BACKGROUND INFORMATION

Gravity waves (GWs) that propagate up into the mesospheric region break and transfer energy into the region. This energy affects seasonal temperatures in the mesosphere and has important implications for rocket launches and GPS satellites. Using the Utah State Mesospheric Temperature Mapper (MTM) located at the Andes Lidar Observatory in Chile, wave activity and seasonal temperature changes were observed over the Andes Mountain Range from Jan 2020 to the first five months of 2021. The primary goal was to continue the longstanding data collection and analysis (since 2009) and to better understand gravity wave climatology. The data derived from this research follows the seasonal temperature trend for the region but was not without its drawbacks. Electronic interference was present in an overwhelming number of nights observed, most likely due to the cable shielding in the MTM camera failing. This has made it difficult to get large amounts of useful wave data but left the temperature relatively unscathed.

Figure 1: The Andes Lidar Observatory, Cerro Pachón Chile (30.3°S, 70.7°W, 2530 m)

INSTRUMENT

Mesospheric Temperature Mapper (MTM) is a sensitive bare CCD imager developed to measure mesospheric temperature variability using the OH and O_2 airglow emissions. Unfortunately, the O_2 band filters failed and cannot be replaced at this time. This means that only the OH band filters and background were used.

- Field of view ~90 degrees, (180 x 180 km)
- Sequential observations (30 sec. exp.) of:
  - Two emission lines ($P_1(2)$, $P_1(4)$) in the NIR OH (6, 2) Band ~ 87 km
  - Background (~857.5 nm)
- Cycle time: ~ 2 min per OH temperature determination. (Precision of ~2K)

