

Characteristics of Electromagnetic Wave Ducts in Different Geographical Locations



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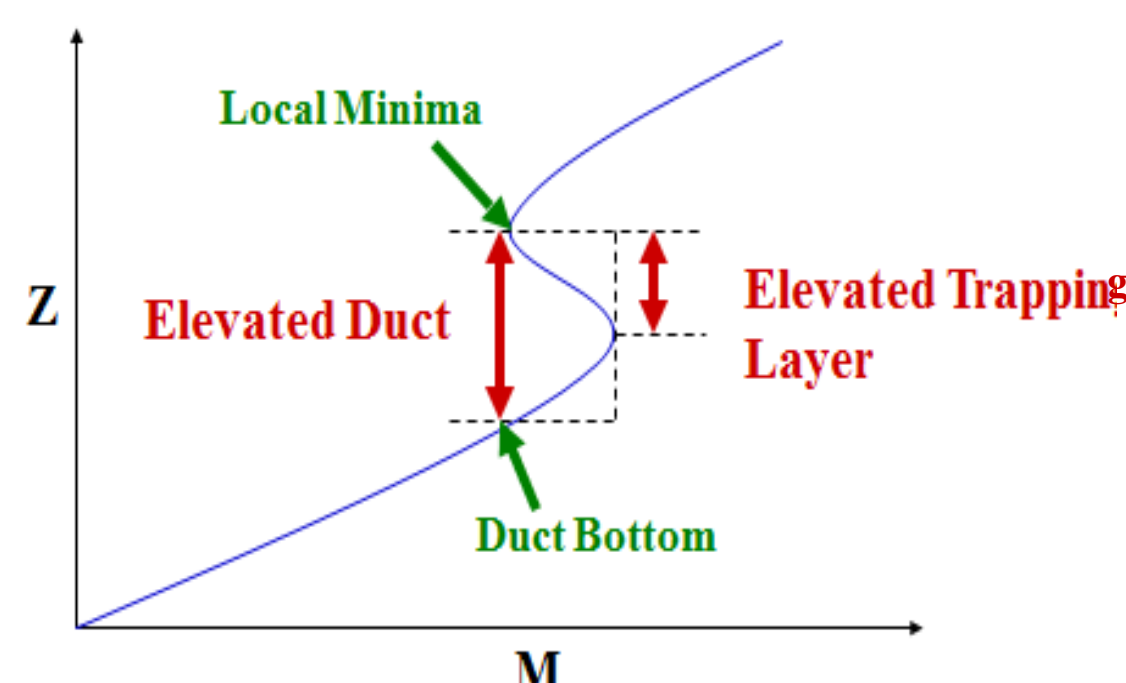


Motivation

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 where wave ducting is more likely and less likely to occur.

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).

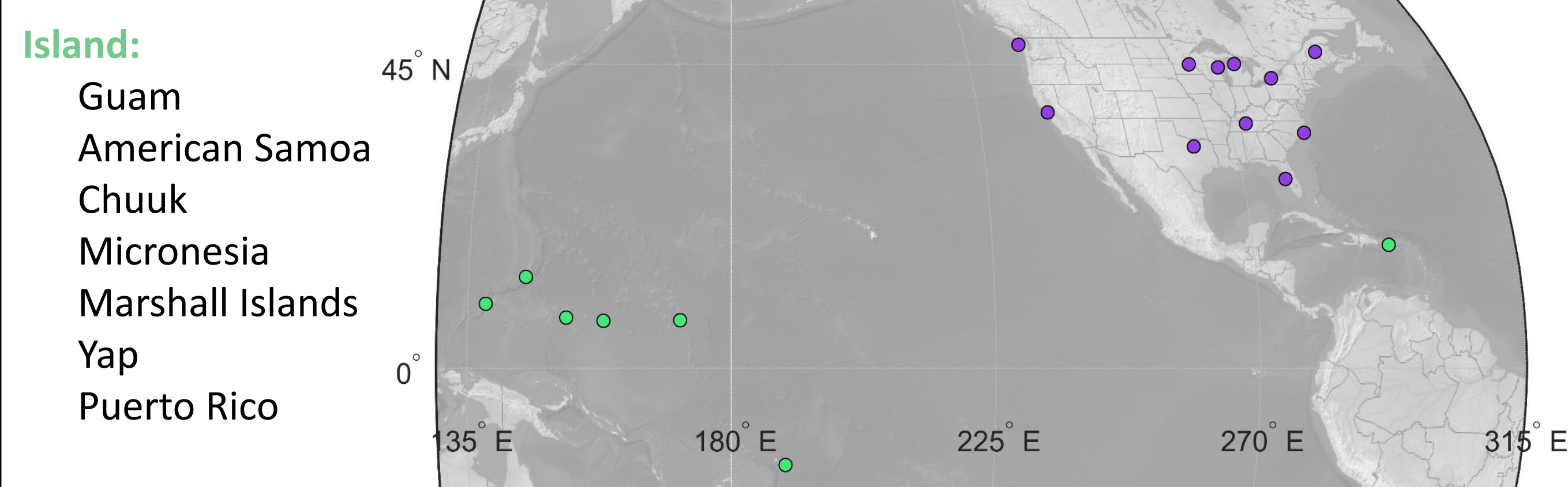


Trapping layers are present when modified refractivity decreases with increasing height.

