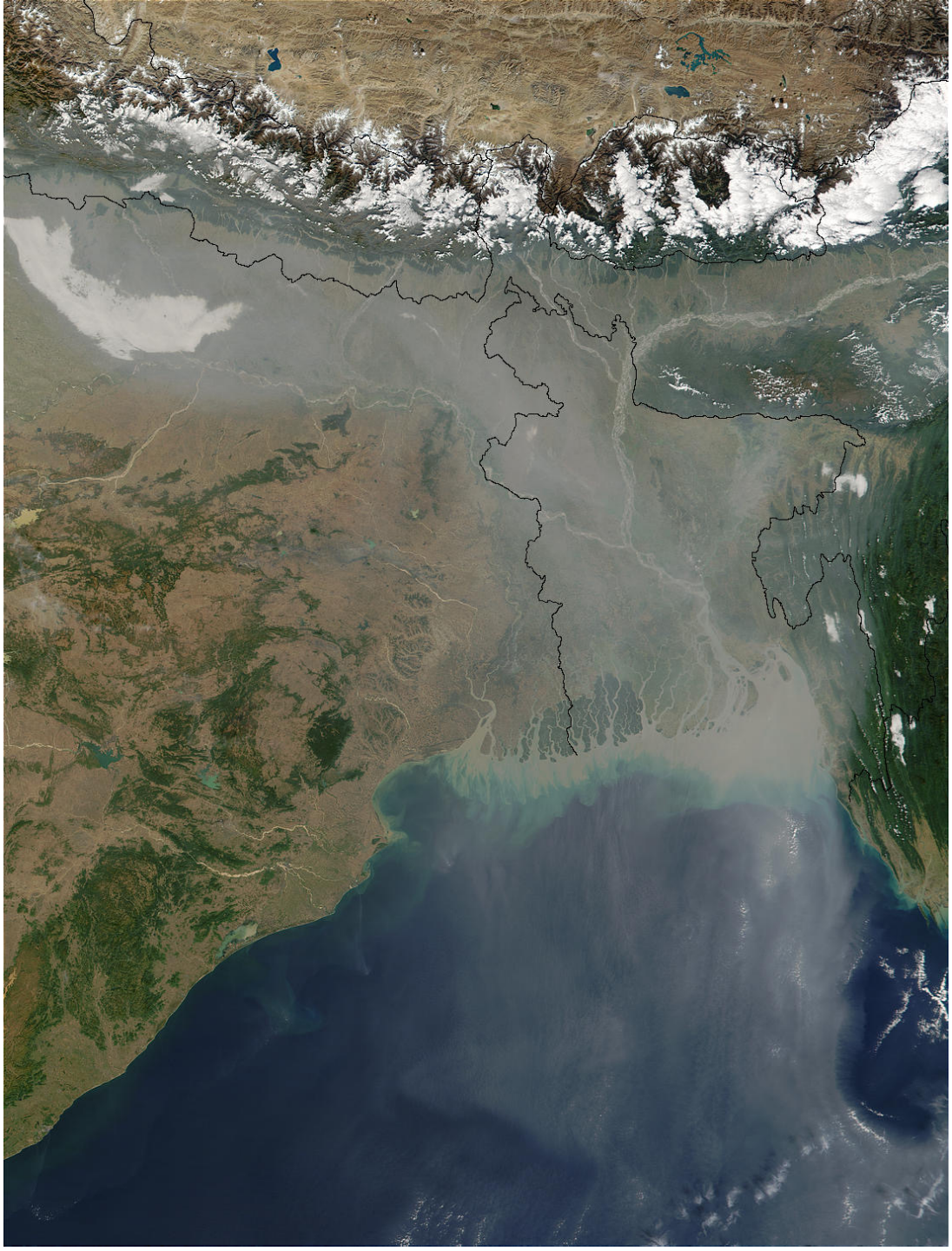
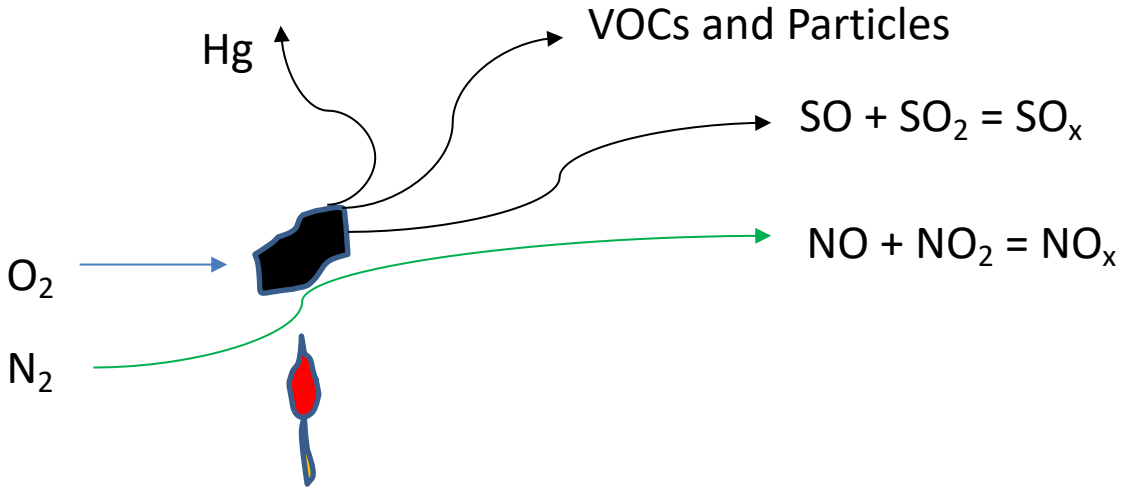
Tropospheric Pollution, Part 1 – Focus on Ozone

1. Issues
2. Burning byproducts
3. Tropospheric ozone chemistry
4. Ozone and plants
5. NASA flight campaign TRACE-P

HAZY HAZARD — Winds carry pollutants from Mexico City into neighboring rural regions, blocking sunlight and decreasing visibility.



Burning Fossil Fuels



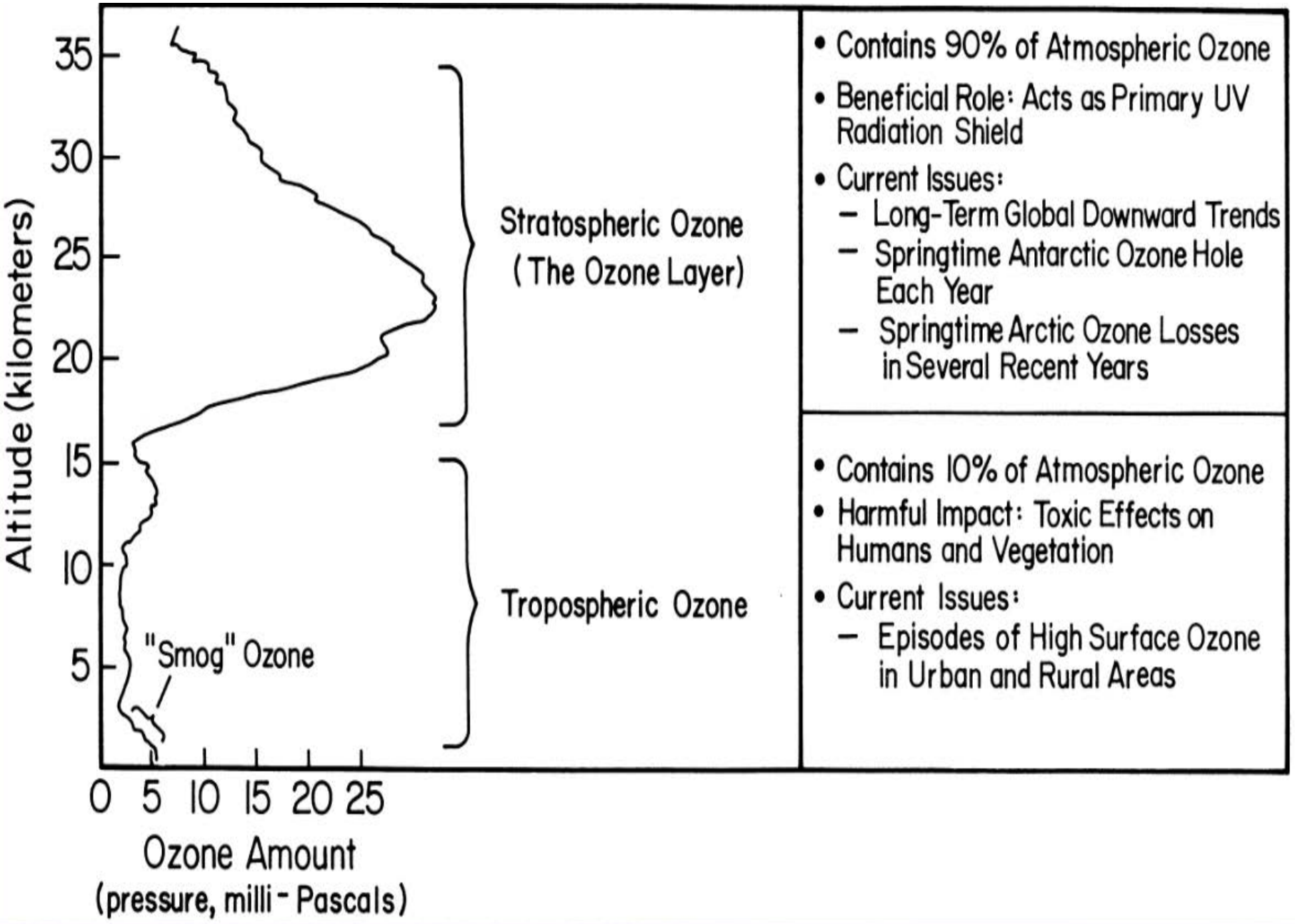
Particles → lungs
Ozone → eyes and lungs
EPA 188 compounds poisonous at any level (e.g., Hg, VOCs)
PM2.5 "bright line" 35 μg/m^3 (65 recently)
Ozone "bright line" 80 ppbv (60 ppbv in Canada and Japan)
1990 Clean Air Act benefits to health care, ecosystems, buildings
U.S.: 100 tons/yr Hg (40% power plants, 60% vehicles)
600,000 babies/yr noticeable effects of Hg poisoning (Johnson 2005)
~30x10^6 tons/yr each NO_x, SO_x, VOCs
1 pound of coal = 1 kW-hr electricity
Family 10,000 kW-hr → 10,000 lb coal ~ 100 ft^3

