# Influence of anthropogenic aerosol on multi-decadal variations of historical climate

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The indirect effect may account for up to 2/3 of aerosol forced changes in precipitation, and almost all aerosol induced cooling [1]. However, this is strongly model-dependent e.g. [2].
CMIP5 provides an unprecedented number of models with an indirect effect
- Do models with an indirect effect better reproduce historical trends?

A subset of CMIP5 models have made anthropogenic aerosol single forcing runs available
- Does aerosol play a key role in temperature and precipitation change?

CMIP5 models show a diverse climate response to aerosol forcing
- How much of this range is due to diversity in the model aerosol, and how much is due to a diversity in the models' response to aerosol changes?

## Aerosol contribution to historical trends

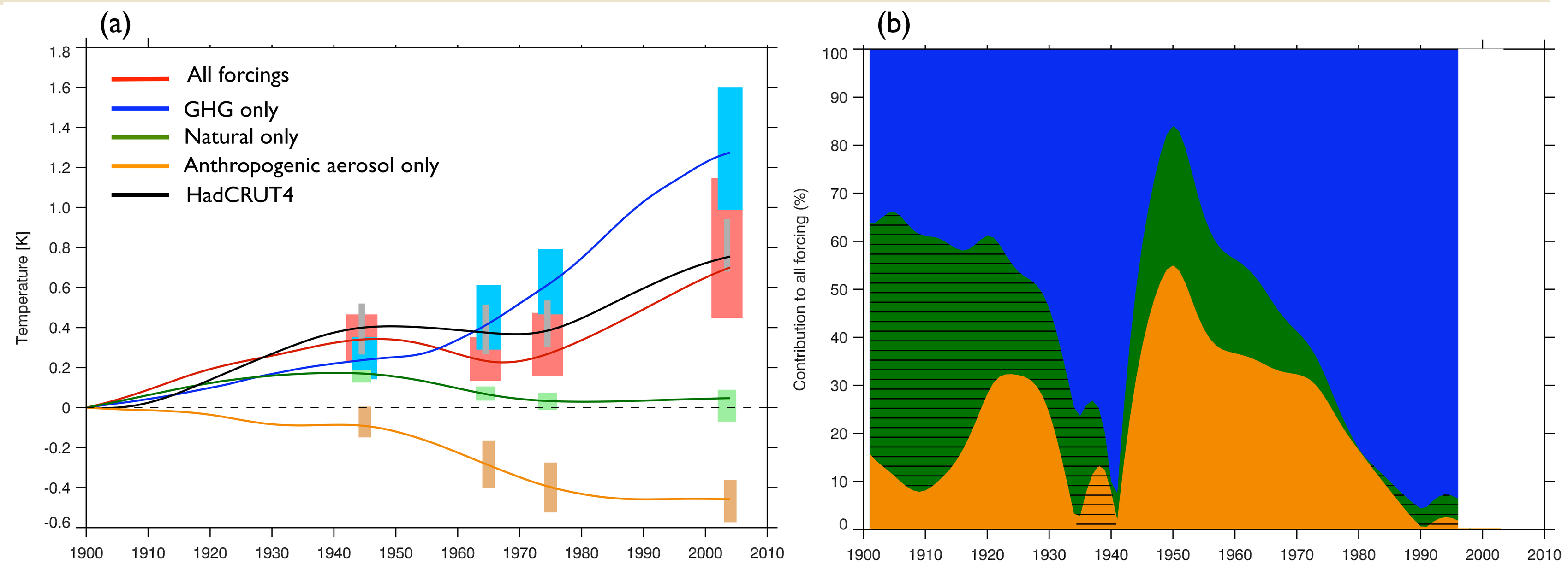


**Figure 1:** *(a): Non-linear trends from single forcing runs and observations for global-mean annual-mean near-surface temperature. Solid lines show the ensemble mean for each run, shading shows the range of the realisations from individual models. (b): Contributions from AA, natural, and GHG forcing to the trend. Hatching where natural and AA forcing are positive.*

