On the interpretation of inter-model spread in CMIP5 climate sensitivity estimates

Jessica Vial · Jean-Louis Dufresne · Sandrine Bony

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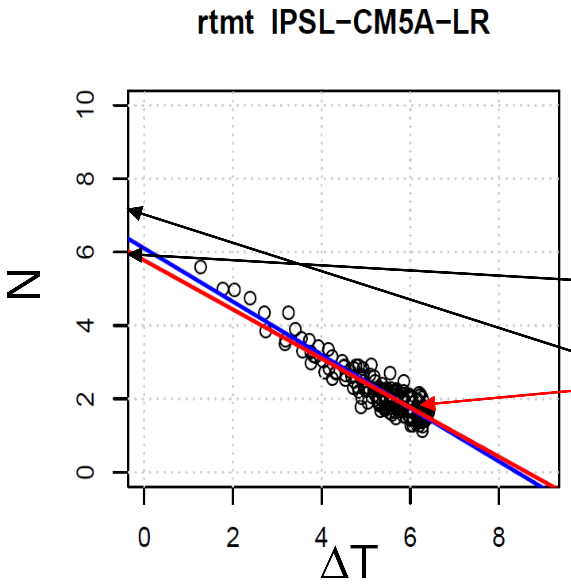
The abrupt 4xCO2 experiment



(Gregory et al., 2004, Gregory and Webb, 2008)

$N \approx \Delta Q_{4x} + \lambda \, \Delta T$

Linear regression between N and ΔT

ΔQ_{4x} : intercept

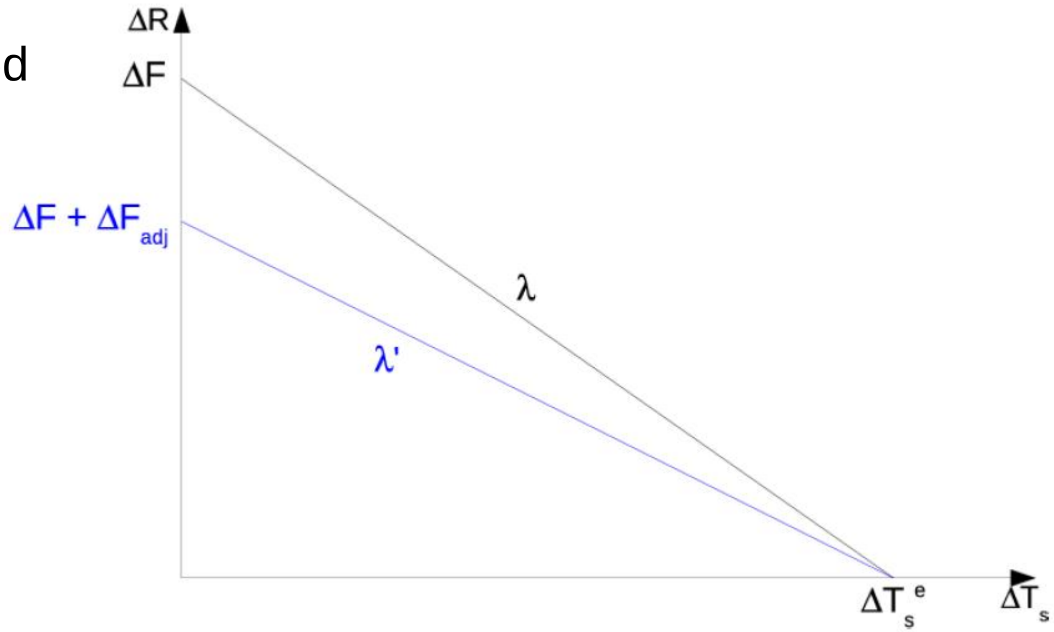
λ : slope

Classical estimate of ΔQ_{4x}

Difference in forcing estimate: fast response

Non adjusted forcing

Adjusted forcing



$$\underbrace{\Delta R(\Delta CO_2, \Delta T_s)}_{\text{abrupt\_4xCO2 - piControl} \approx \text{abrupt\_4xCO2 - SSTclim}} = \underbrace{\Delta R(\Delta CO_2, T)}_{\Delta F' = \Delta F + \Delta F_{adj}} + \underbrace{\Delta R(4 \times CO_2, \Delta T_s)}_{\lambda' \, \Delta T}$$

abrupt_4xCO2 - piControl ≈ abrupt_4xCO2 - SSTclim

SSTclim_4xCO2 - SSTclim

abrupt_4xCO2 – SSTclim_4xCO2

Methode

Decomposition of the adjustment to the forcing:

$$\sum_x \Delta F_x = \Delta F_{adj}$$

$$\Delta F_x = \frac{\partial R}{\partial x} \Delta x = K_x \Delta x$$

Kernel method

Decomposition of the feedbacks:

$$\lambda = \sum_x \lambda_x = \lambda_{pk} + \lambda_{lr} + \lambda_{wv} + \lambda_{alb} + \lambda_{cl}$$

