Cloud Data Product Priorities of the ARM Cloud Modeling Working Group

Stephen Klein
Lawrence Livermore National Laboratory

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What do cloud modelers want?

- I discussed the use of cloud property retrievals by the cloud modeling working group at the November 2007 joint meeting of the Cloud Properties and Cloud Modeling Working Groups
- The answers to this question haven't changed much
- There has been steady progress:
  - New vertical velocity datasets are being used
  - Climate Modeling Best Estimate data facilitates use of basic ARM data
  - The BBHRP project may be an appropriate vehicle for modelers to assess uncertainty
  - Aircraft data packaging has been very successful

What has changed?

- The potential acquisition of new instruments (ARRA) with new capabilities (such as scanning radars) forces us to confirm that the priorities of those performing data retrievals and creating Value Added Products are working on the items of greatest priority
- As far as I know, there is no extra money for more retrievals or science funding to analyze all of the new data. The Cloud Modeling Working Group has recently emphasized the need for increase funding to the ARM management

What are current CMWG priorities?

- What are the quantitative and qualitative uncertainties in cloud property retrievals?
  - Will the CPWG make recommendations on which retrievals to use and in which circumstances?
  - Will modelers be stuck with the range of retrievals as the uncertainty estimate?
- What the cloud and precipitation properties of precipitating clouds? (such as LWP+RWP during precipitation)

What are current CMWG priorities?

- What are the cloud-scale dynamics and how do these relate to other cloud properties?
- We don't know what we will get from scanning cloud instruments.
  - Our intuition is that there is a lot more that can be extracted from cloud property retrievals from vertically pointing instruments – so keep algorithm development going
  - We have consistently recommended to the program that higher priority be placed on the retrievals from vertically pointing instruments than from scanning instruments

Specific data products (examples)

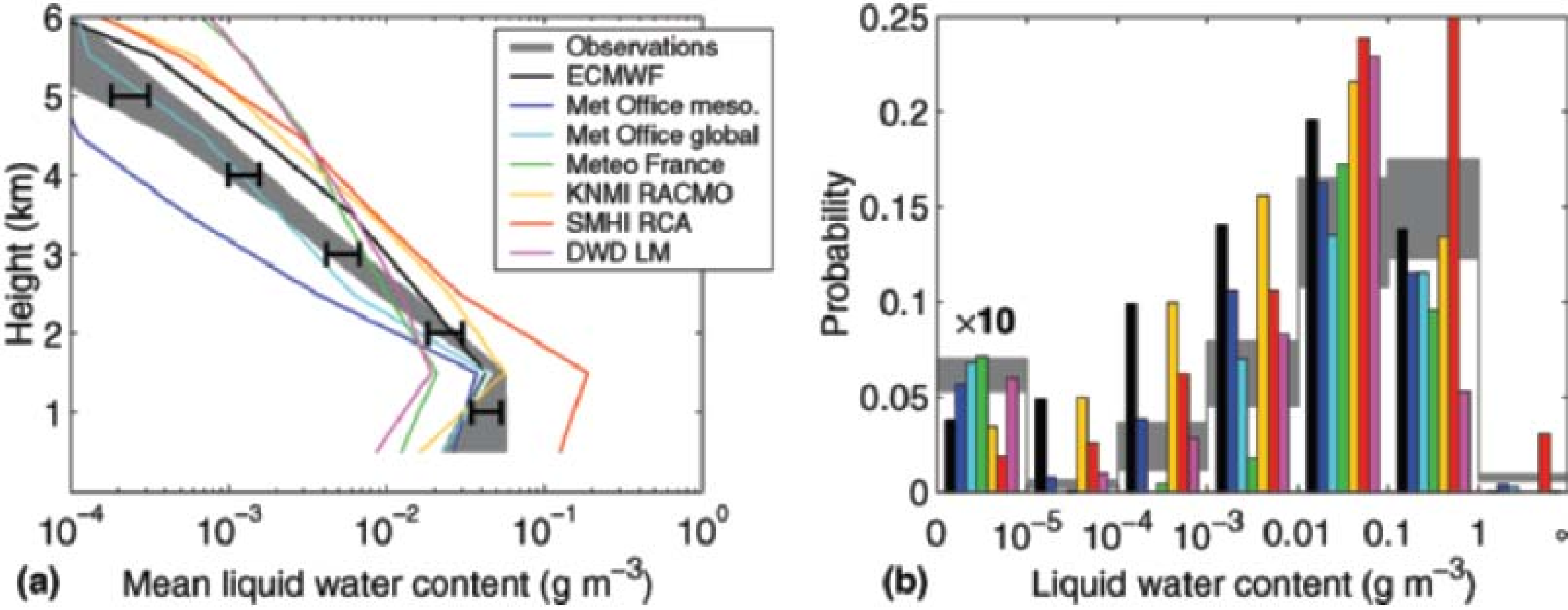
- 2D (z,t) retrievals of double moment microphysics (mass, number, size) in cloud and precipitation particle ranges (wind components too)
- 4D (x,y,z,t) retrievals of hydrometeor occurrence, mass mixing ratios, 3D winds, temperature, and water vapor
- More large-scale variational analysis forcing datasets for AMF and remote sites → contingent on a good scanning precipitation radar

