School of Earth and Environment
INSTITUTE FOR CLIMATE & ATMOSPHERIC SCIENCE

UNIVERSITY OF LEEDS

The anatomy of summer temperature extremes on the Antarctic Peninsula in LESFMIP models

Will Dow[1]

Amanda Maycock[1], Andrew Ross[1], Ryan Williams[2], Tom Bracegirdle[2]
1 - University of Leeds
2 - British Antarctic Survey

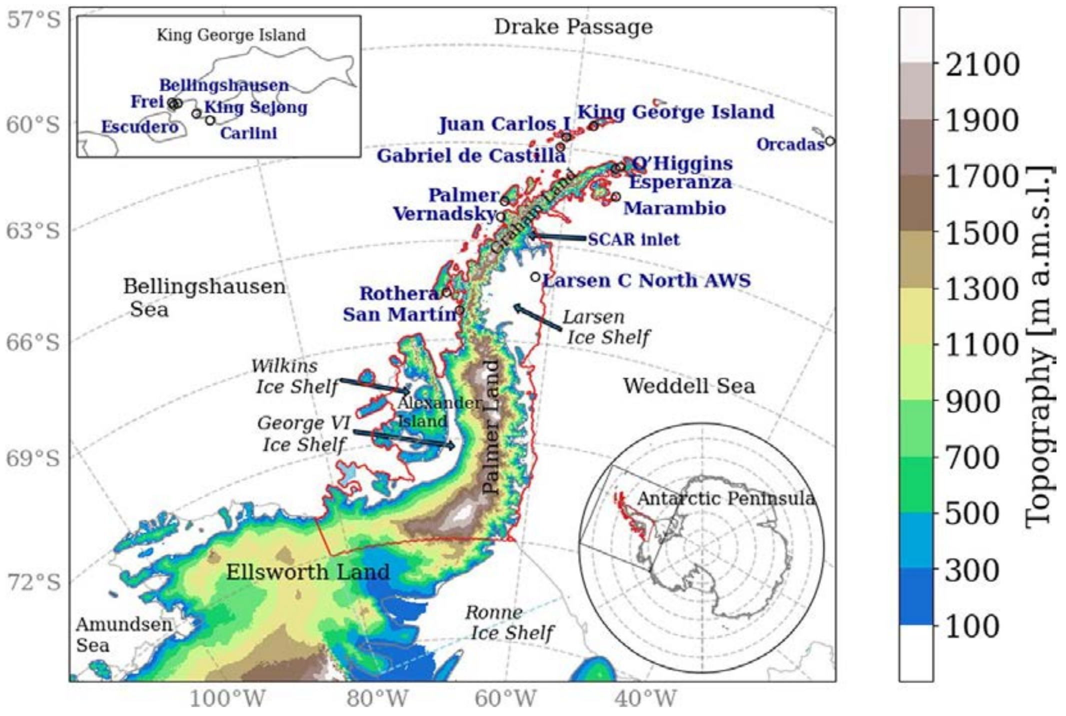
EPESC-LEADER Science Meeting
17 July 2025

