Influence of anthropogenic aerosol on multi-decadal variations of global climate

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Motivation

The indirect effect may account for up to 2/3 of aerosol forced changes in precipitation, and almost all aerosol induced cooling. However, this is strongly model-dependent.

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?

Non-linear trends

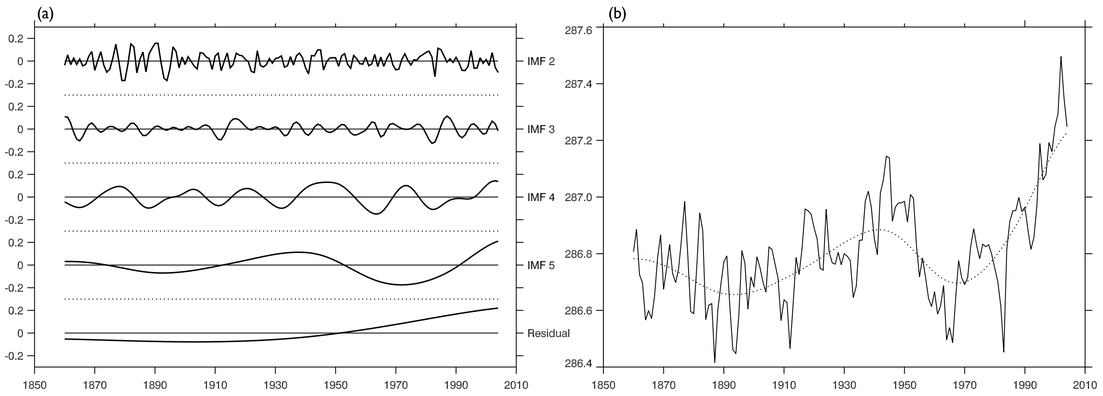

Figure 1: *(a): High-order IMFs and the residual of global-mean annual-mean near-surface temperature (b): The sum of the last IMF, the residual, and the mean (dashed), superimposed on the original time series (solid).*

- EMD is an algorithm that decomposes time series into characteristic frequency modes: IMFs
- EEMD uses the ensemble mean IMFs of the product of a time series and a noise series
  - Assists time scale separation in noisy data
- Non-linear trend defined as the sum of the residual and the last IMF

Global temperature

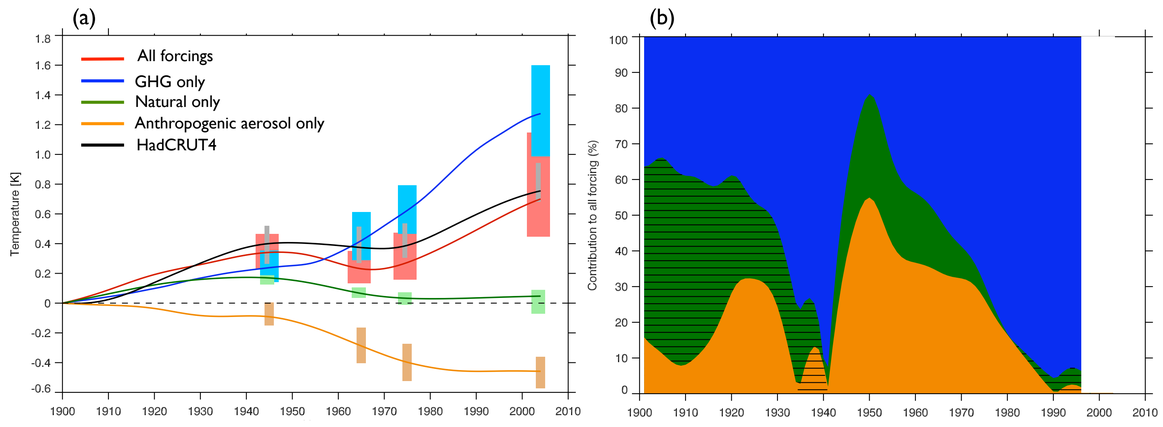

Figure 2: *(a): Non-linear trends from single forcing runs and observations for global-mean annual-mean near-surface temperature. Solid lines show the ensemble mean for each run, shading shows the range of the realisations from individual models. (b): Contributions from AA, natural, and GHG forcing to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

