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Two examples of use of the hierarchy of models

Brian Hoskins

Director, Grantham Institute for Climate Change, Imperial College London
Professor of Meteorology, University of Reading

Grantham Institute for Climate Change

The Hierarchy of Models

Use

- To aid in the diagnosis of more complex models
- To aid in determination of physical significance
- To provide a framework for analysing observational data
- To increase the theoretical base and build understanding
- To aid the development of more complex models

Members of the Hierarchy

- Reduced or simplified representation of physical (chemical or biological) processes
- Simplified geometry
- Simplified dynamics
- Simplified domain
- Focus on a particular process or problem

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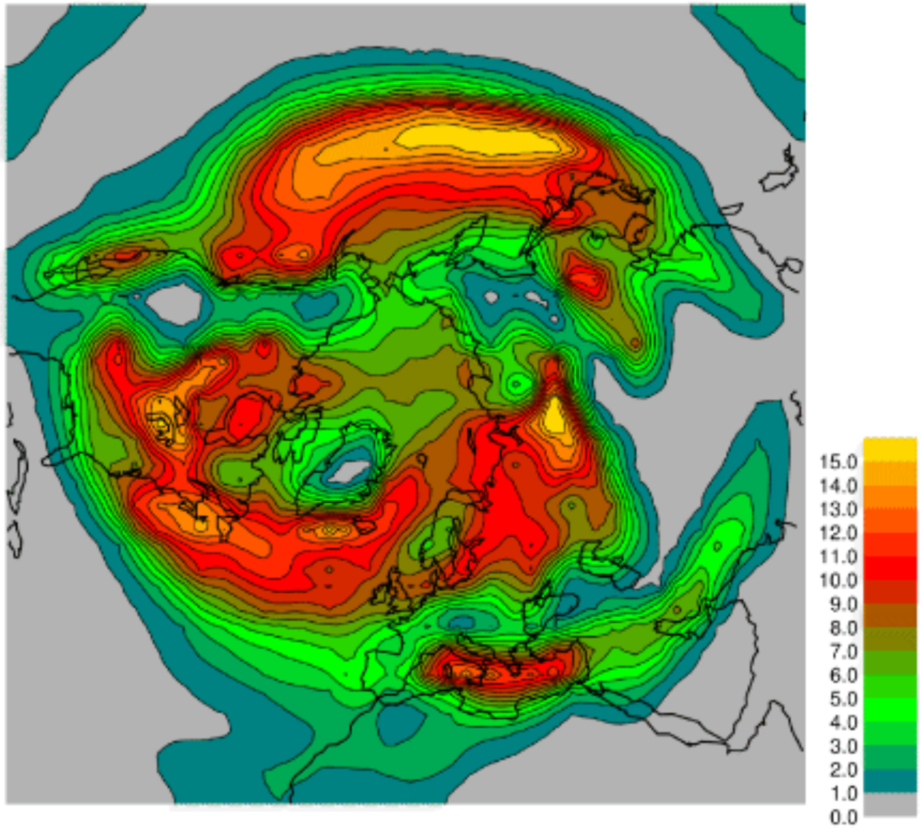
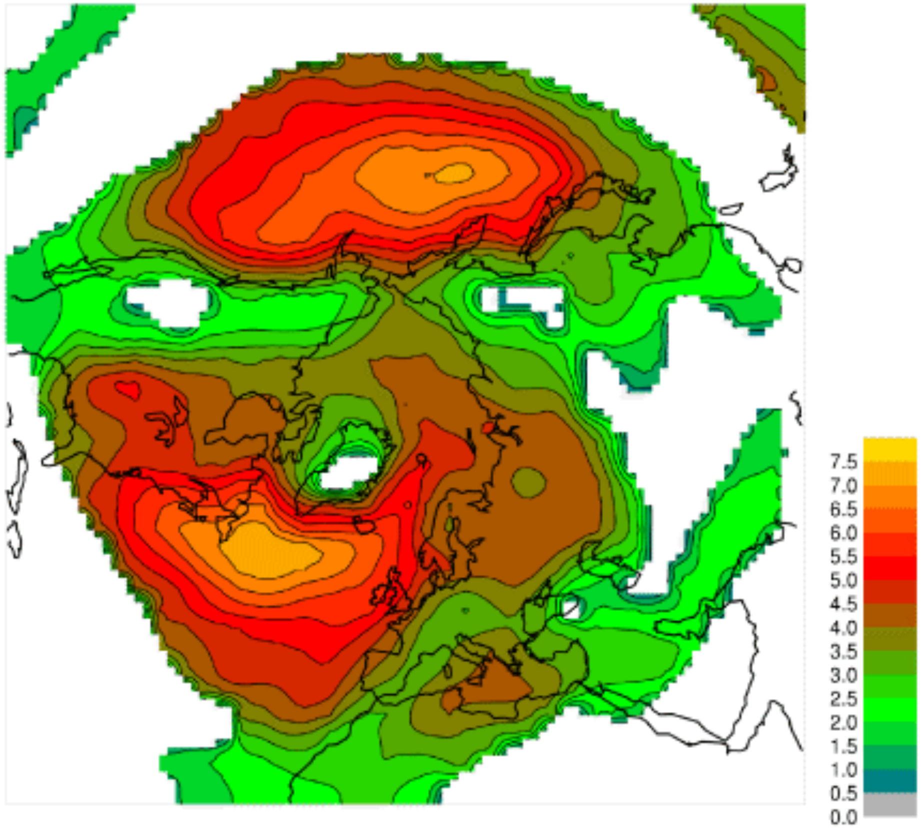
ξ_{850} Tracking Statistics for DJF

Hoskins & Hodges (2002)



Track Density



Mean Intensity

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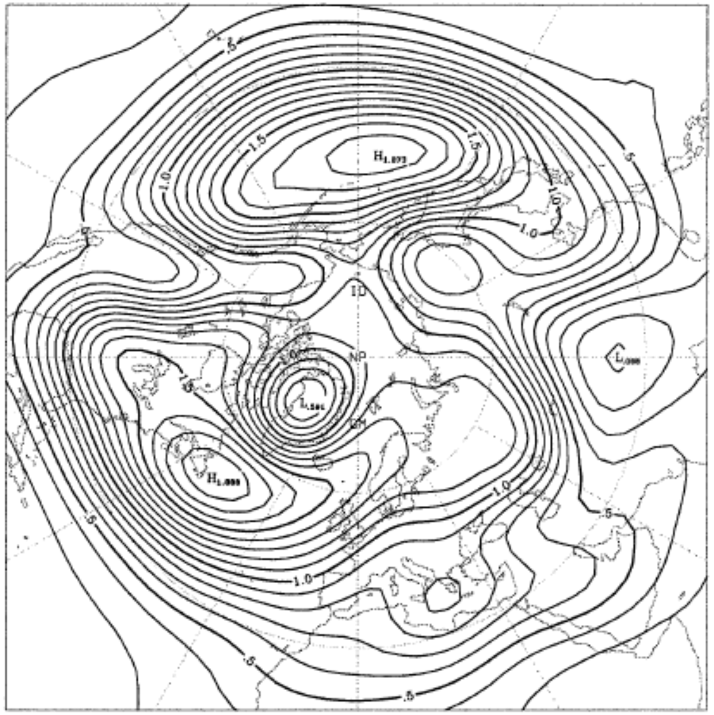
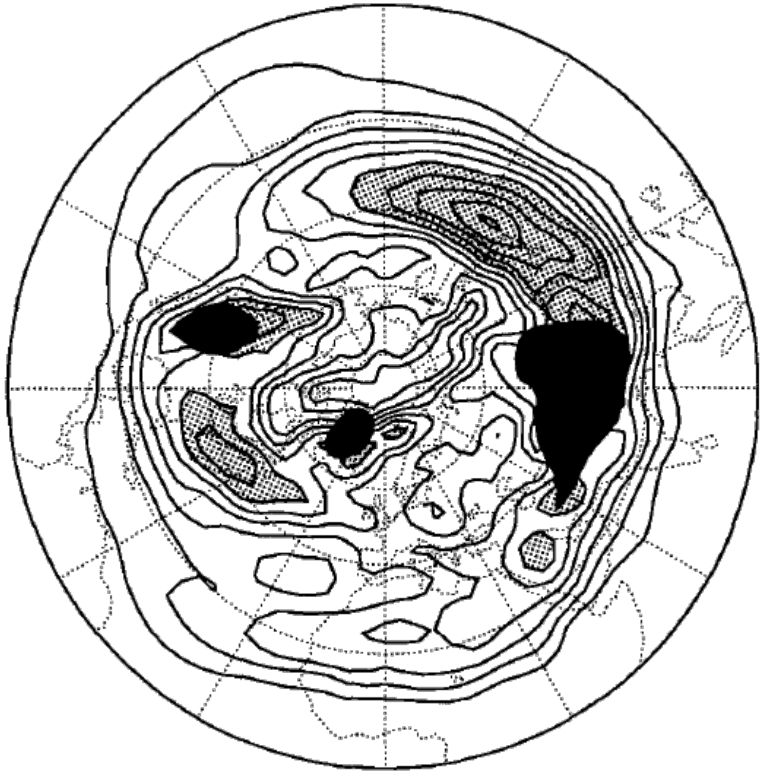
Why do storm-tracks exist?

