ATMOSPHERE

Module course: Ecological geology
Lecture 1
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Lecture structure

* Features of the atmosphere
* Structure and composition
* Functions
* Deposition

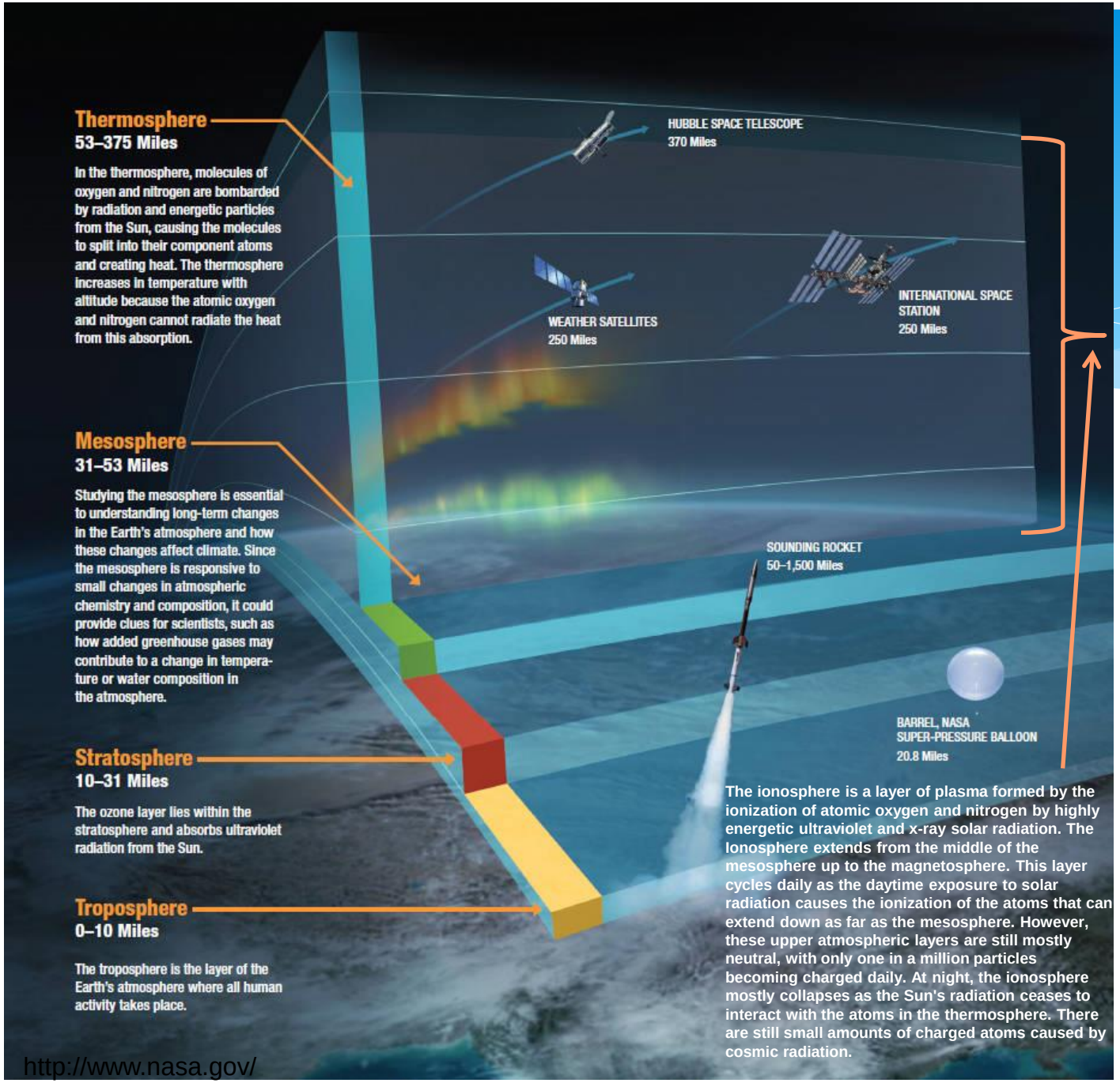
Features

* Atmosphere is a gaseous sphere (layer) of the Earth. An **atmosphere** is from Greek ἀτμός *(atmos)*, meaning "vapour", and σφαῖρα *(sphaira)*.

* It is the lowest mass reservoir of earth.
* It is easily altered.
* It realizes high energy interface between sun and earth.
* It determines climatic changes.
* It realizes transport and mixing of various substances.

Structure

(1 mile: 1.6 km)



http://www.nasa.gov/

Structure, composition and chemical processes in the Earth's atmosphere

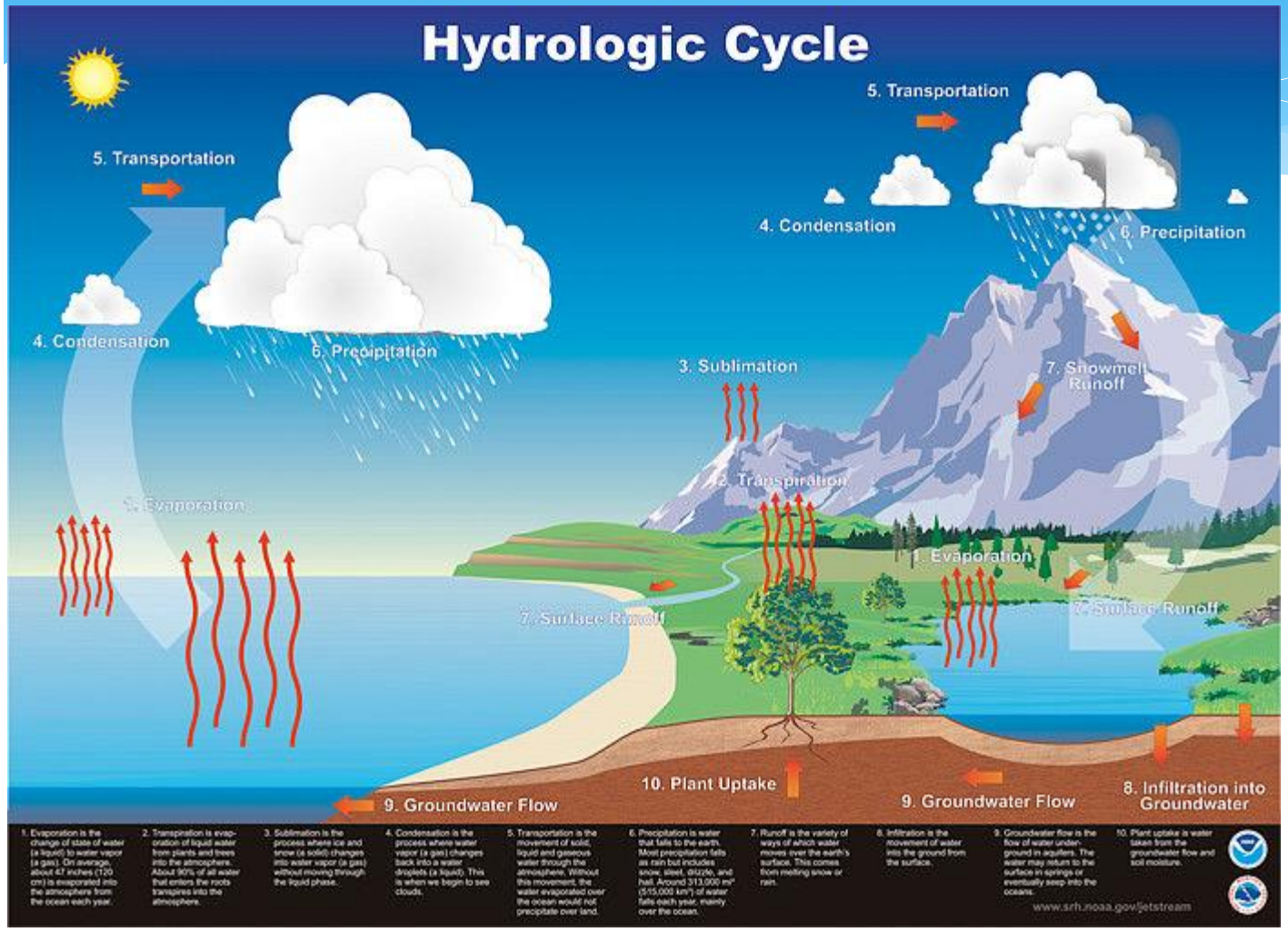
(by G.V. Voytkevich et al., 1976)

Height, km					
	1500	Eluding H, He $O>N_2>O_2$	H^+ H He O	Metasphere	Protosphere
					Exosphere
	500				Isothermy
			p(O)=p(N_2)	Thermopause	
	200	Diffusion O $N_2>O_2>O$ ↑ ↓ O_2	$N+O_2 \rightarrow NO+O$ $N+NO \rightarrow N_2+O$	Thermosphere	
	100			Mesopause	
	85		O_{max} $O+O \rightarrow O_2$ H		
		Homosphere	OH $CH_4+h \rightarrow CH_3+H$ NO $CH_4+O \rightarrow CH_3+OH$	Mesosphere	
	50		$O>O_3$	Stratopause	
			O_3=O $NO_2 \rightarrow$ NO+O O_3>O $N_2O \rightarrow N_2+O$	Stratosphere	
	15	Main composition	Small constituents	Tropopause	
		N_2 78, 084% O_2 20, 946 % Ar 0,934 %	CO_2 O_3 CH_4 NO_2 N_2O H_2 CO H_2O	Troposphere	

Chemical composition of dry air near the Earth's surface

Gas	Volume concentration (%)	Molecular weight
Nitrogen	78,084	28,0134
Oxygen	20,9476	31,9988
Argon	0,934	39,948
Carbon dioxide	0,0314	44,00995
Neon	0,001818	20,179
Helium	0,000524	4,0026
Methane	0,002	16,04303
Krypton	0,000114	83,80
Hydrogen	0,00005	2,01594
Nitrogen protoxide	0,00005	44,0128
Xenon	0,0000087	131,30
Sulfur dioxide	From 0 to 0,0001	64,0628
Ozone	From 0 to 0,000007 in summer From 0 to 0,000002 in winter	47,9982
Nitrogen dioxide	От 0 до 0,000002	46,0055
Ammonia	traces	17,03061
Carbon oxide	traces	28,01055 253,8088
Iodine	traces	Mean molecular weight of dry air

