Effect of tropical sea surface temperatures on meridional moisture transport in the southern hemisphere

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Thanks to Glenn Carver, Oleg Stepanyuk and Juha Lento

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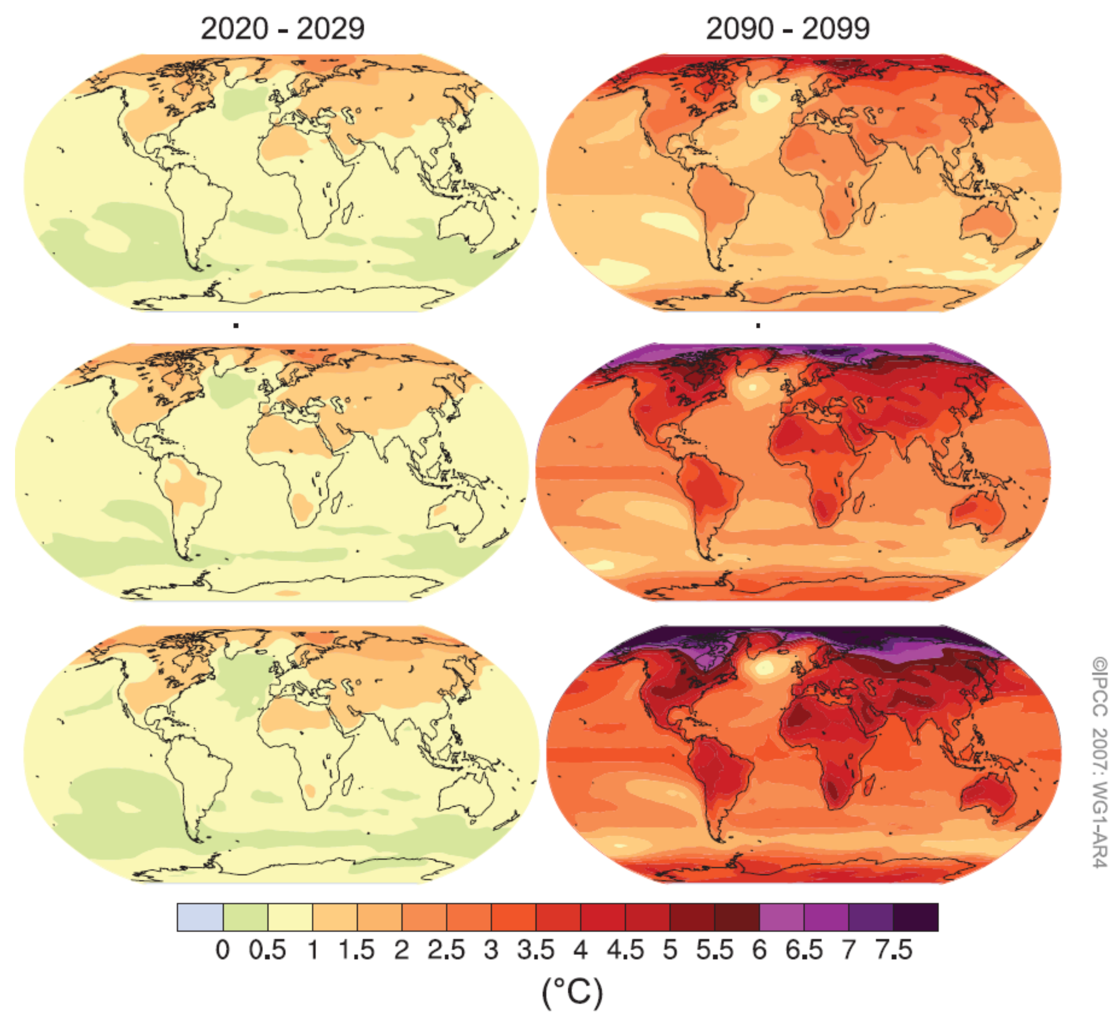
Background and Aims

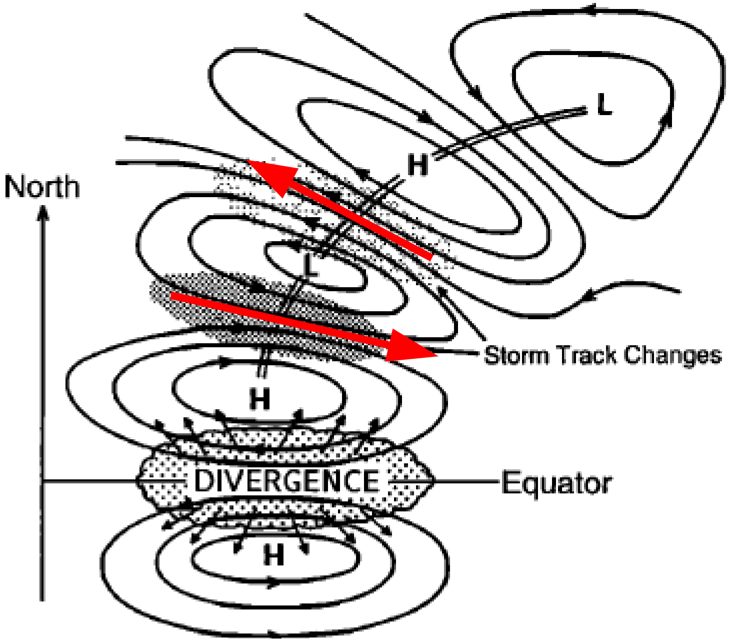
Tropical SSTs are likely to warm more than the subtropics.

