Executive Summary

Title: Modeling ecosystem dynamics in the Indian River Lagoon and assessing the potential impacts of climate change

Project applicant: Mingshun Jiang, Harbor Branch Oceanographic Institute, Florida Atlantic University, 5600 US 1 N, Ft. Pierce, FL 34946, Phone: 772-242-2254, Email: jiangm@fau.edu.

Amount of request: $48,317

Match: $21,956 (FAU)

Project description: We propose to develop a coupled hydrodynamic-ecosystem model for the Indian River Lagoon (IRL) and then use the model 1) to understand IRL ecosystem dynamics including key factors and associated processes controlling the water quality and ecosystem, and 2) to assess the impacts of climate change including warm temperature and sea level rise on the IRL ecosystem.

Project location: Indian River Lagoon

IRL location map:

Project boundary map: Same as above

CCMP action plans addressed: OSDS-3 (high), SG-1 (high), CC-2 (medium), CC-3 (medium)

Project outputs: 1) A coupled hydrodynamic-ecosystem model for the Indian River Lagoon, and 2) A report detailing the IRL ecosystem dynamics including key factors and associated processes that control the water quality and ecosystem, and potential impacts of climate change.

NEP core element addressed: Ecosystem status and trends.

List of CCMP action plans addressed: OSDS-3, SG-1, CC-2, CC-3
Modeling ecosystem dynamics in the Indian River Lagoon and assessing the potential impacts of climate change

IRLCCMP priorities to be addressed (Ranking)

- OSDS-3 (high)
- SG-1 (high)
- CC-2 (medium)
- CC-3 (medium)

Project period: October 1, 2017 – September 30, 2018

Project costs: $70,273 (requested - $48,317, match - $21,956)

Principal Investigator

Mingshun Jiang
Harbor Branch Oceanographic Institute
Florida Atlantic University
5600 US 1 N
Ft. Pierce, FL 34946
Phone: 772-242-2254
Email: jiangm@fau.edu

May 8, 2017
A. Project goals and objectives

Located along the Florida’s east-central coast, the Indian River Lagoon (IRL) is a shallow (mean depth ~0.8 m) and narrow (~3 km wide) estuary extending 251 km between Jupiter Inlet and Ponce Inlet (Figure 1; Steward and Van Arman 1987). The IRL is considered one of the most diverse estuaries in North America valued at $3.7B annually (Hazan and Sawyer, 2008). In the last several years, this system has suffered from massive and prolonged macroalgae and phytoplankton blooms in 2010-2011 (Superbloom), brown-tide blooms in 2012-2013 and 2015, extensive seagrass loss and other damages (see, e.g. Gobler et al. 2013; Philips et al. 2014; Lapointe et al. 2015).

The IRL sub-regions are only weakly connected through tidal mixing, through a few narrow inlets, and wind mixing, with residence time varying from a few days in the south or near the inlets to more than one year in the north (Smith, 1993) and the water properties (e.g. salinity) are spatially heterogeneous (Figure 1). As such the system is susceptible to large spatial and temporal variability. For example, seagrass distribution and its temporal variability (as measured by normalized standard deviation) are highly heterogeneous (Figure 1). This is likely further exacerbated by the aggregated nature of the human populations and associated activities, which lead to a fragmented system with poor connectivity and generally strong north to south gradients of nitrogen (N) and phosphorus (P) with much higher nitrogen and N/P ratio to the north (Lapointe et al. 2015). The heterogeneity of these factors is likely also reflected in the spatial distributions of phytoplankton (Gobler et al. 2013; Philips et al. 2014). Thus understanding of this heterogeneity is important to understanding the IRL ecosystem dynamics.

Fig. 1. Left panel: seagrass coverage (green) in 2009 (Morris et al. 2015); mid-left panel: heterogeneous monthly mean surface salinity in August 2002 (source: http://mrcirl.org/water/saldata.html); mid-right panel: normalized standard deviation of seagrass coverage within each subarea shown in the left panel (re-computed from Morris et al. 2015); and right panels: Concentrations of a) total dissolved nitrogen and b) nitrogen to phosphorus ratios in divided regions (organized from north to south) in the Indian River Lagoon during the 2011 dry and wet seasons and the 2012 wet season (for stations see Fig. 1). The acronyms are: ML – Mosquito Lagoon, BR-Banana River Lagoon, NIRL – northern IRL, CIRL-central IRL, SIRL-southern IRL, and REF-reference.

