Atmospheric Chemistry and Physics (FKFF05)

Register ASAP

Atmospheric Chemistry and Physics (FKFF05)

Parts of the course

- 12 Lectures
  - In English
- 6 Exercises
  - Discussion in Swedish when possible (Sw. terminology)
- 1 Project (1 follow-up, 1 presentation)
  - In English

Examination

- passed project
- written exam
- Grades
  - based on the written exam (u, 3, 4, 5)
  - 30 p max; Grade limits (15, 20, 25)

New Midterm test (optional): Successful gives 1,2, or 3 p => changes the grade limits!

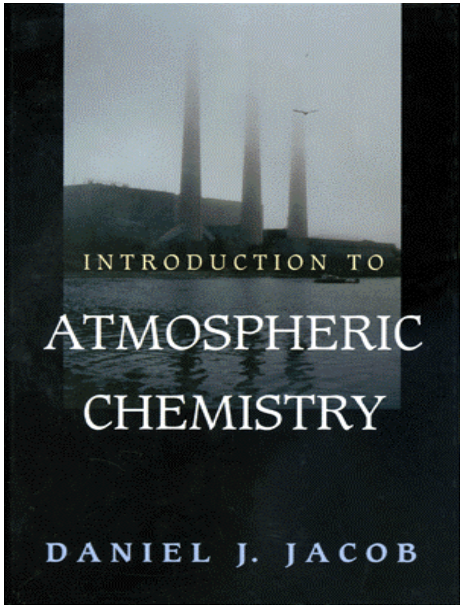
Teachers

- Lectures
  - PhD Johan Friberg (Responsible)
  - PhD Pontus Roldin (Responsible)
  - PhD Moa Sporre (1 lecture)
- Project advisers and Exercises
  - PhD Pontus Roldin
  - PhD Johan Friberg
  - PhD student Oscar Sandvik

Size of the course

- 5 ECTS
- Whereof proj. 1 ECTS (3.3 days)

Literature and Course Requirements



- **Course requirements**
  - Reading instructions (textbook)
  - Lecture slides (added material)
  - Exercise booklet
- **Exam**
  - Descriptive (approx 60%)
  - Calculations (approx 40%)

Literature

Course textbook

- Jacob: Introduction to Atmospheric Chemistry – (*

Added material ***extending*** the textbook

- Heintzenberg: ”The Life Cycle…Aerosol” – Now
- Martinsson: Aerosol, Water and Clouds - Now
  - Lecture slides on: Aerosol and Aerosol cloud, climate – Webpage

Added material to make the course ***up to date*** New

- IPCC on ***Geochemical cycles*** – Webpage
- Scientific review of ***stratospheric ozone*** – Webpage
- Scientific overview of ***air pollution*** in Europe – Webpage
- ***Climate***: IPCC summary for policy makers – Webpage
  - Slides from the four lectures covering these topics - Webpage

Further course material

- Exercise booklet with solutions – Now
- Equation sheet– Now
- Literature for the project - Webpage

*) Available electronically from author (Link at course webpage) [Free] or hardcopy [~700-900 SEK]

Contents

Lecture	Field	Topic	Literature
1a		Introduction	
1b	Physics	Atmos comp, temp, pressure	Jacob Ch 1-2
2	Physics	Meteorology	Jacob Ch 3-4
3	Physics	Cycles, Aerosol	Jacob Ch 6, 8 +added mtrl
4	Chemistry	Atm Chem Basics	Jacob Ch 9
5	Chemistry	Oxidation power of the Tropos	Jacob Ch 11
6	Chemistry	Stratospheric ozone	Jacob Ch 10
7	Chemistry	Air pollution	Jacob Ch 12+added mtrl
8	Physics	Greenhouse effect	Jacob Ch 7
9	Physics	Aerosol, cloud and climate	Jacob Ch 8 +added mtrl
10	Physics and Chemistry	Climate models	
11	Chemistry	Acidification	Jacob Ch 13
12	Summary	Summary	

- **Basic lectures provides knowledge you need for other parts of the course, e.g.:**
  - L1b vertical profiles of temp and pressure -> L6, L7 atmospheric parts; L8, L9 climate
  - L2 Meteorology and models -> L3 geochemical cycles; L3,5-9 (”all”) transport of species
  - L4 Chemical kinetic equations -> L5-7 important tools to study the chemistry of the atm

