The COMET Outreach Program
Sponsored by the National Weather Service

Final Report for Partners and Cooperative Projects

University: ____________________*Kean University*____________________________

Name of University Researcher Preparing Report: _________*Dr. Paul J. Croft*________

NWS/AFWA/Navy Office: _______PHI NWS__________________________________

Name of NWS/AFWA/Navy Researcher Preparing Report: _______*Alan Cope*________

Type of Project: ___*Partners*____

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Section 1: Summary of Project Objectives

The project's goal was to improve understanding of the spatio-temporal characteristics of fog through use of simulated GOES-R products in association with other methods in a multi-modal operational approach. This improved understanding provides the basis for more accurate short-term and highly localized fog forecasts in terms of the occurrence, intensity, and coverage of the phenomenon. The individual project objectives included: (1) Operational examination of fog occurrence using simulated GOES-R with the online KU-NWS fog archive and model guidance; (2) Operational identification and testing of fog occurrence and coverage as related to synoptic regime and physiographic setting; and (3) Assessment, training, and dissemination of project results.

Section 2: Project Accomplishments and Findings
1.1 *(To be completed by academic and forecaster partners)* Summarize progress on COMET-funded work during the last six months of the project.

The first six months of the project focused on initial data collection and review with regard to fog and dense fog cases (including possible null events). Examination was based upon a wide variety of satellite imagery and products from multiple platforms (existing and new/trial) so as to replicate an operational environment. All data sets were considered for the period before, during, and after possible fog (or null) case days. Nominally this represented a 24h window surrounding any potential fog (or null) event. Cases were collected each with differing amounts and types of data (an operational reality) for analysis with regard to fog occurrence (or null), intensity (i.e. dense or not), and location/coverage for the study area. The cases collected included a diversity of fog types and processes (typology) and thus provided opportunities to review fog (or null) case evolution with time (to some extent), particularly with regard to new/experimental satellite data/product availability in an operational setting.

The dataset was used initially to distinguish (when possible) the differences observed between fog, dense fog, and null cases with regard to imagery and guidance products as well as confounding factors. These confounding factors include those due to the atmospheric conditions as well as those due to satellite platform limitations and/or resolution and related issues. The analyses provided insight to the spatio-temporal issues associated with fog and dense fog identification and the "why" of formation and placement (and in some cases with coverage).

These led to suggested tools/imagery that would be useful in refining the nowcast process mentality (versus a hindcast). Two workshops presented in March with NWS PHI staff helped to frame the evaluation with operational input. This interactive exchange ensured a research to operations approach throughout the project. Several students were engaged in the project through Honors Seminar at Kean University and/or through Independent Study. Some of the material was also utilized in the Physical Meteorology course to help illustrate principles and processes found in the atmosphere and its resulting phenomena.

At WFO Mount Holly, collection of the MODIS fog/low-cloud (LC) product continued through June. Thus the total period for saving imagery was June 2011 through June 2012. The process became more reliable in October 2011 when the MODIS imagery was added to the local AWIPS rotating seven-day archive. A total of 444 MODIS fog/LC images were archived on 301 separate days. Corresponding GOES fog/LC images were also collected beginning in September. Both MODIS and GOES images were saved as PNG files, with surface observations of weather, ceiling and visibility overlaid (see figure 1 in the appendix).

Image files were transferred from AWIPS to a PC for viewing and analysis. Focus was on the geographic region from Delaware through New Jersey, eastern Pennsylvania, southeast New York, Long Island and Connecticut, i.e., the forecast areas of WFOs PHI and OKX. A spreadsheet was created with a line entry for each image, including date, time, observed weather and clouds, MODIS-depicted cloud features (fog/stratus, valley fog, mid- or high-cloud obscuration), subjective evaluation of image usefulness for low-cloud or fog detection (very useful, somewhat useful, not useful) and general comments about the image. Frequencies were tabulated for different weather conditions, MODIS image features, and various combinations thereof.

The MODIS fog/LC images were judged to be “very useful” or “somewhat useful” about half the time, for identifying the location and extent of fog or stratus. “Very useful” images, which clearly distinguished clear areas from fog/LC areas over the entire study area, accounted for about 12 percent of the total. The main limitation on usefulness was partial (total) obscuration by higher clouds, which occurred in 34 (19) percent of all cases. Another common issue was misrepresentation of mid-level clouds as low clouds with enhanced coloring (16 percent of cases).

