Vorlesung Atmosphärenchemie – Zeitplan
Mittwochs, 21. September 2011 – 21. Dezember 2011, 8:15-10:00, CHN F46

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Die Besprechung der Übungen *Ü1-Ü11* durch HS/JA geschieht jeweils in den ersten 15' jeder Doppelstunde

21.09.	**Einleitung** - Unterschiede zwischen den „Reaktoren" Trop/Strat - Vertikaltransport, UV-Strahlung, Ozon, Chapman-Chemie - wichtigste (aktuelle) Themen der Atmosphärenchemie	TP	
28.09.	**Kinetische Grundlagen I** - Einzelreaktionen: thermische (inkl. T- und p-Abhängigkeit)	TP	
05.10.	**Kinetische Grundlagen II** - photochemische Reaktionen - Radikalische Kettenreaktionen	TP	*Ü1 (HS/JA)*
12.10	**Beispiele aus der Stratosphärenchemie** - Ozonabbau durch ODS in Gasphase - Ozontrends, Montrealer Protokoll, Recovery	TP	*Ü2 (HS/JA)*
19.10.	**Polare Stratosphärische Ozonchemie** - Polare stratosphärische Wolken	TP	*Ü3 (HS/JA)*

Vorlesung Atmosphärenchemie – Zeitplan – Fortsetzung

26.10.	**Aerosole** - Phys. Grundlagen und heterogene Chemie	TP	*Ü4 (HS/JA)*
02.11.	**Chemie-Klima-Wechelwirkungen** - Klimawirksamkeit im Zusammenhang mit chem. Zs.-setzung	TP	*Ü5 (HS/JA)*
09.11.	**Einführung: troposphärische Gasphasenchemie** - Photooxidantienbildung aus Vorläufersubstanzen - NOx/VOC-Limitierung	JS	*Ü6 (HS/JA)*
16.11.	**Luftschadstoffe/Grenzschichtmeterologie** - Tagesgänge, Jahresgänge - Wintersmog/Sommersmog, Emissionen	JS	*Ü7 (HS/JA)*
23.11.	**Globale Photochemie** - Oxidation Capacity, long-term trends	JS	*Ü8 (HS/JA)*
30.11.	**SO_2-Oxidation und schadstoffbelastete Niederschläge** - Flüssigphasenchemie, Trockendeposition	JS	*Ü9 (HS/JA)*
07.12.	**Globale Zyklen** - Übersicht über die Zyklen	JS	*Ü10 (HS/JA)*
14.12.	**Strahlungsantrieb, Globale Erwärmungspotentiale** - Physikochemische und chemische Grundlagen - Unterschiede von CO_2, N_2O, CH_4, CFCs, HCFCs, SF_6 etc	JS	*Ü11 (HS/JA)*
21.12.	**Fragestunde**	TP	

22./23. Dez. 2011 und 5./6. Jan. 2012: Mündliche Prüfungen (je 20') TP+JS

Vorlesung Atmosphärenchemie – Leistungen

Voraussetzung: VL „Atmosphäre“ erwünscht!

Unterlagen: kein ausformuliertes Skript, aber Kopien der Folien unter:
http://www.iac.ethz.ch/education/bachelor/atmospheric_chemistry

Kreditpunkte: 3 ECTS = 90 Arbeitsstunden
= 30 Kontaktstunden + 60 Stunden Eigenarbeit

Leistungsnachweis: Übungen und Prüfung

Übungen: Je Stunde eine Übungsserie, „leicht-mittelschwer“, selbständig formuliertes Lösungsblatt* ***vor*** der nächsten Stunde abzugeben.

(*) „Selbständig formuliertes Lösungsblatt“ heisst:
Sie können und sollen über den Stoff sprechen.
Sie können und sollen auch über die Aufgaben sprechen und gemeinsam über die Lösung nachdenken.
Sie dürfen sich aber nicht die Lösung bei einem Kollegen „abholen“, geschweige denn, dass Sie sie kopieren dürften!
Die Tutoren sind angewiesen, keine Punkte auf abgeschriebene Aufgaben zu vergeben.

Build working groups! But do not copy!

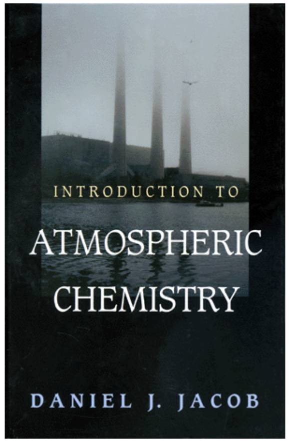
Prüfung: 30 Minuten mündlich
22./23. Dezember Semesterendprüfungen
5./6. Januar Semesterendprüfungen

Note: Ihre Leistung wird benotet:
1/3 Übungen, 2/3 Prüfung
oder
1/2 Übungen, 1/2 Prüfung
(vor Beginn der mündlichen Prüfung festzulegen)

22 Studierende in diesem Kurs (eingeschrieben am 19. Sept):

10 UWIS BSc
6 Geogr. BSc
3 Erdw. BSc
3 MSc UWIS

Vorlesung Atmosphärenchemie – empfohlene Literatur:



Exzellenter Standard:

Daniel J. Jacob, Introduction to Atmospheric Chemistry,
Princeton University Press, 1999.
http://acmg.seas.harvard.edu/publications/jacobbook/index.html

Blick über den Tellerrand:

Thomas E. Graedel and Paul J. Crutzen, Chemie der Atmosphäre:
Eine Systemperspektive, Spektrum Akad. Verlag, Berlin, 1994.

