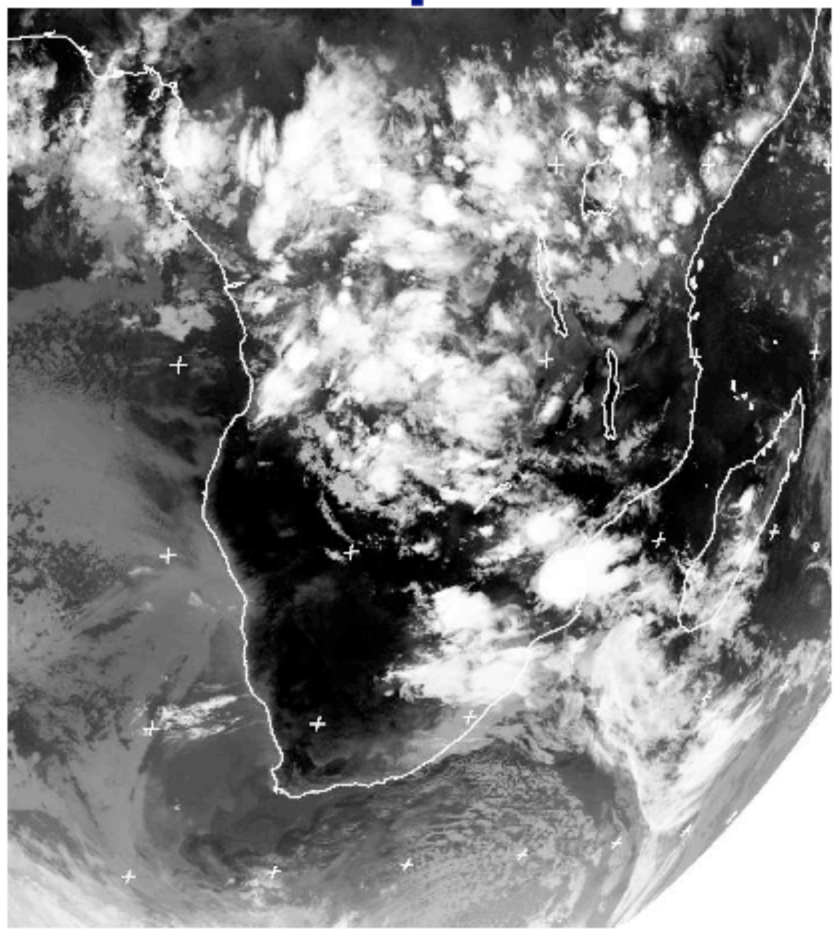
Stronger local overturning in convective-permitting regional climate model improves the simulation of subtropical seasonal cycle



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1 - School of Geography and the Environment, University of Oxford
2 - Met Office, Exeter

With thanks to UMFULA Colleagues

FUTURE CLIMATE FOR AFRICA **UMFULA**

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The Problem: Wet Bias

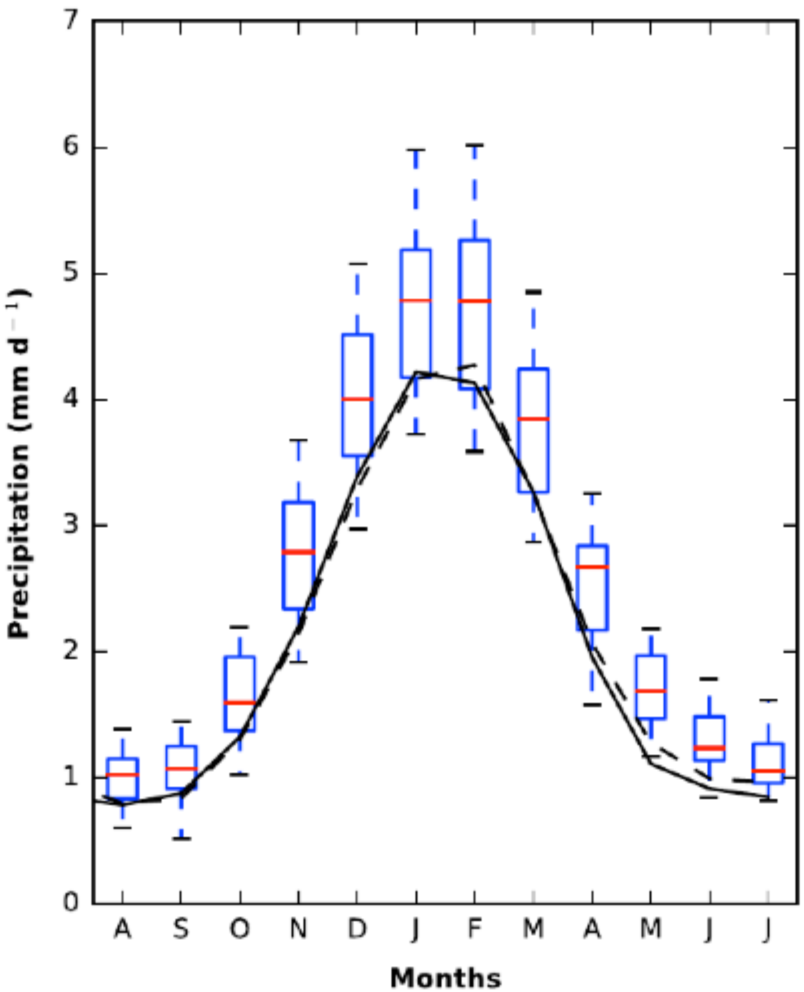
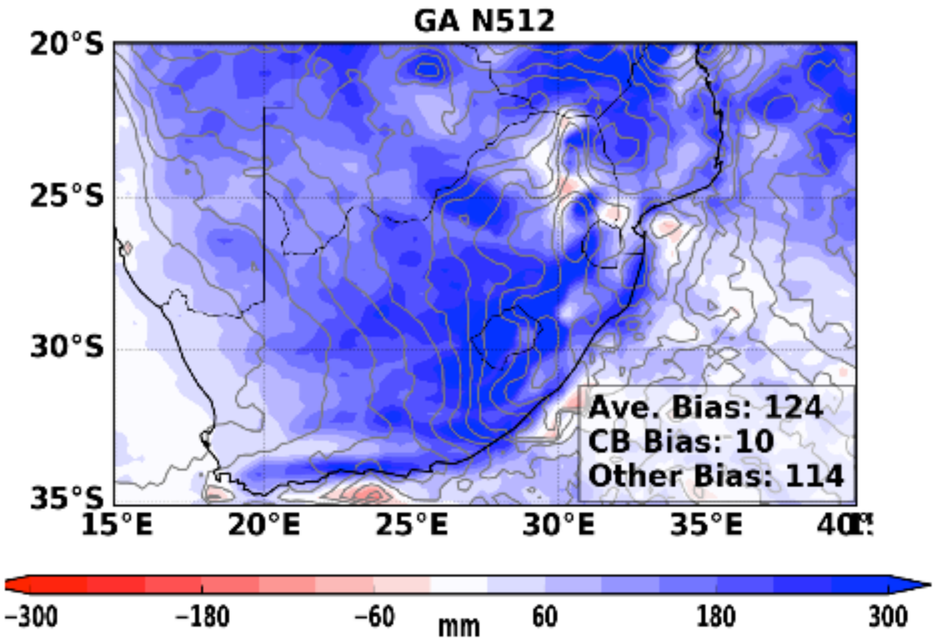


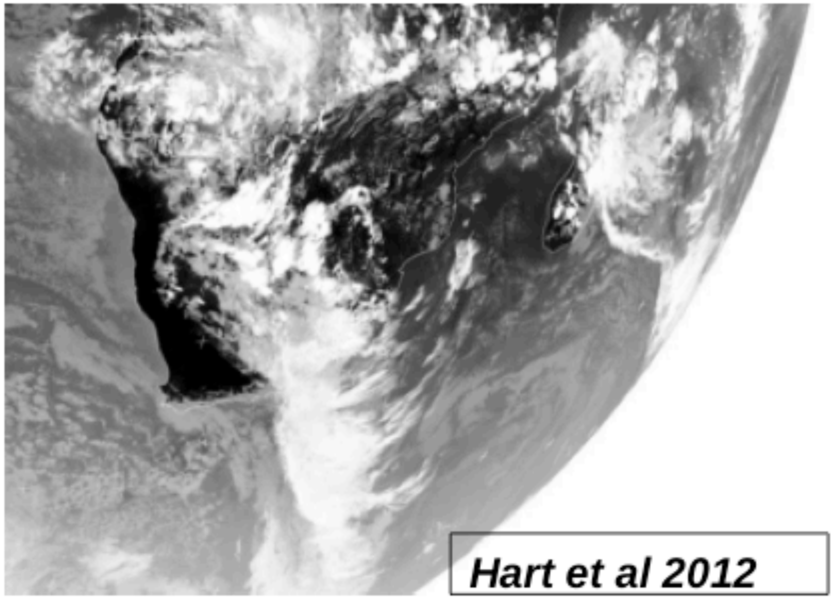
Figure 1. Mean (1979–2005) annual cycle of southern African rainfall (averaged over 10–52°E,10–35°S) in CMIP5 models (box plots) compared to CMAP (dashed line) and GPCP (solid line). The red lines show the median model for each month, the box encompasses the interquartile range of models, and the tails represent the full range.

Munday and Washington 2017 JGR: Atmos.



