



SMALL WARS JOURNAL

Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations

By [David Knapp](#), [Robb Randall](#) and [Jim Staley](#)

Journal Article | Mar 22 2016 - 5:06pm

Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations

David Knapp, Robb Randall and Jim Staley

Introduction

By 2030 it is expected that more than 60% of the world's population will live in dense urban centers and the majority of these Megacity/Dense Urban Areas are/will be in complex terrain environments. Consequently, weather conditions within these dense urban and complex terrain (DUCT) environments will influence a greater populace and can negatively influence military operations, community services, and overall situational understanding needed for Intelligence Preparation of the Battlefield (IPB) and Intelligence, Surveillance, and Reconnaissance (ISR). Extreme weather conditions will impact DUCT areas often already overstressed by uncontrolled growth and a degraded public infrastructure. Unique weather conditions experienced within the DUCT will highlight, and even magnify, weather sensitivities affecting threat, civilian populations, and DoD weapons systems and operations. Current state-of-the-science atmospheric sensing, characterization, and forecasting capabilities cannot accurately represent the rapidly changing and complex atmospheric processes in a DUCT environment. Therefore, innovative and disruptive solutions are required to revolutionize locally fine-tuned weather support for DUCT operations, information critical to IPB and ISR needs. If localized urban and complex terrain domain weather conditions can be accurately sensed, characterized, and predicted, such information will be a force multiplier for local commanders tasked with leading operations in these multifaceted and intricate domains.

Local Duct Weather Concerns Impacting Operations

There are a variety of atmospheric environment concerns that must be addressed to improve the potential for success in a Megacity/DUCT battlefield. A few examples of topics that must be addressed by current and future atmospheric scientists are below:

- **DUCT Winds:** The local complex terrain (natural and man-made urban sprawl, etc.), can significantly influence near-surface wind patterns across just a few city blocks. Unpredicted wind funneling between, around, and over buildings can lead to small unmanned aerial system failure, inaccurate dispersion plume predictions (chemical, biological, smoke, etc., coupled with consequence management), and many other related environmental impacts and effects issues for warfighters in such domains. Significant research and development efforts are needed to determine

such microscale wind effects within unique DUCT environments.

- Severe weather concerns: Flooding, drought, excess heat/cold, precipitation, and wind influences in each particular Megacity can be drastically different from day to day, hour to hour, and from one section of the Megacity to another. Questions regarding what the populace does during expected severe weather events and how best to militarily influence or control civilians during such events must be addressed. Equally important are questions regarding how best to address the need for new decision support applications to aid military planners through mission execution in such extreme weather conditions. Decision tools addressing how the severe weather effects food, communications, fuel, and service distribution, for both military and civilian operations, can enhance leadership's decision toolset for planning and execution.
- Battlefield sensor performance: The often complex and varied local weather conditions within a DUCT domain can wreak havoc on battlefield sensor performance. Since sensors are influenced by not only target, but also background signatures, the complex and oftentimes densely packed structures of the urban environment together with heating and cooling changes, precipitation, and atmospheric aerosol concentrations impact infrared and acoustic sensors and performance.
- Scientific work needed: The spatial resolution of fine-scale atmospheric prediction models must be continuously improved and validated for accurate predictions in difficult DUCT domains. What weather spatial resolution is required to effectively address DUCT weather effects? How often should fine-scale DUCT atmospheric prediction models be run to adequately depict the environment? This information and answers to the questions noted are critical for accurate microscale weather prediction model performance. Additionally, specific weather sensing requirements within the DUCT need to be addressed, insofar as determining ideal numbers, types, placement, etc., to insure weather prediction models are initialized using the most recent and accurate local conditions possible. These sensing advances will provide data to enhance the understanding of Megacity atmospheric processes critical to improving the underlying physics and dynamics of microscale atmospheric models tailored to such domains.

Specific Operational Challenges Within Megacity Domains

1. Military units deploying within a DUCT domain are likely to operate in small teams conducting short duration missions. These teams will often execute different types of missions within city blocks of each other. The DUCT environment can be heavily influenced by microscale weather conditions which are often significantly different from one block to the next.
1. Most DUCT environments are located near significant bodies of water (lakes, rivers, littoral), which further influence micro-climates associated with these high humidity and valley terrain areas.
1. Aviation operations will likely be a preferred method of mission execution. Wind, cloud ceiling, visibility, precipitation, buildings, wires, communication towers, and urban terrain objects such as large signs and billboards within the DUCT domain will significantly influence all aviation operations.
1. Weather conditions within the DUCT domain effect threat operations just as they do friendly force operations. Determining the weather impact differences between friendly and threat forces can significantly contribute to the DUCT battlefield commander's IPB knowledge base. Other related challenges relate to weather's impact on concealment of operations for both friendly and threat forces.
1. Weather sensing and atmospheric characterization capabilities are lacking within DUCT environments. Reliable weather forecasting capabilities (weather forecast models) require local weather observations as input to accurately characterize current/initial atmospheric conditions. Sufficient numbers of weather observations enable meaningful mission watch. Mission watch provides operational commanders a real-time weather picture of the Area of Operations (AO) during

mission execution. Effective weather “mission watch” provides atmospheric monitoring of choke points, avenues of approach and even military objectives within the AO.

