Assessing the Vertical Structure of Radiative Heating Using Radar & Lidar for Cirrus Cloud Events at SGP

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SSEC

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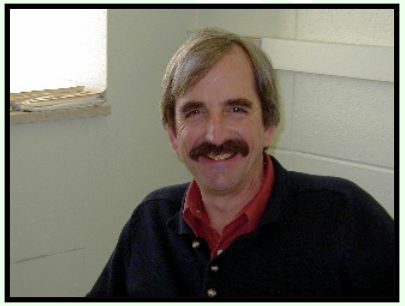


Hank Revercomb

History

Extension of previous work, which assessed ARM Broad Band Heating Rate Profiles (BBHRP) under clear-sky conditions.

BBHRP collaboration of all working groups which produces vertical profiles of fluxes and heating rates to drive climate models.

BBHRP primarily radar (MMCR) based logic for cloud properties.

Motivation

Is radar representing radiative structure of cirrus clouds?

Can radar be combined with lidar to better characterize cirrus?

What is the impact of lidar on the heating rates & fluxes?

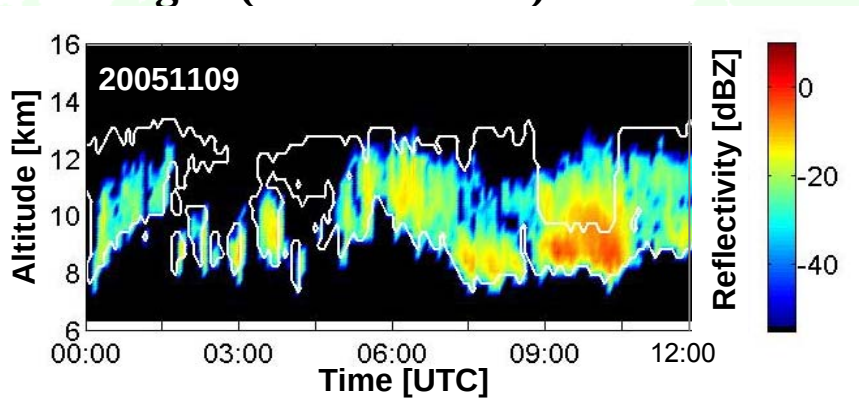
Approach

1. Derive extinction profiles from Raman lidar
2. Produce merged dataset

Radar (MMCR)

Raman Lidar

Merged (Radar+Lidar) Dataset

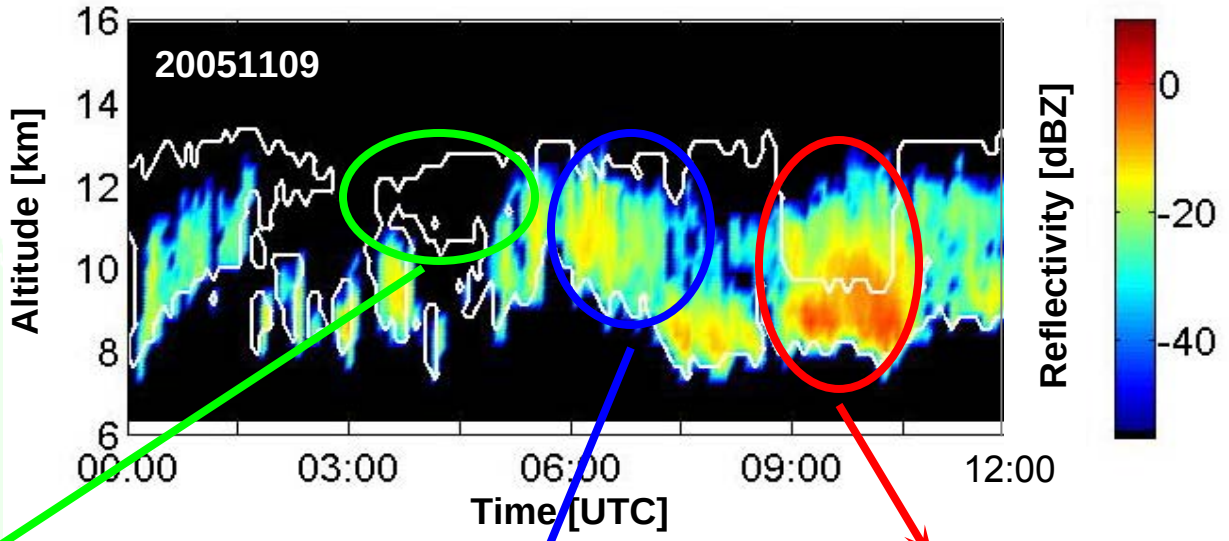


Merged Dataset:

- 5 min time resolution
- 300 m vertical resolution between 6-16 km
- 20040917 - 20071231

Approach

Merged (Radar+Lidar) Dataset



Lidar Data Only
- Direct measurements of lidar extinction and assumed small r_e

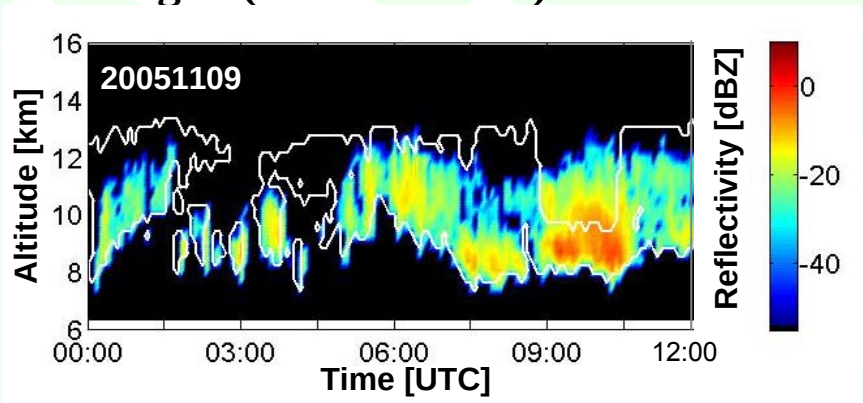
Radar Data Only
- Z-IWC power law
- T function of r_e

} MICROBASE BBHRP logic

Radar + Lidar Data
- Direct measurements of lidar extinction and (radar+lidar) derived r_e

