Using CloudSat and Aqua satellite data to analyze the cloud fields of four major storm systems observed during STAR

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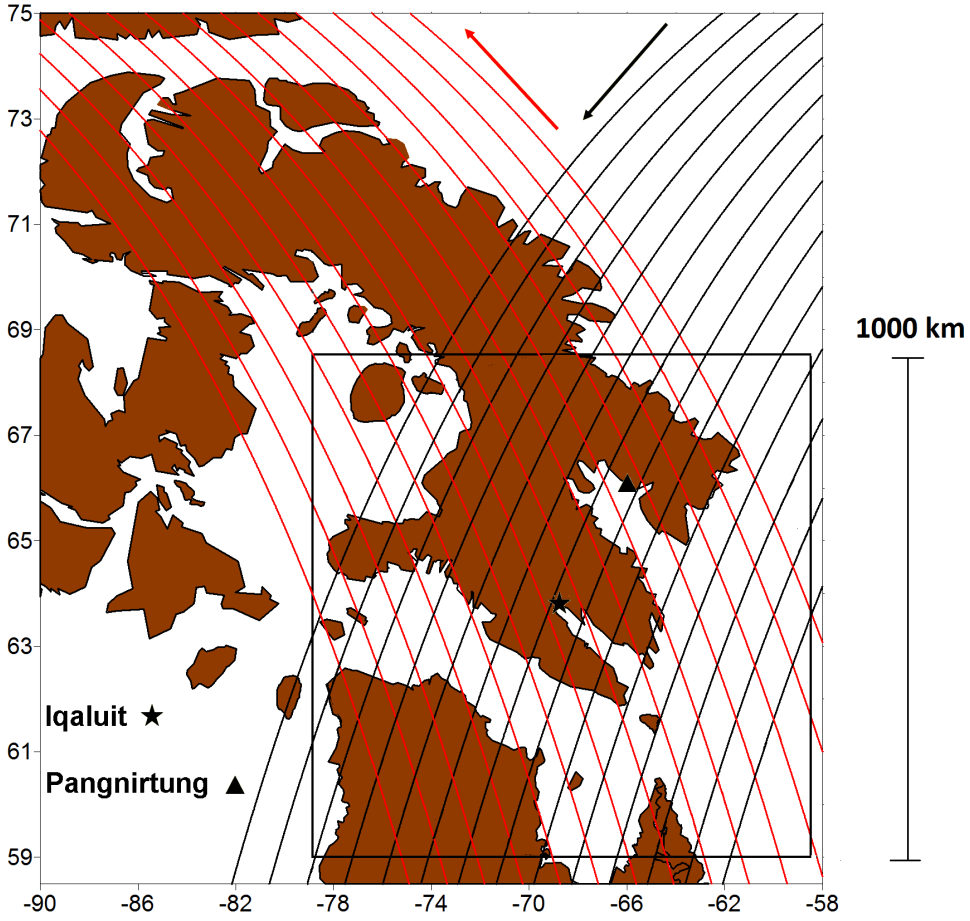
Motivation

- Why satellite data?
  - Because of a sparse and limited observational network in the polar regions, forecasting and modelling Polar storms are particularly difficult problems

  - In an attempt to resolve this issue, satellite data is used to improve our understanding of clouds and precipitation over isolated regions (i.e.: southern Baffin Island and the adjacent oceanic regions)

- **Objective:** to show results obtained for four major storm events using satellite data collected during the STAR observation period
  - » Storm Studies in the Arctic

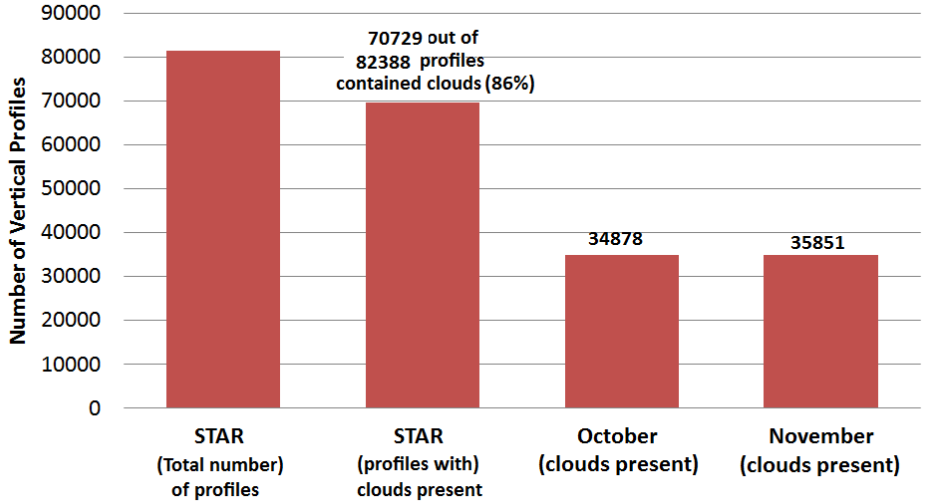
Observational Area



- Spaceborne observations between 1 October and 30 November, 2007 (2 complete months, 60 days in total)

- Data along 91 orbital segments comprising 82,388 vertical profiles (MODIS data extrapolated along CloudSat footprint)

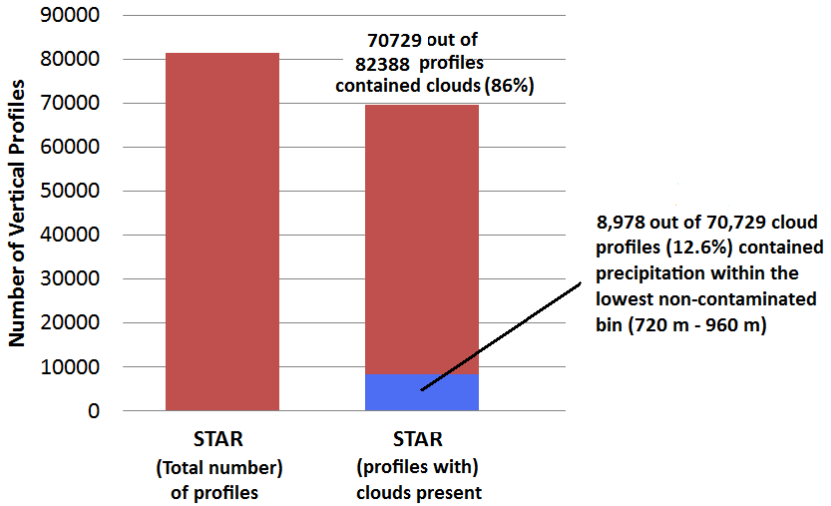
Overview of Overall Observations (60-day)



