Today's main topic: biogeochemical cycles of O_2 , CO_2 and H_2O

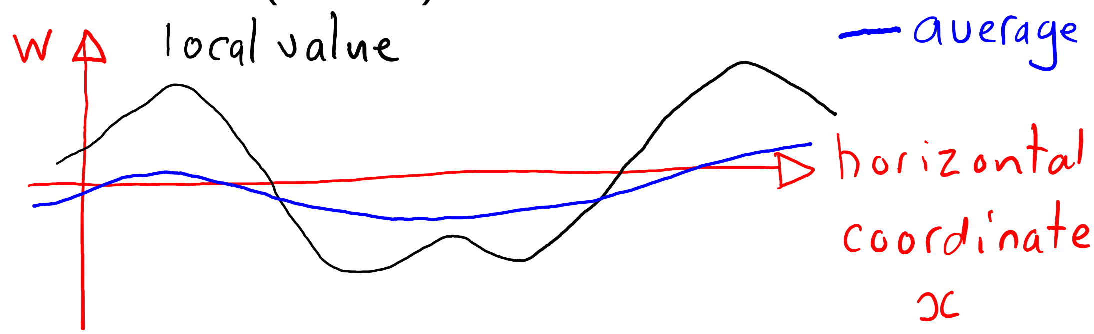
But first – what is "synoptic meteorology"? Why is the pressure field so important to meteorologists? Why the fixation on isobars (or height contours)? What do they tell us?

- Synoptic scale meteorology – concerns "smoothed" pattern of weather variables * that are averages over areas of order 30 km x 30 km or larger, i.e. omitting local detail

a large vertical velocity on the synoptic scale would be 0.1 m/s

- Contemporary weather models – considered "mesoscale" models because they resolve the atmosphere with a "resolution" of about 10 km or finer (2.5 km)... but these are still smoothed fields

* e.g. vertical wind velocity



- Pressure controls the horizontal wind

- Horizontal wind "advects" warmer or colder air (that may be drier or more humid, etc.)

- Horizontal wind also controls the (synoptic scale) vertical wind, thus, cloud and precip

