The Use of Mechanistic Models for Water Quality Management

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Utility of Mechanistic Models

- Simplistic Representation of Reality
  - Cannot Simulate "Everything"
  - All Models are Wrong . . . .
- Interpolate
  - Known and Unknown
- Provides Linkage between
  - Loads and Response Variables
  - Can Determine Important Processes
    - Nutrients/DO/Algae/Light
- Management Strategies
  - Determine Load Reductions to meet WQS
    - Never to Exceed
    - X% Exceedence
    - Duration, Frequency and Magnitude
  - Evaluate Best Management Practices

Mechanistic Models

- Mathematical models based on fundamental equations that produce physical responses to temporal and spatial inputs
- Process-based, time-variable representation of processes
  - Watershed – rainfall/runoff, topography, land use, infiltration
  - Hydrodynamics - circulation, transport, deposition
  - Water Quality – algal growth/death, decay, nitrification, SOD
- Both graphical comparisons and statistical tests are required in model calibration and validation

Types of Mechanistic Models

- Landscape/Loading models
  - Runoff of water and dissolved materials on and through the land surface
  - Erosion of sediment and associated constituents from the land surface
- Receiving water models
  - Flow of water through streams and into lakes and estuaries
  - Transport, deposition, and transformation in receiving waters
- Linked models
  - Combination of landscape and receiving water models

Mechanistic Models -- Linked

Input — **Algorithms** — **Output**

Time series
Meteorology
Streamflow
WQ sampling

Spatial/Landscape
Soils
Topography
Land cover
Pollutant characteristics

Receiving Waters
Physical data
Kinetics data
Fate & transport

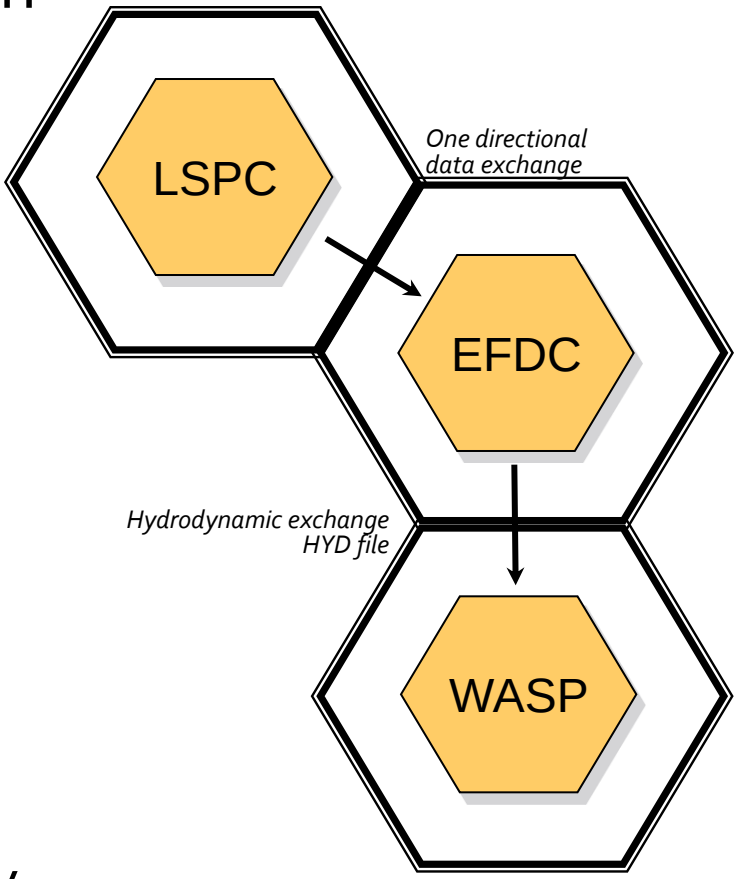
Landscape/ Watershed Models
Hydrology
Buildup
Washoff
Erosion
Overland transport
Fate & transport

Receiving Water Models
Hydraulics
Hydrodynamics
Fate & transport
Scour & deposition
Chemical interactions

