USGS-FAU Workshop on Increasing Confidence in Precipitation Projections for Everglades Restoration

Thursday, September 28th, 2017

Florida Atlantic University Florida Center for Environmental Studies

FAU FLORIDA CENTER FOR ENVIRONMENTAL STUDIES Charles E. Schmidt College of Science Florida Atlantic University

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UNIVERSITY OF MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Table of Contents

Executive Summary

Any model of future precipitation exhibits some uncertainties. Such models are needed for Florida's Everglades restoration efforts, as precipitation is a key driver of that ecosystem's structure and function. Thus until we can characterize, and reduce, the model uncertainties, Everglades restoration efforts will benefit little from precipitation modeling activities. Successful communication of uncertainty across disciplines, such as between climate scientists and user groups in south Florida engaged in Everglades restoration, is an important step in bridging the gap between climate scientists and the climate-data user community.

South Florida user groups, particularly those in Everglades restoration, have expressed interest in better understanding the uncertainty of precipitation projections and reducing the uncertainty where possible. The objective of this workshop was to improve the utility of precipitation projections for south Florida water management and Everglades restoration efforts. In this workshop, the the Western Everglades Restoration Project (WERP) was used as an example and test case, but the workshop was not intended to provide any specific outputs to be used in the WERP planning process. Additionally represented at the workshop were the needs of Everglades fire ecologists.

The goals of this workshop were to improve awareness of how climate data and science can support natural resource management activities, and to identify research directions for a peer-reviewed scholarly publication, including tailored outputs for the represented user groups. The focus of the workshop was on the overlaps and discrepancies between users and user groups pertaining to needs for precipitation temporal and spatial resolution, time periods for planning, parameters (e.g., mean, trend, extremes), and best practices for uncertainty characterization.

Approximately 40 scientists and resource managers with a common goal of Everglades restoration gathered at the FAU Florida Center for Environmental Studies (CES) in Davie, FL. Through a series of presentations and discussions, the workshop facilitated an exchange related to user climate data needs compared to currently available data, while serving to identify existing gaps. The workshop was intended to enhance the credibility and salience of existing climate model data.

This workshop followed the USGS-FAU Precipitation Downscaling Technical Meeting (June 2015), but with greater focus on uncertainty of precipitation projections and new data sources or analyses, and highlighted the changing needs of south Florida resource managers. Ideally, there should be multiple discussions between climatologists and climate data users to refine the exact information users seek in order to facilitate increased interaction between groups. Currently, there is a need for improved communication between climatologists and climate data users, with a common set of terms and methods between both groups. There is also a necessity of better understanding the physical drivers of future changes, and for expert (climatologist) guidance on what data or models are best for use in south Florida.

This report describes the event, discussions, and future directions for research and work. A major theme highlighted during this workshop was the need for greater communication between disciplines, and this workshop will lead to further interaction in the future.

1. Description of Event

The goals of this workshop were two-fold:

1. To improve the awareness of how climate science can support natural resource management activities in South Florida, with emphasis on Everglades restoration.
2. To produce a peer-reviewed scholarly publication that includes tailored outputs for one or more of the three user-groups represented by our three focal topics (the Western Everglades Restoration Project, or WERP, ecosystem modeling, and fire ecology).

In each case (i.e., for WERP and ecosystem modeling), we discussed what existing climate data products exist, and the gaps in these products leading to future work directions. We paid particular attention to three discussion areas:

1. Which precipitation time scale(s) are of greatest interest to improving the management of the domain?
2. Which precipitation parameters(s) (e.g., mean, trend, extremes, intensity-duration-frequency, etc.) are of greatest interest to improving the management of the domain?
3. Recognizing that any model brings some uncertainty, how might this uncertainty influence management of your domain, and how best to characterize the uncertainty of the precipitation projections for improving the management of the domain?

The workshop began with presentations detailing past experience in creating climate scenarios for user groups in south Florida, challenges and solutions in ecological resilience in WERP, and uncertainty of climate projections. These presentations were followed by a group discussion on user experiences with uncertain data. The afternoon consisted of breakout groups (WERP and ecosystem modeling) focusing on our three discussion areas (above).