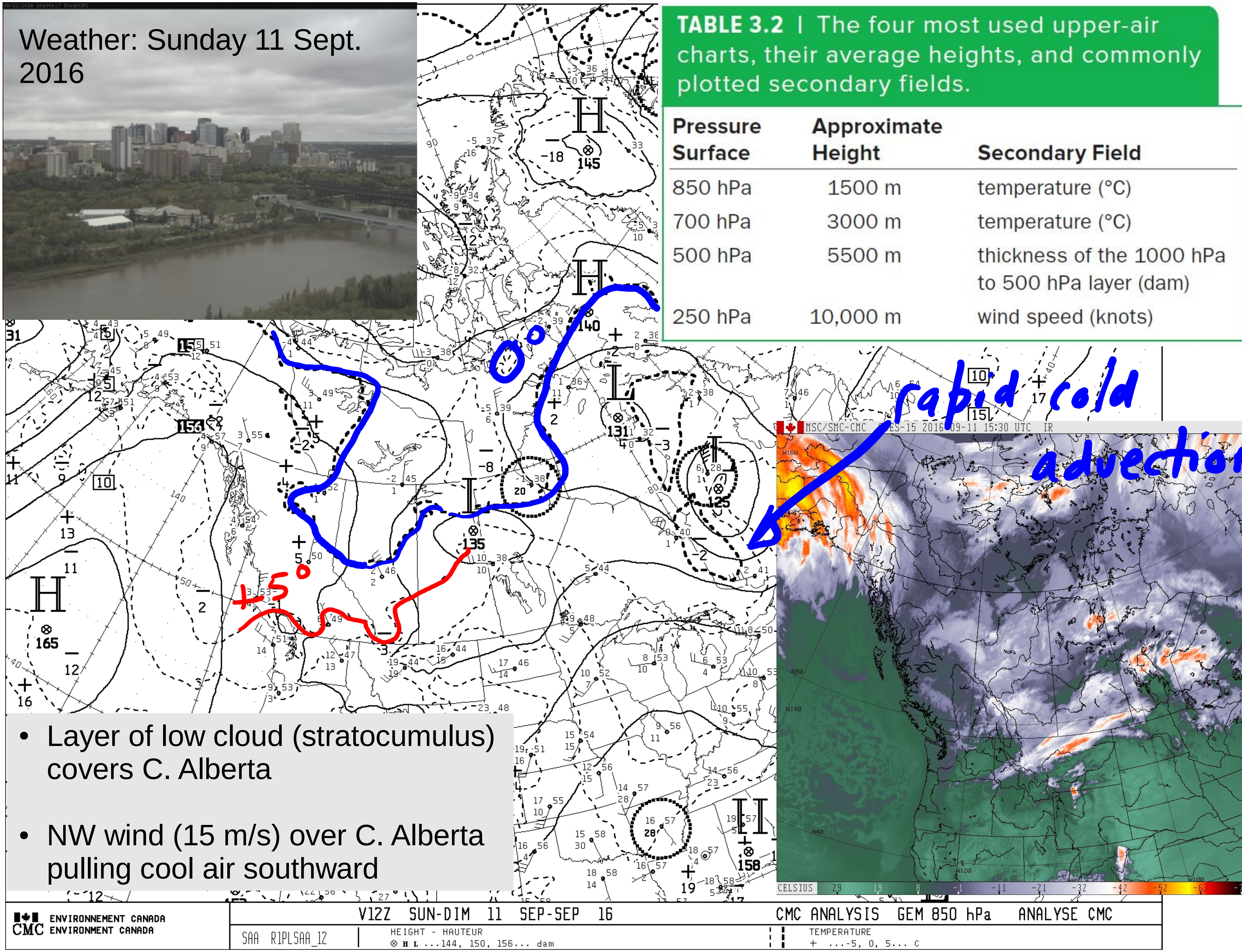


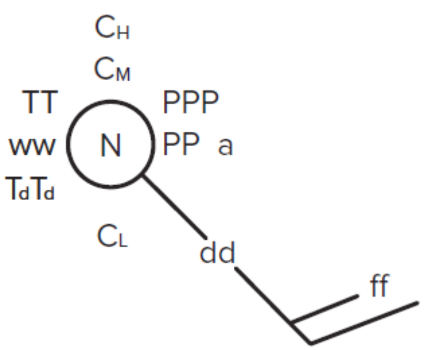
TABLE 3.2 | The four most used upper-air charts, their average heights, and commonly plotted secondary fields.

Pressure Surface	Approximate Height	Secondary Field
850 hPa	1500 m	temperature (°C)
700 hPa	3000 m	temperature (°C)
500 hPa	5500 m	thickness of the 1000 hPa to 500 hPa layer (dam)
250 hPa	10,000 m	wind speed (knots)

- Layer of low cloud (stratocumulus) covers C. Alberta
- NW wind (15 m/s) over C. Alberta pulling cool air southward

Decoding the station symbols – see Appendix of textbook

Key to Surface Weather Station Symbols

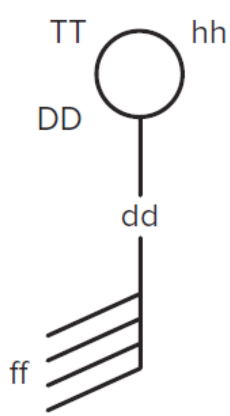


C_H	High Cloud Type	PPP	Sea-Level Pressure*
C_M	Middle Cloud Type	PP	Pressure Change in the Last 3 Hours**
C_L	Low Cloud Type	a	Pressure Tendency
N	Cloud Cover	dd	Wind Direction
TT	Air Temperature (°C)	ff	Wind Speed
T_dT_d	Dew-Point Temperature (°C)		
ww	Present Weather		

*The initial 9 or 10 has been omitted. For example, a pressure of 996.3 hPa is indicated as 963, and a pressure of 1023.5 hPa is indicated as 235.

**For example, a pressure change of 1.1 hPa is indicated as 11.

Key to Upper Air Weather Station Symbol s



TT	Air Temperature (°C)	ff	Wind Speed
DD	Dew-Point Depression (°C)	hh	Height of Pressure Surfaces
dd	Wind Direction		

*For example, a height of 546 decametres is indicated as 46.

Main source: photosynthesis

organic C

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

inorganic C

formaldehyde

Carbohydrate

$C_m(H_2O)_n$

This requires energy – drawn from the "photosynthetically active" part of the solar spectrum "PAR"

Residence time of oxygen? Co-existence of fast and slow processes makes it somewhat ambiguous – considered of order 10^3 years

Main sinks:

- respiration by plants and animals (releases energy to "fuel" activity or cell maintainence
- aerobic decomposition
- combustion of organic material

$$CO_2 + H_2O \leftarrow CH_2O + O_2$$

- anaerobic decomposition

$$2CH_2O \rightarrow CO_2 + CH_4$$

- oxidation of minerals

Figure 2.4

- organic processes: photosynthesis, respiration, decomposition ("short term" or "fast" processes)

- inorganic processes: rock weathering, plate tectonics & volcanism ("long term" processes)

