NCAS-M | NOAA COOPERATIVE SCIENCE CENTER IN ATMOSPHERIC SCIENCES AND METEOROLOGY

Rawinsonde Estimation of Mixing Layer Height

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NOAA-CESSRST
CENTER FOR EARTH SYSTEM SCIENCES AND REMOTE SENSING TECHNOLOGIES

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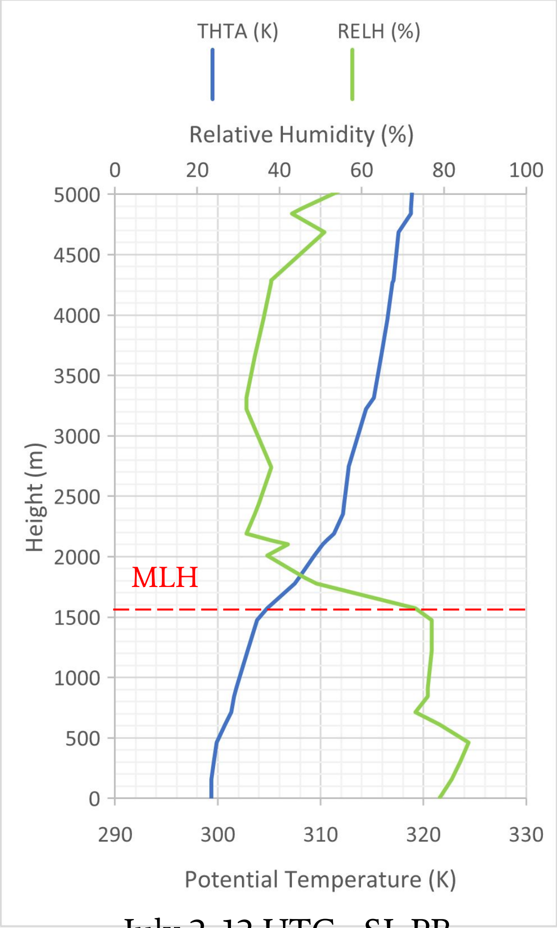
Background

- ➔ The mixing layer is formed when discontinuous turbulence exists due to temperature inversions between the upper and lower layers of the atmosphere.
- ➔ The heights of the mixing layer are usually the highest during daytime periods (1,000-2,000m range) because of the strong solar heating and the lowest during the night.
- ➔ The mixing layer height (MLH) is a very important topic to study because it will help us understand the transport and dispersion processes of pollutants emitted from different sources in the troposphere that affect air pollution, weather and climate change.



July 2: 12 UTC - SJ, PR

Motivation

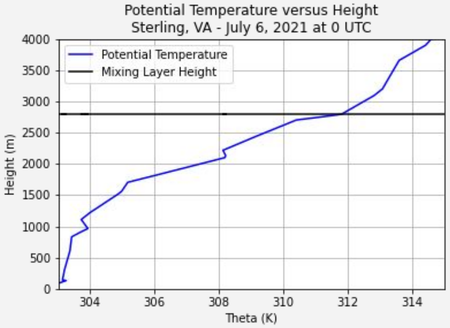
➔ Knowing the mixing layer height for any location on a given day and time is important as it can be communicated to those that have to take into account air pollution in their daily lives or operations.

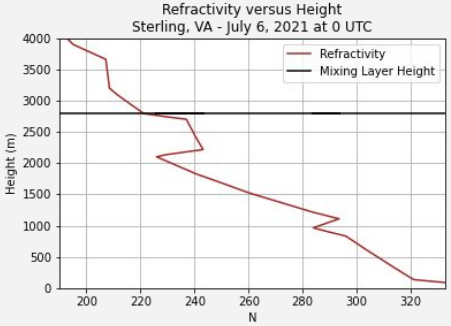
Objectives

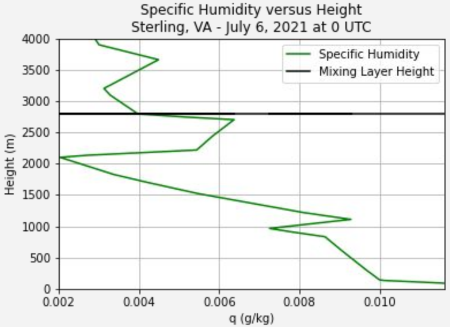
- By identifying the turning point of the radiosonde profile, the mixing layer height can be determined by many methods, such as potential temperature (Θ), relative humidity (RH), specific humidity (q) and atmospheric refractivity (N).