Tropospheric Ozone

- affects eyes and lungs
- together with acid rain, damages plants
- absorbs uv
- absorbs and emits IR at 9.6 μm
- has increased by ~2-5x since 1900
- ozone production in the stratosphere approximately equals ozone loss in the oceanic boundary layer (20×10^{28}/s)
- ozone production in the sunlit, urban boundary layer approximately equals loss in the free troposphere (8×10^{28}/s)

Crutzen (1973), Chameides, and Walker (1973):

$NO_x + \{CH_4 + CO + NMHCs\} + uv \rightarrow O_3 + aldehydes + PAN$


Altitude (kilometers)
35
30
25
20
15
10
5
"Smog" Ozone
Stratospheric Ozone
(The Ozone Layer)
Tropospheric Ozone
0 5 10 15 20 25
Ozone Amount
(pressure, milli-Pascals)
• Contains 90% of Atmospheric Ozone
• Beneficial Role: Acts as Primary UV Radiation Shield
• Current Issues:
– Long-Term Global Downward Trends
– Springtime Antarctic Ozone Hole Each Year
– Springtime Arctic Ozone Losses in Several Recent Years
• Contains 10% of Atmospheric Ozone
• Harmful Impact: Toxic Effects on Humans and Vegetation
• Current Issues:
– Episodes of High Surface Ozone in Urban and Rural Areas

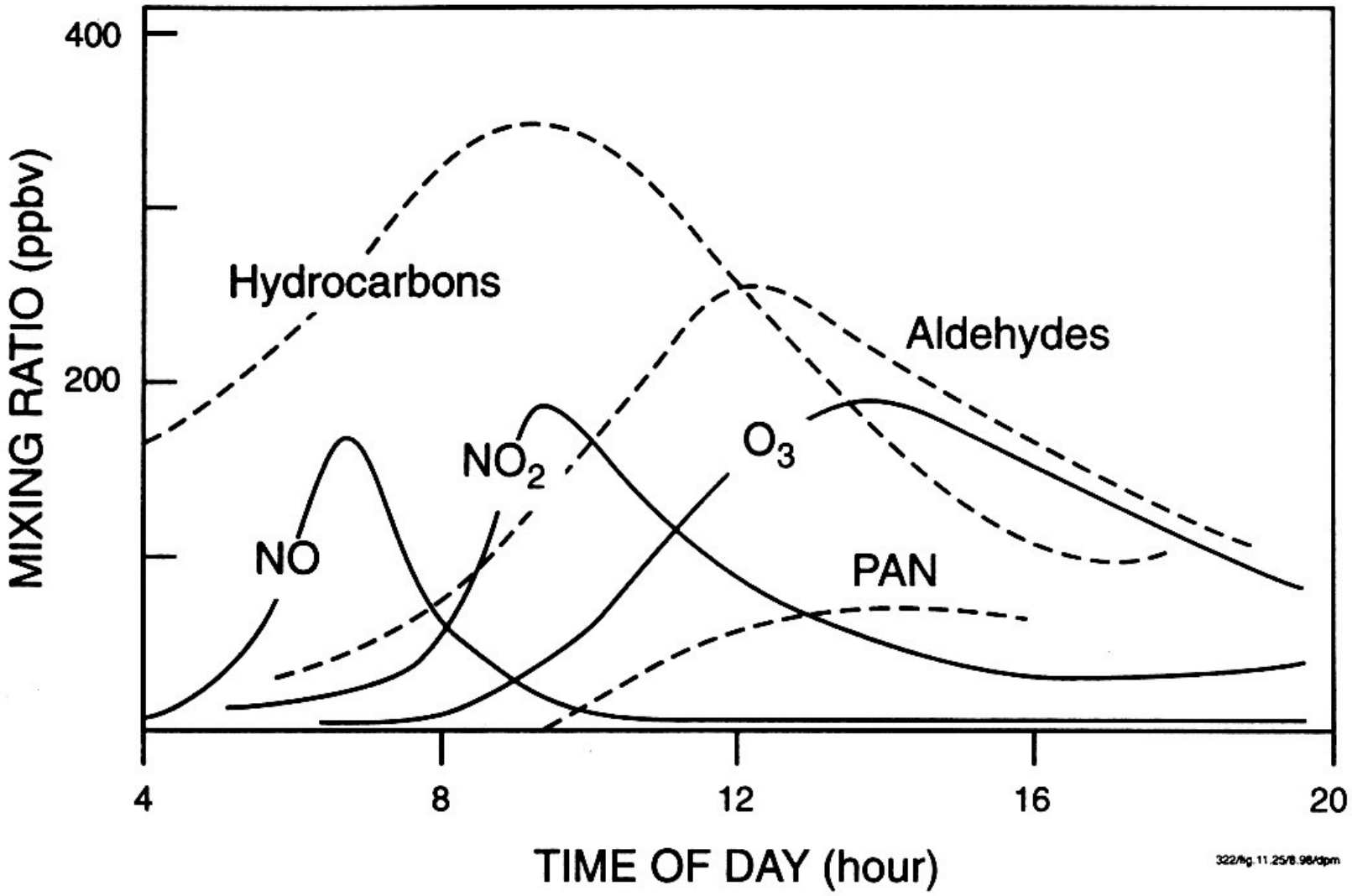
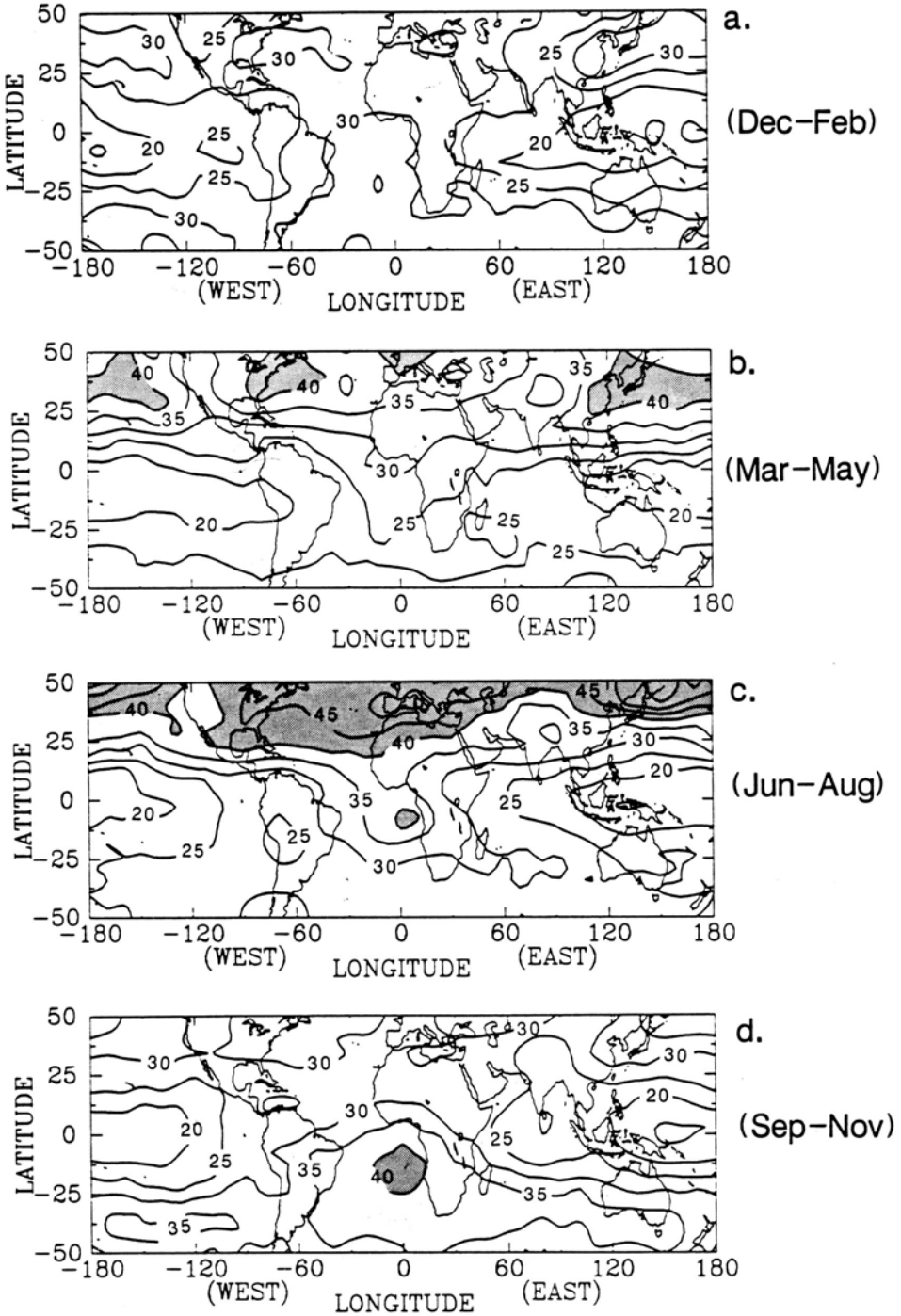
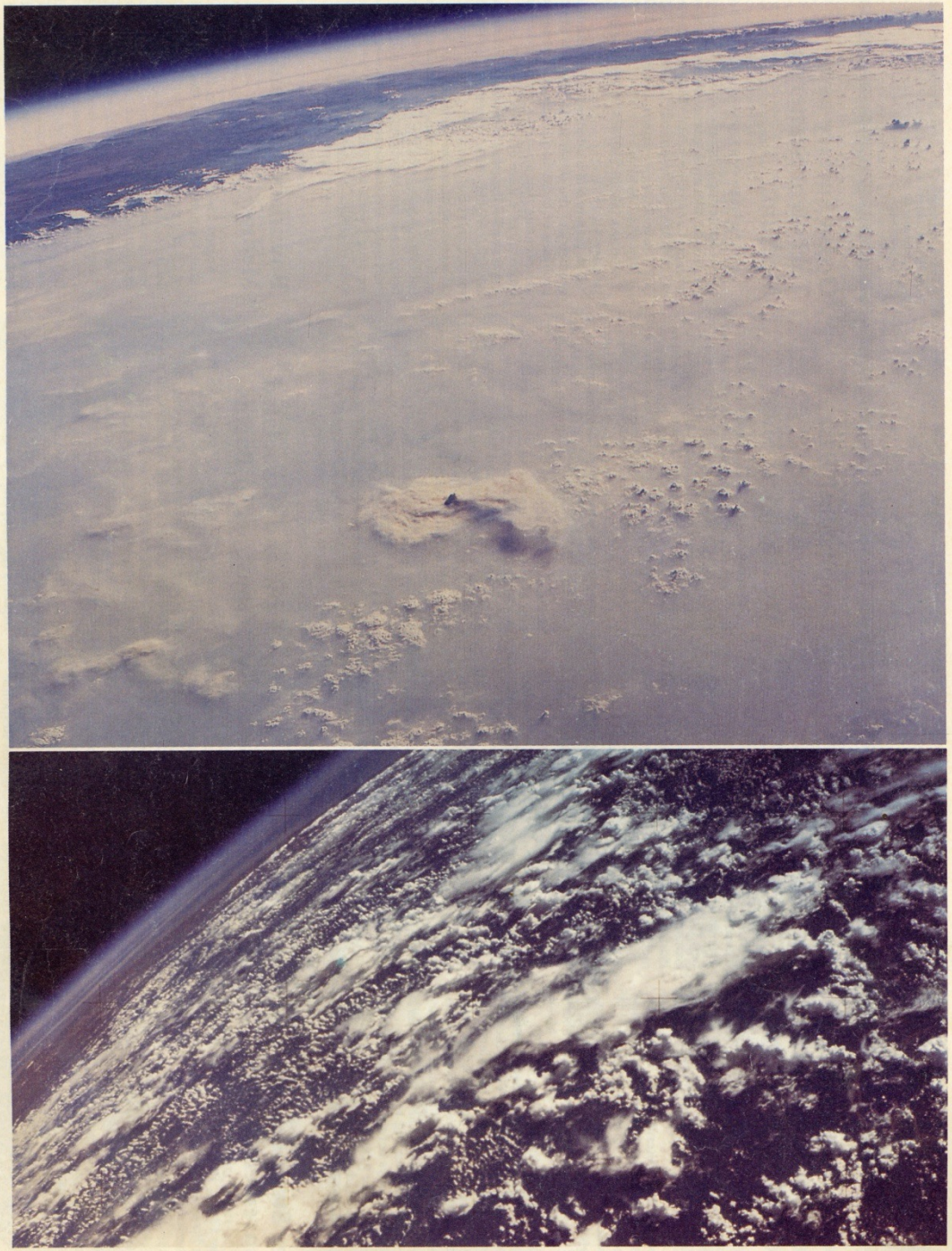


