Review of Lectures 9 to 13

AOSC 433/633 & CHEM 433/633

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Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2013

Today:

- **Health affects: i.e., why it is that so much research is funded in this area**
- **Photolysis and kinetics**
- **One atmosphere, one chemistry**
- **Non-linearity of tropospheric ozone production**
- **Recent improvements in air quality and future challenges**

26 March 2013

Relationship Between UV and Column Ozone

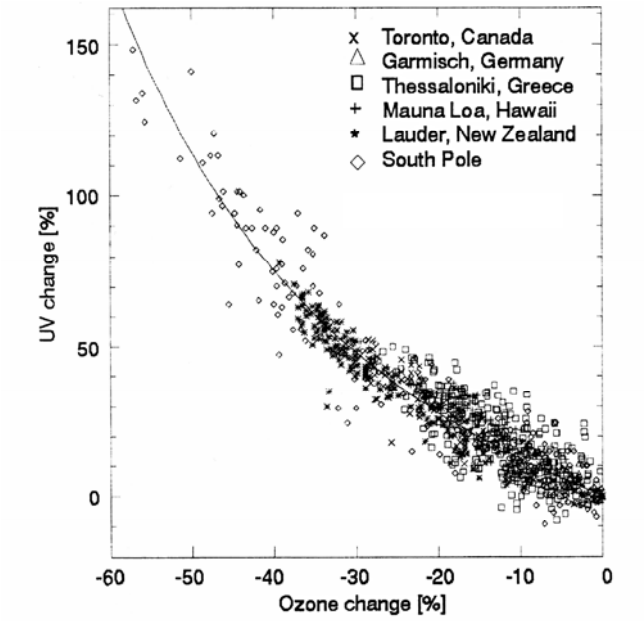


Fig. 2. Dependence of erythemal ultraviolet (UV) radiation at the Earth's surface on atmospheric ozone, measured on cloud-free days at various locations, at fixed solar zenith angles. Legend: South Pole [8]; Mauna Loa, Hawaii [9]; Lauder, New Zealand [10]; Thessaloniki, Greece (updated from Ref. [11]); Garmisch, Germany [12]; and Toronto, Canada (updated from Ref. [13]).

Madronich et al., *J. of Photochemistry and Photobiology B*, Vol. 46, 5–19, 1998.

Biological Effects of UV Radiation (Lecture 10)

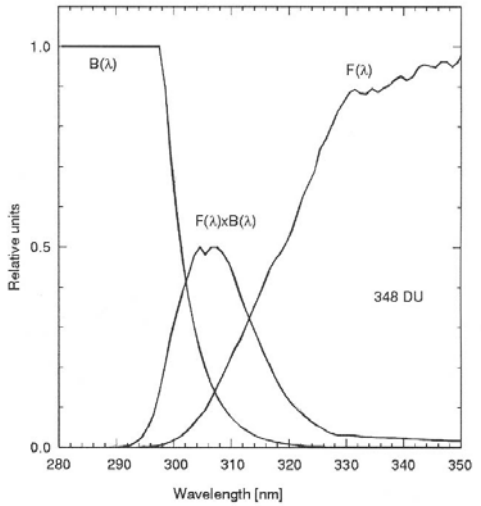


Fig. 1. Biologically active UV radiation. The overlap between the spectral irradiance $F(\lambda)$ and the erythemal action spectrum $B(\lambda)$ given by McKinlay and Diffey [6] shows the spectrum of biologically active radiation, $F(\lambda)B(\lambda)$. The area under the product function $F(\lambda)B(\lambda)$ is the biologically active dose rate. For a total ozone column of 348 DU.

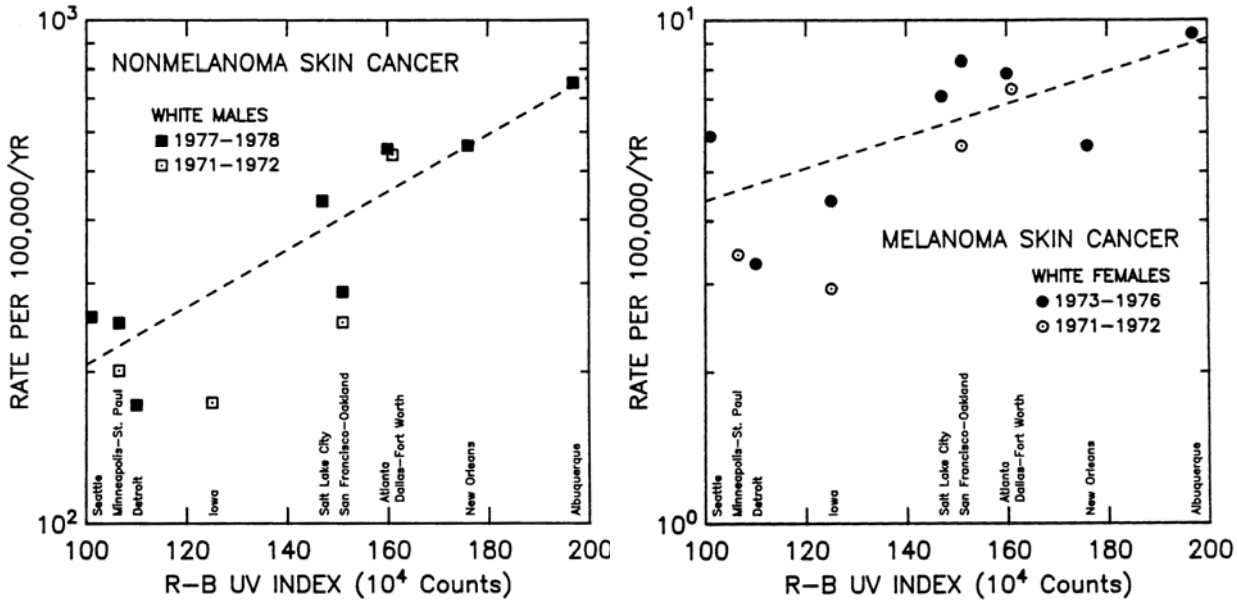
Humans are:

- strongly affected by exposure to UV-C radiation (100 to 280 nm)
- moderately affected by exposure to UV-B radiation (280 to 315 nm)
- weakly affected by exposure to UV-A radiation (315 to 400 nm)

⇐ From Mandronich et al., *J. Photochemistry and Photobiology*, vol. 46, pg. 5, 1998

The "biologically active dose rate" maximizes in the UV-B region at ~305 nm, where $\sigma_{O3} = 3 \times 10^{-19}$ cm^2 $\Rightarrow$ τ (0 km) = 2.4 (for O_3 column= 300 DU)

Relationship Between Cancer and UV

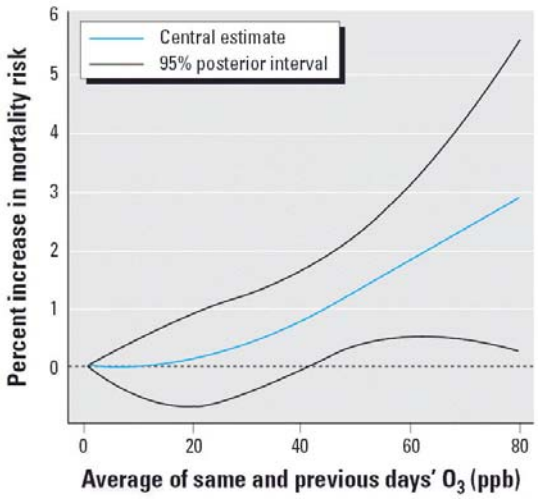


Scotto and Fraumeni, *Cancer Epidemiology*, W. B. Saunders and Co, Philadelphia, 1982.

Air Quality Standards and Why We Care (Lecture 12)

Year	Averaging Period	EPA Surface Ozone Standard
1979	1 hr	125 ppb
1997	8 hr	85 ppb
2008	8 hr *	75 ppb
2013 #	???	???

* The 8 hr standard is met when the 3-yr average of the annual 4th highest daily maximum 8 hr O_3 is less than 75 ppb.



