Modelling Aviation Emissions on a Local and Global Scale

ICAO Colloquium on
Aviation Emissions

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Outline

- Contributing organizations and models used
- Modelling methodology
- ICAO/CAEP Environmental Goals
  - Introduction
  - Observations
  - Example trends
- Summary

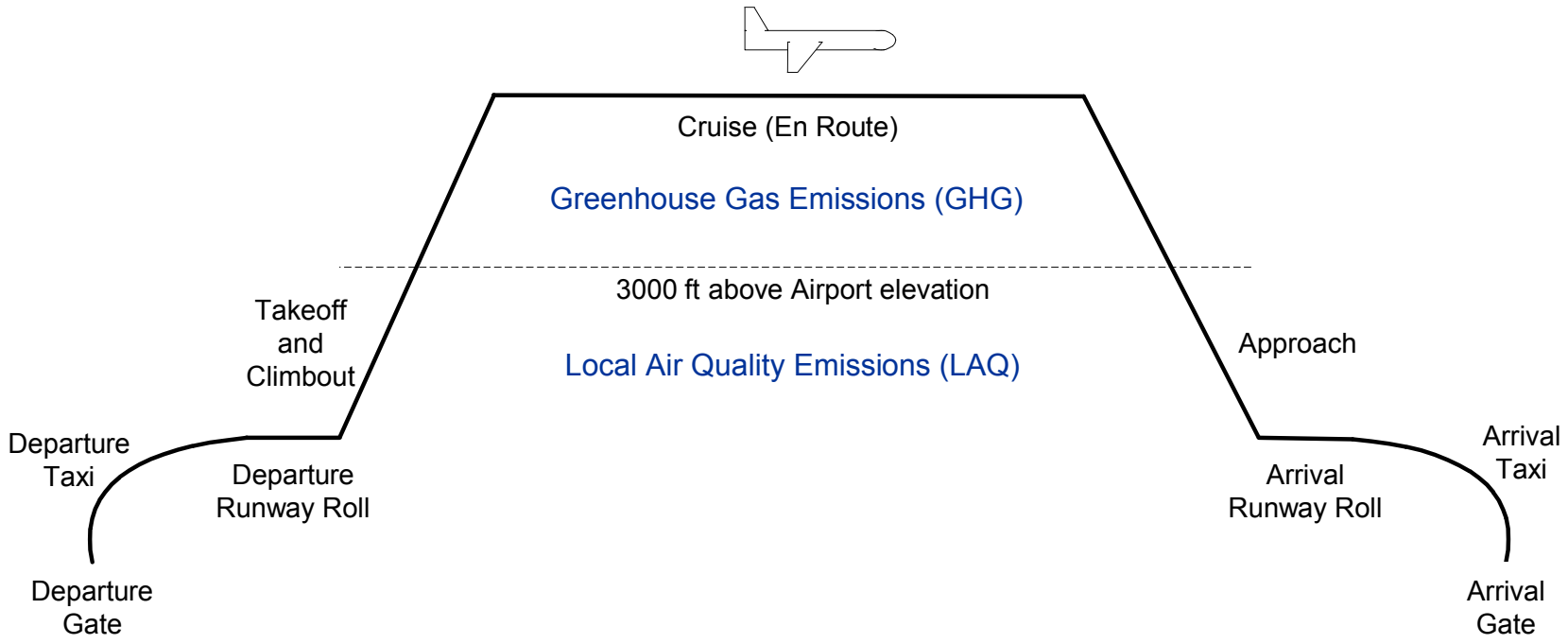
Acknowledgements

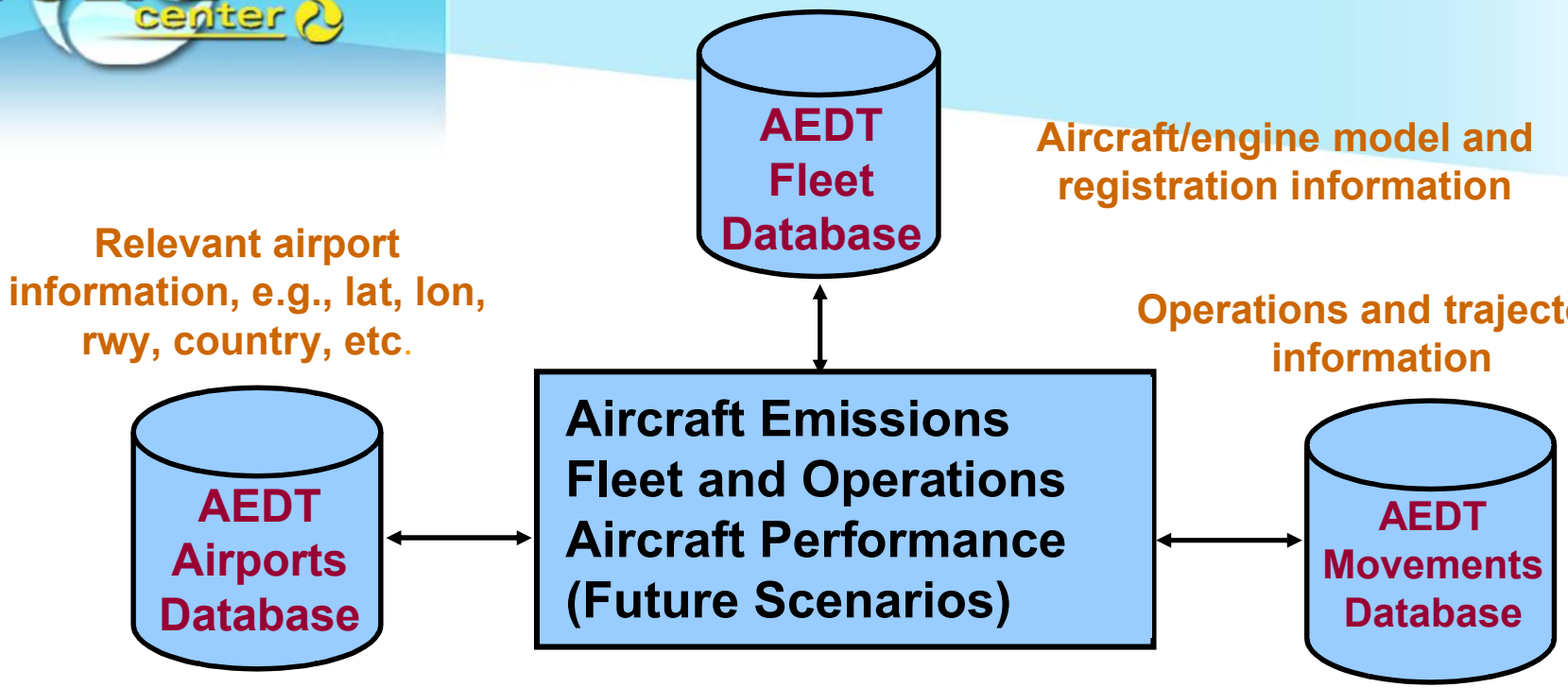
Contributing Organizations and their Models