Approach

Merged (Radar+Lidar) Dataset



Sondes

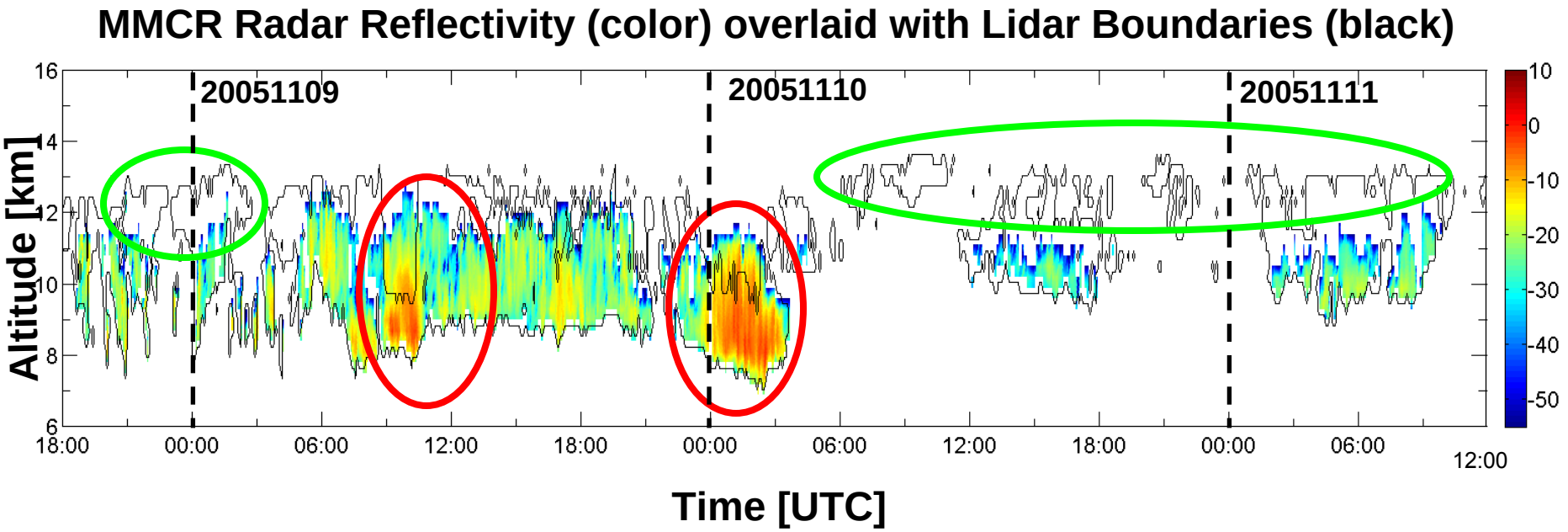
MWR

Radiation Station

aer **RRTM_LW**

IR Radiative Fluxes and Heating Rates

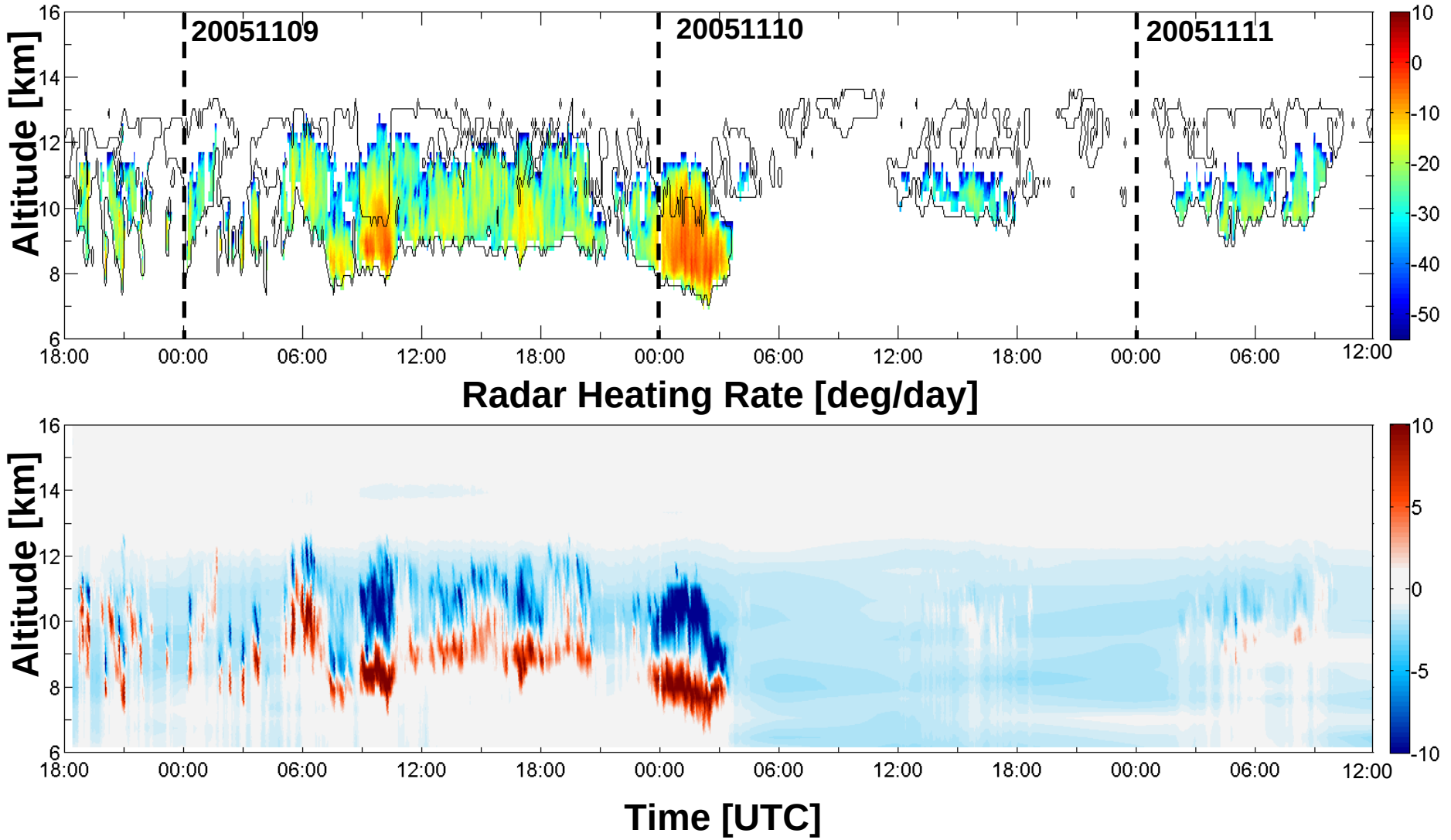
3 Day Case Study



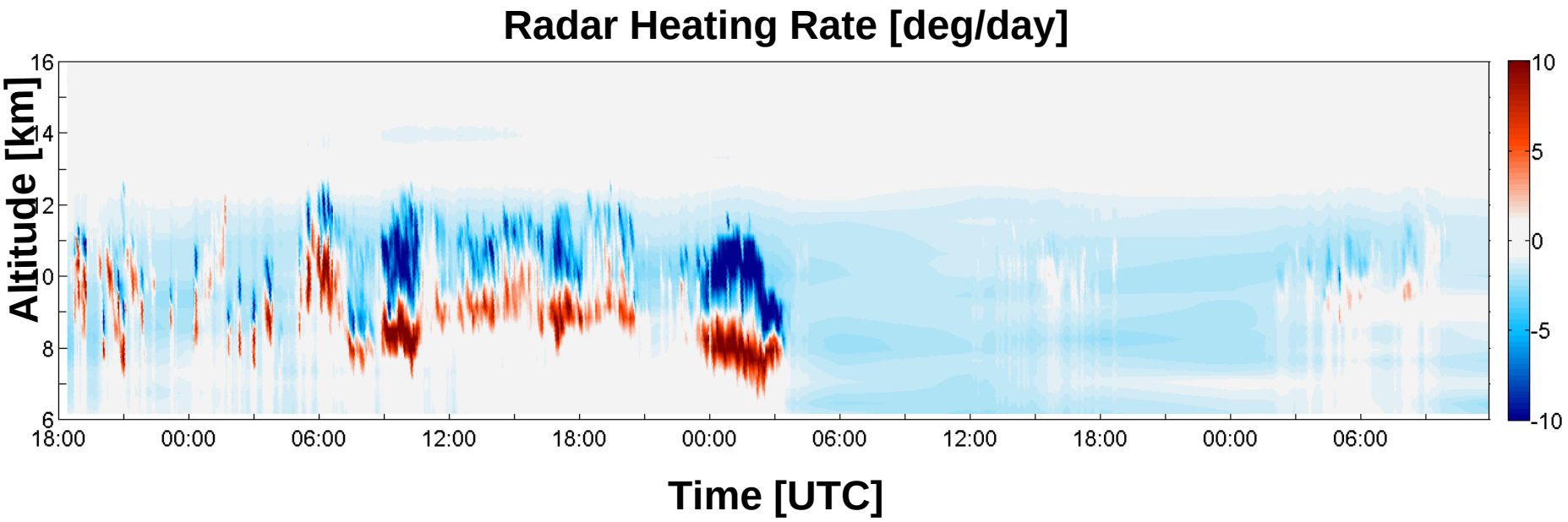
- Case study characterized by single layer cirrus
- 2 time periods where radar seeing more than lidar
- MMCR radar missing significant upper level cirrus

