VALIDATION STUDY OF AQUAMODEL FISH FARM SIMULATION SOFTWARE

World Aquaculture Society, February 2013

Role of Environmental Variability in Aquaculture Ecosystem Models Session

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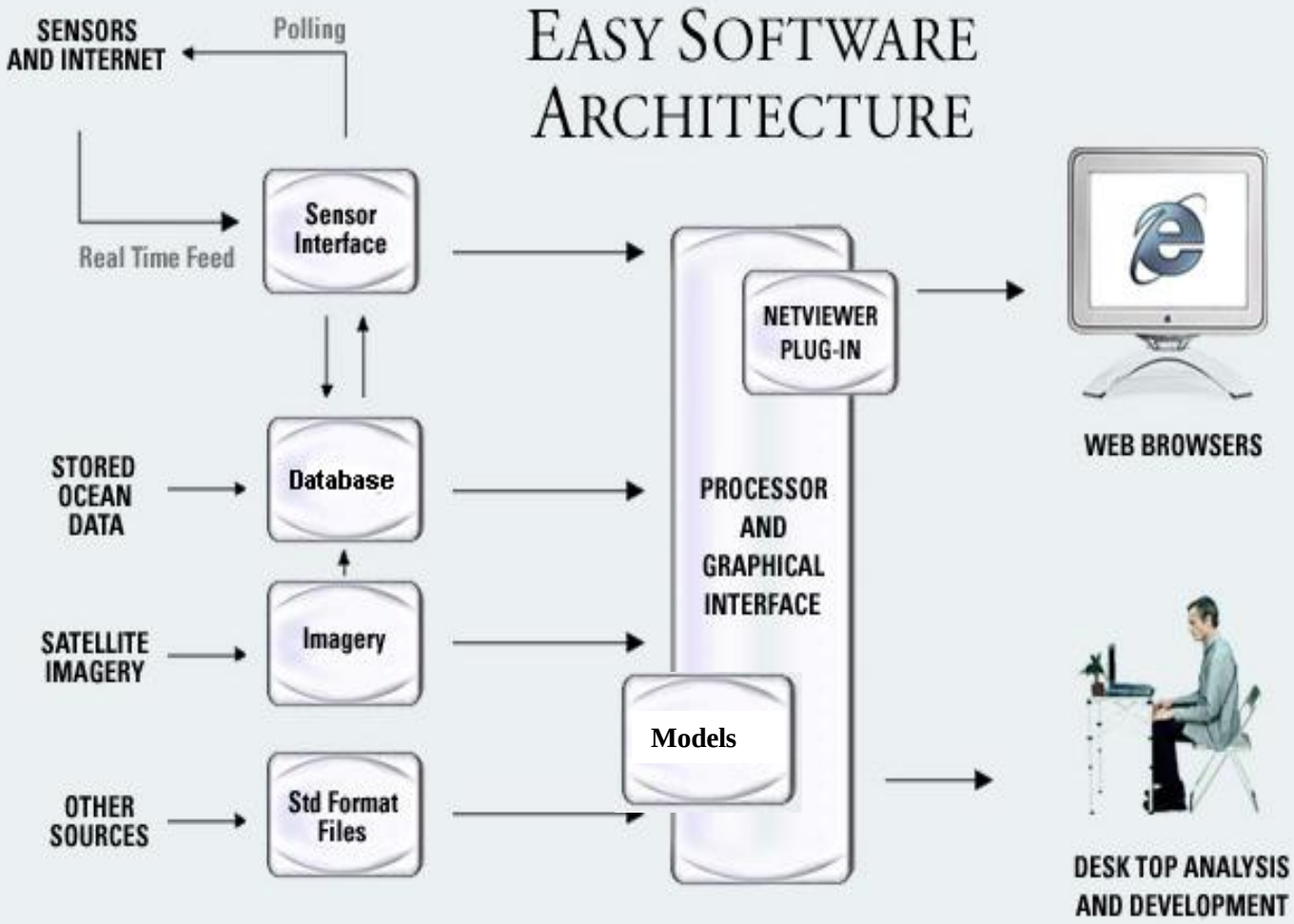
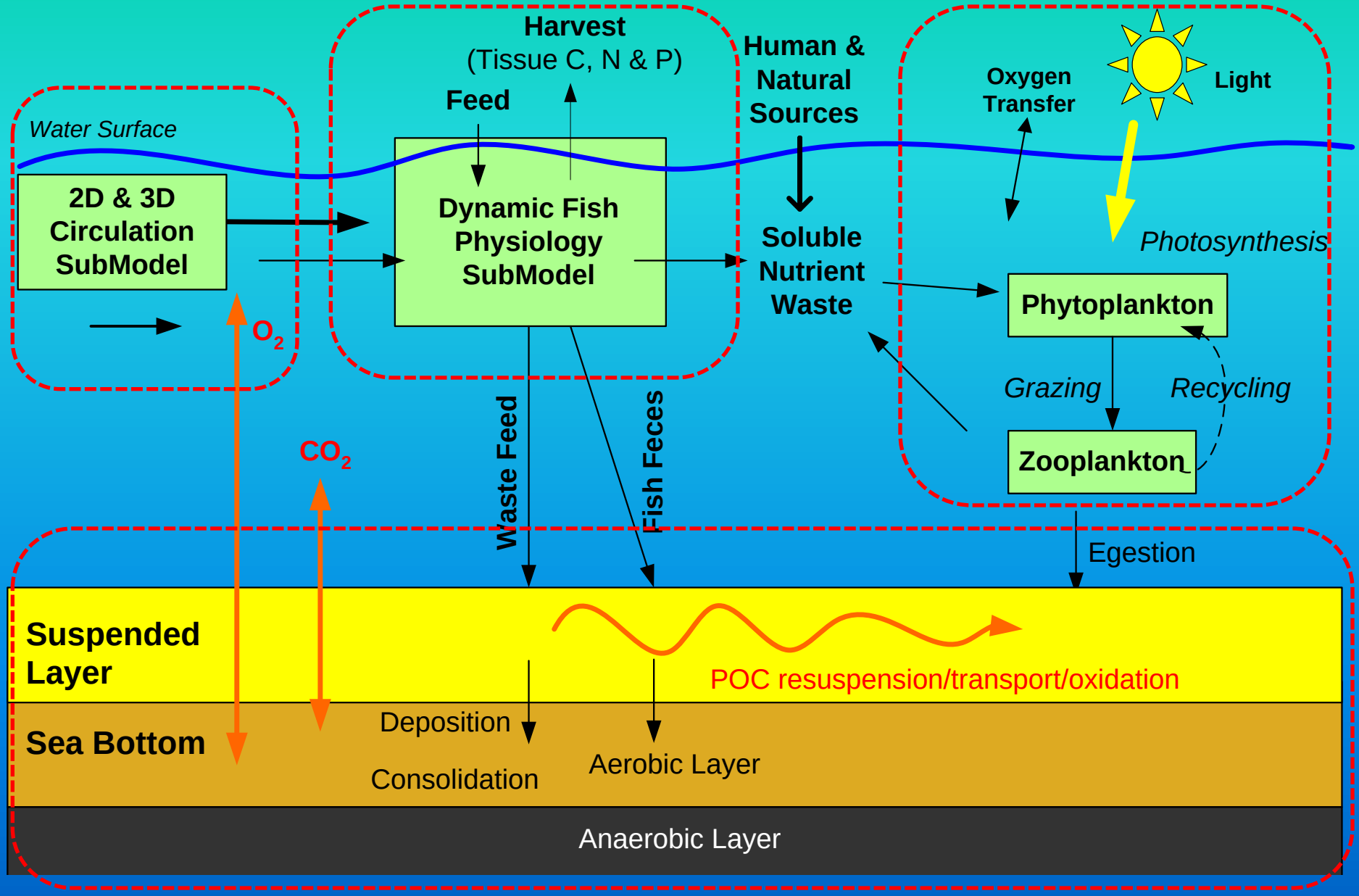


- EASy = Environmental Assessment System , accepts plug in models like AquaModel
- 4-D GIS for marine applications, visual, video-like output of spatial & temporal effects
- Interfaces for models, spreadsheets, databases, 100's of types of RS imagery and Internet

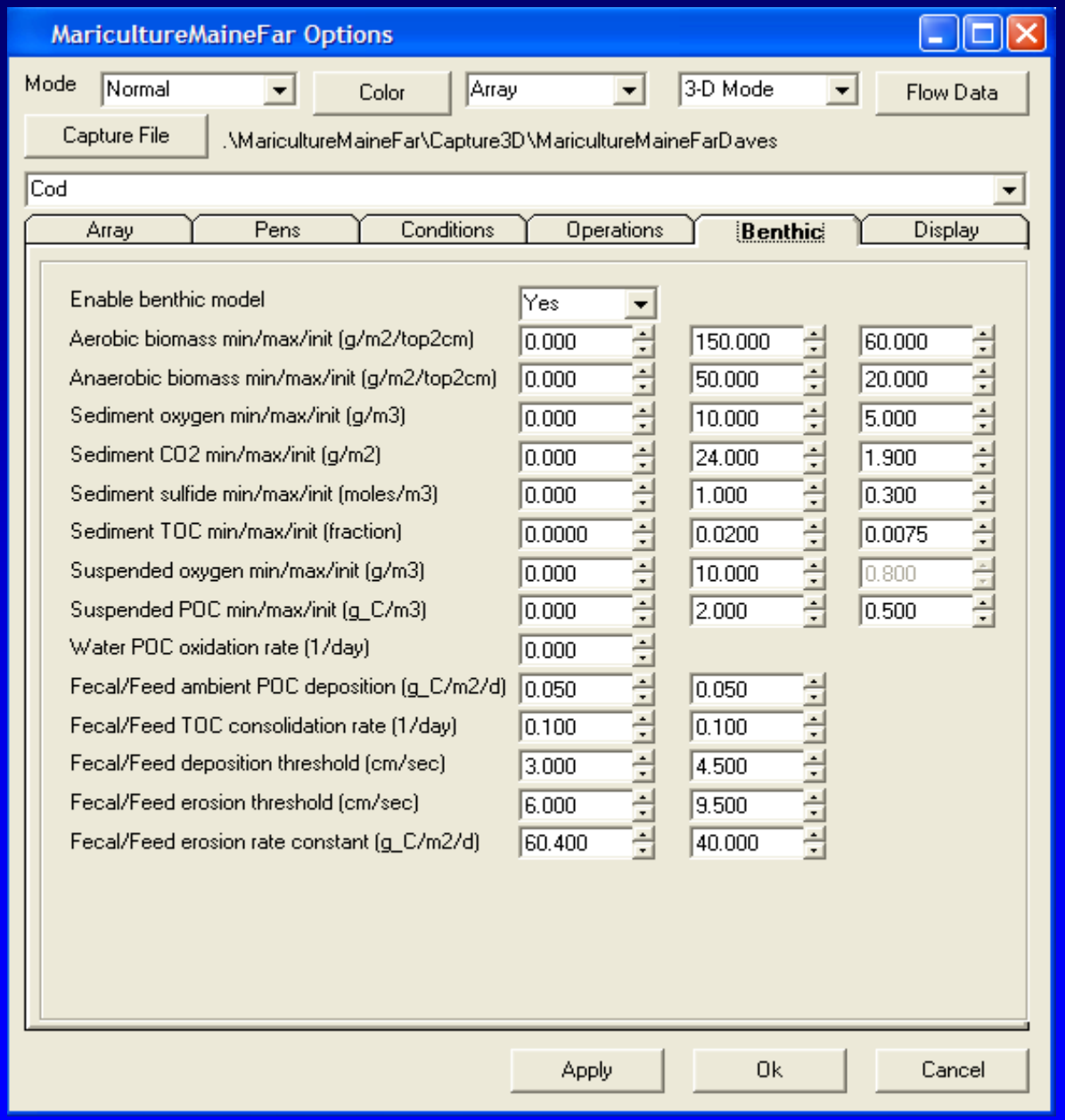
AquaModel Compartments



AquaModel – Example of Initial Settings

Benthic Conditions

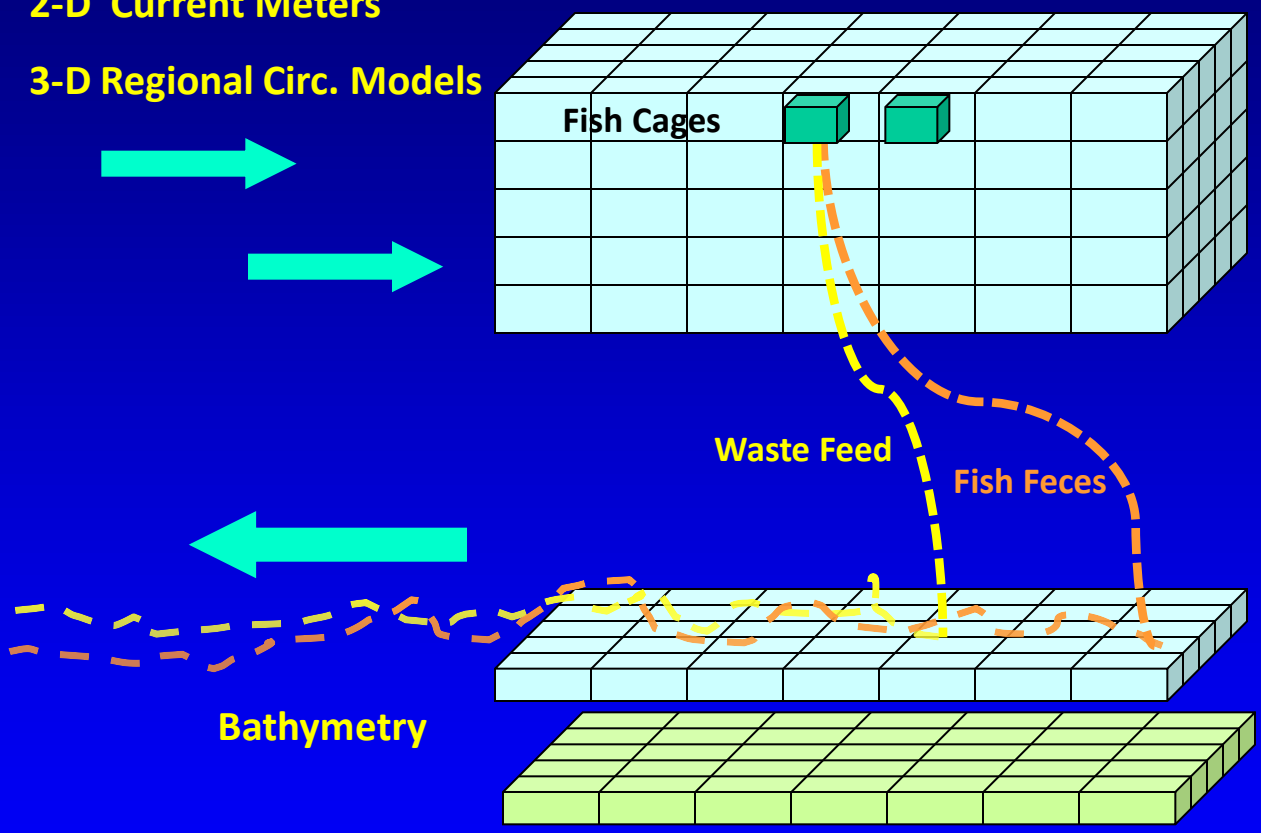
And More



AquaModel Circulation & Material Fluxes

2-D Current Meters

3-D Regional Circ. Models



Mixed Layer Simulation
- Oxygen
- Nitrogen
- Phytoplankton (photic zone)
- Zooplankton
- Fish fecal and waste feed tracking
- Organic carbon particle transport
- Bacterial respiration of same