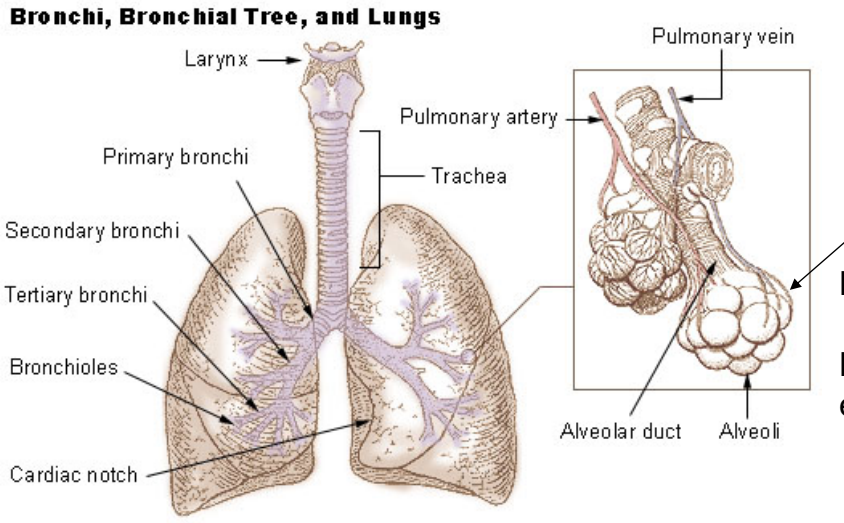
Increased risk of premature mortality for even low levels of surface O_3; further reductions will benefit public health

Bell et al., 2006
http://www.ncbi.nlm.nih.gov/sites/ppmc/articles/PMC1440776

In 2011Obama directed EPA to postpone revising surface O_3 standard so regulation would not interfere with economic recovery:
http://www.bloomberg.com/news/2011-09-02/obama-tells-epa-to-withdraw-ozone-air-quality-standards-hit-by-republicans.html

On 6 March 2013, Obama nominated Gina McCarthy to be EPA administrator:
http://ehstoday.com/environment/obama-epa-nominee-gina-mccarthy-i-m-confident-she-s-going-do-outstanding-job-leading-epa
http://www.washingtonpost.com/blogs/wonkblog/wp/2013/03/04/why-gina-mccarthy-for-epa-could-be-obamas-most-important-nominee

Health Affects of Aerosols (Lecture 13)



Alveoli radius ≈ 0.05-0.1 mm

PM10 may fill alveola

PM2.5 can inhibit oxygen exchange within alveola

Leads to increase risk of respiratory illnesses, cardiopulmonary disease, ischemic heart disease, heart attack, etc.

This is without even considering chemical effects

Health Affects of Aerosols (Lecture 13)

Long-term exposure to air pollution is associated with survival following acute coronary syndrome

Cathryn Tonne and Paul Wilkinson – Feb 19, 2013

Table 4 Sensitivity of the $PM_{2.5}$ associations with mortality following admission for acute coronary syndrome

Hazard ratio (95% CI) per 10 μg/m³ $PM_{2.5}$	
Fully adjusted model	
Education in place of income	1.22 (1.06, 1.40)
Employment in place of income	1.20 (1.04, 1.38)
Income with random effect for hospital	1.17 (1.04, 1.33)
Income with time trend using 3 df	1.20 (1.04, 1.38)

"We found that for every 10μg/m³ increase in PM2.5 there was a 20% increase in the death rate. For example, over one year of follow-up after patients had been admitted to hospital with ACS, there would be 20% more deaths among patients exposed to PM2.5 levels of 20 μg/m³, compared to patients exposed to PM2.5 levels of 10μg/m³."

http://eurheartj.oxfordjournals.org/content/early/2013/02/18/eurheartj.ehs480.full

Health Affects of Surface Ozone and Aerosols

Table 3. Relative Risk of Death Attributable to a 10-ppb Change in the Ambient Ozone Concentration.*

Cause of Death	Single-Pollutant Model†			Two-Pollutant Model‡	
	Ozone (96 MSAs)	Ozone (86 MSAs)	$PM_{2.5}$ (86 MSAs)	Ozone (86 MSAs)	$PM_{2.5}$ (86 MSAs)
			relative risk (95% CI)		
Any cause	1.001 (0.996–1.007)	1.001 (0.996–1.007)	1.048 (1.024–1.071)	0.989 (0.981–0.996)	1.080 (1.048–1.113)
Cardiopulmonary	1.014 (1.007–1.022)	1.016 (1.008–1.024)	1.129 (1.094–1.071)	0.992 (0.982–1.003)	1.153 (1.104–1.204)
Respiratory	1.029 (1.010–1.048)	1.027 (1.007–1.046)	1.031 (0.955–1.113)	1.040 (1.013–1.067)	0.927 (0.836–1.029)
Cardiovascular	1.011 (1.003–1.023)	1.014 (1.005–1.023)	1.150 (1.111–1.191)	0.983 (0.971–0.994)	1.206 (1.150–1.264)
Ischemic heart disease	1.015 (1.003–1.026)	1.017 (1.006–1.029)	1.211 (1.156–1.268)	0.973 (0.958–0.988)	1.306 (1.226–1.390)

* MSA denotes metropolitan statistical area, and $PM_{2.5}$ fine particulate matter consisting of particles that are 2.5 μm or less in aerodynamic diameter. Ozone concentrations were measured from April to September during the years from 1977 to 2000, with follow-up from 1982 to 2000;

There is biologic plausibility for a respiratory effect of ozone. In laboratory studies, ozone can increase airway inflammation[24] and can worsen pulmonary function and gas exchange.[25] In addition, exposure to elevated concentrations of tropospheric ozone has been associated with numerous adverse health effects, including the induction[26] and exacerbation[27,28] of asthma, pulmonary dysfunction,[29,30] and hospitalization for respiratory causes.[31]

In our two-pollutant models, the adjusted estimates of relative risk for the effect of ozone on the risk of death from cardiovascular causes were significantly less than 1.0, seemingly suggesting a protective effect. Such a beneficial influence of ozone, however, is unlikely from a biologic standpoint.

In summary, we investigated the effect of tropospheric ozone on the risk of death from any cause and cause-specific death in a large cohort, using data from 96 metropolitan statistical areas across the United States and controlling for the effect of particulate air pollutants. We were unable to detect a significant effect of exposure to ozone on the risk of death from cardiovascular causes when particulates were taken into account, but we did demonstrate a significant effect of exposure to ozone on the risk of death from respiratory causes.

Jerrett et al., 2009

http://www.nejm.org/doi/full/10.1056/nejmoa0803894

Typical Ozone Profile (Reading, Lecture 2)

Ozone column:

$$\int_{z_1}^{z_2} [O_3(z)]\, dz$$

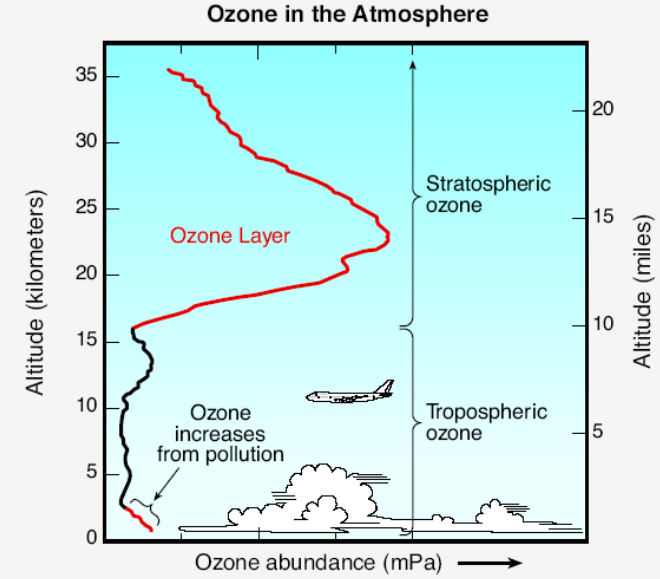


Figure Q1-2. Ozone in the atmosphere. Ozone is present throughout the troposphere and stratosphere… Increases in ozone occur near the surface as a result of pollution from human activities.

