The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to consolidate knowledge from the world’s scientific community on the issue of climate change. The IPCC does not carry out primary research, but it pulls together the peer-reviewed literature on various elements of the climate change issue into consolidated reports.

Approximately every five to seven years, it produces an Assessment Report (AR) which is actually a series of three sub-reports, split by working group, each accompanied by a Summary for Policymakers. Once all three reports have been released, an overall Synthesis Report is also published.

Once they have spent several years drafting their reports, they are submitted, with a draft of a Summary for Policymakers, for review by governments, who request edits to bring the drafts in line with policy. The final drafting session for each of the working groups takes place at a week-long meeting.

The Fifth Assessment Report’s (AR5) WG I report was deliberated in Stockholm over a week and was finalised on Friday 27 September.

The three working groups:
- **WG I** Assesses scientific aspects of the climate system and climate change.
- **WG II** Assesses vulnerability of socio-economic and natural systems to climate change, consequences, and adaptation options.
- **WG III** Assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change.

**THE FULL AR5 WGI REPORT**

Whilst this memo will focus on the aviation-related sections of the WG I report, arguably the headline fact from the report is that its authors have concluded, with 95% certainty, that most of the observed climate change between 1950 and 2010 has been human-induced.

- **Summary for Policymakers:** [www.climate2013.org/spm](http://www.climate2013.org/spm)
- **Full AR5 Working Group I Report:** [http://tinyurl.com/ndlyfdu](http://tinyurl.com/ndlyfdu)
- **Headline summary of the report:** [http://tinyurl.com/pud32a5](http://tinyurl.com/pud32a5)
- **WG I press release:** [http://tinyurl.com/k4k3auy](http://tinyurl.com/k4k3auy)
- **Plain-language summary of key findings from The Guardian:** [http://tinyurl.com/pl6qecc](http://tinyurl.com/pl6qecc)
**ANALYSIS OF THE AR5 WG I REPORT FOR AVIATION**

The majority of references to aviation in AR5 are around the issue of contrails, although it is still evident that the confidence level for assessments of contrail impact on climate change are low. Compared to the previous IPCC assessment (AR4, released in 2007), the combined estimated effect of contrails and cirrus cloud enhancement remains pretty much the same. Aviation is not mentioned in any other part of this first WG report. For example, we cannot find a reference to the sources of carbon dioxide – this may come in the later reports.

Whilst it looks below as if aviation is mentioned a lot, it is important to remember that the *Summary for Policymakers* is 36 pages long and the full *WG I Report* is 2216 pages long.

The only tangential mention of aviation from us appears in black, the text from the IPCC appears in dark blue and links to the relevant chapters appear as light blue. The below is necessarily very technical.

**AR5 WG I: SCIENTIFIC ASPECTS OF THE CLIMATE SYSTEM AND CLIMATE CHANGE, AVIATION-RELEVANT REFERENCES**

This section provides an overview of the aviation-related mentions in both the *Summary for Policymakers* and the full AR5 WG I report.

**Summary for Policymakers**

The only tangential mention of aviation in the *Summary* [www.climate2013.org/spm](http://www.climate2013.org/spm) is a reference to contrails. Compared to earlier drafts, mention of persistent contrails from aviation has disappeared from the final *Summary for Policymakers*. The only reference to contrails in the *Summary for Policymakers* appears on page 12 in a section on ‘drivers of climate change’:

- Small forcings due to contrails (0.05 Wm\(^{-2}\), including contrail-induced cirrus).

Putting these values into context, the *Summary for Policymakers* mentions a total anthropogenic RF best estimate for 2011 of 2.29 [1.13 to 3.33] Wm\(^{-2}\) (down from 2.40 in some of the drafts). This suggests that according to the AR5 WGI, contrails plus contrail-induced cirrus account for 2.18% of total anthropogenic RF (0.05/2.29 Wm\(^{-2}\)).

