Task Force on Hemispheric Transport of Air Pollution

Main Findings of *HTAP 2010* for Ozone and Fine Particles

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Structure of *HTAP 2010*

- **Part A: O3 & PM**
  ~300 pages
- **Part B: Hg**
  +200 pages
- **Part C: POPs**
  +200 pages

Chapters
1. Conceptual Overview
2. Observational Evidence
3. Emissions Inventories & Projections
4. Global & Regional Modeling
5. Impacts
6. Summary of Findings & Recommendations

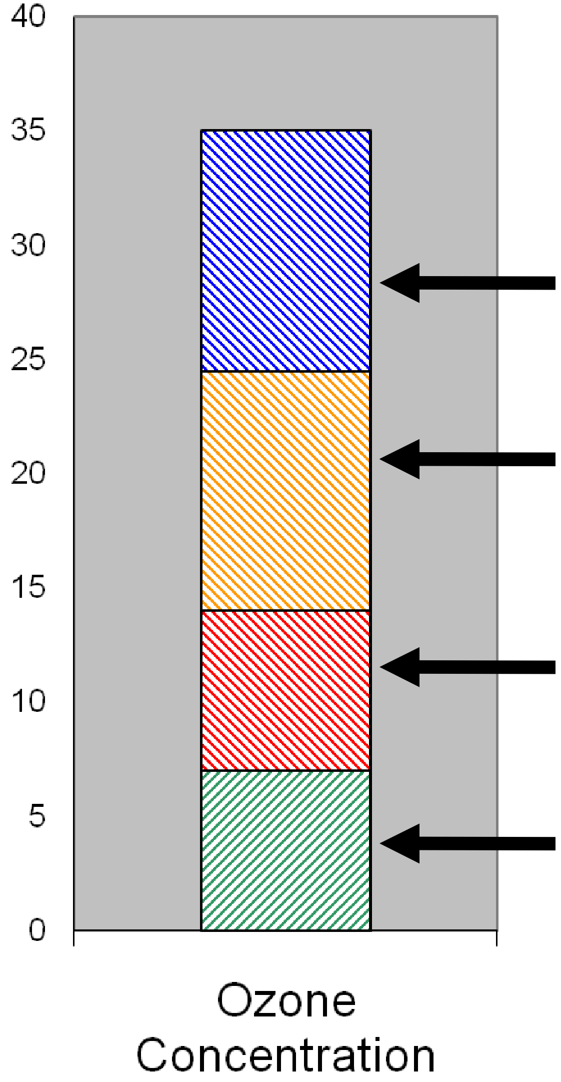
- **Part D: Answers to Policy-Relevant Questions**
  ~40 pages
- **ES: Executive Summary**
  – Official Document to the LRTAP Convention (<15 pages)

General Conclusions

The Main Messages

- O_3, PM, Hg, and POPs are significant environmental problems in many regions of the world.
- In most cases, mitigating local or regional emission sources is most efficient approach to mitigate local impacts.
- However, without further international cooperation to mitigate intercontinental flows of air pollution, many nations will not be able to meet their own goals and objectives for protecting public health and environmental quality.
- It is likely that over the next 20 to 40 years, it will become even more difficult for nations to meet their environmental policy objectives without further cooperation.
- There are significant benefits to both source and receptor countries to cooperate in decreasing emissions that contribute to intercontinental transport of air pollution.

