Local Air Quality
$\text{NO}_x$, HAPs, and PM

Richard C. Miake-Lye
Aerodyne Research, Inc.
CAEP Research Focal Point for LAQ
Current ICAO certification

Current certification requirements

- Nitrogen Oxides ($\text{NO}_x$)
  - Speciation and Tradeoffs
- Carbon Monoxide (CO)
- Unburned Hydrocarbons (UHC)
  - Hazardous Air Pollutants (HAPs): specific HC species
- Smoke Number (SN)
  - Particulate Matter: mass, number, size; non-volatile and volatile
Issues related to NO$_x$ impacts
- NO$_x$ speciation (NO/NO$_2$) versus engine power
- Chemical evolution in the aircraft plume
- Ozone sensitivity depends on location ...

How NO$_x$ enters into trade-offs
- Impacts, metrics, costs ... site specific. Weigh aviation contribution
- Trades versus PM:
  - non-volatile soot and volatile:
    - Sulfate: initially sulfuric acid
    - Organics: many different species, several sources (partially burned fuel, lube oil)
- Trades vs UHCs and HAPs (formaldehyde, acrolein ...)

Emission measurement issues
Speciation of NO$_x$: (note logarithmic scale)

APEX results: Wormhoudt et al., submitted to JPP 2006
Evolution in the plume

- Changes in emissions in concentrated exhaust plume prior to dispersion into region
  - Conversion of NO to NO$_2$ via oxidation by O$_3$
  - Mixing and transport initially driven by aircraft
  - Other plume chemistry, *e.g.*, hydrocarbons

- Making connection (not just NO$_x$) between:
  - engine exit plane measurements (*certification*)
  - deposited emissions to be used by urban and regional models (*impacts*)

- Measurement approaches, ARPs (E-31)
Ozone Isopleths: Ozone dependence on NO_x and Organics Variations within Los Angeles Basin

NARSTO Ozone Assessment 2000 Chapter 3
Trade-offs:
LAQ NO\textsubscript{x} versus ...

- Emissions metrics are in place (need to account for plume effects? ... speciation?)
- Impact metrics need to account for site specificity, to trade versus:
  - Other LAQ emissions impacts (CO, HCs), emerging PM and HAPs (HCHO, acrolein ..)
  - Global impact metrics, e.g. CO\textsubscript{2} as long-lived Green House Gas
- Relative contribution from aviation versus other modes of transport and other industries
Particle Emissions: Non-volatile, Volatile

- Emitted mass dominated by non-volatile particles at high power.
- Many small volatile particles form downstream, dominate numbers and mass at low power.
- Evaluation of other engines and environments underway.

APEX results: Onsch et al., to be submitted
Measurement Issues

- Non-volatile PM: Aerospace Information Report (AIR 5892): path to ARP
- Volatile PM:
  - In context of exit plane measurements?
  - Evolution in plume: What is an aviation particle?
  - How best to measure volatile particles: Probes & Sampling!
- E-31 and research community tackling issues
- HAPs: What specific organics may be regulated?
  - What impact on measurement approaches beyond UHCs (total HCs with FID detector)? Probes, instruments ...
NO₂ Emissions at Heathrow

Source: Heathrow study
Measurement during routine operations

Oakland International Airport  8/2005 Measurements JETS/APEX-2

At JETS/APEX-2, GRE measurements similar to Approach II were performed. Advected plumes were sampled at the runway and across-the-cove sites.
LAQ NO$_x$ impact metric? [Knowing emissions, plume effects] Exploring Ozone Impact Metric:
\[ \text{[O}_3\text{-NO}_x \text{ sensitivity]} \times \text{[Total NO}_x \text{ reduction]} \times \text{[Aviation Fraction]} \]

Trade-offs
- Site specificity. What is aviation aviation contribution?
- Trades versus PM: non-volatile (soot) and volatile
- Trades versus HCs & HAPs (formaldehyde, acrolein ...)
- Trades with Global Impacts: CO$_2$

Measurements issues: plume effects, volatile particles, ... specific HAPs?