Water in the atmosphere



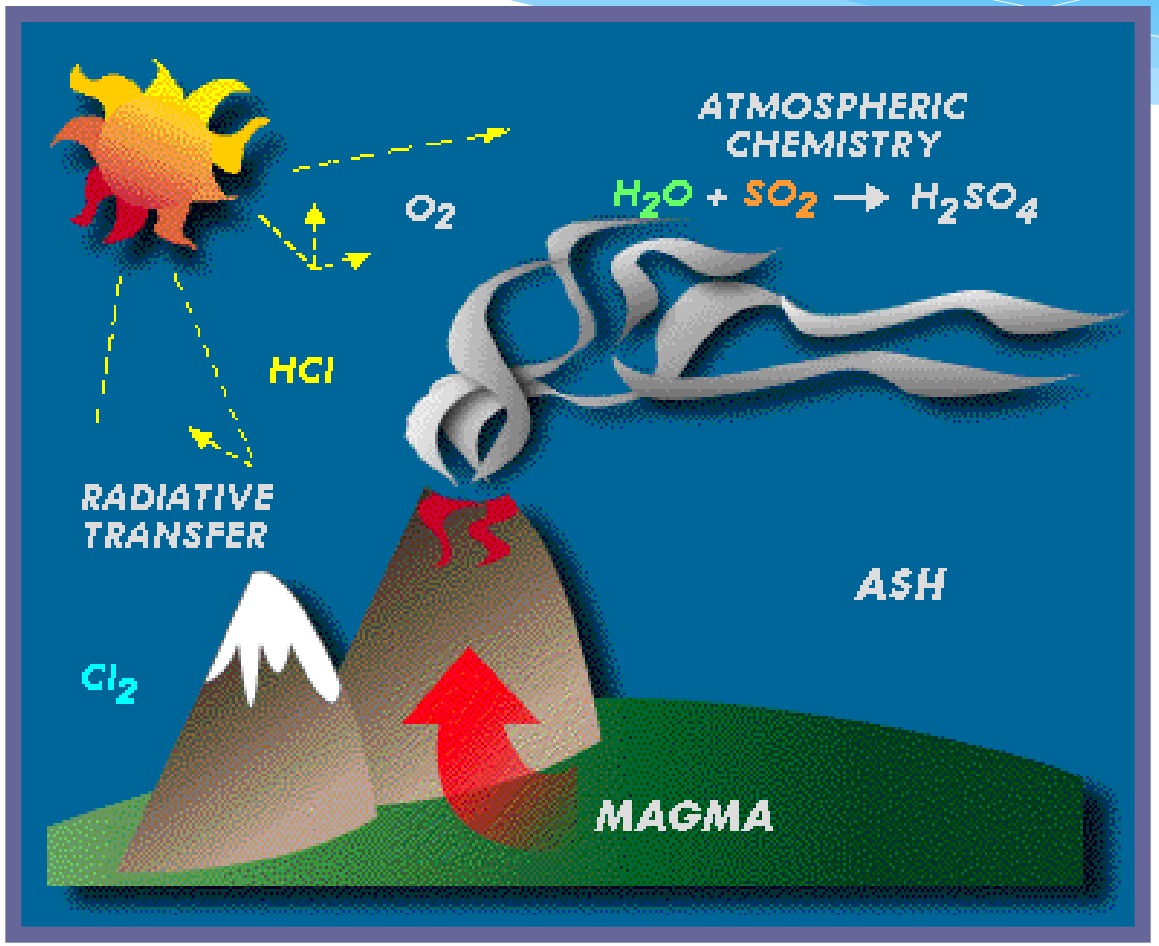
Water exists in all three phases (solid, liquid, and gas) in our atmosphere.

The atmosphere contains 37.5 million billion gallons (about 134,4 million liters) of water, in the invisible vapor phase.

A water vapor molecule has an average residence time in the atmosphere of only nine days.

This huge amount of water is processed through an endless cycle of evaporation, condensation, and precipitation all over the globe.

Sources of the formation of atmospheric composition



Man-induced nature transformations (according to Reimers, 1990)

Environmental sphere and its constituents	Production, changes, release or size of human use in absolute numbers	Production, changes, release or size in percents (of natural quantity)	Notes
ATMOSPHERE Oxygen (consumption)	$2x10^{10}$ t/year	Approximately 1000 times more than the input ($x10^{7}$ t/year). From 12 to 23 of biosphere release	The data of different authors do not coincide. Biosphere is believed not to restore the anthropogenic oxygen consumption, however, oxygen loss has not been recorded by devices yet.
OZONE (depletion)	-	By 2000 up to 8-16, according to some sources - not more than 4.	Due to reagents present at the moment in the atmosphere. The problem has not been studied yet. See Ozone hole
CARBON DIOXIDE (increase)	7 $x10^{10}$t/year	Since the XIX c. 18, in total 25	In recent years the rate of content growth has decreaesd
NITROGEN (increase)	-	110	-
Atmosphere pollution:			
Sulfur dioxide	1,5 $x10^{8}$t/year	75	Noticeable acidification of precipitation is observed (See Acid rain). Small air pollutants (methane etc.) are suggested to change the Earth's climate significantly
Nitrogen oxide	5 $x10^{7}$t/year	7,1	-
Other nitrogen compounds	1,5 $x10^{7}$t/year	1,0	Effect on the air temperature near the Earth's surface.
Carbon monoxide	3 $x10^{8}$t/year	1,0	
Airborne particulates (aerosols)	(960-2615) $x10^{6}$t/year	100	

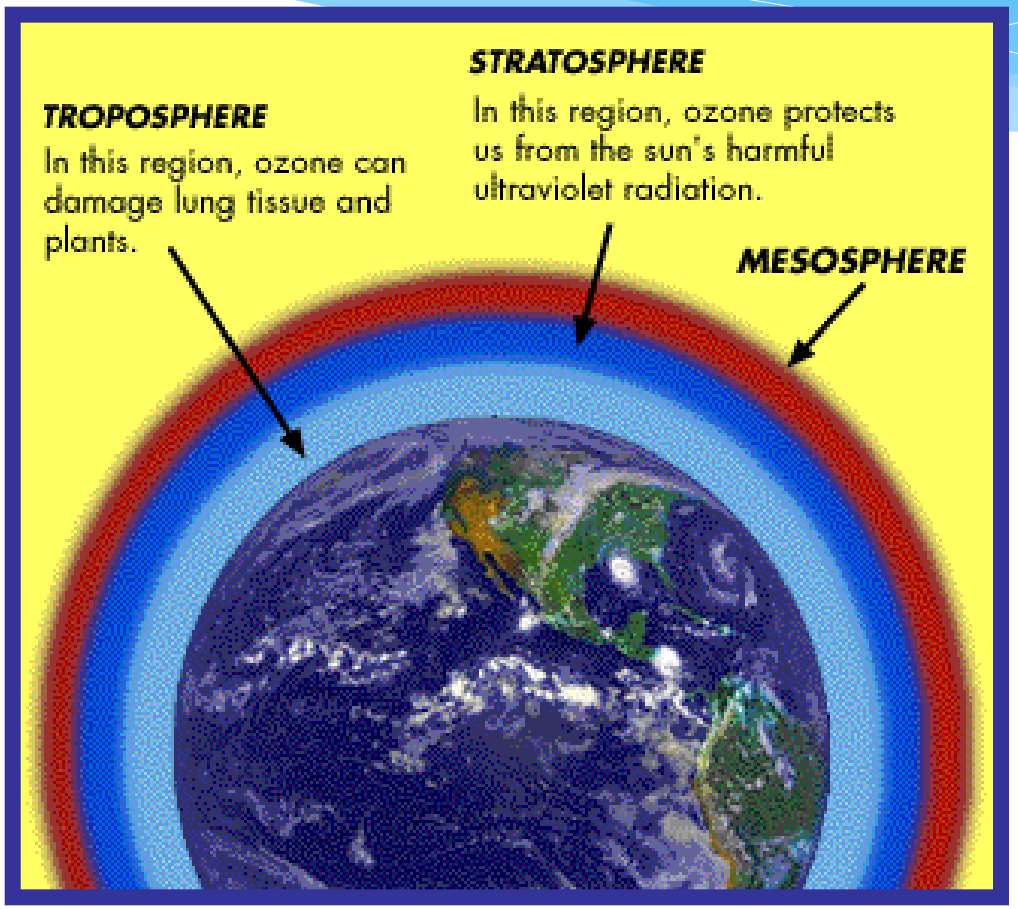
Cities and towns of the former USSR with highest and maximum concentrations of harmful substances (in units of MPC excess)

Substance	City, town	MPC excess (mean value)	City, town	MPC excess (maximum value)
Dust	Kutaisi	7	Komsomolsk-on-Amur Rustavi	24 21
Sulfur dioxide	Alaverdi Norilsk	7 4	Norilsk Alaverdi Villages of Astrakhan Oblast	48 9 9
Carbon oxide	Erevan	2	Frunze Erevan	13 10
Nitrogen dioxide	Kirovakan Zyryanovsk	3 3	Erevan	23
Nitrogen oxide	Magnitogorsk Norilsk	3 3	Norilsk	36
Ammonia	Kirovakan	11	Kirovokan	64
Benzopyrene	Abakan Osh	16 16	Bratsk Frunze	88* 68*
Soot	Yuzhno-Sakhalinsk	6	Yuzhno-Sakhalinsk	70
Hydrogen sulfide	No MPC		Красноярск Волжский	56 47
Carbon sulfide	Kaliningrad Magnitogorsk	5 5	Tver Balakovo	23 18
Phenol	Lisichansk Severodontsk	4 3	Donetsk Lisichansk	15 15
Formaldehyde	Severodonetsk Lisichansk	10 10	Moscow	57
Hydrogen fluoride	Almalyk Kokand	4 3	Saratov Almalyk Kandalaksha	16 9 9
Chlorine	Yavan	1,6	Norilsk Zima	5 4
Hydrogen chloride	Novokuybyshevsk	1,3	Volgograd	32

* From average month values

Functions

* Atmosphere surrounds the Earth and holds the air we breathe; it protects us from outer space; and holds moisture (clouds), gases, and tiny particles.


STRATOSPHERE
In this region, ozone protects us from the sun's harmful ultraviolet radiation.
TROPOSPHERE
In this region, ozone can damage lung tissue and plants.
MESOSPHERE