Figure 13.7. *Evolution of the chemical composition of the lower atmosphere during a smog event (Goody, 1995).*


a.
(Dec-Feb)
b.
(Mar-May)
c.
(Jun-Aug)
d.
(Sep-Nov)
LATITUDE
LONGITUDE
(WEST)
(EAST)
50
25
0
-25
-50
-180
-120
-60
0
60
120
180



Biomass Burning in the Amazon: 1988 (top) and 1973

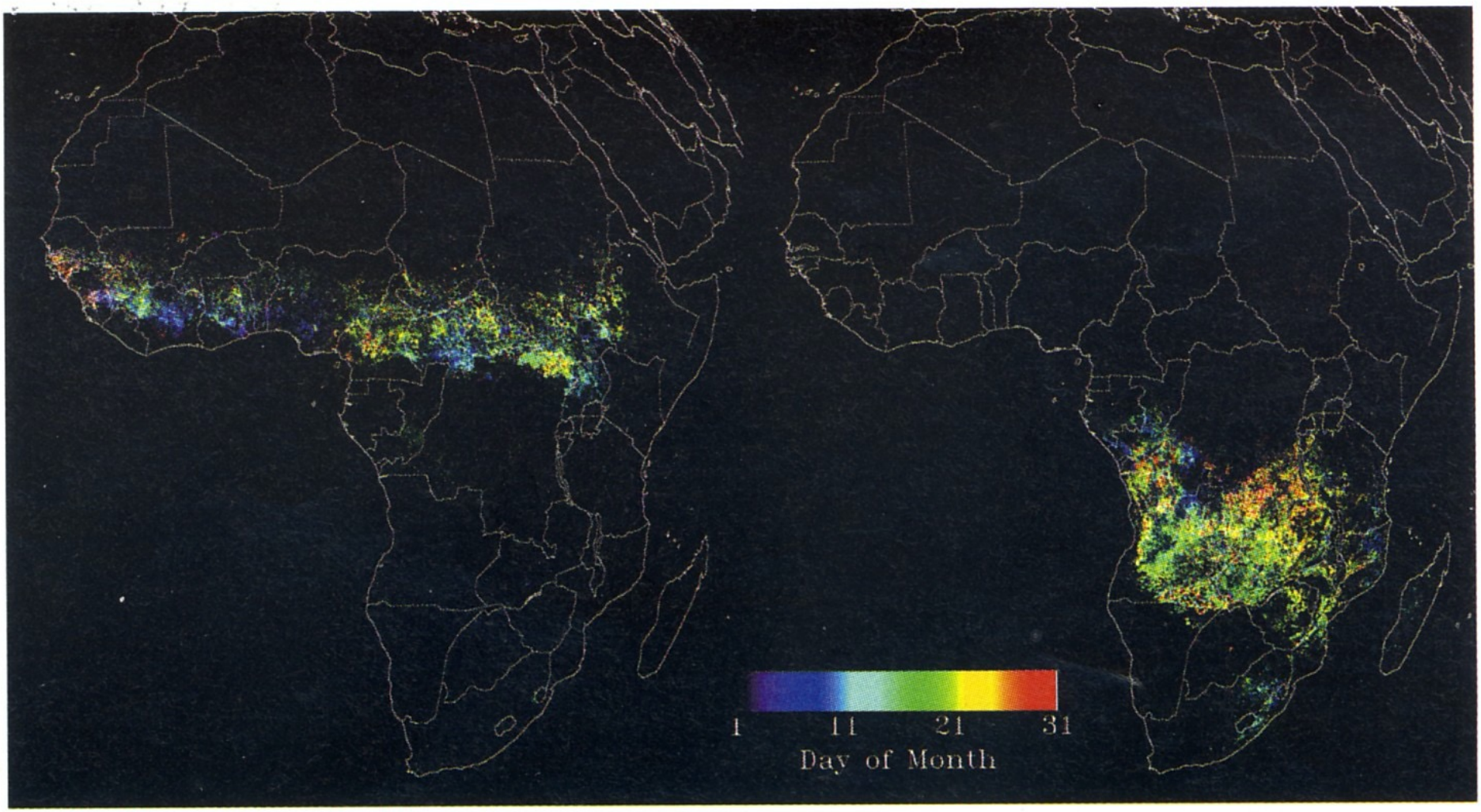
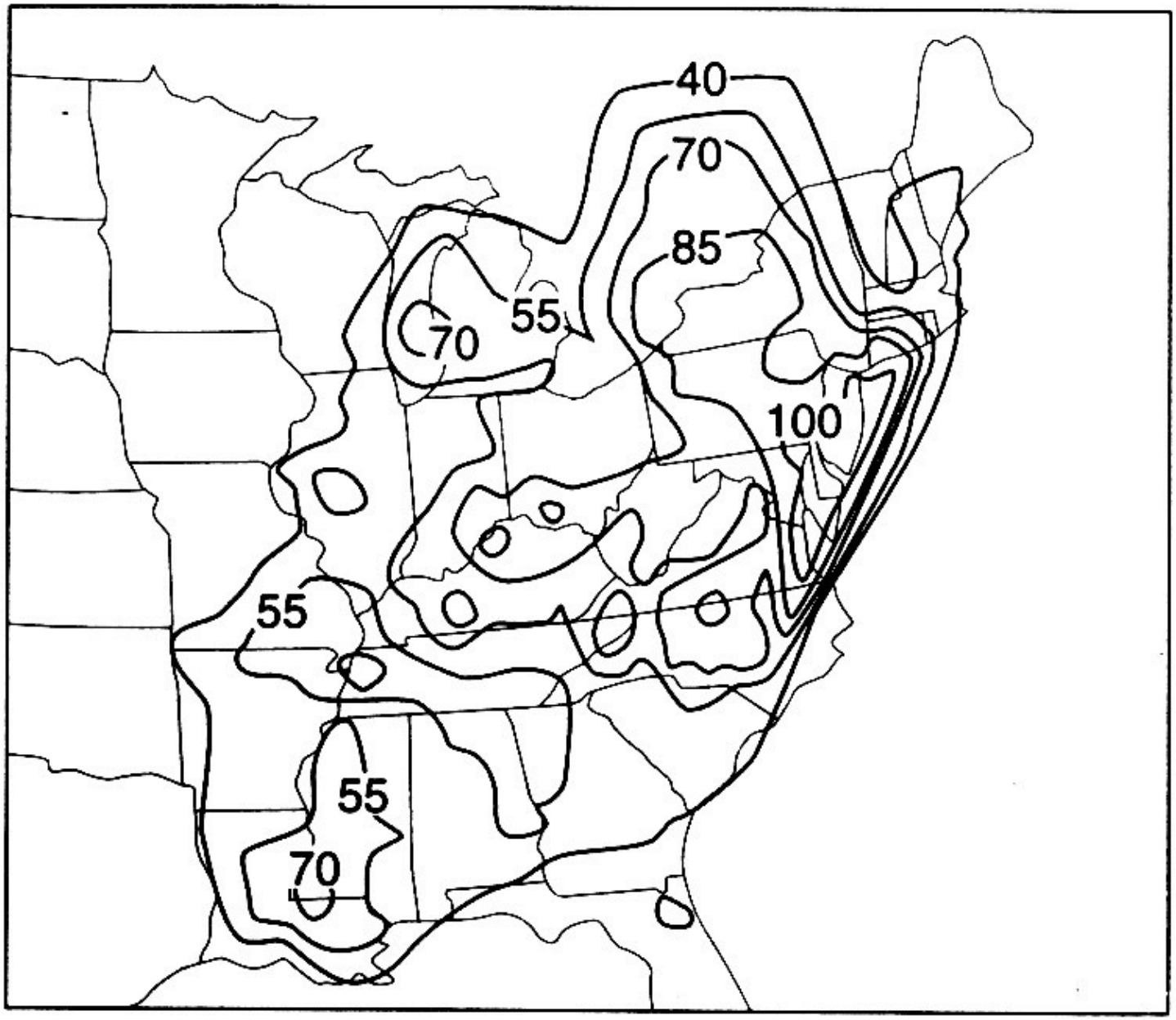


