Models and observations agree on strong reductions of midlatitude cold extremes

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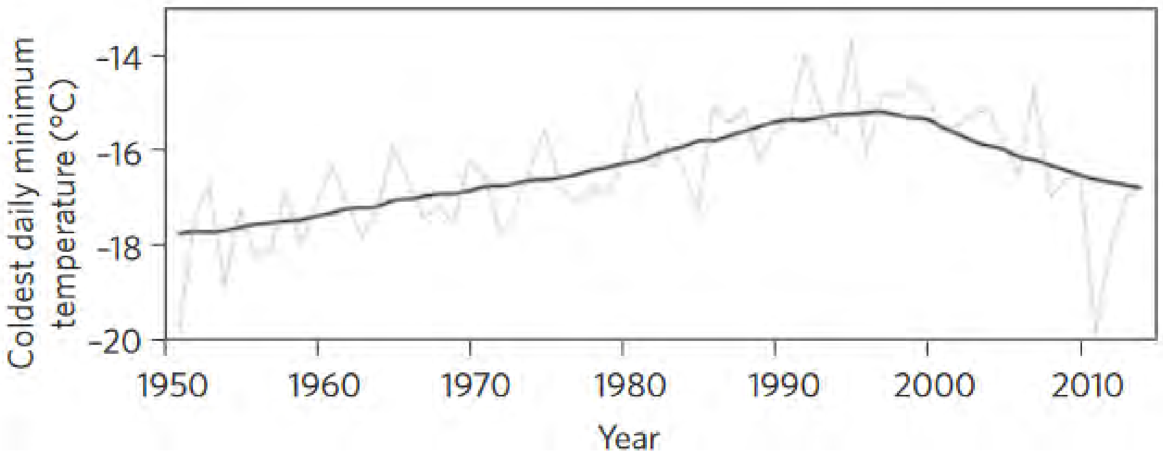
Motivation

- Long-term trends and model projections show a robust decrease in frequency and intensity of cold extremes over the midlatitudes (e.g. IPCC AR6)
- However, some studies have suggested that midlatitude cold extremes have become more intense over the recent period of strong Arctic warming, diverging from climate models



Cohen et al. 2014, *Nature Geoscience*

- This apparent increase in cold extremes has been attributed by some to Arctic warming-induced changes in the jet stream and/or polar vortex, that models poorly capture

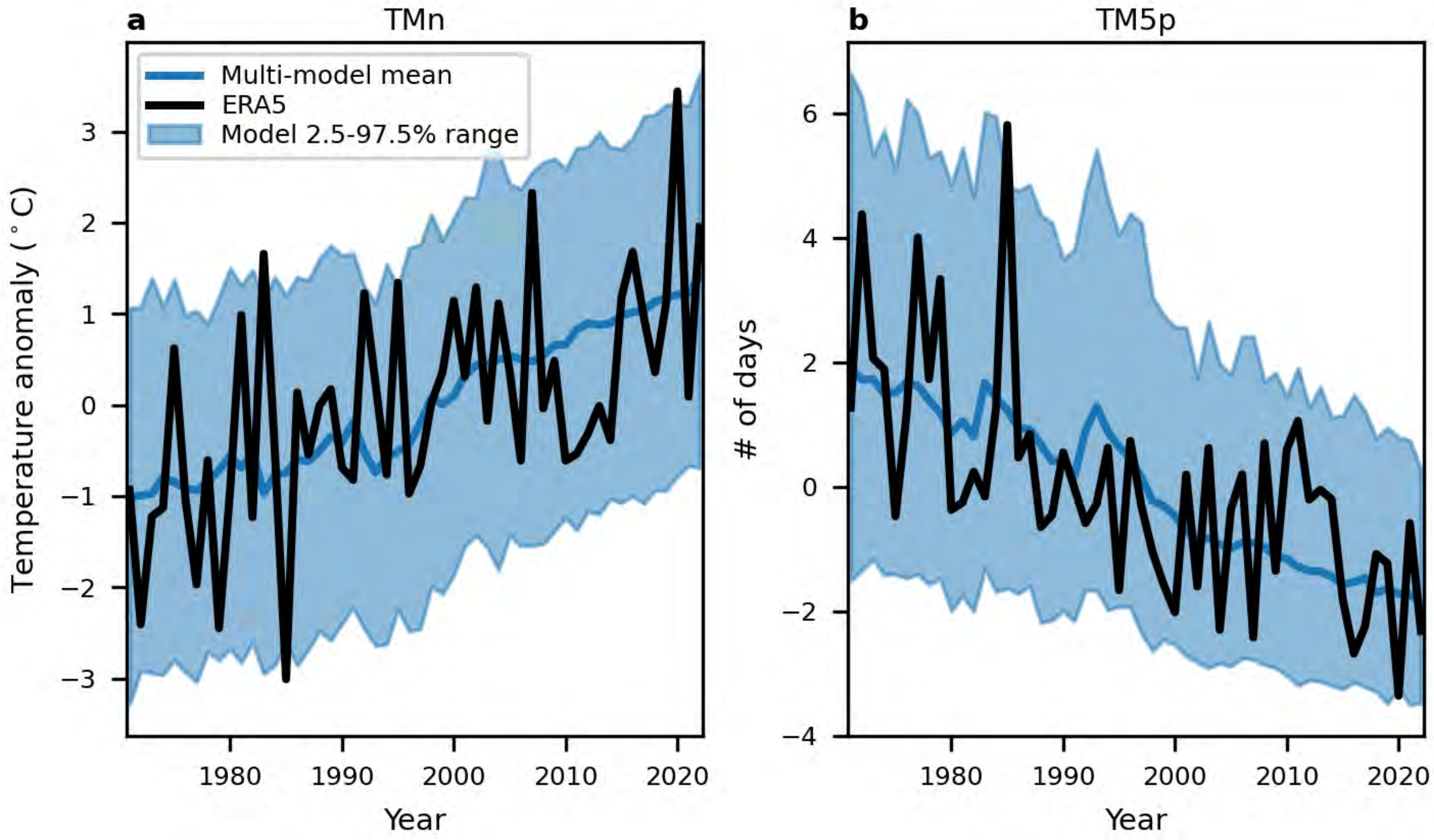
This study

We search for evidence of a model-observation discrepancy in midlatitude cold extreme trends by directly comparing observations to large ensemble climate model simulations