«Seasonal» ozone hole over Antarctic

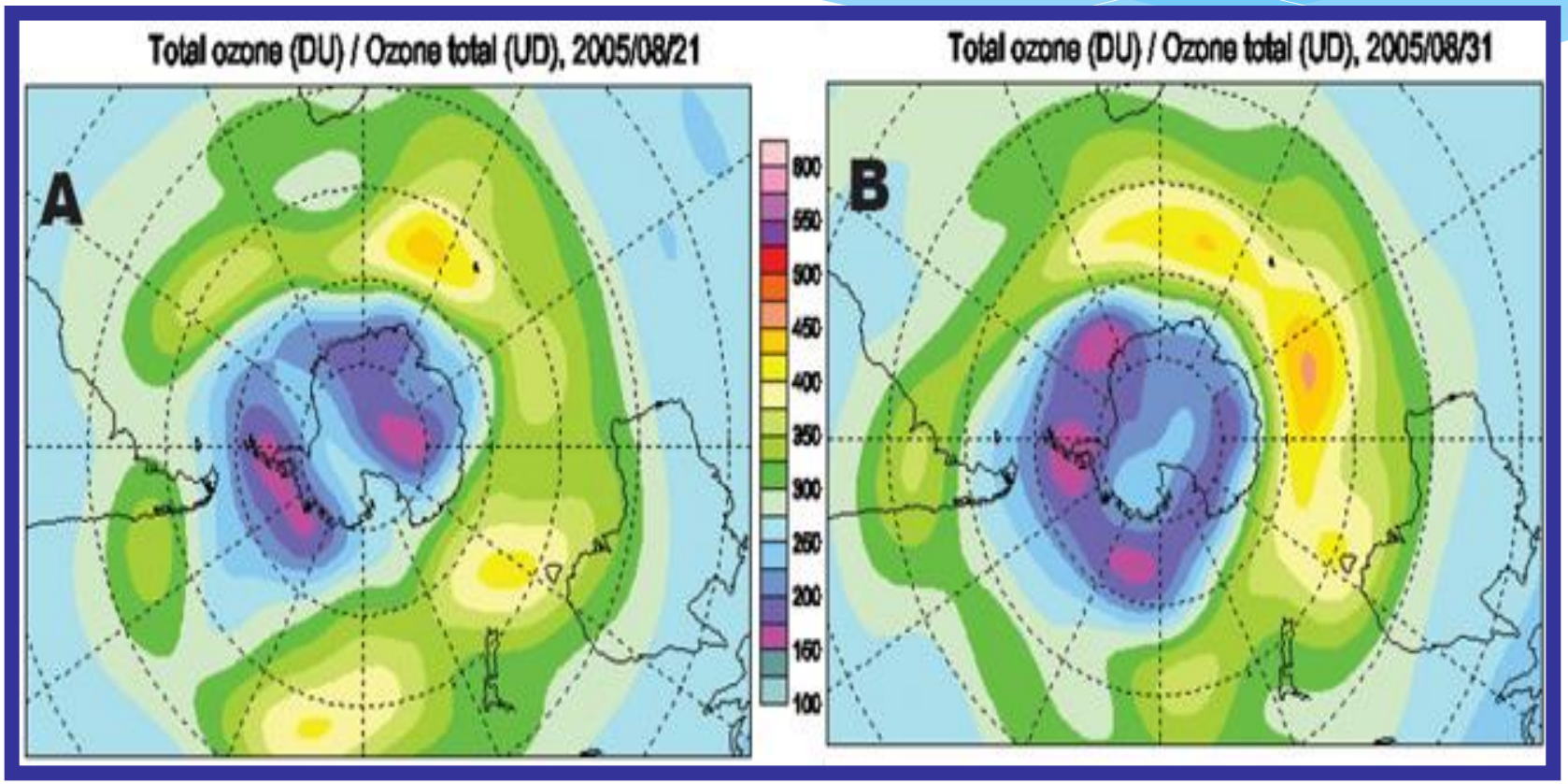
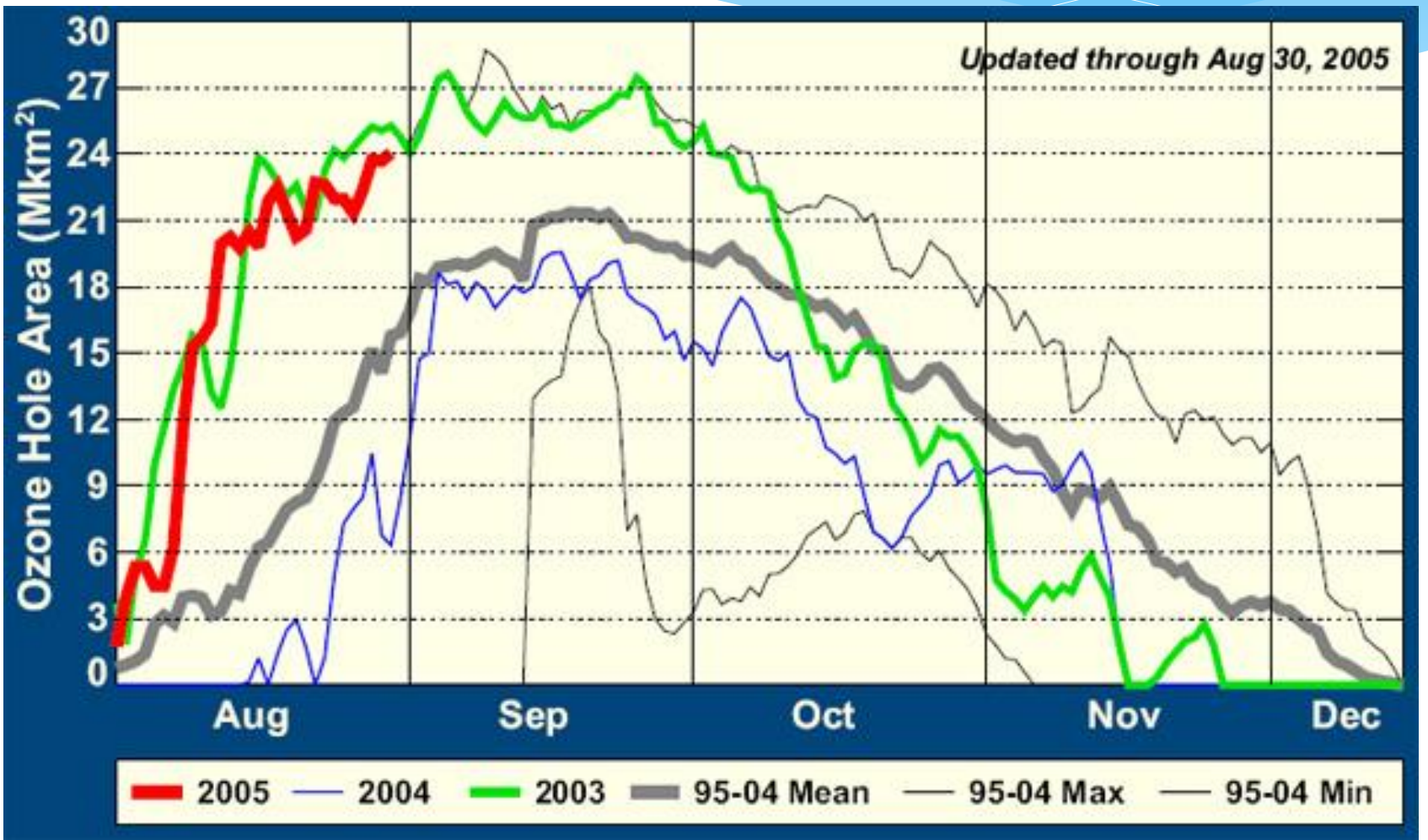
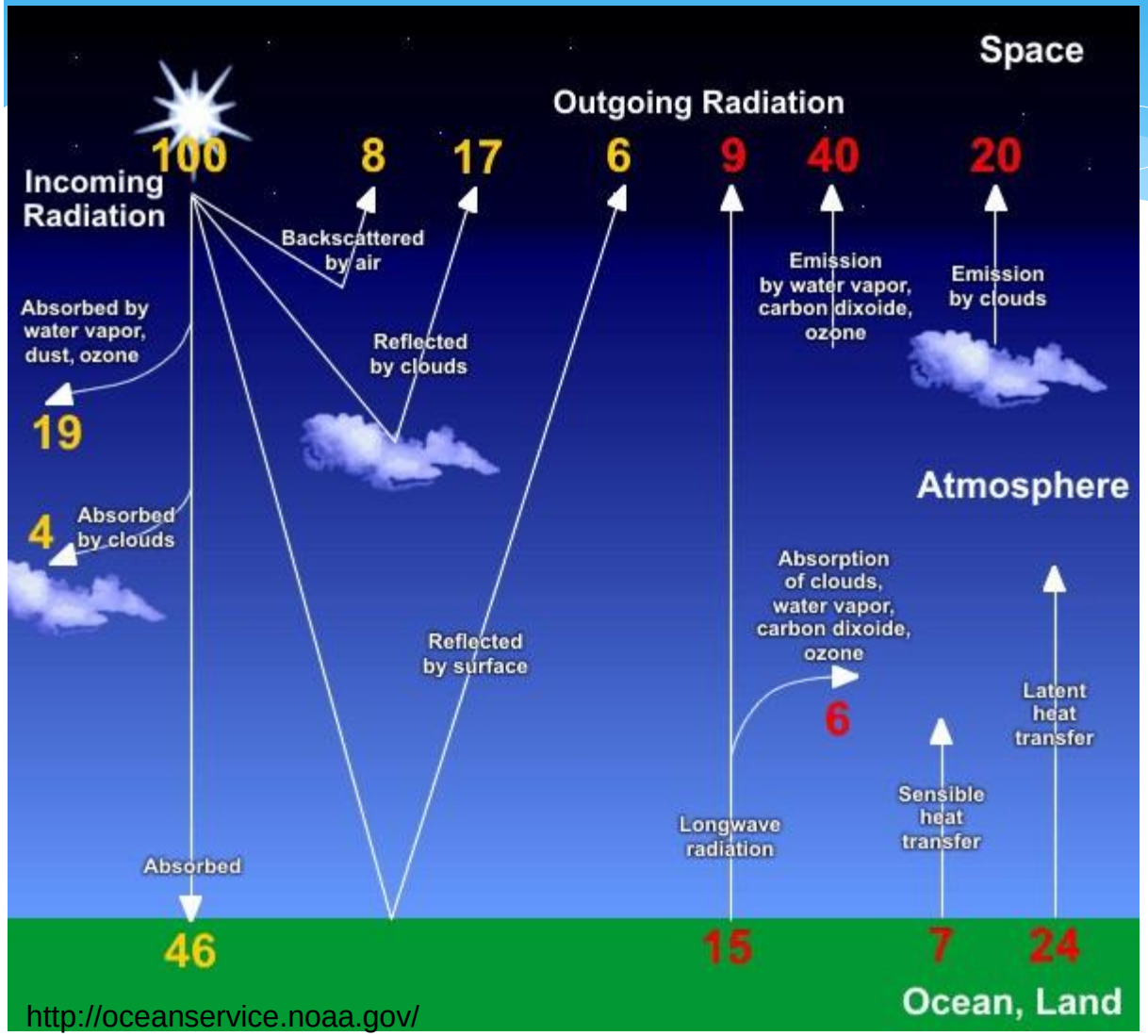


Diagram of dynamics in changing the size of ozone hole (according to the Center of Climate Forecast of Weather National Service, the US).

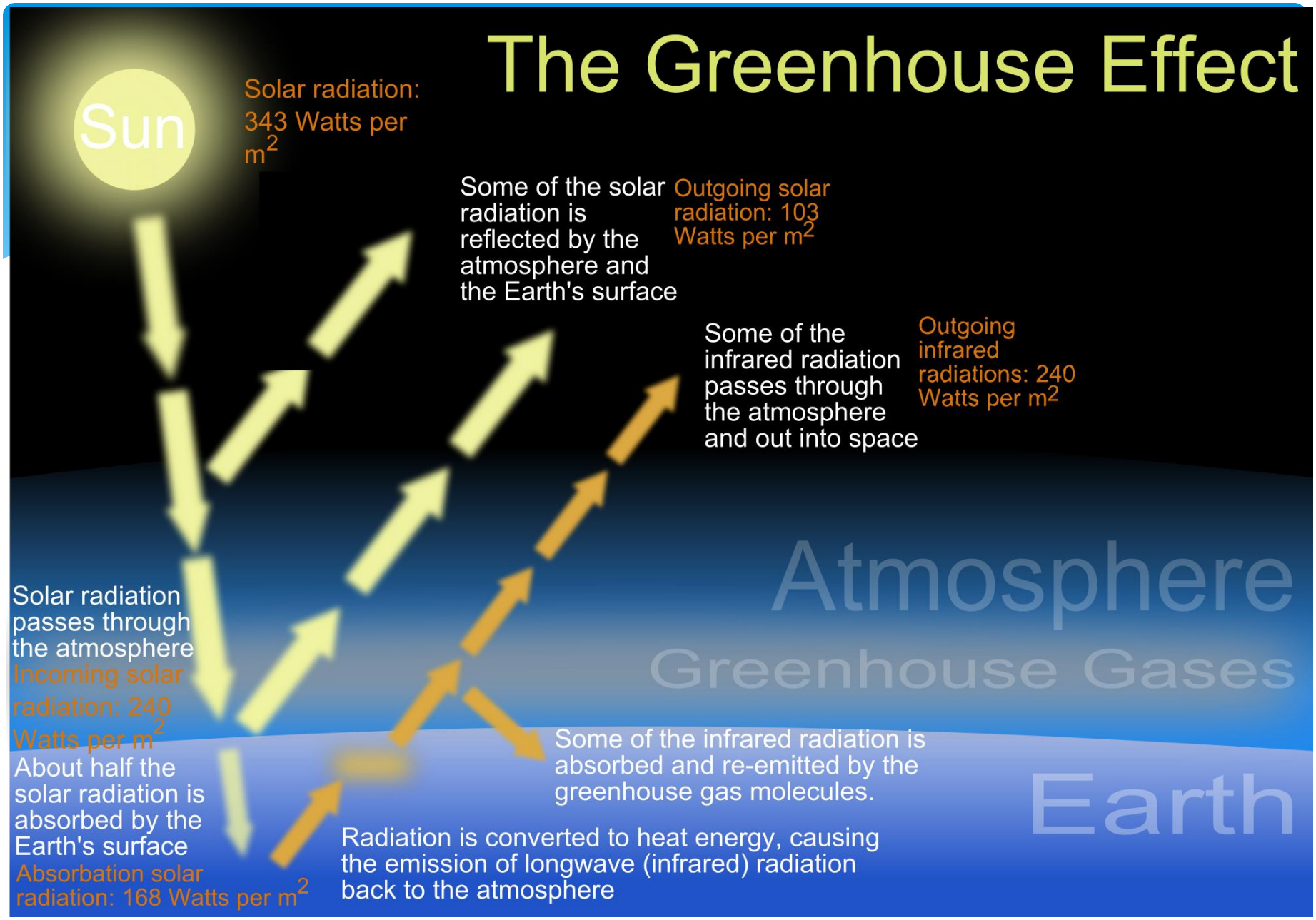
Red curve — data of 2005,
green — 2003,
blue — 2004 (picture from the site www.wmo.ch)