3 Day Case Study

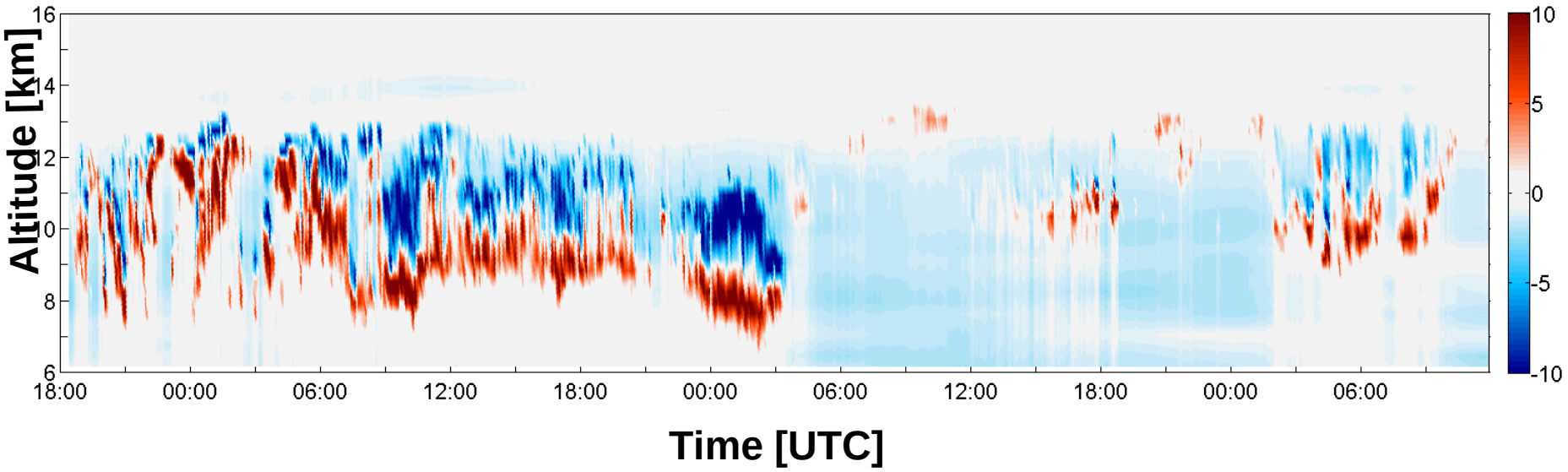
MMCR Radar Reflectivity (dBZ) in color overlaid with Lidar Boundaries in black



