Grantee: University of Miami
DOE Grant #: DE-SC0018272
PI: Paquita Zuidema
Title: Marine Shallow cloud Adjustments to the Presence of Shortwave-Absorbing Aerosols: Advancing Understanding Through a Combined Analysis of Lasic Datasets and Process Modeling
Period of Performance: 09/15/2017-09/14/2021

ACCOMPLISHMENTS

1. What are the major goals of the project?

LASIC (Layered Atlantic Smoke Interactions with Clouds) is a strategy to improve our understanding of aged carbonaceous aerosol, its seasonal evolution, and the mechanisms by which clouds adjust to the presence of the aerosol. The observational strategy centers on deploying the AMF1 cloud, aerosol, and atmospheric profiling instrumentation to Ascension Island, located within the trade-wind shallow cumulus regime (14.50W, 80S) 3000 km offshore of continental Africa. The location is within the latitude zone of the maximum outflow of aerosol, with the deepening boundary layer known to entrain free-tropospheric smoke. The primary activities for LASIC are: 1) to improve current knowledge on aged biomass burning aerosol and its radiative properties as a function of the seasonal cycle; 2) to use surface-based remote sensing to sensitively interrogate the atmosphere for the relative vertical location of aerosol and clouds; 3) to improve our understanding of the cloud adjustments to the presence of shortwave-absorbing aerosol within the vertical column, both through aerosol-radiation and through aerosol-cloud interactions; 4) to aid low cloud parameterization efforts for climate models.
This award supported LASIC-relevant activities.

2. What was accomplished under these goals?

The campaign was successful and continuing work by the instrument mentors is adding ongoing value. A high-quality dataset detailing the properties of aged biomass burning aerosol was collected and continues to be analyzed both within and outside of the ARM community towards increasing their value. The data represent the first characterization of at times heavy smoke loading within the remote Atlantic boundary layer, helping to anchor understanding of the aerosol transport and its interactions with clouds for time eternity. The measurements span June 1, 2016 - October 31, 2017, encompassing two July-October biomass burning seasons. The August-September, 2016, months include an Intensive Observing Period (IOP) with 8x/daily radiosondes. In 2017 a CAPS-SSA instrument belonging to Aerodyne was brought to Ascension, gathering data primarily for August, towards providing a second, independent measurement of aerosol absorption. This coincided with a UK aircraft campaign and the NASA US ORACLES aircraft campaign visited during the same time; a manuscript detailing the instrument inter-comparison between the 3 campaigns is almost ready to be submitted. This manuscript will be important for underpinning studies that are attempting a pseudo-Lagrangian analysis of aerosol and aerosol-cloud behavior between the campaigns. Work at UM supported by this award includes detailing the aerosol-cloud vertical structure using the micropulse lidar at Ascension,assessing the connection between aerosol composition and its optical properties, and using the compositing of time periods into smoky/non-smoky events to better discriminate aerosol impacts on clouds from meteorology.

3. What opportunities for training and professional development has the project provided?

Most directly, a postdoctoral research associate worked on LASIC for two years, a PhD graduate student at U of Miami was fully supported by this award, another PhD graduate student at U of Miami was partially supported, and a PhD graduate student at UCLA has devoted most of their PhD thesis to the analysis of LASIC datasets towards LASIC goals.

4. How have the results been disseminated to communities of interest?

Numerous publications have been supported by this award, detailed further below. Zuidema made LASIC presentations at the AGU annual meeting in 2017 and 2018, the AMS annual meeting in 2018 and 2019, the EGU annual meeting in 2018 and 2019, at the Telluride Science Research Center Workshop in 2018, at several invited seminars, and at a session convened at the annual AMS meeting in 2019. This AMS session explicitly mentioned LASIC in the session title, along with other field campaigns held in the southeast Atlantic (NASA-ORACLES, UK-CLARIFY, French- AEROCLO-Sa) and as such was the first public conference attempting to pull together scientists from the different campaigns but working towards similar goals. Zuidema also helped organize an international workshop in Paris, 2019, the week prior to EGU, that was joint with LASIC international collaborators. The energy that this meeting created led to the decision to hold another

such workshop in May of 2020, this time in Miami. It was moved to a virtual platform in recognition of COVID. Zuidema also convened LASIC break-out sessions at the annual DOE ASR-ARM PI meetings from 2017-2020. Zuidema is also an Editor on a linked Special Issue within the Copernicus Atmos. Chem. Phys. And Atmos. Meas. Tech journals, entitled "*New observations and related modelling studies of the aerosol–cloud–climate system in the Southeast Atlantic and southern Africa regions''*.

