

Cloud Properties and Heating Rates in Tropical Cloud Systems

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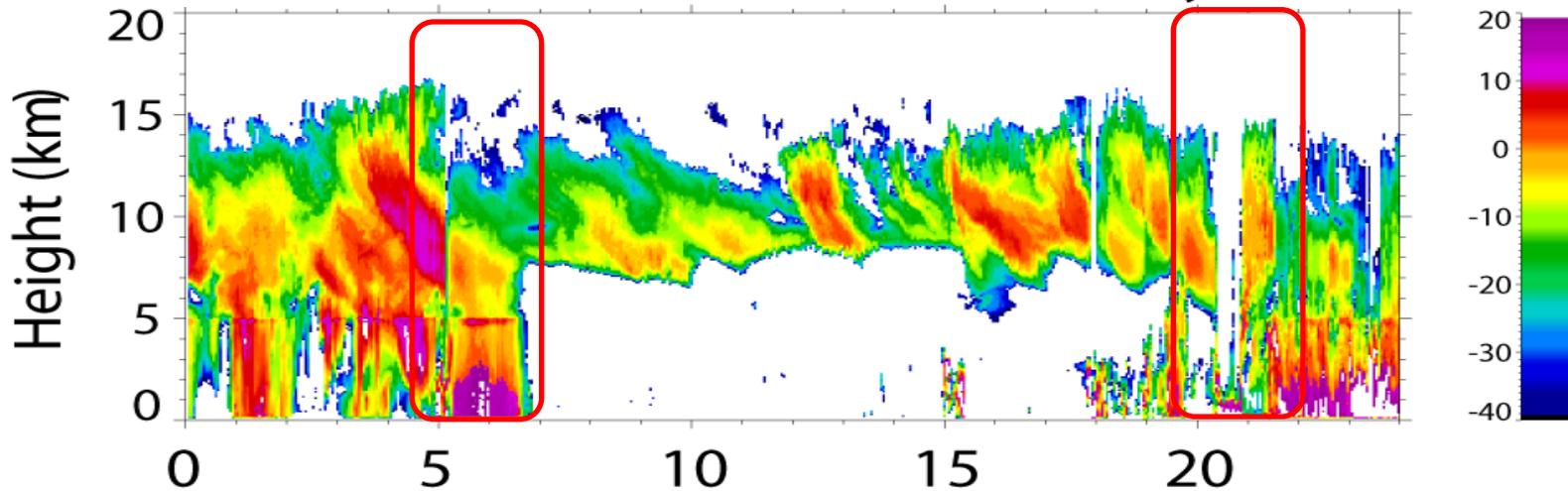
Motivation

- ▶ Cloud properties retrievals
 - Cloud process understanding
 - Cloud Radiative forcing and heating rates
 - Model evaluation on many scales (LES, CRM, SCM...)
- ▶ Quantified uncertainties are needed...

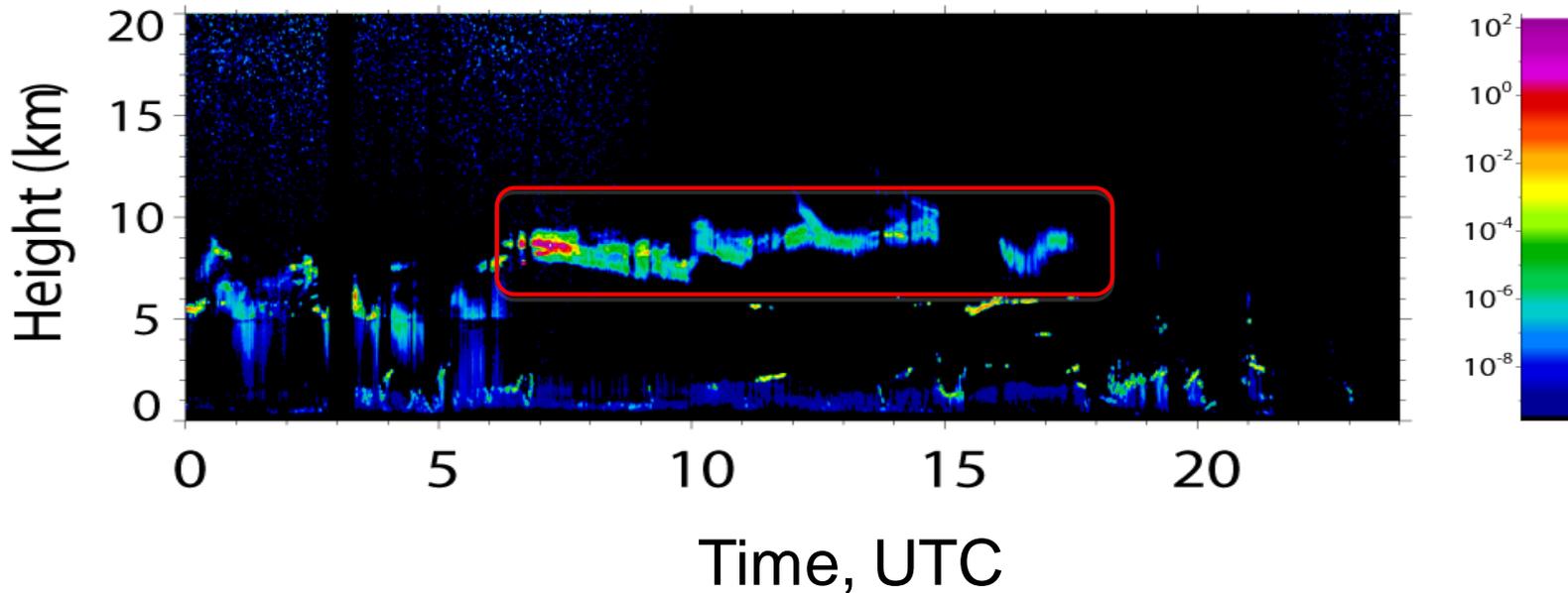
Retrieval Algorithm Evaluation within CPWG

- ▶ Past intercomparisons
 - CLOWD – Clouds with Low Optical Water Depths (Turner et al. 2007)
 - Ice Clouds – (Comstock et al. 2007)
 - One retrieval does not fit all
- ▶ Present algorithm evaluation
 - BBHRP
 - Ice Cloud Retrievals at SGP – Microbase (Dunn, Jensen, Mace, Marchand)
 - Arctic mixed phase clouds – BBHRP (Shupe, Turner)
 - CLOWD – BBHRP Pt. Reyes AMF deployment
 - Ice clouds in tropical cloud systems
 - Abundant cirrus and thick anvils
 - Subvisual cirrus to really thick (COD>30)

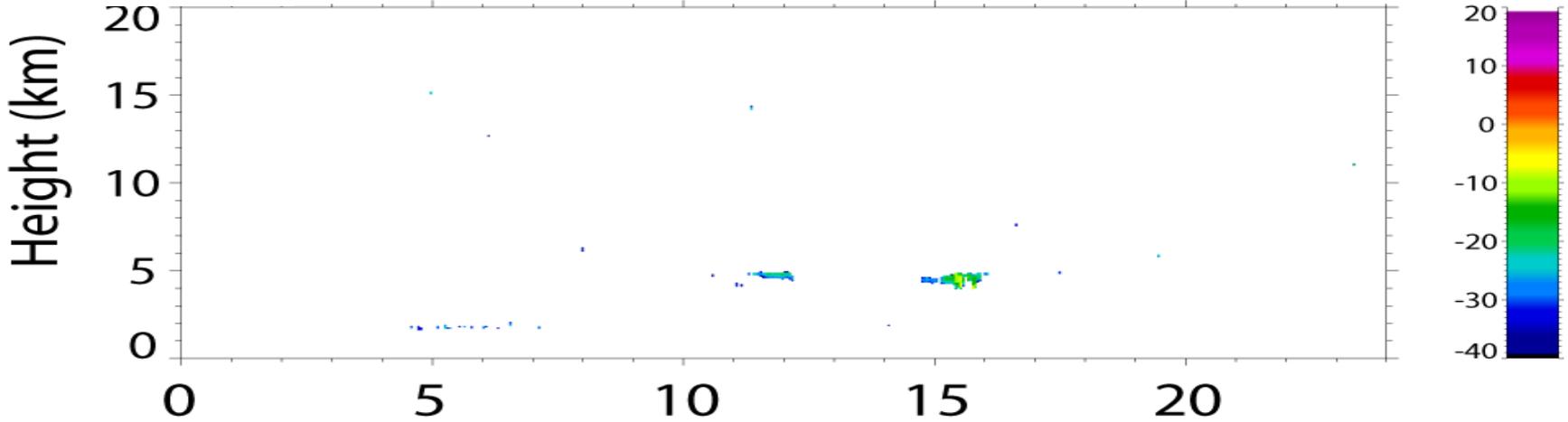
Darwin 2 Feb 2008 MMCR Reflectivity (dBZ)



