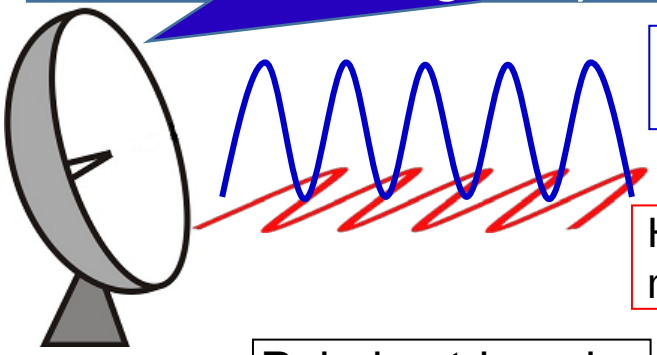
X-band polarimetric radar observations of an Arctic shallow boundary layer cloud

Mariko Oue, Johannes Verlinde, Eugene Clothiaux, and Kultegin Aydin
The Pennsylvania State University
Collaborators: V. Chandrasekar, M. Galletti, and A. Ryzhkov

Introduction

- Arctic mixed-phase clouds, with liquid and ice in the same volume, impact ice growth processes.
- X-band polarimetric radar measurements provide information about ice growth (e.g., ice habit, size, number density).
- Objective: to present mesoscale structure and dominant ice growth processes in a boundary-layer mixed-phase cloud using X-band polarimetric radar measurements (X-SAPR at Barrow).

Reflectivity (Z_h)
→ Size, Number density
Differential reflectivity (Z_{DR})
→ Aspect ratio, Bulk density
Correlation coefficient between H and V (ρ_{hv})
→ Homogeneity

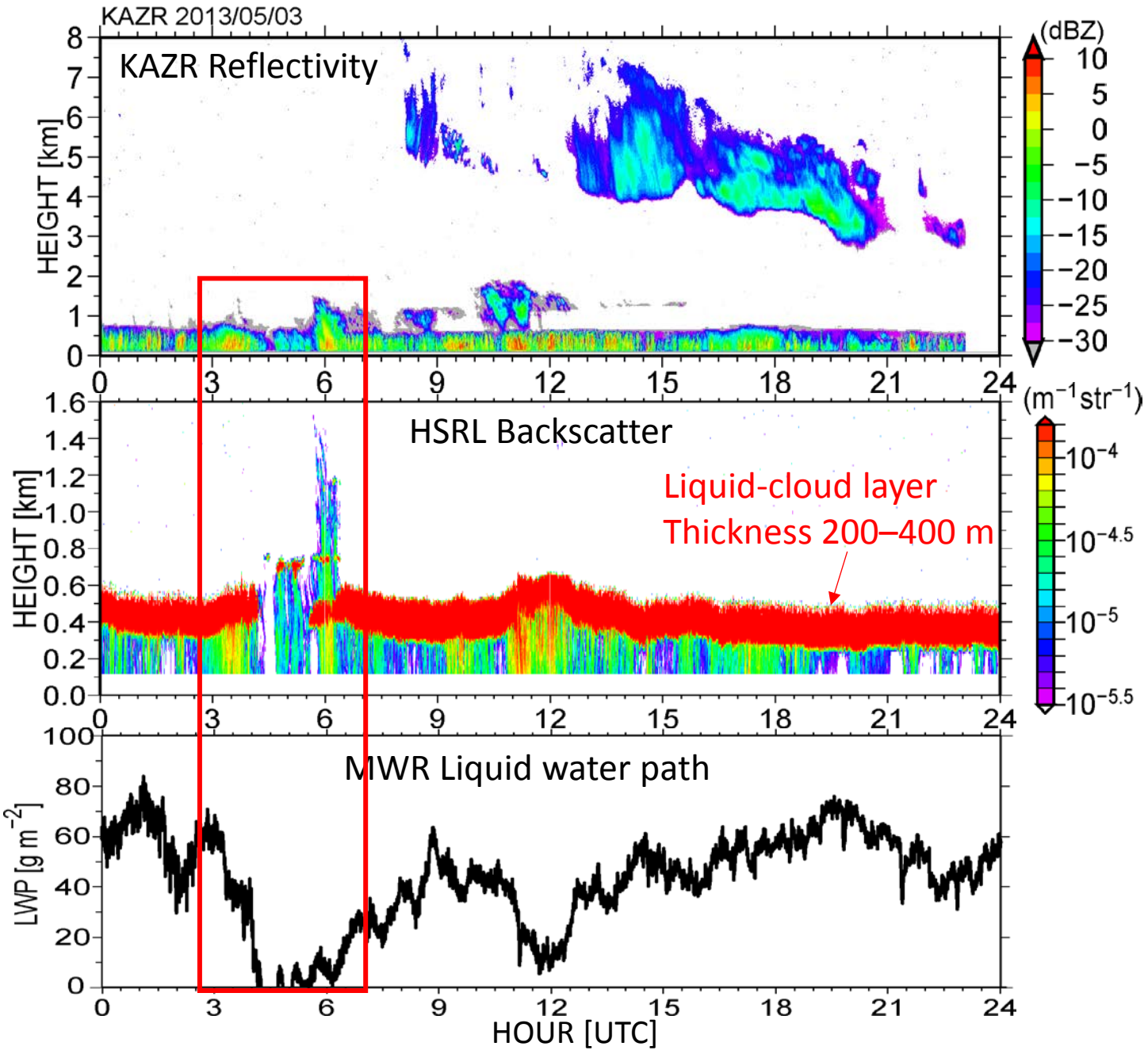


Vertically polarized microwave (V)