Data and metrics

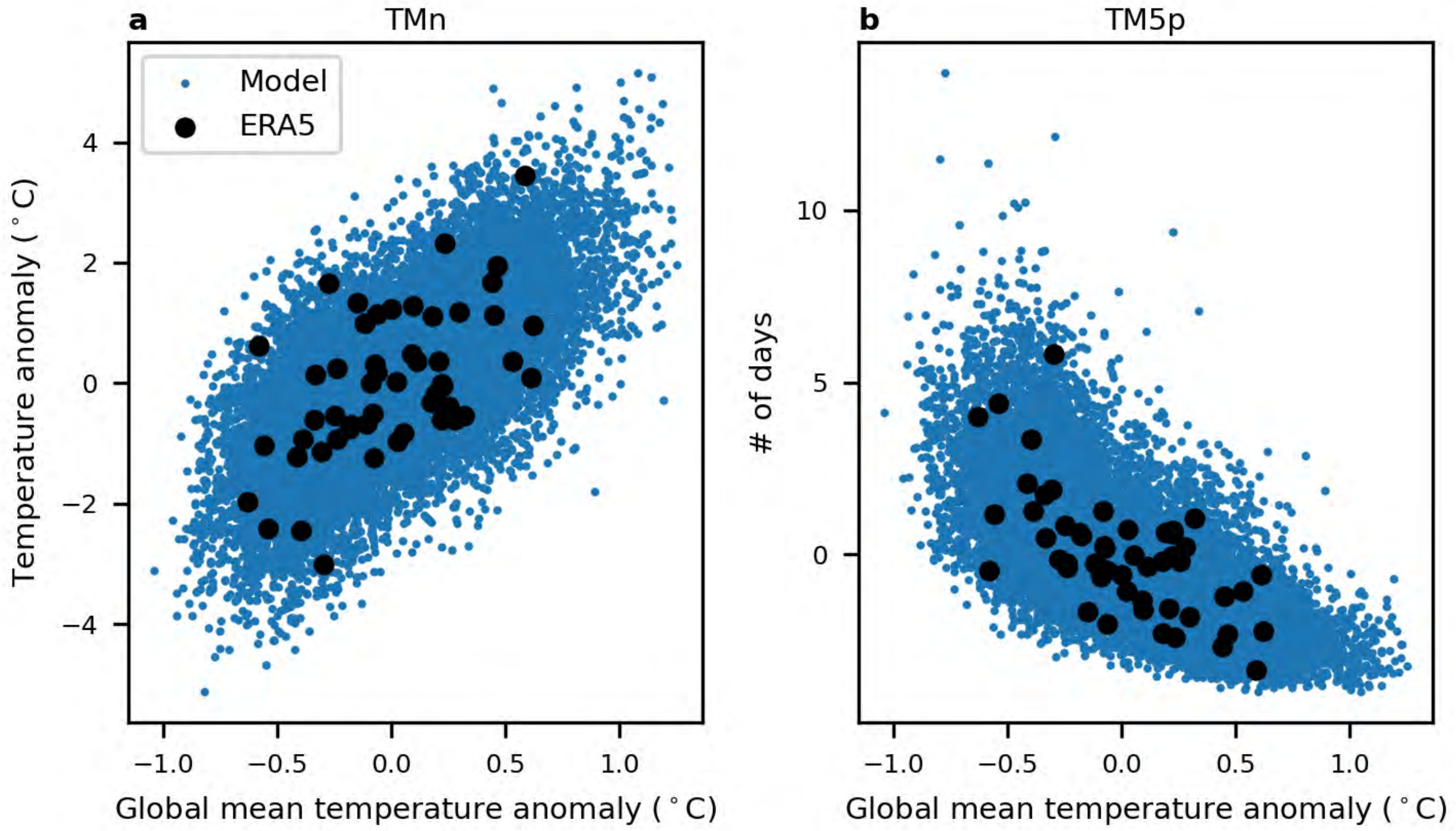
- “Observations”: ERA5 reanalysis
- Models: Historical + ssp simulations from 7 single model, initial condition, large ensembles
  - CanESM5, ACCESS-ESM1-5, CESM2, EC-Earth3, GFDL-SPEAR-MED, MIROC6, MPI-ESM1-2-LR
- Metrics:
  - TMn - minimum daily average temperature in each winter (DJF)
  - TM5p - number of days in each winter that the daily average temperature is below the 5th percentile
- To account for biases in global warming trends, we rescale the model results by the ratio of global warming trends in observations to that found in the model
- We focus on the 1990-2022 period, but we also look at 1971-2022 for the longer-term context
- Land only, 30-60°N

Observed vs modelled time series



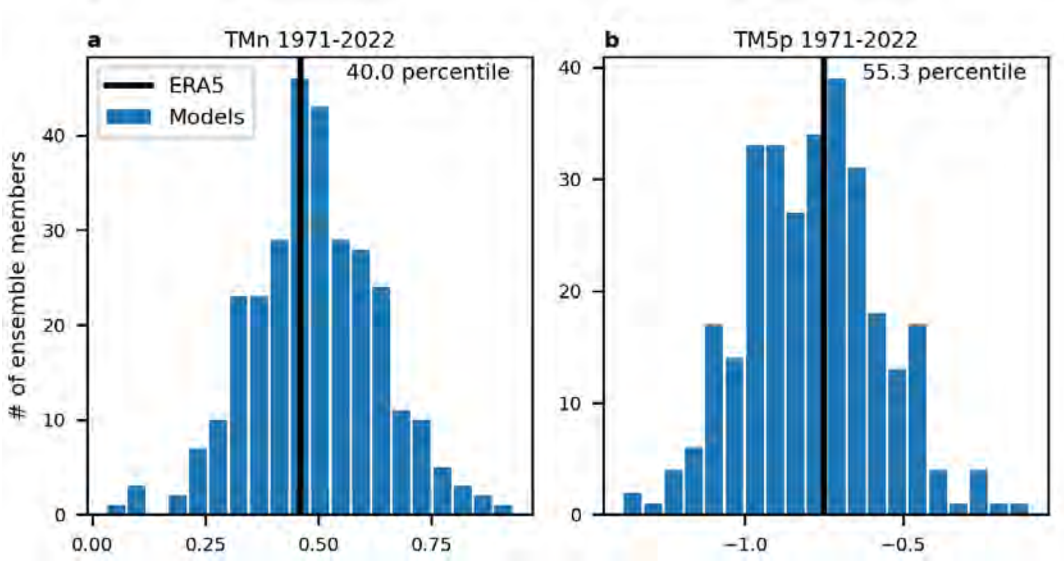
- Observations show decreases in intensity and frequency of midlatitude cold extremes that are well within model spread