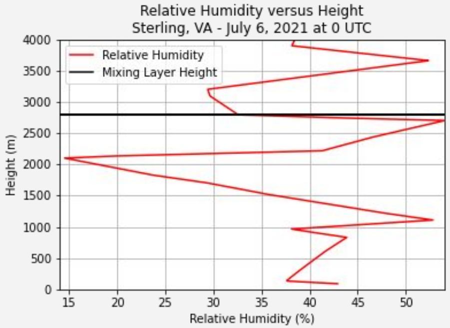
Research Question

- ➔ Making the **best estimate for mixing layer height** to help **understand differences of air pollution in San Juan, PR and Sterling, Virginia.**
- ➔ **Observing the trends in the MLH** for the dates of June 29, 2021 - July 6, 2021.
- ➔ Mixing layer height parameter for verification and validation in numerical weather prediction. Erroneous determination can impact forecasting.
- ➔ MLH is used in model evaluation of chemical transport models to estimate the pollution concentrations under various meteorological conditions and air quality episode analyses for air quality planning and management.









Methodology

- ➔ Utilizing Excel and Python, radiosonde data was obtained from University of Wyoming's Atmospheric Sounding website during June 29th, 2021 to July 6th, 2021 at 0 UTC and 12 UTC from San Juan, Puerto Rico and Sterling, Virginia.
- ➔ Calculated potential temperature, relative humidity, specific humidity and refractivity of the profiles.
- ➔ Collected the 10 greatest gradient values for potential temperature and 10 least gradient values for relative humidity, specific humidity and refractivity at heights between 0 meters and 4,000 meters in altitude.
- ➔ Plotted the mixing layer height where at least three parameters had the same height when going in descending order for potential temperature and ascending order for relative humidity, specific humidity and refractivity.
- ➔ Observed the trends in mixing layer height over the course of the days studied.

Python Coding

- ➔ Libraries used for coding
- ➔ Siphon for data collection
- ➔ MetPy for calculating atmospheric variables

Importing the Data

June 29 2021 at 12Z

```
date29AT12Z = datetime(2021, 6, 29, 12) # Year, month, day, time
station = 'IAD' # Three letter code
```

```
df1 = WyomingUpperAir.request_data(date29AT12Z, station)
```

```
df1 # This prints the table from the website. This is a Pandas data frame. Panda allows you to manipulate, join, and d
```

	pressure	height	temperature	dewpoint	direction	speed	u_wind	v_wind	station	station_number	time	latitude	longitude	elevation	pw
0	1014.0	93	23.2	19.8	170.0	6.0	-1.041889	5.908847	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
1	1000.0	213	22.6	19.6	195.0	7.0	1.811733	6.761481	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
2	998.0	230	22.4	19.5	198.0	7.0	2.163119	6.657396	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
3	991.0	292	22.6	19.3	208.0	9.0	4.225244	7.946528	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
4	989.5	305	23.3	19.1	210.0	9.0	4.500000	7.794229	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
95	18.3	27432	-45.9	-82.2	95.0	21.0	-20.920089	1.830271	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
96	17.4	27753	-44.7	-81.7	96.0	22.0	-21.879482	2.299626	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
97	11.6	30480	-41.0	-79.5	105.0	27.0	-26.079997	6.988114	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
98	10.0	31490	-39.7	-78.7	105.0	21.0	-20.284442	5.435200	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26
99	7.9	33112	-36.5	-77.5	NaN	NaN	NaN	NaN	IAD	72403	2021-06-29 12:00:00	38.98	-77.46	93.0	32.26

100 rows × 15 columns

Python Coding Cont. - Calculating Gradients

Gradient coding for June 29 at 12Z

```
gradTheta1 = np.gradient(Theta1[0:24]) # I set the bounds from 0 meters to just over 4,000 meters. This is the functior
gradTheta1 # This prints the gradient of the Potential Temperature array
largestTheta1 = np.argsort(gradTheta1)[-10:] # This gives us the position of the largest 10 largest gradients for the p
largestTheta1 # This prints the positions of the largest 10 largest gradients for the potential temperature array

# The Theta[0:24] range of atmosphere positions are 20, 18, 15, 19,  7, 21, 23,  5,  4, 22

gradRH1 = np.gradient(RH1[0:24]) # Bounds are set from 0 meters to just over 4,000 meters. This is the function for fir
gradRH1 # This prints the gradient of the Relative Humidity array
smallestRH1 = np.argsort(gradRH1)[:10] # This sorts the Relative humidity gradient array from least to greatest and the
smallestRH1 # This line returns the positions of the 10 smallest gradients, or the first 10 gradients

# # The RH[0:24] range of atmosphere positions are 15, 16, 14,  4,  5,  3,  6, 22, 23, 21


gradq1 = np.gradient(q1[0:24]) # Bounds are set from 0 meters to just over 4,000 meters. This is the function for findi
gradq1 # This prints the gradient of the Specific Humidity array
smallestq1 = np.argsort(gradq1)[:10] # This sorts the Specific humidity gradient array from least to greatest and then
smallestq1 # This line returns the positions of the 10 smallest gradients, or the first 10 gradients

# The q[0:24] range of atmosphere positions are 15, 16, 14,  7,  6,  8,  5, 22, 18, 21


gradN1 = np.gradient(N1[0:24]) # Bounds are set from 0 meters to just over 4,000 meters. This is the function for findi
gradN1 # This prints the gradient of the Refractivity array
smallestN1 = np.argsort(gradN1)[:10] # This sorts the Refractivity gradient array from least to greatest and then picks
smallestN1 # This line returns the positions of the 10 smallest gradients, or the first 10 gradients

# The N[0:24] range of atmosphere positions are 15, 16,  7, 14, 22, 18, 19,  6, 21, 11

# #------------------------------------------------------------------------------

# I then want to print the height where at least three parameters had the same height when going in descending
# order for potential temperature and ascending order for relative humidity, specific humidity and refractivity,
# as that height is said to be the mixing layer height

MLH1 = h1[16]
MLH1 = np.ones(100)*MLH1
MLH1
```

