Tropospheric Ozone and Air Quality

Introduction: Motivation and Background
Jim Wilczak (PSD) and Joost DeGouw (CSD)

Emissions, Chemistry and Transport:
Christoph Senff and Joost DeGouw (CSD)

Profiles, Long Range Transport and Trends:
Russ Schnell (GMD)

Meteorological Processes and Model Evaluation:
Jian-Wen Bao (PSD)

Model Development:
Georg Grell (GSD)

Future Outlook:
Joost DeGouw (CSD)
Impacts of Elevated Ozone: Human Health

- Health-related costs to society >$100 Billion
  - Damages respiratory tract; causes and aggravates asthma
- Reduce lung capacity enhances mortality: >20,000 premature deaths per year
- Adverse health effects are observed at levels below present 84 ppb EPA standard

Bell et al., *JAMA* 2004
Impacts of Elevated Ozone: Ecosystem

- Reduction in crop yields costs $3-5 Billion/year
- Reduced carbon uptake leaves more CO₂ in the atmosphere

Gregg et al., *Nature* 2003
Impacts of Elevated Ozone: Climate

Ozone is a greenhouse gas, accounting for 12% of radiative forcing due to all anthropogenic greenhouse gases.

Relative contribution to radiative forcing from the five main greenhouse gases in the troposphere

IPCC, 4th Assessment report, 2007
Counties Designated Nonattainment for EPA 84 ppb 8-hour Ozone Standard
Formation of Ozone in the Troposphere

Ozone is not directly emitted but formed from the photochemical oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NO$_x$):

$$\text{VOCs} + \text{NO}_x + \text{sunlight} \rightarrow \text{O}_3 + \text{oxidized VOCs}$$

U.S. Sources of VOCs

U.S. Sources of NO$_x$
Model of Ozone Life-Cycle

Chemical Emissions

Chemical Transformation

Meteorology

Transport

Temperature

Sunlight

Temperature

Sunlight

Mixing

Grell (GSD)

Bao (PSD)
California ozone compliance costs

- More than $50 Billion for California to reach compliance with EPA 84 ppb standard
  - Automotive emissions including gasoline reformulation
  - Power plant emissions
  - Ship fuel
  - Catalytic converters on trains, replacing diesel engines on construction and agricultural equipment
  - Consumer products (e.g., paint, lawnmowers, aerosol sprays)
EPA is Conducting a Review of the Ozone Standard

Based on known health effects, recommendation is to reduce maximum allowable ozone from 84 ppb to between 60-80 ppb.

Present Nonattainment Areas

- With new standard, questions regarding meteorological transport will become even more important

Estimated Future Nonattainment Areas
Northern Hemisphere Summer:
- Surface maxima over U.S., Mediterranean and E. Asia
- Transport is a global issue

Lelieveld & Dentener, JGR 2000
Ozone Research in NOAA

• ESRL
  – (CSD-emissions, transformations)
  – (GMD-global distribution)
  – (PSD-meteorological processes)
  – (GSD-model development)
• NOAA (ARL, NWS, GFDL)
• NOAA (research & forecasting)-EPA (mostly regulatory)
Tropospheric Ozone and Air Quality

Introduction: Jim Wilczak (PSD) and Joost DeGouw (CSD)

Emissions, Chemistry and Transport: Christoph Senff and Joost DeGouw (CSD)

Profiles, Long Range Transport and Trends: Russ Schnell (GMD)

Meteorological Processes and Model Evaluation: Jian-Wen Bao (PSD)

Model Development: Georg Grell (GSD)

Future Outlook: Joost DeGouw (CSD)

Ozone ($O_3$)