Sea-effect Precipitation Processes and Orographic Enhancement over Hokkaido Island, Japan

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MOTIVATION

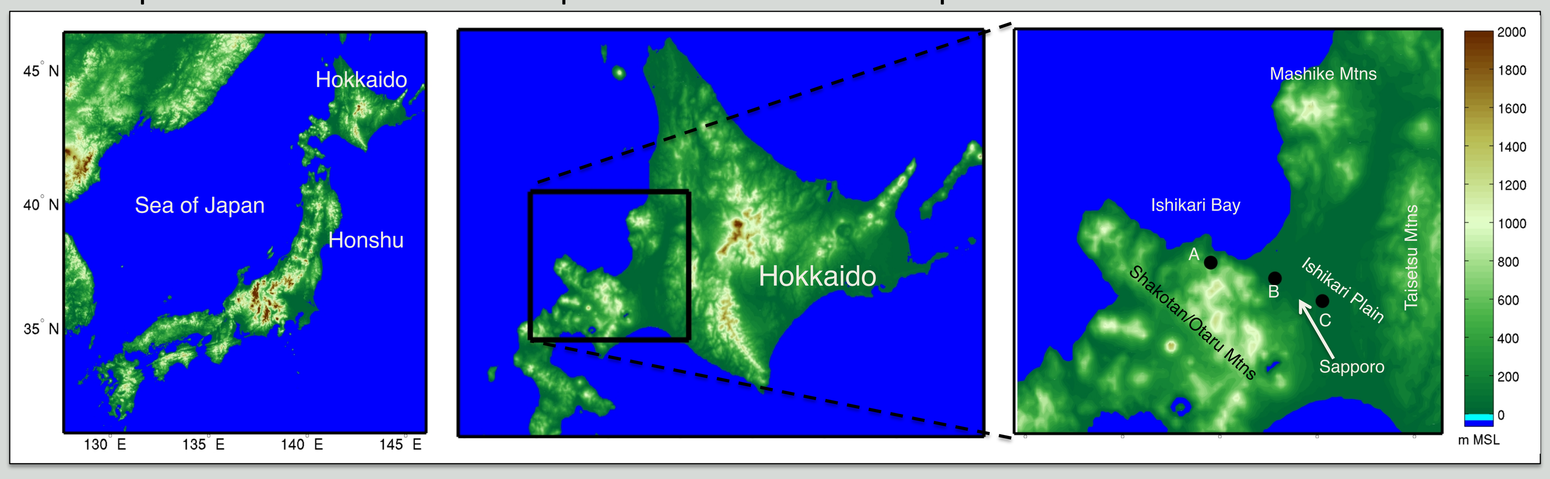
- Sea- and lake-effect snowstorms can inundate affected urban and rural communities with long-duration, intense, and often extremely localized snowfall, disrupting local and regional transportation, education, utilities and commerce.
- Orography dramatically affects the intensity and spatial distribution of sea- and lake-effect snowfall.
- Weather forecasters and numerical models currently struggle with accurately predicting the magnitude, timing, and spatial distribution of this heavy snowfall. An improved understanding of precipitation processes and terrain interactions in sea- and lake-effect storms is imperative to improving forecast skill during these events.

OBJECTIVES

- To describe the structure of transverse-mode snowbands impacting the Ishikari Plain and surrounding mountains on Hokkaido Island, Japan
- To explore the changes in structure and precipitation mechanism that orography induces in transverse-mode snowbands
- To determine the controls of precipitation distribution over the lowlands vs. the mountains

INTRODUCTION

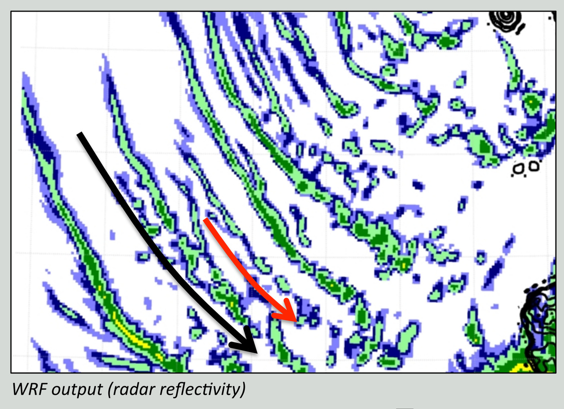
- During the winter cold air from the Asian continent moves across the Sea of Japan (~400 km across), producing seemingly omnipresent snowbands that impact the west coast of Japan