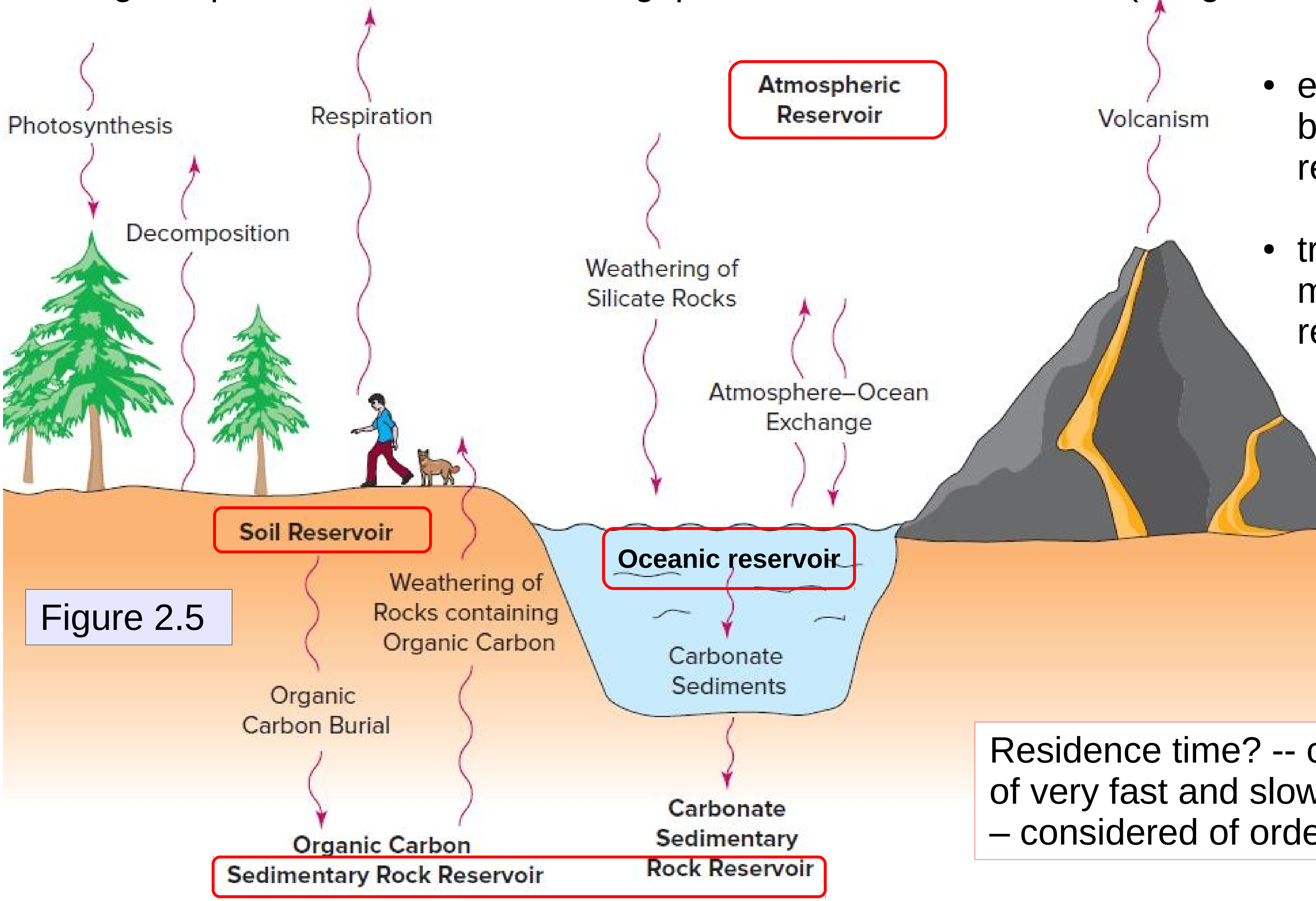


Figure 2.5

- exchanges between reservoirs

- transport and mixing within reservoirs

Residence time? -- coexistence of very fast and slow processes – considered of order 100 years

Seasonal drawdown (Mauna Loa, Hawaii) due to excess of photosynthesis over respiration in the summer hemisphere

inorganic C organic C

$$CO_2 + H_2O \rightarrow CH_2O + O_2 \quad \text{(Photosynthesis)}$$

$$CO_2 + H_2O \leftarrow CH_2O + O_2 \quad \text{(Respiration)}$$

$$\tau_{CO_2} \sim 100 \ [\mathrm{yr}]$$

(Time scales for some CO2 cycles much shorter or much longer)

What is the ratio *R* of the annual range to the annual mean?

