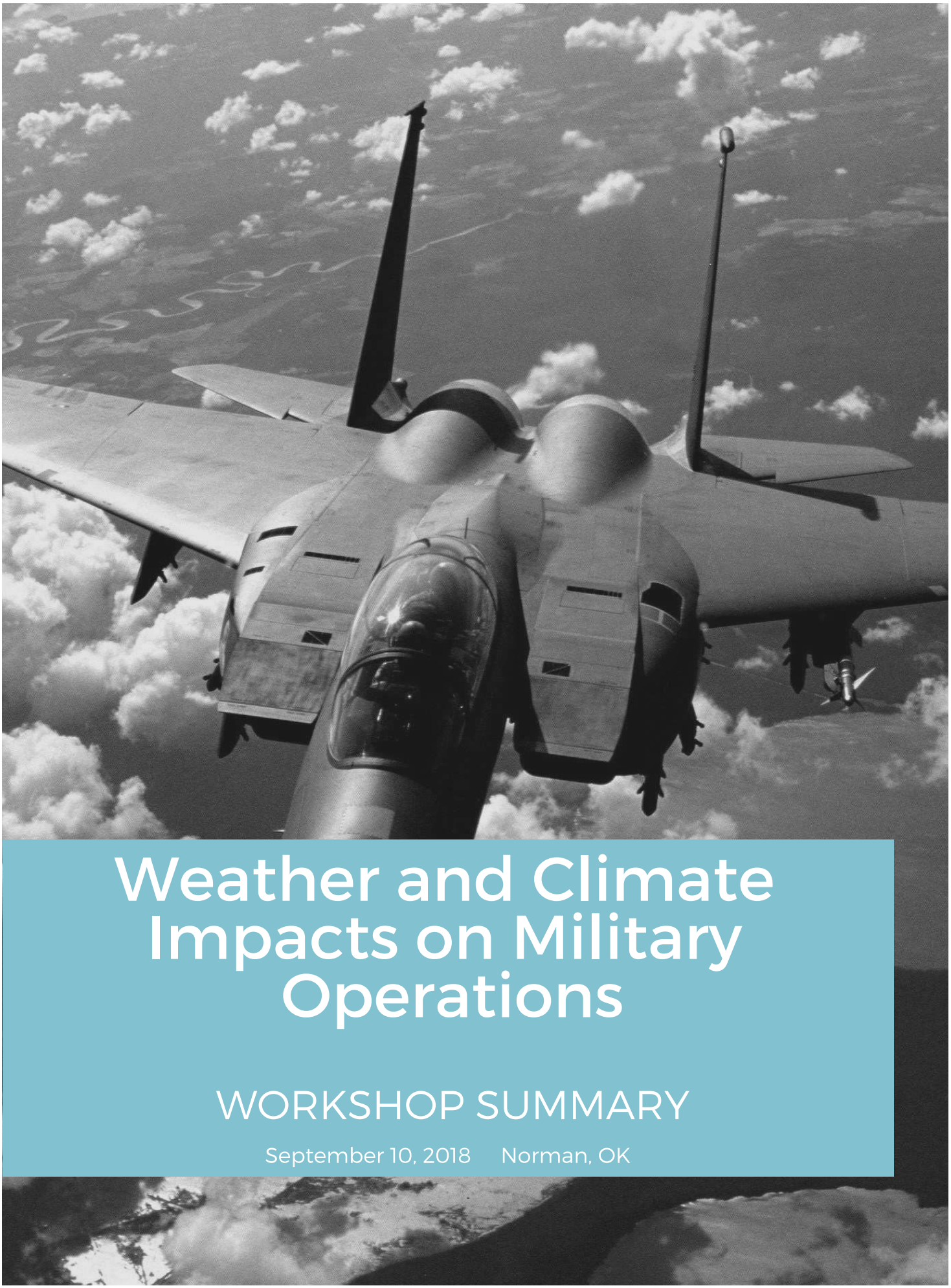

Weather and Climate Impacts on Military Operations

WORKSHOP SUMMARY

September 10, 2018 Norman, OK

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Weather and Climate Impacts on Military Operations Workshop Summary Report

Southern Climate Impacts Planning Program
University of Oklahoma College of Atmospheric and Geographic Sciences
University of Oklahoma College of Engineering

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September 2018

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Executive Summary

In September of 2018, representatives from six Oklahoma military installations along with members of the weather and climate research community across the University of Oklahoma participated in the workshop, *Weather and Climate Impacts on Military Operations.* The Southern Climate Impacts Planning Program (SCIPP), a NOAA RISA team, in conjunction with the Colleges of Atmospheric and Geographic Sciences and Engineering, hosted this workshop. The six military installations represented at the workshop were as follows: Altus Air Force Base, Tinker Air Force Base, Vance Air Force Base, Ft. Sill Fires Center of Excellence, McAlester Army Ammunition Plant (MCAAP) and the Oklahoma National Guard.

