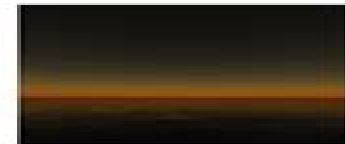
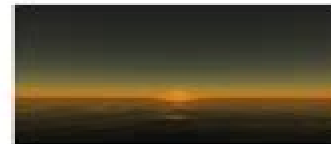
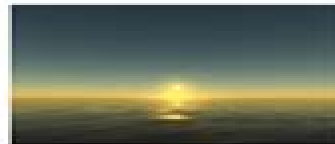
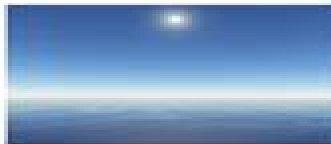


# Rendering Parametrizable Planetary Atmospheres with Multiple Scattering in Real-Time

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## Abstract

In the field of physically-based rendering of natural phenomena, rendering of atmospheric light scattering takes a very important place. Real-time rendering of the sky and planetary atmospheres in general is essential for all outdoor computer games, various simulators, virtual worlds and even for animated movies. In our work we present an accurate and fast method for real-time rendering of parametrizable planetary atmospheres. This is achieved by precomputing the complex volumetric scattering equations into a set of compact lookup tables. The correct atmospheric colour values are then fetched from these in a fragment shader during rendering. The method is capable of rendering planetary atmospheres on today's graphics hardware at the speed of hundreds of frames per second.

**Keywords:** atmospheric light scattering, natural phenomena, GPU programming, participating media, procedural textures

## 1 Introduction

Physically-based rendering of natural phenomena is perhaps one of the most popular areas in the field of computer graphics. Rendering of planetary atmospheres is very important amongst these, because the light and colour of the Earth's atmosphere is well-known to every human, as it accompanies us during all our lives. Thus any rendering system that strives for realistic display of any general outdoor scene needs to incorporate a believable method for rendering a planetary atmosphere. This includes many applications, for example 3D computer games, flight and driving simulators, virtual worlds and so on. Applica-

tions like GoogleEarth, NASA WorldWind or for instance SecondLife use very simplistic and physically unrealistic models for rendering of the Earth's atmosphere. 3D computer games are more advanced in this direction, but they still use either static cubemaps or physically-based but still substantially simplified algorithms.

In this paper we present a method for physically-based real-time rendering of general planetary atmospheres. This is achieved by breaking the procedure down into two steps: precomputation and rendering. During the precomputation step, a set of lookup tables is created by evaluating the light scattering equations in participating medium accounting for both single and multiple scattering. Apart from some acceptable simplifications of the problem, the accent here is on numerical and physical accuracy. The rendering step then utilises this precomputed dataset by fetching the correct atmospheric colour values during the fragment-shading phase. The atmosphere is described by several parameters, where some of them can be changed dynamically during the rendering. By changing these, one can achieve a completely different look of the generated atmosphere, which enables simulation of atmospheres of other planets, not only of Earth.

The next sections are organised as follows. Section 2 gives an overview of existing work on this topic. Section 3 gives a physical introduction into light scattering and then presents the mathematical model for the calculation of atmospheric light scattering. Section 4 contains the description of the precomputation of atmospheric light scattering and then describes the rendering method. Finally Section 5 gives implementation details and concludes our work.

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