NWS Operations Proving Ground
Final Report

CWSU Cloud AWIPS and Collaboration Evaluation

An OPG Virtual Experiment

NWS Operations Proving Ground
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1. Executive Summary

In 2021, managers of the aviation program at local, regional, and national headquarters offices contacted the OPG to inquire about conducting an evaluation focused on Center Weather Service Unit (CWSU) operations. These program managers wanted to better understand how Cloud AWIPS and a Geospatial Collaboration Tool might improve CWSU operations. They were aware of prior OPG evaluations that showed Cloud AWIPS provided a superior user experience to Thin Client, which is the current AWIPS platform used in CWSU operations.

To be clear, the OPG did not conduct this evaluation with the intent to recommend that Cloud AWIPS become operational for CWSUs. Rather, the aviation program managers wanted to understand if Cloud AWIPS provided the user experience required to potentially replace Thin Client in the future. The OPG understands that the decision to make Cloud AWIPS operational for CWSU is related to a host of factors beyond just user experience or preference.

So, in mid January, 2022, the OPG, in collaboration with several members of the aviation program, the Aviation Weather Testbed (AWT), and the Aviation Weather Center (AWC), conducted a virtual evaluation with CWSUs focusing on convective events. Sixteen CWSU forecasters, 2 AWC forecasters, and 2 National Aviation Meteorologists (NAMs) joined the OPG for the two day session over a two week period (Fig. 1). These participants reviewed archived weather data on the OPG Cloud AWIPS instances to make IDSS related forecasts for core partners, and to collaborate on the TFM Convective Forecast (TCF). Further, our participants leveraged ArcGIS Online maps to respond to partner “injects” (requests for forecast information focused on aviation operations) and to provide geospatial collaboration for the TCF.

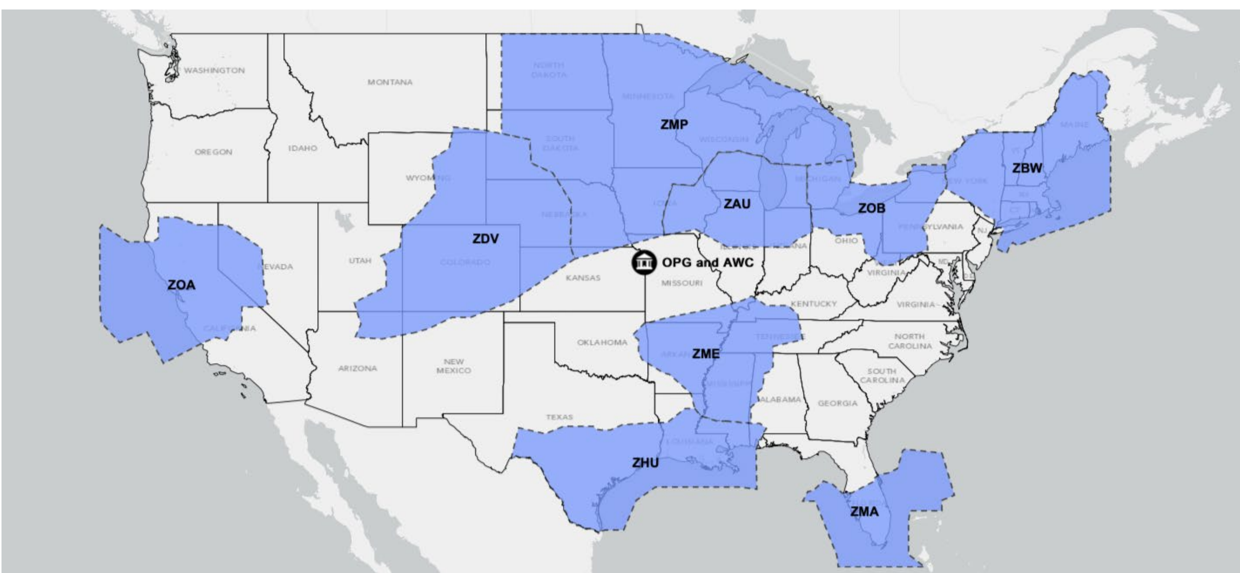

Figure 1: Map showing locations of participant CWSUs, as well as the location of OPG and AWC (which houses the AWT).

Our results from the evaluation confirmed our two main hypothesis related to our objectives:

1. CWSU meteorologists overwhelmingly preferred Cloud AWIPS over Thin Client and believe Cloud AWIPS would provide a superior data analysis and visualization experience than their existing operational tools.
2. Using dynamic and interactive geospatial collaboration tools offers incredible potential to improve upon or solve aviation related forecast collaboration challenges.

This was the first ever OPG evaluation focused specifically on CWSU operations. It was a profound learning experience for the OPG. We came to understand several of the complex challenges facing CWSU operations that, in some cases, were well beyond the scope of our evaluation. We will briefly discuss two of these challenges in our report. One issue is the CWSUs dependency on Federal Aviation Administration (FAA) operations and technology, and the other is related to CWSUs feeling “left out” of various NWS efforts.

Thank you for reading our report and providing the OPG with feedback.

2. Background (Spirit and Intent)

CWSUs are faced with unique operational challenges. Not only do these offices find it challenging at times to collaborate with their neighboring offices, WFOs, and the AWC, but they also operate with technologies or methods dictated largely by the FAA and control tower operations. Further, CWUSs do not have AWIPS workstations and must make due with AWIPS Thin Client and web based data visualization tools for their operations.