This workshop focused on learning about the missions and operations of each military installation and how weather and climate events impact these operations. Likewise, the workshop participants examined the latest technology, research, measurements, and operations that could be harnessed to help address weather-related concerns at their military installations. There is a wealth of expertise at the National Weather Center and the University of Oklahoma that can be made available to help with missions and operations.

The workshop identified a list of potential areas of research that could assist in reducing weather related risks to Oklahoma's military installations as well as increasing collaborations with OU's academic community. These research recommendations may also help guide future efforts of scientists and faculty at the University as they pursue external funding as well as provide opportunities for many qualified students to engage in such endeavors. In particular, the participants recommended the following:

1. Expanding similar discussions at the national level with NOAA and DOD, as well as opening a dialogue with the Air Combat Climatology Center in Asheville, NC.

2. Developing a more in-depth discussion about potential tools that could be available, including hydrologic modeling, winter weather modeling, etc.

3. Having a more in-depth discussion about the economic impacts of weather and climate events through avenues such as trainings and observations with professionals at the Weather Center.

4. Consider holding additional follow-up workshops and increasing the potential for various agencies to work more collaboratively together.

Introduction

The military installations across Oklahoma are vital not only to the safety and security of the nation, but also to the economic livelihood of the state of Oklahoma. In 2010, the value-added economic activity of five of the military installations was $9.6 billion, and that does not include the economic impact of the Oklahoma National Guard[1]. Therefore, it is crucial to understand how weather and climate events impact an industry that represents more than 7% of Oklahoma's entire economy.

In September of 2018, representatives from six Oklahoma military installations and members of the weather and climate research community across the University of Oklahoma participated in the workshop, *Weather and Climate Impacts on Military Operations.* This workshop was hosted by the Southern Climate Impacts Planning Program (SCIPP), a NOAA RISA, in conjunction with the Colleges of Atmospheric and Geographic Sciences and Engineering. The six military installations represented at the workshop were as follows: Altus Air Force Base, Fort Sill Fires Center of Excellence, McAlester Army Ammunition Plant, the Oklahoma National Guard, Tinker Air Force Base and Vance Air Force Base (Figure 1).

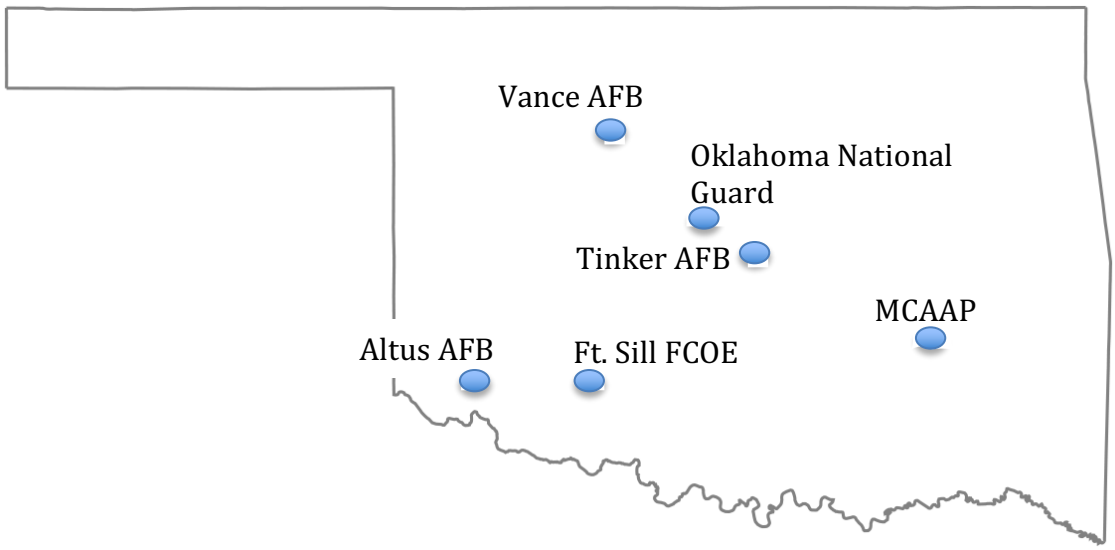

Figure 1: Map of the 6 Oklahoma Military Installation locations.

This report includes an overview of the workshop goals, presentations, discussions, and outcomes. An overview of the workshop successes is also provided, based on the results of the workshop post-event survey.

[1] Oklahoma's Five Military Installations: An Economic Impact Report (2011). Oklahoma Department of Commerce and Oklahoma 21st Century Foundation.

The goals of the meeting were to:
1. identify routine weather events that have adverse impacts, such as icing on aircraft, lightning, or atmospheric turbulence;
2. identify critical thresholds where extreme weather events are disruptive to normal operations, such as extreme temperatures or flooding;
3. explore how improvements in seasonal to sub-seasonal forecasts can improve preparedness and operations;
4. examine how climate change may affect future risks; and
5. identify opportunities for research in engineering systems and atmospheric studies.

