Indian Academy of Sciences, Bengaluru
Indian National Science Academy, New Delhi
The National Academy of Sciences India, Pryagraj

SCIENCE ACADEMIES'
SUMMER RESEARCH FELLOWSHIP PROGRAMME

P. B. No. 8005, C. V. Raman Avenue, Sadashivanagar Psot, Bengaluru 560 080
Telephone: (080) 2266 1207, 2266 1202, 2266 1221, Fax: (080) 2361 6094
Email: sumfel@ias.ac.in Website: www.ias.ac.in

Title	Detection of Convection-Triggered Gravity Waves in the Atmospheric Boundary Layer Using LiDAR Observations
Name	Mr. Sudhan R
Application Number	ENGS1672
Candidate's Institute	Sri Eshwar College of Engineering, Affiliated to Anna University
Name of the Guide	Dr. Y. Bhavani Kumar
Name of the Institute	National Atmospheric Research Laboratory (NARL)
Report	8 – Week Report

1. WORK CARRIED OUT AFTER THE FIRST FOUR WEEKS

After completing the initial understanding of LiDAR data structure and preliminary range-time visualization, the second phase of the project focused on deeper signal extraction, frequency analysis, and interpretation.

- The dataset provided contained over 850 LiDAR profiles in Licel `.C14` binary format, each corresponding to a 30-second vertical scan.
- All files were read using Python and converted into a structured format. A NumPy 2D array was generated where rows represented vertical bins (altitude) and columns represented time.
- The total vertical resolution was ~7.5 m per bin, and the data extended up to ~3.1 km altitude.