- Clouds were observed 86% of the time over the southern Baffin Island region
  - 70,729 vertical profiles with clouds
  - 76% of clouds were single layered cloud (up to 4 layers observed)

- A variety of extreme cloud characteristics were observed:
  - 18% of cloud tops > 7 km ASL (mean cloud top height = 3.4 km)
  - 16% of cloud tops < -40°C (mean CTT = -20°C)
  - 21% of clouds were ≥ 4 km in thickness/depth (mean cloud depth = 2.3 km)

Overview of Overall Observations (60-day)

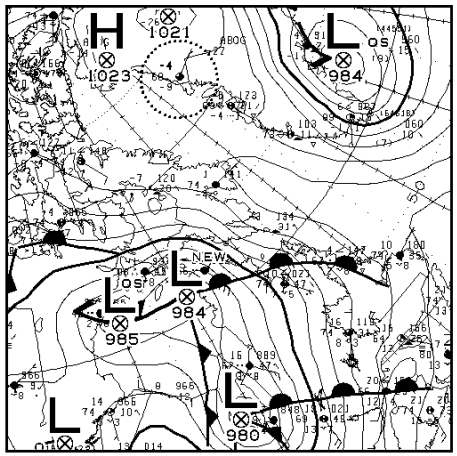


- Precipitation was observed 13% of the time in the presence of clouds
  - 8,978 vertical profiles with clouds contained precipitation (> 0 dBZ) within the lowest vertical bin (720 m – 960 m AGL).

- In the presence of precipitation, cloud characteristics are as follows:
  - 30% of cloud tops > 7 km ASL (mean cloud top height = 4.2 km)
  - 27% of cloud tops < -40°C (mean CTT = -23°C)
  - 54% of clouds were ≥ 4 km in thickness/depth (mean cloud depth = 3.4 km)

Case Studies

a)



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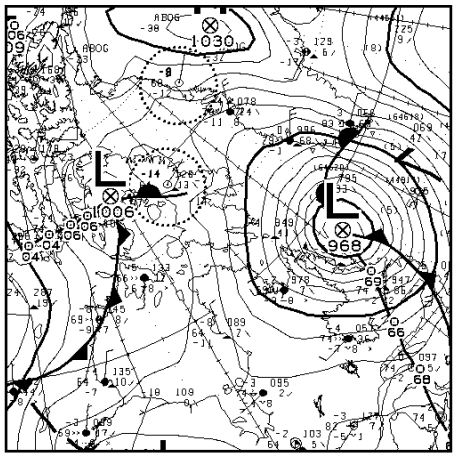
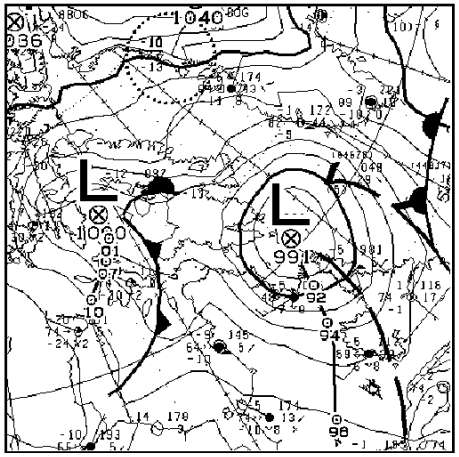
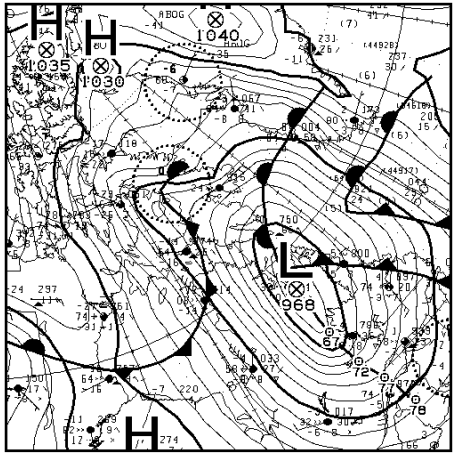


c)