Cold extremes vs global mean temperature



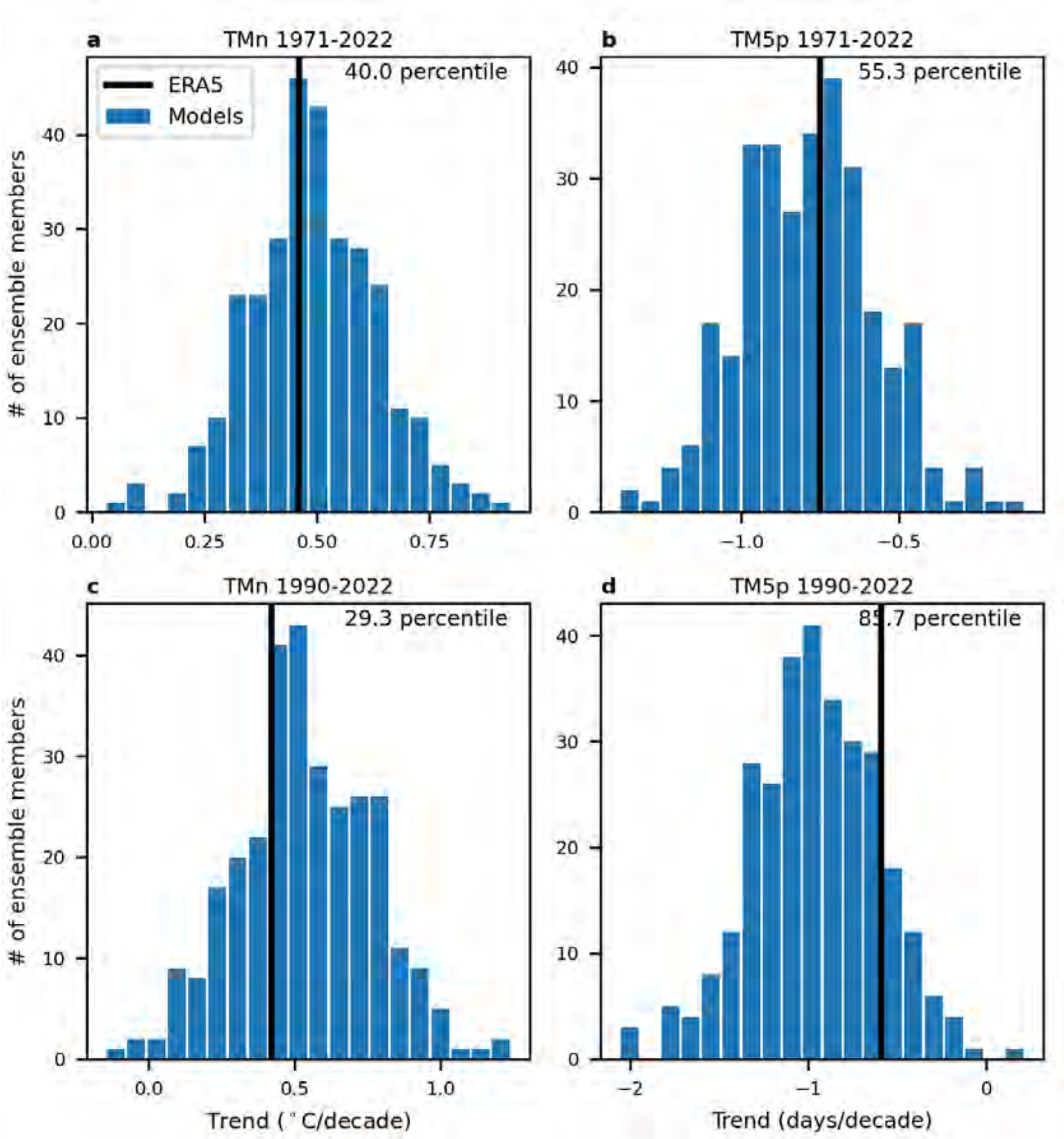
- Observations show decreases in intensity and frequency of midlatitude cold extremes with increasing global mean temperature, in agreement with models

