ARM Cloud Radar Simulator for GCMs: Latest Update and Applications

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Acknowledgments

ARM, the ARM/ASR Radar Group, the COSP Project Management Committee, Steve Klein, Roger Marchand, Pavlos Kollias, Eugene Clothiaux, Scott Collis, Tristan L'Ecuyer, Wuyin Lin, Karen Johnson, etc.

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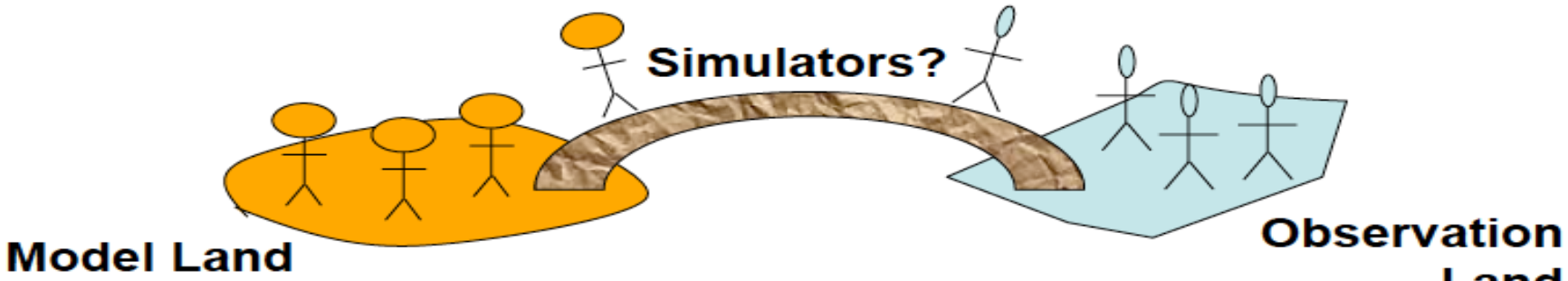
Simulator to Bridge the Gap between GCM Clouds and Cloud Observations

- Significant differences between how a climate model represents clouds and what ARM instruments see
  - scale of model grids (~100 km) vs. point measurements
  - model variables vs. instrument observables
  - different definition for clouds
  - Observation limitations (detected signal and attenuation of signals)



Slide from Klein (2011) (modified by Xie)

