MLTS-02: Investigation of the Role of Water Vapor and Temperature in Noctilucent Cloud Formation

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Abstract

Five noctilucent clouds observed by lidar at Poker Flat (65° N, 147° W) are presented. Microwave limb sounder temperature and water vapor data is used to characterize the mesospheric environment during the NLC lidar observations. All noctilucent clouds occurred during temperatures below 150 K, with most clouds occurring during or near a local cooling. The exception to the local cooling is the 2018 NLC which occurred after a recent local increase in water vapor. NLCs with the highest integrated backscatter coefficients occurred at the lowest temperatures, near 142 K.

Introduction

Noctilucent clouds (NLCs) have become entities of interest to potentially track global climate change through their sensitivity to temperature and water vapor changes in the mesosphere. The focus of this research is to investigate the impact of environmental conditions (i.e., water vapor and temperature) on NLCs observed at Poker Flat Research Range (PFRR). The NLCs are characterized by the lidar measurements. The environmental conditions are characterized by Microwave Limb Sounder (MLS) data.

Lidar Observations of Noctilucent Clouds

Since the installation of the Rayleigh lidar system at PFRR in 1997, NLCs have been observed by the lidar in many summers. Five NLCs are examined here from the summers of 2018, 2010, 2007, and 2005. The most recent NLC observation on August 10, 2018 is highlighted in detail to the right.

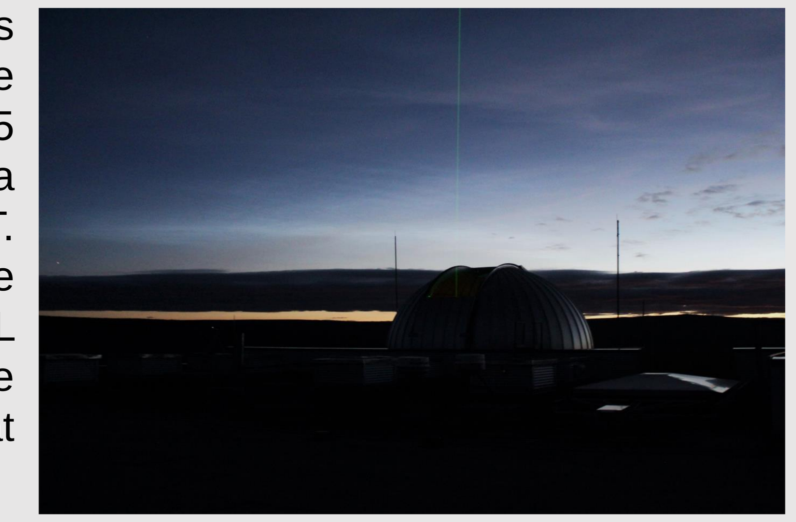
The Rayleigh lidar transmitter is a Nd:YAG laser that operates at 532 nm with a pulse repetition rate of 20 pulses per second. During data acquisition, raw data profiles represent the integration of 1000 pulses over 50 seconds. In NLC data processing, the Rayleigh photon count data is integrated over 300 seconds (6000 shots) and then smoothed with a running average over 0.225 km.

