Is anthropogenic subtropical drying already occurring?

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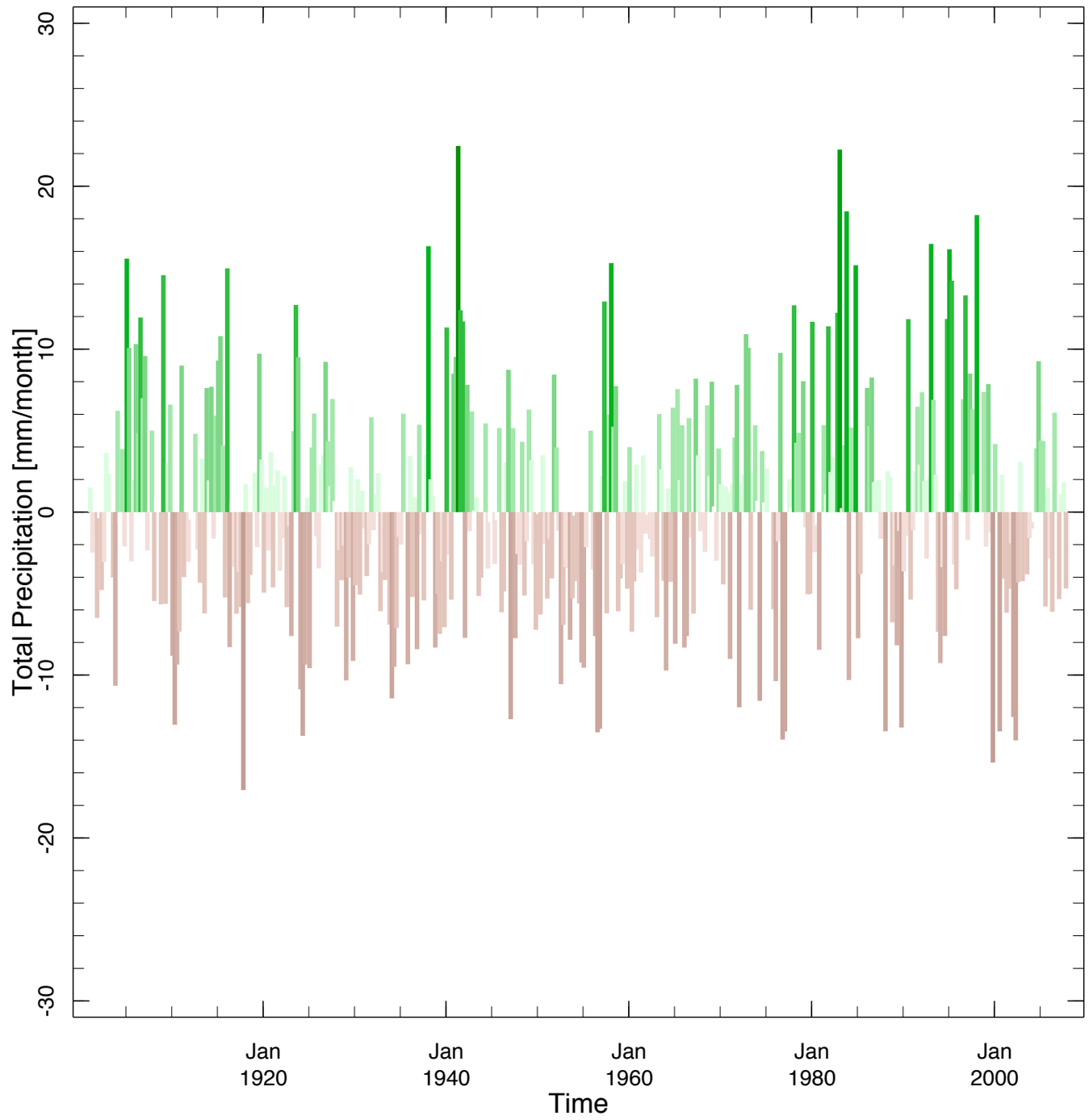
thanks to Yutian Wu, Colin Kelley, Jennifer Nakamura, Naomi Naik

Drying of SW N. America from the early 1980s to now but no clear evidence of a longer timescale shift.

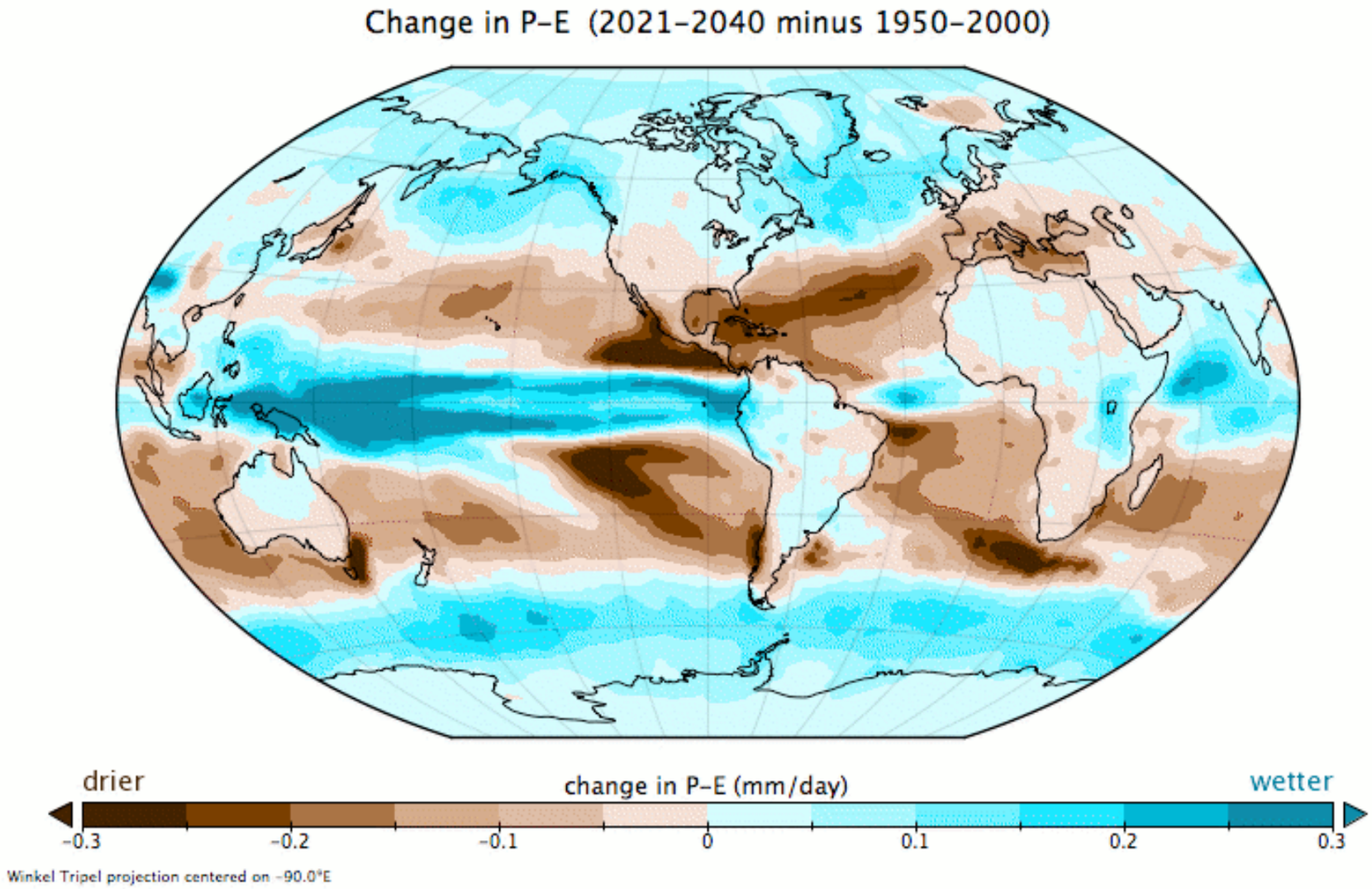
Is the recent drying just natural decadal variability?

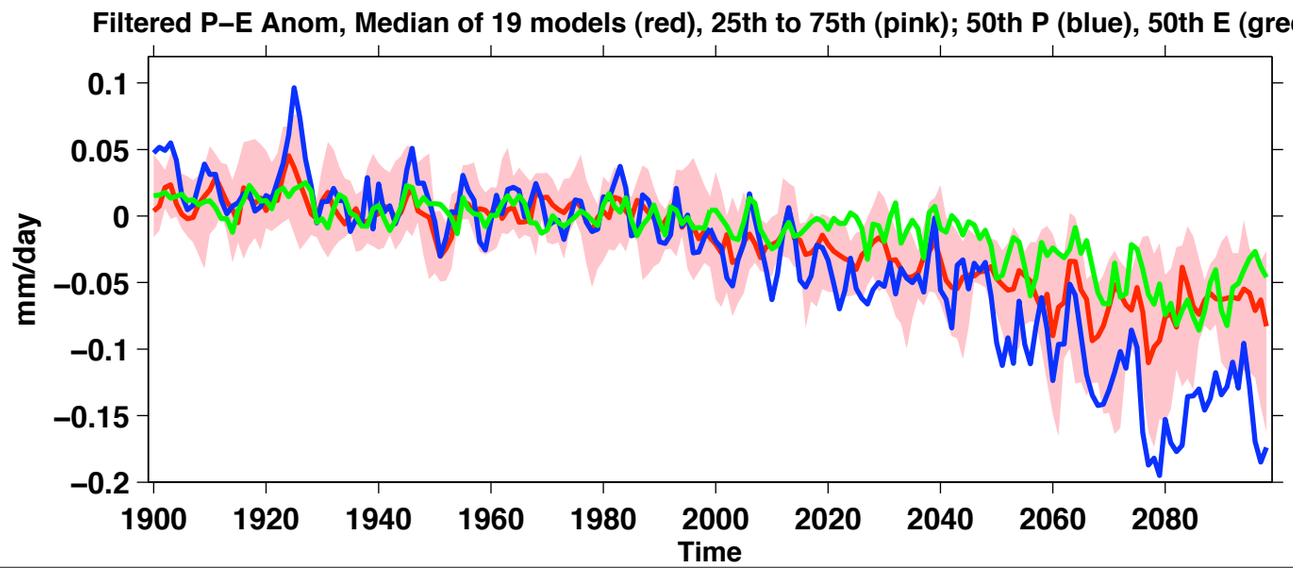
seasonal mean precipitation anomalies for
25-45N, 125-95W, from GPCC rain gauge data



The reason we worry is ‘cos of what IPCC AR4 models project - a robust, potent, imminent, drying of the global subtropics and latitudinal expansion of subtropical dry zones

That will impact southwest North America





"Climate model studies over North America and the global subtropics indicate that subtropical drying will likely intensify and persist in the future due to greenhouse warming. This drying is predicted to move northward into the southwestern United States. If the model results are correct then the southwestern United States may be beginning an abrupt period of increased drought."

