TIME PERIOD ADDRESSED BY REPORT: 10/01/2012 – 9/30/2014

SECTORAL APPLICATIONS RESEARCH PROGRAM (SARP) –
PROJECT ANNUAL REPORT

PROJECT TITLE: Use of seasonal climate forecasts to minimize short-term operational risks for water supply and ecosystem restoration

INVESTIGATORS:

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PROJECT YEARS (Award Period): October 2012- September 2014

I. PRELIMINARY MATERIALS

A. Research project objective.

The overall goal of this project was to improve the regional relevance of seasonal climate forecasts and increase their usability for multiple water managers in Florida to minimize short-term operational risks for water supply as well as ecosystem restoration. This project was integrated with the Florida Water and Climate Alliance, a stakeholder-scientist partnership focused on increasing the relevance of climate science data and tools for water resource planning and supply operations in Florida (*the FloridaWCA was partially funded under NOAA-SARP Grant NA11-OAR4310110 - click here to see final report of that project*).

The specific objectives project were to:

1. Evaluate the skill of the National Multi-Model Ensemble (NMME) seasonal climate predictions (temperature and precipitation) over all seasons and over a common grid across the Southeast US.

2. Statistically downscale the NMME forecasts to the watershed scale and evaluate the skill of these seasonal predictions over three specific domains: Peace River Manasota Regional Water Supply Authority, Tampa Bay Water and the South Florida Water Management District.

3. Conduct a comparative study across three organizations of the benefits and limitations of using seasonal climate forecasts for their operational needs.

B. Stakeholders and decision makers

- Alison Adams and Tirusew Asefa, Tampa Bay Water
- Kevin Morris, Peace River Manasota Regional Water Supply Authority
- Jayantha Obeysekera, South Florida Water Management District

C. Approach

The approaches used in the project are described below by objective.

Objective 1: Evaluate the skill of the NMME seasonal climate predictions (ENSO (i.e. SST in the Niño3.4 region), temperature, precipitation, solar radiation, humidity, and wind speed where available) on a seasonal basis over all seasons and over a common grid (12km NLDAS grid) across the Southeast US.

Objective 2: Statistically downscale and bias correct the NMME forecasts to the watershed scale and disaggregate to the space and time scales needed for application over three specific domains: Peace River Manasota Regional Water Supply Authority (PRMRWSA), Tampa Bay Water and the South Florida Water Management District (SFWMD).

Objective 3: Carry out a comparative study across three organizations of the benefits and limitations of using seasonal climate forecasts for their operational needs.

D. Matching funds/activities

- Funds from Tampa Bay Water were used to fund an additional Ph. D. student who supported this project.
- Significant in-kind contribution of partners' (Tampa Bay Water, the South Florida Water Management District and Peace River Manasota Regional Water Supply Authority) time and effort for project planning, research and specific testing and application efforts at their sites was provided.
- This project is integrated with the Florida Water and Climate Alliance, a stakeholder-scientist partnership focused on increasing the relevance of climate science data and tools for water resource planning and supply operations in Florida (*partially funded under NOAA-SARP Grant NA11-OAR4310110*). Workshops provide venues for project activity and broader stakeholder feedback. All working group members from the Public Water Supply Utilities, Water Management Districts and local governments provide in-kind support through paying their own travel costs to quarterly project meetings and staff time to attend the meetings and conduct project specific activities between quarterly meetings.

E. Partners

- Southeast Climate Consortium (SECC)
- Florida Water and Climate Alliance (FloridaWCA)
- Tampa Bay Water
- Peace River Manasota Regional Water Supply Authority
- South Florida Water Management District

II. ACCOMPLISHMENTS - Project timeline and tasks accomplished

A. Project timeline and tasks accomplished

Project accomplishments are reported here by objectives and tasks in the work plan.