Thin Client is heavily reliant on bandwidth in order to provide a quality user experience. The internet connections at CWSUs have improved in the past few years, but CWSU meteorologists still experience sluggish performance with Thin Client.

As a result, members of the aviation weather community, including program managers, contacted the OPG to see if we would evaluate a few tools that may improve CWSU operations in the future. They were most interested in Cloud AWIPS. Prior OPG technical tests and evaluations focusing on Cloud AWIPS showed the system to be quite stable and fast. Further, technical tests by the OPG showed users only required minimal bandwidth connections (about 5 mbps or greater) to achieve a quality user experience.

Secondly, the OPG suggested the evaluation include ArcGIS Online (AGOL) to demonstrate the value of dynamic and interactive geospatial collaboration. CWSUs and AWC currently use a web application whiteboard to collaborate on the TCF. The whiteboard is a password protected web page displaying three CONUS maps which correspond to the three valid times, or panels, for each TCF issuance. Their collaborative process begins with AWC providing a “first guess TCF” via the whiteboard. The AWC TCF polygons represent sparse (25%-39%) or medium (40%-74%) coverage of convection at specific forecast time frames (4 hours, 6 hours, and 8 hours). The CWSU meteorologists then have a window of time to provide their feedback on the initial polygons by directly drawing on the whiteboard and/or using the chat function. AWC then finalizes the polygons and issues the TCF.

While this process has worked well, there are a few limitations. For instance, the whiteboard maps are static, meaning collaborators do not have the capability to zoom, overlay geospatial features or boundaries, or add meteorological data to the map background. In addition, given the limited collaboration time window, and varying operational workloads, some key collaborators may miss their chance to provide input. because they are simply too busy.

Leveraging AGOL during the evaluation allowed the CWSU meteorologist and AWC meteorologists to experience a more constant flow of collaboration information using interactive polygons in real time.

3. Objectives and Goals (Hypothesis)

Because this was the first evaluation we developed focused on CWSU operations, we decided to maintain a narrow focus with only two main objectives:

1. Determine if Cloud AWIPS provides a user experience that meets or exceeds the needs of CWSU meteorologists.
2. Determine if dynamic and interactive geospatial collaboration tools improve the TCF collaboration experience between CWSUs and AWC.

4. Evaluation Criteria

We relied on the participant and observer feedback from debriefings and surveys to indicate whether or not we met the evaluation objectives. In this case, we did not verify participant predictions objectively because we were not evaluating meteorological skill. However, collaboration was a key component of the evaluation, so we did analyze aspects of the communication methods to determine use of “words of estimative probability” or clarity within text based content.

We compiled both qualitative and quantitative information focusing on user experience, preferences to current operational tools, and both strengths and limitations of the tested tools.

The OPG also gathered data on Cloud AWIPS costs for the evaluation, but we understand that these costs can not be extrapolated to easily estimate an operational cost. Any information presented on Cloud AWIPS costs should therefore be interpreted as the cost of the evaluation.

5. Experiment Design and Technical Specifications

Sixteen total CWSU meteorologists joined the OPG virtually for two day evaluation sessions over the course of two weeks. They were joined by a meteorologist from AWC and a NAM. We split the participants into 2 one-week sessions that lasted 2 days each week for 4 hours each day.

For example, 8 CWSU meteorologists, 1 AWC meteorologist and 1 NAM joined us on a Wednesday and Thursday for four hours each day during week one of the evaluation. These 8 CWSU meteorologists were put into three groups with each group containing 2 or 3 participants. These 2 or 3 participants took on the role of a forecaster at a CWSU during a convective event.

Each group operated independently of the other groups even though they were operating in the same geographic domains. (See tables below for example)

Group 1 includes forecasters Alpha, Beta, and Gamma

Forecaster Name	Day 1 CWSU Assignment	Day 2 CWSU Assignment
Alpha	CWSU Dallas (ZFW)	CWSU Atlanta (ZTL)
Beta	CWSU Houston (ZHU)	CWSU Memphis (ZME)
Gamma	CWSU Memphis (ZME)	CWSU Indiana (ZID)

Group 2 includes forecasters Delta, Epsilon, and Eta

Forecaster Name	Day 1 CWSU Assignment	Day 2 CWSU Assignment
Delta	CWSU Dallas (ZFW)	CWSU Atlanta (ZTL)
Epsilon	CWSU Houston (ZHU)	CWSU Memphis (ZME)
Eta	CWSU Memphis (ZME)	CWSU Indiana (ZID)

Group 3 includes forecasters Theta and Iota

Forecaster Name	Day 1 CWSU Assignment	Day 2 CWSU Assignment
Theta	CWSU Dallas (ZFW)	CWSU Atlanta (ZTL)
Iota	CWSU Houston (ZHU)	CWSU Memphis (ZME)

Our surprisingly large number of Greek participants were informed they could collaborate with members of their group in a google chat room or through an interactive AGOL web app. Participants could see and modify the AGOL information from their own group members, but not other groups.

On the first day of the evaluation, our participants reviewed an archived case within Cloud AWIPS. We used a large-scale strongly forced synoptic event with showers and thunderstorms covering much of Texas, Oklahoma, and Arkansas.