**AR5 WGI full report**

In the main report, aviation is first discussed in the technical summary [http://tinyurl.com/pu6r60s](http://tinyurl.com/pu6r60s). In this opening chapter, aviation is mentioned in the following section:

- **TS.3.4 Radiative Forcing from Land Surface Changes and Contrails**
  
  Persistent contrails from aviation contribute a positive RF of 0.01 [0.005 to 0.03] Wm\(^{-2}\) (medium confidence) for year 2011, and the combined contrail and contrail-cirrus ERF from aviation is assessed to be 0.05 [0.02 to 0.15] Wm\(^{-2}\) (low confidence). This forcing can be much larger regionally but there is now medium confidence that it does not produce observable regional effects on either the mean or diurnal range of surface temperature. [7.2.7]

This fact is repeated in the main two chapters to deal with aviation-related contrails, Chapter 7: clouds and aerosols [http://tinyurl.com/o9lqph](http://tinyurl.com/o9lqph). Of note is the downward adjustment of RF from persistent contrails from +0.02 to +0.01 Wm\(^{-2}\) (2011) compared to the previous draft. The effect from combined contrail and contrail-cirrus from aviation has remained the same (+0.05 Wm\(^{-2}\)). The relevant text in the summary section reads as follows:

- Persistent contrails from aviation contribute a RF of +0.01 (+0.005 to +0.03) Wm\(^{-2}\) for year 2011, and the combined contrail and contrail-cirrus ERF from aviation is assessed to be +0.05 (+0.02 to +0.15) Wm\(^{-2}\). This forcing can be much larger regionally but there is now medium confidence that it does not produce observable regional effects on either the mean or diurnal range of surface temperature. [7.2.7]

The full text in the chapter, starting on page 7-24, says:

- **7.2.7 Anthropogenic Sources of Moisture and Cloudiness**
  
  Human activity can be a source of additional cloudiness through specific processes involving a source of water vapour in the atmosphere. We discuss here the impact of aviation and irrigation on water vapour and cloudiness. The impact of water vapour sources from combustion at the Earth’s surface is thought to be negligible. Changes to the hydrological cycle because of land use change are briefly discussed in Section 12.4.8.

- **7.2.7.1 Contrails and Contrail-Induced Cirrus**
  
  Aviation jet engines emit hot moist air, which can form line shaped persistent condensation trails (contrails) in environments that are supersaturated with respect to ice and colder than about –40°C. The contrails are composed of ice crystals that are typically smaller than those of background cirrus (Heymsfield et al., 2010; Frömming et al., 2011). Their effect on longwave radiation dominates over their shortwave effect (Stuber and Forster, 2007; Rap et al., 2010b; Burkhardt and Kärcher, 2011) but models disagree on the relative importance of the two effects. Contrails have been observed to spread into large cirrus sheets which may persist for several hours, and observational studies confirm their overall positive net RF impact (Haywood et al., 2009). 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 coverage, an observable effect on the mean or diurnal range of surface temperature (medium confidence).

Estimates of the RF from persistent (linear) contrails often correspond to different years and need to be corrected for the continuous increase in air traffic. More recent estimates tend to indicate somewhat smaller RF than assessed in the AR4 (see Table 7.SM.1 and text in *Supplementary Material*). We adopt a RF estimate of +0.01 (+0.005 to +0.03) Wm\(^{-2}\) for persistent (linear) contrails for 2011, with a medium confidence attached to this estimate. An additional RF of +0.003 Wm\(^{-2}\) is due to emissions of water vapour in the stratosphere by aviation as estimated by Lee et al. (2009). 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) Wm⁻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) Wm⁻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 Wm⁻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 assessed the combined contrail and contrail-induced cirrus ERF for the year 2011 to be +0.05 (+0.02 to +0.15) Wm⁻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.

