NWS Operations Proving Ground
Final Report

April 2021 Grassland Fire Weather Experiment

An OPG Virtual Experiment

NWS Operations Proving Ground
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1. Executive Summary

From 5–8 April 2021, the Operations Proving Ground (OPG) in collaboration with the Fire Weather Program, the Program Management Office, and local weather forecast office Subject Matter Experts (SMEs)[1] conducted an experiment leveraging both real-time and archived data. Eighteen participants representing local and regional offices from the four CONUS regions (including four certified incident meteorologists [IMETs]), spent three days evaluating fire weather conditions with real-time data focused on the southern Great Plains. On the fourth day, the OPG loaded archive data from a major fire outbreak in April 2018 into Cloud AWIPS. Participants evaluated data from this case in a displaced-real-time format allowing them to identify fires using satellite imagery and create mesoscale IDSS information using the ArcGIS Online (AGOL) platform.

This exercise represented a series of firsts for the OPG: it was the first fire weather related experiment we have conducted; it was the first time using archived data in displaced real time in the Cloud; and, it was the first time we used AGOL to capture participant forecasts.

Our experiment asked participants to complete three primary tasks each day:

1. Evaluate data, including fuels and probabilistic information, to identify fire weather concerns in the medium to extended range.
2. Assess the mesoscale environment to provide localized IDSS information.
3. Leverage GOES-16/17 imagery to identify "hotspots"[2], or fire locations, in real time.

Because the first three days of the experiment leveraged real-time data, neither the participants nor the OPG knew exactly how the events would unfold. Further, many of our participants lacked experience in Great Plains grassland fire weather. Yet, through a combination of pre-experiment training, and real-time assistance from local SMEs, our participants performed extremely well. They showed a capacity to effectively assess dangerous fire weather conditions in both the short term and medium to extended ranges, and they demonstrated ample skill in identifying "hotspots" in both the real-time and archived scenarios. Also, the experiment showed the value and necessity of collaboration. Collaboration increased forecaster confidence, produced forecast consistency across forecast offices, and generated high-quality decision support information for the fire community.

Finally, coincident with the last day of the experiment, the OPG was presented with an opportunity to provide Cloud AWIPS access to an IMET who was deploying to a prescribed burn in Colorado. While this opportunity was not part of our experiment, we felt the results were relevant and important to include in

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[1] The OPG asked Todd Lindley, SOO in Norman, to serve as the primary SME. During the experiment, one of our participants, Randy Bowers, Forecaster in Norman, became an SME due to his incredible mesoanalysis skills in the fire environment. So Mr. Bowers served as both a participant and SME.

[2] Hotspots are defined here as either new fire ignitions or ongoing fires, detectable through satellite imagery and products

this report. We believe the results of the impromptu test of **Cloud AWIPS by a deployed IMET represent the beginning of a transformational change to the IMET program**.

2. Objectives and Goals

The OPG, in coordination with the Fire Weather Program, established four main objectives for this experiment.

Objective 1: Evaluate Cloud AWIPS performance during real-time fire weather situations, and determine if Cloud AWIPS is capable of supporting IMET dispatches.

As part of an ongoing effort of the OPG to evaluate the user experience of Cloud AWIPS, this experiment asked participants to leverage Cloud AWIPS to interrogate data. The Fire Weather Program is very interested in understanding whether Cloud AWIPS can support IMET dispatches. Data from past IMET dispatches suggest the upper bound of simultaneously deployed IMETs is around 50 individuals (Fig. 1). The upper bound of the 30-year moving average is closer to 15 IMETs on assignment per day. Thus, with 18 participants our experiment closely simulated the average yearly maximum number of deployments on a day. The obvious main difference is that IMETs often lack the reliable and fast Internet connectivity that the participants used in this experiment.

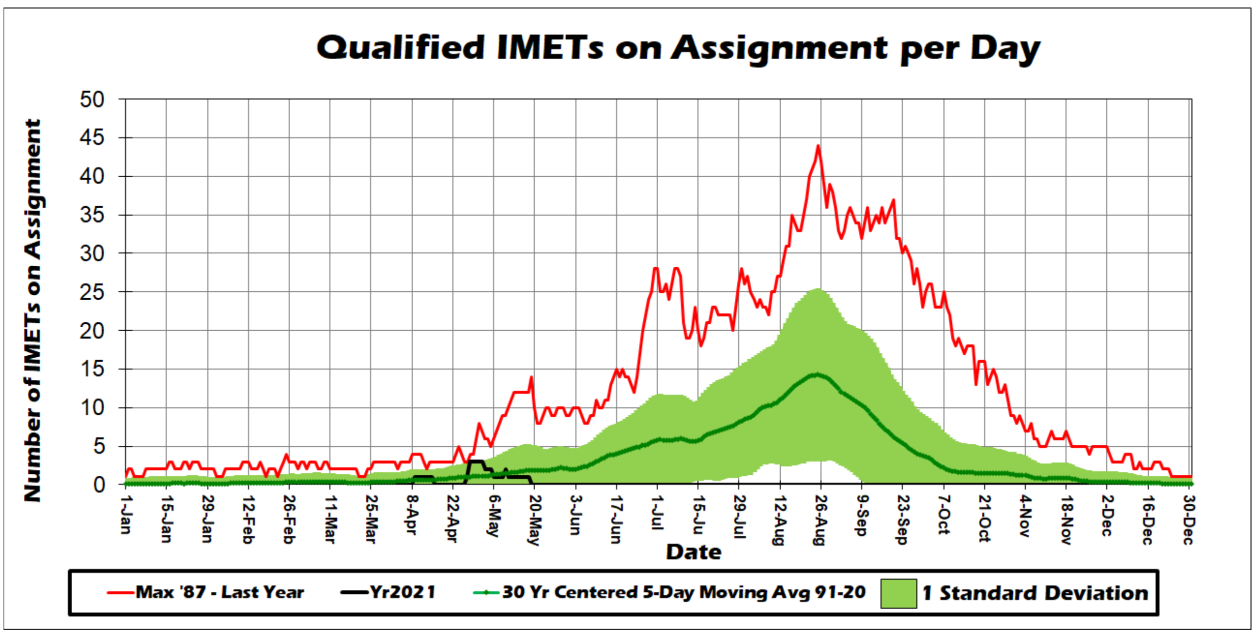

Fig. 1. Number of IMETs on assignment per day. Image courtesy of Mr. Larry Van Bussum, National Fire Weather Operations Coordinator.

Objective 2: Examine how mesoanalysis (including hotspot detections) might be integrated into fire weather operations to improve IDSS for ongoing or emerging fires.

The Fire Weather Program managers and the OPG feel there currently exists a service gap in the short-term fire weather environment. Drew Daily from Oklahoma State Forestry noted during our experiment the critical importance of receiving updated weather information when short-term changes occur. Further, our NWS Strategic Plan describes the need to "Provide more frequent and timely access to forecast information through a continuously-updated and interoperable database." (NWS Strategic Plan, Section 1.12). As such, Objective 2 of our experiment focused on the potential benefit of leveraging mesoscale analysis and providing real-time IDSS, including hotspot detections, to fire partners.

Objective 3: Determine if collaborating from a common set of data using similar methodologies improves the collaborative experiences, produces more confident forecasters, and leads to skillful and consistent fire risk assessment in the day 2–7 period.

In prior OPG experiments where we evaluated collaboration, and through years of combined operational experience, the OPG has noted some potential roadblocks to effective collaboration. Some of these roadblocks are well known, such as the use of inconsistent starting points, but the OPG has noted additional challenges. For example, during the CFP for QPF experiment we found the nature of conversations early in the collaboration time frame to be chaotic—covering multiple themes in a stream of consciousness flow.

Additional roadblocks include a forecasting culture that is individualistic in nature and inconsistencies in: types of data used in analysis, the timeline of the forecast process, and thresholds for various products. Thus, the OPG continues to evaluate the impact of added structure and organization to the forecast and collaborative process.

Objective 4: Assess if a cloud based approach to producing collaborated IDSS improves the quality and consistency of fire weather messaging among multiple WFOs.

In designing the experiment, the OPG required a mechanism to capture and archive participants' predictions and reasoning. We also needed a system that could provide a geospatial collaboration experience. We considered several options, but found AGOL to be the most effective, and available, system to meet our experiment needs. AGOL is a cloud based GIS platform where our participants could draw polygons on a shared map, enter relevant information or reasoning, and view that data from fellow participants. Our intent is not to advocate for or against the use of AGOL for future fire weather collaboration needs, but rather assess the operational potential of a cloud-based geospatial collaboration tool to inform future collaboration needs.

3. Experimental Design

The OPG has now conducted several virtual experiments with various numbers of participants. We have learned a great deal regarding the necessary organization, structure, pre-work (training), and technical details that allow us to create a valuable, quasi-realistic, and effective experience. The information below provides an overview of our experimental design, and there are additional details available by clicking on the various links throughout the section.

3.1 Experiment Process

The OPG conducted this virtual experiment from 9 AM to 5 PM Central Time each day. We began each morning with a welcome, some logistics information, and assigned our participants to WFOs. Our 18 participants were placed in groups of three with each person from the group playing the role of one of our selected WFOs for the day. Thus, we had six total groups operating in parallel. None of the groups could see or hear what the other groups were producing. A member of the OPG served in each group as a facilitator and evaluator.

Each day the participants spent the morning focusing on the medium range (days 2 through 7) fire weather assessment, and the afternoons on the mesoscale environment (including hotspot detections).

We asked participants to review common data at common times. We then focused the collaboration around two key questions: 1) What forecast day appears to have the highest fire weather concerns? and 2) What conditions will be present that cause these increased concerns?