Observed vs modelled trends



- Longer-term observed trends are in the middle of the ensemble spread

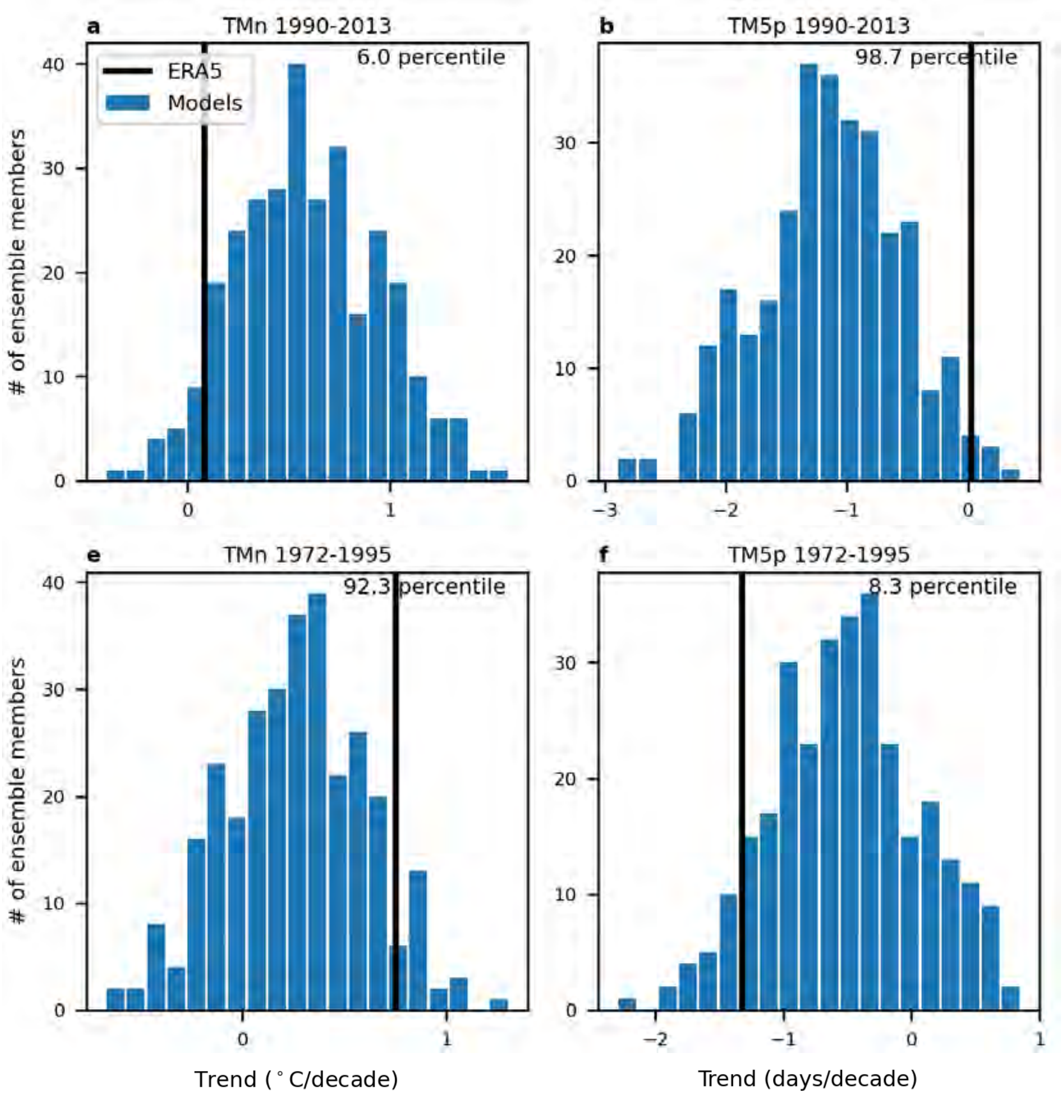
Observed vs modelled trends



- Longer-term observed trends are in the middle of the ensemble spread

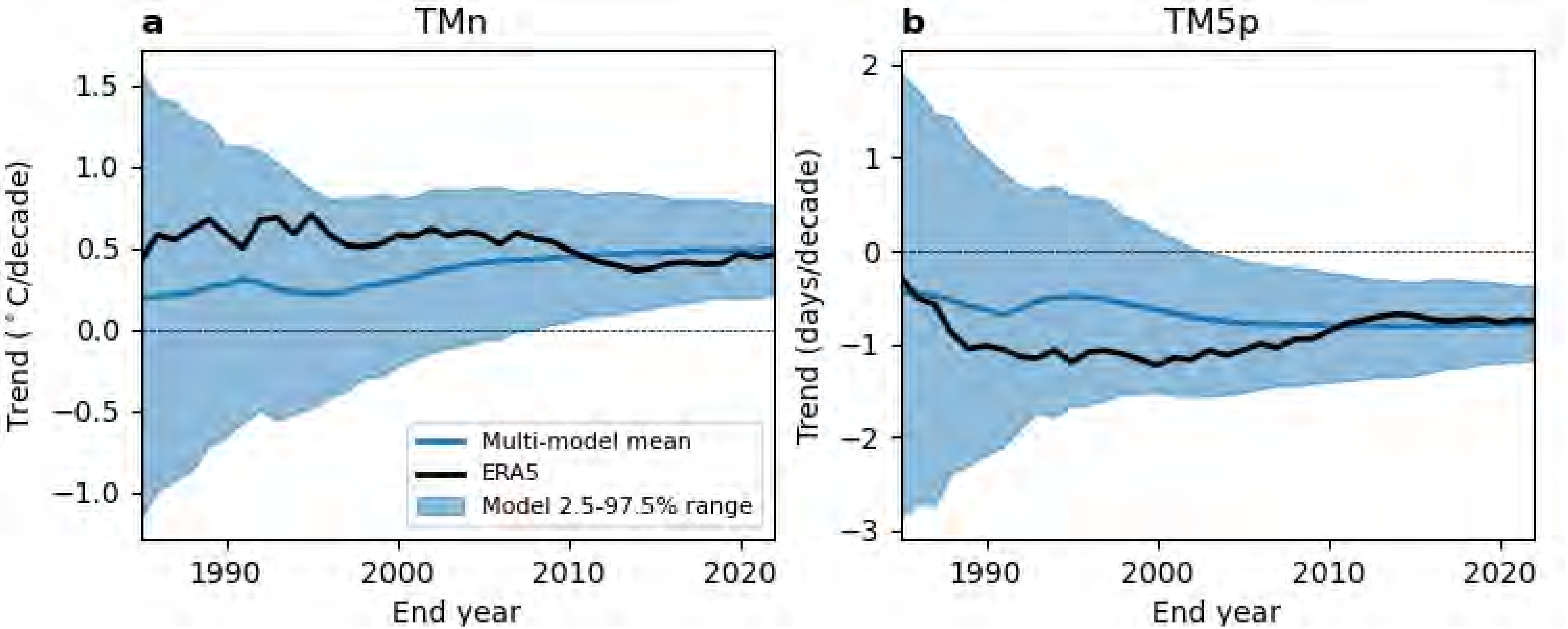
- Observed trends since 1990 are weaker than the model mean trends, but well within the ensemble spread

Extreme observed vs modelled trends



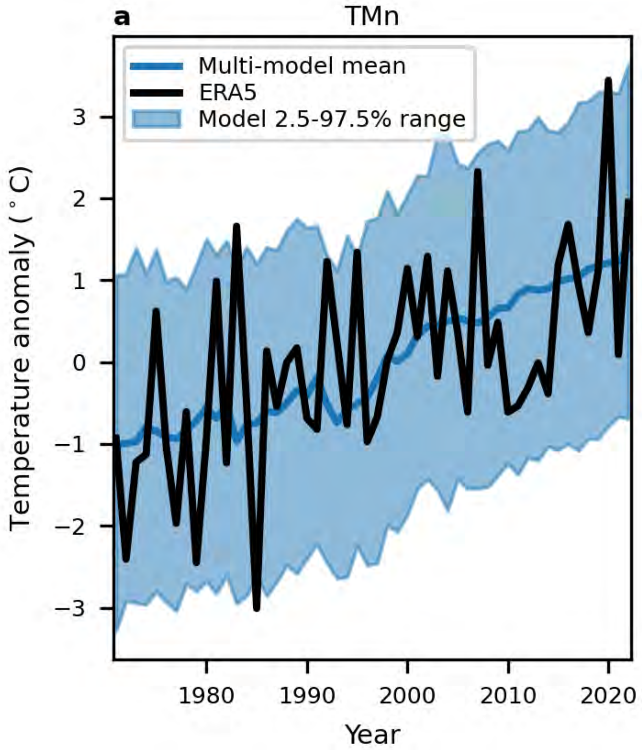
- "Cherrypicked" extreme trends are within the ensemble spread, but more on the extreme end, as expected

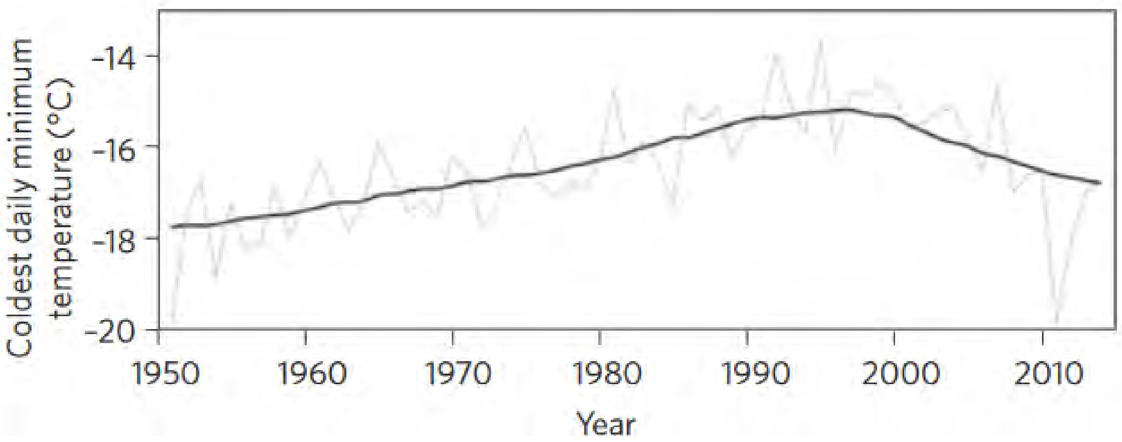
Impact of increasing trend length



- The magnitude of observed trend has converged towards the model mean with increasing trend length

Are cold extremes warming or cooling?