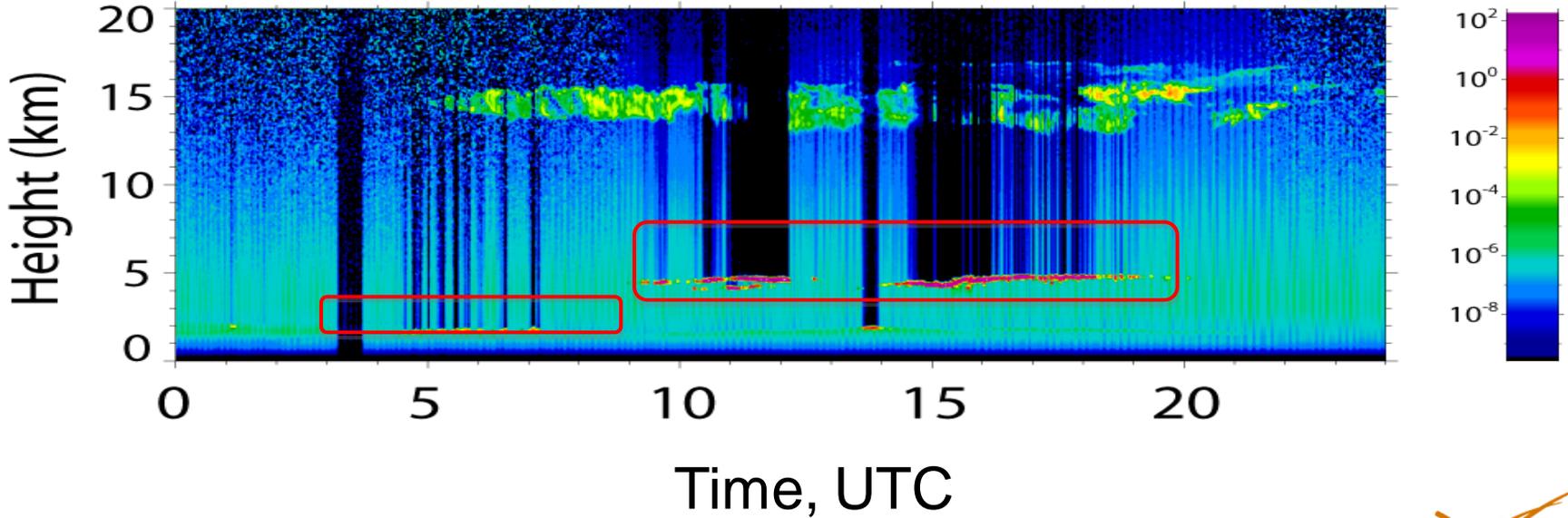
Normalized Lidar Backscatter



Darwin 14 May 2006 MMCR Reflectivity (dBZ)



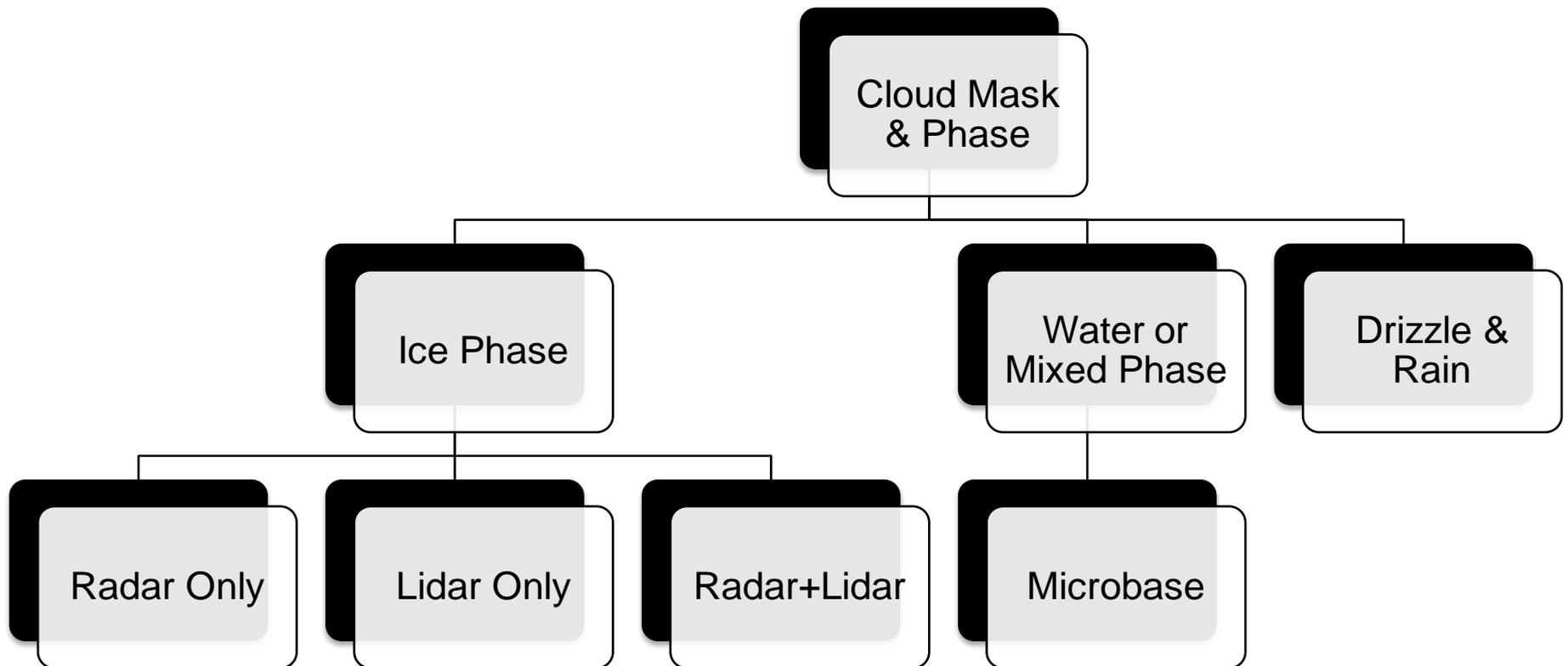
Normalized Lidar Backscatter



Outline

- ▶ Retrieval algorithm description
 - ▶ PNNL Combined Retrieval
 - ▶ Varclouds
- ▶ What (ice) cloud types can we retrieve with confidence?
- A few case studies – Flux closure
- Statistical comparisons
- ▶ Effects on heating rates
- ▶ Suggested path forward for ice clouds
- ▶ Future improvements
- Development of a full retrieval
- Evaluation tools

