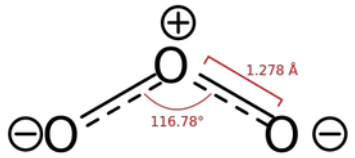
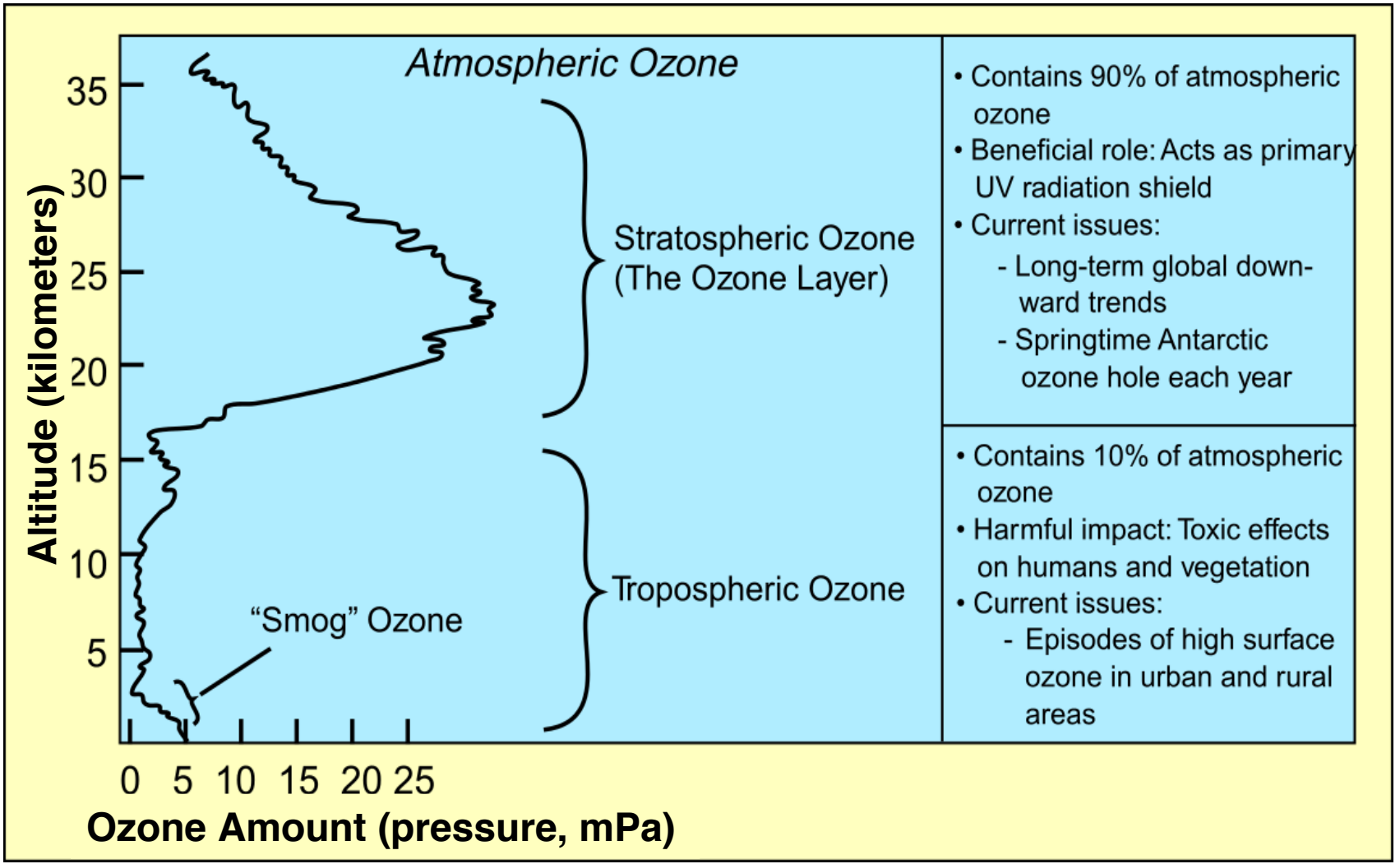
Air Quality and Ozone





