# Goals for today: commence Part 1, “Energy & Mass”

9 Sep. 2011

Chapter 1 sets the stage and addresses such basics as:

- What are the most important components of the atmosphere, and why?
- How much mass is in one cubic metre of “air” ? How much oxygen?
- Does the air get colder or warmer as you ascend from ground?
- What is the difference between weather and climate?
- Why is pressure so important to meteorologists?
- Where in the atmosphere does weather “happen”?

Note that the aim of the course – and of the authors of our textbook (see p4) – is to help you “understand the underlying physical processes.” The challenge is to develop one's own judgment as to *what is most important* – you are not expected to remember every detail and every digit...

# **Table of Contents**: ***Understanding Weather and Climate***



***Here's the scope of our course***

# "Weather" versus "climate" (p4)

Weather: short-term, local phenomena

Climate: long term patterns (statistics: averages, extremes, frequencies of events…)

"Climate is what you expect but weather is what you get"

Environment Canada Environnement Canada

http://www.weatheroffice.gc.ca/canada_e.html

Home > Current Conditions and Forecasts > Alberta >

## Edmonton

**Z ("Zulu") = GMT= UTC**

### Current Conditions

30 °C

| | |
|---|---|
| Observed at: | Edmonton City Centre Airport |
| Date: | 4:00 PM MDT Thursday 8 September 2011 |

| | | | |
|---|---|---|---|
| Condition: | Sunny | Temperature: | 29.8°C |
| Pressure: | 102.1 kPa | Dewpoint: | 9.7°C |
| Tendency: | falling | Humidity: | 29 % |
| Visibility: | 15 km | Wind: | SSE 9 km/h |
| Air Quality Health Index: | 5 | Humidex: | 31 |

**MDT = GMT - 6**

### Historical Data

| Yesterday | | Normals | |
|---|---|---|---|
| Max: | 29.8°C | Max: | 18°C |
| Min: | 10.7°C | Min: | 5°C |
| Precip: | 0.5 mm | | |

**"It is normal for the weather to be abnormal"**

# Vertical Structure – and thinness of atmosphere

Density ( $\rho$ , kg m$^{-3}$) and pressure (p, Pa) both decrease with increasing elevation – shall see why later, Ch 4