WMO/UNEP 2010 Ozone Twenty Questions

Chapman Chemistry (Lecture 9)

- Production of ***stratospheric*** O_3 initiated when O_2 is photo-dissociated by UV sunlight
- O_3 formed when resulting O atom reacts with O_2 :

$$h\nu + O_2 \rightarrow O + O \qquad (1)$$
$$O + O_2 + M \rightarrow O_3 + M \qquad (2)$$

- O_3 removed by photo-dissociation (UV sunlight) or by reaction with O :

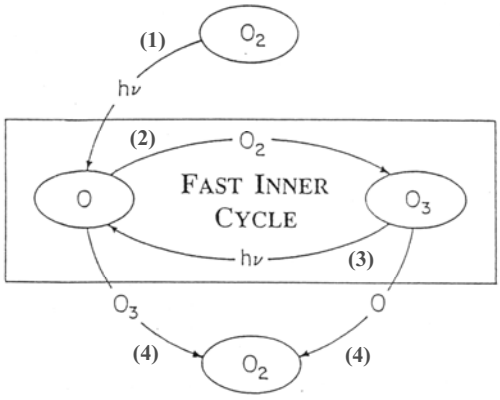
$$h\nu + O_3 \rightarrow O + O_2 \qquad (3)$$
$$O + O_3 \rightarrow O_2 + O_2 \qquad (4)$$

This reaction sequence was first worked out in the 1930s by Sydney Chapman, an English mathematician and geophysicist

Chapman Chemistry (Lecture 9)

- The cycling between O and O_2 (rxns 2 and 3) occurs *much* more rapidly than leakage into (rxn 1) or out of the system (rxn 4)

- The sum O + O_3 is commonly called *"odd oxygen"*



Rxn (1) produces two *odd oxygen* molecules
Rxn (4) consumes two *odd oxygen* molecules

and reactions 2 and 3 recycle *odd oxygen* molecules

Chapman Chemistry (Lecture 9)

$$[O_3] = \left(\frac{J_1 k_2}{J_3 k_4} \right)^{1/2} f_{O2} [M]^{3/2}$$

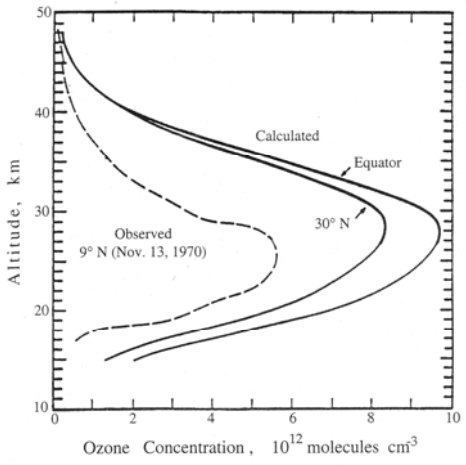


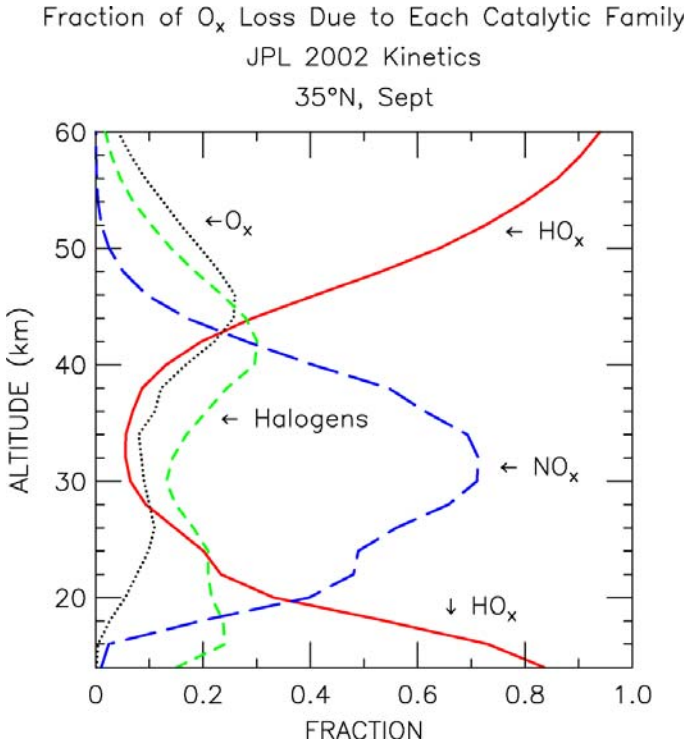
FIGURE 4.6 Comparison of stratospheric ozone concentrations as a function of altitude as predicted by the Chapman mechanism and as observed over Panama (9° N) on November 13, 1970.

$[O_3]$ falls off with increasing altitude (high in stratosphere), at a rate determined by $[M]^{3/2}$, because:

$[O_3]$ falls off with decreasing altitude (low in stratosphere) due to a rapid drop in J_1, reflecting:

Observed $[O_3]$ < Chapman $[O_3]$: why ?!?

Stratospheric Photochemistry: Odd Oxygen Loss By Families (Lecture 9)



Calculated fraction of odd oxygen loss due to various families of radicals

After Osterman et al., GRL, 24, 1107, 1997;
Sen et al., JGR, 103, 3571. 1998;
Sen et al., JGR, 104, 26653, 1999.

One Atmosphere – One Photochemistry (Lecture 9)

Stratosphere

HO_2 formation:

$$OH + O_3 \rightarrow HO_2 + O_2$$

HO_2 loss:

$$HO_2 + O_3 \rightarrow OH + 2\,O_2$$

Net:

$$O_3 + O_3 \rightarrow 3\,O_2$$

Troposphere

HO_2 formation:

$$OH + CO \xrightarrow{O_2} HO_2 + CO_2$$

HO_2 loss:

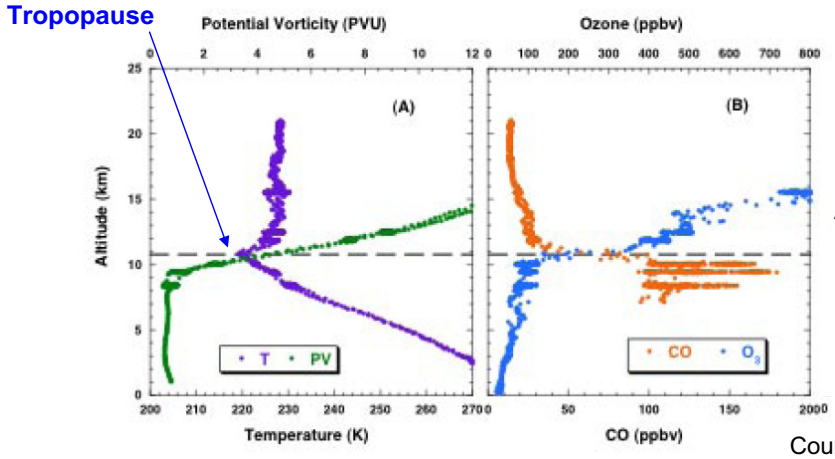
$$HO_2 + NO \rightarrow OH + NO_2$$

Followed by:

$$NO_2 + h\nu \rightarrow NO + O$$
$$O + O_2 + M \rightarrow O_3 + M$$

Net:

$$CO + 2\,O_2 \rightarrow CO_2 + O_3$$



Above Tropopause:
Lots of O_3, little CO

Below Tropopause:
Lots of CO, little O_3

Courtesy of Laura Pan, NCAR

Importance of Radicals (Lectures 9 & 10)

- With a few exceptions, the only reactions between molecules that proceed at appreciable rates are those involving at least one radical
- Radicals require significant energy to form: a bond must be broken
- Radical formation is tied to absorption of photons that "photodissociate" a compound, leading to radical formation

