The response of surface energy balance components and precipitation to climate forcings

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1. Motivation

- Changes in the hydrological cycle caused by global warming are expected to have severe consequences for societies, agriculture and ecosystems (*Meehl et al., 2007*).
- Response of precipitation to the all-forcing scenarios from different models is ambiguous, hence a large uncertainty in the projections.

➡ One forcing at a time to understand physical mechanisms leading to the intensification of the hydrological cycle.

➡ Test additive linearity assumption of the forcing's response.

2. Simulations

- NCAR CCSM3.5, transient simulations with fully coupled ocean
- Resolution: 1.9°x2.5° (finite volume dynamical core)

- **2x**: 1%/yr to $2xCO_2$
- **4x**: 2%/yr to $4xCO_2$
- **37**: 3.7 W/m^2 increase in solar forcing
- **74**: 7.4 W/m^2 increase in solar forcing
- **372x**: 1%/yr to $2xCO_2$ + 3.7 W/m^2 increase in solar forcing

- 5 runs x 100 yrs for each simulation to quantify internal variability.

3. Theoretical concepts

- Global mean precipitation constrained by energy availability at surface (*Allen & Ingram, 2002*).
- *Gregory et al., 2004* developed a method to separate the net flux imbalance of the climate system (N) into a radiative forcing term (F) and climate feedback term ($-\alpha\Delta T_s$):

$$N = F - \alpha\Delta T_s \qquad \text{(eq. 1)}$$

- *Forster & Taylor (2006)* extended the methodology for transient simulations.
- *Andrews (2009)* (*A09* hereafter) applied the methodology to the surface energy budget components (NET, LW, SW, LH, SH) and to precipitation (P).

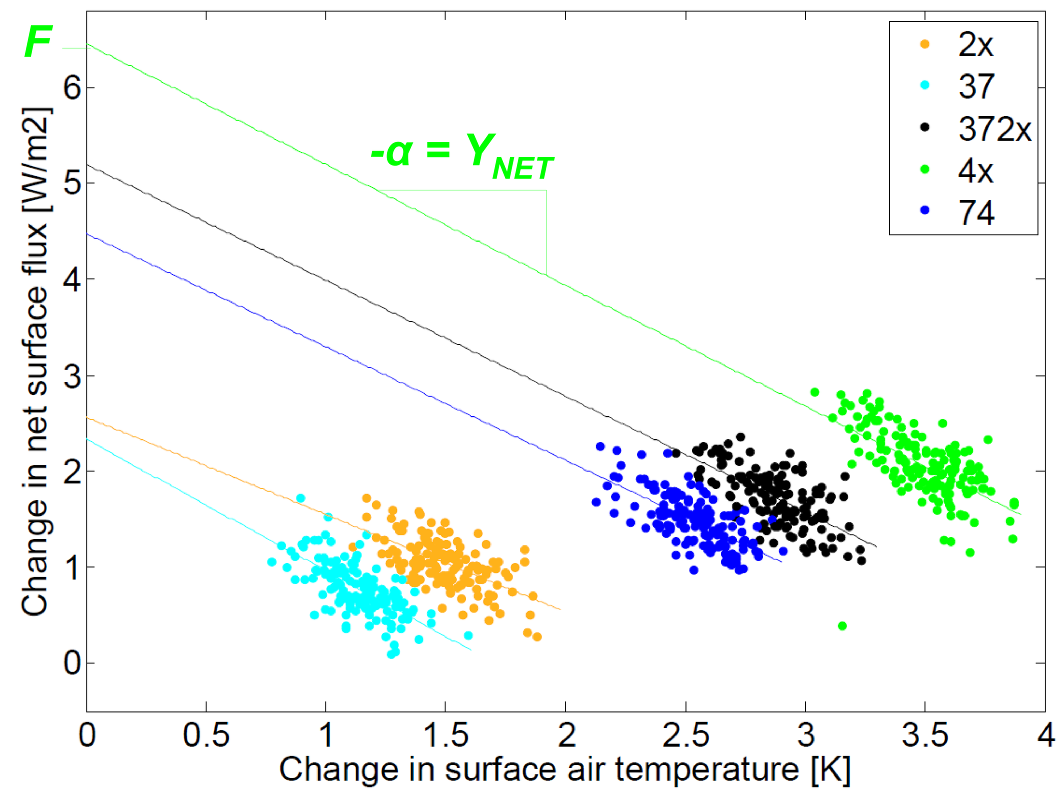

Fig. 1: Regression of change in global mean net surface energy flux against change in global mean surface air temperature after the 70th year of the simulation.

4. Results

a) Surface energy fluxes

Table 1: Components of the global mean surface feedback parameter diagnosed from each simulation. Results published in A09 are also shown. Units: W/m^2, uncertainty range is standard deviations of 5 runs.