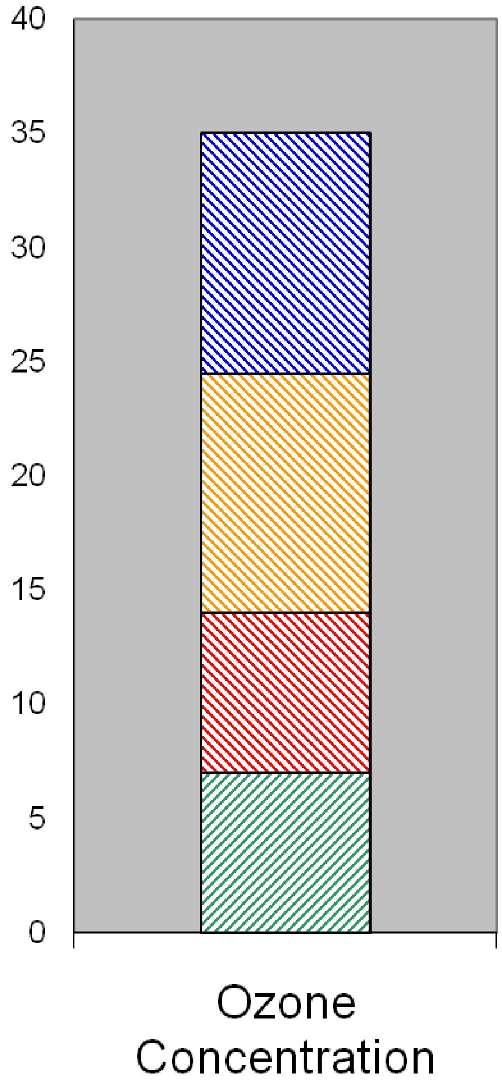
Ozone Source Apportionment



- **Anthropogenic**
  - **Local & Regional**
  - **Intercontinental Transport**
- **Biogenic/Geogenic**
- **Stratospheric**

O_3 & PM Findings

Ozone Source Apportionment



Average Mid-Latitude $O_3 \approx 35$ ppb

- **Anthropogenic**
  - **Local & Regional**

    >25%
  - **Intercontinental Transport**

    ~ 25%
- **Biogenic/Geogenic**

  ~20-25%
- **Stratospheric**

  ~20-25%

PM Source Apportionment

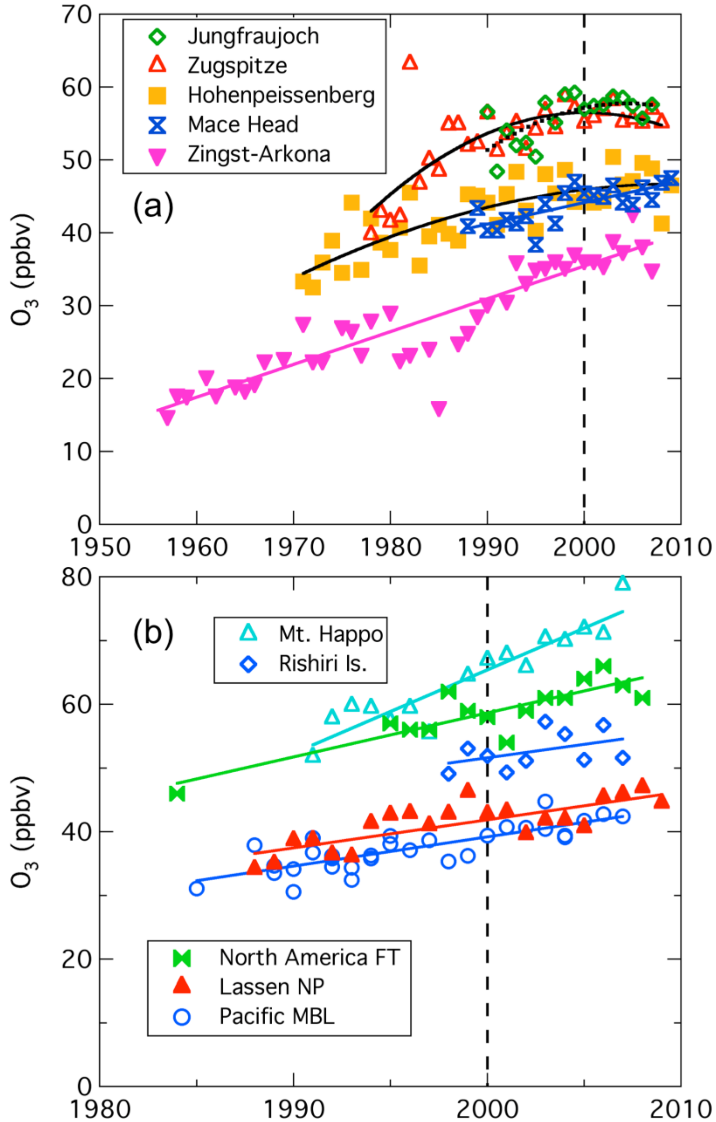
PM can be divided into:

- Volcanic eruptions, vegetation, oceans, and wind-blown dust
- Biomass burning (not fuel)
- Anthropogenic emissions that have been transported on intercontinental scales
- Local and regional anthropogenic emission sources.

