Joint Technology Transfer Initiative

Implementation of Advanced Multi-Sensor Analysis and Data Fusion Algorithms for Real-Time High-Resolution Quantitative Precipitation Estimation

Research to Operations Transition Plan

April 24, 2017

Approval page

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The below parties, by providing signatures, are satisfied with and approve of the transition plan outlined in this document, which may be reviewed on an annual basis and updated as needed. Operational implementation of this new capability is subject to successful completion of the research and development described herein, review by the Water Resources Services SPT, final approval through National Weather Service governance procedures, and availability of funding.

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6/2/2017

Michelle Mainelli-McInerney **Date**
Acting Director, Office of Dissemination NWS/NOAA

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John Cortinas **Date**
Director, OWAQ
OAR/NOAA

1. Purpose/Objective

The purpose of this Research to Operations Transition Plan is to describe an approach for transitioning "Implementation of Advanced Multi-Sensor Analysis and Data Fusion Algorithms for Real-Time High-Resolution Quantitative Precipitation Estimation (QPE)" from a research platform to a long-term sustained operational capability within the NOAA/National Weather Service (NWS).

The purpose of this project is to implement new algorithms for multisensor QPE and multi-QPE fusion on the Multi-Radar Multi-Sensor (MRMS) Testbed for eventual operation at the NCEP Central Operations (NCO). The new algorithms are expected to improve the accuracy of high-resolution QPE and water prediction especially for heavy-to-extreme precipitation and severe-to-extreme flooding events. The proposed upgrades to MRMS are similar in scope to those already introduced for improved quality control of Canadian radar inputs and of hourly rain gauge inputs.

2. Research background

Accurate high-resolution QPE at the continental scale is of critical importance to NWS's weather, water and climate services and to supporting the recently launched National Water Model. The current state of high-resolution QPE, however, suffers from incomplete utilization of multiple sources of complementary precipitation information, lack of theoretically-grounded optimal estimation algorithms capable of addressing conditional biases associated with estimation of heavy-to-extreme precipitation, which inevitably arise in high-resolution QPE due to large variability, and lack of objective, robust and adaptive algorithms for high-resolution fusion of readily available gridded QPE products from different observing platforms. This project aims at addressing the above gaps by implementing new algorithms for multisensor QPE and multi-QPE fusion on the MRMS Testbed.

3. Capabilities and Functions

3.1 Current capability

The current Readiness Level (RL) of the project is 5. The two algorithms have been tested and evaluated in a simulated environment via multi-year retrospective analyses. The testing and evaluation for the multisensor QPE algorithm were based on the National Centers for Environmental Information (NCEI) reanalysis of MRMS radar-only QPE (hourly, 0.01ºx0.01º) from 2002 to 2011 and the NCEI archive of hourly rain gauge data from the Hydrometeorological Automated Data System (HADS) for the same period. The HADS is the source for the real-time rain gauge data used in MRMS. The driver of the algorithm and the interface between the driver and the algorithm module are based on the reanalysis version of the Multisensor Precipitation Estimator (MPE) package originally developed by the PI at the NWS Office of Hydrologic Development (now the Office of Water Prediction (OWP)). This code has been used extensively for testing and evaluation of all scientific algorithms that currently exist in the operational version of MPE, objective integration of satellite, rain gauge, and radar precipitation estimates in MPE and multisensor precipitation reanalysis at NCEI. The multi-QPE fusion algorithm has been tested and evaluated via retrospective analysis at UTA using the MRMS radar-only, MPE multisensor and CASAWX (http://www.nctcog.org/ep/Special_Projects/CASAWX/Index.asp) QPE products.

3.2 Operational Capability

We expect the end RL to be 7 following implementation on the MRMS Testbed and testing, demonstration and evaluation in real time over CONUS in a 24/7 operation. We envision that, following successful completion of the project, a period of evaluation based on real-time operation at NCO will be necessary to reach RL 8. The end products will become operational at NCO and be made available as part of the real-time operational MRMS products to the forecasters and end users via the Satellite Broadcast Network (SBN) and Local Data Manager (LDM). A forecast office can configure their local AWIPS II system to receive all or a subset of the MRMS products broadcast via SBN.

