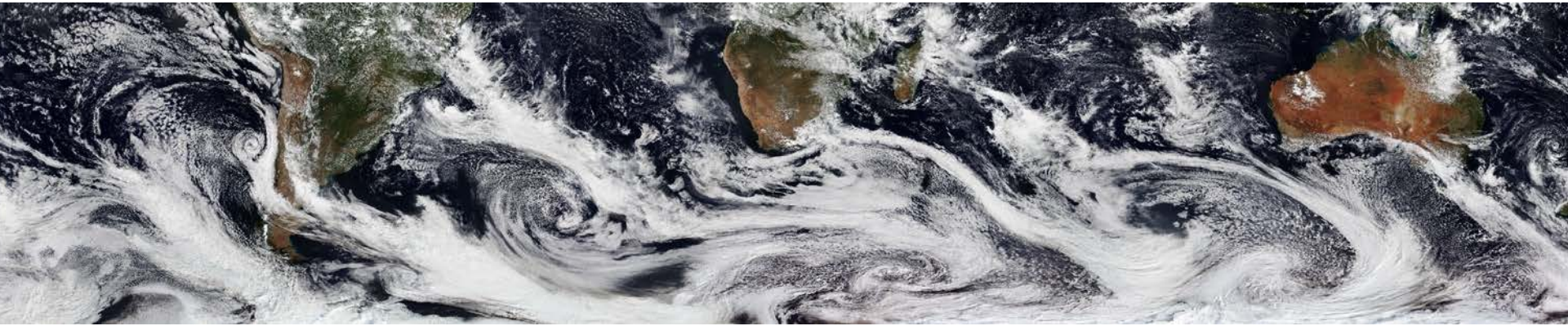
Targeted large-ensemble simulations for elucidating model-reanalysis discrepancies in storm track trends

Collaborators:
Dim Coumou (VU Amserdam), Janni Yuval (Google) and Yi Ming (Boston College)



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Similar results in older CMIP generations: O'Gorman 2010, Chang et al., 2012, Coumou et al. 2015

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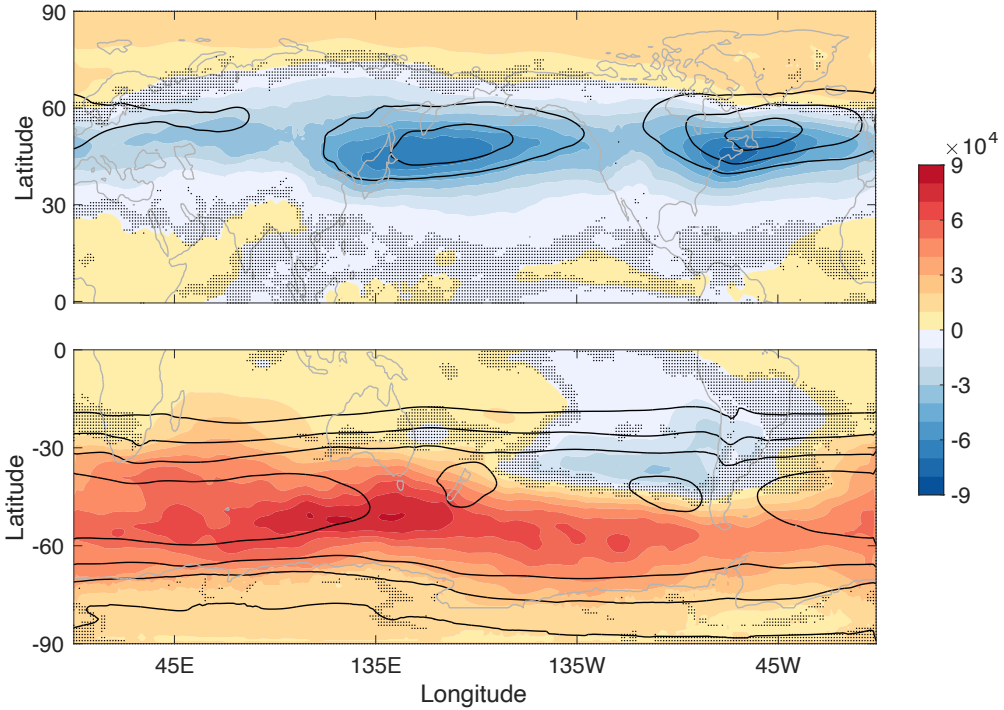
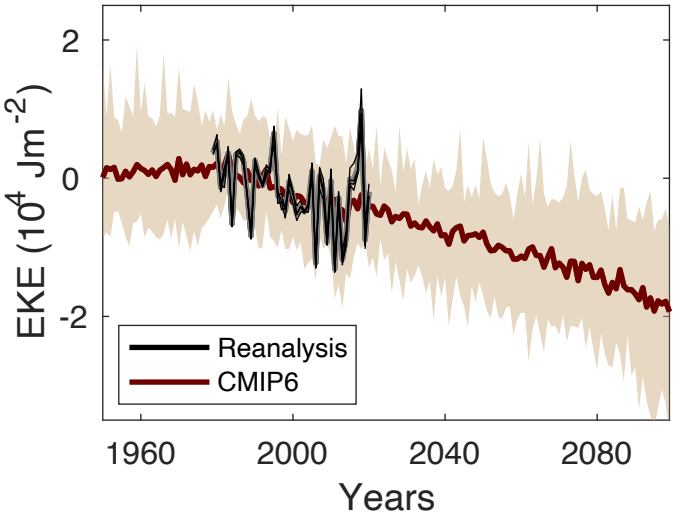