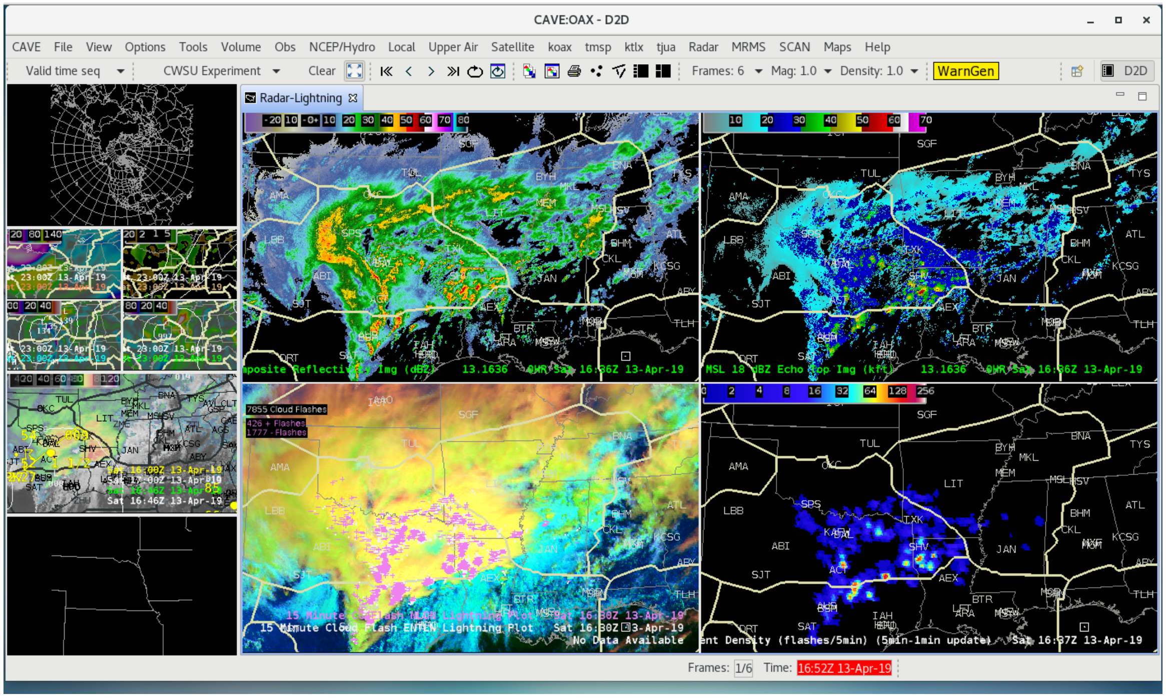

Figure 2: Screen capture of Cloud AWIPS showing a 4 panel display with radar, satellite, and lightning density data.

After allowing the participants some time to analyze data and become familiar with the environment, the OPG sent “injects” to participants using the AGOL web app. The injects showed up as red dots on the shared map. When participants clicked on the red dot, they received information from a fictitious core partner asking for weather information. The participants responded to the inject by editing a “response” field within the inject.

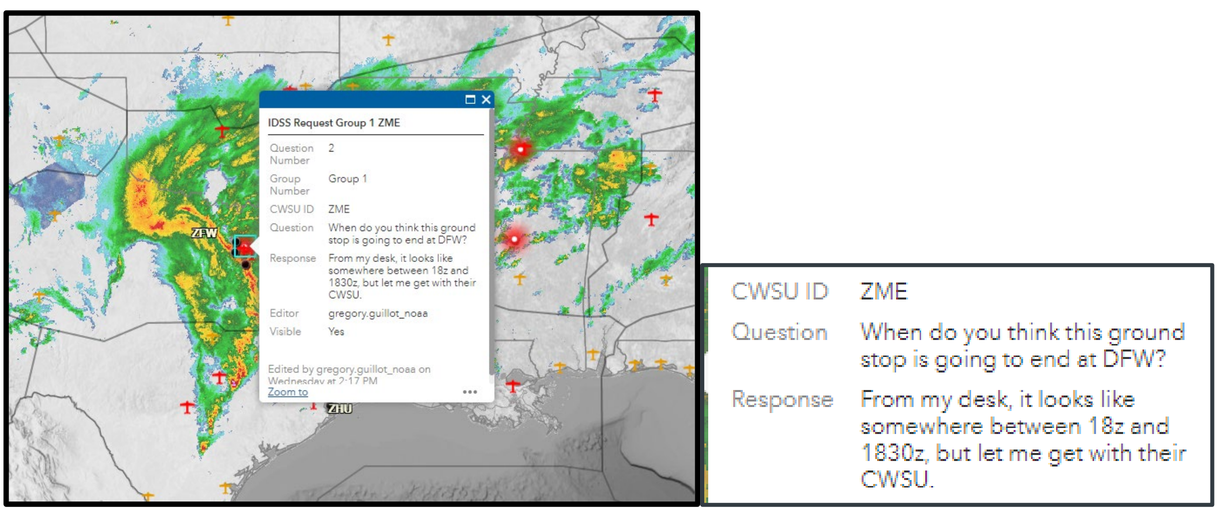

Figure 3: Screen capture of the AGOL display showing details from an inject (red dot) and the participant response (right box).

