Detection, attribution and prediction of decadal-scale rainfall changes over South America using a high-resolution global climate model

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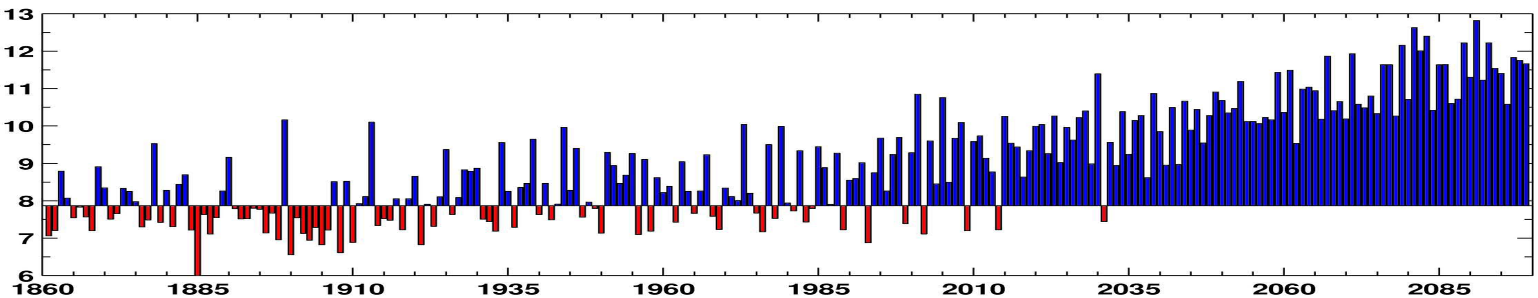
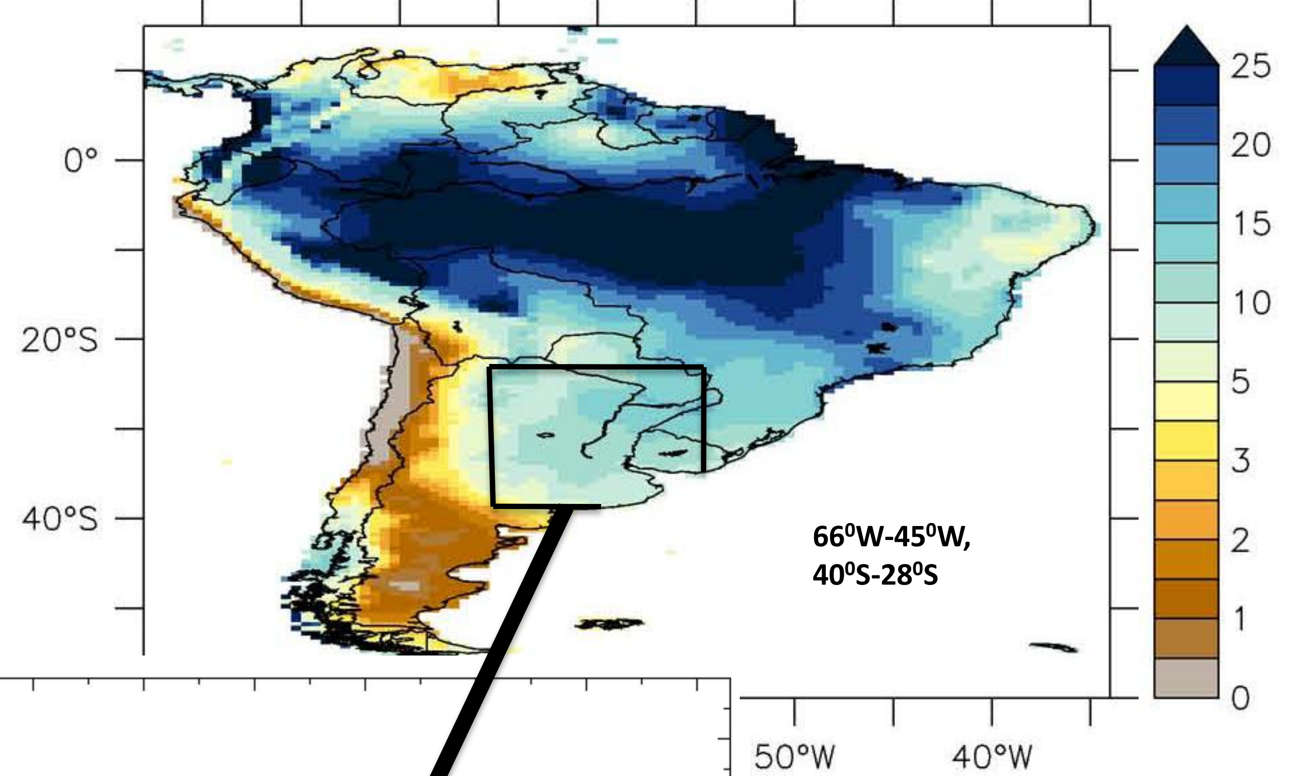
1. Observed precipitation changes over southern South America during Summer

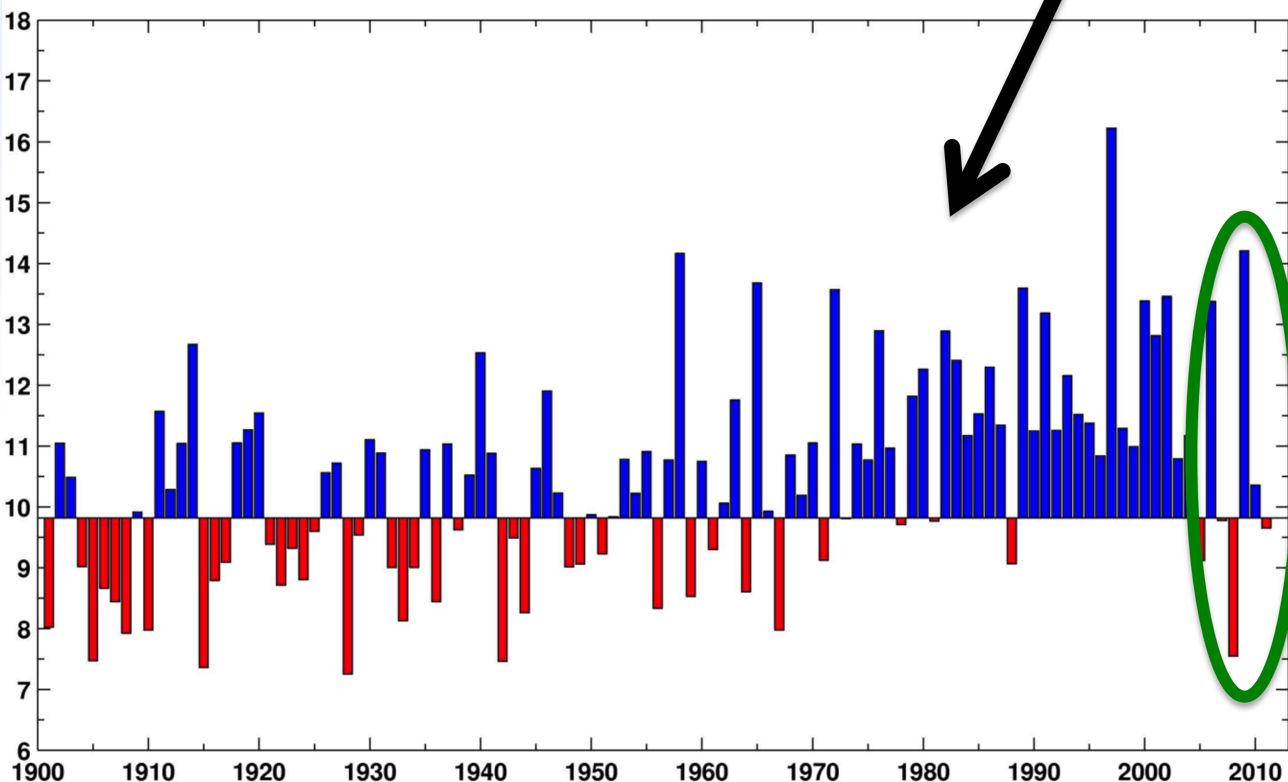
2. Simulations of South American change over the 20th and 21st centuries

3. Detection, attribution and prediction of regional precipitation changes



NDJFMA precipitation
(CRU; cm month^{-1})





