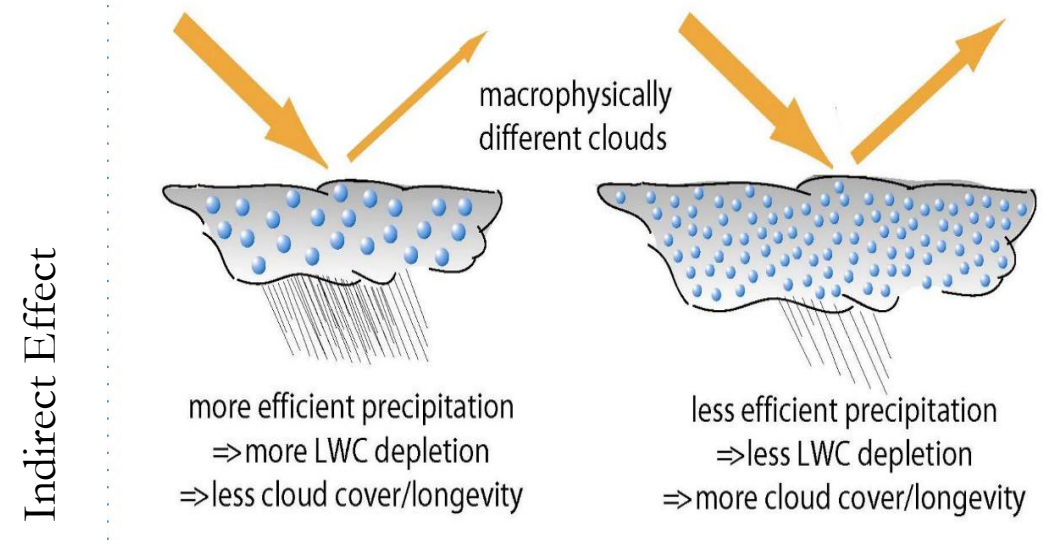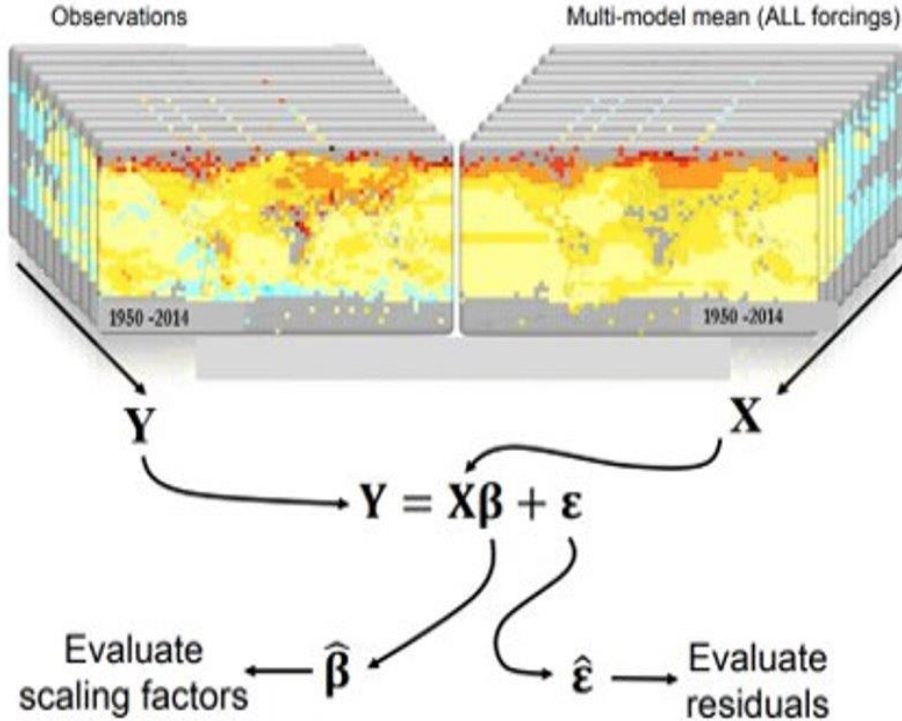❑ **Emissions of greenhouse gasses from human activities are responsible for approximately 1.1°C of earth warming (IPCC AR6).**

▪ Net cooling effect of aerosols was supposed to mitigate warming brought by greenhouse gases.