Significant efforts have been undertaken to investigate the causes of these abnormal events (e.g. Gobler et al. 2013; Philips et al. 2014; Lapointe et al. 2015). These studies point to two important factors, 1) the hypersaline conditions due to the prolonged drought during 2006-2010, before the Superbloom, and 2) nutrient conditions including N/P ratios. Other processes including the competition between macroalgae, phytoplankton and seagrass, reduced grazing due to hypersaline conditions, and slow release of nutrients due to seagrass die-offs, are also deemed important. Yet, there remains a lack of a coherent and systematic view of these events and many processes are either not well understood or quantified.

Climate change and human activities will strongly impacts the IRL ecosystem. For example, sea level rise (SLR) may affect both the lagoon connectivity and the seagrass coverage, through changing
water depth alone. Depending on the areas, however, various factors driven by climate change may not be pushing things toward the same direction. For example, increase in precipitation (Weiland et al., 2012) may negate much of the effects of increasing air temperature on the lagoon salinity (through evaporation). Given the complexity of the IRL ecosystem and threat of climate change and human activities, an integrative modeling approach is needed to systematically examine the IRL ecosystem dynamics and to assess the impacts of climate change.

Herein we propose such a multi-year study. Our goals are to 1) understand the ecosystem dynamics including nutrient cycles, phytoplankton-macroalgae competition, grazing control, and seagrass dynamics, and 2) to investigate the potential impacts of climate change on the IRL ecosystem including harmful algal blooms and seagrass coverage.

This is a multi-year project with first focusing on model development, second year testing/calibration of the model, and third year numerical simulations and analysis. **The first year has been funded and the research is under way.** During the second year, our specific objectives are,

1. Complete the development of the IRL ecosystem model and coupled with the hydrodynamic model
2. Conduct and calibrate numerical simulation for a chosen period (2010-2013); and
3. Analysis of the model results to understand the key drivers and associated processes controlling the IRL ecosystem.

To achieve above objectives, a coupled physical-ecosystem model will be developed for the IRL and this model will be used to conduct numerical simulations for 2006-2015, re-construction of the Superbloom and brown tides events, sensitivity experiments, and climate projections.

**Available data** – Abundant water quality data for the lagoon have been collected in the last several decades, which provide a solid basis for analysis and testing the model. The first dataset, compiled by the SJRWMD, includes water quality data from a monitoring network of more than 100 stations, seagrass coverage and macro-algae distributions. The second dataset was collected by Drs. Lapointe and Hanisak at HBOI, which includes 1) nutrient data and stable isotopes of N:P ratios in macro-algae and macrophytes at 20 selected stations, 2) water quality data at 9 LOBO stations in the central-southern lagoon since 2014, and 3) watershed nutrient loadings from OSTDS and stormwater runoff.

**Model development** - The numerical model will be based on the open source Delft3D modeling system, which comprises of a suite of well-established modules including hydrodynamics, water quality, and biology. The model has been widely used for coastal studies including phytoplankton blooms, water quality, sediment transport and morphology, and coastal inundation (e.g. Chen et al. 2006). The hydrodynamic model is driven by freshwater inputs (rivers and precipitations), tides, and meteorological forcing, and the tidal forcing. The current model grid has a resolution of 50 m in the IRL (Figure 2, left). This model has been developed and run for two years (2013-2014), and calibrated with available data.