Hoskins and Valdes, 1990



ξ'^2_{850} 2-6 day



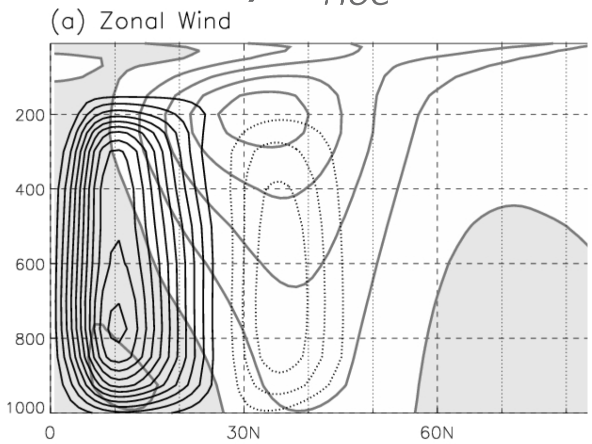
Baroclinicity

(Eady growth rate in lower troposphere)

Aqua-planet AGCM experiments

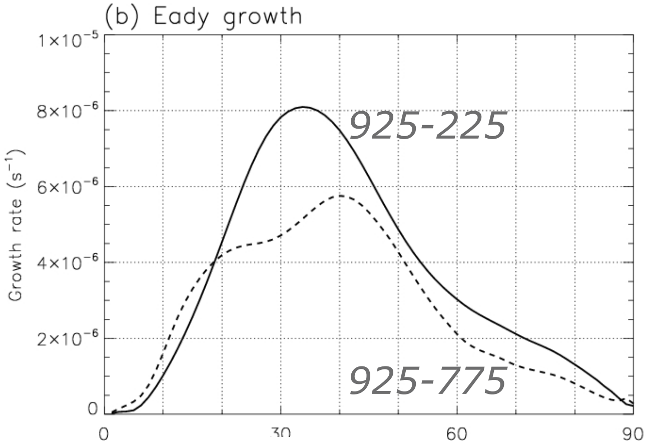
Dave Brayshaw, Mike Blackburn: Brayshaw et al (2008, 2010) JAS

U, Ψ_{MOC}



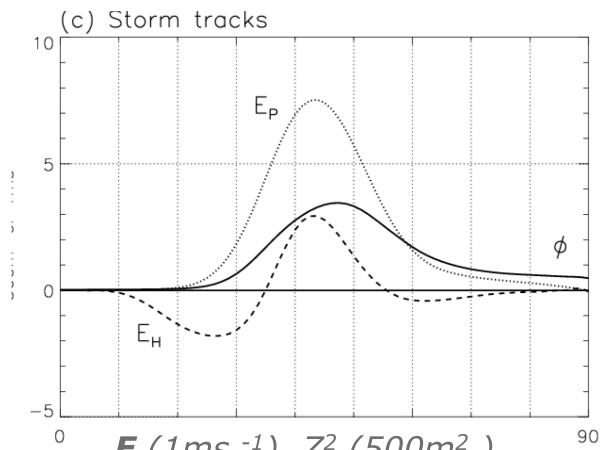
10ms^{-1}, 2.10^{10}kgs^{-1}

σ_{Eady}



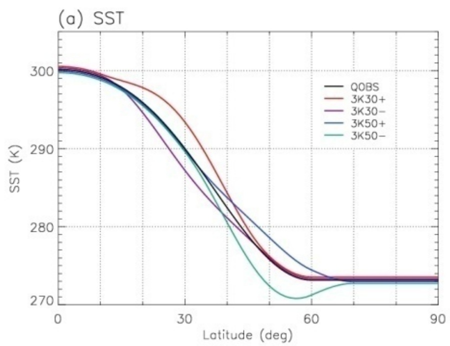
s^{-1}

Storm track measures



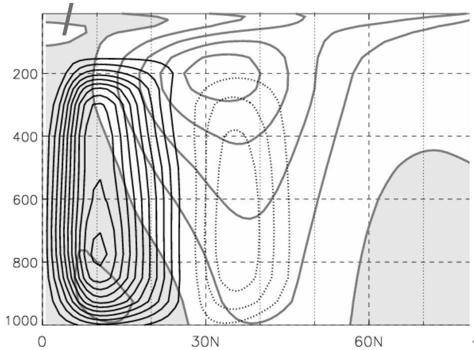
***E** (1ms^{-1}), Z^2 (500m^2)*

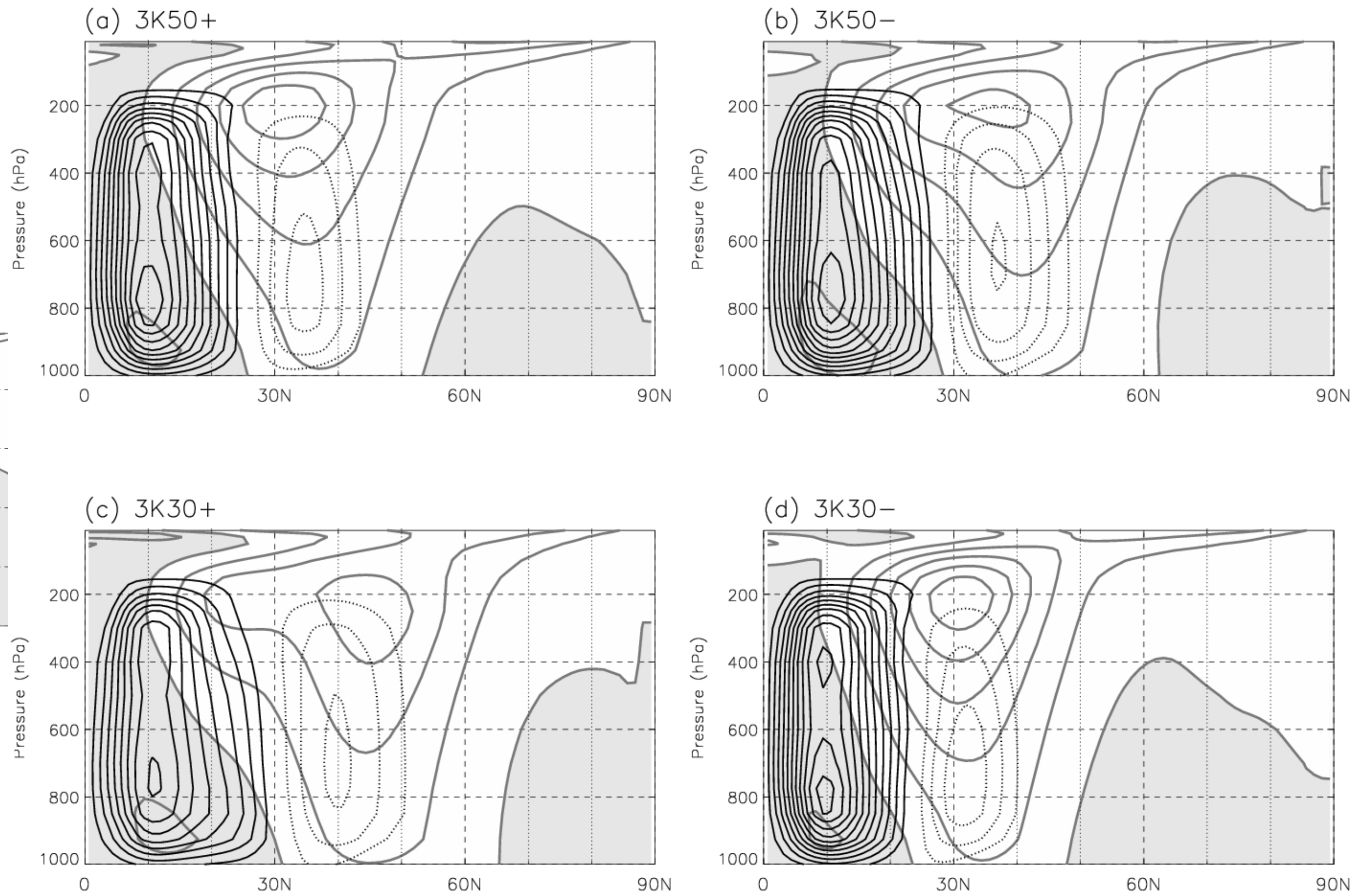
HadAM3 N96L30 (1.875^o x 1.25^o)
5 year runs (10 for control) after spin up
No seasonal cycle (perpetual equinox)



U, Ψ_{MOC} for the 4 experiments

contro l





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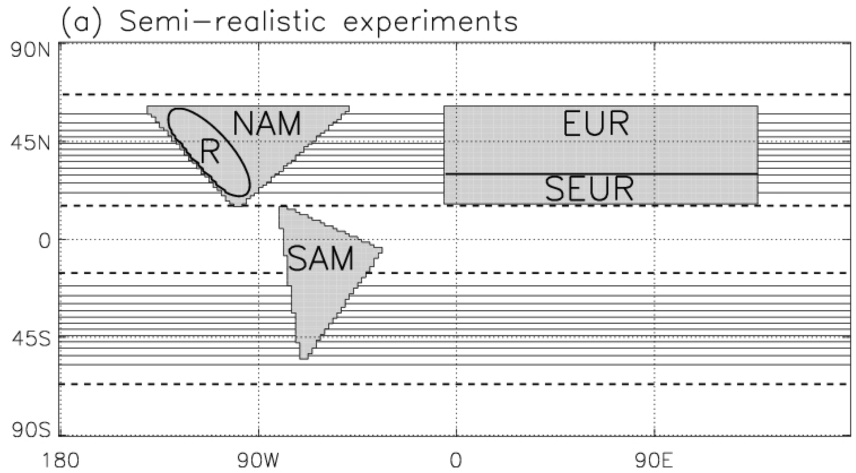
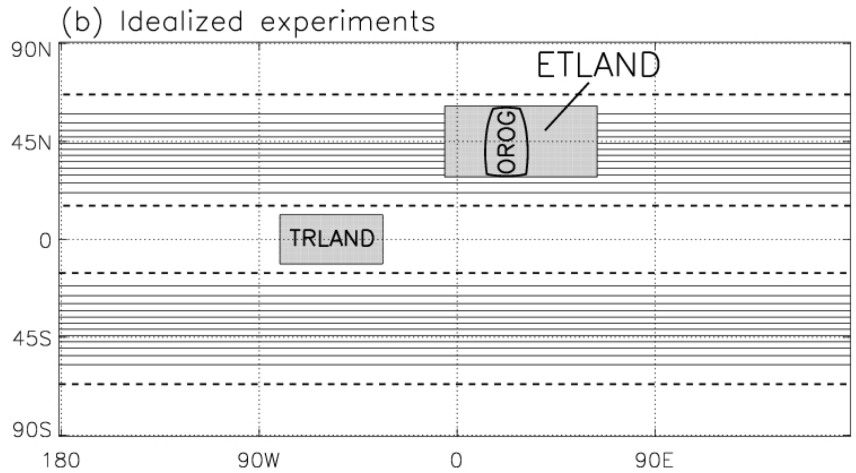
Continents added