$R \simeq \frac{5}{400} \sim 1\%$

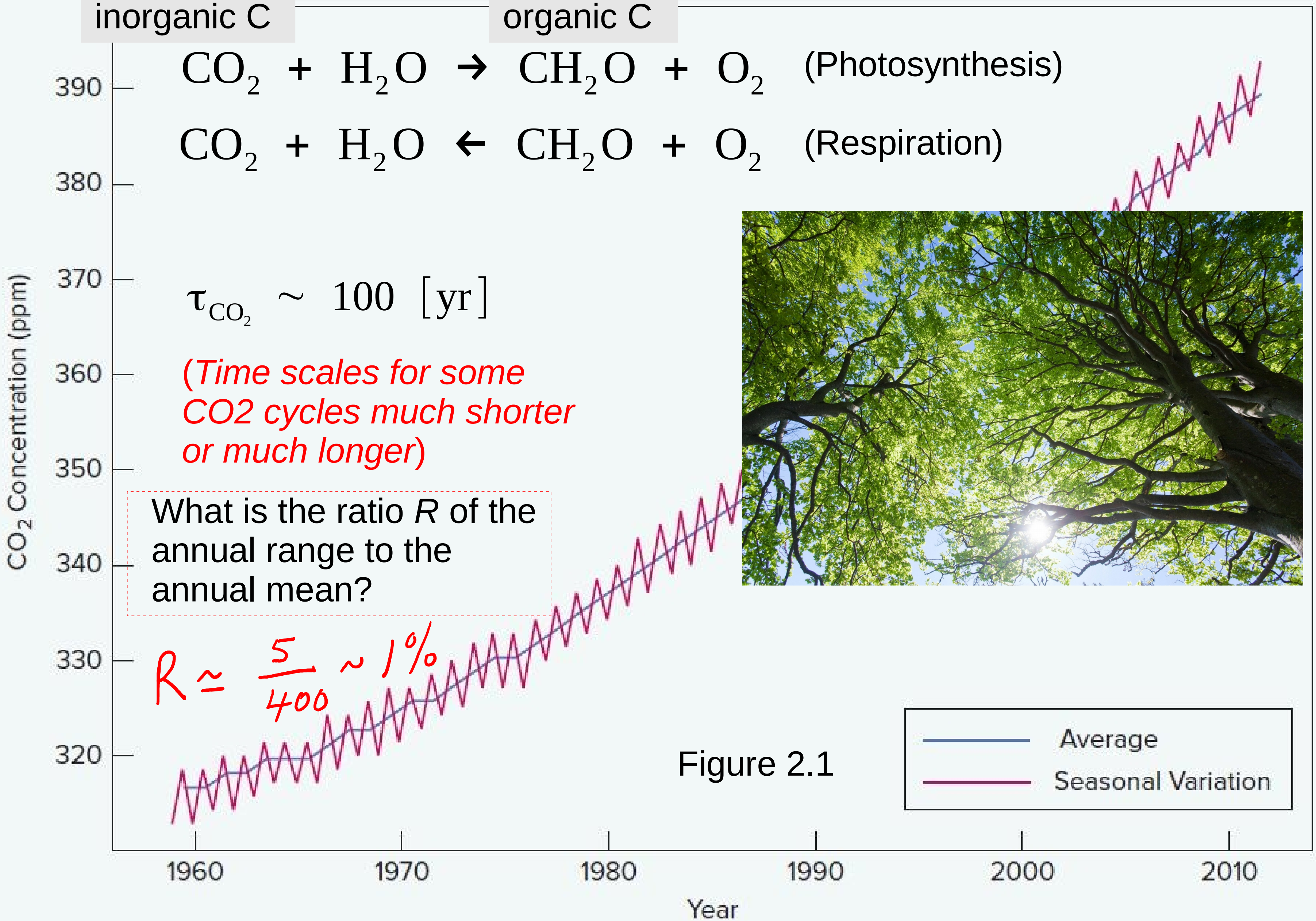