On the UCLA side, this award supported the observational analysis as a way to separate aerosol-climate feedbacks and meteorological co-variability and to assess model representation of these observed feedbacks. Additional work is assessing the processes through which smoke mixes into the boundary layer. This work has primarily been done by PhD student Calvin Howes and is still ongoing; he presented most recently at the AGU 2021 annual meeting.

PRODUCTS - DETAILS

PUBLICATIONS DETAIL

1. Journal Article: The Ascension Island Boundary Layer in the Remote Southeast Atlantic is Often Smoky
Journal: Geophysical Research Letters
Publication Date: 05/16/2018 **Publication Status:** Published
Volume: 45 **First Page Number or eLocation ID:** 4456
Issue: 9 **Publication Location:** USA
Author(s): Zuidema, P; Sedlacek, AJ; Flynn, C; Springston, S; Delgadillo, R; Zhang, JH; Aiken, AC; Koontz, A; Muradyan, P
Publication Identifier Type: DOI **Publication Identifier:** 10.1002/2017GL076926
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

2. **Journal Article:** Simulation of the transport, vertical distribution, optical properties and radiative impact of smoke aerosols with the ALADIN regional climate model during the ORACLES-2016 and LASIC experiments,
Journal: Atmos. Chem. Phys.
Authors: Mallet, M., Nabat, P., Zuidema, P., Redemann, J., Sayer, A. M., Stengel, M., Schmidt, S., Cochrane, S., Burton, S., Ferrare, R., Meyer, K., **Saide, P**., Jethva, H., Torres, O., Wood, R., Saint Martin, D., Roehrig, R., Hsu, C., and Formenti, P.
Publication Identifier Type: DOI **Publication Identifier:** 10.5194/acp-19-4963-2019 **Publication Date:** 2019
Publication Status: Published **Volume:** 19 **First Page Number or eLocation ID:** 4963 **Issue:** 7
Publication Location: Europe **Acknowledgement of DOE Support:** Yes **Peer Reviewed:** Yes

3**. Journal Article:** Characteristics of optically-thin coastal Florida cumuli from surface-based lidar measurements
Journal: J. Geophys. Res.
Authors: Delgadillo, R., K. Voss and P. Zuidema
Publication Identifier Type: doi:10.1029/2018JD028867
Publication Status: Published **Volume:** 123 **First Page Number:** 10,591 **Date:** 2018
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

4**. Journal Article:** Low cloud sensitivity to biomass-burning aerosols and meteorology over the southeast Atlantic.
Journal: J. Climate
Authors: Adebiyi, A. and P. Zuidema
Publication Identifier Type: doi:10.1175/JCLI-D-17-0406.1
Publication Status: published **Volume:** 31 **First Page Number:**4329 **Date:** 2018
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

5**. Journal Article:** The diurnal cycle of the smoky marine boundary layer observed during August in the remote southeast Atlantic.
Journal: Atmos. Chem. Phys.
Authors: J. Zhang and P. Zuidema
Publication Identifier Type: doi:acp-19-14493-2019

Publication Status: published **Volume:** 19 **First Page Number:** 14493 **Date:** 2019
ACP Highlight Article
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

6. Journal Article: Open cells can decrease the mixing of free-tropospheric biomass burning aerosol into the south-east Atlantic boundary layer.
Journal: Atmos. Chem. Phys.
Authors: S. Abel, P. Barrett, P. Zuidema, J. Zhang, M. Christensen, F. Peers, J. Taylor, I. Crawford, K. Bower, and M. Flynn
Publication Identifier Type: doi:10.5194/acp-20-4059-2020
Publication Status: published **Volume:** 20 **First Page Number:** 4059 **Date:** 2020
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

7. Journal Article: Modeling the smoky troposphere of the southeast Atlantic: a comparison to ORACLES airborne observations from September of 2016.
Journal: Atmos. Chem. Phys.
Authors: Shinozuka, Y., P. E. Saide, G. A. Ferrada, etl al., P. Zuidema is senior (last) author
Publication Identifier Type: doi:10.5194/acp-20-11491-2020
Publication Status: published **Volume:** 20 **First Page Number:** 11491 **Date:** 2020
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

8. Journal Article: Direct and semi-direct radiative forcing of biomass burning aerosols over the Southeast Atlantic (SEA)and its sensitivity to absorbing properties: a regional climate modeling study.
Journal: Atmos. Chem. Phys.
Authors: Mallet, M., F. Solmon, P. Nabat, et al. including P. Zuidema
Publication Identifier Type: doi:10.5194/acp-20-13191-2020
Publication Status: published **Volume:** 20 **First Page Number:** 13191 **Date:** 2020
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