Fig. 2. SEVIRI-derived maps of active fire detections for (left) February and (right) August 2004.



963 fig 11.1/10.94 dpm

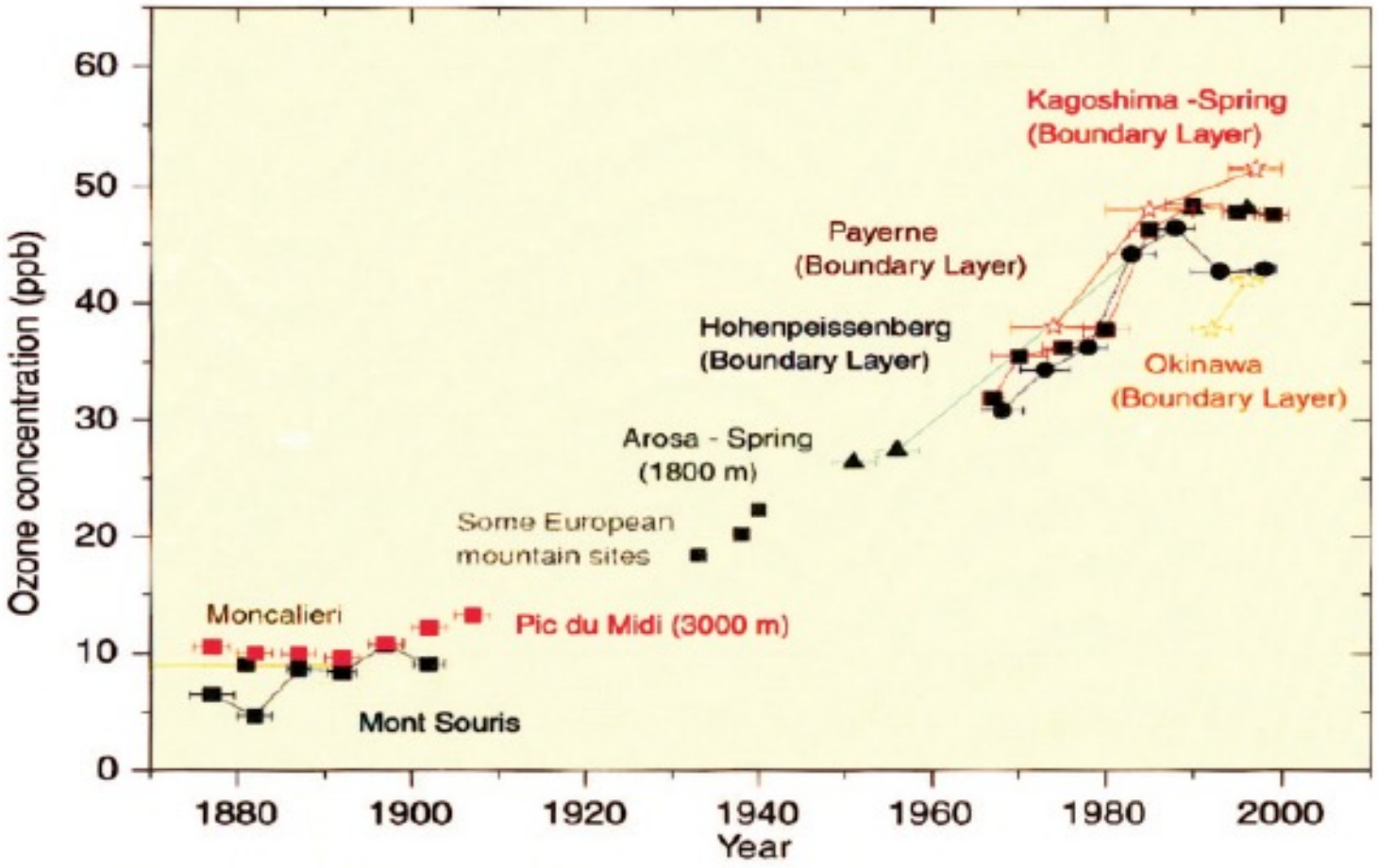


Figure 1-2. Trend of springtime ground-level ozone concentrations in middle and high latitudes of the northern hemisphere from the nineteenth century to the present. (Akimoto 2002)

