Moisture transport in warmer climates as simulated with OpenIFS

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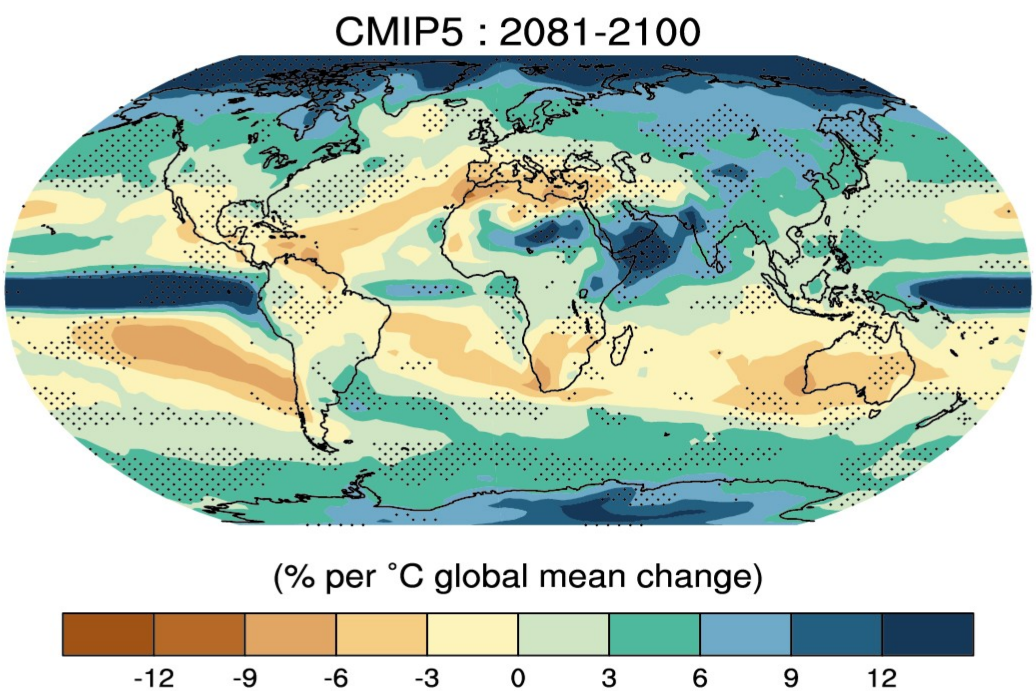
Thanks to Glenn Carver, ECMWF

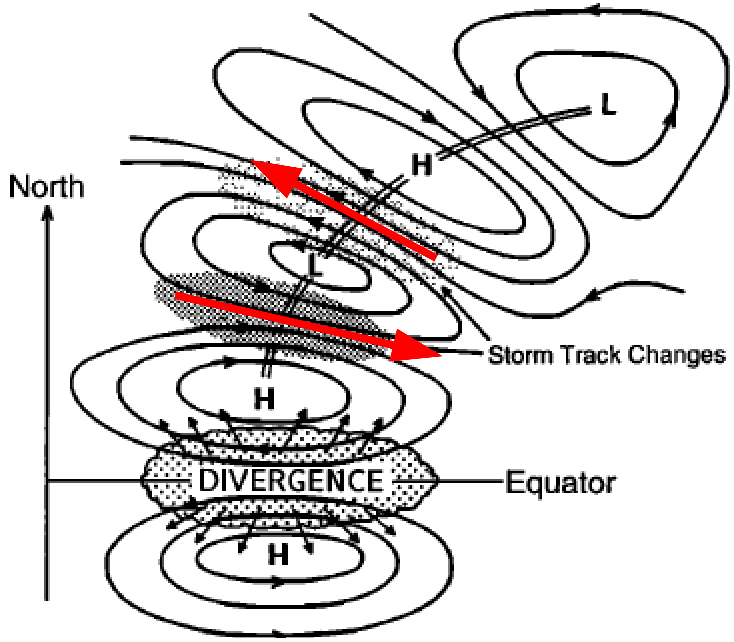
Precipitation patterns will change in the future



Multi-model percent change in precipitation by degree of warming. Stipling: mean change >95th percentile

- Understand physical processes which are responsible for change
- In models, precipitation depends on many parameterized processes
- Moisture transport depends less on small-scale processes