Algorithm Techniques: PNNL Combined Retrieval

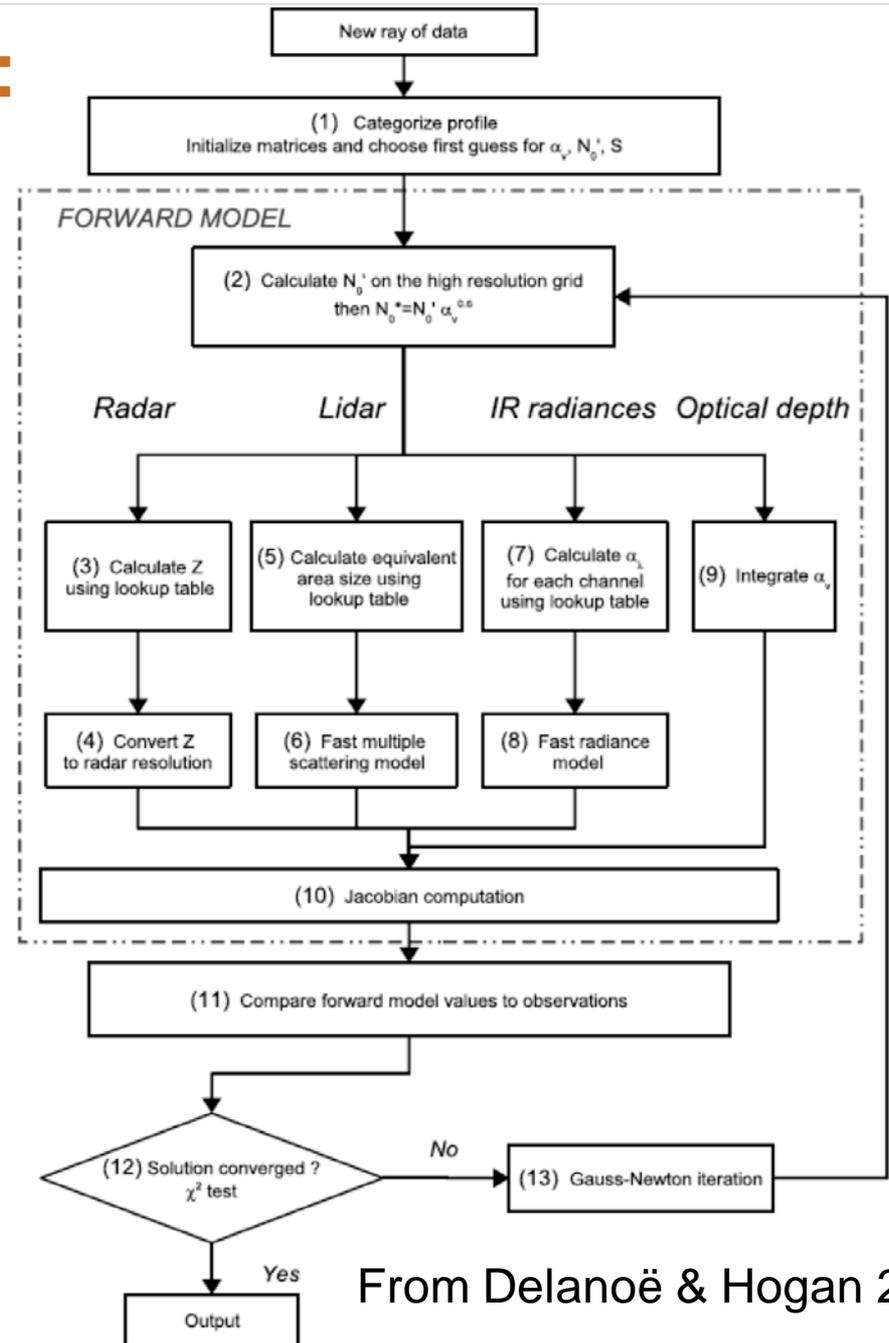


ARSCL
Merged Sonde
MPL

MWR-RET
Surface Met

Algorithm Techniques: Varclouds

- Optimal estimation technique
- Forward models used to converge to a solution depending on available measurements
- Includes IR Radiance
- Ice clouds only
- Some comparisons with Protat et al. (2007) and Z-Doppler approach

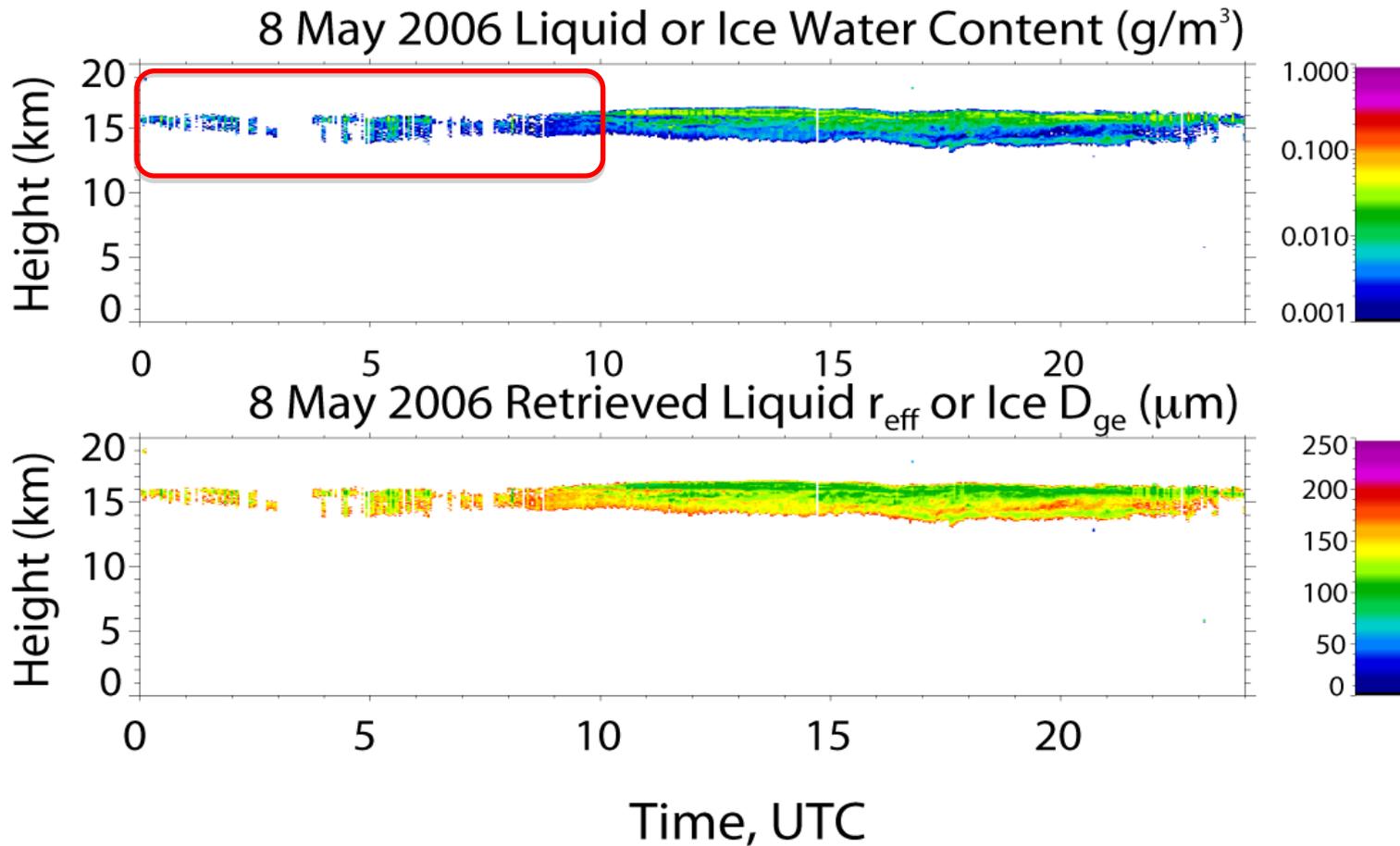


From Delanoë & Hogan 2008

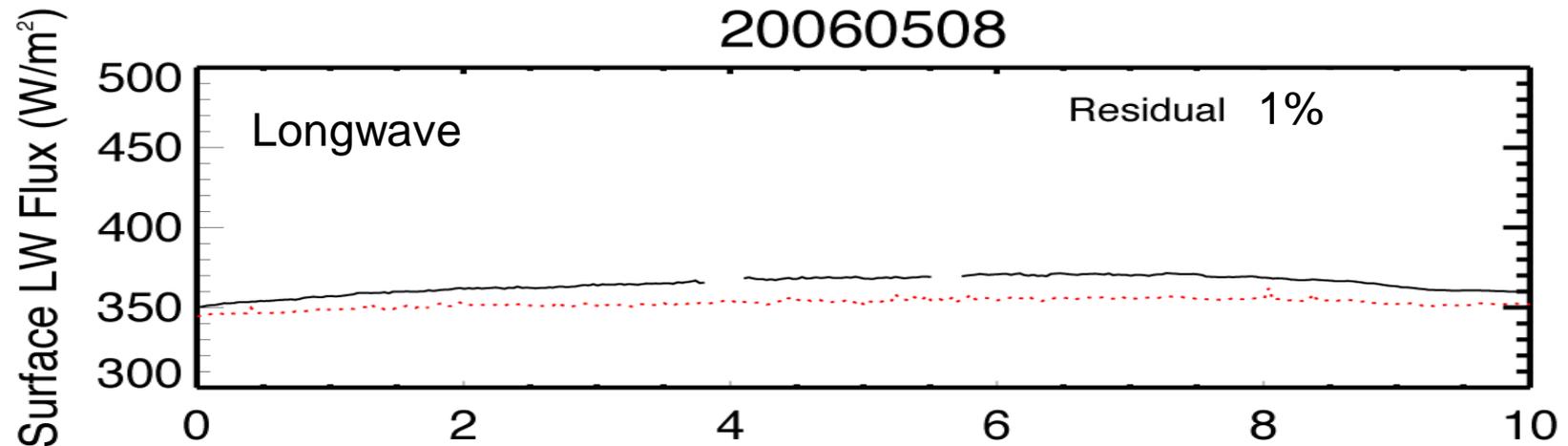
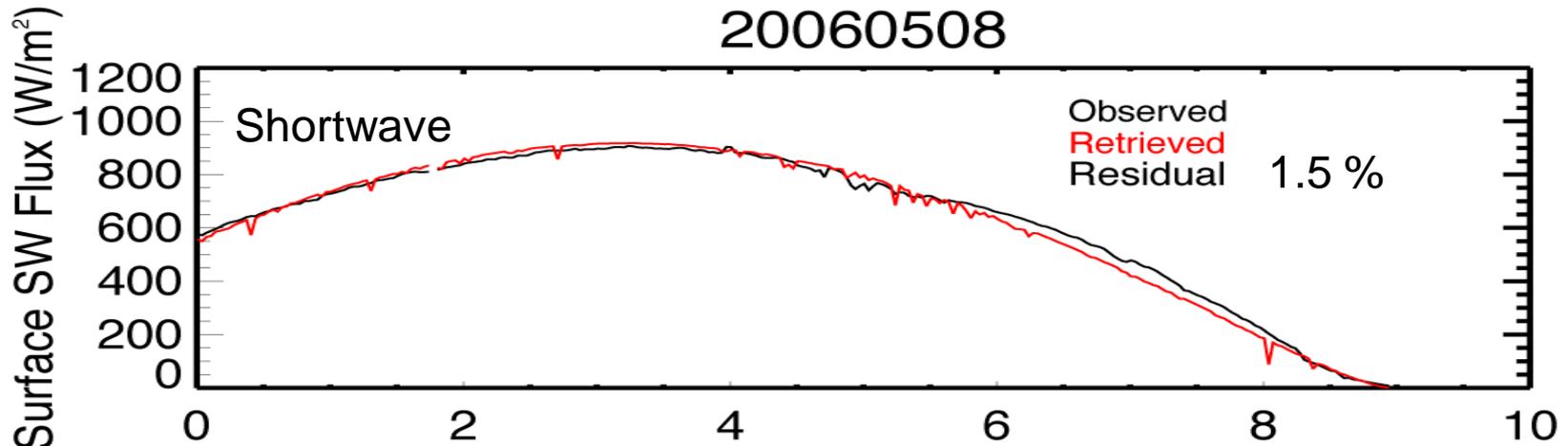
Case Studies - Criteria