Energy balance

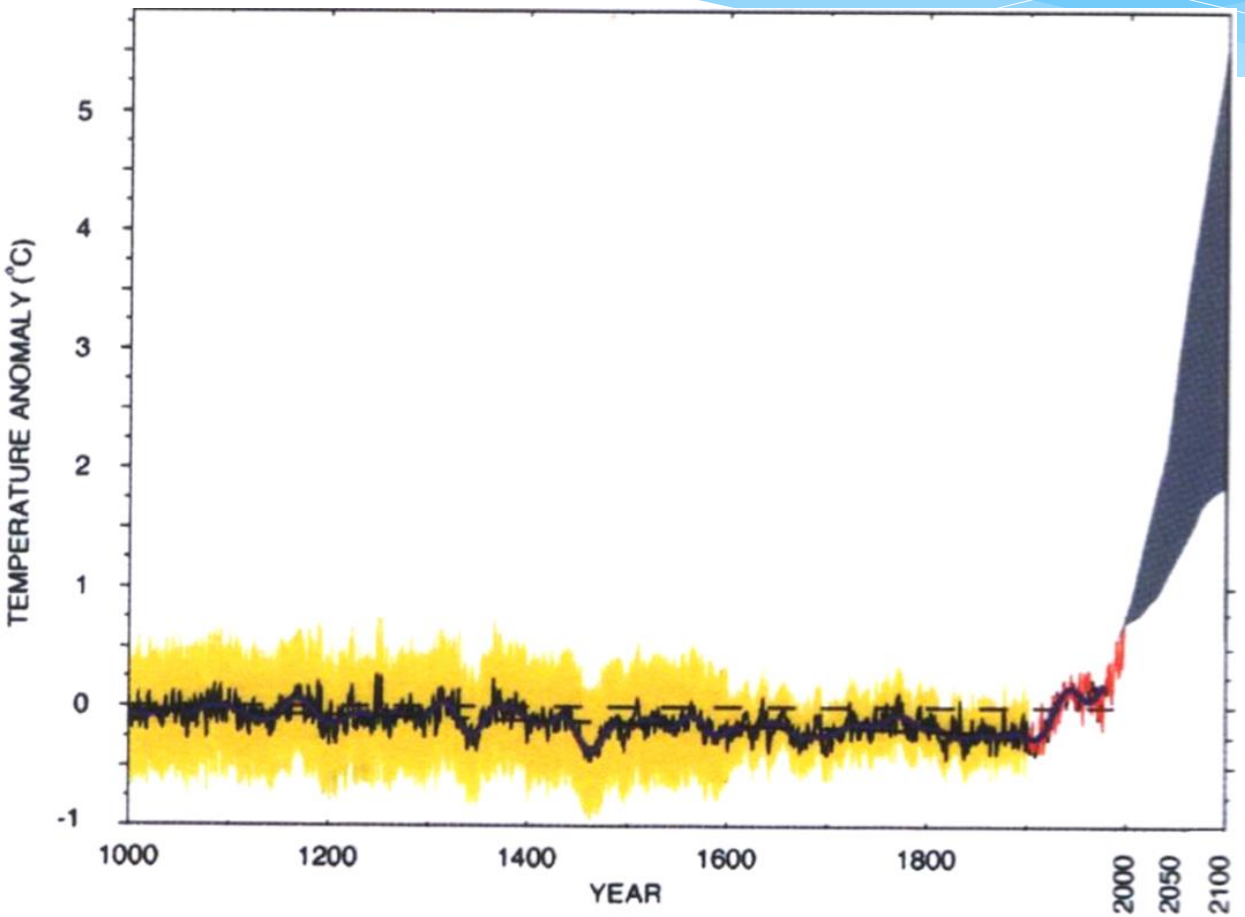


100% of the incoming energy from the sun is balanced by 100% percent total energy outgoing from the earth.

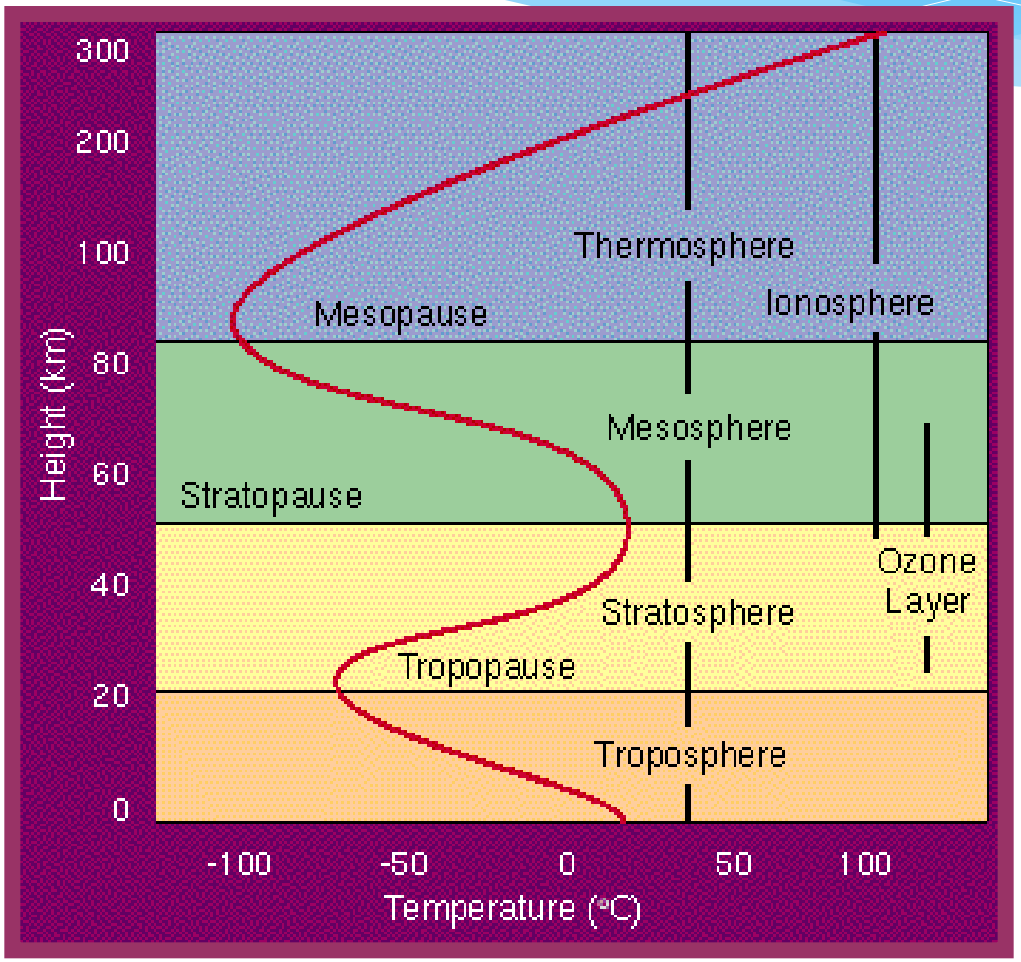


Trenberth, K. E., J. T. Fasullo, and J. Kiehl, 2009: Earth's global energy budget. *Bull. Amer. Meteor. Soc.,* **90,** No. 3, 311-324

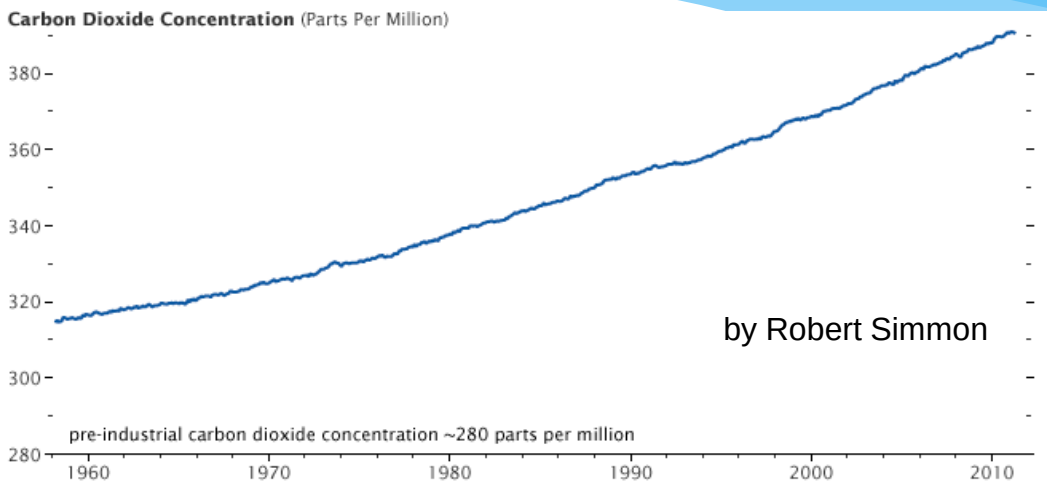
Temperature balance

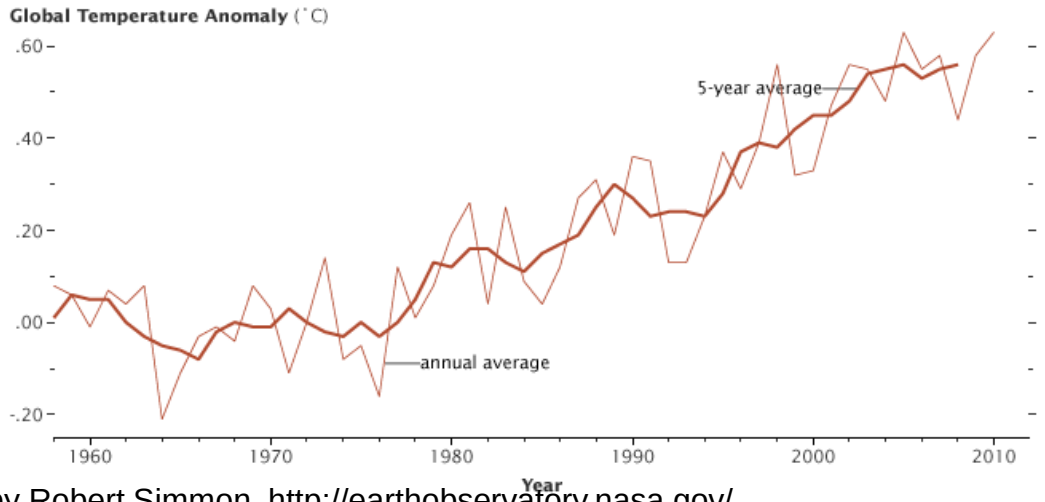


Vertical distribution of temperature in the upper atmosphere according to rocket observation data (according to Ya. Miaki, 1965)



