Partners Project Title Page
Proposal for a Partners Project

Title: Assessing the Accuracy of Multi-Radar/Multi-Sensor (MRMS) Precipitation Estimates in the Phoenix Metropolitan Area to Support Flash Flood Warning Operations

Date: May 20, 2019

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SSD Chief
Name (typed): Andy Edman

Regional Director
Name (typed): Grant Cooper

SUMMARY OF BUDGET REQUEST:

COMET FUNDS: CY2020 $14999

NWS FUNDS: FY20 $2000 FY21 $3000

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Summary

Localized heavy rainfall frequently occurs across the Southwest U.S. during the North American Monsoon (NAM) mainly in form of high-intensity convective thunderstorms of short duration (< 1 h) and small spatial coverage (< 50 km^2). Monsoonal storms are responsible for flash floods that have the potential to cause significant property damage and fatalities on occasion. Operational advances like the Multi-Radar, Multi-Sensor (MRMS) radar-based quantitative precipitation estimates (QPE) and the hydrological modeling systems they force (e.g., CREST simulations for the FLASH product suite) aim to improve our ability to predict the timing and magnitude of flash flooding with increased lead time. However, the accuracy of these products over the southwest U.S is relatively unknown compared to other regions, reducing their potential for improving regional flash flood prediction.

This proposal's primary objective is to quantify the accuracy of MRMS QPE relative to other QPE sources and a dense network of rain gauges across the Phoenix Metropolitan Area for a variety of rainfall events over the past five years (2015-2019). In addition, this proposal will establish a research and educational collaboration between the Phoenix National Weather Service (NWS) Weather Forecast Office (hereafter, WFO Phoenix) and the Hydrosystems Engineering Program at Arizona State University (hereafter, ASU). Convective events during and just after the NAM season will be investigated, performing a multiscale (spatial and temporal) comparison of MRMS, Stage-IV, and single-radar QPE relative to ground observations. Through this comparison, we will identify the types of events and the associated spatiotemporal scales for which MRMS QPE displays higher accuracy than other QPE products. Secondary objectives include i) evaluating what average recurrence interval (ARI) rainfall thresholds are associated with flood impacts, and ii) creating empirical distributions of rainfall for each storm type that may improve the quantile mapping bias correction process used in the National Blend of Models (NBM). The proposed project will facilitate educational exchanges between ASU and the NWS and will allow incorporating new research insights into real-time flash-flood warning operations at WFO Phoenix.

1. Motivation

Improving detection and prediction of flash flood events to support impact-based decision support services is critical, especially since flood-related fatalities and damage costs are rising (Pielke et al. 2002; Downton et al. 2005) due to the increasing occurrence of extreme rainfall events (Trenberth et al. 2003; Boucher et al. 2013). Flooding is the deadliest severe weather hazard in the United States and Arizona, with a 10-yr average of 95 and 2.4 fatalities a year, respectively (NWS 2018). Locally heavy rainfall frequently produces flash flooding across the Desert Southwest during the North American Monsoon (NAM; Adams and Comrie 1997), particularly in August and September when monsoonal rainfall and tropical storms account for 55% of all flood fatalities nationally (Ashley and Ashley 2008). Early monsoon events may also cause significant impacts. For example, heavy rain fell over the Highline Fire's burn scar on 14 July 2017 causing flooding along Ellison Creek near Payson, Arizona that led to 10 casualties. Significant impacts due to flooding may occur after the monsoon ends as well. For instance, during October 2018 (Phoenix's third wettest month on record), rainfall associated with transition events and tropical moisture from Pacific Hurricanes Rosa and Sergio caused one fatality and widespread flood impacts across Arizona.

Predicting flash flood impacts depends upon accurate quantitative precipitation estimates (QPE), quantitative precipitation forecasts (QPF), and land surface hydrological modeling systems. A recent NWS Partner's Project collaboration between co-PI Hopper and UT-Austin showed that QPE accuracy dominated flood prediction skill for two Texas Hill Country record flood events (Lin et al. 2018). That study demonstrated that hydrologic simulations with WRF-Hydro (Gochis et al. 2015) and the RAPID routing model (David et al. 2011) forced by Multi-Radar Multi-Sensor (MRMS; Zhang et al. 2016) QPE outperformed simulations with Stage IV (ST4; Lin 2011) QPE. Algorithmic dependencies on non-zero Maximum Estimated Size of Hail (MESH) values were found to cause low bias for rainfall in the May event, an issue that a dual-pol QPE algorithm in development should rectify (J. Zhang, personal communication). These and additional efforts to evaluate and improve the accuracy of the 2-min radar-only MRMS QPE product that forces CREST simulations for the Flooded Locations and Simulated Hydrographs (FLASH; Gourley et al. 2017) product suite are needed to better inform operational warning decisions. This is particularly required during the monsoon in Arizona, when flash floods often occur within only 1-2 h of causative rainfall.

In addition to providing better initial conditions to improve hydrological simulations, MRMS gauge-corrected QPE may also better inform objective model QPF and forecaster expectations for rainfall prior to and during a heavy rainfall event that may influence warning decisions. First, the 1-km spatial resolution of MRMS QPE may yield more accurate cumulative distribution functions (CDFs) of rainfall for monsoon convection than the 4-km ST4 product currently used as the background observational analysis for the quantile mapping bias correction process utilized by the National Blend of Models (NBM; Hamill et al. 2017). Second, accurate historical CDFs at different spatiotemporal scales based on synoptic patterns (e.g., Maddox et al. 1997), mesoscale surface boundaries and circulations, and environmental parameters investigated by Rogers et al. (2017) may help forecasters anticipate how much additional rainfall may occur when making warning decisions. Although MRMS QPE shows great promise for streamlining flash flood warning operations and impact-based decision support, the accuracy of these products over the Desert Southwest during the monsoon is relatively unknown. In order to enhance their potential for improving regional flash flood prediction, the following questions are in order:

- How accurate is MRMS QPE for monsoonal and other warm season convection over the Phoenix Metropolitan Area (where radar and gauge coverage is high and terrain effects are minimized) at a variety of spatial and temporal scales relative to ST4?
- Are any systematic biases in MRMS QPE (and its algorithm) evident based upon synoptic or mesoscale forcing mechanisms, "extramonsoonal" influences (e.g., tropical cyclones or extratropical waves), environmental parameters, or radar characteristics?
- What average recurrence interval (ARI) rainfall thresholds at varying spatial and temporal scales are associated with flood impacts in the Phoenix Metropolitan Area?
- What implications do answers to three questions above have for real-time operations?

