Project Progress Report[1]

to the
National Oceanic and Atmospheric Administration
Collaborative Science, Technology & Applied Research (CSTAR) Program

Improving Understanding and Prediction of High Impact Weather Associated with Low-Topped Severe Convection in the Southeastern U.S.

NOAA Award: NA14NWS4680013
Award period: 5/1/2014 – 4/30/2017 (no-cost extension through 4/30/2018)
Reporting period: 5/1/2014 – 4/30/2018
Final report? Yes

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[1] This report format follows the OMB guidance on performance progress reporting.

I. ACCOMPLISHMENTS

1. What were the major proposed ***goals, objectives, and tasks*** *of this project?*

a) Improve HSLC nowcasting and warning operations by advancing the understanding and interpretation of HSLC radar imagery. To do this we proposed to perform idealized simulations of HSLC convective storms, within which we will study the dynamical processes at work and compare them to pseudo-radar measurements of the simulated storms.
b) Improve short-range prediction and situational awareness of HSLC scenarios by more thoroughly understanding the quality of convection-permitting NWP forecasts, investigating the resolution requirements for useful guidance, and assessing whether model accuracy is a function of synoptic setting/regime. To do this we proposed to perform operational NWP-like hindcasts of notable HSLC events and nulls and test the sensitivity of these hindcasts to grid spacing, model configuration, and initial conditions/lateral boundary conditions (ICs/LBCs).
c) Improve short-to-medium range prediction and situational awareness of HSLC scenarios by investigating and improving the probabilistic information that is available from operational models. To do this we proposed to apply dynamically-based statistical downscaling techniques in order to exploit the information available from the SREF, GEFS, and ExREF model ensembles.
d) Improve operational "best practices" in HSLC environments by supporting an assessment of a number of experimental HSLC diagnosis and forecast products. To advance this operational effort among our NOAA collaborators we proposed to produce an expanded set of real-time HSLC model forecast products (with in-kind production of mesoanalysis products volunteered by SPC).

2. What was accomplished this period under each task?

a) Keith Sherburn created a climatology of HSLC severe weather focusing on both environmental ingredients and large scale settings. This work led to the development of the modified SHERB/E (MOSH/E) parameter, which incorporates large scale forcing in order to add skill in discriminating HSLC severe events from nulls. Keith also performed a matrix of sensitivity experiments with a high resolution numerical model. He then tracked updrafts and vortices in these simulations in order to study their evolution and governing dynamics. This work concludes that both increased 0-1 km shear and increased 0-3 km lapse rates lead to strong low-level updrafts, which ultimately provide enhanced stretching of surface vortices in HSLC convection. Jessica King performed WRF case study simulations of HSLC events and found that severe events often have extreme destabilization over a very short amount of time (a few hours). In many cases, near-surface warm advection was a predominant contributor. However, four severe events affected by strong synoptic forcing for ascent exhibit characteristics of destabilization by the release of potential instability, including cooling and moistening in the low-to-mid-levels.

b) Lindsay Blank conducted analysis and comparison of WRF model forecasts and observations from one severe HSLC event (February 24-25, 2011), and one null case (December 25-26, 2009). She utilized radar-derived mesocyclone detection observations as an observational source against which to compare model forecasts of updraft helicity and other severe proxy forecast output. The ability of model forecasts to produce rotating convection is apparent at even 3.6 km grid length. The largest gains in prediction of several severe-weather proxy parameters were evident between 3.6 and 1.2 km grid length (Figs. 2 and 3). Smaller gains are evident in going to 400-m grid length.

c) Dianna Francisco has created analysis procedures for interrogating model analyses or forecasts, acquiring environmental data in the neighborhood of HSLC severe weather (or null events), and then building a probabilistic equation via an algorithm that identifies the most skillful set of predictors for separating events from nulls. As a part of the testing and development of these algorithms, Xia Sun worked briefly on the project to contribute several WRF simulations of land-falling tropical cyclones that produced tornadoes. As of the end of this project, Dianna's goals were to apply these probabilistic models to both recent event and null cases as well as to real-time operational model forecasts and analyses. This procedure represents a unique way to identify skillful environmental parameters and convert them into probabilities of severe weather. The technique itself is portable to other forecasting problems and datasets.

