National Oceanic and Atmospheric Administration (NOAA) Response to:

Tornado Warning Improvement and Extension Program Plan

A report prepared by the
Environmental Information Services Working Group
of the NOAA Science Advisory Board
July 2019

December 16, 2019

Background

On July 3, 2019, the National Oceanic and Atmospheric Administration (NOAA) Science Advisory Board's (SAB) Environmental Information Services Working Group (EISWG) submitted their annual Report to Congress to the SAB, as required by the Weather Research and Forecasting Innovation Act of 2017. The SAB approved this report at its July 10-11, 2019 meeting, and the report was transmitted to NOAA on August 8, 2019.

(c) ANNUAL REPORT.—Not less frequently than once each year, the Working Group shall transmit to the Science Advisory Board for submission to the Under Secretary a report on progress made by National Oceanic and Atmospheric Administration in adopting the Working Group's recommendations. The Science Advisory Board shall transmit this report to the Under Secretary. Within 30 days of receipt of such report, the Under Secretary shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a copy of such report.

The EISWG Report to Congress contained a set of recommendations on the Tornado Warning Improvement and Extension Program Plan. NOAA provided the following response to these recommendations on December 16, 2019.

Recommendations on Potential NOAA Actions Related to the Tornado Warning Improvement and Extension Program Plan

***With respect to technological objectives**, the EISWG notes that some of the challenges could be accomplished with currently deployed technologies through software or hardware upgrades, or the deployment of readily adaptable commercial-off-the-shelf technologies. In particular, NOAA should recognize the following:*

***(1)** While convection-allowing models have made great progress, they still do not capture every important mesoscale feature. Timing and position of thunderstorms can be off in time by an hour or two and in space by a county or more. Model forecasts seem less accurate when storms are already present when the model is initialized.*

Recommendation 1: "In its development of Warn on Forecast (WoF) procedures, NOAA should include pattern recognition and artificial intelligence algorithms that take into account and adapt for the various known shortcomings in explicit computer model forecasts."

NOAA Response: NOAA agrees with this recommendation and notes that the agency is already doing this in a research and development environment. The WoF research program uses statistical techniques to pull probabilistic information out of model ensembles (rather than using explicit/deterministic model forecasts). The ensemble forecast output provides a range of possible outcomes based on variations in model physics and initial conditions that represent the variability of the atmosphere. The resultant probabilistic information can provide forecasters with a better understanding of the potential for severe weather, given that storms develop within the area. Output from the WoF research program have been tested and evaluated in the NOAA

Hazardous Weather Testbed and have shown promising capability to assist forecasters with advance notifications to the public. In addition, NOAA is actively researching the use of machine learning methods as a way of post-processing the ensemble output from the WoF system and hopes to test these forecaster tools from the new methods in the Hazardous Weather Testbed with forecasters within the next several years.

(2) *The greatest successes with tornado warnings come in supercell situations; skillful warnings for non-supercell tornadoes remain a serious challenge.*

Recommendation 2: "NOAA should focus more strongly on reducing the false alarm rate (FAR) and other metrics of skill in current generation tornado warnings. Polygon-based warnings challenge the way FAR is determined and so demand new methods to quantify true positive, false positive, true negative, and false negative for precision, recall, and accuracy. As warning polygons are now updated as severe storms evolve, FAR measures will need to be assessed over space and time. The ways these metrics are computed should be transparent. National metrics are nearly meaningless by themselves; NOAA should compute and release metrics by Forecast Office. Importantly, while the focus should be on reducing the FAR, such reductions cannot come at the expense of affecting negatively other tornado warning-based metrics, such as the probability of detection (POD). In other words, reducing the FAR while decreasing the POD would not be a positive outcome. These are related metrics, both very important and clearly improving the quality of tornado warnings will require a balance between these two important metrics to provide people with more accurate warnings to support decision making."