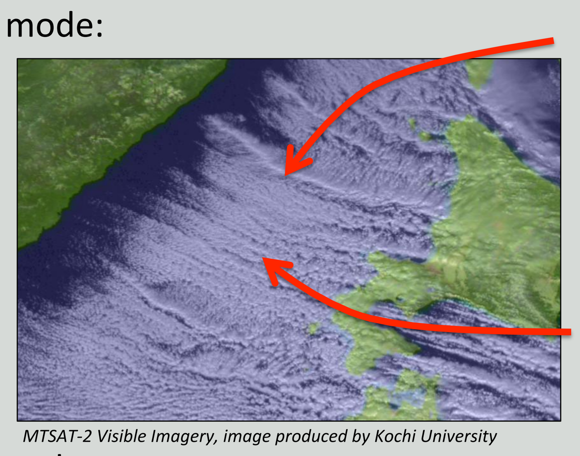


Instrumentation used in this study includes:
- C-band Otaru radar (Point A, near left)
- Snow study station at Hokkaido University (Point B, near left)
- X-band Kitahiroshima radar (Point C, near left)

Sea-effect organizational modes: Longitudinal mode:

- Horizontal roll convection
- Convective cells (red arrow) within the parent bands move parallel to the mean wind direction (black arrow; near right)
- More intense, quasi-stationary longitudinal-mode snowbands are formed in the convergence zones in the lee of mountains on the upstream coast of Asian continent

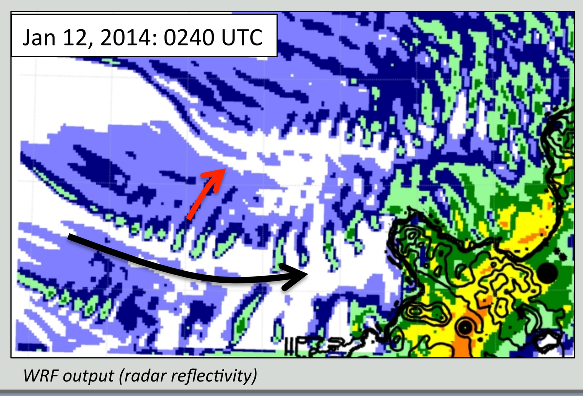

WRF output (radar reflectivity)



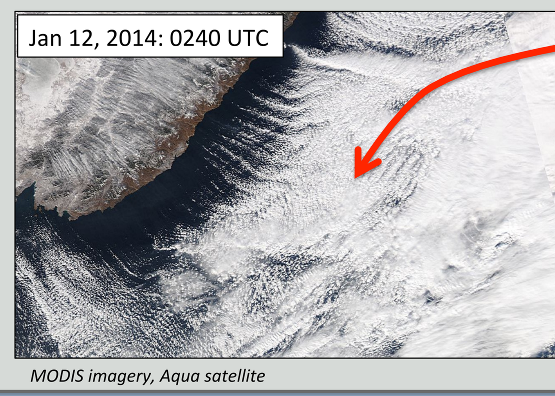
MTSAT-2 Visible Imagery, image produced by Kochi University

Transverse mode:

- Convective cells (red arrow) move roughly parallel to the wind shear vector (between surface and cloud top) and roughly perpendicular to the mean flow direction (black arrow; near right)
- Account for ~12% of observed lake-effect precipitation in the region (Nakai et al. 2005)
- Not studied as frequently as longitudinal-mode bands



WRF output (radar reflectivity)