2. Objectives

The main objective of this project is to establish a collaboration between WFO Phoenix and the Hydrosystems Engineering Program at ASU both on research and educational topics. Our main research objective is to improve the WFO Phoenix's detection and forecasting capabilities of flash flooding using the MRMS system. We will pursue the following specific objectives focusing on the Phoenix Metropolitan Area:

- Performing a multiscale (spatial and temporal) comparison among the MRMS QPEs, the ST4 QPE products, and ground observations of the Flood Control District of the Maricopa County (FCDMC) network of rain gauges;
- Classifying the precipitation events recorded by the MRMS system based on the underlying forcing mechanisms and environmental conditions;
- Applying error metrics to assess whether the MRMS system produces more accurate QPEs relative to ST4 under distinct storm-generating mechanisms and environments; and
- Quantifying the skill of MRMS QPEs to capture heavy rainfall events and associated flood impacts for different ARI thresholds at varying spatial and temporal scales.

Our main educational objectives for the project include:

- Involving a graduate student on operational weather forecasting research;
- Exposing ~20 ASU students to the operational and research activities of WFO Phoenix through workshops and visits to NWS facilities; and
- Disseminating the results of the proposed research to NWS operational forecasters

We expect that these preliminary research and educational activities will lead to a constant and vibrant collaboration between ASU and NWS, two institutions that have a crucial role for the socioeconomic development of the state of Arizona.

3. Research Team

The team involved with the research tasks includes: PI Giuseppe Mascaro, an Assistant Professor at ASU with expertise in hydrologic and applied statistics; co-PI Larry Hopper, a Senior Forecaster at WFO Phoenix who has worked on an NWS Partners Proposal with UT-Austin before; co-PI Paul Iñiguez, the Science Operations Officer at WFO Phoenix who has collaborated on peer-reviewed research with Arizona State University over the past few years; and a graduate research assistant that will be recruited at ASU. More information on the PIs' qualifications are available in their curricula vitae attached to the proposal.

4. Study Region and Datasets

4.1 Study Region

Our study region is the Phoenix Metropolitan Area located in central Arizona (Figs. 1a,b). In this region, the quasi-permanent presence of a subtropical ridge of high-pressure guarantees dry and warm conditions for most of the year (Sheppard et al., 2002) with two distinct wet seasons. From November to June, the area is dominated by westerly flow and relatively dry conditions aside from occasional cold fronts predominantly during the winter months that lead to widespread storm systems with low-to-moderate rainfall intensity and durations of 1 to 3 days (Mascaro 2017). In early July, a change in the mid- and upper tropospheric patterns leads to the onset of the NAM, which lasts until the end of September (Adams and Comrie 1997). During the NAM, about one third of the Phoenix metropolitan area's annual rain falls primarily in form of diurnally modulated (Balling et al. 1987), high-intensity convective thunderstorms of short duration (< 1 h) and small spatial coverage (< 50 km^2). A recent study from PI Mascaro found that elevation strongly controls the precipitation accumulations at both seasonal and annual scales, as well as the peak time of the diurnal cycle in summer (Mascaro 2017).

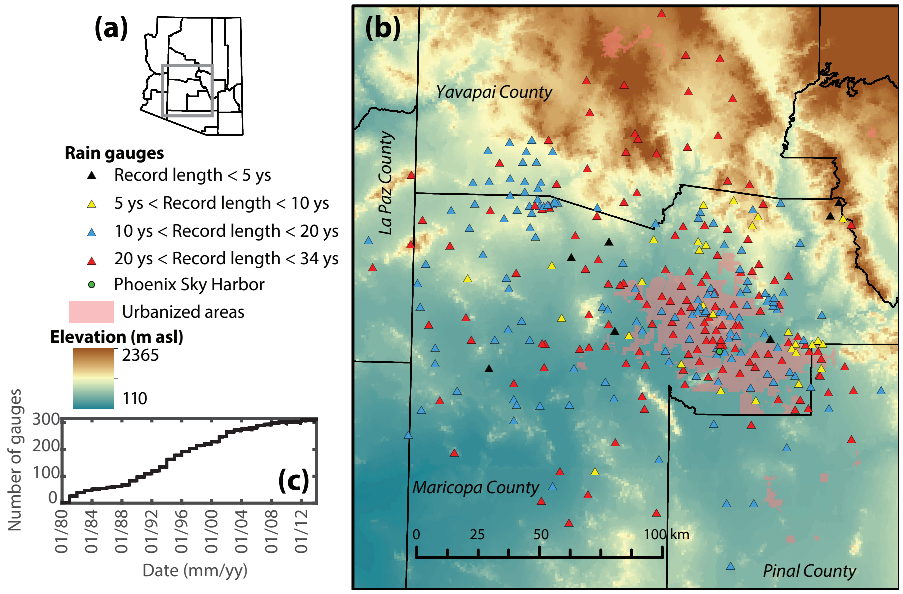

Fig. 1. The Phoenix Metropolitan Area located in Central Arizona along with the rain gauges of the FCDMC network.

4.2 Datasets

We will collect precipitation datasets from three sources:

Ground observations from FCDMC network (PI Mascaro). Precipitation records from 310 gauges of the network managed by the FCDMC will be obtained from Maricopa County (Fig. 1b). These are available in the form of tipping instants, which allow resampling the signals at very high resolutions. PI Mascaro has conducted analyses with these datasets at resolutions ranging from 1 min to 1 year. The network currently includes 310 gauges that have been gradually installed since the early 1980s, as reported in Fig. 1c. These gauges cover an area of ~29600 km^2 with a mean density of 1 gauge every 95 km^2, which increases to 1 gauge every 23 km^2 in the urban region. The gauges cover a wide range of elevations from 220 to 2325 m ASL.

QPE from NCEP Stage-IV (PI Mascaro and Co-PI Hopper). Gridded NCEP Stage-IV QPE (Lin 2011) data at 4-km, hourly resolution that are available since 2002 and processed and quality controlled by hydrologists at regional NWS River Forecast Centers (RFCs) will be acquired from https://data.eol.ucar.edu/dataset/21.093.

QPE from MRMS (PI Mascaro and Co-PI Hopper). Gridded MRMS QPE data will be downloaded from the archive maintained by Iowa State at http://mtarchive.geol.iastate.edu/. Two products will be acquired: (i) the radar-only product (Q3RAD), which is available at resolutions of 1 km and 2 min; and the gauge-corrected product (Q3GC), which is available at resolutions of 1 km and 1 hr. Both products are available from May 2015, with additional data available since then (e.g., Surface Precipitation Types, Radar Quality Index, and various FLASH datasets).

NOAA Atlas 14 (PI Mascaro). Grids of precipitation depths over durations from 5 minutes to 60 days associated with ARI from 2 years to 1000 years will be collected from NOAA Atlas 14. These grids are available at ~500-m resolution.

