Estimate of forcing and feedbacks using both step and ramp idealized experiments

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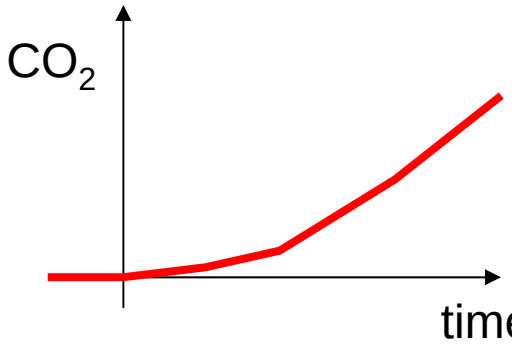
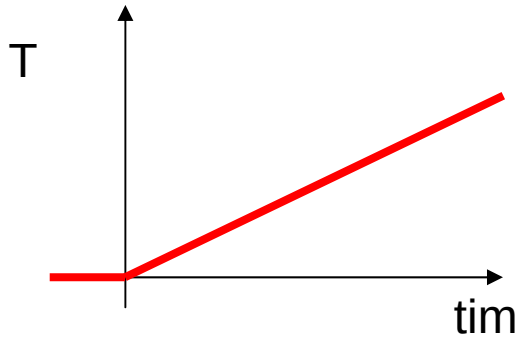
CMIP5 experiments

