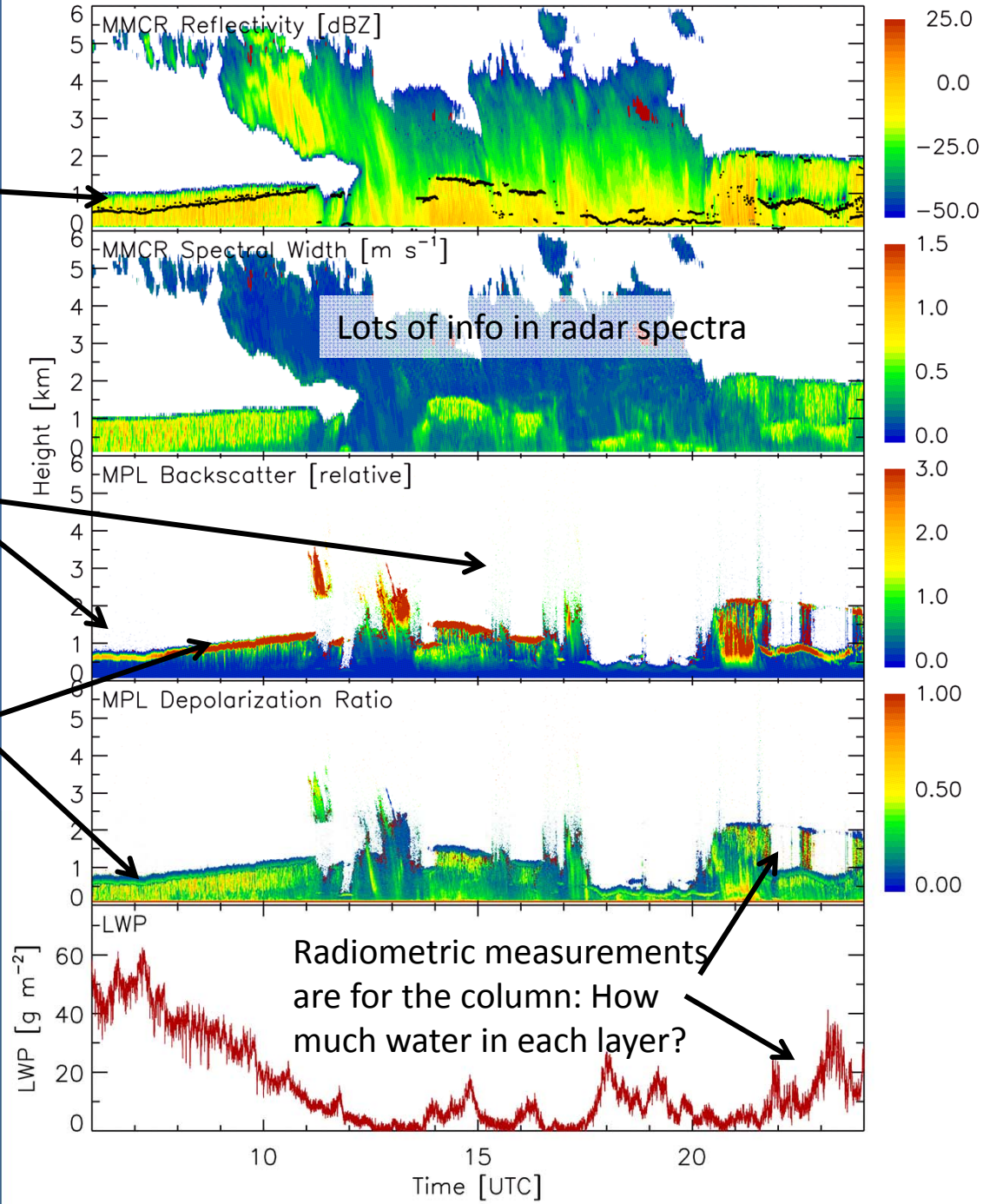
MIXED-PHASE CLOUD RETRIEVALS

Matthew Shupe
QUICR Breakout
ASR Fall 2011

Radar responds predominantly to ice

Lidar attenuation

Lidar responds predominantly to liquid



ARM-supported paper in BAMS outlines the mixed-phase retrieval situation

A FOCUS ON MIXED-PHASE CLOUDS

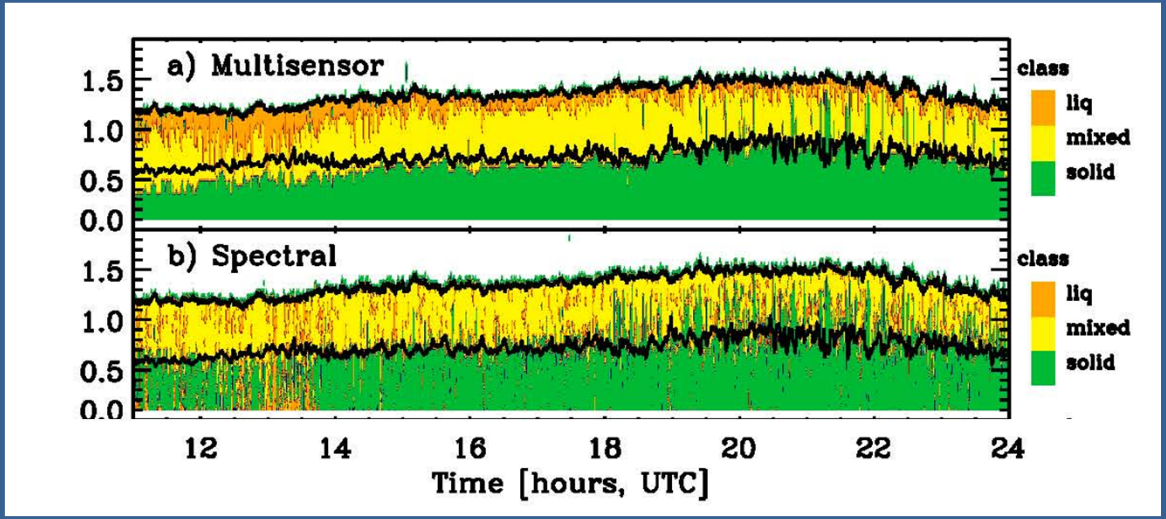
The Status of Ground-Based Observational Methods