Breites Allgemeinwerk, gute Anküpfung mit Laborexperimenten (auch MSc):

Barbara Finnlayson-Pitts and James N. Pitts, Jr., Atmospheric Chemistry:
Fundamentals and Experimental Techniques, Wiley, New York, 1986.

Lesbares Nachschlagewerk (auch MSc):

John H. Seinfeld and Spyros N. Pandis, Atmospheric Chemistry and
Physics: From Air Pollution to Climate Change, Wiley, New York, 1998.

Unter dem Kopfkissen:

Stefan Brönnimann, Ozon in der Atmosphäre, Hauptverlag, Bern, 2002.

Notes to this lecture (in English):

Every 3rd to 5th page of the handout contains information in English language
→ recommended in particular for Johannes Staehelin's parts of the lecture

Introduction:

The evolution of the atmosphere

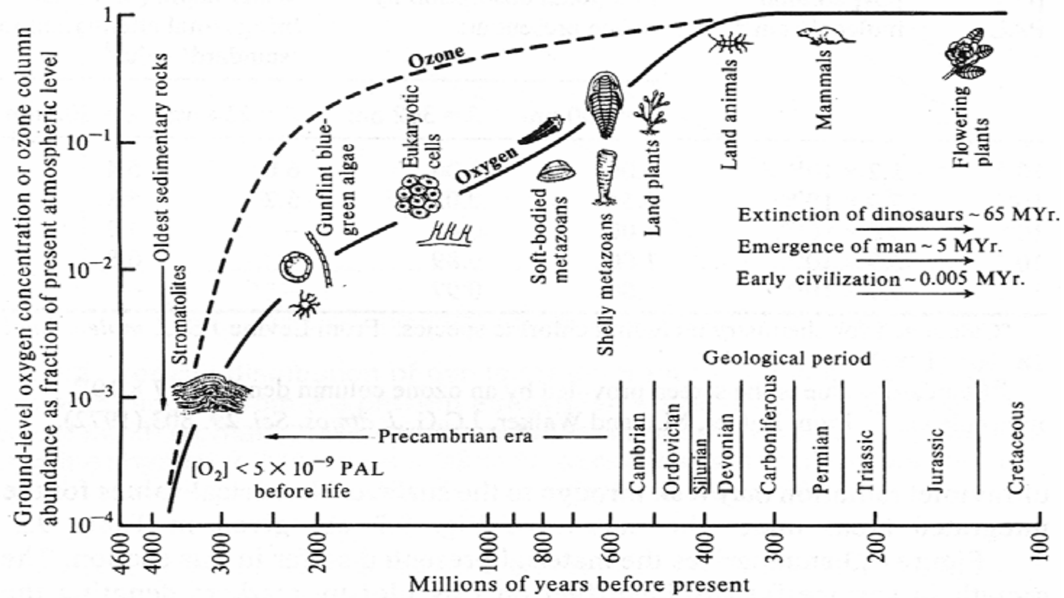
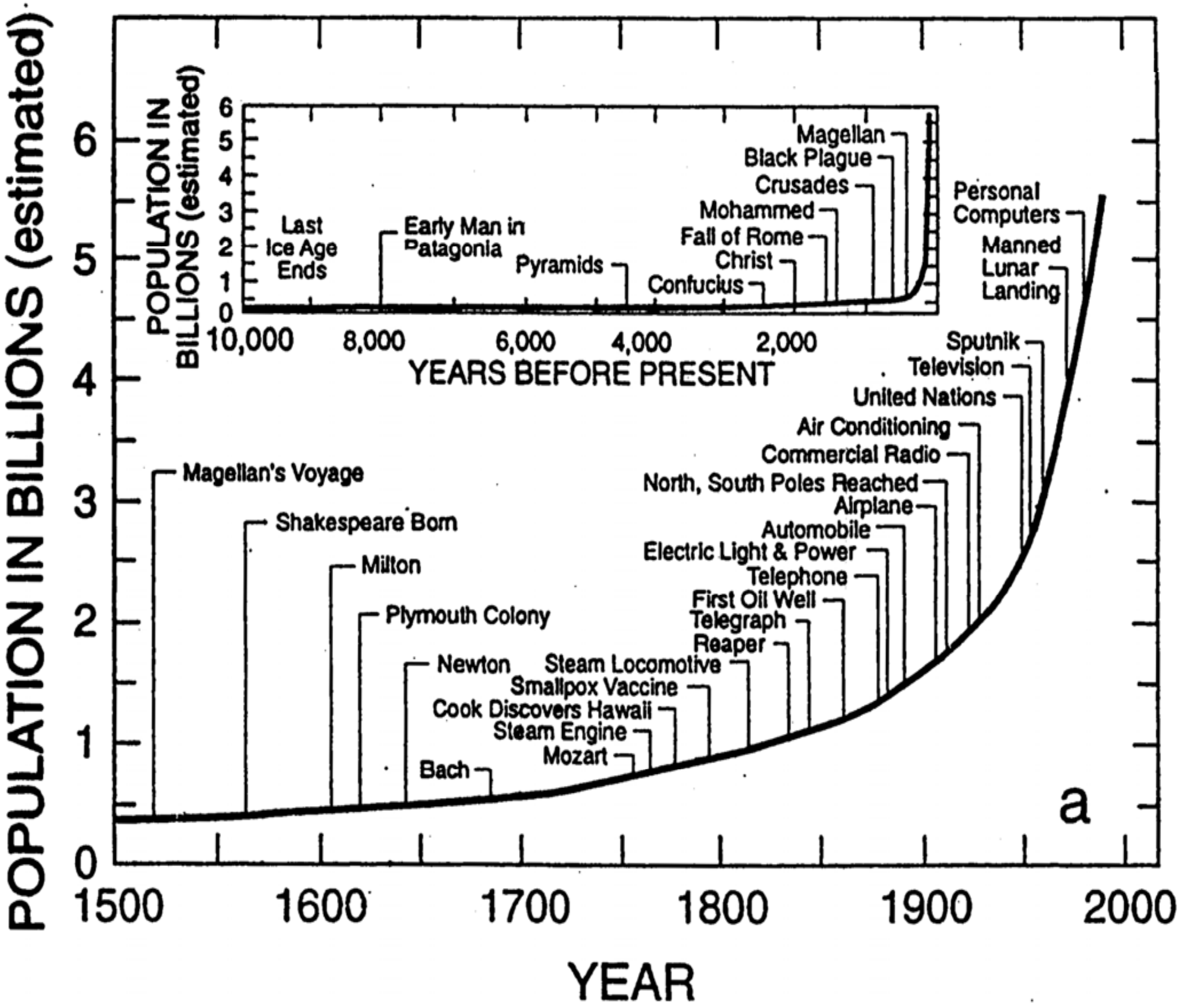