	Y_{NET}	Y_{LW}	Y_{SW}	Y_{LH}	Y_{SH}
A09	*-0.61±0.07*	*0.63±0.06*	*-0.40±0.09*	*-1.91±0.05*	*0.28±0.03*
2x	-1.02±0.18	1.21±0.32	-0.08±0.2	-2.22±0.28	-0.09±0.12
37	-1.37±0.43	1.35±0.17	0.27±0.32	-2.38±0.22	-0.08±0.05
372x	-1.21±0.21	1.18±0.26	-0.06±0.19	-2.36±0.17	-0.09±0.15
4x	-1.26±0.43	1.5±0.3	0.33±0.3	-2.58±0.31	0.15±0.07
74	-1.18±0.1	1.16±0.29	-0.2±0.33	-2.6±0.25	0.06±0.2

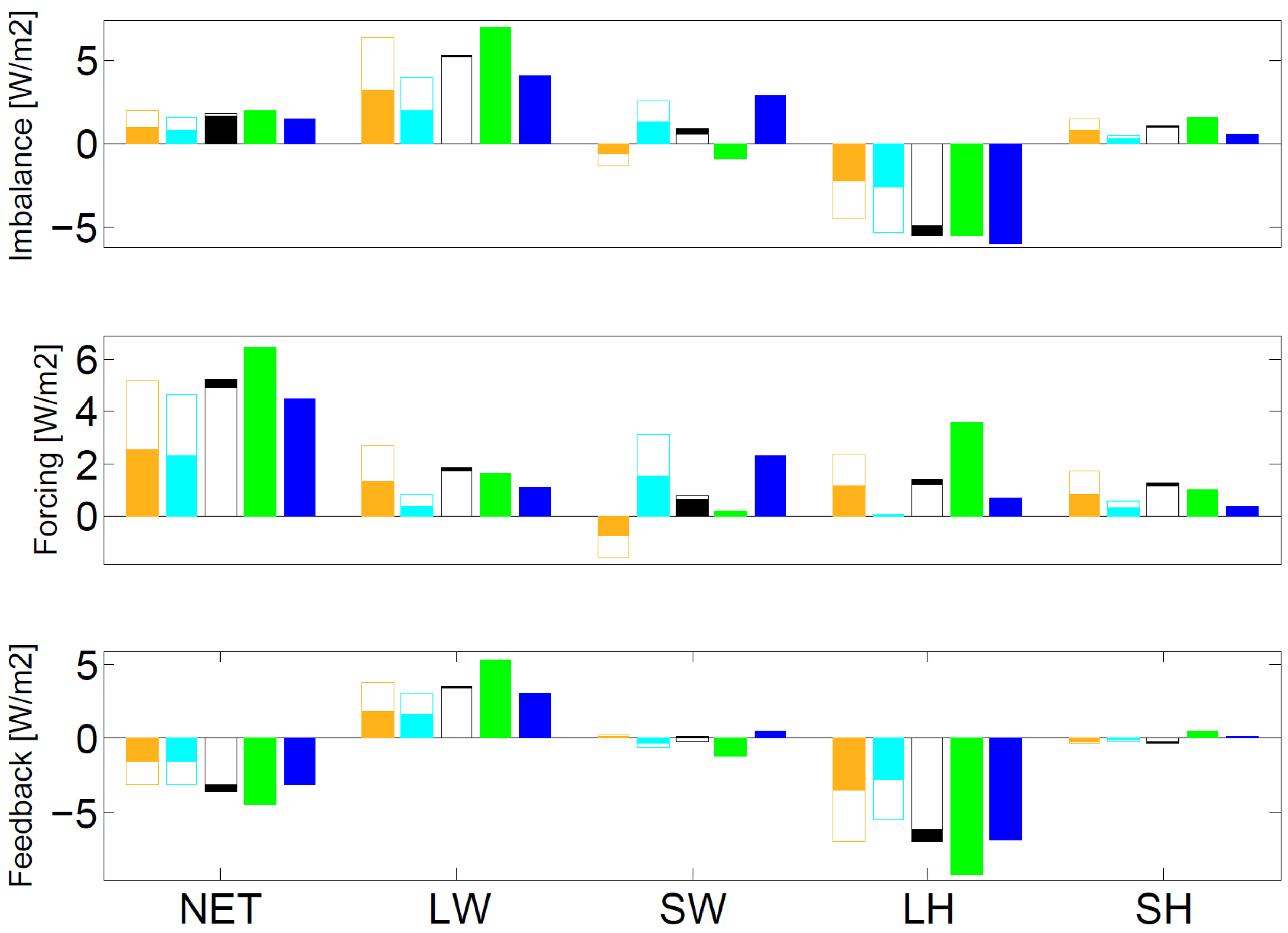

Fig. 2: Summary of the imbalance, forcing and feedback terms from eq. 1 for all five simulations. Values are averaged over the 5 runs and the years 81-100 of the simulation. Results are given for the net surface energy, longwave, shortwave, latent heat and sensible heat fluxes.