Tropical convection has been shown to affect jet structure

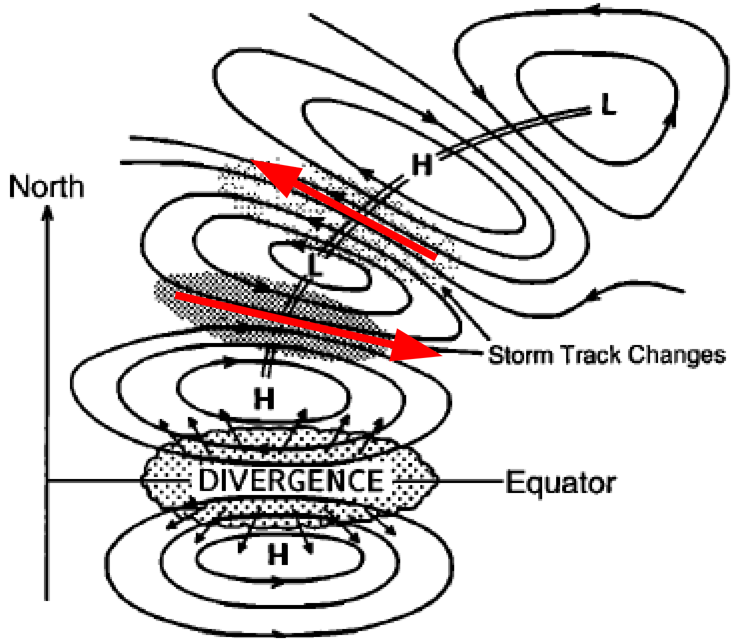


Trenberth et al (1998)

Question:

Can changes in tropical convection also affect poleward moisture transport?

Tropical convection has been shown to affect jet structure



Trenberth et al (1998)

Question:

Can changes in tropical convection also affect poleward moisture transport?

Moisture transport is mainly by extra-tropical cyclones (ETC). Atmospheric Rivers

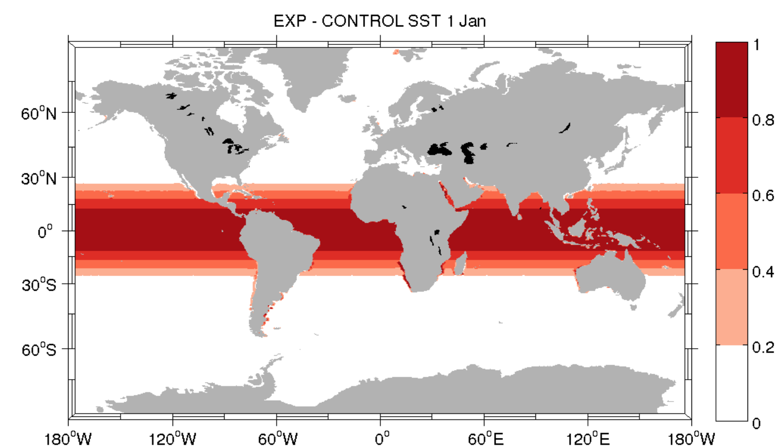
Do the number, intensity or location of ETCs change?

Experiments

- **Two 20-year** simulations with atmosphere only **OpenIFS**
  - T255 (~80km) L60
  - Output frequency 6 hours → enable cyclone tracking
  - Included fixes to ensure conservation of mass & moisture
- Climatological repeating SSTs and sea ice
  - Sensitivity study:

    warm the tropical SSTs

    max SST anomaly 1K



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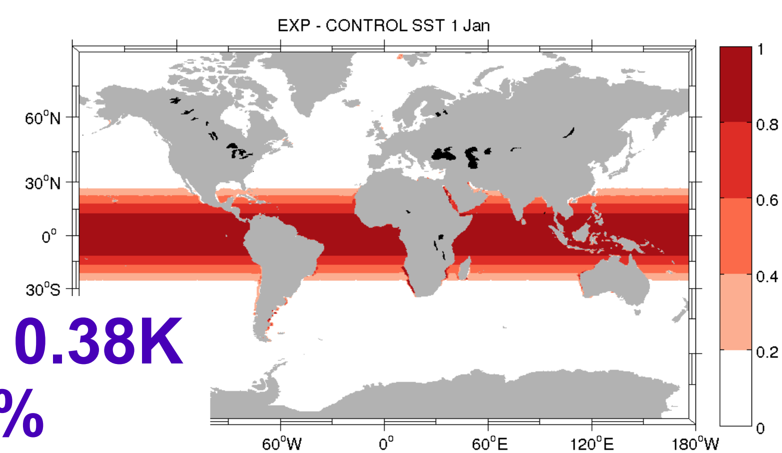


Mean 2-m Temperature increase = 0.38K
Mean precipitation increase = 1.8 %

Warming tropical SSTS: Hypotheses

Dynamic Response

Warmer tropical SSTs

Enhanced tropical convection

More upper tropospheric divergence

Anomalous outflow into each hemisphere

Different jet structures & Rossby wave patterns (?)