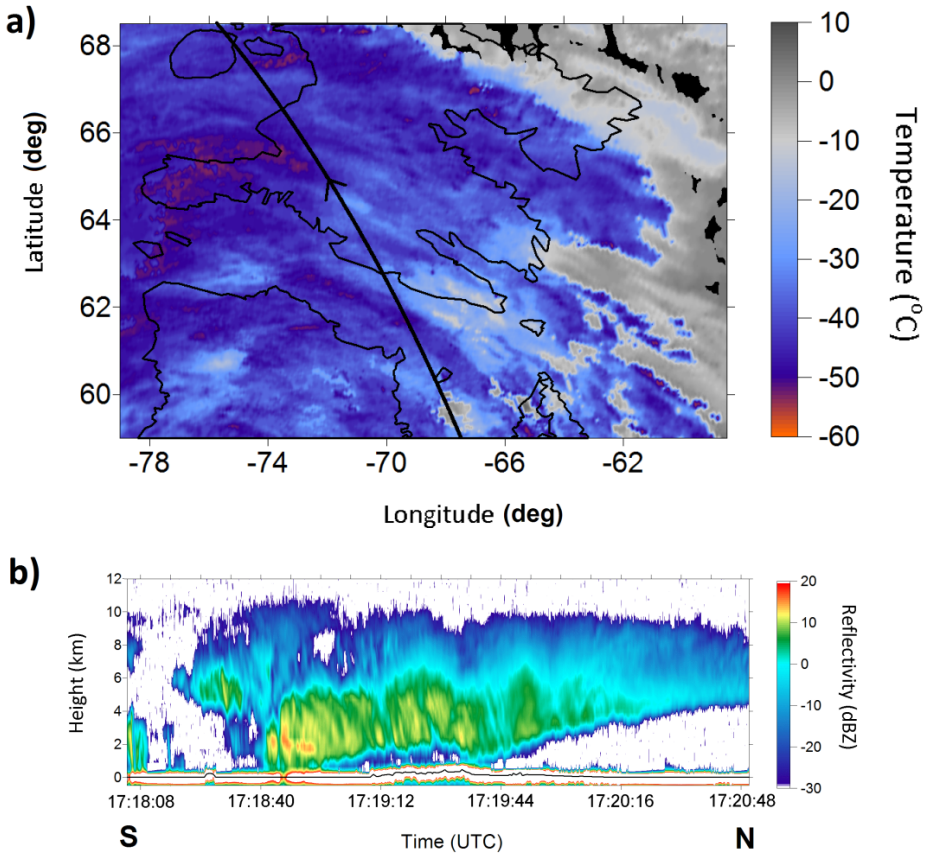
d)



- Four major storm events between 1 October and 30 November, 2007
  - 3 October, 1800 UTC (mid-latitude cyclone)
  - 5 November, 0600 UTC (Hurricane Noel)
  - 8 November, 0600 UTC (non-frontal low)
  - 17 November, 1800 UTC (mid-latitude cyclone)

- different large-scale wind regimes

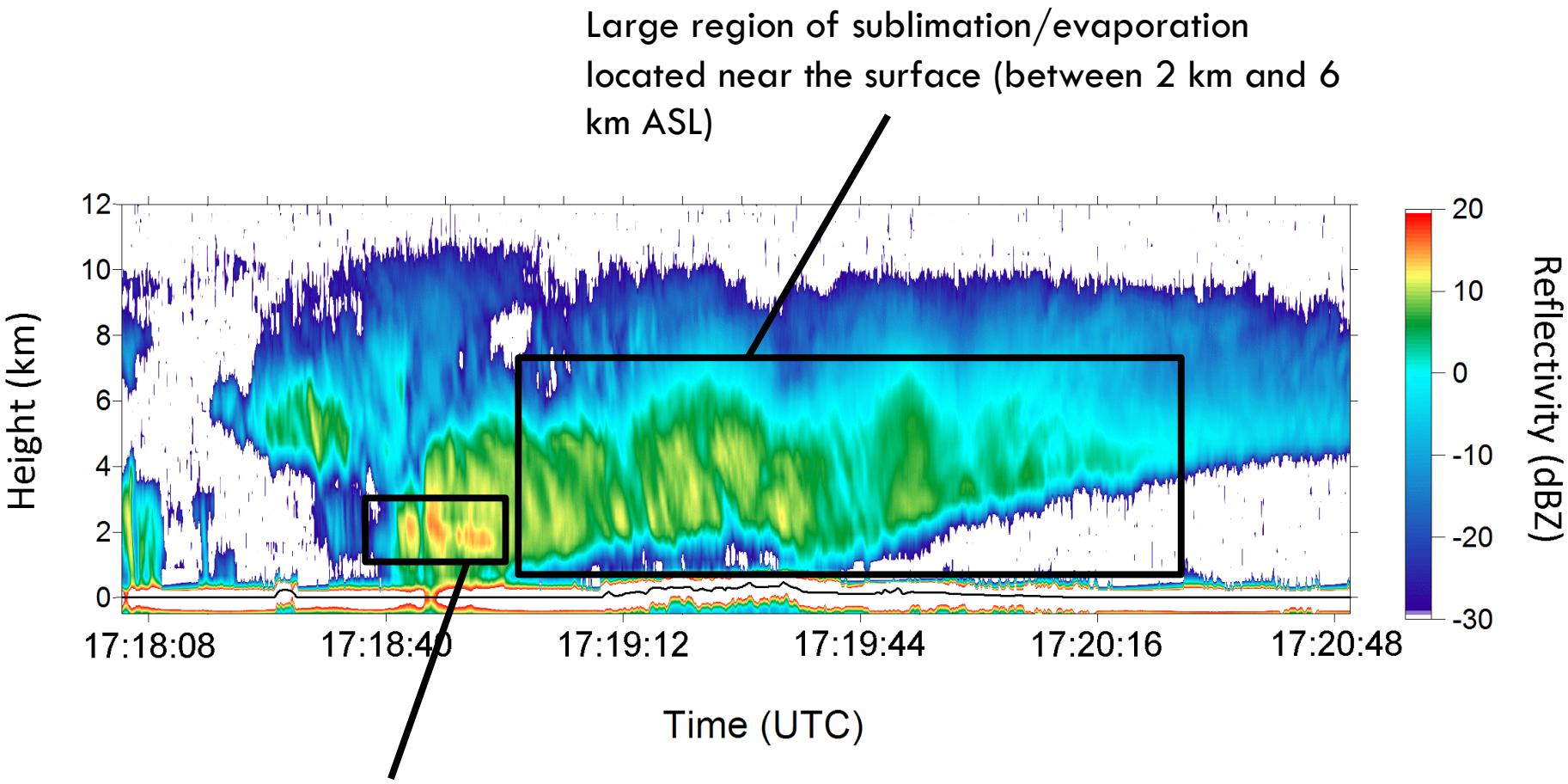
Event 1 (3 October, 1715 UTC)