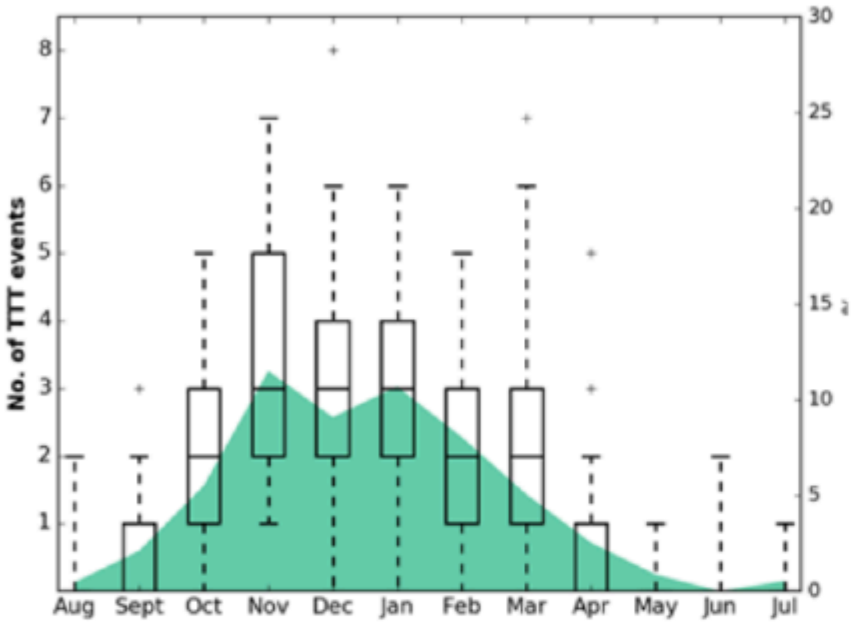
- CMIP5 models overestimate southern African rainfall 150-200%
- Met Office Unified Model (HadGEM) simulates similar wet bias…
    - Persists in both AMIP and CMIP configurations

The Problem: Poor Annual Cycle

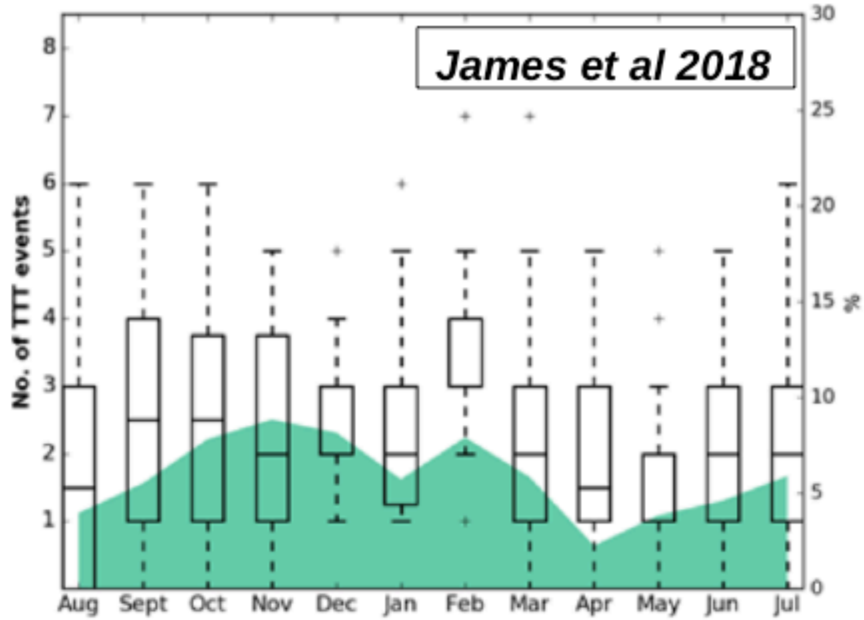


- Tropical-extratropical cloud bands dominate annual cycle of rainfall in the region
- Met Office Unified Model simulations fail to represent this annual cycle
- This is typical of CMIP5 models, with over two-thirds simulating flat annual cycles (pers. comm. Rachel James)

Satellite Observed cloud band count

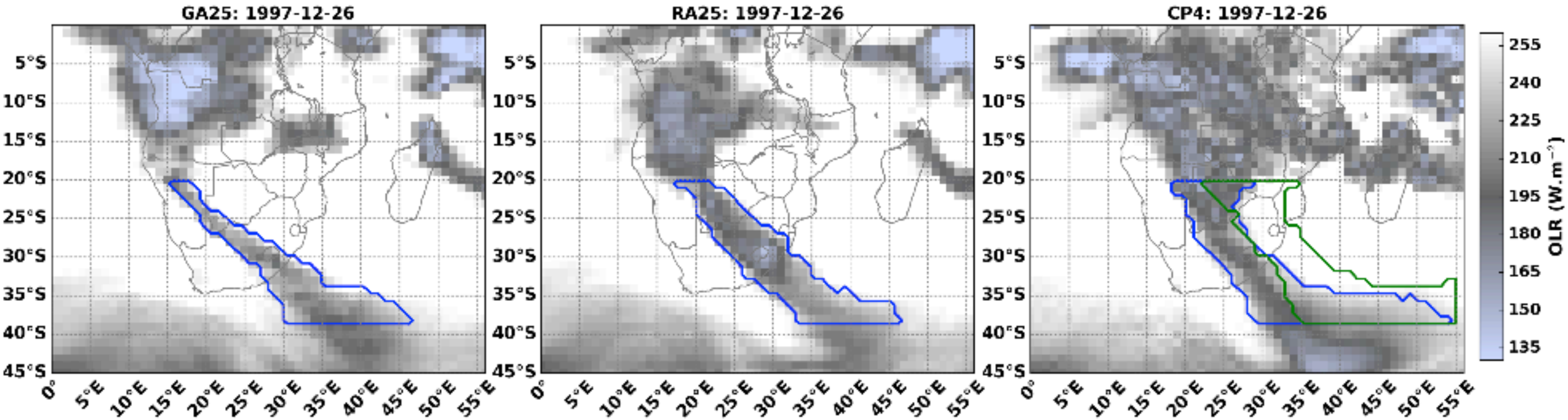


HadGEM3-GC2 cloud band count



Model Experiment

Does explict representation of convection reduce these regional biases?



