Initial Results from SOFIE / AIM

■ McHugh, Martin J. m.j.mchugh@gats-inc.com
■ Gordley, Larry L. l.l.gordley@gats-inc.com
■ Hervig, Mark E. m.e.hervig@gats-inc.com
GATS, Inc., 11864 Canon Blvd., Suite 101, Newport News, VA 23606

■ Russell, James M. james.russell@hamptonu.edu
Hampton University, 23 Tyler St., Hampton, VA 23668

Abstract: SOFIE (the Solar Occultation For Ice Experiment) has been operating since May 2007 onboard AIM (the Aeronomy of Ice in the Mesosphere satellite). SOFIE measurements target the polar mesosphere, where noctilucent clouds form each summer. Increases in the frequency and brightness of these ultra-high clouds have been attributed to global climate change, but conclusive evidence is lacking, and relatively little is known about the processes governing their formation. SOFIE is now providing key measurements to advance our understanding of these clouds and their environment. The instrument acquires limb path transmittances in 16 spectral bandpasses from the UV to the IR. Vertical profiles of cloud properties, temperature, water vapor, ozone, methane and nitric oxide are inverted from these transmittance measurements. With over a year of observations in hand, we now have information leading to a better understanding of the formation of noctilucent clouds, including the first ever measurements of the cosmic dust layer. In this presentation we describe the instrument, outline the retrieval process, and discuss preliminary science results from the SOFIE experiment.

Introduction

AIM is the first satellite mission dedicated to the study of noctilucent clouds (NLCs). Last year it provided the first global-scale view of the clouds over both the Northern and Southern hemispheres. Despite a significant increase in NLC research in recent years, relatively little is known about the basic physics of these clouds at "the edge of space" and why they are changing. They have increased in brightness over time, are being seen more often and appear to be occurring at lower latitudes than ever before. Since the launch of AIM on April 25, 2007, significant progress has been made towards understanding how NLCs form and vary. These data are changing our view of NLCs and their environment. After only one year of observations, startling similarities are emerging between NLC structure observed by AIM and structure of tropospheric clouds, suggesting that the mesosphere may share some of the same dynamical processes responsible for weather near Earth's surface.

Instrument

SOFIE measures solar energy passing through the limb of the Earth's atmosphere as the Sun rises or sets relative to the spacecraft (Fig. 1). These measurements are accomplished using differential absorption radiometry with eight band pairs covering wavelengths from 0.29 to 5.26 microns (Fig. 2). Six SOFIE channels are designed to measure gaseous signals, and two are dedicated to NLC measurements. Measurements in two CO_2 bands will be used to simultaneously retrieve profiles of temperature and CO_2 volume mixing ratio. Each SOFIE channel uses two detectors, one that samples a spectral region where the target gas is strongly absorbing, and one that samples a weakly absorbing region. Measuring the difference of these signals allows precise isolation of the target gas signal and reduces systematic effects. The measurements allow NLC extinction retrievals using the weak bands, so that NLCs will be measured at a total of 11 wavelengths.

Orbit

AIM's orbital geometry produces 15 sunrise and 15 sunset occultations each day. Sunrises occur in the Northern hemisphere between 65 and 85 degrees N latitude; sunsets occur between 65 and 85 degrees S. Fig. 3 shows all Northern hemisphere tangent point locations for a 6-month period (Jun-Dec 2007). This pattern is repeated twice a year, and a similar pattern develops in the Southern hemisphere.

Retrievals

Science products produced by SOFIE are summarized in Table 1. For each occultation vertical profiles are obtained for the following parameters: temperature and pressure, NLC extinction at 7 wavelengths, and volume mixing ratios of H_2O, O_3 and CH_4. Products currently under development (but not yet publicly released) include NO and CO_2.

