MIRAGE

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Megacity **I**mpacts on the **R**egional **A**nd **G**lobal **E**nvironment

An integrated multi-disciplinary program to study the export and transformations of pollutants from large metropolitan areas to regional and global scales.

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Scientific Foci

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Gas Phase Chemistry:

Export of gaseous pollutants and oxidation intermediates, and their role in regional/global ozone and aerosol budgets.

Aerosol Chemistry and Physics:

Evolution of aerosol composition and physical properties, their interactions with gas phase species, and their role in climate directly via scattering/absorption and indirectly via cloud formation.

Radiation:

High pollution levels can alter incident solar radiation, modifying both photochemistry and heating rates.

Local and Regional Meteorology:

Large urban areas can modify local meteorology, which in turn controls ventilation and the export of gases and aerosols.

Urban Metabolism:

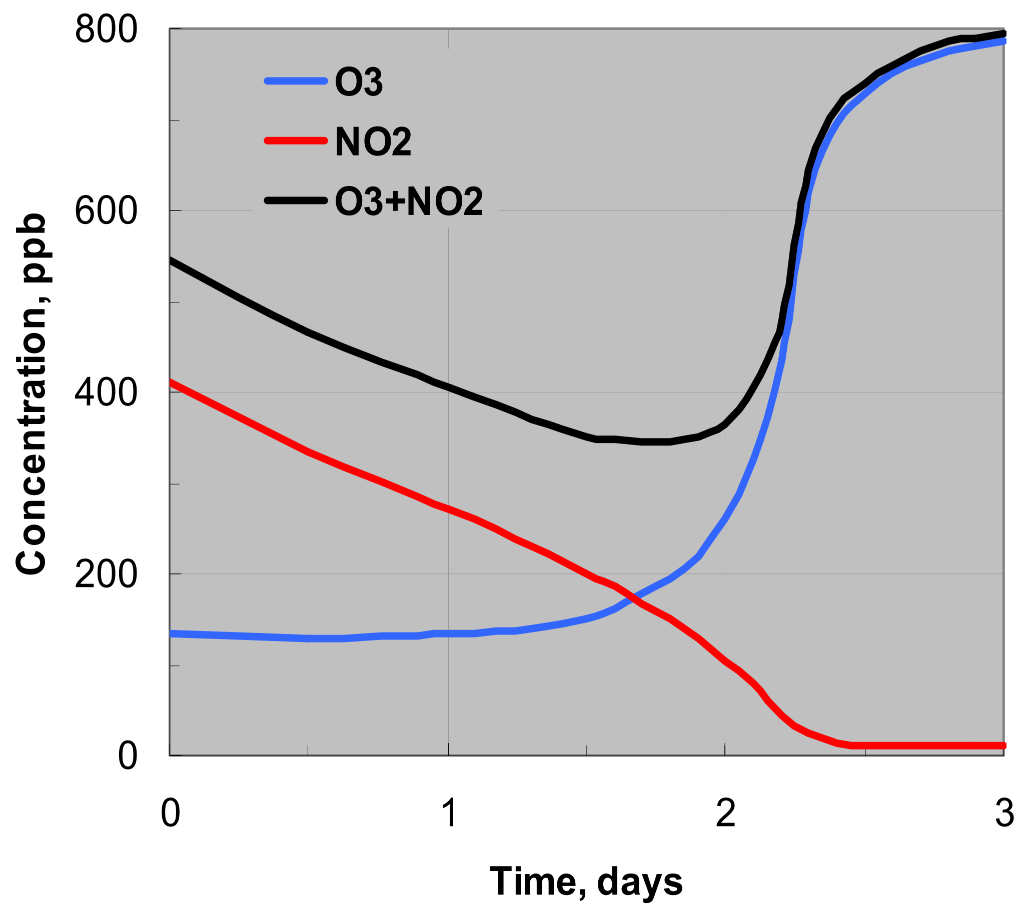
The mix of pollutants in developing cities is very different from that in large industrialized cities. Future growth of emissions will also differ depending on many socio-economic factors.