d) At NCSU we are now producing quasi-operational plots of the modified SHERB and SHERBE (the "MOSH" and "MOSHE") for the GFS, NAM, RAP, and SREF models. To accomplish the goal of careful operational assessment of the SHERB (and other) parameters in HSLC environments, the NCSU team collected (and continues to collect) real-time assessments of forecasting parameters via our web interface. This feedback led to helpful discussion on the CIMMSE blog and during our monthly conference calls.

3. Are the proposed project tasks ***on schedule****? What is the cumulative percent toward completion of each task and the due dates?*

All proposed research has been completed. One or two additional journal articles may yet be prepared and submitted based on this work.

4. What were the major completed ***milestones*** *this period, and how do they compare to your proposed milestones?*

The primary milestones are listed below under the responses for professional development, dissemination, and (in Part II) products. These milestones are in line with what we originally proposed.

5. What opportunities for training and professional development has the project provided?

- Jessica King obtained an M.S. degree via support from this project (May 2016).
- Lindsay Blank obtained an M.S. degree via support from this project (May 2017).
- Keith Sherburn obtained a Ph.D. degree via support from this project (May 2018).
- Dianna Francisco and Xia Sun have made progress toward completion of Ph.D. degrees via support from this project.

- Keith Sherburn was selected to be a NOAA Pathways Program student intern at the Weather Forecast Office in Raleigh, NC. This added a unique blend of O2R and R2O to Keith's work and the CSTAR project as a whole. After graduating, Keith accepted a position at NWSFO-Rapid City, SD.
- During the project, several CSTAR collaborators have participated in various planning and organizing activities and a workshop associated with the Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE).
- Students working on this project helped to coordinate special sounding launches during HSLC severe weather days at NCSU (these launches were funded under a separate NSF grant).

6. How were the results disseminated to communities of interest?

- Peer-reviewed journal articles (see Part II: Products)
- Conference presentations (see Part II: Products)
- Student theses and defense presentations (see Part II: Products)
- Regional CSTAR workshops held in Raleigh in November 2014 and April 2017. CSTAR PIs and students presented research results and there were extended discussions about future directions and regional HSLC forecasting concerns. Roughly 20 NWS personnel (from 10 WFOs as well as Eastern Region Headquarters) attended each workshop, and others were able to teleconference in.
- Regional CSTAR conference calls, held most months throughout the project. CSTAR students shared research results with NOAA personnel and HSLC severe weather events were often discussed by the group. At one time or another there were 14 different NWS WFOs participating on these calls, as well as the Storm Predication Center.
- Keith Sherburn presented his results in national webinars/VLab Forums in October 2014 and June 2017. Jessica King presented her results in a national webinar in April 2016.
- PI Parker travelled to Norman, OK to present a seminar in September 2015, and had an extended meeting with forecasters from the Storm Predication Center. This meeting included an update on the progress of CSTAR student research, as well as time for feedback and input from the SPC forecasters.

7. What do you plan to do during the next reporting period to accomplish the goals and objectives?

N/A

II. PRODUCTS

1. What were the major completed ***products or deliverables*** *this period, and how do they compare to your proposed deliverables?*

a. The following peer-reviewed publications resulted from this grant:

Sherburn, K. D., M. D. Parker, J. R. King, and G. M. Lackmann, 2016: Composite environments of severe and non-severe high-shear, low-CAPE convective events. *Wea. Forecasting*, **31**, 1899-1927.

King, J. R., M. D. Parker, K. D. Sherburn, and G. M. Lackmann, 2017: Rapid evolution of cool season, low CAPE severe thunderstorm environments. *Wea. Forecasting*, **32**, 763-779.

