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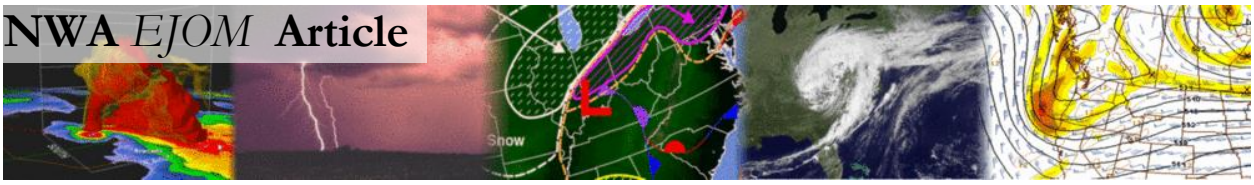

The NWS and VORTEX2: Facilitating Real-Time Communication between Research and Warning Operations

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ABSTRACT

The VORTEX2 tornado research project during the spring seasons of 2009 and 2010 included an effort to tie the research community and NWS warning operations in numerous offices together with real-time communications. This paper discusses the logistics of this interaction and benefits to both the research community and NWS operations.

1. Introduction

During the spring months of 1994 and 1995 the first VORTEX (Verification of the Origins of Rotation in Tornadoes Experiment) research project (VORTEX1) was conducted. Benefits of VORTEX1(V1) included improved understanding of low-level mesocyclones, the three-dimensional structure of thunderstorms producing tornadoes, and the relationship between storms producing strong and violent tornadoes and preexisting mesoscale boundaries. (EOL 2009).

VORTEX2 (V2) was conceived to explore questions that remained after V1, as well as to delve deeper into questions raised as a result of V1 findings. These questions, combined with increasing technical capabilities in Doppler radar, mesoscale observational networks and communications increased demand to continue the research.

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V2 was conducted during the spring months of 2009 and 2010 across large areas of the western U.S. Midwest, as well as the central and western Great Plains (Fig. 1). The four foci of V2 were:

- Tornadogenesis,
- Near –ground wind field in tornadoes,
- Relationships between supercell storms and their environment, and
- Storm-scale numerical weather prediction (NWP; EOL 2009).