- Linear sum of single forcing time series gives excellent approximation of all forcing temperature
  - Anthropogenic aerosol (AA) forcing accounts for >50% of the trend in the decade centred on 1950
  - AA and natural forcing accounts for >50% of the trend from 1940-1970

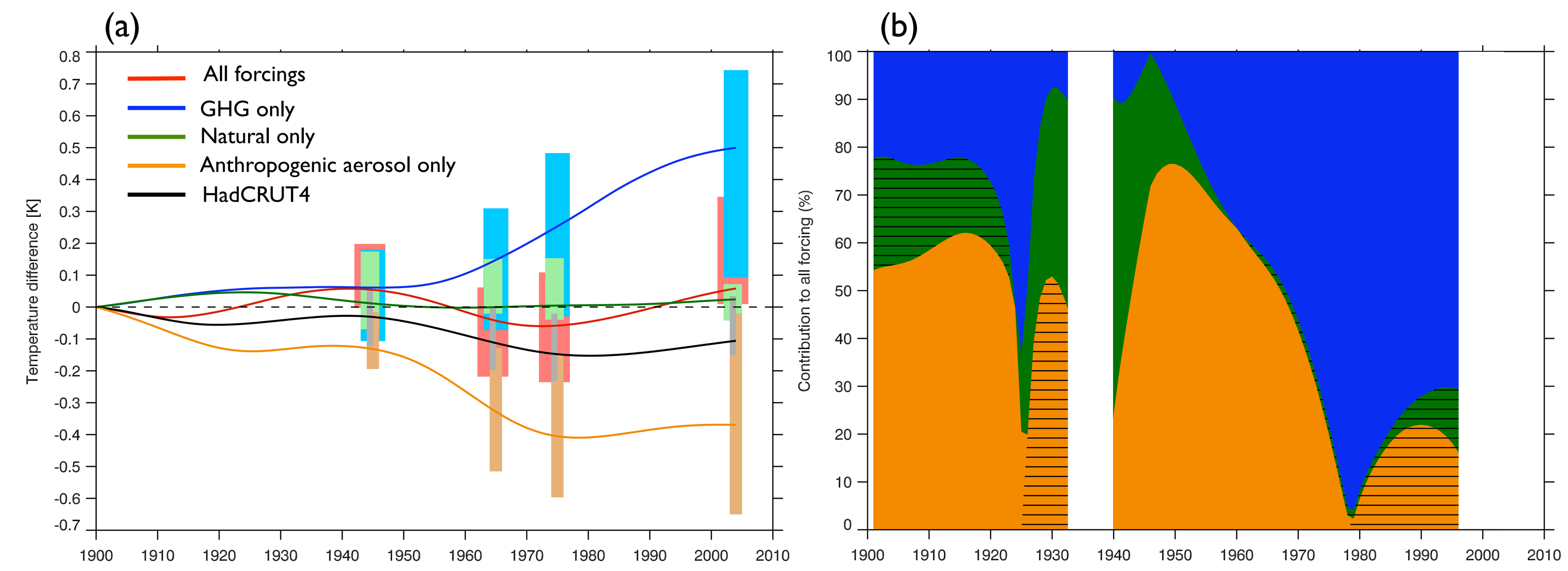


**Figure 2:** *(a): Non-linear trends from single forcing runs and observations for the annual-mean inter-hemispheric temperature difference. Solid lines show the ensemble mean for each run, shading shows the range of the realisations from individual models. (b): Contributions from AA, natural, and GHG forcing to the trend. Hatching where natural and AA forcing are positive.*

- All forcings shows a near cancellation between GHG and AA forcing
  - Variability reflects AA time series
- >50% of trend driven by AA prior to 1970