Sherburn, K. D., M. D. Parker, C. E. Davenport, R. A. Sirico, J. L. Blaes, B. Black, S. E. McLamb, M. C. Mugrage, and R. M. Rackliffe, 2018: Partnering research, education, and operations via a cool season severe weather soundings program. *Bull. Amer. Meteor. Soc*., submitted April 2018.

Sherburn, K. D., and M. D. Parker, 2018: The development of severe vortices within simulated high-shear low-CAPE convection. *Mon. Wea. Rev*., submitted July 2018.

b. The following conference presentations resulted from this grant:

King, J. R., and M. D. Parker, 2014: Synoptic influence on high shear, low CAPE convective events. *27th Conference on Severe Local Storms*, AMS, 2-7 November 2014, Madison, WI.

Sherburn, K. D., and M. D. Parker, 2014: On the usage of composite parameters in high-shear low-CAPE environments. *27th Conference on Severe Local Storms*, AMS, 2-7 November 2014, Madison, WI.

Sherburn, K. D., and M. D. Parker, 2014: High-shear low-CAPE environments: what we know and where to go next. *27th Conference on Severe Local Storms*, AMS, 2-7 November 2014, Madison, WI.

King, J. R., and M. D. Parker, 2015: Conditioning and evolution of high shear, low CAPE severe environments. *16th Conference on Mesoscale Processes*, AMS, 2-6 August 2015, Boston, MA.

Sherburn, K. D., and M. D. Parker, 2015: Examining the sensitivities of high-shear low-CAPE convection to low-level hodograph shape. *16th Conference on Mesoscale Processes*, AMS, 2-6 August 2015, Boston, MA.

Blank, L. and G. Lackmann, 2016: Operational predictability of explicit high-shear low-CAPE convection. Sixth Conference on Transition of Research to Operations, AMS, 11-14 January 2016, New Orleans, LA.

Sherburn, K. D., and M. D. Parker, 2016: Insights from composite environments of high-shear low-CAPE severe convection. *28th Conf. on Severe Local Storms*, AMS, 7-11 November 2016, Portland, OR.

Sherburn, K. D., and M. D. Parker, 2016: The origins of rotation within high-shear, low-CAPE mesovortices and mesocyclones. *28th Conference on Severe Local Storms*, AMS, 7-11 November 2016, Portland, OR.

Sherburn, K. D**.**, and J. Blaes, 2017: Hurricane Matthew: An Ideal Setup for Catastrophic Flooding in Central North Carolina.*17th Conference on Mesoscale Processes*, AMS, 24-27 July 2017, San Diego, CA.

Sherburn, K. D., and M. D. Parker, 2017: Sensitivities of simulated high-shear low-CAPE convection to low-level bulk wind shear and lapse rates. *17th Conference on Mesoscale Processes*, AMS, 24-27 July 2017, San Diego, CA.

Francisco, D. M., and L. Xie, 2017: Constructing a procedure to identify variables associated with storm reports in high-shear low-CAPE severe environments within the Southeastern United States. *24th Conference on Probability and Statistics in the Atmospheric Sciences*, AMS, 27-29 July 2017, Baltimore, MD.

Parker, M.D., 2017: What have we learned about high-shear, low-CAPE severe weather? A review. *9th European Conference on Severe Storms*, 18-22 September 2017, Pula, Croatia. Keynote presentation. Award: *Audience Favorite Oral Presentation.*

Francisco, D. M., and L. Xie, 2018: Probabilistic forecasting of high-shear low-CAPE severe environments in the Southeastern United States. *25th Conference on Probability and Statistics in the Atmospheric Sciences*, AMS, 8-12 January 2018, Austin, TX.

c. The following graduate theses and dissertations resulted from this grant:

Sherburn, K. D., 2017: Environments and Origins of Low-Level Vortices within High-Shear, Low-CAPE Convection. North Carolina State University PhD dissertation available from: http://www.lib.ncsu.edu/resolver/1840.20/35070

