COSMIC RAYS, AEROZOLS, CLIMATE
Registration of the Cosmic Rays of Ultrahigh Energy

Climate researches

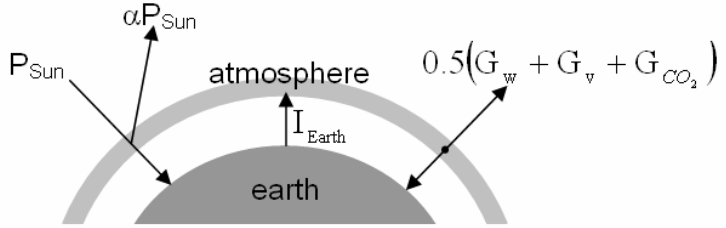
- Milancovic hypothesis
- Energy balance model of Global Climate
- Turbulent heat transfer and reradiation of greenhouse gases (H2O, CO2 …)
- Catastrophe theory of Tom
- “Switching” mechanism near the bifurcation point
- Technogenic and natural impact – cosmic rays, aerosols, ozone, CO2 ets.

Balance of the absorbed and emitted energy currents on the surface of the Earth

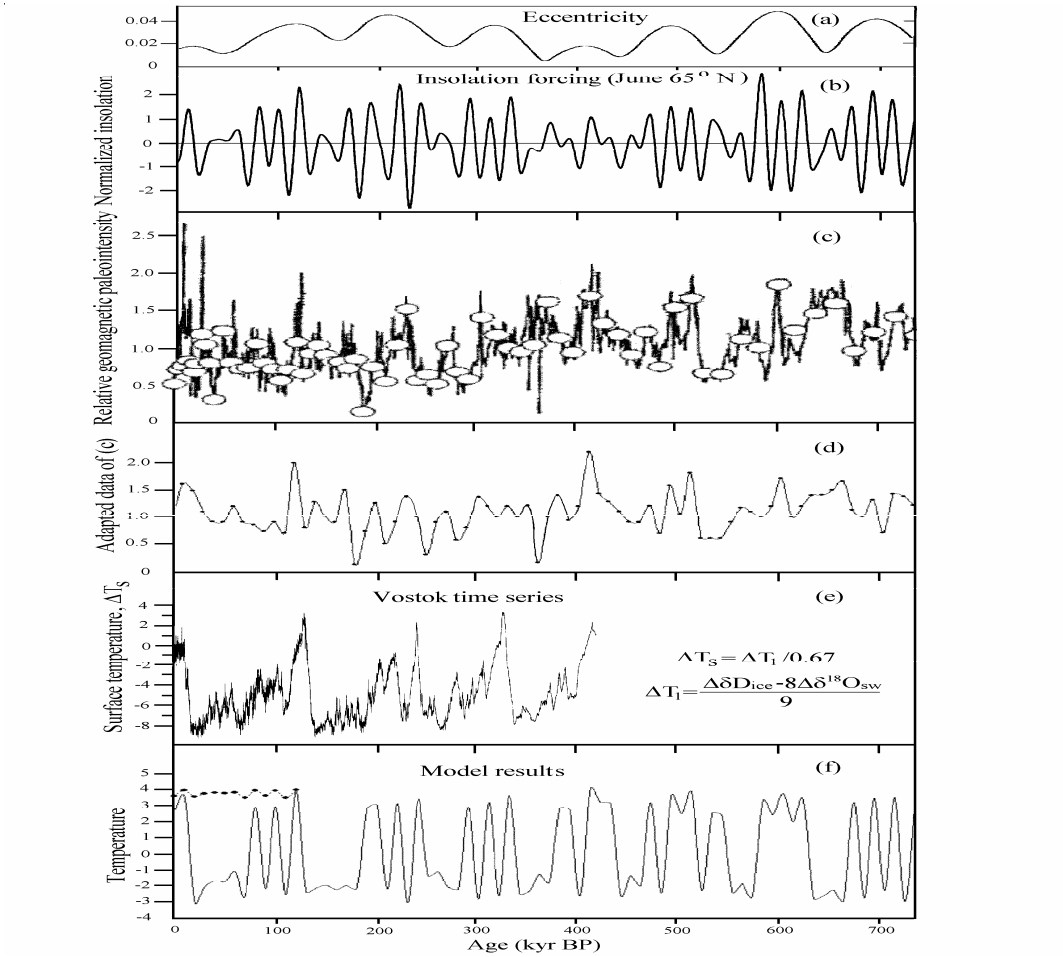
Main equation of the assembly catastrophe

$$\frac{d}{d(\Delta T)}\Delta U^{*}(\Delta T,t)=\Delta T^{3}+\tilde{a}(t)\cdot\Delta T+\tilde{b}(t)=0$$