For more information: Introduction to Atmospheric Chemistry, by Daniel Jacob, Edition 1, Chapter 12

Oxygen Cycle

Photosynthesis: $nCO_2 + nH_2O \xrightarrow{hv} (CH_2O)_n + nO_2$

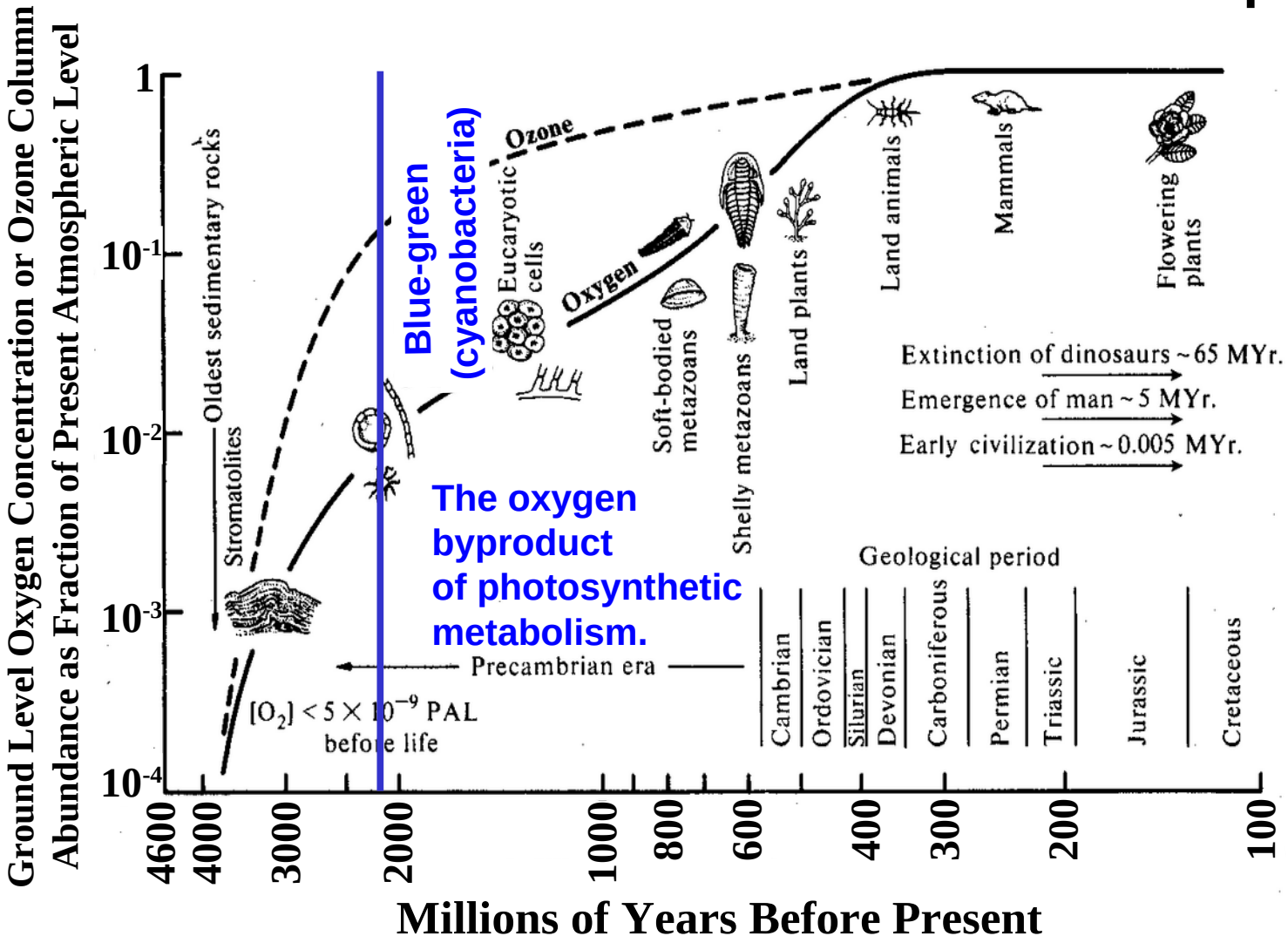
What does “n” represent?