The higher-resolution MODIS imagery (at 1 km, compared with the 4 km GOES) was helpful in some cases, especially for depiction of valley fog in the upper Delaware and Susquehanna River basins. MODIS was also better at detecting nocturnal low-level wave clouds which often occur in cold northwest flow over the Appalachian Mountains. Since the resolution of GOES-R imagery will be 2 km, its ability to detect these phenomena will be somewhere between MODIS and the current GOES satellite.

1.2 Describe the division of labor between the academic and forecaster partners (i.e., which tasks each partner is responsible for).

Project efforts were shared by the academic and forecaster partners and included students from Kean University. Students were involved in data collection, assessment of data in relation to a pre-existing online winter fog archive (developed by the partners prior to this project and was updated), and analysis of fog (and null or dense) events. The forecast partner led the effort with regard to operational implementation for testing as well as the development of the verification scheme while the academic partner has taken the lead in case oversight and compilation of archival information towards the development of an operational implementation model. Each of the partners presented about the project and its findings at conferences. The partners have made efforts to travel to their colleague's respective office in order to conduct the work in a shared fashion.

Section 2: RELATED ACCOMPLISHMENTS

2.1 *(To be completed by academic partner)* Please summarize any other work conducted by the University, which was a result of the COMET Outreach Program collaboration, but was not directly funded by it (for example, seminars at NWS office if these were not part of the original proposal).

A previously established online archive site has been in revision and was updated for continued operational application and demonstration purposes (and March workshops). The site includes additional information on fog patterns and anticipated coverage according to specific definitions of local, regional, and widespread. The site also contains additional parameter fields derived for fog, dense fog, and null cases using the Climate Diagnostics Center website interface (http://www.kean.edu/~ATMFOG/fog/home.htm).

The project was leveraged by Kean University in that the academic partner was provided time towards research through a course load reduction. Students were involved in fog and related work that assists in awareness and enhanced ability to discern fog environments for any winter season synoptic setting in the study area. Students involved in the project also presented their results to the Kean University Student Chapter of the AMS/NWA and contributed to presentations of the research at the National Weather Association & American Meteorological Society Annual Conferences.

2.2. *(To be completed by forecaster partner)* Please summarize any other work conducted by the NWS, which was a result of your collaboration with the university but was not directly funded by it (for example, seminars given by NWS forecasters at the university).

A second source of experimental satellite imagery became available in February 2012. This is the GEOstationary Cloud Algorithm Test-bed (GEOCAT) imagery produced by the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison, Space Science and Engineering Center. Four types of images were provided: Cloud Type, Cloud Depth, Probability of IFR Conditions, and probability of MVFR conditions. These images are based on current GOES data and are produced every 15 minutes. They are available on the local WFO AWIPS and are saved in the rotating archive for seven days. A procedure was developed to display all four images types at once in a four-panel format (see figure 2 in the appendix).

We did not attempt a routine archive of the GEOCAT imagery since the volume of images was much greater than from MODIS. We did identify an “intensive study period” from March 15 to 23, when low clouds and/or dense fog developed over the study area for several consecutive days. All MODIS and GEOCAT imagery was saved during this time, along with surface observations and RUC model data. A study of this event is underway and an abstract was accepted for the 2nd NWS/Eastern Region Virtual Satellite Workshop. Otherwise, the GEOCAT imagery was routinely monitored for “interesting” cases. One such case was identified on June 1 with fog forming overnight over the coastal waters of New Jersey and Delaware. A slide show illustrating the usefulness of the imagery in this case was prepared and provided to the forecasters.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective
3.1 *(To be completed by academic partner)* Please list the benefits to the University resulting from the collaboration (new understanding of forecasting problems, exposure of students to operational forecasting, access to new observing systems, changes in course offerings, use of NWS personnel as a resource, etc.).

Students and faculty have worked on an end-to-end research project and had some direct interaction with NWS personnel. Skills from their coursework and others learned were useful to the project as well as their career and professional development – especially the integration of GIS. The project work contributed to the revision of a manuscript between partners as well as the presentation of research at professional conferences.