CMIP6 models adequately reproduce the historic downward trends of the boreal summer storm track

- The strom track in reanalyses (ERA5, JRA55, NCEP2 and MERRA2) has weakened by ~6% since 1979
- CMIP6 models project a decline in EKE of ~25% by the end of this century



Chemke and Coumou, npj Climate Atmos. Sci., 2024

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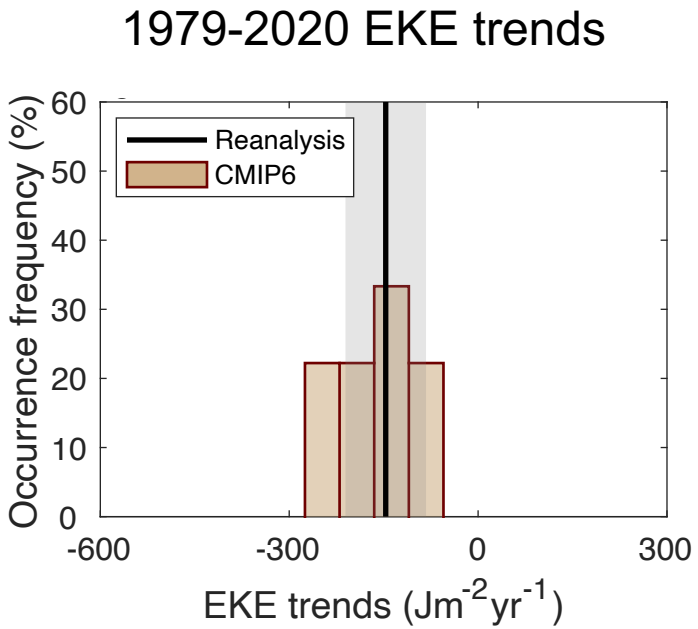