An IRL ecosystem model (Figure 2, right) will be developed and coupled with the physical model. This is building on previous modeling efforts in the Southeast Florida estuaries (Fong and Harwell 1994, Sheng et al. 2009). The model will include both nitrogen and phosphorous, which will be separated into several inorganic species, and four dominant types of phytoplankton (diatoms, dinoflagellates, cyanobacteria, and *Aureoumbra lagunensis*). Silicate is generally not considered a limiting nutrient in this area, although it can become relatively low (<1 mg/l) (Phlips et al. 2011), and hence will not be included in the model. The macroalgae and seagrasses are represented with one variable each and the seagrass parameterization will be largely based on the dominant species, shoal grass Halodule wrightii. The model will also include variables to represent organic matter, and dissolved oxygen. Choices of the model parameters will be based on literature values in this and nearby areas.

The IRL mainly derives its nutrients from surface runoff and groundwater inputs through sediment fluxes. The watershed input for our modeling including river discharges and nutrient fluxes will be derived from the Hydrological Simulation Program—Fortran (HSPF) model output provided by SJRMWD. The sediment fluxes consist of two parts: terrestrial groundwater (fresh) discharge within 20 m of the coastline and marine (saline) sediment flux. The terrestrial groundwater nutrient flux can be
estimated from historical data (e.g. Martin et al. 2007) and available OSTDS input information collected by Dr. Lapointe at HBOI. The marine sediment fluxes will be computed internally within the model.

**Baseline simulation and process studies** - A one-year spin-up simulation will be carried out using climatological mean forcing (derived from multi-year means of historical data). Sensitivity experiments will be carried out to test and finalize key model parameters using mean seasonal cycles of major variables such as temperature, salinity, nutrients, chlorophyll, and dissolved oxygen concentrations derived from historical data. A 10-year simulation (2006-2015) will be carried out using the end results of the spin-up simulation as initial conditions. Using this simulation, we will compute the means and standard deviations of key parameters (nutrients, chlorophyll, macro-algal biomass, and seagrass coverage) over time and space. The results will be analyzed to examine 1) the residence time and connectivity of the IRL subregions, 2) impacts of nutrient fluxes from river runoff, groundwater, and sediment (Martin et al. 2007), and 3) dynamics of phytoplankton and macro-algal blooms, and seagrass successions and die-off (Phillips et al. 2014). This simulation will be used as a baseline simulation.

**Sensitivity experiments** – We will explore the parameter space using Monte-Carlo simulations for key model parameters (e.g., growth rate, grazing rate, nutrient quota) because of their known uncertainty. Values of these model parameters will be shifted to the left and right from the standard values chosen after the model calibration/validation. Then a set of randomly selected parameter combinations will be used to run the model. The results of these experiments will be used to define the envelope of the baseline simulation. With these experiments, one can assess how robust/stable the ecosystem state is within the current modeling framework.

**Perturbation experiments of varying external conditions** – We will examine the stability of the current attraction basin by perturbing the external forcing conditions, a useful method for detecting regime shift. For example, we may increase precipitation by 10% throughout the modeling period to see if the brown tides still occur in 2012-2013. Similarly, we can test the importance of SLR, air temperature, nutrient inputs from runoff and OSTDS.

**Climate projections** – To understand the potential impacts of climate change and human activities, we will project future ecosystem state under various management and climate change scenarios for 2020 and 2050 using IPCC RCP8.5 scenario. Four parameters will be considered, 1) temperature, 2) precipitation (evaporation is computed within the model), 3) SLR and 4) N loading due to population increase (by scaling the current fluxes using projected populations in the future). The anomaly will be superimposed on current conditions for the baseline simulation (IPCC, 2013). The management scenarios considered may include reduced OSTDS and reduced nutrient input (N, P, or both) from surface runoff.

**B. Technical merits and justifications**

A numerical modeling system will serve as an expensive but mechanistic and quantitative tool to examine a system without actually disturbing it. In particular, the model can be used to diagnose key
drivers and processes that control the water quality and ecosystem (e.g. phytoplankton blooms). If properly designed, manipulated experiments will enable us to simulate and evaluate the effects of various management actions (e.g. reduction of nutrient loading), restoration efforts (e.g. seagrass restoration), and climate change (e.g. SLR).