Extra-tropical cyclones with different characteristics (?)

Changes in meridional moisture transport (?)

Thermodynamic Response

Warmer tropical SSTs

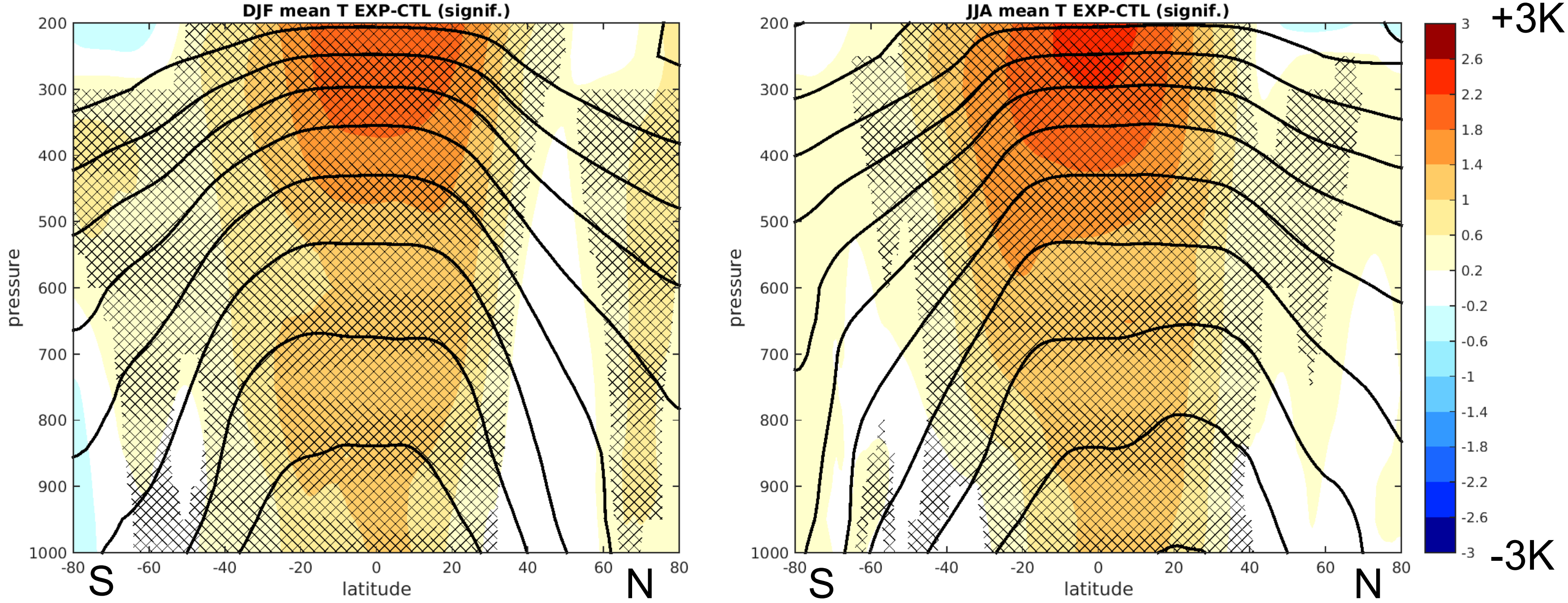
Warmer air temperatures

Increased tropospheric humidity

More moisture available to transport to the extra-tropics