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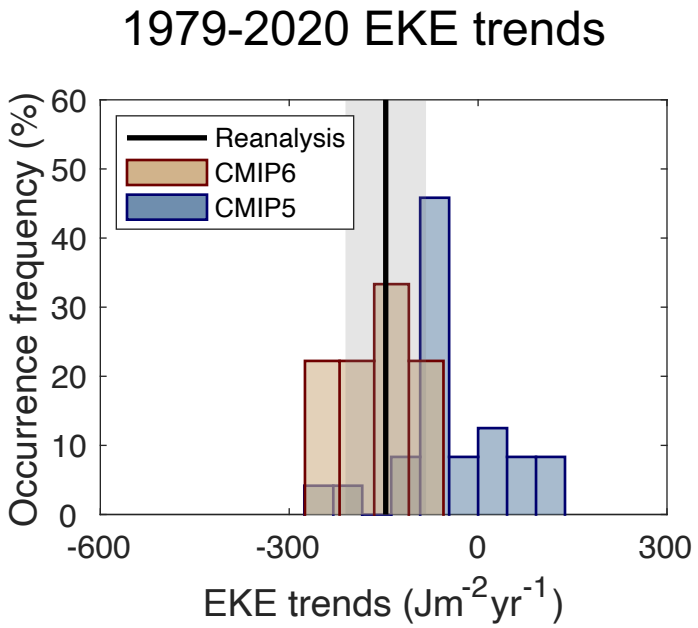
- CMIP5 models underestimate the storm tracks' weakening
- Only 2 CMIP5 models capture the reanalyses trend
  - Most do not capture its uncertainty



Could the recent weakening of the storm tracks be attributed to anthropogenic emissions?

Fractional Attributional Risks (FAR) analysis

- Estimate the probability of having such a trend across CMIP6 simulations with (P_{AE}) and without (P_{NAT}) anthropogenic emissions

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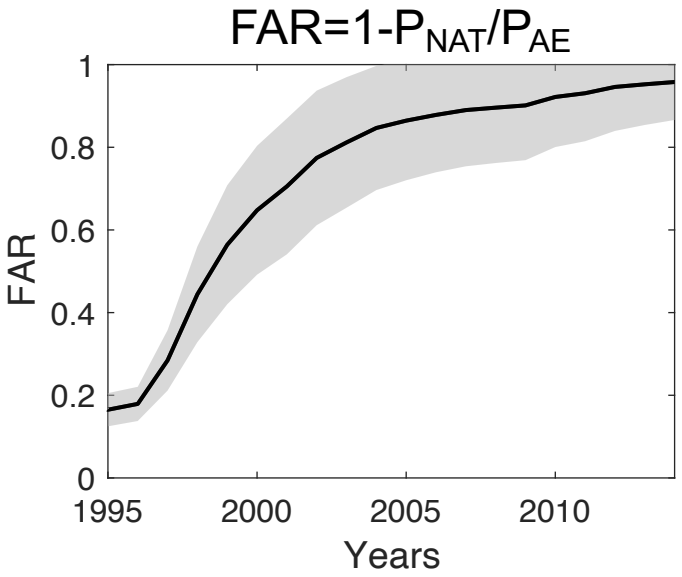
- By 2014, the FAR of the reanalysis EKE trend reached a value of 0.96
  - More than 95% confidence that the trend can be attributed to anthropogenic emissions



The mechanism underlying the human-induced weakening of the storms

- Eddy growth rate
- Conduct a linear normal-mode instability analysis and examine the maximum growth rate of mid-latitude eddies
- Vertical instability analysis to the linearized QG equations: T_y, N^2, H

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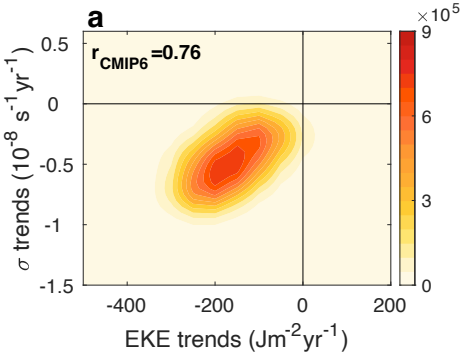

