Undergraduate Earth System Science Education

NSF, CC, EV, ESS, POGIL & STELLA too...

Howard Drossman

CMMAP Team Meeting

New York University

January 6, 2009

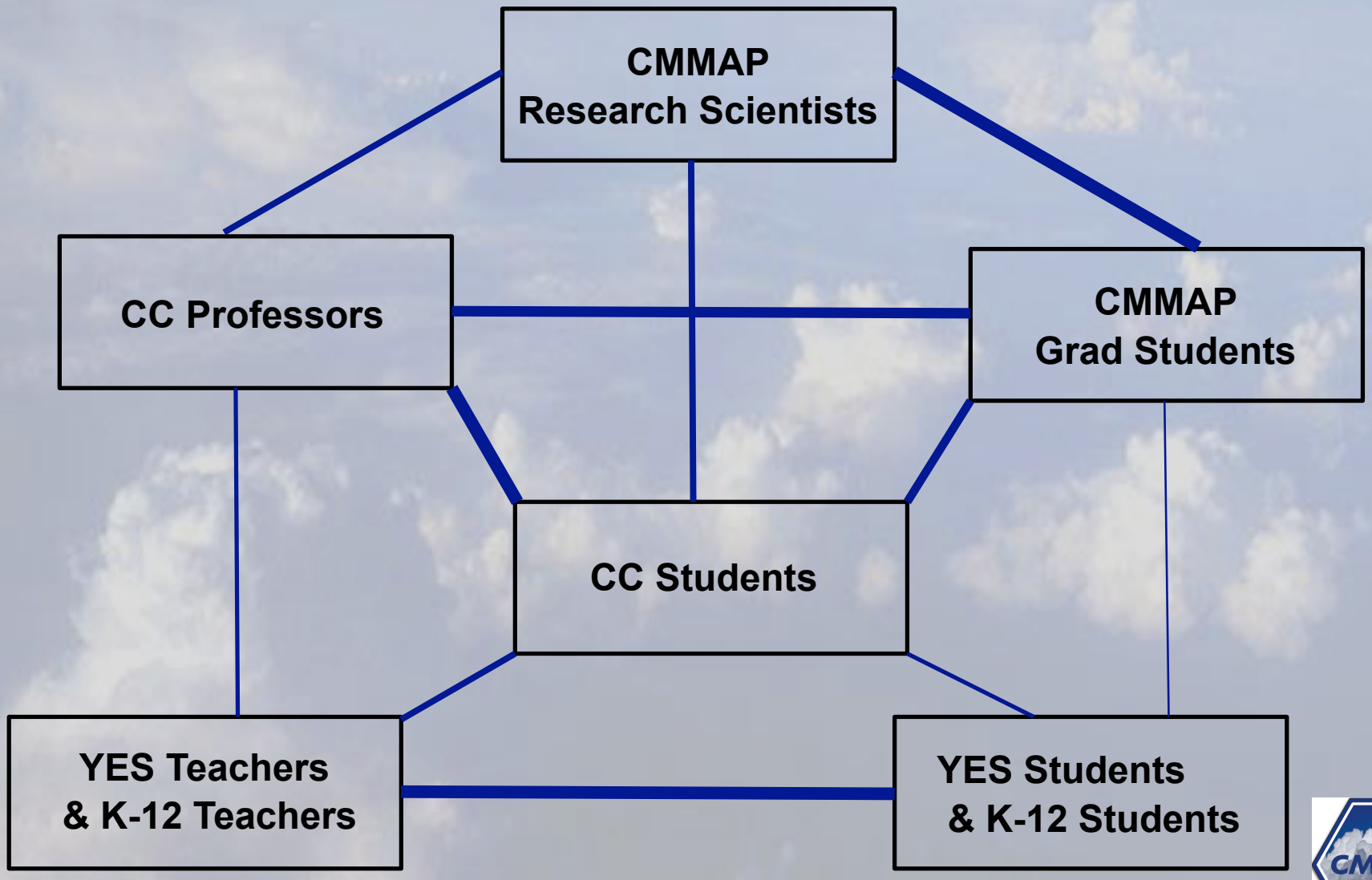
Outline

- CC-CMMAP Education & Diversity Initiatives
- CC-Earth System Science (ESS) Curriculum
- Undergraduate ESS Classes
  - EV 128: Introduction to Global Climate Change
  - EV 211: Human Impacts on Biogeochemical Cycles
  - EV 431: Air-Atmospheric Physics & Chemistry
- What's Next?
  - Enhance the web of connections
  - Focus on modes of inquiry
  - Teach about paradigms
  - Design and implement useful assessments
  - Disseminate classes and strategies

CMMAP Education & Diversity Initiatives

- **Improve undergraduate Earth Systems Science and climate education.**
- Teach next generation of leading climate scientists to be better teachers.
- Improve the retention of women in the science and engineering "pipeline" from middle school through graduate school.
- Improve recruitment of under-represented groups into Earth Science at the undergraduate level.

