Characteristics of temperature inversions in wintry mix storms

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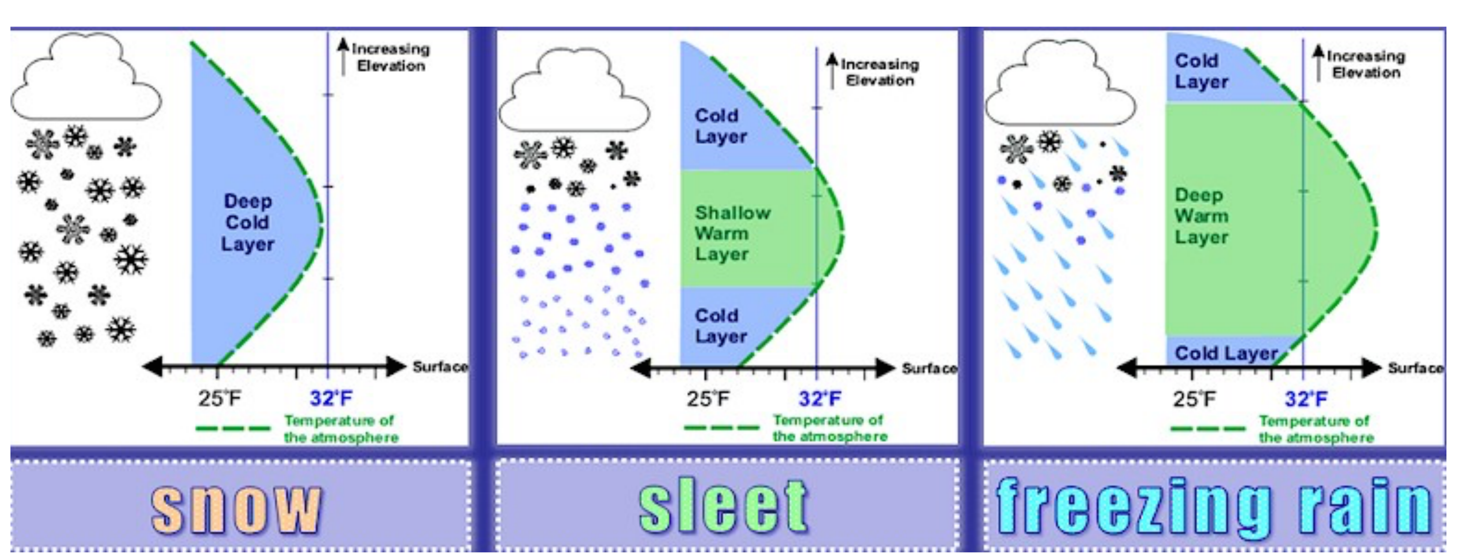
Introduction

Most winter storms on the east coast of the US produce a wintry mix of precipitation–some combination of sleet, snow, rain, freezing rain, and graupel–caused by the presence of one or more layers of temperatures greater than 0˚C. These layers take the form of a temperature inversion within the lowest 5 km of the atmosphere, or are simply a layer of above-freezing temperatures at the surface. We remark on shortcomings in many standard textbook approaches to teaching this structure, and investigate the characteristics of temperature inversions at Long Island, NY using soundings from the Integrated Global Radiosonde Archive, radar data from a vertically-pointing MicroRainRadar at Stony Brook, NY (MRR, wavelength = 1.25 cm), images from a Multi-Angle Snowflake Camera, and surface precipitation data from the Islip Automated Surface Observation System (ASOS).

