An ARSCL Simulator: Generation and Application to LASSO Case Studies

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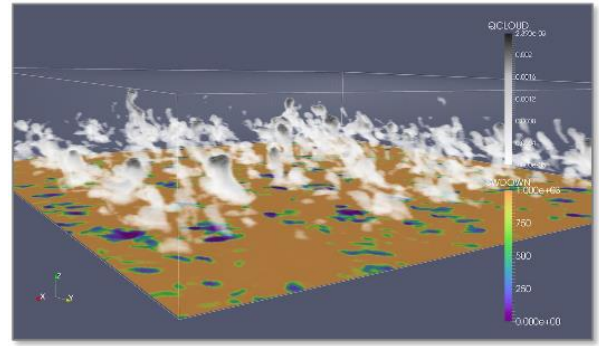
Session A1, Poster # 168, Tues 3:30 - 5:00 pm

Motivation

Real Cloud Fields

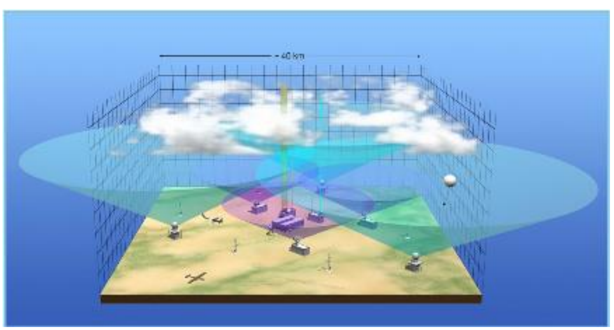
Cloud Model Simulations (e.g. LES)



Cloud properties: Water content, u, v, w, etc.

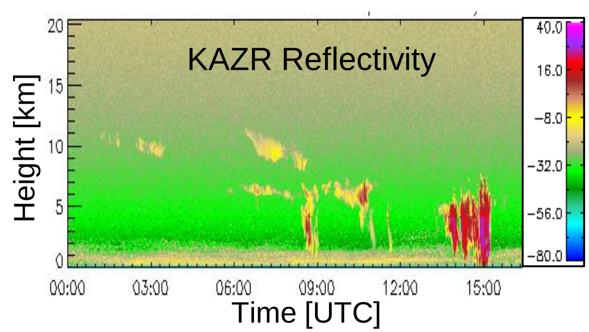
How does the **simulation** represent the real cloud field?

Observation



Remote sensing (e.g., radar, lidar)

Observational data



Observation limitations:

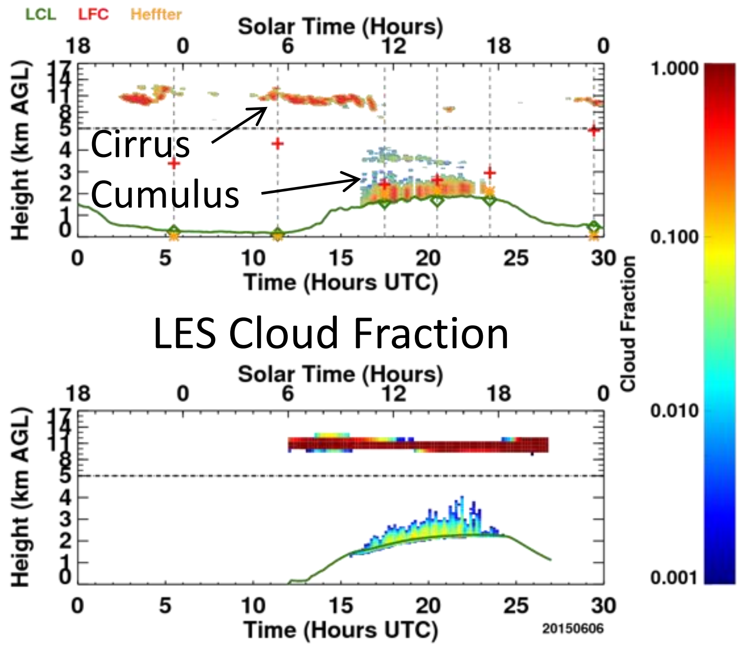
- Sensitivity
- Limited observation range
- Attenuation
- Spatial representation

Variables: Backscatter, Z, etc.→ Retrieve cloud properties

How does the **observation** represent the real cloud field?