How will increased tropical SSTs affect meridional moisture transport, precipitation and weather systems in the SH extra-tropics?



IPCC 4th assessment report.
Change in surface temperature

Tropical convection affects extra-tropical circulations



Enhanced tropical convection can alter the location and strength of the storm track.

Trenberth et al (1998)

Warming tropical SSTS: Hypotheses

Dynamic Response

Warmer tropical SSTs

Enhanced tropical convection

More upper tropospheric divergence

Anomalous outflow into each hemisphere,

Different Rossby wave source

Different jet structures

Extra-tropical cyclones with different characteristics (?)

Changes in meridional moisture transport

Thermodynamic Response

Warmer tropical SSTs

Warmer air temperatures

Increased lower tropospheric humidity

Increases convection and transport of moisture to the mid / upper tropical troposphere

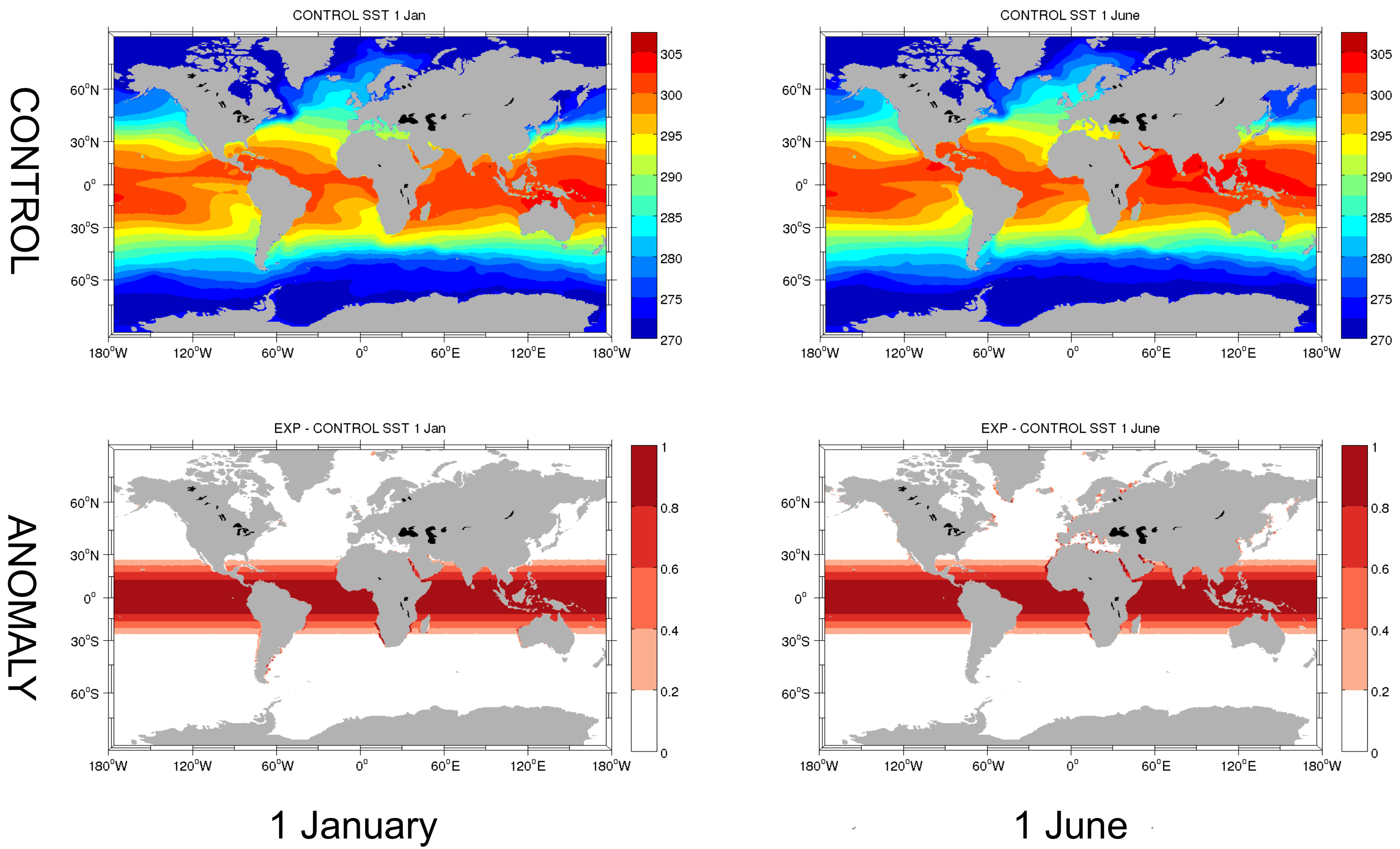
More moisture available to transport to the extra-tropics