C. Benefits to the IRL

This project will provide critical scientific information for better understanding of the IRL ecosystem and the potential impacts of climate change. For the YR1 objectives, understanding and climate projections of residence time, connectivity and hypersaline conditions will help us to better understand the IRL system, and how it may potentially function in the future. During YR2 and YR3, the ecosystem dynamics in response to climate change and human activities (e.g. seagrass coverage change, impacts of OSTDS) will be studied. We expect all of these will be beneficial to management applications.

D. Local commitment

N/A

E. Project readiness

We expect to complete the tasks of Yr1 project by the end of October 2017. Therefor at the beginning of Yr2 project, the physical model will have been developed and fully calibrated. The initial development of the ecosystem model will have been completed as well. Significant water quality data have been collected (see above). The Yr2 project will start on October 1, 2017 with following timeline:

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Q1 (Oct-Dec)</th>
<th>Q2 (Jan-Mar)</th>
<th>Q2 (Apr-Jun)</th>
<th>Q4 (Jul-Sep)</th>
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<tr>
<td>a) Project starts and planning; and b) development of the ecosystem model, and c) data processing for modeling</td>
<td>a) coupling of the ecosystem model with the hydrodynamic model, b) initial simulation for select periods</td>
<td>Simulation and calibration of the coupled model for two contrasting years (e.g. 2010 vs. 2012).</td>
<td>a) Complete a multi-year (2010-10213) simulation; and b) analysis of the results, presentations and reporting</td>
<td></td>
</tr>
</tbody>
</table>

F. Project monitoring/evaluation and maintenance plans

At the outset of the Yr2 project period, a project plan with a detailed timeline will be developed. The project progress and planning will be conducted at the end of each quarter. Quarterly reports will be produced to evaluate the project progress and to modify the plan.

The PI has been actively seeking funding for modeling the IRL ecosystem. Currently one related proposal is under review by NIH review, in which the PI, in collaboration with colleagues at HBOI, seeks to model the IRL ecosystem and to understand the bloom dynamics and the impacts on human health. The PI will continue to pursue funding from other sources.

G. Outreach and education

The project results will be presented and communicated with local stakeholders and academia through various venues (emails, workshops, meetings) including two formal presentations (one at the annual IRL symposium, and the other through the Ocean Science Lecture Series, both at HBOI). We also expect to produce one draft manuscript by the end of the first year for publication. The project results will also be incorporated into the Semester By The Sea class (~20 students) and the newly installed Marine Science MS degree program (beginning fall 2017), both of which the PI is teaching at HBOI.

H. Experience and past performance

Mingshun Jiang (PI, Associate Research Professor) has a background in fluid dynamics and physical oceanography, and more than 15 years of coupled physical-ecosystem modeling experience. Funded by NSF, NOAA and MWRA, Dr. Jiang has been developing a number of coastal water quality and ecosystem models in several estuarine, coastal and shelf regions and published more than 28 peer-reviewed journal papers. He has two ongoing projects related to the IRL: 1) studying the IRL ventilation rate using in situ monitoring and modeling, funded by Save Our Sea license plate, and 2) studying the water quality and carbon cycle to understand the impacts of freshwater input from Lake Okeechobee on the St. Lucie estuary and adjacent reefs area, using field surveys and modeling, funded by NOAA. Last year, PI Jiang was funded by the IRLNEP (Yr1 of this proposal). The project is ongoing but significant progress have been made in improving the hydrodynamic model and model calibration (Jiang, 2017).
I. Special requirements

This project will provide critical information regarding the vulnerabilities of IRL ecosystem to climate change including increasing air temperature and SLR, all of which may help management decisions such as targeted restoration of seagrass and reduction of nutrient loading. The outreach program will help promoting the climate change awareness and change of citizen behaviors.

