Air Pollution Control and Air Chemistry:

Introduction to fundamental processes in the atmosphere

(1st lecture)

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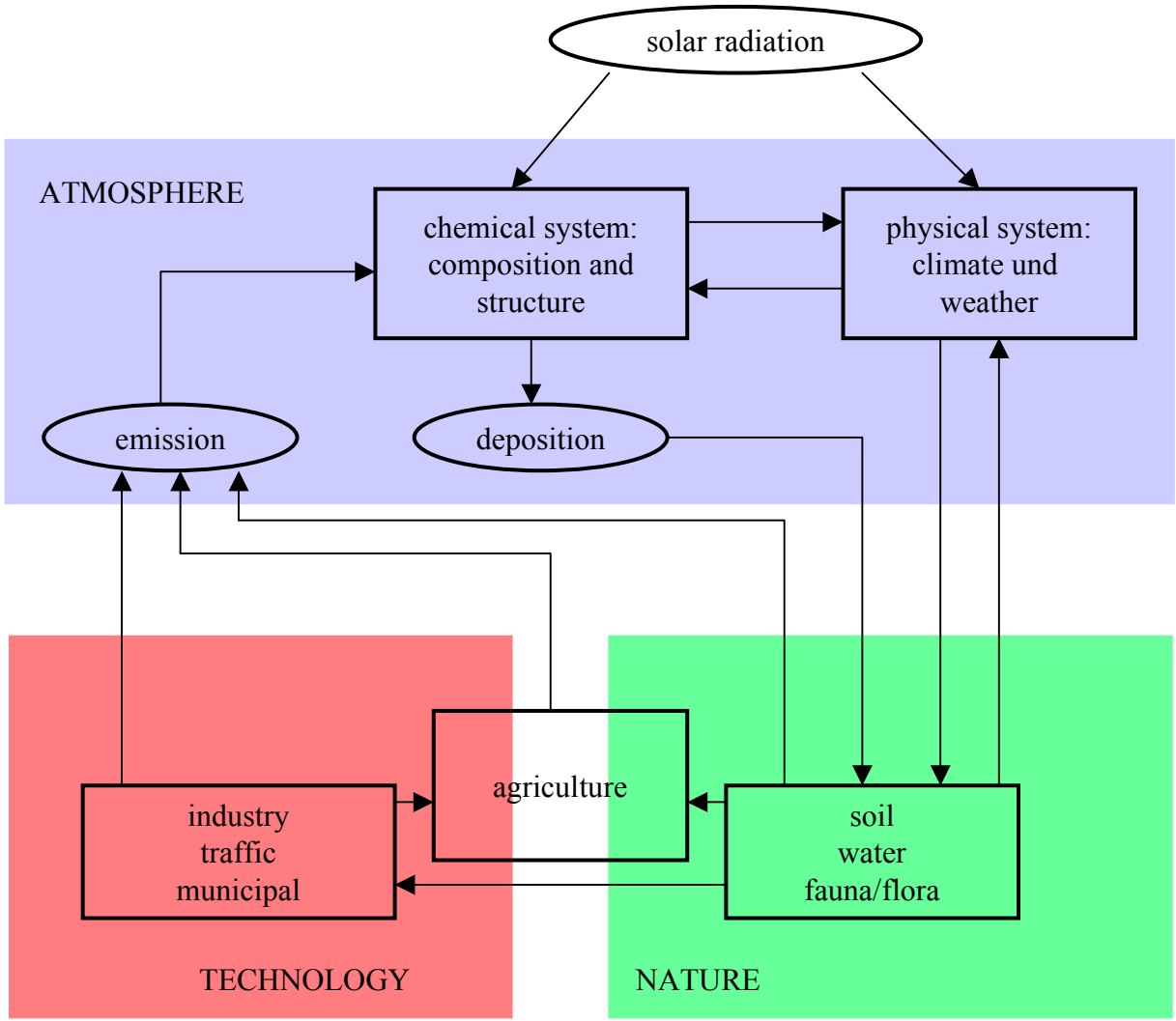
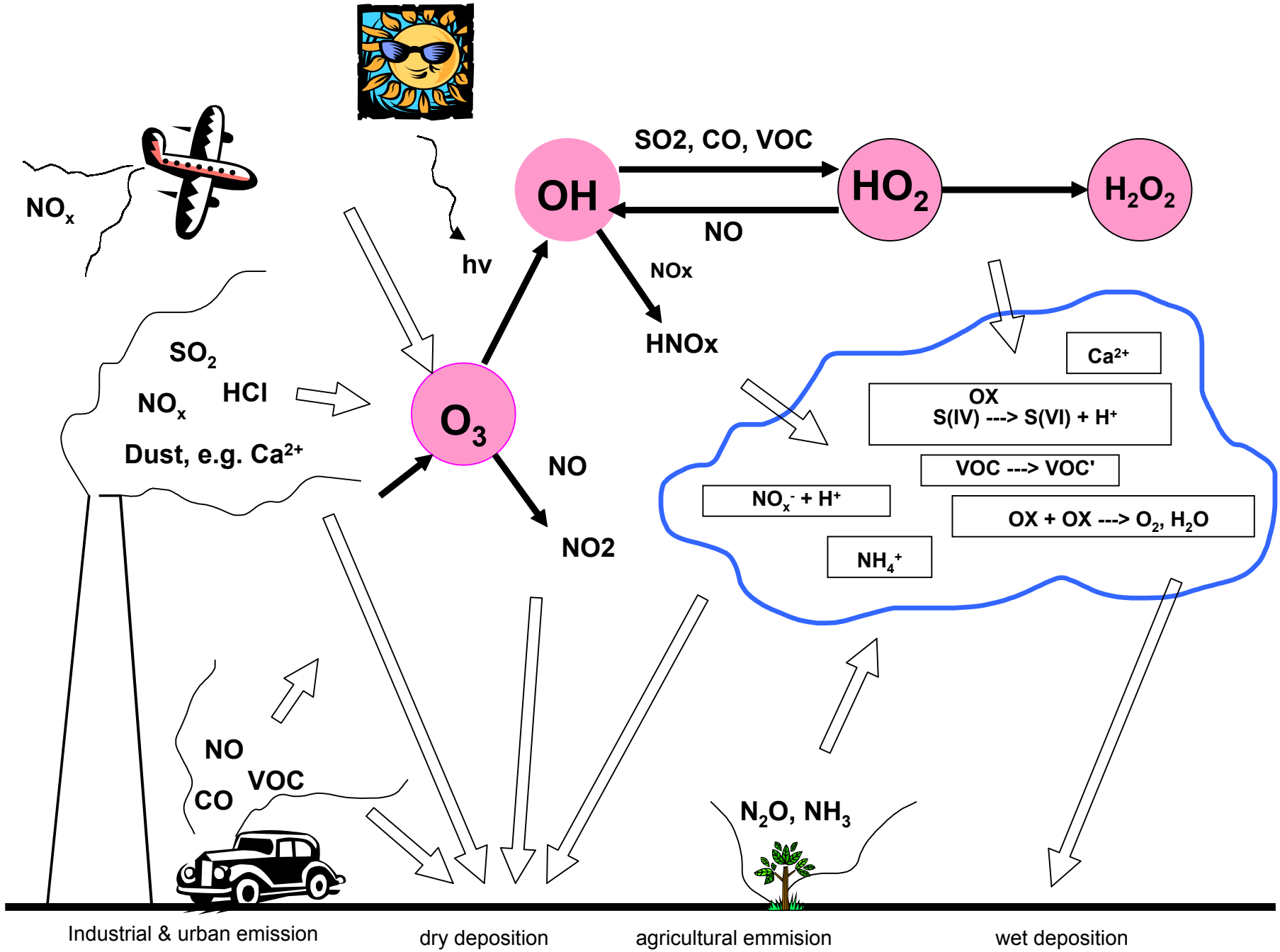
Objectives:

To describe the atmosphere as a chemical and physical system, controlled by solar radiation, terrestrial natural (biogenic and geogenic) processes as well anthropogenic activities.