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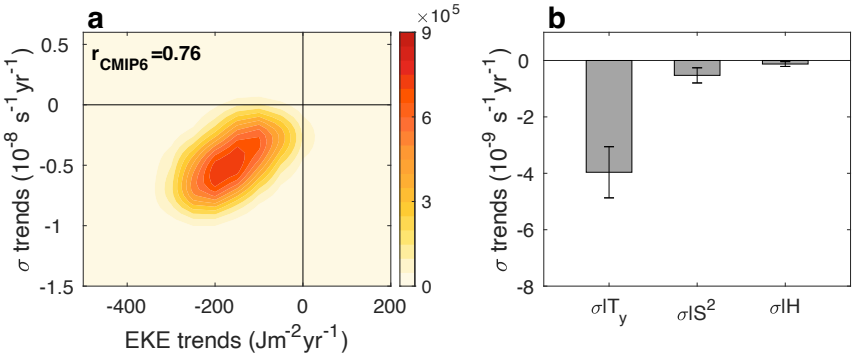

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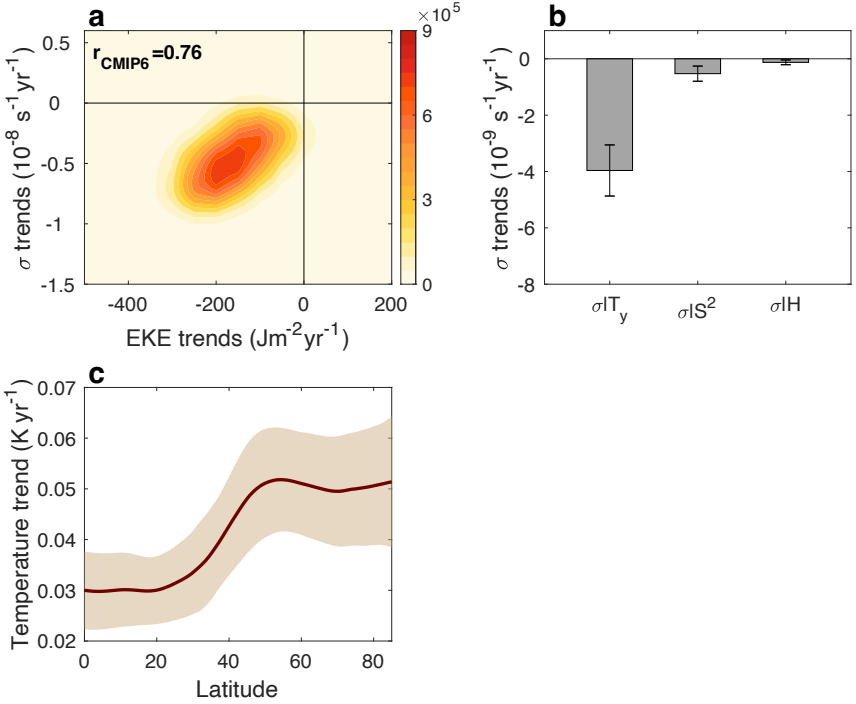

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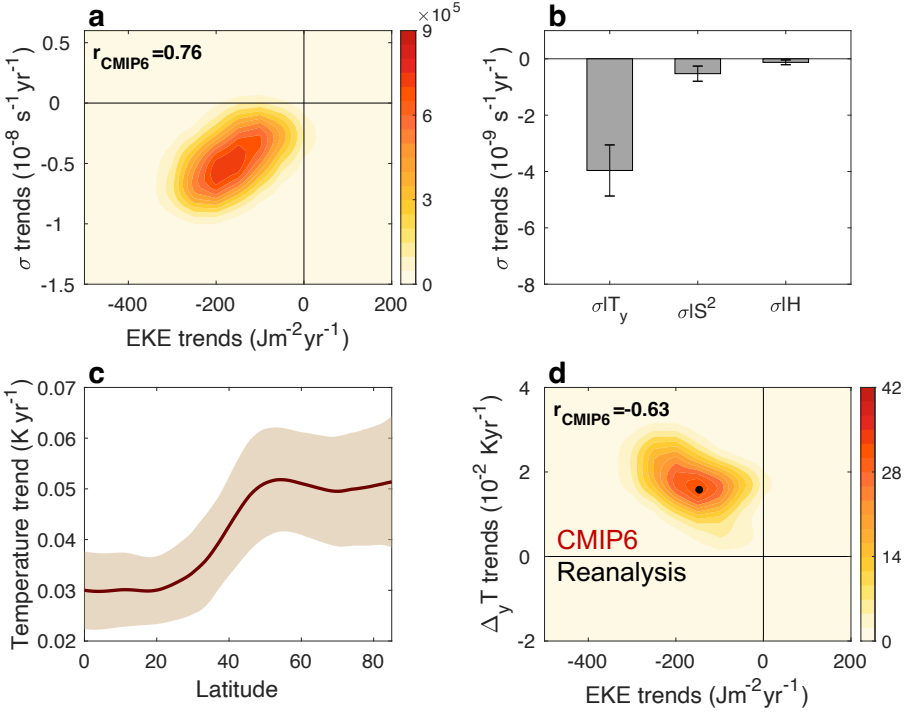