## The importance of the indirect effect

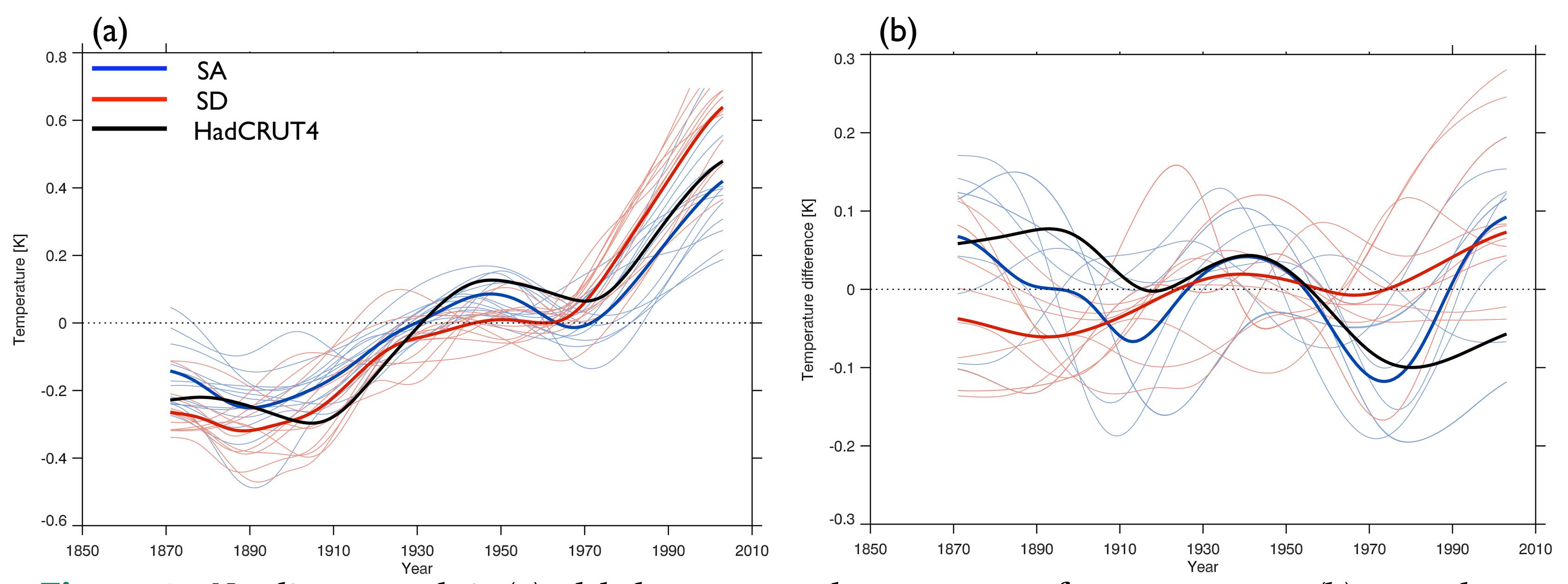


**Figure 3:** *Non-linear trends in (a): global-mean annual-mean near-surface temperature; (b): annual-mean inter-hemispheric temperature difference*

**SA**: models with the direct and indirect effects
**SD**: models with the direct effect only
- Better representation of trend magnitude and variability in SA vs. SD

Learn more:
Wilcox et al., (2013). *Environmental Research Letters*, **8**, 024033.