- Good agreement between all forcings run and HadCRUT4
- Decrease in temperature from 1950-1970 occurs despite increasing temperature from greenhouse gas (GHG) forcing

- 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

Land precipitation

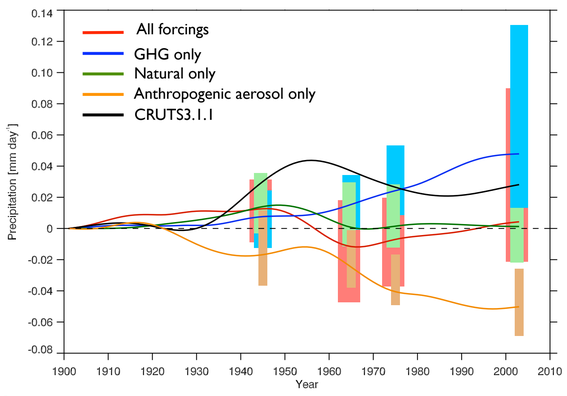

Figure 3: *Non-linear trends from single forcing runs and observations for land-mean annual-mean precipitation.*

- GHG+AA+Natural≠All
- Still a clear role for natural and AA forcing in the mid twentieth century
  - Coincident decrease in Natural, AA, and all forcing time series

Learn more:

Wilcox et al., (2013). *Environ. Res. Lett.*, **submitted**.

Inter-hemispheric temperature difference

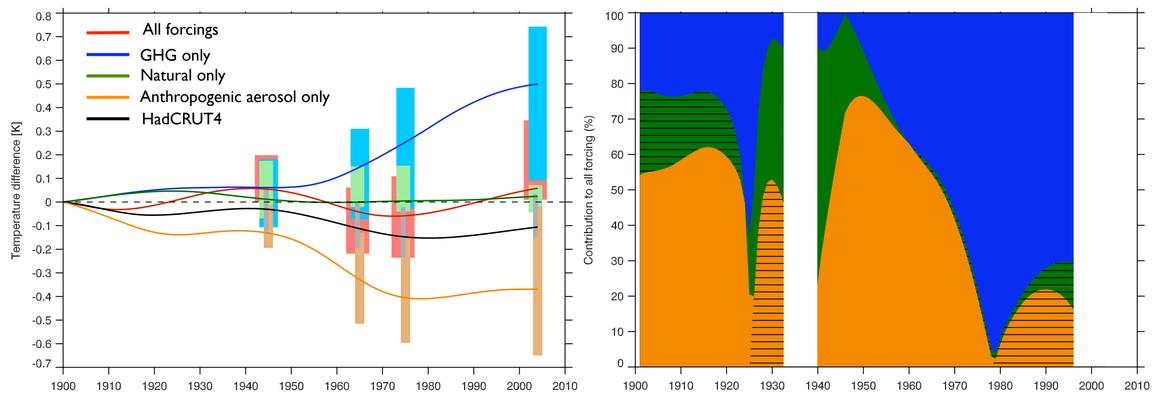

Figure 2: *(a): Non-linear trends from single forcing runs and observations for the annual-mean inter-hemispheric temperature difference. Solid lines show the ensemble mean for each run, shading shows the range of the realisations from individual models. (b): Contributions from AA, natural, and GHG forcing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

- Hemispheric contrasts in single forcing:
  - NH warms faster than SH under GHG forcing
  - NH cools more than SH under AA forcing
  - Symmetric response to natural forcing

- 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

- Divergence of models and observations in recent decades suggests possible overestimate of aerosol influence in models