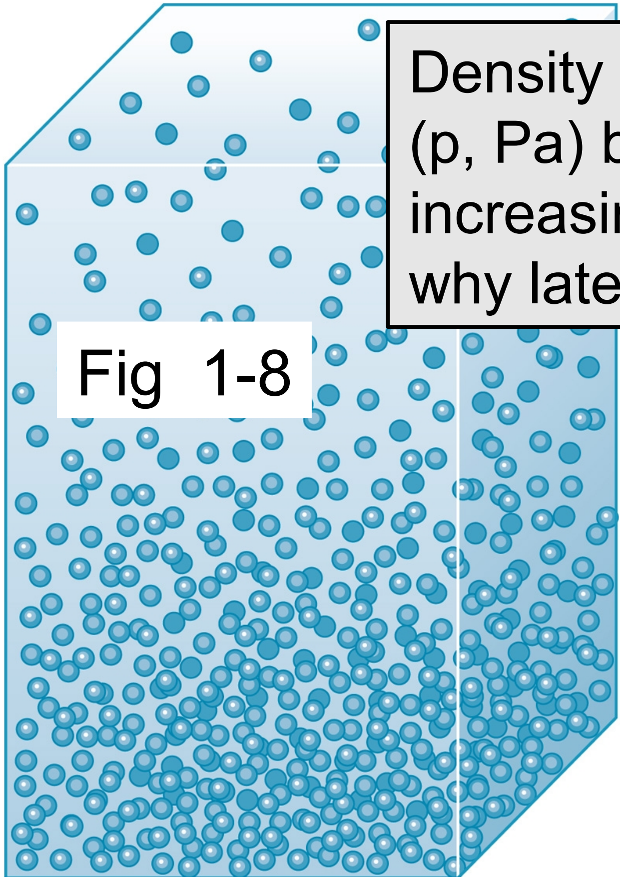


Fig 1-8

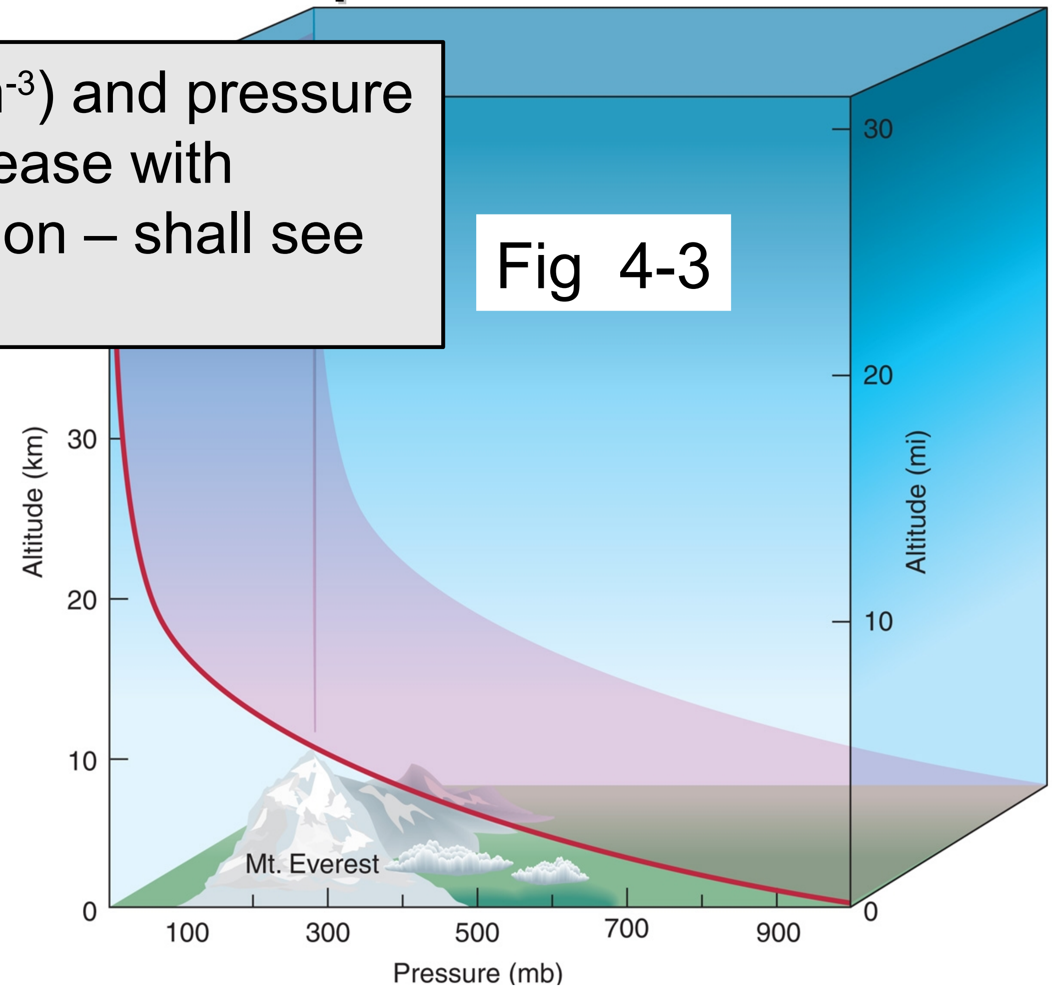



Fig 4-3

“Given the shallowness of the atmosphere, its motion *(when averaged)* over large areas must be primarily horizontal”... yet “Paradoxically, the least impressive motions – vertical – determine much of atmospheric behaviour”

# "Mandatory" (Conventional) Reporting/Analysis Levels

Increasing height, decreasing pressure


250 hPa , z ≈ 10.5 km = 1050 dam (34,000 feet)

