ITMA-1: GeoMAL Rayleigh Lidar Observations of the Arctic Middle Atmosphere at Poker Flat

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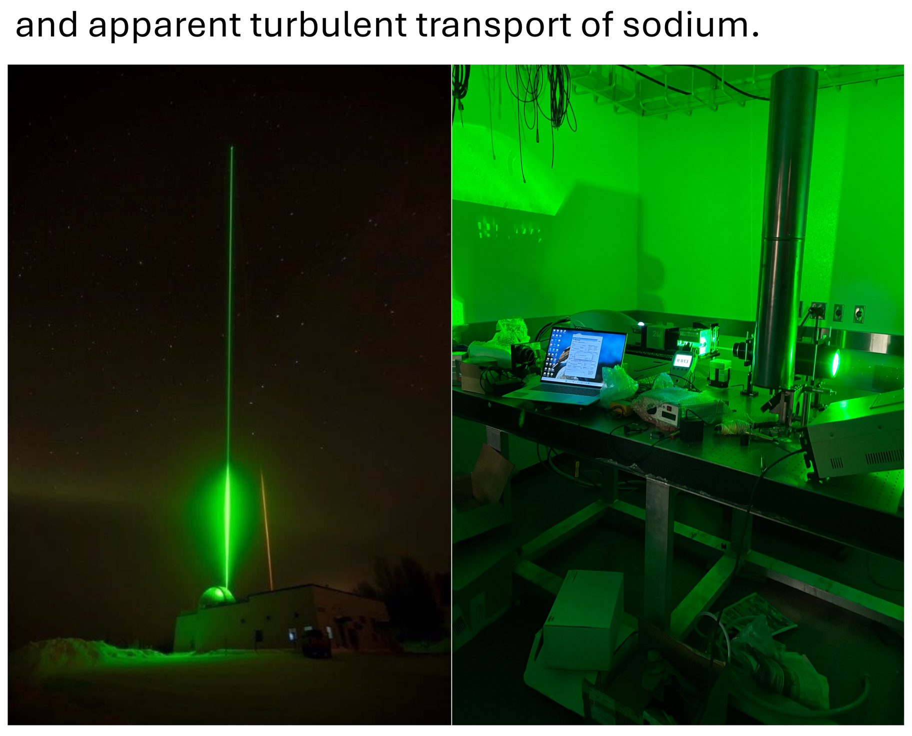
Abstract

The Geospace and Middle Atmosphere Lidar (GeoMAL) system is being developed at Poker Flat Research Range to support Arctic middle atmosphere studies. This poster presents preliminary analysis of early GeoMAL Rayleigh lidar measurements, including signal quality, background subtraction, range correction, and altitude-dependent signal behavior. The analysis also includes recent coordinated observations with the sodium resonance wind-temperature lidar system, which provide useful test cases for future combined Rayleigh–sodium lidar studies. These preliminary results help evaluate the current GeoMAL performance and support future improvements in lidar alignment, data processing, and observation strategy

Introduction

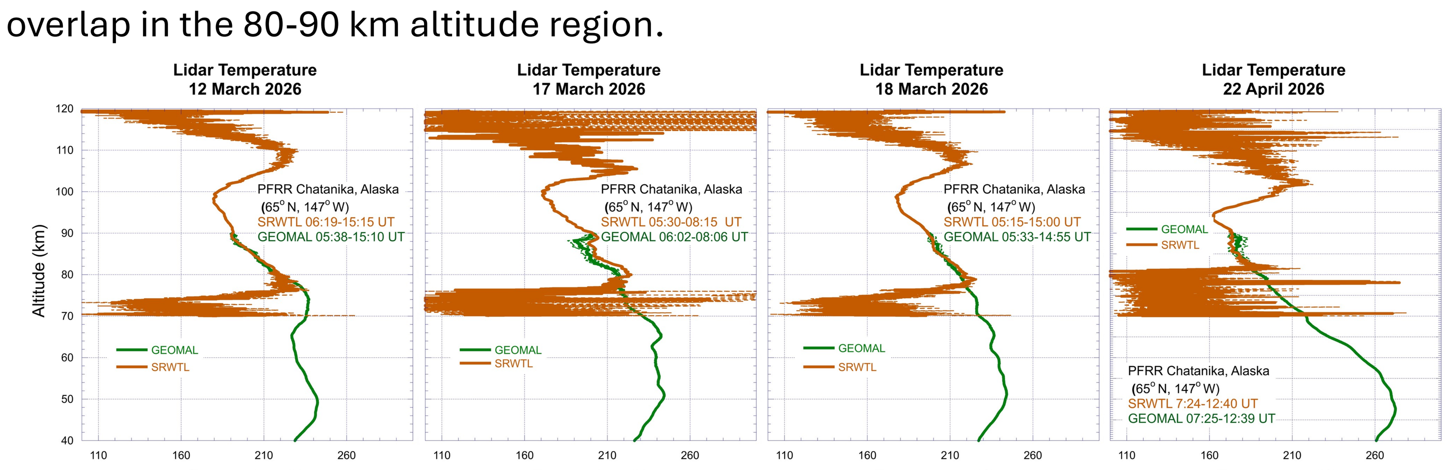
Wave-breaking in the mesosphere and lower thermosphere is a major contribution to circulation and transport in the middle atmosphere. Breaking waves are associated with convective instability that gives rise to turbulent transport. This transport is not well described in current models. In this paper we present initial observations of convective instabilities and apparent turbulent transport of sodium.