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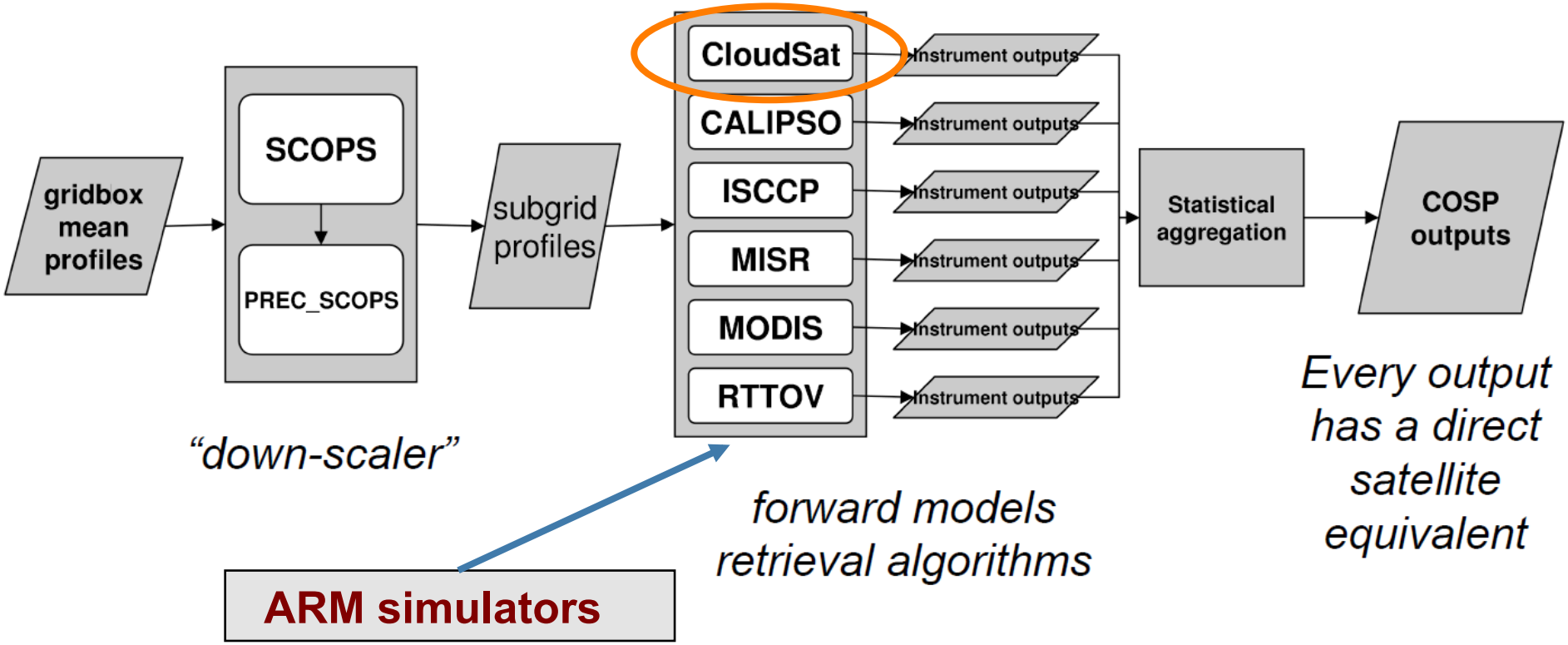
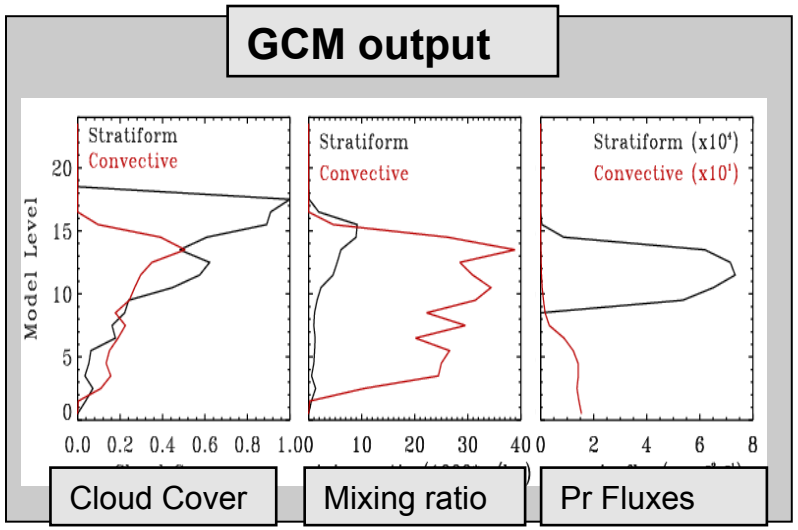
Ideas on the ARM Radar Simulator

- Take the advantage of COSP**, the CFMIP Observation Simulator Package**, by inverting the COSP CloudSat simulator for view from the ground and run at a different wavelength for the ARM ground-based remote sensors
- Make it as part of **COSP** for a broad use by the climate modeling community