Ramp experiment: 1%/year CO2 increase

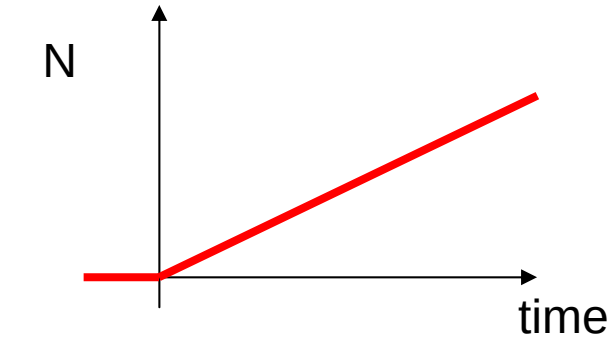
CO2 concentration



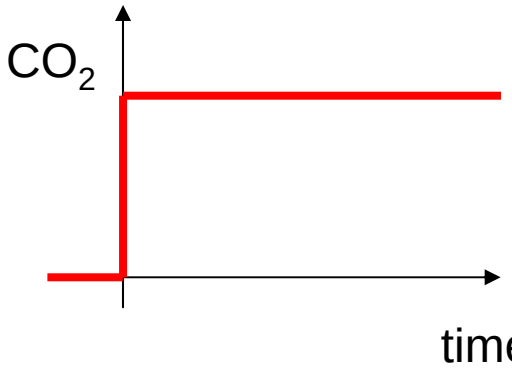
Surface temperature

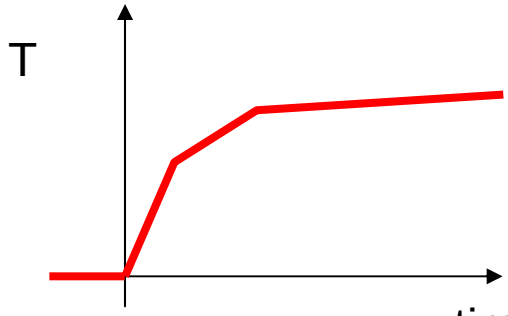


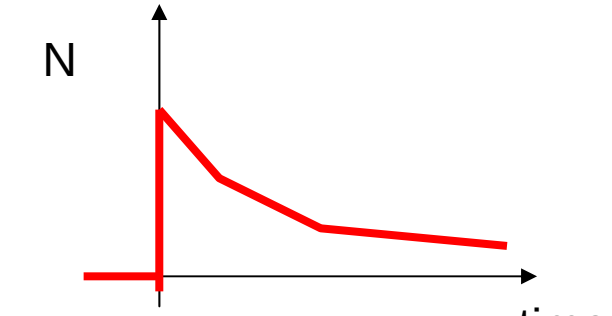
Net TOA flux



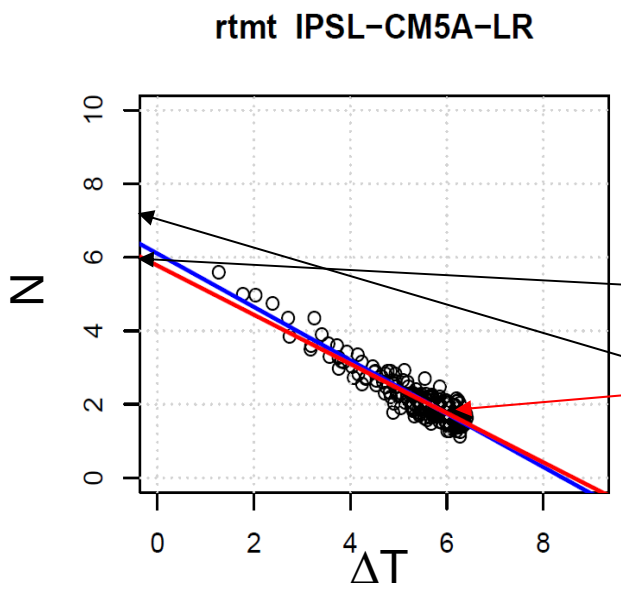
Step experiment: abrupt 4xCO2 increase

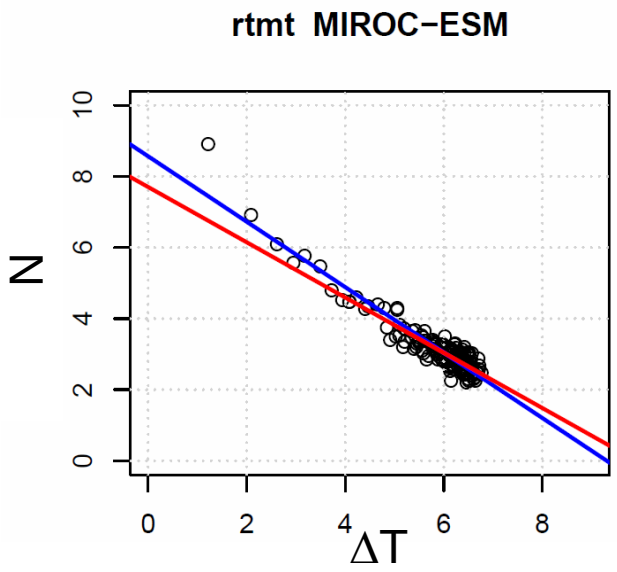






The abrupt 4xCO2 experiment





(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

Questions:

- is λ constant ?
- how to define ΔQ?
- does the fast and slow response concept apply to other then step experiments ?
- how to improve the estimate of λ and ΔQ ?

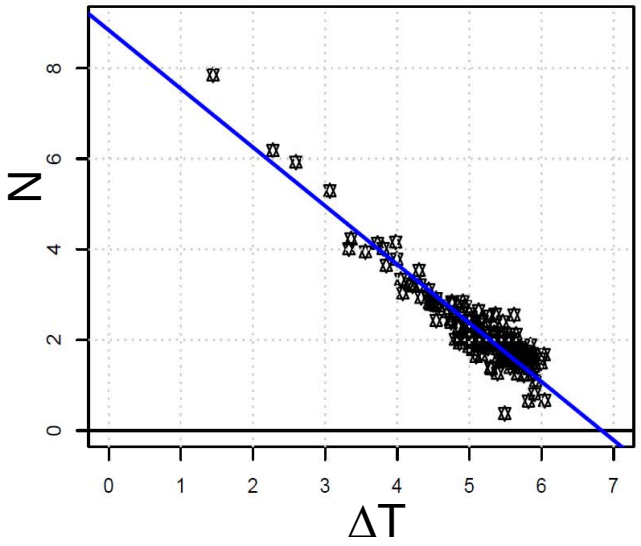
Climate feedback framework: $N(t) \approx \Delta Q(t) + \lambda \Delta T(t)$

N(t) and $\Delta T(t)$ are GCMs outputs ; $\Delta Q(t)$ and λ need to be estimate

Step experiment (4xCO2) :
$\Delta Q(t) = Cte = \Delta Q_{4x}$

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

- ΔQ_{4x} and λ are estimated by linear regression between N and ΔT



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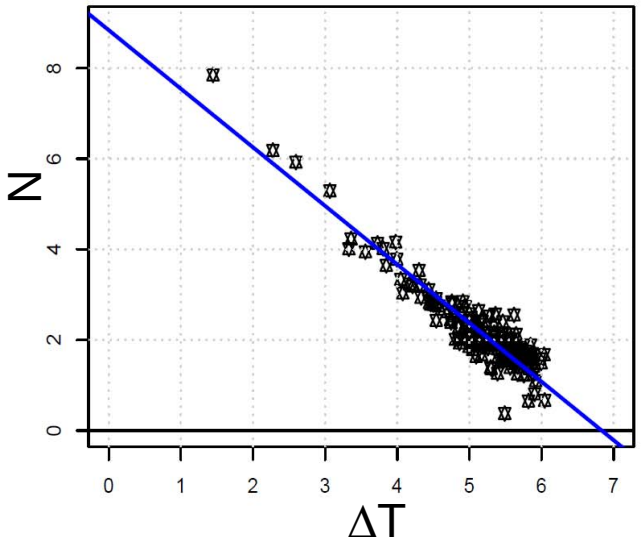
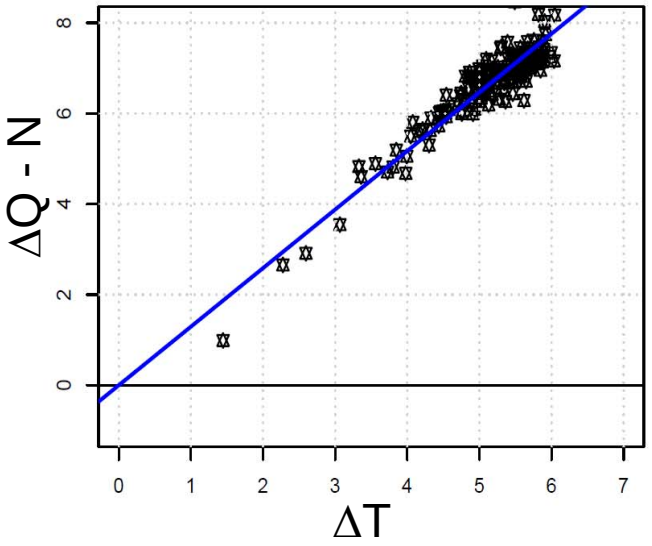
- $N' = \Delta Q_{4x} + \lambda \Delta T$
- ΔQ_{4x} and λ are estimated by minimizing $((N'-N)/\sigma)^2$
- $N'-N \approx 0$
  $\Delta Q_{4x} - N \approx \lambda \Delta T$





