Adv. Space Res. Vol.4, No.4, pp.153-156, 1984
Printed in Great Britain.
0273-1177/85 $0.00 + .50

TEMPERATURE MEASUREMENTS DURING THE CAMP PROGRAM

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ABSTRACT

The Cold Arctic Mesopause Program (CAMP) was conducted at ESRANGE, Sweden, in July/August 1982. During the time period of several weeks, the temperature was monitored by ground-based OH emission spectrometers and by stellite radiance measurements. Rocket launchings occurred on the nights of 3/4 and 11/12 August. On 3/4 August, seven rocket payloads were launched during a period of noctilucent cloud sighting over ESRANGE. The presence of the NLC was confirmed by several rocket-borne photometer profiles. The temperature measurements showed that the temperature profiles in the stratosphere and lower mesosphere were near the expected values of high latitude summer models. A large amplitude wave structure with three temperature minima of 139K, 114K and 111K were observed at altitudes between 83 and 94 km. The temperature minimum at 83 km was the location of the observed NLC. The temperature minima caused by the growth of the gravity wave amplitude in the highly stable mesosphere provide the regions for the growth of particles by nucleation to optical scattering size, as well as regions where the nuclei for condensation can be formed through ion chemistry paths.

INTRODUCTION

The high latitude summer mesosphere has been known to possess the unique quality of containing the highest altitude clouds, noctilucent clouds (NLC). The study of properties of noctilucent clouds have been the focus of numerous investigations. A major effort to bring together the instrumentation to measure the several properties necessary to describe the NLC during the same investigation was carried out in CAMP (Cold Arctic Mesopause Program) in 1982 at ESRANGE, Sweden /1/. The coldest atmospheric temperatures occur in the summer mesopause because of the dynamical state of the region. The global circulation results in upward vertical velocities over the summer polar region which causes adiabatic cooling of the mesosphere and in addition the contribution to mesospheric heating from turbulent dissipation and transport is thought to be a minimum in the summer mesopause. The wave energy which could result in turbulence heating is not extracted until higher altitudes, upper mesosphere/lower thermosphere, because of the stability of the lower mesosphere.

The CAMP Program was designed to bring together the best current techniques for measuring the properties of the summer mesosphere in order to develop a better understanding of the detailed processes and properties in that region. The techniques included optical photometers to detect the NLC particles, mass spectrometers for positive and negative ion species, high resolution electron probes, accelerometer measurements of density, temperature and wind, chemical release wind measurements, ionization rates from solar and particle sources, and concentration of minor neutral species such as atomic oxygen and argon. This paper will present the measurements of the structure parameters, particularly temperature, obtained during the campaign. Other papers in this collection will present results from the other measuring techniques.

MEASUREMENTS

The temperature measurements obtained from satellite and ground-based techniques provided an indication of the development of the high-latitude mesosphere conditions. Radiance measurements from the NIMBUS 7 satellite data provided the opportunity to follow the day-to-day variation in the temperature as indicated by radiance measurements in the 50 to 70 km altitude region. While the radiance measurements are not capable of providing the mesopause temperature, they do provide useful trend data on whether the region appears to be cooling or warming. Mesospheric cooling pulses in the high latitude region were inferred from the satellite measurements several times during the summer. Observing the temperature in the stratosphere is useful because of the anti-correlation which exists between the stratospheric and mesospheric temperatures. The ground-based measurements of temperature, based on OH Meinel band measurements, provided additional information on day-to-day variations. Measurements were made from two sites, Stockholm (59°N) and Kiruna (68°N), Sweden. The Stockholm measurements were made with an infrared spectrometer instrument from the University of Wuppertal, FRG, and the Kiruna measurements were made by an interferometer from Utah State University, USA. Figure 1 shows the values obtained during the period between the end of July and mid August 1982. The measurements between 1 mbar and 0.03 mbar are from the NIMBUS 7 satellite. The values represent an average value for the high latitude region which correspond to vicinity of Stockholm and ESRANGE. The 0.3 mbar and 0.1 regions indicate that the stratosphere above ESRANGE is about 5 to 7 degrees warmer than above Stockholm, in good agreement with models /2/. The upper curve is from the Stockholm OH temperature measurement. The anti-correlation between the stratospheric and mesospheric temperature is apparent. Those days which correspond to minima in the OH temperature were the days on which NLC conditions were observed to exist at ESRANGE. The OH measurements at ESRANGE (not shown) were only obtained on five nights between 2 and 14 August because of the difficulties of measuring during periods of small solar depression angles. The measured values averaged 143°K, about 25°K colder than the values at Stockholm. The model /2/ would indicate a difference of about 15K. The fact that the model is based on a small number of high latitude measurements and that the latitude gradient of temperature is very steep lead to the conclusion that the measurements are generally consistant. The major rocket salvos were conducted on 3/4 August (Day 215/216), Salvo A, and 11/12 August (Day 223/224), Salvo B. The Salvo A was launched into NLC conditions which occurred in conjunction with the local minimum in the OH temperature and maximum in the stratopause temperature.