Motivation

UNIVERSITY OF LEEDS

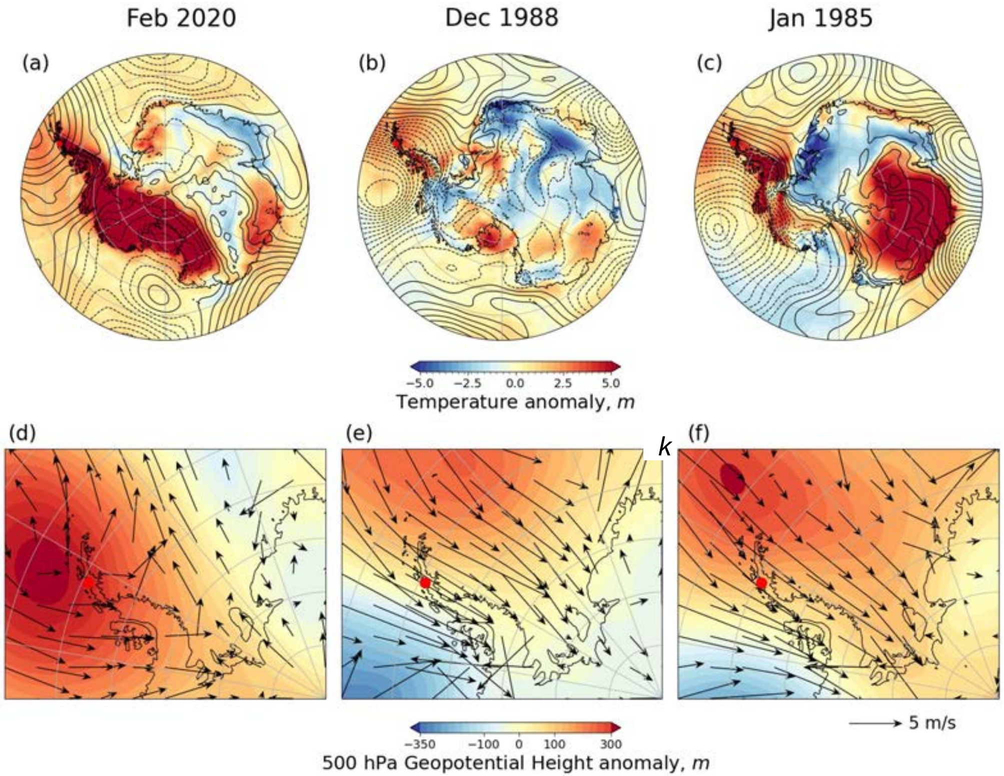
- The Antarctic Peninsula is one of the fastest warming regions in the Southern Hemisphere (e.g. Gorodestkaya et al. 2023; Turner et al. 2019).

- Annual warming trend since 1950s most pronounced in the northern and northwestern Peninsula:
  - Faraday–Vernadsky station annual mean trend: 0.46 °C ± 0.15 °C per decade (1951–2018)
  - Esperanza station annual trend: 0.29 °C ± 0.16 °C per decade (1957–2016)



Recent Antarctic warm extremes

UNIVERSITY OF LEEDS



New all-time temperature record over the continent observed on 6 February at Esperanza station (18.3 °C). The heatwave was widespread across the region from 6 to 11 February 2020.

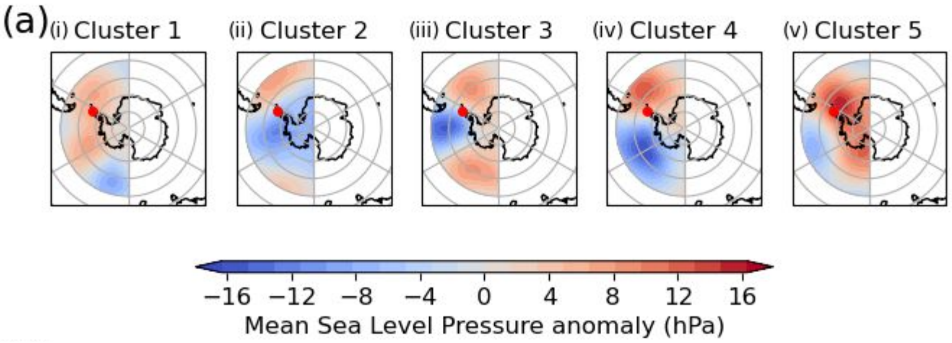
Recent warm extremes on the Antarctic Peninsula show distinct temperature anomaly and atmospheric circulation patterns → similar extremes can occur via a variety of synoptic situations.

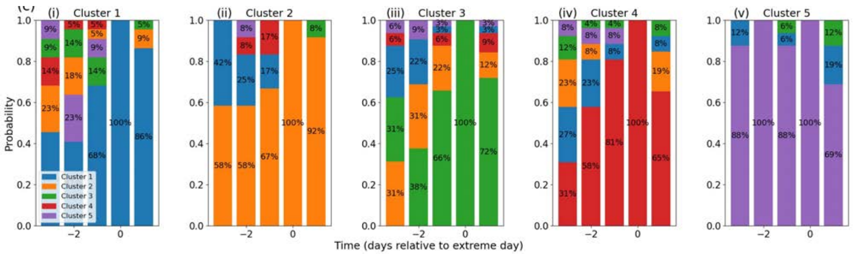
How can we characterise this diversity?