Adapted from https://www.nc.nps.edu/NWDC_EM_Course/course_materials/module3_2.html

Ducts are objectively identified when modified refractivity strength (ΔM) is $> 1.7 M$ and thickness (ΔZ) is > 40 meters. These thresholds filtered out very small duct layers. Eighteen locations were analyzed over 4 years (2019-2022) with 4 inland locations, 4 coastal, 3 Great Lake, & 7 islands. We examine the wave duct characteristics of strength, thickness, and duct base height.

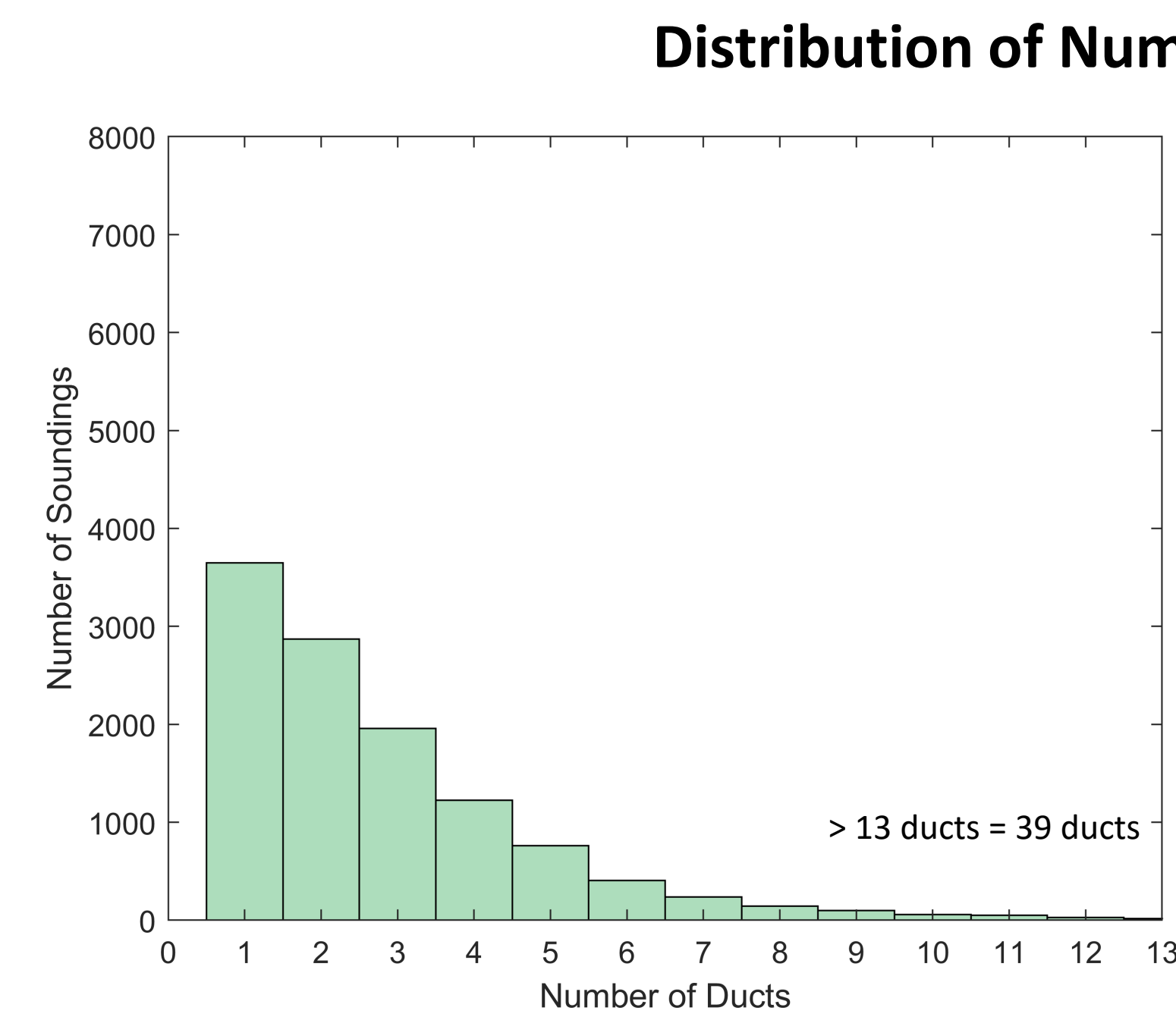
Inland:	Great Lake:	Coastal:
Fort Worth, TX	Buffalo, NY	Oakland, CA
Nashville, TN	Gaylord, MI	Quillayute, WA
Caribou, ME	Green Bay, WI	Tampa, FL
Minneapolis, MN		Newport, NC