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- CMIP5 models underestimate the reduction in temperature gradients, and thus in EKE

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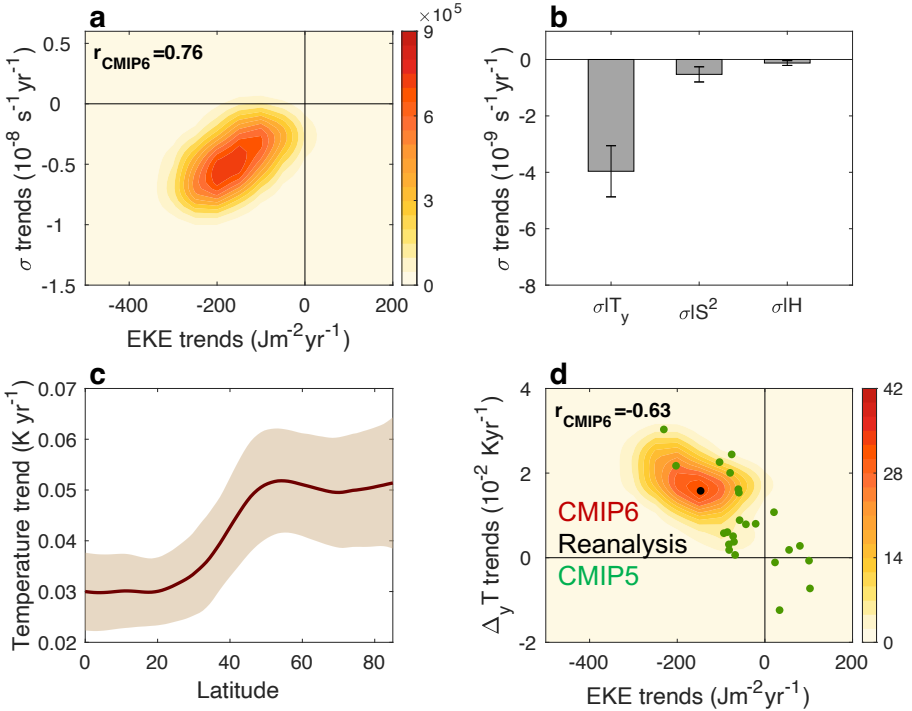

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- CESM1 (CMIP5 class)
- CESM2 (CMIP6 class)
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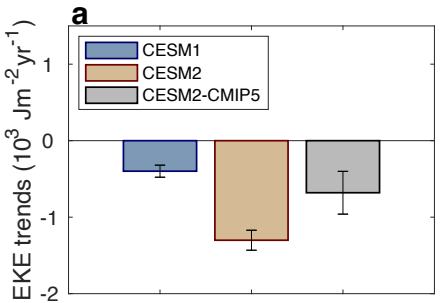

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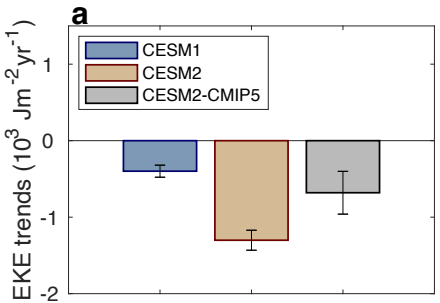

