A new look at mechanisms of action of volcanogenic disturbance of the stratosphere on climate and ecological systems

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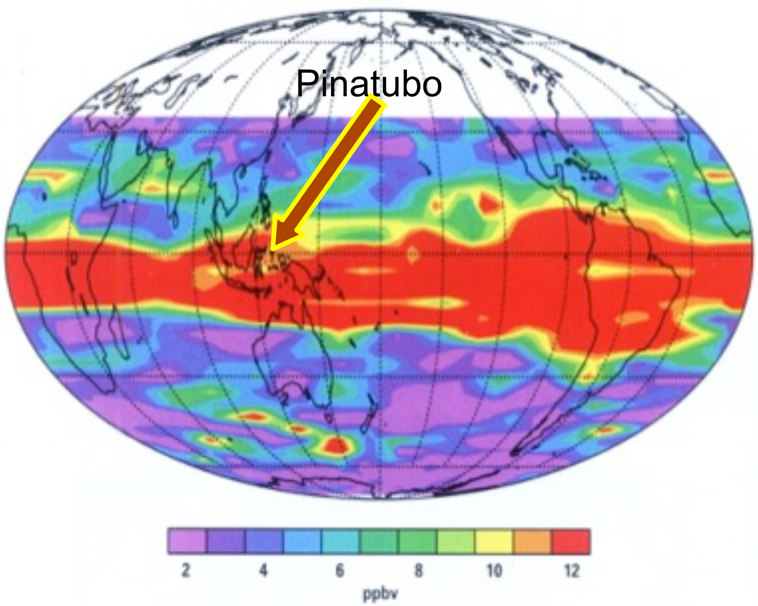
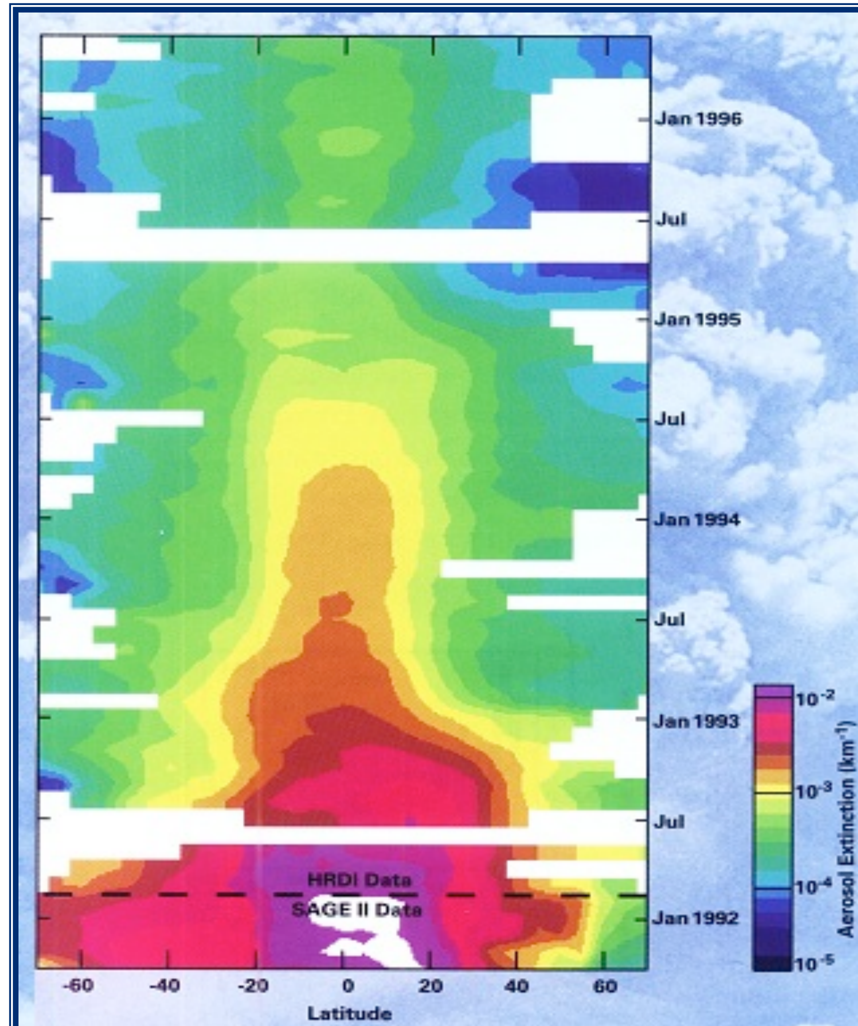
Formation of sulfuric acid aerosol in the stratosphere after the eruption of Mount Pinatubo

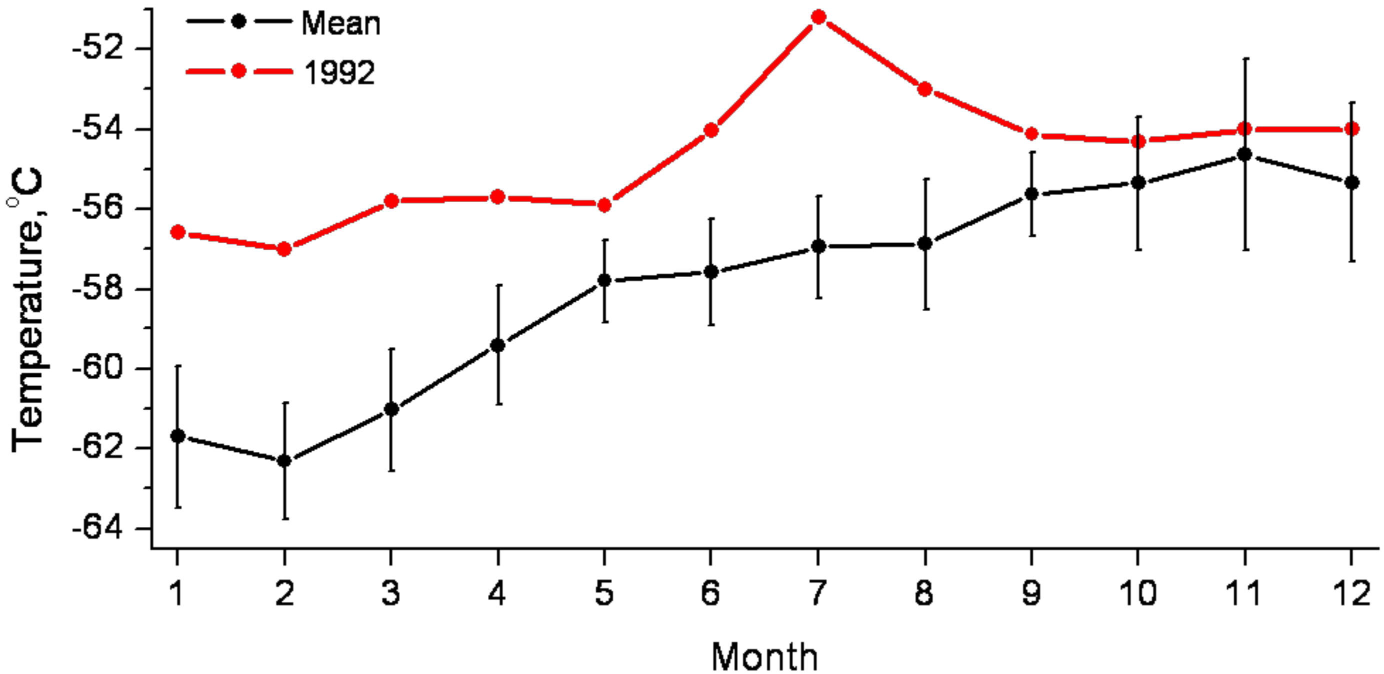


Distribution of SO_2
in the stratosphere in June 1991



The latitude-time distribution of
volcanogenic aerosol at the altitude of 25 km

Heating of the tropical stratosphere in a volcanogenic sulfuric acid aerosol layer