J. Project funding

a. Partnership and cost sharing

To achieve our modeling objectives, we will partner with SJRWMD, SFWMD, Drs. Brian Lapointe, Dennis Hanisak, and Jim Sullivan at HBOI, and other researchers to develop and test the model. Dr. Jiang will commit 1.5 months additional effort to this project as an in-kind match. The match will be documented through a financial report that includes the effort allocation from FAU.

\[
\begin{align*}
\text{Requested Grant Funds} & \quad \text{Match Funds} \\
\$48,317 & \quad \$0 \\
\text{Value of In-kind Match (volunteer labor time is $22.14/hr)} & \\
\$21,956 & \\
\text{Match as percentage of Total Project Costs} & = \boxed{45\%}
\end{align*}
\]

b. Project budget

<table>
<thead>
<tr>
<th>Task number</th>
<th>Task description</th>
<th>IRL funding amount</th>
<th>Cost share amount</th>
<th>Cost-share sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Development of the ecosystem model and data processing</td>
<td>$8,000</td>
<td>$4,000</td>
<td>FAU</td>
</tr>
<tr>
<td>2</td>
<td>Coupling of hydrodynamic and the ecosystem model and initial testing</td>
<td>$8,000</td>
<td>$4,000</td>
<td>FAU</td>
</tr>
<tr>
<td>3</td>
<td>Simulation and calibration of the coupled model for two chosen years</td>
<td>$16,000</td>
<td>$8,000</td>
<td>FAU</td>
</tr>
<tr>
<td>4</td>
<td>Completion and validation of a multi-year simulation and result analysis</td>
<td>$16,317</td>
<td>$5,956</td>
<td>FAU</td>
</tr>
</tbody>
</table>


1. Mingshun Jiang – 1.5 months support (requested) and 1.5 month (match).
2. Research Tech (TBD) - 4 months support (requested).

J2. Fringe Benefits (if charged as direct costs) ($7,624 – requested, $3,324 - match)

1. Fringe benefits are calculated at 29.25% for Faculty, 32.25% for research technician.

J3. Other Direct Costs ($0)

J4. Indirect costs ($15,998 – requested, $7,270 - match)

The IDC rate is 49.5% F&A over the base cost.

J5. Total direct and indirect costs ($48,317 – requested, $21,956 - match)

K. References cited


Smith N. P. 1993, Estuaries 16:739-746


ATTACHMENT A – STATEMENT OF WORK

Modeling ecosystem dynamics in the Indian River Lagoon and assessing the potential impacts of climate change

I. INTRODUCTION

Located along the Florida’s east-central coast, the Indian River Lagoon (IRL) is a shallow (mean depth ~0.8 m) and narrow (~3 km wide) estuary extending 251 km between Jupiter Inlet and Ponce Inlet (Figure 1; Steward and Van Arman 1987). The IRL is considered one of the most diverse estuaries in North America valued at $3.7B annually (Hazen and Sawyer, 2008). In the last several years, this system has suffered from massive and prolonged macroalgae and phytoplankton blooms in 2010-2011, typically referred to as Superbloom, unprecedented brown-tide blooms in 2012-2013, extensive seagrass die-off (with some signs of recovery recently), and unusual mortalities of protected species, most notably manatees, dolphins and pelicans (see, e.g. Gobler et al. 2013; Philips et al. 2014; Lapointe et al. 2015).

The IRL sub-regions are only weakly connected through tidal mixing, through a few narrow inlets, and wind mixing, with residence time varying from a few days in the south or near the inlets to more than one year in the north (Smith, 1993) and the water properties (e.g. salinity) are spatially heterogeneous. As such the system is susceptible to large spatial and temporal variability. For example, seagrass distribution and its temporal variability (as measured by normalized standard deviation) are highly heterogeneous. This is likely further exacerbated by the aggregated nature of the human populations and associated activities, which, coupled with physical dispersion, lead to strong north to south gradients of nitrogen (N) and phosphorus (P) with much higher nitrogen and N/P ratio to the north (Lapointe et al. 2015). The heterogeneity of these factors is likely also reflected in the spatial distributions of phytoplankton (Gobler et al. 2013; Philips et al. 2014). Thus understanding of this heterogeneity is important to understanding the IRL ecosystem dynamics.