The importance of the indirect effect

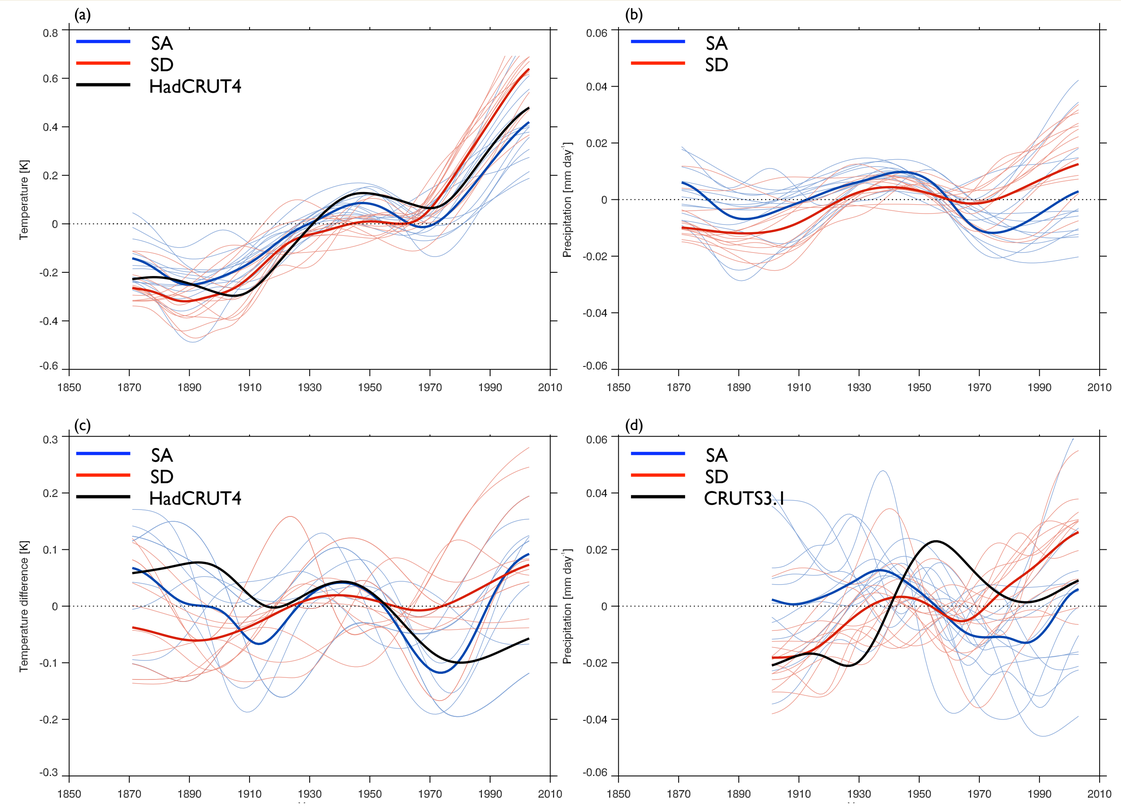

Figure 4: *Non-linear trends in (a): global-mean annual-mean near-surface temperature; (b): global-mean annual-mean precipitation; (c) annual-mean inter-hemispheric temperature gradient; (d): land-mean annual-mean precipitation.*

SA: models with the direct and indirect effects
SD: models with the direct effect only
  - SA in better agreement with observations than SD

- Temperature
  - SA and HadCRUT4 have local maximum in 1950
  - Smaller positive trends, larger negative trends, in SA vs. SD
- Precipitation
  - Noisier, but similar patterns to temperature can be seen
- Temperature difference
  - SA overestimates recent trend compared to observations
  - Better representation of variability in SA vs. SD

- Changes in AA can strongly influence global mean climate
- 1950-1970 cooling due to natural and AA forcing offsetting GHG
- AA accounts for over a third of the trend in global temperature in the mid twentieth century, and for over 50% of the trend in temperature difference prior to 1970
- Models with a representation of the indirect effect better reproduce historical variability, and will likely produce more reliable projections of near-term climate