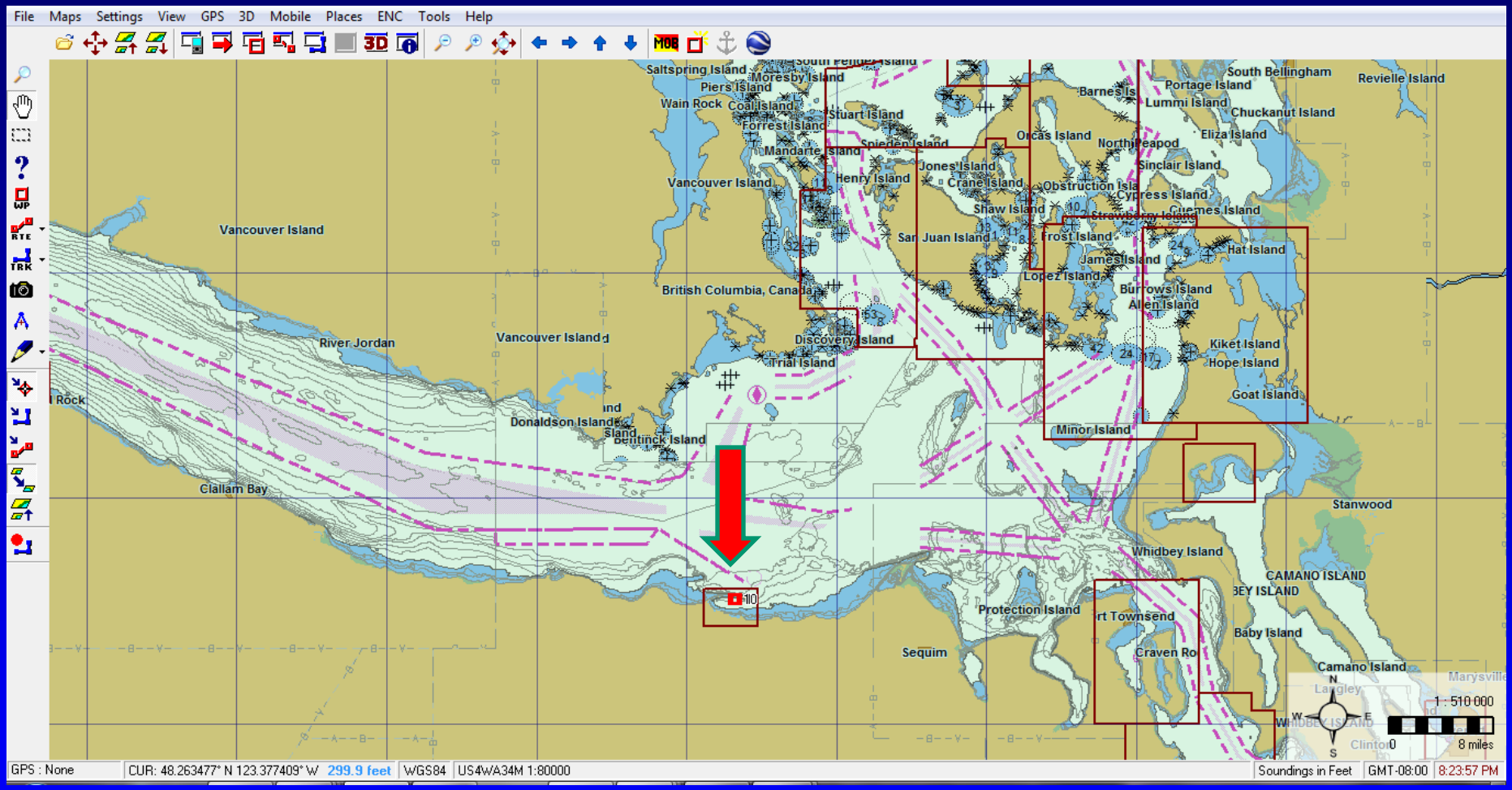
Deep Layer Simulation

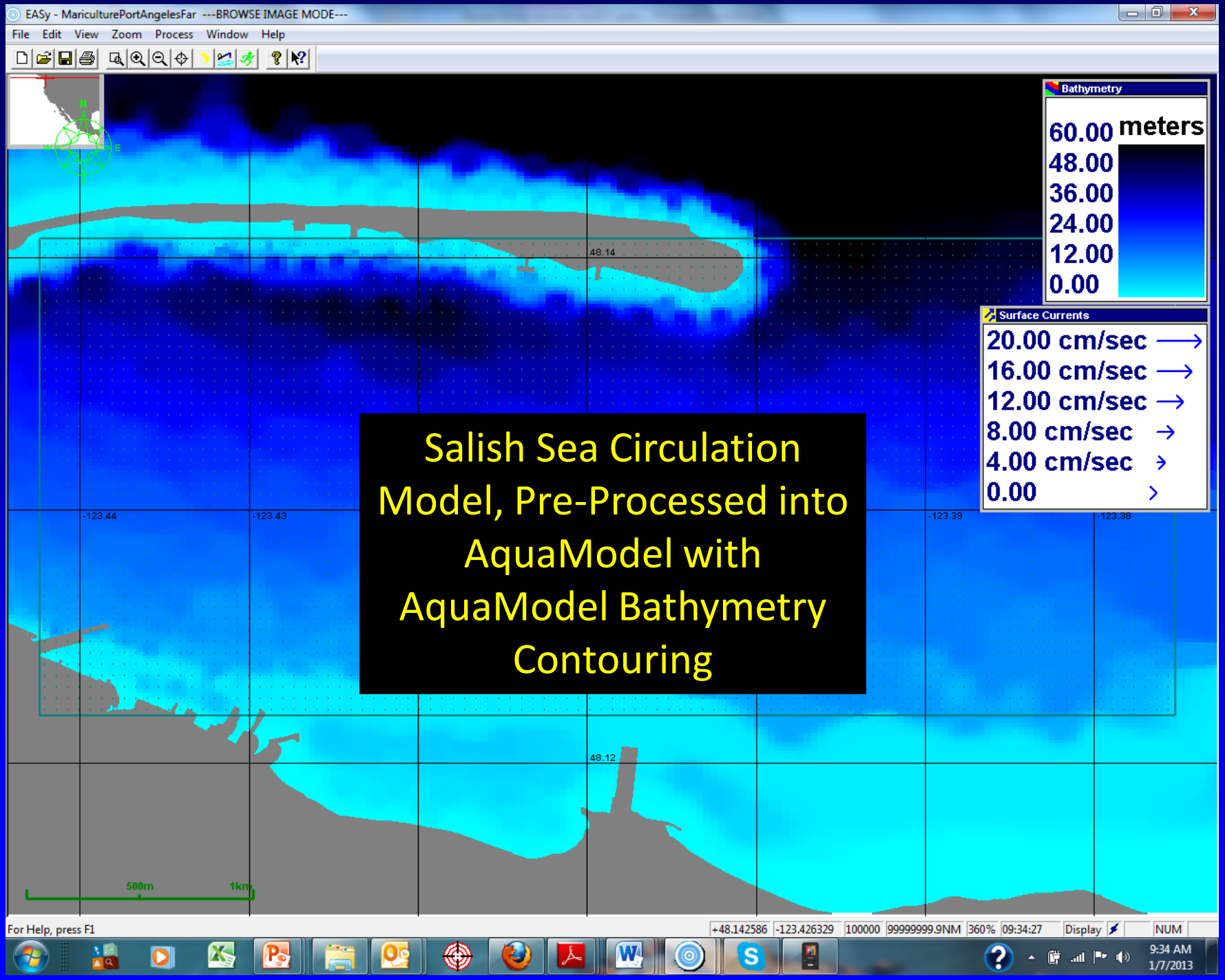
Suspended Layer
- Particle deposition/resuspension
- Waste assimilation

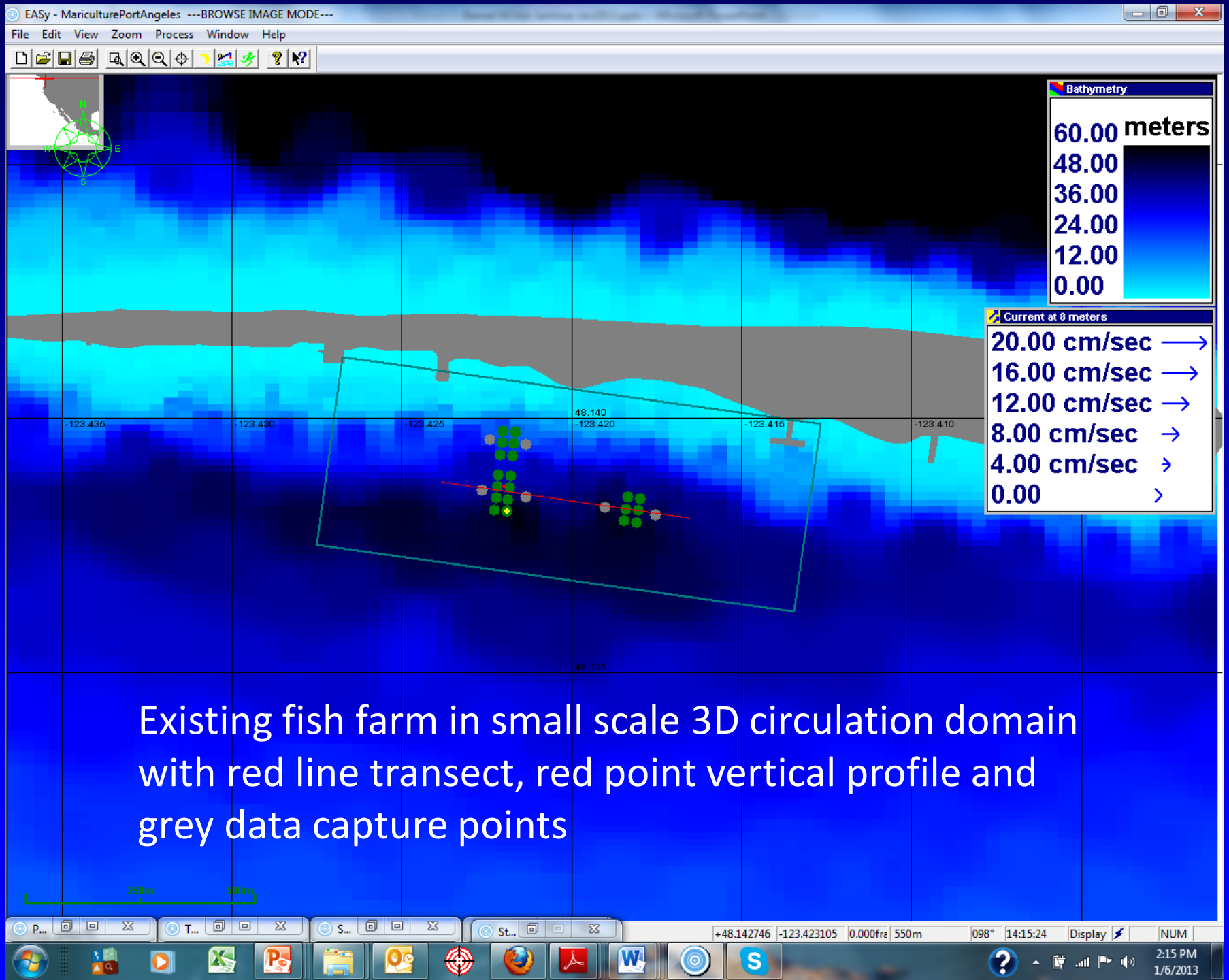
Sediment Layer
- Feed, Fish Feces, Oxygen
- Aerobic, Anaerobic bacteria populations
- Oxygen & sulfide fluxes
- Waste assimilation, consolidation, burial

2D for benthic single farms, 3D w/current meter for multiple farms

2 min. Flash Card Demonstration




EASy - MariculturePortAngelesFar ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Bathymetry
60.00 meters
48.00
36.00
24.00
12.00
0.00
Surface Currents
20.00 cm/sec
16.00 cm/sec
12.00 cm/sec
8.00 cm/sec
4.00 cm/sec
0.00
Salish Sea Circulation Model, Pre-Processed into AquaModel with AquaModel Bathymetry Contouring
48.14
48.12
-123.44
-123.43
-123.39
-123.38
500m
1km
For Help, press F1
+48.142586 -123.426329 100000 99999999.9NM 360% 09:34:27 Display NUM
9:34 AM
1/7/2013


