Open Sourcing Radar Simulators: Efforts and Challenges

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Discussion at the Past Forward Simulators Breakout Sessions…

- Radar forward simulators are useful to bridge a gap between observations and models.
- Quantify and report uncertainties in forward space.
- Need for open source of simulators.
- Need for communication between developer and user, and observation and model communities.
- Building a place to communicate developer – user and observation – model communities (e.g., websites)

Cloud Resolving Radar Simulator (CR-SIM):

Simulation Parameters Are Being Continuously Added in Response to User's Demands

- Simulate multiple radar observables (reflectivity, Doppler velocity, polarimetric fields, Doppler spectra)
- Simulate multi ARM sensors, such as ceilometer lidar and micro-pulse lidar observables (backscatter, extinction)
- Provide virtual value added product (e.g., cloud base height, ARSCL, MWR LWP)

Extended to Input Different CRMs with Several Microphysics Schemes Following User's Demands

- Weather Research and Forecasting Model (WRF)
  - Morrison 2 moments, Milbrandt and Yau multi moments, Thompson single and double moments predicted particle properties (P3) scheme, spectral bin
- ICOsahedral Non-hydrostatic general circulation model (ICON)
  - Seifert and Beheng 2-moment
- Regional Atmospheric Modeling System (RAMS)
  - 2 moments
- System for Atmospheric Modeling (SAM)
  - Tel Aviv University (TAU) 2-moment bin, Morrison double moments

Applications to Investigate Uncertainties in Observations

Input
Model simulated cloud field (e.g., Q, U, V)

Forward Models
Zhh, DV, SW, Zvv, Zdr, Kdp, Ah, Av, LDRh for each hydrometeor type, at each gridbox.
Account for radar elevation angles.

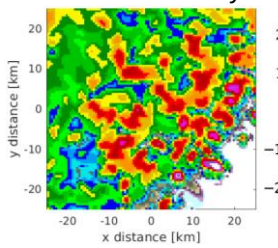
Instrument Model
Sampling geometry, sampling volume, attenuation, and sensitivity.

Retrieval Model
3DVAR multi-Doppler radar wind retrieval
Cloud fraction estimates

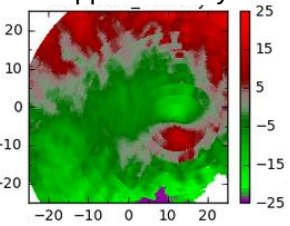
Output
Simulated retrieval parameters

Compare and investigate uncertainties

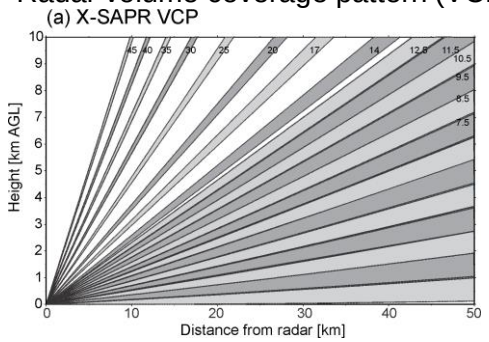
Radar reflectivity



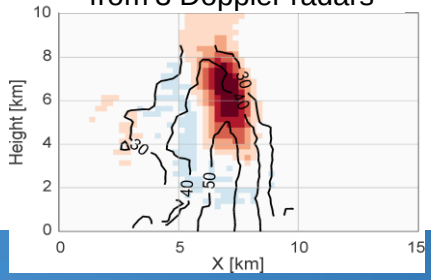
Doppler velocity



Radar volume coverage pattern (VCP)