Climate Change Science Program, Synthesis and Assessment Report 3.4, Abrupt Climate Change, USGS, 2008.

But the CCSP, SAR 3.2 report also says that:

"There is no clear evidence to date of human-induced global climate change on North American precipitation amounts."

a statement that is fully aware of the huge natural range of precipitation in the SW

First of all, why does subtropical drying in a warming world occur?

To understand model projections of drying we need to understand regional atmospheric moisture budget:

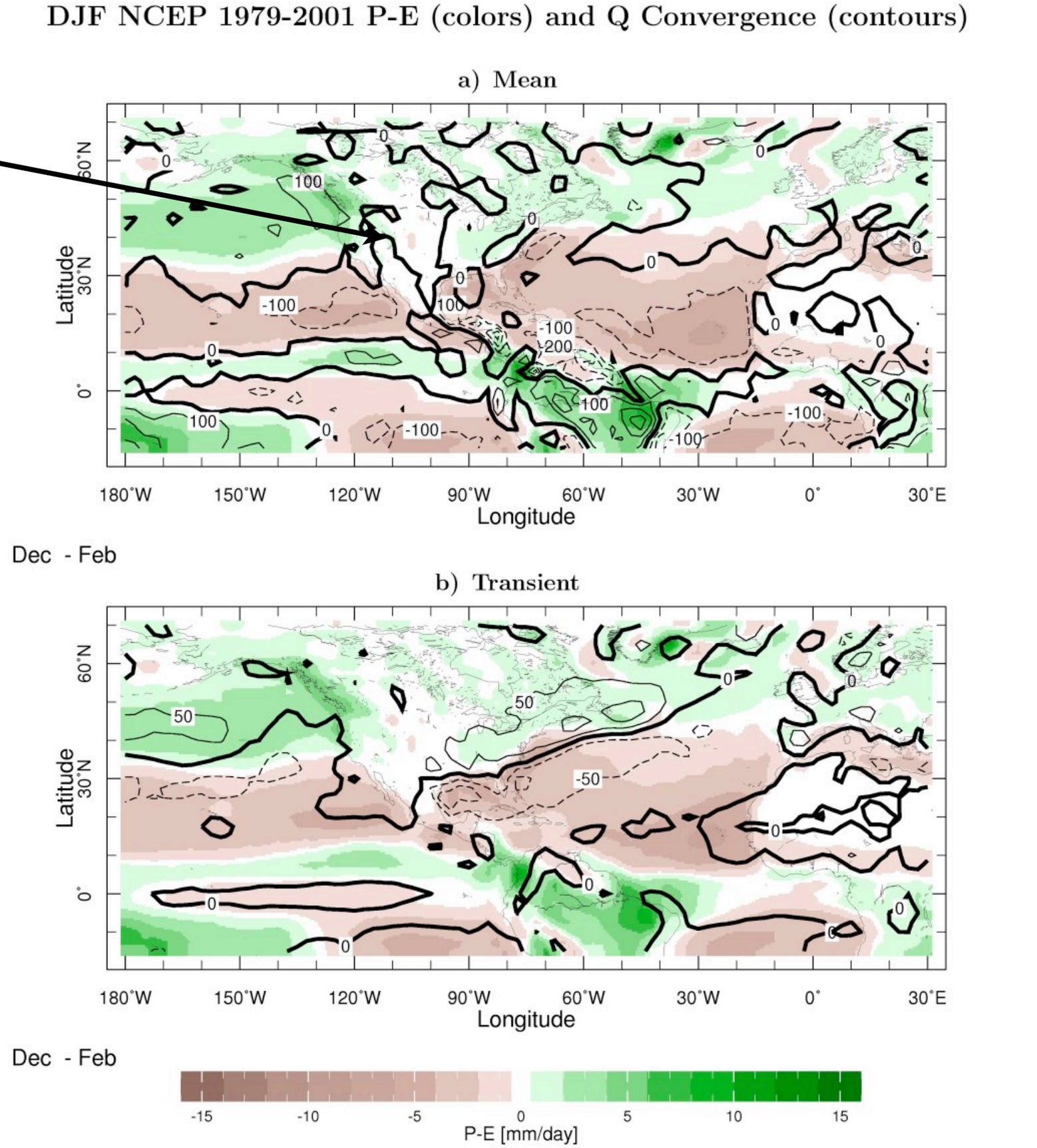
$$\rho_w g(P-E) = -\int_0^{p_s} \nabla \cdot (\underline{\bar{u}}\bar{q})dp - \int_0^{p_s} \nabla \cdot (\underline{\overline{u'q'}})dp.$$

Precip - Evap = moisture convergence by the mean flow + moisture convergence by the transient flow

Southwest N. America (SWNA)

In winter P-E is positive over SWNA

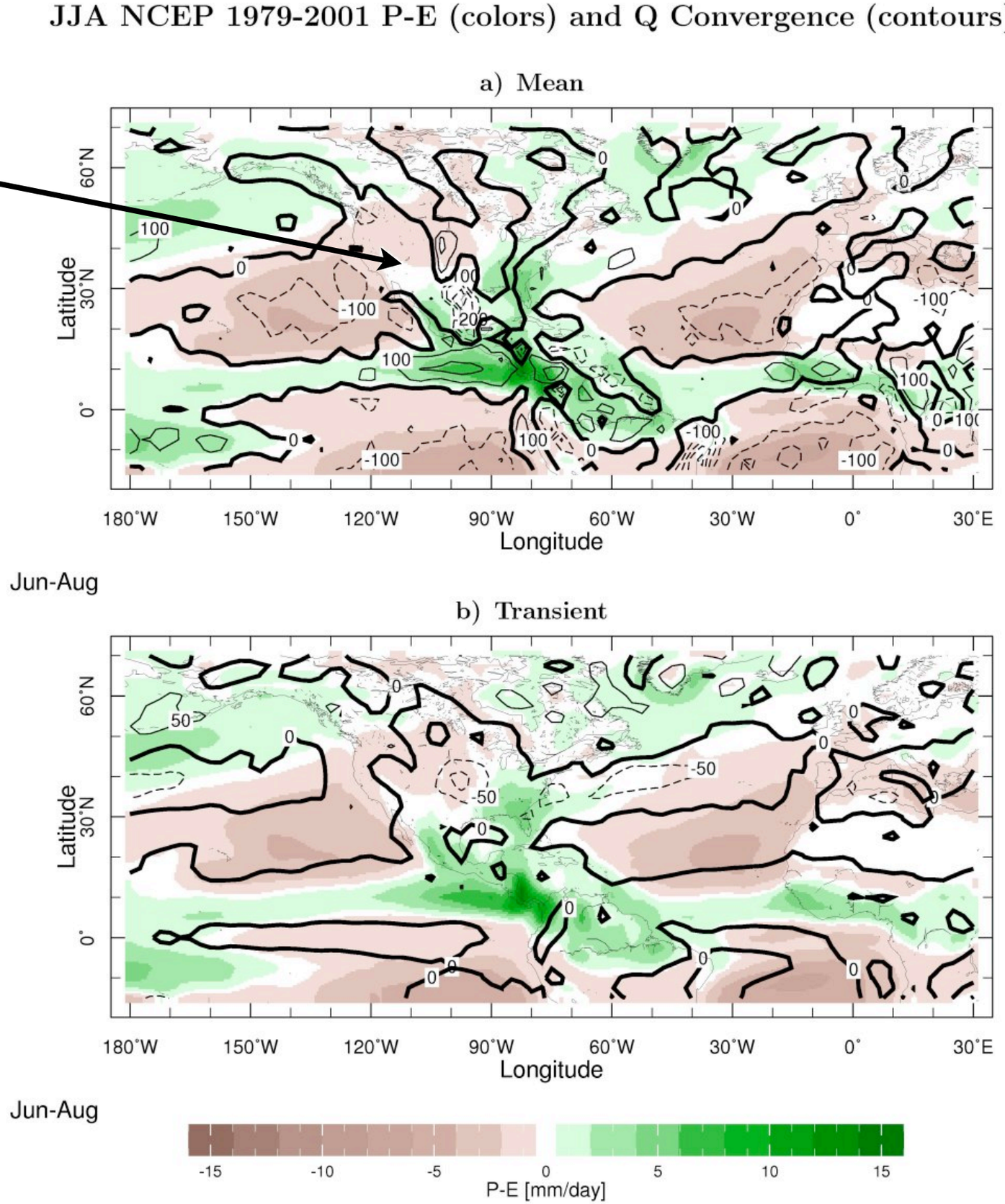
moisture convergence is supplied by transient weather systems



Southwest N. America

In summer P-E is negative over SWNA

moisture divergence is by the mean flow



Change in P-E, δ (P-E), caused by 1) change in flow and 2) by warming-driven increase in specific humidity

$$\rho_w g\delta(P-E) \sim -\int_0^{p_s} \nabla\cdot(\bar{q}_p\delta\,\underline{\bar{u}} + \underline{\bar{u}}_p\delta\bar{q})dp$$
$$-\delta\int_0^{p_s} \nabla\cdot(\underline{\overline{u'q'}})dp \qquad (2)$$