EASy - MaricultePortAngeles ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Bathymetry
60.00 meters
48.00
36.00
24.00
12.00
0.00
Current at 8 meters
20.00 cm/sec
16.00 cm/sec
12.00 cm/sec
8.00 cm/sec
4.00 cm/sec
0.00
-123.435
-123.430
-123.425
48.140
-123.420
-123.415
-123.410
48.135
Existing fish farm in small scale 3D circulation domain with red line transect, red point vertical profile and grey data capture points
+48.142746 -123.423105 0.000fre 550m 098° 14:15:24 Display NUM
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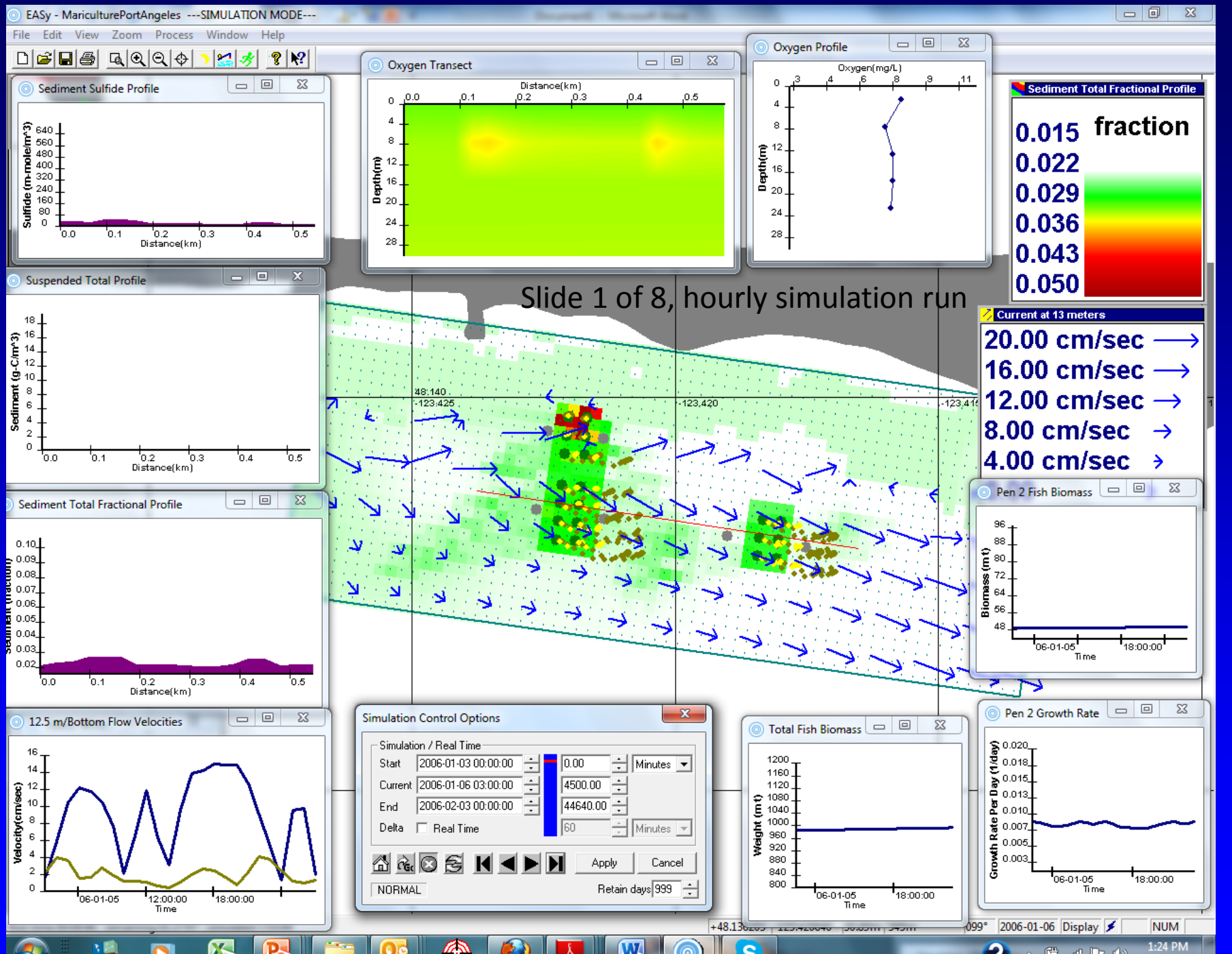
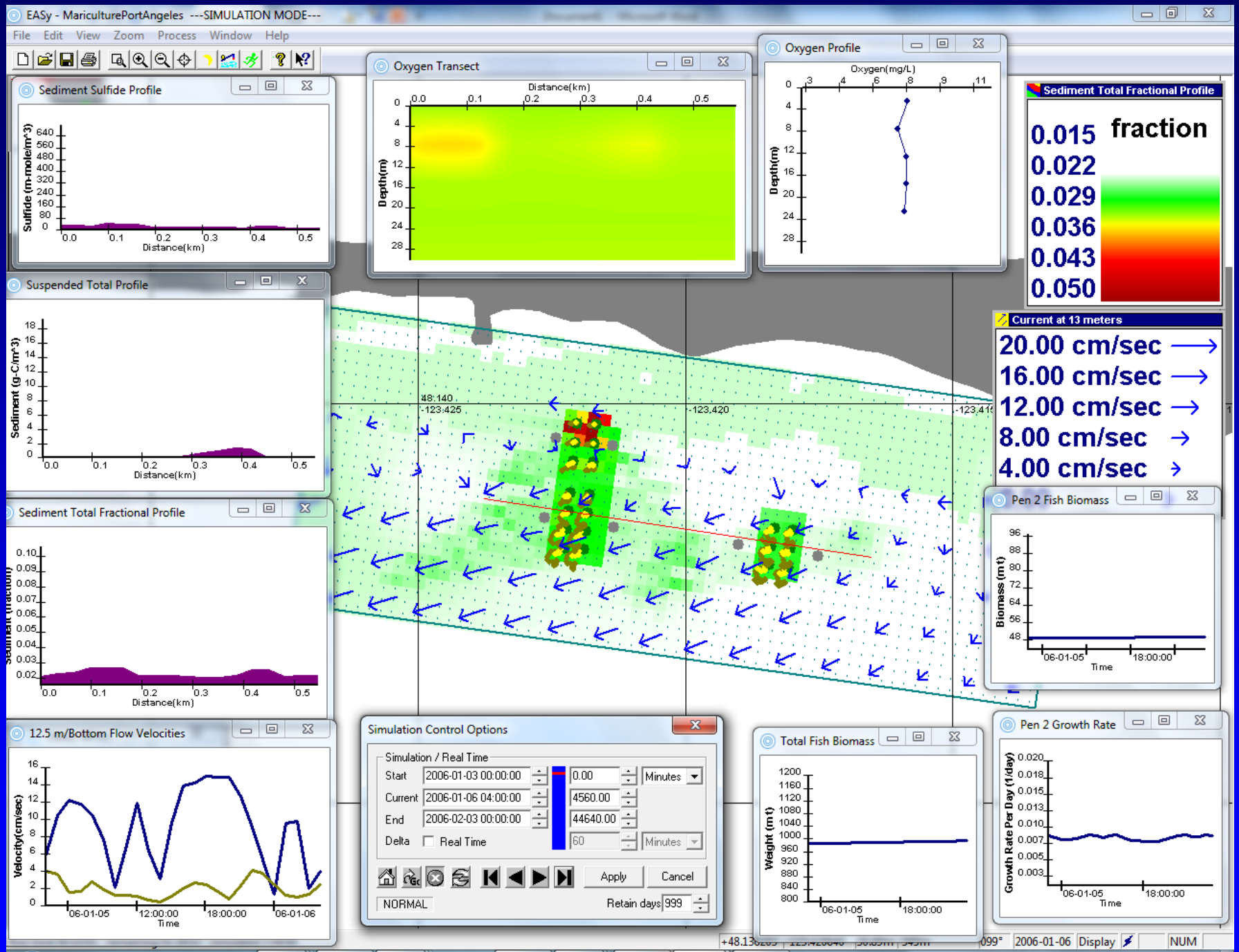
1/6/2013


EASy - MaricultePortAngeles ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Sediment Sulfide Profile
Sulfide (m-mole/m^3)
Distance(km)
Oxygen Transect
Distance(km)
Depth(m)
Oxygen Profile
Oxygen(mg/L)
Depth(m)
Sediment Total Fractional Profile
0.015 fraction
0.022
0.029
0.036
0.043
0.050
Slide 1 of 8, hourly simulation run
Suspended Total Profile
Sediment (g-C/m^3)
Distance(km)
Current at 13 meters
20.00 cm/sec
16.00 cm/sec
12.00 cm/sec
8.00 cm/sec
4.00 cm/sec
48.140
-123.425
-123.420
Sediment Total Fractional Profile
Distance(km)
Pen 2 Fish Biomass
Biomass (mt)
Time
12.5 m/Bottom Flow Velocities
Velocity(cm/sec)
Time
Simulation Control Options
Simulation / Real Time
Start 2006-01-03 00:00:00
Current 2006-01-06 03:00:00
End 2006-02-03 00:00:00
Delta Real Time
0.00 Minutes
4500.00
44640.00
60 Minutes
Apply
Cancel
NORMAL
Retain days 999
Total Fish Biomass
Weight (mt)
Time
Pen 2 Growth Rate
Growth Rate Per Day (1/day)
Time
2006-01-06
Display
NUM
1:24 PM
1/7/2013