Variability in temperature inversions

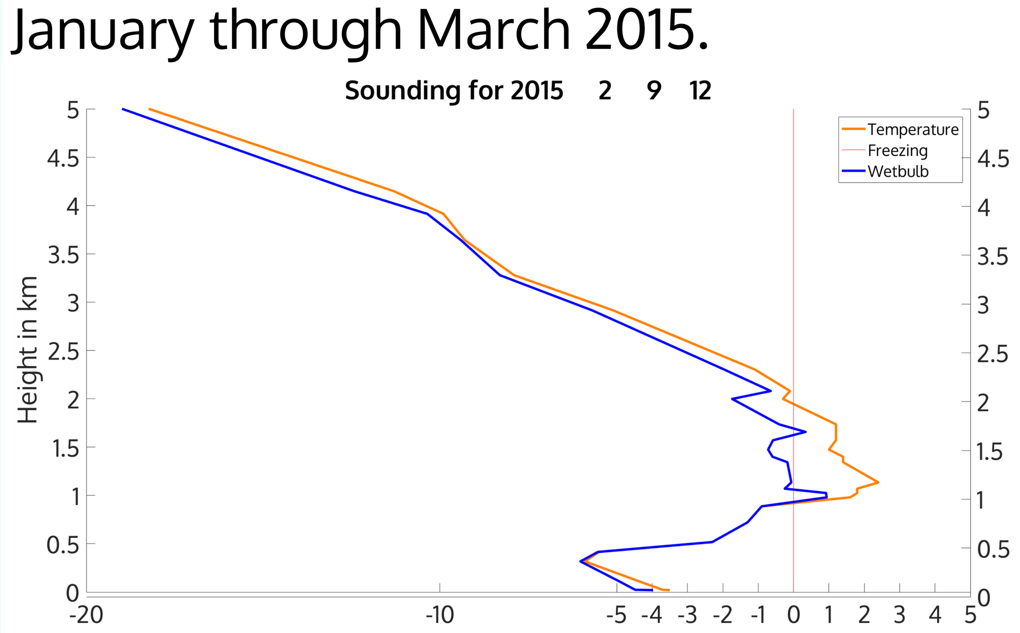
Textbooks and other introductory materials commonly depict the formation of different winter precipitation types with temperature-height figures such as the following:

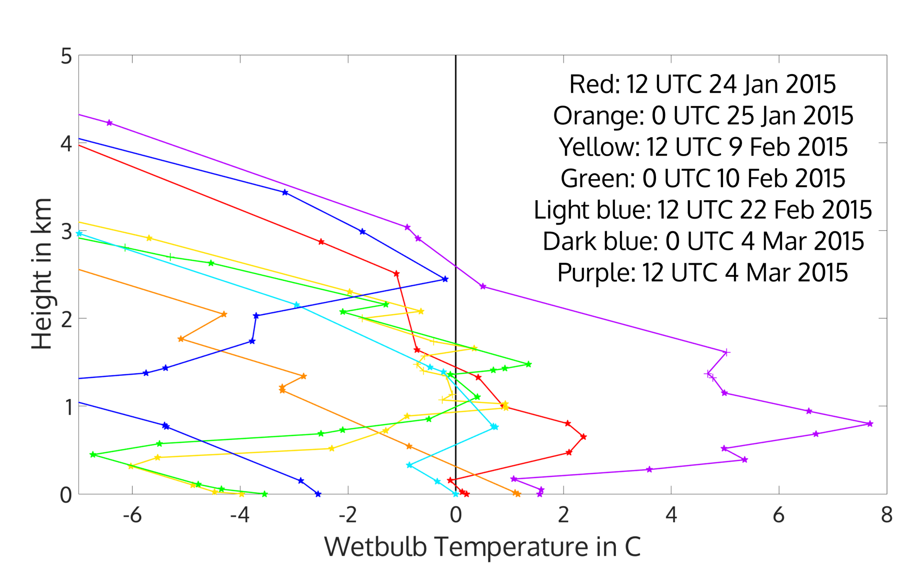


"Winter Weather Precipitation Types" graphic from NWS Mobile training website

Real temperature profiles deviate significantly from this idealization. The inversion rarely continues to the ground; instead, it is usually shallow and fully aloft, with the near-surface lapse rate returning to a non-inverted value. Real profiles commonly exhibited several separate inversion layers—sometimes even three separate inversions, each reaching greater than or equal to 0˚C.

An example of a real temperature-height profile from a sleet event on 12 UTC 9 February 2015 follows, as well as a composite of seven wintry mix events from January through March 2015.