- The atmosphere
- Air composition and problems
- Air pollution
- The climate system


solar radiation
ATMOSPHERE
chemical system:
composition and
structure
physical system:
climate und
weather
emission
deposition
agriculture
industry
traffic
municipal
soil
water
fauna/flora
TECHNOLOGY
NATURE


NOx
hv
OH
SO2, CO, VOC
HO2
H2O2
NO
NOx
HNOx
SO2
NOx
HCl
Dust, e.g. Ca2+
O3
NO
NO2
Ca2+
OX
S(IV) ---> S(VI) + H+
VOC ---> VOC'
NOx- + H+
OX + OX ---> O2, H2O
NH4+
NO
VOC
CO
N2O, NH3
Industrial & urban emission
dry deposition
agricultural emmision
wet deposition

Definitions & statements

Air = chemical multiphase system consisting from gaseous species, particulate matter and droplets (= chemical system of the lower atmosphere. i.e. until the meso pause)

Atmosphere = reservoir sourrounding the earth surface; including the high atmosphere where air is not longer defined

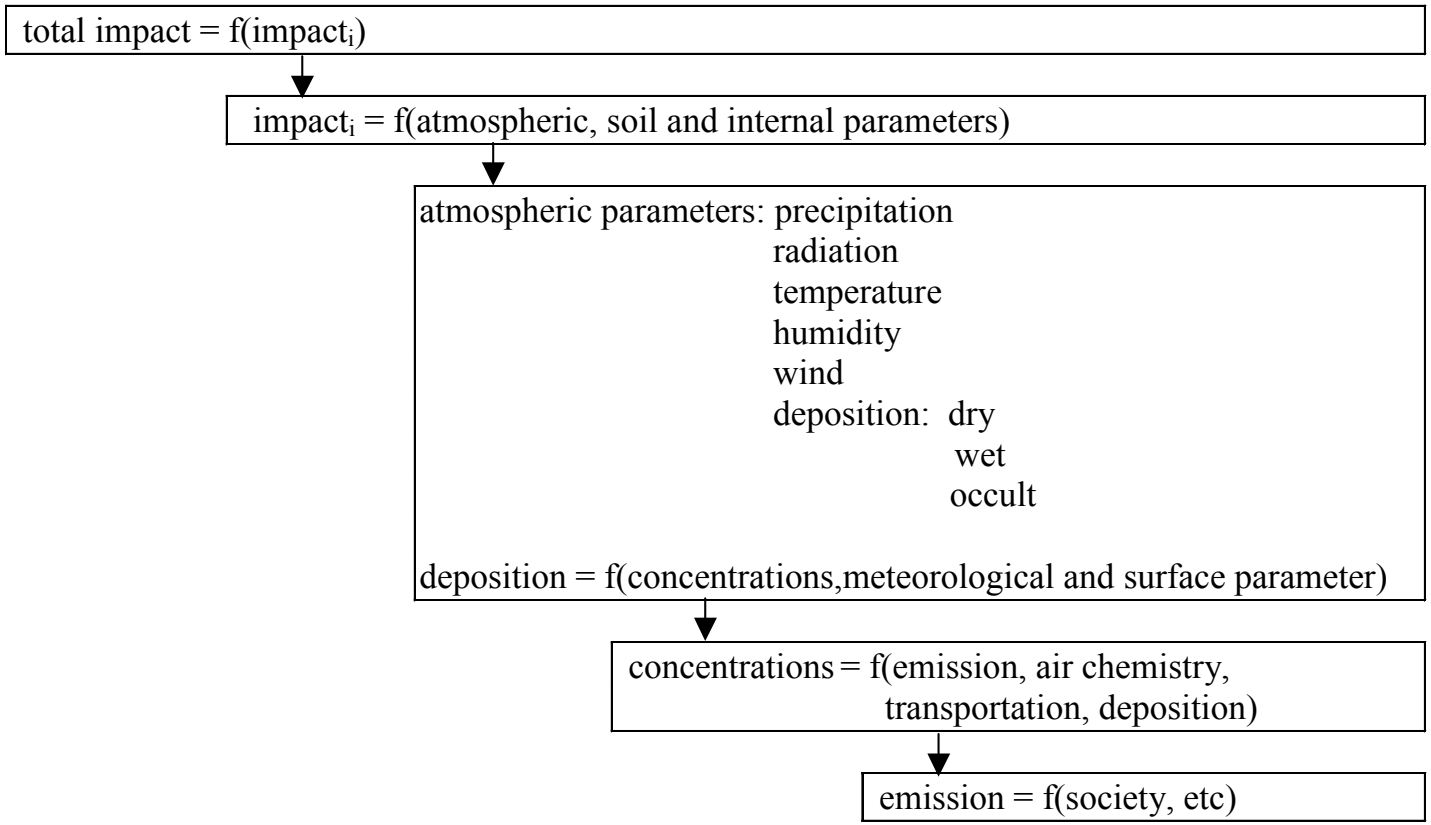
The chemical composition of the atmosphere (i.e. "**Air Chemistry"**) is a result of emissions into the atmosphere, chemical reactions (transformation), transport processes (mixing) and energetic processes ("**Physics of the Atmosphere**"). The **natural** air chemistry is a result of the evolution of the biosphere-atmosphere interaction.

Man-made activities lead to a *changing chemical composition* of the atmosphere, which is called **Air Pollution**, i.e., $x_{present} - x_{natural} = x_{pollutant}$

An **Effect** is a results of an **Impact**, which, however, is given by the total concentration ($x_{natural} + x_{pollutant}$). Therefore, impact assessment needs a separation between natural and man-made influences suggesting abatement strategies. Co-impacts (external and internal) must be considered. Effects only occur when the impact exceeds a threshold.

The impact to an ecosystem is a system of hiercharchic functional relationsships

(Deposition as an example for atmospheric parameter):



example for feedback relations:

air chemistry depends from the ecosystem (i.e. the impact itself) in sense of emission and deposition fluxes

Air chemistry is defined ... as the branch of atmospheric science concerned with the constituents and chemical processes of the atmosphere ... (Christian Junge, 1963)

A clean atmosphere is a political target, i.e., an air chemical composition (defined in time and scale) which should provide a sustainable development.