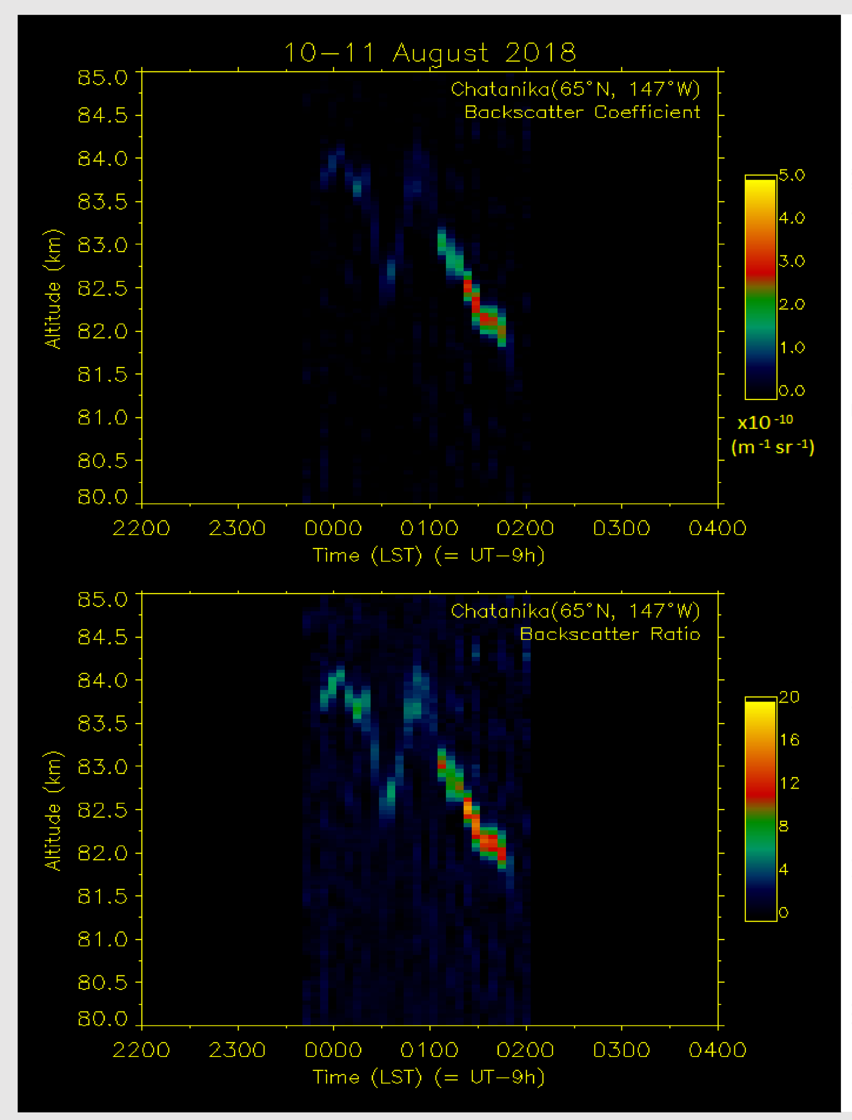
The lidar signal is the sum of the signal due to aerosol scatter and the molecular Rayleigh scatter. The lidar signal below the cloud is extrapolated upwards to yield an estimate of the Rayleigh scatter signal at the cloud altitude. The ratio of the total lidar signal to the estimated Rayleigh scatter signal yields the total (molecular plus aerosol) backscatter ratio (BR). The aerosol BR is the total BR minus one. The volume aerosol backscatter coefficient (BC) is the product of the aerosol BR and the Rayleigh BC. The BR and BC show the evolution of the cloud. The IBC is calculated by integrating the BC over a 4km altitude range of the cloud.

