Relating to Sec 2.6 – a "back of the envelope" calculation (upper limit for evaporation rate)

- evaporation is energy limited – need 2.5 MJ/kg to supply the needed latent heat
- supply rate cannot (naturally) exceed the "solar constant", S_0=1365 J s^{-1} m^{-2} (Sec 5.8)
- upper limit:

$$E = \frac{1365 \ J \ m^{-2} \ s^{-1}}{2.5 \times 10^{6} \ J \ kg^{-1}} = 5 \times 10^{-4} \ kg \ m^{-2} \ s^{-1}$$

- challenge: given that the density of liquid water ρ_w= 1000 kg m^{-3}, express this estimate of evaporation in the unit [mm/day]

$$\hat{E} = \left[\frac{kg \ m^{-2} \ s^{-1}}{kg \ m^{-3}} = m \ s^{-1} \right]$$

$$\hat{\hat{E}} \ [mm/dy] = \frac{E \times 3600 \times 24}{\rho_w} \simeq 40$$

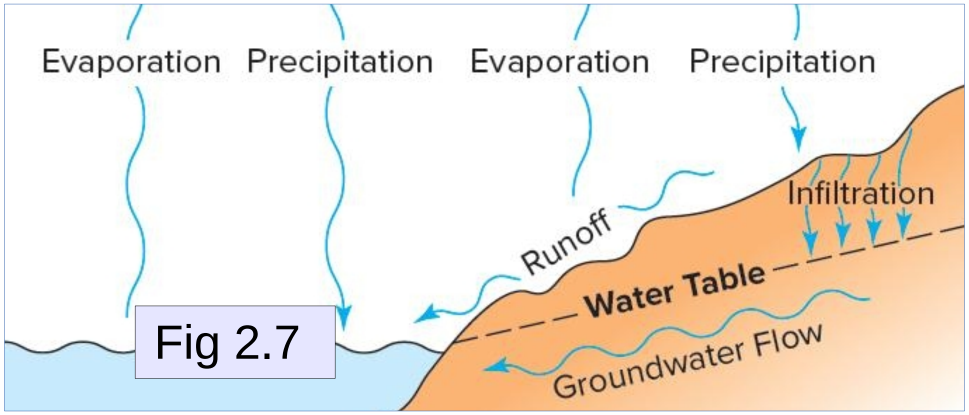
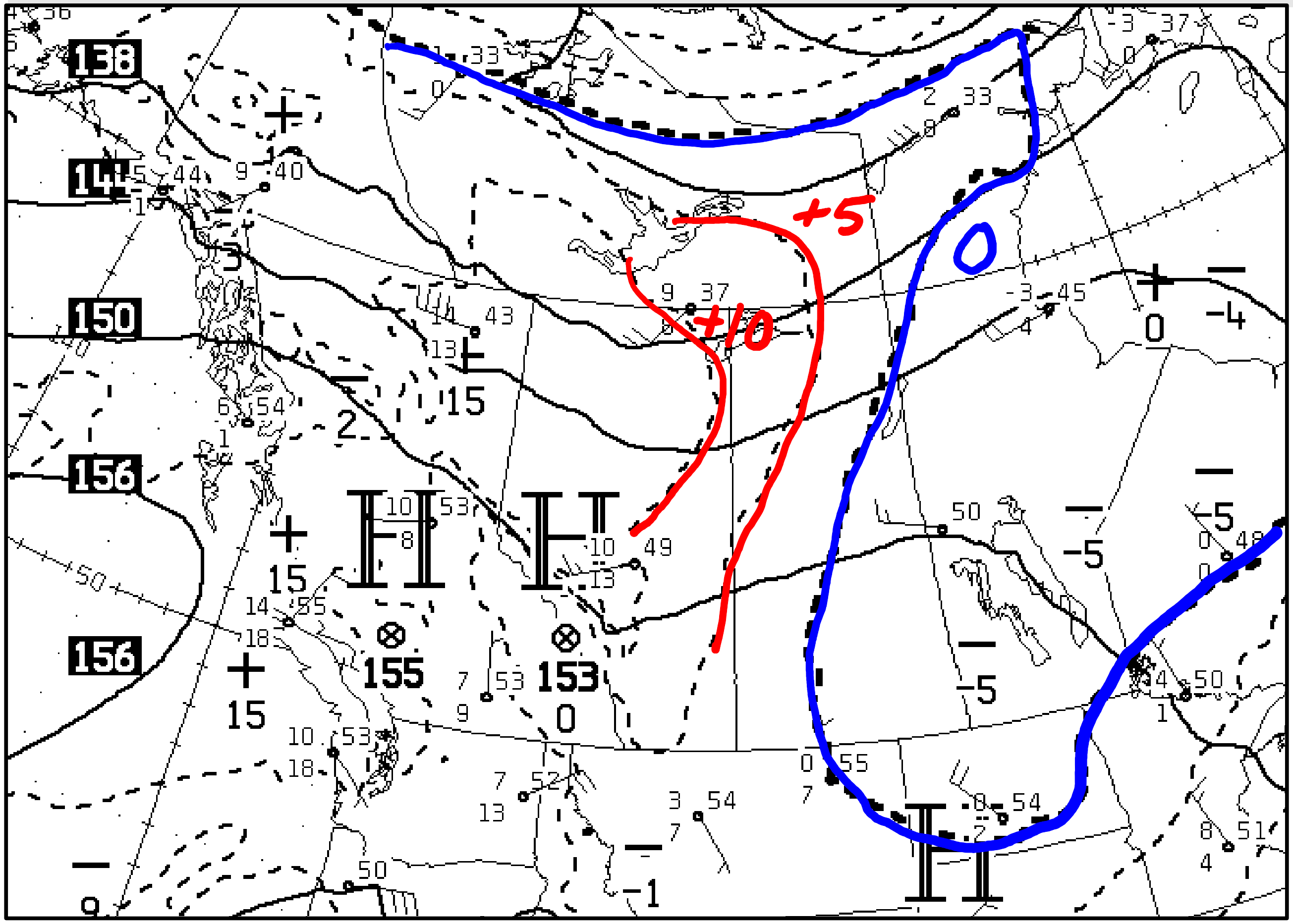