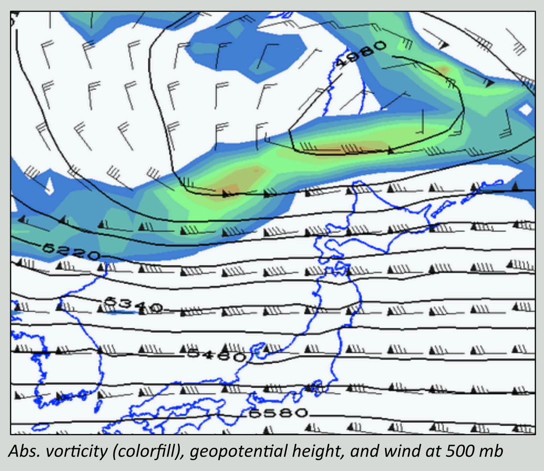


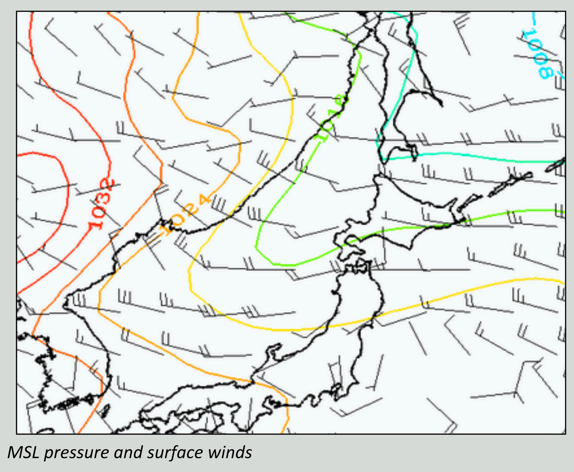
MODIS imagery, Aqua satellite

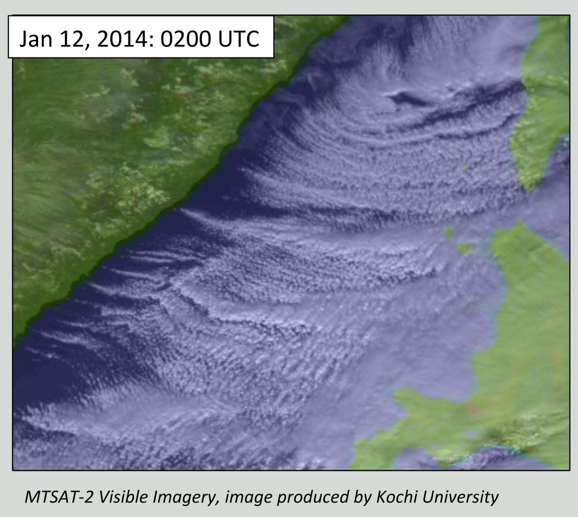
RESULTS

Event Overview

- Transverse bands formed upstream of Hokkaido island following the passage of a shortwave trough around 0000 UTC January 12 (right).

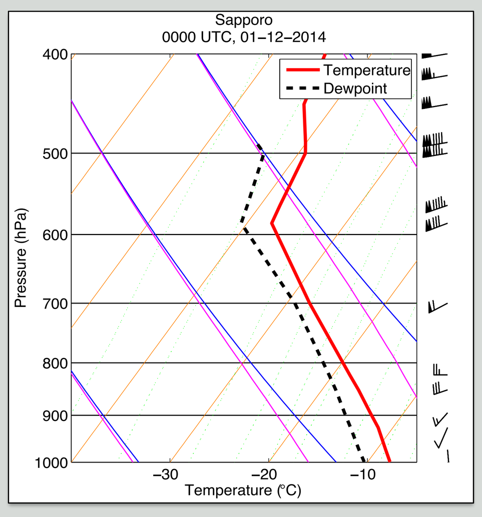

Abs. vorticity (colorfill), geopotential height, and wind at 500 mb


MSL pressure and surface winds



MTSAT-2 Visible Imagery, image produced by Kochi University

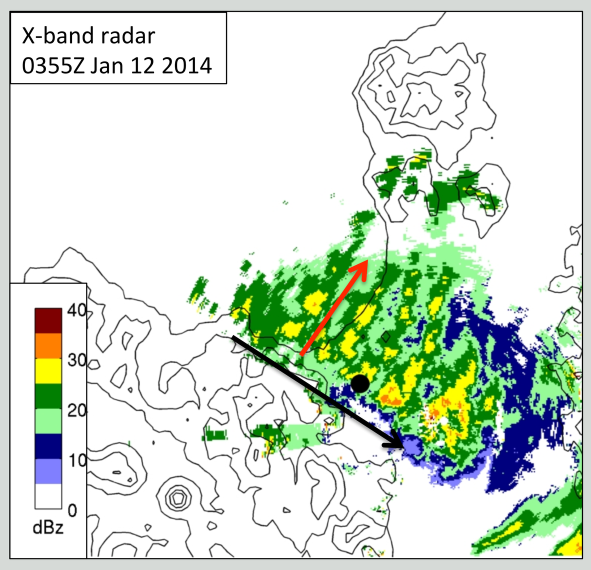
Note transverse bands and cloud band associated with trough passage