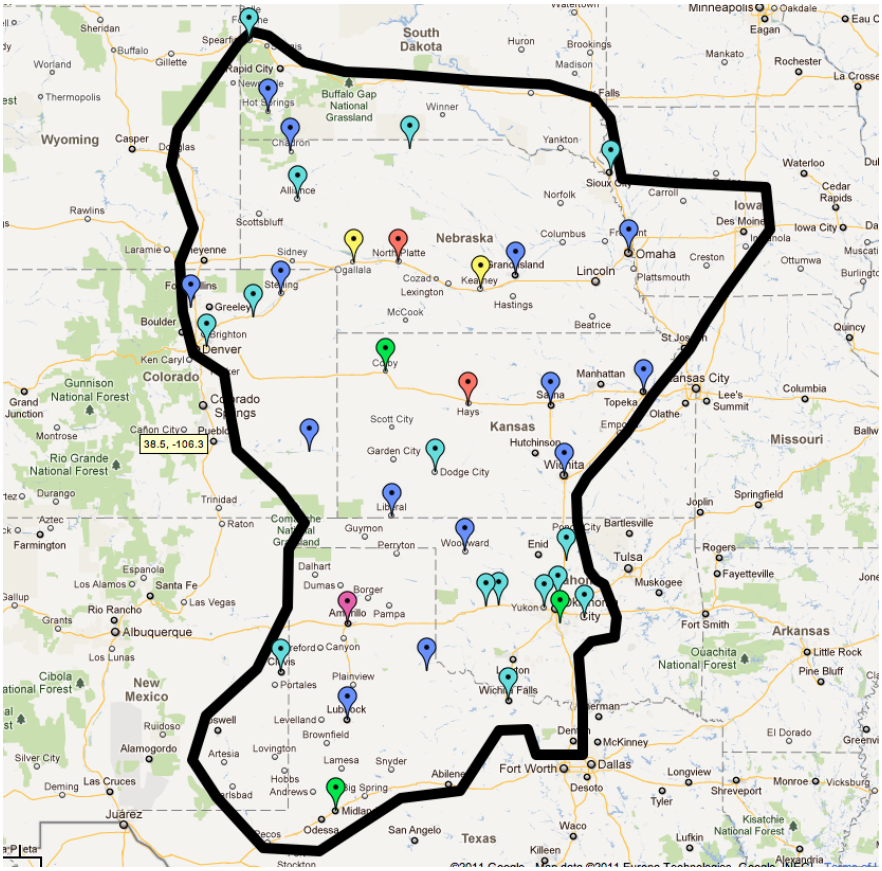

Figure 1. The V2 domain for 2009 and 2010. Locations marked are overnight stays for the armada. Pin colors indicate number of nights stayed in an area for 2009-2010, a relative indicator of V2 activity in that area: magenta: 6, red: 5, yellow: 4, green: 3, blue: 2, teal: 1.

During V1, while there was limited communication between research teams in vehicle and research aircraft, little or no information was available real-time to the National Weather Service (NWS), emergency managers, media or other groups. With dramatic improvement in mobile voice and Internet communication, the need for NWS forecasters to integrate multiple data sources into tornado and severe thunderstorm warnings, and the ability to pass NWS spotter reports to the V2 field teams, a decision was made to add an NWS liaison to the VORTEX Operations Center (VOC).

2. The VORTEX operations center (VOC)

The VOC was located at the National Weather Center (NWC) building in Norman, Oklahoma. The VOC Mission was to:

- Provide forecast support to supplement field briefers,
- Provide ”mesoscale view” during storm intercepts to negotiate changes to target area/storm,
- Communicate primarily with Field Coordinator (FC) with focus on safety of the V2 armada,
- Support safe return of armada to hotels at the end of daily missions, and
- Contribute scientific/situational data not available in the field. (Louis Wicker, personal communication)

The VOC staffing included representatives of the various universities participating in the project, National Severe Storms Laboratory (NSSL), and NWS. NWS roles included a short-term forecaster (nowcaster) and the NWS liaison (Figs. 2 and 3). The structure of the VOC evolved from the original concept of experiment coordination outlined in the Experimental Design Overview (VORTEX2 Steering Committee, 2007).

3. The NWS liaison

a. Overview

The NWS liaison to V2 served to facilitate research to operations for the NWS Weather Forecast Offices (WFOs) located within the domain of the project. There was one NWS liaison for the 2009 project and two for the 2010 project. The liaison communicated mostly with the WFOs via NWSChat (NWS 2008), but e-mail was also used, as well as a direct phone call in emergency situations where immediate contact with the WFO was needed. A special NWSChat room was set up for V2. Each WFO also maintains a chat room for its media and emergency management partners, but the NWS liaison messages could be seen only by NWS personnel. This allowed the local WFOs to decide whether the V2 information should remain internal.

Information shared on NWSChat included a general “Plan of the Day” briefing on V2 operational target areas and observations from V2 teams in the field. An Internet link to a Gibson Ridge 2 (GR2; http://www.grlevelx.com/gr2analyst) overlay consisting of current base reflectivity and V2 armada positions/mesonet observations was frequently posted on the NWSChat for the NWS forecasters. (See Fig. 4 as an example.) Links to special soundings taken by V2 were available in real-time via link to an Internet page.

There were 30 NWS offices (512 individual participants) signed up for V2 chat. In 2009 there were as many as 67 participants in the chat room at one time.