EASy - MariculturePortAngeles ---SIMULATION MODE---
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8.00 cm/sec
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Biomass (m t)
Time
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Simulation Control Options
Simulation / Real Time
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Current 2006-01-06 04:00:00
End 2006-02-03 00:00:00
Delta Real Time
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Apply
Cancel
NORMAL
Retain days 999
Total Fish Biomass
Weight (m t)
Time
Pen 2 Growth Rate
Growth Rate Per Day (1/day)
Time
2006-01-06
Display
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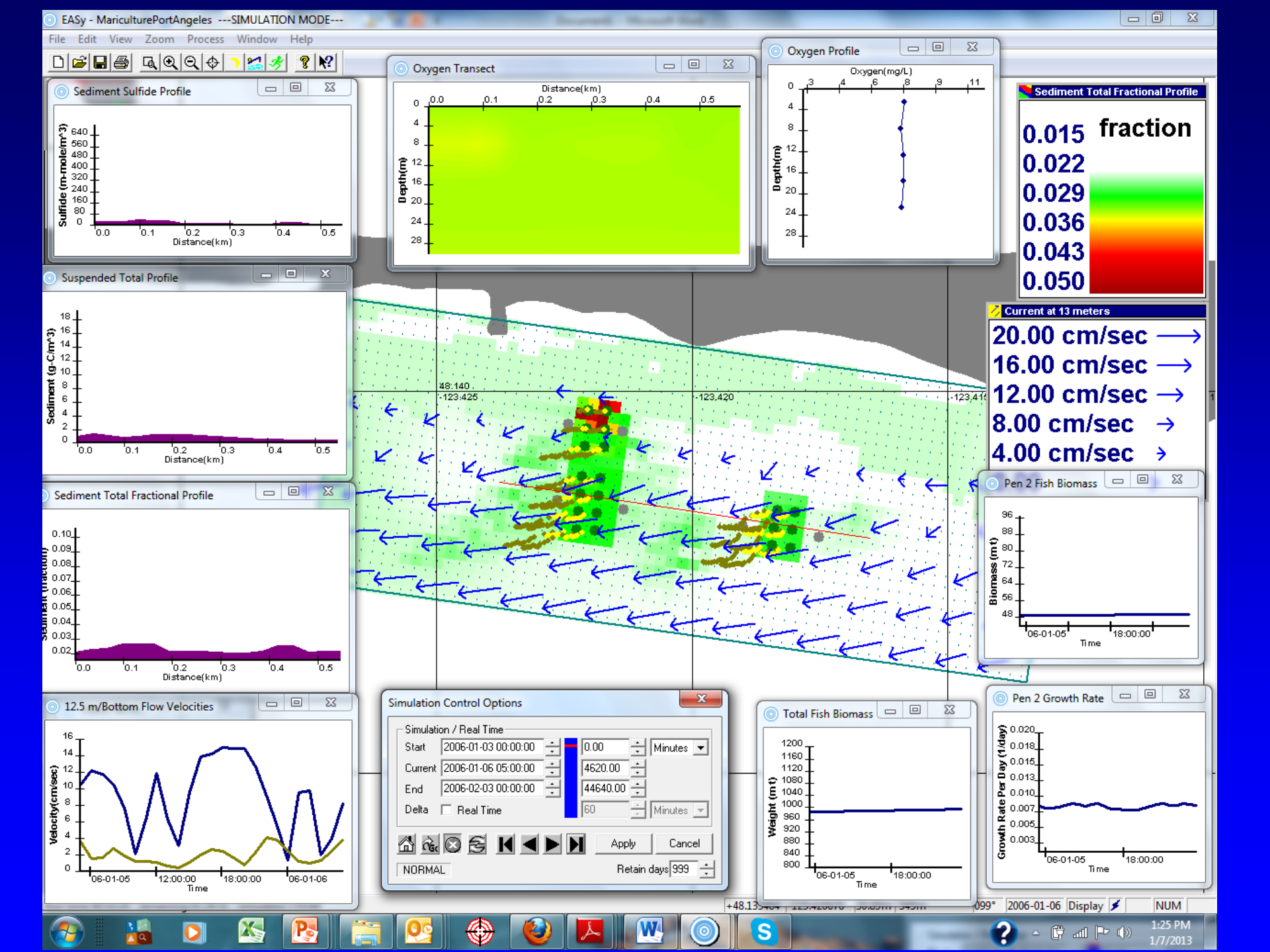
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8.00 cm/sec
4.00 cm/sec
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-123.420
Sediment Total Fractional Profile
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Biomass (m t)
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12.5 m/Bottom Flow Velocities
Velocity(cm/sec)
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Simulation / Real Time
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Current 2006-01-06 05:00:00
End 2006-02-03 00:00:00
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Retain days 999
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Weight (m t)
06-01-05
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Time
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Growth Rate Per Day (1/day)
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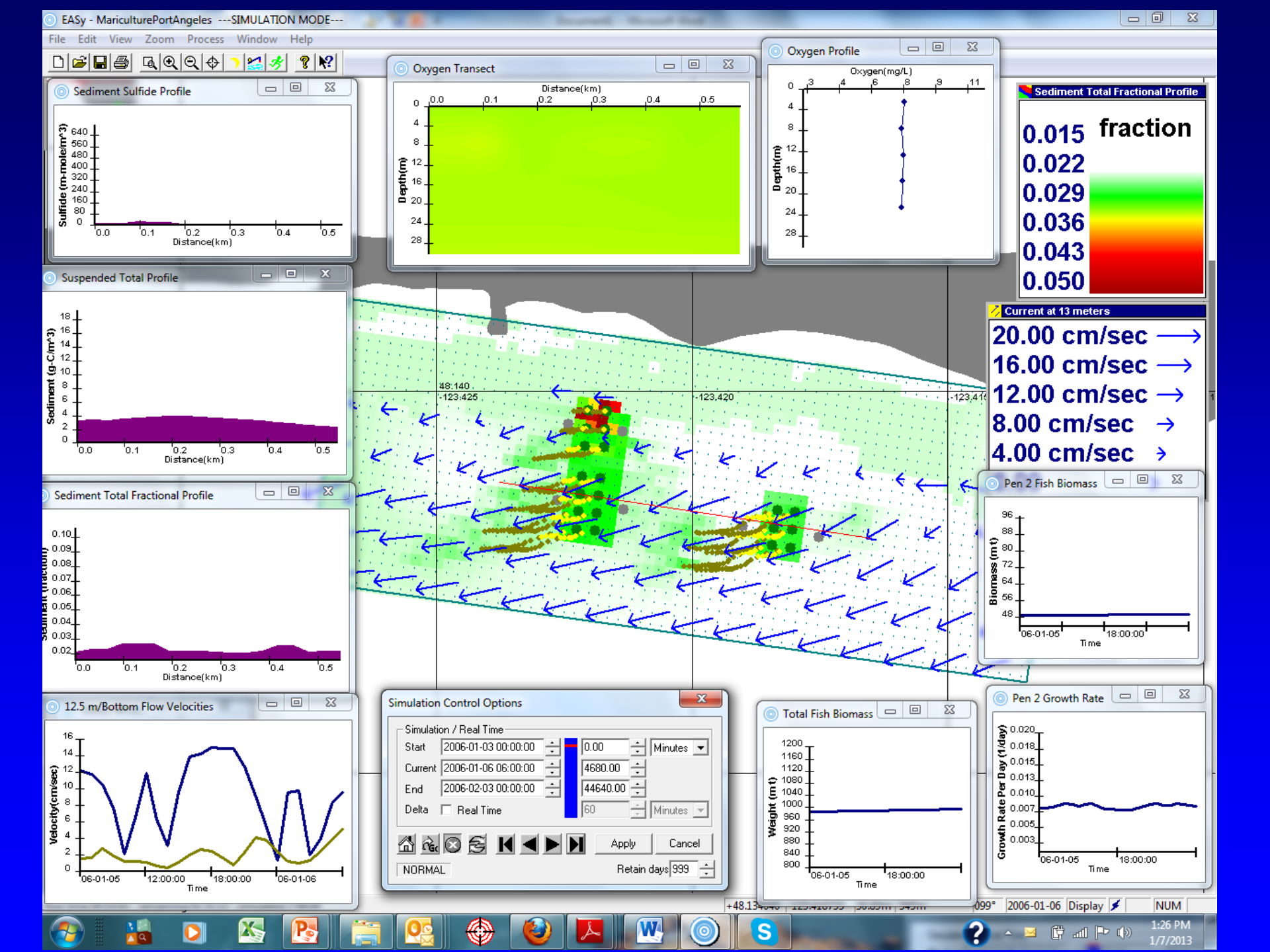
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Biomass (mt)
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Weight (mt)
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Growth Rate Per Day (1/day)
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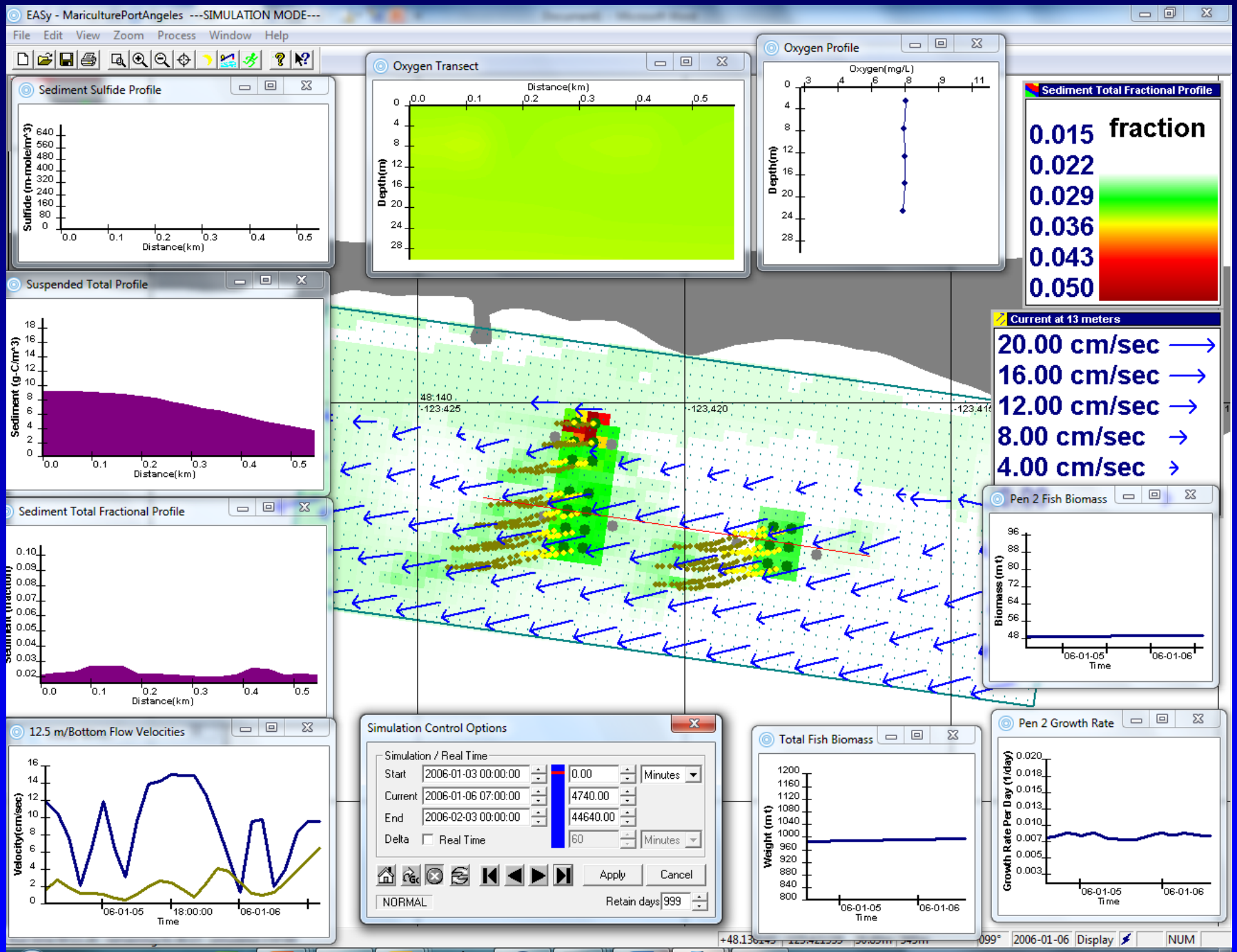
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Current 2006-01-06 07:00:00
End 2006-02-03 00:00:00
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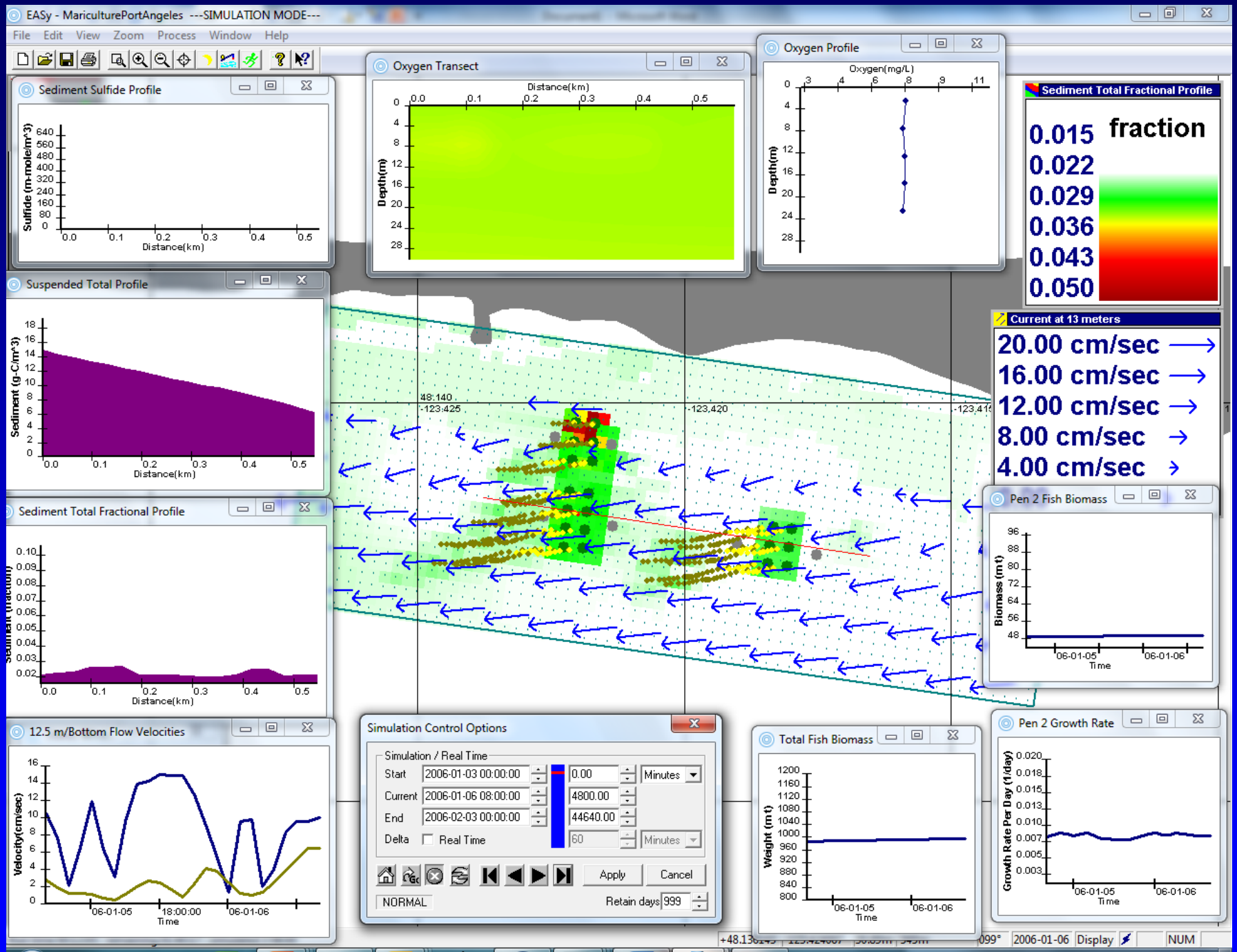
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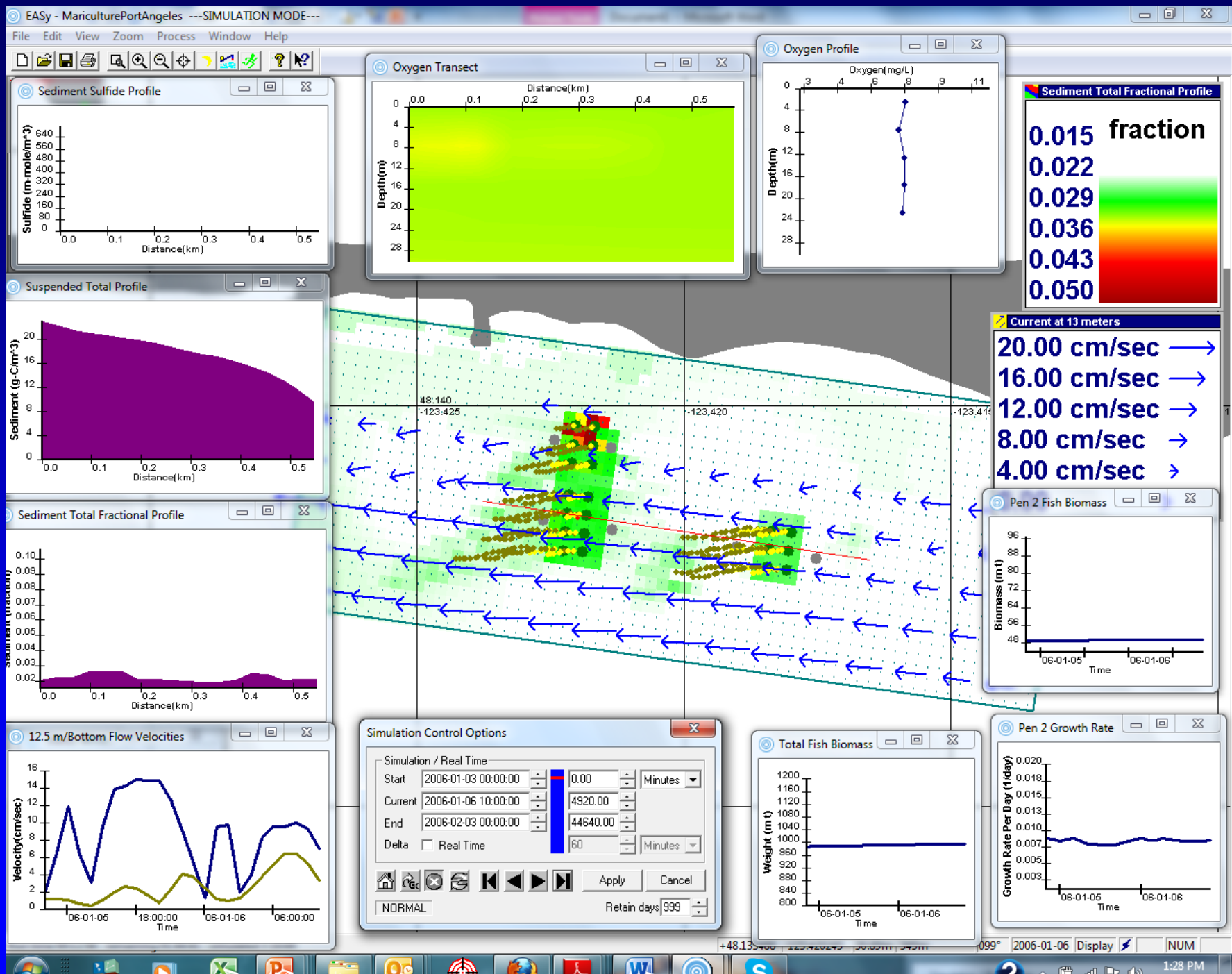
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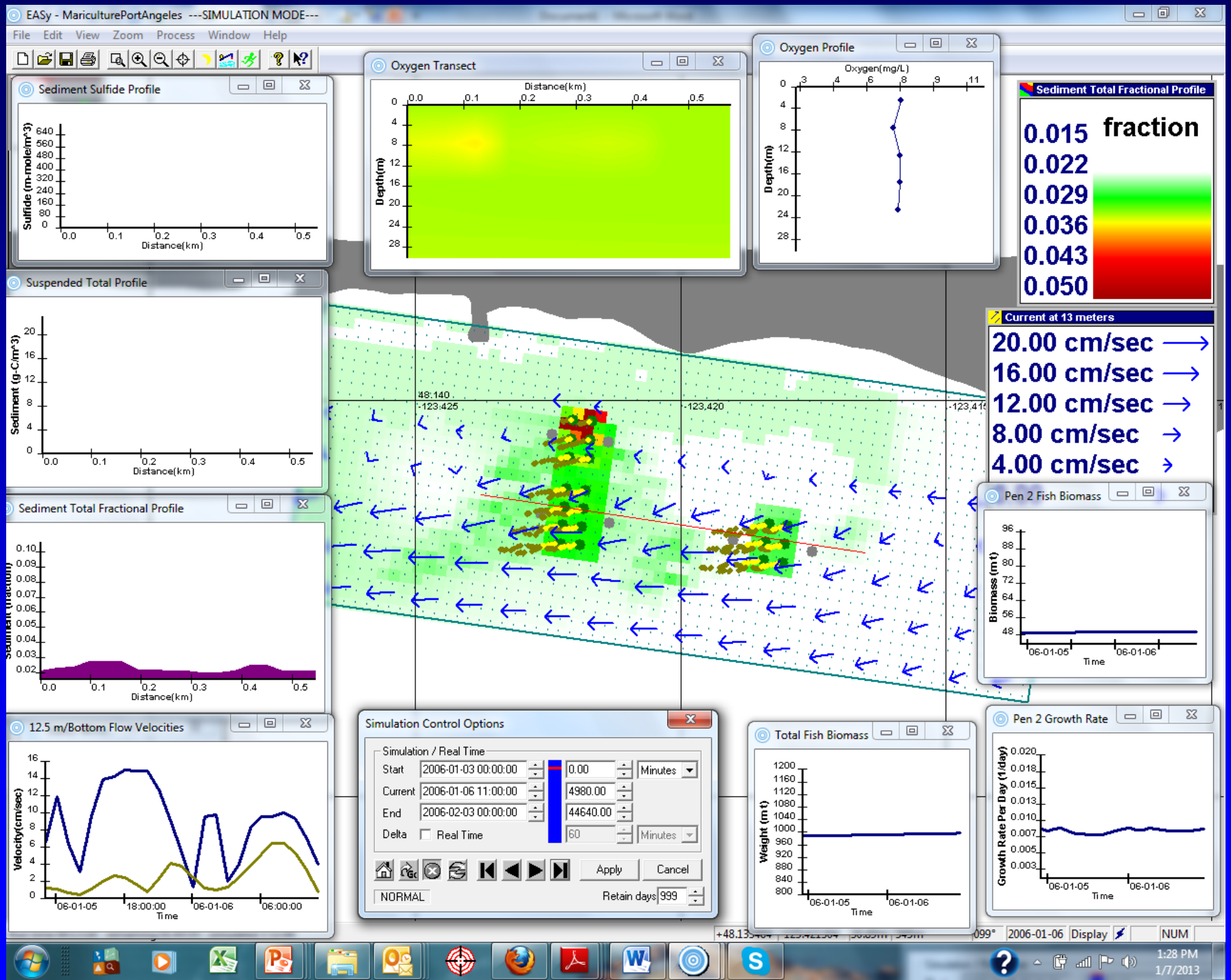
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Velocity(cm/sec)
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Simulation Control Options
Simulation / Real Time
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Current 2006-01-06 11:00:00
End 2006-02-03 00:00:00
Delta Real Time
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Minutes
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Cancel
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06-01-06
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Growth Rate Per Day (1/day)
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06-01-06
Time
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End excerpt from simulation,
only 8 hours of an 18 month grow out period.
12,960 time steps with data recorded
from each cell in the domain