- ▶ Focus on surface shortwave flux closure
 - Daytime
 - No low or middle level clouds, or precipitation
 - Several contiguous hours
- ▶ Looked for thin, medium and thick cases
 - Lidar (thin) Cloud Optical Depth < 0.1
 - Radar+lidar (medium) $0.1 < \text{COD} < 2$
 - Radar (thick) $\text{COD} > 2$
- ▶ Differences in heating rates due to cloud properties

Thin Cirrus - Lidar Only Algorithm

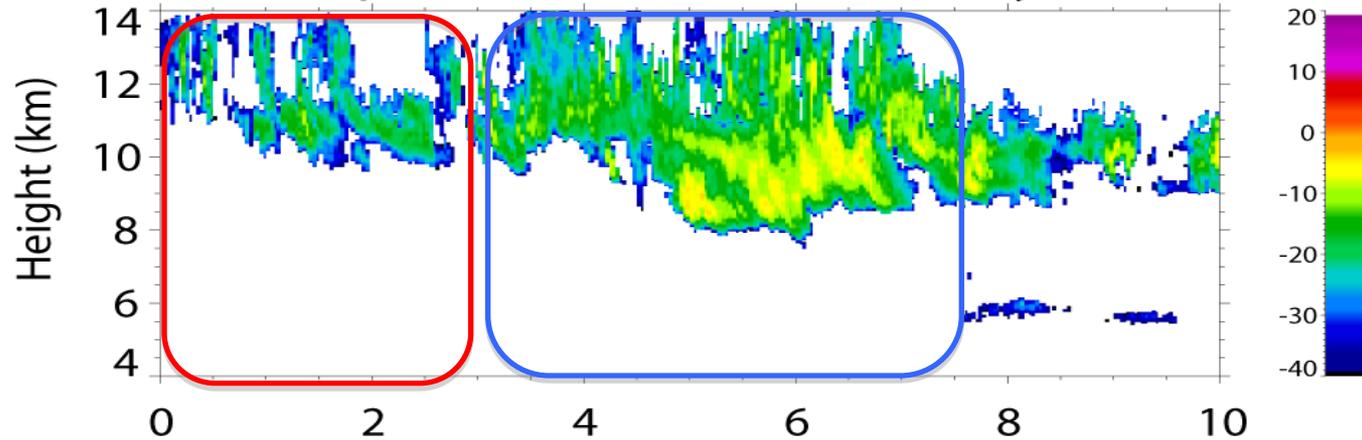


Thin Cirrus – Surface Fluxes

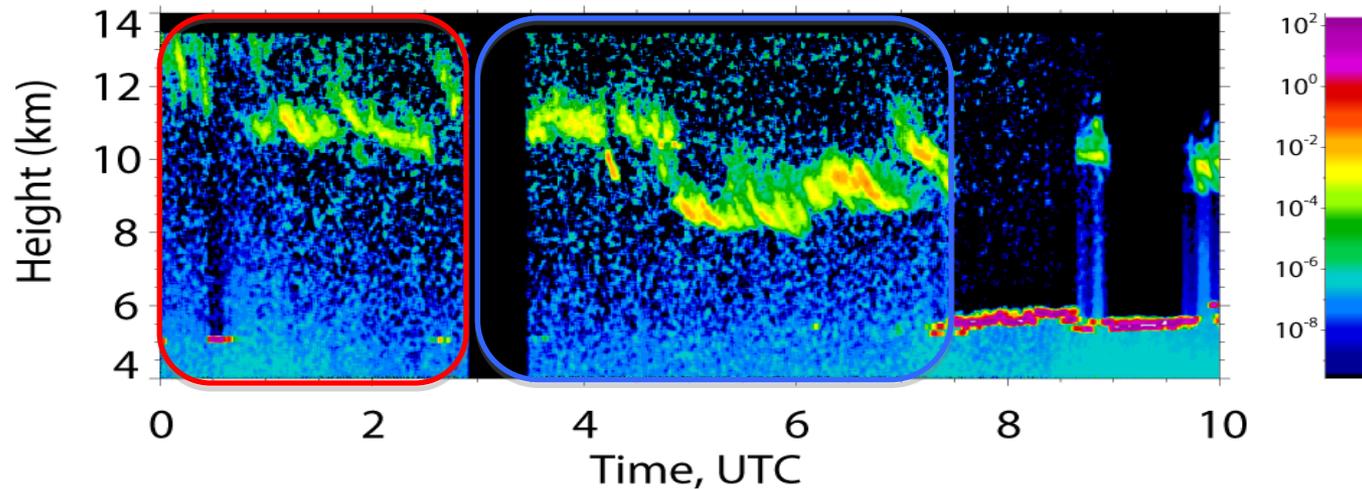


Anvil Case – Thin to Thick

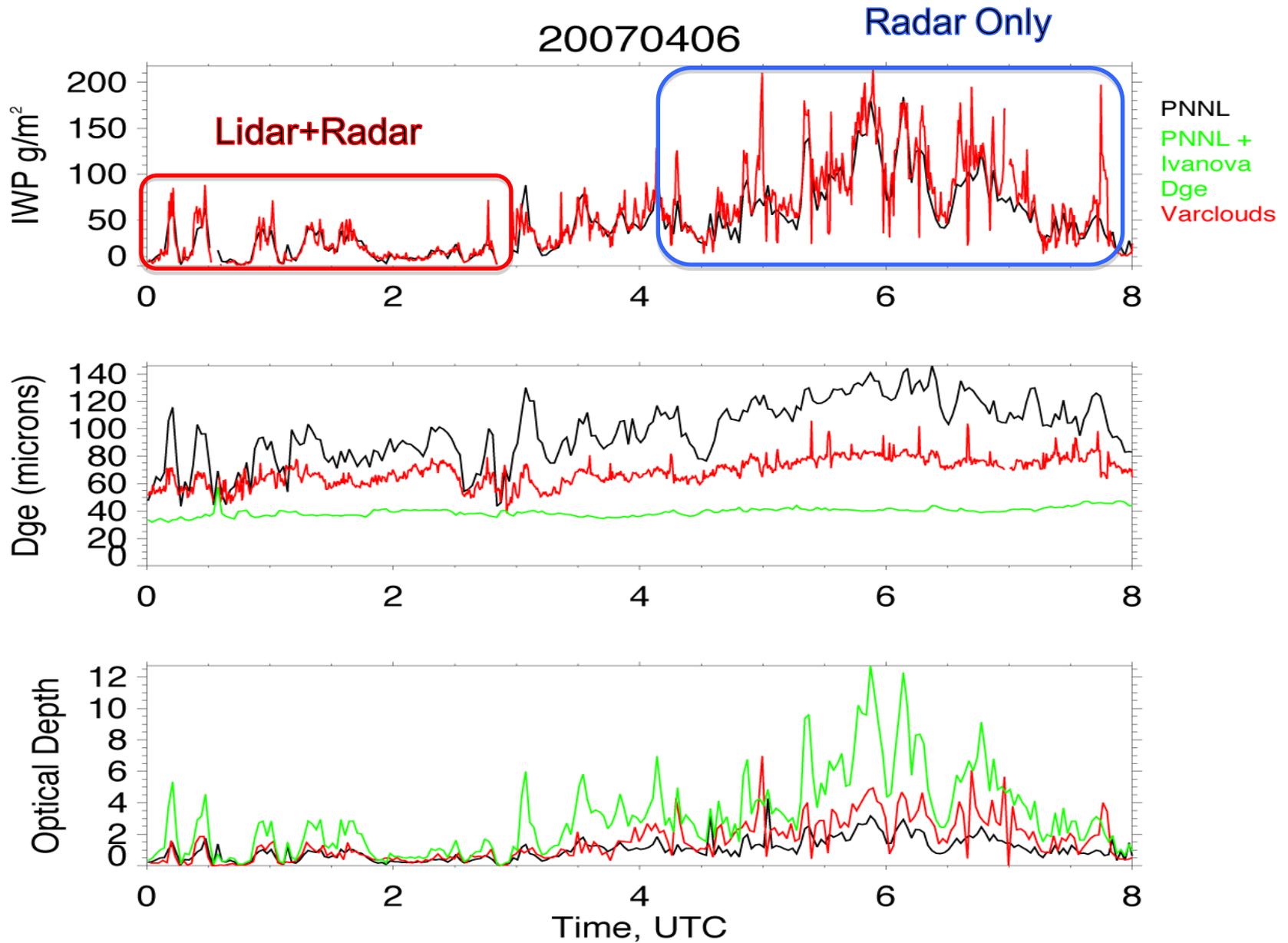
6 Apr 2007 MMCR Reflectivity (dBZ)