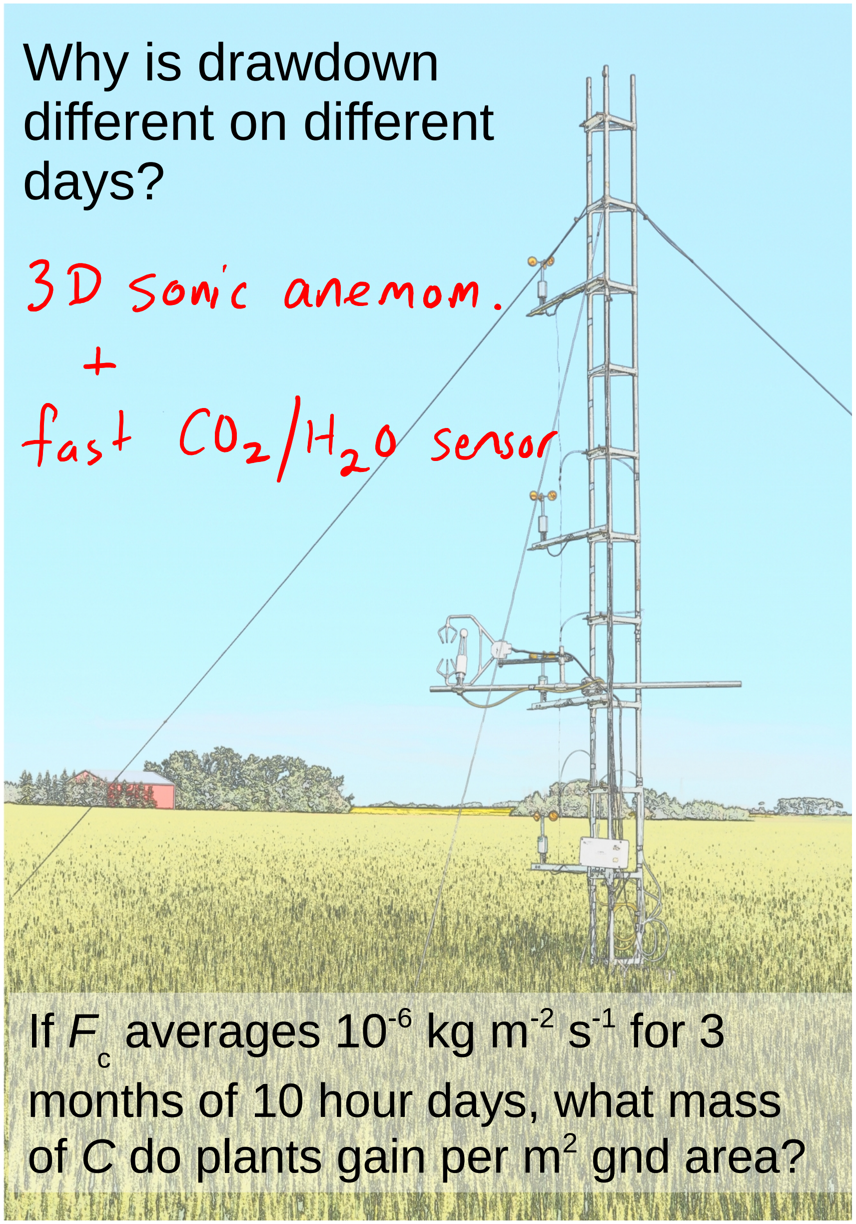
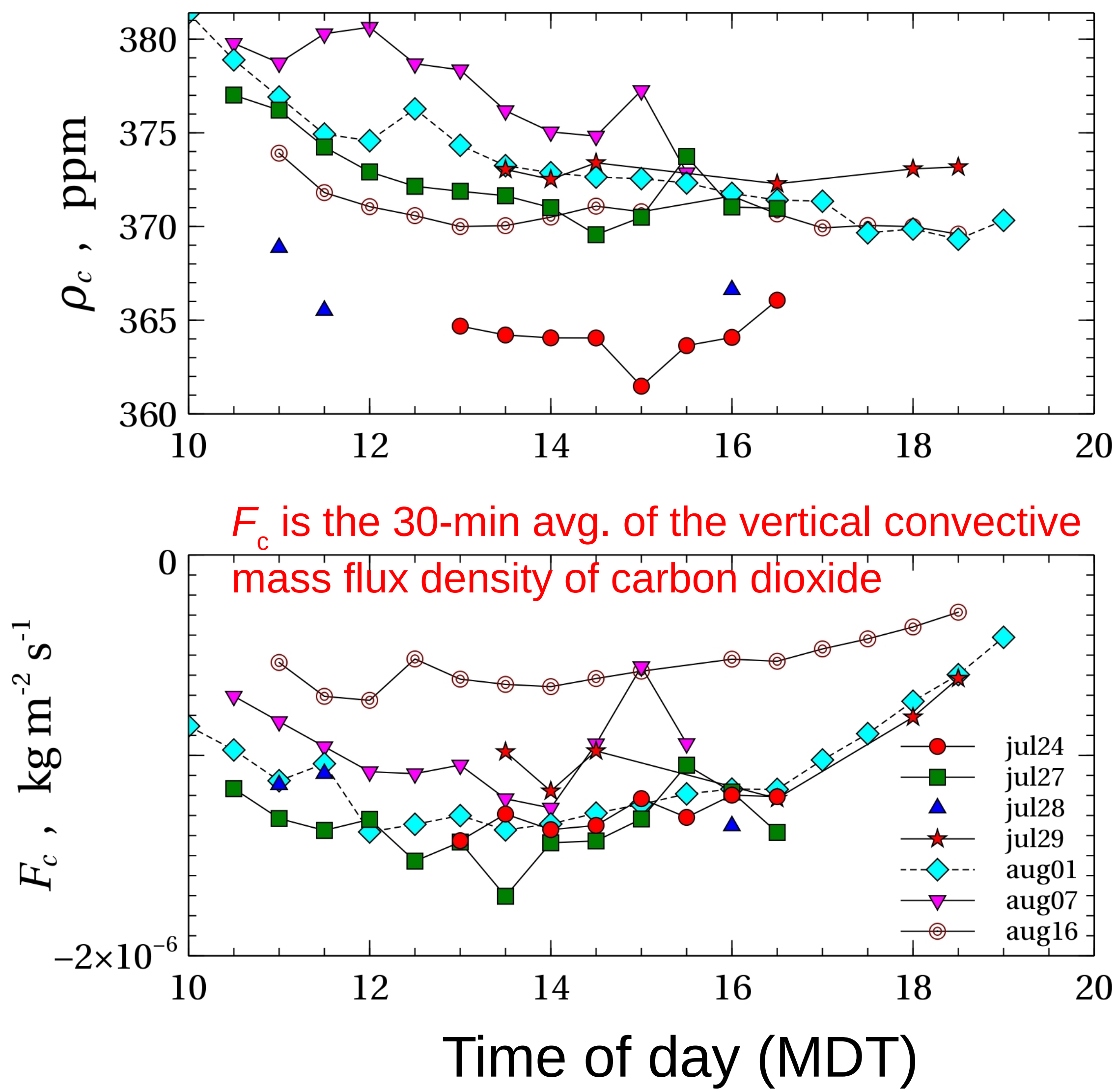