5. Tasks

Task 1: Identification of Rainfall Events (PI Mascaro) and Storm Types (Co-PI Hopper)

After collecting and quality controlling the precipitation data, PI Mascaro will utilize the FCDMC rain gauge observations to identify all rainfall events that occurred between June and October during the past five monsoon seasons (2015-2019) when MRMS QPE data is available. Criteria for including rainfall events in this study will be determined by PI Mascaro and Co-PI Hopper using a combination of rainfall amounts at specific percentiles and areal coverage thresholds similar to Hopper and Hampshire (2016)'s criteria, but adjusted for Phoenix. Rainfall events associated with "extramonsoonal" influences including deep extratropical waves and moisture associated with named tropical cyclones that account for 15-25% of Arizona warm season rainfall on average (Ritchie et al. 2011) will be analyzed separately. Rainfall events with at least one flash flood warning or storm report in the Phoenix Metropolitan Area, for which at least 30 cases exist from 2015-2018, will be included unless areal coverage is too low.

Additional parallel studies will also be performed at WFO Phoenix to help provide context for the results discovered from evaluating the accuracy of MRMS QPE over the past five years to ensure they are representative of the multidecadal local monsoon climatology. The main objective of this task is to develop a climatology of distinct monsoon storm types based on common synoptic patterns and their mesoscale surface boundaries and/or circulations that help trigger convection back to 2002 (when ST4 data is available). In particular, efforts will focus on subjectively and objectively verifying the three mid-to-upper level synoptic patterns for severe thunderstorms previously identified by Maddox et al. (1997), ensuring that low-level flow and moisture parameters are representative of the monsoon. Environmental conditions investigated by Rogers et al. (2017) will also be analyzed to evaluate whether historical rainfall CDFs for each storm type may be tuned according to moisture, stability, and/or shear parameters. In addition, events will be subdivided by whether severe or flash flood reports (or a combination) were dominant along with looking at radar and lightning characteristics of the convective cells.

Task 2: Comparison of Precipitation Products (PI Mascaro)

For each precipitation event identified in Task 1, we will resample the gridded and point-based precipitation datasets into a common grid. This will be done for multiple spatial resolutions,(λ) ranging from λ = 1 km to λ = 32 km, and temporal aggregations (τ) ranging from τ = 10 min (available for gauges and MRMS) to τ = 24 h. Different resampling techniques will be tested to minimize interpolation errors, as done in Mascaro et al. (2018). The common grids will then be used to compare QPEs from MRMS and Stage-IV against ground observations (hereafter, Gauges), assumed as reference. We will conduct two groups of analyses:

1. We will first compare the precipitation depths. For the pairs (i) MRMS vs. Gauges, and (ii) Stage-IV vs. Gauges, we will compute the spatial correlation coefficient (CC), root mean square error (RMSE), spatial standard deviation (SSTD), and generate Q-Q plots (Wilks, 2011). These analyses will be performed for different values of λ and τ.

2. We will then compare binary grids defined as:

$$\mathbf{P}_{\boldsymbol{\lambda},\boldsymbol{\tau}}^{bin} = \mathbf{P}_{\lambda,\tau} > \mathbf{P}_{\boldsymbol{\lambda},\boldsymbol{\tau},\mathbf{ARI}}^{*} , \quad (1)$$

where $\mathbf{P}_{\lambda,\tau}$ is the grid of precipitation totals at spatial resolution λ and duration τ; $\mathbf{P}^{*}_{\lambda,\tau,\mathbf{ARI}}$ is the grid of precipitation depths associated with λ, τ, and average recurrence interval ARI (e.g., ARI = 10 years) provided by NOAA Atlas 14; and $\mathbf{P}^{bin}_{\lambda,\tau}$ is the corresponding binary grid. For each precipitation event, the pairs of binary grids MRMS vs. Gauges and Stage-IV vs. Gauges will be analyzed through 2 x 2 contingency tables (see Table 1 for an example). From these tables, metrics that quantify the correspondence between the grids will be computed, including Critical Success Index, False Alarm Ratio, and Probability of Detection (POD) (Wilks 2011).

Table 1. Structure of the 2 x 2 contingency table used to compare binary grids of MRMS and Gauges. n_{ij} (i, j = 0 or 1) is the number of pixels where the binary grid of MRMS is equal to i and the binary grid of Gauges is equal to j.

	Gauges = 0	Gauges = 1
MRMS = 0	n_{00}	n_{01}
MRMS = 1	n_{10}	n_{11}

Task 3: Performance for Different Storm-Generating Mechanisms (PI Mascaro)

We will evaluate the correspondence between the two radar-derived MRMS and ST4 products and the gauge observations through different visualization tools. We will plot the relations between (i) the different performance metrics characterizing precipitation depths and binary images, and (ii) the spatial (λ) and temporal (τ) scales of aggregation. These relations will be plotted using all events and for distinct storm-generating mechanisms. Box plots will be used to summarize the variability across all events for each value of λ or τ. An example of a possible outcome of these relations is shown in Fig. 2.

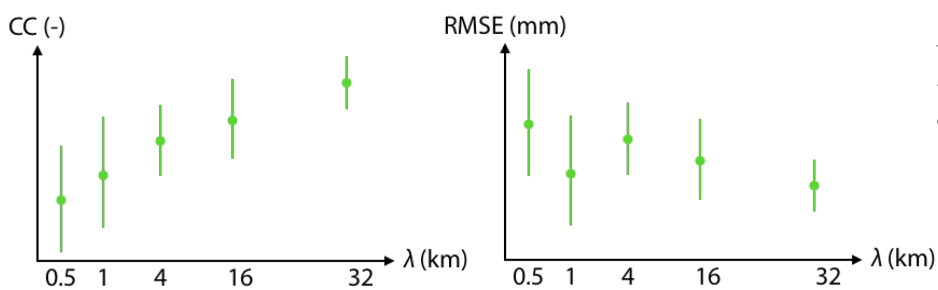

Fig. 2. Example of relations CC vs. λ and RMSE vs. λ.

In addition, we will use the normalized Taylor diagram, which plots in the same space CC, RMSE and SSTD (Taylor 2001). An example of a Taylor diagram from PI Mascaro's previous work is presented in Fig. 3, which shows the performance of different climate models in reproducing the spatial distribution of summer precipitation in a study site in Italy. Taylor diagrams will be generated for different combinations of λ and τ. In each case, events will be displayed with different colors depending on the storm-generating mechanism; clustering of the colors will be an indication of similar performance.

