

Capitalizing on Coastal Blue Carbon

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A User-Friendly Model for Predicting Greenhouse Gas Fluxes and Carbon Sequestration in Tidal Wetlands

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Background

- Tidal wetlands play an important role in soil-atmospheric exchanges of the greenhouse gases (GHGs) of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O).
- A delicate balance in climate, land uses (nutrient sources), hydrology and other ecological drivers determine the role of wetlands as the net source or sink of GHGs.
- A user-friendly model is needed to predict the GHG fluxes and carbon (C) storage from tidal wetlands.
- The model can facilitate appropriate management of C stocks in tidal wetlands and their incorporation into the C market.



The BWM Wetland Carbon and GHG Model

- The BWM wetland C and GHG model is a non-linear empirical model developed by fitting data for four different wetlands of Waquoit Bay, MA representing biogeochemical gradients.
- The model takes soil temperature, soil salinity, water depth relative to marsh surface, and light as inputs to predict the corresponding CO₂ and CH₄ fluxes.
- The model estimates the potential wetland carbon storage by upscaling the instantaneous predicted fluxes to the growing season and subtracting the corresponding net lateral flux with the bay.
- The model is presented in a simple macro enabled Excel spreadsheet file as a user-friendly engineering tool for coastal carbon management without requiring much input data.



How Can the Model Help?



The model will act as an ecological engineering tool to aid tidal wetland restoration and maintenance projects



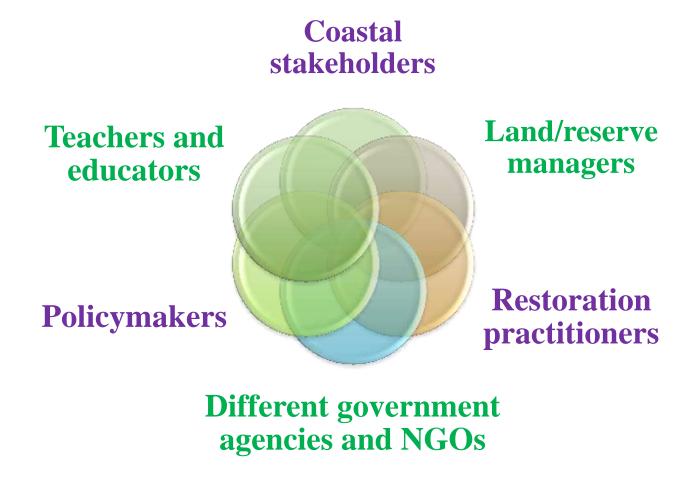
The model will reduce the cost of wetland C and GHG flux monitoring by estimating them from climatic and environmental drivers



The model can predict wetland GHG fluxes and C sequestration under various IPCC climate change and sea level rise scenarios



Beneficiaries and Users





Model Assumptions

- ➤ Coastal salt marshes are productive mainly during the extended growing season (e.g., May to October).
- $ightharpoonup CH_4$ fluxes from tidal wetlands mainly represent CH_4 emissions to the atmosphere.
- ➤ Model is spatially explicit for the tidal salt marshes of Cape Cod area. However, the current model can be extended for similar wetlands of the New England region.
- The net ecosystem carbon balance (NECB) represents the potential C storage in wetlands. NECB = CO_2 sequestration flux- CO_2 and CH_4 emission flux lateral C flux.
- ➤ If lateral flux data are not available, user can assume zero (0) for the net lateral C flux between the wetland and estuary/bay.



Model Structure and Work-Flow

Predicted instantaneous

wetland CO₂ and CH₄

fluxes

Soil temperature (ST), soil **Model Inputs** salinity (SS), water depth (WD), and light (PAR) Water depth Photosynthetically relative to the Soil salinity Soil active radiation marsh (SS, units: **Model** temperature (PAR, units: elevation parts per (ST, units: °C) mircomole/m²/s) (WD, units: thousand) m). Wetland CO₂ and CH₄ fluxes **Model Outputs** Net Ecosystem Carbon Balance (NECB)

Net CO₂ and CH₄

fluxes over the

growing period

Net Ecosystem Carbon

Balance (NECB) in

units of gC/m2 and

metricton C/hectare

Brief Input Data Guide

Enable macros in your Microsoft Excel file (Excel options>trust center> trust center settings> macro setting)

At least 2 sets of input measurement are required (Day time averages and night time averages)

Recommendation is to use 6 sets of observations to incorporate seasonal variation.