500 hPa , z ≈ 5.5 km = 550 dam

700 hPa , z ≈ 3 km = 300 dam

850 hPa , z ≈ 1.5 km = 150 dam

Edmonton Int'l, z = 723 m

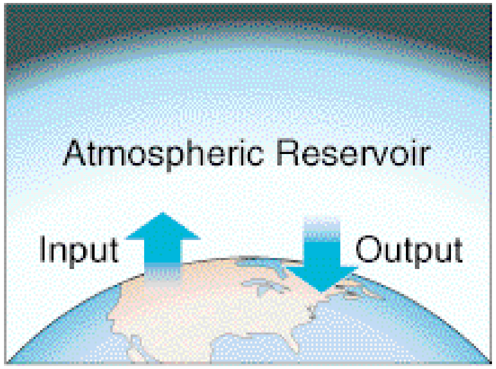
density $\rho \approx 1$ kg $m^{-3}$

MSL: p ≈ 1000 hPa, z ≡ 0 m

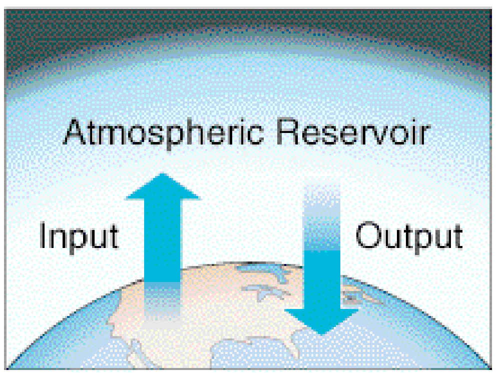
1 millibar (mb) = 1 hectoPascal (hPa) = 100 Pascals (Pa)

# Atmospheric composition

Fig. 1-2



(a)



(b)

Sfc-atmos. exchange by phys., chem. or biological processes + internal product'n/destruct'n

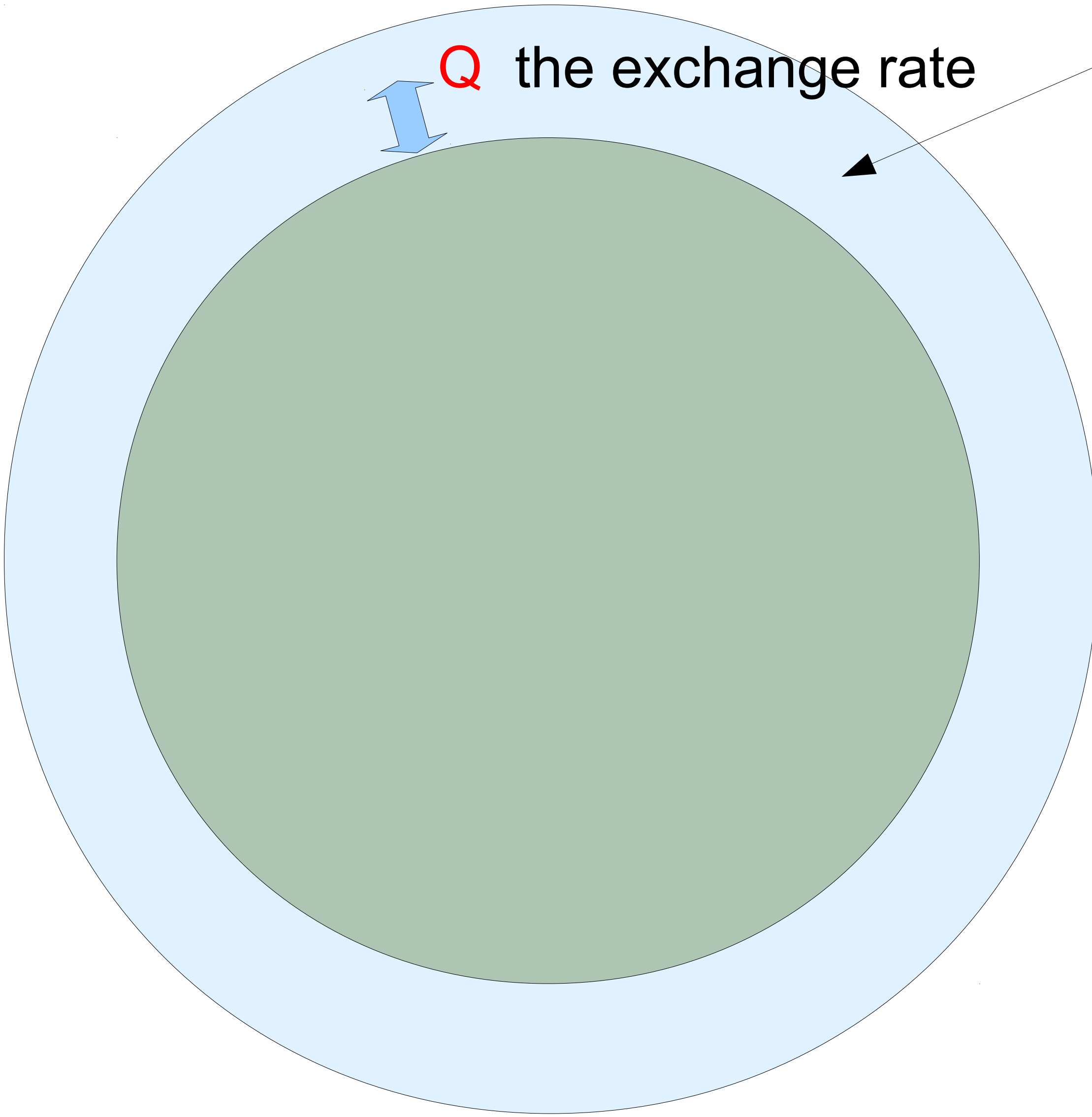
<u>Permanent Gases</u> ← uniformly-mixed in the "homosphere" (lowest 80 km) and "<u>inactive</u>"

