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Brussels

Nitrogen Oxides (NOx)

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Flightpath 2020 Workshop:

Beyond CO_2: Bio kerosene, engine emissions and technical constraints

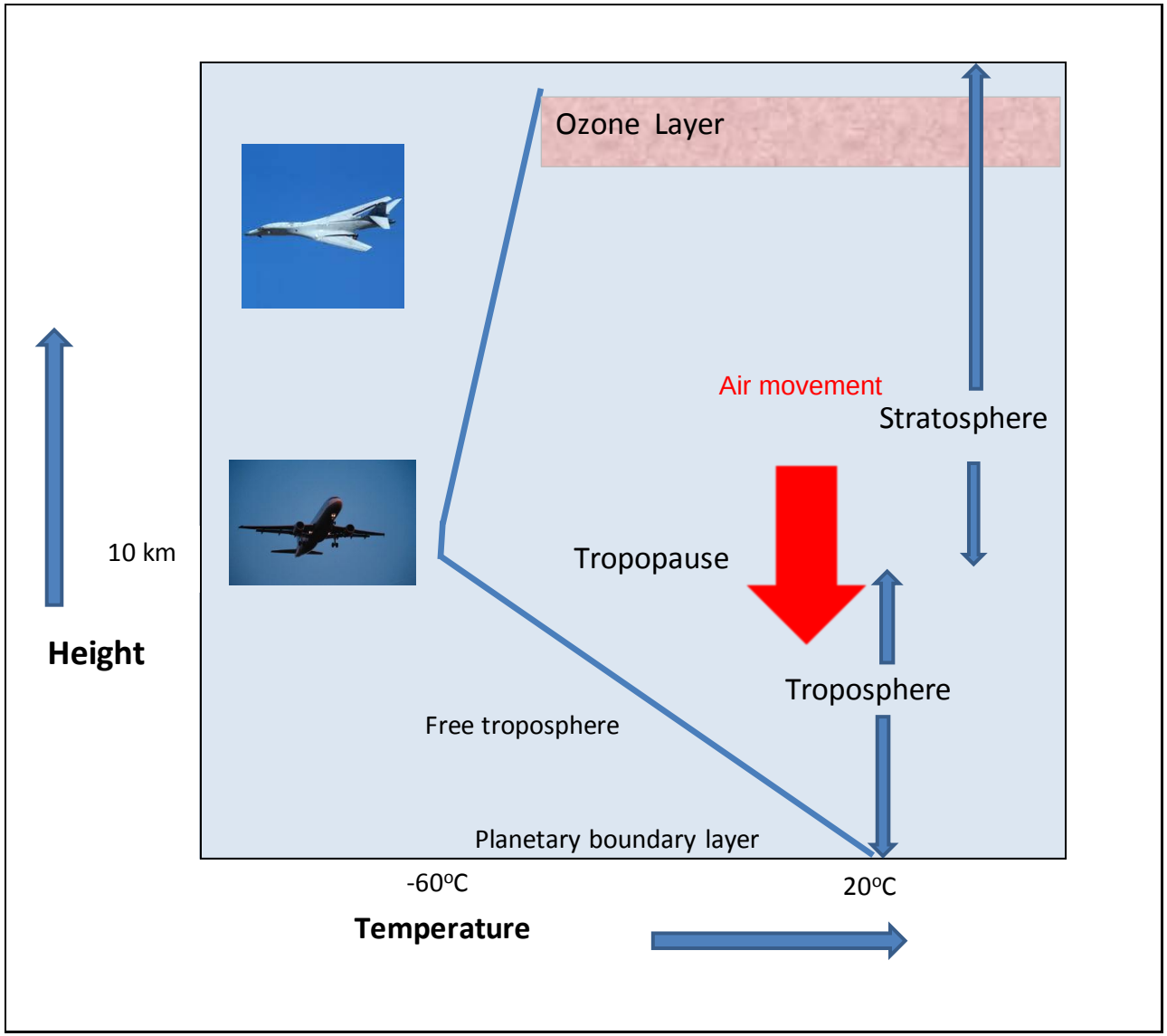
ENVIRON

Content

- Introduction
- NOx impacts
- Aviation contribution
- NOx control

Introduction

Troposphere/Stratosphere



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Atmospheric chemistry

- Pollutants interact
- Cannot consider NOx in isolation
- Chemistry complex
- Location of emissions e.g. altitude and latitude

NOx Impacts

NOx Impacts 1: Human Health

$NOx = NO + NO_2$

$NO + O_3 \Rightarrow NO_2$

Human health effects

NO_2 concentrations exceed EU limit value in many urban areas

Direct aircraft emissions may contribute to exceedences; but unlikely to be the major cause