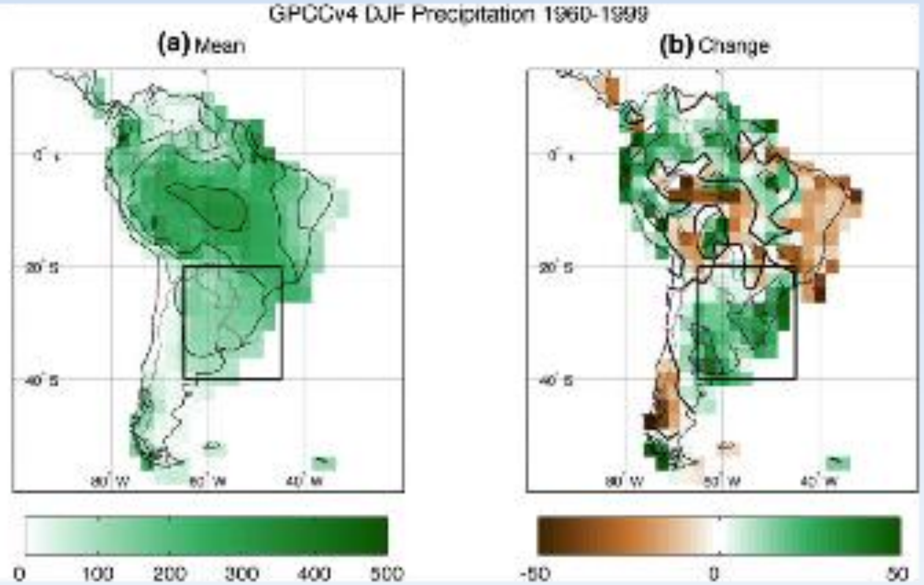


Fig. 1 GPCCv4 DJF precipitation over South America for the period 1960–1999. **a** Time mean precipitation over that period, with a 100 mm/month contour interval. **b** Linear trends over the same period, with the *thick black* showing the zero contour, and additional contours at −25 and 25 mm/month intervals. The *magenta dots* indicate grid points were the linear trend is significant at the 90 % level, according to a Mann-Kendall test. In *both panels*, the *black box* shows our definition of SESA

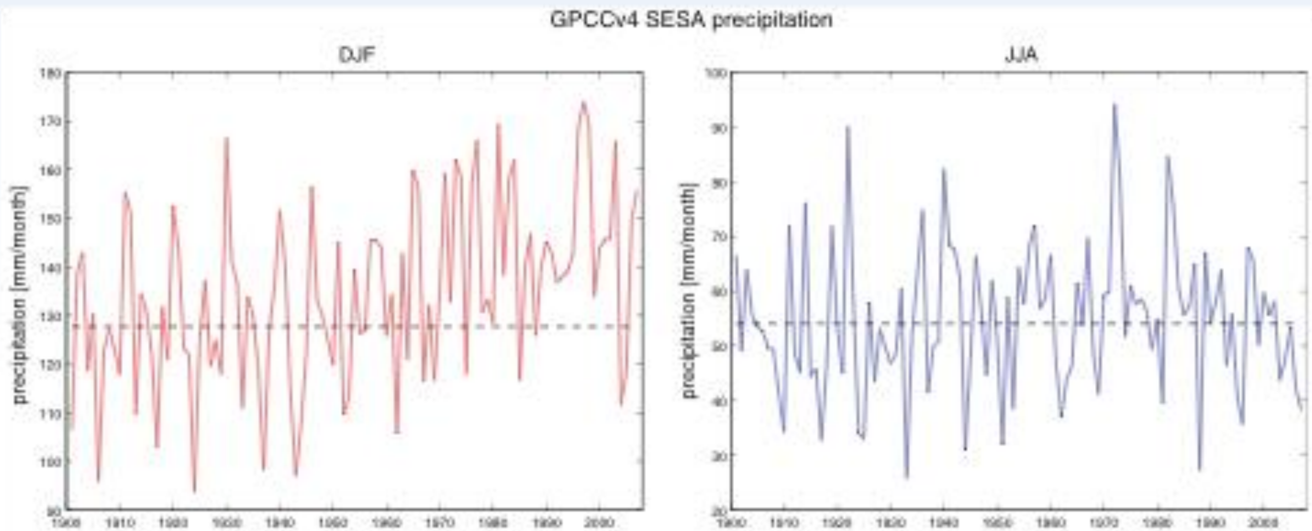
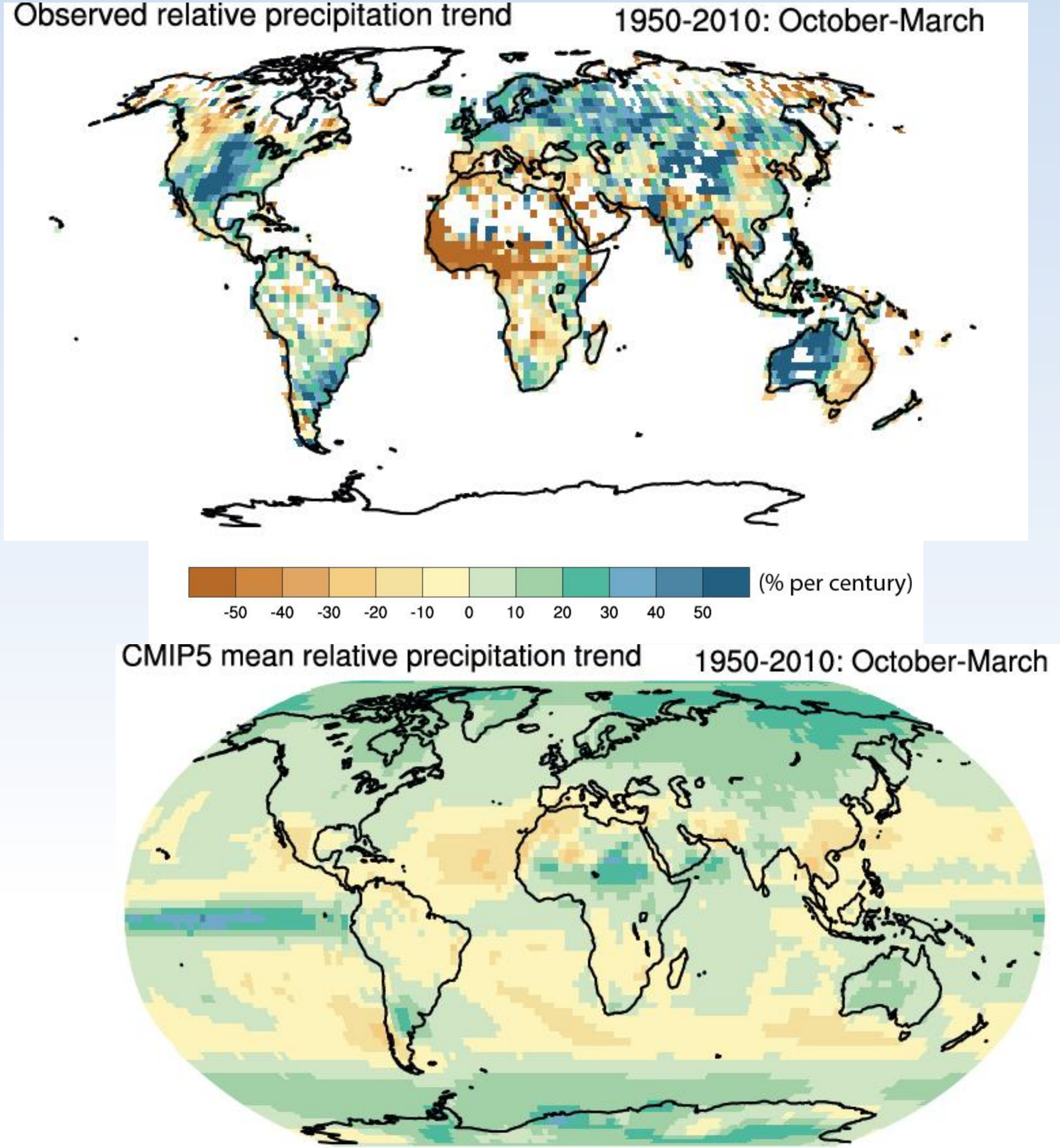


Fig. 2 GPCCv4 precipitation time series, averaged over the SESA region, for (*left*) DJF and (*right*) JJA, in the period 1901–2007. The *dashed black line* indicates the 1901–1960 mean value