Significant efforts have been undertaken to investigate the causes of these abnormal events (e.g. Gobler et al. 2013; Philips et al. 2014; Lapointe et al. 2015). These studies point to two important factors, 1) the hypersaline conditions due to the prolonged draught during 2006-2010, before the Superbloom, and 2) nutrient conditions including N/P ratios. Other processes including the competition between macroalgae, phytoplankton and seagrass, reduced grazing due to hypersaline conditions, and slow release of nutrients due to seagrass die-offs, are also deemed important. Yet, there remains a lack of a coherent view of these events and many processes are either not well understood or quantified.

Climate change and human activities will strongly impacts the IRL ecosystem. For example, sea level rise (SLR) may affect both the lagoon connectivity and the seagrass coverage, through changing water depth alone. Depending on the areas, however, various factors driven by climate change may not be pushing things toward the same direction. For example, it is projected that Florida waters may experience 10% increase in precipitation by 2100 (Weiland et al., 2012). This, along with the expected increase in connectivity, may negate much of the effects of increasing air temperature on the lagoon salinity (through evaporation). Given the complexity of the IRL ecosystem and threat of climate change and human activities, an integrative modeling approach is needed to systematically examine the IRL ecosystem dynamics and to assess the impacts of climate change.

Herein we propose such a multi-year study. Our goals are to 1) understand the ecosystem dynamics including nutrient cycles, phytoplankton-macroalgae competition, grazing control, and seagrass dynamics, and 2) to investigate the potential impacts of climate change on the IRL ecosystem including harmful algal blooms and seagrass coverage.
II. OBJECTIVES

This is a multi-year project with first focusing on model development, second year testing/calibration of the model, and third year numerical simulations and analysis. The first year has been funded and the research is under way. During the second year, our specific objectives are,

1) Complete the development of the IRL ecosystem model and coupled with the hydrodynamic model
2) Conduct and calibrate numerical simulation for a chosen period (2010-2013); and
3) Analysis of the model results to understand the key drivers and associated processes controlling the IRL ecosystem.

III. LOCATION OF THE PROJECT

The modeling area will cover the entire lagoon and adjacent coastal area (Figure 1).

IV. SCOPE

To achieve above objectives, a coupled physical-ecosystem model will be developed for the IRL and this model will be used to conduct numerical simulations for 2006-2015, re-construction of the Superbloom and brown tides events, sensitivity experiments, and climate projections.

Available data – Abundant water quality data for the lagoon have been collected in the last several decades, which provide a solid basis for analysis and testing the model. The first dataset, compiled by the SJRWMD, includes water quality data from a monitoring network of more than 100 stations, seagrass coverage and macro-algae distributions. The second dataset was collected by Drs. Lapointe and Hanisak at HBOI, which includes 1) nutrient data and stable isotopes of N:P ratios in macro-algae and
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An IRL ecosystem model (Figure 2, right) will be developed and coupled with the physical model. This is building on previous modeling efforts in the Southeast Florida estuaries (Fong and Harwell 1994, Sheng et al. 2009). The model will include both nitrogen and phosphorous, which will be separated into several inorganic and organic species, and four dominant types of phytoplankton (diatoms, dinoflagellates, cyanobacteria, and *Aureoumbra lagunensis*). Silicate is generally not considered a limiting nutrient in this area, although it can become relatively low (<1 mg/l) (Phlips et al. 2011), and hence will not be included in the model. The macroalgae and seagrasses are represented with one variable each and the seagrass parameterization will be largely based on the dominant species, shoal grass *Halodule wrightii*. The model will also include variables to represent organic matter, and dissolved oxygen. Choices of the model parameters will be based on literature values in this and nearby areas.

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**Baseline simulation and process studies** - A one-year spin-up simulation will be carried out using climatological mean forcing (derived from multi-year means of historical data). Sensitivity experiments will be carried out to test and finalize key model parameters using mean seasonal cycles of major variables such as temperature, salinity, nutrients, chlorophyll, and dissolved oxygen concentrations derived from historical data. A 10-year simulation (2006-2015) will be carried out using the end results of the spin-up simulation as initial conditions. Using this simulation, we will compute the means and standard deviations of key parameters (nutrients, chlorophyll, macro-algal biomass, and seagrass coverage) over time and space. The results will be analyzed to examine 1) the residence time and connectivity of the IRL subregions, 2) impacts of nutrient fluxes from river runoff, groundwater, and sediment (Martin et al. 2007), and 3) dynamics of phytoplankton and macro-algal blooms, and seagrass successions and die-off (Phlips et al. 2014). This simulation will be used as a baseline simulation.

