Initial Results of Na Lidar Measured Stratospheric Temperatures at Andes Lidar Observatory (30.3°S, 70.7°W)

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Introduction

Na lidar technique has been used to investigate thermal and dynamic process in mesosphere and lower thermosphere (MLT) for decades which plays important role in understanding the atmospheric circulations. Traditional research based on Na lidar data has been concentrated on the 85-105 km region, especially the gravity waves studies. However, gravity waves exist not only in MLT region but also in troposphere and stratosphere. To better understand the thermal structure and the propagation characteristics of gravity waves from lower atmosphere like stratosphere to mesosphere, we use the Rayleigh signals from a Na lidar to derive the stratospheric temperature and study the gravity waves. In this study, we use MSIS-00 model and TIMED-SABER data to calibrate the retrieved stratospheric temperature, and one night was chosen to investigate gravity waves characteristics and propagation with the earlier published case study in the mesopause region[*Huang,2017*].

Lidar Data

ALO Lidar location	**30.3°S 70.7°W**
Date	**7/21/2015**
Raw Data Resolutions	**6 s, 25 m**
Retrieved Temperature Resolution	**10min, 1 km**
Altitude	**30-70km**

Methods

Temperature retrieval:

The method of *Hauchecorne and Chanin* [1980]

Relative Density

$$\frac{\rho(z)}{\rho(z_0)} = \frac{z^2\left(N(z)-N_B\right)}{z_0^2\left(N(z_0)-N_B\right)}$$