Semi-realistic

Idealised

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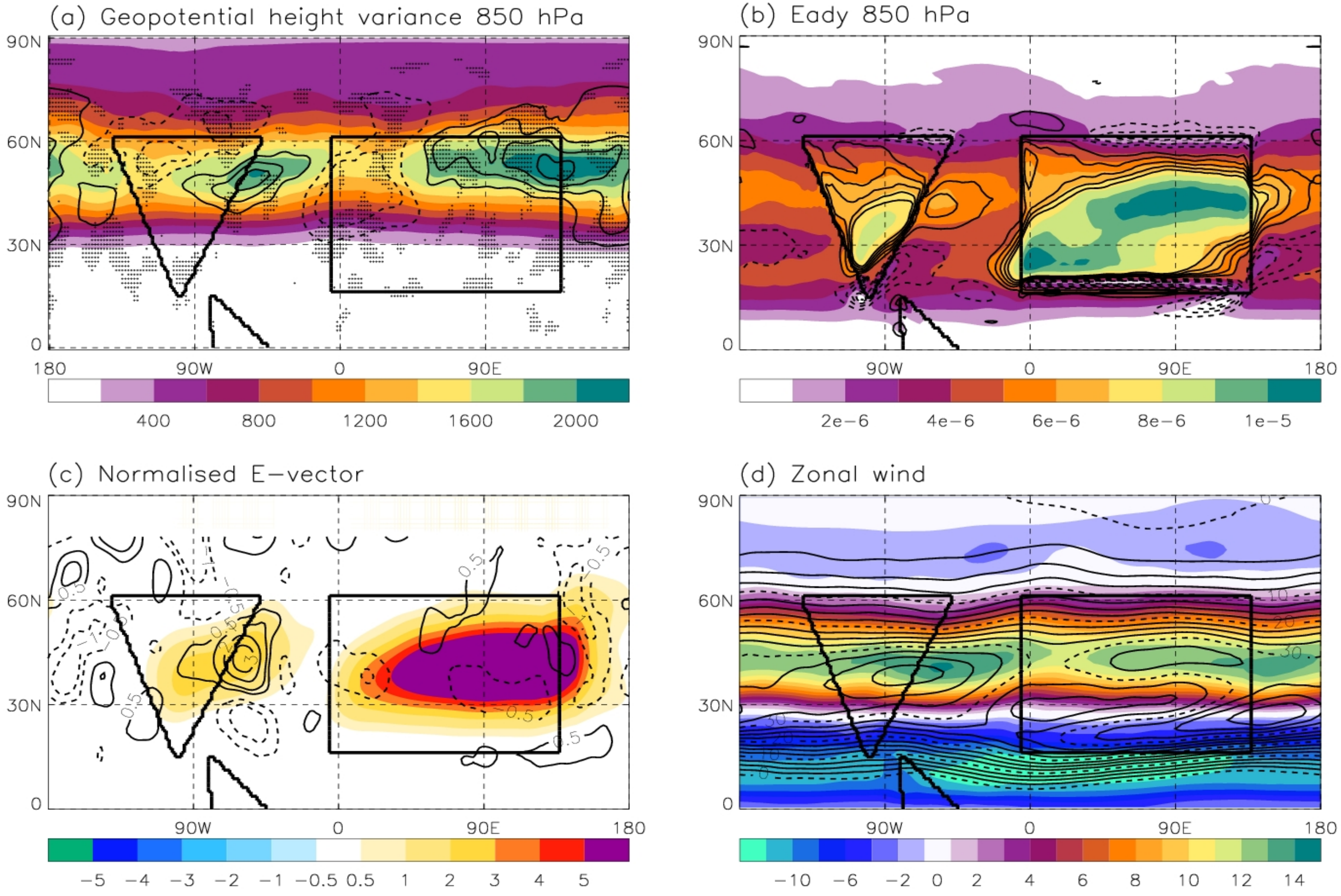
Three Continents



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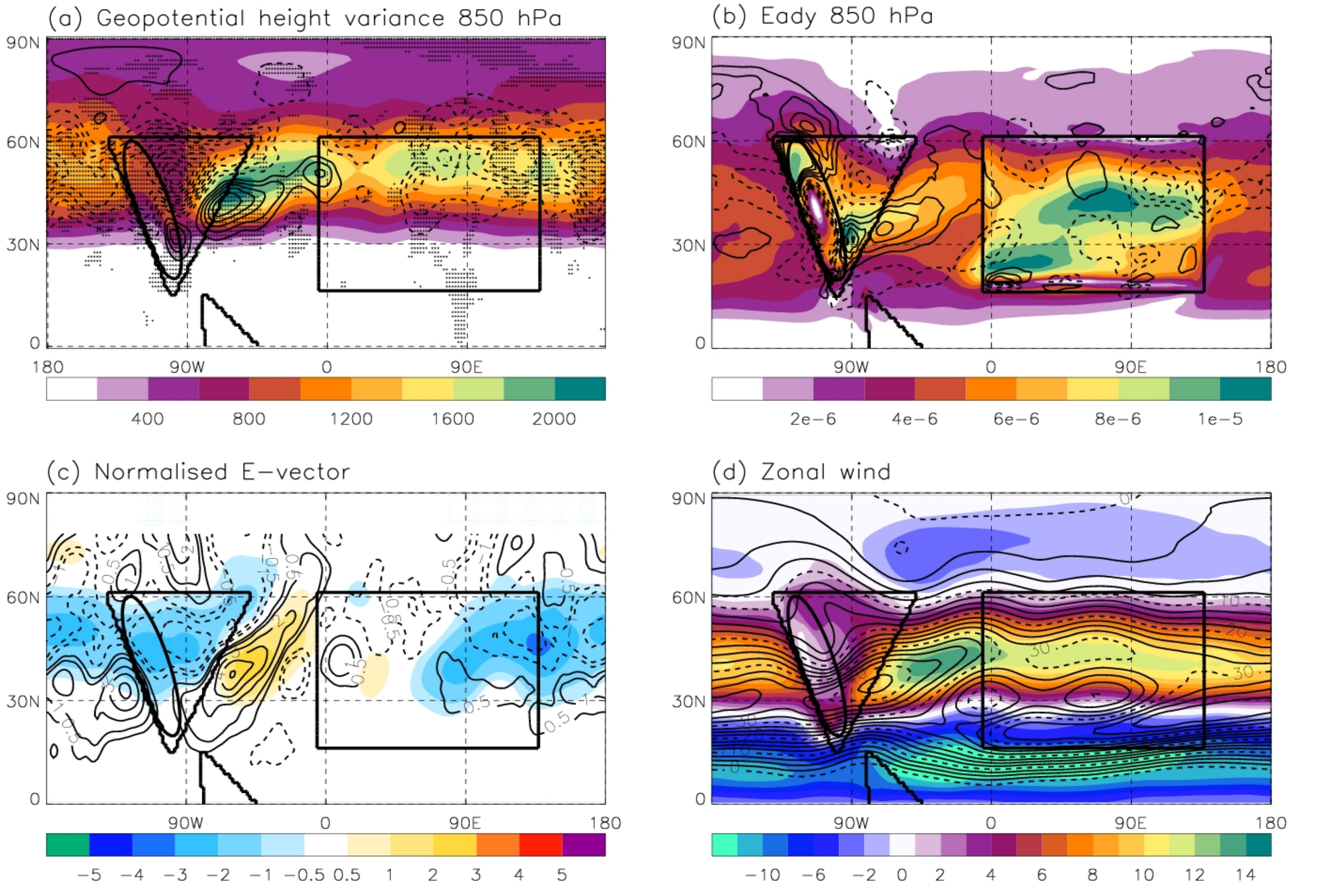
3 Continents + "Rockies"



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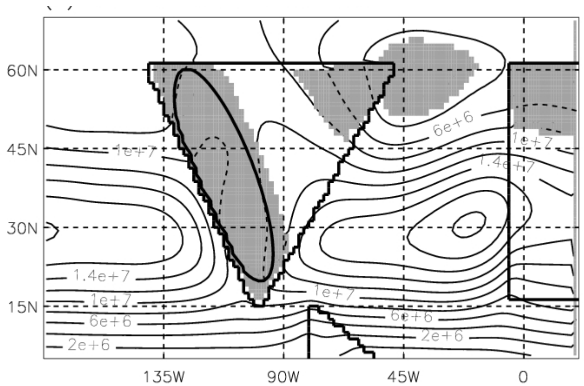
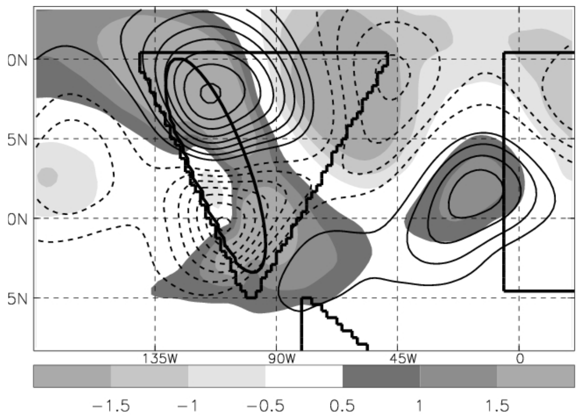
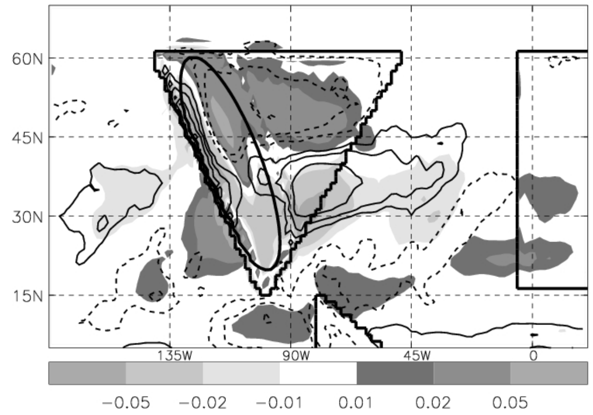
The Impact of Adding the "Rockies"





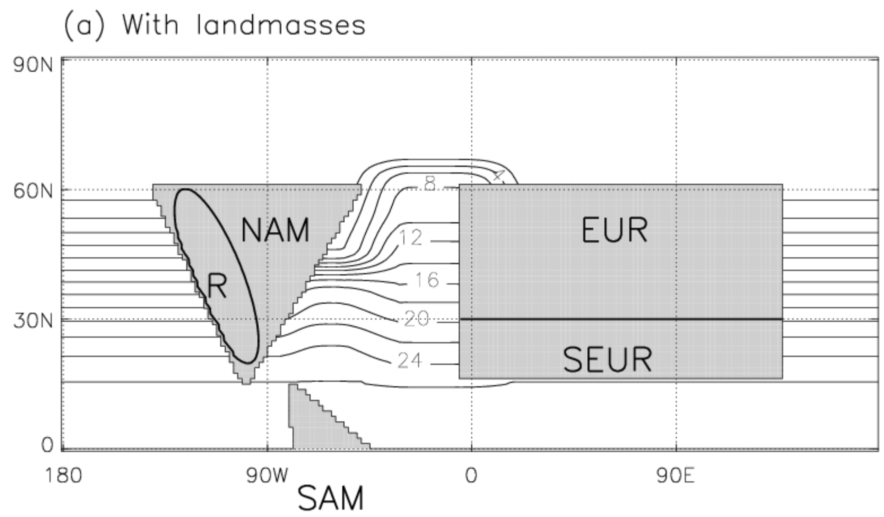


ψ_{1000}

ΔT_{700}: shading
$\Delta\psi_{700}$: contours

$\Delta\omega_{700}$: shading
Δprecip: contours

Adding the "Gulf Stream" & "N Atlantic Drift"