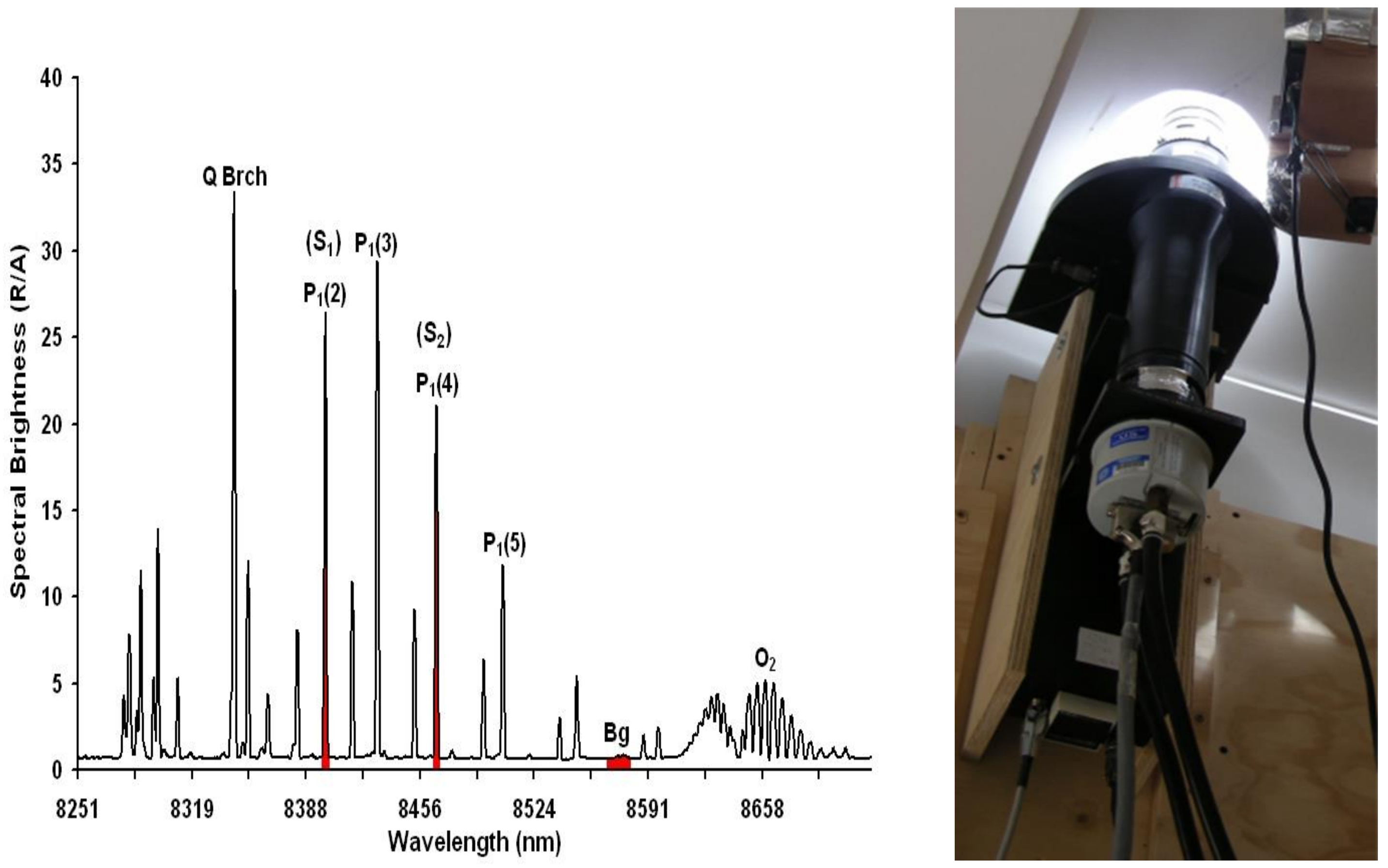
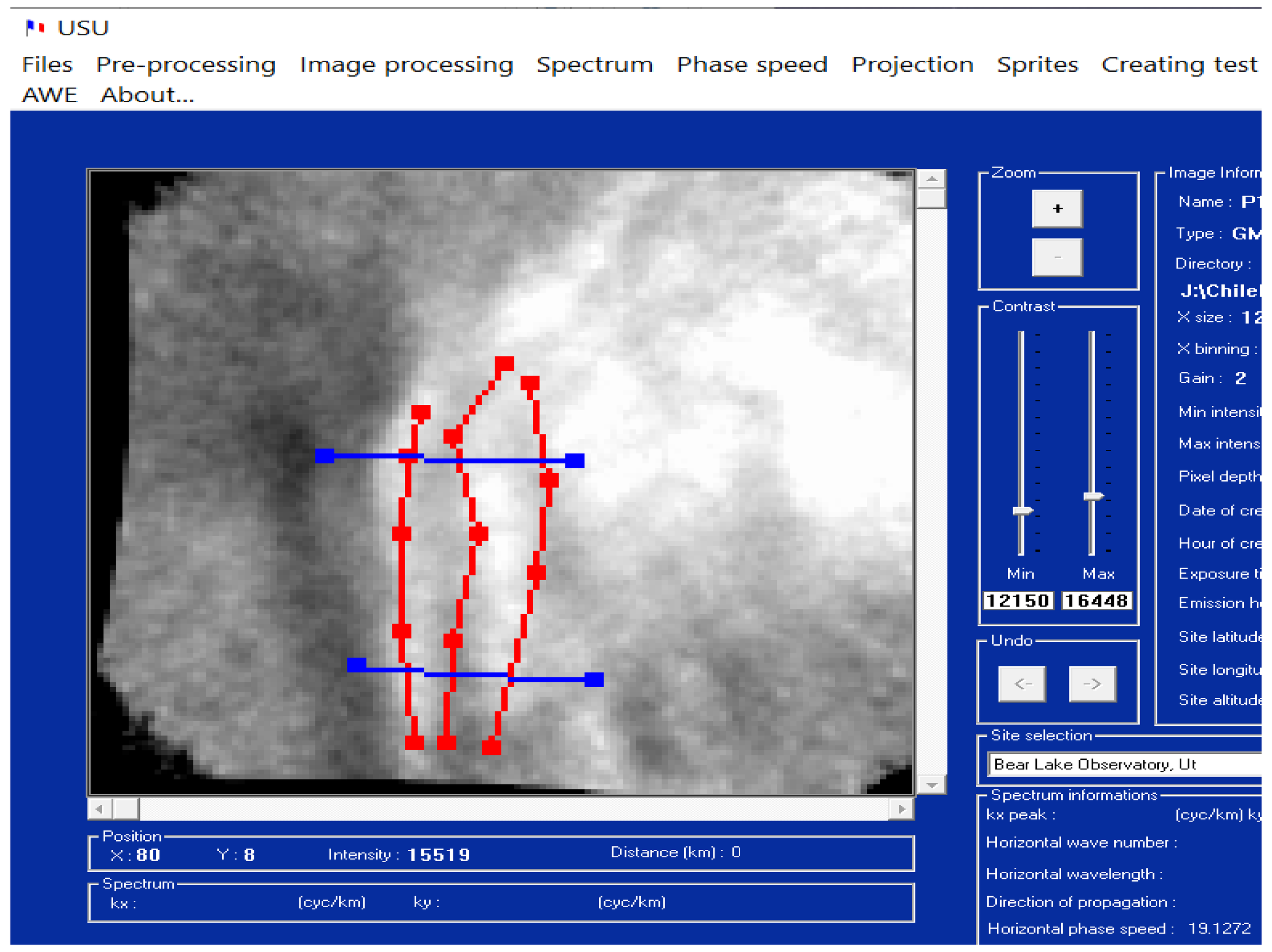