9. Journal Article: Overview: The CLoud-Aerosol-Radiation Interaction and Forcing: Year-2017 (CLARIFY-2017) measurement campaign
Journal: Atmos. Chem. Phys.
Authors: J. M. Haywood, S. Abel, P. Barrett, et al. including P. Zuidema
Publication Identifier Type: doi:10.5194/acp-21-1049-2021
Publication Status: published **Volume:** 21 **First Page Number:** 1049 **Date:** 2021
includes description of the flights performed from Ascension Island, towards coordinating with LASIC
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

10. Journal Article: An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol-cloud-radiation interactions
in the Southeast Atlantic basin.
Journal: Atmos. Chem. Phys
Authors: Redemann, J., R. Wood, P. Zuidema, et al.,
Publication Identifier Type: doi:10.5194/acp-21-1507-2021
Publication Status: published **Volume:** 21 **First Page Number**: 1507 **Date:** 2021
includes description of the flights performed from Ascension Island, towards coordinating with LASIC
Acknowledgement of DOE Support: Yes **Peer Reviewed:** Yes

2. Other Publications:
1. Layered Atlantic Smoke Interactions with Clouds: LASIC Final Field Campaign Report
Description: Final Campaign Report
Publication Date: 04/2018 **Publication Status:** Submitted
Author(s): Paquita Zuidema, Matthew Alvarado, Christine Chiu, Simon DeSzoeke, Chris Fairall, Graham Feingold, Andrew

Freedman, Steve Ghan, James Haywood, Pavlos Kollias, Ernie Lewis, Greg McFarquhar, Oklahoma University Allison McComiskey, David Mechem, Tim Onasch, Jens Redemann, David Romps, David Turner, Hailong Wang, Robert Wood, Sandra Yuter, University Ping Zhu
Acknowledgement of DOE Support: Yes
2. U.S. DOE. 2019. Atmospheric Radiation Measurement (ARM) User Facility ARM Mobile Facility Workshop Report,
Description: Workshop report
DOE/SC-0197 Office of Biological and Environmental Research, U.S. Department of Energy Office of Science, Germantown, Maryland, USA. (not peer reviewed; on writing team of)

INTELLECTUAL PROPERTIES DETAIL
There are no intellectual properties to report.
TECHNOLOGIES AND TECHNIQUES DETAIL
There are no technologies or techniques to report.
OTHER PRODUCTS DETAIL
There are no other products to report.

PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS
PARTICIPANTS DETAIL
1. Participant: Rodrigo Delgadillo
Project Role: Postdoctoral Research Associated
Person Months Worked: 24 total **Funding Support (if other than this award)**: Not Provided
Contribution to the Project: Rodrigo is an expert in the analysis of micropulse lidar datasets. He is assessing the aerosol vertical structure - aerosol layer boundaries, aerosol layer boundaries relative to the cloud layers, and aerosol extinction profiles, from the LASIC micropulse lidar data. This includes assessing ancillary datasets such as the radiosondes, sun photometer aerosol optical depths, and ceilometer. We are currently developing a manuscript on these with an anticipated submission date of this summer, and he will be presenting on these at the AMS atmospheric radiation meeting. We worked together with the ARM instrument mentors (primarily Paytsar Muradyan) to develop bestestimates of the aerosol extinctions, and collaborating with the UK CLARIFY campaign to assess their quality (using the CLARIFY in-situ aircraft extinction values).
International Collaboration: No
International Travel: No
2. Participant: Jianhao Zhang
Project Role: Graduate Student (Research Assistant)
Person Months Worked: 12 **Funding Support (if other than this award)**: this award and NSF
Contribution to the Project: Jianhao and I worked together to assess the cloudy boundary layer adjustment to the presence of the shortwave-absorbing biomass-burning aerosols in the atmosphere above Ascension Island. This is an integral portion of his PhD thesis, and of the overall project. Two publications have resulted from this.
International Collaboration: No
International Travel: No
3. Participant: Dr. Paquita Zuidema
Project Role: Principal Investigator/Project Director
Person Months Worked: 1 **Funding Support (if other than this award)**: Not Provided
Contribution to the Project: focus and oversee the internal U of Miami contribution towards addressing research goals, lead publications both internally-driven and collaborative, make public presentations towards increasing the visibility of LASIC research and datasets, facilitate collaborations between LASIC researchers (e.g., through organizing and leading a LASIC breakout session at the annual ASR meeting, and, organizing a collaborative session between all the southeast Atlantic fieldwork campaigns at the upcoming annual AMS meeting). Supervise Rodrigo Delgadillo and Jianhao Zhang, a postdoc and graduate student respectively at U Miami. They are both primarily focused on analysis of LASIC datasets.
4. Participant:Dr. Pablo Saide
Project Role: Co-PI
Person Months Worked: 1