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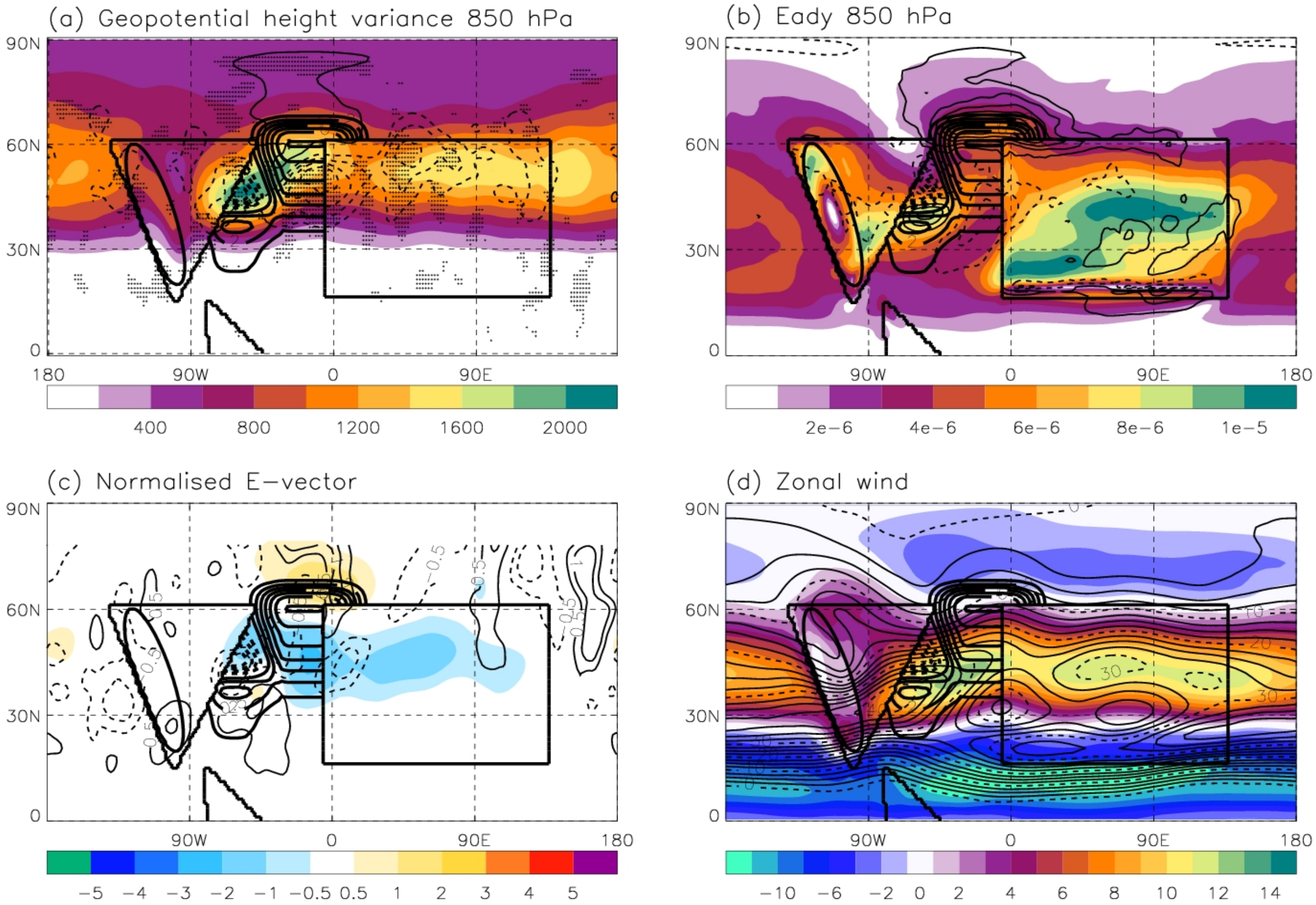
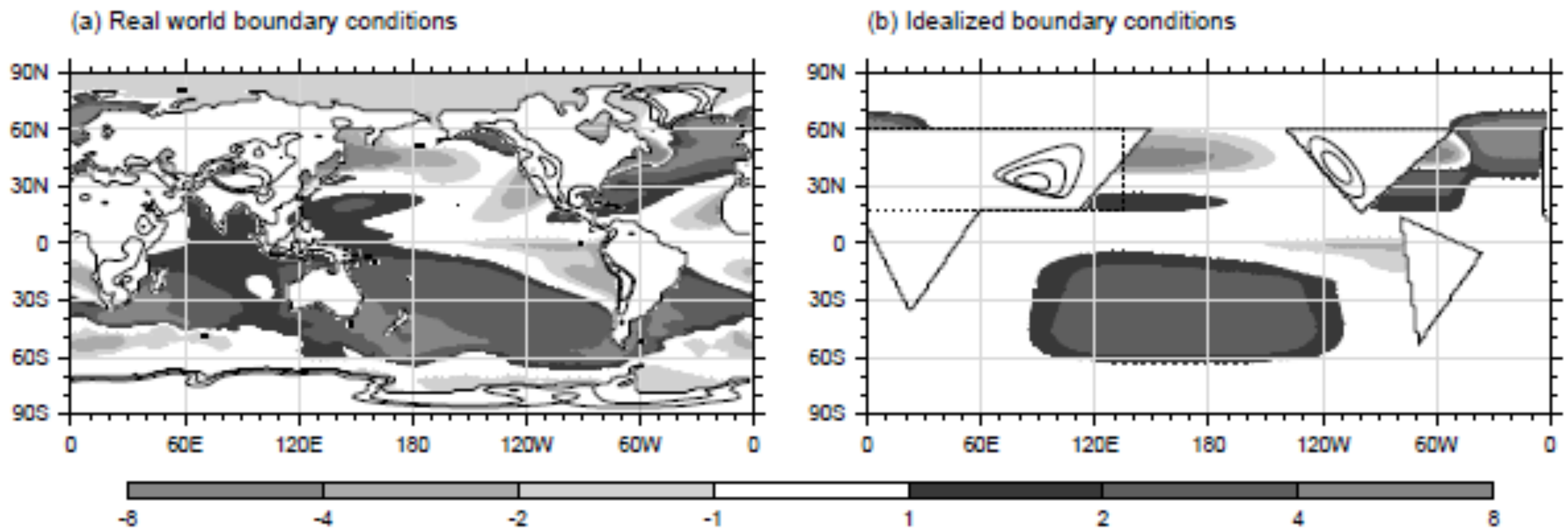
Adding the "Gulf Stream" & the "N Atlantic Drift"