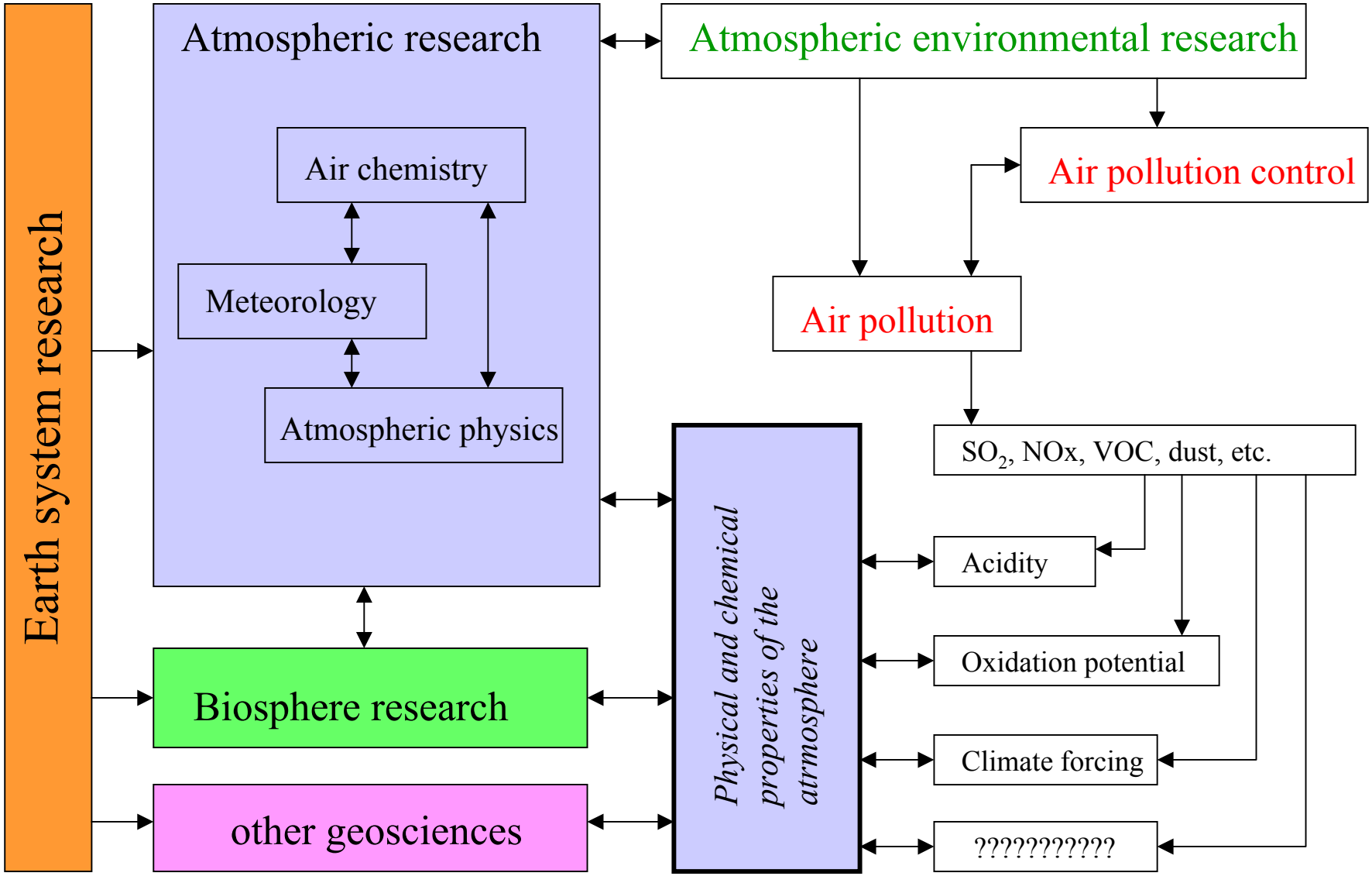
The natural atmosphere does not longer exist; it was the air chemical composition without man-made influence. However, the definition is not exactly because humans ar part of the nature...

On the other hand, humans – by decoupling of her life cycle from only natural conditions – have altered „natural“ biogeochemical cycles. *Vernadsky* understood with noosphere a new dimension of the biosphere, developing under the evolutionary influence of humans on natural processes.

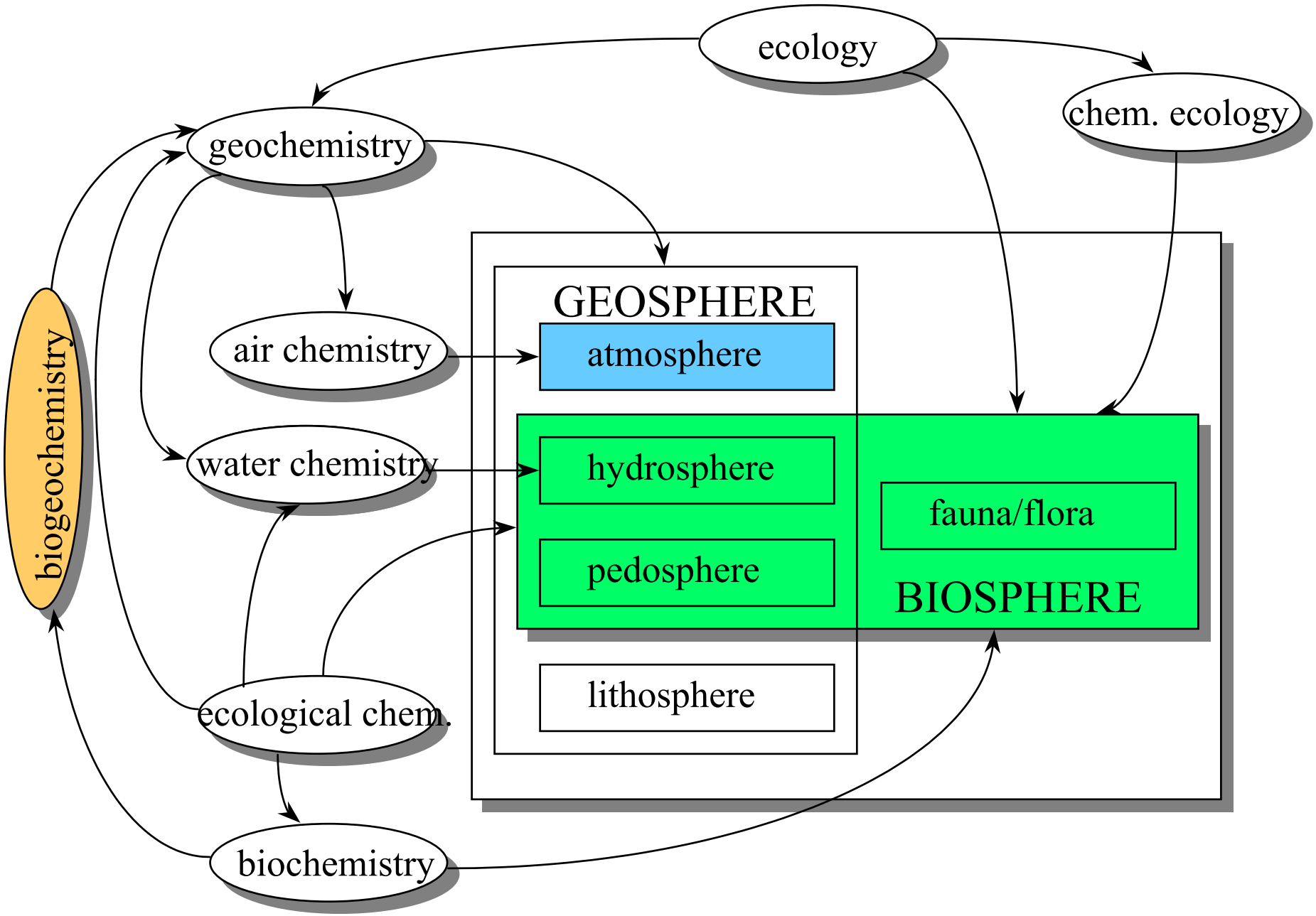
composition of the dry remote atmosphere (global mean concentrations)

