campaign participation  campaign participation  Kristen L. Rasmussen <sup>1*</sup> , Melissa A. Burt*, Angela Rowe*, Rebecca Haacker#, Deanna Hence Lorena Medina Luna#, Stephen W. Nesbitt^, and Julie Maertens <sup>\$</sup> 10	eld
Kristen L. Rasmussen <sup>1*</sup> , Melissa A. Burt*, Angela Rowe <sup>+</sup> , Rebecca Haacker <sup>#</sup> , Deanna Hence Lorena Medina Luna <sup>#</sup> , Stephen W. Nesbitt <sup>^</sup> , and Julie Maertens <sup>\$</sup> 9	THE S
5 6 7 Kristen L. Rasmussen <sup>1*</sup> , Melissa A. Burt*, Angela Rowe <sup>+</sup> , Rebecca Haacker <sup>#</sup> , Deanna Hence 8 Lorena Medina Luna <sup>#</sup> , Stephen W. Nesbittˆ, and Julie Maertens <sup>\$</sup> 9 10	AMEKI ETEOROL SOCIE
Kristen L. Rasmussen <sup>1*</sup> , Melissa A. Burt <sup>*</sup> , Angela Rowe <sup>+</sup> , Rebecca Haacker <sup>#</sup> , Deanna Hence Lorena Medina Luna <sup>#</sup> , Stephen W. Nesbitt <sup>^</sup> , and Julie Maertens <sup>\$</sup>	1919 1919 1919 1919
<ul> <li>Kristen L. Rasmussen<sup>1*</sup>, Melissa A. Burt*, Angela Rowe*, Rebecca Haacker#, Deanna Hence</li> <li>Lorena Medina Luna#, Stephen W. Nesbitt^, and Julie Maertens\$</li> <li>10</li> </ul>	
8 Lorena Medina Luna <sup>#</sup> , Stephen W. Nesbitt <sup>^</sup> , and Julie Maertens <sup>\$</sup> 9 10	
9 10	ıce^,
10	
***************************************	
*Department of Atmospheric Science	
13 Colorado State University, Fort Collins, CO	
14	
<sup>+</sup> Department of Atmospheric and Oceanic Sciences	
16 University of Wisconsin-Madison, Madison, WI	
17 18 **Education and Outreach	
National Center for Atmospheric Research, Boulder, CO 20	
21 ^Department of Atmospheric Sciences	
22 University of Illinois at Urbana-Champaign, Urbana, IL	
23	
24 \$Colorado State University STEM Center	
25 Colorado State University, Fort Collins, CO	
26	
27	
28	
Submitted to the Bulletin of the American Meteorological Society	
30 October 2020	
Revised March 2021	
32	
33	
34	

<sup>1</sup> Corresponding Author: Kristen L. Rasmussen, Department of Atmospheric Science, Colorado

State University, Fort Collins, CO

Email address: <u>kristenr@rams.colostate.edu</u>

Phone number: (970) 491-8983 Fax number: (970) 491-8449

1

**Early Online Release**: This preliminary version has been accepted for publication in *Bulletin of the American Meteorological Society*, may be fully cited, and has been assigned DOI 10.1175/BAMS-D-20-0062.1. The final typeset copyedited article will replace the EOR at the above DOI when it is published.

#### Abstract

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

53

54

55

This article provides an overview of the Advanced Study Institute: Field Studies of Convection in Argentina (ASI-FSCA) program, a 3-week dynamic and collaborative hands-on experience that allowed 16 highly motivated and diverse graduate students from the U.S. to 2018-19 Remote sensing of Electrification, participate in the Lightning, Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) field campaign. This program is unique as it represents the first effort to integrate an intensive Advanced Study Institute with a field campaign in atmospheric science. ASI-FSCA activities and successful program outcomes for five key elements are described: (1) Intensive field research with field campaign instrumentation platforms; (2) Recruitment of diverse graduate students who would not otherwise have opportunities to participate in intensive field research; (3) Tailored curriculum focused on scientific understanding of cloud and mesoscale processes and professional/academic development topics; (4) Outreach to local K-12 schools and the general public; and (5) Building a collaborative international research network to promote weather and climate research. These five elements served to increase motivation and improve confidence and self-efficacy of students to participate in scientific research and field work with goals of increasing retention and a sense of belonging in STEM graduate programs and advancing the careers of students from underrepresented groups as evidenced by a formal program evaluation effort. Given the success of the ASI-FSCA program, our team strongly recommends considering this model for expanding the opportunities for a broader and more diverse student community to participate in dynamic and intensive field work in atmospheric science.

5/	BAMS Capsule: The ASI-FSCA program allowed 16 graduate students to participate in the
58	RELAMPAGO field campaign and provides a model for improving access to the unique
59	environments in field campaigns.
60	
61	
62	
63	
64	
65	
66	
67	
86	
69	
70	
71	
72	
73	
74	
75	
76	
77	
78	
79	

#### Introduction

Many successful scientists in atmospheric science were drawn into this area of study through participation in field campaigns, often when they were students. Atmospheric science has a long history of including both graduate and undergraduate students in field campaigns to provide scientific training, career-broadening, and networking opportunities (Hallett et al. 1990; Stith and Rogers 2004; Rauber et al. 2007; Kristovich et al. 2017). For example, the leaders of the Rain in Cumulus over the Ocean (RICO) field campaign developed a robust educational plan that included having students direct a complete scientific mission for the first time (Rauber et al. 2007). Airborne, ground-based, and ship-based platforms have all been used in educational efforts to include graduate and undergraduate students in field research (Fabry et al. 1995; Hallett et al. 1993; Borys and Wetzel 1997; Wetzel et al. 2003; Rauber et al. 2007; Kristovich et al. 2017).

