EPSC Abstracts
Vol. 7 EPSC2012-619 2012
European Planetary Science Congress 2012

Modelling cloud microphysics on Titan using a two-moment hybrid bulk-bin scheme for use in climate models

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Abstract

Microphysical models describe the way aerosols and clouds behave in the atmosphere. Two approaches can be used to model these processes : Aerosol and nuclei distributions can be described in term of number of particle given per radius bins, or with several moments of distribution. However, with the latter approach, one needs to have a *a priori* knowledge of the size distributions. In this work, we describe how to transform the equations of the cloud microphysics to work with a description in moments, in the specific case of Titan atmosphere. Because the aerosols have a fractal structure, the size distributions do not follow a log-normal law as in the cases of spherical or compact aerosols which are generally treated in planetary sciences (e.g., Earth, Mars, Venus). This implies some modifications of the laws which are published in the literature. We also performed simulations with the model using the description in moments that we compare with a bin model. The results show that the differences between the two models are small (few %), and therefore that this approach is valid.

1. Introduction

On Titan, the haze layer is a dominant component of the atmosphere and clouds where long suspected before their first detection [7] and first imaging [9]. As a part of the effort to understand Titan climate, the study of the haze and the putative cloud layer leaded to develop microphysical models (e.g, [1, 3, 4, 5, 6]). The recent advance in the knowledge of Titan leaded many teams to produce models simulating the haze and cloud microphysics in details, with multiple condensing species, to explain specific observations [11, 12, 14, 15]. Beyond one dimensional models, cloud and haze microphysical models were also included in climate models [10, 13] to investigate the geographical variation of the cloud cover and the link with the atmosphere dynamics. The most complete microphysical models used for Titan deal with a description of the aerosols size distribution using a system of radius bins. The distribution is given by the concentration of aerosol per bins (sectional representation), and the law describing the physical processes (coagulation, coalescance; condensation, etc...) manage the particles growth in term of transfer of population from one bin to the others [3, 6]. The advantage of this description is that no *a priori* distribution is needed, and the size distribution can evolve following the law of physics. The major drawback is its computational time cost. In this work we present an alternative way to compute microphysical processes using the moments of the size distribution.

2. Moments representation

Instead of using the "classical" sectional representation of the size distribution, one can use the moment of this function as described in equation 1 and a prescribed law (eq. 2) to account for the size distribution of microphysical tracers in a model [2, 8].

$$M_n = \int_0^\infty n(r) \times r^n \, \mathrm{d}r \tag{1}$$

Most of these kind of models use log-normal law to account for the prescribed distribution law. Unfortunately, on Titan, due to the fractal shape of aerosols, log-normal law type can not be used (see fig. 1). We first define a law which is representative of the modeled size distribution (see eq. 2). This law can not be analytically integrated and this fact is the first limitation of our method.

$$n(r) = \frac{a_0}{\sum_{i=1}^{\nu} a_i \times \left(\frac{r}{r_0}\right)^{N_i}} \tag{2}$$

On Titan, aerosol microphysical processes must take into account several aspects such as the coexistence of spherical and fractal aerosols or the effects of electric charge. These aspects increase the complexity of their modelling. On the contrary, under few as-

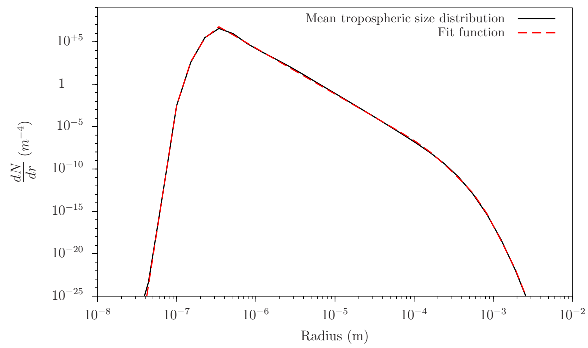

Figure 1: Modeled size distribution in the troposphere in the ISPL-2D Titan GCM (black) and prescribed law from eq. 2 (red).

sumptions, clouds microphysical processes are much easier to represent in terms of moments.

3. First insights

We developed a 1D model of clouds microphysics with a two-moment scheme (model H1) and compared the results with a reference model using the sectional approach (model R). As an example, we compared the evolution of the cloud opacity for the two model which are in good agreement (see fig. 2). In the frame of a 1D model, discrepancies on opacities (both clouds or haze) are at most 10% leading to smaller errors on the temperature field of about 1%.

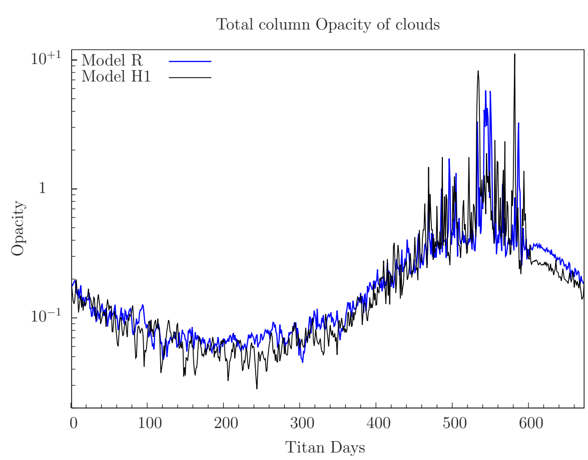

Figure 2: Evolution of cloud opacity for one Titan year using the two moment-scheme (blue curve, model H1) and the sectional representation (black curve, model R).

The first results validate the approach of the two-moment scheme for clouds microphysics. The next step of this work will be the development of a complete two-moment scheme microphysics model including both haze and clouds. Finally, this model will be included the IPSL Titan 3D-GCM to enable the use of a fast and accurate microphysical model in the GCM.

Acknowledgements

The authors thank the ANR project Exoclimats. This work has been supported by the regional Champagne Ardennes phD grant.

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