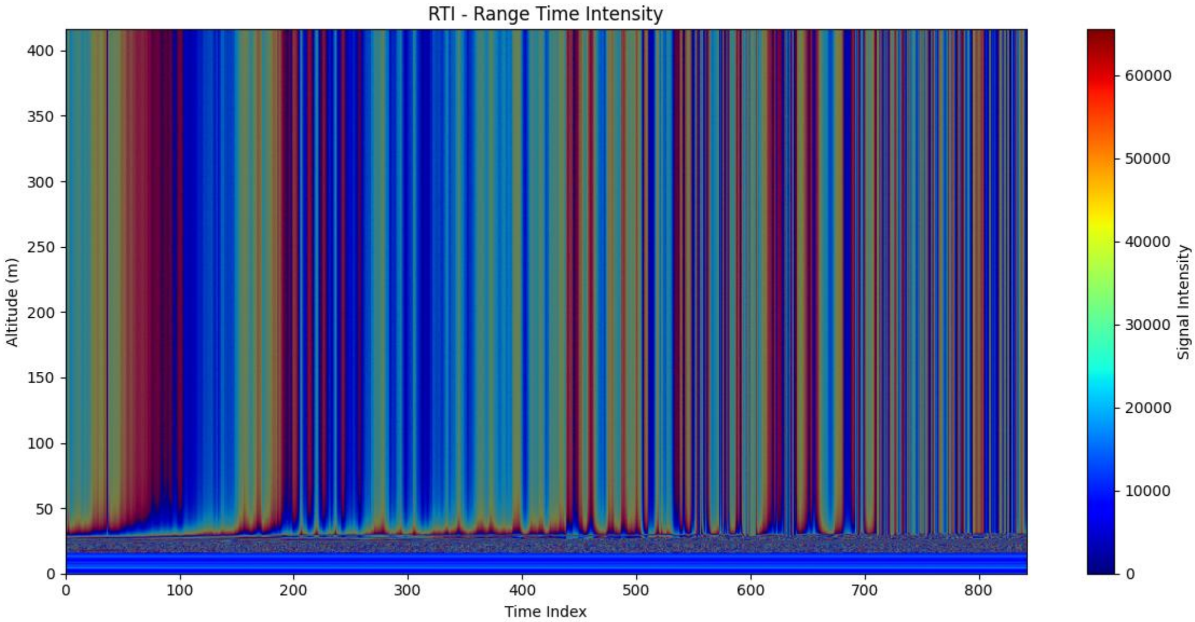


Figure 1: RTI - Range Time Intensity

2. SELECTION OF ALTITUDES AND TIME SERIES ANALYSIS

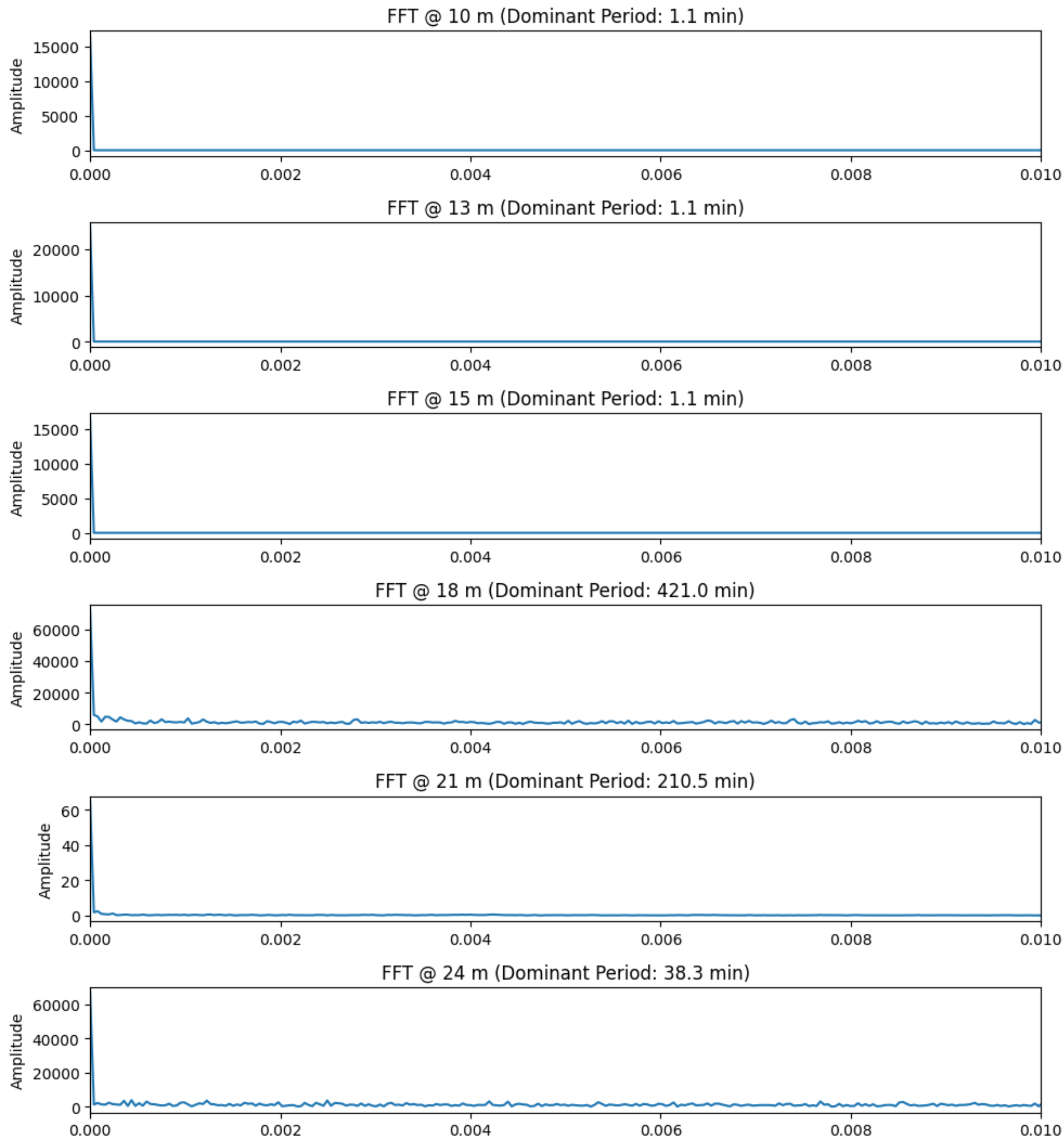
Based on RTI visual inspection, altitude bins between **750 m and 2600 m** showed clear periodic signal variations. Ten specific bins were selected at 200–250 m intervals for detailed time-series analysis.

- Time-series plots were generated for each altitude to observe visual oscillations.
- These plots helped in identifying potential regions where convection-triggered gravity wave activity was visible.

3. SPECTRAL (FFT) ANALYSIS

Fast Fourier Transform (FFT) was applied to each time series to detect dominant frequencies.

- Dominant peaks were identified in the range of **0.00027 to 0.00043 Hz**, corresponding to wave periods of **38 to 60 minutes**.
- These values match theoretical expectations for gravity waves generated by convective activity in the ABL.



