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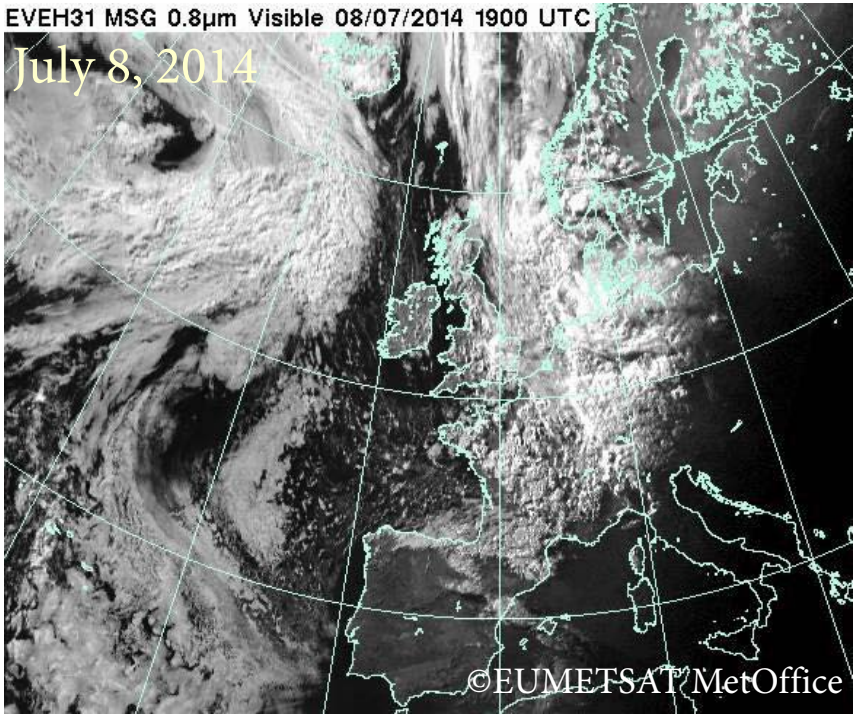
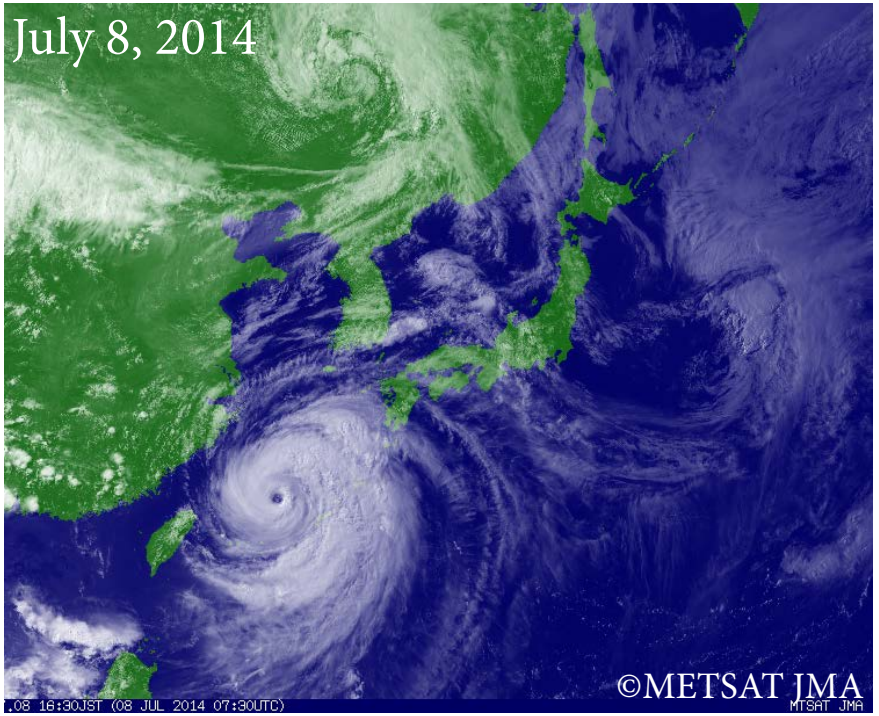
Robust increase of the equatorial Pacific rainfall and its variability in a warmed climate





THE UNIVERSITY OF TOKYO

Robust increase of the equatorial Pacific rainfall and its variability in a warmed climate

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Watanabe, M., Y. Kamae, and M. Kimoto, 2014: Robust increase of the equatorial Pacific rainfall and its variability in a warmed climate. Geophys. Res. Lett., doi:10.1002/2014GL059692.

