Aviation and mitigation of climate change

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Introduction

Non-CO_2 multiplier relevant for

* Carbon calculators

* Emission Trading Scheme

Non-CO_2 effects of aviation are significant

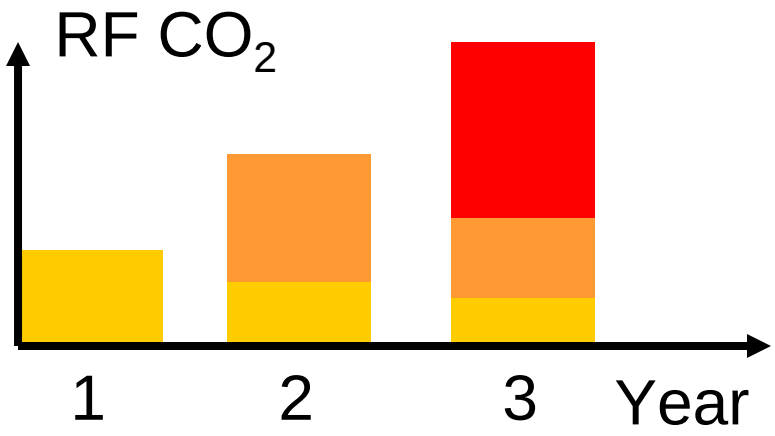
Some non-CO_2 effects, in particular induced cirrus, are uncertain
(but correspond to positive RF, hence global warming)
(therefore possible to calculate a conservative estimate)

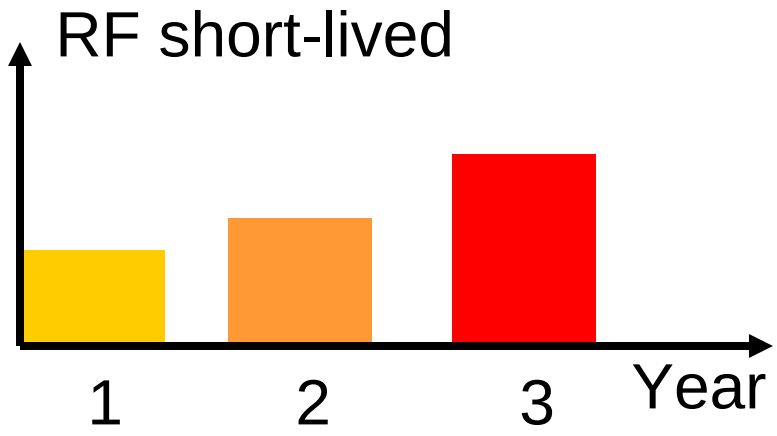
RFI is inappropriate as a non-CO_2 multiplier

But other climate metrics are more appropriate…

Radiative Forcing Index

Radiative forcing measures the change in the radiative budget from pre-industrial to present-day. It is a measure of the cumulative effect of aviation on the radiation budget.