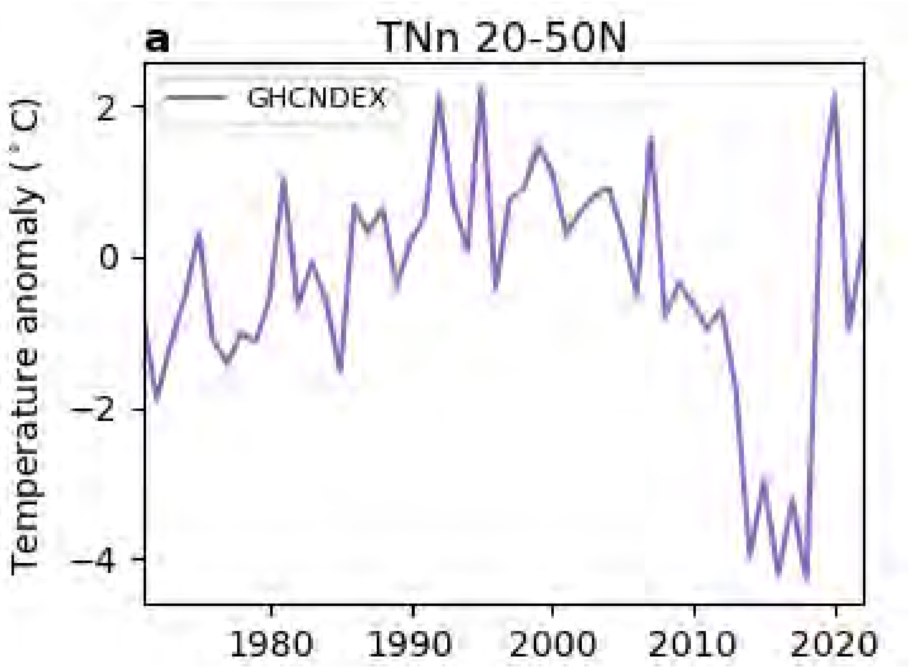




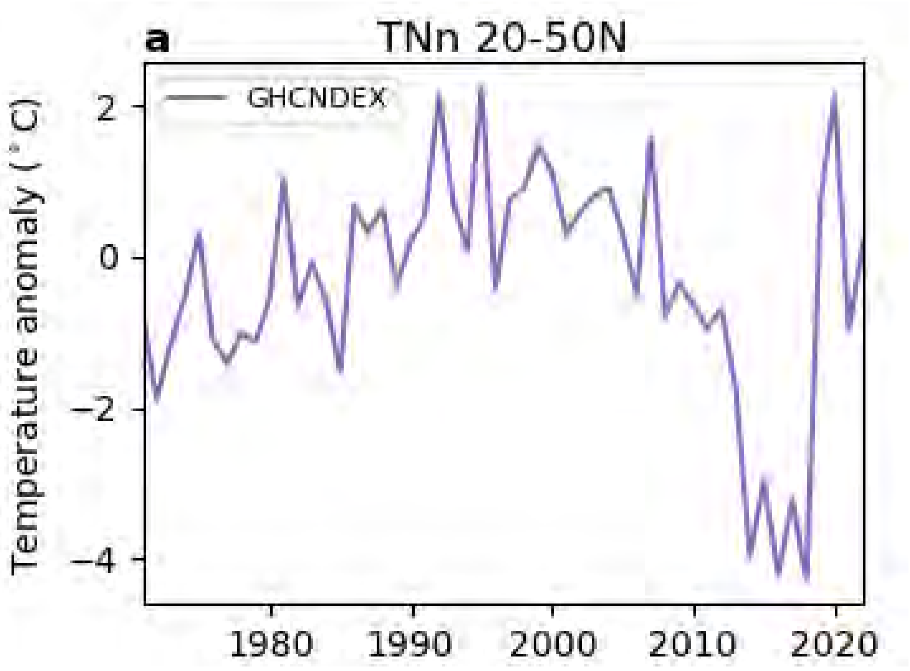
Cohen et al. 2014, *Nature Geoscience*

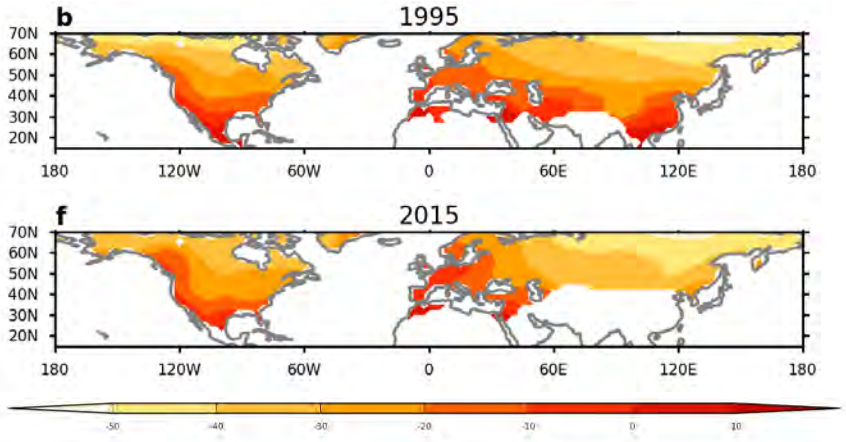
- How can we reconcile the decrease in intensity (warming of extreme cold) we find over recent decades with the increase in intensity previously found in Cohen et al. 2014?

