OMB Number: 0690-0032
Expiration Date: 08/31/2021

DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

For instructions, please visit
http://www.osec.doc.gov/oam/grants_management/policy/documents/RPPR%20Instructions%20and%20Privacy%20Statement.pdf

AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA19NWS4680004
3. Project Title: Improving Situational Awareness of Impactful Post-Fire Debris Flows	
4. Award Period of Performance Start Date: 06/01/2019	5. Award Period of Performance End Date: 05/31/2022
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
6. Last Name and Suffix: Hatchett , null	7. First and Middle Name: Benjamin ,
8. Title:	
9. Email: Benjamin.Hatchett@dri.edu	10. Phone Number: 775-674-7111
AUTHORIZING OFFICIAL	
11. Last Name and Suffix: Stuart , null	12. First and Middle Name: Margie ,
13. Title: Business Manager	
14. Email: margie.stuart@dri.edu	15. Phone Number: 775-674-7028
REPORTING INFORMATION	
Signature of Submitting Official: Rachael Solano	
16. Submission Date and Time Stamp: 08/16/2022	17. Reporting Period End Date: 05/31/2022
18. Reporting Frequency: ○ Annual ◉ Semi-Annual ○ Quarterly	19. Report Type: ○ Not Final ◉ Final
RECIPIENT ORGANIZATION	
20. Recipient Name: NEVADA SYSTEM OF HIGHER EDUCATION	
21. Recipient Address: 2215 RAGGIO PKWY, RENO, NV 89512-1095 USA	
22. Recipient UEI: MV1JFXA4S621	23. Recipient EIN: 886000024

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

The major goals for this project are: (1) Increase forecaster confidence as to whether a predicted storm and associated precipitation will produce post-fire debris flows (PFDF) and the spatial extent over which impacts may occur. (2) Inform further development of the NWS Western Region Headquarters debris flow tool and/or other debris flow tools (3) Improve forecaster ability to interpret and communicate information on short-duration, high-intensity precipitation forecasts and on PFDF hazards in general, to partners and public.
The above is to be accomplished through four objectives: (1) Evaluate HRRR performance on short-duration, high-intensity rainfall in the southwestern US, (2) Identify storm characteristics associated with widespread and/or high volume debris flow activity, (3) Quantify the sensitivity of PFDF magnitude to changes in rainfall intensity and duration within different geologic and climatologic settings, (4) Development of productive relationships between researchers and NWS personnel and support for PFDF communication efforts.

25. What was accomplished under these goals?

1. We have seven research articles published and two currently in the publication process on these topics that advance understanding of post-fire debris flows related to the project goals, listed in Question 29.

2. Our team gave numerous presentations to various audiences as well as conducted media interviews. These audiences included NWS forecasters, NWS partners, other research scientists, and the public. Presentations listed in Question 27.

3. Built stronger collaborations with NWS offices through discussions about post-fire debris flow events, challenges, and needs. Discussions with NWS and partners suggest our research has helped highlight atmospheric features that may produce debris flows and how flash flood and debris flow responses vary with different storm characteristics. This has provided additional insight on post-fire debris-flow hazards and forecasting at critical lead times for decision support.

4. The team has developed numerous technologies and techniques, novel modeling approaches and data analysis methodologies and created new datasets that can be used in future research. These are described in Question 30.

5. Results of research have provided information that can be incorporated into various operational debris flows tools. Several papers explore the utility, capabilities or insights that can be derived from various post-fire debris flow and flash flood models. We also assess HRRR performance, which can inform tool development. The final research paper produced under this project proposes a method for linking ensemble precipitation forecasts with debris flow likelihood and volume models.

ACCOMPLISHMENTS *(cont'd)*

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

This work has supported early career researchers Nina Oakley, Luke McGuire, Forest Cannon, and Ben Hatchett in conducting interdisciplinary research, managing a project, developing new research techniques for post-wildfire debris flows. Post-docs Tao Liu and Luke Odell have also been involved with the project and gained experience in model development, using new datasets, and conducting and interdisciplinary work. Research interns Marian de Orla-Barile and Lauren Bolotin also contributed to this project, offering them an opportunity to develop their technical skills, research skills, and participate in interdisciplinary research. Both carried on to do graduate work in extreme precipitation and post-fire hydrology, respectively. We also incorporated mesoscale modeler Matthew Simpson during the last two performance periods; he has gained the opportunity to learn more about the relationship between atmospheric conditions and debris flow hazards as well as gain experience working in an interdisciplinary group. The project has provided all involved the opportunity to collaborate with the operational meteorology and debris-flow hazard community.