Met Office UM

GA7 AMIP-style N512

1988-2010

Provides LBCs to →

Met Office UM

LAM: Pan-African 25km

Parametrized Convection

1997-2007

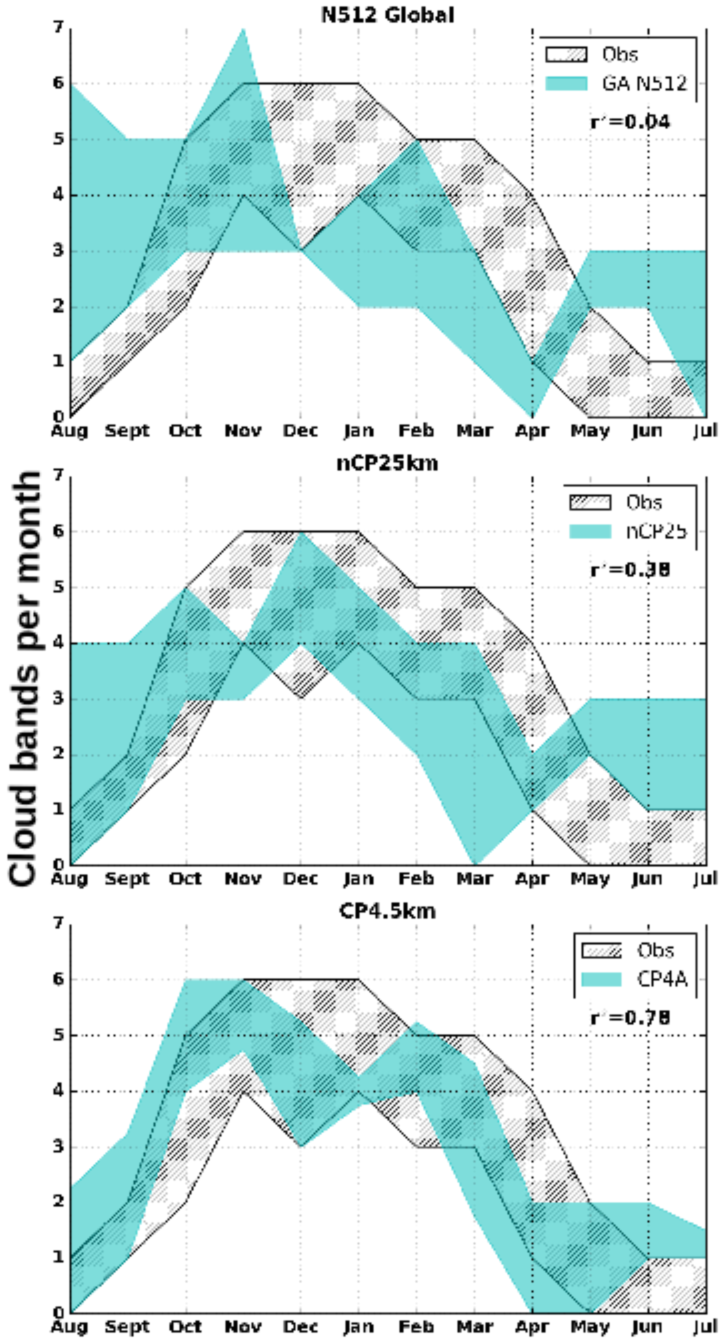
Met Office UM

LAM: Pan-African 4.5km

Explicit Convection

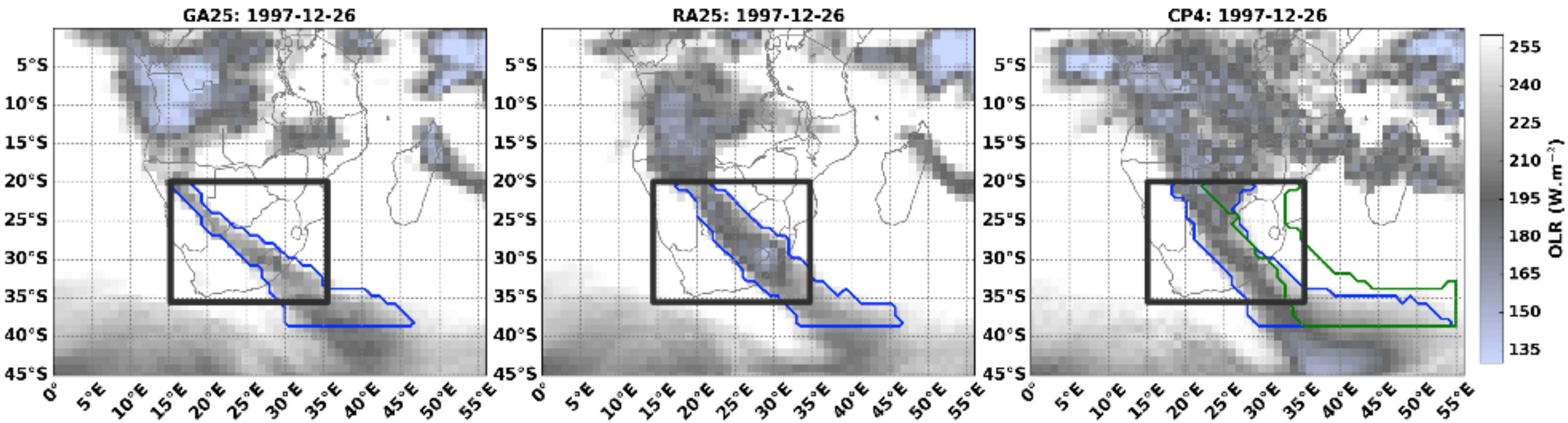
1997-2007

Simulated cloud band seasonality



- Global and regional convective-parametrized models very similar and simulate poor annual cycle in cloud band likelihood
- CP4 dramatically improves annual cycle
  - Increased event frequency during core summer months
  - Few events during winter
- Indicates regional forcing is a strong component of simulated biases in tropical-extratropical interaction frequency

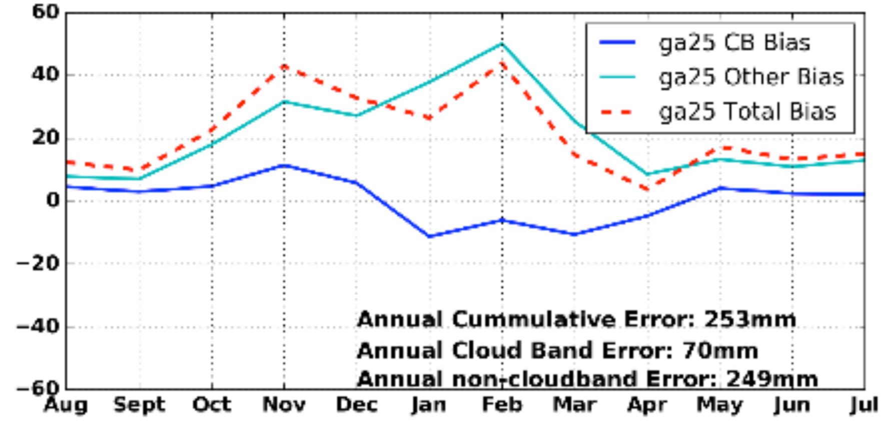
Area-averaged Rainfall Bias

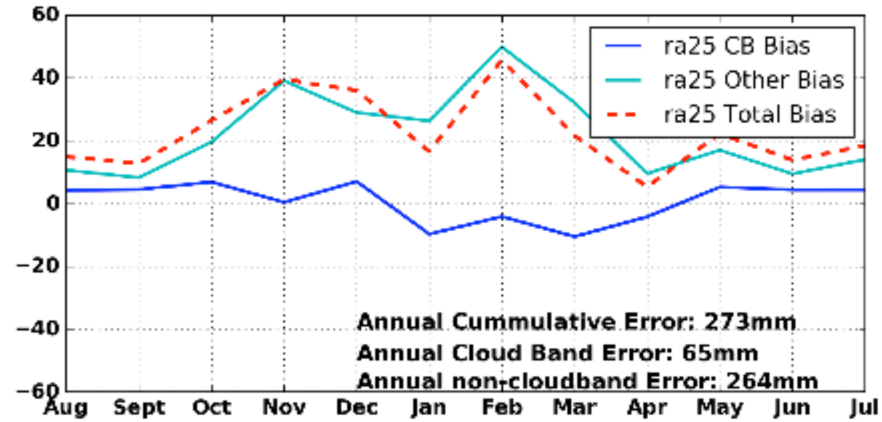


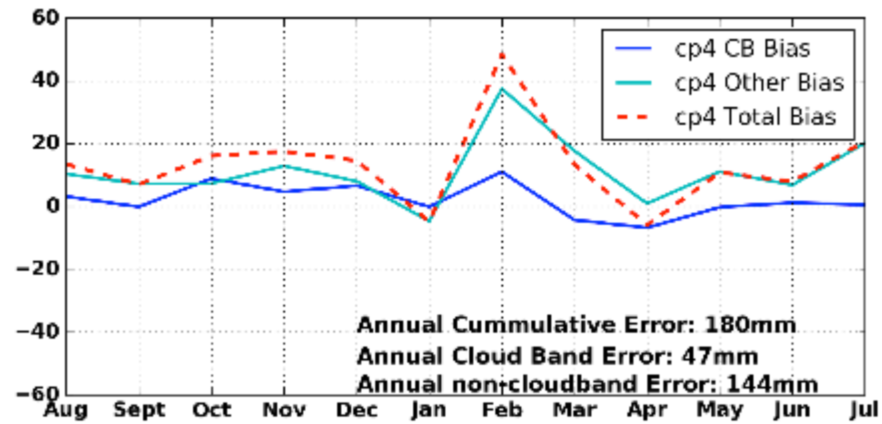
MetUM	MetUM	MetUM
GA6 AMIP-style N512	Regional All Africa 25km	LAM: All Africa 4.5km
1988-2010	Param. Convection	Expl. Convection
Provides LBCs to →	1997-2007	1997-2007

Area-averaged Rainfall Bias

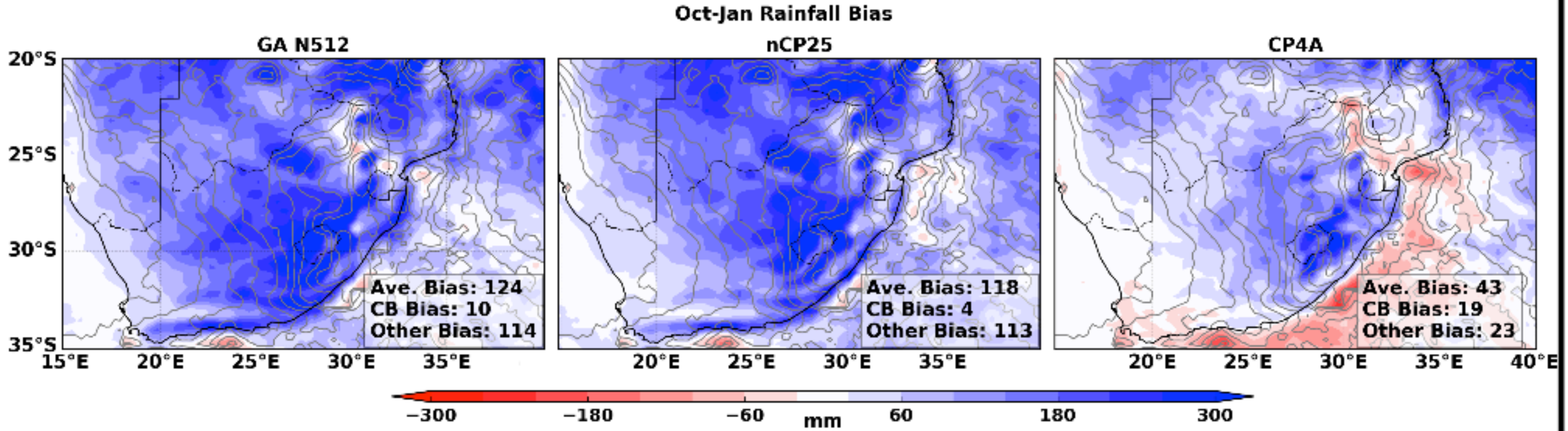
- Global and regional convective-parametrized models maintain wet season wet bias
- CP4 simulation halves the wet bias
  - Cloud band rainfall has improved seasonality
  - Much of the improvement in total bias is reduction in rainfall from not related to cloud band events.
- CP4 improvements are during October to January
  - Large bias in February related to Mozambique Channel convection-circulation feedback errors