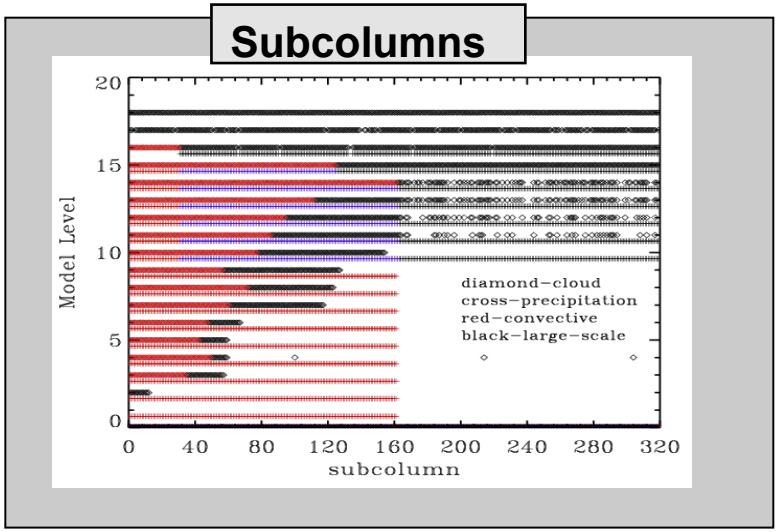


A Flowchart – ARM Radar Simulator

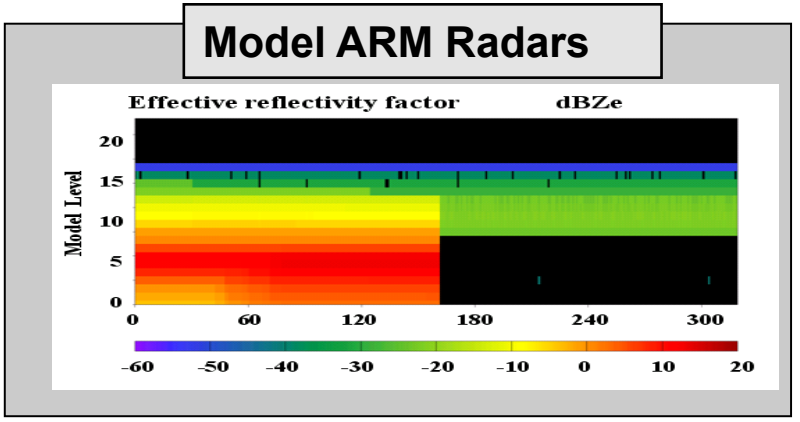


COSP "down-scaler" to generate subcolumn distribution

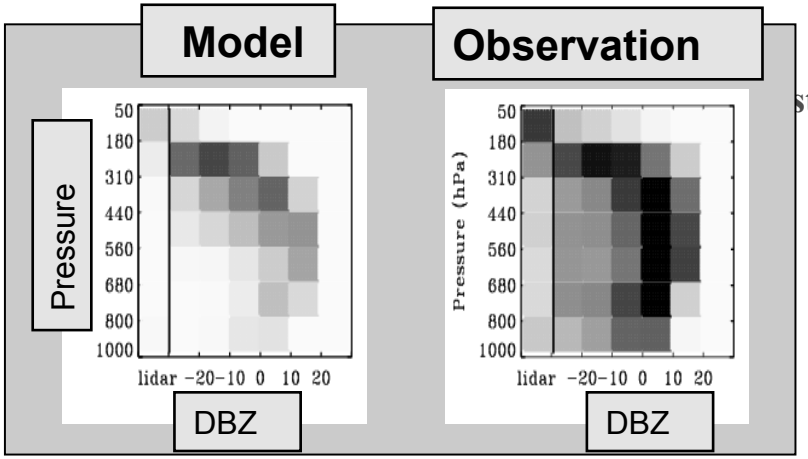
SCOPS + PREC_SCOPS



Radar simulator to convert model variables into pseudo-instrument obs



Statistical processing (a statistical module) to produce joint histogram



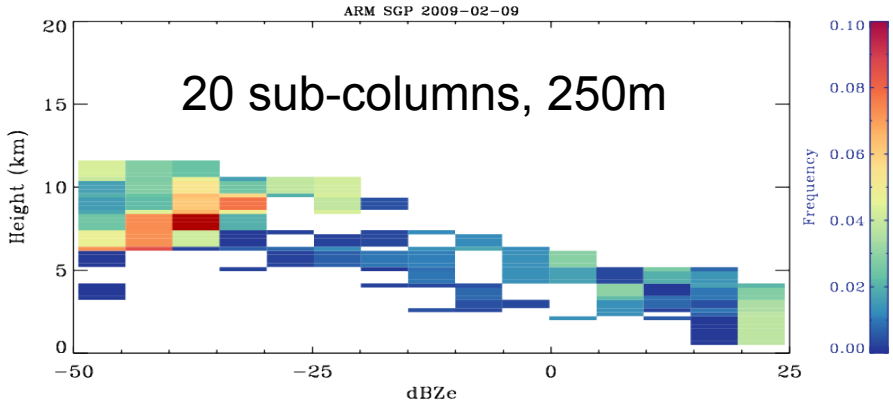
CFAD - The Contoured Frequency by Altitude Diagram (the reflectivity-height histogram)