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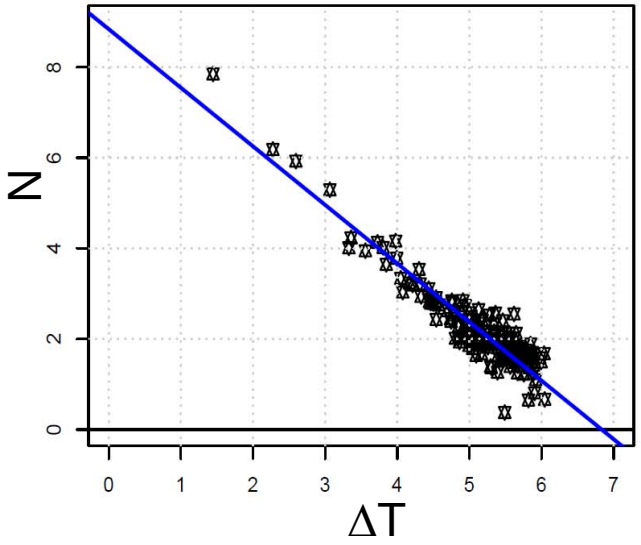
  $\Delta Q_{4x} - N \approx \lambda \Delta T$

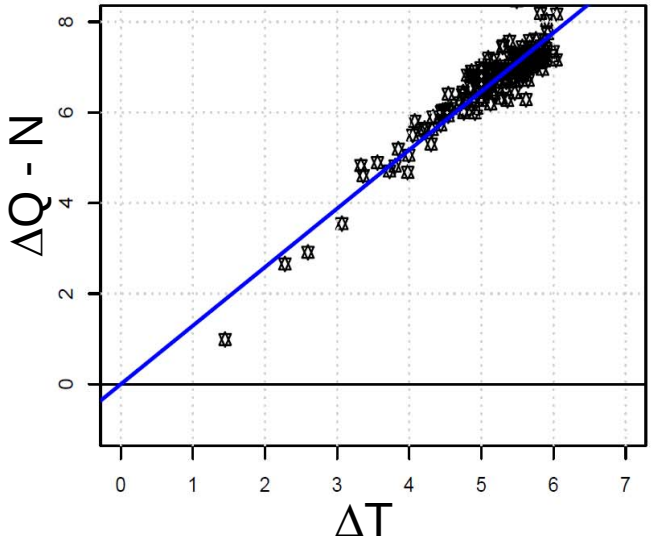
Ramp experiment
(1%CO2/year) :

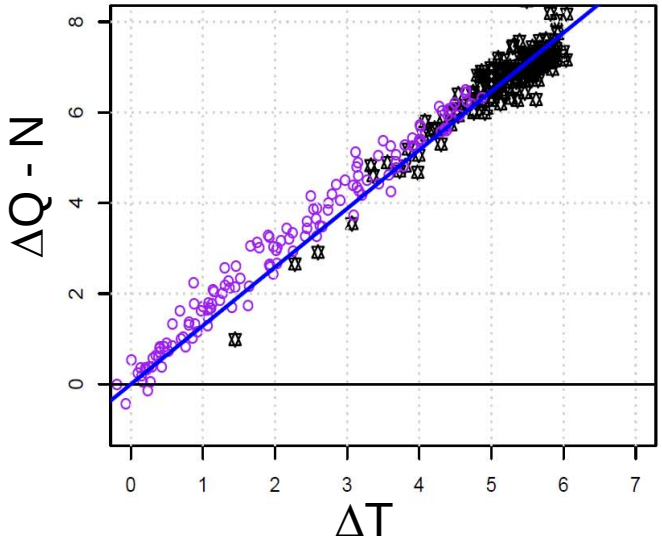
$\Delta Q(t) = \Delta Q_{4x}$
$\log(C(t)/Co) / \log(4)$

