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The aircraft emissions model: Future Aviation Scenario Tool (FAST)

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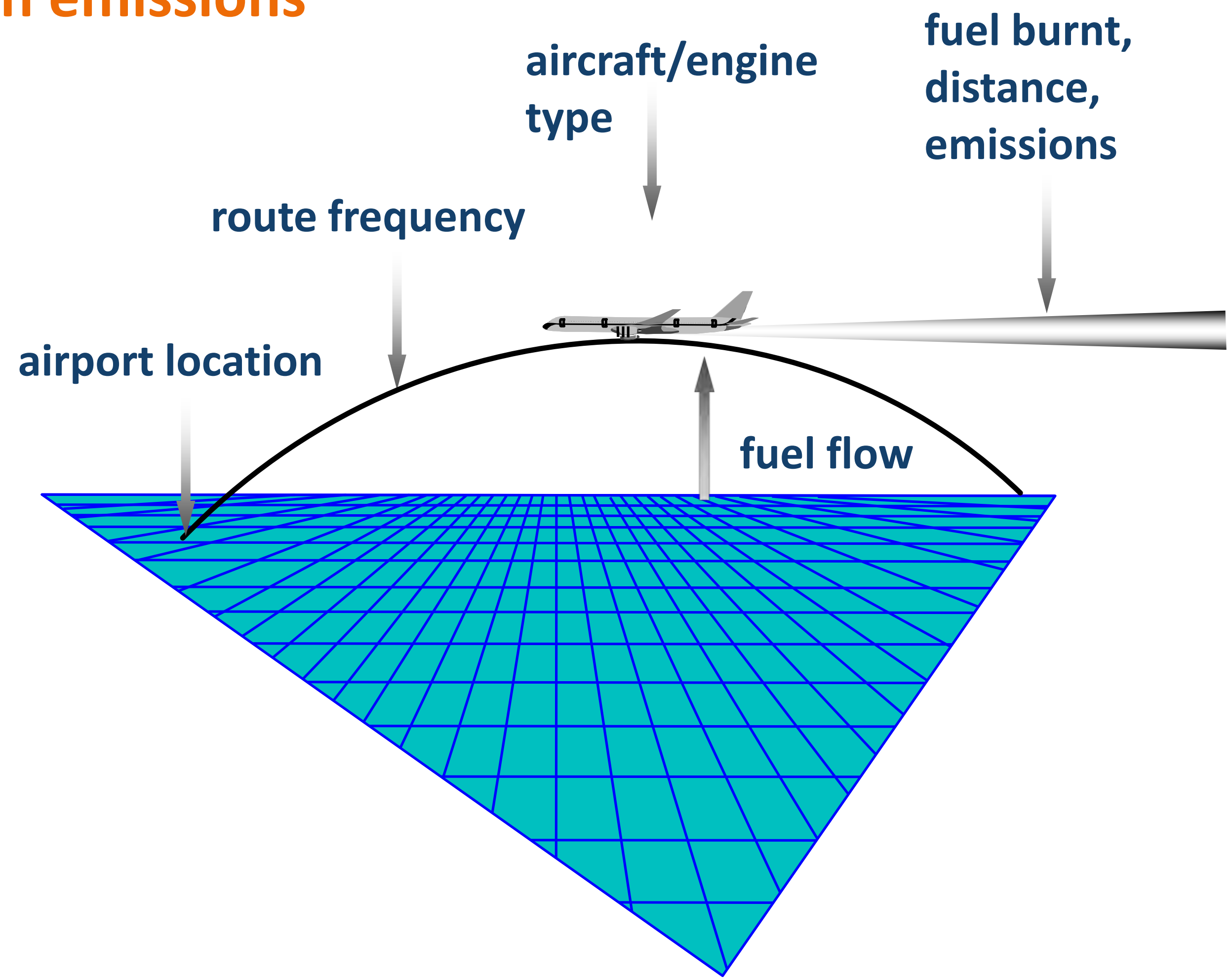
Overview

- Introduction to the FAST model
- Calculating aviation emissions
- Sample output: Case studies
- Future outlook

Introduction to the FAST model

- Global 3D GHG aircraft emissions model
- Developed in the late 1990s
- Maintained by MMU and currently funded by the UK Department for Transport
- One of three GHG model approved by ICAO-CAEP for CAEP analyses

Calculating aviation emissions



Calculating cruise emissions

- PIANO aircraft performance tool
- Run for specific aircraft type → different combinations of altitude, mission distance, payload assumptions
- Provides cruise fuel burn based on aircraft type and operating conditions (altitude, speed, weight)
- Accounts for weight changes during flight due to fuel burn
- FAST uses operations data to match nearest PIANO mission distance and corrects cruise fuel burn

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Case study: Comparison with other models

- Skowron et al., 2013

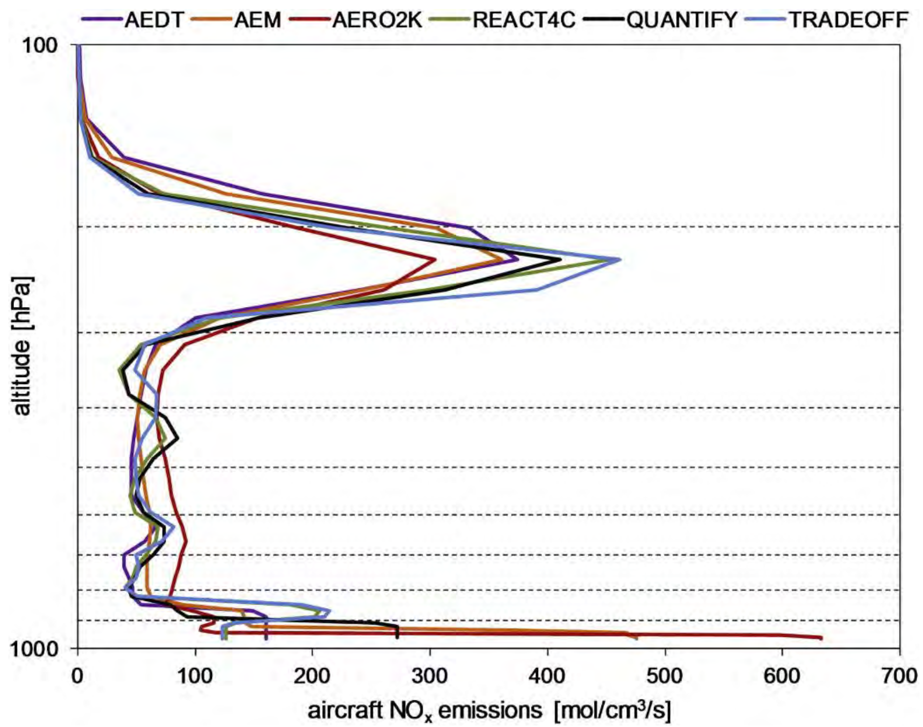
The summary of specifications of six aircraft inventories used in this study: AEDT, AEM, AERO2K, REACT4C, QUANTIFY and TRADEOFF.