substituent		conventration (in ppm ≡ 10^{-4} %)	remarek
nitrogen	N_2	780840[a]	constant
oxygen	O_2	209460[a]	constant
argon	Ar	9340[a]	constant
carbon dioxide	CO_2	360	increasing
neon	Ne	18,18	constant
helium	He	5,24	constant
methane	CH_4	1,73	increasing
krypton	Kr	1,14	constant
hydrogen	H_2	0,5	constant
dinitrogen monoxid	N_2O	0,31	steigend
carbon monoxid	CO	0,120	increasing
xenon	Xe	0,087	constant
ozone	O_3	0,03	variabel
carbonylsulfid	CSO	0,00066	increasing
nitric acid[b]	HNO_3	≤ 0,001	variable
radikals[c]		< 0,00001	variable
hydroxyl radikal	OH	0,0000003	variable

[a] related to the "clean" atmosphere $O_2 + N_2 + Ar + CO_2$
[b] and many other trace substances (NH_3, NO_x, HCl, NMHC, H_2O_2, DMS, CFC´s et. al.)
[c] e.g. HO_2, NO_3, Cl


Earth system research
Atmospheric research
Air chemistry
Meteorology
Atmospheric physics
Biosphere research
other geosciences
Atmospheric environmental research
Air pollution control
Air pollution
SO2, NOx, VOC, dust, etc.
Physical and chemical properties of the atmosphere
Acidity
Oxidation potential
Climate forcing
???????????

CHEMICAL ENVIRONMENTAL RESEACH



Chemistry and physics being sciences of „observing“ the environment (our “senses”)

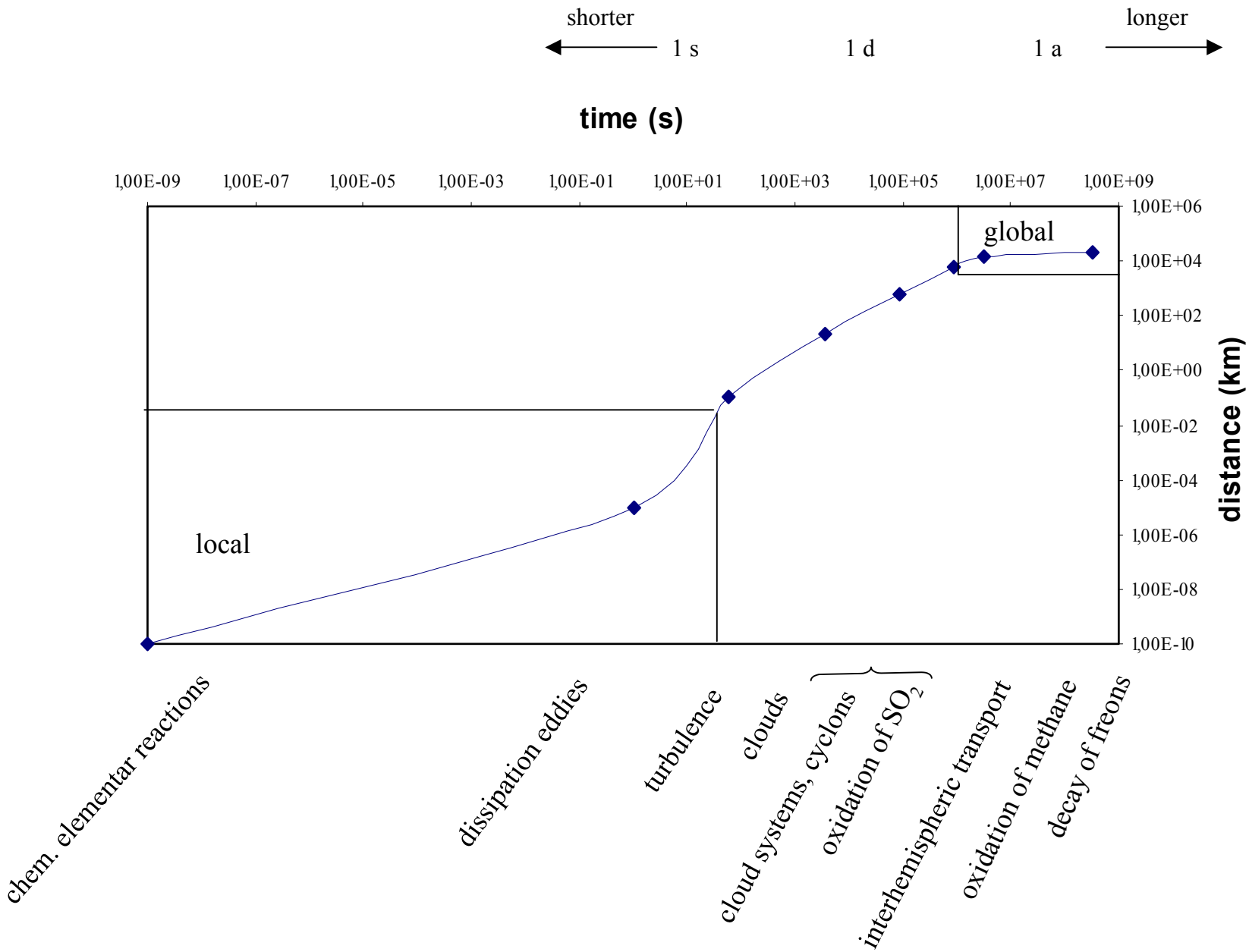
„extern“ disciplins ↓		information interface „human“ ↓	„intern“ disciplin ↓
Chemistry →	*Substances*	smell	→ *Biology*
		taste	
↑ *Physics* →	*Optics*	seeing	
	Akustics	hear	
	Thermodynamics	feel	
	Mechanics	touch	