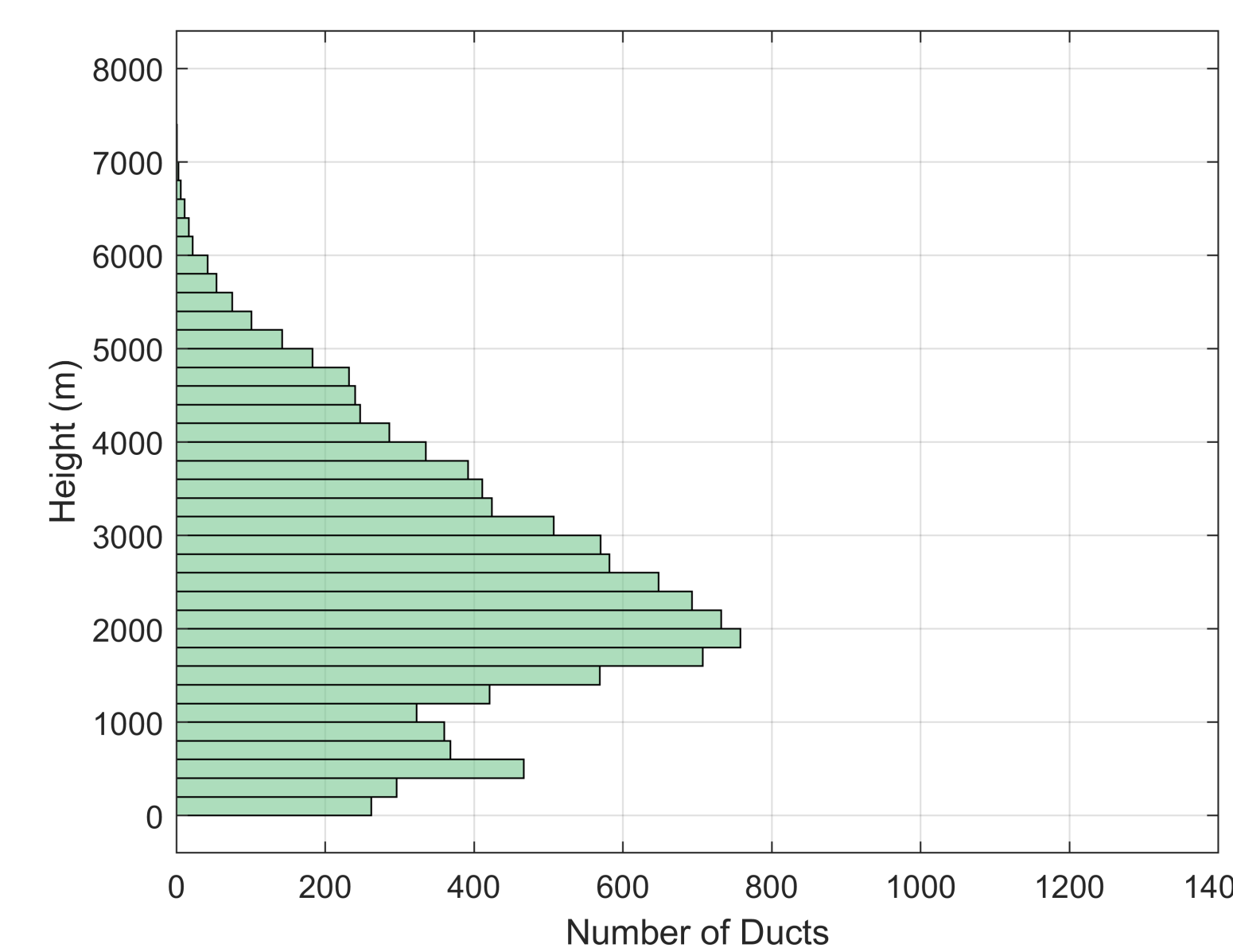
Island Duct Count:
11,538

Inland, Coastal, & Lake Duct Count:
12,270

Island

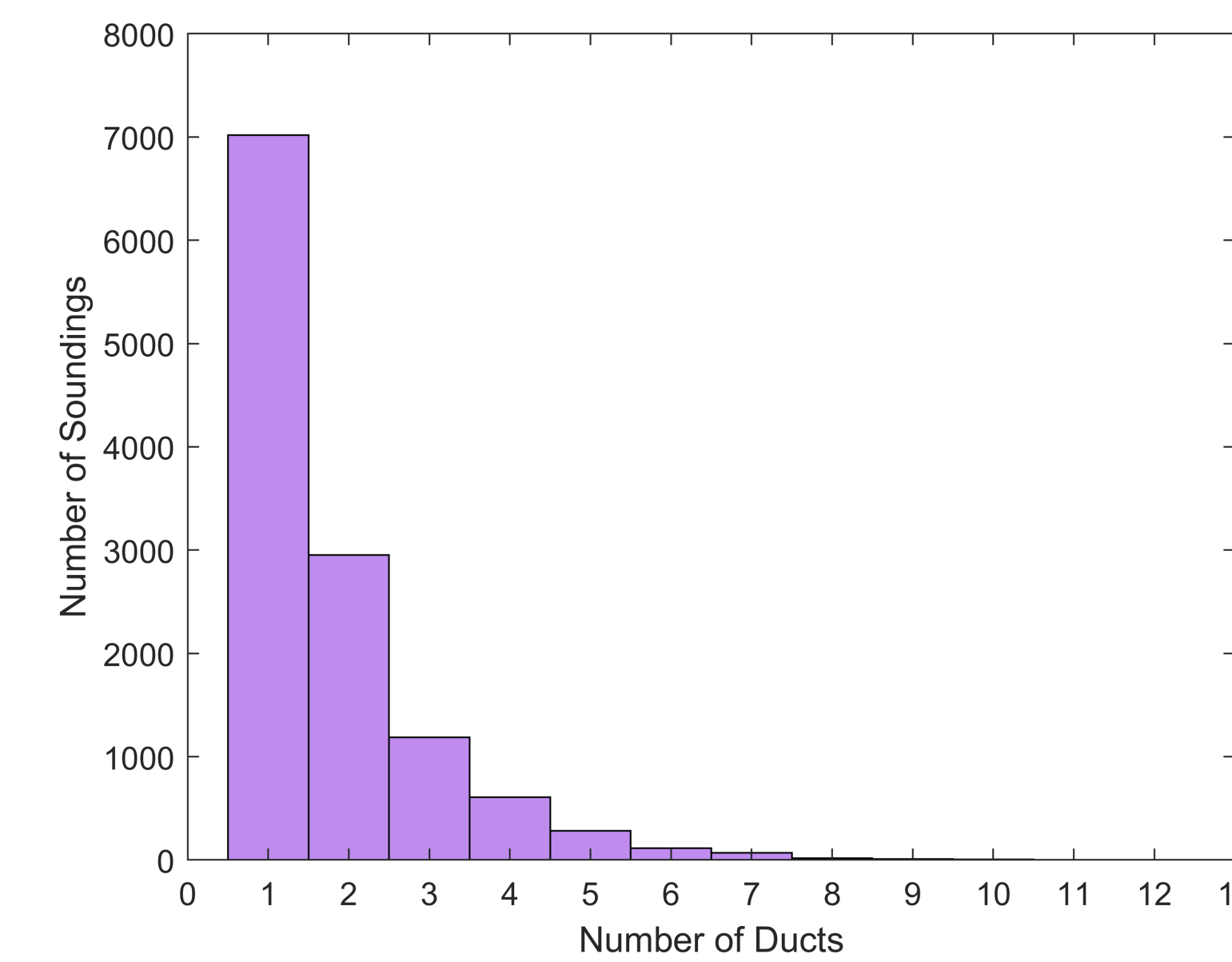