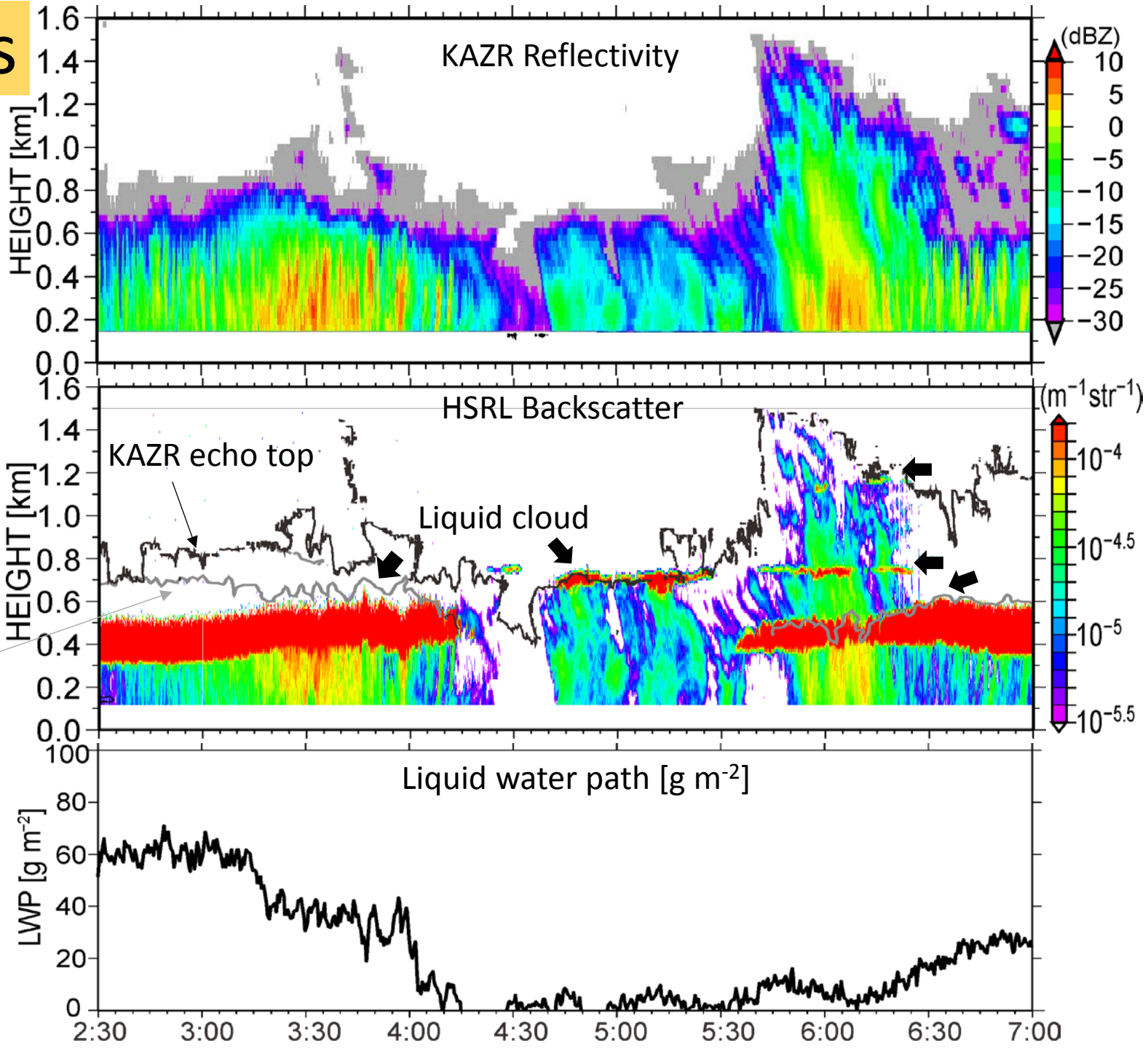
Horizontally polarized microwave (H)

Polarimetric radar

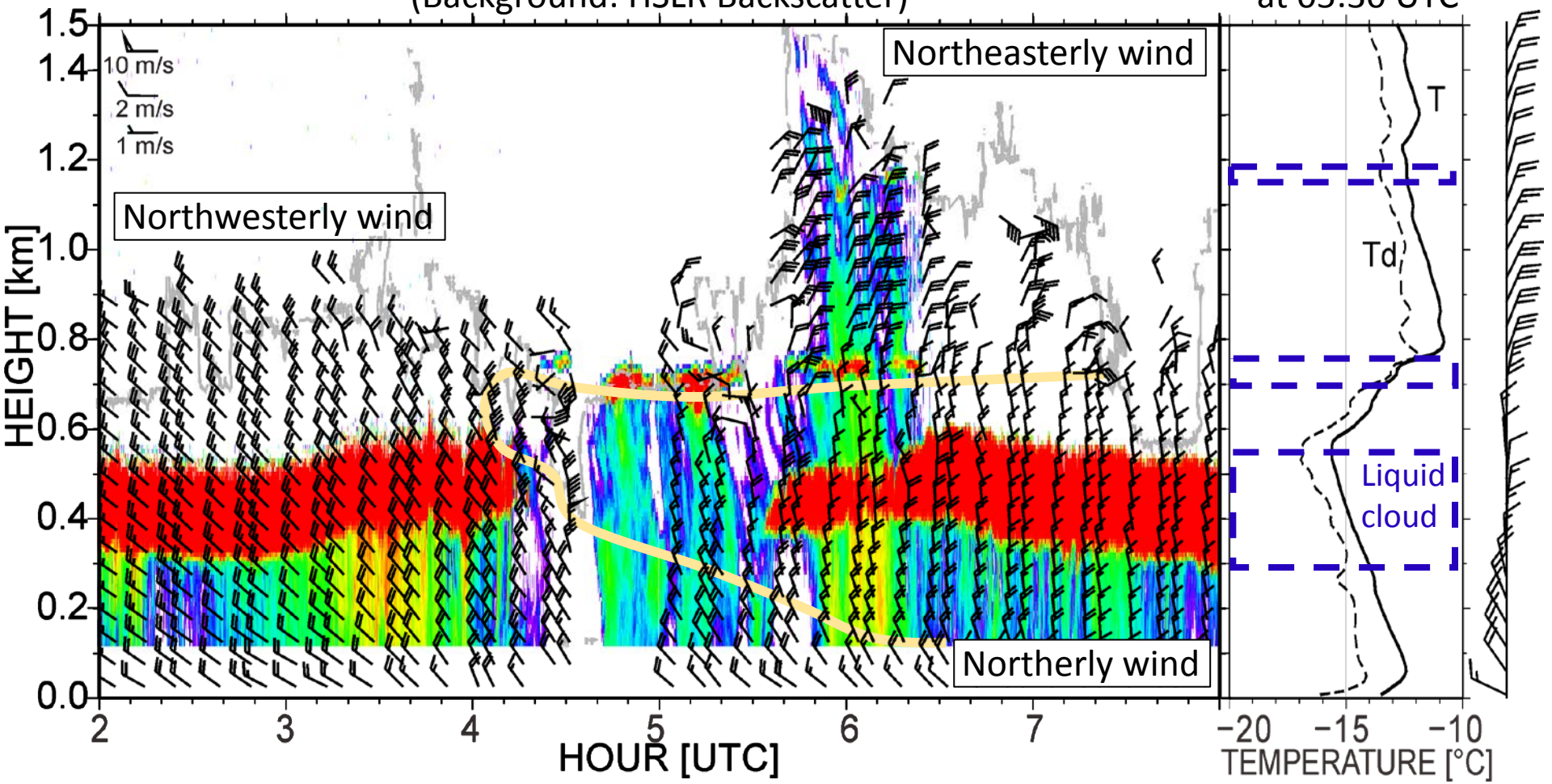
Case: Shallow boundary-layer cloud on 3 May 2013