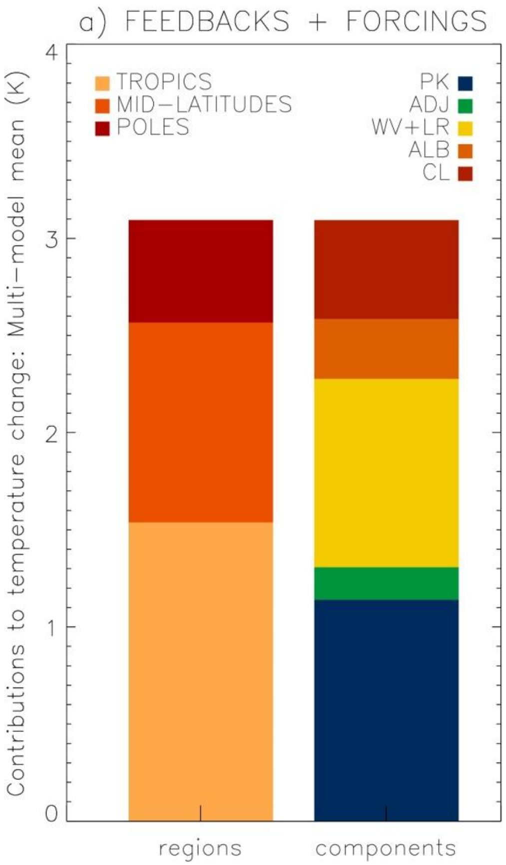
$$\Delta R_x = \frac{\partial R}{\partial x} \Delta x = K_x \Delta x$$

$$\lambda_x = \frac{\Delta R_x - \Delta F_x}{\Delta T_s}$$

Decomposition the contribution to temperature increase for a CO2 doubling

$$\Delta T_s = \Delta T_{s,pk} + \Delta T_{s,adj} + \sum_{x \neq pk,adj} \Delta T_{s,x}$$

$$\Delta T_{s,pk} \rightarrow -\frac{\Delta F}{\lambda_{pk}} \qquad \Delta T_{s,adj} \rightarrow -\frac{\sum_x \Delta F_x}{\lambda_{pk}} \qquad \Delta T_{s,x} \rightarrow -\frac{\lambda_x}{\lambda_{pk}} \Delta T_s$$

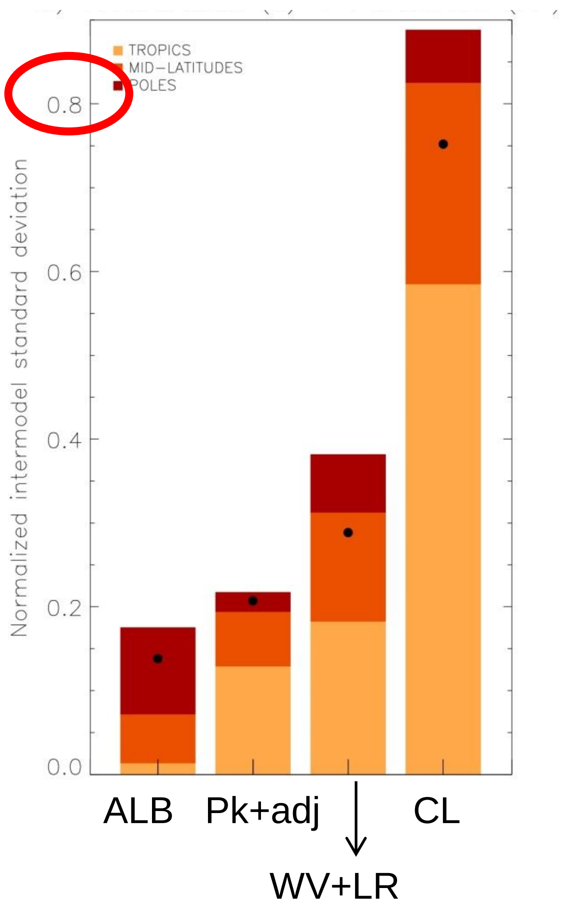


La contribution des rétroactions de chacune des régions est approx. proportionelle à sa surface

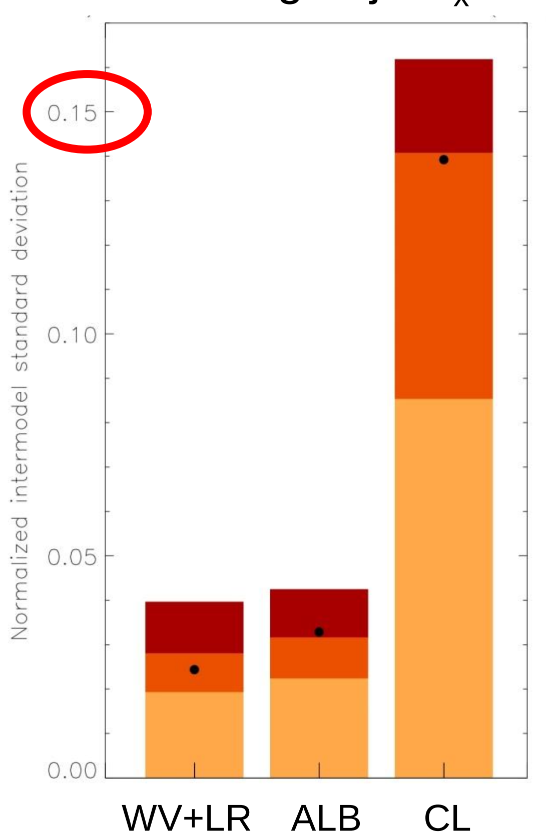
Decomposition the contribution to the ***spread*** of the temperature increase for a CO2 doubling

Normalized spread σ(ΔTx) / (Δ T)