Zonal mean temperature response

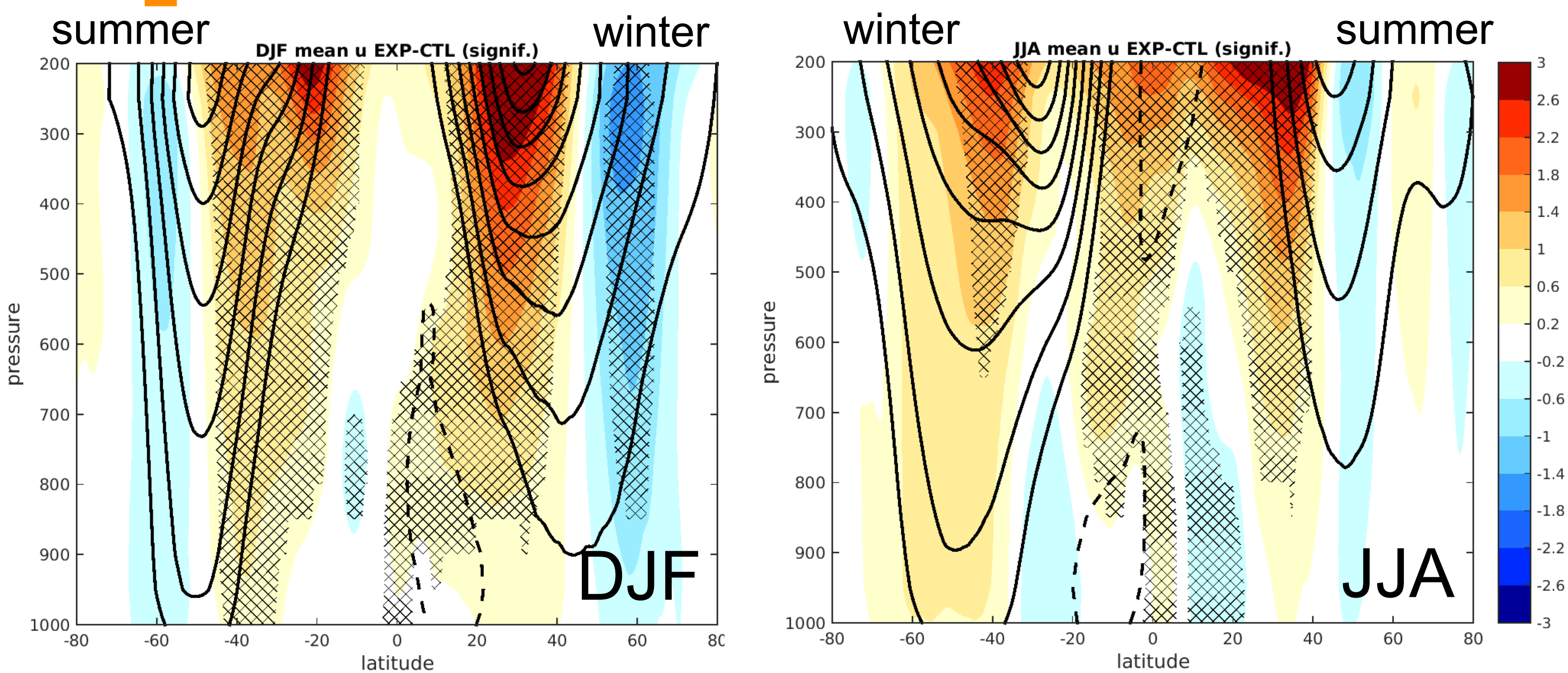
Shading show change, hatching where significant
Black contours show temperature in control. Contour interval 10K



Upper tropical troposphere temperature increases
(enhanced convection and diabatic heating)