Where mean flow diverges moisture, it will diverge more in a warmer moister, climate

Added to this thermodynamic drying is a poleward expansion of the Hadley Cell and poleward shift of the mid-latitude storm track

u'v' and v'v' from GFDL model, 2080-2099 minus 1961-2000

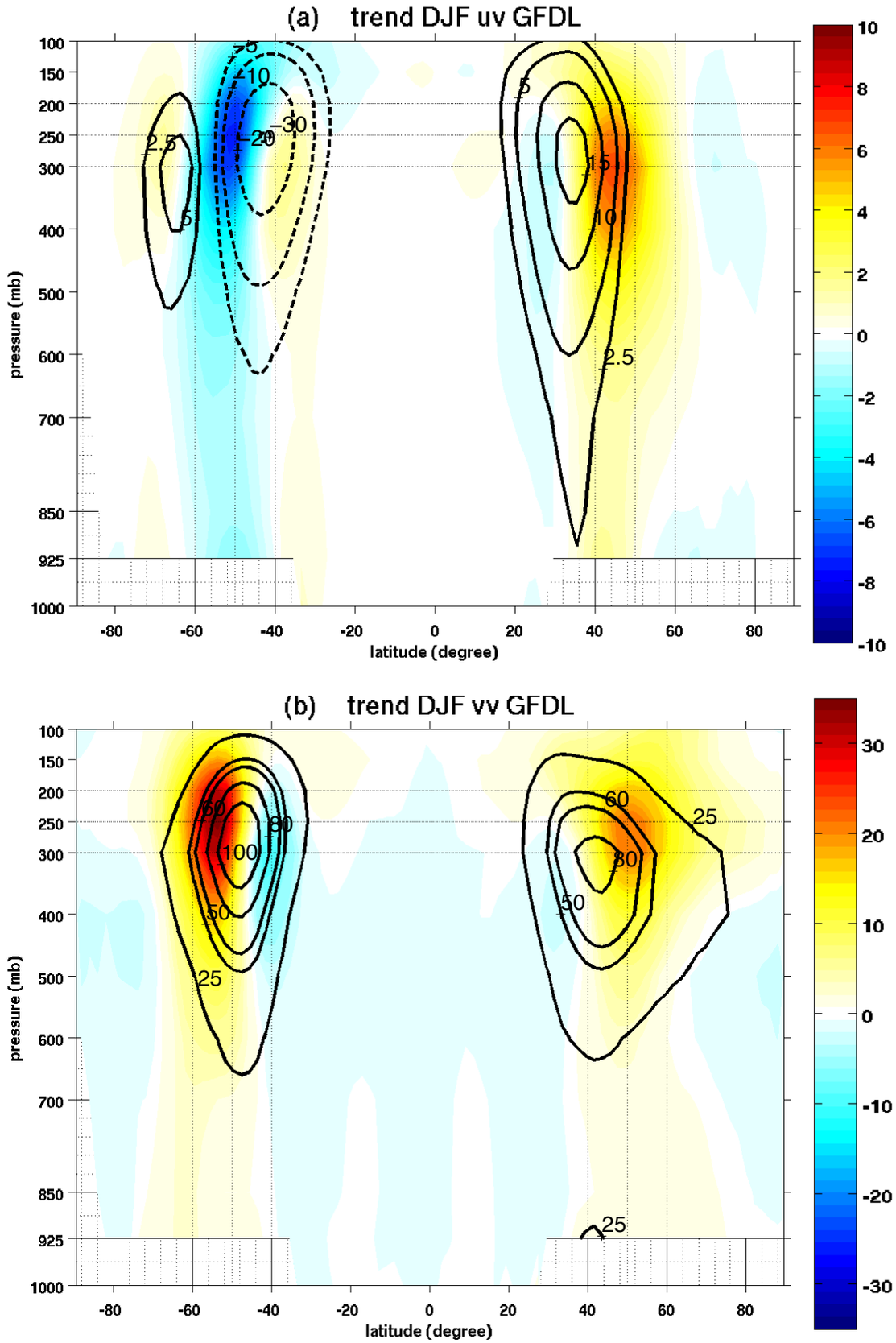
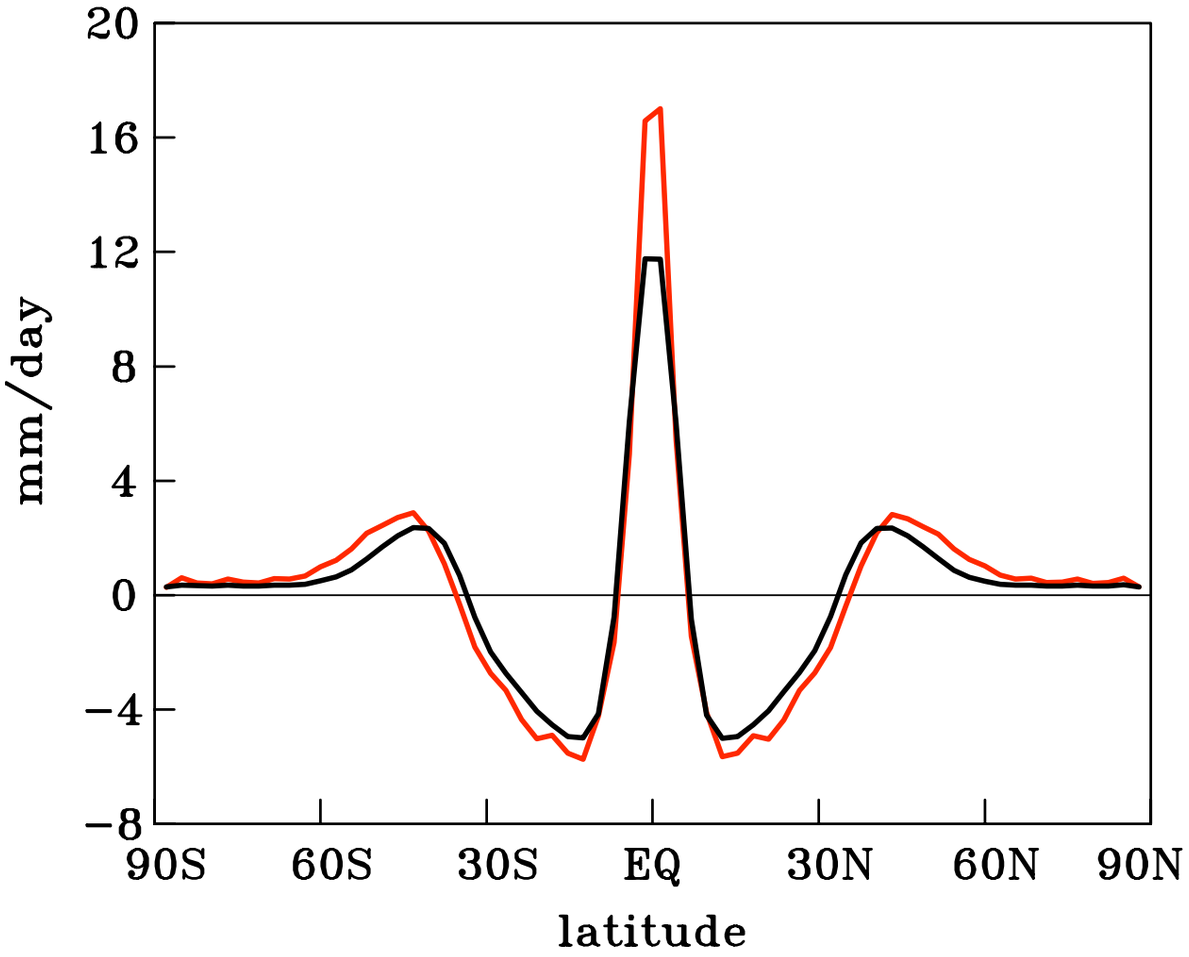


figure by Yutian Wu

In fact the dynamics of projected subtropical drying and expansion is so simple that it can be reproduced in models with an all ocean surface.