Background and a question

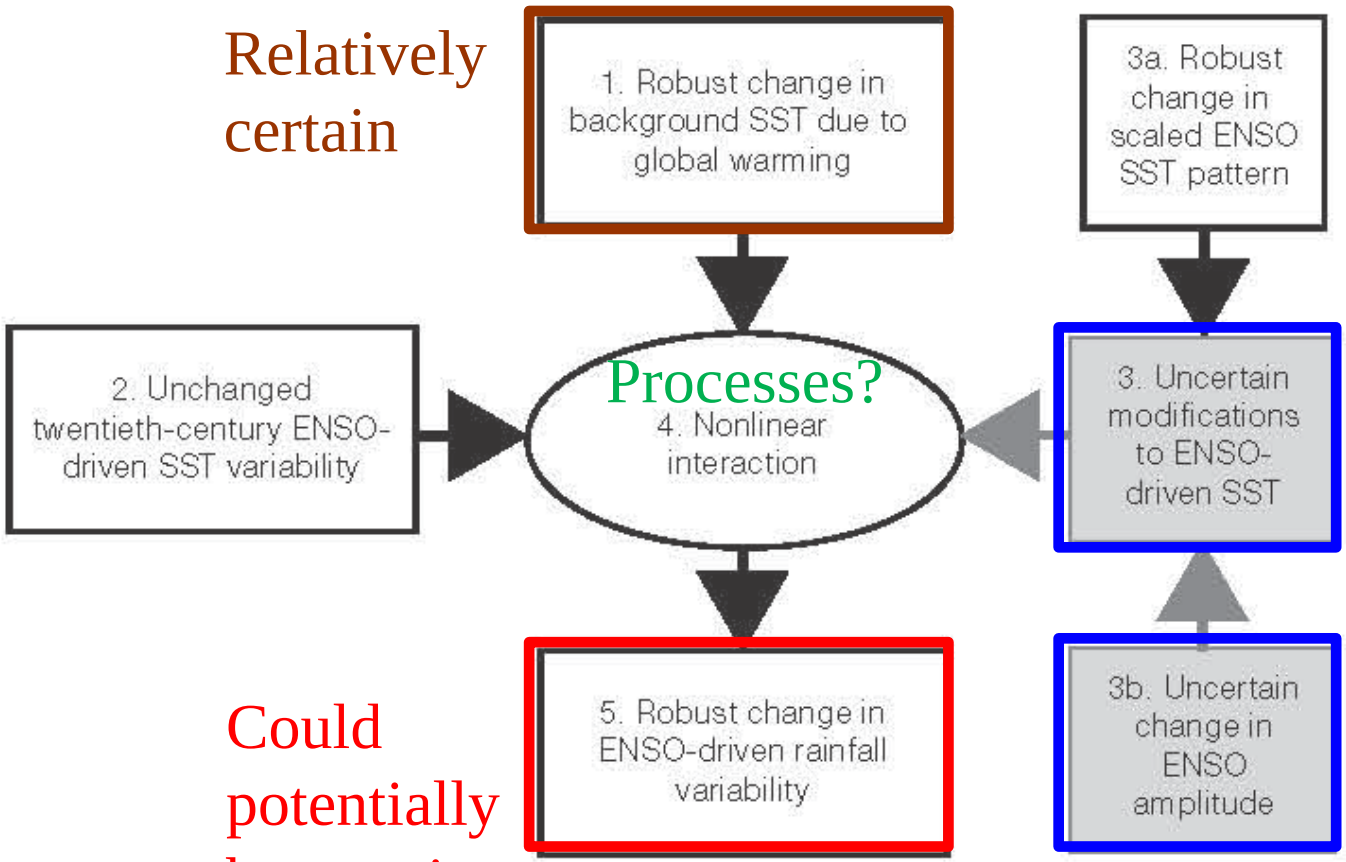
0. Tropical precipitation *anomaly* affects regional weather

1. Large uncertainty in the change of natural SST variability (eg ENSO and IOD) (Meehl et al. 2007; Cai et al. 2009; Collins et al. 2010)

2. *Relatively* robust regional change in mean state (eg SST and precip) (Held and Soden 2006; Xie et al. 2010; Huang et al. 2013; Chadwick et al. 2014)

3. Can we be confident about the change in precip variability if it depends more on 2. rather than 1. ?

Background and a question



Power et al. (2013, Nature)
also Cai et al. (2014, Nature Clim Change)

Change in tropical precip variability

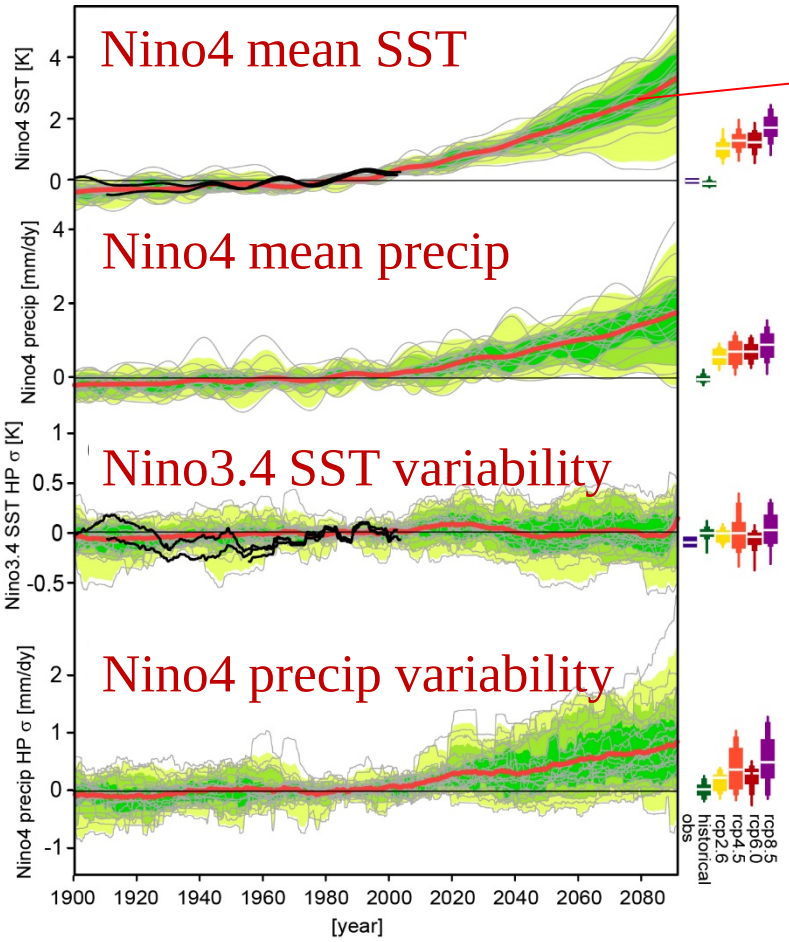
CMIP5 historical+RCPs

Increase

Increase

Unchanged?

Increase!