Motivation

Observation (ARSCL) Cloud Fraction

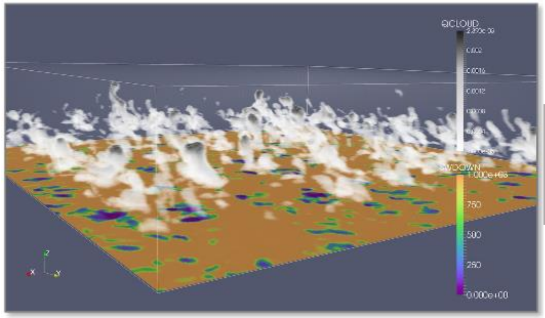


Active Remotely-Sensed Cloud Locations (ARSCL) provides hydrometeor height locations based on multiple active remote sensors.

However, the observational data potentially have uncertainties due to the limitations.

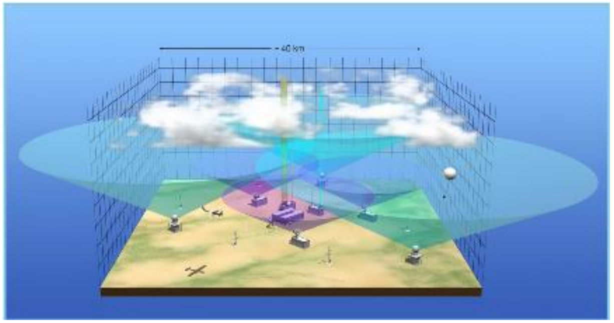
The cirrus clouds were not present when cumulus clouds were present?
Or, the observation failed to detect the cirrus?

Cloud Model Simulations



Cloud Resolving Model Radar SIMulator (CR-SIM)

Virtual Observational Products



Simulation Overview

Cloud model output (e.g., WRF, DHARMA) with various microphysics scheme

CR-SIM

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 angles (0° -90°)
   - 3, 5.5, 9.5, 35, and 94 GHz
2) Calculate particle size distributions according to a selected microphysics scheme for each model hydrometeor type
3) Resample data to radar coordinate

Zhh, DV, SW, Zvv, Zdr, Kdp, Ah, Av, LDRh for each model hydrometeor type

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

Backscatter (including attenuation), extinction, lidar ratio, first cloud base

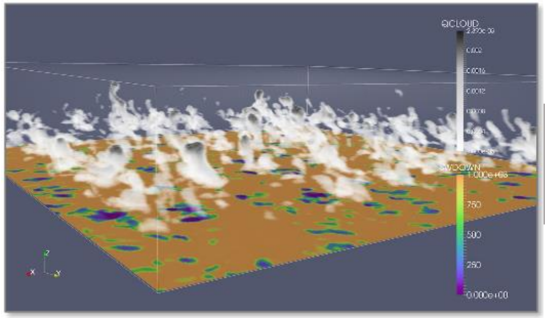
Micro Pulse Lidar (MPL) simulator

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

Backscatter (including attenuation), extinction, lidar ratio

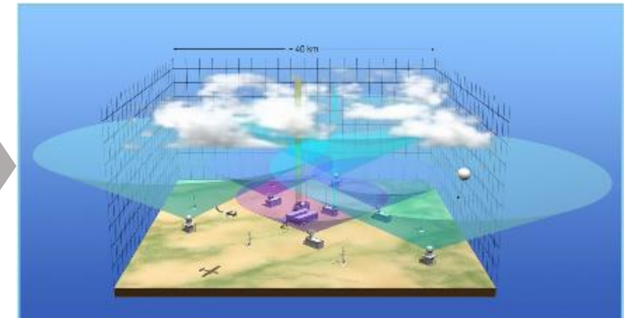
CR-SIM Applications

Cloud Model Simulations

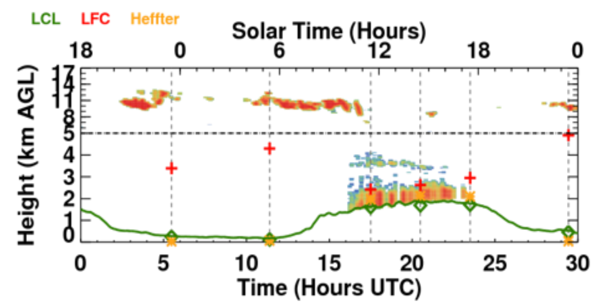


Cloud Resolving Model Radar SIMulator (CR-SIM)