Hydrostatic Equilibrium

$$dp = -\rho g dz$$

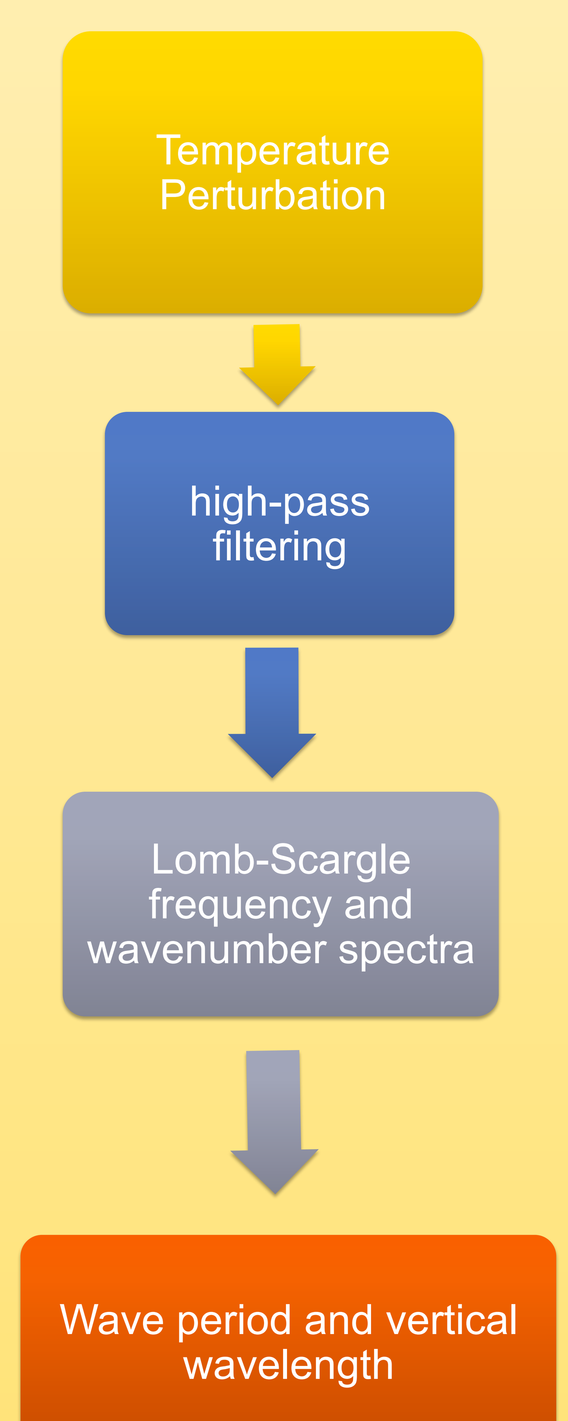
Idea Gas Law

$$p = \rho R T$$

Temperature

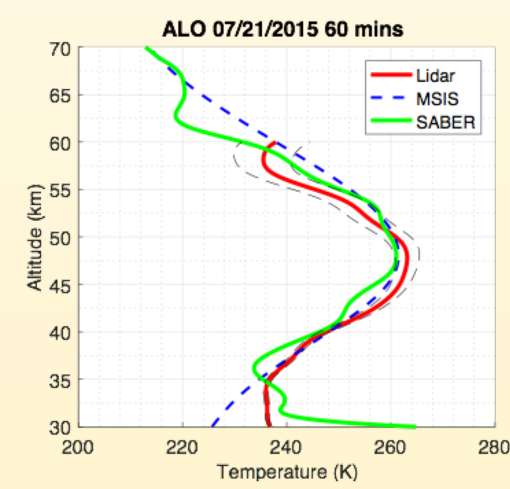
$$T(z) = T(z_0)\frac{\rho(z0)}{\rho(z)} + \frac{1}{R}\int_z^{z_0} g(r)\frac{\rho(r)}{\rho(z)}dr$$

Gravity waves parameters extraction:

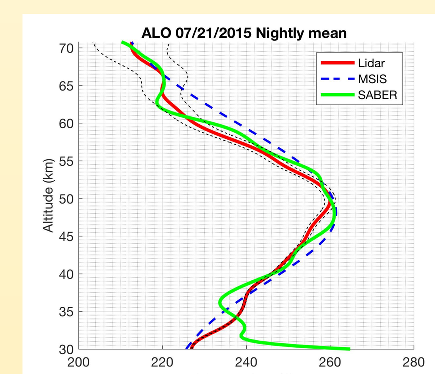


Results

Temperature profile



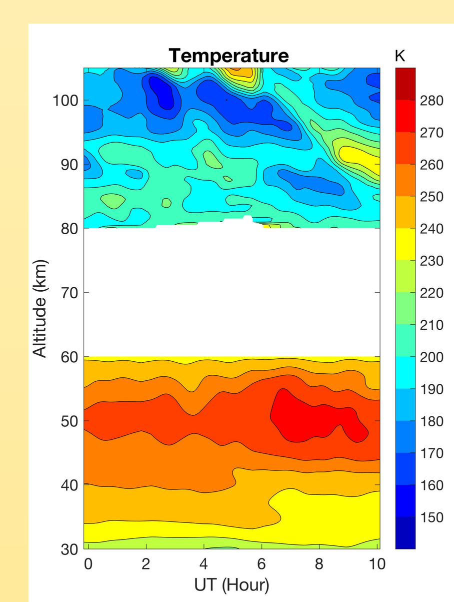
Altitude (km)	Uncertainty (K)
30	0.4
40	1.2
50	3.5
60	7.1



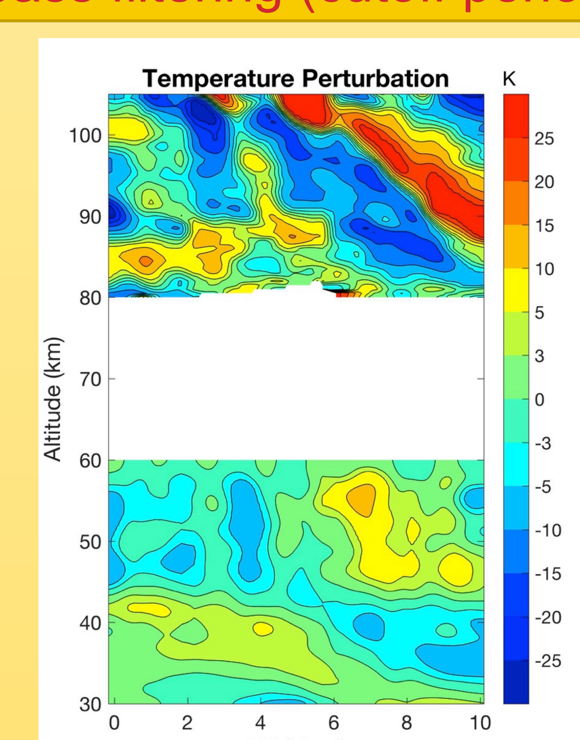
Altitude (km)	Uncertainty (K)
30	0.2
40	0.6
50	1.7
60	3.7
70	9.6

The retrieved Rayleigh temperatures agree very well with MSIS-00 model and SABER temperature. Both hourly mean and nighty mean temperature uncertainties are less than 10K.