Analysis



Liquid cloud top from KAZR Spectral width



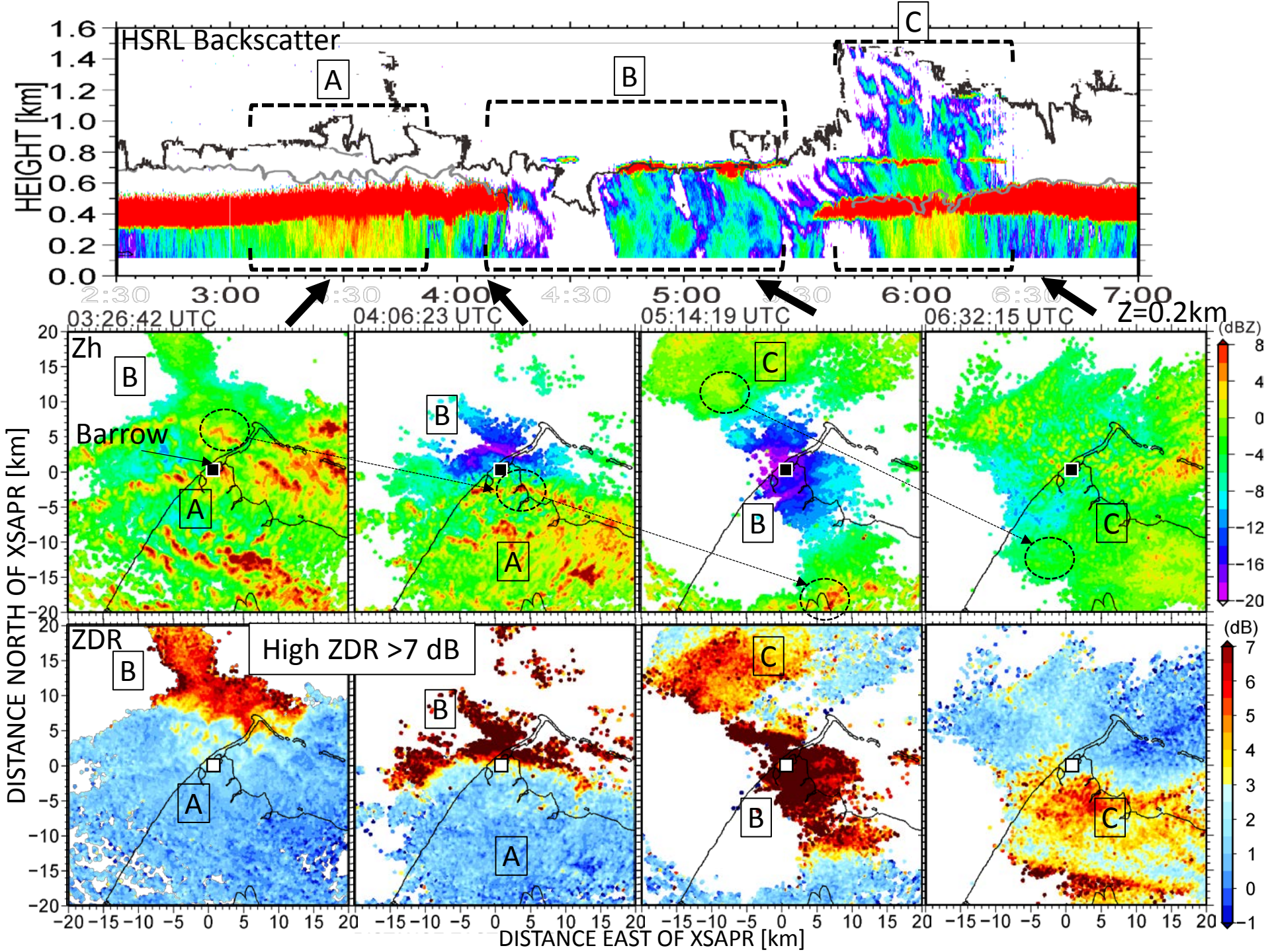
Liquid-cloud layers formed in different airmasses by advection.

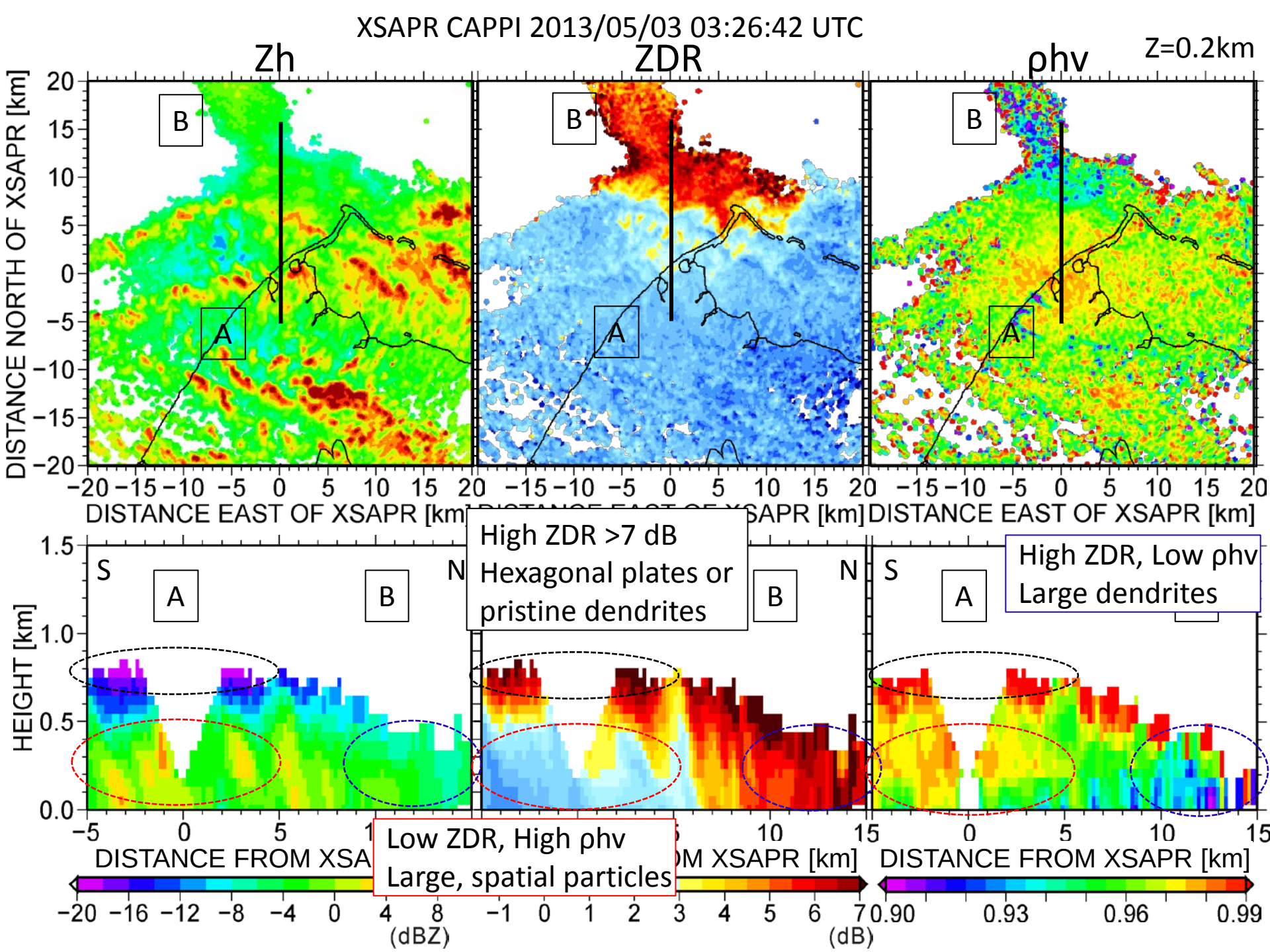
Former thick liquid-cloud layer: Northwesterly-wind airmass