▪ Huge uncertainties in aerosol composition and hygroscopicity contribute to large uncertainties

Indirect Effect

macrophysically different clouds

more efficient precipitation
⇒more LWC depletion
⇒less cloud cover/longevity

less efficient precipitation
⇒less LWC depletion
⇒more cloud cover/longevity

❑ Obscure our understanding of how much greenhouse gases (GHG) has warmed the atmosphere.

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❑ Optimal Fingerprinting (Allen and Scott 2003)

$$Y_{OBS} = \beta_M X_M + \varepsilon$$

$$Y_{OBS} = \beta_{ANT} X_{ANT} + \beta_{NAT} X_{NAT} + \varepsilon$$

$$X_{ALL} = X_{ANT} + X_{NAT}$$

$$Y_{OBS} = \beta_{GHG} X_{GHG} + \beta_{AER} X_{AER} + \beta_{NAT} X_{NAT} + \varepsilon$$

$$X_{ALL} = X_{GHG} + X_{AER} + X_{NAT}$$

Two-Signal Detection

$$Y_{OBS} = \beta_1 X_{ALL} + \beta_2 X_{AER} + \beta_3 X_{NAT} + \varepsilon$$

$$X_{ALL} = X_{GHG} + X_{AER} + X_{NAT}$$

$$Y_{OBS} = \beta_{GHG} X_{GHG} + \beta_{AER} X_{AER} + \beta_{NAT} X_{NAT} + \varepsilon$$

Three-Signal Detection

❑ **Best estimates of the attributable and 5%–95% range are obtained**
❑ **If the confidence level of β is > 0: modelled signal are detected in observation.**

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❑ Analysis variables

▪ Extremely wet precipitation days exceeding the 99 and 95 percentile (R99pTOT, R95pTOT), Very heavy precipitation days (R20mm), Max 5-day precipitation (RX5day).

▪ Simulated MME agree with REGEN.

▪ Biases are found regionally.

