DOE/SC-ASR-23-001

CSAPR2 Optimized Convective Cell Tracking Data during TRACER

M Oue
EP Luke
BP Treserras
P Kollias

September 2023

U.S. DEPARTMENT OF ENERGY

Office of Science

ASR Atmospheric System Research

DISCLAIMER

DOE/SC-ASR-23-001

CSAPR2 Optimized Convective Cell Tracking Data during TRACER

M Oue, Stony Brook University (SBU)
BP Treserras, McGill University
EP Luke, Brookhaven National Laboratory
P Kollias, SBU

September 2023

How to cite this document:

Oue, M, BP Treserras, EP Luke, and P Kollias. 2023. CSAPR2 Optimized Convective Cell Tracking Data during TRACER. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SC-ASR-23-001.

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

Acronyms and Abbreviations

3D	three-dimensional
ARM	Atmospheric Radiation Measurement
ASR	Atmospheric System Research
CSAPR2	2nd Generation C-band Scanning ARM Precipitation Radar
LROSE	Lidar Radar Open Software Environment
LT	local time
MAAS	Multisensor Agile Adaptive Sampling
NetCDF	Network Common Data Form
NEXRAD	Next-Generation Weather Radar
PPI	plan position indicator
Py-ART	Python ARM Radar Toolkit
RHI	range height indicator
TRACER	Tracking Aerosol Convection Interactions Experiment
VIL	vertically integrated liquid

Contents

Figures

Tables

1.0 Introduction

One of the challenges in analyzing convective cell properties is to observe the quick evolution of individual convective cells. While the operational radar data provide a volumetric data set to analyze radar observables of convective precipitation clouds, previous studies also suggested the quick evolution of cell life cycle that might not be captured by conventional radar volume scan strategies that take ~5-7 minutes. Aiming at enhancing our understanding of the links between convective cloud kinematic and microphysical processes as well as life cycles, the Tracking Aerosol Convection Interactions ExpeRiment (TRACER; Jensen et al. 2019) was conducted at Houston, Texas, in 2022. The TRACER campaign deployed the 2nd generation C-band Scanning ARM Precipitation Radar (CSAPR2), which performed frequent updates of range height indicator (RHI) and sector plan position indicator (PPI) scans to track individual convective cells every < 2 minutes, guided by a new cell tracking framework, Multisensor Agile Adaptive Sampling (MAAS; Kollias et al. 2020). This allows for capturing fast-evolving radar observables. We provide the processed CSAPR2 cell tracking data in CfRadial format collected during the TRACER field campaign from June to September 2022. The data files include processed radar variables: noise-masked reflectivity and differential reflectivity corrected for rain attenuation and systematic biases, noise-masked dealiased radial velocity, specific differential phase, locations of target cells (latitude, longitude, radar range), and radar-echo classification. Figure 1 provides an example of a 3D image of CSAPR2 reflectivity from the lowest PPI scan and an RHI scan after data processing.