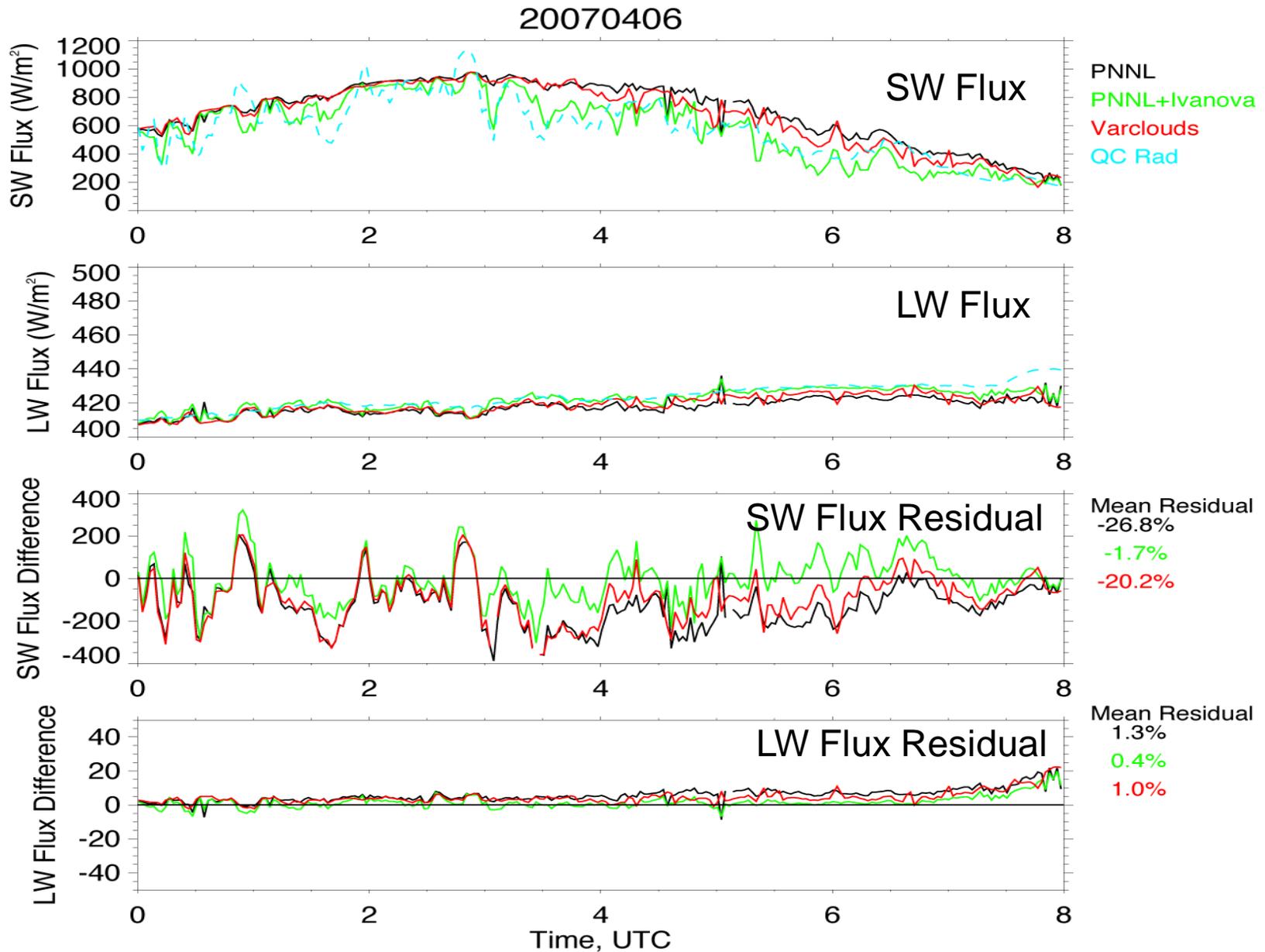
Normalized Lidar Backscatter



Anvil Case - Microphysics



Anvil Case – Flux Residuals



Anvil Case – Surface Flux Residuals

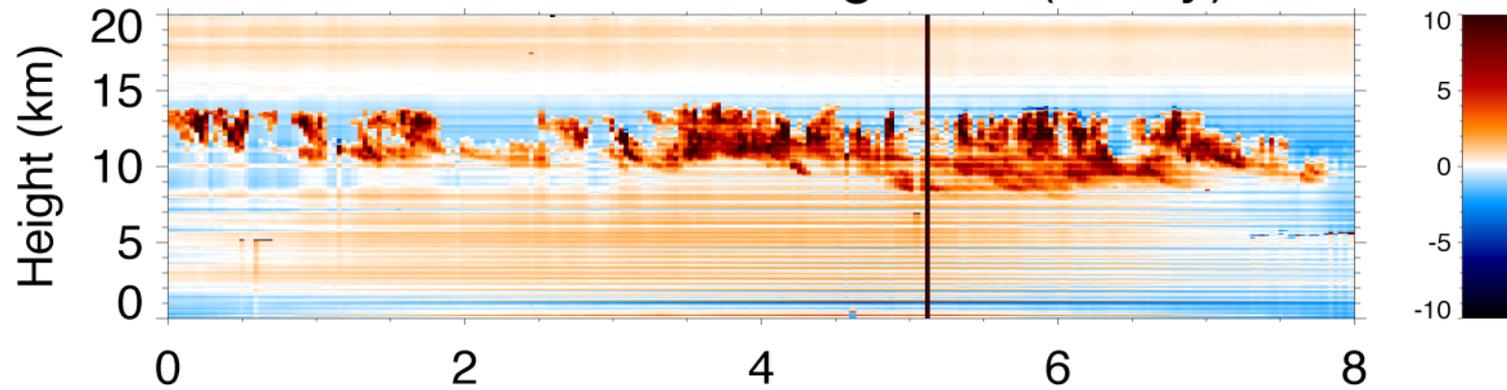
Shortwave

Time Periods	PNNL Retrieval	PNNL+Ivanova	Varclouds
0000-0300 UTC	-15.0%	-5.3%	-14.7%
0300-0730 UTC	-35.1%	0.8%	-24.4%

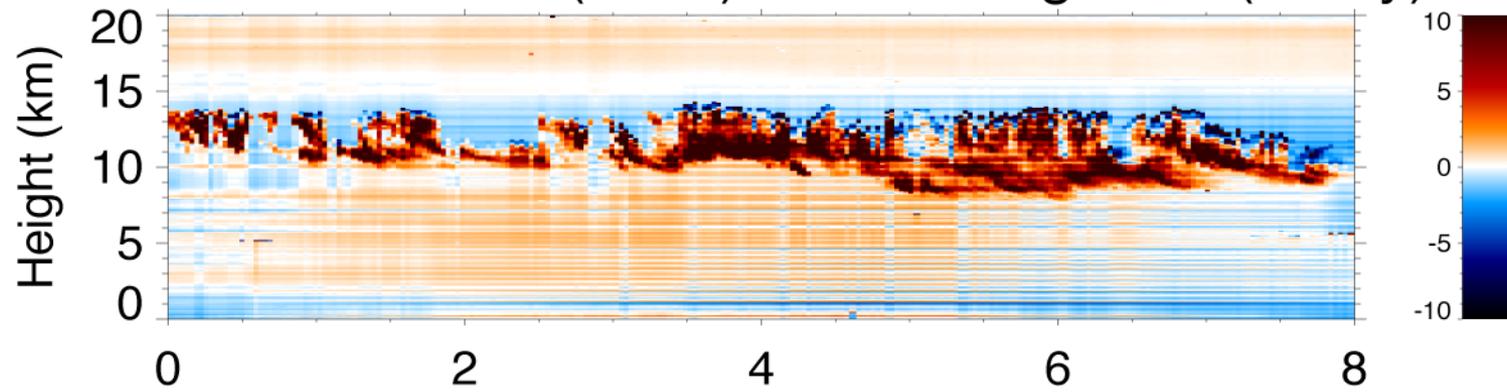
Longwave

Time Periods	PNNL Retrieval	PNNL+Ivanova	Varclouds
0000-0300 UTC	0.7%	0.2%	0.7%
0300-0730 UTC	1.5%	0.3%	1.0%

