A Brief Summary of the Special Report on Aviation and the Global Atmosphere*

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The report assesses the effect of aircraft on climate and atmospheric ozone. It was prepared by the Intergovernmental Panel on Climate Change (IPCC) in collaboration with the Scientific Assessment Panel of the Montreal Protocol at the request of the International Civil Aviation Organization (ICAO), which also provided some technical assistance.

The Special Report in its Foreword, explains that "the state of understanding of the relevant science of the atmosphere, aviation technology, and socio-economic issues associated with mitigation options is assessed and reported for both subsonic and supersonic fleets. The potential effects that aviation has had in the past and may have in the future on both stratospheric ozone depletion and global climate change are covered; environmental impacts of aviation at the local scale, however, are not addressed".

Some of the findings relevant to the ozone layer are:

- Aircraft emit gases and particles directly into the upper troposphere and lower stratosphere where they have an impact on atmospheric composition;

- Aircraft-emitted nitrogen oxides participate in ozone chemistry;

- Subsonic aircraft fly in the upper troposphere and lower stratosphere (at altitudes

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of about 9-13 kilometers), whereas supersonic aircraft cruise several kilometers higher (at about 17-20 km) in the stratosphere. Ozone in the upper troposphere and lower stratosphere is expected to increase in response to NOx increases and methane is expected to decrease.

- At altitudes higher than 13 km, increases in NOx lead to decreases in the stratospheric ozone layer.

- Ozone lifetimes in these regions increase with altitude and hence perturbations to ozone by aircraft depend on the altitude of NOx injection and vary from regional in scale in the troposphere to global in scale in the stratosphere.

- Water vapor, sulfur oxides (SOx) and soot (these last two are both examples of aerosols) emitted by aircraft play both direct and indirect roles in climate change and ozone chemistry;

- Aircraft sulfur and water emissions in the stratosphere tend to deplete ozone, partially offsetting the NOx-induced ozone (tropospheric) increases. The degree to which this occurs is, as yet, unquantified. **The Special Report concluded that the impact of subsonic aircraft emissions on stratospheric ozone requires further evaluation.**

- One possibility for the future is the development of a fleet of second generation supersonic aircraft, although there is considerable uncertainty whether any such fleet will be developed. These supersonic aircraft are projected to cruise at an altitude of about 19 km, about 8 km higher than subsonic aircraft, and to emit carbon dioxide, water vapor, NOx, SOx, and soot into the stratosphere.

- NOx, water vapor, and SOx from supersonic aircraft emissions all contribute to changes in stratospheric ozone;

- The effect of introducing a civil supersonic fleet of 1,000 aircraft (one scenario considered) is to reduce stratospheric ozone.

- Flying higher leads to larger ozone column decreases, while flying lower leads to smaller ozone column decreases and may even result in an ozone column increase for flight in the lowermost stratosphere.

- In addition, emissions from supersonic aircraft in the Northern Hemisphere stratosphere may be transported to the Southern Hemisphere where they cause ozone depletion.

Some of the findings relevant to climate change are:

- The gases and particles emitted by the aircraft alter the concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), ozone (O_3), and methane (CH_4); trigger formation of condensation trails and may increase cirrus cloudiness-, all of which contribute to climate change.

- Emissions of carbon dioxide by aircraft were 0.14 Carbon Gigaton per year (Gt C/ year) in 1992. This is about 2% of total anthropogenic carbon dioxide emissions in 1992 or about 13% of carbon dioxide emissions from all transportation sources;

• The range of scenarios considered in the report projects that aircraft emissions of carbon dioxide will continue to grow and by 2050 will be 0.23 to 1.45 Gt C/year. It means 1.6 to 10 times the value in 1992.

• NOx emissions are expected to decrease the concentration of methane, these reductions tend to cool the surface of the Earth.

• The effect of subsonic aircraft water emissions is smaller than those of other aircraft emissions such as carbon dioxide and NOx.

• In 1992, aircraft line-shaped condensation trails (contrails) were estimated to cover 0.1% of the Earth's surface on an annually averaged basis with larger regional values. Contrails tend to warm the Earth. The contrail cover is projected to grow to 0.5% by 2050 in the reference scenario of the report.

• The climate impacts of different anthropogenic emissions can be compared using the concept of radiative forcing. The best estimate of the radiative forcing in 1992 by subsonic aircraft is 0.05 Wm^{-2} or about 3.5% of the total radiative forcing by all anthropogenic activities;

• For the reference scenario (it assumes 3.1% traffic growth per year and 1.7% average annual growth rate of fuel burn from 1990 to 2050, 2,9 % economic and 1.4% population average annual growth for 1990-2025, 2,3 % economic and 0.7% population average annual growth for 1990-2100, corresponding to a 6.4 ratio of traffic 2050/1990 and 2.7 ratio of fuel burn 2050/1990), the radiative forcing in 2050 is 0.19 Wm^{-2}, approximately four times the value in 1992. According to the range of scenarios considered in the report, the forcing is projected to grow to 0.13 to 0.56 Wm^{-2} in 2050, from 2.6 to 11 times the value in 1992.

· The combined fleet (assuming that 1,000 supersonic aircraft would replace 11% of the subsonic fleet, the civil subsonic fleet at the end of 1997 was 12,000 aircraft) is projected to add 0.08 Wm^{-2} (42%) to the 0.19 Wm^{-2} radiative forcing of the reference scenario in 2050. Most of this additional forcing is due to accumulation of stratospheric water vapor.

What are the options to reduce emissions and impacts?

There is a range of options to reduce the impact of aviation emissions:

1. Changes in aircraft and engine technology;

2. Changes in fuel;

3. Improvements in air traffic management and other operational procedures;

4. Regulatory, economic and other options. Policy options to reduce emissions further include more stringent aircraft engine emissions regulations, removal of subsidies and incentives that have negative environmental consequences, market-based options such as environmental levies (charges and taxes) and emissions trading, voluntary agreements, research programs, and substitution of aviation by rail and coach.