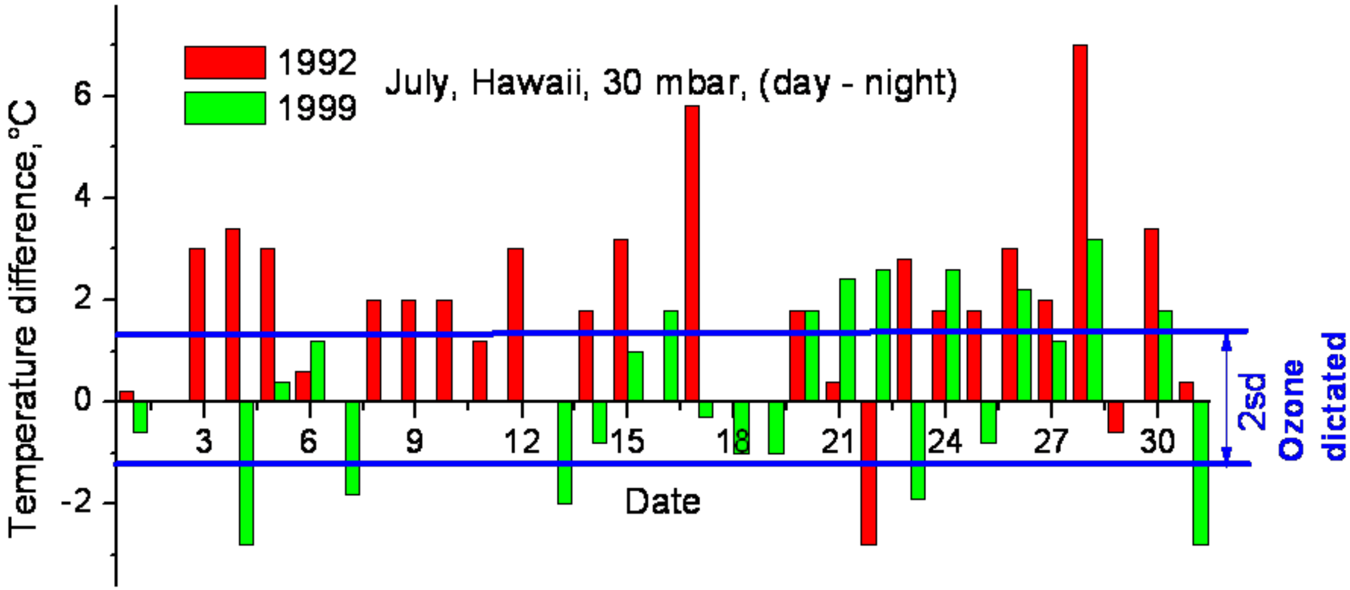


Annual changes in temperature at 30 mbar in 1992 compared with long-term average for the same quasi-biennial oscillation phase according to the weather station in Singapore.

Inconsistencies in the traditional view on sulfuric acid aerosol in the stratosphere

I – absence of significant absorption of shortwave radiation
(absorbs only thermal infrared radiation)

In fact: specific heating of the stratosphere during the day in July 1992 indicates the effective absorption of shortwave radiation

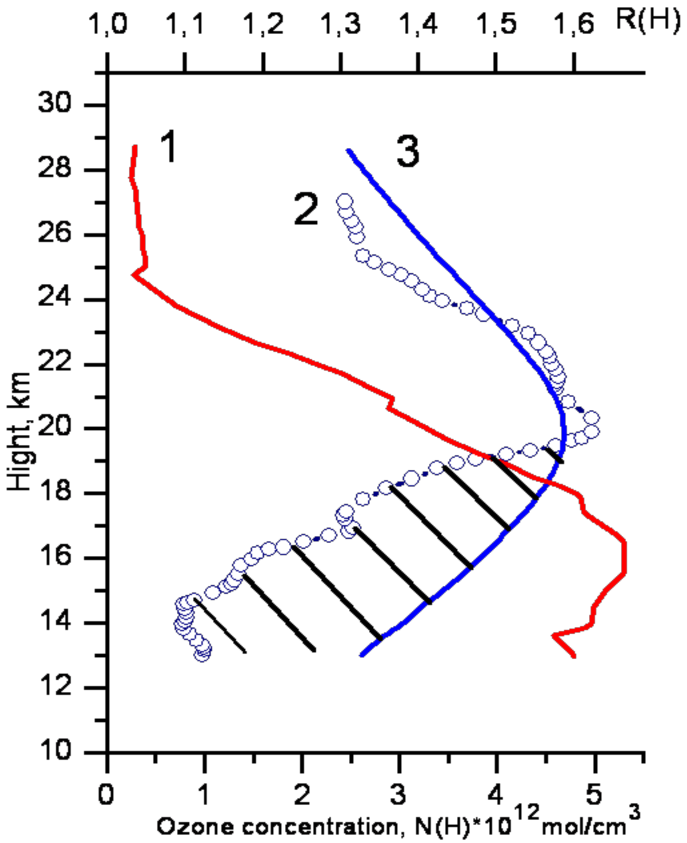


Temperature differences (day-night) at 30 mbar (about 24 km) from observations of the Hawaiian station in 1992 and the perturbed image in 1992 and background image in 1999.

Inconsistencies in the traditional view on sulfuric acid aerosol in the stratosphere

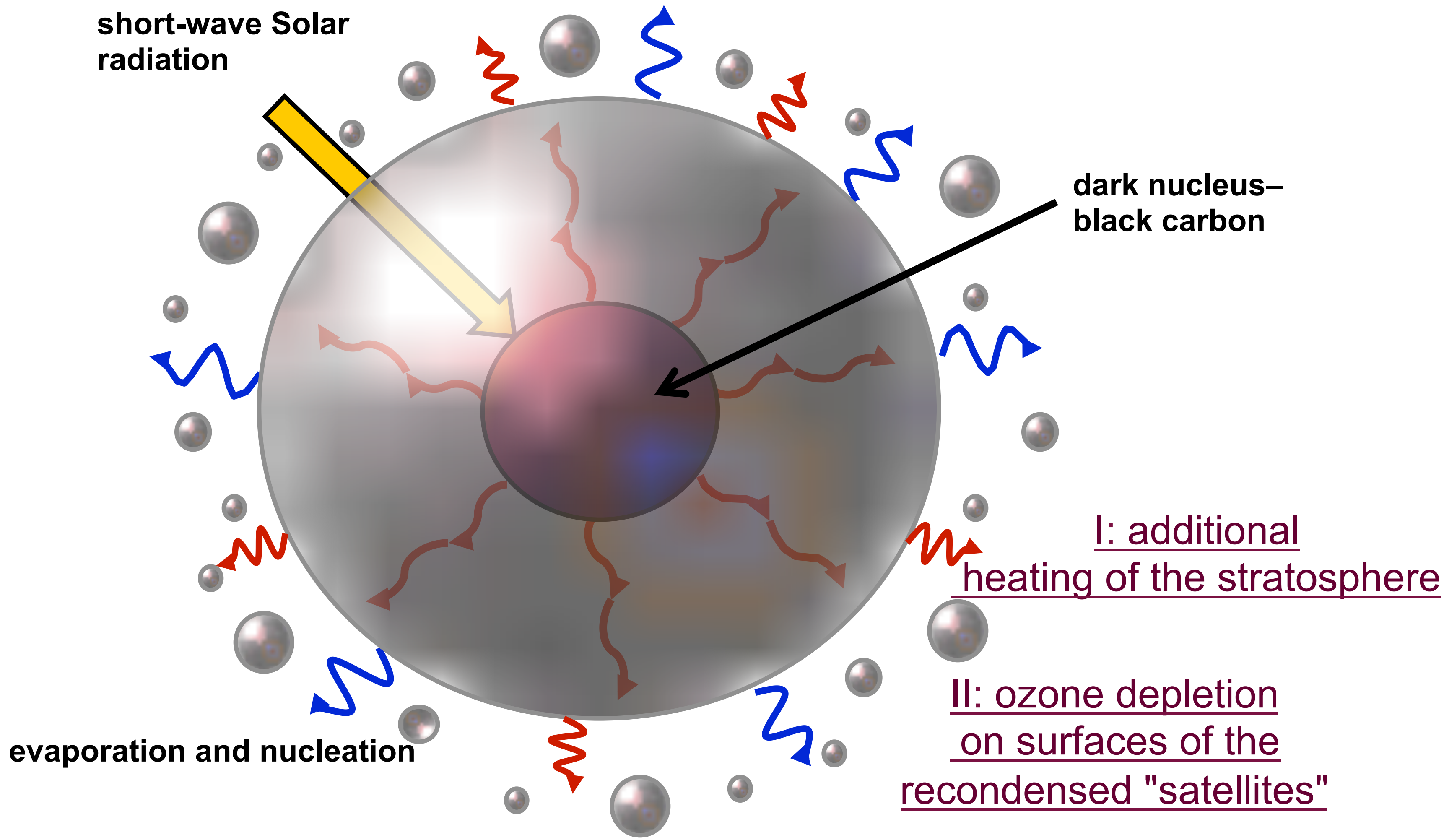
II – poor effectiveness of ozone depletion on the surface of submicron sulfuric acid aerosol (only nanosized aerosol is active)

<u>In fact:</u>
extensive ozone destruction within the aerosol layer was observed three years after the eruption when aerosol "aged" and was enlarged

