Does global warming cause intensified interannual hydroclimate variability?

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THE INDEPENDENT

Global warming 'will cause more forest fires, droughts and floods'

By Steve Connor, Science Editor

Tuesday, 15 August 2006

Forest fires, droughts and floods are all likely to become more severe and more common if global warming heats the planet as seriously as some scientists predict.

The Telegraph

Doomsday vision of global warming: droughts, floods and economic chaos

By Graeme Wilson, Political Correspondent
12:01AM GMT 31 Oct 2006

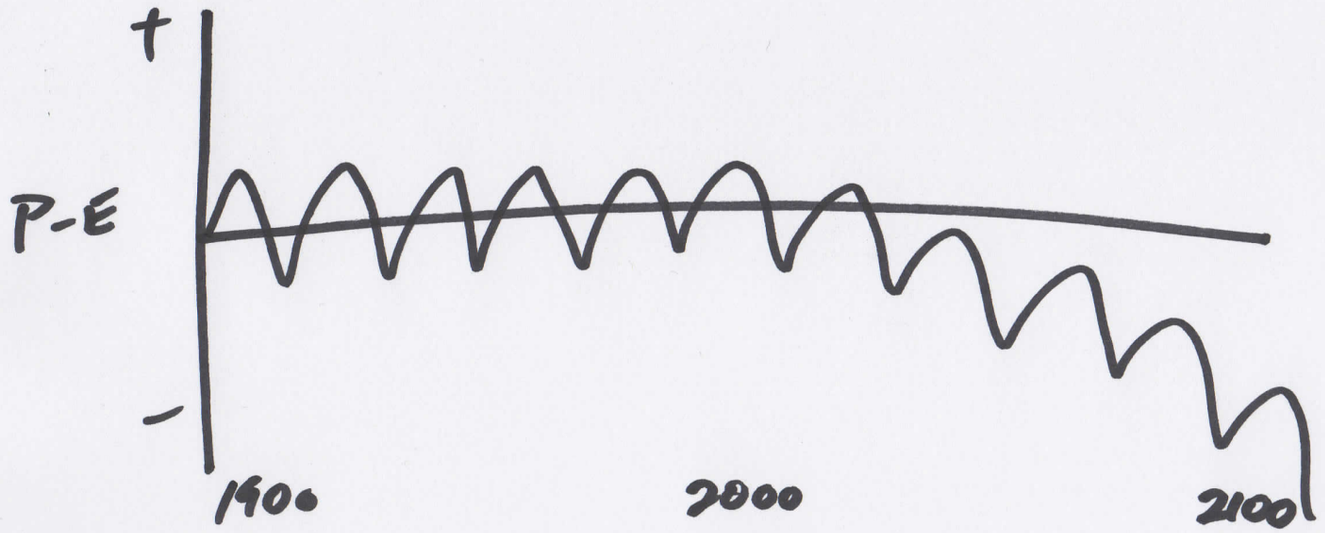
In 600 pages, Sir Nicholas Stern spells out a bleak vision of a future gripped by violent storms, rising sea-levels, crippling droughts and economic chaos unless urgent action is taken to tackle global warming.

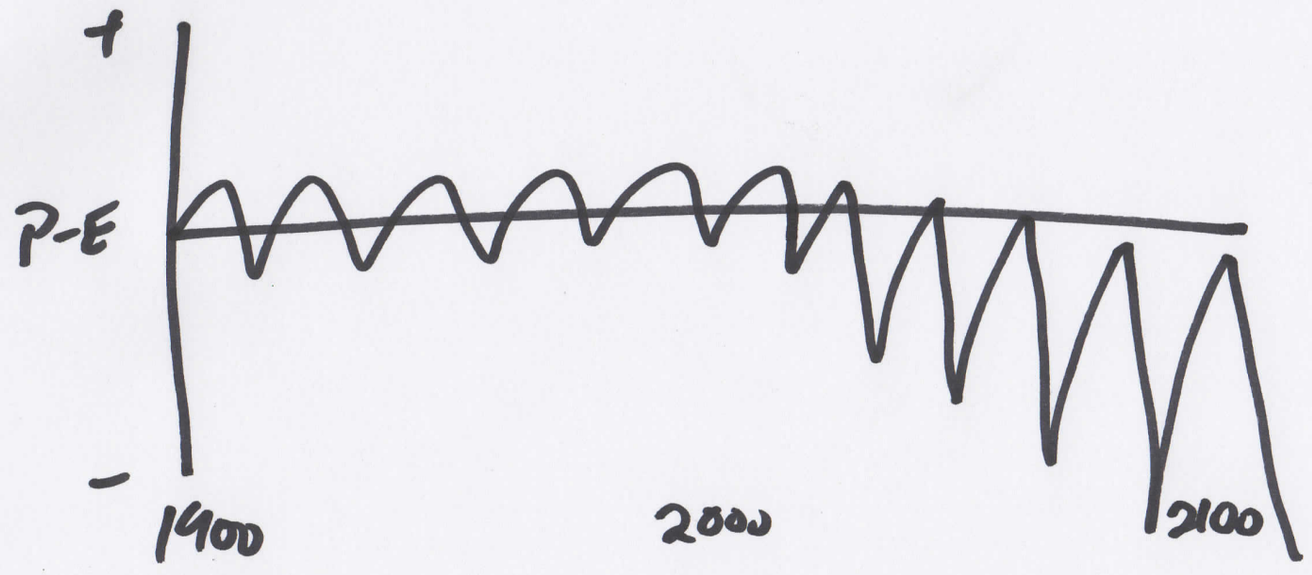
Is it true?

... 'more droughts and floods ...'

does this mean trends creating droughts somewhere and floods somewhere else?

Or more variability everywhere?





Begin with the moisture equation
bars = monthly means, primes daily departures

$$\rho_w g(P-E) = -\int_0^{p_s} \left(\nabla\cdot(\bar{\mathbf{u}}\bar{q}) + \nabla\cdot(\overline{\mathbf{u'q'}})\right) dp - q_s \mathbf{u_s}\cdot\nabla\mathbf{p_s}.$$

Break La Nina - El Nino anomaly in *P-E* down into thermodynamic (*q* variability only), dynamic (***u*** variability only) and transient eddy terms

$$\rho_w g\delta(P-E) \approx \delta TH + \delta MCD + \delta TE - \delta S,$$

$$\delta TH = -\delta\int_0^{\bar{p}_s} \nabla\cdot(\bar{\bar{\mathbf{u}}}\bar{q})\, dp,$$

$$\delta MCD = -\delta\int_0^{\bar{p}_s} \nabla\cdot(\bar{\mathbf{u}}\bar{\bar{q}})\, dp,$$

$$\delta TE = -\delta\int_0^{\bar{p}_s} \nabla\cdot(\overline{\mathbf{u'q'}})dp.$$

$$\delta(\cdot) = (\cdot)_{LN} - (\cdot)_{EN},$$

Next look at change in variability from 20th to 21st Centuries

$$\Delta(\cdot) = (\cdot)_{21} - (\cdot)_{20},$$

$$\rho_w g \Delta\left(\delta(P-E)\right) \approx \Delta\left(\delta TH\right) + \Delta\left(\delta MCD\right) + \Delta\left(\delta TE\right) - \Delta\left(\delta S\right).$$

The dominant cause of ENSO P-E variability is circulation change, MCD term, and this can be broken down as:

$$\Delta\left(\delta MCD\right) = \Delta\left(\delta MCD_q\right) + \Delta\left(\delta MCD_u\right),$$

$$\Delta\left(MCD_q\right) = -\int_0^{p_s} \nabla \cdot \left(\delta \bar{\mathbf{u}}_{20} \Delta \bar{q}\right) dp,$$

$$\Delta\left(MCD_u\right) = -\int_0^{p_s} \nabla \cdot \left(\Delta\left[\delta \bar{\mathbf{u}}\right] \bar{q}_{20}\right) dp,$$

Data and methods:

19 IPCC AR4/CMIP3 models (some excluded for really unrealistic ENSO or data missing (e.g. HadCM3))

20th Century simulations
21st Century SResA1B projections

Variability assessed over 100 years of each

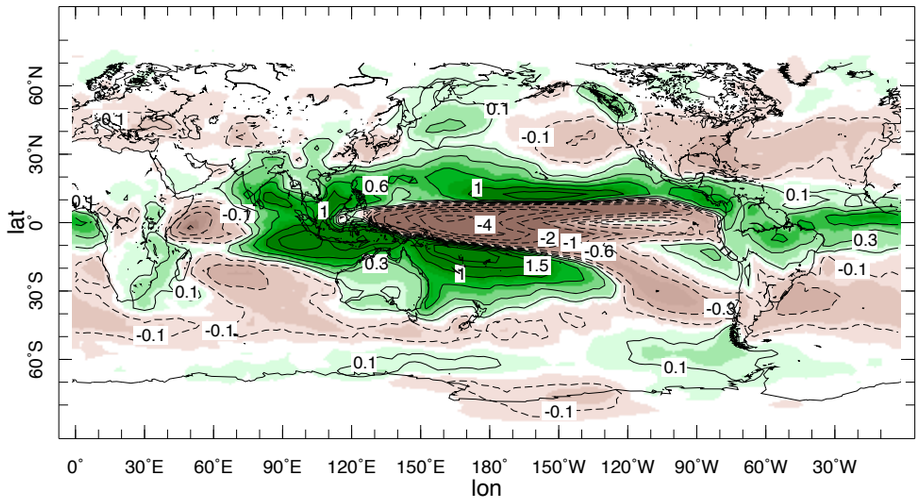
ENSO-driven variability assessed as La Nina minus El Nino composites based on PCs of first EOFs of annual mean P-E for each model

First of all, no evidence that ENSO itself changes from 20th to 21st Century in a way that is consistent and robust across models (Coelho and Goddard 2009) - so ignore that and focus on P-E teleconnections.

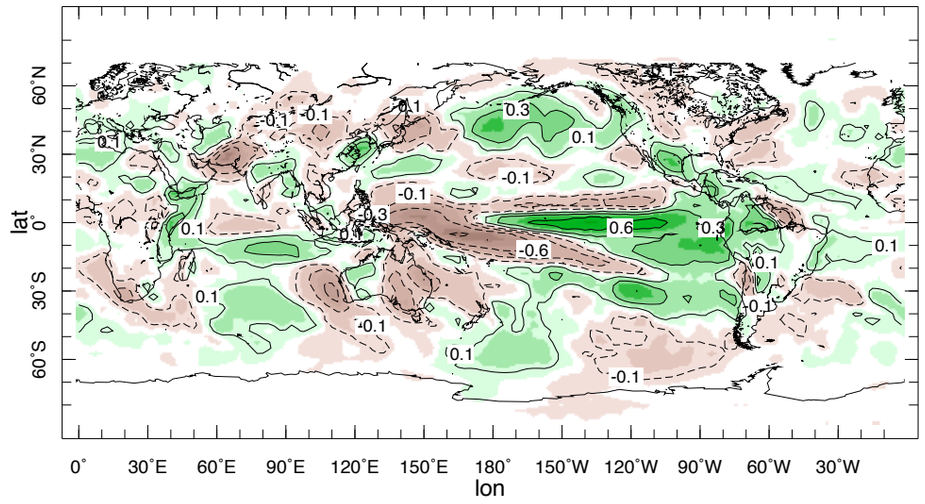
How realistic is model ENSO-driven P-E ?