- $N_2$ 78 % (by volume)
- $O_2$ 21 %
- Ar 1 %

<u>Variable Gases</u> ← not uniformly-mixed, these gases "<u>active</u>"

- $H_2O$ < 4 % (¼ % globally)
- $CO_2$ 0.038% (386 ppm)
- ozone
- methane
- 

# Concept of "residence time"




M the total mass of a given gas averaged over a long time (years or longer)

- If the net transport Q from sfc to atmos vanishes over the averaging time and there is no net production internally, we say the concentration is in "steady state"

$N_2$ – a long residence-time gas (slow volcanic source) that is unimportant (inactive) with respect to "weather"

- crucial to plant nutrition
- added to atmos by decay of organic material
- removed by soil bacteria

} "slowly" (small $Q$)

huge

$$T^{res} = \frac{M}{Q} \quad \left[\frac{\text{kg}}{\text{kg yr}^{-1}}\right]$$

= tens of millions of years

small

$H_2O$ – a variable gas that is ***not*** uniformly mixed and is “active”

(“thermal”)

- interacts with longwave radiation (“radiatively active” or “greenhouse” gas)
- affects atmospheric motion by means of buoyancy (moist air is lighter)
- every 1 kg of vapour stores 2.5 million Joules of latent heat (ie. energy)

small

$$T^{res} = \frac{M}{Q} \quad \left[ \frac{\text{kg}}{\text{kg yr}^{-1}} \right]$$

= about 10 days

large
(evaporation, precipitation)

To get a sense of the enormous amount of energy tied up in water vapour:

Calculation: how long ( "$t$" ) must you run a 100 W light bulb to consume 2.5 million Joules of energy (i.e. an amount sufficient to evaporate 1 kg of water)?