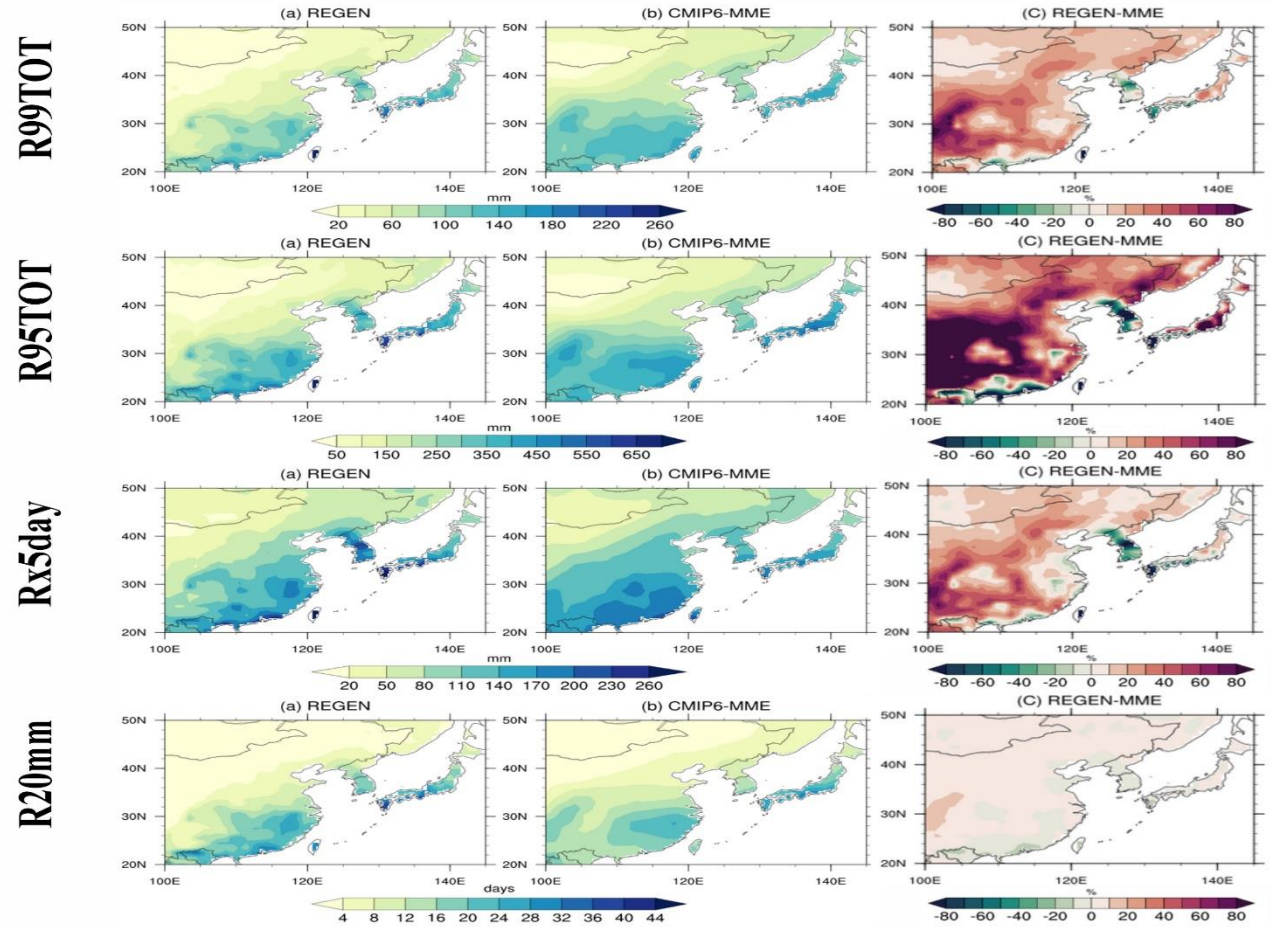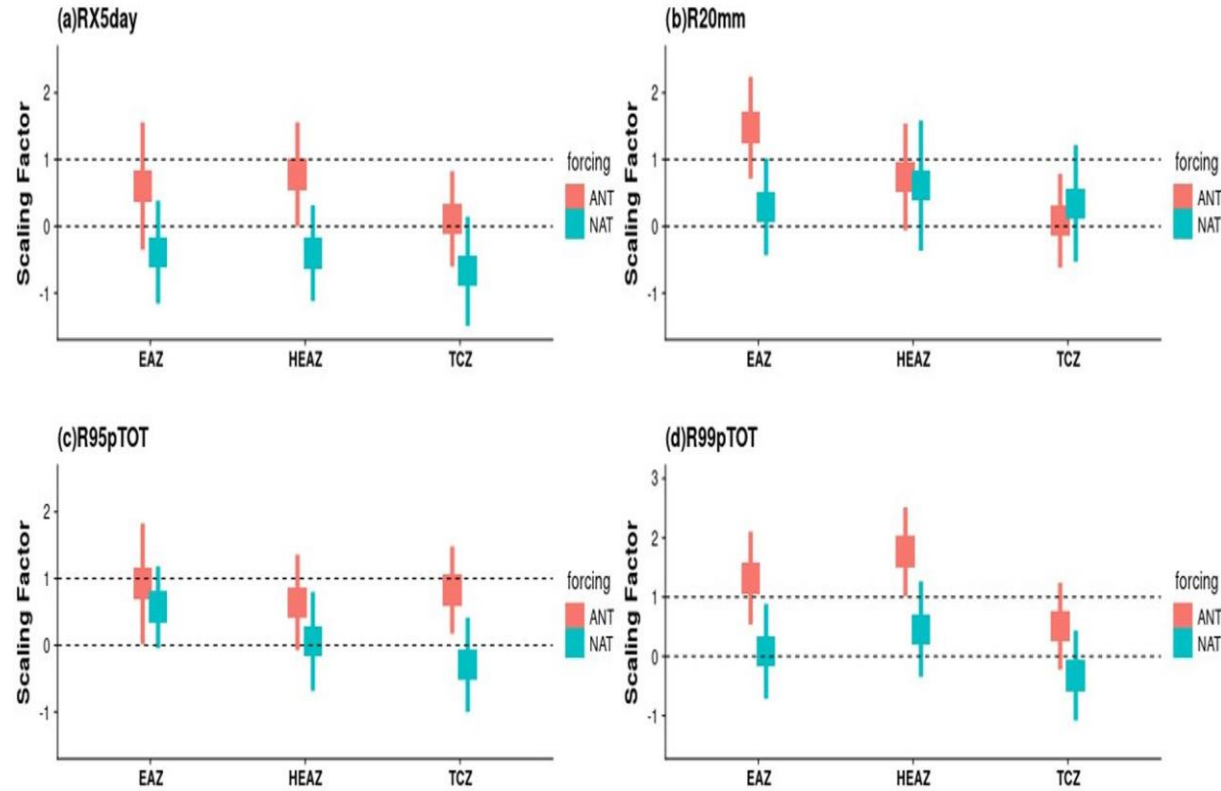▪ CMIP6-MME is a viable tool for our Attribution study.