CO_2 is controlling Earth's temperature

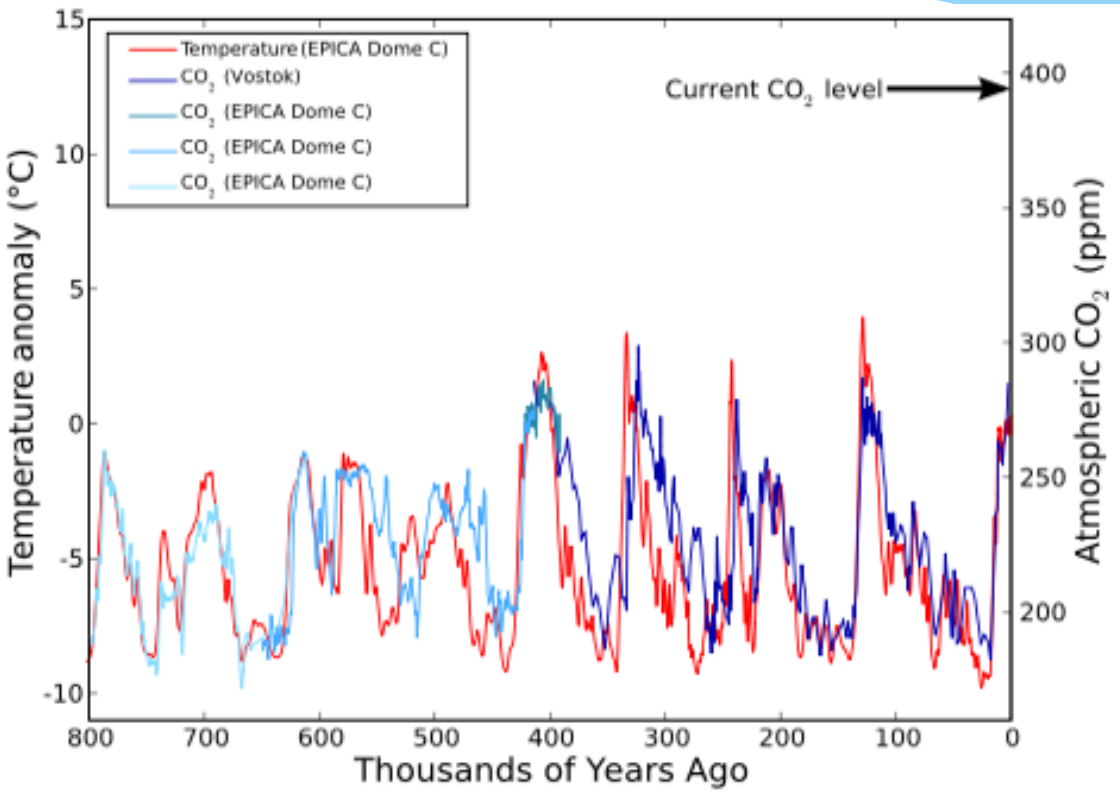




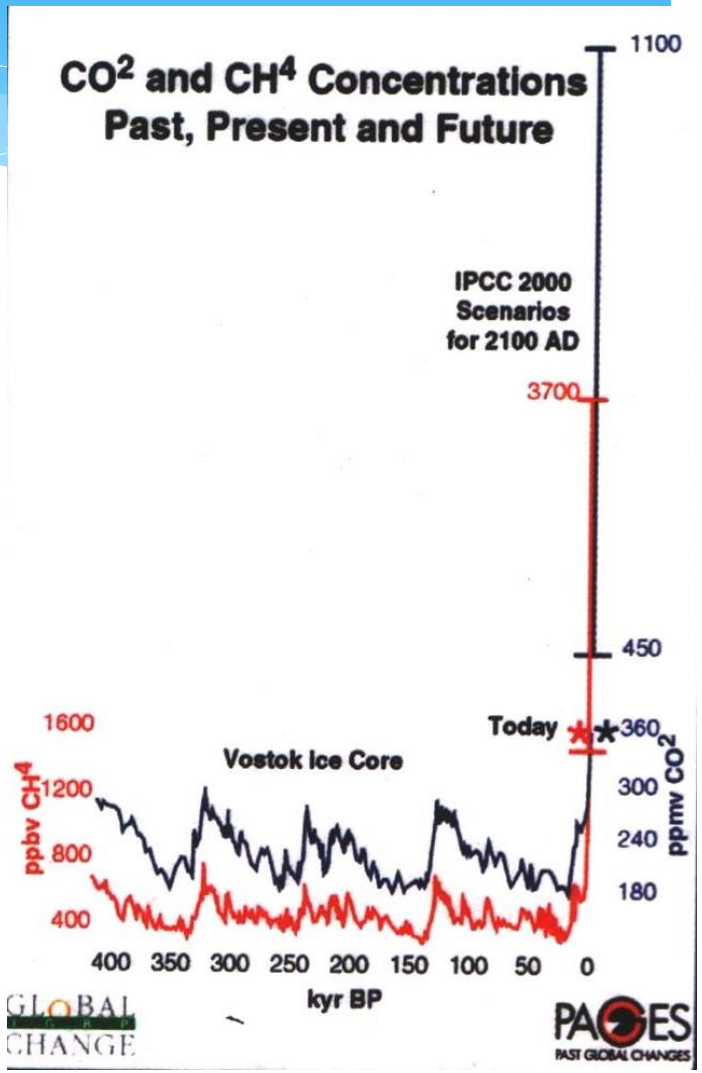
by Robert Simmon, http://earthobservatory.nasa.gov/

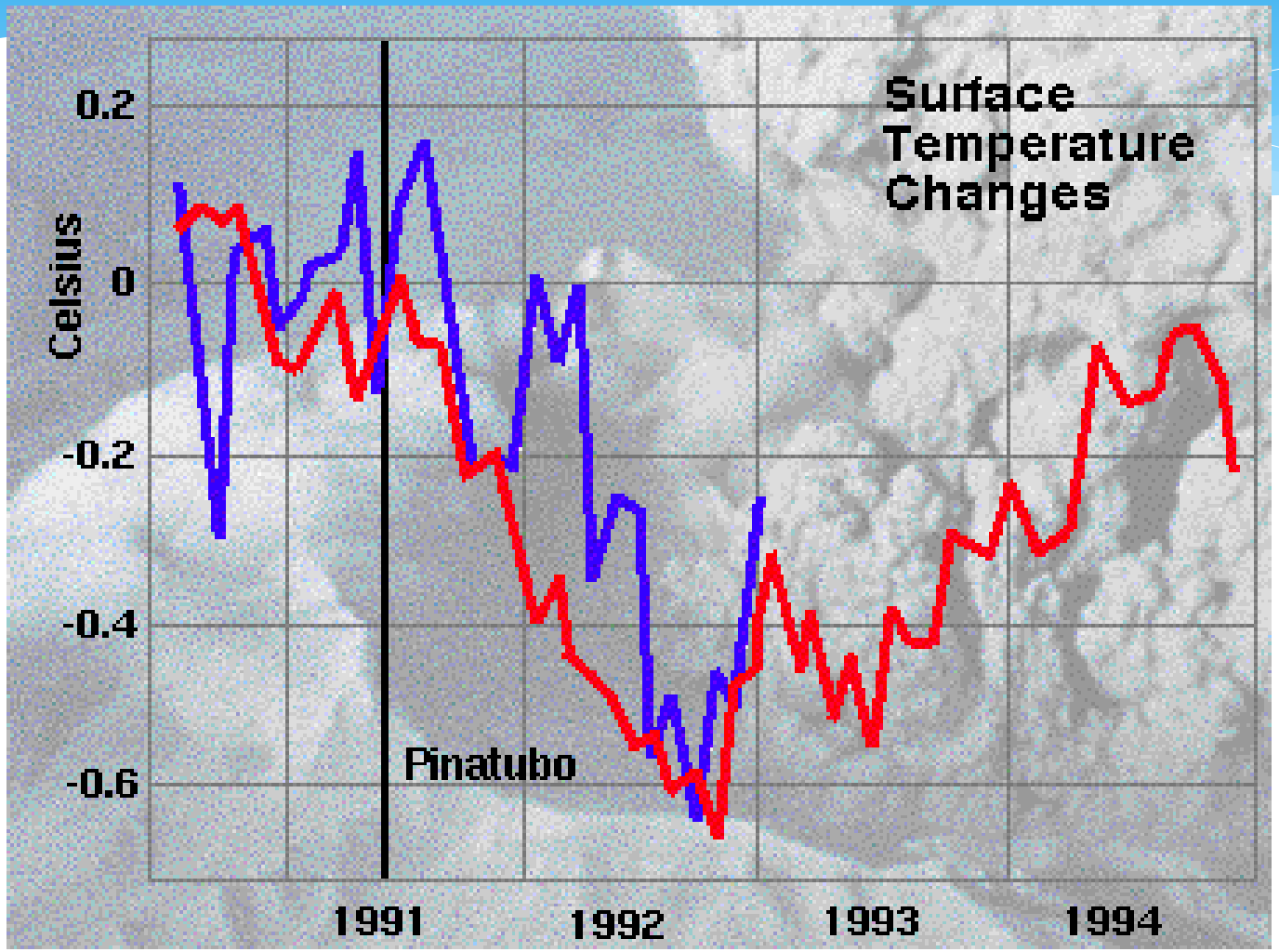
CO_2 is the most important gas for controlling Earth's temperature. Carbon dioxide, methane, and halocarbons are greenhouse gases that absorb a wide range of energy—including infrared energy (heat) emitted by the Earth—and then re-emit it. The re-emitted energy travels out in all directions, but some returns to Earth, where it heats the surface.

Rising carbon dioxide concentrations are already causing the planet to heat up.