**Sensitivity experiments** – We will explore the parameter space using Monte-Carlo simulations for key model parameters (e.g., growth rate, grazing rate, nutrient quota) because of their known uncertainty. Values of these model parameters will be shifted to the left and right from the standard values chosen after the model calibration/validation. Then a set of randomly selected parameter combinations will be used to run the model. The results of these experiments will be used to define the envelope of the baseline simulation. With these experiments, one can assess how robust/stable the ecosystem state is within the current modeling framework.

**Perturbation experiments of varying external conditions** – We will examine the stability of the current attraction basin by perturbing the external forcing conditions, a useful method for detecting regime shift. For example, we may increase precipitation by 10% throughout the modeling period to see if the brown tides still occur in 2012-2013. Similarly, we can test the importance of SLR, air temperature, nutrient inputs from runoff and OSTDS.
Climate projections – To understand the potential impacts of climate change and human activities, we will project future ecosystem state under various management and climate change scenarios for 2020 and 2050 using IPCC RCP8.5 scenario. Four parameters will be considered, 1) temperature, 2) precipitation (evaporation is computed within the model), 3) SLR and 4) N loading due to population increase (by scaling the current fluxes using projected populations in the future). The anomaly will be superimposed on current conditions for the baseline simulation (IPCC, 2013). The management scenarios considered may include reduced OSTDS and reduced nutrient input (N, P, or both) from surface runoff.

V. TASK IDENTIFICATION

Following tasks will be performed through this project period (2017-2018)

- Task 1: Development of the ecosystem model – We will continue to develop and test the ecosystem
- Task 2: Data processing – We will process available historical water quality data for 2010-2013, which include nutrient loading from watershed model(s), OSTS inputs, open boundary conditions, and in situ water quality data for the lagoon (for model validation)
- Task 3: Coupling of the ecosystem model with hydrodynamic model and initial simulations – The ecosystem model will be coupled with the hydrodynamic model and initial simulation will be done for chosen periods (e.g. summer 2012 and summer 2010).
- Task 4: Simulation and calibration of the coupled model for two chosen years (e.g. 2010 vs. 2012) – Two contrasting years (e.g. 2010 - dry with Superbloom vs. 2012 – moderately wet but with brown-tide bloom) will be chosen for the model calibration.
- Task 5: A multi-year simulation (2010-2013) and result analysis – The model results will be analyzed to understand the key drivers and processes that control the IRL water quality and ecosystem
- Task 6: Interim and final reports. – An interim report will be written to summarize the progress of the project; and a final report will be written to present the research findings

VI. TIME FRAMES and DELIVERABLES

We expect to complete the tasks of Yr1 project by the end of October 2017. Therefor at the beginning of Yr2 project, the physical model will have been developed and fully calibrated. The initial development of the ecosystem model will have been completed as well. Significant water quality data have been collected (see above). The Yr2 project will start on October 1, 2017 with following timeline:

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<td>a) Complete a multi-year (2010-10213) simulation; and b) analysis of the results, presentations and reporting</td>
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Deliverables shall include the following,

- Interim report due into the Council office by February 28, 2018.
  