3.2 *(To be completed by forecaster partner)* Please list the benefits to the NWS office resulting thus far from the collaboration (promising new forecasting technique, heightened interest in research in the office, better understanding of new observing systems, potential new hires, use of university personnel as resource, etc.). Please be as specific as possible, particularly in regard to any improvements in forecasting operations resulting from this project (**see examples**).

The experimental GOES-R Proving Ground imagery via MODIS and GEOCAT has proven to be of some value for forecast operations at WFO Mount Holly. Please see section 2 above for discussion of the MODIS data. The GEOCAT imagery was available every 15 minutes all day and night, and thus is better suited for operations. One forecaster recalled a specific instance when IFR/MVFR probability imagery was useful: “*I found them useful with regard to the TAFs in determining whether to forecast MVFR or IFR ceilings and in trying to determine the ultimate areal extent of low clouds*.” Another forecaster made frequent use of the MVFR probability imagery, and was disappointed when that imagery ended unexpectedly in August (see section 6.2 below).

It should be noted that all satellite data, both operational and experimental, is used at the WFO in the context of many other sources of data (surface observations, radar, aircraft soundings, hi-res model forecasts, etc.). A fairly dense network of surface observations gives us a good idea of the extent of fog and stratus in most cases. However, this network does not extend over marine forecast areas (Delaware Bay and the Atlantic coastal waters of Delaware and New Jersey), so it is easier for satellites to provide useful information.

On March 14th and again on the 28th, a fog-forecasting seminar/workshop was held at WFO Mount Holly. The seminar included presentations by Dr. Croft (who travelled to Mount Holly) and SOO Al Cope. Most of the forecast staff participated, at one session or the other. The seminar combined information about the satellite imagery with fog climatology, new forecast tools based on Dr. Croft and students' work, and a general discussion of operational fog forecasting issues.

Dr. Croft has visited WFO Mount Holly many times during the past year and has spent time with members of the staff and the SOO especially. We have all benefited from his perspective and the work of his students. Finally, through this project our forecast staff became more aware of the experimental imagery and the new types of data that will be available in the future from GOES-R.

Section 4: Benefits and Lessons Learned: University Partner Perspective

Kean University once again received the benefit of cooperative and collaborative efforts with the NWS PHI partner. These include student interactions, operational training, and an opportunity to contribute to the R2O modality of NOAA. Greater coordination of time and efforts (i.e. more frequent interaction) would prove even more beneficial. A monthly visit and/or exchange, while logistically difficult, would likely benefit both partners over the longer term of research and operational engagement.

Section 5: Publications and Presentations

5.1. *(To be completed by academic and forecaster partners)* Please provide complete citations using the AMS bibliographic format for each thesis, dissertation, publication or presentation prepared as part of this COMET Outreach project.

National Weather Association Conference (Birmingham, AL 2011): Operational Fog Forecasting: Multimodal Understanding of Fog Formation, Evolution and Location in Real-time.

American Meteorological Society (New Orleans, LA 2012): Investigation of Fog Evolution and Aerosols in Real-time.

Croft, P. J., A. Cope, and others, 2012. Operational assessment & prediction of winter season fog occurrence & coverage (Parts I and II). In revision: Weather and Forecasting.

Encyclopedia of Natural Hazards, 2012 – revision completed (Springer).

Cope, Alan M., 2012. Utility of GOES-R Proving Ground Experimental Satellite Imagery For the March 2012 Mid-Atlantic Multi-Day Fog Event. Abstract accepted for the 2nd NWS Eastern Region Virtual Satellite Workshop, Oct. 30, 2012.

Section 6: Summary of Problems Encountered

6.1 *(To be completed by academic partner)* Please describe problems encountered on the University side in the last six months and their resolution, if any.

Data availability and consistency were difficult but this was expected given the use of both experimental data/platforms and the spatio-temporal limitations of specific satellites and/or products (e.g., time of day system passes over study area; resolution).

6.2 *(To be completed by forecaster partner)* Please describe problems encountered on the NWS side in the last six months and their resolution, if any.