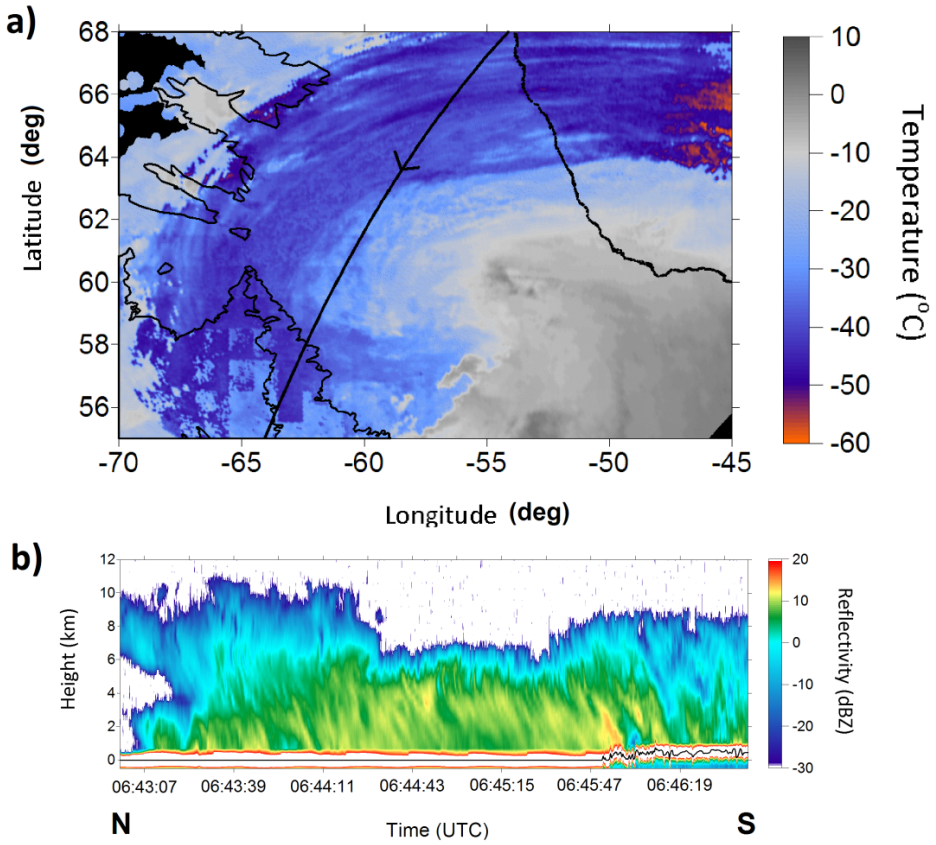
- Large storm system with little precipitation reaching the surface
  - mean CTT = -39°C
  - mean cloud top height = 9.3 km (88% of cloud tops > 7 km)
  - mean cloud depth = 7.4 km
  - mean number of layers = 1.21

- 12% of the vertical profiles containing clouds had precipitation (> 0 dBZ) within the lowest bin
  - mean cloud depth = 9.8 km

Event 1 (3 October, 1715 UTC)



Event 2 (5 November, 0640 UTC)



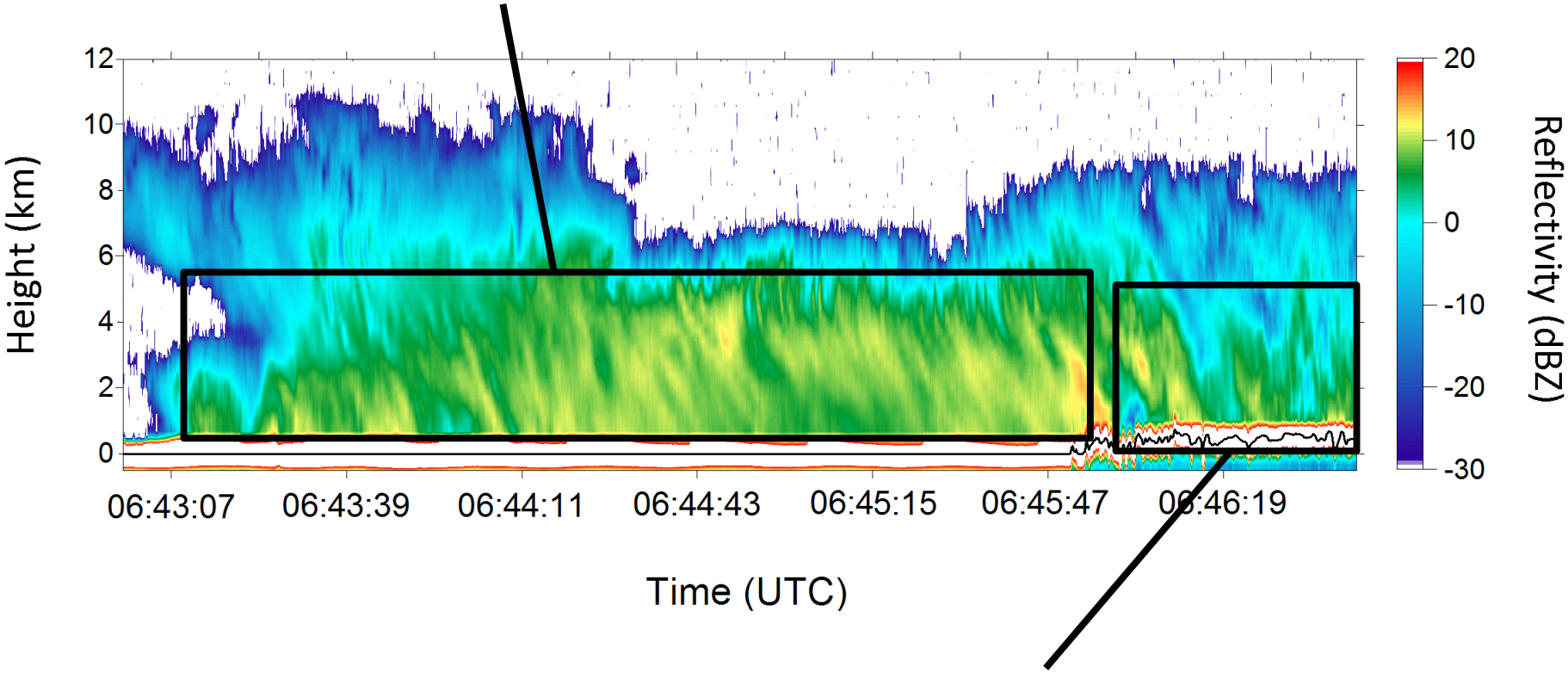
- Remnants of Hurricane Noel as is travels across Davis Strait
  - mean CTT = -37°C
  - mean cloud top height = 8.3 km (73% of cloud tops > 7 km)
  - mean cloud depth = 7.2 km
  - mean number of layers = 1.12