Inventory	AEDT	AEM	AERO2K[a]	REACT4C	QUANTIFY	TRADEOFF
Year	2006	2006	2002	2006	2000	1992
Fuel (Tg $year^{-1}$)	187	210	156	178	152	114
Distance (billion km $year^{-1}$)	38.9	43.6	33.2	38.9	30.5	17.4
CO_2 (Tg $year^{-1}$)	590	508	492	562	479	n/a
NO_x (Tg(NO_2) $year^{-1}$)	2.72	2.99	2.06	2.33	1.98	1.61
Vertical spacing	1 km	500 ft	500 ft	610 m	610 m	610 m
Temporal resolution	Annual	Monthly	Monthly	Monthly	Monthly	Seasonal
Air traffic movements	Radar data, OAG	Radar data, OAG	Radar data, BACK	Radar data, OAG	OAG for schedule & AERO2K for non-schedule traffic	OAG, scheduled data
Modelling tool	SAGE, BADA	AEM, BADA	AERO2K, PIANO	FAST, PIANO	FAST, PIANO	FAST, PIANO

[a] Based on civil aviation data only.

Case study: Comparison with other models

- Skowron et al., 2013



Absolute radiative forcings (in mW m^{-2}) due to short-term O_3, CH_4-induced O_3, CH_4, stratospheric water vapour (SWV) and NO_x (net of all 4 components) for series of normalized aircraft inventories. The radiative forcings per unit emission of N (in mW m^{-2} Tg(N) yr^{-1}) are presented in the brackets.

Inventory	Radiative forcings				
	Short-term O_3	CH_4-induced O_3	CH_4	SWV	Net NO_x
AEDT	14.3 (20.5)	−3.0 (−4.3)	−6.7 (−9.5)	−1.0 (−1.4)	3.6 (5.2)
AEM	13.8 (19.7)	−3.0 (−4.2)	−6.8 (−9.7)	−1.0 (−1.5)	3.0 (4.2)
AERO2K	11.5 (16.5)	−3.1 (−4.5)	−7.1 (−10.4)	−1.1 (−1.5)	0.2 (0.3)
REACT4C	13.4 (19.2)	−3.1 (−4.4)	−7.0 (−10.0)	−1.1 (−1.5)	2.3 (3.3)
QUANTIFY	12.8 (18.3)	−3.1 (−4.4)	−7.0 (−10.0)	−1.1 (−1.5)	1.7 (2.4)
TRADEOFF	13.1 (18.7)	−3.1 (−4.5)	−7.1 (−10.2)	−1.1 (−1.5)	1.8 (2.6)

Case study: Modelling future emission scenarios

- Traffic demand forecast – e.g. route level forecasts
- Fleet forecast – how demand forecast will be met → aircraft types and sizes
- Technology assumptions – rate of change of fuel burn efficiency and other aircraft/engine changes
- Future changes in fuel type – rate of penetration of alternative fuel