1. Lastly, addressing environmental intelligence for autonomous systems in Megacities, swarms of unmanned ground/air micro-vehicles could be equipped with weather sensors to dramatically improve currently inadequate local weather condition sensing and thus improve the accuracy of local DUCT atmospheric prediction models.

Needed Solutions: Weather Technologies to Change Warfare for Decision Makers at All Echelons

Looking ahead at the Megacity/DUCT battlefields of 2030 and beyond, there is an overwhelming need to revolutionize the science of atmospheric sensing, characterizing, and predicting local conditions in DUCT environments. The Battlefield Environment Division at Army Research Laboratory (ARL), in conjunction with research partners across the DoD, academia, and civilian public and private arenas, will be using a combination of existing very fine-scale resolution (microscale) meteorological tower arrays, unmanned system-hosted existing/emerging sensor technologies, and optimized sensor placement strategies to include crowdsourcing techniques to sense and characterize DUCT atmospheric domains. Applying sensor data and characterization improvements (separately and combined) to novel, forward-deployed microscale Nowcasting ("pocket modeling") technology hosted on computationally complex but extremely efficient General Purpose Graphics Processing Units (GPGPU) and smaller portable devices such as warfighter-hosted communications platforms is the way of the future for DUCT operational weather forecasting.

Observed data must be used to verify/validate the atmospheric modeling weather forecast improvements as related to value-added to the DUCT warfighter, showing how improved localized weather forecasts significantly enhance warfighter operations. Applying all such fine-scale technology improvement lessons learned to advanced automated state-of-the-science decision tools focused on predicting attrition rates from operations in adverse DUCT weather conditions will be one critical result this long-term effort. Thus, Megacity battlefield commanders will be provided with a full picture of predicted atmospheric effects and impacts on local operations, including expected losses due to hazardous weather. Pocket modeling (focused local atmospheric prediction technology hosted on personal communications devices), crowdsourcing sensed data, and GPGPU advances for atmospheric prediction computing are just a few of the disruptive technologies to be used as the capability to run a complex terrain atmospheric model is pushed to the lowest echelons in the battlefield which will positively affect current DoD processes. Development of deployable hardware and software system prototypes for weather effects intelligence and decision tools for DUCT environments is the planned culmination of ARL's work on meteorological sensor arrays, microscale atmospheric prediction systems, and unmanned system and atmospheric sensing platform resources to reach these technological goals.

There are a number of critical steps being addressed to move the science forward as the needed technological advances are developed:

- Perform research to understand atmospheric processes in DUCT environments. Effective weather sensing and atmospheric characterization of the AO will optimize mission execution by providing essential input to weather forecast models. This improves forecast accuracy and therefore confidence in planning and execution of all military operations; forecast accuracy improvements mean a safer operating environment for military and civilian personnel, with few, if any, weather surprises. Weather sensing in DUCT domains also provides critical, real-time situational awareness supporting current operations. A comprehensive understanding of current atmospheric conditions enables the commander's full utilization of the AO, in both time and space, allowing for the selection of tactics, weapons, and targets based, at least in part, on atmospheric conditions. Accurate and

timely weather observations are a true force multiplier, protecting military and civilian operations from the uncertainty of mission-limiting weather conditions.

- Advanced development of microscale models. Develop DUCT fine-scale operational local atmospheric modeling capabilities suitable for forecast center and forward-deployed implementation on the smallest computational platforms possible. Such capabilities will support both operational theater forecast centers as well as the lowest battlefield echelons with on-scene local atmospheric predictions. These forecasts will have the capability to ingest the most current, locally-sensed atmospheric data. Local forward-deployed atmospheric modeling capabilities will ensure timely weather forecast updates to Megacity commanders and decision-makers down to actionable Soldier levels. Today, precise prediction of local weather events is limited by the resolution of currently fielded weather forecast modeling capabilities and the availability of weather observations. Improving the resolution of weather predictions, especially in the complex terrain of a Megacity, requires a significant increase in the number of weather observations and optimized placement of weather sensors in the domain to initialize the weather predictions. Research will consider the value of remotely-sensed observations (e.g. satellite, radar, etc) as input to these improved forecast model capabilities. Weather sensing capabilities, combined with better model physics, will significantly improve the weather forecast accuracies within an urban environment. Additionally, developing forward-deployed and frequently updated small “pocket” computer platform atmospheric modeling capabilities, providing data to on-board weather decision tools will significantly enhance the local timeliness and accuracy of microscale DUCT weather predictions.
- New weather related decision aids include sensor performance tools for multiple modalities, including acoustic, infrared, radar, and seismic. Urban routing tools must account for manned and unmanned ground and aerial vehicles. Decision aid development must include applications supporting a prediction of human domain conditions based on weather and climate combined with and including populace reactions to military operations. DUCT-focused ensemble probabilistic predictions will produce forecast confidence output for decision support tools of high interest and use by military commanders and decision makers within the Megacity.