- $N'-N \approx 0$

  $\Delta Q(t) - N \approx \lambda \Delta T$







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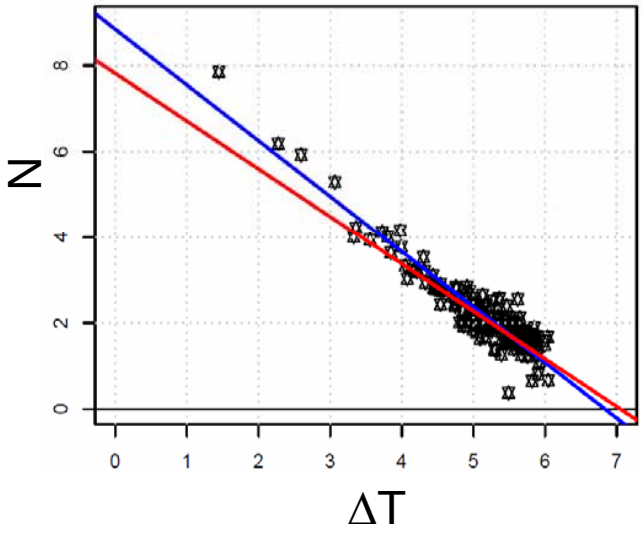
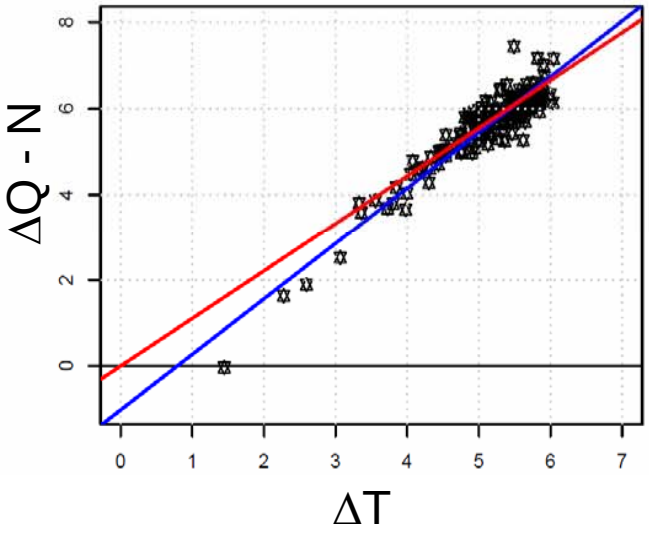
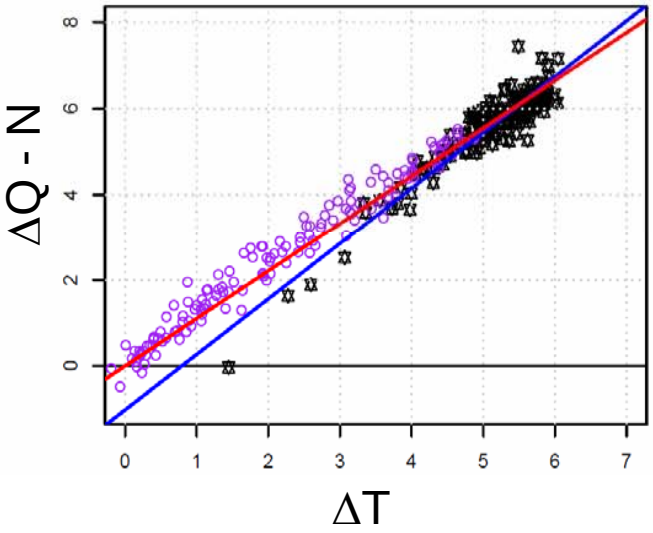
Ramp experiment (1%CO2/year) :