These discussions were designed to be a beginning step towards or identifying opportunities to improve monitoring, modeling, prediction, assessments, and research surrounding topics collaboratively identified at the workshop.

Participants

There were 48 participants that attended the event. Below is a summary of the military installations, university weather and climate programs, and federal agencies represented at the workshop.

Military Installation Participants:
Altus Air Force Base
Tinker Air Force Base
Vance Air Force Base
Fort Sill Fires Center of Excellence
McAlester Army Ammunition Plant
Oklahoma National Guard

Federal Agency Participants:
NOAA National Severe Storms Laboratory
NOAA Storm Prediction Center
National Oceanic and Atmospheric Administration (NOAA) Climate Program Office

University of Oklahoma (OU) Participants:
OU College of Atmospheric and Geographic Sciences
OU Gallogly College of Engineering
OU College of Architecture
Advanced Radar Research Center
Center for Analysis and Prediction of Storms
Cooperative Institute for Mesoscale Meteorological Studies
Oklahoma Climatological Survey
South Central Climate Adaptation Science Center
Southern Climate Impacts Planning Program

Workshop Purpose

The purpose of the workshop was to begin a conversation about the impacts of weather and climate on missions and operations at the six military installations in Oklahoma and broader regional, national, and global operations, as well as how the weather and climate programs at the University of Oklahoma and the National Weather Center could assist with analyzing weather- and climate-related risks.

This workshop also discussed the latest technology, research, measurements, and operations that could be harnessed to help address weather-related concerns. In addition, another desired outcome was identifying other areas of needed research that may guide future efforts of scientists and faculty at the University as they pursue external funding. It is imperative that research both advances fundamental knowledge and offers practical applications that improve the resilience of society to severe weather, weather extremes and climate change.

Overview of Workshop Presentations

Sixteen presentations were delivered, providing overviews of each of the six military installations in Oklahoma as well as ten weather, climate, and other programs at the University of Oklahoma. These presentations are linked on the SCIPP website, http://www.southernclimate.org/pages/past-meetings-and-workshops.

Oklahoma Military Installations:

Altus Air Force Base

Altus Air Force Base (Altus AFB) is located in Altus, Oklahoma, which is in southwest Oklahoma. In FY 2010, Altus AFB contributed $519.7 million to Oklahoma's economy. Altus AFB is an air education and training center for KC-135, C-17 and KC-46 (coming soon) aircraft. The 97th Operations Support Squadron Weather Flight team operates from Altus AFB. The weather flight team mission is to protect the resources of Altus AFB, which is $6.7 billion in assets, provide mission support for the various aircraft, and work with civil authorities (emergency managers, storm spotters) as needed. The weather flight team assists with mission execution forecast and planning weather products, 5-day forecasts, and other mission critical items. They provide support for 7 different organizations across the base.

Tinker Air Force Base

Tinker Air Force Base (Tinker AFB) is located in Midwest City, Oklahoma, which is in central Oklahoma. In FY 2010, Tinker AFB contributed $4.4 billion to the Oklahoma economy. The 72nd Operations and Support Squadron Weather Team provides information to the Air Force Sustainment Center, the Air Logistics Center, and 5 wings across Tinker AFB. Their main support customer is the E-3 Sentry AWACS, which provide airborne commence and control to all US, Joint and Combined aviation forces as part of the 552nd Air Control Wing. They also provide mission support for the E-6B Mercury, part of the Command Strategic Communications Wing One. These are very sensitive to hail damage. Up to 24 hours lead time is necessary to move or protect all aircraft in the event of severe weather.

Vance Air Force Base

Vance Air Force Base (Vance AFB) is located near Enid, Oklahoma, which is in northwest Oklahoma. In FY 2010, Vance AFB contributed $250.1 million to Oklahoma's economy. The 71st Operations Support Squadron (OSS) Weather Flight team operates from Vance AFB. Their mission is to provide specific weather information to the 71st Flight Training Wing (FTW) in order for them to conduct missions safely and efficiently. Similar to Altus AFB, they provide support for several aircraft, including the T-1, T-6 and T-38, and 5 organizations across Vance AFB. Along with the aircraft and squadron support, the 71st OSS brief wing, group and squadron leaders on outlooks, provide support agencies with updates, and give severe/significant weather notifications to key leaders. They are on weather standby 24/7, average 7,000 mission briefs, and give notice of 900 weather watches/warnings/advisories per year.

Fort Sill Fires Center of Excellence

Fort Sill Fires Center of Excellence (FCOE) is located in Lawton, Oklahoma, which is in southwest Oklahoma. In FY 2010, Fort Sill FCOE contributed $4.1 billion to the state's economy. It is the only remaining active fort that has been continually active since 1869. It is the original home of the infantry and aviation, and home of the artillery and USMC artillery. Nearly 3,000 officers, non-commissioned officers, and initial entry personnel are trained at Fort Sill annually. Flooding, drought, heat, and ice are the major weather impacts to Fort Sill.