Distribution of Duct Base Heights.

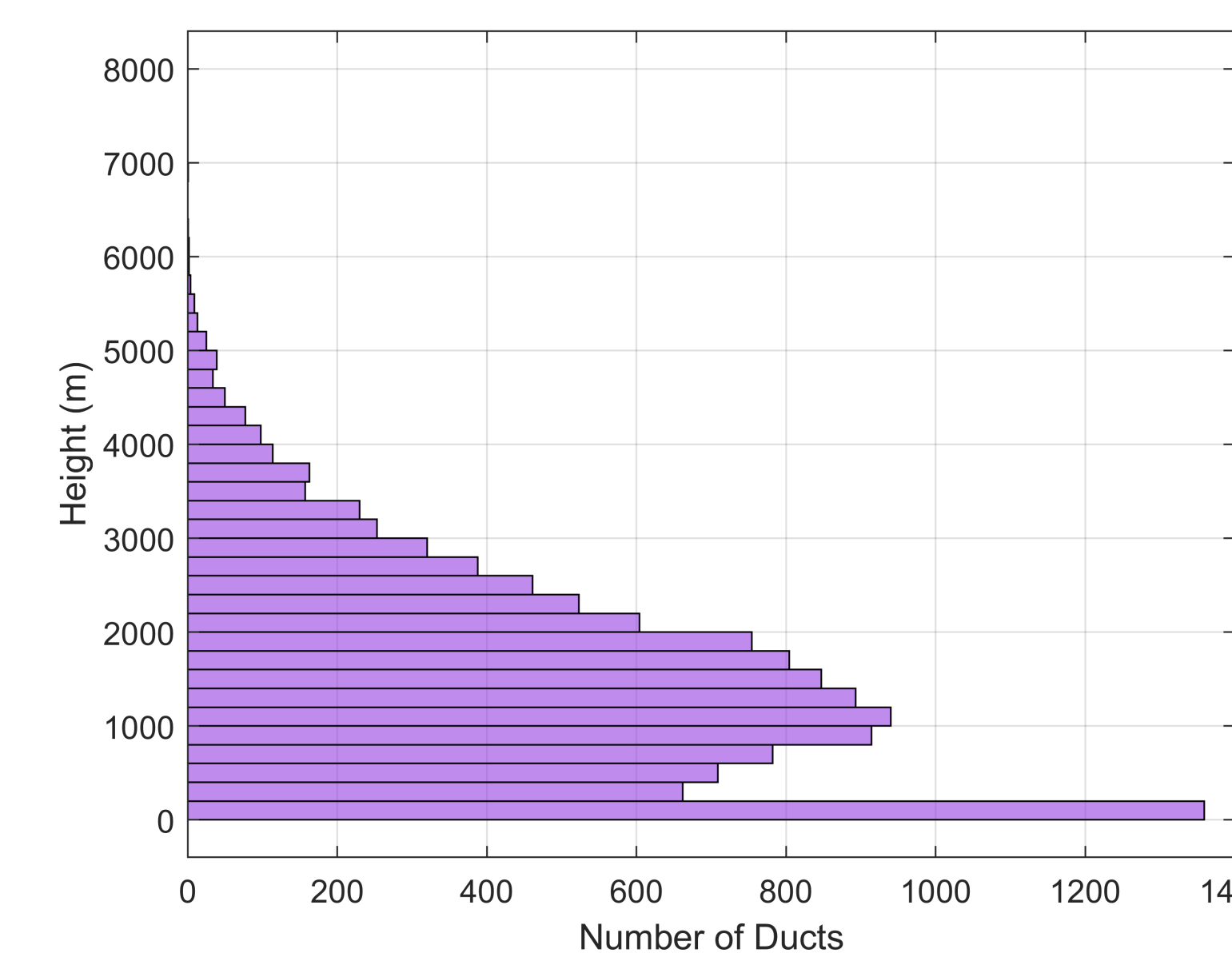


Coastal, Inland and Lake

Distribution of Number of Ducts in a Given Sounding.