Building on this tradition, the leadership of the RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations) field campaign (Nesbitt et al. 2021) created a robust and unique plan to include students from diverse backgrounds and institutions in a facilitated Advanced Study Institute - *the first of its kind associated with a field campaign in atmospheric science*. Advanced Study Institutes (ASI) are funded by the National Science Foundation's (NSF) International Research Experiences for Students (IRES) program and are short 3-week courses intended to "engage advanced graduate students in active learning and research at the frontiers of knowledge" (NSF IRES solicitation). The RELAMPAGO field campaign was conducted from 1 November – 15 December 2018 in west central Argentina and, to date, has been the largest land-based international field campaign conducted in atmospheric science (Nesbitt et al. 2021). This region arguably has among the most intense convective systems in the world with respect to the frequency of large

hail, high storm tops, and extreme lightning activity (Zipser et al. 2006; Houze et al. 2015; Rasmussen et al. 2014; Rasmussen and Houze 2011, 2016), yet the processes that give rise to such extremes are unclear because of a scarcity of observations. Given the critical role of clouds in Earth's climate system in determining a large proportion of water and energy budgets (Allen and Ingram 2002), a greater understanding of cloud and mesoscale processes in remote regions of the globe is important for understanding the global distribution and impacts of convective storms (Zipser et al. 2006; Houze et al. 2015).

Although some opportunities for undergraduate and graduate student participation in field research are sometimes available (e.g., the Saharan Dust AERosols and Ocean Science Expeditions (AEROSE) program<sup>2</sup>), major international field campaigns of this type do not happen often and are typically only accessible to student advisees of the campaign Principal Investigators (PIs). It is often the case that students from institutions that do not typically conduct field work (e.g., smaller atmospheric science programs, Minority Serving Institutions or MSIs), or those doing computational or theoretical research projects, may not have the opportunity to participate in a major field campaign in an international setting. When students are given the opportunity for hands-on research through lab or field activities, many students excel and rapidly expand their interest in research (Dahlberg et al. 2008), regardless of their background. The International Institute of Education's 2009 report, Promoting Study Abroad in Science and Technology Fields, says "curricular innovation, international collaborative research, development of dual/joint-degree programs across borders and distance learning will all be needed to provide students with an international perspective and to produce globally competent professionals." Given the significant benefits of participating in international field work, including networking and career-advancement

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

121

122

123

 $<sup>^2\</sup> http://ncas.howard.edu/research-programs/aerose/$ 

opportunities, the *primary goals* of the Advanced Study Institute: Field Studies of Convection in Argentina (ASI-FSCA) program were to *provide a dynamic and highly collaborative* international research experience for 16 diverse and motivated graduate students to promote career advancement through professional development activities, participate in intensive field research, improve scientific understanding of cloud and mesoscale processes of the atmosphere, and interact with the local community and K-12 students to communicate the science of RELAMPAGO. In addition, these elements serve to increase motivation and improve self-confidence of students to participate in scientific research and field work with goals of increasing retention in STEM graduate programs and advancing the careers of students from underrepresented groups.

#### **ASI-FSCA Overview**

With support from the NSF International Research Experiences for Students (IRES) program, the ASI-FSCA program provided an opportunity for 16 graduate students from diverse backgrounds and a wide variety of institutions to participate in the RELAMPAGO field campaign in Argentina for 21 days in November 2018 (Figure 1). The ASI-FSCA program was coordinated by U.S.-based atmospheric scientists involved in RELAMPAGO (Table 1). The ASI-FSCA program provided a dynamic and highly collaborative international research experience by focusing on five key elements: (i) intensive field research with active field campaign instrumentation platforms under the guidance of the instrument PIs; (ii) recruitment of diverse graduate students, including those from underrepresented groups in the geosciences, first generation, and from MSIs, who would not otherwise have opportunities to participate in intensive field research; (iii) tailored curriculum focused on scientific understanding of cloud and mesoscale

processes of the atmosphere and professional/academic development topics; (iv) outreach to the local K-12 schools and organized cultural activities; and (v) building a collaborative international research network between the U.S., Argentina, and Brazil to promote weather and climate research.

148

149

150

151

152

153

154

155

156

157

158

159

160

161

162

163

164

165

166

167

168

169

170

One of the primary goals of the ASI-FSCA program was to recruit diverse graduate students, including students from smaller atmospheric science programs and minority serving institutions (MSIs), including Hispanic serving institutions (HSIs) and historically Black colleges and Universities (HBCUs), who would potentially not have opportunities to participate in intensive field research through their home institutions. We also aimed to build a cohort with other diversity metrics, including gender, historically underrepresented groups in the geosciences, first generation, and a broad representation of institutions. A partnership with the National Center for Atmospheric Research (NCAR)'s Advanced Study Program (ASP), in collaboration with the Significant Opportunities in Atmospheric Research and Science (SOARS) Program, helped recruit graduate students from diverse backgrounds. Both programs have a history of success in recruiting and mentoring diverse students, graduate visitors, and postdoctoral fellows. NCAR-ASP led the recruitment efforts by advertising the opportunity on the ASP website, via social media, with professional societies such as AMS and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), through the ASP and SOARS Program alumni networks - many include faculty at smaller colleges and MSIs - , and through UCAR member organizations.

Recruiting through these extensive networks provided a set of student applications from a wide range of backgrounds. However, out of 46 applications, we only received three applications from students at HSIs and no applications from students at HBCUs, despite advertising at several HBCU institutions. The remainder of the students who applied to the program were from well-

established programs in atmospheric science of varying sizes. With that being said, many ASI-FSCA students of color attend larger PWIs (primarily white institutions). The experience as a student of color or from another historically underrepresented group can be challenging at large PWIs. Although we did not have as many students who were from Minority Serving Institutions as hoped, recruiting diverse students from PWI schools can provide them with a sense of community and belonging, and in addition access to other opportunities that they may not have had otherwise.

171

172

173

174

175

176

177

178

179

180

181

182

183

184

185

186

187

188

189

190

191

192

193

Students submitted applications to the program and included (1) information on prior participation in field campaign opportunities, (2) a personal statement on what they hoped to gain from the ASI and field experience, (3) what it would mean to them to participate in an international field school and campaign, (4) how their participation in the ASI would help with their graduate school journey and career aspirations, and (5) preferences for instrumentation platform placements. The ASI-FSCA leadership team and one outside member (total of six people) participated in a two-part review process to select applications. Evaluation criteria for the selection of students included a priority for students with no prior field campaign experience to maximize the impact of the program, representation of schools (including MSIs, HSIs, and HBCUs), demographics, and a balance of instrument platform preferences. The first round consisted of a process where each application was reviewed by a minimum of four evaluators based on the criteria mentioned above. Dr. Rasmussen evaluated all of the applications to ensure consistency in the selection process. Once the first round was completed, the second round of evaluations was conducted as a phone call in which all reviewers were present. The committee discussed how each student would fit into the overall ASI objectives and used the evaluation criteria described previously to meet our diversity goals from the applications we received. The demographics of the

16 graduate student participants selected for the ASI-FSCA program included attracting students from historically underrepresented groups in STEM (50% female, 13% LGBTQ, 25% Hispanic/Latino, 38% 1st generation students, 7% American Indian/Alaska Native, and 7% African American), from 13 different institutions including three MSIs highlighted in italics (Colorado State University, Columbia University, Louisiana State University, Massachusetts Institute of Technology, Montana State University, Pennsylvania State University, San Jose State, University at Albany, University of California Santa Barbara, University of Kansas, University of Oklahoma, University of Texas El Paso, University Wisconsin-Madison), and 50% M.S. and 50% Ph.D. students.