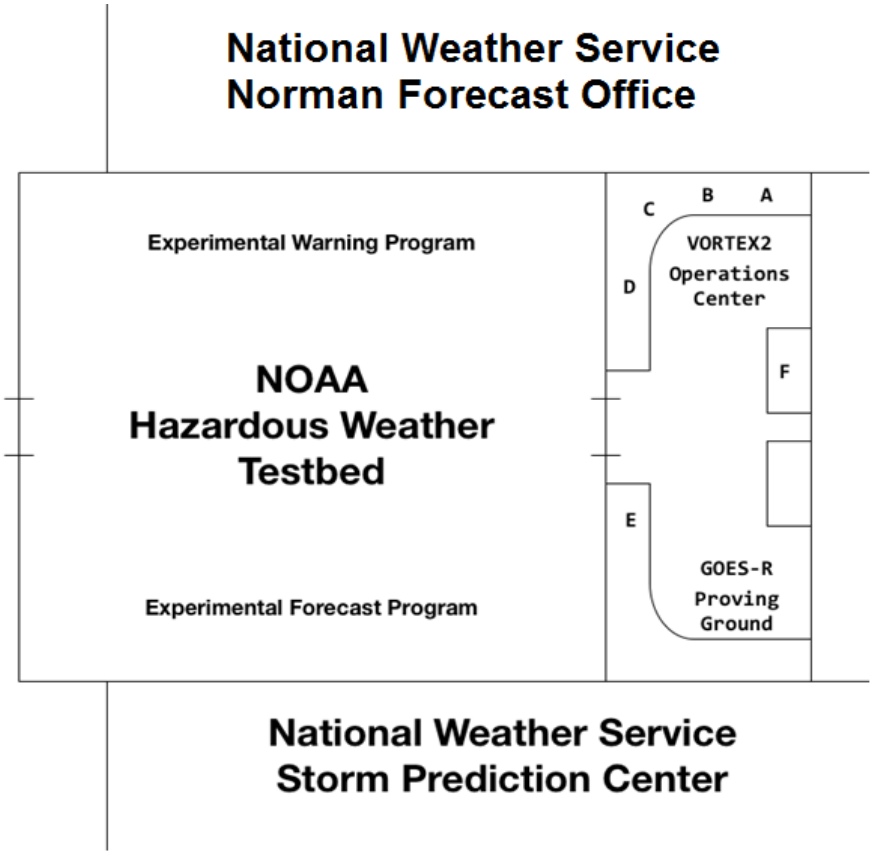

Figure 2. The VOC office in relation to the NWS Forecast Office, the NWS Storm Prediction Center, the Experimental Warning Program, the Hazardous Weather Testbed, and the Experimental Forecast Program. The NWS liaison to V2 generally worked at position E in 2009 and in position F in 2010. Position A - Radar Analyst, Position B - Radar Analyst, Position C - VOC Coordinator, Position D - SASSI (Situation Awareness for Severe Storms Intercept) Workstation, Position E - 2009 NWS Liaison, Position F- 2009 Hand Analyst / 2010 NWS Liaison.

The NWS liaison also helped with posting to social media. Both Facebook and Twitter were considered for this project. Facebook proved quite successful in helping keep "fans" up to date. As of June 2009 there were 6000+ fans in Facebook. (The Facebook page was still used to share V2 information after the end of the project, and as of February 2012 had over 14,200 fans.) V2 operations did not disclose locations in real-time, thus Facebook was used for summaries of the day's operations. (For the same reason, Twitter was considered for this project but was not used.) Fans often began to respond to V2 updates on Facebook in one minute or less after posting.

Figure 3. Positions A, B, C and D in the VOC from Figure 2 The NWS WFO is in the background. Image was taken from 2009 NWS liaison position (E).

In addition to observing the storms, V2 teams occasionally conducted storm damage surveys to gather data comparing radar data to estimated ground level wind speeds (EOL 2009). In most cases, the local NWS was also surveying storm damage following these events, and it was important to coordinate damage survey activities between the groups, especially with regard to making announcements concerning EF scale ratings to the media. The NWS liaison played a key role in facilitating this coordination.

b. Additional NWS participation

The NWS liaisons were not the only National Weather Service participants in the VOC, and the authors would be remiss to not recognize the important contributions from these people. Two NWS forecast offices provided two forecasters each to the VOC for a week at a time: Mark Britt and Fred Glass from the St. Louis, Missouri WFO and Kevin Brown and Chris Sohl from the Norman, Oklahoma WFO. Additionally, Kevin Scharfenberg from the NWS Office of Climate, Water, and Weather Services volunteered his time for the duration of the project.