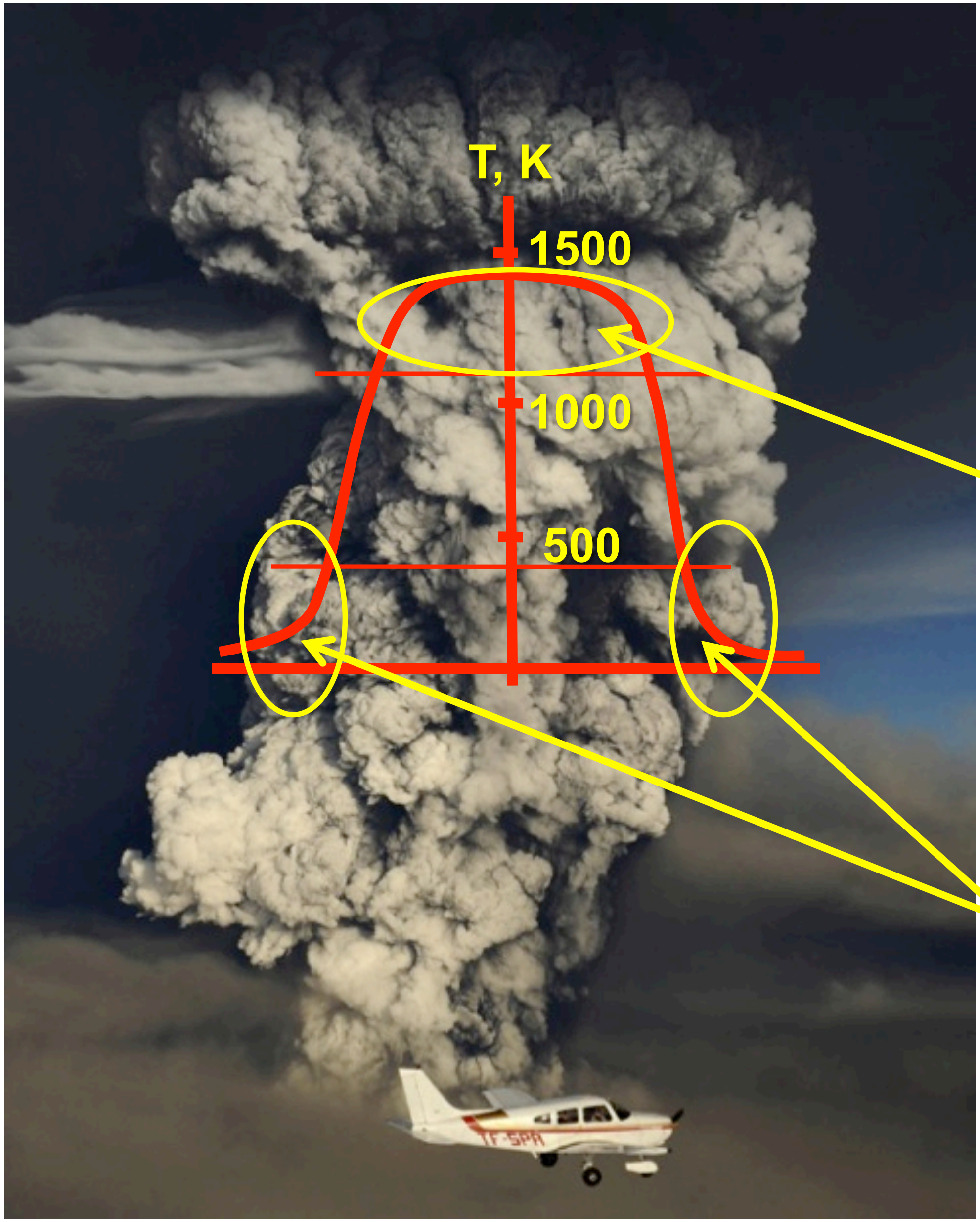


Profiles of scattering ratio at a wavelength of 353 nm (1) and the vertical ozone distribution (2) 25.04.1994 in comparison with many years of background ozone profile (3) averaged over a period of lidar observations from 1998 to 2006.

A new look at the volcanogenic sulfuric acid aerosol



‘Black carbon” in the eruption column



Basis - carbon monoxide CO
(The main catalyst – Fe)

The Fischer-Tropsch synthesis (synthesis gas)

$$nCO+(2n+1)H_2 \rightarrow C_nH_{2n+2}+nH_2O$$

(for n = 1 methane is produced)

soot of the size of 10-50 nm is generated during high-temperature hydrocarbon combustion

Bell-Boudouard reaction

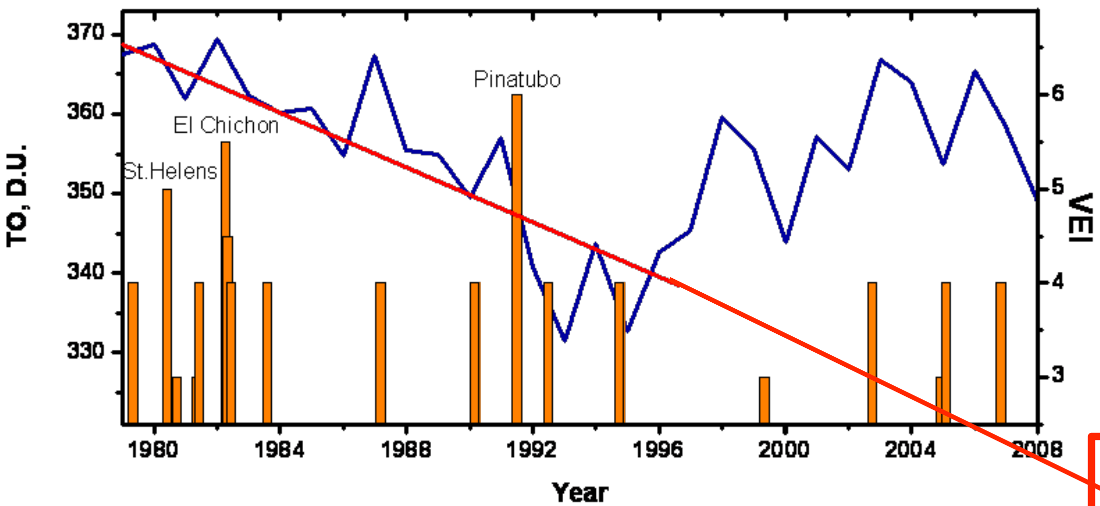
$$2CO \rightarrow CO_2 + C$$

Terms and conditions: pressure from 1 - 30 atmosphere, temperature 190—240 °C (for Co и Fe) or 320—350 °C (for Fe). Fullerenes, astralenes, and etc. with the size of 10-30 nm are formed.

Influence of volcanogenic depression of the ozone layer on climate and ecological systems

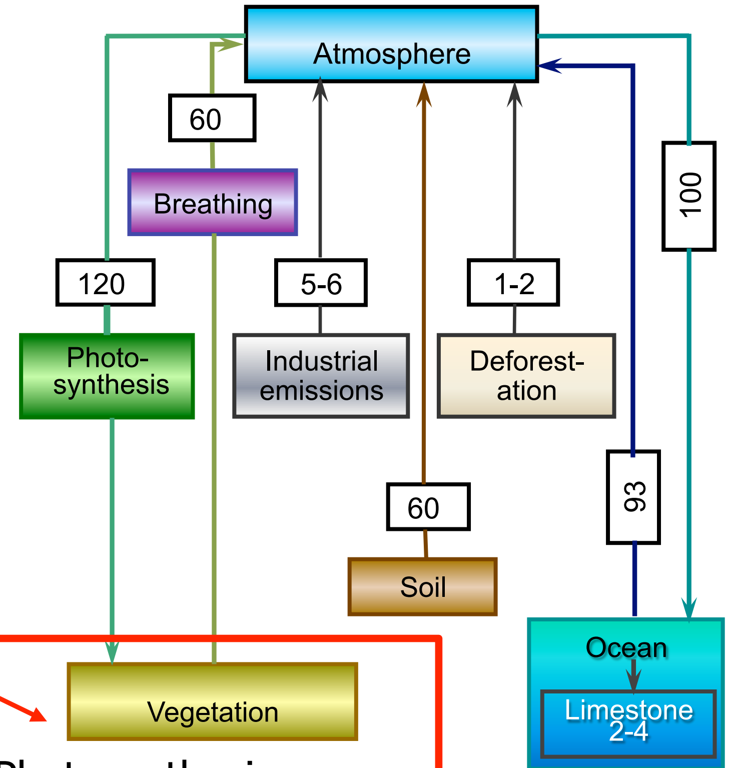
Influence of volcanogenic depression of the ozone layer on the carbon cycle

Volcanogenic depression of the ozone layer during the period of 1979-1996.



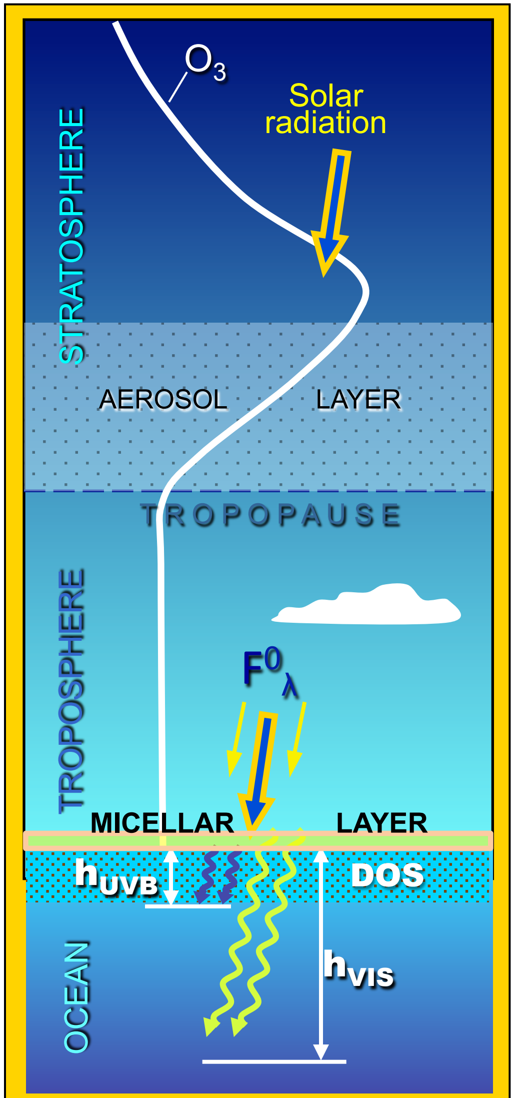
The behavior of the TOC in the temperate zone of the Northern Hemisphere on the background of volcanic eruptions with VEI≥3