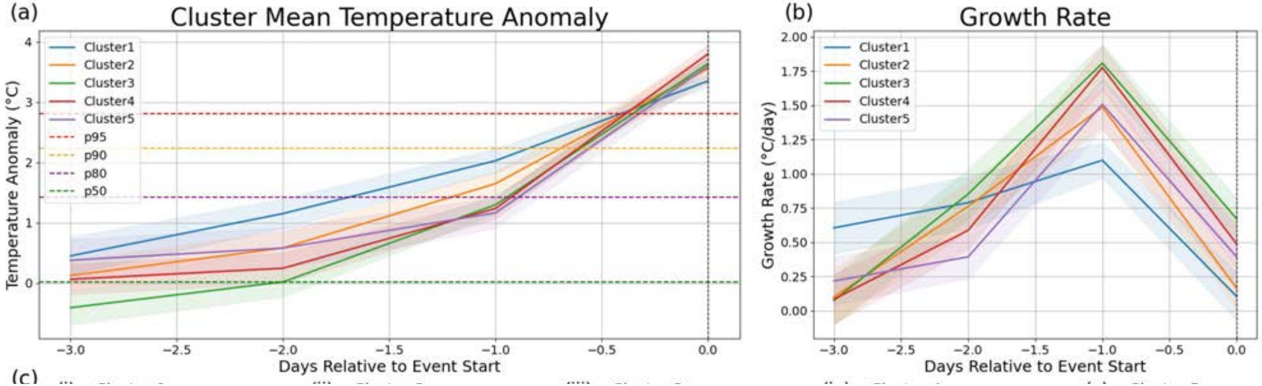
ERA5 analysis

UNIVERSITY OF LEEDS

K-Means Cluster Centroids



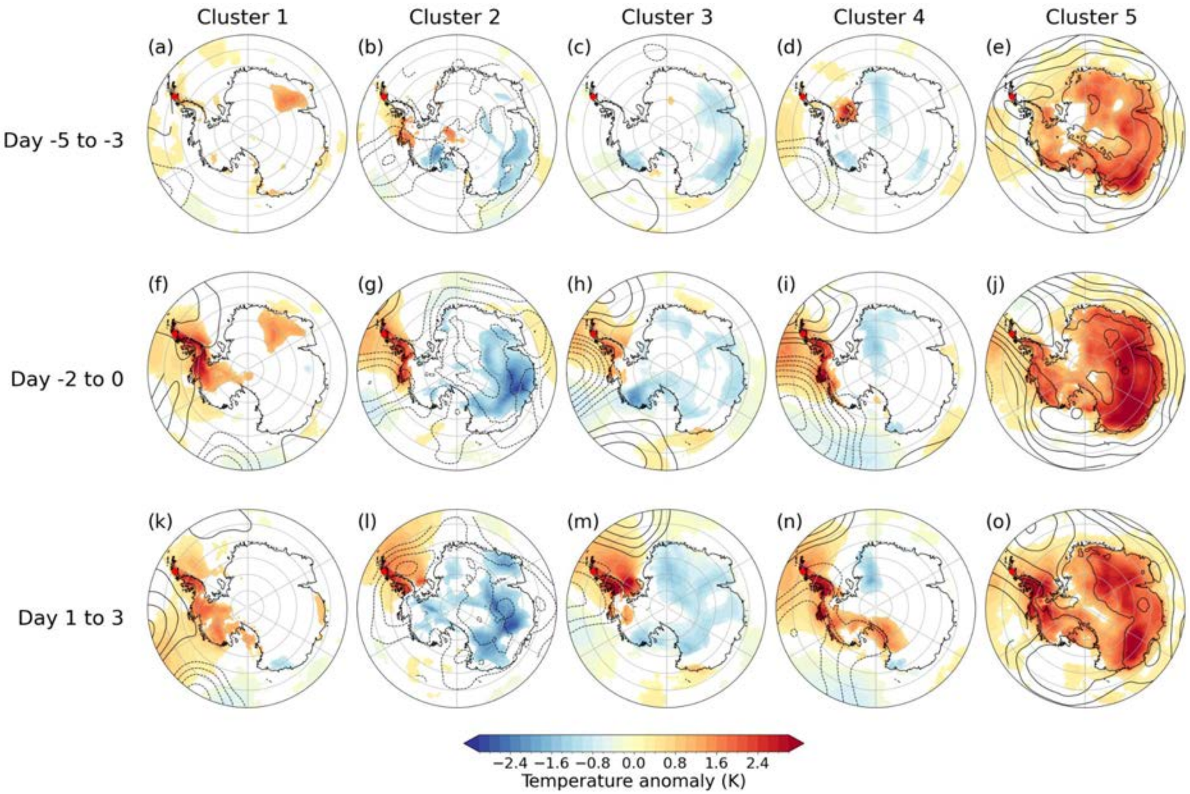




- Clustering of MSLP during Faraday/Vernadsky daily temperature extremes (DJF) identifies five distinct large-scale circulation patterns.
- Clusters show distinct patterns of near-surface temperature, wind and pressure and different persistence.