GHCNDEX midlatitude cold extremes

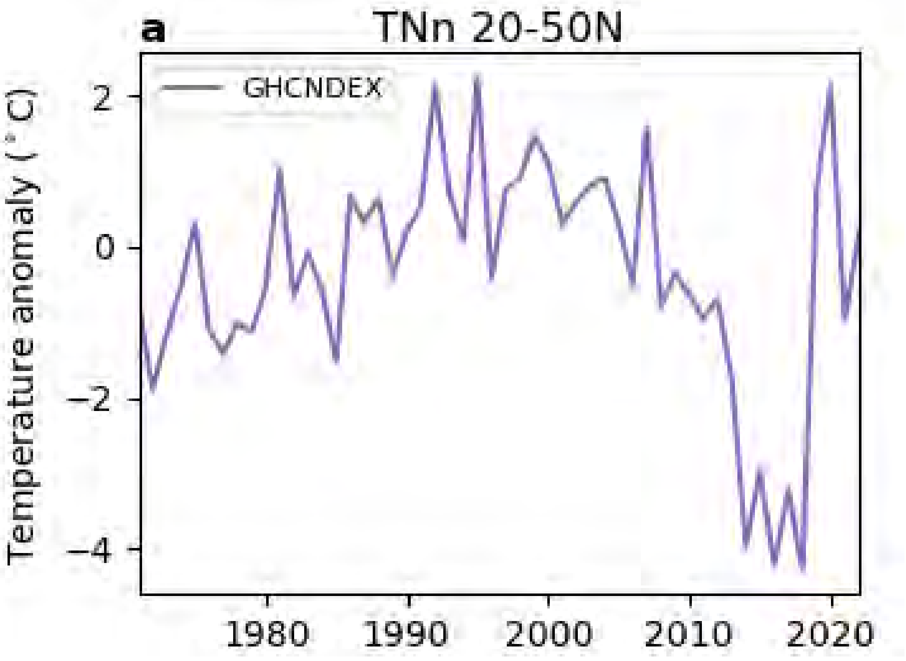


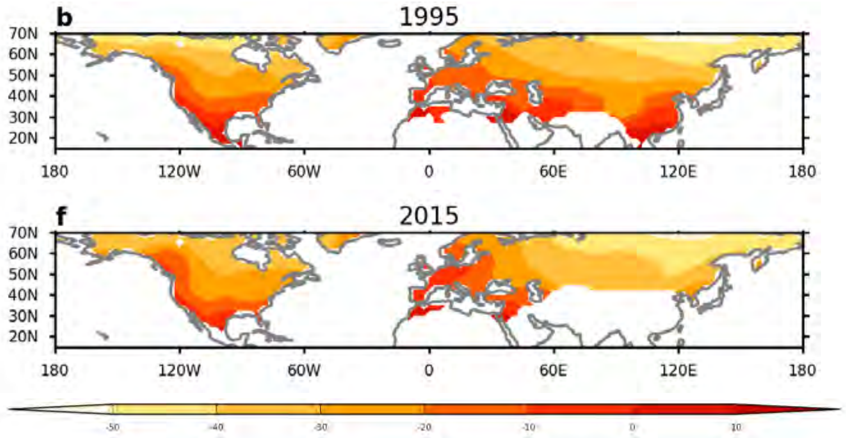
GHCNDEX midlatitude cold extremes

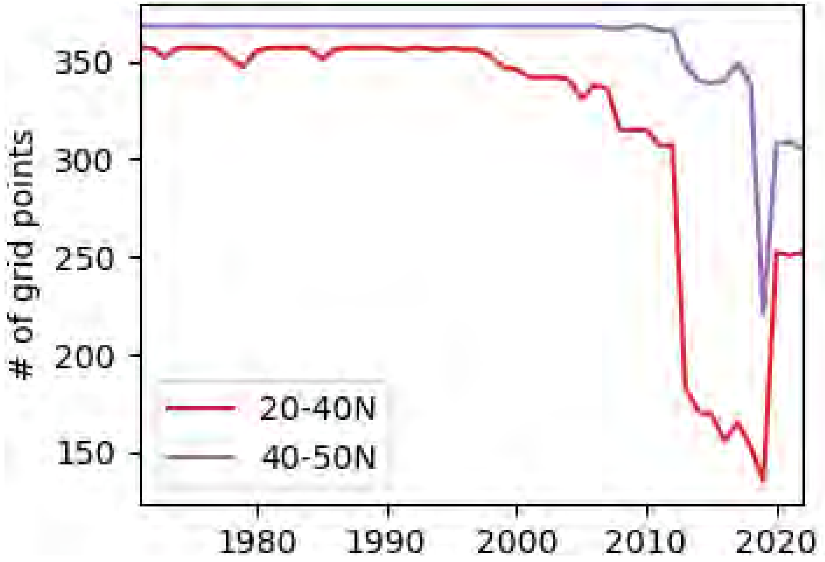




GHCNDEX midlatitude cold extremes

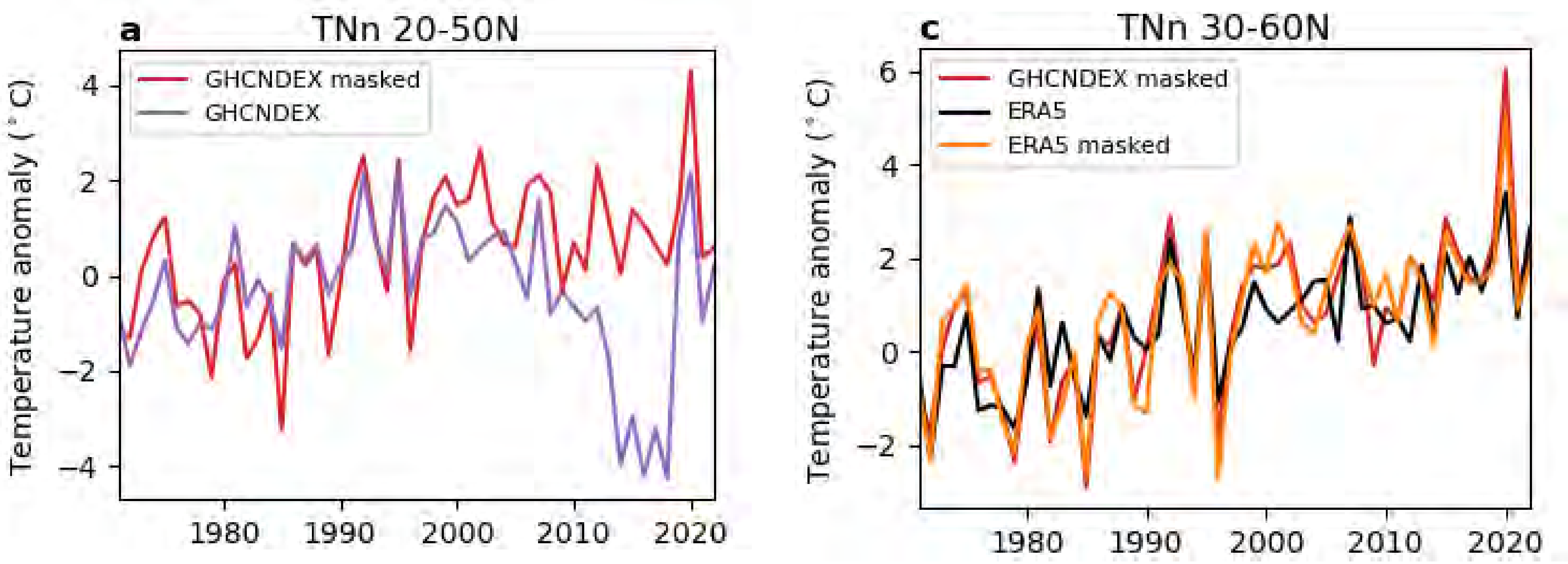






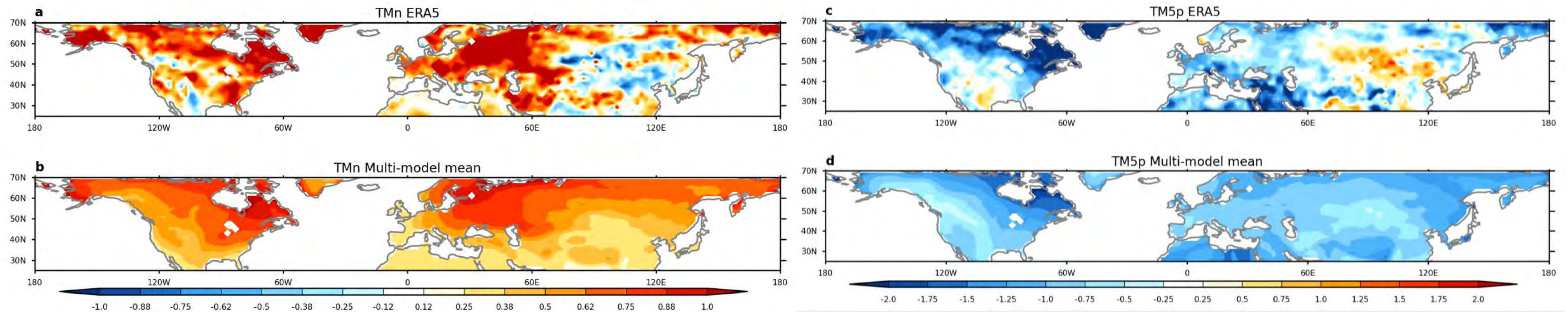
- GHCNDEX time series shows a rapid cooling of extreme cold temperature followed by a rapid warming that coincided with changes in spatial coverage of the data

Masked GHCNDEX time series



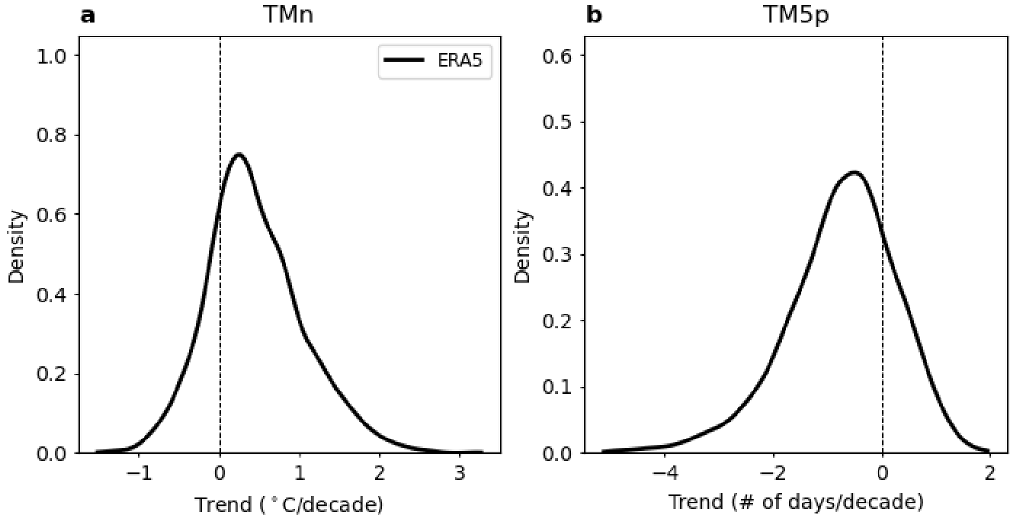
- The decrease in temperature disappears when an appropriate mask is applied to the data

