

Simulation of the 3D Radiative Transfer with Anisotropic Scattering for Convective Trails

Olivier Pirouneau and Pierre-Henri Tournier

1 Introduction

Airplane combustion engines generate CO_2 (carbon dioxide), a gas which stays in the Earth atmosphere for ~ 500 years before being partially absorbed by the oceans.

Currently used fuels and potential future substitutes like hydrogen, synthetic or agricultural fuel combustion generate also NO_x (Nitrous oxides). Typically a nitrous oxide stays in the atmosphere ~ 100 years.

Carbon dioxide, nitrous oxides, methane, ozone and water vapor are "green house gases", (GHG), in the sense that atmospheric and past climates measurements indicate that they are most likely responsible for the additional heat received by Earth (global warming).

Air travel – around 100.000 flights/day – produces 3% of CO_2 (or 12% of what is produced by all transport vehicles). It is still small, but the contribution of airplanes to global warming is expected to rise from today's $0.024\text{W}/\text{m}^2$ to $0.084\text{W}/\text{m}^2$ by 2050 [13].

A cloud similar to a cirrus, called "contrail (short for condensation trail) may appear in the airplane wake if atmospheric pressure and temperature are on the left side of a threshold curve, and further left of that pressure versus temperature curve the contrail will persist [14]. Several studies claim that these clouds have a warming effect perhaps 3 times stronger than the one caused by the combustion gases [12].

Olivier Pirouneau

Applied Mathematics, Jacques-Louis Lions Lab, Sorbonne Université, 75252 Paris cedex 5, France, e-mail: olivier.pirouneau@sorbonne-universite.fr

Pierre-Henri Tournier

Applied Mathematics, Jacques-Louis Lions Lab, Sorbonne Université, 75252 Paris cedex 5, France, e-mail: Pierre-Henri.Tournier@sorbonne-universite.fr

3 D Radiative Transfer In The Atmosphere

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3D Radiative Transfer in Cloudy Atmospheres Alexander Marshak, Anthony Davis, 2006-05-27 Developments in three dimensional cloud radiation over the past few decades are assessed and distilled into this contributed volume Chapters are authored by subject matter experts who address a broad audience of graduate students researchers and anyone interested in cloud radiation processes in the solar and infrared spectral regions After two introductory chapters and a section on the fundamental physics and computational techniques the volume extensively treats two main application areas the impact of clouds on the Earth s radiation budget which is an essential aspect of climate modeling and remote observation of clouds especially with the advanced sensors on current and future satellite missions *Fast Processes in Large-Scale Atmospheric Models* Yangang Liu, Pavlos Kollias, 2023-12-19 Improving weather and climate prediction with better representation of fast processes in atmospheric models Many atmospheric processes that influence Earth s weather and climate occur at spatiotemporal scales that are too small to be resolved in large scale models They must be parameterized which means approximately representing them by variables that can be resolved by model grids *Fast Processes in Large Scale Atmospheric Models Progress Challenges and Opportunities* explores ways to better investigate and represent multiple parameterized processes in models and thus improve their ability to make accurate climate and weather predictions Volume highlights include Historical development of the parameterization of fast processes in numerical models Different types of major sub grid processes and their parameterizations Efforts to unify the treatment of individual processes and their interactions Top down versus bottom up approaches across multiple scales Measurement techniques observational studies and frameworks for model evaluation Emerging challenges new opportunities and future research directions The American Geophysical Union promotes discovery in Earth and space science for the benefit of humanity Its publications disseminate scientific knowledge and provide resources for researchers students and professionals **Microwave Radiometry and Remote Sensing of The Environment** Domenico Solimini, 1995-09 This volume contains a collection of refereed papers which were presented at the Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment 14 17 February 1994 Rome Italy The last decade has marked a period of steady advancement and new developments in the observation of the terrestrial environment by passive microwave sensors Both ground based and satellite borne systems have improved their accuracy stability and spatial resolution and are providing a wealth of quantitative data which are increasingly being employed in application oriented projects The contributions in this volume cover different fields of applications of microwave radiometry the various observation and retrieval techniques and the recent technological developments The articles are divided into four sections measurement of atmospheric water vapor and cloud liquid measurement of rain observation of the surface and new radiometric systems **Workshop on Cloud Microphysics Parameterizations in Global Atmospheric Circulation Models** ,1995 *Journal of Atmospheric and Oceanic*

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Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting ,1997 **Chinese Journal of Atmospheric Sciences** ,1996 *Atmospheric Radiation* Knut Stamnes,1993 *Current Problems in Atmospheric Radiation (IRS 2008)* Teruyuki Nakajima, Marcia Akemi Yamasoe,2009-04-03 All papers have been peer reviewed The International Radiation Symposium IRS is organized every four years by the International Radiation Commission IRC and this book presents a compilation on the current problems in atmospheric radiation from theory and modeling to measurements and applications on weather and climate from spectroscopy to satellite remote sensing of the many land ocean atmosphere components **Stellar Atmosphere Modeling** Ivan Hubeny, Dimitri Mihalas, Klaus Werner,2003 *Journal of Climate* ,2001 **Digest** ,1989 **Remote Sensing and Modeling of the Atmosphere, Oceans, and Interactions** Tiruvalam Natarajan Krishnamurti, B. N. Goswami, Toshiki Iwasaki,2006 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature **IEEE International Geoscience and Remote Sensing Symposium Proceedings** ,2003 **On Style in Research and Development** Amrom H. Katz,1960 **IGARSS '88** ,1988 Modeling, Simulation, and Visualization of Sensory Response for Defense Applications Nickolas Lea Faust, John D. Illgen,1997 **Annales Geophysicae** ,2006 **IGARSS 2003** ,2003

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