Project

- Read and present results from a scientific paper at mini symposium
- Group size: 2 or 3
- All group members present
- Method for the presentation
  - Use the ordinary course literature to present the background to the problem
  - Present the paper
- Target audience: members of the course

- Schedule
  - 1 Follow-up (not compulsory)
  - 1 Mini symposium (compulsory)

The symposium – A good opportunity to learn more about important environmental issues

In the Break

Collect Course Literature (6 items):

- Schedule
- Course information
- Heintzenberg: The life cycle of atmospheric aerosols
- Martinsson: Aerosol, Water and Clouds
- Exercise booklet
- Equation sheet
  - Remaining literature at/or from the course homepage

Sign up for a paper for your project + exercise group

- Check your schedule before signing for a group!
- By signing for project group you also sign for exercise group
  - Project groups 1a and 1b – Exercise group 1
  - Project groups 2a and 2b – Exercise group 2

FKFF01 – Project Groups 1a

Calculation Exercise group 1 (Mondays 15 – 17)
Project Follow-up: May 3 at 10:15 – 12:00
Oral Presentation: May 18 at 13:15 – 15:00

Instructions

1. Write names of group members (2 or 3 members per group) on one row
2. Select project theme and write your project group (e.g. "C1a") in the empty column in front of your selected theme.
3. Only one project group per theme. (If another group has chosen your favorite, take your 2nd favorite.)

Proj Group	Group Member 1	Group Member 2	Group Member 3
A1a	NN1	NN2	NN3
B1a	NN4	NN5	
C1a	Bo Ek	Lina Gran	Sven Ohlsson
D1a			
E1a			
F1a			

Proj Group	Theme
	1. How does the CO_2 concentration evolution the last 100 years compare with the concentration and variation during the last 650 000 years?
	2. Is the carbon cycle affected by climate change?
	3. Have we humans committed to a larger greenhouse warming than the observed global temperature change?
	4. Can global temperature change from increased greenhouse effect be neutralized by well-planned aerosol emissions to the atmosphere?
C1a	5. Do explosive volcanic eruptions affect life on earth in a global perspective?
	6. Do industrial emissions affect the radiative properties of clouds and/or the formation of precipitation?
	7. Has the global air quality changed during the last century?
	8. Can sources contributing to ozone pollution be determined from satellite-based measurements of NOx and formaldehyde?

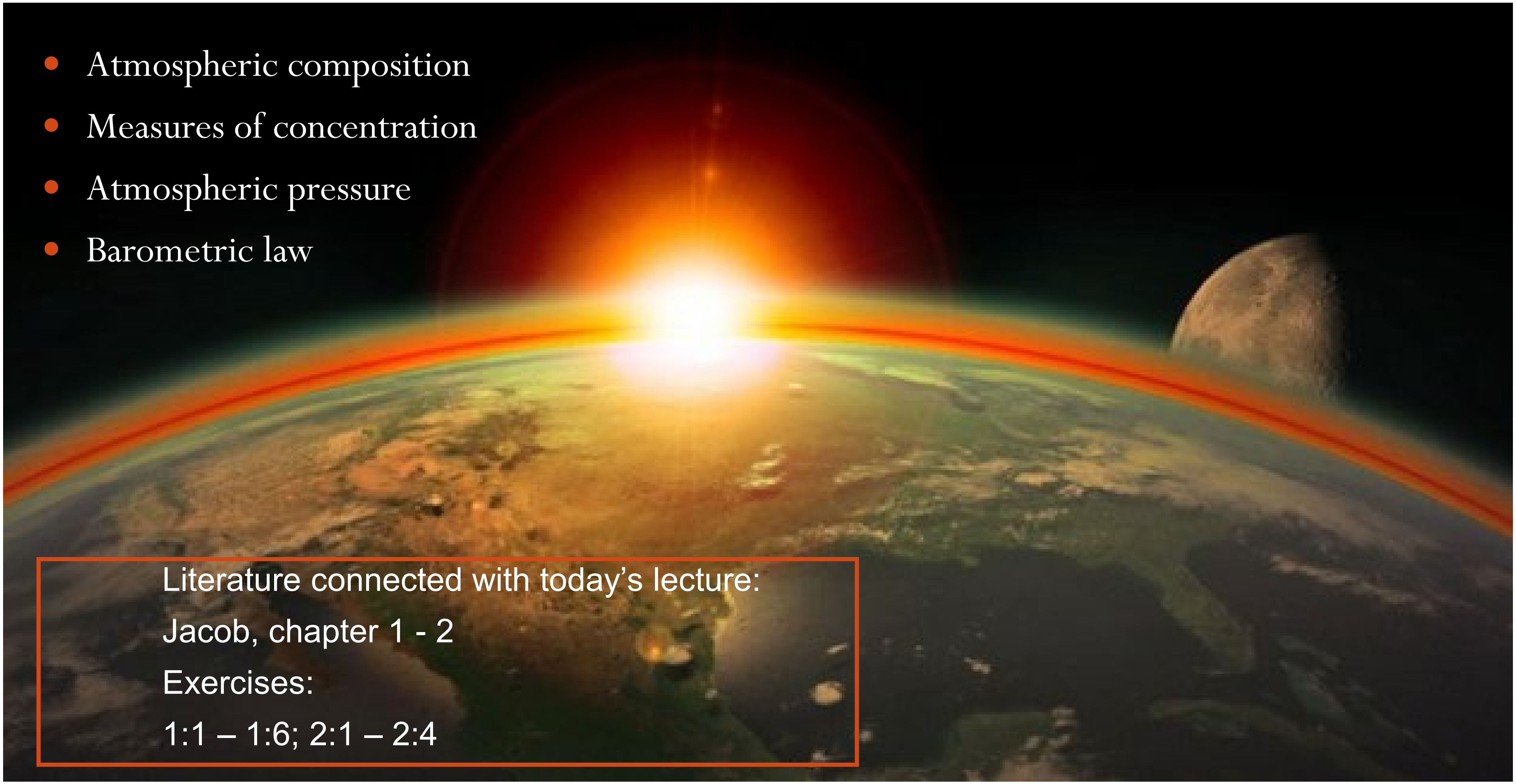
Atmospheric Chemistry and Physics (FKFF05) 2019

