

# Characteristics of Electromagnetic Wave Ducts in Different Weather Conditions



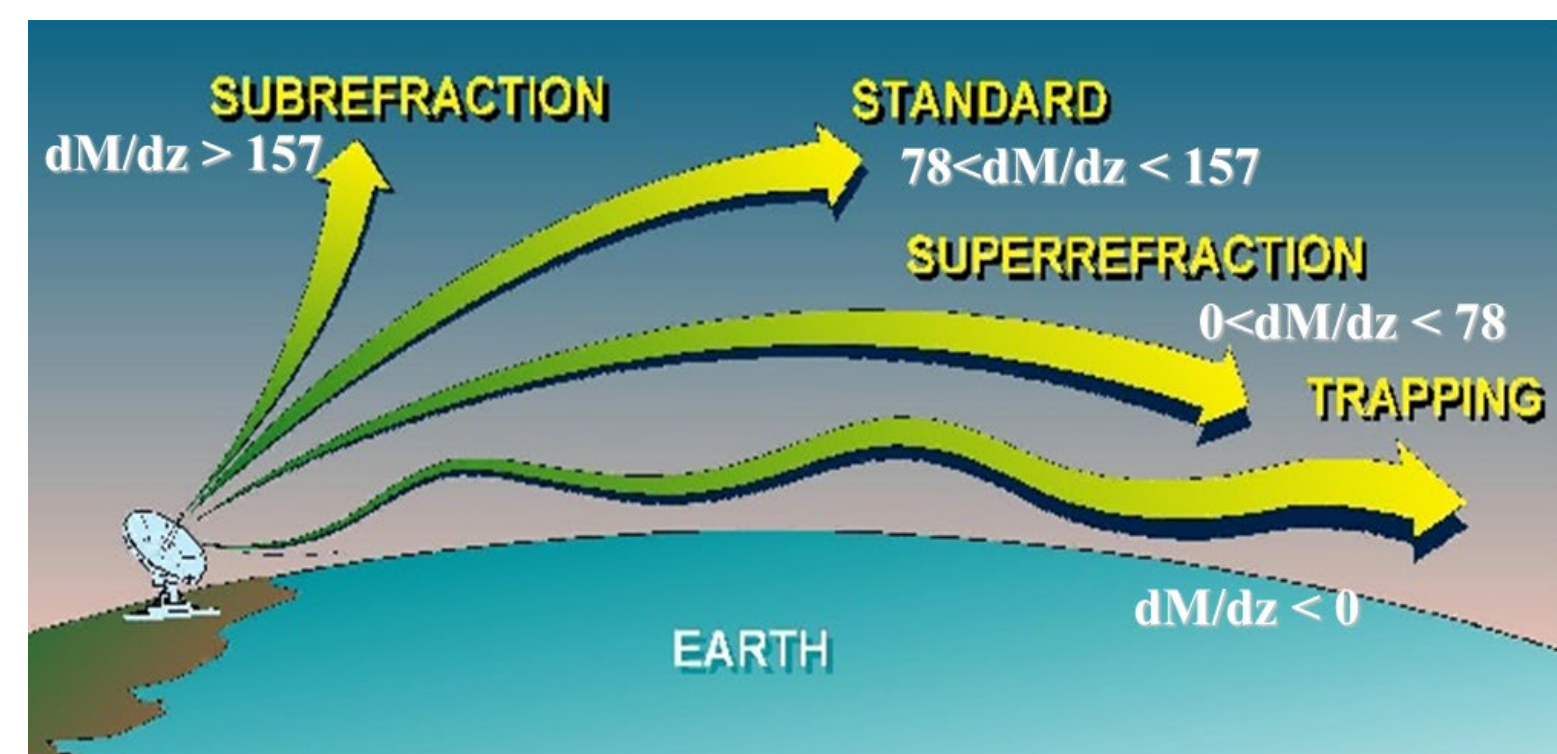
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## Motivation