What does *hv* represent?

What the stoichiometric representation of respiration and microbial decay?

What does M represent?

Evolution of O2 and O3 In Earth's Atmosphere



What are Algae? Has O_2 declined recently?

Original figure courtesy of Daniel J. Jacob, text added.

Photochemical Formation of Ozone From Nitrogen Dioxide

$NO_2 + h\nu \rightarrow NO + O \qquad \lambda < 430\ nm$

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

$NO + O_3 \rightarrow NO_2 + O_2$

What does M represent?

What does λ represent?

Scheme for O3 by Oxidation of Carbon in Presence of NOx

$RH + OH\cdot \rightarrow R\cdot + H_2O$

$R\cdot + O_2 + M \rightarrow RO_2\cdot + M$

$RO_2\cdot + NO \rightarrow RO\cdot + NO_2$

$RO\cdot + O_2 \rightarrow HO_2\cdot + R'CHO$

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

$2[NO_2 + h\nu \rightarrow NO + O]$

$2[O + O_2 + M \rightarrow O_3 + M]$

What does R represent?

What does R' represent?

Net: $RH + 4O_2 + 2\ h\nu \rightarrow R'CHO + H_2O + 2\ O_3$

Oxidation of Methane Mechanism: NMVOC Concentration is Low

$CH_4 + OH\cdot \rightarrow CH_3\cdot + H_2O$

$CH_3\cdot + O_2 + M \rightarrow CH_3O_2\cdot + M$

$CH_3O_2\cdot + NO \rightarrow CH_3O\cdot + NO_2$

$CH_3O\cdot + O_2 \rightarrow HO_2\cdot + CH_2O$

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

$2[NO_2 + h\nu \rightarrow NO + O]$

$2[O + O_2 + M \rightarrow O_3 + M]$

What does NMVOC represent?

Net: $CH_4 + 4O_2 + 2\,h\nu \rightarrow CH_2O + H_2O + 2\,O_3$

Carbon Monoxide Mechanism:

$CO + OH\cdot \rightarrow CO_2\cdot + H\cdot$

$H\cdot + O_2 + M \rightarrow HO_2\cdot + M$

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

$NO_2 + h\nu \rightarrow NO + O$

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

Net: $CO + 2O_2 + h\nu \rightarrow CO_2 + O_3$

Remove of Ozone

Deposition onto Earth's Surface

Photochemical Lost:

$$O_3 + h\nu \rightarrow O_2\cdot + O\cdot$$

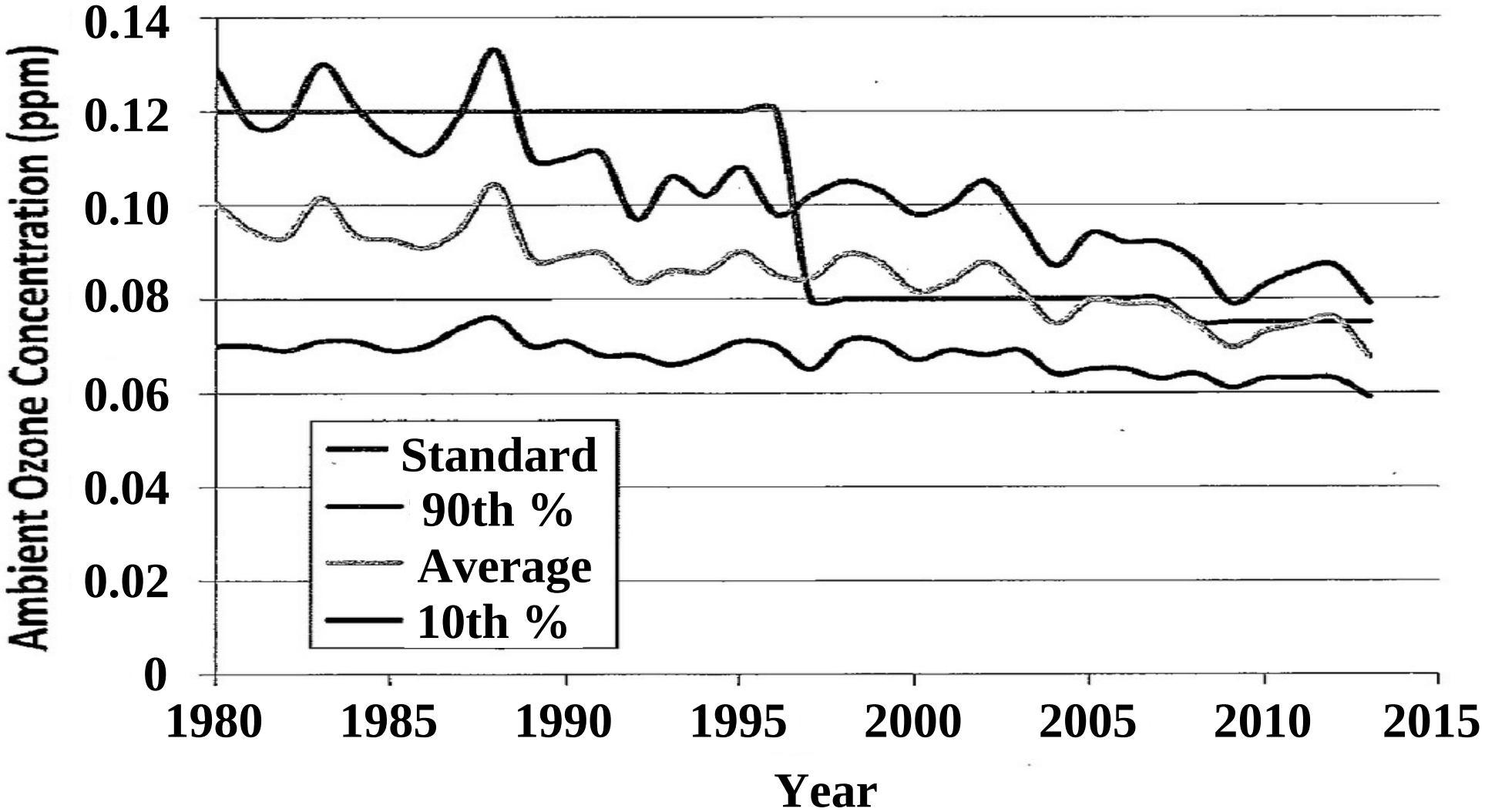
$$O\cdot + H_2O \rightarrow 2OH\cdot$$

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

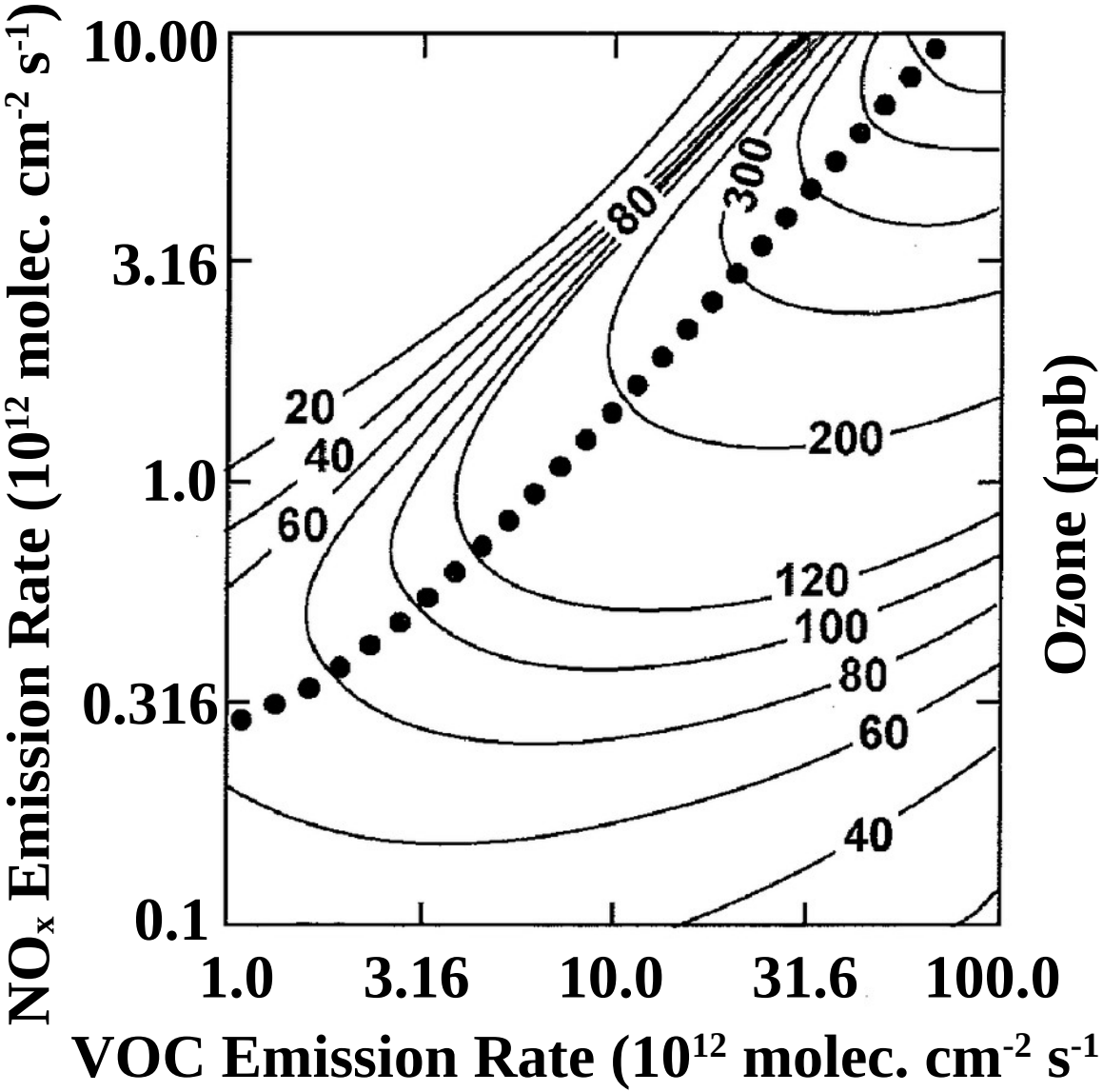
Lifetime of Ozone in Troposphere

Season	Altitude	40 ^{0}N Lat	20 ^{0}N Lat
Summer	0 km	8 days	5 days
Winter	0 km	100 days	17 days
Summer	5 km	15 days	10 days
Winter	5 km	160 days	35 days
Summer	10 km	40 days	30 days
Winter	10 km	300 days	90 days