The balance of the global carbon cycle (flows), Gt/year



Photosynthesis depression and stress respiration increase estimate is 2-3 Gt C/ year)

Ozone layer depression and sea surface temperature



The rate of radiation heating of water :

$$\frac{dT(h)}{dt} = -\frac{1}{\rho_B c_p}\int_{\Delta\lambda}\frac{dF_{\Delta\lambda}(h)}{dh}d\lambda \quad ,$$

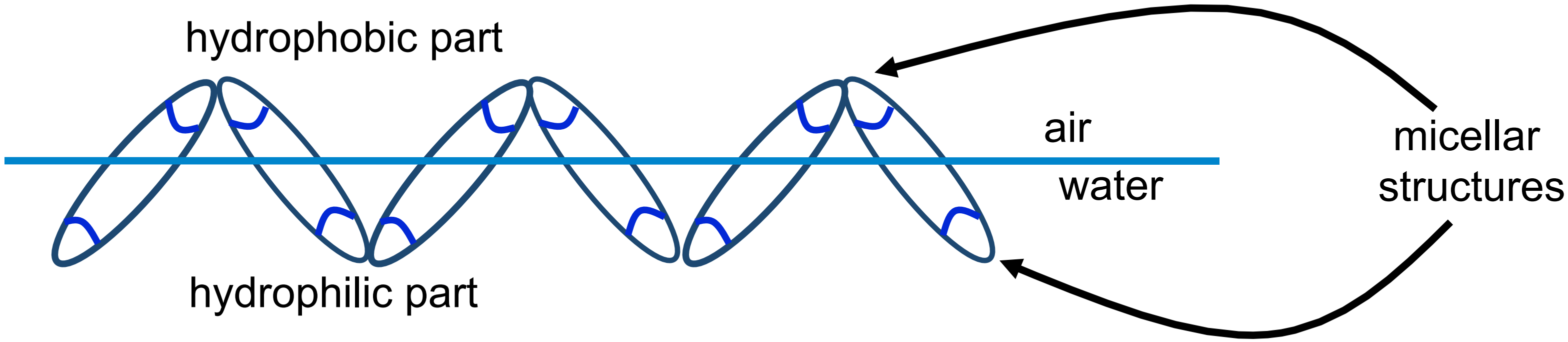
where ρ_B – density, c_P – water specific heat

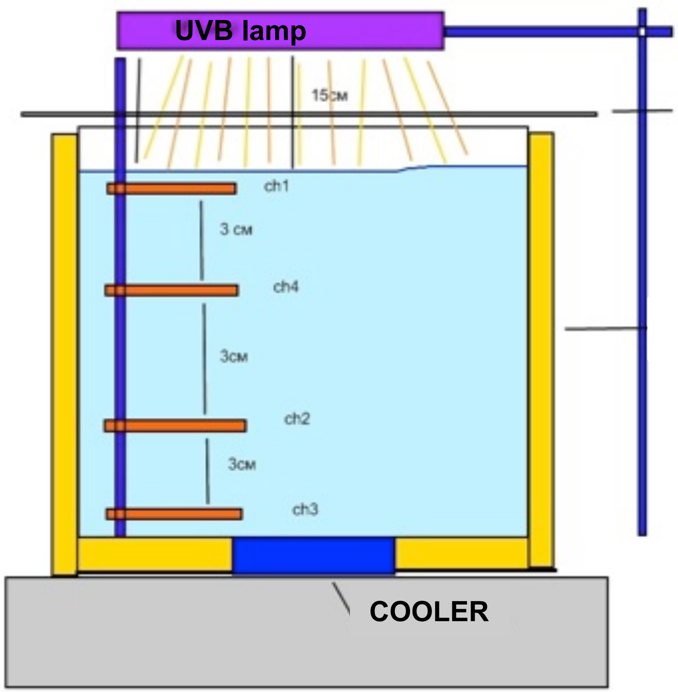
$$\frac{dF_{\Delta\lambda}(h)}{dh} = -F^0_{\Delta\lambda}(h)\,\alpha_{\Delta\lambda}(h)$$ – Bouguer-Beer law.

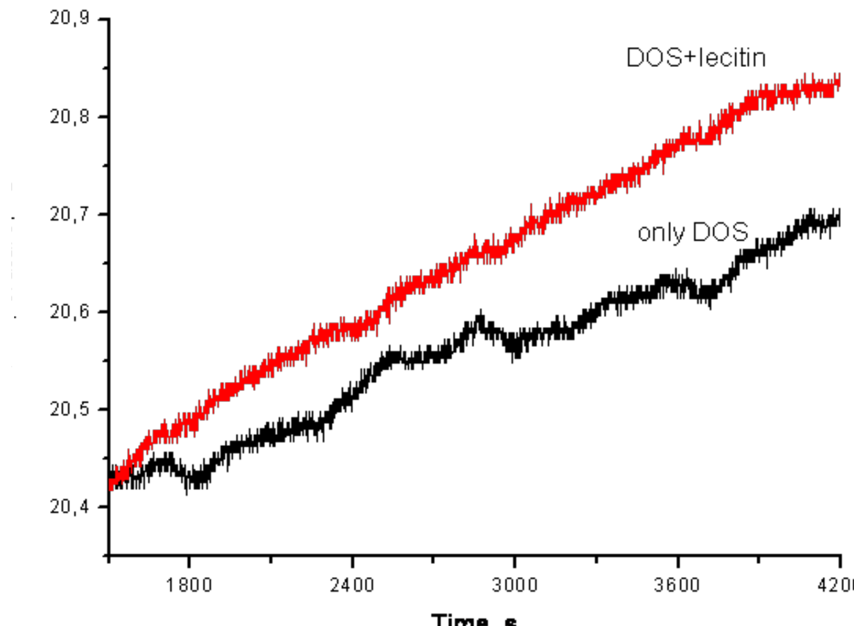
> The contribution of *UV-B* radiation to the water surface heating is by order of magnitude higher than in the visible range. It is due to a much more efficient absorption of micellar layer and dissolved organic substance (DOS)

$$\downarrow O_3 \longrightarrow \uparrow F^0_{UVB} \longrightarrow \uparrow SST$$