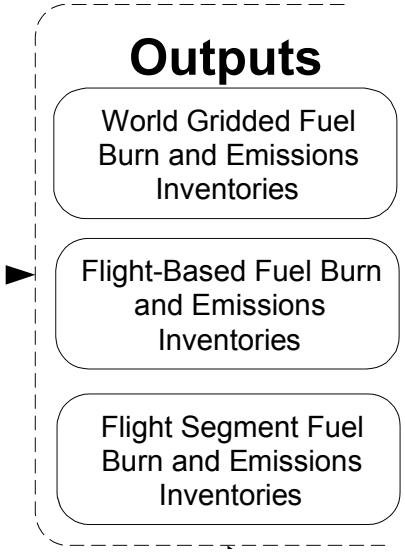
- AEDT/SAGE (US/FAA)
  http://www.faa.gov/about/office_org/headquarters_offices/aep/models/sage)
- AEM (EUROCONTROL)
  http://www.eurocontrol.int/eec/public/standard_page/SEE_2004_report_15.html
- AERO2k (UK/QinetiQ)
  http://www.cate.mmu.ac.uk/aero2k.asp
- FAST (UK/MMU)

Basic Modelling Principle

Models used for computing local (LAQ) and global (GHG) inventories of aviation emissions and fuel useage.