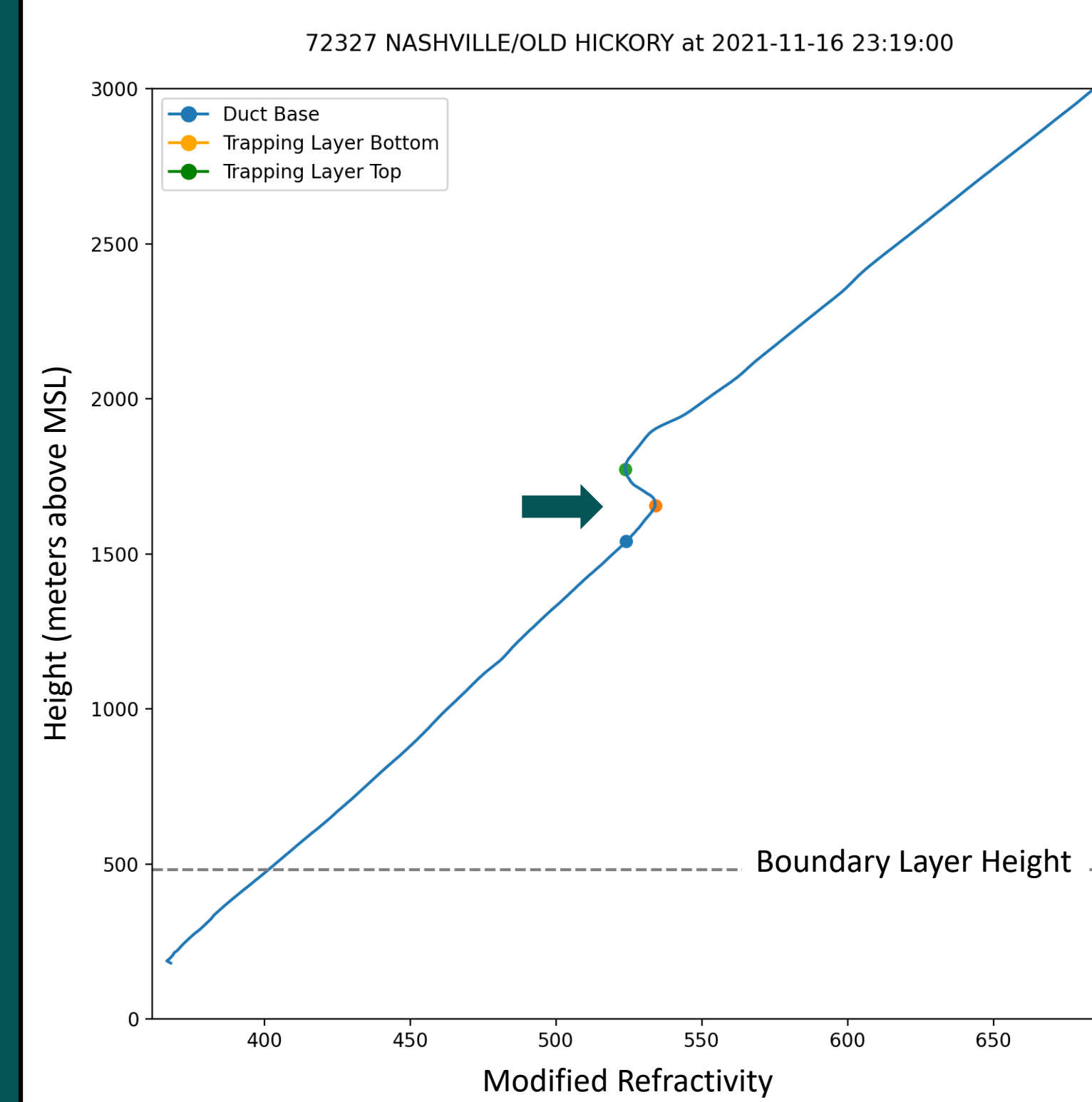
Electromagnetic (EM) waves are used in communications and remote sensing including weather radar. Refraction deflects an EM wave from a straight path. The refractivity properties of a layer of atmosphere are a function of temperature and moisture and impact how much the EM wave bends as it moves through the layer. A wave duct describes conditions where waves bend downward more than the curvature of the earth trapping these waves within the duct. This study aims to improve understanding of the sets of weather conditions when wave ducting is more likely and less likely to occur.