Reduction of wet bias in CP4

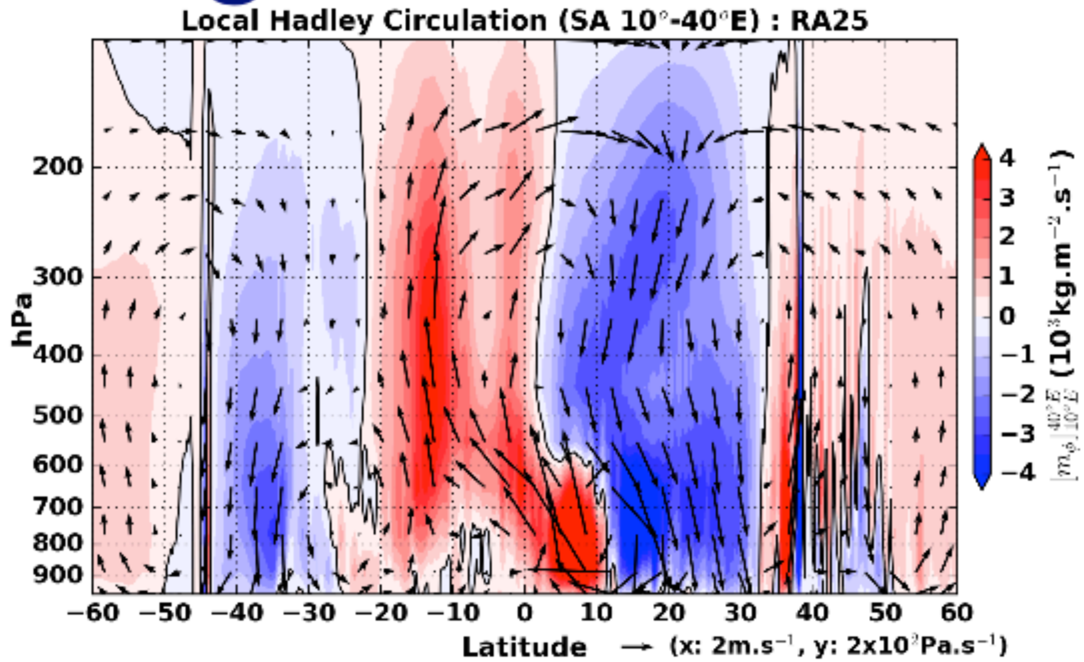


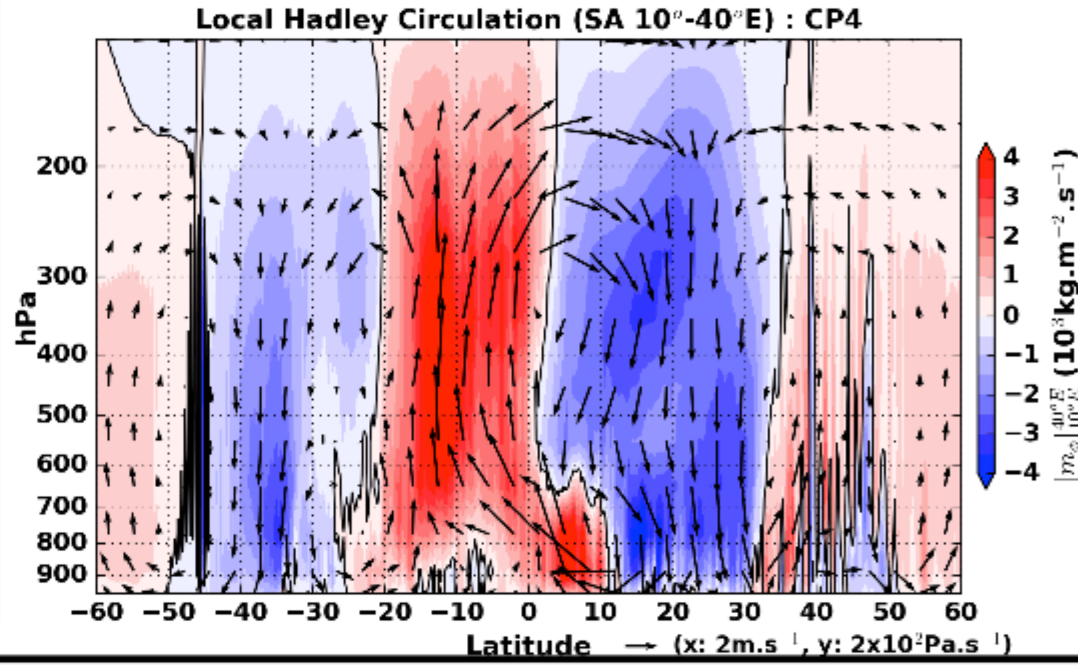
- Reduced October to January rainfall bias in CP4 and improved maintenance of east-west rainfall gradient

Local Overturning Circulation

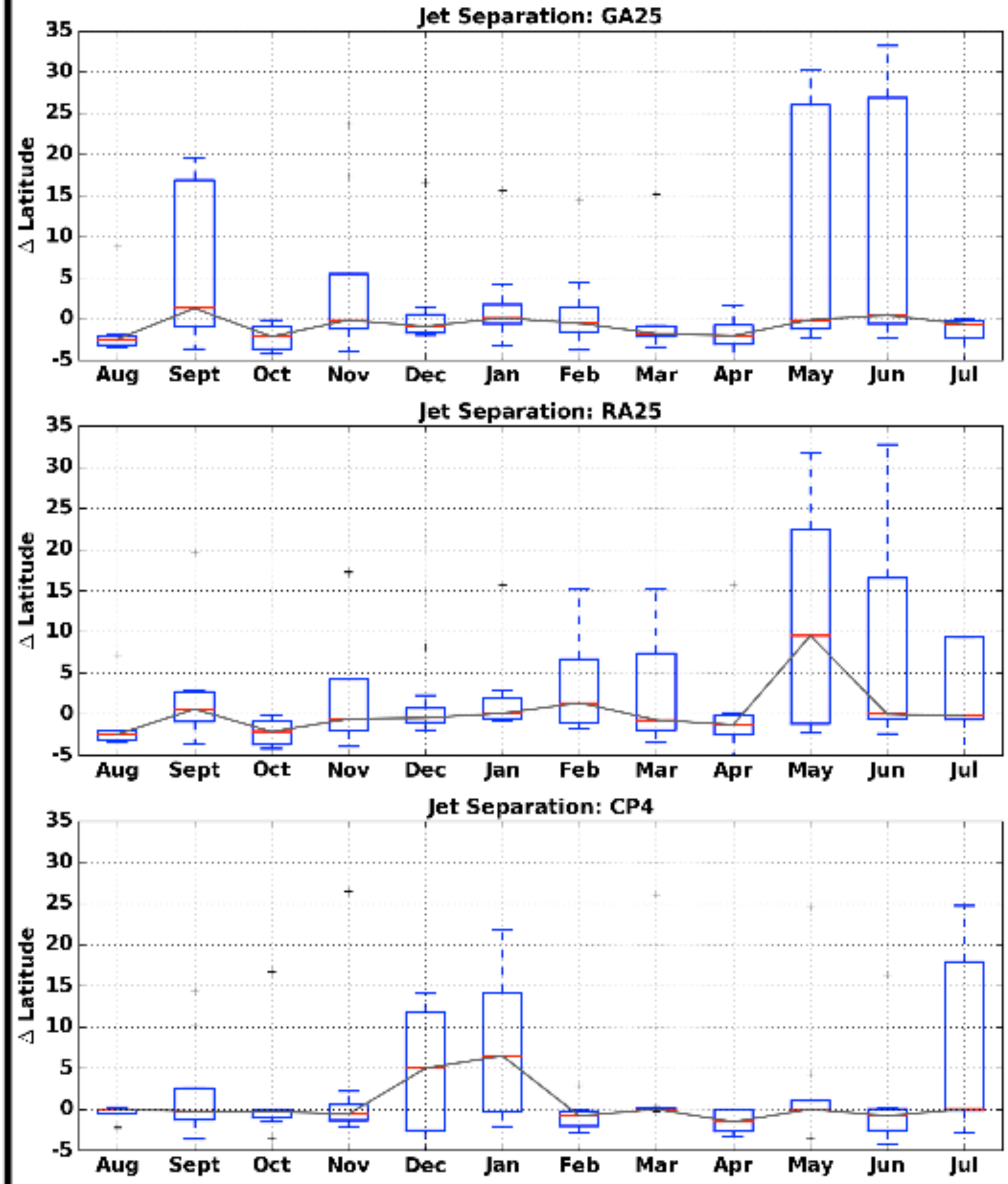
- Vertical mass flux is locally decomposed into meridional and zonal components of circulation following ***Schwendike et al 2014***
- Zonal mean of meridional components across southern African sector gives the local Hadley circulation