Gas Phase Photochemistry - 1

Example of non-linearity of chemistry: Downwind re-inflation of Ox production

d[Ox]/dt > 0 when

$R(OH+CO)>R(OH+NO_2)$

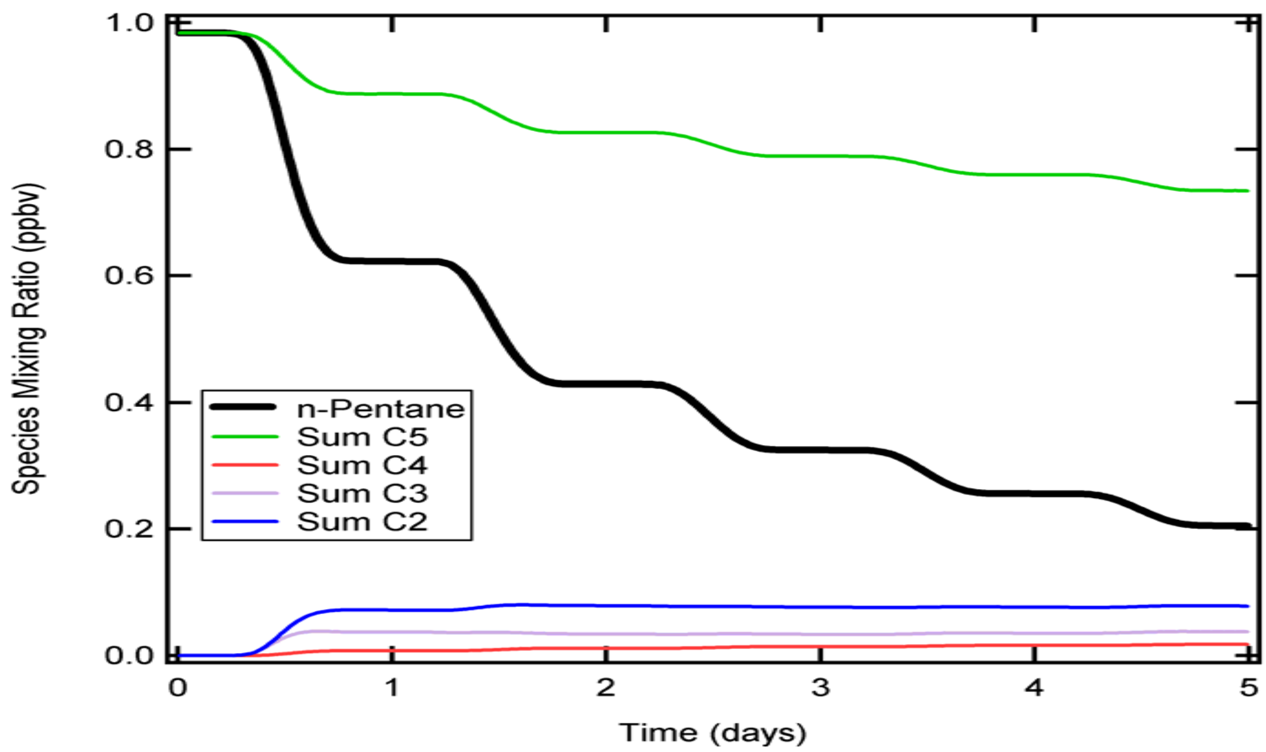


S. Rivale (SOARS) and S. Madronich, unpubl. 1999

Gas Phase Photochemistry - 2

Example of chemical complexity:

Persistence of oxygenated organic intermediates

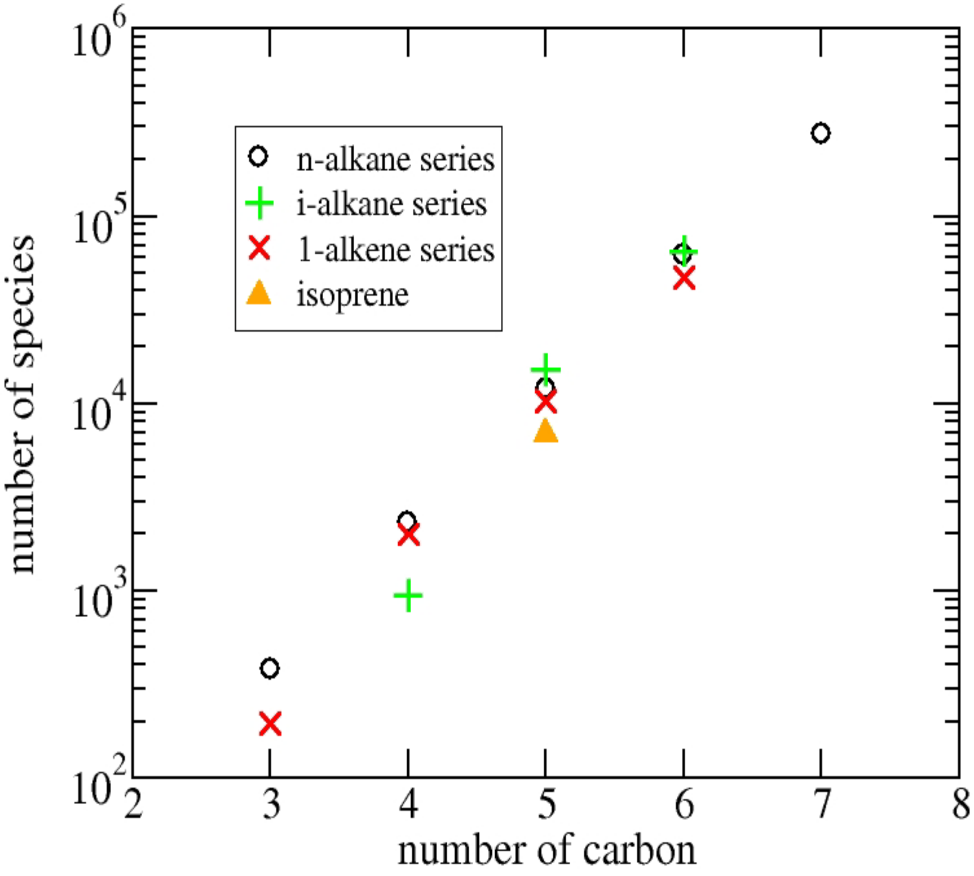


Madronich and Calvert 1990, uptdated by C. Stroud 2001

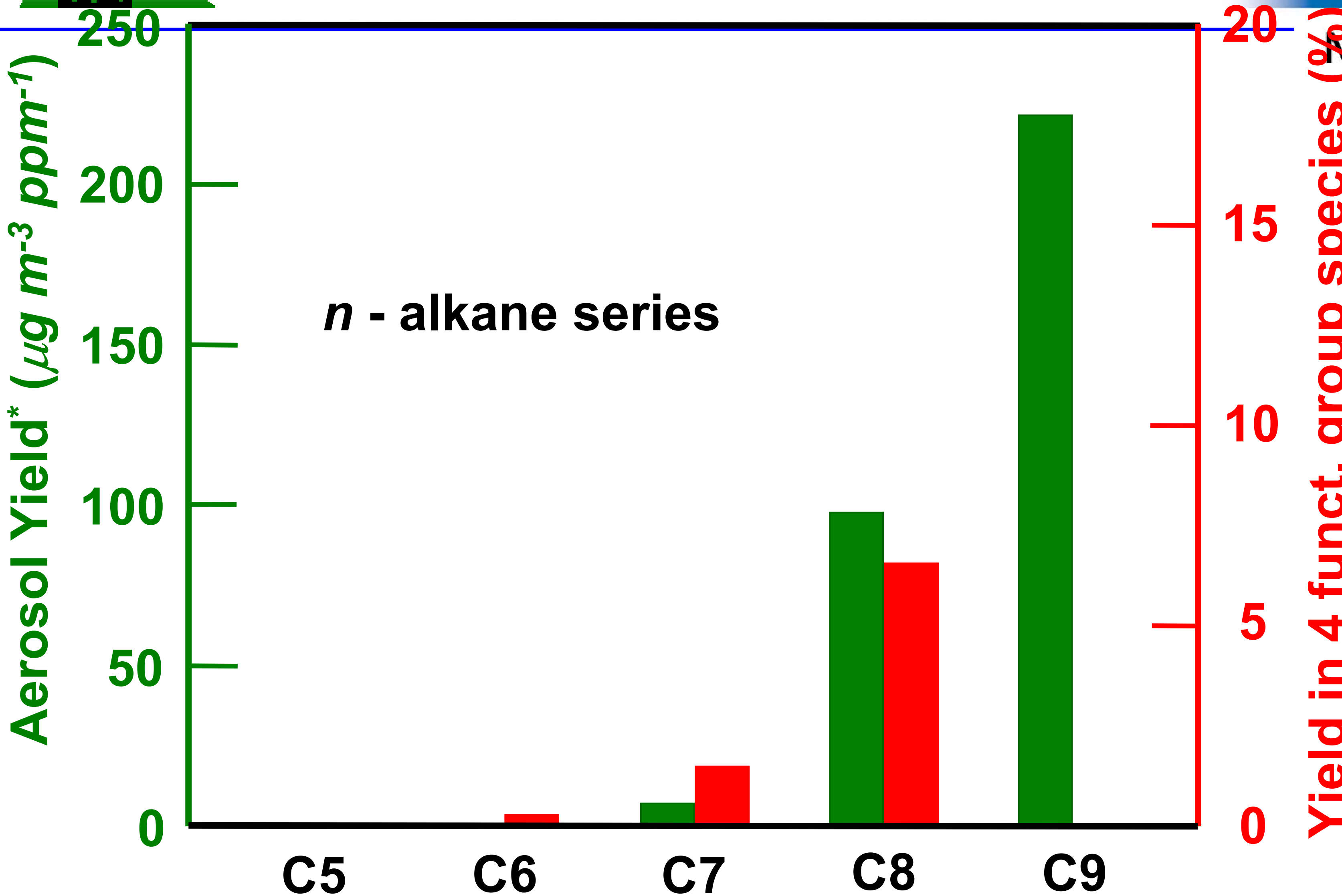
Gas-phase photochemistry - 3

- VOC oxidation produces a large number of intermediates. These intermediates play a key role in the HOx and NOx budget and therefore in tropospheric O_3 formation.