P-E in two aquaplanet models, red line has a 2 deg C warmer surface

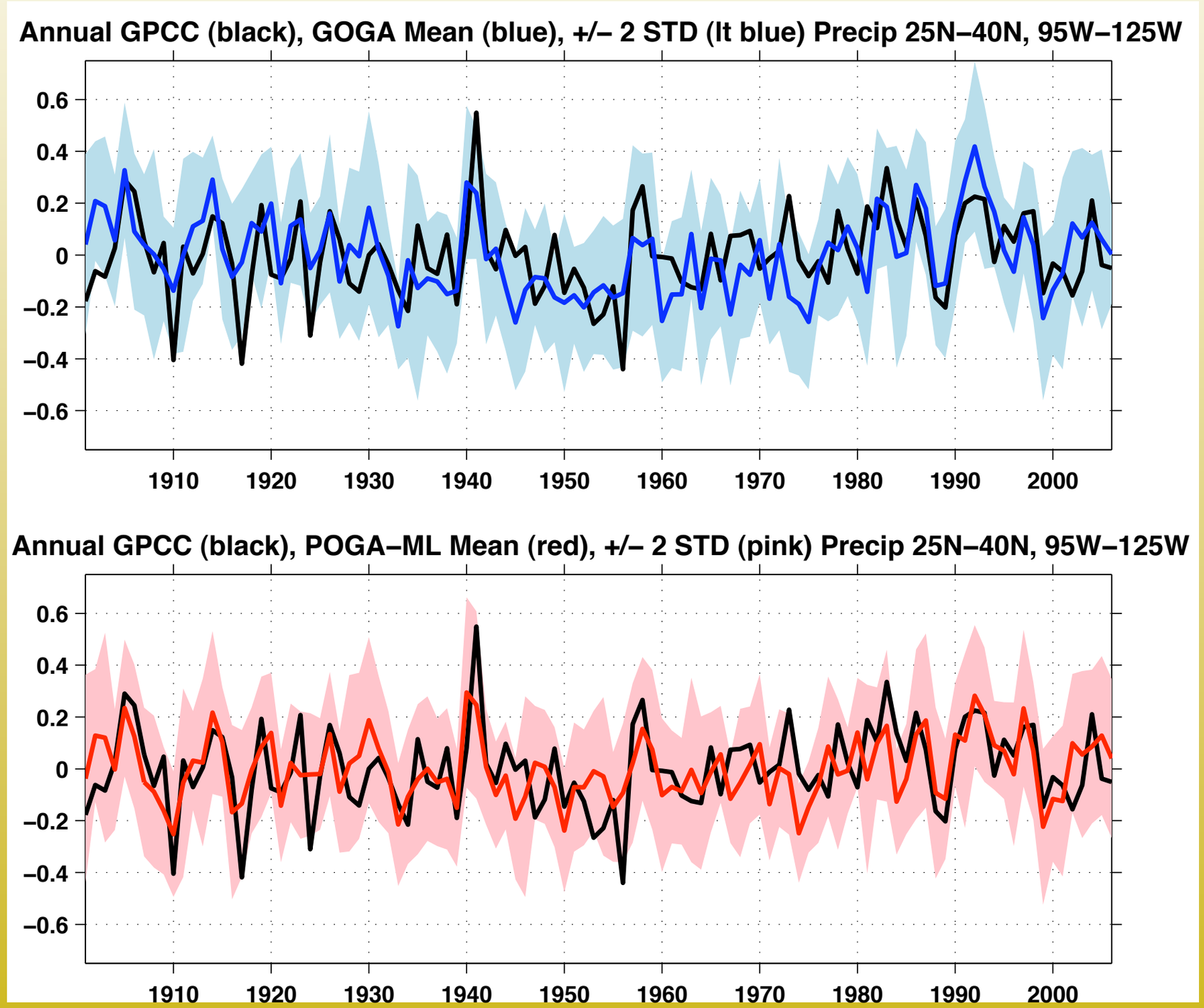


subtropical drying and expansion is a consequence of overall warming

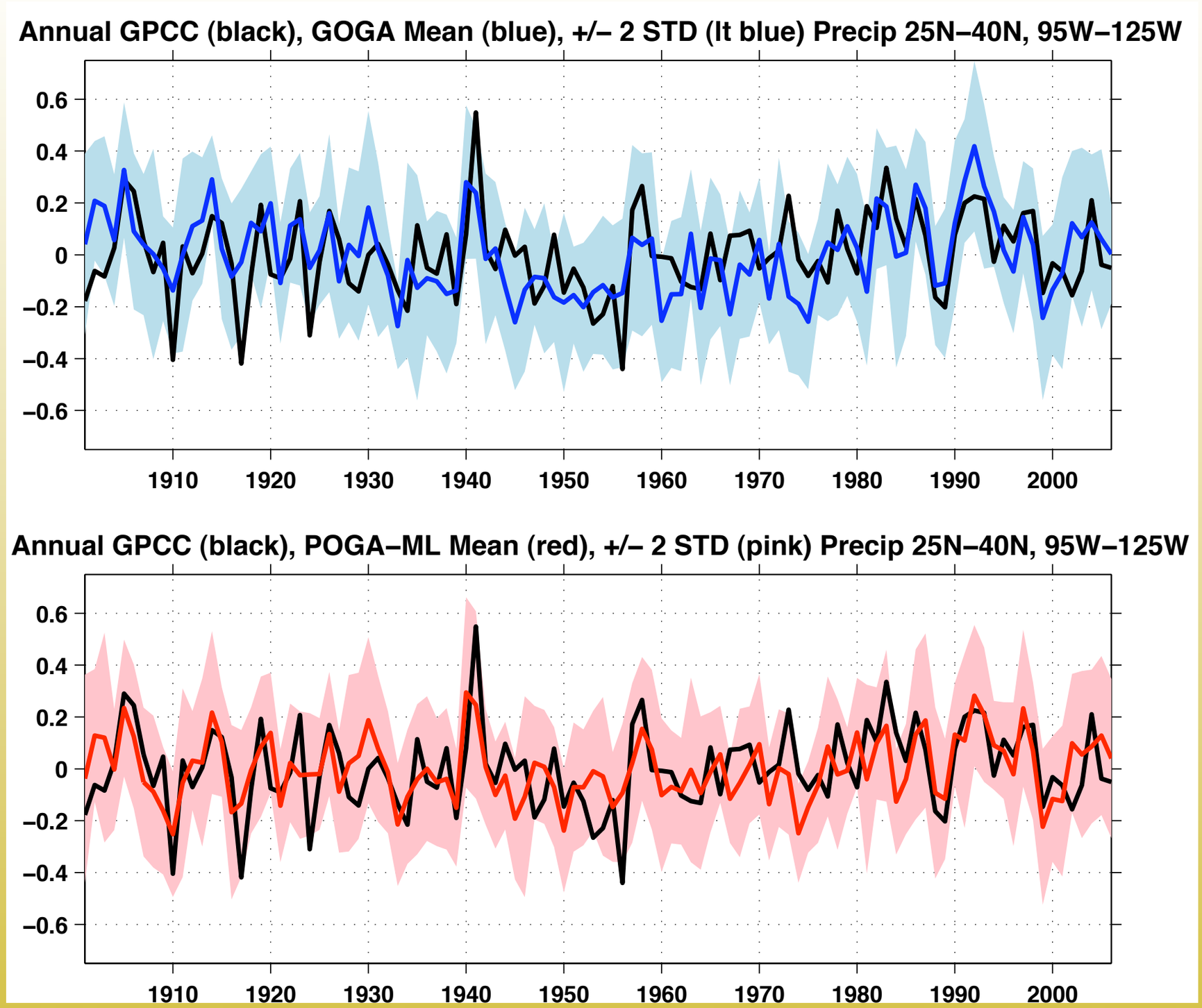
But we also know that Southwest precipitation is highly controlled by variations of tropical Pacific and Atlantic SSTs

And for the Southwest, the observed precipitation history is well captured by models forced by global SST ..