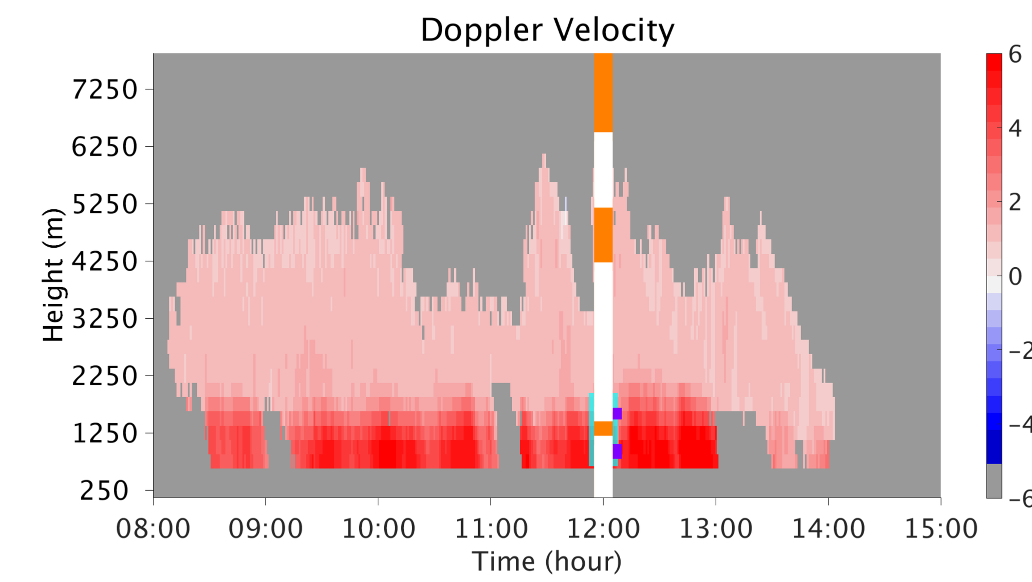


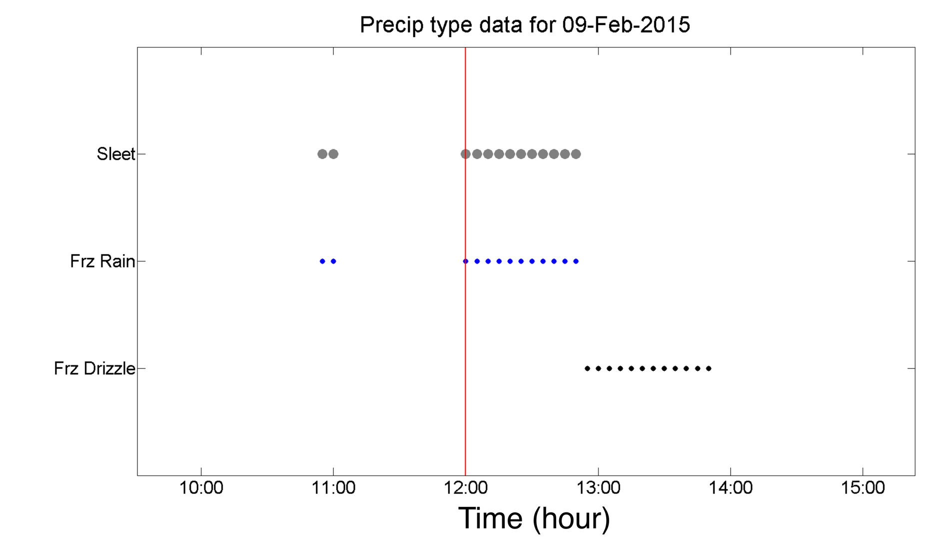
Wetbulb temperature represents the very local environment of hydrometeors, and helps to visualize changes in moisture with height (Kinzer and Gunn 1951).

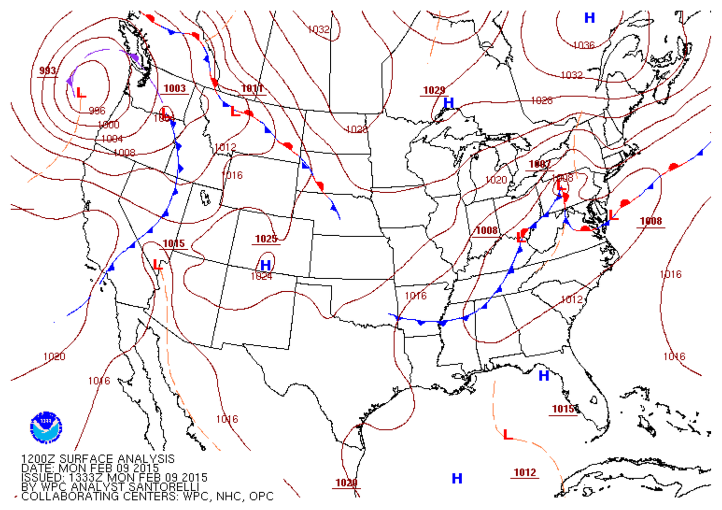
Kinzer, Gilbert and Ross Gunn. "The Evaporation, Temperature, and Thermal Relaxing of Freely Falling Waterdrops." Journal of Meteorology, vol 8 no 2 (1951).