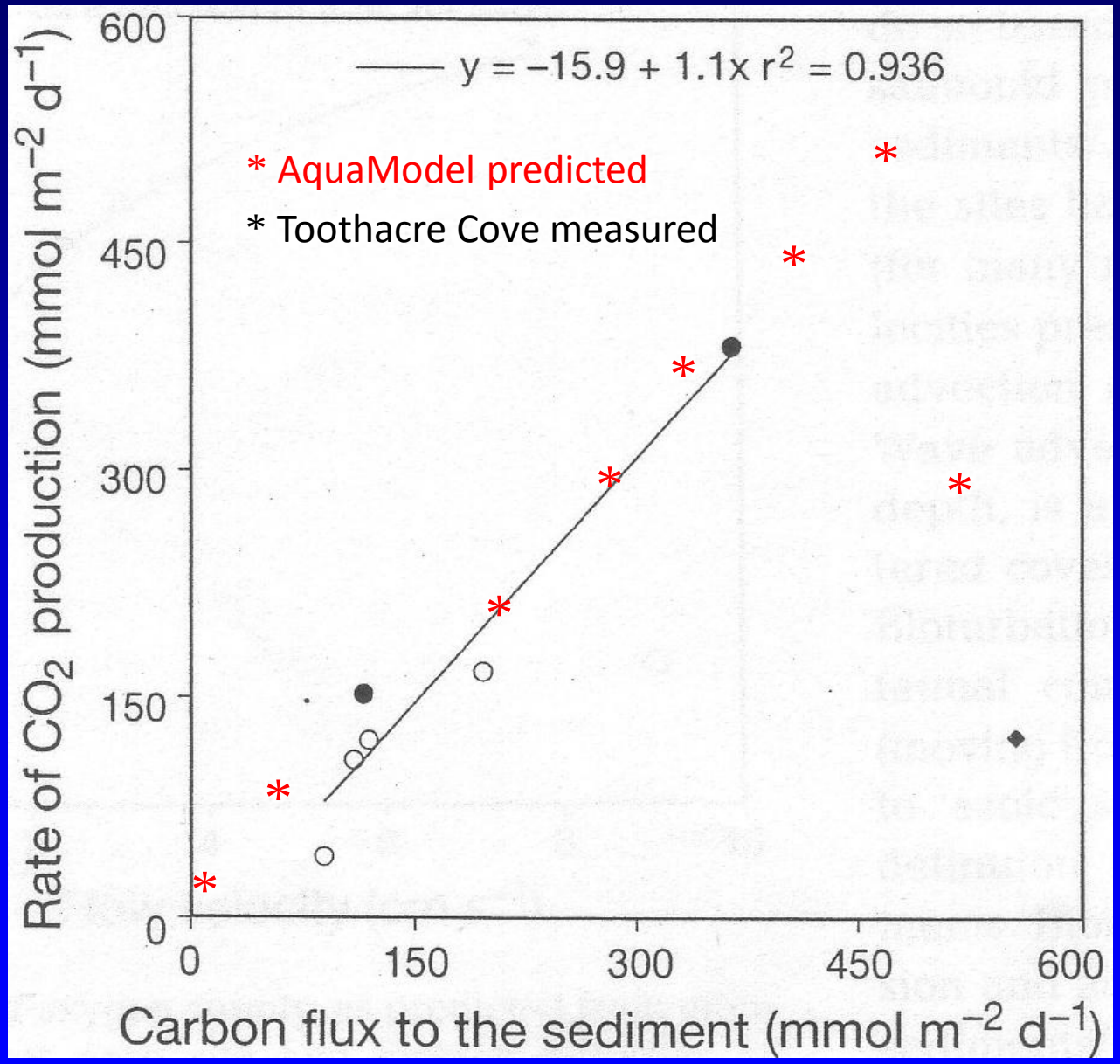
Software validation defined:
"checking that a software system meets specifications and fulfills its intended purpose"

More fun to model than to validate! Many published models make no mention of it.

Validation is not calibration and model forcing isn't copasetic unless stated clearly

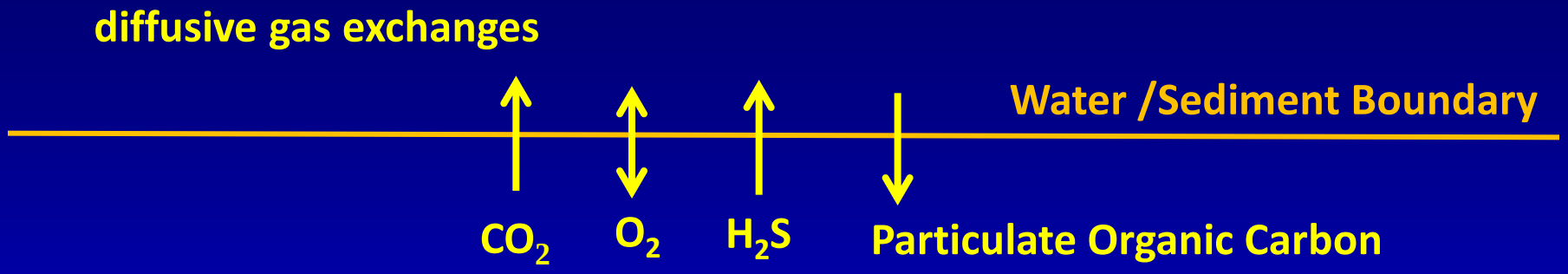
- **Water column** validation:
  D.O. & NPZ near and far field
  - Fish submodel calibrated by lab data. Validated with field data for flux calc.
  - NPZ time and space scales limit Phytos and Zoops to far field applications
  - Diffusivity measured and compared to literature including net pen literature
- **Benthic** validation:
  - Sensitivity analysis: sediment consolidation, deposition/resuspension rates, sediment porosity/gas flux rates, others.
  - Using field studies with TOC conc./rates and detailed water current records.
- Various internal model mass balance and conservation of mass checks needed.