- Number of reactions ~
  ~ 5 x number of species



Aerosol Physics and Photochemistry - 1

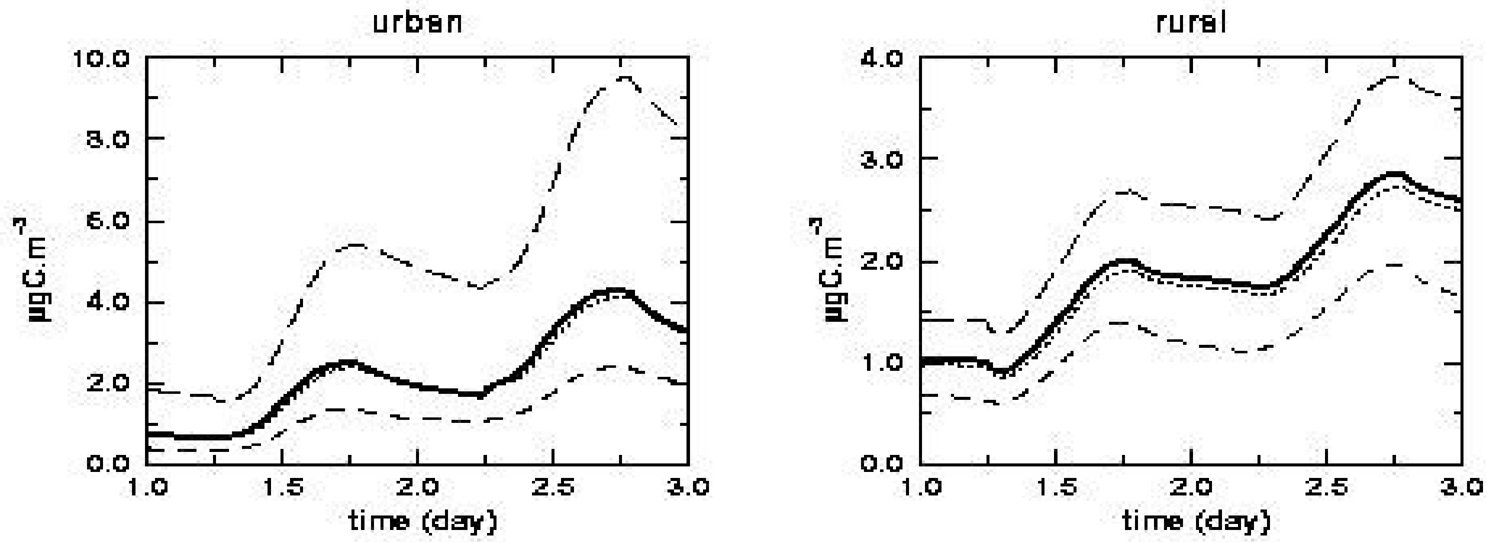


Yields from Seinfeld et Pandis, 1998

Aerosol Physics and Photochemistry - 2

Example of aerosol-gas phase coupling:

Growth of organic aerosol by dissolution of gas phase species



Aumont et al., 2000

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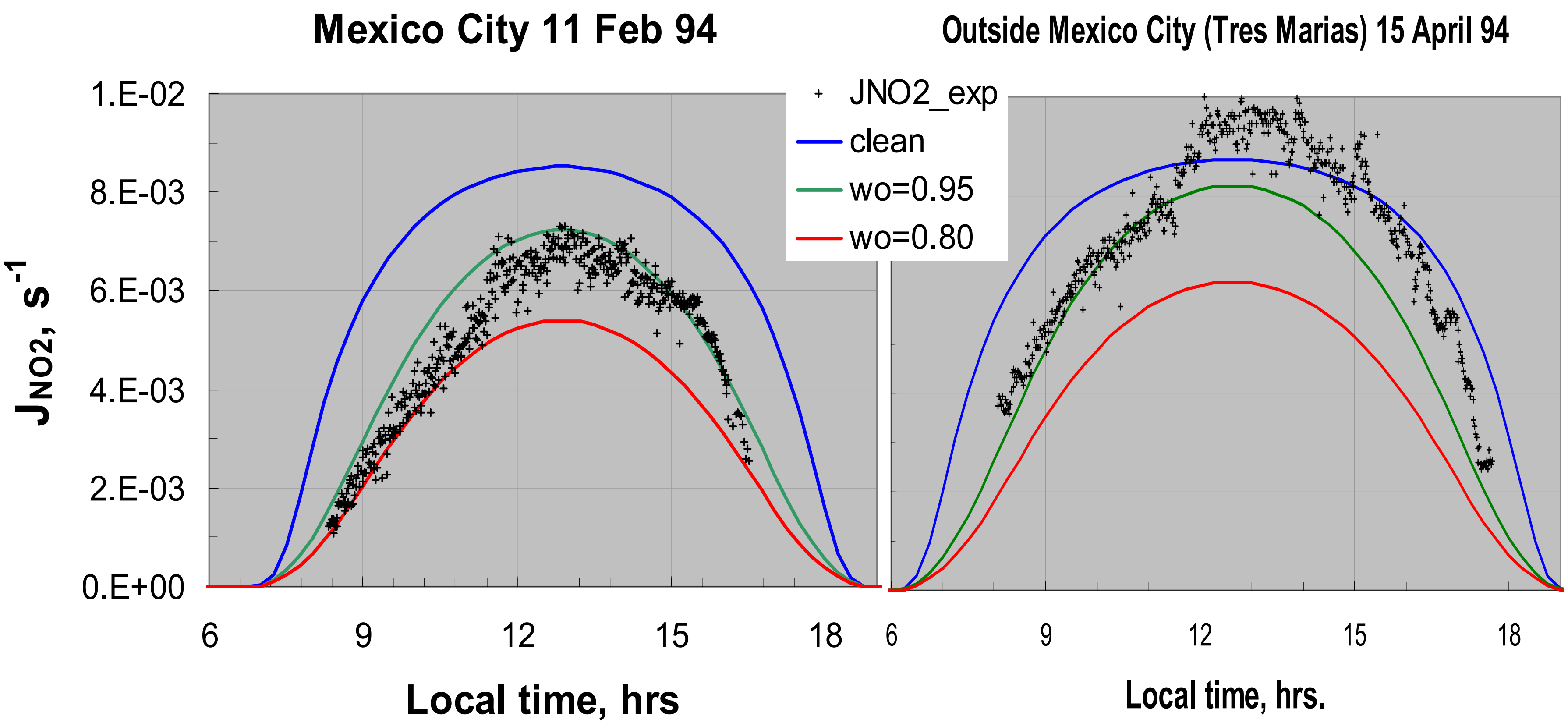
Photolysis rates in polluted conditions:



Castro et al. 2001

Local and Regional Meteorology

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- Changed Geophysical Properties of Urban Surfaces
  - Anthropogenic sensible heat flux (up to 200 W m^{-2})
  - Anthropogenic latent heat flux (not well known)
  - Aerodynamic roughness (z_o values up to several meters)
  - Aerodynamic displacement height (tens of meters)
  - Surface runoff
  - Heat transfer characteristics of the “ground” (thermal conductivity and volumetric heat capacity); surface and soil wetness
  - Surface albedo

- Potential Interactions with Air Pollution
  - Radiative (e.g. vertical distributions soot)
  - Chemical (e.g. amount and type of cloud condensation nuclei)

Urban Metabolism

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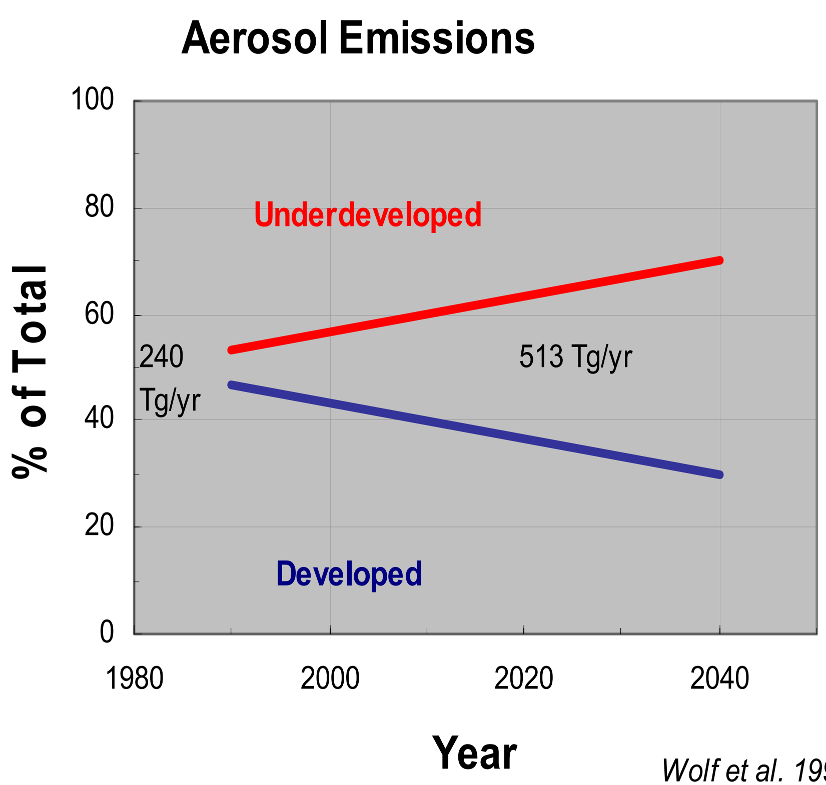
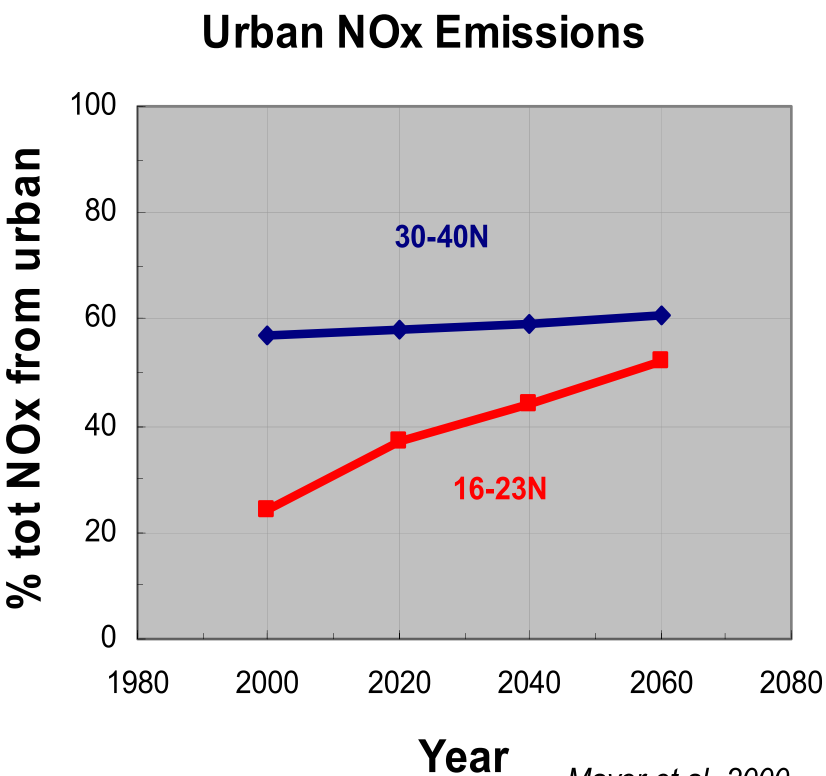
Emissions in developing cities are very different than in developed cities