Contribution to surface concentrations of sources other than local & regional anthropogenic emissions:

Sulfate	21-42%
Black Carbon	10-27%
POM	35-71%
Mineral Dust	67-90%

Observed Ozone Trends

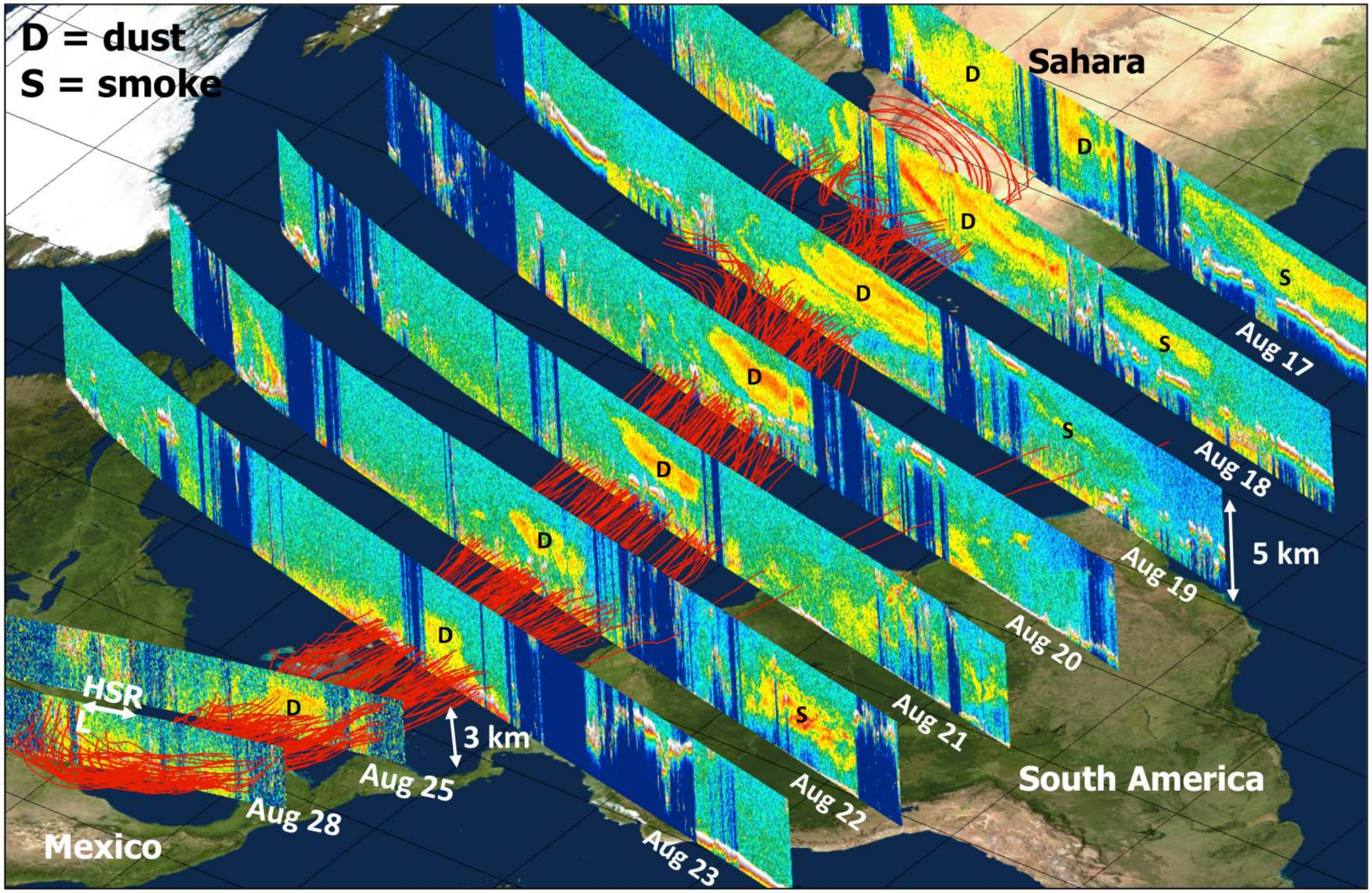


- Since 1950, baseline O_3 in northern mid-latitudes has increased by at least a factor of two.
- Measurements of marine air flowing into continental regions show levels approaching or exceeding levels of ambient standards or objectives.

O_3 & PM Findings

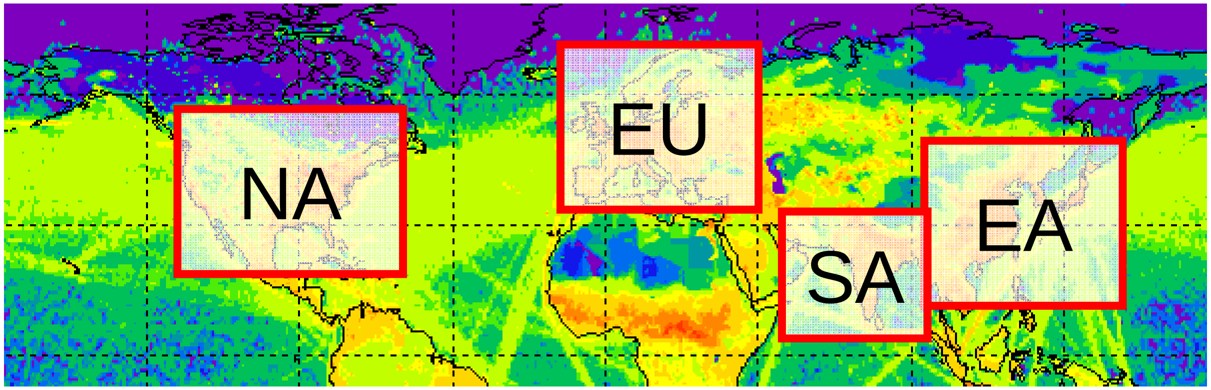
Observed PM Events

Most tangible evidence for PM is associated with wind-blown dust and biomass burning events.



HTAP Model Intercomparison

Design of Multi-Model Experiments



1. SR1 = base case (methane prescribed 1760 ppb)
2. SR2 = global methane reduction by 20% (1408 ppb)
3. 4x SR3 = regional **NO_x** anthropogenic emissions reduced by 20%
4. 4x SR4 = regional **NMVOC** anthropogenic emissions reduced by 20%
5. 4x SR5 = regional **CO** anthropogenic emissions reduced by 20%
6. 4x SR6 = regional reduction of **NO_x, NMVOC, CO, SO2, and PM** by 20%

Import Sensitivity =

$$\frac{\text{Sum of Concentration Changes in Region X due Emission Changes in 3 Other Regions}}{\text{Concentration Change in Region X due to Emission Change in Region X Itself}}$$

O_3 & PM Findings

Ozone Source/Receptor Relationships

	Import Sensitivity in Receptor Regions			
Parameter	**North America**	**Europe**	**South Asia**	**East Asia**
O_3 Surface Concentration	46%	74%	46%	66%
O_3 Total Trop Column	64%	161%	62%	148%

- Intercontinental transport of O_3 is affected most by NO_x, VOC, and CO in decreasing order.
- NO_x, VOC, and CO reductions are generally additive, but are less than additive when combined with PM controls.
- Equal % emission reduction of methane produces equal decrease in O_3 as combined control of NO_x, VOC, and CO.
- Doesn’t matter where methane emissions are decreased, but takes a decade to realize full benefit.