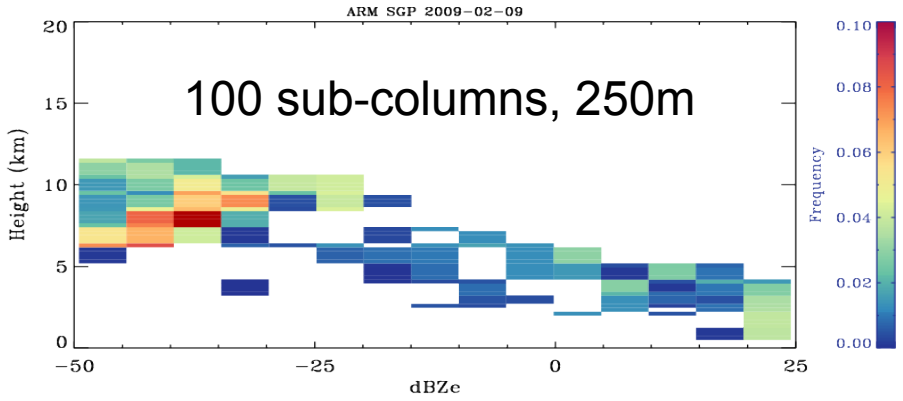
Issues Need to be Addressed for an ARM Simulator

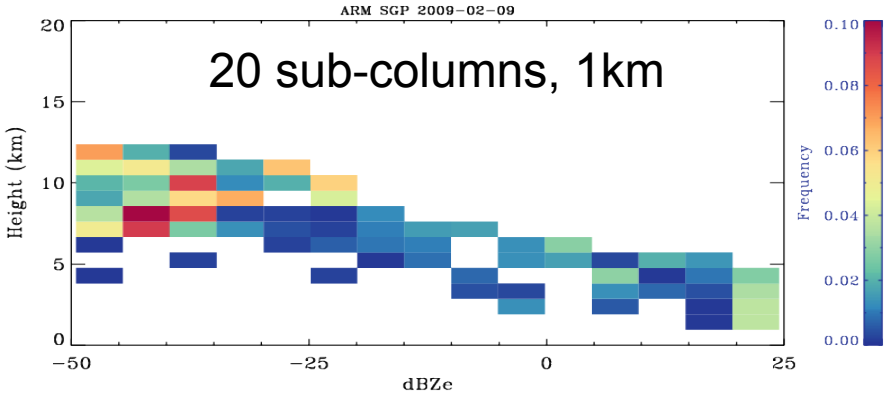
- Explore simulator uncertainties
  - Resolution
  - # of subcolumn
  - Minimum detectable signal threshold
  - Saturation value of radar reflectivity
  - Subgrid precipitation distribution
  - Simulator uncertainties associated with particle size distribution
- Address clutter issue with ARM cloud observations
  - How to address the clutter issue in ARM CFAD
- Explore strategies for model and ARM cloud comparison
  - *What is a suitable time and space scale for the comparison?*
    - *Diurnal cycle of clouds*
    - *seasonal mean and variability*

Sensitivity to the Number of Sub-column and Vertical Resolution

Feb 9th, 2009







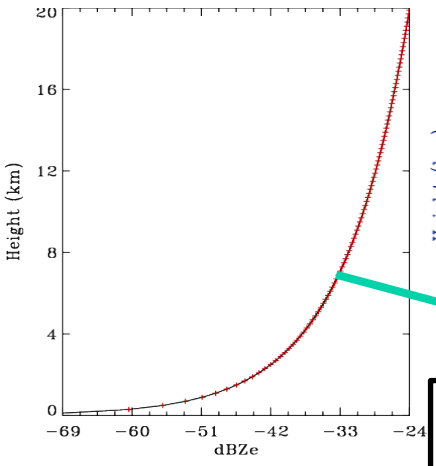
Currently we use 20 sub-columns and 100m resolution.

