Frequently Asked Questions
FAQ 7.1 | How Do Clouds Affect Climate and Climate Change?

Clouds strongly affect the current climate, but observations alone cannot yet tell us how they will affect a future, warmer climate. Comprehensive prediction of changes in cloudiness requires a global climate model. Such models simulate cloud fields that roughly resemble those observed, but important errors and uncertainties remain. Different climate models produce different projections of how clouds will change in a warmer climate. Based on all available evidence, it seems likely that the net cloud–climate feedback amplifies global warming. If so, the strength of this amplification remains uncertain.

Since the 1970s, scientists have recognized the critical importance of clouds for the climate system, and for climate change. Clouds affect the climate system in a variety of ways. They produce precipitation (rain and snow) that is necessary for most life on land. They warm the atmosphere as water vapour condenses. Although some of the condensed water re-evaporates, the precipitation that reaches the surface represents a net warming of the air. Clouds strongly affect the flows of both sunlight (warming the planet) and infrared light (cooling the planet as it is radiated to space) through the atmosphere. Finally, clouds contain powerful updraughts that can rapidly carry air from near the surface to great heights. The updraughts carry energy, moisture, momentum, trace gases, and aerosol particles. For decades, climate scientists have been using both observations and models to study how clouds change with the daily weather, with the seasonal cycle, and with year-to-year changes such as those associated with El Niño.

All cloud processes have the potential to change as the climate state changes. Cloud feedbacks are of intense interest in the context of climate change. Any change in a cloud process that is caused by climate change—and in turn influences climate—represents a cloud–climate feedback. Because clouds interact so strongly with both sunlight and infrared light, small changes in cloudiness can have a potent effect on the climate system.

Many possible types of cloud–climate feedbacks have been suggested, involving changes in cloud amount, cloud-top height and/or cloud reflectivity (see FAQ 7.1, Figure 1). The literature shows consistently that high clouds amplify global warming as they interact with infrared radiation emitted by the atmosphere and surface. There is more uncertainty, however, about the feedbacks associated with low-altitude clouds, and about cloud feedbacks associated with amount and reflectivity in general.

Thick high clouds efficiently reflect sunlight, and both thick and thin high clouds strongly reduce the amount of infrared light that the atmosphere and surface emit to space. The compensation between these two effects makes

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Aerosol emitted within the aircraft exhaust may also affect high-level cloudiness. This last effect is classified as an aerosol–cloud interaction and is deemed too uncertain to be further assessed here (see also Section 7.4.4). Climate model experiments (Rap et al., 2010a) confirm earlier results (Kalkstein and Balling Jr, 2004; Ponater et al., 2005) that aviation contrails do not have, at current levels of air traffic, an observable forcing for aviation-induced cirrus (including linear contrails) to +0.03 (+0.01 to +0.08) $W \cdot m^{-2}$ but did not consider this to be a best estimate because of large uncertainties. Schumann and Graf (2013) constrained their model with observations of the diurnal cycle of contrails and cirrus in a region with high air traffic relative to a region with little air traffic, and estimated a RF of +0.05 (+0.04 to +0.08) $W \cdot m^{-2}$ for contrails and contrail-induced cirrus in 2006, but their model has a large shortwave contribution, and larger estimates are possible. An alternative approach was taken by Burkhardt and Kärcher (2011), who estimated a global RF for 2002 of +0.03 $W \cdot m^{-2}$ from contrails and contrail cirrus within a climate model (Burkhardt and Kärcher, 2009), after compensating for reduced background cirrus cloudiness in the main traffic areas. Based on these two studies we assess the combined contrail and contrail-induced cirrus ERF for the year 2011 to be +0.05 (+0.02 to +0.15) $W \cdot m^{-2}$ to take into uncertainties on spreading rate, optical depth, ice particle shape and radiative transfer and the ongoing increase in air traffic (see also Supplementary Material). A low confidence is attached to this estimate.

Forster et al. (2007) quoted Sausen et al. (2005) to update the 2000 forcing for aviation-induced cirrus (including linear contrails) to +0.03 (+0.01 to +0.08) $W \cdot m^{-2}$ but did not consider this to be a best estimate because of large uncertainties. Schumann and Graf (2013) constrained their model with observations of the diurnal cycle of contrails and cirrus in a region with high air traffic relative to a region with little air traffic, and estimated a RF of +0.05 (+0.04 to +0.08) $W \cdot m^{-2}$ for contrails and contrail-induced cirrus in 2006, but their model has a large shortwave contribution, and larger estimates are possible. An alternative approach was taken by Burkhardt and Kärcher (2011), who estimated a global RF for 2002 of +0.03 $W \cdot m^{-2}$ from contrails and contrail cirrus within a climate model (Burkhardt and Kärcher, 2009), after compensating for reduced background cirrus cloudiness in the main traffic areas. Based on these two studies we assess the combined contrail and contrail-induced cirrus ERF for the year 2011 to be +0.05 (+0.02 to +0.15) $W \cdot m^{-2}$ to take into uncertainties on spreading rate, optical depth, ice particle shape and radiative transfer and the ongoing increase in air traffic (see also Supplementary Material). A low confidence is attached to this estimate.