MME mean

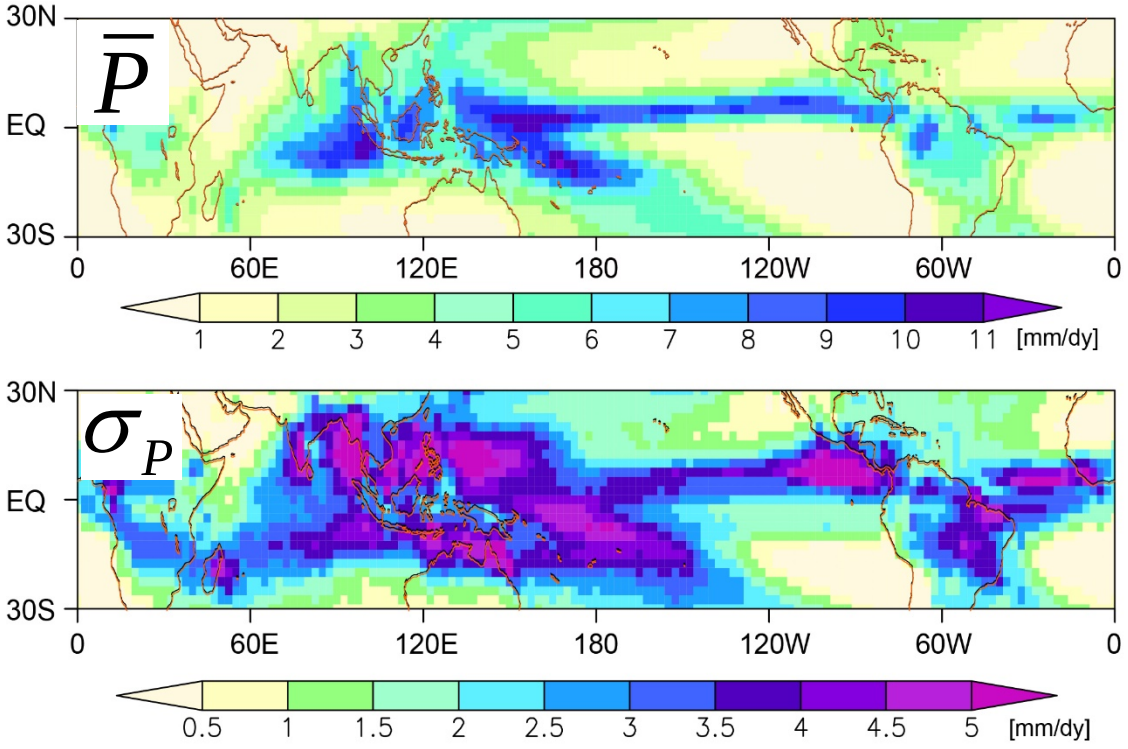
Mean state =
20y low-pass fields

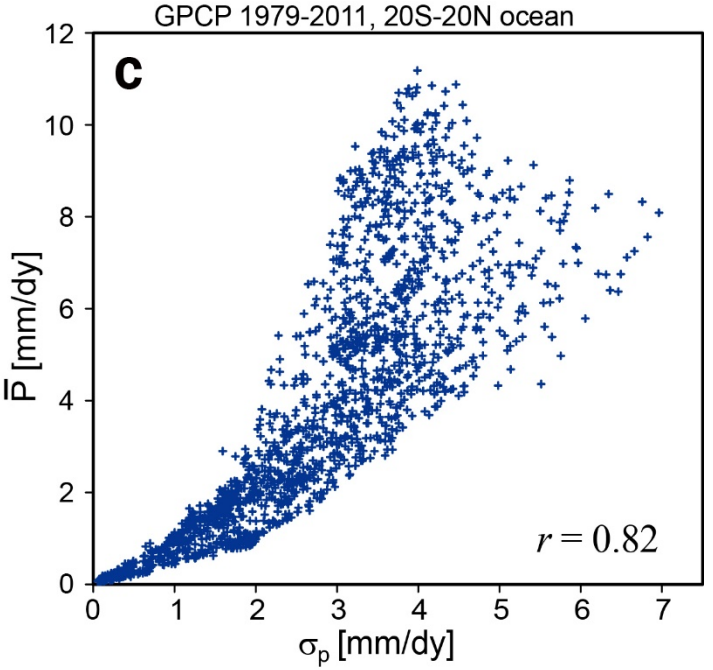
Variability =
Std Dev of monthly deviations from the mean states

Is change in precip variability anchored by mean precip change ?