Problems in spatial scale

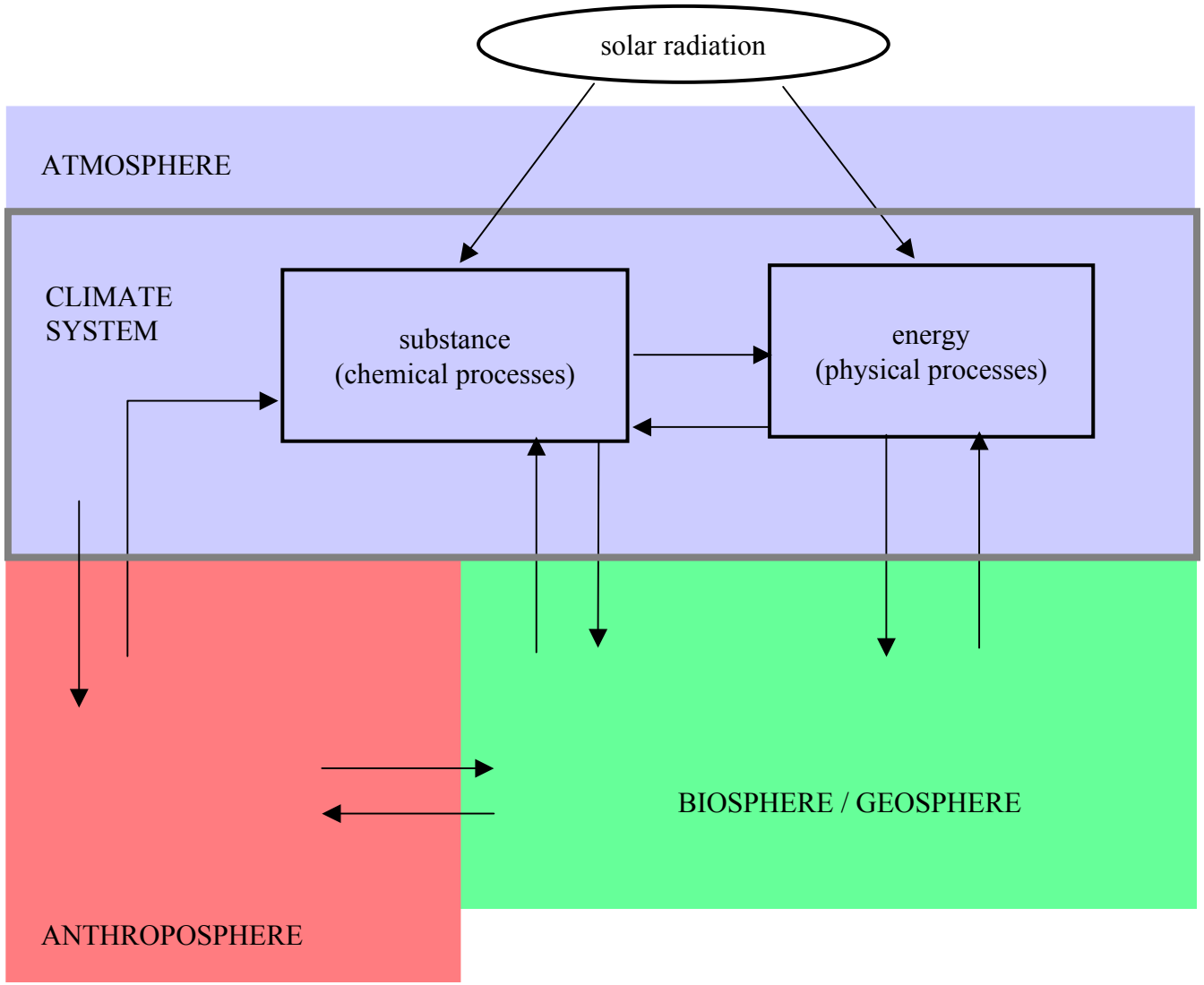
local			dust
local	→ regional		SO_2, aerosol
local	→	global	CO_2, CH_4, N_2O
local	→ regional →	global	O_3
$space_1$	→	$space_2$	„acid rain“

Atmospheric problems in temporal scale

Positive climate forcing (greenhouse effect)	100 years
Background ozone	50 years
Negative climate forcing (aerosol)	2 weeks
Sommermog	1 week
Wintersmog	1 week
Disaster	1 day


shorter
longer
1 s
1 d
1 a
time (s)
1,00E-09
1,00E-07
1,00E-05
1,00E-03
1,00E-01
1,00E+01
1,00E+03
1,00E+05
1,00E+07
1,00E+09
1,00E+06
1,00E+04
1,00E+02
1,00E+00
1,00E-02
1,00E-04
1,00E-06
1,00E-08
1,00E-10
distance (km)
global
local
chem. elementar reactions
dissipation eddies
turbulence
clouds
cloud systems, cyclons
oxidation of SO_2
interhemispheric transport
oxidation of methane
decay of freons

The climate system



clima [Latin: slope]

κλίμα [Greek]

Behind **climate** the meteorologists understand

> the sum of meteorological factors (elements) / the summary of weather / the mean (averaged) weather,

describing the **mean status of the atmosphere** at a given site of the Earth surface, represented by the statistical total properties (mean values, frequencies, durations etc.) of a long enough time periode.

(Julius v. Hann 1983, W. Köppen 1923, E. S. Rubinstein 1956, K. Schneider-Carius 1961, J. Blüthgen 1964, WMO 1979)

Climate is a function of space and time.

Climate can not be described as a single unit.

Cosmos.

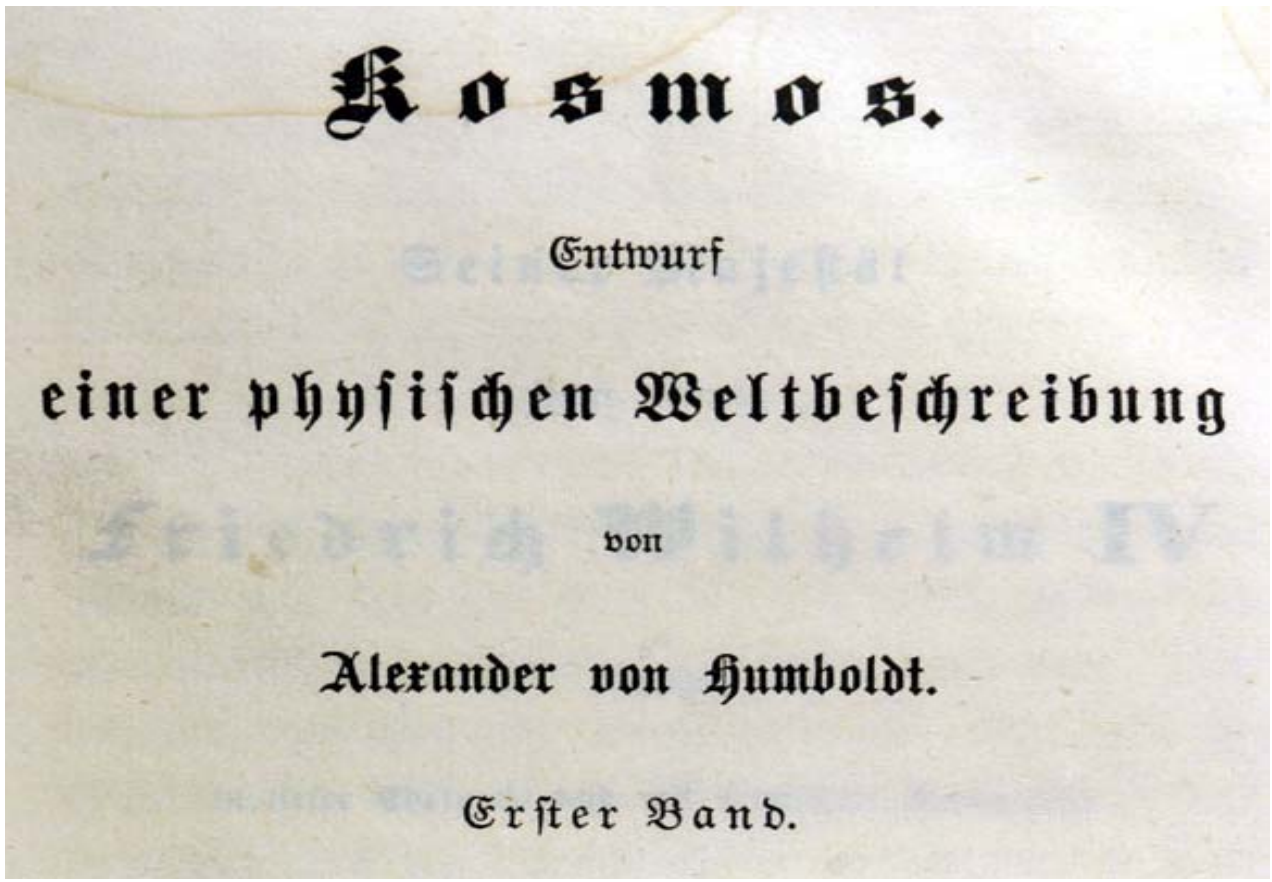
Outline

of a physical world description

by

Alexander von Humboldt

First Volume. (1845)



Kosmos.