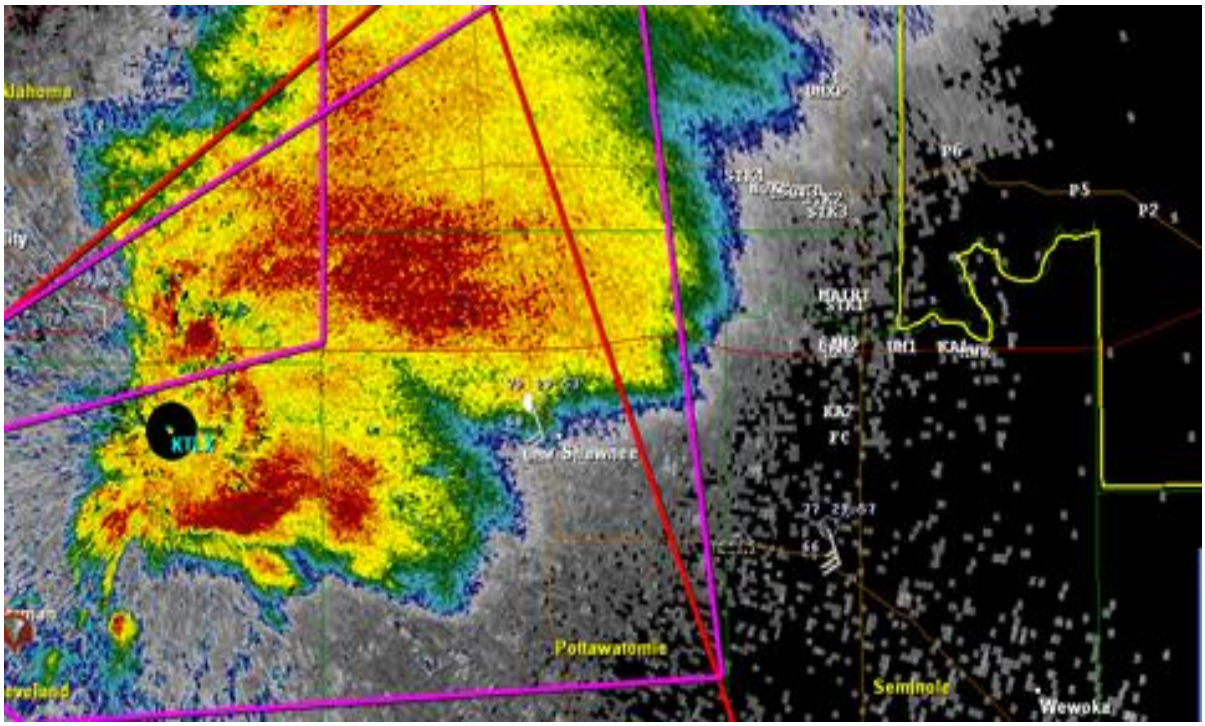

Figure 4. GR2 display of base reflectivity 0.5 degrees elevation for KTLX 2240 UTC 10 May 2010. Note the tornadic storm entering south Norman (south of KTLX radar). GR2 display shows real-time positions of V2 armada in white letters north of Seminole. Polygons indicate a tornado warning (pink) and a severe thunderstorm warning (red) in effect.

These forecasters were originally designated to serve as radar operators in support of keeping the V2 armada out of danger during severe-storm intercepts. However, the unique skills of each forecaster were utilized in ways that were unforeseen ahead of time. These NWS forecasters fulfilled unexpected duties ranging from leading damage survey teams to providing researchers an operational meteorologist's perspective on radar interpretation during severe-storm intercepts. The participation of these individuals certainly enhanced the liaison's ability to support warning operations at the local WFO while providing additional resources for ancillary functions of the VOC.

c. Liaison benefits to NWS operations

NWS offices within the V2 domain benefitted from the knowledge of armada operations within their county warning area (CWA). The armada served as a reliable source of ground-truth information for relaying real-time storm reports to WFOs. Much of this was accomplished using NWSChat to forward reports received from the armada. While reports were beneficial to the warning process, information about storm-scale structure and evolution was also important to the WFOs. Live images from the portable radars were not shared with the WFOs. However, the NWS liaison had access to information to share with WFOs from the mobile mesonets and proximity soundings. Armada chats would also reveal visual indications of the near-storm environment. NWS operations benefitted greatly from this in-situ information shared in real-

time, to help better assess the state of the atmosphere and anticipate storm-scale development and evolution.