Impact of Minimum Detectable Signal Threshold and Maximum Instrument Recording Signal

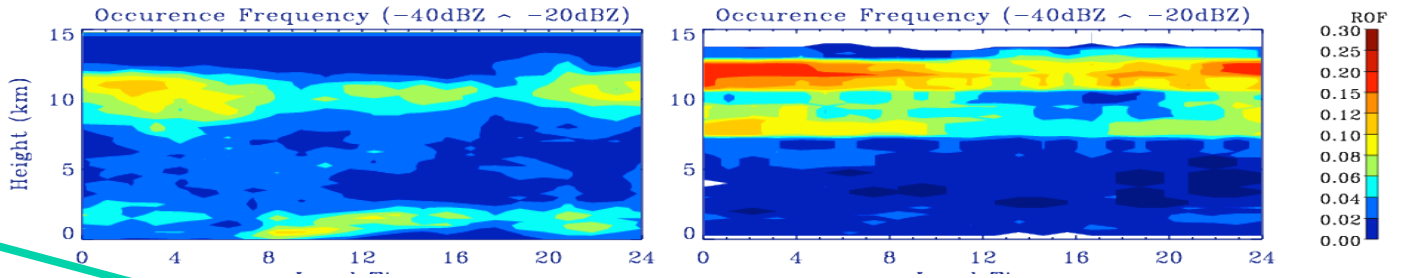
Summer Diurnal Precipitation at SGP (2009)

Observation **ACME**

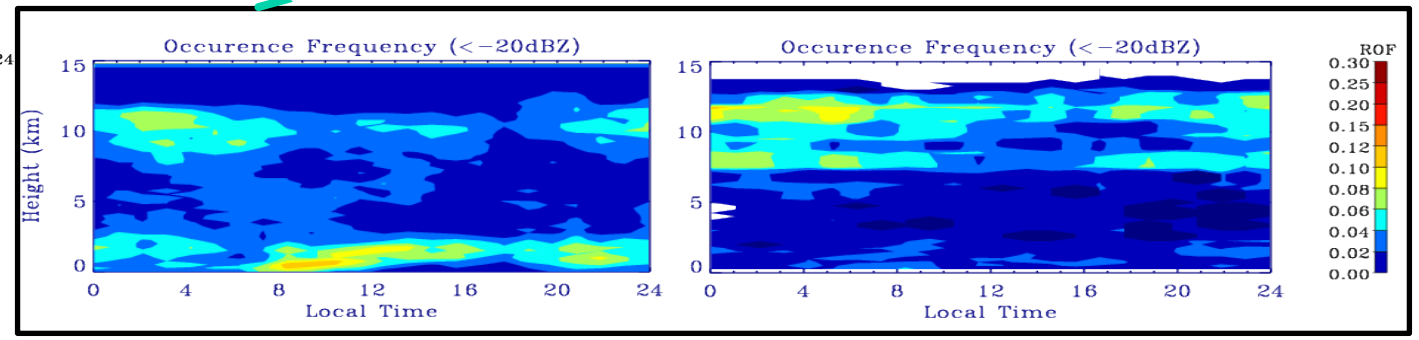
Minimum Detectable Signal



Minimum detectable threshold set by -40 dBZ, constant with height



New minimum detectable profile suggested by Pavlos



We also tested the saturation value of radar reflectivity as a function of height: dBZ_max (h, in km) = 20+20*log10(h, km). The impact is insignificant