MMM - Natural Variability

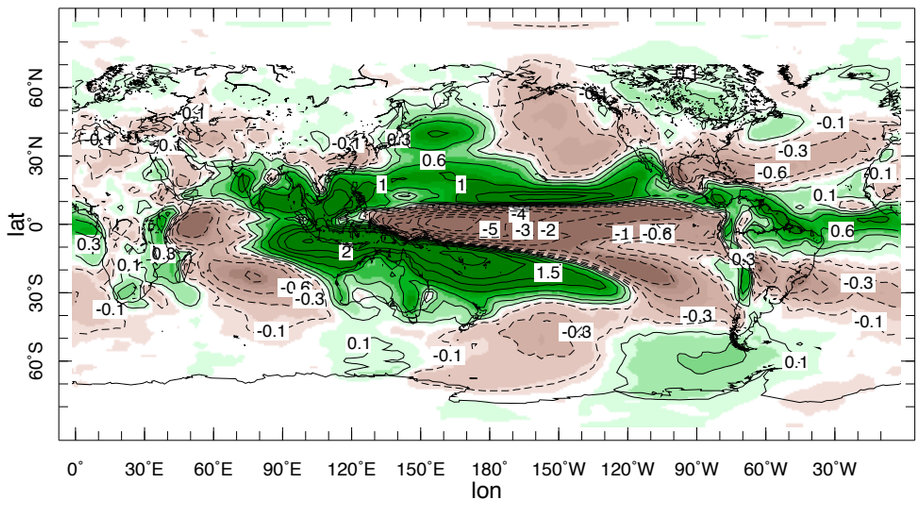
$\delta(P-E)$



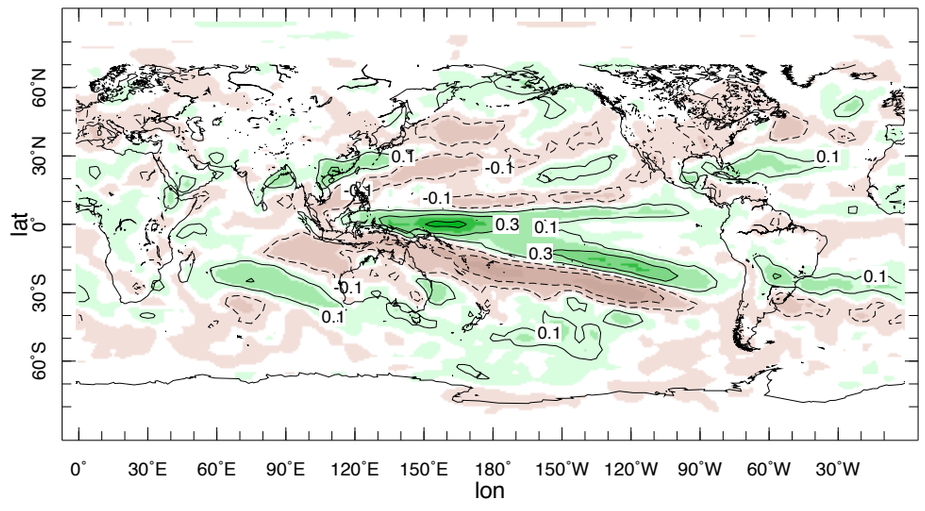
δTH



δMCD



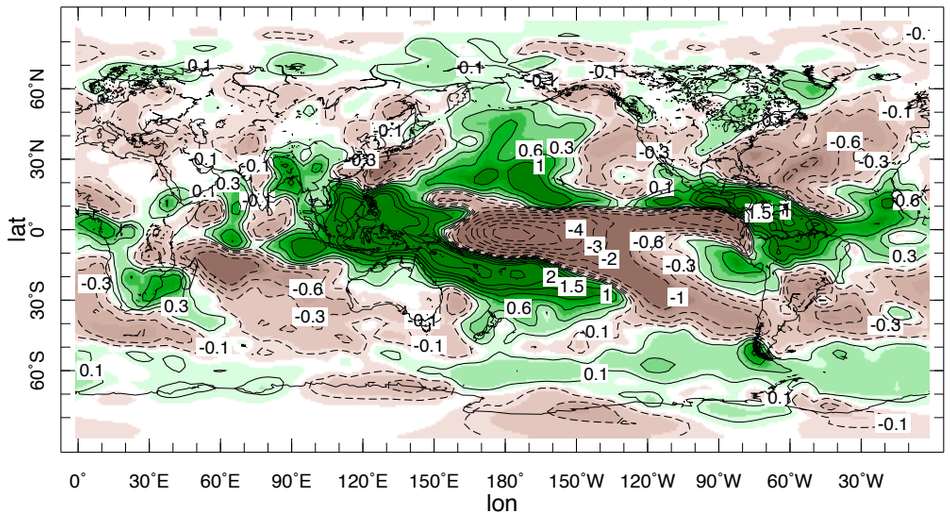
δTE



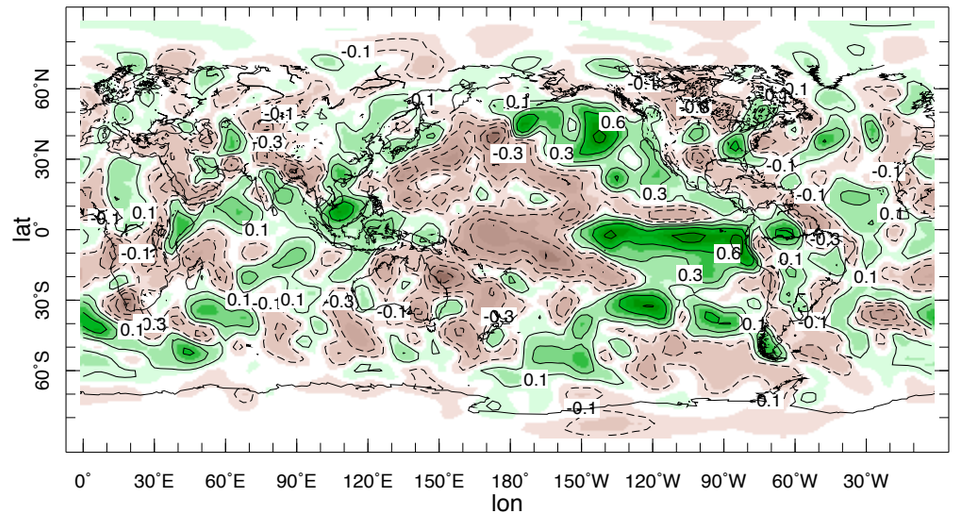
For internal variability - mostly ENSO - thermodynamic contribution is weak and *P-E* is ***'Dynamics dominated'***.

Compo - Natural Variability

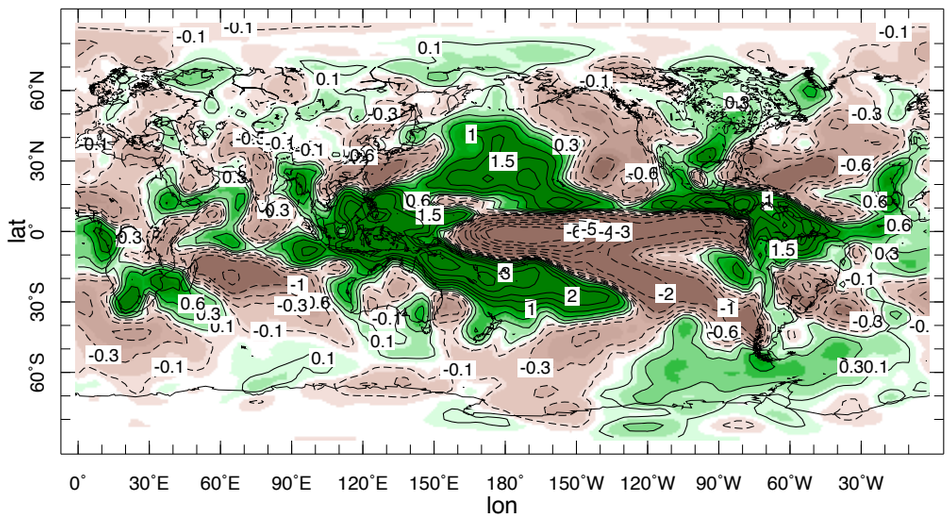
$\delta(P-E)$



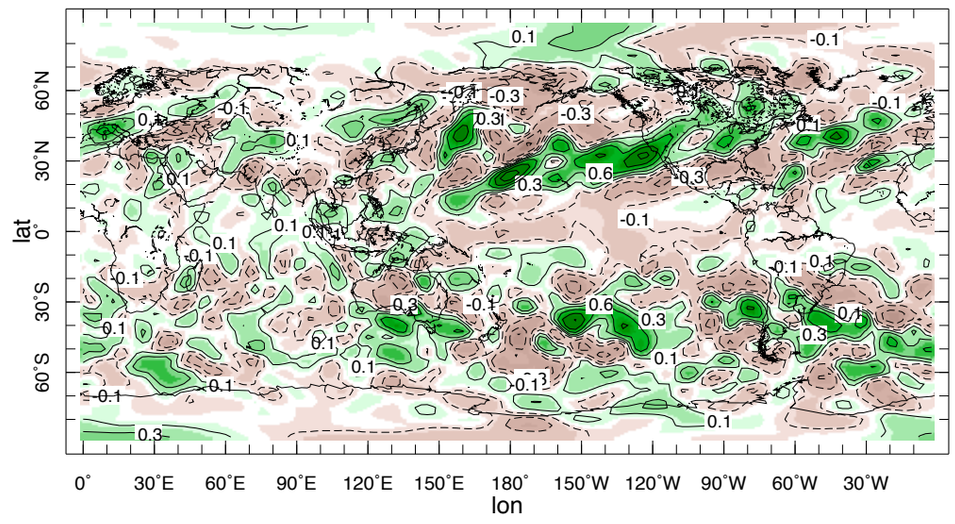
δTH



δMCD



δTE



IPCC AR4 mechanisms of internal P-E variability are remarkably similar to observed.

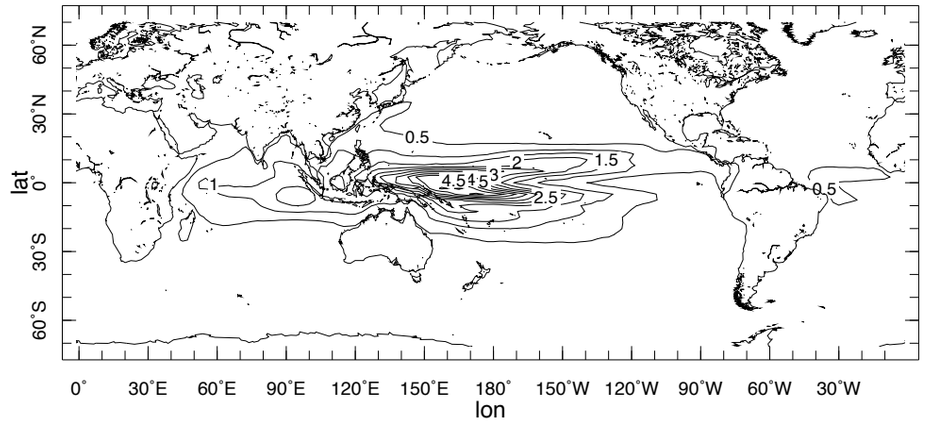
But first lets look at change in total variance of annual mean P-E

Variance increases almost everywhere.

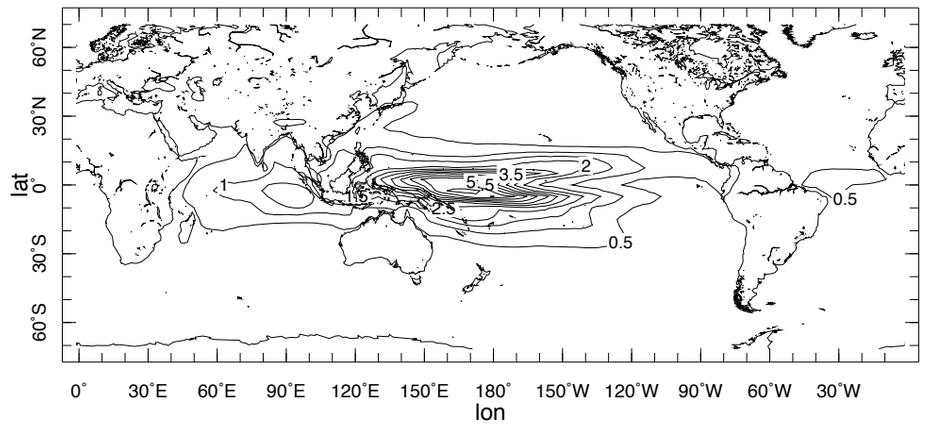
But not everywhere! Actually decreases over SW N. America.