On the second day, our participants again leveraged Cloud AWIPS to review an archived case focused more on Tennessee, Indiana and Georgia. In this case, the convection was more scattered with weaker forcing. Our CWSU participants were asked to draw polygons in AGOL indicating where they felt a TCF may be warranted by AWC. They added information to the polygon corresponding to typical TCF fields such as:

- Forecast Valid Time
- Expected Coverage Type (Sparse or Medium)
- Expected Echo Tops
- Confidence Level (Scale 0 to 100)

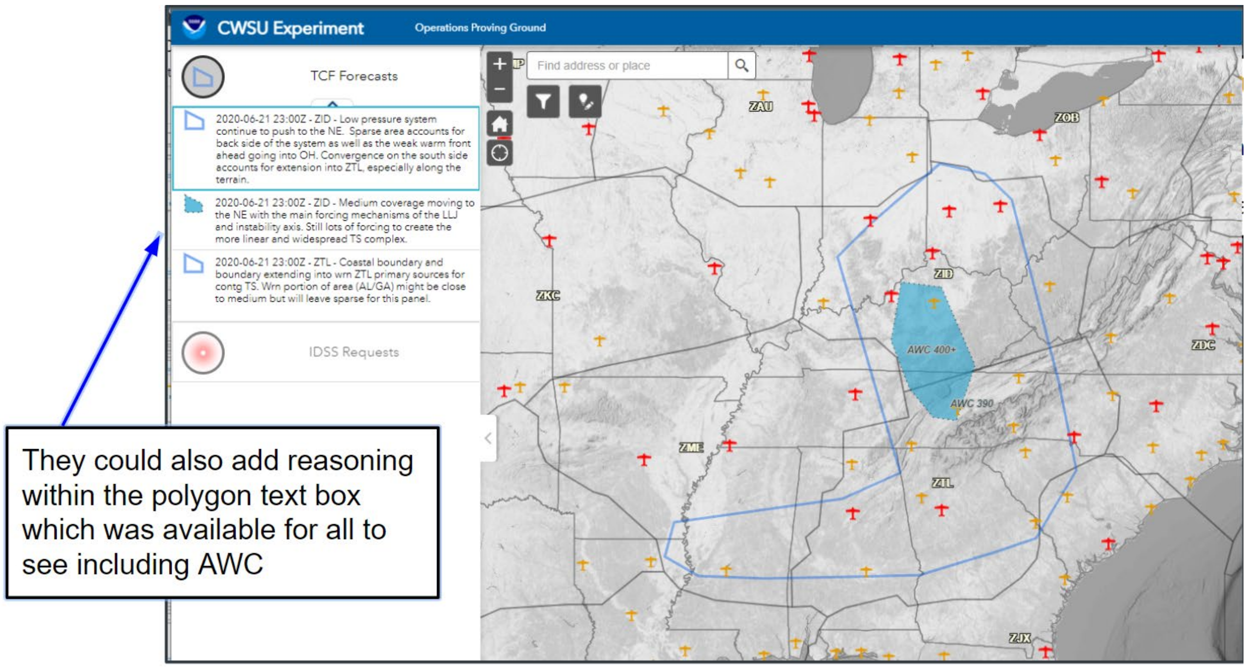

Figure 4: Screen capture of the AGOL dashboard created for the participant's collaboration portion of the evaluation.

At the same time, our AWC and NAM participants were also reviewing data in Cloud AWIPS and could provide their thoughts on the polygons produced by the CWSU participants. Once the group came to a consensus, the AWC participant drew a final polygon representing the "official TCF".

In addition to our participants, the OPG invited several individuals at local, regional and national offices to observe the evaluation. We set up a google chat room and google meet session for the observers to discuss the evaluation with the OPG. The observers also had access to the AGOL web app used by the participants. They were able to review participant responses to injections or polygons created in real time.

We also developed an AGOL "Dashboard" that allowed our observers to filter participant data and review information as they saw fit. In fact, you (the reader) can review the data by using your CAC or LDAP credentials to log in.

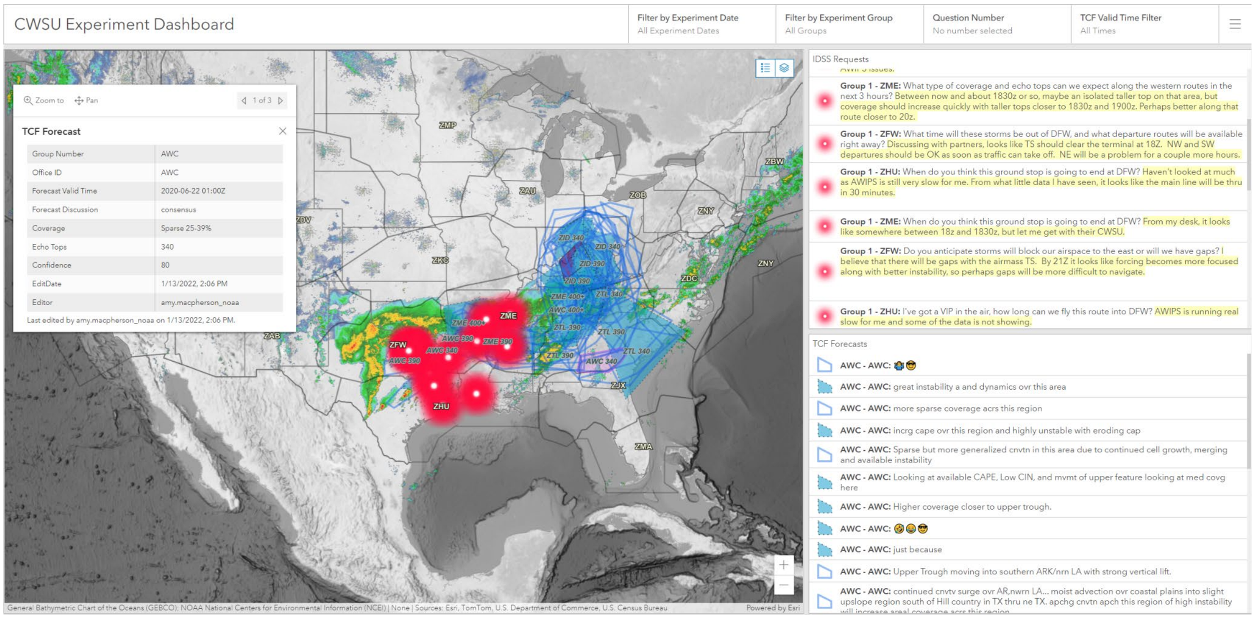

Figure 5: Screen capture of the AGOL dashboard created for the observers to view all of the data from the evaluation. The observers could reduce the amount of data using filters.