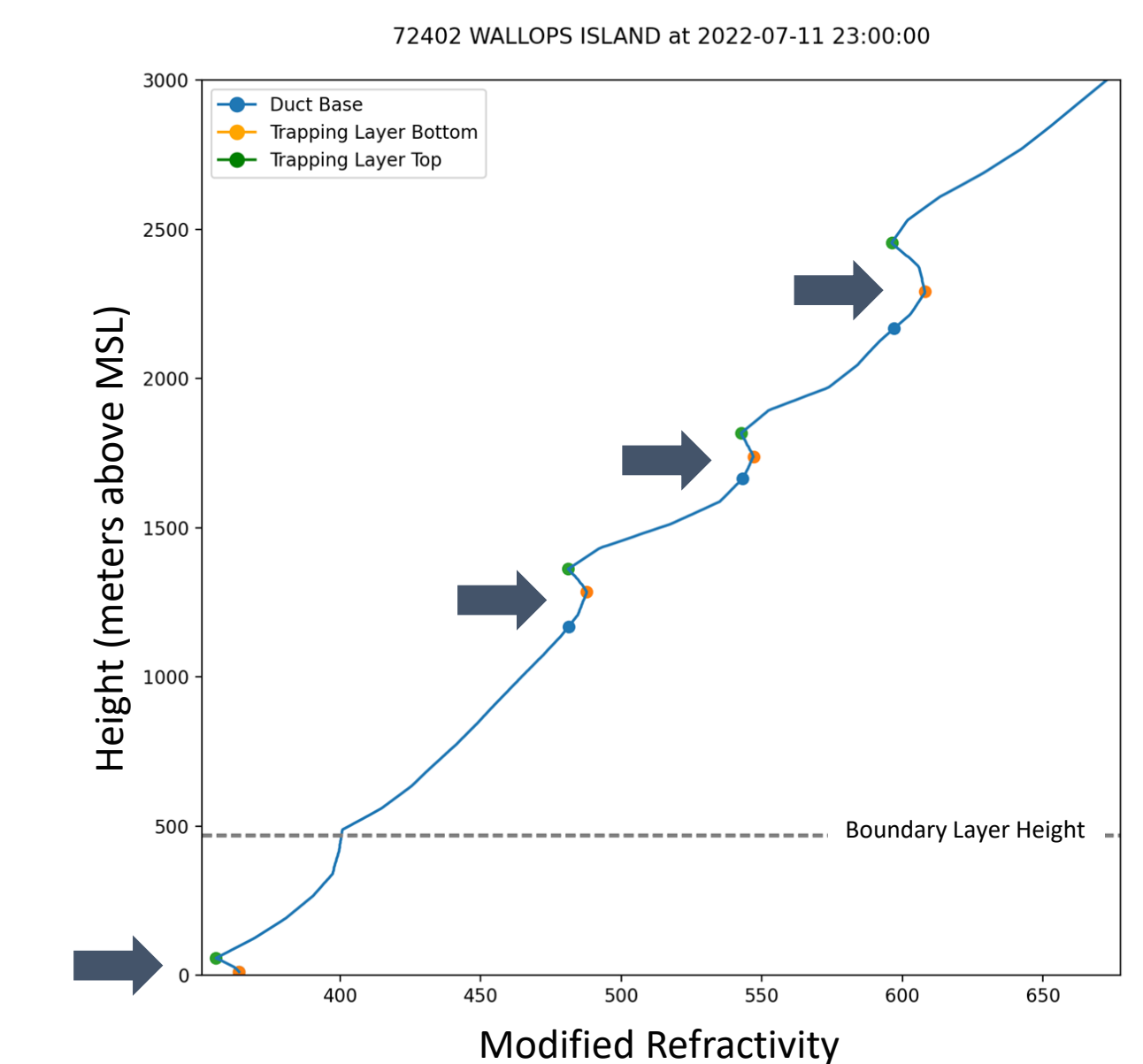
Distribution of Duct Base Heights.



Many soundings have more than one duct. Island locations have a wider distribution of duct counts.

If a sounding has more than one duct, each duct is counted separately. Island ducts tend to occur at higher altitudes than those at Coastal, Inland, & Lake locations.

Duct Example



Refractivity profile computed from weather balloon sounding from Wallops, VA on July 11th, 2022, demonstrates multiple ducts and a surface duct.