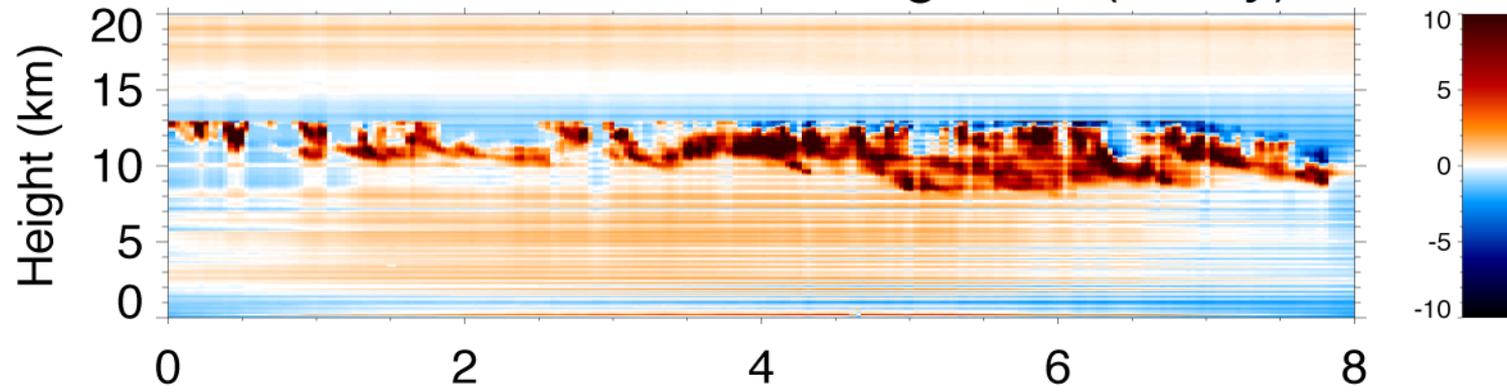
Retrieved Net Heating Rate (K/day)



Ivanova et al. (2001) Net Heating Rate (K/day)



Varclouds Net Heating Rate (K/day)

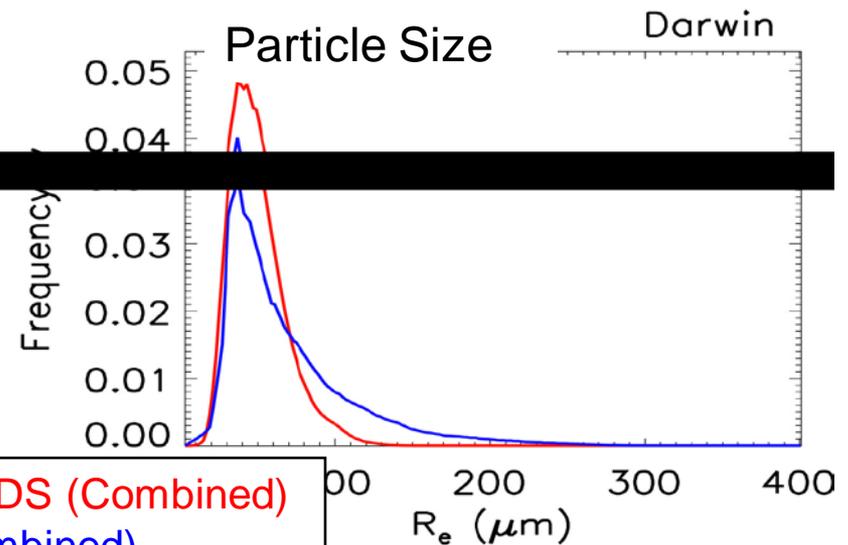
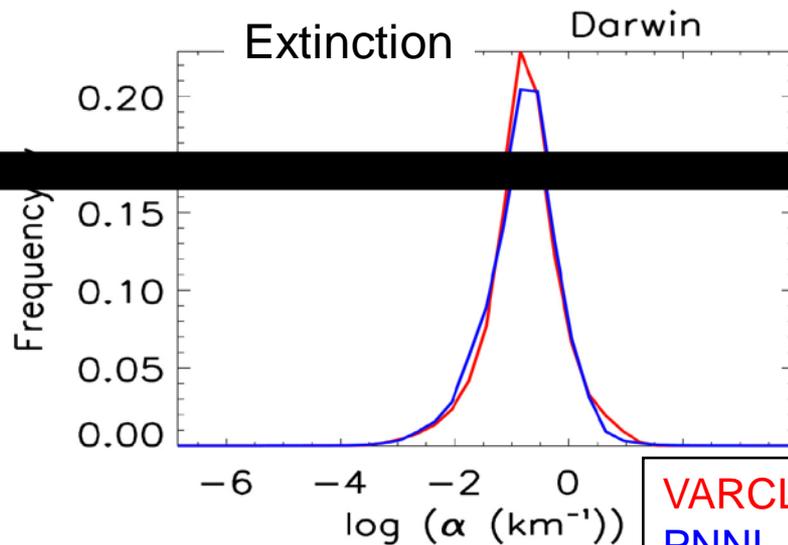
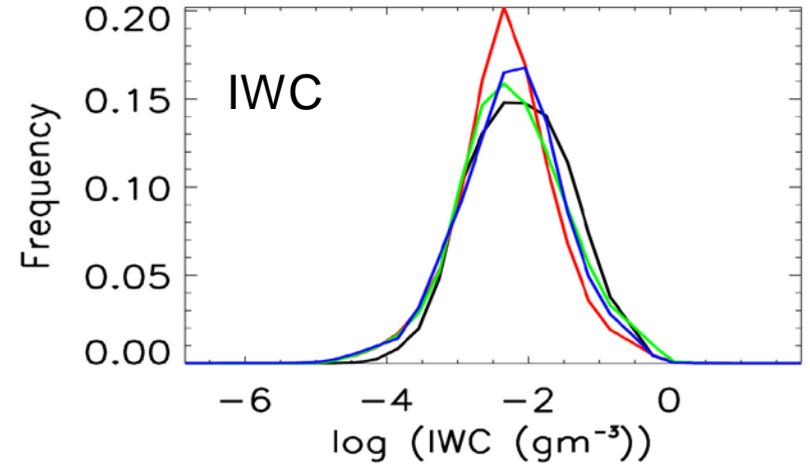
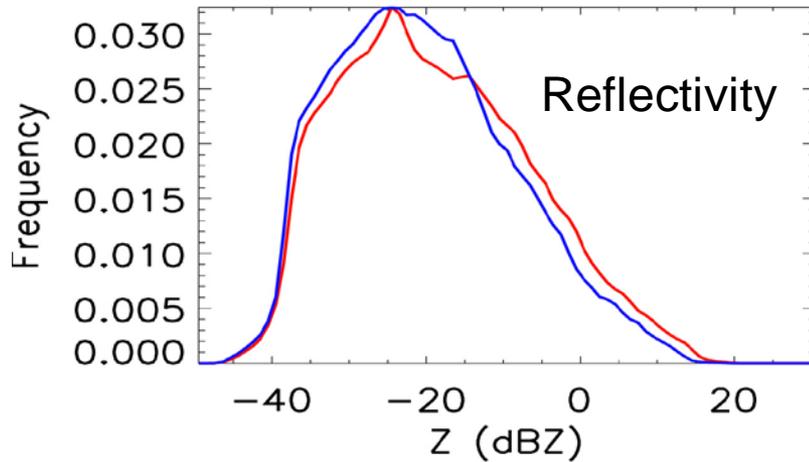