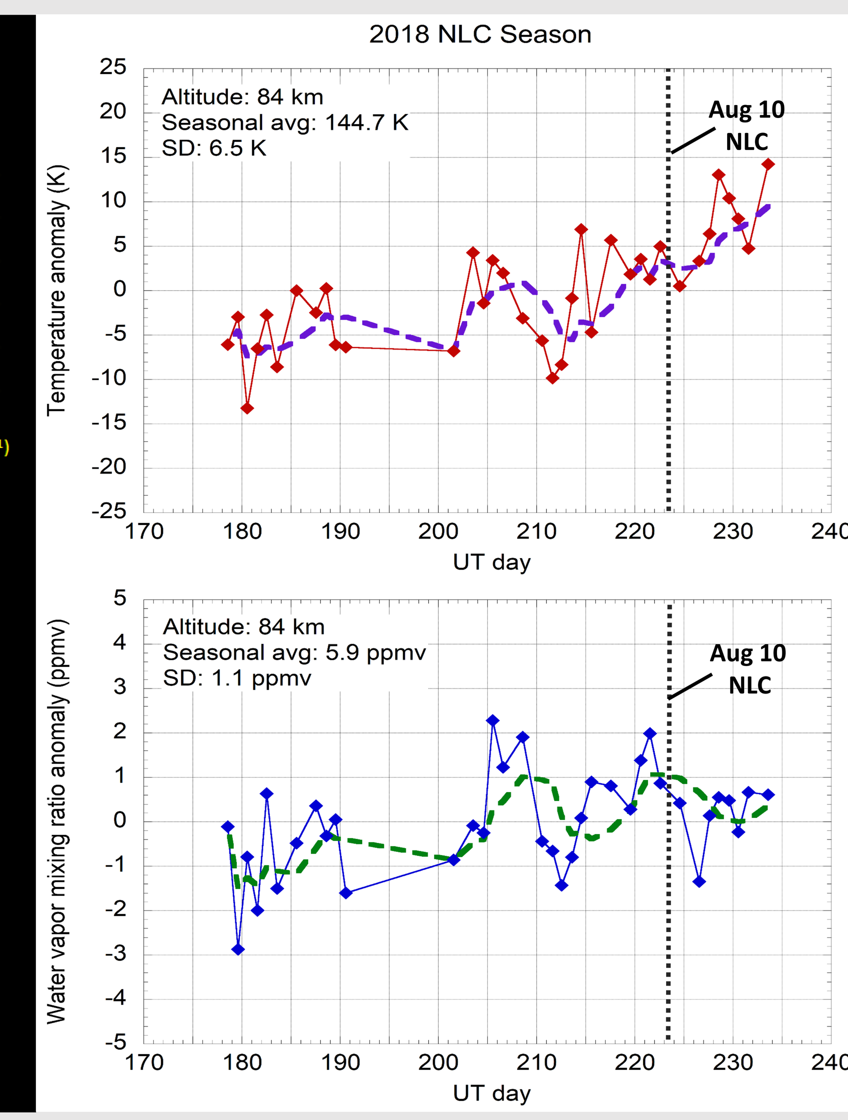
Lidar data is displayed in 2-D plots of BC and BR against time and altitude for each NLC. BC values of 5 x10^{-10} m^{-1} sr^{-1} and BR values of 20 are contoured in white. Maximum and average integrated backscatter coefficients (IBC) are reported in the summary table.

The 2018 Noctilucent Cloud

The Rayleigh lidar and Sodium Resonance Wind Temperature Lidar (SRWTL) were operated during an NLC observation on August 10, 2018. The NLC was detected by the Rayleigh lidar just before 2400 (LST) and remained visible in the data and to ground observers for over 2 hours. The photo below shows NLC structure to the northwest of the PFRR lidar lab. The 2-D BC and BR plots show that the NLC was detected as a single layer with a vertical thickness of less than 0.25 km for most of the night. The cloud reached a maximum IBC of 1.4 x 10^{-7} sr^{-1} at 0128 LST. The peak BC was 3.1 x 10^{-7} m^{-1} sr^{-1} and the peak BR was 15 at this time. SRWTL measurements show an average temperature of 144 K and a southward wind of 25 m/s at 84.5 km.