A website was created for the event to provide information and the agenda. The agenda and participant list can be accessed in the appendix.

2. Overview of Presentations

2.1 Meeting overview and goals

Dr. Nick Aumen, Dr. Ben Kirtman, Dr. Colin Polsky, and Dr. Johnna Infanti provided an introduction of the days activities. The main points of this overview follow:

- Increased confidence in precipitation forecasts and projections for future research related to the Everglades restoration could be achieved through quantification and reduction of uncertainty of climate model data
- We must learn how to make the best use of available tools and clearly identify the problems we are trying to solve.

- Though there are many tools and data available, much of this is focused on "what-if" projections of the future, involving assumptions about plausible future socio-economic states. These projections do not provide a comprehensive prediction, but are intended for use in determining how robust different decisions or options may be under a wide range of possible futures.
- Currently available tools are based on a top-down approach, where climatologists provide data that are not specific to any group or problem. It would be advantageous to shift to a bottom-up or co-production approach in which climate experiments are explicitly driven by user needs. Though workshops such as this facilitate discussions on possible avenues for co-production, this bottom-up approach is currently not widely used.


Dr. Nick Aumen and audience during meeting overview

2.2 Experience in developing climate projections for South Florida

Dr. Jayantha Obeysekera (South Florida Water Management District) presented some of the past and current research in climate for south Florida water resource management, as well as gaps in existing understanding.

Climate model data, such as the data included in the widely used Coupled Model Intercomparison Project Phase 5 (CMIP5, https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip5, and Taylor et al. 2011), are not well-suited to regional studies due to their coarse spatial resolution. While there have been efforts to downscale these data to spatial scales more relevant to users, these efforts typically assume stationarity (in statistical downscaling), or data are limited for CMIP5 (in dynamical downscaling). Additionally, though both statistical and dynamical downscaled CMIP5 data exist, these data were created with the idea of being useful globally, and are not necessarily targeted toward south Florida. For example, a large push in CMIP5 was to resolve western boundary currents, which are important globally. However, for south Florida, some important processes are evapotranspiration (ET) and sea breezes, which are not parameterized well in climate models and were less of a priority in global downscaling efforts.

Prior research in south Florida was based on a scenario approach assuming future change of + or – 10% in precipitation, a +1.5 degree C change in temperature, and a +0.46 m change in sea level, which were used in a variety of ecological modeling studies (Aumen et al. 2015; Obeysekera et al. 2015). However, this effort was based on a prior phase of CMIP, and this research could benefit from more information on uncertainty about changes, seasonality, extremes, and model performance metrics. Dr. Obeysekera notes that it is difficult to trust climate model data when they do not capture the observed seasonality of precipitation, and that

CMIP5 data showed an opposite response than CMIP3, again causing a loss of credibility. Dr. Ben Kirtman noted that it is reasonable to correct the seasonal cycle of precipitation statistically (and methodologies to correct this are widely in use), and that we need to focus on if the *change* in the seasonal cycle is realistic. This approach could be done though determination of changes to large-scale drivers of precipitation such as the El Niño Southern Oscillation (ENSO) or the Atlantic Multi-Decadal Oscillation (AMO).

2.3 Western Everglades Restoration Project (WERP) Ecological Resilience Measure: Challenges and Solutions

Presented by Dr. Kelly Keefe (United States Army Corps of Engineers), this presentation focused on WERP and how alternative restoration plans can be considered as a case study in this workshop. WERP is part of the Comprehensive Everglades Restoration Plan (CERP), and one of the main goals (and a National Environmental Policy Act requirement) is to compare the restoration performance of an array of alternative plans, ultimately proposing one plan to move forward to restore the western Everglades. The restoration objectives of WERP are to restore freshwater flow paths, flow volumes and timing, seasonal hydroperiods, and historic distribution of sheetflow. The ultimate restoration goals are to reestablish ecological connectivity and ecological resilience of the historic wetland, to reduce wildfires by restoring hydrology, and to restore aquatic low nutrient conditions to reestablish native flora and fauna.