Experiments

- **Two 10-year** (+2 months) simulations with **OpenIFS** (38r1v04)
  - 1st November 2004 – 31st December 2014 (dates arbitrary)
  - ERA-Interim initial conditions + climate data
  - Resolution: T255 (~80km) L60
  - Included fixes to ensure conservation of moisture
- Climatological repeating SSTs and sea ice, land surface varied according to ERA-Interim
  - Sensitivity study: **warm the tropical SSTs**
- Jennifer Catto repeated the same experiments with ACCESS (1.5 degrees x 1.875 degrees)
- Each simulation took 56 hours of CPU time on 128 nodes

Sea surface temperatures

Sensitivity study: Tropical SSTs increased between 30S and 30N following a SIN function (Marshall and Connelley, 2006)



Results

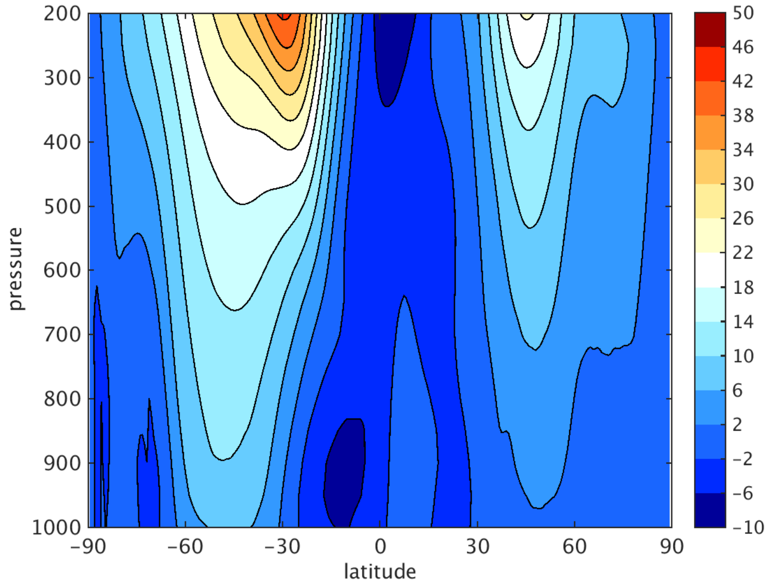
- Mean jet structure + response
- Mean moisture + response
- Cyclone characteristics
- Moisture transport

All results shown are for southern hemisphere winter JJA

Zonal mean u-wind component

Control

pressure



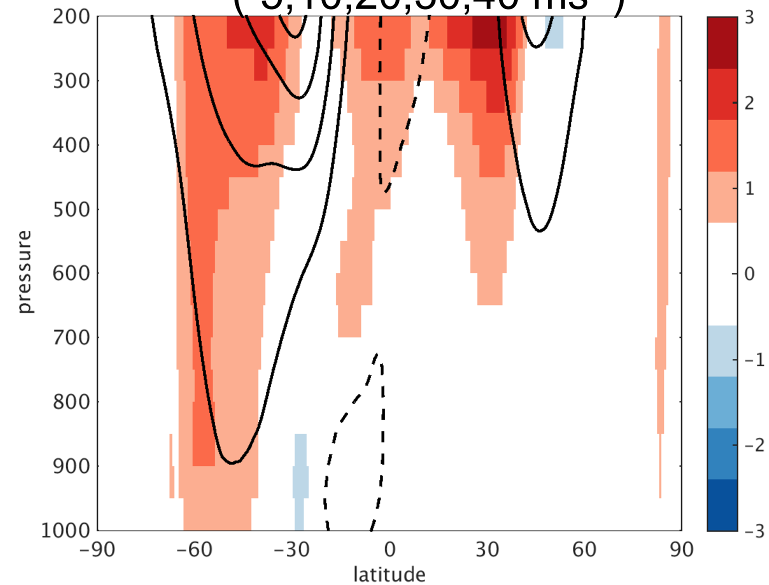
SP latitude NP

Difference = EXP – Control

Black contours show the control

(-5,10,20,30,40 ms^{-1})

pressure



SP latitude NP

In the SH the jet strengthens and moves poleward.