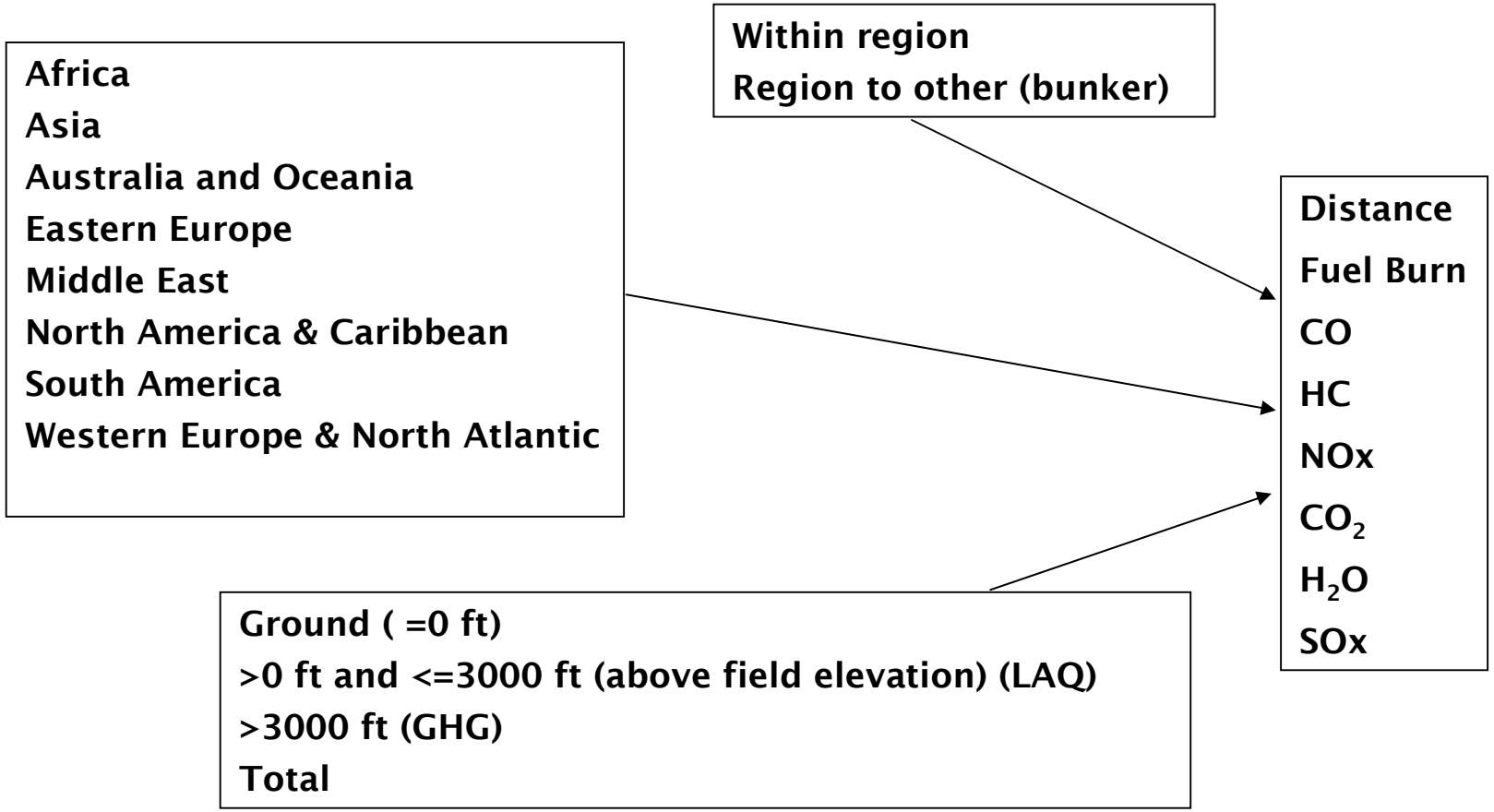


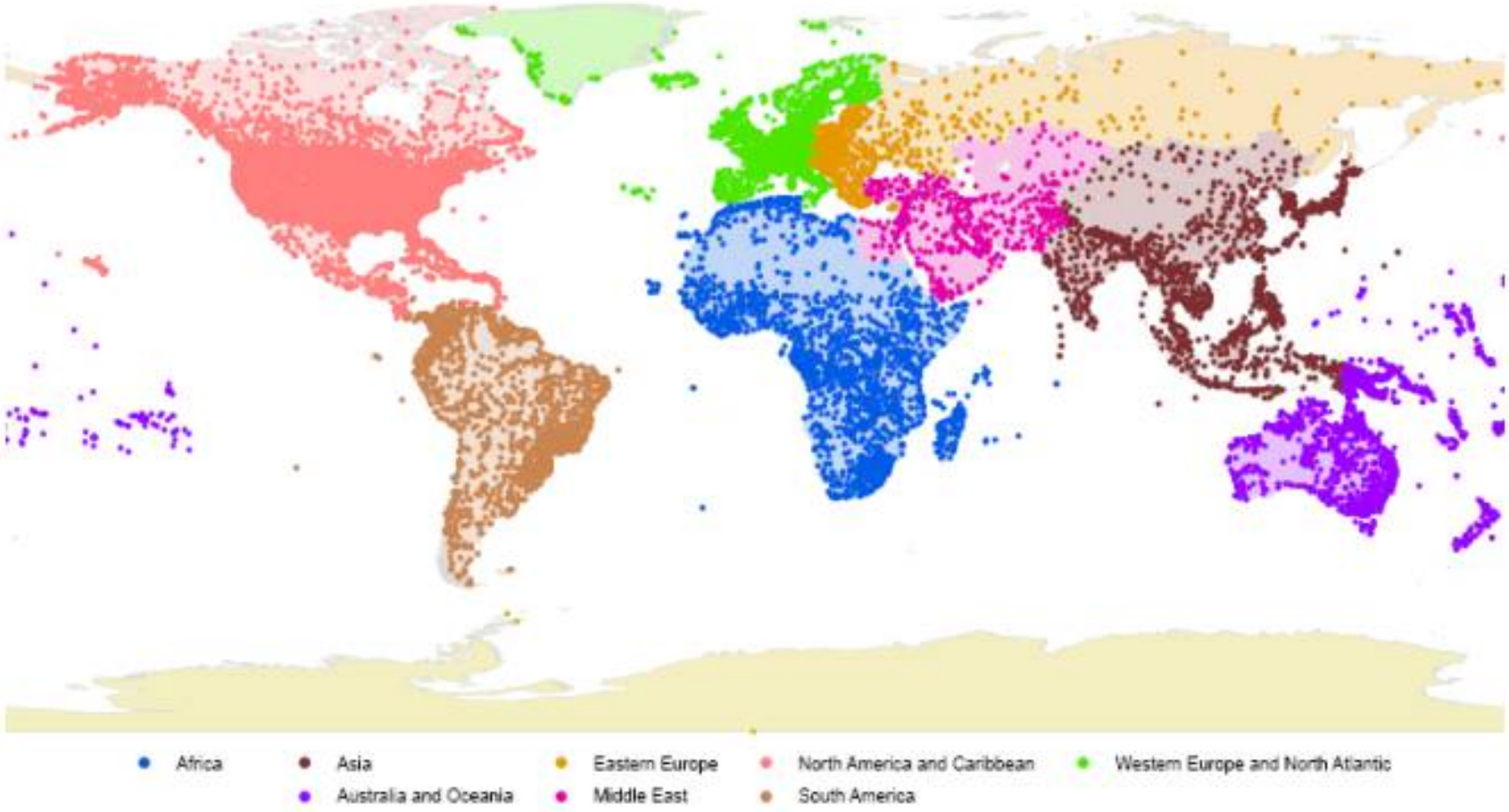

AEDT
Fleet
Database
Aircraft/engine model and
registration information
Relevant airport
information, e.g., lat, lon,
rwy, country, etc.
Operations and trajectory
information
AEDT
Airports
Database
Aircraft Emissions
Fleet and Operations
Aircraft Performance
(Future Scenarios)
AEDT
Movements
Database