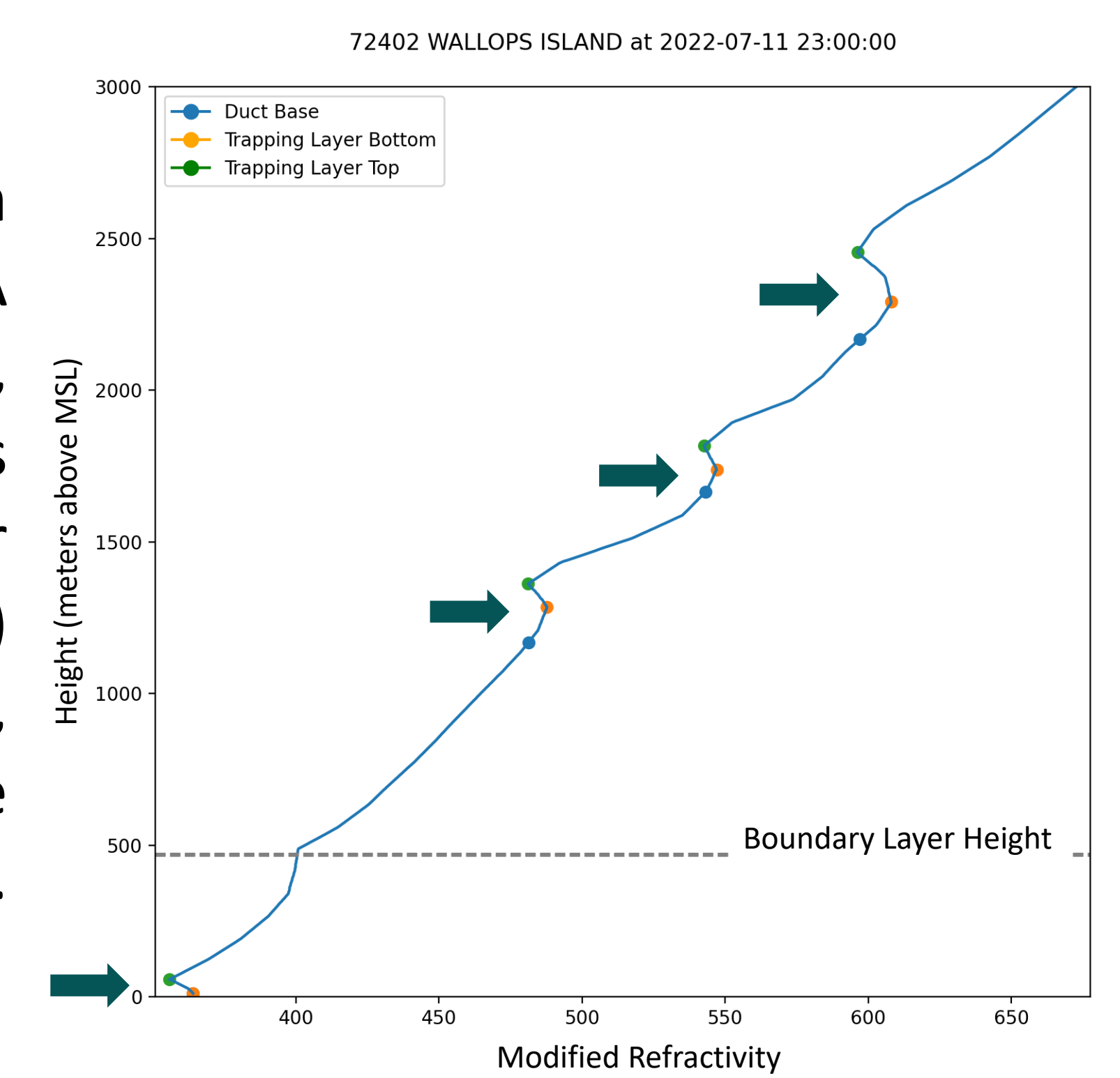
Adapted from [https://www.oc.nps.edu/NWDC\\_EM\\_Course/course\\_materials/module3\\_1.html](https://www.oc.nps.edu/NWDC_EM_Course/course_materials/module3_1.html)

## Duct Examples

This weather balloon sounding from Nashville, TN on November 16<sup>th</sup>, 2021, shows one duct aloft. Surface conditions at 6 pm local time (23 UTC) were partly cloudy skies, 62°F, and a relative humidity of 78%.