Stratospheric temperatures on 07/21/2015

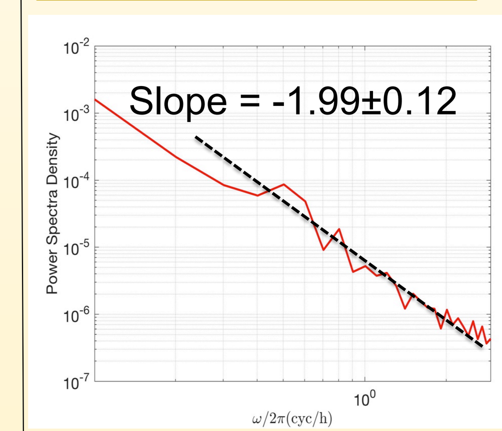


Temperature perturbations with high-pass filtering (cutoff period: 8h)

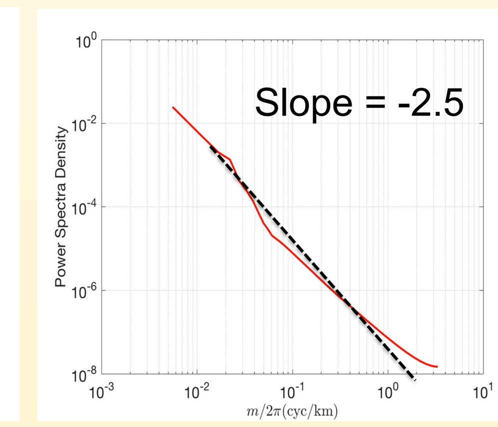


Results

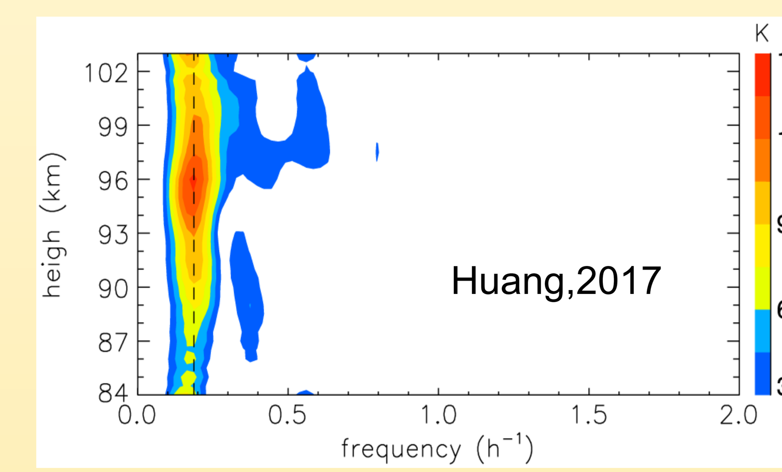
Frequency power spectrum

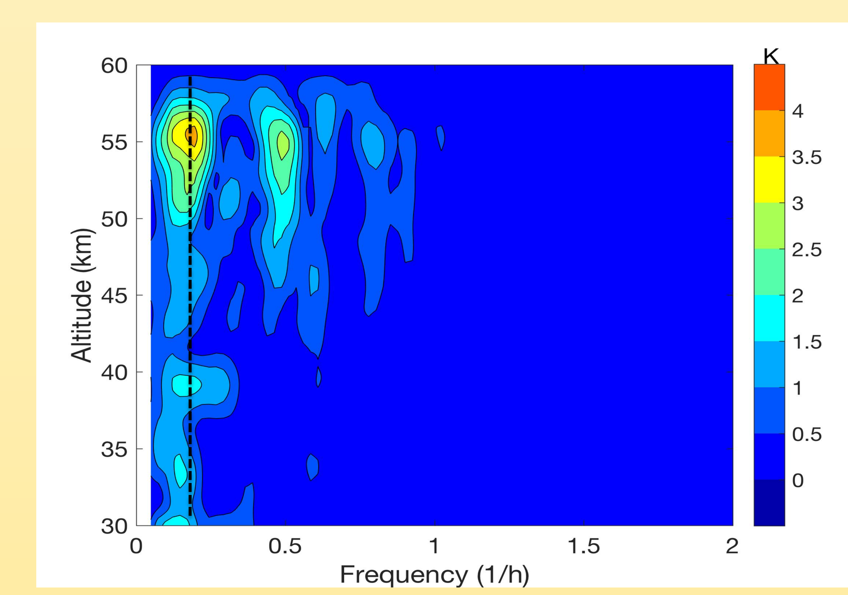


Vertical wavenumber power spectrum

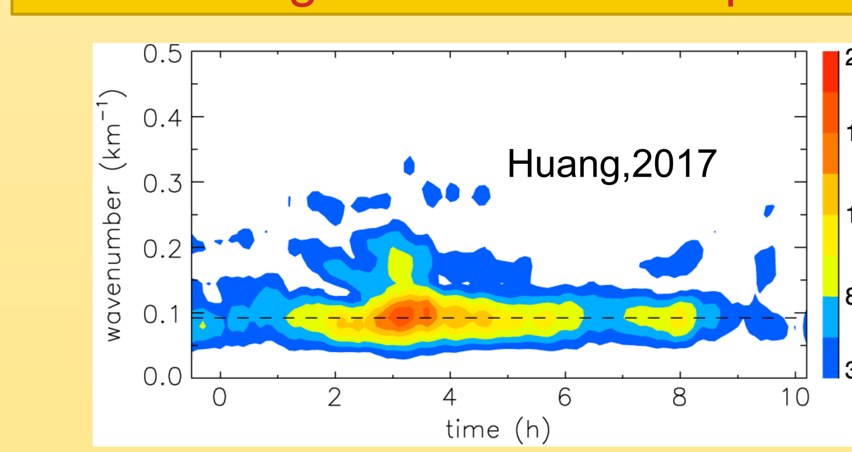


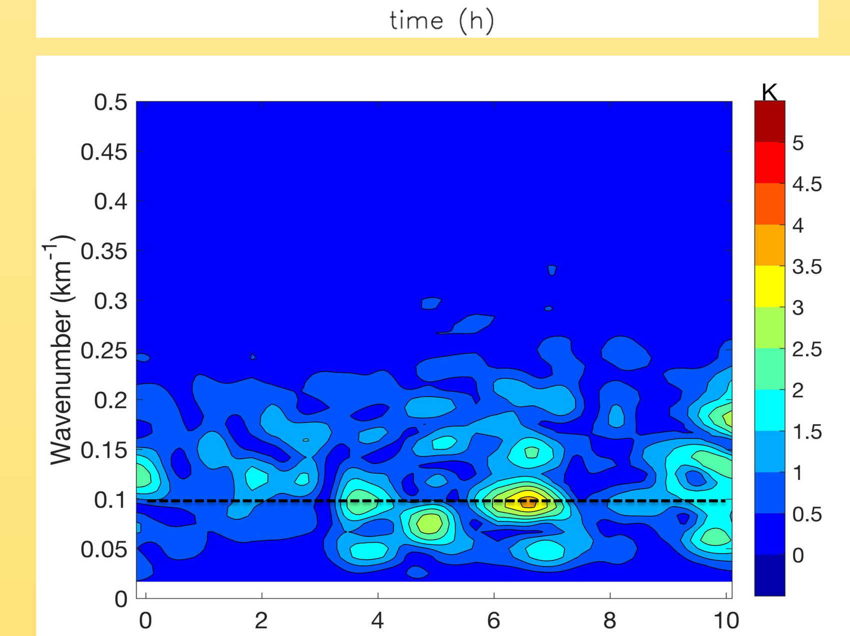
Lomb-Scargle frequency spectra





Lomb-Scargle wavenumber spectra





Conclusion

- The results show that nightly mean temperature profiles can be derived between 30 km to 70 km and hourly mean temperature profiles can be derived between 30 km to 50 km, with error less than 10K.
- The Lomb-Scargle frequency spectra and Lomb-Scargle wavenumber spectra show that a ~5 h period and 10 km wavelength gravity waves which are consistent with the parameters in MLT found by *Huang* [2017] using Na layer signals at the same time.
- This work confirms the possibility of obtaining stratospheric temperature using Na lidar data, will enrich the stratospheric temperature dataset, and enable the study of gravity wave propagation from the stratosphere to the mesopause at ALO.

Acknowledgement

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References

Hauchecorne, A., & Chanin, M. L. (1980). Density and temperature profiles obtained by lidar between 35 and 70 km. *Geophysical Research Letters*, *7*(8), 565-568.

Huang, K. M., A. Z. Liu, S. D. Zhang, F. Yi, C. M. Huang, Y. Gong, Q. Gan, Y. H. Zhang, and R. Wang (2017), Simultaneous upward and downward propagating inertia-gravity waves in the MLT observed at Andes Lidar Observatory, *J. Geophys. Res. Atmos.*, 122, 2812–2830, doi: 10.1002/ 2016JD026178.

Lu, X., A. Z. Liu, G. R. Swenson, T. Li, T. Leblanc, I. S. McDermid (2009), Gravity wave propagation and dissipation from the stratosphere to the lower thermosphere, *J. Geophys. Res.*, *114*, D11101.