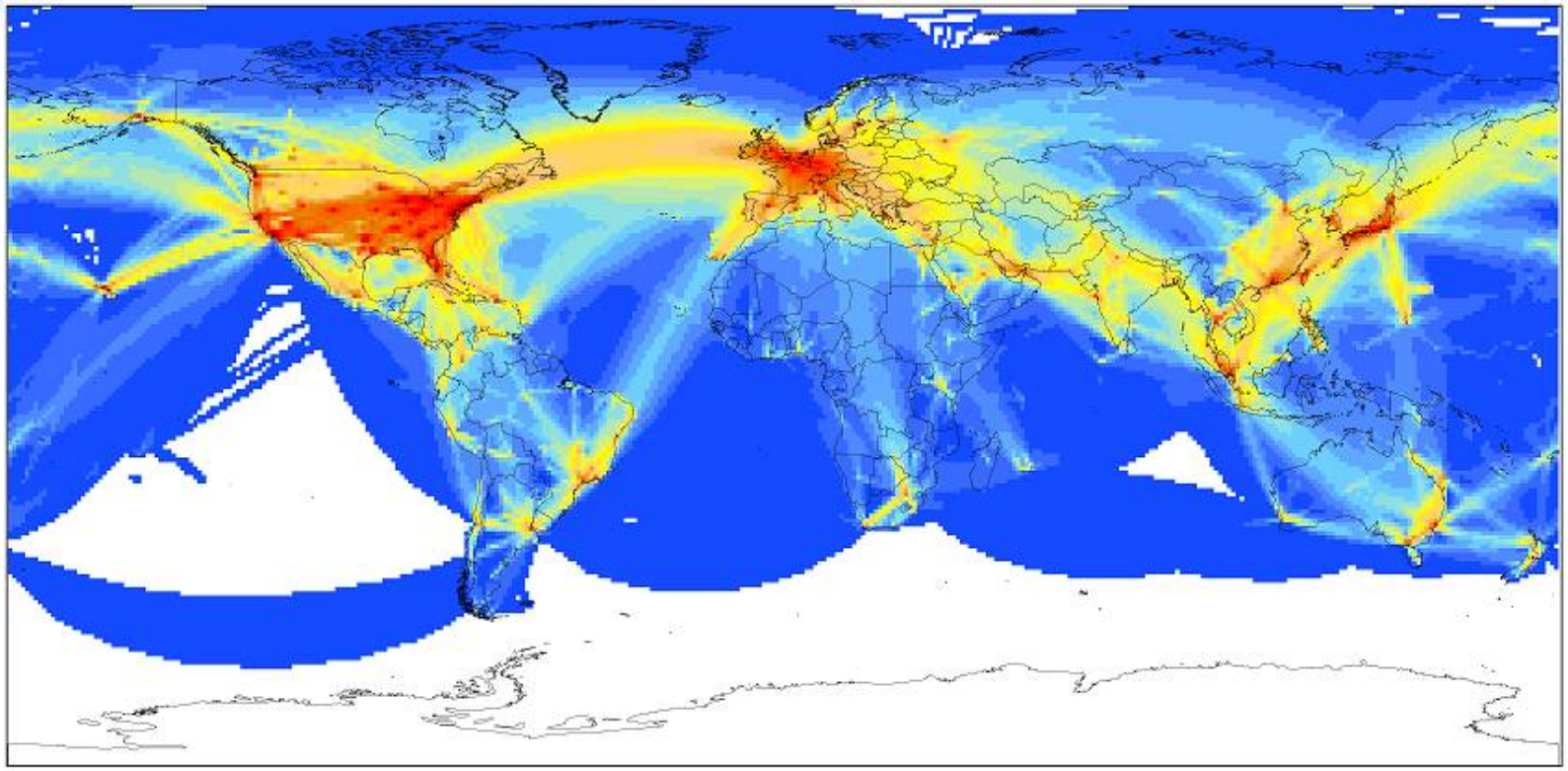

Outputs
World Gridded Fuel
Burn and Emissions
Inventories
Flight-Based Fuel Burn
and Emissions
Inventories
Flight Segment Fuel
Burn and Emissions
Inventories

OUTPUT DATA/RESULTS

Aggregate (Queried) Results: **Results by region, country and/or mode Regions/countries are defined by the airports within an area**




Africa
Asia
Australia and Oceania
Eastern Europe
Middle East
North America and Caribbean
South America
Western Europe and North Atlantic



Fuel Burn (Kg/Year/1 Degree Latitude by 1 Degree Longitude)

0.00e+000 - 3.01e+005	5.81e+006 - 7.22e+006	2.49e+007 - 3.01e+007	9.49e+007 - 1.14e+008
3.02e+005 - 7.66e+005	7.23e+006 - 8.79e+006	3.02e+007 - 3.59e+007	1.15e+008 - 1.38e+008
7.67e+005 - 1.31e+006	8.80e+006 - 1.05e+007	3.60e+007 - 4.20e+007	1.39e+008 - 1.69e+008
1.32e+006 - 1.93e+006	1.06e+007 - 1.24e+007	4.21e+007 - 4.89e+007	1.70e+008 - 2.23e+008
1.94e+006 - 2.65e+006	1.25e+007 - 1.48e+007	4.90e+007 - 5.64e+007	2.24e+008 - 2.86e+008
2.66e+006 - 3.51e+006	1.49e+007 - 1.75e+007	5.65e+007 - 6.60e+007	2.87e+008 - 4.02e+008
3.52e+006 - 4.54e+006	1.76e+007 - 2.07e+007	6.61e+007 - 7.88e+007	4.03e+008 - 5.95e+008
4.55e+006 - 5.80e+006	2.08e+007 - 2.48e+007	7.89e+007 - 9.48e+007	5.96e+008 - 1.09e+009

CAEP Environmental Goals (1)

- SG20041-WP/11 presented a recommendation from Appendix A of A35 to report on three environmental goals:
  - limit or reduce the number of people impacted by noise;
  - limit or reduce the impact of aviation emissions on local air quality; and
  - limit or reduce the impact of aviation greenhouse gas emissions on the global climate.
- There is no accepted metric or modelling system for reporting impact of local air quality (LAQ) and greenhouse gas (GHG) emissions.
- Model evaluations are currently ongoing.

CAEP Environmental Goals (2)

- Use existing GHG models, offered under the model evaluation process by CAEP Member States, to provide initial emission trends from:

  - AEDT/SAGE (US/FAA)
  - AEM (EUROCONTROL)
  - AERO2k (UK/QinetiQ)
  - FAST (UK/MMU)

CAEP Environmental Goals (3)

Assumptions of *initial* emissions trends:

- 2002 CAEP forecast
- No projections of future aircraft technology developments
- No use of CNS/ATM (communication navigation surveillance, air traffic management) technologies
- No benefits from operational improvements

As such, the assessment should be regarded as underselling that which aviation might be expected to be able to achieve through continued technological and operational improvements.

GHG Observations

Anual carbon dioxide (CO2) emissions, are directly related to fuel burn. In 2002 the annual CO2 emissions were 500[1] million tonnes, substantially lower than in 2000 due to the events of 9/11, the SARS epidemic and the economic downturn. Exact values are model-dependent. In the 3 years to the end of 2005, market recovery had resulted in an up to 13%[2] rise in CO2 emissions, exceeding the pre-9/11-SARS (year 2000) values in 2004. CO2 forecast text included here.