Day	Date	Time	#Theme; L=lecture; Ex=exercise	Teacher	§Place	Literature
Wed	27/3	13-15	Introduction (L1)	JF	Rydberg	Jacob Ch 1-2
Thu	28/3	13-15	Meteorology (L2)	JF	Rydberg	Jacob Ch 3-4
Mon	1/4	13-15	Exercise A Gr 1	JF	H421	
Tue	2/4	8-10	Exercise A Gr 2	PR	H421	
Wed	3/4	15-17	Cycles, Aerosol (L3)	JF	Rydberg	Jacob Ch 6, 8 +added mtrl
Thu	4/4	13-15	Atm Chem Basics (L4)	PR	Rydberg	Jacob Ch 9
Mon	8/4	8-10	Exercise B Gr 1	JF	H421	
Mon	8/4	13-15	Exercise B Gr 2	PR	H421	
Wed	10/4	15-17	Oxidation power of Trop. (L5)	PR	Rydberg	Jacob Ch 11
Thu	11/4	13-15	Stratospheric ozone (L6)	PR	Rydberg	Jacob Ch 10
Mon	15/4	8-10	Exercise D Gr 1	JF	H221	
Mon	15/4	13-15	Exercise D Gr 2	PR	H421	
Tue	**16/4**	**8-10**	**Midterm test**	**JF/PR**	**MA8**	**Lectures 1 - 6**
Wed	17/4	15-17	Air pollution (L7)	PR	Rydberg	Jacob Ch 12+added mtrl
Mon	6/5	10-12	*Project Follow-up Gr 2a,b p 4-6	PR	B113	*Gr 2a and b Proj 4-6*
Mon	6/5	15-17	*Project Follow-up Gr 2a,b p7-9	OS	B113	*Gr 2a and b Proj 7-9*
Mon	6/5	15-17	Exercise E Gr 1	JF	H421	
Tue	7/5	8-10	*Project Follow-up Gr 1a,b p4-6	PR	B113	*Gr 1a and b Proj 4-6*
Tue	7/5	15-17	*Project Follow-up Gr 1a,b p7-9	OS	B113	*Gr 1a and b Proj 7-9*
Tue	7/5	15-17	Exercise E Gr 2	PR	H421	
Wed	8/5	13-15	*Project Follow-up Gr 1a,b p1-3	JF	B113	*Gr 1a and b Proj 1-3*
Wed	8/5	15-17	Greenhouse effect (L8)	JF	Rydberg	Jacob Ch 7
Thu	9/5	8-10	*Project Follow-up Gr 2a,b p1-3	JF	B113	*Gr 2a and b Proj 1-3*
Thu	9/5	13-15	Aerosol, cloud and climate (L9)	JF	Rydberg	Jacob Ch 8 +added mtrl
Mon	13/5	13-15	Exercise C Gr1	JF	H421	
Wed	15/5	8-10	Climate models (L10)	MS	Rydberg	
Wed	15/5	10-12	Exercise C Gr2	PR	H421	
Thu	16/5	13-15	Acidification (L11)	PR	Rydberg	Jacob Ch 13
Mon	20/5	13-15	Exercise F Gr 1	JF	H421	
Tue	21/5	8-10	Exercise F Gr 2	PR	H421	
Wed	22/5	8-10	**Proj: Oral Presentation Gr 1a#**	PR,JF	H322	***Compulsory***
Wed	22/5	10-12	**Proj: Oral Presentation Gr 1b#**	JF,OS	H322	***Compulsory***
Thu	23/5	8-10	**Proj: Oral Presentation Gr 2a#**	OS, PR	H322	***Compulsory***
Thu	23/5	10-12	**Proj: Oral Presentation Gr 2b#**	PR,JF	H322	***Compulsory***
Mon	27/5	9-10	Summary (L12)	PR,JF	Rydberg	
Tue	**4/6**	**8^{00}-13^{00}**	**Written exam**		**Eden 022, 025**	**Entire course**