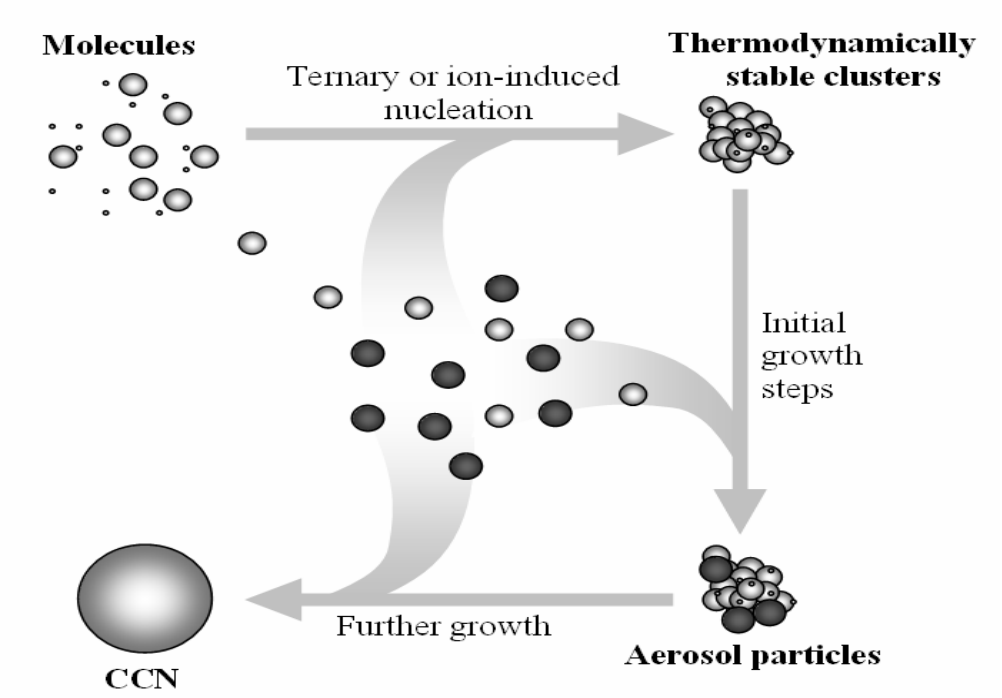
a(t), b(t) – controll parameters of the model determined by changes of insolation, quantity of water and greenhouse gases in the atmosphere and intensity of the cosmic rays



Model of climatic response to insolation and magnetic field variation of the past 730 kyr compared to isotopic temperature datd of the past 420 kyr



Inerrelations between cosmic ray intension and aerozol concentration



Inerrelations between cosmic ray intension and aerozol concentration

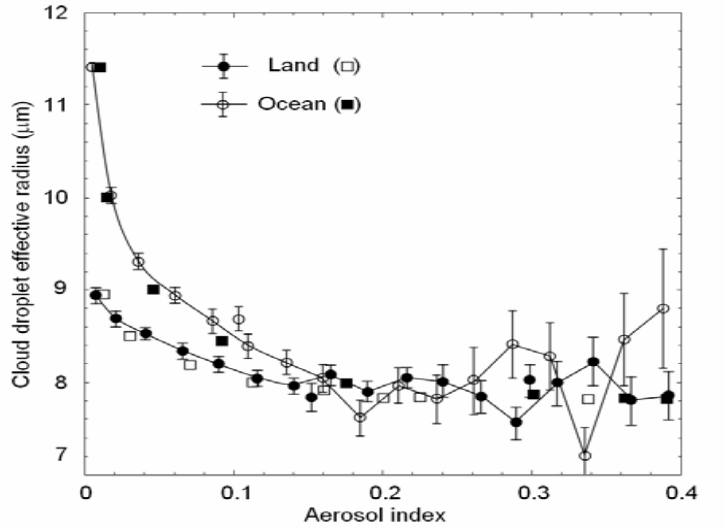
How particles form and grow [*Kulmala*, 2003**]**:

> Nucleation may involve homogeneous ternary water-sulfuric acid-ammonia mixture or may be ion-induced. The initial steps of growth include activation of inorganic clusters by soluble organic molecules, heterogeneous nucleation of insoluble organic vapors on inorganic clusters, and chemical reactions of organic molecules at surfaces of inorganic clusters. Finally, cloud condensation nuclei (CCN) form through addition of organic and sulfuric acid molecules.