Change in P-E variance using 19 AR4 models

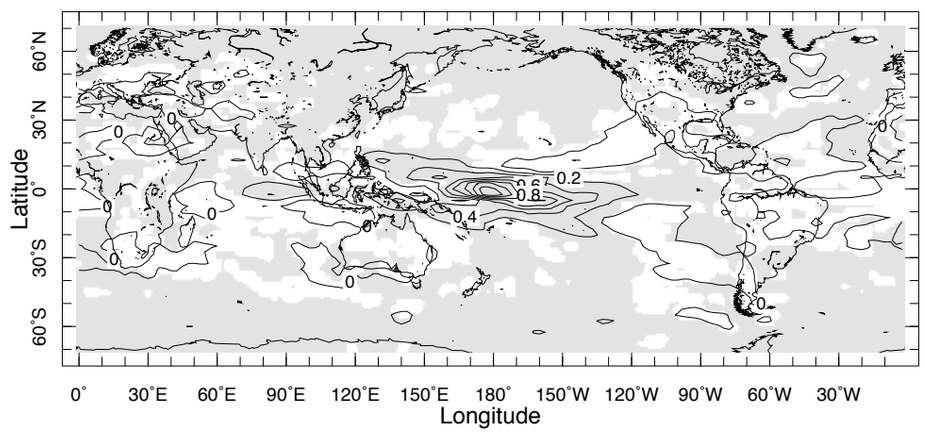
$\sigma^2(P-E)_{20c}$



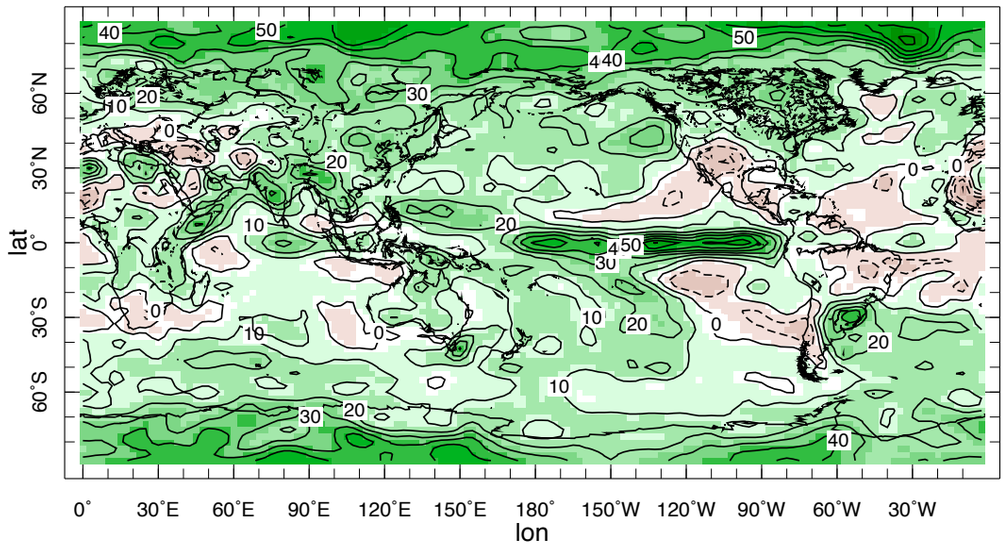
$\sigma^2(P-E)_{21c}$



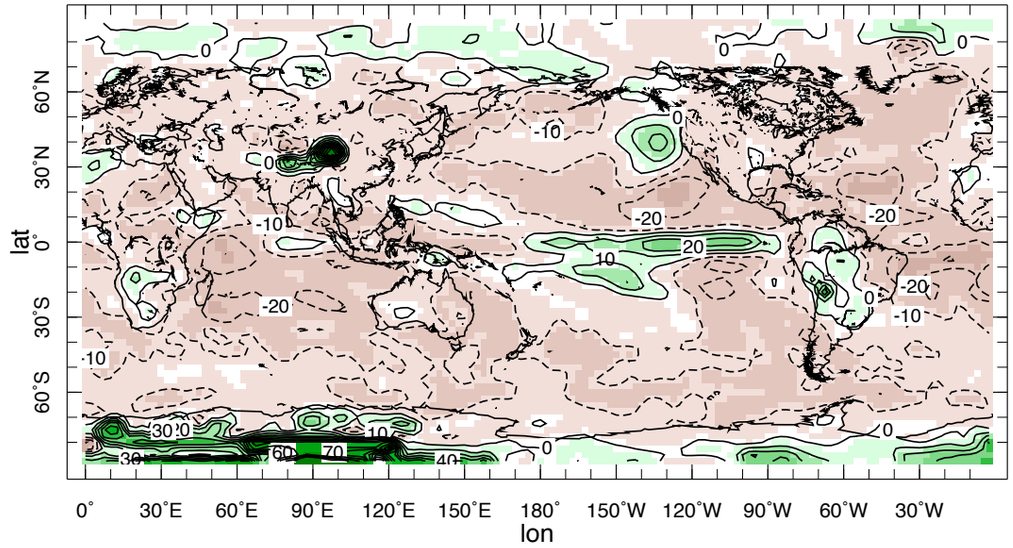
$\sigma^2(P-E)_{21c} - \sigma^2(P-E)_{20c}$



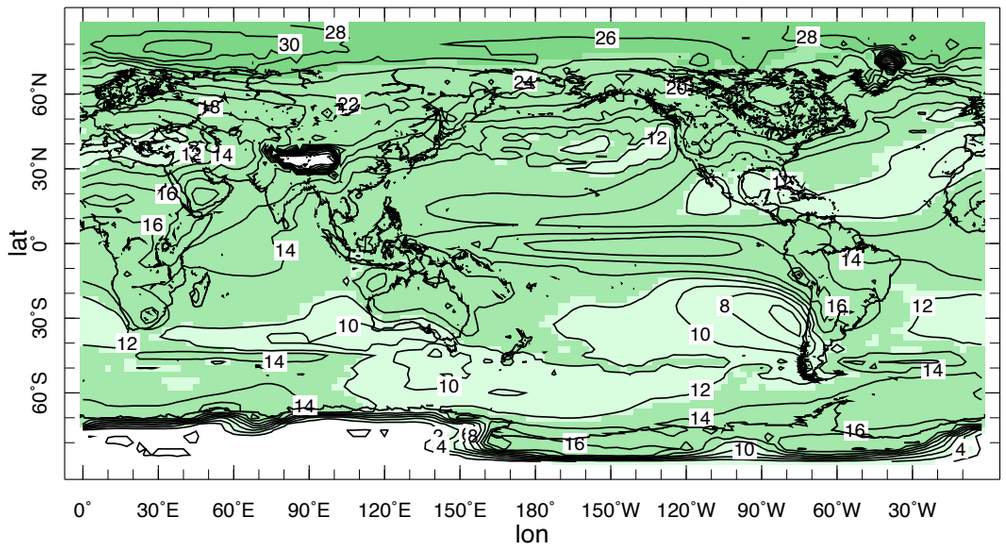
% change in σ^2(P-E)



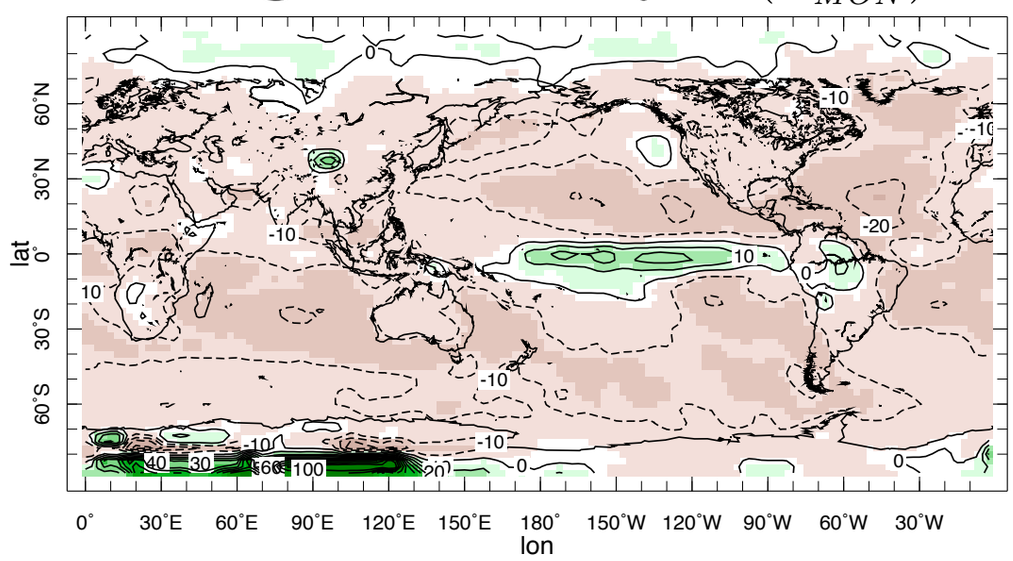
% change in $\sigma^2(\omega_{ANN})$



% change in moisture, 1000mb to 700mb



% change in monthly $\sigma^2(\omega_{MON})$



Lower tropospheric moisture content increases everywhere but P-E variance does not. Vertical velocity variance decreases except in equatorial Pacific and polar regions. P-E variance influenced by both.

