# Modeling the Liquid Jungle: Biological-Physical Interactions in Isla Canales de Tierra and nearby Bahia Honda Bay, Panama

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**Abstract:**

There is an increasing demand for the understanding of regional hydrodynamic processes and their potential impacts on the ecosystem in the coastal waters surrounding Isla Canales de Tierra and nearby Bahia Honda Bay (ICT-BHB). This demand comes from the on-going OLI research conducted in this region, such as the installation of Panama Liquid Jungle Laboratory Underwater Tropical Observatory (PLUTO) (S. Gallager), laval transport and recruitment of coastal invertebrates in Bahia Honda Bay (J. Pineda), Tunicate distribution and invasion (M. Carman), and tropic mangrove ecosystem study (I. Valiela). A biological-physical coupled modeling system will provide a unique tool to study this tropical marine ecosystem relatively untouched by pollution and development, providing critical information in terms of circulation pattern, stratification/mixing dynamics, and the potential impact of hydrodynamic processes on the distribution and transport of biological quantities including nutrients and plankton.

High resolution coastline and bathymetry data collected recently by R. Ji and S. Gallager, along with the data from PLUTO and a hydrographic survey proposed here will make it possible for the development of a high-resolution hydrodynamic model in ICT-BHB. This model will serve as a first step towards building a coupled biological-physical modeling system in this region. We propose to conduct hydrographic surveys of temperature, salinity, dissolved oxygen, and fluorescence in the coastal waters around the Isla Canales de Tierra during the dry (February 2007) and wet (October 2008) seasons, and to apply a state-of-the-art hydrodynamic model, the Finite-Volume Coastal Ocean Model (FVCOM), driven by tidal forcing, fresh water input, and surface forcing (wind, heating, and net precipitation). The objective of this modeling study is to (1) quantify the seasonal variation and spatial distribution of water properties, such as temperature and salinity; (2) study the dynamics of stratification/mixing during dry and wet seasons and under different meteorological forcing conditions; (3) gain a better understanding of the dominant hydrodynamic processes that are likely to impact ecosystem dynamics; and (4) identify the needs for future observation and modeling efforts and optimize the design of field work for both physical and ecological studies. We plan to use a lightweight profiling CTD deployed from a small boat supplied by the Liquid Jungle Laboratory (LJL) on Canales and the surveys will extend both east and west along the coast from Canales and include Bahia Honda. The resulting maps of water properties will define the basic temperature, salinity, density structure, their seasonal change, and help identify the relative importance of tidal currents and mixing, surface buoyancy (rain, radiation), terrestrial runoff, wind forcing and mixing, and offshore forcing on local water properties, stratification, and circulation.

**Background**

A major long-term goal of OLI is to improve our scientific understanding of marine ecosystem processes and health that help provide the scientific basis for ecosystem sustainability and environmental conservation/remediation activities. The coastal waters in the Gulf of Chiriqui off southwestern Panama provide a unique setting to advance this goal. The Liquid Jungle Lab (LJL) recently established on Isla Canales de Tierra with OLI help has started to foster innovative research into processes occurring in tropical coastal systems from the jungle canopy, to mangroves, to shallow shelf and deep mesopelagic waters (Figure 1). The waters around Isla Canales de Tierra and nearby Bahia Honda Bay (ICT-BHB) provide a superb natural laboratory to study the relative roles of land input of freshwater, nutrients and particulates through terrestrial runoff, surface forcing (winds, insolation, and precipitation–evaporation) and offshore ocean forcing (tidal, sub-thermocline water rich in nutrients, biota, larger-scale currents) in establishing and sustaining local ecosystems. Coiba Island, located near the shelfbreak off the LJL, has several of the largest coral reefs in the eastern Pacific. The Smithsonian Tropic Research Institute (STRI) supports an active research effort on reef response to natural and anthropogenic forcing, work which compliments LJL.