Regarding oxides of nitrogen (NOx) emissions, around 2.25 million tonnes[3] were computed for 2002. For the three years to 2005, the modeling indicated a similar, perhaps slightly larger, percentage rise in NOx emissions than for CO2[4], probably resulting from the opposing influences of the replacement of older lower pressure ratio engines with higher pressure ratio engines with higher NOx per unit thrust, offset by improved combustor technology in those newer engines.

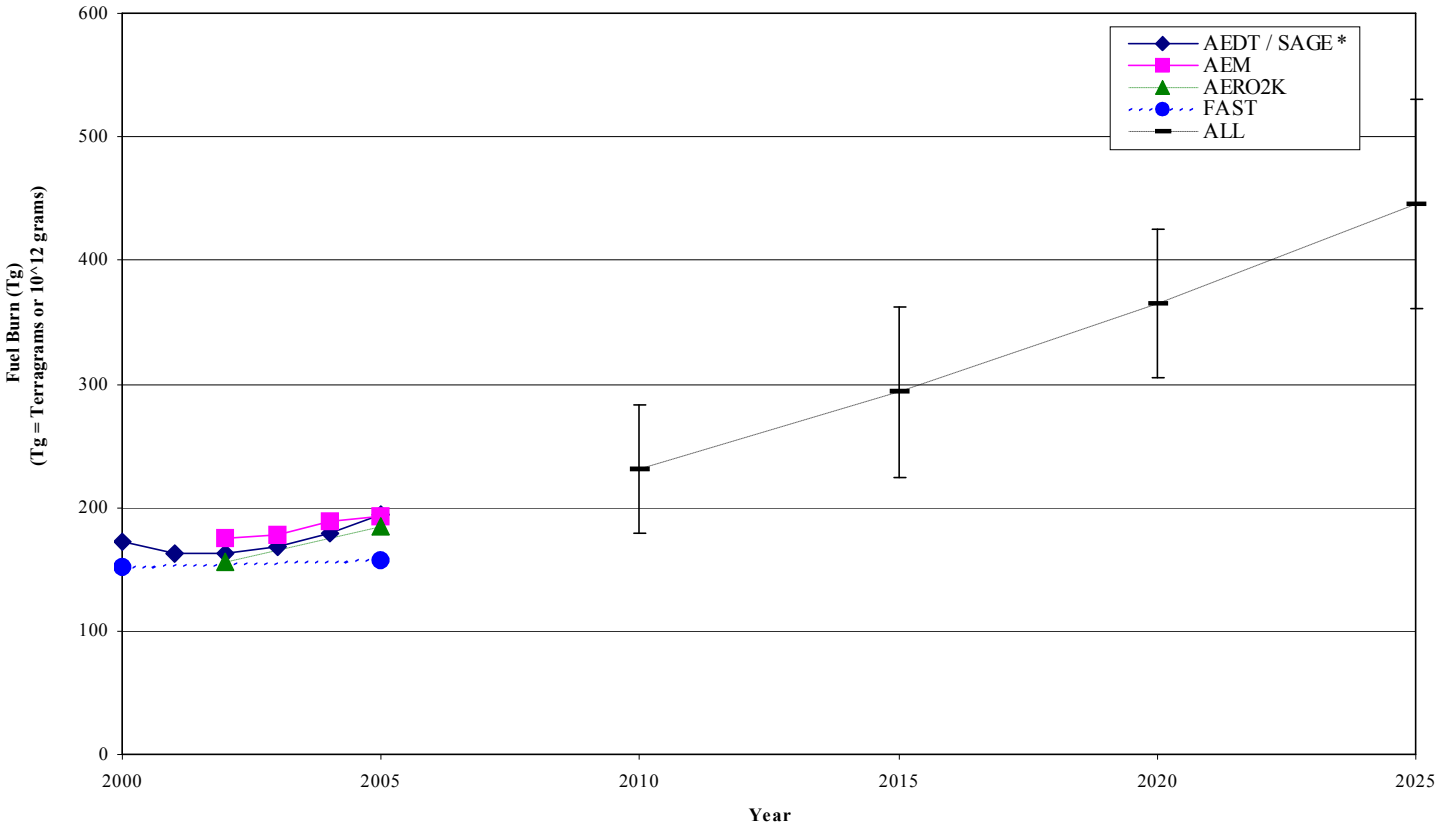
Forecast future greenhouse gas emissions were computed for CO2 and NOx up to the year 2025. 2025 annual CO2 emissions were computed to be approximately 2.25 times higher than CO2 emissions in 2005. NOx emissions by 2025 were computed to be approximately 2.75 times the 2005 values, indicating how, for the current fleet, the absence of any improved technology beyond 2005 would result in the migration of the fleet to higher NOx emissions per unit fuel. The benefit of the introduction of future improvements in technology has not been modeled.