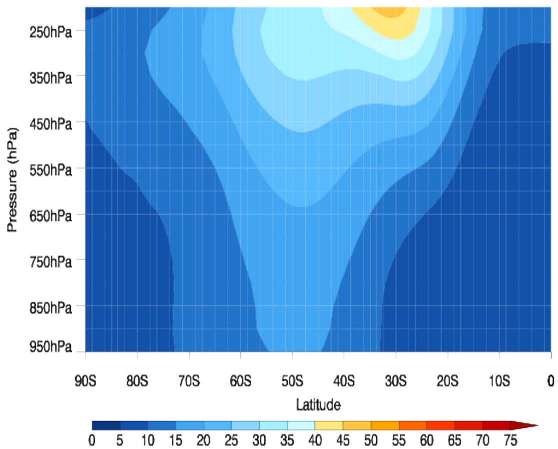
Max increases in SH is at 40S

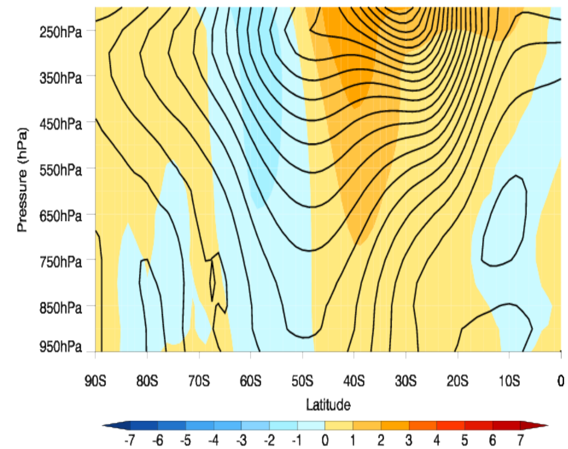
In the NH the jet moves equatorward

Comparison between ACCESS and OIFS

EXP – Control (shading)

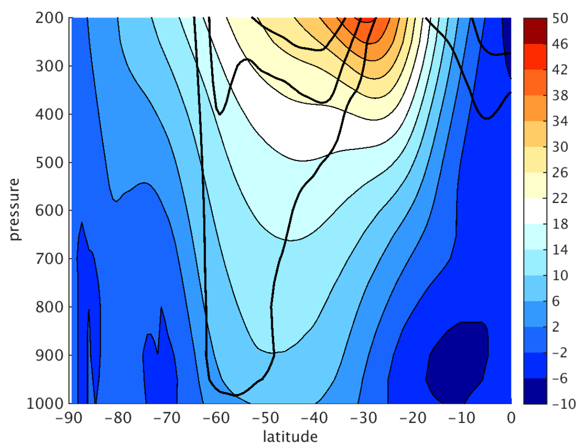
ACCESS





OIFS.

Colours show mean contours show difference



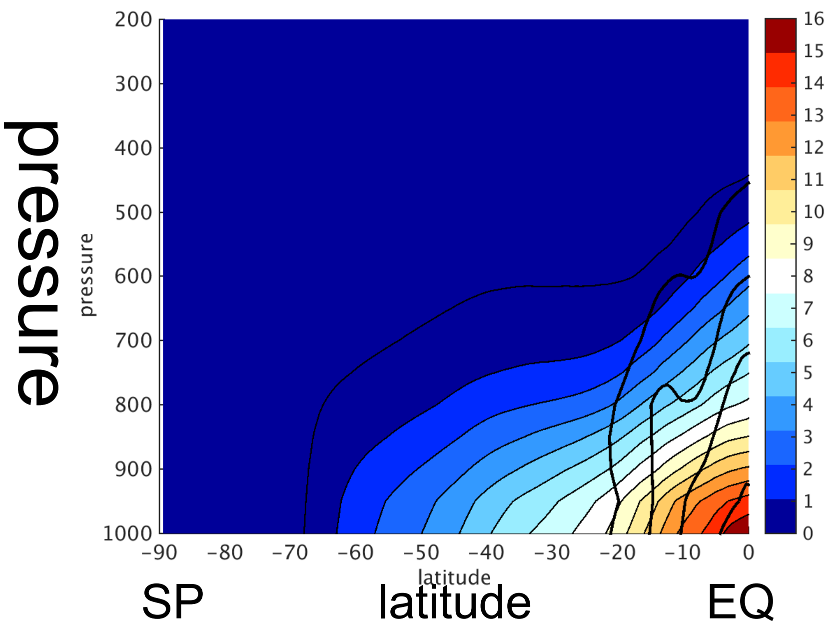
Both models have similar jet in the control

Both models have an increase in u upper levels at 40S

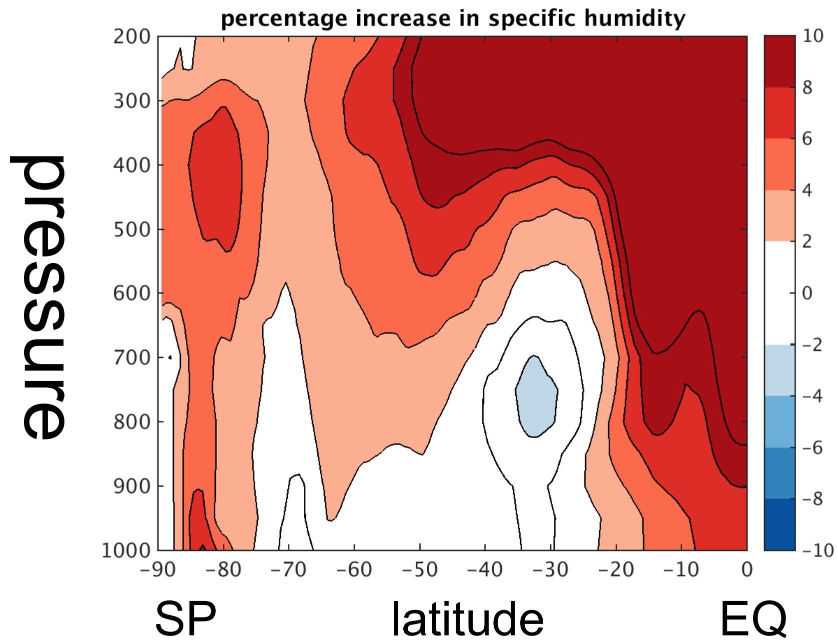
ACCESS has a slight decrease in wind speed at 60S. Increase at 40S does not extend as close to the surface as it does in OIFS