Mean precip & precip variability

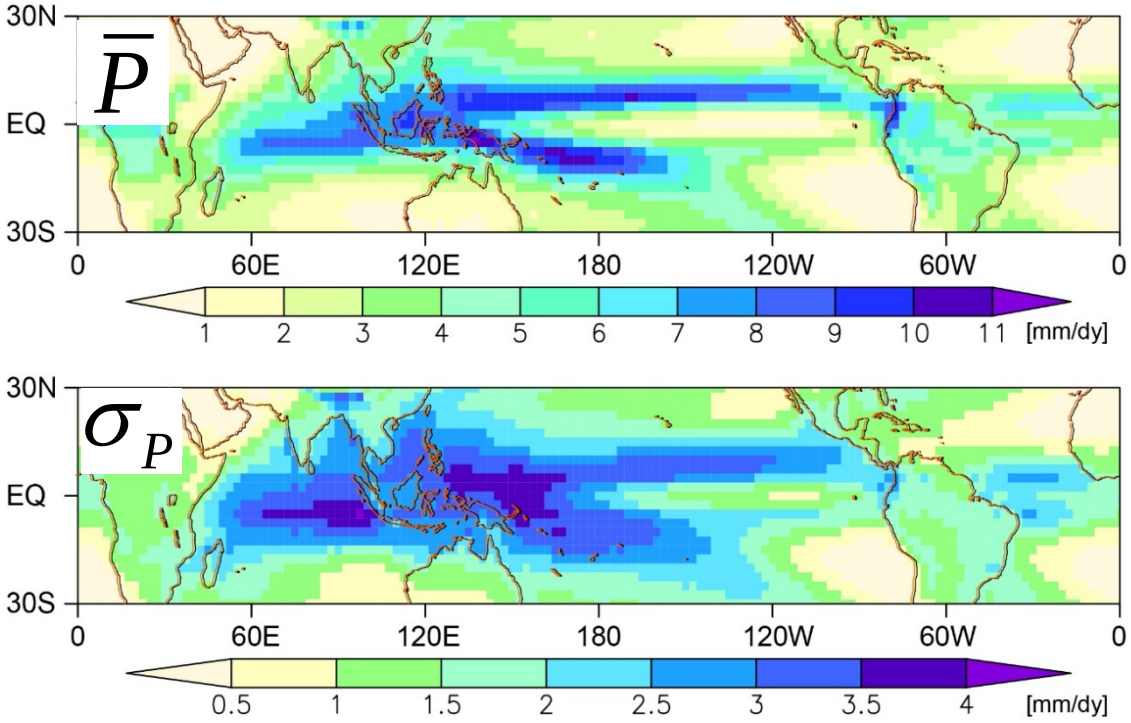
GPCP precipitation data for 1979-2011

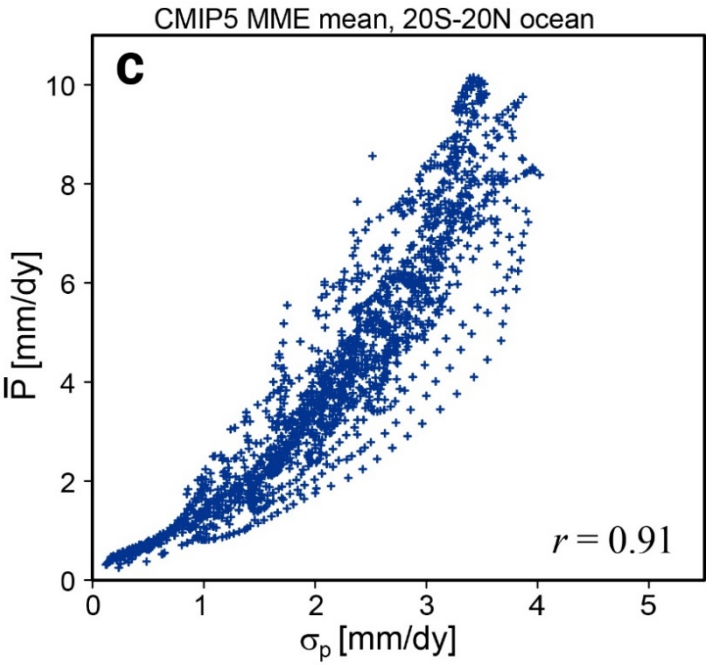




Mean precip & precip variability

CMIP5 MME mean for 1941-2000

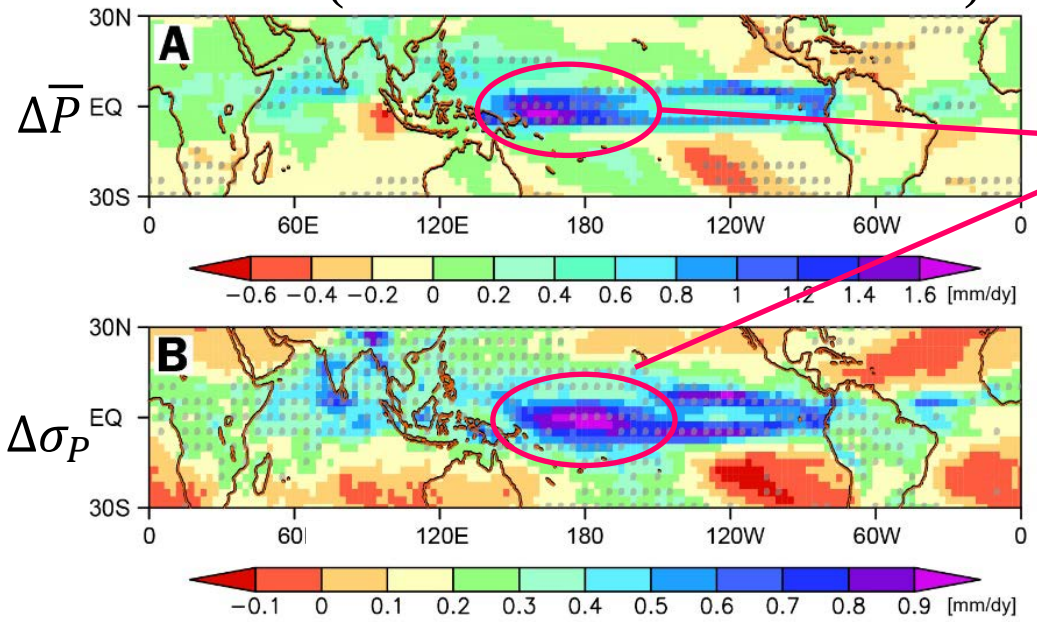




Models underestimate the precip variability, but reproduce a nonlinear relationship between $\overline{P}$ and σ_P

Change in tropical precip variability

CMIP5 (2040-2099 minus 1940-1999)