Figure 2.1

Daily “drawdown” of CO_2 concentration ρ_c due to crop uptake, and the corresponding CO_2 **flux** F_c – measured by JDW over wheat at St. Albert in 20122





Carbonate-silicate cycle

**feedbacks, p7

- very long time scale
- stabilizing (negative) feedback** on climate
- weathering of silicate rock SINKS atmos. CO_2
  - CO_2 dissolves in cloud water $CO_2 + H_2O \Leftrightarrow \underset{\text{carbonic acid}}{H_2CO_3}$
  - carbonic acid dissociates (aloft) $H_2CO_3 \Leftrightarrow H^+ + \underset{\text{bicarbonate}}{HCO_3^-}$
  - result is acid rain – elevated level of hydrogen ions (low pH)
    - reacts with rocks, producing Ca^{2+} in solution
    - ionic solution runs to ocean, where

$$Ca^{2+} + 2\,HCO_3^- \Leftrightarrow \underset{\text{calcium carbonate}}{CaCO_3} + H_2CO_3$$

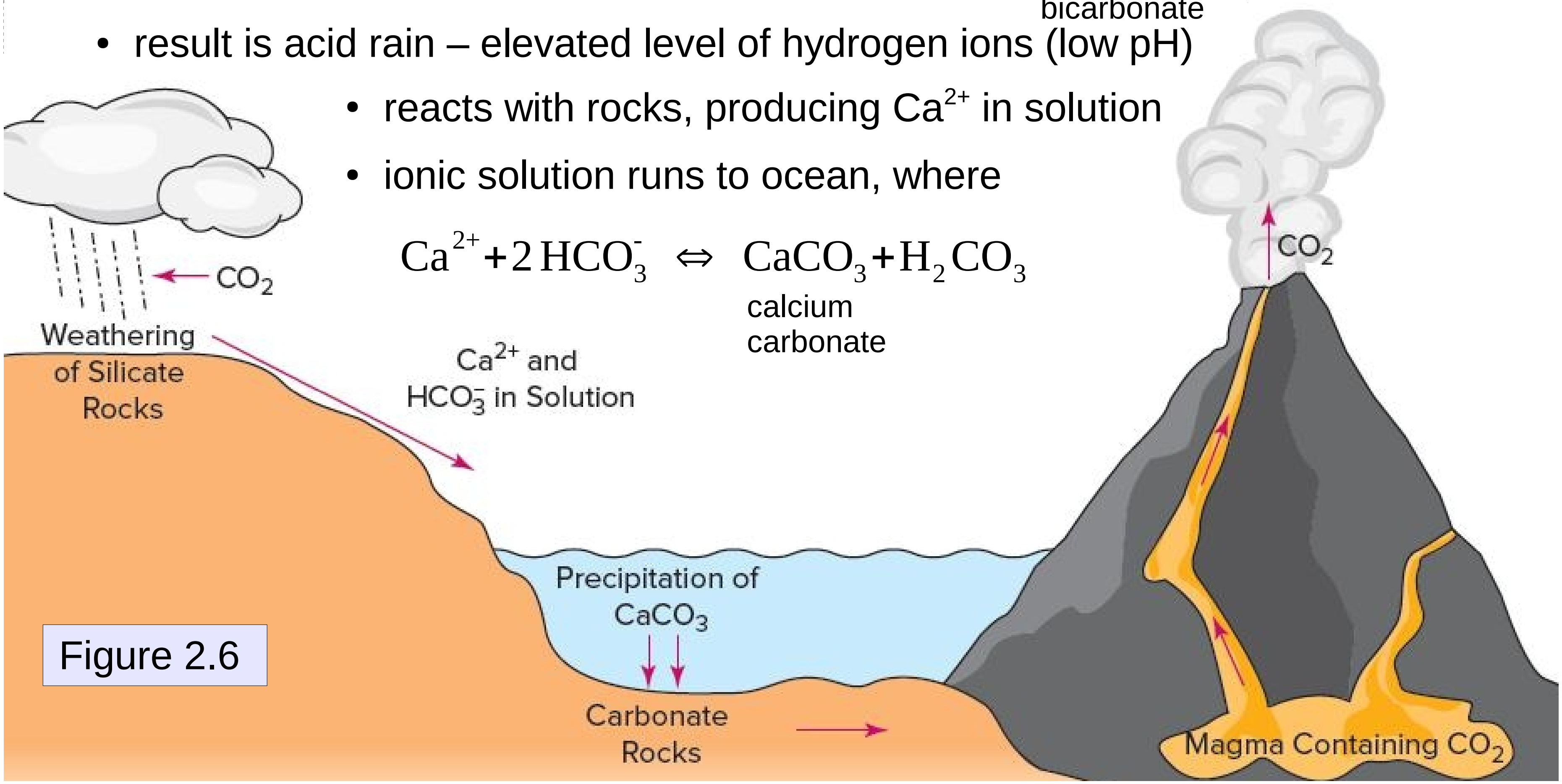


Figure 2.6

- What are the meteorological roles of water vapour ?

① GHG

② stores energy as "latent heat" fuel for atmosph. motion

③ converts to cloud water/ice

Mixing ratio of water vapour highly variable, up to about 4% in very warm, saturated air.

$\tau_{H_2O} \sim 10 \ \ \text{days}$ (nominally; Table 2.2)

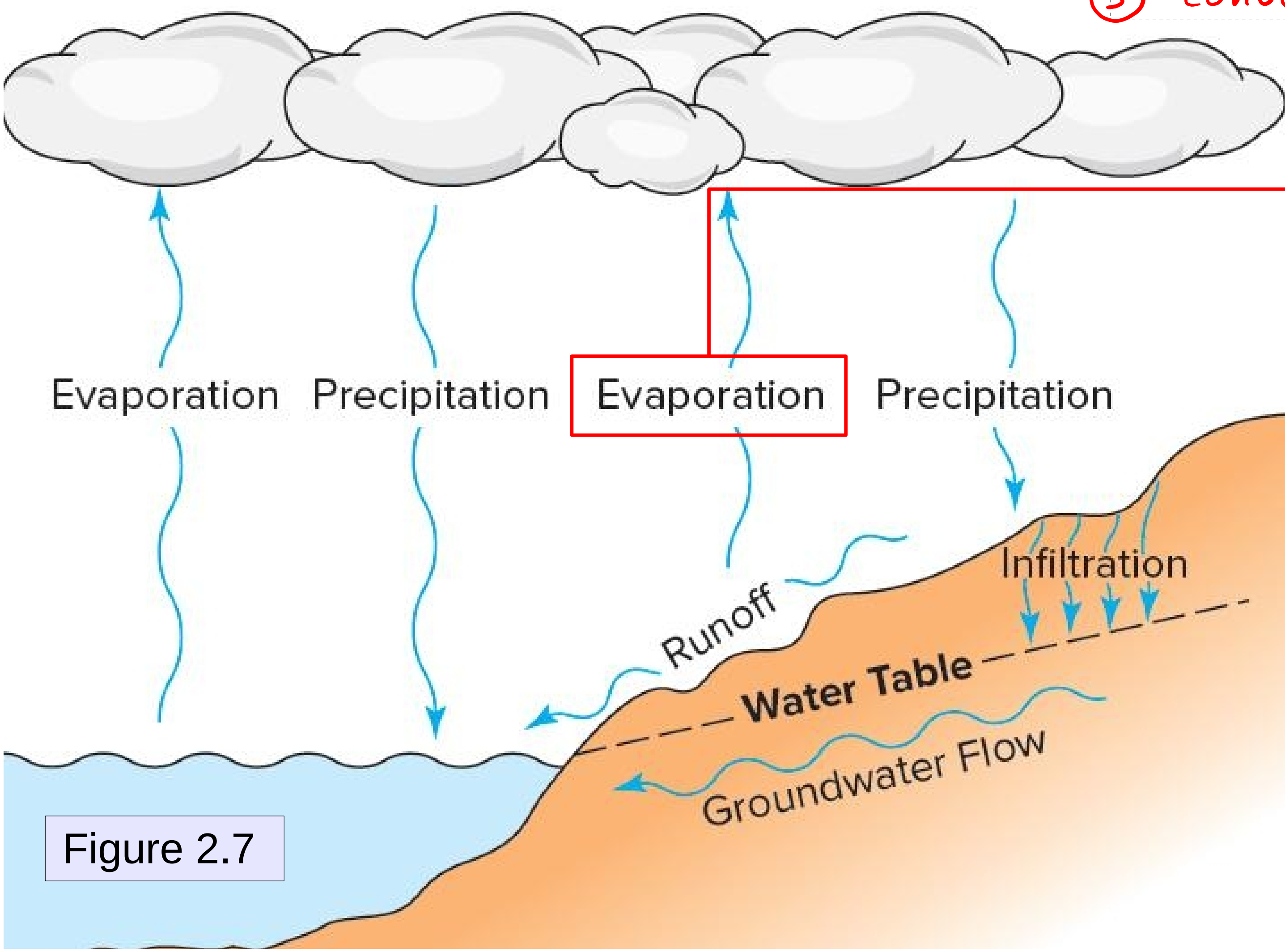
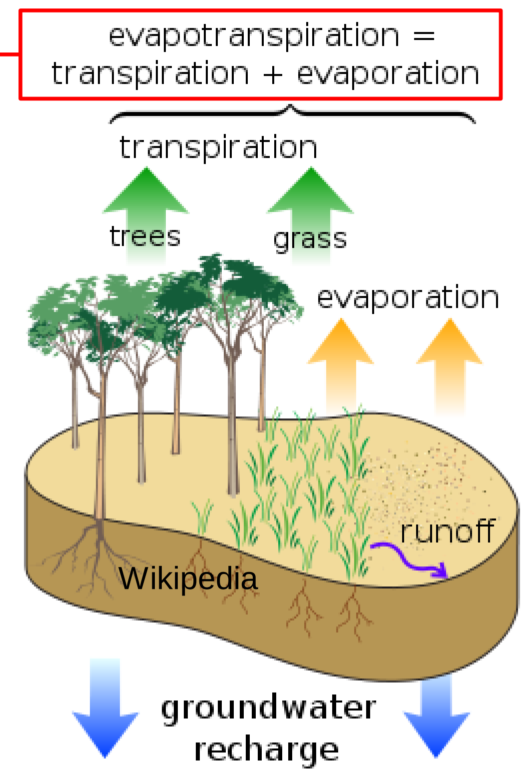