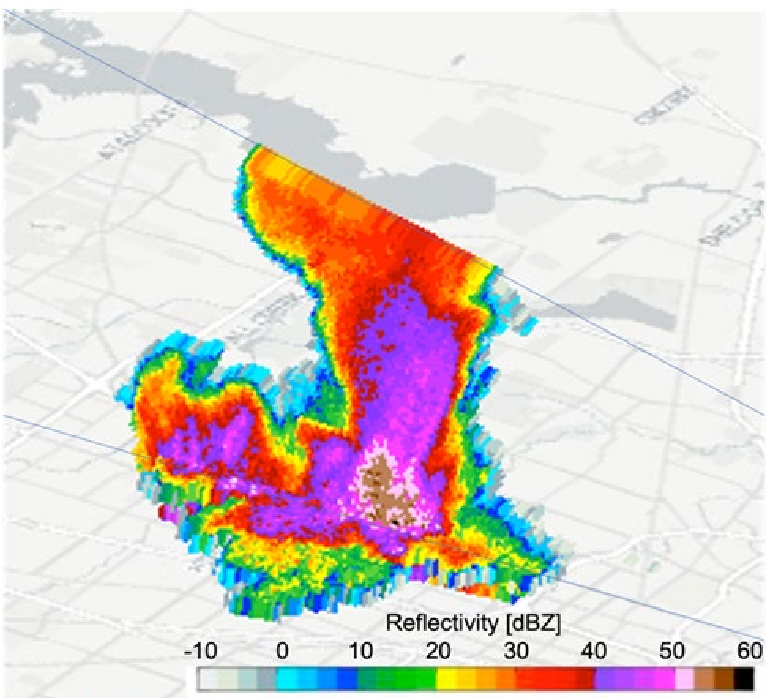

Figure 1. 3D image of CSAPR2 reflectivity from the lowest PPI scan and an RHI scan after data processing.

2.0 Algorithm and Methodology

2.1 Input Data

To observe rapid changes of convective cell properties, CSAPR2 performed cell tracking scans during the TRACER field campaign from June to September 2022. CSAPR2 first performed sector PPI scans at three elevation angles (low, middle, and high) followed by four to six RHI scans with different criteria (Table 1) targeting a convective cell. The scan strategies (e.g., PPI sector range, PPI elevation angles, RHI elevation range, RHI direction) were optimized in the MAAS framework using eternal sources of measurements (i.e., Next-Generation Weather Radar [NEXRAD], satellite) by real-time cell tracking using the NEXRAD at Houston (KHGX) PPI scan data (used vertically integrated liquid, VIL). Each set of the scans were achieved within two minutes. The data period used is 2022/06/04–2022/09/25.

Table 1. Criteria for the CSAPR2 scans. $\frac{\Delta \mathrm{DV}}{\Delta \mathrm{r}}$ is the radial gradient of Doppler velocity at PPI_3.

<table>
<tr><th>Time period</th><th>PPI</th><th colspan="2">RHI</th></tr>
<tr><td>06/01/22–06/15/22</td><td rowspan="4">PPI_1: cell top
PPI_2: cell middle
PPI_3: 3º elevation</td><td colspan="2">RHI_1: cell centroid</td></tr>
<tr><td>06/16/22–08/01/22</td><td>RHI_1: cell centroid
RHI_2: cell max VIL</td><td>RHI_3: cell max Z_{HH}
RHI_4: cell max Z_{DR}</td></tr>
<tr><td>08/02/22–09/08/22</td><td>RHI_1: cell centroid
RHI_2: cell max VIL
RHI_3: cell max Z_{HH}</td><td>RHI_4: cell max Z_{DR}
RHI_5: cell max Z_{HH}
RHI_6: cell max Z_{DR}</td></tr>
<tr><td>09/09/22–09/30/22</td><td>RHI_1: cell centroid
RHI_2: cell max VIL
RHI_3: cell max Z_{HH}</td><td>RHI_4: cell max $\frac{\Delta DV}{\Delta r}$
RHI_5: cell max Z_{HH}
RHI_6: cell max $\frac{\Delta DV}{\Delta r}$</td></tr>
</table>

2.2 Processing Radar Data

The collected data were converted into CfRadial NetCDF format (https://www.eol.ucar.edu/system/files/CfRadialDoc.v1.4.20160801.pdf).

An open-source radar processing tool (Lidar Radar Open Software Environment [LROSE]); (Bell et al. 2022) was used to compute specific differential phase (K_{DP}) and correct radar reflectivity (Z_{HH}) and differential reflectivity (Z_{DR}) for rain attenuation using K_{DP} (Jameson 1990). We also provided radar-echo classification using LROSE.

In addition, we computed K_{DP} using an iterative algorithm proposed by Hubbert and Bringi (1995) and provided attenuation corrected Z_{HH} and Z_{DR} using this K_{DP}, so that the users can choose a better product.

Aliased Doppler velocity was corrected using the Python ARM Radar Toolkit (Py-ART; Helmus and Collis 2016).

Figure 2 shows processed radar variables from an RHI scan.