In-situ measurements of temperature were made in Salvo A, 3/4 August, using accelerometer measurements of density /3/, bead thermistor measurements of temperature /4/, and scale height temperature measurements from molecular scattered sunlight. In Salvo B, temperature measurements were obtained from the meteorological rocket bead with thermistor and optical measurements of molecular scattering. In Figure 2 the temperature and density measurements obtained from the meteorological rockets launched in Salvo A and B are shown together with the model profiles from the USSA 76 and AF Reference Atmosphere (August, 75°N). For altitudes between 20 and 60 km, the measurements indicate that the summer conditions modeled were similar to those observed. Figure 3 shows the temperature measurements from the accelerometer in the altitude range between 55 and 130 km. The region between 80 and 100 km exhibits a strong wave structure with 3 minima. At 83.5 km, a minimum of 139K was observed in the region where the noctilucent clouds were measured. Minima at 89.4 and 93.6 km reached values of 119 and 111K respectively. These temperatures are significantly lower than any which have been previously measured in the atmosphere. Prior measurements of high latitude temperature were primarily obtained using the grenade technique /5/ at Pt. Barrow, Alaska. The grenade technique does not have sufficient altitude resolution to accurately define minima associated with short wavelength waves such as observed here.

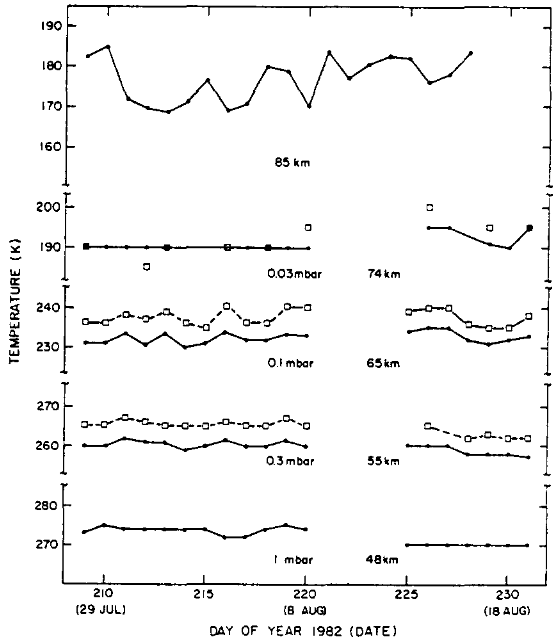

Fig. 1. Temperature measurements at several heights above Stockholm (dots) and ESRANGE (squares), Sweden, for late July and early August 1982 from satellite and ground-based observations.

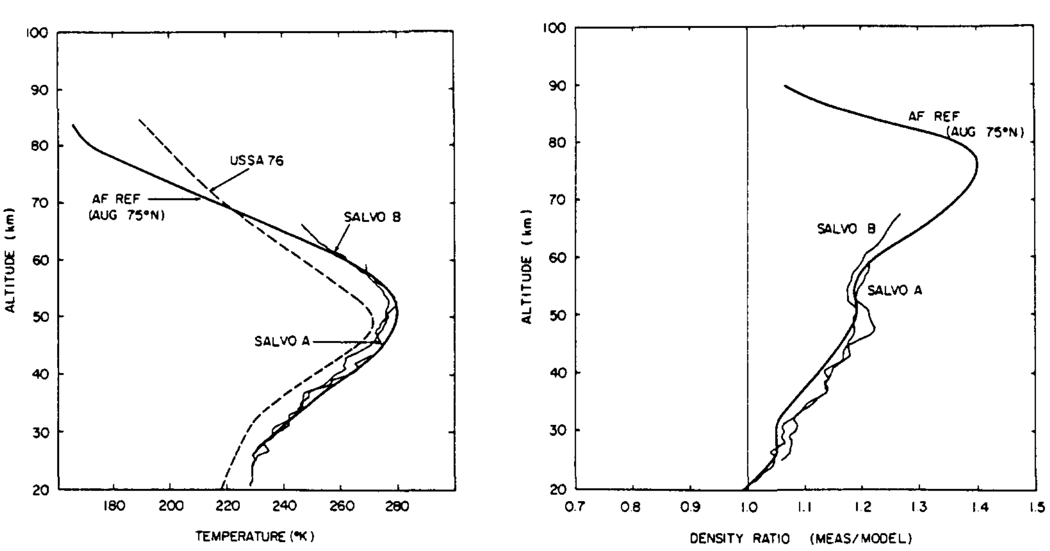

Fig. 2. Temperature and density measurements from meteorological rockets launched during Salvo A and Salvo B of the CAMP program. The temperature measurements are compared to the USSA 76 and the AF Reference model. The density measurements are shown as a ratio to the USSA 76 and the AF Reference model is shown for comparison.