Cloud-free layers

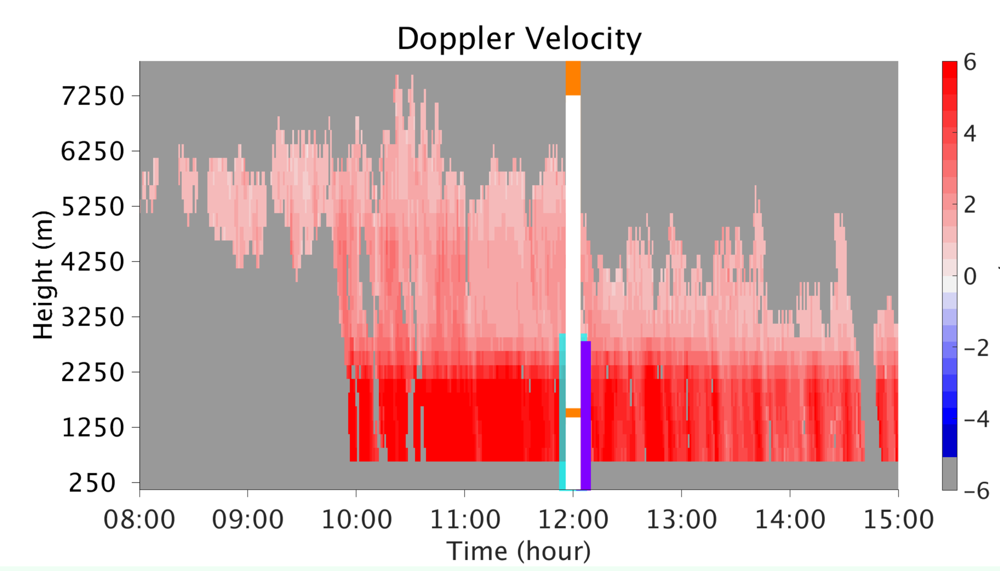
The cloud layer in a winter storm is usually assumed to overlap with the radar echo of the storm. However, relative humidity data reveals that there are often layers of dry air within the precipitating region. In the following figure, cloud layers (white), cloud-free layers (orange), temperatures greater than 0˚C (blue), and wetbulb temperature greater than 0˚C (purple) are superimposed on the MRR data from the 12 UTC 9 February 2015 sleet event. ASOS precipitation type data are also shown.