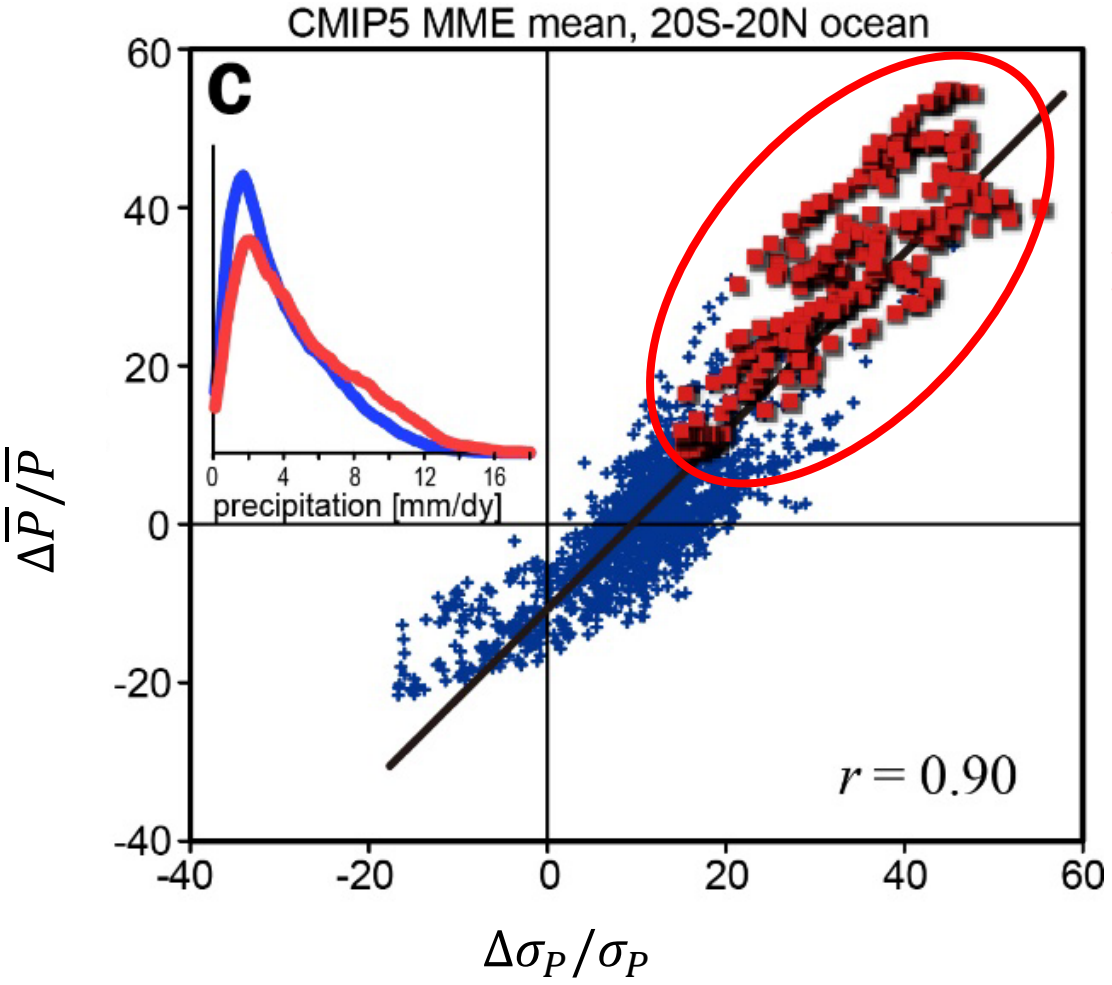
Common increase in the central equatorial Pacific (CEP region)

Assuming precip PDF follows a Gamma distribution (Bladley et al. 1987)

$$f(P) = P^{k-1}\frac{e^{-P/\theta}}{\Gamma(k)\theta^k} \Rightarrow \frac{\Delta\overline{P}}{\overline{P}} = \frac{\Delta k}{k} + \frac{\Delta\theta}{\theta}, \quad \frac{\Delta\sigma_P}{\sigma_P} = \frac{\Delta k}{2k} + \frac{\Delta\theta}{\theta}$$

Mean precip & its variability should be linearly related

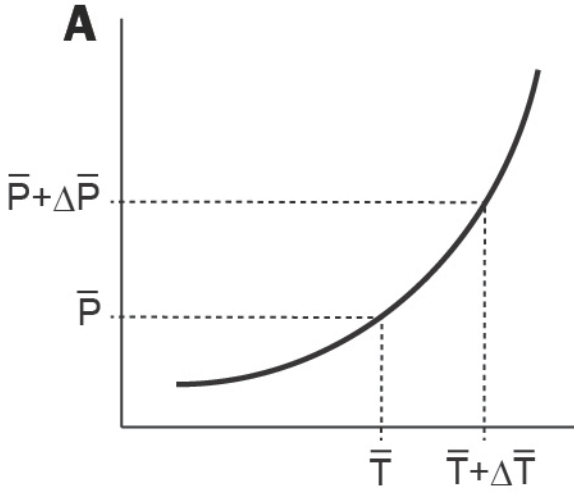
Change in tropical precip variability



Equatorial Pacific

What is the physical interpretation?

Variability Increases with mean Precipitation ('VIP') mechanism



Change in precip variability depends on

- mean precip in current climate (→ dP/dT)
- SST variance (= ENSO intensity)

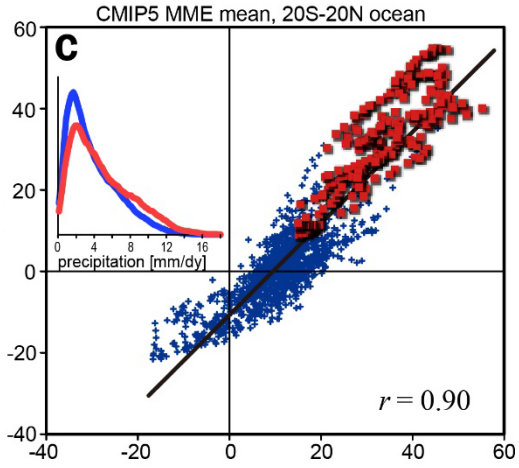
In CMIP5 models, σ_P is highly correlated with $\bar{P}\sigma_T$ (r = 0.88)

