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Interhemispheric differences in polar mesospheric clouds observed by the HALOE instrument

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Abstract

HALOE data have been used to study Polar Mesospheric Clouds (PMCs) and to investigate differences in the characteristics of the clouds between the northern and southern hemispheres. HALOE has been observing the high latitude summer regions since the fall of 1991, which has provided observations of 14 northern hemisphere and southern hemisphere PMC seasons. HALOE infrared extinction profiles are used to extract PMC extinction and the altitude of the PMC for each cloud observation. We present evidence of higher PMC occurrence frequencies, lower cloud altitudes and larger PMC extinction in the NH compared to the SH. When the PMC data are combined for all years between the latitudes of 55° and 70°, we find that the northern hemisphere clouds are brighter by 29 ± 5% and the peak altitude occurs at 0.9 ± 0.1 km lower than the southern hemisphere clouds. In addition, we find that PMCs occur twice as frequently in the northern hemisphere. Seasonal distributions of PMC extinction and occurrence frequency for the combined multi-year datasets reveal an offset between the two hemispheres with the SH season starting about 10 days earlier than for the NH. Interhemispheric PMC altitude differences are supported by a lower altitude region of saturation in the NH and by a lower H_2O peak altitude in the NH. HALOE mean temperature profiles for PMC events alone reveal a colder NH up to ~82 km, but NH and SH profile error bars overlap above this altitude. Analysis of all temperature profiles (PMC and non-PMC) measured during the high-altitude polar summer reveal a colder NH at all altitudes suggesting this as one possible cause for the observed interhemispheric differences in PMC properties.

Keywords: Polar mesospheric clouds; Mesosphere temperature; Mesosphere water vapor; Microphysics

1. Introduction

Polar mesospheric clouds (PMCs) are one of the more unusual phenomena of the mesosphere. These clouds usually occur at latitudes poleward of 50° during the summer, and they exist at very high altitudes (~83 km), making them the highest clouds on Earth. They are composed primarily of water-ice (Hervig et al., 2001). Although many details of their existence are still lacking, they are believed to form because of the unique meteorological conditions that occur due to the global circulation of the middle atmosphere. Upward movement of air in the high-latitude mesosphere cools adiabatically and lowers the temperatures to ~135 K near the mesopause creating a super-saturated environment for the clouds to form and grow in; however, the

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physics that controls the growth and evolution process is not well understood.

PMCs have been studied from satellite platforms since their initial observation from space in 1972 (Donahue et al., 1972). Since then, several space-borne instruments have observed PMCs, e.g. the Solar Mesosphere Explorer (SME) satellite (Olivero and Thomas, 1986; Thomas and Olivero, 1989), the Wind Imaging Interferometer (WINDII) on UARS (Evans et al., 1995), the Polar Ozone and Aerosol Measurement (POAM II) instrument on SPOT-3 (Debrestian et al., 1997), the Ultraviolet and Visible Imaging and Spectrographic Imaging (UVISI) experiment on MSX (Carbary et al., 2001), the Optical Spectrograph and Infrared Imaging System (OSIRIS) (Petelina et al., 2001), the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) (Stevens et al., 2001, 2003), the Halogen Occultation Experiment (HALOE) aboard the Upper Atmosphere Research Satellite (UARS) (Hervig et al., 2001), the Stratospheric and Aerosol Gas Experiment (SAGE II) (Shettle et al., 2002), the Student Nitric Oxide Explorer (SNOE) (Merkel, 2002), the SBUV suite of instruments (DeLand et al., 2003), the Scanning Imaging Absorption Spectrometer from Atmospheric Chartography (SCIAMACHY) aboard ENVISAT (von Savigny et al., 2004), and the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) on the SciSat satellite (Eremenko et al., 2005). Much information about the nature of PMCs has come from these instruments. The purpose of this paper is to describe interhemispheric differences seen in PMC extinction, altitude and occurrence frequency using HALOE data and suggest possible reasons for the differences. Interhemispheric differences in PMC properties are important because they may provide clues into differences in the atmosphere between the northern and southern hemisphere. They also allow for important test cases in model simulations of PMCs to aid in our theoretical understanding of this phenomena. We will demonstrate evidence of higher PMC occurrence frequencies, lower cloud altitudes and larger PMC extinction in the NH compared with the SH from the HALOE data.

Interhemispheric differences have been observed from ground-based lidar and a variety of space-based platforms. In the next three subsections, we provide a brief history of the documented observations of interhemispheric differences in PMC brightness, altitude, and occurrence frequency. The HALOE instrument is briefly described in Section 2. The algorithm that is used to extract PMC events from the dataset is explained in Section 3. Section 4 contains the results from the analysis of HALOE data. These results are further discussed in Section 5 along with possible explanations for their behavior. The last section provides a summary of the findings of the results and conclusions.

1.1. PMC brightness

A study of literature on the subject of interhemispheric differences in PMC extinction reveals that several satellite instruments have observed this phenomenon. Analysis of a special subset of the SME dataset during which the satellite was viewing light scattered at similar angles in the NH and SH revealed that NH PMCs were on average brighter than the SH PMCs during the period from 1981 to 1984 (Olivero and Thomas, 1986). The ratio of the NH PMC radiances to the SH PMC radiances for individual pairs of NH/SH seasons ranged from 1% to 83%. Data from the SBUV suite of instruments were analyzed by Thomas et al. (2003) and showed larger average PMC albedoes at 252 nm in the NH for all PMC seasons since 1980 with the exception of 2001 and 2002. DeLand et al. have analyzed a newer version of the SBUV data and reported that the mean PMC albedoes are greater in the NH for all years since 1979 (DeLand et al., 2006). A special subset of SNOE data taken during 2000 and 2001 during which PMCs were observed at similar scattering angles in each hemisphere revealed greater PMC brightnesses in the NH with larger interhemispheric differences at lower latitudes (Scott Bailey, LPMR meeting, 2004). More recently, PMC data taken by the OSIRIS instrument from the two SH summers of 2001/2002 and 2002/2003 and the two NH summers of 2002 and 2003 have been analyzed and show that NH PMCs are ~35–40% brighter on average compared to SH PMCs (Petelina et al., 2006). It should be noted that all of these instruments have varying sensitivities to PMC brightness, and this will likely influence a comparison between them. In spite of this fact, the above collection of results overwhelmingly supports interhemispheric differences in PMC brightness. Many of these results have also been nicely summarized in a recent overview paper on satellite PMC observations (DeLand et al., 2006).

Recently, a number of lidar observations of PMCs have taken place from Sondrestrom, Greenland