Virtual Observational Products



Real Observational Data



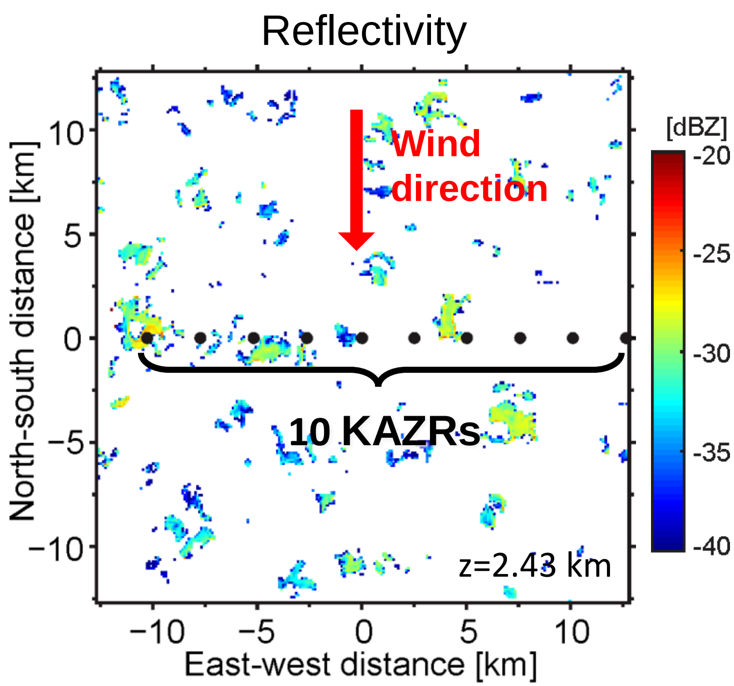
1. Compare with the original model output to address potential uncertainties in observational products.
2. Compare with real observational data for LES evaluation.

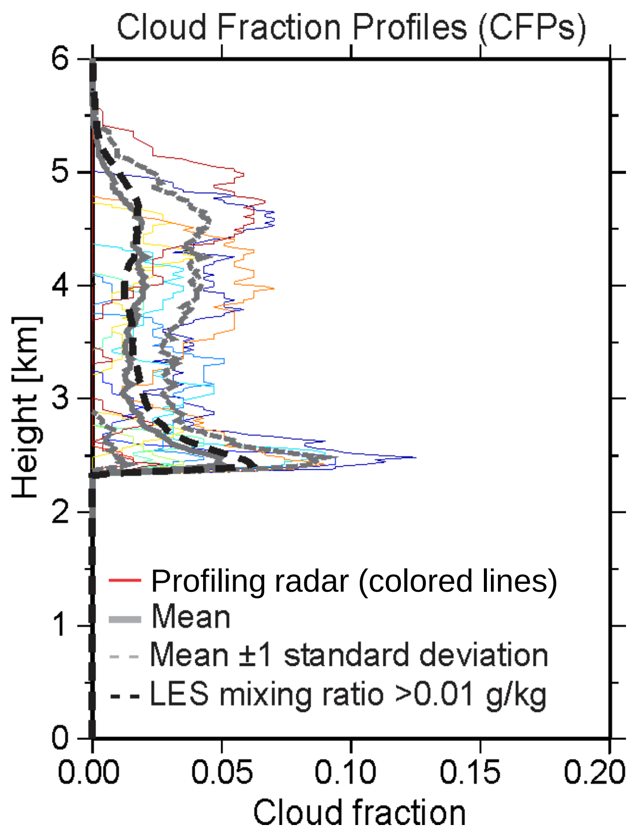
LES ARM Symbiotic Simulation and Observation (LASSO) Case Studies

- Address observation uncertainties in cloud fraction estimates.
- Suggest best estimates of cloud fraction.
- Provide virtual observational products (virtual ARSCL) to evaluate LES.