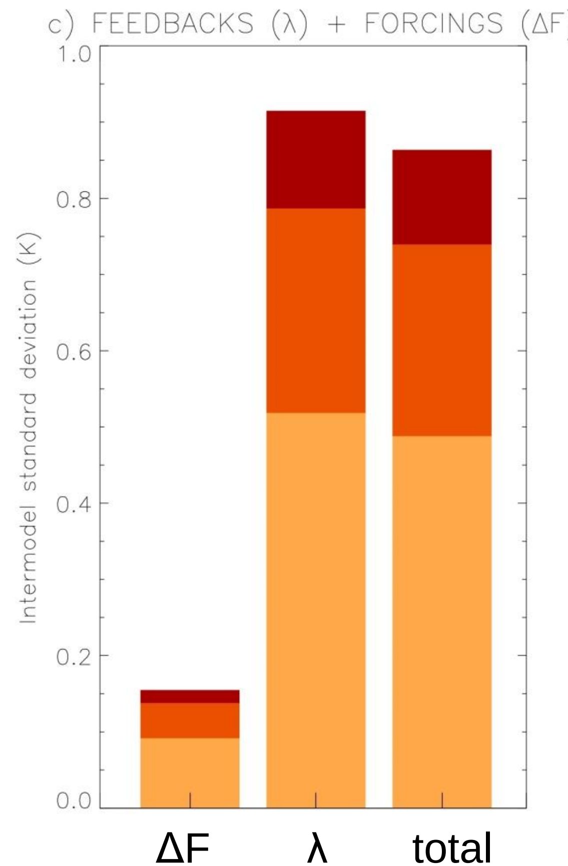
feedback λ_x
+forcing adj ΔF



forcing adj ΔF_x

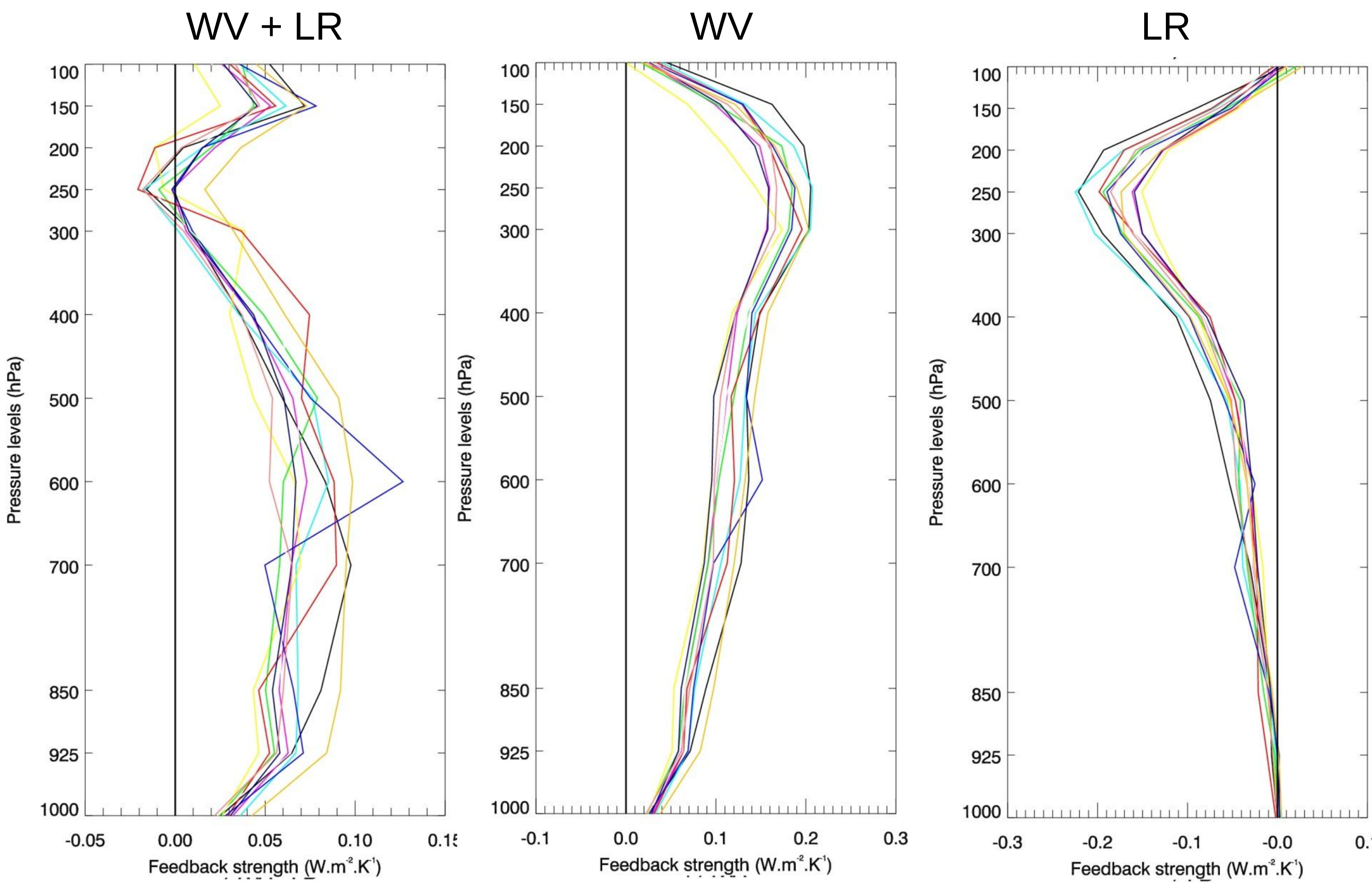


Spread σ(ΔTx)

