Antarctic stratospheric ozone and seasonal predictability over southern Africa

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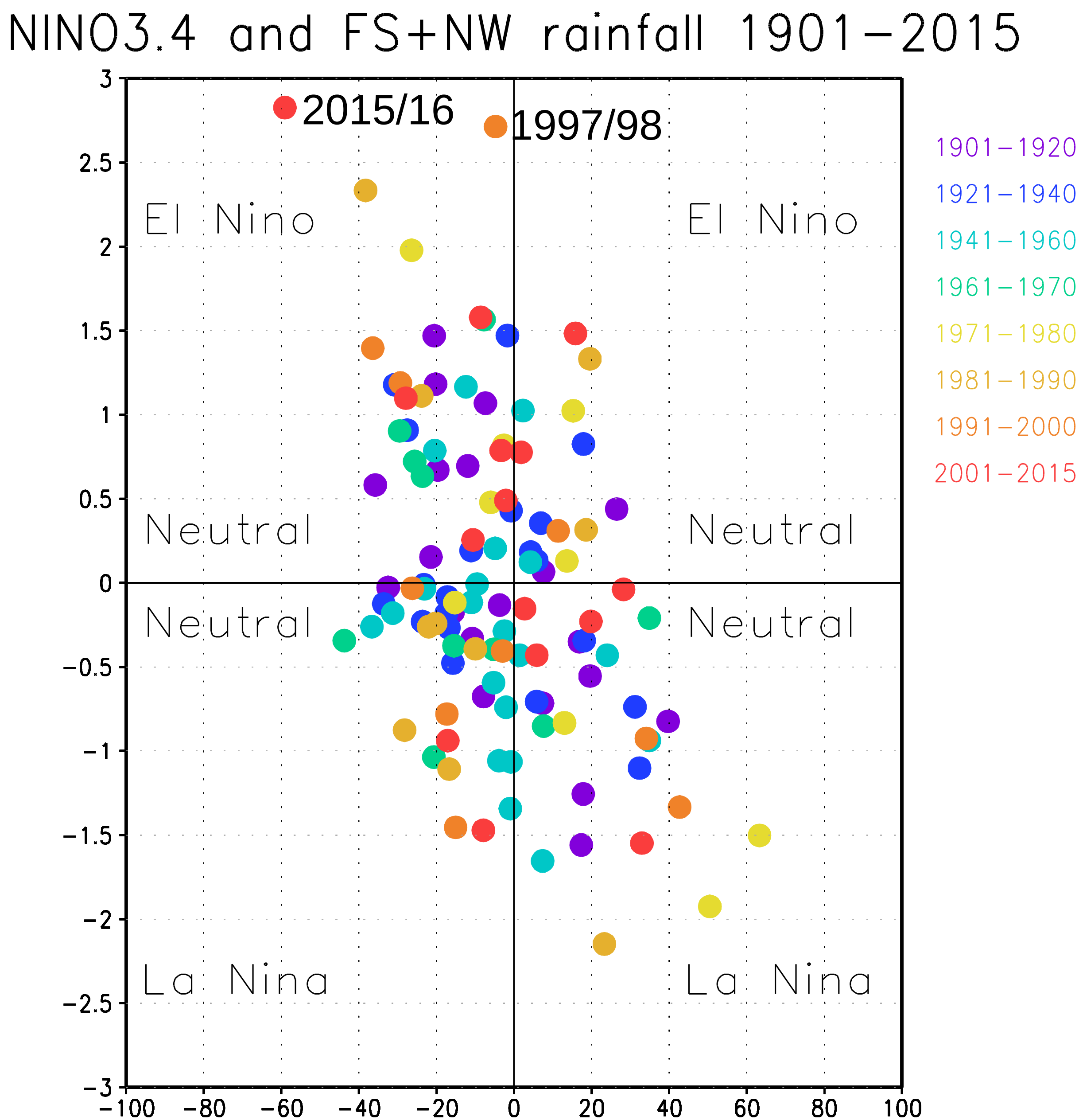
Drought in southern Africa

Depleted grazing in Kruger Park in September 2016.

By September 2016, The entire summer rainfall region was in a state of mild drought, or worse, after the 2015/16 super El Niño

The Free State, northern KwaZulu-Natal, eastern Mpumalanga and Kruger Park was in a state of severe drought .



Summer-season rainfall anomalies over the Free State and North West provinces (x-axis) and Niño 3.4 sea-surface temperature anomalies (y-axis) for 1901-2015.

Rainfall anomalies from CRU and GCPC are for DJF. SST anomalies from AMIPII are for OND.

All anomalies were calculated with respect to the 1971-2000 baseline period.

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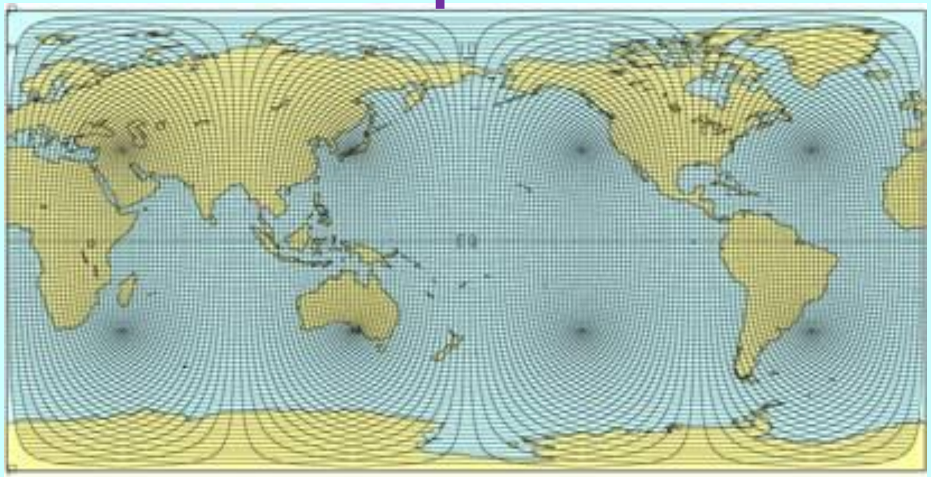
CCAM AMIP-style simulations

Control experiment



Climatological CO_2

Climatological ozone

Climatological aerosols

Observed SSTs and sea-ice

CCAM experimental design

C48 (200 km horizontal resolution)