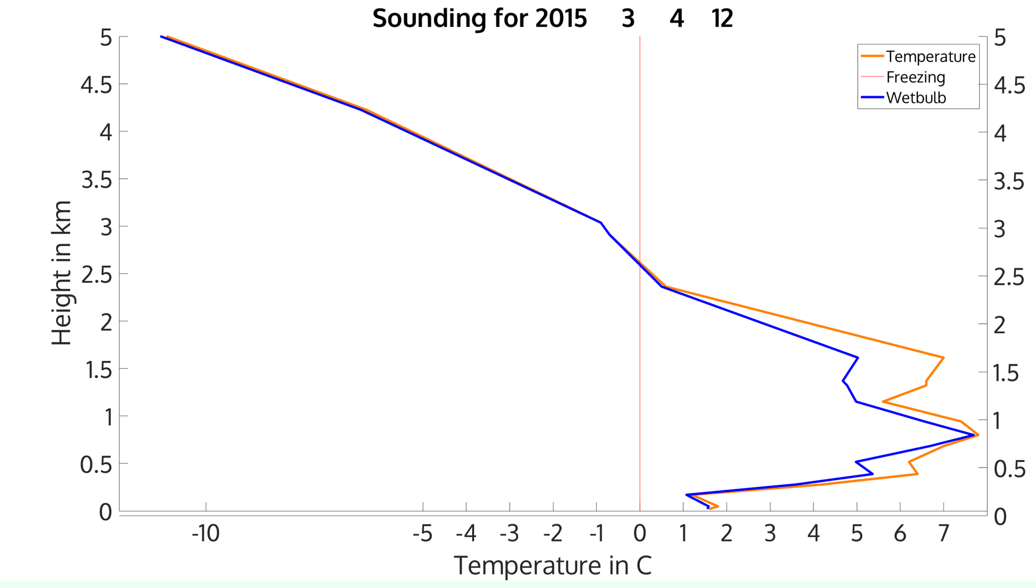


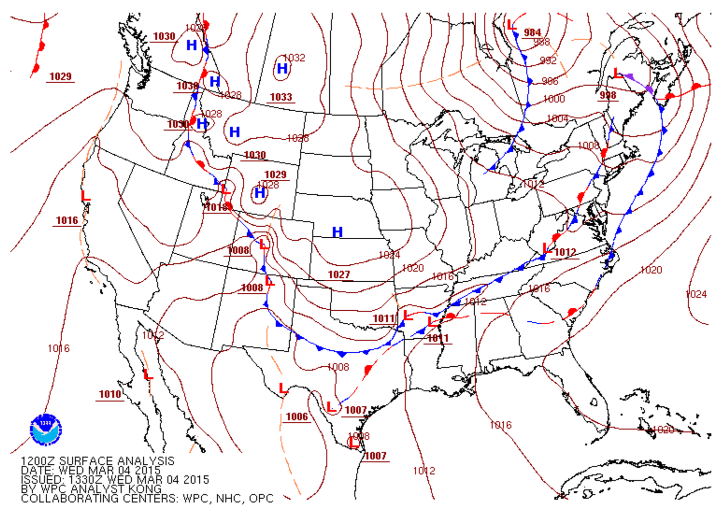




At times, the dry layers proved capable of persisting through prolonged periods of precipitation. During a mixed-precipitation event on March 4, 2015, we found that precipitation (in this case, rain) at the surface began around 10 UTC, but a narrow cloud-free layer remained until the 12 UTC sounding.