In preparation for the field campaign, students participated in four workshops to build their scientific and cultural knowledge prior to traveling to Argentina. Topics of the workshops included: (1) The Science of RELAMPAGO (10 September 2018); (2) Instrumentation Overview (24 September 2018); (3) Professional Development (8 October 2018); (4) Cultural Overview (22 October 2018). These four lectures served as important and necessary preparation for the scientific and cultural aspects of the international RELAMPAGO field campaign. In addition, students were provided with a Spanish language summary document of commonly used phrases prior to their departure for Argentina to assist with in-country communication.

Once the students arrived in Córdoba, Argentina at the start of the RELAMPAGO campaign, the intensive and immersive ASI-FSCA program included coordinated educational and scientific activities with RELAMPAGO instrument facilities, as well as those from the Department of Energy (DOE) Clouds, Aerosols, and Complex Terrain Interactions complementary field campaign (CACTI; Varble et al. 2021). This wide variety of activities included instrument training sessions, scientific seminars/lectures, professional development activities, direct integration with

the field campaign observational teams, a field trip to visit the DOE G-1 aircraft (Fig. 1b), and cultural exchange opportunities with local K-12 students. A summary of the scientific and professional development lectures given during the ASI-FSCA program is provided in Table 2. At the start of the program, the students participated in facilitated team-building sessions with an external expert (https://www.yarbgroup.com) and the RELAMPAGO Code of Conduct and Sexual Harassment training session led by RELAMPAGO leadership (Fischer et al. 2021). During the project, the students attended all RELAMPAGO campaign forecast briefings that occurred daily at 9am and 5pm local time. In addition to the planned activities, networking with the instrument teams and RELAMPAGO scientists was an opportunity for the students in building their professional networks. To synthesize their field experience, the students gave a short 5-minute presentation at the end of the program on the observations they collected and any insights into the science of RELAMPAGO gained during their immersive time in the field.

The program culminated with an ASI-FSCA Fall workshop one year after the field campaign in October 2019 in Boulder, CO. Fourteen of the 16 students who participated in the field campaign were able to attend the workshop. The workshop focused on professional development activities, research discussions, and career-oriented panels that were not possible in the short 3-week intensive program in Argentina (Table 3).

#### **ASI-FSCA Objectives**

The ASI-FSCA program was the first NSF-IRES funded Advanced Study Institute conducted in concert with a major international field campaign in atmospheric science. A robust curriculum and syllabus (available at https://rasmussen.atmos.colostate.edu/asi/) were developed

239	to ensure positive and meaningful outcomes for all student participants. The primary objectives of
240	the ASI-FSCA were as follows:

241

242

249

- 1. Recruit a diverse set of graduate students who would not otherwise have opportunities to participate in intensive international field research.
- 243 2. Teach students how to observe the atmosphere through operation of a variety of state-of-244 the-art instruments and conduct successful field research to collect high-quality data during 245 the RELAMPAGO field campaign.
- 246 3. Provide active learning experiences on how multi-platform field campaigns are conducted 247 in terms of understanding the complex communications and decision-making from 248 experienced PIs such that this group can become future leaders in this field.
  - 4. Professional networking with top scientists in atmospheric science that can provide future employment and collaboration opportunities.
- 5. Increase students' knowledge of cloud physics, mesoscale dynamics, convective weatherforecasting, and mountain meteorology.
- 6. Guide students to complete a student-led project during the ASI that may include observations from their field experience instrument platform.
- 255 7. Enhance the students' professional and academic development.
- 8. Build a collaborative international network of young scientists between the U.S.,
  Argentina, and Brazil to promote weather and climate research.
- 9. Increase student motivation and self-confidence in scientific research and field work.
- 10. Increase retention in STEM graduate programs and further the careers of underrepresentedstudent groups.

These objectives were developed to enhance the students' scientific identity and self-confidence (Carlone and Johnson 2007; Cooper et al. 2019), encourage persistence through graduate school and in STEM careers (Trott et al. 2020), and provide deeper insight into the research process associated with field campaigns (Trott et al. 2020) as has been found for long-term student outcomes for undergraduate students participating in coordinated research opportunities (e.g., Research Experiences for Undergraduates programs).

#### **RELAMPAGO Field Campaign**

The NSF-sponsored RELAMPAGO field campaign was conducted from 1 November – 15 December 2018 in west central Argentina in the general vicinity of the Sierras de Córdoba and the Andes foothills (Nesbitt et al. 2021). RELAMPAGO, leveraging the repeatability of storms in the region, aimed to address science questions related to the pre-initiation to initiation, initial organization/severe-weather generation, and growth/backbuilding stages of storm development, all of which are poorly understood. New insights into connections between the extreme hydroclimate, high impact weather, and atmospheric dynamical processes in meteorological and geographical settings unique to this region were obtained by bringing together NSF facilities with (1) new operational dual-polarization radars in Argentina, (2) significant contributions from Argentina, Brazil, Chile, NOAA, and NASA, and (3) a major, complementary U.S. DOE field campaign (CACTI). For more details on the RELAMPAGO field campaign, see Nesbitt et al. (2021), and for more details on CACTI, see Varble et al. (2021).