Enhancement of the *UV-B* radiation absorption efficiency by micellar layer

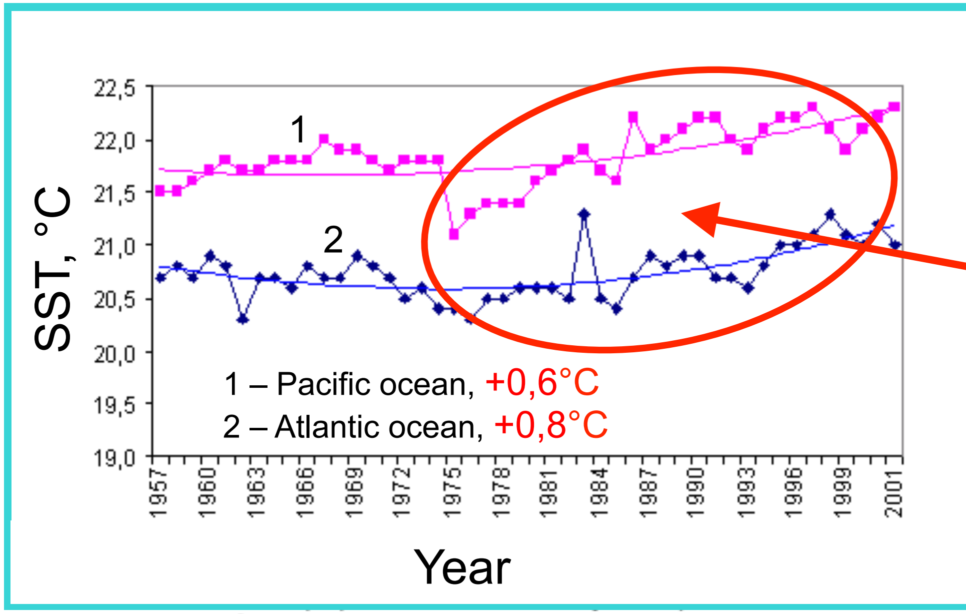




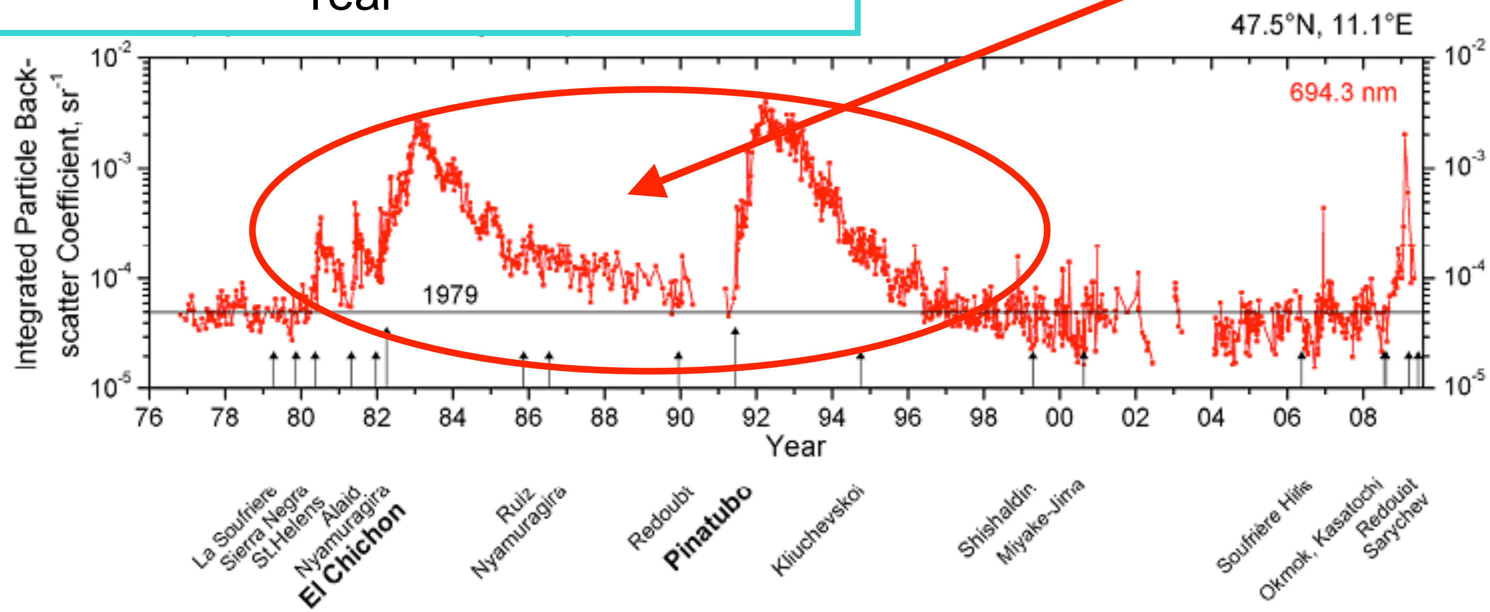


Growth acceleration of the water surface temperature with adding lecithin micellar structures

Growth of SST during volcanogenic disturbance of the stratosphere



The growth of SST in the late XXth century occurred during the aerosol perturbation of the stratosphere which caused long-term ozone layer depression



Modelling of climate changes in the Northern Hemisphere at weakening of the thermohaline circulation

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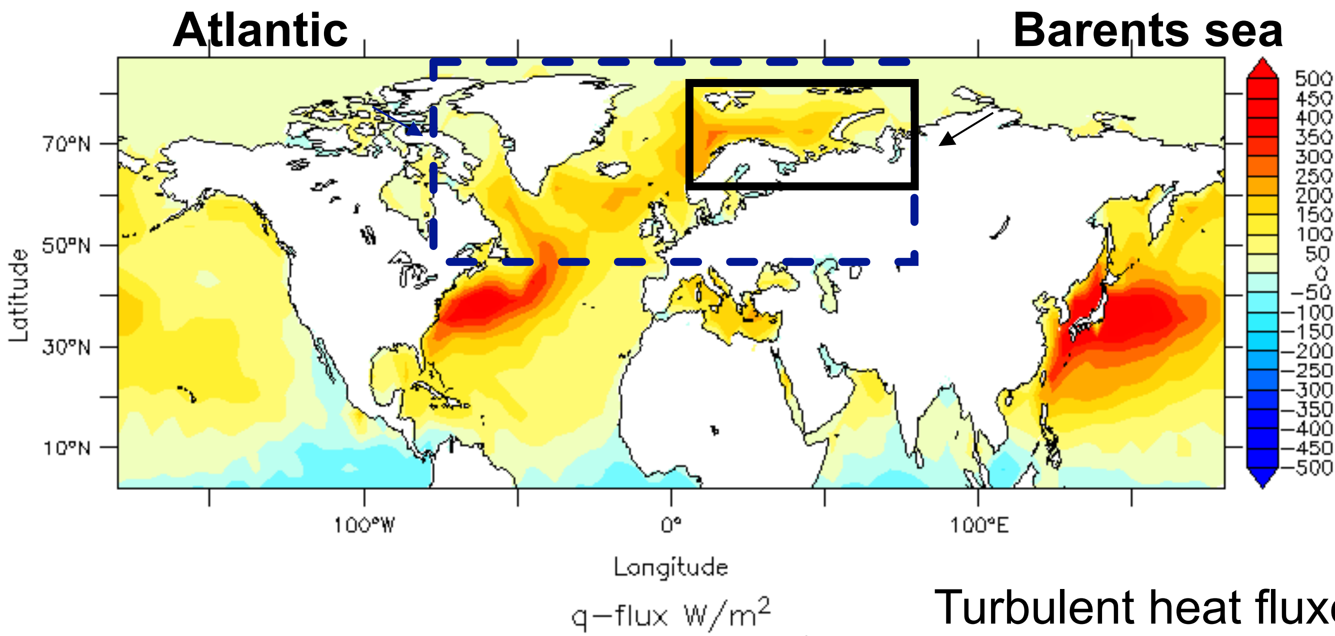
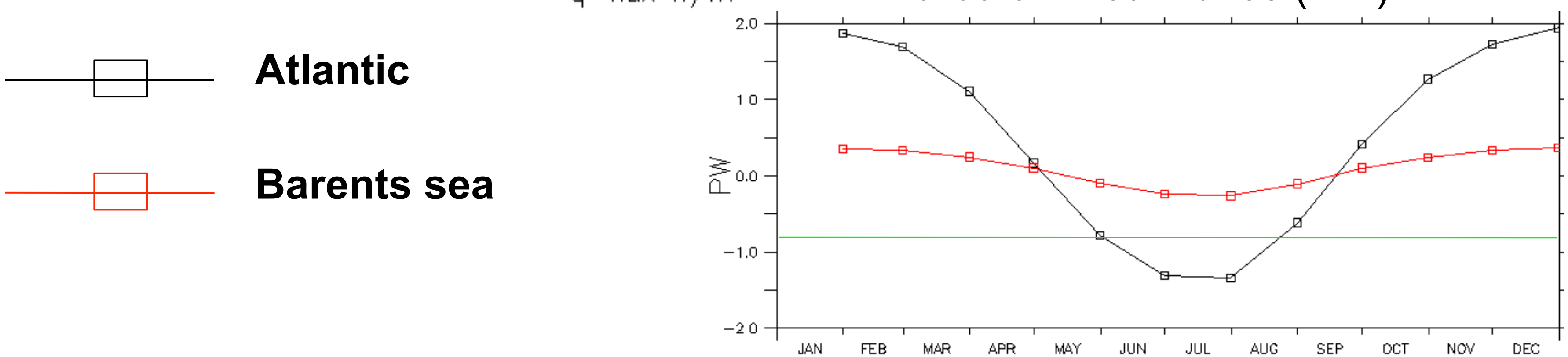
Turbulent heat fluxes

Winter season mean turbulent fluxes (W/m^{-2})



Turbulent heat fluxes (PW)

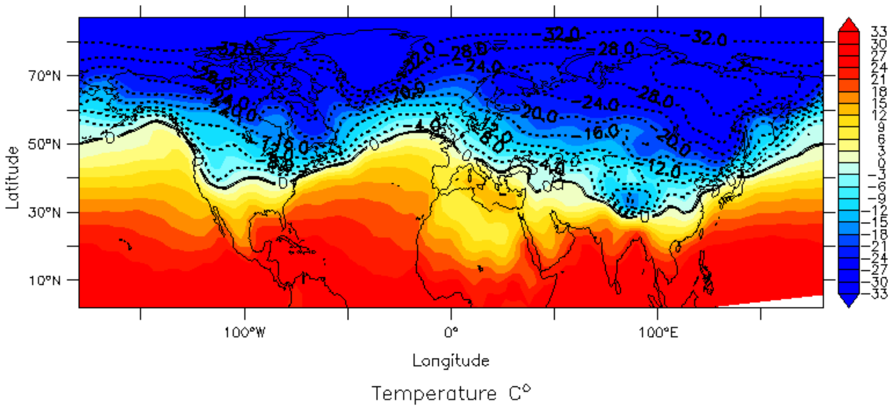


Experiment description

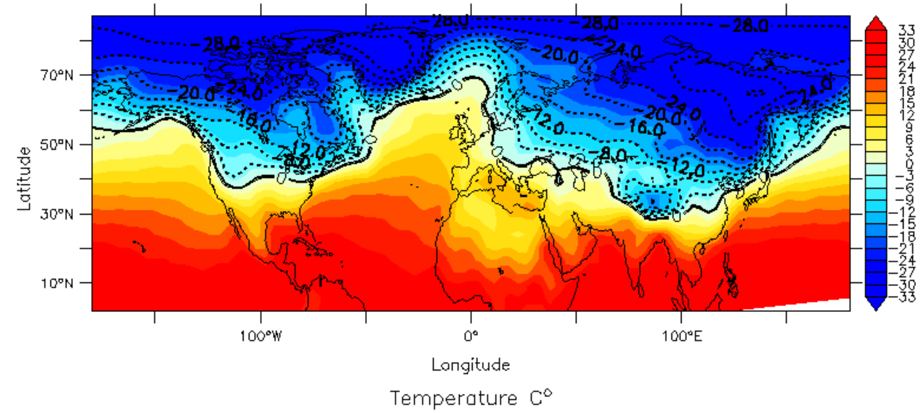
- AGCM (Atmospheric General Circulation Model) ECHAM5 (The Max Planck Institute for Meteorology (MPI-M), Germany)
- Spectral horizontal resolution T31(~ 3.75^{o}x3.75^{o} in latitude and longitude)
- Boundary conditions of the model :
  - sea surface temperature (SST)
  - sea ice concentration (SIC)
- climatological boundary conditions
- Experiment duration: 100 model years
- Basic data to determine the boundary conditions:
  - archive of monthly averages of SST and SIC over a period of 1870-2006. HadISST1.1