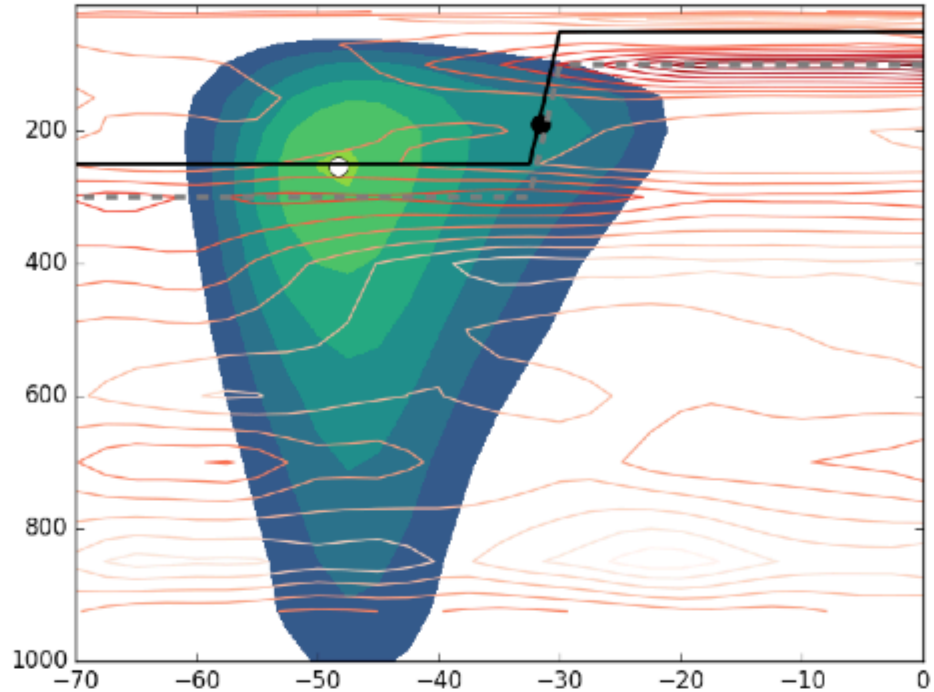
- CP4 produces greater tropical ascending mass flux than regional model with parameterised convection
- CP4 simulates strengthened poleward flow into summer hemisphere, and associated increase in subtropical descent





Local subtropical jet in CP4

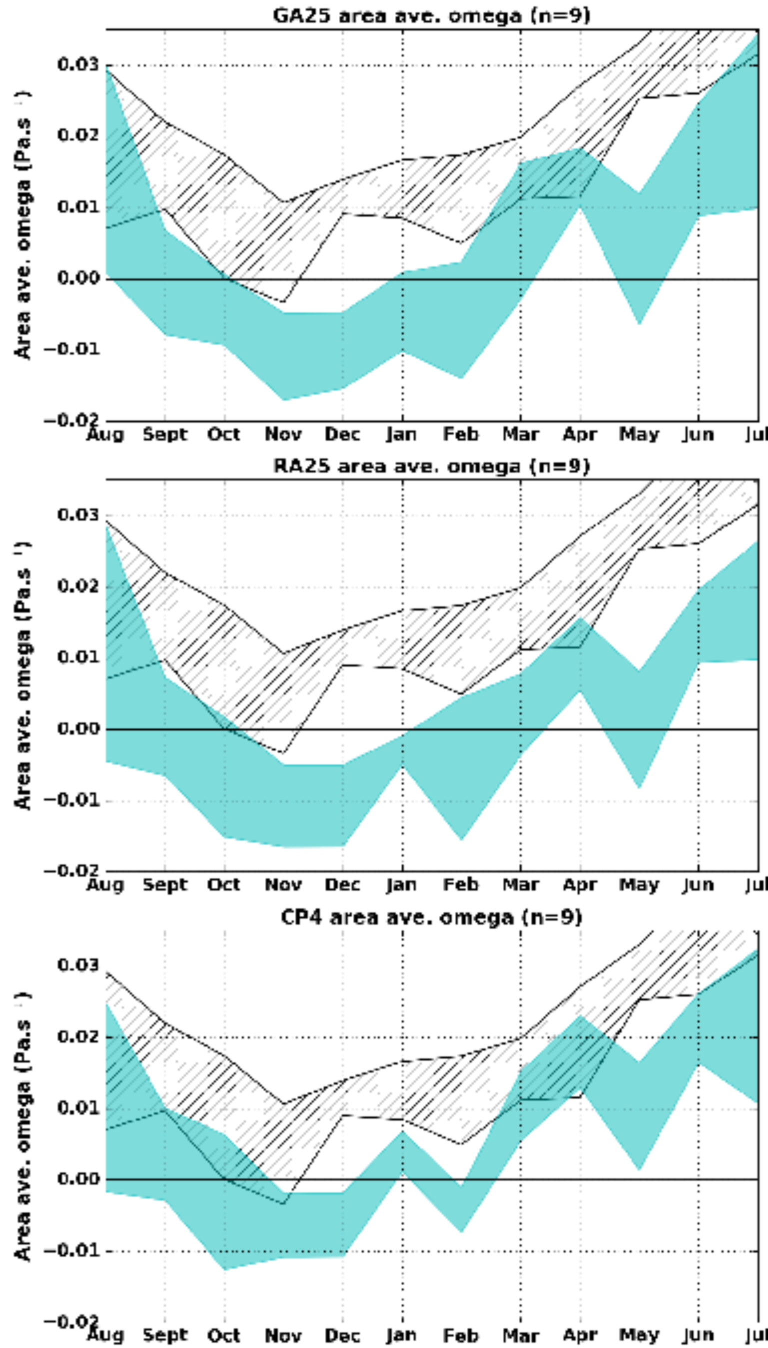




- Stronger poleward flow is associated with stronger forcing of subtropical jet
- The resulting westerly flow structure favours more frequent cloud band development, as demonstrated in ***Hart et al 2018***

Reduced vertical ascent bias

- ERA-Interim shows mid-level (500mb) descent over subtropical southern Africa
- Models simulate mid-level ascent, consistent with wet bias in rainfall
- Ascent bias is halved in CP4 simulation, consistent with reduced wet bias



Conclusions

- Climate simulation using a convective-permitting regional model results in wholesale improvements in southern African subtropical annual cycle in tropical-extratropical cloud bands and rainfall.
- These improvements are shown to be associated with increased vertical mass flux over the tropics.
- This increased mass flux invigorates the local overturning into the summer hemisphere which amplifies the forcing of a subtropical jet and increases subtropical subsidence.
- This results suggests that the rainfall bias over subtropical southern Africa is forced regionally, not remotely.

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Many thanks to the GEWEX OSC organising committee and sponsors for travel funding support

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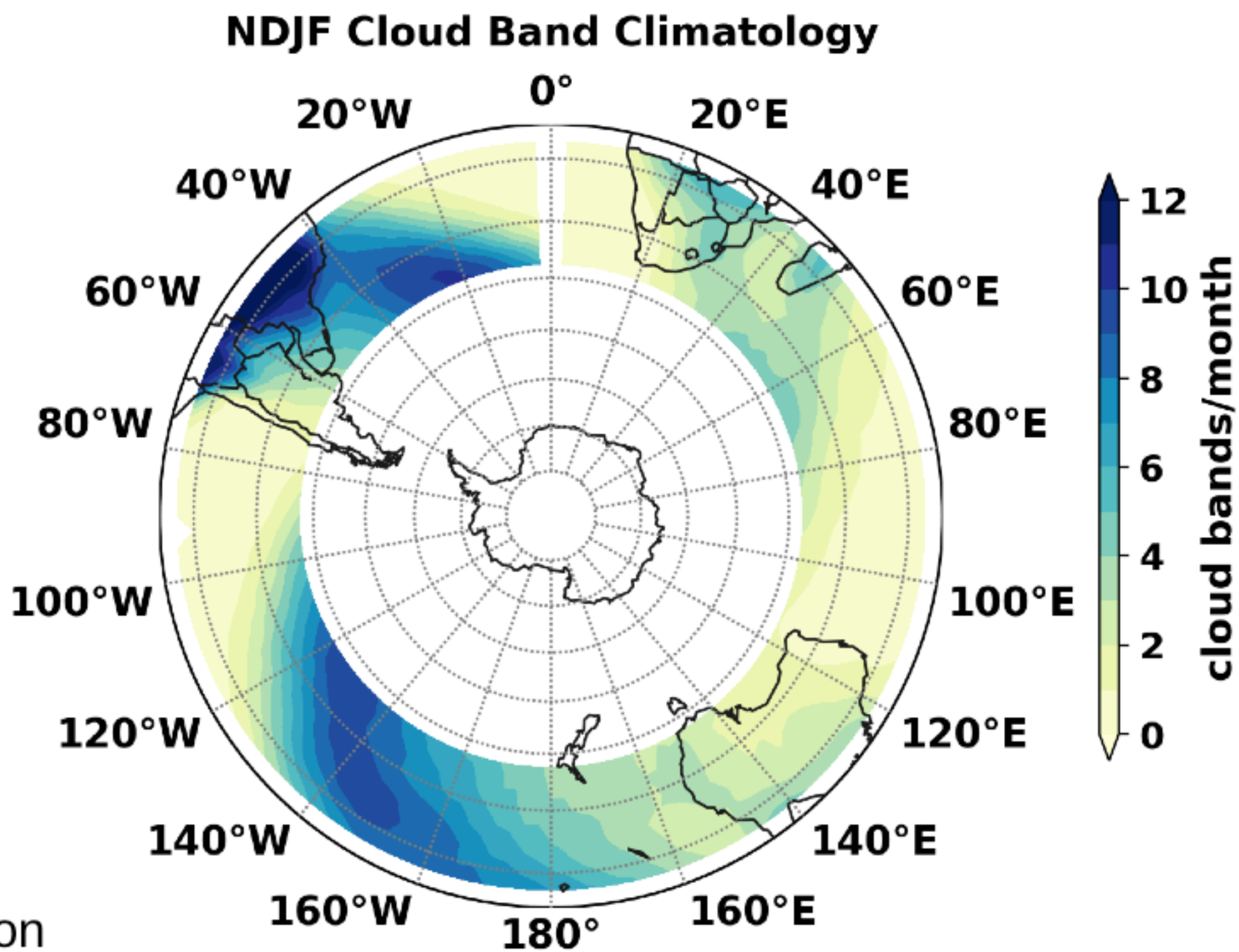
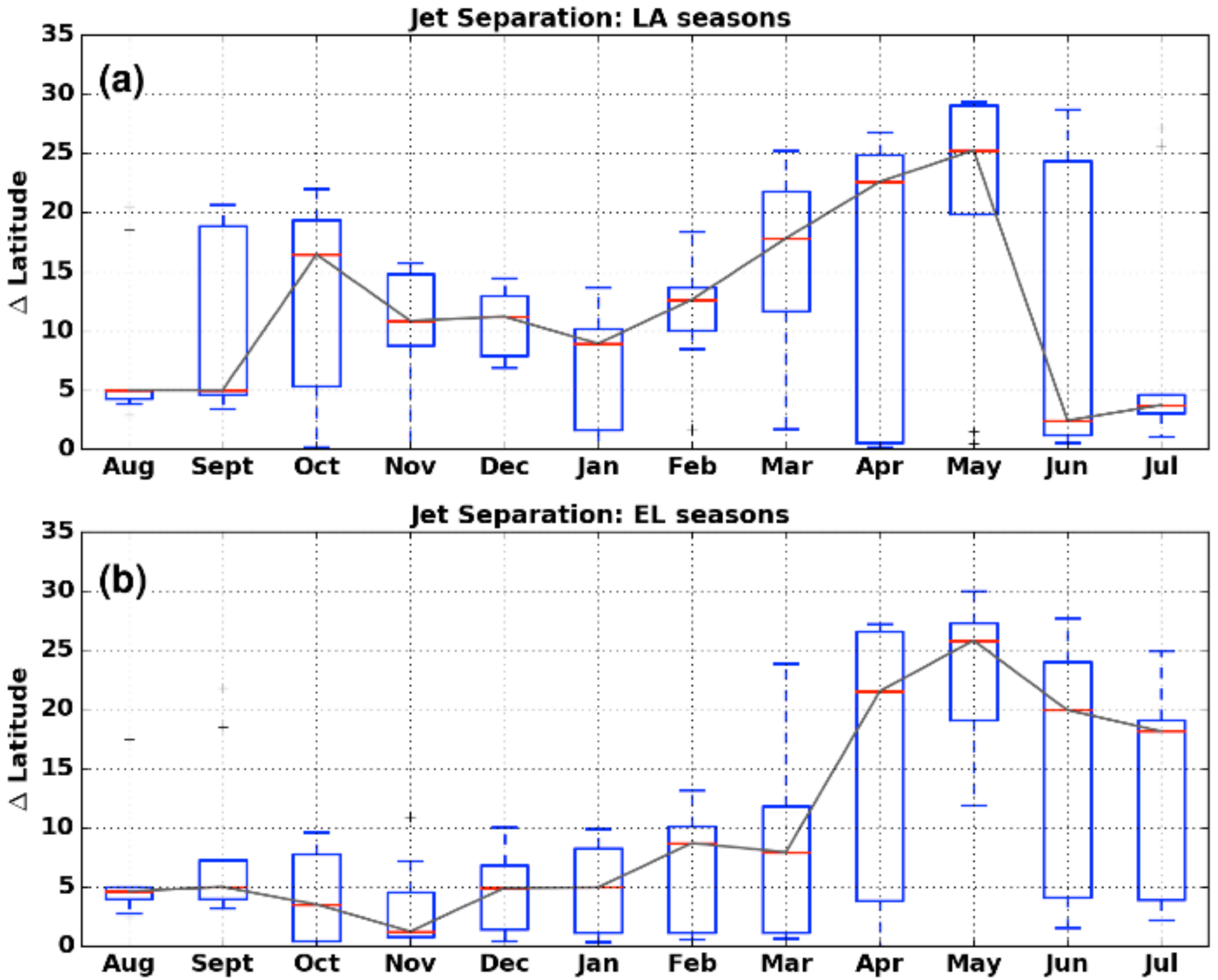
Additional Slides

