An ARSCL Simulator: Generation and Application to LASSO Case Studies

Mariko Oue[1], Pavlos Kollias[1,2], Aleksandra Tatarevic[3], Tami Toto[2], Andrew M. Vogelmann[2], Satoshi Endo[2], and William I. Gustafson Jr[4].
1. Stony Brook University, 2. Brookhaven National Laboratory, 3. McGill University, 4. Pacific Northwest National Laboratory
E-mail: mariko.oue@stonybrook.edu

Introduction

Remote sensing cloud measurements are used to evaluate cloud model simulations. Particularly, Active Remotely-Sensed Cloud Locations (ARSCL) is a very useful product to evaluate cloud fields simulated by large-eddy simulation (LES). However, remote sensing measurements can have uncertainties due to instrument limitations:

- Sensitivity,
- Attenuation, and
- Larger sampling volume than model grid spacing.

These issues can cause errors in evaluation of the model outputs. We need to understand how observations represent real cloud fields and to emulate observation variables from LES while including the limitations as much as possible. The Cloud Resolving Model Radar SImulator (CR-SIM) simulator helps to address the uncertainties and produces observables including observation errors.

Methodology

Cloud Resolving Model Radar SImulator (CR-SIM)

Input

CRM/LES data (e.g., WRF, DHARMA) with various microphysics schemes

- 2-moment (Morrison et al., 2005, 2009, Milbrandt and Yau, 2005a,b, and Thompson et al. 2007), spectral bin (Fan et al., 2012)
- Input in this study: LASSO outputs (WRF with Morrison 2-moment microphysics)

Simulator

Radar (scanning/profiling) simulator

1) T-matrix scattering calculation.
   - For cloud water, cloud ice, rain, snow, graupel and hail for each size.
   - A fixed orientation for every elevation angle (0° to 90°).
   - Frequencies of 3, 5.5, 9.5, 35, and 94 GHz.
2) Calculate particle size distributions according to the selected microphysics scheme for each hydrometeor type.
3) Resample data to radar coordinate.

Ceilometer simulator

1) Calculate droplet size distribution.
2) Compute single particle extinction and backscattering cross sections for spherical droplets at a wavelength of 905 nm.
3) Estimate first cloud base height at each column.

MPL simulator

1) Calculate droplet and cloud ice size distributions.
2) Compute particle extinction and backscattering cross sections for spherical droplets and ice at a wavelength of 353 or 532 nm.
3) Calibrate by aerosol and molecule backscattering.

Outputs

- Radar: Zhh, DV, SW, Zvv, Zdr, Kdp, Ah, Av, LDRh for each hydrometeor type, elevation and azimuth angle
- Ceilometer: Backscatter (including attenuation), extinction, lidar ratio, first cloud base
- MPL: Backscatter (including attenuation), extinction, lidar ratio

Applications

Virtual Observatory

Multi sensor application	Single radar application	Multi radar application
• Virtual ARSCL • Virtual MWR LWP	• Best estimates of cloud properties • Polarimetric observables	• 3DVAR Wind retrieval • Polarimetric observables