$\Delta Q(t) = \Delta Q_{4x}$ $\log(C(t)/Co) / \log(4)$

ΔQ_{4x} and λ are estimated using both step and ramp experiment

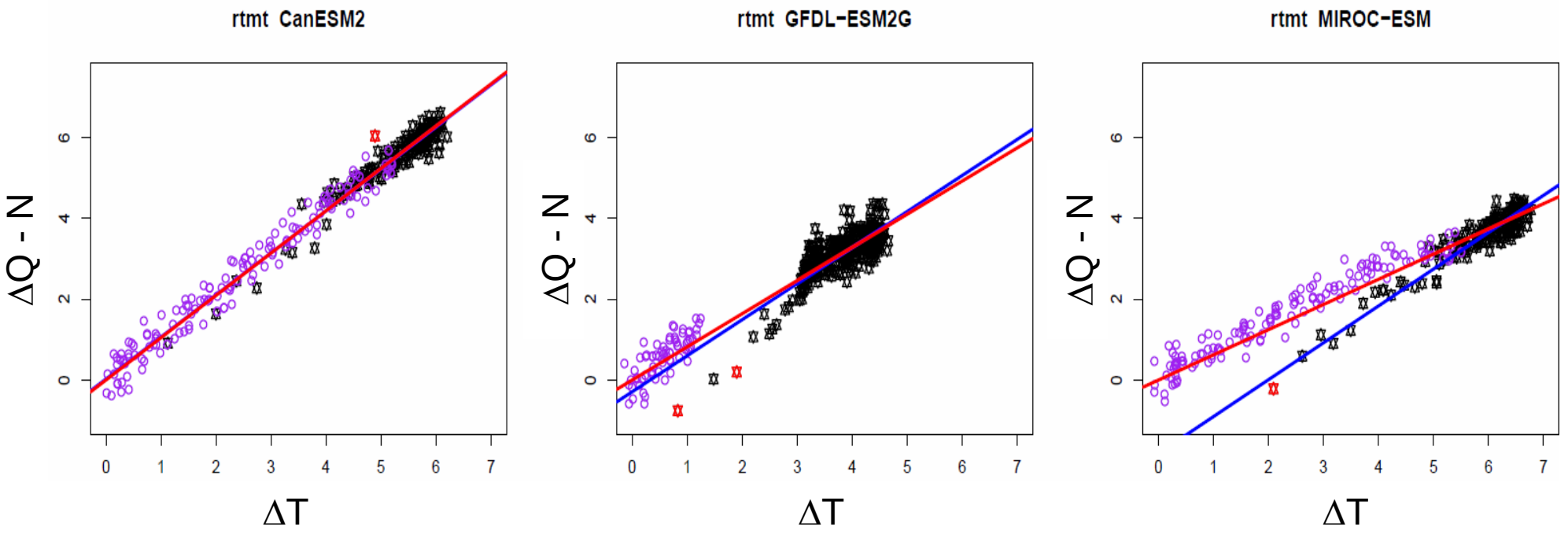






Estimate of λ and ΔQ_{4x}

- λ and ΔQ_{4x} are fitted together, using the data of both the step (abrupt 4xCO2) and ramp experiment (1%/year CO2 increase)
- residual analysis on radiative flux (N-N') : the aberrant points (i.e. where residual > 3 standard deviation) are mainly present during first years of the step experiment

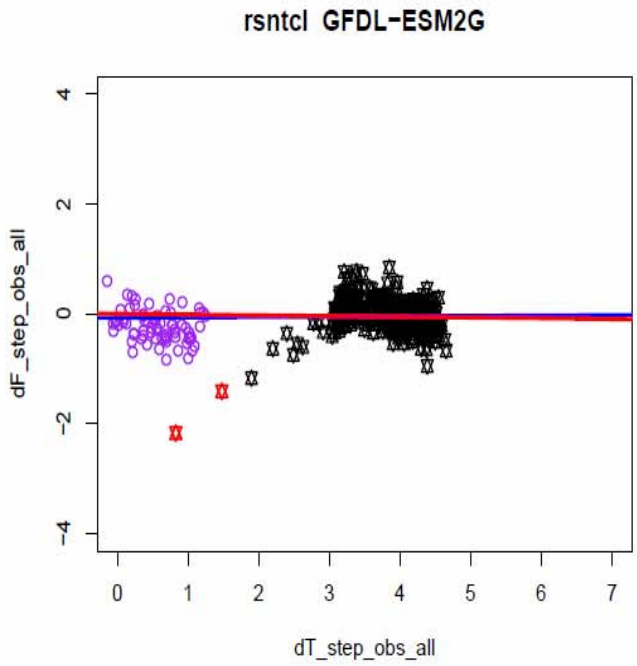


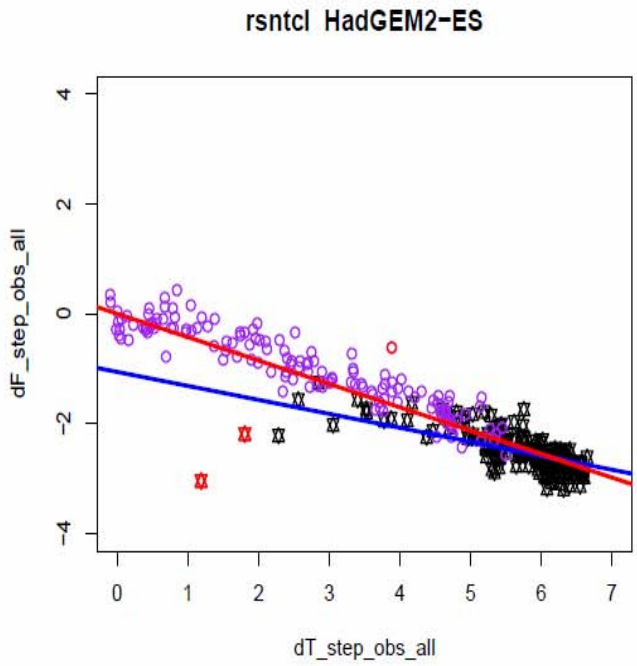
What causes the curvature of the relationship between the TOA flux and the surface temperature?

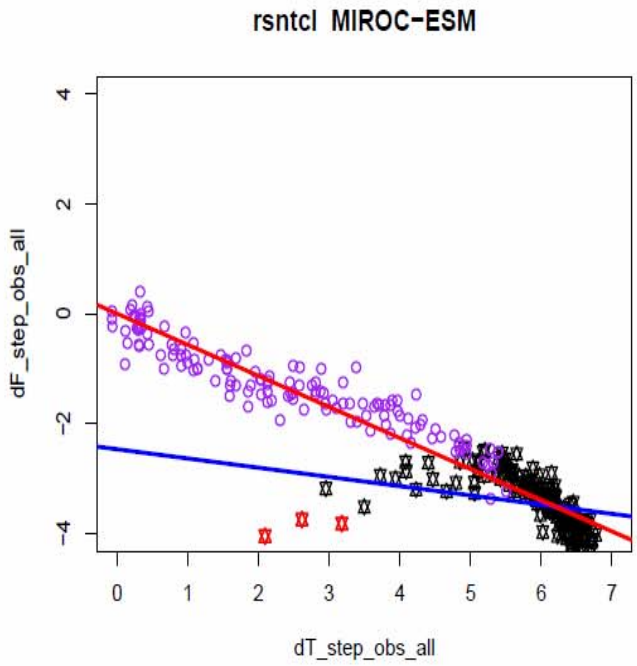
Partitioning the TOA flux : (all sky, clear sky, cloudy sky) / (net, LW, SW)