King, J. R., 2016: Environmental Conditioning of Cool Season, Low Instability Thunderstorm Environments in the Tennessee and Ohio Valleys and Southeastern U.S. North Carolina State University MS Thesis, available from: http://www.lib.ncsu.edu/resolver/1840.16/10983

Blank, L. R., 2016: Operational Predictability of Explicit High Shear, Low CAPE Convection. North Carolina State University MS Thesis, available from: http://www.lib.ncsu.edu/resolver/1840.20/33739

2. What has the project produced?

- Quasi-operational plots of HSLC parameters, including the newly-developed Modified SHERB/E (MOSH/E) from this grant, are being created in real-time for the NAM, GFS, RAP, and SREF, and shared on our local server.
  - http://storms.meas.ncsu.edu/users/mdparker/nam/index.html
  - http://storms.meas.ncsu.edu/users/mdparker/gfs/index.html
  - http://storms.meas.ncsu.edu/users/mdparker/rap/index.html
  - http://storms.meas.ncsu.edu/users/mdparker/sref/index.html

  These products will continue to be available to the community so long as local computer resources continue to function at current capabilities.
- In response to concerns that some forecasters might not fully understand the SHERBS3 and SHERBE products, or might be misusing them, the NCSU team created a centralized web resource for information (including operational caveats) about these parameters. This "one stop shop" includes a compact overview, links to relevant articles and presentations,

and an easy way to access all of the SHERB products that are presently available on the web.

  - http://www.meas.ncsu.edu/mdparker/sherb/

- To accomplish the goal of careful operational assessment of the SHERB (and other) parameters in HSLC environments, the NCSU team created a web-based feedback form that forecasters can use to describe HSLC events (and nulls) and evaluate the performances of the products they've inspected.
  - http://www.meas.ncsu.edu/mdparker/sherb/feedback/
- The CIMMSE blog continues to be a hub for discussion and real time O2R2O. Many of the posts generated comments and offline discussion.
  - https://cimmse.wordpress.com
- Although not produced directly by our research team, new HSLC products were also added to SPC's Mesoanalysis page as a collaborative result of this project ("in-kind" support from NOAA):
  - https://www.spc.noaa.gov/exper/mesoanalysis/s19/sherb3/sherb3.gif
  - https://www.spc.noaa.gov/exper/mesoanalysis/s19/sherbe/sherbe.gif
  - https://www.spc.noaa.gov/exper/mesoanalysis/s19/moshe/moshe.gif
- Although not produced directly by our research team, the SHERB parameters were added to the NWS Software Collaboration Portal (SCP) as a collaborative result of this project ("in-kind" support from NOAA). The SCP is the standard clearinghouse for sharing new utilities and software for AWIPS. WFOs can now obtain the code, installation instructions, full documentation, and support for the viewing HSLC parameters in AWIPS-1, AWIPS-2 and GFE.

III. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

1. What individuals have worked on this project?

Principal Investigators - North Carolina State University:

Dr. Gary Lackmann
Dr. Matthew Parker
Dr. Lian Xie

Student Researchers – North Carolina State University:

Ms. Lindsay Blank
Ms. Dianna Francisco
Ms. Jessica King
Mr. Keith Sherburn
Ms. Xia (Sharon) Sun

2. Has there been a change in the PD/PI(s) or senior/key personnel since the last reporting period?

No.