Extended Time Series Comparisons

Courtesy Alain Protat

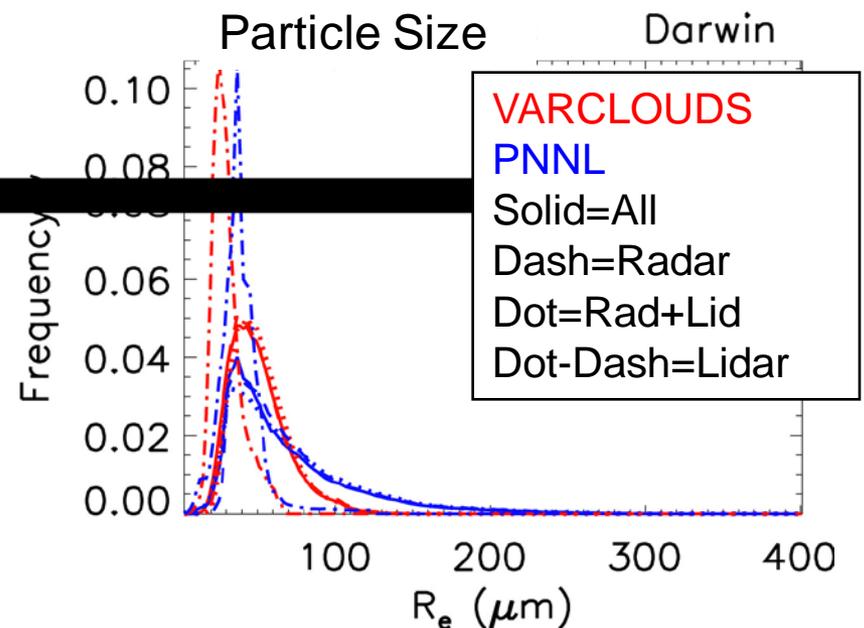
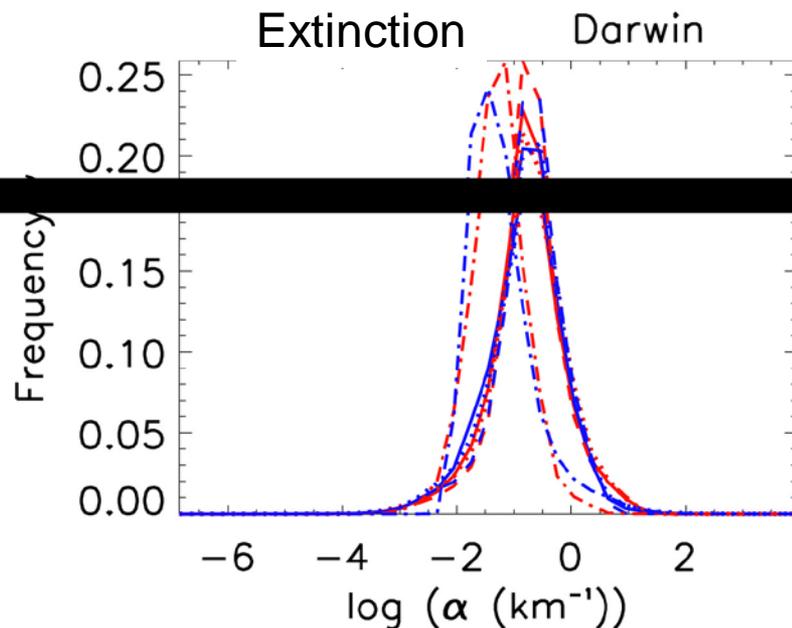
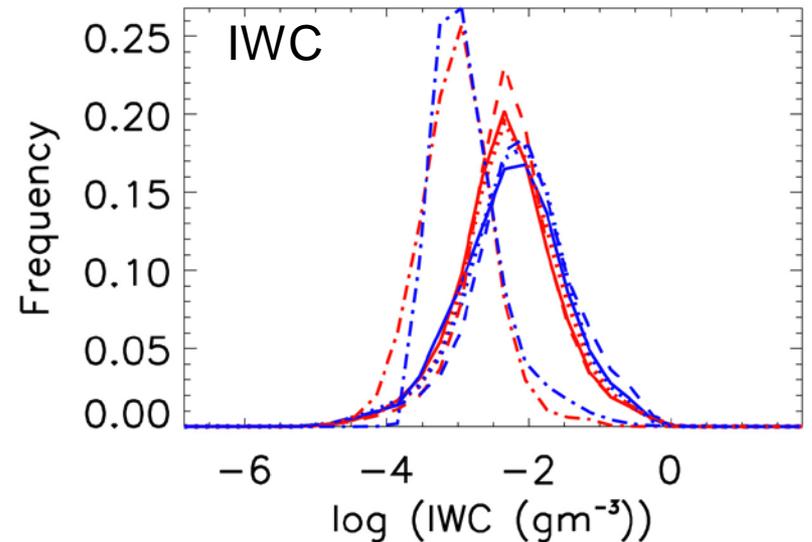
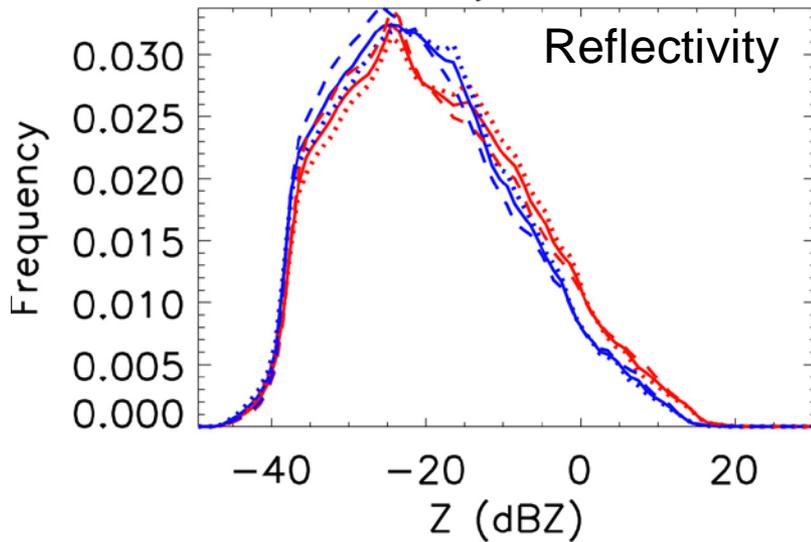
- ▶ Dec 2006 – April 2007
 - Radar sensitivity improved after Jan 2006 lightning strike
- ▶ Data sets screened to capture same clouds
 - Different cloud and phase masks used
 - Different usage of radar and radar+lidar
- ▶ Divide into retrieval types
 - Lidar only
 - Radar only
 - Radar + Lidar