Cloud Fraction Using Profiling Radar

Profiling by 10 KAZRs





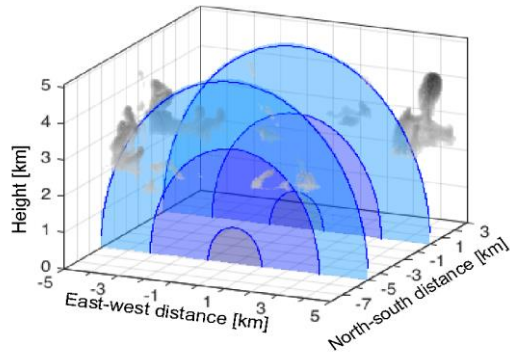
- CFP from each KAZR measurement can have large uncertainty.
- Average over 10 KAZR zenith pointing dwells comes close to the domain averaged CFP. But having > 10 KAZRs is not a realistic way.

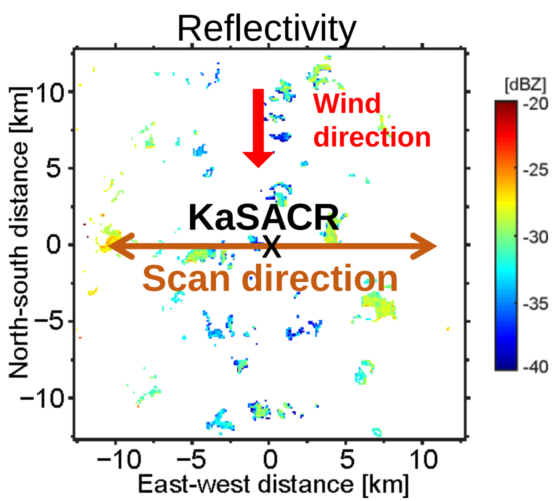
LASSO LES for 2015/06/09 at SGP