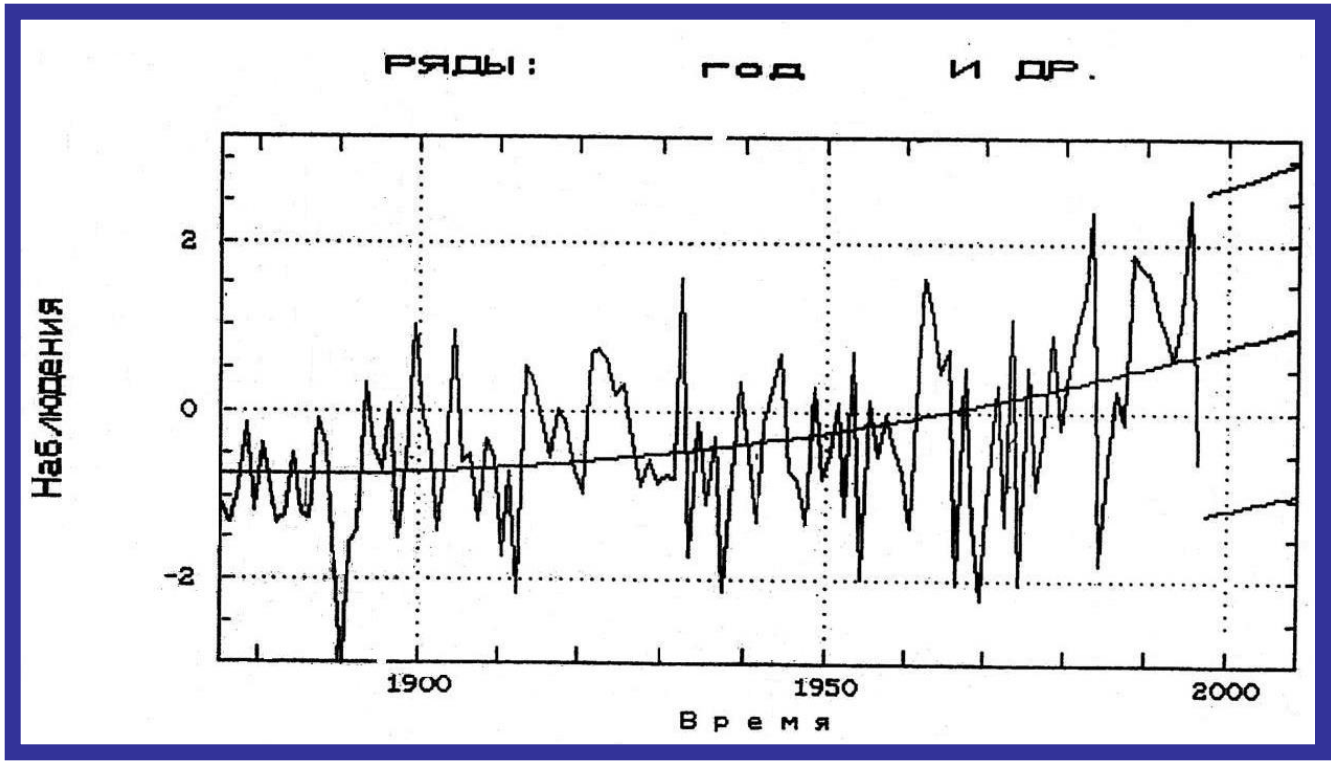
www.skepticalscience.com



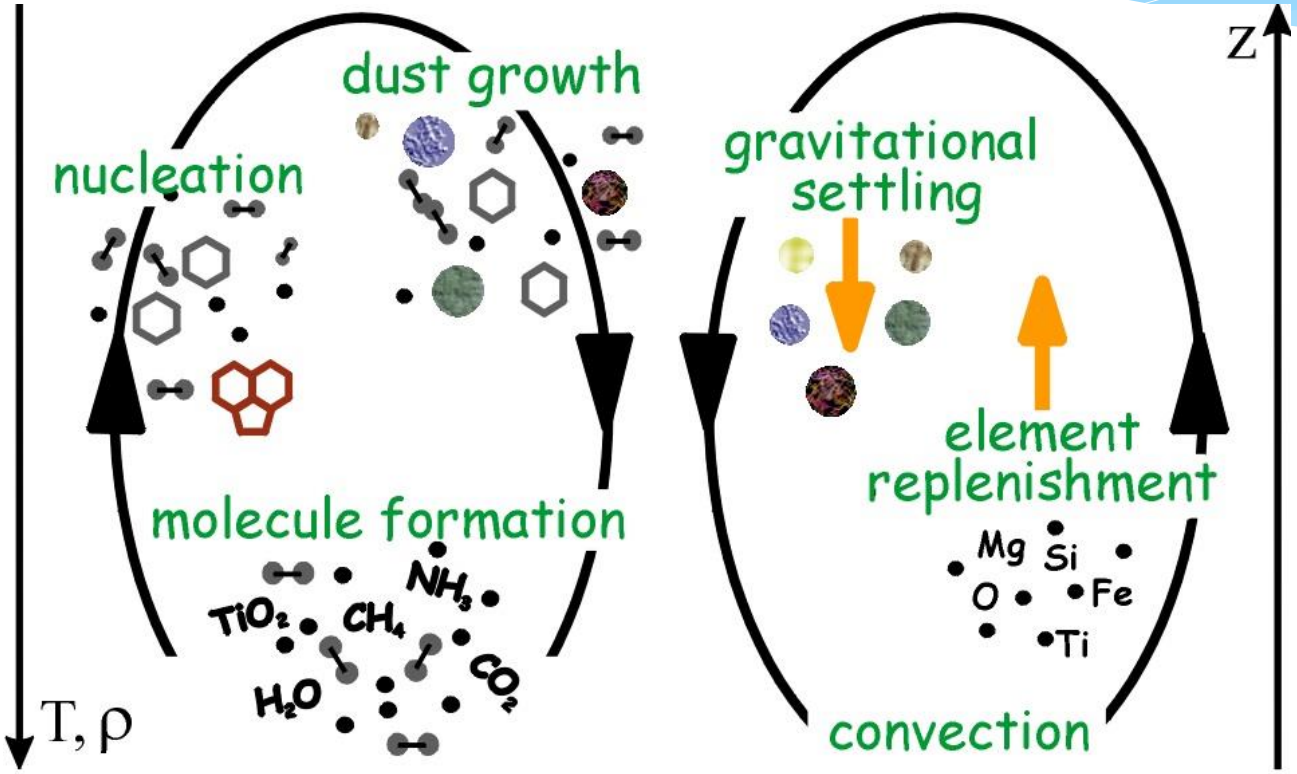

Surface
Temperature
Changes
Celsius
0.2
0
-0.2
-0.4
-0.6
Pinatubo
1991
1992
1993
1994

Changes in average-year temperature in the region of Tomsk city according to meteorological observations since 1870

(according to V.I. Slutskiy' material)



Deposition

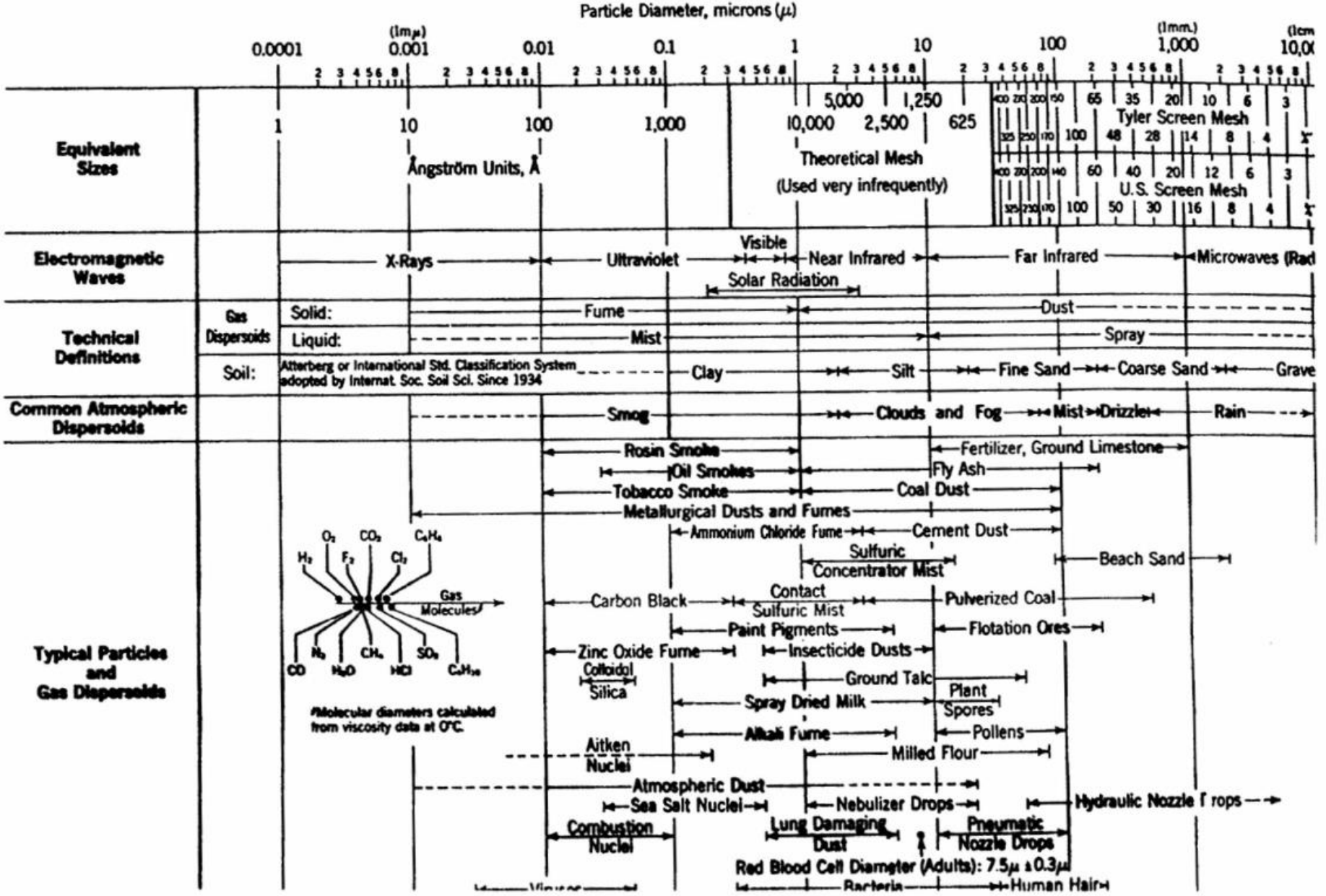


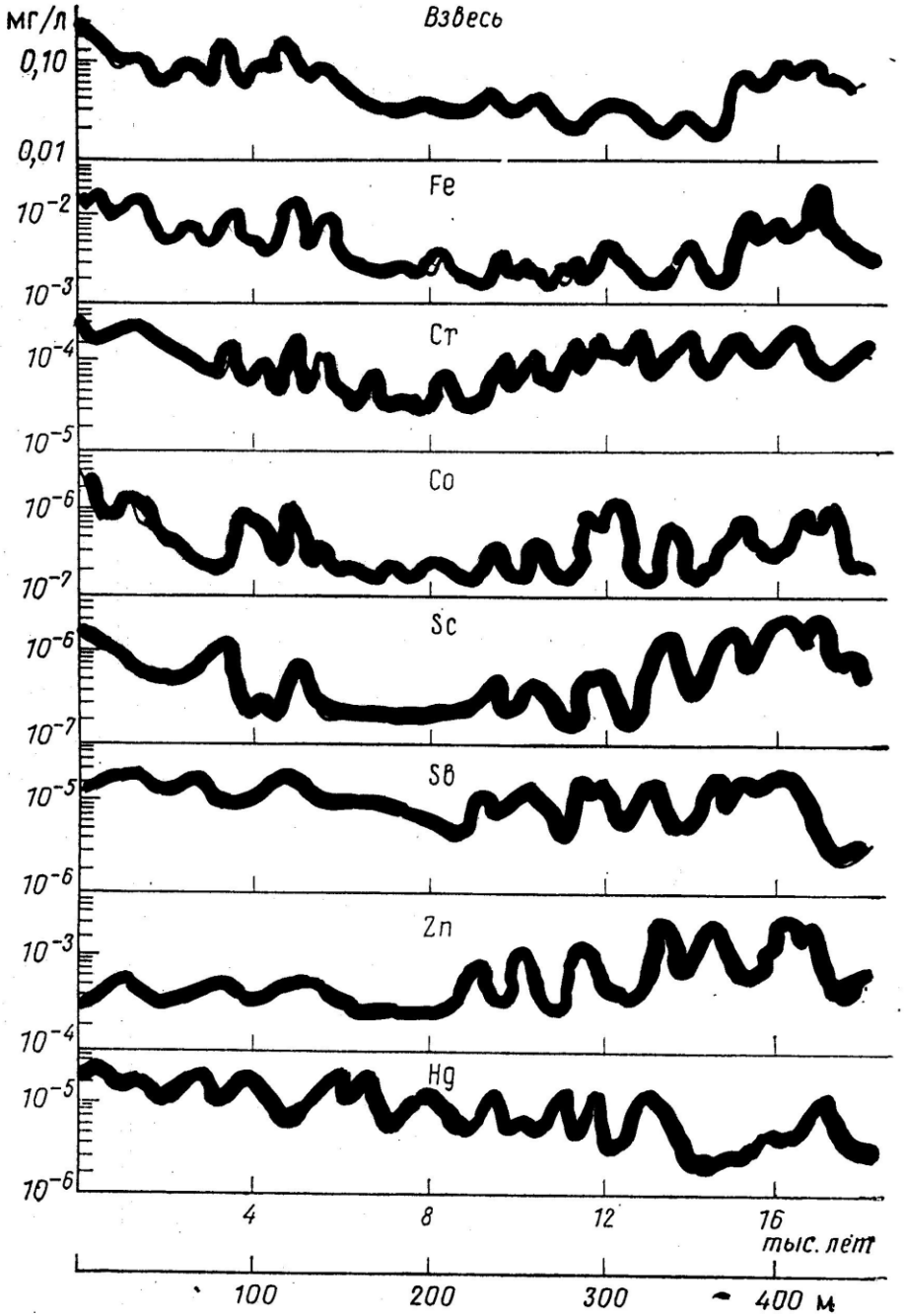
Nucleation (seed formation), dust growth (and evaporation), gravitational settling (rain-out) and element replenishment are processes involved into the formation of a cloud.

The inner part of an atmosphere is typically warmer than the outer part in a brown dwarf, and no cloud particles can form.