ERA5 analysis

UNIVERSITY OF LEEDS



- Clusters show distinct patterns of near-surface temperature, wind and pressure and different persistence.

LESFMIP analysis

UNIVERSITY OF LEEDS

- **Aim:** To better understand the evolution of extreme temperature events at the Antarctic Peninsula
- To improve our understanding of the role of different forcing agents in driving daily extreme temperature events through local circulation changes

Models, experiments and ensemble members included in current analysis

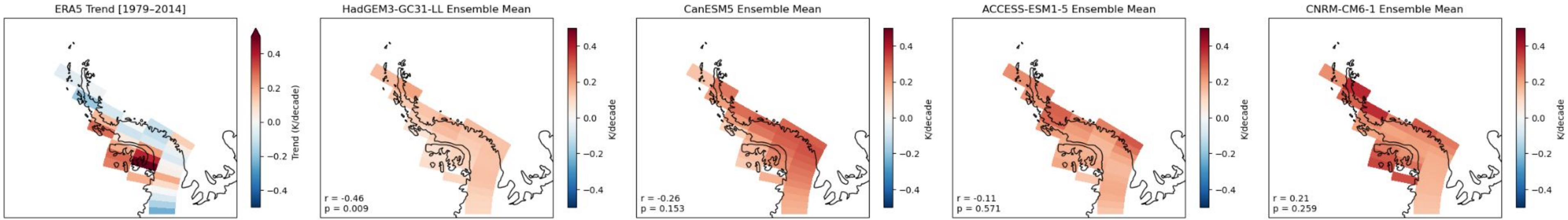
Daily data!

Model	Experiments			
	Historical	hist-GHG	hist-aer	hist-totalO3
	Members	Members	Members	Members
ACCESS-ESM1-5	r(1:40)i1p1f1 **(40)**	r(1:10)i1p1f1 **(10)**	r(1:10)i1p1f1 **(10)**	
CanESM5	r(1:25)i1p1f1+r(1:40)i1p2f1 **(65)**	r(1:25)i1p1f1+r(1:25)i1p2f1 **(50)**	r(1:15)i1p1f1+r(1:15)i1p2f1 **(30)**	r(1:10)i1p1f1 **(10)**
CMCC-CM2-SR5	r(2:11)i1p2f1 **(10)**	r(2:11)i1p1f1 **(10)**	r(2:11)i1p1f1 **(10)**	
CNRM-CM6-1	r(1:30)i1p1f2 **(30)**	r(1:10)i1p1f2 **(10)**	r(1:10)i1p1f2 **(10)**	
GISS-E2-1-G	r(1:20)p1f2 + r(1:20)p3f1 **(40)**	r(1:20)p1f2 + r(1:20)p3f1 **(40)**	r(1:20)p1f2 + r(1:20)p3f1 **(40)**	r(1:20)p1f2 + r(1:20)p3f1 **(40)**
HadGEM3GC31-LL	r(1:5)i1p1f3+r(11:60)i1p1f3 **(55)**	r(1:5)i1p1f3+r(11:60)i1p1f3 **(55)**	r(1:5)i1p1f3+r(11:60)i1p1f3 **(55)**	r(11:60)i1p1f3 **(50)**
IPSL-CM6A-LR	r(1:33)i1p1f1 **(33)**	r(1:10)i1p1f1 **(10)**	r(1:10)i1p1f1 **(10)**	
MIROC6	r(1:50)i1p1f1 **(50)**	r(1:50)i1p1f1 **(50)**	r(1:10)i1p1f1 **(10)**	r(1:10)i1p1f1 **(10)**
MPI-ESM1-2-LR	r(1:50)i1p1f1 **(50)**	r(1:30)i1p1f1 **(30)**	r(1:30)i1p1f1 **(30)**	r(1:30)i1p1f1 **(30)**
NorESM2-LM	r(1:43)i1p1f1 **(43)**	r(1:23)i1p1f1 **(23)**	r(1:23)i1p1f1 **(23)**	r(4:23)i1p1f1 **(20)**