6. Results, Findings and Recommendations

Our participants performed exceptionally well. They were open to trying new tools and methods and provided insightful feedback during debriefings. Further, the observers provided thoughtful feedback throughout the evaluation and in post evaluation debriefings.

FINDINGS

As a result, the OPG is confident in confirming the following two main findings:

1. Cloud AWIPS provides a superior user experience than Thin Client for CWSU operations.
2. Using dynamic and interactive geospatial collaboration tools offers incredible potential to improve upon or solve aviation related forecast collaboration challenges.

RECOMMENDATIONS

From these findings, the OPG recommends the following actions:

1. If not already completed, the NWS should consider drafting a formal assessment of the cost, IT requirements, and potential path to transitions Cloud AWIPS into CWSU Operations.
2. CWSUs and AWC should further investigate use of AGOL to support collaborative efforts between AWC, CWSUs, NAMs, and WFOs.

Through post-evaluation surveys, we gauged participants' qualitative opinions in order to better understand how and when AWIPS (Thin Client) was used in CWSU operations. A total of 11 out of 16 participants completed the survey. We believe that these opinions are samples representative of the much larger population of CWSU forecasters and, therefore, these findings can be more broadly applied to CWSU operations as a whole.

We asked participants to estimate the amount of time they spent during typical convective forecast operations using AWIPS (as opposed to other websites) to analyze data. Perhaps surprisingly, the majority of the participants (73%; 8 out of 11 participants) indicated that they spend less than 50% of their time using AWIPS to analyze their data (Fig. 6). 27% of respondents indicated that they used AWIPS to analyze data approximately 60–80% of the time.

Overall, participants expressed that while AWIPS (via Thin Client) at CWSUs is adept at displaying observational data (i.e., surface observations, lightning, radar, and satellite imagery), paneling of data, and overlaying AWC/CWSU/WFO products on live data, it has limitations that impact its use in operations. One participant noted, *"AWIPS thin client still has speed and efficiency issues in the CWSU setting."* Which is why they leveraged web based resources instead because*, "The internet is fast, easy and has a variety of good forecasting tools."*

Another participant indicated that viewing of sounding data is arduous and clunky in AWIPS, it is at times hard to copy and paste graphics from AWIPS into shift log, and AWIPS has a steep learning curve and configuration is at times cluttered/clunky. In comparison, other web-based data is readily available, fast, responsive, and intuitive[1]. Further, certain CAMs or CAM derived products (such as ProbSevere Lightning Cast) are not readily available in AWIPS, but are available on other webpages. Thus, model data is perhaps best visualized from other non-AWIPS web-resources. In particular, participants noted heavily using the SPC mesoanalysis page in convective and winter weather setups as well as the NOAA/NWS WSUP page. However, many of these issues in using AWIPS are based upon the poor performance and user experience of Thin Client. These above findings are elaborated upon further in section 6.

54.5% (6 out of 11 survey responses) believe that there is data (model or observational) in AWIPS that does not adequately meet the operational needs for CWSUs; in fact, only 9.1% (1 out of 11 survey responses) believed that the data within AWIPS meets their operational needs. While most of the gap in need can be attributed to previously discussed issues (slow AWIPS via Thin Client, poor performance of AWIPS-based soundings, etc.), three themes emerged through analysis of participant feedback:

1. User Experience. Forecasters note the web platforms are visually appealing, easy to navigate, and are reliable and stable.
2. Data visualization. Forecasters want options for visualizing ensemble data such as: point based plumes, box and whisker/violin plots, PDF curves, probability of exceedance, and threshold probabilities.

[1] All depending on personal internet speed

3. Data availability. Forecasters note that web platforms often provide data not available in AWIPS. This includes higher resolution versions of deterministic models from the UK and ECMWF and various ensemble systems.

With regard to visualization, participants noted needing better ways to present data such as PIREPS, SIGMETS, Center Weather Advisories (CWAs), route labels, ITWS winds, more options for composite reflectivity from high resolution models, and color-deficient accommodations. There was also an expressed desire to be able to view data by altitude or at standard flight levels. With regard to accessibility, a few participants noted that despite a plethora of information in AWIPS, it is sometimes difficult to find what they need (in agreement with the topic of a steep learning curve for AWIPS previously discussed), which is exacerbated by slow AWIPS performance in the CWSU.