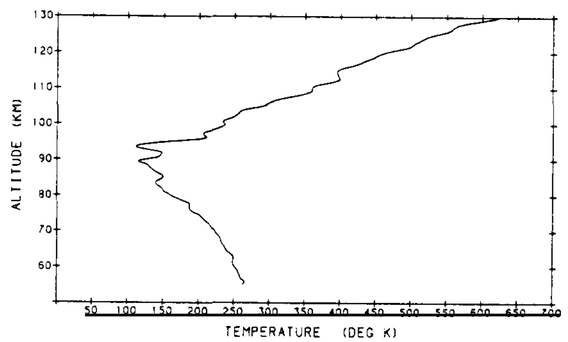

Fig. 3. The temperature profile obtained from the accelerometer measurements of density is shown between 55 and 130 km. The minimum at 83.5 km is the location of the NLC.

The rather large amplitude wave features in the mesosphere correspond to wavelengths of 5 to 7 km in the vertical direction. The measurements of the wind field also showed strong wavelike character with predominent wave lengths ranging between 5 and 10 km. The wave amplitudes are large because of the strongly stable condition of the atmospheric structure in the summer mesosphere. In Figure 4 the density results obtained from the accelerometer are shown. The density as a function of altitude shows a strong departure from the normal exponential decrease in atmospheric density. This effect is more strongly emphasized when the density measurements are shown as a ratio to the USSA 76 model. In the vicinity of 80 km to 95 km the gradient in the density decreases sharply, resulting in a stablizing condition /6/. If small amplitude waves are present in the upper stratosphere and lower mesosphere, then their amplitude would be expected to grow within this region since the dissipative effects of turbulence would be absent. The large amplitude waves observed in these vertical profiles are certainly related to the wave field observed horizontally in most all NLC displays /7/.

In Figure 5, the temperature profiles determined from integrating the profile of the molecular scattering optical measurements are shown. The SOAP 1 profile was obtained by integrating the optical signal proportional to molecular density downward from an assumed temperature. This technique assumes hydrostatic equilibrium and the ideal gas law are valid in order to procede. While the profiles obained differ from the accelerometer values, it is expected that the optical technique does not have sufficient resolution to follow the detail but that the general features should correspond. A temperature minimum in the vicinity of 93 km of about 120K is indicated for both measurements on 3/4 August.

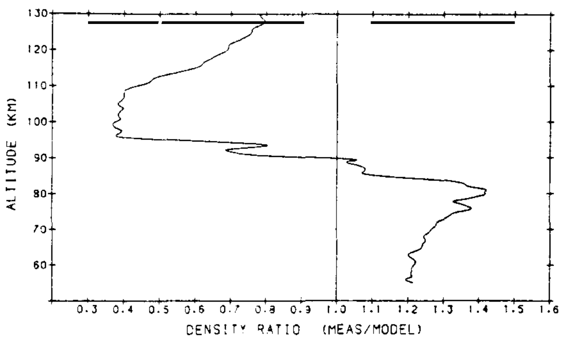

Fig. 4. Density measurements obtained from the accelerometer are shown as a ratio to the USSA 76 model.

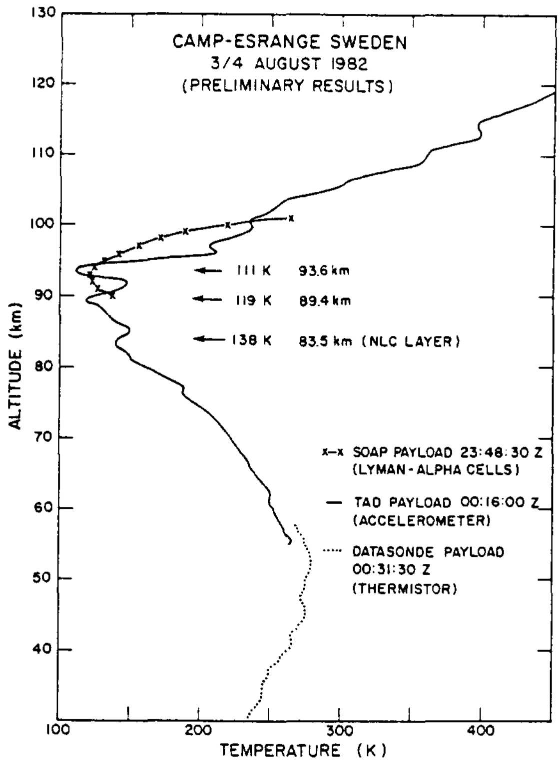

Fig. 5. Comparison of the three temperature profiles obtained during the NLC display on 3/4 August.

CONCLUSIONS

The noctilucent cloud which was observed on 3/4 August from the ground, aircraft, and in six vertical profiles from optical photometers was located in the temperature minimum at 83.5 km measured by the accelerometer. The two colder minima at altitudes of 89.4 and 93.6 km could be associated with regions of formation of precondensation nucleii /8/ which could replinish the particle content in the main NLC layer. A detailed picture of the transport, vertical and horizontal, of the NLC particles and their subvisual counterparts will be necessary to fully understand the evolution and development of the visual clouds. When the measurements from the other instruments and techniques are combined with these results, a better understanding of the physical and chemical processes in the region is expected.

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