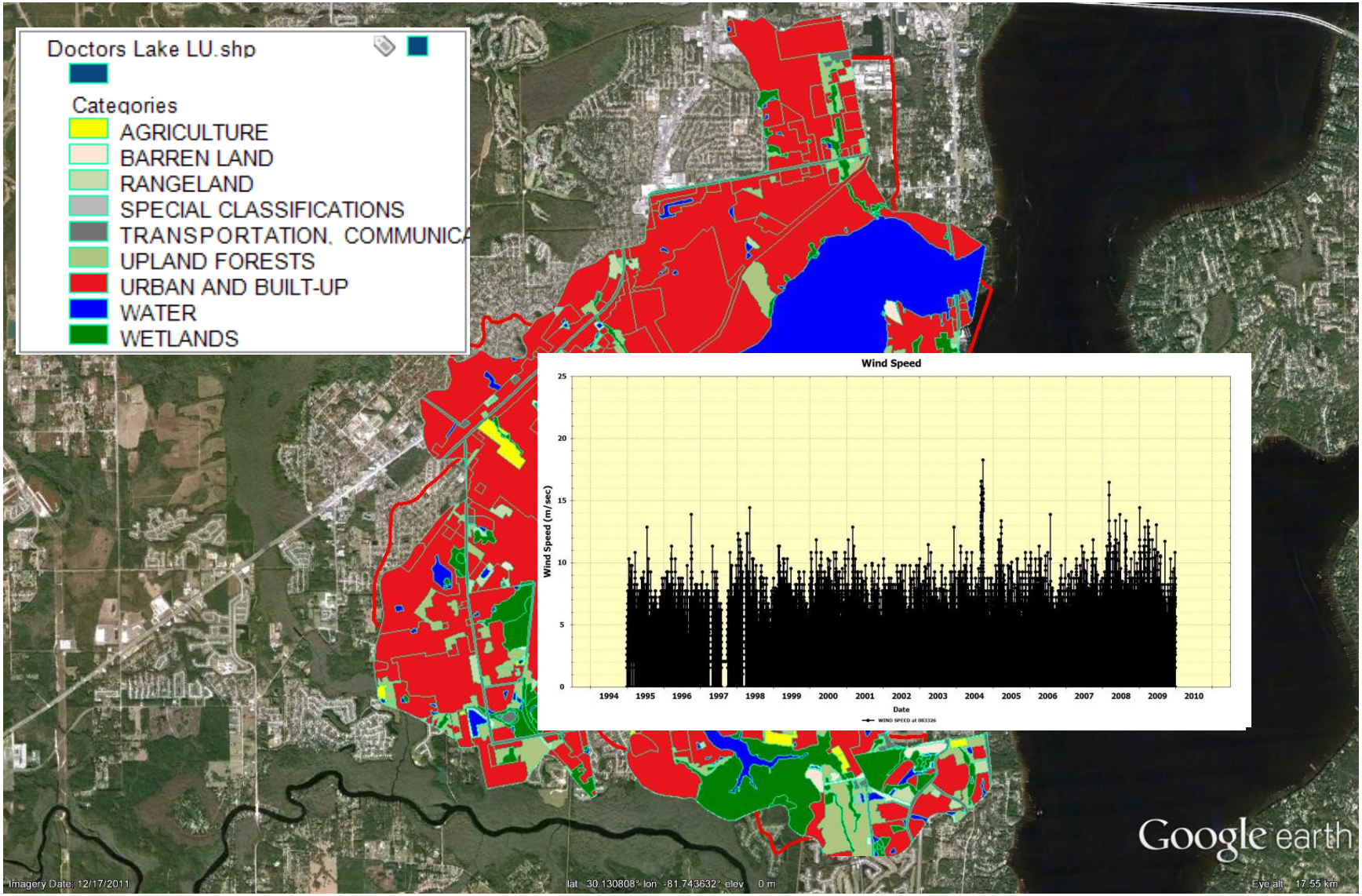
Time series
Summary statistics
% change/Improvement
Violations
Classification maps
Impact maps

Mechanistic Models -- Linked

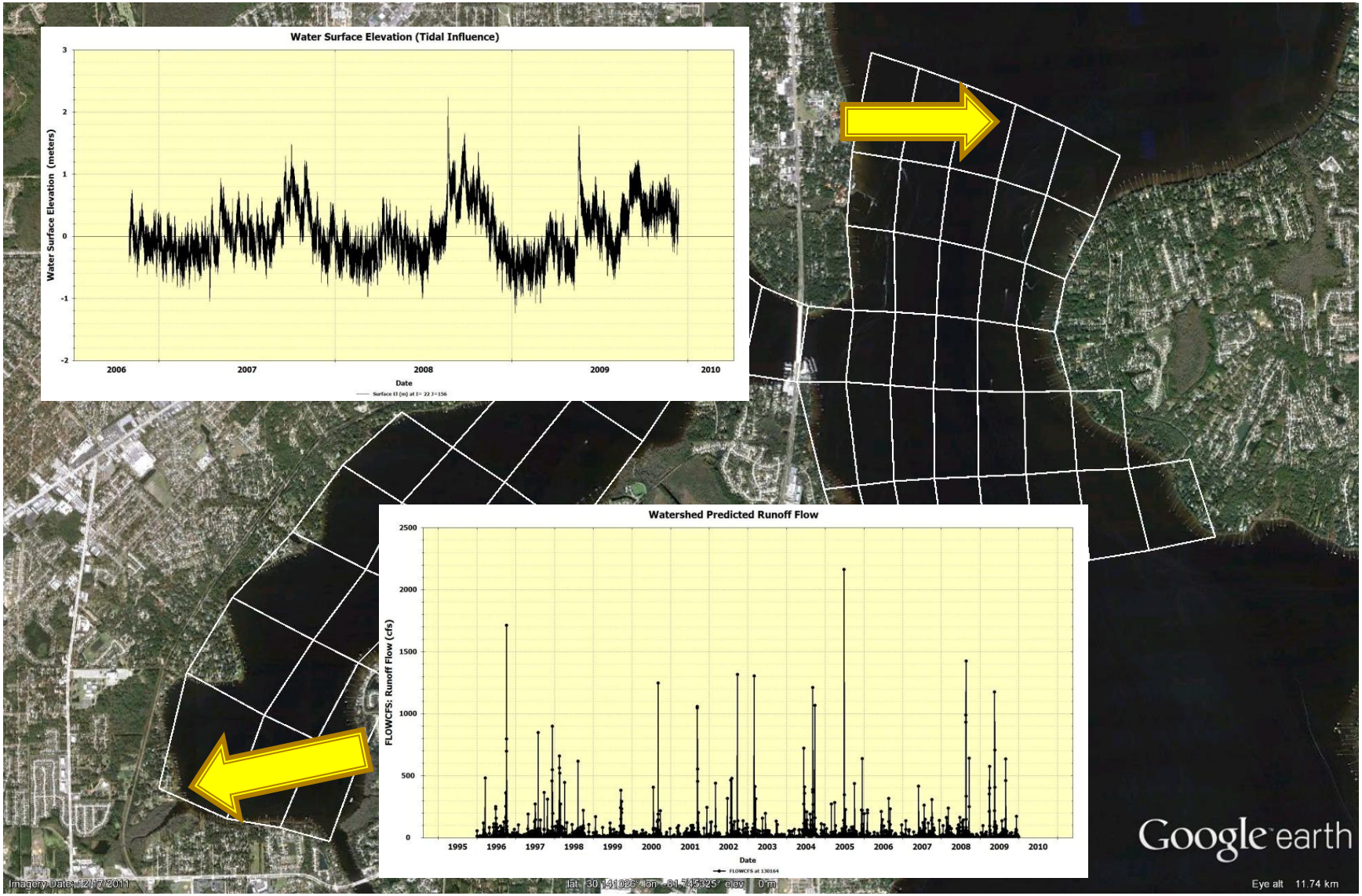
- LSPC – Loading Simulation Program C++
  - Simulates watershed loadings delivered to the estuary
- EFDC – Environmental Fluid Dynamics Code
  - Simulates the hydrodynamics within the estuary
- WASP – Water Quality Analysis Simulation Program
  - Simulates the water quality response within the estuary