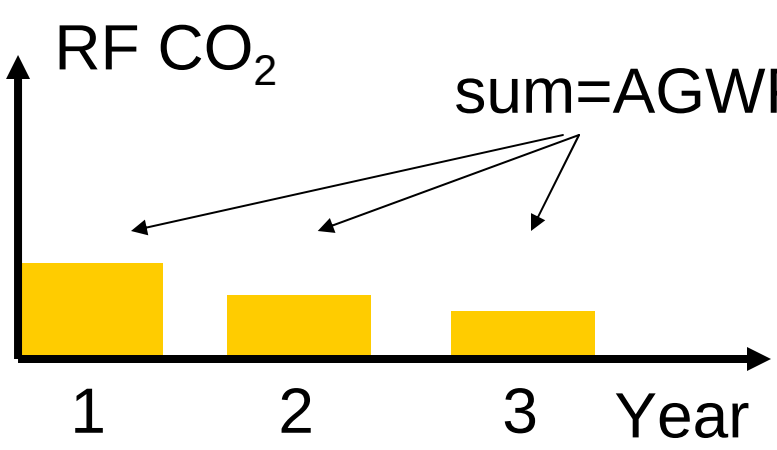


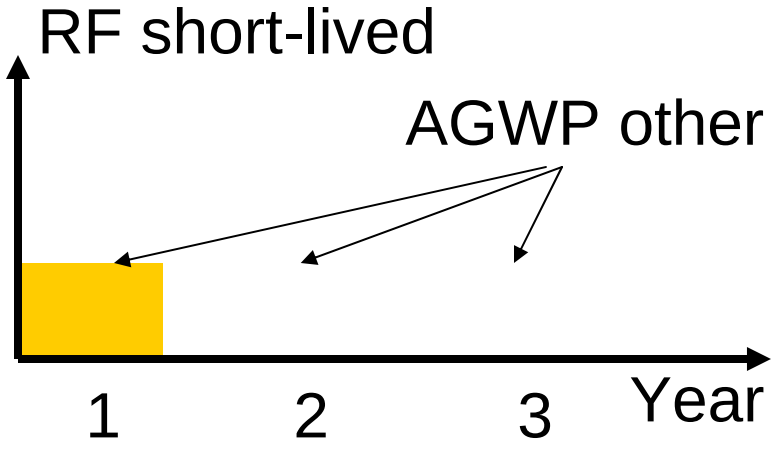


RFI=2 As of now, the non-CO_2 climate change mechanisms associated with aviation have doubled the climate warming due to CO_2 only emissions from aviation.

Global Warming Potential (GWP)

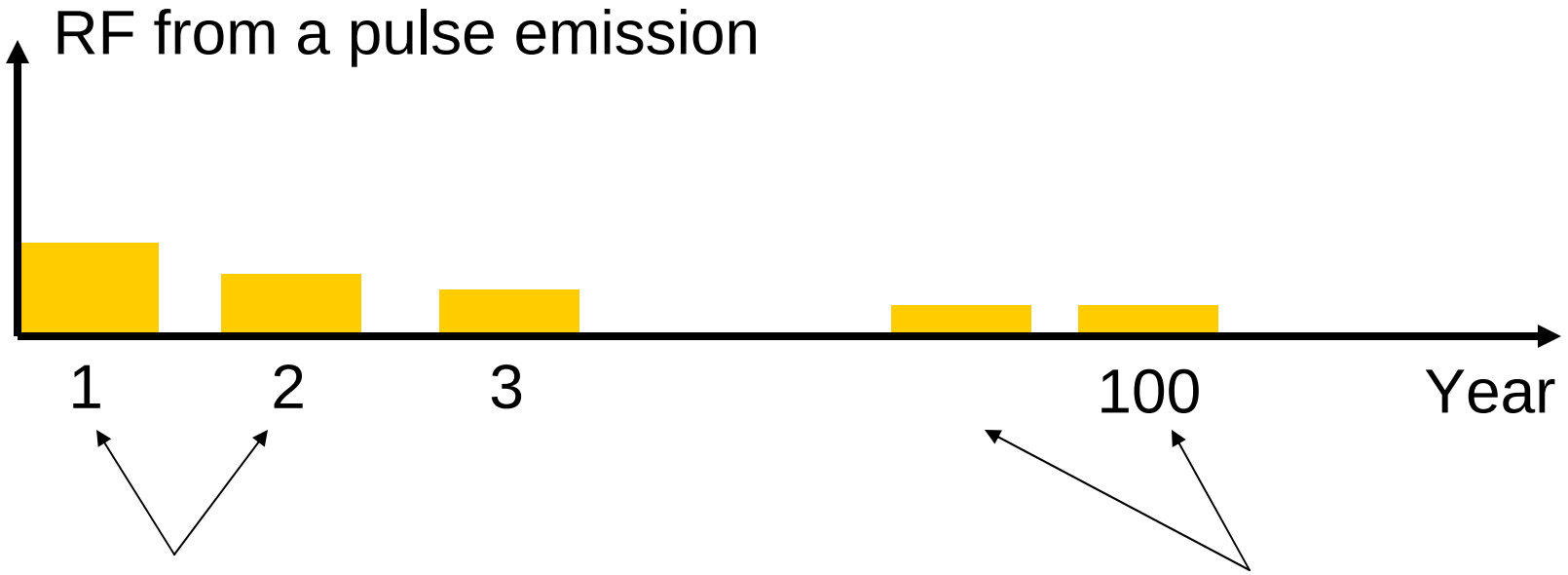
Absolute GWP measures the cumulative radiative forcing into the **future** of a **pulse** emission made **today**.