#### From beginner to expert: Collecting and analyzing observations during RELAMPAGO

A primary component of the ASI-FSCA educational and research experience (ASI-FSCA program goals 2-3) included each student being placed with an observational platform or the international forecasting team involved in RELAMPAGO. Students were placed with the following instrument platforms: Radars (Colorado State University's C-band radar; Center for Severe Weather Research's Doppler-on-Wheels X-band (Fig. 3b) and C-band-on-Wheels (COW) radars), mesonet/sounding teams (mobile teams launching weather balloons and collecting in-situ weather observations; Fig. 2), lightning team (Lightning Mapping Array observations; Lang et al. 2020; Fig. 3d), hydrometeorology team (acoustic doppler current profiler; Fig. 3a), and real-time data analysis and interpretation in the RELAMPAGO Operations Center (Fig. 3c). The students were assigned to an instrument platform or forecasting team based on their previously stated preferences and helped conduct RELAMPAGO operations. Due to the length of the program and training required for each platform, each student was placed with one platform. However, if time permitted the students to work with more than one observational platform, this activity was encouraged to broaden their experiences. These experiences provided an opportunity for the students to work with diverse and international teams that exemplifies that productive and innovative science benefits from diverse teams (McLeod et al., 1996) and generally met the ASI-FSCA goals 2, 3, 4, 5, 7, 8, and 9.

300

301

302

303

304

305

299

283

284

285

286

287

288

289

290

291

292

293

294

295

296

297

298

#### Learning from the scientists: ASI-FSCA scientific seminar series

One advantage of hosting the ASI-FSCA program alongside the RELAMPAGO field campaign was the unique opportunity to interact with and learn from a wide range of scientific experts (Table 1). To achieve the ASI-FSCA program objectives (ASI-FSCA goals 2, 4, and 5), a seminar series with 12 in-field lectures was organized and took place during the 3-week ASI-FSCA

program in Argentina (Table 2). While a schedule was created for the 3-week program, flexibility was critical - as the formation of severe storms sometimes meant scientists and students needed to rapidly deploy on field missions and thus the lectures were rescheduled. The lecture topics included a general introduction to the science of RELAMPAGO and continued with more specific topics such as mesoscale convective systems, lightning, low-level jets, radar meteorology, and hydrometeorology. Scientists incorporated RELAMPAGO-related themes into most of the presentations and the Powerpoint slides were made available to the students after the ASI-FSCA program through a shared Google drive folder and at the following ASI-FSCA website: https://rasmussen.atmos.colostate.edu/asi/index.php.

### **Learning from the experts: Professional development**

Experts on scientific education, outreach, and career development formed an intentional and major part of the ASI-FSCA leadership team (Table 1). Access to and availability of professional development and career-enhancing training is not the same for all students across institutions in the U.S. A key component of the ASI-FSCA program was to integrate a variety of professional development lectures and activities into the curriculum to meet our program objectives (Fig. 4; ASI-FSCA goals 4, 6, 7, 9, 10). The lectures began with a student-requested session on stress-management and culture shock, and continued with discussions on building a supportive network and finding mentors, how to represent the ASI-FSCA experience on your curriculum vitae/resume, and science communication (Table 2). In response to feedback from the students, the ASI-FSCA Fall 2019 Workshop was organized to provide enhanced professional development opportunities and career perspectives for the students (Table 3). Professional development lectures during the workshop focused on scientific writing and communication, how

to think like a scientist, time management skills, finding and applying for academic/research jobs, work-life balance, and mentor mapping and beyond, as well as networking opportunities. In addition, two career panels were organized that focused on (1) postdoctoral researchers and (2) careers in atmospheric science that included a wide range of scientists from the public, private, and government sectors.

#### **Cultural Immersion and Science Outreach**

As the first international travel experience for several of the ASI-FSCA students, the program in Argentina provided students with cultural broadening and opportunities for professional networking and outreach to K-12 students in the local community. RELAMPAGO student participants from Argentina and Brazil were invited to all ASI-FSCA lectures and outreach events to facilitate networking and cross-cultural discussions among the students (estimated at ~25 additional participants). ASI-FSCA leadership created bilingual brochures and handouts that provided an overview about the field campaign and general atmospheric science topics (i.e., hail, tornadoes, thunderstorms). These materials were widely distributed by RELAMPAGO students and scientists when conducting field work, at outreach events, and to the local community who often inquired about instruments operating on roadsides during operations.

ASI-FSCA students interacted with the local community, experienced cultural activities in Villa Carlos Paz, Argentina, and were active participants in the K-12 outreach activities organized by RELAMPAGO leadership (ASI-FSCA goals 7-10). As is described in Nesbitt et al. (2021), the RELAMPAGO outreach program included a media day and Open House for K-12 students to explore various RELAMPAGO instruments (Fig. 5a) prior to the start of the field campaign, and four K-12 outreach events at local schools (Fig. 5b) organized by Prof. Carlos Marcelo Garcia of

the University of Cordoba. It is estimated that a total of 2,000 K-12 students were reached by the RELAMPAGO outreach program (Nesbitt et al. 2021) and the ASI-FSCA students and leadership participated in all of these events.

Finally, the ASI-FSCA program partnered with the NCAR Explorer Series program, which was created in 2016. The goals of the program are to share science conducted at NCAR and partnering institutions, to inspire, inform, and engage the public in society-relevant research and studies of atmospheric and related scientific phenomena. The NCAR Explorer Series consists of monthly lectures, expert panels, and short science videos that have attracted hundreds of attendees at in-person and virtual events, and have received several thousand views on YouTube. A total of eight three-minute videos were filmed during the RELAMPAGO field campaign. These videos highlight the science of RELAMPAGO, the science and engineering challenges of field work, and feature the scientists, engineers, technicians, and students who participated and led different components of the field campaign, with interviews in both English and Spanish (http://bit.ly/NCAR\_ExplorerSeries\_FieldCampaigns\_RELAMPAGO). In addition, a short video profiled the ASI-FSCA program (http://bit.ly/RELAMPAGO-ASI-Program), including interviews with student participants and the leadership team.

#### **Student experiences**

- The ASI student objectives were as follows:
- 1. Enhance basic knowledge on cloud and mesoscale processes and mountain meteorology.
  - 2. Participate in a major international field campaign at the frontier of atmospheric research.
  - 3. Operate and collect data from an instrument platform or participate in forecasting during a major field campaign.

4. Develop advanced professional development skills for transitioning to the next stage of their career

To evaluate the experiences of the ASI-FSCA students, an external evaluator with the Colorado State University STEM Center implemented three surveys that were conducted several weeks before the ASI-FSCA program began, several weeks following the conclusion of the ASI-FSCA program, and 6-months after the conclusion of the program. According to the pre-survey, students sought to participate in the ASI experience with the objectives of gaining hands-on experience in research, meeting other graduate students in their field, and networking with scientists. The students were also hoping to enhance their curriculum vitae and clarify whether they wanted to pursue a science career, but these objectives were less important overall.