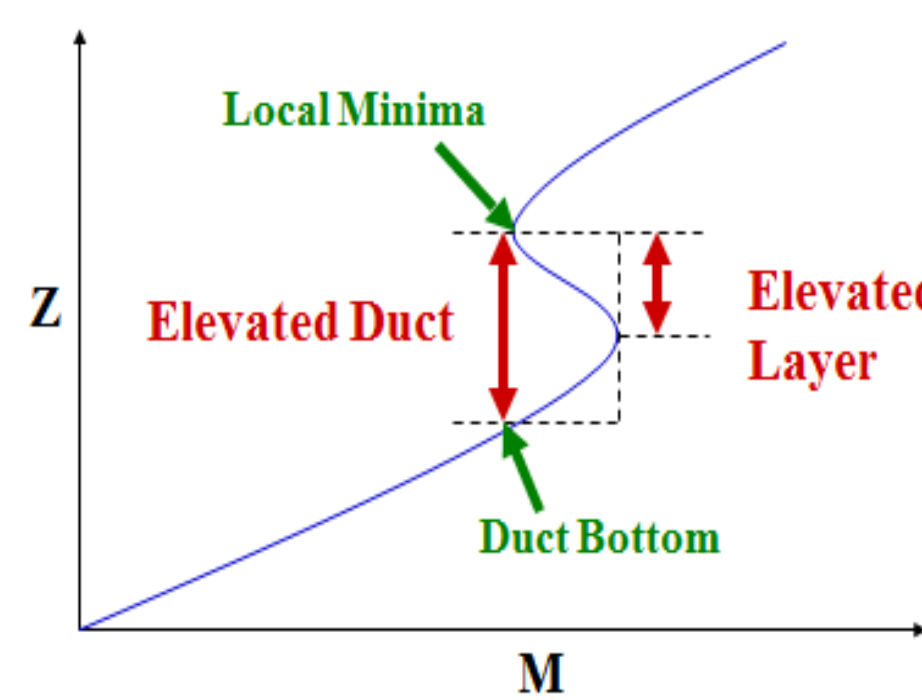


This weather balloon sounding from Wallops, VA on July 11<sup>th</sup>, 2022, demonstrates multiple ducts and a surface duct. Weather conditions at 7 pm (23 UTC) local time were clear skies, 76°F, and 74% relative humidity.



## Methods

To determine where and when ducts are present, modified refractivity is calculated from weather balloon soundings which provide profiles of temperature, pressure, and moisture in the atmosphere. These soundings are obtained from the archive at the National Centers for Environmental Information (NCEI).

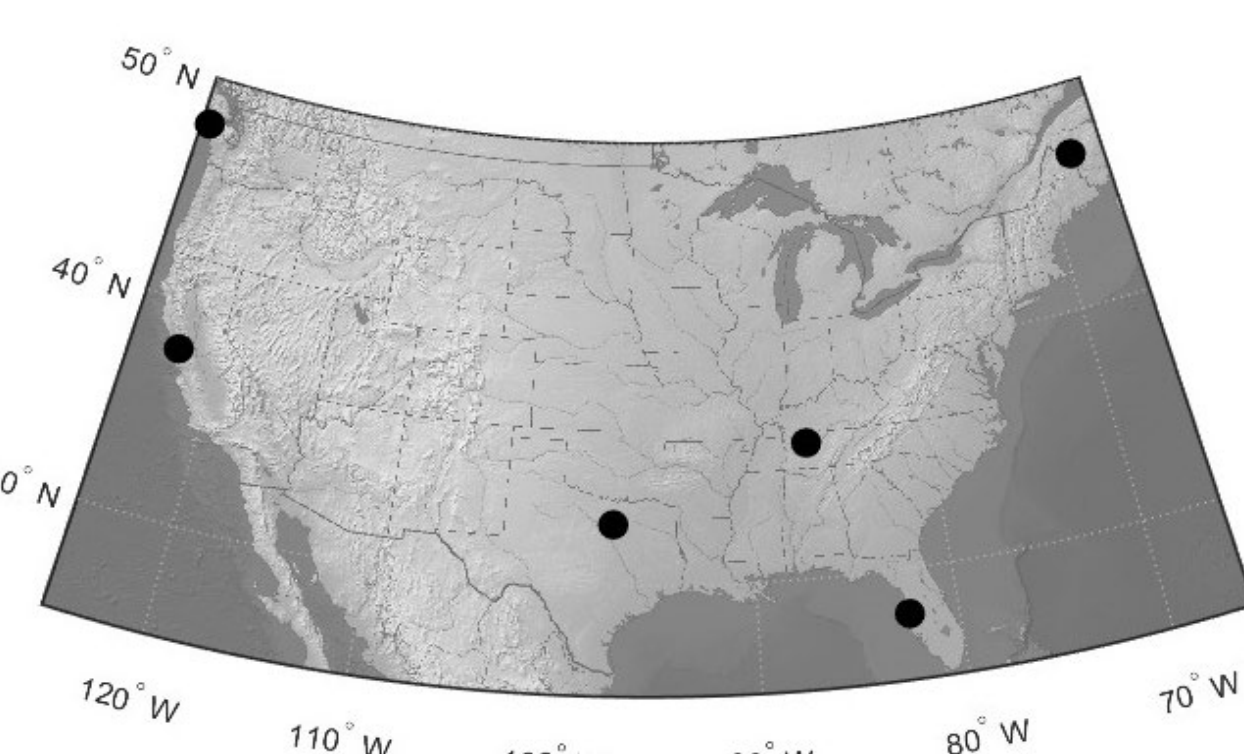


Trapping layers are present when modified refractivity decreases with increasing height.