Fig. 9.3. Evolution of oxygen, ozone, and life on Earth. In the absence of life, surface oxygen concentrations are unlikely to have exceeded ~ 5×10^{-9} of the present value. The build-up of oxygen to its present level is largely a result of photosynthesis. Early organisms would have found high oxygen concentrations toxic, but eukaryotic (nucleated) cells require at least several per cent of the present level for their respiration. Soft-bodied metazoans could have survived at similar oxygen levels, but the reduced surface oxygen uptake area available once the species had developed shells must mean that the concentration was approaching one-tenth of its current value about 570 Myr ago. Considerations such as these are used in drawing up the oxygen growth curve. Ozone concentrations can be derived from a photochemical model. Life could not have become established on land until there was enough ozone to afford protection from solar ultraviolet radiation.

Source: Wayne, 2000

Atmospheric chemistry and the evolution of world populatoin



From Graedel & Crutzen

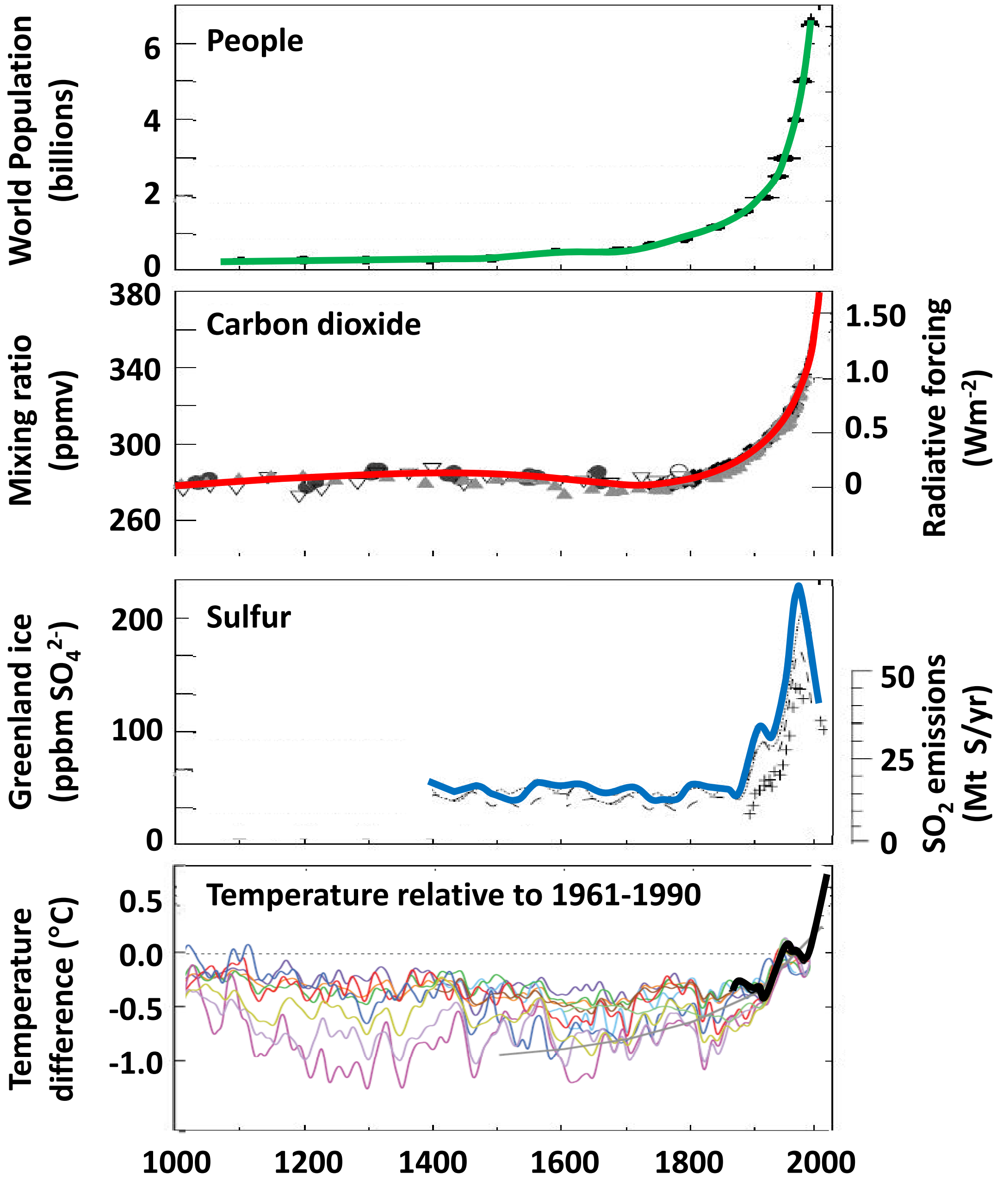
The most recent millennium

World Population

Heating the Planet

Cooling the Planet

Temperature Change



Evolution of the Earth‘s Atmosphere

- Evolution of ground-level oxygen, column ozone and life in Earth‘s history
- Increase of oxygen concentration to present-day surface levels would have been impossible in absence of photolysis