Entwurf

einer phyſiſchen Weltbeſchreibung

von

Alexander von Humboldt.

Erſter Band.

Climate definition by Humboldt (from: Kosmos, 1845)

Die Einsicht in die Wärme-Vertheilung im Luftkreise hat einigermaßen an Klarheit gewonnen, seitdem man versucht hat die Punkte, in welchen die mittleren Temperaturen des Jahres, des Sommers und des Winters genau ergründet worden sind, durch Linien mit einander zu verbinden. Das System der Isothermen, Isotheren und Isochimenen, welches ich zuerst im Jahr 1817 aufgestellt, kann vielleicht, wenn es durch vereinte Bemühungen der Physiker allmälig vervollkommnet wird, eine der Hauptgrundlagen der vergleichenden Klimatologie abgeben. Auch die Ergründung des Erd-Magnetismus hat eine wissenschaftliche Form erst dadurch erlangt, daß man die zerstreuten partiellen Resultate in Linien gleicher Abweichung, gleicher Neigung und gleicher Kraft-Intensität mit einander graphisch verband.

Der Ausdruck Klima bezeichnet in seinem allgemeinsten Sinne alle Veränderungen in der Atmosphäre, die unsre Organe merklich afficiren: die Temperatur, die Feuchtigkeit, die Veränderungen des barometrischen Druckes, den ruhigen Luftzustand oder die Wirkungen ungleichnamiger Winde, die Größe der electrischen Spannung, die Reinheit der Atmosphäre oder die Vermengung mit mehr oder minder schädlichen gasförmigen Exhalationen, endlich den Grad habitueller Durchsichtigkeit und Heiterkeit des Himmels: welcher nicht bloß wichtig ist für die vermehrte Wärmestrahlung des Bodens, die organische Entwicklung der Gewächse und die Reifung der Früchte, sondern auch für die Gefühle und ganze Seelenstimmung des Menschen.

Wenn die Oberfläche der Erde aus einer und derselben homogenen flüssigen Masse; oder aus Gesteinschichten zusam-

The term climate denotes in his most general sense all changes in the atmosphere, affecting our organs remarkable: the temperature, the humidity, die barometric pressure change, the silent air status or the impacts of windy airs, the size of electricity, the purity of the atmosphere or its mixing with more or less harmful gaseous exhalations and finally the degree of its transparency and sky-blueness: which not only is important for the increased heat radiation of the soil, the organic development of plants and mature of fruits but also for the human feeling and his spititual welfare.

WMO definitions

Climate

Synthesis of weather conditions in a given area, characterized by long-term statistics (mean values, variances, probabilities of extreme values, etc.) of the meteorological elements in that area.

Weather

The state of the atmosphere mainly with respect to its effects upon life and human activities. As distinguished from climate, weather consists of the short-term (minutes to about 15 days) variations of the atmosphere state.

Meteorological Elements

Any one of the properties or conditions of the atmosphere which together specify the weather at a given place for any particular time (for example, air temperature, pressure, wind, humidity, thunderstorm and fog)

Atmosphere

The envelope of air surrounding the Earth and bound to it more or less permanently by virtue of the Earth's gravitational attraction; the system whose chemical properties, dynamic motions, and physical processes constitute the subject matter of meteorology.

Chemistry (chem. weather)

Climatological Elements

meteorological:

- temperature
- precipitation
- wind
- cloudiness
- humidity
- sun shine duration
- air pressure
- radiation

physico-chemical:

- deposition (dry, wet)
- trace gas concentration (ozone, greenhouse gase etc.)
- aerosol (number, mass, surface, properties)
- climate forcing
- acidifying potential
- oxidation potential

The term **climate system** often is named by following terms:

- natural Earth system, Ecosphere, Nature (*Alexander von Humboldt*),
- Biosphere (*Vladimir Iwanowitsch Vernadsky*) or
- GAIA (*James Lovelock* and *Lynn Margulis*).

By influencing the natural system by humans it is changing and creating a new „anthropogenic (man-made) system“ (anthroposphere[1]) which, however, is linked with the nature. We can state that new by humans modified Earth system has been developed, the

- Noosphere (*Vladimir Iwanowitsch Vernadskij*)[2].

Thus, we define among climate system the **Earth System**:

Earth system (= noosphere) = nature + anthroposphere.

nature = climate system/natural Earth system

anthroposphere = human life sphere (=culture)