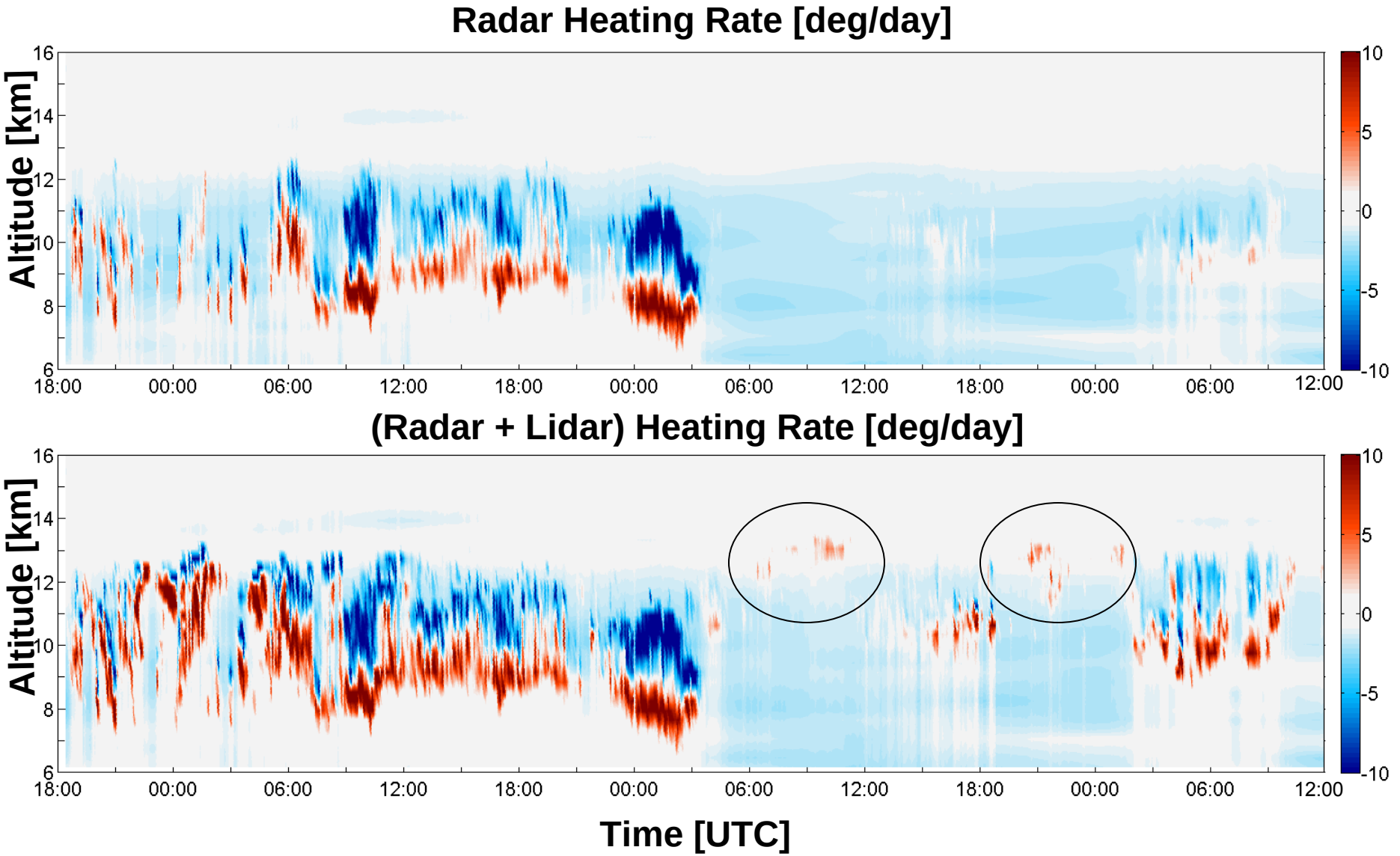
3 Day Case Study



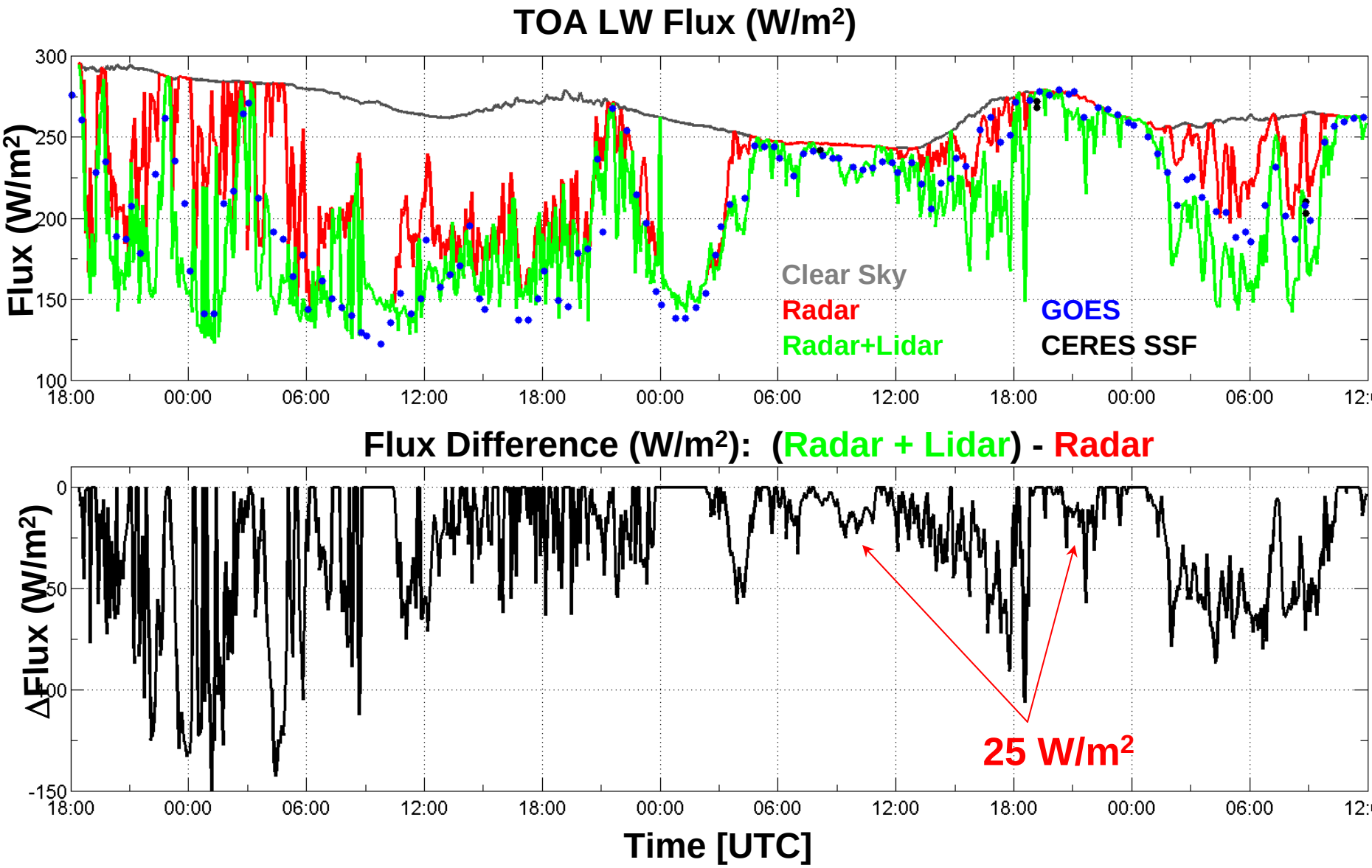
3 Day Case Study



3 Day Case Study



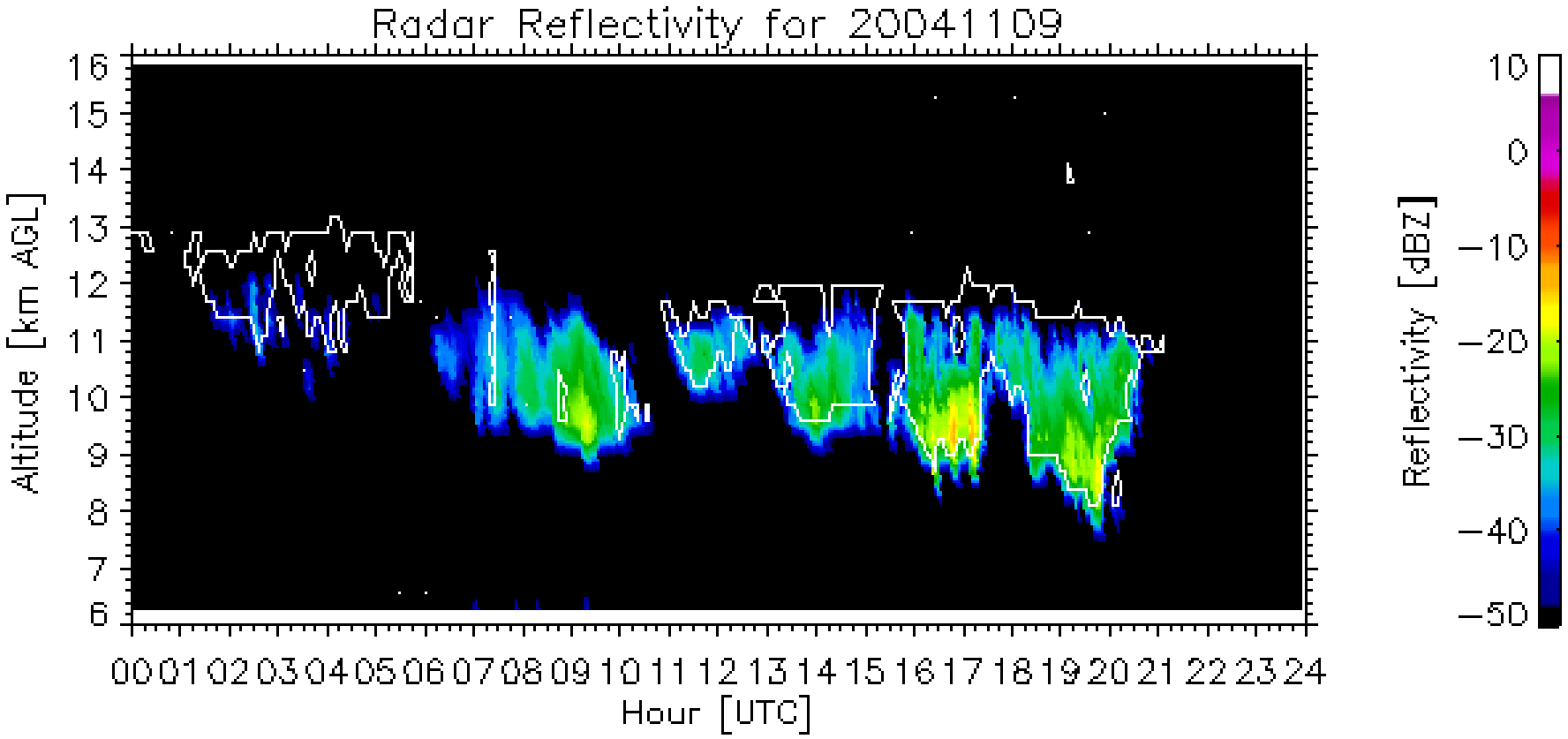
3 Day Case Study



Conclusions: Case Study

- Radar alone misses significant upper level cirrus resulting in large errors in computed fluxes and heating rates.
- Accurate characterization of thin cirrus requires Lidar extinction plus Radar.