Wolf et al. 1997



Mayer et al. 2000

Proposed Field Campaign

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Where: Mexico City

When: Early 2005 (tentative)

Science objectives:

Study chemical and physical transformations of pollutants during the first few hours to days following emissions, and specifically address the fate of secondary gaseous and particulate products of atmospheric photo-oxidation.

Why Mexico City - 1

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- Size: Mexico City is, and will continue to be, one of the world's most populous cities, with a current population of ca. 20 million.
- Economy: Its emission characteristics are roughly intermediate between those of a city in emerging economies and those of a city in fully developed countries.
- Location: It is situated in the tropics, as are most of the world's fastest growing megacities.
- Signal to background: It is a very strong source surrounded by a region that is only moderately polluted.

Why Mexico City - 2

- Anthropogenic emissions: Inventories for Mexico City are already being developed.
- Biogenic emissions: Studies are underway to characterize emissions from the areas surrounding the city.
- Air quality monitoring: Ground-based network has been operating continuously for over a decade (NO_x, O_3, CO, SO_2, PM).

Why Mexico City - 3

- Knowledge baseline: Experimental and modeling studies have been done on photochemistry, aerosols (chemical and physical properties), surface radiation (visible, UV), boundary layer evolution and regional-scale diurnal circulations.
- Collaborations: Extensive air quality research is being conducted locally at university, government, and industrial laboratories.
- Logistics: Compared with other tropical megacities, Mexico City offers good infrastructure and logistics for carrying out an intensive measurement campaign involving aircraft.

Tools for Field Campaign

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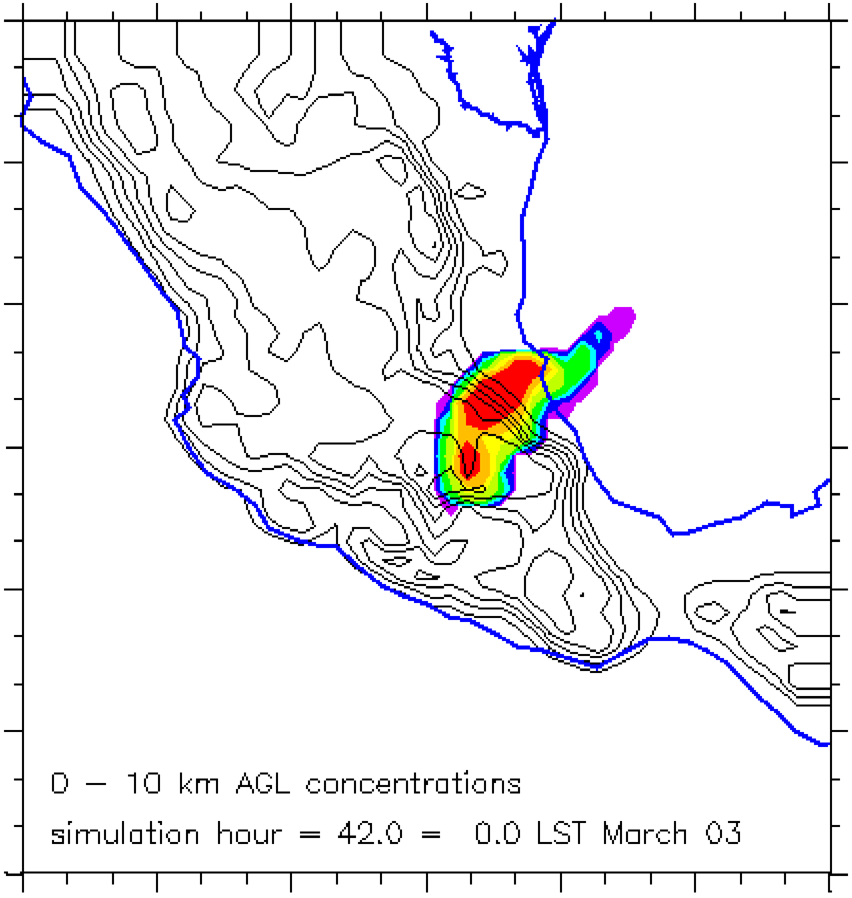
- Observations near and down-wind of Mexico City over a period of 3-6 weeks, using the NSF/NCAR C-130 aircraft,
- Ground based observations in and around the city
- Satellite observations
- Modeling