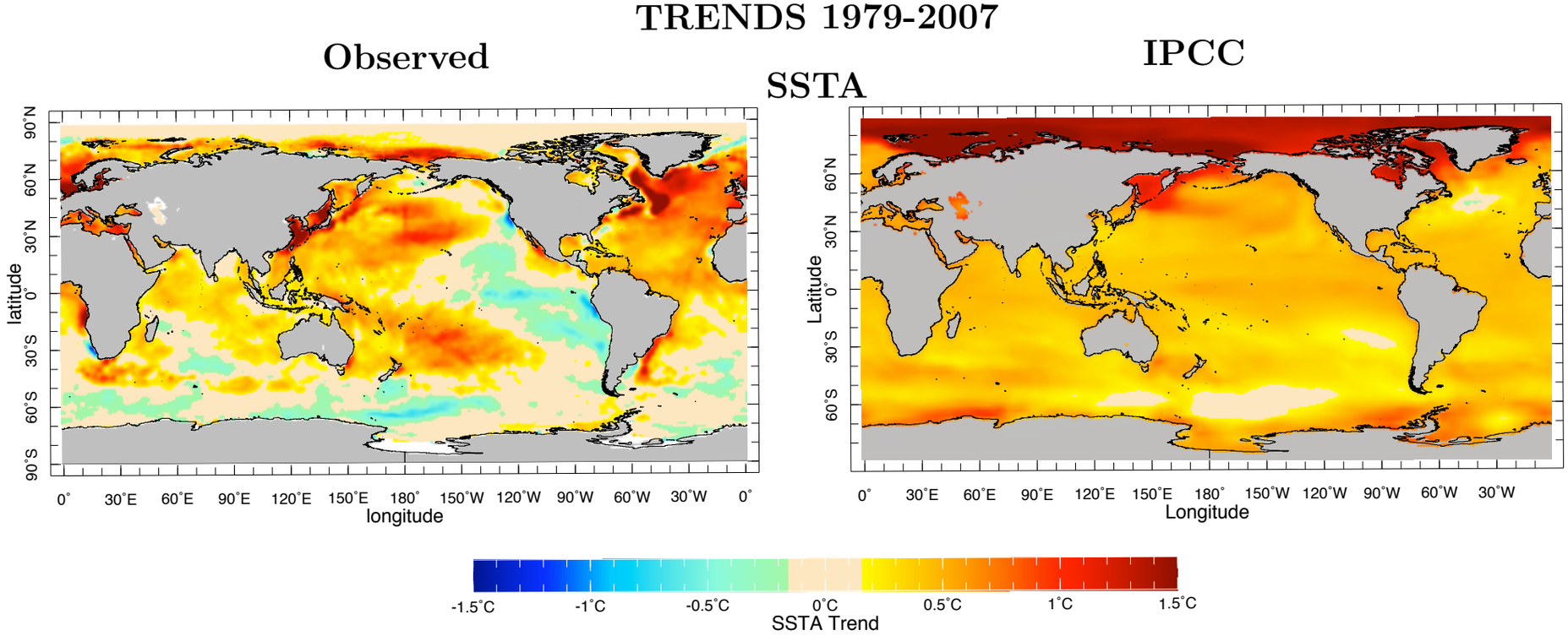
or by tropical Pacific SSTs alone

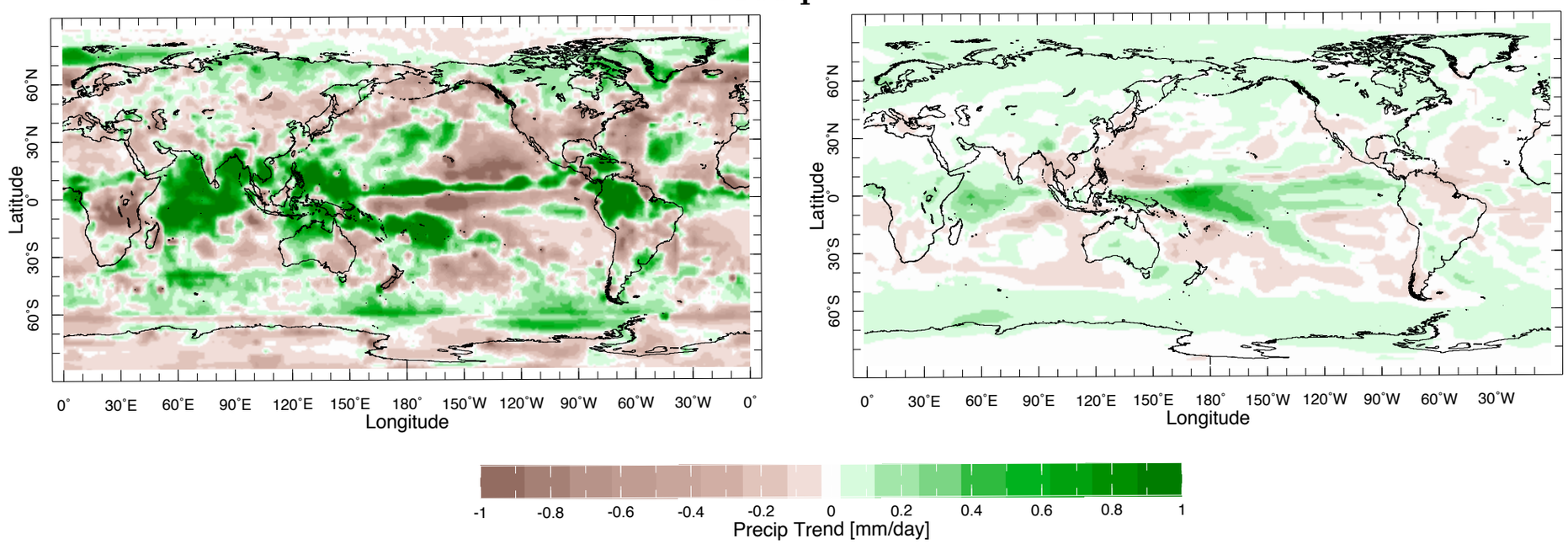


GCM soil moisture matches VIC model soil moisture less well but, again, no sign of anything going on not controlled by SSTs



Satellite `measurements` of precipitation begin in 1979 allowing examination of global hydroclimate variability and change

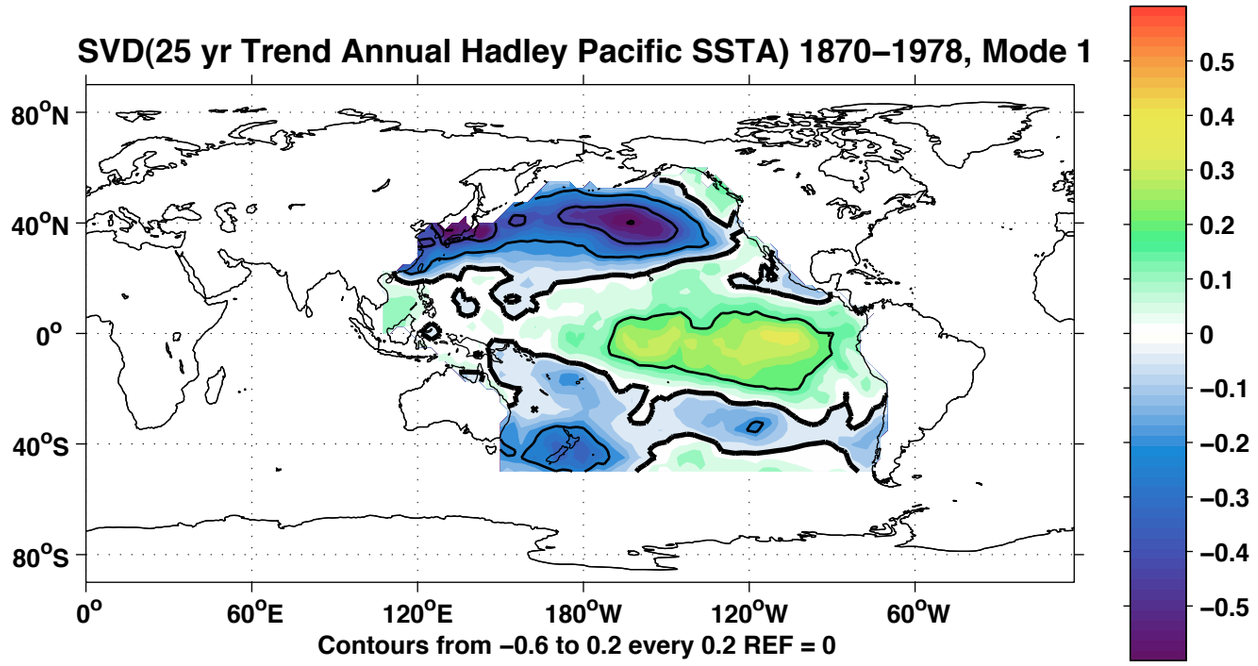


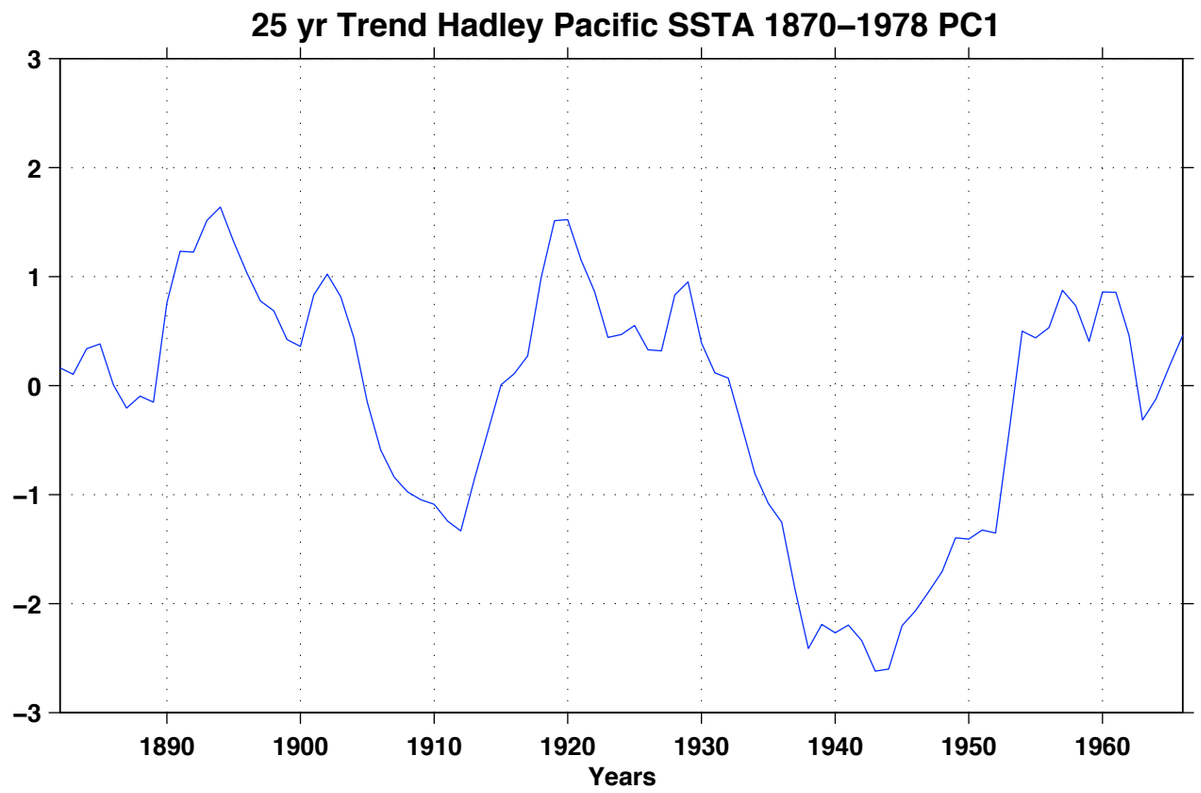


So is anthropogenic subtropical drying and expansion already occurring?

Or are we primarily seeing natural decadal variability?

The first EOF of the ***25 year trend*** in observed sea surface temperature (SST) 1870-1978. Note cooling trend centered on the 1940s