In the LW: relationship between N and T almost linear for both clear and cloudy sky

The curvature mainly originates from the **cloud response in the SW**





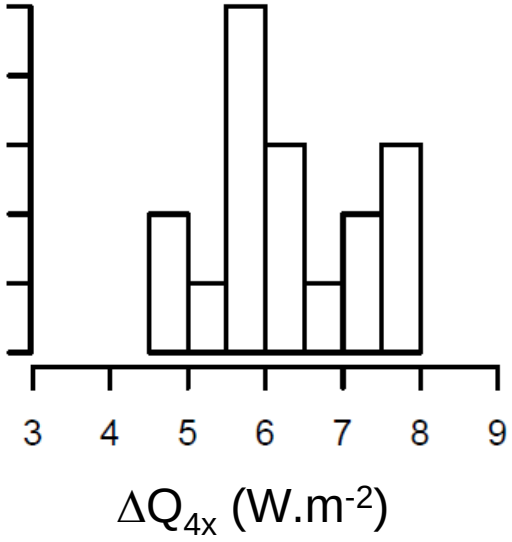


Spread of the 4xCO2 forcing estimate

(17 CMIP5 models)

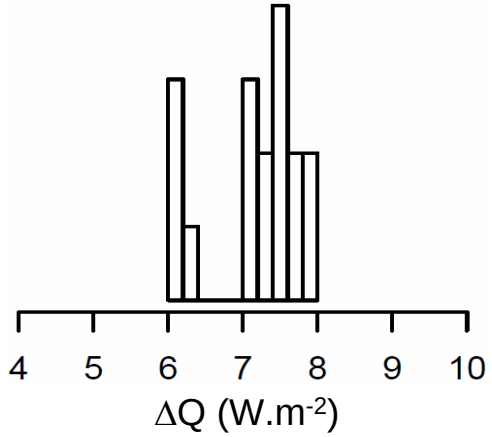
all sky

Net

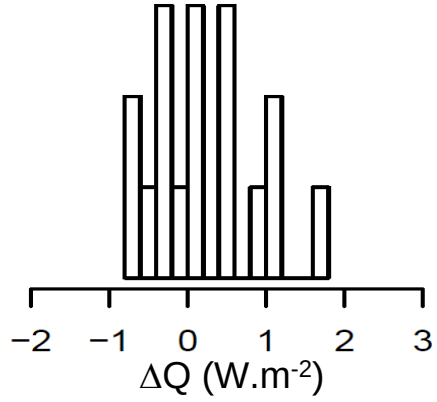


clear sky

LW

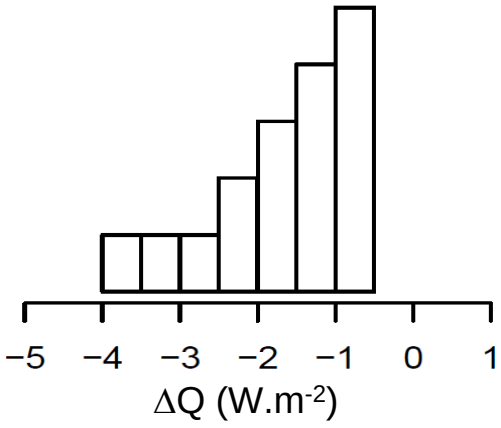


SW

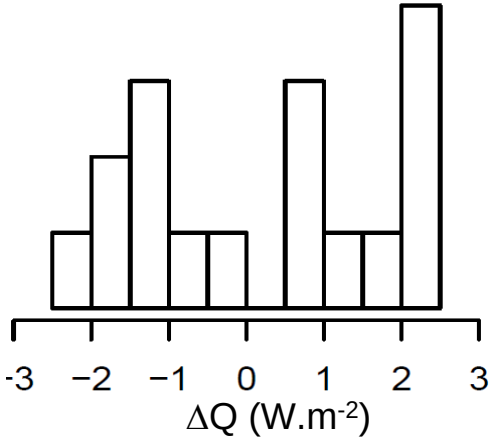


cloudy sky

LW



SW

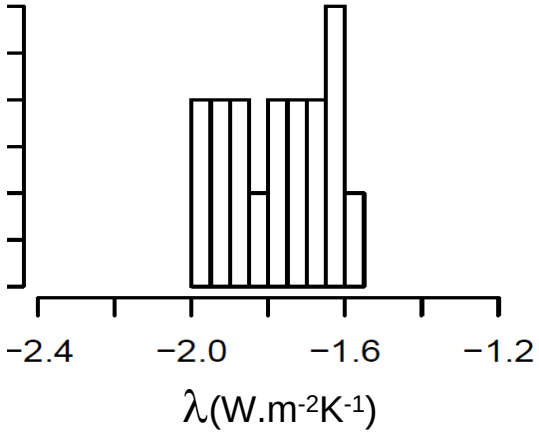


Spread of the climate feedback estimate

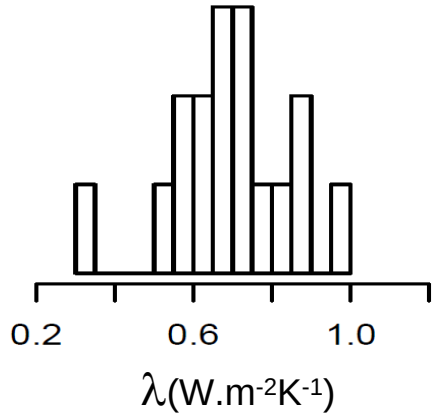
(17 CMIP5 models)

