The International Research Institute for Climate and Society

Impact of the 20th Century stratospheric ozone depletion on increasing precipitation in South Eastern South America

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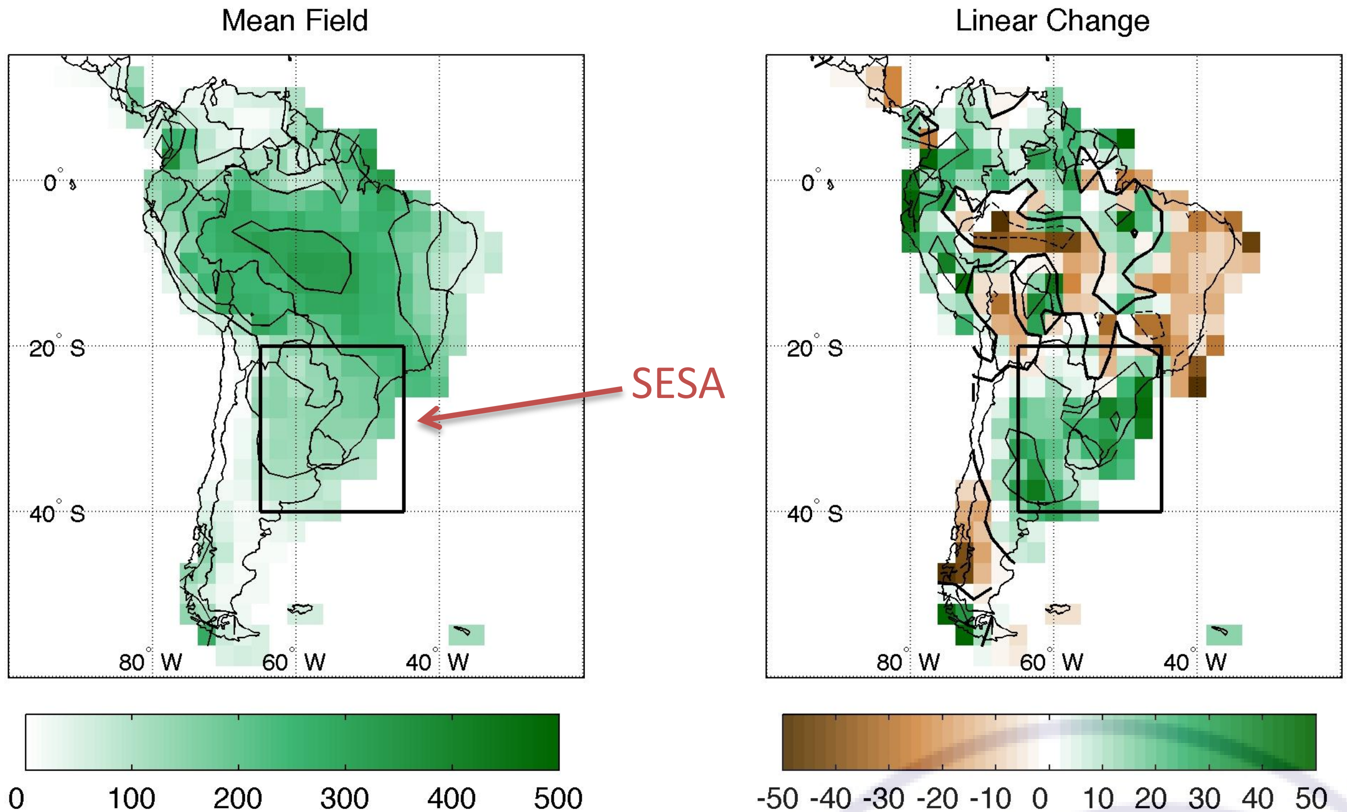
MOTIVATIONS

SESA has experienced a strong wetting trend over the complete 20th Century.

GPCCv4 DJF Precipitation 1960-1999



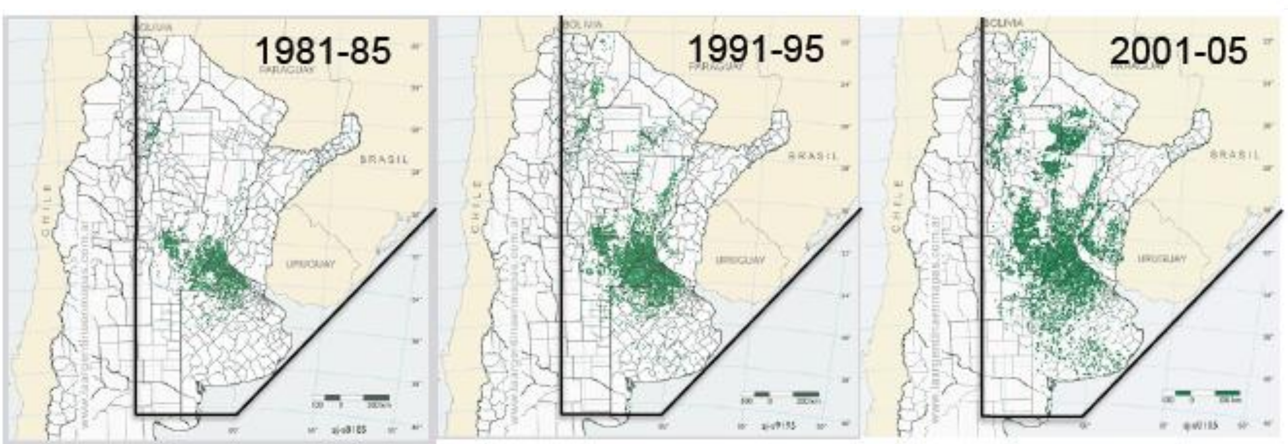
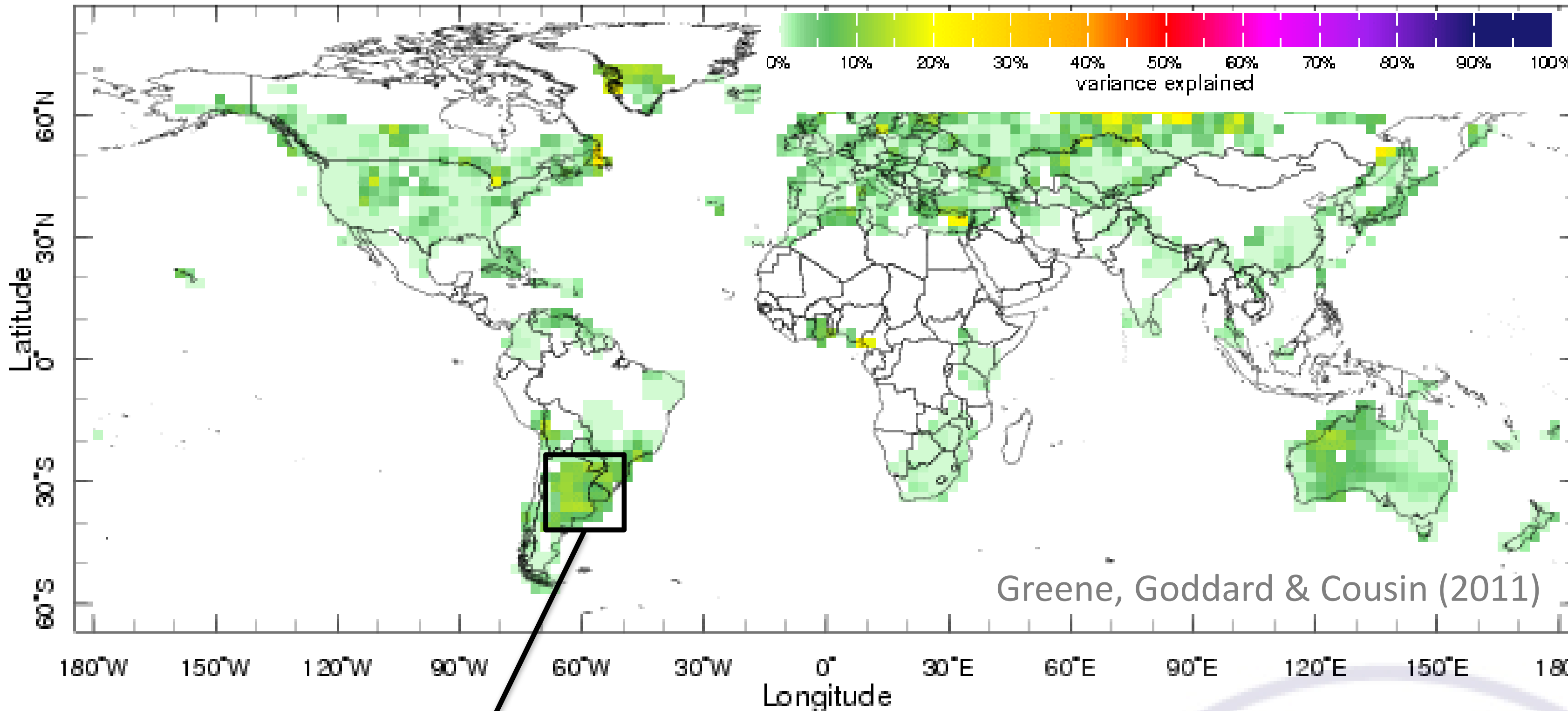
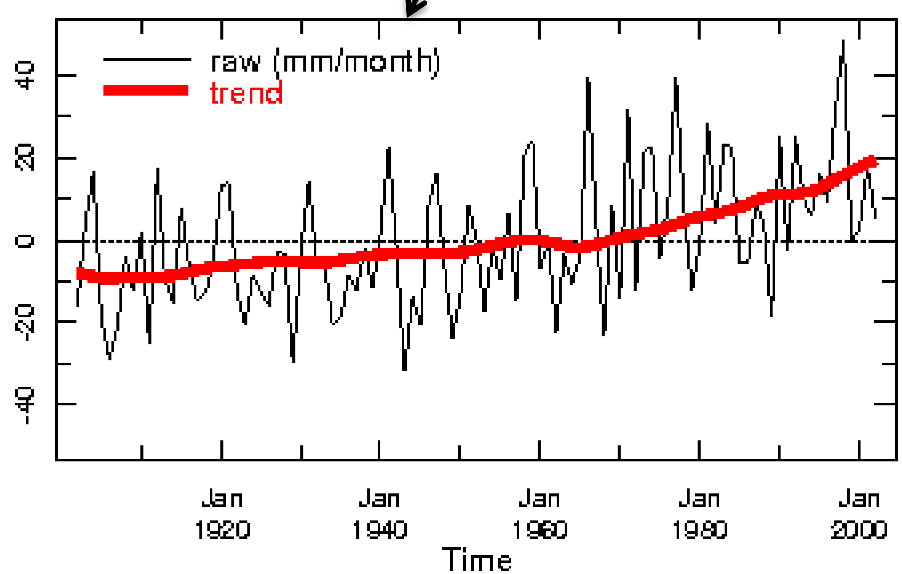


