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

- aircraft/engine type
- fuel burnt, distance, emissions
- route frequency
- airport location
- fuel flow
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
Case study: Comparison with other models

- Skowron et al., 2013

<table>
<thead>
<tr>
<th>Inventory</th>
<th>AEDT</th>
<th>AEM</th>
<th>AERO2K*</th>
<th>REACT4C</th>
<th>QUANTIFY</th>
<th>TRADEOFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel (Tg year⁻¹)</td>
<td>187</td>
<td>210</td>
<td>156</td>
<td>178</td>
<td>152</td>
<td>114</td>
</tr>
<tr>
<td>Distance (billion km year⁻¹)</td>
<td>38.9</td>
<td>43.6</td>
<td>33.2</td>
<td>38.9</td>
<td>30.5</td>
<td>17.4</td>
</tr>
<tr>
<td>CO₂ (Tg year⁻¹)</td>
<td>590</td>
<td>508</td>
<td>492</td>
<td>562</td>
<td>479</td>
<td>n/a</td>
</tr>
<tr>
<td>NOₓ (Tg(NOₓ) year⁻¹)</td>
<td>2.72</td>
<td>2.99</td>
<td>2.06</td>
<td>2.33</td>
<td>1.98</td>
<td>1.61</td>
</tr>
<tr>
<td>Vertical spacing</td>
<td>1 km</td>
<td>500 ft</td>
<td>500 ft</td>
<td>1.60</td>
<td>1.98</td>
<td>1.61</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>Annual</td>
<td>Monthly</td>
<td>Monthly</td>
<td>Monthly</td>
<td>Monthly</td>
<td>Seasonal</td>
</tr>
<tr>
<td>Air traffic movements</td>
<td>Radar data, OAG</td>
<td>Radar data, OAG</td>
<td>Radar data, OAG</td>
<td>Radar data, OAG for schedule &amp; AERO2K</td>
<td>OAG, scheduled data</td>
<td>OAG, scheduled data</td>
</tr>
<tr>
<td>Modelling tool</td>
<td>SAGE, BADA</td>
<td>AEM, BADA</td>
<td>AERO2K, PIANO</td>
<td>FAST, PIANO</td>
<td>FAST, PIANO</td>
<td>FAST, PIANO</td>
</tr>
</tbody>
</table>

* Based on civil aviation data only.
Case study: Comparison with other models

- Skowron et al., 2013
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
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
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)
Case study: CAEP/10 trends

![Graph showing International Aviation Fuel Burn (Mt) from 2005 to 2050. The graph includes lines for Baseline Including Fleet Renewal, Contribution of Technology Improvements, Contribution of Improved ATM and Infrastructure Use, and a dashed line for 2% Fuel Efficiency Aspirational Goal.]

- 1.39% per annum FE
- 2% per annum FE
- Minimum gap to CNG2020 (without alt fuels)

*Dashed line in technology contribution slice 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
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.

- Commencement of GMBM
- Aviation emissions of CO$_2$ to be avoided through offsetting
- CNG2020
- Aviation CO$_2$ emissions ‘allowed’

Time

2020

2035
Case study: Linkages to other MMU models

- **FAST** (Aircraft Emissions Model)
  - Contact: Dr Bethan Owen
  - Emissions (Fuel, Distance, NOx)

- **COMA** (Offline Contrail Coverage Model)
  - Contact: Dr Ling Lim

- **MOZART** (3D Chemical Transport Model)
  - Contact: Dr Agnieszka Skowron

- **TROPOS** (2D Chemical Transport Model)

- **Edwards-Slingo code** (Radiative Transfer Model)
  - Contact: Dr Rubén Rodríguez De León
  - Chemical perturbations (O3, CH4)

- **LinClim** (Simple Climate Model)
  - Contact: Dr Ling Lim
  - Radiative Forcing, Temperature Response
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)

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<th>NOₓ (Tg NO₂)</th>
<th>Distance (billion km)</th>
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<tr>
<td>FAST</td>
<td>178.3</td>
<td>562.2</td>
<td>2.33</td>
<td>38.9</td>
</tr>
<tr>
<td>AEDT/SAGE</td>
<td>187.0 (+4.9)</td>
<td>589.6 (+4.9)</td>
<td>2.72 (+16.7)</td>
<td>38.9</td>
</tr>
<tr>
<td>AEM</td>
<td>189.8 (+6.4)</td>
<td>598.4 (+6.4)</td>
<td>2.79 (+19.7)</td>
<td></td>
</tr>
<tr>
<td>Aero2K</td>
<td>170.0 (-4.7)</td>
<td>536.0 (-4.7)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Number in brackets denote % difference compared to FAST

[Source: CAEP/MDG working group]
Historical fuel use

Source: Lee et al., 2009
IEA vs inventories

Inventories
- Civil only
- Scheduled (some regions)
- Representative aircrafts
- Idealized missions (some regions)

IEA fuel
- Small aircraft gasoline
- Civil and military
- Scheduled and charter
- Actual aircraft
- Actual routes
IEA vs inventories

**Inventories**
- Correction factor
- Civil only
- Scheduled (some regions)
- Representative aircrafts
- Idealized missions (some regions)

**IEA fuel**
- Small aircraft gasoline
- Civil and military
- Scheduled and charter
- Actual aircraft
- Actual routes
Aviation emissions scenarios

- 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

CAEP 2010 Operations Database
CAEP Airports Database
CAEP Population Database
CAEP C-H Fleet Database

CAEP Growth and Replacement DB

Future Fleet & Operations

CAEP Technical Scenario Assumptions

FAST CAEP GHG Model

CAEP Future Scenarios to 2040