ATMOSPHERIC DYNAMICS SIMULATION FOR FINELY DISPERSED METEORIC DUST

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Introduction: It is known that the influx of extraterrestrial matter comes in two main categories, namely meteoroids and cosmic dust, e.g. [1]. While the former smoothly slips into the latter one, it is plausible to consider the cosmic dust to be composed from individually unobservable particles. The estimates show that 20 % of total mass influx originate from particles with initial masses in the range from 10^{-6} g up to 10^{-5} g [2]. However, the particle influx is not limited to cosmic dust, as the fine-grained product of meteoroid fragmentation also contributes to particle influx. The dispersed fraction like this has the distinctive feature of prolonged deposition in the planetary atmosphere due to near equilibrium of gravity and lift forces. The similar feature is also shared by the volcanic ash particles but on a larger spatial scale. The necessity to estimate propagation of dispersed admixture comes from the fact that the high volume concentrations of millimeter particles present a hazard to a safety of airborne vessels, especially for turbine engines. There are several known well documented incidents with aircraft, the most notable of which are the cases of British Airways Flight 9 on 24 June 1982 [3] and KLM Flight 867 on 15 December 1989 [4]. Moreover, the plumes of much lesser micrometer-sized hard particles also can be dangerous to high altitude supersonic and hypersonic vessels due to thermo erosion of the frontal heat shield (e.g. [5,6]).

Mathematical Model and Sumulation Algorithm: The dispersed admixture dynamics in the atmosphere can be simulated numerically as a discrete particle ensemble propagating through the gaseous phase. Since we investigate the long-term phenomenon, the particles of interest are considered to have low velocity relative to surrounding carrier media. Therefore, we suppose the carrier gas is not affected by the discrete phase, resulting in its computational model to be decoupled from the particle simulation. In addition, due to the large spatial scale of an ensemble, we concerned with a study of specific volumetric concentrations of the averaged particle groups.

There are two approaches to simulate admixture evolution in carrier phase by using Eulerian and Lagrangian variables respectively. The first group of methods discretizes the field of concentration on computational grid and applies differential transport equations approximated with finite difference schemes. However, this technique suffers from high artificial diffusion leading to significant admixture mass loss and boundary smearing in the simulation process. The second group of methods represents the field of concentration with set of generalized markers, each aggregating some of the initial particles. Therefore, we have implemented a Largrangian model for the cloud of meteoric dust. The dynamics of spherical particle-representatives is approximated via a system of differential equations of motion. This system of equations in Lagrange's variables is integrated using the Runge-Kutta methods. The particle trajectories are modelled with respect to the World Geodetic System (WGS84) as a reference coordinate system.. To account for possible shoch-scale perturbations of the surrounding atmosphere, the drag force of the atmospheric air is computed using Henderson formula valid for wide ranges of Reynolds and Mach numbers. The parameters of surrounding gas are obtained from the COSPAR International Reference Atmosphere (CIRA-86), which includes monthly zonal wind chart. To increase perfomance of the method we have implemented parallel processing in the form of multithreaded multicore computations. Since the classic Lagrangian methods with fixed amount of markers are unable to track concentration quantities lesser than that of a single marker, we also used the recently proposed dipole method, where each computational particle can split into lesser particles when its poles diverge in the flow field sufficiently far from each other.

Field of Applicability: The developed model for simulation of meteoric dust dispersion in the atmosphere can be used to predict evolution of areas hazardous to air traffic. Moreover, this technique can facilitate radar and optical remote probing of meteoric particle clouds for spectral analysis as well as improve sample acquisition via high altitude weather balloons.

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