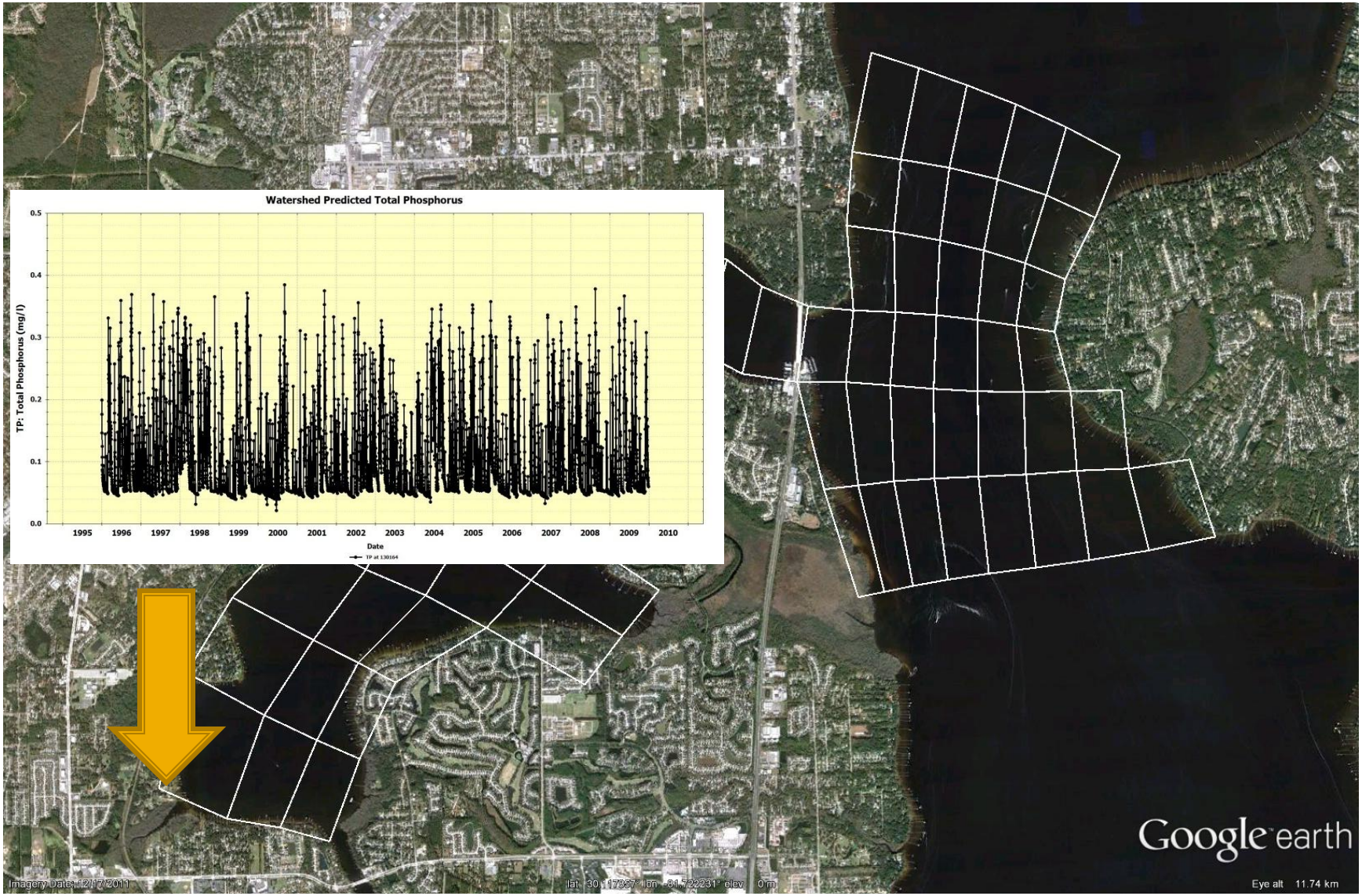
Example of Linked Models


Doctors Lake LU.shp
Categories
AGRICULTURE
BARREN LAND
RANGELAND
SPECIAL CLASSIFICATIONS
TRANSPORTATION, COMMUNICA
UPLAND FORESTS
URBAN AND BUILT-UP
WATER
WETLANDS
Wind Speed
Wind Speed (m/sec)
25
20
15
10
5
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Date
WIND SPEED at 083326
Google earth
Imagery Date: 12/17/2011
lat 30.130808° lon -81.743632° elev 0 m
Eye alt 17.55 km