27 sigma levels

Simulation period 1978-2005

12 ensemble members

CHPC

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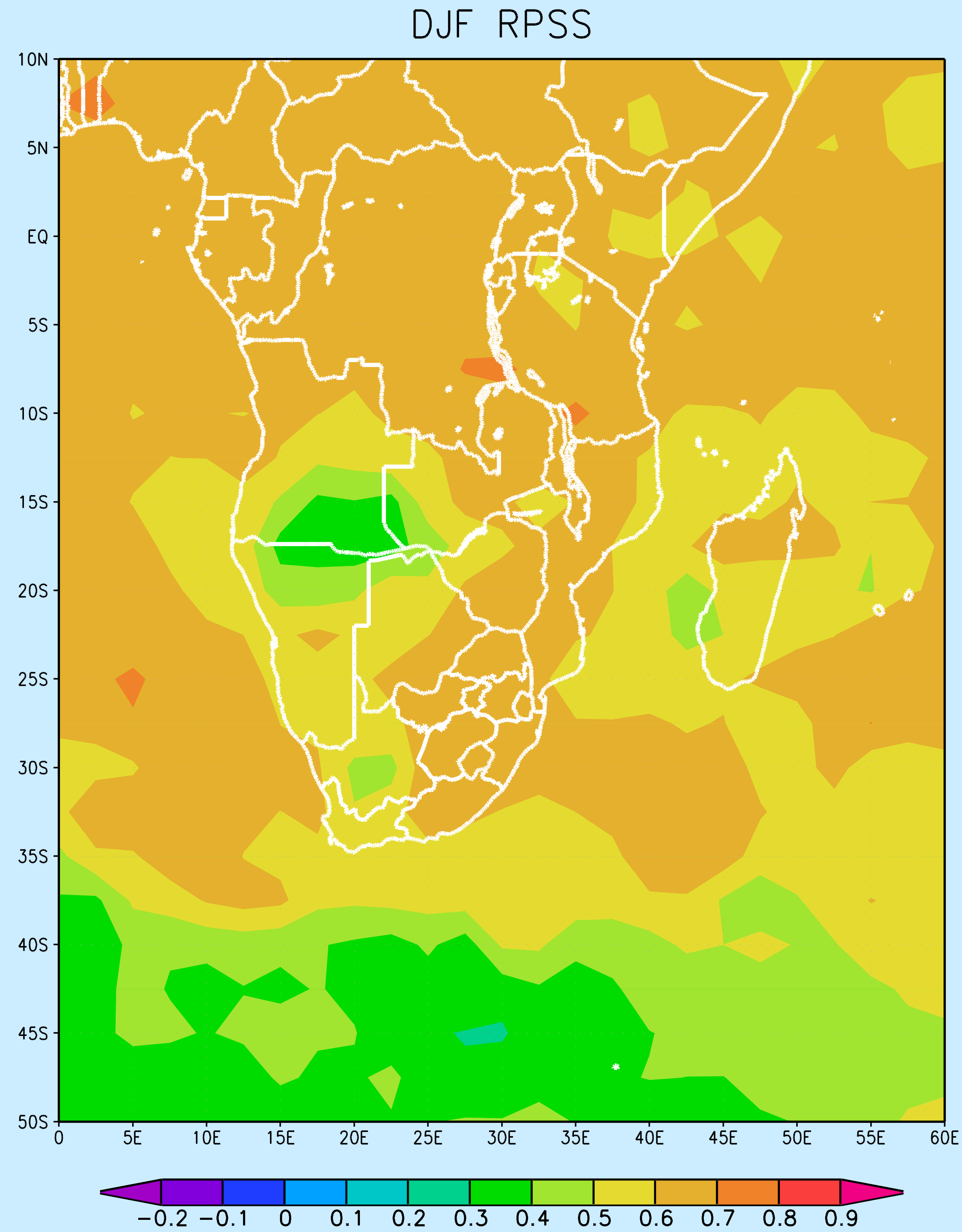
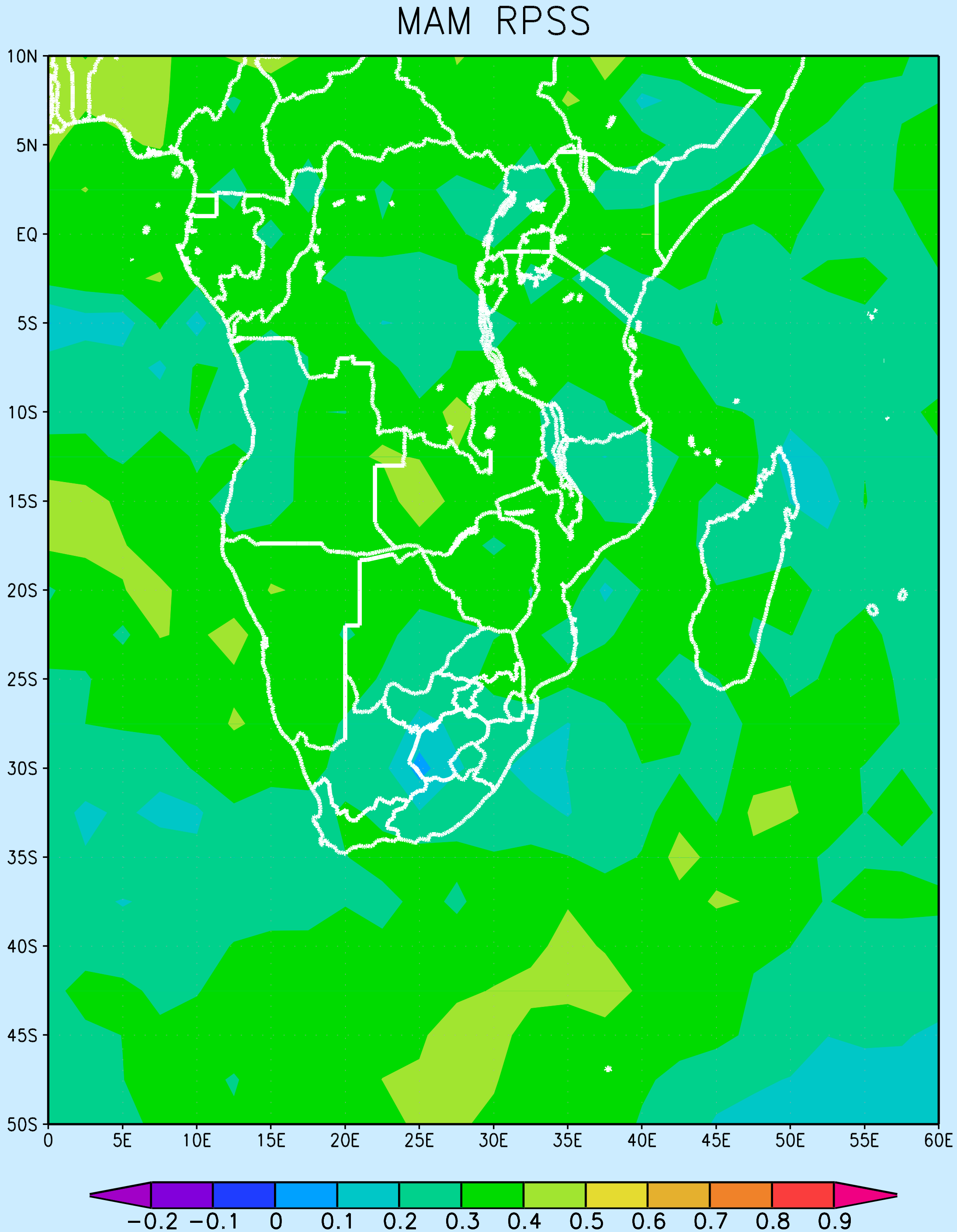


DJF CCAM AMIP-simulation skill in simulating the inter-annual variability in circulation (850 hPa geopotential heights) over southern and tropical Africa

$$\text{RPS} = \sum_{k=1}^{K}(S_k - O_k)^2$$

$$\text{RPSS} = 1 - \frac{\text{RPS}}{\text{RPS}_c}$$



MAM CCAM AMIP-simulation skill in simulating the inter-annual variability in circulation (850 hPa geopotential heights) over southern and tropical Africa

$$\mathrm{RPS} = \sum_{k=1}^{K} (S_k - O_k)^2$$

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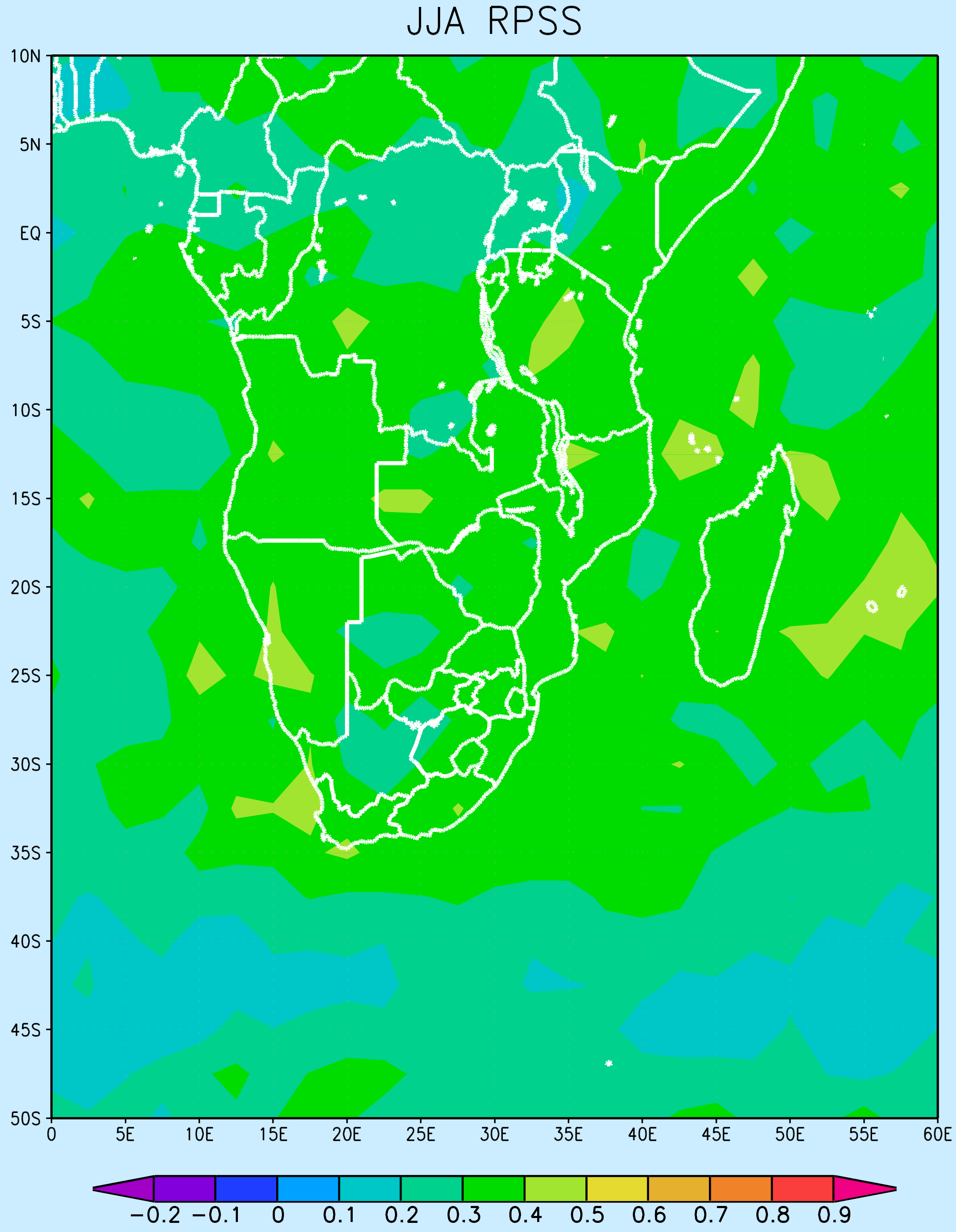

