BAMS
Meeting Summary

Current and Future Uses of UAS for Improved Forecasts/Warnings and Scientific Studies

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Workshop on Current and Future Uses of Unmanned Aircraft Systems (UASs) for Improved Forecasts/Warnings and Scientific Studies

What: Sixty-three participants including graduate students, postdoctoral fellows, and senior researchers working in the atmospheric sciences at U.S. and international universities, private companies, and government laboratories met to discuss scientific applications of UASs.

When: 29–31 October 2019

Where: Norman, Oklahoma

https://doi.org/10.1175/BAMS-D-20-0015.1
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In final form 24 January 2020

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Unmanned aircraft systems (UASs) provide unique observations not readily available from piloted aircraft or ground- and satellite-based remote sensors. For example, they can reach difficult to observe areas in the Arctic (Reuder et al. 2012; de Boer et al. 2016b, 2018), in tropical cyclones (Cione et al. 2020), and within the atmospheric boundary layer (Jacob et al. 2018), and provide more routine measurements over a longer time range with repetitive vertical and horizontal profiles than piloted aircraft can. Furthermore, there are many scientific applications of UASs that go beyond weather research, which can aid weather applications and, in some instances, draw from weather applications. Although recent efforts have accelerated the development of UAS platforms and instruments (e.g., Wildmann et al. 2014; de Boer 2016a; Barbieri et al. 2019; Bell et al. 2020), there is still considerable uncertainty in how to best acquire and use these observations for improving forecasts, how to integrate them with other observations currently being obtained, and to enable process studies to improve conceptual and numerical modeling of the atmosphere and its constituent gases, aerosols, pollutants, and hydrometeors. To initiate a community effort for addressing such issues and to build upon the efforts of other community groups, such as the International Society for Atmospheric Research using Remotely-Piloted Aircraft (ISARRA; http://isarra.org; de Boer et al. 2019), a workshop emphasizing the scientific applications of UASs was held at the National Weather Center (NWC) in Norman, Oklahoma, in October 2019 (all presentations are available at https://cimms.ou.edu/index.php/research/symposiums/symposium2019/). The workshop[1] brought together diverse communities actively working on various aspects of UAS-based atmospheric science.

[1] The local hosts for the workshop included the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), University of Oklahoma Center for Autonomous Sensing and Sampling (CASS), Center for the Analysis and Prediction of Storms (CAPS), Advanced Radar Research Center (ARRC), School of Meteorology, NOAA's National Severe Storms Laboratory (NSSL) and Air Resources Laboratory (ARL), and other entities within the NWC.

Session topic overviews

The first day of the workshop consisted of a series of invited presentations in the following four broad topic areas: 1) acquisition of data by UASs, including platform development, instrumentation, access to air space, calibration, validation, and other observational issues; 2) modeling and data assimilation efforts related to UAS data including, but not limited to, observing system [simulation] experiments (OSEs/OSSEs); 3) integration of UAS measurements with other observing systems; and 4) additional atmospheric applications of UAS and related scientific issues. Each broad topic area featured four to five speakers who were asked to give overview presentations to the workshop participants in plenary. Speakers were selected to ensure a variety of backgrounds and approaches. Presenters were asked to not only summarize the state of the art in platforms, instruments, deployment logistics, and applications, but also to provide visions for how the use of UAS can support the atmospheric science and related communities in the future through the identification of impediments to progress and potential solutions to those impediments.

Figure 1 shows a word cloud generated from 26 pages of notes taken by student/early career scientist rapporteurs for these four plenary sessions, highlighting the topics covered in the presentations and in the discussions that followed the presentations. During the first plenary session (Acquisition of data by UASs, including instrumentation, access to air space, calibration, validation, and other observational issues), it was noted that sensor integration was being addressed but that challenges in sensor characterization and complying with operational regulations from the Federal Aviation Administration (FAA) still existed. Discussion suggested that advancements could be accelerated by demonstrating progress in appropriate environments and test beds, if resources were available for multi-institutional collaborations.