And again in Chapter 8: anthropogenic and natural radiative forcing: http://tinyurl.com/oy64ct8, where Page 8-25 of the chapter has this text:

> **8.3.3.3 Stratospheric Water Vapour**

Stratospheric water vapour is dependent upon the amount entering from the tropical troposphere and from direct injection by volcanic plumes (Joshi and Jones, 2009) and aircraft, and the in situ chemical production from the oxidation of methane and hydrogen. This contrasts with tropospheric water vapour which is almost entirely controlled by the balance between evaporation and precipitation (see FAQ 8.1). We consider trends in the transport (for instance due to the Brewer-Dobson circulation or tropopause temperature changes) to be climate feedback rather than a forcing so the anthropogenic RFs come from oxidation of methane and hydrogen, and emissions from stratospheric aircraft.

Page 8-26 says:

RF from the current aircraft fleet through stratospheric water vapour emissions is very small. Wilcox et al. (2012) estimate a contribution from civilian aircraft in 2005 of 0.00009 (0.0003–0.0013) Wm⁻² with high confidence in the upper limit. Water vapour emissions from aircraft in the troposphere also contribute to contrails which are discussed in Section 8.3.4.5.

And page 8-29 says:

> **8.3.4.5 Contrails and Contrail-Induced Cirrus**

AR4 assessed the RF of contrails (persistent linear contrails) as +0.01 (+0.007 to +0.02) Wm⁻² and provided no estimate for contrail induced cirrus. In AR5, Chapter 7 gives a best estimate of RF due to contrails of +0.01 (+0.005 to +0.03) Wm⁻² and an ERF estimate of the combined contrails and contrail induced cirrus of +0.05 (+0.02 to +0.15) Wm⁻². Since AR4, the evidence for contrail induced cirrus has increased due to observational studies (see further details Chapter 7, Section 7.2.5).

In sum, and against the background of a total anthropogenic RF best estimate for 2011 of 2.29 [1.13 to 3.33] Wm⁻², AR5 WG I estimates that contrails account for 0.44% of total anthropogenic RF (0.01/2.29 Wm⁻²) and combined with contrail-induced cirrus for 2.18% of total anthropogenic RF (0.05/2.29 Wm⁻²). Therefore, the best estimate for RF from contrail-induced cirrus alone would appear to be 1.74% (0.04/2.29 Wm⁻²).

In table 8.5 on page 8-39, looking at the confidence levels of the impact of various radiative forcing elements, the above is presented for contrails and contrail-induced cirrus.

From page 8-65, there is a discussion about the metrics and impacts by sector:

Metrics for individual land-based sectors are often similar to the global mean metric values (Shindell et al., 2008). In contrast, metrics for emissions from aviation and shipping usually show large differences from global mean metric values (Table 8.A.3 vs Table 8.A.7). Though there can sometimes be substantial variation in the impact of land-based sectors across regions, and for a particular region even from one sector to another, variability between different land-based sources is generally smaller than between land, sea and air emissions.

NOx from aviation is one example where the metric type is especially important. GWP100 values are positive due to the strong response of short-lived O₃. Reported GWP100 and GTP100 values are of either sign, however, due to the differences in balance between the individual effects modelled. Even if the models agree on the net effect of NOx, the individual contributions can differ significantly, with large uncertainties stemming from the relative magnitudes of the methane and O₃ contributions can differ significantly, with large uncertainties stemming from the relative magnitudes of the methane and O₃ responses (Myhre et al., 2011) and the background tropospheric concentrations of NOx (Holmes et al., 2011; Stevenson and Derwent, 2009). Köhler et al. (2013), find strong regional sensitivity of O₃ and CH₄ to NOx particularly at cruise altitude. Generally, they find the strongest effects at low latitudes. For the aviation sector contrails and contrail induced cirrus are also important. Based on detailed studies in the literature, Fuglestvedt et al. (2010) produced GWP and GTP for contrails, water vapor, and contrail induced cirrus.

Figure 8.17 on page 8-120 also shows the RF of aircraft, as does figure 8.34 on page 8-137.

**NEXT STEPS**

Working Group II will meet in Yokohama between 25-29 March 2014, WG III will meet in Berlin between 7-11 April 2014 and the final Synthesis Report will be released from Copenhagen in October 2014.