How particles form and grow

- Primary inoculate centers – ions (cosmic rays), ternary (water-sulfuric acid-amonia mixture), soil particles
- Growth: geterogeneous nucleation, diffusion driven aggregation (fractals)
- Formation of CCN
- Condensation of droplets

Interrelation between cloud droplet radius and aerosol index



- Effect of aerosol on cloud droplet: mean cloud droplet effective radius (CDR) as a function of aerosol load [Breon et al., 2002]. The two curves show the mean CDR as a function of aerosol index (AI) for land (lower curve) and ocean (upper curve). The error bars represent the confidence level of the mean value, i.e. , where *n* and σ are the number of CDR measurements within the bin and their standard deviation [Breon et al., 2002]. The empirical dependence CDR=*f* (AI) of type (1) for land (■) and ocean (□) is also represented
- .

$$AI = \left[\frac{1}{(0.6 r_{eff} - 4.385) r_{eff}} - \frac{\eta}{r_{eff}} \right]^{1.429}, \quad \eta = \begin{cases} 0, & over \quad ocean, \\ 0.63, & over \quad land, \end{cases}$$

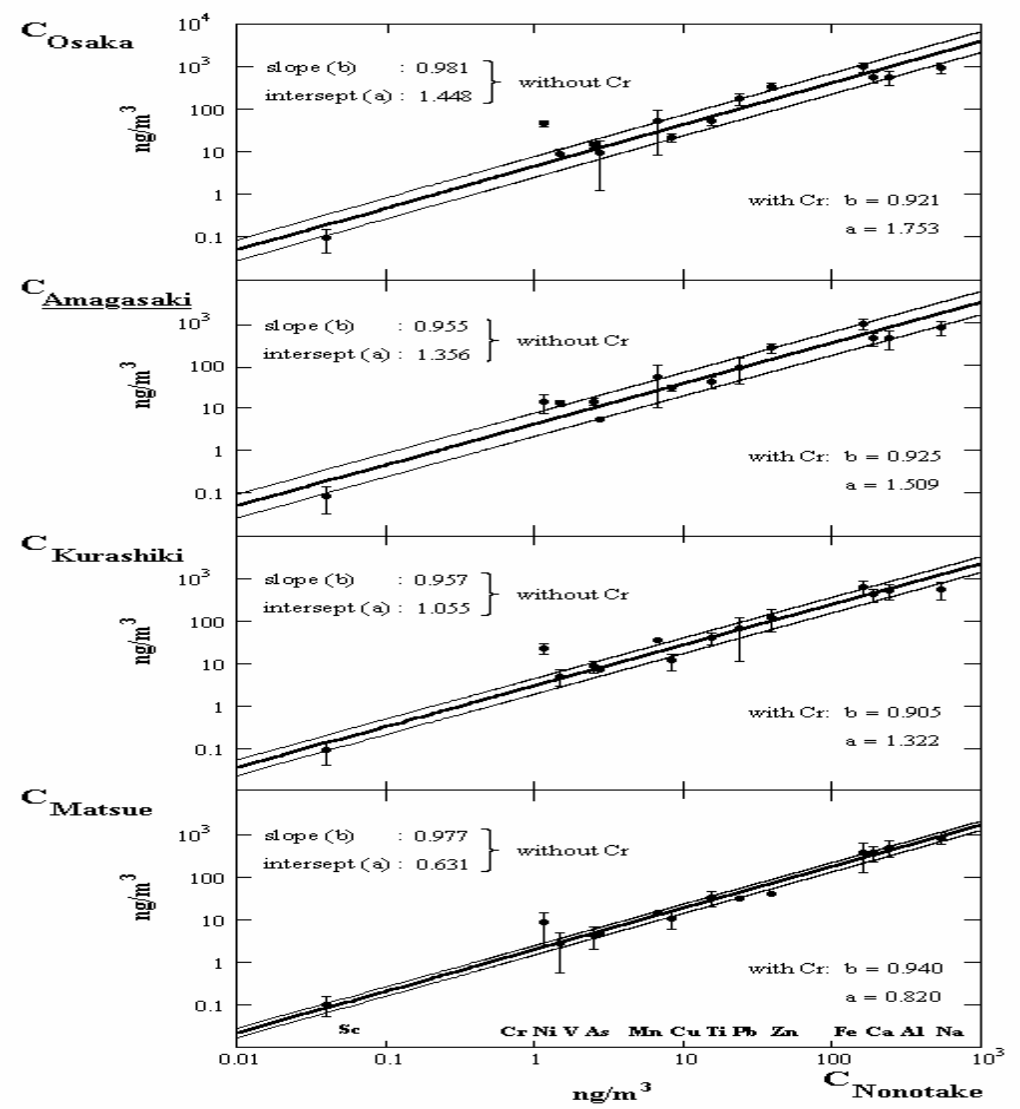
Fractal Properties of Atmospheric Aerosols