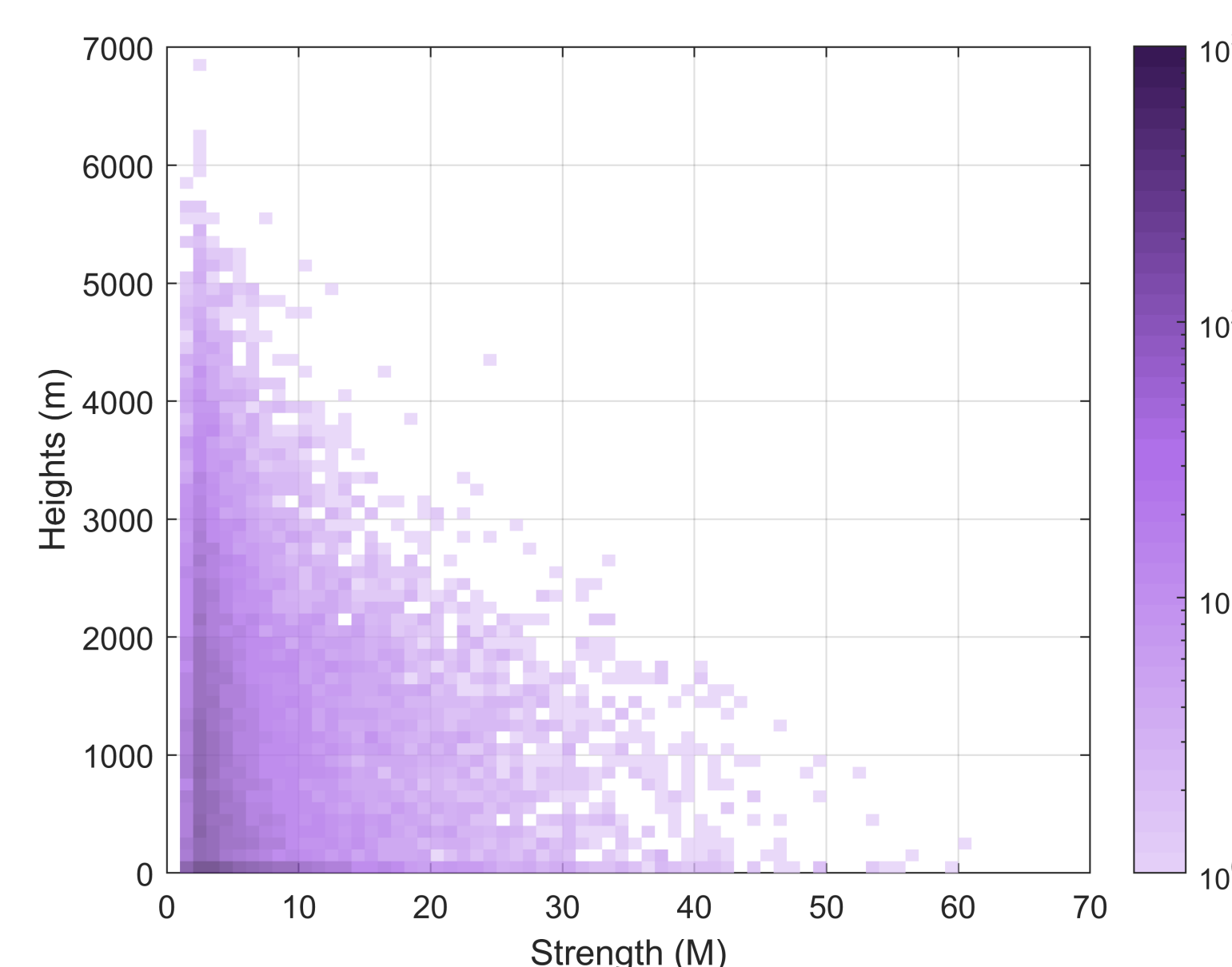
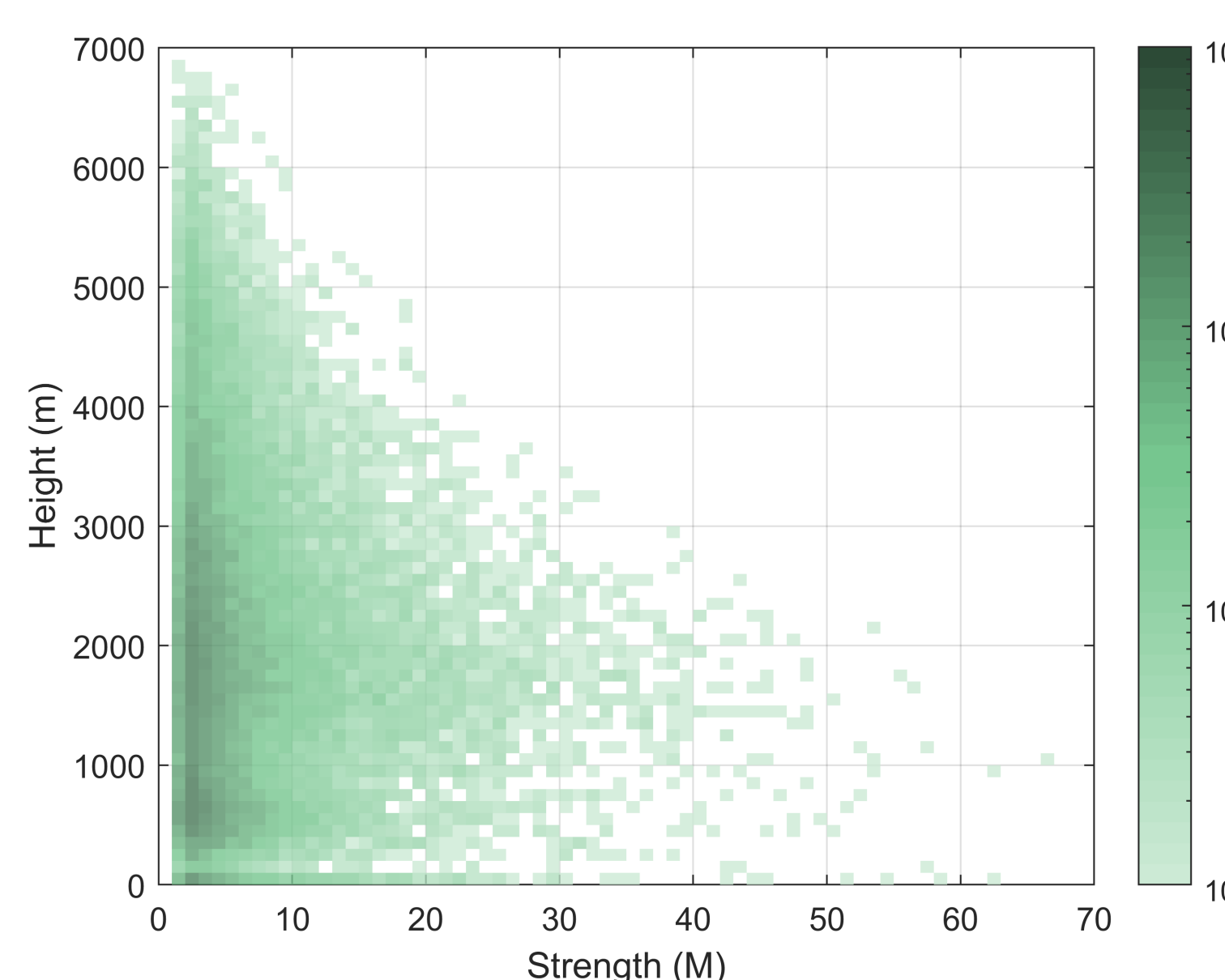
Duct Occurrence