- ➔ The ten highest gradient values for potential temperature were ranked from lowest to highest (e.g. 1, 2, 3, 4, 5...)
- ➔ The ten lowest gradient values for relative humidity, specific humidity, and refractivity were ranked from highest to lowest (e.g. -1, -2, -3, -4, -5...)
- ➔ Starting from the highest gradient value for potential temperature and lowest values for relative humidity, specific humidity, and refractivity, we observed where at least three of the variables had the same height. That height is the MLH.
- ➔ In this example, the MLH was at position 16 corresponding to 2134 meters.
- ➔ An array having the same number of data points collected from the radiosonde was created and filled with the MLH to be used for plotting.

Summary of results

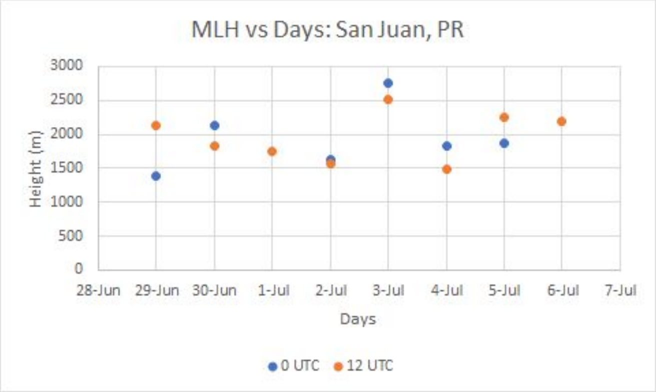
GRAPHS MLH VERSUS DAYS

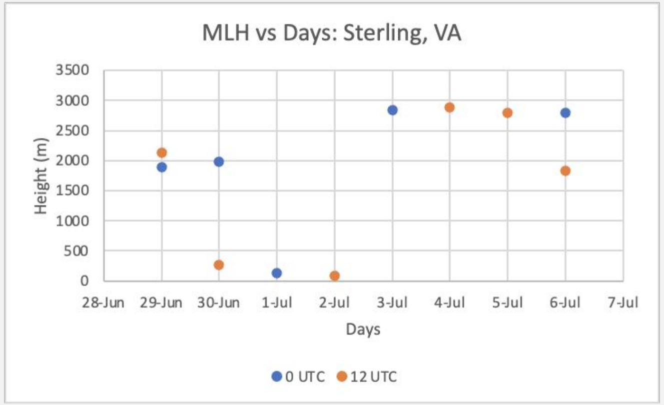
- MLH not present due to several reasons (e.g. no turbulence, inconsistent vertical resolution)
- San Juan, PR

MLH	0 UTC	12 UTC
Mean	1936.7 m	1964.25 m
Std. Dev.	435.7 m	335.09 m

- Sterling, VA

MLH	0 UTC	12 UTC
Mean	1974.2 m	1666.33 m
Std. Dev.	1093.03 m	1220.48 m





Conclusion & Future Work

- Potential temperature, relative humidity, specific humidity, and refractivity gradients served as a good estimates for mixing layer height at the time of data capture. → Method provided by Wang and Wang (2014) was effective in estimating the MLH.
- Common to see relative humidity, specific humidity and refractivity have ranks coinciding with each other → minimum of three variables as criteria for MLH estimation
- Future: Increasing the vertical resolution of the radiosonde → Closer to 30 m resolution → better estimation of MLH

	pressure	height
0	1012.0	93
1	1000.0	196
2	987.8	305
3	954.4	610
4	925.0	887

References

- University of Wyoming College of Engineering http://weather.uwyo.edu/upperair/sounding.html
- X. Y. Wang and K. C. Wang,. (2014). Estimation of atmospheric mixing layer height from radiosonde data. Atmos. Meas. Tech., 7, 1701–1709.
- Caicedo et al. (2020). An automated common algorithm for planetary boundary layer retrievals using aerosol lidars in support of the U.S. EPA Photochemical Assessment Monitoring Stations Program, J. Atmos. Oceanic Technol., doi.org: 10.1175/JTECH-D-20-0050.1, 2020.

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