FIGURE 1. Changes in soybean cropping area over time for Argentina. One dot = 1000 ha. Lines delimit Southeastern South America region shown in Figure 2.

Over the last decades, the wetting has been followed by the expansion of the agricultural frontiers.

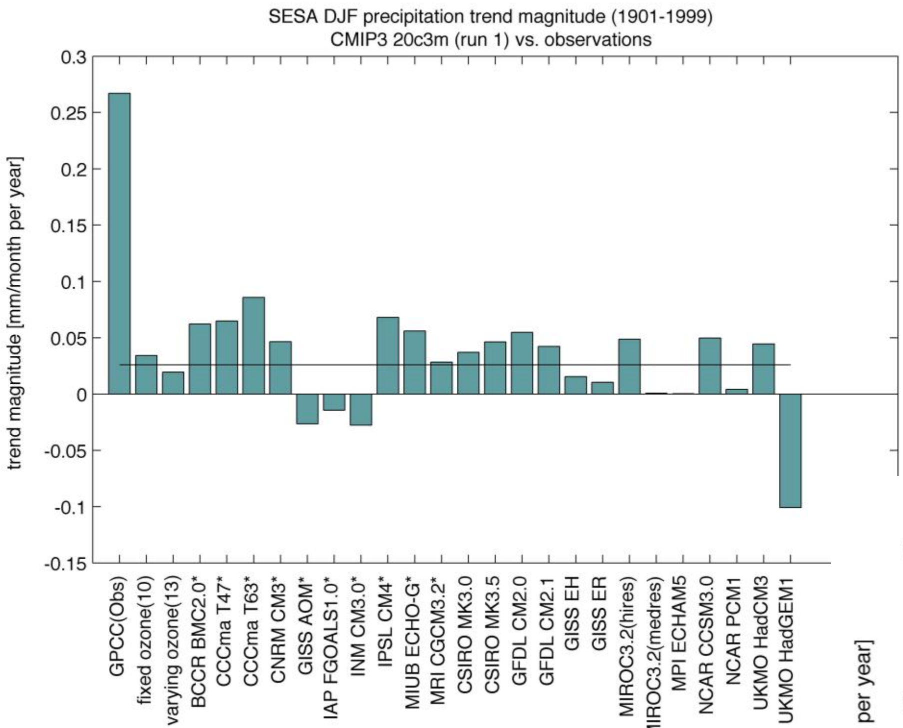
MOTIVATIONS

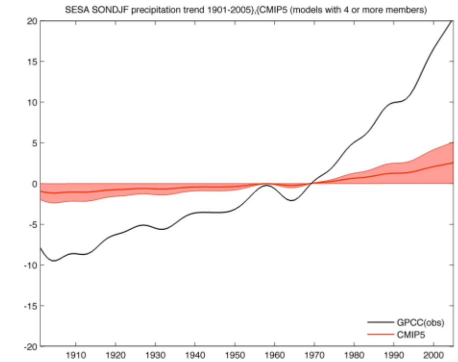




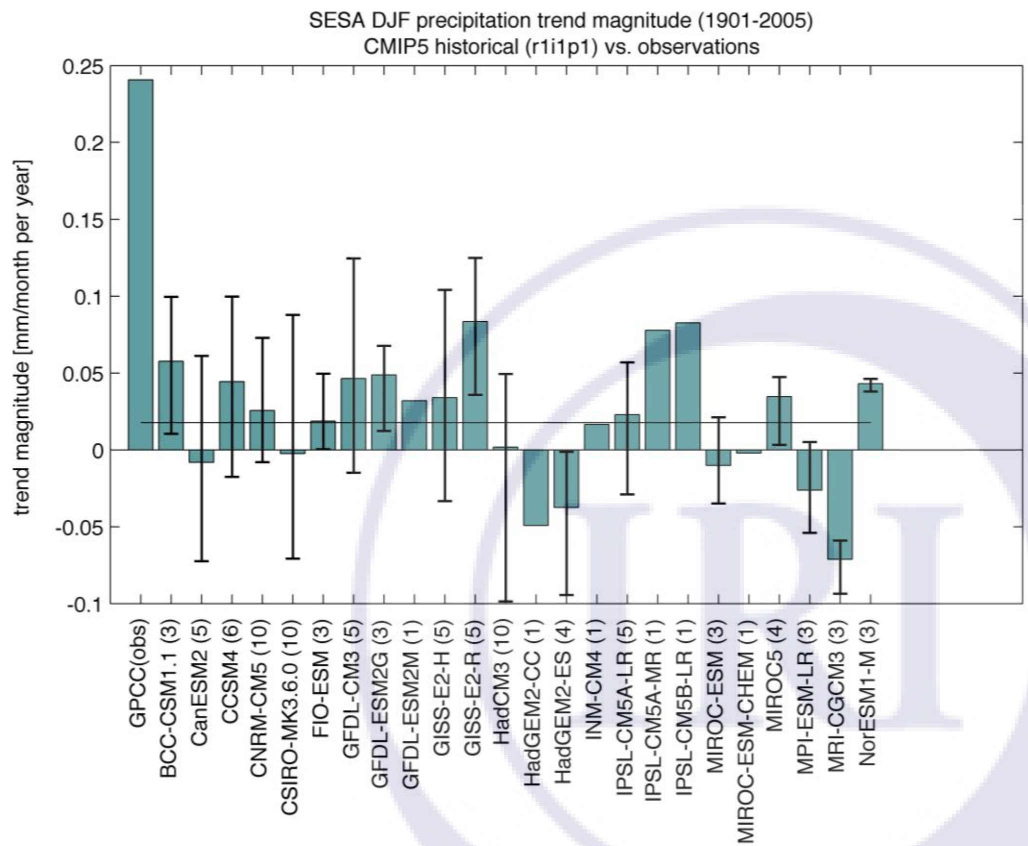
The trend explains in average 20% of the summer precipitation variance

MOTIVATIONS: CMIP3/CMIP5 – 20th Century





CMIP3 and CMIP5 models fail to reproduce the 20th Century wetting.



MOTIVATIONS: why thinking about ozone?