In WERP, alternative restoration plans are ranked on how well they improve conditions for restoration objectives while remaining within planning constraints, which are mainly budget, policy, and time-frame related. For example, one may rank the ability of the WERP plans to reduce the conditions for destructive wildfires associated with overdrainage. A “stress-test” is performed in which variables are held constant within the plans (such as ET, precipitation, etc.), to determine how well each plan preforms under increasingly stressful conditions. As precipitation is a large contributor, the alternative plans, objectives, and goals are impacted by changes in precipitation. However, WERP currently uses synthetic data in their alternative plans, as current climate data was both difficult to implement and less credible than desired. While these alternative plans could benefit from climate data, particularly the likelihood of a given outcome, the path forward is unclear. Though, through continued communication and further interaction, credibility and more targeted analyses are certainly achievable.

2.4 Predictions and Projections of south Florida Precipitation

One of the goals identified in the 2015 USGS-CES Downscaling Technical meeting was consistency in procedures for calculating uncertainty. Presented by Dr. Johnna Infanti (University Corporation for Atmospheric Research, University of Miami Rosenstiel School of Marine and Atmospheric Sciences, Florida Atlantic University, and the United States Geological Survey), this presentation focused on education about existing climate data and topics, and quantification of the uncertainty of precipitation projections.

Dr. Johnna Infanti, Dr. Colin Polsky, and audience

The presentation began with educational material about climate data and modeling, and an introduction to some of the freely available data. Dr. Infanti highlighted the difference between predictions and projections of precipitation, which is a widely understood nuance of climate data, and very important for users to understand. In brief, a climate prediction is an initial condition problem in which a climate model is run from observed initial states, used to predict the upcoming weeks (sub-seasonal predictions), upcoming 1 to 12 months (seasonal predictions), or up to 10-35 years in the future (decadal predictions). The idea behind a prediction is that slowly evolving surface conditions, such as sea surface temperatures (SSTs), will influence the upcoming months or years in a likely way. A projection is a boundary condition problem that is based on assumptions about how the future could develop. In CMIP5, these assumptions are included in a scenario approach, referred to as Representative Concentration Pathways (RCPs). Each RCP describes an emissions scenario based on assumptions about the major driving forces of future emissions, such as physical, ecological, and socio-economical. However, because these scenarios are based on assumptions about how the future could develop, they are not intended to be used as a prediction of the future, and instead should be used as “what-if” scenarios to consider how robust different decisions or options may be under a wide range of possible futures. This distinction is important because users may not be aware of the different types of data available, and depending on their needs, predictions or projections may be more appropriate.

In the remainder of the presentation, Dr. Infanti discussed uncertainty of precipitation projections on seasonal time-scales. The sources of uncertainty of precipitation projections stem from internal variability (natural processes that cause short term changes in climate, which is dominant for the next decade), model uncertainty (arising from incomplete understanding of the Earth system and representation in climate models, dominant after about a decade to 30 years), and scenario uncertainty (we are unsure what the future will hold, dominant after about 50 years, but negligible over most land areas). Dr. Infanti highlighted the uncertainty of downscaled CMIP5 projections of precipitation for November-January (NDJ) 2019 – 2045, and June-August 2019 – 2045 (JJA), i.e. before scenario uncertainty becomes a key player. Uncertainty about the CMIP5 mean change is defined using the coefficient of variation and robustness. NDJ precipitation is projected to increase, and this result is likely to very likely across the entire domain. In JJA, precipitation is projected to increase in the northern part of the domain and decrease in the southern part, and these changes are less certain, with high uncertainty around the transition from wet to dry. Dr. Infanti concluded her presentation with a question to the audience of “What time-scales, spatial resolution(s), and parameters of predictions or projections would interest you?” which kicked off the group discussions.