Initial Science results

- Ice is more frequent and appears about 10 days earlier in the north compared to the south.
- NLCs occur about 3 km higher in the south, consistent with the elevated southern mesopause.
- Northern NLCs have greater ice mass densities, and are characterized by slightly more aspherical particles than in the south.
- Water vapor measurements in NLCs are similar in both hemispheres.
- A population of very small ice particles, at higher altitudes than the visible NLC particles, has been measured. This layer is likely what causes the strong radar echoes found in the summertime mesosphere.
- Mesospheric ice particles occur in one continuous layer extending from below the main peak at 83 km up to around 90 km.

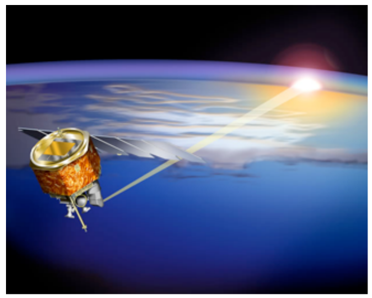

FIGURE 1. Illustration of the AIM spacecraft in orbit. SOFIE is visible on the bottom of the platform, as it collects limb transmittance profiles in solar occultation, viewing the Sun through the limb of the atmosphere. SOFIE records 30 such occultations each day.

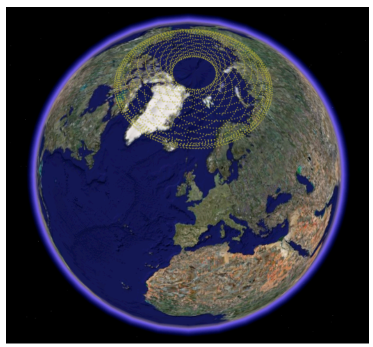

FIGURE 2. Measurement locations for SOFIE. Yellow dots indicate tangent point locations for a six-month period (Jun – Dec, 2007). The tangent point latitude oscillates slowly between 65 deg N at solstice and 85 deg N at equinox. A similar pattern develops in the Southern hemisphere (not shown).

species	wavebands (microns)	altitude range (km)	precision
T	4.3	50 – 105	0.1 K
T	2.5, 2.6, 4.3, 4.6	15 – 110	TBD
T	0.70	5 – 50	0.5 K
O_3	0.29	50 – 100	3 ppbv
H_2O	0.87	50 – 95 15 – 105	21 ppbv TBD
CO_2	2.5, 2.6, 4.3, 4.6	15 – 95	TBD
CH_4	3.4	50 – 79 15 – 90	13 ppbv TBD
NO	5.0, 5.3	80 – 110	TBD
NLC extinction	0.87, 1.0, 2.5, 2.9, 3.1, 3.2, 3.5, 4.6	78 – 90	2 x10^{-8} km^{-1}

TABLE 1. SOFIE data products. For each product, the wavebands used in the retrieval, the approximate altitude range of the retrieved profiles, and the average precision achieved are listed. Items in grey are under development, and will be available to the public in a future data release.

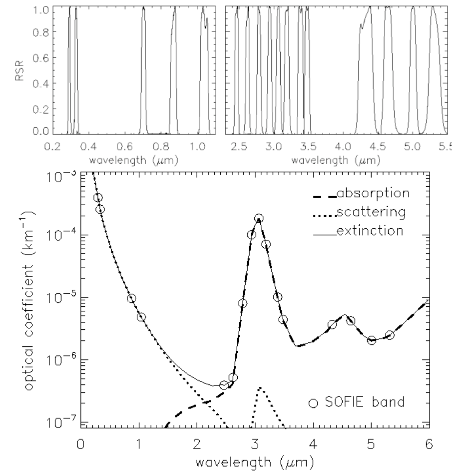

FIGURE 3. SOFIE spectral coverage. Top panel: relative spectral response (RSR) of each of the 16 SOFIE bandpasses, and sun sensor (0.7 microns). Bottom panel: location of these measurements (circles) on a simulated NLC spectrum. The contributions of scattering and absorption are shown separately as dotted and dashed lines respectively. Their cumulative effect is the extinction, shown as the solid line. The prominent ice O-H stretch feature at 3 microns is well sampled by several SOFIE bands.

