

1st Year Report for COMET proposal entitled:

***Integration of GOES Satellite-based Evapotranspiration Products in
Operational Streamflow Forecasting***

**Colorado School of Mines and Colorado Basin River Forecast Center
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Section 1: Overall Project Objectives

The goal of the proposed research is to collaborate with the scientists at the CBRFC to develop a merged MODIS-GOES based PET satellite product for basins in the western US and to apply these advanced data products to streamflow forecast operations. This collaboration will involve numerous meetings to develop, test, and integrate the GOES-based products within the CBRFC. Personnel from both the CSM and ISU teams will travel to the CBRFC to interact, discuss, and develop appropriate methodologies and the operational framework for testing. This proposal was designed to bring together academic scientists with proven expertise in remote sensing product development and skilled operational hydrologists to develop data products that will increase forecasting efficiency and accuracy.

Specific project objectives include: (1) Development of a GOES PET product for use in operational forecasting through adaptation of the previously developed UCLA-MODIS product. (2) Evaluation of the GOES PET product against traditional NOAA-ATLAS and NLDAS-derived PET products being developed at the CBRFC, (3) Testing GOES PET product at select forecast points (study basins) using the SAC-SMA model within the CHPS framework, and (4) Assessing the skill of seasonal to long-term hindcasts resulting from integrating GOES PET into the modeling framework for CBRFC modeled basins.

After initial research collaboration on development of the calibration procedure, various outreach and education activities will continue, including documentation of study methodologies and algorithms as well as training for CBRFC and other RFC hydrologists. We will produce a report summarizing results of the study and specific guidelines on implementing the developed procedures. We also expect to produce 2-3 peer-reviewed journal articles with study results. The report and journal articles will be distributed to the thirteen RFCs and the NWS Office of Hydrologic Development.

Responsibilities of various participants:

1. Acquisition of data products (GOES, MODIS): **CSM**
2. Adaptation of UCLA-MODIS PET algorithm for GOES products: **CSM**
3. Derivation of GOES-PET product for study basins: **CSM**
4. Off-line comparison of GOES, PenPan and NOAA-ATLAS Pan PET: **CSM and CBRFC**
5. Integration of GOES PET into SAC-SMA Model: **CSM, ISU and NWS RFCs + ESRL**
6. Evaluation of GOES PET in operational forecasting system: **CM, ISU and NWS RFCs + ESRL**
7. Travel by CSM-ISU team to CBRFC
8. Journal Publications: **CSM, ISU and NWS RFCs + ESRL**
9. Presentations at the AGU Fall National Meeting: **CSM, ISU and NWS RFCs + ESRL**
10. Training document and report for NOAA RFCs: **NWS RFCs + ESRL and CSM**
11. Regional workshop for GOES satellite integration at RFCs: **NWS RFCs, CSM and ISU**

Accomplishments to Date:

To this point, the project has made good progress and is generally on track with the original task schedule outlined in the proposal (below). Four forecast basins were selected in conjunction with the CBRFC. We have acquired all forecast basin and model parameters and have integrated this information into a Matlab modeling framework at CSM. We have also acquired PenPan data for all four basins from Mike Hobbins to be used in the off-line comparison. We have developed MODIS-based PET products for several of the study basins. Calibrations for the forecast basins with the PenPan data have been undertaken and calibrations to the MODIS products are ongoing. Several presentations have been given on the project work.

Table 1 List of project tasks and approximate schedule for completion of activities.

Tasks	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Acquisition of data products (GOES, MODIS)	√	√						
2. Adaptation of UCLA-MODIS PET algorithm for GOES products		√	√					
3. Derivation of GOES PET product for study basins				√	√			
4. Off-line comparison of GOES, PenPan and NOAA-ATLAS Pan PET				√	√			
5. Integration of GOES PET into SAC-SMA model					√	√		
6. Evaluation of GOES PET in operational forecasting system (CHPS)						√	√	√
7. Travel by UCLA-ISU team to CBRFC	√				√			√
8. Journal publications				√				√
9. Presentations at the AGU Fall Meeting						√		
10. Training document and report for NOAA RFCs							√	√
11. Regional workshop for GOES satellite integration at RFCs								√

Changes to scope of work:

A key change in the original project has been the movement of the PI (Terri Hogue) to the Colorado School of Mines (CSM) from UCLA (July 2012), of Jongyoun Kim to the University of California, Riverside (UC-Riverside) from UCLA (January 2013), and of collaborators Wood and Hobbins, to NWRFC and ESRL, respectively, from the CBRFC. However, there has been no change in the overall scope of work and the UCLA graduate student has also relocated to CSM and is continuing work on this project. Dr. Alicia Kinoshita (post-doc at CSM with Dr. Hogue) will also be assisting in the project as she specializes in remote sensing algorithms and applications to hydrologic systems.

Section 2: Summary of Research and Educational Exchanges

In the first 12 months of this project, the majority of exchanges between the CBRFC and the CSM have included emails, phone calls, and meetings at national conferences and meetings. The primary purpose of these exchanges was to initialize the study, to select study basins and to transfer data and the CBRFC NWSRFS forecasting parameters to CSM. After data and the CBRFC structure were transferred, subsequent email exchanges occurred to discuss initialization and other issues in getting the data inputs and modeling framework setup and running at CSM.