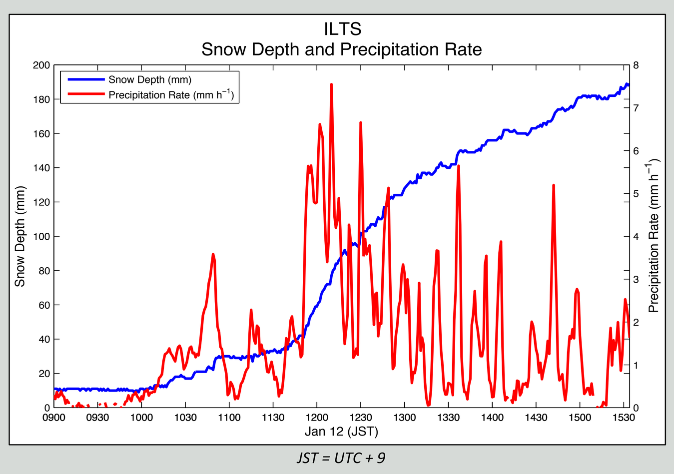
Sounding from 0000 UTC Jan 12 shows a nearly moist-adiabatic profile (above)

Band Structure and Characteristics

X-band radar imagery shows the band's structure (right). Black arrow denotes motion of the overall band, red arrow indicates direction of movement of cells within each transverse sub-band.

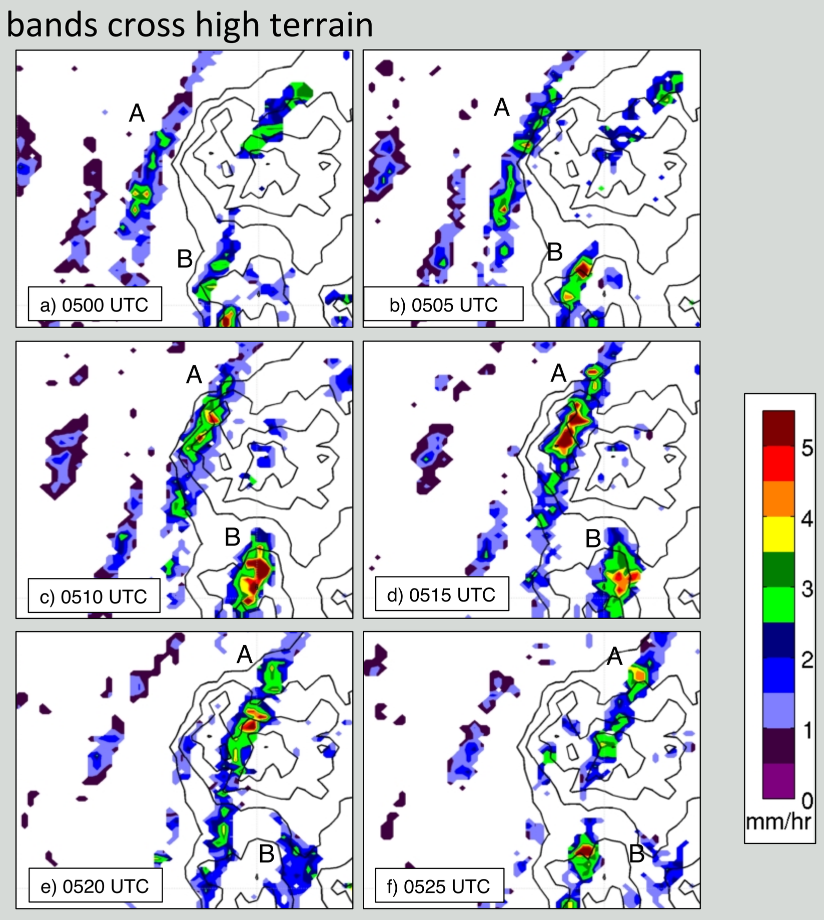


A trace of precipitation rate (right) taken at Hokkaido University (above right, black dot), demonstrates the sporadic nature of precipitation as transverse bands impacted the Ishikari Plain.