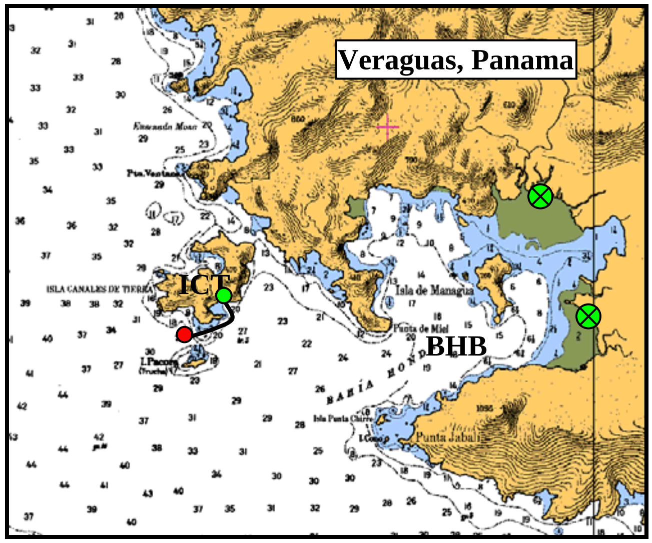


Figure 1. The location of ICT-BHB. ICT: Isla Canales de Tierra; BHB: Bahia Honda Bay. The Liquid Jungle Laboratory and WHOI building are indicated with green dot on ICT. Black line is the 800-m length of 0.68 inch electro-optical cable leading out to Pacora Island where PLUTO (red dot) is deployed at a depth of about 18 m. The cross green circles show where the major mangrove swamps are located. The light blue is the intertidal zone. The background chart was scanned by Gallager from a NOAA/NOS raster nautical chart.

In January 2006 with OLI support, S. Gallager and co-workers installed the Panama Liquid Jungle Laboratory Underwater Tropical Observatory (PLUTO) (Figure 1). Envisaged as a first step towards long-term study of biological, chemical, and physical processes controlling community structure in tropical systems, PLUTO features sensors for salinity, temperature, pressure, water current speed and direction, chlorophyll, turbidity, oxygen, down-welling light at two depths, array of temperature sensors, and an underwater camera. The data are cabled to the LJL, stored and posted on the website (http://4dgeo.whoi.edu/panama) for further analysis. The preliminary data from PLUTO suggest several physical processes which probably strongly influence the local ecosystem, including high frequency internal waves and rapid hydrographic variations associated with freshwater and tidal forcings, and have sparked our interest and collaboration on this fascinating coastal region.

We combined two past proposals into the one proposal submitted here to OLI to study the coastal physical oceanographic environment in ICT-BHB. This new proposal seeks to develop a high-resolution coastal circulation model in this region and use it to explore the relative roles of different physical processes on circulation, stratification, and mixing. We also plan to make the first-ever detailed surveys of water structure (T, S, DO, PAR, fluorescence, turbidity) and currents during the rainy and dry seasons and relate them to the PLUTO time series and our model experiments. This proposal links field measurements with the modeling effort and the model results will help the interpretation of the survey and PLUTO observations and identify critical new field measurements. We view this as an essential first step towards a comprehensive understanding of the coupled biological-physical processes that govern ecosystems in tropical waters.

**Objectives**

This proposal requests support to conduct seasonal hydrographic surveys in the waters surrounding PLUTO including Bahia Honda Bay. We plan to use a small, lightweight internally-recording CTD to profile P, T, C(S), DO, and fluorescence by lowering the CTD to the bottom from a LJL small boat using a hand rope or small winch. We also propose to apply a state-of-the-art hydrodynamic model, the Finite-Volume Coastal Ocean Model (FVCOM), to the ICT-BHB region. The model will be used to gain a better understanding of the hydrodynamic processes and their potential impact on ecosystem dynamics in this region. Specifically, we propose to achieve the following objectives: 1) build a high resolution 3D hydrodynamic model driven by tides, river discharge, rainfall and surface forcing (wind stress and heat flux), 2) quantify the seasonal variation and spatial distribution of water properties, such as temperature and salinity, 3) study the dynamics of stratification in different seasons under different meteorological forcing conditions and fresh water runoff and rainfall regimes, and 4) identify the needs for future modeling and observation efforts and optimize the design of field work for both physical and ecological studies. The development of this tested hydrodynamic model is the first step towards our goal of building a coupled biological-physical model of the region.