Funding Support (if other than this award): UCLA as well as this grant
Contribution to the Project: Overseeing project in the UCLA side, advising students, presenting results in seminar and conferences
5. Participant: Calvin Howes
Project Role: Graduate Student (Research Assistant)
Person Months Worked: 12
Funding Support (if other than this award): UCLA (fellowship, TA ship) in addition to this grant
Contribution to the Project: Calvin is working on the regional modeling of the project in the projects mentioned earlier. This is part of his PhD Research

International Collaborations: Yes
 # Country of Collaborator
1 United Kingdom (GBR) (CLARIFY science team, notably Jim Haywood and Hugh Coe), and France (Marc Mallet, modeler)
International Travel: Yes # Country of Travel Duration of Stay (in days) 1 Austria (AUT) 3. In 2019.

PARTNERS DETAIL

There are no partners to report.

OTHER COLLABORATORS DETAIL

There are no other collaborators to report.

IMPACT

1. What is the impact on the development of the principal discipline(s) of the project?
Smoke covers the entire southeast Atlantic basin for much of one-third of the year, and its properties to date have only been characterized near the Namibian coast in 2000-2001 through the SAFARI experiment. Everything we learn from the LASIC dataset will be new. One important intrinsic aerosol property we are after is the single-scattering albedo (SSA), as this has a first-order effect on how much sunlight is absorbed by the coupled earth system as opposed to reflected back to space. An early achievement already is a documentation of SSA values that vary from monthly-means of 0.78 +/-0.02 (August), 0.81 +/- 0.03 (September) and 0.83 +/- 0.03 (October) at the green wavelength based on filter measurements (PSAP + nephelometer). These values are lower than was measured during SAFARI, by about 0.05, but the deployment of the CAPS-SSA monitor in August-September 2017 confirmed the light absorption measurements were accurate, using a completely different methodology. Thus we have some confidence in the filter measurements, and it means we can likely trust them over most of the campaign (one exception being when large dust particles are present).
Further work has evaluated the consequence of the absorbing aerosol for the boundary layer clouds. There is evidence of a strong boundary layer semi-direct effect, with cloud cover reducing substantially during the afternoon, and, interestingly, the cloud liquid water paths reducing during the night. The latter is attributed to a suppression of turbulence, with more moisture stratification evident between the sub-cloud and cloud layer during the night. The sub-cloud layer accumulates moisture during the night, but loses its thermal stratification. When the sun comes out in the morning, the radiative warming drives vertical ascent within the well-mixed layer, and a clear deepening of the boundary layer is evident, both in the soundings and in the radar data – this is the time of day when the cumulus clouds are most pronounced. This contrasts from a more typical stratocumulus diurnal cycle, in which the clouds are deepest and most precipitating prior to sunrise, as opposed to after sunrise.
2. What is the impact on other disciplines?
LASIC cross-cuts across the aerosol and cloud research communities, and ultimately its results will have bearing on the climate modeling community. A first model-observational intercomparison is documented in Mallet et al., 2018, and uses LASIC measurements to assess the French ALADIN-Climat model. A more ambitious project under discussion is to compare observations from the LASIC and ORACLES campaigns to various climate models, towards extending the value of LASIC measurements for larger-scale models. This will be developed more at the June, 2019 meeting.
3. What is the impact on the development of human resources?
A postdoctoral research associated and graduate student are explicitly being trained by Zuidema and Saide, while the LASIC project also has a larger impact in developing the talents of all actively involved.
4. What is the impact on physical, institutional, and information resources that form infrastructure?
These are occurring primarily within the internal DOE ASR and ARM communities.

5. What is the impact on technology transfer?
N/A
6. What is the impact on society beyond science and technology?
see LASIC goals. The ultimate goal is to support better predictions of future climate. An anticipated regional impact is better precipitation predictions for Africa, a region considered to become hotter and drier under future climate scenarios. The knowledge gained about intrinsic BBA properties will extend beyond the southeast Atlantic, however, as will the knowledge about how the low cloud behavior is affected.
7. Foreign Spending
Not Provided

CHANGES - PROBLEMS

1. Changes in approach and reasons for change
none
2. Actual or anticipated problems or delays and actions or plans to resolve them
none
3. Changes that have a significant impact on expenditures
none
4. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards
none
5. Change of primary performance site location from that originally proposed
none