Then, using AGOL[3], and in collaboration with the neighboring offices, our participants highlighted the area they felt represented the worst expected fire weather conditions of the week[4]. They first drew "initial polygons" as a way to share their thoughts collaboratively with neighboring WFOs. We asked each participant to supply the following information when creating a polygon:

- The "valid date" of the forecast (the date when participants expected the worst fire conditions)
- One of four options relating to the fire weather severity that included both atmospheric and fuel information:
  - Level 1: Routine Fire Weather Activity - Initial Attack Can Handle
  - Level 2: Low to Moderate Potential for Significant Fire Weather Conditions
  - Level 3: High Potential for Significant Fire Weather Conditions - Outbreak Possible
  - Level 4: Significant Fire Weather Conditions Expected - Outbreak Likely
- The reasoning for their prediction

For example, on the first day of the experiment, each participant from "Group 2" (which included WFOs Midland, Lubbock, and Amarillo) drew three initial polygons as shown in Figure 2. After some discussion via either chat or video, the participants created a single "final polygon" representing a collaborated forecast covering multiple CWAs. For example, "Group 2" ended up producing this polygon representing a "Risk Level 3" (Fig. 3).

It is important to note that the OPG understands forecasters do not currently think about, or forecast, fire weather conditions in the manner which we conducted during the experiment. However, both the Fire

[3] Accessing this AGOL link requires a NOAA CAC or LDAP login

[4] Because local offices have different criteria for issuing Red Flag Warnings, or Fire Weather Watches, the OPG asked participants to think about the environment in terms of risk (atmospheric conditions plus fuels), versus specific element based thresholds. They were not predicting the location of red flag warnings, fire watches, or SPC risk outlooks.

Weather program and the OPG felt it was worth investigating the value of incorporating fuel information into the fire weather forecast process. As such, we introduced a fire weather risk level concept to understand how this might support future evolutions to the Red Flag or Fire Weather Watch product suite. The OPG is not advocating for or suggesting local offices begin issuing "Fire Weather Risk Areas" operationally or for IDSS purposes.

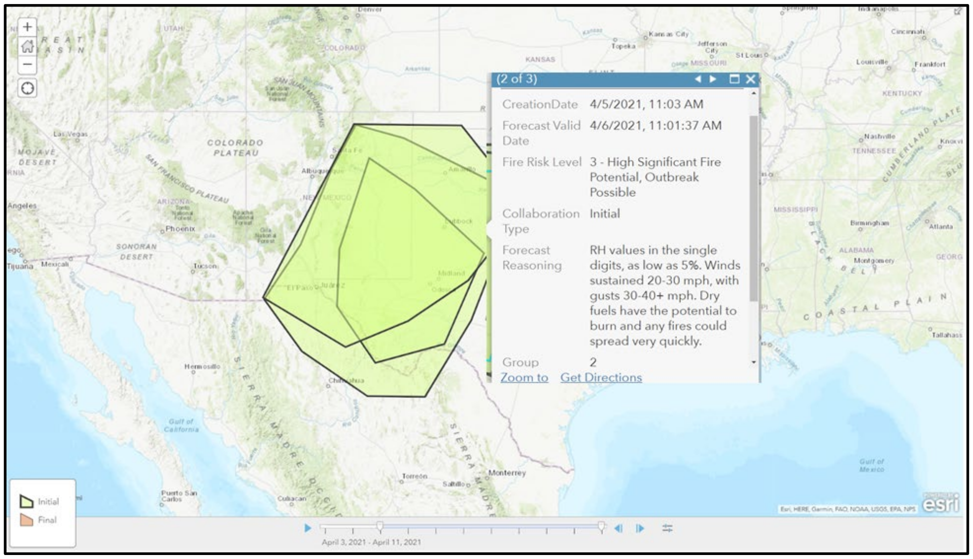

Fig. 2. Example of three initial polygons (yellow) drawn by the members of "Group 2" on 5 April 2021, valid for the following day (6 April 2021). The inset text box shows the fire risk level and forecast reasoning for one of the three initial polygons.

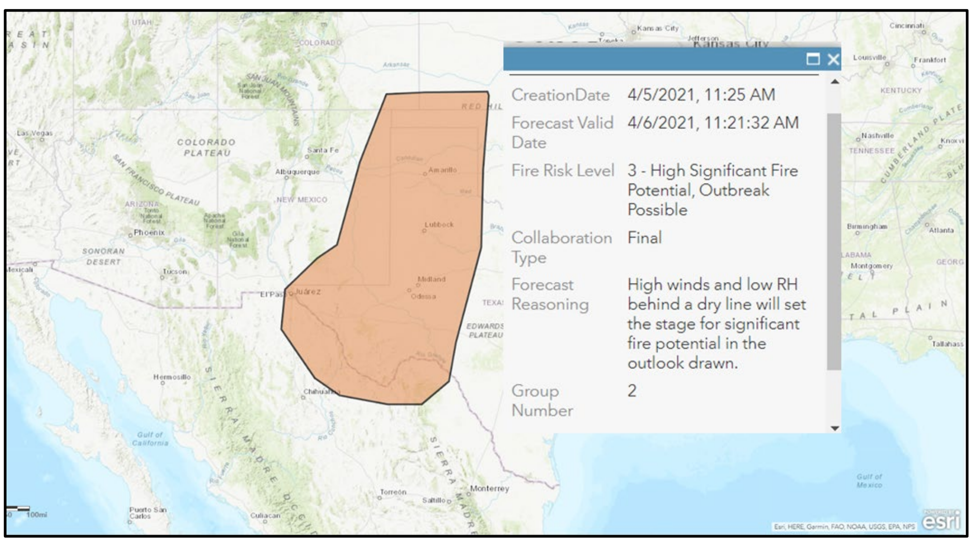

Fig. 3. Example of a final polygon (orange) drawn by the members of "Group 2" on 5 April 2021, valid for the following day (6 April 2021), with their forecast reasoning and fire risk level shown in the inset text box.

After lunch, the participants turned their attention from the medium/extended range to the short-term mesoscale environment. Figure 4 is an example from 6 April 2021 where a participant noted the increase in low-level wind speeds and rapidly drying air.

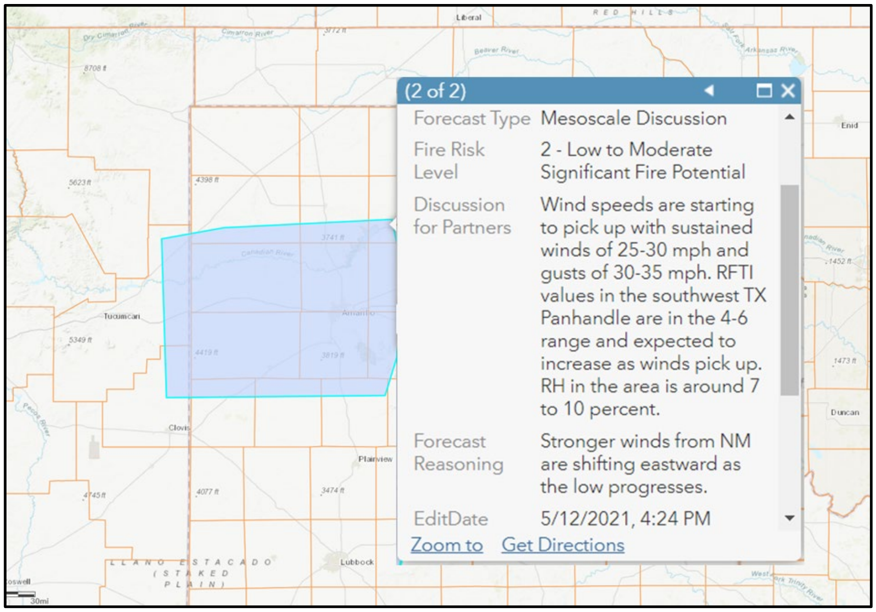

Fig. 4. Example of a medium/extended range mesoscale forecast discussion (inset text box) for the highlighted area (blue) for 6 April 2021.

Finally, we asked our participants to use GOES-16/17 satellite data to identify any new fire ignitions or hotspots, in real time. There were several prescribed burns and small wildfires that occurred during our three-day live-data test. As an example, on the first day of the experiment, our participants identified several prescribed burns in eastern Oklahoma and Kansas (Fig. 5).

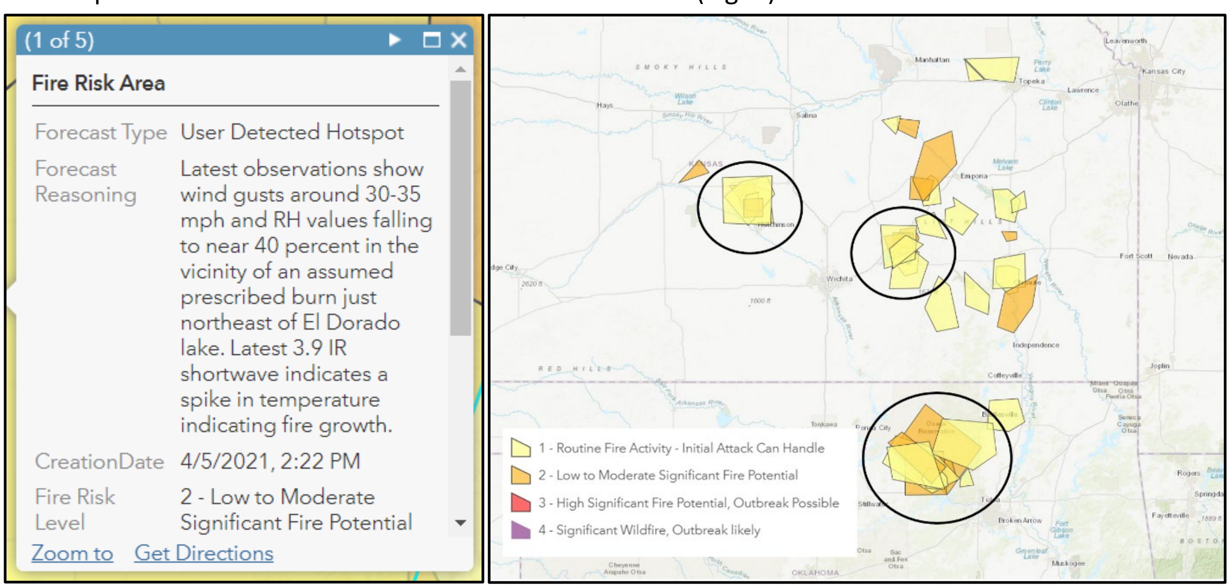

Fig. 5. Example of real-time hotspot detection conducted by the participants on 5 April 2021 (left). The general locations of the detected hotspots are the polygons, colored by the associated risk level. The text (right) is an example of the forecast reasoning provided by the participants for the associated risk level. The black circles denote clusters with subjectively high congruence of identified hotspots.