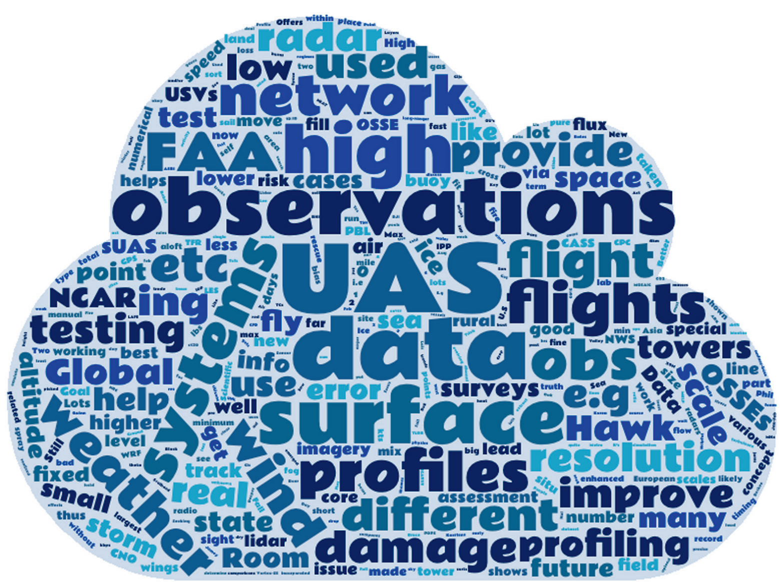

Fig. 1. Word cloud generated from 26 pages of notes taken by student/early career scientist rapporteurs for four plenary sessions on first day of conference, highlighting topics covered in presentations and subsequent discussions.

In the second plenary session (Relevance of UAS to OSEs and model development), several experiments that had indicated potential impacts of UAS observations were summarized. Speakers emphasized that more boundary layer profiles are sorely needed to fully realize the value of such observations, and that the execution of OSSEs and other methods by which simulated UAS can be used to explore the potential role of UAS in research and operations, as well as field campaigns should be explored in parallel and in a coordinated fashion to assess the optimal mix of observations needed for forecasts and warnings. In short, observational requirements for model applications (i.e., how many, where, and when) need to be better established, and may be pursuable through coordinated sampling campaigns. Further, the capabilities of UASs required to support the full forecast process from heuristics to NWP and evaluation must be better clarified.

The third session (Integration of UAS observations with other observing networks) covered positive developments related to the integration of highly capable surface networks, UAS platforms, and ground-based profilers currently in existence. There was specific discussion on the ongoing efforts to deploy a network of low-cost airspace surveillance radars to help mitigate concerns about airspace conflicts associated with routine UAS operations. It was emphasized that UAS observations are meant to complement rather than replace contemporary observations (e.g., UAS profiles are complementary to ground-based profilers). Remaining challenges for optimal observing strategies include the need to unify platforms and their data and associated metadata, how to better apply the infrastructure that exists for traditional observations to UAS, and how to determine the best and most complementary systems in which to invest.

Finally, the fourth session (additional atmospheric applications of UAS and other scientific discussions) included discussion and presentations on the potential for UAS to contribute to our understanding of cloud properties, aerosols, surface and radiative fluxes, stress terms, complex flows, albedo, surface heterogeneity, vegetation indices, photogrammetry, site surveys, and ocean properties. Additional discussion centered on the ability of UAS to make observations in challenging environments and to collect data that go beyond in situ measurements for weather prediction (e.g., climate and disaster response, air quality). Identified challenges were similar to those in previous sessions, including regulatory challenges, analysis of big datasets, quality assurance, scale of operation, inconsistent data formats, and scarcity of some platforms and sensors.