Gonzalez et al, 2013

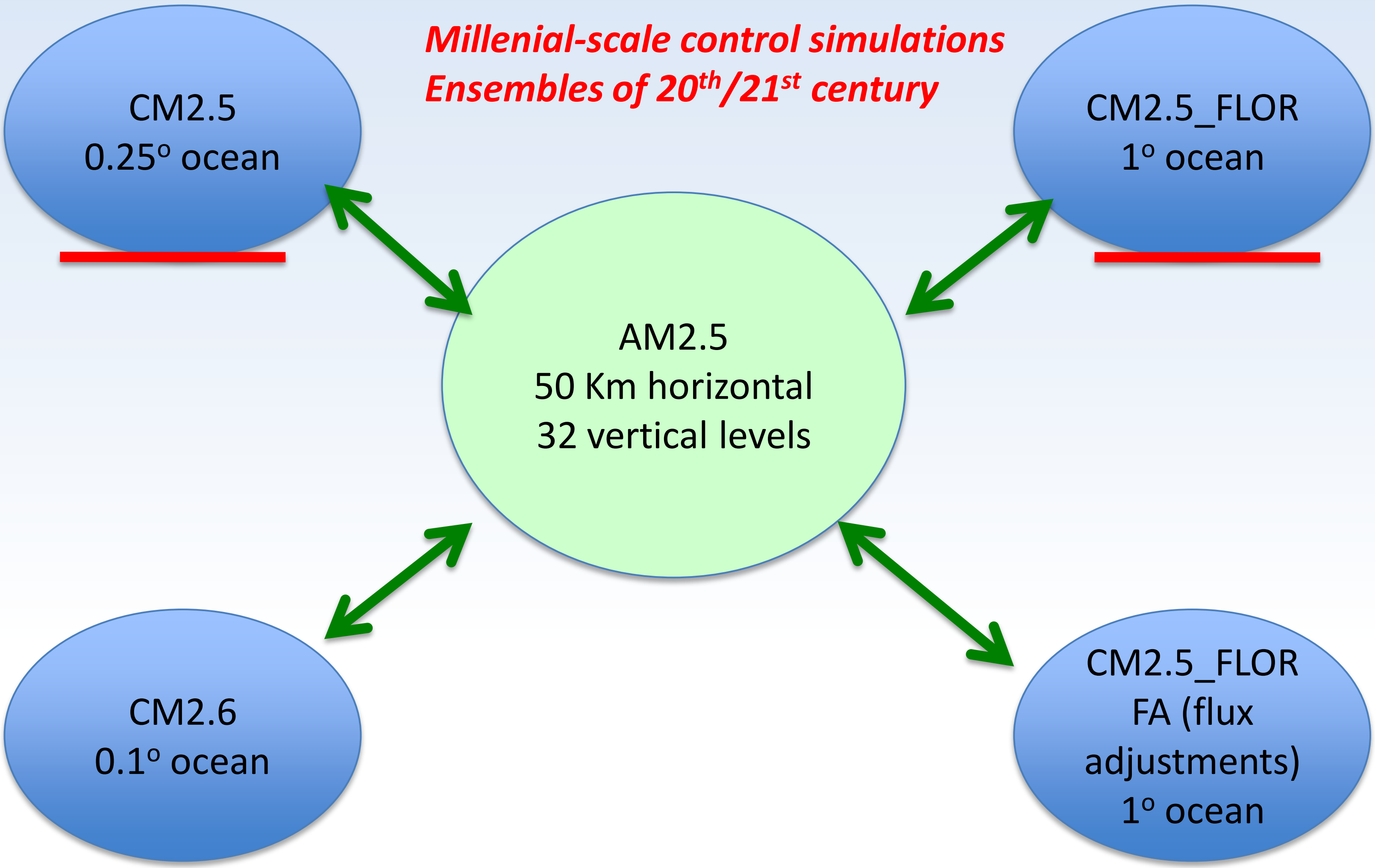


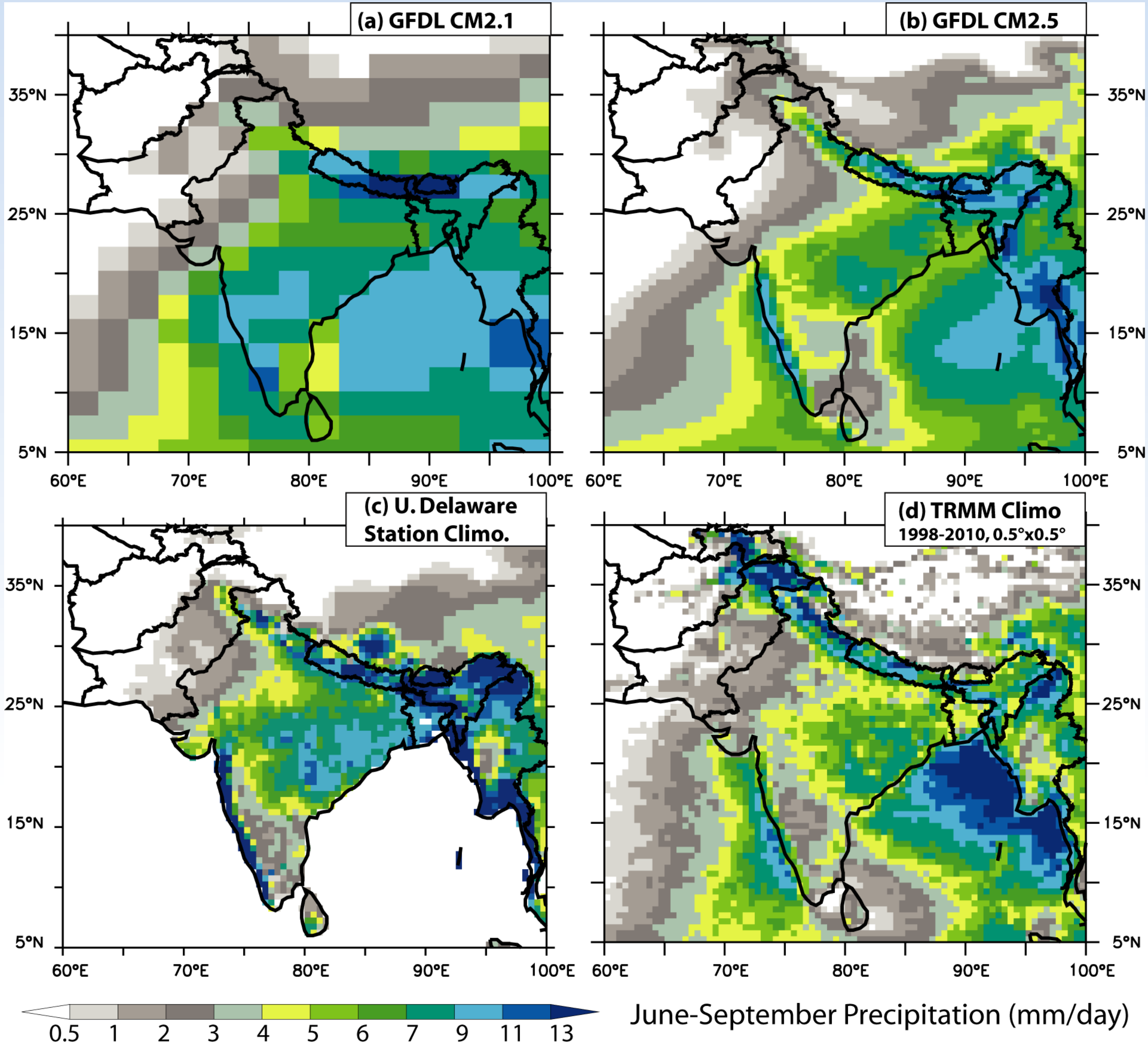
IPCC AR5 Box 11.2

For this study we use a family of new high-resolution global coupled models, descendants of the CM2.1 model.