## Diversity in aerosol load and distribution

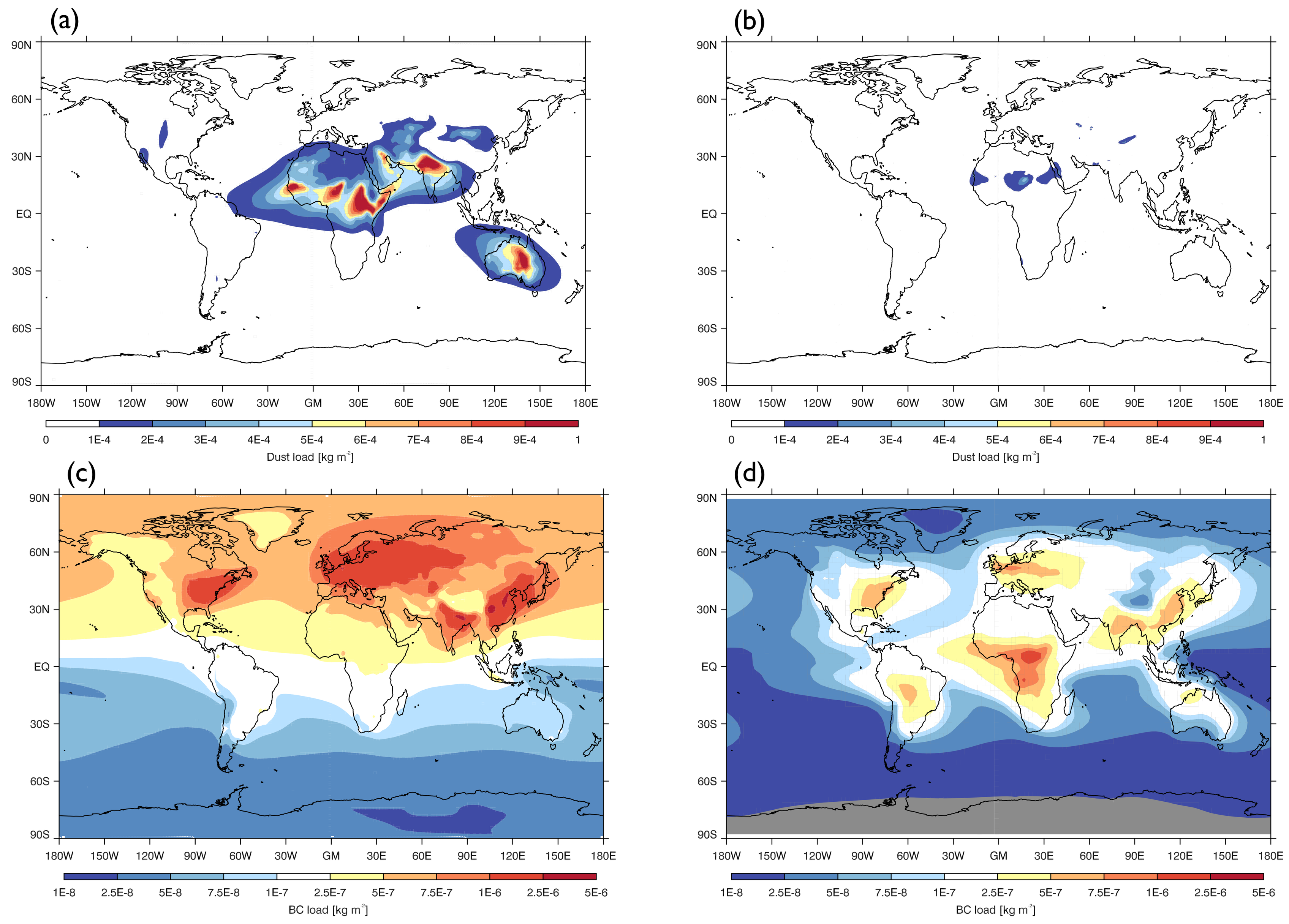


**Figure 4:** *Historical-mean mass load of dust from (a): HadGEM2-ES, (b): MIROC4h, and of black carbon from (c): HadGEM2-ES, (d): MIROC-ESM-CHEM.*

- Considerable diversity in load and distribution of both natural and anthropogenic aerosol
- Diversity in aerosol categorisation across modelling centres

