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The timescales of climate responses to carbon dioxide and aerosols

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Enhanced emissions of both greenhouse gases and aerosols generate climate responses on a wide range of time scales. An initial radiative response triggers a set of rapid adjustments, which are eventually followed by surface-temperature-driven feedbacks. While a lot happens during the first days and months after a perturbation, the monthly mean data typically used in climate studies are too coarse to show the temporal evolution of responses. In these analyses, we take a closer look at how the climate system responds during the very first hours and days after a sudden increase in carbon dioxide (CO2), in black carbon (BC) or in sulfate (SO4). Five models have performed PDRMIP simulations with hourly output, and we also compare results to monthly PDRMIP and CMIP6 results. We find that the effect of increasing ocean temperatures kicks in after a couple of months. Rapid precipitation reductions are for all three climate perturbations established after just a couple of days, and does for BC not differ much from the full-time response. For CO2 and SO4, the magnitude of the precipitation response gradually increases with surface warming, and for CO2 the sign of the response changes for negative to positive after two years. Rapid cloud adjustments are typically established within the first 24 hours and while the magnitude of cloud feedbacks for CO2 and SO4 increases over time, the latitude-height pattern of the total cloud changes is clearly present after one year. While previously known that climate responses to BC are dominated by rapid adjustments, this work underlines the swiftness of the processes involved.