JJA CCAM AMIP-simulation skill in simulating the inter-annual variability in circulation (850 hPa geopotential heights) over southern and tropical Africa

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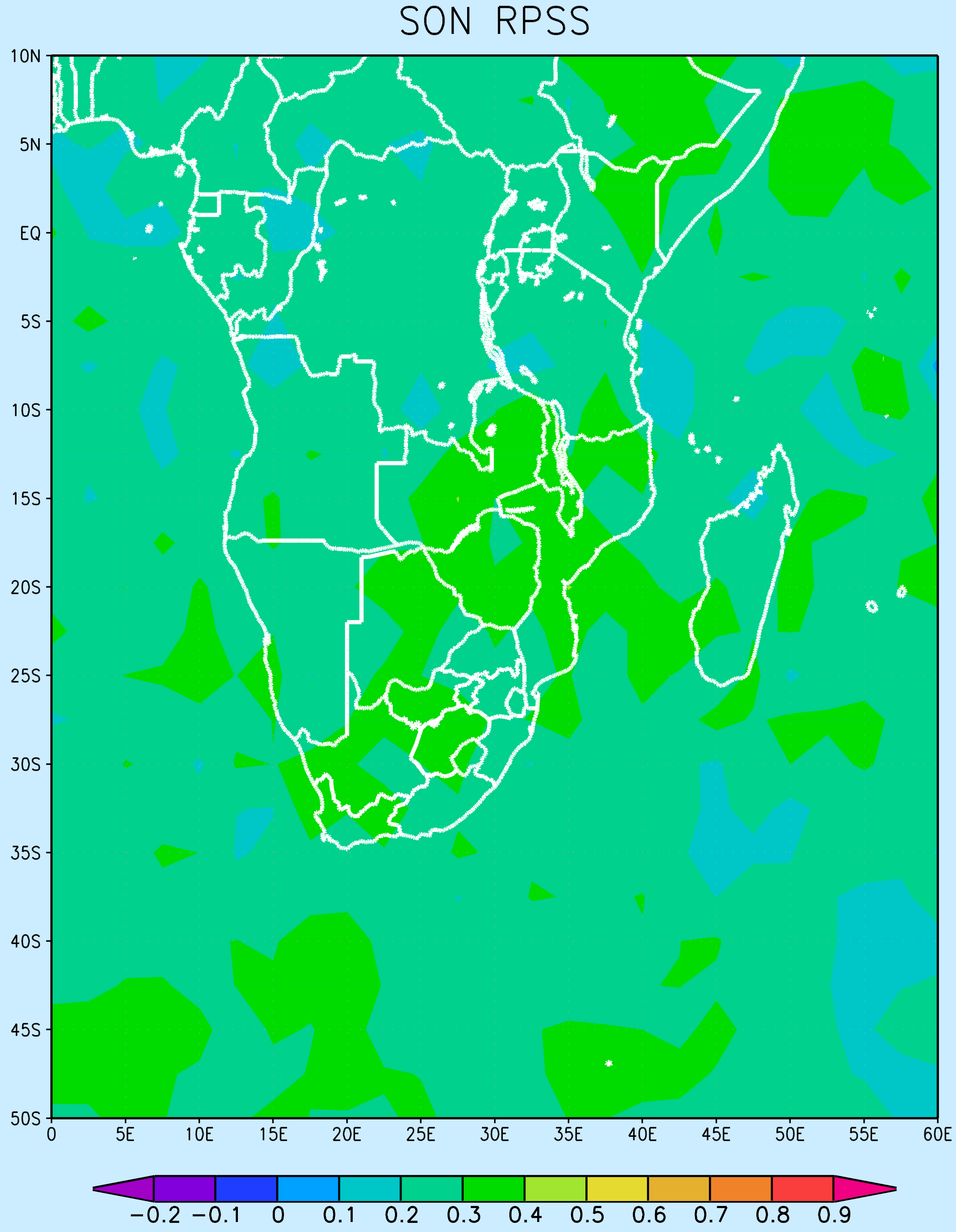

SON CCAM AMIP-simulation skill in simulating the inter-annual variability in circulation (850 hPa geopotential heights) over southern and tropical Africa

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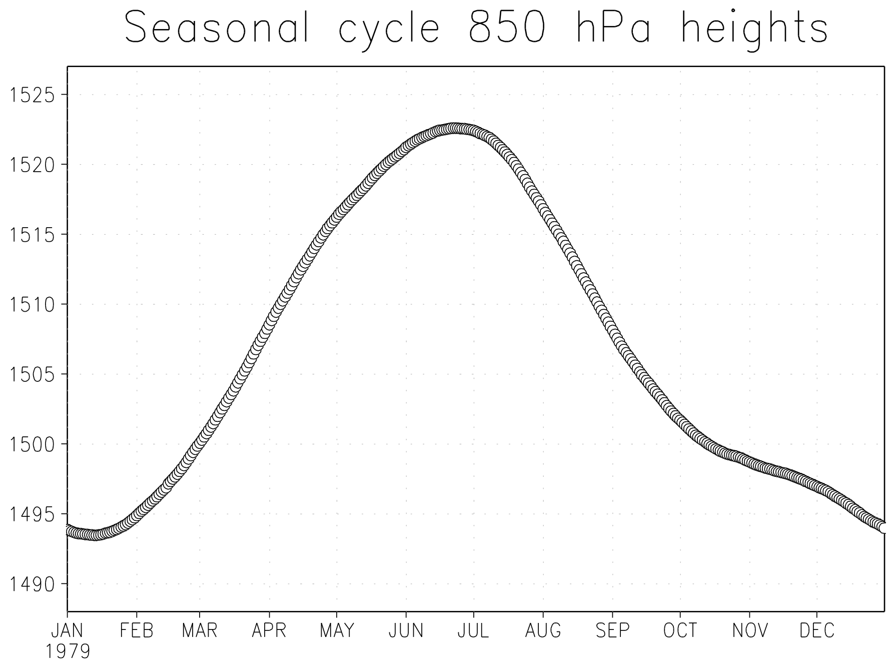

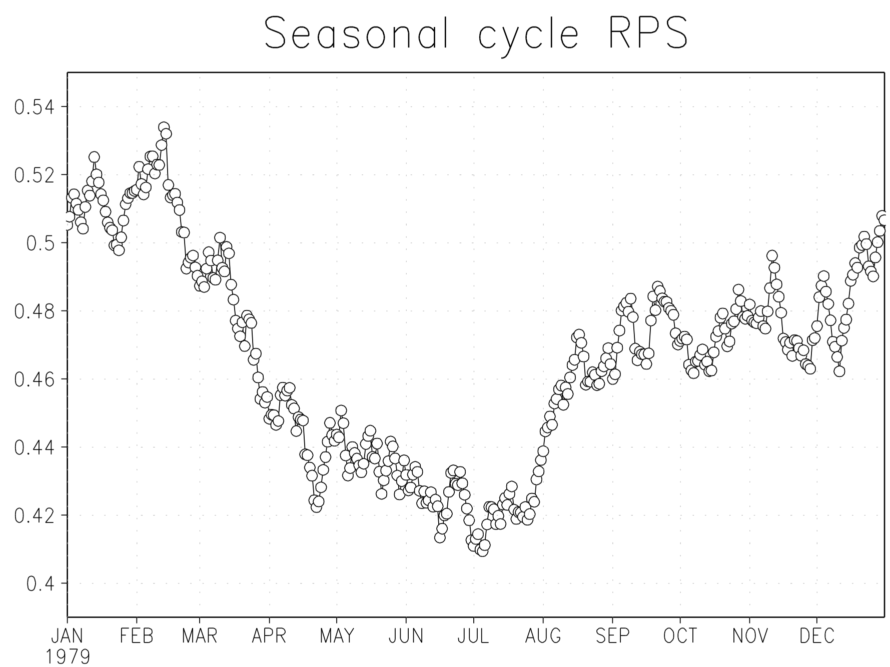

Seasonal cycle in circulation and seasonal forecast skill as deduced from AMIP-style simulations

SA domain: 30 S to 10 S and 15 E to 35 E

Climatological values of radiative forcings (control experiment)