Input set	Description
1, 2	Daytime and nighttime average of the input variables at the beginning of the growing period (May- June)
3, 4	Daytime and nighttime averages at the peak of the growing period (July- August)
5,6	Daytime and nighttime average at the end of the growing period (September- October)



Input Measuring Devices



PAR (Light): Photosynthetically active radiation (PAR) represents the fraction of sunlight with a spectral range from 400 to 700 nm, usually expressed in μmol (photons) m⁻² s⁻¹ Measured by using Quantum sensors



Soil Salinity is the salt content in the soil sediment.

Often measured by using Electrical Conductivity meter



Input Measuring Devices



Soil Temperature

Measured by using Digital Thermometers



Water Level measuring device to calculate water depth

Measured by using automatic gauge attached with a sensor



Excel Model Interface

Excel Model Interface



Example Using Two Sets of Inputs

Set 1: Daytime (PAR>300 umole/m²/s)

Average Soil Temperature, ST = 20.43 °C

Soil Salinity, SS = 29.58 ppt

Light, PAR = 1454.29 micromole/m²/s

Water depth, WD = 0.07 m

Set 2: Nighttime (PAR<300 umole/m²/s)

Average Soil Temperature, ST =17.92 °C

Soil Salinity, SS = 30.67 ppt

Light, PAR = 32.52 micromole/m²/s

Water depth, WD = 0.067 m

Click RUN

Outputs

(assuming an extended growing period from May to October and "zero" net lateral flux)

Net CO_2 sequestration = 514.54 gC/m²

Net CH_4 emission = 0.16 gC/m²

Net Ecosystem Carbon Balance = 514.38 gC/m^2 or 5.14 metric ton C/hectare



Application: Scenario Analysis

Scenario

- (A).1% increase in daytime temperature (ST)
- (B). 3% increase in nighttime ST
- (C).0.05m increase in mean water depth (RD) due to sea level rise
- (D). 2% increase in salinity (SS).

Results

NECB will be 494.18 gC/m2 or 4.94 metric ton C/hectare

Interpretation

The assumed temperature and sea level rise will reduce 20.2 gC/m² or 0.20 metric tonC/hectare from the wetland relative to its baseline C storage.



Next Step: Model Generalization

- Model generalization will increase model space (e.g., New England) and time (annual and inter-annual scales) domain.
- The model needs to be tested (i.e., validated) by collecting and gathering more data for GHG and lateral fluxes, and for climatic, environmental and ecological drivers.
- The validation data sets should incorporate seasonal and inter-annual variation, and include different wetland regimes.
- Model generalization and robustness is the subject of our working proposal, BWM Phase 2 (to be submitted to NOAA-NERRS on May 18, 2015)

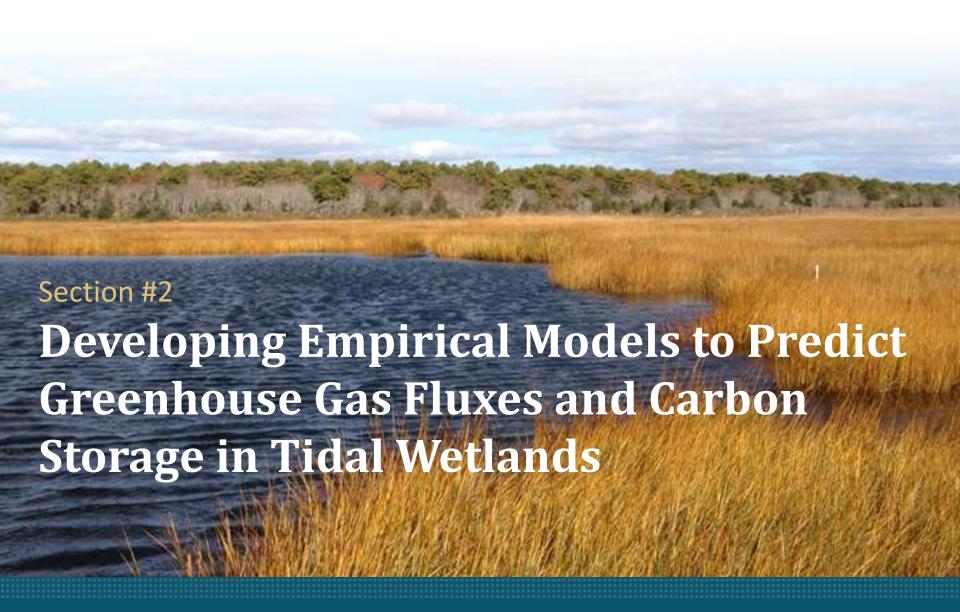


Contact the Developers

• For any query about the model, methodology and Excel spreadsheet, please contact the following persons:

- 1. Dr. Omar I. Abdul-Aziz (email: <u>oabdulaz@fiu.edu</u>; <u>omariaaziz@gmail.com</u>)
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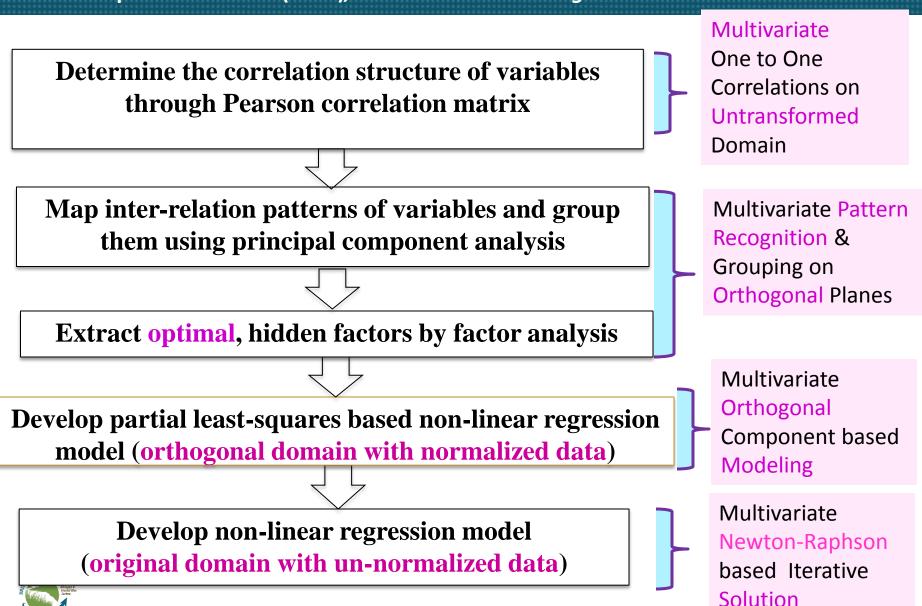
Background

- Modeling and prediction of wetland GHGs (CO₂, CH₄, N₂O) has been an extremely challenging undertaking.
- Available models are mostly mechanistic, often failing to provide spatiotemporally robust predictions.
- We proposed a systematic data-analytics approach to
 - achieve mechanistic insights and determine the relative linkages of wetland GHG fluxes with different climatic, hydrologic, biogeochemical and ecological drivers;
 - classify and group process variables based on their similarity and interrelation patterns;
 - develop parsimonious empirical models to predict wetland
 GHGs by leveraging the mechanistic insights.

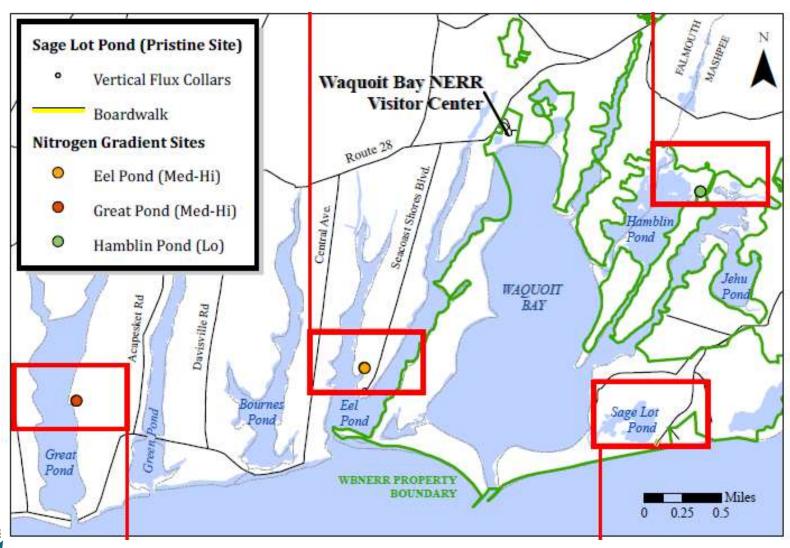


The Data-Analytics Approach

Ishtiaq and Abdul-Aziz (2015), Environmental Management.