Turning to ENSO-forced variability ....

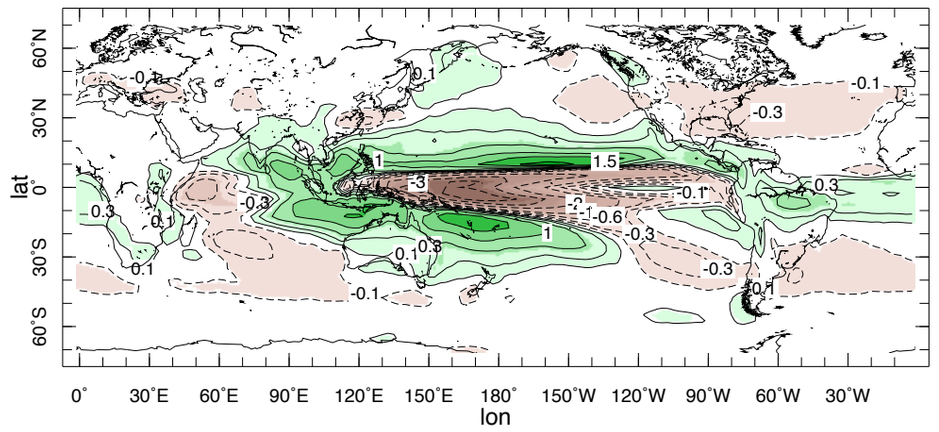
General increase in the tropical Pacific.

Some areas of decrease e.g. equatorial Atlantic

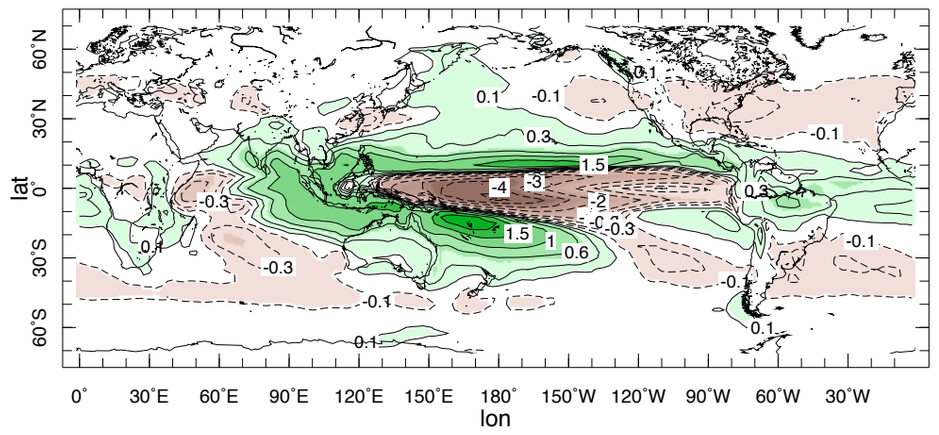
Natural variability using 19 AR4 models

$\delta(P-E)$

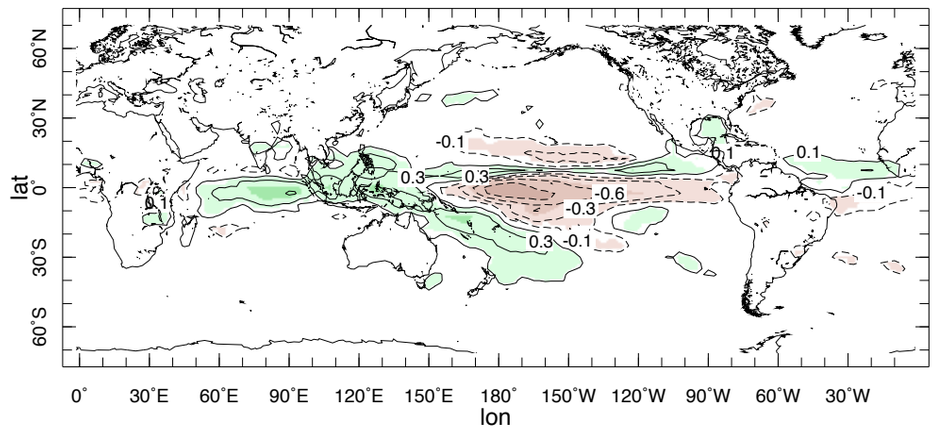
20c: 1900 to 1999



21c: 2000 to 2099



21c-20c:

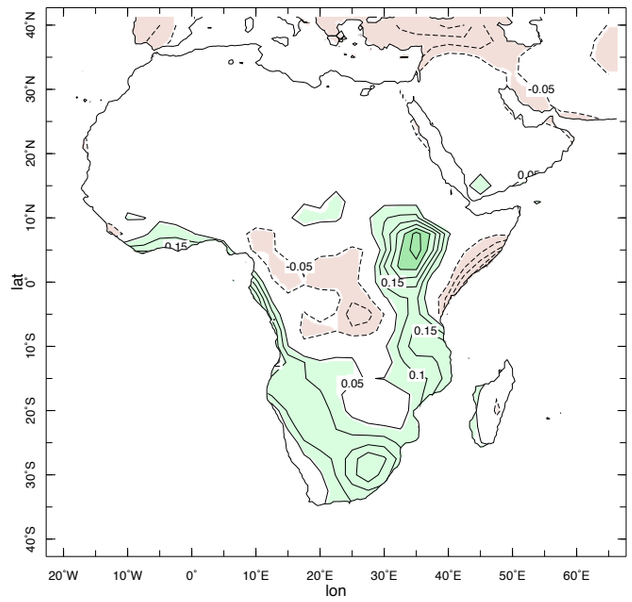


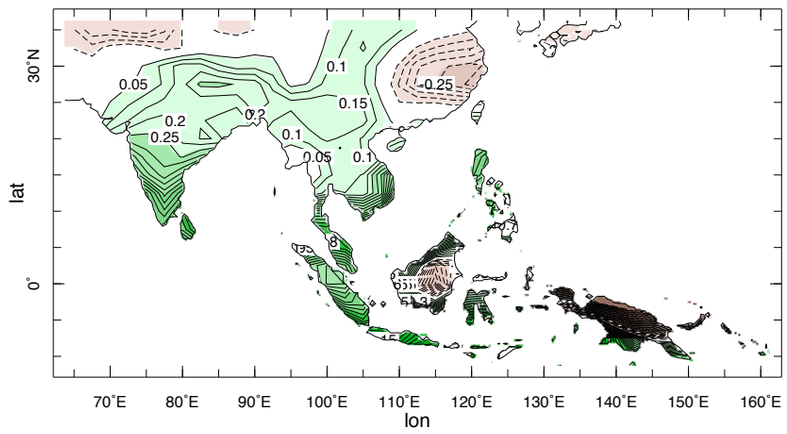
ENSO driven P-E variability ...