SH subtropical convergence zones

- South Atlantic and South Pacific Czs more defined
- South Indian only present in austral summer
- Two preferential zones for TE cloudband formation

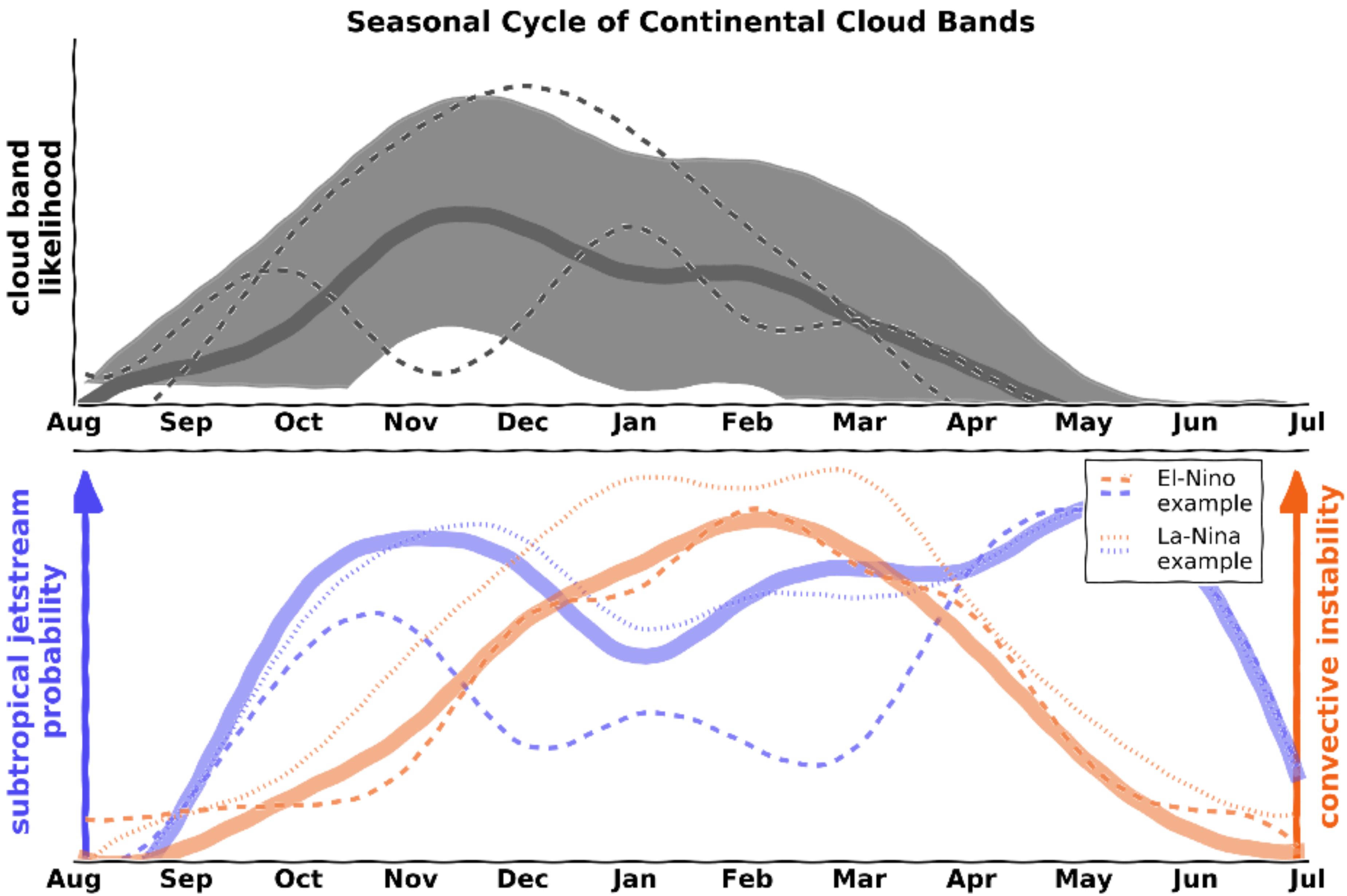


Jet Separation in SICZ



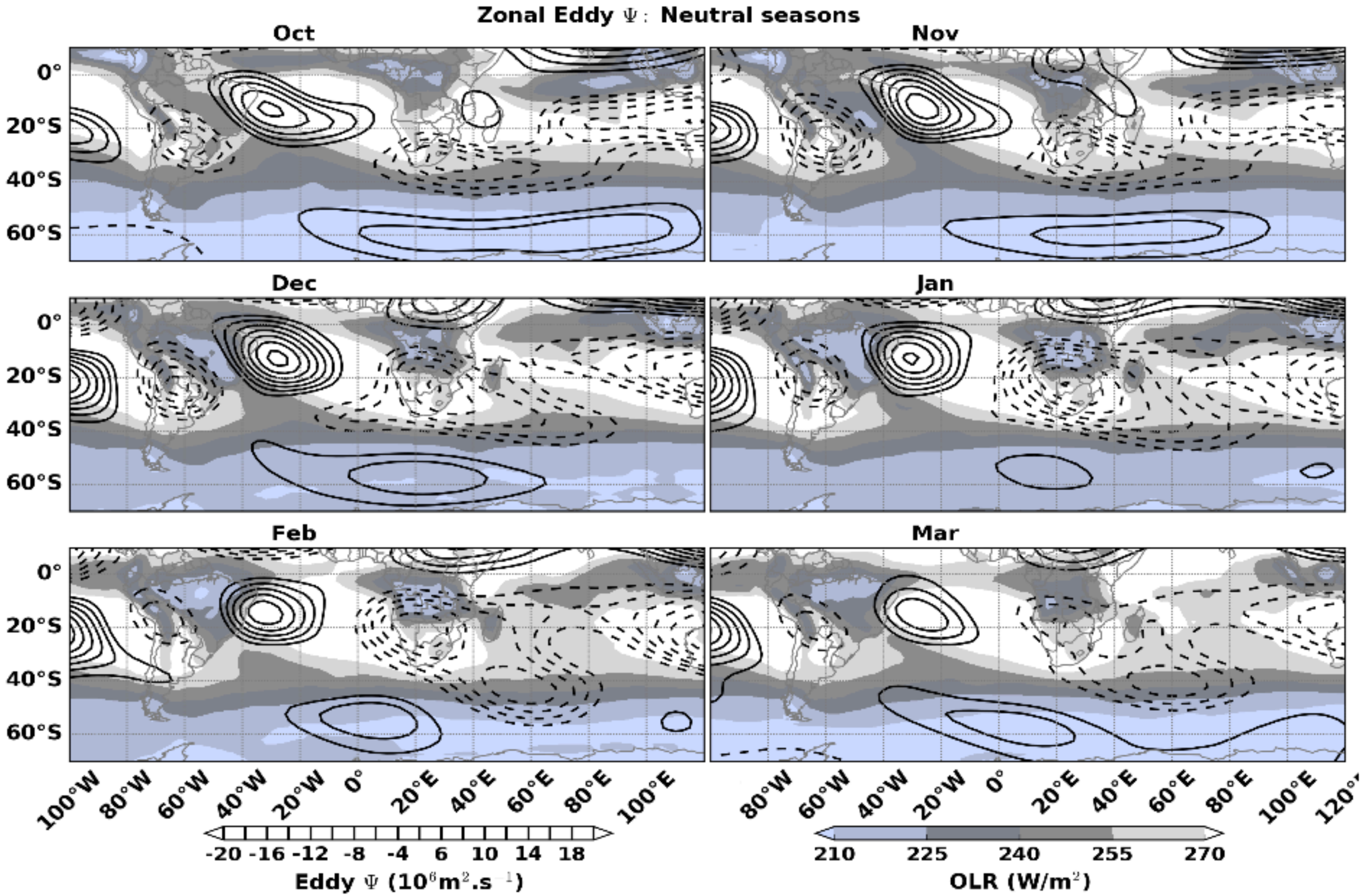
- Separation of a distinct STJ from eddy-driven jet during La-Nina
- Failure of distinct STJ to form in El-Nino seasons

TE cloud bands annual cycle



Hart et al 2018 J. Climate