BY MATTHEW D. SHUPE, JOHN S. DANIEL, GIJS DE BOER, EDWIN W. ELORANTA, PAVLOS KOLLIAS, CHARLES N. LONG, EDWARD P. LUKE, DAVID D. TURNER, AND JOHANNES VERLINDE

Ground-based observational methods provide key insights into mixed-phase cloud macrophysical, microphysical, radiative, and dynamical properties, although significant deficiencies still exist.

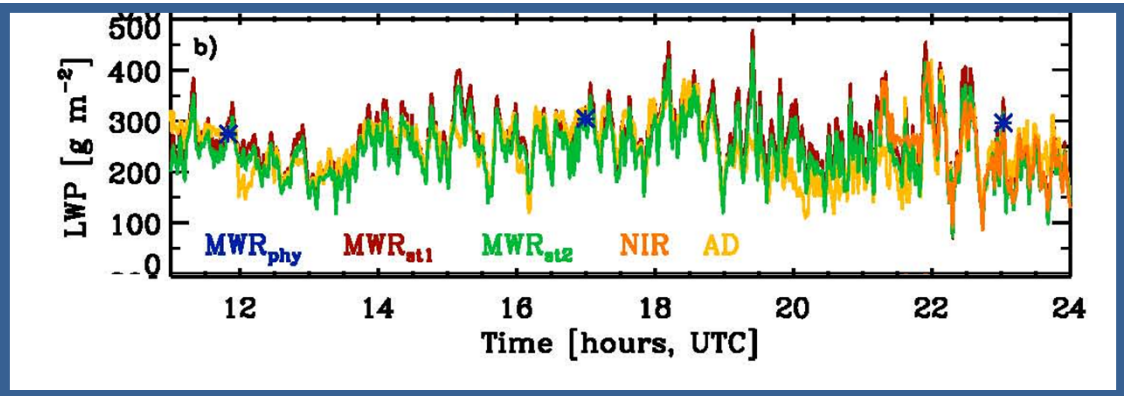
Current Retrievals - Phase Identification/classification

