

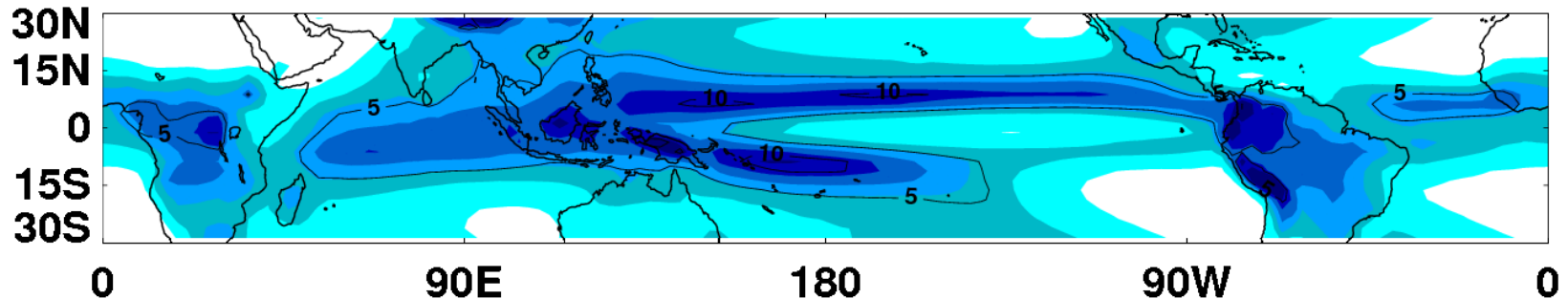
Spatial Patterns of Precipitation Change in CMIP5: Why the Rich don't get Richer in the Tropics

Rob Chadwick, Ian Boutle and Gill Martin

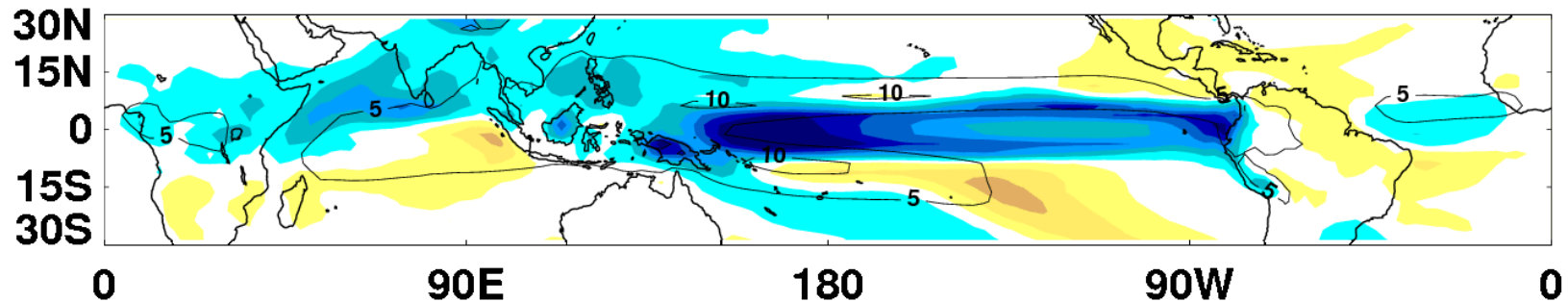
With thanks to: Peter Good, Peili Wu, Mark Webb, Mark Ringer, Jamie Kettleborough, Ian Edmond & Emma Hibling

'Rich get Richer' in the tropics?

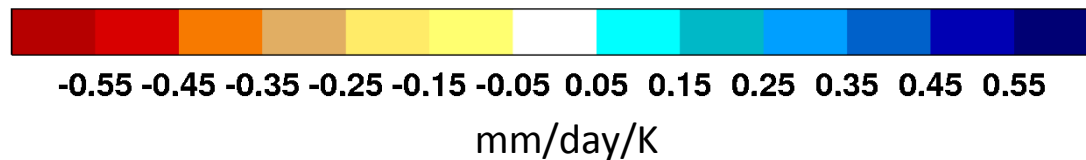
Thermodynamic multi-model mean CMIP5 precip change



Total multi-model mean CMIP5 precip change



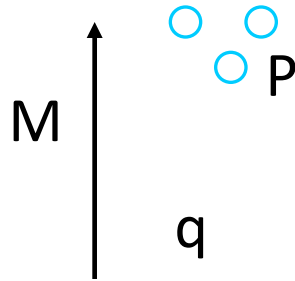
Colours = RCP8.5
2071-2100 –
1971-2000 precip
change



Line contours
= 1971-2000
climatological
precip

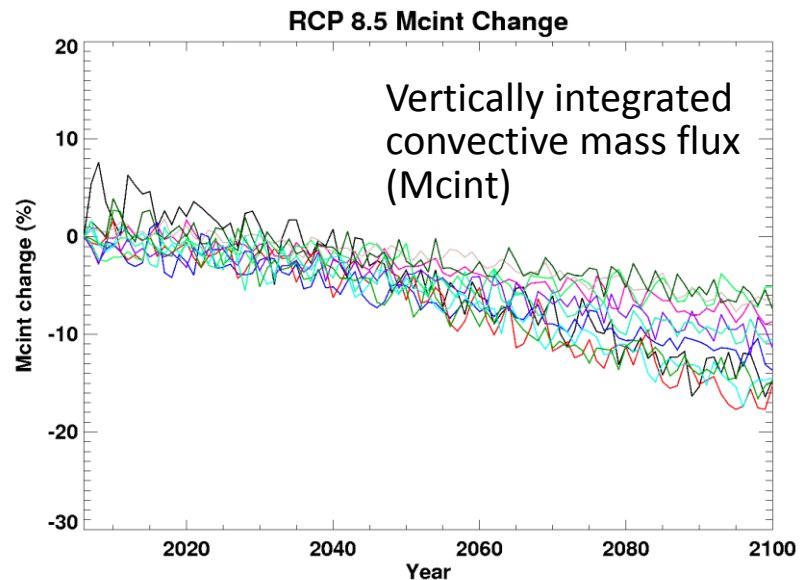
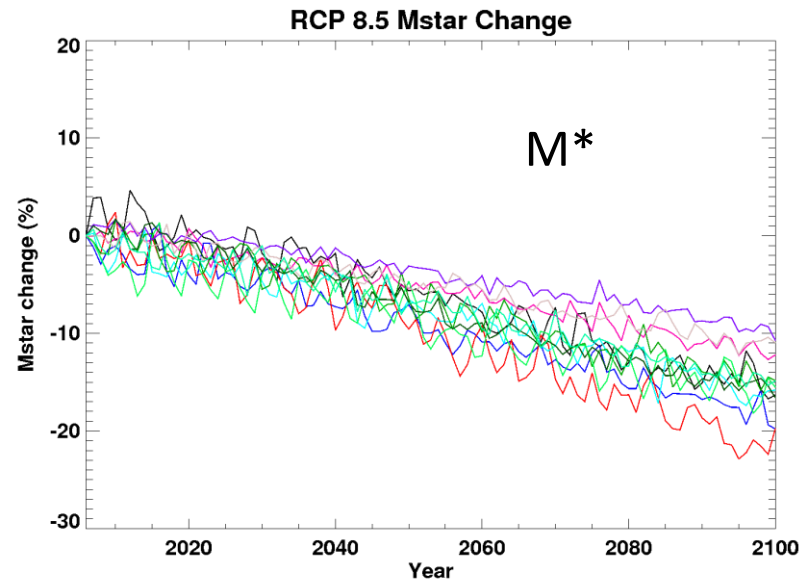
Tropical mean circulation change