- all use the same atmosphere: 50 Km horizontal, 32 vertical levels

(same atmospheric physics as GFDL CM2.1, more vertical levels, vastly improved land model)





June-September Precipitation (mm/day)

Delworth et al, 2012

Suites of model simulations used

CONTROL: 1000 year simulation with constant 1860 radiative forcing

HISTORICAL: 5-member ensemble with estimate of "observed" forcing for 1861-2005

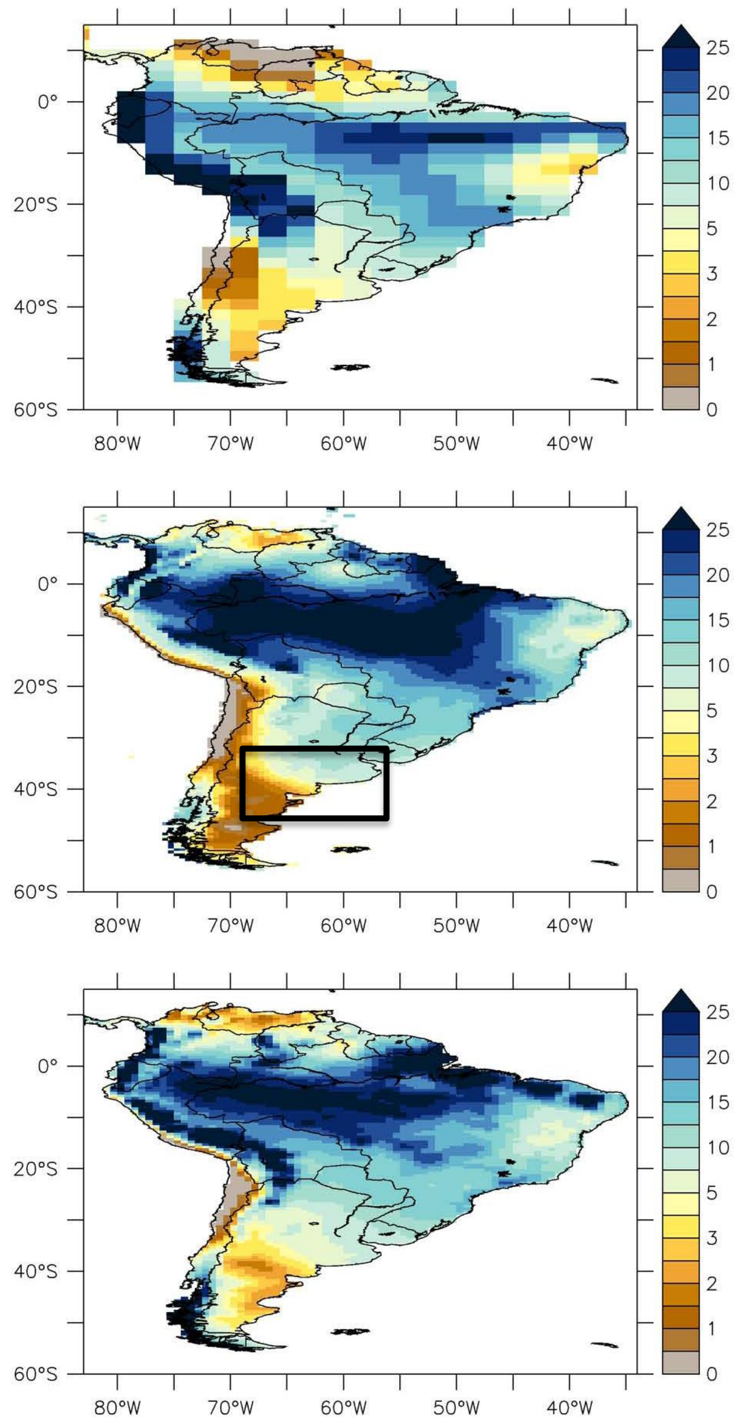
FUTURE: 5-member ensemble for period 2006-2100 using RCP 8.5 scenario

ATTRIBUTION RUNS (only use subset of forcing changes):

ANTHRO: 3-member ensemble for 1861-2005 with only "anthropogenic" forcing

NATURAL: 3-member ensemble for 1861-2005 with only "anthropogenic" forcing

Other attribution runs having forcing from:
(i) Ozone (ii) Anthropogenic aerosols (iii) Well-mixed greenhouse gases



CM2.1

("medium" resolution model, ~200 Km atmosphere)

Absolute error in simulated precipitation reduced by 40% in going from CM2.1 to CM2.5

CRU Observations

Using Koppen climate classification as a measure of error, largest model improvements occurred over South America with greatly improved Amazon (23% reduction globally, more in SA)

CM2.5

("high" resolution model, 50 Km atmosphere)

Nov-Apr mean precipitation (mm day^{-1})

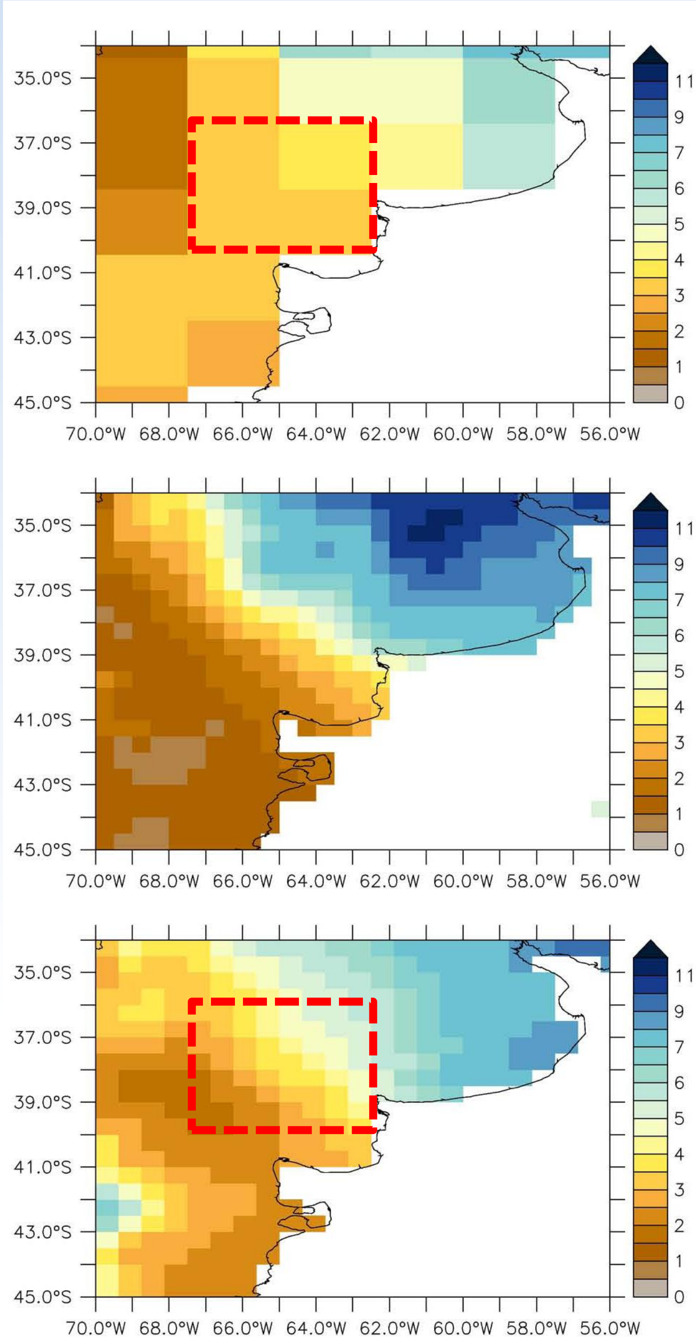
4 grid boxes

CM2.1
(200 Km atmosphere)

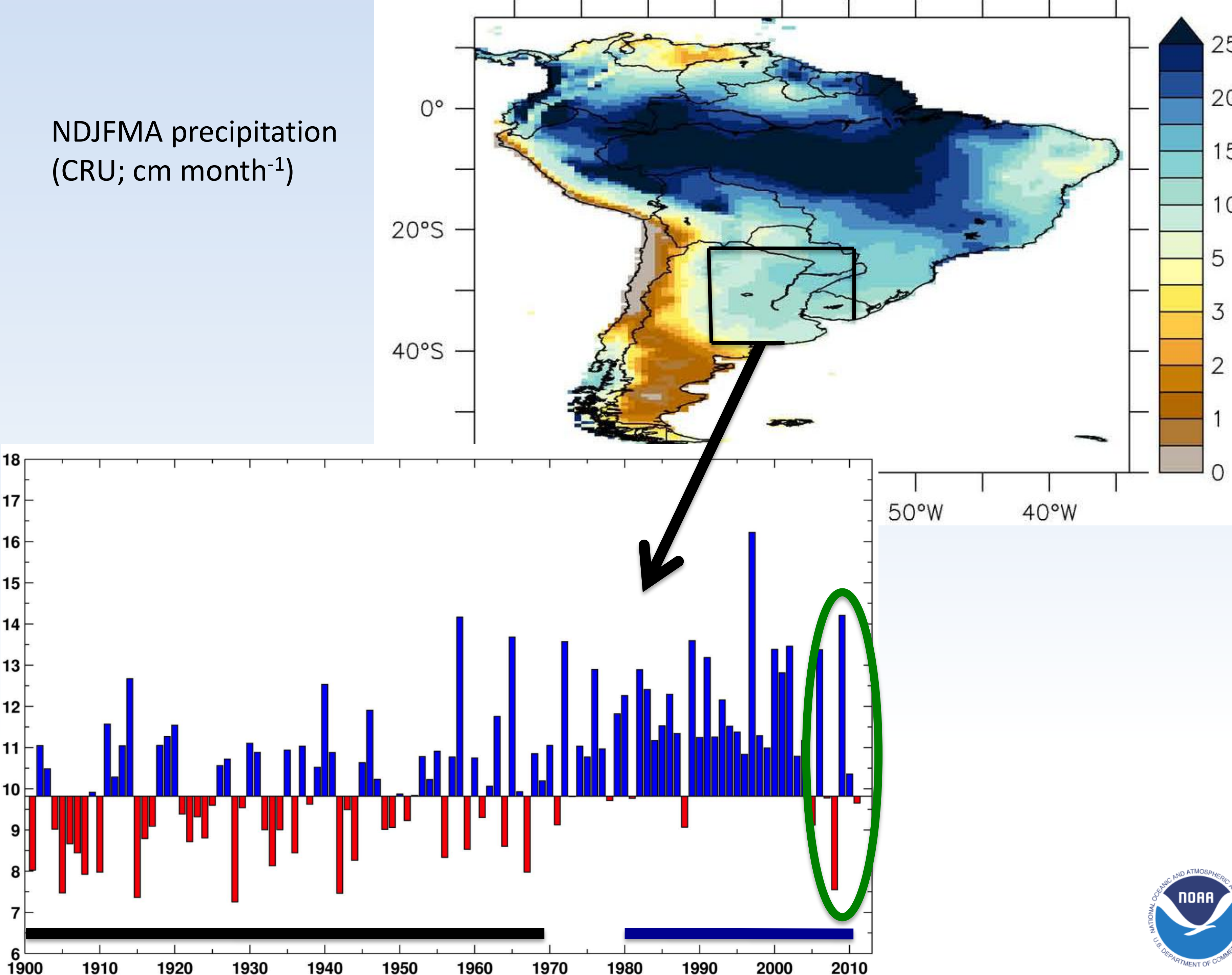
Observations
(CRU)