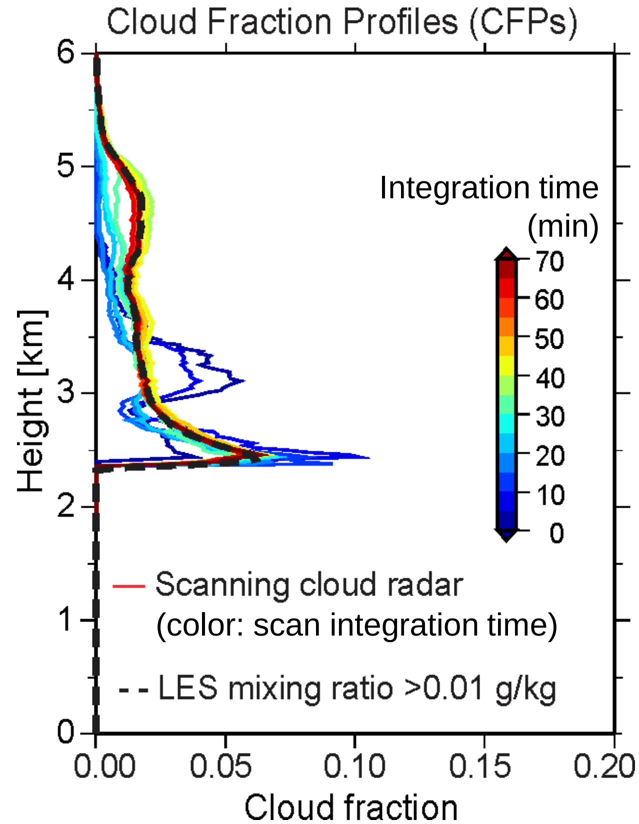
Oue et al., 2016, GRL

Cloud Fraction Using Scanning Cloud Radar

Cross-wind scan (CWRHI) by KaSACR every 30 sec





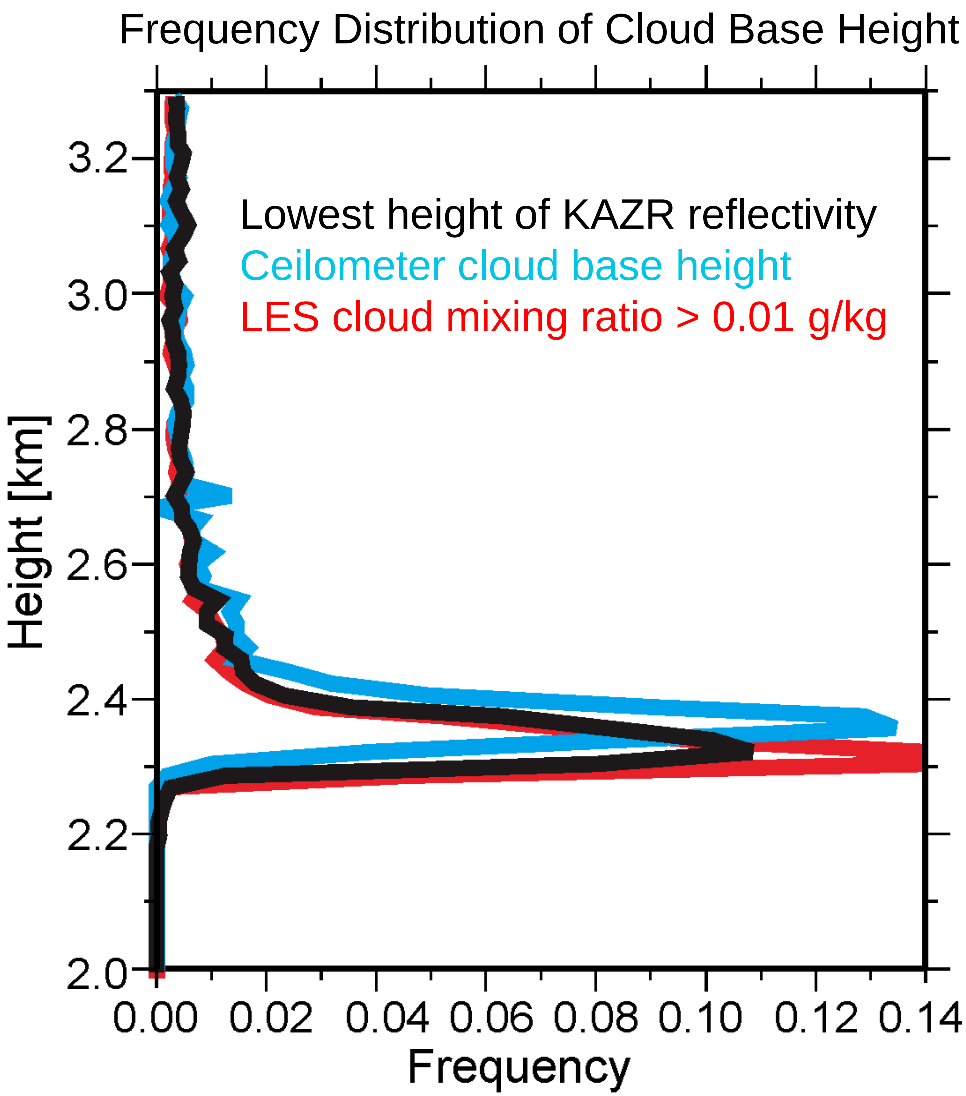


- Radar sensitivity decreases with distance from the radar.
- Estimate domain is optimized using reflectivity probability density at each height. 35 min or more CWRHI scans can capture the domain averaged CFP.