Can be used to define a GWP index that is a non-CO_2 multiplier
Future means 20, 50, or more usually **100** years
Pulse emission means that the index can change with technology

Global Warming Potential (GWP)



<u>This radiative forcing</u> is less efficient than **<u>this radiative forcing</u>** at creating climate change in a 100 year time from now.

A GWP index is recommended if you are interested to limit a cumulative effect over a period of time but it is not if you are only interested to limit the amount of climate change in 2100.

Global Temperature Potential

The (absolute) GTP is defined as the change in surface temperature at a given time horizon due to a pulse emission at the beginning of the time horizon.

More suited for policy making. We can define a GTP index.

In particular it makes a lot sense if a temperature target is agreed on.

But GTP is more model-dependent than GWP.

So which climate metric is best?

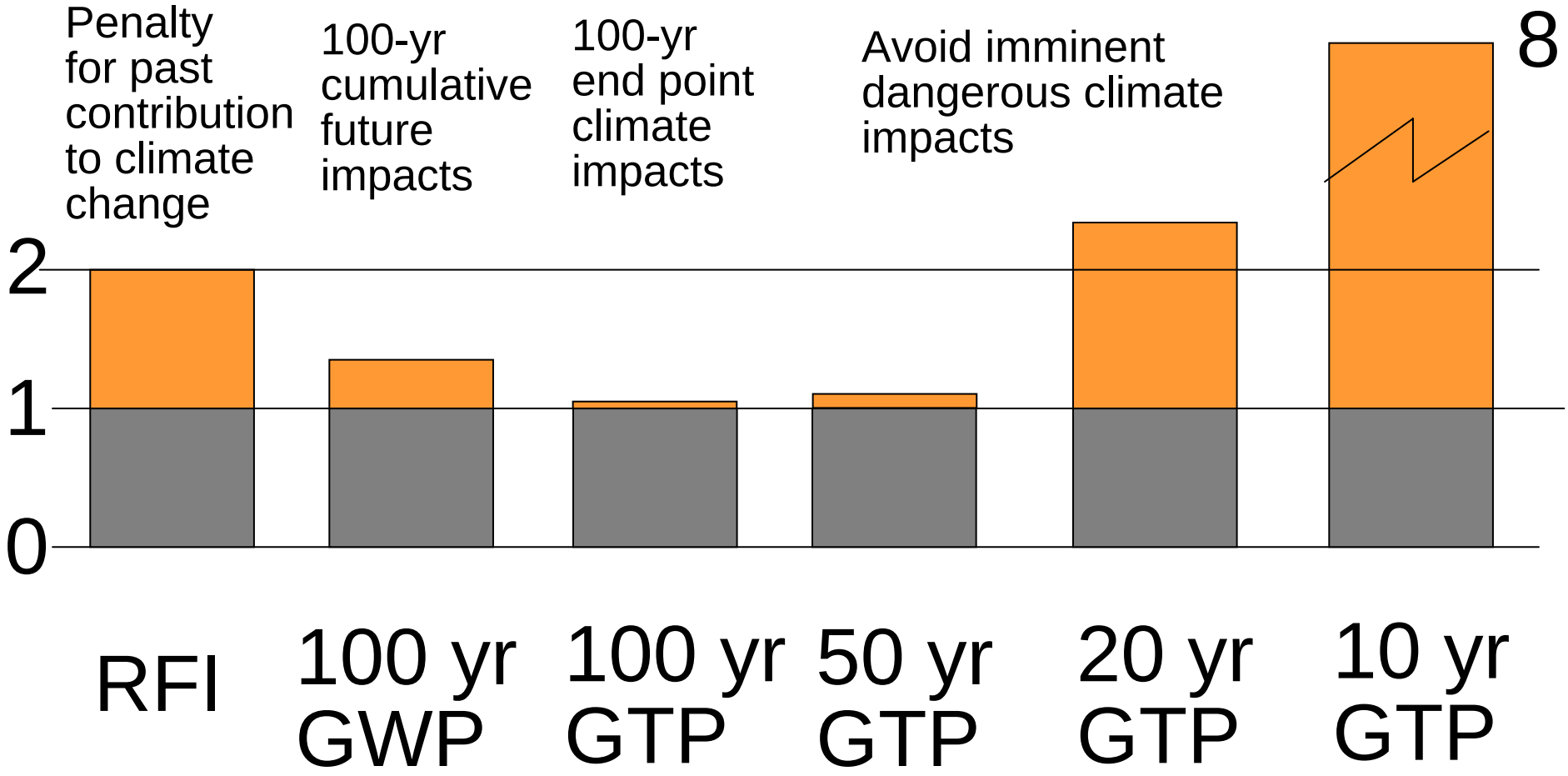
It depends on the policy question:

- Penalty for past contribution of aviation to today's climate change
- Trade/offset the future climate impacts of today's emissions against a saving in another economical sector
  - How do we measure impacts of climate change in the future?
    - End point? e.g. 2050, 2100, 2200
    - Cumulative? i.e. integrated over all timescales
    - Rate of change?
  - Targets to avoid dangerous climate change (eg 3°C or 550 ppm CO_2 eq)

What is the right multiplier?

A simple example

CO_2 RF = 0.02 Wm^{-2}, contrails&cirrus=0.02 Wm^{-2}, 650 Gt CO_2/yr



Why is it important to have the correct multiplier?

Example 1: Emission Trading Scheme
x2 multiplier is used for aviation
but x1 should be used

	Non-aviation sector	Aviation sector	Total effect
Default	6	4	10
Aviation sector grows	4	5	9
Aviation sector shrinks	8	3	11

Good for climate!
More expensive for aviation

Bad for climate!
Aviation wins on C permits

Why is it important to have the correct multiplier?

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Example 2: Emission Trading Scheme
x1 multiplier is used for aviation but x2 should be used

	Non-aviation sector	Aviation sector	Total effect
Default	6	4	14
Aviation sector grows	5	5	15
Aviation sector shrinks	7	3	13

Bad for climate!
Aviation should pay more

Good for climate!
Aviation should get more

The climate impact and non-CO_2 multiplier are different for each **individual flight**

WHAT MAKES CLIMATE IMPACTS OF AVIATION FLIGHT-DEPENDENT?

- Flight altitude
  - Troposphere versus stratosphere: water vapour
  - Ozone formation and radiative efficiency
  - Contrail formation
- Flight latitude
  - Ozone and contrail formation
- Temperature and humidify conditions
  - Contrail formation
- Engine efficiency
  - CO_2
  - Contrail formation
- Time of flight
  - Contrail RF different at day and at night

Non-CO_2 effects can be an opportunity for the aviation sector…

- Non-CO_2 multiplier does not allow much flexibility
- Minimising the total effect of aviation on climate (through the optimal combination of fuel consumption, NOx emissions and contrail formation) might be a more flexible solution
- It can be achieved
  - by optimal air traffic management (route & altitude)
  - by optimising engines and aircraft
  - by optimal deployment of a mixed fleet of aircraft

Right metric for comparing CO_2 and non-CO_2 effects!!