At post-survey, students were asked about areas where they felt they experienced the most gain during the ASI-FSCA program. Beyond conducting field research, several areas that students indicated the most gain were in giving oral presentations, explaining their project to others, conducting field observations, and managing time (ASI-FSCA goals 2, 3, 6, 9, 10). It is important for students to develop confidence in, as well as skills for conducting research during their graduate school years (ASI-FSCA goal 9). Students were asked at post-survey about their overall satisfaction with their ASI experience (Table 4). Overall, students were very satisfied, indicating that it was an important and applicable learning environment that will be useful to them in the future. Students were asked about the most and least valuable aspects of their research experience, along with any improvements they would recommend. Students most valued the opportunity to collect data in the field and additionally noted that the ability to work with "big" scientists and engage in professional networking was helpful and beneficial (ASI-FSCA goals 4, 7, 8).

In the survey conducted six months following the end of the ASI-FSCA program, students were asked whether they had the opportunity to use any of the information or skills they learned during their ASI-FSCA experience. Of all students who answered this question (not just those who had a completed pre- and follow-up survey; n=9), seven agreed that they had used teamwork and networking skills, improved their curriculum vitae, developed proposals or presentations, and applied field work skills. Though students' confidence levels did not decrease below their baseline level over time, they did not generally maintain post-program levels six months later. This suggests that 'booster' training or supplemental information updates to promote additional learning and/or skills may be helpful for maintaining confidence gains. At follow-up, students mentioned that a bigger focus on writing skills and job application information may be helpful for similar future programs.

A recent study explored the long-term academic and career impacts of hands-on undergraduate research experiences (Trott et al. 2020). Their study showed that 4-7 years after the research experience, students described key long-term impacts of their undergraduate research experiences in three categories: (1) research/science, (2) graduate school, and (3) careers. The combination of mentors and other significant relationships formed during these experiences and increased self-confidence and self-awareness of career aspirations either retained or gained significance over time (Trott et al. 2020). Participants in our program were graduate students, but similar long-term impacts may be expected based on our curriculum of hands-on field research, networking with scientists of RELAMPAGO, mentoring from the ASI-FSCA leadership team and instrument mentors, professional development exercises designed to help students find their science identity, and career discussions at the Fall 2019 workshop. Our leadership team organized informal meet-ups at the American Meteorological Society (AMS) Annual Meeting in 2019 and

2020 and we will continue this activity in future in-person conferences. In addition, the student participants' professional networks were expanded through participation in the ASI-FSCA program, including working with international and U.S. scientists in the field and through the Earth Science Women's Network meet-ups at the AMS Annual Meetings. Further connections on social media (i.e., Facebook, Twitter) has enabled continued cohort interactions that will likely persist well into the future.

#### **Lessons Learned**

The ASI-FSCA program consisted of a variety of programmatic and hands-on field experiences for 16 graduate student participants and was successful with strategic and collaborative efforts from experts at various institutions in the U.S., Argentina, and Brazil. Through active surveys, mentoring, and final project presentations, we were also able to assess the success of the program in providing students with an experience that they would not have otherwise been able to participate in. They only had a few recommendations for improvement, including adding a few lecture topics of interest, splitting up the lecture time, and allowing more time for presentation of final projects. More specifically, the students requested that more professional development topics be covered, including career-related topics like job applications and interviewing. This request was the primary motivation for the 2019 Fall Workshop, where we were able to spend a considerable amount of time on specific professional development topics requested by the students in the survey responses (Table 4).

Although we broadly advertised the ASI-FSCA program to UCAR Member Organizations, the NCAR ASP and UCAR SOARS alumni networks, professional societies and via social media, we only received three applications from HSIs and HBCUs combined out of 46. Based on previous

recruiting experiences we hoped to get a pool of applications from a diverse set of institutions. Although we generally met our program's diversity goals (ASI-FSCA goal 1), one recommendation for future programs of this type in the atmospheric sciences is to individually reach out to the leadership of more MSIs and smaller colleges with relevant programs to encourage their students to apply for opportunities of this type. In addition, intentional recruiting should be carefully considered using established resources like the "Diversifying Study Abroad and Expanding Equity for MSI Students<sup>3</sup>" published by the Center for MSIs at the University of Pennsylvania.

Given the success of the ASI-FSCA program, our team strongly recommends this model for expanding the opportunities for a broader and more diverse student community to participate in dynamic and intensive field work in atmospheric science. The student outcomes and lessons learned in the field are unmatched by typical classroom activities as mentioned by several students. One of the most notable achievements we can make to the advancement of science is to inspire the next generation of scientists in atmospheric science. Field campaigns provide unique hands-on and dynamic environments that allow for the students to understand the value of observations and models, learn how science is conducted, and develop new questions about the world around them. As the first ASI organized in collaboration with a major field campaign in atmospheric science, the ASI-FSCA program provides a model for future programs that can potentially improve access to a broader demographic of students to the unique environments in field campaigns. The benefits of participating in hands-on field research should also be considered for upper-level undergraduate students in addition to graduate students to reach a broader population of students who may be interested in careers in atmospheric science, but are from smaller programs or colleges. Beyond

<sup>&</sup>lt;sup>3</sup> https://cmsi.gse.rutgers.edu/content/diversifying-study-abroad-and-expanding-equity-minority-serving-institution-students

increasing student exposure to and enthusiasm for atmospheric observations, experiential programs can serve to potentially increase diversity and retention of underrepresented students in atmospheric science through increasing professional networking opportunities and building science identity and confidence.

## Acknowledgements

Funding for graduate student participation as part of the ASI-FSCA program during RELAMPAGO was provided by the National Science Foundation International Research Experiences for Students (IRES) Program under grant OISE-1828935. Major funding for RELAMPAGO was provided by the National Science Foundation. Kristen Rasmussen acknowledges support from NSF AGS-1661657 for research and scientific outreach associated with the RELAMPAGO field campaign and NSF HRD-1835055 for supporting the harassment training program for RELAMPAGO. The authors thank the many RELAMPAGO scientists who mentored and trained the graduate students to collect observations and interpret the data.