$$P = Mq$$



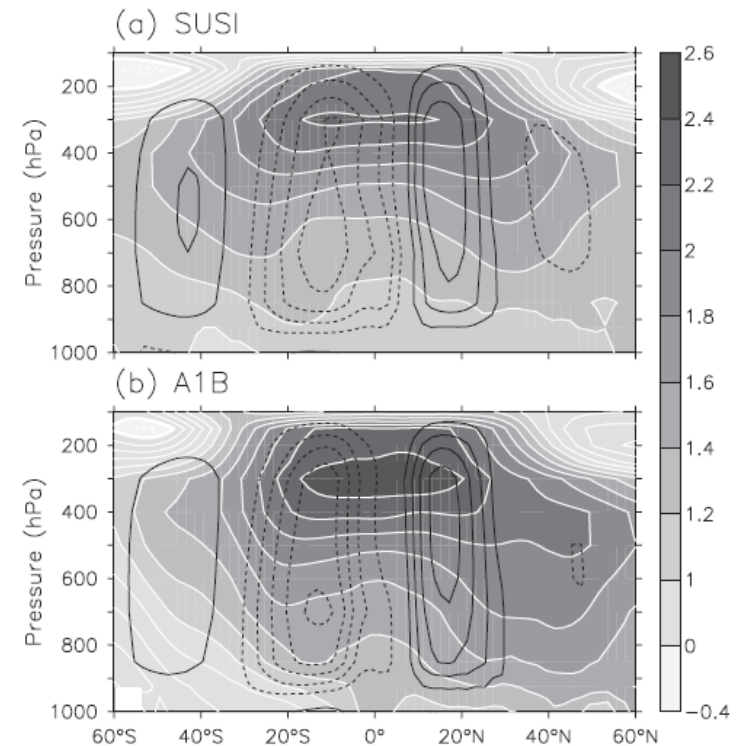
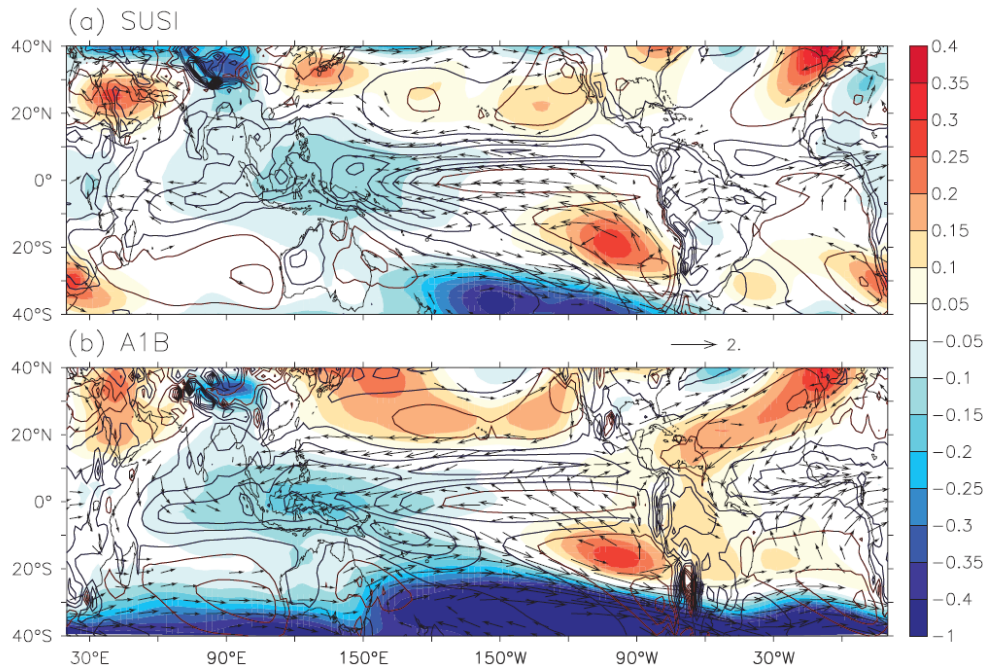
$$M^* = \frac{P}{q}$$

Held & Soden '06,
Vecchi & Soden '07



Mechanisms behind tropical circulation change

SUSI = +2K uniform SST experiment

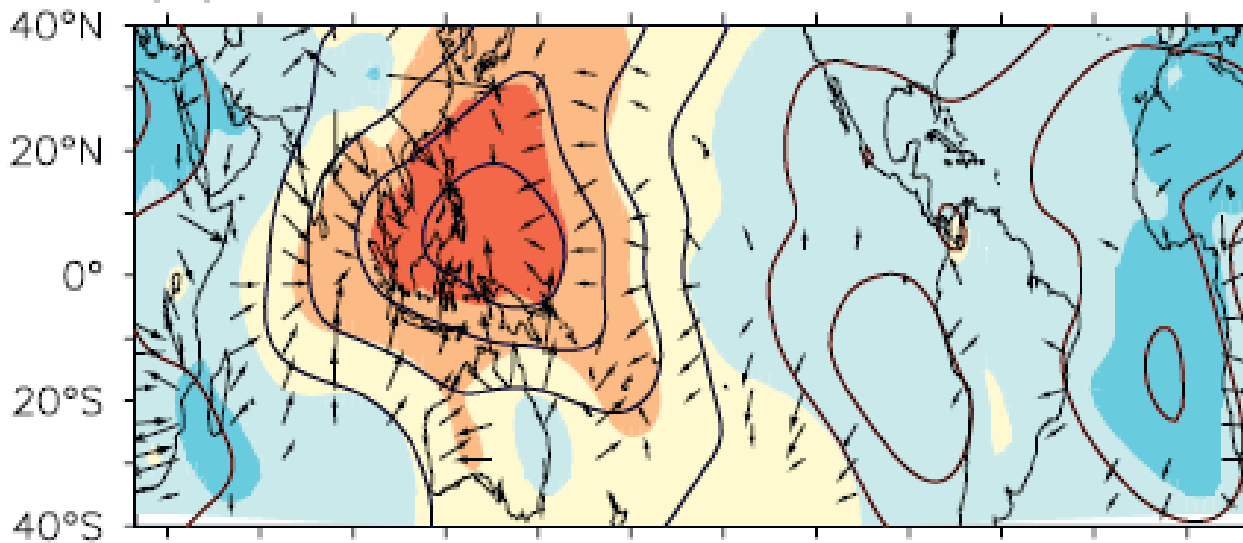


Ma et al '12

Knutson & Manabe '95

A Divergence Feedback on Precipitation change

(a) MASC (Mean Advection of Stratification Change)