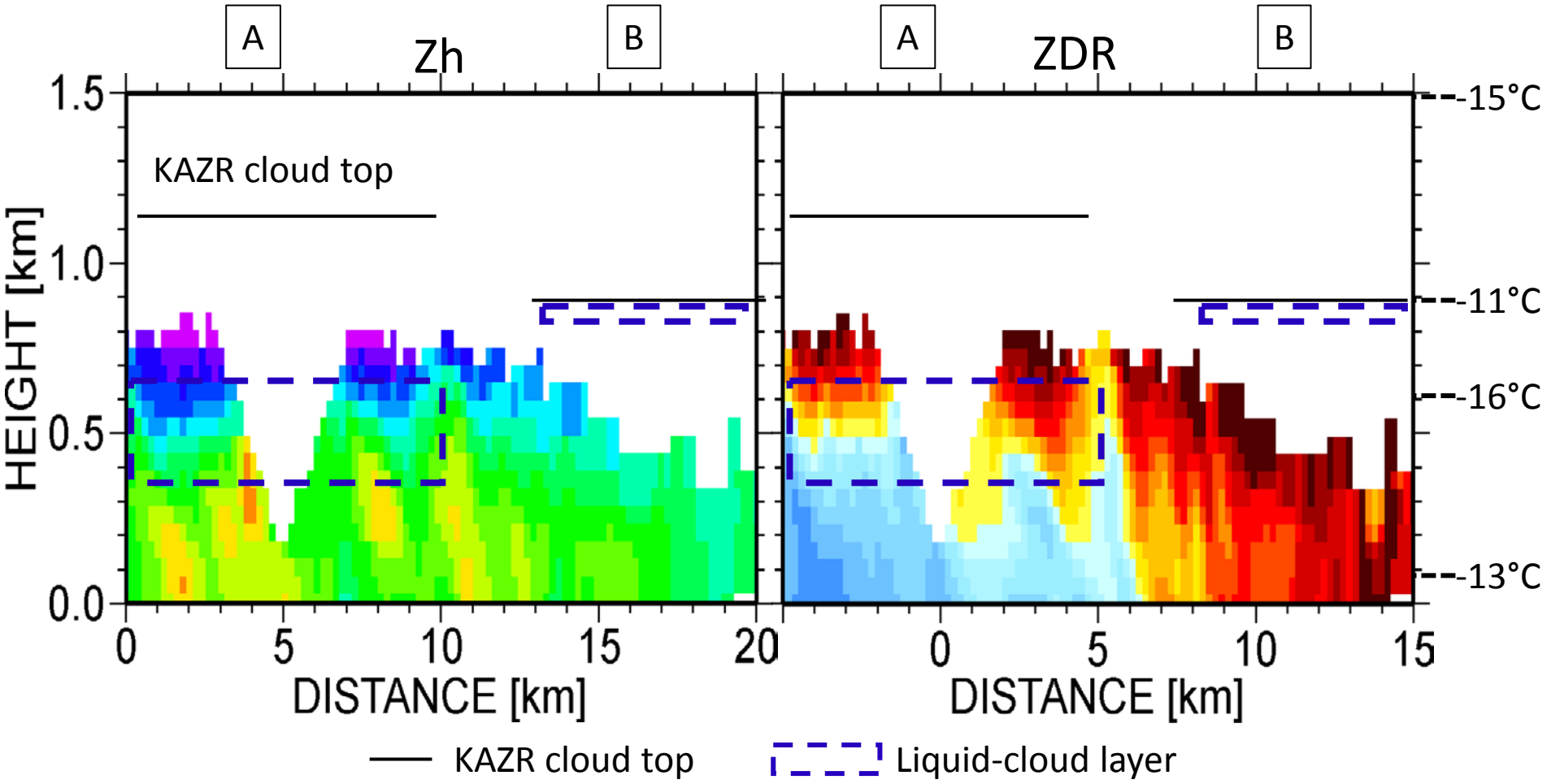
Latter thick liquid-cloud layer: Northerly-wind airmass

Middle thin liquid-cloud layer: Bottom of Northeasterly-wind airmass

Upper thin liquid-cloud layer: Northeasterly-wind airmass

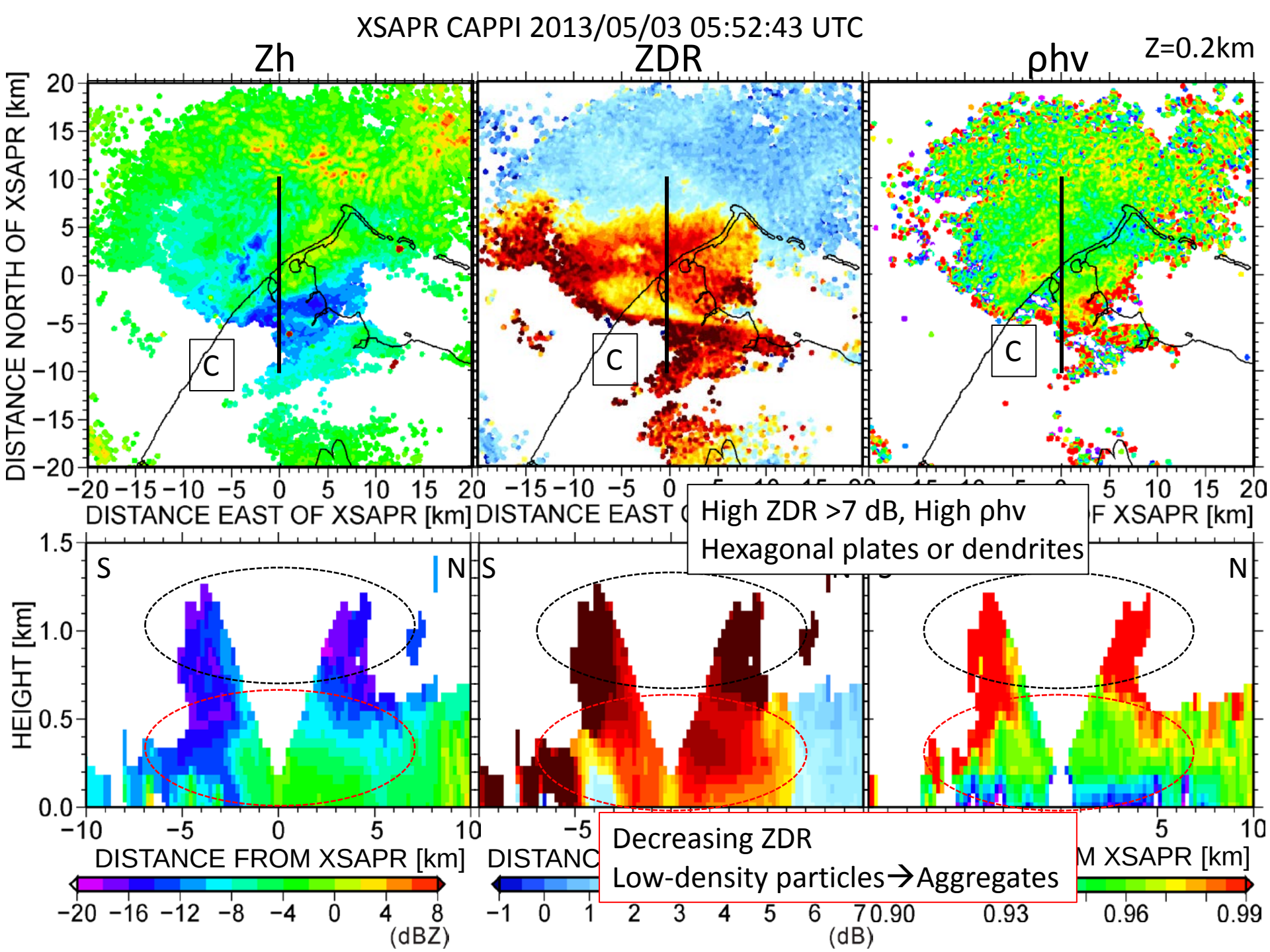

HSRL Backscatter
HEIGHT [km]
A
B
C
03:26:42 UTC
04:06:23 UTC
05:14:19 UTC
06:32:15 UTC
Z=0.2km
Zh
Barrow
ZDR
High ZDR >7 dB
(dBZ)
(dB)
DISTANCE NORTH OF XSAPR [km]
DISTANCE EAST OF XSAPR [km]

