Exploring the impact of aerosol radiative forcing uncertainty on shifts in ITCZ position and tropical rainfall in the near-term future

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Background

1. Anthropogenic aerosols increased in the period of 1950-1980s, which lead to a negative radiative forcing (cooling) in the northern hemisphere, and hence altered the atmospheric energy balance.

2. Over the same period a southward shift in tropical precipitation was observed over land. This southward shift is due to a southward migration of the ITCZ, which broadly moves to the warmer hemisphere, and hence northern hemisphere anthropogenic aerosol cooling has been attributed as a cause.

3. The magnitude of southward shift of the tropical rain has a strong correlation with the magnitude of aerosol forcing in CMIP5 models *(Allen et al. 2015).*

4. Anthropogenic aerosol reductions in the near-term future, will warm the northern hemisphere, therefore will it be possible to observe a relationship between the magnitude of aerosol forcing and a northward shift in tropical precipitation in the near-term future, or will GHG warming dominate the response?

We use a perturbed parameter ensemble (PPE) that spans a range of aerosol forcings to investigate the relationship between aerosol forcing and tropical precipitation shifts in the near-term future.

References: Interhemispheric Aerosol Radiative Forcing and Tropical Precipitation Shifts during the Late Twentieth Century, Allen et al., 2015

Methods

PPE of HadGEM3-GC3.05

- 15 member PPE of global coupled ocean-atmosphere model from 1900-2100 with RCP8.5 and 2.6 from 2005
- Designed to provide known uncertainties in future climate changes for a given emissions scenario, and is used in UK Climate Projections (UKCP18).
- The PPE has 47 perturbed parameters from convection, gravity wave drag, boundary layer, cloud, aerosol and land surface schemes.
- There are 7 aerosol parameters perturbed, and the PPE spans a PI-PD aerosol ERF of -0.9 to -1.8 Wm^{-2}.

Quantifying tropical precipitation shifts

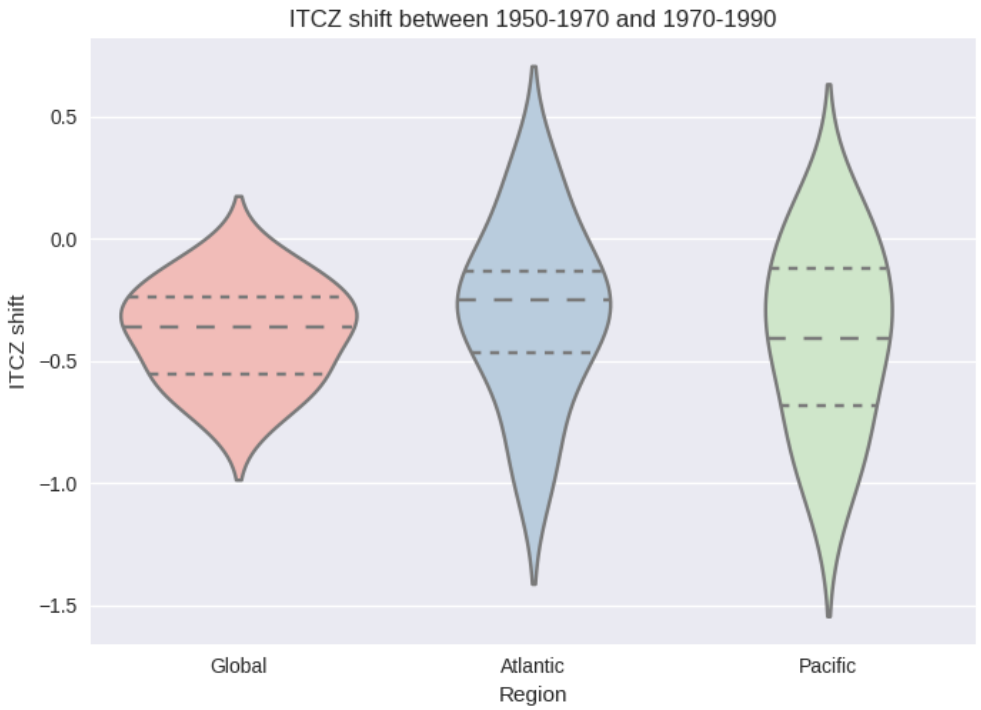
- We use precipitation based metrics to quantify the shifts in tropical precipitation and ITCZ across the ensemble members.
- Simple metric which uses the trend in the difference between 0-20°N and 0-20°S precipitation to quantify shifts over time.
- Centroid of precipitation (P_{cent}) to identify the location of ITCZ and how it changes over time.

