajectory of:
- surface temperature
- downward longwave radiation at surface
- anomaly temperature from climatology
- cloud radiative forcing
- cloud fraction



References

Pithan, F. et al. Arctic amplification dominated by temperature feedbacks in contemporary climate models. *Nature Geoscience* **7**, 181–184 (2014).

Cronin, T. W. et al. Low clouds suppress Arctic air formation and amplify high-latitude continental winter warming. *Proceedings of the National Academy of Sciences* **112**, 11490–11495 (Sept. 2015).

Hu, Z. et al. Suppression of Cold Weather Events over High-Latitude Continents in Warm Climates. *Journal of Climate* **31**, 9625–9640 (Oct. 2018).