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DOE/SC-ARM-19-026

Real-Time Boundary-Layer Profiling at the Southern Great Plains Field Campaign Report

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October 2019

ARM

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

ADC	ARM Data Center
AERI	atmospheric emitted radiance interferometer
ARM	Atmospheric Radiation Measurement
CLAMPS	Collaborative Lower Atmospheric Mobile Profiling Systems
CONUS	conterminous United States
DL	Doppler lidar
FFaIR	Flash Flood and Intense Rainfall
FTP	File Transfer Protocol
HMT	Hydrometeorological Testbed
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
PECAN	Plains Elevated Convection at Night
PISA	PECAN Integrated Sounding Array
PPI	plain-parallel-indicator
RASS	radio acoustic sounding system
SGP	Southern Great Plains
UTC	Coordinated Universal Time
UW	University of Wisconsin
VAD	velocity-azimuth-display
WOFS	Warn-on-Forecast system
WRF	Weather Research and Forecasting model

Contents

Figures

1.0 Summary

The National Research Council (NRC 2009, 2010) has argued that the nation needs to establish a boundary-layer profiling network across the conterminous United States (CONUS). These observations would benefit a wide range of applications including short-term severe weather forecasting by providing better initial conditions for weather prediction models (Wulfmeyer et al. 2015).

While active remote sensors like Raman lidars (e.g., Turner et al. 2016) and differential absorption lidars (e.g., Spuler et al. 2015) are able to provide high-temporal-and-vertical-resolution profiles of water vapor and temperature from the ground, these systems are not yet available commercially. Passive remote-sensing systems, such as multi-channel microwave radiometers and infrared spectrometers, are commercially available and can provide retrieved profiles of temperature and humidity (e.g., Löhnert et al. 2009; Blumberg et al. 2015). These passive thermodynamic profiling systems are certainly a candidate for a possible boundary-layer network. Radio acoustic sounding systems (RASS), coupled with either a radar or sodar, can provide partial profiles of virtual temperature and are another option. However, the RASS signal is audible and considered by many to be annoying, and strong winds blow the acoustic signal away from the radar and greatly hamper its maximum vertical range.

Three basic ground-based remote sensing technologies are used for wind profiling. All of these are active remote sensors that take advantage of a Doppler-shifted signal along different radial directions to determine the wind speed and direction. The three approaches are sodar (which uses pulses of sonic energy), radar (pulses of microwave energy), or lidar (pulses of laser energy). All three methods use either plane-parallel-indicator (PPI; constant elevation) scans that are analyzed with a velocity-azimuth-display (VAD) technique or Doppler beam-swinging observing strategies, which are then analyzed to provide the horizontal wind speed and direction profiles as a function of range.

The operational weather community seeks to investigate the impact of assimilating these ground-based boundary-layer profiling technologies on weather forecasts. One example of the positive impact is shown by Hu et al. (2019), which used similar observations collected during the Plains Elevated Convection at Night (PECAN) experiment (Geerts et al. 2017). During PECAN, the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) user facility contributed five atmospheric emitted radiation interferometers (AERIs), in addition to the system already installed at ARM's Southern Great Plains (SGP) observatory Central Facility, to provide thermodynamic profiles at the PECAN Integrated Sounding Array (PISA) sites. Each PISA site also included either a Doppler lidar or radar wind profiler to provide wind profiles to complement the thermodynamic profiling of the AERI.

On 13 July, a tornadic supercell storm formed near Nickerson, Kansas, which then propagated southwest (an atypical direction for the central plains) and ultimately achieved EF-3 status. This storm was not warned by the National Weather Service (NWS), and indeed was not simulated by the operational weather forecast models run by the NWS. Hu et al. (2019) assimilated the remotely sensed thermodynamic and wind profiles from the PISA network into the experimental Warn-on-Forecast system (WOFS; Stensrud et al. 2013; Wheatley et al. 2015) being developed at the National Oceanic and Atmospheric Administration (NOAA) National Severe Storms Laboratory (NSSL). Assimilating the AERI and wind profile data in the WOFS enabled forecast of convective initiation with 90 minutes lead time. Those observations increased the moisture in the near-storm WOFS environment and low-level convergence along the pressure trough, which helped initiate convection in the WOFS forecast. Without those observations, the WOFS failed to initiate convection. Those observation also enabled WOFS to forecast the tornadic storm in the right place at the right time, and the modeled storm even propagated in the correct direction (Figure 1). This single case demonstrated the potential value of these ground-based profiling remote-sensing systems. However, additional cases are needed to confirm that these profiling systems indeed do add value to the forecasts, and there was a desire to have the WOFS and other forecast models run in real time so that the NWS forecasters could see the impact as the storm was evolving.