3.2 Collaborative IDSS Content Production

To create IDSS content, the OPG used a Google Slides template from Western Region (Fig. 6). By using Google Slides, participants had the ability to collaborate with neighboring offices on a single shared message. For example, the slide below produced by "Group 1" represents the contributions of four offices (ABQ, AMA, LUB, and MAF). In theory, each of these offices could leverage this slide for briefings or web page graphics increasing both efficiency and consistency.

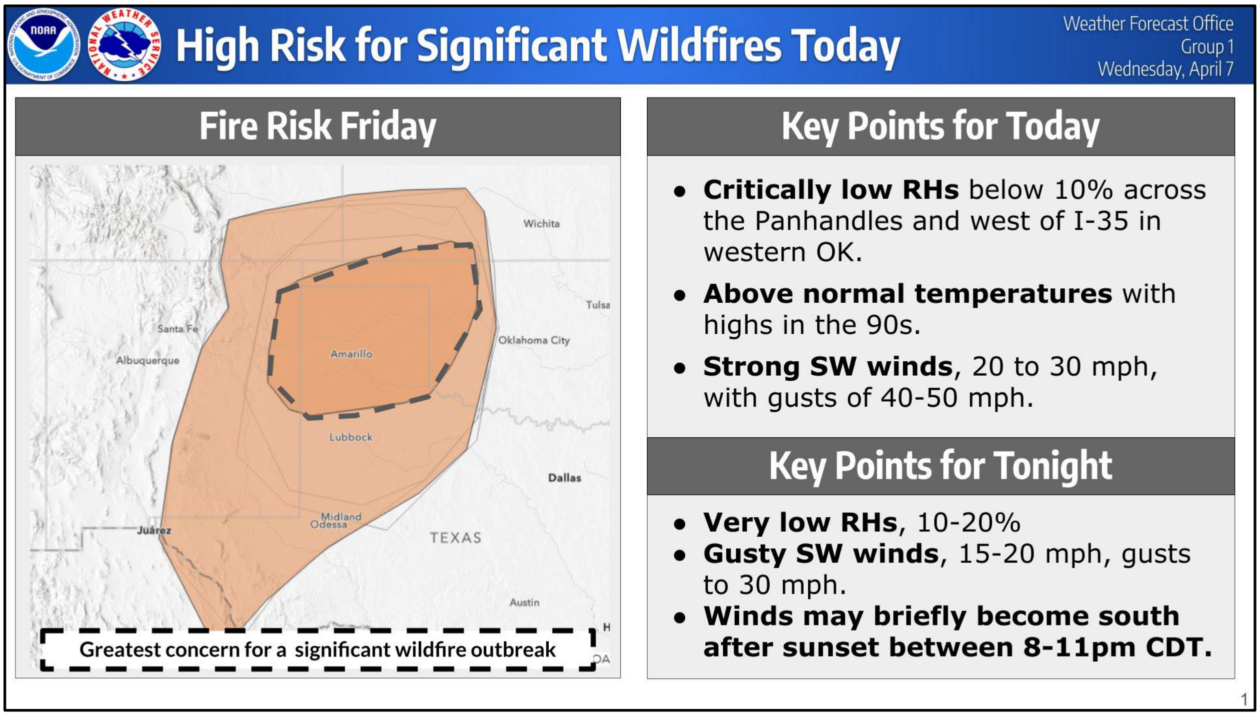

Fig. 6. Google slide template, adapted from Western Region, used in the experiment. The left-hand column highlights the fire risk and area of greatest concern for a significant wildfire outbreak. The right-hand column summarizes the key points of the forecast or conditions.

3.3 Collaboration Tools and Methods

Each group collaborated via their own Google Chat chat room, intended to represent the AWIPS chat application, and Google Meet (video) sessions (the Google Meet sessions occurred organically when participants felt video collaboration was necessary). Because one of the primary means of collaboration during the experiment was expected to be text-based chat, the OPG provided the participants with a document describing chat best practices. The best practices were created by the OPG based on results from previous virtual experiments focused on the Collaborative Forecast Process for QPF.

4. Results

Our invited SME, Todd Lindley, provided real-time expertise on assessing the Great Plains fire environment. Several participants noted the value of Mr. Lindley's training and real-time support as a trusted expert. Further, Mr. Lindley invited Mr. Drew Daily, of the State of Oklahoma Forestry Services to provide real-time partner feedback on the experiment. In particular, Mr. Daily noted the potential value of smaller scale, frequently updated information based on mesoscale analysis. He noted the fire community is well aware of the hot, dry, and windy conditions expected on a red flag day so they really need to know about real time changes including new hot spots, changes in hotspot characteristics, or rapid changes in winds, temperatures, or humidity:

> *"If you see a change coming, or if you feel things aren't adding up, by all means, say it. Because we can get that (information on new hotspots, changes in fire characteristics, changes in wind or humidity) out there quicker (to field fire fighters). That may be a critical piece of information (for the front line fire fighters)."* Drew Daily, State of Oklahoma Forestry

4.1 Cloud AWIPS

Objective #1 - Evaluate Cloud AWIPS performance during real-time fire weather situations, and determine if Cloud AWIPS is capable of supporting IMET dispatches.

Participants were given access to the OPG's Cloud AWIPS resources for the duration of the experiment and provided mostly positive feedback. For example, one forecaster stated, *"AWIPS Cloud was a great tool to have for this project. Would be nice to get to use this in the field too, especially for those teleworking during hazardous weather days."* Cloud AWIPS was often compared very favorably to Thin Client.

There were a few technical issues experienced by some users. Notably, a couple of users experienced issues when accessing the system from Apple OS/X based systems:

> *"It was pretty hard to use on a Mac because of the scrolling and right click issues."*

There was a clear delineation in how heavily Cloud AWIPS was used depending on the task. When the forecasters were performing the Day 2–7 forecast activities of the experiment, there was a much greater dependence on web-based data sources. One participant said, *"I honestly wasn't looking at much in AWIPS and relied heavily on the WRF for hi res details, weatherbell for ensemble data, and the EPS fire weather EFIs...''*. Another forecaster noted, *"AWIPS has fallen behind with its ability to display model data in innovative ways such as many of the newer websites. Most forecasters have gravitated toward web-based sources in recent years."* When the participants switched to Day 1 activities (i.e. hotspot detection and associated IDSS), there was a clear shift in the amount of reliance on AWIPS. *"Cloud AWIPS was most useful for the hotspot identification, because you cannot beat the satellite capabilities in it."*, and another participant noted, *"For satellite detection and overlaying observations which is important in the mesoanalysis phase and hotspot detection phase, AWIPS remains superior [to web-based sources]."*

Half of the participants indicated that their use of Cloud AWIPS was hampered by not being able to have the D2D procedures that they use at their home office, which was a likely contributor to the heavy reliance on web-based resources for model data. Specifically, when asked "What could be better [about the experiment]?" one participant noted, *"Identifying risk areas needed less AWIPS as it is easier to view various model data quicker through websites,* ***especially when you don't have all your normal procedures available.****"* (emphasis added) The OPG is aware of this concern and will work to include forecaster procedures in the future.

The cost of using Cloud AWIPS, which is hosted by Amazon Web Services (AWS), was analyzed for the period of the exercise. The total cost for the four days was approximately $85 per day for a total of about $340. The majority of that (about $44 per day) was the cost of running the "on-demand" AWS instances, which are those the OPG starts and stops on an as-needed basis. About $30 per day was attributed to storage costs, and around $10 per day was from "reserved" instances. Reserved instances are those which have been paid for a year in advance to run 24x7 at a substantial saving versus per-hour instances.

4.2 Grassland Fire Weather Mesoanalysis and Associated Hotspot Identification

Our participants were asked to conduct real-time mesoanalysis of the fire weather environment, hotspot identification, and create targeted IDSS discussing fire weather risk and new or emerging fires. Participants felt that the tasks asked of them were feasible, not ‘extremely challenging’, and worthwhile, but did note that certain tasks were more difficult than others. Participants felt that hotspot detection was fairly easy to complete, especially after training, and was generally easier than performing mesoanalysis or IDSS for hotspots (Fig. 7). Mesoanalysis was *perhaps* the most challenging, as there were less participants that believed it was ‘not challenging’ and more participants that believed it was ‘slightly challenging’ compared to providing IDSS information on hotspots in real time (Fig. 7). The following subsections discuss these results and the objectives they address in more detail.

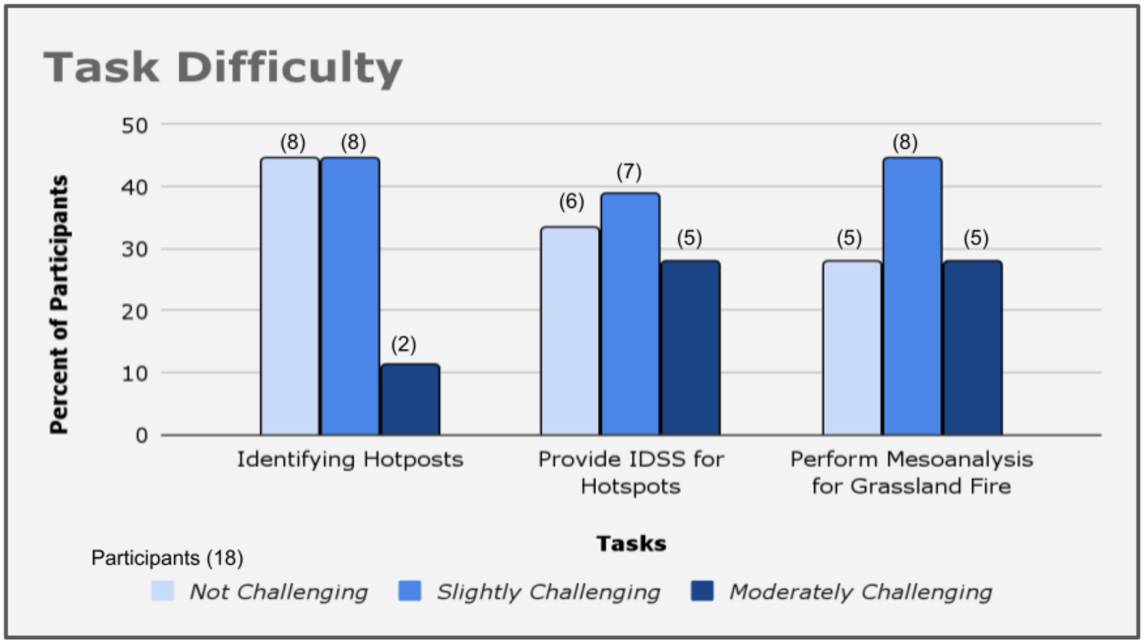

Fig. 7. Relative task difficulty, reflected as a percentage of participants, for the following tasks: identifying hotspots, providing IDSS, and performing mesoanalysis, as noted by participant surveys. The number of participants who indicated a specific category is provided within the parentheses above each bar plot.