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- The larger EKE trends in CESM2, relative to CESM1, stem from biomass burning emissions

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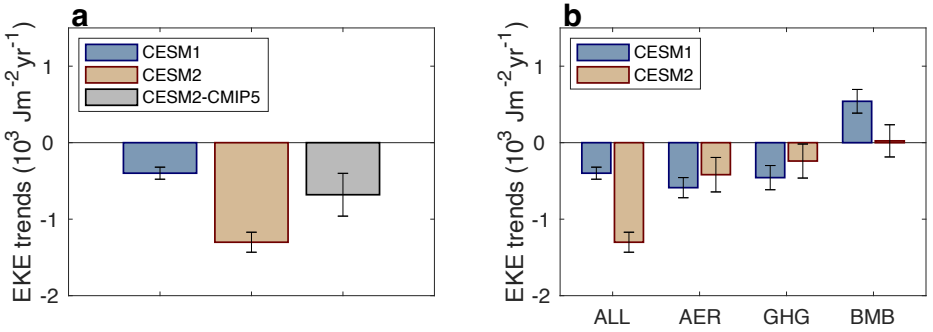

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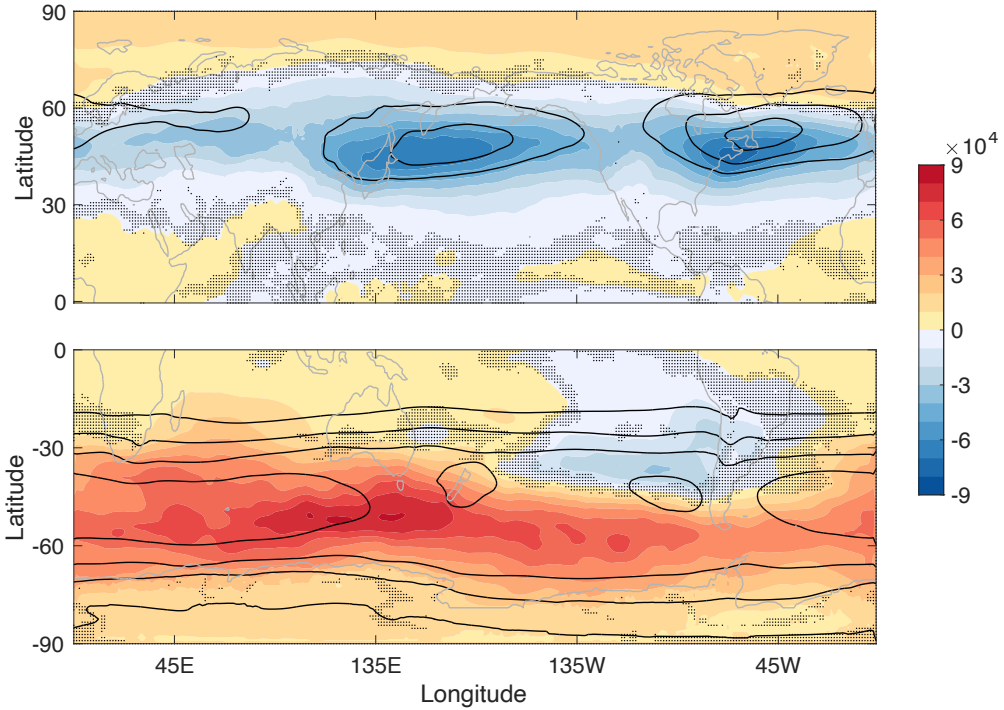
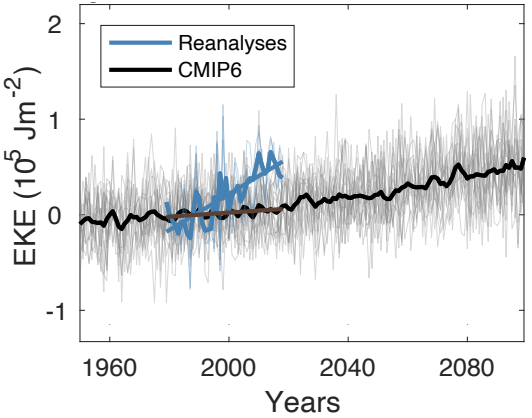