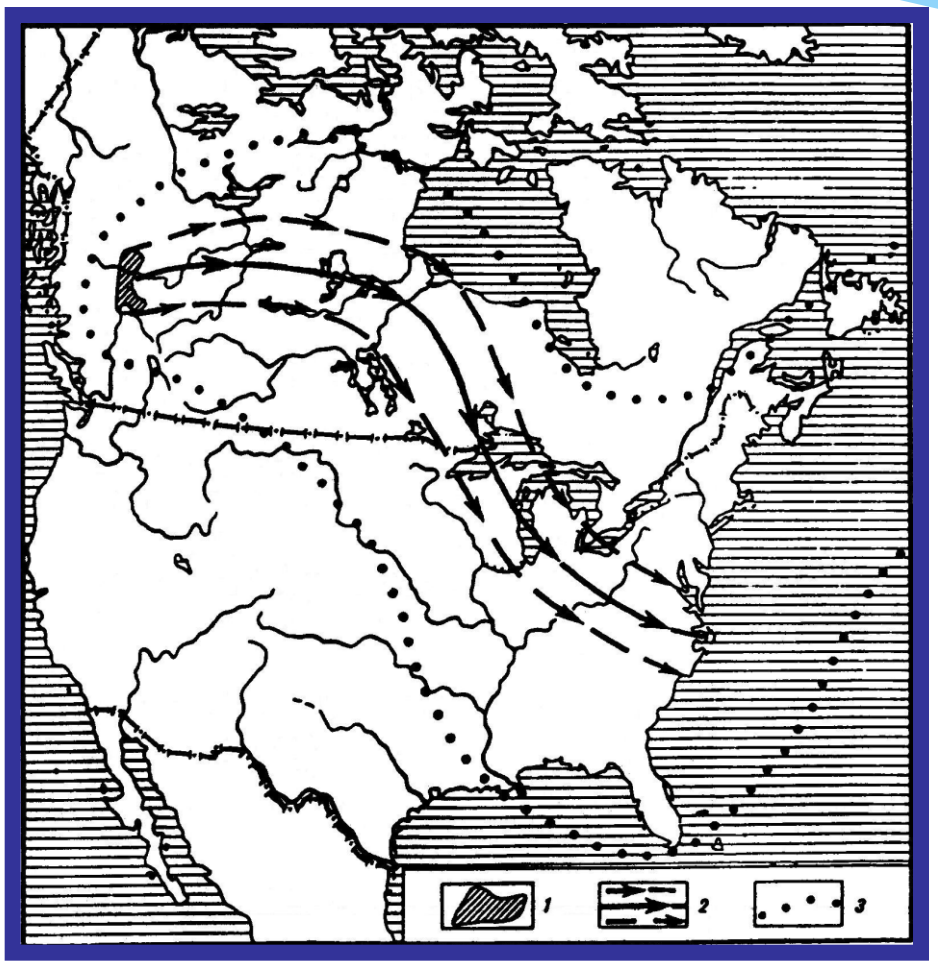
(by Woitke & Helling (2004))

CHARACTERISTICS OF PARTICLES AND PARTICLE DISPERSOIDS





Changes in the content and chemical composition in mineral part of ice caps depending on the deposit age



Gigantic smoke plume from fires in the South-East Canada in September 1950

Results of analysis of matter particles (mk/m^3) for the cities with population from 500 000 to 2 mln. (according to X. Yunge, 1965)

	Cincinnati	Kansas-City	Portland (Oregon)	Atlanta	Houston	San-Francisco	Minneapolis
General weight Substance dissolved in acetone	176 31,4	146 18,4	143 32,1	137 24,2	129 18,5	104 19,4	120 15,4
Fe	4,5	4,1	5,1	3,3	4,0	2,4	4,4
Pb	1,6	1,0	1,2	1,8	1,0	2,4	0,5
F	0,21	0,01	0,0	0,05	0,0	0,37	0,06
Mn	0,24	0,08	0,23	0,12	0,23	0,11	0,08
Cu	0,18	0,04	0,05	0,01	0,02	0,07	0,60
V	0,09	0,002	0,009	0,024	0,001	0,002	0,002
Ti	0,06	0,21	0,24	0,12	0,29	0,04	0,11
Sn	0,03	0,03	0,01	0,03	0,02	0,02	0,01
As	0,02	0,02	0,02	<0,01	0,01	0,01	0,01
Be	0,0002	0,0003	0,0003	0,0002	0,0002	0,0001	0,0002
SO^2_4	5,6	1,5	0,8	1,0	2,4	1,8	0,8
NO_3	1,0	0,6	0,2	0,8	1,0	3,4	1,3

Results of analysis of matter particles (mk/m^3) for suburb areas (according to X. Yunge, 1965)

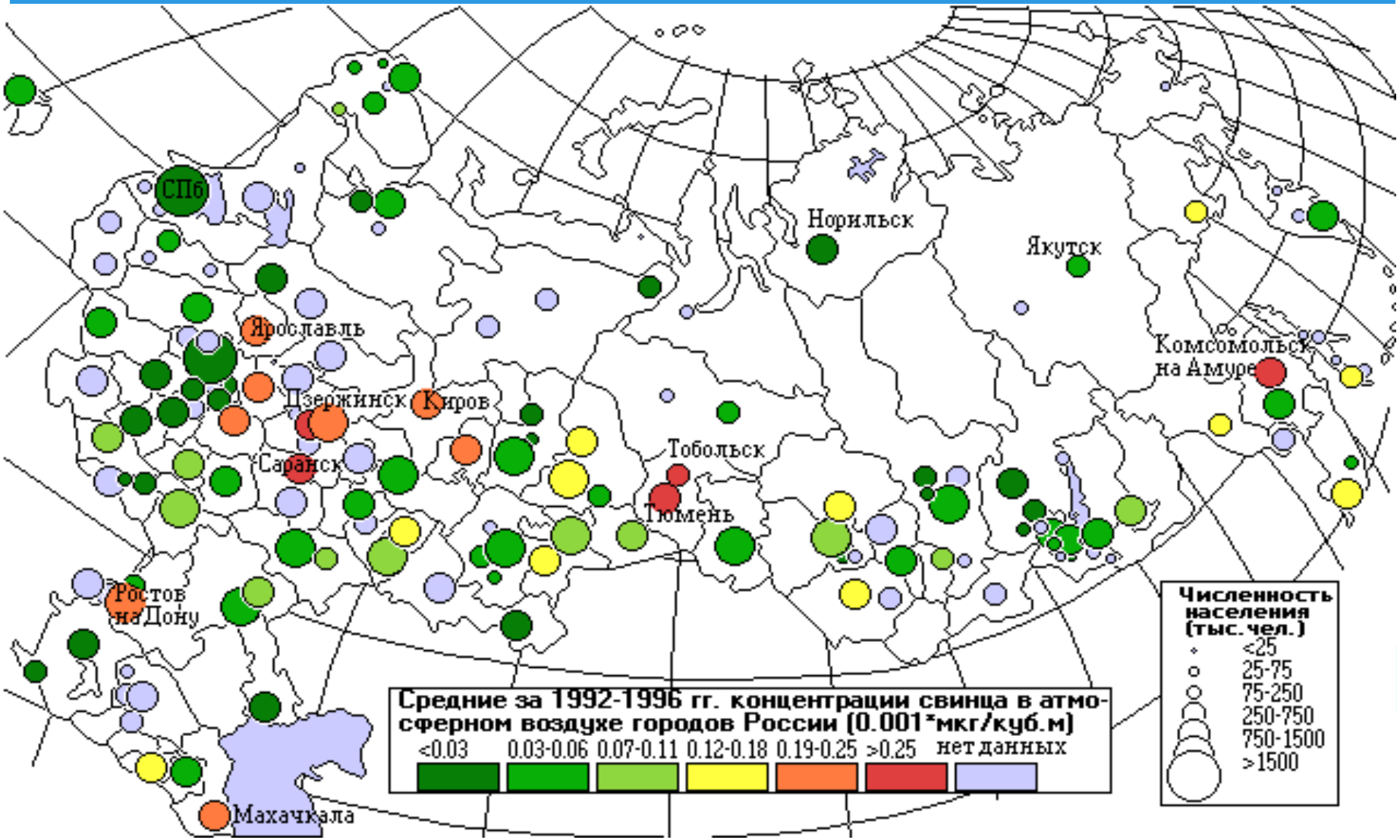
	Boonsboro	Salt-Lake City	Atlanta	Cincinnati	Portland (Oregon)
General weight Substance dissolved in acetone	68 8,7	55 6,2	71 9,3	45 9,0	86 12,6
Fe	3,7	4,1	27	2,4	3,6
Pb	0,1	0,1	0,9	0,4	0,3
F	-	-	0,0	0,26	-
Mn	0,0	0,28	0,1	0,19	<0,01
Cu	0,00	0,04	0,11	0,07	0,04
V	0,003	0,0	0,004	<0,001	0,002
Ti	0,026	0,0	0,13	0,01	0,0
Sn	<0,01	<0,01	<0,01	0,01	<0,01
As	0,01	0,03	0,01	<0,01	0,04
Be	0,0001	<0,0001	0,0002	0,0001	0,0001
SO^2_4	0,3	<0,01	0,5	1,9	0,4
NO_3	-	-	-	0,7	-

Concentration of lead, cadmium, and arsenic in atmospheric fallouts of background areas, mkg/l

Observation area	Observation period	Precipitation	Lead	Mercury	Cadmium	Arsenic
Polar areas						
Alaska	Before 1975	Snow	-	0,005	0,08	-
Antarctica, st. Amundsen. Skott (2880 m. above sea level)	1928-1977	Snow in layers	0,005-0,02	-	-	-
	1976-1977	Snow	0,03	-	0,026	-
	Before 1979		0,04	-	0,009	-
Antarctica	1975-1978	Ice	0,14	0,011	0,639	0,019
		Snow	0,41	-	0,005	-
Greenland						

Map of metal average concentration distribution: lead, constructed according to the observation data for 1989 - 1993 in 123 cities

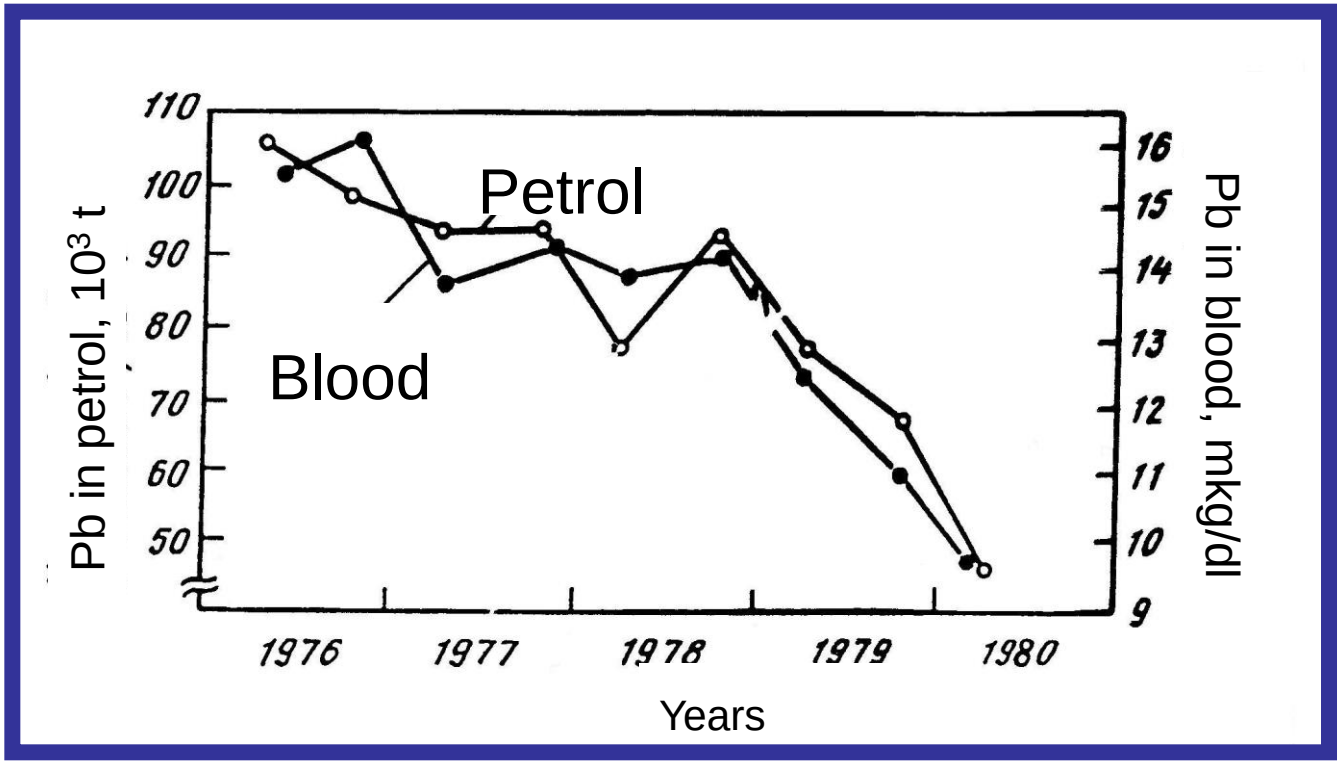
(by Bezuglaya E.Yu., Abrosimova Yu.E. 1998)



Effects of selective toxicity at metal pollution (OECD, Paris, 1991)