4.2.1 Real-time Hotspot Identification

Objective 2: Examine how mesoanalysis (including hotspot detections) might be integrated into fire weather operations to improve IDSS for ongoing or emerging fires.

Participants were asked to use GOES-16/17 Advanced Baseline Imagery (ABI) to identify fire hotspots in real time. Participants primarily used the following GOES products for conducting hotspot identification: red visible (0.64 µm), Fire Temperature Red-Green-Blue composite (RGB), Fire Power and Fire Area Level-2 products, Day Fog (3.9–10.3 µm), and shortwave IR (3.9 µm). While the 3.9 µm shortwave IR is traditionally used in hotspot identification by locating high-brightness temperature anomalies, many participants noted that the use of the Day Fog difference product can show changes in temperature more readily, allowing for quicker identification of changes in intensity or size.

Participants also noted that the training and insight of our SMEs was crucial in quickly identifying hotspots: "*As a forecaster with limited experience in real time fire identification, the task alone would be moderately challenging to start off with. However, the tools/collaboration/training helped the task from becoming extremely challenging.*" Participants felt that the training increased their confidence and ability to quickly identify hotspots. Correspondingly, hotspot detection became more challenging when looking over larger (multi-state) areas and when cloud cover was obscuring the hotspots. These findings are succinctly summarized by one participant; it is more challenging when, "*looking at a large satellite picture and trying to find small pixels of hotspots. I can see why a hot spot detection program could come in handy*."

While our participants were clear that hotspot detection was relatively easy, especially in situations where forecasters were looking over small areas and there was little cloud coverage, they expressed a desire for an algorithm that will alert them when a new hotspot is detected, analogous to a Tornado Vortex Signature. Such an automated algorithm is available (Dan Bikos, personal communication), but is not widely distributed or installed among all WFOs nationwide. Most participants agreed that having someone to identify hotspots or an automated hotspot detection would be optimal for fire weather operations. The ability to detect emerging fires quickly without an automated system, while manageable and feasible, becomes problematic when considering staffing. Many participants noted that hotspot detection "*should be more widespread in NWS offices*", but due to limited forecasters and overall task management, "*staffing could be a concern for monitoring hotspots if a large event is ongoing or forecasted*".

While the data collected during the experiment was not enough to fully assess the participants' skill in detecting hotspots or their mesoanalysis polygons within AGOL, anecdotal evidence suggests that there is value and skill in conducting fire risk assessment, mesoscale analysis, and real-time hotspot detection and consistent messaging through IDSS. Two of our participants tasked with monitoring the state of Kansas noticed anomalously high pixels on the GOES-16 Fire Temperature RBG at approximately 19 UTC on 5 April 2021 near Council Grove, KS in Morris County (Fig. 8a). These two participants then drew hotspot polygons over this area as noted in Figure 9. Morris County [KS] emergency management later noted and publicly issued a statement via Facebook that there was a brush fire that ignited near the city lake shortly before being detected by the participants (Fig. 8b).

Fig. 8. Fire Temperature satellite product (a) and accompanying brush fire (b) from Council Grove, KS in Morris County at approximately 19 UTC on 5 April 2021 [Photo Credit: Council Grove City Lake Community].

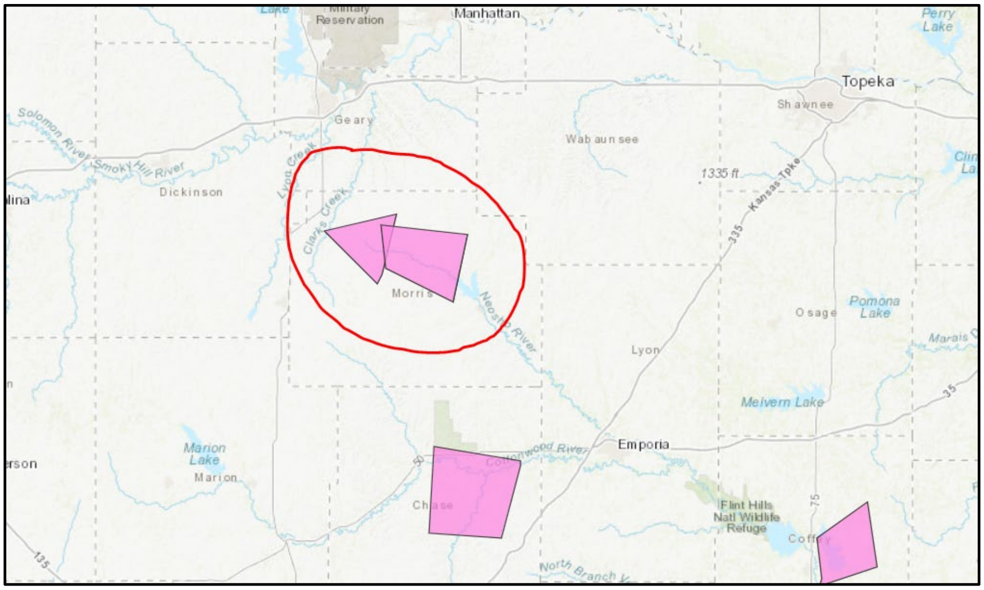

Fig. 9. Example of hotspot polygons from 5 April 2021 (magenta), with the Council Grove, KS hotspot polygons circled (red).

4.2.2 Fire Weather Mesoanalysis

Objective 2: Examine how mesoanalysis (including hotspot detections) might be integrated into fire weather operations to improve IDSS for ongoing or emerging fires.

Participants generally felt that mesoanalysis was more challenging than hotspot detection. Forecasters noted that it was harder to fully focus on mesoanalysis when busy with other tasks, especially while working in an unfamiliar geographical area. This was alleviated, however, largely by the division of labor between the two participants within a WFO, having one person dedicated to hotspot detection and the other dedicated to conducting mesoanalysis. Further, some participants thought mesoanalysis was relatively easy given the plethora of high spatiotemporal resolution observation and model data and training. Perhaps, mesoanalysis would not be so challenging in a more familiar area and if it is prioritized as a constant activity rather than a 'one-off'. As stated by one of our participants: "*...the mesoanalysis in real time shouldn't be challenging if we prioritize this as a constant activity in operations that serves as the foundation for the enhanced services we provide.*"

With that being said, the participants believed that performing mesoanalysis was fundamental to providing high-quality short-term forecasting, not just grassland fire weather forecasting. One participant stated: "*Analyzing the current state of the atmosphere will always increase the confidence in any weather hazard. Fire weather is unique in its broad scale and requires an unknown aspect in what will start a fire. Being aware of the atmosphere helps you prepare for active fires.*" **In fact, 89% of the participants (16 out of 18) said that analyzing the mesoscale environment increased their confidence in providing actionable information to partners for new or emerging fires.** Further, approximately 72% of participants (13 out of 18) thought performing mesoanalysis for fire weather was 'slightly challenging' or 'not challenging' (Fig. 7). Thus, performing mesoanalysis for grassland fire potential could be feasible if appropriately managed.

Given that the participants felt performing fire weather mesoanalysis was important, it follows that they also believed the overall concept of having a mesoanalyst performing fire weather mesoscale discussions would be beneficial. Specifically, 67% of participants (12 out of 18) noted needing at least one fire weather shift/mesoanalyst for fire weather operations when asked about an ideal operational fire weather environment. However, participants offered differences on specific roles that the mesoanalyst would conduct. Additionally, some individuals noted that there should ideally be differences in staffing based on the fire risk (e.g., elevated or critical). For example, if a significant fire event was expected, then it could be treated like a severe weather outbreak with a coordinator and multiple people in the hotspot/feedback positions (akin to radar operators issuing warnings). A few participants also mentioned the potential for external mesoanalysts or SMEs (i.e., a mutual aid group) focused on the mesoscale environment as it pertains to fire weather at a national center, or at least better collaboration with national centers.

4.2.3 IDSS Content Development

Objective 4: Assess if a cloud based approach to producing collaborated IDSS improves the quality and consistency of fire weather messaging among multiple WFOs.

In addition to hotspot detection and mesoanalysis, participants were asked to provide IDSS content for new or emerging fires in real time and conduct mesoscale analysis focused on fire risk. In comparison to performing hotspot detection, providing IDSS information on those detections in real time was more challenging; however, it was perhaps slightly less challenging than conducting mesoanalysis (Fig. 7). Training and overall forecaster confidence was important for the participants in producing high-quality IDSS content. In fact, nearly all the participants noted that their comfort with providing IDSS improved with training and insight from our SMEs.

Participants were uncertain what information the partners would want, when they would want it, and how much information they wanted in the IDSS content. This uncertainty becomes critical when considering high-impact fires where lives can be lost quickly if something is missed or not communicated well. Participants noted that delivering clear messaging is critical, not just to the public, but also for fire management and ground crews. This uncertainty extended also into the messaging, especially with regard to participants not knowing what else to provide other than using ‘hot, dry, windy’ descriptors and they were uncertain about how much potential fire behavior they should discuss (for more details, please see Appendix 2).