64 grid boxes

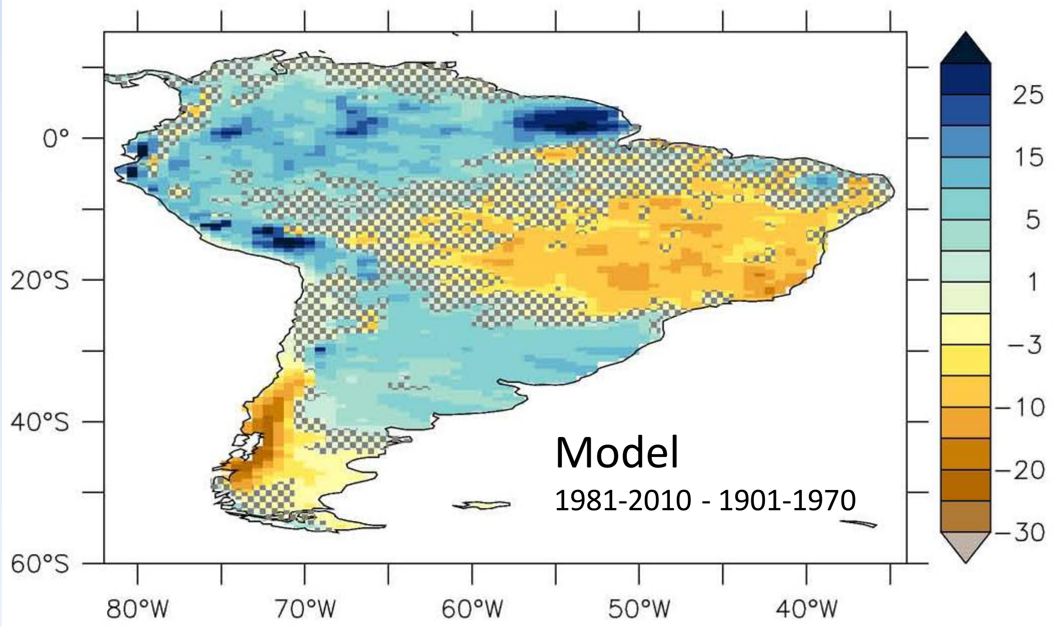
CM2.5
(50 Km atmosphere)



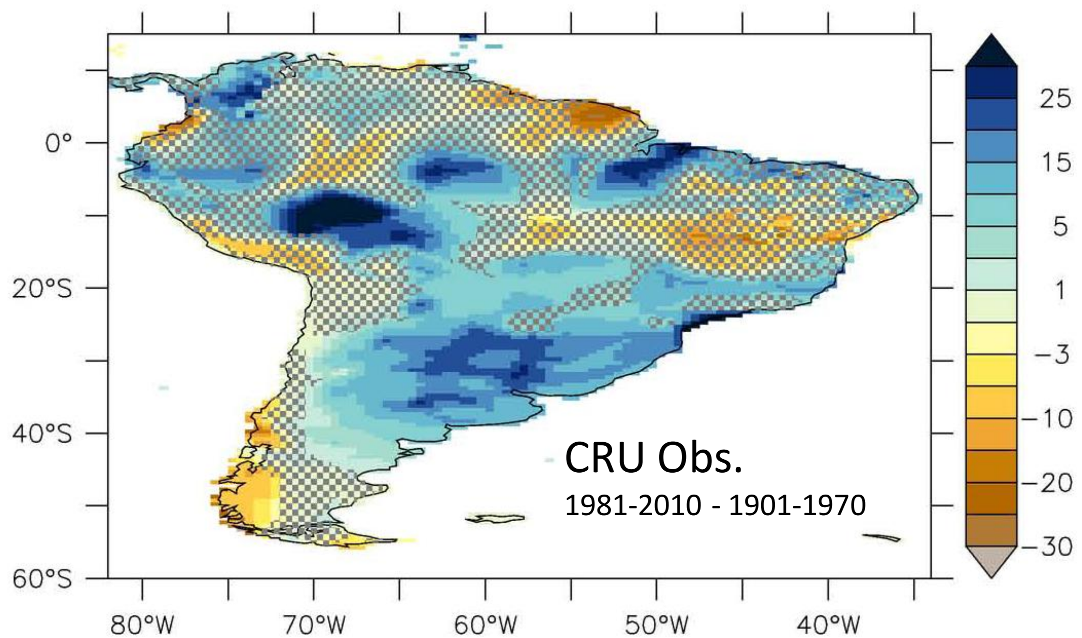
NDJFMA precipitation
(CRU; cm month^{-1})



Precipitation changes for NDJFMA (relative to 1901-1970; cm month^{-1})



The model is forced with observational and projected estimates of radiative forcing changes over 1861-2013

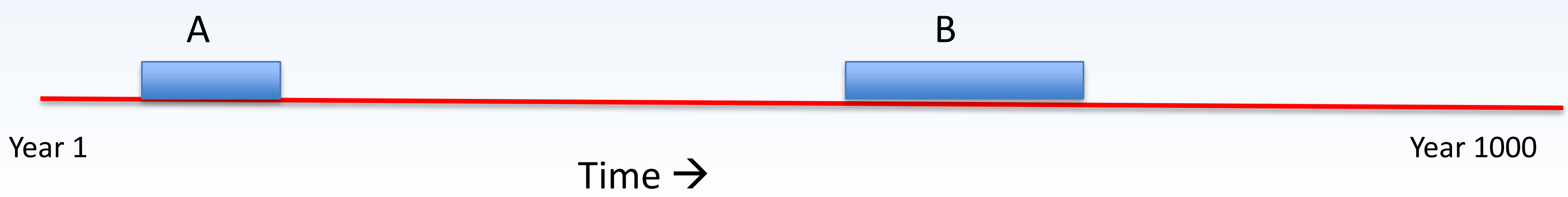


Question: Do we simulate these changes in response to radiative forcing changes?

Simulated ensemble mean precipitation differences are “significant” …
… but variability is still critical!