27. How were the results disseminated to communities of interest?

COVID-19 took hold of the US during years 2 and 3 of the project, which created unprecedented challenges in collaboration and communication. This made it far more difficult to visit with NWS offices and presented a period of challenge when the world went "online." We did our best to overcome this and communicate as we were able.

The research team has contributed to numerous news articles.
¿Strong cold front is soaking California, triggering flood alerts. March 28, 2022.
https://www.washingtonpost.com/weather/2022/03/28/california-rain-cold-front-band/
The devastating mudslides that follow forest fires. Nature, January 2022. https://www.nature.com/articles/d41586- 022-00028-3
https://www.tucsonsentinel.com/local/report/062122_wildfires_arizona/wildfires-continue-rage-across-arizona/
https://www.azcentral.com/story/news/local/arizona-science/2022/06/27/future-arizona-wildfires-impact-land/7666112001/
https://www.kgun9.com/news/wildfires/effects-on-geography-of-catalinas-during-bighorn-fire
USA Today: https://www.usatoday.com/in-depth/news/investigations/2021/11/30/wildfire-rainfall-mudslides-disasters/6201564001/
Climate Nexus press conference on debris flows: https://blog.waterhub.org/wildfires-and-water-in-the-west
https://news.agu.org/press-release/new-study-improves-understanding-of-southern-californias-intense-winter-rains/

For the published paper in Weather and Forecasting, a summary was written [https://cw3e.ucsd.edu/cw3e-publication-notice-observations-and-predictability-of-a-high-impact-narrow-cold-frontal-rainband-over-southern-california-on-2-february-2019/] and shared with NWS and other partners.

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Meeting with NWS Western Region Hydrology Program to discuss results (June 16, 2020), and various discussions and meetings with NWS WFO personnel.

Oakley participated in Burned Area Emergency Response assignments with USFS in 2021 and shared knowledge with USFS, CA Geological Survey through this process.

The team has also given numerous presentations, described in Question 29.

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

This is the final reporting period; however, we will move forward with revisions to the Weather and Forecasting paper currently in review and with submission of a paper to Bulletin of the American Meteorological Society on our large ensemble simulation after the completion of this award.

PRODUCTS

29. Publications, conference papers, and presentations

Presentations:
Oakley: presentation on forecasting high-intensity rainfall and post-fire hazards at the ALERT User Group Bi-Annual Conference, Palm Springs, May 2022. This conference included attendees from NWS San Diego, Oxnard WFOs as well as many hydrologists/floodplain managers that often work with NWS.
McGuire gave a presentation titled "From rainfall to runout: A model for rapid assessments of post-fire debris flow inundation" at the CW3E Annual Meeting in San Diego in June 2022. Attendees included NWS San Diego staff as well as a representative from NOAA WPC.
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Oakley presented on extreme precipitation and debris flow research and monitoring at the ALERT User Group bi-annual conference on Oct 15, 2020
Oakley presented on climate change and precipitation intensification as it relates to debris flow hazards as a panelist in the Floodplain Management Association annual meeting in October [https://floodplain.org/page/AnnualConference]
McGuire presented on debris flow modeling at the USGS Landslide Hazards Program Colloquium on 21 October 2020
McGuire presented on debris flow modeling and post-fire hazards at the Department of Geosciences Colloquium at the University of Arizona on 8 October 2020
Cannon presented on the predictability of short-duration, high-intensity precipitation at the International Atmospheric Rivers conference and the Forecast Informed Reservoir Operations Workshop, 2020
Oakley gave a presentation for the California Geological Survey Brown Bag seminar: High intensity rainfall in California: drivers, impacts, challenges, and the future on 4 Nov 2021
Oakley gave a presentation for Hazards Caucus briefing on post-fire hazards called "America Is Burning: The Growing Onslaught of Wildfires and Post-Fire Landslides in the U.S." Title: Weather climate and post-fire debris flows, 4 June 2021
Liu gave a presentation at the GSA annual meeting: Modeling changes in rainfall intensity-duration thresholds for flash floods in a southern California watershed over five years of post-fire recovery, Geological Society of America Annual Meeting, Portland, Oregon, (2021)
McGuire was a speaker and panelist at "Natural and Prescribed Wildland Fire Impacts on Soil Health: Fall Event of the National Academy of Sciences Board on Earth Sciences and Resources", 2 November 2021.
See attached for additional presentations & publications