Location Status:	Total Soundings Examined:	# of Soundings with ≥ 1 duct:	Percent of Soundings with ≥ 1 duct:
Inland	6158	3570	58%
Coastal	11016	6343	58%
Lake	4104	2367	58%
Island	20201	11587	57%

Summary

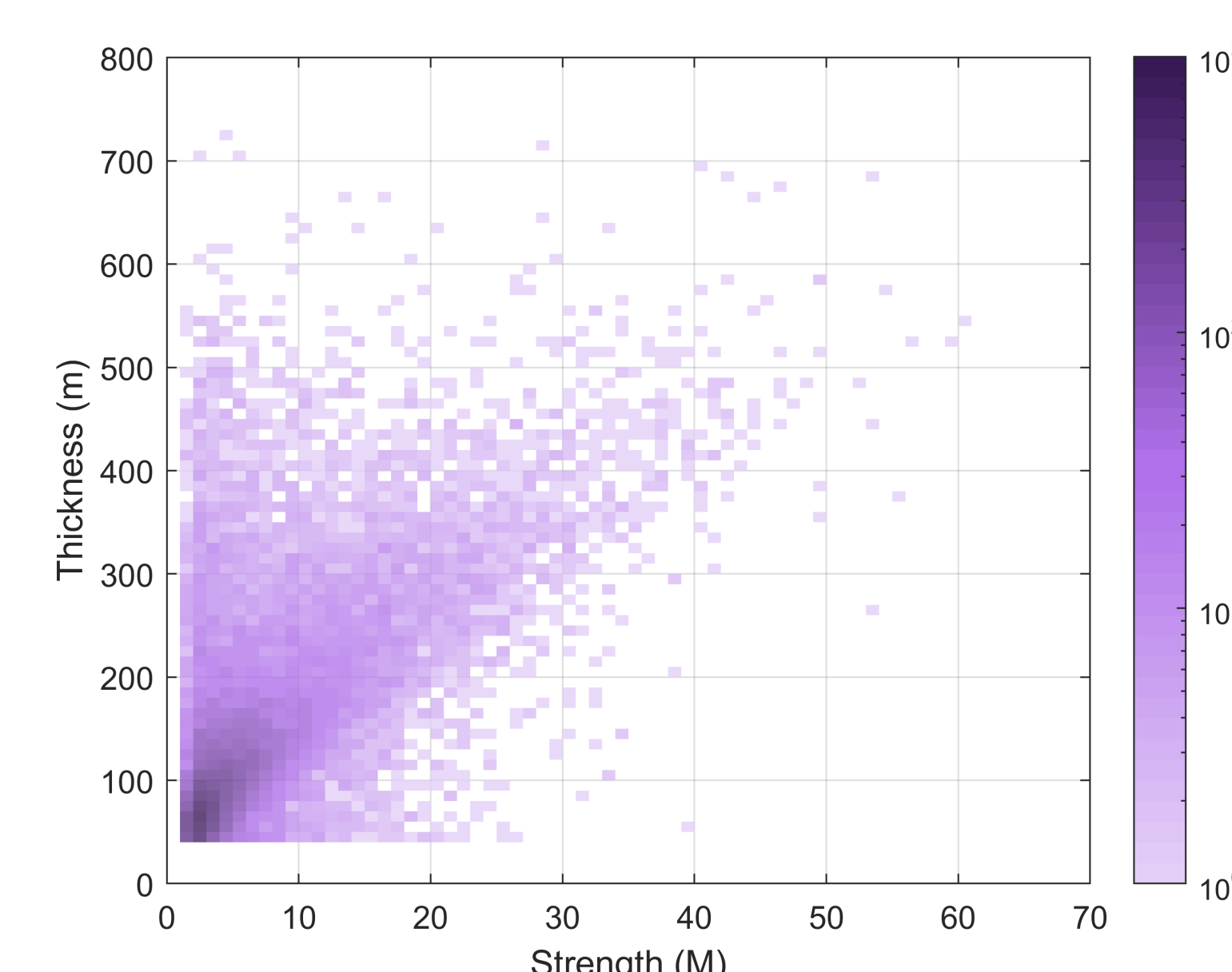
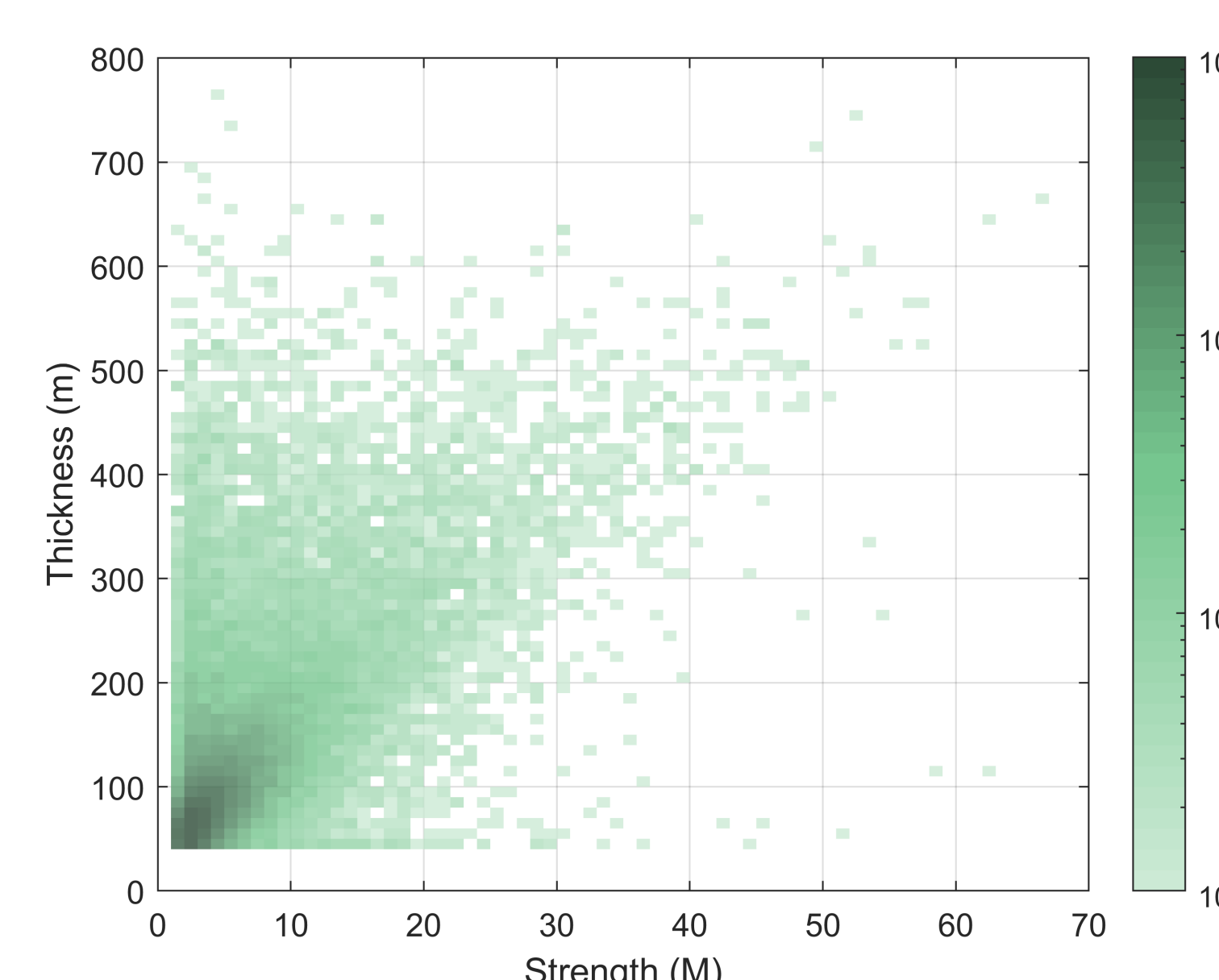
- At these locations, more than half of the soundings have at least one wave duct > 40 m in thickness.
- Median duct base height was 2332 m for islands and 1364 m for inland, coastal, and lake locations. Distributions show the expected higher occurrence of low-level radiation inversions over land than islands.
- Stronger duct magnitudes tend to be associated with thicker ducts.
- No clear relation between height of duct base and duct strength.

Duct Height vs. Strength



Most ducts are weak at all altitudes.

Duct Thickness vs. Strength



Uncommon to get strong ducts in a thin layer.

Acknowledgements

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