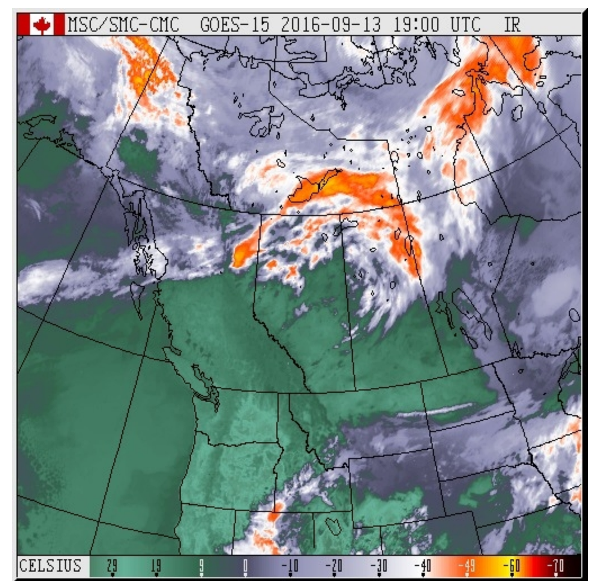
Fig 2.7

CMC 850 hPa analysis (cropped) valid 12Z Tues. 13 Sept. 2016 (6 am MDT)



- height of the 850 hPa "isobaric surface" over Edmonton is 149 dam ASL
- solid lines height contours
- WNW wind pushing milder air towards the east
- dashed lines are isotherms
- heavy dashed line is 0^{o}C, and here it identifies a mass of colder air that has been blown eastward (a couple of days back it was over Alberta)

SIGNIFICANT WEATHER DISCUSSION ISSUED BY THE PRAIRIE AND ARCTIC STORM PREDICTION CENTRE OF ENVIRONMENT CANADA AT 7:00 AM CDT TUES. SEPT. 13 2016.... WESTERN PRAIRIES... BUILDING UPPER RIDGE WILL PUSH WARMER AIR AND CLOUD OVER THE PROVINCE.