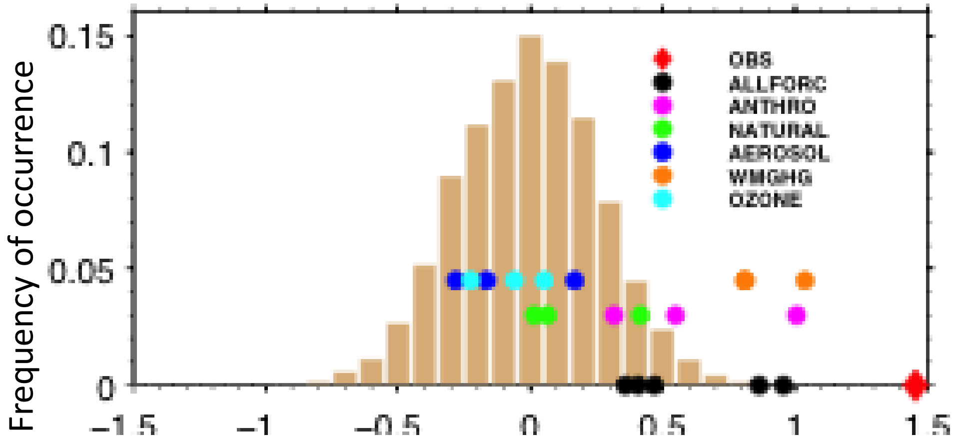
Use long control simulation to estimate natural variability of differences between 30 year periods and 70 year periods (as in 1981-2010 minus 1901-1970)

Select two periods randomly from control, one of 30 years and one of 70 years



“A” – “B” is one estimate of what a random difference between a 30 year and 70 year period

Repeat this 1000 times to form a distribution of such differences

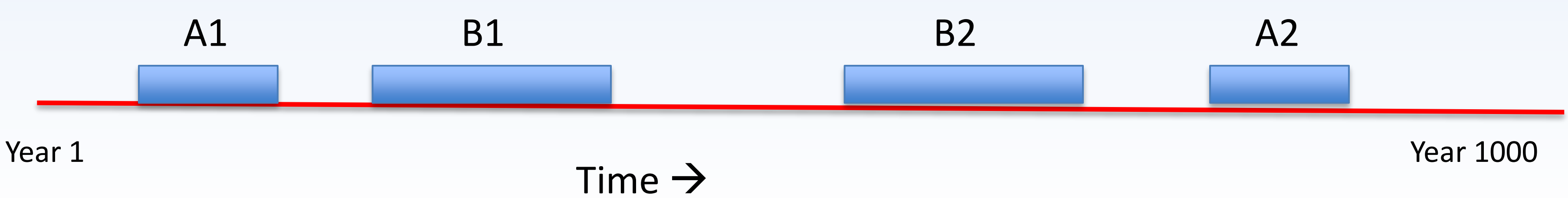


Difference in precipitation between 30 year average and 70 year average

An assessment of how unusual the simulated precipitation changes are, and the physical factors driving them

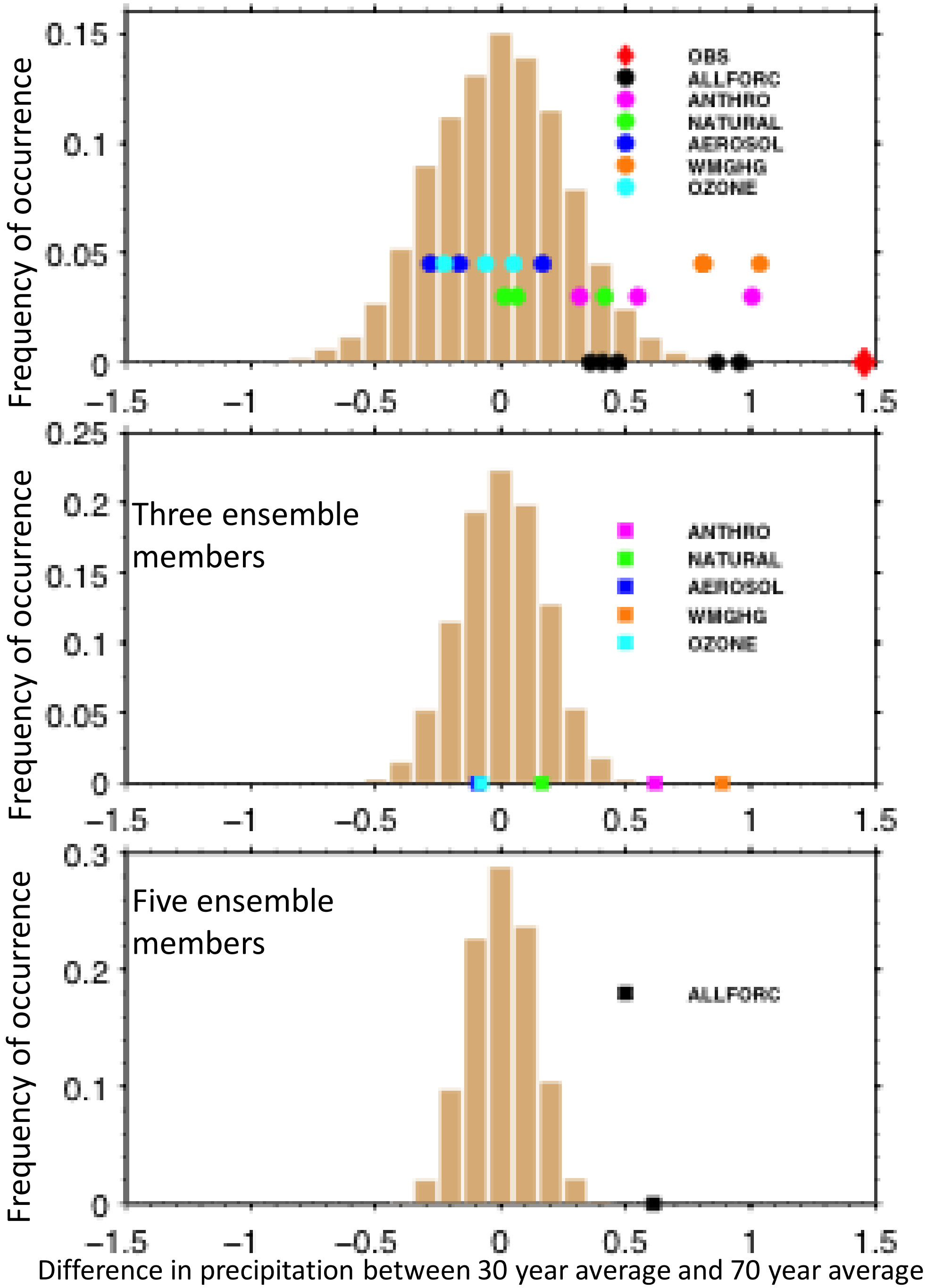
For the distribution of ensemble means, we use a similar process …

Select two periods randomly from control, one of 30 years and one of 70 years



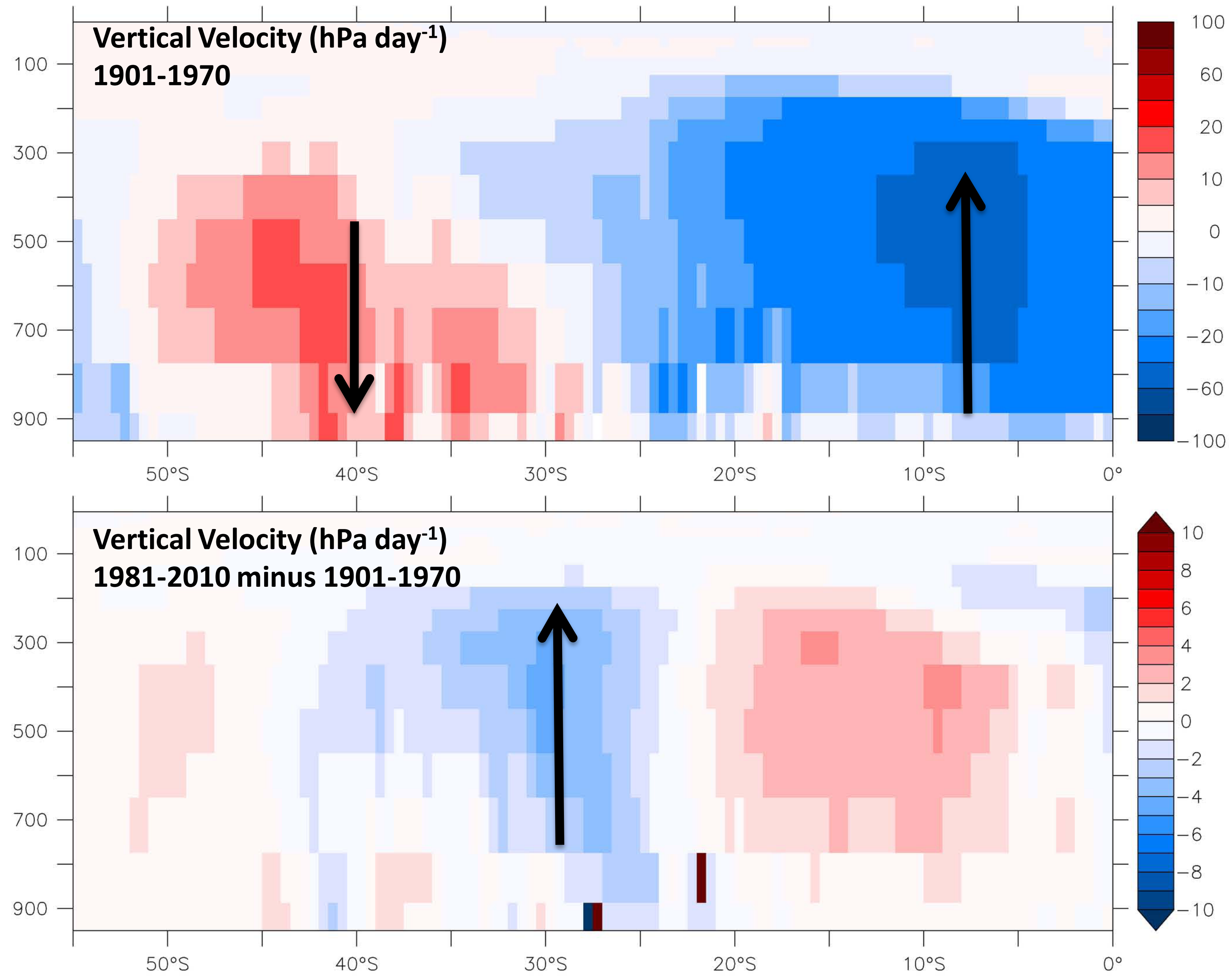
"(A1+A2)/2" – "(B1+B2)/2" is one estimate of what a random difference between two 30 year periods and two and 70 year periods would be