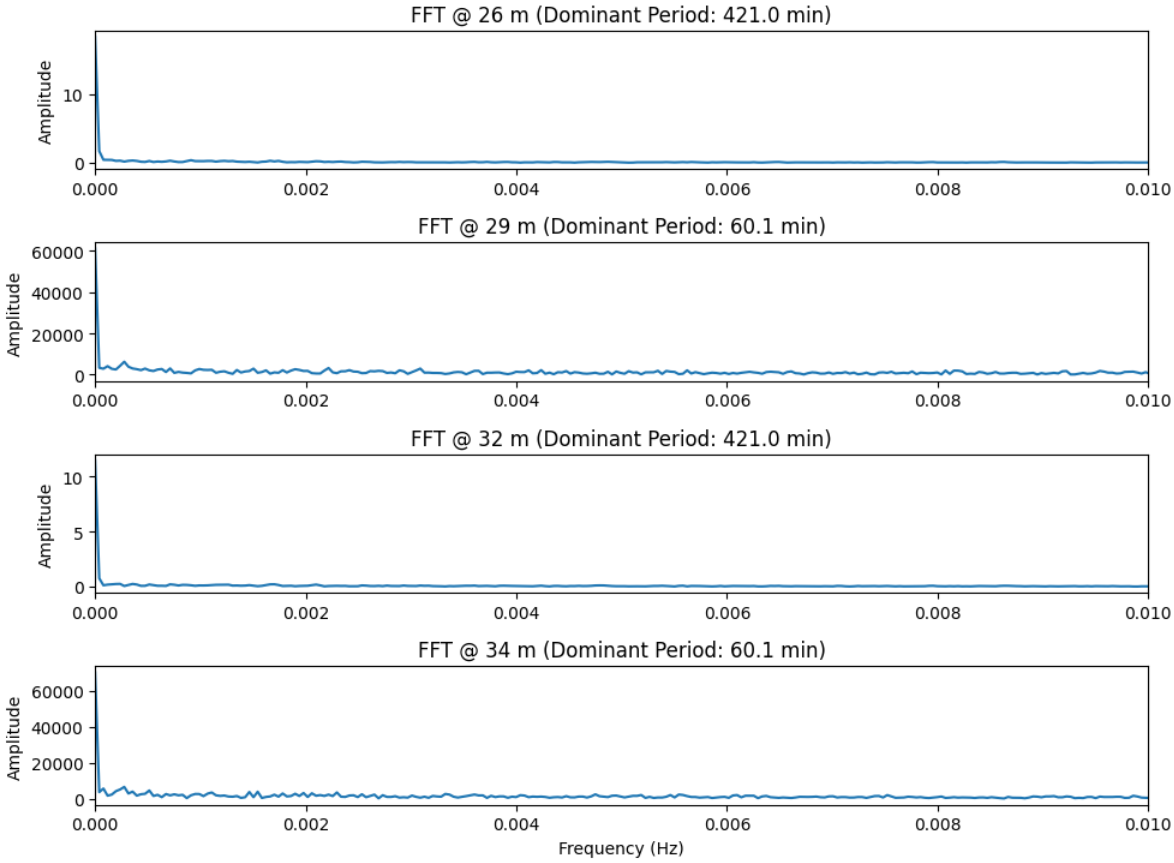
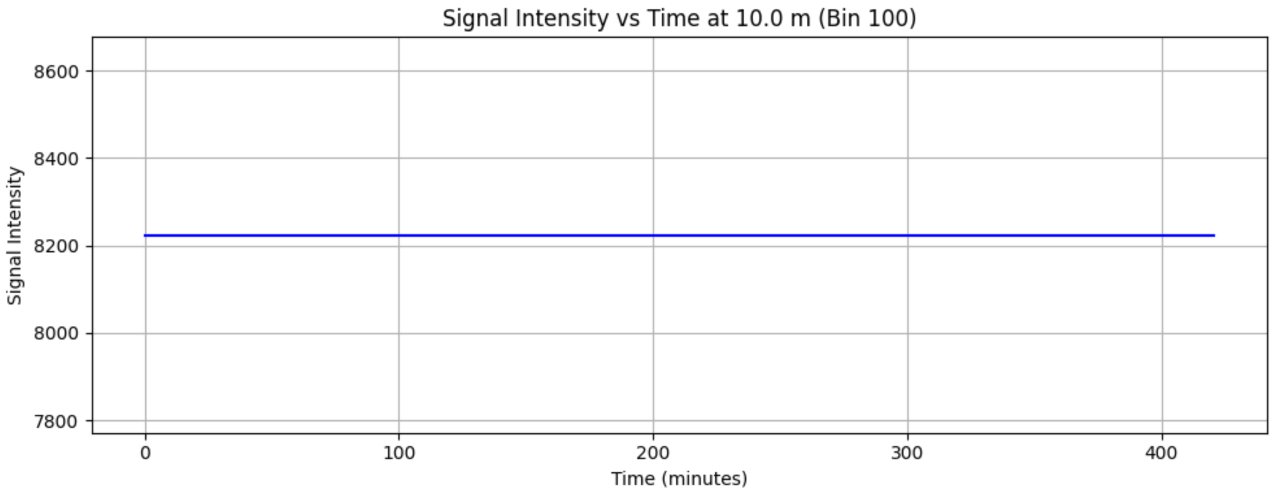