Figure 2: the OH band with emission lines $P_1(2)$, $P_1(4)$ and Background in red used by MTM (left), and a photo of the MTM camera at ALO (right)

DATA ANALYSIS

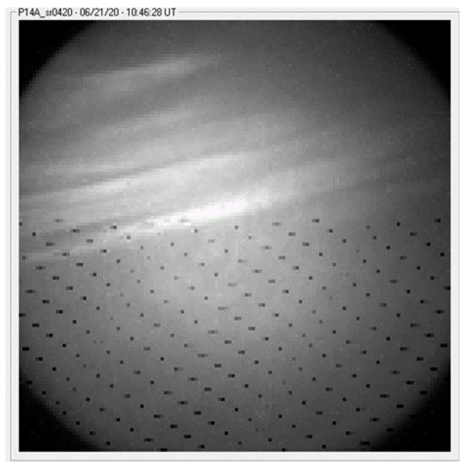
- Download daily image collection from the MTM camera
- Image processing: star removal, flat fielding, calibrating, unwarping, temp and band maps
- Generate zenith temperature CSV Files, clean contaminated twilight measurements in Origin
- Use python to generate daily average temperature from zenith temps and generate a CSV file
- Use Origin to create a yearly plot with a 30-day running mean
- Use USU Image Processing program developed by Dominique Pautet to calculate propagation direction, wavelength and phase speed of gravity waves
- Statistical analysis of 2020 MTM data quality and gravity wave activity.

Figure 3. Left to right $P_1(2)$ images on May 10-11, 2020; raw image, star removed image, calibrated and unwarped image with propagation direction



Phase Speed Calculation:

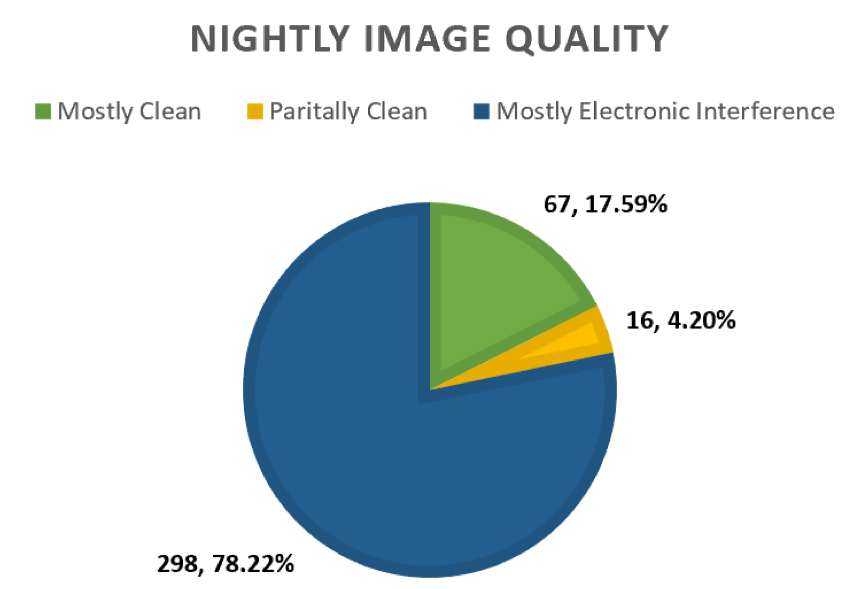
- using the distance a wave crest has moved.
- Red lines indicate the same wave crest over multiple images (3 images here),
- the blue lines are the limits over which the calculation is done.