#) Project elements in **bold** letters are compulsory (but only the session where you present).
*) Optional follow-up in the project. §) Premises at Physics Department except for the written exam.

Register ASAP

The Atmosphere



- Atmospheric composition
- Measures of concentration
- Atmospheric pressure
- Barometric law

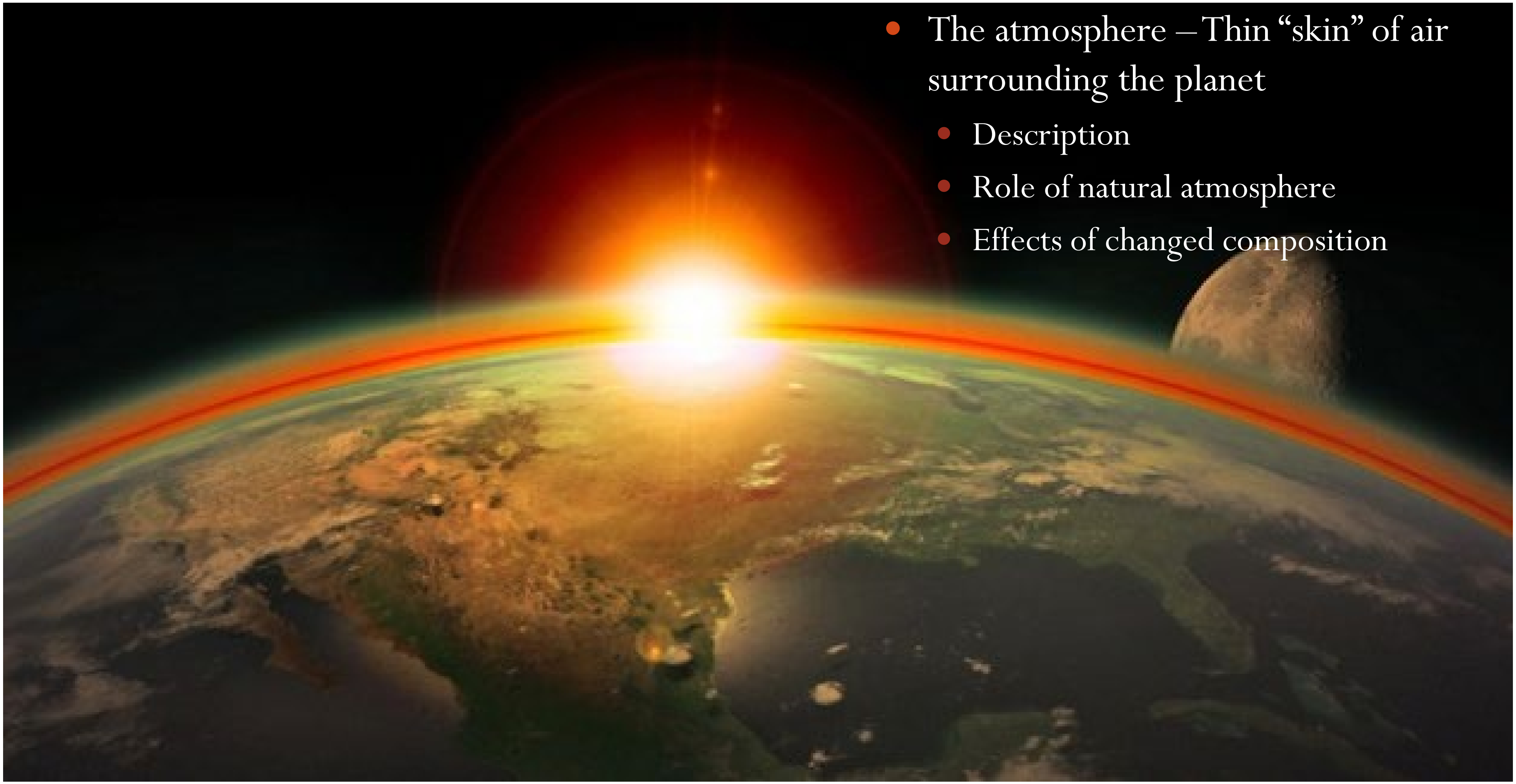
Literature connected with today's lecture:

Jacob, chapter 1 - 2

Exercises:

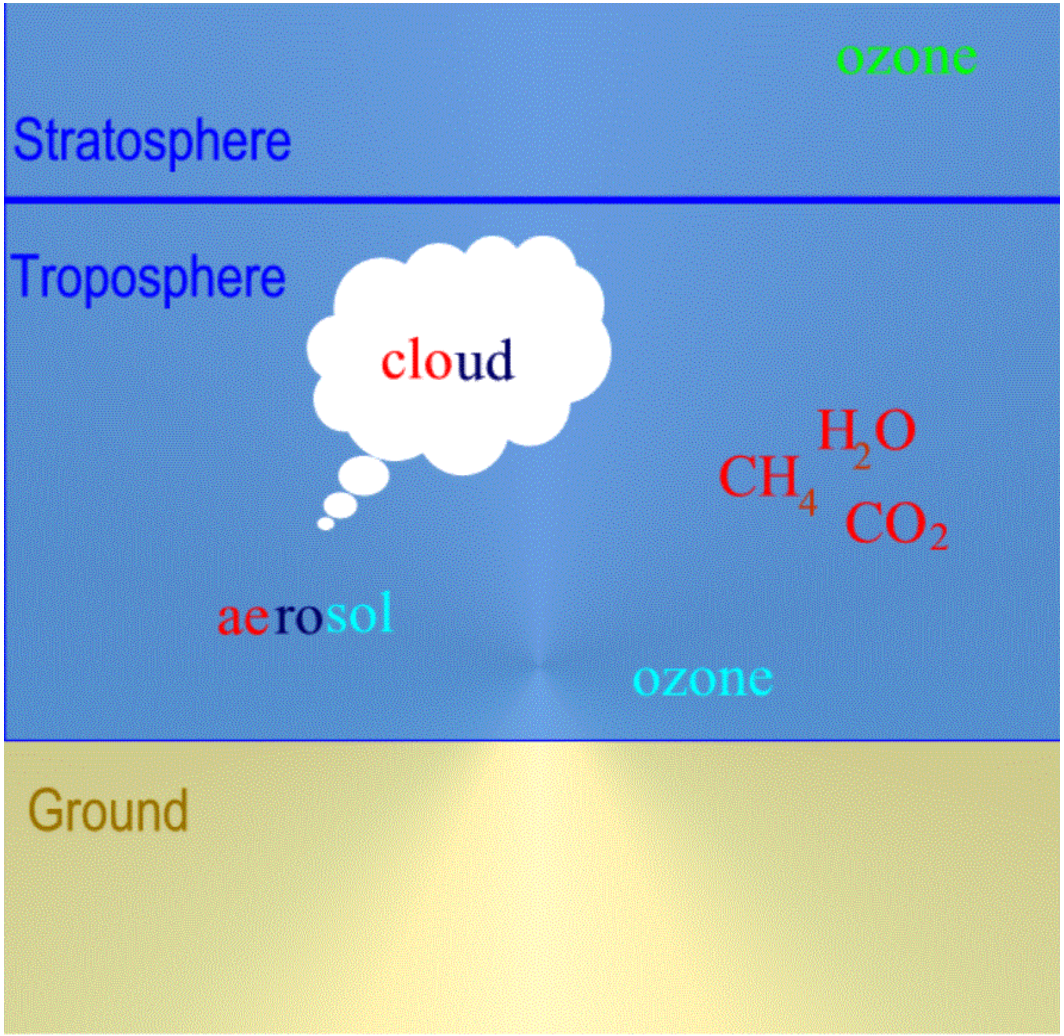
1:1 – 1:6; 2:1 – 2:4

The Atmosphere



- The atmosphere – Thin "skin" of air surrounding the planet
  - Description
  - Role of natural atmosphere
  - Effects of changed composition