Band Intensification over Terrain

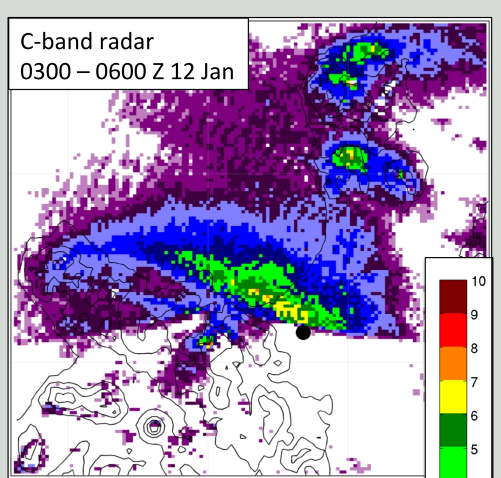
A time series of transverse bands crossing the Mashike Mtns (below) shows that reflectivity increases over the mountains, suggesting that convection is invigorated as the bands cross high terrain

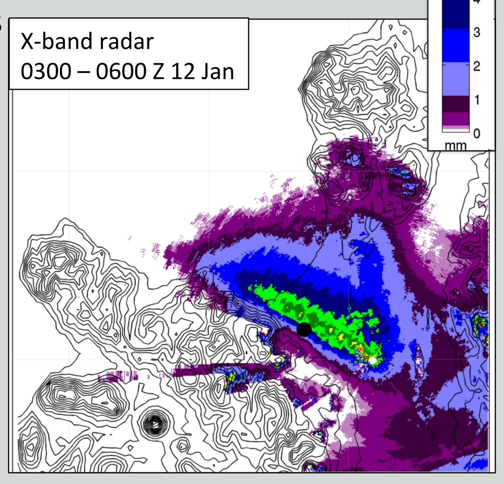


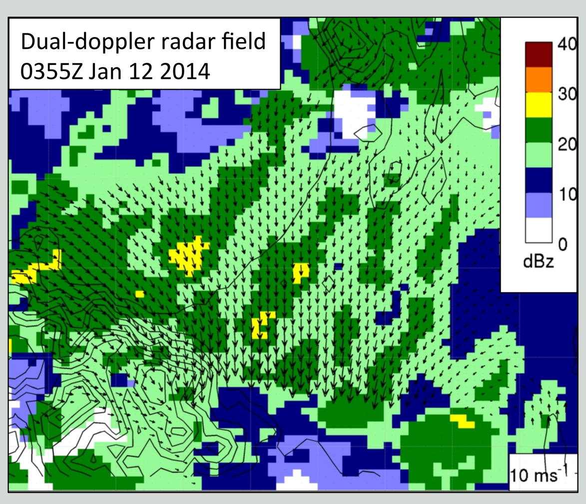
Enhanced Precipitation East of Otaru Mountains

Radar-derived precipitation estimates from the C-band (right, upper) and X-band radars (right, lower) both show a precipitation maximum over the Ishikari Plain along the eastern flank of the Otaru Mountains

Is this precipitation maximum a product of band location or some other factor?





