

SPRING 1999

EARTH SYSTEMS SIMULATION MODELLING

COURSE DESCRIPTION

MEA 400

- CLASS:** MWF 1435 - 1525
(3 credits)
- LAB:** Mon 1530 - 1700
(1 credit)
- TEXT:** MEA 400 Course Pak available in
Natural Resource Library
- REFERENCE MATERIAL:** Reference Material reserved in the
Natural Resources Library
- Class Web Page
www2.ncsu.edu/unity/lockers/class/mea400/
- EXTEND Modelling Software, Student Version
available in laboratory session.
- INSTRUCTOR:** Dr. Tom Hopkins
4146 Jordan Hall
Tel: 515-7771
tom_hopkins@ncsu.edu
- OFFICE HOURS:** MWF 3:30-5:00 pm

EARTH SYSTEMS SIMULATION MODELLING

MEA/ES 400

A. JUSTIFICATION: Quantitative assessments of the impacts of anthropogenic stresses is increasingly needed to guide decision-making processes during the inevitable transition to a 'sustainable management' of our natural resources. Computer-based simulation models, involving the quantitative assessment of anthropogenic impact on natural systems, represent the most promising common language between the science and policy sectors of our society. Dynamic and graphic modelling software, that utilizes pre-programmed dynamical blocks to represent mass, energy and information exchange in a user-friendly way, is now being used in both the science and business communities. Students graduating in the Environmental Science (and Natural Resources) Curricula need to be proficient both in the design and application of this genre of simulation models: e.g., for those with scientific interests to improve the model dynamics and the quality of the data input, and for those with managerial interests to more accurately include resource degradation into decision making and cost/benefit analyses. Furthermore, the course offers an opportunity for students, from the different concentrations within the Environmental Curriculum, to work together on a quantitative assessment of real systems.

B. OBJECTIVES: The general objective of this course is to provide a learning opportunity for students through their participation in a multidisciplinary exercise of quantifying a major natural system with respect to its anthropogenic stresses. The student will:

1. Learn the procedures and rationale for constructing conceptual models of a complicated interactive systems.
2. Learn how to parameterize data input, formulate internal processes, utilize dimensional analysis, and validate model output.
3. Gain experience in applying EXTEND software in an application to a major watershed-estuary system.
4. Gain experience in designing simulations and in discussing their results both from the scientific and managerial points of view.
5. Have an opportunity, through a individual effort, to construct a more detailed, smaller-scaled model in the area of his/her expertise.

C. CATALOG DESCRIPTION: Conceptual ecosystems modelling, dynamics, parameterization, boundary conditions, data integration, validation, interactions between sub-systems, and anthropogenic-coupling. Construction of simulation models using programmable blocks for quantitative simulations. Class will focus on a watershed-river-

estuarine system (Neuse River Watershed & Coastal Zone) in order to develop modelling skills and illustrate simulations of science and management questions.

D. STRUCTURE: The course (3-credit) will be organized on three levels: Lectures, including invited speakers; individual and group homework; and computer laboratory exercises. Generally, the Tuesday-Thursday sessions will be for lectures and Invited Speakers and the Monday Laboratory session for and Computer exercises and exams. The student will be responsible for presented material covered and assigned readings. The grade for the lecture portion will be based on the exams (80%), Homework (20%) and Participation (5%). The grade for the laboratory portion will be based on the Individual Project (70%) and Lab-related homework (30%).

The Laboratory (1-credit) sessions will be conducted in a computer lab with individual monitors and using EXTEND software through a Macintosh emulator. Student versions of the software (with manual) will be provided. Students will start with tutorials and basic model construction. They will then construct a simplified model of the Neuse Watershed (Neuse.0) followed by a more detailed version (Neuse.1) that will allow them to address simulations of scientific and managerial questions. In addition they will complete some specific improvement of the model in the area of their own interest as an individual projects.