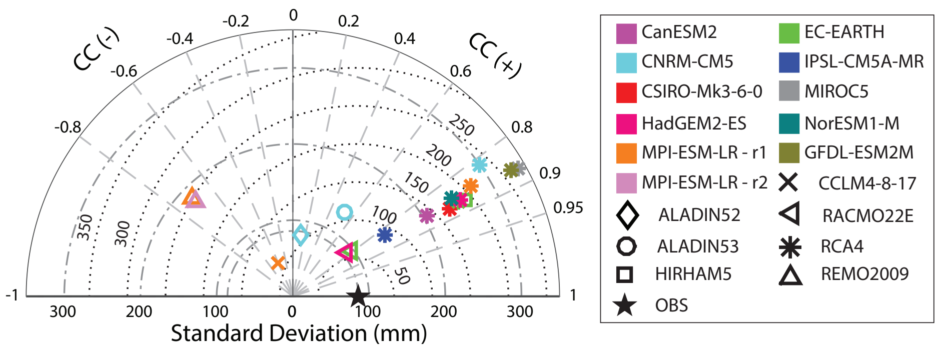

Fig. 3. Normalized Taylor diagram comparing the spatial patterns of summer precipitation in Sardinia, Italy, simulated by several climate models. Adapted from Mascaro et al. (2018).

Task 4: Interpreting and incorporating results into operations (Co-PIs Hopper and Iñiguez)

As the project unfolds, monthly to quarterly meetings will be held between ASU and WFO Phoenix to discuss progress, early findings, and any potential to incorporate these findings into WFO Phoenix operations. Meetings will occur at both institutions, involving the PIs and students working on the project. As opportunity arises, ASU participants will be invited to WFO Phoenix to observe flash flood warning operations first-hand and gain insight into current processes.

Once the final results are obtained, they will be incorporated into WFO Phoenix operations through several means. At a minimum, this includes presenting at seasonal readiness workshops, updating flash flood warning operations training for forecasters with direct support from the NWS co-PIs, and internally sharing results with WFOs across the southwest U.S. via webinars. Results with larger operational implications will also be conveyed to the MRMS group at NSSL as co-PI Hopper has done for a previous NWS Partners Project that identified a low rainfall bias associated with hail (MESH < 0) for a flood event described in Lin et al. (2018). A new dual-pol synthetic QPE algorithm that linearly increases the influence of the hail cap was developed to rectify this issue (https://blog.nssl.noaa.gov/mrms/2018/10/hail-caps-and-rain-rates/).

6. Educational Plan

A graduate student will be trained on research topics related to operational weather forecasting. This student will carry out most of the proposed research activities, supervised by the PIs. We will also expose ~20 ASU students to the operational and research activities of the NWS office through one or two seminars that WFO Phoenix staff will offer within a seminar course (CEE 598: Hydrosystems Engineering Seminar). Students will also have the opportunity to visit WFO Phoenix to observe their operations and interact with NWS staff. Finally, results of the proposed research will be disseminated to NWS operational forecasters through the monthly to quarterly meetings and a final workshop hosted at WFO Phoenix.

7. Timeline

Table 2 summarizes the timeline of the activities that will be conducted assuming a starting date of September 1, 2019 and an end date of August 31, 2020, if not earlier. The tasks are described in Section 4.

Table 2. Timeline of the proposed four tasks.

	Fall 2019: 9/19-12/19	**Spring 2020: 1/20-4/20**	**Summer 2020: 5/20-8/20**
Task 1: *Identification of Rainfall Events (PI Mascaro) and Storm Types (Co-PI Hopper)*	X		
Task 2: *Comparison of Precipitation Products (PI Mascaro)*	X	X	
Task 3: *Performance for Different Storm-Generating Mechanisms (PI Mascaro)*		X	X
Task 4: *Interpreting and incorporating results into operations (Co-PIs Hopper and Iñiguez)*			X

8. Budget Justification

Student stipend: $6,343; Student fringe: $464
Tuition: $1,172
Travel: $2,000
Total direct costs: $9,979
Indirect costs: $5,020
Total costs: $14,999

Journal Charges: $3000 (FY2020)

NWS Staff Conference Attendance/presentation: $2000 (FY2021)

Personnel*:

- The PI, Dr. Giuseppe Mascaro will direct the research effort by working closely with NWS Co-PIs Larry Hopper and Paul Iñiguez and the graduate research assistant to ensure the project proceeds smoothly. He does not require any summer month salary from this project.
- One Graduate Research Assistant (GRA), TBN, (0.5 AY person months and 1.5 summer person months all years of the project) will assist with all the research activities described above. The GRA will work approximately 20 hours per week during the AY and the SUM. *Based upon the ASU Graduate College policy, GRA effort during the AY cannot exceed 20 hours per week and is thus considered 100% effort.*

* All rates of pay are based on salary currently being paid to the named individuals or to the named job description for key personnel and other personnel. Annual escalations occur for salary increases and has been budgeted in out years as per standard ASU practice

Fringe Benefits*:* Arizona State University defines fringe benefits as direct costs, estimates benefits as a standard percent of salary applied uniformly to all types of sponsored activities, and charges benefits to sponsors in accordance with the Federally-negotiated rates in effect at the time salaries are incurred. The rates used in the proposal budget are based on the current Federally-negotiated Rate Agreement plus annual escalation for out years beyond FY2023. For GRA, the ERE rate estimates is 7.31% in FY2020.

Travel**:** $2,000 support is requested for domestic travel. The purpose of this trip is for the GRA to attend a national conference to disseminate research results, engage with collaborators and the scientific community. Domestic conference travel includes the approximate costs per person for airline tickets, hotel, per diem, conference registration, and ground transportation. ASU's travel system software provider, Concur Technologies, assesses a charge of $10.45/per person for each travel expense report submitted. The expense is a direct cost charged per trip. These meetings will be held in various locations within in US. The estimated duration for trips is 3-4 days. Travel expenses will be based on ASU authorized reimbursement rates for lodging, and per diem. Airfare based on internet pricing.

Tuition Remission: The tuition charge for the graduate student is $19,178 ($18,006 for the AY and $ 1,172 for summer). Tuition for the graduate student is included as a mandatory benefit and is charged in proportion to the amount of effort the graduate student will work on the project. Tuition charges are exempt from Facilities & Administrative costs.

ASU defines graduate tuition costs as direct costs and charges sponsors actual rates in effect during the period the graduate student performs on project. Tuition for the graduate student is included as a mandatory benefit and is charged in proportion to the amount of effort the graduate student will work on the project (e.g., full or part time during nine-month academic year).

Indirect Charges ($5,020): Indirect costs were calculated on Modified Total Direct Costs (MTDC) using F&A rates approved by the U.S. Department of Health and Human Services. The current rate for projects like the one proposed here, organized research, is 57%. The most current rate agreement is dated July 2, 2018. Items excluded from F&A calculation include: capital equipment, tuition remission, subcontracts over the first $25,000, participant support, rental/maintenance of off-campus space, and patient care fees.