3. Group Discussions and Breakout Group Outcomes

The intention of the group discussion and breakout groups was to identify overlaps and discrepancies in needs between users, and identify where the needs and knowledge gaps currently exist with respect to climate data. The group discussion (Section 3.1) was held with the entire audience, and much of the focus of this discussion was on proper communication between climatologists and climate data users. The breakout group discussions (Sections 3.2 and 3.3) split the audience into two groups (ecosystem modeling and WERP) depending on interests, to focus on our three discussion areas (see Section 2.1). The ecosystem modeling group focused on how to make existing data more relevant, and the WERP group focused on future directions. However, there were commonalities between both groups such as the need for increased communication and information about projections and more information on the likelihood of future drying or changes to drought events.

3.1 Group Discussion: Impacts of uncertainty on decision making

The main points of this discussion follow:

- Communication and standardization of terms is very important. For example, how a climatologist defines prediction versus projection versus the understanding of a climate data user, how uncertainty is defined across user groups, etc. There is concern that the audience will over-state what they are learning due to disconnects in understanding. A glossary of standardized terms would be very useful.
- Information should be presented with risk assessment, and thresholds or tipping points in the Everglades system should be used to communicate probability. A question the users have is when will a change create an impact of a magnitude significant to the system.
- Users are interested in communication and expert assessment of why one model is better than another, and explanation on why a projection evolves a certain way. Climatologist assessment is an integral part of communication (hurricane forecasts are a great example).

Group Discussion

3.2 Ecosystem Modeling

The ecosystem modeling group consisted of climate data users who mainly use data to run ecological models. This group focused on how to best use existing data for their needs related to our three discussion areas. The main points from each discussion area are included below:

1. **Discussion Topic 1: Parameters**
    a. The most significant areas of focus are changes to the number of drought events, changes to the number of dry days, mean changes in precipitation, and changes in precipitation above or below a certain threshold (e.g., number of days with precipitation above or below 10 to 20 mm). Additionally mentioned were changes in the number of wet days, relative lengths of the wet and dry seasons, and their start and end times.
    b. The above areas of focus are very useful for discussion, but not helpful for the practical purpose of modeling. The modelers need data in netCDF format for temperature, moisture, precipitation, and relative humidity on daily time-steps. Anything more refined than daily is unnecessary. Most group members agreed that if there were better confidence in monthly data, they would be more willing to use monthly data than daily.
    c. The modelers wish to know what models are best for south Florida as opposed to putting all data together in an ensemble of models. Discussion and information on the pitfalls, confidence, how bias correction is or is not applied, etc., is very important, and users want the addition of climatologist assessment.
    d. Developing a superset of models that is generally best over south Florida would be of use. A decision matrix including a range of parameters of interest and what models best represent those parameters would be very helpful.

2. **Discussion Topic 2: Temporal Resolution, Time-Periods, and Spatial Resolution**
    a. The most important temporal resolution is daily as ecological models typically call for this resolution. The most important time-periods are the upcoming year, and 30-40 years from now, but we need to bridge the gap between 1 and 30 years.
    b. Domains of interest include the entire state, but south Florida should have the highest resolution. Resolving the Keys and Dry Tortugas would be useful, also.
    c. Higher spatial resolution is better, but the users are willing to sacrifice higher resolution for more confidence or better performance. There is no need for resolution smaller than 6 km.

3. **Discussion Topic 3: Uncertainty Characterization**
    a. Communication of uncertainty is very important, and the users desire explanation of the calculated uncertainty and models in use. For example, a model might show a projection that is very good for the Everglades, but that model might be the most far-fetched because it does not simulate precipitation well. It is also important to use methods to characterize uncertainty that are familiar across audiences, as data can be easily misunderstood.

b. The user confusion about uncertainty arises not from how much uncertainty (quantitatively) there is around a projection, but what trajectory we are on (i.e., a prediction vs. projection problem).
c. The most important uncertainty characterizations are the full distribution of models, skewness, and robustness. Also mentioned were the best and worst case based on the models. The users desired bar graphs and maps for best understanding. An important question is that of robustness, e.g., how likely (or unlikely) does an outcome need to be before we can make a decision, the idea of how robust an outcome needs to be may differ based on context, such as individual user or decision.

