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TURKISH AVIATION ACADEMY

İTÜ



Environmental Regulation

Modules 5 and 6

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Outline

- **Aviation and impact on the environment.**
- Governments regulation of environmental issues
- **Emissions: the challenge of technology and regulation**
- The Kyoto Protocol
- ICAO's Standards and Recommended Practices
- Unilateralism? The EU Emissions Trading Scheme



Whose Environment is it...?

Everyone thinks chiefly of his own,
hardly ever of the public, interest.

Aristotle



Aviation and impact on the environment

Noise



dB

Noise decibels

Gaseous Emissions



Carbon Dioxide

CO₂

Nitrogen Oxide

NO_x

volatile organic compounds

VOC

HC

Hydrogen Carbons

PM₁₀

Particulate matters

Carbon Monoxide

CO

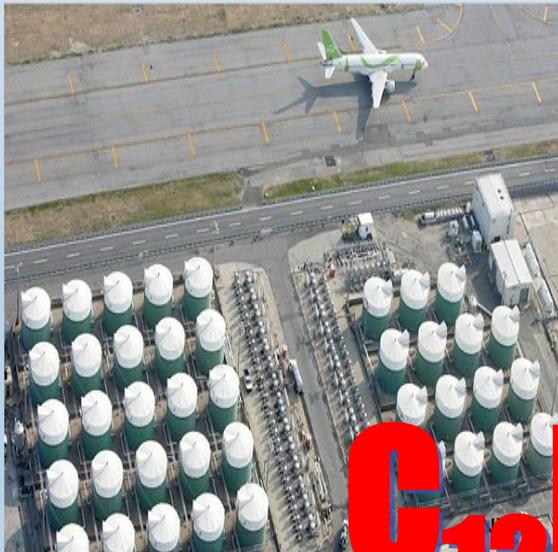
C₂H₄ Ethylene

C₁₂H₂₄ Kerosene

Surface and ground water pollution

Surface and ground water pollution

- Spills of aircraft fuel may damage soil and water ecosystems, and affect drinking water and agriculture
- Fire training and use of fire-retardant chemicals



C₁₂H₂₄

<http://www.flickr.com/photos/Ad0PDN4wqSh/Airlines+Face+Rapidly+Rising+Fuel+Costs/yEqUHGAGUNh>

Deicing / anti-icing fluid

- ethylene- and propylenebased glycol mixtures, wetting agents, corrosion inhibitors, dyes and thickeners, and even fire retardant solution
- Some of the fluid sticks to the plane, but 75 to 80% escapes into the environment
- No real understanding of environmental impact as ingredients of deicing fluid “industry secrets”



1.5
MILLION

THE MOST DEICING FLUID, IN LITRES, APPLIED IN A DAY AT TORONTO PEARSON INTERNATIONAL AIRPORT.

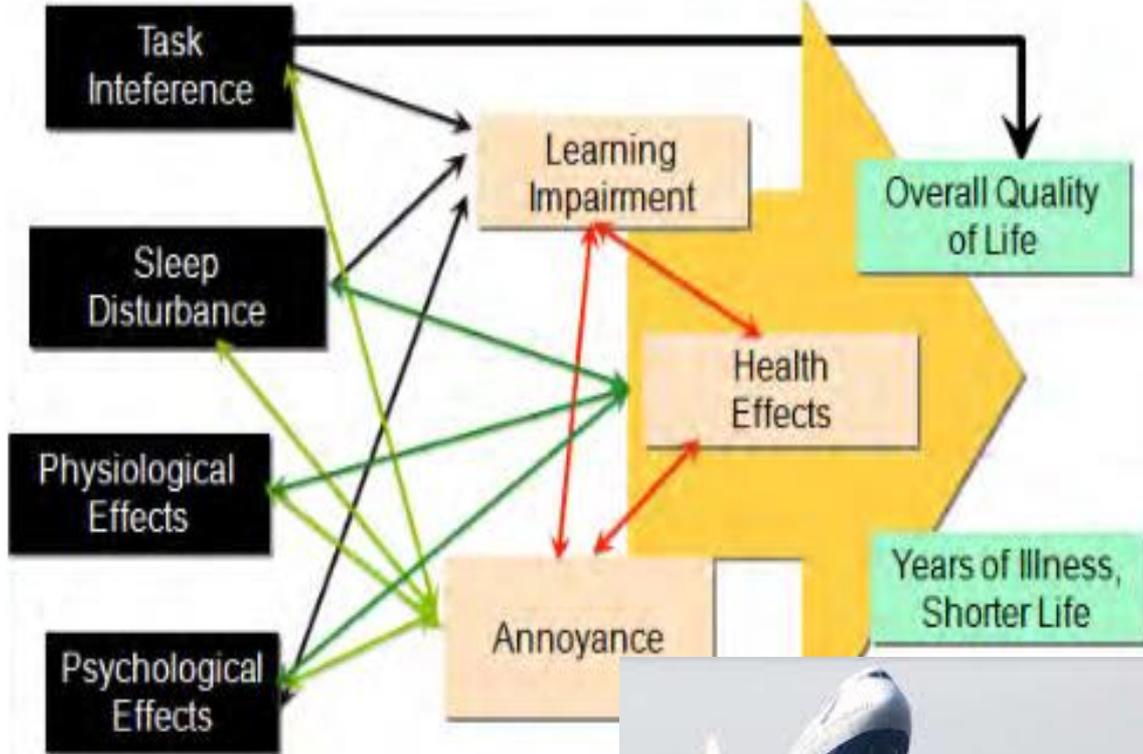


Noise



- Main objection for the construction or expansion of airport
- particularly serious political issue in many **highly developed countries**
- Scheduling aircraft landings and departures would become increasingly complex if these curfews were imposed globally.
- Export of noise to countries where there are no restrictions on landing/take-off
- ICAO has adopted several standards to reduce aircraft noise
- New ICAO policy is a "balanced approach" to noise.

Effects of noise



<http://web.mit.edu/aeroastro/partner/reports/proj19/healtheffectnoise.pdf>

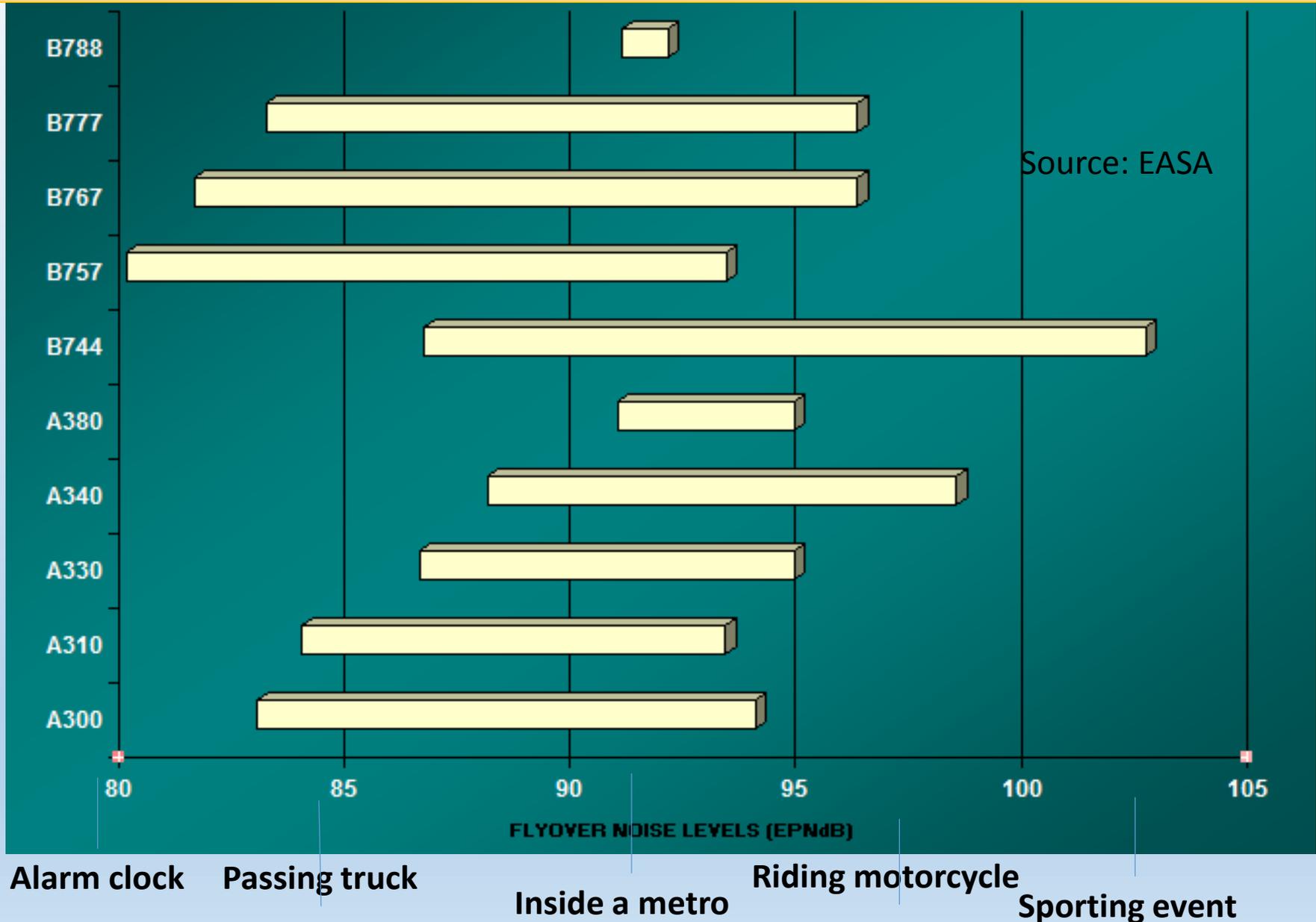
Health Effects of Noise Context



“acute dysregulation of the organism both in a **physiological and psychological sense**”

- Heart disease
- Diabetes
- Obesity
- Hypertension
- Depression

Different aircraft noise emissions compared with other sources of noise



Annex 16 to the Convention on International Civil Aviation Volume I: Noise

- **Chapter 2** adopted in 1971, contain rules that apply to aircraft for which the certificate of airworthiness for the prototype was granted **before 6 October 1977**.

e.g. *Boeing 727 and the Douglas DC-9*

- **Chapter 3** adopted in 1975, aimed to regulate aircraft for which the prototype was certified **after 6 October 1977**.