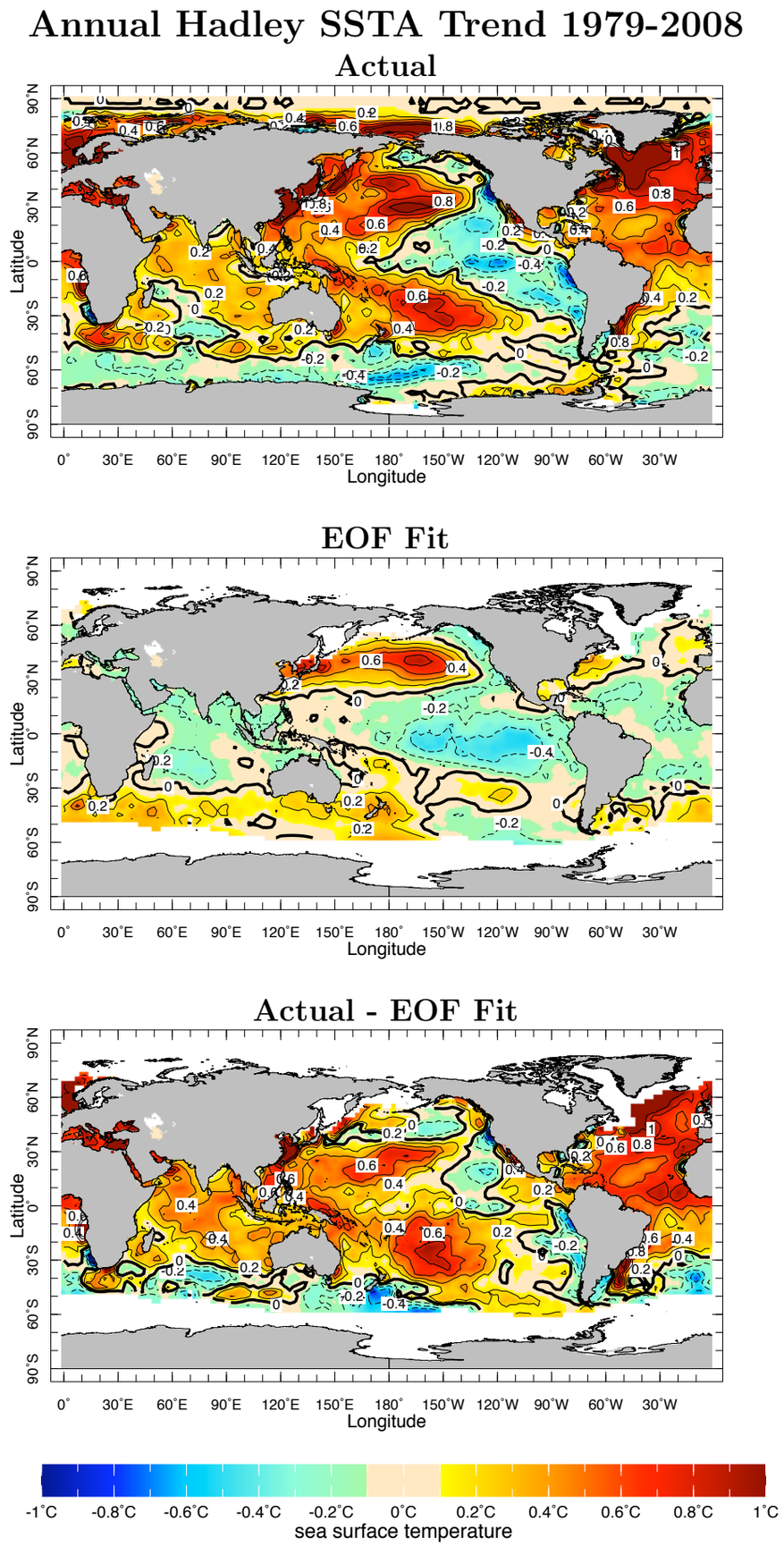




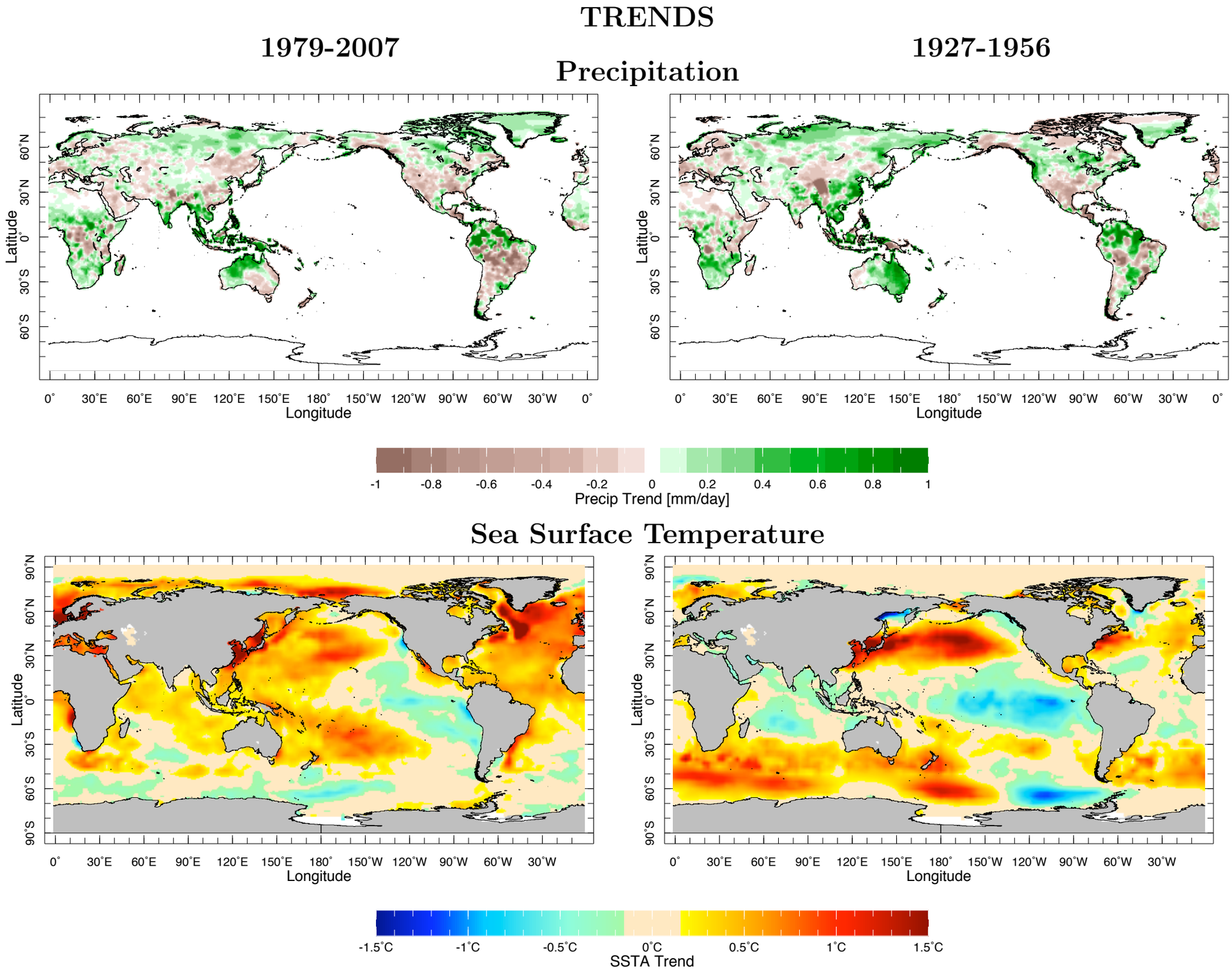
How much of the post 1979 trend is natural decadal variability?

Subtract from observed SST trend that part spatially congruent with the pattern of pre-1979 natural SST trends

After removal of *potential* natural trend the residual is more uniform and more IPCC-like



Indeed, a three decade drying trend akin to the post 1979 one has occurred before