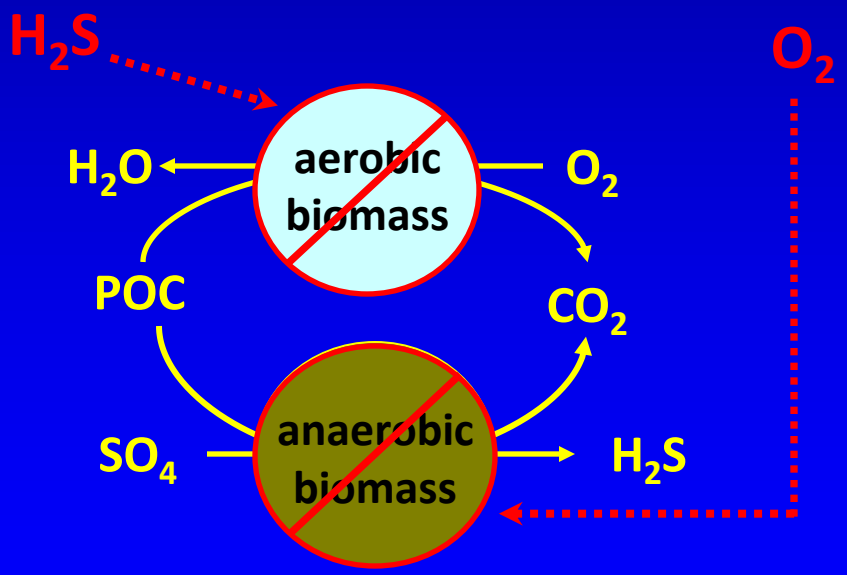
CO_2 Production vs. Carbon Deposition



Measured data: Findlay and Watling 1997

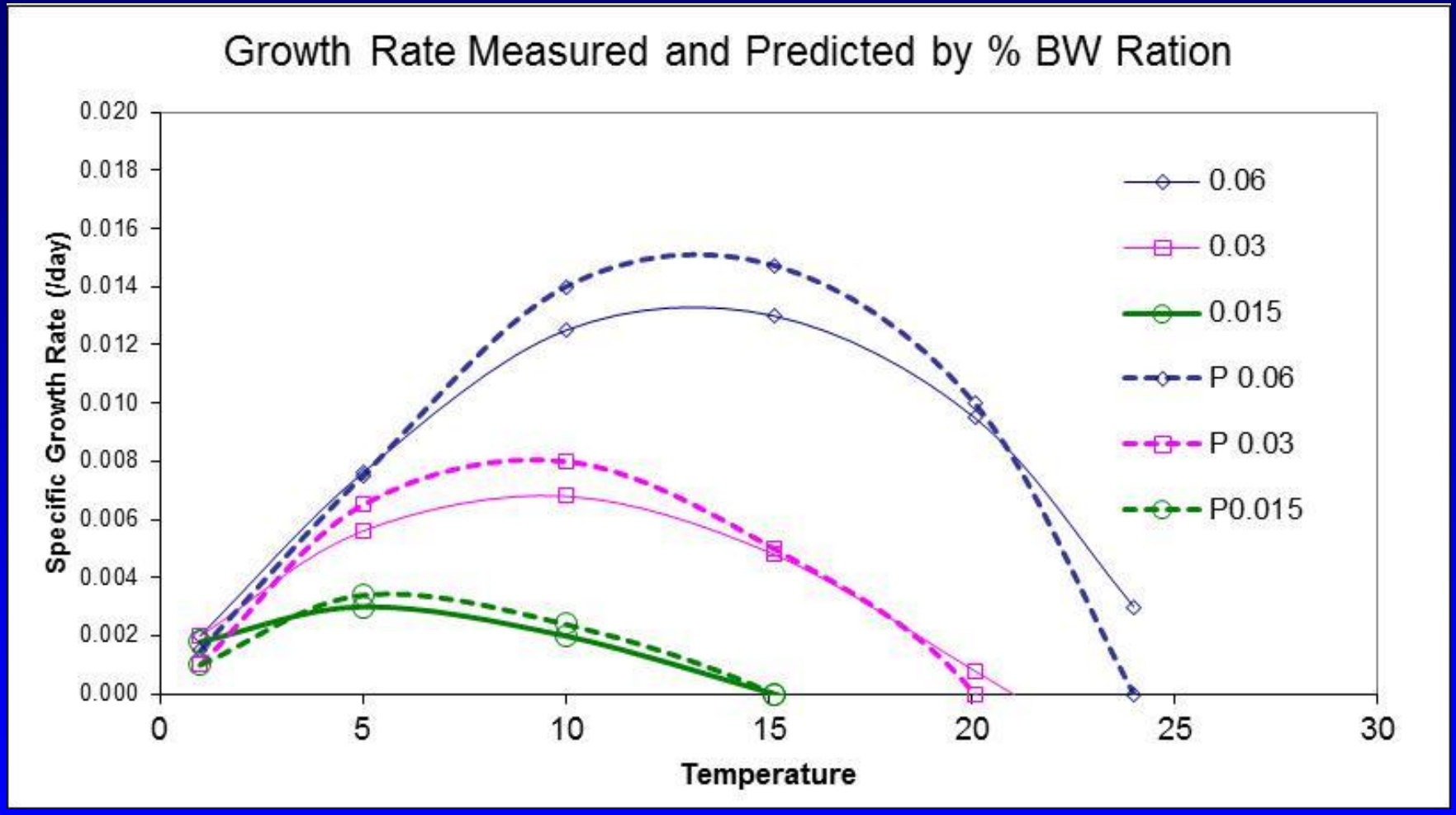
Benthic Module Concept





benthic respiration

Physiology Validation: Salmon Growth Rates
AquaModel Predicted vs. Measured



Validation Projects & Ecoregions

Benthic

- Salish Sea: Puget Sound (steady state TOC)
- Salish Sea: British Columbia (sulfides)
- Tropical venue: Pending (TOC)

Water Column

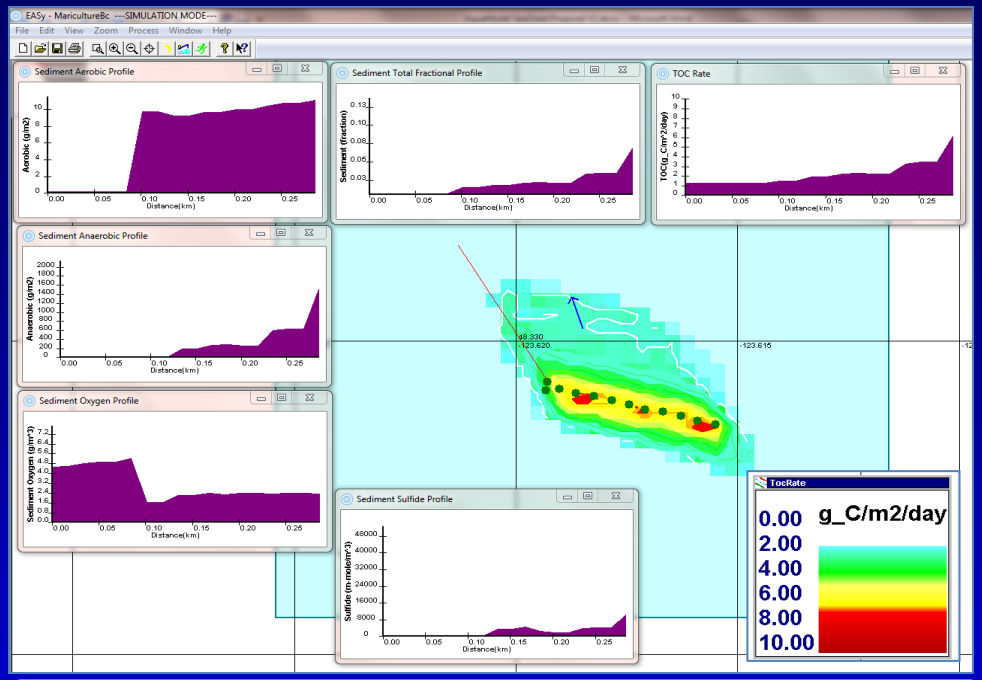
- Salish Sea: Puget Sound (near field)
- Gulf of Maine: Isle of Shoals (far field NPZ)

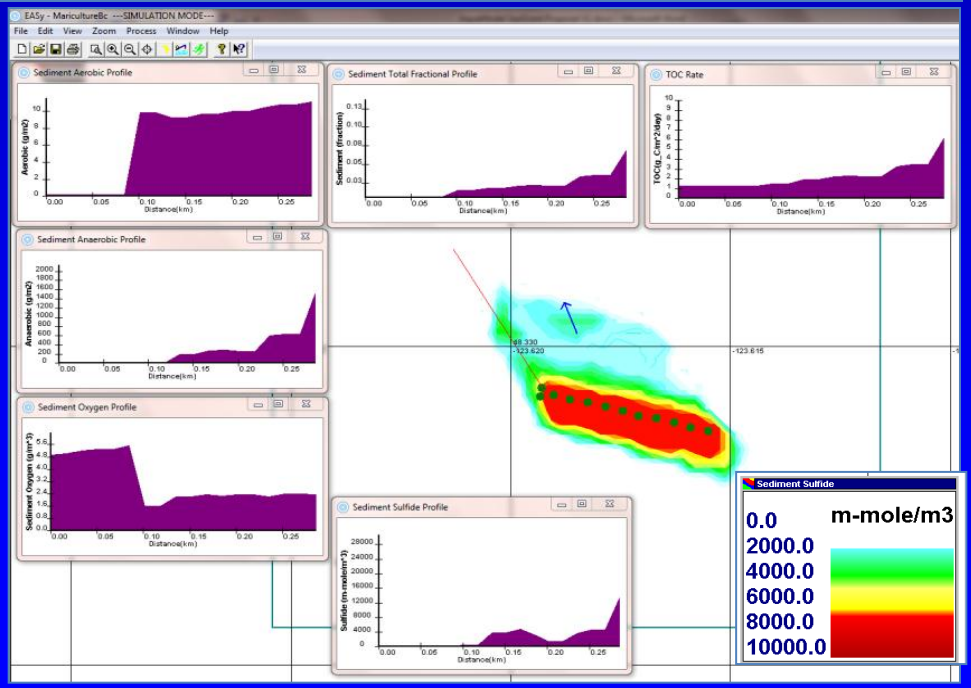
Vast majority of fish farm effects studies do not have suitable or complete data for model validation!
Usually missing adequate current data, almost always missing TOC.
TVS & redox are poor surrogates for TOC or sediment oxygen

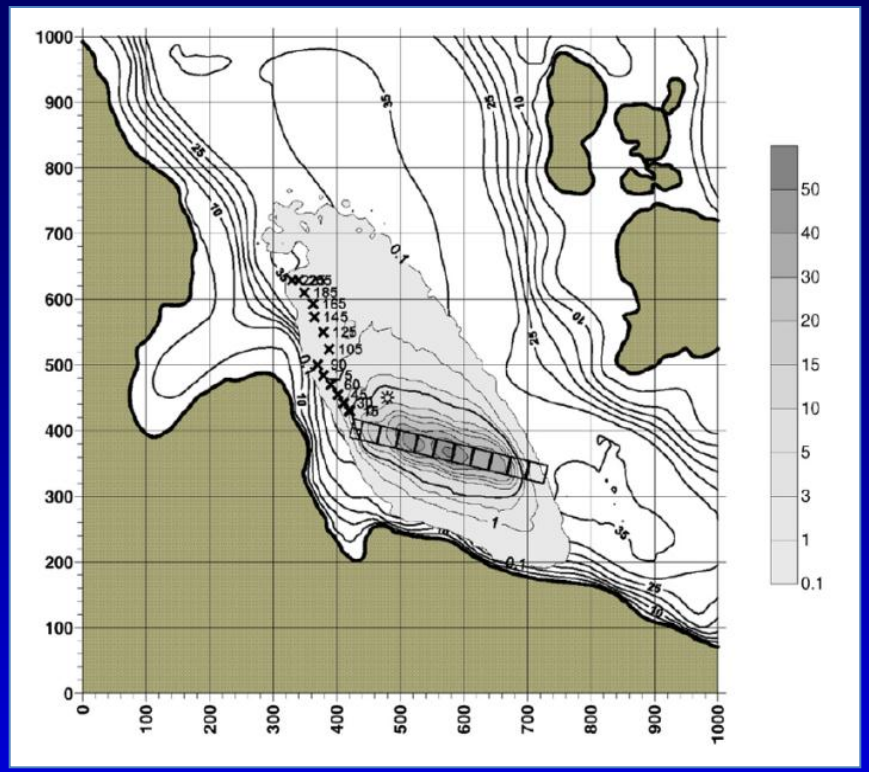
British Columbia Validation Site

- Chamberlain & Stucchi 2007: Sediment sulfides & TOC
  Necessitated new AquaModel farm grow out utility:
  - variable feed rate vs. optimum for growth model
  - transfer fish among cages
  - variable mortality and harvest rates and timing

- Initial results without above:
  - Approx. simulation of measured sulfide concentrations, work in progress.
  - Modeled sulfide concentration have high temporal variability, concurs with recent Canadian field work (Page et al. unpublished)
  - TOC flux rate to sediments very different than DEPOMOD, possibly a different definition or moving average method
  - Sediment consolidation rate sensitivity analysis findings: not a dominant factor in moderately active sites







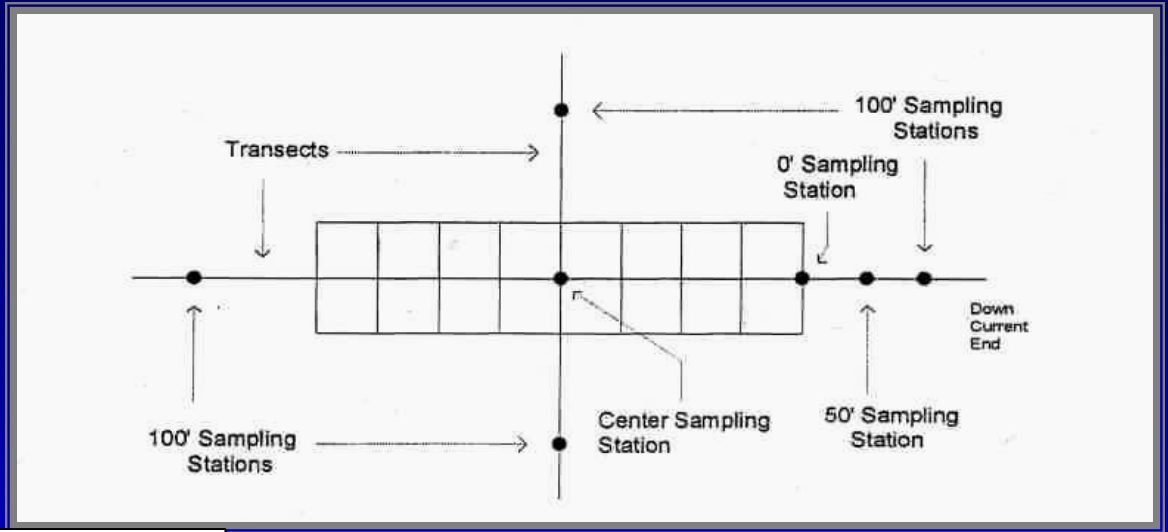
DEPOMOD Estimated TOC rate

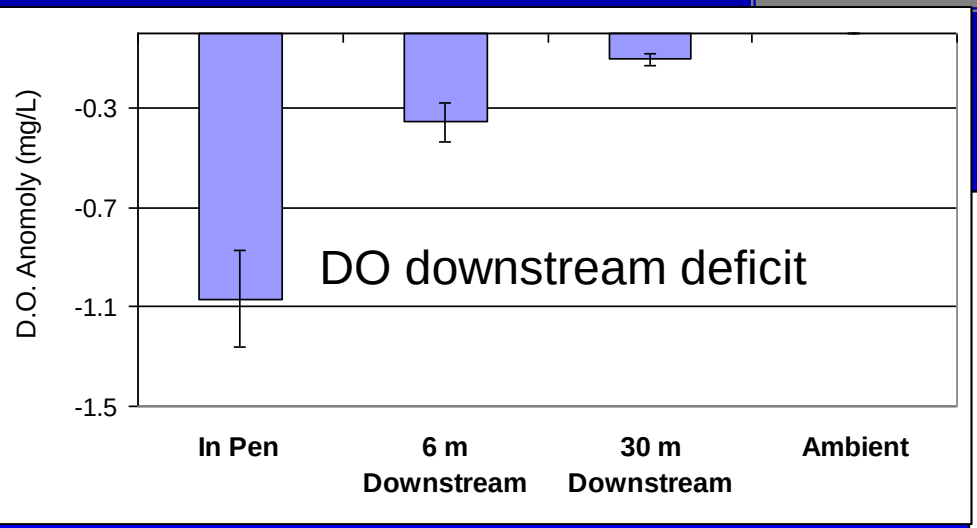
Estimated sulfides for comparison with measured values