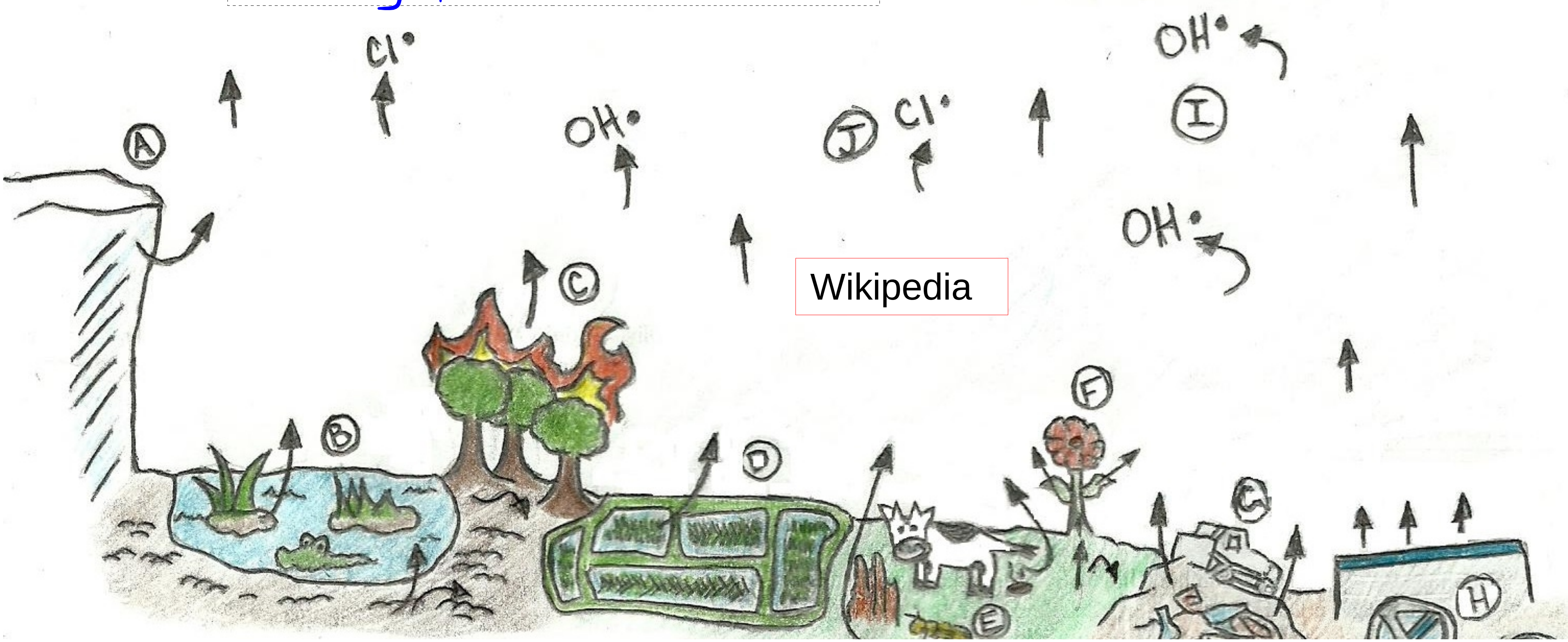
Sources of methane:

- Wetlands z anaerobic decay
- Forest fires, biomass burning
- Rice cultivation
- Ruminent digestion, termites
- Landfill decay
- Wastewater, sewage
- Melting permafrost

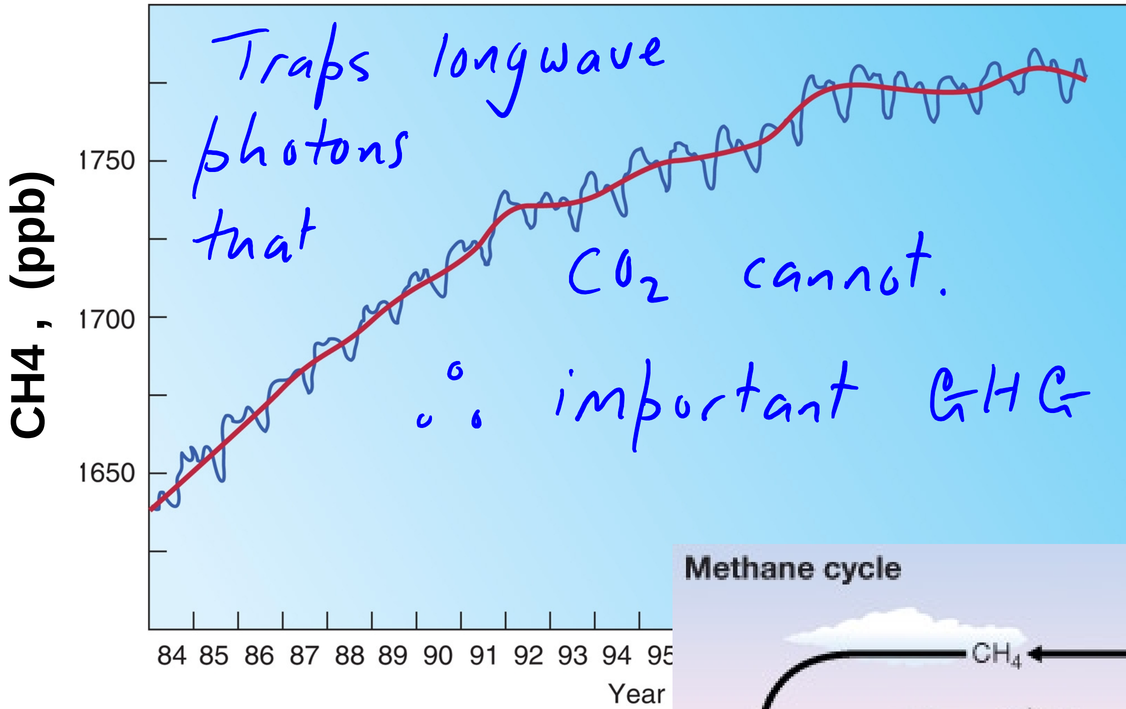
Sinks of methane:

- Reactions with atmosph. OH^-, and Cl^-
- Soil methanotrophic bacteria

- $\tau_{CH_4} \approx 10$ yr



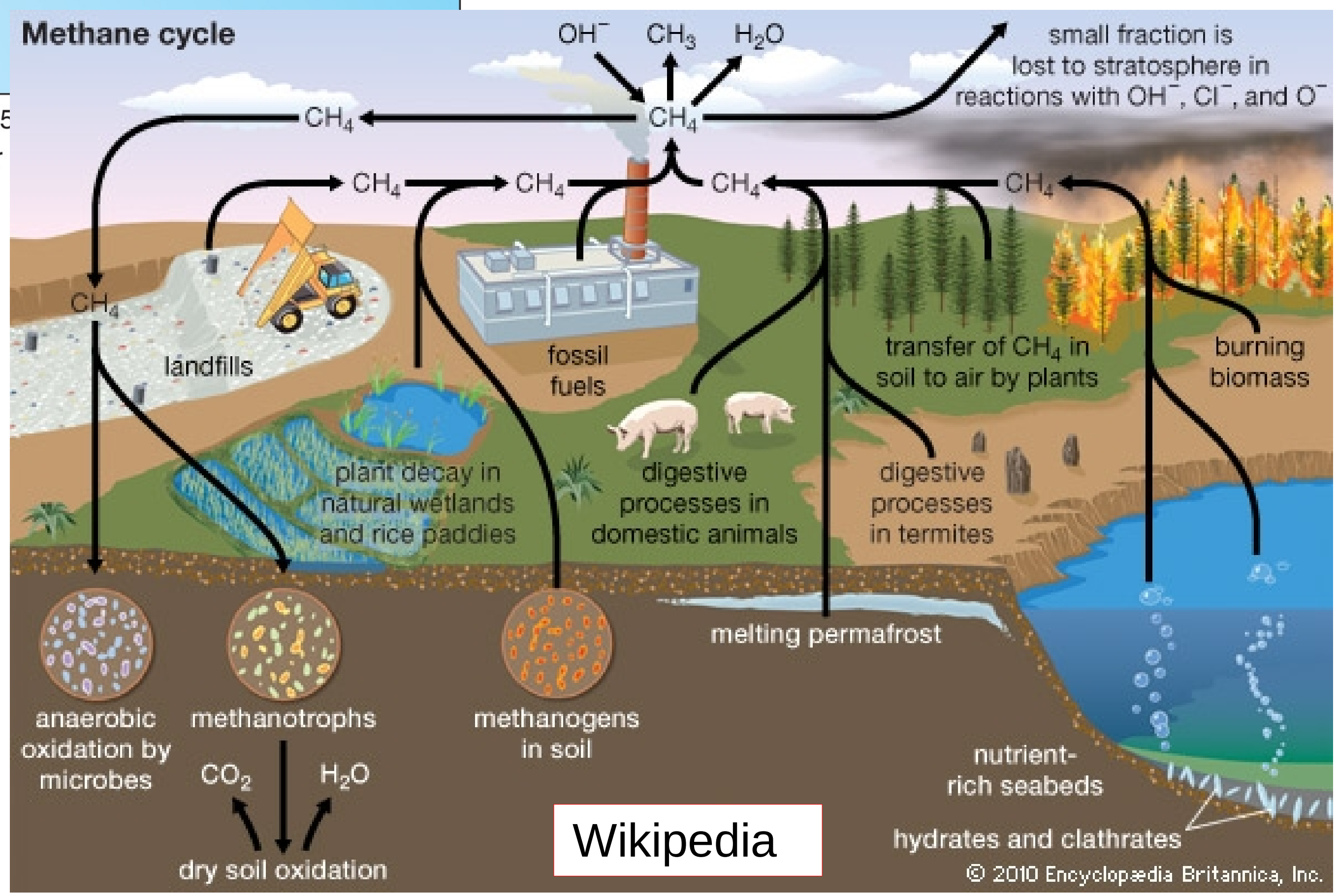
Wikipedia



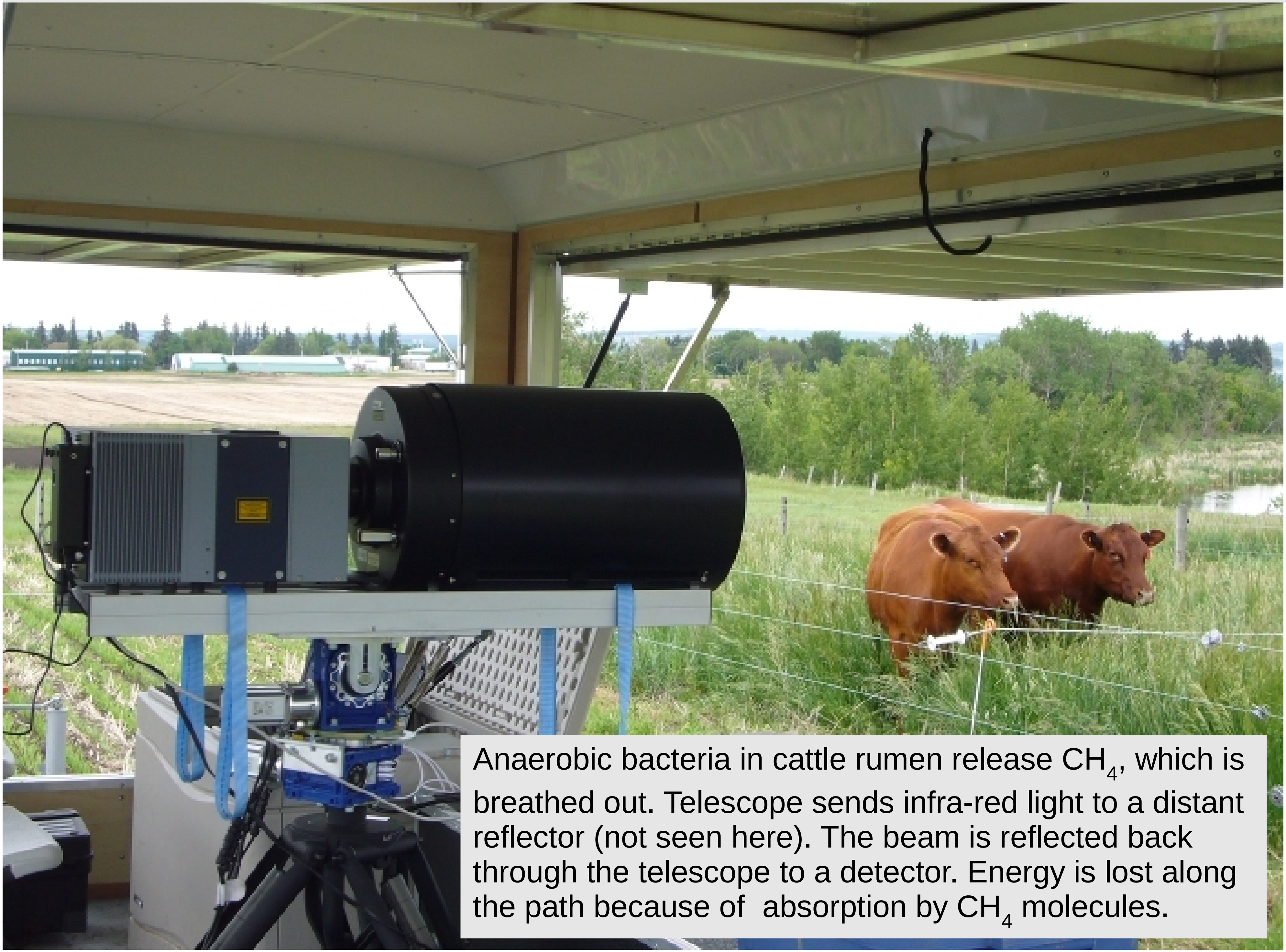
Specific chemical energy content of methane:
55.6 MJ kg^{-1}. Recall 1 kg of water vapour stores 2.5 MJ of latent heat.

Why don't we consider methane to be a fuel for atmospheric motion?

Water releases energy on phase change, but CH_4 has to burn.
"Lower flammability limit" is 4.5% (45000 ppm) at 25°C, 10^5 Pa



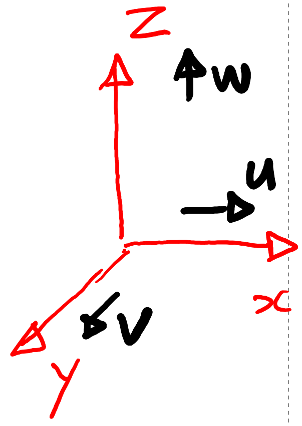
Measuring CH4 emission from cattle, Lacombe (Ab.), 2013 (EAS team)