Spatial distribution of trends (1990-2022)

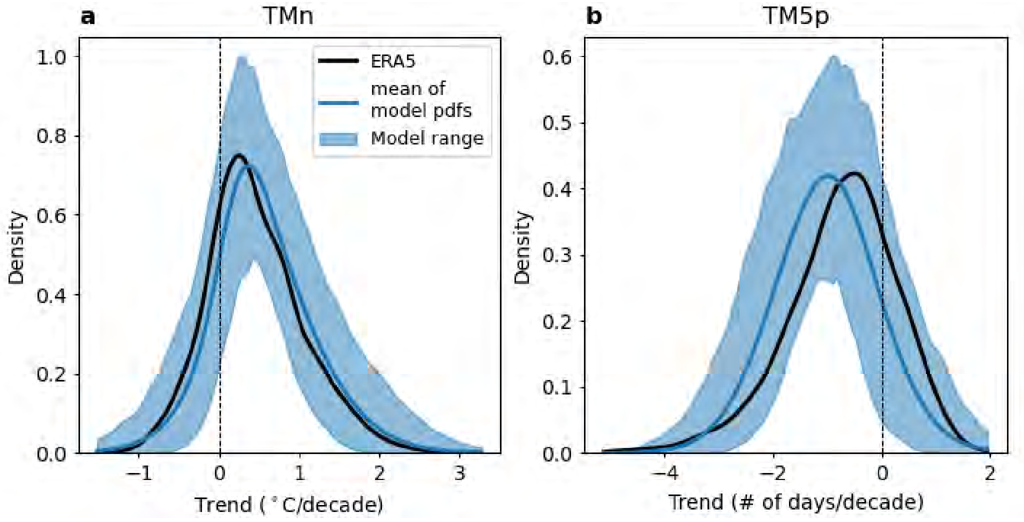


- Observed trends show some regions (primarily central and eastern Asia) with weak increases in cold extremes
- Is this consistent with what is expected from models?

Spatial PDFs (1990-2022)

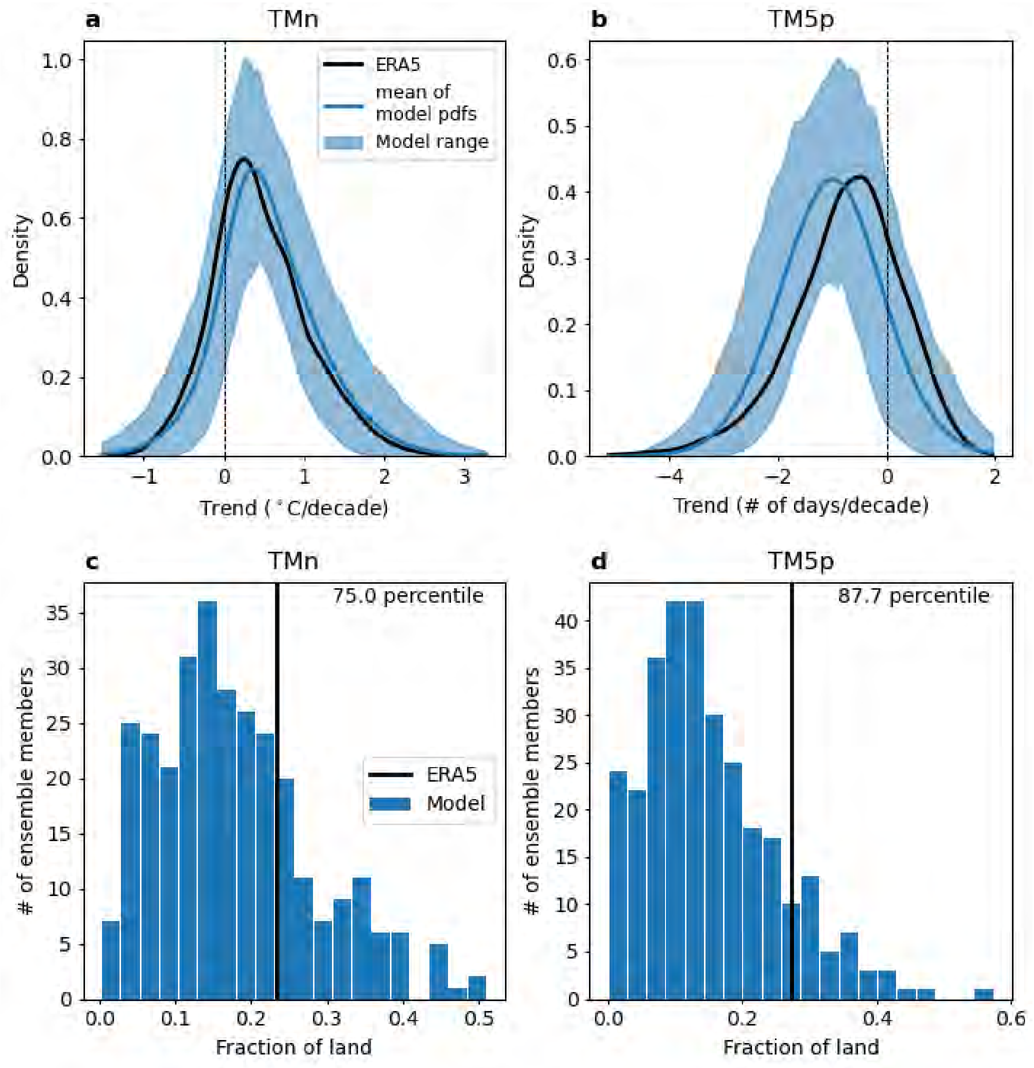


Spatial PDFs (1990-2022)



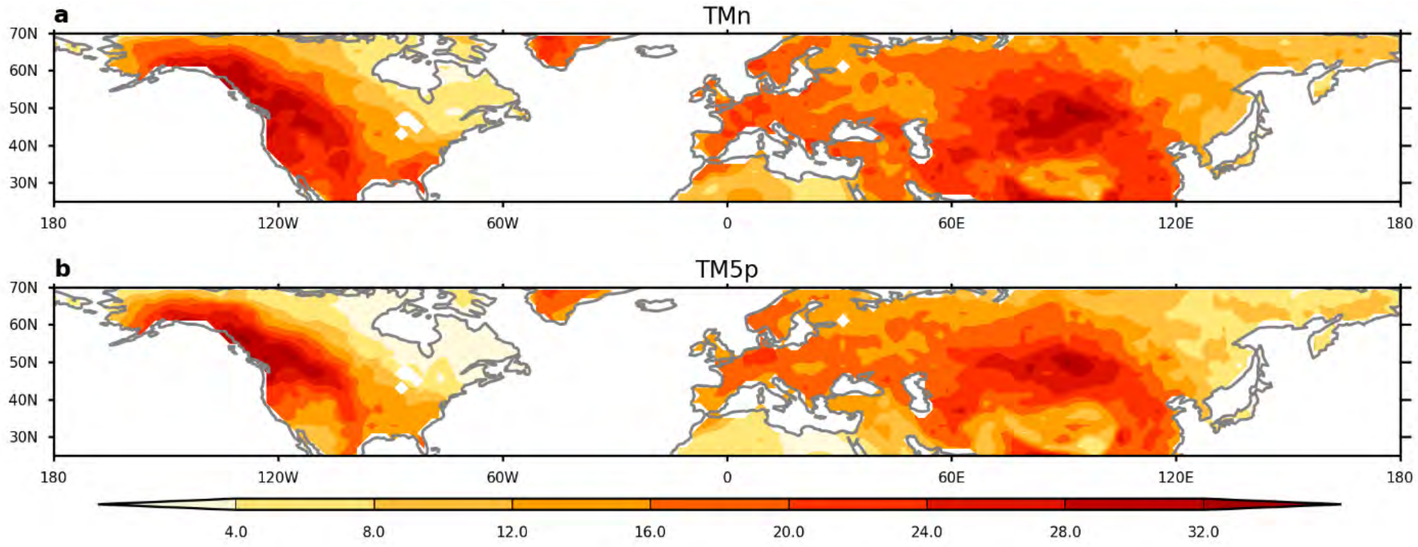
- PDFs of the trends at each midlatitude grid point are consistent between models and observations