The Atmosphere



- The atmosphere – Thin "skin" of air surrounding the planet
  - Description
  - Role of natural atmosphere
  - Effects of changed composition

- Atmospheric change
  - Climate
  - UV protection
  - Acidification
  - Health

Composition of the Atmosphere

Dry atmosphere (excl. H_2O):

Gas	Mixing ratio (mole/mole)
Nitrogen (N_2)	0.78
Oxygen (O_2)	0.21
Argon (Ar)	0.0093
Carbon dioxide (CO_2)	365×10^{-6}
Neon (Ne)	18×10^{-6}
Ozone (O_3)	$0.01-10 \times 10^{-6}$
Helium (He)	5.2×10^{-6}
Methane (CH_4)	1.7×10^{-6}
Krypton (Kr)	1.1×10^{-6}
Hydrogen (H_2)	500×10^{-9}
Nitrous oxide (N_2O)	320×10^{-9}

Dry atmosphere:

- Dominated by nitrogen and oxygen
- Noble gases, in particular argon
- Conc. ($O_2 + N_2 + Ar$) $\approx$ 1 mole/mole
- Remaining components trace gases: E.g. Carbon dioxide, ozone, methane

Humid atmosphere:

- Water vapour: Varies, up to approx. 0.03 moles/mole

Calculation Example: Calculate the density of dry air at $T = 280$ K and $P = 1000$ hPa!

The atmosphere an ideal gas (in most cases): $PV = nRT$

Density:

$\rho = m/V = nM/V$

From the gas law: $n/V = P/RT$ =>

$\rho = MP/RT$

Air is a mixture of gases – average molar mass: $M_a = 29,0$ kg/kmole

Gas constant: $R = 8314,3$ J/(kmole K)

Insert numbers:

$\rho = M_aP/RT = 29,0*1000*100/(280*8314,3) = 1,25$ kg/m^3

Atmospheric Concentration of Species

Expressions atmospheric concentration:

Number concentration:

- number of moles or molecules of type X per volume unit of air

Mass concentration:

- mass of X per volume unit of air

- Air compressible ⇒ These measures of concentration change with local atmospheric pressure

Mixing ratio:

- (No. moles of X)/(No. moles air molecules)
  - Or: mass X/mass air
- Unaffected by expansion/compression

- Trace gases ⇒ small numbers
  - ppm (parts per million): 10^{-6}
  - ppb (parts per billion): 10^{-9}
  - ppt (parts per trillion): 10^{-12}
- Kinds of mixing ratios:
  - ppb**v** (v = volume) based on number
  - ppt**m** based on mass

Example helium:

[He] = 5.2 10^{-6} mole He / mole air = 5.2 ppmv

Mixing ratio

- C = moles of X / total No. moles
- $C = n_x/n$

Apply the gas law: $n = PV/RT \Rightarrow$

- $C = (P_xV_x/RT_x)/(PV/RT)$
  - …and we assume $T_x = T$; $V_x = V$ $\Rightarrow$
- $C = P_x/P$ = (partial P of X) / (total P)

Example:
The mixing ratio of He is 5.2 ppmv.
Calculate the He partial pressure at sea level!

Average sea level atmospheric pressure P = 1013 hPa

$C_{He} = n_{He}/n = P_{He}/P \Rightarrow$

$P_{He} = C_{He} \cdot P =$

$= 5.2\text{x}10^{-6} \cdot 1013\ \text{hPa} = 0.53\ \text{Pa}$

Exercise 2-1 in Jacob: The atmospheric CO_2 concentration has during the industrial era increased from 280 to 400 ppmv. How large is this increase expressed as mass of atmospheric carbon?

$$C = \frac{n_C}{n_a};$$

n_C and n_a are No. moles CO_2 and air molecules

$$\Delta C = \frac{n_{C2}}{n_a} - \frac{n_{C1}}{n_a} = \frac{\Delta n_C}{n_a}$$

ΔC = 400 – 280 ppmv = 120 ppmv = 120 x10^{-6}

Increase of the carbon mass:

$$\Delta m_C = \Delta n_C M_C = \Delta C n_a M_C = \Delta C \frac{m_a}{M_a} M_C$$

M_C = molar mass of carbon;
m_a = mass of the atmosphere;

M_a = average molar mass of air
Δm_C = increase of the carbon mass

With known m_a: Δm_C = 250 billion tonnes = 250x10^{12} kg

Problem

How can we calculate the mass of the atmosphere?