Metric for mean precip changes on regional scale

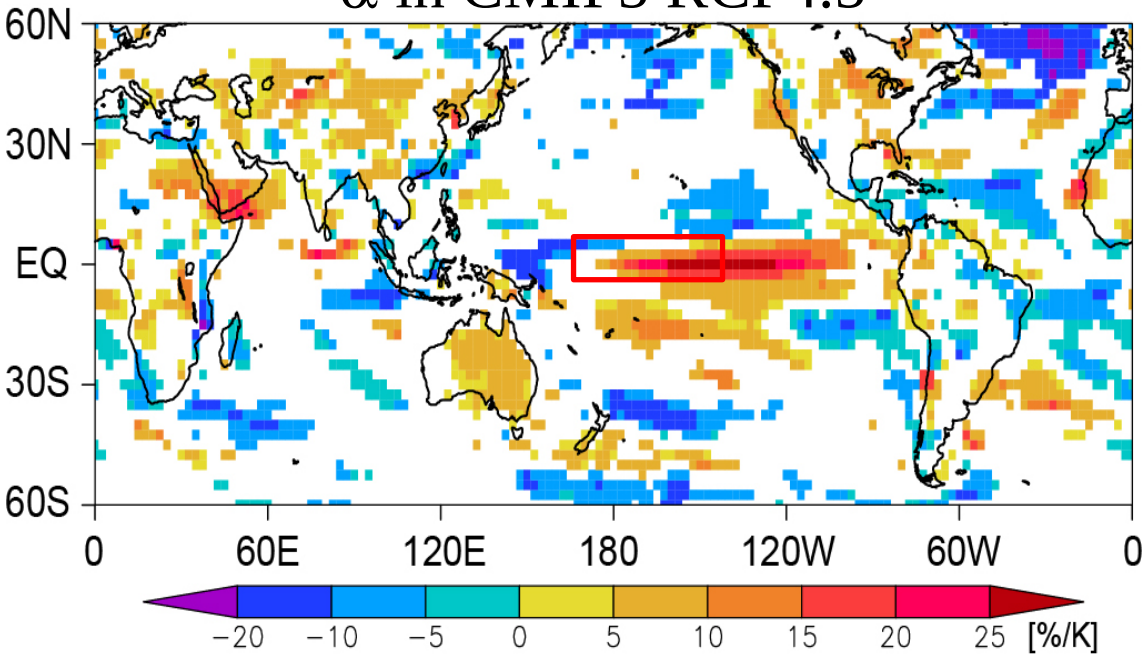
Scaled increasing ratio (α)

$$\overline{P}_{\text{Future}} = \overline{P}_{\text{Present}} + \Delta\overline{P}^{*}$$

$$\Delta\overline{P}^{*} \equiv \Delta\overline{P} / \Delta\text{SAT}_{g} = \alpha \overline{P}_{\text{Present}}$$



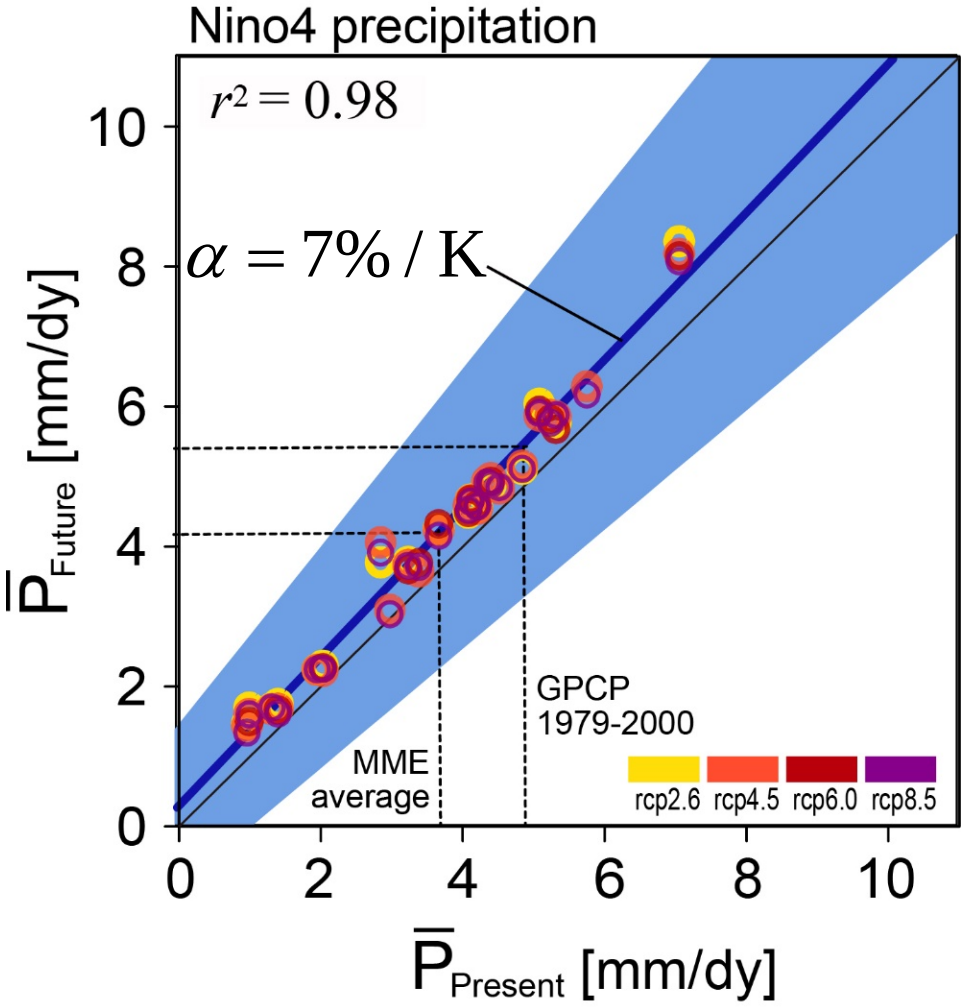
α in CMIP5 RCP4.5



Shaded where $r(\overline{P}_{\text{Present}}, \Delta\overline{P}^{*})$ is significant at the 99% level