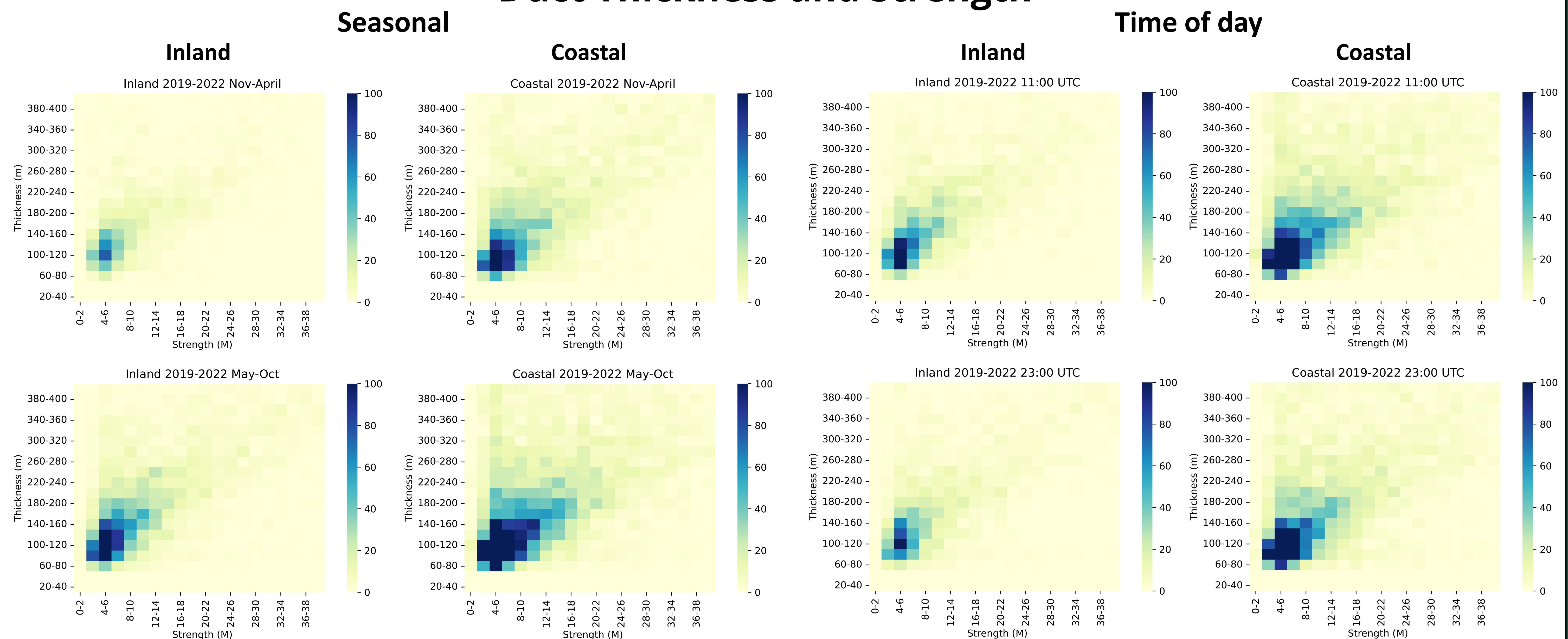
Adapted from [https://www.oc.nps.edu/NWDC\\_EM\\_Course/course\\_materials/module3\\_2.html](https://www.oc.nps.edu/NWDC_EM_Course/course_materials/module3_2.html)

Ducts are automatically identified when modified refractivity strength ( $\Delta M$ ) is  $> 1.7$  M and thickness ( $\Delta Z$ ) is  $> 40$  meters. These thresholds filtered out very small duct layers. Six locations were analyzed over 4 years (2019-2022) with 3 inland locations and 3 coastal locations. Weather balloons are launched twice a day in the early morning and early evening.

- Coastal: Oakland, CA, Quillayute, WA, Tampa, FL
- Inland: Fort Worth, TX, Nashville, TN, Caribou, ME



## Duct Thickness and Strength



Density plots of our 6-site dataset over 4 years shows the duct characteristics by season.

Density plots of our 6-site dataset over 4 years show the duct characteristics at early morning (11 UTC) and early evening (23 UTC).

## Summary and Future Work

The coastal locations produced more frequent and stronger ducts throughout the year as compared to the inland locations. Future work will extend the analysis to more sites and examine the relationships between duct characteristics and weather conditions such as cloud cover and proximity to storms.

## Acknowledgements

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