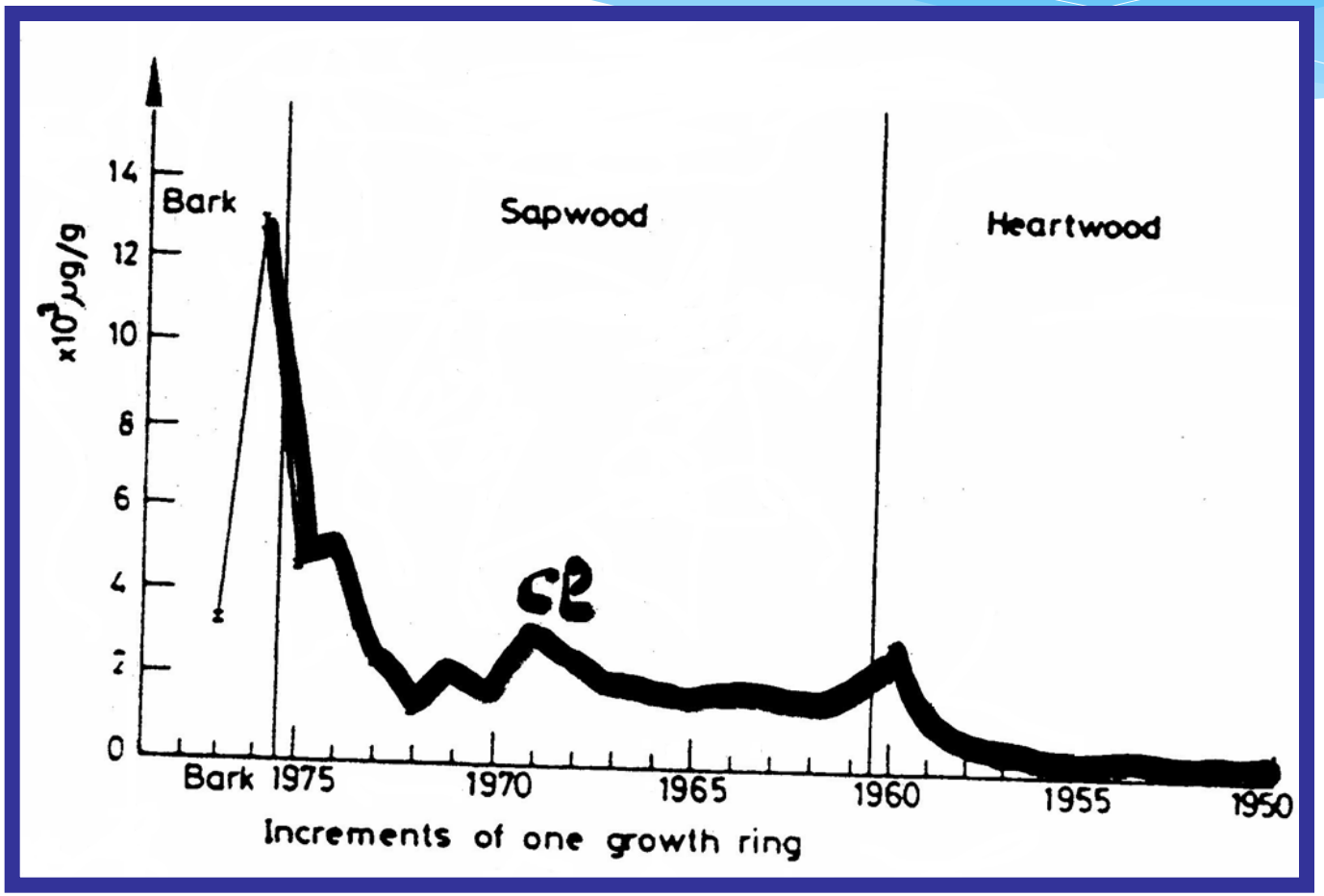
Pollutants	Effect on health
Arsenic (As)	Lung cancer, skin disease including ulcers, hematologic effect including anemia
Cadmium (Cd)	Acute and chronic respiratory diseases, renal dysfunction, malignant tumors
Chromium(Cr)	Lung cancer, malignant tumors in gastrointestinal tract, dermatitis
Lead (Pb)	Impaired haemopoiesis, renal and liver damage, nervous system effect
Mercury (Hg)	Nervous system effect including short-term memory, sensory and coordination disorders, kidney disease
Nickel (Ni)	Respiratory diseases including asthma, respiratory impairment, congenital malformations and deformities, nose and lung cancer
Vanadium (V)	Respiratory irritation, asthma, nervous disorder, changes in blood formula.

Decrease of lead in blood of USA population (by X. Zilbergeld, 1995)



The radial variation of Cl across the in Reading Cedar

(по R.E. Tout a.e., 1977)

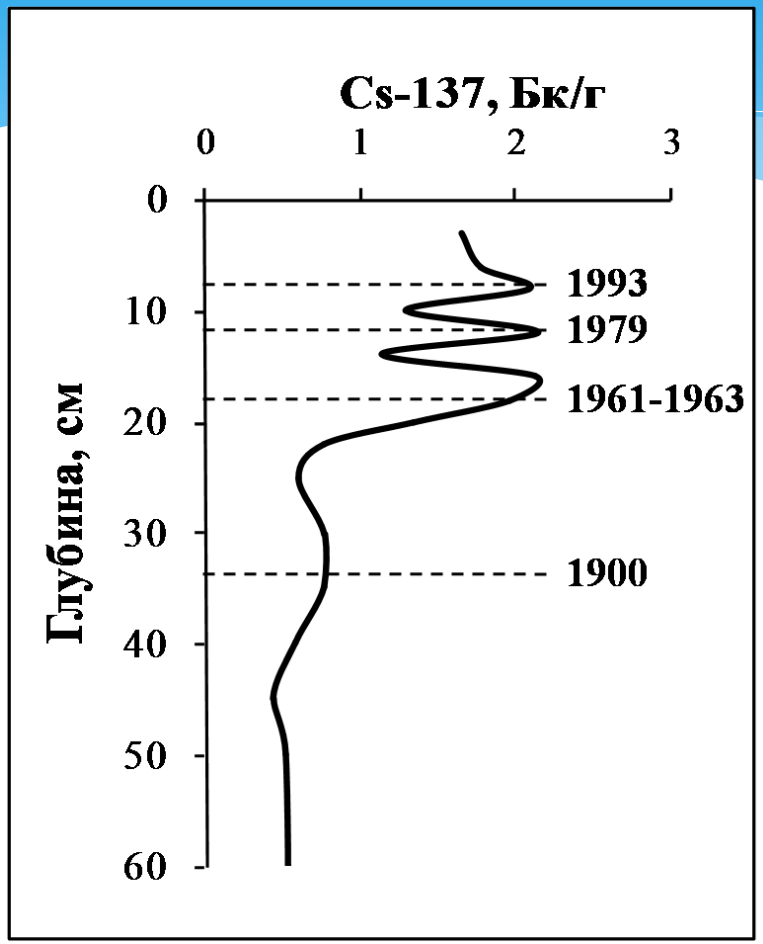


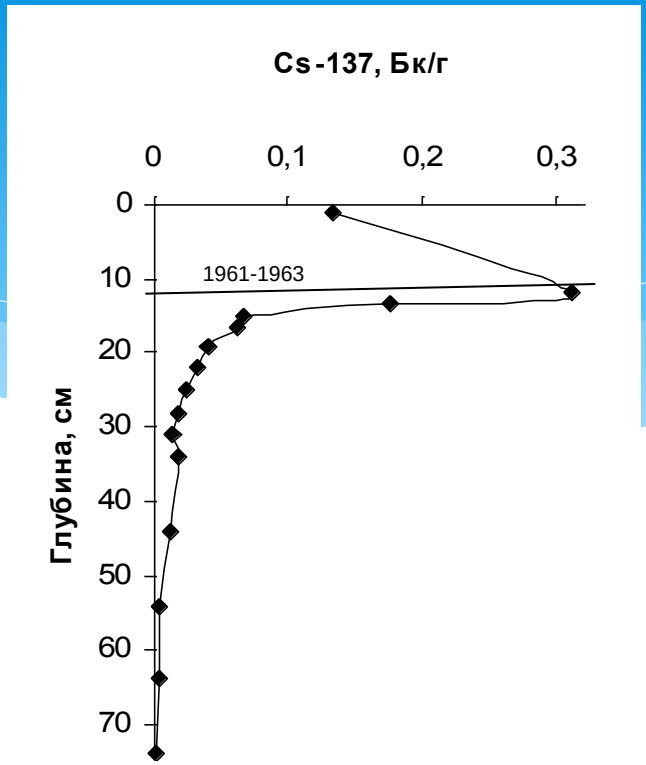
Effect of acid rains on lakes and their species

Country	Effect
Canada	By 1908 fish disappeared in nearly 140 lakes of the province, 10 000 lakes were damaged
Denmark	Lake acidification in some regions, soils with high concentration of natural salts.
Finland	Half of 107 lakes in vicinity to Helsinki, as was observed in 1984, was highly acidified and fish population was to extinct
Norway	Significant damage was stated in the South of the country: of 5000 fishing lakes fish disappeared in 1750, in 900 more – serious effects are expected in the nearest future
Sweden	All sources of fresh water are acidified; nearly 15 thous. by air pollutants; 6,5 thous. are acidified by other sources (in addition to atmospheric ones); 1800 – almost completely lost any vital signs
Great Britain	Drop in haul in Scotland, Wales and Lake Distrikt; owners of fishery had great losses in Cumberland (England)
Eastern part of the USA	Nearly 9000 lakes are endangered; by 1980 in Mississippi 3000 lakes were damaged; 212 lakes in Adi mountains lost fish completely.
Western part of the USA	No lake ecosystem was damaged to high extent, the most damaged are lakes in the system of Sierra-Nevada range and Rocky Mountains as well as coastal sites.

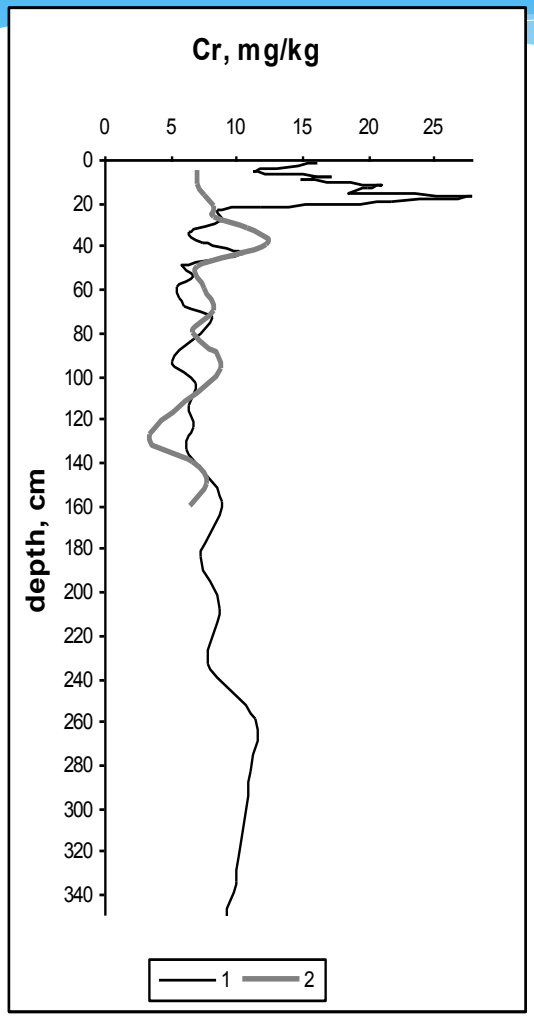
Sourcefrom Worldwatch Institute by John McCormicla (Washington, D.C.: International Institute of Environment and Development, 1985) and other sources.

Vertical distribution of ^{137}Cs in the section of Petropavlovskiy Ryam bog





Vertical distribution of ^{137}Cs in the section of Kirsanovskoe bog [*Gavshin et al., 2003*]



* Distribution of cromium in peat cores:
* 1- Petropavlovskiy Ryam, 2 – core Vodorazdelnoe (near Tomsk city).