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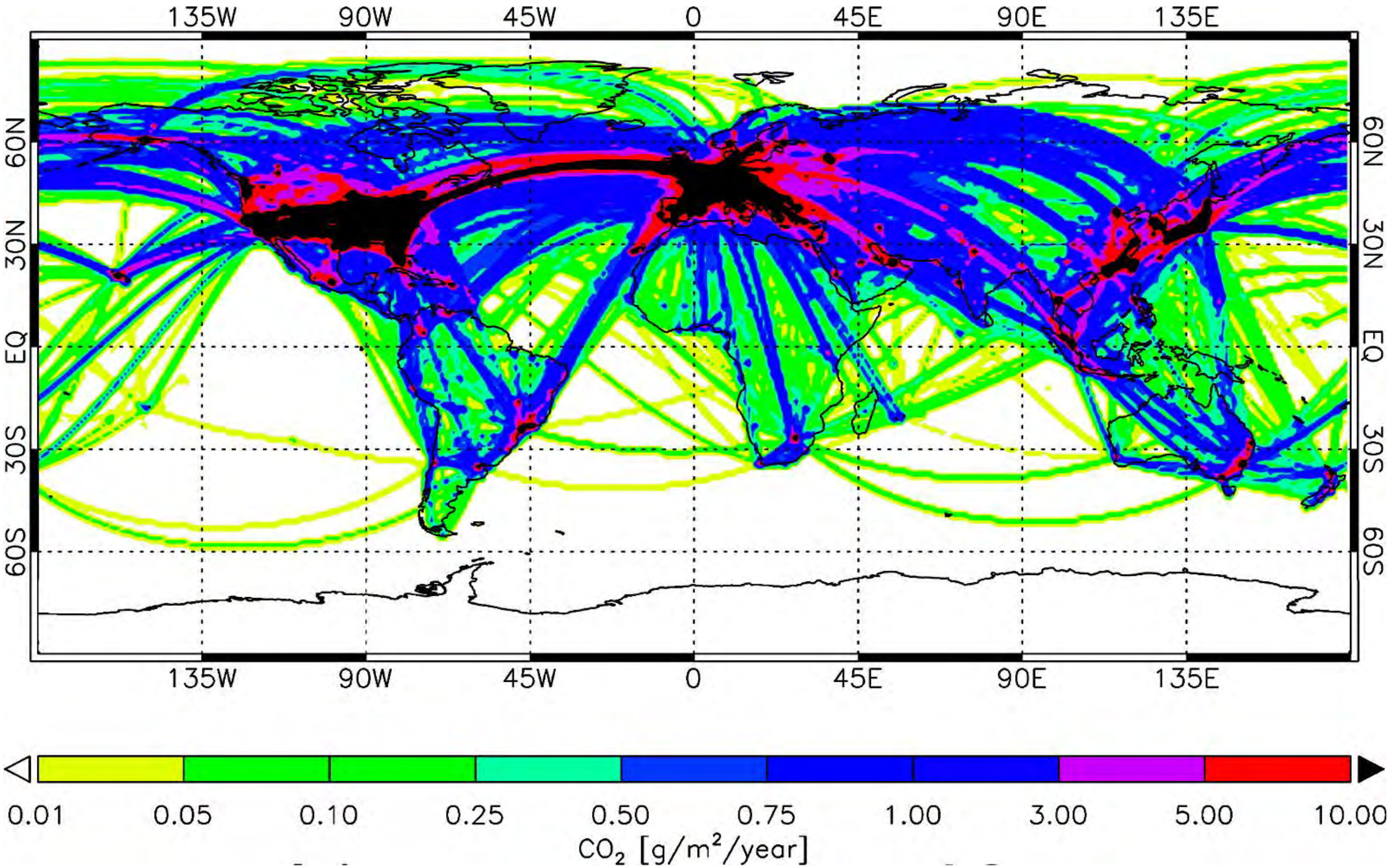
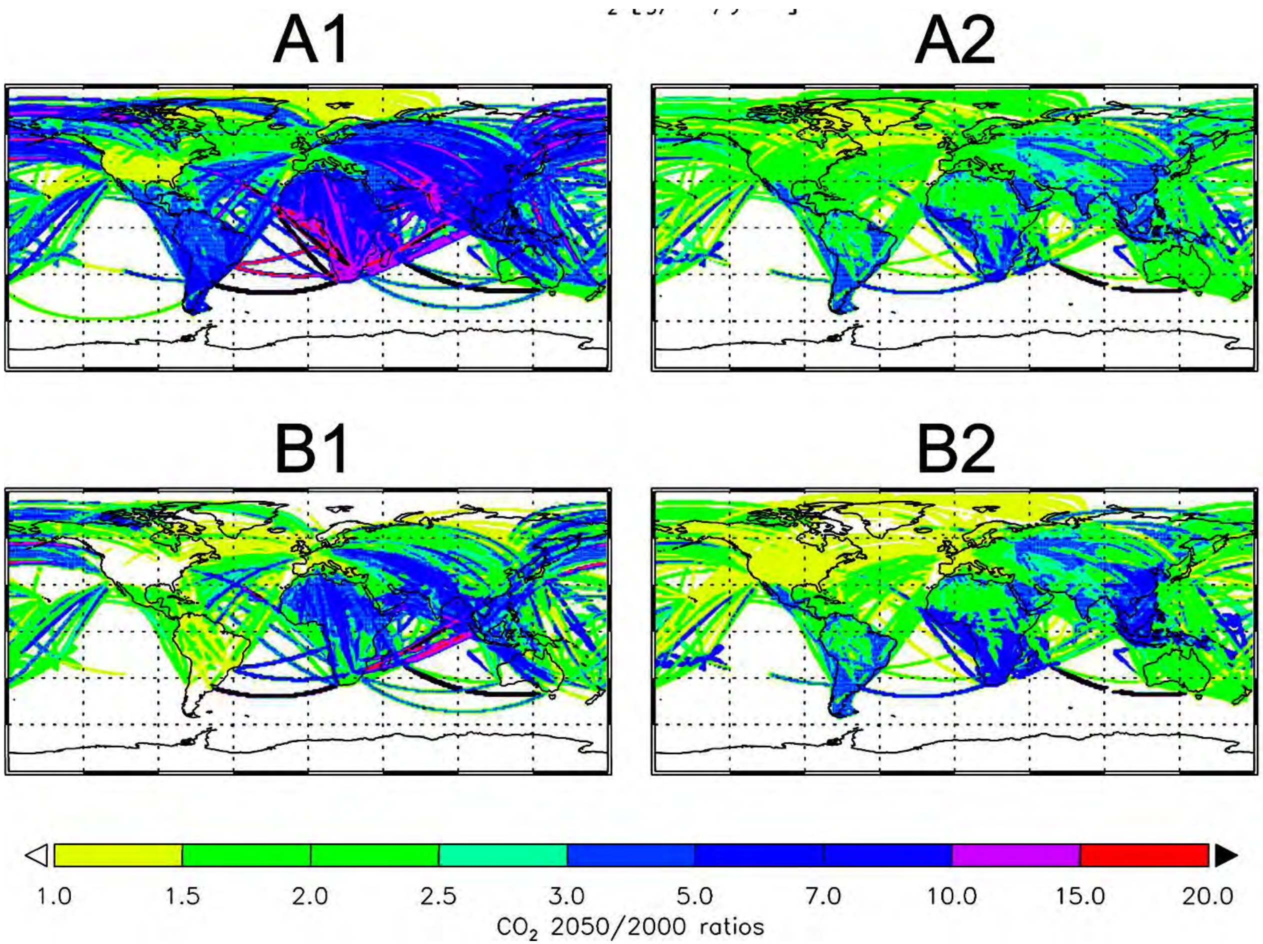
Case study: Modelling future emission scenarios



Base year 2000, EU FP6 QUANTIFY (Owen et al., 2010)