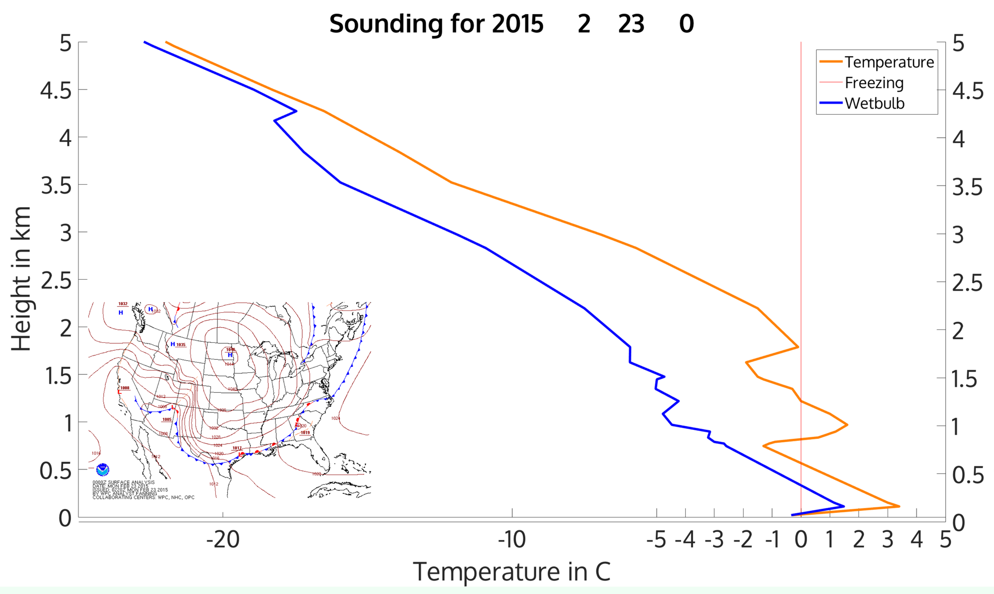


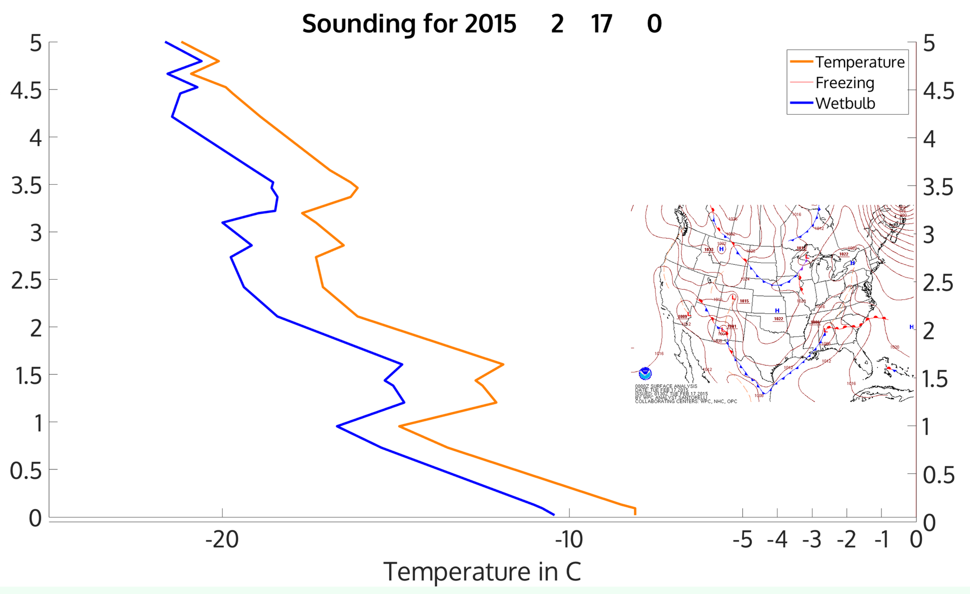


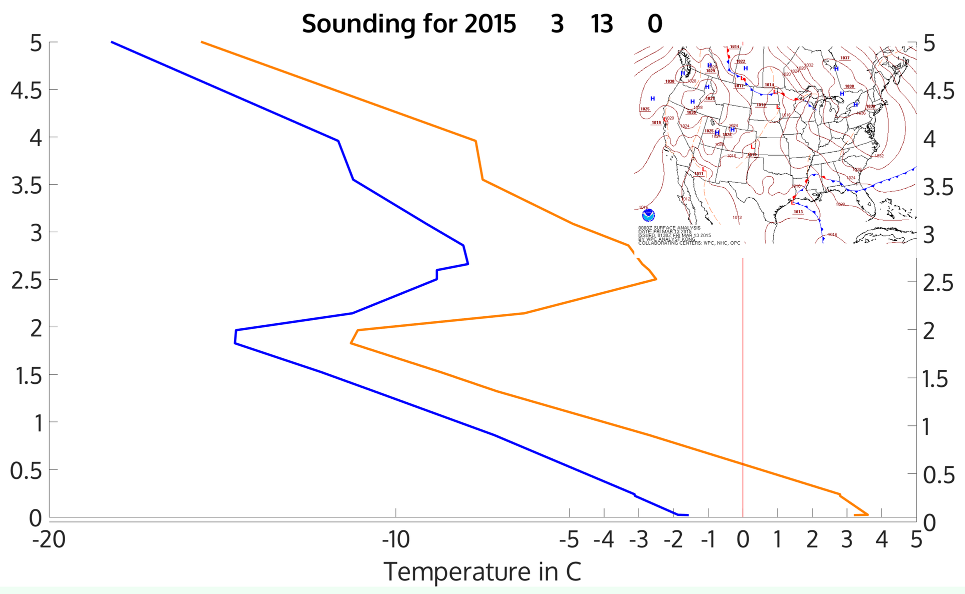


Inversion frequency

Temperature inversions in the lowest 5 km of the atmosphere of 200 meters or greater thickness are common in the Long Island area in the winter, appearing in 93% of November through March soundings from 1980 through 2016. Similar inversion frequencies are seen at many sites elsewhere in the US and Canada. Frequently, these temperature inversions are not associated with obvious surface air mass boundaries.







Conclusion

Temperature profiles in wintry mix storms are significantly more complex than standard textbooks depict.
Dry, cloud-free layers can exist within the three-dimensional radar echo of winter storms.
The presence of temperature inversions is the climatological norm over Long Island in the winter.

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