Mesoscale structure of a frontal snow system around Barrow, Alaska: An observational and modeling study

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INTRODUCTION

Many researchers have studied synoptic and microphysical characteristics of Arctic clouds. They demonstrated synoptic pressure patterns and radiation and microphysical processes in mixed-phase clouds in the Arctic. However, mesoscale structures of Arctic frontal precipitation systems is still unclear: wind fields and spatial distributions of snow particles and cloud droplets. To elucidate the characteristics of Arctic frontal snow cloud systems, the mesoscale structure of a frontal snow system passing through Barrow on 16-18 October 2012 was analyzed taking advantage of the new radar systems deployed at Barrow and using a cloud resolving model.

SUMMARY

Structure of an Arctic frontal snow system on 16-18 October 2012 was analyzed using observational data at Barrow and a cloud resolving model. Simulated wind, snow, and cloud droplets were in good agreement with radar and lidar measurements.

Observation: Snow bands passed over the radar range from east. The -10 dBZ echo-top heights decreased from a height of 6 km. The radar reflectivity below a height of 2 km reached peak values up to 25 dBZ. Radar-estimated horizontal winds showed a predominance of northerly and northwesterly winds below a height of 3 km and southeasterly winds above a height of 3.5 km. The HSRL backscatters suggested a presence of cloud droplets below a height of 2 km.

Model: The upper-level southeasterly winds ran across the Brooks Range. The high-θe northeasterly winds overran a preexisting northerly wind layer below a height of 3 km. Snow bands developed in the frontal zone and moved toward west. The snow mixing ratios increased up to 0.7 g kg^{-1} below the height of 2 km. Cloud droplets were formed in the layer of northerly wind below the height of 2 km.

DATA

Observational data

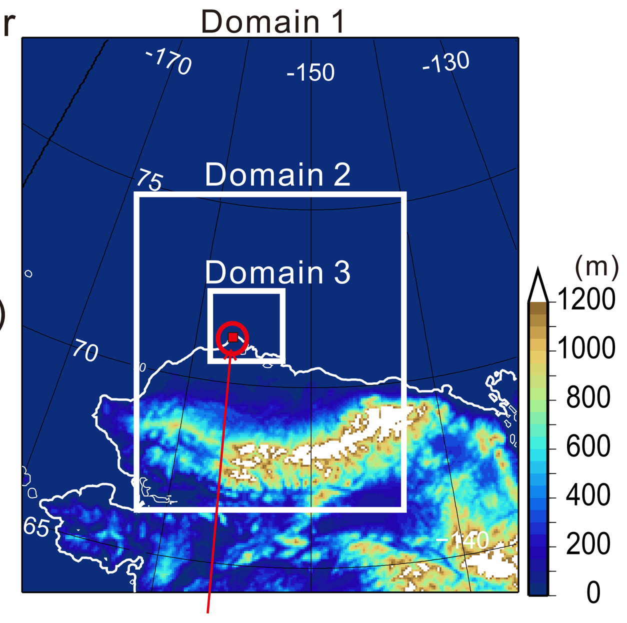
X-band Scanning ARM Precipitation Radar (X-SAPR, ✕)
- Radar reflectivity, Zh (horizontally polarized)
- Radial velocity

Ka-band ARM Zenith Radar (KAZR, ●)

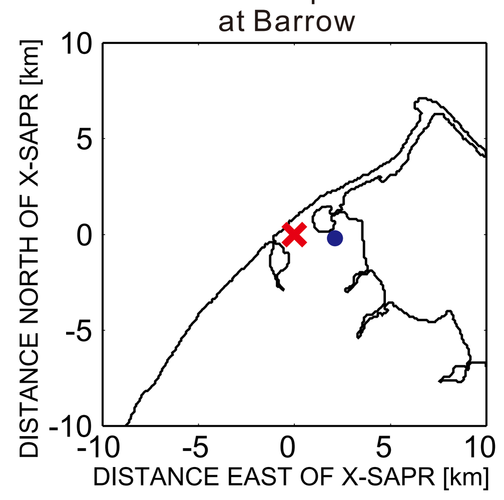
High Spectral Resolution Lidar (HSRL, ●)

Soundings (06 and 18 UTC, ●)