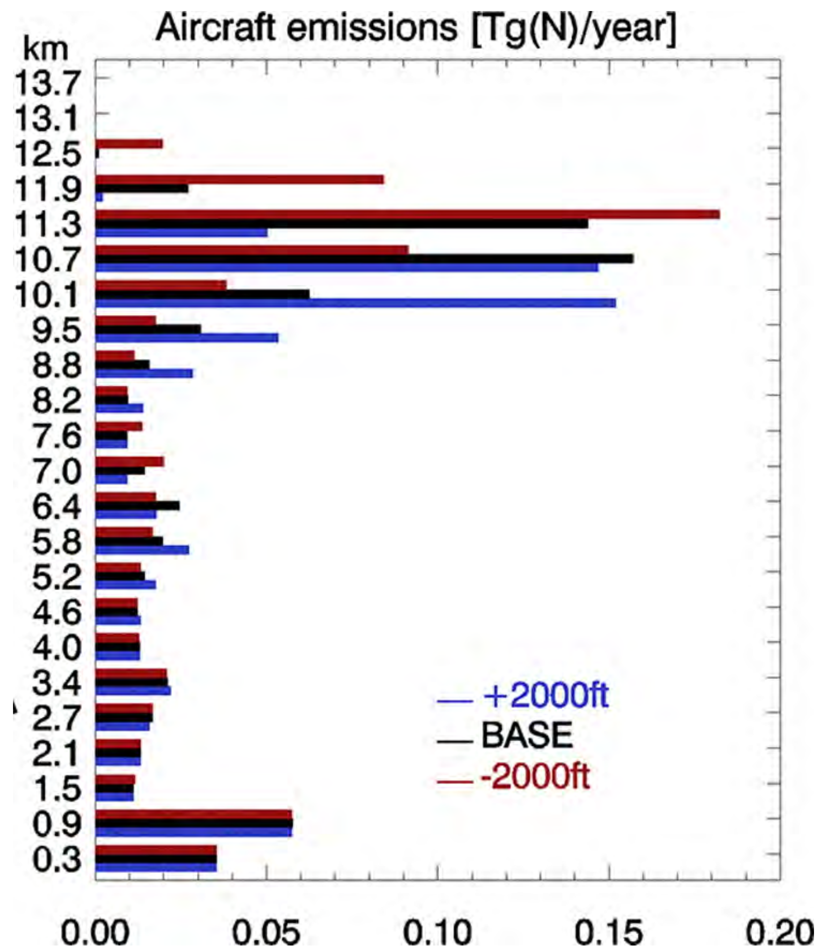
Case study: Modelling future emission scenarios



EU FP6 QUANTIFY (Owen et al., 2010)

Case study: Simple mitigation

- EU FP7 REACT4C
- Cruise altitudes for aircraft types contributing > 1% to base case global fuel and distance flown → shifted upwards and downwards by 2,000 ft
- Example results from Søvde et al., 2014



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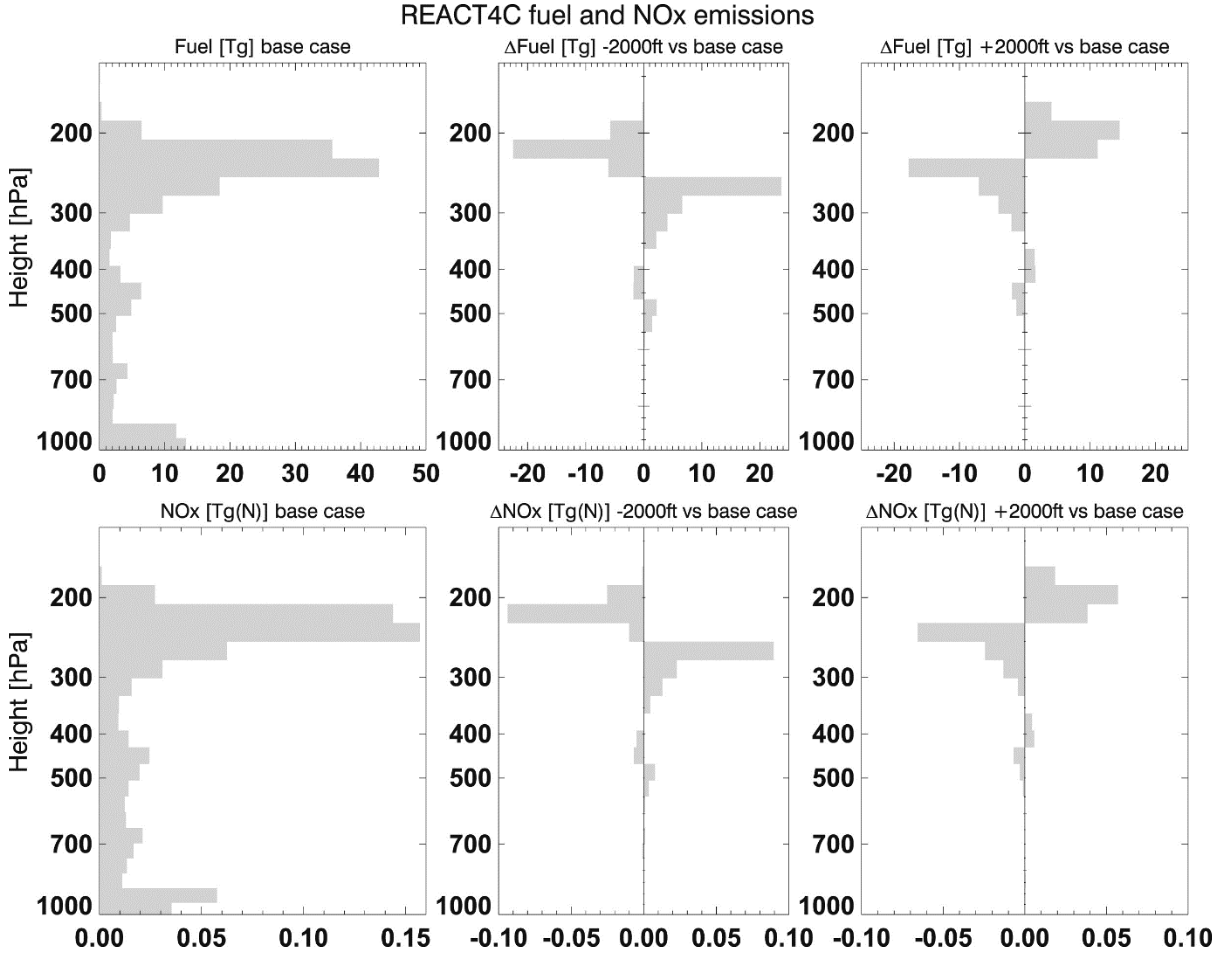
Case study: Simple mitigation



EU FP7 REACT4C (Søvde et al., 2014)