One significant benefit to having the NWS liaison position within the VOC was simply promoting the visibility of the V2 project within the NWS itself. When the armada was conducting operations within a WFO's CWA, the WFO staff had heightened situational awareness of their presence, objectives, and information being collected. Some NWS personnel were directly involved in V2 field operations, and the liaison was able to share information about their participation and effectiveness to NWS senior leadership. The dialog between the liaison and other VOC personnel, and occasionally a visit to the VOC from one of the principal investigators (PIs), helped foster a two-way dialog about research goals and operational needs, better facilitating research-to-operations and operations-to-research. Finally, during the very busy days during May 2010, when ongoing operations needed balance against post-storm damage assessment, the NWS liaison facilitated efficiencies between the V2 team and local office survey crews, so that efforts to survey the damage could be coordinated and time then better spent by each group on their pressing research and operational requirements.

4. A typical operations day

- PI Conference Call (arrival ~ 8 - 9am)
    - This call was a briefing/discussion of model data, and local/Storm Prediction Center (SPC) forecasts. Generally consensus determined the target area. If no consensus could be reached the PI made the final decision.
- Briefing posted on NWSChat (~ 11 am). A private chat room was used that was not available to media or emergency managers. (The local WFOs decided whether to provide any of this information to their local customers in their individual WFO chat rooms.)
- Viewed 1200 UTC model data
- As target storms develop, operations began, initial destination/target storm declared (1pm – 3 pm).
- Began continuous updates on NWSChat to NWS offices. Updates included link to images of V2 armada location maps, and V2 special soundings. NWS spotter reports are also relayed to the armada as received.
- Operations ended when no targets were within driving range for the day, or light was inadequate for visual observations (usually 8 to 9 pm).
- VOC coordinator remained in contact with armada until all members arrived safely at hotel.

5. Case studies and discussion

a. 10 May 2010

The tornado outbreak that occurred 10 May 2010 was one of the most challenging events for the V2 armada as well as for those working in the VOC due to the widespread nature of the event, the speed at which it evolved, and the direct impact of the activity to the NWC and the VOC personnel.

Prior to the morning briefing, the NWS liaison posted announcements in NWSChat of the availability of special intermediate upper-air soundings from the Atmospheric Radiation

Measurement (ARM) Southern Great Plains (SGP) Central Facility (C1) site near Lamont, Oklahoma, the initial V2 sounding time, as well as planned NWS soundings staggered through the day from northern Kansas to central Texas.

[13:36:53] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN All: several intermediate soundings are planned for today. At 15Z-first V2 mobile sounding@Perry; at 18Z-AMA, DDC, FWD; at 21Z-TOP, OUN.

Due to the collocation of the VOC with the Storm Prediction Center, coordination of very high temporal resolution satellite imagery was also possible.

[17:04:34] <nws-kenneth.cook@nwschat.weather.gov/Home> steve cobb - does v2 have the 1 min sat imagery like last year?

[17:55:29] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN:All - a request has been made for super rapidscan - 1 min updates- awaiting approval. If approved, starting 20 or 21Z through 00Z or 03Z.

As the time of convective initiation grew closer early in the afternoon, updates and descriptions of the mobile soundings were provided to NWS forecasters. Comparisons were made between the previous model forecast soundings and the observed mobile soundings as variations in convective inhibition became more evident especially in the southern portion of the V2 operating domain.

By 2119 UTC significant storms had begun to develop and the armada declared its first target storm. Convection continued to rapidly grow southward along the advancing dryline southwest of the Oklahoma City metro area. At 2155 UTC the V2 armada repositioned south from their initial deployment in order to capture the activity as it moved out of the urban interface. A V2 member reported storm-relative inflow was ramping up with one cell approaching Moore from the west. Radar indicated a quick evolution with this storm as it depicted a distinct hook echo. Similarly another cell intensified rapidly southwest of Norman and became tornadic as it crossed over the NWC building.

[22:48:38] <nws-steve.cobb@nwschat.weather.gov/Home> from OUN - funnel cloud was originally observed descending rapidly at 532 pm from the national weather center building. damage and touchdown reported just east of the building along highway 9. tornado then grew in size...significant and large tornado still on the ground causing damage.

The armada successfully intercepted the tornado as it positioned several observational platforms in a picket-fence style ahead of the fast moving supercell. V2 members continued to provide updated positions on the long-track tornado as it crossed the Norman (OUN) CWA and entered the Tulsa (TSA) CWA.