PRODUCTS *(cont'd)*

30. Technologies or techniques

Univ. of Arizona has continued development of a modeling methodology to explore links between point-scale soil hydraulic measurements and post-fire runoff at the hillslope and watershed scale.
Univ. of Arizona has continued development of a numerical model that couples rainfall, infiltration, runoff, and sediment transport processes in order to explore relationships between rainfall characteristics and debris-flow processes
Developed and tested a configuration of KINEROS-2 for flash flooding on recent burn areas that can be applied as they recover.
Ran two 100-member large ensemble simulations for two narrow cold frontal rainband events. These data can be used in future research and model development for burn areas, regardless of their presence at the time of the storm event.
Ran a small ensemble for Feb 2, 2019, NCFR that impacted Southern CA to investigate model performance for NCFRs
Experimented with the use of an "ensemble" of radar-derived precipitation using different Z-R relationships for input to flash flood model.
Explored use of neighborhood method for evaluating models based on gauge data when no gridded QPE is available.
Identified different storm types and developed 1 min timeseries to input to debris flow models to assess variability in outcomes related to storm characteristics
Developed catalog of Narrow Cold Frontal Rainbands in Southern California

31. Inventions, patent applications, and/or licenses

None.

Attach a separate document if more space is needed for #6-10, or #24-50.

PRODUCTS *(cont'd)*

32. Other products

None.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

UCSD/SIO: Nina Oakley (research scientist), Luke Odell (postdoc), Matthew Simpson (research scientist), Forest Cannon (research scientist), Marian de Orla-Barile (research intern), Lauren Bolotin (research intern)
University of Arizona: Luke McGuire (assistant professor), Tao Liu (post-doc)
DRI: Benjamin Hatchett (PI, assistant professor)

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Forest Cannon left UCSD/SIO for a new position in the private sector in October 2021.

35. What other organizations have been involved as partners?

US Geological Survey, National Weather Service, California Geological Survey, and Arizona Geological survey, as well as researchers from other institutions have been engaged in the activities or recipients of information from this project.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

Only persons mentioned in question 33 and 35.

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

In atmospheric science, we have made progress in our general understanding of the spatial and temporal characteristics associated with different types of cool season storms producing high intensity-short duration West Coast precipitation events and the challenges and opportunities in forecasting these types of events. This includes how skillfully mesoscale models capture short-duration, high-intensity precipitation. We are gaining knowledge about the physical processes in these storms leading to high-intensity rainfall, and climatology of some of these features in Southern California. We are also learning how to better communicate this information with a non-meteorology audience.
In hydrology, we have made progress in the ability to model post-fire flash floods as well as define flash flood thresholds that can be utilized in an operational setting. In geomorphology, we are moving towards an understanding of the sensitivity of debris flow characteristics to different rainfall characteristics. Results also enhance our ability to predict changes in process dominance, namely when and where transitions from floods to debris flows are likely to occur, which has implications for both hazard predictions and the long-term transport of sediment throughout the landscape. We are also contributing to the growing knowledge base on burn area recovery and changes in flash flood and debris flow thresholds in time across different landscapes and climate regions.
Combining the three disciplines, we have explored the feasibility and benefits of combining ensemble atmospheric modeling with debris flow likelihood and volume models. This allows us to envision future tools that provide probabilistic hazard information on debris flow hazards.

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

This is an interdisciplinary project, working across atmospheric science, hydrology, and geomorphology. It is hard to determine whether we have had impacts outside of these disciplines. We anticipate that our work will benefit emergency management and hazard communications as well.