Case study: CAEP/10 trends

- ICAO Assembly resolution A37-18: “assess the present and future impact and trends of aircraft noise and aircraft engine emissions”
- Each 3-year cycle, ICAO-CAEP MDG develops environmental trends in aviation → noise, LAQ, GHG
- CAEP/MDG aims to use latest input data and related assumptions
    - Demand forecast: FESG central/low/high to 2040 (extrapolated to 2050)
    - Fleet forecasts populated from Growth and Replacement database
    - Fleet-wide assumptions on Technical or Operational improvements for 9 scenarios
- CAEP-approved GHG models include AEDT (US), AEM/IMPACT (Eurocontrol/EASA) and FAST (UK DfT/MMU)

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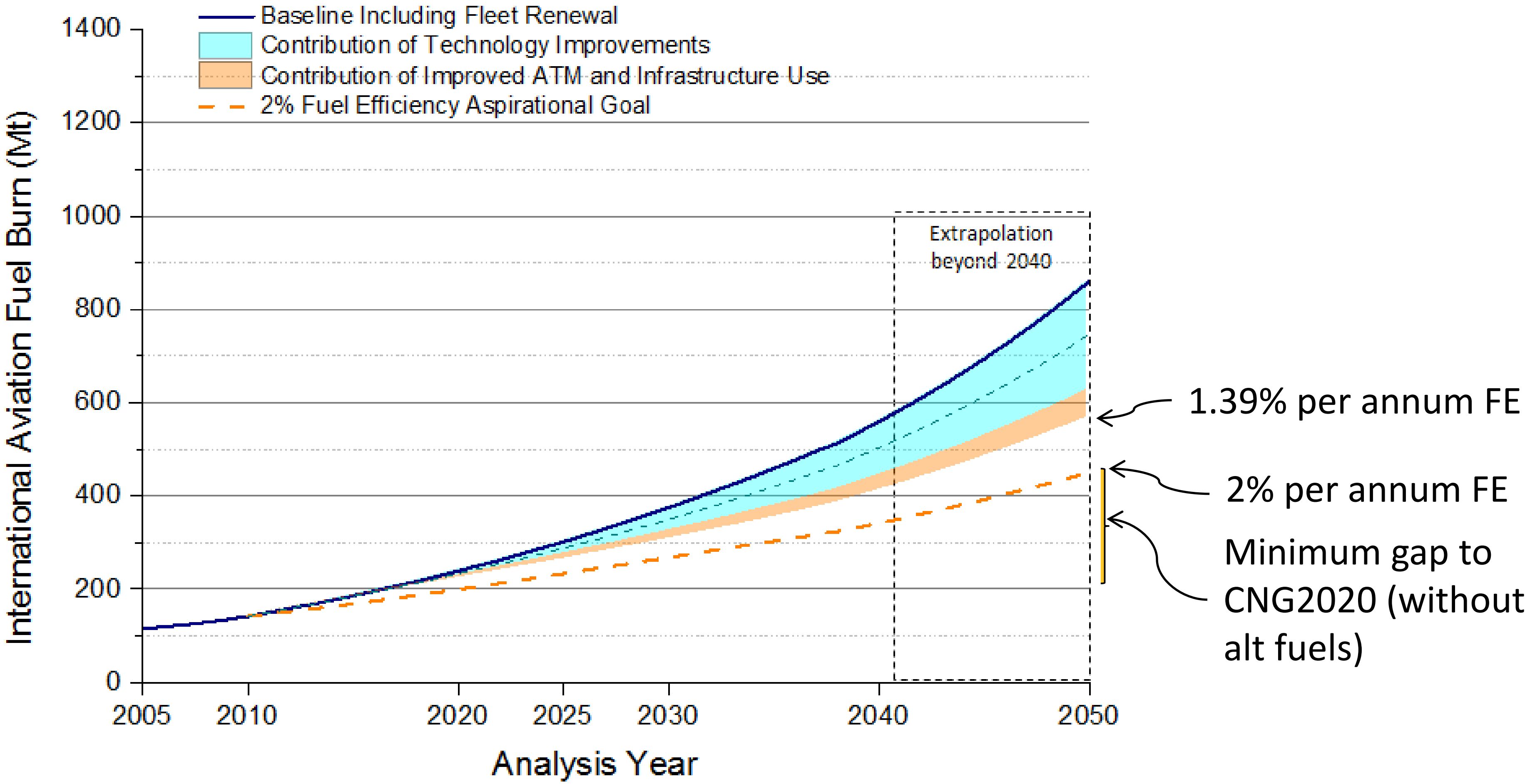
Case study: CAEP/10 trends



*Dashed line in technology contribution sliver represents the "Low Aircraft Technology Scenario."
Note: Results were modelled for 2005, 2006, 2010, 2020, 2025, 2030, and 2040 then extrapolated to 2050.

Case study: ICAO global MBM

- Route-based adjustments investigated for GMBM
- Assessment uses state-to-state information on emissions derived from GHG inventories such as FAST
- Operator-based data are not usually retained in CAEP trends work but for the MBM work, these data are included