Pole-to-Equator temperature gradient increases at upper levels

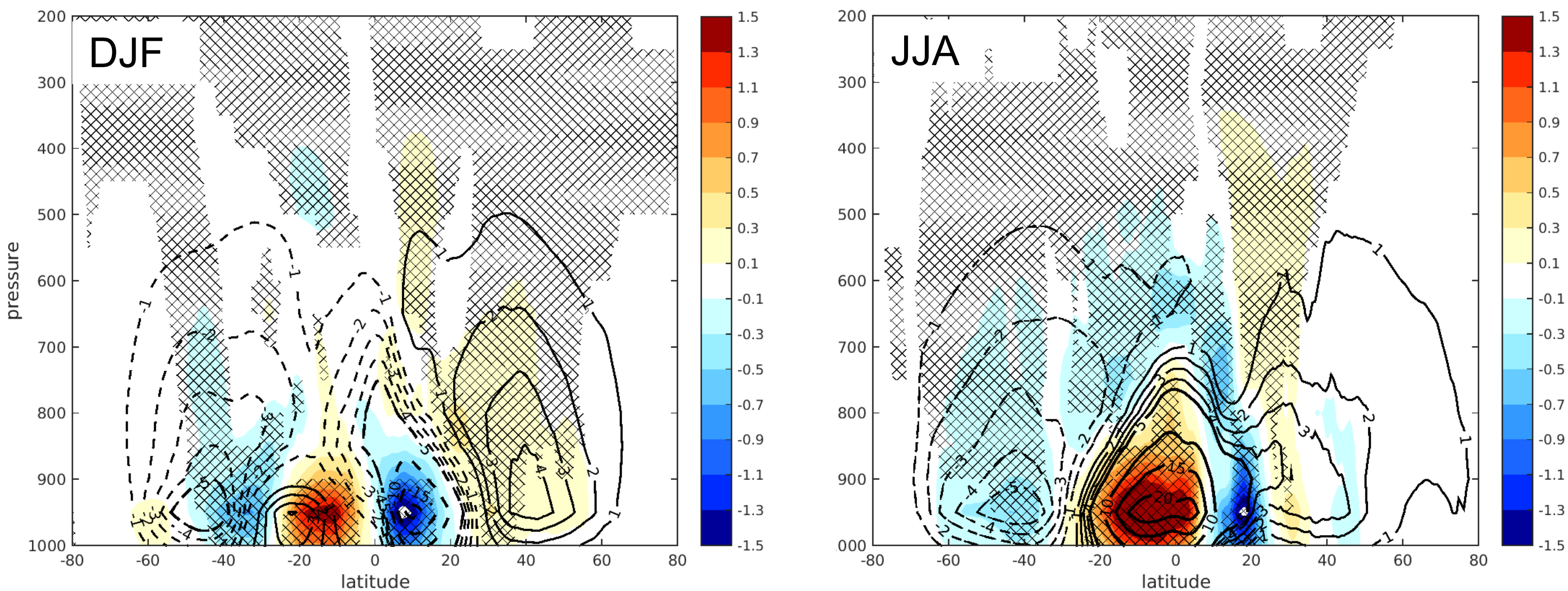
Response of zonal mean jet to tropical warming



Summer hemispheres → equatorward shift in the jet stream
SH winter: strengthening & poleward shift
NH winter: strengthening & equatorward shift

Colors shows the difference.
Significant areas hatched.
Black contours show control contour interval $5ms^{-1}$

More poleward moisture transport in both winter hemispheres



Zonal mean meridional moisture flux

Red: more northward transport, Blue: more southward transport

Increases of ~10% in extra-tropics in winter

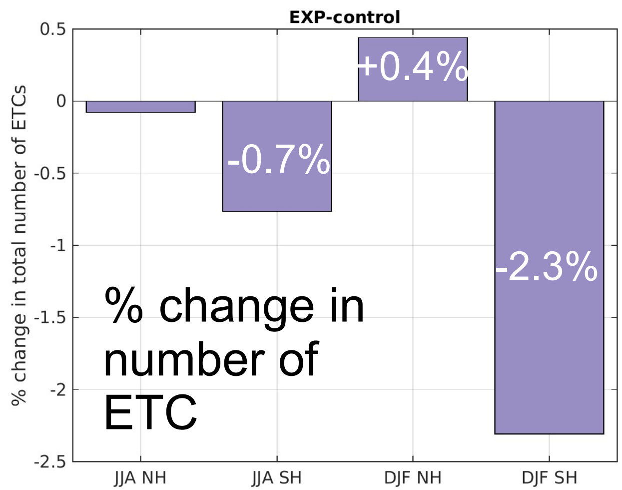
More low-level moisture convergence near the equator and divergence in sub-tropics

Zonal mean poleward moisture transport increases

Do the number or intensity of extra-tropical cyclones change?

Do spatial patterns of moisture flux change?