November 2007 Talk to the Joint Meeting of the Cloud Modeling and Cloud Properties Working Groups

What do cloud modelers want?

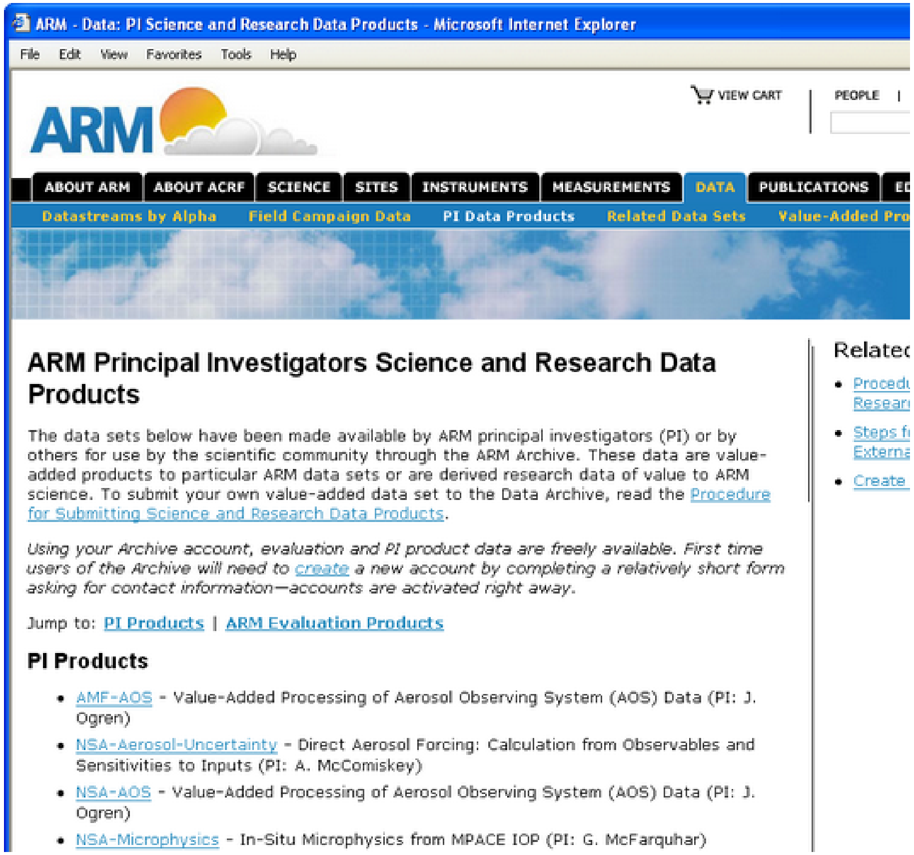
- There is no single answer to this…the diversity of cloud types and models governs this
- Quantities of interest:
  - cloud boundaries
  - cloud particle sizes
  - cloud optical depth
  - cloud water contents
  - integrated water contents
- Need more continuous (at all ARM sites, all the time) vs. IOP (quite good at)
- Why continuous?
  - Statistical comparison to models (to alleviate the sampling issue)
  - Look for relationships in the data between meteorology, aerosols, and cloud properties

CloudNet (Illingworth et al. 2007)



Recent progress

- PI datasets of multi-year continuous cloud microphysics (Microbase + Mace) are now released
- Facilitates wide use of cloud property data
- This is quite an increase in cloud property datasets – in general we have been limited to ARSCL and LWP



Which cloud property data set?

Table 2. Algorithms and participants in the first CLOWD intercomparison.