[23:21:41] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN: OUN/TSA - microphysics probe unit reports LARGE TORNADO just north of Seminole.

[23:23:41] <nws-alex.lamers@nwschat.weather.gov/Office> Thanks Steve...we were waiting on a solid report. Sent via LSR. -AL

b. 18 May 2010 Texas Panhandle

A southern stream shortwave trough and remnant surface boundaries provided a focus for convection across west Texas on 18 May 2010. With cyclogenesis taking place in southeast Colorado, low-level moisture advected northward into the region to create moderate instability while wind fields associated with the trough provided strong vertical shear and favorable veering wind profiles for supercell storms in the warm sector east of the dryline. Despite rather encouraging model forecasts for initiation there was still some concern about where development would begin as a dense cirrus shield spread over the outlook area in advance of the storm system. One storm did initiate in a region of more favorable jet dynamics north of the upper-level jet axis and on the back side of the thinning cirrus shield in the northwest Texas Panhandle by around 2130 UTC. Within an hour of initiation the storm had organized and produced a well-defined wall cloud as observed by an off-duty NWS employee as the armada was positioning itself to intercept the storm. Through the remaining life-cycle of the supercell, visual reports and real-time in-situ and radar observations from the armada were relayed to the Amarillo NWS office to support their warning operations.

[22:44:55] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN AMA: DOW reports a tornado in occluded part of storm.
[22:45:47] <nws-steve.cobb@nwschat.weather.gov/Home> …south of 87 about 2 mi e of 385.

[22:57:13] <nws-steve.cobb@nwschat.weather.gov/Home> Rapidly rotating rain curtains from probe on county line rd and road R.
[23:00:11] <nws-steve.cobb@nwschat.weather.gov/Home> Strong rotation reported along 87, 6-7 mi w of Dumas with low wall cloud. Descending refl. core also present on radar.
[23:13:24] <nws-steve.cobb@nwschat.weather.gov/Home> Probes showing strong rotation within their network centered 4 mi sw of Dumas, beneath newly developing meso on 88D.
[23:22:24] <nws-steve.cobb@nwschat.weather.gov/Home> Circulation according to probe network is between 2 and 2.5 mi sw of Dumas (intersection of 87 and 287).
[23:26:23] <nws-steve.cobb@nwschat.weather.gov/Home> Circulation is entering western part of urban area of Dumas.
[23:27:50] <nws-edward.andrade@nwschat.weather.gov/Gaim> Thanks for that piece of information. New tornado warning was issued a few minutes ago.
[23:28:04] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN AMA: Tornado on south side of Dumas.

The storm continued to move east into more rural areas of the north-central Texas Panhandle and armada reports and data continued to provide information helpful to the local NWS office in assessing the tornado potential.

[00:10:36] <nws-edward.andrade@nwschat.weather.gov/Gaim> How does that storm east of Dumas look to you guys now. We are deciding what to do with our Tornado Warning.
[00:11:20] <nws-steve.cobb@nwschat.weather.gov/Home> Circulation appears to be tightening up again, all probes to the east showing 40+ mph easterly winds. Strong indication of trying to tornado again.
[00:44:22] <nws-steve.cobb@nwschat.weather.gov/Home> ATTN AMA: Cone tornado west of Stinnett / 744 pm.
[00:46:14] <nws-steve.cobb@nwschat.weather.gov/Home> …about 7 mi northwest of Stinnet
[00:48:30] <nws-edward.andrade@nwschat.weather.gov/Gaim> is it still on the ground now?
[00:48:51] <nws-steve.cobb@nwschat.weather.gov/Home> It passed out of visibility but they did NOT see it lift.
[00:49:26] <nws-steve.cobb@nwschat.weather.gov/Home> Other chasers say it is still on the ground but V2 cannot confirm.
[00:50:52] <nws-edward.andrade@nwschat.weather.gov/Gaim> Ok Steve. That helps us out. thanks.
[01:25:42] <nws-steve.cobb@nwschat.weather.gov/Home> We are working on the need to coordinate any damage surveys tonight. Will give you a call when we know for sure.
[01:26:56] <nws-edward.andrade@nwschat.weather.gov/Gaim> Thanks Steve. We appreciate all the reports you provided to us this evening. They were very helpful in the warning process.

