FATHOM Model for Florida Bay:
Overview and Applications

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Cosby, Marshall, Nuttle, Boyer
General

• FATHOM is a dynamic, spatially explicit, mass-balance model
• Designed to investigate responses to water movement and salinity in Florida Bay to runoff, climate, tides, and the topography of the Bay
• FATHOM account for the water and salt budgets in each of 54 well-mixed basins
Mr. Natural

“Use the right tool for the job”
** Overview

Model Structure
Bathymetry
Input Data

Applications - Simulations for period 1970-2002
base simulation - goodness-of-fit
coupled to output of 2x2 model
Model Structure

The arrangement of the banks and shoals in Florida Bay effectively divides the bay into a network of interconnected basins with exchange between the basins limited by the shallowness of the banks and the presence of islands in the bay.

Based on bathymetric data for the bay, 54 distinct basins can be identified. These basins form the basic structure of the FATHOM model.

Transfer of water and solutes between basins is controlled by the bathymetry of the banks.
Model Structure

Volume transport across banks
(Velocity) x (Cross-Section Area)

Velocity = f[ friction - depth of flow
substrate material, width of bank, ... ]

X-section = f[ bathymetry - width, depth distribution ]

Manning's Equation

\[
v^2 = \frac{2g(h_1 - h_2)}{1 + 2gn^2wR^{-4/3}}
\]

\[
R = \frac{1}{2} \left[ h_1 - \frac{v^2}{2g} + h_2 \right]
\]
Model Structure

Output variables for Basins

<table>
<thead>
<tr>
<th>Basin State Variable</th>
<th>units</th>
<th>Fluxes Into or Out of the Basins</th>
<th>Water</th>
<th>Solutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Level</td>
<td>m</td>
<td>Transport over banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Area</td>
<td>m²</td>
<td>Groundwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Depth</td>
<td>m</td>
<td>Rainfall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Volume</td>
<td>m³</td>
<td>Runoff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Mass</td>
<td>mol</td>
<td>Evaporation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>psu</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Output variables for Shoals

<table>
<thead>
<tr>
<th>Shoal State Variable</th>
<th>units</th>
<th>Fluxes Across the Shoal</th>
<th>Water</th>
<th>Solutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Level</td>
<td>m</td>
<td>Net Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet Length</td>
<td>m</td>
<td>Total Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Depth</td>
<td>m</td>
<td>Max Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-sect Area</td>
<td>m²</td>
<td>Min Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level Difference</td>
<td>m</td>
<td>Runoff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Conc Diff</td>
<td>psu</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Bathymetry

Combined data sources

More recent “best available data”
USGS bathymetric survey
(interpreted by SFWMD)

Original “best available data”
ENP-FIU based on charts, aerial photographs, local knowledge
## Inputs

**Data Availability**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>ENP platform data (1993 – 2000)</td>
<td>N/A</td>
<td>Rainfall data for Flamingo, Royal Palm, Tavernier, Division 7 (Keys), Division 5 (Everglades)</td>
</tr>
<tr>
<td>Evaporation</td>
<td>N/A</td>
<td>Dalton Law, SFWMD model</td>
<td>Air temperature (mean and range) from Flamingo, Royal Palm and Tavernier, relative humidity and wind speed (seasonal pattern) from Joe Bay</td>
</tr>
<tr>
<td>Fresh water inflow</td>
<td>USGS creek discharge (1996 – 2000)</td>
<td>PHAST, SFWMM, USGS/SICS</td>
<td>TSB flow, S18c flow, S197 flow, S12T flow, P33 level, S196a (Homestead well), Royal Palm rainfall</td>
</tr>
<tr>
<td>Sea level and tides</td>
<td>ENP platform data (summarized by Smith 1997; not used in this study)</td>
<td>N/A</td>
<td>NOAA tide tables, Key West sea level</td>
</tr>
</tbody>
</table>

N/A – no information available
Inputs

Spatial Distribution of Inputs to the FATHOM model

Runoff

Rainfall - Evaporation

Boundary salinity - tides - sea level

Runoff inputs based on “wetland basin” concept to route canal discharge (& wetland net precip) to FATHOM input regions - maintains capability to link different models of runoff
Inputs - Example Climate data 1970 2002

NCDC Division 7

Rainfall

Ave Air Temperature

Palmer Hydrological Drought index
Inputs - Example Freshwater Discharge 1970-2002

Taylor Slough Bridge

Monthly Discharge (10^6 m³/mo), 1970-2002

Annual Total Discharge (10^6 m³/yr), 1970-2002

S18c Bridge

Monthly Discharge (10^6 m³/mo), 1970-2002

Annual Total Discharge (10^6 m³/yr), 1970-2002

S197c Bridge

Monthly Discharge (10^6 m³/mo), 1970-2002

Annual Total Discharge (10^6 m³/yr), 1970-2002
Inputs - Example Boundary Salinity 1991 2002

SERC 26
Monthly Salinity (psu), SERC Station 26

SERC 25
Monthly Salinity (psu), SERC Station 25

SERC 27
Monthly Salinity (psu), SERC Station 27

Annual Mean Salinity (psu), SERC Station 25

Annual Mean Salinity (psu), SERC Station 27
NOAA coops sea level sites

Inputs - Sea Level 1970-2002

Mean Sea Level, cm (above MLLW), Key West

Monthly Mean Sea Level, cm, 70-02, Key West

Annual Mean Sea Level, cm, Key West

Key West
Overview

Model Structure
Bathymetry
Input Data

** Applications - Simulations for period 1970-2002
base simulation - goodness-of-fit
coupled to output of 2x2 model
Model Goodness-of-fit
Simulated vs Observed Salinity
1991 - 2002

SERC salinity sampling sites
Model Goodness-of-fit
Simulated vs Observed Salinity
1991 - 2002
(time series)

North Bay Region
East Bay Region
Model Goodness-of-fit
Simulated vs Observed Salinity
1991 - 2002
(time series)

Northeast Region
Central Region

Aggregated FATHOM Groups

Efficiency %

Ave sim-obs

Northeast Region
Salinity (psu) Duck Key

Central Region
Salinity (psu) Terrapin Bay

Northeast Region
Salinity (psu) Park Key

Central Region
Salinity (psu) Whipray Basin

Northeast Region
Salinity (psu) Butternut Key

Central Region
Salinity (psu) Garfield/Rankin
Model Goodness-of-fit
Simulated vs Observed Salinity
1991 - 2002
(time series)

South Region

West Region
Simulated vs Observed Salinity Distributions
1991 - 2002

All Seasons

Wet Seasons

Dry Seasons
FATHOM runoff input regions

Coupling 2x2 Simulated Discharges to FATHOM

The 2x2 Model grid and structures used to link to FATHOM runoff regions
Hydraulic Applications

• For each basin:
  - residence times,
  - water depths,
  - wetted surface areas, and
  - water volumes.
Hydraulic Applications

• For each shoal:
  - exchange between basins,
  - monthly gross and residual fluxes of water and solutes across each shoal, and
  - velocity profiles
Salinity Applications

- Salinity in each basin
- Salinity by region
- Tracer (salt) time series
- Paleosalinity simulations
  - Uses creek flows from regression models
- Input to seagrass models (see Hebert presentation Wed. morning)
Water Quality Applications

- Total N, NO3, NH4, TON
- Total P, PO4
- Total Organic Carbon
- Temperature
- DO
THANKS!