Spatial PDFs (1990-2022)



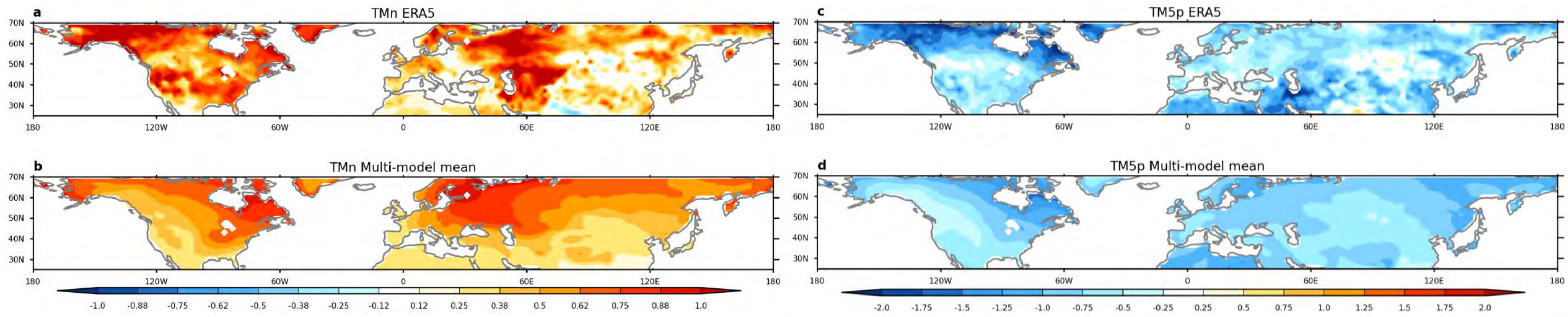
- PDFs of the trends at each midlatitude grid point are consistent between models and observations
- Fraction of land with increases in cold extremes in observations is within expected range from the models

Probability of seeing an increase in cold extremes over 1990-2022



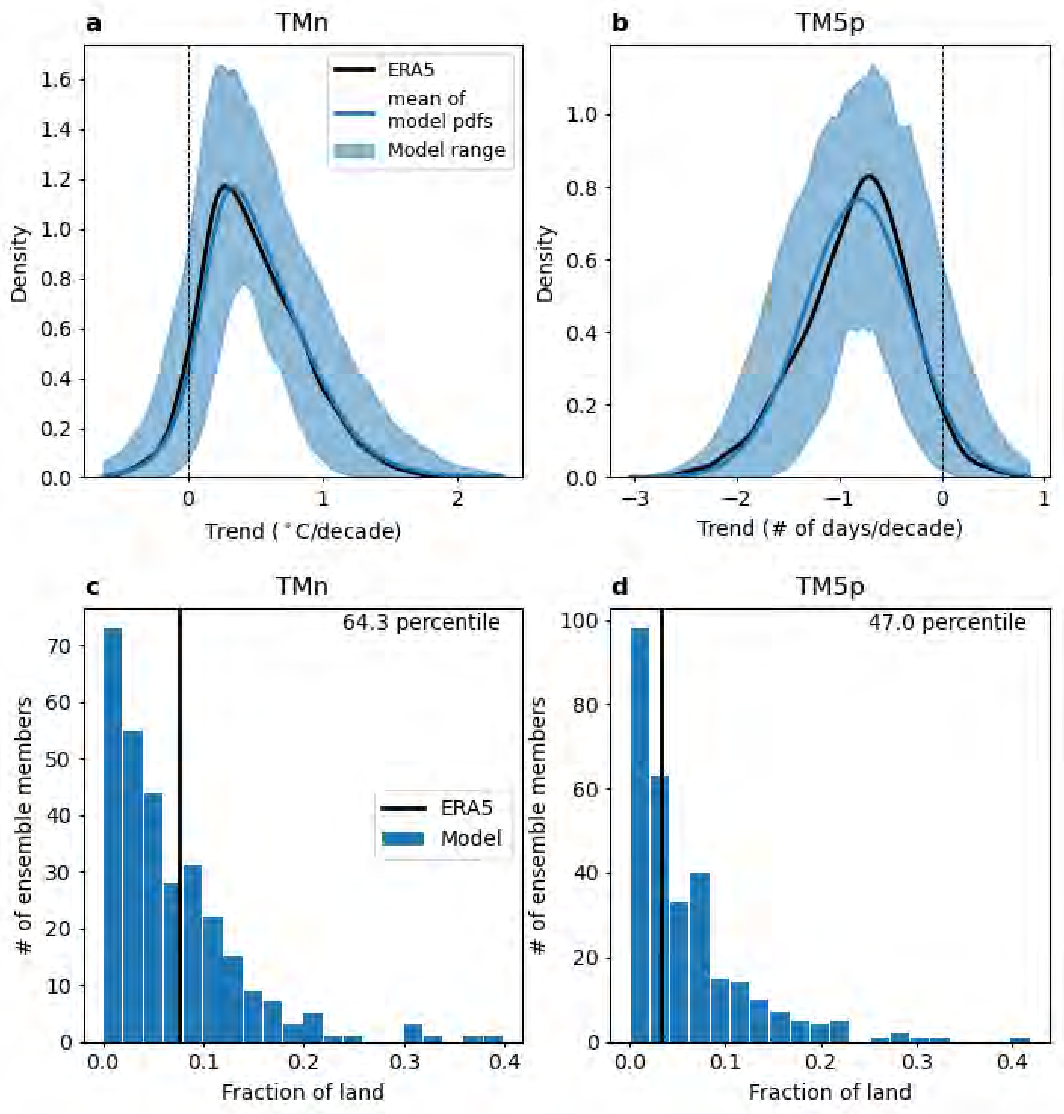
- Increases in cold extremes can occur anywhere over the midlatitudes

Spatial distribution of trends (1971-2022)



- Longer-term observed trends show more spatially uniform decreases in cold extremes

Spatial PDFs (1971-2022)



- PDFs of longer-term trends show even better agreement between models and observations

Conclusions

- Midlatitude cold extremes have decreased in intensity and frequency even over the recent period of rapid Arctic warming, in agreement with models

- While some regions show an increase in cold extremes over recent decades, the spatial distribution of trends are consistent with modelled internal variability on top of a forced, near-uniform decrease across the midlatitudes

- Overall, we find no evidence of a model-observation discrepancy in midlatitude cold extreme trends, even over recent decades

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