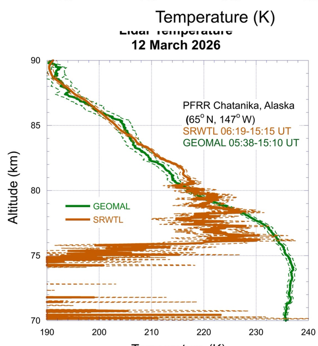


Coordinated measurements were made with both Rayleigh and Resonance Lidars that yielded continuous measurements from the stratopause to the lower thermosphere (approximately 40-110 km). This poster presents observations made with the new GeoMAL Rayleigh Lidar (pictured externally and internally above) collocated with the Sodium Resonance Wind-Temperature Lidar (SRWTL) at Poker Flat Research Range, Chatanika, Alaska (65° N, 147° W) in Spring of 2026. GeoMAL measured temperature and density in the stratosphere and mesosphere (~40-90 km). The SRWTL measured temperature and sodium density in the sodium layer (~80-110 km).

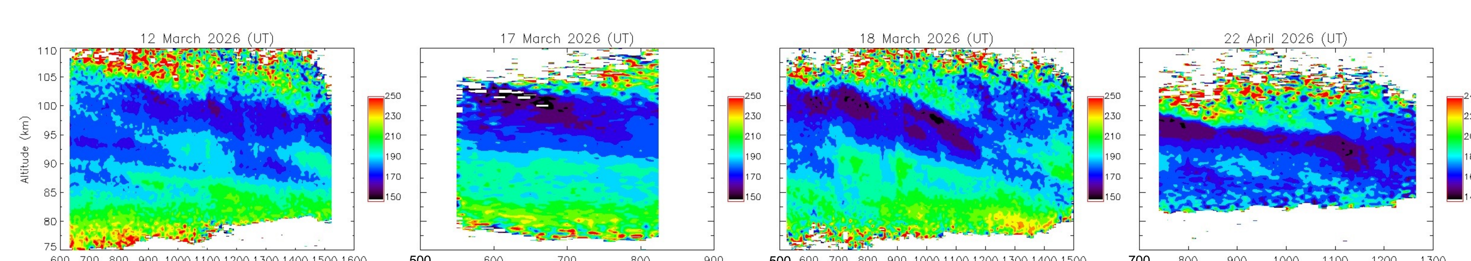
Rayleigh and resonance lidar temperatures

GeoMAL yield temperature profiles from 40 to 90 km at 1 h resolution. The SRWTL yielded temperature profiles from ~80 km to ~105 km at 5 min resolution. GeoMAL is powerful enough to yield measurements that extend upward into sodium layer at 90 km. Thus, the two lidars yield a continuous temperature profile from 40- km to ~105 km. The Rayleigh and resonance lidar temperature profiles are consistent where they overlap in the 80-90 km altitude region.



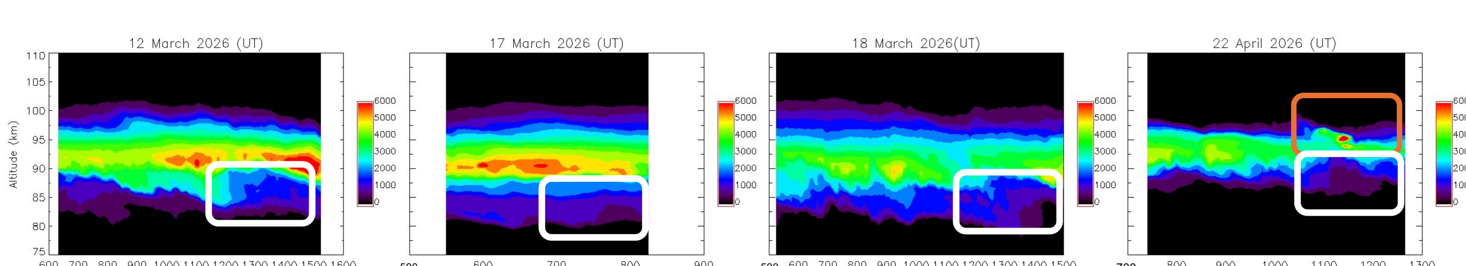


These four nights of data show the stratosphere warming between mid-March (~240 K) and late April (~270 K). The stratopause decreases in altitude from ~ 50 km to ~45 km. The mesopause also decreases in altitude from ~100 km to 95 km and cools from ~ 170 K to ~ 160 K. The SRWTL temperature measurements show the presence of strong tides with characteristic downward phase progressions.



