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FORMATION of POLAR STRATOSPHERIC CLOUDS in the ATMOSPHERE

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A new mathematical model of the global transport of gaseous species and aerosols in the atmosphere and the formation of polar stratospheric clouds (PSCs) in both hemispheres was constructed. PSCs play a significant role in ozone chemistry since heterogeneous reactions proceed on their particle surfaces and in the bulk, affecting the gas composition of the atmosphere, specifically, the content of chlorine and nitrogen compounds, which are actively involved in the destruction of ozone.

Stratospheric clouds are generated by co-condensation of water vapor and nitric acid on sulfate particles and in some cases during the freezing of supercooled water as well as when nitric acid vapors are dissolved in sulfate aerosol particles [1]. These clouds differ in their chemical composition and microphysics [2]. In this study, we propose new kinetic equations describing the variability of species in the gas and condensed phases to simulate the formation of PSCs. Most models for the formation of PSCs use constant background values of sulfate aerosols in the lower stratosphere. This approach is too simplistic since sulfate aerosols in the stratosphere are characterized by considerably nonuniform spatial and temporal variations.

Two PSC types are considered: Type 1 refers to the formation of nitric acid trihydrate (NAT) and Type 2 refers to the formation of particles composed of different proportions of H2SO4/HNO_3/H_2O. Their formation is coupled with the spatial problem of sulfate aerosol generation in the upper troposphere and lower stratosphere incorporating the chemical and kinetic transformation processes (photochemistry, nucleation, condensation/evaporation, and coagulation) and using a non-equilibrium particle-size distribution [3]. In this formulation, the system of equations is closed and allows an adequate description of the PSC dynamics in the stratosphere.

Using the model developed, numerical experiments were performed to reproduce the spatial and temporal variability of polar clouds in both hemispheres for the winter time period. The numerical experiments were performed in the following sequence. In the first stage, we address the transport of multicomponent gaseous species, the formation of sulfate aerosols in the troposphere and lower stratosphere (spherical atmosphere), the chemical and kinetic transformations, and the biogenic and anthropogenic emissions of related chemical components [3]. This model makes it possible to reproduce the distribution of sulfate particles in the size range from 3 nm to 1 mcm. Next, the base model was improved by using a new module describing the dynamics of phase transition of substances in gaseous and condensed phases that are typical for different types of PSCs. Here, we used the methods of thermodynamics.

Conclusions

•The model developed allow us to reproduce the size distribution of sulfate particles generated from precursor gases in the troposphere and stratosphere;

•The numerical experiments show that the model adequately reproduces the spatial characteristics of the PSC formation in the atmosphere.

References

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