Ozone depletion has been shown to be one of the main drivers of climate change in the Southern Hemisphere (e.g. Polvani et al. 2011)

In particular, it has been linked to the observed wetting of the SH subtropics (Kang et al 2011)

Kang et al. 2011

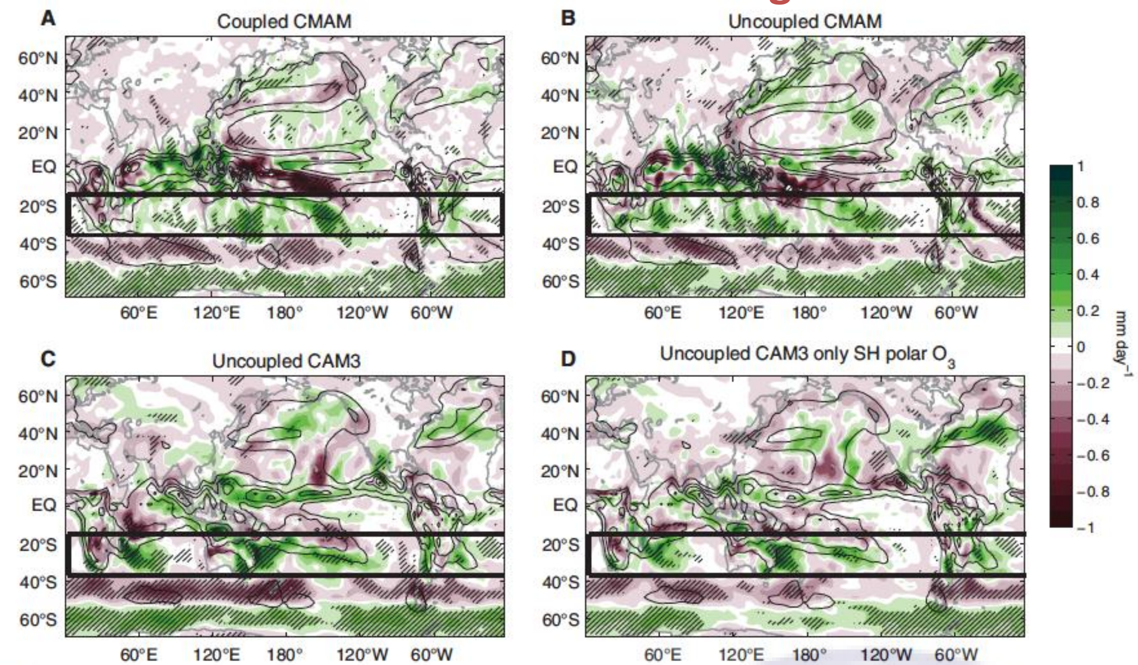
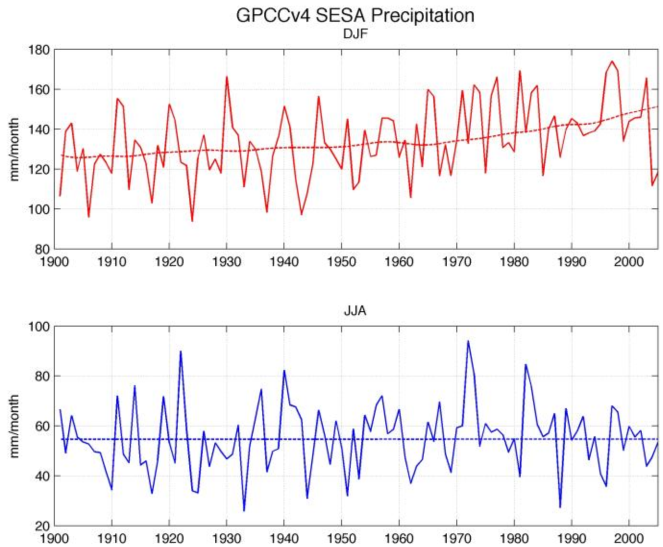
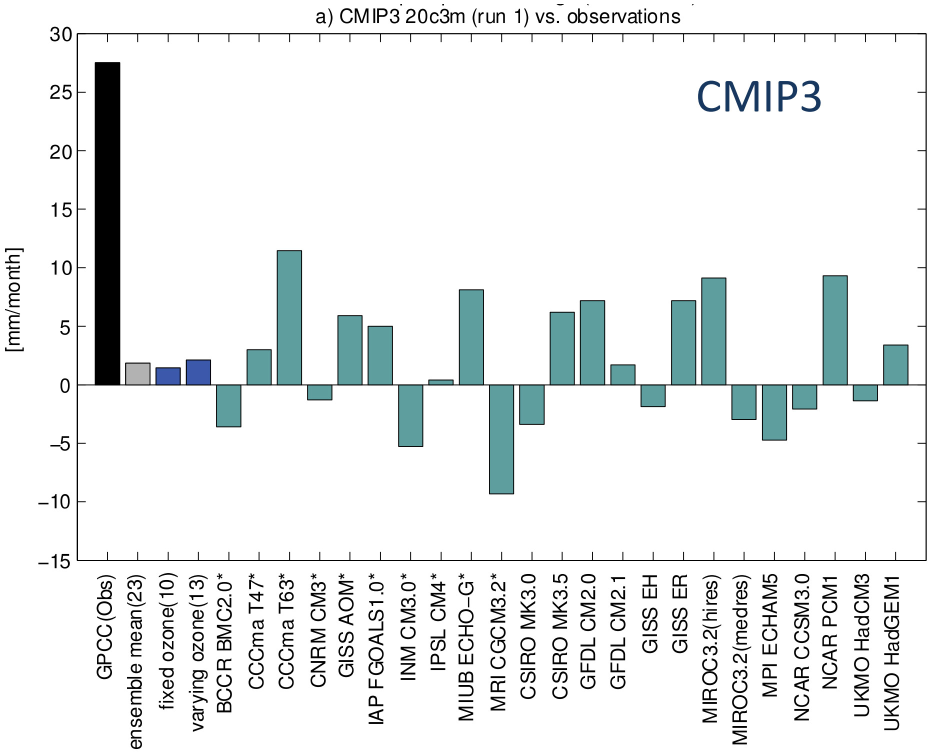


Fig. 2. Modeled precipitation change caused by the ozone hole. Shading shows austral summer precipitation difference (in mm day^{-1}) induced by ozone depletion in **(A)** the coupled CMAM, **(B)** the uncoupled CMAM, **(C)** the uncoupled CAM3, and **(D)** the uncoupled CAM3 with ozone depletion confined to 40°S to 90°S. Black contours show the mean precipitation in the respective reference integrations, with contour interval of 3 mm day^{-1}. Locations where the response is significant at the 95% confidence level are hatched.



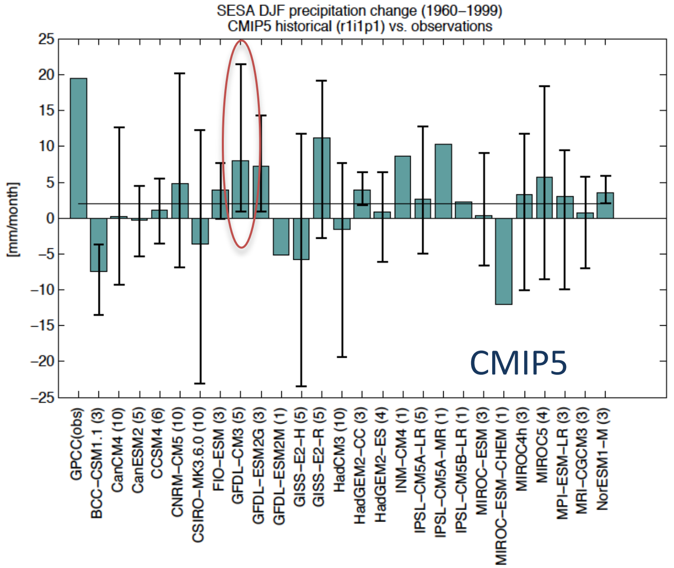
The fact that that the trend in SESA strengthens around 1960 and that this is only seen during summer could be evidences of the influence of ozone depletion.

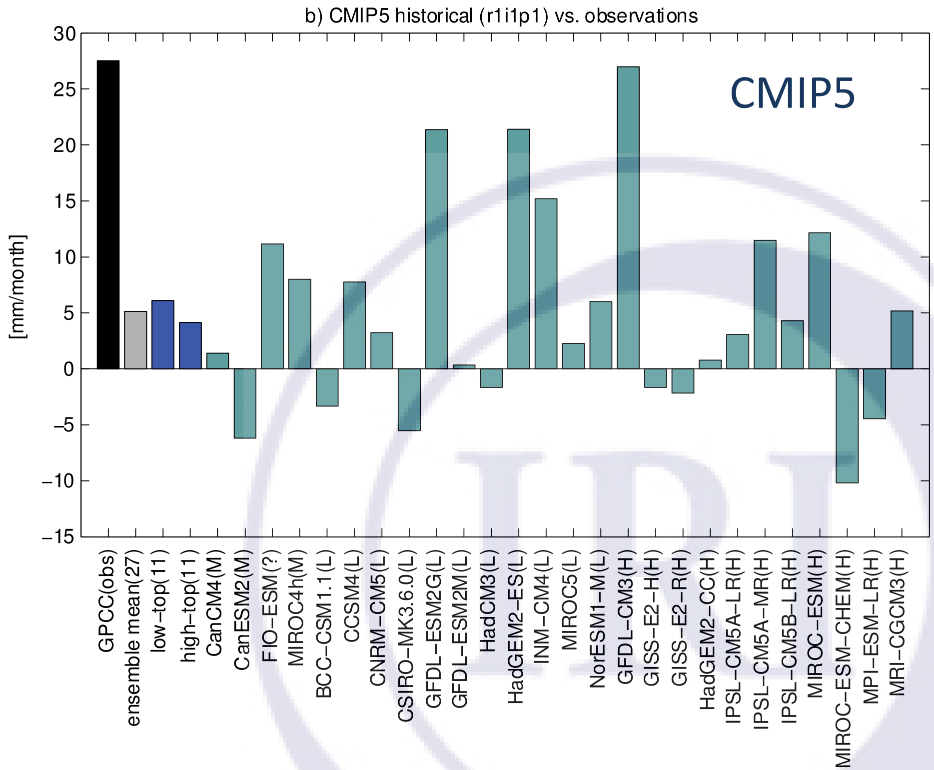
MOTIVATIONS: CMIP3/CMIP5 - 1960-1999



* Some CMIP5 models do better (e.g. GFDL CM3) but the spread is still very large .