Characterizing the Mesosphere with MLS

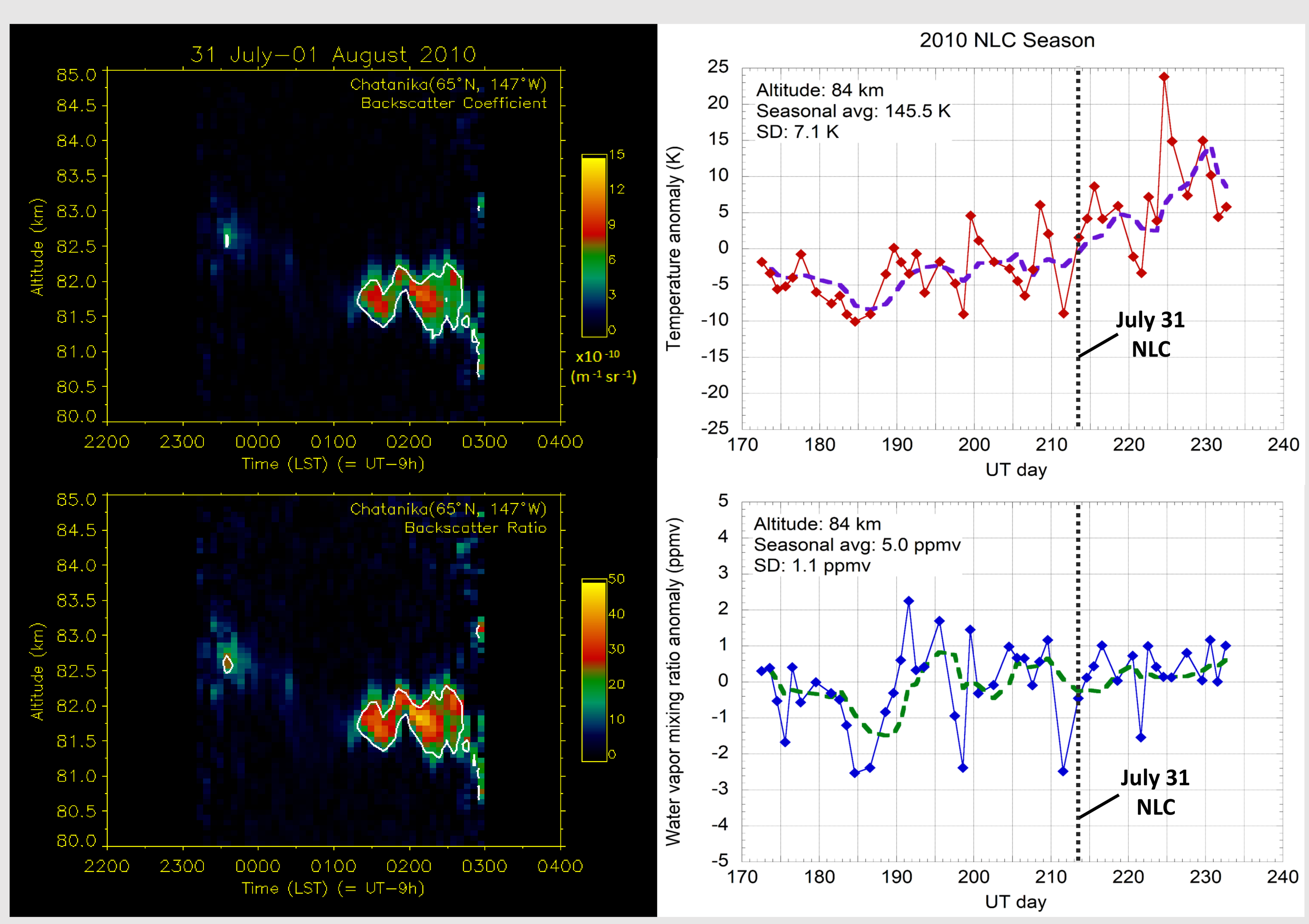
The MLS is an instrument onboard NASA's Aura satellite and began operation in August 2004. MLS water vapor and temperature data is used to characterize the mesosphere during NLC season. Here, an NLC season is defined a 61 day period beginning on summer solstice (June 21-August 21). MLS water vapor and temperature data within the range of [(154° W, 62° N),(140° W, 68° N)] and time ~3AM LST are averaged per day. Seasonal water vapor and temperature means are calculated and daily anomalies are shown in red (blue) for temperature (water vapor). A 7-day running average is plotted as the purple (green) dashed line for temperature (water vapor).