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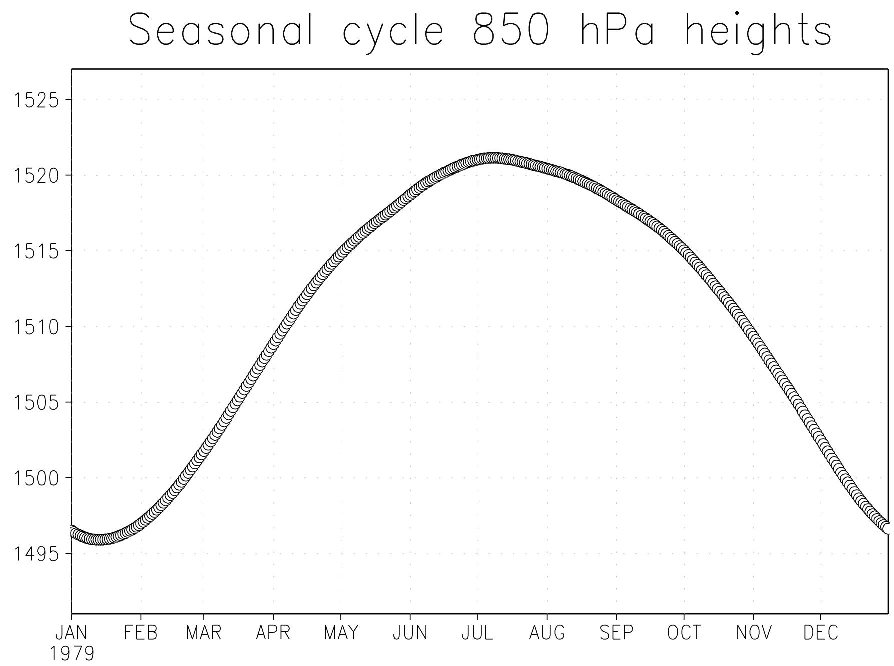

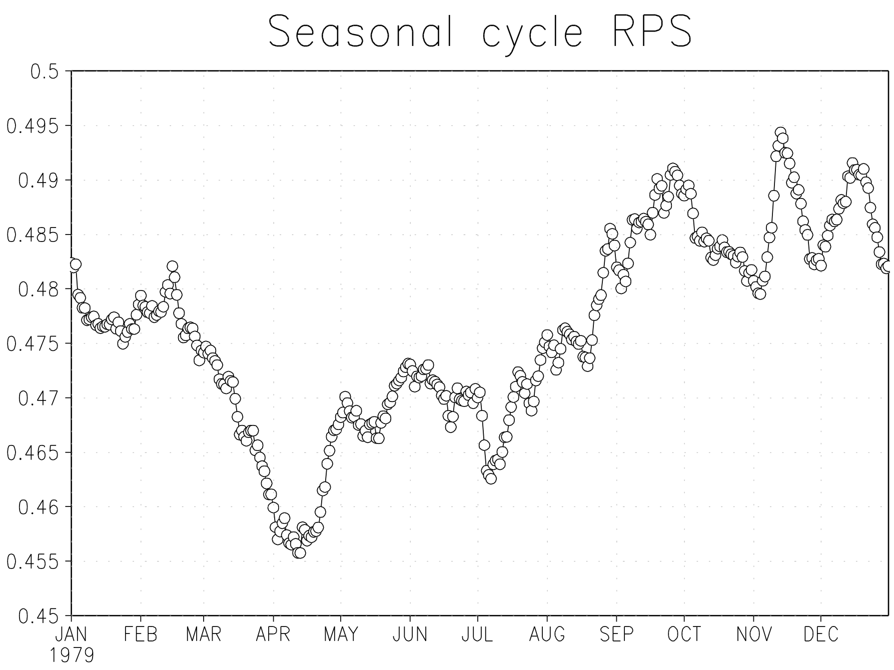

Seasonal cycle in circulation and seasonal forecast skill as deduced from AMIP-style simulations

SHS domain: 35 S to 10 S and 0 E to 360 E

Climatological values of radiative forcings (control experiment)

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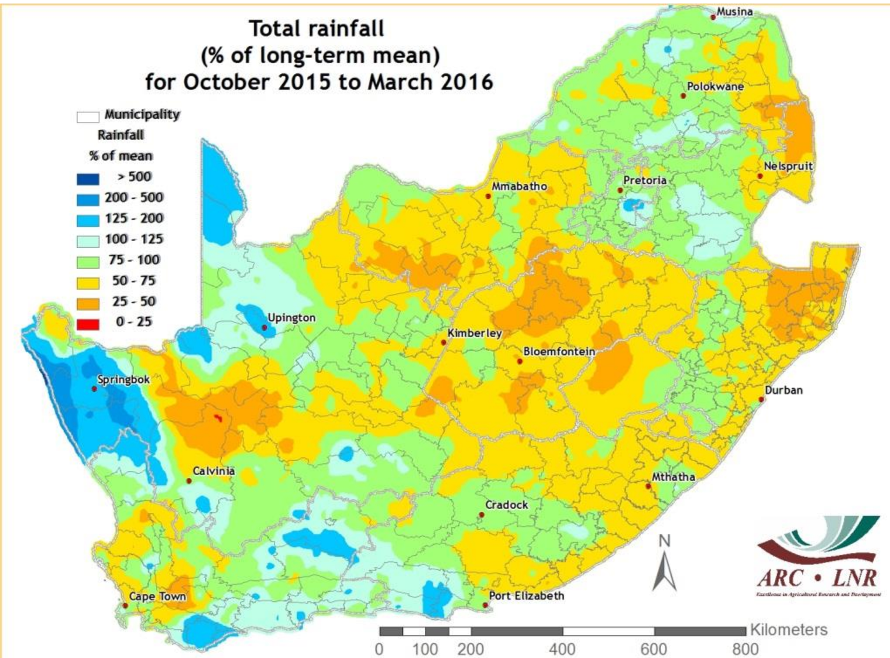
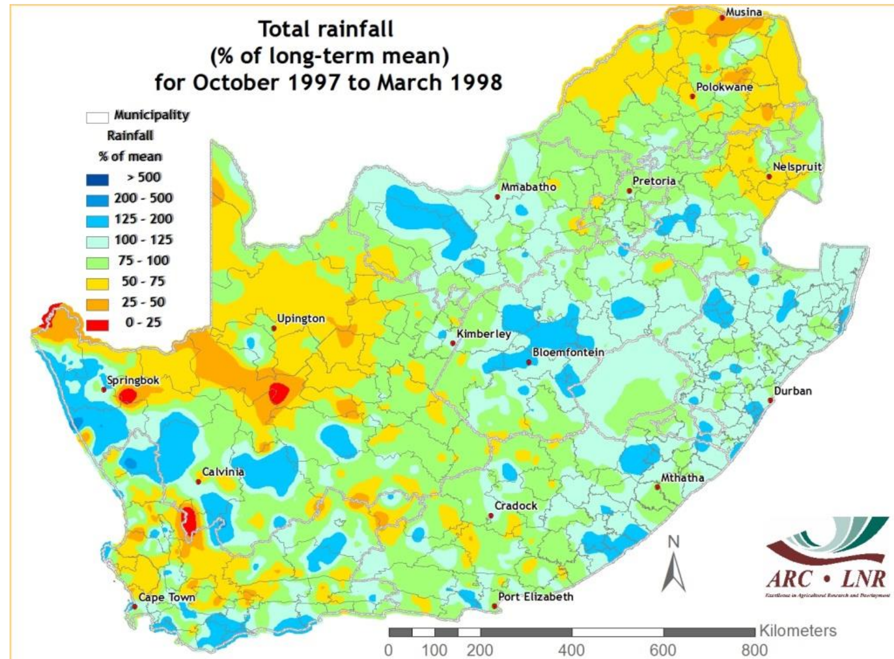
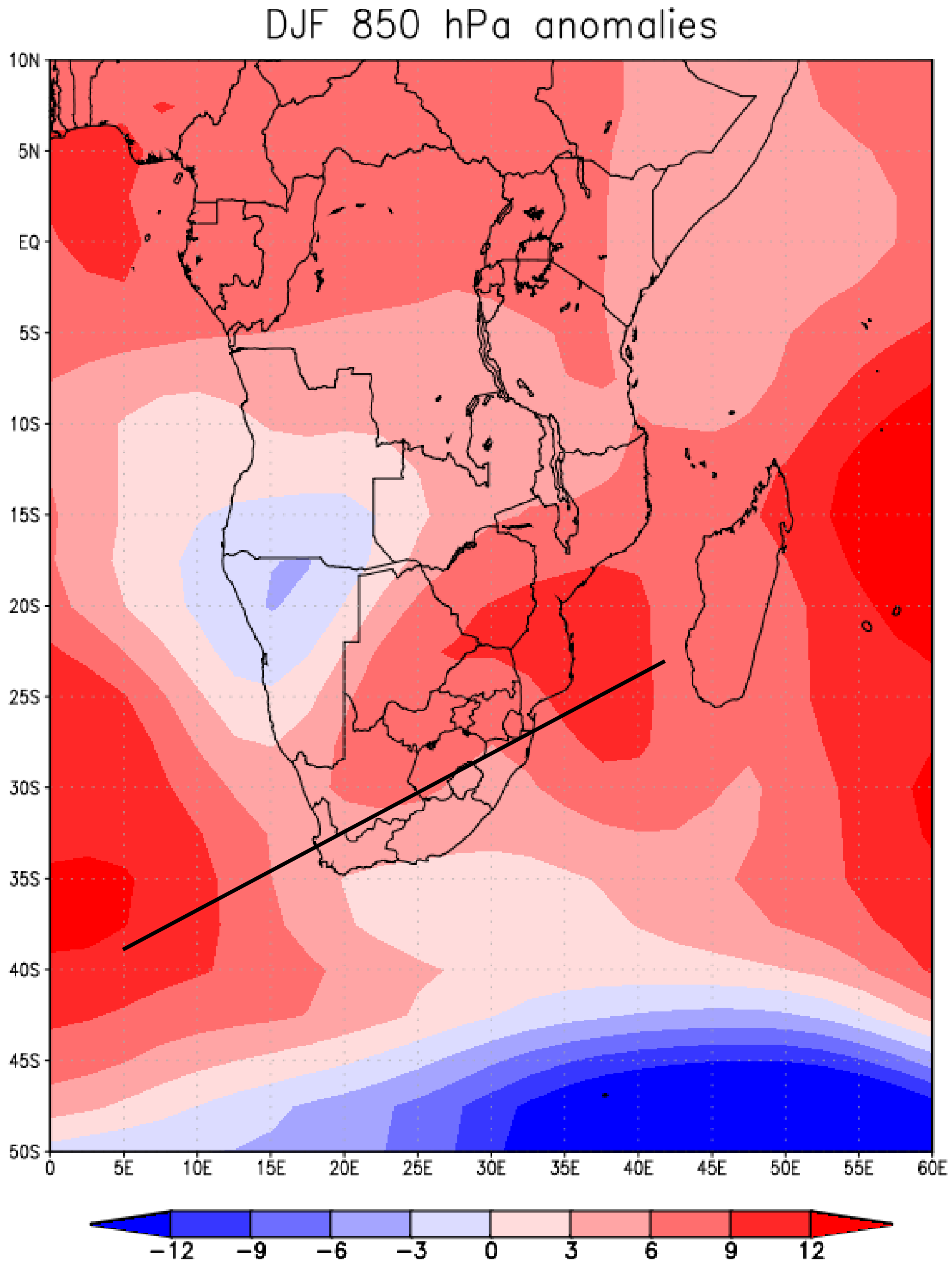
The strong El Niño’s of 1997/1998 and 2015/16 and rainfall over SA