Initiation

$O_2 + photon \rightarrow O + O$

Propagation

$O + O_2 + M \rightarrow O_3 + M$

$O_3 + photon \rightarrow O(^1D) + O_2$

$O(^1D) + H_2O \rightarrow OH + OH$

$OH + O_3 \rightarrow HO_2 + O_2$

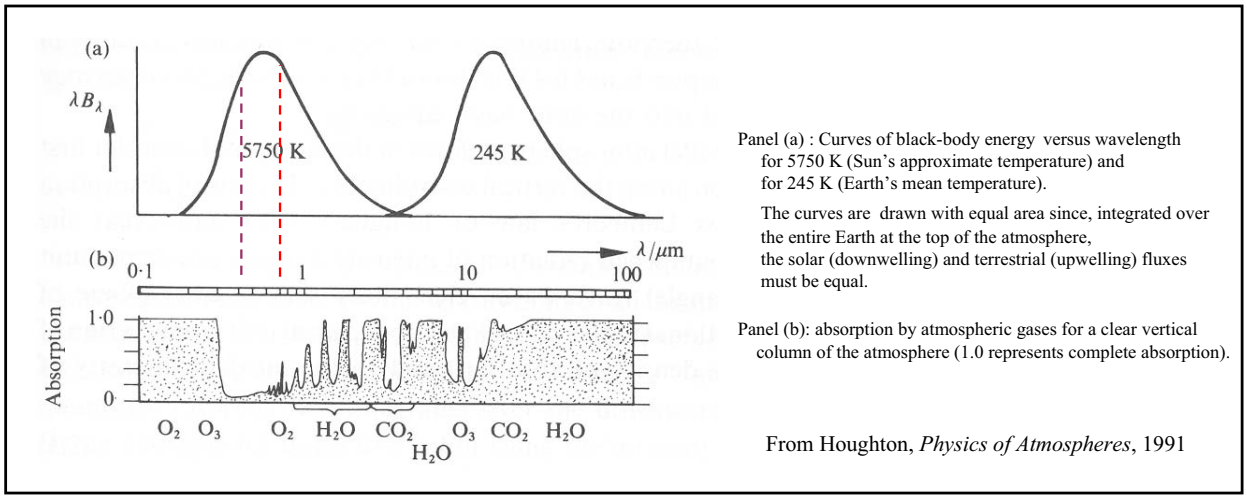
$HO_2 + O \rightarrow OH + O_2$

Termination

$OH + HO_2 \rightarrow H_2O + O_2$

Atmospheric Radiation (Lecture 10)

- Solar irradiance (downwelling) at top of atmosphere occurs at wavelengths between ~200 and 2000 nm (~5750 K "black body" temperature)



Panel (a) : Curves of black-body energy versus wavelength for 5750 K (Sun's approximate temperature) and for 245 K (Earth's mean temperature).

The curves are drawn with equal area since, integrated over the entire Earth at the top of the atmosphere, the solar (downwelling) and terrestrial (upwelling) fluxes must be equal.

Panel (b): absorption by atmospheric gases for a clear vertical column of the atmosphere (1.0 represents complete absorption).

From Houghton, *Physics of Atmospheres*, 1991

- Absorption and photodissociation in the UV occurs due to changes in the electronic state (orbital configuration) of molecules

Beer-Lambert Law (Lecture 10)

$$F(z,\lambda) = F_{TOA}(\lambda)\, e^{-\tau(z,\lambda)}$$ (TOA : Top of Atmosphere)

where:

$$\tau(z,\lambda) = m \int_{z}^{\infty} \sigma_{\lambda}\,[C]\,dz'$$ (τ: optical depth)

F : solar irradiance (photons/cm^2/sec)
σ_λ : absorption cross section
C : concentration of absorbing gas (molecules/cm^3)
m : ratio of slant path to vertical path, equal to 1/cos(θ) for $\theta < \sim 75°$
θ : solar zenith angle

Governs basics of radiative transfer in the UV and near IR regions

Photolysis Frequency (Lecture 10)

For a specific spectral interval, the photolysis frequency (***partial J value***) of a gas is given by the product of its absorption cross section and the solar irradiance:

$$J_{gas}(z,\lambda) = \text{Quantum\_Yield}(\lambda)\, \sigma_{gas}(\lambda,T)\, F(z,\lambda)$$

Units: s^{-1} nm^{-1}

The total ***photolysis frequency*** (***J value***) is found by integrating $J_{gas}(z,\lambda)$ over all wavelengths for which the gas photodissociates:

$$J_{gas}(z) = \int_{\lambda_{min}}^{\lambda_{max}} J_{gas}(z,\lambda)\, d\lambda$$ Units: s^{-1}

$$\text{Rate of Reaction} = \frac{dO_3}{dt} = J\,[O_3]; \quad \text{Units of } J \text{ are } s^{-1}$$

More precisely, calculations of photolysis frequencies consider the "spectral actinic flux", which represents the amount of available photons integrated over all angles, rather than "solar irradiance". These two quantities differ because of scattering of solar radiation by gases and aerosols, and reflection of radiation by clouds and the surface.

Solar Spectral Actinic Flux (Lecture 10)

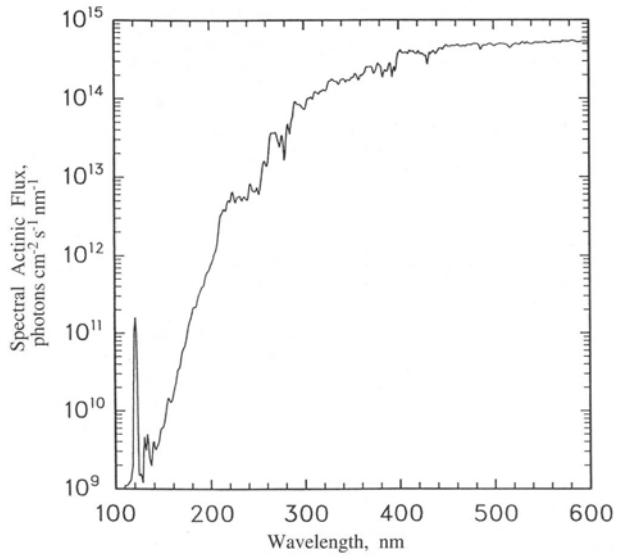
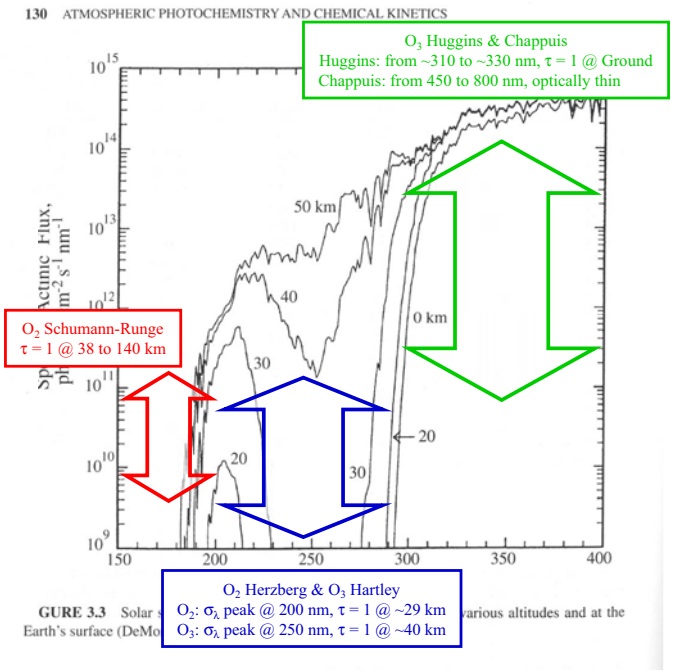


FIGURE 6. Solar spectral actinic flux (photons cm^{-2} s^{-1} nm^{-1}) at the top of Earth's atmosphere.

From DeMore et al., *Chemical Kinetics and Photochemical Data for Use in Stratospheric Modeling*, Evaluation No. 11, 1994.



From Seinfeld and Pandis, *Atmospheric Chemistry and Physics*, 1998.

Admission Ticket Lecture 11

Gibbs Free energy involves both enthalpy and entropy. Briefly describe the relative roles of the change in enthalpy and entropy in affecting the rate of a chemical reaction.

Under what conditions will each term tend to dominate the rate of a chemical reaction.

Briefly: why is kinetic information needed, in addition to thermodynamic information, to quantity our understanding of atmospheric chemistry?