Objective 1: Robustly evaluate the skill of the NMME seasonal climate predictions

Forecast skill was evaluated as a function of lead time, season, and geographical location. Both probabilistic (Briar Skill Score) and deterministic (Mean Square Error Skill Score) skill was evaluated. We used the NMME set of seasonal hindcasts which are from multiple different global coupled ocean-atmosphere models (http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/). Forecast skill was evaluated for precipitation and temperature. The skill of additional variables were evaluated for the Climate Forecast System version 2 (CFSv2).

Obj. 1, Task 1: *Evaluate the skill of the NMME seasonal climate predictions (temperature and precipitation), using probabilistic and deterministic skill measures, over all seasons and over a common grid across the Southeast US.*

Results: Two approaches were used to downscale seasonal precipitation (P) and 2 meter air temperature (T2M) forecasts from NMME seasonal climate predictions over the states of Alabama, Georgia, and Florida in the southeastern United States (SEUS). The 12 km downscaled P and T2M forecasts from 0- to 7-month lead were produced from individual model forecasts and multi-model ensemble (MME) forecasts of the NMME system. Two MME schemes were tested by combining all forecast members (SuperEns) or assigning equal weights to each model (MeanEns). One of the downscaling approaches was a model output statistics (MOS) method, which was based on spatial disaggregation and bias correction of the NMME P and T2M forecasts using the quantile mapping technique (SDBC). The other approach was a perfect prognosis (PP) method using nonparametric locally weighted polynomial regression (LWPR) models, which used the NMME forecasts of Niño3.4 sea surface temperatures (SSTs) to forecast local-scale P and T2M. Both SDBC and LWPR downscaled P showed skill in winter but no skill or limited skill in summer at all lead times for all NMME models. The SDBC downscaled T2M were skillful only for the Climate Forecast System, version 2 (CFSv2), model even at far lead times, whereas the LWPR downscaled T2M showed limited skill or no skill for all NMME models. In many cases, the LWPR method showed significantly higher skill than the SDBC. After bias correction, the SuperEns mostly showed higher skill than the MeanEns and most of the single models, but its skill did not outperform the best single model. The results of this work have been published in the Journal of Climate (Tian et al. 2014a; http://dx/doi.org/10.1175/JCLI-D-13-00481.1).

Obj. 1, Task 2: *Evaluate the skill of additional variables from the CFSv2 model*.

Results: This task explored the potential of using the Climate Forecast System version 2 (CFSv2) for seasonal predictions of ETo over the states of Alabama, Georgia, and Florida. The fine resolution (12 km) ETo forecasts were produced by downscaling coarse-scale (1.0^{o}) ETo forecasts from the CFSv2 retrospective forecast (reforecast) archive and by downscaling CFSv2 maximum temperature (Tmax), minimum temperature (Tmin), mean temperature (Tmean), solar radiation (Rs), and wind speed (Wind) individually and calculating fine-scale ETo using those downscaled variables. All the ETo forecasts were calculated by the Penman-Monteith equation. Two statistical downscaling methods were tested: 1) spatial disaggregation (SD); and 2) spatial disaggregation with bias correction using the quantile mapping technique (SDBC). The forcing dataset of Phase 2 of the North American Land Data Assimilation System was employed for both verification and bias correction. Deterministic forecasts and probabilistic forecasts in terciles were evaluated using the mean square error skill score and the Brier skill score, respectively. The ETo forecast that was downscaled from the coarse-scale ETo showed similar skill to those obtained by downscaling individual variables first and then calculating ETo. Among the downscaled CFSv2 variables, Tmax showed highest predictability, followed by Tmean, Tmin, Rs, and Wind. SDBC had slightly better performance than SD for both probabilistic and deterministic forecasts due to the quantile mapping bias-correction procedure. The skill is regionally and seasonally dependent. The CFSv2-based ETo forecasts showed higher predictability in cold seasons than in warm seasons. The CFSv2 model could better predict the ETo in cold seasons during the El Nino Southern Oscillation (ENSO) only when the forecast initial months are in ENSO. The results of this work have been published in the Journal of Hydrometeorology (Tian et al. 2014b).

Objective 2: Statistically downscale and bias correct the NMME forecasts to the watershed scale.