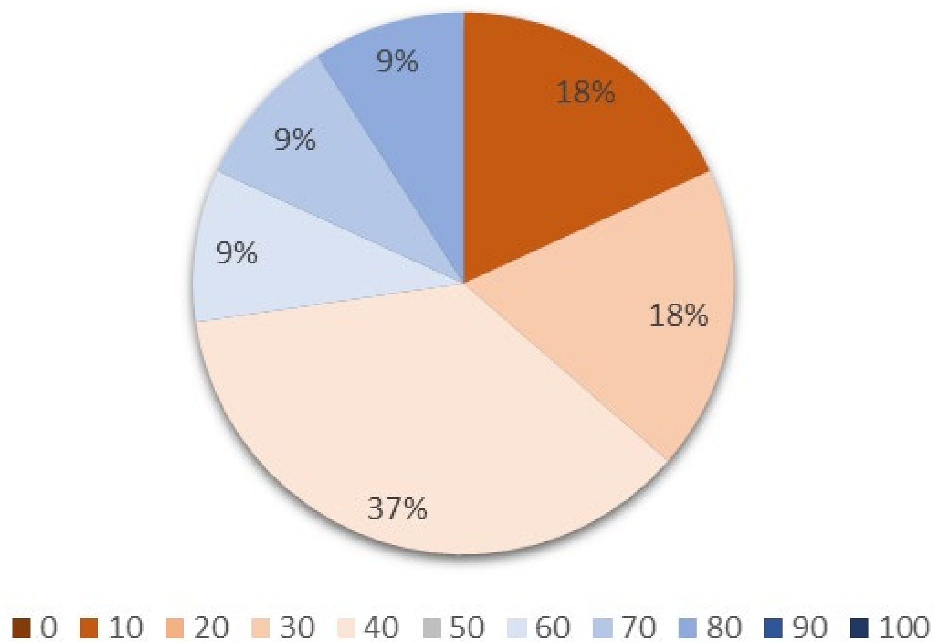

Figure 6: Pie chart showing the amount of time spent (in percent) using AWIPS for data analysis in typical CWSU convective operations, with 100% being using AWIPS exclusively. Percentage usage below 50% is shaded in reds, above 50% is shaded in blues.

Regarding Collaboration

There remains various individual preferences regarding the optimal collaboration tool or environment. After every OPG experiment, including this CWSU example, we find survey responses often produce seemingly contradictory information. For example, some participants in our experiment simply prefer a phone call over chat, or a chat room over a google meet, or a google meet over a phone call. The reality is that each collaboration tool has pros and cons that work well in certain situations, but fail in others.

One common sentiment though is the need for geospatial collaboration. It's becoming increasingly clear to the OPG that simply discussing spatial information in chat, on the phone, or in google meet poses serious collaboration challenges.

As mentioned in the Background section of this report, the AWC and CWSUs currently leverage an internal web based whiteboard application that allows for geospatial collaboration. While this tool has worked well in general, our CWSU participants noted a few limitations with the concept:

1. The lack of geospatial reference locations on the white CONUS maps
2. Once polygons are created, they cannot be edited
3. The polygons drawn on the map are not archived
4. Forecasters can only use the white board in set collaboration windows.

The last point appears to be one of the bigger issues as one participant noted, *"I know we have the ability to chat up AWC-TCF between the official collaborations, but it's easy to get wrapped up in briefings and weather watching when there is a lot going on (and miss the collaboration window)."*

The OPG introduced participants to an AGOL dashboard that provided a more interactive geospatial collaboration experience. Most participants in the CWSU experiment felt the geospatial collaboration function provided by AGOL was very promising, *"I think the main collaboration tool that was different was the AGOL platform. This platform has a ton of potential for collaboration with multiple CWSUs, NAMs, and AWC so that we can all visualize what each of us are talking about. Right now most things are done over the phone so there is always some communication issues due to not seeing the same graphics, satellite, or radar."* However, there is a concern about leveraging yet another platform for collaboration. Further, the AGOL platform lacks an embedded chat function which is utilized heavily in the AWC whiteboard application.

The key message to be learned is that we are still struggling to provide an effective collaboration experience for our forecasters. While they have tools at their disposal to engage in collaboration, various limitations with these tools produce a less than ideal collaborative experience as a whole.

Unique CWSU Challenges

Throughout the process of developing, conducting and evaluating our CWSU experiment, the OPG learned about a few unique challenges facing CWSUs. These items were not within the scope of our evaluation, but we felt it was important to share these lessons with the NWS. Consider the OPG to be a messenger in this case and an entity willing to help address challenges in the future as the agency sees fit.

First, CWSU meteorologists can feel isolated or even left behind by the agency. Our participants referenced several projects or programs that they feel have "left them out". For example, they noted the recent software program called GraphiDSS which produces IDSS graphics based on

GFE data. However, because CWSUs do not have AWIPS nor GFE, they can not take advantage of a program that is becoming widely used by WFOs to create IDSS graphics.

One participant even noted their appreciation of the OPG including CWSUs in an evaluation stating, *"Thanks for putting this experiment together, it is nice to see the CWSU being involved with the OPG and possible improvements to our operations. CWSUs have been so separate and different than WFOs, increasing the knowledge of what the CWSUs do and how they can improve now that so much funding and efforts are getting into the WFOs."*

Second, CWSUs are contractually bound to support the FAA. Because of this, CWSUs are also bound by the technology or tools used by the FAA. As such, CWSUs are limited in their capacity to innovate or even consider new products or services if those innovations are not designed to FAA technologies.

Third, there appears to be little standardization among the tools or software used by CWSUs to accomplish their mission. As a result, CWSUs are heavily reliant on locally developed software to either analyze data or disseminate information. When the OPG initially began discussions with aviation program representatives about hosting a CWSU evaluation, we quickly realized we could not fully simulate a CWSU environment because they are so inconsistent. This was a major factor in our decision to keep the evaluation focused on general concepts such as geospatial collaboration or responding to partner requests.