Breakout discussions of relevant issues

The second day of the workshop consisted of breakout group discussions designed to synthesize the collective expertise of the participants and develop strategies for better use of UAS data. Each group was tasked with determining hindrances to progress on use of UAS, the additional models, tools, instruments, and resources needed to address these impediments, and the research work and scientific questions that should be pursued to overcome these hindrances. Implicit to these discussions was identifying how government and university scientists should interact with the private sector and the administrative agencies to overcome these challenges. Participants were divided into four smaller groups for the discussions to maximize input from the broad range of participants. In the morning, attendees were sorted into groups based on their self-reported areas of interest and expertise, with each group focusing on one of the four topic areas introduced on the first day. Then, in the afternoon, participants were assigned to a group, with the groups arranged to include a diverse combination of participants across both areas of expertise and career stage to maximize interactions. A summary of the discussions from these groups is included below, only mentioning those points that went beyond those identified in the first day of overview talks. It should be noted that many of the topics were discussed in several of the groups, but each topic is listed here just once. The final day consisted of reports from each of the eight breakout groups, along with a plenary follow-up discussion.

Students and early career scientists from the University of Oklahoma acted as rapporteurs for all sessions and the authors have leaned heavily on these notes in the preparation of this article. Notes from all the discussion groups are available online (https://drive.google.com/drive/folders/1VpkkwNhKg63vHyjIZbGjJjO3LLey_UD6).

The instrument and platform group identified calibration and comparison of sensors being a major impediment to standardizing our expectation of UAS data quality and moving forward with expected performance standards. Currently, there is no gold standard for the often challenging comparisons that need to be made between data from UAS-mounted instrumentation and data from other sensors (e.g., towers, radiometers, lidar, radiosondes). Thus, the biggest need for making progress on establishing confidence in UAS data is a reference platform or set of reference instruments that could be robustly tested. This standard would ensure that the performance of UAS-based sensors can be adequately quantified and their accuracy determined outside of calibration laboratories for use in environmental conditions. Often NWP radiosondes are treated as the "gold standard" but they also have sampling issues. Who or what agency would take the lead was not clear within the group discussions. Additional discussion items included the need for a standard data format (including information on response time and sensor accuracy) and system requirements like those established for radiosondes. The latter was largely acceptable to the group and a starting point of requirements similar to a radiosonde were discussed, though no specific requirements were defined here.

The modeling/OSE/OSSE group identified a number of hindrances to progress in fully quantifying benefits of UAS measurements to model improvement, including the fact that large numbers of assimilation experiments are needed to delineate the impact of observations from different platform types. Additionally, it was noted that a shortage of resources (personnel, funding and computing power), together with a moving target of measurement error characteristics from evolving UAS platform designs results in some OSSEs using incorrect accuracy assumptions and potentially obtaining misleading results for some of today's platforms. Furthermore, actual UAS observations with sufficient temporal and spatial coverage to conduct full-scale OSEs are not yet available; fully developed systems to assimilate existing data are lacking, and the need to balance operational needs against model development and process studies hampers progress in the implementation of UAS-based data assimilation efforts. This group had wide-ranging discussions on what resources are needed to overcome these limitations and several community reports were cited. Specifically, the National Academies of Sciences (NAS) report on the future of boundary layer observing (National Academies of Sciences 2018) and the NASA decadal survey (National Academies of Sciences 2017) highlighted the need for more boundary layer observations, but so far there has been no dedicated initiative to collect and use such observations. Finally, participants noted that the complexity of OSSEs and OSEs suggests that a research center or group focused on this specific topic and properly integrated with collaborating groups at other universities and institutes might be optimum for the focused effort needed to reach this lofty goal. For example, the NOAA Quantitative Observing System Assessment Program (QOSAP; https://nosc.noaa.gov/QOSAP/) might be able to lead this effort.

The group focused on the integration of UAS with other observations identified various impediments including the need for more observations in harsh and remote environments, acquisition of measurements at different scales by different platforms, the potentially expensive staffing requirements that reduce the financial efficiency of UAS operations, particularly under current flight regulations, the risk-averse approaches that are sometimes followed by funding agencies and host institutions, weather and climate research not being a major concern to most UAS-centric companies and operators, infrastructure requirements for the use of big data, and the current limited spatial sampling of small UASs. In addition to the aforementioned resource limitations, this group identified the need for test bed environments to offer opportunities to complete "proof of concept" field campaigns, work through regulatory concerns, and to offer a shared framework for OSSEs and other modeling studies. Additional discussion was centered on the desirability of a centralized hub for data access and establishment of data standards. Research needs included exploration of horizontal flights in network configurations, expanded cost/benefit analysis for routine UAS operations, building and use of open source data access, evaluation of adaptive networks for various weather regimes, and quantification of survey/site characteristics.