Influence of a more realistic Eurasia & Pacific

Jerome Sauliere: Sauliere et al JAS 2011

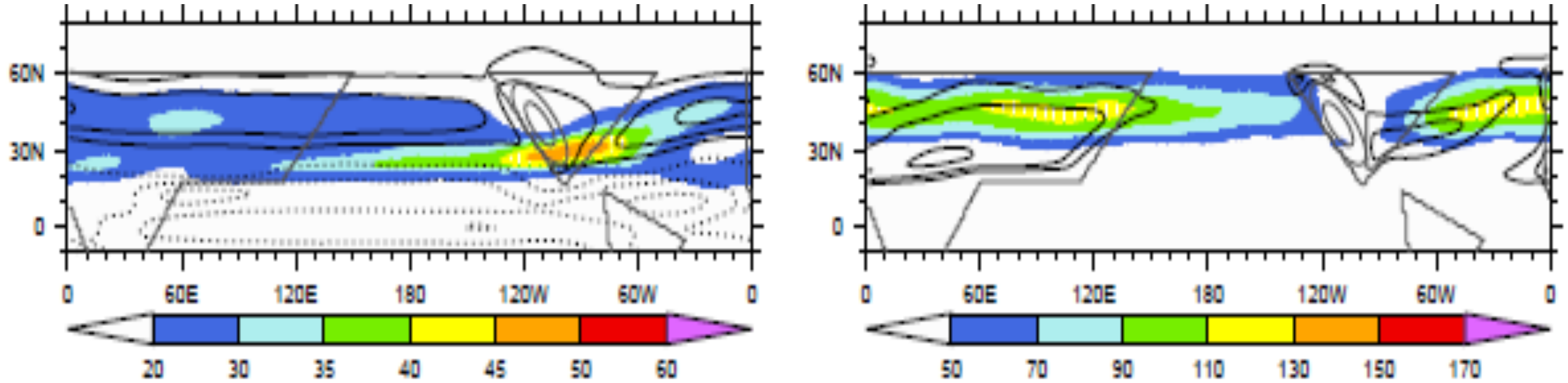
Model used:HadGAM1



Four Continents: better Eurasia & Africa

U_{250} colours; U_{850} contours

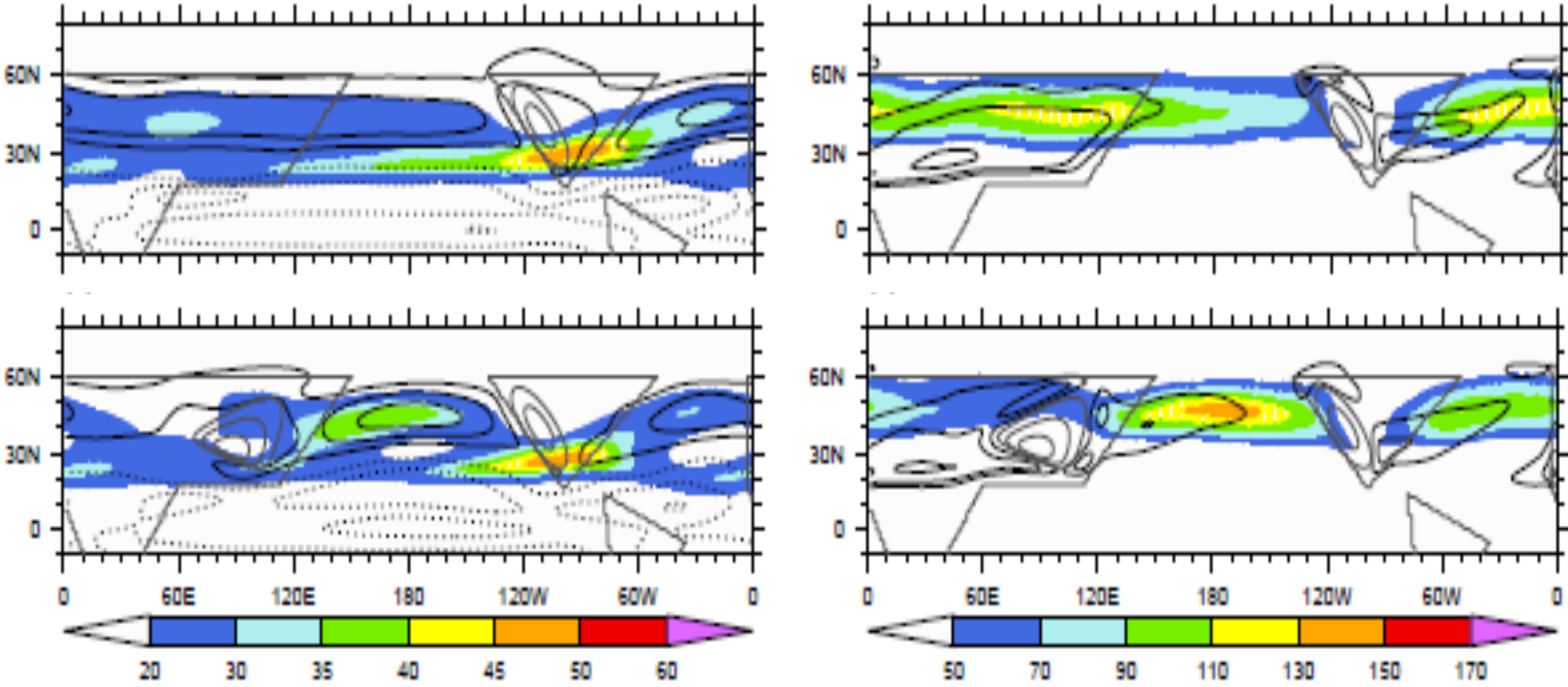
EKE$_{250}$ colours; Baroclinicity$_{850}$ contours



Adding "Tibet"

U_{250} colours; U_{850} contours

EKE_{250} colours; $Baroclinicity_{850}$ contours



4C

4C+T

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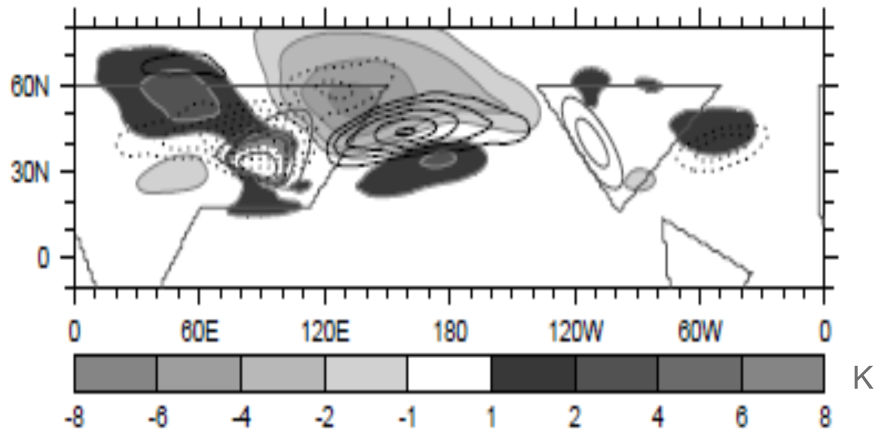
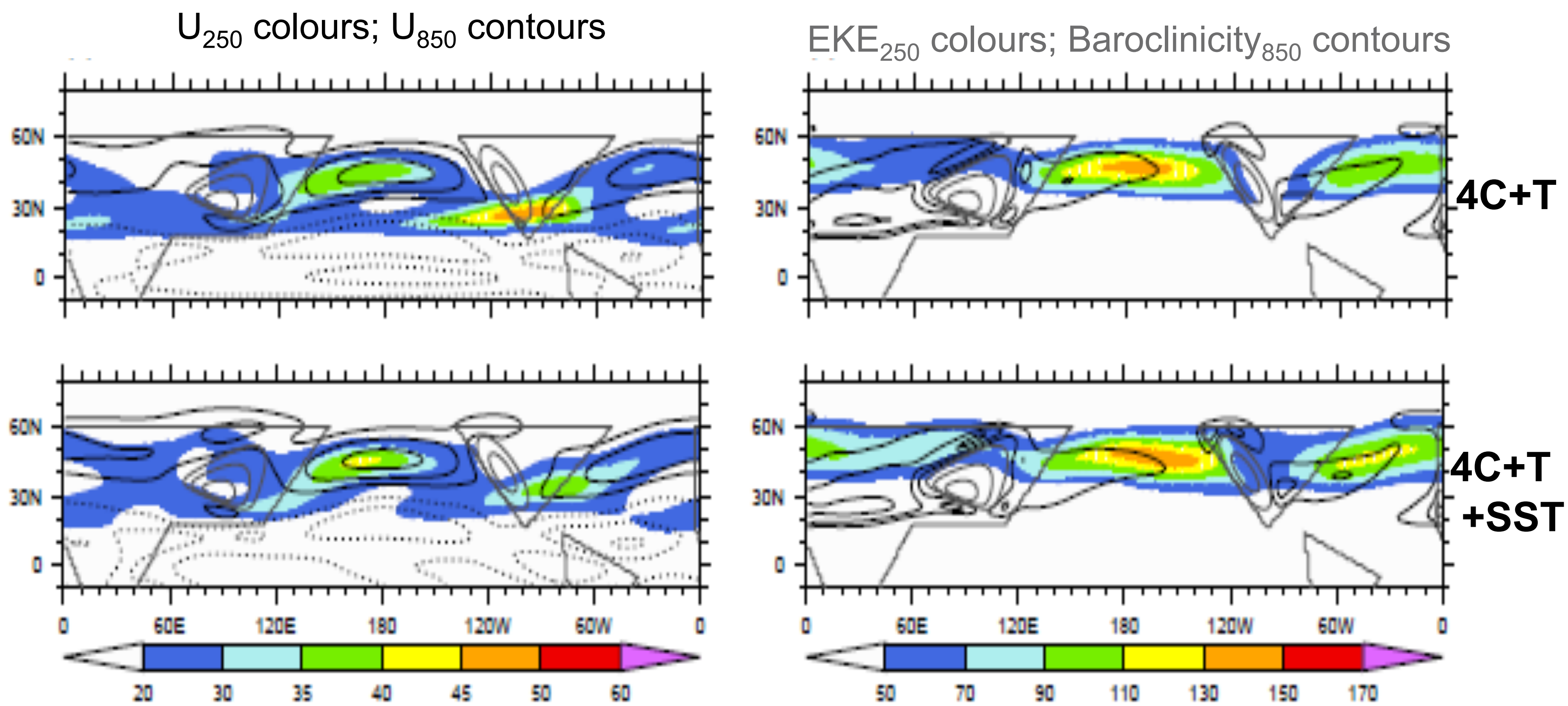
Impact of Tibet

Θ_{850} shading; $\omega'T'_{700}$ contours



Adding Pacific SST structure



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Some aspects highlighted by the experiments

- Importance of the strength & position (wrt downward branch of Hadley Cell) of the mid-latitude SST gradient
- Small impact of extra-tropical continents: localise storm-tracks
- Strong impact of "Rockies" & "Tibet", for N Atlantic & N Pacific storm-tracks, respectively
- "Gulf Stream" & "Kuroshio" produce small enhancements
- North Atlantic Drift helps stop the Atlantic storm-track continuing into "Eurasia"
- Eurasia/Pacific changes (particularly "Tibet") influence N Atlantic storm-track

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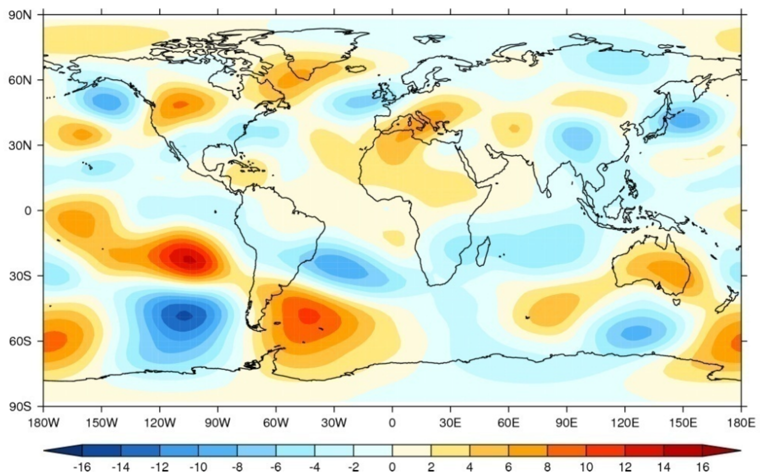
Idealised model investigation of seasonal anomalies

Ricardo Fonseca, Mike Blackburn

Adiabatic spectral model with simple damping
run in time-dependent mode (usually 30 days)
Climatological mean flow maintained by forcing terms

1. ***Impose tropical heating anomalies*** inferred from "observation"
2. Determine extra forcing terms to maintain mean anomalous flow & investigate the role played by components of this –***Inverse Technique***
3. Relax aspects of the flow back to observed anomalies –***Relaxation***