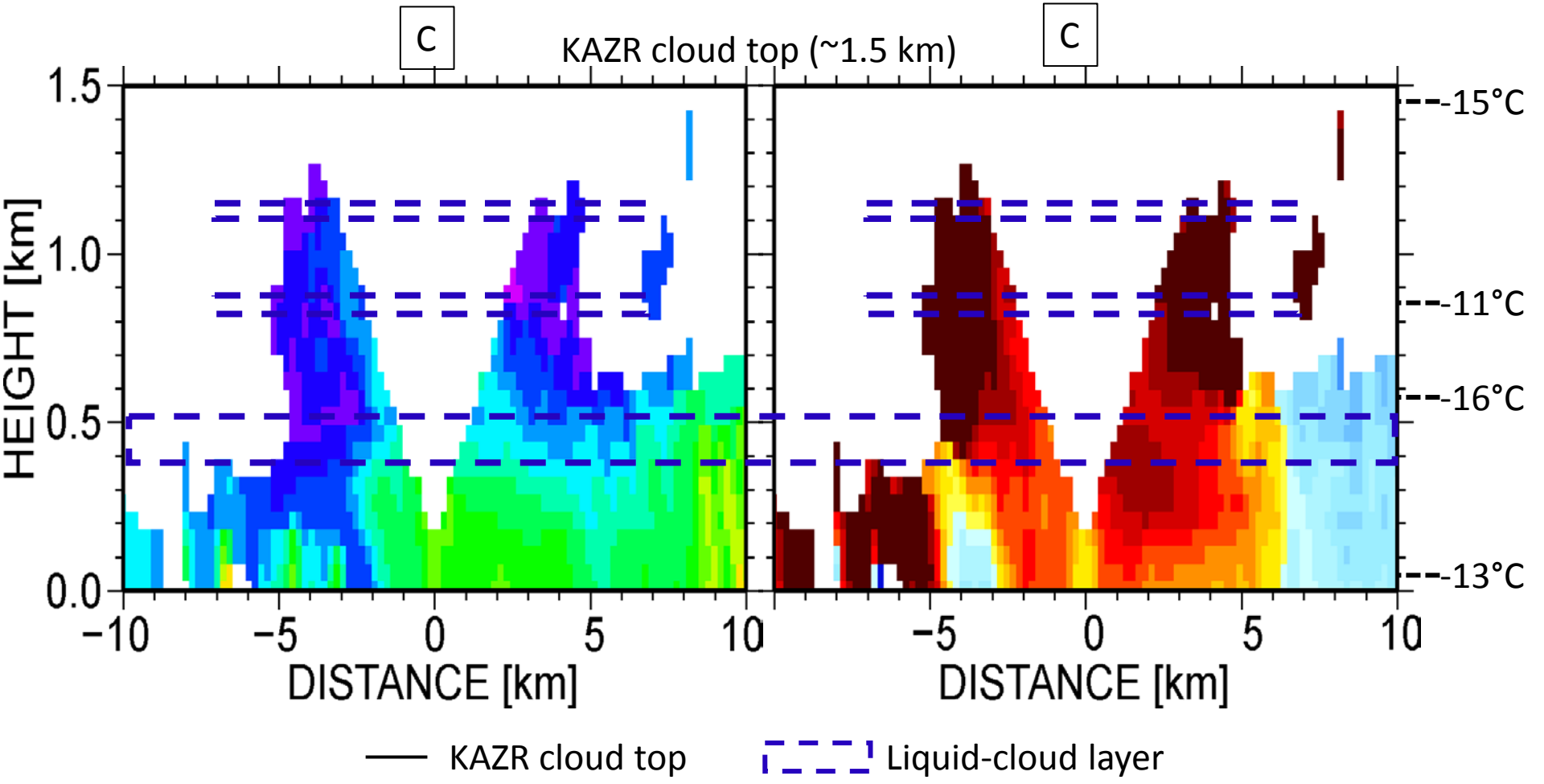

XSAPR CAPPI 2013/05/03 03:26:42 UTC
Zh
ZDR
ρhv
Z=0.2km
B
A
DISTANCE NORTH OF XSAPR [km]
DISTANCE EAST OF XSAPR [km]
High ZDR >7 dB
Hexagonal plates or
pristine dendrites
High ZDR, Low ρhv
Large dendrites
Low ZDR, High ρhv
Large, spatial particles
S
N
HEIGHT [km]
DISTANCE FROM XSAPR [km]
(dBZ)
(dB)



A: Upper cloud ice particles growing as hexagonal plates or pristine dendrites seeded and quickly grew as spatial particles by riming and aggregation.