Line contours = climatological 200hPa velocity potential (χ), (black lines -ve, brown +ve)

Colours = change in 200hPa velocity potential (χ) under MASC forcing (red +ve, blue -ve)

$$\Delta\chi \propto -\chi$$

$$\Delta\chi = -\alpha\chi$$

where α is constant

$$\Rightarrow \Delta\delta = -\alpha\delta$$

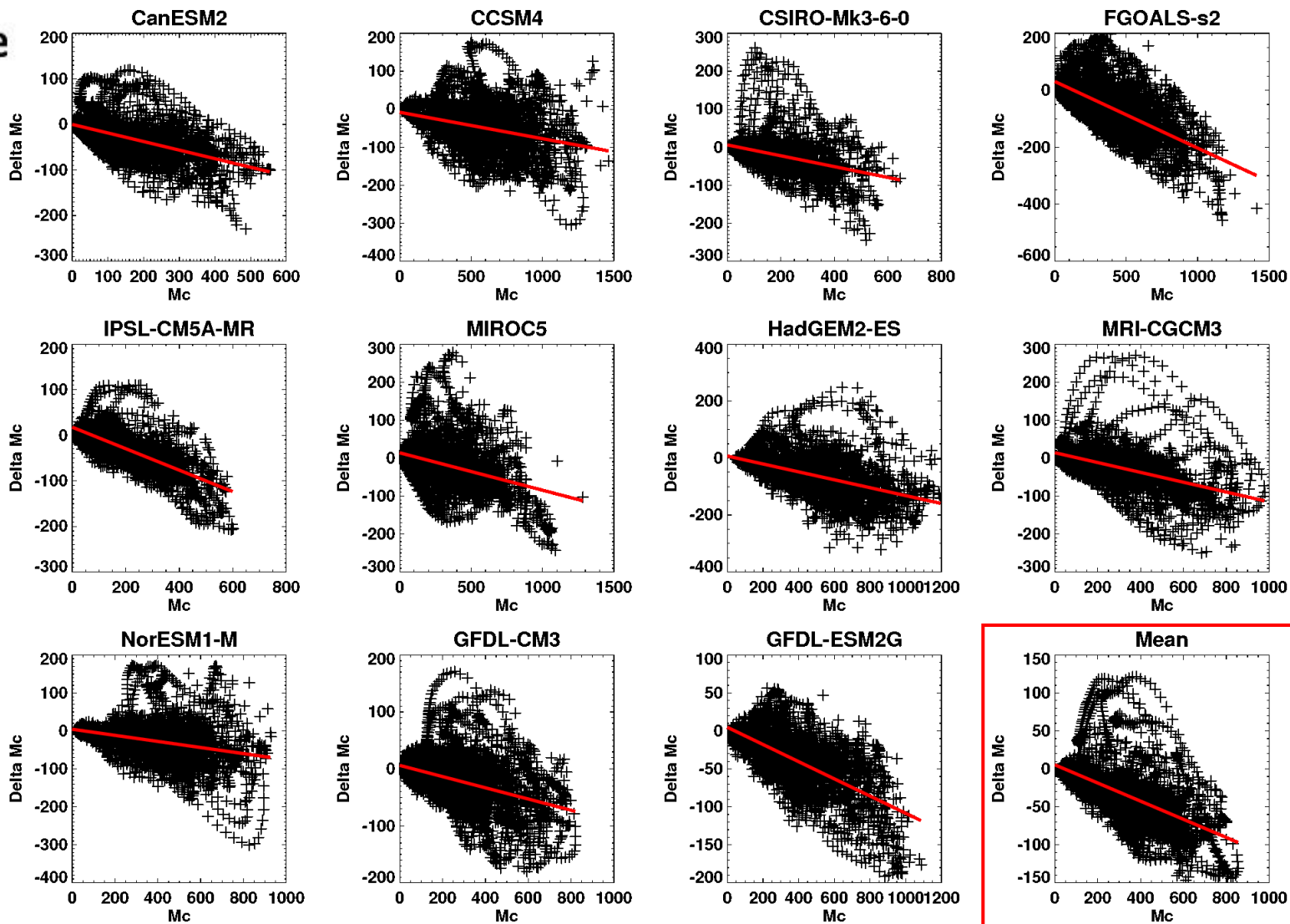
Ma et al '12

Mass flux change

$$\Delta M_{div} = -\alpha M$$

Scatterplots compare all tropical gridpoints for periods 1971-2000 and 2071-2100 under the RCP8.5 scenario