McAlester Army Ammunition Plant

McAlester Army Ammunition Plant (MCAAP) is located near McAlester, Oklahoma, which is in east central Oklahoma. MCAAP supports conventional munitions, missiles, and logistics around the globe. It is the largest employer in the region,

and has a $463 million dollar impact to the state of Oklahoma. MCAAP not only produces ammunition, it also conducts ammunition maintenance, demilitarization, and rail-line maintenance. MCAAP also has an award-winning conservation program.

Oklahoma National Guard

The Oklahoma National Guard supports state and local authorities during emergencies. They also support overseas missions. The Oklahoma National Guard has headquarters in Oklahoma City, with reserve centers and training sites located across the state. They respond to a wide variety of natural disasters, including tornadoes, flooding, wildfires, and ice storms. The Oklahoma National Guard also has agreements with surrounding states, and can provide mission support during emergencies to other states as well. As a whole, weather accounts for over 90% of the Oklahoma National Guard local support missions. Knowing when and where weather events may occur can help them with equipment staging and personnel use.

University and Federal Programs:

College of Atmospheric and Geographic Sciences

The College of Atmospheric and Geographic Sciences academic programs include the School of Meteorology and the Department of Geography and Environmental Sustainability. There are 9 associated research centers, including the Cooperative Institute of Mesoscale Meteorological Studies (CIMMS), the Oklahoma Climate Survey (OCS) and the Oklahoma Mesonet, the South-Central Climate Adaptation Science Center (SC CASC), the Center for Analysis and Prediction of Storms (CAPS), the Advanced Radar Research Center (ARRC), the Center for Spatial Analysis (CSA), the Oklahoma Alliance for Geographical Education (OKAGE), Center for Autonomous Sensing and Sampling (CASS), and the Hydrometeorology and Remote Sensing Laboratory (HyDROS). Ongoing research within the School of Meteorology that is relevant to military installations includes the following: weather and climate extremes in a changing climate, multiscale data assimilation and predictability, observations of atmospheric aerosols (dust, smoke), weather radar applications, flow and dispersion in complex terrain, and polar meteorology and artic sea ice retreat. Research expertise within the Department of Geography and Environmental Sustainability includes wildlife conservation (previous work with Tinker AFB), soil moisture and water availability, landscape and land use change, natural hazards, climate change, and indigenous geographies.

College of Engineering

The Gallogly College of Engineering hosts numerous academic programs. Of greatest relevance to military operations is their expertise in civil engineerin, flood modeling/infrastructure, hydrology and water security, and aerospace and mechanical engineering. Within civil engineering, they are creating hydraulic models of coastal/riverine zones, studying urban hydrology, LID/green infrastructure, risk and resilience, and other items. OU Hydrology and water security integrates remote-sensing, water, weather, and climate. Current research in the college includes an integrated smart materials and intelligent systems for sensing and healing, sensors and inspection of infrastructure, and energy-efficient built environments.

College of Architecture

The strategic goal of the College of Architecture is to expand support for resilience-centered research, teaching and creative activity. There are 4 main divisions within the College that have relevance to the military installations: Division of Architecture, Construction Science, Landscape Architecture, and Regional and City Planning. The Division of Architecture looks at resilient structural design. The Division of Construction Science researches Building Information Modeling (BIM), Occupational Safety, Instructional Design, Construction Project Management, Lean Construction and Best Value Procurement. The Division of Landscape Architecture has invested in vegetative roofing systems and storm water management strategies for catastrophic rain events. Regional and City Planning focuses on transportation systems planning, food systems resiliency, base/community land use plans and analysis, emergency/short term housing, core infrastructure resiliency, resiliency and the aged, and urban designs that mitigate event impacts.

Advanced Radar Research Center (ARRC)

The Advanced Radar Research Center (ARRC) was established in 2005 to conduct interdisciplinary research and development of innovative radar solutions to a wide range of societal challenges. The over-arching goal of the ARRC is to provide students the most comprehensive educational experience in radar, applied electromagnetics, electronic warfare, atmospheric science, and remote sensing in the world. This is accomplished by creating a curriculum composed of the complementary disciplines of meteorology, electrical and computing engineering, and system-level thinking. Radar observations are used in many studies of the geophysical environment other than those directly related to the atmosphere. With recent faculty hires who have research interests that focus on defense applications for radar, antennas, and high-frequency electronics, the overall program is expanding to an even broader scope.

Center for Analysis and Prediction of Storms (CAPS)

The Center for Analysis and Prediction of Storms (CAPS) is a research center at the University of Oklahoma that focuses on mesoscale/convective storm processes and data assimilation research, and how that can be applied to numerical weather prediction, Warn-on-Forecasting, and the Hazardous Weather Testbed. The goal is to go from basic research, to applied research, and make the bridge to operations. Likewise, there is emphasis on testing new observing systems through the Collaborative-Adaptive Sensing of the Atmosphere (CASA) project. CAPS is also working on delivering fine-scale forecasts.

Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) is the second oldest research center at the University of Oklahoma. It focuses on mesoscale meteorology, modeling, improving forecasts, and impacts of climate change. Current research emphasis includes investigating scientific and operational advantage of rapid-scan radar data, warn-on-detection and warn-on-forecasts, and Forecasting a Continuum of Environmental Threats (FACETS). CIMMS is also a part of the hazardous weather testbed (HWT) and the Experimental Warning Program (EWP), which is a joint effort between CIMMS, the National Severe Storms Laboratory (NSSL), the National Weather Service (NWS), and the Joint Polar Satellite System (JPSS). The research ongoing at CIMMS has potential applications and collaborative opportunities with military installations with regards to radar technology, flooding and severe storms, forecasting, transportation, and understanding changing patterns/frequency of extreme weather events.

NOAA National Severe Storms Laboratory (NSSL)

The NOAA National Severe Storms Laboratory (NSSL) is a NOAA federal research laboratory located at the University of Oklahoma. Their research focus is to apply new science to severe weather forecasting. Recent advances in radar technology, including the Dual-Pol and Phased Array radars are being studied and tested at NSSL. NSSL also collaborates with CIMMS on the warn-on-forecast project (WoF), which uses computer modeling to predict severe weather threats within two hours. Another collaboration with CIMMS is FACETS, which looks at taking the WoF and creating the next generation of warning information, resulting in detailed threat probabilities and greater advanced warning. Other areas of research and development include high resolution hydrologic forecasting, boundary layer studies, and lightning observation and prediction.

NOAA Storm Prediction Center

The Storm Prediction Center (SPC) is part of the National Weather Service (NWS) and the National Centers for Environmental Prediction (NCEP). Their mission is to provide timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. The SPC also monitors hazardous winter weather and fire weather events across the U.S. and issues specific products for those hazards. They use the most advanced technology and scientific methods available to achieve this goal. Many SPC forecasters and support staff are heavily involved in scientific research into severe and hazardous weather. This involves conducting applied research and writing technical papers, developing training materials, giving seminars and other presentations locally and nationwide, attending scientific conferences, and participating in weather experiments.

Oklahoma Climatological Survey (OCS)

The Oklahoma Climatological Survey (OCS) was established to provide climate services to the people of Oklahoma. There are two main projects at OCS: the Oklahoma Mesonet and the Southern Climate Impacts Planning Program (SCIPP). SCIPP is one of 11 NOAA Regional Integrated Sciences and Assessments (RISA) teams. The RISA program bridges the gap between the science and the general public, by advancing understanding of context and risk, supporting knowledge-to-action networks, innovating services and tools for use in decision-making, and advancing science policy. SCIPP is focused on Oklahoma, Texas, Louisiana, Arkansas and coastal Mississippi. The Oklahoma Mesonet is a weather and climate network of 120 automated weather stations across the state of Oklahoma that report data at 5-min resolution. It is unique for capturing localized rainfall, air temperature, wet bulb globe temperature, and predicting fire danger. The Mesonet also offers outreach, training, and support for emergency managers, planners and others to enhance preparedness for Oklahoma's weather extremes.

South Central Climate Adaptation Science Center (SC CASC)

The South-Central Climate Adaptation Science Center (SC CASC) is part of a network of 8 regional U.S. Department of Interior centers with 1 national office. Their mission is to deliver science to help decision makers adapt to climate variability and change. The SC CASC includes Oklahoma, New Mexico, Texas and Louisiana. The SC CASC projects include effects of climate change on natural and cultural resources and integrating climate projections into studies, assessments, and planning processes. The goal is to help decision makers integrate climate science into their planning processes.

Workshop Discussions

The second half of the workshop focused on the interactive dialogue between the installations and researchers through two main discussion sessions. These discussions included a (1) small group discussion and a (2) risks and opportunities group discussion. During the small group topics discussion, the participants were able to spend roughly ten minutes each at 5 different tables. Each table featured 2-3 researchers with expertise in the following topics: warning and preparedness, climate variability and change, land use/GIS/remote sensing, preparing for extreme events severe storm forecasting, and forecasts and outlooks (1-30 days). Two other topics were discussed but not summarized. Those include radar design and applications and flooding and water resources. The participants selected tables based on their own interests, therefore each topic summary may not have the same number of group summaries. This section provides as overview of the summarized findings of the small group topic discussions. The findings of the large group discussion will be described in the following section.

Small Group Topic Discussion I: Warning and Preparedness

Group 1: Discussed the need for consistency in watch, warning, and advisory information. The Fort Sill Emergency Manager noted he changed his emergency action plan colors and wording to match that of the National Weather Service. It is challenging for the end-user to understand the watches, warnings and advisories when the television stations use different colors and wording.

Group 2: Discussion centered around what tools and products were used to determine the severity of the storm. Participants from Vance AFB noted they used the intensity of radar data, and how high in the atmosphere the reflectivity goes. They also try to differentiate liquid rain from hail stones on the reflectivity data. Hail has the potential to be very harmful to training planes, so they need to know the threat so they can issue their own watches and warnings for their pilots. Vance AFB also mentioned they need 2 hours lead time to move any planes if needed.