Type	Key name	Contributor	Comments and reference
MICROWAVE	ARM Stat	N/a	MWR LWP, standard ARM product, uses monthly retrieval coefficients determined from Liebe and Layton (1987) (dry air and water vapor) and Grant et al. (1957) (liquid water) absorption model (Liljegren and Lesht 1996)
	Clough Phys	Clough, Cady-Pereira, and Turner	MWR LWP, physical iterative method using optimal estimation, absorption model is monoRTM (Marchand et al. 2003; Turner et al. 2004)
	Lilj Stat2	Liljegren and Turner	MWR LWP, "variable coefficient" method where retrieval coefficients are predicted from surface meteorological observations; absorption model is Rosenkranz (1998) (Liljegren et al. 2001; Turner et al. 2004)
	Lin Phys	Lin	MWR LWP, physical iterative method using the absorption model Liebe and Layton (1987) for dry air and water vapor and Ray (1972) for liquid water (Lin et al. 2001)
CLOUD RADAR	MICROBASE	Miller and Johnson	MMCR LWC and r_e profiles, using the Liao and Sassen (1994) parameterization of Z–LWC and scaling the LWC profile to match the MWR's LWP (Lilj Stat2) (Miller et al. 2003)
	aMMCR	Austin	MMCR-only retrievals of LWC and r_e profiles for nondrizzling clouds, assuming a column-constant value for the droplet number density [an improved algorithm derived from Austin and Stephens (2001)]
	aMMCRvod	Austin	Retrieval of LWC and r_e profiles for nondrizzling clouds, assuming a column-constant value for the droplet number density, from MMCR reflectivities and MFRSR-derived visible optical depths [an improved algorithm derived from Austin and Stephens (2001)]
	mMMCR	Matrosov	MMCR-only retrievals of LWC and r_e profiles, where drizzle regions are identified by simple thresholds (Matrosov et al. 2004)
VISIBLE	MFRSR	Min	MFRSR-derived τ, and when MWR LWP (ARM Stat) is included, r_e is also retrieved and more accurate retrievals of τ are realized (Min and Harrison (1996)
	NFOV	Marshak and Chiu	Retrievals of τ from the narrow field-of-view zenith radiometer (870 nm) [a one-channel approach similar to Marshak et al. (2004); Chiu et al. (2006)]
	Not shown*	Long	Broadband shortwave retrievals of τ using an empirical relationship derived from Min and Harrison (1996), effective radius is assumed to be 10 μm (Barnard and Long 2004)
INFRARED	MIXCRA v2	Turner	AERI-derived τ and r_e, and hence LWP, using radiance observations from 8 to 13 μm (Turner 2005)
	MIXCRA v3	Turner	AERI-derived τ and r_e, and hence LWP, using radiance observations from 8–13 to 3–5 μm (Turner and Holz 2005)
SATELLITE	VISST	Minnis and Khaiyer	*GOES-8* visible infrared solar split-window technique applied to 10-km-diameter footprint centered on the SGP site, providing τ, r_e, and LWP (Minnis et al. 1995)
	Not shown*	Minnis	*Terra* Moderate Resolution Imaging Spectroradiometer (MODIS)-retrieved cloud properties (Minnis et al. 1995)
LIDAR	Lidar–radar	McFarlane	Lidar–radar retrievals of τ and r_e profiles, for cloud elements seen simultaneously by the lidar (MPL) and radar (Donovan and van Lammeren 2001)
	Not shown*	Wang	Raman lidar retrievals of τ
	Not shown*	Flynn	MPL retrievals of τ

Turner et al. (2007)

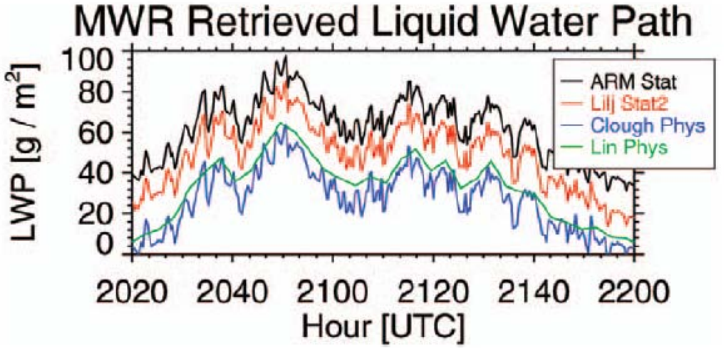
Table 1. Algorithms included in the high clouds retrieval intercomparison.