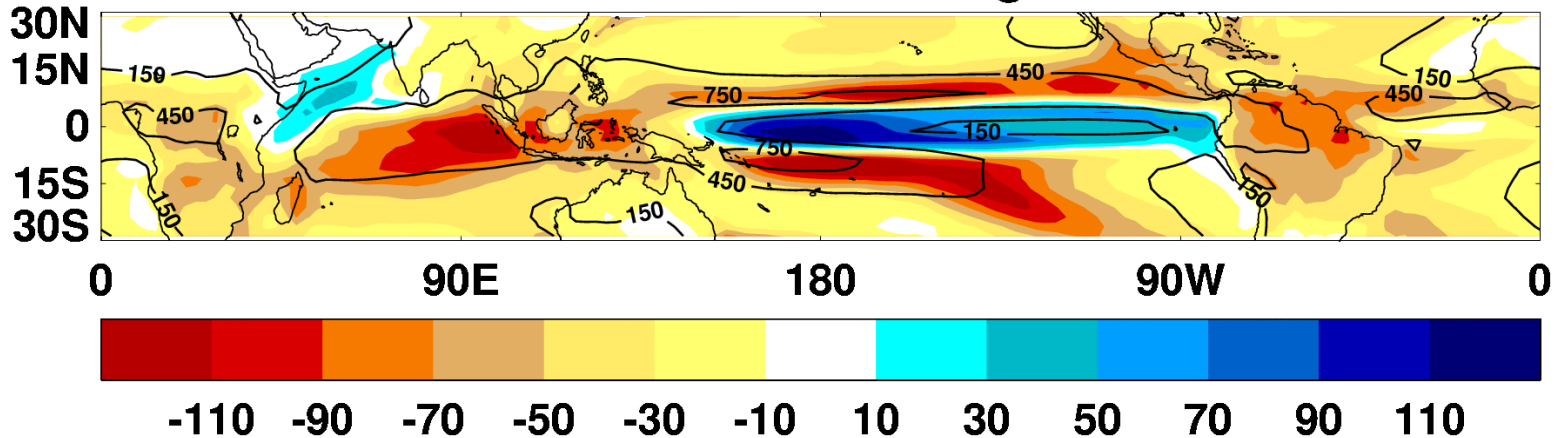
Least squares fit



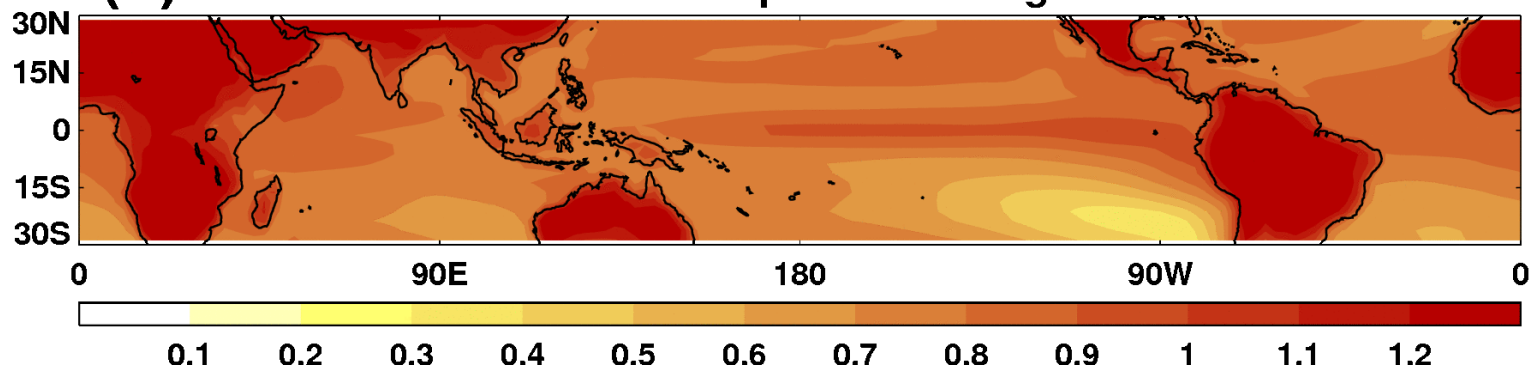
Multi-model mean changes

Line contours
= 1971-2000
climatological
mass flux

Mean Mint change

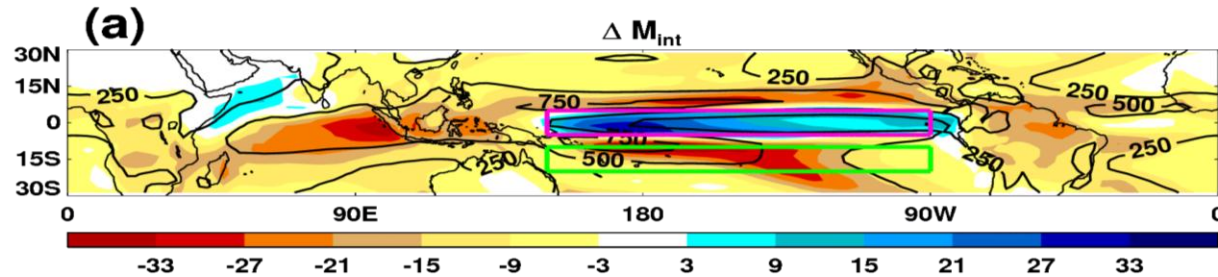


Mean Surface temperature change (K)



Spatial and weakening components of Mass-flux change

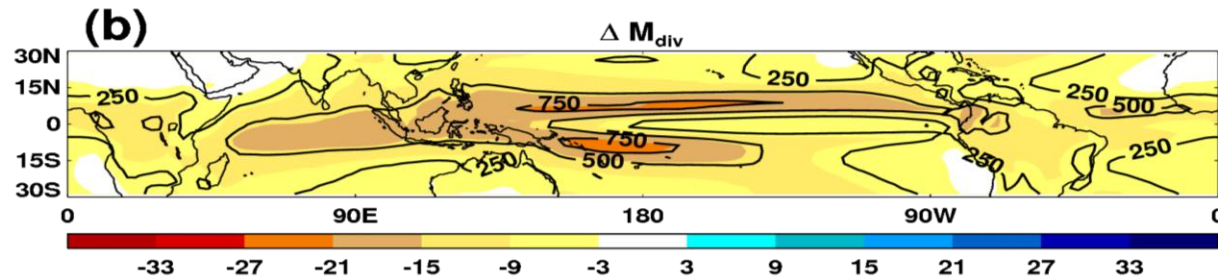
Total



Line contours
= 1971-2000
climatological
mass flux

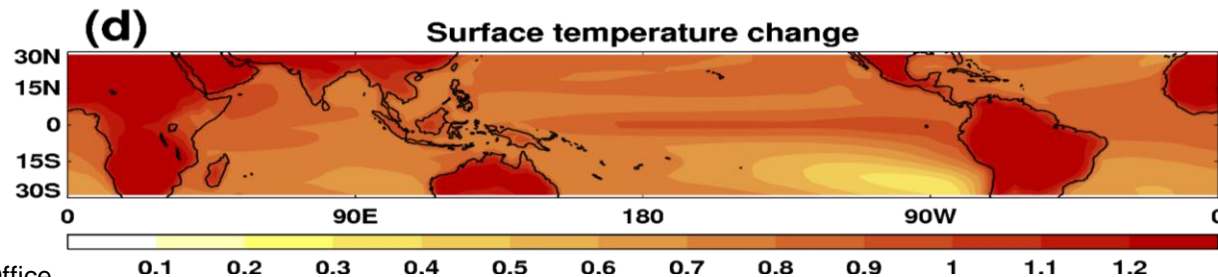
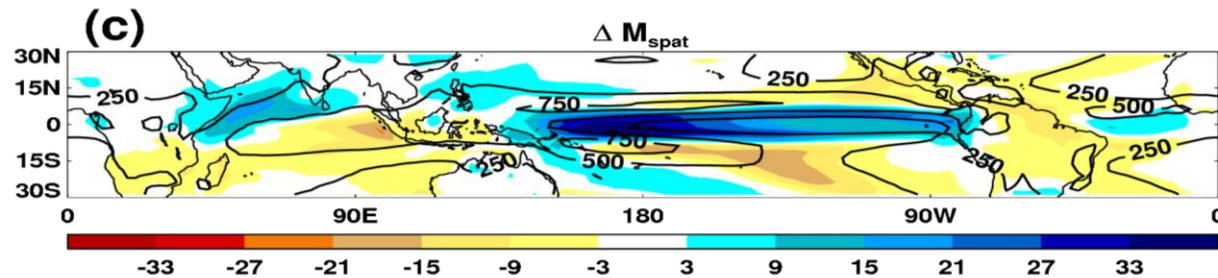
Weakening
component