Resonance lidar sodium

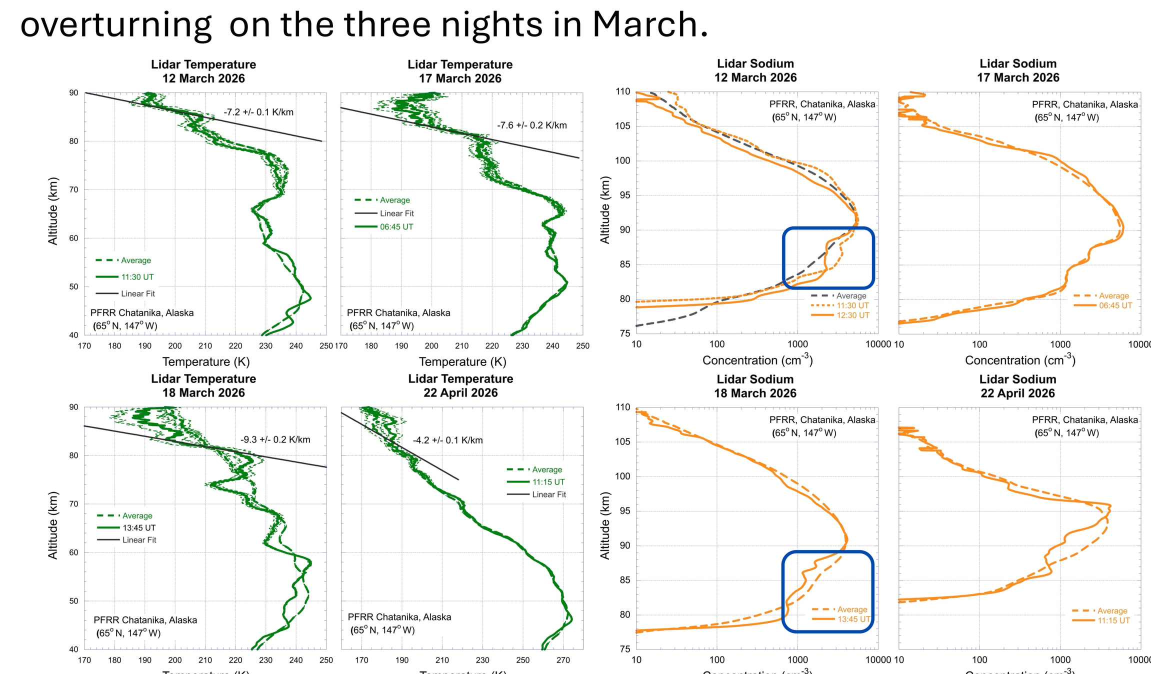
The SRWTL also yields sodium measurements in the sodium layer. The sodium serves as a material tracer of waves. In the lower edge of the sodium layer the sodium is in a fast equilibrium with other more abundant chemicals (e.g., atomic oxygen, ozone) having time constants of ~ 1 h.



Overturning (white boxes) is observed in the bottom side of the layer where the regions of higher sodium are found beneath regions of lower concentration (i.e., a reversal of the vertical gradient) at altitudes below 90 km on 12 March and 18 March 2026. On 17 March there is a not a reversal of the vertical gradient, but there is a significant reduction in the vertical gradient. On the 22 April the lower edge of the sodium layer is about 5 km higher than in March consistent with the cooling of the upper mesosphere as spring progresses into summer. A sporadic layer is also evident (orange box) near 95 km. This indicates a significant plasma enhancement at that altitude that may complicate the interpretation of gradients in the sodium layer.

Instability and sodium transport

The GeoMAL temperature show near adiabatic lapse rates (i.e., 9.8 K/km) in the 80-90 km region profiles during the periods of sodium overturning on the three nights in March.



On March 12 and 18 there is spreading of the sodium layer coincident with the near adiabatic lapse rates. This initial analysis suggests that the near adiabatic lapse rate coincides with a well-mixed turbulent layer that arises from wave-breaking.

Conclusions & Further Work

Initial GeoMAL and SRWTL measurements have revealed adiabatic lapse rates associated with material spreading of the sodium layer. This suggests generation of turbulence by breaking waves. Further analysis of the mixing ratios and a mass continuity model will yield estimates of turbulent diffusion.

Acknowledgements

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Reading

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Student Profile

Anthony Zumpano is in his final year of a BS in Physics. He assisted in making the GeoMAL observations, operating the GeoMAL Rayleigh Lidar. He has conducted the retrieval, analysis and interpretation of the data as part of the lidar research team. Contact him at: **aazumpano@alaska.edu**