Source: ARC (statistics by Johan Malherbe). October- March rainfall anomalies for 2015/16 (left) and (1997/1998). Anomalies calculated with respect tot the long-term average.



850 hPa circulation anomalies during December-February of 1997/98

Pattern of trough formation and relatively deep Angola low in the west, with a ridge-axis from the southwest to the north-east over southern Africa occurred, which promoted moisture advection from the east

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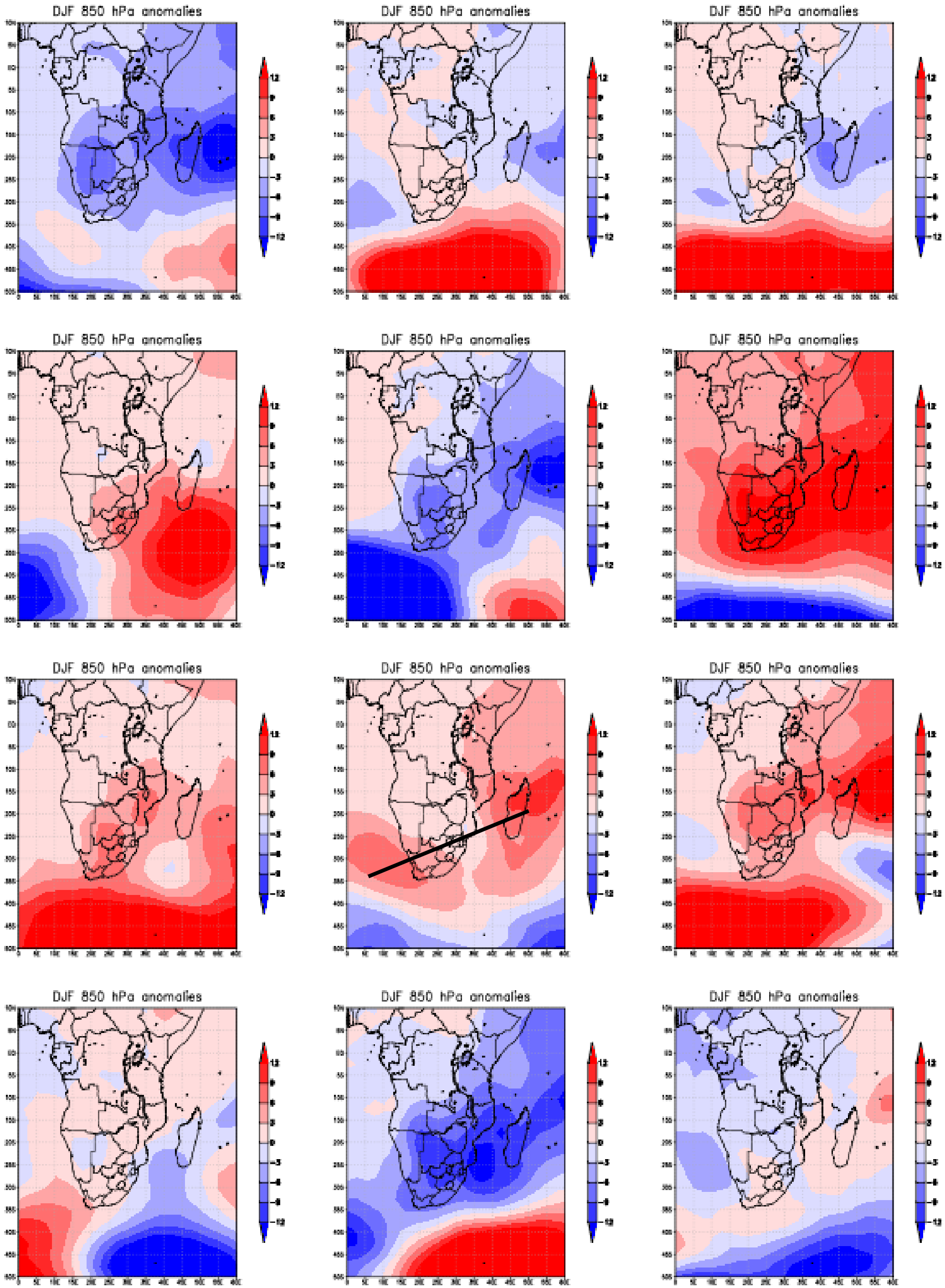
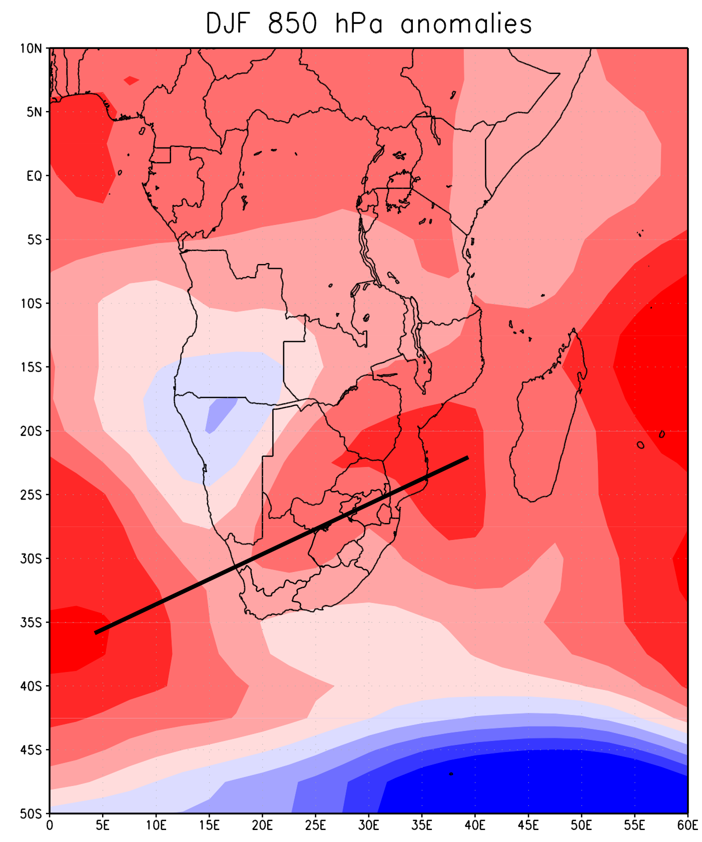
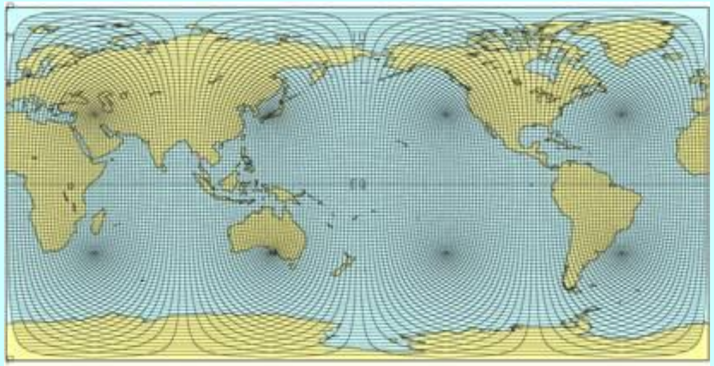