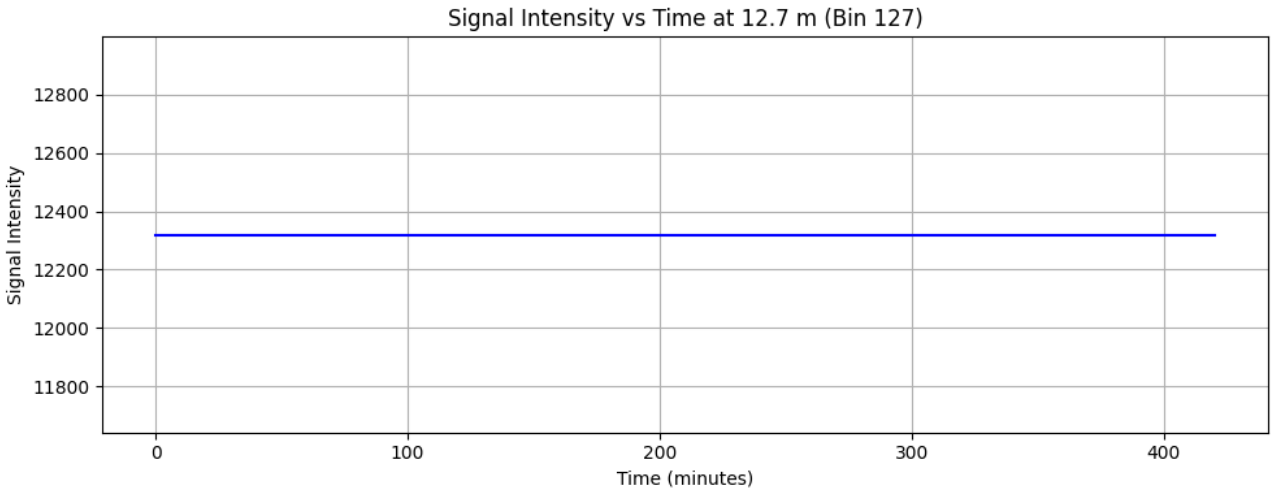
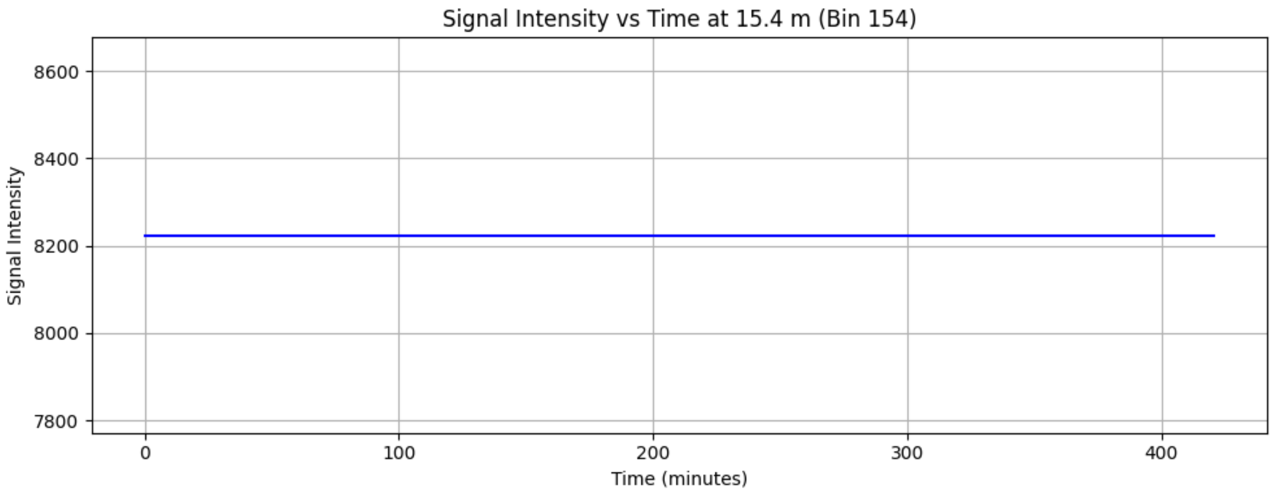