- 93% of the vertical profiles containing clouds had precipitation (> 0 dBZ) within the lowest bin
  - mean cloud depth = 7.3 km

Event 2 (5 November, 0640 UTC)

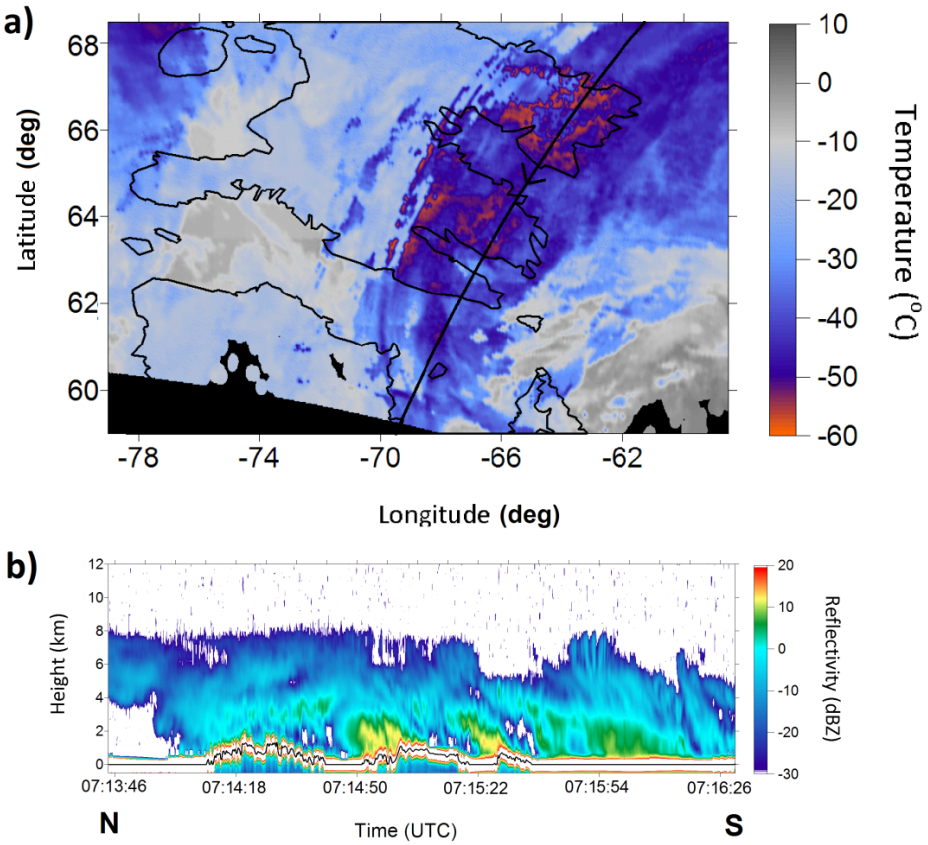
Large and continuous stratiform precipitation field (uniform)

- tilted towards the south



diminished precipitation field over northern Quebec

Event 3 (8 November, 0710 UTC)



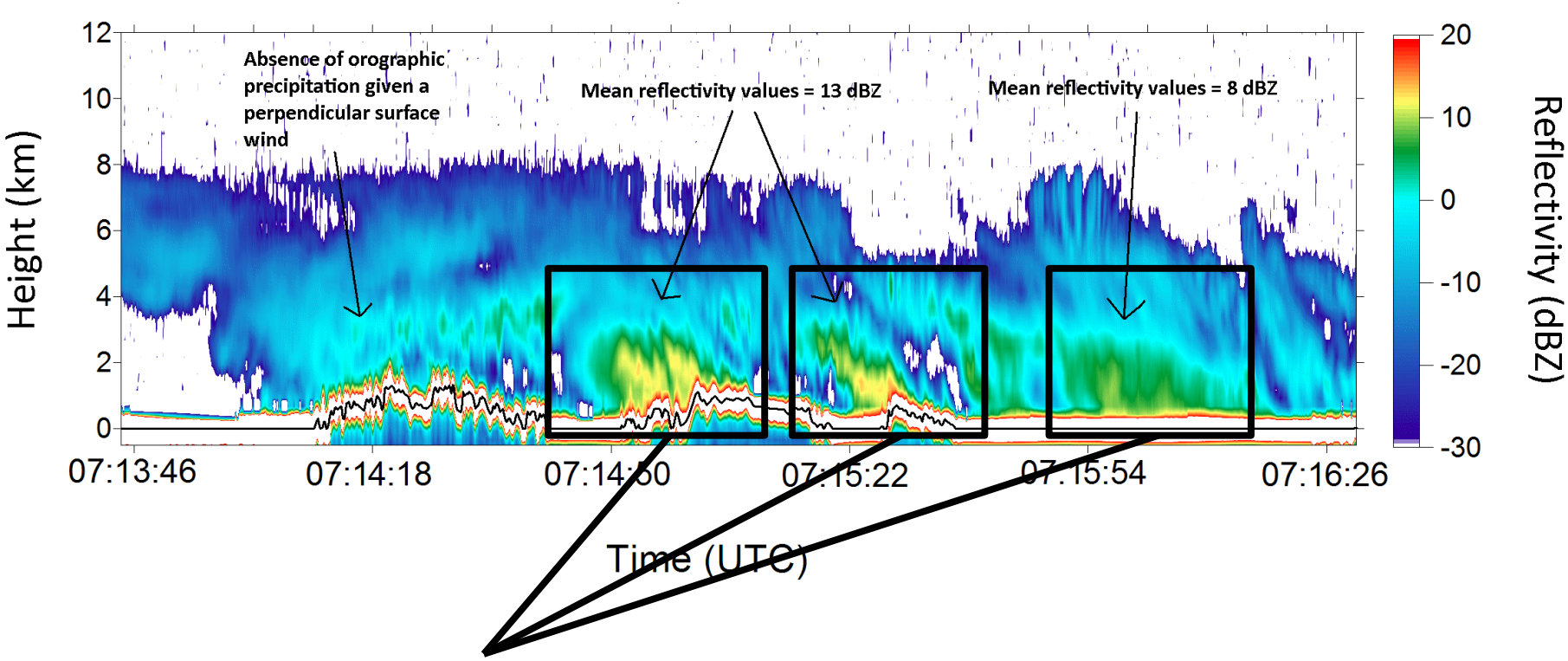
•Moderately-sized arching storm system with identifiable orographic precipitation