From J. Fast, PNNL

Mexico City from Satellites - 1

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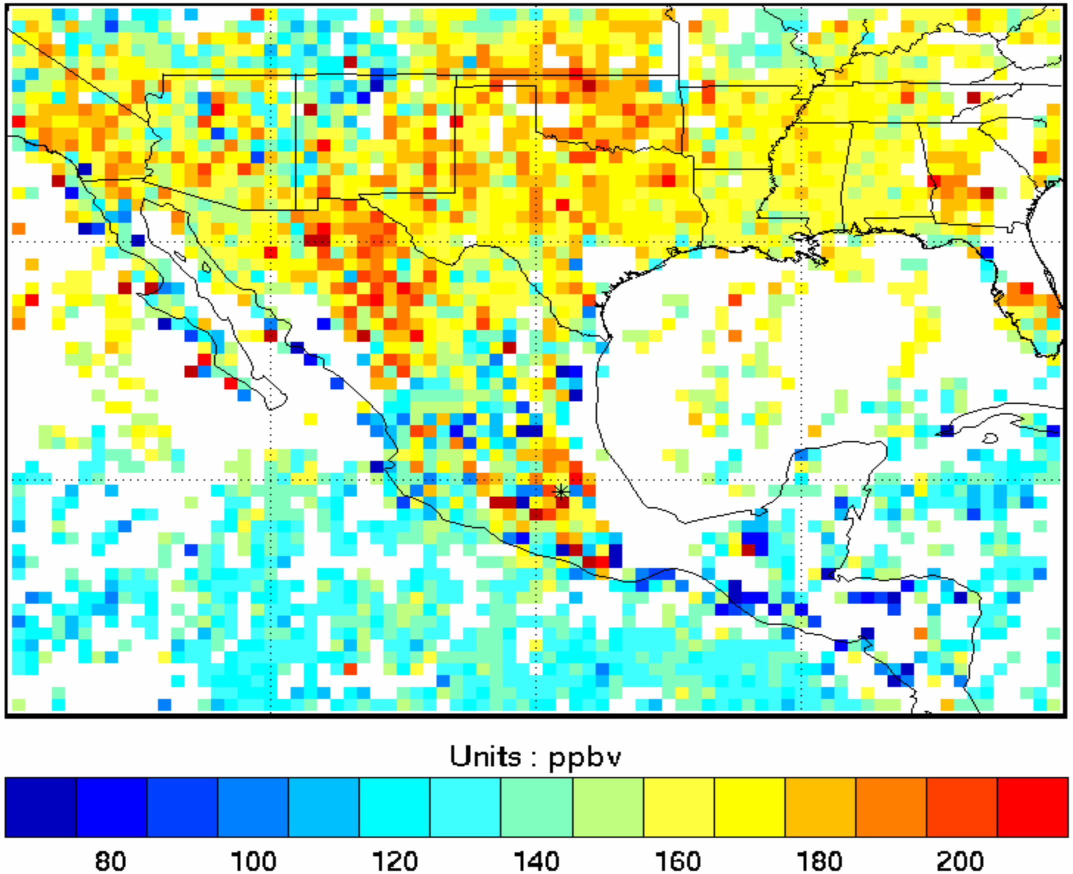
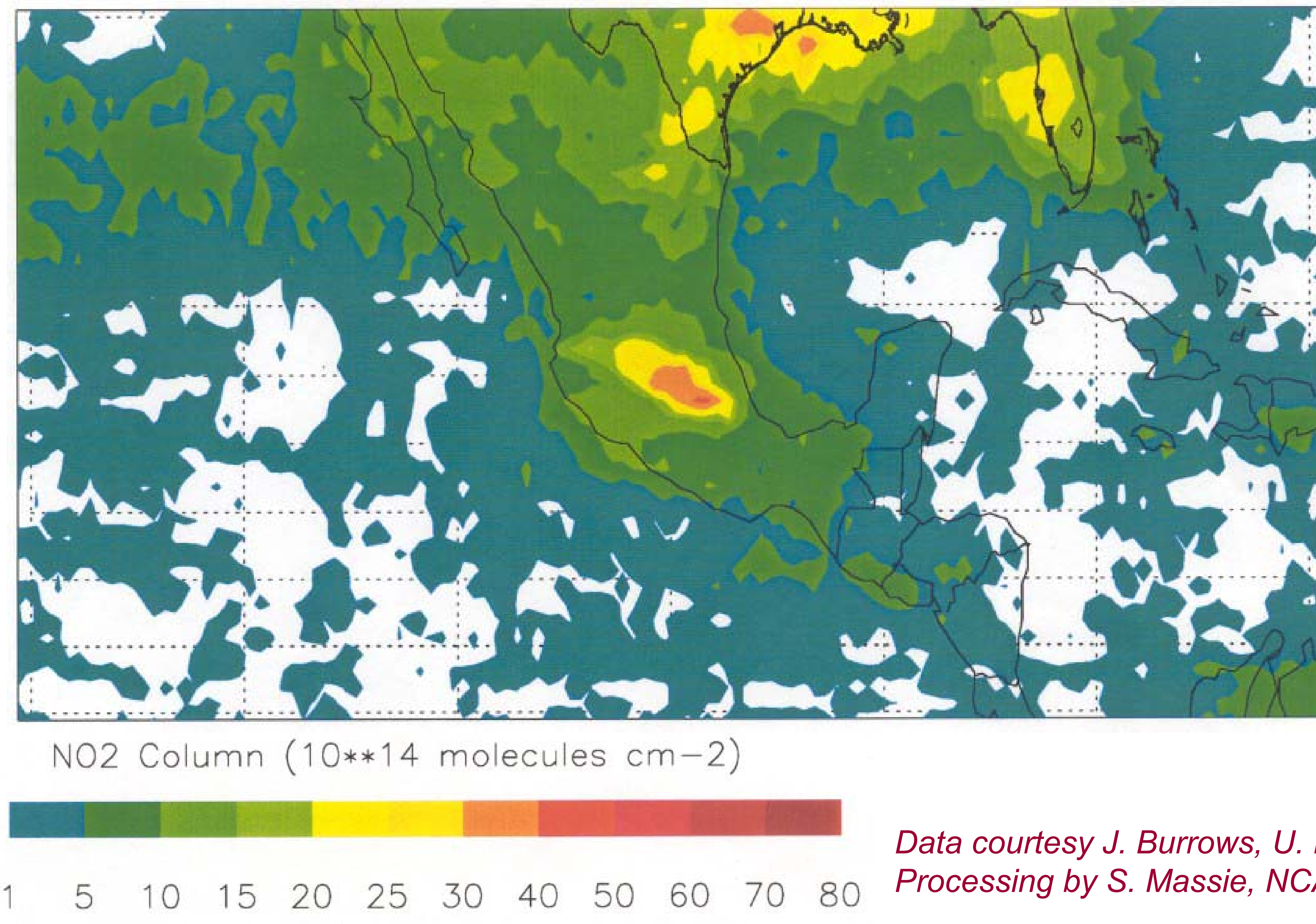
- Pollution signal strength relative to background

CO from MOPPIT



Mexico City from Satellites - 2



Data courtesy J. Burrows, U. Bremen
Processing by S. Massie, NCAR

SCIENCE OPPORTUNITIES

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➢ Gas phase photochemistry:

- How much potential for O_3 production remains in middle-aged air?
- What is the fate of oxidized hydrocarbons and their contribution to the regional scale HO_x budget?
- What is the extent and partitioning of NO_y species, and what is their potential impact on the regional and global NO_x budgets?

SCIENCE OPPORTUNITIES - 2

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➢Aerosol chemistry and physics

- What is the chemical evolution of aerosols, and how is it related to the gas phase chemistry (e.g., organic dissolution, surface chemistry)?
- What is the physical evolution of aerosols, and how is it related to composition changes (e.g. CCN, optical properties)?

➢Atmosphere-biosphere interactions

- Regional air quality and deposition
- Biogenic emissions
- Biomass burning

Planning Workshop

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- When: 13-14 November, 2002
- Where: NCAR, Boulder, Colorado USA
- Who: Open to research community

- Purposes:
  - refine the science questions
  - identify instrument and modeling needs
  - develop a measurement strategy
  - establish a time frame for the campaign
  - discuss funding opportunities

Scientific Steering Committee

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