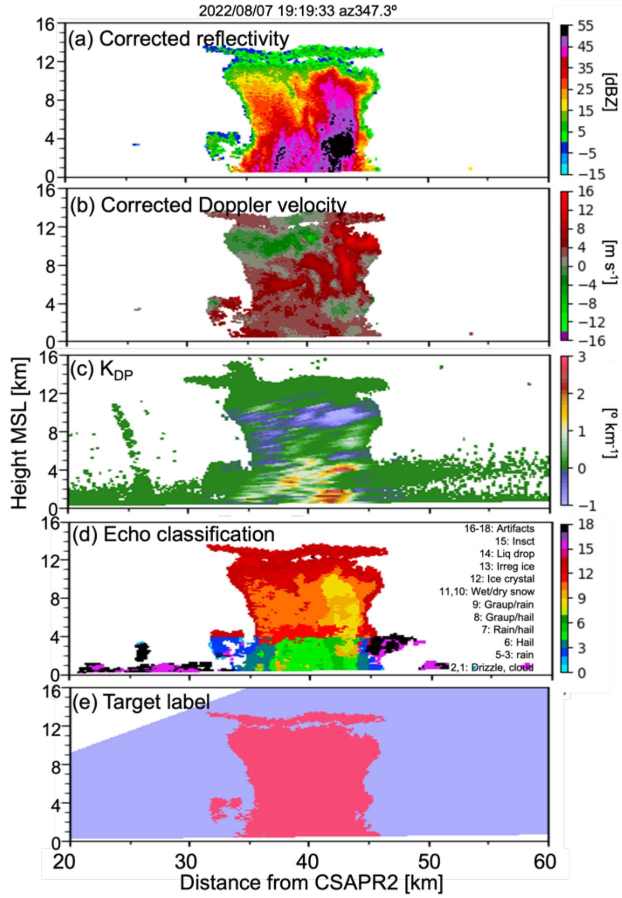

Figure 2. Processed radar variables from an RGI scan on 2022/08/07.

2.3 Calibration

A systematic bias of Z_{HH} was estimated by comparing the low-level Z_{HH} around the Houston ARM Mobile Facility site and reflectivity at C band calculated using the Parsivel disdrometer measurements for stratiform rain cases. The bias-corrected, attenuation-corrected CSAPR Z_{HH} was also evaluated using the NEXRAD Z_{HH}.

A systematic bias of Z_{DR} was estimated by a self-constraint technique. The data collected for rain were plotted in the Z_{DR} versus Z_{HH} domain and the bias for Z_{DR} was estimated so that the observed Z_{DR}-versus-Z_{HH} relationship should be consistent with the theoretical relationship.

2.4 Identifying Target Cell

The PPI and RHI scan data included echoes from target and non-target precipitation clouds. We masked non-target echoes and provided latitude/longitude information for the target cell.

2.5 Output Data

Each set of the three PPI scans and four or six RHI scans was bundled into a single file in the CfRadial format. The variables include observed Z_{HH}, Z_{DR}, Doppler velocity, spectrum width, correlation coefficient, and differential phase, calculated K_{DP}, calibrated Z_{HH} and Z_{DR} corrected for rain attenuation and systematic biases, dealiased Doppler velocity, radar-echo classification, latitude, longitude, and distance from the radar of target cells, and label of the target cell.

The data are available as an ARM principal investigator product at https://doi.org/10.5439/1969992.

The data set included 24,423 scan bundles. Figure 3 shows horizontal distributions of the occurrences of convective cells tracked by CSAPR2 during the observation period at the three time ranges. CSAPR2 observed the largest number of cells in the afternoon (12–18 LT), most of which were collected in the west-to-southwest domain.