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Mascaro, G., 2017: Multiscale spatial and temporal statistical properties of rainfall in central Arizona. *J. Hydrometeor.*, **18**, 227-2475, https://doi.org/10.1175/JHM-D-16-0167.1.

Mascaro, G., F. Viola, and R. Deidda, 2018: Evaluation of precipitation from EURO-CORDEX regional climate simulations in a small-scale Mediterranean site. *J. of Geophys. Res. Atmos.*, **123,** 1604-1625, https://doi.org/10.1002/2017JD02746.

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Ritchie, E. A., K. M. Wood, D. S. Gutzler, and S. W. White, 2011: The influence of eastern Pacific tropical cyclone remnants on the southwestern United States. *Mon. Wea. Rev.*, **139,** 192-210,

Rogers, J. W., A. E. Cohen, and L. B. Carlaw, 2017: Convection during the North American Monsoon across central and southern Arizona: Applications to operational meteorology. *Wea. Forecasting,* **32,** 377-390, https://doi.org/10.1175/WAF-D-15-0097.1.

Sheppard, P., A. Comrie, G. Packin, K. Angersbach, and M. Hughes, 2002: The climate of the U.S. Southwest. *Clim. Res.*, **21**, 219–238, https://doi.org/10.3354/cr021219.

Taylor, K. E., 2001: Summarizing multiple aspects of model performance in a single diagram. *J. Geophys. Res. Atmos.*, **106,** 7183–7192. https://doi.org/10.1029/2000JD900719.

Wilks, D. S., 2011: *Statistical methods in the atmospheric sciences*. *Academic Press,* 704 pp.

Zhang, J., and Coauthours, 2016; Multi-Radar, Multi-Sensor (MRMS) quantitative precipitation estimation: Initial operating capabilities. *Bull. Amer. Meteor. Soc.,* **97,** 621-638, https://doi.org/10.1175/BAMS-D-14-00174.1.

Giuseppe Mascaro, Ph.D.

(a) Professional Preparation

University of Cagliari	Cagliari, Italy	Civil Engineering	Laurea (M.S.), 2001
University of Cagliari	Cagliari, Italy	Hydrology	Ph.D., 2008
New Mexico Tech	Socorro, NM	Hydrology	Post-doc, 2008
University of Cagliari	Cagliari, Italy	Civil & Env. Eng.	Post-doc, 2009-2012

(b) Appointments

8/2016 – Present	Assistant Professor, Arizona State University; School of Sustainable Engineering and the Built Environment.
11/2012 – 7/2016	Research Engineer, Arizona State University; Julie Ann Wrigley Global Institute of Sustainability.
1/2009 – 10/2012	Research Associate, University of Cagliari, Italy; Department of Civil Engineering.

(c) Products

(i) Related Products

1. Mascaro, G. 2018. On the distributions of annual and seasonal daily rainfall extremes in central Arizona and their spatial variability. *Journal of Hydrology*, 559, 266-281. https://doi.org/10.1016/j.jhydrol.2018.02.011
2. Mascaro, G., 2017. Multiscale spatial and temporal statistical properties of rainfall in central Arizona. *Journal of Hydrometeorology,* 18, 227–245. https://doi.org/10.1175/JHM-D-16-0167.1
3. Kim, Y., D. A., Eisenberg, E. N. Bondank, M. V. Chester, G. Mascaro, and B. S. Underwood, 2017. Fail-safe and safe-to-fail adaptation: decision-making for urban flooding under climate change. *Climatic Change*, 145(3-4), 397-412.
4. Mascaro, G., R. Deidda and M. Hellies, 2013. On the nature of rainfall intermittency as revealed by different metrics and sampling approaches, *Hydrology and Earth System Sciences*, 17, 1-15, doi:10.5194/hess-17-1-2013.
5. Mascaro, G., E.R. Vivoni and R. Deidda, 2010. Implications of ensemble quantitative precipitation forecast errors on distributed streamflow forecasting. *Journal of Hydrometeorology*, 11, 69-86. https://doi.org/10.1175/2009JHM1144.1

(ii) Other Products:

1. Mascaro, G., F. Viola, and R. Deidda, 2018. Evaluation of precipitation from EURO-CORDEX regional climate simulations in a small-scale Mediterranean Site. *Journal of Geophysical Research – Atmosphere*, 123, https://doi.org/10.1002/2017JD027463
2. Gautam, J., and G. Mascaro, 2018. Evaluation of CMIP5 historical simulations in the Colorado River Basin. *International Journal of Climatology*, 1-17, https://doi.org/10.1002/joc.5540
3. Mascaro, G., D. D. White, P. Westerhoff, and N. Bliss, 2015. Performance of the CORDEX-Africa regional climate simulations in representing the hydrological cycle of the Niger River basin. *Journal of Geophysical Research - Atmosphere*, 120, doi:10.1002/2015JD023905
4. Mascaro, G., E. R. Vivoni, D. J. Gochis, C. J. Watts, and J. C. Rodriguez, 2014. Temporal downscaling and statistical analysis of rainfall across a topographic transect in northwest

Mexico, *Journal of Applied Meteorology and Climatology*, 53, 910–927, doi: http://dx.doi.org/10.1175/JAMC-D-13-0330.1.
5. Mascaro, G, R. Deidda and E. R. Vivoni, 2008. A new verification method to ensure consistent ensemble forecasts through calibrated precipitation downscaling models. *Monthly Weather Review*, 136 (9), 3374-3391

(d) Synergistic Activities

1. Dr. Mascaro is an Assistant Professor in ASU's School of Sustainable Engineering and the Built Environment (SSEBE). He is also a Senior Sustainability Scientist at the ASU's Julie Ann Wrigley Global Institute of Sustainability and an affiliate researcher at ASU's Future H_2O Initiative, and Urban Climate Research Center, Global Security Initiative. He teaches undergraduate and graduate courses in SSEBE on fluid mechanics, hydrology, water resources engineering, and applied statistics.
2. Dr. Mascaro was a supervisor in the NSF-funded UMB-WEST (US-Mexico Border Water & Environmental Sustainability Training) 2013 field campaign, held in Sonora (Mexico) with a participation of thirty undergraduate and graduate students from ASU and Mexican academic institutions. The campaign had two goals: (i) to expose students to water resource issues in a water-scarce region through visits to infrastructures and meetings with stakeholders, and (ii) to involve students in field research in hydrologic science.
3. Dr. Mascaro was an instructor of the Summer School: "Hydrometeorological Extremes: Processes, Models and Human Impacts", sponsored by the Italian Hydrological Society (SII), the Hydraulic Italian Group (GII), and the Italian Universities Consortium for Hydrology (CINID). The summer school was addressed to PhD students and young researchers, and was hosted by the University of Cagliari in July 2017.
4. Dr. Mascaro has copyrighted a software code for the automatic recognition of high-resolution precipitation signal recorded in stripping charts. The software was utilized to digitize the precipitation signals of 1060 years recorded by 103 gauges in Sardinia, Italy.