Mechanisms that determine regional values of α yet unclear

Metric for mean precip changes on regional scale



Value of α much larger than for global-mean precipitation (~2%/K)

ΔP = 0.26 mm/day

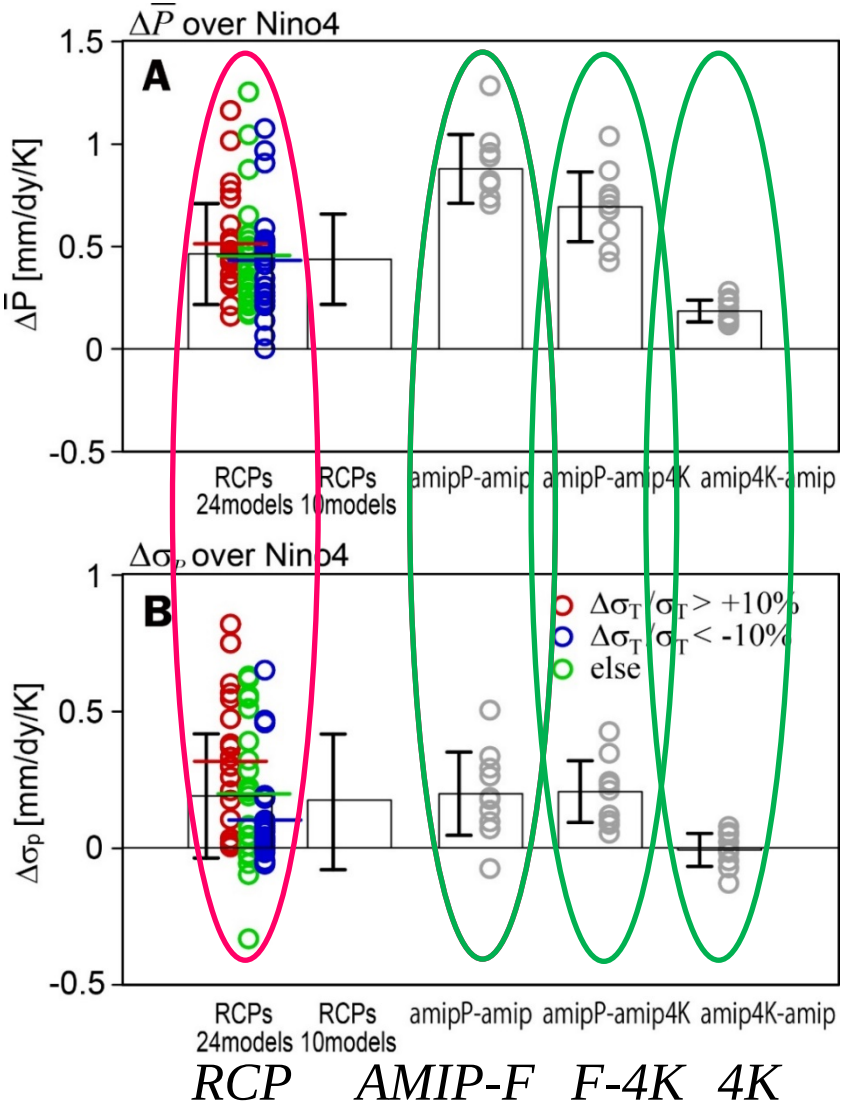
→ ΔP = 0.33 mm/day (+27%)

Observed $\overline{P}_{Present}$ could constrain $\overline{P}_{Future}$ → perhaps larger than the MME

Metric for mean precip changes on regional scale

Nino4 $\Delta\overline{P}$

Nino4 $\Delta\sigma_P$



Effect of *changing SST gradient* >> effect of uniform SST increase

(cf. Xie et al. 2010 JC and others)

Summary

1. Precipitation variability in CEP (mostly related with ENSO) will amplify with increase of mean precipitation

2. The increasing variability is explained by the VIP mechanism and is robustly detected despite uncertainty in the future ENSO amplitude change

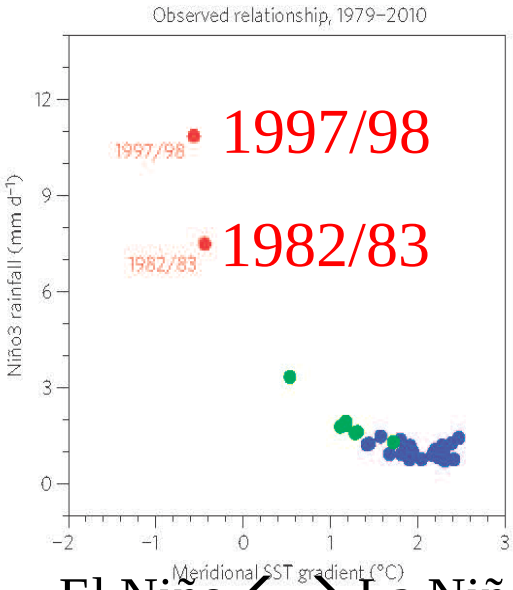
3. Future mean precipitation in CEP shows a 7%/K increase, and the amount of change may be underestimated in CMIP5 models