Is this study period representative of other single layer high altitude cirrus cases?


Radar Reflectivity for 20041109
Altitude [km AGL]
16
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00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour [UTC]
Reflectivity [dBZ]
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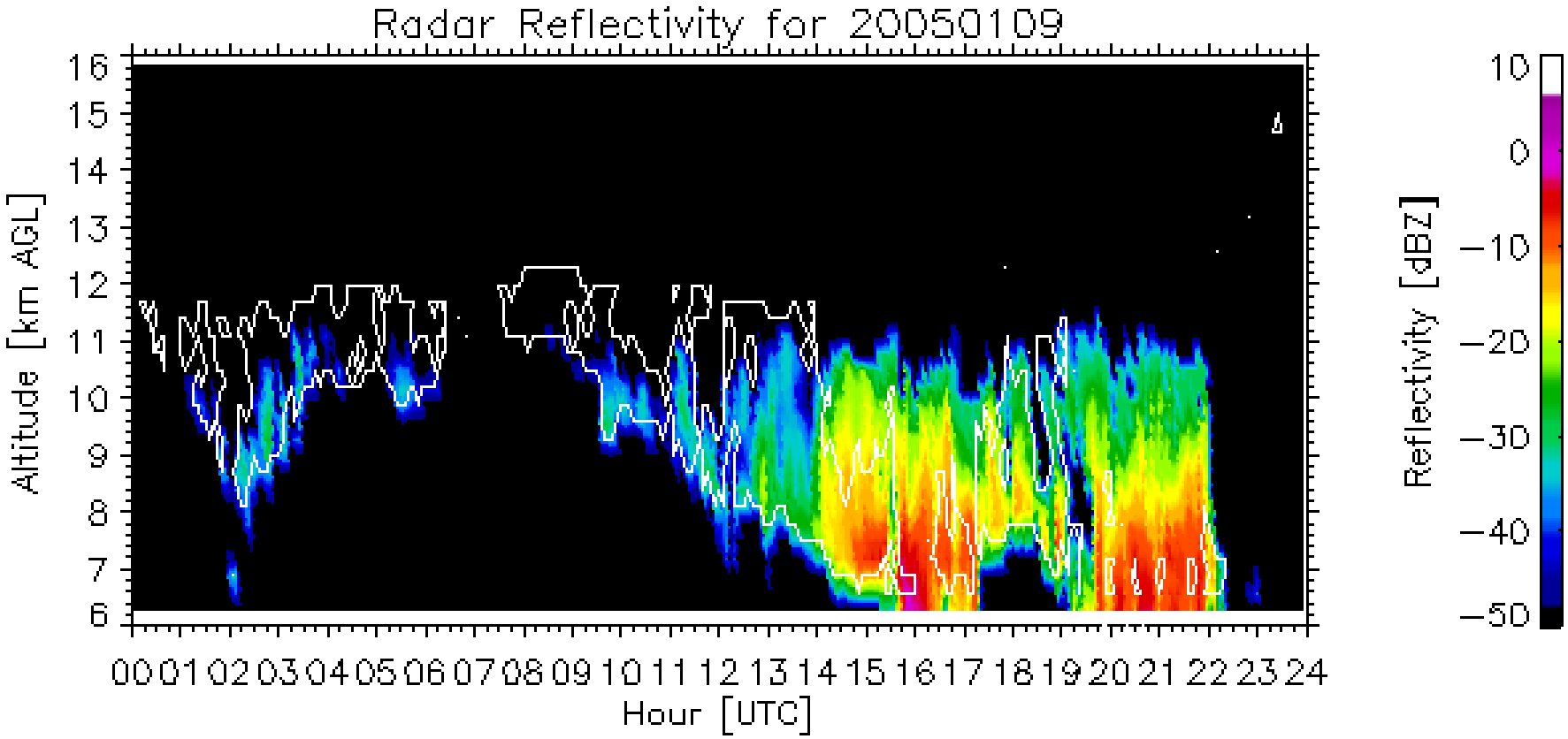
−50