39. What was the impact on the development of human resources?

This project has provided experience for early career researchers Oakley, Cannon, and McGuire in managing a research project and developing methods to conduct interdisciplinary research. For the post-docs involved, this project provides the opportunity to develop novel research methods and produce publications that will advance their careers, as well as build collaborators and interdisciplinary working skills. The students involved gained exposure to research and data analysis skills and had the opportunity to lead a research publication. Further description is in the response to question 26.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

We have used the numerous presentations and publications produced related to this project as opportunities to educate a broad range of people (e.g., students, scientists, emergency managers, floodplain managers, forecasters) on post-fire hazards and rainfall extremes, as described in question 29. Experiences for students and staff are described in the response to question 26. McGuire taught a graduate level class (Field Studies in Geomorphology) in Spring 2020 at the University of Arizona that involved field trips to a burn scar to educate students on debris flow hazards and observation methods.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

The models developed and calibrated for this project provide infrastructure that can be used in future research projects. The large ensemble simulations run with WRF can also be used for future projects focusing on extreme rainfall and narrow cold frontal rainbands in Southern California. The knowledge and skills gained by researchers on storm characteristics and running and interpreting model results from this project also serve as information resources that build capacity and support future work. A library of research papers, presentations, and news articles was developed in this project that will support future education and research on post-fire hazards.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

None.

43. What was the impact on society beyond science and technology?

As we share our research with operational colleagues, we anticipate the information will factor into their situational awareness and decision-making. Through our communication and outreach efforts, we have educated communities susceptible to post-fire hazards about the differences between high intensity-short duration rainfall and storm total rainfall i.e., "with debris flows, it's not about the multi-day storm total". Through these efforts, we have contributed to reducing impacts to life, property, and infrastructure during high impact weather events.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , None.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Not applicable as this is the final report.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

Not applicable as this is the final report.

47. Changes that had a significant impact on expenditures

None.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

None.

49. Change of primary performance site location from that originally proposed

None.

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

Through the work completed in this project, we have made major advances in designing and developing operational tools for evaluating and forecasting post-fire debris flow hazards. We have developed a good understanding of what needs to be done to move forward on operational tools and will continue to develop them under other funding sources. This award helped us develop the fundamentals, including refining existing models and coupling atmospheric and land surface models in novel ways (notably, a chain of models approach applied in a probabilistic manner), that will contribute to future tool development.

We have added to the body of knowledge on the topic of post-fire debris flows and flash floods and the storm characteristics that drive them through publication of seven papers, and two more in the publication process. The people who have participated in this project, including students and postdoctoral researchers, are contributing to a STEM workforce with in-depth knowledge on this topic who can support NWS and public interests with respect to post-fire hydrologic hazards moving into the future. This award has also helped early career scientists develop project management and research skills that support future success.

Our outreach through media, presentations, and conversations and collaborations with NWS personnel and others have helped to raise awareness on post-fire hydrologic hazards as well as give insight to these topics (e.g., communicate that debris flows are driven by mesoscale features and elucidate the importance of the rainfall characteristics in influencing debris-flow response). Our team has given numerous presentations to a wide variety of stakeholders who can benefit by applying our findings and information we have provided in their decision-making process.

This work has helped our research team strengthen connections with NWS that we can build on in future research and throughout our careers. Through our research, we have learned more about NWS challenges in forecasting for post-fire hazards that we can build upon in future research. We have already been able to leverage the work done and knowledge gained here to help us obtain funding from other agencies such as USGS, NSF, State of California, several programs within NOAA (including NIDIS and WPO), and others.

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

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CSTAR Final Report

Semi-annual performance period 6/1/2019 through 5/31/2022

24. What were the major goals and objectives of this project?

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The research team has contributed to numerous news articles.

- Strong cold front is soaking California, triggering flood alerts. March 28, 2022. https://www.washingtonpost.com/weather/2022/03/28/california-rain-cold-front-band/
- The devastating mudslides that follow forest fires. *Nature*, January 2022. https://www.nature.com/articles/d41586- 022-00028-3
- https://www.tucsonsentinel.com/local/report/062122_wildfires_arizona/wildfires-continue-rage-across-arizona/
- https://www.azcentral.com/story/news/local/arizona-science/2022/06/27/future-arizona-wildfires-impact-land/7666112001/
- https://www.kgun9.com/news/wildfires/effects-on-geography-of-catalinas-during-bighorn-fire
- USA Today: https://www.usatoday.com/in-depth/news/investigations/2021/11/30/wildfire-rainfall-mudslides-disasters/6201564001/
- Climate Nexus press conference on debris flows: https://blog.waterhub.org/wildfires-and-water-in-the-west
- https://news.agu.org/press-release/new-study-improves-understanding-of-southern-californias-intense-winter-rains/

