EPSC Abstracts
Vol. 5, EPSC2010-439, 2010
European Planetary Science Congress 2010

The life supporting zone II: Computation of its extension

D. Neubauer (1,2), A. Vrtala (2), J. J. Leitner (1,3), M. G. Firneis (1,3) and R. Hitzenberger (1,2)
(1) Research Platform: ExoLife, University of Vienna, Türkenschanzstrasse 17, 1180, Vienna, Austria, (2) Aerosol Physics and Environmental Physics Group, Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090, Vienna, Austria, (d.neubauer@univie.ac.at), (3) Institute of Astronomy, University of Vienna, Türkenschanzstraße 17, 1080, Vienna, Austria

Abstract

A radiative convective model to calculate the widths of life supporting zones (LSZs) for different, alternative solvents (i.e. other than water) is presented. Cloud droplet formation and growth are investigated in the atmosphere of exoplanets as well as hypothetical Earth-like exoplanets using a cloud parcel model. Clouds are incorporated into the radiative transfer calculations.

1. Introduction

Energy balance calculations show that the widths and the locations of LSZs for alternative solvents [7] are quite different from those for the classical habitable zone [6] because of the different temperature ranges for liquid alternative solvents. To calculate the LSZs a radiative convective model was further developed. As clouds dominate the radiative transfer through a planet's atmosphere when they are present, clouds are incorporated in the radiative convective model.

1.1 Cloud droplet formation and growth

A cloud model developed for terrestrial water clouds by D. Neubauer at the University of Vienna [11] is used to investigate cloud droplet formation and growth. Physico-chemical constants for the alternative solvents available in the literature are used for the computations. As nothing is known about possible cloud condensation nuclei (CCN) in the atmosphere of exoplanets, we assume that aerosol formation processes follow the same physical principles of nucleation from the gas phase and assume the presence of wettable CCN.

1.2 Surface temperature

Besides the spectral class of the star and the distance between the star and the exoplanets, the surface temperature strongly depends on the amount of atmospheric gases (in particular greenhouse gases), aerosol particles, clouds and surface albedo. The surface temperatures of exoplanets are computed using a radiative convective model. Different scenarios (e.g. varying cloud amount, surface albedo, amount of atmospheric gases, etc.) are investigated for each solvent to calculate the width and the location of the LSZ belonging to the solvent.

2. Model description

Two models are used: a cloud model and a radiative convective model. The cloud model is used to calculate cloud droplet distributions. The optical properties of these droplet distributions are computed by a Mie routine [1] and used as an input for the radiative convective model. These optical properties depend on the refractive indices of the solvents, which will be taken from literature where available. The radiative convective model then yields the surface temperature of exoplanets.

2.1 Cloud model

The cloud model is a cloud parcel model which describes an ascending air parcel containing the droplets (following [3], [5], [12]). The model includes the microphysical processes of nucleation, condensation and coagulation and radiative effects [2]. Turbulent diffusion is also considered [10]. The cloud model provides cloud droplet size distributions for different cloud liquid solvent content (e.g. cloud liquid water content) which are stored in a database.

2.2 Radiative convective model

The equilibrium temperature profile of the atmosphere of exoplanets is obtained with a model based on [8], [9] which was further developed for our purposes. The atmospheric lapse rate calculated for radiative equilibrium is adjusted not to exceed a given lapse rate (e.g. the applicable dry adiabatic lapse rate). This lapse rate adjustment is called convective adjustment. The model computes the horizontally and annually averaged global surface and atmospheric temperatures.

For radiative transfer calculations, the radiative transfer code of the public domain program 'Streamer' [4] was adapted to our purposes. 'Streamer' accounts for scattering and absorption of radiation in the whole spectral region by gases and particles. Built-in types of surface albedo as well as other values can be chosen. The radiative transfer equation can be solved by two different numerical methods to increase the precision of the calculation [13], [14]. The cloud optical properties calculated by the cloud model and a Mie routine [1] are used as an input for 'Streamer'.

A test run for Earth with typical gas amounts, a surface albedo of 0.10 and an average cloud cover resulting in a planetary albedo of 0.30 showed a good agreement of the atmospheric temperature profile and surface temperature with observed values.

3. Summary

A radiative convective model was further developed to compute the width and the location of LSZs for different, alternative solvents around the Sun and other main sequence stars. The formation and growth of cloud droplets are investigated for the different solvents. Clouds are included in the calculation of the widths and the locations of the LSZs.

Acknowledgements

This work was performed within the research platform on ExoLife. We acknowledge financial funding from the University of Vienna, FPL 234, http://www.univie.ac.at/EPH/exolife. We would like to thank the members of the Rax field campaign 2000 for the aerosol data for this study. D. Neubauer gratefully acknowledges the support by research fellowship F-369, University of Vienna. The computational results presented have been achieved in part using the Vienna Scientific Cluster (VSC).

References

[1] Bohren, C. F. and Huffman, D. R.: Absorption and scattering of light by small particles. Wiley-VCH, 2004.

[2] Chen, J. P. and Lamb, D.: Simulation of cloud microphysical and chemical processes using a multicomponent framework. Part I: Description of the microphysical model, J. Atmos. Sci., Vol. 51, pp. 2613–2630, 1994.

[3] Houze, R. A.: Cloud dynamics, Academic Press, 1993.

[4] Key, J. and Schweiger, A. J.: Tools for atmospheric radiative transfer: Streamer and FluxNet, Computers & Geosciences, Vol. 24(5), pp. 443-451, 1998.

[5] Kornfeld, P.: Numerical solution for condensation of atmospheric vapor on soluble and insoluble nuclei, J. Atmos. Sci., Vol. 27, pp. 256-264, 1970.

[6] Leitner, J., Neubauer, D., Schwarz, R, Eggl, S., Firneis, M. G. and Hitzenberger R: The life supporting zone I - From classic to exotic life, European Planetary Science Congress 2010, 19-24 September 2010, Rome, Italy, 2010.

[7] Leitner, J. J., Schwarz, R., Firneis, M. G., Hitzenberger, R., Neubauer, D.: Generalizing habitable zones in exoplanetary systems – The concept of the life supporting zone, Astrobiology Science Conference 2010, 26-29 April 2010, League City, USA, 2010.

[8] Manabe, S. and Stricker, R. F.: Thermal equilibrium of the atmosphere with a convective adjustment, J. Atmos. Sci., Vol. 21, pp. 361-385. 1964

[9] Manabe, S. and Wetherald, R. T.: Thermal equilibrium of the atmosphere with a given distribution of relative humidity, J. Atmos. Sci., Vol. 24, pp. 241-259. 1967

[10] Mason, B. J.: The evolution of droplet spectra in stratus cloud, J. Atmos. Sci., Vol. 17, pp. 459–462, 1960.

[11] Neubauer, D.: Modellierung des indirekten Strahlungseffekts des Hintergrundaerosols in Österreich, Phd thesis, 2009.

[12] Pruppacher, H. R. and Klett, J. D.: Microphysics of clouds and precipitation, Kluwer Academic Publishers, 1997.

[13] Stamnes, K., Tsay, S. C., Wiscombe, W. and Jayaweera, K.: Numerically stable algorithm for discrete-ordinate-method radiative transfer in multiple scattering and emitting layered media, Appl.Opt., Vol. 27, pp. 2502-2509, 1988.

[14] Toon, O. B., McKay, C. P., Ackerman, T. P. and Santhanam, K.: Rapid calculation of radiative heating rates and photodissociation rates in inhomogeneous multiple scattering atmospheres, J. Geophys. Res., Vol. 94(D13), pp. 16,287–16,301, 1989.