- mean CTT = -43°C
- mean cloud top height = 7.3 km (46% of cloud tops > 7 km)
- mean cloud depth = 5.5 km
- mean number of layers = 1.24

• 41% of the vertical profiles containing clouds had precipitation (> 0 dBZ) within the lowest bin

- mean cloud depth = 6.7 km

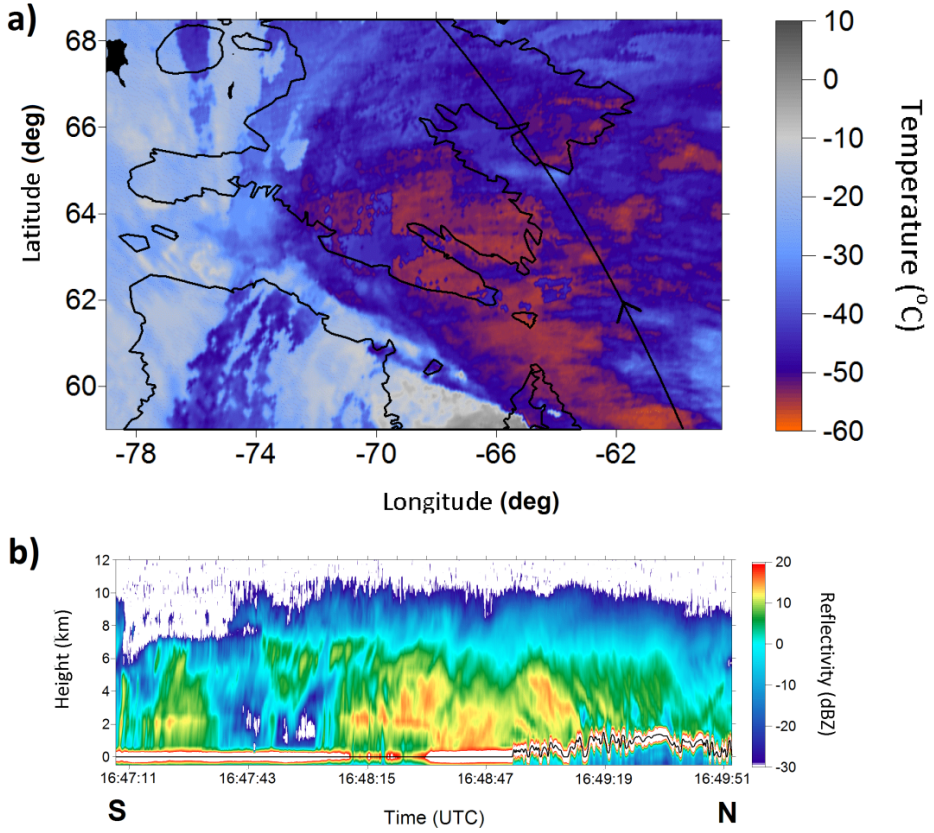
Event 3 (8 November, 0710 UTC)



Three primary precipitation regions

- orographic precipitation (Meta Incognita and Hall Peninsula)
- isolated precipitation (Hudson St.)
- note: lack of orographic precipitation on windward side of Cumberland Peninsula

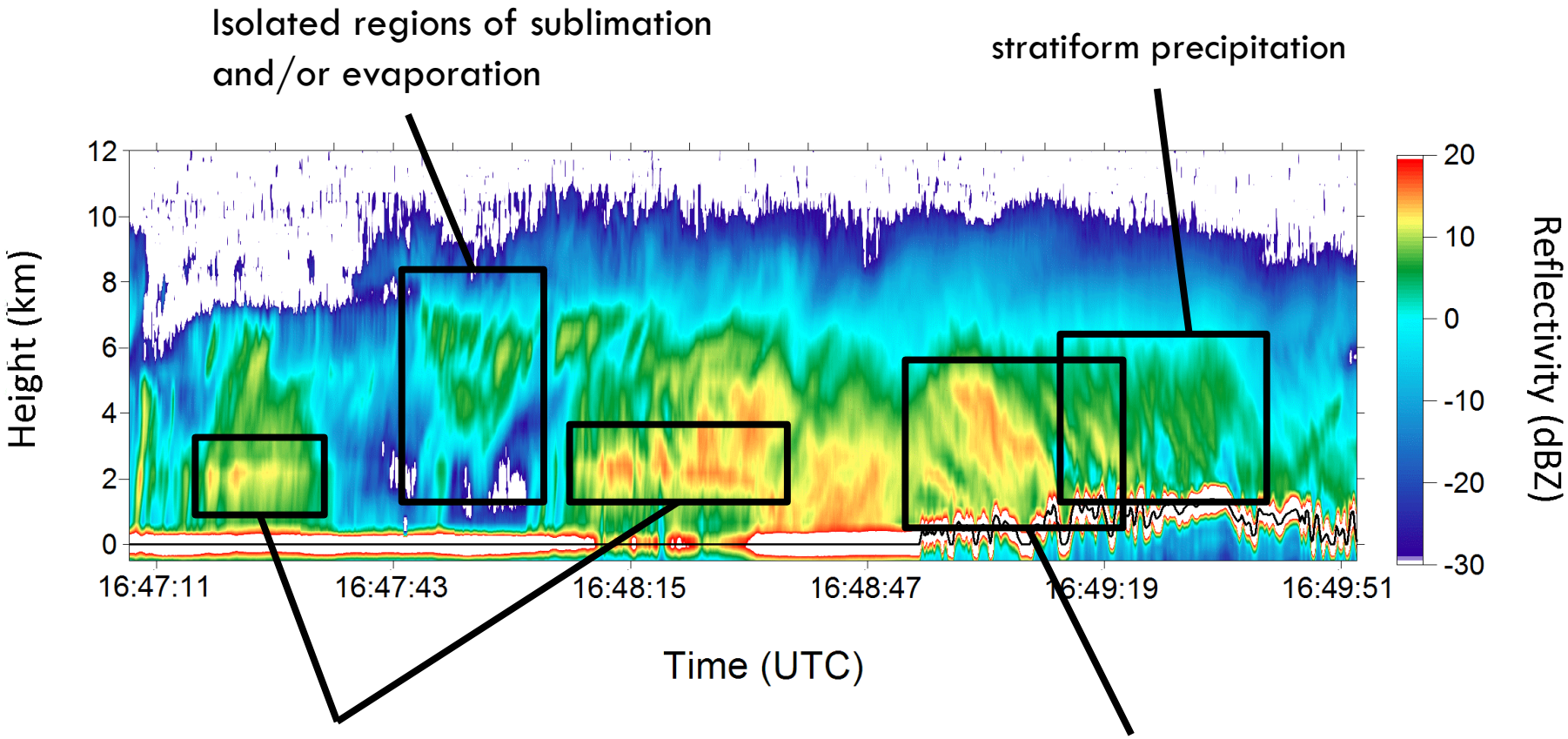
Event 4 (17 November, 1645 UTC)