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Presentations:

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- McGuire was a speaker and panelist at "Natural and Prescribed Wildland Fire Impacts on Soil Health: Fall Event of the National Academy of Sciences Board on Earth Sciences and Resources", 2 November 2021.
- Oakley presented in the Scripps Institution of Oceanography Birch Aquarium public lecture series on post-fire debris flows and climate change in southern CA, recording online at https://www.ucsd.tv/search-details.aspx?showid=36729)
- Oakley presented at a NOAA/NCEI media briefing about the late January 2021 atmospheric river and debris flows in southern CA
- Oakley presented at the Bretz Club Annual meeting on "Meteorology as a tool for enhanced understanding of rainfall induced landslides" on 30 April 2021.
- de Orla-Barile presented a poster on the NCFR catalog at the American Meteorological Society annual meeting in January 2021
- Liu presented a poster at the University of Arizona "Geodaze" conference on 2 April 2021
- Liu presented a poster at the University of Arizona "Los Alamos--Arizona Days" conference on 17 May 2021
- McGuire presented to "Sustainable Tucson" on "The Fire, Flood, and Debris Flow Sequence" on 11 May 2021
- McGuire gave a colloquium talk ("Hydrologic impacts of wildfire and implications for debris flow hazards") at the Department of Hydrology and Atmospheric Sciences at the University of Arizona on January 30th 2020
- Oakley presented at a Northern California post-wildfire processes conference on November 6 2019 in Moffett Field, CA. USGS, NWS, PG&E, and State of California

stakeholders were present. https://cw3e.ucsd.edu/cw3e-at-northern-california-post-wildfire-processes-meeting/
- Oakley gave an invited presentation at the AGU Fall Meeting titled: “Application and Advancement of Meteorological Tools and Information to Assess Landslide Hazards”. https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/490491
- Cannon presented at AGU 2019: An Ensemble-Based Evaluation of WRF Precipitation Forecast Uncertainty in California Watersheds, which included an analysis of WRF sensitivity in precipitation events featuring NCFRs. https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/608351
- Luke McGuire presented at AGU 2019: “Evolving thresholds for mass movement following disturbance by wildfire.”
- Nina Oakley participated as an organizer, panel member, and moderator for the After the Flames virtual science symposium, May 2020: https://aftertheflames.com/science-session-resources/

Publications:

- Oakley, N. S., Liu, T., McGuire, L., Hatchett, B., Simpson, M., Kean, J. Tardy, A., Steinhoff, D. (*in preparation*). Toward probabilistic post-fire debris-flow hazard decision support. *Bulletin of the American Meteorological Society.*
- Odell, L., Oakley, N., Cannon, F. (submitted). Evaluation of HRRR for short-duration, high-intensity rainfall in Southern California. *Weather and Forecasting.*
- de Orla- Barile, M., Cannon, F., Oakley, N. S., & Ralph, F. M. (2022). A Climatology of Narrow Cold- Frontal Rainbands in Southern California. *Geophysical Research Letters*, *49*(2), e2021GL095362. https://doi.org/10.1029/2021GL095362
- Liu, T., McGuire, L. A., Wei, H., Rengers, F. K., Gupta, H., Ji, L., & Goodrich, D. C. (2021). The timing and magnitude of changes to Hortonian overland flow at the watershed scale during the post-fire recovery process. *Hydrological Processes*, 35(5), e14208. https://doi.org/10.1002/hyp.14208
- Luke A. McGuire, Francis K. Rengers, Nina Oakley, Jason W. Kean, Dennis M. Staley, Hui Tang, Marian de Orla-Barile, Ann M. Youberg; Time Since Burning and Rainfall Characteristics Impact Post-Fire Debris-Flow Initiation and Magnitude. *Environmental and Engineering Geoscience* 2021;; 27 (1): 43–56. doi: https://doi.org/10.2113/EEG-D-20-00029
- Schwartz, Jonathan Yonni, Nina S. Oakley, and Paul Alessio. "Assessment of a Post-Fire Debris Flow Impacting El Capitan Watershed, Santa Barbara County, California, USA." *Environmental & Engineering Geoscience* 27.4 (2021): 423-437. https://doi.org/10.2113/EEG-D-21-00008
- Oakley, N. S. (2021). A warming climate adds complexity to post-fire hydrologic hazard planning. *Earth's Future*, 9, e2021EF002149. https://doi.org/10.1029/2021EF002149
- Liu, T., McGuire, L. A., Oakley, N**.**, and Cannon, F. (2022). Temporal changes in rainfall intensity–duration thresholds for post-wildfire flash floods in southern California, *Nat. Hazards Earth Syst. Sci.*, 22, 361–376. https://doi.org/10.5194/nhess-22-361-2022
- Cannon, F., N.S. Oakley, C.W. Hecht, A. Michaelis, J.M. Cordeira, B. Kawzenuk, R. Demirdjian, R. Weihs, M.A. Fish, A.M. Wilson, and F.M. Ralph, Observations and