	X-SAPR	KAZR
Frequency	9375 MHz	34.83 GHz
Observation range	50000 m	17500 m
Operation mode	Range height indicator (RHI) Plan position indicator (PPI)	Zenith
Range gate spacing	75.0 m (RHI) 50.0 m (PPI)	30.0 m
Pulse repetition frequency	1950 Hz (RHI) 2300 Hz (PPI)	2711.3 Hz
Pulse width	0.5 μs (RHI) 0.37 μs (PPI)	0.3 μs
Nyquist velocity	15.11 m s^{-1} (RHI) 17.83 m s^{-1} (PPI)	5.96 m s^{-1}
Rotation rate of antenna	1.0 rpm (RHI) 2.3-4 rpm (PPI)	



DOE ARM North Slope of Alaska site at Barrow



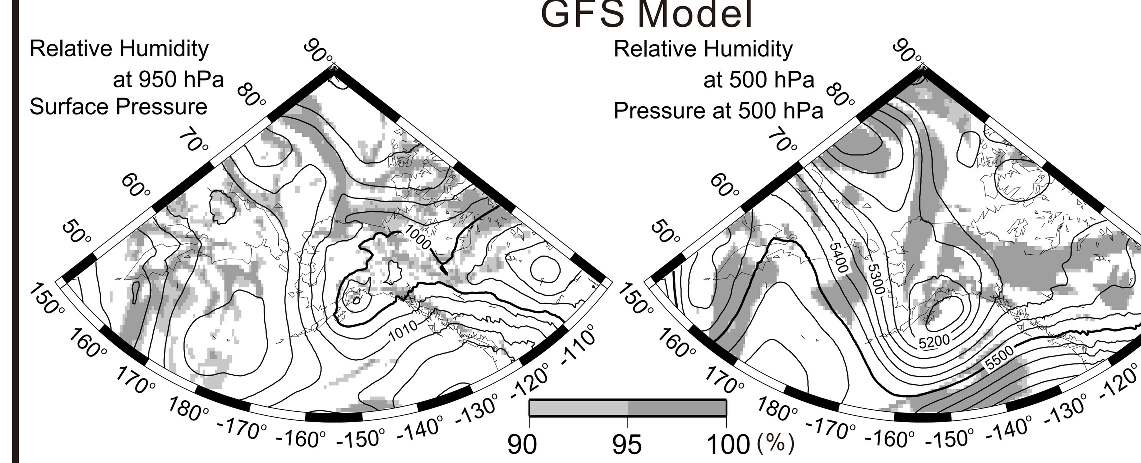
Model settings

Weather Research Forecast (WRF) Model Version 3.4.1

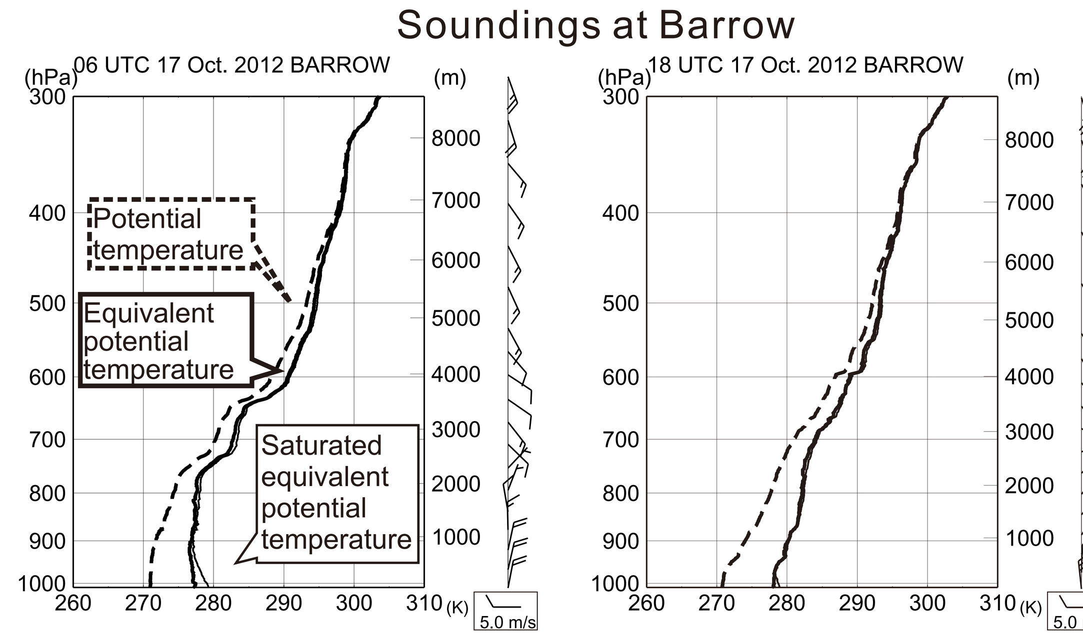
	Domain 1	Domain 2	Domain 3
Domain	1488 × 1662 (km)	800 × 944 (km)	216 × 210 (km)
dx × dy	6 × 6 (km)	2 × 2 (km)	0.5 × 0.5 (km)
Time step	36 sec	12 sec	6 sec
Calculation time	42 hours	39 hours	36 hours
Start time	2012.10.16 18:00:00	2012.10.16 21:00:00	2012.10.17 00:00:00
Initial and boundary data	North America Mesoscale Model (11.25-km resolution, 2012.10.16 12:00:00)	Domain 1	Domain 2
Microphysics	Morrison double-moment scheme (Qc, Qi, Qs, Qg, Qr, Nc, Ni, Ns, Ng, Nr)		
Cumulus parameterization	No		
Model top	200 hPa		
Number of levels	49 (20 levels below 2 km)		
Planetary boundary layer physics	Yonsei University Scheme		