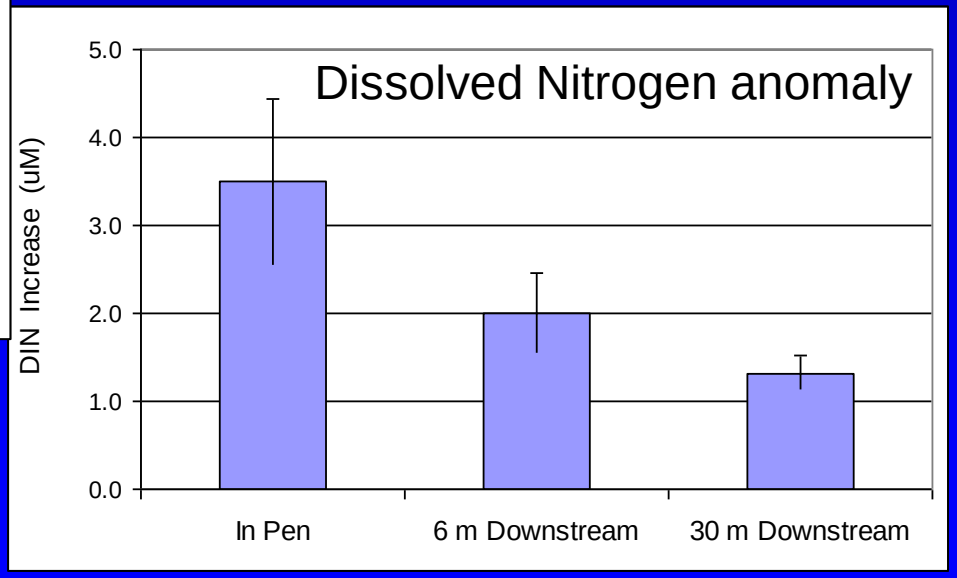
Salish Sea: Dissolved Oxygen and Nitrogen Flux Validation

12 small fish farms ~300 MT
Small is good for validation!

Strict protocols, time post feeding, current meters x concentration for for flux calc., drogues to insure linear flow, near neap tide period to raise signal to noise ratio



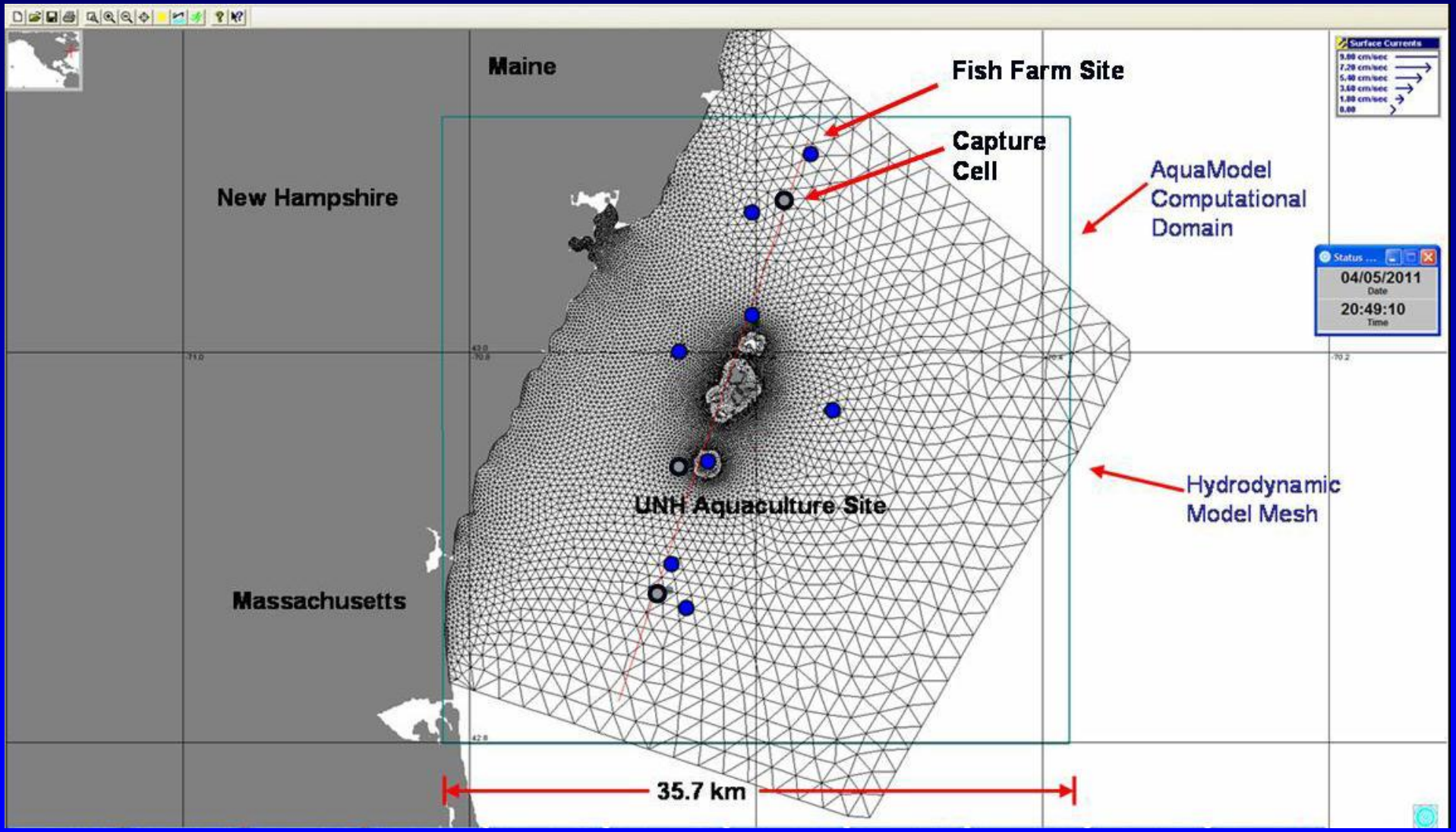




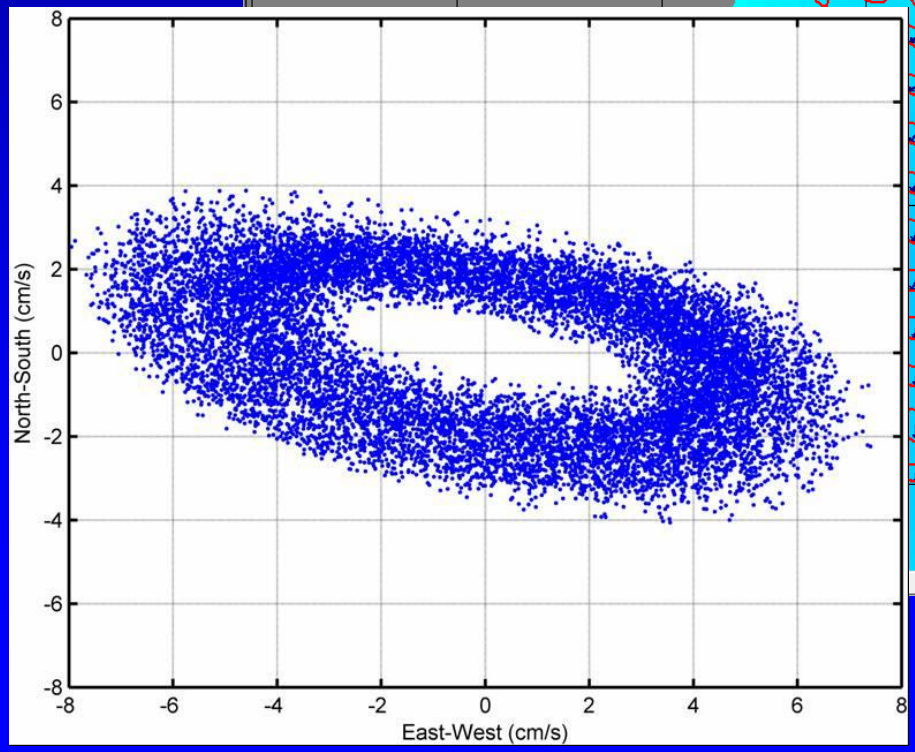
Far Field NPZ Testing

- High quality UNH-WHOI water quality and ADCP buoy data, 15 min interval for > 1 year for highly accurate description of background conditions.
- Detailed phytoplankton and zooplankton datasets obtained, irradiance, wind/wave data, etc.
- Built ADCIRC regional model, comparing with ADCP current meter data in center of region
- Calibrate run without fish in cages to validate base model
- Run with fish to estimate effects, compare output with validated near field runs
- Team member Dave Fredriksson and Jim Irish major contributors

Far Field Validation: Gulf of Maine, UNH Island Of shoals



Advanced Circulation Model (ADCIR) Grid, finite element, unstructured grid



MaineTidalEllipses - EASy

File Edit View Zoom Process Window Help

Tidal Ellipse Tool

ADCIRC Vectors
10.00 cm/sec
8.00 cm/sec
6.00 cm/sec
4.00 cm/sec
2.00 cm/sec
0.00

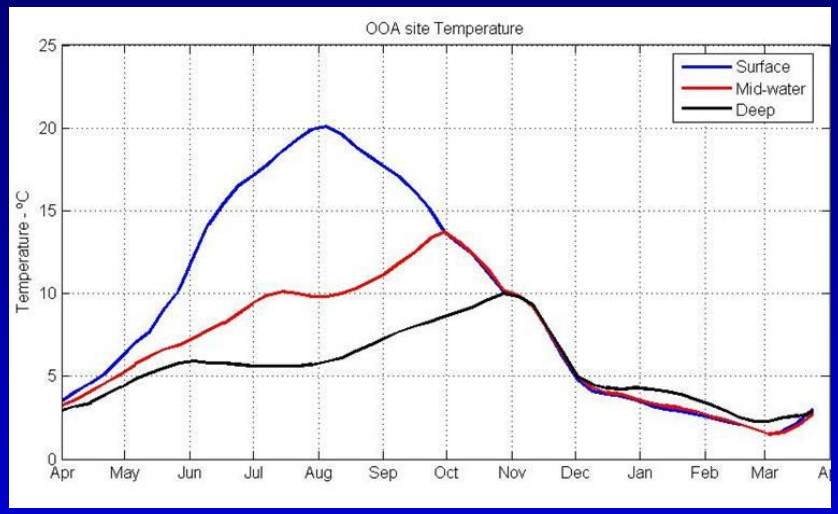
Status Window
01/01/2008
Date
13:00:00
Time

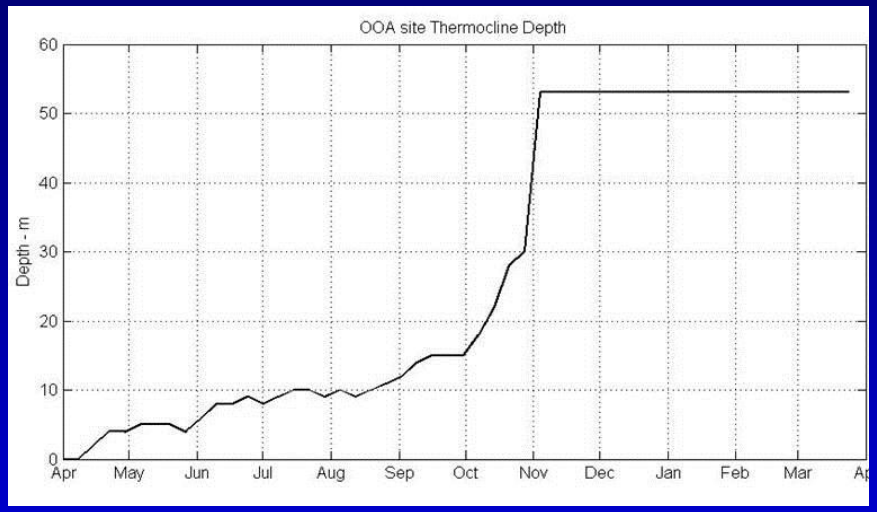
43.1
43.0
-71.0
-70.9
-70.8
-70.7
-70.6
-70.5
-70.4
-70.3

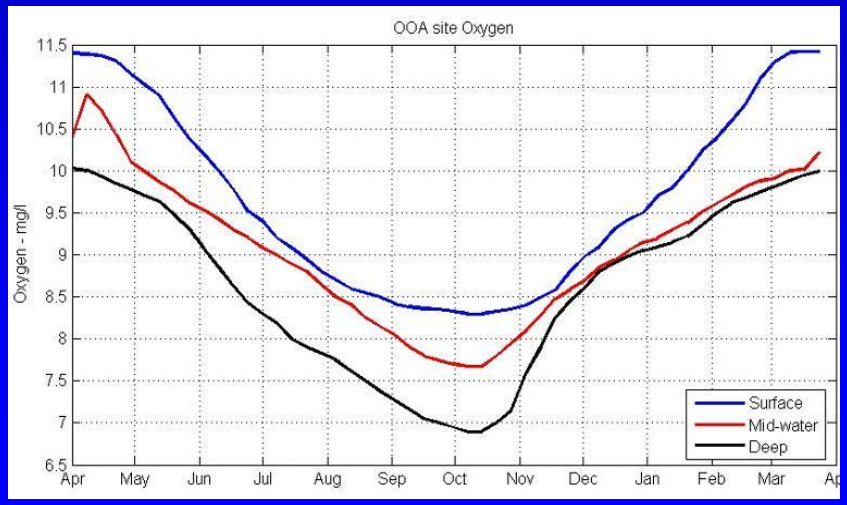
N99-99.999 W999-99.999 100000 99999999.9NM 360% 01/01/2008 Display