- Over time the vertical profile of ozone concentration was shifting from a maximum at the surface (past times) to a maximum at an altitude of around 25 km (present-day). This prevented harmful shortwave radiation reaching the Earth‘s surface and avoided having high ozone concentrations down to the ground, hence enabling life to develop on land.

The vertical dimension

Troposphere and middle atmosphere

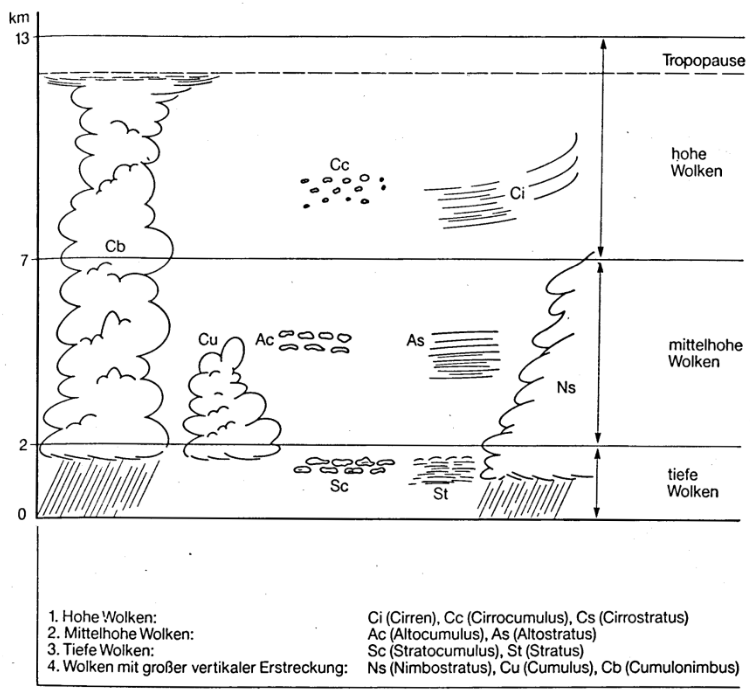


Abb. 1
Die 10 Wolkengattungen nach der internationalen Wolkenklassifikation, zusammengefaßt in 4 Wolkenfamilien

Source: http://ppfeyte.free.fr/images/weekpic/cumulonimbus.htm

Source: http://amesnews.arc.nasa.gov/multimedia/images/00images/pscpix/PSC2.jpg

Troposphere and Stratosphere

- 10 cloud types (according to international classification) together with their vertical appearence and extension
- Due to the vertical temperature structure with a minimum at the tropopause of 180 – 220 K, cloud formation is almost entirely restricted to the tropospheric layer. The exception are polar stratospheric clouds (PSCs) which play an important role in ozone chemistry (see later).
- The high saturation of air with water vapour in the upper troposphere hinders water to enter the stratosphere to a large degree (rainout/snowout). This makes the stratosphere very dry with typical mixing ratios of around 5 ppmv H_2O.