Frequency Distributions of Microphysical Properties – All Types Combined

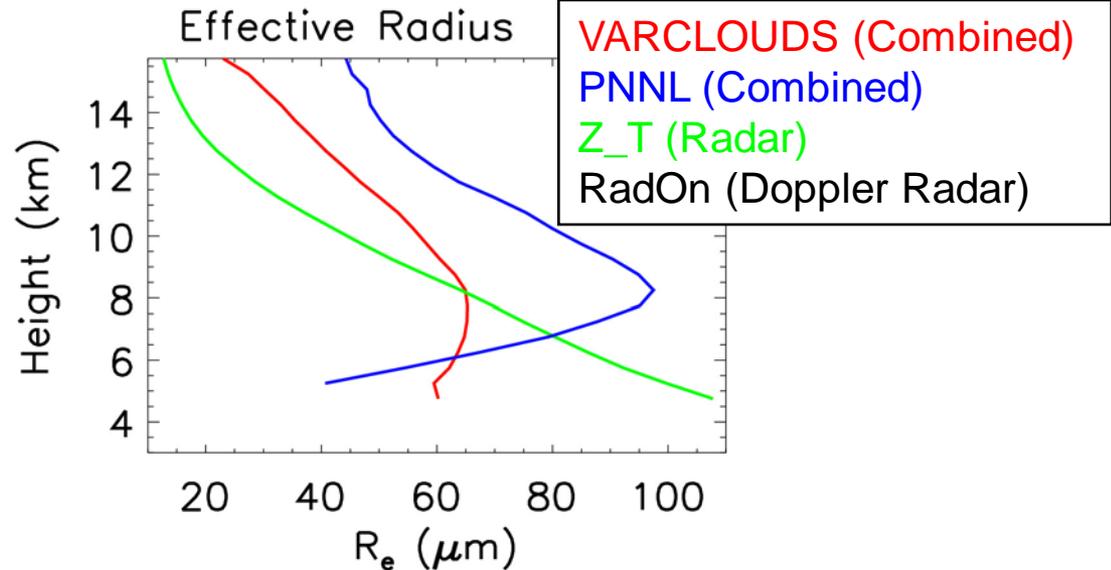
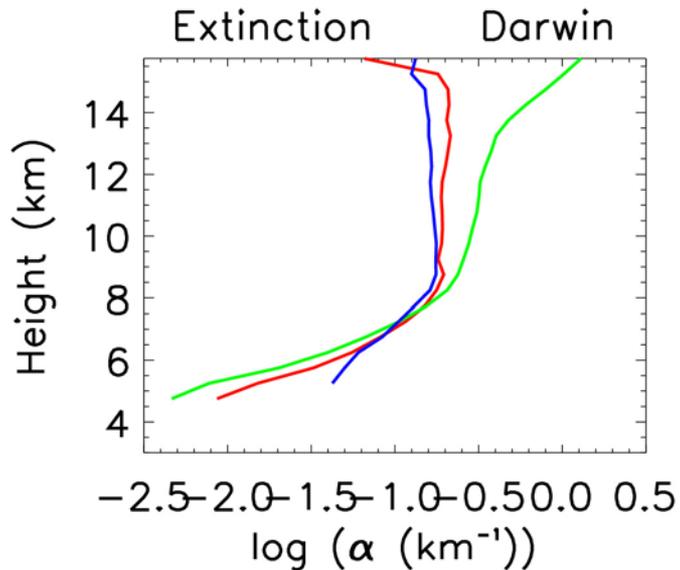
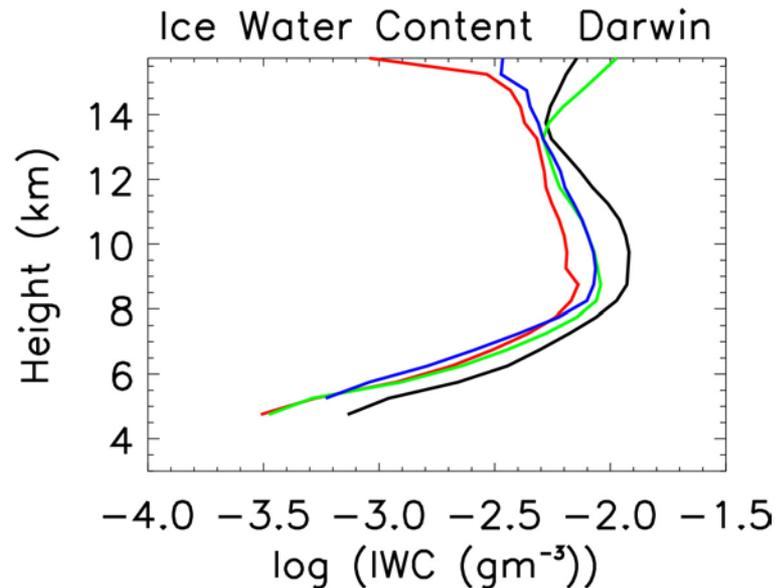
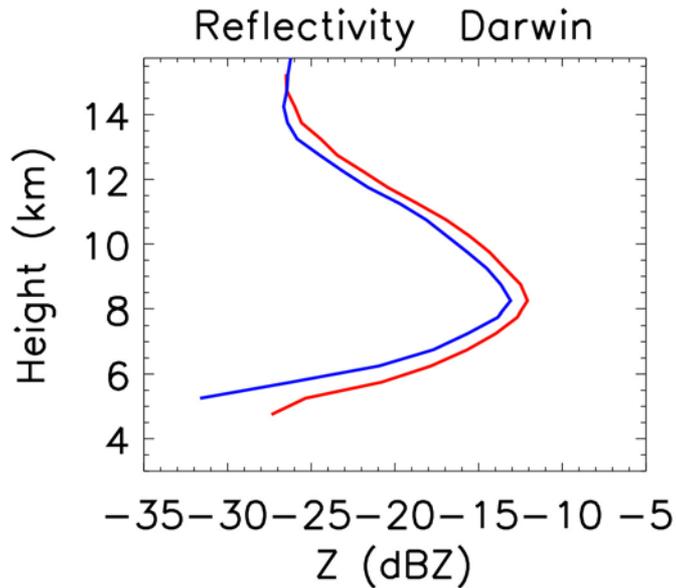


VARCLOUDS (Combined)
PNNL (Combined)
Z_T (Radar)
RadOn (Doppler Radar)

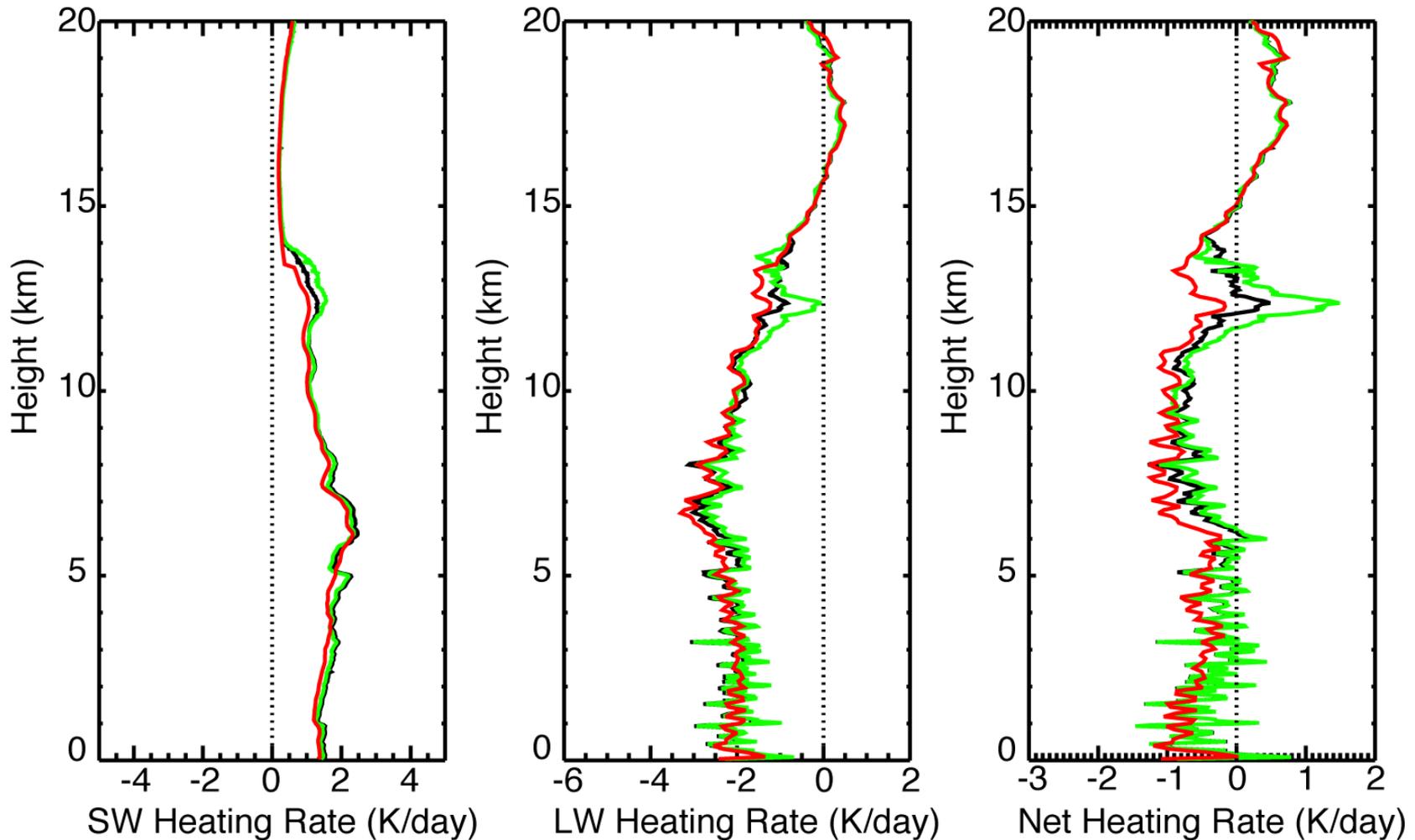
Frequency Distributions – By Retrieval Type



Vertical Profiles – All Retrieval Types



Heating Rate Profiles



VARCLOUDS
PNNL
PNNL+Ivanova

Path Forward

Apply Radar+Lidar Cloud Mask & Phase Determination

Thin clouds: Apply Lidar Only Retrieval; Requires good extinction.

Medium Thick Clouds: Apply radar lidar algorithm when complete overlap is achieved

Thick Ice Clouds: Apply Radar Only technique; need to evaluate Z-V algorithms

Passive IR and Visible

Mixed Phase

Boundary Layer

Microbase: middle level and boundary layer clouds

Full Retrieval: Precipitation Radar Retrievals During Precip. Times

Summary/Future Plans

▶ Ice Cloud Retrievals

- Ice crystal shape (aggregates vs. hexagonal crystals)
- Midlatitude vs. Tropical particle size distributions
- “Radiative” effective size vs. “physical” effective size
- Evaluate Z-Velocity algorithms or “bimodal” algorithms (Mace, Matrosov, Protat, others?); better characterize thick anvils

▶ Work towards a “Seamless” Combined Retrieval

- How can we bring in passive retrievals?
- Mixed phase and boundary layer clouds
- Precipitation radar

▶ Common framework for vetting algorithms

- BBHRP