Vertical velocity from from 3 Doppler radars



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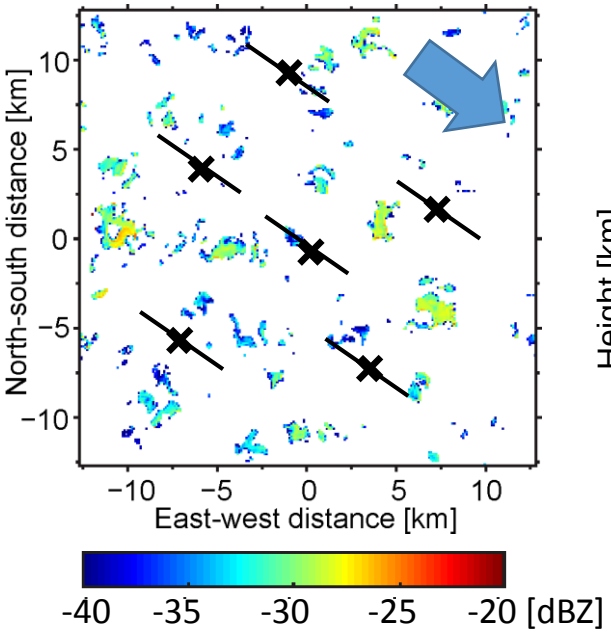
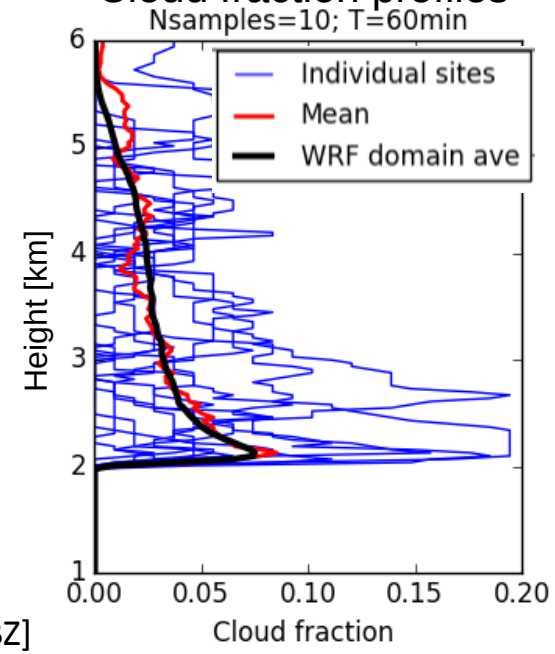
How many sites, how long integration are needed to estimate domain wide cloud fraction?