NOAA Response: NOAA agrees with this recommendation, and we are already working to revise how FARs are calculated. We disagree, however, that "… national metrics are nearly meaningless by themselves." They provide the national perspective on warning performance. Also, the NOAA National Weather Service (NWS) Performance Management website already provides warning statistics for each Workforce Management Office (WFO), multiple WFOs, NWS Regions, and nationally. NOAA concurs that FAR needs to be improved without negatively impacting POD. NOAA is continuing its research and development activities to better understand the tendencies that lead to FAR and how to address them.

Recommendation 3: "As a means for obtaining greater low-level radar coverage of non-supercell tornadic circulations and so significantly aiding in the warning of tornadoes, NOAA should consider …

> **a)** … reducing the lowest allowable elevation angle on all NEXRAD/WSR88D radars to the minimum possible value, consistent with ground clutter and local environmental considerations, and
> **b)** … adding one or two tower sections to selected existing NEXRAD to reduce ground clutter, increase the radar horizon, and allow better overall coverage."

NOAA Response:

a) NOAA notes that we have done this already in several locations; however, it is not practical in all locations due to terrain blockage and other environmental impacts. NOAA has lowered the angle for the Next Generation Weather Radar (NEXRAD) at 10 sites so far – Langley Hill, Washington; Monterey, California; Cedar City, Utah; Medford, Oregon; Buffalo, New York; Minot, North Dakota; Greenville-Spartanburg, South Carolina; Raleigh, North Carolina; Jackson, Mississippi; and Shreveport, Louisiana. The NWS Regions are prioritizing NEXRAD sites where lowering the angle will provide maximum benefits. Lowering the angle costs about $100,000 per site to conduct the environmental assessment and make the software changes in the NEXRAD unit and also to the WFO's Advanced Weather Interactive Processing System (AWIPS) to be able to use the data from the lower angles.
b) NOAA disagrees with the recommendation. While increasing radar height could reduce blockage from nearby terrain, trees, and buildings, it will further extend the range of ground clutter. Furthermore, it is very expensive to raise the tower, and benefits are limited except in very few locations. NOAA considers raising the tower as a last resort when beam blockage has increased since the radars were installed, and lowest angles of data are no longer available. To date, we have raised the tower at only one site. Furthermore, the maximum height of the radar is 30 meters. It is not feasible to raise the tower greater than 30 meters due to the resultant degraded data quality related to distance between the feedhorn and signal processor, as well as the increased potential for high wind damage.

Recommendation 4: "To aid in the warning of short-lived tornadoes, NOAA should build on the experiences in south-central Oklahoma and across the multicounty Dallas-Fort Worth metropolitan area and include networked X- or C-band as gap-filling radars to obtain greater low-level coverage of non-supercell circulations and strong winds."

NOAA Response: NOAA notes that this is technically feasible, but not cost effective at this time. The proven benefits of such systems have not been categorically demonstrated to have a significant impact on NWS warnings. In the Dallas-Fort Worth area, the NEXRAD coverage is excellent. Via the National Mesonet program, NWS provides support to Collaborative Adaptive Sensing of the Atmosphere (CASA), a network of commercial X-band radars supplementing NEXRAD coverage in the DFW region. Given the NEXRAD coverage, the CASA data are supplemental and most useful in determining where to conduct post-storm surveys, rather than to warn for tornadoes. Forecasters appreciate having the CASA data, but still rely predominantly on the NEXRAD for issuing warnings in the Dallas-Fort Worth area. The real challenge remains to better understand these short-lived tornadoes and be able to warn before they form.

Recommendation 5: "The NEXRAD processing software used to detect mesocyclone and tornado vortex signatures should be modernized/upgraded to reflect the best science now available. An example is provided by the Mesocyclone Detection Algorithm (MDA), which currently uses only a portion of the available shear information. A modernization of this key algorithm might allow circulations of (weak) intensity levels 1 and 2 to be detected sooner and utilized with some confidence. This could make possible earlier (by several minutes, or equivalently two or three volume scans) detection of the earliest stages of formation of long-

lived tornadoes, and allow tracking of at least a portion of the life cycle of short-lived tornadoes."