Hint: The pressure at a level is caused by the weight of the overlying atmosphere

Exercise 2-1 – Continued: How can the mass of the atmosphere be calculated?

Gravitational field and no other forces affecting the pressure:

The pressure at a given level is caused by the weight of the overlying air $\Rightarrow$

Force: $m_a g = A_{earth} P$ where $A_{earth} = 4\pi R^2$

Average pressure at surface (P): 984 hPa

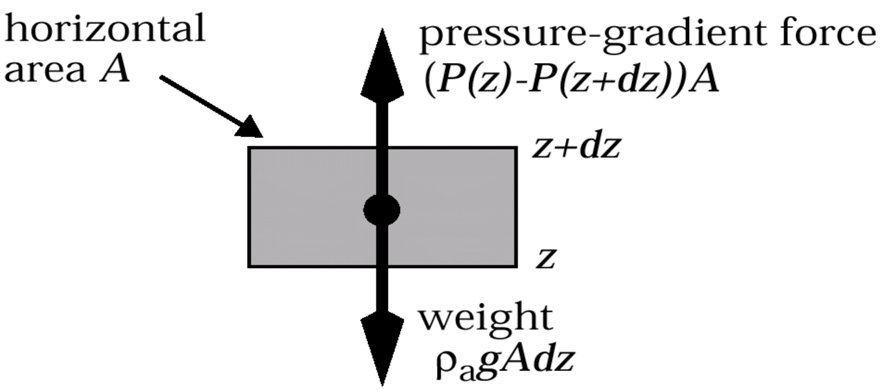
Radius of the earth (R): 6400 km

Reorganize:

$m_a = 4\pi R^2 P/g = 5.2 \times 10^{18}$ kg

Atmospheric Pressure – Dependence on Altitude

Vertical element dz:



Equilibrium: The gravimetric force is balanced by the force from a pressure gradient

Gravimetric force = Gradient force

$-g\rho_a A dz = (P(z + dz) - P(z))A = dPA$

(A = horizontal surface area)

$dP = -\rho_a g \, dz$

From the ideal gas law:

$\rho_a = PM_a/(RT)$

$dP = -PM_a g/(RT) \, dz$

Rearrange:

$dP/P = -M_a g/(RT) \, dz$

M_a, g and R are constant

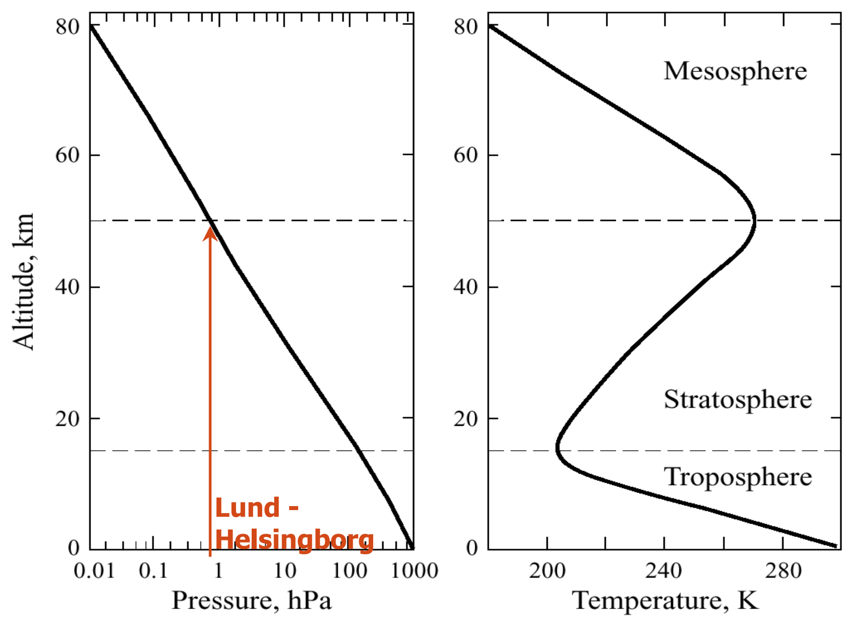
Approximation: T independent of z $\Rightarrow$

