Geophysical Research Abstracts
Vol. 21, EGU2019-1968, 2019
EGU General Assembly 2019


# Characteristics of sea-effect and orographic precipitation systems in the heavy snow region of Japan

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A remarkable snow climate exists on the Japanese islands of Honshu and Hokkaido near the Sea of Japan. Mean annual snowfall in this heavy snow region approaches or exceeds 600 cm in some near-sea-level cities and exceeds 1300 cm at some mountain locations. The majority of this snow falls from December to February during the East Asian winter monsoon when frequent cold-air outbreaks occur over the Sea of Japan. The resulting sea-effect precipitation systems interact with mountains that rise to 1000–3000 m MSL, but feature large variations in the lowland-upland snowfall distribution that complicate weather forecasting and future projections of climate change.

Using data from the NASA A-Train Satellite Constellation, the Mt. Yahiko C-band radar, and an extensive network of precipitation gauges operated by the Japanese Meteorological Agency and Japanese National Research Institute for Earth Science and Disaster Resilience Snow and Ice Research Center, we examine the factors affecting the distribution and intensity of snowfall in the broader Sea of Japan region and in the Hokuriku region of central Honshu. A-Train data illustrate that during winter (December–February), sea-effect clouds and precipitation occur most frequently in the western Sea of Japan where the Japan-Sea Polar-Airmass Convergence Zone (JPCZ) forms frequently downstream of the Korean Highlands and east of the Korean Peninsula, as well as along and upstream of the Sea of Japan coast of central Honshu northward to Hokkaido Island. Sea-effect cloud and precipitation systems are deepest along the JPCZ and the central Honshu coast where formidable topography exists near the Sea of Japan, and more frequent but shallower along the Sea of Japan coast of Hokkaido. Detailed analysis of Mt. Yahiko radar data shows that the inland and orographic enhancement of sea-effect precipitation is strongly dependent on air-sea interactions (quantified by the magnitude of the sea-induced convective available potential energy, SCAPE), the direction and strength of the boundary layer flow, and interactions with the complex three-dimensional topography. For a given flow direction, high (low) values of boundary layer wind speed and SCAPE favor high (low) water-equivalent precipitation rates and an upland and inland (lowland and near-coast) precipitation maximum. However, precipitation rates frequently decline as one moves inland from the first major mountain barrier, even in regions where topography increases in elevation.

These results highlight how air-sea interactions, shoreline geometry, and orographic effects upstream and downstream of the Sea of Japan modulate the distribution of sea-effect precipitation in a region of complex and formidable topography. Knowledge of the mechanisms affecting the lowland-upland snowfall distribution may be broadly applicable to other regions where cold-air outbreaks over relatively warm water initiate boundary layer convection that interacts with complex terrain.