* These ensembles provide inconsistent evidences of the influence of ozone depletion.





OBJECTIVE

To assess if stratospheric ozone depletion contributed to the increase in precipitation over SESA during 1960-1999.

METHODOLOGY

Create a hierarchy of GCMs simulations from different modeling centers that allow to assess the regional impact of ozone depletion and, in some cases, to differentiate it from the impact of increased GHGs.

EXPERIMENTS

‘time-slice’ integrations

CMAM
- reference: 80-yrs run, O_3@1979 concentrations
- ozone hole: 80-yrs run, O_3@2005 concentrations

uncoupled (1m) & coupled (3m) versions

CAM3
- REF1960: 50-yrs run, O_3@1960, GHGs@1960, SSTs@1952-1968 ave.
- GHG2000: 50-yrs run, O_3@1960, GHGs@2000, SSTs@1992-2008 ave.
- OZONE2000: 50-yrs run, O_3@2000, GHGs@1960, SSTs@1952-1968 ave.
- BOTH2000: 50-yrs run, O_3@2000, GHGs@2000, SSTs@1992-2008 ave.

CMAM

‘GHG-only’: difference between ozone hole and reference climatologies

CAM3

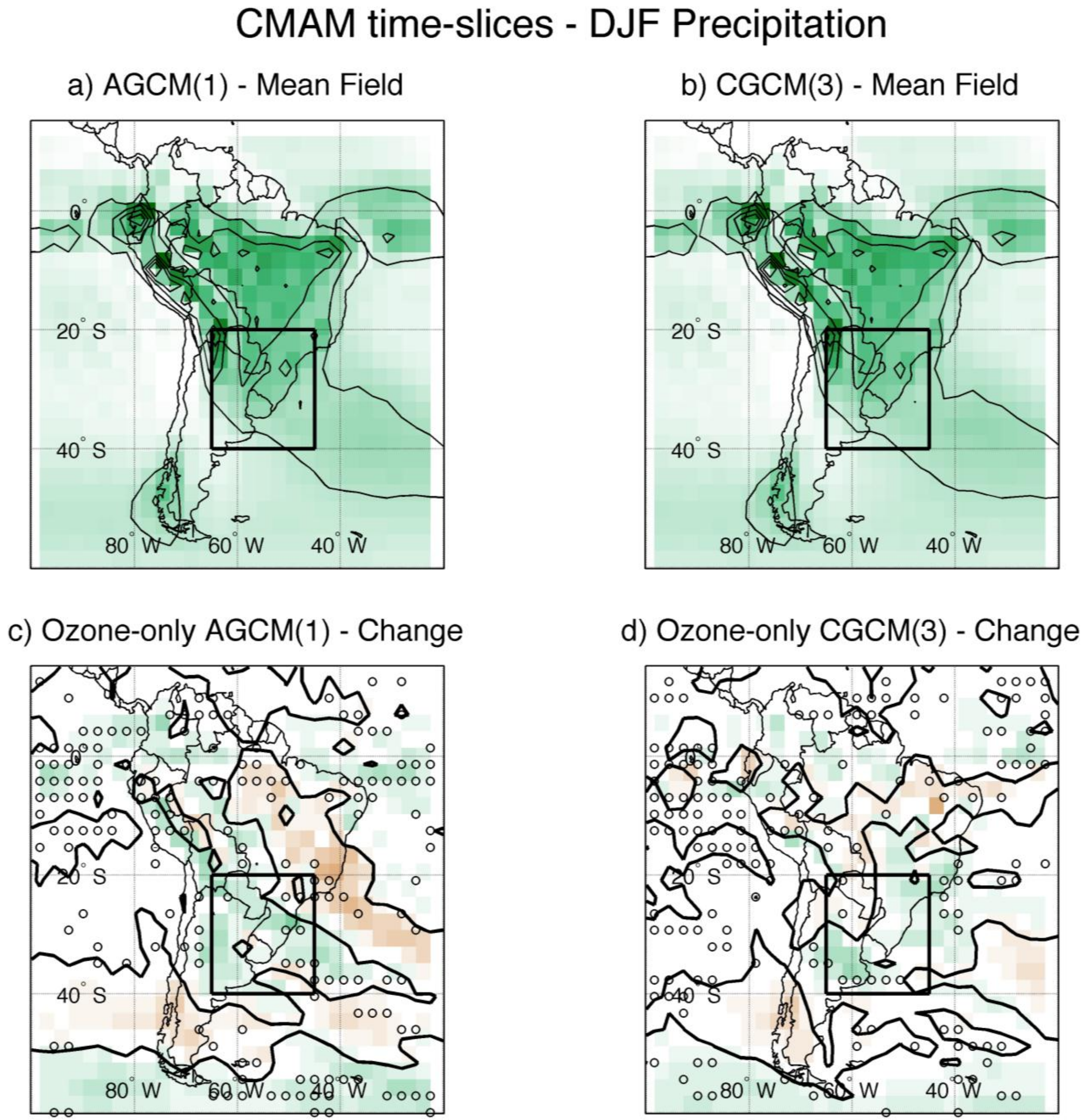
‘all forcings’: difference between BOTH2000 and REF1960 climatologies

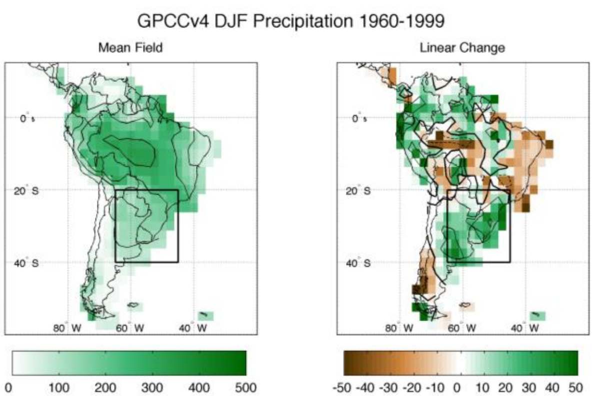
‘GHG-only’: difference between GHG2000 and REF1960 climatologies

‘ozone-only’: difference between OZONE2000 and REF1960 climatologies

EXPERIMENTS: CMAM time-slice runs

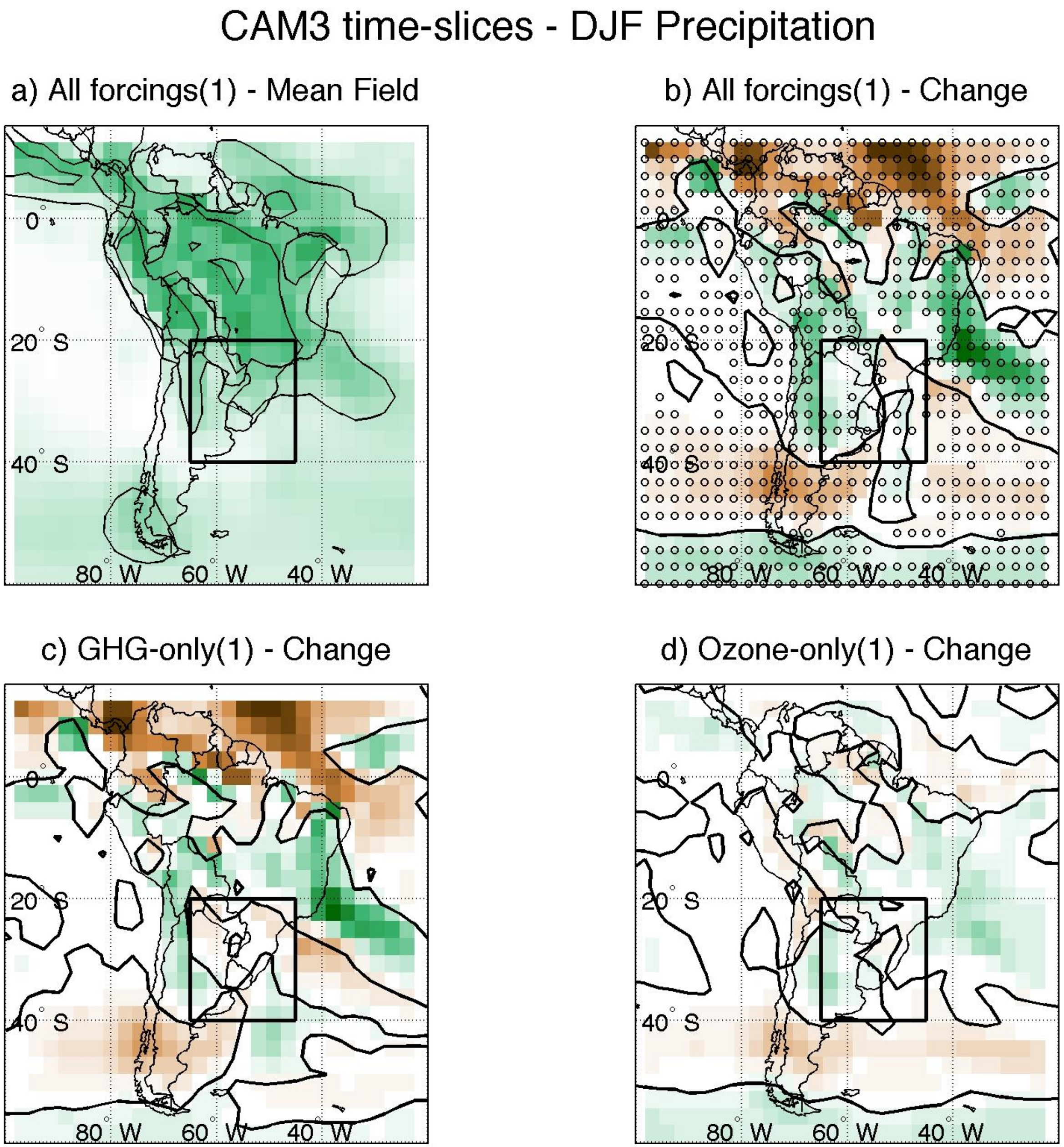
CMAM
(Environment Canada/CCCma)
uncoupled/coupled
T63 L71 - top: 100km
AGCM(1m)
CGCM(3m)
Kang et al. 2011