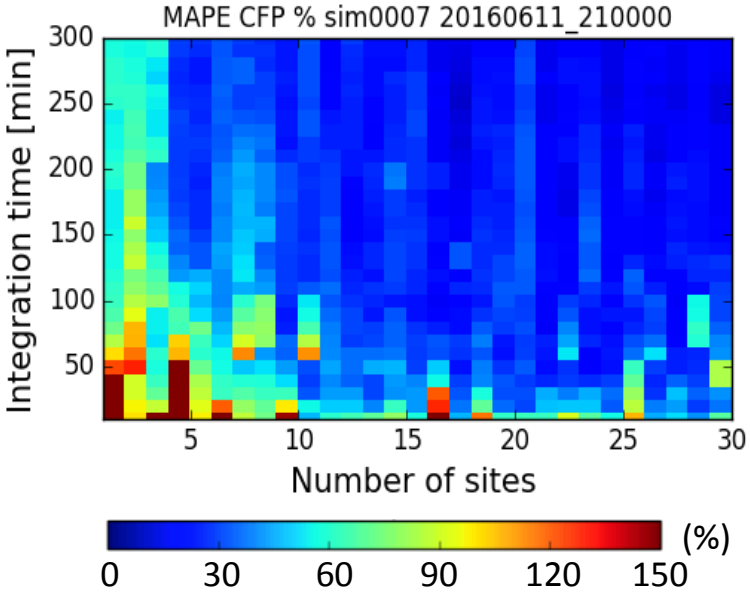
Simulated KAZR reflectivity



Cloud fraction profiles



Mean absolute percentage error

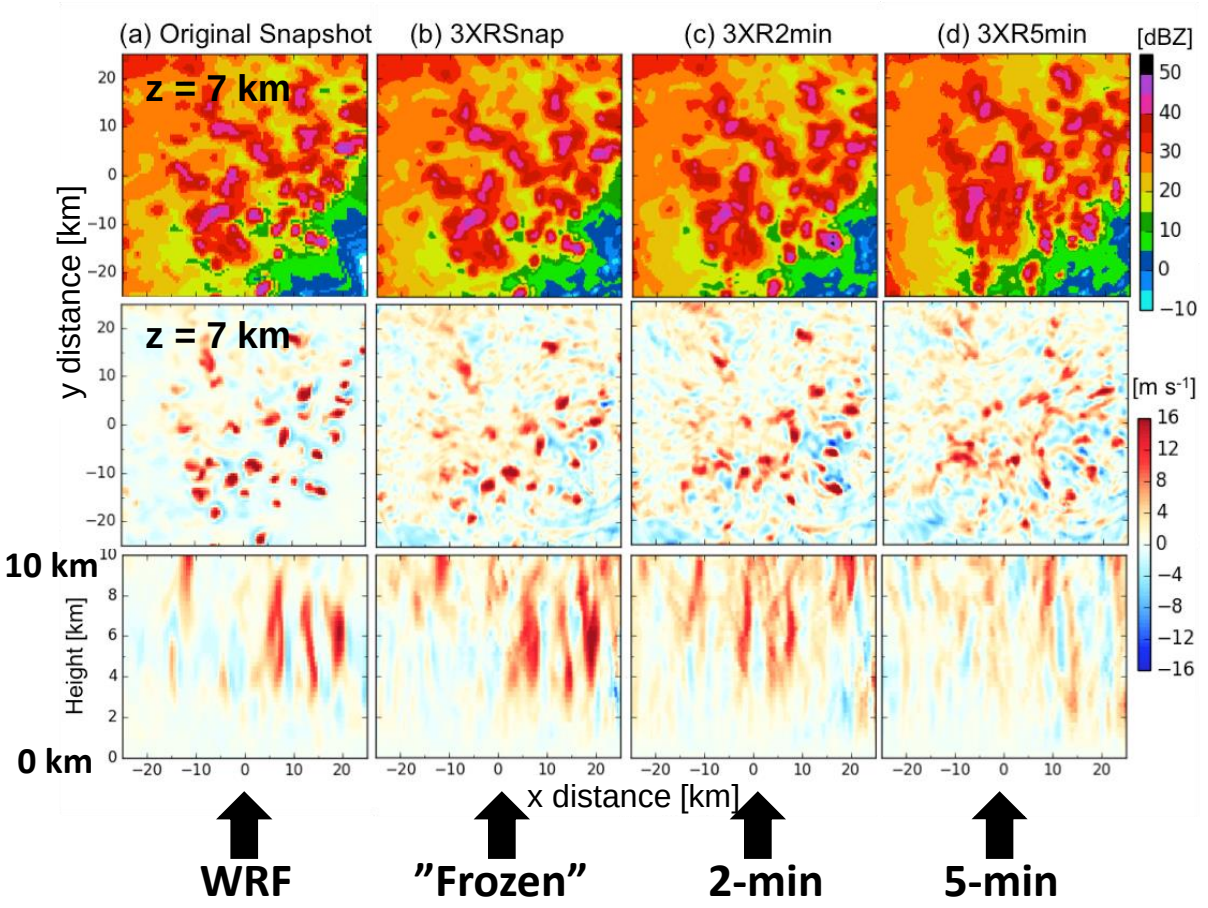


- Profiling radar sites were randomly selected.
- Cloud fraction was integrated over time and averaged over sites.
- Time integration >2 hours from >4 sites would be needed for better estimates.