3.2 Acceptance criteria for transition

The following criteria will be used to determine acceptance for transition, which were developed by the UTA Team, the OU-NSSL Team, the NWS Collaborators of David Kitzmiller and Greg Fall of OWP, and the main developers of CMORPH and SCaMPR, Pingping Xie of NWS/CPC and Bob Kuligowski of NOAA/STAR, respectively:

1) Algorithm integration/implementation on MRMS: Are the algorithms successfully unit- and integration-tested on the MRMS Testbed according to the test plan?
2) Algorithm computational performance: Do the projected computational requirements of the algorithms verify on the MRMS Testbed in real-time operation?
3) Quantitative evaluation of new products: Do the new products quantitatively improve over the existing products in terms of representing both moderate and heavy precipitation? What are the specific attributes in which the new products provide improvement? Are the margins of improvement significant?
4) Qualitative evaluation of new products: Are the new products free from visual artifacts or incongruencies?

For each criterion above, positive evaluation from the MRMS testbed manager will be required for acceptance for transition. For Criterion 3 above, positive improvement in error statistics compared to the current MRMS products will also be required for which we will utilize the gauge vs. QPE comparison utility, Gauge/QPE Compare, available on the MRMS Testbed (http://nmq.ou.edu/applications/qvs_gauge_qpe_comp_main.html). The comparison utility provides spatial display of biases, scatter plot display of QPE vs. gauge, and a suite of verification statistics, including mean bias, additive bias, mean error, mean absolute error, root mean square error, G-R error standard deviation, correlation coefficient, fractional bias, fractional RMSE, fractional standard deviation, probability of detection, false alarm rate, equitable threat score, Heidke Skill Score and Peirce Skill Score.

4. Transition Activities

The following activities, including those involving the MRMS Testbed, are being carried out:
1. Refine evaluation plan
2. Identify interface between the algorithm modules and MRMS
3. Make necessary changes to the modules for porting to MRMS
4. Develop test cases for unit and integration testing on the MRMS Testbed
5. Develop technical documentation for integration and operation on the MRMS Testbed
6. Implement the modules on the MRMS Testbed
7. Test the modules on the MRMS Testbed using the test cases
8. Conduct real-time implementation
9. Carry out evaluation based on the evaluation plan
10. Document the results
11. Develop/Finalize required Capabilities and Requirements Decision Support (CaRDS) documentation
12. Review by Water Resources Services SPT

13. **Final approval and funding via NWS governance (Mission Delivery Council, Portfolio Integration Council, etc)**
14. Upon final approval, NCO, as directed by Office of Dissemination will implement this new capability with the MRMS suite of the operational IDP environment.

The intention of this transition plan is to transition this project to operations **only if the project is completed successfully satisfying NWS metrics for success and operational constraints. The ultimate decision to transition this project to operations will be based on National Weather Service governance procedures, availability of necessary funding, and implementation schedules for MRMS upgrades.**

5. Milestones and deliverables

Milestones

Timeline		Milestones
Yr 1	Jan 2017	Hold planning meeting, identify interface between algorithms and MRMS
	Apr 2017	Begin software engineering of algorithm modules for MRMS
	Jul 2017	Produce algorithm modules for MRMS and test cases
	Oct 2017	Produce technical documentation of algorithm modules
Yr 2	Nov 2017	The PI will hold a meeting with NWS and OAR management to discuss the path to operations
	Jan 2018	Implement algorithm modules on MRMS Testbed, complete testing
	Apr 2018	Begin real-time operation and evaluation
	Jul 2018	Complete real-time operation and evaluation
	Oct 2018	Complete analysis and documentation

Deliverables

1) Modules for the multisensor QPE and multi-QPE fusion algorithms that have been tested, demonstrated and evaluated on the MRMS Testbed
2) Technical documentation of the algorithms for training and operational support
3) Scientific publications and presentations
4) Semiannual and final reports per the Announcement of Federal Funding Opportunity

6. Roles and Responsibilities

6.1 The University of Texas at Arlington's role

The Lead PI, Seo of UTA, will direct and manage the overall project in close consultations and coordination with the OU PI, Tang, NSSL Co-I, Zhang, and the OWP Collaborators, Kitzmiller and Fall. The following table identifies the task-specific roles of the UTA, OU & NSSL and OWP.