CH_4 is lost by reaction with OH (Lecture 6)

$CH_4 + OH \rightarrow H_2O + CH_3$

$$\frac{dCH_4}{dt} = \text{Production} - \text{Loss} = \text{Production} - k[OH][CH_4]$$

Arrhenius Expression for rate constant:

$$k = 2.45\times10^{-12}\times e^{-1775/T}\ \text{cm}^3\ \text{sec}^{-1}$$

$$\text{Lifetime of } CH_4 = \frac{\text{Abundance}}{\text{Loss}} = \frac{[CH_4]}{k[OH][CH_4]} = \frac{1}{k[OH]}$$

Commonly T = 272 K and **[OH] = 1 × 10^6 molec cm^{-3}** are used (see Box 1-3 of http://www.unep.ch/ozone/Assessment_Panels/SAP/Scientific_Assessment_2010/03-Chapter_1.pdf) yielding :

$$\text{Lifetime of } CH_4 = \frac{1}{3.59\times10^{-15}\ \text{cm}^3\ \text{s}^{-1}\cdot 1\times10^6\ \text{molecules cm}^{-3}} = \frac{1}{3.59\times10^{-9}\ \text{s}^{-1}} = 8.9\ \text{yr}$$

Bimolecular Gas Phase Reactions

8.9 kcal/mole **35.1 kcal/mole**
–17.8 kcal/mole **–57.8 kcal/mole**

$OH + CH_4 \rightarrow CH_3 + H_2O$ **ΔEnthalpy = –13.8 kcal/mole**

Exothermic !

$$\text{Rate of Reaction} = \frac{dCH_4}{dt} = k[OH][CH_4]$$

E_A / R ⇒ Activation Energy / Gas Constant

Arrhenius Expression for rate constant:

$$k = 2.45\times10^{-12}\times e^{-1775/T}\ \text{cm}^3\ \text{sec}^{-1}$$

A factor

Tropospheric Ozone Production (Lecture 12)

$$OH + \mathbf{CO} \rightarrow \mathbf{CO_2} + H$$
$$H + \mathbf{O_2} + M \rightarrow HO_2 + M$$
$$NO + HO_2 \rightarrow NO_2 + OH$$
$$NO_2 + h\nu \rightarrow NO + O$$
$$O + \mathbf{O_2} + M \rightarrow \mathbf{O_3} + M$$
$$\text{Net:} \quad \mathbf{CO + 2\ O_2 \rightarrow CO_2 + O_3}$$

NO & NO_2 : Emitted by fossil fuel combustion & biomass burning

$$N_2 + O_2 \xrightarrow{\text{High T}} 2\ NO$$

CO: Emitted by fossil fuel combustion & biomass burning

Complete combustion:

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$$

Extreme, incomplete combustion:

$$2\ C_8H_{18} + 17\ O_2 \rightarrow 16\ CO + 18\ H_2O$$

OH & HO_2: ???

Tropospheric Ozone Production (Lecture 12)

$$OH + \mathbf{CO} \rightarrow \mathbf{CO_2} + H$$
$$H + \mathbf{O_2} + M \rightarrow HO_2 + M$$
$$\mathbf{NO + HO_2 \rightarrow NO_2 + OH}$$
$$NO_2 + h\nu \rightarrow NO + O$$
$$O + \mathbf{O_2} + M \rightarrow \mathbf{O_3} + M$$
$$\text{Net:} \quad \mathbf{CO + 2\ O_2 \rightarrow CO_2 + O_3}$$

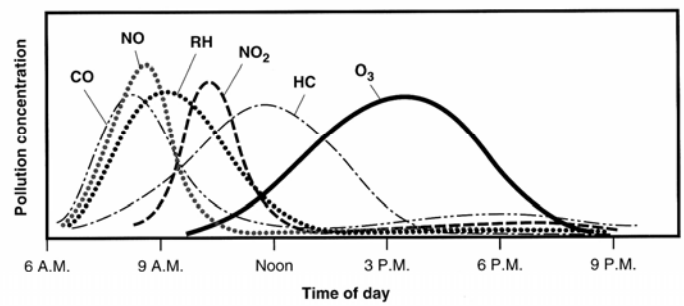


Figure 6.10 The time evolution of the principal chemical components of photochemical smog: carbon monoxide (CO), reactive hydrocarbons (RH), nitric oxide (NO), nitrogen dioxide (NO_2), hydrocarbon by-products (HC), and ozone (O_3). This behavior of the pollutants is observed during a day in a smoggy city. The sequential appearance of the pollutants is related to the timing of the emissions and rates at which CO, NO, and reactive hydrocarbons are transformed into secondary pollutants by photochemical reactions, as explained in the text.

Turco, Earth Under Siege, 1997

Tropospheric Ozone Production (Lecture 12)

$$\begin{aligned}
&CO + OH \rightarrow CO_2 + H \\
&H + O_2 + M \rightarrow HO_2 + M \\
&HO_2 + NO \rightarrow OH + NO_2 \\
&NO_2 + h\nu \rightarrow NO + O \\
&O + O_2 + M \rightarrow O_3 + M \\
\text{Net:}\quad &CO + 2\,O_2 \rightarrow CO_2 + O_3
\end{aligned}$$

$$\begin{aligned}
&RH + OH \rightarrow R + H_2O \\
&R + O_2 + M \rightarrow RO_2 + M \\
&RO_2 + NO \rightarrow RO + NO_2 \\
&RO + O_2 \rightarrow HO_2 + R'CHO \\
&HO_2 + NO \rightarrow OH + NO_2 \\
2\times\ &NO_2 + h\nu \rightarrow NO + O \\
2\times\ &O + O_2 + M \rightarrow O_3 + M \\
\text{Net:}\quad &RH + 4O_2 \rightarrow R'CHO + H_2O + 2\,O_3
\end{aligned}$$

Chain Mechanism for production of ozone

Chemical Initiation: Human emission of NO, CO and either human (RO_2) or natural (HO_2) hydrogen radicals

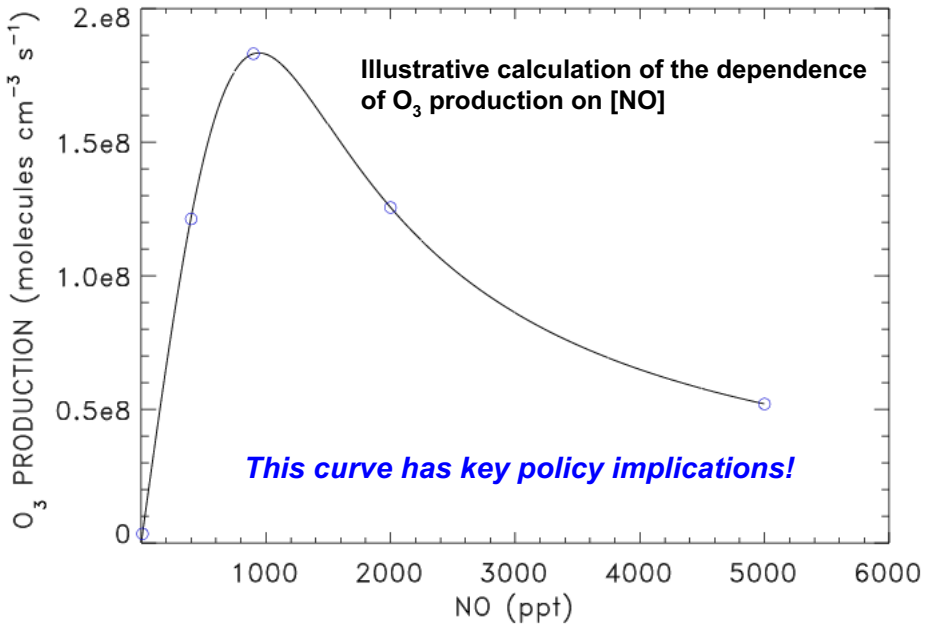
Ozone production: k[HO_2][NO]

Termination: refers to "loss of radicals" in the chain mechanism

Tropospheric Ozone Production versus NO (Lecture 12)

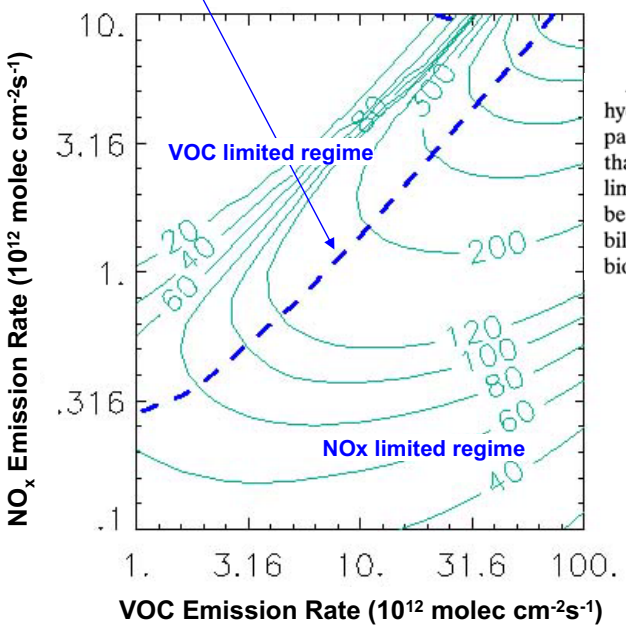
As NO_x rises:

[HO_2] falls faster than [NO] rises,
leading to a decrease in the value of the product of k [HO_2] [NO],
and hence the production rate of O_3.