OIFS

Zonal mean specific humidity



Mean specific humidity (control) + absolute increases (black contours)

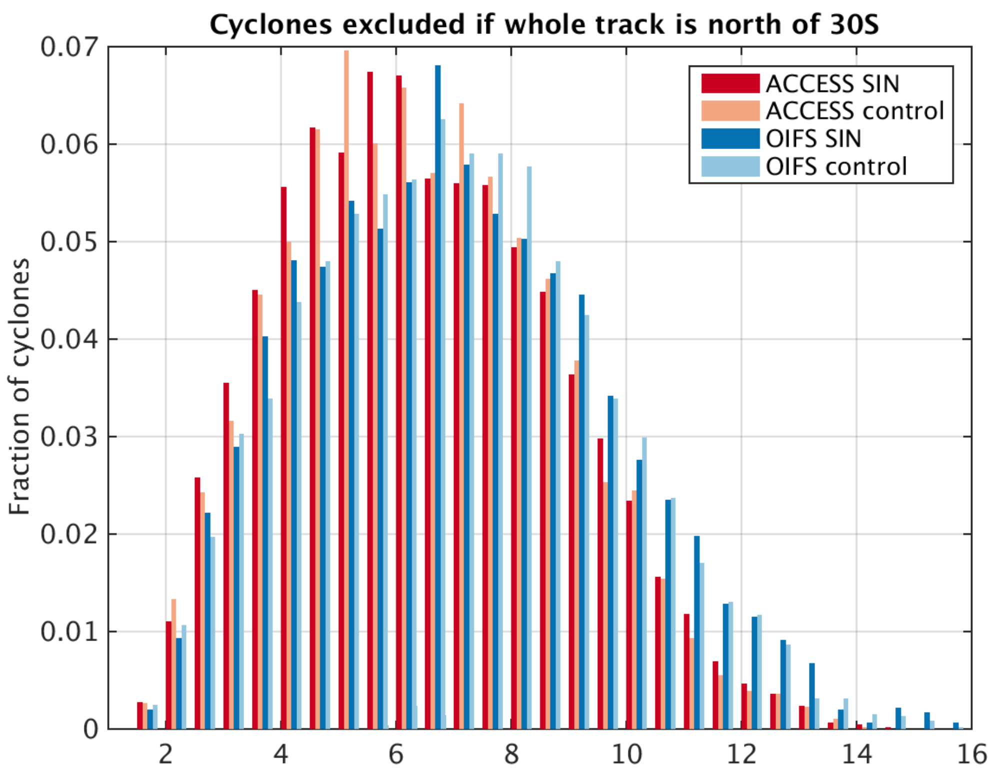


Percentage change in zonal mean specific humidity

The tropics get moister and the sub-tropical get drier.

The SH mid-latitudes have more moisture in the mid- and upper-troposphere

Intensity of cyclones
PDF of max relative vorticity



Max vorticity x10^{-5}

Cyclones were identified using TRACK. Finds maximums in T42 850-hPa relative vorticity

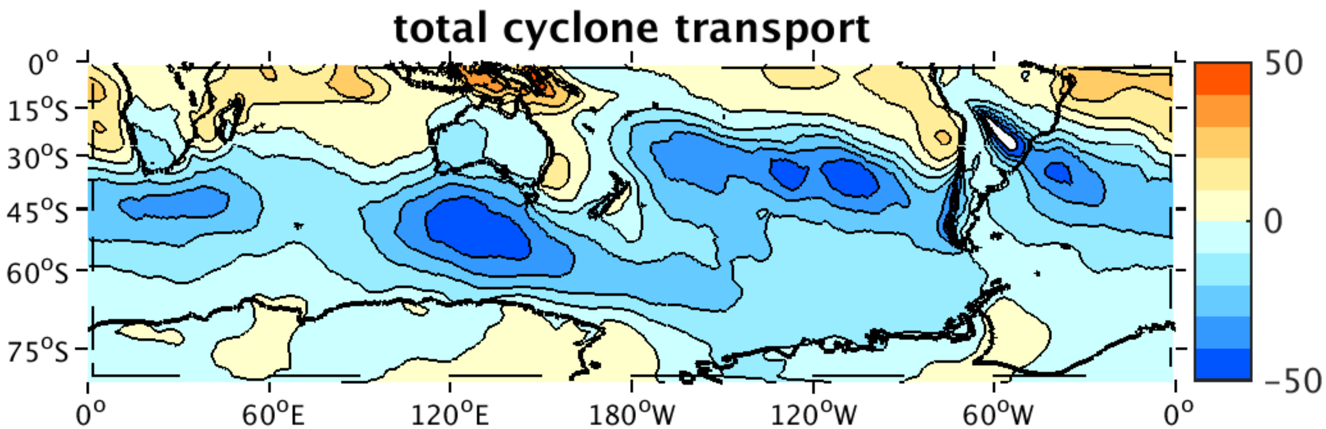
OpenIFS has stronger cyclones than ACCESS → higher resolution

