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Contributions to the observed surface warming from different radiative forcing components

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The energy balance is key to understand the Earth's climate and its variations caused by natural and anthropogenic changes in the atmospheric composition. Despite abundant observational evidence for changes in the energy balance and bottom up estimates of radiative forcings, the formal detection and attribution of the observed warming to human influence has so far relied mostly on optimal fingerprinting methods. Those do not rely strongly on the radiative forcing amplitude, but are based on the fact that spatio-temporal warming patterns of natural and anthropogenic origin are different. If a model underestimates the response to a given forcing, or underestimates the forcing itself, the response is simply scaled. We demonstrate a strong constraint on the anthropogenic warming based on the observed changes in the global energy balance combined with bottom up estimates of radiative forcing. We find that since the mid-20th century, greenhouse gases alone contributed 0.86°C with a 5-95% uncertainty of 0.6-1.1°C to the total observed change of about 0.56°C in global temperature. The observed trends are extremely unlikely (<5%) to be caused by internal variability even if current models were found to strongly underestimate internal variability. Our method makes few assumption besides fundamental principles on the conservation of energy. It also takes into account observed ocean heat content, considers uncertainties in all radiative forcing components, and in contrast to optimal fingerprinting does not rely on model simulated spatial patterns and does require any scaling of responses. Combining the results based the global energy balance presented here and the spatial information in optimal fingerprinting suggest an even higher confidence in anthropogenic causes dominating the observed warming of ocean and atmosphere.