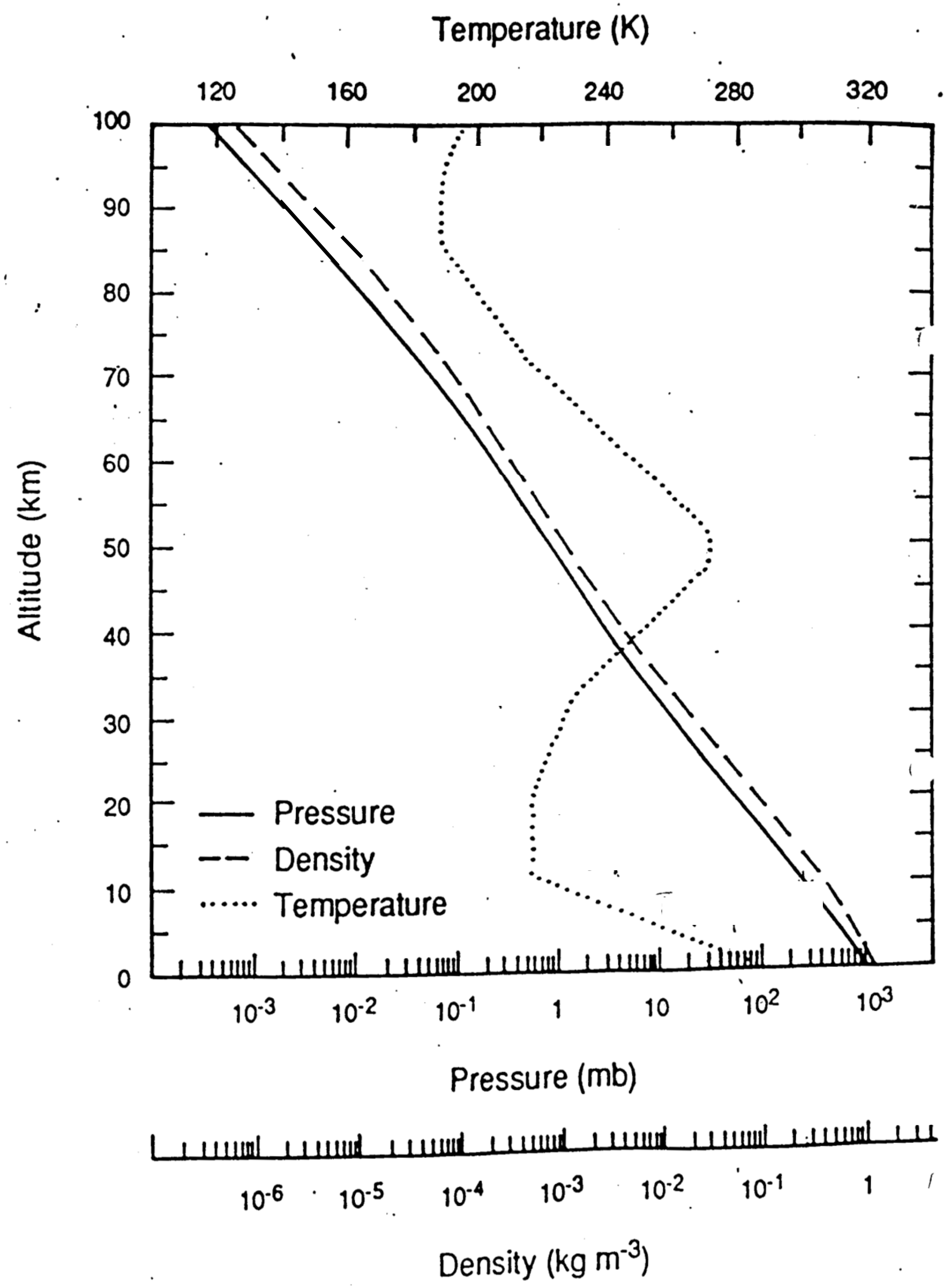
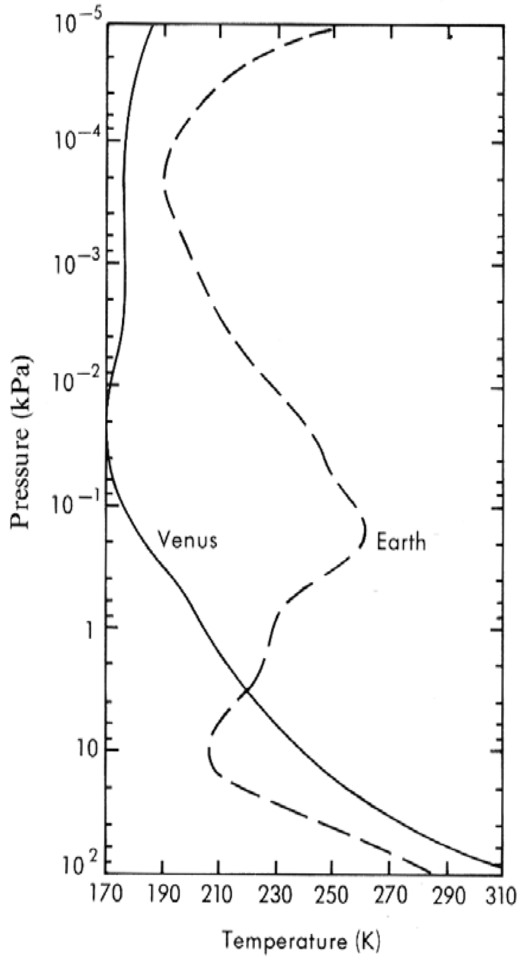

Temperature (K)
120
160
200
240
280
320
100
90
80
70
60
50
40
30
20
10
0
Altitude (km)
Pressure
Density
Temperature
10-3
10-2
10-1
1
10
10²
10³
Pressure (mb)
10-6
10-5
10-4
10-3
10-2
10-1
1
Density (kg m-3)

Fig. 12.16. Vertical temperatures profiles of temperature versus pressure at 30N latitude as measured on Venus by the VORTEX experiment and on earth by the Nimbus 7 Stratospheric and Mesospheric sounder. Further details of both instruments in Houghton, Taylor & Rodgers 1984.

Source: Houghton, 1989



Temperature Profile in the Atmosphere

- Surface: Transformation of incoming shortwave radiation into outgoing infrared radiation („hot plate“)
- Middle Atmosphere (Stratosphere): Photolysis of ozone and recombination to ozone via reaction of oxygen and atomic oxygen, thereby transformation of photon energy into kinetic energy which increases temperature
- Thermosphere: Heating through ionisation of N_2 and O_2

- On other planets (e.g. Venus) the O_2 / O_3 – heating mechanism is missing and hence the related warming in the middle atmosphere is missing