LAQ Observations

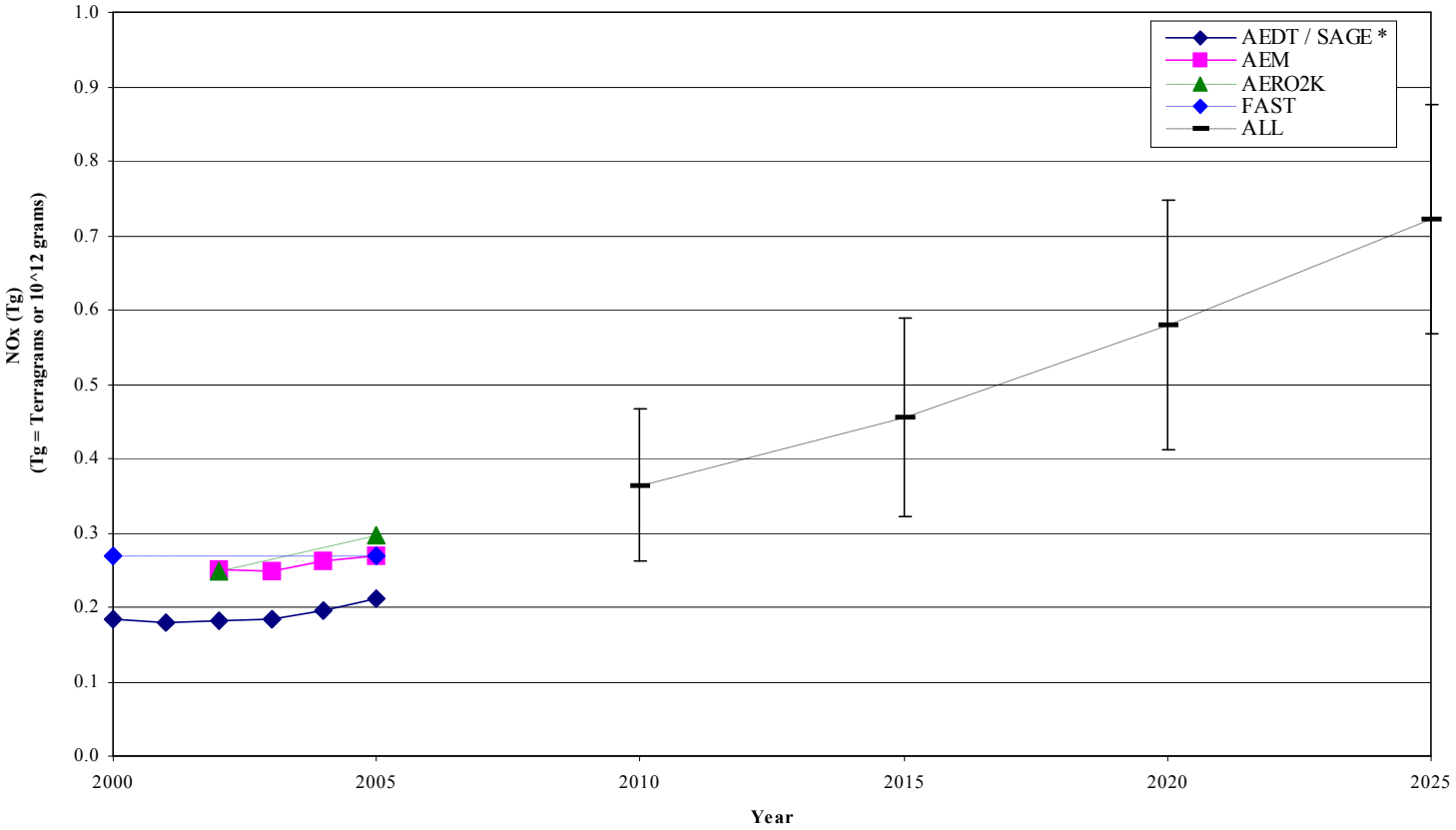
Regarding aircraft emissions in the environs of airports, for each airport these emissions are sensitive to operational and other local assumptions which are not fully captured in the global scale modeling undertaken. Dependant upon the operational assumptions used, NOx emissions below 3000ft comprised between 7 and 12%[5] of the total annual NOx emissions from aircraft. In contrast to NOx, a larger proportion of total flight carbon monoxide (CO) and hydrocarbon (HC) is emitted below 3000 ft. However emissions of CO and HC generally remain at low levels relative to air quality concerns, all models showing an increase[6] from 2002 to 2005.