## Diversity in sensitivity to aerosol

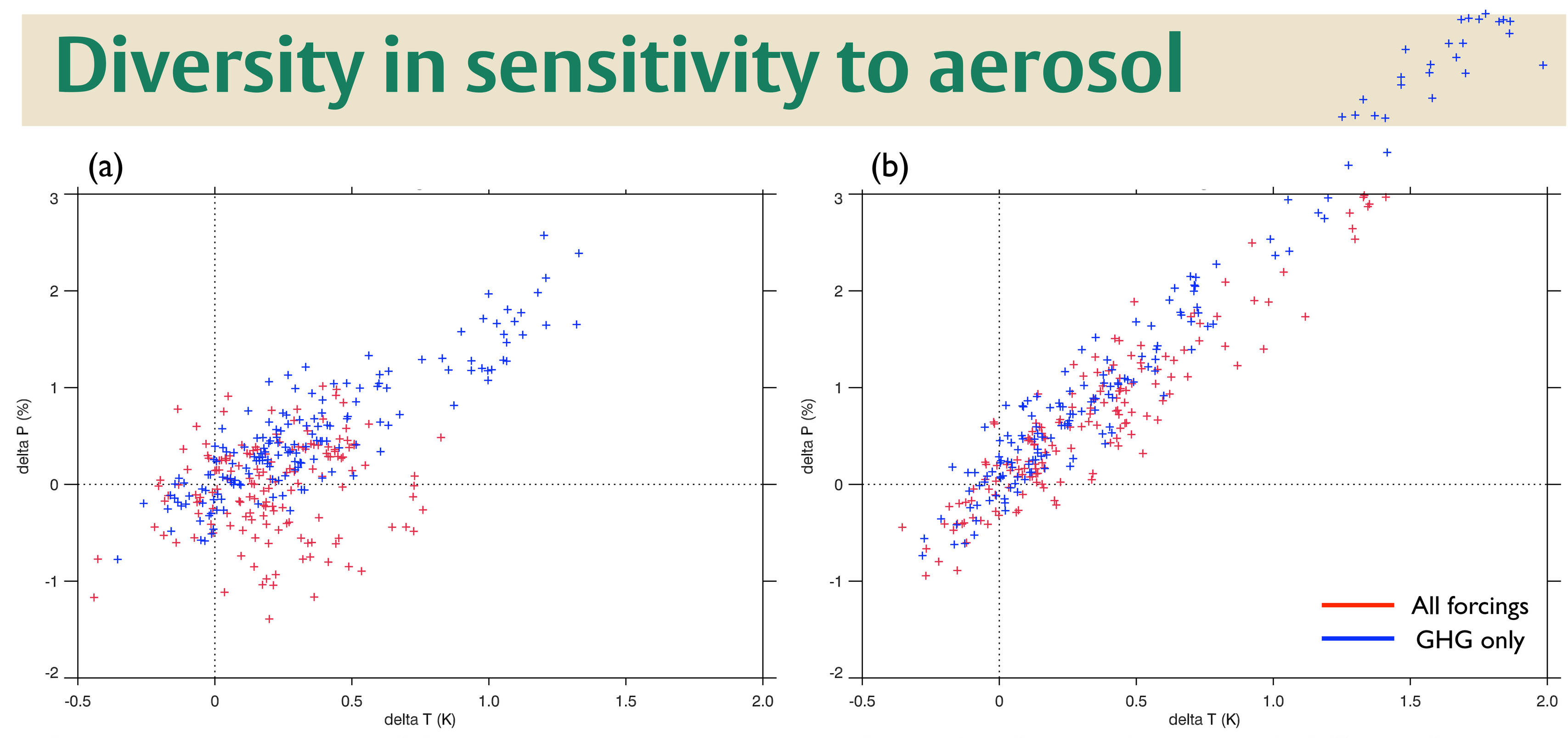


**Figure 5:** *Comparison of the temperature-precipitation relationship for simulations with different forcings from (a): CSIRO-Mk3.6.0, and (b): IPSL-CM5A-LR.*

- Precipitation increases linearly with temperature under GHG forcing
- In many models (e.g. Fig. 5(a)), when all forcings are included in simulations, this relationship becomes bi-modal, and precipitation changes are reduced
  - AA forcing is the dominant cause of this difference [3]
- This response pattern is not present in some models (e.g. Fig 5(b)), suggesting they may be less sensitive to AA forcing.