$$\Delta M_{div} = -\alpha M$$



Spatial
component

$$\Delta M_{spat} = \Delta M - \Delta M_{div}$$



Components of precip change

$$P = Mq$$

$$P' = (Mq)'$$

$$= M_1 q' + M' q_1 + M' q'$$

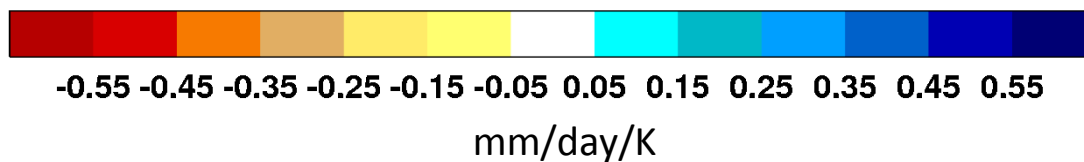
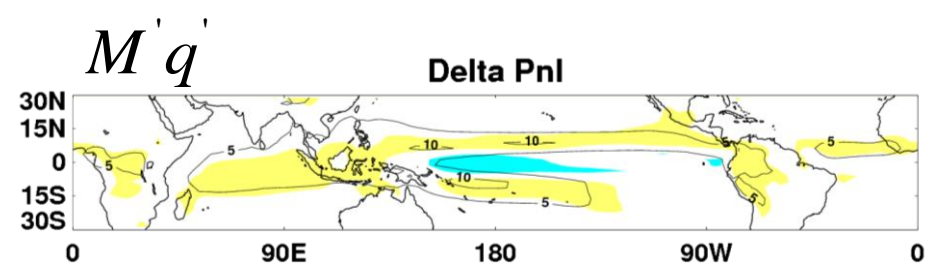
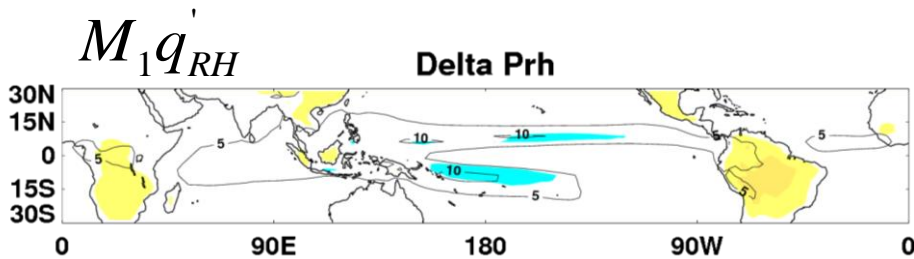
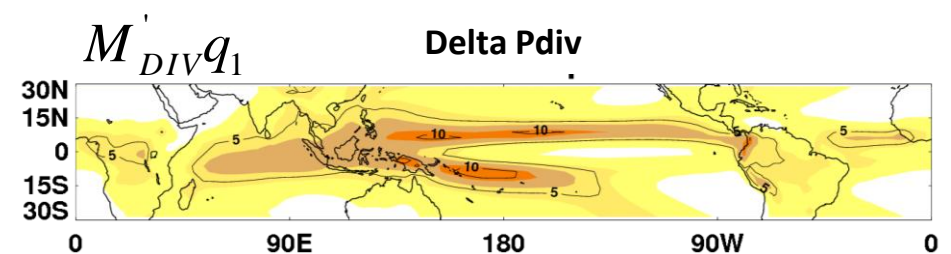
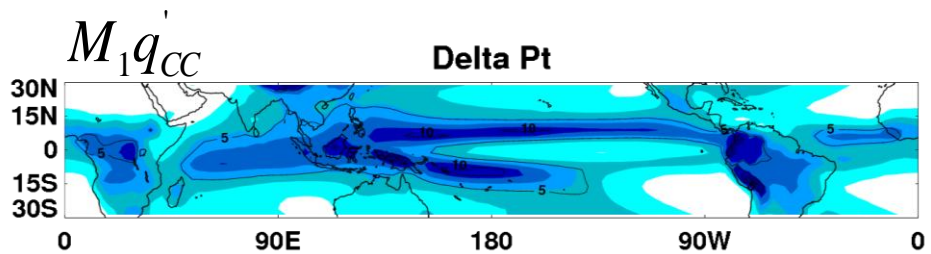
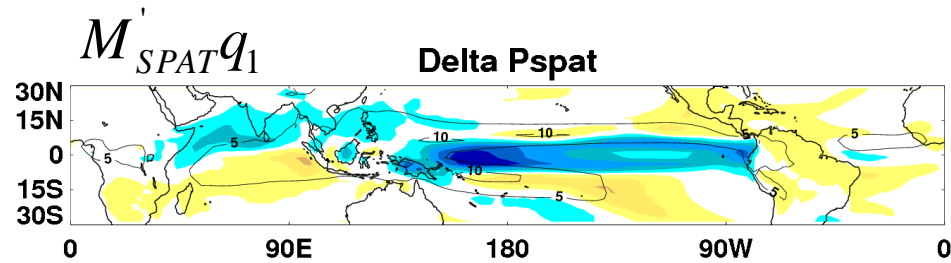
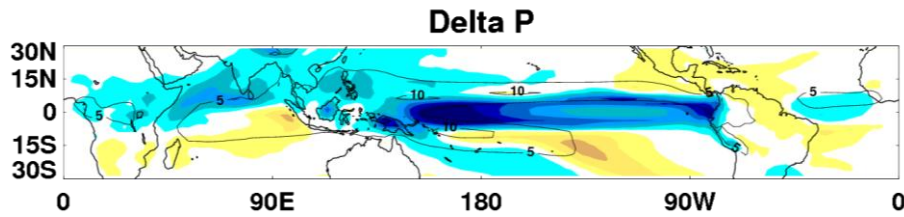
$$= M_1 q'_{CC} + M_1 q'_{RH} + M'_{DIV} q_1 + M'_{SPAT} q_1 + M' q'$$

$$= P'_T + P'_{RH} + P'_{DIV} + P'_{SPAT} + P'_{NL}$$

Prime (') denotes climate change perturbation

Subscript 1 denotes 1971-2000 mean

Multi-model mean precip change



Line contours
= 1971-2000
climatological
precip



Met Office

Zonal mean precip change

P'

