

# MEETING SUMMARIES

## ADVANCING UNMANNED AERIAL CAPABILITIES FOR ATMOSPHERIC RESEARCH

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**P**olicy development for a stable and forward-looking society requires we understand the Earth system, its weather and climate patterns, and the impacts of the natural world on our activities. In the United States, recent storms, flooding, and wildfires strongly reinforce this requirement, as our ability to understand these events, to predict their occurrence, and to evaluate impacts heavily relies on the performance of numerical models across a variety of scales. Of particular interest are processes related to conditions in the lowest part of the atmosphere, including boundary layer temperature and turbulent structure, clouds, precipitation, aerosol particles, and the interactions between them. To support the continued development of modeling capabilities that can help us to predict high-impact events, we must continue to provide and advance observational

### SIXTH INTERNATIONAL SOCIETY FOR ATMOSPHERIC RESEARCH USING REMOTELY PILOTED AIRCRAFT CONFERENCE

**WHAT:** Atmospheric scientists, engineers, and industry participants discussed recent and upcoming atmospheric measurement efforts using unmanned aircraft systems (UAS) as well as the latest technology supporting UAS-based atmospheric science.

**WHEN:** 9–12 July 2018

**WHERE:** Boulder, Colorado

perspectives, enhancing our understanding of key physical and chemical processes.

To gain new perspectives on vertical and horizontal structures, and to sample the atmosphere in difficult-to-reach environments, unmanned aircraft systems (UAS) have been highlighted in several community reports (e.g., U.S. Department of Energy 2015; National Academies of Sciences, Engineering and Medicine 2018) as offering substantial promise. While UAS have been deployed for atmospheric measurement purposes for several decades, the use of such systems has expanded significantly over the past two decades. This is a direct result of decreasing costs of key electronic components and manufacturing capabilities supporting both the miniaturization of key sensors and the advancement of the UAS platforms. In recognition of this ongoing advancement, the European Union sponsored a Cooperation in Science

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and Technology (COST) Action supporting development of a community around activities related to deployment of UAS for atmospheric science in 2008. From this action, the International Society for Atmospheric Research Using Remotely Piloted Aircraft (ISARRA) was established. ISARRA held its first annual meeting in Palma de Mallorca, Spain, in 2013. Since that time, annual meetings have been hosted in Europe on three more occasions and in the United States twice. The sixth overall (and second United States-based) conference was recently held (9–12 July 2018) in Boulder, Colorado. This summary provides an overview of the conference and the societal discussions that occurred over the course of this meeting.

**OVERVIEW OF CONFERENCE.** In total, 130 registered participants took part in the sixth ISARRA conference. Of these participants, 99 were from North America (76%), 25 were from Europe (19%), 5 were from Asia (4%), and 1 was from Australia (1%). Thanks to support from the U.S. National Science Foundation, the U.S. Department of Energy, and the International Union of Geodesy and Geophysics (IUGG) International Association of Meteorology and Atmospheric Sciences (IAMAS), 42 of the participants were provided with some level of financial support to help offset meeting costs. This included 22 student participants, 7 postdoctoral or other early-career professionals, and 13 other attendees. Of the 42 people supported, 18 were female or minority participants.

Over the course of the conference, eight oral sessions and one poster session were held. The first oral session included introductory material for the conference as well as two keynote presentations on recent UAS efforts to understand the flux of aerosol particles into the atmosphere from the ocean and stable boundary layers at high latitudes. The other seven oral sessions were separated by topic areas in order to allow presenters to summarize ongoing work related to the following:

- Turbulence
- Clouds, aerosols, and trace gases
- Use of UAS for advancing numerical weather prediction
- Boundary layer structure
- Advancement of UAS technologies and capabilities
- High-latitude research
- Severe weather research

Poster presentations additionally touched upon all of the topics above. In this section, we provide a brief

overview of these sessions and summarize the results presented.

In the area of understanding turbulence and turbulent fluxes, both oral and poster presentations highlighted the utilization of different measurement techniques, including the use of multihole probes and fine-wire temperature sensors to evaluate turbulence parameters such as the structure function of temperature  $C_T^2$  over the depth of the lower atmosphere. Such measurements are being used in a variety of ways, ranging from the development of basic knowledge to understanding optical refraction to improving and evaluating simulations of the hurricane environment. Presentations on the topics of clouds, aerosols, and trace gases provided several nice examples of how miniaturized instrumentation is shedding new light onto aerosol fluxes and transport, aerosol–cloud interactions, and new particle formation across a variety of environments. The session on the use of UAS for advancing numerical weather prediction also featured a variety of different topics. These included overviews of programmatic efforts to develop UAS to provide information to weather models used by the National Oceanic and Atmospheric Administration (NOAA), numerical weather forecasts being developed specifically for UAS operations, the impact of UAS observations on forecast quality, and newly developed platforms for routine atmospheric sounding of the atmosphere. Presentations on the measurement of boundary layer structure included examples of the potential for UAS to provide new perspectives on the structure of boundary layer thermodynamic state, vertical flux divergence, and gas concentrations. These observations were provided through both in situ measurements and UAS integration into acoustic tomography, which was demonstrated to have the potential to provide three-dimensional measurements of the temperature and winds of the lower atmosphere. Talks on the topic of UAS capability advancement included overviews of new sampling techniques and patterns, innovative sensor development, and community-centric platform and team development. The high-latitude presentations provided information on several recent, ongoing, and upcoming field campaigns to better understand high-latitude boundary layers, aerosols, clouds, and atmosphere–surface interactions, along with interesting anecdotes about challenges associated with the operation of UAS in the extreme conditions faced there. Finally, the session on the use of UAS in severe weather research included presentations highlighting the use of UAS to measure and understand supercell thunderstorms and tropical cyclones.