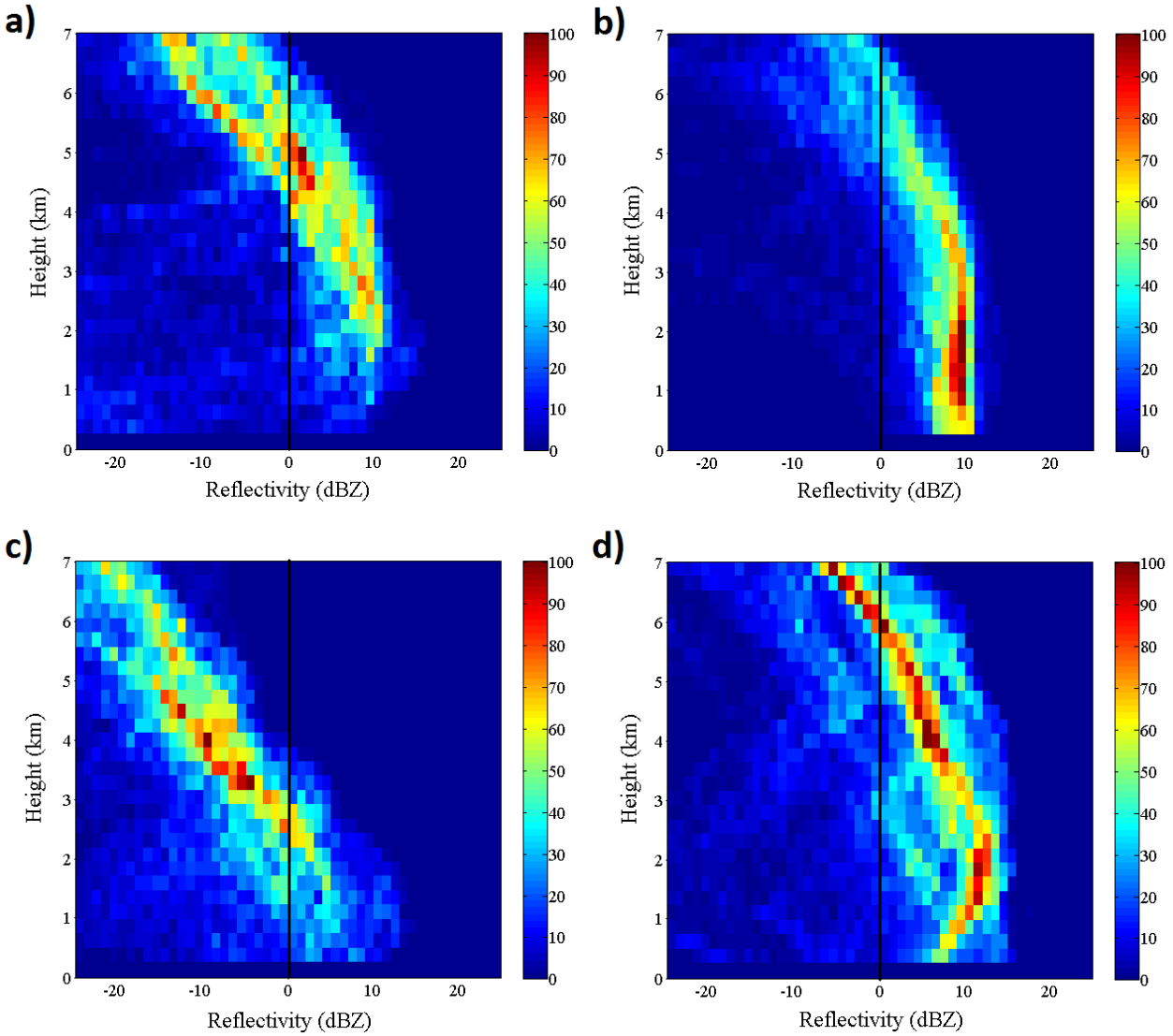
- Significant storm system with multiple precipitation regions
  - mean CTT = -47°C
  - mean cloud top height = 10.2 km (96% of cloud tops > 7 km)
  - mean cloud depth = 9.3 km
  - mean number of layers = 1.18