The “control” simulation (climatological ozone) fails to simulate the circulation anomalies of the 1997/98 El Niño (12 ensemble members)



AMIP-style simulations: Antarctic stratospheric forcing

Control experiment



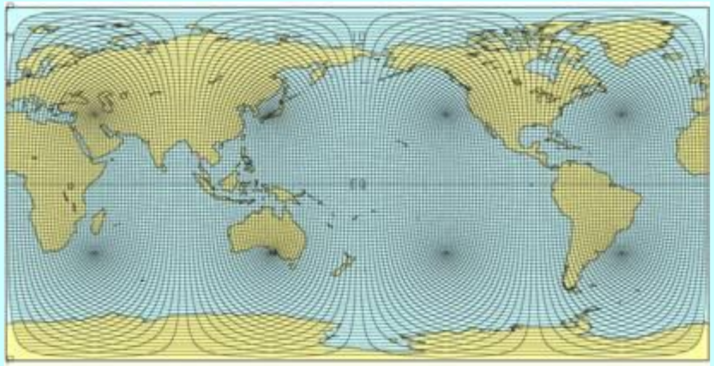
Climatological CO_2

Climatological ozone

Climatological aerosols

Observed SSTs and sea-ice

Radiative forcing: ozone



Climatological CO_2

Ozone time-varying

Climatological aerosols

Observed SSTs and sea-ice

CCAM experimental design

C48 (200 km horizontal resolution)

27 sigma levels

Simulation period 1978-2005

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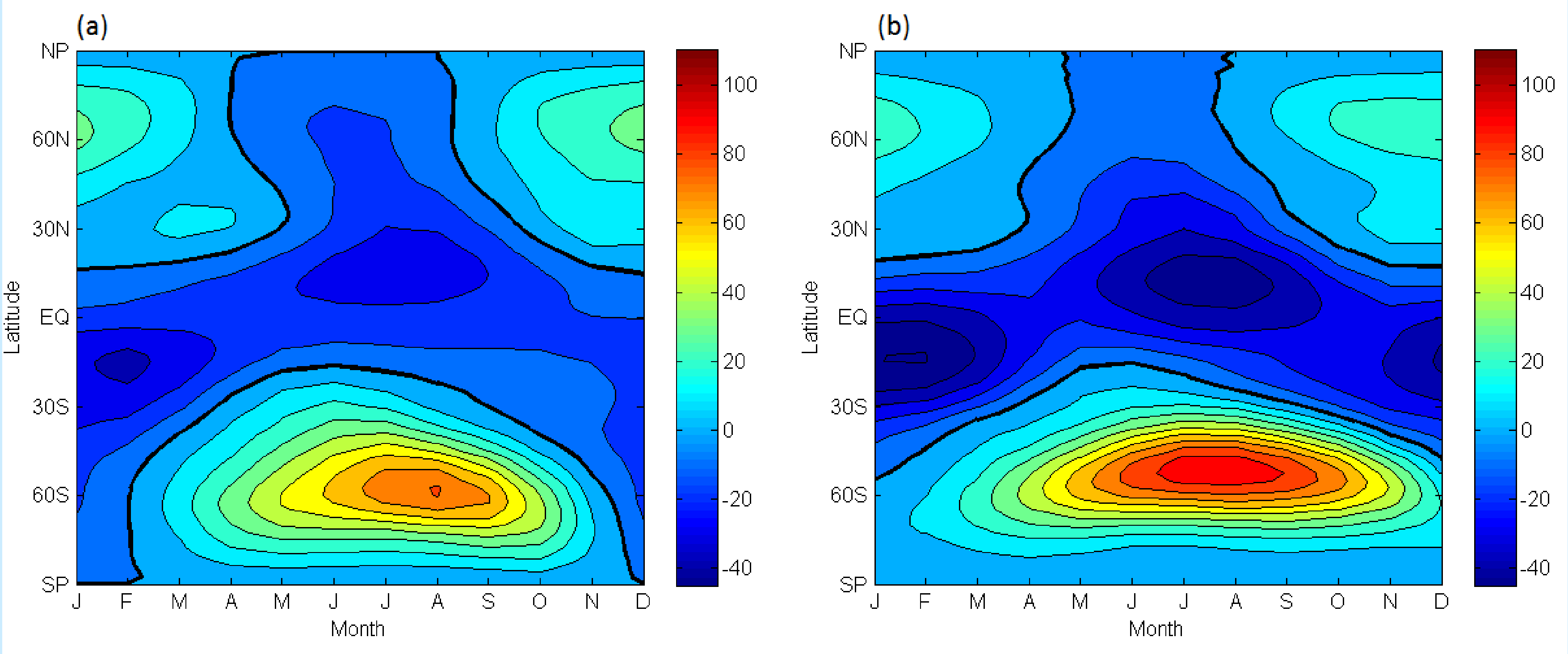
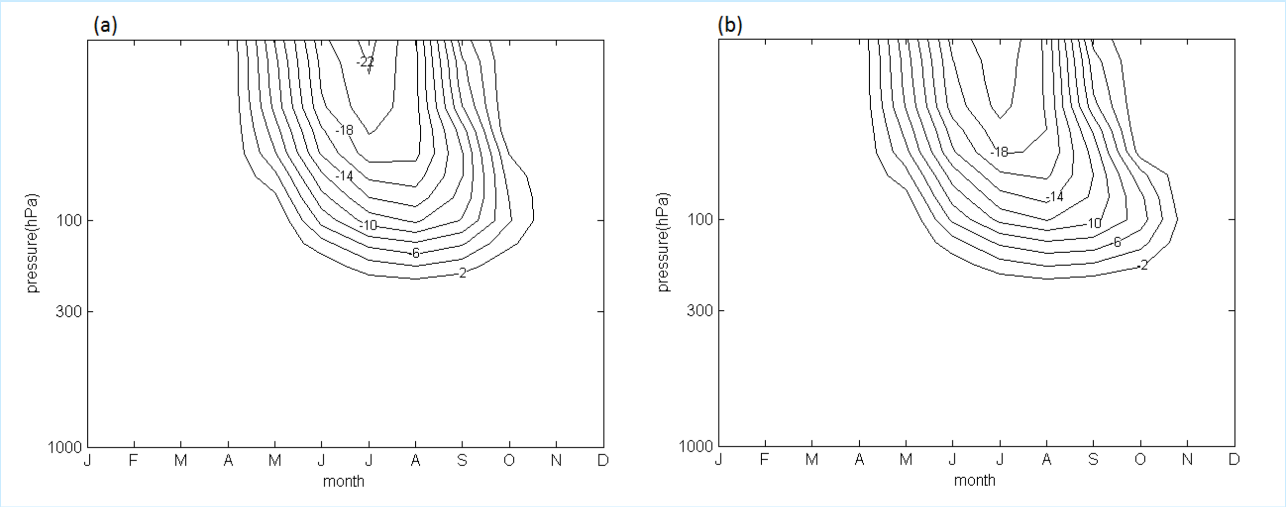
CCAM simulations of the polar vortex

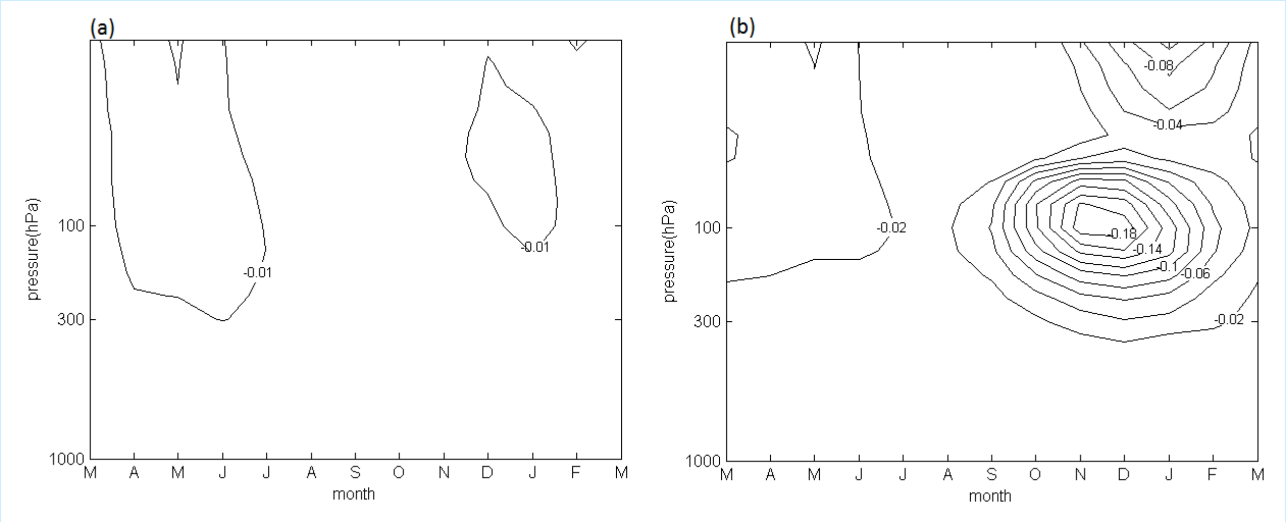


Zonally averaged winds at the 10 hPa for (a) NCEP reanalysis data and (b) CCAM-AMIP simulation in which stratospheric ozone concentrations vary in space and time. The thick black contour represents the 0 m/s isotach.