No significant problems were encountered. However, it was a challenge making operational use of MODIS polar-orbiter imagery which was available only a few times per day. (Forecasters were used to GOES data every 15 minutes.) However, the overall flow of data was fairly reliable. For the MODIS data there seemed to be a latency period of 30 to 60 minutes between image time and receipt of the image on AWIPS.

The GOES-based GEOCAT imagery was also reliable and arrived in AWIPS with a delay of only about 15 minutes. However, on August 22, the “Cloud Type” and “Probability of MVFR” images were discontinued without warning, and replaced by “Cloud Phase” and “Probability of LIFR”. We have adjusted our AWIPS configuration to receive the new images.

APPENDIX

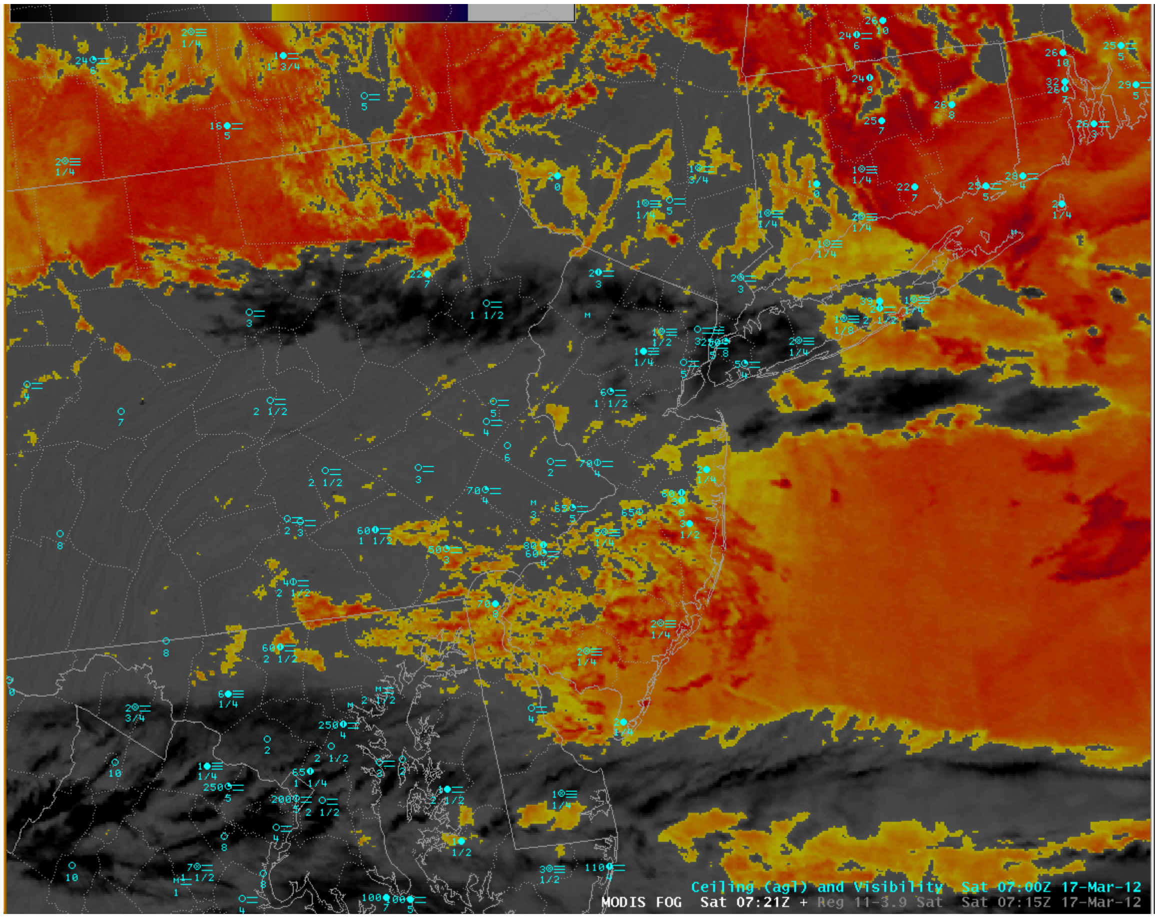

Fig 1. Example of the MODIS Fog/LC imagery collected for study. Typical MODIS image shows low clouds/fog (yellow/orange/red enhancement) with partial cirrus obscuration (dark streaks) over northern New Jersey, Southern Delaware, and adjacent areas east-west. Overlaid surface observations show visibility in miles (below station circle) ceiling height in hundreds of feet (left) and standard weather symbols (right).