Tropospheric Ozone Production versus NO_x and VOCs (Lecture 12)

Ridge: local maximum for O_3 that separates the NOx-limited regime from and VOC limited regime



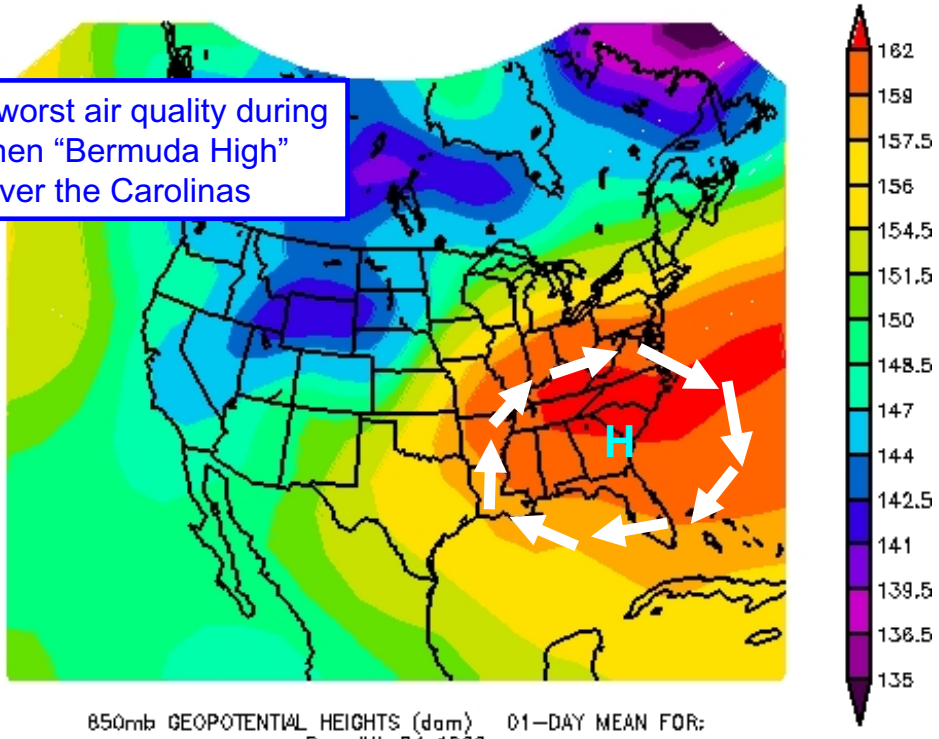
An important discovery in the past decade is that the focus on hydrocarbon emission controls to combat O_3 pollution may have been partly misdirected. Measurements and model calculations now show that O_3 production over most of the United States is primarily NO_x limited, not hydrocarbon limited. The early models were in error in part because they underestimated emissions of hydrocarbons from automobiles, and in part because they did not account for natural emission of biogenic hydrocarbons from trees and crops.

Jacob, Chapter 12, Introduction to Atmospheric Chemistry, 1999

Figure: http://www-personal.umich.edu/~sillman/ozone.htm

Day-to-day meteorology (weather!) affects severity and duration of pollution episodes

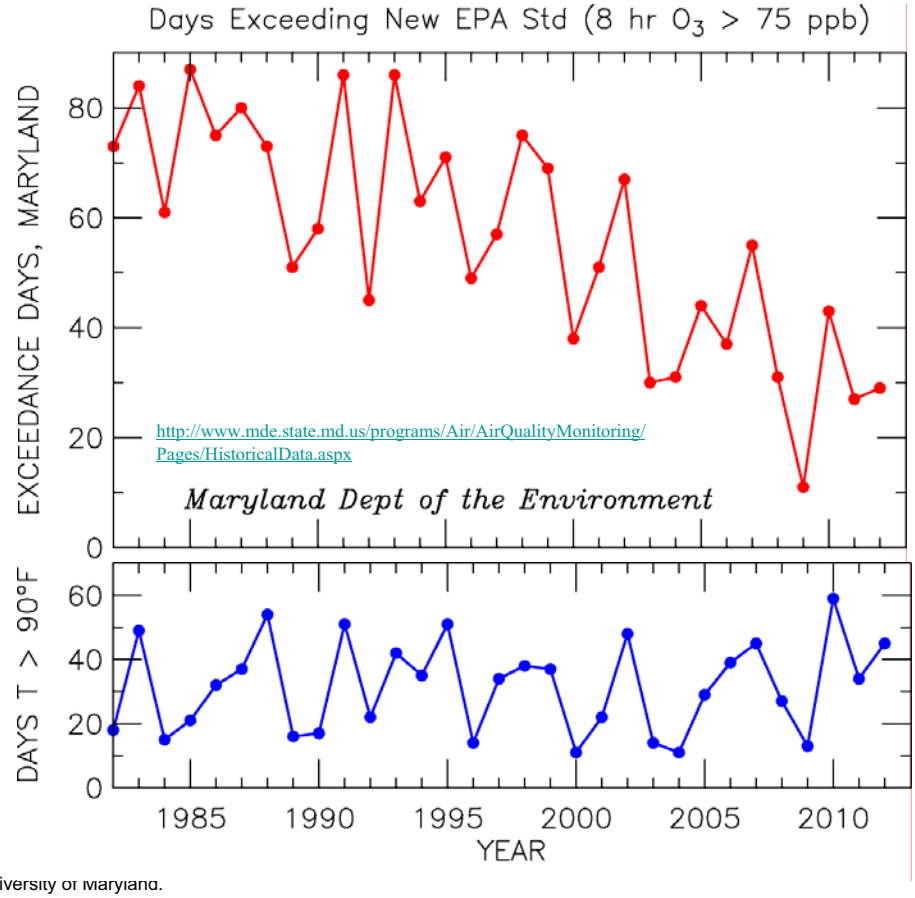
Maryland has worst air quality during summer, when "Bermuda High" sets up over the Carolinas



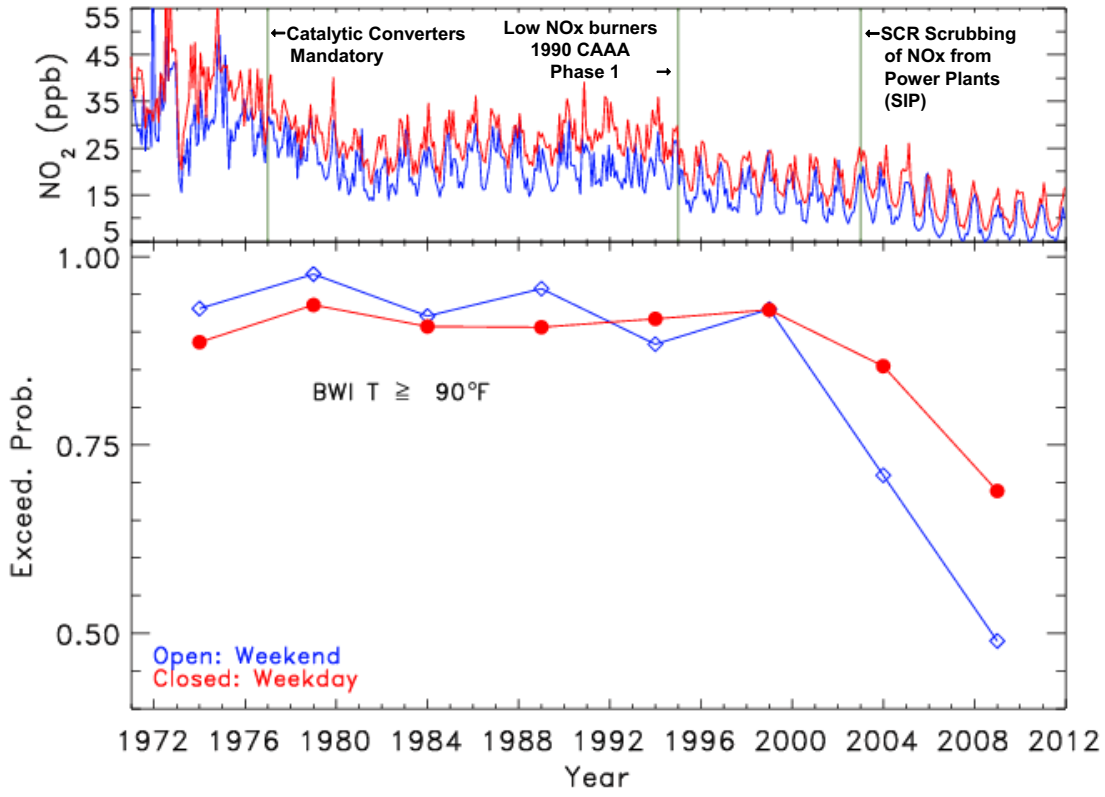
850mb GEOPOTENTIAL HEIGHTS (dam) 01-DAY MEAN FOR:
Sun JUL 04 1999
NCEP OPERATIONAL DATASET