3 Dimensional Hydrodynamic Model



Water Quality Model



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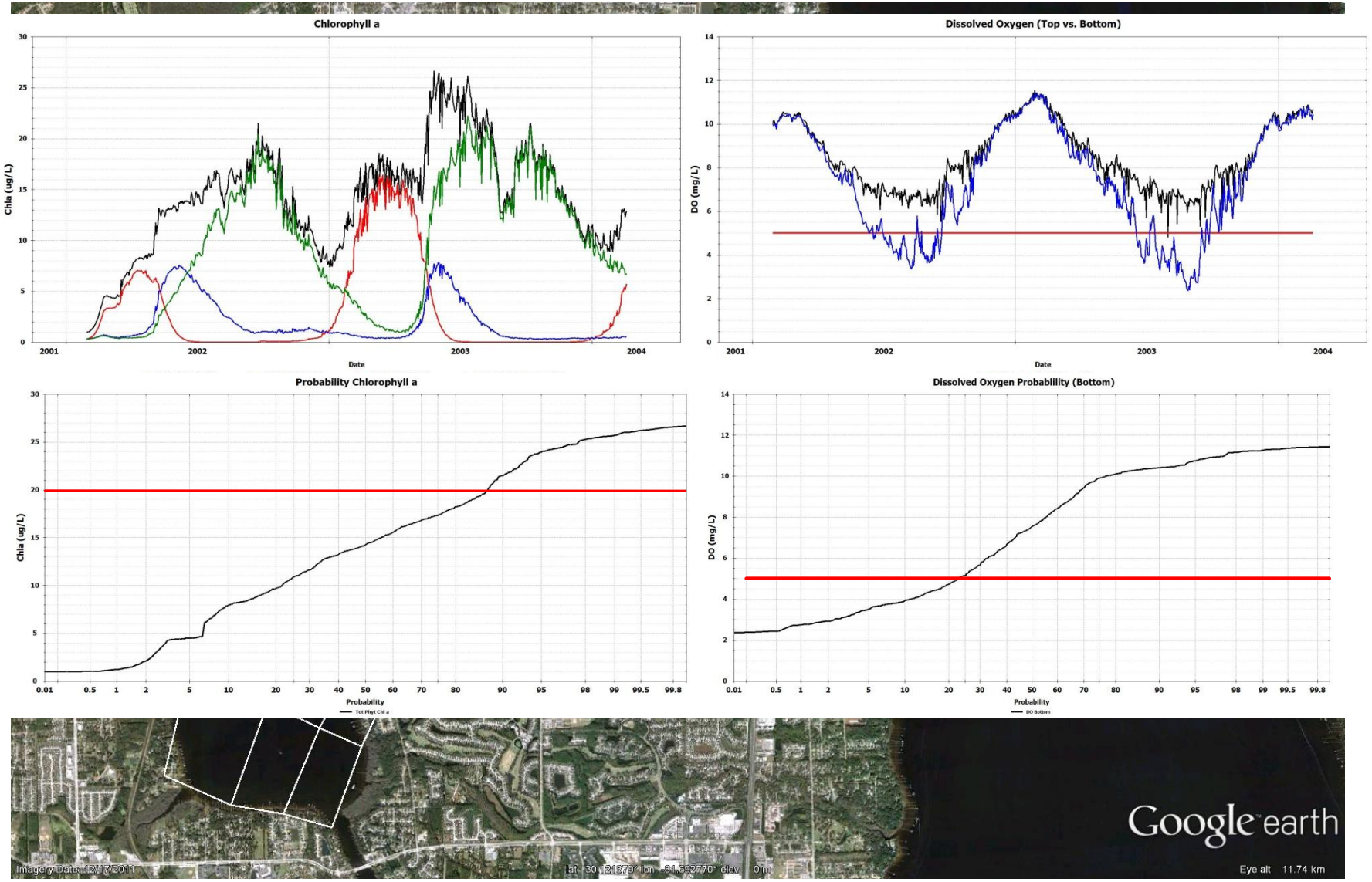
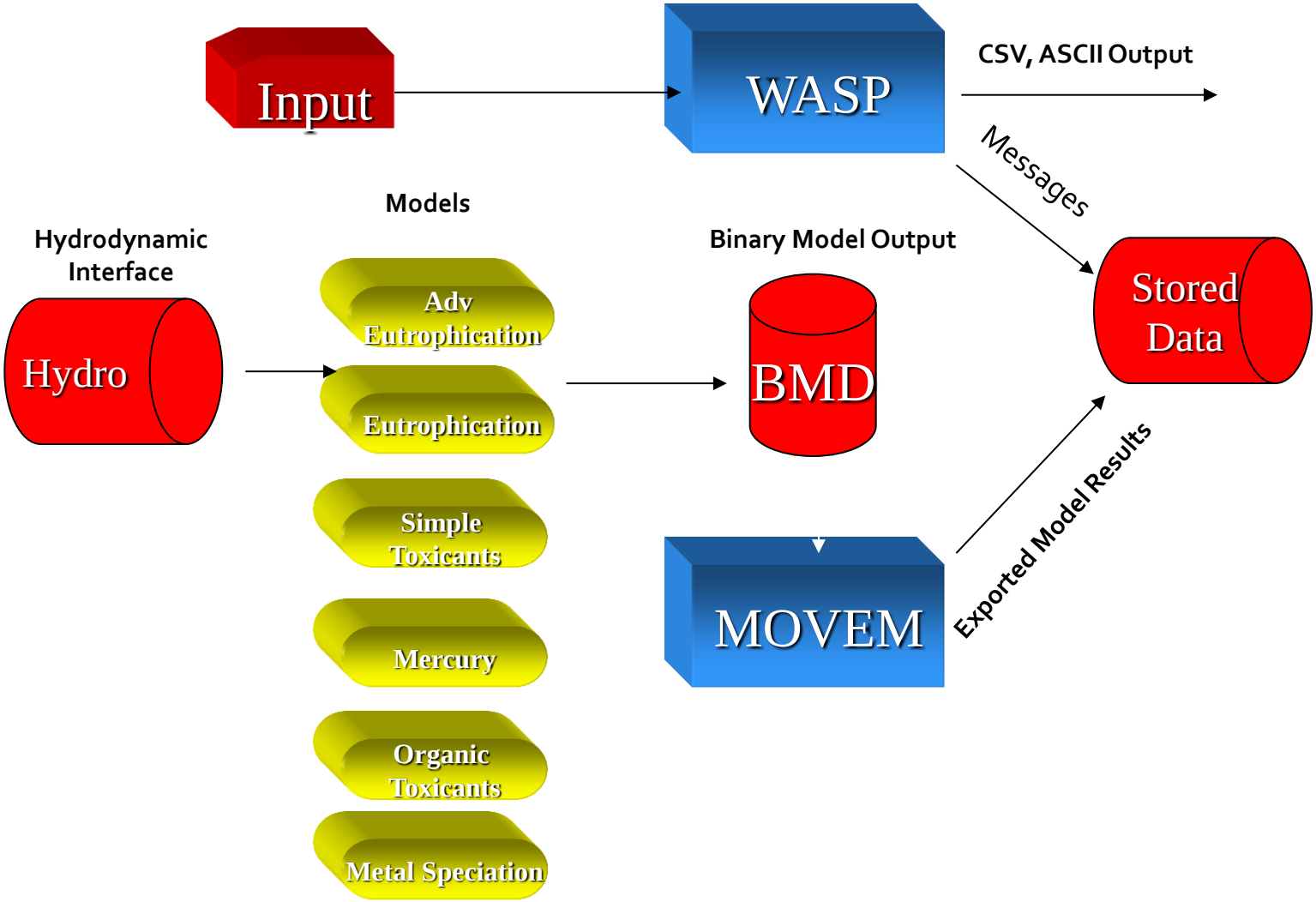
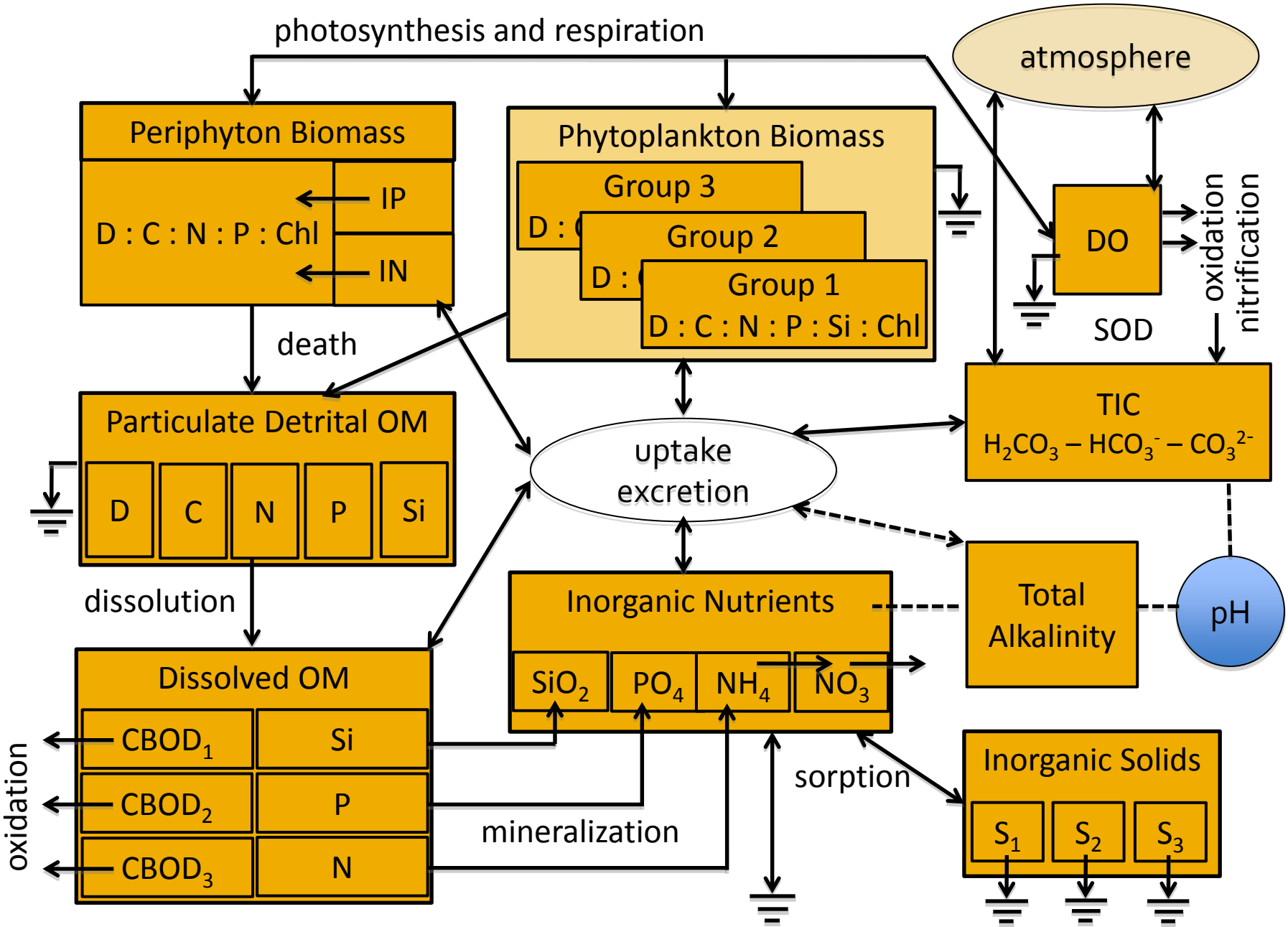