High primary NO_2 emissions at idle (~50%)

NOx Impacts 2 : Ozone

Ozone formation

NOx + VOC + hν ⇨ ozone

Background tropospheric ozone concentrations increasing

Material damage

Crop damage

Human health

Greenhouse gas

Impacts

Important in boundary layer and free troposphere

NOx Impacts 3: Particulate Matter (PM)

NOx ⇨ secondary inorganic aerosols

Contributes to $PM_{2.5}$ concentrations

Human health impacts

NOx increases oxidation capacity of atmosphere, increasing SO_2 oxidation to form secondary inorganic aerosol

NOx Impacts 4: Ecology

Wet and dry deposition of nitrogen

Regional Pollution

Acidification of freshwater and terrestrial habitats

Eutrophication of semi natural habitats

Impacts

Aircraft emissions unlikely to be important

NOx Impacts 5: Climate Change

NOx is a greenhouse gas

Direct GHG

- Nitrogen deposition in forest results in N_2O emissions
- NOx forms Ozone

Indirect GHG

Methane reduction

Neutralises O_3 impact?

Ozone Layer

No evidence of aircraft NOx emissions depleting ozone in the ozone layer

Upper Troposphere/Lower Stratosphere

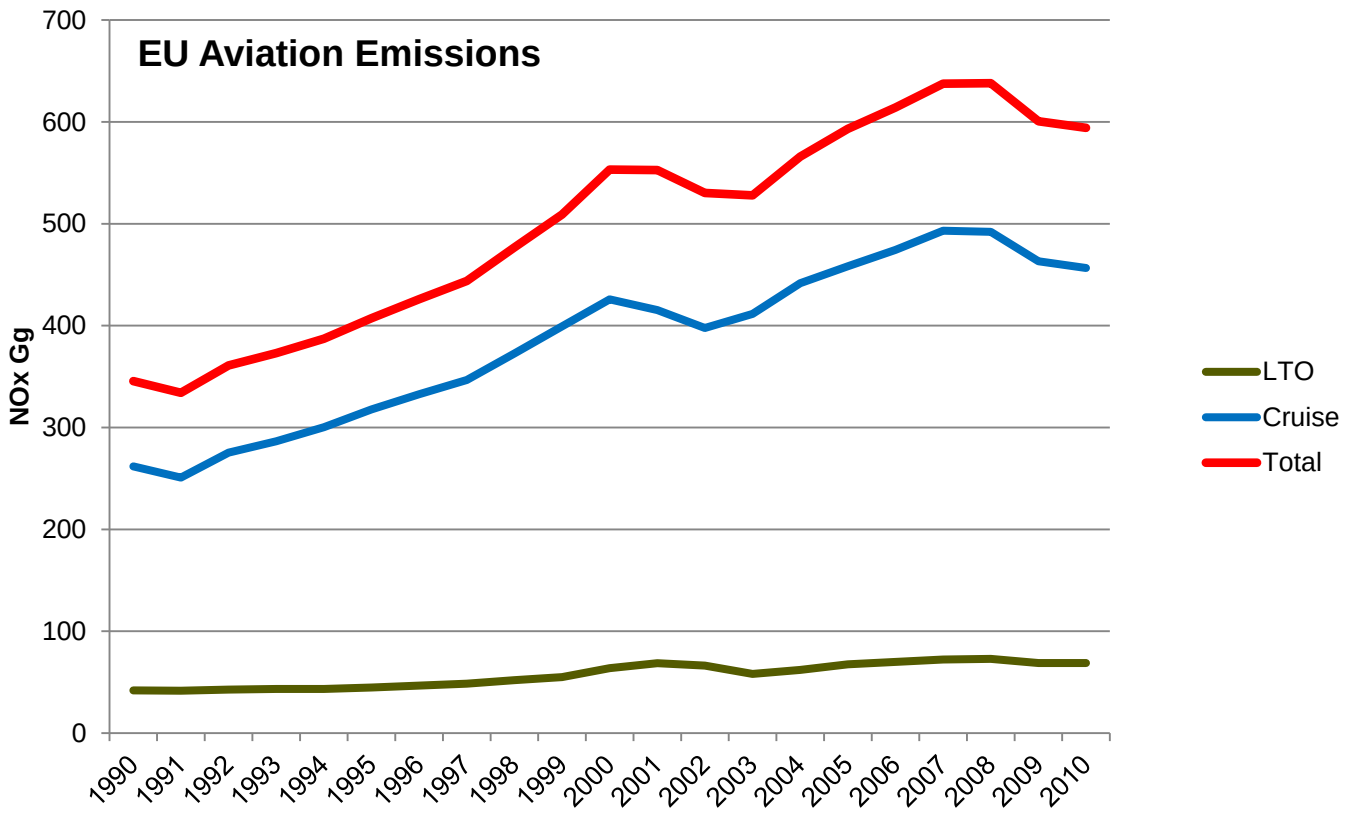
- 60% of NOx emitted @ 9-12km
- Aircraft dominant anthropogenic source of NOx
- (other main source - lightning)
- Ozone in these altitudes has stronger specific radiative forcing ($mWm^{-2}/TgN\ yr^{-1}$) >5.5 than for other NOx sources
- NOx reduced methane (CH_4)
- Ozone/CH_4 impacts on different temporal and spatial scales