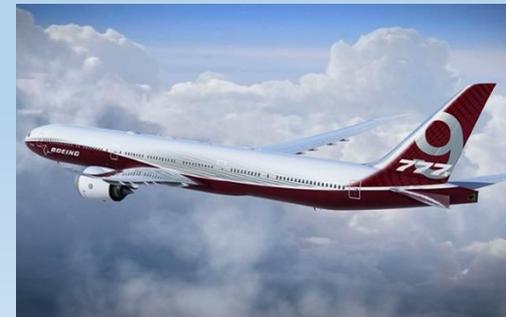
e.g. *Boeing 737-300/400, Boeing 767 and Airbus A319*

- **Chapter 4** adopted in 2001, for aircraft certified after **1 January 2006**

e.g. *Airbus 380, Boeing 787-8/9, Boeing 747-8, Airbus 350*

- **Chapter 14**, adopted in 2013 for large aircraft certified after **31 December 2017**

e.g. *Boeing 777X*



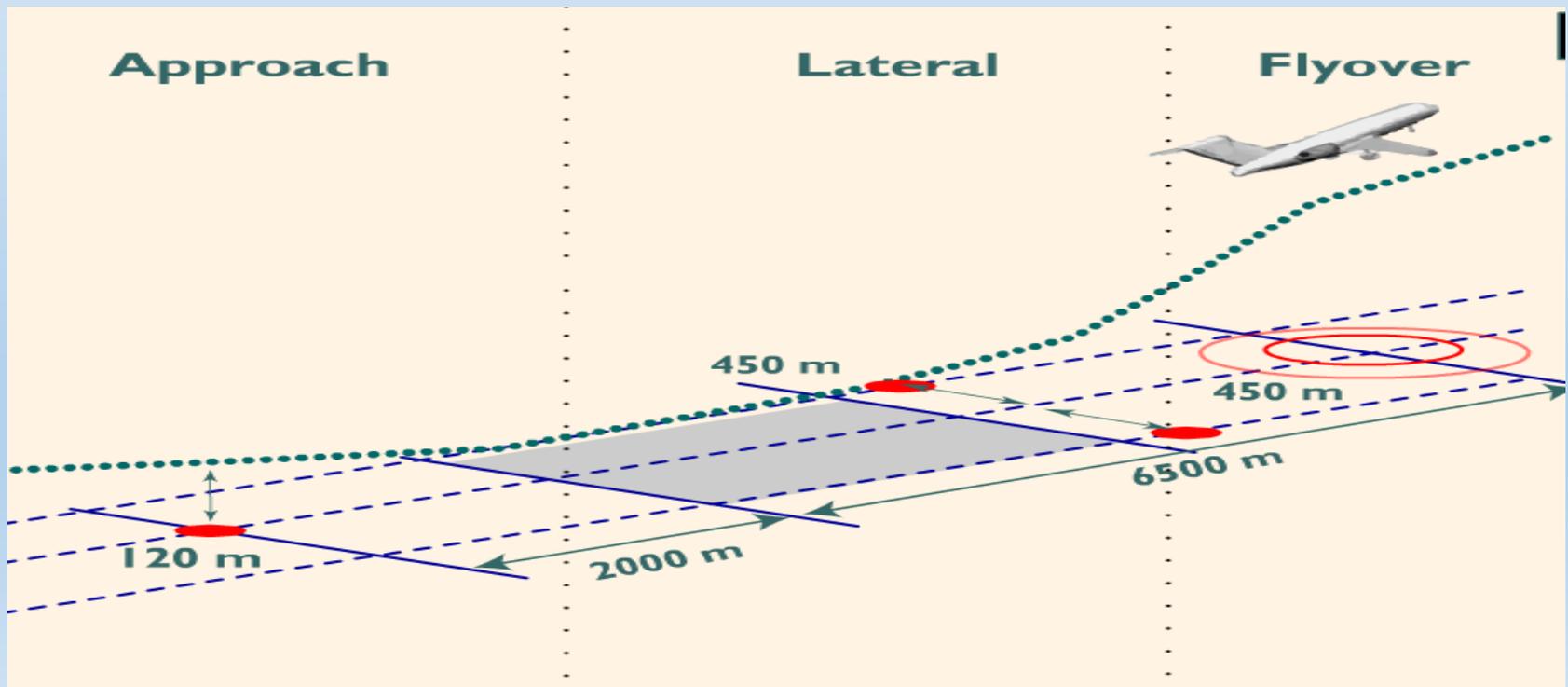
The maximum limits are expressed in
EPNdB (Effective Perceived Noise in Decibels)

Measured at:

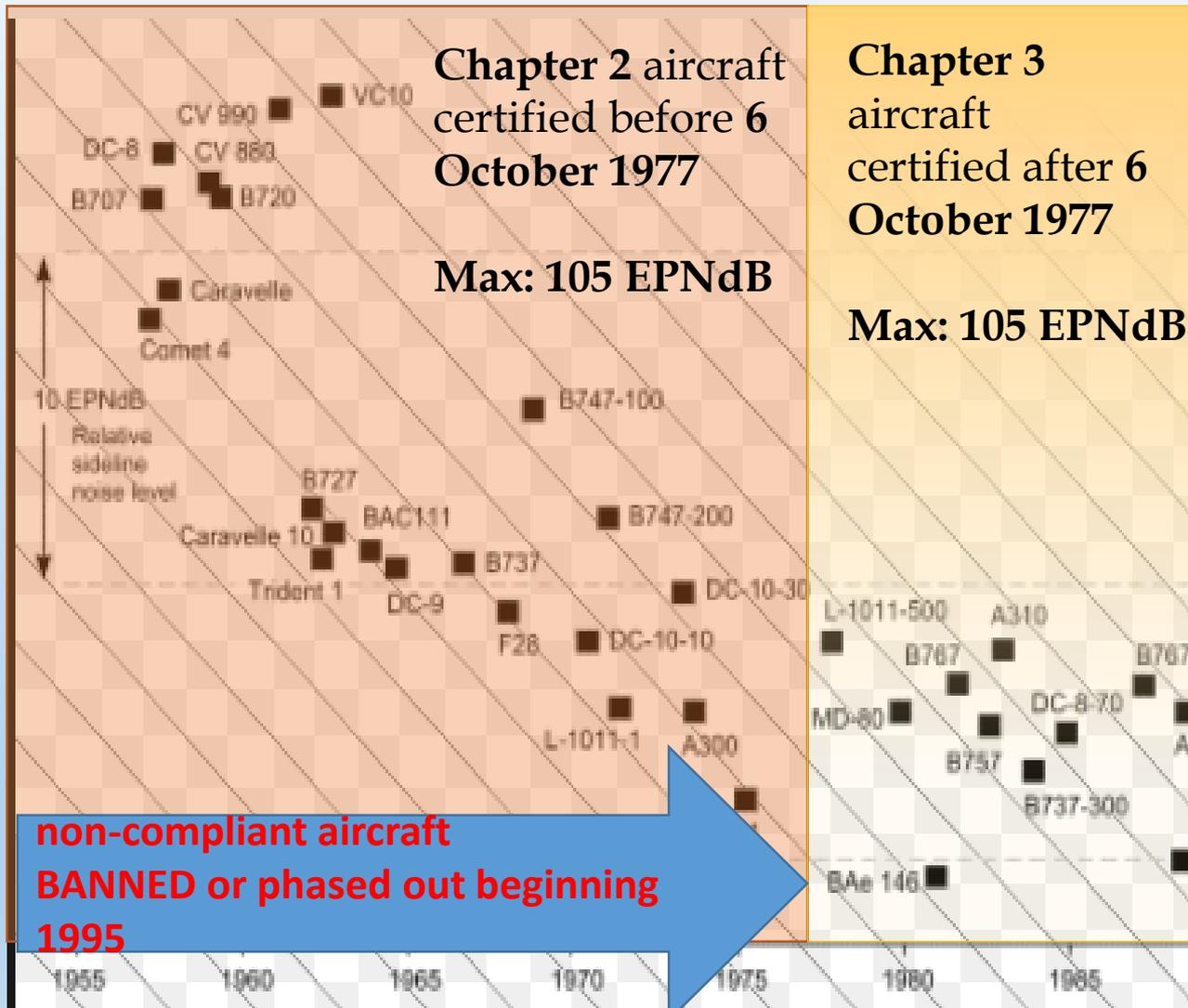
Approach: a point 120 meters above the ground with a descent gradient of three degrees

Lateral: a point on take off on a line which is parallel to and 650 meters above the runway

Flyover: a point 6.5 kilometers away from the point of commencement of takeoff



Various aircraft and their ICAO Annex 16 compliance



75 % quieter from 1960s-2000s (ICAO)

Response to ICAO requirements

- Noise issue prompted technological development by aircraft manufacturer (**cut-off production**)
- **Phase-out** is banning of aircraft which was certified earlier
- **US and EU** implemented a **stage-by-stage** phase out of aircraft to ensure compliance with minimum Chapter 3 standards.
- **Hushkitting**: modifying engines to make older aircraft comply with Chapter 3.
 - In 1999, EU passed legislation which essentially would ban all hushkitted aircraft from EU skies
 - Complaint by US to ICAO



ICAO's "Balanced Approach to Noise"

- Noise significantly reduced with engines and aircraft, but technology can only develop at a certain pace.
- Demand for aviation > technological development
- In 2001, ICAO called for
"balanced approach"
 to reduce the number of people affected by noise without restricting operations or growth of industry



- 1. Limit noise at source**
- 2. Land-use Planning and Management**
- 3. Noise Abatement Operational Procedures:**
- 4. Operating Restrictions**

Noise and emissions restrictions: Atatürk International Airport (IST)

CONTINUOUS DESCENT ARRIVAL (CDA) - **NONE**
AIRPORT CURFEWS - **NONE**

PREFERENTIAL RUNWAYS

05 for landing 35R for departure.