(e) Collaborators from the Past Five Years:

Rimjhim Aggarwal, Nadia Bliss, Emily Bondank, Jorge Cazares-Rodriguez, Mikhail Chester, Daniel Eisenberg, Yeowon Kim, Ara Ko, Enrique R. Vivoni, Paul Westerhoff, Dave White, Tiantian Xiang, Leah Jones, Abba Gumel, Ross Maciejewski, Jenita Guatam, Adil Mounir, Xin Guan (Arizona State University); Adam Schreiner-McGraw (UC Rivserside); Roberto Deidda, Francesco Viola, Monica Piras (University of Cagliari, Italy); Benjamin Mirus, Richard Niswonger, Brian Ebel (U.S. Geological Survey); Matteo Camporese (University of Padua, Italy); Jason H. Davison (University of Waterloo, Canada); Francina Dominguez (University of Illinois at Urbana-Champaign); Charles W. Downer (Hydrologic Systems Branch); Simone Fatichi (ETH Zurich, Switzerland); David Gochis (National Center for Atmospheric Research); Valeriy Y. Ivanov, Jongho Kim (University of Michigan); Norm Jones (Brigham Young University); Wei Luo (UC Santa Barbara); Luis Mendez-Barroso (Instituto Tecnológico de Sonora, Mexico); Fred L. Ogden (University of Wyoming); Claudio Paniconi (Institut National de la Recherche Scientifique, Canada); Pedro Restrepo (NWS North Central River Forecast Center); Riccardo Rigon (University of Trento, Italy); Chaopeng Shen (Pennsylvania State University); Mauro Sulis (University of Bonn); David Taborton (Utah State University); Franz Trenton (University of Nebraska-Lincoln); Shane Underwood (North Carolina State).

Larry J. Hopper, Jr.
National Weather Service (NWS)
Phoenix Weather Forecast Office (WFO)
Office: (602) 275-7418; Fax: (602) 267-8051
Mobile: (405) 213-4771
Email: larry.hopper@noaa.gov

EDUCATION:

Texas A&M University	Atmospheric Sciences	Ph.D., 2011
Texas A&M University	Atmospheric Sciences	M.S., 2008
University of Oklahoma	Meteorology (mathematics minor)	B. S., 2005

POSITIONS HELD:

2018-present	Senior Forecaster, National Weather Service, Phoenix WFO
2016-2018	General Forecaster, National Weather Service, Austin/San Antonio WFO
2014-2016	Meteorologist, National Weather Service, Austin/San Antonio WFO
2011-2014	Assistant Professor, Atmospheric Sciences, Univ. of Louisiana at Monroe
2005-2011	Graduate Research Assistant, Texas A&M University
2002-2005	General Chemistry Lab Teaching Assistant, University of Oklahoma
2002-2005	Weather Intern, KOCO-TV (ABC), Oklahoma City, OK

SIGNIFICANT PUBLICATIONS RELATED TO THIS PROJECT:

Lin, P., **L. J. Hopper, Jr.**, Z.-L. Yang, M. Lenz, and J. Zeitler, 2018: Insights into hydrometeorological factors constraining flood prediction skill during the May and October 2015 Texas Hill Country flood events. *J. Hydrometeor.,* **19,** 1339-1361.

Homeyer, C., C. Schumacher, and **L. J. Hopper, Jr.,** 2014: Assessing the applicability of the tropical stratiform-convective paradigm in the extratropics using radar divergence profiles. *J. Climate,* **27,** 6673-6686.

Hopper, L. J., Jr., C. Schumacher, and J. Stachnik, 2013: Implementation and assessment of undergraduate experiences in SOAP: An atmospheric science research and education program, *J. Geoscience Education,* **61(4),** 515-527.

Hopper, L. J., Jr., and C. Schumacher, 2012: Modeled and observed variations in storm divergence and stratiform rain production in southeastern Texas. *J. Atmos. Sci.*, **69,** 1159-1181.

Hopper, L. J., Jr., and C. Schumacher, 2009: Baroclinicity influences on storm divergence and stratiform rain: Subtropical upper-level disturbances. *Mon. Wea. Rev.,* **137,** 1338-1357.

SYNERGISTIC ACTIVITIES:

2006-2010	Coordinator for the Student Operational ADRAD Project (SOAP), an NSF-funded undergraduate research and education program to measure and understand the climatology of storms in Southeast Texas at Texas A&M University
2009-2011	Committee Appointment, American Meteorological Society's STAC Committee on Mesoscale Processes
2011-2014	Committee Appointment, Weather Challenge National Forecasting Contest Advisory Board
2015-2018	Associate Editor, *Journal of Operational Meteorology* (National Weather Assoc.)
2019-present	Chief Editor, *Journal of Operational Meteorology* (National Weather Assoc.)

COLLABORATORS FROM PAST FIVE YEARS:

Ty Dickinson (University of Oklahoma)
Anne Case Hanks (University of Louisiana at Monroe)
Nick Hampshire (Austin-San Antonio NWS WFO)
Cameron Homeyer (University of Oklahoma; previously NCAR)
Mark Lenz (Austin-San Antonio NWS WFO)
Peirong Lin (Princeton University; previously University of Texas at Austin)
Justin Pullin (Tallahassee NWS WFO)
Courtney Schumacher (Texas A&M University)
Justin Stachnik (University of Kansas)
Zong-Liang Yang (University of Texas at Austin)
Jon Zeitler (Austin-San Antonio NWS WFO)

Paul M. Iñiguez
1500 N Mill Ave, Tempe, AZ | 602-275-7002 x224 | paul.iniguez@noaa.gov

Education
St. Cloud State University, B.S Meteorology, 2003
Arizona State University, M.A. Geography, 2009

Career Positions

Science & Operations Officer	WFO Phoenix, AZ	March 2015 - Present
Meteorologist-in-Charge (Acting)	WFO Hanford, CA	Jan 2015 - Mar 2015
Science & Operations Officer	WFO Hanford, CA	Mar 2012 - Jan 2015
General Forecaster	WFO Phoenix, AZ	Apr 2006 - Mar 2012
Meteorologist Intern	WFO Little Rock, AR	Sep 2003 - Apr 2006
SCEP	WFO Twin Cities, MN	Sep 2002 - Sep 2003
SCEP	WFO La Crosse, WI	May 2002 - Sep 2002