After the skill of the NMME forecasts was evaluated at the watershed-scale, we worked with each of the three users to incorporate the forecasts in their operational models (Tampa Bay Water and the South Florida Water Management District) and decision support systems (Peace River Manasota Regional Water Supply Authority).

Obj. 2, Task 1: *Garner feedback from project participants on relevant space-time resolution needed for forecasts*

Results: In discussion with project participants, it was determined that a seasonal-scale forecast (3-month) was the desirable temporal scale and that a 12-km resolution was the desirable spatial scale. The seasonal scale was chosen from our discussions since the "state" of the climate was determined of most importance. In addition, it was determined that the evaluation of the skill of the NMME and CFSv2 at their native resolutions (1 degree latitude and longitude) was not deemed useful. Thus this project evaluated the skill of downscaled forecasts of both the NMME and CFSv2 (and reported above in Objective 1) rather than evaluating skill at native resolutions and then downscaling forecasts as initially proposed.

Obj. 2, Task 2: *Translate downscaled monthly forecasts to space and time scales needed*

Results: Forecasts of the NMME and CFSv2 were downscaled to the 12-km resolution of the North American Land Data Assimilation System phase 2 (NLDASv2) forcing dataset. The NLDASv2 was chosen since it contains all the relevant variables, is at a suitable spatial resolution, and is updated in near real-time. Downscaling was conducting using the Statistical Downscaling with Bias Correction (SDBC) method and by developing locally weighted polynomial regression models using Niño 3.4 forecasts as the predictor for precipitation and temperature forecasts. The forecast evaluation discussed above was conducted at the 12-km resolution for the states of Alabama, Florida, and Georgia. Thus our evaluation included, and went beyond, that initially proposed in this project.

Obj. 2, Task 3: *Downscale daily climate model output if/when it is available.*

Results: During the first year, only daily values for the CFSv2 model were available and the group debated whether it was better to downscale daily values from seasonal forecasts or to downscale seasonal values and then disaggregate as appropriate. Seasonal forecasts were not disaggregated to the daily scale and daily climate output was not used in this project. The decision to focus on seasonal scale forecasts was made during discussions with project participants where the "state" of the climate was deemed as most important. In lieu of conducting daily downscaling/disaggregation, the project team and participants chose to expand our downscaling and evaluation of forecasts beyond the 3 domains originally proposed to include the entire states of Alabama, Florida, and Georgia at the 12-km resolution.

Objective 3: Comparative study across three organizations of the benefits and limitations of using seasonal climate forecasts

Obj. 3, Task 1: *Complete background research, designed interview questions, and carried out interviews of three organizations.*

Results: Interview tools to assess climate information use and needs across the agency case studies were developed and collaboratively reviewed by project team members. Six individual phone interviews were conducted with research participants at the water agencies. The interviews provided detailed input on climate information needs, current use of climate data at seasonal scale, and institutional constraints to using information across the agencies. In addition, interviews provided insights on how decisions are made at each of the agencies including those that could potentially be improved with the input of seasonal climate information. Kevin Morris, PRMWSA Science and Technology Officer, agreed to develop an outline of the decision making process they currently use as a start to begin to understand smaller utilities. This moved forward significantly as an additional exercise complementing the study (see more detail in section B.2 of this report.) The initial findings were shared with the rest of the Project Team, and discussions took place regarding potential next steps for moving forward on the study.

Obj. 3, Task 2: *Conduct site visits/ observations at each of the water management agencies*

Results: Team members worked closely with stakeholders to understand current use of climate information across agencies. From the interviews conducted and observations made through attending meetings and reviewing agency minutes, we learned that there was a large difference between the three agencies in terms of use of seasonal climate forecasts and agency capacity to translate seasonal climate forecasts into usable products. Specifically, the SFWMD and Tampa Bay Water both already had highly advanced technical systems in place for integrating climate forecasts into decision-making as well as technical staff devoted to this task. The Peace River Manasota Regional Water Supply Authority, however was not using climate information in any formal way. Further, it was not directly clear where climate information could be used to benefit agency decisions. We decided to focus our research efforts on identifying points of entry for climate information in this agency, and working to identify bridges that facilitated climate information use in the other two agencies.