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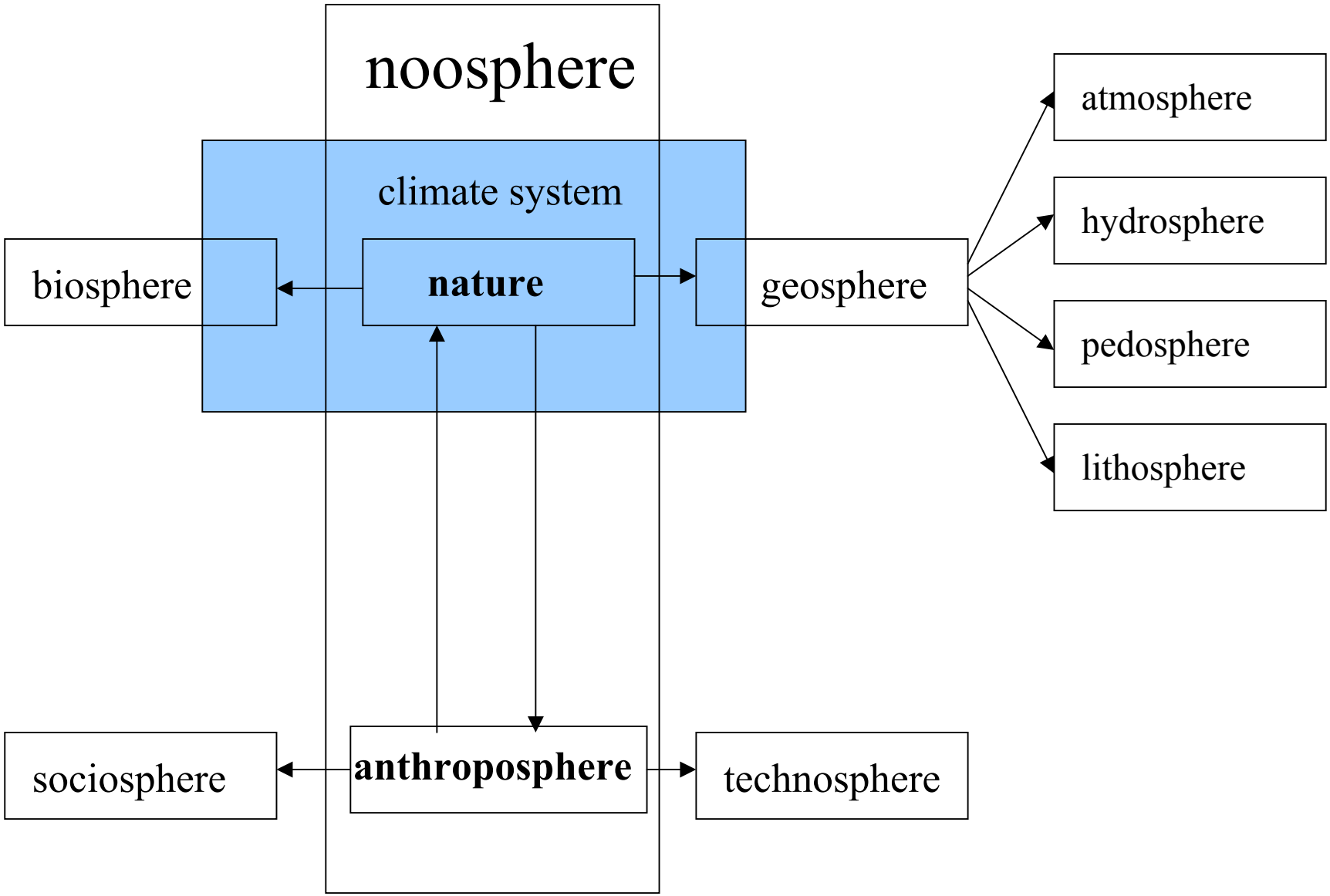
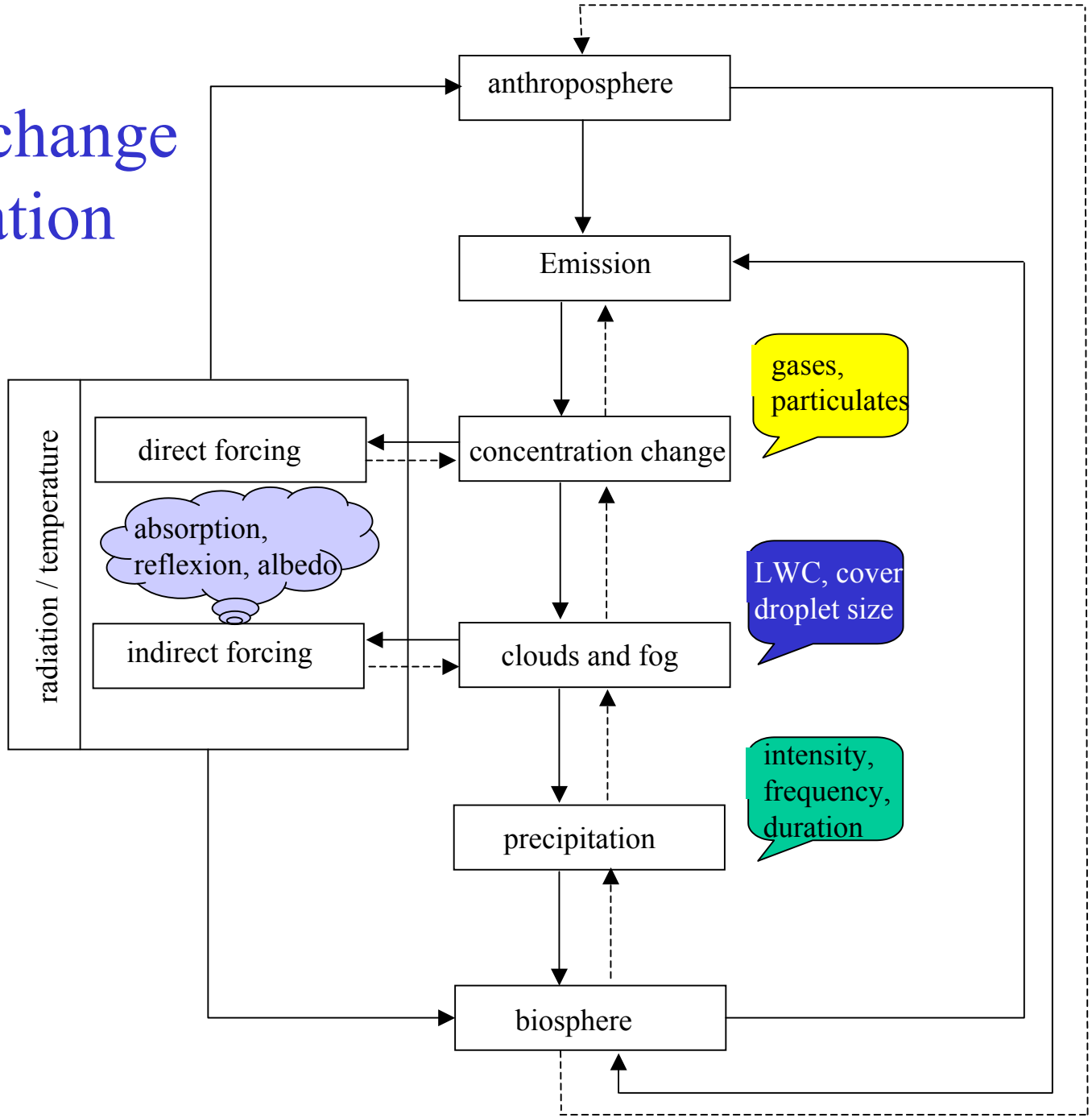
[1] Paul J. Crutzen proposed, to subdived the present epoch *Holozän* by *Anthropozän.*.

[2] This term *Vernadsky* got from the french priest and philosopher *Pierre Teilhard de Chardin* (they met in Paris end of 1920er). V. understood with noosphere a new dimension of the biosphere, developing under the evolutionary influence of humans on natural processes.