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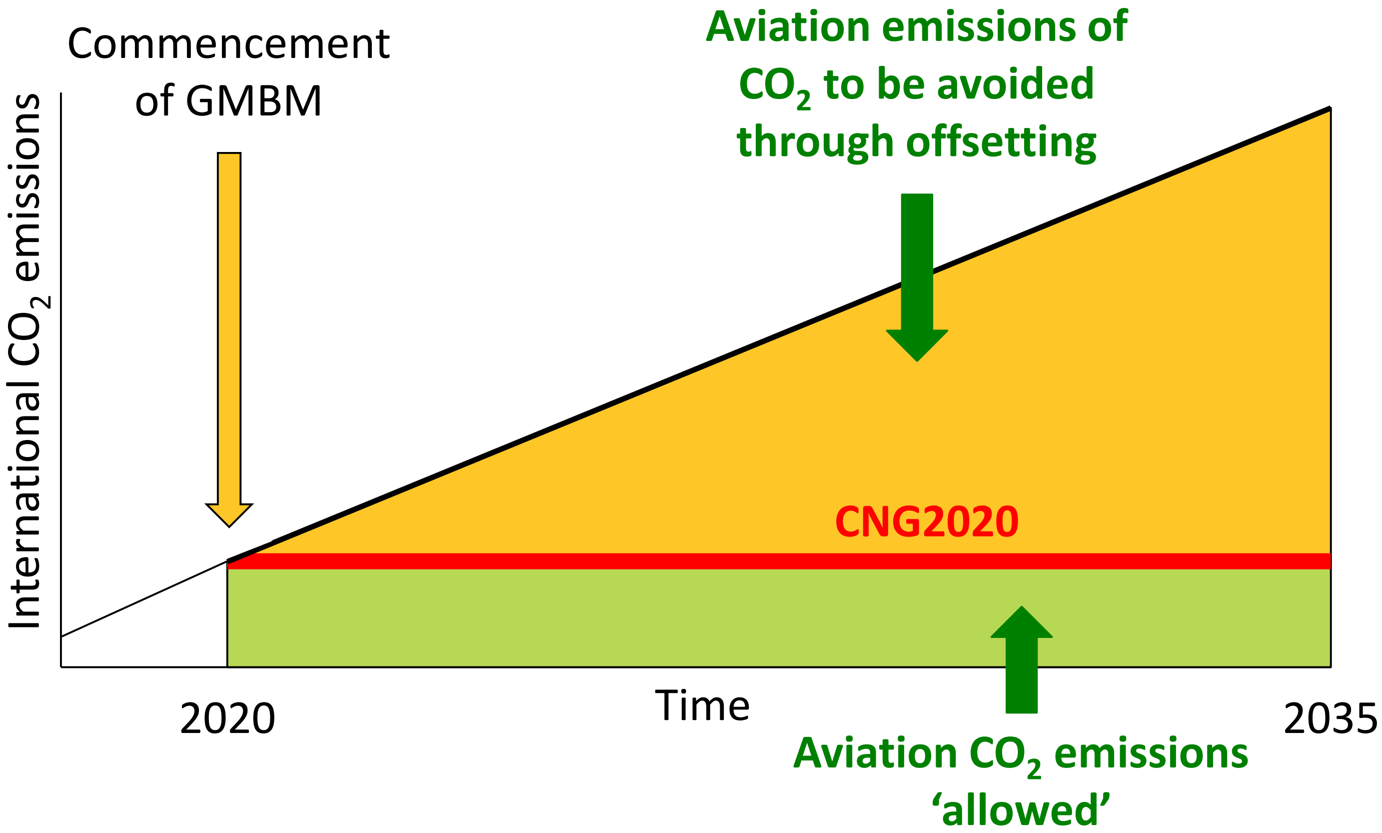
Case study: ICAO global MBM



This shows the basic premise of the scheme which uses CAEP/10 trends data for projected CO_2 emissions bounded by the high and low fuel efficiency scenarios

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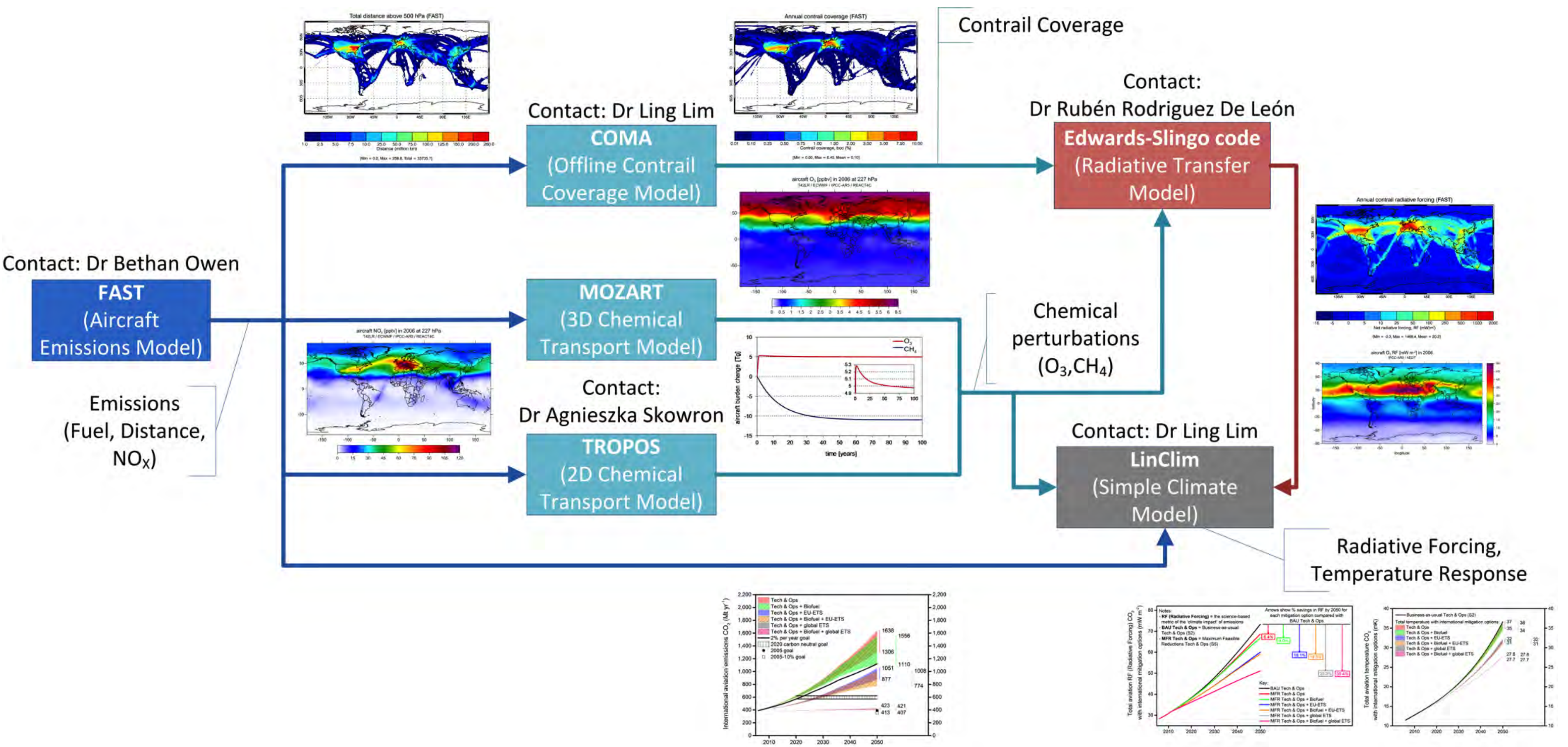
Case study: Linkages to other MMU models