Objective 4: *(note- originally in proposal as part of objective 2)* Work with each of the three users to incorporate appropriate space-time scale forecasts in their operational models (Tampa Bay Water and SFWMD) and decision support systems (Peace River Manasota Water Supply Authority).

Results: Researchers worked closely with the Peace River Manasota Regional Water Supply Authority representatives. The collaborations allowed the internal agency representative to identify the most appropriate entry point for the application of climate information into agency decision making, which was in guiding decisions about when to initiate water recovery from an Aquifer Storage and Recovery (ASR) system. A decision support tool was developed and presented at numerous professional meetings including the University of Florida Water Institute Symposium, a workshop of the Florida Water Climate Alliance, and the American Water Resources Association (AWRA) Summer 2014 Conference on Integrated Water Resources Management. In addition to a recent publication in the Florida Water Resources Journal, entitled Developing a surface water resiliency model for the 21st century, (Morris, K. M. Coates, and M. Heyl, 2014), a working paper has been drafted and we are currently preparing a manuscript for submission.

B. Application of your findings to inform decision making

1. Provide access to seasonal forecast data evaluated in the project

The skill of the downscaled forecasts produced in this project have been shared with the participants of this project. To-date, the greatest interest expressed by partners has been for access to bias-corrected seasonal Niño 3.4 forecasts from the NMME. In response, our bias-corrected Niño 3.4 forecasts were combined into a single netCDF file and shared with the project participants. The netCDF file format was chosen since our project participants are familiar with this format.

2. Using probabilistic seasonal forecasts in operations planning.

Recognizing that our partners differ in size and use of modeling, we were interested in considering usefulness from both extremes. Tampa Bay Water and SFWMD have similar expertise and both organizations use predictive models for operational decisions. Peace River Manasota Regional Water Supply Authority is a smaller utility, and currently is not using predictive models for operational decisions, however, with the knowledge developed through this research, the potential benefit to using climate information to guide decision making at The Peace River Water Authority has been realized. Although the PRMRWSA has not formally adopted seasonal climate information use, discussions between agency staff and the Governing Board about how to begin the process are occurring.

Tampa Bay Water and SFWMD, who are currently working with their own models, are considering whether to switch to using the downscaled forecasts generated in this project or to continue their use of "official" forecasts of precipitation, temperature, and ENSO currently available from the Climate Prediction Center and the International Research Institute for Climate and Society. The results from this work presented them with information on when, and to what lead-time the models of the NMME are skillful. However, in order to continue using the NMME forecasts, downscaled using the methods used in this project, will require additional on-going effort. In contrast, use of the existing official forecasts, while not necessarily available at as fine a spatial resolution, requires little additional effort by the agencies. Overall, this project demonstrated the skill of the NMME, the variability of skill between models of the NMME, and the time periods and lead-times where the NMME is not skillful and thus climatology is a more appropriate forecast.

As the Peace River Manasota Regional Water Supply Authority is at an early stage of considering climate information use, more research was needed on exactly how information could be used. Kevin Morris conducted this research and as a result, developed a draft document "Peace River Manasota Regional Water Supply Authority Decision Processes Related to Water Supply Management Choices. This draft was developed as an exercise to explore and demonstrate application of Decision Science Methods to framing and articulating utility management decisions employing a widely varied pool of historic data observations coupled with scientific forecast products. Kevin worked with Jessica Bolson and Lisette Staal to engage the Florida Water and Climate Alliance for discussion and feedback. He developed a presentation for the Florida Water and Climate Alliance workshop held on June 26th, 2013, Decision Tool Development Exerciser: When to Start ASR Recovery?" and shared both his learning experience, the tool developed, and the need for future refinement and data access. FloridaWCA participants provided comments during the workshop and have been in contact with Kevin following the workshop.