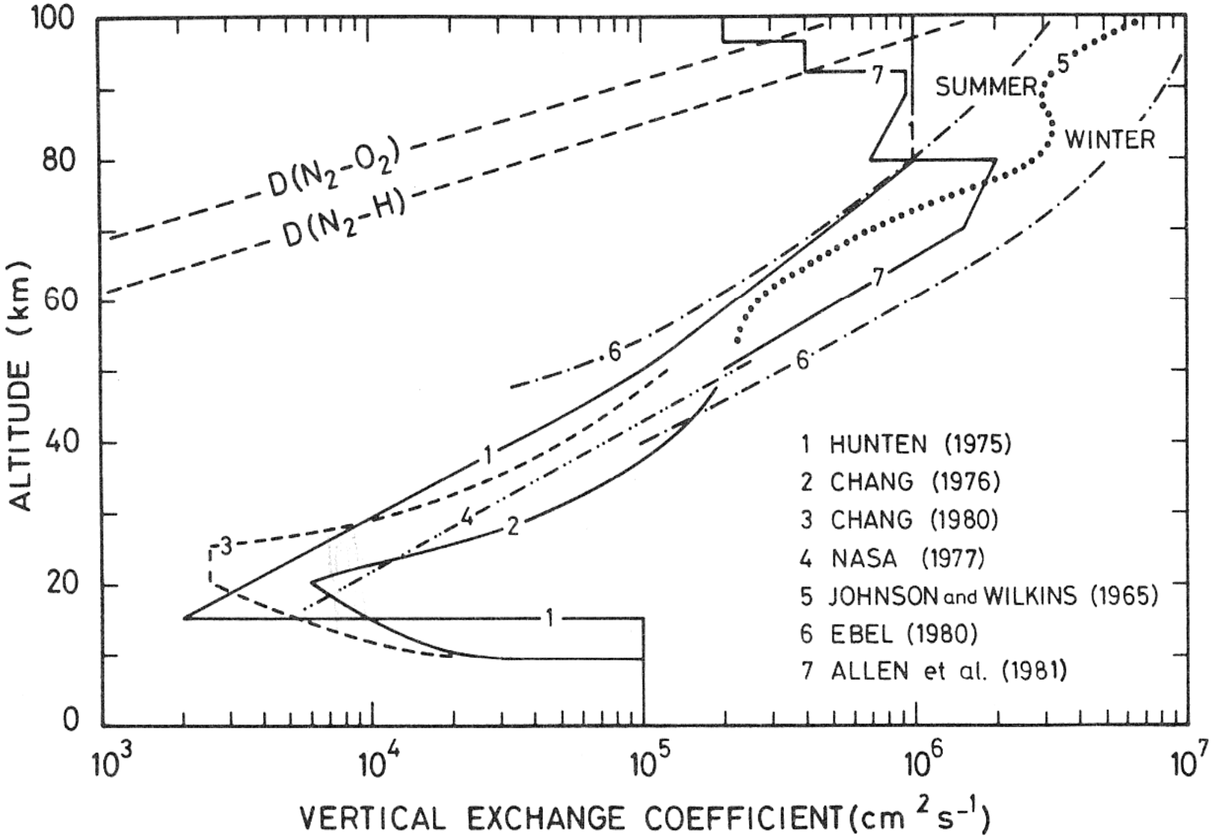


Fig. 3.22. One-dimensional eddy diffusion coefficients used in various aeronomic models.

Source: Brasseur and Solomon, 1986

Vertical Exchange in the Atmosphere

- Vertical Exchange Coefficient = Eddy Diffusion Coefficient
- In the lower stratosphere the Eddy diffusion coefficient is at its minimum and hence vertical mixing is very low („stratified“). The vertical exchange coefficient strongly increases with altitude because the air is getting thinner, upward traveling waves develop larger amplitudes and lead to more mixing upon breaking (and hence more vertical exchange).
- The troposphere exhibits much stronger vertical mixing than the lower stratosphere. The reason is the development of deep convection (i.e. high-rising thunderstorms transport air quickly from the boundary layer to the upper troposphere). The tropopause acts as a distinct transport barrier.