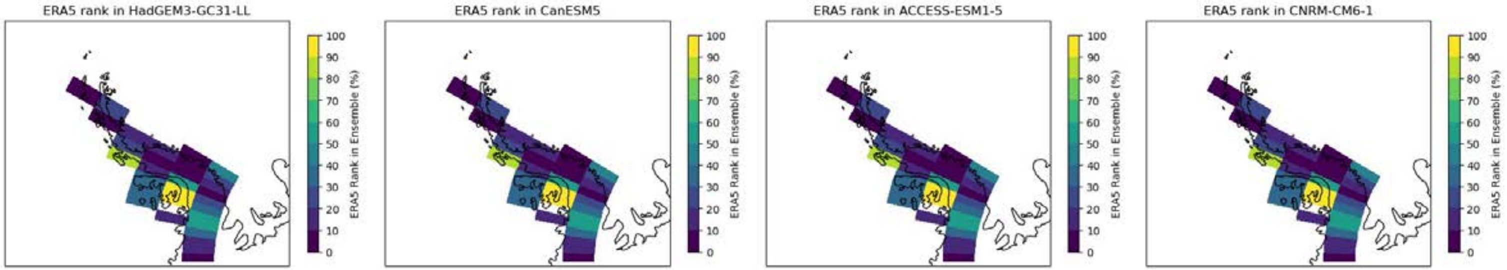
Near surface temperature trends (1979-2014, DJF)