Investigation of effect of VCP strategies on multi-Doppler radar wind retrieval

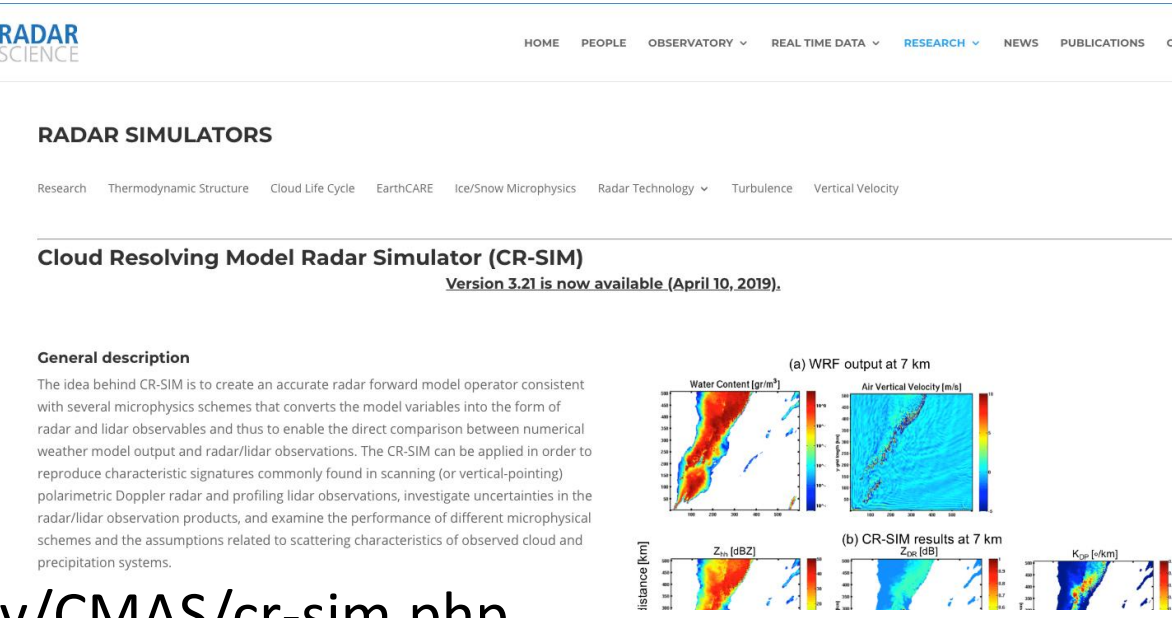
- Simulated snapshot, 2-min VCP, and 5-min VCP, different number of elevation angles in VCP, and different number of radars.
- The VCP elevation strategy and sampling time have a significant effect on the retrieved updraft properties above 6 km altitude.
- 2-min or shorter VCPs have small impacts.
- Increasing the density of elevation angles is more effective to reduce the uncertainty.

Simulated radar reflectivity and vertical velocity retrieval



Oue, M., P. Kollias, A. Shapiro, A. Tatarevic, and T. Matsui, 2019: Investigation of observational error sources in multi-Doppler-radar three-dimensional variational vertical air motion retrievals, *Atmos. Meas. Tech.*, **12**, 1999-2018, https://doi.org/10.5194/amt-12-1999-2019.

Open Source



- Available at
  - https://www.bnl.gov/CMAS/cr-sim.php
  - https://you.stonybrook.edu/radar/research/radar-simulators/
- Under the GNU General Public License (GNU GPL)
  - Note: earlier CR-SIM versions were licensed under GNU LGPL
- Contact:
  - Mariko Oue, mariko.oue@stonybrook.edu
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Future Work Toward More User-Friendly CR-SIM

- Create a platform to interact between developers and users (e.g. e-mailing list, website)
- Frequent updates and organizing versions
  - Stable version and buggier version
  - Separate source code and lookup tables
  - Utilize development tools (e.g. Git, Github)
- Develop visualization tools which will help to improve the CR-SIM and maintenance activities

Summary

- CR-SIM package is a useful tool to evaluate cloud model simulations and observation-based retrievals, and also can be used to asses the effectiveness of new observation strategies.
- Wide user community (it is used by more than 9 institutions)
- Open source: Available under GNU GPL license at

  https://www.bnl.gov/CMAS/cr-sim.php

  https://you.stonybrook.edu/radar/research/radar-simulators/
- Being continuously improved by interacting with users
- Can be easily extended to different CRMs and LESs with various microphysical schemes