  **Deliverable:** Interim report documenting the model development, numerical simulation, and data.

  
  **Deliverable:** Final report shall include a description of the data and model development, the numerical simulations and the validation, result analysis and a summary of research findings.
All Deliverables shall be sent to the Council office located at:
IRL Council
1235 Main Street
Sebastian, Florida 32958
Deliverables shall be addressed to the attention of Frank Sakuma, Project Manager. Electronic delivery shall be submitted by email to: sakuma@irlcouncil.org

VII. BUDGET

<table>
<thead>
<tr>
<th>Task Line Items</th>
<th>Task Description</th>
<th>EPA CWA 320 Funding</th>
<th>Recipient Cost Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Development of the ecosystem model</td>
<td>$7,000</td>
<td>$3,500</td>
</tr>
<tr>
<td>2</td>
<td>Data processing</td>
<td>$5,000</td>
<td>$2,500</td>
</tr>
<tr>
<td>3</td>
<td>Coupling of the hydrodynamic and ecosystem model; Initial tests</td>
<td>$7,000</td>
<td>$3,500</td>
</tr>
<tr>
<td>4</td>
<td>Simulation and calibration of the coupled model for two chosen years (e.g. 2010 vs. 2012)</td>
<td>$12,000</td>
<td>$6,000</td>
</tr>
<tr>
<td>5</td>
<td>A multi-year simulation (2010-2013) and result analysis</td>
<td>$7,000</td>
<td>$3,500</td>
</tr>
<tr>
<td>6</td>
<td>Interim and final reports</td>
<td>$10,317</td>
<td>$2,956</td>
</tr>
<tr>
<td></td>
<td><strong>Total Project Cost</strong></td>
<td><strong>$48,317</strong></td>
<td><strong>$21,956</strong></td>
</tr>
</tbody>
</table>

Invoices shall be submitted quarterly on a percent task complete basis, with supporting information detailing the source and amount of cost share funding. Any In-Kind match used for cost share funding shall be documented by providing reports detailing labor expended and the relevant pay rate. The labor reports shall quantify the time spent on each project objective as either Grant supported or In-Kind match. A cumulative total of In-Kind match shall be included in the final report.

Works Cited

IPCC. 2013. Climate Change 2013: The Physical Science Basis
Geneva, Switzerland. 1552pp.
Smith N. P. 1993, Estuaries 16:739-746
May 16, 2017

Frank Sakuma  
Chief Operating Officer  
IRL Council COO  

Dear Mr. Sakuma:

This letter serves as an endorsement of the proposal titled “Modeling Ecosystem Dynamics in the Indian River Lagoon and Assessing the Potential Impacts of Climate Change” being submitted by Dr. Mingshun Jiang.

As outline in the proposal budget, FAU is requesting $48,317 in funding from the Indian River Lagoon National Estuary Program and will commit to a match of $21,957. Dr. Jiang will contribute 1.5 months salary to the project from grant funds and an additional 1.5 months effort as match.

We look forward to a productive collaboration should this project be selected for award.

Sincerely,

Tracy Vuong, Assistant Director  
Office of Sponsored Programs  
Division of Research
**FLORIDA ATLANTIC UNIVERSITY**

**Cost Share Form (Institutional Contribution Statement)**

- **Date**: 5/8/2017
- **Sponsoring Agency**: IRLNEP
- **Project Period**: 11/1/2017 to 10/31/2018

**Principal Investigator**: Mingshun Jiang

**Project Title**: Modeling ecosystem dynamics in the Indian River Lagoon and assessing the potential impacts of climate change

### Salaries / Wages:

<table>
<thead>
<tr>
<th>*Names</th>
<th>Effort/MMS</th>
<th>Amount</th>
<th>Total Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mingshun Jiang</td>
<td>1.50</td>
<td>11,363.00</td>
<td>11,363.00</td>
</tr>
</tbody>
</table>

- **Faculty Fringe Benefits (28% or 29.25%)**: 3,324.00
- **AMP Fringe Benefits (31% or 32.25%)**: 
- **SP Fringe Benefits (39% or 40.25%)**: 
- **OPS Fringe Benefits (FICA 7.65%)**: 
- **Expense**: 
- **Travel**: 
- **Equipment**: 
- **Tuition**: 
- **Indirect Cost**: 7,270.00
- **Totals**: 21,957.00

**Signature Approvals:**

- Department Chair
- College Dean
- Director, Sponsored Programs
- FAU/HBOI Foundation (if applicable)

*Auxiliary Accts are not an authorized source of cost share funds. Foundation and SP funds require the approval of the Foundation or Sponsor before it can be included as cost-share.*