Do responses to different anthropogenic forcings add linearly in climate models?

Motivation

Many D&A studies assume that different drivers of radiative forcing changes are additive. This implies that the sum of responses to different forcings is statistically indistinguishable from the response to the sum of forcings. As models become more complex, this assumption must be tested.

Approach

- We calculated trends in global, annual-mean T and P of varying lengths and times from CCSM4 and GISS single-forcing (*SF*) ensembles (aerosols; LU; O_3; natural forcings; GHG), and compared their sum to trends calculated from historical (*HIST*) ensembles.
- T trends are generally additive but nonlinearities appear in P trends in GISS with interactive chemistry.
- This arise from nonlinear interactions between chemical species captured in *HIST* but absent in *SF* runs. Specifically, ozone depletion is lower in *HIST* run, with major consequences for global mean P.

Impacts

- *SF* runs help us to attribute phenomena in the real world. If the climate response to multiple forcings is not additive, this may complicate certain D&A studies.
- *SF* runs were not a priority in CMIP5. Our results should encourage modeling groups to perform these experiments.

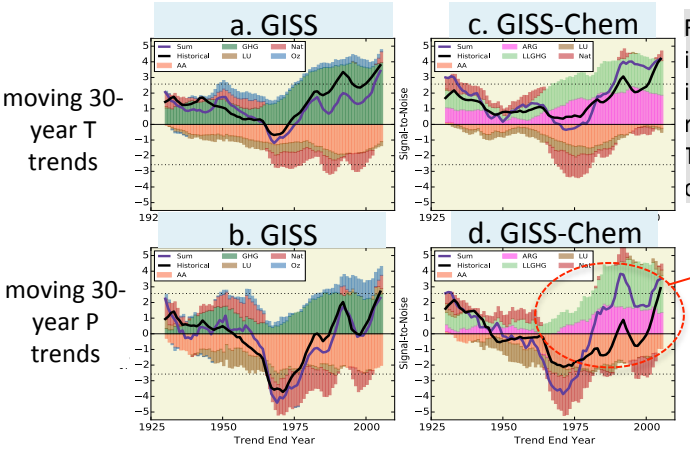

Fig. 1: S/N ratios in non-interactive (a,b) and interactive chemistry (c,d) runs as a function of time. Trends overlap by all but one year.

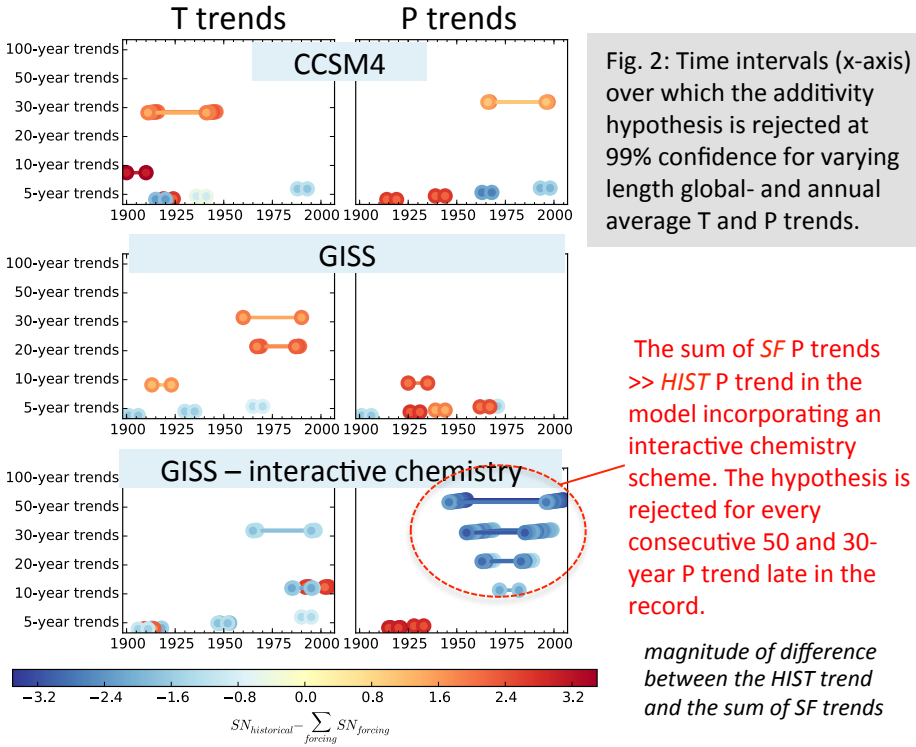

Fig. 2: Time intervals (x-axis) over which the additivity hypothesis is rejected at 99% confidence for varying length global- and annual average T and P trends.

Marvel K, G Schmidt, D Shindell, C Bonfils, A Legrande, L Nazarenko, K Tsigaridis, 2015: Do responses to different anthropogenic forcings add linearly in climate models? ERL, 10, 104010. NEW