Approach (parameter)	Shortcomings/Comments
Multisensor	Little external validation, location-dependent?
Radar Doppler spectra	Little validation, needs development



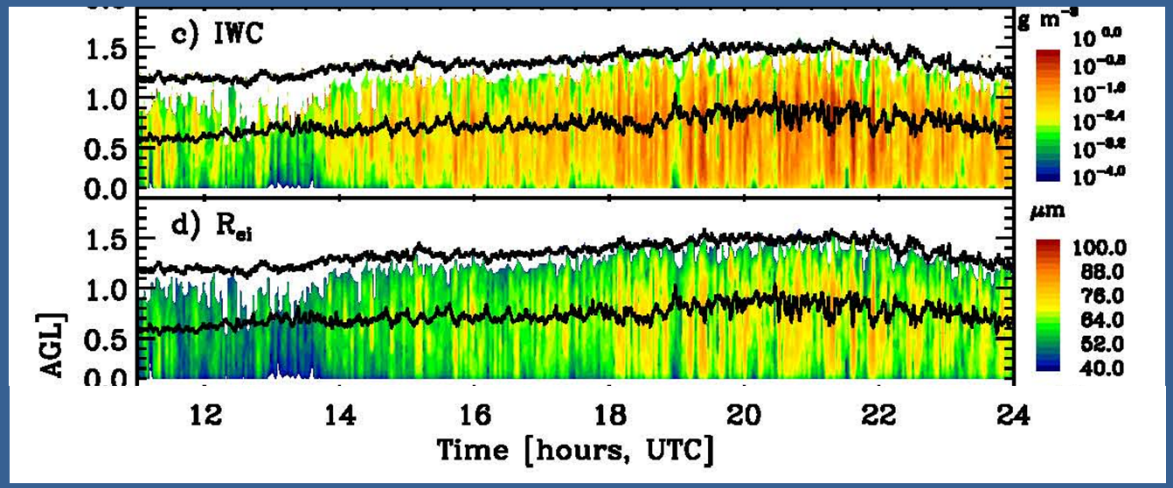
Current Retrievals - Cloud liquid properties

Approach (parameter)	Shortcomings/Comments
MWR (LWP)	High uncertainty at low values (improved with higher freq.)
AERI (LWP)	Only for optically thin
MWR+AERI (LWP)	Current best combination
Near-IR (LWP)	Requires sunlight
Adiabatic (LWC)	Unknown adiabadicity
Radar Doppler spectra (LWC)	Difficult to apply generally, small signal pulled from a large signal
AERI (Re)	Only for optically thin, column-average value
Doppler spectra + MWR/AERI (Nd or LWC)	Undeveloped



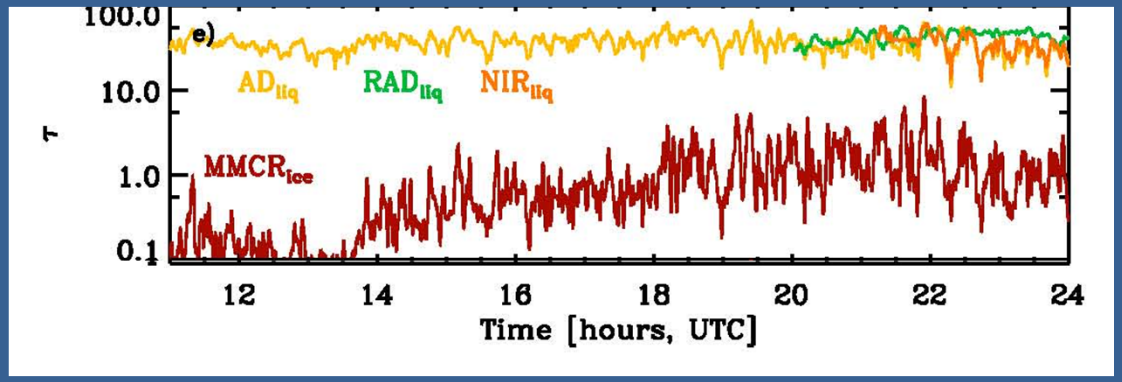
Current Retrievals - Cloud ice properties

