# Convective Removal of the Aerosol in the Southern Aral Sea Region

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**Abstract:** ***The Aral Sea crisis, along with global warming, planetary environmental pollution, deforestation and desertification, is one of the most significant environmental problems that threaten regional and global security. Large-scale changes in the ecosphere of Central Asia, occurring as a result of the anthropogenic reduction in the flow of the Amudarya and Syrdarya, have been attracting the attention of the world community for over 60 years.***

**Keywords:** soil, mathematical modeling, dynamics, factor

## 1. Annotation

In the article, the convective removal of soil microparticles from desert surfaces is considered for the first time as a potential factor for an increase in summer air temperatures in the Southern Aral Sea region. The paper presents the results of calculations of the mass concentration of aerosol in the surface layer of the atmosphere, caused by convective flows. Calculations have shown the importance of convective aerosol transport in the Southern Aral Sea region, which increases the aerosol concentration to 1.2 mg/m3. Conclusions are made about the features of the process under consideration in the conditions of the Southern Aral Sea region. The absence of precipitation in the Southern Aral Sea region in July-August, which counteracts the convective removal of soil aerosol by washing out the aerosol from the atmosphere and wetting the underlying surface, ensures a continuous supply of aerosol particles into the atmosphere, which increases the climate-forming effect of the process under consideration. Strengthening the wind (3m/s and higher) suppresses free convection. Thus, a significant convective aerosol carryover occurs only at a small range of wind speed (0-2 m/s).

## 2. Introduction

Environmental pollution in the modern world has become one of the most important but stubbon problems of humanity. The main aspect of this problem is aerosol pollution of the atmosphere, which affects both the ecological situation and climatic characteristics. In the Southern Aral Sea region this problem is strained by the fact that in this agricultural region the polluting aerosol carried out from the drained bottom of the Aral Sea consists of 60-70% of toxic sulfate and chloride salts, which significantly affect the health of the population, salinization of already saline soils, as well as the climate [1].

Massive and large-scale salt removal occurs during dust storms. In addition to the wind removal of aerosol during dust storms, there is another mechanism of removal of fine aerosol by convective air flows due to the heating of the earth's surface by the Sun, which is almost daily operating [2]. Convective outflow is the reason of the accumulation of salt aerosol in the entire thickness of the lower troposphere directly above the outflow centers. The dayly occurrence of the convective mechanism of particle raising allows us to consider it responsible for the formation of background aerosol pollution of the atmosphere of natural origin and background dry precipitation on the surface [3]. To determine the background dry deposition of aerosol, a radiation-balance model of its formation was created. Calculations based on it revealed us to obtain the values of the average long-term background dry precipitation caused by convective flows in the Aral Sea region, which, for example, in Takhiatash district of Karakalpakstan reach 79 t/km$^2$ per year [3].

Convective aerosol removal was studied by mathematical modeling methods in [4,5]. In [4] fluctuations in the aerosol concentration in the Aral Sea region under convective conditions were analyzed. It is shown that the statistical characteristics of the concentration fluctuation, including the coefficient of variation, asymmetry, kurtosis, empirical distribution functions and fluctuation spectra, differ significantly for the regimes of burst and quasi-continuous aerosol generation by the underlying surface.

In [5] on the basis of field measurements in the Caspian desert and estimates of hydrodynamic parameters in a viscous thermal boundary layer near the soil surface asymptotes for the mass concentration of fine aerosol were obtained.

Convective aerosol removal in the aspect of climate forcing is investigated by us for the first time. Scientific research on climate change is particularly relevant for regions, such as the Southern Aral Sea region, with a predominance of the agricultural sector in the economy, which largely depends on the temperature and humidity regimes of soils and the surface layer of the atmosphere.

Climate change in the Aral Sea region is mainly associated with a decrease of the water area of the Aral Sea, which significantly softened the continentality of temperature condition. Meanwhile, climate change largely depends on aerosol pollution of the atmosphere, which is recognized by the world scientific community as the most important factor in climate change, including global warming.

Aerosol forcing of the climate in the Aral Sea region is divided into two types: 1) the effect of sulfates carried out by wind from the drained bottom of the Aral Sea on atmospheric processes of the boundary layer and 2) the effect of soil particles carried out by convective flows from heated desert surfaces on the temperature of the adjacent air layers. The genesis of the first type of forcing is dust storms on the drained bottom of the Aral Sea. The genesis of the second type of aerosol forcing of the climate is desert surfaces that heat up to 70-80 $^0$C in summer, which causes significant convection of small soil particles resulting in increase the temperature of the near-surface soil layers by heat exchange.

The factor of desertification in numerous studies is considered only as an effect on the climate of a large-scale reduction in the area of vegetation cover, i.e. deforestization, through significant changes in albedo and heat and moisture exchange. For the first time, we consider desertification as a generator of aerosol forcing of climate change, the significance of which is determined by the fact that the evolution of landscapes in the Aral Sea region goes in the direction of the formation of desert complexes. Thus, the area of reeds decreased from 600 000 hectares to 30 000 hectares and tugai forests - from 1300 000 to 50 000 hectares.

The importance of convective aerosol removal in climate changes is increasing due to the increasing processes of desertification, which are characteristic not only in the Aral Sea region, but also on a global scale. In that way the results of the study of convective outflow can also be used to estimate global warming.

Convection is an important factor in heat and mass transfer in the atmosphere, and is able to raise large amounts of salt and dust in the upper atmosphere. In low wind and hot weather (surface temperature 50-60 $^0$C, relative humidity 20-30%, wind speed 2-3 m/s), the mechanism of air mixing in the near-surface layer practically does not differ from the mechanism of free convection of fine (less than 0.4 microns) desert aerosol.

