The Operational Ground-Based Retrieval Evaluation for Clouds (OGRE-CLOUDS) Framework

BROOKHAVEN NATIONAL LABORATORY
ARM CLIMATE RESEARCH FACILITY
Meng Wang[1], Michael P. Jensen[1], Pavlos Kollias[1,2]
[1]Brookhaven National Laboratory [2] Stony Brook University
Corresponding author: Meng Wang, mwang@bnl.gov, (631) 344-2383

ABSTRACT

The OGRE-CLOUDS framework project is a new effort within ARM to: 1) produce vertically resolved cloud and precipitation properties (with accompanying uncertainties) in the column above an ARM site under all cloud conditions with 2) the ability to implement new, conditional (i.e., applicable under specified cloud conditions) retrieval techniques and 3) a diagnostic package for comparison and evaluation of the new retrieval.

The development activities will include:1) The use of an improved version of the MICROBASE algorithm as the underlying background for the new framework. The current MICROBASE algorithm will be updated to fully integrate it into the ARM Data Integrator (ADI) framework, include regular unit testing, quantification of uncertainties, and improved modularity to facilitate testing of new algorithms, 2) implementation and testing of state-of-the art retrieval algorithms for ice clouds and drizzling clouds and 3) a pathway towards four diagnostic components including radiative closure using the ARM BBHRP framework, comparison to existing retrievals and in situ observations, and forward modeling of independent instrument observations.

1. MOTIVATION

- Cloud radiative effects are defined by their microphysical properties.
- Long-term estimate of cloud microphysical properties combined with field and model studies provide an opportunity to improve process understanding.
- Need for development of an algorithm framework that is publicly available and version controlled.
- Provide a resource to the community for developing and testing new
- retrieval algorithms.

2. PROJECT WORKFLOW

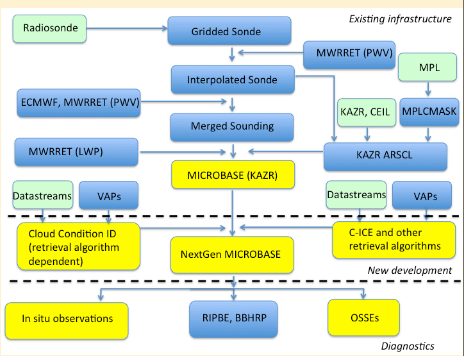


***Figure 1 The OGRE-CLOUDS** framework split generally into "existing infrastructure", "new development", and "diagnostics. Green boxes represent ARM instrument datastreams, blue boxes represent ARM value-added products and yellow boxes represent new development activities. VAPs included in the framework are: MicroWave Radiometer Retrieval (MWRRET), Active Remote Sensing of CLouds (ARSCL), Radiatively Important Parameters Best Estimate (RIPBE), Broadband Radiative Hearting Rate Profile (BBHRP).*

OGRE-CLOUDS development activity includes:

- The use of an improved version of the MICROBASE algorithm as the underlying background for the new framework. The current MICROBASE algorithm will be updated to fully integrate it into the ARM Data Integrator (ADI) framework, include regular unit testing, quantification of uncertainties (incorporating the work of Zhao et al. 2013) and improved modularity to facilitate testing of new algorithms.

- Implementation and testing of state-of-the art retrieval algorithms for ice clouds and drizzling clouds. This implementation will include the need for a "Cloud Condition Identification" algorithm, which is retrieval dependent, for quantitatively defining the conditions under which a new retrieval is applicable.

- A pathway towards four diagnostic components including radiative closure using the ARM BBHRP framework, comparison to existing retrievals and in situ observations, and forward modeling of independent instrument observations.

- The new framework will be developed within the construct of the ADI, hosted in GitHub, and made available as a resource for the community to facilitate developing and testing new retrieval algorithms. Note that this integration with ADI will require OGRE-CLOUDS users to have access to ADI, either via the ARM Data Cluster or on their own work stations.

3. IMPROVEMENTS TO MICROBASE

The Microbase algorithm (Dunn et al. 2011) is simple, but robust and produces cloud properties for **all time-steps** where the input observations are available. Not unexpectedly, the algorithm does not perform equally well in all cloud conditions.

Temperature Range	Water Content [gm-3]	Cloud Particle Effective Radius [microns]
$T \geq 0^oC$ [Liquid]	$LWC = (N_o Z_e/3.6)^{1/1.8}$ Scaled by MWR LWP (Liao and Sassen 1994)	$R_{el}=1.358[3LWC/4\pi\rho\exp(9\sigma^2/2)]^{1/3}$ (Frisch et al. 1995)
$-16 < T < 0^oC$ [Mixed]	Ze(ice)=(-TZe)/16, Ze(liquid)=Ze(total)-Ze(ice)	
$T \leq -16^oC$ [Ice]	$IWC=0.097Zi^{0.59}$ Liu and Illingworth (2000)	$r_{ei}= (75.3 + 0.589T)/2$ Ivanova et al. (2001)

***Table 1 Summary of the MICROBASE algorithm**. T = Dry bulb temperature from the Merged Sounding VAP, N_o=100 cm^{-3}, Ze = equivalent radar reflectivity (35 GHz], Zi is the radar reflectivity (35 GHz) assuming the scatterers are ice particles, ρ is the density of water and σ the width of a log-normal distribution and is set to a value of 0.35. In the mixed phase region, the radar reflectivity is partitioned linearly with temperature and the liquid/ice parameterizations are applied.*

The OGRE-CLOUDS framework will use the MICROBASE VAP, with a few improvements, as the background for the testing and evaluation of new cloud retrieval algorithms:

- A perturbation method (Zhao et al. 2013) will be used to estimate **uncertainties** in the microbase output.
- **Unit testing** will be added focusing on the determination of cloud phase, and cloud L/IWC and liquid/ice effective radius.
- The microbase code will be **modularized** to separate the cloud phase determination, and liquid, ice and mixed phase cloud microphysics retrievals.