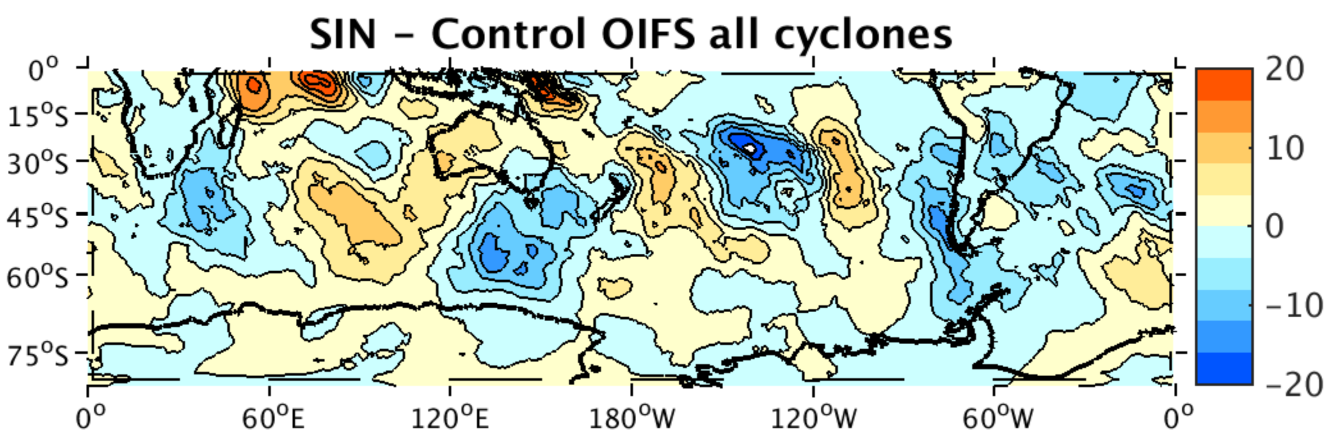
Warming the tropical SSTs does not increase the number of cyclones or the mean intensity.

The width of the distribution increases slightly

OIFS

Mean vertically integrated meridional moisture flux





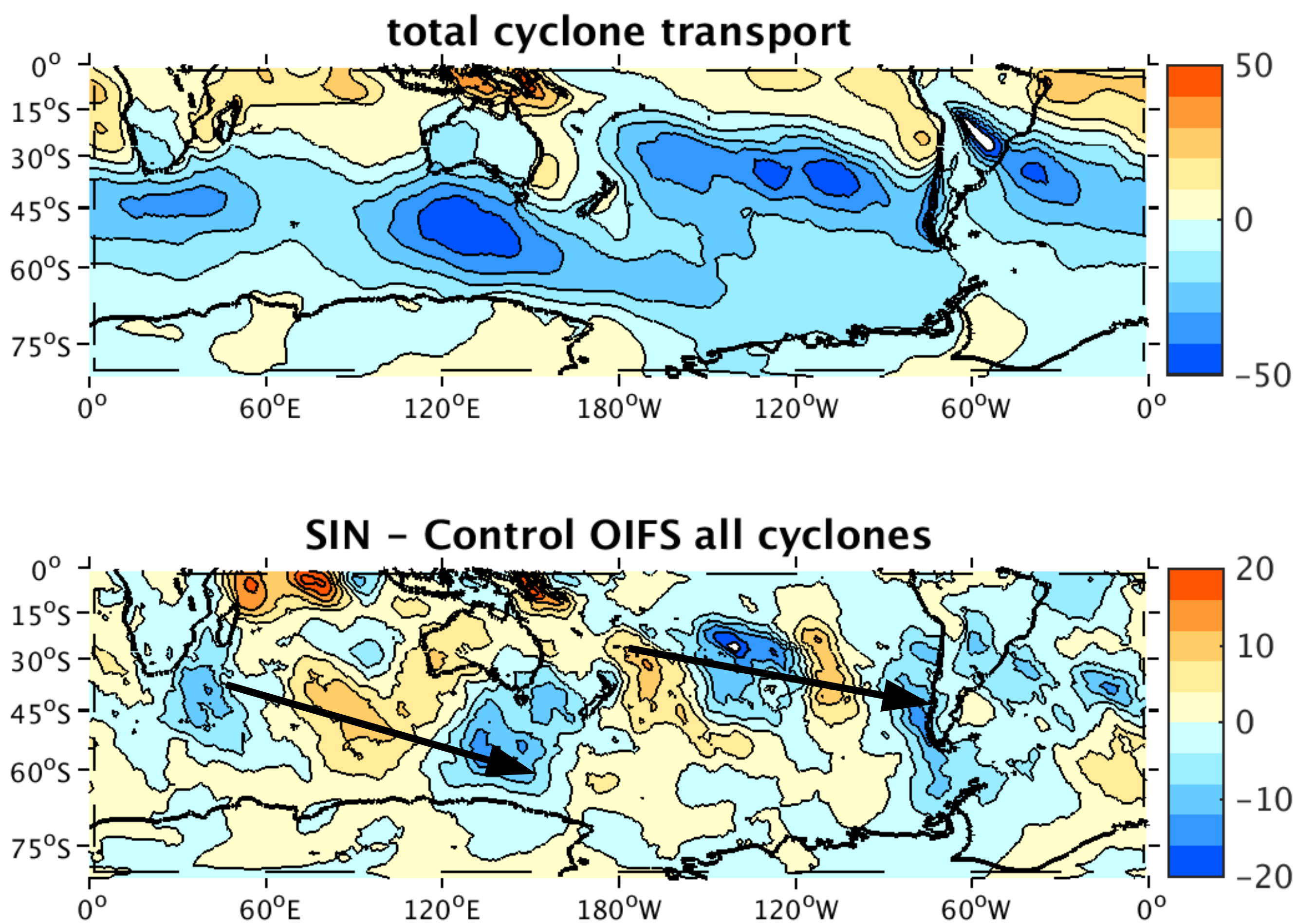
SH winter spiral storm track is evident in MMF