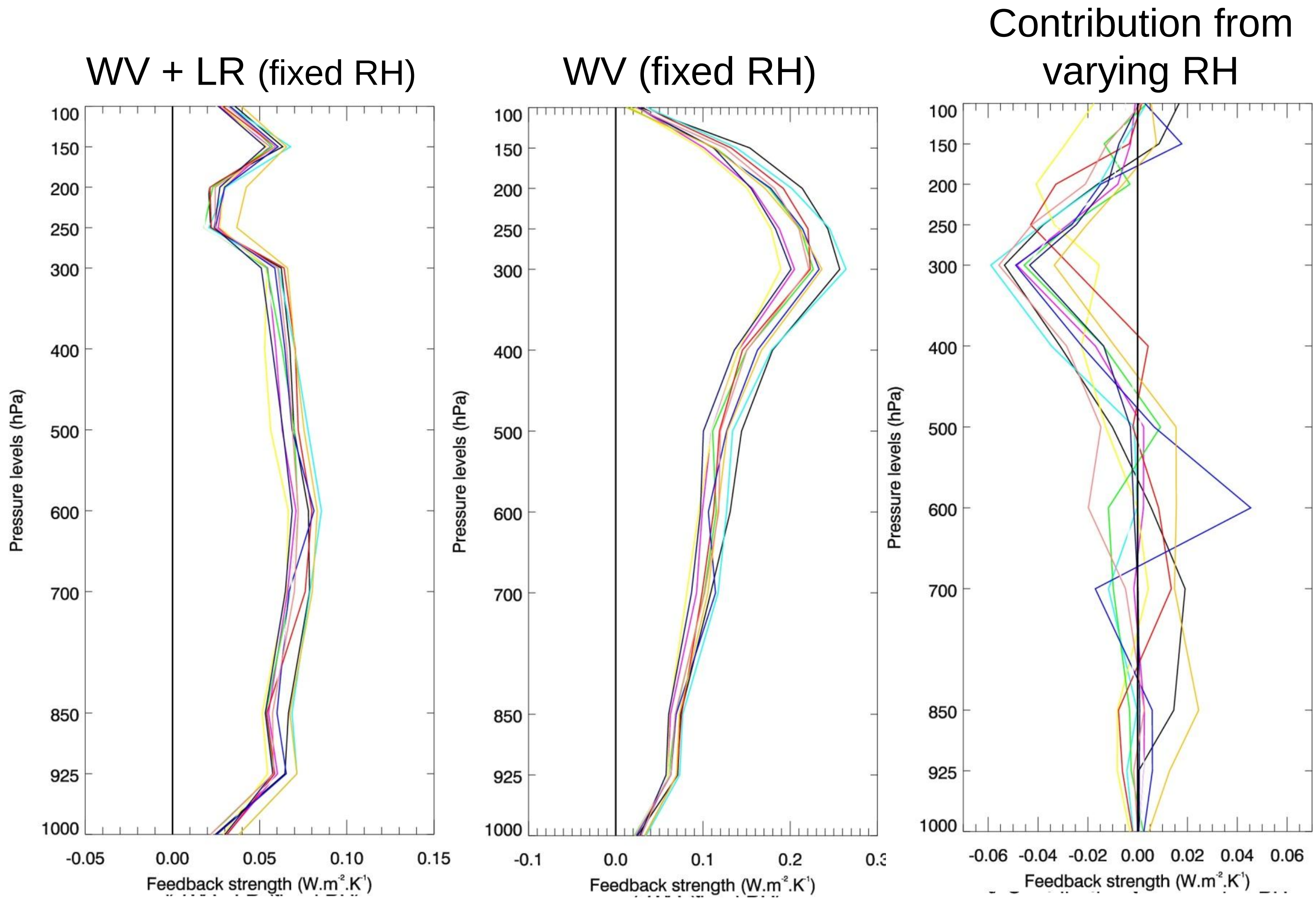


Water vapor + lapse rate feedback, in the tropics

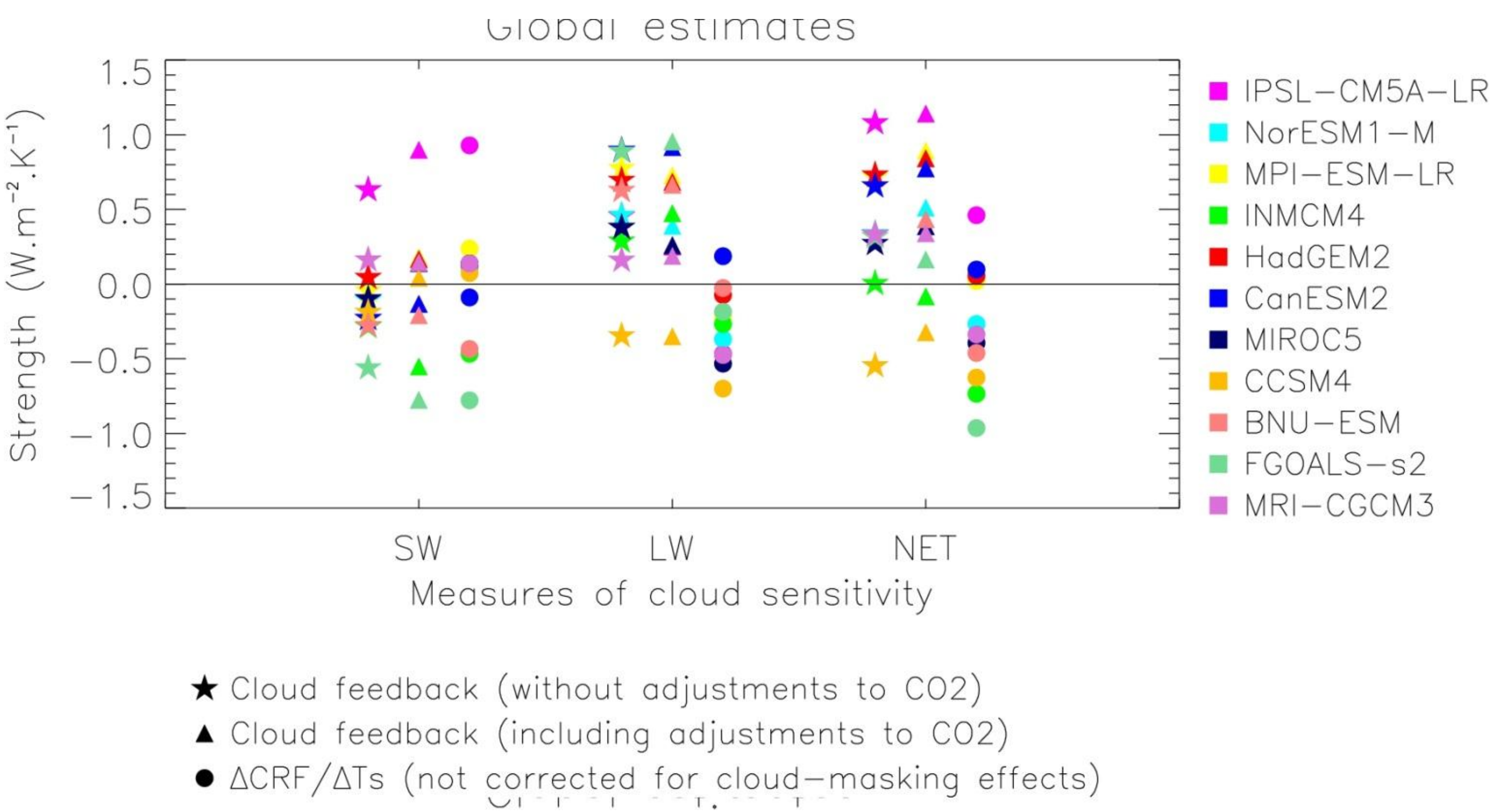
$$\Delta F_x = \frac{\partial R}{\partial x}\Delta x = K_x \Delta x$$