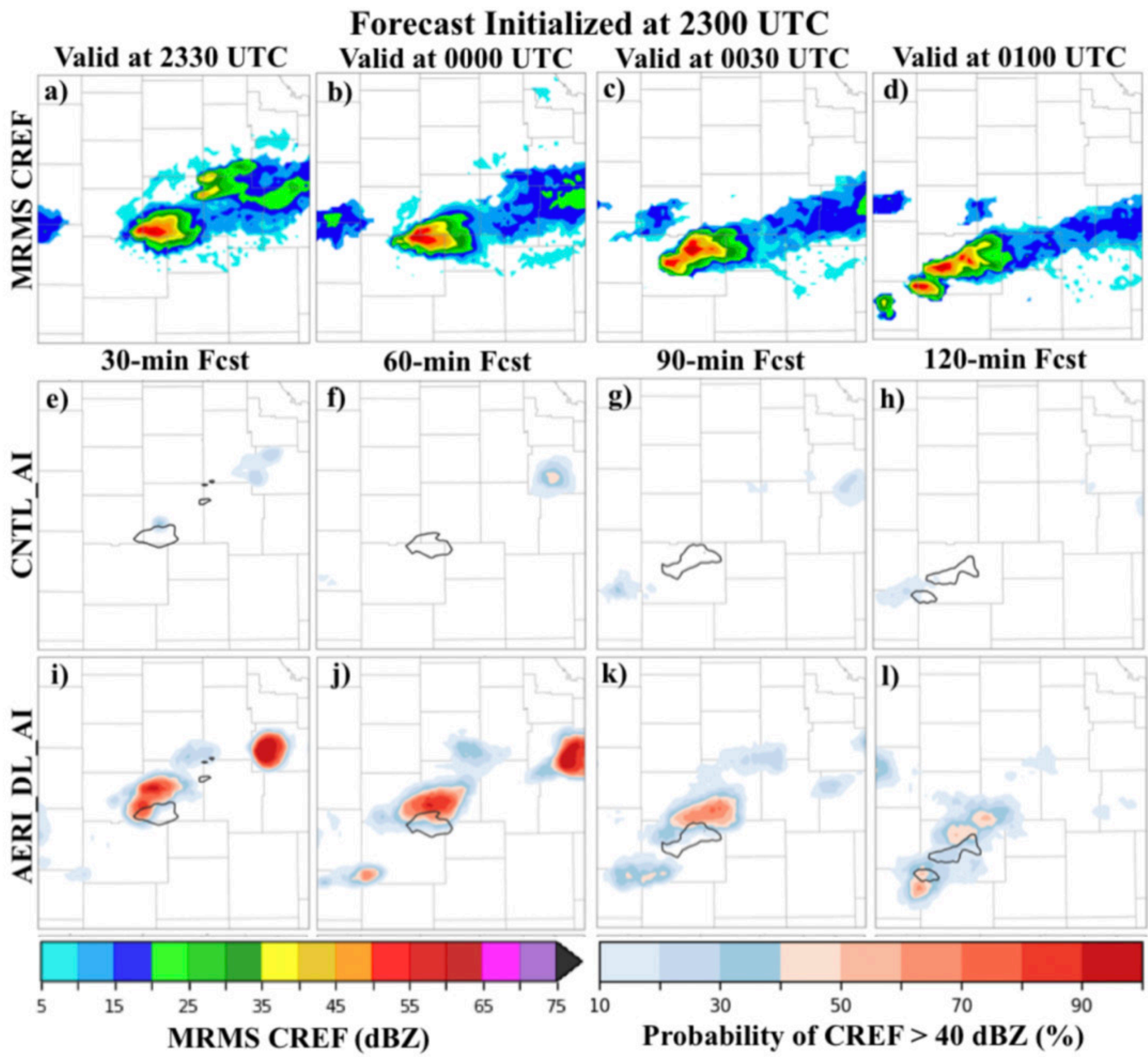


Figure 1. The observed radar reflectivity (top row), and the probability that the reflectivity would be above 40 dBZ from the WOF ensemble system for the control forecast that did not use the AERI and Doppler lidar data in the model initialization (middle row) and included the remotely sensed thermodynamic and wind profiles (bottom row). The black contours on the middle and bottom rows indicate regions where the observed reflectivity was larger than 40 dBZ. From Hu et al. (2019).

The ARM user facility has established a prototype network at its SGP observatory, with five sites able to provide high-temporal-resolution (better than 5 min) profiles of temperature and humidity (retrieved from the AERI) and wind (from the Doppler lidar [DL]) profiles. These five sites are the sgpC1, sgpE32, sgpE37, sgpE39, and sgpE41 sites (Figure 2). The goal of this project was to provide the wind and thermodynamic profiles from these five sites with minimal latency (ideally less than 15 minutes) so that weather prediction models could assimilate these observations.