Ambient Ozone Trend

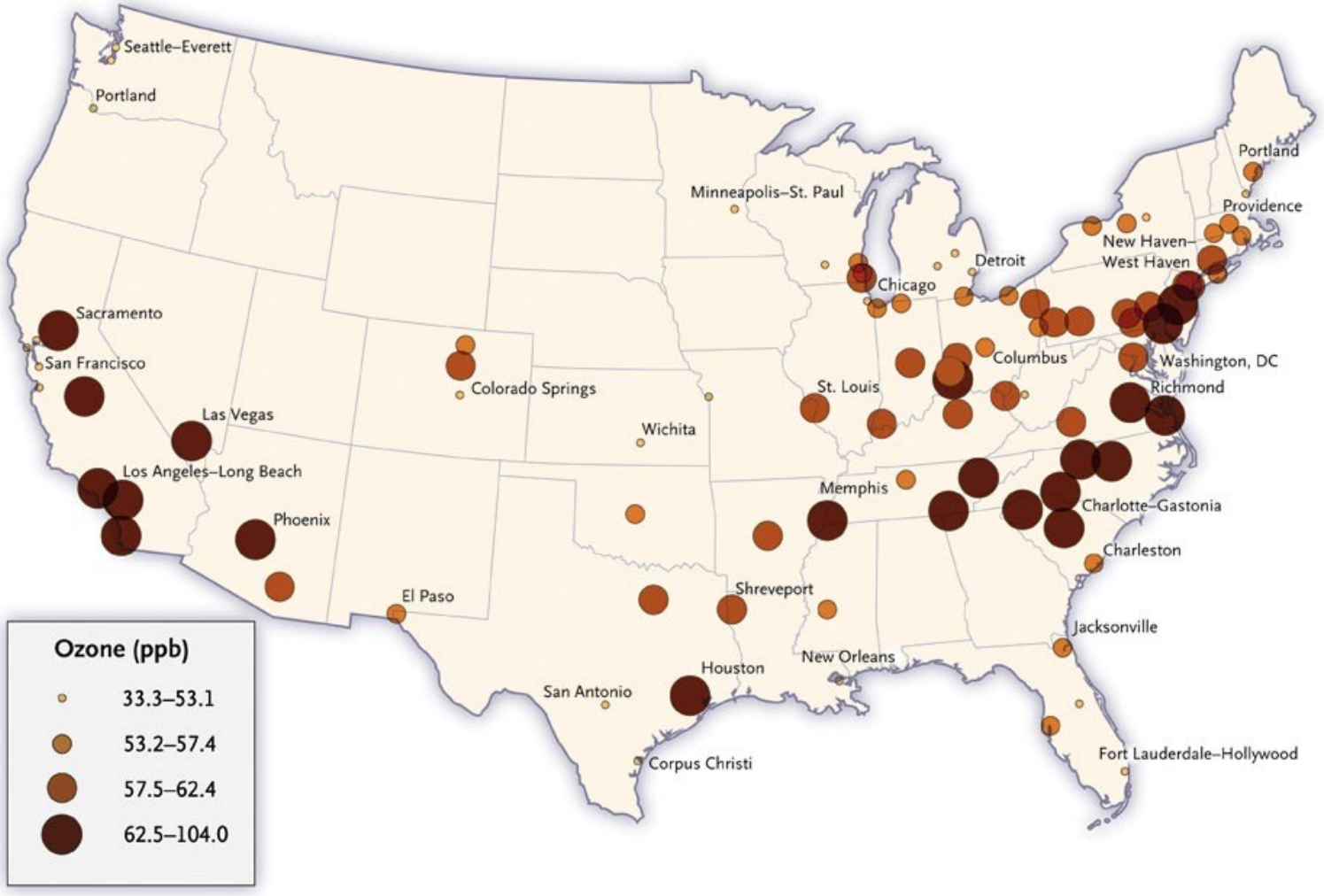


Ozone Isopleths



Ref: Air Pollution: Engineering, Science, and Policy by Steven Sternberg, Figure 12-5

Ozone Concentrations in the 96 Metropolitan Statistical Areas in Which Members of the American Cancer Society Cohort Resided in 1982