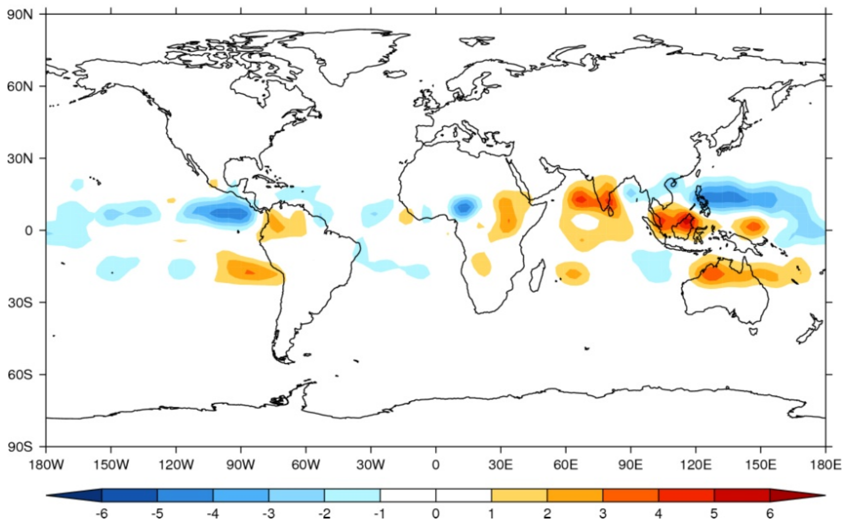
June-July 2007



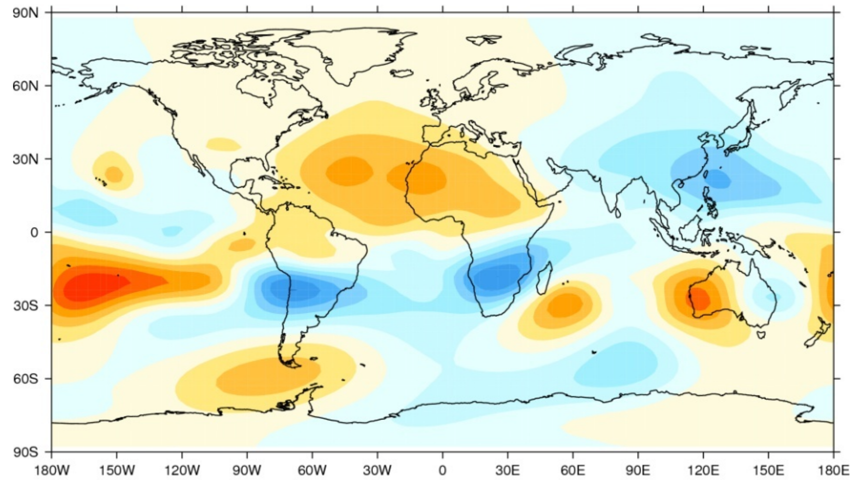
Ψ_{200} anomalies

Imposed tropical heating anomalies

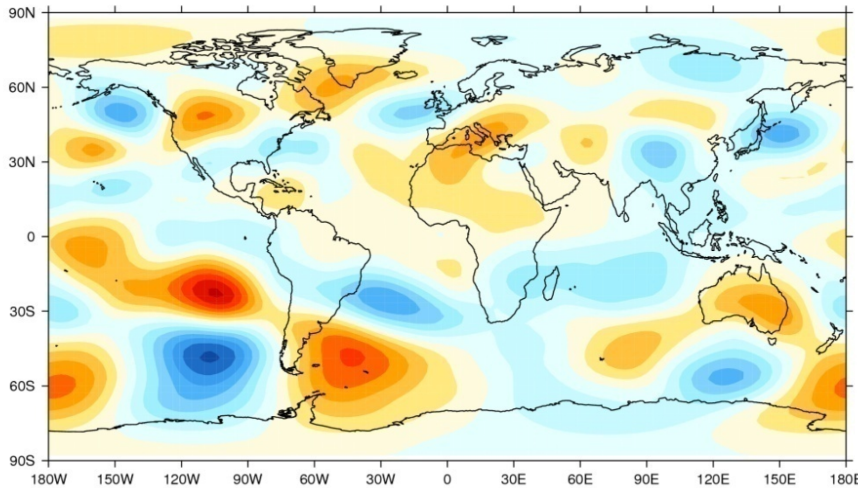
Heating at 400hPa



Ψ_{200} response



Observed



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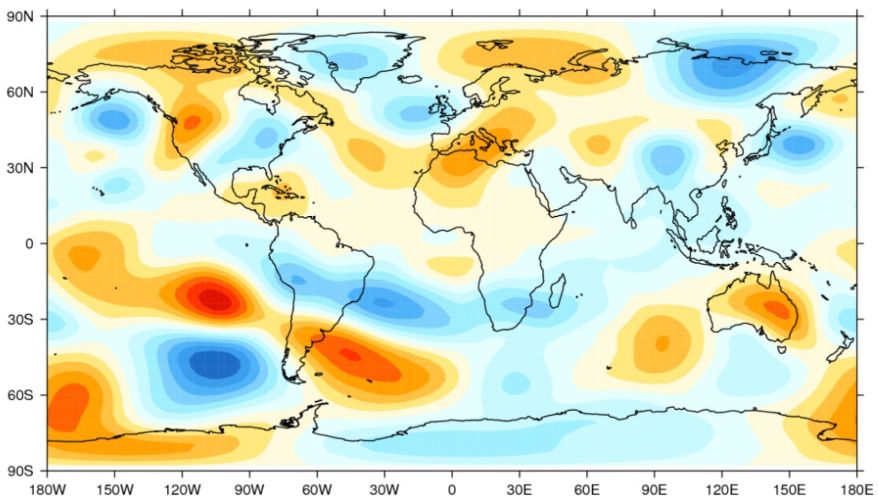
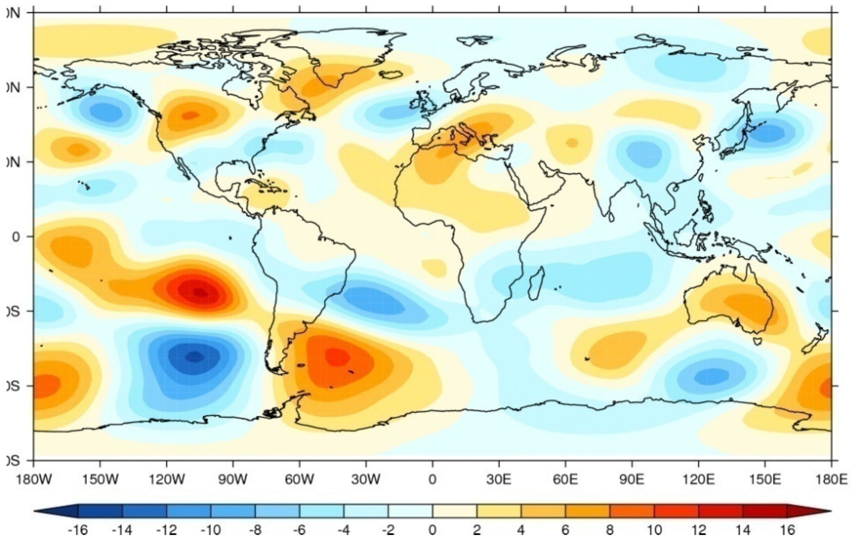
Inverse technique: check