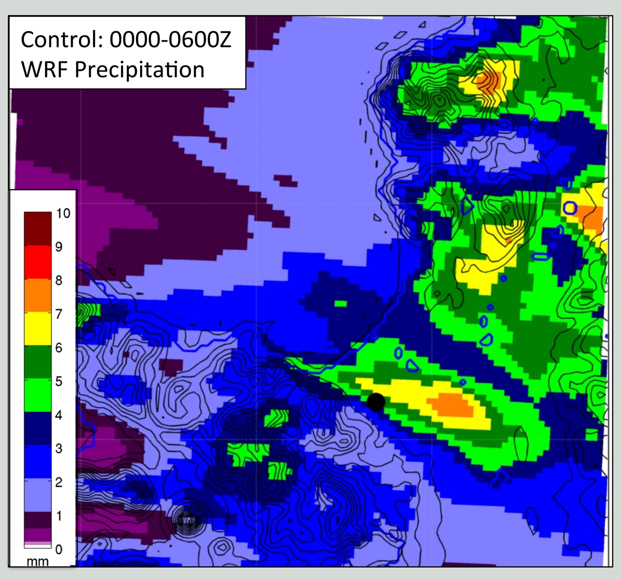


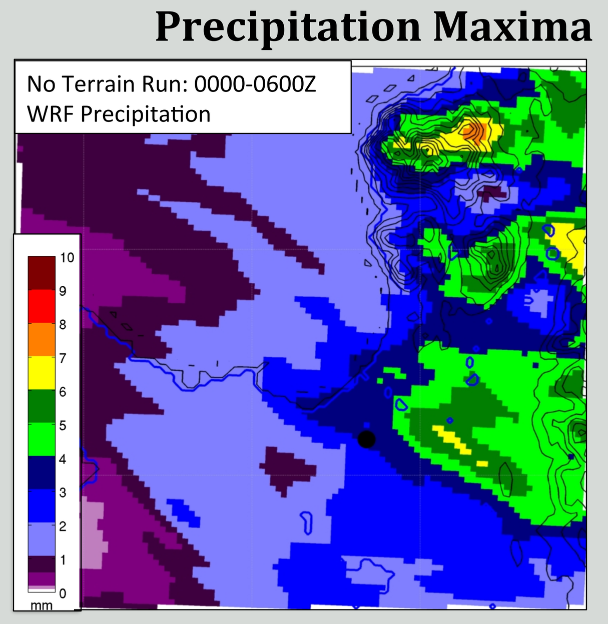
Dual-Doppler winds show convergence over the Ishikari Plain as winds are funneled to the east of the coastal mountains (above)

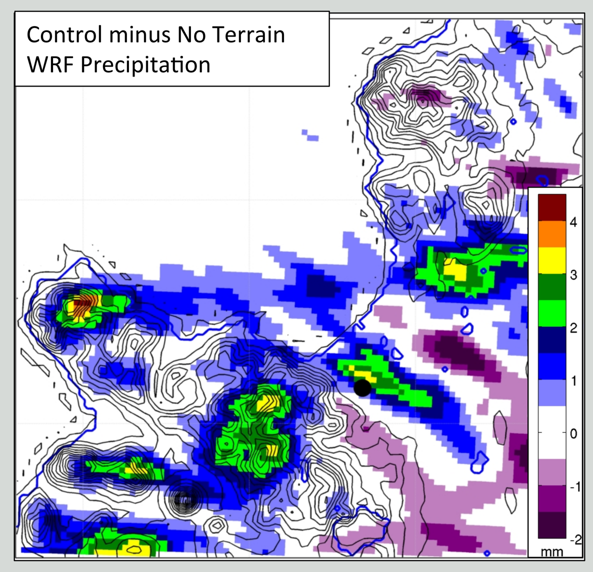
Convergence alongside the Otaru Mtns may contribute to the precipitation maximum

FUTURE WORK: Complete dual-Doppler analysis to produce a three-dimensional analysis of transverse band structure and evolution

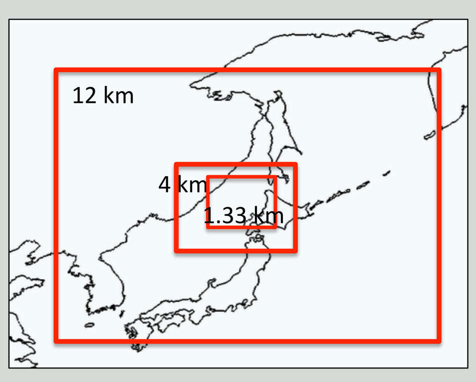
WRF Simulations Show that Both Terrain and Band Location Affect Precipitation Maxima







- WRF ARW Version 3.5.1
- NCEP Reanalysis
- NOAA analysis Sea Surface Temperatures
- 3 nested domains: 12 km, 4 km, and 1.33km resolution
- Thompson microphysics
- Noah land-surface model
- YSL boundary layer scheme
- Kain Fritsch cumulus scheme for outer two domains



Precipitation distribution over Ishikari Plain (above left) is similar to that observed by radars (far left)

Run with no terrain on southern half of island changes the magnitude and width but not the location of the precipitation maximum on the Ishikari Plain (c.f., above center, above left; above right)

Precipitation maxima over Shakotan/Otaru Mtns disappear in No Terrain run

FUTURE WORK: Analyze microphysics and structure using WRF runs; Perform additional sensitivity studies including removal of terrain north of the Ishikari Plain.

CONCLUSIONS

- Transverse-mode bands produce sporadic bursts of precipitation and focused precipitation maxima over and around affected terrain
- Transverse bands intensify as they cross high terrain, suggesting an invigoration of convection
- Flow diverted around coastal terrain creates acceleration and convergence just upstream of the precipitation maximum
- High coastal terrain creates precipitation maxima that disappear when model simulations are run with no terrain

ACKNOWLEDGEMENTS

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Nakai, S., K. Iwanami, R. Misumi, S.-G. Park, and T. Kobayashi, 2005: A Classification of Snow Clouds by Doppler Radar Observations at Nagaoka, Japan. *SOLA*, **1**, 161–164.