ENVIRONMENT

00 UTC 17 Oct. 2012 GFS Model



Soundings at Barrow



GFS at 00 UTC on 17 October

There was a depression on the surface around the Gulf of Alaska. The depression corresponded to a low pressure at 500 hPa.

A high relative humidity (> 90 %) airmass existed to the east of Barrow at the low level.

Soundings at Barrow

There were northerly winds below a height of 2.5 km and southwesterly winds above a height of 3 km at 00 UTC on 17.

The northerly wind layer showed a constant equivalent potential temperature (θe) of 276 K.

There were northeasterly winds with θe of greater than 280 K at heights between 0.5 and 3 km at 18 UTC.

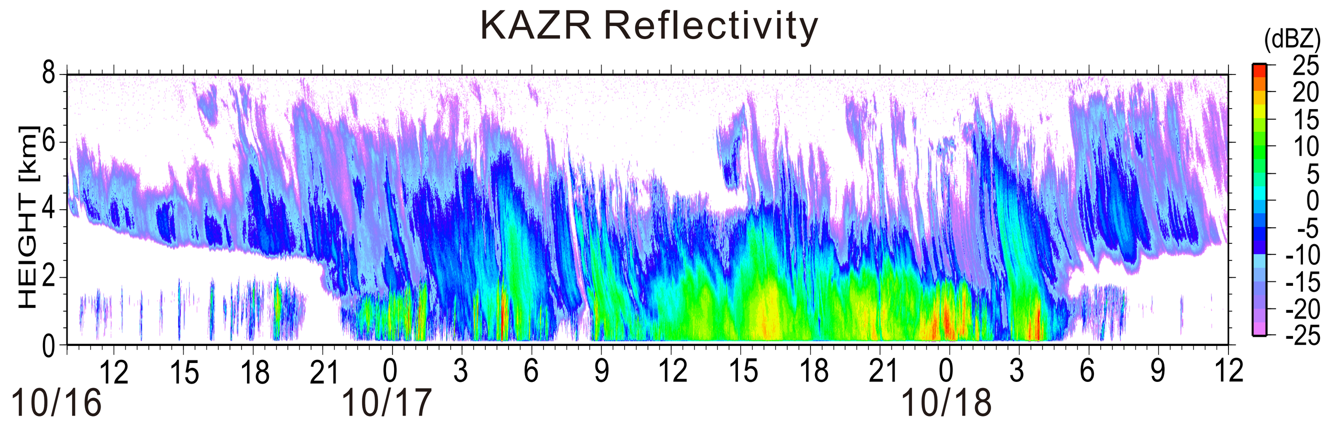
OBSERVATIONAL ANALYSIS

Radar reflectivity from KAZR

The -10 dBZ echo-top heights decreased from a height of 6 km.

For the period of lower echo-top heights (after 12 UTC on 17) the radar reflectivity below a height of 2 km reached peak values up to 25 dBZ.