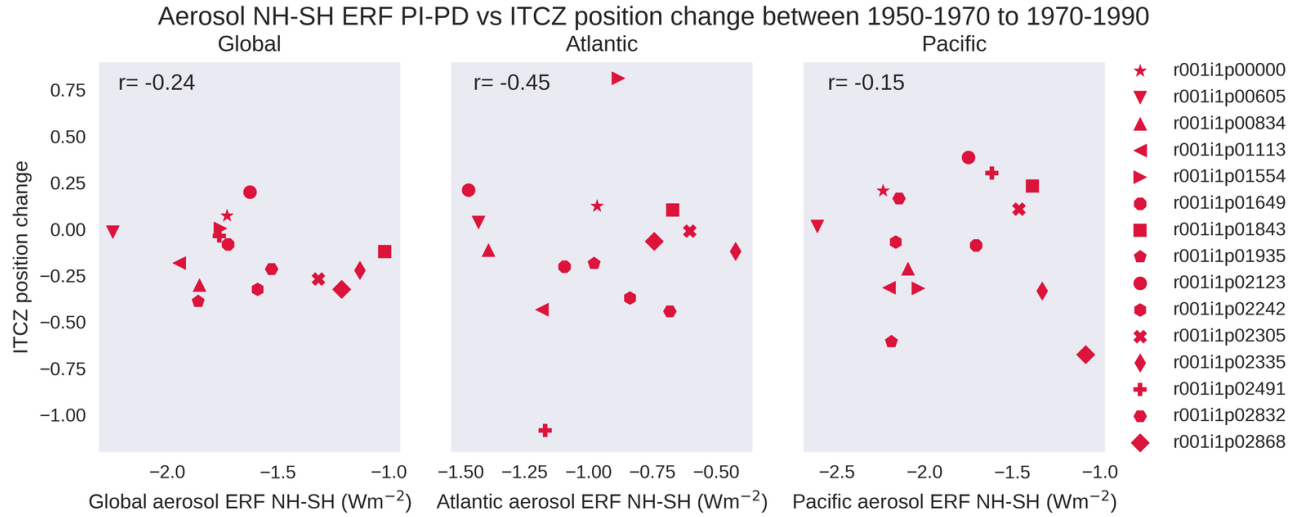
References: UKCP Land Projections: Science Report, Murphy et al., 2018

Tropical precipitation shifts | 1950-1990

Do we observe a relationship between aerosol forcing and tropical precipitation shifts historically?