E. TEXTBOOKS: No comprehensive textbook has been found to cover the watershed, river, estuary system. The Course Pak comprised of selected readings will serve as the text. Several copies are in the Library, two of which are available for copying. Students making copies must (Please!!) take care not to shuffle the order of the pages for the next student. In addition, the students will be given supplemental material in the form of Handouts.

F. RESOURCES: The course requires a lecture room with standard audio-visual equipment and a computer laboratory with up to 19 monitors. It requires a TA (funded by a ESSE NASA Grant) for the computer lab sessions and for assistance with the exams, group and individual-project evaluations. Student versions of the EXTEND software will be provided.

G. SYLLABUS: A semester will consist of 29 class room lectures, several of which will be invited talks from among the ES Faculty and non academic professionals. There will be 14 laboratory sessions during which 4 exams will be given. The lecture material is divided into 4 components, each of which has an exam. The lecture material has the objective to introduce the student to a systems approach, model formulation using the dynamic case study of the runoff in the Neuse Watershed.

COURSE CONTENT

SYSTEMS

- Introduction to Earth Systems
- Systems Concepts
- Systems Theory
- Conceptual Modelling
- Forcing/Internal Processing/Response
- Modelling Tools & Extend

WATERSHEDS

- Atmospheric Input
- Source Emissions & Acid Rain
- Biogeochemical Cycles
- Water-Land Use Conflicts
- Water Pollution
- Non-Point Effluents
- Vadose Zone
- Vegetation
- Ground Water
- Wetlands

COASTAL ZONES

- Rivers and Controls
- Two-Layered Systems
- Estuaries, Circulation
- Eutrophication, Nutrients
- Eutrophication, Carbon
- Estuaries, Benthic
- Coastal Zones
- Neuse Estuary Characteristics
- Habitat Issues

SIMULATIONS

- Linking Interactive Systems
- Change of State & Event Analysis
- Monitoring & Data Acquisition
- Natural Capital
- Sensitivity Analysis
- Final Project Issues
- Coastal Zone Rehabilitation
- Simulations

LABORATORY SESSIONS

Laboratory exercises are intended to be accumulative in the use of the Extend Software and in the expertise of formulating models. Most of the lab assignments will involve building simple submodels that will be linked up toward the end of the course.

Introduction: Extend Software basics, tutorial examples.

Building, Diagnosing and Constructing simple Extend models.

Constructing Data Input Models: Atmospheric and Pollution.