Trop. Convection – Subtropical Anticyclone



Forcing of local subtropical jet

The Generation of Global Rotational Flow by Steady Idealized Tropical Divergence

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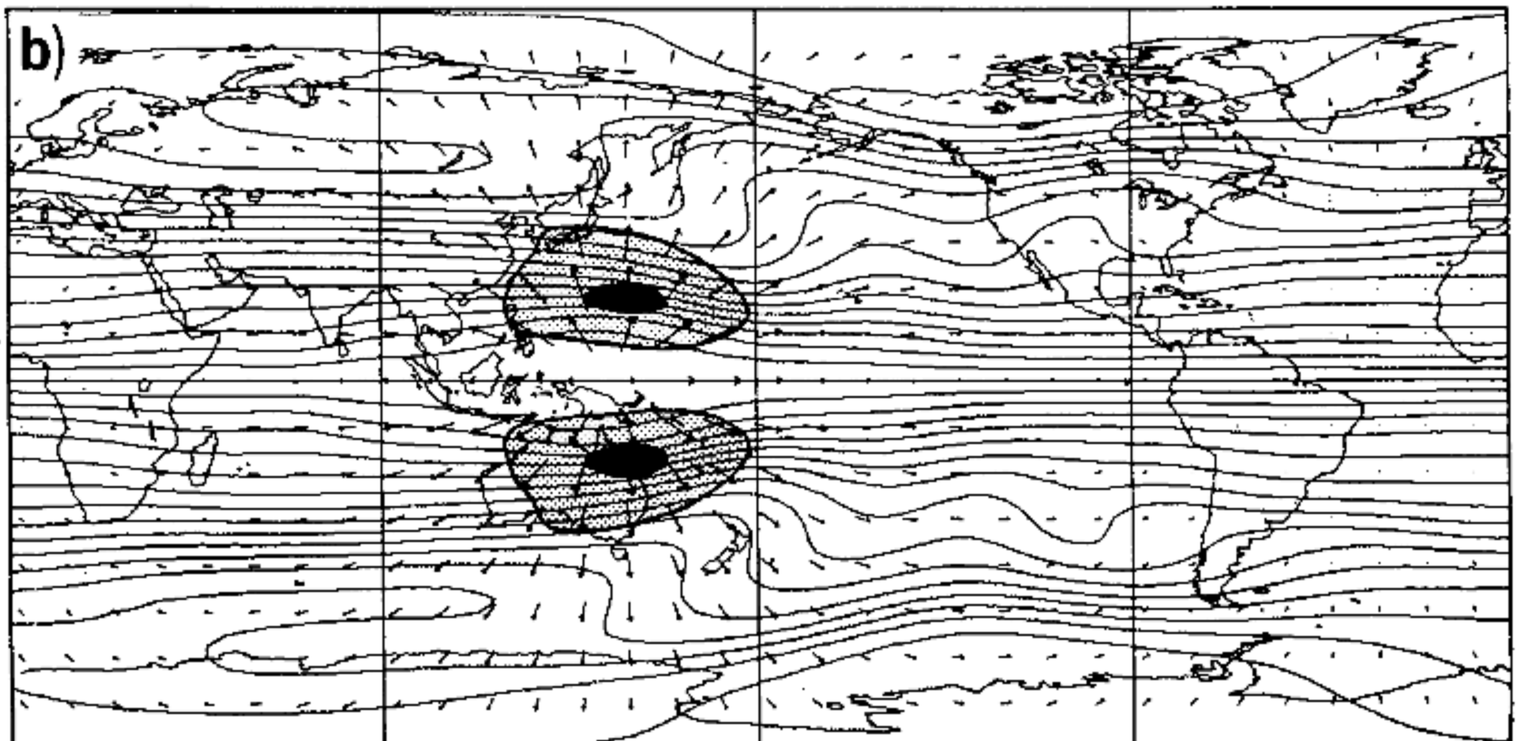
European Centre for Medium-range Weather Forecasts, Reading, United Kingdom

BRIAN J. HOSKINS

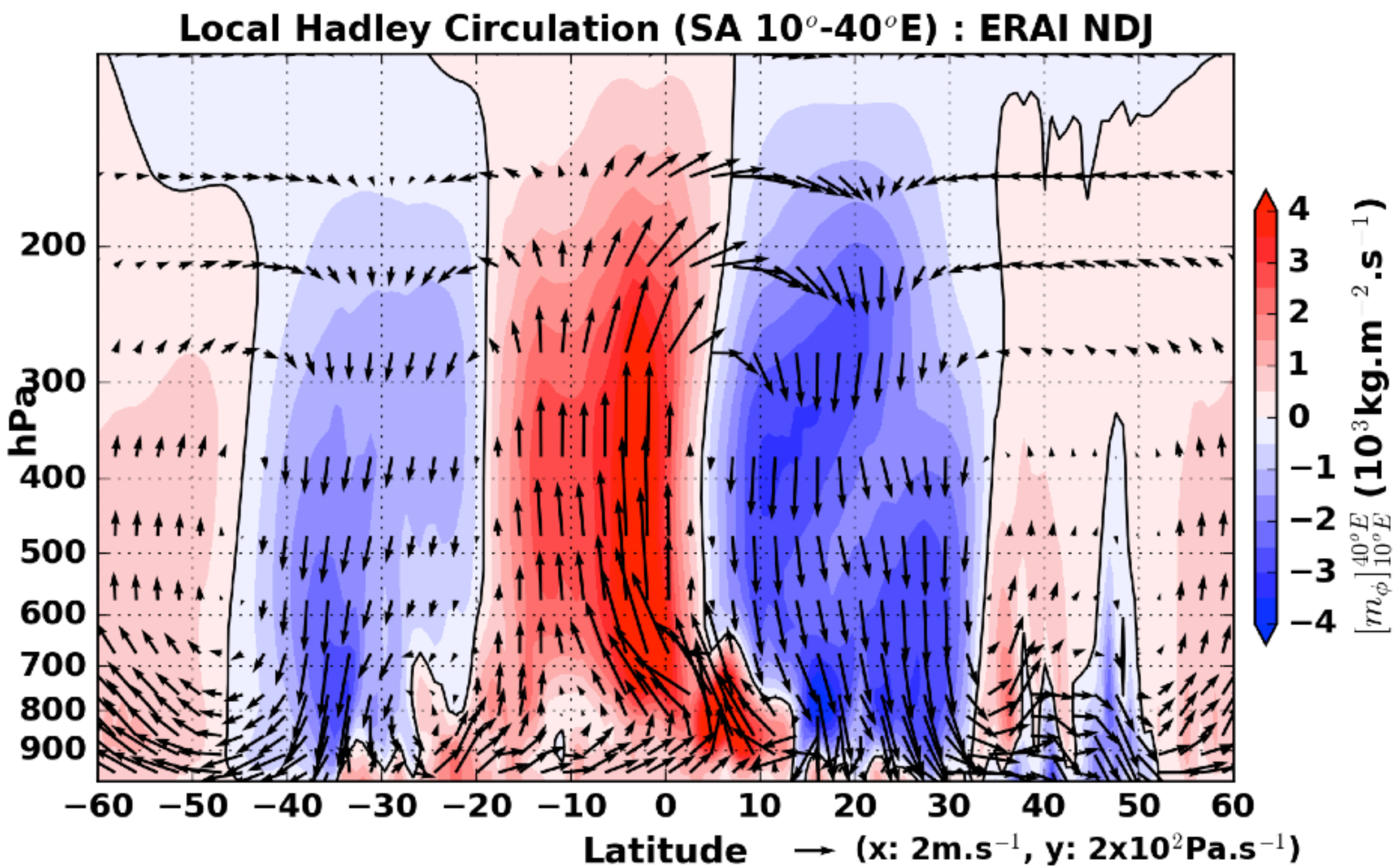
Department of Meteorology, University of Reading, Reading, United Kingdom