23 Arrival/17L/R Departure 05 Arrival/Departure

APU OPERATING RESTRICTIONS - **NONE**

NOISE BUDGET RESTRICTIONS - **NONE**

NOISE SURCHARGE - **NONE**

ENGINE RUN-UP RESTRICTIONS

N22, AN124, AN225, C5 aeroplanes are not allowed.

NOISE LEVEL LIMITS - **NONE**

CHAPTER 2 RESTRICTIONS - **NONE**

CHAPTER 3 RESTRICTIONS **NONE**



Noise and emissions restrictions: Amsterdam Schiphol Airport (AMS)

NOISE ABATEMENT PROCEDURES

Minimum noise routing in effect

Reduced Flaps

Engine run-up

APU (ground power units) controlled

Operating quota in effect

No operation between 2200-0600 (2100-0500)

NOISE SURCHARGE

one by airport, one by government

NOISE MITIGATION/LAND USE PLANNING

insulation of residential and public buildings,
demolition of houses and buildings,



CHAPTER 2 RESTRICTIONS – **banned 1 April 2002**

CHAPTER 3 RESTRICTIONS **Applicable**

In Lden
1990

2002

2010

Reduced
impact

on
population



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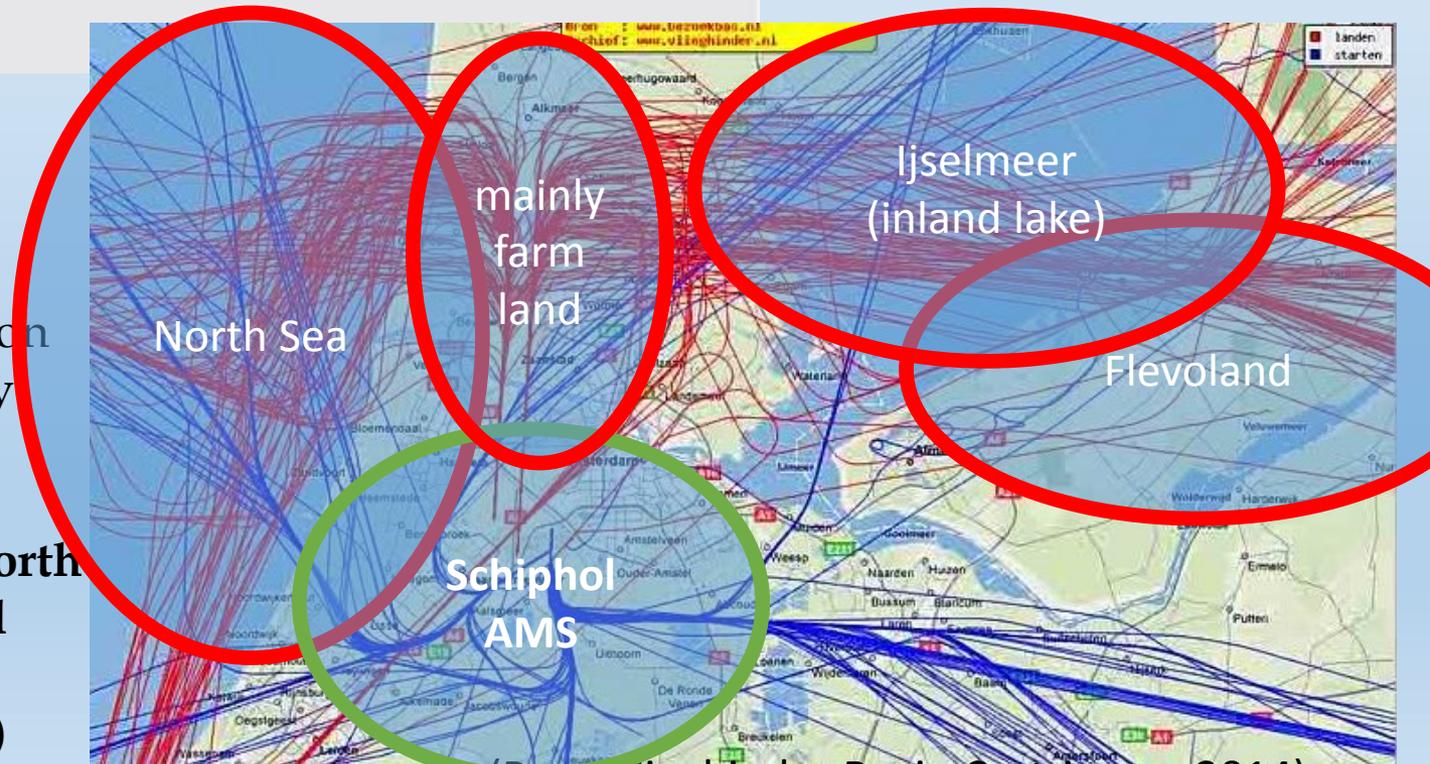


Noise levels and runway use at Schiphol Airport (AMS)

— 53 dB(A)
— 58 dB(A)

Red: landing
Blue: take off

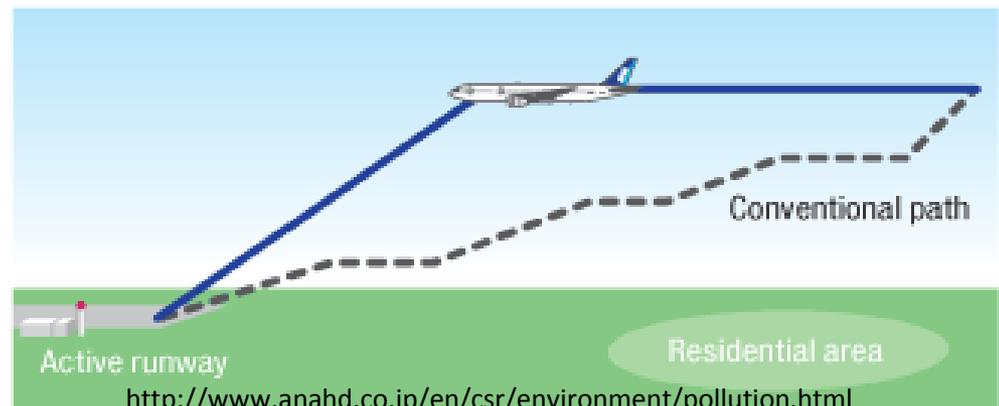
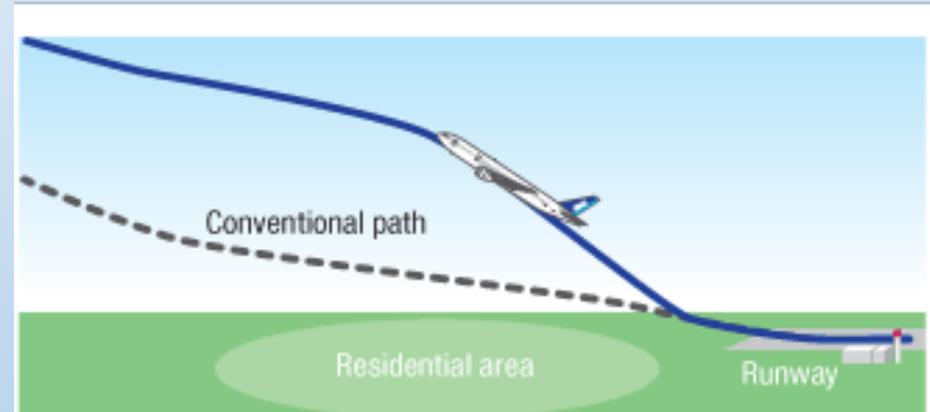
- Significant reduction of areas affected by noise in 20yrs
- Approach to AMS mainly over the **North Sea and Flevoland** (artificial island, sparsely populated)