Repeat this 1000 times to form a distribution of such differences

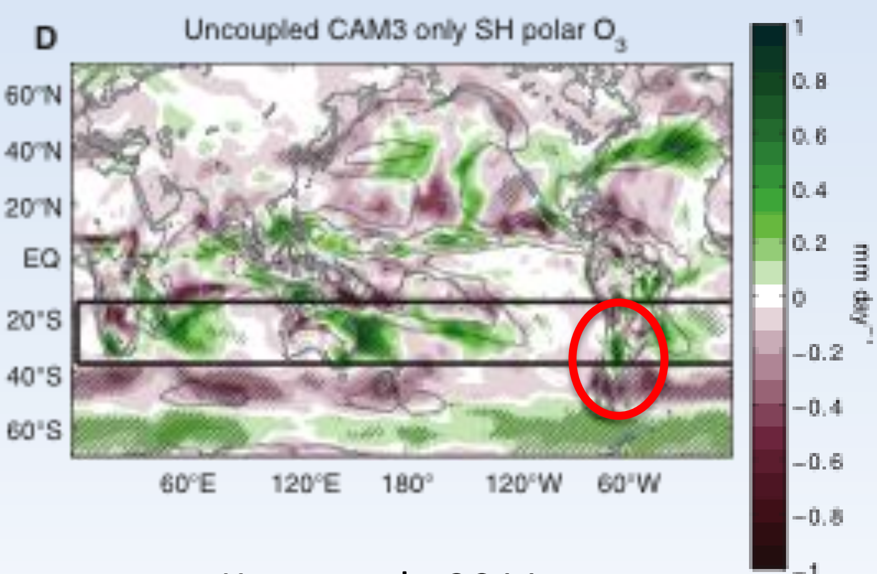


An assessment of how unusual the simulated precipitation changes are, and the physical factors driving them

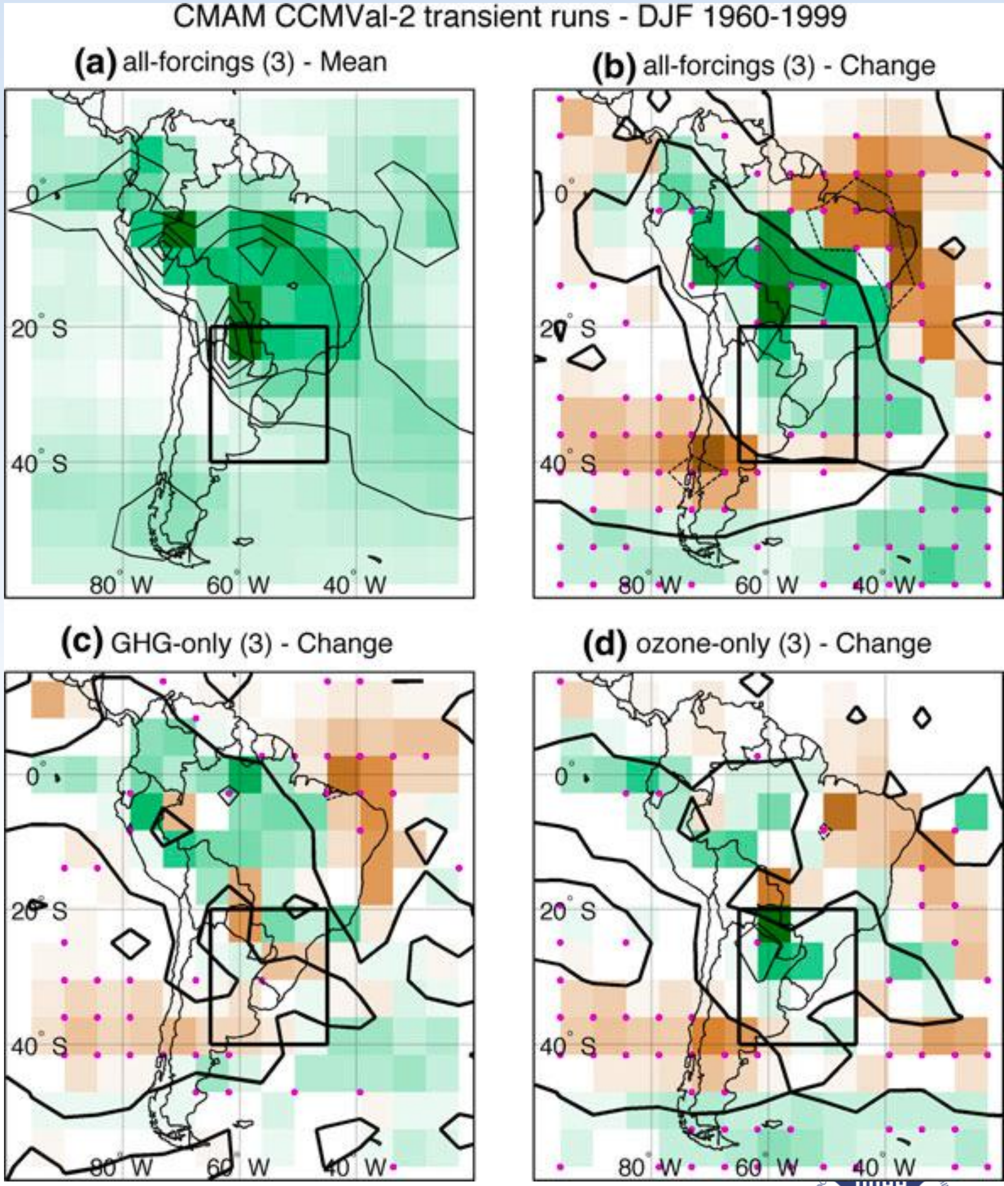
Using ensemble means provides a more significant response, but Nature is always a single realization!


Vertical Velocity (hPa day-1)
1901-1970
Vertical Velocity (hPa day-1)
1981-2010 minus 1901-1970
100
300
500
700
900
50°S
40°S
30°S
20°S
10°S
0°
100
60
20
10
0
−10
−20
−60
−100
10
8
6
4
2
0
−2
−4
−6
−8
−10