KAZR Reflectivity



Horizontal wind estimated from X-SAPR

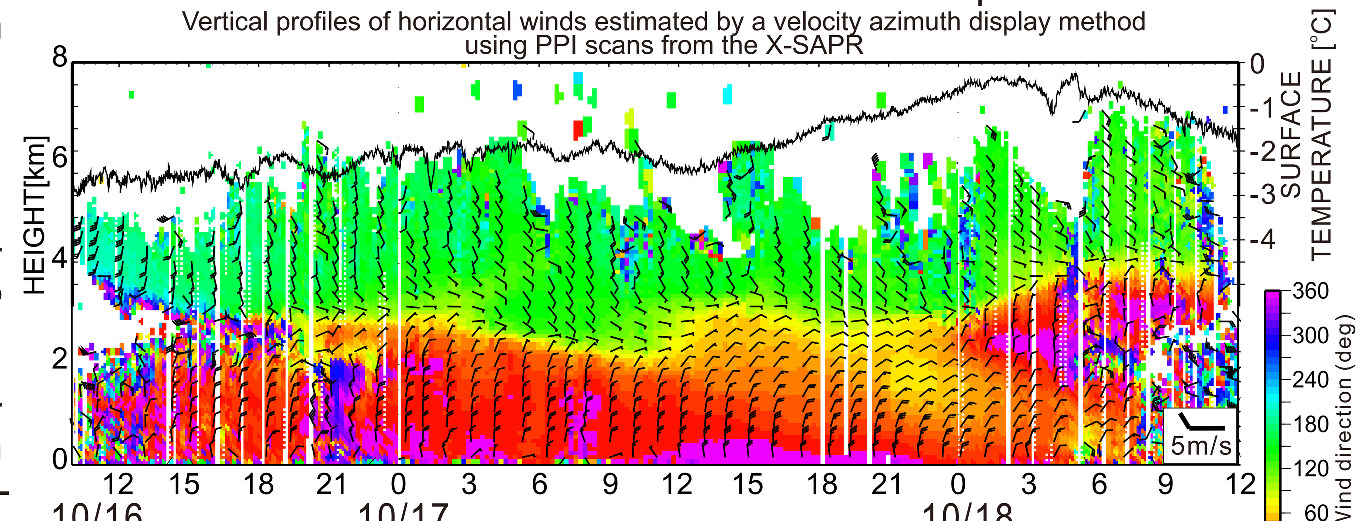
Northerly winds predominated below a height of 3 km.

Southeasterly winds predominated above a height of 3.5 km.

The top of the layer of northerly winds decreased with height even as the surface temperature increased and the winds above backed, becoming northeasterly.

X-SAPR Horizontal wind and surface temperature

Vertical profiles of horizontal winds estimated by a velocity azimuth display method using PPI scans from the X-SAPR



Radar reflectivity and radial velocity from X-SAPR

Snow bands of north-south length passed through the radar range from east to west between 12 UTC on 17 and 03 UTC on 18.

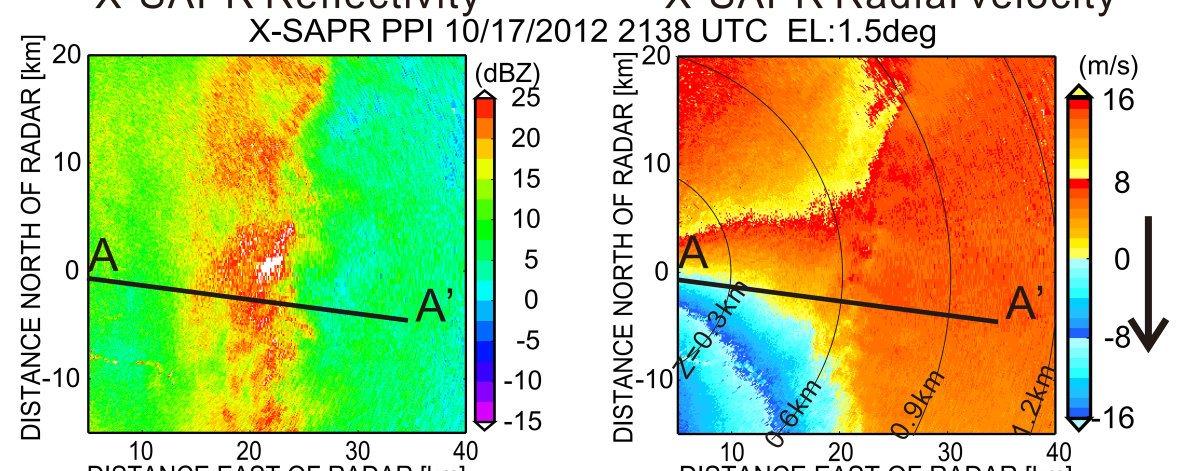
A strong convergence zone passed through the radar range from east to west between 21 UTC on 17 and 03 UTC on 18.