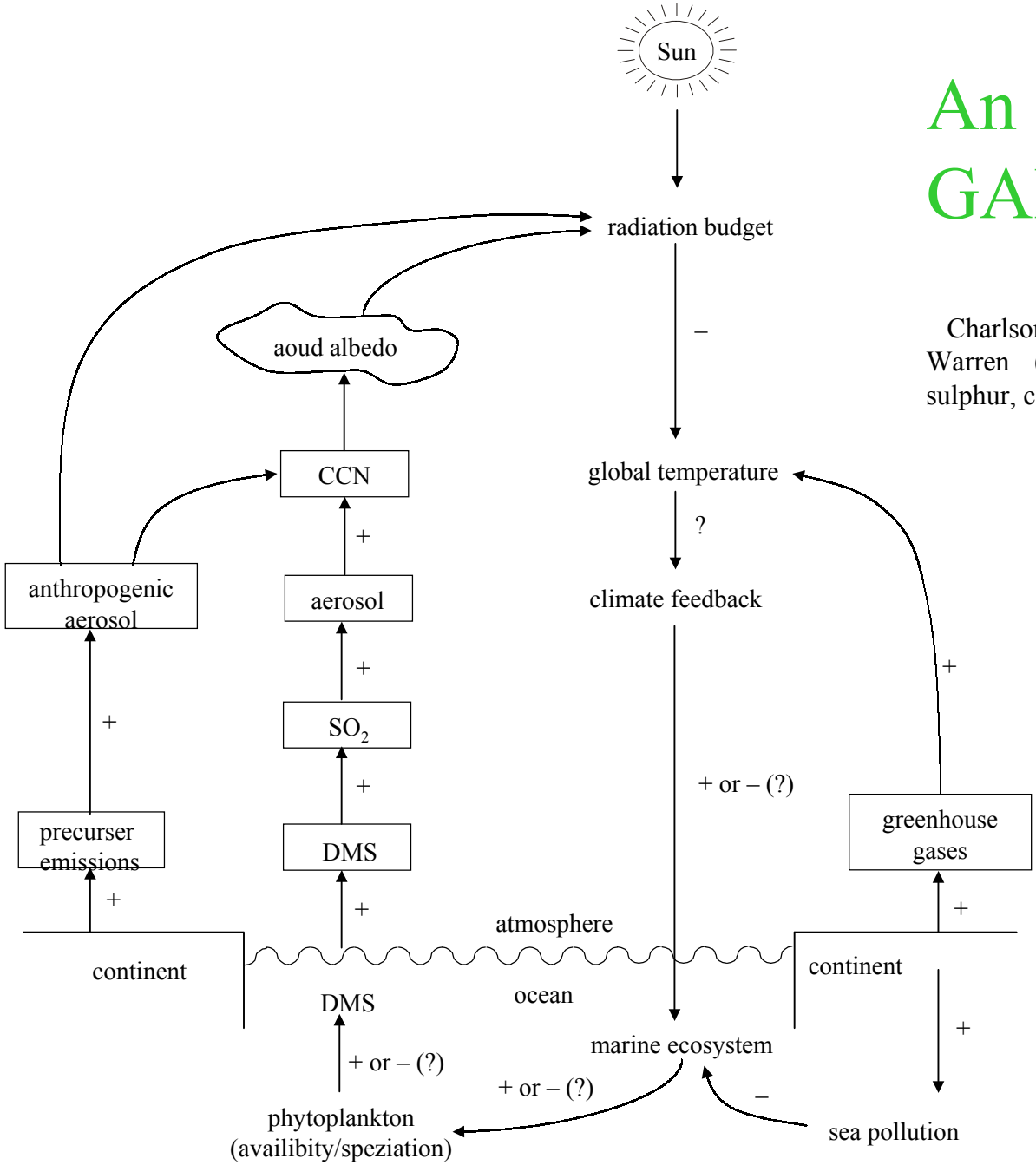

noosphere
climate system
biosphere
nature
geosphere
atmosphere
hydrosphere
pedosphere
lithosphere
sociosphere
anthroposphere
technosphere

Some examples for complex relationships resulting into climate change when system parameters are changing.

The climate change feedback relation



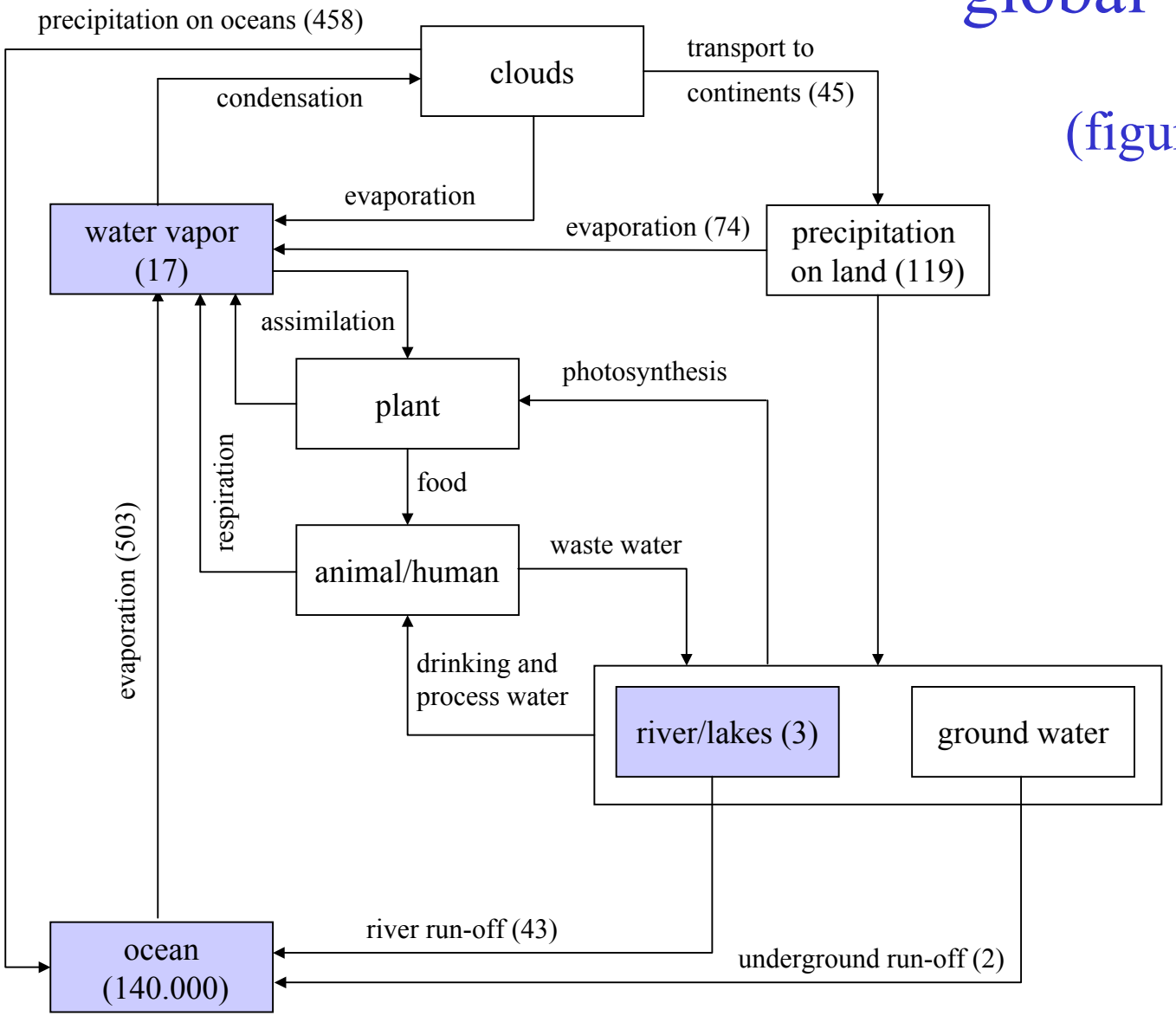
An example for the GAIA hypothesis



Charlson, R. J., J. E. Lovelock, M. O. Andreae und S. G. Warren (1987) Oceanic phytoplankton, atmospheric sulphur, cloud albedo, and climate. *Nature* **326**, 655-661

global water cycle

(figures in 10^3 km^3)
($\tau_{H2O} \approx 11$ d)



weather modification:

1. water resource
2. mitigate severe weather

precipitation

gases

CCN

water vapour

condensation

evaporation

chemical processor
visibility
water ressource

fog

deposition

dew

biosphere (interaction with atmosphere)