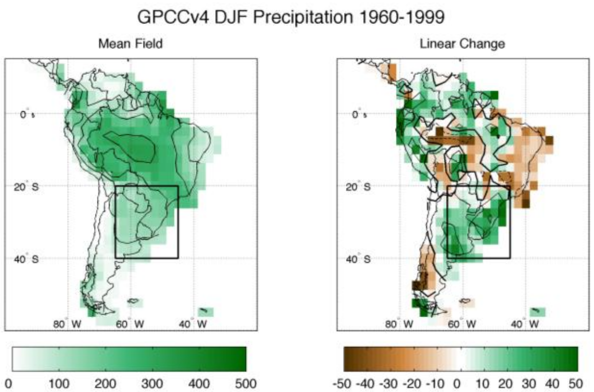




EXPERIMENTS: CAM3 time-slice runs

CAM3
(UCAR)
uncoupled
T42 L26 - top: 2.2hPa
single runs
Polvani et al. 2011





EXPERIMENTS

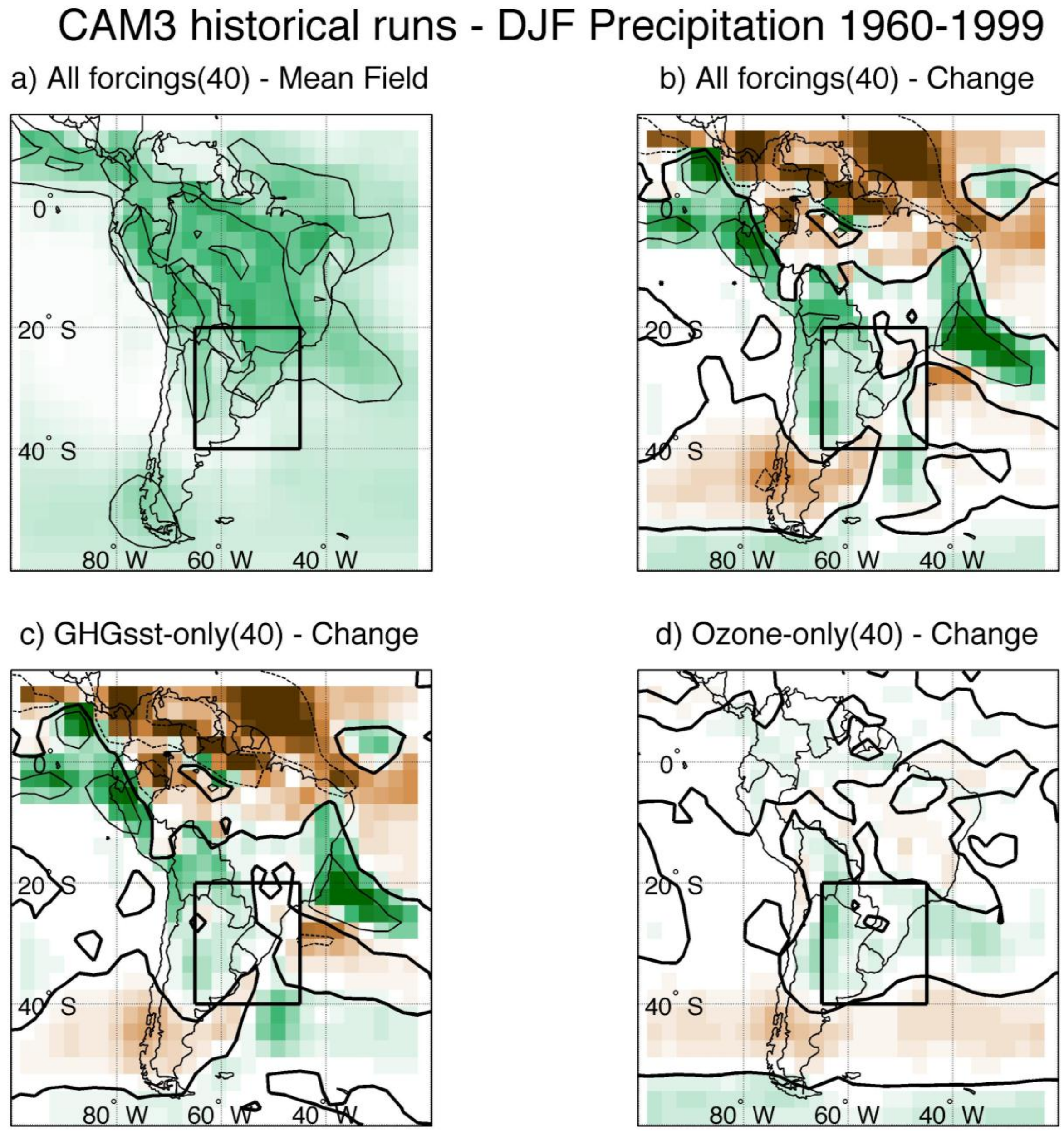
CAM3 LDEO historical integrations → **CAM3**

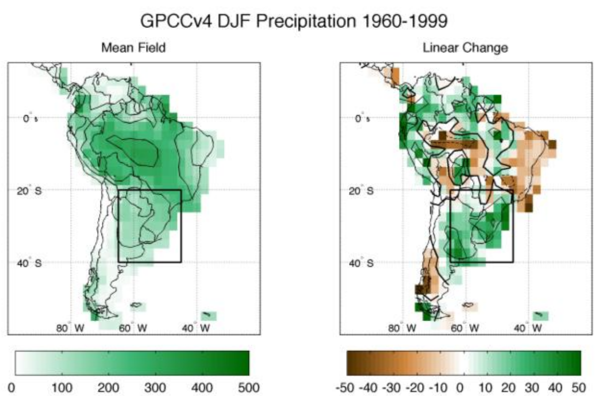
- all forcings(all): 1950-2009, time-varying O_3, GHGs and SSTs/SICs.
- GHG-only(ghgsst): 1950-2009, like 'all forcings' but O_3@1960 levels
- ozone-only(o3): 1950-2009, like 'all forcings' but GHGs/SSTs/SICs@1960