Predictability of a High-Impact Narrow Cold-Frontal Rainband over Southern California on 2 February 2019. *Wea. Forecasting*, **35**, 2083–2097, doi:https://doi.org/10.1175/WAF-D-20-0012.1.

30. Technologies or techniques

- Univ. of Arizona has continued development of a modeling methodology to explore links between point-scale soil hydraulic measurements and post-fire runoff at the hillslope and watershed scale.
- Univ. of Arizona has continued development of a numerical model that couples rainfall, infiltration, runoff, and sediment transport processes in order to explore relationships between rainfall characteristics and debris-flow processes
- Developed and tested a configuration of KINEROS-2 for flash flooding on recent burn areas that can be applied as they recover.
- Ran two 100-member large ensemble simulations for two narrow cold frontal rainband events. These data can be used in future research and model development for burn areas, regardless of their presence at the time of the storm event.
- Ran a small ensemble for Feb 2, 2019, NCFR that impacted Southern CA to investigate model performance for NCFRs
- Experimented with the use of an “ensemble” of radar-derived precipitation using different Z-R relationships for input to flash flood model.
- Explored use of neighborhood method for evaluating models based on gauge data when no gridded QPE is available.
- Identified different storm types and developed 1 min timeseries to input to debris flow models to assess variability in outcomes related to storm characteristics
- Developed catalog of Narrow Cold Frontal Rainbands in Southern California

31. Inventions, patent applications, and/or licenses

None.

32. Other products

None.

33. What individuals have worked on this project?

UCSD/SIO: Nina Oakley (research scientist), Luke Odell (postdoc), Matthew Simpson (research scientist), Forest Cannon (research scientist), Marian de Orla-Barile (research intern), Lauren Bolotin (research intern)
University of Arizona: Luke McGuire (assistant professor), Tao Liu (post-doc)
DRI: Benjamin Hatchett (PI, assistant professor)

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Forest Cannon left UCSD/SIO for a new position in the private sector in October 2021.

35. What other organizations have been involved as partners?

US Geological Survey, National Weather Service, California Geological Survey, and Arizona Geological survey, as well as researchers from other institutions have been engaged in the activities or recipients of information from this project.

36. Have other collaborators or contacts been involved?

Only persons mentioned in question 33 and 35.

37. What was the impact on the development of the principal discipline(s) of the project?

In atmospheric science, we have made progress in our general understanding of the spatial and temporal characteristics associated with different types of cool season storms producing high intensity-short duration West Coast precipitation events and the challenges and opportunities in forecasting these types of events. This includes how skillfully mesoscale models capture short-duration, high-intensity precipitation. We are gaining knowledge about the physical processes in these storms leading to high-intensity rainfall, and climatology of some of these features in Southern California. We are also learning how to better communicate this information with a non-meteorology audience.

In hydrology, we have made progress in the ability to model post-fire flash floods as well as define flash flood thresholds that can be utilized in an operational setting. In geomorphology, we are moving towards an understanding of the sensitivity of debris flow characteristics to different rainfall characteristics. Results also enhance our ability to predict changes in process dominance, namely when and where transitions from floods to debris flows are likely to occur, which has implications for both hazard predictions and the long-term transport of sediment throughout the landscape. We are also contributing to the growing knowledge base on burn area recovery and changes in flash flood and debris flow thresholds in time across different landscapes and climate regions.