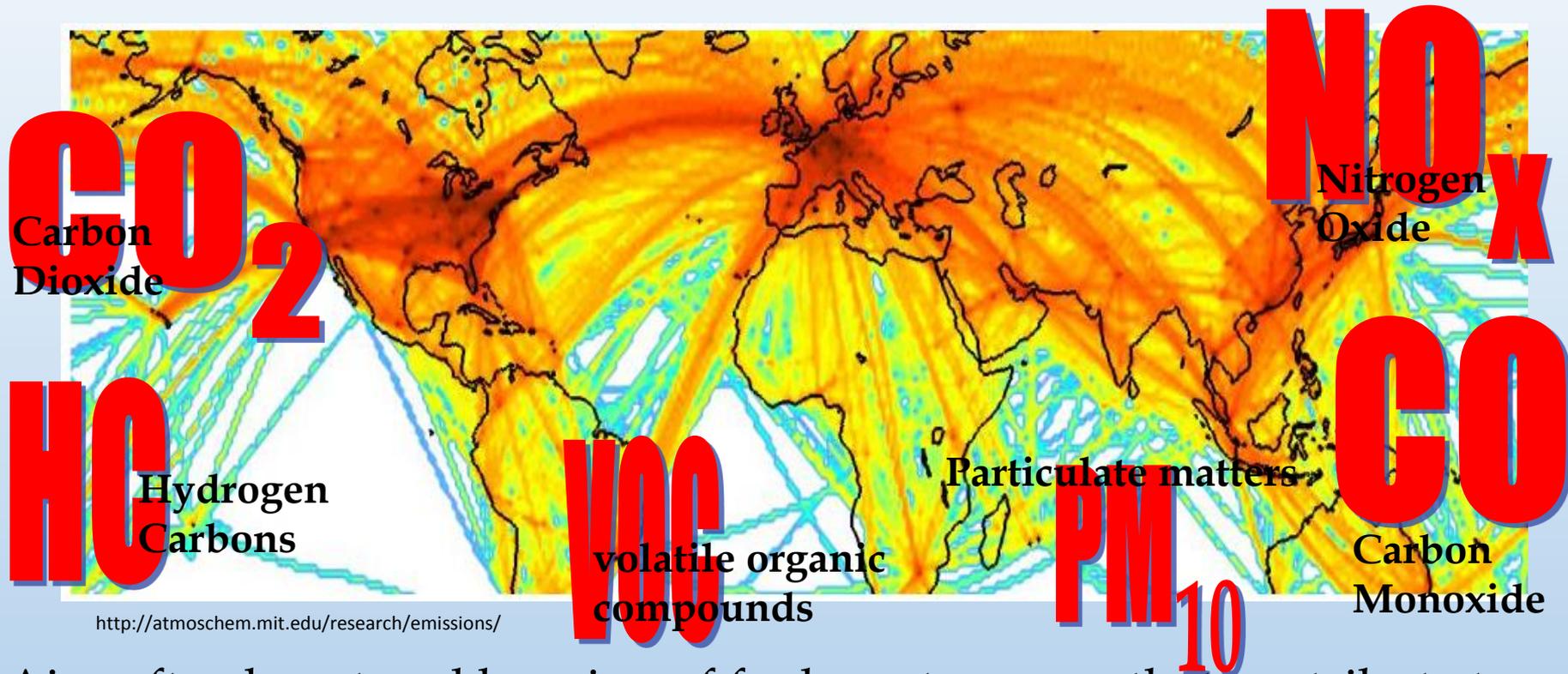
(Dron Vlieghinder Regio Castricum - 2014)

Ways to reduce aircraft noise

- Modified approach to landing and take off
- Steeper take off/landing to avoid residential areas
- Better air traffic control to avoid residential areas
- **Continuous descent approach**, less use of thrust, less noise



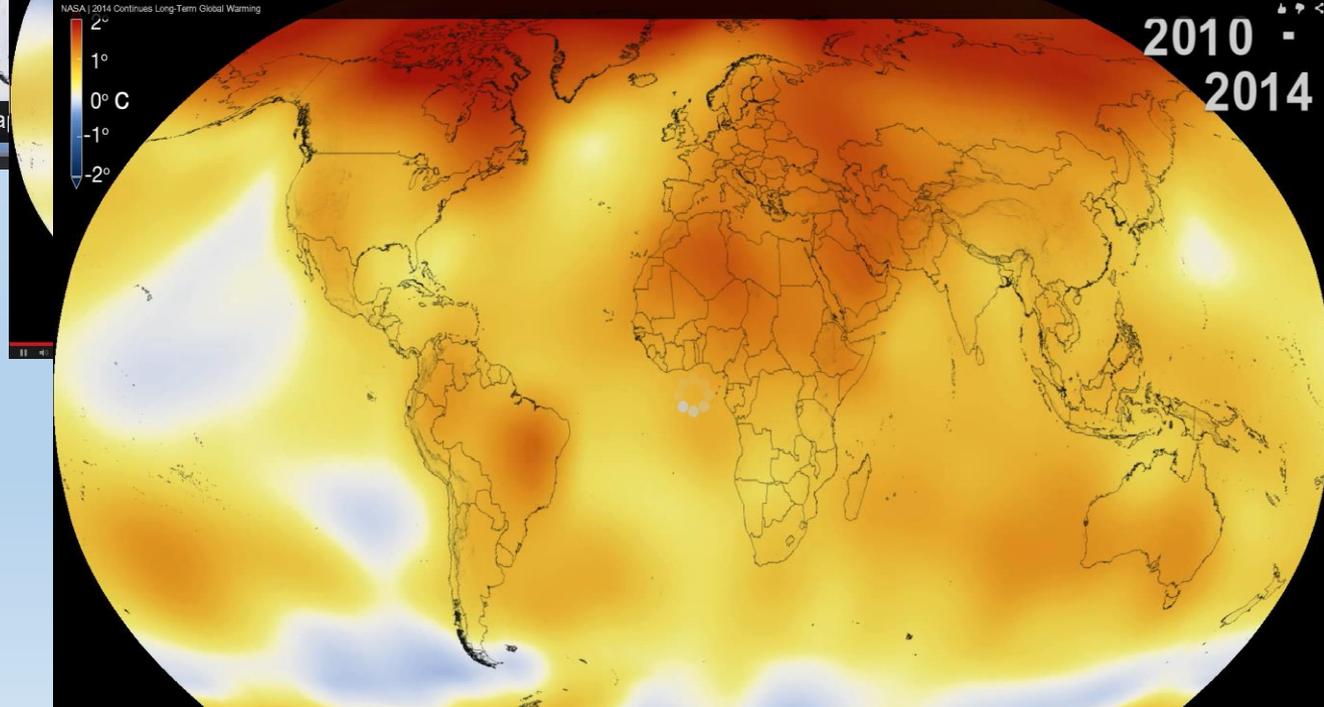
Aircraft Emissions



- Aircraft exhaust and burning of fuel creates gases that contribute to global warming
- ICAO has tried to deal with issue of aircraft emissions, but little progress
- Very complex and political matter
- EU tried to adopt **unilateral measures**

Global warming is a: **FACT**

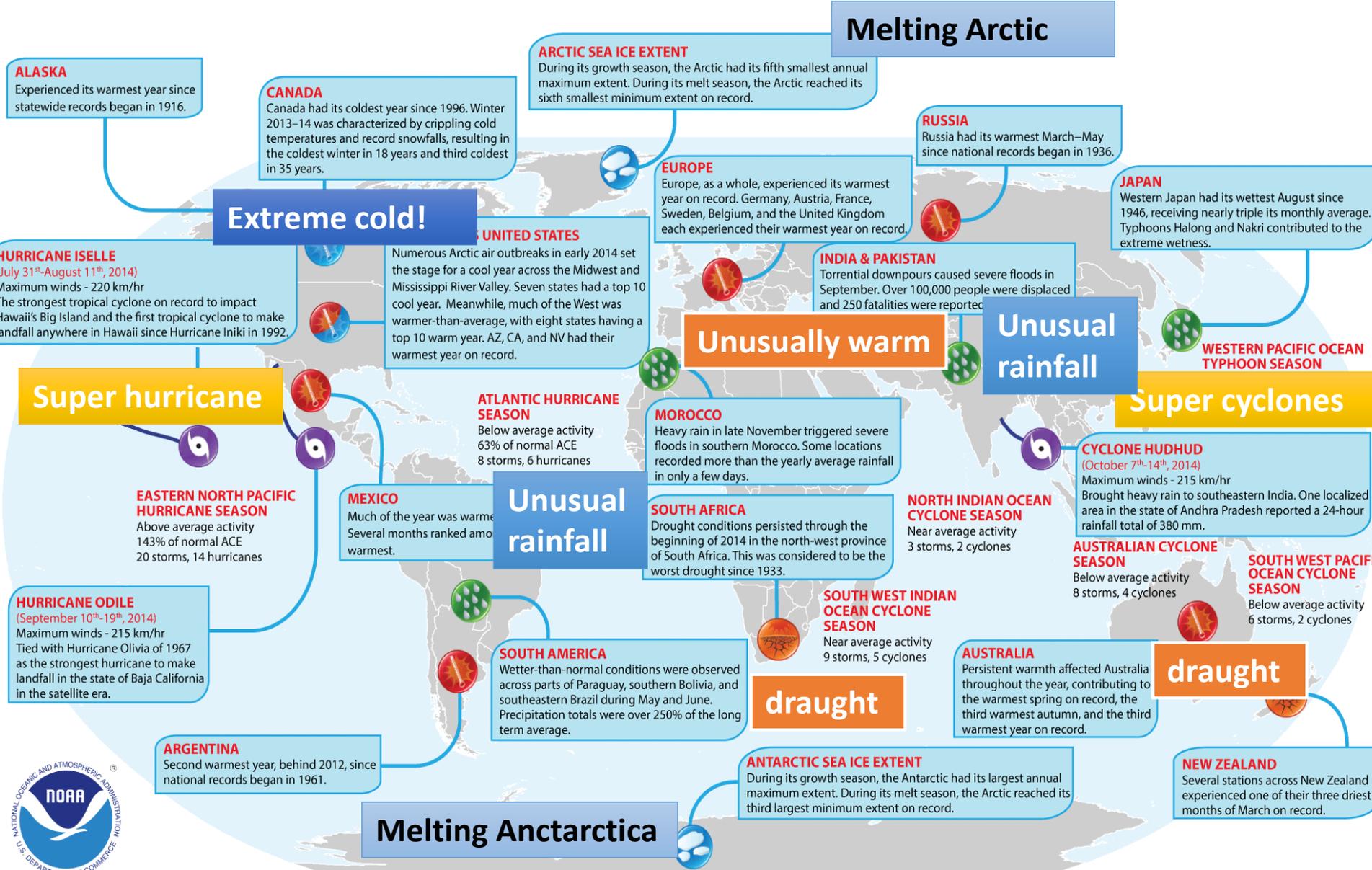
NASA Goddard Institute for Space Studies:
world temperatures showed
'2014 was the warmest year
on record'