Results: temperature

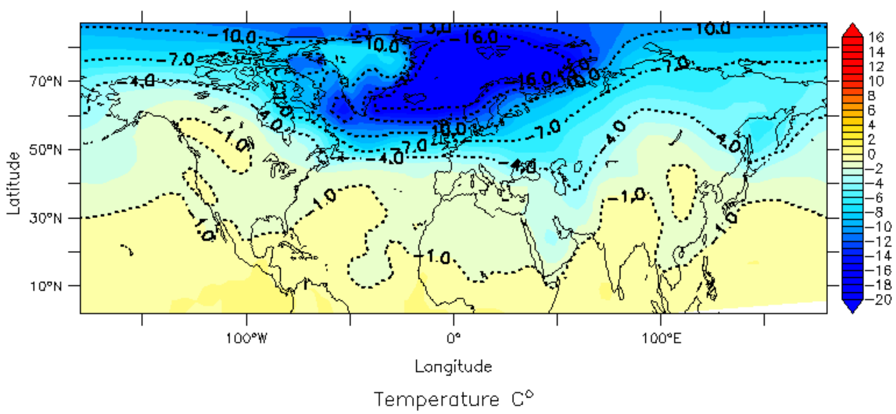
Atlantic



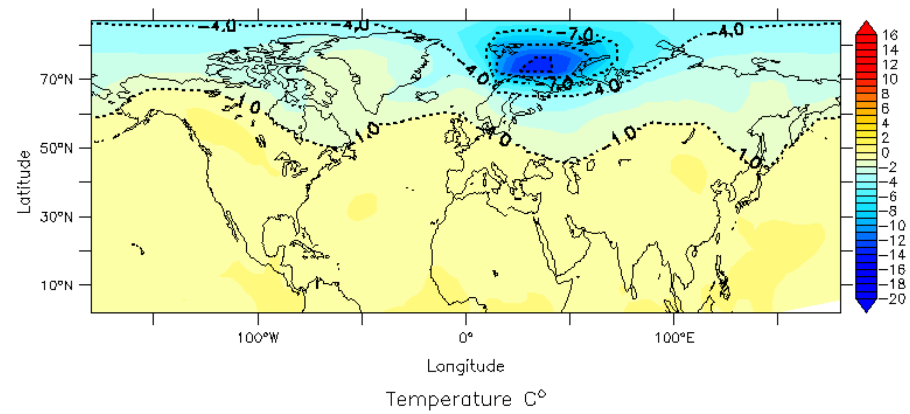
Control



Atlantic-Control

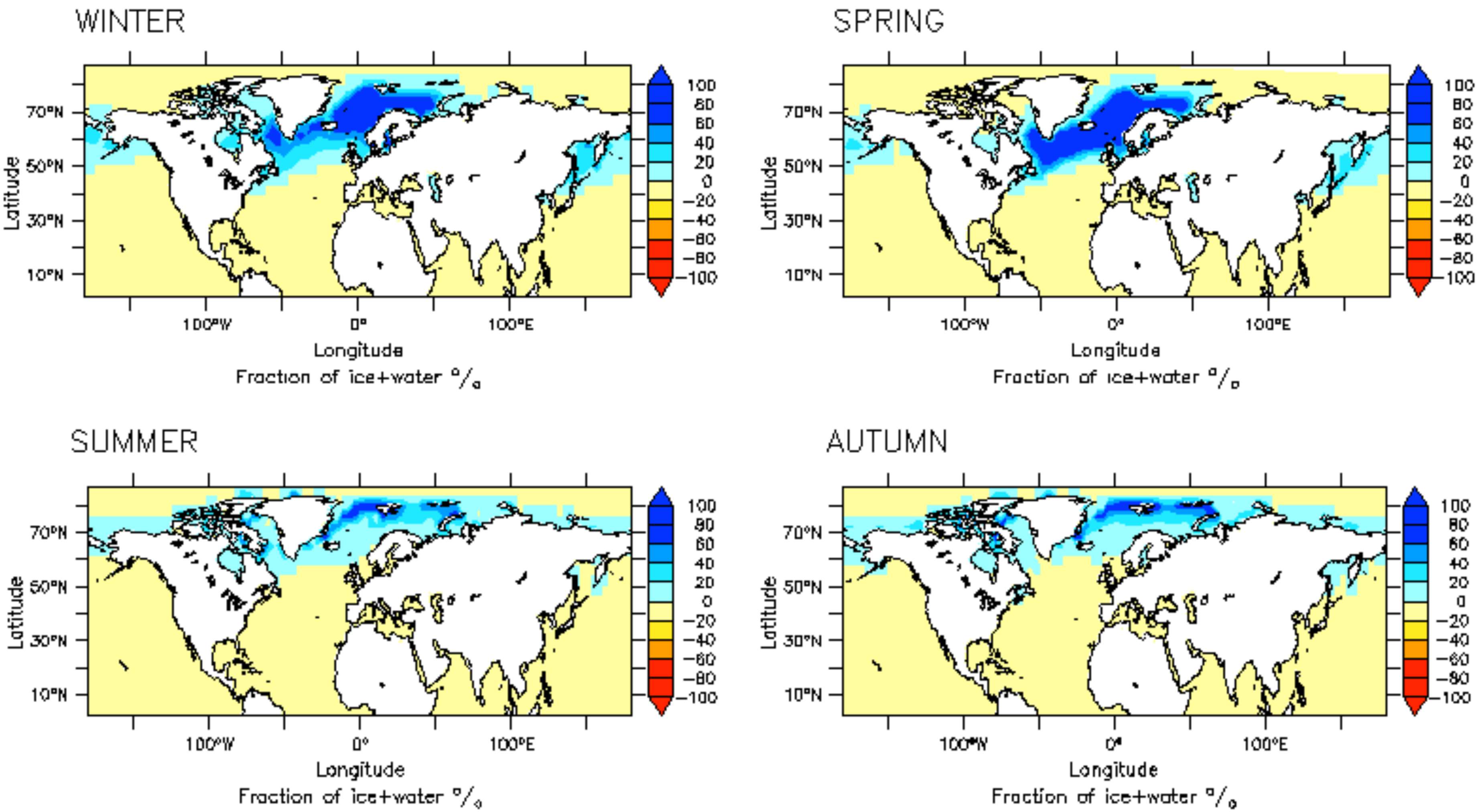


Barents sea-Control



Results: Ice Fraction (seasonal changes)