3.3 WERP

The WERP group focused on the gaps in existing data, and the spirited atmosphere of the resulting discussion did not specifically follow the above topical areas. The priorities of this group and main discussion points follow:

- **Priorities:**
    - Changes in the number of extreme events (droughts and pluvials), 100-year flood and drought frequency, changes in drivers of climate (ENSO, AMO, etc.), changes in solar radiation and other drivers of ET, below-groundwater level and the risk of fire, Everglades water temperature, joint probability distribution of rainfall extremes, storm surges, and groundwater table for coastal areas.

WERP Breakout Group

    - 10-year predictions of extremes and non-stationarity assumptions, both in the form of time-series and spatial distribution, on interannual and decadal time-scales. Users desire the probability density functions of changes, as well as probabilistic and deterministic representation of data.
    - A spatial resolution of 2km x 2km on hourly to daily time-steps (currently not available).
- **Main Discussion Points:**
    - A question was raised that as we obtain new data, is the uncertainty getting smaller? Or, perhaps the question should be do we better understand the sources of uncertainty and are they well-quantified? As advances are made in understanding and computing, climate models become more credible, thus climatologists are more certain about the range of uncertainty presented in models. However, there are still uncertainties in future emissions rates.
    - Climatologists attempt to tell hydrologists what is going to change under certain climate change scenarios, but hydrologists want the reason why the change will

occur, i.e., what is the change in physical mechanisms leading to a change in local or regional precipitation?
    - For the upcoming 1 to 30 years, the question of future precipitation change could be treated as a forecast problem. Because scenario uncertainty does not dominate until roughly 50 years, the prediction problem is the lower bound. However, decadal predictions are not at the level of, for example, seasonal climate predictions.
- **Hydrology needs:** A standard climate data set to drive a hydrological model. 2km x 2km hourly to daily data.
- **Fire ecology needs:** Weekly and daily data for prescribed fires, but hourly data is necessary for firefighting. Precipitation deficit and temperature determines fuel for fire and time-scale for fire growth, while ignitability is dependent on moisture. Fire/weather indices use weekly to monthly data on time-periods of seasonal climate predictions.

4. The path forward

The initial goals of this workshop were to seek input from our user groups, which would then provide the basis for a peer-reviewed scientific manuscript tailored to improve awareness of how climate science and data can support natural resource activities in south Florida. The workshop served to identify future climatological scientific research directions that will advance climate modeling science while taking into consideration user needs, the need for outputs such as an online portal including data and educational materials, and the need for improved communication between climate scientists and climate data users. We identify some practical goals and tailored outputs and research directions based on user needs, summarized as follows:

1. **Tailored outputs**
    a. An online portal including graphical forecasts, data, information about climate models, and resources on climate data with a teaching or informational focus. This portal should utilize language and techniques that span disciplines, and include a glossary of important terms.
    b. Improved communication between climate scientists and climate data users, using terminology and methods that span both user groups. Continued communication by skilled communicators who can translate scientific concepts from one domain to scientists and practitioners in other domains will serve to reduce misunderstandings, and improve the credibility of data for climate data users.
    c. The need for climate data on a 2km by 2km grid on hourly to daily time-steps that was identified in the 2015 USGS-FAU Downscaling Technical Meeting still exists. This need is underscored by the necessity of including convective-scale processes in climate models, which makes up a large portion of the summer season rainfall in Florida, and processes leading to evapotranspiration.
2. **Research directions**
    a. The WERP working group identified the need for additional assessment beyond statistical characterization of uncertainty that includes information on how teleconnections may change in a changing climate, and if that provides

explanation for a given change. For example, if the change in future precipitation is due to a shift in the El Niño Southern Oscillation (ENSO), etc.