UNIVERSITY OF LEEDS

ERA5 vs. LESFMIP models ensemble mean

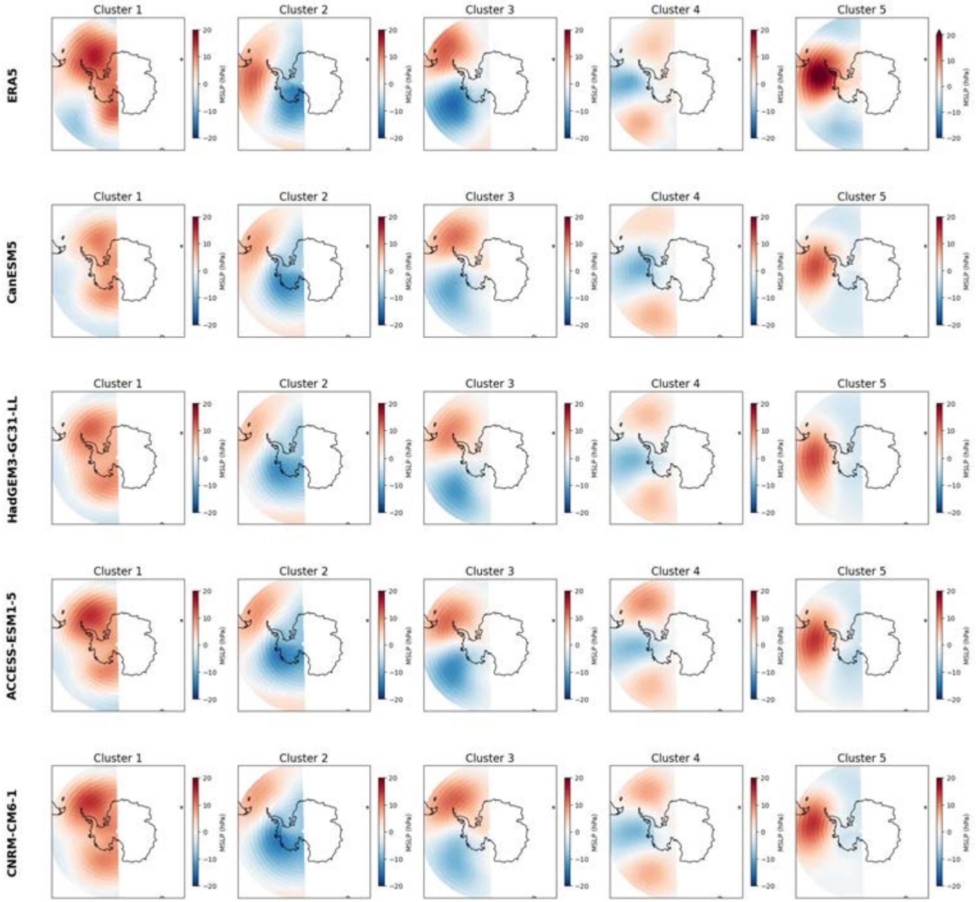


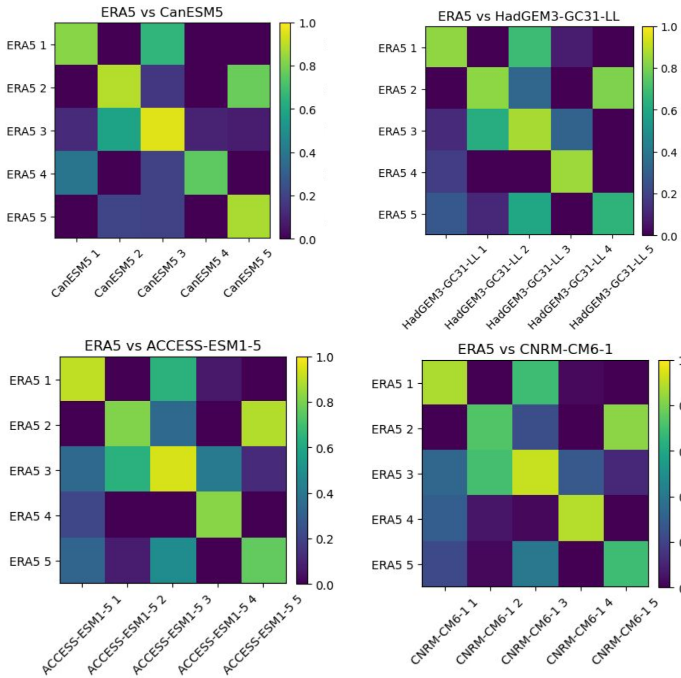
Rank of ERA5 trend within spread of ensemble members in LESFMIP models.



- Variable (positive and negative) trends across the Peninsula between 1979-2014 in ERA5.
- Ensemble mean in all models shows positive temperature trend across entire Peninsula.
- Model ensembles fail to capture trends on eastern Peninsula but do a better job on the western side.