Given, energy $E$:

$$E = 2.5 \text{ x } 10^6 = 2{,}500{,}000 \, [\text{J}]$$

Formula:

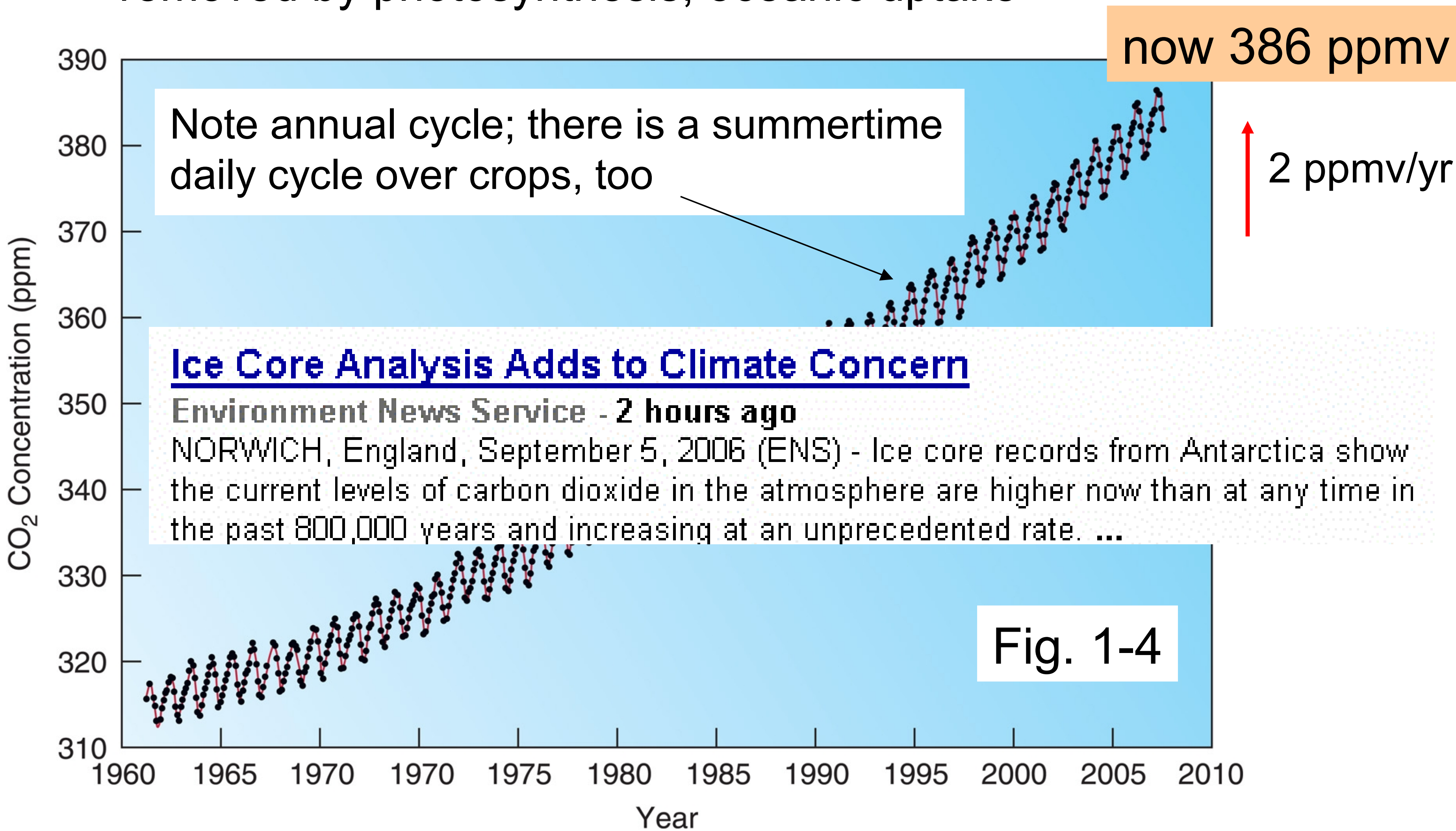
$$E = P\, t$$

(where $P$ = Power [W], $t$ = time [s] )