Climate models underestimate the intensification of winter storm tracks

- The EKE intensification over the last decades:
  - Reanalyses (Era-Interim, JRA55, NCEP2) >10%
  - CMIP6 models < 5%

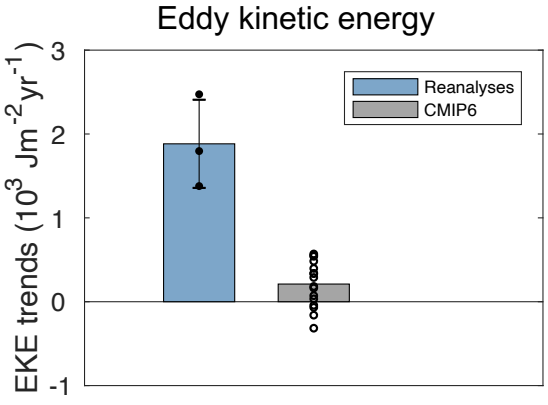
- In CMIP6 models, a similar intensification as observed in reanalyses is only projected to occur by the late 21st century.



Chemke et al., Nature Climate Change, 2022

1979-2018 trends in Southern Hemisphere mid-latitude winter storm tracks

- Not a single model is able to capture the intensification of the EKE in reanalyses (compare black dots on blue and gray bars)
- This models-reanalyses discrepancy is also evident over shorter time periods (10-, 20- and 30-year trends)



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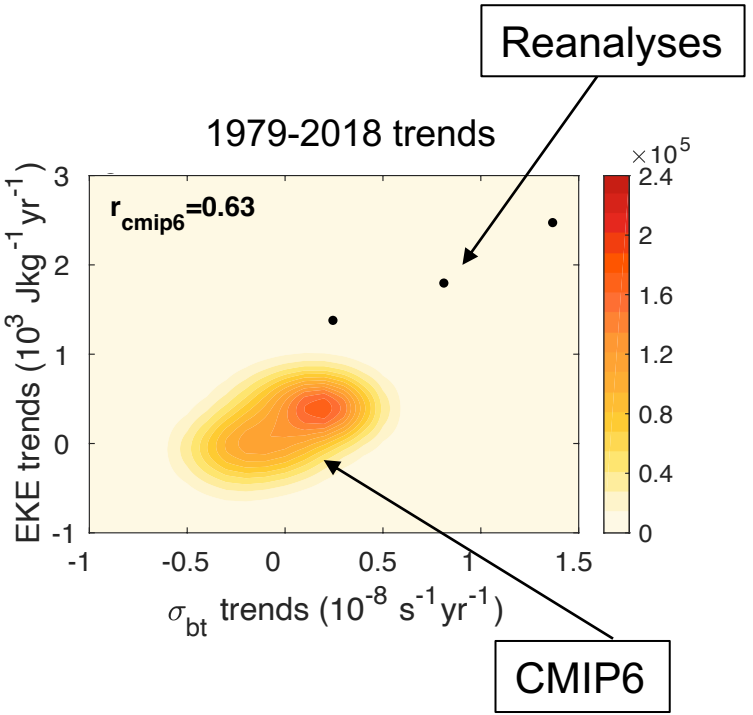
- The growth rate is well correlated with EKE trends across CMIP6 models and reanalyses, and, as in EKE, reanalyses also show larger growth rate trends than the models



The weaker intensification in models might stem from biases in changes in the meridional structure of the flow

Main take-home messages

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- Anthropogenic emissions have weakened the summer NH storm track by warming the high latitudes more than the lower latitudes
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- Climate models underestimate the intensification of the SH winter storm track in reanalyses, which is only projected to occur in models by the late 21st century
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Thank you