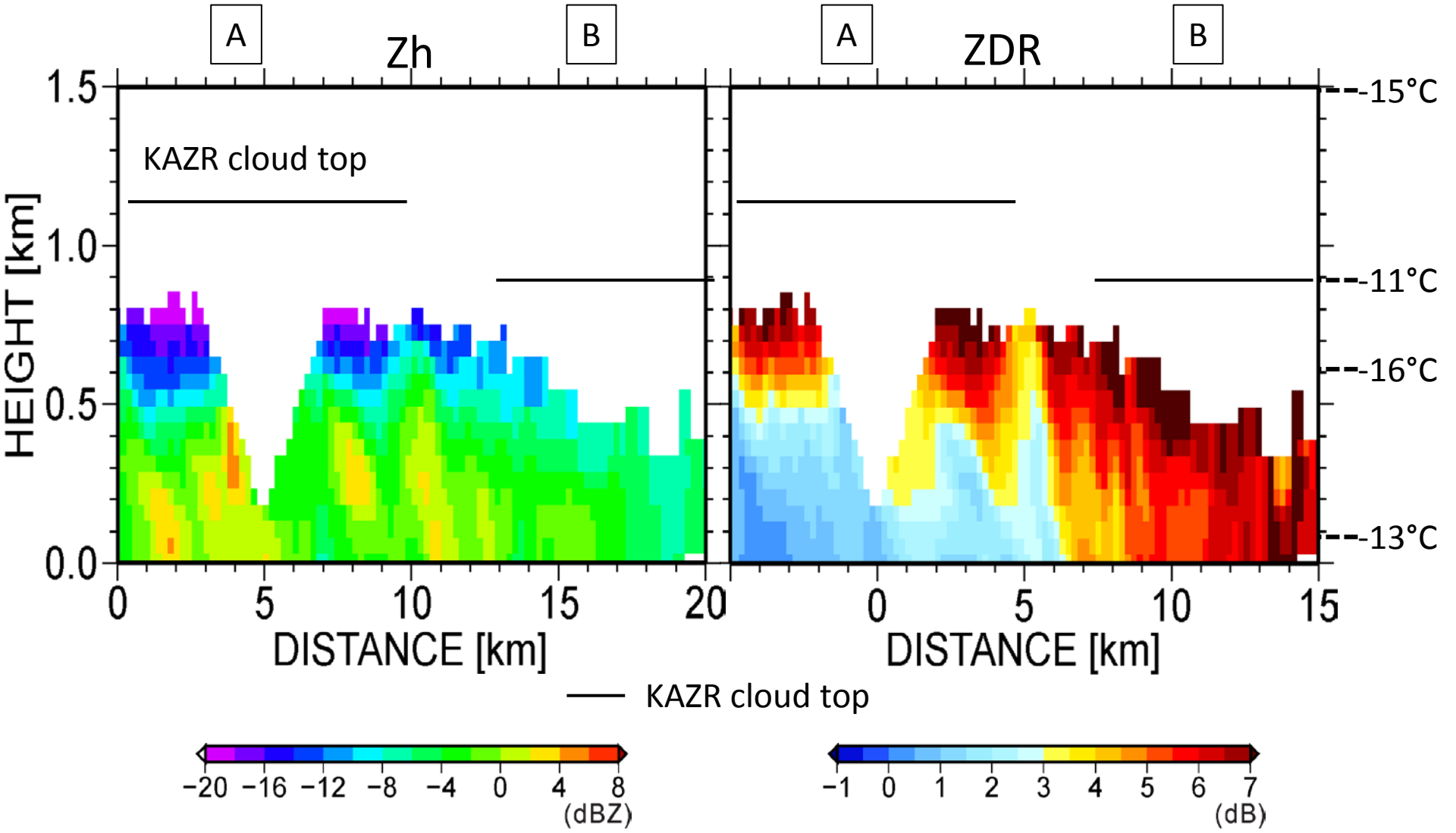
B: Ice particles formed near the thin liquid cloud layer and individually grew as dendrites by depositional growth.


XSAPR CAPPI 2013/05/03 05:52:43 UTC
Zh
ZDR
ρhv
Z=0.2km
DISTANCE NORTH OF XSAPR [km]
DISTANCE EAST OF XSAPR [km]
C
High ZDR >7 dB, High ρhv
Hexagonal plates or dendrites
HEIGHT [km]
S
N
DISTANCE FROM XSAPR [km]
Decreasing ZDR
Low-density particles→Aggregates
(dBZ)
(dB)



C: Upper cloud ice particles individually grew as pristine plate or dendrites while falling through multiple thin liquid-cloud layers by depositional growth.

Dendrites were rimed in the low-level thicker liquid layer and aggregated below the low-level thicker liquid-cloud layer.

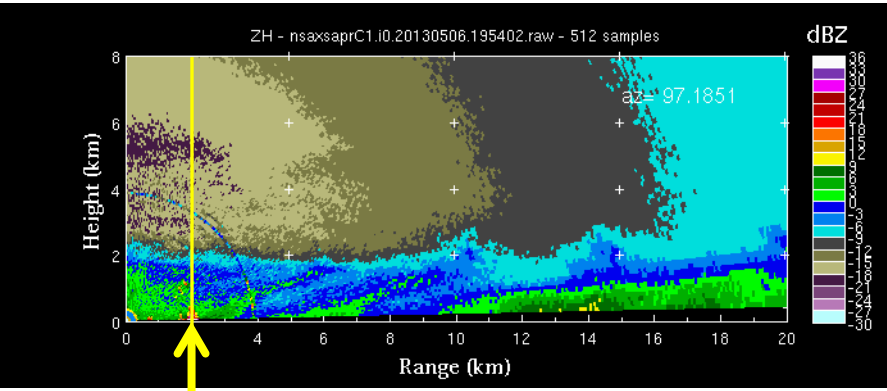


X-SAPR echo-top height was lower than KAZR echo top due to low sensitivity.

Comparison of vertical profiles from KAZR and HH/HV signals of XSAPR

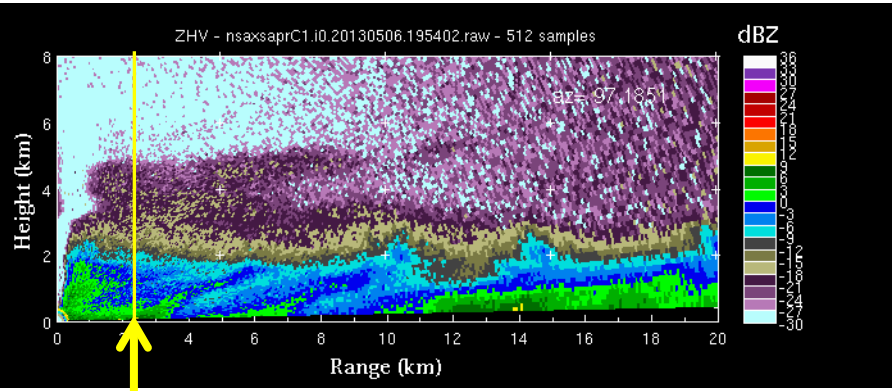
Case study #1: xsaprC1 195402 UTC, 20130506