Water vapor + lapse rate feedback, in the tropics



Cloud feedback



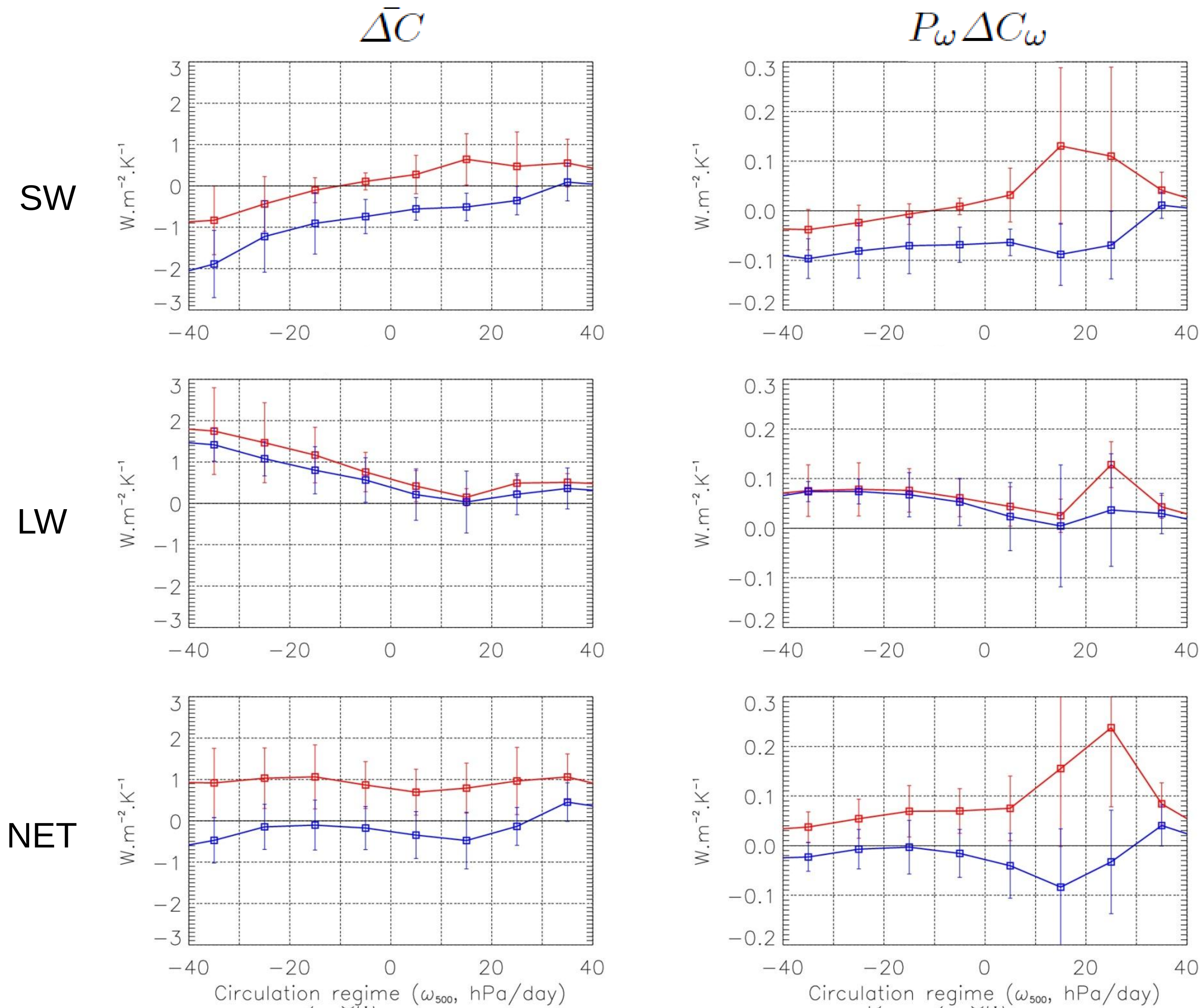
Cloud feedback

Over the tropical oceans,
Compositing into different dynamical regimes

$$\bar{C} = \sum_{\omega} P_{\omega} C_{\omega}$$

$$\Delta\bar{C} = \sum_{\omega} C_{\omega} \Delta P_{\omega} + \sum_{\omega} P_{\omega} \Delta C_{\omega} + \sum_{\omega} \Delta C_{\omega} \Delta P_{\omega}$$