The Ozone Layer

Source: Brasseur and Solomon, 1986

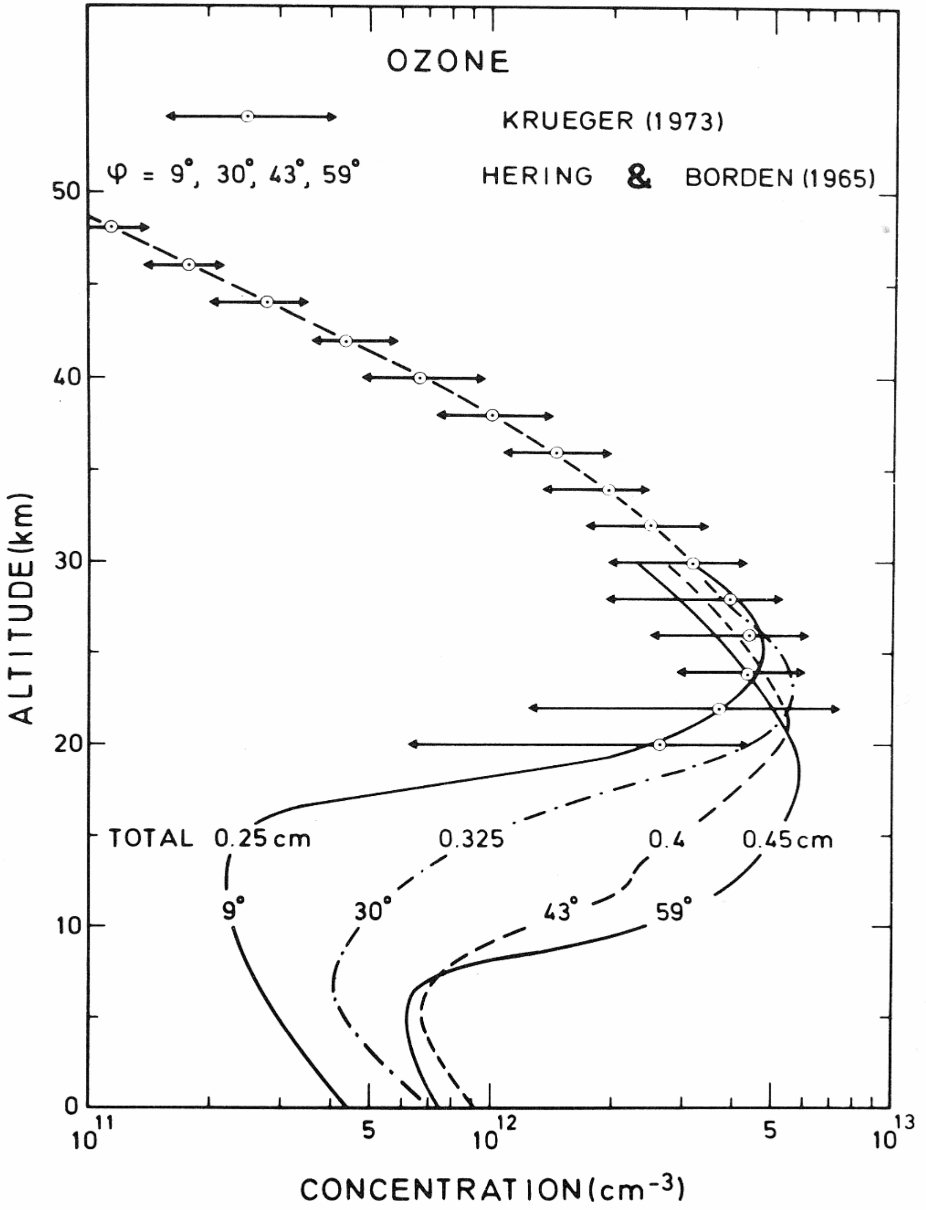
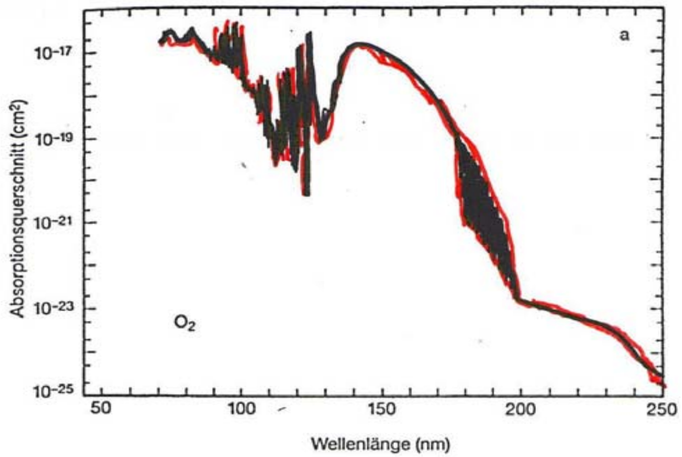


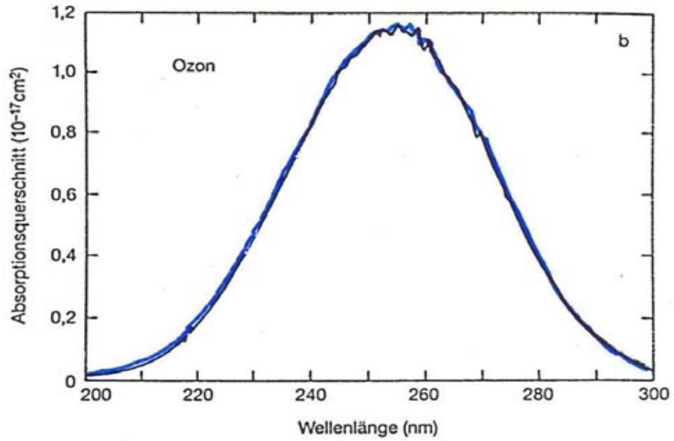
Fig. 5.7. Mean vertical distribution of the ozone concentration according to observations at different latitudes. Note the variations in total column abundance.

The Ozone Layer

- Vertical profiles derived from ozone sondes and satellite measurements.
- The ozone concentration (number of molecules per cm^3) shows a maximum at 20 to 25 km altitude, depending on latitude.
- The „ozone layer“ is regarded as the layer between 20 and 40 km, where ozone concentration is most abundant.
- The ozone minimum at the tropopause (also referred to as the „ozonopause“) varies with latitude, reflecting the height of the tropopause (increasing from the Poles towards Equator)

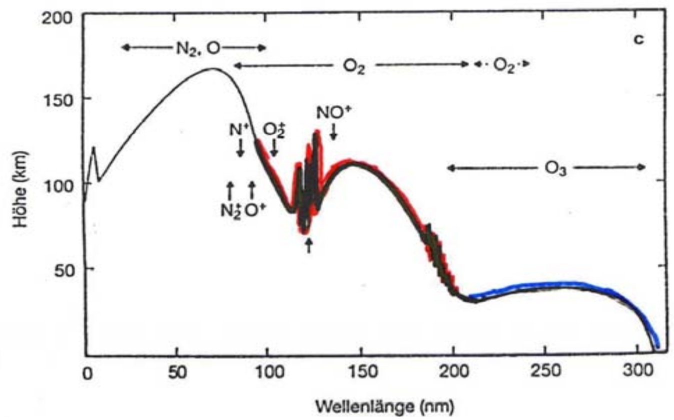


Absorptionsquerschnitt von molekularem Sauerstoff (O_2)