WASP Modeling Framework



Conventional Water Quality

- Important Processes
  - Nutrient Dynamics
    - Nitrogen (Ammonia, Nitrate, DON, PON)
    - Phosphorus (Orthophosphate, DOP, POP)
    - Silica (Dissolved, Particulate)
  - Algal Dynamics
    - Multiple Algal Groups (Green, Blue Green, Diatoms)
    - Light (Algal Self Shading, DOC, TSS)
  - Dissolved Oxygen Dynamics
    - Multiple BOD (Slow, Med, Fast or Biotic, Watershed, WWTP)
    - Reaeration (Wind, Hydraulic)
    - Sediment Diagenesis (Oxygen Consumption, Nutrient Fluxes)


photosynthesis and respiration
atmosphere
Periphyton Biomass
D : C : N : P : Chl
IP
IN
Phytoplankton Biomass
Group 3
Group 2
Group 1
D : C : N : P : Si : Chl
DO
oxidation
nitrification
SOD
death
Particulate Detrital OM
D
C
N
P
Si
uptake
excretion
TIC
$H_2CO_3 – HCO_3^- – CO_3^{2-}$
dissolution
Inorganic Nutrients
SiO_2
PO_4
NH_4
NO_3
Total Alkalinity
pH
Dissolved OM
$CBOD_1$
$CBOD_2$
$CBOD_3$
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P
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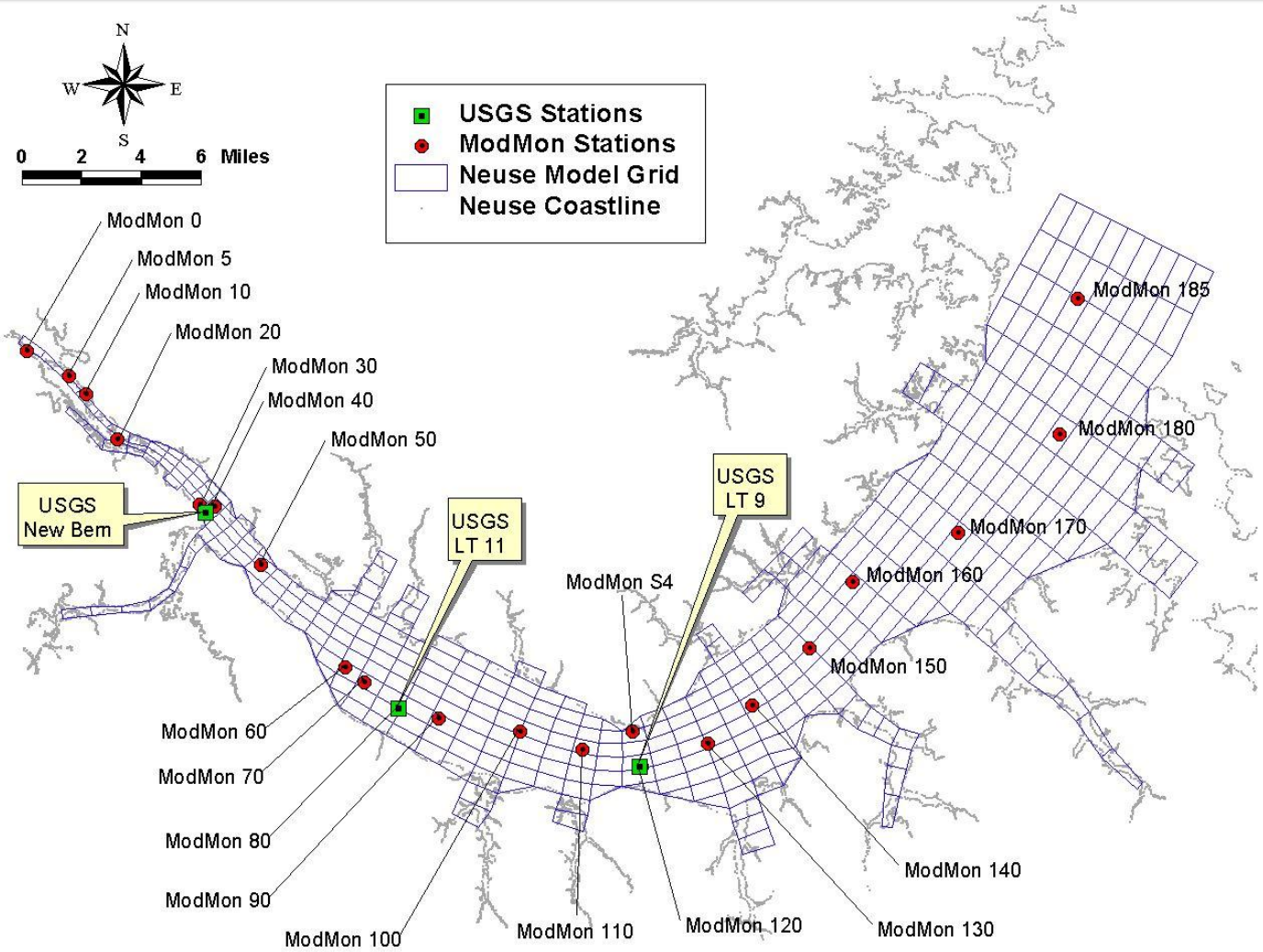
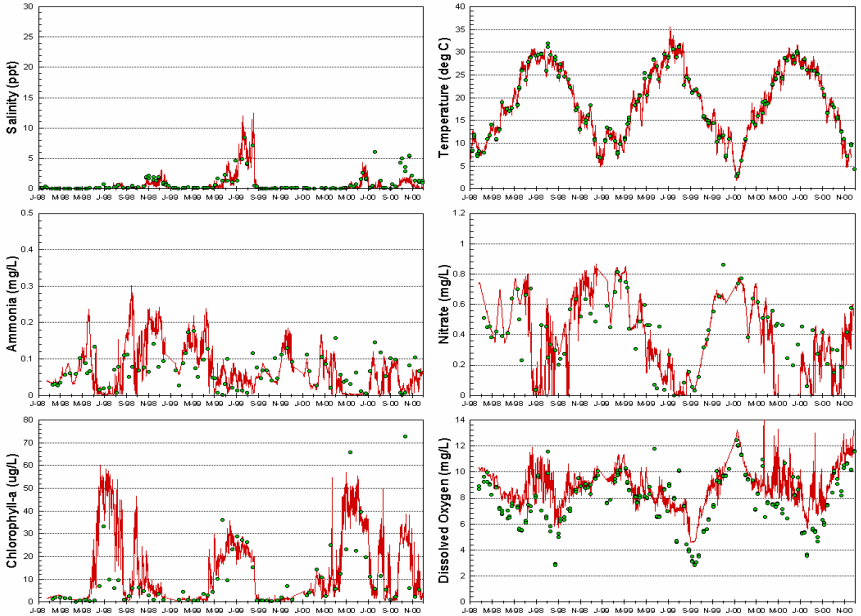
oxidation
mineralization
sorption
Inorganic Solids
S_1
S_2
S_3