Similar to the challenges of mesoanalysis, participants noted challenges with not knowing the geographical area well enough; if they had known the area better, IDSS would have been less challenging. Another challenge was not being immersed enough into the previous observations, current forecasts, and any prior IDSS content. Specifically, not knowing the current forecast of the relative humidity, winds, temperature, and dew point temperature made it difficult to assess the relative values for the mesoscale environment (i.e., have the conditions *become* drier and hotter, are they *forecasted* to become drier and hotter) and it made communication through IDSS more complex. This disconnect (the unfamiliarity of location, uncertainty of the forecast, and specifics of IDSS content) made it hard to know what information was truly valuable to give to partners. However, a few participants believed it was fairly easy to perform the IDSS regardless of the location. Participants further noted that the tools used during the experiment "*...made it very easy to provide meso-analysis and IDSS*".

Multiple participants also advocated for "*...a better way to communicate with core partners*" on current trends and updates to the forecast rather than relying on issuing products through multiple mediums for information dissemination. For example, one participant stated: "*I think the biggest challenge is having a way to easily disseminate an MD [mesoscale discussion] sort of product to a wide (but limited) audience. Right now our main means of communication is through a fire weather email list, which isn't the best way to distribute real-time (and sometimes critical) information.*" Further, participants stated that the NWS needs more robust tools (such as ArcGIS online or other online/cloud-based interfaces) to communicate with partners for spot forecasts, fire weather mesoscale discussions, and other IDSS:

> "*We're making it work with the technology we have but so much of our time is spent trying to find work-arounds for NWSChat, unstable AWIPS, internet outages, etc., that it's very distracting to our core mission. Let's fix our infrastructure, and push forward with a cloud based approach, revisit our priorities, and re-define what is meaningful IDSS (like fire hotspots) vs what's busy work which limits time from the deep analysis needed to support truly effective IDSS.*"

4.3 Collaboration Process

Objective 3: Determine if collaborating from a common set of data using similar methodologies improves the collaborative experiences, produces more confident forecasters, and leads to skillful and consistent fire risk assessment in the day 2–7 period.

Fostering a collaborative process to arrive at an agreed upon fire risk assessment was a key component of this experiment. As such, there were several unique aspects to the collaborative approach that were tested in an effort to assess effective collaboration. The approach included collaborating via Google Chat, Google Meet (video), and AGOL; collaborating on a regional risk of fire potential instead of CWA centric fire weather products; collaborating during a common time frame and early in the forecast process. Most participants expressed that they liked the fire weather collaboration process the OPG created for the experiment. Specifically, several participants noted the ease of coming to an agreed upon forecast/message as an advantage to the collaborative approach to fire weather forecasting in this experiment. One forecaster stated, "*I prefer the collaborative approach used in the exercise to the typical process. The collaborative method was easier to come to agreement as it was based on science, which we can all get behind. It also made the process of 'discussing the science' easier.*"

4.3.1 Collaboration Tools

Participants were given multiple tools to facilitate collaboration, namely Google Chat (text chat), Google Meet (video chat), and AGOL (geospatial information). After the week-long experiment concluded, participants were asked to rate the effectiveness of each tool (from "Not Effective" to "Extremely Effective''), discuss their thoughts on these tools, and describe their ideal collaboration experience. The results are displayed in Figure 10.

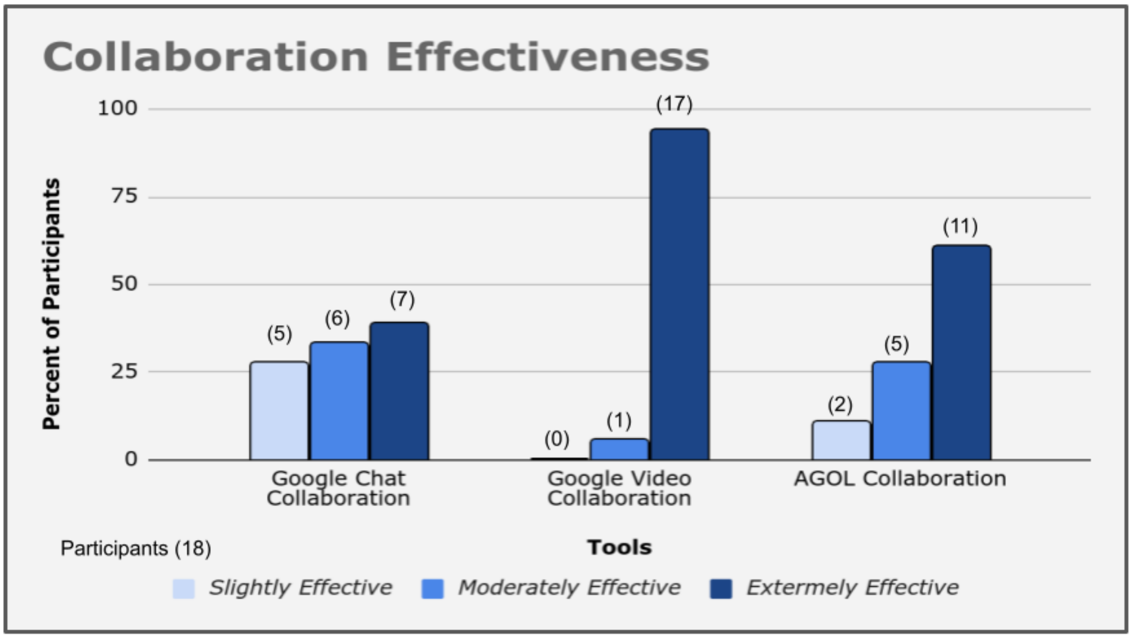

Fig. 10. Collaboration effectiveness, reflected as a percentage of participants, for the following tools: Google Chat (text chat), Google Video (or Google Meet; video chat), and AGOL (geospatial collaboration), as noted by participant surveys. The number of participants who indicated a specific category is provided within the parentheses above each bar plot.

All participants felt that Google Chat was at least 'slightly' effective, with the majority of participants (72%; 13 out of 18) feeling that it was 'moderately' to 'extremely' effective. In particular, the ability to share images was positively noted by some, such as one individual who said, "*Being able to share images on chat was awesome…*" Another participant noted the utility of collaborating via text chat when workflows are not aligned (see more on aligning workflows in section 4.3.3):

> *"Chat is best in some situations, particularly in irregular workflow or when not everyone involved is synced up at the same part of the process. A quick note can allow time for a forecaster to dive deeper into that particular part of the forecast problem and respond slightly delayed."*

Yet some individuals stated that use of Google Chat offered little more than AWIPS collaboration. And finally, one individual noted a drawback of collaborating via chat: "*Sometimes it's hard to get your point across via text and things could be misconstrued.*"

Video chat was explicitly stated as being preferred to chatting via text by multiple participants. One participant said, "*Chat was good but video was better for collaborating*." Survey results substantiate these comments. Google Meet was overwhelmingly (94%; 17 out of 18) considered as 'extremely effective' for collaboration in this experiment, with only one participant noting that Google Meet was 'moderately effective.' The reasons that participants felt that video collaboration was effective included the ability to share screens, the ability to see one another, and the overall ability to quickly and efficiently make decisions. The following participant quote highlights the benefits of using video for effective collaboration.

> *"Chat by video and voice was most helpful to getting quick collaboration between my group's participants. It was easy to share thoughts and actually see a shared product or outlook while it was being worked on by my group. I believe it also helped us move more quickly from analysis and preliminary thoughts to a final product and messaging."*

When asked in an open response format what they would love to see transitioned into operations, nine participants (50%) said video collaboration, which was specifically noted more than anything else (Fig. 11). Moreover, ten participants (55%) specifically mentioned video chat as a part of their ideal collaboration experience for determining grassland fire weather risk areas across multiple WFOs.

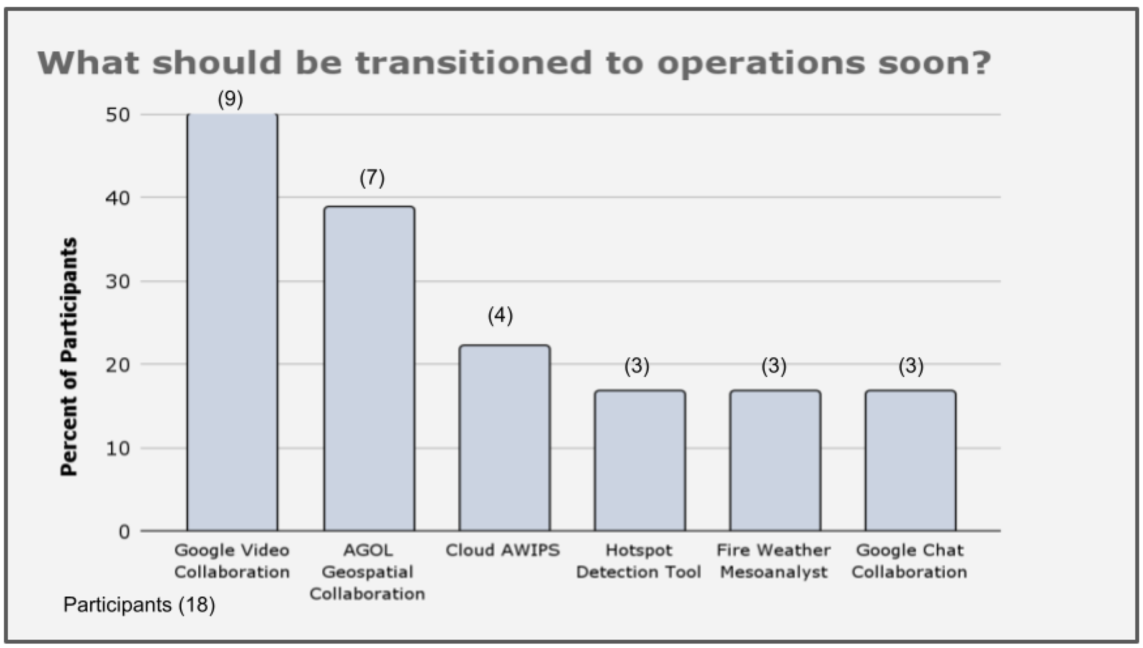

Fig. 11. Survey results from an open response question, "Please tell us what you experienced this week that you would LOVE to see transitioned into operations 'soon'." Responses were categorized by OPG staff into six common themes: Google video (Meet; video chat) for collaboration; AGOL (geospatial) for collaboration; Cloud AWIPS; hotspot detection including the hotspot detection tool; fire weather mesoanalysis support (either in-office or remotely); and Google Chat (text chat). Participants' responses may have been included in multiple categories. Data is expressed as a percentage of participants per category. The number of participants who indicated a specific category is provided within the parentheses above each bar plot.