“The globe is warmer now than it has been in the last 100 years and more likely in at least 5,000 years”

the globally-averaged land surface temperature was 1.80°F (1.00°C) above the 20th century average

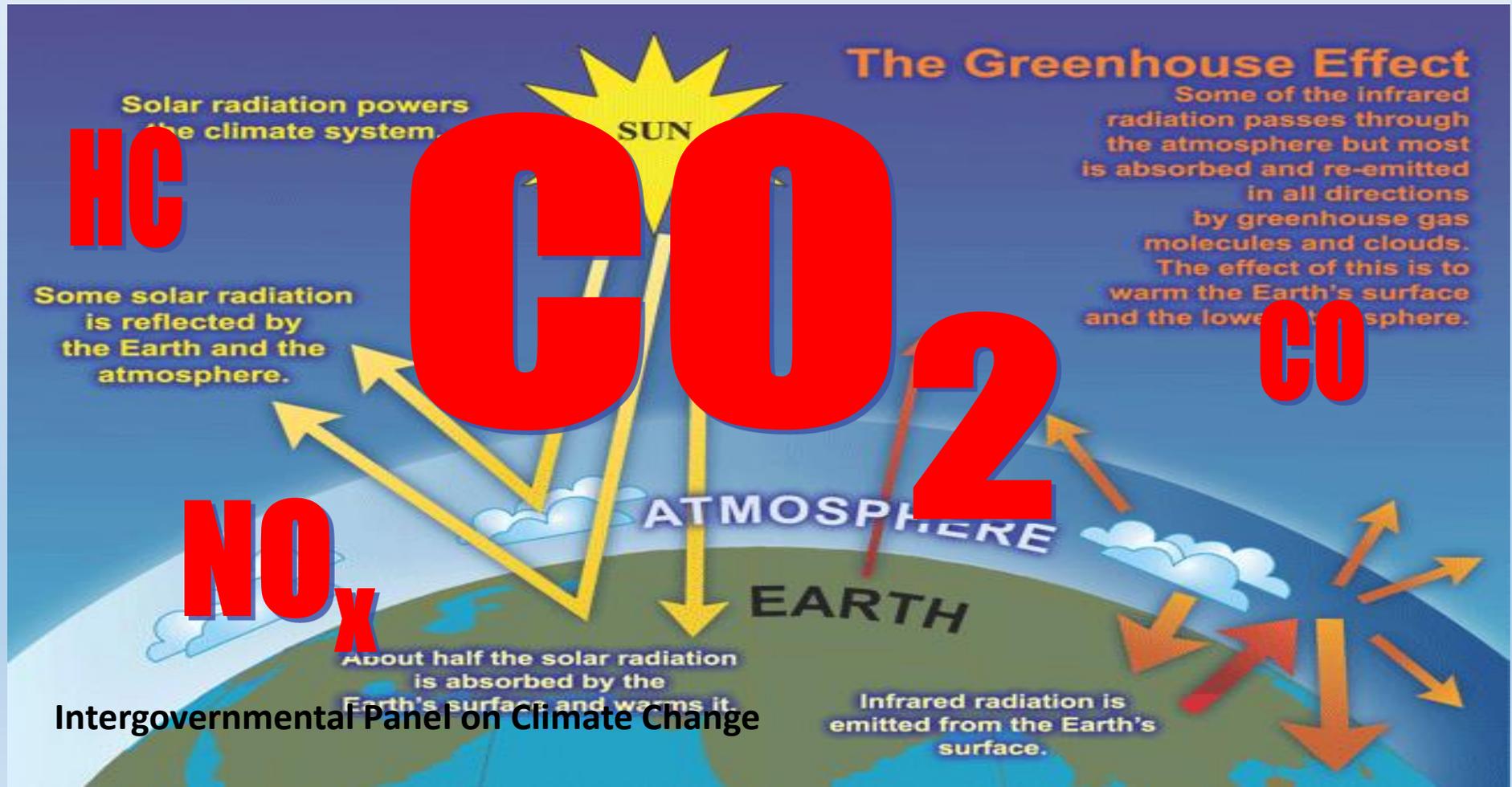
Selected Significant Climate Anomalies and Events in 2014



Please Note: Material provided in this map was compiled from NOAA's NCDL State of the Climate Reports and the WMO Provisional Status of the Climate in 2014. For more information please visit: <http://www.ncdc.noaa.gov/sotc>

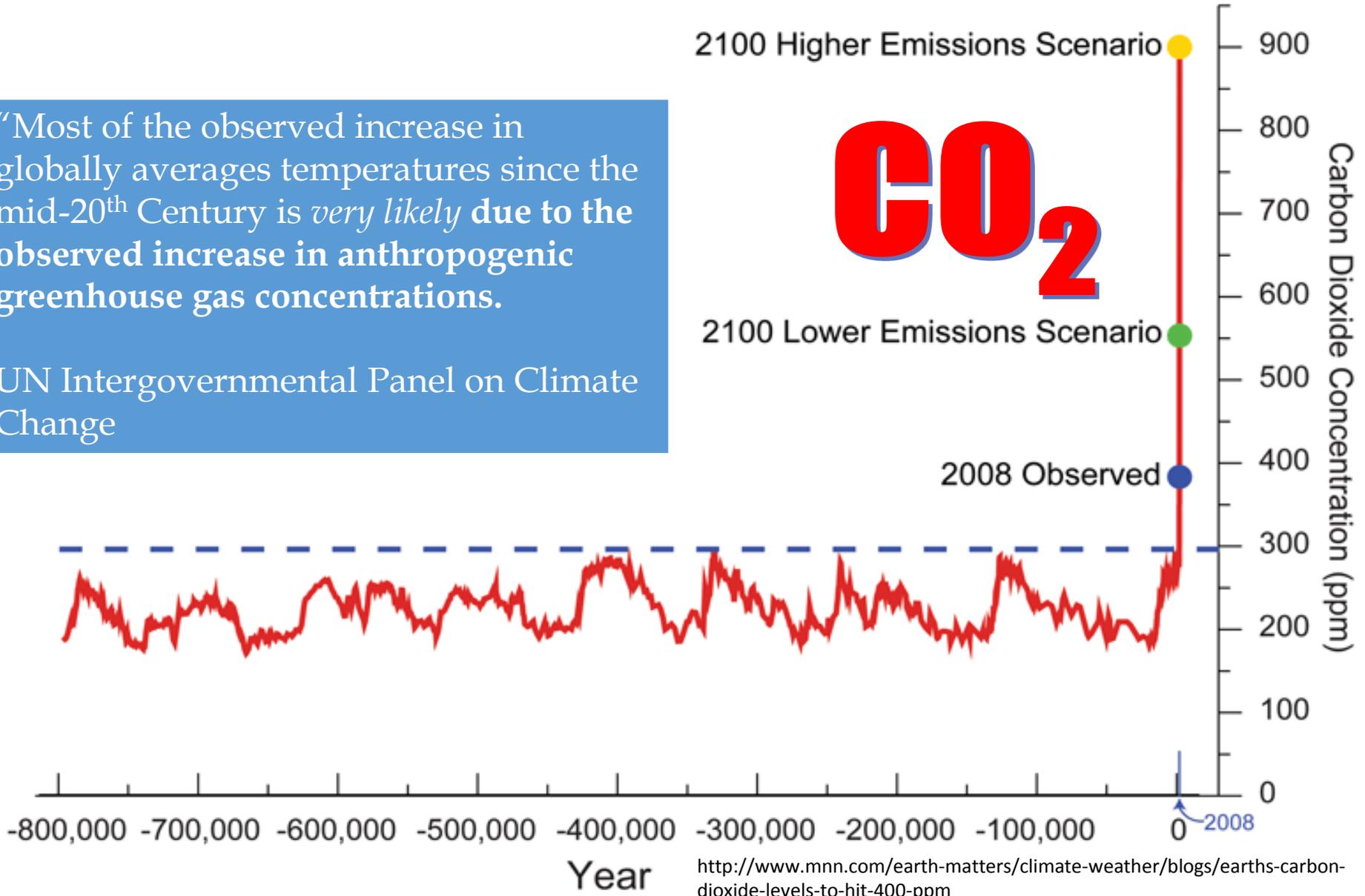
Greenhouse effect is made worse by release of certain gases