Approach (parameter)	Shortcomings/Comments
Radar Z, VZ (IWC, Re)	Significant assumptions
Radar-lidar (IWC, Re)	Attenuation limited
AERI (Re)	Only for optically thin, column average value
Near-IR (IWP)	Requires sunlight
Microwave (IWP)	Undeveloped
Scanning polarimetric radar (habit)	Still to be demonstrated generally
??? (Ni)	



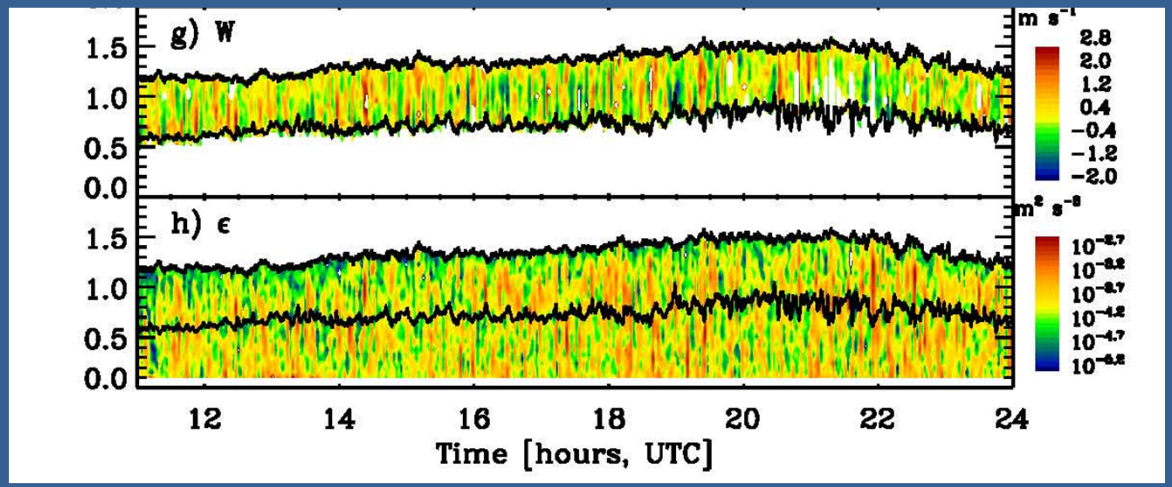
Current Retrievals - Cloud radiative properties

Approach (parameter)	Shortcomings/Comments
SW broadband (tau)	Requires sunlight
AERI (tau)	Only for optically thin
Near-IR (tau)	Requires sunlight
Lidar (tau, extinction)	Attenuation limited
Radar (tau, extinction)	Ice only



Current Retrievals - Cloud dynamical properties

Approach (parameter)	Shortcomings/Comments
Radar Doppler spectra (W)	Applicable only in liquid cloud
Radar moments (ε)	Not yet evaluated fully
Doppler lidar (W, ε)	Attenuation limited, mostly below cloud
Radar wind profiler (W)	Long time average, low resolution



What have we learned about mixed-phase clouds from ground-based sensors?

- **Basic structure** (Zawadzki et al. 2001; Hogan et al. 2003a; Wang et al. 2004; Turner 2005; Zuidema et al. 2005; Shupe et al. 2001; 2004; 2006; 2008; 2011; Verlinde et al. 2007)
- **Frequency of occurrence** (Hogan et al. 2003b; Shupe et al. 2006; de Boer et al. 2009; Shupe 2011)
- **Microphysical properties** (Hogan et al. 2003a; Turner et al. 2003; Wang et al. 2004; Shupe et al. 2004; 2006; 2008; 2011; Turner 2005; Zuidema et al. 2005; Daniel et al. 2006; Verlinde et al. 2007)
- **Microphysical processes** (Morrison et al. 2005; Shupe et al. 2008; de Boer et al. 2011)
- **Dynamical processes** (Hogan et al. 2002; Shupe et al. 2006;2008)

Biggest Challenges in Mixed-Phase Retrievals

Liquid water profile

Liquid R_e in thick clouds

Liquid droplet concentration

Extinction profile

Ice concentration

Ice habit

Uncertainties for most retrievals