All of the presentations from the meeting are being made available for public download through the main ISARRA society website ([www.isarra.org](http://www.isarra.org)).

### **ADDITIONAL ACTIVITIES.**

In addition to the presentations, the conference provided several additional opportunities to discuss capabilities and the general advancement of the use of UAS in atmospheric research. One of the highlights of this conference was the strong level of industry engagement. In addition to having 11 companies provide some level of financial sponsorship to help support the costs associated with holding the event, there were two dedicated exhibit sessions on the first day of the meeting. In total, 16 companies were on hand to exhibit their equipment and services, with companies including sensor and instrument producers, aircraft manufacturers, and software (including aircraft guidance software) developers. These sessions offered an opportunity for companies to demonstrate their equipment to meeting participants, and a chance for the scientific community to hear firsthand about the most recent technological developments supporting its research. Discussions held during these sessions were informative for both sides, and there was general consensus that providing opportunities to connect researchers and industry should continue to be a central role for ISARRA as a society.

During the second (evening) exhibit session, the University of Colorado Boulder, as the hosting institution, provided a high-level overview of its active programs leveraging use of UAS in a variety of scientific pursuits (Fig. 1). This overview included several specific examples supporting atmospheric science, including recent campaigns at high latitudes, to study severe weather in the continental United States and to understand surface-atmosphere exchange processes. The overview highlighted that these efforts were the direct result of collaborative efforts between a variety of geographically collocated entities, specifically including campus departments (e.g., Aerospace Engineering, Atmospheric and Oceanic Sciences, Geography); institutes and laboratories, including the university's Cooperative Institute for Research in Environmental Sciences (CIRES), the National Center for Atmospheric Research (NCAR), and the



**Fig. 1. A University of Colorado Boulder UAS is launched to measure atmospheric thermodynamic state and winds during LAPSE-RATE.**

NOAA Earth System Research Laboratory; and campus projects, such as the Integrated Remote and In Situ Sensing (IRISS) campus grand challenge project.

In addition to the sessions and activities listed above, the conference offered participants ample time for casual conversation about ongoing advancements and opportunities in the field. Scheduled events supporting such discussions included an opening icebreaker, regular coffee and snack breaks, group lunches in a nearby campus facility, and a conference banquet held at the NCAR Mesa Laboratory. Given the international nature of the group, these events provided unique opportunities for focused information sharing, identification of common challenges associated with UAS-based atmospheric research, and the discussion of possible future collaborations to make progress on key scientific issues.

### **LOOKING AHEAD: FROM DISCUSSION TO ACTIONS.**

In addition to the social discussion periods discussed in the previous paragraph, the last day of the meeting also included a scheduled time period for a focused discussion on the role of the ISARRA society and its future governance. Meeting attendees agreed that ISARRA plays an important role in steering the direction of a rapidly advancing field. Specific areas that were identified as key items for ISARRA to support included the following:

- Continued annual meetings and support of additional opportunities to foster discussion among

society members, including the research community and industry

- Serving as an information-sharing hub by offering opportunities for discussion on key (and rapidly evolving) areas, including flight permissions, sensors and instrumentation, and aircraft technology; it was specifically discussed that it may be useful for ISARRA to maintain a database of known sensors and systems supporting atmospheric science
- General advocacy for advancement and implementation of best practices in UAS-based atmospheric science
- Increased efforts to engage communities outside of North America and Europe using UAS for atmospheric research
- Continued support of the involvement of early-career and minority (including female) participants in a discipline that brings together science and engineering

In addition, there was extended discussion about what the governance structure for ISARRA should look like. There was general support for the development of a steering/executive committee to support the organization and logistics associated with ISARRA as an expanding international society. Work on the development of such a committee is currently ongoing.

The conference additionally included several discussions on opportunities for community measurement campaigns. With some previous ISARRA conferences hosting “flight weeks,” which offer participants a chance to operate their equipment in a coordinated fashion, the annual ISARRA conference has become a fantastic opportunity for community members to test and evaluate their equipment and sampling techniques. This year’s conference was no exception, with a substantial number of conference participants (>100) heading to southern Colorado’s San Luis Valley directly after the conclusion of the ISARRA conference to conduct a week’s worth of sampling as part of the Lower Atmospheric Process Studies at Elevation—A Remotely-Piloted Aircraft Team Experiment (LAPSE-RATE) campaign. Over the course of the flight week, university, laboratory, and industry participants were able to conduct nearly 1,300 flights supporting advancement of process understanding on various boundary layer phenomenon, interaircraft comparisons, and technological

evaluation of new capabilities. This campaign was additionally supported by high-resolution numerical modeling work, a variety of ground-based observations, and the launch of numerous radiosondes. In addition to planning discussions for LAPSE-RATE held during the conference, there were additional discussions on potential future campaigns in Finland, Oklahoma, Spain, and elsewhere.

In the coming year, ISARRA’s influence will extend beyond the annual meeting, with society members helping to support focused sessions on UAS in atmospheric science at other community events, such as the American Meteorological Society’s Annual Meeting and the American Geophysical Union Fall Meeting. At the current pace of expansion in the use of these systems, it is very important to provide ample opportunities to discuss such advancement. In that light, planning is already underway for the seventh ISARRA conference, which will be hosted by Spain’s Instituto Nacional de Técnica Aeroespacial (INTA) in Lugo, Spain from 15–19 July 2019. Readers are encouraged to sign up as ISARRA members ([www.isarra.org](http://www.isarra.org)) to stay up to date on planning for this meeting and other societal news.

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