Two classes of models: **high senstive** and **low sentive** models



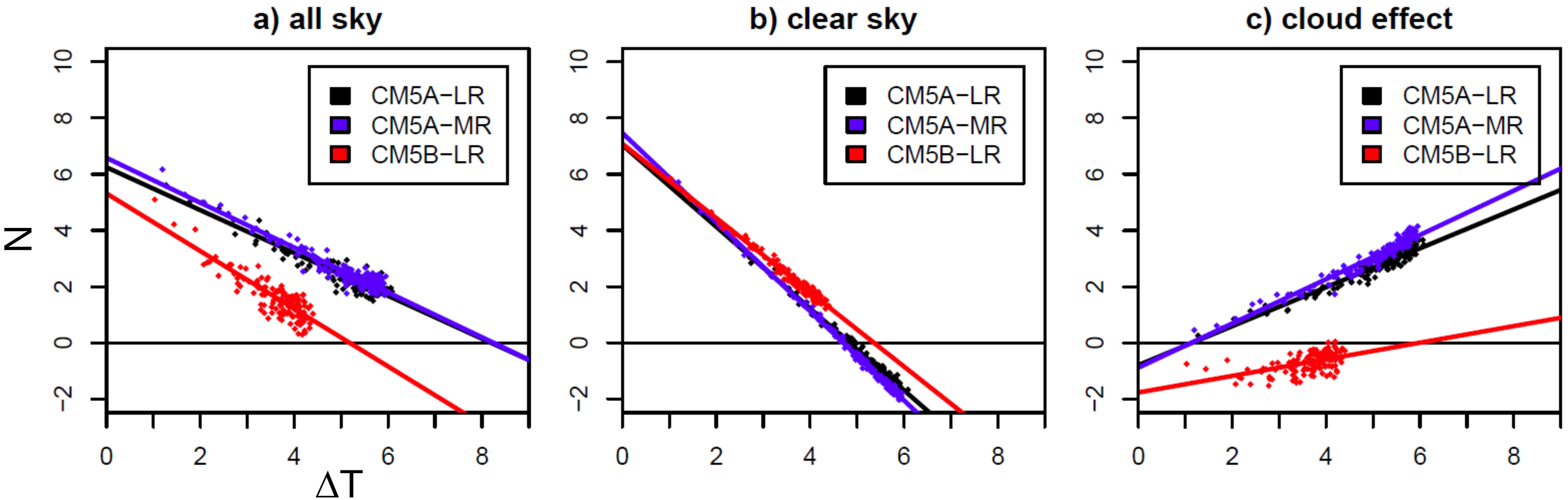
$\bar{\Delta C}$
$P_\omega \Delta C_\omega$
SW
LW
NET
W.m⁻².K⁻¹
Circulation regime (ω_{500}, hPa/day)

Conclusion

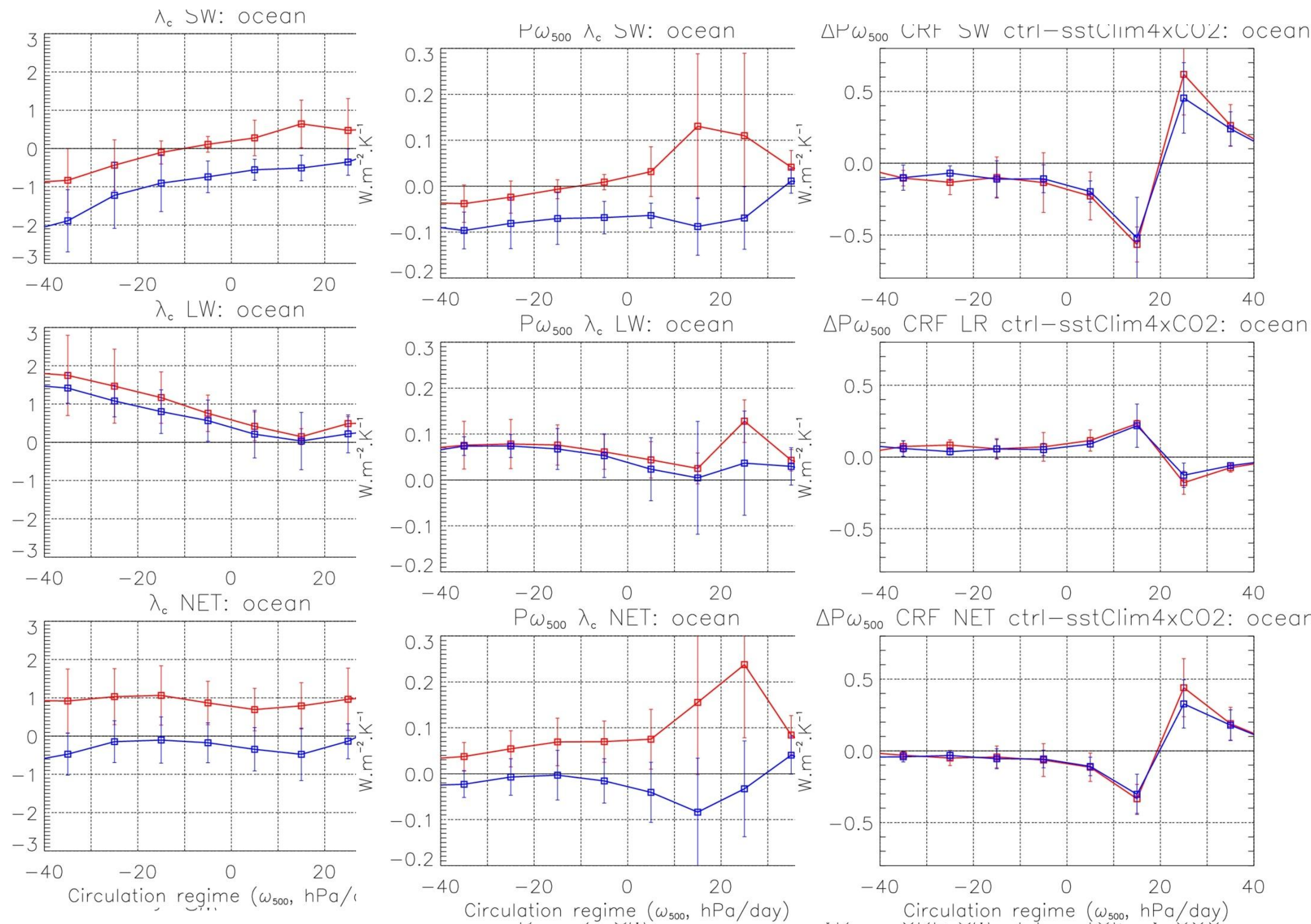
- Total feedback parameter is reduced by about 10% when considering effect of adjusment on the forcing
- The consideration of adjustemnt does not reduce the inetr-model spread of feedbacks
- Clouds remains the majotr contributor to the spread of climate sensitivity
- The spread of combined water vapour + lapse rate feedback is entirely due to differences in RH changes
- Spread in tropical clouds: mainly in the SW in region of shallow convection