Radar reflectivities increased below a height of 2 km.

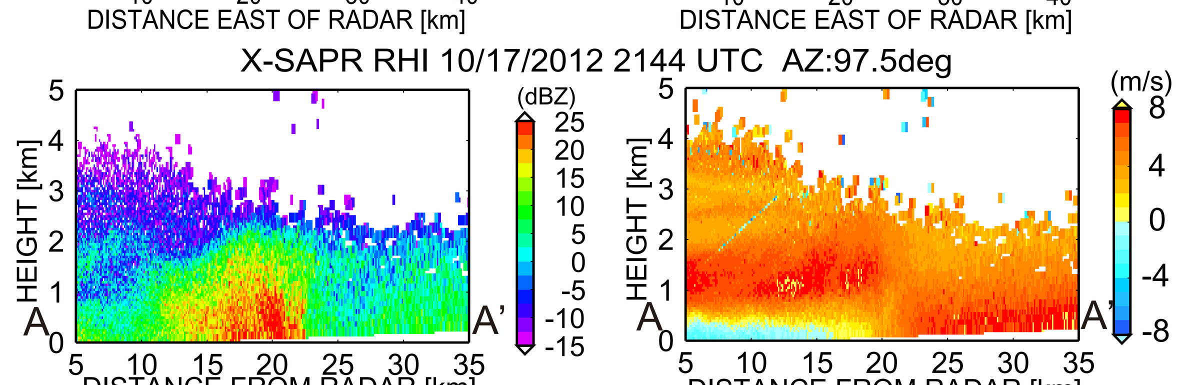
Radial velocities showed a low-level convergence.

X-SAPR Reflectivity / X-SAPR Radial velocity

X-SAPR PPI 10/17/2012 2138 UTC EL:1.5deg



X-SAPR RHI 10/17/2012 2144 UTC AZ:97.5deg

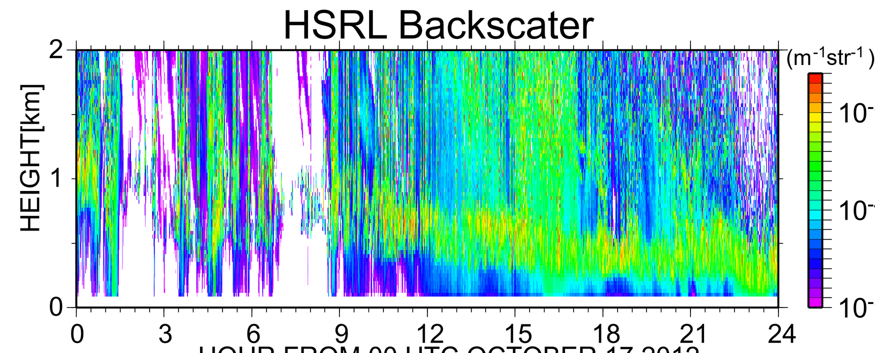


Backscatter from HSRL

Strong backscatters existed below a height of 2 km. This indicates a presence of cloud droplets.

Heights of strong backscatters decreased with time.