Despite the overwhelming support for the use of video collaboration for effective collaboration on fire risk assessment, some participants also expressed their concerns with how the tool might be used in operations. One of these concerns centered on how video collaboration calls could be scaled up to several offices, as only three WFOs were represented in this experiment. As an example, one individual stated that they preferred using video chat to text chat for collaboration but then also commented, "*this method* *is not practical for the operations because: who's all on the call? Who's leading it? How do you avoid having to attend 6 different collaboration meetings for a forecast?"*[5]

Some participants responded with possible solutions to this problem such as having a representative from each office within a critical fire risk on a call with a national center such as SPC. A similar idea was that SPC would select the offices that would be on the call and that SPC would facilitate the call and coordinate collaboration. Another possible solution was to use the "sandbox approach" early in the day to inform a collaboration call organized by a national center. In this experiment, the "sandbox" was the AGOL platform where forecasters could highlight areas of concern. One forecaster said, ***"I think the AGOL would be a good tool for WFO's to lay down areas they're concerned with, prior to the 'official' collaboration and setting up the grids. That way if there's any disagreements between offices, you know exactly who you need to collaborate with, which could also ease some of the concerns with using video chat."*** (emphasis added) This idea of using the "sandbox," such as AGOL for drawing areas, to help a national center organize a collaboration call was also noted by participants in the OPG's August Collaborative Forecast Process for QPF experiment held in August of 2020.

Participants also pointed out that the time to coordinate a video collaboration call can be a limiting factor to the use of video collaboration. As one forecaster said, "*Time is the one limiting factor that would preclude video conferencing because someone has to set up that video collaboration, host the session, and it takes time to create slides, etc.*" Others also noted the difficulty of finding an appropriate time to collaborate via video. A more thorough discussion on the time at which collaboration would occur is discussed in section 4.3.3.

Finally, participants also felt that the AGOL platform was an effective tool for collaboration, with 11 participants (61%) feeling that collaboration via AGOL was 'extremely effective' and five feeling that it was 'moderately effective' (28%). Only two individuals considered AGOL 'slightly effective' (11%). In particular, participants commented on the effectiveness of the AGOL platform provided by the ability to denote areas visually in the collaborative process. And as already noted, highlighting areas of concern in AGOL could be used to help determine what offices need to be involved in video chat collaboration calls. Although some participants noted the need for some improvements to the platform in order for it to run more smoothly and remain stable, most recognized its potential.

The following quote from a participant highlights the benefits of using AGOL as a collaboration tool.

> *"AGOL helped us identify areas more efficiently because we didn't have to understand the exact locations someone was referring to as you could visually identify what areas your colleagues selected and where discrepancies existed to collaborate on."*

Seven participants explicitly stated they would love to see ArcGIS/AGOL transitioned into operations soon. Furthermore, seven participants (39%) also considered ArcGIS/AGOL to be a part of their ideal

[5] The same statement was noted in section 9.4 of the OPG hosted CFP for QPF Experiment in Aug. 2020.

collaboration process for grassland fire weather risk assessment. Of particular note, participants expressed that the AGOL platform allowed them to easily put thoughts onto a map before making firm decisions. That is in contrast to using GFE as a way to geospatially inform neighboring WFOs of your thoughts, in which case forecaster decisions have already been made. See section 4.3.4 for a complete discussion on how AGOL allows forecasters to more easily collaborate early in the forecast process.

Finally, one participant did express some displeasure in the AGOL platform used in this experiment because there was not the ability to overlay model guidance or forecast information onto the map as there would be in GFE.

4.3.2 Regional Collaboration on Fire Risk

In this experiment participants were asked to assess the day 2–7 fire risk on a regional basis as opposed to focusing only on the localized CWA fire risk. Thus, participants were free to use the AGOL platform to highlight where there was fire risk based on favorable fuels and meteorological conditions and not based partially on geopolitical boundaries. One participant noted that forecasters often have a mentality of "*this is my forecast*" and "*I don't really want that in my area*." In other words, forecasters take on forecast ownership with respect to their CWA's forecast. That same participant stated that the regional approach tested in this experiment "*blurs those lines a little bit in a more productive way to make it more collaborative.*" Another participant stated, "*With the experiment, we were all looking at things regionally and less focused on our own CWA, plus we only had to outline a critical area versus getting into specific counties/timing for a FWW/RFW, which made it infinitely easier.*" Not only does that statement note that the regional approach contributed to an easier process, but that collaborating on areas of fire risk and not whether certain product criteria are met was also factored into creating an easier process.

One participant described different Red Flag Warning (RFW) criteria as the "*biggest hurdle I've seen in regards to messaging fire weather risk and collaboration with neighboring offices/national center.*" They went on to add, "*I've personally witnessed offices 'go at it' in chat because of these differences and it impacts messaging in a HUGE way across state and CWA borders.*" Another participant said "*using the same criteria*" would be part of their ideal collaboration experience for determining grassland fire weather risk across multiple WFOs. Another individual expressed the need for criteria in order to make decisions but also noted that differing criteria can make collaboration with neighboring offices difficult.

Ultimately, the OPG believes that the regional approach for fire risk assessment—specifically fire risk assessment that was based on meteorological and fuel conditions, as opposed to discussing specific criteria—contributed to a more successful and efficient collaborative process. We intentionally avoided focusing on Red Flag Warning (or Fire Watch) collaboration because of inconsistent office-to-office issuance criteria. These inconsistent criteria create an environment with artificial barriers to healthy collaboration. Further, this regional approach may have broader impacts beyond forecaster-to-forecaster collaboration with regard to probabilistic data. One forecaster noted:

> *"**My first thought with AGOL is how the ensemble of forecasters could be aggregated into probabilistic data**. Where everyone overlaps is clearly the most confident (90th percentile) area, and where just a few outlier forecasters have highlighted would be the low-confidence (10th percentile) area. This type of system leverages the human aspect of pattern recognition and conceptual models instead of just a model-based ensemble probabilistic approach and its inherent limitations mainly tied to under dispersion."* (emphasis added)

However, the OPG also acknowledges operational limitations to our experiment approach. Anecdotal evidence suggests forecasters collaborate on fire weather headlines versus fire weather risk. Further, collaborating on headlines has proven to be challenging for local offices. Thus, participants suggested the OPG conduct future experiments focused on Red Flag Warning, or Fire Weather Watch collaboration: "*Instead of fire weather risk, focus in on RFW decision making. That is truly where a lot of collaboration issues come up.*" With respect to RFWs, having common criteria might seem like a logical way to create more efficient collaboration, but RFWs are often based on partner specific needs. As such, the RFW criteria are typically coordinated with local partners. One of our participants even stated that the "*Minnesota Interagency Fire Center has the ultimate say on whether fire weather headlines are issued (regardless of conditions or criteria).*" That same participant then asked, "*How would an internal collaborative process account for this?*" How such issues are resolved are beyond the scope of this experiment.

An additional operational limitation of this experiment was that the regional approach taken was not representative of the operational NWS WFO structure. The intent of the experiment was not that participants would entirely abandon a sense of being in a WFO, but that was the case for some. This is evident in one participant's comment:

> "*Half the time, I wasn't even paying attention to which WFO I was to be honest. I guess I'm Midland but I'm looking at this whole huge area, which obviously isn't going to be the case back in your office.*"

Furthermore, participants did not feel a sense of forecast ownership, something that does occur within WFOs, due to both the regional approach to the risk assessment and because forecasters were in an experiment and not representing their home office as expressed in the following forecaster comment.

> "*I think it's a lot easier to give in to the people you're collaborating with in this experiment versus the real world. If you're in an operational environment, you have priorities and partners that you're thinking of in your CWA. And even if we went to this collaborative process, I can envision more people taking a stand on budging. Whereas in the experiment, I don't care where we draw the line; it's close enough.*"

4.3.3 Common Focus and Collaboration Time

Another factor that the OPG believes added to an effective collaboration experience during this experiment was that all forecasters were tasked with assessing the fire weather risk, and only the fire weather risk, during a specific time frame. One forecaster made the following statement during one of the debriefs that expresses this point.

> "*I think it's mainly like* ***putting everyone's efforts in the right direction at the right time to get the most effective collaboration****. Whereas some people are doing their fire grids right at 11. Or these guys wait till about 11:45…* ***The ability for us to all focus on that same thing at the same time, you'd probably be able to turn through any set of problems you'd be put up against whether it's fire weather or not****...*" (emphasis added)

To quantify the time commitment required to analyze and collaborate when given a common focus and common start time we measured the time it took groups to arrive at a final fire risk polygon on each day of the experiment. During the experiment, groups were given roughly 90 minutes to produce a collaborated fire risk polygon and associated IDSS messaging. Figure 12 shows that on average it took groups 47 to 59 minutes to produce a final collaborated polygon. We noted that 4 out of the 5 groups improved on their times between the first day and last day of the experiment. Improvement on analysis and collaboration time may have been due to increasing familiarity with group members or increased comfort with experiment tools (AGOL, Cloud AWIPS), however we did not test those hypotheses directly.