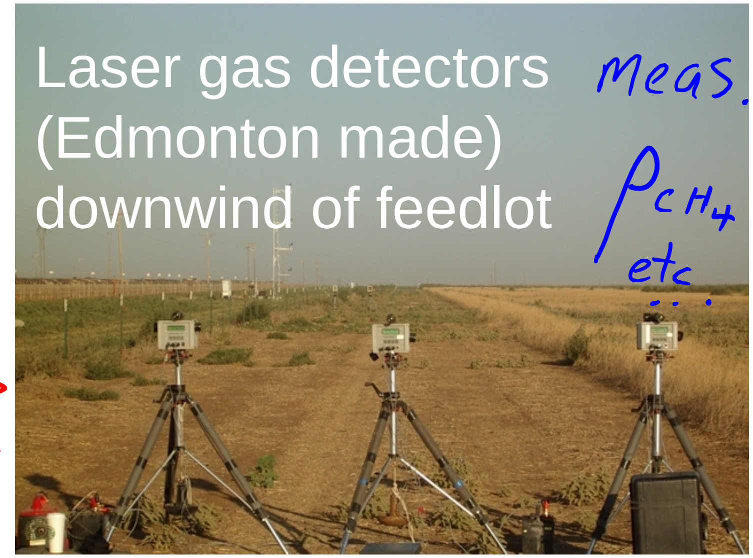


Anaerobic bacteria in cattle rumen release CH_4, which is breathed out. Telescope sends infra-red light to a distant reflector (not seen here). The beam is reflected back through the telescope to a detector. Energy is lost along the path because of absorption by CH_4 molecules.

"3D sonic anemometer"

Measures temperature plus all 3 wind components (u, v, w) at 20 Hz





Inverse dispersion**

Use atmospheric transport model to deduce the value of source strength best explaining observed concentration.

**atmospheric "dispersion" is the term used for mixing of atmospheric constituents (also, but less properly, sometimes called "atmospheric diffusion")

- absorbs solar uv radiation (uv band 0.1 – 0.4 μm) shorter than 0.3 μm
- absorbs and re-radiates terrestrial (thermal) (longwave) (infrared) radiation, i.e. is a GHG
- pollutant

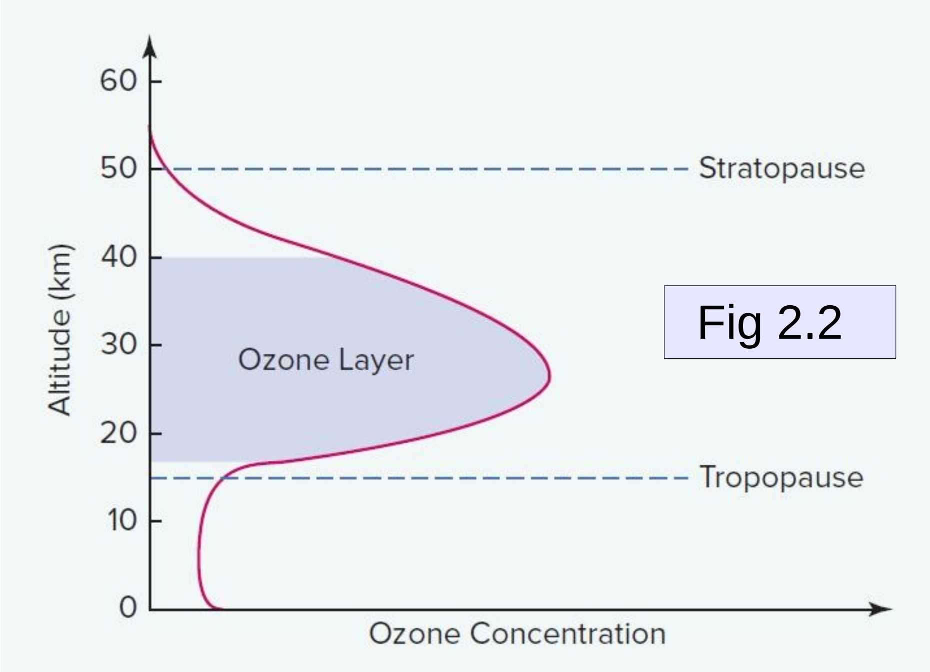


Fig 2.2

Two step photo-production

$$O_2 + uv \rightarrow O + O \quad \text{(uv: 0.1-0.2 μm)}$$

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

(entails collision; *M* any other gas, carries away kinetic energy, heating the atmos.)

Photodestruction

$$O_3 + uv \rightarrow O + O_2 \quad \text{(uv: 0.2-0.3 μm)}$$

Why is ozone concentrated above the tropopause?

Need high uv load

Low enough that gas density permits collisions.