40-member ensemble

EXPERIMENTS: CAM3 historical runs

CAM3
(UCAR)
uncoupled
T42 L26 - top: 3.5hPa
40-member ensemble





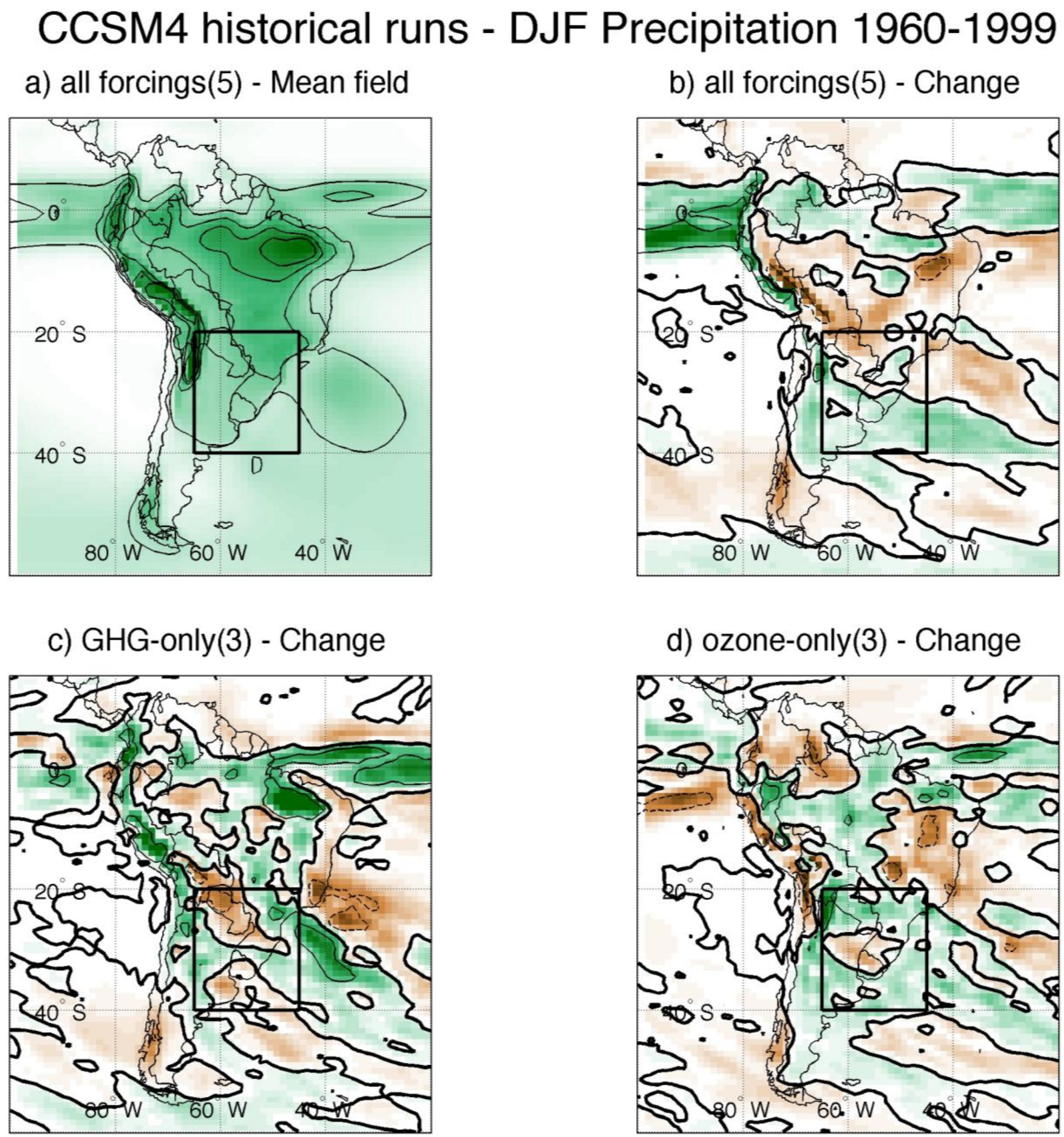
EXPERIMENTS

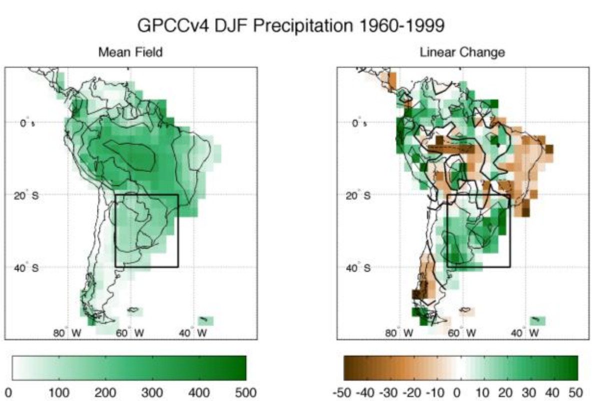
CMIP5 single-forcing historical integrations → **CCSM4**

- all forcings: 1850-2005, all forcings are time-varying
- GHG-only: 1850-2005, pre-industrial O_3 levels, observed evolving GHGs
- ozone-only: 1850-2005, pre-industrial GHGs, observed evolving O_3

EXPERIMENTS: CCSM4 single-forcing historical runs

CCSM4
(UCAR)
coupled
(CAM4/POP2)
“1°” - L26
all forcings (5m)
GHG-only (3m)
ozone-only (3m)
Gent et al. 2011





EXPERIMENTS

CCMVal-2 historical integrations

- REF-B1(all forcings): 1960-2006, all forcings from observations, prescribed SSTs/SICs
- REF-B2(all forcings): 1960-2100, all forcings from observations + SRES A1B from 2000, simulated SSTs/SICs or CGCM
- SCN-B2b(GHG-only): 1960-2100, analogous to REF-B2 but O_3@1960 levels
- SCN-B2c(ozone-only): 1960-2100, as REF-B2 but GHGs@1960 levels and SSTs/SICs@1955-1964 average (REF-B2)

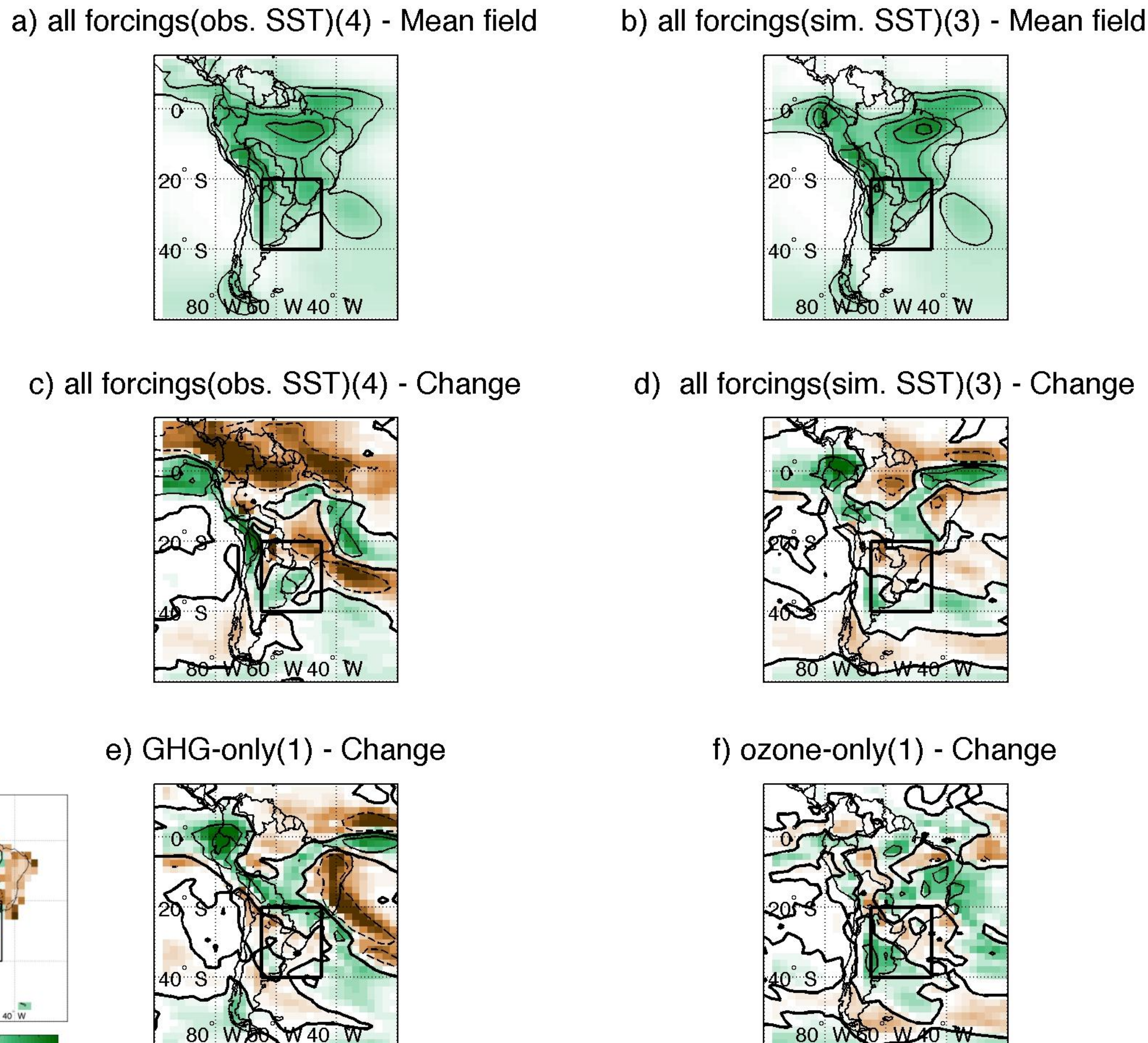
WACCM

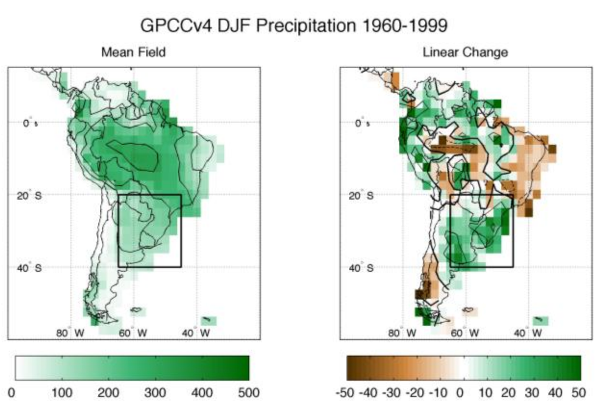
CMAM

CCMVal-2 : Chemistry-Climate Model Validation Activity – Part 2
Eyring et al. 2008, Morgenstern et al. 2010