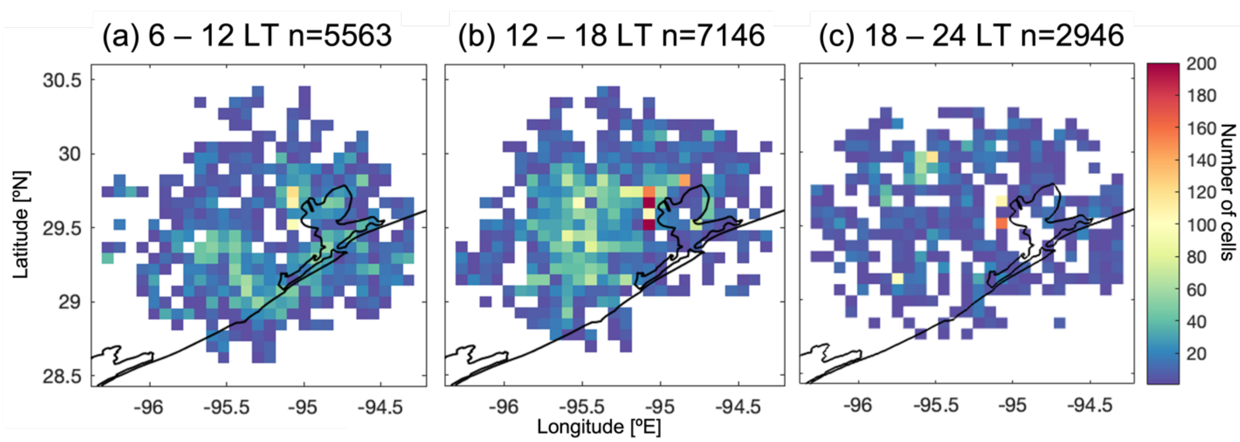

Figure 3. Horizontal distributions of occurrences of cells observed by CSAPR2 at the three time ranges (a) 6-12 local time (LT), (b) 12-18 LT, and (c) 18-24 LT from the entire observation period. The total number of cells (n) during each period is displayed on each panel.

3.0 Summary

CSAPR2 performed rapid scan observations targeting individual convective cells to capture evolutions of microphysical and dynamical characteristics of convective cells during TRACER 2022. We provide the quality-controlled, value-added CSAPR2 sector PPI and RHI scan data. This allows us to capture rapid changes of radar observables that represent dynamical and microphysical evolutions of convective cores. The data set includes 24,423 scan bundles, most of which were collected in the afternoon and the total of >1000 cells tracked from June to September 2022. The data files include processed radar variables including noise-masked reflectivity and differential reflectivity corrected for rain attenuation and systematic biases, noise-masked dealiased radial velocity, specific differential phase, locations of target cells, and radar-echo classification. The data set is expected to provide not only a complement to the volumetric analysis from the operational radar measurements, but also new insights into cell evolution.

4.0 References

Bell, MM, M Dixon, W-C Lee, B Javornik, J DeHart, T-Y Cha, and A DesRosiers. 2022. Nsf-lrose/lrose-topaz: lrose-topaz stable final release 20220222 (lrose-topaz-2022022). Zenodo. https://doi.org/10.5281/zenodo.6909479

Helmus, JJ, and SM Collis. 2016. "The Python ARM Radar Toolkit (Py-ART), a Library for Working with Weather Radar Data in the Python Programming Language". *Journal of Open Research Software* 4(1): e25, https://doi.org//10.5334/jors.119

Hubbert, J, and VN Bringi. 1995 "An iterative filtering technique for the analysis of copolar differential phase and dual-Frequency Radar Measurements." *Journal of Atmospheric and Oceanic Technology* 12(3): 643–648, https://doi.org/10.1175/1520-0426(1995)012<0643:AIFTFT>2.0.CO;2

Jensen, M, E Bruning, D Collins, A Fridlind, P Kollias, C Kuang, D Rosenfeld, AV Ryzhkov, A Varble, SD Brooks, S Collis, E Defer, J Fan, J Flynn, S Giangrande, R Griffin, J Hu, R Jackson, MR Kumjian, T Logan, T Matsui, G McFarquhar, C Nowotarski, J Quaas, M Oue, R Sheesley, J Snyder, P Stier, S Usenko, S van den Heever, M van Lier Walqui, Y Wang, Y Xu, and G Zhang.2019. Tracking Aerosol Convection Interactions ExpeRiment (TRACER) Science Plan. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SC-ARM-19-017.

Kollias, P, EP Luke, M Oue, and K Lamer. 2020. "Agile adaptive radar sampling of fast-evolving atmospheric phenomena guided by satellite imagery and surface cameras." *Geophysical Research Letters* 47(14), e2020GL088440, https://doi.org/10.1029/2020GL088440