LASSO case studies

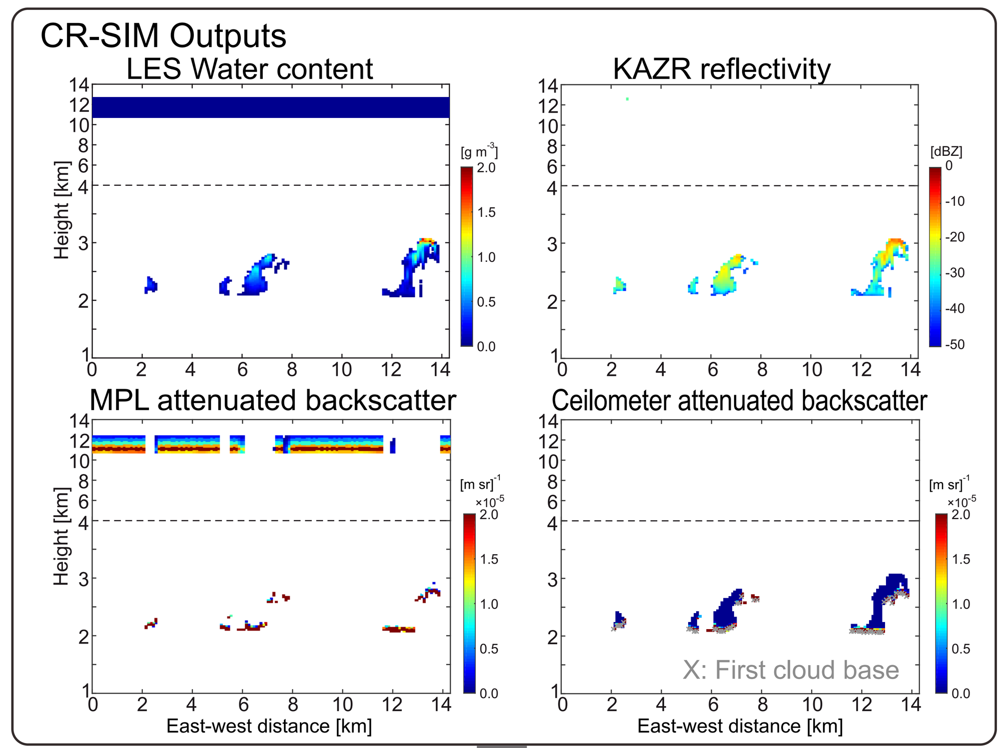
- Address observation uncertainties (multi sensor & single radar application)
- Best estimates of cloud fraction (single radar application)
- Observation-like products (virtual ARSCL and MWR LWP) to evaluate LES (multi sensor application)

Application

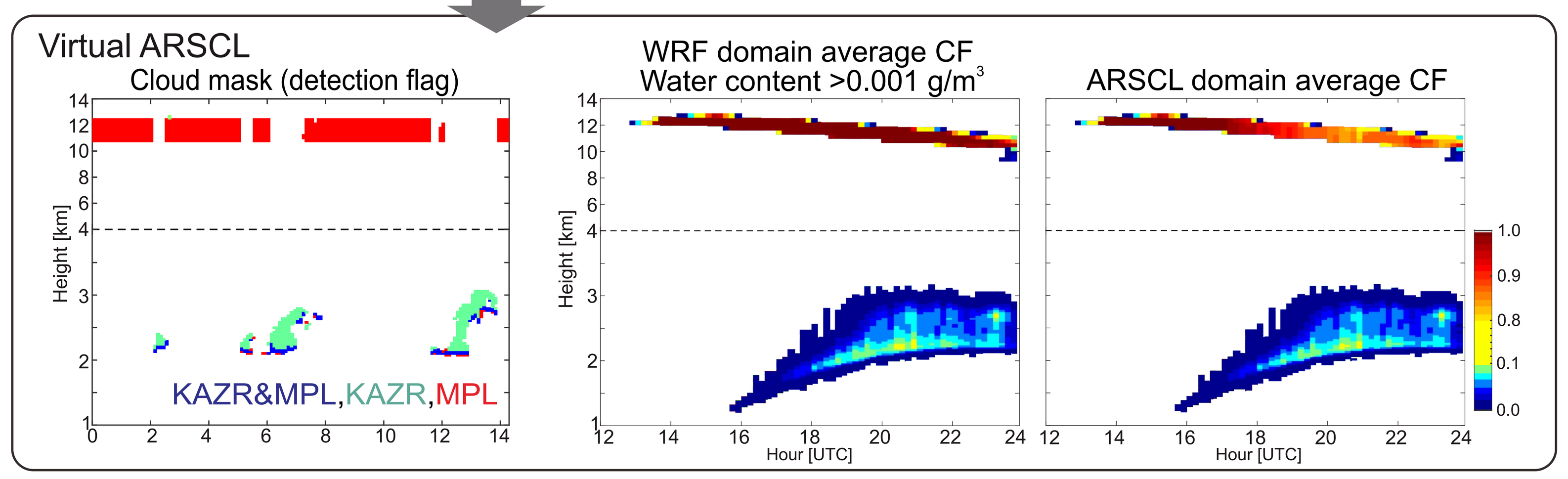
Multi sensor application

LASSO case: 2015/06/27 sim0013 (WRF)