Climate sensitivity for different IPSL-CM models

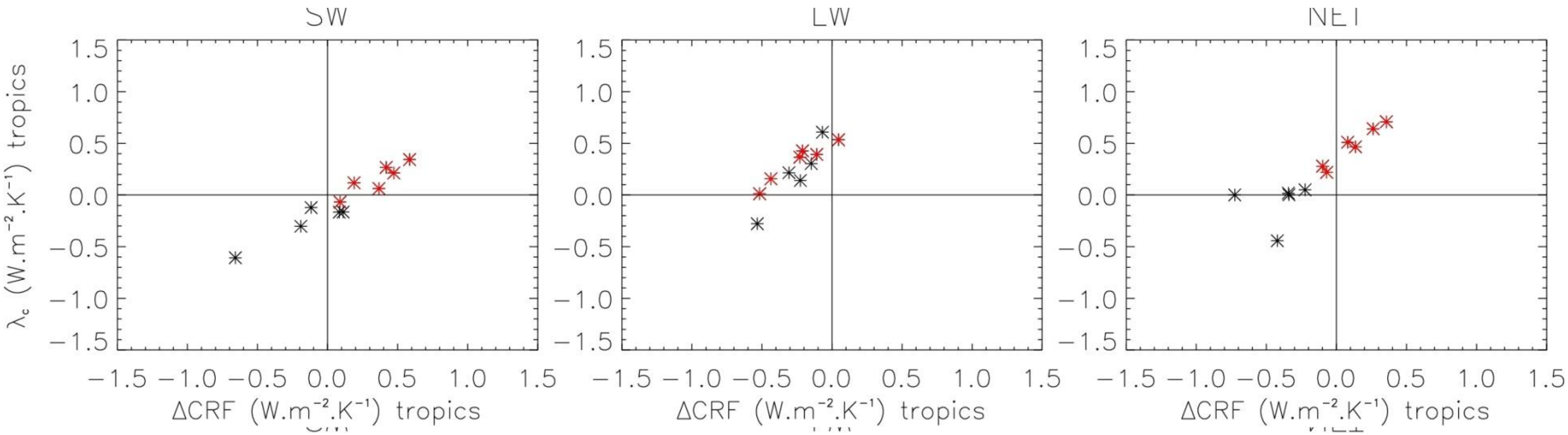
Flux TOA vs surface temperature for the abrupt 4xCO2 simulations