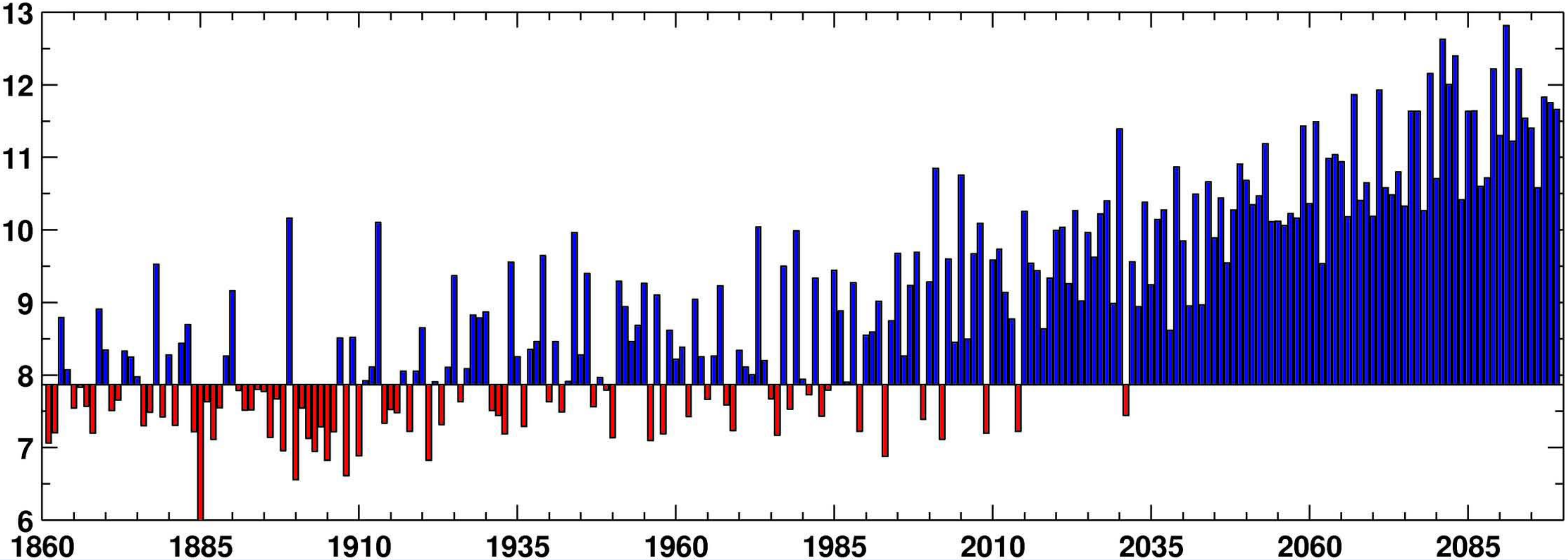
Issue to explore: Our model results do not show a string role for ozone changes, but previous work has shown a substantial role for ozone.

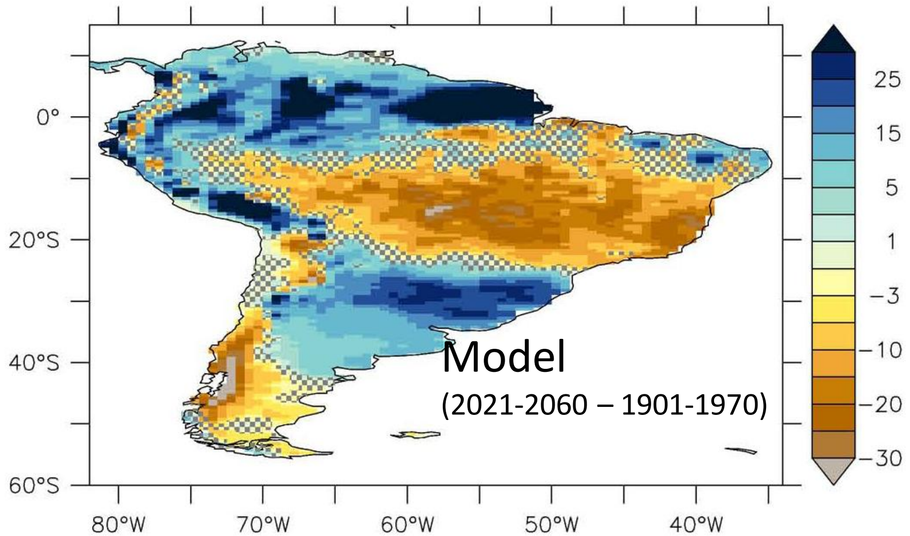


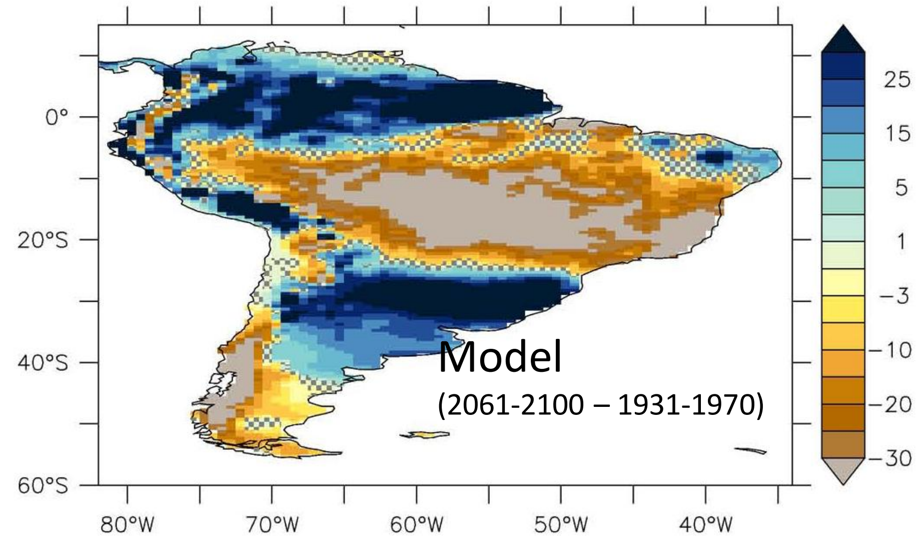
Kang et al., 2011



Gonzalez et al., 2013


13
12
11
10
9
8
7
6
1860
1885
1910
1935
1960
1985
2010
2035
2060
2085

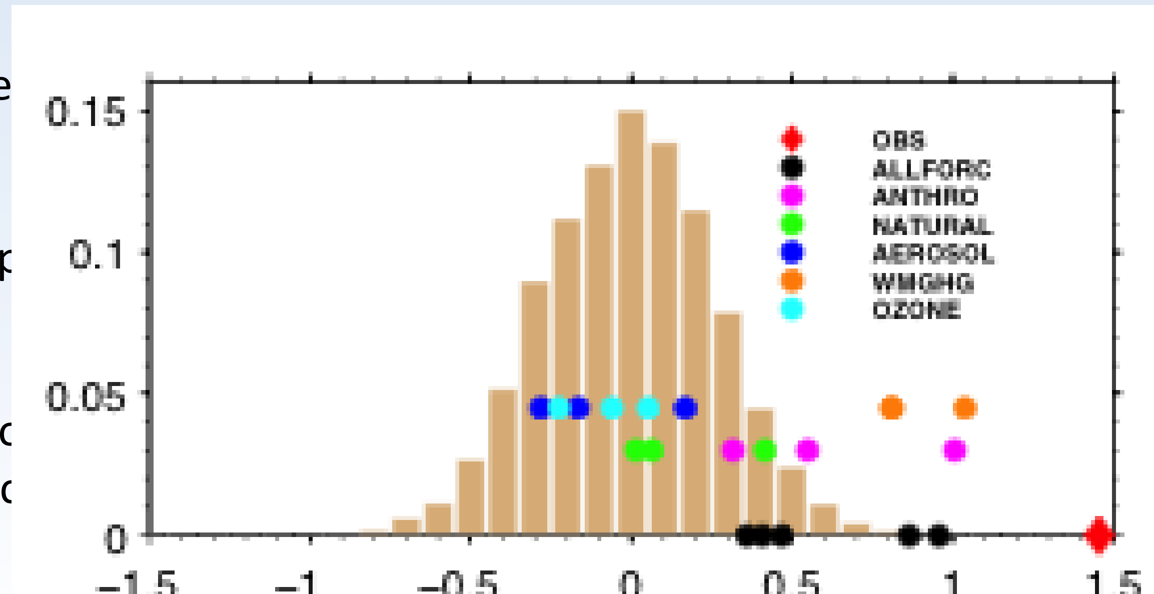

0°
20°S
40°S
60°S
80°W
70°W
60°W
50°W
40°W
25
15
5
1
−3
−10
−20
−30
Model
(2021-2060 – 1901-1970)


0°
20°S
40°S
60°S
80°W
70°W
60°W
50°W
40°W
25
15
5
1
−3
−10
−20
−30
Model
(2061-2100 – 1931-1970)

Summary

• New high-resolution global climate model has significantly improved simulation of South American precipitation (40% reduction in absolute error for austral summer)

• Observed multi-decadal precipitation changes reproduced in response to changing radiative forcing.



• Simulated changes have smalle
variability!

• Well-mixed greenhouse gases p
precipitation changes

• Other studies (ie, Kang et al, Go
why we do not see a strong effec

• Future projections show an amplification of the primary pattern, but substantial role for decadal/interdecadal variability (see Barreiro et al poster, CMPP43) – can this be predicted?

• Simulation of mean changes is important … but also critical is projection of future distribution of possible changes to characterize extremes. Requires large ensembles of simulations!