Rossby wave patterns (+ve / -ve repeating dipoles) evident in the difference

Potentially 2 anomalous Rossby wave patterns

OIFS

Mean vertically integrated meridional moisture flux



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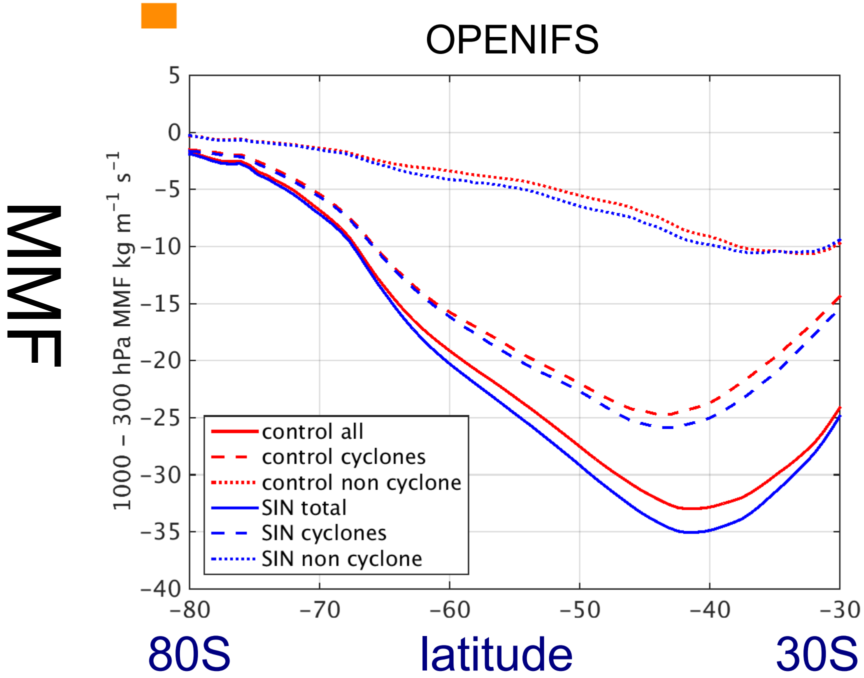
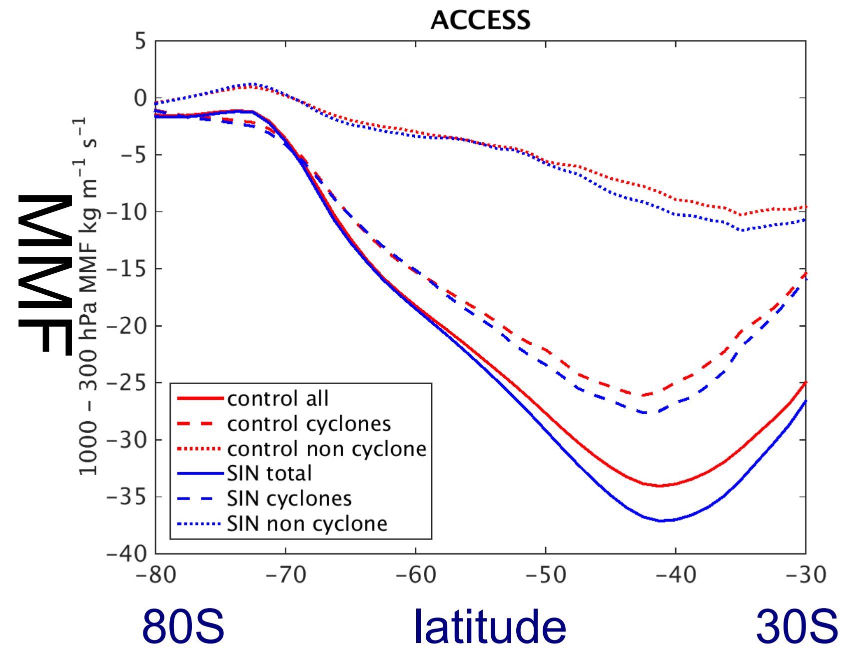
Zonal mean vertically integrated meridional moisture flux





The cyclone-related meridional moisture flux increase despite that there are no more cyclones or stronger cyclones.