Increases over Asia

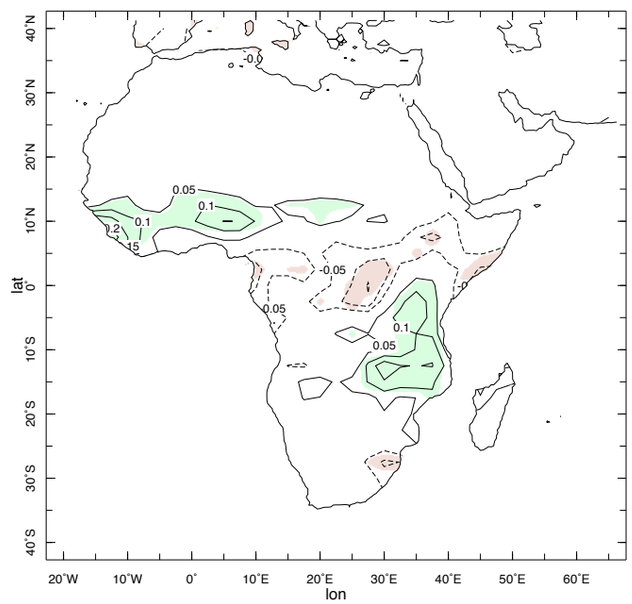
Increases over Sahel and much of Africa

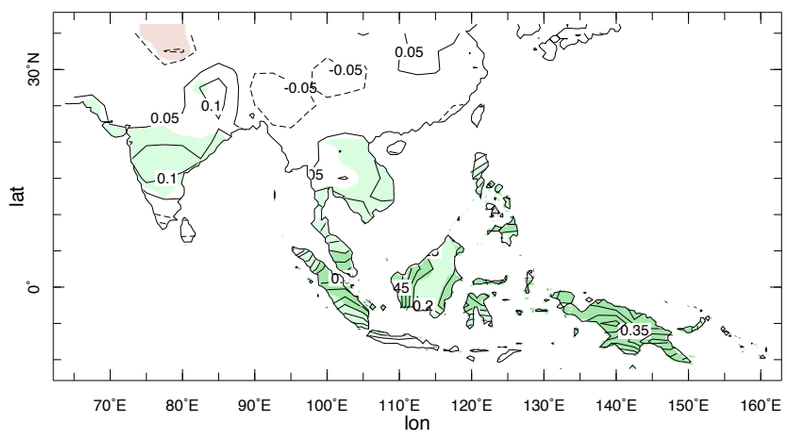
20^{th}C ENSO-driven P-E variability





20^{th}C to 21^{st}C change





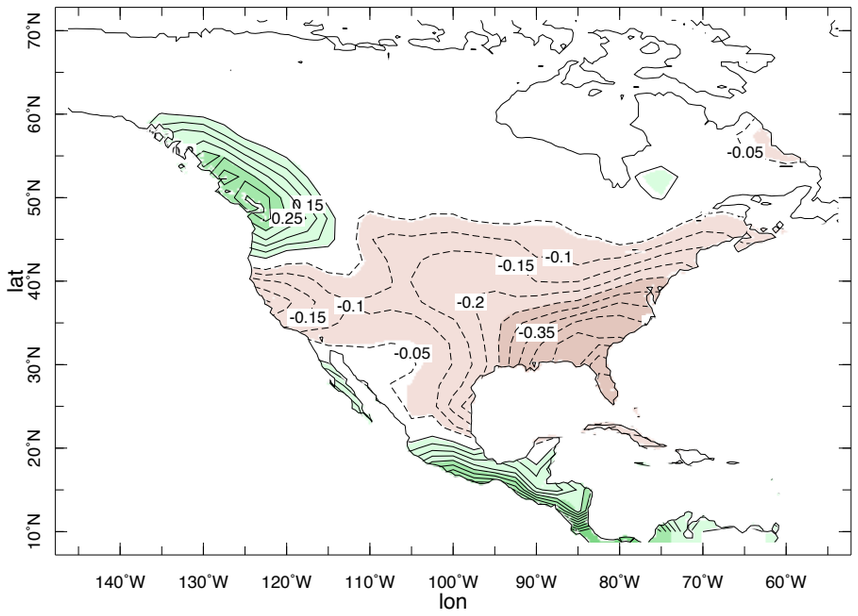
ENSO-forced P-E variability ...

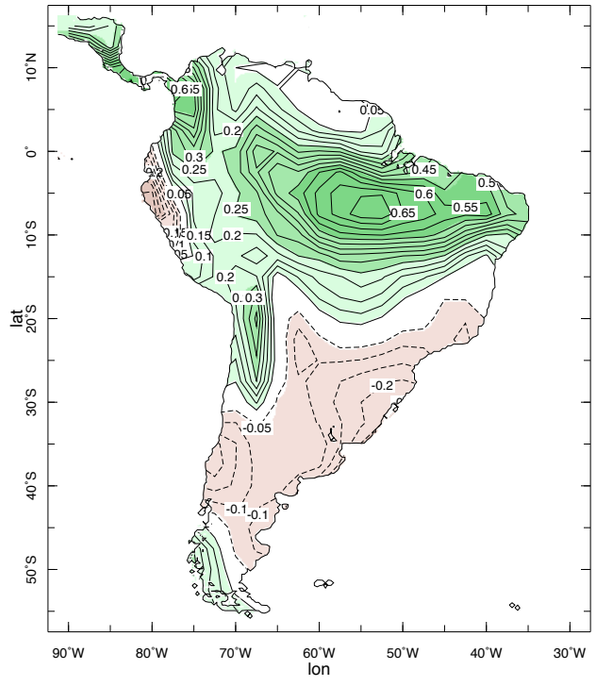
decreases over southern N. America and Pacific NW

Increases over Central America

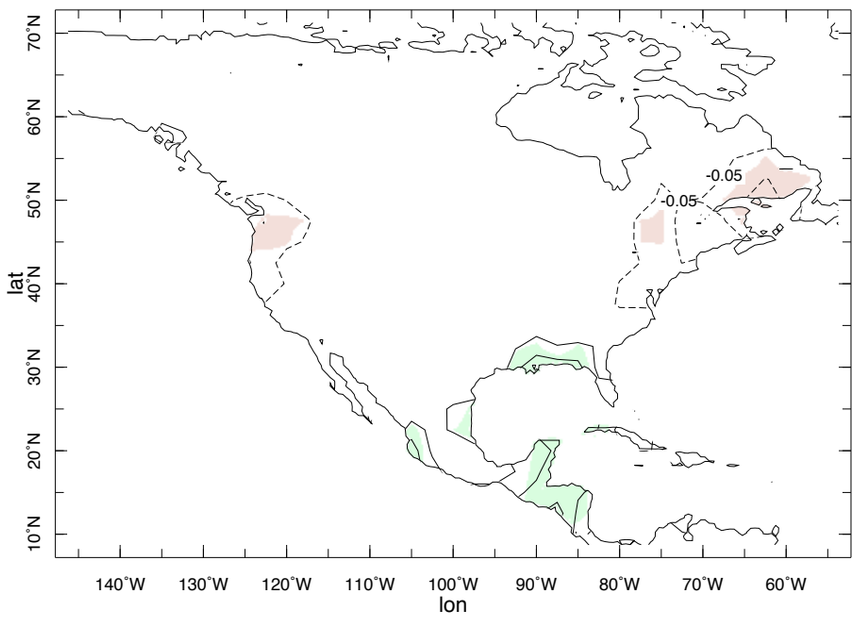
Decreases over NE Brazil

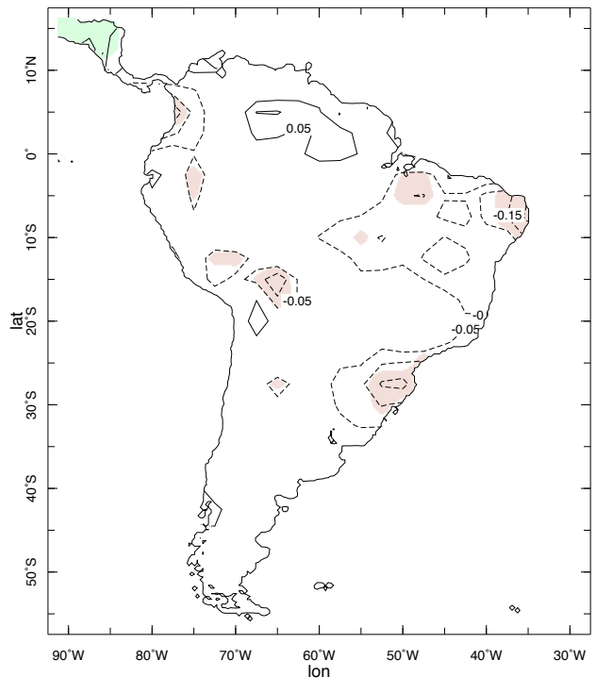
20^{th}C ENSO-driven P-E variability





20^{th}C to 21^{st}C change



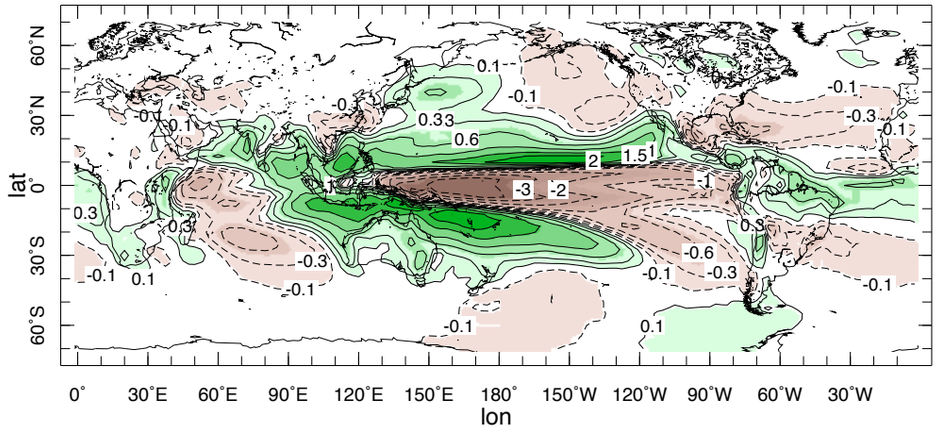


Circulation variability (with climatological humidity) dominates ENSO P-E variability