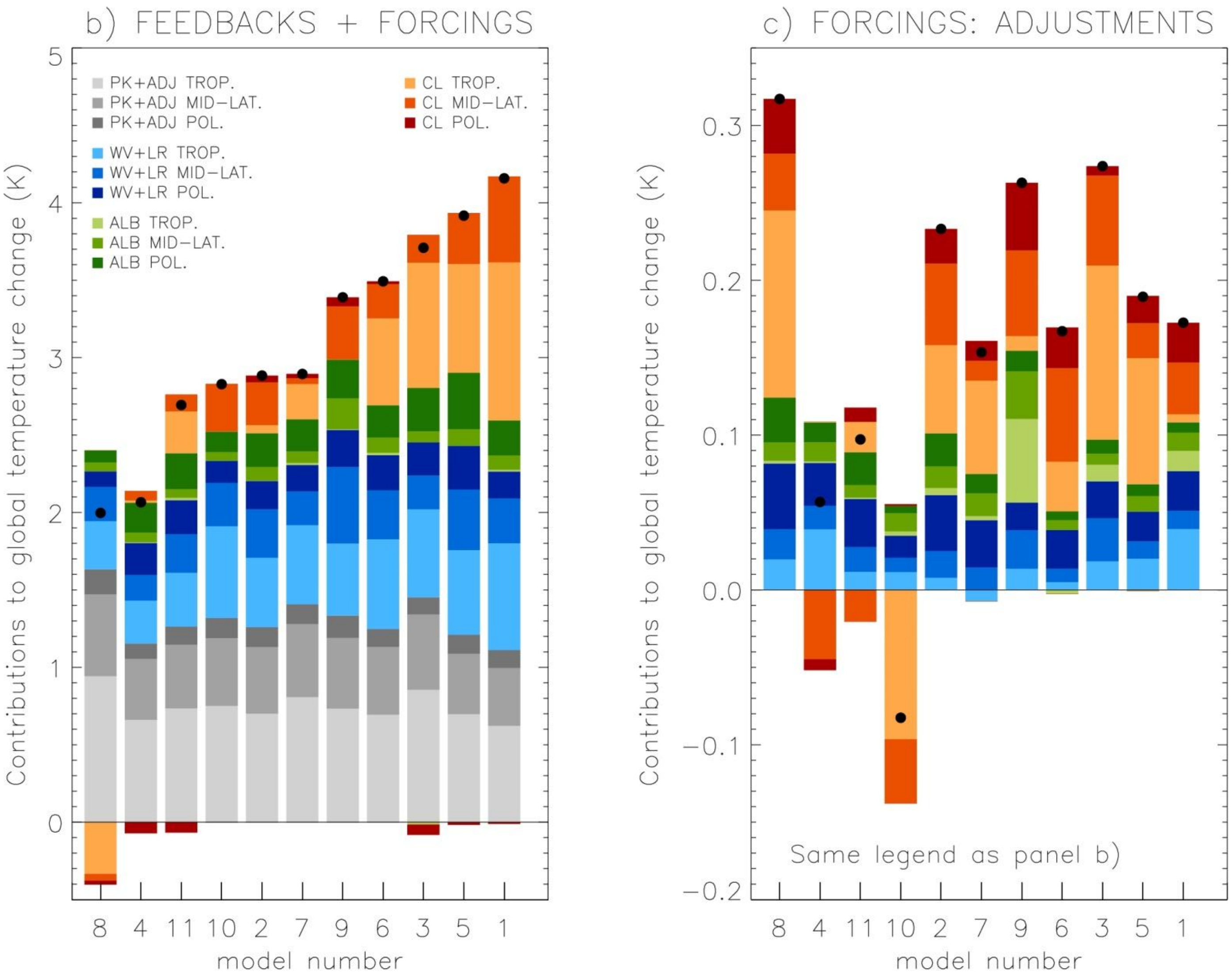
model	1%/year CO_2 increase				abrupt $4xCO_2$		
	$\Delta Q_t(2CO_2)$ (Wm^{-2})	λ ($Wm^{-2}K^{-1}$)	TCR($2CO_2$) (K)	$\Delta T_s^e(2CO_2)$ (K)	$\Delta Q_t(2CO_2)$ (Wm^{-2})	λ ($Wm^{-2}K^{-1}$)	$\Delta T_s^e(2CO_2)$ (K)
IPSL-CM4	3.5	-0.92	2.13	3.79			
IPSL-CM5A-LR	3.5	-0.98	2.09	3.59	3.12	-0.76	4.10
IPSL-CM5A-MR	3.5	-1.01	2.05	3.47	3.29	-0.80	4.12
IPSL-CM5B-LR	3.5	-1.68	1.52	2.09	2.66	-1.03	2.59



λc SW: ocean
Pω500 λc SW: ocean
ΔPω500 CRF SW ctrl−sstClim4xCO2: ocean
λc LW: ocean
Pω500 λc LW: ocean
ΔPω500 CRF LR ctrl−sstClim4xCO2: ocean
λc NET: ocean
Pω500 λc NET: ocean
ΔPω500 CRF NET ctrl−sstClim4xCO2: ocean
W.m−2.K−1
Circulation regime (ω500, hPa/day)



SW
LW
NET
λc (W.m⁻².K⁻¹) tropics
ΔCRF (W.m⁻².K⁻¹) tropics

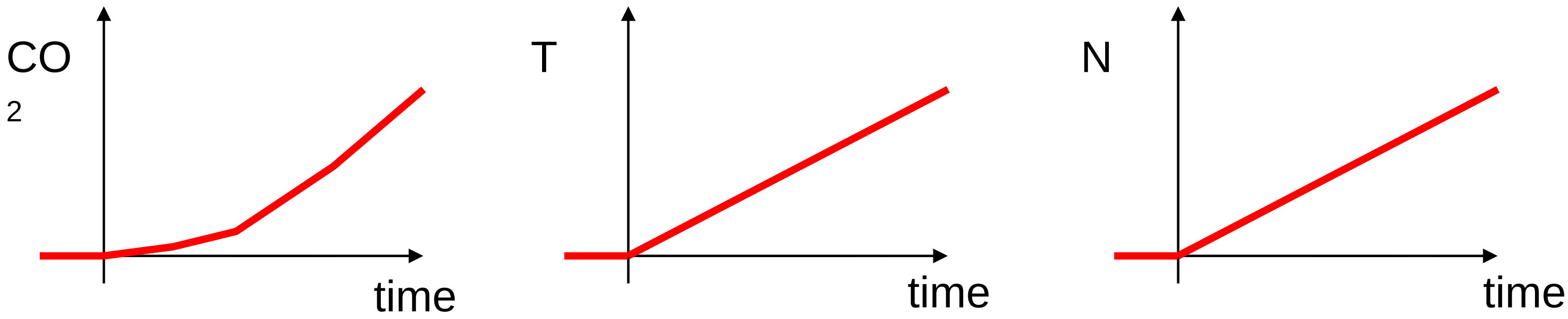


b) FEEDBACKS + FORCINGS
c) FORCINGS: ADJUSTMENTS
PK+ADJ TROP.
PK+ADJ MID-LAT.
PK+ADJ POL.
WV+LR TROP.
WV+LR MID-LAT.
WV+LR POL.
ALB TROP.
ALB MID-LAT.
ALB POL.
CL TROP.
CL MID-LAT.
CL POL.
Contributions to global temperature change (K)
model number
8 4 11 10 2 7 9 6 3 5 1
Same legend as panel b)

CMIP5 experiments

Ramp experiment: 1%/year CO2 increase

CO2 concentration Surface temperature Net TOA flux



Step experiment: abrupt 4xCO2 increase