The MIDAS campaign 2002

– studies of strong radar echoes and clouds in the Earth's upper atmosphere

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During the Arctic summer, when the temperature in the 80-90 km height region becomes very low, cirrostratous like clouds called Noctilucent Clouds (NLC) can be observed around 82 km height. These are the highest clouds in the Earths atmosphere and are caused by low temperatures in combination with the existence of water vapour in the upper mesosphere. In the same height region as the clouds, very strong radar echoes in the VHF (30-300 MHz), and sometimes UHF (300-3000 MHz) bands, can be observed. This phenomenon has been named Polar Mesosphere Summer Echoes (PMSE). The two phenomena seem to be related through the existence of aerosol particles, charged or neutral. Dedicated and co-ordinated in situ and ground-based observations of NLC and PMSE are needed to understand the existence and behaviour of these phenomena. This year's MIDAS (Middle atmosphere Dynamics And Structure) campaign from Andøya Rocket Range in northern Norway (69° N) is dedicated to the studies of PMSE and NLC, and will take place in the period 29 June – 13 July. It will also be closely coordinated with the NASA MACWAVE campaign for studies of turbulence and wave dynamics in the mesosphere and lower thermosphere (50-120 km) that will be conducted simultaneously.

Introduction

MIDAS is a bi-lateral Norwegian-German project. The main scientific aim is to perform detailed studies of a few selected phenomena occurring in the Earth's mesosphere (50-90 km height). Amongst these are NLC and PMSE, as well as atmospheric turbulence and waves. This year's campaign is the fourth in a series of campaigns that have been conducted since 1999. MIDAS utilizes a combination of in situ measurements by means of instrumented rockets and a number of ground-based instruments. In the latter category are different radars and optical instruments at the ALOMAR (Arctic Lidar Observatory for Middle Atmosphere Reseach) facility at Andøya. This unique combination of different experiments and their location makes it possible to perform simultaneous and common volume measurements of a number of different phenomena, e.g. PMSE and NLC.

The region around the mesopause (80-90 km) is interesting because changes in this region may be an early indicator or a precursor for changes that occur in other regions of the atmosphere. Changes with time of the phenomena that occur at mesopause heights are therefore of importance not only for the scientists that study them, but for other parts of the scientific community as well. This includes, amongst others, atmospheric chemistry, dynamics and

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Figure 1. Noctilucent Clouds seen from Oslo, Norway. Photograph by Dag Thrane.

radiation, and may also be of interest to meteorology and oceanography since the atmosphere and the ocean are known to influence one another. Two of the most interesting phenomena that are observed near the cold summer mesopause are Noctilucent Clouds (NLC) and Polar Mesosphere Summer Echoes (PMSE). It is believed that these intriguing phenomena are related to ice particles that can exist at these heights when the temperature in the region drops below 140-150 °C.

NLC, or night shining clouds as they are also called, were first observed in the summer of 1884 following the volcanic eruption that destroyed the island of Krakatoa the year before. These spectacular clouds can be seen from the ground during twilight when the sun is below the horizon, but still illuminates the clouds in the mesosphere. The clouds are seen at an average height of about 83 km, i.e. below the summertime mesopause in a region of increasing temperature with decreasing height. They can only be seen from the ground during summertime, and at latitudes between about 50° and 65°, where the viewing conditions are best. In summer 1999 an NLC was, however, seen as far south as Colorado, USA (40°N). Most of the observations are from the northern hemisphere; only a very few sightings of NLC have been reported in the southern hemisphere. An example of a Noctilucent Cloud can be seen in Figure 1. This figure is also a proof that dynamics play an essential role in the upper atmosphere. It is evident that atmospheric waves are present in the height region of the NLC. If the reader turns the picture upside down the waves look almost like waves on a water surface. An interesting feature of NLC is that the average occurrence frequency seems to have increased during the last decades, possibly related to climate change. In addition, NLC exhibit a solar cycle variation, with maximum number of NLC sightings during solar minimum.

Polar Mesosphere Summer Echoes (PMSE) have been studied extensively since they were first detected by the Poker Flat 50 MHz radar in Alaska, USA in 1979. In the years thereafter, PMSE have been detected and studied both at VHF and UHF frequencies and over a wide latitude band (about 50°-80°). As is the case for NLC, measurements of PMSE in the southern hemisphere are scarce. Figure 2 shows the first PMSE observed by the EISCAT 224 MHz VHF radar at Ramfjordmoen close to Tromsø. Note the large power (on a relative scale) and extremely variable behaviour of the PMSE.