Traditional Measurement

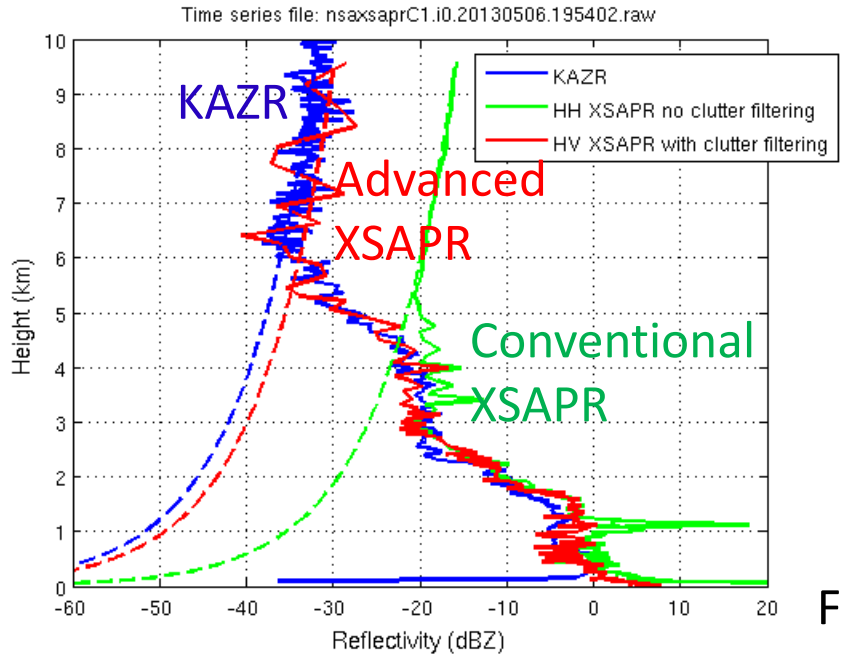


KAZR

GMAP-TD on dual-pol signal



KAZR

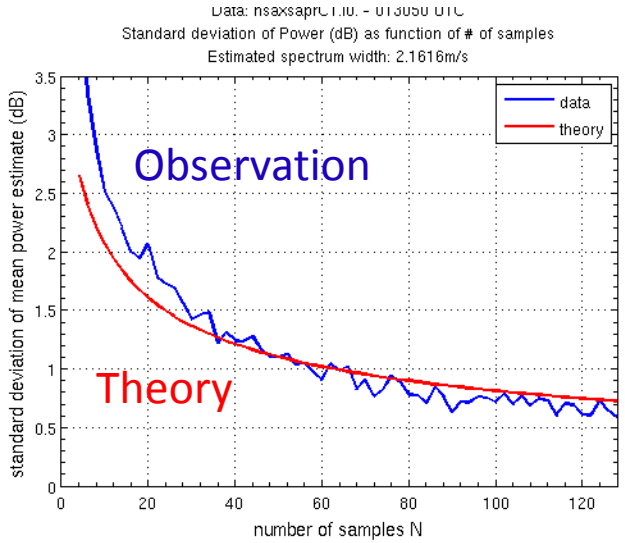


The X-SAPR with the advanced method makes the same sensitivity as KAZR.