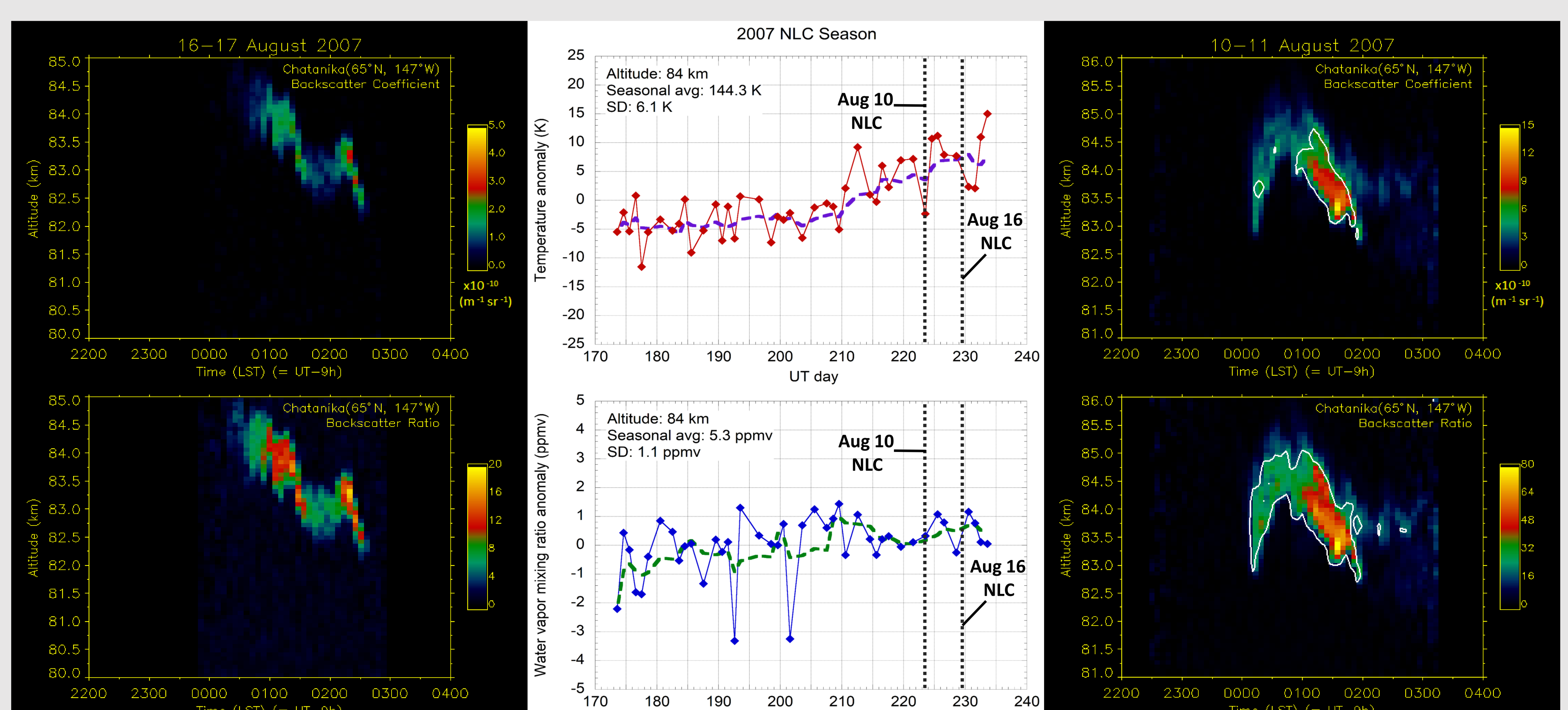
The 2010, 2007, and 2005 NLCs all occurred during or near a local cooling. The 2018 NLC occurred after a water vapor increase. All NLCs occurred during temperatures below 150 K. The table below summarizes the temperature and water vapor levels and the corresponding maximum and average IBC for each NLC. The NLCs on August 10, 2007 and August 9, 2005 have the highest IBCs and occurred in an environment at least 5 K colder than the other three NLCs. The two NLCs in 2007 may demonstrate the effect of temperature on NLC brightness; the water vapor levels are nearly the same, but the NLC with the higher IBC occurred in an environment that was over 7 K colder.