- Greenhouse gases absorb longer radiation, and trapping it in the atmosphere



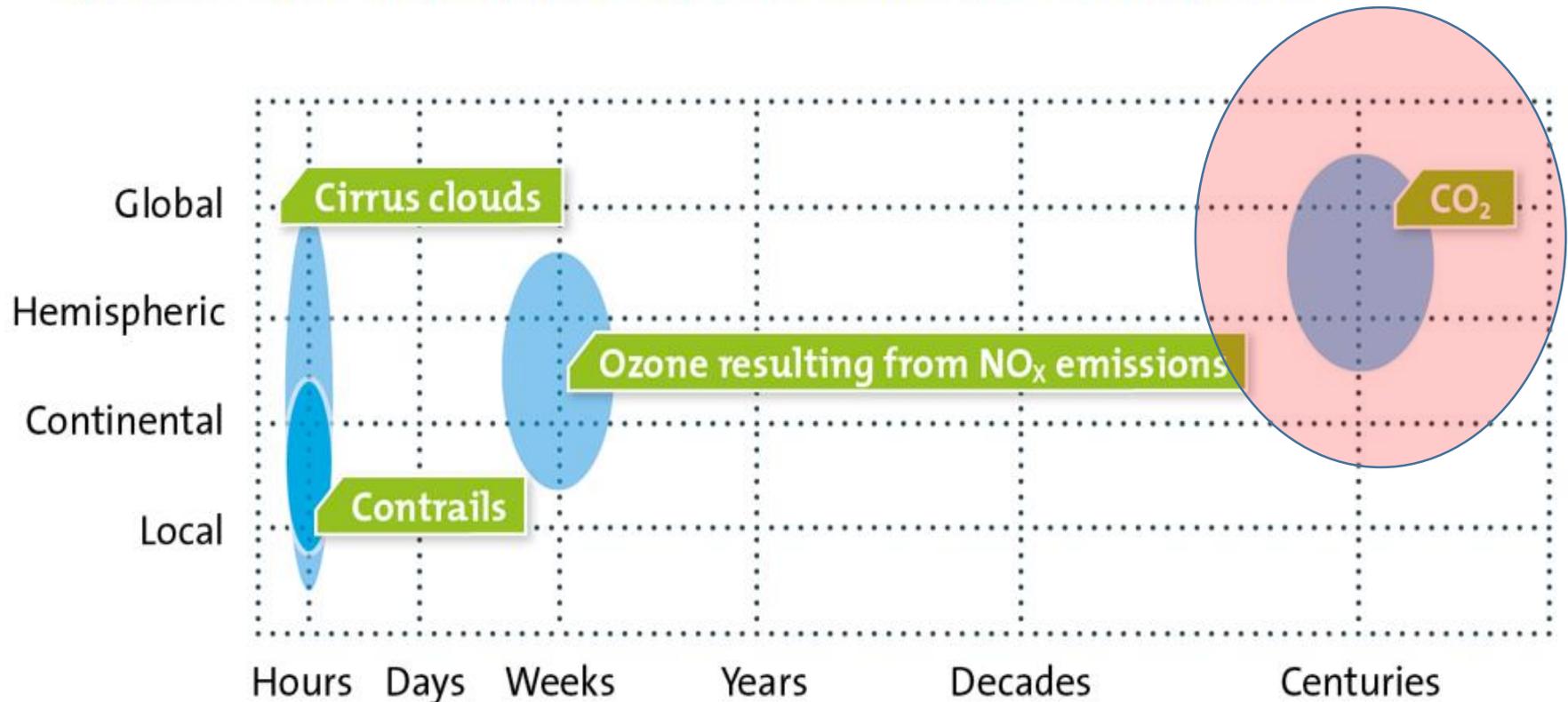
“Most of the observed increase in globally averages temperatures since the mid-20th Century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.

UN Intergovernmental Panel on Climate Change



Greatest concern of aircraft emissions

Spread and residence times of aviation emissions



http://www.bdl.aero/download/1376/bdl_ee2014_eng_s19.png

Source: BDL based on data from Lee et al. Aviation and global climate change in the 21st century, 2009

www.bdl.aero

- Aircraft emissions relevant to **climate change and global warming include:**

- **Carbon dioxide (CO₂)** (around 70% of total emissions),
- **Water vapor (H₂O)** (around 30%),

- **Nitric oxide (NO)** (less than 1%),
- **Nitrogen dioxide (NO₂)** (less than 1%),
- **Sulfur oxides (SO_xO)** (less than 1%), and
- **Soot.**

A blue rectangular box containing the text "Acid rain" in red, positioned above a photograph of a forest with many dead, white trees.

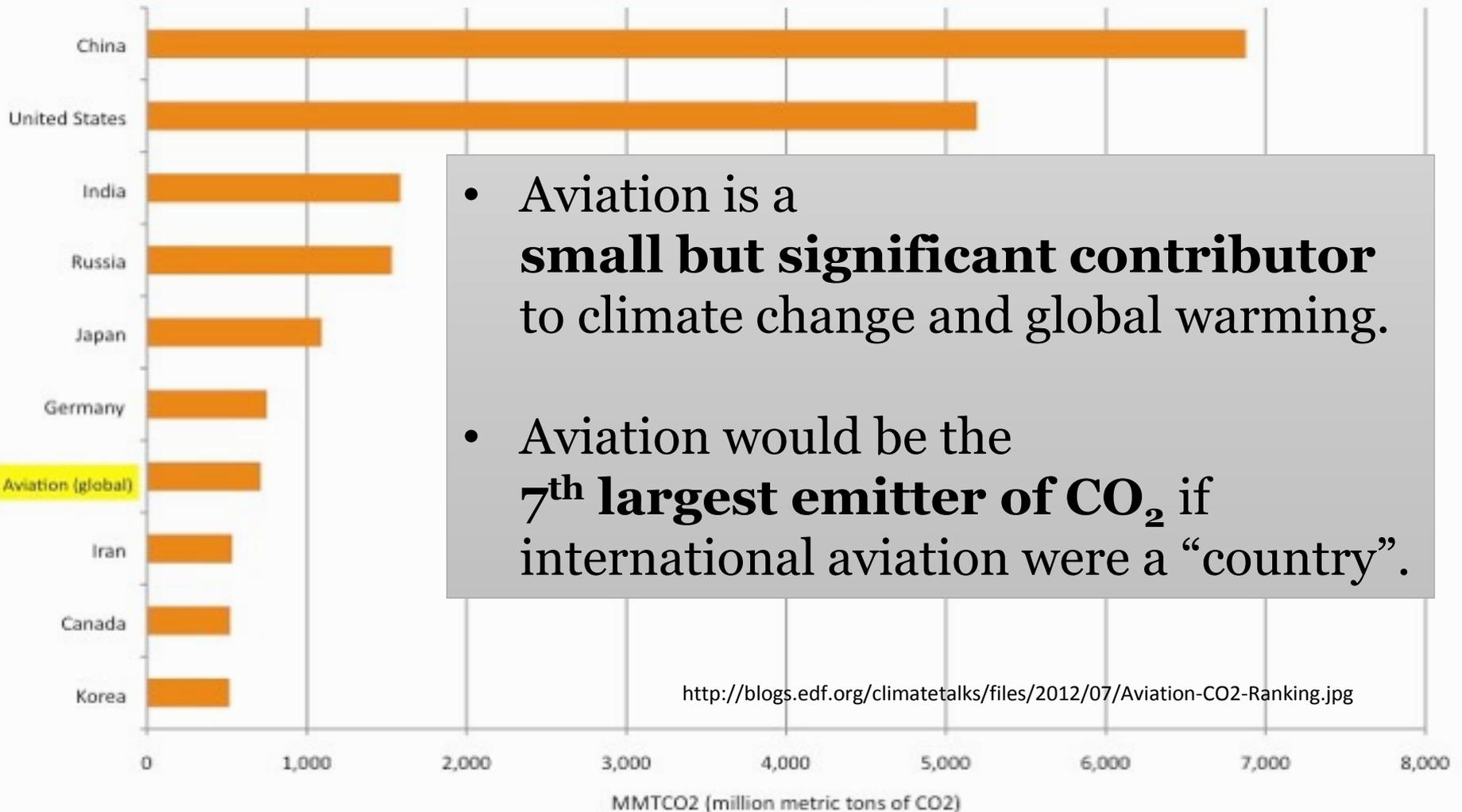
Aviation's (growing) contribution to global warming

- **2%** - civil aviation accounts for less than 2% of total global CO₂ emissions.
- **12%** - Aviation is responsible for 12% of total CO₂ emissions from the transportation sector (74% from road transport)
- **23%** - CO₂ emissions from aviation are projected to **grow to 23% by 2050!**



Aircraft Emissions: a growing problem

2009 Ranking of CO₂ Emissions from Fuel Combustion



- Aviation is a **small but significant contributor** to climate change and global warming.
- Aviation would be the **7th largest emitter of CO₂** if international aviation were a “country”.

<http://blogs.edf.org/climatetalks/files/2012/07/Aviation-CO2-Ranking.jpg>

Aviation's (growing) contribution to global warming

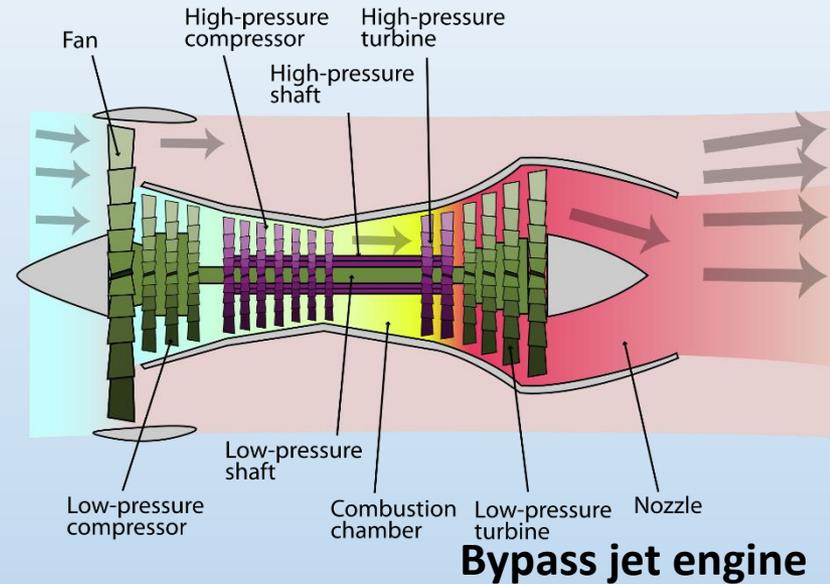
- Growth of aviation and related activities
 - > **technological reductions in emissions**
- Aviation is the only human activity to **emit pollutants directly into** the upper troposphere and lower stratosphere
- climate change and natural disasters will cause great **disruption of air transport** and aviation facilities



- Prevention is better than cure
- Global, simultaneous and collective action by all sectors is required.