Summary

Weather conditions significantly influence military operations within Megacity DUCT operational domains. Confident execution of military operations demand comprehensive weather support at spatial and temporal resolutions that accurately depict microclimates found in every DUCT environment. These weather conditions effect all aspects of the geospatial environment within the Megacity.

Increased resolution and accuracy of deployed weather support products is crucial, especially so in the DUCT environment. Effective weather sensing, atmospheric characterization and prediction will optimize mission execution by providing critical, real-time situational awareness supporting future operations as well as providing essential input to weather forecast models and decision support tools. This improves forecast accuracy and confidence in planning and execution of all military operations. Forecast accuracy improvements mean a safer operating environment for military and civilian personnel.

This disruptive-based approach ensures DoD DUCT battlefield Commanders will have a full picture of predicted atmospheric effects and impacts on DUCT operations, including expected losses due to hazardous weather. The work highlighted in this paper will optimize our understanding and application of crucial weather conditions within the Megacity operations as future urban operating environments become the norm.

About the Authors

No
Photo
Available

David Knapp

Mr. David Knapp is the Associate Division Chief for Science and Technology in the Battlefield Environment Division at Army Research Laboratory (ARL). He supports the laboratory's new Atmospheric Science Center by leading efforts to develop new and strengthen current research collaborations in the areas of atmospheric sensing, characterization, and modeling for the Army's future battlefield needs. He recently completed a 10-year stint as chief of the Division's Atmospheric Modeling Branch, providing technical leadership to scientists and engineers focused on developing, validating, and fielding innovative atmospheric prediction capabilities tailored for all Army battlefield operational scales. Mr. Knapp has been with ARL for over 20 years in different research capacities related to battlefield weather forecasting. He retired from the Air Force Reserves in 2003 after serving a combined 22 years of active and reserve duty as a weather officer in a variety of operational forecasting, research, and leadership positions. He has extensive experience focused on applied research addressing specific Army weather capability gaps, with additional expertise in aviation weather research topics. Mr. Knapp received his B.S. in Meteorology from the University of Utah in 1981 and his M.S. in Meteorology in 1988 from North Carolina State University.

No
Photo
Available

Robb Randall

Dr. Robb Randall leads the Army Research Laboratory's (ARL) Atmospheric Science Center, the Battlefield Environment Division's entity managing and coordinating ARL's open campus initiative, bringing together government, industry, and academia for the mission of advancing atmospheric science and its application to critical defense technologies through a collaborative, innovative research ecosystem. He is also Chief (A) of the Atmospheric Dynamics Branch. Dr. Randall recently retired from the Air Force after 28+ years. During his career he served in Special Operations, Operational Weather Squadron, as a FOA Military Deputy Director and Division Chief, Advisor to the Iraqi Air Force, and Air Force Institute of Technology Professor. Before his retirement he served as the Commander, 16th Weather Squadron. The 16th Weather Squadron functions as the Air Force's center of excellence for atmospheric model development, implementation, and visualization. As Commander, he executed a worldwide weather support mission that delivered advanced terrestrial and space environmental intelligence tools to Joint warfighters, national agencies, and allied nations for planning and execution of full-spectrum military operations in addition to providing meteorological support to DoD research and development, acquisition, testing and sustainment. Dr. Randall received a B.S. in Meteorology from the University of Oklahoma in 1995, M.S in Meteorology from the Air Force Institute of Technology in 2002 and PhD from the University of Arizona in 2007.



Jim Staley

Mr. Jim Staley leads the Army Weather Proponent Office (AWPO) at the U.S. Army Intelligence Center of Excellence, Ft Huachuca AZ. Since inception in 2008, the AWPO is responsible for investigating and processing Army-unique weather support requirements utilizing the DoD's Joint Capabilities Integration and Development System (JCIDS). The AWPO also identifies and disseminates Army weather support doctrine. Additionally, the AWPO interfaces with the Army-wide weather Research and Development community to incorporate Army weather requirements into collective R&D efforts. Mr. Staley has extensive experience focused on tactical Army and Special Operations weather support to world-wide DoD missions. During his career he led weather support to Joint Special Operations forces, conventional Army units at multiple levels, and to the Air Force Special Operations Command. In 2007 Mr. Staley retired from the U.S. Air Force after 23 years of service. Mr. Staley received his B.S. in Geophysics from Boise State University in 1984, and his M.S. in Atmospheric Science from Colorado State University in 1990.

Available online at : <http://smallwarsjournal.com/jrnl/art/atmospheric-impacts-and-effects-predictions-and-applications-for-future-megacity-and-dense->

Links:

- { 1 } <http://smallwarsjournal.com/author/david-knapp>
- { 2 } <http://smallwarsjournal.com/author/robb-randall>
- { 3 } <http://smallwarsjournal.com/author/jim-staley>
- { 4 } <http://smallwarsjournal.com/comment/reply/42068#comment-form>

Copyright © 2016, Small Wars Foundation.



Select uses allowed by Creative Commons BY-NC-SA 3.0 license per our [Terms of Use](#).
Please help us support the [Small Wars Community](#).