- 76% of the vertical profiles containing clouds had precipitation (> 0 dBZ) within the lowest bin
  - mean cloud depth = 9.3 km

Event 4 (17 November, 1645 UTC)



Contour Frequency Altitude Diagram (CFAD)



- Commonalities:
  - continuous growth aloft
  - precipitation at the surface

- Differences
  - cloud and precipitation features (sublimation, reflectivity inflections)
  - height and depth of transition region (growth to precipitation)
  - depth of precipitation layer

Case Studies against the 60-day Observations

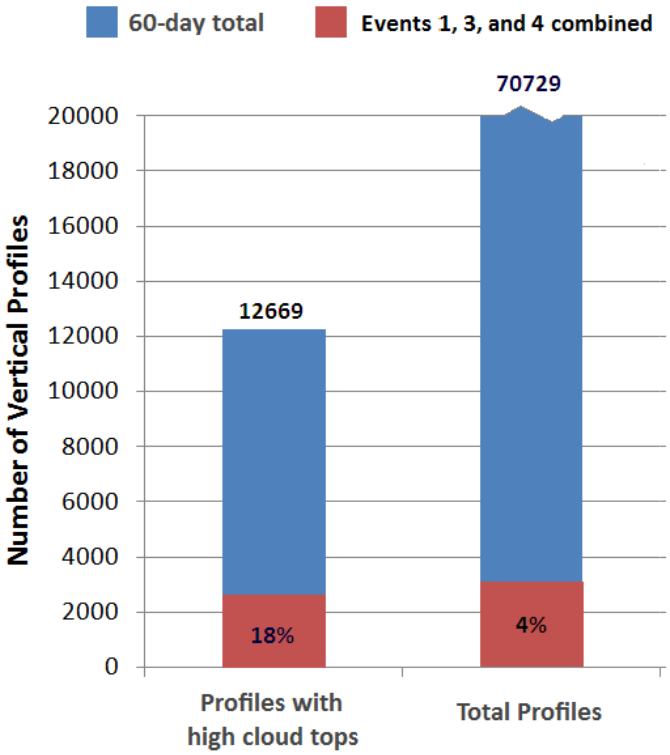
• Three of the four case studies Event 1, 3 and 4) greatly contributed to some of the extreme values observed for the period between 1 October and 30 November, 2007 (Hurricane Noel exempted)

• Events 1, 3 and 4 combined:

  • 18% of vertical profiles (2,323 of 12,669) with high cloud tops (> 7 km; right)

  • 22% of vertical profiles (2,352 of 10,818) with a cloud top temperature < -40°C

  • 19% of vertical profiles (2,813 of 14,836) with high cloud thicknesses (> 4 km)



Summary

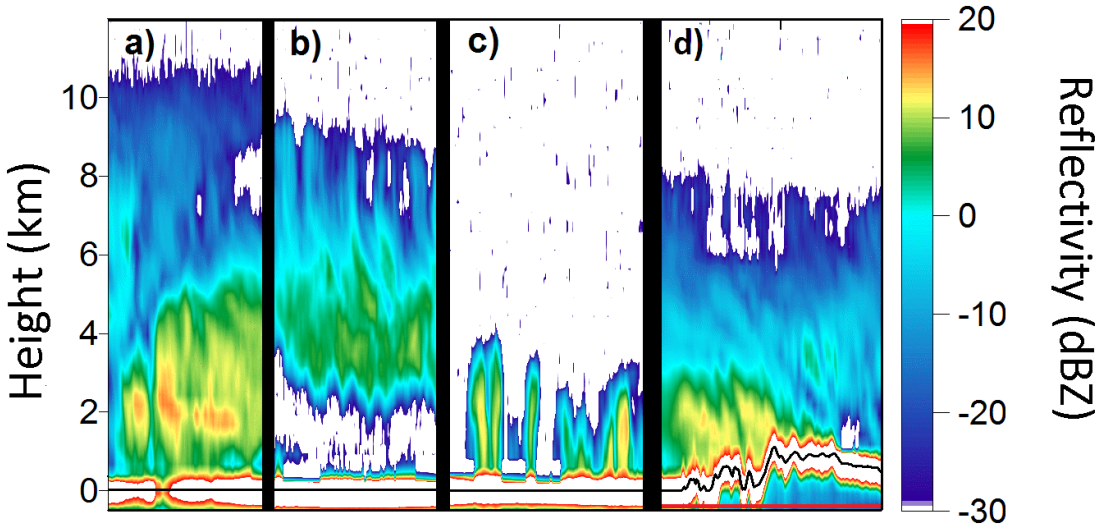
- Four major storm events with distinct cloud and precipitation features were observed during the STAR observation period by satellite
  - cold (mean < -35°C) and high (mean > 7 km) cloud tops.
  - mean cloud depth > 5 km
  - a variety of precipitation features observed :
    - Event 1 – sublimation / evaporation (+ reflectivity inflection)
    - Event 2 – stratiform precipitation
    - Event 3 – orographic precipitation
    - Event 4 – multiple reflectivity inflections (+ sublimation / evaporation)

- Distinct reflectivity distribution

- Three of the four major events have significantly contributed to some of the extreme values observed during STAR:
  - mean cloud characteristics were approximately 100% - 300% above the 60-day mean values


Questions?

Overview of Overall Observations (cont'd)



N = 91	Bright Band*	Sublimation / Evaporation	Isolated/Banded Precipitation	Orographic Precipitation
October	2	9	8	5
November	1	3	18	3
Total	3 (3.3%)	12 (13%)	26 (27%)	8 (9%)

A variety of cloud and precipitation features were observed

- Sublimation and/or evaporation were the most commonly observed feature in October

- Reflectivity columns (representing isolated and banded precipitation) were commonly observed in November and overall

Case Studies against the 60-day Observations

Cloud characteristics for each storm as compared against the 60-day observation

% above the mean for each event

Case Studies against the 60-day Observations

Cloud characteristics in the presence of precipitation for each storm as compared against the 60-day observation

- % above the mean for each event
- number of profiles