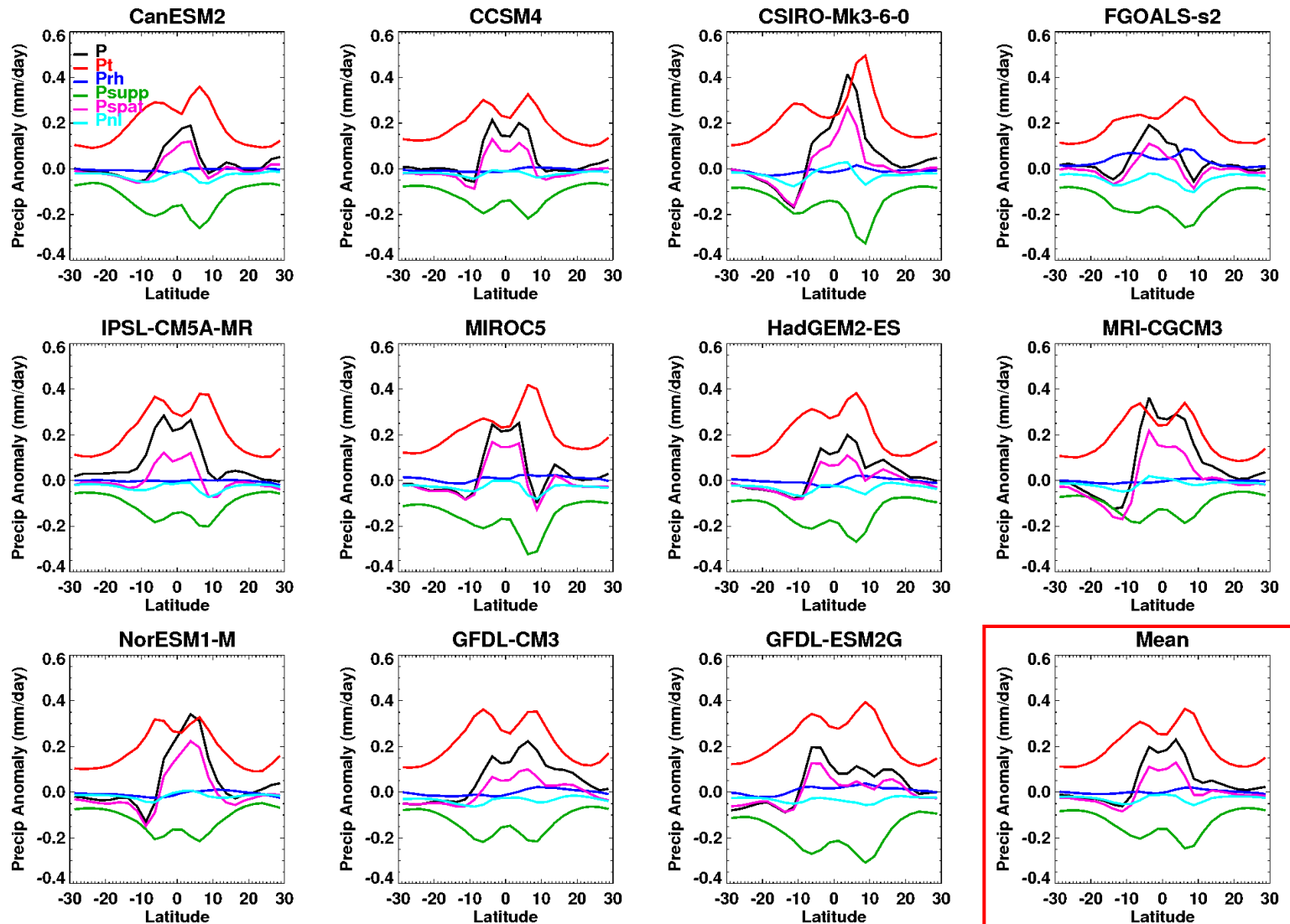
Pt'

Prh'

Pdiv'

Pspat'

Pnl'



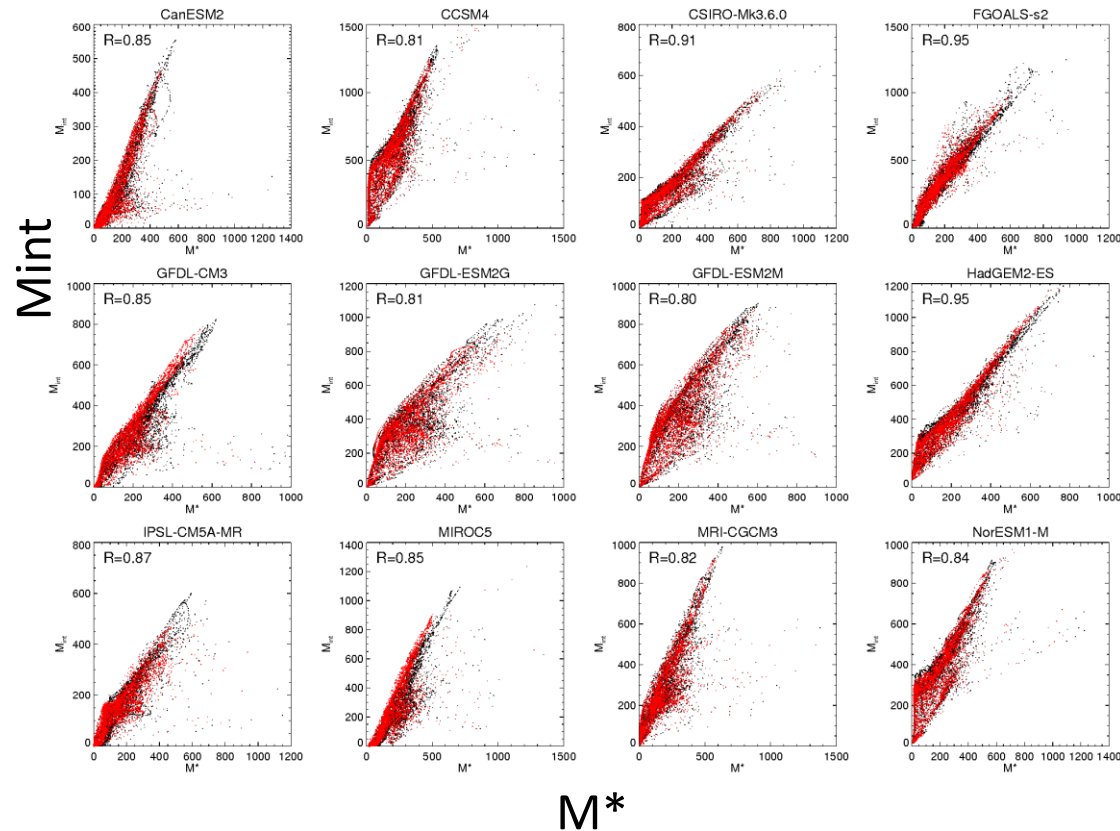
Summary & Conclusions

- CMIP5 models show a robust weakening of the tropical circulation, with climatological ascent regions weakening the most (a divergence feedback).
- The pattern of tropical precipitation change can be understood as a sum of different components. Useful tool for understanding uncertainty in precip change.
- The 'rich get richer' mechanism is not the dominant factor in shaping the patterns of tropical precip change. Largely negated by the weakened circulation.
- The spatial component of precip change dominates the shape of both the mean and inter-model uncertainty in the pattern of precip change.
- Spatial component is associated with SST pattern change, land-sea temperature gradient change, and any other mechanisms which can alter regions of convergence and convection.

See Chadwick et al. 2013, 'Spatial Patterns of Precipitation Change in CMIP5: Why the Rich don't get Richer in the Tropics', J. Climate, 26, 3803-3822.