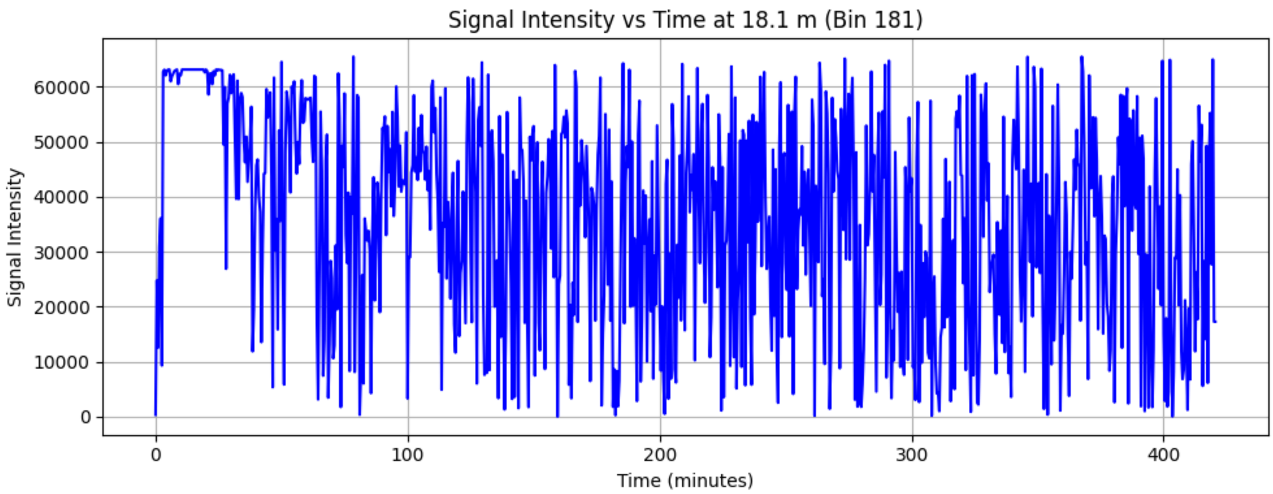
Figure 2: Fast Fourier Transform (FFT)

