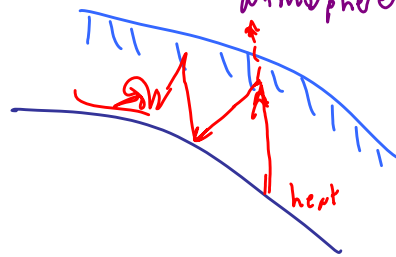**Today, we will**:
- Discuss some more terminology related to the study of air pollution
- Begin a discussion of EFs (Emission Factors) – how to estimate emissions

More terminology & Definitions

- Greenhouse gases $\equiv$ gas that alters the radiative properties of the atmosphere by trapping terrestrial infrared radiation

  eg.

  CO_2, CH_4, N_2O (nitrous oxide)

  H_2O — see HW 2

Is CO_2 a HAP? — No it is not on list of HAPs

CO_2 is not "air pollutant"

- Ozone depleting gas $\equiv$ gas that destroys ozone (O_3) in the stratosphere   eg. R-11, R-12, Freon CFC's

- O_3 is harmful to breathe in the troposphere (where we live)

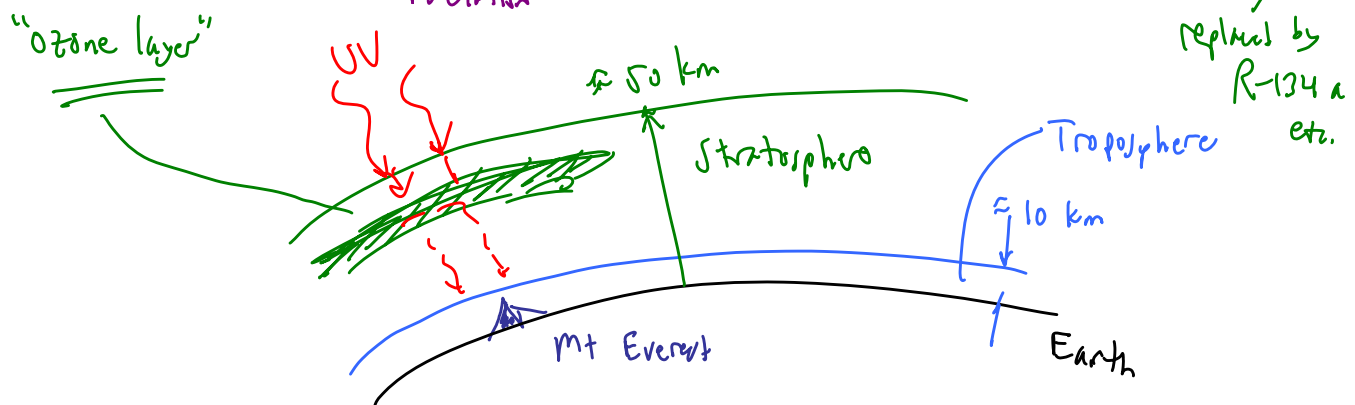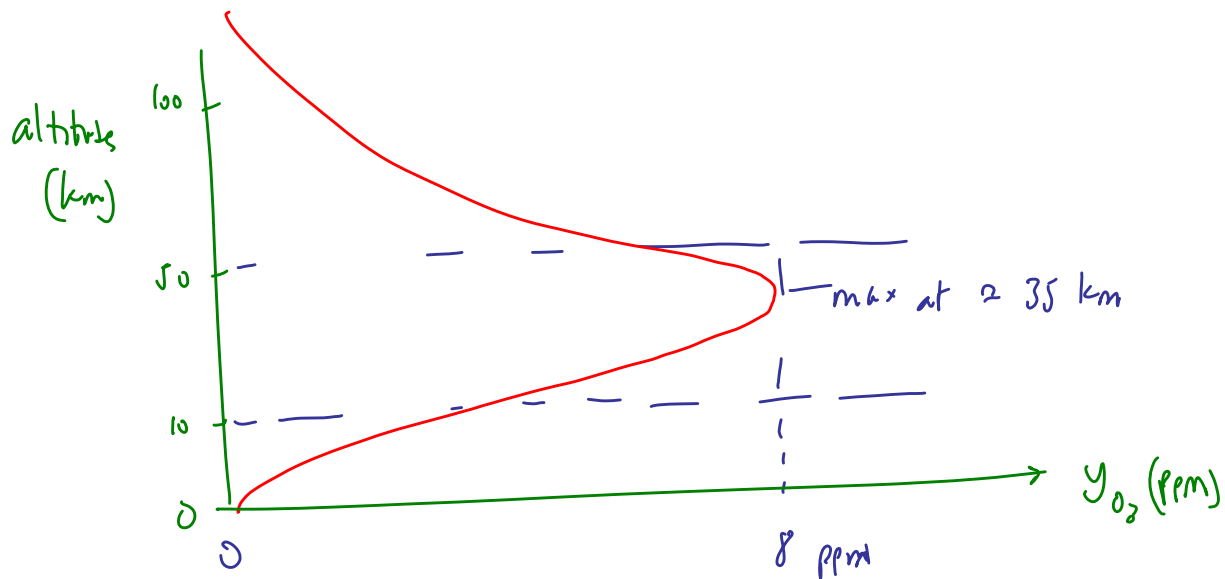- O_3 is desirable in the stratosphere → blocks harmful UV radiation

"ozone layer"

UV

≈ 50 km

Stratosphere

≈ 10 km

Troposphere

replaced by R-134 a etc.