**Approach**

FVCOM will be applied to the ICT-BHB domain. FVCOM is a prognostic, unstructured-grid, finite-volume, free-surface, 3D primitive equation coastal ocean circulation model (Chen et al., 2003). Unlike existing coastal finite-difference and finite-element models, FVCOM is solved numerically by the flux calculation in the integral form of the governing equations over an unstructured triangular grid. This approach combines the best features of finite-element methods (grid flexibility) and finite-difference methods (numerical efficiency and code simplicity) and provides a much better numerical representation of momentum, mass, salt, heat, and tracer conservation. In addition, FVCOM includes a mass conservative wet/dry treatment technique to simulate the flooding/drying process over the coastal-estuarine-tidal complex, which is well suited for resolving the large intertidal

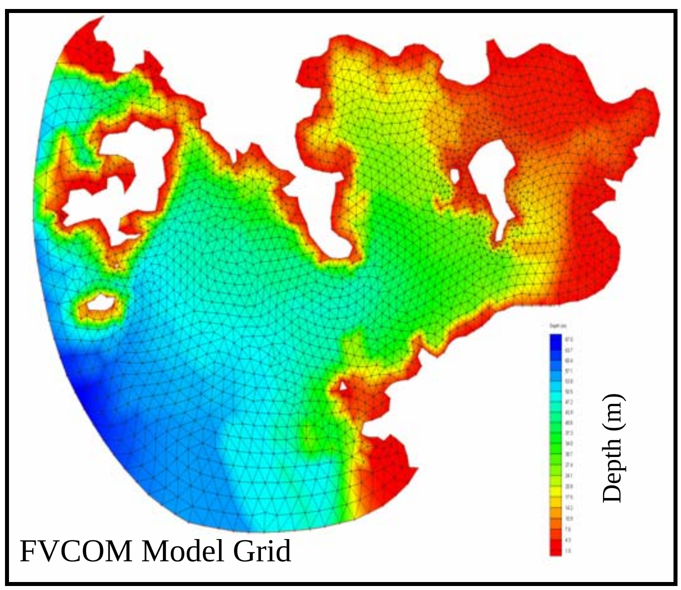


Figure 2. A preliminary configuration of FVCOM grid for the ICT-BHB domain. The bathymetry data were collected during a recent survey conducted by Ji and Gallager, and are shown as filled color contours. The model grid will be further refined as necessary to resolve details near the islands and coastline. The grid is generated in SMS software package.

zone inside BHB. More details about FVCOM can be found at http://codfish.smast.umassd.edu.

The computational domain of FVCOM covers the entire ICT-BHB region, with an open boundary connecting the coastal waters (Figure 2). The model is configured with non-overlapping, unstructured triangular grids in the horizontal and the σ-coordinate transformation in the vertical. The horizontal resolution varies from 30 m to 100 m between adjacent grid points; 20 sigma levels will be used vertically in the model.

The model will run prognostically as an initial value problem forced by an oscillating surface elevation with amplitudes and phases of the $M_2$ tide at the open boundary. After the tide reaches an equilibrium state, fresh water discharge from the rivers will be added into the model domain. We will also examine the influences of net precipitation and surface wind stress and heating on the stratification/mixing process. The residence time of Bahia Honda Bay will be computed in both dry and wet seasons.

**Data acquisition**

The data necessary to configure and run the ICT-BHB FVCOM include initial and boundary conditions, as well as surface forcing. Specifically, the following data have been/need to be collected:

1) High resolution bathymetry and coastline data. We have obtained this dataset during our recent survey (January 2006).
2) Tidal amplitudes and phases at the open boundary. NOAA CO-OP provides tidal prediction for Bahia Honda as a subordinate station with a reference station in Balboa. In addition, a SeaBird Tide Gauge will be installed near ICT by Limeburner and Beardsley to obtain more accurate tidal information.
3) Meteorological data including precipitation and evaporation, surface wind stress and heat flux. Data will be obtained from the Smithsonian Tropical Research Institute at Coiba or Pariba.
4) Initial fields of temperature and salinity. A small, lightweight internally-recording CTD will be used to profile P, T, C(S), DO, and fluorescence along the survey grid which will cover the whole model domain. The survey stations will be determined by the horizontal gradients in water properties. The extent and duration of the surveys will depend on the small boat capabilities and weather conditions.

**Work Schedule**

We will start with data collection, model set-up and preliminary model test in Year 1. After more data being obtained, comprehensive model runs with realistic initial and boundary conditions will be conducted in Year 2. Model results will be compared with data to validate the model. A website will be built for this project to host data and model results. This website can be linked to the LJL main website, and be accessible by other researchers and the general public. Model results will also be synthesized for publications on scientific journals.

**References**

Chen, C., Liu, H., Beardsley, R.C., 2003. An unstructured, finite-volume, three-dimensional, primitive equation Oceanography model: application to coastal Oceanography and estuaries. Journal of Atmospheric and Oceanic Technology 20, 159-186.