Atlantic-Control



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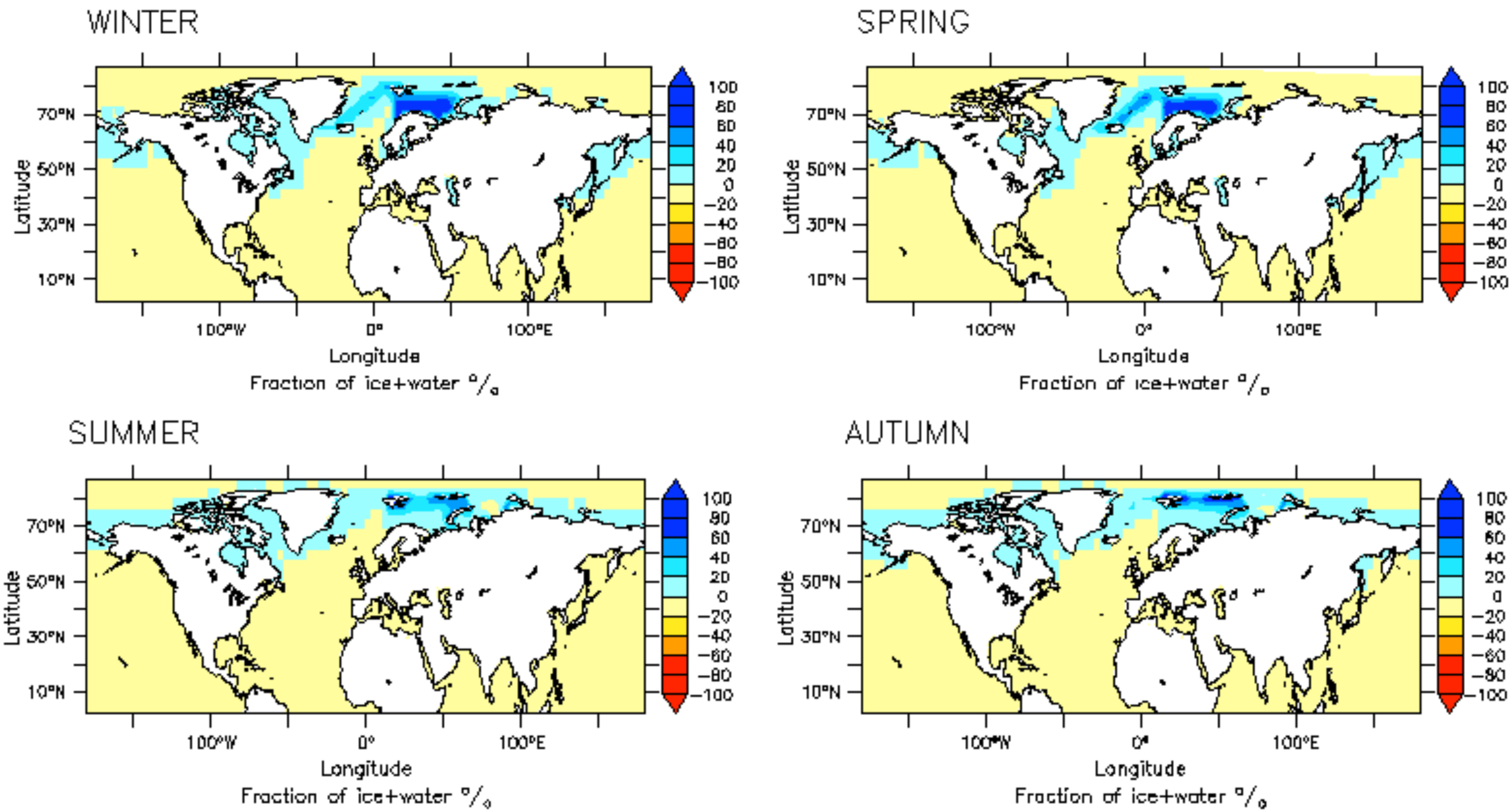
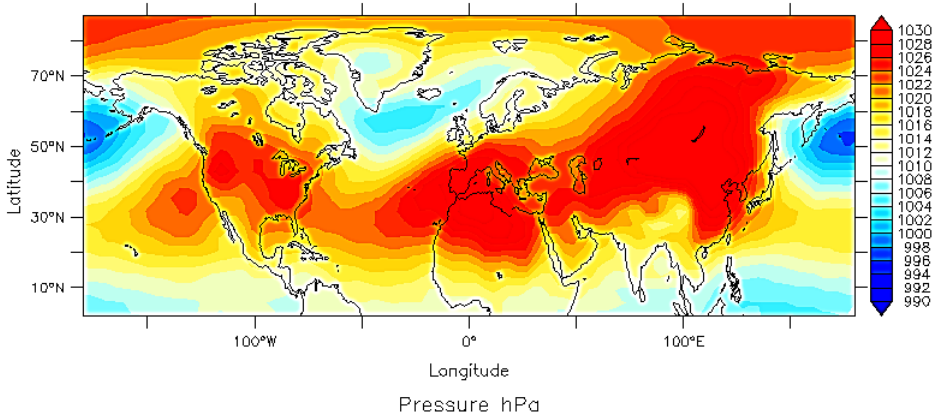
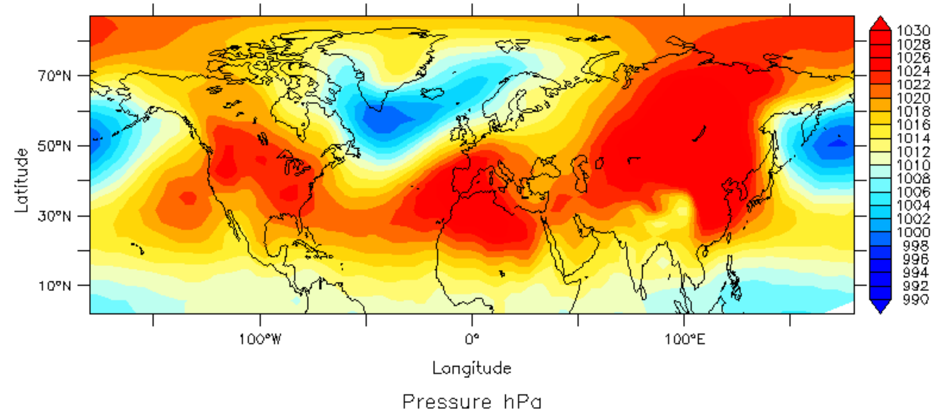


Results: pressure

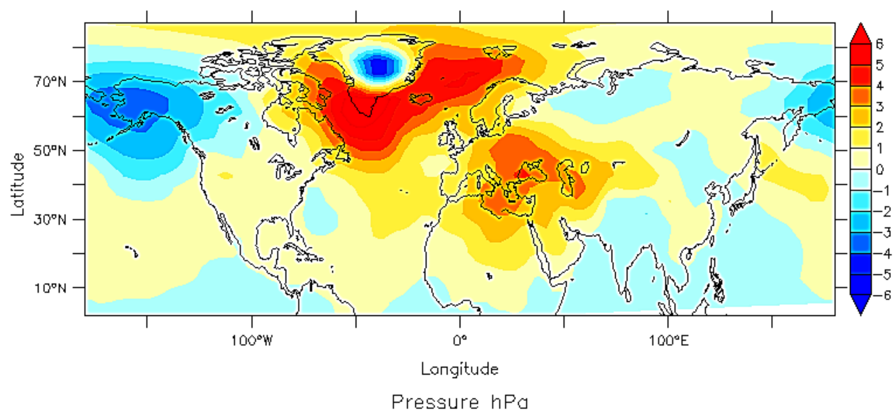
Atlantic



Control

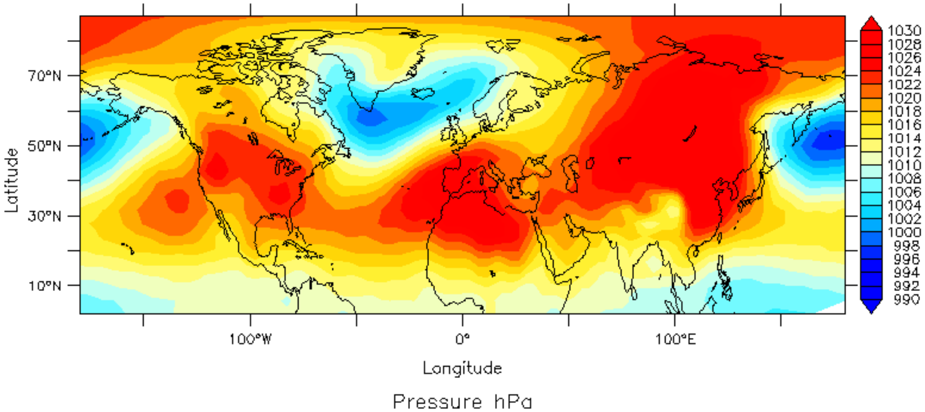


Atlantic-Control

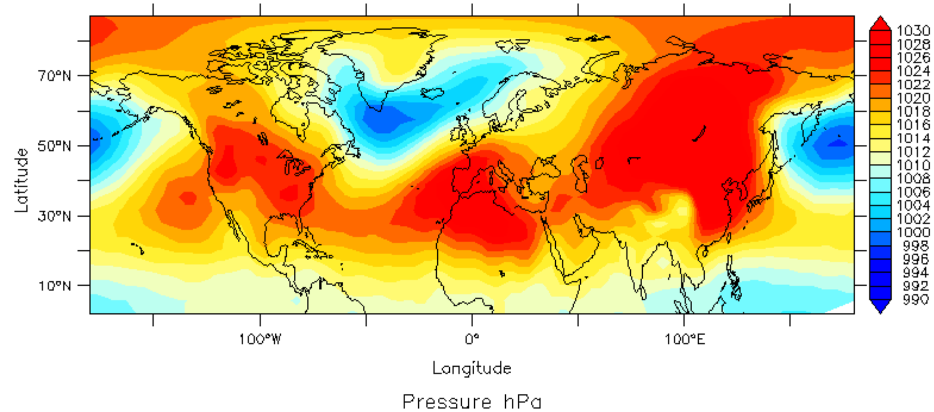


Results: pressure

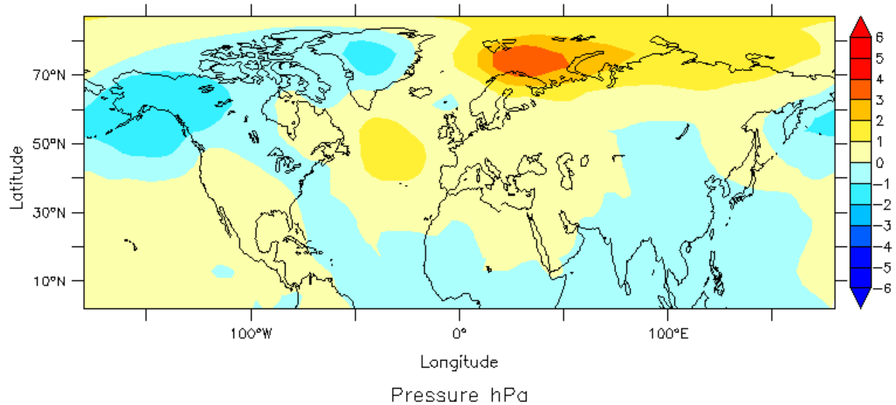
Barents sea



Control



Barents sea-Control



Modelling of climate changes in the Northern Hemisphere at subtropical stratosphere overheating