Group 3: Tinker AFB mentioned heat conditions affect the base, and extreme rainfall affects base operations. Anytime the base closes there is an economic loss. This is especially true of base closures during winter weather.

Small Group Discussion II: Climate Variability and Change

Group 1: Discussion centered on the economic impact and resource management. The Oklahoma National Guard mentioned that flooding and heat/drought concerns were critical issues to them. If drought is projected to become worse, the Oklahoma National Guard can use that as justification for preparing more for wildfires. It is

also helpful to have an understanding of the economic impact of these events, because economic impacts carry more weight with elected officials.

Group 2: Participants from Tinker AFB emphasized the need for seasonal to sub-seasonal forecasting, as longer-term forecasting plays a part in the Commander's decisions. They maintain a strong connection with the Air Force Climatology combat center in Asheville, NC. They provide deterministic data, past climatology, and other information. It was noted that projections beyond seasonal time scales would be more strategic thinking for the military installation, and not necessarily actionable. Heat, especially wet bulb globe temperature, is important, along with winter weather impacts. Tinker AFB has closed base operations in the past due to predicted winter weather, and then the conditions were not as bad as predicted. Those situations have an economic impact on the base.

Group 3: Participants from Altus AFB also mentioned the need for seasonal to sub-seasonal forecasts. For example, they use climatology from the Air Force Climatology Combat Center to make a winter forecast that civil engineers then use to forecast a budget. They also mentioned that point-based projections are what they need. There is a definite need for seasonal to sub-seasonal point-based climate projections as well as more education and information on uncertainties and limitations of climate models.

Small Group Discussion III: Land Use / GIS / Remote Sensing

Group 1: Vance AFB mentioned that they have a severe weather action team, mission weather products, and provide forecasts for both their air force base and surrounding airports and cities. They only serve as a source of information, and can not implement action, such as grounding planes. It is important to have both deterministic and probabilistic forecasts, and a way to ensure data can be validated.

Group 2: Additional Vance AFB participants noted that the base has micro weather stations that measure humidity, dew point, lightning, and cloud cover. They need multiple weather stations to help validate the data. They noted the importance of the Oklahoma Mesonet, but that it covered only a portion of their base, and there was a disconnect at times but what was seen on one side of the base versus the other. Thus, having more sources of weather data points to validate conditions is critical for day-to-day operations.

Small Group Discussion IV: Preparing for Extreme Events

Group 1: For MCAAP, the greatest economic impact from weather events occurs with lightning. They have not noticed any changes in severe weather occurrences or heat waves for the past 15-20 years. The main buildings at MCAAP are

concrete, and made to withstand bomb blasts. Therefore they are secure shelters in the event of tornadoes. The administrative buildings are not concrete, and would be more susceptible. MCAAP also has to take care of any fuel load around the installation that might cause wildfires.

Group 2: Fort Sill is designed by the Corps of Engineers for the Army, and uses their codes for building resiliency. In the event of a severe weather event, they start making recommendations based on those codes. They utilized OKFirst, a training program for Emergency Managers offered by the Oklahoma Mesonet, at Fort Sill, but can only use it on a phone due to limitations with software installation on DOD network computers.

Group 3: Vance AFB mentioned that their planes are very sensitive to icing, and only one type of aircraft has de-icing equipment. Most of the aircraft are training aircraft, which are sensitive to hail and tail winds. They issue wind warnings for their aircraft using Oklahoma Mesonet wind data. Heat can also have an impact on the pilots.

Small Group Discussion V: Severe Storm Forecasting

Group 1: The first group's discussion trended more toward the severity of winter weather. Military installations have a focus on the operational and forecasting side of winter weather. Because winter weather can vary in Oklahoma, it causes more of a challenge with a greater potential for economic loss. They need to focus on how to manage their resources during the winter, but don't necessarily have a threshold for what triggers the distribution of resources. It would be useful to create tools that could help in the decision-making process.

Group 2: The second group's discussion focused on forecasting for pilots and decision-making. Based on hail forecasts, the Air Force will evacuate aircraft out of the area. In order to make the decision to evacuate, they use forecast model data and observations. For aviation, pilots focus on icing, turbulence, and convective development. Because of the lack of icing products, pilots use model extrapolation and observations to determine icing risks. With regards to severe weather, they use theta-E and advection, surface observations, straight-line wind shear, storm-relative helicity, low-level buoyancy, and other parameters. Essentially, anything that could damage an aircraft is taken into consideration due to the potential for high economic losses, especially hail.

Group 3: The most impactful weather events included wildfires, floods, tornadoes, winter weather, and most importantly hail. Potential research projects could utilize operational and military meteorologists to provide feedback on what could make forecasting more accurate, and how to improve it going forward. Forecasting for the military installations looks similar to Storm Prediction Center outlooks. They

know risk increases when only using forecaster input, especially if the forecaster lacks experience. Subsequently, risk tolerance is low for military installations. The National Weather Service is their main resource for forecasts.