In this work we present a part of the results concerning the determination of the mass concentration of fine aerosol carried out to atmosphere by convective flows in the conditions of the Southern Aral Sea region.

## 3. Methods and Conditions of Research

For calculations we used empirical relations obtained in [5] by simulation modeling for the dependence of the deviation $\Delta\rho$ from the background mass concentration in mg / m$^3$ of aerosol particles with a size of 0.15-5 microns on the temperature difference $\delta T$ on the soil surface and at a height of 0.2 m:

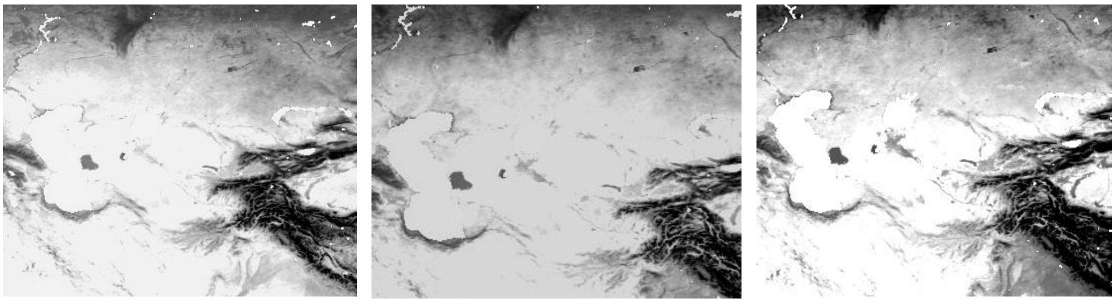
$$\Delta\rho = 0{,}12\ \delta T^{0{,}58}\ u_* < 20 \text{ sm/s correlation } r = 0{,}47; \quad (1)$$

The dynamic velocity $u_*$ is calculated by measuring of the average horizontal velocity u(z) at a height of z = 3 m using the formula

$$u_* = \frac{\chi u(z)}{\ln(\frac{z}{y_0})}, \quad (2)$$

where $y_0 = 10^{-4}$ m, $\chi = 0.4$ is the Karmann constant.

Standard weather data for the Southern Aral Sea region for July and August used in calculations, which are characterized by calm conditions and lack of precipitation, i.e. the most favorable conditions for the formation of free convection. To determine the temperature of the Earth's surface, data from remote sensing of the Earth for the Aral Sea region were also used [6] (Fig. 1):



a) b) c)

Figure 1

a) June 2019 (Earth surface temperature 69°C)
b) July 2019 (Earth surface temperature 70°C)
c) August 2019 (Earth surface temperature 67°C)

## 4. Results and Discussions

With a light breeze (1-2 m/s), the dynamic velocity values are small ($u_* \approx$ 1-2 cm/s) and the wind velocity amplitude $u_T$, calculated according to the formulas given in [5], in the 0-3 m layer takes the following value:

$$u_T \sim \left(\frac{\delta T}{T_0}\right)^{2/3} \cdot C_1$$

$$C_1(l, \nu, k_T) = \frac{gl}{(g\nu)^{1/3}} \cdot \Pr^{-1/3} \quad (3)$$

Here g=9.8 m/s$^2$, the viscosity coefficient is $\nu=0.13 \cdot 10^{-4}$ m$^2$/s, for air the dimensionless Prandtl number Pr=0.72, l is the horizontal scale of velocity field disturbances, $T_0$ is the earth's surface temperature.

From (3) we find the values of the size factor $C_1$=218.75 cm/s ≈ 2.19 m/s and δT. Substituting the values of δT in formula (1) we calculate the deviation of the mass concentration from the background values of the aerosol concentration (table 1).

**Table 1:** Deviation of mass concentration (mg/m$^3$) for desert regions of the Southern Aral Sea region

| Months | Air temperature, °C | Soil temperature, °C | $u_T$, m/s | $\Delta\rho$, mg/m$^3$ |
|---|---|---|---|---|
| June | 32 | 60 | 1,32 | 0,829 |
| July | 40 | 80 | 1,38 | 1,02 |
| August | 36 | 70 | 1,352 | 0,928 |

Calculations have shown the significance of convective aerosol removal in the Southern Aral Sea region. For comparison, the average aerosol concentration in dust storms is 2-3 mg/m$^3$. As can be seen from the table, the maximum concentration of aerosols carried out by convective flows in the summer months in the conditions of the Southern Aral Sea reaches in the hottest and windless July.

Comparison of the results of calculations with the data of calculations in [5] for the Caspian deserts in the Republic of Kalmykia (maximum = 0.7 mg/m$^3$) showed a significant variability of convective aerosol removal depending on the climatic conditions of different regions, which should certainly be taken into account when calculating the contribution of this process to global climate warming.

Numerical experiments with various combinations of air temperature and soil temperature revealed that in the range of their variations indicated in the Table 1, the dependence of the deviation of the mass concentration approaches linear.

## 5. Conclusions

1. Convective removal of aerosol from a heated desert surface is determined by micro-processes occurring in a thin (of the order of m$^{-7}$) near-surface viscous sublayer.
2. There is a critical value of the dynamic velocity ≈ 30 sm/s, at which the vertical gradient of the mass concentration changes sign (from " + " to " -").
3. Wind velocity gain (≈3 m/s) suppresses free convection. Thus, significant convective aerosol removal occurs only at a small wind velocity range (0-2 m/s).
4. The lack of rainfall in the southern Aral sea region in July-August, opposing convective removal of soil aerosol, aerosol washout from the atmosphere and wetting the underlying surface, provides a continuous flow of aerosol particles in the atmosphere, which increases the climate effect of this process.

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