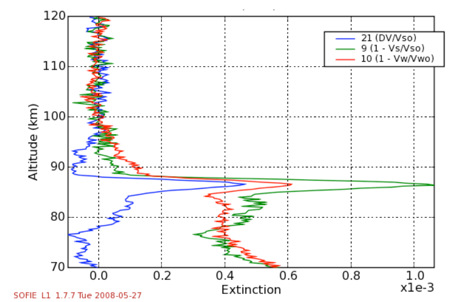

FIGURE 4. Example NLC extinction profile. This was the first NLC seen by SOFIE this season (2008 Northern hemisphere). Extinctions are in units of km^{-1}. The NLC signature is unmistakable as the peak in extinction near 87 km. The green and red lines are the extinction profiles from the 3.1 and 3.2 micron channels (bands 9 and 10) respectively. The blue line indicates the differential signal formed from this channel pair.

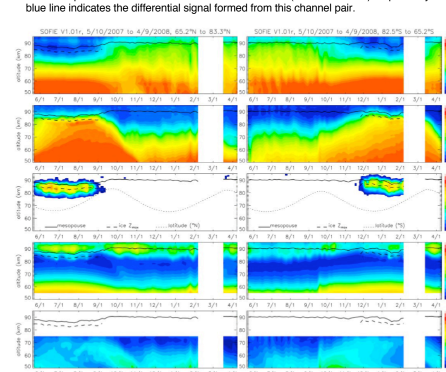

FIGURE 5. Time versus altitude cross-sections of SOFIE temperature, H_2O, NLC occurrence frequency, O_3, and CH_4. Left panels are Northern hemisphere; right are Southern. Apparent in both are the increasing H_2O and the sudden appearance of ice.

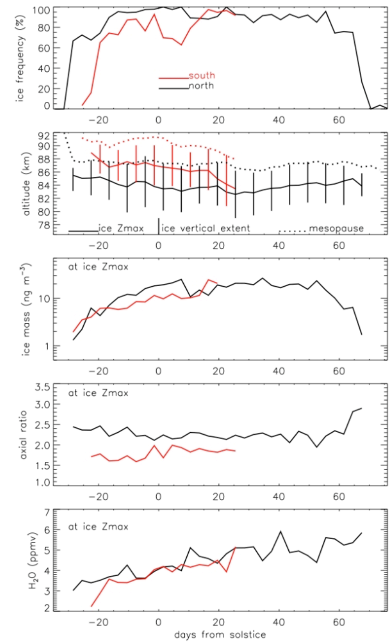

FIGURE 6. Hemispheric differences in NLCs and their environment. SOFIE results for the Northern polar region during Jun – Aug 2007, and the southern polar region during Dec 2007 – Feb 2008. Ice is more frequent and appears about 10 days earlier in the north compared to the south. The altitude of peak extinction (Zmax) for southern NLCs is about 3 km higher, consistent with the southern mesopause being about 3 km higher than in the north. Northern NLCs have greater ice mass densities, and are characterized by slightly more aspherical particles, than in the south. Water vapor measurements at Zmax are similar in the north and south.

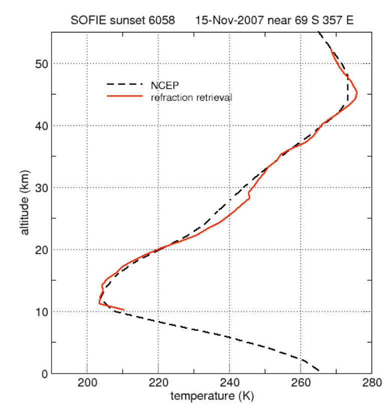

FIGURE 7. Example of SOFIE temperature retrieval based on refraction angle measurements. Data from the solar imager provide a measure of the angular height of the refracted Sun. Using these data we retrieve refraction angle profiles, which are subsequently inverted into temperature profiles. In the next release of science products we anticipate using this technique to compliment the existing CO_2-based temperature retrievals, extending the profiles into the troposphere.