Group 4: The fourth group highlighted the need to train forecasters, and forecasting challenges. The forecasters with the most experience train those with the least experience, and training is done on-site and on the job. As mentioned in other groups, most impactful weather is icing, especially in flight. The toughest weather to forecast is fog. Severe weather is considered higher impact, but is easier to forecast than winter weather. Another challenge is many military forecasters do not have NWS-based training, and many staff do not have long-term forecasting experience. There's also a need for training on how to forecast in different regions. The Air Force is using more automated forecasts, with some forecaster input, and it may take costly damage from a weather event to go back to mainly human-input forecasting.

Small Group Discussion VI: Forecasts and Outlooks (1-30 days)

Group 1: Tinker AFB discussed runway operations. For example, when deciding the best time to lay concrete, they look at the forecasts and outlooks to plan ahead. For reducing flooding risk, it would be useful to know the confidence in wet weather patterns 15-30 days in advance. For transportation, the useful information includes probabilistic hazards information including probability of convective SIGMET, probability of hail greater than a certain size in a certain number of hours. Tinker AFB also noted that the 15th Weather Squadron does get backed up doing convective SIGMETs. It is also important to know the forecasts and outlooks for moving the AWACs aircraft. For the AWACs, a forecast of SIGMET within 15 miles would be good.

Group 2: Vance AFB was interested in the availability of tools. They use 5-day outlooks weekly, and 10 day outlooks every-other-week. They primarily use the Euro model, but they can use other models if they justify why they are using them. They have their own Air Force ensemble models, but they are not always easily accessible. For planning purposes, the installation could be briefed on 2-4 week forecasts/outlooks. It could also help anticipate how many hours/days there may not be sufficient visibility for using the training airspace. Ceiling forecasts are also important, so knowing them ahead of time can help create back-up training options. It would also be beneficial to have a tool to track forecast accuracy.

Group 3: Trainees from Vance AFB use the severe weather outlooks for planning purposes, but do not alert others until about 1 day from the event unless significant severe weather in expected. They use SPC outlooks for thunderstorms. They need the forecasts and outlooks for planning on weather where they are going. They trainees have standardized training initially, then more specialized on-the-job

training. They also have quarterly training to keep up with technology and models. The biggest forecasting issue they see is icing.

Potential Post Workshop Follow-Up Activities

Following the small groups topics session, the participants and researchers convened back for the risks and opportunities large group discussion to share near-term and longer-term potential project ideas and discuss overall meeting goals. From this discussion, four potential activities were identified and are explained in further detail below.

Activity #1: National Follow-Up
There is a need to have a similar discussion with NOAA and DOD at the national level. While each base has local priorities and management practices that they can change and influence, any major policy change has to be made at the national level. There is also an opportunity to be more involved with the Air Force Climatology Combat Center in Asheville, NC, which is co-located with the National Center for Environmental Information, and the 26th Operational Weather Squadron at Barksdale Air Force Base in Shreveport, Louisiana.

Activity #2: Project Opportunities, Impacts, Connections
There was interest in learning more about deployable radar systems and phased array radars. There is a interest in learning about severe weather forecasting operations, and deterministic versus probabilistic weather. Hydrologic forecasting was also deemed important. It would be useful to utilize GIS to get more specific, localized information to military operations so they can have more situational awareness. There were practical discussions about the consistency of weather information, and how that affects the bases, which operate under different severe weather criteria.

Activity #3: Moving Forward
There is an emphasis on understanding the economic impact of weather events, and how weather has strategic implications on funding. It is also critical to tie together how the capabilities of the different programs can be applied to the military installations operationally. There are also potential opportunities for training and observation for the military participants with researchers and forecasters in the National Weather Center.

Activity #4: More Collaboration
There was interest in continuing the discussion that began at the workshop in the form of additional workshops, maybe on a bi-annual or annual basis. There exists potential for more in-depth topic analysis and one-on-one discussion time.

Conclusion

The *Weather and Climate Impacts to Military Operations* workshop was a successful first step in beginning an open dialogue between the military installations in Oklahoma and the weather and climate programs at the University of Oklahoma and the National Weather Center. Participants from the Military installations were given the opportunity to explain their specific missions and operations, while participants from the University explained their research projects and potential areas of collaboration. Likewise, participants were given the opportunity for a more one-on-one discussion during the afternoon break-out groups. Several recurring topics arose from the break-out discussions, including the need for a more national level discussion, a need for a better understanding of winter weather, and better tools for predicting and forecasting both winter weather and hail events, more opportunities to learn from forecasters in the state, and more tools and products related to hydrologic modeling. There was also interest in continuing the discussion, with more in-depth topics.

The findings from this initial workshop indicate the need and desire to continue communication between these two entities and provide motivation for future endeavors in increasing collaborations and opportunities to help reduce weather and climate impacts on Oklahoma's military installations.