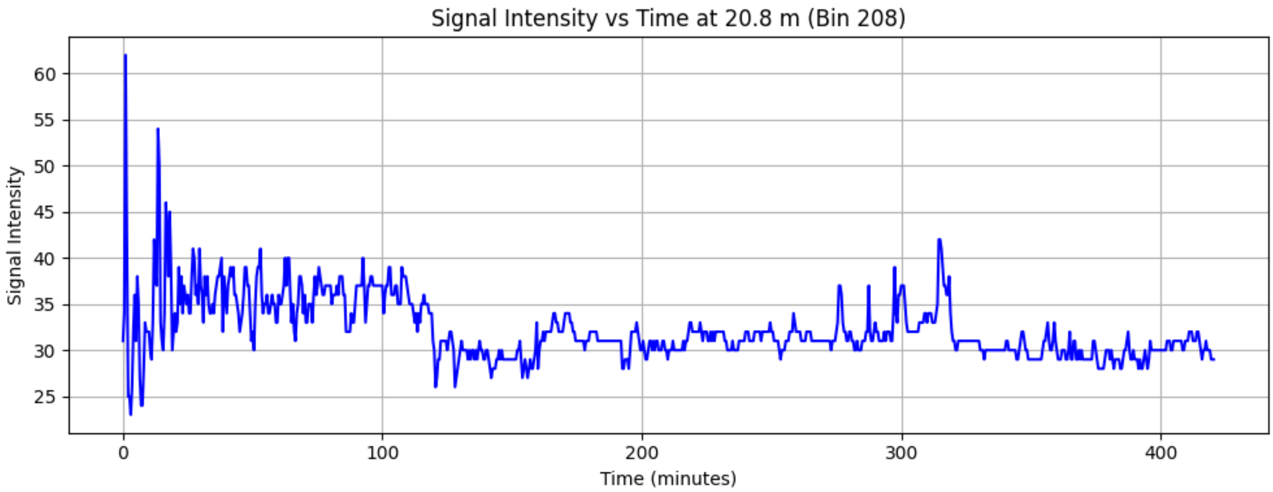
4. SIGNAL INTENSITY VS TIME

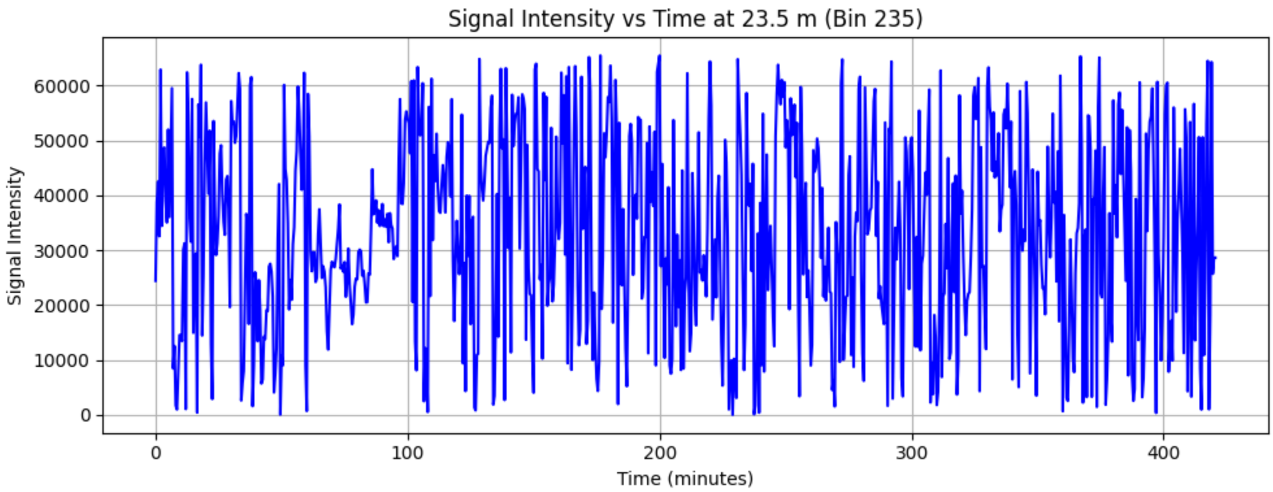


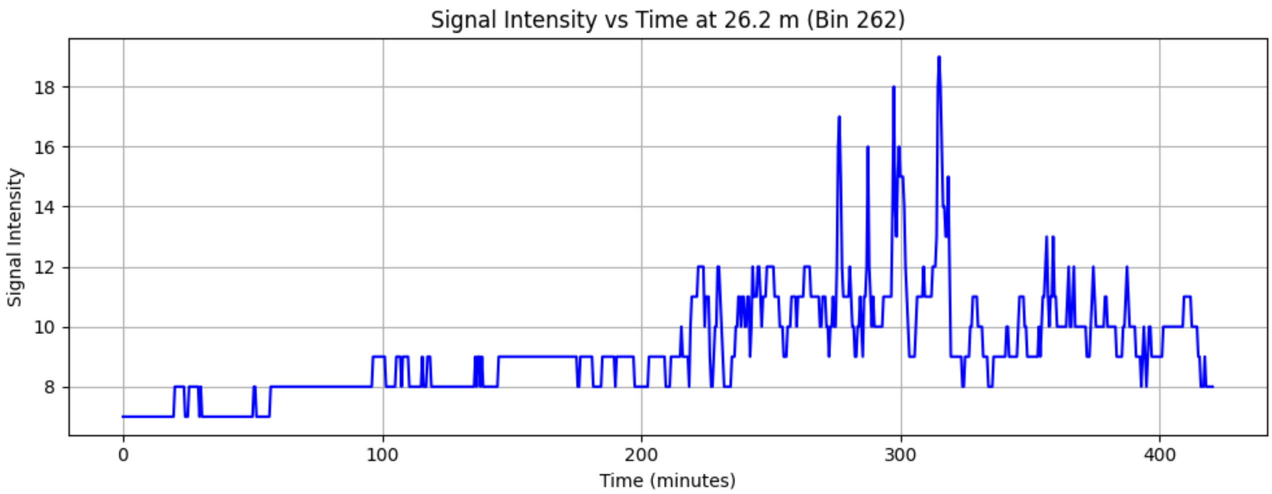

Signal Intensity vs Time at 12.7 m (Bin 127)
Signal Intensity
Time (minutes)
12800
12600
12400
12200
12000
11800
0
100
200
300
400