Fourth, as the agency further evaluates collaborative forecast processes, CWSUs are concerned they will be left out of programmatic based CFP plans. Aviation meteorologists do have unique forecast collaboration challenges for elements like icing or turbulence, but they also deal with common events across the winter, severe, tropical and even fire hazard types. As such, they want to ensure CWSUs, AWC, and NAM forecasters can collaborate efficiently with WFOs and other NCEP centers as needed.

A. Appendix: Data usage

During the evaluation, we offered a set of seven pre-built AWIPS procedures that could be used to quickly analyze observational and model data from the two archived cases used. We then asked the participants after the evaluation the importance of the various data used in these procedures in typical CWSU convective operations (Fig. 7). Participants indicated that the most important[2] data out of the procedures was: 1.) METAR observations; 2.) composite reflectivity; 3.) HRRR forecasted reflectivity; 4.) radar-derived echo top height; and, 5.) visible satellite imagery (Fig. 7). The least important data available in the procedures was perhaps the RAP forecasted moisture flux divergence, RAP forecasted fields (e.g., 300-hPa height, wind, omega, etc.), and HRRR forecasted surface wind, as none of the participants indicated that they were "extremely important" and ≤ 50% thought they were "very important" (Fig. 7). However, it should be

[2] Here we, somewhat arbitrarily, define "most valuable" as a combined response of 80% or higher for "extremely important" and "very important"

emphasized that just because these data were perceived as “less important” does not imply that they are “not important”. Indeed, none of the participants, sans one instance, indicated that any of these data were “not at all important” (Fig. 7).

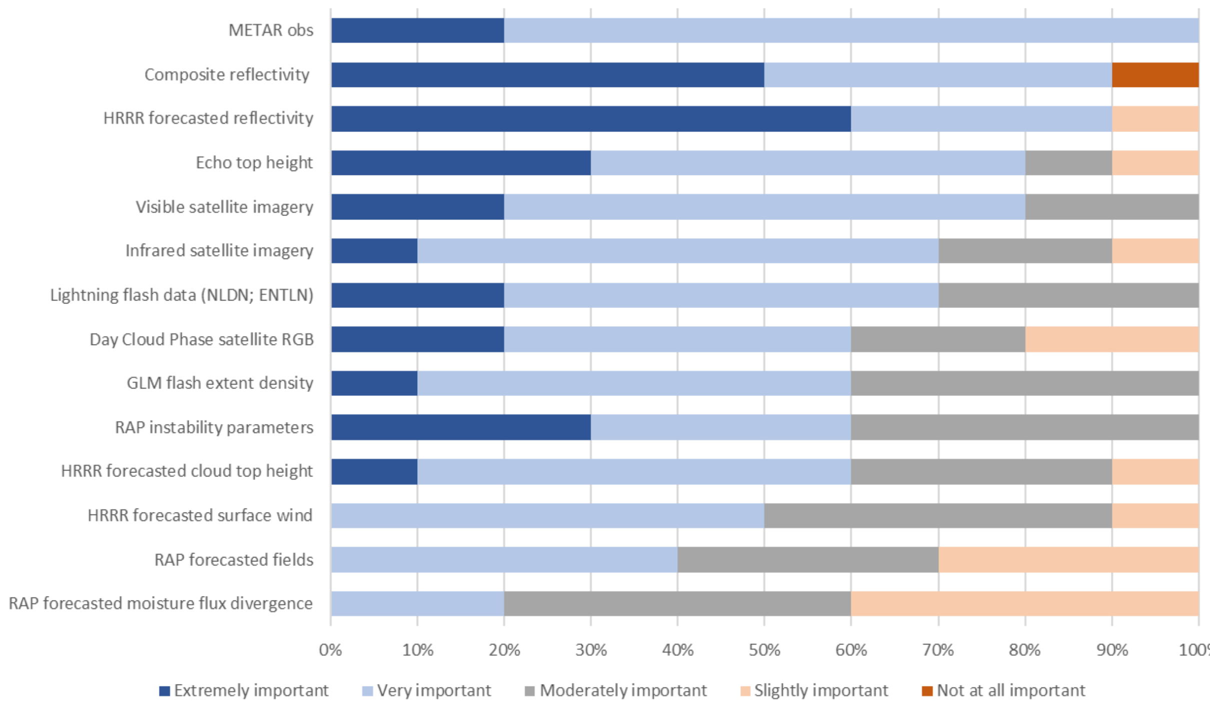

Figure 7: Stacked bar plot showing the importance of various data used in the pre-built procedures during the evaluation, as indicated by the percent of polled participants. Data are in descending order, with the largest percentages of “extremely” or “very” important towards the top. One out of the 11 participants indicated that they did not use the pre-built procedures at all and, therefore, did not rate the data importance.

Satellite data is one of the most utilized observational datasets in CWSU convective operations and as shown in Figure 7 and through other feedback, is one of the most crucial datasets for CWSU operations. When specifically asked about satellite data, participants noted that their most frequently[3] used imagery, RGBs, or products were: 1.) visible imagery; 2.) infrared (IR) imagery; 3.) nighttime microphysics RGB; and, 4.) GLM data (e.g., flash extent density) (Fig. 8). However, day cloud phase RGB, water vapor imagery, and day cloud/fog RGB are also used fairly frequently in CWSU operations, with 50–60% of participants indicating “always” or “very frequently” (Fig. 8). The products used less often in operations are cloud geometric thickness and cloud optical depth, with most participants indicating “very rarely” or “never” (Fig. 8).