Section 3: Presentations and Publications

The first year of work on this project involved primarily satellite data collection and processing, synthesis and comparison of operational (PenPan and climatology) and CSM PET products, and model setup and calibration relative to study inputs. Several presentations were given at national meetings which discussed the COMET project and highlighted ongoing activities' results to date:

- Hogue, T.S., and J. Kim, 2011: Development of High Resolution Multi-platform Satellite Products for Hydrologic Applications, American Geophysical Union Fall National Meeting, San Francisco, CA, December, 2011..
- Hogue, T.S., 2012: Development of High Spatial and Temporal Resolution Evapotranspiration Products Through Integration of Landsat and MODIS Land Surface Data, American Meteorological Society, 26th Conference on Hydrology, New Orleans, January, 2012.

Section 4: Summary of Benefits and Problems Encountered

4.1 Academic Partner - CSM

Benefits: Several benefits have been experienced over the first year of this research project, including:

- Training CSM graduate students on NWSRFS modeling platforms and current meteorological data needs and inputs
- Collaboration and interaction with CBRFC hydrologists, allowing improved understanding of operational problems in forecasting methods, data issues and requirements
- Several NASA proposals written with RFCs (CBRFC and CNRFC) on integration of remote sensing products in operations, and other hydrologic modeling advances).
- We plan to pursue further collaborations and interactions with RFC hydrologists on upcoming proposals.

Difficulties: Slight delay in second year of activities given Dr. Hogue's (PI) relocation to the Colorado School of Mines. However, funding for the second year's activities is nearly in place and we expect to move forward quickly on the remaining activities.

4.2 Forecast Partner

Benefits: Current and potential benefits are occurring through cooperative research project, including:

The major benefits to date for CBRFC and to NWS river forecasting from this project are the following: (1) the assessment of current, legacy PET forcings (ie using static monthly average

pan-based estimates) versus modern dynamic PET forcing, which has identified deficiencies in the spatial and elevational depictions of RFC evaporative demand estimates; (2) the preliminary assessment of contributions of static PET forcing errors to streamflow errors has been confirmed in the study basins, suggesting that dynamic PET will improve simulations; and (3) routines for preparation of watershed-scale dynamic PET and use as a forcing for the CHPS version of the SAC-SMA hydrology model have been developed. In the near future, a journal article will be completed describing the results to date, for submission to the AMS Journal of Hydrometeorology, and the existence of the new dynamic forcing datasets and CHPS ingest routines will be advertised internally to the RFCs and OHD. Ultimately, the work will facilitate a shift toward more modern evaporative forcings within RFC operations.

Section 5: Plan of Work for the Next Year

Work for the next year of this COMET proposal will stay on schedule with the above timeline (Table 1). We have most of the data products and models in place to undertake initial spatial and temporal comparison of three of the developed PET products (MODIS-PET, PenPan and RFC Climatology). We also are starting sensitivity analysis and calibration of the three PET products with the NWSRFS/CHPS forecasts models, including the SACSMA and SNOW17, for the four CBRFC basins. This upcoming year will also involve initial merging of several GOES products to produce the integrated MODIS-GOES-R PET product, which will be the fourth PET product for this study. Much of the MODIS-GOES work will consist of synthetic studies (given GOES-R is not launched yet) or will consist of integrating some version of current operational GOES products. The current MODIS algorithm uses a synthetic diurnal curve based on sunrise and sunset times, to estimate a daily average PET. We hypothesize that improved temporal resolution of the GOES products will provide better representation of the diurnal variation of PET and ultimately provide improved daily average values to be used in the SACSMA.

The final six months of the COMET work will entail report writing, training and outreach activities. Results will be presented to CBRFC, NWRFC and the NWS Office of Hydrologic Development (OHD) hydrologists. We plan to provide training documents and materials for RFC and other hydrologists. The goal is to advance training within the CBRFC and other RFCs via training manuals and presentations, along with formulation of a report outlining the methodology and results from this study. Results from this study will also be presented at one of the major scientific conferences (American Meteorological Society Annual Meeting, American Geophysical Annual Meeting, or other appropriate conference). A peer-reviewed journal article, detailing the methodology and all results developed in this research, will also be written and published. This paper, along with the final report from the study will be distributed to all RFCs and the NWS OHD.

Section 6: Funding Request

The originally proposed budget will remain the same for the second year of this COMET proposal.

Relocation of PI: The PI (Terri Hogue) relocated in July of 2012 to the Colorado School of Mines (CSM) from UCLA. There has been no change in the overall scope of the project but given the move and subsequent startup at CSM, we have experienced a slight delay in the year two activities and we are just now finalizing the contract to obtain the second year of funding at

CSM. We expect to complete all activities within a year of receiving this second year of funds; hence the original end date (August, 2013) will likely need to be extended to allow us to finish the proposed work.