Current engine designs...

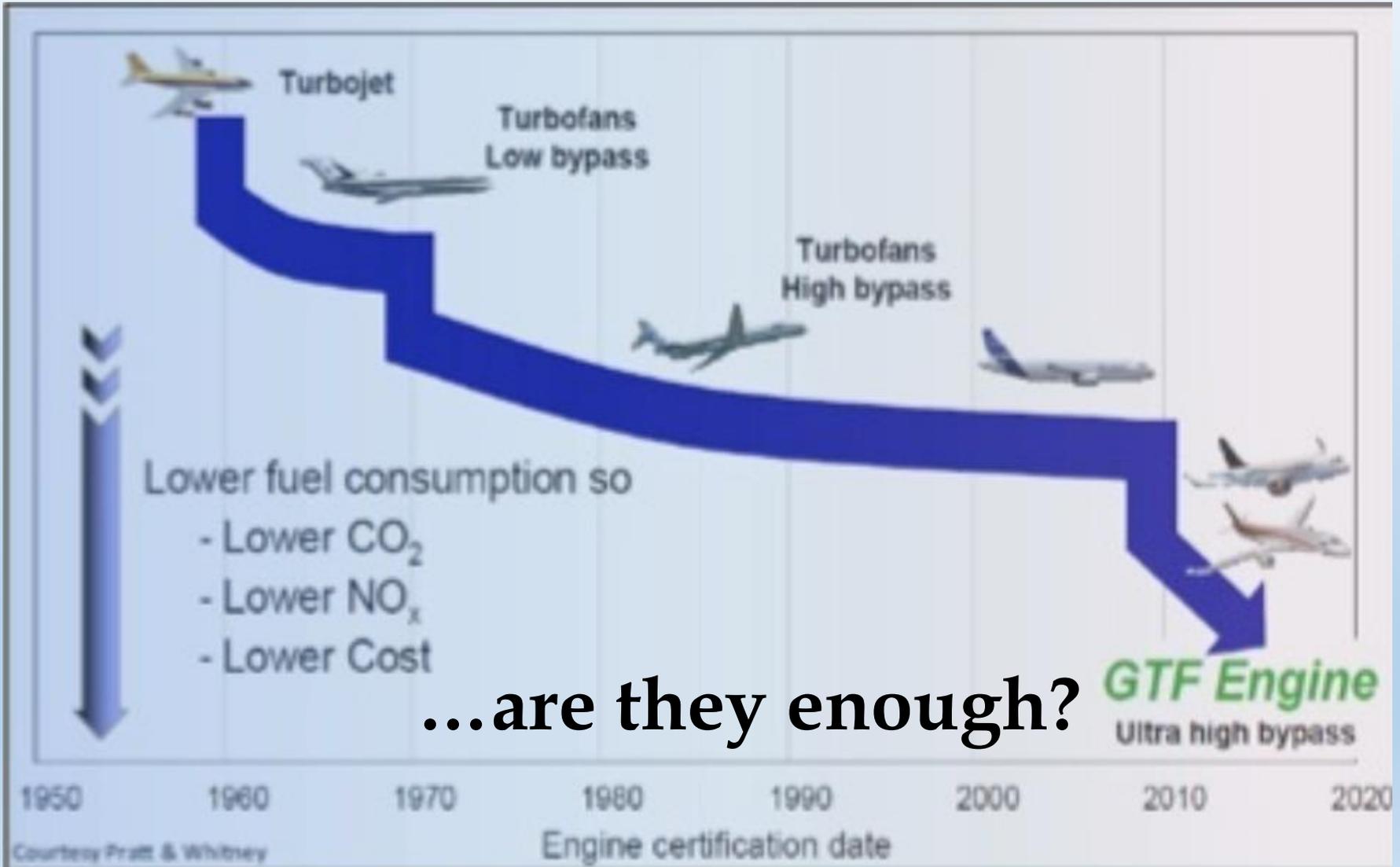
- Always a trade off... between **noise, fuel consumption and emissions.**
- NO_x vs CO₂
- Noise vs emissions
- Fuel efficiency = less CO₂ vs more NO_x
- Hybrid engine 2050?
hydrogen and biofuel



Hybrid engine?



Technological improvements...



International Efforts to address Climate Change and Emissions

- From Stockholm (1972) to Rio (1992) to Kyoto (1997)

The Environment: a growing international concern

1972
United Nations
Conference on the
Human Environment

Stockholm
Declaration



- Right to a healthy
environment



United Nations
Framework Convention on
Climate Change

1992
UN Conference on the
Environment and
Development

Rio Declaration on
Environment and
Development

UN Framework
Convention on Climate
Change

- Need to address
greenhouse gases

1997
Kyoto
Conference

Kyoto Protocol to the United
Nations Framework Convention
on Climate Change

- Danger of “**anthropogenic
inference**” (human-made)
- Set targets for reduction of
emissions



Kyoto Protocol

Article 2(2):
States shall pursue limitation or
reduction of emissions of greenhouse
gases from aviation through ICAO

ICAO efforts to deal with aviation's effects on environment

- **1971:** noise a concern, but emissions “not harmful”!
- **Committee on Aviation Environmental Protection** created in 1983 to deal with noise and emissions

The Environment: ICAO's growing concern?

1981

Annex 16 Volume I: **Noise**
Annex 16 Volume II: **Emissions**



- Standards on HC, CO and NO_x, smoke
- BUT not on CO₂, SO_x, H₂O and soot

1995

Kyoto Protocol to the United Nations Framework Convention on Climate Change

- Set targets for reduction of emissions of CO₂...

Progress...?

What has ICAO done to combat aviation emissions?

- Standards focused on HC, CO and NO_x, not more pressing CO₂
- standards on reduction, but not phase-out of engines
- **Annex 16, Volume III on CO₂ expected to be adopted... when?**

The Environment: ICAO's growing concern?

1995
Kyoto Protocol to the United Nations Framework Convention on Climate Change

- Set targets for reduction of emissions of CO₂...

“ICAO has abdicated the leadership role given to it in the Kyoto Protocol”

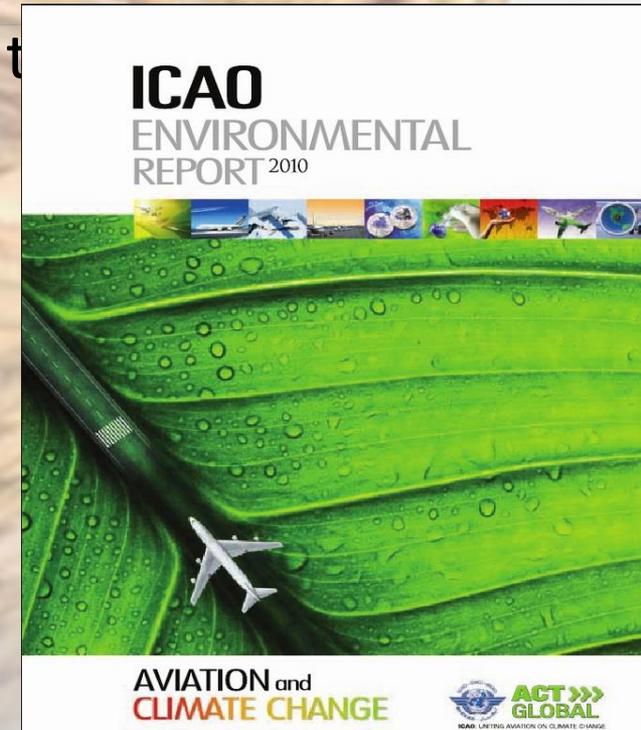
2007
Group on International Aviation and Climate Change



ICAO's Basket of Measures

Combination of measures necessary to stop emissions from aviation:

- **Technological improvements,**
- **Operational improvements,**
- **Sustainable alternative fuels, and**
- **Market-based measures**



Technological improvements

Factors to increase energy efficiency

Good aerodynamics
(reduce kerosene consumption)

Efficient propulsion systems
(reduce kerosene consumption)

New materials
(reduce weight)

Curved wing tips



-5%

Engines with a high bypass ratio



-15%

Lighter materials inside



-1t

Special sharkskin coating



-1%

Light composite fuselage



-40t



Technological improvements



Fuel burn and cash cost comparison

<u>Aircraft</u>	<u>Fuel burn/seat</u>	<u>Cash cost/seat</u>
A320	Datum	Datum
A320 Sharklet (2012)	-2.4% to -3.5%	-1% to -2%
A320 neo* (2015)	-13% to -15%	-5% to -6%
All new aircraft (2020)	-18% to -20%	-9 to -11%
All new geared open rotor (2025+)	-35% to -40%	-20% to -25%

- No drastic technology advances in the technological improvement field of aviation,
- very expensive and time-consuming process

Other CO2 reduction measures

CO2 REDUCTIONS: PUTTING AIRCRAFT ON A DIET

FOR EACH 10KG WEIGHT REDUCTION, ABOUT 4 TONS OF CO2 CAN BE AVOIDED IN ONE YEAR

THE WEIGHT OF A TEABAG

1 KG OF CO2



WINGTIP DEVICES

CAN REDUCE CO2 EMISSIONS BY UP TO 6%



REPLACING PAPER MANUALS WITH TABLETS



LIGHTWEIGHT SEATS AND TROLLEYS



LIGHTWEIGHT PAINTS

USER PREFERRED ROUTES

INITIATIVES HAVE BEEN TAKEN WHERE THE AIRLINE CAN SELECT THE MOST EFFICIENT ROUTE BASED ON AIRCRAFT AND WEATHER CONDITIONS.