Aviation Contribution

EU Emissions in Perspective

- NOx emissions in EU in 2010
  - LTO + Cruise = ca. 4 %
  - LTO = ca. 0.4%
- Road transport - ground level
  - 32% EU emissions
  - ca. 75 x LTO
  - 8 x (LTO + Cruise)

EU LTO + Cruise NOx Emissions



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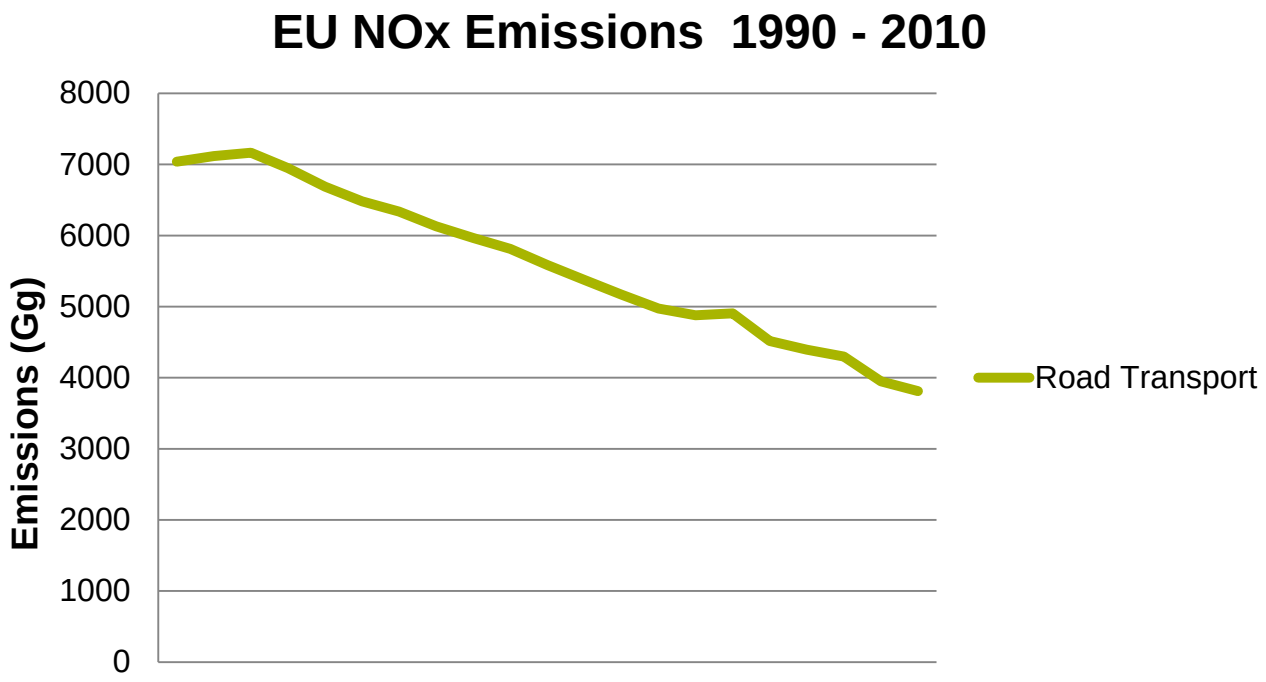
Road Transport NOx Emissions



Controlling emissions

Controlling Emissions

- ICAO/CAEP NOx LTO emission limits since 1981
- Test procedure does not control cruise emissions
- Slow fleet turnover
- NOx formed during high temperature/pressure combustion, oxidation of atmospheric (and fuel) N_2
- Trade-off between fuel efficiency and NOx
- Improved combustion (air to fuel ratio, flame temperature, pressure and residence time).
- BUT to achieve large emission reductions, to more than compensate for growth, radical steps may be required

Summary

Summary

- NOx emissions have many environmental impacts
- Most emissions occur during cruising
- Unique impacts in the upper troposphere/lower stratosphere
- Trade offs between fuel efficiency/NOx emissions
- Significant emission control challenging