CCAM simulations of polar cap temperatures (Temp -200 K)



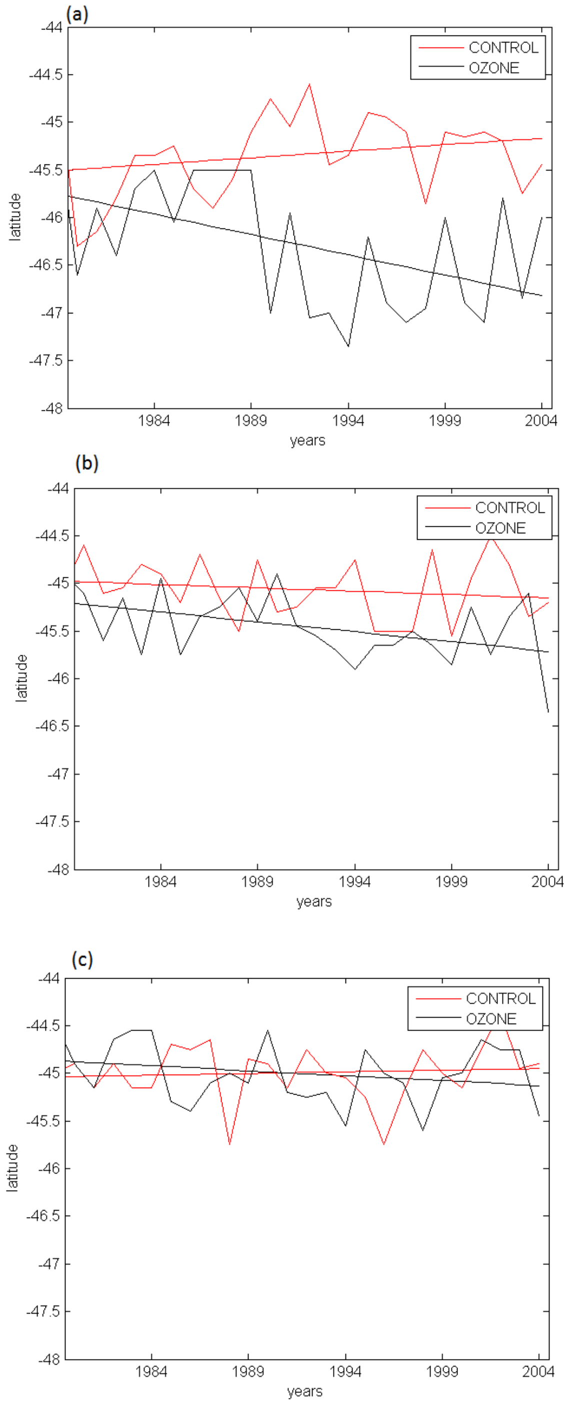
Simulated seasonal evolution of polar-cap (70S-90S) temperatures