Synergistic Activities (Print)
Guyer, H., Putnam, H., Roach, M., Iñiguez, P., and Hondula, D., 2019: Cross-Sector Management of Extreme Heat Risks in Arizona. *Bulletin of the American Meteorological Society. https://journals.ametsoc.org/doi/10.1175/BAMS-D-18-0183.1*
Iñiguez, P. M. 2009. An assessment of anthropogenic effects on precipitation in and near the Phoenix, Arizona, Metropolitan Area. MA thesis, Arizona State University.
Iñiguez, P. M., 2009: An assessment of anthropogenic effects on precipitation in and near the Phoenix, Arizona, Metropolitan Area. Preprints, Symposium on Urban High Impact Weather, Phoenix, AZ, Amer. Meteor. Soc., P1.13.
Green, G. D., P. M. Iniguez, J. W. Rogers, and M. Leuthold, 2009: Unusual severe weather outbreak over the Greater Phoenix Metropolitan Area on 28-29 August 2008. Preprints, 23rd Conf. on Weather Analysis and Forecasting, Omaha, NE, Amer. Meteor. Soc.
Iñiguez, P.M., 2009: *An Assessment of Anthropogenic Effects on Precipitation Across the Phoenix, AZ Metropolitan Area.* Masters Thesis, Arizona State University, Tempe, AZ.
Iñiguez, P. M., 2009: The Phoenix Rainfall Index (PRI). Preprints, Symposium on Urban High Impact Weather, Phoenix, AZ, Amer. Meteor. Soc., JP2.9.

Synergistic Activities (Oral)
Co-organizer (with ASU and ADHS) and presenter at the Arizona Extreme Heat Planning Workshop 2019 (Apr 2019).
Presenter at the NWA 43rd Annual Meeting, "Arizona Heat - Collaboratively Tackling America's Deadliest Weather Phenomenon" (Aug 2018).
Co-organizer and presenter at the Arizona Extreme Heat Planning Workshop 2018 (Apr 2018).
Co-organizer (with ASU and ADHS) and presenter at the Arizona Extreme Heat Planning Workshop 2017 (May 2017).
Presenter (keynote) at the Arizona Department of Health Service's Extreme Weather and Public Health Workshop, "Arizona's Big Weather" (June 2016).
Co-presenter at the NWA 39th Annual Meeting, "Using NOAA Atlas-14 Precipitation Recurrence Interval Data to Improve the Communication of Flood Threats in National Weather Service Flash Flood Warnings" (Oct 2014).

Co-presenter at the NWA 39th Annual Meeting, "Utilizing a WFO-Owned High-Resolution Mesonet to Provide Decision Support Services for Localized High Impact Events" (Oct 2014).

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Western Region Headquarters
125 S. State St Rm 1311
Salt Lake City, UT 84138

May 30, 2019

MEMORANDUM FOR: Comet Review Team

FROM: Grant Cooper, Ph.D.
Western Region Director

SUBJECT: MRMS Quantitative Precipitation Estimates (QPE) Proposal

I have reviewed the proposal entitled; ***Assessing the Accuracy of Multi-radar/Multi Sensor (MRMS) precipitation estimates in the Phoenix Metropolitan area to support Flash Flood Warning Operations"*** submitted by Arizona State University and the Phoenix WFO.

The proposal addresses an important operational concern validating the real time MRMS QPE in a summer monsoon environment. The project is logical and consistent with the funding requested.

I endorse this proposal

Project Budget Page

	COMET Funds	NWS Contributions
University Senior Personnel		
1. Giuseppe Mascaro	**Not Requested**	**NA**
2.		**NA**
Other University Personnel		
1. TBD – Graduate Research Assistant	**$6,343**	**NA**
2.		**NA**
Fringe Benefits on University Personnel	**$464**	**NA**
Total Salaries + Fringe Benefits	**$6,807**	**NA**
NWS Personnel		
1. Larry Hopper	**NA**	16 hours per month
2. Paul Iñiguez	**NA**	4 hours per month
Travel		
1. Research Trips		
2. Conference Trips	**$2,000**	**$2,000** – *NWS Staff conference attendance and talk (FY 2020)*
3. Other		
Total Travel	**$2,000**	**$2,000**
Other Direct Costs		
1. Materials & Supplies		**NA**
2. Publication Costs (put in the NWS column if a co-author will be an NWS employee)		**$3,000** – *Journal Publication Charges (FY 2021)*
3. Other Data		
4. NWS Computers & Related Hardware	**NA**	
5. Other (specify) – Tuition Remission	**$1,172**	
Total Other Direct Costs	**$1,172**	**$3,000**
Indirect Costs		**NA**
1. Indirect Cost Rate	**57%**	
2. Applied to which items?	**F&A is applied to all of the direct costs minus the following: equipment, capital expenditures, charges for patient care, participant support costs, student tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000.**	
Total Indirect Costs	**$5,020**	**NA**
Total Costs (Direct + Indirect)	**$14,999 (CY 2020)**	**$5,000**

NWS Checklist for Submitting a COMET Outreach Proposal

Actions Before Proposal is Submitted to COMET	**YES**	**NO**	**DATE**
1. Did NWS office staff and university staff meet to discuss and form outline and scope of project?	X		5/3/2019
2. Did NWS office consult Scientific Services Division (SSD) staff?	X		12/20/2018 5/7/2019
3. Was Statement of Work and budget formulated as a team effort between university and NWS staffs?	X		5/15/2019
4. Was proposal submitted to SSD for review?	X		5/21/2019
5. Did SSD forward copies of proposals dealing with WSR-88D data to Radar Operations Center (ROC), Applications Branch Chief for review?		X	
6. Did SSD forward copies of proposals dealing with hydrometeorology to the Senior Scientist of OHD for review?		X	
7. Did SSD review the data request for project to ensure its scope and criticality for proposal?	X		5/30/2019
8. Is all data for the project being ordered by NWS offices through the National Climatic Data Center's (NCDC) Research Customer Service Group free of charge?			N/A
9. Does budget include publication charges and travel costs for NWS employees to present results at scientific conferences?		X	5/31/2019
10.Does budget separate NWS costs into fiscal year costs and university costs into calendar year costs?	X		5/20/2019
11.Does proposal include a separate justification for university hardware purchases which are usually not funded by the COMET Outreach Program?		X	5/31/2019
12. Have the following people signed off on the proposal cover sheet: - MIC/HIC? - SSD Chief? - Regional Director?	X		6/7/2019
13. Is a letter of endorsement signed by regional director attached?	X		6/7/2019

NWS Checklist for Submitting a COMET Outreach Proposal

Actions after Endorsement by NWS	YES	NO	DATE
1. University submits proposal to the COMET Program.	X		6/7/2019
2. Proposal acknowledgment letter sent by the COMET Program to submitting university with copies to SSDs and NWS office.			
3. COMET review of proposal (internal review for Partners Project proposals and formal review for Cooperative Project proposals).			
4. The COMET Program sends acceptance, rejection, or modification letters to university with copies to SSD, NWS office, and OST12.			
5. The COMET Program allocates funds for university.			
6. OST12 obligates funds for NWS offices.			
7. SSD/NWS office orders data from NCDC.			
8. NWS office or SSD calls OST12 for accounting code for expenses.			
9. NWS office sends copies of all travel vouchers and expense records to OST12.			
10. NWS office or SSD sends copies of publication page charge forms to OST12.			
11. NWS office keeps SSD informed of progress on the project and any results or benefits derived from the project.			

COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN:

ORGANIZATION:

Arizona State University
Fulton Center 410, Rm. 4478
P.O. Box 87705
Tempe, AZ 85287-7605

DATE:07/02/2018

FILING REF.: The preceding agreement was dated 07/05/2017

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

SECTION I: INDIRECT COST RATES

RATE TYPES: FIXED FINAL PROV. (PROVISIONAL) PRED. (PREDETERMINED)

	EFFECTIVE PERIOD				
TYPE	**FROM**	**TO**	**RATE(%)**	**LOCATION**	**APPLICABLE TO**
PRED.	07/01/2016	06/30/2017	54.50	On-Campus	Organized Research
PRED.	07/01/2017	06/30/2018	56.00	On-Campus	Organized Research
PRED.	07/01/2018	06/30/2019	56.50	On-Campus	Organized Research
PRED.	07/01/2019	06/30/2020	57.00	On-Campus	Organized Research
PRED.	07/01/2016	06/30/2020	26.00	Off-Campus	Organized Research
PRED.	07/01/2016	06/30/2017	51.60	On-Campus	Instruction
PRED.	07/01/2017	06/30/2020	48.00	On-Campus	Instruction
PRED.	07/01/2016	06/30/2020	26.00	Off-Campus	Instruction
PRED.	07/01/2016	06/30/2017	37.50	On-Campus	Other Sponsored Activities
PRED.	07/01/2017	06/30/2020	44.40	On-Campus	Other Sponsored Activities
PRED.	07/01/2016	06/30/2020	26.00	Off-Campus	Other Sponsored Activities

ORGANIZATION: Arizona State University
AGREEMENT DATE: 7/2/2018

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
PROV.	07/01/2020	Until Amended		(1)	

*BASE

Modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, participant support costs, student tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000.

(1) Use same rates and conditions as those cited for fiscal year ending June 30, 2020.

SECTION I: FRINGE BENEFIT RATES**

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
FIXED	7/1/2018	6/30/2019	27.30	All (A)	Faculty
FIXED	7/1/2018	6/30/2019	36.10	All (A)	Staff
FIXED	7/1/2018	6/30/2019	9.40	All (A)	Part Time
FIXED	7/1/2018	6/30/2019	2.10	All (A)	Students
FIXED	7/1/2018	6/30/2019	7.10	All (A)	RA/TA
FIXED	7/1/2018	6/30/2019	25.10	All (A)	Post DOC
PROV.	7/1/2019	6/30/2022		(B)	

** DESCRIPTION OF FRINGE BENEFITS RATE BASE:

(A) Salaries and wages including vacation, holiday, sick leave pay and other paid absences.

(B) Use same rates and conditions as those cited for fiscal year ending June 30, 2019.

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

The fringe benefits are charged using the rate(s) listed in the Fringe Benefits Section of this Agreement. The fringe benefits included in the rate(s) are listed below.

TREATMENT OF PAID ABSENCES

Vacation, holiday, sick leave pay and other paid absences are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal costs for salaries and wages. Separate claims for the costs of these paid absences are not made except for paid absences that have been earned but not taken when an individual separates from the university prior to the completion of the grant, contract or other agreement.

OFF-CAMPUS DEFINITION
An off-campus rate is applicable to those projects conducted in facilities not owned or operated by the University, which include charges for facility rental as a direct expenditure, and for which more than 50% of the project salaries and wages are for effort conducted in the rental facility.

DEFINITION OF EQUIPMENT
Equipment means tangible personal property (including information technology systems) having a useful life of more than one year and a per-unit acquisition cost which equals or exceeds $5,000.

The following fringe benefits are included in the fringe benefit rate(s): FICA, WORKERS COMPENSATION, HEALTH/DENTAL/LIFE INSURANCE, UNEMPLOYMENT INSURANCE, DISABILITY INSURANCE, ACCIDENTAL DEATH, RETIREMENT PLANS (STATE RETIREMENT PROGRAMS AND TIAA/CREF), FLEXIBLE SPENDING PLAN, RETIREE ACCUMULATIVE SICK LEAVE, AND EMPLOYEE TUITION REMISSION, EMPLOYEE WELLNESS, SABBATICAL PAYMENTS, EMPLOYEE ASSISTANCE, AND TERMINAL LEAVE.

NEXT PROPOSAL DUE DATE
A proposal based on actual costs for fiscal year ended 06/30/18, will be due no later than 12/31/18.

This rate agreement updates the fringe benefits only.

SECTION III: GENERAL

A. LIMITATIONS:

The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:

This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:

If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:

The rates in this Agreement were approved in accordance with the authority in Title 2 of the Code of Federal Regulations, Part 200 (2 CFR 200), and should be applied to grants, contracts and other agreements covered by 2 CFR 200, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

E. OTHER:

If any Federal contract, grant or other agreement is reimbursing facilities and administrative costs by a means other than the approved rate(s) in this Agreement, the organization should (1) credit such costs to the affected programs, and (2) apply the approved rate(s) to the appropriate base to identify the proper amount of facilities and administrative costs allocable to these programs.

BY THE INSTITUTION:	ON BEHALF OF THE FEDERAL GOVERNMENT:
Arizona State University	DEPARTMENT OF HEALTH AND HUMAN SERVICES
(INSTITUTION)	(AGENCY)
Tamara K Deuser	Arif M. Karim -S Digitally signed by Arif M. Karim -S DN: c=US, o=U.S. Government, ou=HHS, ou=PSC, ou=People, cn=Arif M. Karim -S, 0.9.2342.19200300.100.1.1=2000212895 Date: 2018.07.09 09:29:29 -05'00'
(SIGNATURE)	(SIGNATURE)
Tamara Deuser	Arif Karim
(NAME)	(NAME)
Associate Vice President	Director, Cost Allocation Services
(TITLE)	(TITLE)
07/27/2018	7/2/2018
(DATE)	(DATE) 1353

HHS REPRESENTATIVE: Cora Coleman

Telephone: (415) 437-7820