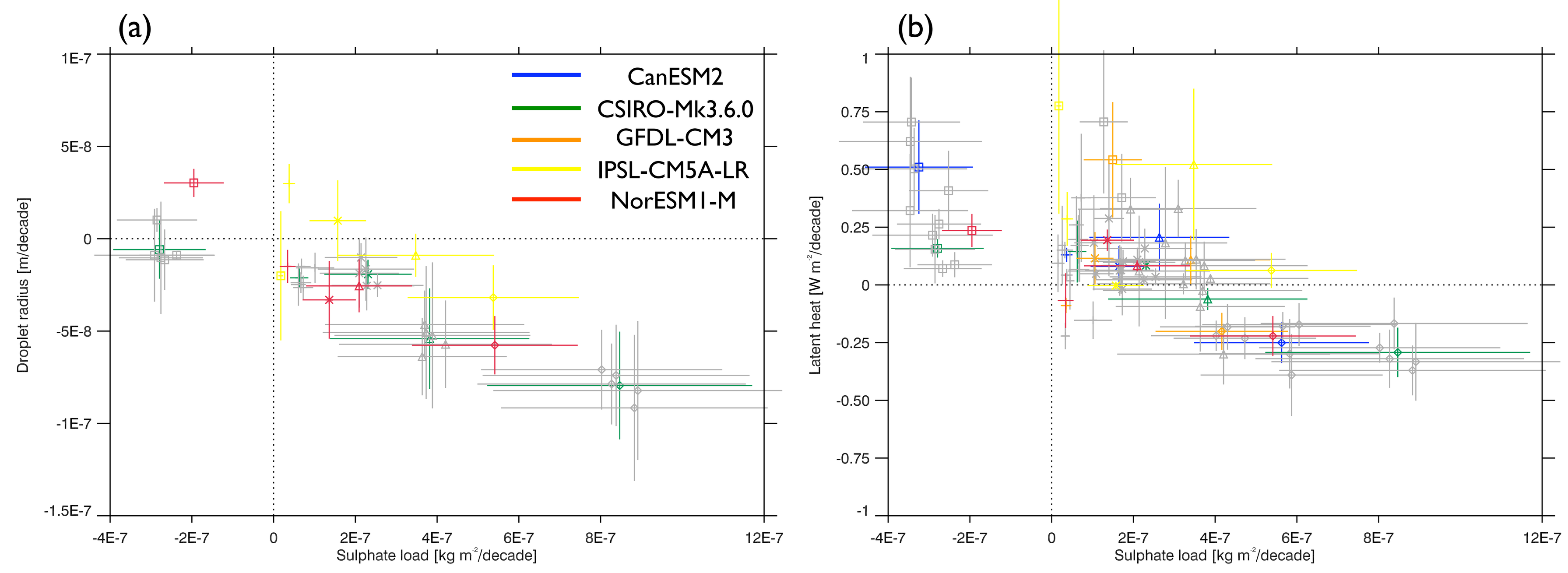


**Figure 6:** *Response of (a): droplet radius and (b): latent heat flux to changes in sulphate load. Colours show model means, grey shows the individual ensemble members.*

- Consistent with the precipitation response to temperature, IPSL-CM5A-LR can also be seen to have muted shortwave and heat flux responses to changes in sulphate load, relative to other models

Next steps:
- Regional case studies
  - Quantify model diversity in aerosol and water cycle variables
  - Quantify sensitivity of the response of water cycle variables to aerosol changes
- Identification of aerosol-sensitive regions

[1] Levy et al., (2013). *Journal of Geophysical Research - Atmospheres*, **118**, 4521-4532.
[2] Shindell et al., (2012). *Atmospheric Chemistry and Physics*, **12**, 6969-6982.
[3] Wu et al., (2013). *Nature Climate Change*, **3**, 807-810.