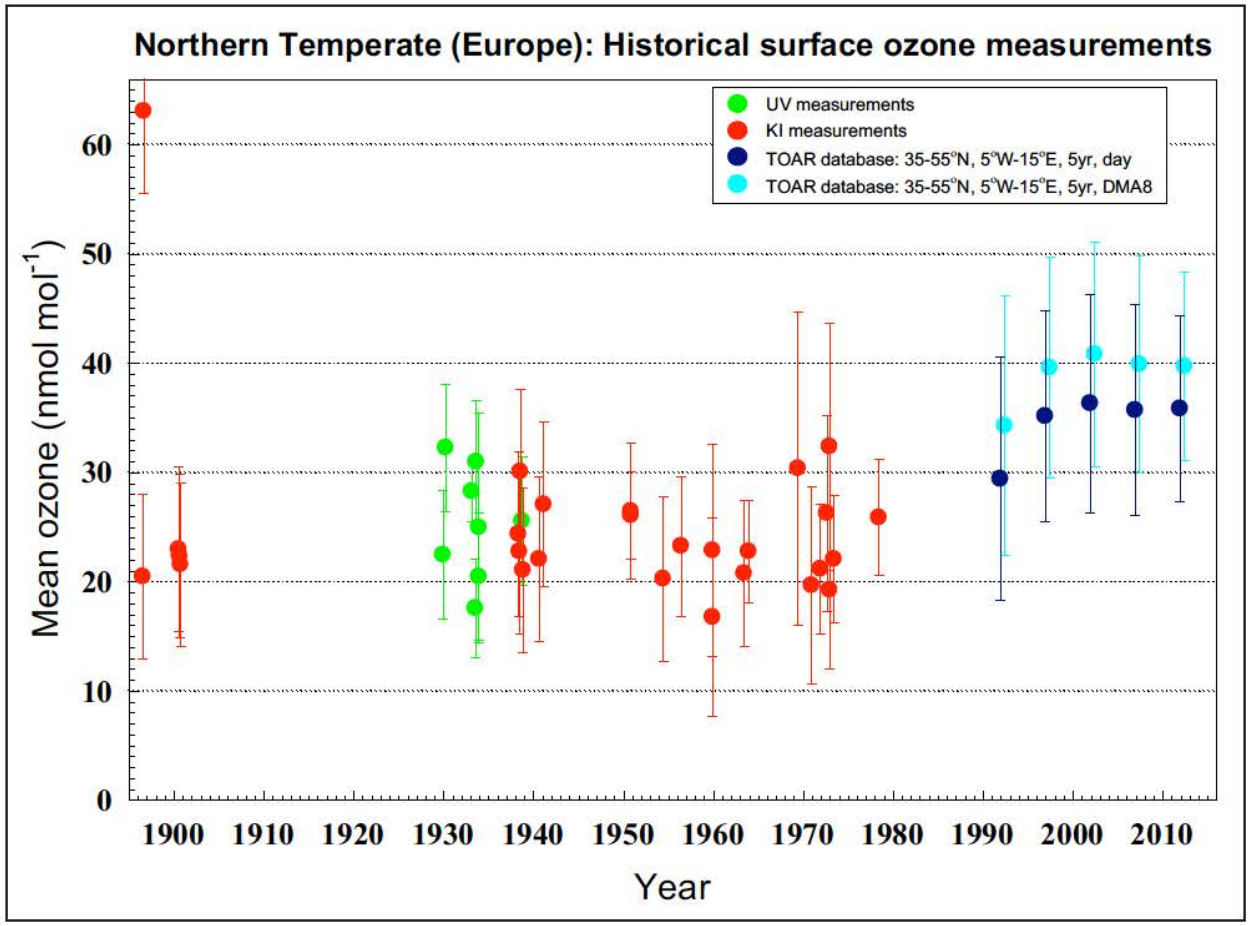
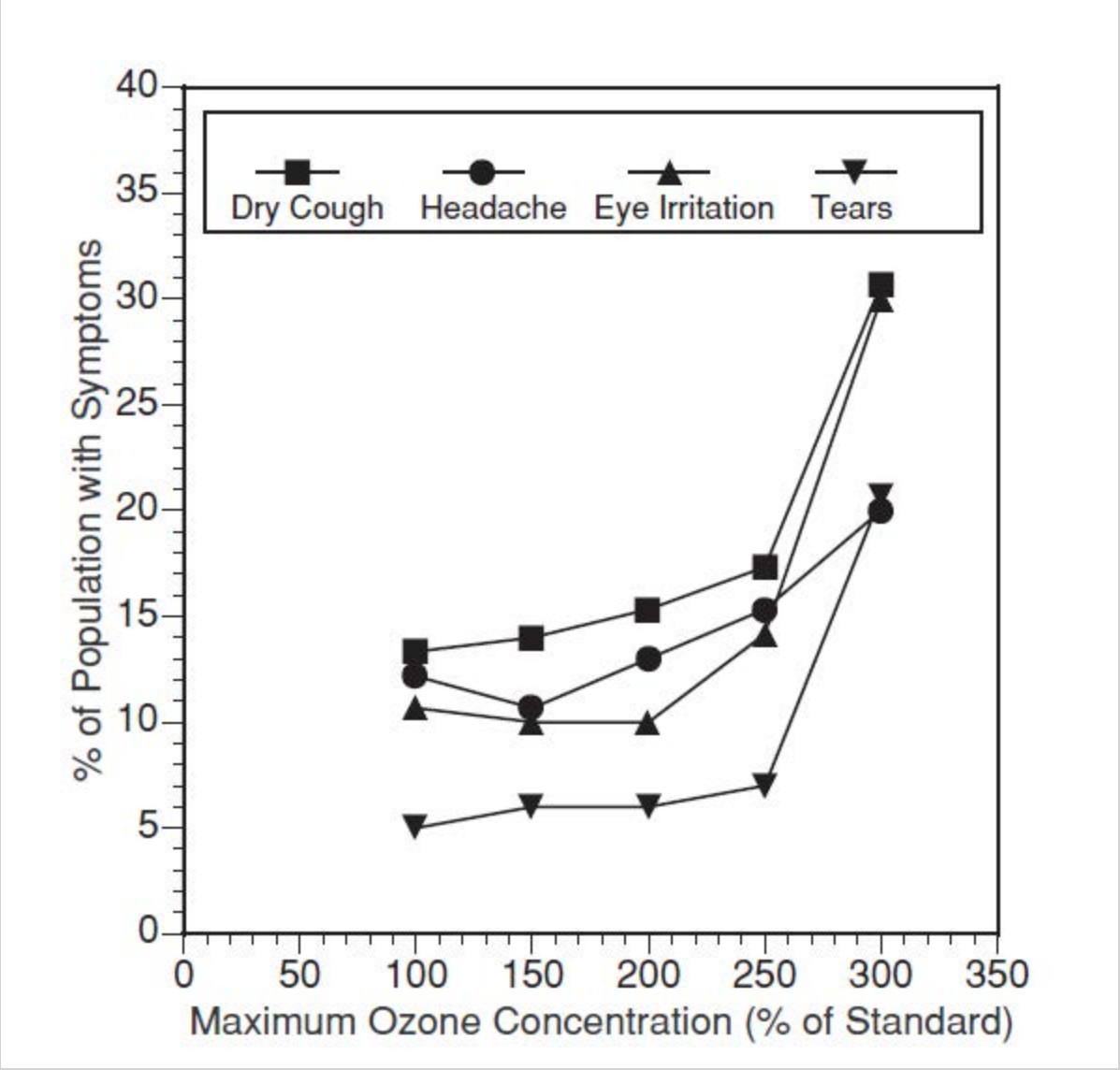


Figure 2: Historical measurements of surface ozone in the Northern Temperate region, 30°N–60°N (30 European, three Asian, one North American and one North African data sets; see Table 4 for details). Error bars represent standard deviations of the measurement averages (atmospheric variability), not uncertainty of the measurement. 5-year averages of modern UV measurements at sites below 2000 m, classified as "rural", in the 5 × 5 degree gridded product from the TOAR database are also shown, both daytime averages (day) and daily 8-hour maxima (DMA8) (Schultz et al., 2017). DOI: https://doi.org/10.1525/elementa.376.f2

Tarasick, D, et al. 2019. Tropospheric Ozone Assessment Report

Ozone and Health



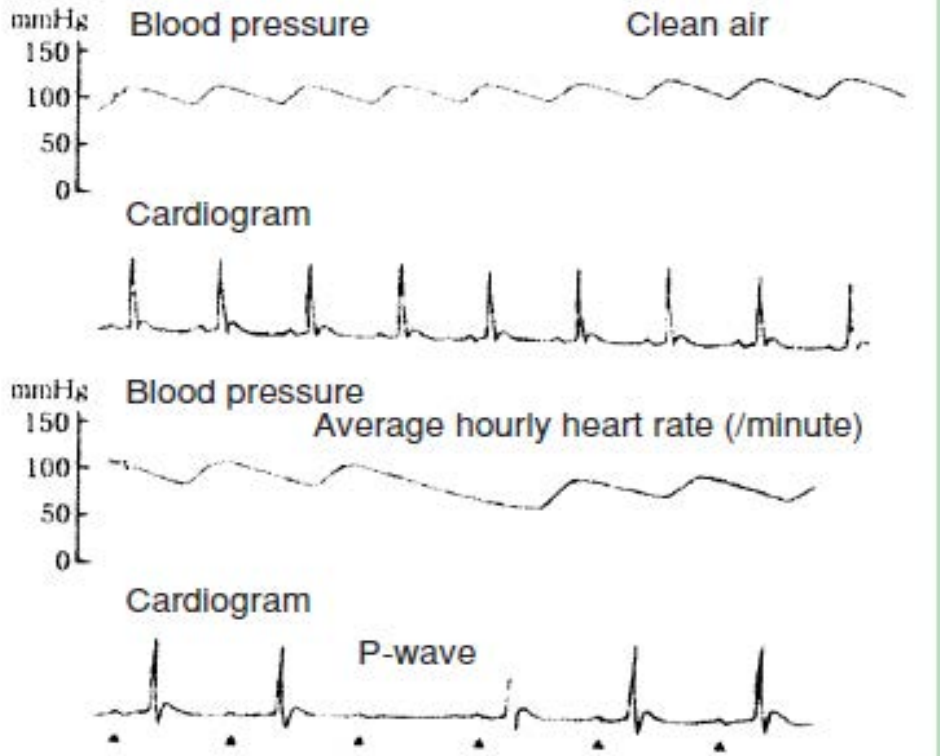
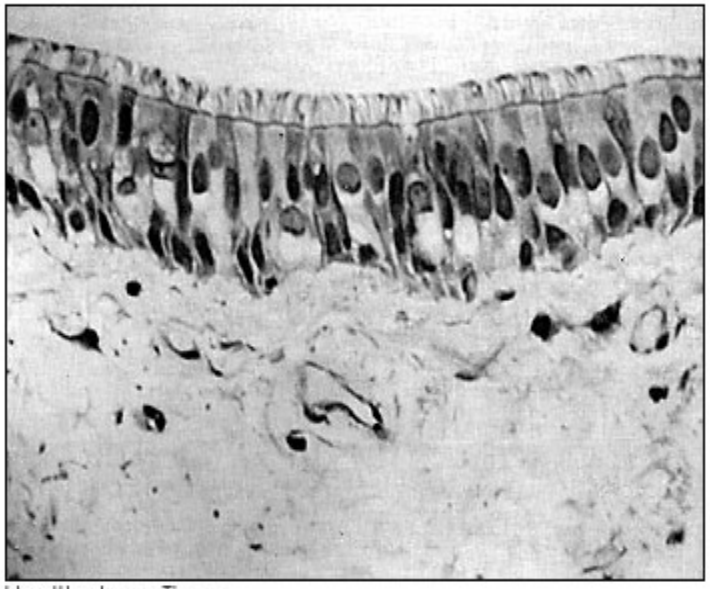
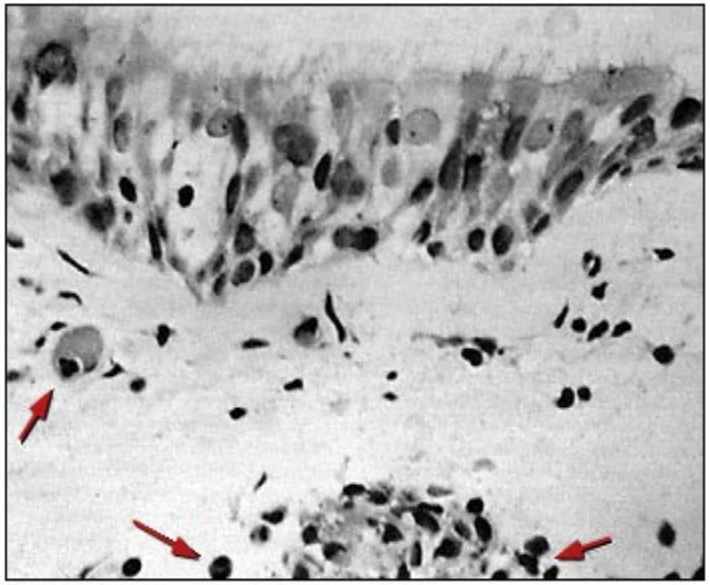


Figure 4-1. Blood pressure decrease and irregular pulse in rats exposed to 1 ppm-ozone for three hours. (Uchiyama 2003)



Healthy Lung Tissue



Ozone-damaged Lung Tissue

Microscopic views of human lung tissue (epithelium, or lining) show damage resulting from exposure to relatively low levels of ozone. In the control image (upper) from the lung of a person exposed only to air, the tiny cilia that clear the lungs of mucus appear along the top of the image in a neat and regular row. In the lung exposed to 20 ppb of ozone added to the air for four hours during moderate exercise, many cilia appear missing and others appear misshapen. Arrows point to tiny bodies called neutrophils in the ozone-exposed subject. The presence of neutrophils indicates inflammation. Magnification: x400. (Micrographs courtesy of the American Thoracic Society, from *American Review of Respiratory Diseases,* Vol. 148, 1993, Robert Aris et al., pp. 1368-1369.)