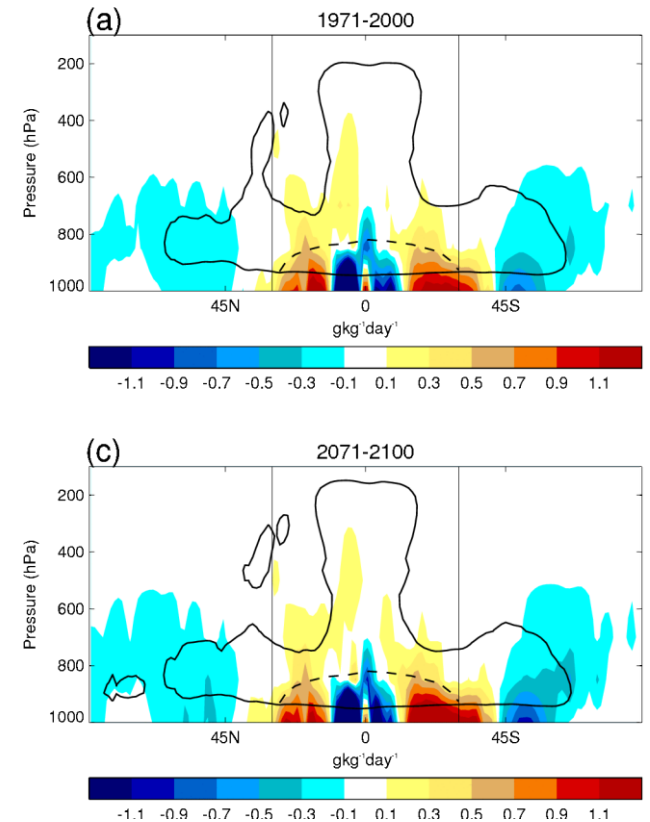
Thanks for listening. Any questions?

Physical meaning of M^*



1971-2000

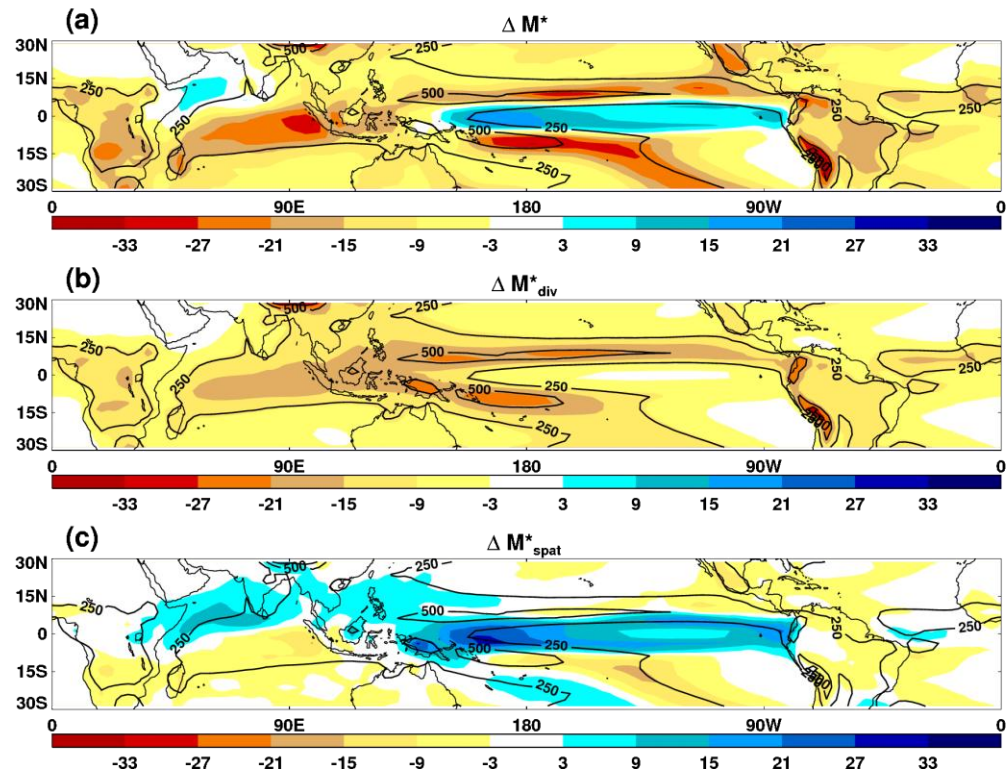
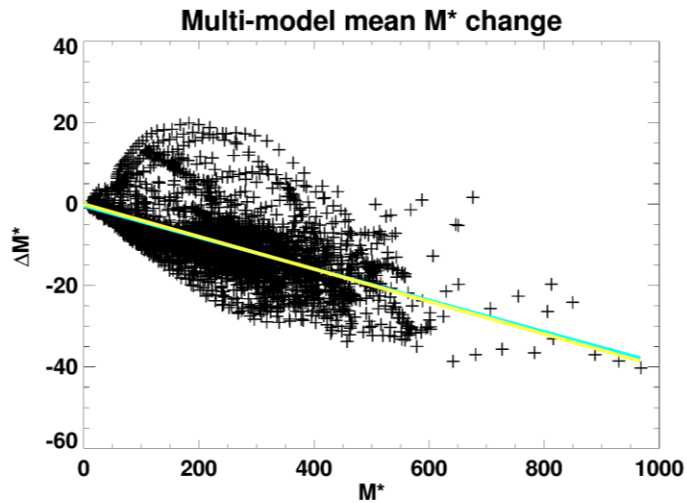
2071-2100



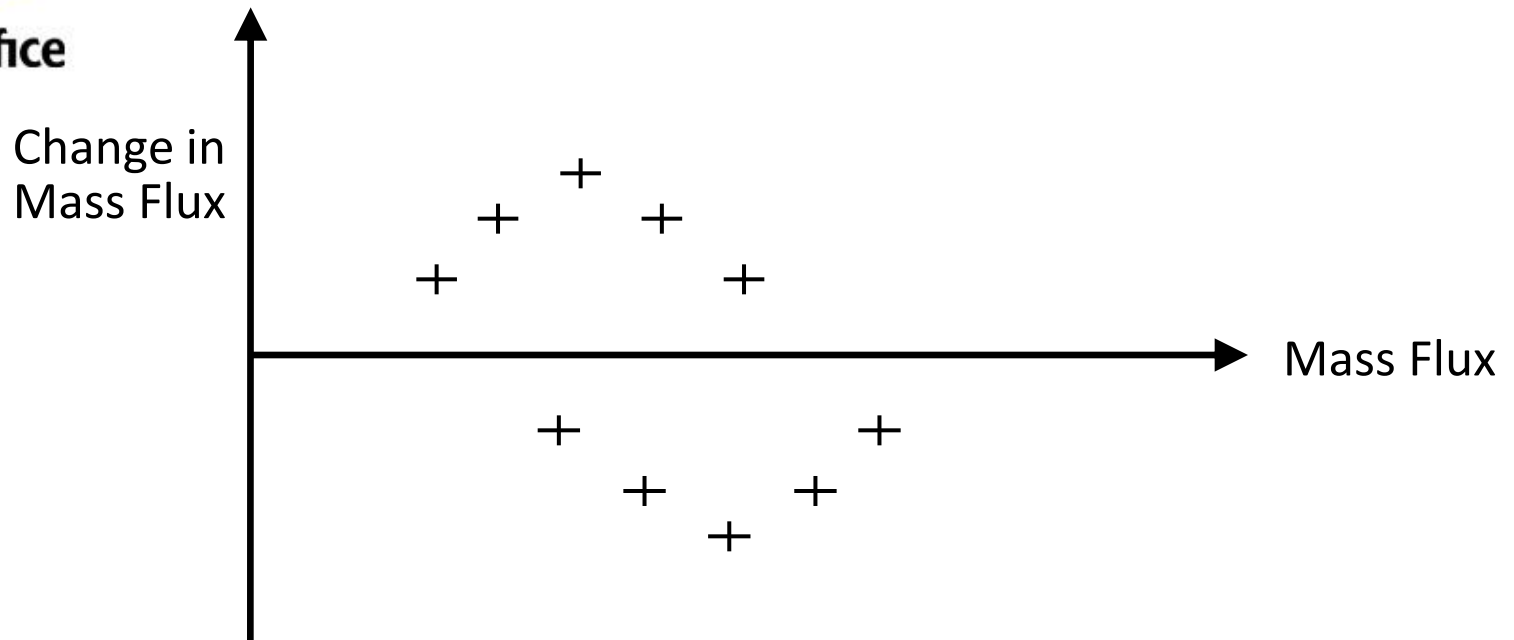
Colours = zonal mean moisture divergence

