EPSC Abstracts
Vol. 8, EPSC2013-155, 2013
European Planetary Science Congress 2013

Investigating the Effects of Meteor Showers on Terrestrial Atmospheres

Elisavet Proedrou (1,2), Klemens Hocke (1,2), Niklaus Kämpfer (1,2), Peter Wurz (2,3), Helmut Lammer (4)
(1) Institute of Applied Physics, University of Bern, Bern, Switzerland,
(2) Center for Space and Habitability, University of Bern, Bern, Switzerland,
(3) Physics Institute, Space Research and Planetary Sciences, University of Bern, Bern, Switzerland,
(4) Space Research Institute, Austrian Academy of Sciences, Graz, Austria
(elisavet.proedrou@iap.unibe.ch)

Abstract

Meteor showers can change the atmospheric composition and ionization of the terrestrial planets, but their influence on the thermal state and dynamics of the middle atmospheres have not been studied in depth. The progress in Earth observation and atmospheric modelling of the past decades allows us to revisit the question of atmospheric heating by meteor showers. As an initial test, we performed a simulation with the Whole Atmosphere Community Climate model (WACCM). We assumed that the kinetic energy of the meteor shower heats up the mesosphere by 10 K at the start of the simulation. This perturbation caused significant differences in the evolution of the wind and temperature distribution of the lower and middle atmosphere even after 31 days. Particularly a Sudden Stratospheric Warming was suppressed by the change of the initial conditions in the mesosphere.

1. Introduction

Meteors range in masses from 10^{-20} kg to tons. Meteors with masses between 10^{-12} to 1 kg, are observable as "falling stars" ablating at altitudes between 90 - 60 km, depositing most of their heat and mass in this region [1]. Meteors with masses smaller than 10^{-12} kg, which are known as meteoric dust, do not ablate, but drift to the ground over a long period of time or evaporate by absorption of short wave solar radiation. The total mass influx of meteors and interplanetary dust particles into the Earth's atmosphere is estimated to be 110 ± 55 tons/day [2] [3].

We began to investigate the effects of meteor showers on the middle atmosphere. Besides atmospheric composition changes we expect small changes in the circulation and the thermal state of the mesosphere. Particularly a meteor shower may generate a planetary wave-like perturbation in the mesosphere since the kinetic energy of the meteors is mainly transformed into heat [1]. The average effect of a meteor shower on the thermal state and dynamics of the middle atmosphere is almost not described in the literature. [4] estimated that the effect of atmospheric heating by a meteor shower is negligible. However, the progress in Earth observation and atmospheric modelling, allows us to revisit the question of atmospheric heating by meteor showers and we are optimistic that satellite observations and simulations with the Whole Atmosphere Community Climate Model (WACCM) can answer the question.

2. The WACCM model

The WACCM is an extension of the Community Earth System Model (CESM) version 1.04. The upper boundary of the model is lifted up to 150 km altitude. The detailed photochemistry and parameterization of the gravity wave flux of WACCM lead to realistic simulations of the composition and the circulation of the middle atmosphere. In addition, the sectional microphysical model Community Aerosol and Radiation Model for Atmospheres (CARMA) will be included in the WACCM model in the near future. It will allow transport studies of meteoric dust, pure sulfate aerosol, and sulfates condensed on meteoritic dust cores and, a more detailed study of the impact of meteoric dust on Polar Mesospheric Clouds (PMC), Polar Stratospheric Clouds (PSC) [5] and metallic ion layers.

3. The model setup

As a first test we attempted to simulate the effects of a temperature increase of 10 K in the middle atmosphere (90 - 60 km) at the beginning of the simulation (on the first hour). The temperature estimate was obtained using a rough calculation, where the kinetic energy of the shower was redistributed to all molecules of the mesosphere. The perpetual year 2000 AD compset (F_2000_WACCM) was used and the simulation lasted five months (1.1.2000 - 31.5.2000).