	Short name	Retrieval type	Reference/participant
Provides vertical profiles of microphysics	DV-LR-ros	Lidar–radar assuming bullet rosette crystals	Donnovan and van Lammeren (2001)/McFarlane
	DV-LR-col	Lidar–radar assuming hexagonal column crystals	Donovan and van Lammeren (2001)/McFarlane
	ZW-LR	Lidar–radar	Wang and Sassen (2002)/Wang
	MAT-ZV	Radar reflectivity-Doppler velocity	Matrosov et al. (2002)/ Matrosov
	MACE-ZV	Radar reflectivity-Doppler velocity	Mace et al. (2002)/Mace
	MAT-EMP	Empirical	Matrosov et al. (2003)/ Matrosov
	KS-EMP	Empirical	Sassen (1987)/Sassen
	ILL-EMP	Empirical	Liu and Illingworth (2000)/ Comstock
Provides cloud layer-averaged microphysics	Raman	Lidar only	Beer's law/Comstock
	COM-lidar	Lidar only	Comstock and Sassen (2001)/ Comstock
	MAT-ZIR	Radar reflectivity–IR radiance	Matrosov et al. (1992); Matrosov (1999)/Matrosov
	MACE-ZIR	Radar reflectivity–IR radiance	Mace et al. (1998)/Mace
	DT-AERI-hex	Spectral IR assuming hexagonal column crystals	Turner (2005)/Turner
	DT-AERI-sph	Spectral IR assuming spheres	Turner (2005)/Turner
	DES-AERI	Spectral IR	DeSlover et al. (1999)/ DeSlover
	MD-AERI	Spectral IR	Mitchell et al. (2006)/Mitchell and d'Entremont

Comstock et al. (2007)

Which cloud property data set?

- Comstock et al. (2007) shows that for an intercomparison of retrievals for a thin cirrus case that the ice water path varied from 3.5 to 31.3 g m^{-2}



Turner et al. (2007)

- These articles are careful not to say which one is best – so what is a modeler to do?
- From the modeler's perspective, it is natural to treat the spread of results as a measure of uncertainty
- We will want to use multiple retrieval datasets to compare to models (PI2BBHRP + CMWG efforts have begun)
- Are the retrievals good enough to constrain models?
- Does the CPWG want to tackle the question of which cloud property datasets to recommend?

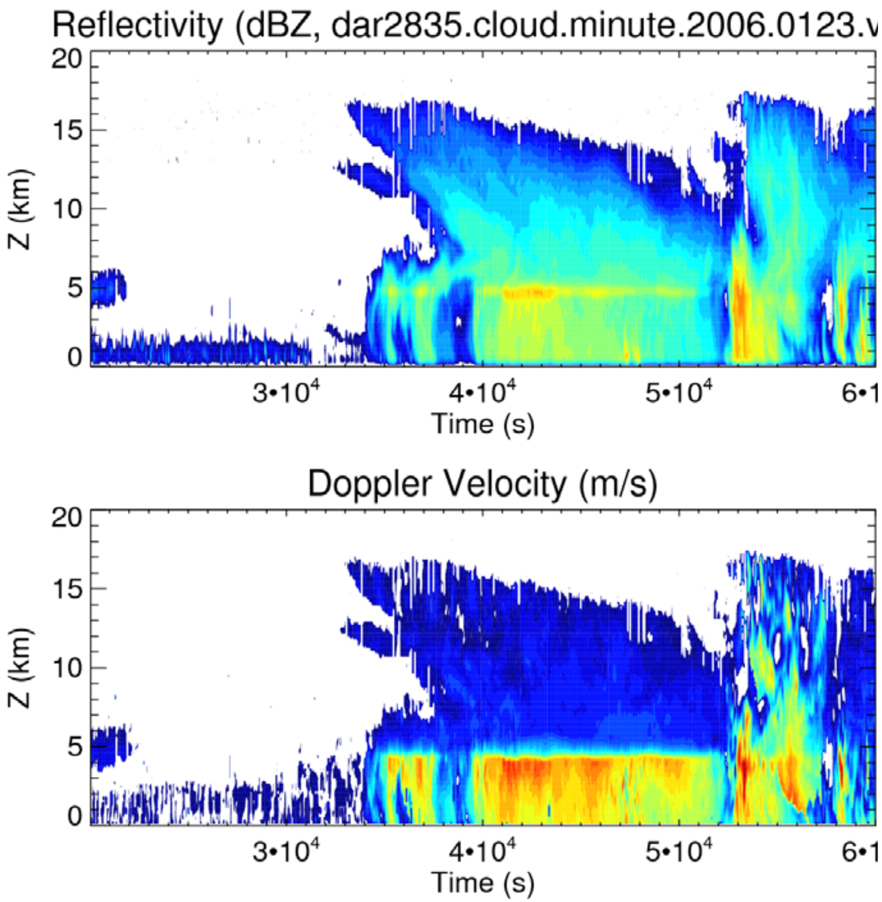
Informal uncertainty estimates

- LWP: greater of 10% or 30 g m^{-2} (if non-precipitating)
- IWC, LWC ~ factor of 2.
- Limitations: Avoid precipitation periods
  – This eliminates a large percentage of the liquid water containing clouds
  – How much precipitation before the data is not reliable?
  – Are retrievals of ice properties above liquid water precipitating clouds still usable?
  – Can we ever get around this limitation?
- Proposition: The CPWG provide a short (1-3 page) document to modelers summarizing the recommend cloud property datasets to use, what their limitations are, and what their accuracy and uncertainties are.