#### 488 References

- 489 Allen, M. R., W., J. Ingram, 2002: Constraints on future changes in climate and the hydrologic cycle.
- 490 *Nature*, **419**, 224-232.
- Borys, R. D., and M. A. Wetzel, 1997: Storm Peak Laboratory: A research, teaching and service
- facility for the atmospheric sciences. *Bull. Amer. Meteor. Soc.*, **78**, 2115-2123.
- 493 Cooper, J., K. Jabanoski, and M. Kaplan, 2019: Exploring experiential opportunity impacts on
- 494 undergraduate outcomes in the geosciences. *Journal of Geoscience Education*, **67:3**, 249-
- 495 265, DOI: 10.1080/10899995.2019.1581394
- 496 Dahlberg, K., Dahlberg, H., Nyström, M. (2008). Reflective Lifeworld Research. Lund:
- 497 Studentlitteratur.
- 498 Fischer, E. V., B. Bloodhart, K. L. Rasmussen, I. B. Pollack, M. G. Hastings, E. Marin-Spiotta,
- A. R. Desai, J. P. Schwarz, S. Nesbitt, and D. Hence, 2021: Leveraging Field-Campaign
- Networks to Effect Collaborative Change on Sexual Harassment. *Bulletin of the*
- *American Meteorological Society*, in review.
- Fabry, F., B. J. Turner, and S. A. Cohn, 1995: The University of Wyoming King Air educational
- initiative at McGill University. *Bull. Amer. Meteor. Soc.*, **76**, 1806-1811.
- Hallett, J., J. G. Hudson, and A. Schanot, 1990: Student training in facilities in atmospheric
- sciences: A teaching experiment. Bull. Amer. Meteor. Soc., 71, 1637-1644.
- Hallett, J., M. Wetzel, and S. Rutledge, 1993: Field training in radar meteorology. *Bull. Amer.*
- 507 *Meteor. Soc.*, **74**, 17-22.
- Houze, R. A., K. L. Rasmussen, M. D. Zuluaga, and S. R. Brodzik, 2015: The variable nature of
- convection in the tropics and subtropics: A legacy of 16 years of the Tropical Rainfall
- Measuring Mission (TRMM) satellite. Rev. Geophys., 53, doi:10.1002/2015RG000488.
- Institute of International Education (IIE), 2009: Promoting Study Abroad in Science and

512	Technology Fields, https://www.nafsa.org/_/File/_/ie_julaug11_edabroad.pdf.
513	McLeod PL, Lobel SA, Cox TH, 1996: Ethnic Diversity and Creativity in Small Groups. Small
514	Group Research, 27(2), 248-264. doi:10.1177/1046496496272003.
515	Nesbitt, S., and coauthors, 2021: A storm safari in Argentina: proyecto RELAMPAGO. Bull.
516	Amer. Meteor. Soc., in review.
517	Rasmussen, K. L., and R. A. Houze, Jr., 2011: Orogenic convection in South America as seen by the
518	TRMM satellite. Mon. Wea. Rev., 139, 2399-2420.
519	Rasmussen, K. L., and R. A. Houze, Jr., 2016: Convective initiation near the Andes in subtropical
520	South America. Mon. Wea. Rev., 144, 2351-2374.
521	Rasmussen, K. L., M. D. Zuluaga, and R. A. Houze, Jr., 2014: Severe convection and lightning in
522	subtropical South America. Geophys. Res. Lett., 41, 7359-7366, doi:10.1002/2014GL061767
523	Rauber, Robert M., B. Stevens, J. Davidson, S. Goke, O. L. Mayol-Bracero, D. Rogers, P.
524	Zuidema, H. T. Ochs, C. Knight, J. Jensen, S. Bereznicki, S. Bordoni, H. Caro-Gautier,
525	M. Colon-Robles, M. Deliz, S. Donaher, V. Ghate, E. Grzeszczak, C. Henry, A. M.
526	Hertel, I. Jo, M. Kruk, J. Lowenstein, J. Malley, B. Medeiros, Y. Mendez-Lopez, S.
527	Mishra, F. Morales-Garcia, L. A. Nuijens, D. O.Donnell, D. L. Ortiz-Montalvo, K.
528	Rasmussen, E. Riepe, S. Scalia, E. Serpetzouglou, H. Shen, M. Siedsma, J. Small, E.
529	Snodgrass, P. Trivej, and J. Zawislak, 2007: In the Driver's Seat: Rico and Education.
530	Bull. Amer. Meteor. Soc., 88, 1929-1937.
531	Stith, J. L., and D. C. Rogers, 2004: Instrument development and education in airborne science.
532	Preprints, 13th Symp. on Education, Seattle, WA, Amer. Meteor. Soc., CD-ROM, 4.12.
533	Trott, C. D., L. B. Sample McMeeking, C. L. Bowker, and K. J. Boyd, 2020: Exploring the long
534	term academic and career impacts of undergraduate research in geoscience: A case study
525	Journal of Conscious Education 69:1 65 70 DOI:10.1090/10900005.2010.1501146

536	varble, A. v., and coauthors, 2021: Utilizing a storm-generating notspot to study convective
537	cloud transitions: The CACTI experiment. Bull. Amer. Meteor. Soc., in review.
538	Wetzel, M. A., R. D. Borys, and D. R. Lowenthal, 2003: Graduate field training in atmospheric
539	measurements. Preprints, 12th Symp. on Education, Long Beach, CA, Amer. Meteor.
540	Soc., CD-ROM, 5.10.
541	Zipser, E. J., C. Liu, D. J. Cecil, S. W. Nesbitt, and D. P. Yorty, 2006: Where are the most intense
542	thunderstorms on Earth? Bulletin of the American Meteorological Society, 87, 1057-1071.
543 544	
545	
546	
547	
548	
549	
550	
551	
552	
553	
554	
555	
556	
557	
558	
559	
560 561	
562	
563	
564	
565	
566	
567	
568	
569	
570	

#### Sidebar feature

A separate inquiry requesting overall feedback on the ASI-FSCA program from student participants for the purpose of this article was requested in Fall 2020. The information collected generally supported the findings from the formal evaluation program summarized in the Student Experiences section. A selection of the student feedback is presented below.