Many participants noted the ability to use satellite data not only as a tool for situational awareness, but also for use in pre-convection initiation mesoscale analysis, determining local boundaries, assessment of turbulence, and dissipation of morning status or fog. In short, one participant stated: “*Proper mesoanalysis can not be done without satellite data.*” Some participants also indicated that they lean heavily on satellite imagery when models have not initialized well.

[3] Here we, somewhat arbitrarily, define “most frequent” as a combined response of 70% or higher for “always” and “very frequent”

However, one participant noted that due to data overload and time, it is hard to use satellite data beyond situational awareness.

"Satellite data is more of an situational awareness tool - and frankly, part of that is still learning how to best utilize all of the available satellite data. Data overload and lack of time can be an issue - better knowledge of how to better utilize the various imagery types would be very helpful, especially in an environment like ours, where we simply don't have a lot of time to pour over gobs of data given briefing needs."

Based upon this feedback, it is apparent that satellite imagery is of considerable importance in CWSU operations; however, it would be advantageous to investigate and develop best practices and strategies for using satellite data for convective operations, especially given the plethora of available satellite imagery afforded by the GOES series of satellites and ever growing innovative satellite-based tools and applications for forecasting convective hazards.

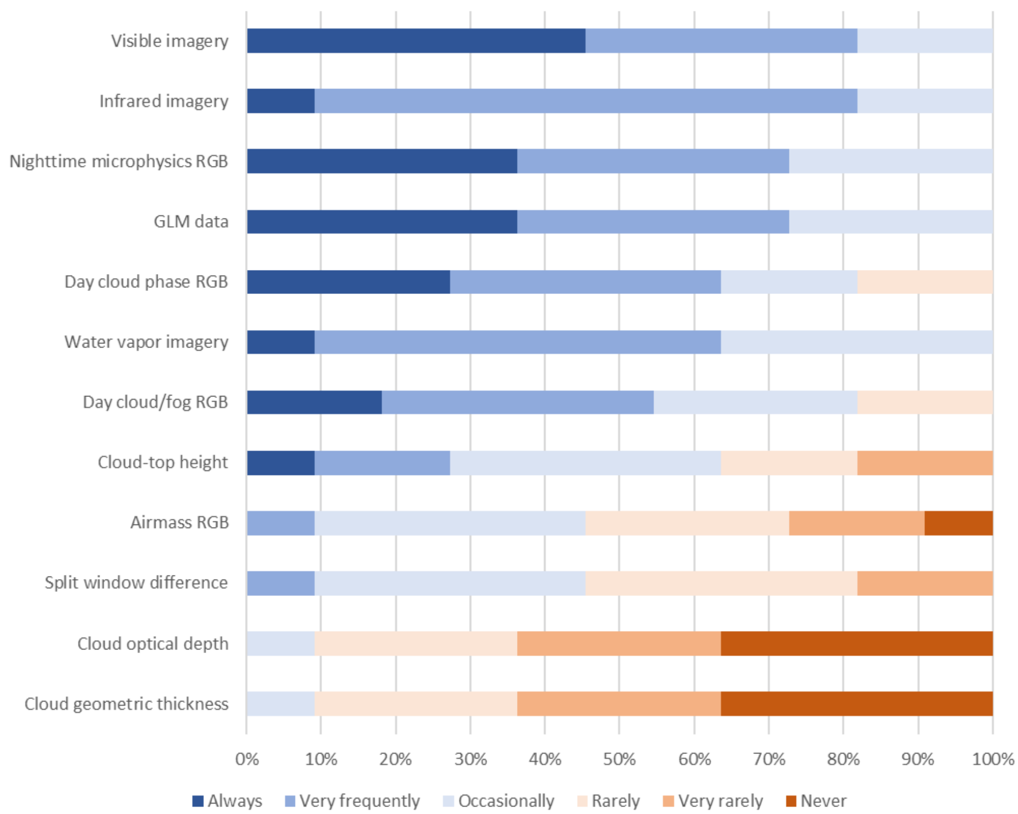

Figure 8: Stacked bar plot showing the frequency of satellite data used in typical CWSU operations, as indicated by the percent of polled participants. Data are in descending order, with the largest percentages of "always" or "very frequently" important towards the top.

Specifically related to satellite data, participants also expressed interest in having other imagery or derived products available in their procedures, including: day convection RGB, NOAA/CIMSS ProbSevere products, overlays of MRMS data, NUCAPS data, and GOES-R convection initiation data. Other (non-satellite related) data forecasters desire include, but are not limited to: SPC mesoanalysis products (*including experimental models*[4]), hourly ECMWF data, HRDPS (high-resolution Canadian model), additional CAM output (i.e., comparisons of multiple CAM forecasted reflectivity), forecasted and observational soundings, VAD wind profiles, OPC data, and CIWS/CoSPA data. Other data that participants thought were the most important to CWSU operations not previously mentioned are: mesonet data, terminal Doppler data, ellrod, ellrod-knox, GTG, icing products (CIP/FIP, etc.), 100-hPa bulk shear (useful for turbulence), turbulence indices, HREF aviation parameters, altitudinal relative humidity (or wet bulb temperature) and slices of relative humidity, LAMP MOS guidance, TAFs, AIRMETS, SIGMETs, CWAs, and MRMs data.

[4] Some participants expressed that they would like to see more CAMs data available for their analyses, and explicitly called out these SPC experimental models.