Radar Reflectivity for 20050109
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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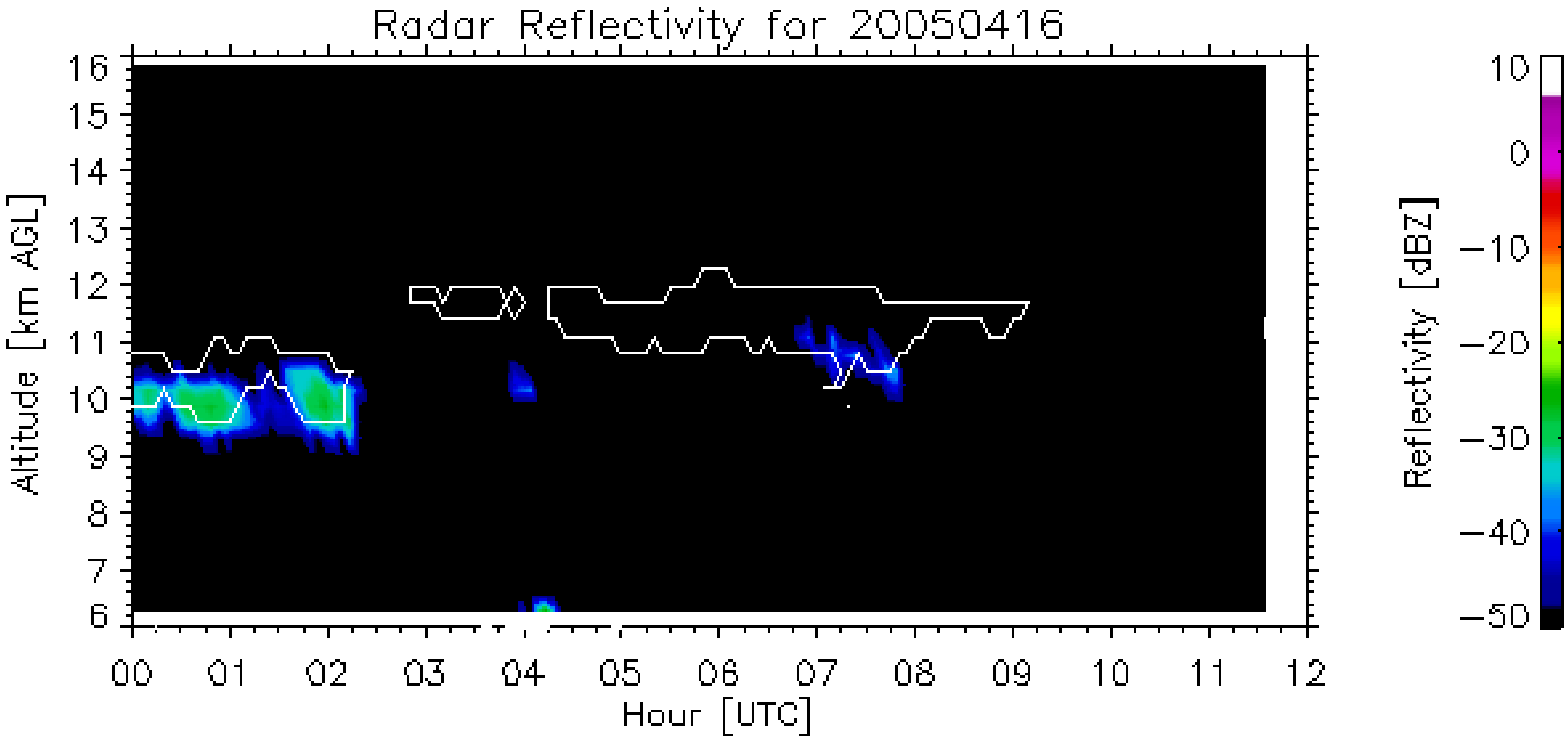
Radar Reflectivity for 20050416
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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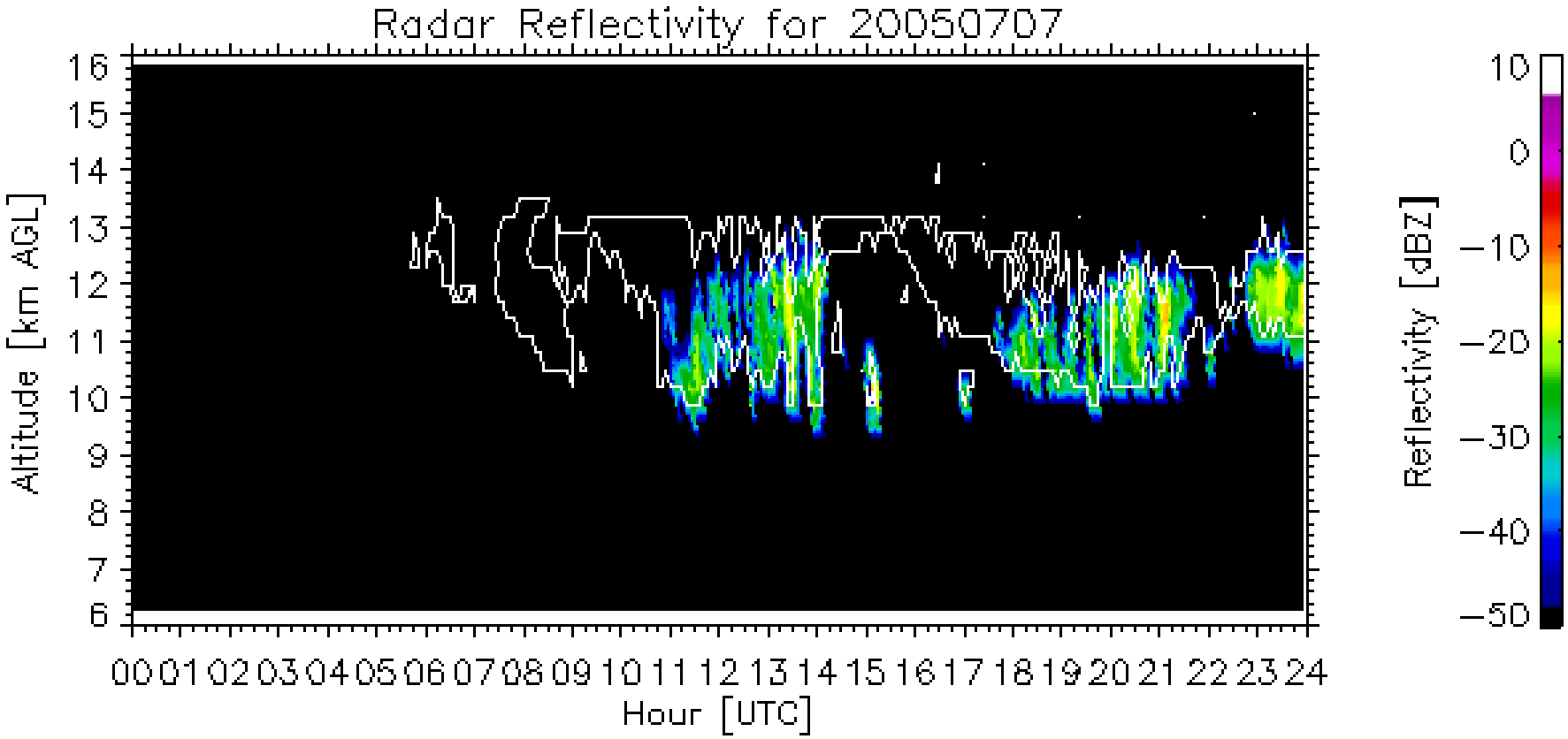
Radar Reflectivity for 20050707
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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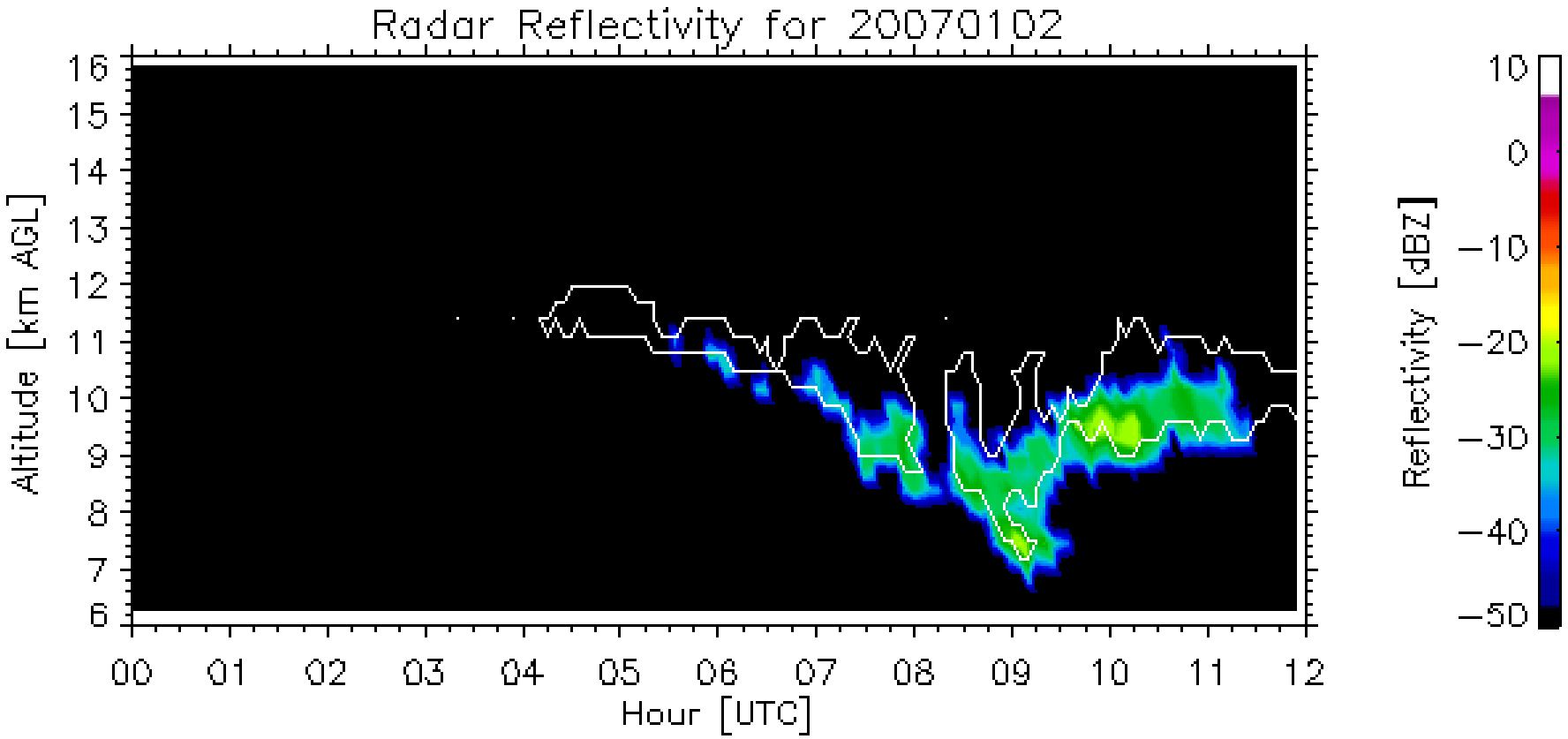
Radar Reflectivity for 20070102
