Haze Transport in Titan's Stratosphere

E.L. Barth and T.I. Michaels

Southwest Research Institute, Boulder, CO, USA, (ebarth@boulder.swri.edu / Fax: +01-303-5469687)

Abstract

We continue development of a new Titan General Circulation Model (GCM) using the Flexible Modeling System (FMS) dynamical core from the Geophysical Fluid Dynamics Laboratory (GFDL). The FMS core is state-of-the-art and conserves angular momentum better than other existing dynamical cores which is especially important for modeling Titan's thick atmosphere. Furthermore, an aerosol microphysics package has been developed and linked to the core model. This microphysics is based on the modified version of the Community and Radiation Model for Atmospheres (CARMA) used to study haze and cloud physical processes in Titan's atmosphere [1], [2]. The model also uses a radiative transfer package that is based on the correlated-k two-stream model of [3].

1. Introduction

A general circulation model (GCM; a global scale model that simulates the large scale behavior of an atmosphere) is the most complete tool available to comprehensively model planetary atmospheres. Adapting terrestrial GCMs to study Titan's extensive atmosphere has met with a number of complications from factors such as the long radiative time constant in Titan's lower atmosphere and the extensive haze layer which is the primary visible feature of Titan's atmosphere. Despite this, a number of platforms exist, such as [4],[5],[6]. We present a further attempt at understanding Titan's atmospheric circultion using the Flexible Modeling System (FMS) dynamical core which we have coupled to the physics packages described below.

2. Radiative Transfer and Microphysics

The core of the radiative transfer code uses a generalized two-stream approximation for radiative transfer in an inhomogeneous multiple scattering atmosphere [7]. The two stream approximation is reasonably accurate for most uses; for solar wavelengths it reduces to an exact result in the limit of no scattering and no reflecting surface; for ir wavelengths the results are not exact in the limit of no scattering except for a semi-infinite atmosphere. The two-stream source function technique is exact in the limit of pure absorption but retains the accuracy of the two stream approach when scattering occurs. Fluxes are recalculated for infrared wavelengths for a more accurate solution to the two-stream equation. Gas opacities are calculated using a correlated-k approach. A number of databases are included for various atmospheric gases (methane, ethane, acetylene) over a range of temperatures and pressures, as well as pressure induced absorption contributions from N_2-N_2, H_2-N_2, CH_4-CH_4, and CH_4-N_2. A Mie code calculates the scattering and extinction efficiency values for atmospheric particles.

The microphysics package was adapted from the Community Aerosol and Radiation Model for Atmospheres (CARMA), described by [2]). The model solves the continuity equation for a particle n of volume v, with the form

$$\frac{\partial n}{\partial t} = -\frac{\partial}{\partial z}(nv_{fall}) - n_{gas}K_{diff}\frac{\partial[n(v)/n_{gas}]}{\partial z}$$
$$+\frac{1}{2}\int_0^v K_{coag}(v', v-v')n(v')n(v-v')dv'$$
$$-\int_0^\infty K_{coag}(v', v)n(v)n(v')dv'$$
$$+P(v) - L(v) \quad (1)$$

Particles are transported vertically through sedimentation (regulated by fall velocity, $vfall$) and eddy diffusion (with coefficient, K_{diff}); though due to their sizes, haze particle movement is most influenced by atmospheric circulation rather than sedimentation. All particles are also subject to coagulation (with coagulation kernel K_{coag}). Collisions between involatile particle groups are generally handled by the equations for Brownian coagulation. Titan's haze particles also carry charge which reduces the sticking coefficient to

less than unity. The production term, $P(v)$ in Eqn. 1 describes the creation of involatile particles, such as by photochemistry. Aerosol particles are lost, $L(v)$, through nucleation to produce cloud particles. The particles are represented by a number of radius bins, defined by a user specified minimum value and a mass ratio between bins.

3. Summary

Now that we have coupled these core physics packages to the FMS core we are in a position to demonstrate the applicability of the FMS core to Titan studies by showing simulations of the haze transport on seasonal timescales.

Acknowledgements

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