Fig 2(a-d): R95pTOT, R99pTOT R20mm, Rx5day, REGEN and CMIP6 multi-model Ensemble, right bias over EA from 1950–2014

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Detection and Attribution

Two-signal Detection
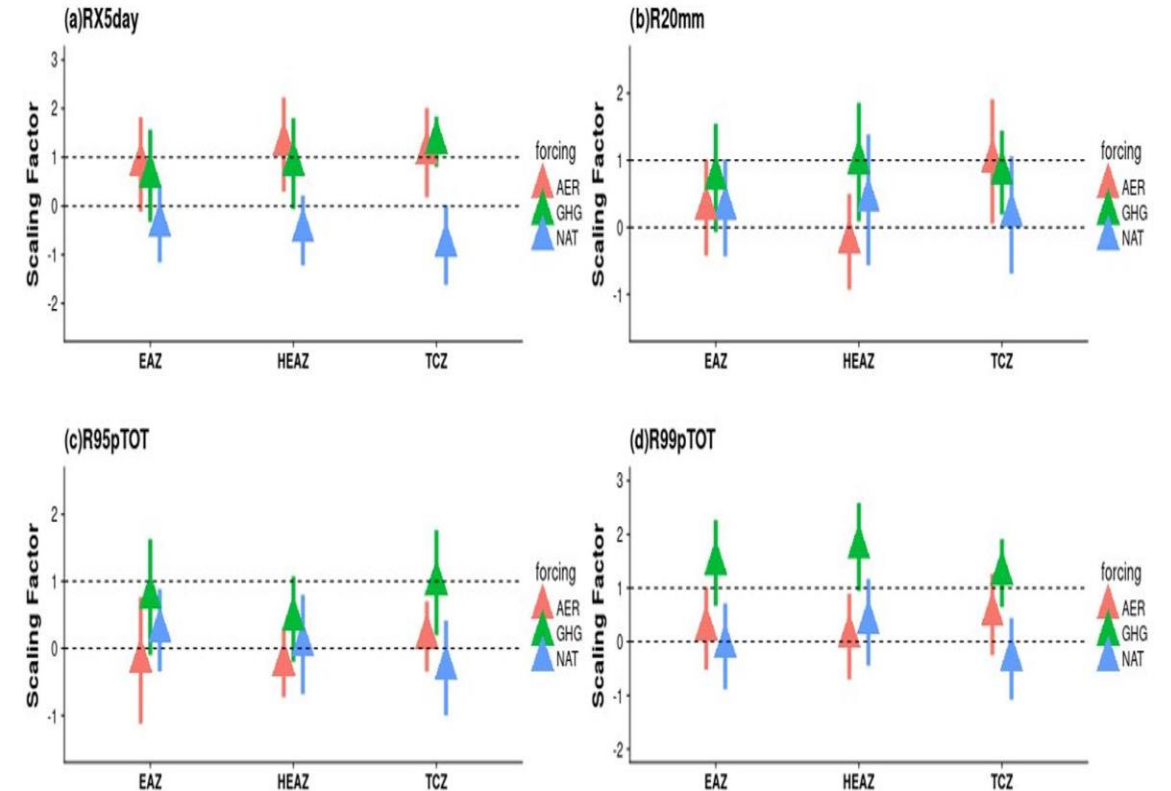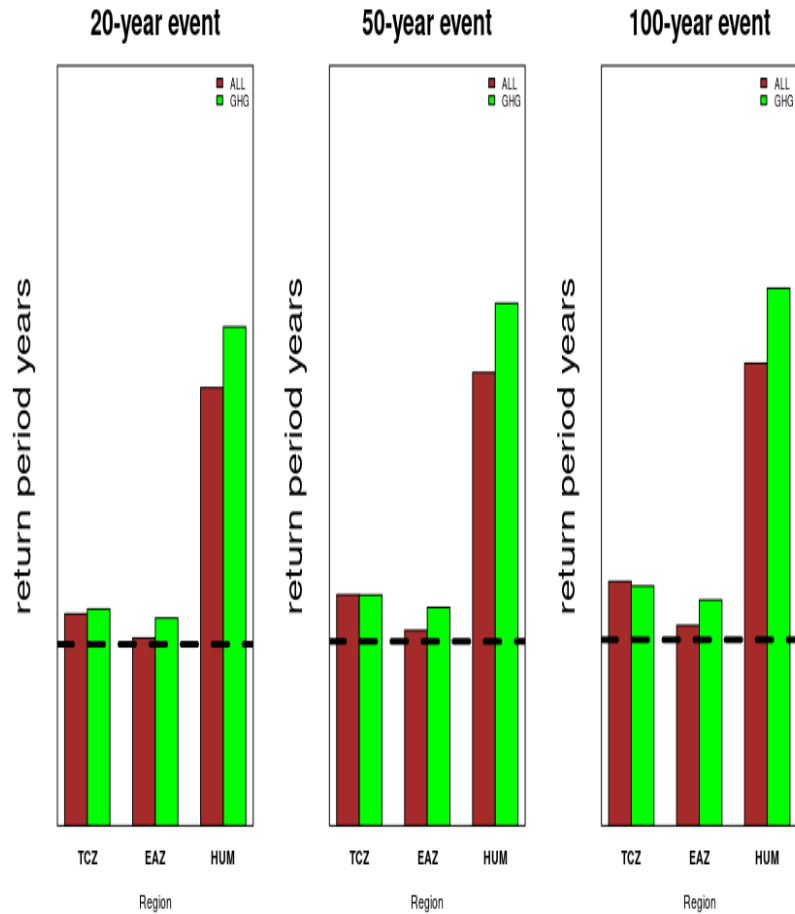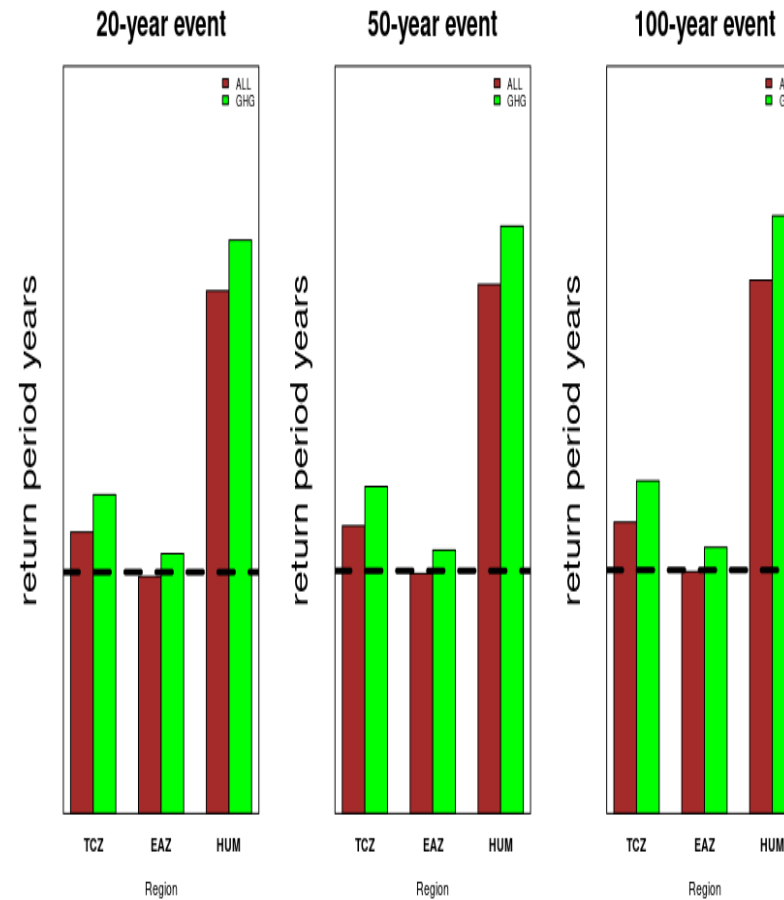
Three-signal Detection

Fig 3 (a-d): Best estimates scaling factors and their 5%–95% confidence intervals from the two-signal analysis involving ANT and NAT.

Fig 4: (a-d) Same as fig 3 but for GHG, AER and NAT

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R99pT0T

Rx5day

Fig. 5: Return event for R99PTOT (mm) 20y, 50y,100y events for GHG and ALL forcing. event thresholds are defined from NAT. note different event uses different vertical axis.

Fig 6: Same as figure 5 but for Rx5day

- Increase in the probability of modelled return events.

- Robust increases in likelihood events under GHG forcing scenario

- Consistent with previous result.

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