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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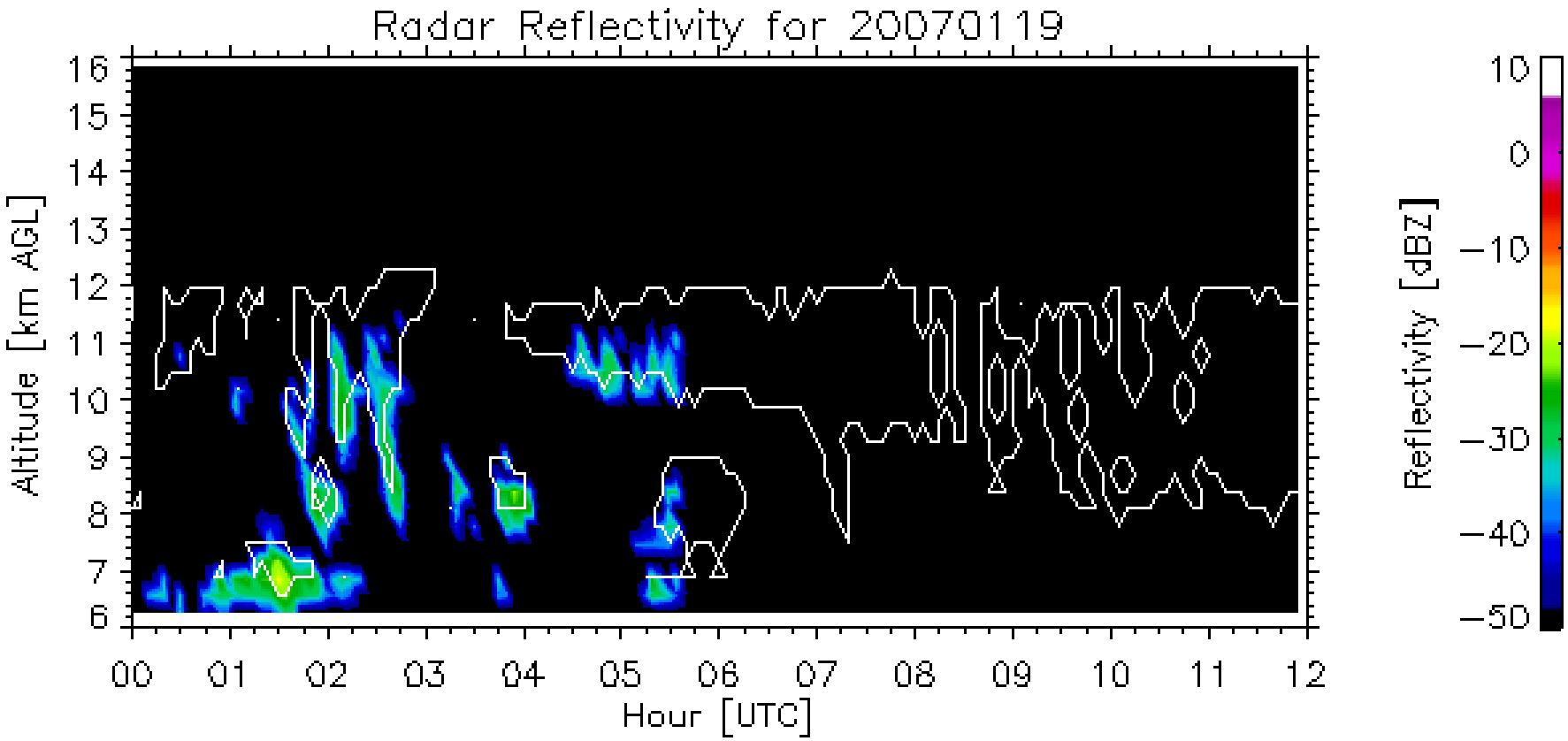
Radar Reflectivity for 20070119
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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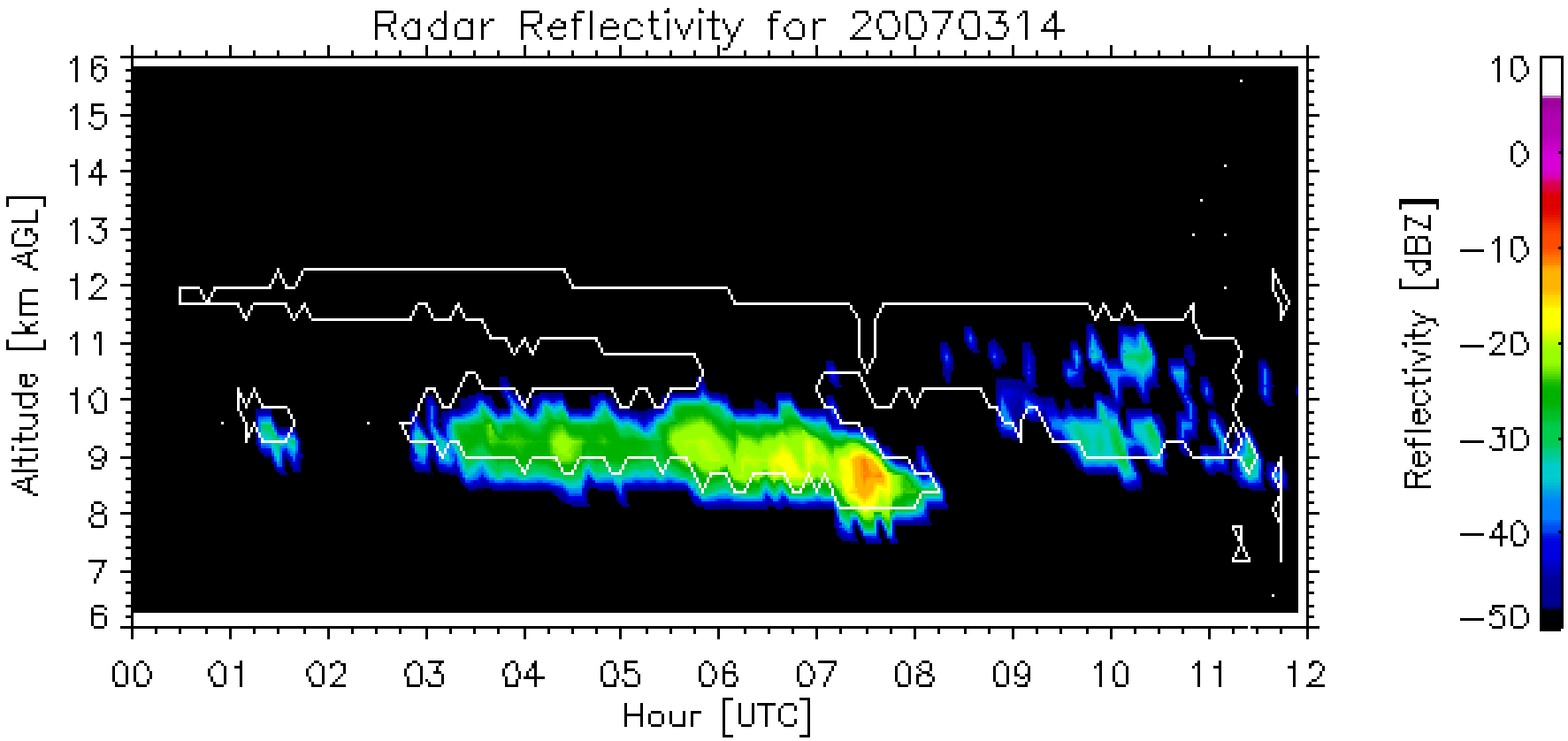
Radar Reflectivity for 20070314
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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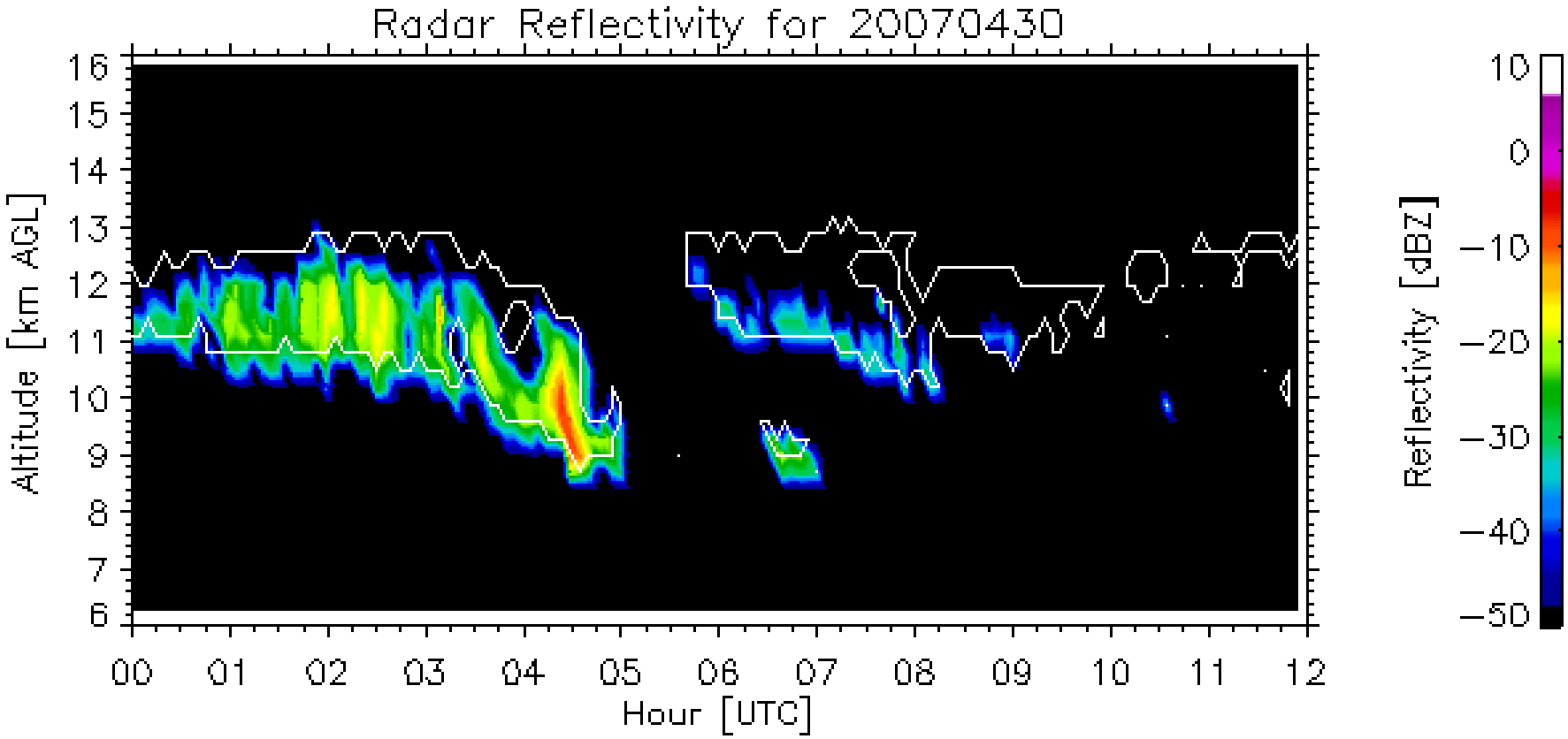
Radar Reflectivity for 20070430
Altitude [km AGL]
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Hour [UTC]
Reflectivity [dBZ]
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−50