Barometric law:

$$P(z) = P(0)e^{-M_a gz/RT}$$

Vertical Profiles in the Atmosphere

- The pressure decreases exponentially with altitude
  - Example: at 50 km 0.1% of the pressure at the surface



Temperature profile:

- Troposphere
  - T decreases with z
  - Earth's surface warm due to absorption of solar radiation
  - Cooling with altitude due to adiabatic expansion
- Stratosphere
  - T increases with z
  - Ozone absorbs solar radiation and heats the stratosphere
- Mesosphere
  - T decreases with z

Exercise 2:3 Calculate the altitude that divides the mass of the atmosphere in two equal halfs (Assume T constant at 260 K)!

$m_a g = 4\pi R^2 P \;\Rightarrow\; m_a \sim P \;\Rightarrow\; m_a/2$ appears at $P/2$

Use the barometric law:

$P(Z) = P(0)e^{-M_a gz/RT}$ and find $P(Z) = P(0)/2$

$P(Z)/P(0) = e^{-M_a gz/RT} = 0.5$

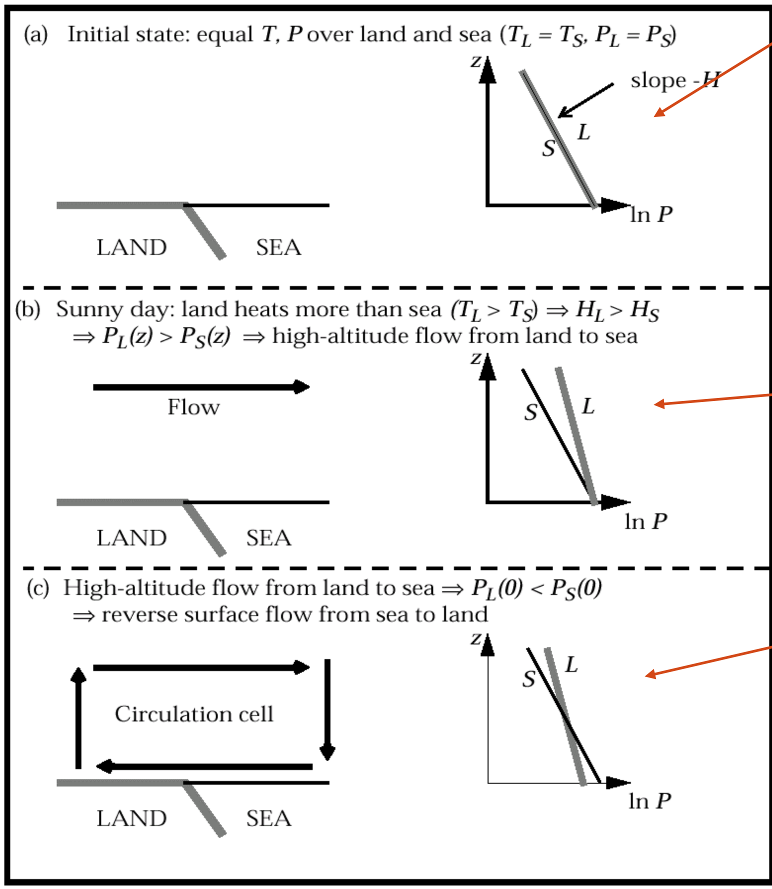
Logarithm at both sides:

$-M_a gz/RT = \ln(0.5)$

Rearrange:

$z = -RT\ln(0.5)/M_a g = 5.27$ km

Sea-Breeze



- Initially: $T_L = T_S$; $P_L = P_S$; no wind
- Solar heating of land strongest:
  - Water has higher heat capacitivity
  - Evaporation of H_2O cools
- $P(z) = P(0)\exp(-M_a g z/RT)$
- ⇒ Difference in vertical pressure gradient
  - $P_L - P_S$ increases with altitude
  - High altitude wind from land to sea
- ⇒ Air column over land decreases
  - ⇒ $P_L < P_S$
  - Low altitude wind from sea to land
- Circulation cell:
  - 10km horizontally, 1km vertically