LASSO LES for 2015/06/09 at SGP

Oue et al., 2016, GRL

Cloud Base Height Observed by Ceilometer

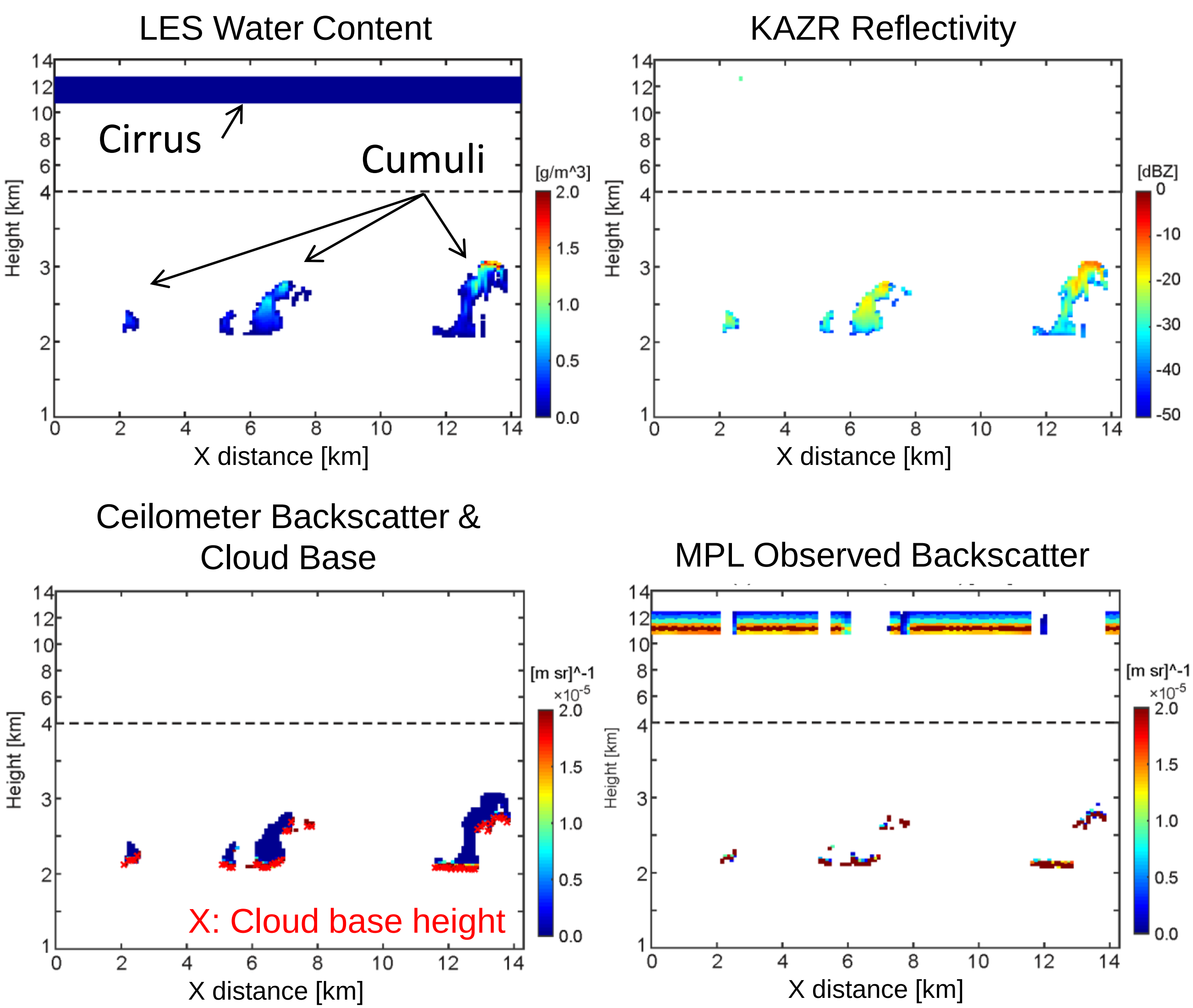


Ceilometer can well capture cloud base height.

→ Improve cloud detection near the cloud base.