Future outlook

- nvPM emission estimates to be developed this CAEP/11 cycle to model the impact of new ICAO-CAEP nvPM engine certification standard
- Inclusion of trajectory modules for ATM research
- Better communication between the inventory modellers and end user

Backup slides

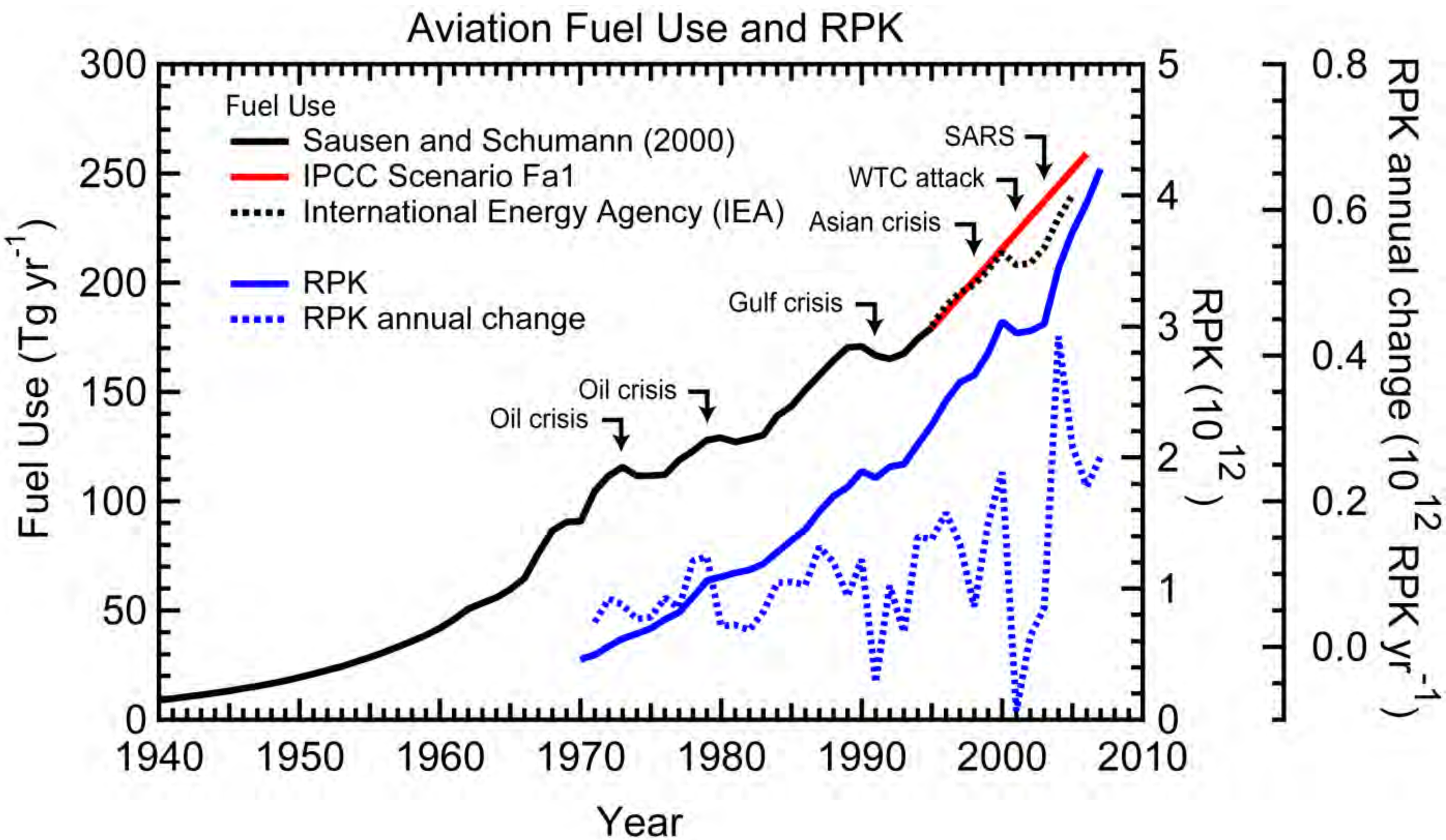
CAEP/8 models comparison (2006 base year)

Inventory	Fuel (Tg)	CO_2 (Tg)	NO_X (Tg NO_2)	Distance (billion km)
FAST	178.3	562.2	2.33	38.9
AEDT/SAGE	187.0 (+4.9)	589.6 (+4.9)	2.72 (+16.7)	38.9
AEM	189.8 (+6.4)	598.4 (+6.4)	2.79 (+19.7)	
Aero2K	170.0 (-4.7)	536.0 (-4.7)		