Figure 2.7



The latent heat of evaporation is: $L_v = 2.5 \text{ x } 10^6 \ [\text{J} \ \ \text{kg}^{-1}]$

How much time *t* does it take for a 100 W light bulb to consume 2.5 x 10^6 J of energy?

Power x time = Energy [W x s = J]

$100\,t = 2.5 \times 10^6 \ [\text{J}]$ $\left[\frac{J}{s} \times s = J\right]$

$t = 2.5 \times 10^4 \ s = 6.94 \ hr$

What mass *M* of water, when lifted *h* = 100 m from its starting elevation, would gain 2.5 x 10^6 J of gravitational potential energy?

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

Challenge: given that the density of liquid water is ρ_w=1000 kg m^{-3}, can you express this estimate of evapotranspiration in the velocity unit [mm/day]?

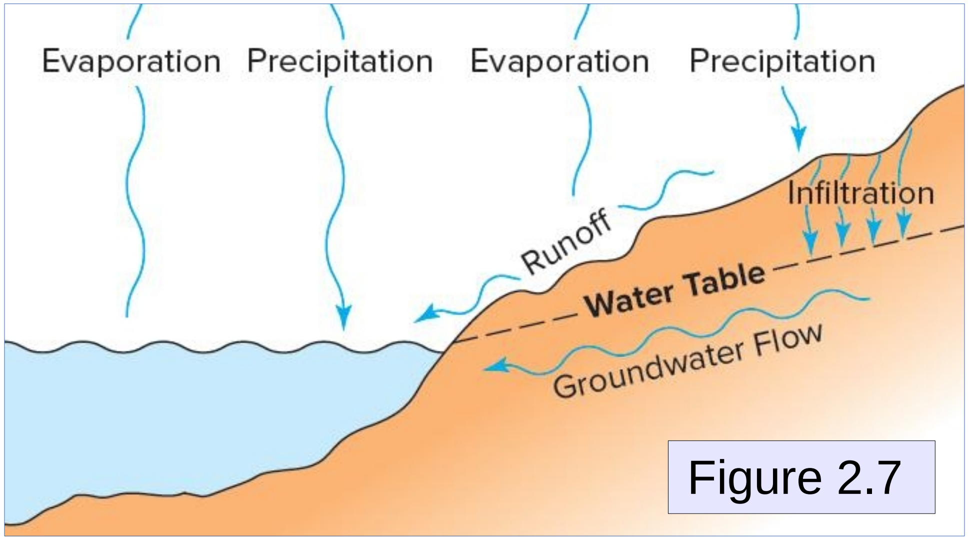


Figure 2.7

Lecture of 12 Sept.

- crucial role of pressure in synoptic scale meteorology (i.e. in controlling weather)
- the oxygen and carbon dioxide cycles
- disparate time scales of variability in atmospheric gases (e.g. daily & annual cycles)
- units of fluxes
- roles and enegetics of water vapour; conversion between unit systems for evaporation (velocity versus mass flux density)