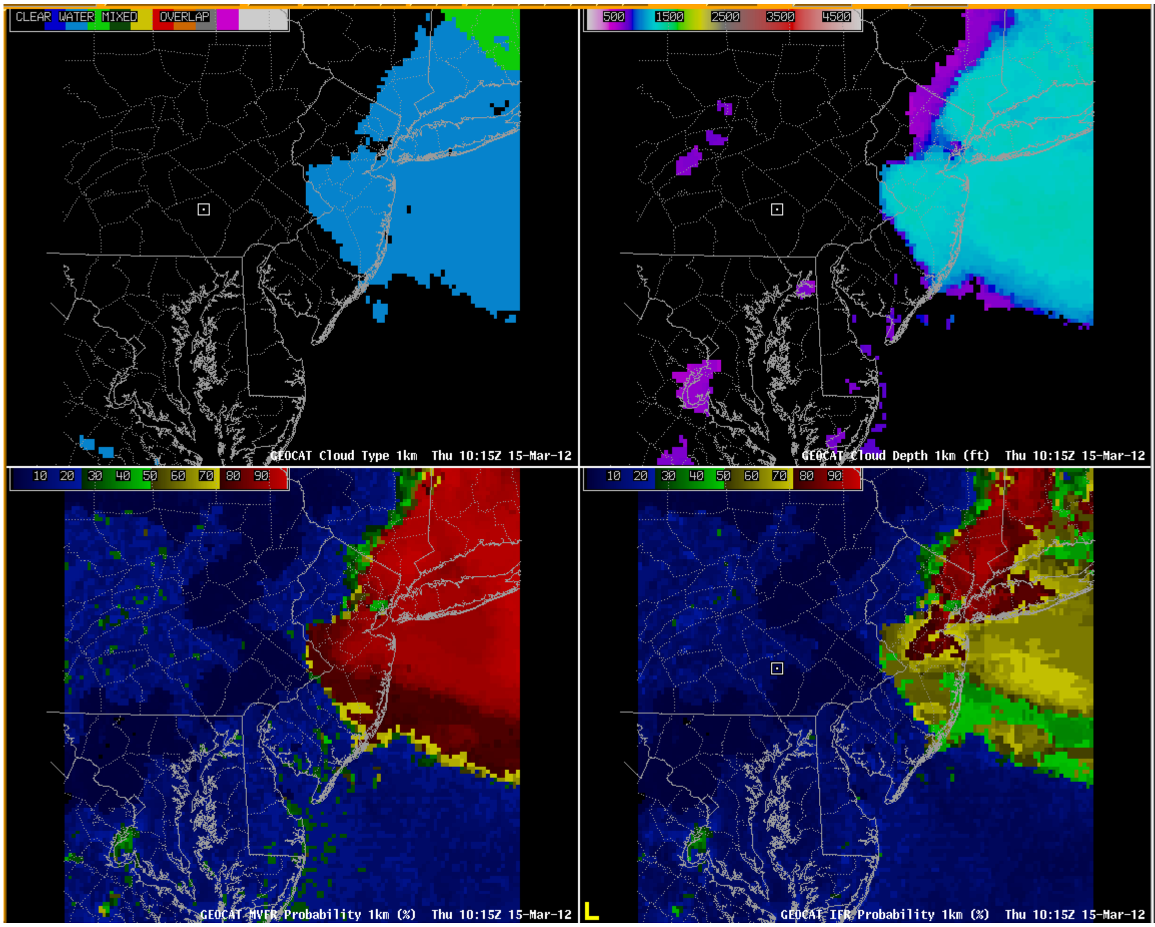

Fig. 2 AWIPS four-panel display of GEOCAT imagery from 1015 UTC, 15 March 2012. Upper-left: Cloud Type; Upper-right: Cloud Depth; Lower-left: Probability of MVFR; Lower-right: Probability of IFR. A low stratus cloud deck is invading New Jersey from the east.