USER-PREFERRED ROUTES CAN SAVE MORE THAN 30 TONS OF CO2 ON A SINGLE TRANSPACIFIC FLIGHT

Sustainable alternative fuels

REDUCE LIFE-CYCLE EMISSIONS BY UP TO **80%**

DERIVED FROM SUSTAINABLE CROPS, ALGAE, WASTE, ETC

SUSTAINABLE ALTERNATIVE FUELS

1600+ PASSENGER FLIGHTS HAVE ALREADY BEEN OPERATED

20+ AIRLINES HAVE USED THESE FUELS ON COMMERCIAL FLIGHTS

Cooking oil
Algae
Camelina
Jatropha



- high and uncertain costs of such fuels
- lack of availability to meet the demand of aviation industry

Operational improvements

- Performance Based Navigation (PBN)
- Use of satellite technology



NEXT GEN Components: RNAV/RNP

Moving to Performance-Based Navigation

Conventional Routes

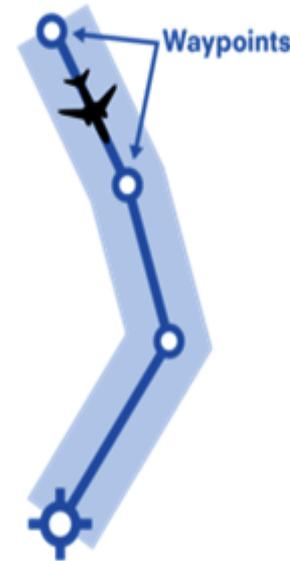
Today's airways connect ground-based navigation aids



Limited Design Flexibility

RNAV

Area Navigation (RNAV) routes follow defined "waypoints"



Increased Airspace Efficiency

RNP

Required Navigation Performance (RNP) routes within specified "containment area"



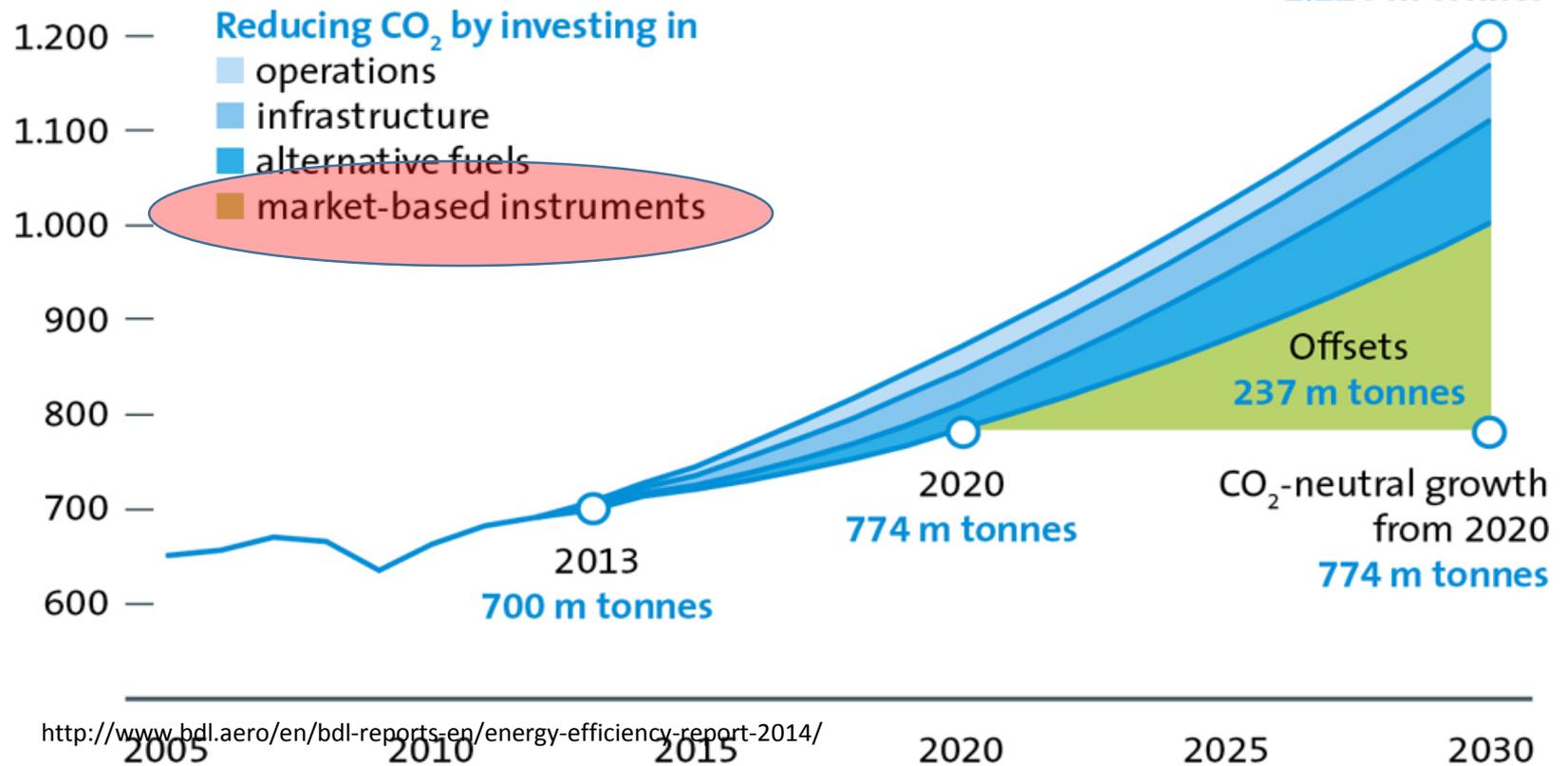
Optimize Use of Airspace

Source: Federal Aviation Administration

Measures to achieve CO₂ reduction targets

Global CO₂ emissions from air travel in million tonnes per year

after upgrading the fleet and increasing the passenger load factor



<http://www.bdl.aero/en/bdl-reports-en/energy-efficiency-report-2014/>

Market-based measures

- Identified in 2001 as
“to achieve environmental goals at a lower cost and in a more flexible manner than traditional regulatory measures”
- **Environmental Tax / charge**
 - Zurich and Stockholm have introduced **Local Air Quality Charges**
 - UK introduced in 2006: **Air Passenger Duty**
- **Emissions Trading**

Market Based Measure: *Emissions Trading*

- Based on predetermined “polluting” quota permits
- permit may be bought and sold on an open market, depending on need
- Considered more effective than taxation and does not distort market as much
- Provides incentive for industry to be efficient



ICAO inaction, EU unilateralism?



- 2003: EU ETS was identified as the most "cost-effective and economically efficient" market-based measure to combat emissions and address global warming
- 2008: legally included **international aviation into the EU ETS**, effective 1 January 2012
- **Coverage:**
all carriers with operations within, flying out of or into the EU
(EU Member States, Iceland, Lichtenstein and Norway)!



Criticism of original EU ETS

- Coverage over the high seas
- Coverage over non-EU airspace
- Extraterritorial application



- Violations of **Chicago Convention:**

Article 1: airspace sovereignty.

Article 2: territory of State: includes airspace above territorial sea.

Article 6: special permission or authorization required for scheduled international air service.

Article 11: State laws and regulations apply and must be complied with.

Article 12: over high seas, rules of ICAO apply.

Article 15: no charges imposed solely for transit over or entry into or exist from territory

Article 24: fuel is free from customs duty or other national or local duties or charges

International backlash to EU ETS

- Strong reaction from US, China and “coalition of the unwilling”.
- ICAO Resolution A36-22 urged implementation of measures only with agreement by other States
- Strong reaction from industry (IATA), lawsuit that reached the European Court of Justice

- April 2013:
EU ETS suspended

- April 2014:
EU ETS applicable only to EU flights until 2016



EU Unilateralism forced ICAO into action

- **ICAO Assembly Resolution A38 (2013)**
 - global Market-Based Measure (MBM) for international aviation should be developed for implementation from 2020
 - MBM must have agreement between States
 - Decision be made by the 39th Assembly in 2016
-
- **Differences between developed and developing countries:**
 - The principle of common but differentiated responsibility
 - The principle of special circumstances and respective capabilities
 - The concept of *de minimis* threshold

Conclusion

- Aviation puts increasing pressure on the environment: **noise and gaseous emissions**
- States have tried to tackle this issue for decades through ICAO
- Various measures are being adopted to reduce emissions
- Particularly the matter of gaseous emissions is a source of disagreement among States
- The EU has unilaterally adopted the EU ETS prompting ICAO to be more proactive