EXPERIMENTS: WACCM CCMVal-2 historical runs

WACCM
(NCAR)
uncoupled
sim. SSTs from CCSM3
1.9°x2.5° L66 –
top:6×10^{-6} hPa
all forcings (obs) (4m)
all forcings (sim) (3m)
GHG-only (1m)
ozone-only (1m)
Garcia et al. 2007

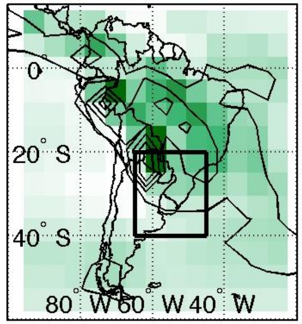




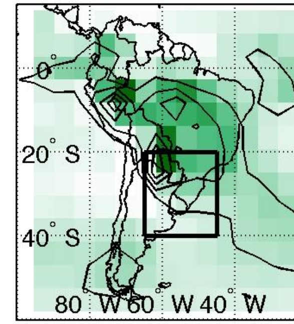
EXPERIMENTS: CMAM CCMVal-2 historical runs

CMAM
(Environment Canada/CCCma)
coupled (NCOM1.3)
T31L71 – top: 0.00081 hPa
all forcings (AGCM) (3m)
all forcings (CGCM) (3m)
GHG-only (3m)
ozone-only (3m)
Morgentsen et al. 2011

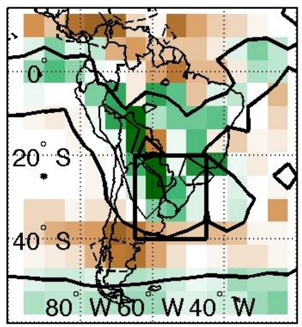
a) all forcings(obs. SST)(3) - Mean field