Appendix A: Agenda

Weather and Climate Impacts on Military Operations Workshop

National Weather Center
120 David L Boren Blvd., Norman, OK
September 10, 2018

9:30 Welcome & Introductions (NWC 1350)
- Ask participants to think of two projects:
  1. One project that could be addressed with existing resources and knowledge
  2. One project that could be developed further into a collaborative research proposal

9:40 Military Operations & Weather Risks (NWC 1350)
- Altus Air Force Base
- Tinker Air Force Base
- Vance Air Force Base
- Fort Sill
- McAlester Army Ammunition Plant
- Oklahoma National Guard

10:40 Weather and Climate Programs (OU & National Weather Center) (NWC 1350)
- Cooperative Institute for Mesoscale Meteorological Studies
- NOAA National Severe Storms Laboratory
- NOAA Storm Prediction Center
- College of Atmospheric & Geographic Sciences
- College of Engineering
- College of Architecture
- Center for Analysis and Prediction of Storms
- Advanced Radar Research Center
- Oklahoma Climatological Survey
- South Central Climate Adaptation Science Center

12:00 Working Lunch (Atrium)

1:00 Small Group Topics Discussion (Atrium)
- Participants can visit with OU/NWC representatives for one-on-one discussions, rotating each 10 minutes
- Topics will be set up at each table:
  - Warning and Preparedness
  - Severe Storm Forecasting
  - Forecasts and Outlooks (1-30 days)
  - Climate Variability and Change
  - Preparing for Extreme Events
  - Radar Design and Applications
  - Flooding & Water Resources
  - Land Use / GIS / Remote Sensing
- Participants may also visit with other OU/NWC representatives not represented at these tables

2:00 Risks and Opportunities (Group Discussion; Atrium)

- Re-convene in a general forum to share near-term and longer-term potential projects
- Discuss overall meeting goals
  a. Identify routine weather events that have adverse impacts, such as icing on aircraft, lightning, or atmospheric turbulence;
  b. Identify critical thresholds where extreme weather events are disruptive to normal operations, such as extreme temperatures or flooding;
  c. Explore how improvements in seasonal to sub-seasonal forecasts can improve preparedness and operations;
  d. Examine how climate change may affect future risks; and
  e. Identify opportunities for research in engineering systems and atmospheric studies.

2:40 Next Steps & Recommendations (Atrium)

3:00 Adjourn

3:15 Combined Tour of the National Weather Center and the Radar Innovations Laboratory (Optional)

Appendix B: Participant List

Military Installation Participants

MSgt De'Erick Gray	Altus Air Force Base
Ricky Rosas	Altus Air Force
Steve Gluck	Fort Sill Fires Center of Excellence
Travis G. Boxley	McAlester Army Ammunition Plant
William Tollett	McAlester Army Ammunition Plant
Greg Farr	Oklahoma National Guard
Hiriam Tabler	Oklahoma National Guard
Robert Walter	Oklahoma National Guard
Capt. John Martin	Tinker Air Force Base
Diann Riter	Tinker Air Force Base
SMSgt Philip Mohr	Tinker Air Force Base
Capt. Jesse Brown	Vance Air Force Base
Faith Glas	Vance Air Force Base
Gregory Demyon	Vance Air Force Base
Jacqueline Van Gemert	Vance Air Force Base
Johnathan Maat	Vance Air Force Base
Nickolas Pedri-Miranda	Vance Air Force Base
Phillip Mathews	Vance Air Force Base
Billy Cochran	
Charles Henderson	

OU/NWC Participants

Alexander Ryzhkov	ARRC
Mark Yeary	ARRC
Keith Brewster	CAPS
Cassandra Shivers-Williams	CIMMS
Greg McFarquhar	CIMMS
Heather Reeves	CIMMS
Nustrat Youssouf	CIMMS
Randy Peppler	CIMMS
Stephen Cocks	CIMMS/NSSL
Travis Smith	CIMMS - FACETS
Bill Bunting	NOAA Storm Prediction Center
Harold Brooks	NOAA NSSL
Lans Rothfusz	NOAA NSSL
Rick Smith	NOAA National Weather Service Norman
Chris Fiebrich	OCS/Oklahoma Mesonet
James Hocker	OCS/OKFirst
Jeff Widener	OU Center for Spatial Analysis
Melissa Scott	OU Center for Spatial Analysis

Ben Bigelow	OU College of Architecture
Shideh Shadravan	OU College of Architecture
Tammy McCuen	OU College of Architecture
Petra Klein	OU College of Atmospheric and Geographic Sciences
John Antonio	OU College of Engineering
Pierre Kirstetter	OU College of Engineering
Zahed Siddique	OU College of Engineering
Hernan Moreno	Department of Geography and Environmental Sustainability
Derek Rosendahl	South Central Climate Adaptation Science Center
Emma Kuster	South Central Climate Adaptation Science Center
Renee McPherson	South Central Climate Adaptation Science Center
Leah Kos	SCIPP
Margret Boone	SCIPP
Mark Shafer	SCIPP

Other Participants

Sean Bath	NOAA Climate Program Office
Wayne Higgins	NOAA Climate Program Office

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