With these improvements to the MICROBASE code, it will serve as a background cloud microphysics field (available under all cloud conditions) onto which new retrievals may be implemented, inserted and tested for the cloud conditions under which they are applicable. ***In this manner, a continuous cloud microphysical product will always be retained, but with opportunities for improvements under given cloud conditions following a set of diagnostic tests.***

4. DEMONSTRATION ALGORITHMS

Development of the OGRE CLOUDS framework will include the implementation and testing of two new state-of-the-art retrieval algorithms:

***Ice and Snow Retrieval Algorithm* –** The Szyrmer et al. (2012) retrieval is performed over ice/snow layers, with or without riming conditions (based on temperature thresholds), if:
1) temperature lower than -5 degrees C,
2) maximum reflectivity less than +15 dBZ,
3) Doppler velocity in no riming conditions lower than 1.75 ms^{-1},
4) Doppler velocity in riming conditions lower than 2.5 ms^{-1},
5) cloud depth larger than 100 m.
The algorithm applies an optimal estimation (OE) method as described in Rodgers (2000), which is a variational approach that employs Gauss-Newton method and allows a quantitative evaluation of the uncertainty of the retrieved quantities. The forward model within the OE approach maps the retrieved parameters (mean mass-weighted melted equivalent diameter D_m, and ice mass (water) content) to the measurements (radar reflectivity Z_e, Doppler velocity corrected for air motion, U_D). The ice/snow particles number concentration is also retrieved as a by-product of the retrieval.

Liquid Cloud and Drizzle Retrieval Algorithm - Profiling cloud radar observations, combined with LWP and ceilometer backscatter measurements provide a good observational framework for the retrieval of cloud and drizzle properties in warm stratiform clouds.

- Vertical air motion and reflectivity-weighted particle fall velocity, retrieved from decomposed Doppler spectra, enables us to relate the mean Doppler velocity to the drizzle particle size distribution parameters (Luke and Kollias, 2016).
- Recent advancements in the decomposition of the radar Doppler spectrum width to its two primary components: spectra broadening due to turbulence and spectra broadening due to the different fall velocities of the hydrometeors. This enables us to relate the recorded radar Doppler spectrum width to the drizzle particle size distribution parameters (Borque et al., 2016).
- The use of the radar-lidar technique for the retrieval of the drizzle particle size distribution below the cloud base (O'Connor et al., 2005).

5. WHAT IS THE CLOUD CONDITION ID?

Each new algorithm to be implemented will need an accompanying quantitative CCI algorithm that defines the conditions for which the retrieval algorithm can be applied. This CCI algorithm may use ARM instrument datastreams, high-order value-added products or other inputs but will likely be different for each new retrieval algorithm. **The CCI should output a binary mask in time-height space identifying when and here the new algorithm can be properly applied.** It is important that these criteria be describable as a quantitative criteria in order to facilitate "hands-off" algorithm operation.

6. DIAGNOSTICS

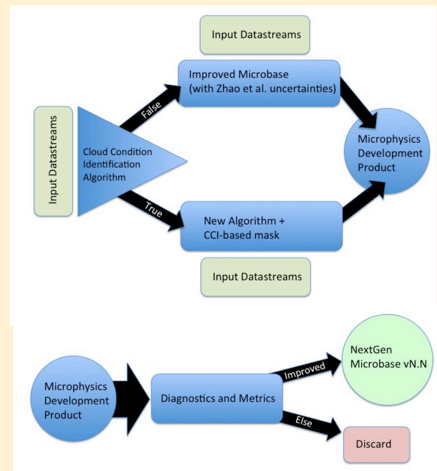
An important component of the framework is the diagnosis and evaluation of the microphysical properties retrieved by each new algorithm with the end goal of producing a "best estimate" cloud microphysical product.

a) Radiative closure through RIPBE and BBHRP

b) Comparison to available aircraft in situ observations and observations that were not used as input in the retrieval algorithm

c) Use of Observing System Simulation Experiments

7. OGRE-CLOUDS FRAMEWORK



8. TIMELINE

The proposed work will be completed over the course of a 24-month time period. Here we present a work plan timeline with deliverables:

Months 0-6
- Implement improvements to MICROBASE algorithm
- Begin development of new ice retrieval algorithm

Deliverable: Release improved MICROBASE algorithm code

Months 6-12
- Complete development of new ice retrieval algorithm
- Incorporate ice retrieval algorithm into OGRE-CLOUDS framework
- Begin development of new drizzling cloud retrieval

Deliverable: Produce NextGen MICRO output incorporating ice retrieval algorithm

Months 12-18
- Complete development of new drizzling cloud retrieval
- Incorporate drizzling cloud retrieval into OGRE-CLOUDS framework
- Begin development of OGRE-CLOUDS diagnostics

Deliverable: Produce NextGen MICRO output incorporating drizzling cloud retrieval algorithm

Months 18-24
- Complete development of OGRE-CLOUDS diagnostics
- Write technical report

Deliverable: Technical report and OGRE-CLOUDS code

All software, data products and documentation will be developed in cooperation with the ARM data management facility, and hosted in GitHub for the purpose of version identification and tracking.

8. REFERENCES

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