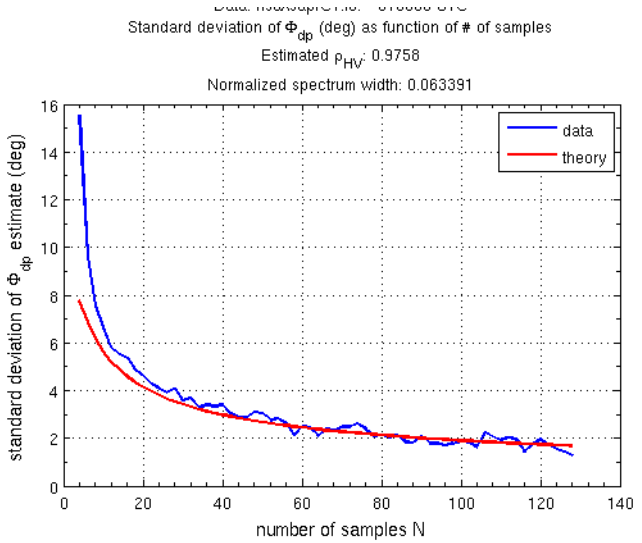
Figures provided by Dr. Chandrasekar

Standard deviation vs number of samples @ range =23 km

Std(P) vs N

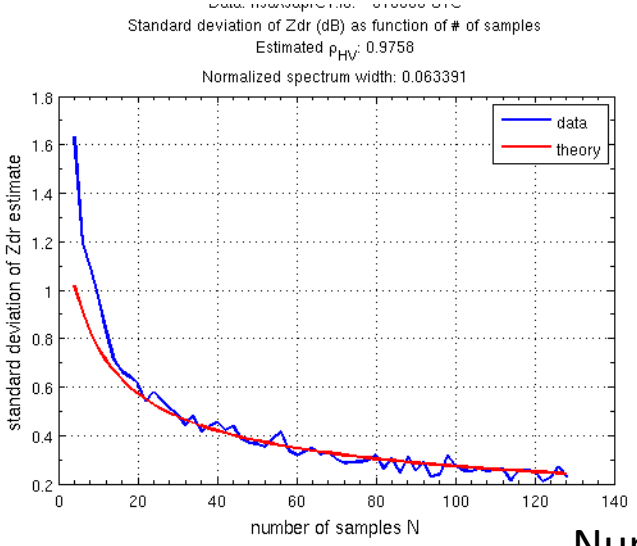


Std(Zdr) vs N

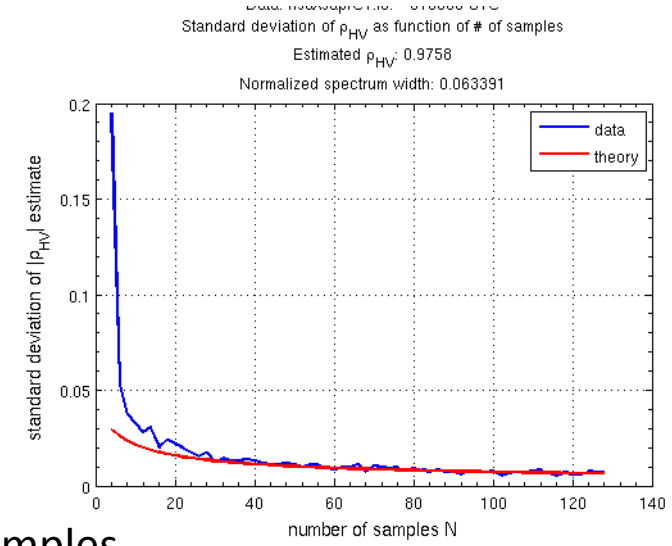


Standard deviation

Std(Phidp) vs N



Std(rhoHV) vs N



Standard deviation

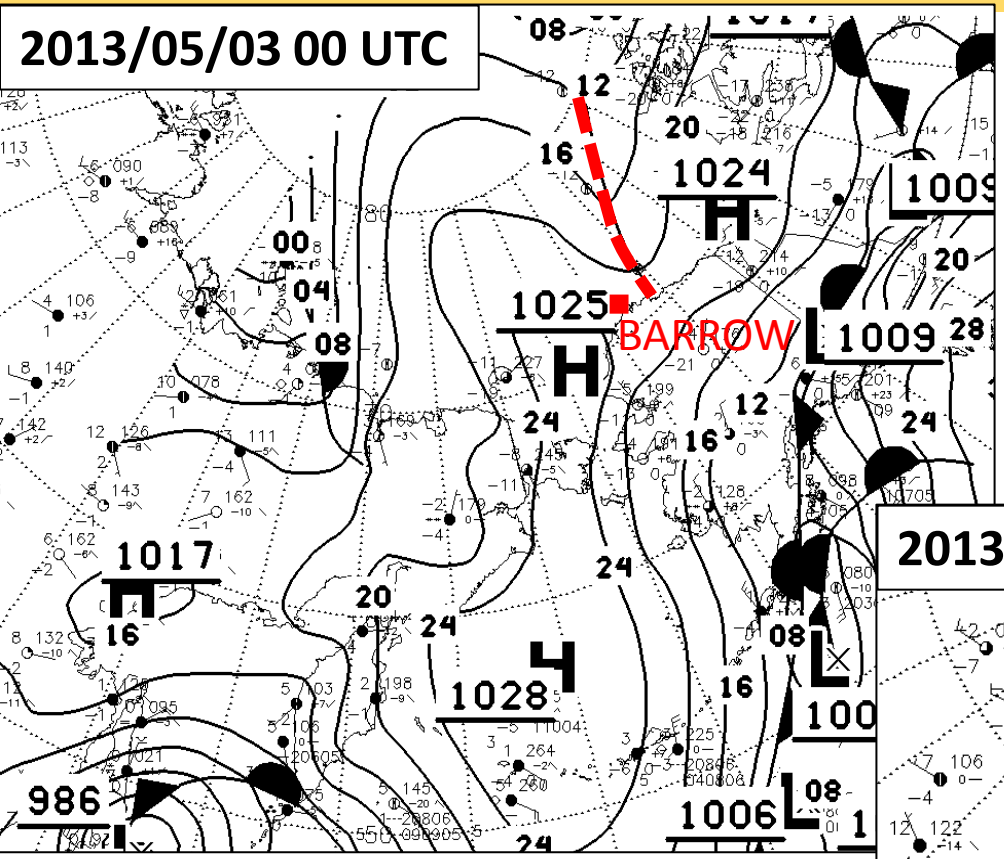
Number of samples

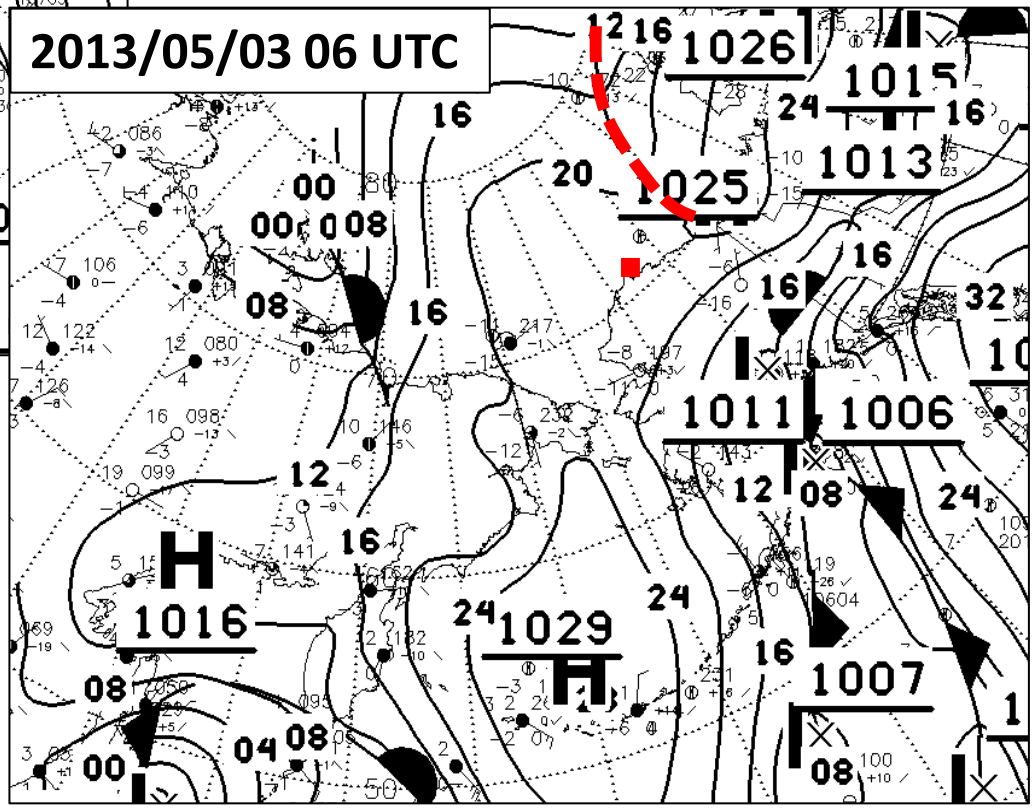
Figures provided by Dr. Chandrasekar

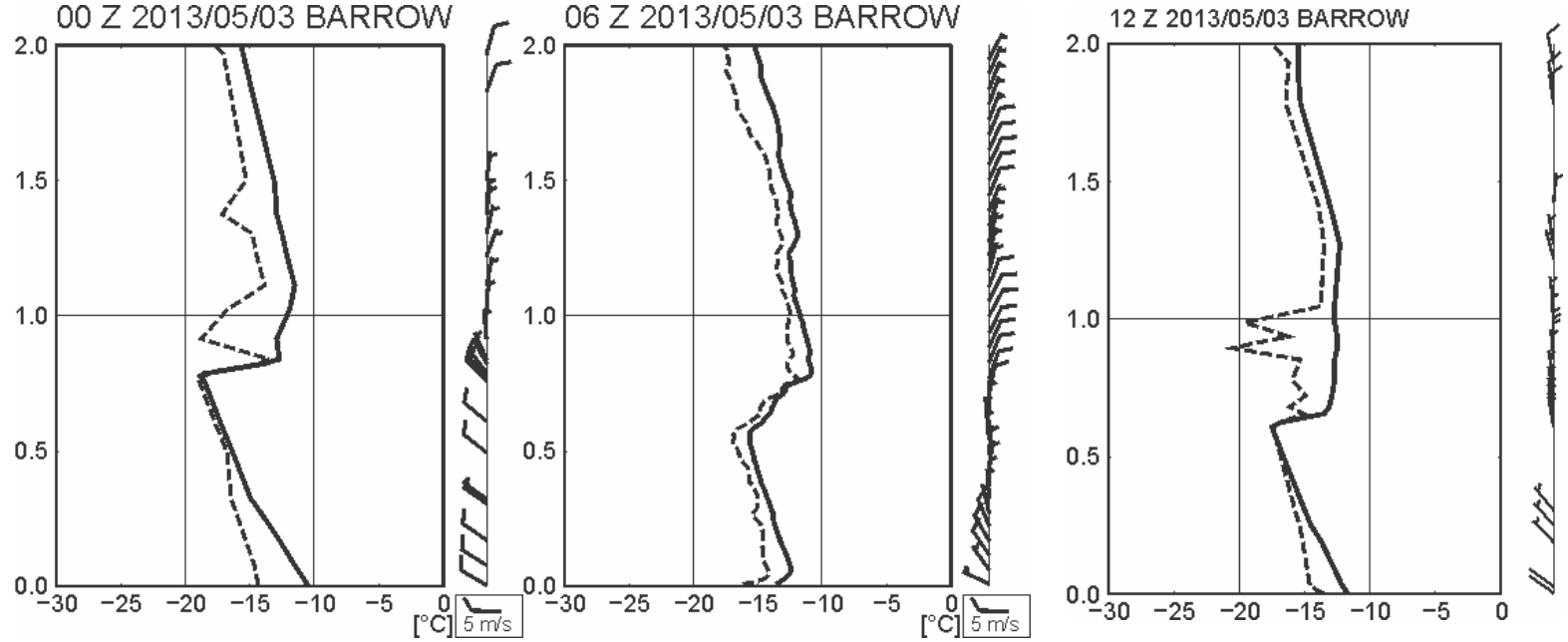
Summary

- Mesoscale structure and dominant ice growth processes in an Arctic boundary-layer mixed-phase cloud observed by the X-band polarimetric radar:
  - Multiple liquid-cloud layers in different airmasses (northwesterly-, northerly-, and northeasterly-wind layers)
  - Depositional growth of dendrites in (multi-layered) thin (<100 m) liquid-cloud layer
  - Riming process in a thick (200 – 250 m) liquid-cloud layer
  - Aggregation process below a thick liquid-cloud layer

Environment






00 Z 2013/05/03 BARROW
06 Z 2013/05/03 BARROW
12 Z 2013/05/03 BARROW
2.0
1.5
1.0
0.5
0.0
−30 −25 −20 −15 −10 −5 0
[°C]
5 m/s