Ψ_{200} response at day 30

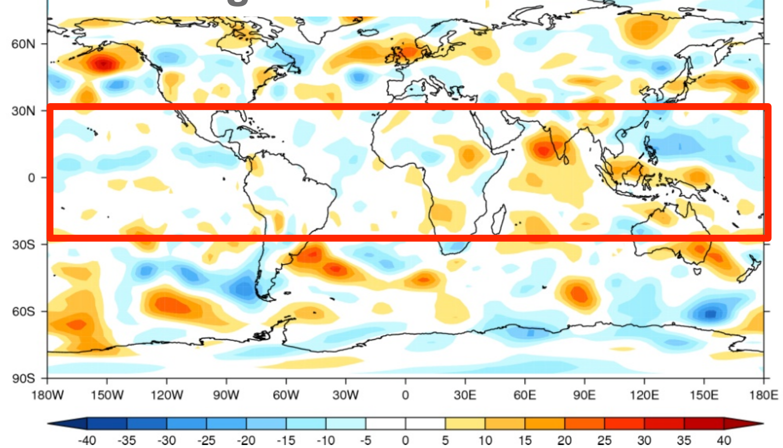


Ψ_{200} observed

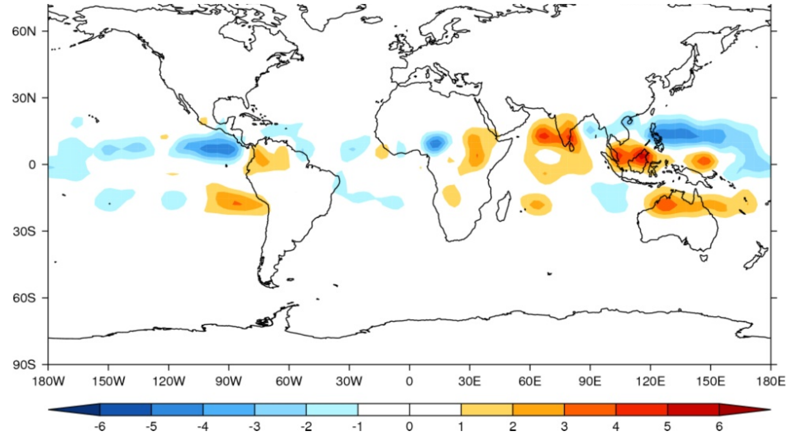


Inverse technique: tropical T forcing

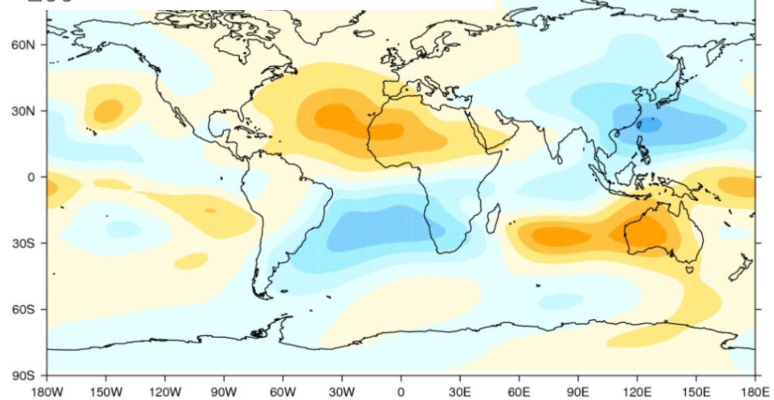
T forcing at 400hPa

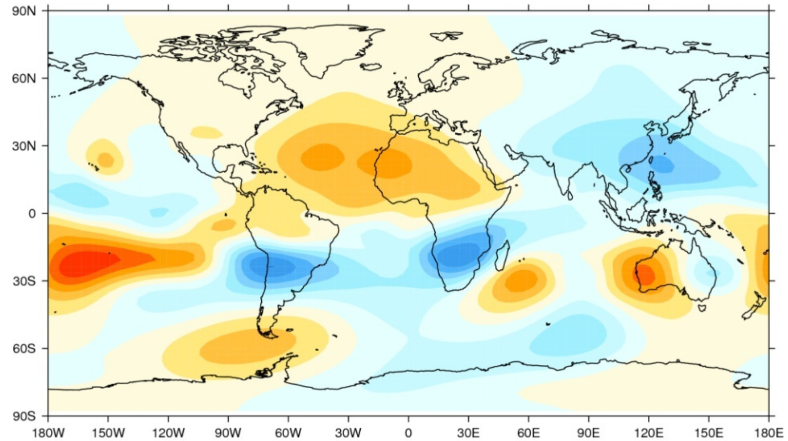


"Observed" tropical heating anomalies



Ψ_{200} response at day 30





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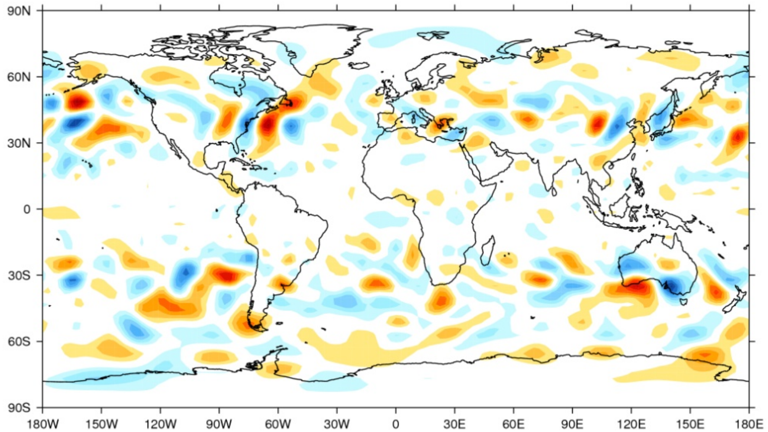
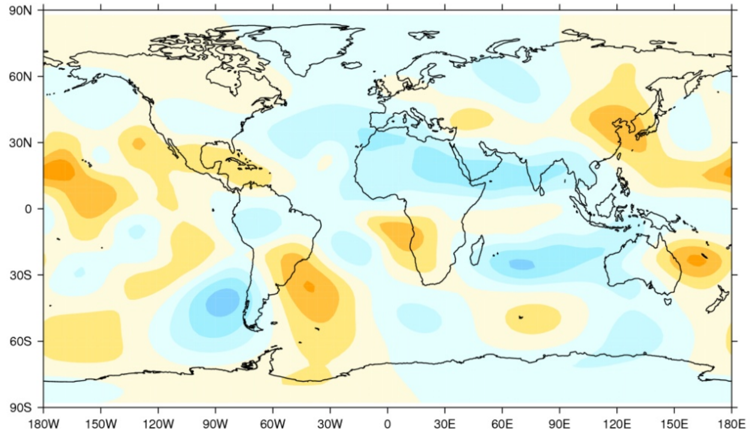
Inverse technique: vorticity forcing

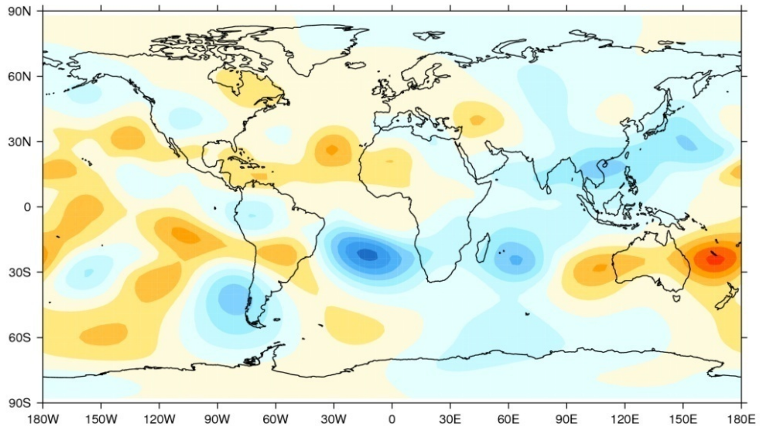
ζ Forcing at 200hPa



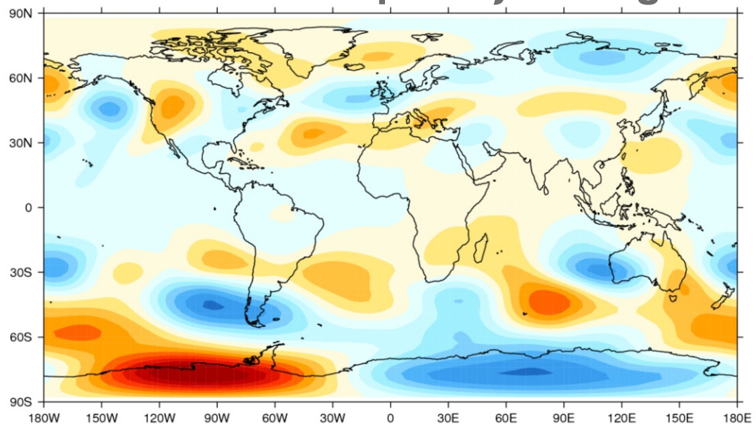
Ψ_{200} response at day 30: tropical ζ forcing



Tropical ζ & T forcing



Extra-tropical ζ forcing



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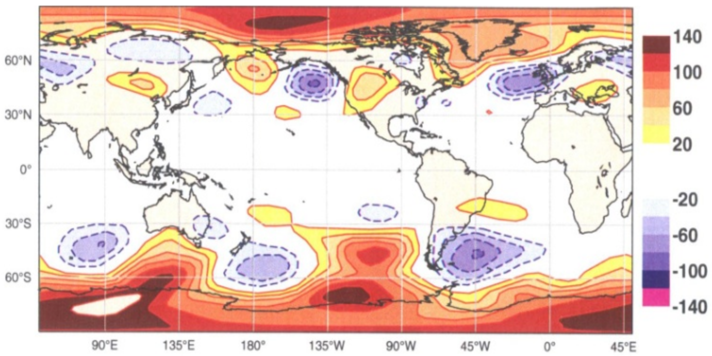
Relaxation: comparison ECMWF ensemble