Statistics

% Total Sky

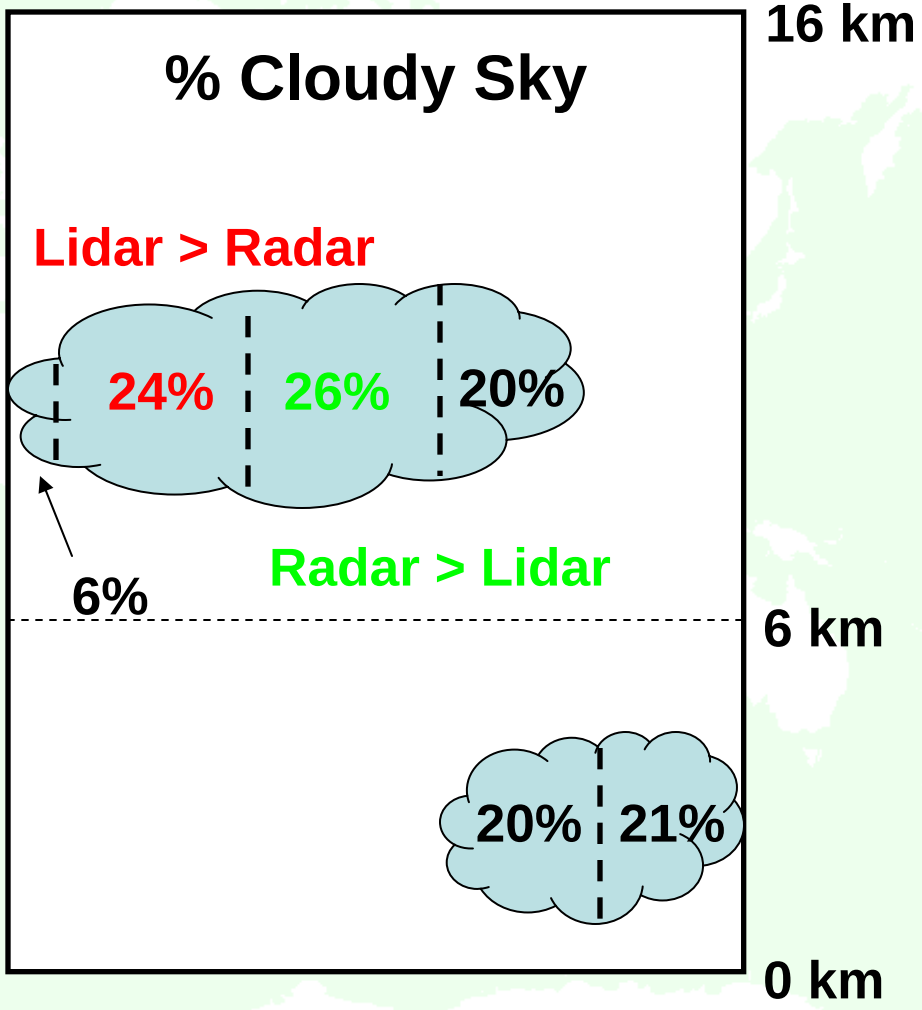
Clear Sky	Cloudy
52%	48%

% Cloudy Sky

Single Layer Cirrus - 56%

Lidar > Radar - 24%

Radar > Lidar - 26%

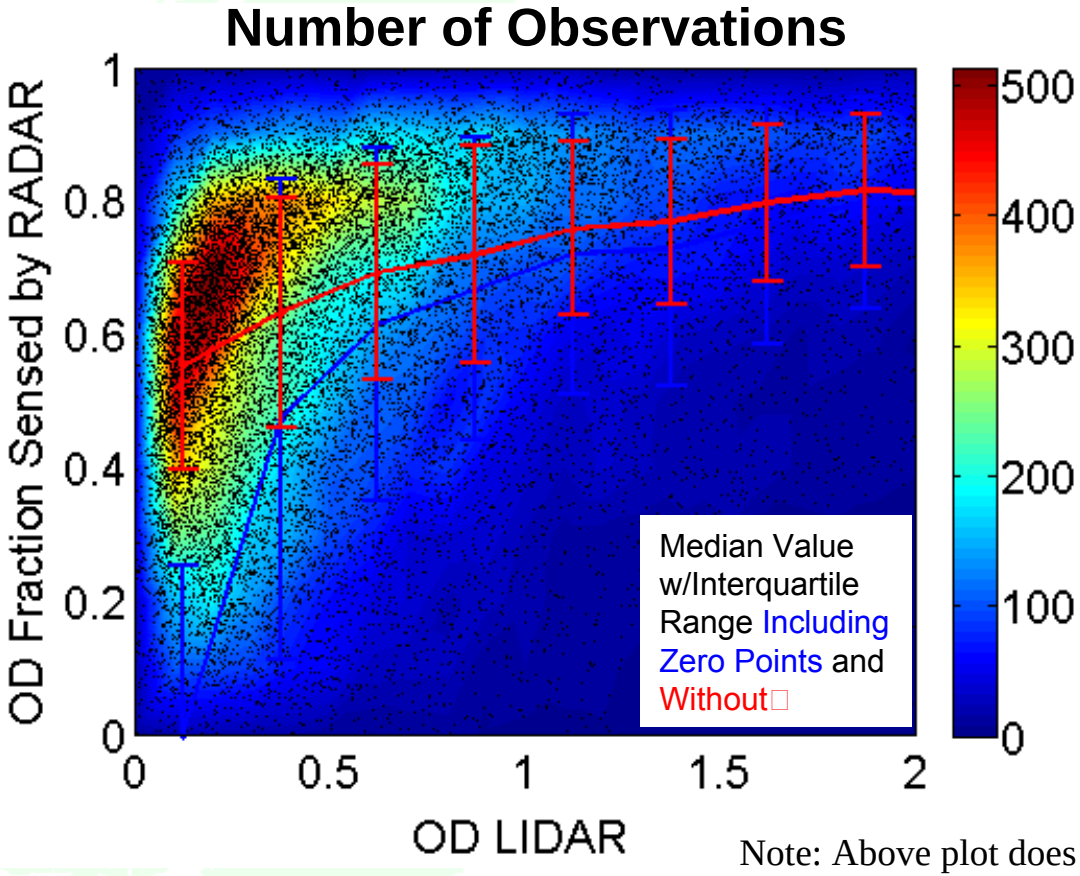


Radar missing some portion - 43% cirrus cases!

2+ Year Study

Dataset: 17 Sep. 2004 - 31 Dec. 2006

- Removed known time periods when MMCR problematic
- When Lidar NOT attenuated …



Note: Above plot does NOT display the points when Lidar sees cloud and Radar does not.

Conclusions

- Single layer cirrus is prevalent over SGP: 56% of cloudy cases.
- MMCR radar missing significant upper level cirrus resulting in large errors in fluxes and heating rates
- Accurate characterization of thin cirrus requires lidar extinction plus radar or AERI plus lidar boundaries.
- Vertical distribution of extinction and particle size are significantly less important than optical depth in computing heating rates.

Future Directions

- Add merged (radar+lidar) dataset to BBHRP as alternative to MICROBASE.
  - BBHRP WG announced development of testbed
- Extend outwards from soda-straw point-of-view for meaningful comparisons with satellite measurements & GCMs
- Think globally using same methodology with CloudSat & CALIPSO

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