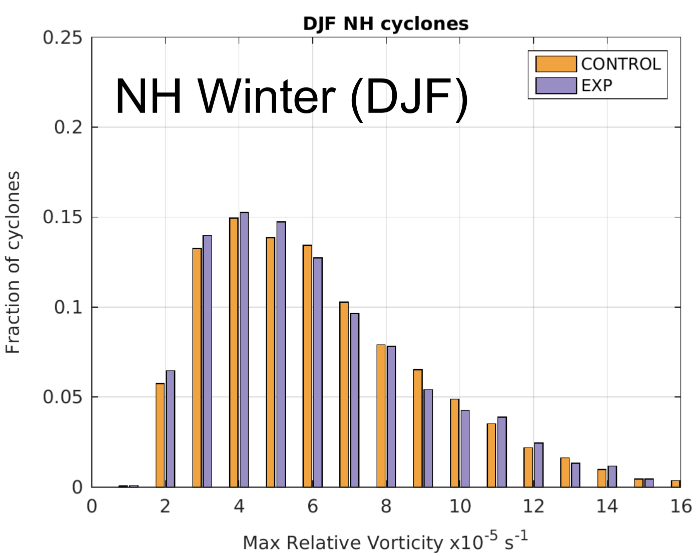
The number or intensity of extra-tropical cyclones does not change

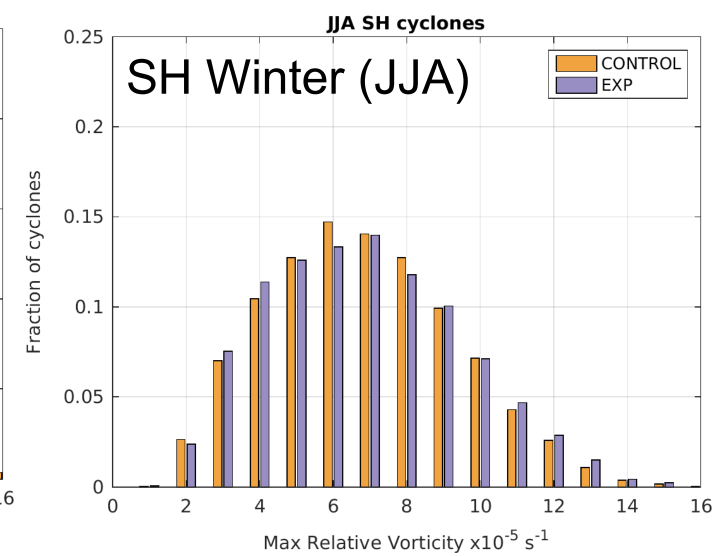


Cyclones tracked based on 850-hPa vorticity

“Synoptic-scale”

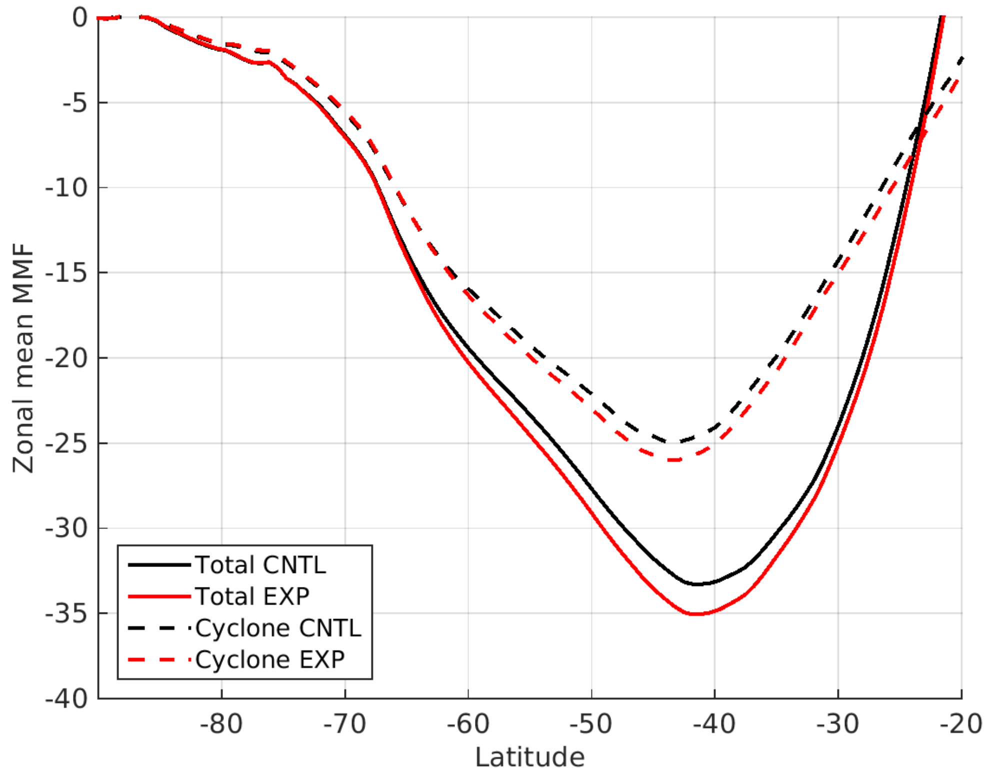
Must last for 2 days and travel 1000 km





Zonal mean vertically integrated MMF (JJA)