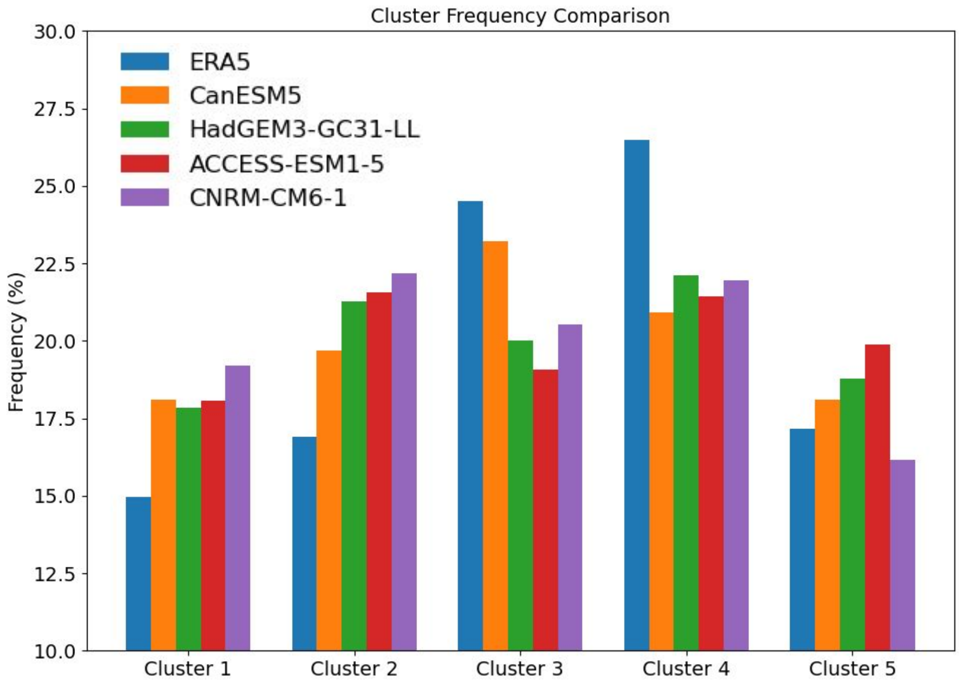
Cluster centroid comparison





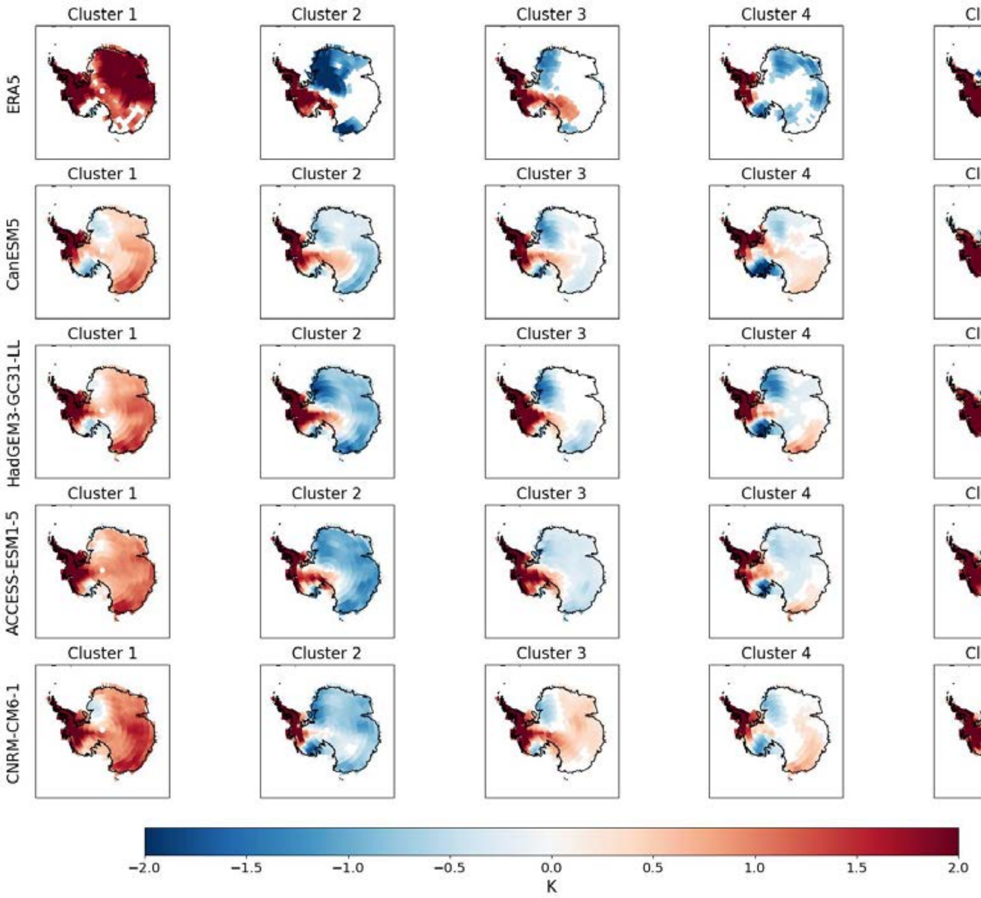
- All models capture the 5 cluster centroids in ERA5
- Spatially consistent although differences in magnitude and spatial correlation across models

Frequency of clusters across ensembles



- Although spatially consistent, there is some difference in the relative frequency of each cluster across models
- What is the cause of this? Due to model biases in representing teleconnections? Representation of SAM, ZW3?