Educational Objectives Integration



CC-CMMAP Funded Grad & Faculty Activities

Graduate Student Teaching Mentorships

- Luke Van Roekel (EV 431-07): Drossman
- Jim Benedict (EV 431-08): Drossman
- Kate Thayer-Calder (EV 128-08): Leonard
- Kelley Wells (EV 431-09): Drossman
- Rachel McCrary (EV128-09): Taber
- Anna Harper (EV 128-09): Fricke

Faculty Visits (CC Seminars & Class Visits)

- David Randall (2007; EV 431)
- Scott Denning (2008; EV 128)
- Jeff Collett & students (2008; EV 431)

CC-CMMAP Funded UG Students

Annual student scholarships, 2008:

Alice DuVivier & Jette Petersen: Laplacian operators (Randall)

Tyler Ruggles:Community GHG Reduction Strategies (Betsill)

Zoe Keve: Biomass Fuel Policy (Kathlene)-Thesis

David Sullivan: Carbon Pricing Policy (Kathlene)-Thesis

Brittany Vogel: K-12 Education (LSOP, NCAR, Catamount)

Sarah Waldo: BEACHON (NCAR/Drossman)-Thesis

Summer Roberts: BEACHON (NCAR/Drossman)

Rich Brereton: EV 431 Assistant-Grad School, Ecosystems

Annual student scholarships, 2007:

Rebecca Simpson (Kreidenweiss): Atmospheric Science, U Hawaii

Parker Kraus (Denning): Atmospheric Science, CSU

Gillian Bobier (NCAR, Catamount): K-12 Education?

Beth Beckel (Collett): Grad school?

CC Graduate Student Mentors

- Barb Whitten (Physics)
- Mike Taber (Education)
- Matt Reuer (Environmental Science)
- Raj Pandhya (NCAR)
- Sally Meyer (Chemistry)
- Eric Leonard (Geology)
- Miro Kummel (Environmental Science)
- Steven Janke (Math)
- Henry Fricke (Geology)
- Howard Drossman (Environmental Science & Chemistry)

Our Education Mission:
Inspire the Next Generation of Earth System Scientists

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Reach for the sky.

Earth System Science (ESS) Classes

"Earth System Science courses are distinguished from Earth Science courses through their explicit **multidisciplinary** focus on the **connections, interactions and feedbacks** between the system components: atmosphere, hydrosphere, lithosphere, biosphere, anthroposphere, and exosphere."*

*Science Education Resource Center at Carleton College:
http://serc.carleton.edu/introgeo/earthcoursedesign/whatis.html