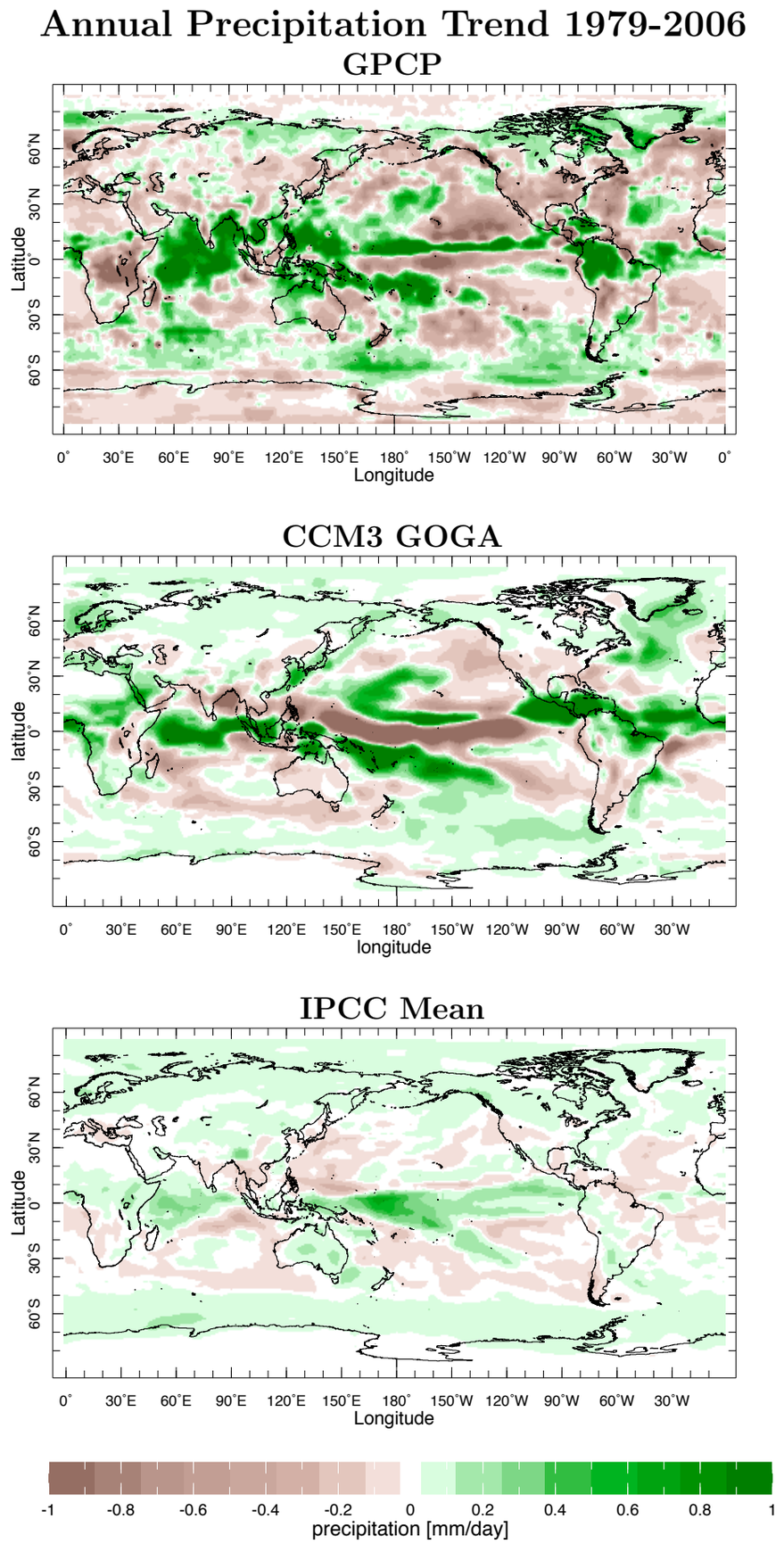


And, as expected, SST-forced models can largely reproduce the post-1979 trend

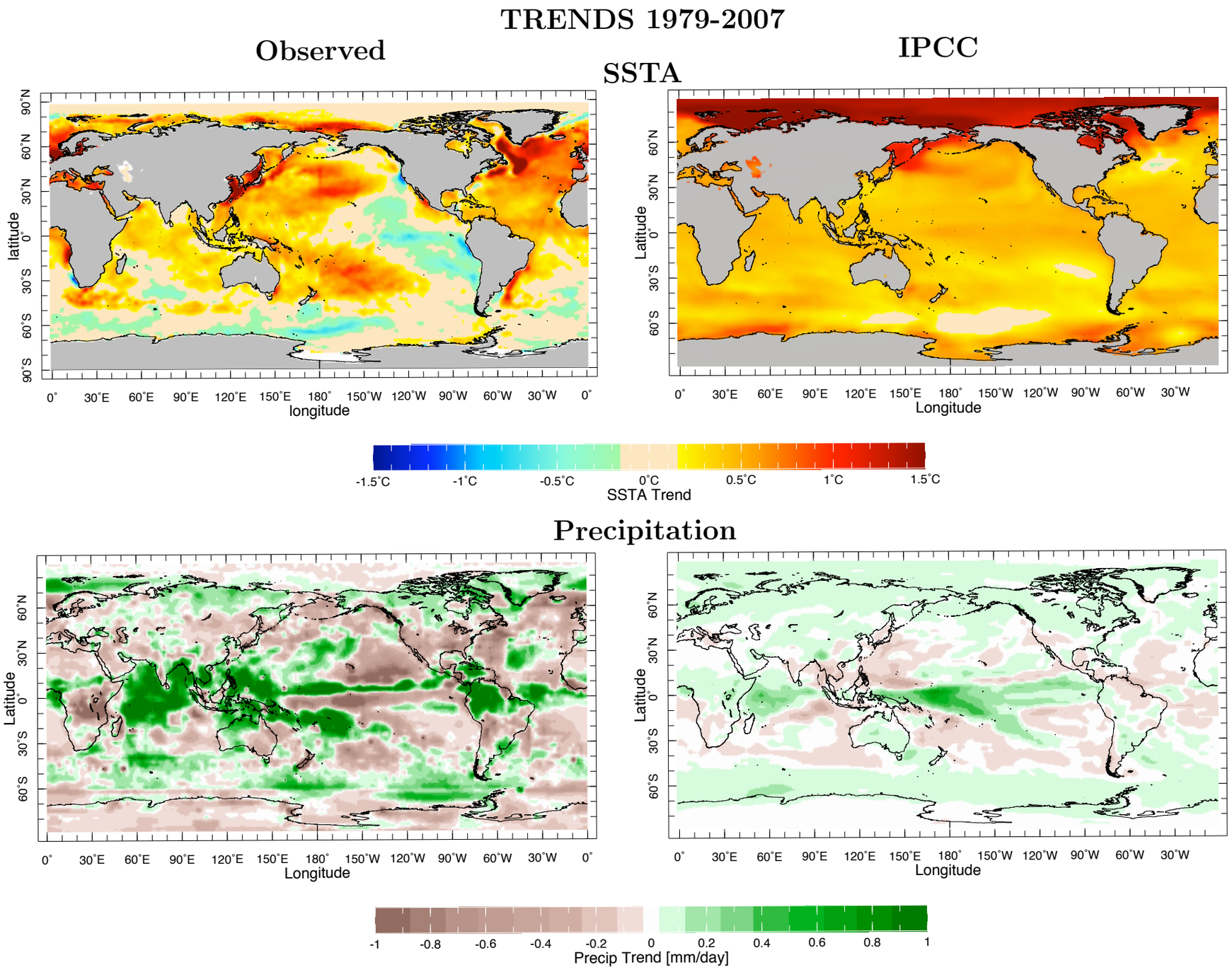
observed

model forced by global SST

multimodel IPCC response to radiative forcing



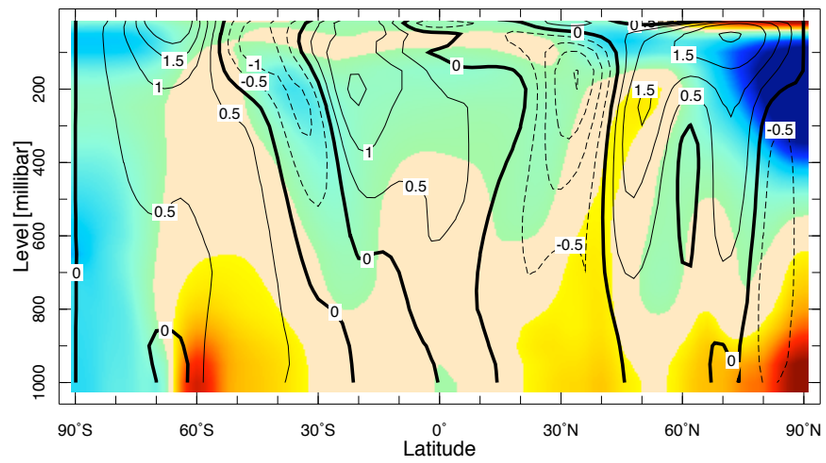
post 1979 drying of the Southwest more strongly influenced by natural decadal variability than by anthropogenic change



Importance of decadal variability in recent trends confirmed by analysis of zonal wind and temperature

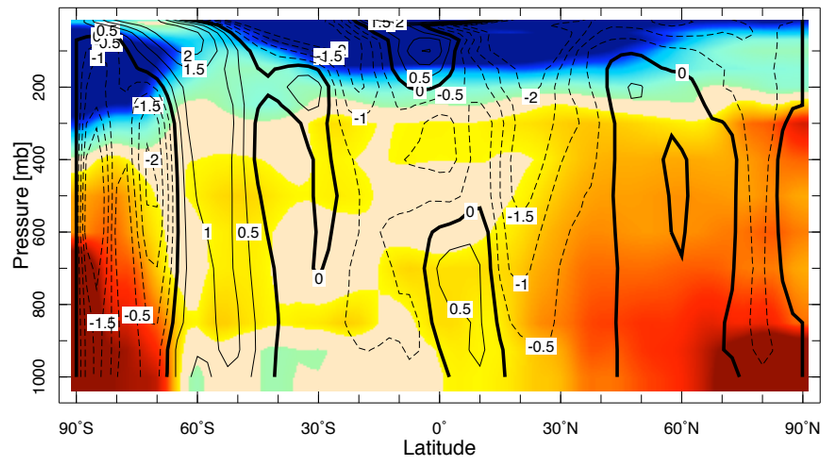
Zonal Mean Temperature (color) and Zonal Wind (contour) Trends

Compo 1927-1957



1927-1957
Compo reanalysis

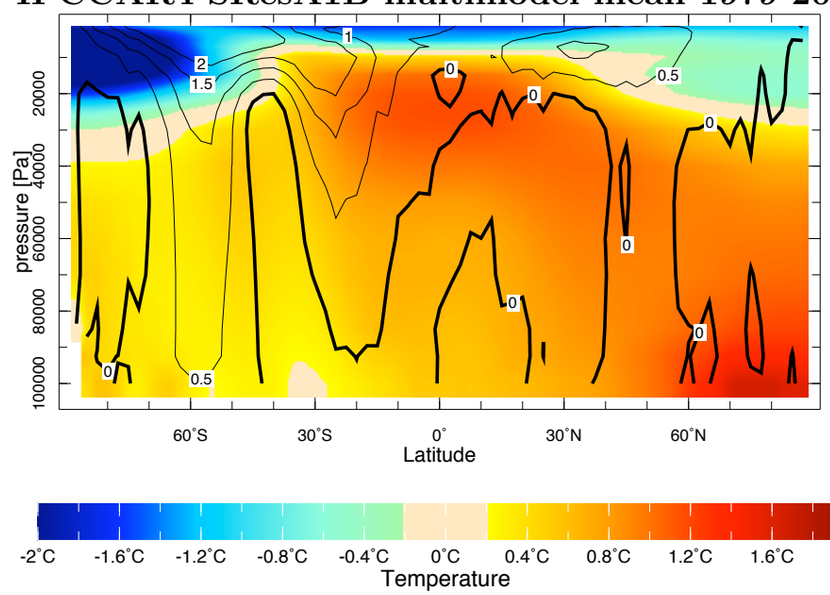
NCEP 1979-2008



1979-2008
NCEP reanalysis

Observed 1979-2008 circulation trend probably combines decadal variability and forced change