4. Results

The simulation produced a disturbance of the temperature and wind structure of the entire atmosphere for at least five months. The temperature change moved downwards as time progressed, reaching the troposphere on the 24^{th} day. The increased mesospheric temperature on day 0 leads to a suppression of a mesospheric cooling and a stratospheric warming on day 31 compared to the Control run (Figure 1). The velocity changes were more pronounced in the Northern than the Southern hemisphere from January to March. The atmospheric state of the summer hemisphere is much more stable compared to the winter hemisphere, and meteor heating has almost no effect in the summer hemisphere.

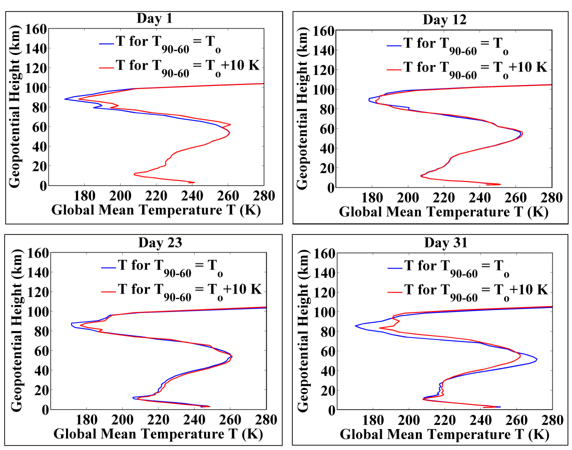

Figure 1: Evolution of global mean temperature profile for different mesospheric state on day 0: Control run $T = T_o$, Simulation run $T = T_o + 10$ K

5. Summary and Conclusion

The initialisation of the model with a mesospheric temperature increase of 10 K, results in different wind and temperature conditions in the atmosphere for at least one month. Therefore the state of the mesosphere influences the temperature, the meridional and the zonal wind of the whole atmosphere. This poses the question of whether long term weather forecast requires a Whole Atmospheric Model with inclusion of upper atmospheric processes such as meteor showers.

6. Outlook

Our goal is to simulate the meteor mass influx and heating more realistically as a function of longitude, latitude and local time. A visualization of the evolution of the meteoric mass influx density of the meteor shower in this improved simulation scenario, can be seen in Figure 2. We believe that the meteor shower may induce a planetary wave in the circulation, thermal state, and composition of terrestrial planets.

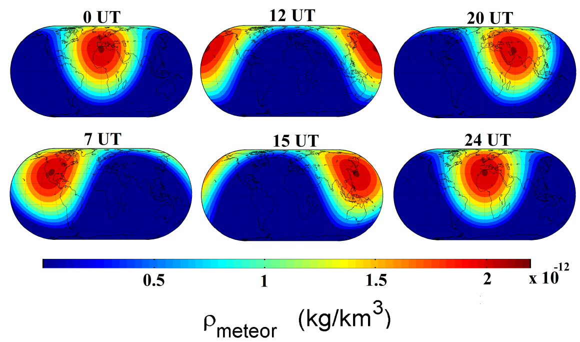

Figure 2: Meteoric mass influx density of the Geminids meteor shower, at 90 - 60 km altitude over 24 h

References

[1] Jenniskens, P.: Meteor Showers and their Parent Comets, UK Cambridge University Press, 2006.

[2] P. Brown, R. E. Spalding, D. O. ReVelle†, E. Tagliaferri, S. P. Wordenk: The flux of small near-Earth objects colliding with the Earth, Nature, Vol. 420, pp. 294-296, 2002.

[3] Love, S. G., Brownlee, D. E.: A Direct Measurement of the Terrestrial Mass Accretion Rate of Cosmic Dust, Science, Vol. 262, pp. 550-553, 1993.

[4] Lebedinets, V. N., Manochina, A. V., Shushkova, V. B.: Interaction of the lower thermosphere with the solid component of the interplanetary medium, Planetary and Space Science, Vol. 21, pp.1317-1332, 1973.

[5] Bardeen, C. G., Toon, O. B., Jensen, E. J.,Marsh, D. R., Harvey, V. L.: Numerical simulations of the three-dimensional distribution of meteoric dust in the mesosphere and upper stratosphere, Journal of Geophysical Research: Atmospheres, Vol. 113, pp. 17202, 2008.