The 18 May 2010 case showed significant contribution from the V2 armada and VOC in helping warning forecasters at WFO Amarillo assess the evolution of a tornadic supercell as it crossed their CWA. Not only were visual reports confirming the tornado and large hail helpful but sensor observations from armada vehicles allowed the NWS liaison to give a heads up to low-level mesocyclogenesis and near-storm environmental conditions. With continuous updates provided through NWSChat, the operational forecasters were able to receive time-sensitive information and ask specific questions on tornado location and storm evolution that directly impacted their warning decisions.

c. 5 June 2009 La Grange, Wyoming, tornado

The project year 2009 had very few significant storm days, but 5 June 2009 was a notable exception. A near record minimum number of tornadoes for the spring season meant the V2 armada traveled to the boundaries of the High Plains at times.

As a northeastward moving upper-level speed max exited the Great Basin area, a weak lee cyclone developed over northeast Colorado. To the north of the low over southeastern Wyoming, upslope flow transported air with dew points in the low to mid 50s °F (10-15 °C) into the area. As convection began it encountered favorable shear profiles with 50-60 kt (25-30 m s^{-1}) westerly flow above the low-level easterly to southeasterly flow, setting the stage for tornadic supercells.

The 5 June event was the first significant storm interaction for the project. During the morning briefing from the VOC 4 June NWSChat told NWS offices in the V2 domain:

[16:26:30] <nws-jim.purpura@nwschat.weather.gov/Home>…*Tomorrow looks to be possibly the most significant ops day of the 2009 project.*

The 5 June morning briefing mentioned…
[16:46:16] <nws-jim.purpura@nwschat.weather.gov/Home> Day 1 (Friday)...ATTN CYS...BOU...GLD One of the better days for the V2 operations is anticipated. … Shear looks to be excellent, and instability is increasing. The decision was made to first target the areas across western Nebraska, then re-evaluate. With that in mind the Armada will move to Kimball, Ne by 1:30 pm CDT. Target could include the Cheyenne Ridge in Wyoming…

By midafternoon V2 was located near LaGrange, Wyoming
[21:50:22] <nws-jim.purpura@nwschat.weather.gov/Home> V2 Field Coordinator says tornadogenesis likely next few minutes. Probe 2 is headed toward the circulation center. See ***link.*** (A link to the GR2 radar with armada positions overlaid was posted here.)
[22:04:47] <nws-jim.purpura@nwschat.weather.gov/Home> FC2 Tornado! 70 M/S delta - v on radar
[22:07:07] <nws-david.thede@nwschat.weather.gov/Office> NICE tornado, live on the wx channel.
[22:10:32] <nws-scott.carpenter@nwschat.weather.gov/Home> Thanks. Great reports.
[22:11:22] <nws-jim.purpura@nwschat.weather.gov/Home> Wall cloud image pasted on our VORTEX2 Facebook page now...

In this particular example, the NWS Cheyenne office (CYS) was able to receive real-time observations, radar measurements, and spotter reports from V2. This proved to be important input to the warning decision process. (J. Eise 2009, personal communication).

6. Conclusions

- The NWS liaison provided a useful conduit for operations-to-research and research-to-operations. NWSChat and improved mobile communications facilitated real-time sharing of storm information between research and NWS operations to a greater extent and on a larger scale than any other project of its kind.
    - Research operations were able to take advantage of real-time spotter reports from the NWS as well as shared special soundings.
    - NWS operations received information from specific research radar observations, mobile mesonet temperature, dew point, wind measurements and additional visual observations immediately adjacent to the developing storm. This provided additional input to the warning decision process.
- The NWS liaison helped coordinate damage surveys ensuring a consistent message was sent to media and the public concerning the strength of tornadic winds.
- The NWS liaison used social media, particularly Facebook, as a useful tool to tell the story of the intercepts just after the day's operations were complete. Real-time positions were not posted.

- Future projects of this nature should build upon this activity to strengthen the tie between research and operations. Adding a dedicated person disseminating information via social media would be one example. Another step forward could be real time sharing of storm video and live research radar images sent to NWS Forecast Offices.

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