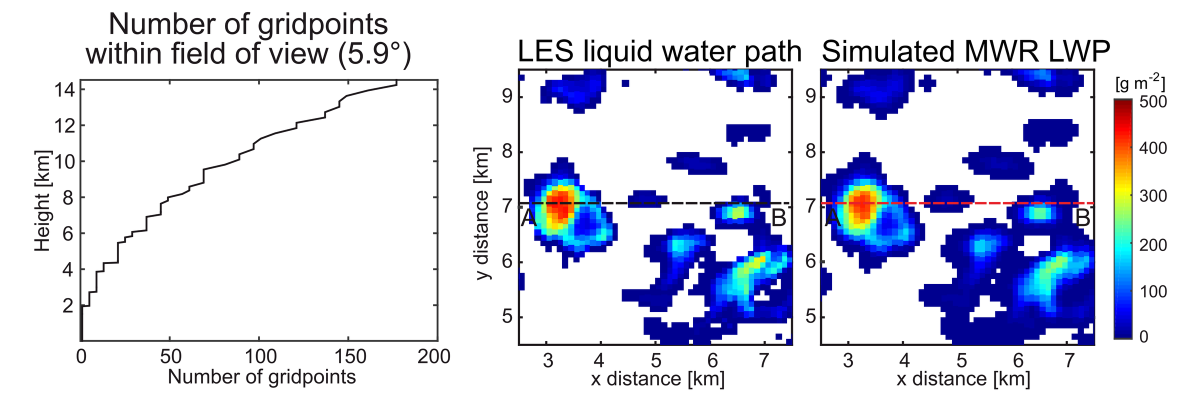
Virtual ARSCL



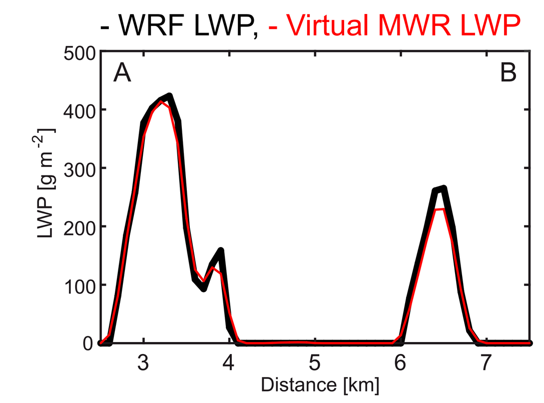
- KAZR cannot detect cirrus clouds due to its sensitivity.
- Ceilometer can well capture cloud base heights of cumulus convection.
- MPL can detect cumulus cloud bases and cirrus clouds, but cannot detect cirrus when cumulus cloud existed at lower altitudes due to attenuation.
- Virtual ARSCL cirrus cloud fraction decreased by ~20%.



Virtual MWR liquid water path (LWP)



- LWP are distance-weighted averaged using a Gaussian function over the field of view of 5.9°.