Line contours = mean convective cloud base and top

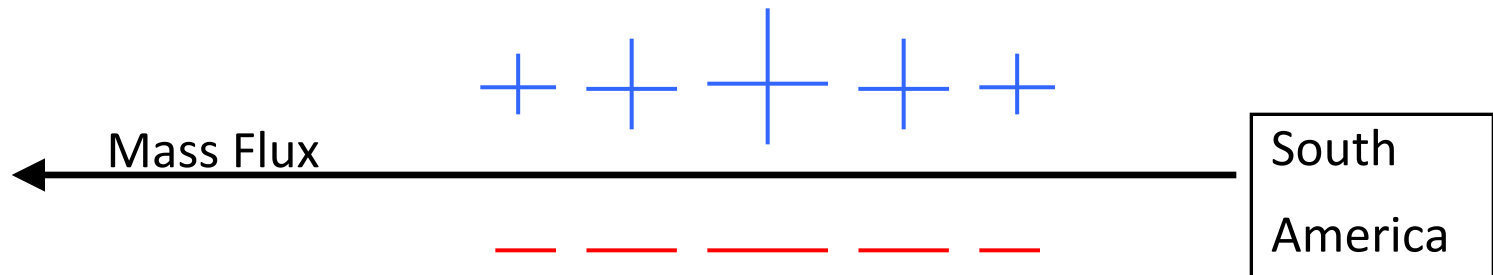
Use of proxy mass-flux



Spatial shifts in mass flux



Maritime
Continent



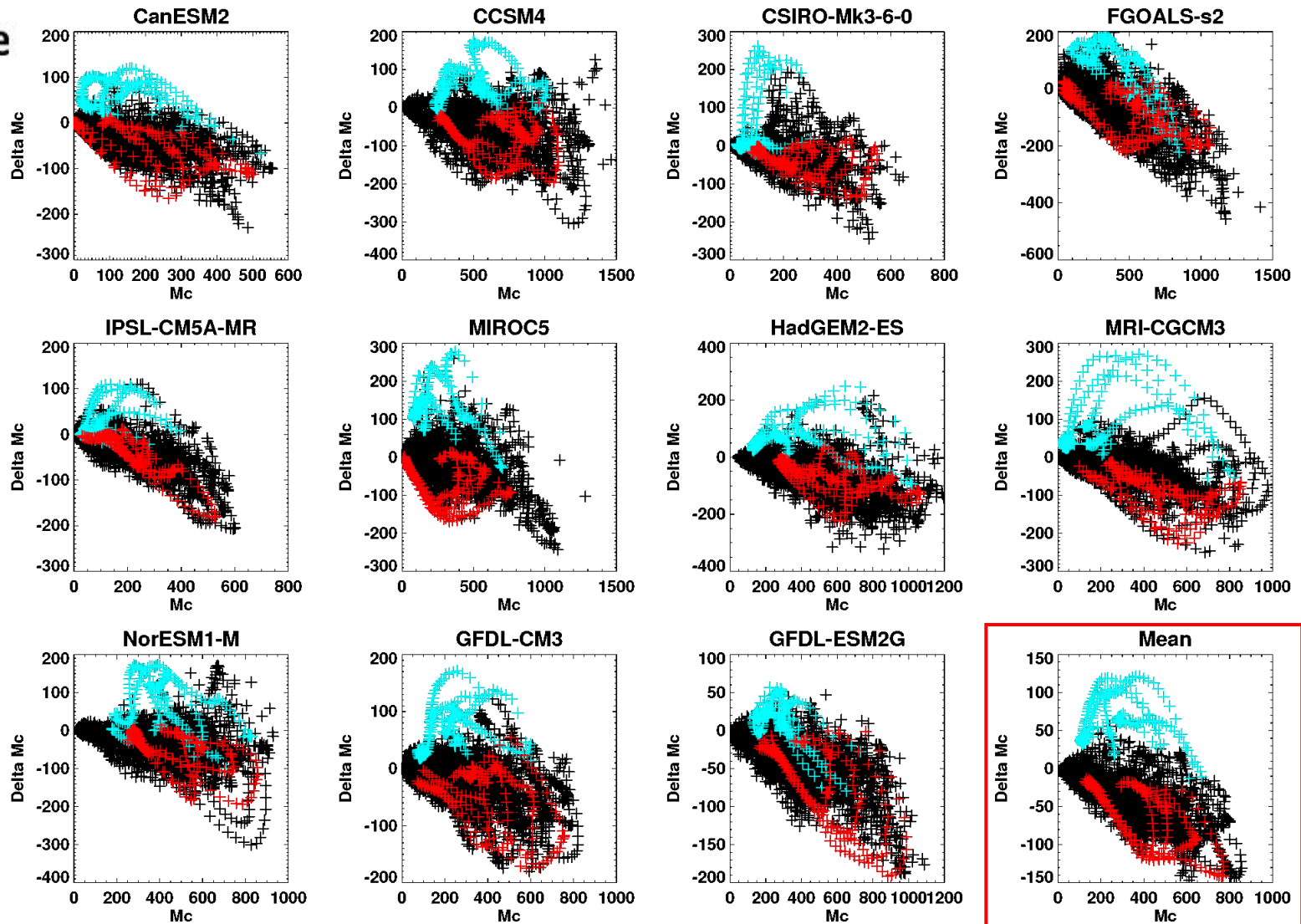


Met Office

5N-5S

10S-20S

Tropical Pacific mass flux change



Convection depth change