Absorptionsquerschnitt von Ozon (O_3)

Ausschnitt, die Absorption geht bis 1140 nm

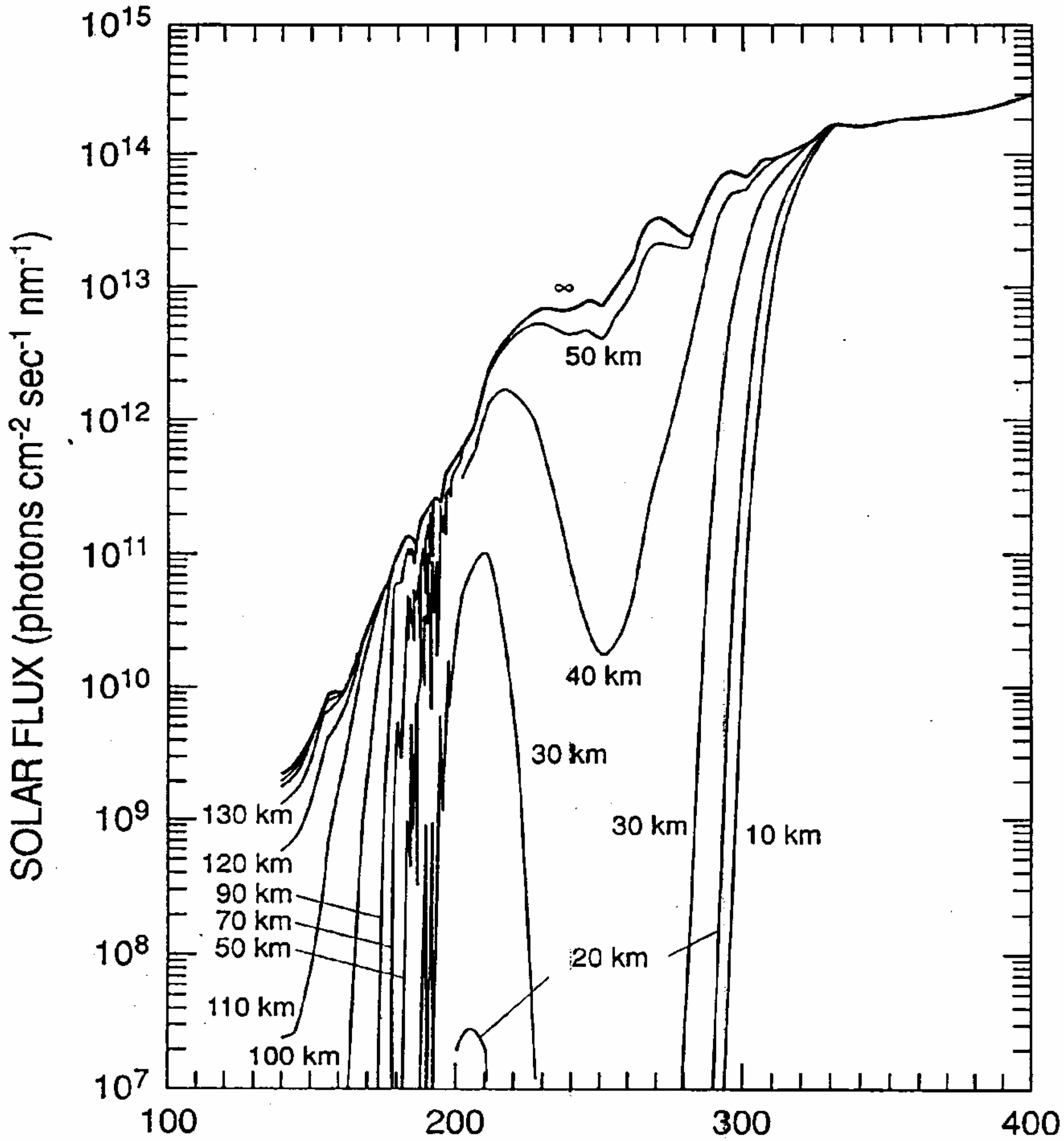


Eindringtiefe von Sonnenstrahlung in Abhängigkeit von der Wellenlänge in die Erdatmosphäre.

Source: Brasseur and Solomon, 1986

Absorption of shortwave solar radiation

- Absorption cross section of molecular oxygen (a), ozone (b) (only part of the whole wavelength band) and depth of solar radiation penetrating into the Earth‘s atmosphere (c) as a function of wavelength
- Strong dependence of absorption cross section upon wavelength
- For wavelengths below 100 nm radiation is almost completely absorbed above 100 km by atomic and molecular oxygen and molecular nitrogen
- Between 100 and 300 nm, the main drivers in the absorption of UV solar radiation are O_2 (O_2 + hv → O + O) and O_3 (O_3 + hv → O_2 + O).
- O_2 effectively absorbs UV in distinct bands:
  Lyman-α line: 121.6 nm
  Schumann-Runge band: 175 – 200 nm
  Herzberg continuum: 200 – 242 nm
- O_3 absorbs in the Hartley band: 200 – 310 nm



The atmosphere as a UV filter

Source: Falkowski et al., Scence, 2000