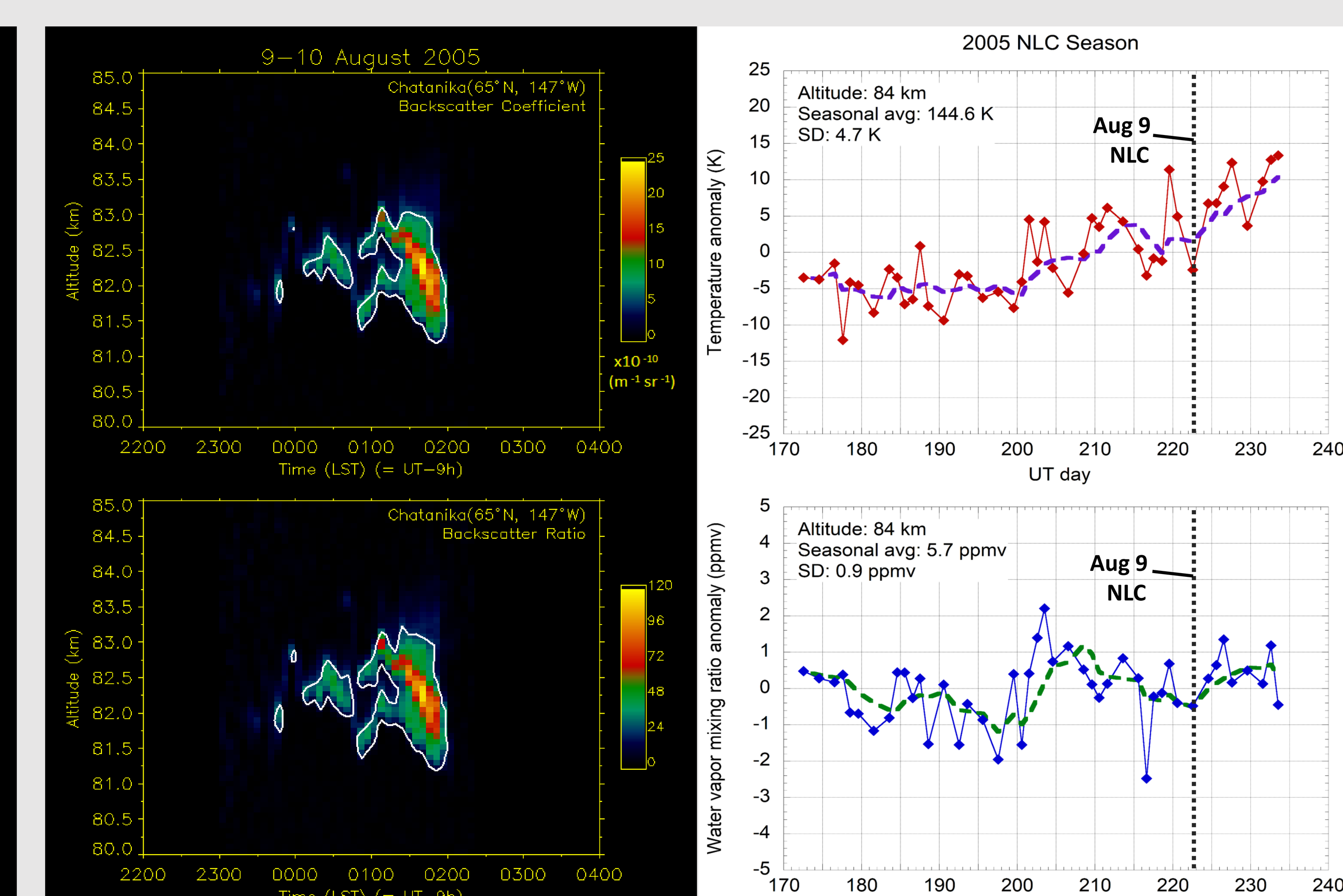
NLC lidar observation date	UT Day of Year	MLS temperature (K)	MLS water vapor (ppmv)	Maximum IBC (sr^{-1})	Average IBC (sr^{-1})
August 10, 2018	223	147.4	6.6	1.4 x 10^{-7}	4.4 x 10^{-8}
July 31, 2010	213	147	4.5	8.1 x 10^{-7}	3.3 x 10^{-7}
August 16, 2007	229	149.4	5.7	1.6 x 10^{-7}	9.3 x 10^{-8}
August 10, 2007	223	142	5.6	1.1 x 10^{-6}	4.8 x 10^{-7}
August 9, 2005	222	142.2	5.2	2.3 x 10^{-6}	6.7 x 10^{-7}

Future Work

The Rayleigh lidar and SRWTL will be operated during NLC season in 2019. The installation of a third channel in the SRWTL will provide 3-D winds, which will further characterize the mesospheric environment during future NLC observations. MLS analysis will be further developed and be used to investigate planetary wave activity in the summer mesosphere.







Acknowledgements

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Further Reading

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