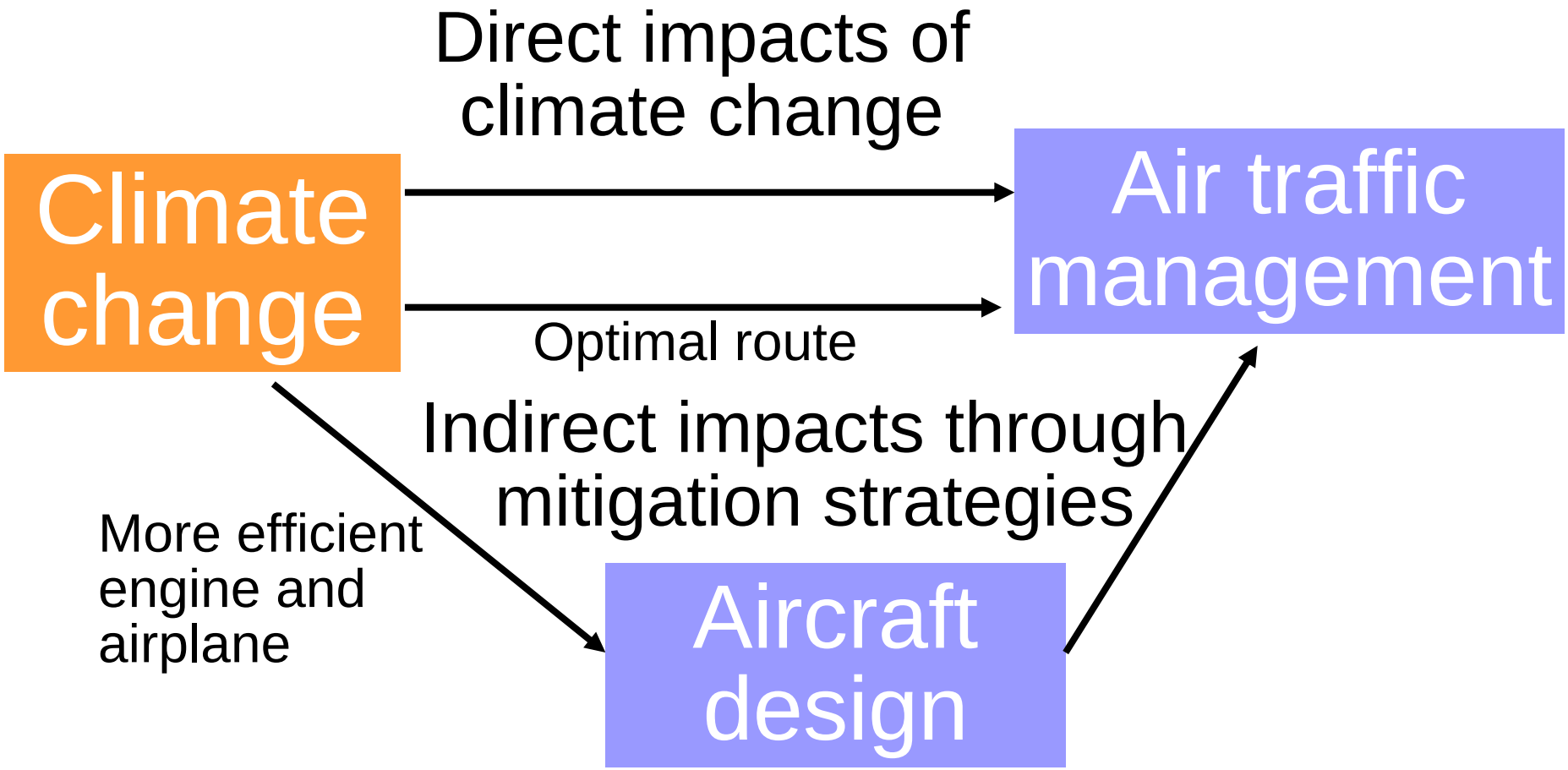
Mixed fleet of aircraft

Aircraft can be deployed to minimise the overall climate effect

Potential for contrail formation depends on latitude/altitude

Deploy new aircraft on routes where contrail formation is minimised

Direct and indirect impacts of climate change on ATM



Conclusions

- RFI not the right multiplier. GWP and GTP are better.
  Consensus is emerging among scientists. However the right multiplier depends on the climate question.

- There are uncertainties but they can be dealt with adequately in the metric implementation.

- We can estimate the non-CO_2 effects for each flight. In the medium-term climate mitigation policy could be more effective, fairer and possibly cheaper if non-CO_2 effects were accounted for explicitly rather than through a fixed non-CO_2 multiplier.

- It is timely for atmospheric scientists, aircraft manufacturers, air traffic management and regulators to cooperate more closely to minimise the impact of aviation on climate.

Thank you for your attention
Questions?