Backup

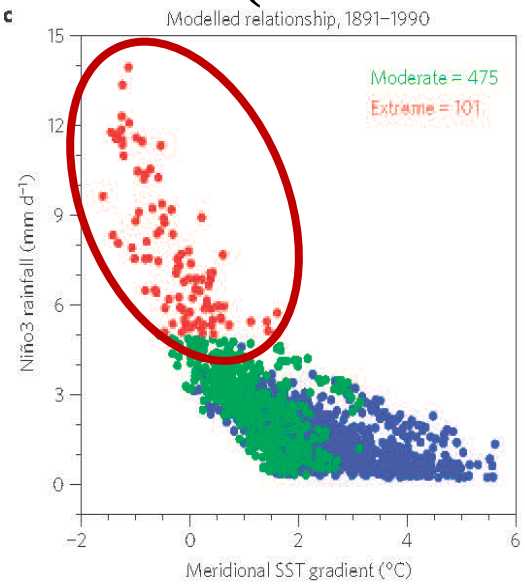
Change in tropical precip variability

Nino3 rainfall

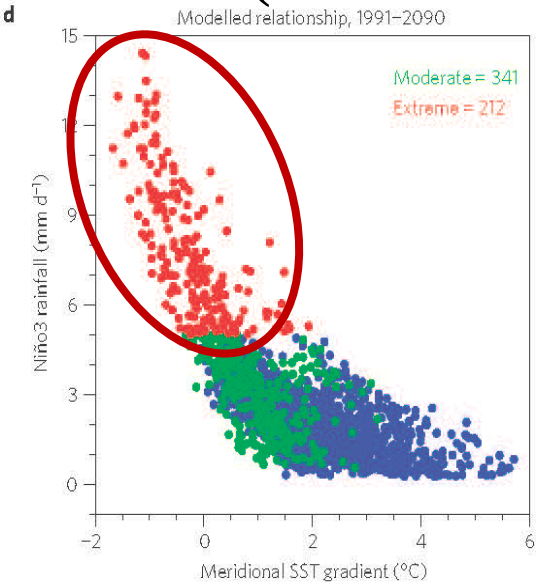
Observations



CMIP5 (1891-1990)



CMIP5 (1991-2090)



El Niño ←→ La Niña

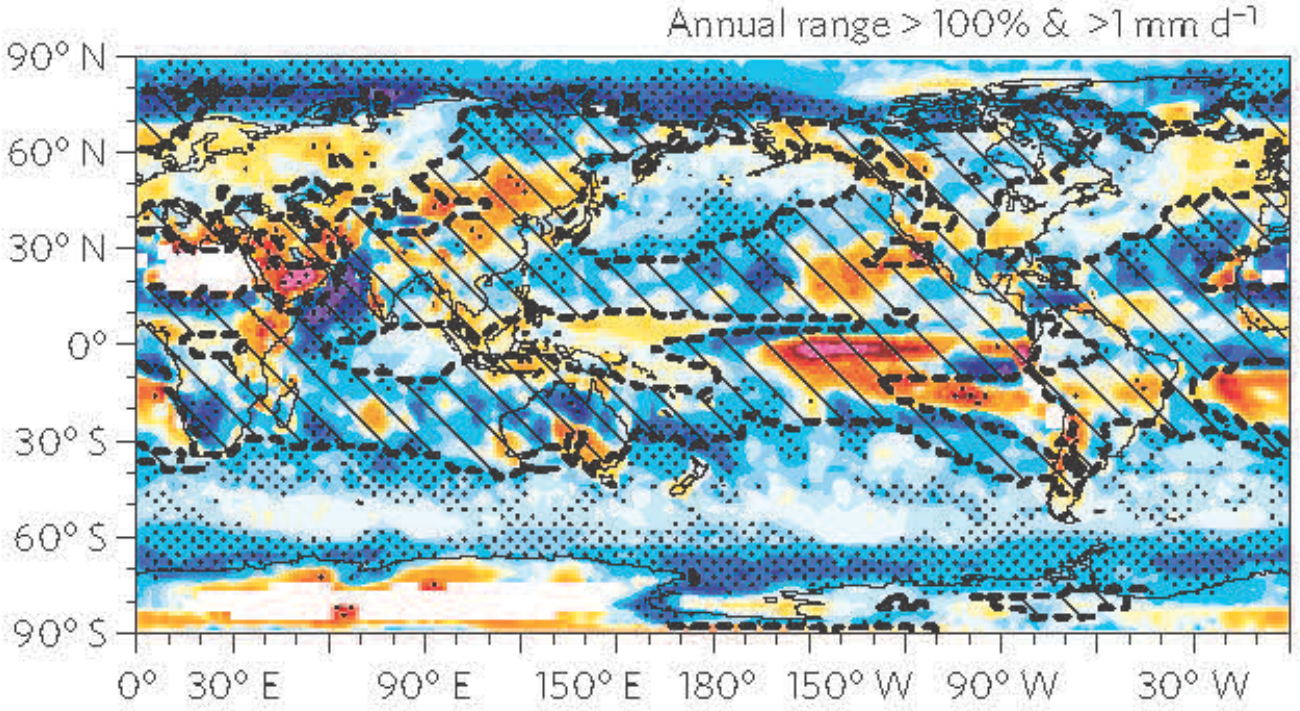
Meridional SST gradient (5–10N, 90–150W minus 2.5S–2.5N, 90–150W)

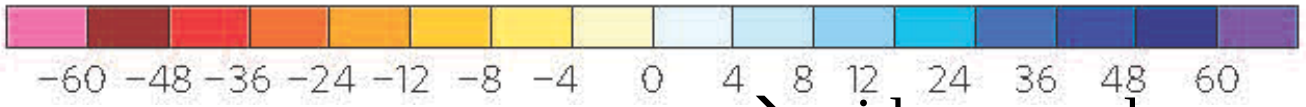
Increasing number of extreme El Niños *if* rainfall measure were used

Cai et al. (2014)

Wet season wetter, dry season drier

Observed linear trend for precip annual range (1979-2010)





(%/decade)

→ wider annual range

Chou et al. (2013)