Nitrogen processing submodels

Vadose Zone submodel

Ground Water submodel

Adding River effluent to a 2-layer Lake Model

Predator-Prey and Biological Growth Models

Primary Productivity and Nutrient Uptake

Modifying the Lake to be an Estuary

Linking Submodels

Sensitivity-Analysis Exercises

Individual Projects: Extend construction

Individual Projects: Simulations

CLASS SCHEDULE SPRING '99

Date	Day	Lect	Topic	Reading
4-Jan	M	1	Intro to Earth Systems	Hop; Southwick Ch25
6-Jan	W	2	Systems Concepts	Hop; Southwick Ch4; Odum Ch1
8-Jan	F	3	Systems Theory	Jeffers Ch1; Odum Ch1
11-Jan	M	4	Continue/Discuss	
13-Jan	W	5	Concept Modelling	Unesco Excerpt; Jorgensen Sect2
15-Jan	F	6	Forcing --- Response	Hop
20-Jan	M	7	Modelling Tools	Hop
22-Jan	W	8	Review/Discuss	
25-Jan	F	9	Quiz	
27-Jan	W	10	Atmospheric Input	Schlesinger Ch10; Nat'l Acad Press
29-Jan	F	11	Source Emissions	Hop; Southwick Ch5
1-Feb	M	12	Biogeochemical Cycles	Schlesinger Ch12; Berner p.101
3-Feb	W	13	Continue/Discuss	
5-Feb	F	14	Water-Land Use	Hop
8-Feb	M	15	Water Quality	Buchholz Ch7; Moore Ch7; Gower Ch5
10-Feb	W	16	Non Point Effluents	Moore Ch5
12-Feb	F	17	Continue/Discuss	
15-Feb	M	18	Vadose Zone	Black Ch5; Fetter Ch3; Mount p83
17-Feb	W	19	Vegetation	Black 4; Schlesinger p179-205
19-Feb	F	20	Ground Water	Black Ch5; Schlesinger p261-270
22-Feb	M	21	Wetlands	Gregory
24-Feb	W	22	Review/Discuss	
26-Feb	F	23	Quiz	
1-Mar	M	24	Rivers & Controls	Vannote; Berher p221-205
3-Mar	W	25	Two-Layered Systems	Hop
5-Mar	F	26	Estuaries - Circulation	Berner Ch7
15-Mar	M	27	Continue/Discuss	
17-Mar	W	28	Estuaries - Nutrients	Schlesinger p279-290; Nixon
18-Mar	F	29	Estuaries - Production	Lalli & Parsons 3.2-3.5, 5.1-5.2
22-Mar	M	30	Estuaries - Benthic	Hop; Eggleston
24-Mar	W	31	Continue/Discuss	
26-Mar	F	32	Coastal Zone Rehabilitation	Klee Ch1; Schlesinger p340-343
29-Mar	W	33	Neuse Estuary Characteristics	WRRI
2-Apr	F	34	Habitat Issues	Hop; Wolcott
5-Apr	M	35	Review/Discuss	

SCHEDULE Cont.

9-Apr	F	37	Linking Interactive Systems	Hop
12-Apr	M	38	Change of State & Event Analysis	Hop
14-Apr	W	39	Monitoring/Observations	Hop
16-Apr	F	40	Continue/Discuss	
19-Apr	M	41	Sensitivity Analysis	Extend Ch7
21-Apr	W	42	Final Project Issues	
23-Apr	F	43	Natural Capital	Costanza; Story Ch9
26-Apr	M	44	CZ Rehabilitation	Klee Ch2
28-Apr	W	45	Simulations	Hop
30-Apr	F	46	Review/Discuss	
1-May	M		Quiz	
5-May	M		Final Projects Due	

COMPUTER LAB SCHEDULE SPRING '99

Date	Day	Lab	Activity	
11-Jan	M	1	Introduction: Extend Software basics, tutorial examples.	
25-Jan	M	2	Building, Diagnosing and Constructing simple Extend models.	
1-Feb	M	3	Constructing Data Input Models: Atmospheric and Pollution.	
8-Feb	M	4	Nitrogen processing submodels	
15-Feb	M	5	Vadose Zone submodel	
22-Feb	M	6	Ground Water submodel	
1-Mar	M	7	Adding River effluent to a 2-layer Lake Model	
15-Mar	M	8	Predator-Prey and Biological Growth Models	
22-Mar	M	9	Primary Productivity and Nutrient Uptake	
29-Mar	M	10	Modifying the Lake to be an Estuary	
5-Apr	M	11	Linking Submodels	
12-Apr	M	12	Sensitivity-Analysis Exercises	
19-Apr	M	13	Individual Projects: Extend construction	
26-Apr	M	14	Individual Projects: Simulation	

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**Review Points for Quiz I
SYSTEMS INTRODUCTION**

A. Lecture Material on Systems Component

B. Hop Handouts

Earth System Science
Definitions
System Approach
Dimensional Analysis

C. Reading

Southwick Ch 25, 4
Odum Ch 1
Unesco excerpt on Modelling
Jeffers Ch 1
Jorgensen Sect 2

D. Extend

1. Read Ch 2
2. Basic information as you learned to complete your homework: e.g. blocks, connections, text, printing, etc.
3. Lake Pollution Model - understand what it does and what you did to it.

E. Conceptual Models - understand assumptions, relevance, scientific basis and Odum representation.