Task	Lead institution - collaborating institutions
1. Refine evaluation plan	UTA – OU & NSSL, OWP
2. Identify interface between the algorithm modules and MRMS	UTA – OU & NSSL
3. Make necessary changes to the modules for porting to MRMS	UTA

4. Develop test cases for unit and integration testing on the MRMS Testbed	UTA – OU & NSSL, OWP
5. Develop technical documentation for integration and operation on the MRMS Testbed	UTA
6. Implement the modules on the MRMS Testbed	OU & NSSL
7. Test the modules on the MRMS Testbed using the test cases	OU & NSSL - UTA
8. Conduct real-time implementation	OU & NSSL - UTA
9. Carry out evaluation based on the evaluation plan	OU & NSSL - UTA, OWP
10. Document the results	UTA – OU & NSSL

6.2 NWS Role

The NWS/OWP Collaborators, Kitzmiller and Fall, will participate in refining the evaluation plan (Task 1), in developing test cases (Task 4) and in evaluation (Task 9). They will review gauge/multisensor QPE and rain gauge comparisons as outlined in section 3.2 of the project plan. The OWP collaborators will select approximately ten heavy precipitation test cases for individual verification, including at least three from the real-time trial period, with the remainder taken from the existing archive of events from recent years. Current operational MRMS QPE will be compared with the new multi-sensor and multi-QPE algorithm output, to verify that areas of heavy precipitation are better detected or delineated by the new algorithms. The precipitation will also be input to existing hydrologic model platforms to verify positive impacts on streamflow simulations, as determined from stream gauge observations.

It is expected that NWS/ASFO and the Water Resources Services SPT will review the project team results/products and determine readiness and priority for operational implementation. For this, the project team will provide ASFO with the necessary information, including descriptions on how the new product may look like in the operational environment. They will also (in coordination with NCO) provide updated estimates of the resources required to support operational implementation at NCO. Final approval funding for the transition to operations will follow NWS governance procedures (Mission Delivery Council, Portfolio Integration Council, etc) as required.

The project team understands that the Office of Dissemination's representative's signature is not a commitment to operational implementation but an indication of willingness to operationalize the proposed products subject to NWS governance, availability of funds, and MRMS upgrade schedules.

6.3 OAR Role:

Subject to availability of funds, the Office of Weather and Air Quality (OWAQ)/OAR, will fund this project under NOAA cooperative agreements No. NA16OAR4590232 and No. NA16OAR4590235, both of which describe the terms and conditions of this project, for a period of two years starting in October 2016. OWAQ will also provide the management oversight of the project for the above funding duration.

7. Budget Overview

7.1 Cost of current system

Subject to availability of appropriated funds, the demonstration part of this project is funded by the NOAA/Office of Oceanic and Atmospheric Research/Office of Weather and Air Quality/Joint Technology Transfer Initiative Program at a cost of $385,988 over two years starting in October 2016.

7.2 Cost of transition

The transition cost provided in this section is subject to availability of appropriated funds.

The cost of transition to NCO is projected to be ~3.5 months of a software engineer/system administrator or ~ $40,000. This covers manpower needed to transition the two specific algorithms into the NCO MRMS system. The manpower includes system administrator and software engineers from both NSSL and NCO.

7.3 Cost of operational system maintenance including computational resources needed

The cost provided in this section is contingent upon NWS' decision regarding operational implementation of this project, and subject to availability of appropriated funds.

The cost of operational system maintenance of the two products resulting from this project is projected to be ~1 month/year of a software engineer/system administrator or ~$10,000/year. The computational resources needed for generating the two products operationally are estimated at ~$43,500 for a one-time hardware cost of $43,500 and $1500/yr for a recurring cost annually ("virtual machine" license).

The above are rough estimates based on the project team's previous experience including first guesses for the computational resources needed by the two new algorithms.

8. Risks and Mitigation

The project team has identified two potential risks for transition to operations: 1) excessive computational requirements for the multisensor QPE algorithm and 2) lack of availability of the new versions of the operational CMORPH and SCaMPR products for the multi-QPE fusion algorithm. To mitigate 1), the project team will assess the actual amount of computation on the MRMS Testbed for each update and optimize the code to meet the projected availability of computing resources. To mitigate 2), the project team will closely coordinate with Pingping Xie of NWS/CPC and Bob Kuligowski of NOAA/STAR throughout the project duration to ensure that the multi-QPE algorithm utilize the best available products when operationalized at NCO.