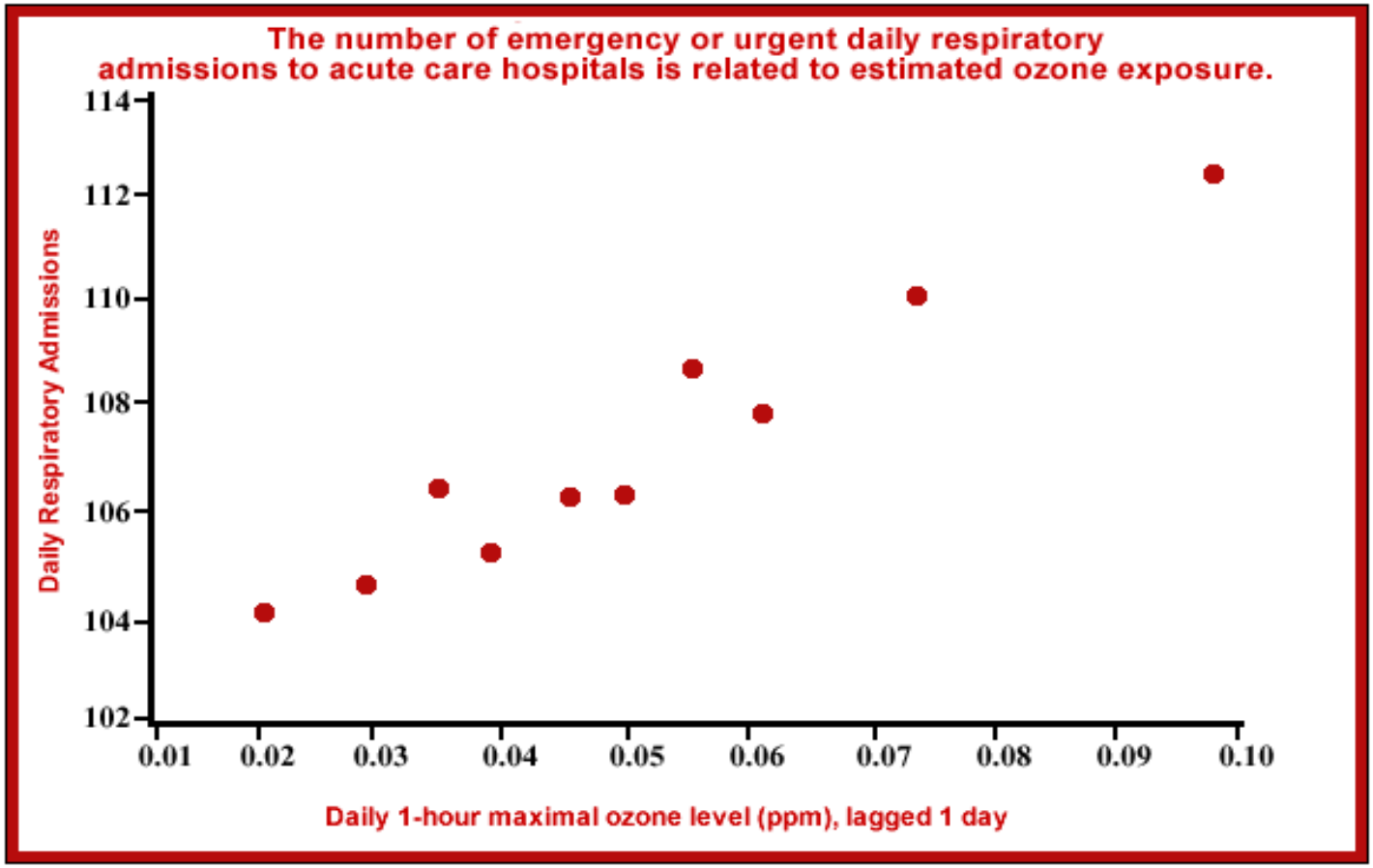
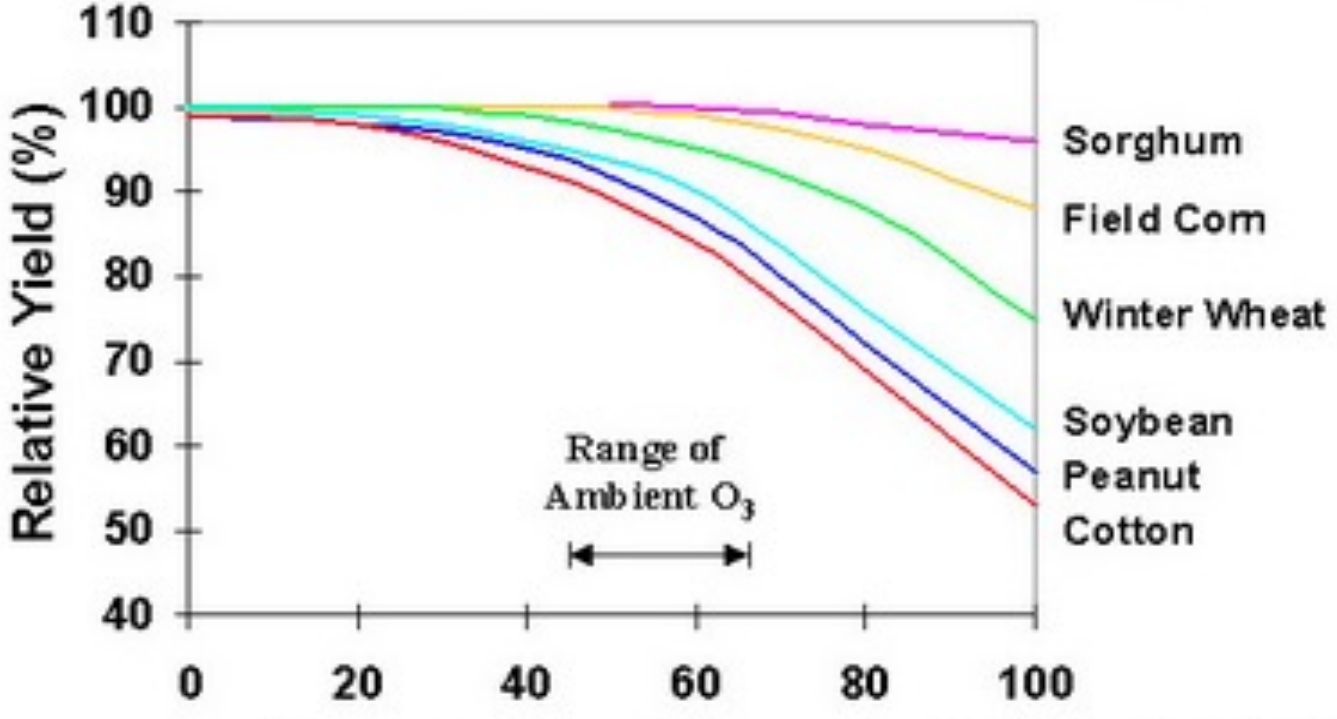


Figure 9: The number of emergency or urgent daily respiratory admissions to acute care hospitals is related to estimated ozone exposure. Respiratory admission rates to 168 hospitals in Ontario, Canada during the period 1983 through 1988 are plotted against deciles of the daily 1-hour maximum ozone concentration, lagged by 1 day. Admission rates were adjusted for seasonal patterns, day-of-week effects, and hospital effects. Ozone displayed a positive and statistically significant association with respiratory admissions for 91% of the hospitals during the Spring through Fall seasons, but not during the Winter months of December to March when ozone levels were low. *Source: Burnett et al., 1994; U.S. EPA, 1996*

Effect of O_3 on Yield of Crops



(Heck et al. 1983. Environ Sci Tech 17: 572A)