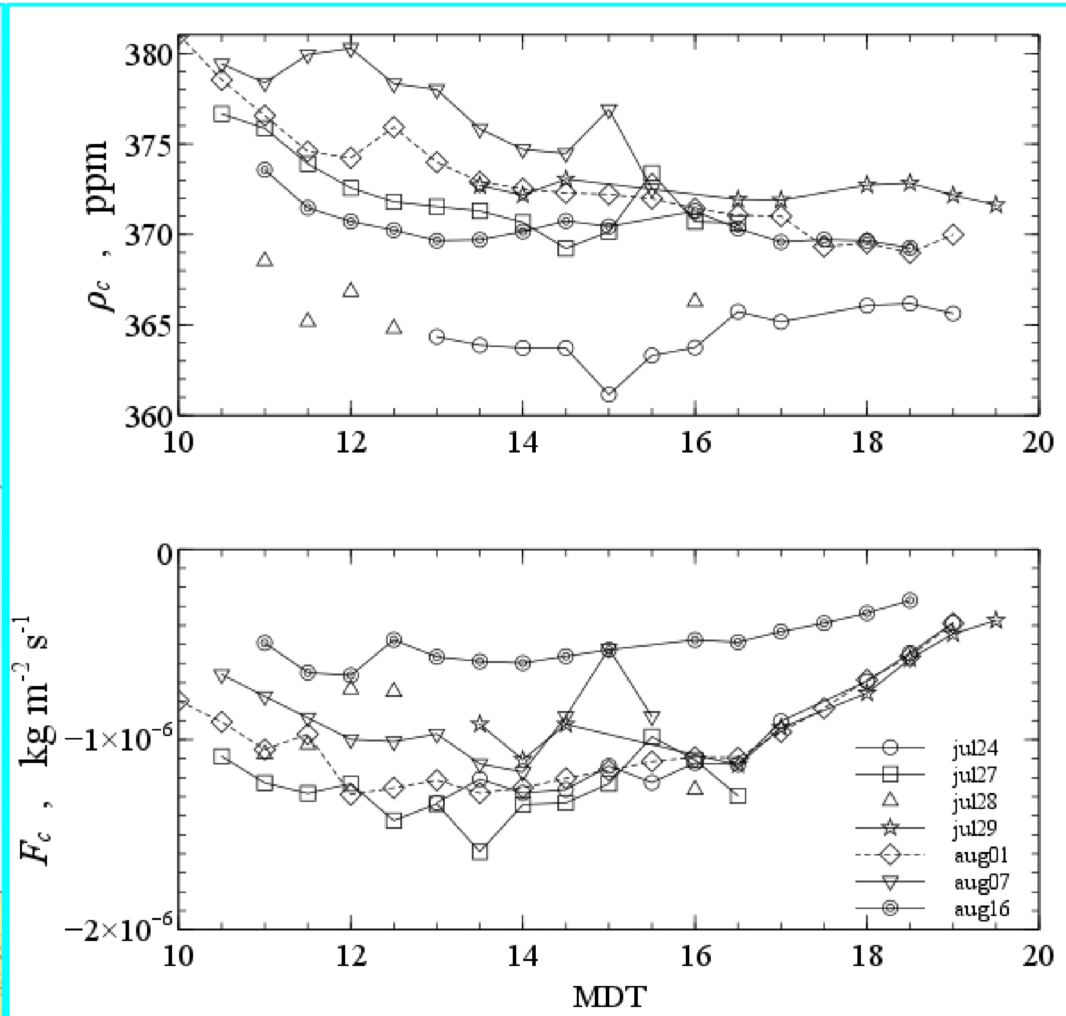
Unknown, time $t$ :

$CO_2$ – a variable gas that is (fairly) uniformly mixed and is "active"

- radiatively active (greenhouse gas)
- added to atmos by volcanoes, respiration and decay of vegetation, breathing, burning fuels
- removed by photosynthesis, oceanic uptake