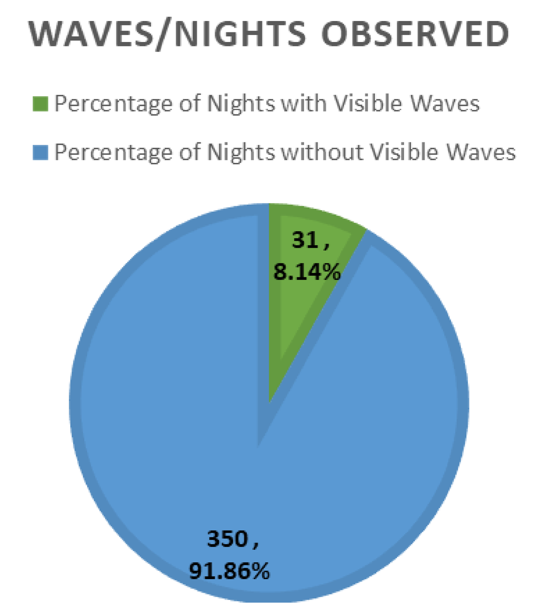


Sample image with noise caused by interference

RESULTS

Statistics of 2020-2021 data

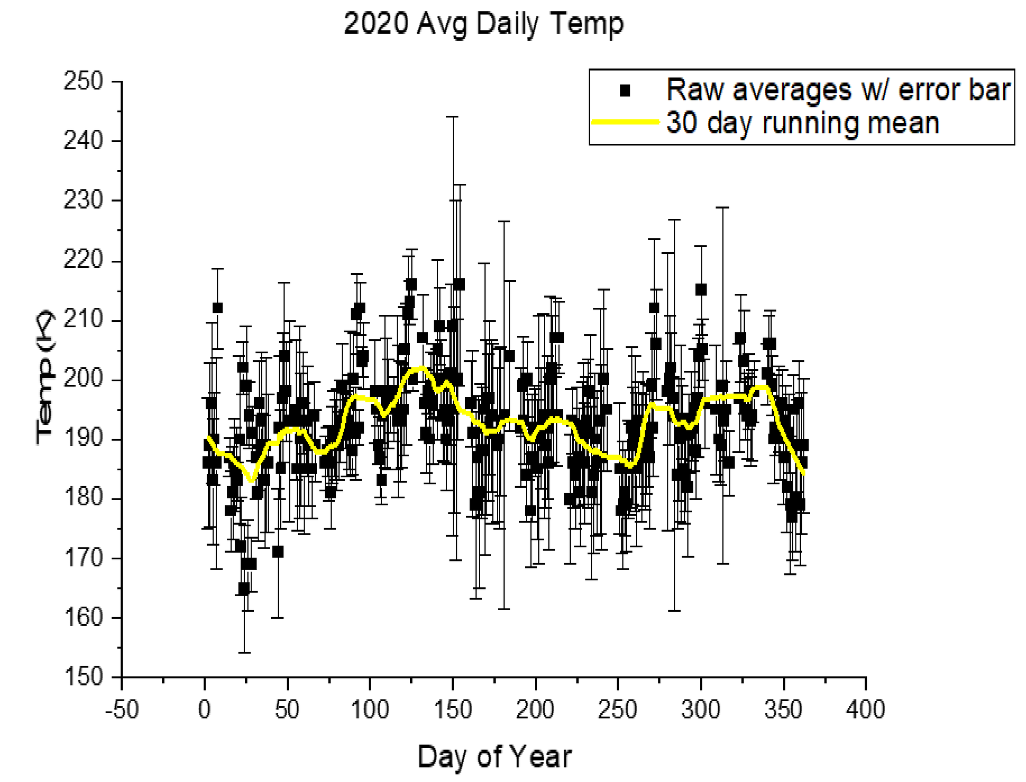




Nights with GWs: 31
Partially Clean: 17
Interference: 14
Nights GWs are not detected: 350

Pie charts: left showing the number of nights with or without interference as a percentage of all nights observed, right showing the number of nights with waves as a percentage of all nights observed.
Total of 381 nights of data collected between Jan. 1, 2020, and May 31, 2021.

2020 Nightly Mean Mesospheric Temperature



The nightly mean OH temperature of 2020, the yellow line indicates a 30-day running mean that shows seasonal characteristics. This data matches up well with previous years, sharing similar features (Pugmire, 2018).

Clean, Clear Wave Events

Date (2020)	Time (UT)	Wavelength (Km)	Phase speed (m/s)	Direction (degrees from north)
Mar25-26	0:45-1:37	28	61.9	3.9
Apr02-03	3:59-4:47	20.4	24.5	7.6
Apr22-23	0:56-4:13	36.2	13.7	356.6
Apr29-30	2:37-4:53	30.7	14.6	26.6
May10-11	**23:18-1:37**	**25.7**	**19.1**	**270**
May22-23	3:44-4:45	22	26.5	0
May25-26	22:38-3:01	47.3	15.1	274.4

List of date and time for distinct gravity wave events from 2020-2021, and the calculated horizontal wavelength, phase speed and direction of propagation from north. The May10-11 wave event is shown in Figure 3.

SUMMARY

- Zenith temperature shows an annual mean temperature of ~192 K with seasonal variation.
- Horizontal wavelength of GWs: 20-50 km
- GW phase speed: 15-60 m/s
- Duration: several minutes to nearly an hour
- More GWs were observed during the nights when radar interference present. Wave characteristics are not analyzed at this stage.
- Following May 25-26, 2020, clean nights became much rarer.
- The electronic interference was a hindrance in wave measurements.

ACKNOWLEDGEMENTS:

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References:

Pugmire, J. R., *Mesospheric Gravity Wave Climatology and Variances Over the Andes Mountains, 2018. USU Ph.D Thesis. https://doi.org/10.26076/4a0e-3308.*

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