b) Precipitation

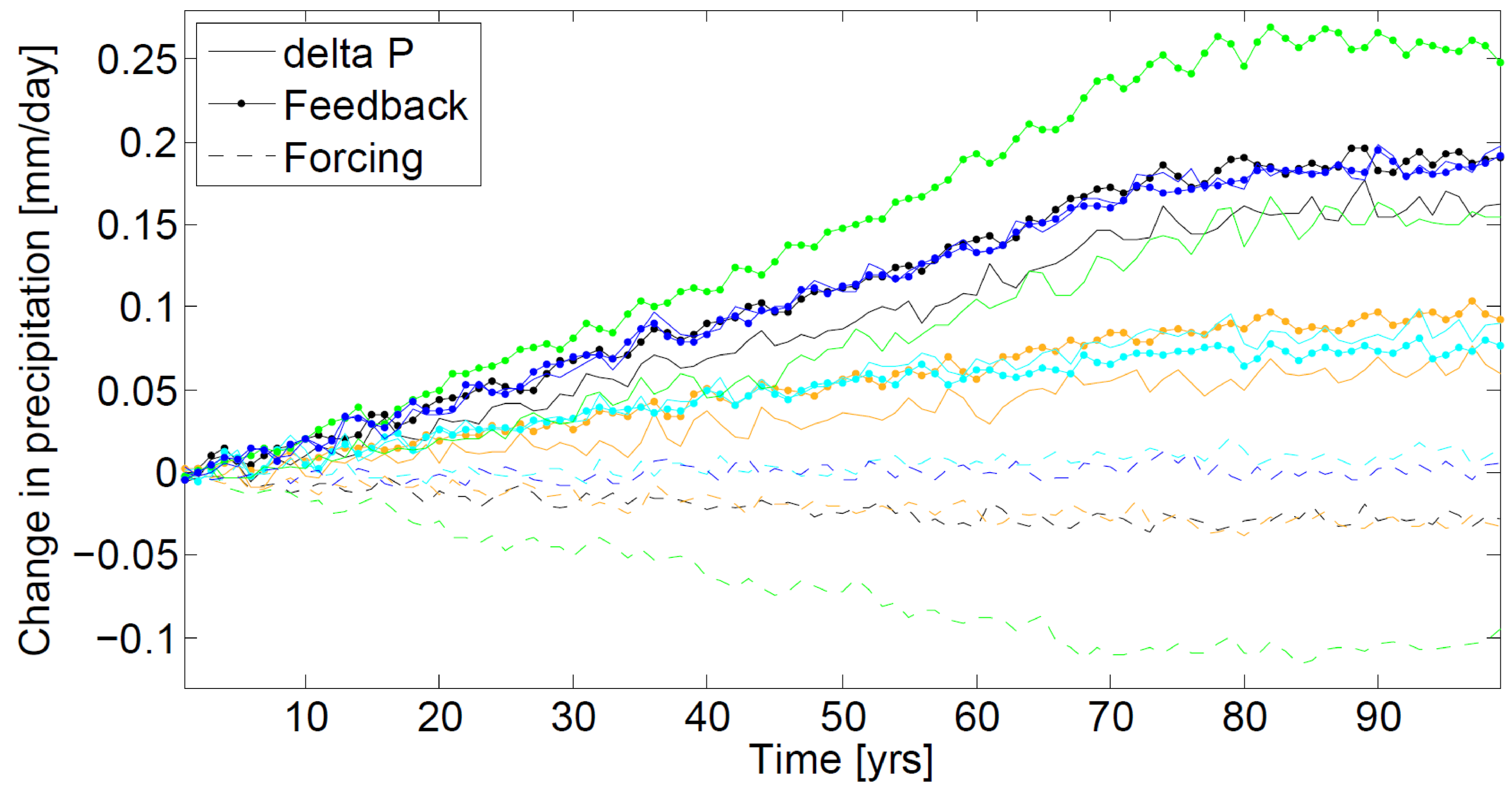

Fig. 3: Time series of net change in precipitation and its separation into forcing and feedback response averaged over the 5 runs of each simulation.

5. Summary and outlook

- Changes in surface energy budget components and precipitation are calculated for different idealized simulations.
- Feedback parameters are well constrained for NET, LW, LH and P but uncertain for SW and SH.
- Results are model dependent (see comparison with *A09*) because feedback parameter reflects the climate sensitivity of the model.

- Test assumption of linear additivity of response to a given forcing:
  - Imbalance: seem to add linearly but not for LH and P
  - Forcing: not lin. add. for CO_2, less clear for solar simulations
  - Feedback: the same since α acts to counterbalance forcing

- For precipitation, forcing term <0 in simulations with CO_2 (**2x**, **4x**, **372x**) while it is =0 for the solar-only simulations (**37**, **74**).

➡ Perform same analysis for TOA fluxes (*Forster & Taylor, 2006*).
➡ Test if assumption that feedback parameter α is not forcing dependent is justified.
➡ Investigate linear additivity of spatial patterns of precipitation, evaporation and cloud cover.

References

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