3. What other organizations have been involved as partners? Have other collaborators or contacts been involved?

Collaborators in NOAA:

NOAA Earth System Research Laboratory (expected)
NWS/NCEP Environmental Modeling Center (expected)
NWS/NCEP Storm Prediction Center
NWS WFO-Birmingham, Alabama
NWS WFO-Blacksburg, Virginia
NWS WFO-Charleston, South Carolina
NWS WFO-Columbia, South Carolina
NWS WFO-Greer/Greenville, South Carolina
NWS WFO-Huntsville, Alabama
NWS WFO-Morehead City/Newport, North Carolina
NWS WFO-Peachtree City, Georgia
NWS WFO-Raleigh, North Carolina
NWS WFO-Sterling, Virginia
NWS WFO-Tallahassee, Florida
NWS WFO-Wakefield, Virginia
NWS WFO-Wilmington, North Carolina
NWS WFO-Wilmington, Ohio

IV. IMPACT

1. What was the impact on the development of the principal discipline(s) of the project?

There is growing nationwide awareness that HSLC severe weather is an important forecasting problem. These environments are often plagued by both low probability of detection and high false alarm rates in outlooks, watches, and warning products. The most important findings of this project are:

- Demonstration that the strength of large scale forcing is an important component in distinguishing HSLC severe events from nulls, and development of a new forecasting metric (MOSH/E) that incorporates this effect.
- Physical explanation for the skill of lower tropospheric vertical wind shear and lower tropospheric lapse rates in distinguishing HSLC severe events from nulls. These environmental sensitivities largely hinge on their direct influence on the intensity of low-level updrafts, which in turn are responsible for stretching near-surface vortices in HSLC convection.
- Demonstration that rapid destabilization of the environment is an important concern in HSLC environments, especially in severe events. The short timescale and large magnitude (in some cases, increases from <200 J/kg to over 800 J/kg in 3 hours) require particularly diligent situational awareness from forecasters.
- Demonstration that convection-allowing model forecasts provide operational utility in anticipating HSLC severe weather (both convective mode and intensity), with a suggestion that currently-common ~3 km grid spacings are adequate for this purpose, but that ~1 km grid spacings probably would provide the best ratio of benefit to cost.

- Demonstration of a viable technique from the statistics community for producing calibrated probabilities of HSLC severe weather using environmental parameters as input. Once mature, this approach may help chip away at the low POD and high FAR issues in HSLC environments.

2. What was the impact on other disciplines?

N/A

3. What was the impact on the development of human resources?

This project supported the mentoring and professional development of five graduate students, four of whom are women, and one of whom went on to work in the NWS.

4. What was the impact on teaching and educational experiences?

The primary educational impacts included training of five different graduate students, as well as the incorporation of research results into the NCSU courses taught by the PIs.

5. What was the impact on physical, institutional, and information resources that form infrastructure?

As detailed under Part II: Products, a number of online resources have been developed for the community (forecasting and mesoanalysis plots, tools for use in AWIPS/GFE). These will continue to be available and assist forecasters even though the project has ended.

The probabilistic forecasting algorithms developed by Dianna Francisco may also be useful in other forecasting problems beyond the HSLC topic.

6. What was the impact on technology transfer?

N/A

7. What was the impact on society beyond science and technology?

It is hoped that improvements in HSLC forecasting will lead to enhanced public safety.

8. What percentage of the award's budget was spent in a foreign country(ies)?

None (0%).

V. CHANGES/PROBLEMS

Describe the following:

1. Changes in approach and reasons for the change.

None.

2. Actual or anticipated problems or delays and actions or plans to resolve them.

None. Several ongoing research tasks related to this award continue under our subsequent CSTAR grant.

3. Changes that had a significant impact on expenditures.

None.

4. Change of primary performance site location from that originally proposed.

None.

VI. SPECIAL REPORTING REQUIREMENTS

N/A

VII. BUDGETARY INFORMATION

The grant was spent to very near zero and is in final closeout.

VIII. PROJECT OUTCOMES

What are the outcomes of the award?

The outcomes of this award include advances in both physical understanding of HSLC convection and in products and concepts that forecasters can use to enhance their situational awareness of HSLC severe weather. In addition to the dissemination that has occurred via four journal articles and numerous presentations, conference calls, and two regional workshops, we continue working on this topic under our subsequent award, NA17NWS4680002. Our long-range goal is to continue transitioning these research results into NWS operations.

Are performance measures defined in the proposal being achieved and to what extent?

N/A