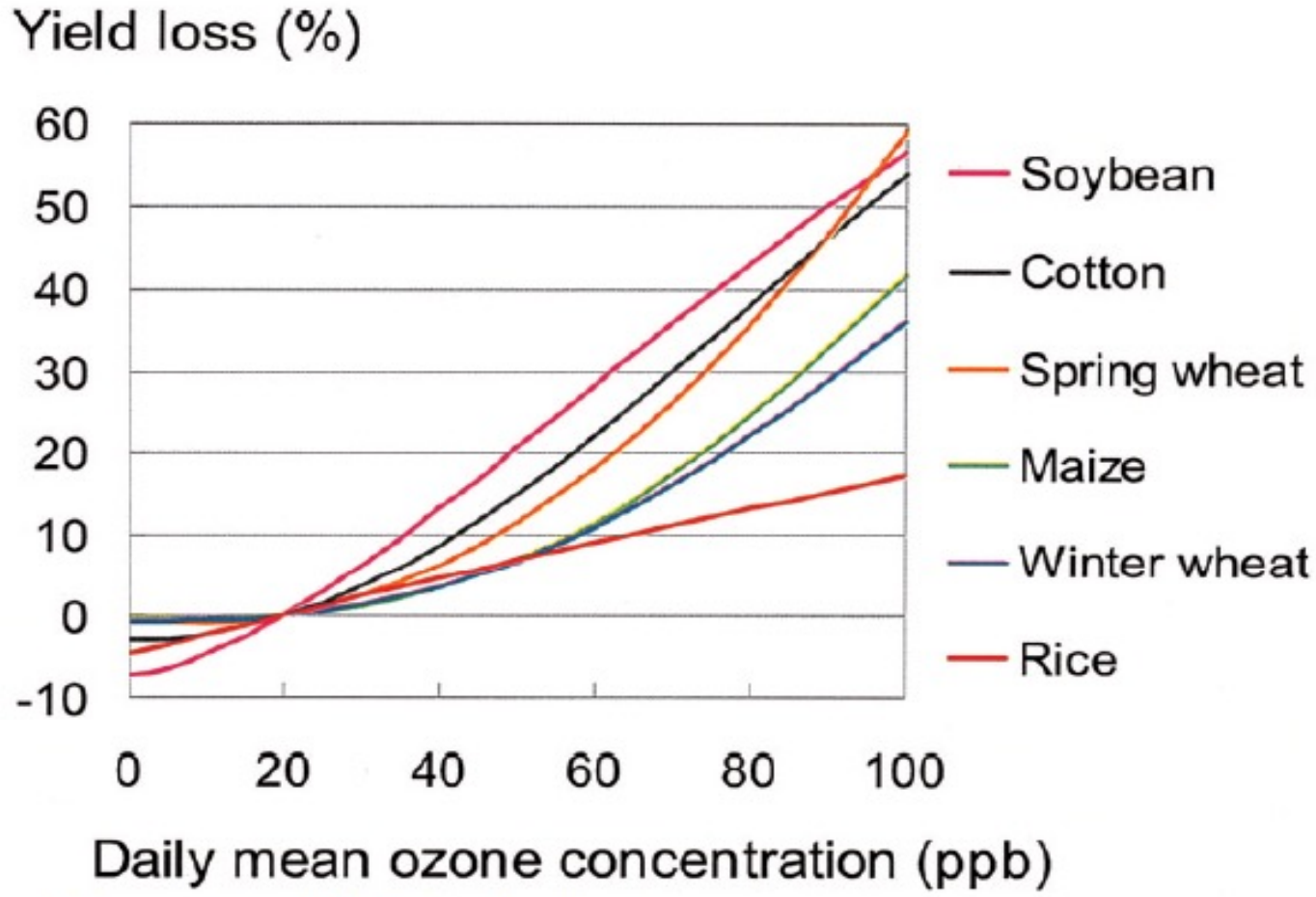
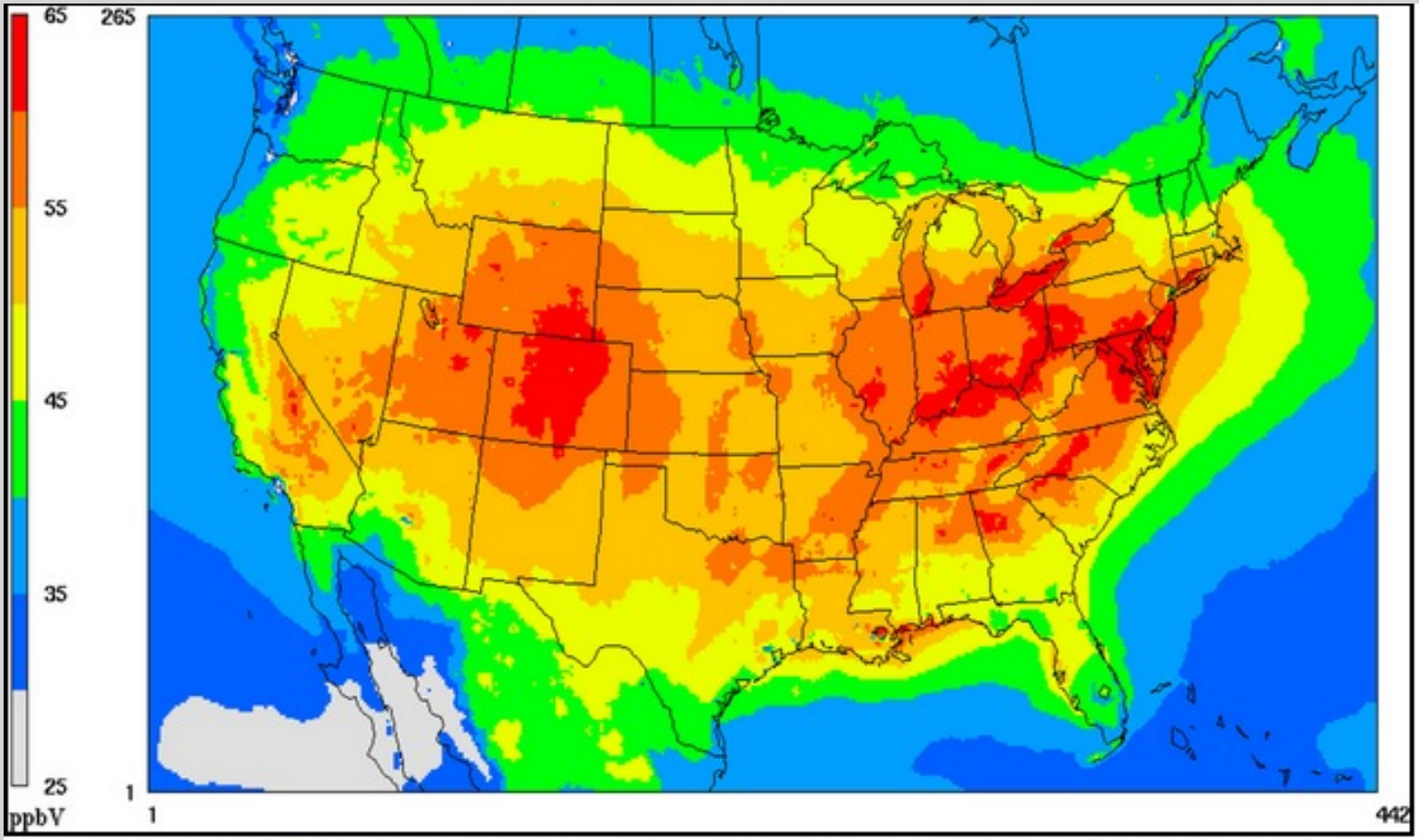
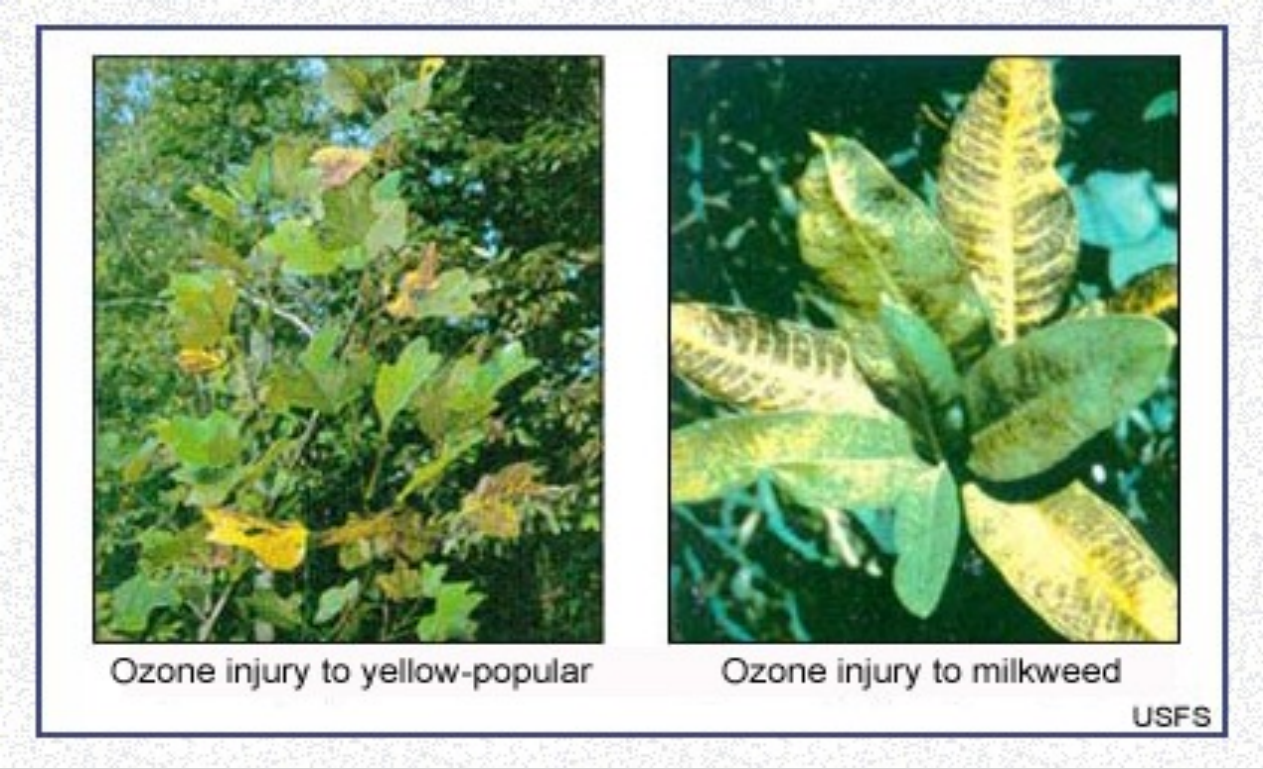


Figure 5-1. Relationships between ozone concentrations and yield losses in major agricultural crops. (Lesser et al. 1990; Skärby et al. 1993; Kobayashi et al. 1995)



Seasonal mean of ambient ozone concentrations between 09:00 and 16:00 h over the continental United States from 1 July to 31 September 2005 (Tong et al. 2007Atmos. Environ. 41:8772). Areas shown in brown, orange and red can experience significant crop yield loss and damage to ecosystem function from ambient ozone.