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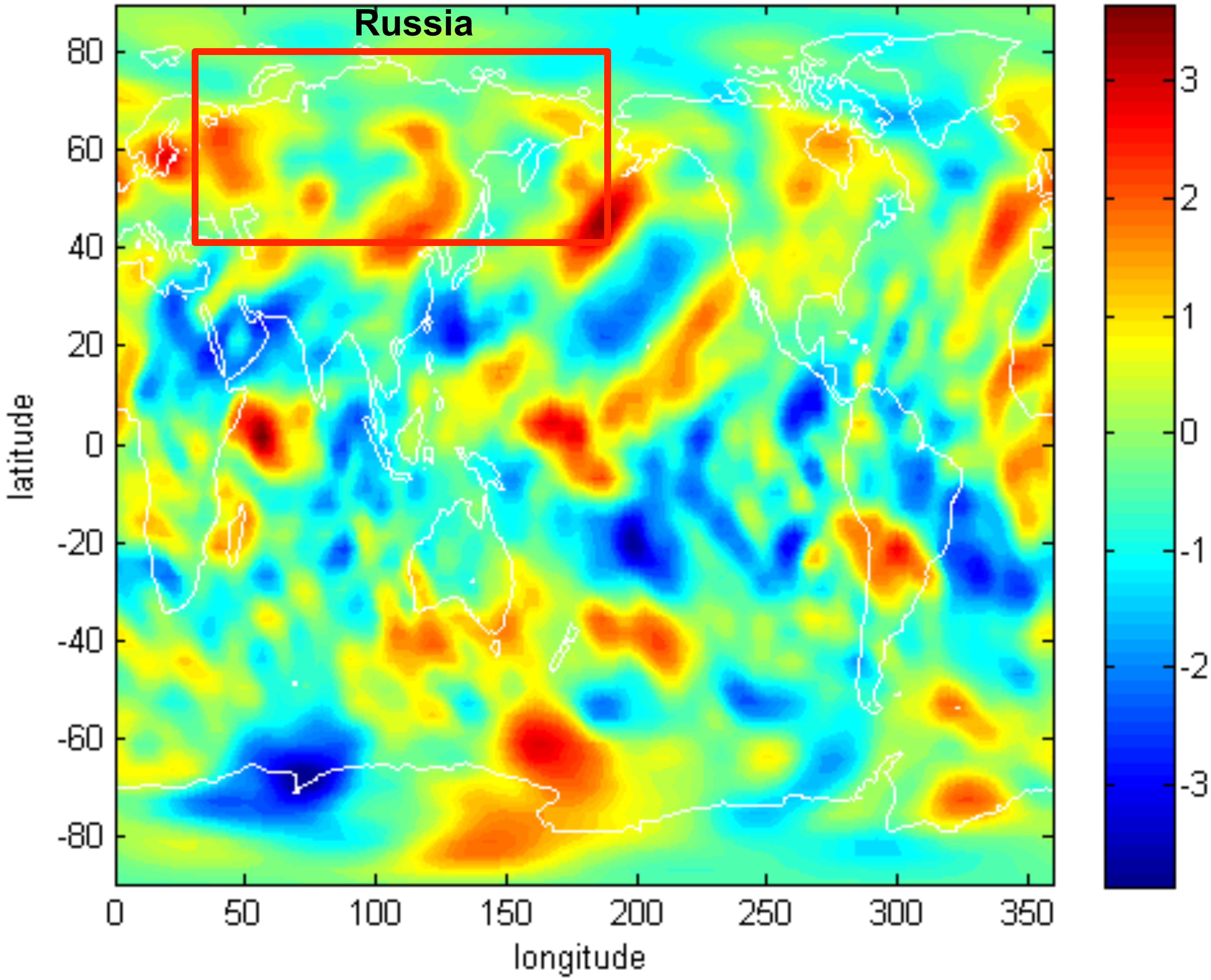
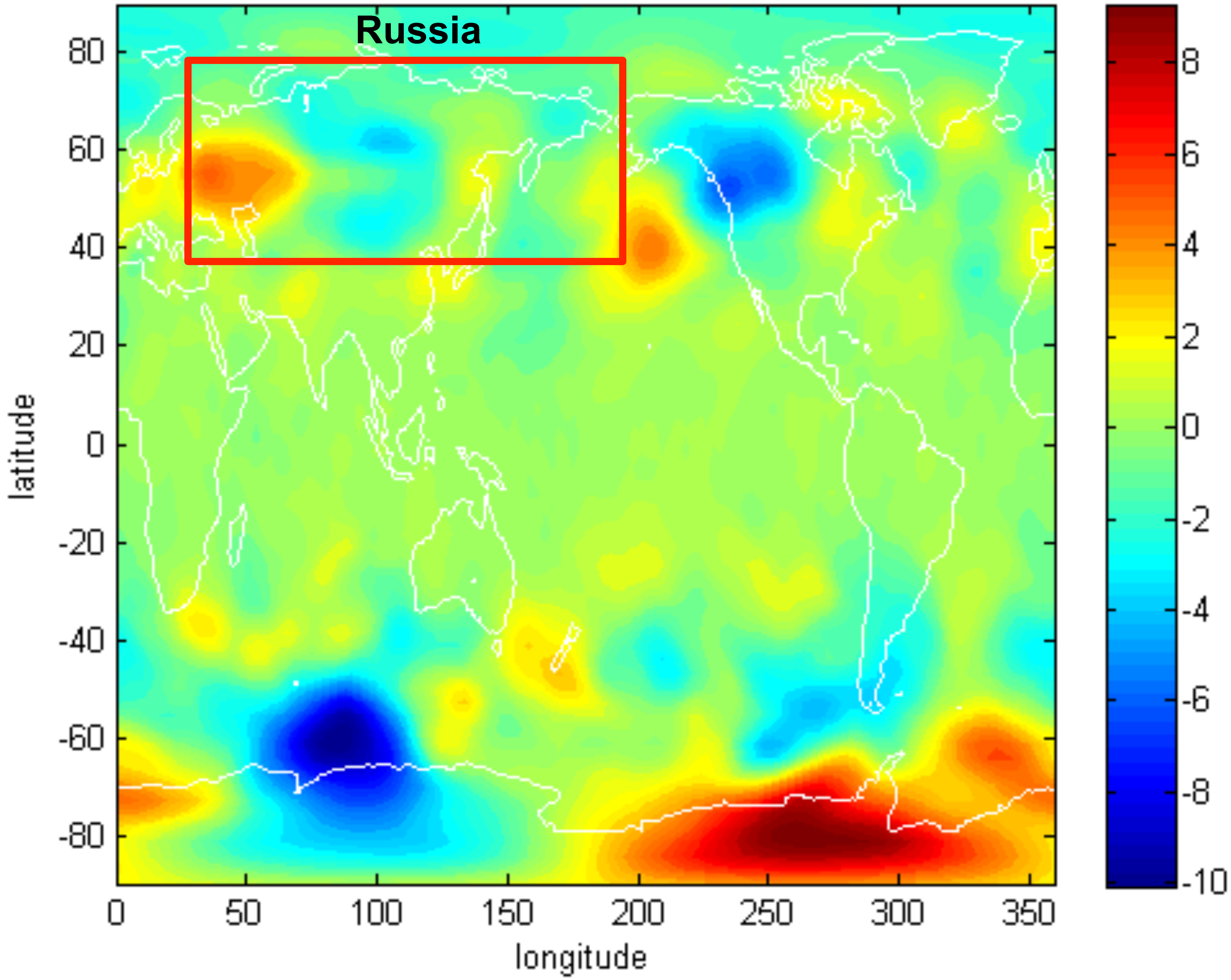
Experiments descriptions

- model of intermediate complexity (Reding, GB)
- horizontal resolution (~ 5^ox5^o in latitude and longitude)
- 31 altitudes levels
- boundary conditions of the model :
  - standard atmosphere
  - heat belt generation in the subtropical stratosphere (+2 °C, 30 mbar)
- duration of each experiment: 10 model years
- model acceleration: 8 years

Results: temperature (disturbance – control)



Results: pressure (disturbance – control)



Summary

1. Model of compound sulfuric acid aerosol with "dark" nucleus can simultaneously explain the overheating of the tropical stratosphere and long-term ozone depression
2. “Dark” nucleus is most probably presented by black carbon which formation is due to catalytic processes of Fischer-Tropsch and Bell-Boudoir in different parts of the eruptive column
3. The accelerated heating of the ocean surface helps its desalination which leads to slowing down of the thermohaline circulation with the climatic cooling in the Northern Hemisphere comparable with the estimates of anthropogenic warming
4. Prolonged volcanogenic heating of the tropical and subtropical stratosphere increases the locking in the Eastern Europe. It can be assumed that volcanogenic disturbances of the stratosphere play a significant role in the observed blockings over the European part of Russia in recent years.

Thank you for your attention