clear sky

LW

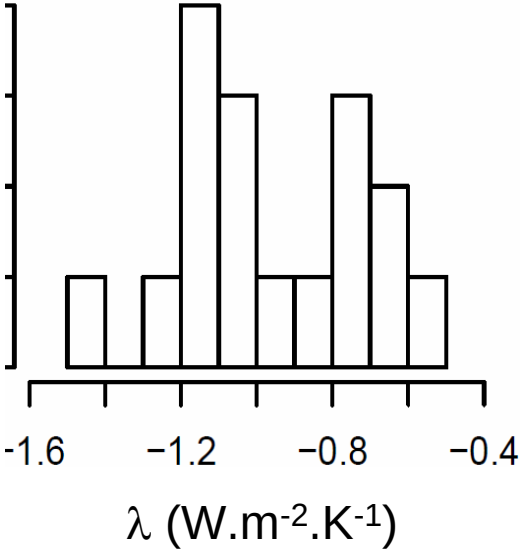


SW

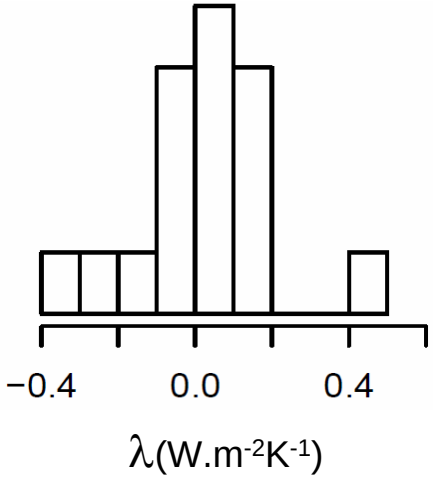


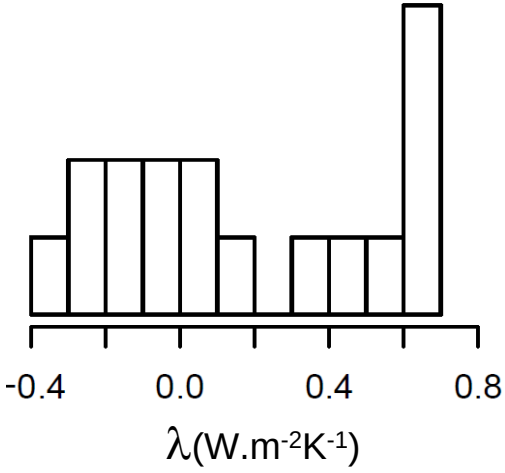
all sky

Net



cloudy sky



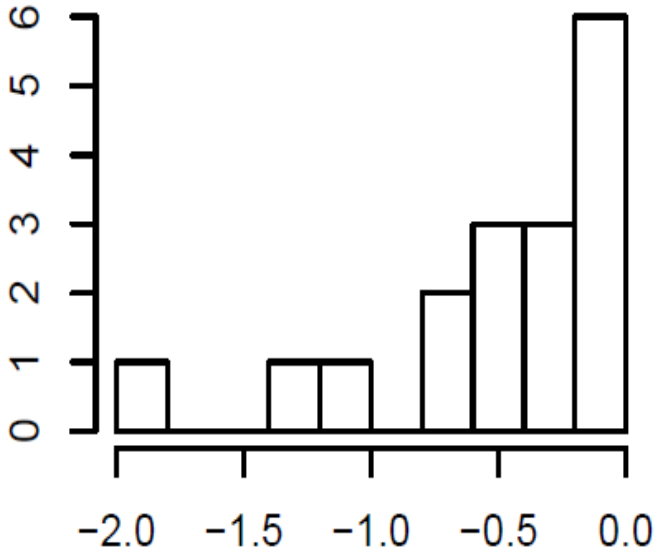


Difference of the estimates between the fitting methods

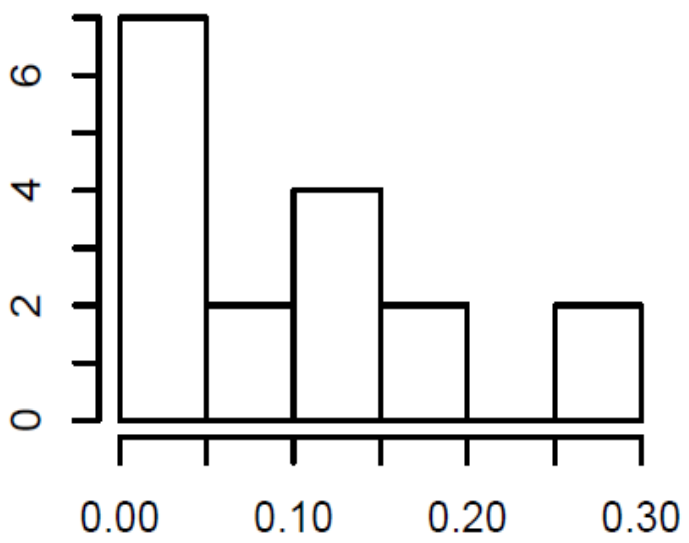
(17 CMIP5 models)