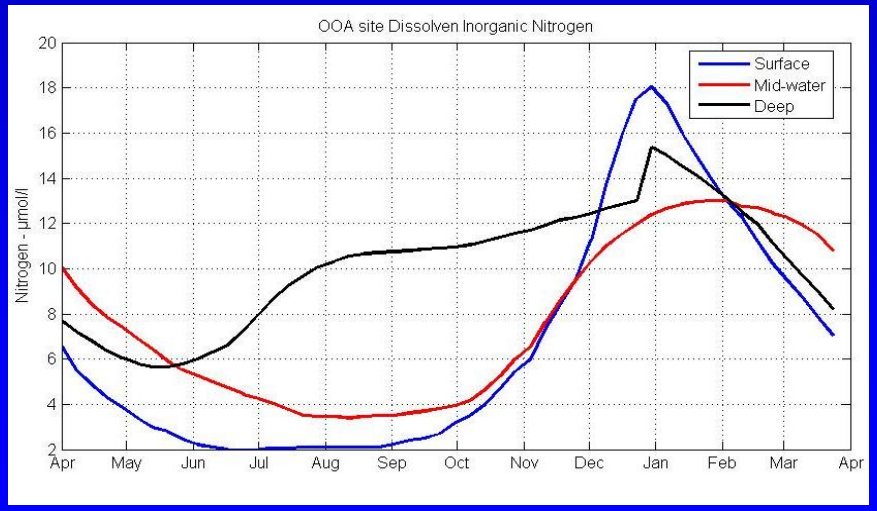
Gulf of Maine: NPZ submodel validation

Highly Variable Boundary Conditions, example parameters





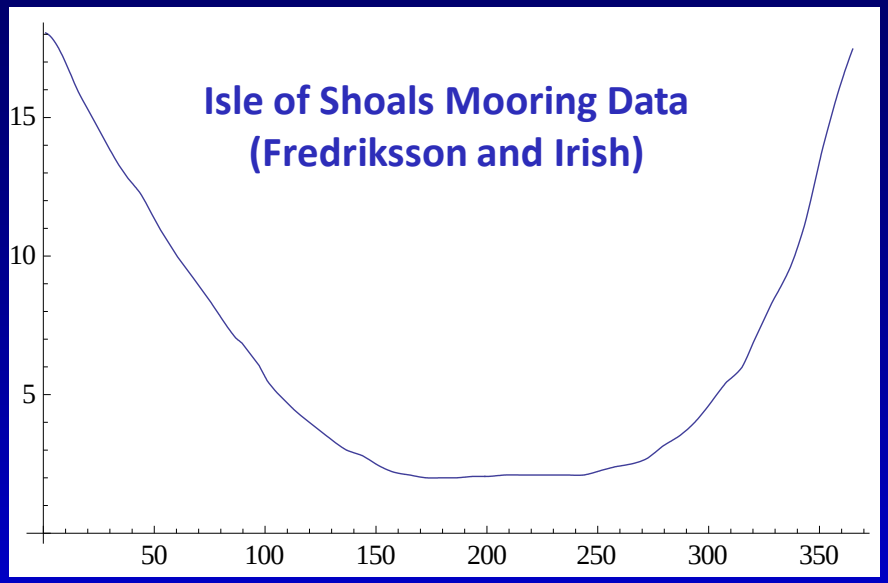




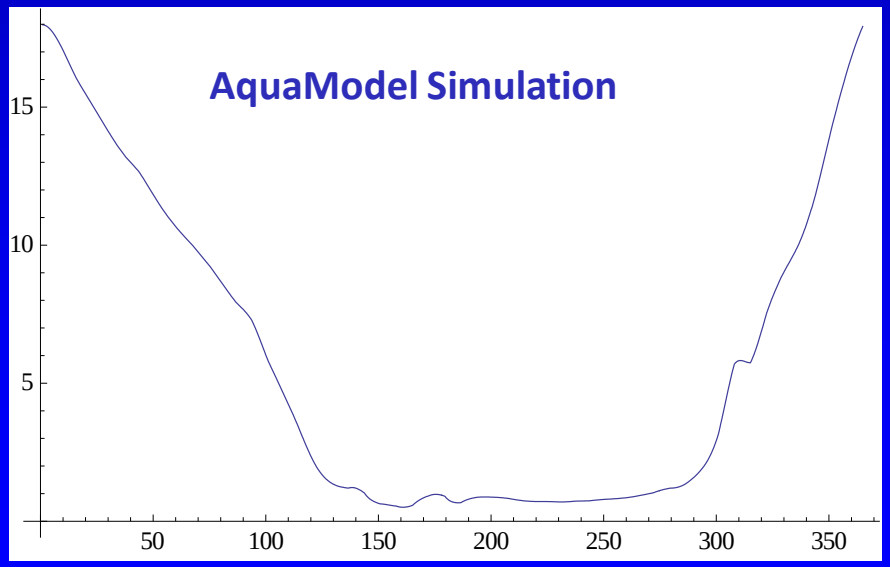
Source: Kiefer, Rensel, O'Brien ,Fredriksson and Irish, 2011

Capturing Dynamics of the Plankton Community 1

Dissolved Inorganic Nitrogen (mg-at/m3)



Dissolved Inorganic Nitrogen mg-at/m3



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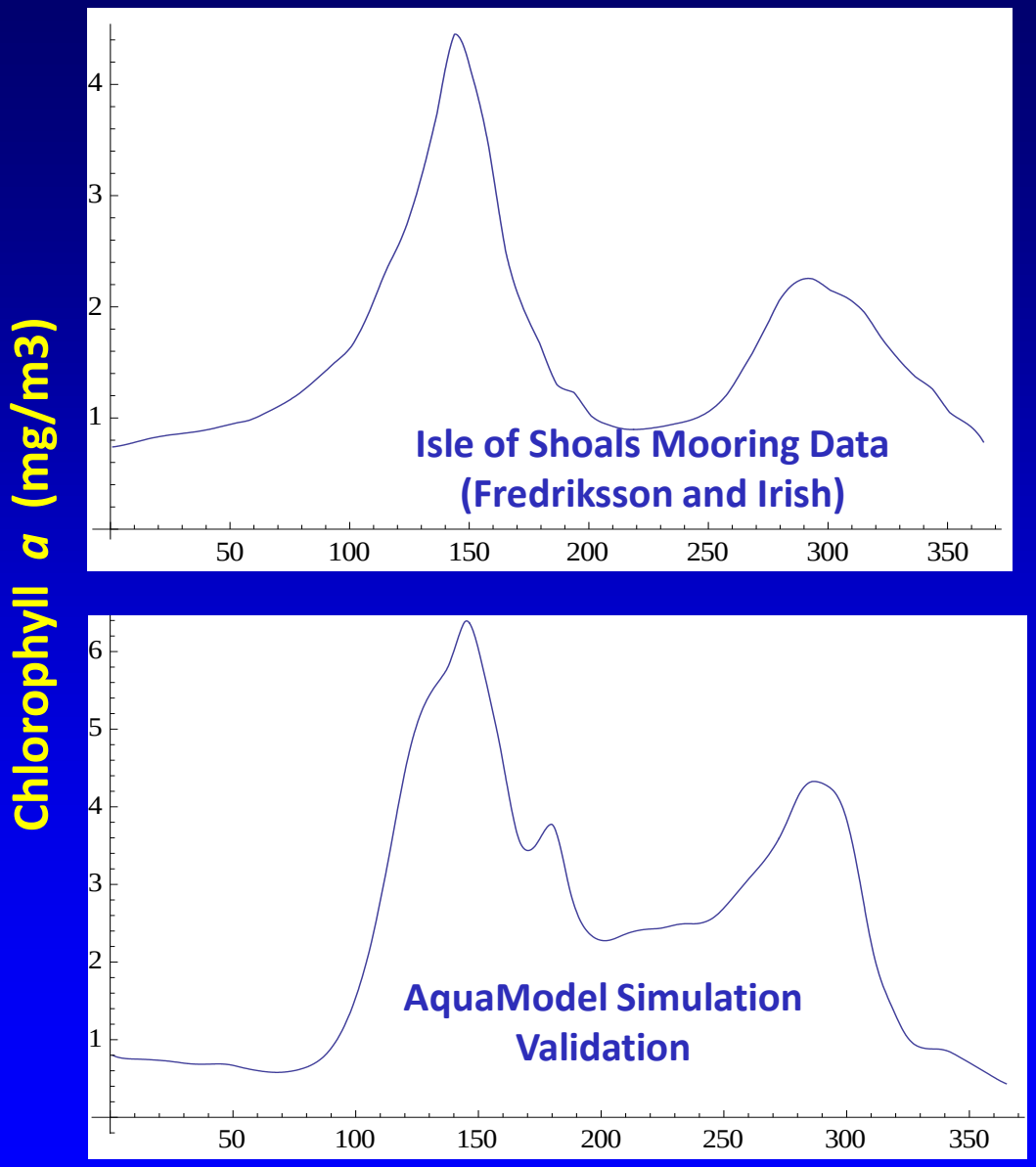
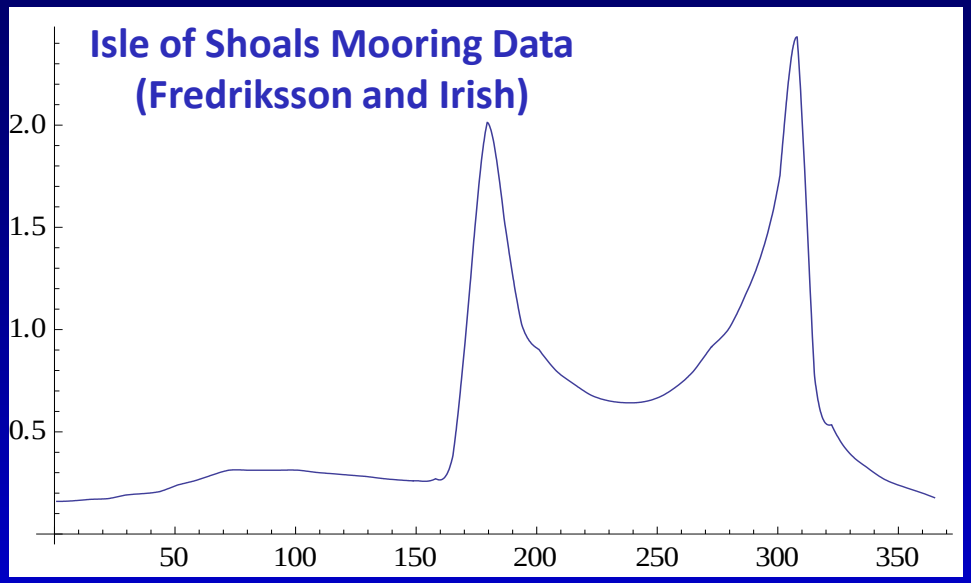
Capturing Dynamics of the Plankton Community 2

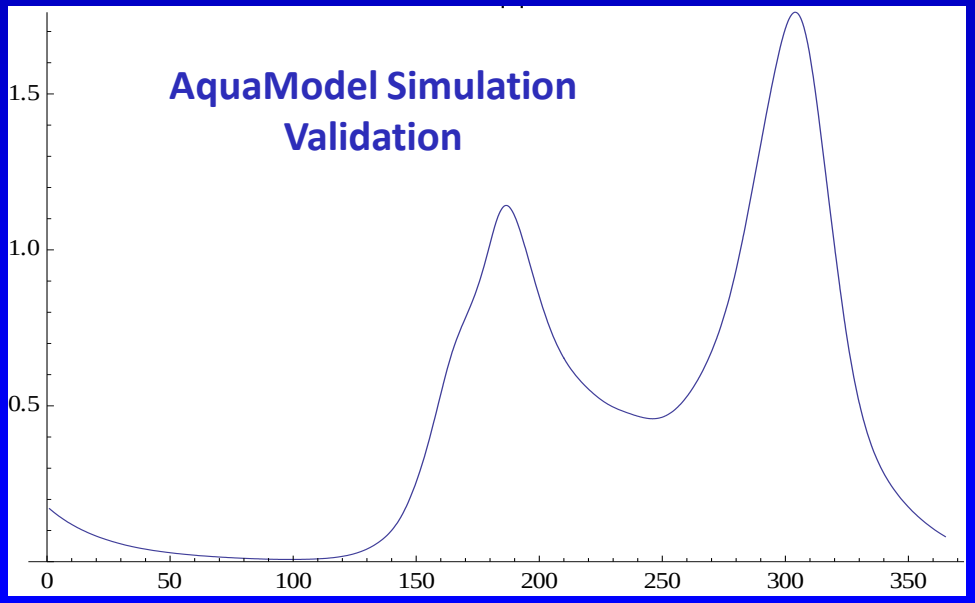


Capturing Dynamics of the Plankton Community 3

Zooplankton Nitrogen (mg-at/m3)



Zooplankton Nitrogen (mg-at/m3)



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Wrap Up

- Our validation work just begun, but a long time coming.
- Validation is difficult, almost all fish farm studies fail to collect complete data sets needed
- Many if not most fish aquaculture models have little or no validation work.
- Focus on key variables with most impact on model outcome.
- Circulation inputs are highly important, choice of many tools and physical models now sync with AquaModel

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