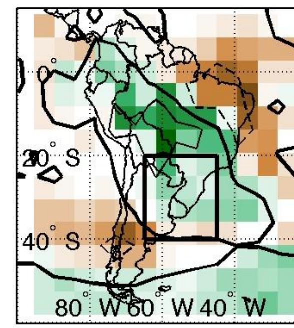
b) all forcings(CGCM)(3) - Mean field



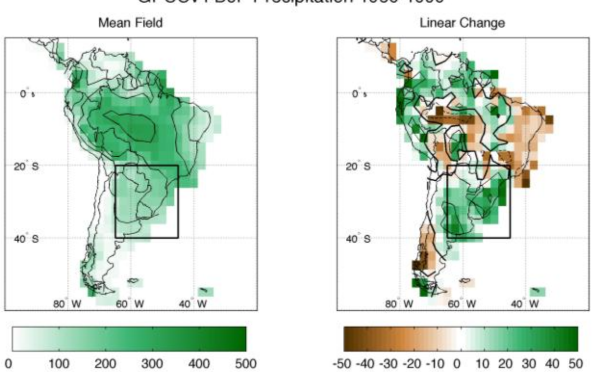
c) all forcings(obs. SST)(3) - Change



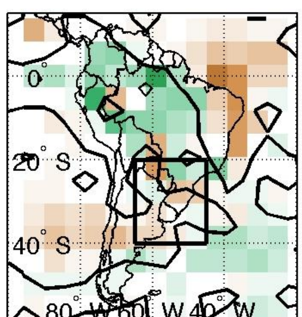
d) all forcings(CGCM)(3) - Change



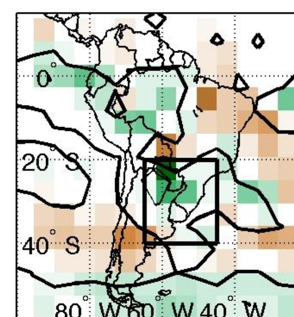
GPCCv4 DJF Precipitation 1960-1999



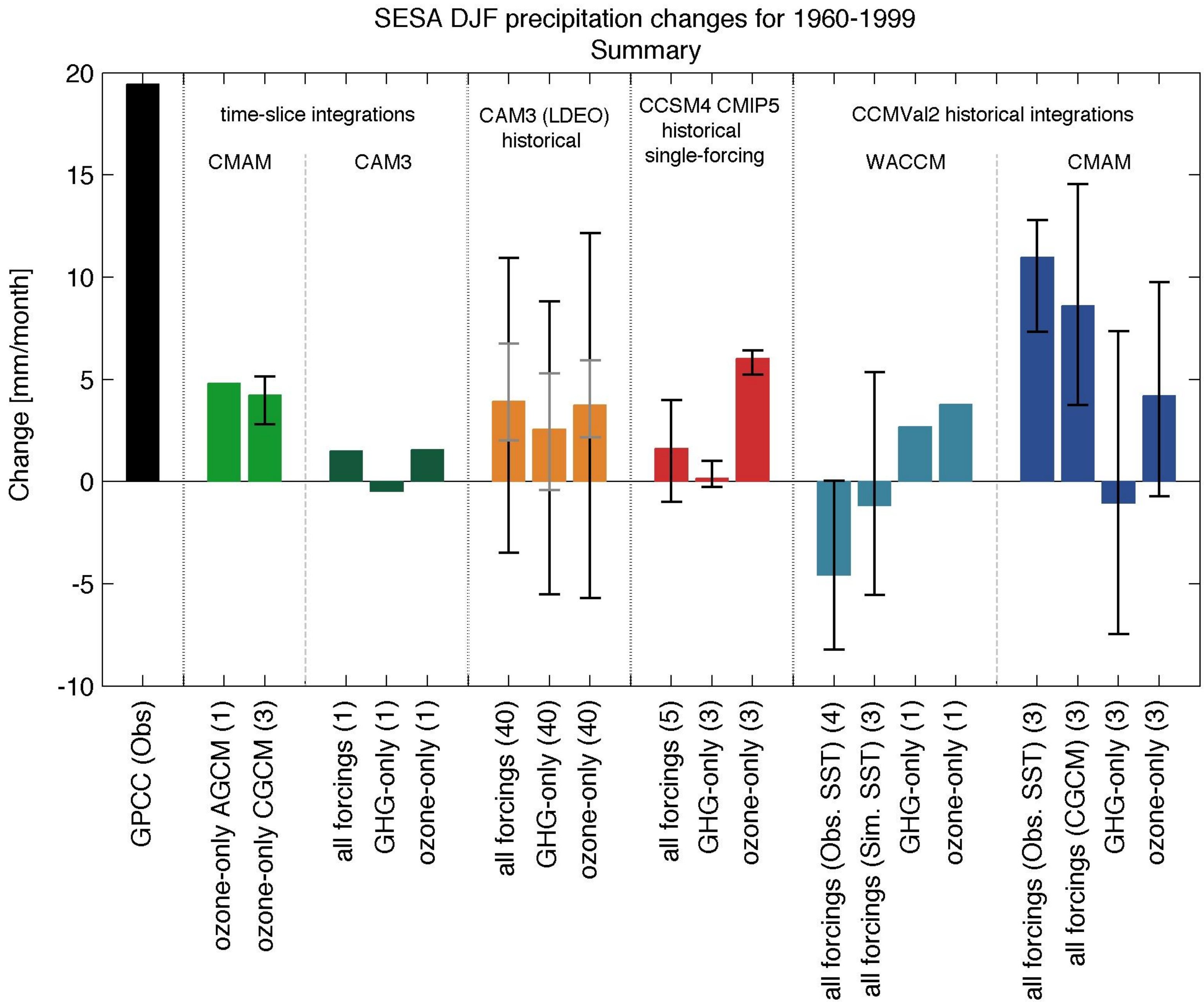
e) GHG-only(3) - Change



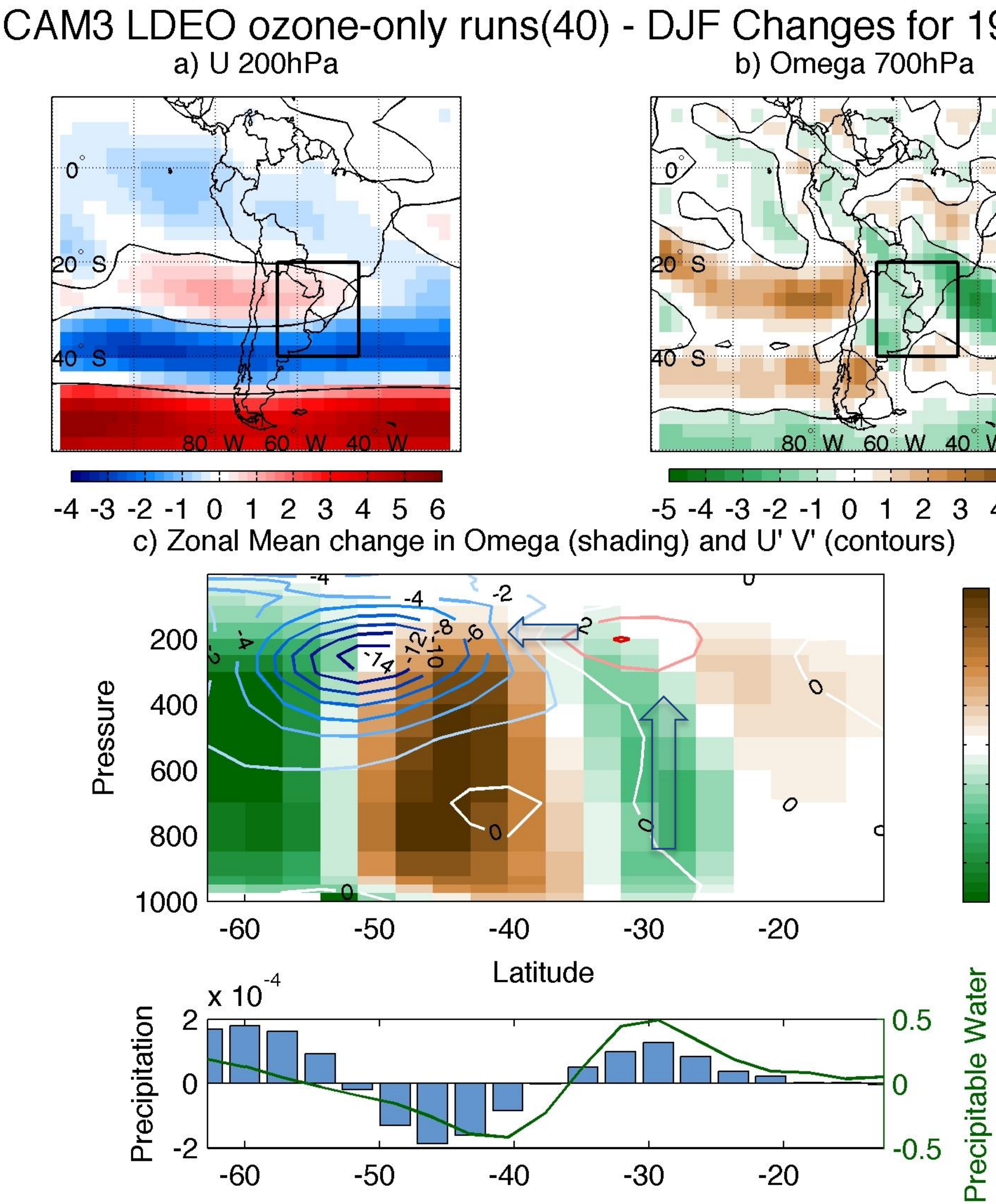
f) ozone-only(3) - Change



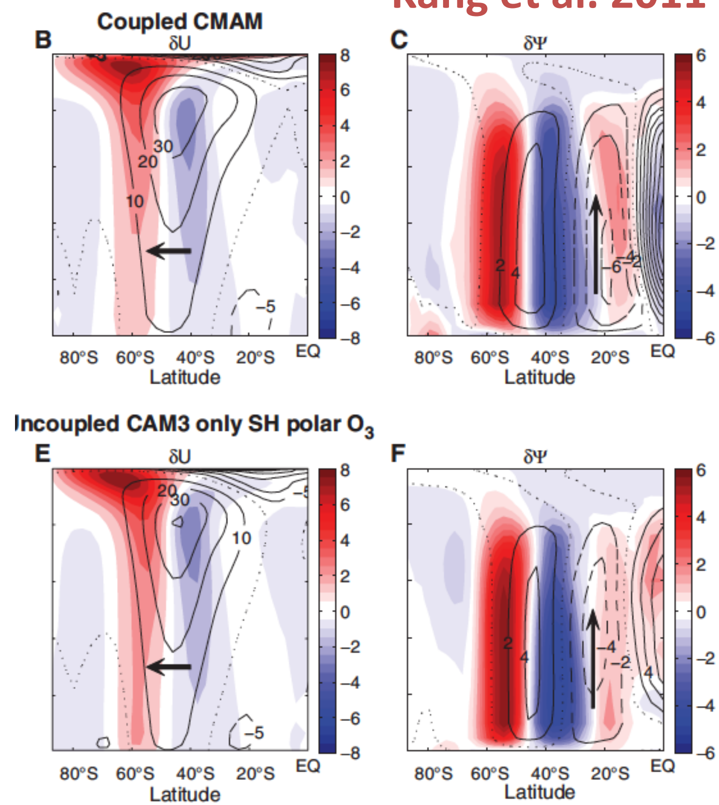
EXPERIMENTS: Summary



EXPERIMENTS: Dynamics of the simulated change



Kang et al. 2011



- poleward shift of extratropical jet
- upper level eddy momentum flux divergence (Eq flank)
- divergence balanced by southward upper tropospheric flow forcing upward motion
- increase in PW and precipitation

CONCLUDING REMARKS

- Throughout the analyzed experiments stratospheric ozone depletion caused a precipitation increase in SESA

- In addition, the increase in GHGs causer smaller increases in precipitation or even a slight drying over SESA

- All the models considered underestimate the precipitation trend over SESA, but so do the CMIP3 and CMIP5 ensembles …

- In the ozone-only experiment using **CAM3** (40 members), as shown by Kang et al. (2011), the radiative-driven changes in the stratosphere force the **extratropical jet** to **shift poleward**. The associated changes in the **eddy momentum fluxes** in the vicinity of South America generate an **upper level mass divergence** that is compensated with **upward motion** and **moisture convergence**, forcing increased precipitation in SESA.

Thanks!
¡Muchas Gracias!

Ozone recovery

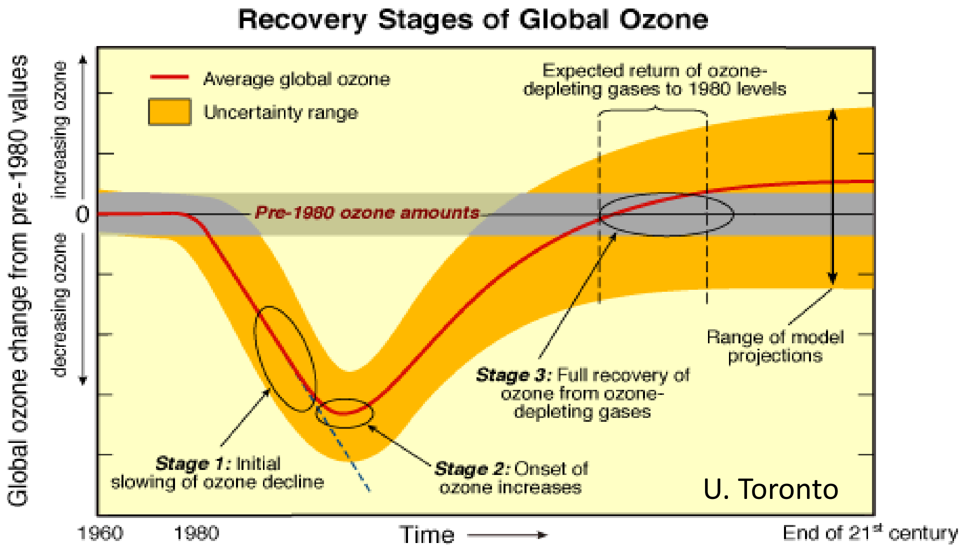


Table 3. Date of return to 1980 column and 50 hPa ozone in the AC&C/SPARC ozone database compared to the 1980 baseline-adjusted time series of Eyring et al. (2010a). The range in brackets in the right most columns provides the uncertainty range from the 18 CCMs in Eyring et al. (2010a). For the AC&C ozone database, the stratospheric ozone is shown since tropospheric column ozone differs substantially among the RCP scenarios (see Eyring et al., 2010b).

Region	AC&C/SPARC Stratospheric column ozone	Eyring et al. (2010a) Total column ozone	AC&C/SPARC Ozone at 50 hPa	Eyring et al. (2010a) Ozone at 50 hPa
Tropics annual mean	–	2042 [2028, –]	–	– [–, –]
Midlatitude NH annual mean	2054	2021 [2014, 2029]	–	2043 [2024, –]
Midlatitude SH annual mean	2031	2035 [2030, 2040]	2049	2058 [2035, –]
Antarctic October mean	2045	2051 [2046, 2057]	2065	2057 [2049-2065]
Arctic March mean	2031	2026 [2023, 2031]	2035	2031 [2023–2041]

Cionni et al. 2011

GHG-only dynamics