Signal Intensity vs Time at 15.4 m (Bin 154)
Signal Intensity
Time (minutes)
8600
8400
8200
8000
7800
0
100
200
300
400


Signal Intensity vs Time at 18.1 m (Bin 181)
Signal Intensity
Time (minutes)
60000
50000
40000
30000
20000
10000
0
0
100
200
300
400


Signal Intensity vs Time at 20.8 m (Bin 208)
Signal Intensity
Time (minutes)


Signal Intensity vs Time at 23.5 m (Bin 235)
Signal Intensity
Time (minutes)


Signal Intensity vs Time at 26.2 m (Bin 262)
Signal Intensity
Time (minutes)

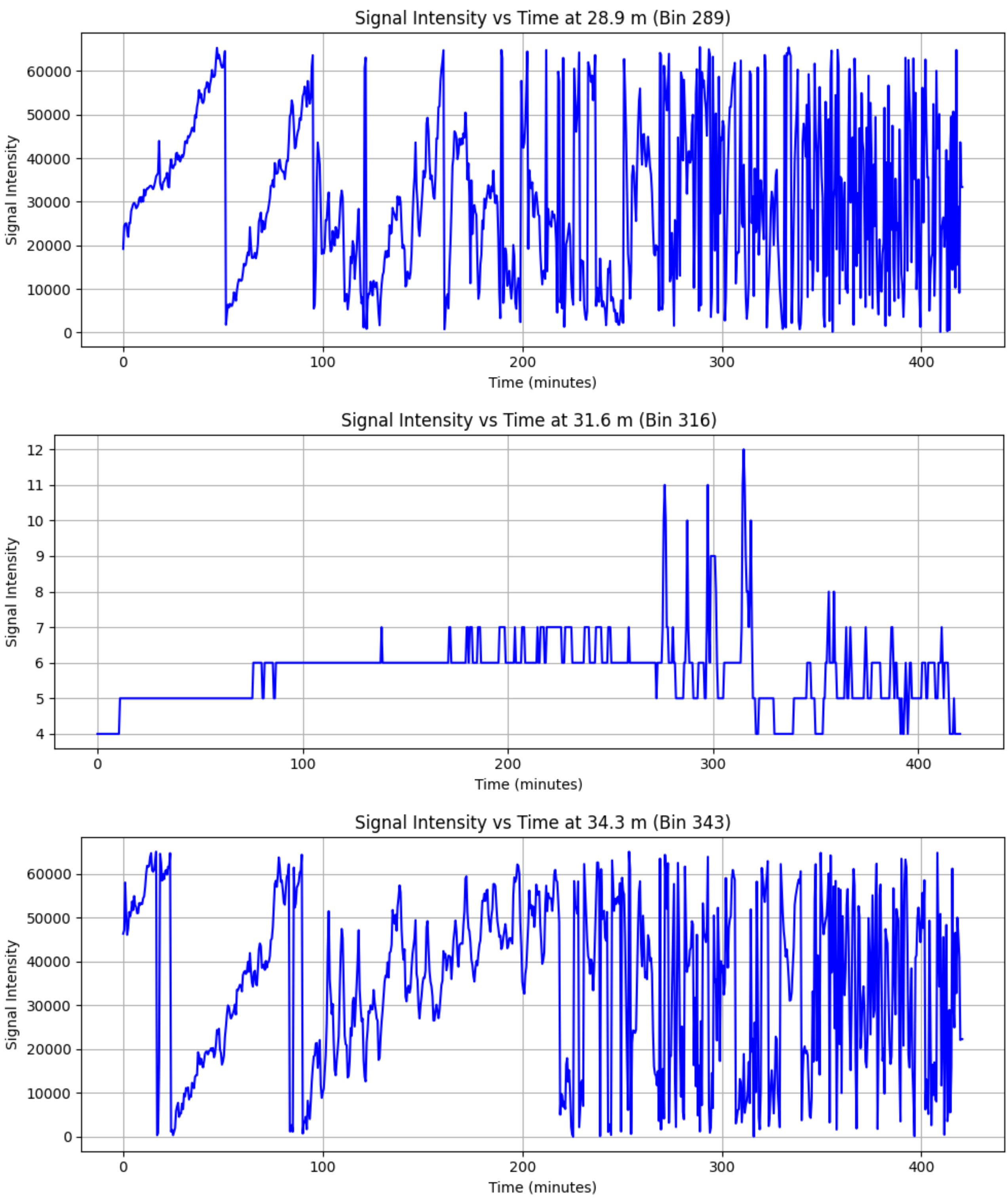


Figure 3: Signal Intensity vs Time

5. INTERPRETATION OF RESULTS

- Dominant gravity wave signatures were observed at **~1762.5 m, 2167.5 m, and 2572.5 m**.
- These layers showed both visual periodicity and matching frequency peaks.
- Above 2700 m, the signal dropped significantly, and below 500 m, wave signatures were weak or noisy.

Bin Index	Altitude (m)	Dominant Frequency (Hz)	Wave Period (min)
100	750.0	0.015044	1.10
127	952.5	0.015044	1.10
154	1155.0	0.015044	1.10
181	1357.5	0.000040	421.0
208	1560.0	0.000079	210.5
235	1762.5	0.000435	38.2
262	1965.0	0.000040	421.0
289	2167.5	0.000277	60.1
316	2370.0	0.000040	421.0
343	2572.5	0.000277	60.1

Table 1: FFT Summary Table

Altitude (m)	Wave Period (min)	Interpretation
750–1155	~1.1 mins	Could be **high-frequency noise** or local turbulence, not gravity waves
1357–2370	210–421 mins	This is in the **long-period gravity wave** or **convective plume** range
1762.5	~38 mins	This is **very relevant**! Likely a **gravity wave signal**
2167.5, 2572.5	~60 mins	Classic **CBL convection-triggered wave periods**

Table 2: Interpretation

6. TOOLS AND METHODS USED

- **Google Colab (Python)**: For binary file reading, reshaping, plotting, FFT
- **NumPy, Matplotlib, SciPy**: For signal processing
- **Licel Binary Format Decoding**: Using manual specs
- **Manual RTI Inspection + Programmatic Filtering**