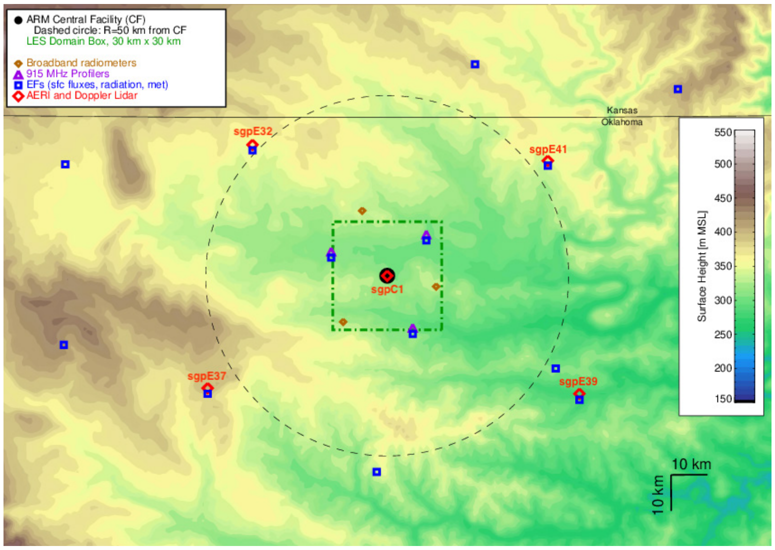


Figure 2. The ARM Southern Great Plains site. The red diamonds indicate where there are AERIs and Doppler lidars, with the exception that the sgpE41 site does not have an AERI (only a Doppler lidar).

NOAA has funded two projects (led by Drs. Wagner and Yussouf, respectively) to evaluate the impact of assimilating AERI and Doppler lidar profiles in real time into the Weather Research and Forecasting (WRF) model. They were the primary customers of these data.

2.0 Results

It was non-trivial to establish the automatic data flow needed for this project. The steps needed included:

1. Transfer of the data from the instruments to the ARM Data Center (ADC)
2. Transfer of the data from the ADC to the processing machines at the University of Wisconsin – Madison (UW)
3. Derivation of the higher-order products
    a. Application of the VAD technique to derive wind profiles from the DL data
    b. Application of the AERI noise filter (Turner et al. 2006) to the AERI radiance data
    c. Application of the AERIoe retrieval (Turner and Blumberg 2019) to derive thermodynamic profiles
4. Transfer of these higher-order products to the modeling groups at UW and NSSL
5. If the case has "interesting weather", assimilate these observations into the WOF system (NSSL) or the WRF model (UW).

Several hurdles had to be overcome in this process. The first was to handle the fact that ARM operates two different versions of the AERI; the version2 system was built in the 1990s by UW and the version4 systems are commercially available and purchased by ARM in the 2010s. Specialized software had to be written to move data from the version2 systems to the ADC, and there were several hiccups that occurred during the campaigns that required addressing. Data transfer from the version4 AERIs and DLs were more straightforward.

Additionally, the ADC needed to develop a new approach to provide data in real time to users that enabled the ADC staff to know who was getting the data. ADC staff developed the "LiveData" product during this campaign. Several iterations were needed between Dr. Turner and the ADC staff to work the bugs out of these codes.

The derivation of the higher-order products from the AERIs and DLs was relatively straightforward, as this process had been developed as part of the Collaborative Lower Atmospheric Mobile Profiling Systems (CLAMPS; Wagner et al. 2019) developed when Dr. Turner was at NSSL. This software was ported to an internal UW computer, where the processing was performed. Higher-order output from these routines were then staged on a protected FTP site that Drs. Yussouf and Wagner could access for their model runs.

Ultimately, we succeeded in providing thermodynamic and wind profiles from the ARM SGP sites with an average latency of approximately 15 minutes.

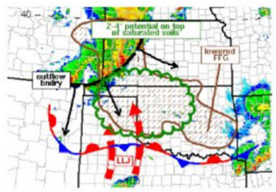
The WOFS being developed at NSSL is often highlighted in NOAA Testbed activities, especially when dynamic events occur. Unfortunately, and partially due to the small area covered by the ARM SGP site, very few storms were analyzed by the WOFS during this campaign because they did not come through the ARM domain. On 23–24 June 2018, a large convective storm did propagate over the SGP, and the ARM observations were used in the WOFS forecasts. The results from this model run were analyzed in real time during the Hydrometeorological Testbed (HMT) Flash Flood and Intense Rainfall (FFaIR) experiment activity, and the results influenced the operational forecast that was issued for this event (see red box, Figure 3). Work is currently underway to perform a data denial experiment to demonstrate the additional value that was added by the remote sensors relative to the baseline observations.