Mt Everest   Earth

Fig 5.5 in P.i.P   Ozone levels

altitude
(km)

max at ≈ 35 km

y_{O_3} (ppm)

8 ppm

Dominant Anthropogenic sources of Air Pollutants

Pollutant	#1 Source	#2 Source
CO (carbon monoxide)	On-road vehicles (cars & trucks)	off-road vehicles (trains, planes, construc eq.)
NO_x (all nitrogen-oxygen) NO, NO_2, N_2O, etc	Power plants (on-road + off-road vehicles together would be #1)	On-road vehicles
VOC_s (volatile organic compounds)	Solvents like paint	On-road vehicles
SO_2 (sulfur dioxide)	Power plants (coal & oil)	Other industrial processes
PM_{10} (particle, $2.5 < D_p < 10 \mu m$) (coarse particles)	Fugitive dust from roads	Fugitive dust from construction /mining
$PM_{2.5}$ ($D_p < 2.5 \mu m$) "fine"	Industry (chemical plants)	Vehicles

Emission Factors (EFs)

Emission factors are a quick and dirty way to estimate emissions of air pollutants from various activities or manufacturing processes.

Definition of **Emission Factor**:

$$EF = \frac{\text{mass of contaminent emitted} \quad ^a}{\text{mass of raw material used or product produced}}$$

- Typical units are kg/Mg, but sometimes other units like mg/cigarette (for a particular product), kg/m^2 (for evaporation of liquid solvents), kg/mile (for auto emissions), etc.
- EPA publishes EFs in document AP-42, so EFs are often called "**AP-42 Emission Factors**".
- Sometimes EF is called **Emission Index**, **EI**, particularly for fuel combustion and power production.
- See EPA website www.epa.gov/ttn/chief.
- **CHIEF** = ClearingHouse for Inventories and Emission Factors.
- EFs are "ballpark" estimates for "back of the envelope" calculations – typically good to only one or two significant digits.
- EFs are listed for ***uncontrolled emissions*** (no APCS used), but sometimes also list emissions with some APCS used (**APCS = Air Pollution Control System**).

(Sometimes are listed also with some common APCS's)

- If no APCS, use EF directly to estimate emissions

- If an APCS is used, define

$$\boxed{E = \text{removal efficiency of the APCS}}$$

(Some texts use η
EPA w/os ER
(emission reduction))

notation of Phelan & Phelan

E is removal efficiency, so the emitted portion is $1-E$

$$\boxed{m_{\text{discharged}} = (1-E)\, m_{\text{generated}}}$$

rates

$$\boxed{\dot{m}_d = (1-E)\, \dot{m}_g}$$

Estimate $m_{\text{generated}}$ from the EF

E.g. if E = 90%, only 10% of the generated pollutant is actually emitted to the atmosphere

Example EFs ⟶ See EPA CHIEF website

⟶ " Appendix from Heinsohm & Cimbala

(Indoor Air Quality)

On Links tab of our course website

Example, Open Hearth Furnace (OHF) for steel production.

Source	Units	Emission Factor		EMISSION FACTOR RATING	Particle Size Data
Open hearth furnace					
Melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled		10.55	(21.1)	D	Yes
Controlled by ESP		0.14	(0.28)	D	Yes
Roof monitor		0.084	(0.168)	C	

Example, Basic Oxygen Furnace (BOF) for steel production.

Basic oxygen furnace (BOF)					
Top blown furnace melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled		14.25	(28.5)	B	
Controlled by open hood venter to:					
ESP		0.065	(0.13)	A	
Scrubber		0.045	(0.09)	B	

Electrostatic precipitator

$$EF = 14.25 \frac{kg}{Mg} \text{ of particulate air pollution}$$

meaning ⟶ 14.25 kg of particulate air pollution are emitted by a BOF for every Mg of steel produced

Example: Emission Factors

Given: A steel mill has an open hearth furnace with which it does melting and refining. The furnace refines about 8 tons of steel per hour on average. (rate) $\dot{m}$

To do: Estimate the uncontrolled emission rate of particles in kg/hr.

Solution: First we look up the EF of particle emissions in an open hearth furnace: EF = 10.55 kg/Mg.

$$EF$$
$$\downarrow$$

$$\dot{M}_{particles} = 8 \frac{tons\ steel}{hr} \cdot \frac{10.55\ kg\ particles}{Mg\ steel} \left(\frac{2000\ lbm\ steel}{1\ ton\ steel} \right) \cdot \left(\frac{1\ kg\ steel}{2.205\ lbm\ steel} \right)$$

$$\cdot \left(\frac{1\ Mg\ steel}{1000\ kg\ steel} \right) = 76.55\ \frac{kg}{hr}$$

or $\boxed{77\ \frac{kg}{hr}}$

Most of these EF problems are good to only 1 or 2 significant digits. Let's typically give answers to 2 sig. digits

This is a typical example of how to use EFs