One ASI-FSCA participant said that, "as a graduate student who primarily came from a numerical weather prediction background before RELAMPAGO, the opportunity to be a part of the planning and execution of field-work to gather observations was new and exciting. The importance and challenges of collecting real-world observations in an ever-changing environment, such as in Argentina, was discovered first-hand. In addition to the time in Argentina, the 2019 ASI-FSCA Fall Workshop was a place to ask questions regarding future career possibilities, explore new ways of thinking through collaborative projects, and stay connected with those who shared a similar field experience — all things that aren't necessarily invited or appropriate in a classroom setting."

Another participant remarked that, "the entire experience was surreal. Partaking in an international field campaign has given me experience that I would have otherwise never gained in a classroom. The field experience combined with the supplemental lectures, both during the field campaign and during the ASI-FSCA Fall Workshop, have truly formulated an advanced study opportunity. Knowledge and confidence gained through the ASI-FSCA program was key to my success in [other research projects]."

From an inclusion perspective, student feedback has shown that project goals were achieved as well. In the words of one ASI-FSCA participant, "this experience serves as the most

rewarding way that I've been able to incorporate my Latin roots into my academic career thus far, which has further validated and encouraged my position as a scientist in Meteorology."

Another ASI-FSCA participant said that, "the program's effort to set clear guidelines for respectful interactions with one another went a long way to help me feel supported as a woman graduate student participating in a campaign far from home with new collaborators. This training impacted me beyond the scope of the campaign by setting a professional standard for conduct that I will carry with me through my career. It already improved my self-confidence by illustrating that there are communities in the atmospheric sciences committed to creating an inclusive environment, and I aim to apply this experience and background toward improving support for others from underrepresented demographics in my own workplace...the representation and strong leadership of women coordinating the ASI-FSCA has motivated me to aspire to new heights in a career in research. I am the first in my family to attend graduate school, and the professional skills training offered through the ASI-FSCA is the only formal guidance I have received toward pursuing a longer-term career in research. I found the ASI-FSCA training on effective and accountable writing to be a crucial contributor to my professional development as a graduate student. I've found that a lack of confidence, rather than a lack of knowledge or results, most often restricts my path to prolific writing. However, the ASI-FSCA professional skills sessions gave me new tools to overcome this barrier. I have since published my first lead-author paper and drafted a second by using the "storyboard" technique I learned through the ASI-FSCA."

613

593

594

595

596

597

598

599

600

601

602

603

604

605

606

607

608

609

610

611

612

614

615

616

617

# 619 Tables

**Table 1.** List of ASI-FSCA scientific mentors, lecturers, and leadership team members.

Name	Role in ASI	University/Research Lab	Research specialties		
Rachel Albrecht	International collaborator	Univ. Sao Paulo, Brazil	Atmospheric electrification		
Eldo Avila	International collaborator	National Univ. of Cordoba, Argentina	Mesoscale meteorology, electrification		
Michael Bell	Fall Workshop Lecturer	Colorado State University	Radar and tropical meteorology		
Howie Bluestein	Lecturer	University of Oklahoma	Severe storms, radar observations		
Melissa Burt	ASI-FSCA Assistant Director, Lecturer, Fall Workshop organizer and lecturer, Mentor	Colorado State Univ.	Climate modeling, diversity in STEM		
Larry Carey	Lecturer, Lightning team leader, Mentor	Univ. Alabama	Atmospheric electrification		
Chris Davis	Lecturer, Mentor	NCAR/Mesoscale and Microscale Meteorology Laboratory	Mesoscale meteorology, tropical cyclones		
Wiebke Deierling	Lightning team leader, Mentor	NCAR/CU Boulder	Atmospheric electrification		
Francina Dominguez	Lecturer, Hydrometeorology team leader, Mentor	Univ. Illinois	Hydrometeorology		
Brody Fuchs	Mentor	Colorado State University	Radar meteorology		
Rebecca Haacker	Recruiting Coordinator, Lecturer, Mentor	NCAR/ASP/SOARS	Professional development and outreach		
Deanna Hence	Professional Development Coordinator, Lecturer, Mentor	Univ. Illinois	Tropical convection; Mesoscale analysis		
Karen Kosiba	Mentor, Mesonet and DOW team leader	Center for Severe Weather Research	Severe weather; radar observations		
Matthew Kumjian	Lecturer	Penn. State. Univ.	Radar observations, severe weather		
Lorena Medina Luna	Mentor, Outreach organization, Fall Workshop Lecturer	NCAR Education & Outreach	Professional development and outreach		
Luiz Machado	Lecturer, International collaborator	National Institute for Space Research (INPE), Brazil  Convective processes, modeling			
Stephen Nesbitt	Lecturer, Radar and sounding team leader, Mentor	Univ. Illinois	Satellite and radar obs.; severe storms		

Kristen Rasmussen	ASI-FSCA Director, Lecturer, Radar team leader, Fall	Colorado State Univ.	Cloud and mesoscale processes; severe storms;
	Workshop organizer and lecturer, Mentor		radar meteorology
Angela Rowe	Field Experience Coordinator, Lecturer, Radar team leader, Mentor	Univ. of Wisconsin- Madison	Radar observations, cloud and mesoscale processes
Paola Salio	International collaborator, pre- ASI-FSCA lecturer	Univ. of Buenos Aires, Argentina	Mesoscale systems; severe storms
Russ Schumacher	Mentor, Sounding team leader	Colorado State Univ.	Mesoscale meteorology; heavy precipitation
Jeff Trapp	Lecturer, Sounding team leader, Mentor	Univ. Illinois	Severe weather; mesoscale meteorology
Adam Varble	Mentor, CACTI team leader	Univ. Utah	Convection and modeling
Josh Wurman	Mentor, DOW/COW team leader	Center for Severe Weather Research	Severe weather; radar observations

# Table 2. ASI-FSCA Seminars and Professional Development Activities during RELAMPAGO

Speaker(s)	Lecture topic(s)
Kristen Rasmussen	Global Perspectives on Convection; RELAMPAGO Science Overview
Melissa Burt and Rebecca Haacker	Professional Development Series: Stress management and culture shock, Building a supportive network and finding mentors, How to bring this experience to your curriculum vitae
Jeff Trapp	Convective Storms
Francina Dominguez	Hydrometeorology of the La Plata Basin
Larry Carey and Brody Fuchs	Lightning Science; Lightning Instrumentation
Matthew Kumjian	Hail Science
Chris Davis	Mesoscale Convective Systems; Mesoscale Meteorology
Deanna Hence	Communicating Your Science