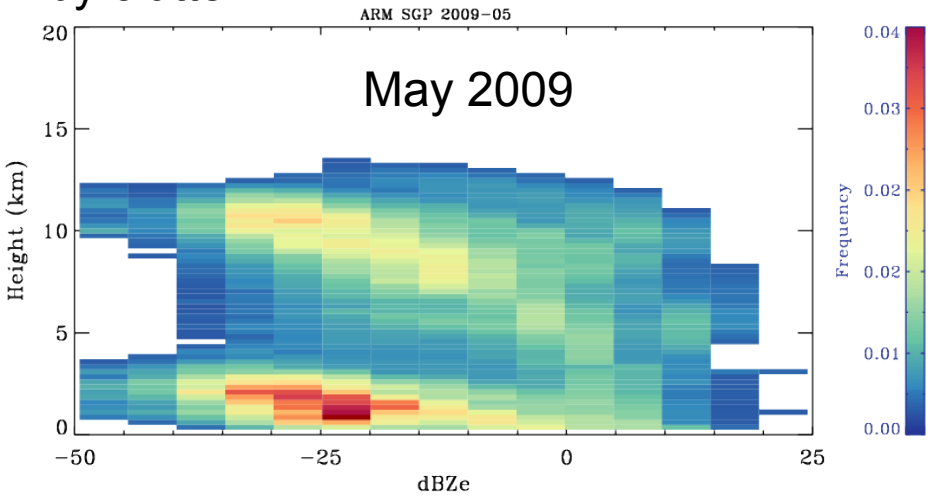
Thank Pavlos Kollias and Eugene Clothiaux for providing the MDS and the maximum radar reflectivity profiles and valuable comments/suggestions

Clutter Issue

CFAD generated with & without clutter

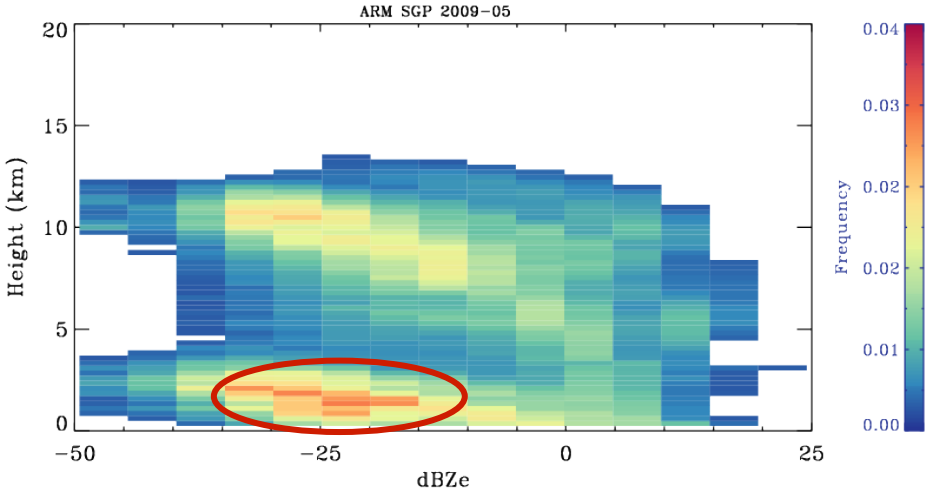
qc-flag = 1 or 2

MMCR reflectivity may be contaminated by clutter



qc-flag = 1

MMCR reflectivity with clutter removed, but also lose some cloud information



Karen Johnson is appreciated for her valuable comments and suggestions

Application to ACME

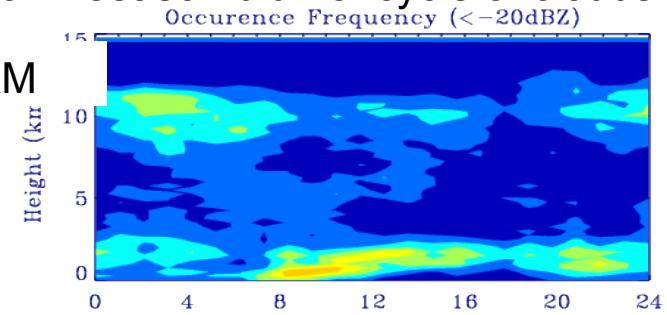
High Frequency ARM OBS Allows Model Evaluation on Different Time Scales