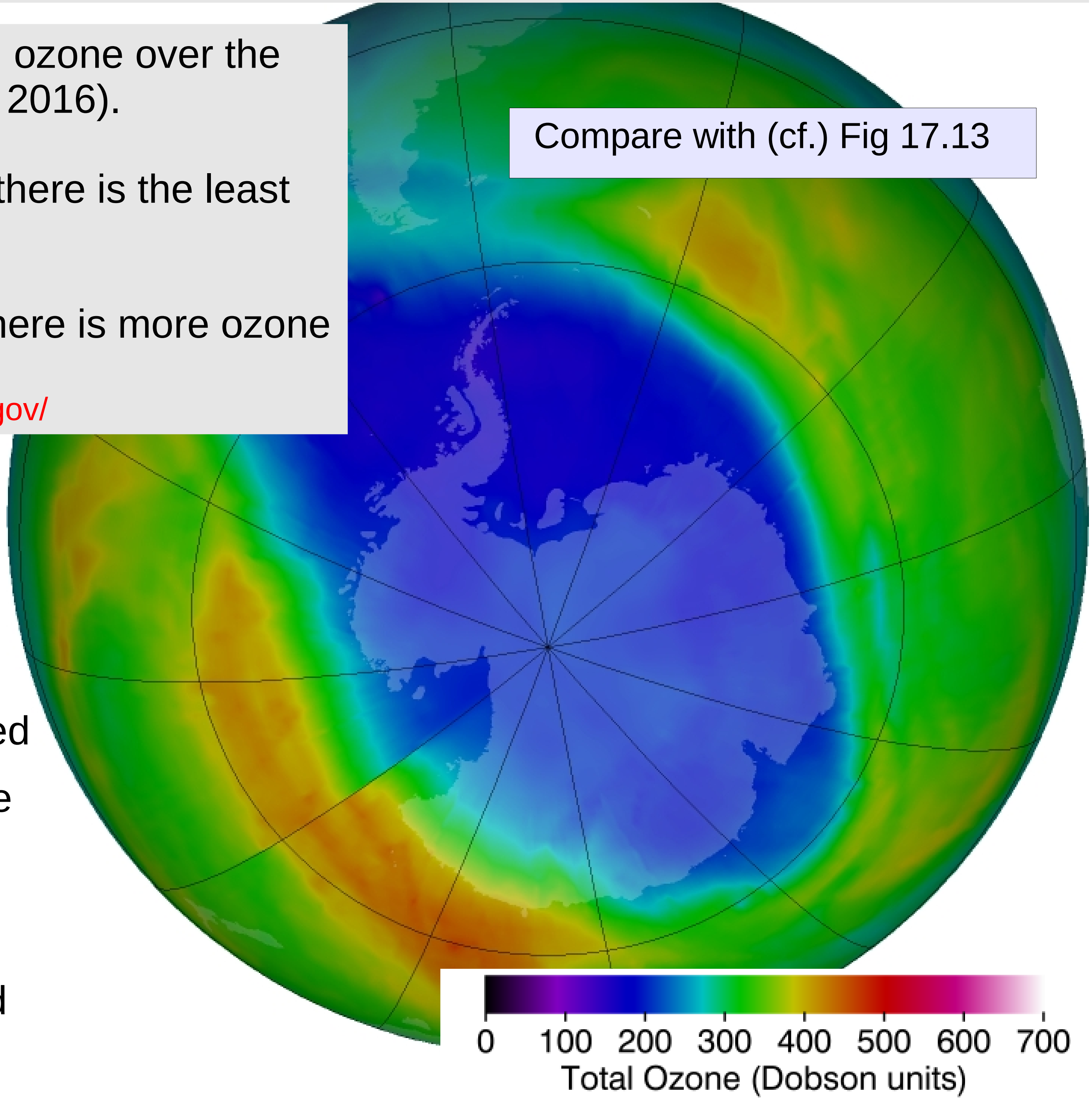
False-color view of total ozone over the Antarctic pole (11 Sept. 2016).

Purple and blue where there is the least ozone

Yellow and red where there is more ozone

http://ozonewatch.gsfc.nasa.gov/

Compare with (cf.) Fig 17.13



300 DU – if all ozone molecules were collected as a layer of pure ozone adjacent to ground (at standard temp. & press.), that layer would be 3 mm thick

Sources: Primary aerosols

Evaporating ocean spray; dust, spores, pollen, bacteria, volcanoes.

Combustion, mining, agriculture

Roles of aerosols:

① Cloud condensation nuclei (important in cloud processes)

② Scatter and absorb rad.