The non-cyclone MMF also increases suggesting that thermodynamics response is dominating

Good agreement between the models on this “bulk” diagnostic of MMF

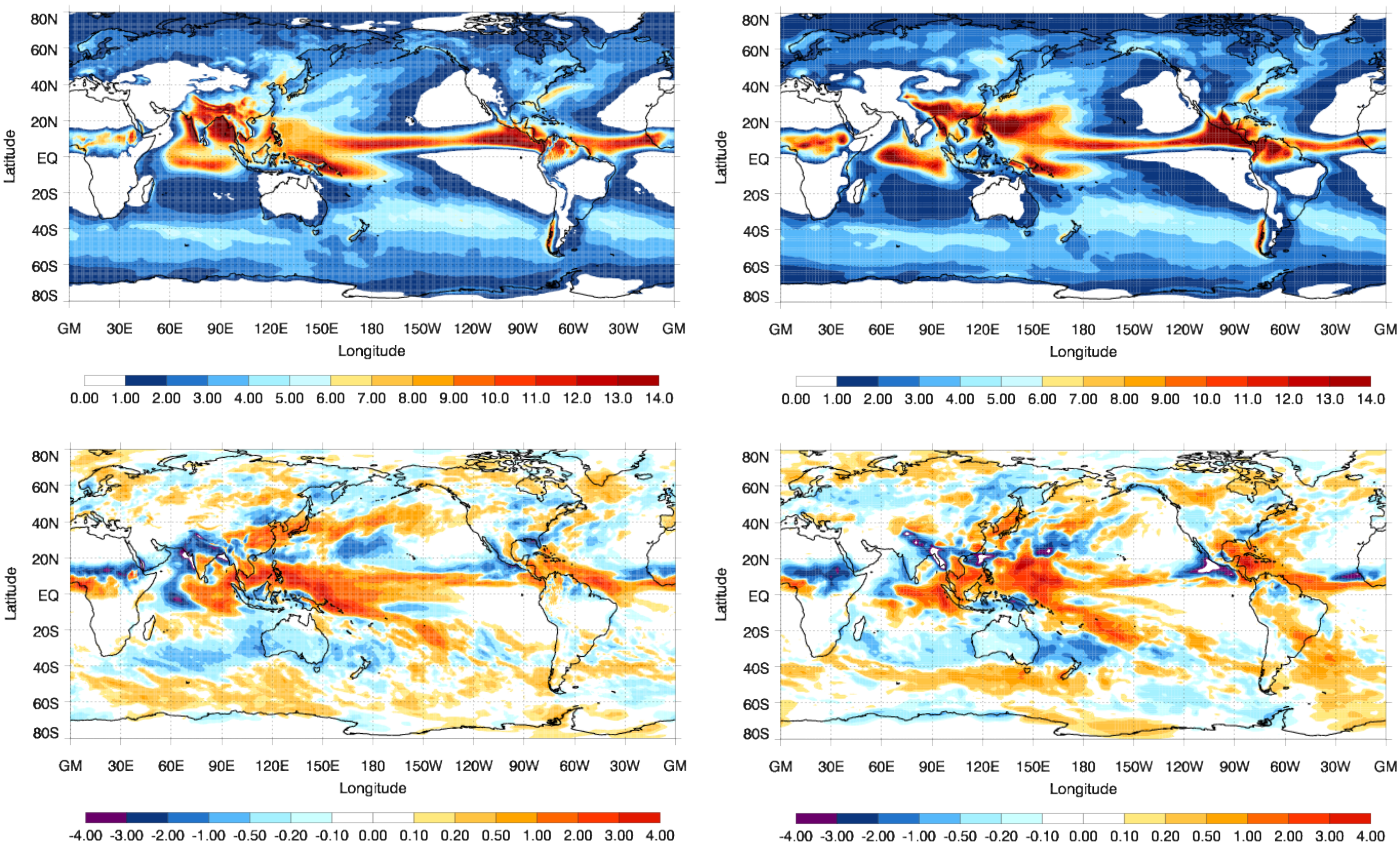
Daily mean precipitation

OIFS

ACCESS

CONTROL

Difference



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UNIVERS

Conclusions

- Running OpenIFS for 10 years is possible and produces sensible results.
  - “Climatology” agrees well with ERA-Interim and results from ACCESS

Conclusions

- Both the eddy-driven and subtropical jet in the SH move slightly polewards and strengthen in response to warmer tropical SSTs
- The number and intensity of cyclones does not change significantly
- Poleward meridional moisture transport increases in both models. Both the non-cyclone and the cyclone transport increases.
- Thermodynamics response appears more dominant than the dynamic response
  - The same cyclones can transport more moisture as there is more moisture available.