b. The ecosystem modeling working group identified the need for a credible assessment of the climate models used in the assessment of changes and uncertainty, based on the climatologists' expertise, similar to hurricane forecast discussions. A decision matrix including what models best simulate a given parameter, such as summer-time dry events, was proposed as an idea for better decision making under deep uncertainty.
c. While there were many climate parameters highlighted as being important research needs, such as changes in precipitation extremes, changes in mean precipitation, changes in the length of the wet and dry season, both groups discussed the need for research on how drought patterns and variability may change in the future, as well as associated uncertainties and potential process-based explanations for any projected changes. As the Everglades are a wetland system, drying or decreased precipitation in the future has a greater ecological impact than increased precipitation.
d. Identification of a tipping point in the Everglades system, i.e., at what point will the system change significantly or fail. The identification of tipping points necessitates communication between users and climatologists. Alternatively, a tipping point can be defined when climatologists believe we have a level of certainty in the direction of a predicted or projected change.

Concluding Remarks and Reception

Appendix: Agenda and Participant List

AGENDA

SESSION 1 (9:00am to 2:00pm) - SPEAKERS AND GROUP DISCUSSION		
9:00 am	**9:30 am**	**Continental Breakfast and Check-In**
9:30 am	9:45 am	**Welcome and Meeting Goals** Speakers: Dr. Nick Aumen, Dr. Johnna Infanti, Dr. Colin Polsky, Dr. Ben Kirtman
9:50 am	**10:20 am**	**Experience in developing climate projections for South Florida** Speaker: Dr. Jayantha Obeysekera (South Florida Water Management District)
10:20 am	10:30 am	Q and A with Dr. Jayantha Obeysekera
10:35 am	**11:05 am**	**WERP Ecological Resilience Measure: Challenges and Solutions** Speaker: Dr. Kelly Keefe (United States Army Corps of Engineers)
11:05 am	11:15 am	Q and A with Dr. Kelly Keefe
11:15 am	**11:30 am**	**Break**
11:30 am	12:00 pm	**Precipitation uncertainty in downscaled precipitation projections over Florida** Speaker: Dr. Johnna Infanti (University Corporation for Atmospheric Research, Florida Atlantic University, University of Miami, United States Geological Survey)
12:00 pm	**12:10 pm**	**Q and A with Dr. Johnna Infanti**
12:10 pm	1:00 pm	Lunch
1:00 pm	**1:45 pm**	**Group Discussion: Impacts of uncertainty on decision making**
1:45 pm	2:00 pm	**Introduction to Case Study Groups and Discussion Topics** Speakers: Dr. Nick Aumen, Dr. Johnna Infanti
SESSION 2 (2:15pm to 4:15pm) - CASE STUDY GROUP DISCUSSIONS		
2:15 pm	2:50 pm	Discussion Topic 1: High Priority Precipitation Parameters and Variables
2:50 pm	**3:15 pm**	**Discussion Topic 2: Time Periods, Temporal Resolution, Spatial Resolution**
3:15 pm	3:30 pm	Break
3:30 pm	**4:15 pm**	**Discussion Topic 3: Uncertainty Characterization**
SESSION 3 (4:15pm to 6:00pm) - WRAP-UP AND RECEPTION		
4:25 pm	**5:00 pm**	**Wrap-Up and Concluding Remarks** Speaker: Dr. Johnna Infanti, Dr. Nick Aumen, Dr. Colin Polsky, Dr. Ben Kirtman
5:00 pm	6:00 pm	Networking Reception

Steering Committee:

- Colin Polsky, Director, Florida Center for Environmental Studies; Professor, Geosciences, FAU
- Nick Aumen, Regional Science Advisor, USGS
- Ben Kirtman, Director, Cooperative Institute for Marine and Atmospheric Studies; Director, Cener for Computational Science climate and Environmental Hazards Program; Professor, Atmospheric Sciences, RSMAS
- Dorothy Sifuentes, Supervisory Hydrologist, USGS
- John Stamm, Supervisory Hydrologist, USGS
- Jayantha Obeysekera, Chief Modeler, Hydrologic & Environmental Systems Modeling, South Florida Water Management District
- Johnna Infanti, Postdoctoral Researcher, Postdocs Applying Climate Expertise Fellowship, University Corporation for Atmospheric Research, USGS, FAU, RSMAS

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