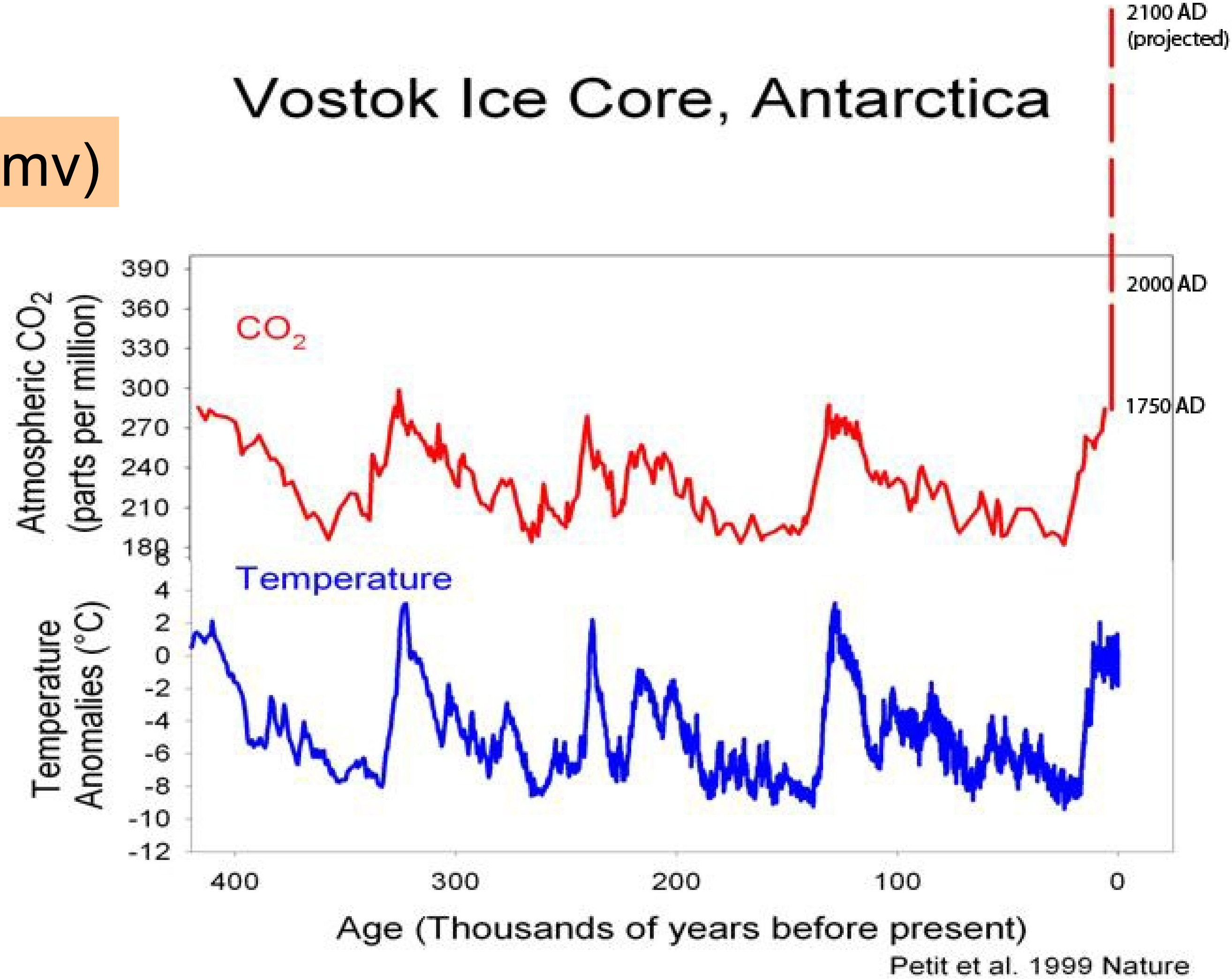


# Measured concentration and flux of $CO_2$ at St. Albert, 2011




- Wheat canopy is absorbing about __ mg per square metre per hour

(now 386 ppmv)




Dr Eric Wolff, British Antarctic Survey: “Ice cores reveal the Earth's natural climate rhythm over the last 800,000 years. When carbon dioxide changed there was always an accompanying climate change…”