http://www.mde.state.md.us/assets/document/BJH%20-%20Basics%20on%20Ozone%20Transport.ppt

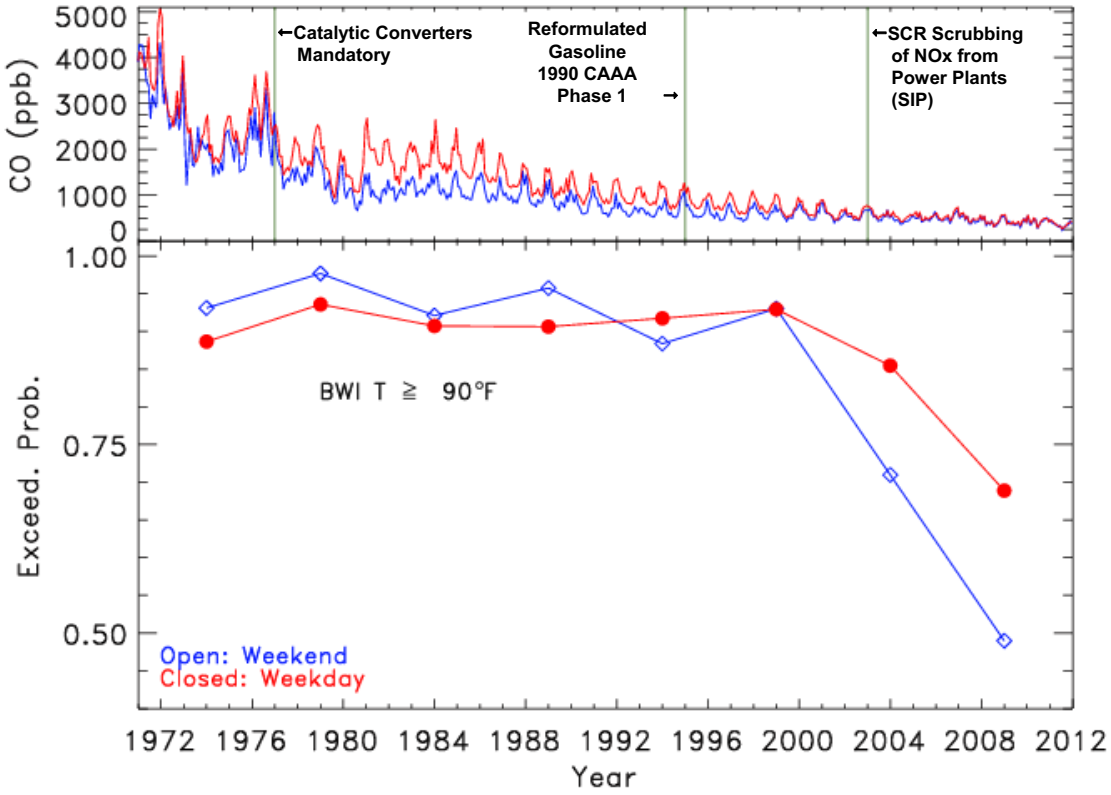
Significant Improvements in *Local* Air Quality since early 1980s



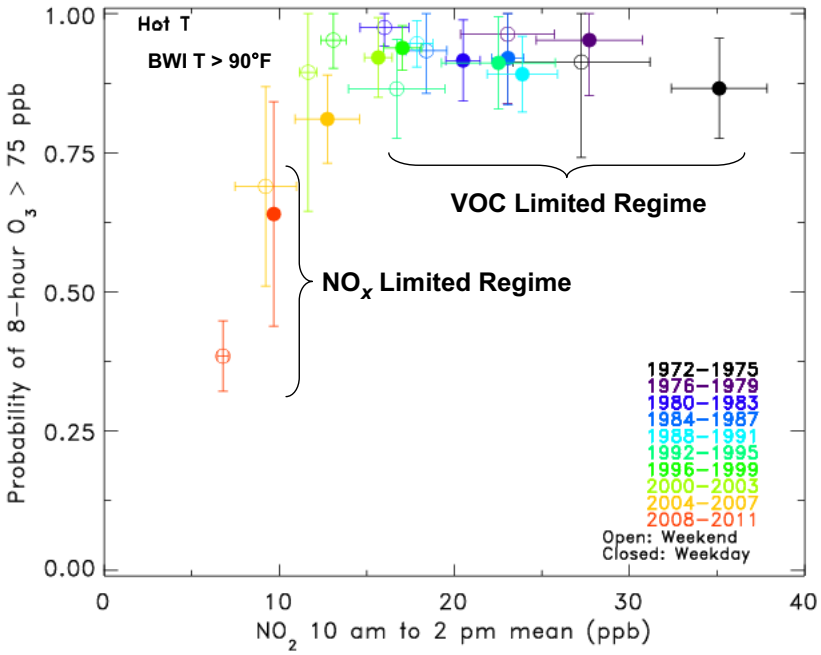
Probability of Surface O_3 Exceedance: DC, MD, and Northern VA



Probability of Surface O_3 Exceedance: DC, MD, and Northern VA



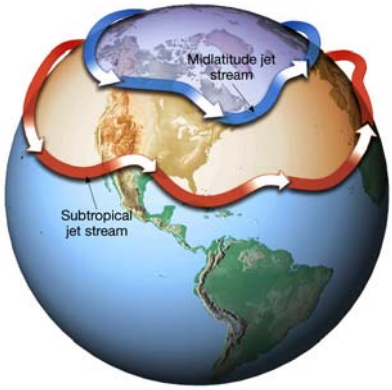
Probability of Surface O_3 Exceedance (DC, MD, No. VA) vs Daytime NO_2 Hot Summer Days (T_{BWI} > 90°F)



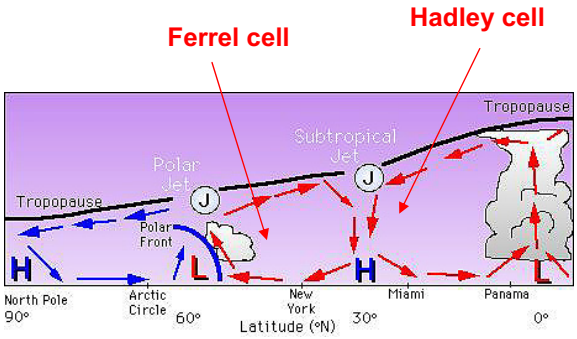
Hosley, Canty, and Salawitch, in preparation, 2013

Analysis in this framework motivated by Pusede and Cohen, ACP, 2012
http://www.atmos-chem-phys.net/12/8323/2012/acp-12-8323-2012.html

Subtropical Jet



http://www.ux1.eiu.edu/~cfjps/1400/FIG07_014A.jpg



http://www.fas.org/irp/imint/docs/rst/Sect14/jet_stream.jpg

Subtropical Jet: area where poleward descending branch of the Hadley Circulation meets the equatorward descending of the Ferrel Cell (see Lecture 3)