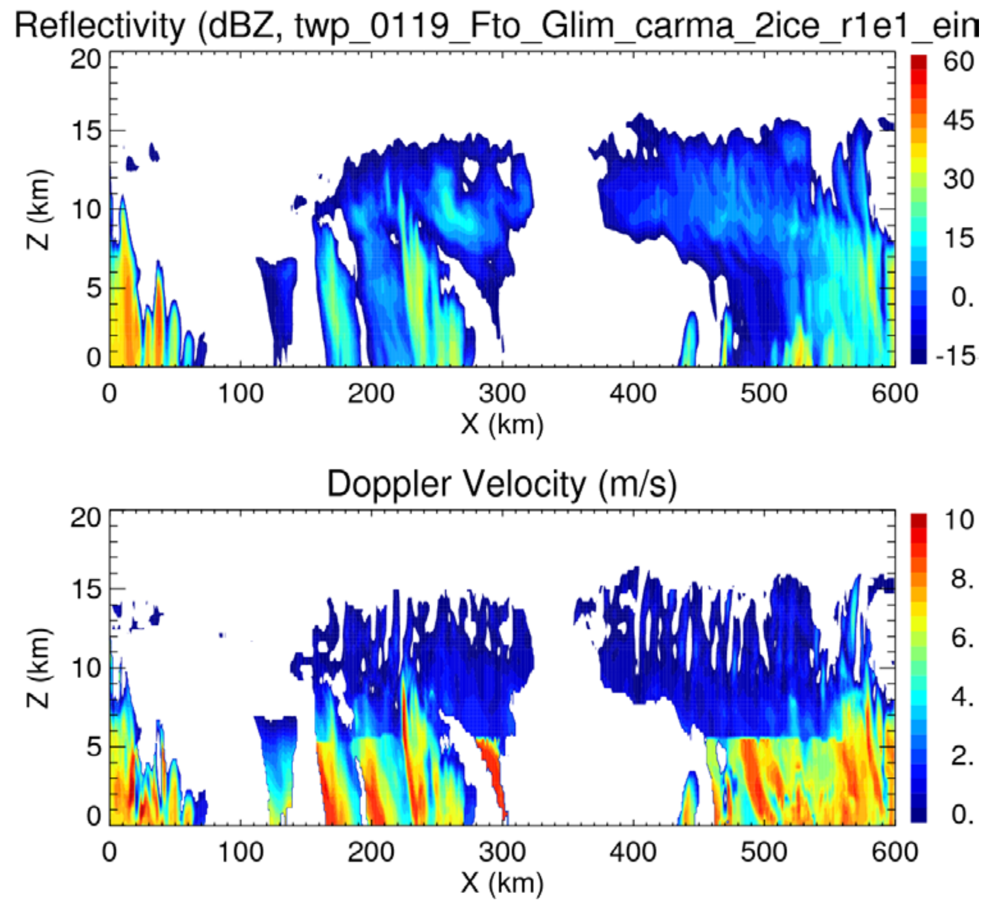
Simulators

- Tools to convert model data to synthetic observations such as Tb and dBZ.
- Doesn't obviate the need for cloud property retrievals
- Useful in situations where retrievals are very difficult (e.g. precipitating clouds)
- This is an area of cooperation between CPWG and CMWG
- Ann Fridlind has suggested that a library of simulators to be made available through ARM which have the recommended settings for ARM instruments (cloud radar/lidar, etc.)

Simulator example: TWP-ICE



Chris Williams S-Band Radar



Ann Fridlind CRM Simulation

What new cloud properties?

- Precipitating cloud properties – Can we get anything from them? How do we separate cloud water from rain water?
- Vertical velocity and air motions at the cloud scale in general
  - Vertical air motions are central for so many problems and very useful for diagnosing CRMs
  - This seems possible at least for non-precipitating clouds some of the time?
- Are 3-dimensional or scanning radars necessary for this or can you get this out of the radar spectra?
- CMWG last year said that it is a higher priority to fully realize the large investment ARM has put into retrievals from the vertically pointing instruments
- CMWG said it favored a gradual exploration of the new technology and its capabilities