WPC Met Watch

Mesoscale Precipitation Discussion: #0355 (2018)
(Issued at 932 PM EDT SUN JUN 24 2018)

MPD Selection

Latest | Previous | Next | MPD Summary Page



180625/0130 NATL 1 KM COMP REFL 1.00
WPC MPD #0355

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MESOSCALE PRECIPITATION DISCUSSION 0355
NWS WEATHER PREDICTION CENTER COLLEGE PARK MD
932 PM EDT SUN JUN 24 2018

AREAS AFFECTED...SRN KS INTO OK AND THE TX PANHANDLE

CONCERNING...HEAVY RAINFALL...FLASH FLOODING POSSIBLE

VALID 250130Z - 250730Z

SUMMARY...FLASH FLOODING WILL BE POSSIBLE FROM HEAVY RAIN EXPECTED
TO MOVE ACROSS SATURATED SOILS OF THE NORTHEASTERN TEXAS AND
EASTERN OKLAHOMA PANHANDLES INTO PORTIONS OF CENTRAL OKLAHOMA.
LOCALIZED TOTALS OF 2-4 INCHES WILL BE POSSIBLE.

DISCUSSION...01Z RADAR SHOWED A FORWARD PROPAGATING MCS MOVING
EAST-SOUTHEASTWARD INTO WESTERN KANSAS...WITH STRONG OUTFLOW
ARCING SOUTHWESTWARD TO THE COLORADO/NEW MEXICO BORDER. THE 00Z
RAOB FROM AMA SHOWED STEEP 700-500 MB LAPSE RATES OF 9 C/KM AND
3900 J/KG MUCAPE AMID A LOW LEVEL CAPPING INVERSION AT 700 MB WITH
17C NOTED. AS THE OUTFLOW BOUNDARY NEAR THE OKLAHOMA PANHANDLE
CONTINUES TO THE SOUTH...ENOUGH LIFT IS EXPECTED TO BE PROVIDED TO
OVERCOME THE CAPPING INVERSION NOTED TO THE SOUTH...ALONG WITH AN
INCREASING SOUTHERLY LOW LEVEL JET OVER WEST TEXAS. RAP FORECASTS
HAVE BEEN CONSISTENT WITH THE DEVELOPMENT OF 45-55 KT OF 850 MB
FLOW OVER THE TEXAS PANHANDLE MEETING UP WITH THE ADVANCING
OUTFLOW BOUNDARY FROM THE NORTH ALLOWING FOR STRONG LOW LEVEL
CONVERGENCE AND LIKELY SUBSEQUENT CONVECTIVE DEVELOPMENT BENEATH
INCREASING DIVERGENT/DIFFLUENT FLOW AHEAD OF AN ADVANCING UPPER
LEVEL TROUGH AXIS.

RECENT RAINFALL OVER MUCH OF THE REGION...INCLUDING A STRIPE OF
2-4 INCHES OVER THE PAST 24 HOURS IN WESTERN/CENTRAL
OKLAHOMA...HAS LOWERED FLASH FLOOD GUIDANCE TO 1.5 TO 2.5 INCHES
IN 3 HOURS. WHILE CONVECTION SHOULD BE LARGELY PROGRESSIVE OFF TO
THE SOUTH AND EAST...RAP FORECASTS SHOW GROWING ALIGNMENT OF
850-300 MB MEAN FLOW AND 850 MB WINDS ACROSS THE TEXAS PANHANDLE
INTO CENTRAL OKLAHOMA SETTING UP BY ABOUT 06Z WHICH MAY ALLOW FOR
TRAINING. RECENT RUNS OF THE HRRR AND EXPERIMENTAL NSSL NEWS-E
GUIDANCE HAVE SUGGESTED THE POTENTIAL FOR 2-4 INCHES FROM THE
TEXAS PANHANDLE INTO NORTHWESTERN OKLAHOMA THROUGH 07Z. GIVEN THE
WET ANTECEDENT CONDITIONS...FLASH FLOODING WILL BE POSSIBLE.

OTTO

ATTN...WFO...AMA...DDC...ICT...OUN...

ATTN...RFC...ABRFC...

LAT...LON   37589998 37349835 36859732 36089702 35469727
            35099819 34909936 35110135 35890212 36530208
            37230158
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Last Updated: 932 PM EDT SUN JUN 24 2018

Figure 3. The NWS-issued mesoscale precipitation discussion that highlights the use of the experimental WOF system (called NEWS-E in this announcement). AERI and Doppler lidar data from this real-time campaign were used in that forecast.

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