Near surface temperature composites

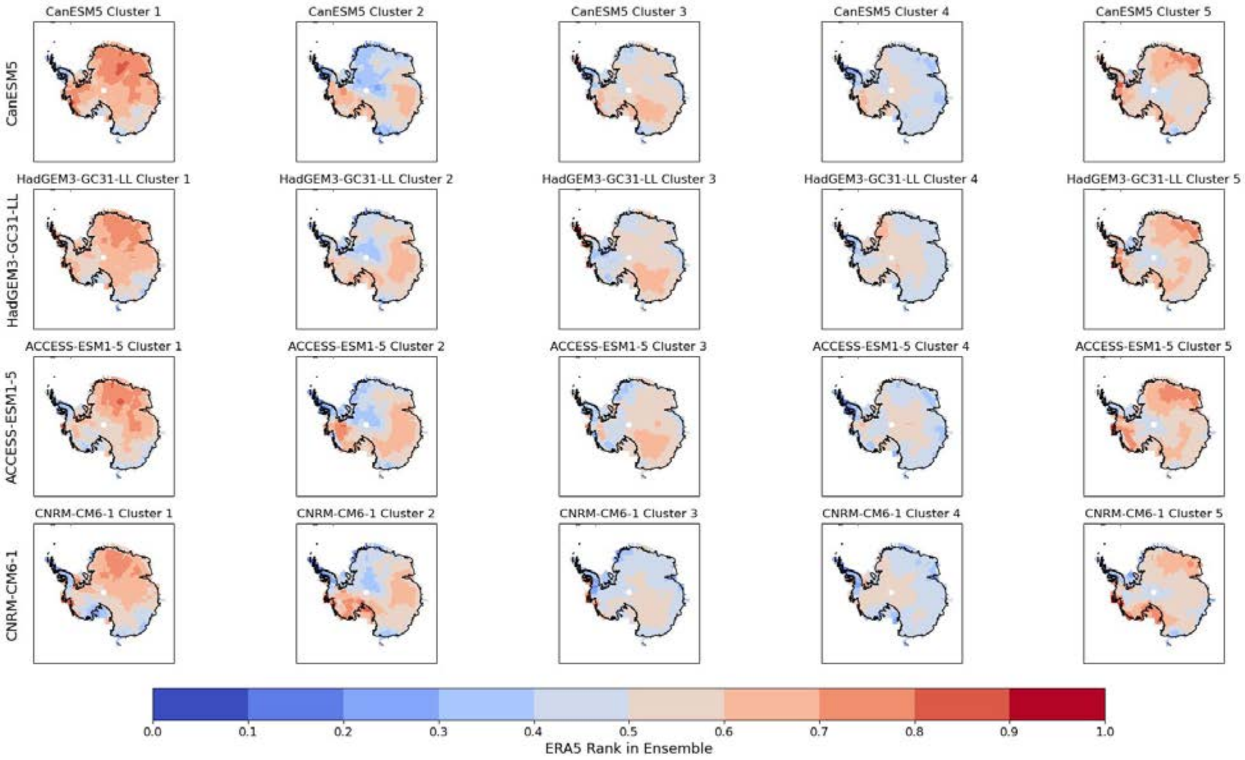


Temperature anomalies associated with p95 events in each cluster

- Widespread continental warming associated with Cluster 1 in ERA5 and across models
- Cooling across northern Antarctica associated with cluster 2 in ERA5 and models (not as significant in CanESM5)
- Variability in model response in Cluster 3 events across East Antarctica (Warming: CNRM-CM6-1; Cooling: ACCESS-ESM1-5) with no significant response in ERA5 and HadGEM3-GC31-LL)
- Strong warming extends across Ross Sea into SE Antarctica across all Cluster 5 models and ERA5

Ensemble spread across clusters

UNIVERSITY OF LEEDS



Rank of ERA5 within the ensemble spread by cluster

- Widespread high rank of ERA5 across models in cluster 1 across much of the continent.
- Dipole feature across all models for cluster 2 (North central Antarctica - East Antarctica), showing low - high ERA5 rank within all model ensemble spreads
- ERA5 lies towards the upper end of the ensemble spread for all models across Cluster 5 in North east Antarctica
- ERA5 lies within the model ensemble members across all models and clusters

Summary

UNIVERSITY OF LEEDS

1. Work builds upon ERA5 analysis on extreme temperature events at the Antarctic Peninsula which classified events into 5 clusters based on MSLP - where clusters show distinct patterns of near-surface temperature, wind and pressure and different persistence
2. Models struggle to capture DJF temperature trend on eastern side of the Peninsula, better on the western side. Models analysed here have strong positive trends over whole Antarctic continent during DJF
3. Cluster centroids defined in ERA5 represented in the LE models, their relative frequency differs across models
4. Temperature composites broadly captured by the model ensemble means with reanalysis data falling within the ensemble spread

Next steps:

1. Extend analysis to all models! - historical simulations
2. Repeat analysis with single forcing experiments to assess the role of external forcing on local circulation driving extreme events