IPCCAR4 SResA1B multimodel mean 1979-2008

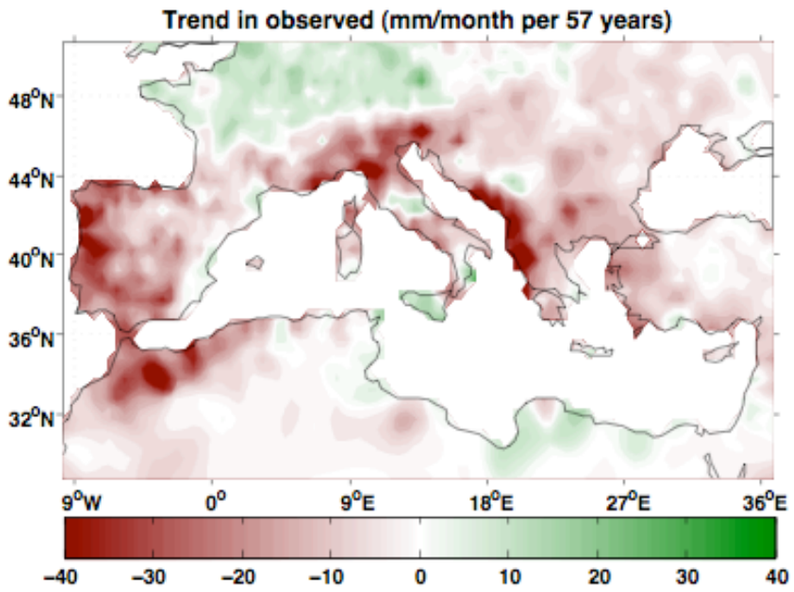


1979-2008
IPCC multimodel mean

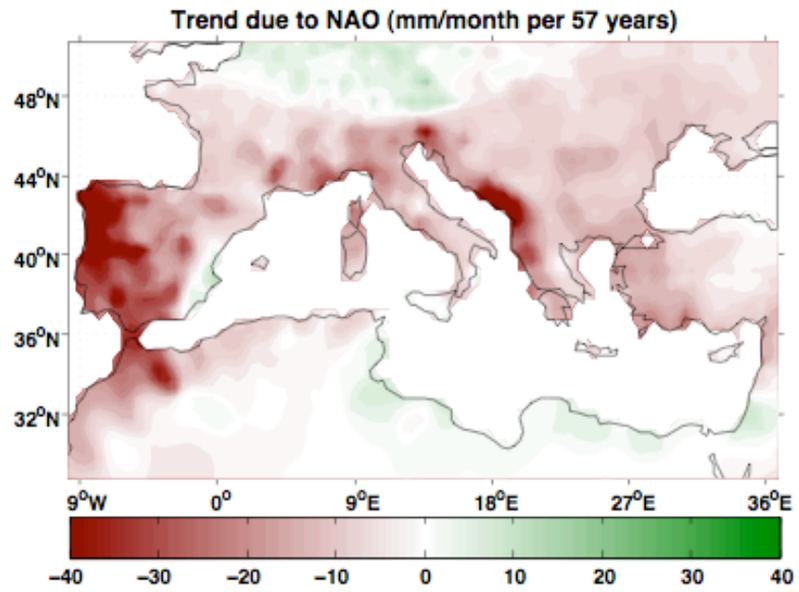
And as a brief aside, Mediterranean region drying dominated by the NAO trend

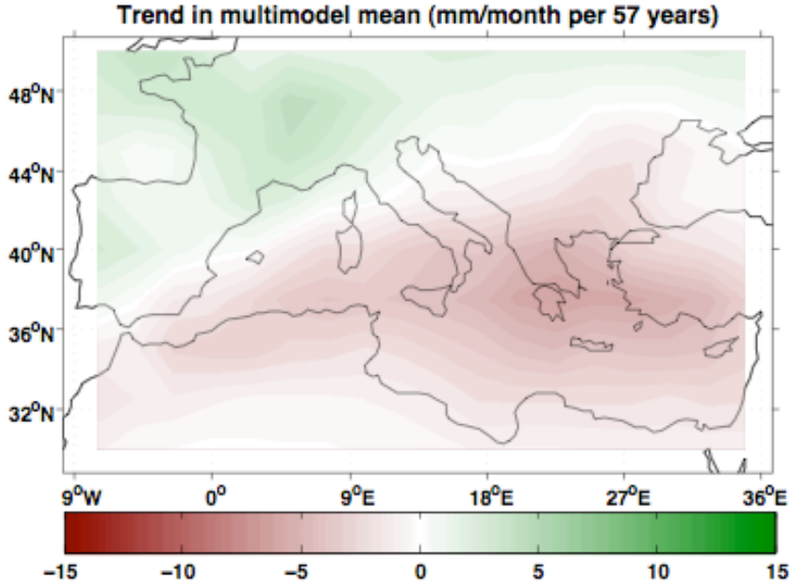
figure from Colin Kelley

observed P trend 1950-2007

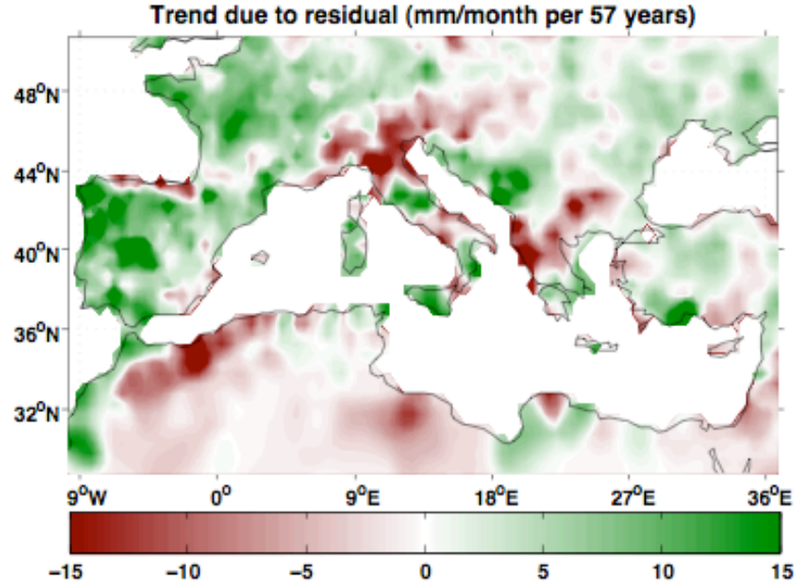


part due to NAO trend





IPCC multimodel mean trend

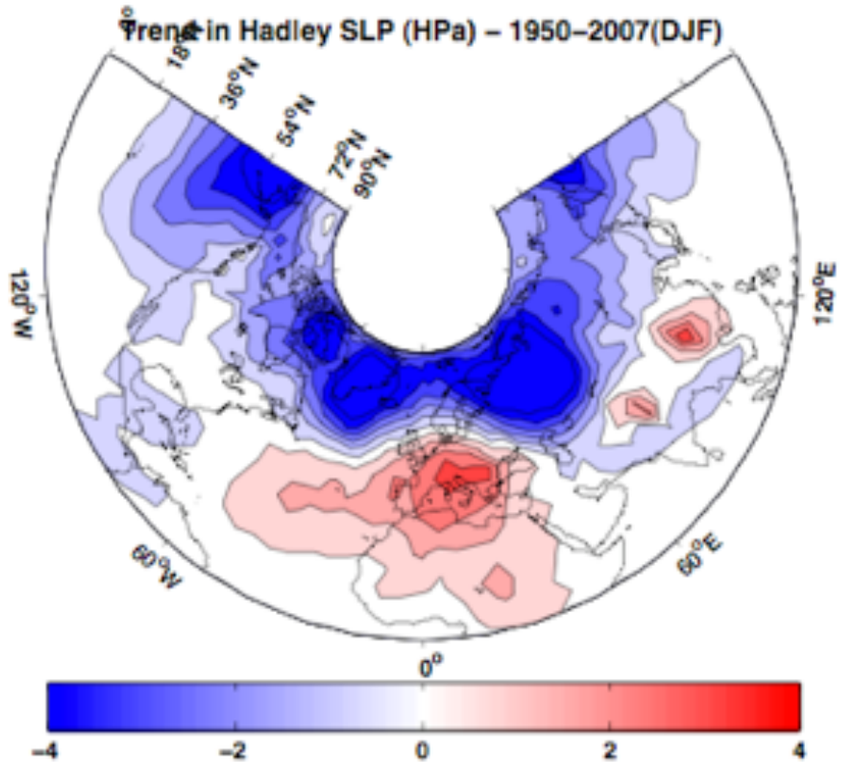


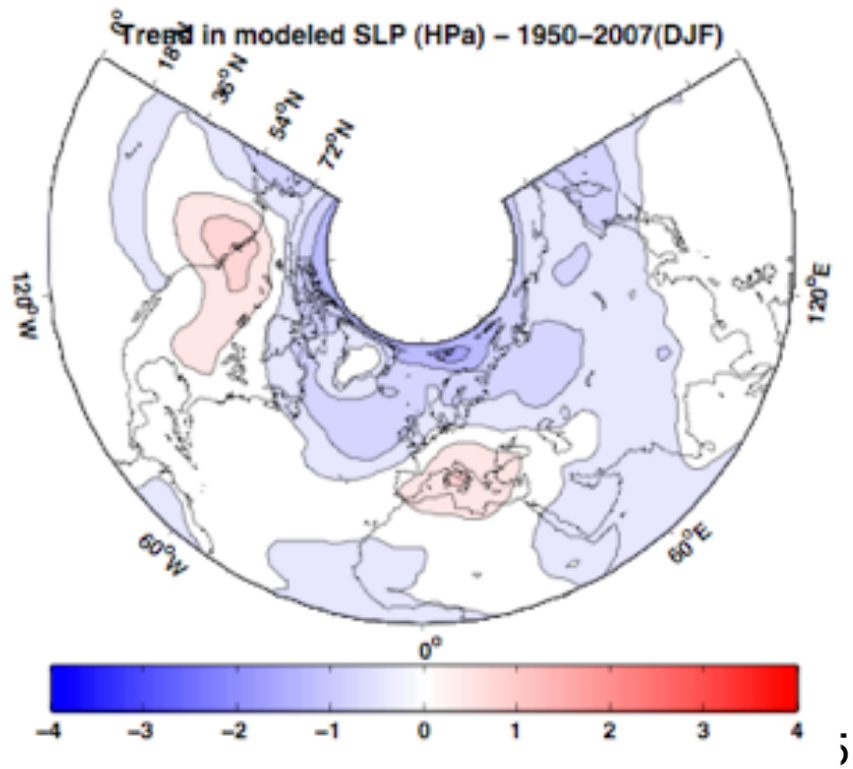
part unexplained by NAO, ENSO

And the observed trend in the NAO ...

... is much stronger than the IPCC 24 model mean trend ...

... suggesting observed S. Europe drying is mostly natural variability ...





Conclusions

1. The amplitude of natural decadal variability of Southwest precipitation currently exceeds the anthropogenic signal.

2. Decadal variability gave us the wet 1977-1998 period and seems to have begun an extended drier period.

3. This is why the drying trend of the last few decades exceeds the IPCC projections.

4. However, hard to imagine how anthropogenic subtropical drying and expansion could not occur.

5. If we are right about all of this, it's not going to get wetter on the interannual to decadal timescale any time soon, if ever.