Marine Air

$< 10^3$ cm^{-3}

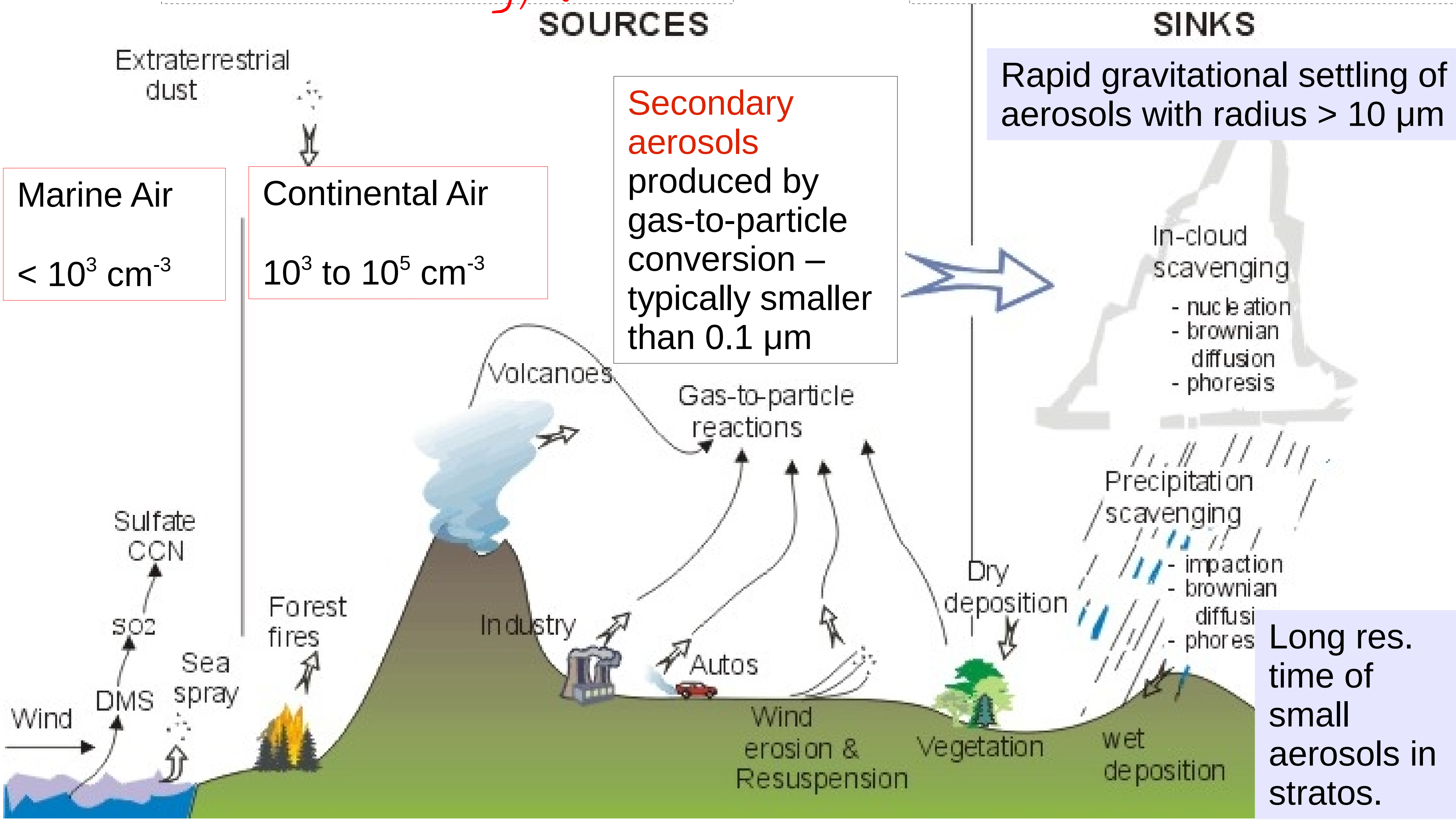
Continental Air

10^3 to 10^5 cm^{-3}

Secondary aerosols produced by gas-to-particle conversion – typically smaller than 0.1 μm

Rapid gravitational settling of aerosols with radius > 10 μm

Long res. time of small aerosols in stratos.



Salient differences & similarities in relation to terrestrial and Martian atmospheres

Characteristic	Earth	Mars	Comment
Composition	78% N_2 , 21% O_2	95% CO_2 , 2.7% N_2	
Surface pressure P_0	~ 10^5 Pa = 1000 hPa	~700 Pa = 7 hPa	(Mars: large seasonal variation)
Annual global mean T_{sfc}	~ 15°C	~ -53°C	
Distance D from sun	150 x 10^6 km	228 x 10^6 km	
Solar constant S_0	1365 W m^{-2} (p105)	591 W m^{-2}	$S_0 \propto 1/D^2$, see Eq 5.10
Radius	6371 km	3390 km	
Daylength [earth hrs]	24	24.66	
Gravitational accel'n g	9.81 m s^{-2}	3.71 m s^{-2}	
Surface density [kg m^{-3}]	$\rho \sim \frac{10^5}{287 \times 300} \sim 1$	$\rho \sim \frac{700}{189 \times 220} \sim 0.02$	$\rho = \frac{P}{R_d\ T}$, Eq 3.6
Specific gas const. R_d	287 J kg^{-1} K^{-1}	189 J kg^{-1} K^{-1}	(dry air / pure CO_2)

Lecture of 14 Sept.

- the methane cycle; measuring methane production
- conventional symbols for the 3 velocity components of the wind; existence of very distinct methodologies for measuring (or inferring) fluxes
- roles of ozone; its production/destruction
- sources, and roles, of aerosols
- comparison of Earth versus Mars (you may later like to compare their values for the specific heat capacity of their "air" and the implied adiabatic lapse rate (neither of which we have as yet defined). The Phoenix mission observed water-ice clouds in the Martian boundary layer, so there is "weather" on Mars)