From the feedback collected and through on-going collaborations with project team members, Kevin Morris continues to refine and expand upon the decision-support tool. The product of these efforts, a Decision Tool for Initiating Recovery from an Aquifer Storage and Recovery System, has been presented to agency staff at the PRMRWSA, as well as in professional meetings including the Florida Water Institute Symposium and the AWRA Summer Conference in Reno, Nevada. A working paper has been drafted (Morris, 2014) and a manuscript is in preparation for submission.

C. Planned methods to transfer the information and lessons learned from this project

The project was fully integrated into the Florida Water and Climate Alliance workshops and website, providing broad access to both FloridaWCA participants and the public. In the June 26th Florida WCA workshop three presentations were provided that covered the results of the evaluation of skill of forecast data, as well as specific efforts on using seasonal data in the operations planning at Tampa Bay Water and Peace River Manasota Regional Water Supply Authority In particular, the development of the

PRMRWA case study provided excellent example for discussion, and stimulated ideas similar types of activities from other stakeholders in future workshops.

D. Significant deviations from proposed work plan

None to report.

E. Completed publications, white papers, or reports (with internet links if possible)

1. Tian, D., Martinez, C.J., Graham, W.D. and S. Hwang. 2014a. Statistical downscaling multi-model forecasts for seasonal precipitation and temperature over southeastern USA. Journal of Climate 27(22): 8384-8411. http://dx/doi.org/10.1175/JCLI-D-13-00481.1
2. Tian, D., Martinez, C.J., and W.D. Graham. 2014b. Seasonal prediction of regional reference evapotranspiration based on Climate Forecast System version 2. *Journal of Hydrometeorology*, 15(3): 1166-1188. http://dx.doi.org/10.1175/JHM-D-13-087.1
3. Tian, D. and C.J. Martinez. 2014. The GEFS-based daily reference evapotranspiration (ETo) forecast and its implication for water management in the southeastern United States. Journal of Hydrometeorology, 15(3): 1152-1165. http://dx.doi.org/10.1175/JHM-D-13-0119.1
4. Tian, D., Martinez, C.J. and T. Asefa. Improving short-term urban water demand forecasts using forecast analogs of the Global Ensemble Forecast System (GEFS). Submitted to Journal of Hydrology.
5. Tian Di, and C. Martinez, Seasonal forecasting skill of the National multimodel Ensemble (NMME) over southeastern Unitized States, Presentation at Florida Water and Climate Alliance Workshop 9, June 26, 2013
6. Asefa, Tirusew, How we use seasonal forecasts at Tampa Bay Water, presentation at Florida Water and Climate Alliance Workshop 9, June 26, 2013
7. Morris, Kevin, "Peace River Manasota Regional Water Supply Authority Decision Processes Related to Water Supply Management Choices," case study shared at the Florida Water and Climate alliance Workshop 9, June 26, 2013
8. Morris, Kevin, PRMRWA Decision Tool Case Study- When to start ASR? presentation at Florida Water and Climate Alliance Workshop 9, June 26, 2013
9. Morris, Kevin (2013). Elements of decision science in utility decision making. A working paper for the Peace River Manasota Regional Water Supply Authority, June 30, 2013.
10. Morris, Kevin (2014). Synthesis of diverse data in developing a decision tool for initiating ASR recovery. Presentation at University of Florida Water Institute Symposium, Gainesville, Florida, February 11, 2014.
11. Morris, Kevin, Bolson, Jessica, and Coates, Mike (2014). Synthesis of diverse data in developing a decision tool for initiating ASR recovery. Presentation at American Water Resources Association, Summer Conference, Reno, Nevada, June 30, 2014.
12. Morris, K. M. Coates, and M. Heyl, 2014, Developing a surface water resiliency model for the 21st century, Florida Water Resources Journal, September 2014.

III. GRAPHICS: JPEG document included as a separate attachment.

IV. WEBSITE ADDRESS FOR FURTHER INFORMATION

- http://waterinstitute.ufl.edu/research/projects_detail.asp?TA=Water+and+Climate&Contract=86885
- http://FloridaWCA.org

V. ADDITIONAL RELEVANT INFORMATION NOT COVERED UNDER THE ABOVE CATEGORIES

NA