Experimental data and some theoretical and model approaches

Experimental data from Antarctica, Slovenia, Ukraine, Japan

Element content of aerozols

Experimental data



Element content of aerozols

Experimental data

- (i) the elemental content of atmospheric aerosols is practically the same and does not depend on the recording location at least for most widespread elements;
- (ii) the linear relation (on a logarithmic scale) of different pairs of experimental samples of element concentrations in atmospheric aerosols indicates the statistically significant power mass growth of the *i*–th element in atmospheric aerosol, thus substantiating the assumption (19 - 20) about the fractal nature of the genesis of atmospheric (secondary) aerosols, so $C_{i1} = a_i (C_{i2})^b$
- or more correctly
- , $\frac{C_{i1}}{C_r} = a_i' \left(\frac{C_{i2}}{C_r} \right)^b$
- where Cr is some reference concentration;
- (iii) those elements which depart from linear dependence, are different in their genesis, which indicates the technogenic nature of their sources;
- (iv) the multicomponent properties of atmospheric (secondary) aerosol point to their being a non-homogeneous fractal, or, what is the same, a multifractal.
- (v) the model of linear regression is satisfactory for all pairs of data obtained in different regions of the Earth.

Element content of aerozols

Experimental data

- It can be considered as the low of linear correlation dependence between the components of two-dimensional (at the Earth surface) random variable $\left(u = \frac{\ln C_{1i} - \langle \ln C_{1i} \rangle}{\sigma}, v = \frac{\ln C_{2i} - \langle \ln C_{2i} \rangle}{\sigma} \right)$. It is well known from the probability theory that the components of the two-dimensional normal distribution

$$P(\ln C_{1i}, \ln C_{2i}) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-r^2}} \exp\left[-\frac{1}{2(1-r^2)} \left(u^2 + \upsilon^2 - 2ru\upsilon \right) \right]$$

- Where *r* is the correlation coefficient,is connected by the linear correlation dependence. In other words, the parameters of two-dimensional normal distribution is connected by the equations of direct linear regression

- $$\ln C_{1i} - \langle \ln C_{1i} \rangle = r \frac{\sigma_1}{\sigma_2} \left[\ln C_{2i} - \langle \ln C_{2i} \rangle \right]$$ and inverse linear regression.The components of two-dimensional normal distribution have also normal distribution

$$P(\ln C_i) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{ -\frac{1}{2\sigma^2} \left[\ln C_i - \langle \ln C_i \rangle \right]^2 \right\}$$ or

$$P(C_i) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{ -\frac{1}{2\sigma^2} \left[\ln C_i - \langle \ln C_i \rangle \right]^2 \right\}$$

Back to fractals

It is interesting to note that the occupation numbers pij of multifractals have also log-normal distribution (if one can approximate the spectrum of fractal dimensions *f(α)* by parabola

$$P(p_{ij}) = \exp\left(\mu - \frac{1}{2}\sigma^2\right) \cdot \exp\left[-\frac{1}{2\sigma^2}\left(\ln p_{ij} - \mu\right)^2\right]$$

where $\mu = \ln p_0$, $\sigma^2 = 2\ln\frac{1}{p_0 N_{D_0}}$ $\ln p_0 = \alpha_0 \ln\frac{1}{l}$ $\ln N_{D_0} = -D_0 \ln\frac{1}{l}$

Back to cosmic rays

- Our knowledge about cosmic rays forms not only our ideas of Earth climate, but in general our concept of Universe
- We Know that:

1. CR is universal phenomenon and play sufficient energetic role in Universe.
2. Main part of CR has Galactic origin with small modulation by solar CR.
3. Main source of GCR are supernova stars

GCR of ultrahigh energy

- 1 particle/100yr km*2 sr
- Several events with energy >E20 eV were detected by usual methods
- CR of 3.E20 eV has the age not exceeding E8yr due to interaction with photons of relict radiation
- In our Galactic there are no such obvious objects which can accelerate protons to such energy

Radiomethod of CR detecting

- Cherenkov radio tail and geomagnetic radiation induced by air shower -30-50 MG
- Showers in dense matter – 1-10 MG:
- δ- and excess electrons of the shower – 0.5 MG
- Transition radiation due to transition of shower from air to sea water – 5 MG
- Preliminary Antarctic results