For the period from 2005 to 2025, computed future NOx emissions below 3000ft, showed slightly smaller increases[7] compared with the increases in total (GHG) NOx emissions, perhaps due to fleet mix and stage length changes within the traffic and fleet forecast. Similarly, increases in HC and CO emissions below 3000ft over the same 20 year period were computed[8] to be considerably less than the increase in traffic and fuel used, although the individual modeled values varied significantly. One important factor here is the retirement of older-technology engines during the period of the forecast. More recent engines have significantly lower CO and HC emissions levels per unit thrust.

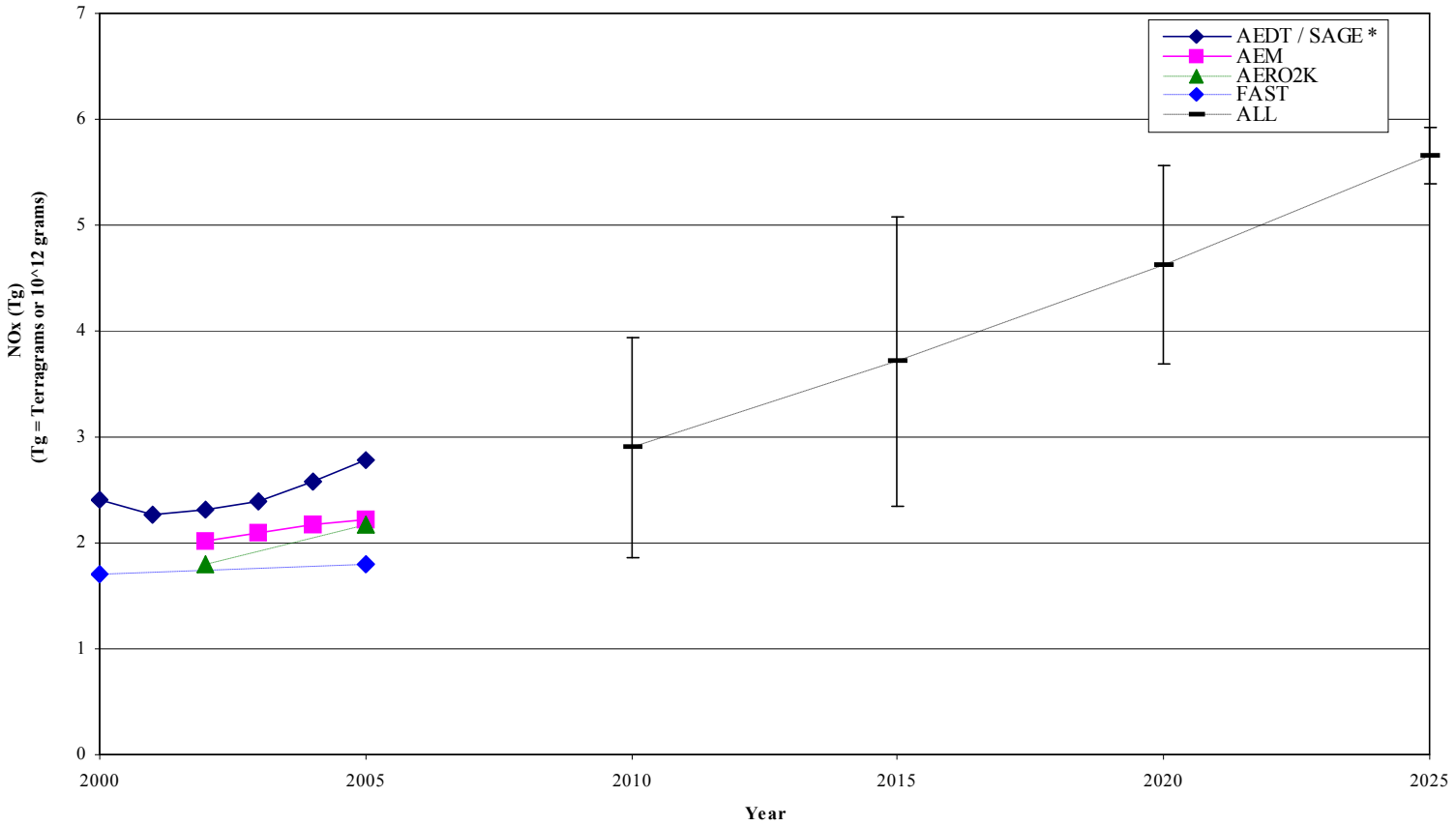
Trends in Global Fuel Burn



Trends in Global NOx (LAQ)



Trends in Global NOx (GHG)



Summary

- Four GHG models are currently under evaluation by CAEP.
- Use generally consistent methodologies.
- Used to compute LAQ and GHG trends for CAEP/7
- Plans to refine process for CAEP/8:
  - Aircraft technology
  - CNS/ATM technology
  - Operational improvements

??? Questions ???