Hourly radar CFAD

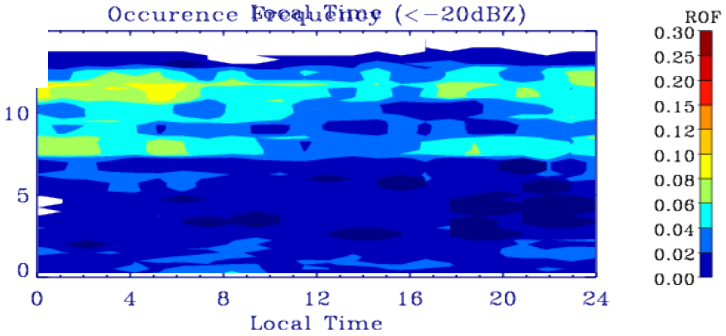
Diurnal Cycle

Warm season diurnal cycle of clouds at SGP

ARM



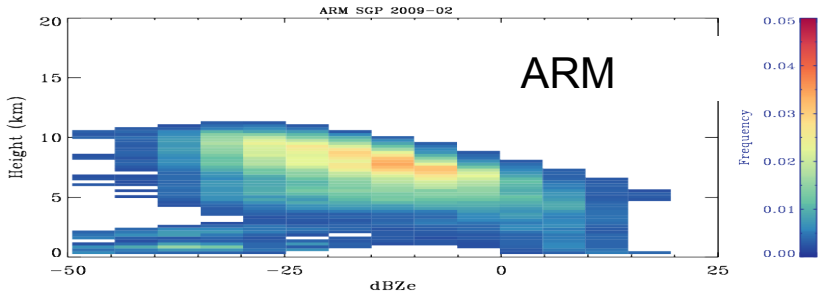
ACME

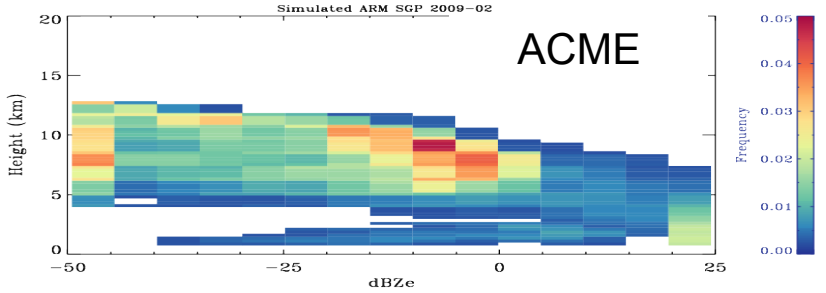


lack of non-precipitating shallow clouds

Monthly/Seasonal Mean

CFAD for the month of Feb 2009





produces too much precipitating clouds at middle and high levels

Progress

- Completed V0 ARM cloud radar simulator development
  - ✓ Incorporate the ARM cloud radar simulator onto both COSP1.4 and COSP2.0 and ready to release
  - ○ V1 will add the non-attenuated, Rayleigh-scattering only, radar reflectivity CFAD to the simulator output
- Developed Multi-year CFAD from ARSCL/KAZR-ARSCL for model evaluation
  - ✓ *Data are at hourly, 100m vertical resolution, 5 dBZ bin in the range of -50 dBZ to 25 dBZ.*
  - ✓ *Consider impact of clutter/insects on radar signal*
  - ✓ *5-yr CFAD for 2006-2010 and some months in 2011 are done*
  - ○ *Will extend the data to the most recent years once the KAZR-ARSCL data are available*
- Applied to ACME
  - ✓ Applied the ARM cloud radar simulator offline on sample output from ACME around the ARM SGP site during its convection tests
  - ○ will work with other modeling centers including both NWP and climate centers (ECMWF, NCEP, GFDL, MetOffice, Metro-France, ...) to promote its application