Negative impacts on plants from tropospheric ozone



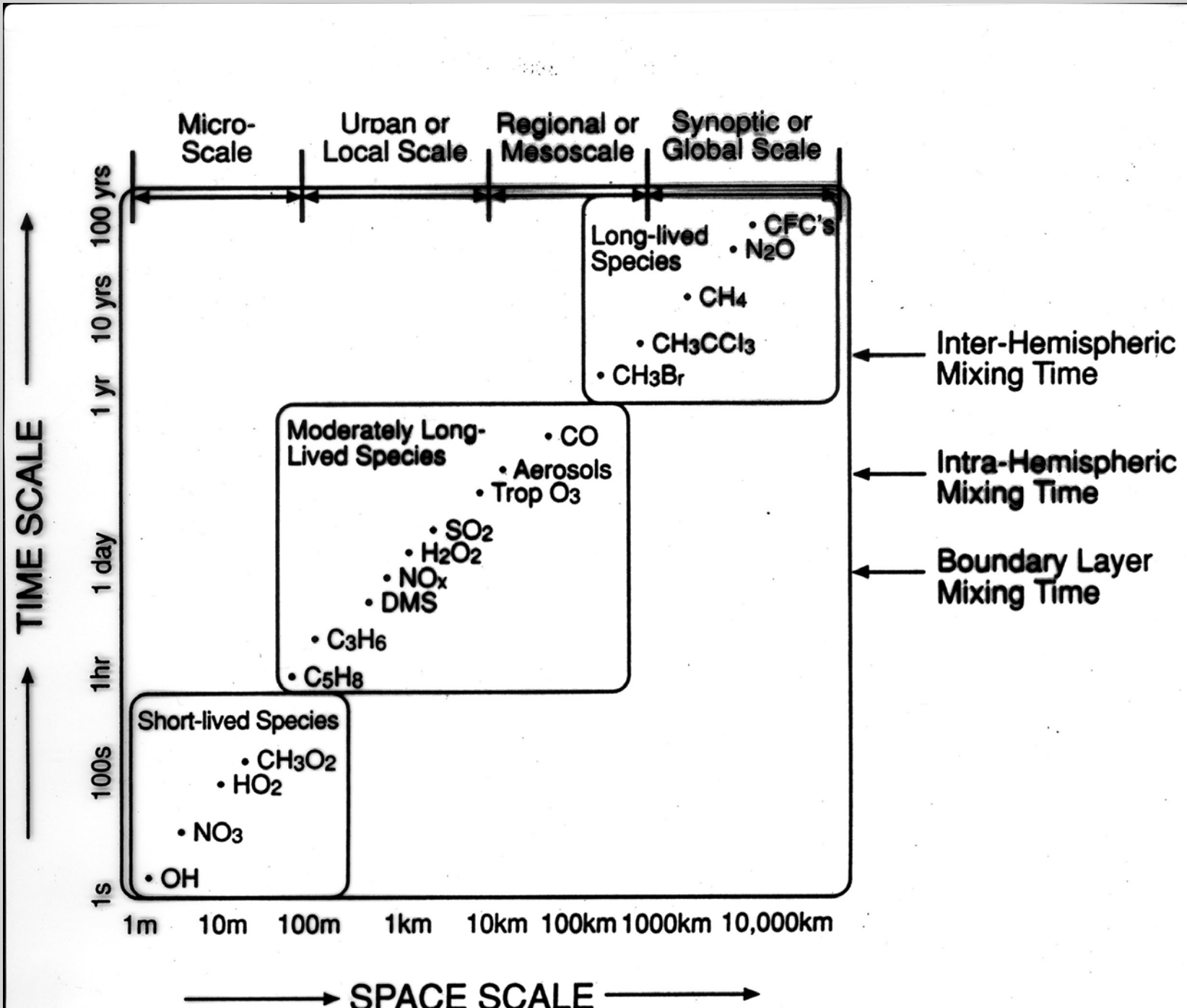
1) High concentrations of ozone cause plants to close their stomata
2) The stomata are the cells on the underside of the plant that allow carbon dioxide and water to diffuse into the plant tissue
3) If the stomata are closed it slows down photosynthesis and plant growth

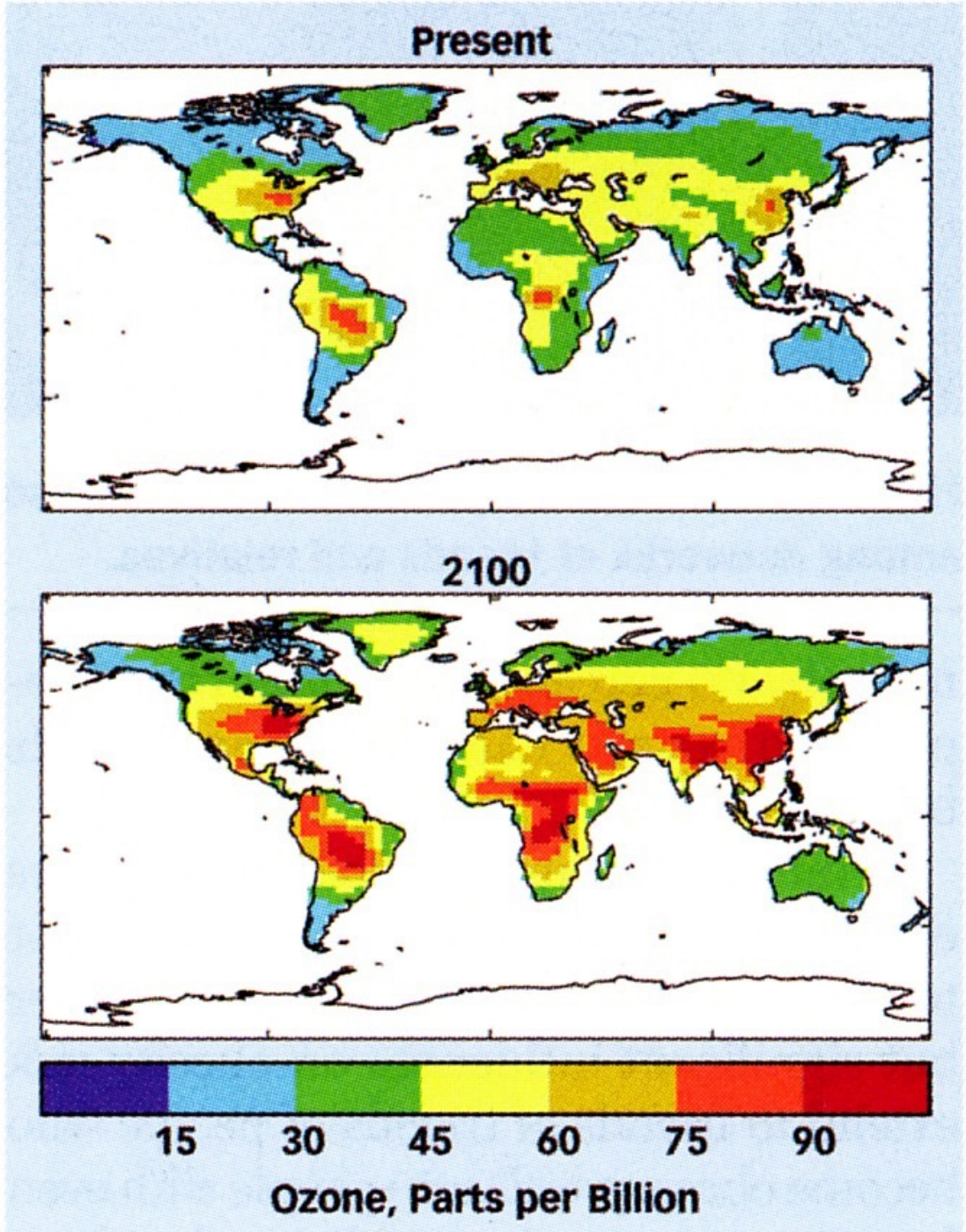
Cut-leaf Coneflower showing ozone damage.
NPS photo

Tall milkweed with no ozone injury.

Heavily injured Tall milkweed

Photo 5-1. Ozone damage to spinach leaves. (Photo courtesy by Dr. Isamu Nouchi, National Institute for Agro-Environmental Sciences)


Micro-Scale
Urban or Local Scale
Regional or Mesoscale
Synoptic or Global Scale
TIME SCALE
100 yrs
10 yrs
1 yr
1 day
1hr
100s
1s
Long-lived Species
• CFC's
• N_2O
• CH_4
• CH_3CCl_3
• CH_3Br
Moderately Long-Lived Species
• CO
• Aerosols
• Trop O_3
• SO_2
• H_2O_2
• NO_x
• DMS
• C_3H_6
• C_5H_8
Short-lived Species
• CH_3O_2
• HO_2
• NO_3
• OH
Inter-Hemispheric Mixing Time
Intra-Hemispheric Mixing Time
Boundary Layer Mixing Time
1m
10m
100m
1km
10km
100km
1000km
10,000km
SPACE SCALE


Present
2100
15
30
45
60
75
90
Ozone, Parts per Billion