Case Study Area: Field campaign 2012-2013 (Salt Marshes, Waquoit Bay NERR, MA)





Collected Data Set (2012-2013)

Low and High Marshes

CO2, CH4 and N2O fluxes

Air Temperature (AT)

Sediment Temperature (ST)

Photosynthetically Active Radiation (PAR)

Sediment Moisture (SM)

Water Level (WL); converted to relative water depth (WD)

Sediment Salinity (SS)

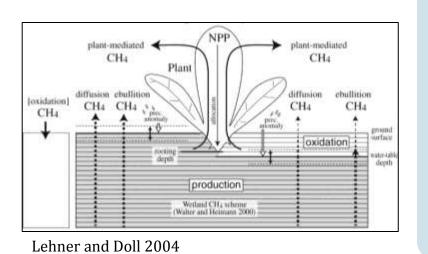
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NO3⁻ and NH4⁺ (2013 only)



Analysis Criteria Based on Water Depth

• Soil water level can play an important role in wetland CO₂ and CH₄ exchanges since it controls aerobic-anaerobic condition driven biogeochemical activities.



Relative linkages and modeling

Classification Criterion

Water above marsh (WD>0)

Flux

Water below march (WD<0)

PAR.

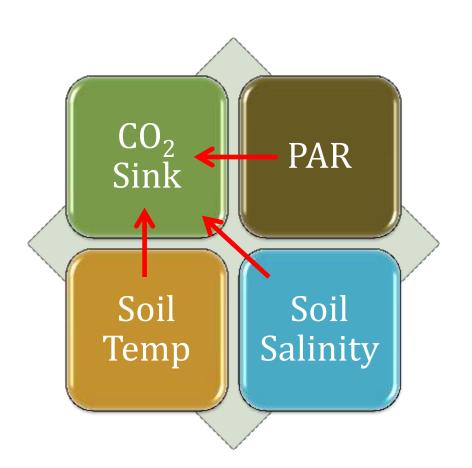
AT, ST,

SM, SS,

рН



CO₂ Sequestration



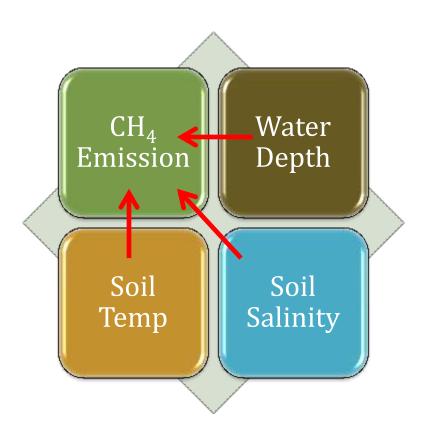
■ Relative Water Depth (WD) was not a strong predictor of net sequestrated CO₂ fluxes.

Therefore, the final predictive model combines data from both WD>0 and WD<0 conditions for model parsimony.



CH₄ Emission

For both WD>0 and WD<0



■ Relative Water Depth
(WD) was a strong
predictor of CH₄ emission
for both WD>0 and WD<0
condition.

☐ Therefore, predictive models were developed for the two cases separately.



Up-scaling to Estimate Net Ecosystem Carbon Balance

- Instantaneous predicted Net CO₂ sequestration and CH₄ emission fluxes were up-scaled over the growing period of 2013 (June to October, 153 days) to calculate **net ecosystem carbon balance** (**NECB**) for Waquoit Bay area.
- NECB = Net CO₂ Sequestration-Net CH₄ Emission Net Lateral C Flux
- Predicted instantaneous C fluxes are in **micromole C/m2** over the growing season. It is then converted to **g C/m2** to estimate NECB.



Handy VBA based Excel Tool to Estimate Wetland Carbon Balance

• Excel Tool developed using Visual Basic



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