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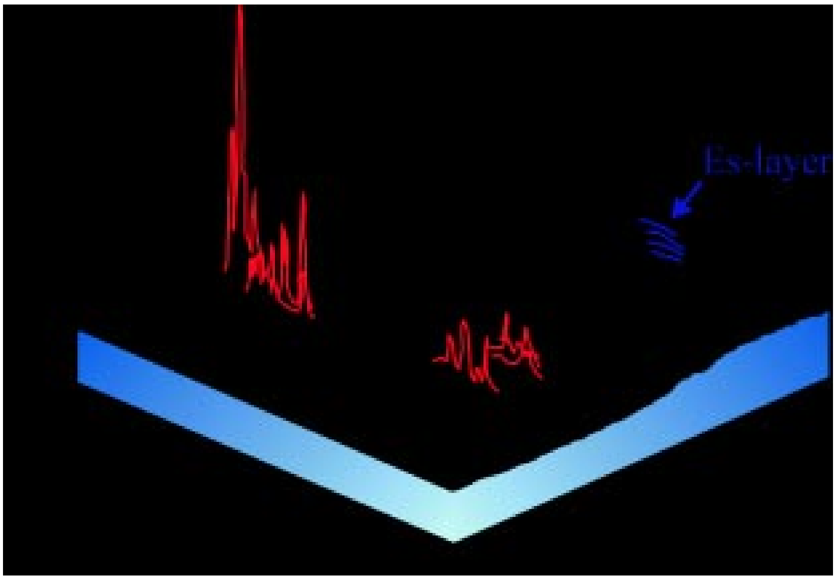
Figure 2. Polar Mesosphere Summer Echoes measured by the EISCAT 224 MHz VHF radar. The power is on a relative scale.



Observations

A number of campaigns have been conducted from northern Scandinavia since 1990 to study the fine scale structure of NLC and PMSE, as well as turbulence and atmospheric waves. Several rocket launches have taken place together with intensive ground-based measurements by different lidar and radar stations. One of the main ground-based facilities is the ALOMAR observatory located close to the launch site at Andøya Rocket Range (ARR; 69°N, 16°E). The European Incoherent Scatter Facility (EISCAT) outside Tromsø (69.5°N, 19°E) has also played an essential role in these studies. The European MIDAS and the NASA lead MACWAVE campaigns will utilize this combination of instruments in a concerted effort to perform detailed common volume studies of the upper mesosphere, lower thermosphere region, with launches that are closely coordinated. It is today possible to launch rockets through both the Rayleigh/Mie/Raman (RMR) lidar and the VHF radar beams from the observatory in the height range 80-90 km on the upleg part of the trajectory by tilting the beams. This summer the new sodium lidar, that uses the same mirrors as the RMR lidar, will make detailed studies of the wind field in the 80-110 km height range. MIDAS and MACWAVE have different, but complementary, scientific aims, and the rocket launches will take place in salvoes as close as possible in time. Three MIDAS and two MACWAVE payloads will be launched during the campaign. In addition to the major rockets, a number of smaller meteorological rockets will be launched. These will measure the temperature and wind fields up to about 90 km, and will be distributed over a sequence lasting ideally for 12 hours. This depends, however, on the weather situation as the optical instruments need clear sky for their measurements.

Science objectives

It has for a long time been known that the structure of electrons and ions changes in the height region of NLC and PMSE. This has been measured in situ by several rocket experiments and has also been described by a number of models. The spatial scales of these variations range from fractions of a meter to kilometers. A relatively common feature of the electron measurements is a depletion (or bite-out as some tend to call it) close to the region of NLC and/or PMSE. This reduced electron density is associated with the presence of nanometer-sized aerosol particles. Because of the very low temperatures in the mesopause region, and the presence of water vapour, it is believed that ice particles can grow to considerable sizes at these heights. Such particles can grow from nuclei of large water cluster ions or more probably meteoric debris that exist around the mesopause. These particles grow to larger sizes as they sediment downwards. Because they are exposed to the ionospheric plasma, most of the aerosol particles get charged, and they play an essential role in the charge balance in the 80-90 km height range. We will measure charged aerosol particles, electrons, ions and neutrals on the MIDAS payloads this summer. In addition, one of the three payloads will be equipped with an electric field probe.

There are at least two major questions related to NLC and PMSE that need to be solved:

a) Is the increase of NLC sigthings an indication of climate change in the middle atmosphere? If yes, which processes contribute to the observed increase?

b) Which processes lead to the presence/creation of PMSE?

The problem of climatic changes in the upper mesosphere is not new, but has attracted more and more attention to our community as the increase in the frequency of NLC has been observed for more than 30 years. The question is whether the observed changes are due to natural variations or caused by human activity. A number of theories have been put forward to explain the existence and behaviour of PMSE. Most of these theories depend on the presence of charged aerosol particles. Direct measurements of such particles in the upper mesosphere have only recently been made possible by the development of impact sensors. The MIDAS campaign this summer will give more detailed information about structures in the upper mesosphere than before, a factor that is of major importance for understanding these interesting phenomena.