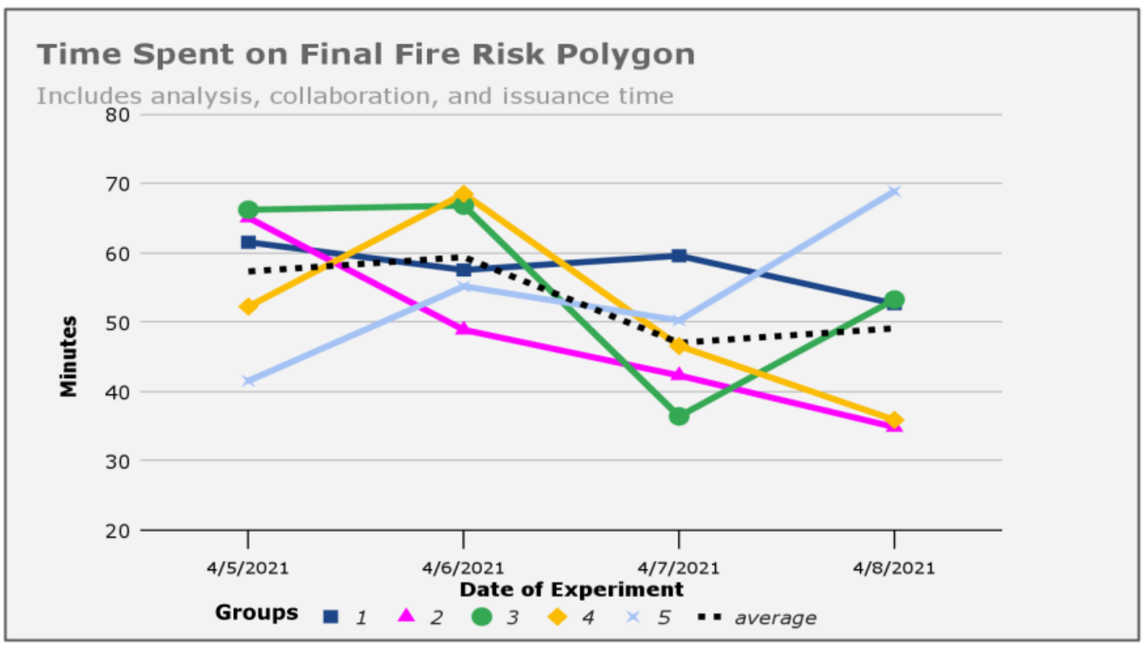

Fig. 12. Time (in min) it took for each group (colored, labeled) to issue their final fire risk polygons on each day of the experiment. The average across all five groups is plotted in the dashed black line.

Several participants noted the difficulty of collaboration when neighboring offices are on differing schedules. One individual stated that a limitation for the collaborative approaches performed in this experiment was "*finding the time to collaborate such issues, since we deal with offices in different time zones and whose forecasters work different shifts.*" Another individual noted the benefits of using video to collaborate but then stated, "*The main issue is getting everyone to collaborate together at the same* *time. There are different workflows for each office, so decisions are made at different times.*" Finally, one participant went as far as to say that ***"getting every WFO to agree on a time during the day that allows for sufficient collaboration"*** was a ***"major roadblock."*** (emphasis added)

Clearly participants feel that different office schedules and forecasting routines are a hindrance to the type of collaboration that was done in this experiment. Thus, it stands to reason that the alignment of office-to-office schedules and forecasting routines is key to achieving an effective collaborative process for fire weather risk, or for any hazard or forecast element. One participant noted that if better alignment of office-to-office schedules occurs, some forecasters may feel rushed if forced into a different workflow. However, that participant also mentioned that the resulting effective collaboration may save time when making decisions.

> "*The timing of the collaboration could force a change in timing of these (e.g. making me look at things right off the bat instead of an hour or two in after getting settled). Time zones would also play a part in this change of workflow. Depending on how long this process takes and when, it may make some forecasters feel rushed. However, time would likely be saved when making decisions about watches/warnings, so that may be moot.*"

On a related note, collaborating at a common time on a common topic (such as fire weather risk) will likely compete for other duties in the office. A couple of participants mentioned that finding the time to focus on fire weather risk or to take the time to collaborate on the risk with other offices would be difficult.

> "*One 'issue' I think would come up with operations workflow is finding time for someone to participate in the collaboration period. With a number of other duties, public forecasts, aviation forecasts, marine forecasts, updating social media, other phone calls and collaboration efforts etc, having another duty added on could be a problem with some.*[6]"

Finally, another participant acknowledged that the collaborative approach to fire risk assessment "*would certainly add an additional task to an already busy shift*," but that participant also noted that "*if the event is high impact enough, it will likely provide a lot of utility from a forecast and messaging standpoint.*"

4.3.4 Collaboration Early in the Forecast Process

Another key component of the collaborative process in this experiment was the use of AGOL for forecasters to each communicate their **initial** regional assessment of fire weather risk. Once each of the three participants representing neighboring WFOs completed their initial assessment of the fire weather

[6] It is important to note that in every OPG experiment focusing on either collaboration or mesoscale analysis, participants have brought up the issue of "workload". They seem to universally agree that collaboration and/or mesoscale analysis are critically important, but they state they are busy with other duties and therefore question whether they can take on more responsibility. The OPG strongly believes the root cause of this sentiment is inefficiency in operations. We did not explicitly test this theory during the fire experiment and would like to investigate efficiency concepts in future experiments.

risk, they collaborated in order to reach a **final** collaborated assessment of the fire weather risk which they indicated with a single polygon in AGOL. In other words, the decision making was done collaboratively early in the forecast process before final decisions were made. During the final debrief discussion at the end of the experiment, one of the forecasters noted that they appreciated the "safe space" where the participants "*weren't making the final decision on where our product would be, but just kind of a sandbox to get in there with your neighbors and talk about stuff."* That same individual felt that this process probably allowed them to improve their forecast area.

The process just described is opposed to making a decision about the forecast and then collaborating, or coordinating, on the final product as is often done in operations today; a method that is ineffective according to our participants. In a debrief on Day 2 of the experiment, one participant stated that an office might say "*Here's what we're doing. … You can either match us or stick out.*" That participant also said, "*I think it's better when it's more of a regional thing and you're discussing it early on.*"

Several individuals specifically highlighted the inefficiencies of using GFE as a collaboration tool. Notably, there was agreement that once grids have been produced in GFE, a decision has already been made and thus the opportunity for effective collaboration has already passed. As one participant stated, "*In GFE, the decision's already been made when the grids [are] in there. It's not like, you save it and you're like, 'Hey, do you guys want to collaborate?'*" Other individuals noted the amount of work that goes into using GFE as a collaboration tool, as expressed in the following participant comment.

> **"*It's a bit of work to generate those grids just to be like, 'Oh, hey, I'm thinking about doing some fire weather watch for these zones.'*** *So having something that's a lot quicker to draw, and just be like,* ***'Oh, hey, I'm thinking about this area,' with the circle or whatever, is a lot more efficient than going through all the hoops in GFE.*"** (emphasis added)

These comments emphasize the need to collaborate early on in the forecast process before a decision has been effectively made by putting the forecast or product into the grids in GFE. One of the participants expressed it this way, ***"It's 100% easier to collaborate before a decision is made*** *and you are on board before really anyone's kind of thrown out anything.*" (emphasis added) Furthermore, these statements underscore the utility of a tool like AGOL where forecasters can easily highlight an area and express their thoughts on the forecast without going through the work required to edit the grids and make them available for a neighboring office to view. Finally, participants also believe that collaborating before decisions are made instead of after decisions are made may improve forecasting capabilities. As one participant stated, it would *"improve operational workflow as decision making would be easier because* ***it would be based on science that is agreed upon in the early stages****"* (emphasis added) and *"...make it easier to follow the methodologies used in other areas such as Targets of Opportunity."*

5. Summary, Findings, and Recommendations

The OPG set out to better understand the value of applied mesoscale analysis in fire weather events, the capacity of forecasters to skilfully identify hotspots, the importance of a structured collaborative environment, and the impact of cloud based solutions to produce consistent IDSS. When we evaluated our experiment results through the lens of current operations, published research, and anecdotal evidence from operational experience, we arrived at five main findings.

The most challenging aspect of the experiment is related to hotspot detections. The OPG understands that there are legitimate concerns about whether or not local offices should provide hotspot notifications to fire partners. These concerns are outside the scope of this OPG experiment.

Readers of prior OPG reports will notice common themes emerging about the collaborative process and mesoscale analysis. In particular, participants in the fire experiment discussed ideal collaborative environments that are highly similar to prior experiment participants. So we know: collaborating early in any process is ideal, video chat is critical for effective communication, GFE is not an effective collaboration tool, forecasters desire a geospatial collaborative environment, and we need structure to collaboration to make the experience efficient.

It is clear that no one in the agency has time to conduct multiple hour-long collaboration sessions each day, and selecting the appropriate collaboration participants is still challenging. Further, forecasters are highly concerned about the increasing number of duties they are being asked to complete in operations even when the newer duties are viewed as extremely valuable and beneficial to forecaster confidence.

Most importantly though, we have consistently found that a healthy collaborative experience, and a focus on analyzing the mesoscale environment, creates the most consistent and accurate forecast, the most confident forecasters, and the best overall service to partners and the public.

Finding 1: The OPG is convinced without reservation that forecasters are capable of identifying hotspots using GOES-16/17 satellite imagery, but having an algorithm capable of providing automated detections of potential hotspots would be useful.

Evidence from our experiment, combined with anecdotal evidence from local offices who issue hotspot detections in real time, strongly suggests that forecasters can identify hotspots associated with fires in real time with skill using ABI from the GOES-16/17 satellites. However, routine monitoring for hotspots requires focused attention to rapidly updating satellite data.

We are not suggesting NWS forecasters should or should not routinely notify partners of hotspot detections, but we have found forecasters are certainly capable of this activity and this information is critically important to core partners. Further, hotspot detections and monitoring are important for informing quality mesoanalysis of the fire environment.

Recommendation 1a: The NWS should investigate automated methods of providing real-time notifications to WFO forecasters of potential fire hotspots. **Further, when hotspots are detected, the NWS should consider including new detections, or changes in hotspot characteristics, in IDSS content or updates to official products (Spot Forecasts, Red Flag Warnings - etc).** The OPG could host further experiments focused on providing such information to core partners if desired.

Recommendation 1b: As local office forecasters become more aware of and skilled at identifying hotspots, **they will feel compelled to share such information with fire partners**. Thus, the NWS should consider co-hosting a multi-jurisdictional meeting with various fire partners to determine an appropriate path forward for hotspot notifications.

Finding 2: Based on feedback from the fire partner who joined the OPG experiment, and anecdotal evidence from participants, **the OPG believes our fire partners desire IDSS focused on real-time mesoscale environment changes including hotspot detections.** This is especially true when there is no IMET deployed to a fire. We believe our partners need information regarding wind speed and direction changes, boundary interactions with a fire, and either new hotspots, or changes to hotspot character afforded by an expert level of satellite interpretation.