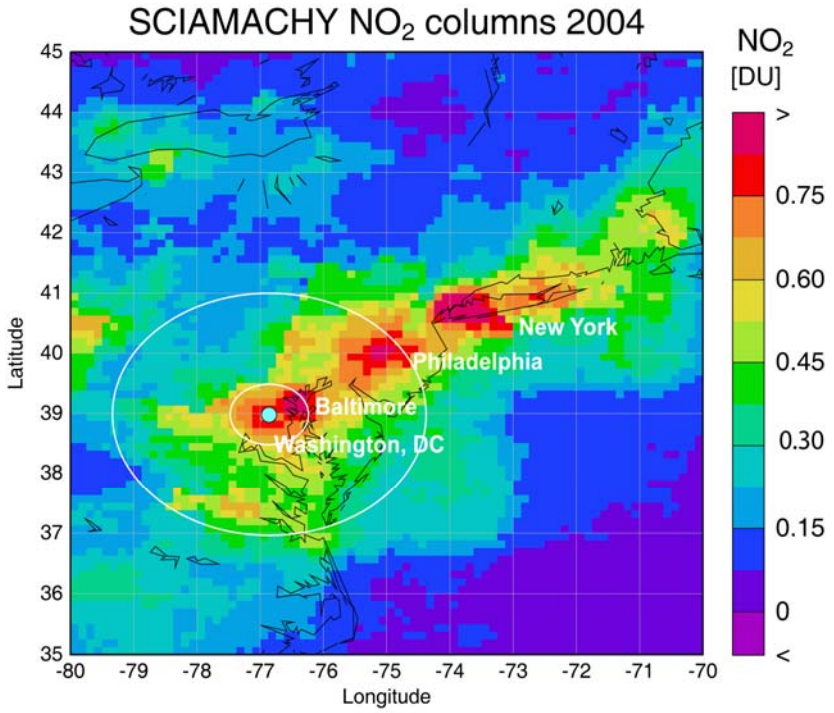
Semi-permanent area of high pressure, fair weather, low rainfall:
conditions conductive to high ozone

Climate Change and Air Pollution

Poleward expansion of the sub-tropical jet:

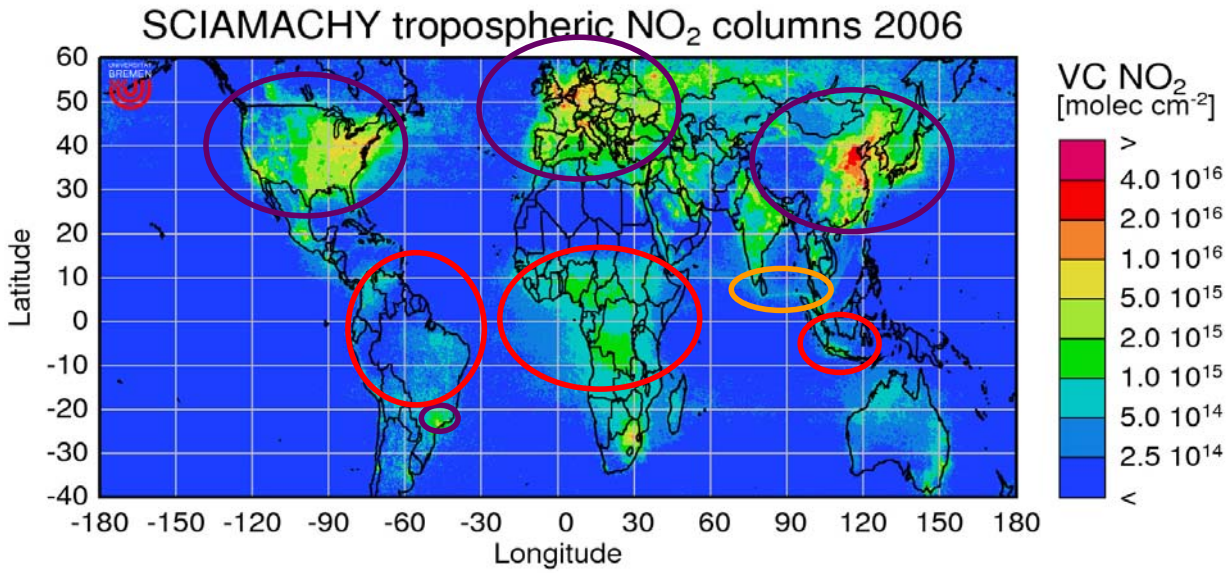
- ***Surface ozone highs occur along Subtropical Jet***
- Number of days Subtropical Jet within 150 miles of Baltimore has increased by ~50% between 1979 and 2003, due to "frontal movement" (expansion of the Hadley Cell)
- Driving force: weakening of the equator to pole temperature gradient, caused by more rapid warming at high latitudes compared to tropics

- **As a consequence, models predict increase in severity and duration of surface O_3 episodes in the Mid-Atlantic, even for constant emissions**



Tropospheric NO_2 columns derived from SCIAMACHY measurements, 2004. The NO_2 hot-spots coincide with the locations of the labeled cities.

Herman *et al.*, *NCAR Air Quality Remote Sensing from Space*, 2006



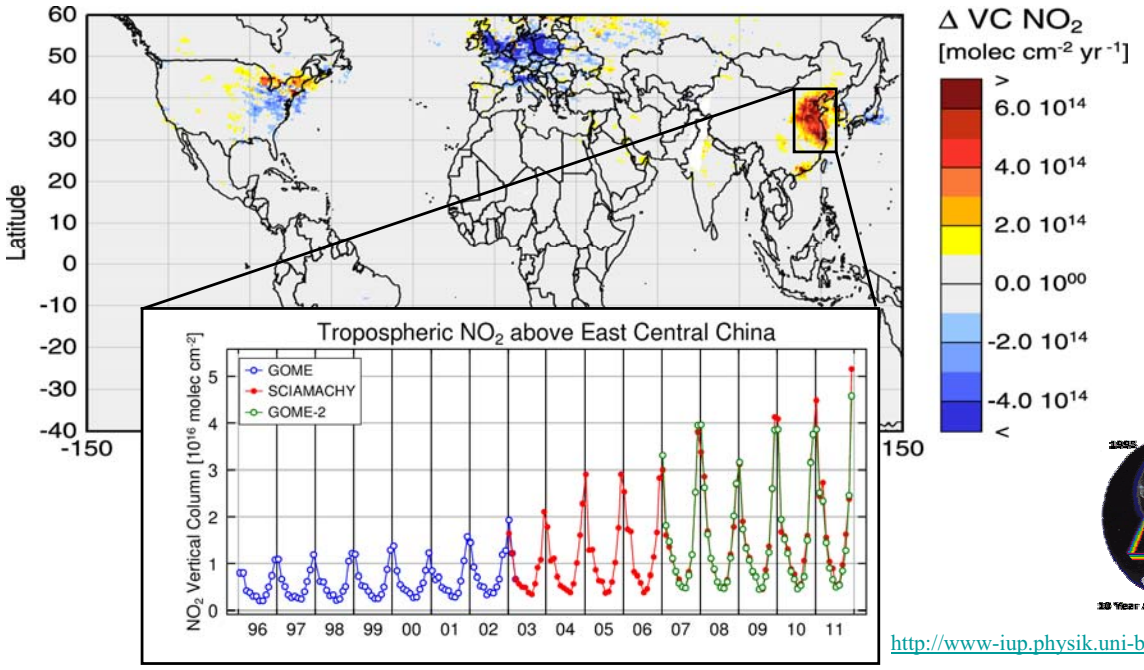
ships

anthropogenic pollution

biomass burning

http://www.doas-bremen.de/lectures/richter_nox_erca_100126.ppt

Change in tropospheric NO_2, 2002 minus 1996
GOME: Global Ozone Monitoring Instrument



http://www-iup.physik.uni-bremen.de/gome

A. Richter et al., Increase in tropospheric NO_2 over China observed from space, *Nature*, 2005

http://www.doas-bremen.de/lectures/richter_nox_erca_120203.ppt

Surface O_3: ***Temporal Transition from Local to Regional***