NOAA Response: In regards to NEXRAD software, NOAA is currently working to update both the Mesocyclone Detection Algorithm (MDA) and the Tornado Detection Algorithm (TDA), the latter of which identifies the Tornado Vortex Signature. NOAA is researching advanced algorithm technologies to track storm-scale circulation features of all intensities. These Rotation Track products are implemented on the Multi-Radar Multi-Sensor system which is available to forecasters. Additionally, new MDA and TDA are being developed that also includes dual polarization variables as well as shear estimates. The new TDA will be evaluated in the Hazardous Weather Testbed in spring 2020.

With respect to the sociological objectives, *NOAA should recognize that the protection of life and property from the impact of tornadoes is not only a meteorological challenge, but also a sociological one. For example, to justify the costs and effort involved in developing and deploying WoF systems that may provide people advance skillful warnings of an hour or more, NOAA needs to understand better if people will take appropriate actions upon receipt of such lengthy advance warnings.*

Recommendation 6: "Given the limited number of federal social science positions within the agency, NOAA should utilize its set of joint and cooperative institutes to access social science expertise in the national university community."

NOAA Response: NOAA concurs with this recommendation and is beginning discussions to implement this action with the cooperative institutes. For example, NWS is working with the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) and the Center for Risk and Crisis Management (CRCS) on the conveyance of uncertainty and probabilistic forecasts.

Recommendation 7: "NOAA should have social science programs charged with investigating questions such as the following: Will people take action more than a few minutes in advance, even if given warnings an hour in advance? Where is the balance between lead-time and good decision-making? If actions are taken based upon lead times an hour or longer than at present, will this include fleeing and, if so, will road infrastructure and traffic management suffice? Will the public take action based upon probabilistic tornado warnings? How should the public best receive such warnings? Will the public be responsive to repeatedly updated warnings (N.B., The Report (see Attachment 1), p. 7 suggests that such warnings could be updated every 2 minutes), or simply confused by such frequent updates, and so waiting until the last minute to attempt to take action?"

NOAA Response: NOAA agrees with this recommendation and notes that we are doing this now, however, expanding these efforts merits additional consideration. As an example, the National Weather Service is working with CIMMS and CRCS on the conveyance of uncertainty and probabilistic forecasts. Both WoF and the Forecasting a Continuum of Environmental Threats (FACET) programs have social science based research initiatives focused on the public response to these new warning techniques.

Recommendation 8: "To reduce impacts in terms of minimizing property losses (as well as improve life safety measures), it will be necessary to implement stronger building codes. NOAA should develop and implement - in partnership with NIST, universities such as Texas Tech, and entities such as the Institute for Business and Home Safety - a weather-ready home certification program as an extension of its StormReady community and Weather-Ready Nation program,. This could encourage in-home shelters, hurricane clips to hold on roofs, etc."

NOAA Response: While this may be beyond the scope of the agency's mission, it is a good idea and NOAA will continue to build partnerships with other Federal agencies, non-governmental organizations, and industry to marry weather, water, and climate information from NOAA with structural information to help save lives and protect property. For example, NOAA works with NIST as they are the lead agency for the National Windstorm Impact Reduction Act. The NIST National Windstorm Impact Reduction Program was created to improve the understanding of windstorms and their impacts and to develop measures to reduce the damage they cause. In various storm areas (i.e., Great Plains, Southeast U.S.), or within regions associated with land-falling hurricanes, NOAA has deployed mobile observation platforms to better understand the winds embedded within the tornadoes.

In closing, *the EISWG notes the resources portion of the plan seems generic. This leads to questions such as, "Has a detailed action plan been produced?" "If so, what are the detailed timelines?" "Has a detailed cost/benefit analysis been performed?" Such information is needed by the EISWG to know if NOAA is tracking favorably against the intended deliverables when reviewing subsequent reports.*

NOAA Response: Resource requirements are still being considered within the agency and will be reflected in NOAA's future year budget requests, as well as in the annual budget plan required by Section 103 of the Weather Act.