Finding 3: In order to provide highly-critical, rapidly-updating information to partners during fire events, participants stated, and the OPG strongly agrees, that the NWS needs to consider new communication methods. Current communication methods can be effective in certain situations, but possess a few inherent limitations[7].

Finding 4: Having an emphasis on analyzing the mesoscale environment during fire events significantly improves forecaster confidence in providing precise, actionable information to partners during new and emerging fires. However, participants in the experiment were, at times, unsure how to provide information beyond the known hot, dry, or windy conditions.

Finding 5: There were several key factors that produced an effective collaboration experience for participants during the experiment. These factors are not exclusive to fire weather events and can be applied to any program area. These factors include: common data for environmental analysis, a common time frame for collaboration, common goals or expectations of any collaboration sessions, video calls for collaboration, and AGOL for collaborating geospatial information. It is further important to note that several participants in several OPG experiments have stated similar sentiments regarding the factors above.

Recommendation for Findings 2, 3, 4 and 5: The NWS should strongly consider developing and testing a new collaborative operations framework during fire events[8]. The OPG would offer our capabilities to support such tests. This framework should include a designated mesoanalyst, and leverage new or existing technologies/tools (**such as AGOL or other cloud-based solutions**) for improved communication of real time information to fellow forecasters and partners.

6. Thank You

The OPG would like to thank Heath Hoeckenberry, Robyn Heffernan, and Larry Van Bussum for the support and collaborative efforts for this experiment. We would also like to thank Todd Lindley (SOO in Norman) and Randy Bowers (Forecaster in Norman) for their extraordinary subject matter expertise.

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[7] Here are four common communication methods for IDSS and their associated drawbacks: (1) A one to one phone call to a single partner can suffer from the "telephone game" effect where information changes meaning when exchanged several times independently. (2) A conference call with many fire officials requires fire officials to join at a specific time (when they may be busy with other matters). (3) A powerpoint briefing, "heads up mail", requires partners to check their e-mail regularly. Further, any information delivered via e-mail/powerpoint becomes stale shortly after sending. (4) Spot Forecasts can be lengthy (because they include several forecast parameters), and are not necessarily designed to provide rapid updates. Spot Forecasts are based on NDFD which means forecasters should first update the gridded forecast prior to generating a Spot update.

[8] See Finding and Recommendation 8 from the OPG Mesoscale Bootcamp Report.

Finally, we would like to thank Drew Daily with the State of Oklahoma Forestry for his expert opinion on the experiment and our results.

The OPG sincerely thanks our experiment participants and observers who performed extremely well in this virtual activity.

Finally, I would like to thank the incredible team at the OPG for their dedication to sound science, thoughtful analysis of our experiment results, and desire to help answer complicated questions.

John J. Brost

Director, Operations Proving Ground

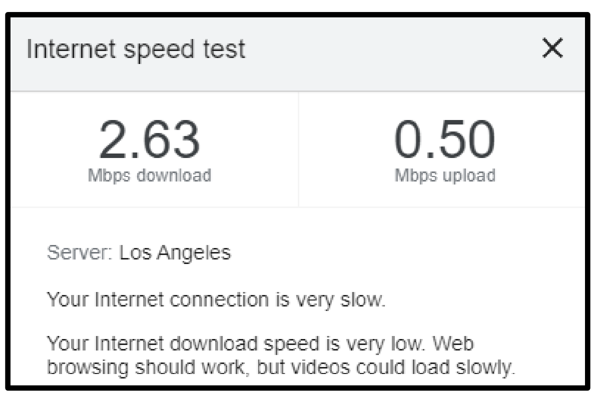
7. Appendix 1: Cloud AWIPS on IMET Deployment

Central Region IMET, Jeff Colton, was deployed on 9 April 2021 to provide support for a prescribed burn in the Grand Junction, CO county warning area. The Operations Proving Ground (OPG) made arrangements for Jeff to have access to its AWIPS in the Cloud resources for the duration of his deployment through the subsequent weekend. While this opportunity was not a planned aspect of the OPG experiment, we felt strongly that results from Mr. Colton's experience should be shared in this report.

Overall, Jeff's feedback on the user experience with Cloud AWIPS was favorable; suggesting that it could be a viable alternative to the AWIPS Thin Client. Thin Client can provide acceptable performance under favorable bandwidth conditions (e.g. >20 Mbps), but performance suffers significantly as bandwidth falls, as is often the case during IMET deployments.

The following are direct quotes and images that Jeff shared regarding the experience.

> *"Well, day 1 and no major issues. ... On average, I've been running 8–9 meg and for the most part everything has been operating like normal."*
>
> *...It performed great yesterday. I was able to observe the fire, look at model data, generate a forecast and provide radio updates to the fire fighters all from the top of a mountain. So cool. I have to admit, I'm excited to see where this goes. I know there will be hard work ahead as no system is perfect, but this is definitely a positive development. I'm sure there will be a lot of excited IT folks on incidents that will be happier since we can operate at a lower rate (but I'll still want the hardwire!)."*
>
> *"...speed test attached. Loading products and watching a webinar. Ridiculous."*



During the 5 days of usage, Cloud AWIPS was very stable, reliable, and operated well at even low bandwidth speeds. From a cost perspective, the usage increased our daily average Cloud AWIPS cost of ~$30–80.

8. Appendix 2: Additional Supporting Quotes

8.1 IDSS Content Development

An additional quote from a separate participant supporting the need for more robust tools to communicate with partners for spot forecasts is provided below:

> *"We have too many different agencies to be able to just pick up the phone and call 1 or 2 dispatch centers. Having a new product (sorry HazSimp) that could be pushed through iNWS and placed on the web would be more ideal."*

Some of our participants also noted that it was hard to add much to IDSS content, beyond the canonical 'hot, dry, windy' descriptors. Further, they also noted that there is some uncertainty with regard to the role meterorologists play in discussing fire behavor. The following quotes from participant are in reference to these issues:

> "*Coming from an office that is largely kind of land use is more in the agriculture area, rather than any range land or anything like that. I am not sure how much mesoanalysis could be really improved and brought to our partners. ... We can provide the hotspot notification, but you're just dealing with a general, just a windy, southerly wind day with relative humidities around 25%. Where it's kind of hard to pick out anything in particular. Maybe there's just things that we need to dial in even further on. But in terms of trying to pick out in small details, it's kind of hard in certain areas of the U.S.*"

> "*[We] we're kind of hedging back and forth, like should we say that we're, you know, erratic fire baby behavior is going to happen? Or should we be saying that we think there might be fire whirls. Where is that line for us as forecasters to say, "Hey, we're seeing unstable conditions, we're seeing low-level convergence." Do we say those things or do we say the things that are going to produce what's actually going to happen? So I guess that's where I kind of felt like, Where's the line drawn there? Because we're seeing these conditions that will produce those things, but I don't know. ... We both felt a little uneasy. Are we just supposed to say, winds 15 to 25 miles an hour, RH this. What translates better?*"

> "*You know, we as forecasters, especially now that we're in this realm of DSS, you know, it's not enough to just say this is what the forecast is going to be, but this is what it possibly means for you. ... what's going to be the ability to control the fire, you know, how resistant is it to suppression? So maybe that's an area where we can hedge and say, you know, what, there's going to be the potential for, you know, very hazardous suppression conditions, or it's going to be difficult to suppress based on fuels, you know, the entire fire triangle.*"

“...what should I say, it needs to be more specific than what is in Red Flag Warning. But I liked what you said, about having it be like, erratic fire behavior, likely. Something like that, where it kind of draws more attention to what you're trying to outline, rather than just like, you know, wind gusts 30 to 40 miles an hour? It's like, well, that's what it says in the Red Flag Warning. How do you dial that information a little bit better to have it be more useful?”

8.2 Collaboration Process

Quotes on Video Collaboration:

- *“Video is more efficient. In a time sensitive forecasting environment, being able to spin up a video and chat right away was imperative, especially during the high impact archive case.”*
- *“Being able to see and hear the people you were collaborating with on video made it feel more personal and it's easier to talk things out, show your screen so they can see what you're seeing, etc. … Plus you're forced to talk through things and finish the conversation instead of conveniently ignoring chat messages!”*

Quotes on AGOL:

- *“AGOL, specifically was a great approach to view what others thought where the best fire weather risk was.”*
- *“AGOL has some drawbacks, but serves as a VERY useful sandbox where we can propose areas and show these areas to each other with little latency.”*

Quote on Collaboration on a Larger Scale:

- During the final debrief discussion someone stated: “*How would the video chat work exactly given that we all have different boundaries and that sort of thing without being in an entire room with 122 people? … Like, I love the concept. But I just don't know how you can make it work yet. I mean, they have to have a boundary somewhere and then somebody is being excluded. Right?*”

Quotes on Text Chat being similar to AWIPS Collaborate:

- *“Text chat is similar to what we use now for coordination in AWIPS with the added bonus of being able to share pictures.”*
- *“Google chat wasn't any different than the ol AWIPS collaborate (although at least we were all logged in to GChat....).”*

Quote on focusing on RFW decisions:

- “*Having us play our WFOs more and forcing us to make RFW decisions*” in order to “*help us see how the collaboration tools could apply in ‘real life’ better.*”

Quote on a Routine Collaboration Period:

- In the final survey, one participant noted a potential benefit of a routine collaboration period for fire weather: ***“If there was a routine time period each day for collaborating with neighbors*** *on* *fire weather outlooks, I feel like that **would be less impactful to our operations** than the event-driven **scattershot approach we currently use** when the weather or fuels become critical.*"

Quote on Time to Collaborate on Fire Wx:

- "*Having a half hour long collaboration with other offices is a big time sink when there's other aspects of the forecast and other duties to worry about. The best way to solve that I think is to have someone who is just focused on forecasting for fire weather, but I'm not sure how doable that is at most offices.*"

Quote on Decision Making in GFE:

- "*Whenever you put the grid [in], at least everything that I've ever collaborated with, you've already made your decision and you basically are waiting for someone to tell you why your decision isn't good enough or why their decision is better.*"