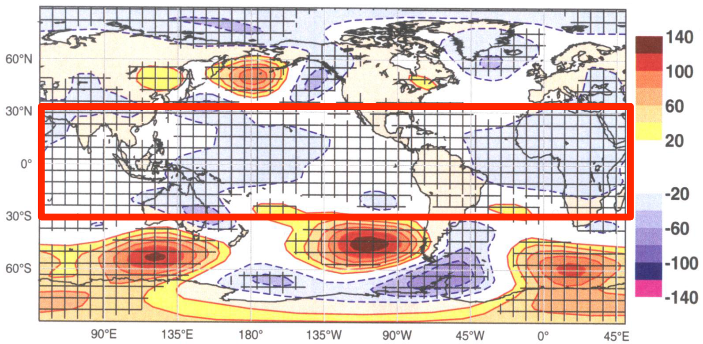
Time-scale 10h in both

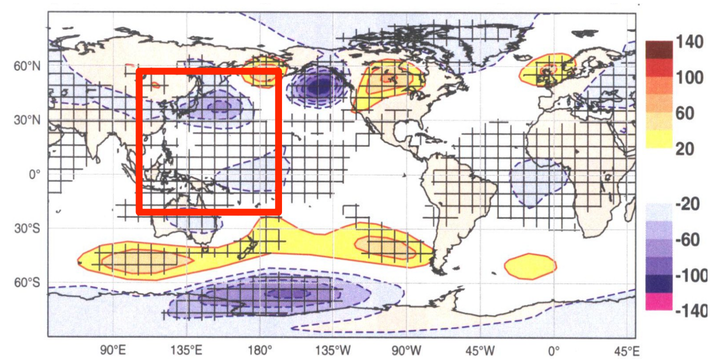
Z_{500} observed



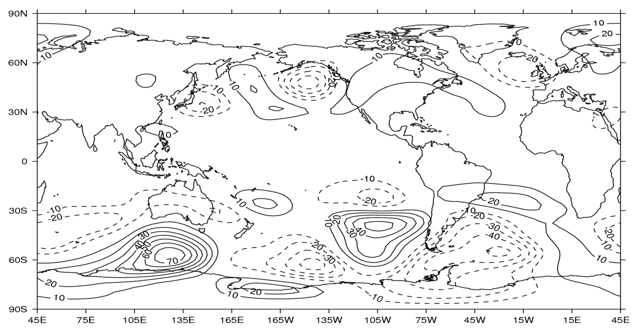
ECMWF MODEL c.i.20m

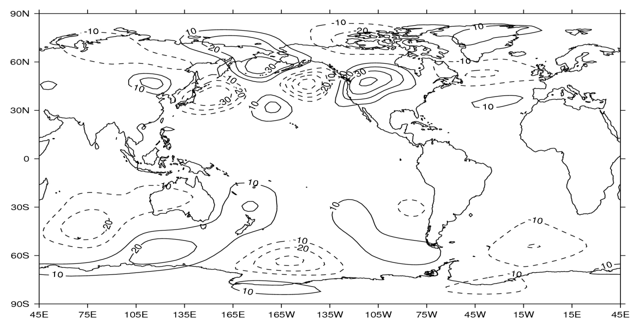
T Jung





IGCM c.i.10m





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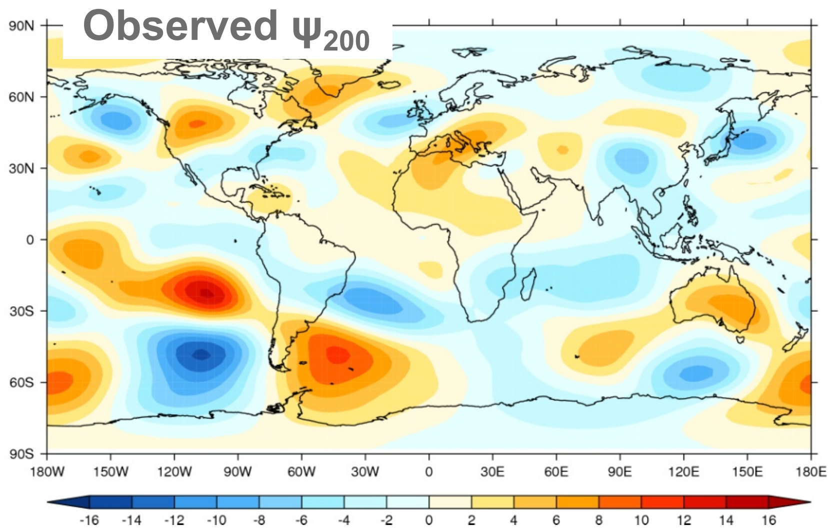
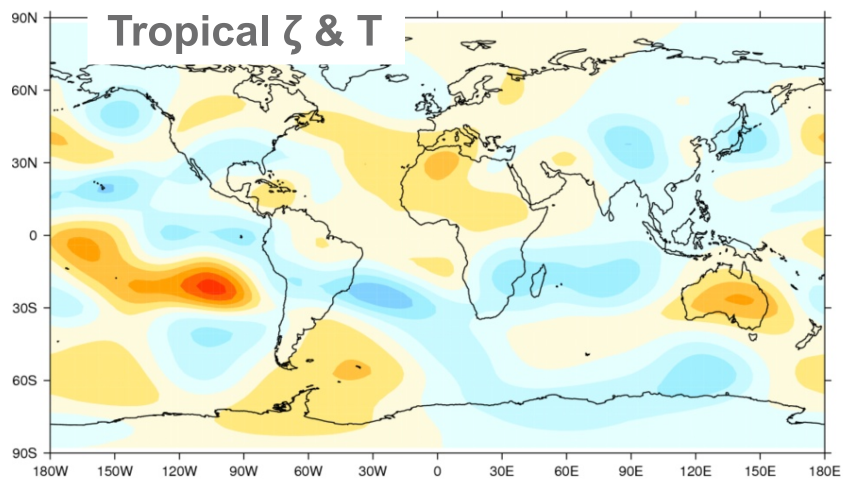
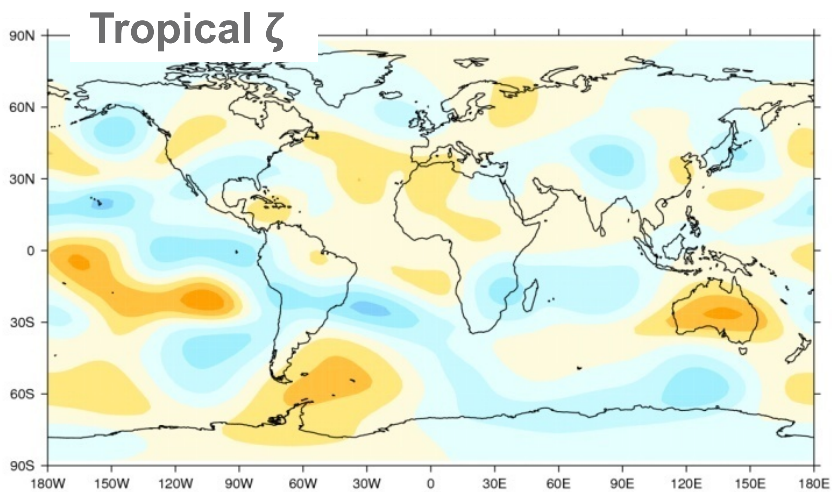
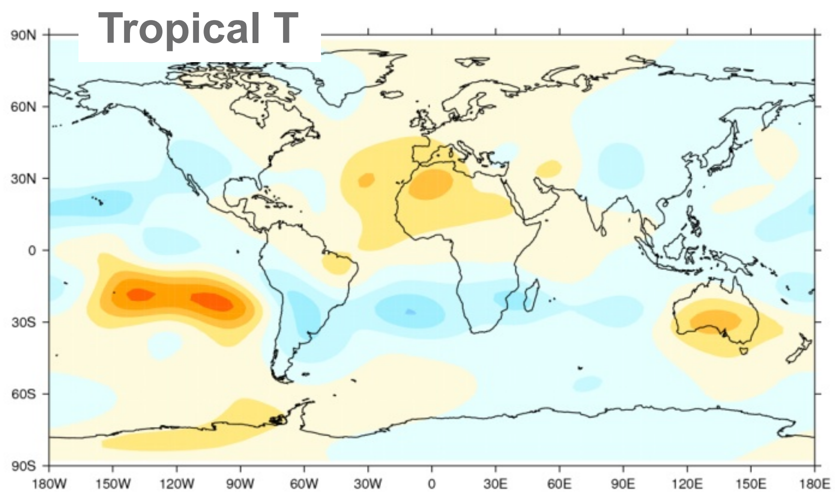
Tropical Relaxation

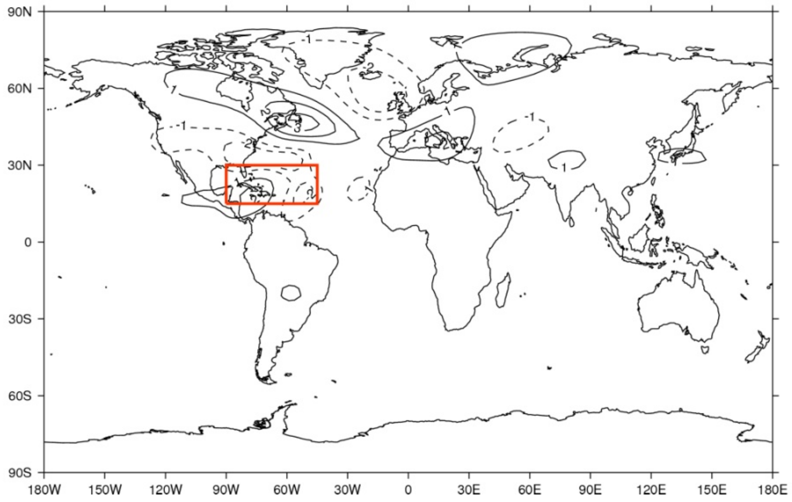


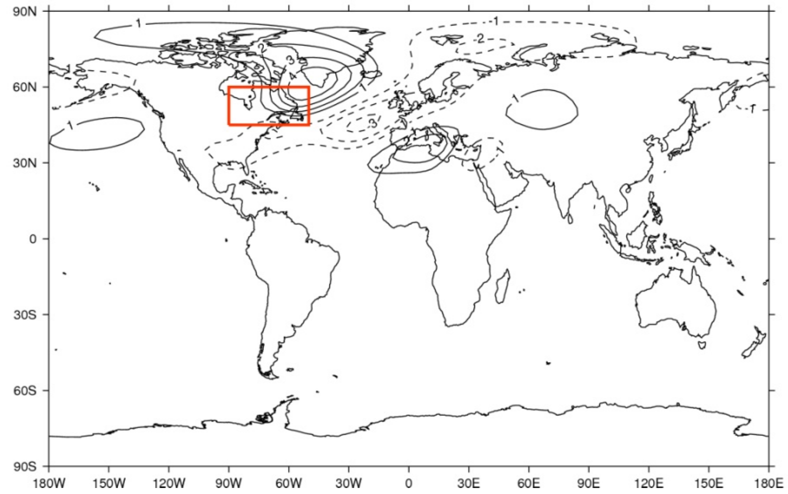


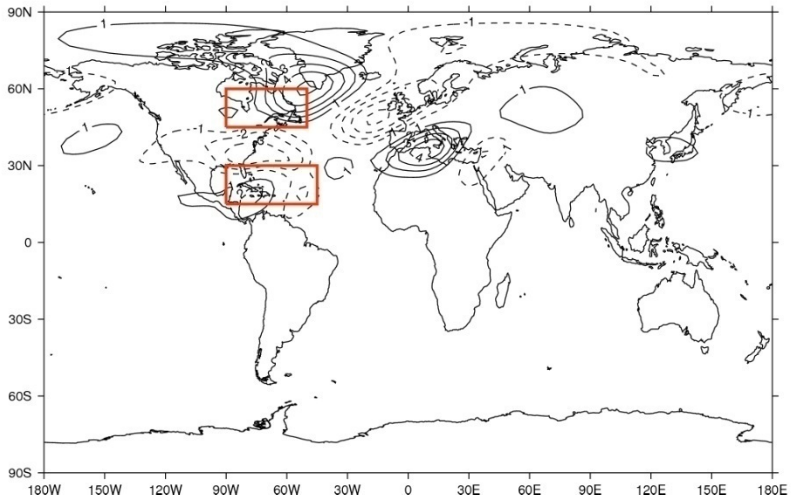


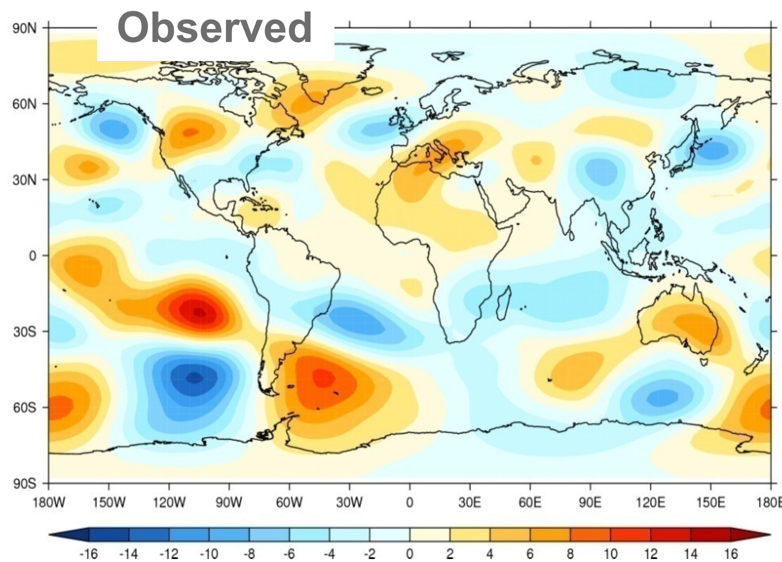


Relaxation: localised









Conclusion

- 3 techniques with a simple time-dependent baroclinic model yield useful, complimentary insights
- They provide support for experiments/forecasting with complex models.

- Importance of tropical vorticity as well as thermal forcing
- Important for Europe in summer: Caribbean region
  upstream storm-track vorticity transients

Long live the hierarchy of models!