(Manuscript received 24 March 1987, in final form 29 October 1987)

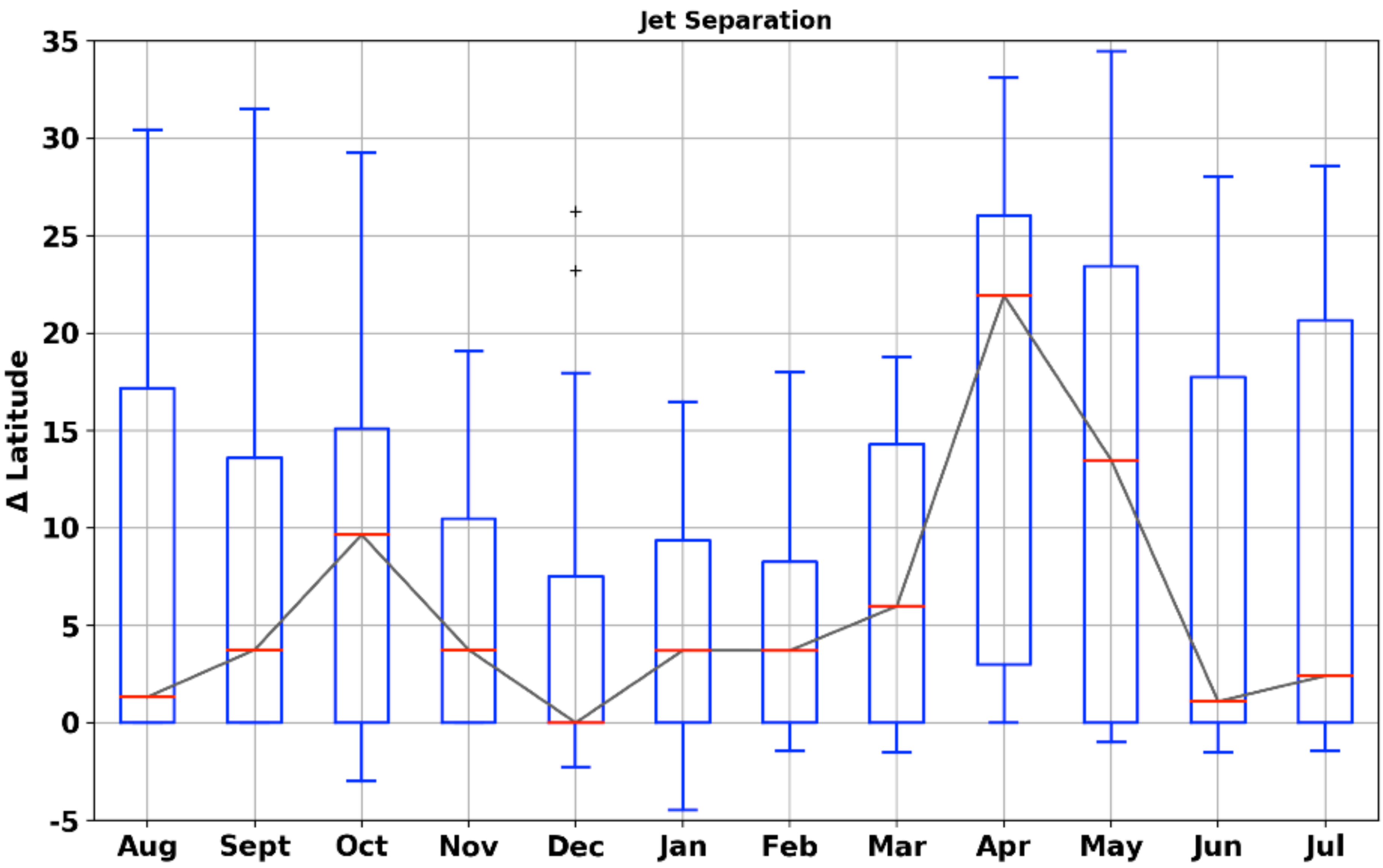


Sardeshmukh & Hoskins 1988, JAS

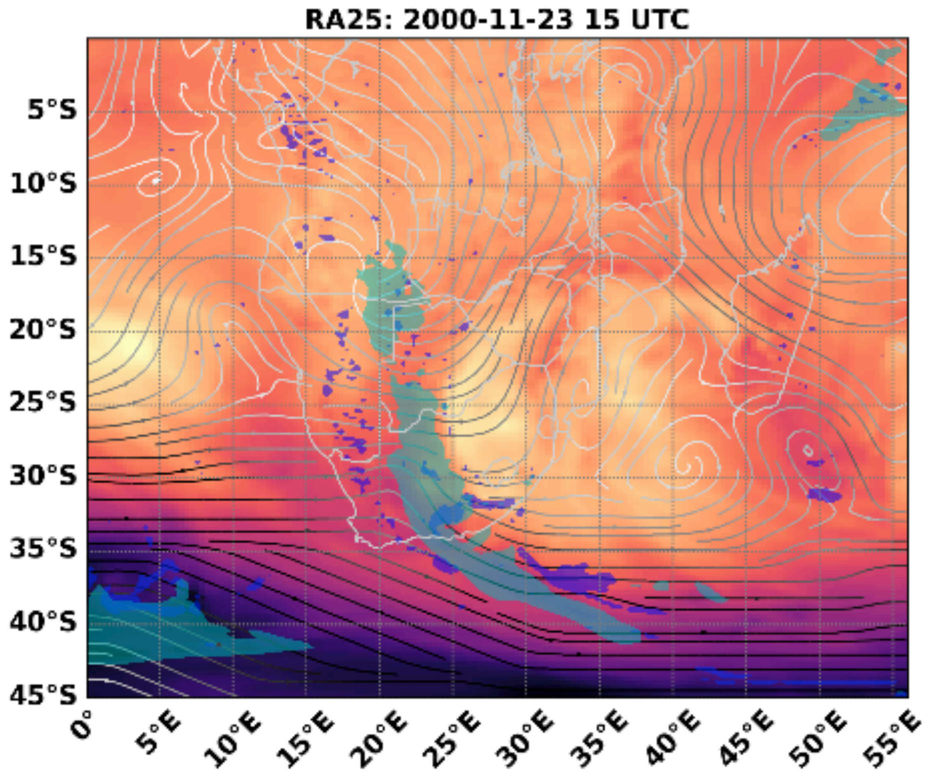
Local Overturning: ERA-Interim

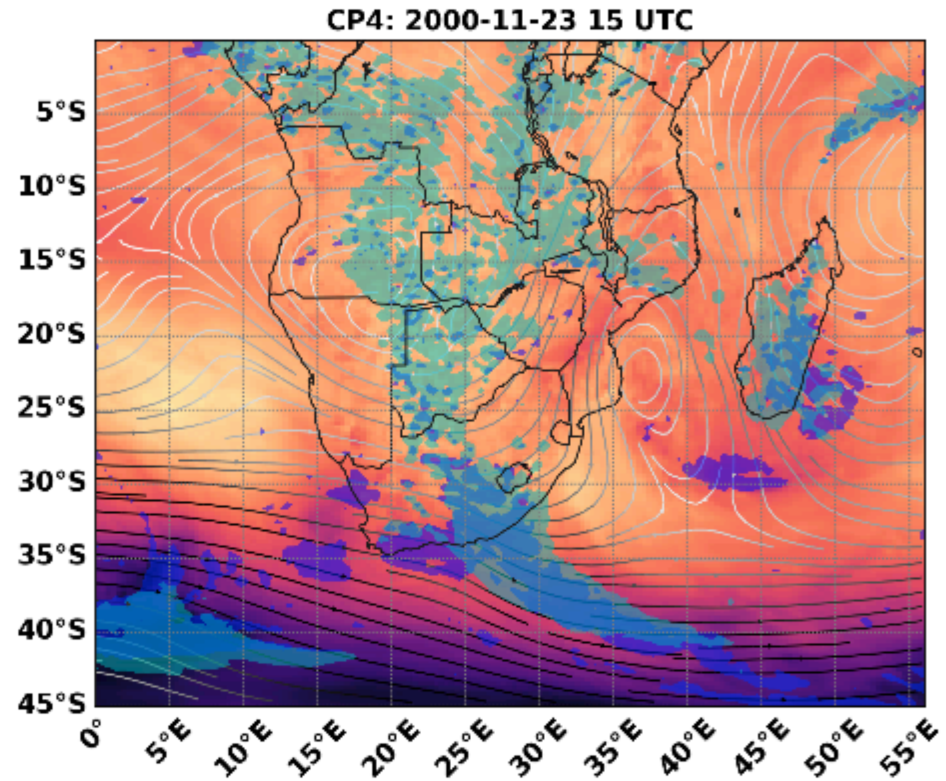


ERA-Interim Subtropical Jet



Diurnal Cycle of Convection during CBs





- Convective activity persists throughout afternoon and evening in CP4