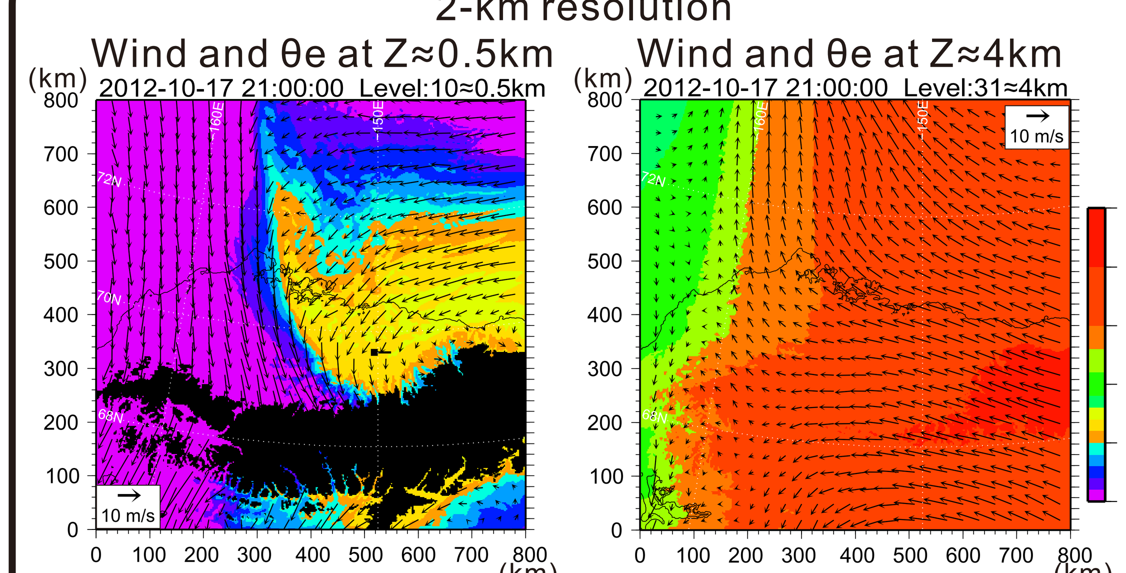
HSRL Backscater



MODEL RESULTS

2-km resolution

Wind and θe at Z≈0.5km / Wind and θe at Z≈4km



Horizontal wind and θe (2-km resolution)

Northerly winds preexisted at a height of 0.5 km around Barrow.

A high-θe airmass (> 280 K) ran into Barrow by northeasterly wind at the low level.

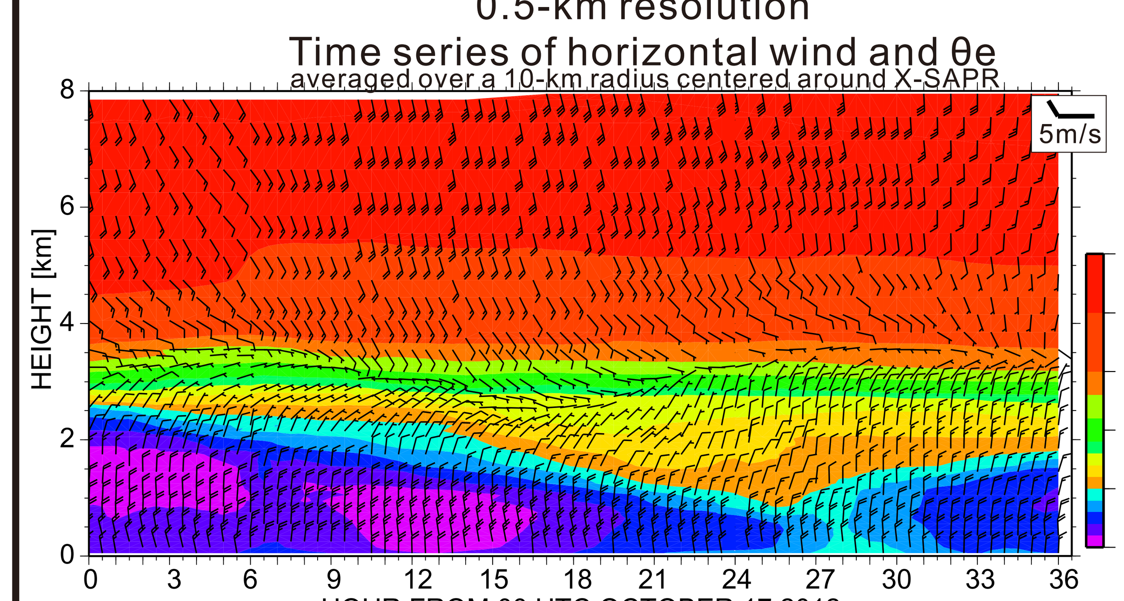
The simulated frontal system formed by convergence of the low-level northerly and northeasterly winds and moved toward west.

Southerly and southeasterly winds prevailed around Barrow at a height of 4 km. The southeasterly winds ran across the Brooks Range.