Southward shift in ITCZ and tropical precipitation

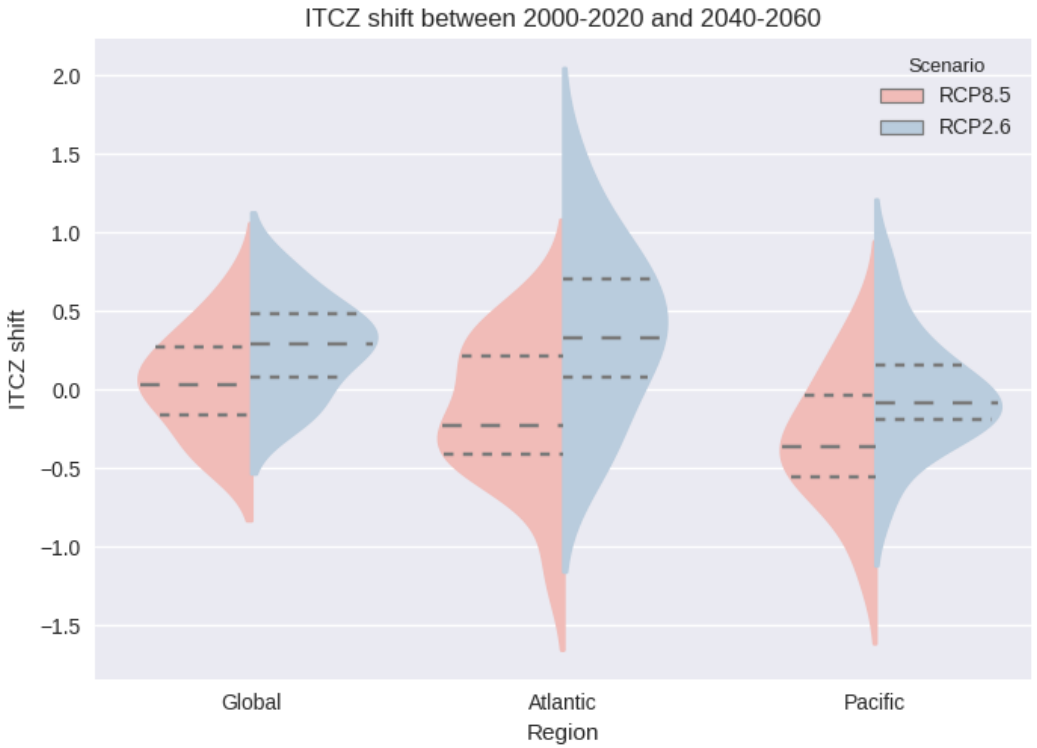


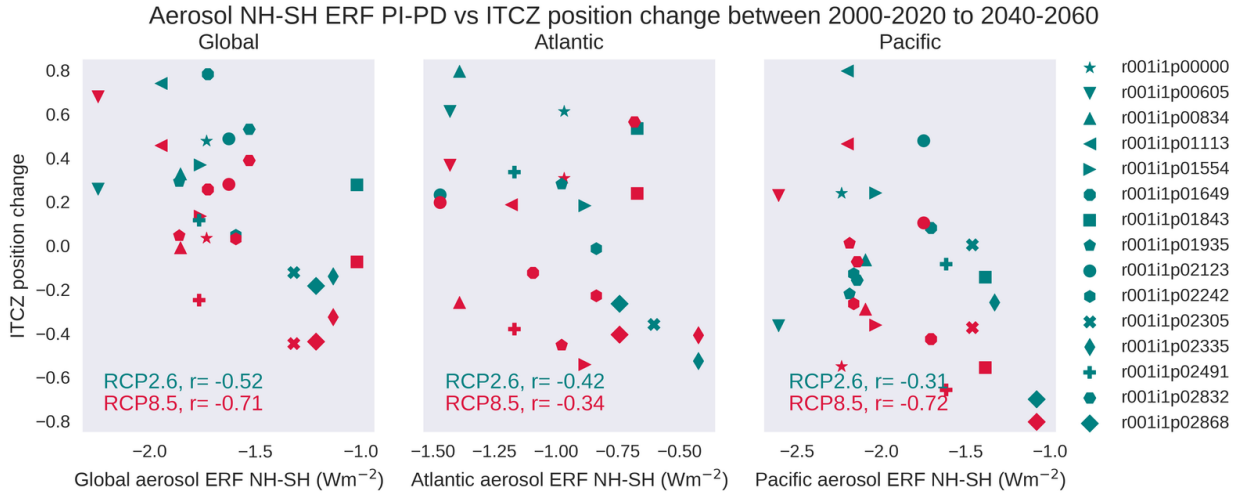


The relationship between tropical precipitation shifts and interhemispheric aerosol ERF is weaker in our PPE than CMIP5.

Tropical precipitation shifts | 2000-2060

- Direction of near-term shift depends on scenario and region
- Greater northward shift in RCP2.6 than RCP8.5 by 2060





There is a strong correlation between aerosol ERF and the ITCZ shift in the Pacific and global mean for RCP8.5, with RCP2.6 weaker.

Conclusions

- The relationship between tropical precipitation shifts in 1950-1980s and pre-industrial to present day aerosol forcing in the PPE is weaker than relationship observed across CMIP5 models.
- In the near-term future, there are both positive and negative shifts in ITCZ across the ensemble, with RCP2.6 shifting further northward.
- There is a strong correlation between aerosol forcing and the ITCZ shift in the RCP8.5 near-term future over the Pacific and global mean. However, the correlation is weaker for RCP2.6.
- **Next steps:** Further analysis to interpret the results of this study.
- **Future work:** Compare our model output to aerosol, cloud and radiation observations in attempt to identify the most plausible future aerosol-driven climate responses.