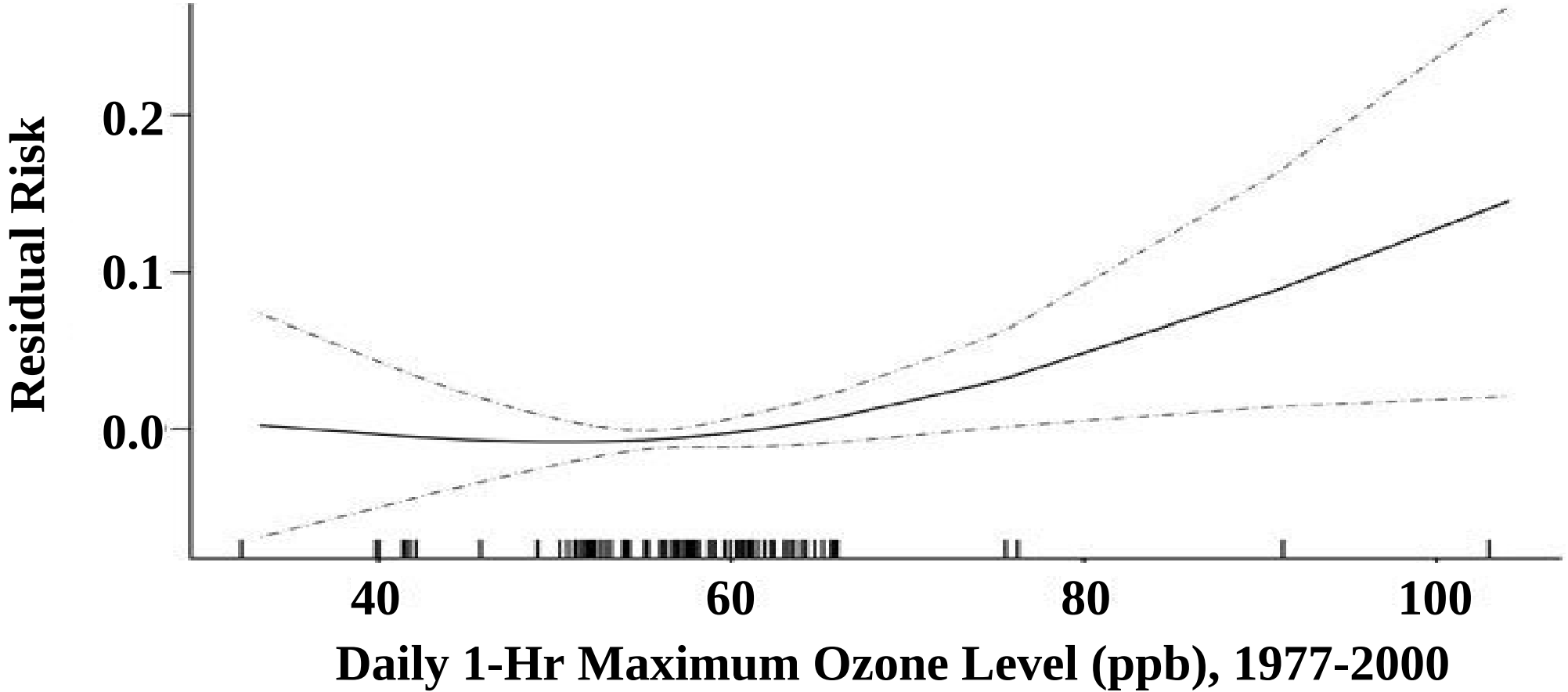


Number of Deaths in the Entire Cohort and According to Exposure to Ozone

Cause of Death	Entire Cohort	Concentration of Ozone [ppb]			
		33.3-53.1	53.2-57.4	57.5-62.4	62.5-104.0
	N=448,850	N=126,206	N=95,740	N=106,545	N=120,359
Any Cause	118,777	32,957	25,642	27,782	32,396
Cardiopulmonary	58,775	16,328	12,621	13,544	16,282
Cardiovascular	48,884	13,605	10,657	11,280	13,342
Heart Disease	27,642	7,714	6,384	6,276	7,268
Respiratory	9,891	2,723	1,964	2,264	2,940

Jerrett M et al. N Engl J Med 2009;360:1085-1095

Exposure-Response Curve



The curve is based on a natural spline with 2 df estimated from the residual relative risk of death within a metropolitan statistical area (MSA) according to a randomeffects survival model. The dashed lines indicate the 95% confidence interval of fit, and the hash marks indicate the ozone levels of each of the 96 MSAs. Ref: Jerrett M et al. N Engl J Med 2009;360:1085-1095

Summary

- Fine particulate air pollution was associated with increased morality
- Ozone Pollution:
  - Not able to detect an effect of ozone on the risk of death from cardiovascular causes when the concentration of PM2.5 was taken into account.
  - There is a significant increase in the risk of death from respiratory causes in association with an increase in ozone.