Howie Bluestein	Convective storms and tornadoes; Low-Level Jets
Stephen Nesbitt	RELAMPAGO Radar Applications

## Table 3. ASI-FSCA 2019 Fall Workshop presentations and panels

Speaker(s)	Lecture topic(s)
Kristen Rasmussen	RELAMPAGO Science and Data update; RELAMPAGO Research; How to think like a scientist; Developing Scientific Ideas; Time Management Skills; How to connect field research to non-field research; Finding and applying for academic/research jobs
Melissa Burt	Work-life balance; Mentor mapping and beyond; Networking
Lorena Medina Luna and Valerie Sloan	Scientific Writing and Communication
Christina McClusky, Annareli Morales, and Christopher Kruse	Advanced Study Postdoctoral Fellow Panel discussion
Michael Bell	Keynote lecture: Planning and Executing a Field Campaign in Atmospheric Science
Luke Madaus, Evan Kalina, Elliott Foust, Julie DeMuth, Kristen Rasmussen, and Roy Rasmussen	Careers in Atmospheric Science Panel discussion

**Table 4.** Students' general satisfaction with the ASI-FSCA program (post-survey only; n=8).

Please indicate your agreement v	vith the fol	lowing state	ements:		
	Strongly disagree (n)	Disagree (n)	Neither (n)	Agree (n)	Strongly agree (n)
The Advanced Study Institute (ASI) lived up to my expectations	0	0	0	1	7
The content of the ASI was relevant to me	0	0	0	1	7
The ASI activities stimulated my learning	0	0	0	1	7
The ASI activities gave me sufficient practice and feedback	0	0	0	2	6
I will be able to use what I learned in this ASI	0	0	0	1	7
The ASI was a good way for me to learn this content	0	0	0	1	7

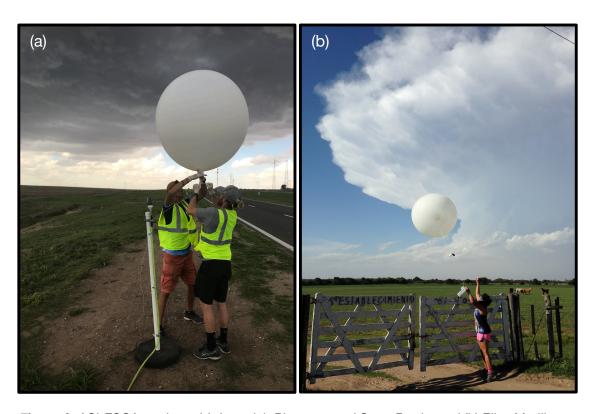
633	Figure List
634	
635	Figure 1. ASI-FSCA students and leadership pictured (a) in front of the Doppler on Wheels rada
636	(31 October 2018, Cordoba, Argentina) and (b) visiting the DOE G-1 aircraft as part of the
637	CACTI field campaign (15 November 2018, Rio Cuarto, Argentina). Photo credits: Kristen
638	Rasmussen.
639	
640	Figure 2. ASI-FSCA students (a) Jeremiah Piersante and Scott Purdy, and (b) Elisa Murillo
641	launch atmospheric soundings (weather balloons) as part of the RELAMPAGO field campaign.
642	Photo credits: (a) Scott Purdy and (b) Brandi Gamelin.
643	
644	Figure 3. ASI-FSCA students and leadership in the field: (a) Matthew Holliday with the
645	hydrometeorology team; (b) Laura Tomkins, Melissa Burt, Chelsey Laurencin, and Brandi
646	Gamelin with the Doppler on Wheels radar; (c) Karly Riemel, Chelsey Laurencin, Laura
647	Tomkins, and Kristen Rasmussen in the RELAMPAGO Operations Center; and (d) Miguel
648	Cortez, Karly Riemel, and Larry Carey assembling the Lightning Mapping Array station. Photo
649	credits: (a) Kristen Rasmussen, (b) Brandi Gamelin, (c, d) Lorena Medina Luna.
650	
651	Figure 4. Deanna Hence leading a professional development lecture as part of the ASI-FSCA
652	program. Photo credit: Kristen Rasmussen.
653	
654	Figure 5. (a) ASI-FSCA students participating in outreach as part of the RELAMPAGO Open
655	House on 31 October 2018. (b) Students from an elementary school in Rio Ceballos, Argentina,

- participate in inflating and launching a weather balloon during a RELAMPAGO science
- education and outreach event. Photo credits: (a) Kristen Rasmussen, (b) Lorena Medina Luna.





**Figure 1.** ASI-FSCA students and leadership pictured (a) in front of the Doppler on Wheels radar (31 October 2018, Cordoba, Argentina) and (b) visiting the DOE G-1 aircraft as part of the CACTI field campaign (15 November 2018, Rio Cuarto, Argentina). Photo credits: Kristen Rasmussen.



**Figure 2.** ASI-FSCA students (a) Jeremiah Piersante and Scott Purdy, and (b) Elisa Murillo launch atmospheric soundings (weather balloons) as part of the RELAMPAGO field campaign. Photo credits: (a) Scott Purdy and (b) Brandi Gamelin.



**Figure 3**. ASI-FSCA students and leadership in the field: (a) Matthew Holliday with the hydrometeorology team; (b) Laura Tomkins, Melissa Burt, Chelsey Laurencin, and Brandi Gamelin with the Doppler on Wheels radar; (c) Karly Riemel, Chelsey Laurencin, Laura Tomkins, and Kristen Rasmussen in the RELAMPAGO Operations Center; and (d) Miguel Cortez, Karly Riemel, and Larry Carey assembling the Lightning Mapping Array station. Photo credits: (a) Kristen Rasmussen, (b) Brandi Gamelin, (c, d) Lorena Medina Luna.



**Figure 4.**Deanna Hence leading a professional development lecture as part of the ASI-FSCA program. Photo credit: Kristen Rasmussen.





Figure 5. (a) ASI-FSCA students participating in outreach as part of the RELAMPAGO Open House on 31 October 2018. (b) Students from an elementary school in Rio Ceballos, Argentina, participate in inflating and launching a weather balloon during a RELAMPAGO science education and outreach event. Photo credits: (a) Kristen Rasmussen, (b) Lorena Medina Luna.