The fourth group on scientific applications identified some other hindrances not highlighted by other groups. These included discussions on the lag in sensor availability for chemical, pressure, temperature, and humidity applications, and current challenges associated with operation in clouds and over urban areas, and how newer groups less familiar with UAS can face significant challenges associated with compliance with rules and regulations of FAA and with integration into the broader UAS research community. This last obstacle is furthered by the current lack of community UAS resources and facilities, as are offered for piloted research aircraft. Suggested steps for making progress on some of these issues included developing relationships with military installations to provide access to restricted airspace areas to mitigate risks associated with more complex flight operations (e.g., UAS swarms, in-cloud flight), collaborating with existing FAA UAS test ranges, and supporting FAA and NASA's efforts on UAS flight demonstrations. This group also emphasized the need to better link the science coming from UAS to societal needs (e.g., public health issues) and to work with industries that stand to benefit from the increased use of these platforms. Additionally, they questioned whether the current framework, which features independent funding of different research groups pursuing a variety of different topics, was best for making progress as a community. It was noted that a top-down approach supported by funding initiatives could allow for faster and more sustainable progress. Finally, data sharing and improvement of the efficiency of data sharing were also noted as a priority.

Given the distribution of the group's expertise, afternoon discussions overlapped the morning sessions substantially but covered various additional topics. To address the standardization issue, one group recommended creating a library of peer-reviewed documents describing platform designs, sensors, calibrations, data file formatting, intercomparisons, and more to help new investigators get entrained into the field more quickly and ensure some level of standardization. Community platforms for sharing software (e.g., GitHub) were also noted as a framework that could enhance operational consistency. Additional discussion included an expression of need for continued development of small, lightweight, high precision instrumentation and for long horizontal transects and frequent vertical profiling. These latter two items were identified as being at odds with current battery technology and this sparked a discussion on the potential for newer technologies (solar, fuel cell) to support extended flight operations. The need for a formal research test bed, and the need for increased funding and enhancement of interagency and private sector partnerships also came up. In this way, perhaps training of forecasters in a test bed to see the utility of UAS observations in a test bed environment could be established so that there would be more impetus to get a greater number of observations. Finally, it was noted that scientists need to do a better job of advocating the benefits of this technology to stakeholders and to society at large including allaying fears brought on by the public potentially confusing scientific UAVs with military or government surveillance drones that might be viewed as threatening or too invasive of privacy. For example, UAS could be routinely used for conducting damage surveys.

On the last day of the workshop, all the breakout groups reported their findings and discussion focused on overarching themes and visions for the future. Because the field is changing so quickly, participants felt it is necessary to continue to hold workshops such as this either annually or biennially and to integrate these workshops with discussion within established groups (e.g., ISARRA). Additionally, there was significant discussion on how to leverage alternate venues to entrain the broader atmospheric science community; linkages with major meetings of the American Meteorological Society or the American Geophysical Union would support such outreach. For example, holding town halls and short courses to discuss UASs at major meetings would be useful for expanding the number of people engaged with UAS studies. Discussions about ways to more successfully integrate industry professionals were held, noting that improved demonstration of the value of UAS measurements (e.g., custom forecasts for targeted needs) could help to make a sustained business case for such observations. However, it was again noted that to make such a case, a consistent framework (e.g., a test bed to advance the use of frequent boundary layer profiling to support weather forecast improvement) would be required.

Acknowledgments. We are indebted to the many scientists and students who participated in the workshop. This work, as well as travel for invited speakers for the symposium, was sponsored by the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma. We greatly appreciate the efforts of the following graduate students and early career scientists who acted as rapporteurs for the different sessions of the meeting: Tyler Bell, Jacob Carlin, Austin Dixon, Kathryn Gebauer, Brian Greene, Francesca Lappin, Marcela Loria-Salazar, Temple Lee, Joshua Martin, Michael Montalbano, and Morgan Schneider. Mandi Campbell and Tracy Reinke of the CIMMS Office were helpful in administrative support of the workshop.

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