Simulated seasonal trends in polar-cap (70S-90S) temperatures

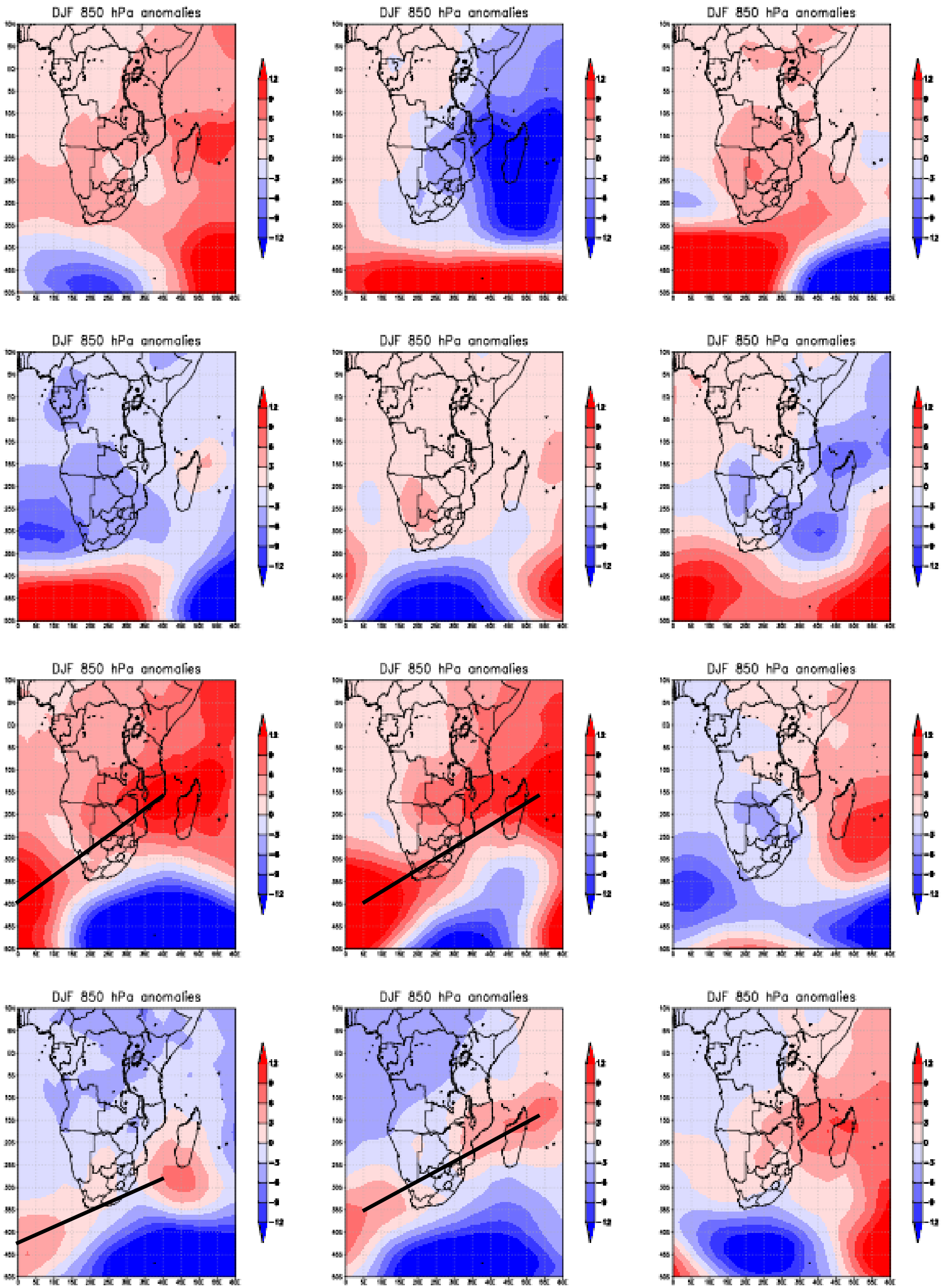
Control experiment

Ozone Radiative forcing experiment

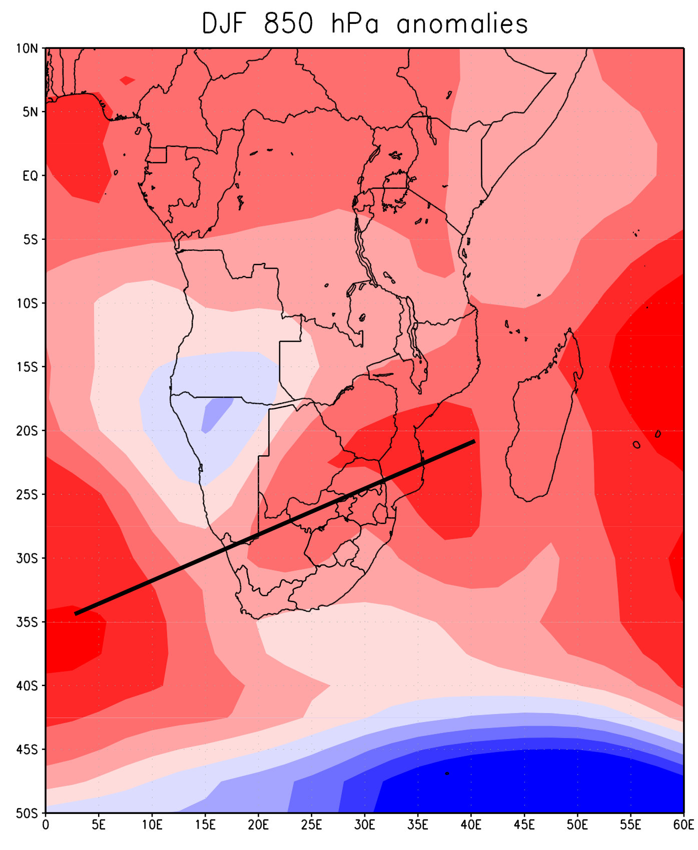


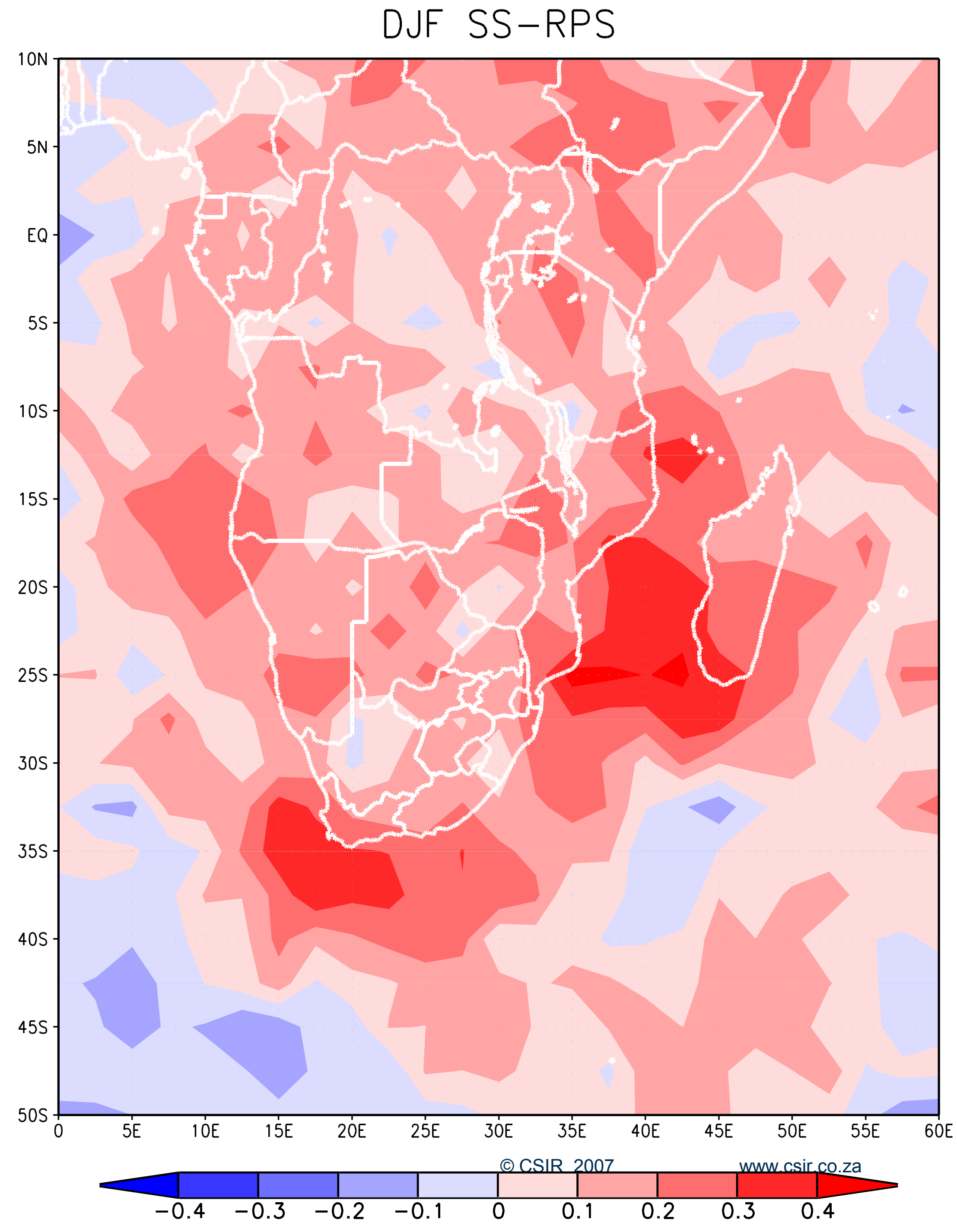
CCAM simulations of the latitudinal location of the SH jet

Variability of the latitudinal location of the jet and its trend for (a) December, (b) January and (c) February. The red and black lines are for the control and ozone-varying experiment, respectively.



"Ozone experiment": Anomalous Antarctic stratospheric ozone concentrations may have contributed to the "normal rainfall" of the 1997/1998 El Niño over southern Africa





Change in skill for DJF: Time-varying ozone vs climatological values (control experiment)

Inclusion of time-varying stratospheric ozone leads to a step-up change in DJF predictability – the ozone signal is seemingly sufficiently strong to overcome the westerly-wave chaos-barrier

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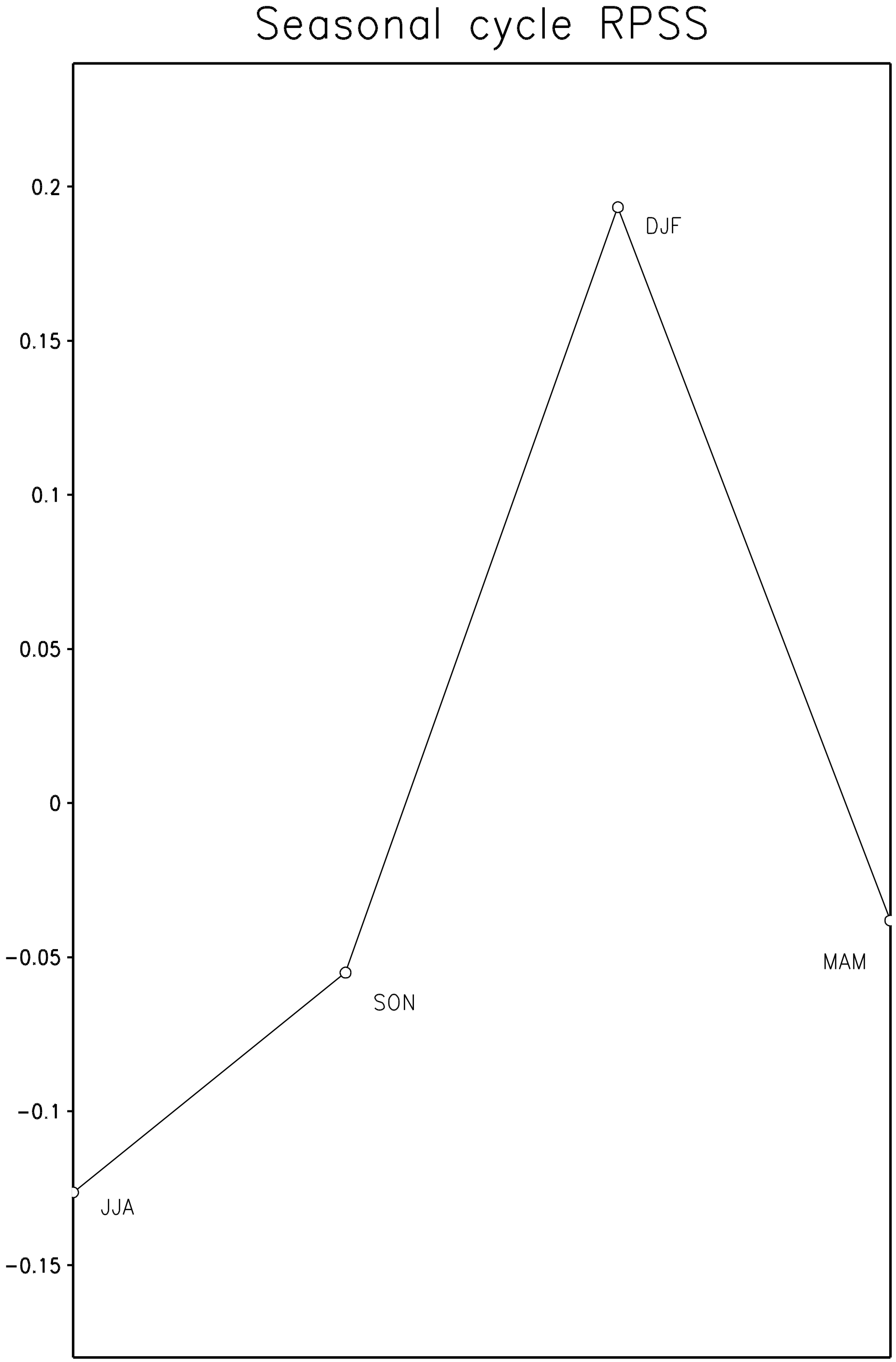

Change in skill over South Africa across seasons:

Time-varying ozone vs climatological values (control experiment)

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Conclusions

- **CCAM forced with observed time-varying ozone concentrations is capable of simulating the observed cooling trends in SH polar-cap stratospheric temperatures that have occurred over the last few decades**
- **Simulations of inter-annual variability are most skilful for DJF over southern Africa**
- **High-latitude tentacles of low predictability reach southern Africa during MAM, JJA and SON**
- **Inclusion of time-varying stratospheric ozone leads to a step-up change in DJF predictability – the ozone signal is seemingly sufficiently strong to overcome the westerly-wave chaos-barrier**
- **Further investigations with 72 level versions of CCAM and additional climate models to confirm this finding**