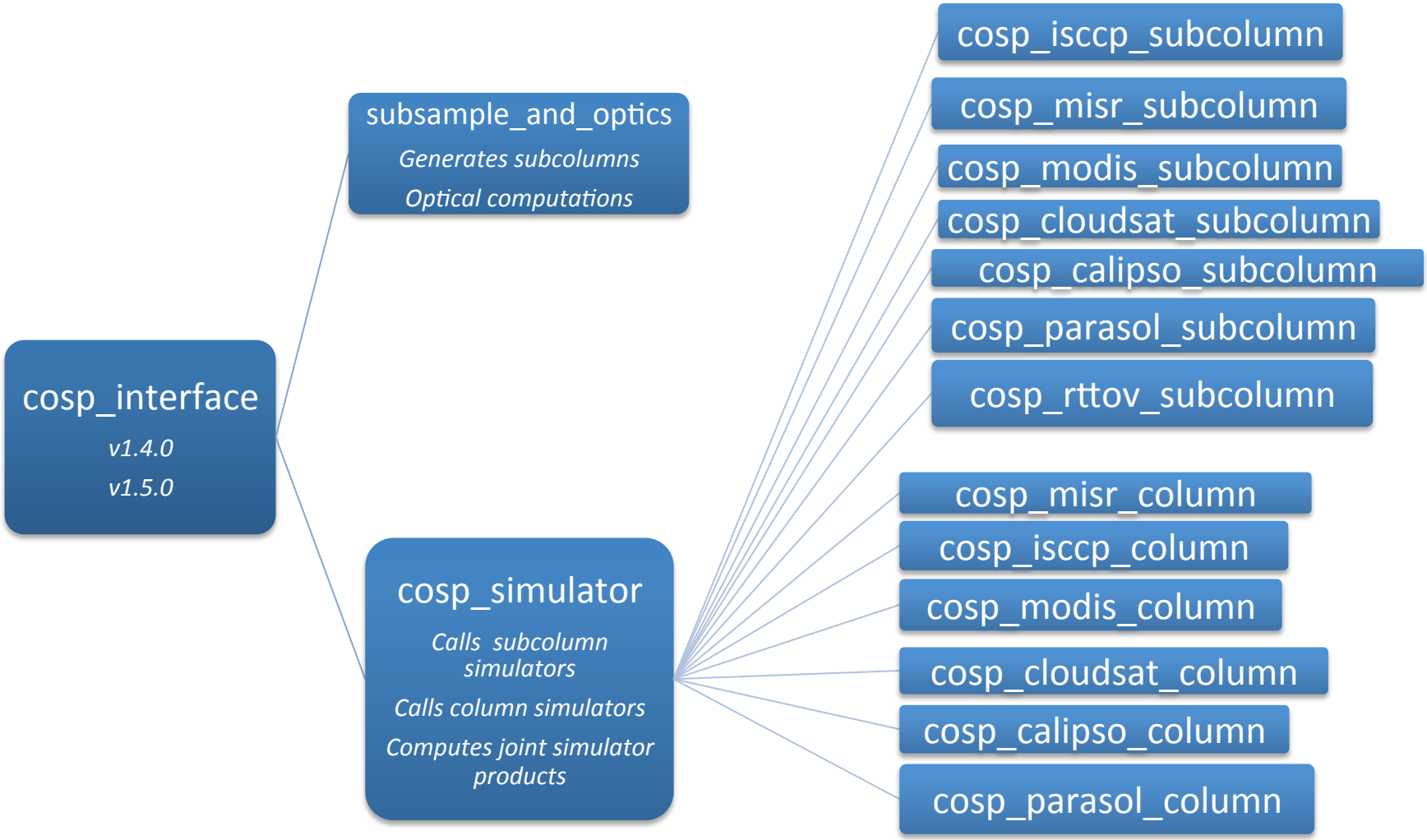
Future plan

- Working with ARM and the COSP PMC to release the ARM simulator to the committee
- Extend the long-term ARM GCM-oriented cloud radar data (CFAD) at ARM permanent sites and AMF sites once the KAZR-ARSCL data are available
- Refine and improve the ARM radar simulator

  Add the non-attenuated, Rayleigh-scattering only, radar reflectivity CFAD to the simulator output and refine the code structure to make it more flexible for future modification
- Work with modeling centers for its applications

  ACME, CESM, ECMWF, NCEP, GFDL, MetOffice, Metro-France, ...
- Explore strategies for model-observation comparison and provide recommendation to the community
- Documentation, user guide, and distribution

  Journal papers, Technical report, distributing the ARM simulator package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v1.5.0
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Optical computations
cosp_simulator
Calls subcolumn simulators
Calls column simulators
Computes joint simulator products
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