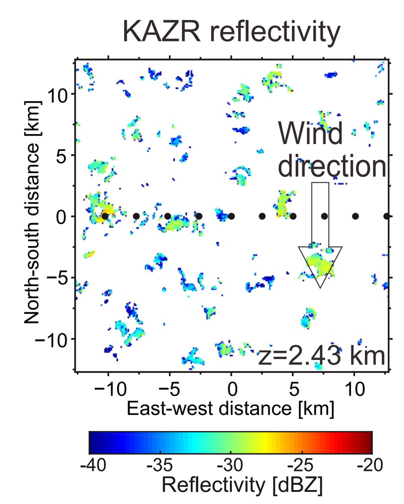


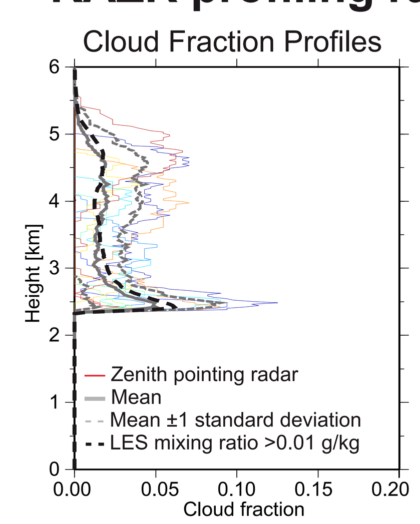
- For larger-size clouds, the MWR field of view would not produce significant error in LES LWP evaluation.
- For smaller-size clouds (<1 km diameter), the MWR field of view could over-sample and underestimate peak values.

Single radar application: Cloud fraction profile (CFP) estimates

LASSO case: 2015/06/09 (WRF)

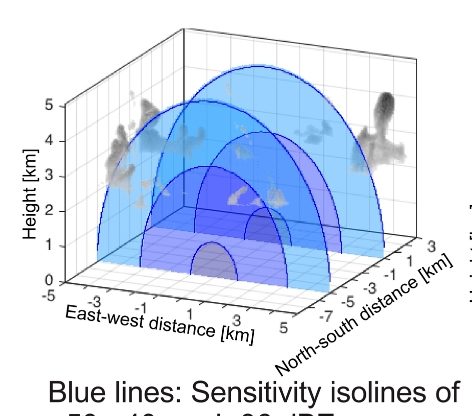
KAZR profiling radar



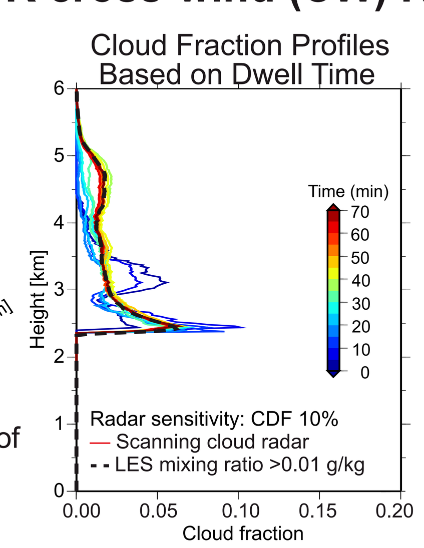


- CFP was estimated from each of 10 KAZR profiling measurements (•), assuming that clouds moved in north-south direction.
- KAZR zenith pointing observations cannot capture the domain-averaged CFP.

Ka-SACR cross-wind (CW) RHI



Blue lines: Sensitivity isolines of -50, -40, and -36 dBZ



- Sensitivity limitations can cause undersampling of clouds.
- The estimate domain is optimized using reflectivity probability density at each height. CFP was estimated over Ka-SACR CWRHI scans (taking 30 sec/scan).
- 35 min or more CWRHI scans can capture the domain averaged CFP.

Future Work

- Implement in various CRMs and LES with different microphysics schemes.
  - ►RAMS with double moment (Walko et al., 1995; Meyers et al., 1997; Saleeby and Cotton, 2004; Saleeby and van den Heever, 2013)
  - ►SAM with double moment
  - ►Predicted particle properties (P3) microphysics scheme (Morrison and Milbrandt, 2015)
- Code optimization to incorporate into real-time LES.

Summary

Single radar application (Cloud fraction profile estimates)

- KAZR zenith pointing observations cannot capture the domain averaged CFP.
- 35 min or more Ka-SACR CWRHI observations that use an optimized sampling strategy can much better capture the domain-averaged CFP.

Multi sensor application

- Virtual ARSCL was produced from KAZR, MPL, and ceilometer simulations. Radar sensitivity and lidar attenuation can result in missed cloud.
- MWR LWP was calculated taking into account the MWR field of view. MWR field of view could over sample and underestimate peak values for small size clouds.

Latest software packages are available at:

- CR-SIM: ftp://ftp.radar.bnl.gov/outgoing/moue/crsim/src/crsim2.2.1_beta.tar.gz
- Radar resampling: ftp://ftp.radar.bnl.gov/outgoing/moue/crsim/src/radar_filter_v1.2.tar.gz