LASSO LES for 2015/06/09 at SGP

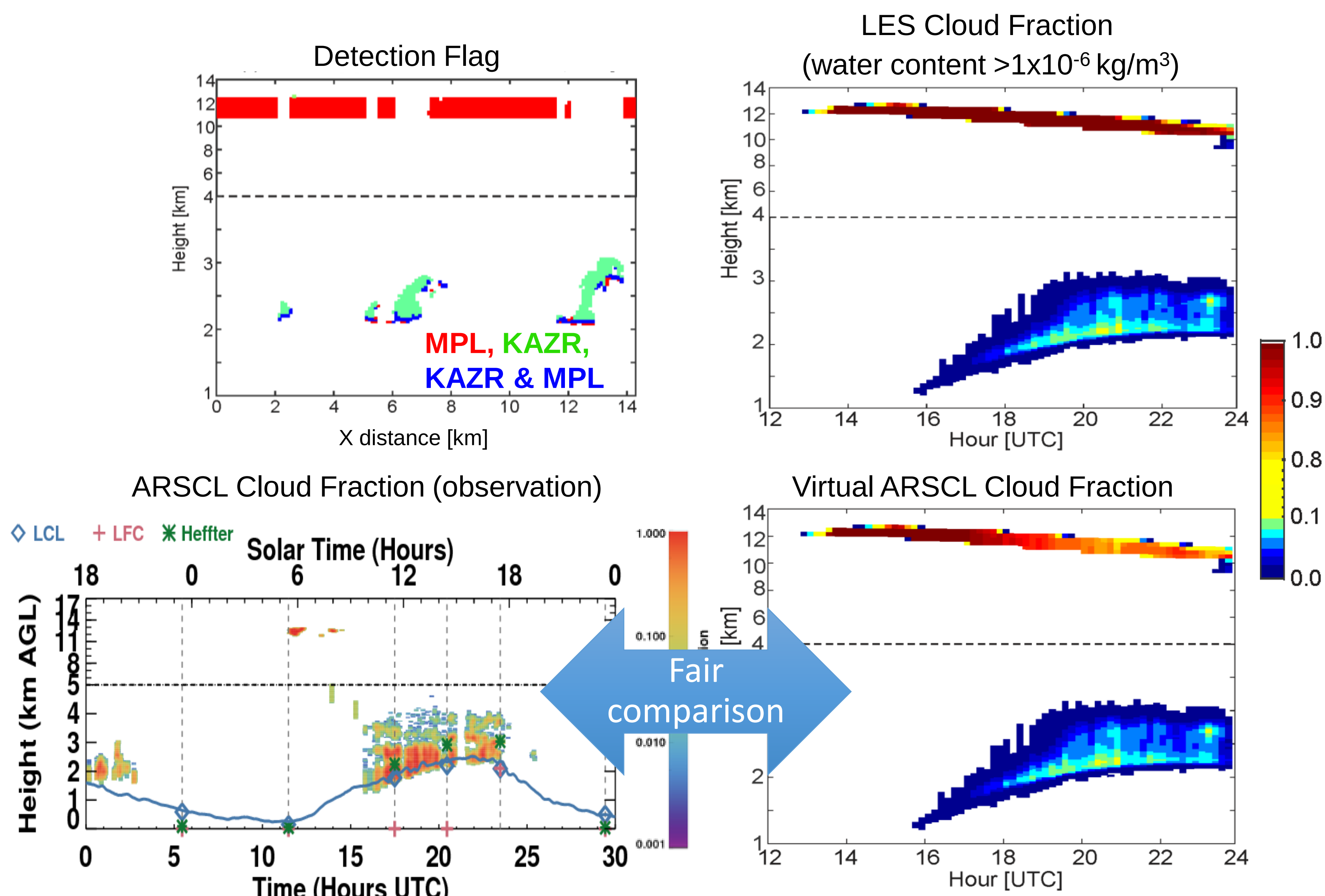
Virtual ARSCL from Multi Sensor Simulations



- KAZR cannot detect cirrus clouds due to sensitivity issue.
- Ceilometer can well capture cloud base heights of cumulus clouds.
- MPL can detect cumulus cloud bases and cirrus clouds, but not detect cirrus when cumulus clouds existed at lower altitudes due to attenuation.

LASSO LES for 2015/06/27 at SGP

Virtual ARSCL from Multi Sensor Simulations



Virtual ARSCL cirrus cloud fraction decreased by ~20%.

LASSO LES for 2015/06/27 at SGP

Summary

- Virtual observational products were simulated from LES outputs using CR-SIM.
- The virtual observational products are useful to address observation uncertainties.
  - Radar cloud fraction profiles (CFP)
    - KAZR zenith pointing dwells 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.
  - Virtual ARSCL
    - Radar sensitivity and lidar attenuation can cause missing of cloud locations.
- The virtual observational products can help for evaluation of LES output with real observations.

Future Work

- Implement interfaces to various cloud models & different microphysics schemes.
  - Predicted particle properties (P3) microphysics scheme (Morrison and Milbrandt, 2015)
  - 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
- Code optimization to incorporate into real-time LES.
- 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