Colorado College Environmental Program

Environmental Science

Environmental Science-Physics

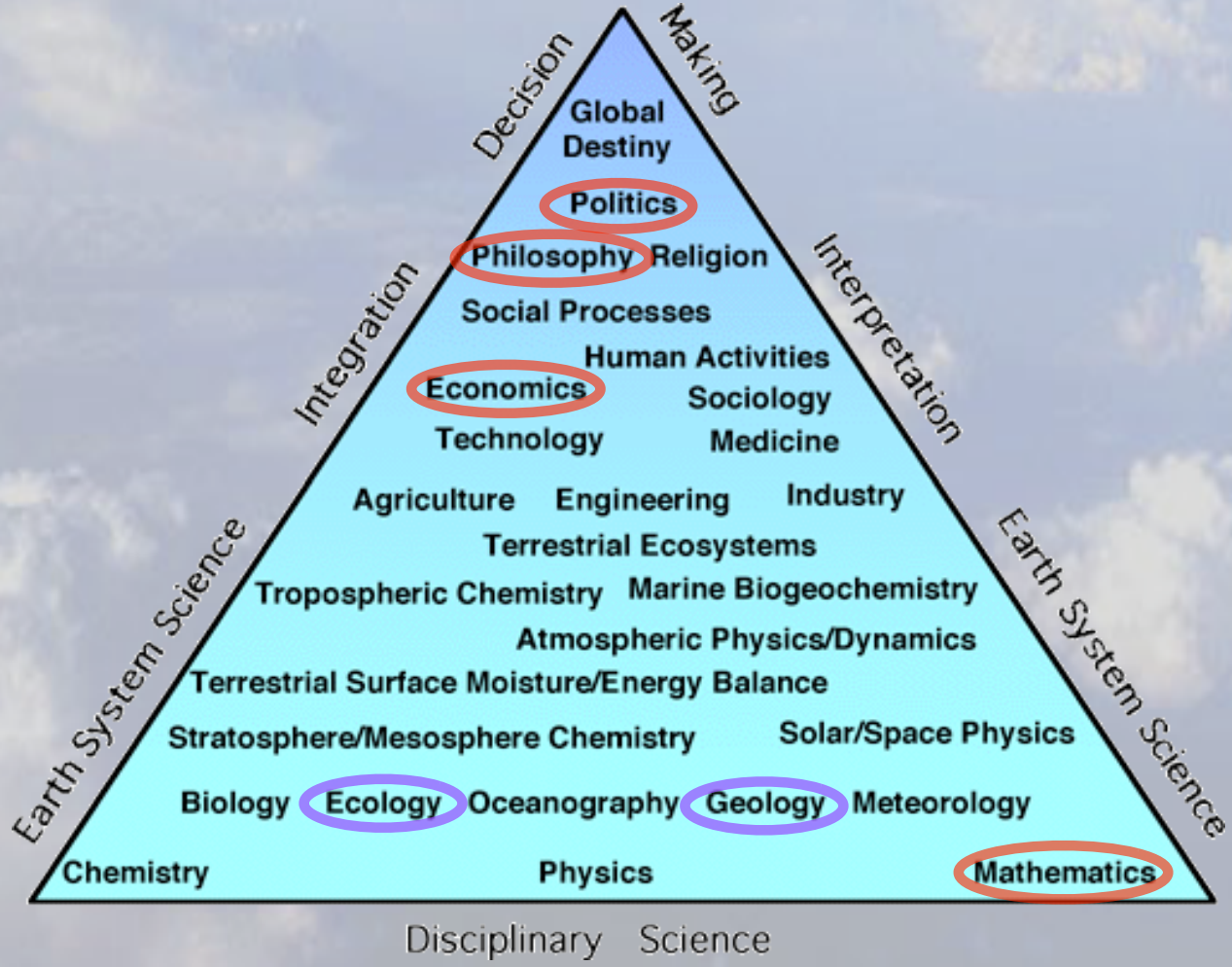
Environmental Science-Chemistry

Environmental Policy

LAS Major in Environmental Science

Environmental Issues Minor

Environmental Program Discipline-Based Classes



Lower Level ESS Classes

EV 128: Introduction to Global Climate Change (no pre-reqs)

Calculus 1

EV 211: Human Impacts on Biogeochemical Cycles

Upper Level ESS Classes

EV 212: Energy

Environmental Thermo & Dynamics

EV 311: Water

Hydrology, Aquatic Chemistry & Ecology

EV 431: Air

Atmospheric Physics & Chemistry

Three-Year Capstone Sequence

EV 221
Environmental Inquiry (Sophomore)

EV 321
Environmental Management (Junior)

EV 421
Environmental Synthesis (Senior)

EV 128
Introduction to Global Climate Change

Some Key Questions:

- How do scientists deal with uncertainty?
- Does science provide the “correct” answers?
- How do scientists reach a consensus?
- What can science provide to policy makers?
- What ethical issues relate to climate change?