Fitting using both step and ramp – fitting using only step experiment

Radiative forcing ΔQ ($W.m^{-2}$)
mean : -0.5 ; stdv = 0.5



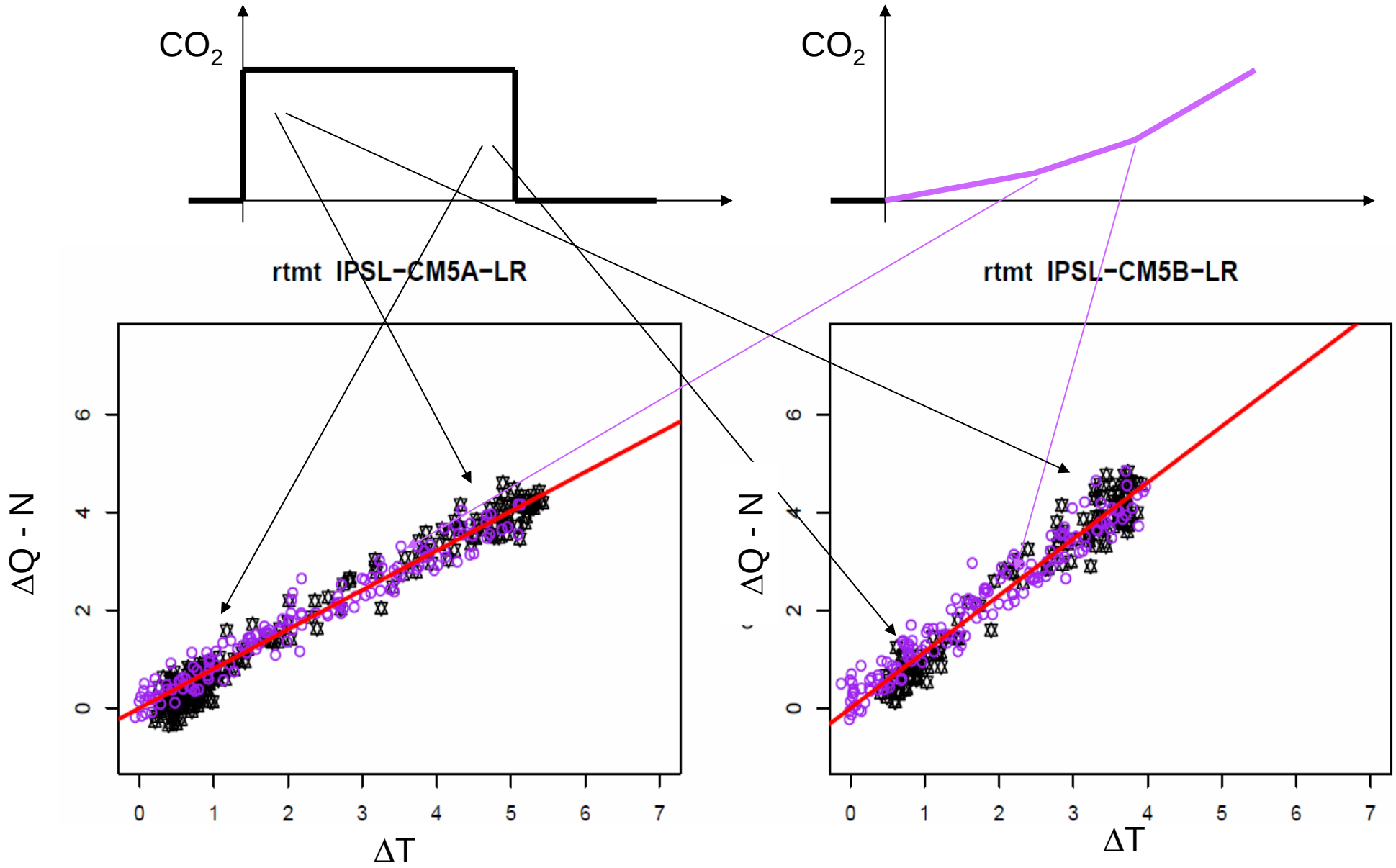
Climat feedback λ ($W.m^{-2}.K^{-1}$)
mean : 0.1 ; stdv = 0.1



Using both step and ramp experiment:

- decreases the CO_2 forcing , i.e. increases the « fast » response of to CO_2
- mainly due to the SW « fast » response of clouds

Reducing the estimate uncertainties ?



Conclusion

- Response of TOA flux may be partitioned in a direct response ΔQ to CO_2 and a response λ to Ts for both step and ramp experiments
- Using both step and ramp experiments:
  - the non linearity of λ occurs during the first 5-20 years
  - this is mainly due to the cloud response
  - on decadal to centennial time scales, λ may be assumed constant for ramp-like experiments
- Uncertainty on ΔQ and λ are quite large, larger than the statistical estimate alone, depends on the method fitting
- Using both step and ramp experiments increases the validity domain of the “feedback model”, but not the accuracy of the estimate of ΔQ and λ