O_3 & PM Findings

PM Source/Receptor Relationships

	Import Sensitivity in Receptor Regions			
Parameter	**North America**	**Europe**	**South Asia**	**East Asia**
PM Surface Concentration	7%	5%	25%	10%
Sulfate Deposition	9%	10%	32%	13%
BC Deposition	4%	1%	13%	3%
Sulfate Total Trop Column	33%	33%	59%	31%
BC Total Trop Column	32%	21%	19%	17%

- PM concentrations in the Arctic respond linearly to emission changes, and are most sensitive to changes in Europe. Total column loadings of PM over the Arctic are equally sensitive to changes in Europe and East Asia.

O_3 & PM Findings

Impacts of Intercontinental Transport

- Exceedance of Objectives

  O_3: currently exceed objectives for vegetation protection

  PM: currently exceed short-term standards for health protection

- Human Health

  O_3: contributes 20% to >50% of ozone-related premature adult mortalities in a given receptor region, subject to large uncertainty

  PM: natural and anthropogenic intercontinental transport is responsible for 64,800-912,000 annual premature mortalities, ~25% is associated with anthropogenic emissions

  Emission reductions in North America and Europe will avoid more mortalities outside these source regions than within the regions themselves

- Ecosystem

  O_3: crop yield losses may be as high as 40%, may explain yield gap observed across Asia, has important food security implications

O_3 & PM Findings

Impacts of Intercontinental Transport

- Climate Change

O_3: Benefits of Precursor Control CH_4 > VOC > CO > NO_x (globally)

PM: Change of global annual average TOA all-sky aerosol direct RF (unit: mW m^{-2}, mean ± std. dev) in response to the 20% reduction of anthropogenic emissions :

Source Region	Sulfate	POM	BC	Sulfate+POM+BC
NA	16.1±5.6	1.6±1.0	-4.5±1.9	13.2±5.2
EU	26.7±9.5	1.9±1.2	-7.4±2.3	21.2±9.5
EA	19.6±7.2	3.2±1.8	-14.5±8.0	8.4±10.2
SA	6.1±1.9	2.5±1.3	-5.5±2.4	3.1±3.2
NA+EU+EA+SA	68.4±22.9	9.1±5.0	-31.9±13.7	45.9±24.6

O_3 & PM Findings

Effect of Future Emissions Changes

O_3 Surface Concentration Import Sensitivity in Receptor Regions				
Scenario	**North America**	**Europe**	**South Asia**	**East Asia**
2001	47%	72%	49%	66%
2030 (High)	112%	82%	25%	42%
2050 (Low)	98%	77%	16%	69%

- Under future scenarios, expected changes in CH_4 concentrations have a large influence on surface O_3 changes, in some cases offsetting significant changes in O_3 formation associated with local and regional emissions.

O_3 & PM Findings

Effect of Climate Change

- Climate change is expected to exacerbate O_3 problems over source regions (imposing a "climate penalty" and increasing local control costs).
- Climate change is expected to decrease the effects of precursor emissions on O_3 in downwind regions.
- However, the magnitude of these effects is relatively small, and is driven by changes in atmospheric chemistry and not by changes in transport patterns.
- The effect of natural emission changes and wider climate-related feedbacks on O_3 have not been evaluated fully yet.
- The effects of climate change on PM levels are are likely to differ by region.

Main Recommendations

Future Directions

- A program of monitoring, research, and analysis activities is needed that is
  - Intentional, making source attribution on global to intercontinental scales an explicit objective of on-going and future efforts
  - Innovative, employing novel techniques and developing new methods where needed
  - Integrated, generating new insights by combining and comparing information within disciplines and across disciplines, as well as across different pollutants
  - Inclusive, engaging a broader community of scientists and air quality management officials in developed and developing countries throughout the Northern Hemisphere.
  - Supported by institutions and information networks, fostering and facilitating cooperation between experts within and across disciplinary and community boundaries

Main Recommendations

Future Directions

- The costs and implications of sector-based control strategies of intercontinental transport should be explored.
- No global or hemispheric institution exists that addresses O_3 and PM. A global confederation of regional cooperative agreements that can maintain linkages to global institutions may be the best path forward.
- The TF HTAP can continue to play a leadership role in bringing together different expert communities and connecting different regional and global institutions. For the LRTAP Convention, continuing and expanding such efforts is important.