- **FFT + Time-Domain Overlay Interpretation**

7. CONCLUSION

This project successfully demonstrated the use of LiDAR signal profiles to detect convection-triggered gravity waves within the atmospheric boundary layer. The chosen methodology — combining time-series analysis with frequency domain inspection — confirmed the presence of periodic wave patterns in the 1.7 km to 2.6 km altitude band.

8. REFERENCES

[1] Y. B. Kumar, V. B. Rao, and D. Narayana Rao, "Wave structures in the atmospheric boundary layer observed with lidar," *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 63, no. 16, pp. 1641–1650, 2001.

[2] T. Foken, "Micrometeorology," *Springer Atmospheric Sciences*, Berlin, Heidelberg: Springer, 2008.

[3] Licel GmbH, "Transient Recorder Data Format," Licel Instruments, Berlin, Germany. [Online]. Available: https://www.licel.com/manuals/programmingManual.pdf

[4] M. J. Alexander et al., "Recent developments in gravity-wave effects in climate models and the global distribution of gravity-wave momentum flux from observations and models," *Quarterly Journal of the Royal Meteorological Society*, vol. 136, no. 650, pp. 1103–1124, Apr. 2010.

[5] S. Mallik, P. Kumar, and R. Singh, "Atmospheric gravity waves and their role in the middle atmosphere," *Current Science*, vol. 111, no. 3, pp. 495–503, 2016.

[6] J. W. Goodman, *Statistical Optics*, 2nd ed., Wiley, 2015.

[7] E. E. Clothiaux and M. L. Van Baelen, "Technical Note: Use of lidar for boundary layer height estimation," *Atmospheric Measurement Techniques*, vol. 6, no. 12, pp. 3253–3264, 2013.

[8] J. D. Hunter, "Matplotlib: A 2D graphics environment," *Computing in Science & Engineering*, vol. 9, no. 3, pp. 90–95, 2007.

[9] W. McKinney, "Data structures for statistical computing in Python," in *Proc. 9th Python in Science Conf.*, Austin, TX, USA, 2010, pp. 51–56.