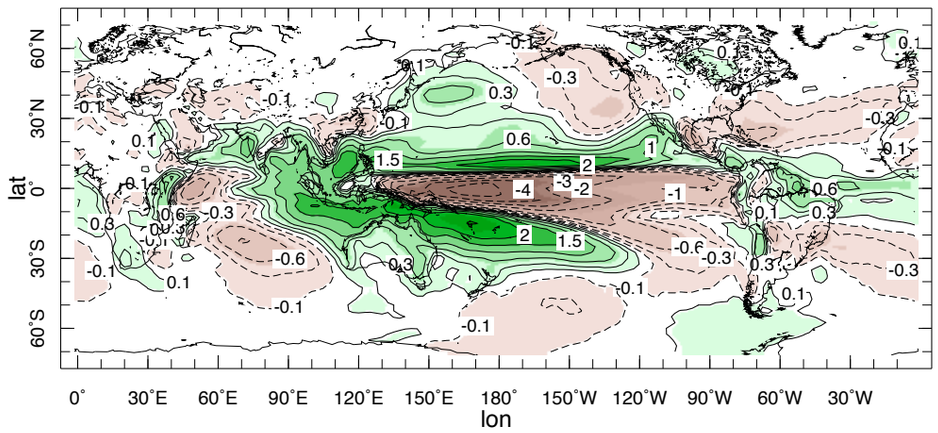
This term intensifies in the 21st Century

Natural variability using 19 AR4 models
δMCD

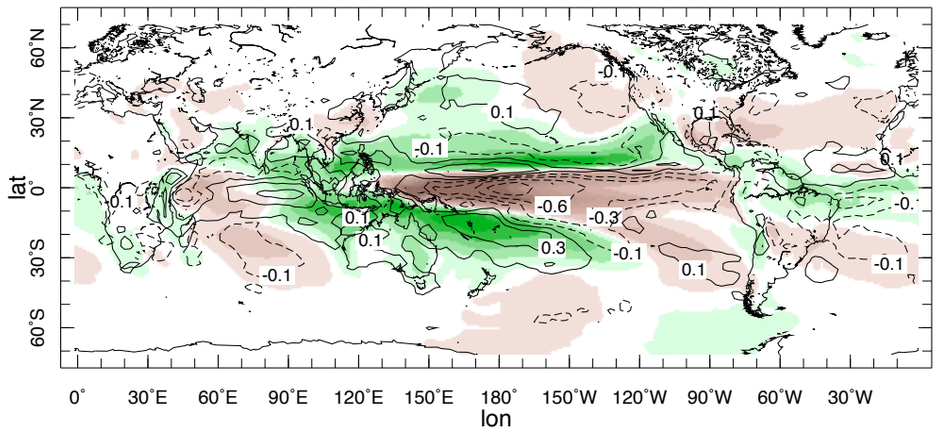
20c: 1900 to 1999



21c: 2000 to 2099



21c-20c(contours), 20c(colors)

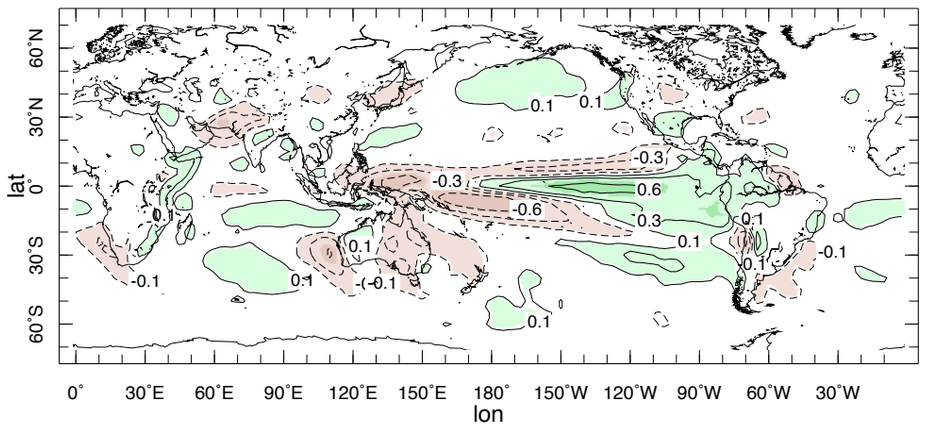


Contribution of moisture variability to ENSO-driven P-E variability is small ...

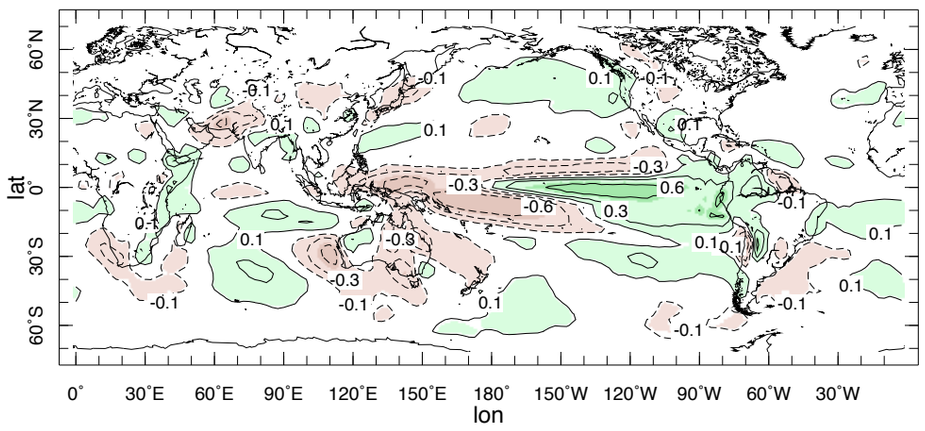
...with little change

Natural variability using 19 AR4 models
δTH

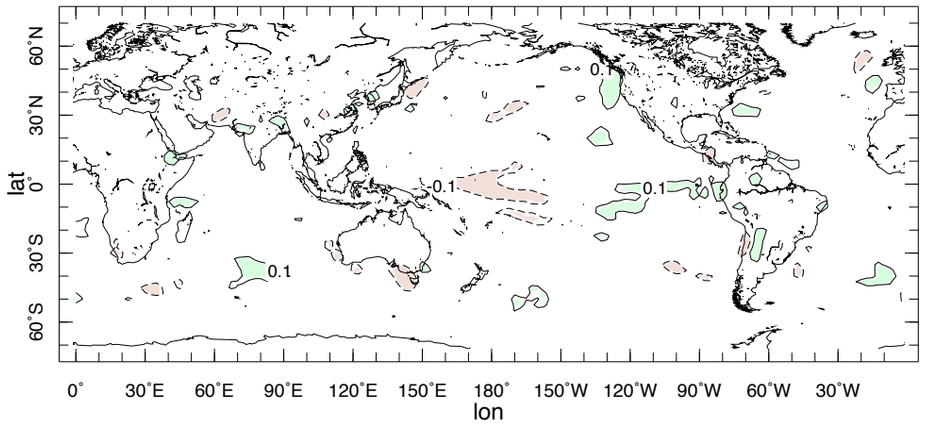
20c: 1900 to 1999



21c: 2000 to 2099



21c-20c:



The circulation term that dominates ENSO-driven P-E variability can increase due to:

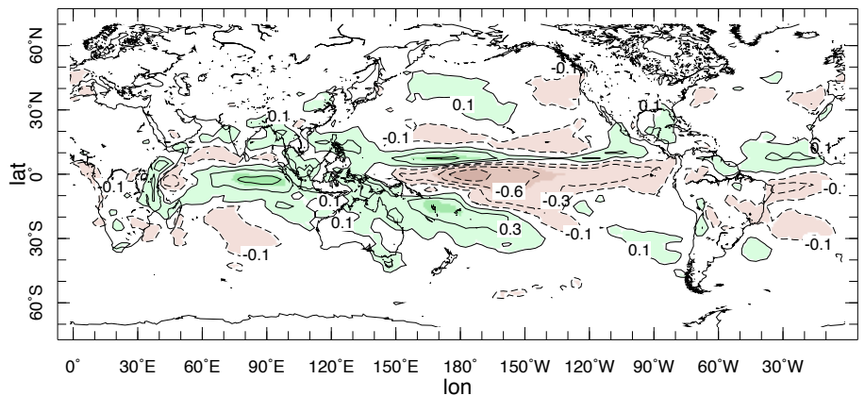
increase in climatological humidity

change in circulation variability

Both matter

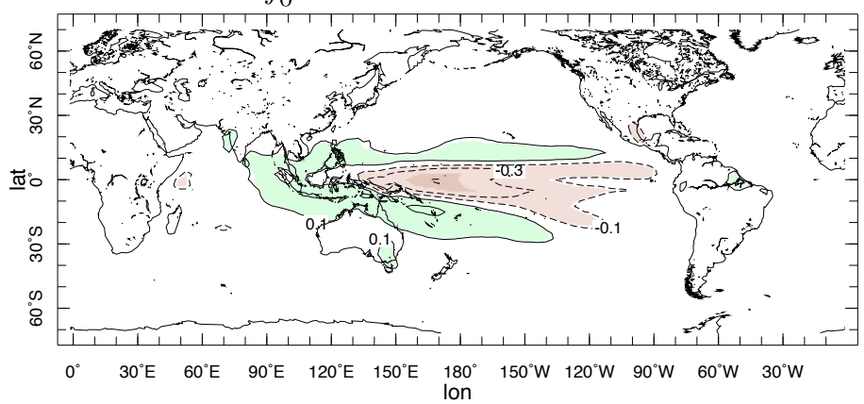
Change in natural variability using 19 AR4 models

MCD, 21c-20c



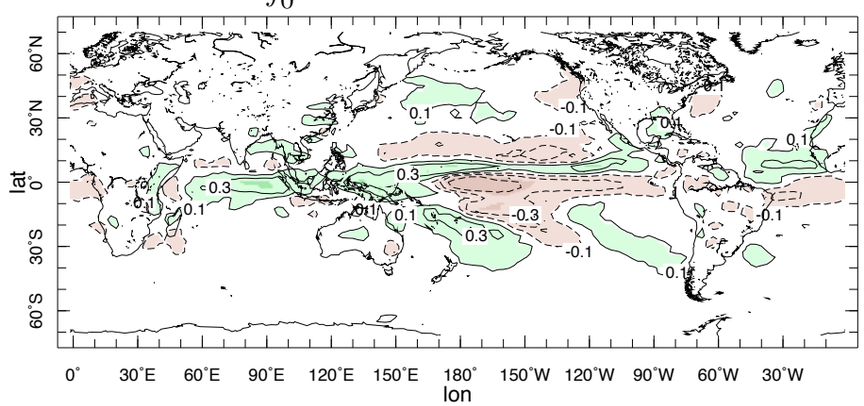
MCD mean humidity term

$$-\int_0^{p_s} \nabla \cdot (\delta u_{20c}\, \Delta \bar{q}) dp$$



MCD variable circulation term

$$-\int_0^{p_s} \nabla \cdot (\Delta \delta u\, \bar{q}_{20c}) dp$$

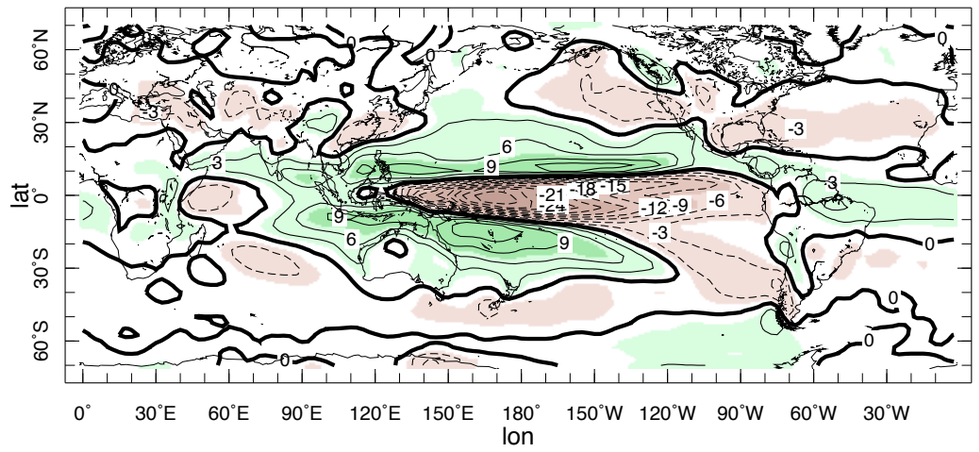


The change in the circulation variability contribution to change in P-E variability is easily accounted for ....

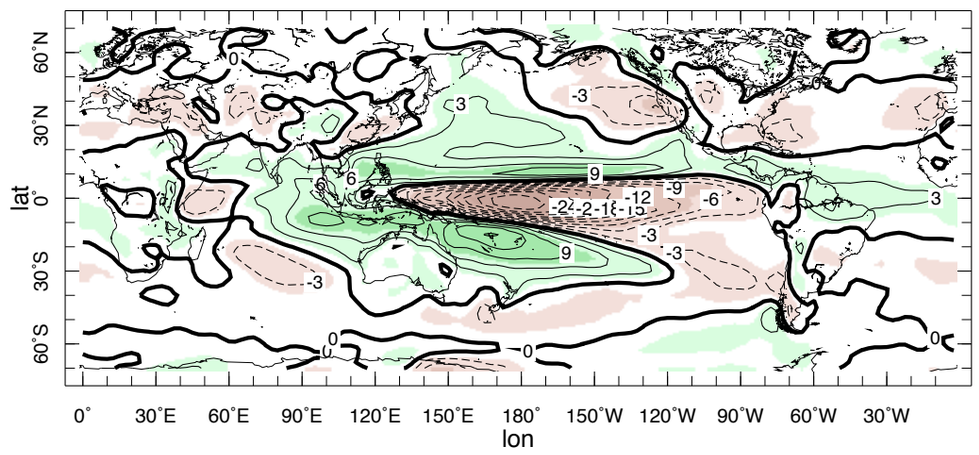
.... by change in vertical velocity variability

Change in ENSO variability of 700mb vertical velocity

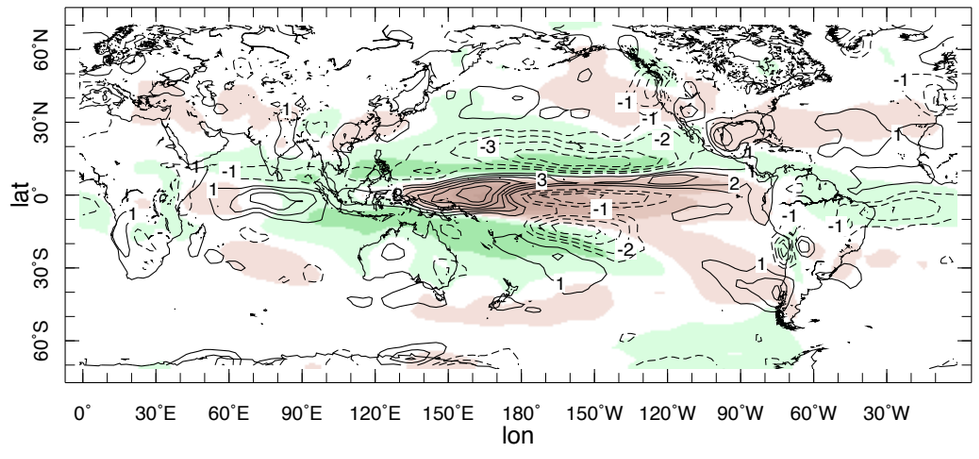
$\delta(\text{-}\omega_{700mb})_{20c}$



$\delta(\text{-}\omega_{700mb})_{21c}$



$\delta(\text{-}\omega_{700mb})_{20c}$ **(colors) and** $\Delta\delta(\text{-}\omega_{700mb})$ **(contours)**



Conclusions

Total interannual P-E variance increases almost everywhere scaling as square of increase in climatological humidity

In some places (e.g. southern N. America) it decreases

ENSO-driven P-E variability change is more complex:

Rising humidity causes circulation variability to intensify P-E variability

But change in the circulation variability - shifts in teleconnection patterns and amplitudes - equally as important in many regions of world