PNNL-30502

Assimilating Scanning Radar Data into High-Resolution Models

September 2020

James N Marquis
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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Technical Report

1. Background:

The aim of this project is to improve the initial conditions of km-scale simulations of deep convective storms by assimilating cloud-scale weather radar observations. Accomplishment of this goal may result in more accurate numerical forecasts of clouds and precipitation than if the background meteorological conditions are solely relied upon for convection initiation and intensification, as is typical of most operational and research models. These more accurate numerical analyses will increase the effectiveness of research efforts using LES cloud models as tool to better understand land-atmosphere coupling, boundary layer turbulence, and cloud processes, each used for model parameterization development. Our work performed during this reporting period included: i) assessment of radar data sets for use in data assimilation ('DA') experiments, ii) quality control of the radar data set and format conversion to one acceptable to DA schemes utilized by the Weather Research and Forecasting (WRF) model, and iii) examination of the sensitivity of the numerical representation of cloud-scale wind and microphysical features to a variety of tunable DA parameters.

2. Method:

We assimilated 3D plan-projection-indicator (PPI) volumes collected by the ARM CSAPR2 radar during the ARM CACTI project (https://www.arm.gov/publications/programdocs/doe-sc-arm-19-028.pdf) because of the vertically-deep scanning strategy utilized and the excellent spatial resolution frequently achieved within nearby convective storms. We focused on 2 hours of data collected on 4 November 2018, during which a deep convective precipitating cloud developed within 30-40 km of the radar. Radar reflectivity and velocity fields were first processed using Taranis (a tool developed by the CMDV-MCS and ICLASS-SFA projects) and further revised to dealias radial velocity, and to remove ground clutter, clear-air returns, and occasional small-scale noise. Subsequent processing smoothed the data using a 2-pass running filter and interpolated to a 1 km horizontal grid spacing using a matlab script written by PI Marquis. We coupled the WRF model with a 3DVAR DA scheme for most of our experiments. Commensurate with the smoothed radar observations, the model employed a 1-km grid and was initialized from an operation model analysis. We performed a variety of sensitivity tests altering observation and DA parameters, including: i) assimilation of single reflectivity and velocity control observations, ii) individual and multiple PPI scan volumes, iii) prescribed length and weighting scales of observations upon the model variables, and iv) forecasting between consecutive DA time steps (i.e., DA cycling).

3. Outcomes:

Our sensitivity experiments focused on tuning the impact of observations toward the accurate reproduction of storm morphology and location on the model grid. We initially performed a few DA experiments using a more complex 4DVAR DA scheme. Although many aspects of desired storm structure were reproduced, there was also a significant amount of spurious convective clouds in the analyses. These experiments were computationally much more expensive than our 3DVAR experiments and would require significantly more effort to properly tune the DA parameters and background meteorological state to optimize its performance. Therefore, the majority of our focus was on our 3DVAR analyses.

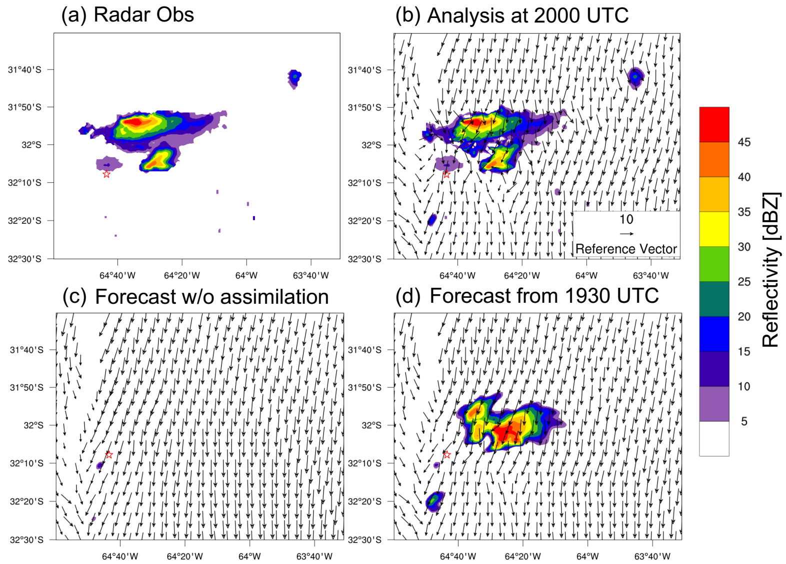

Figure 1. Radar reflectivity (dBZ) and wind vectors (b-d) valid at z = 2 km at 2000 UTC on 4 Nov 2018 as: (a) observed by CSAPR2, (b) analyzed by WRF after assimilation of the 1915-2000 UTC CSAPR2 volumes, (c) forecasted by WRF without any radar DA, and (d) forecasted by WRF from initial conditions produced through DA of the 1915-1930 UTC CSAPR2 volumes.

The bulk of our tests focused on tuning precipitation and velocity increment (i.e., difference between the numerical analysis before and after assimilation) structure to a range of radii of influence and weighting of individual observations to the model analysis. Results were most sensitive to the prescribed horizontal radius of influence. After testing a variety of values, we converged on a set of length scales that produced convincing simulated radar reflectivity and draft structure after assimilating only a few radar PPI volumes (c.f., Fig. 1a and 1b). This success is emphasized by the lack of *any* convective precipitation in analogous experiments when no radar data are assimilated (c.f., Fig. 1b and Fig. 1c). The largest hydrometeor discrepancies between observations and DA analyses in our experiments occurs above the environmental freezing level (not shown), suggesting that there exists room for improvement in the conversion of observed radar reflectivity to simulated ice phase particles during DA. Despite generally promising precipitation and wind analyses after only a few DA cycles, subsequent short-term forecasts of storm structure did not verify as well against observations (c.f., Fig. 1a and 1d); precipitation structure often deteriorated or was unrealistic within 30 minutes after the last prescribed assimilation (e.g., the southern convective cell is erroneously favored over the northern one; Fig. 1d). These simulation errors may be a result of: only assimilating a few PPI radar volumes prior to forecasting; ice microphysical misrepresentation aloft; errors in the background environmental condition; and model physics errors.

4. Considerations for future application:

Although these results are promising, we had to limit our research scope because of the short work period afforded to the project (July - Sept 2020). We recognize several opportunities for future efforts that could improve upon this seed work, including: i) assimilation of CSAPR2 range-height-indicator (RHI) radar scans that characterize the deep vertical structure of clouds and increase the amount of data available for DA, ii) increasing model and radar data resolution toward smaller grid spacing (e.g. 250 m) to further improve resolvable details of updraft and microphysical structure for LES applications, iii) improvement of the background meteorological state by assimilating environmental observations, and iv) improvement of frozen hydrometeor analyses above the freezing level. Performance of these experiments on additional cases will provide a greater perspective on the generality of DA parameters required to apply our technique to other radar data sets.

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