Combine cyclone tracks with a masking method to calculate cyclone-related MMF

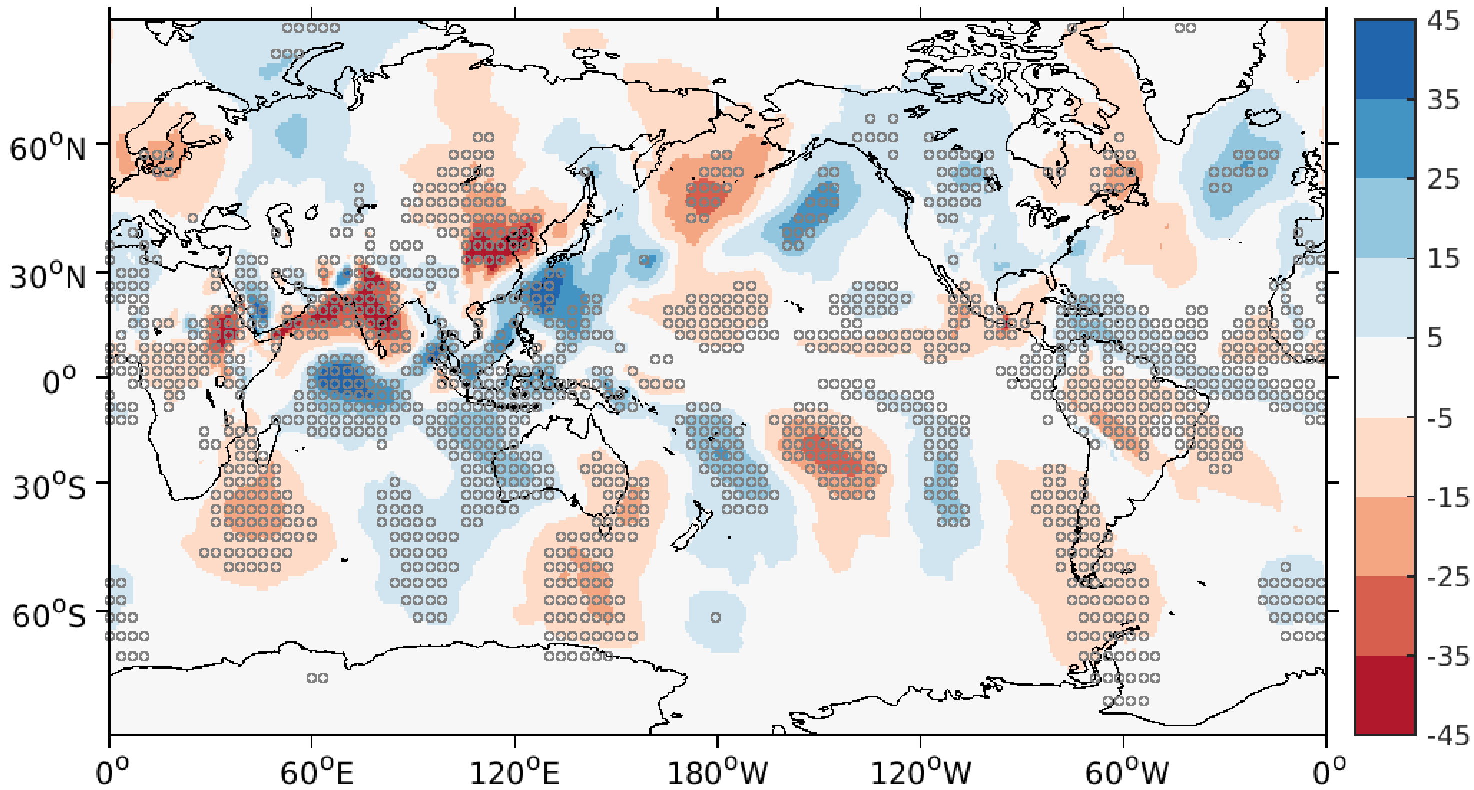


Both total and cyclone-related moisture transport increase

The same cyclones transport more moisture

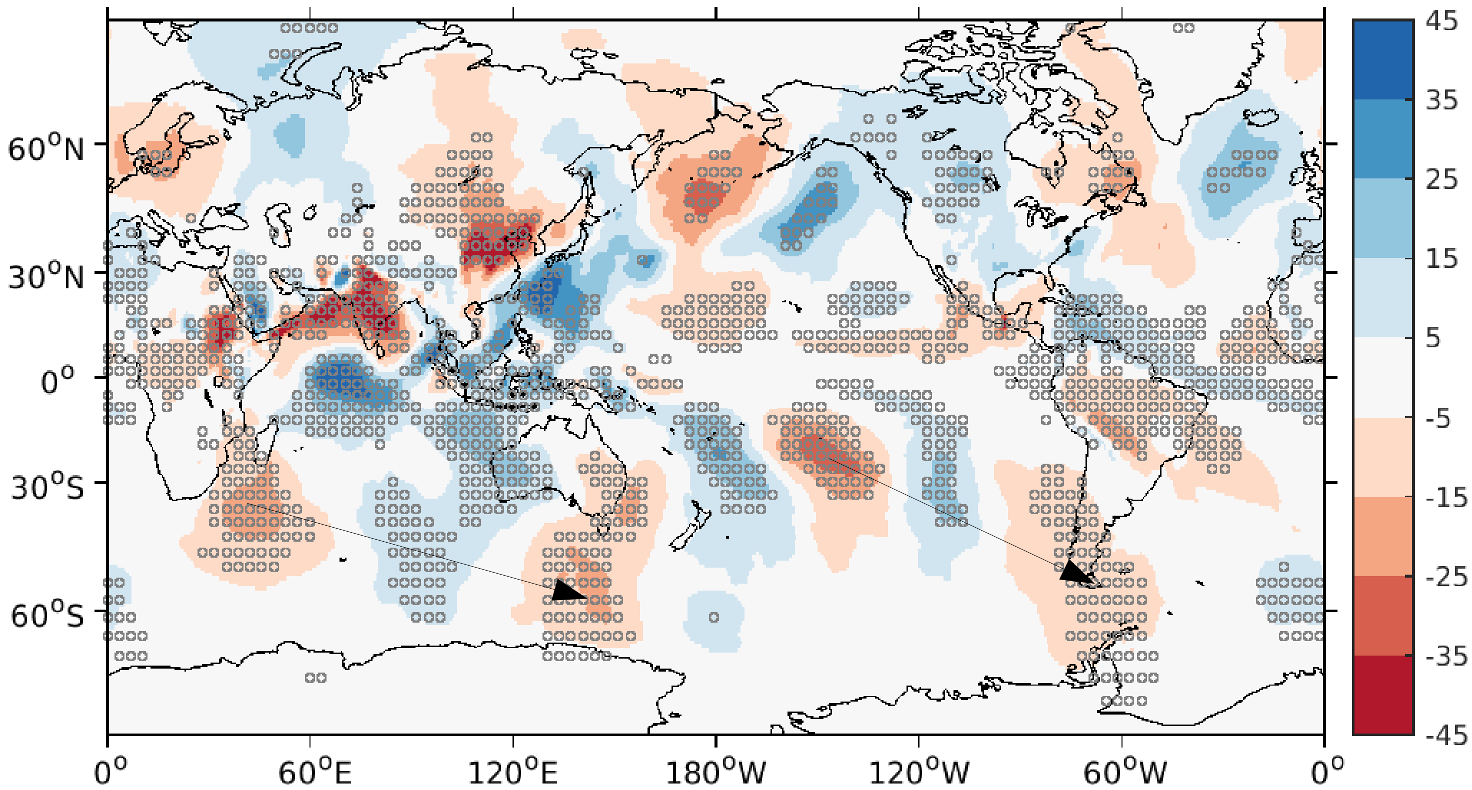
In the zonal mean, thermodynamics win

Spatial change in total vertically integrated MMF (JJA)



Regional changes are determined by circulation changes

Spatial change in total vertically integrated MMF (JJA)



Indications of anomalous Rossby wave patterns

Conclusions

- Zonal mean meridional moisture transport increases due to changes in moisture content
- Globally, number and intensity of extra-tropical cyclones do not change
- Indications of anomalous Rossby waves
  - Regional changes in moisture transport due to changes in circulation
- More research needed on understanding regional circulation changes, not the zonal mean