Nitrogen TMDL -- Neuse River/Estuary North Carolina

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Temperature (deg C)
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Ammonia (mg/L)
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0.5
Nitrate (mg/L)
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Chlorophyll-a (ug/L)
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Dissolved Oxygen (mg/L)
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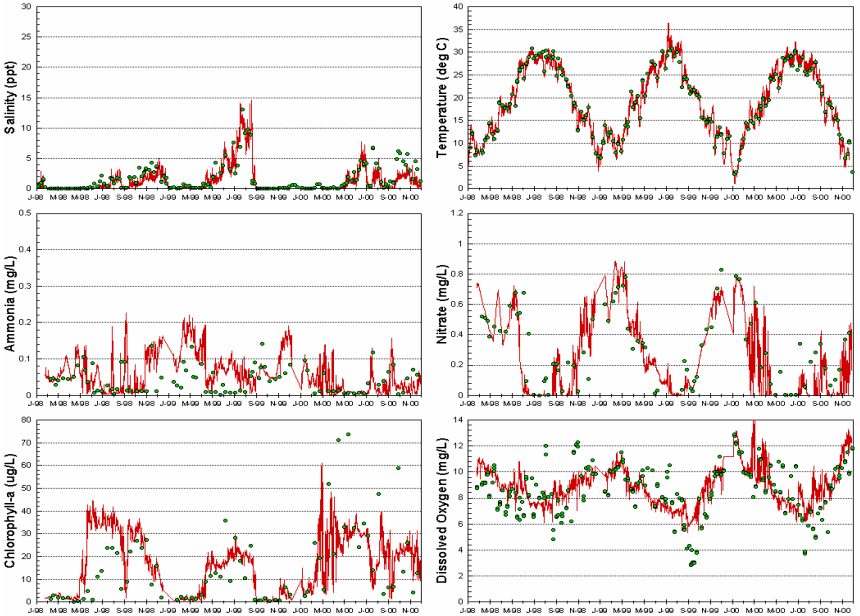
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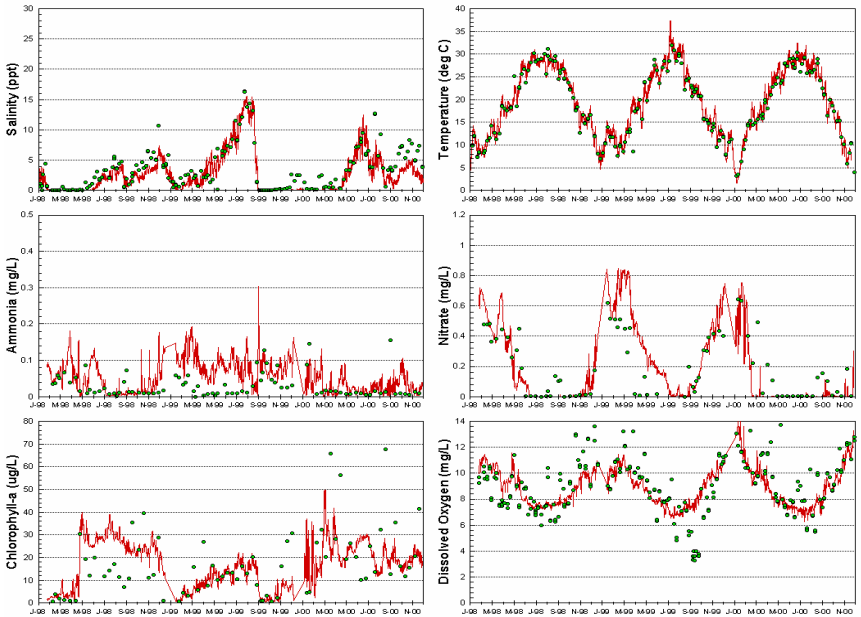
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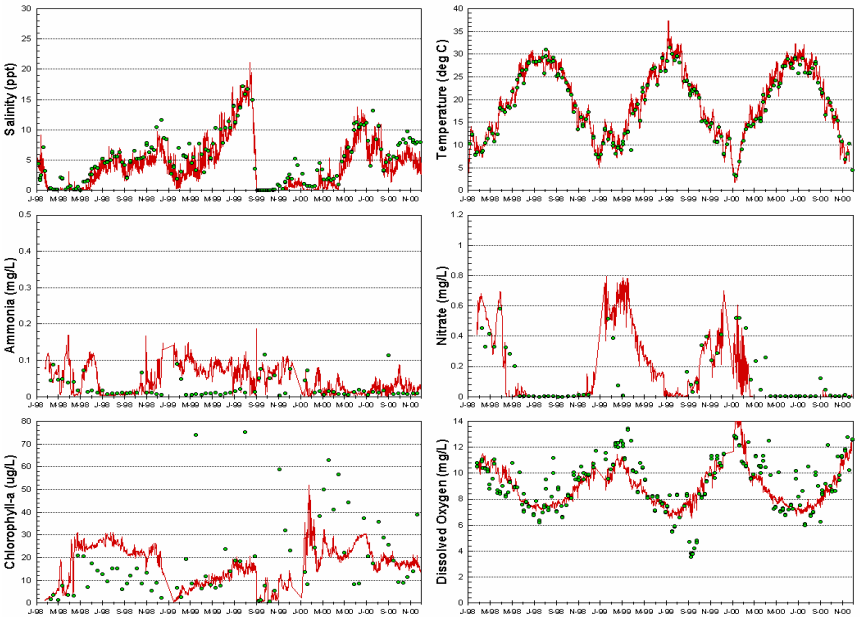
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Questions ?

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