0.5-km resolution

Time series of horizontal wind and θe

averaged over a 10-km radius centered around X-SAPR



Time series of horizontal wind and θe around Barrow (0.5-km resolution)

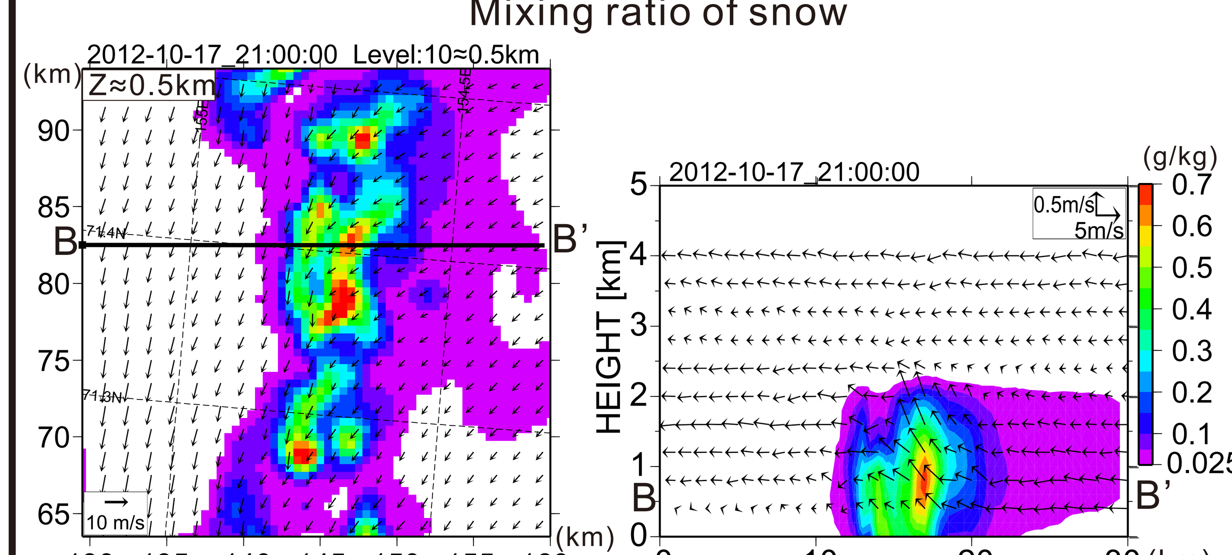
Northerly winds predominated below a height of 3 km.

Southerly and southeasterly winds predominated above the height of 3 km.

A high-θe airmass (> 280 K) with northeasterly wind overran a preexisting layer of lower θe and northerly wind below the height of 3 km.

The simulated wind field is in good agreement with the horizontal wind estimated from the X-SAPR.

Mixing ratio of snow



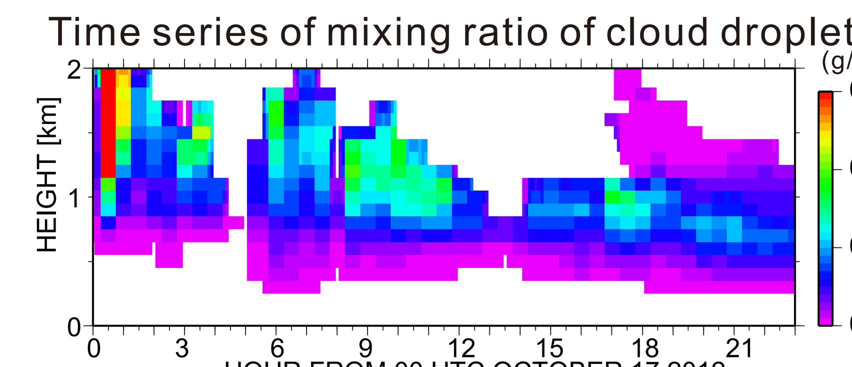
Mixing ratio of snow (0.5-km resolution)

Simulated snow bands formed in the convergence area and moved from east to west.

Simulated snow mixing ratios increased up to 0.7 g kg^{-1} below a height of 2 km.

These characteristics of simulated snow mixing ratio are consistent with the measured radar reflectivity.

Time series of mixing ratio of cloud droplets



Mixing ratio of cloud droplets (0.5-km resolution)

Simulated cloud droplets existed in the layer of northerly wind below a height of 2 km. Heights of large mixing ratio of cloud droplets decreased with time. This is consistent with the measured HSRL backscatters.

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