Combining the three disciplines, we have explored the feasibility and benefits of combining ensemble atmospheric modeling with debris flow likelihood and volume models. This allows us to envision future tools that provide probabilistic hazard information on debris flow hazards.

38. What was the impact on other disciplines?

This is an interdisciplinary project, working across atmospheric science, hydrology, and geomorphology. It is hard to determine whether we have had impacts outside of these disciplines. We anticipate that our work will benefit emergency management and hazard communications as well.

39. What was the impact on the development of human resources?

This project has provided experience for early career researchers Oakley, Cannon, and McGuire in managing a research project and developing methods to conduct interdisciplinary research. For the post-docs involved, this project provides the opportunity to develop novel research methods and produce publications that will advance their careers, as well as build collaborators and interdisciplinary working skills. The students involved gained exposure to research and data analysis skills and had the opportunity to lead a research publication. Further description is in the response to question 26.

40. What was the impact on teaching and educational experiences?

We have used the numerous presentations and publications produced related to this project as opportunities to educate a broad range of people (e.g., students, scientists, emergency managers, floodplain managers, forecasters) on post-fire hazards and rainfall extremes, as described in question 29. Experiences for students and staff are described in the response to question 26. McGuire taught a graduate level class (*Field Studies in Geomorphology*) in Spring 2020 at the University of Arizona that involved field trips to a burn scar to educate students on debris flow hazards and observation methods.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

The models developed and calibrated for this project provide infrastructure that can be used in future research projects. The large ensemble simulations run with WRF can also be used for future projects focusing on extreme rainfall and narrow cold frontal rainbands in Southern California. The knowledge and skills gained by researchers on storm characteristics and running and interpreting model results from this project also serve as information resources that build capacity and support future work. A library of research papers, presentations, and news articles was developed in this project that will support future education and research on post-fire hazards.

42. What was the impact on technology transfer?

None.

43. What was the impact on society beyond science and technology?

As we share our research with operational colleagues, we anticipate the information will factor into their situational awareness and decision-making. Through our communication and outreach efforts, we have educated communities susceptible to post-fire hazards about the differences between high intensity-short duration rainfall and storm total rainfall i.e., “with debris flows, it’s not about the multi-day storm total”. Through these efforts, we have contributed to reducing impacts to life, property, and infrastructure during high impact weather events.

44. What percentage of the award’s budget was spent in foreign country(ies)?

None.

45. Changes in approach and reasons for change

Not applicable as this is the final report.

46. Actual or anticipated problems or delays and actions or plans to resolve them

Not applicable as this is the final report.

47. Changes that had a significant impact on expenditures

None.

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

None.

49. Change of primary performance site location from that originally proposed

None.

50. What were the outcomes of the award?

Through the work completed in this project, we have made major advances in designing and developing operational tools for evaluating and forecasting post-fire debris flow hazards. We have developed a good understanding of what needs to be done to move forward on operational tools and will continue to develop them under other funding sources. This award helped us develop the fundamentals, including refining existing models and coupling atmospheric and land surface models in novel ways (notably, a chain of models approach applied in a probabilistic manner), that will contribute to future tool development.

We have added to the body of knowledge on the topic of post-fire debris flows and flash floods and the storm characteristics that drive them through publication of seven papers, and two more in the publication process. The people who have participated in this project, including students and postdoctoral researchers, are contributing to a STEM workforce with in-depth knowledge on this topic who can support NWS and public interests with respect to post-fire hydrologic hazards moving into the future. This award has also helped early career scientists develop project management and research skills that support future success.

Our outreach through media, presentations, and conversations and collaborations with NWS personnel and others have helped to raise awareness on post-fire hydrologic hazards as well as give insight to these topics (e.g., communicate that debris flows are driven by mesoscale features and elucidate the importance of the rainfall characteristics in influencing debris-flow response). Our team has given numerous presentations to a wide variety of stakeholders who can benefit by applying our findings and information we have provided in their decision-making process.

This work has helped our research team strengthen connections with NWS that we can build on in future research and throughout our careers. Through our research, we have learned more about NWS challenges in forecasting for post-fire hazards that we can build upon in future research. We have already been able to leverage the work done and knowledge gained here to help us obtain funding from other agencies such as USGS, NSF, State of California, several programs within NOAA (including NIDIS and WPO), and others.