* Number in brackets denote % difference compared to FAST

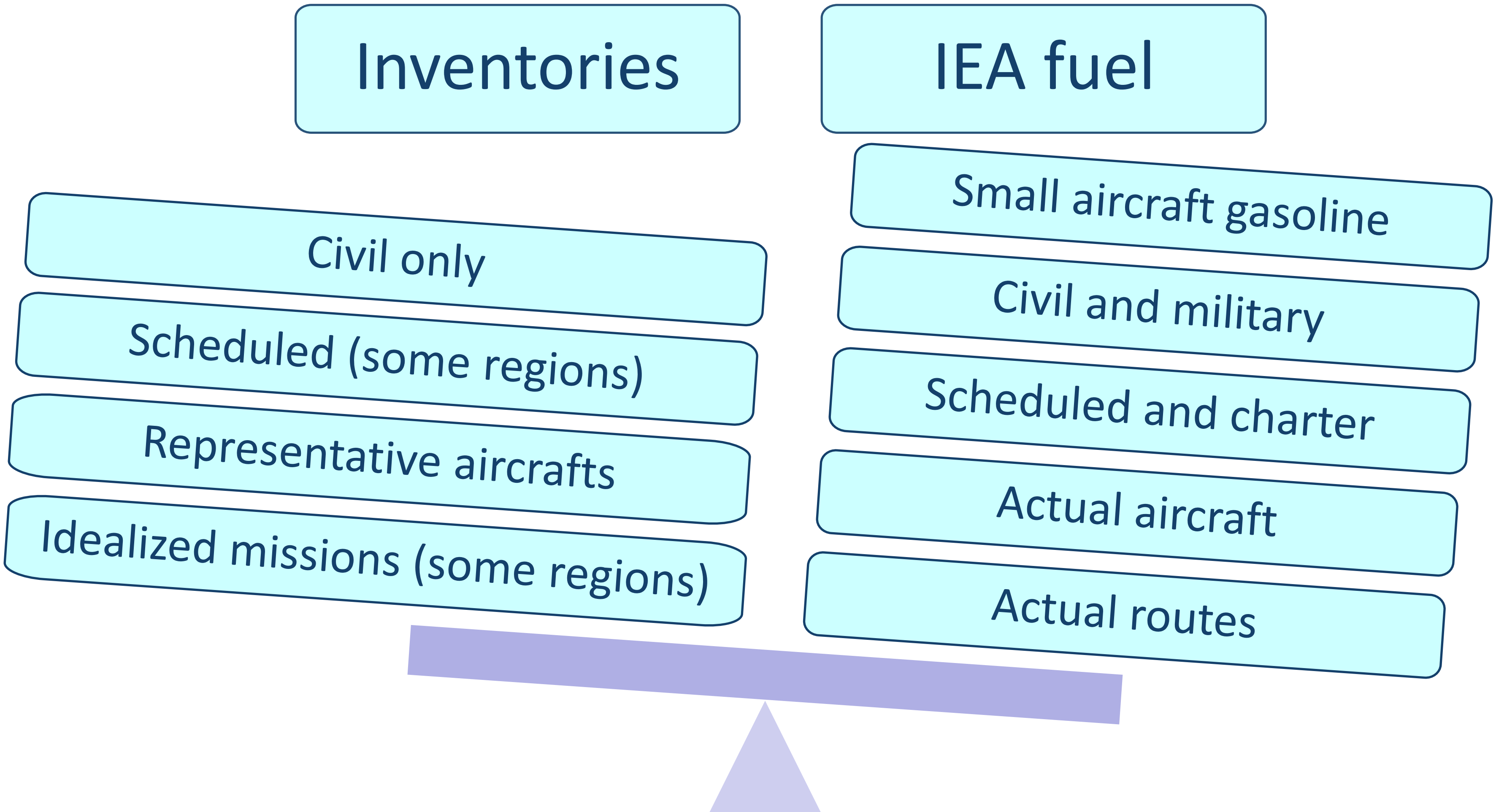
[Source: CAEP/MDG working group]

Historical fuel use



Source: Lee et al., 2009

IEA vs inventories



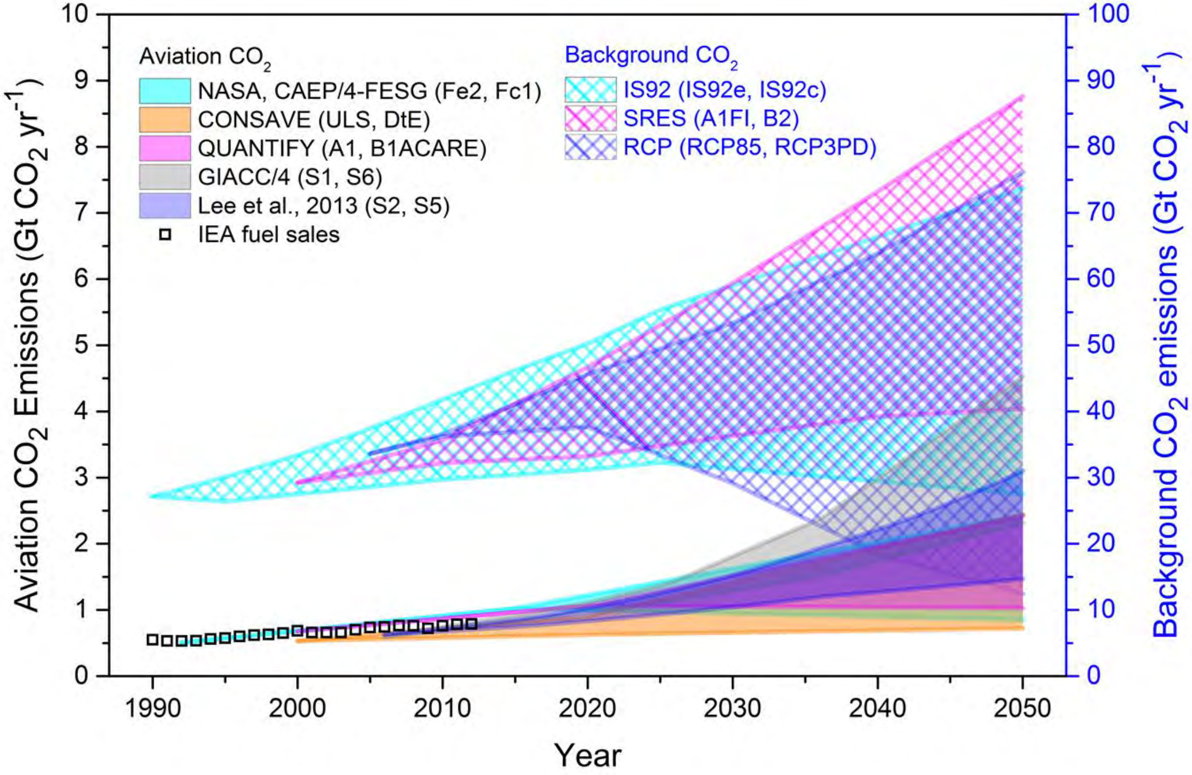
IEA vs inventories

Inventories	IEA fuel
Correction factor	Small aircraft gasoline
Civil only	Civil and military
Scheduled (some regions)	Scheduled and charter
Representative aircrafts	Actual aircraft
Idealized missions (some regions)	Actual routes

Aviation emissions scenarios

- NASA, CAEP-4/FESG for years 1992, 2015 and 2050 (IPCC, 1999)
- CONSAVE for years 2000, 2020, 2050 (Berghof et al., 2005)
- QUANTIFY for years 2000, 2020, 2050 (Owen et al., 2010)
- GIACC/4 for years 2006, 2012, 2016, 2020, 2025, 2026, 2036, 2050 (ICAO, no date)
- Lee et al. (2013) for years between 2006 and 2050

How good are the forecasts?



CAEP trends type analysis