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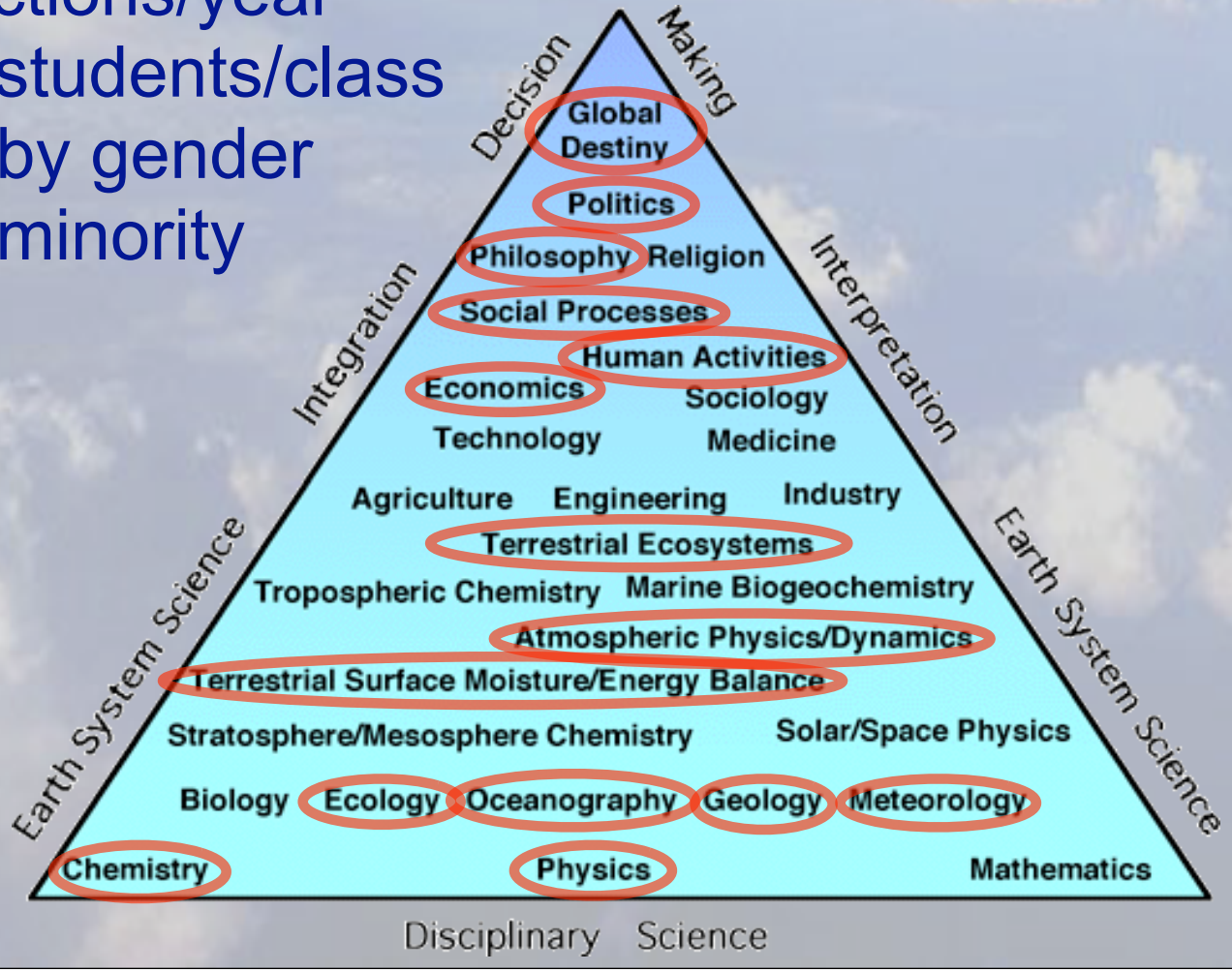
EV 128

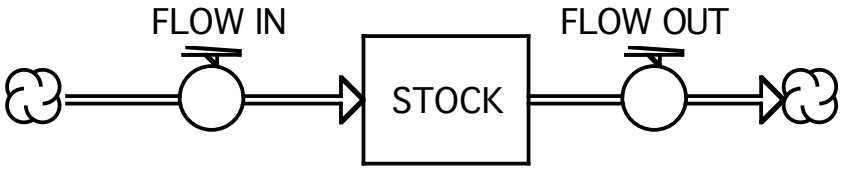
Introduction to Global Climate Change

- 4-5 sections/year
- 16-25 students/class
- ~50% by gender
- ~10% minority

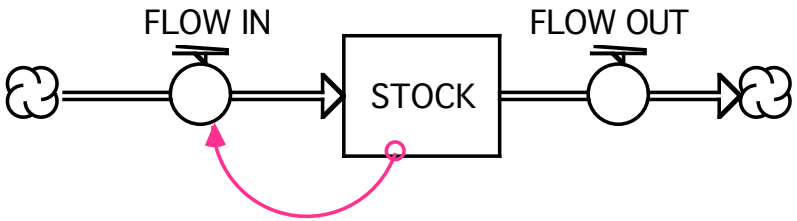


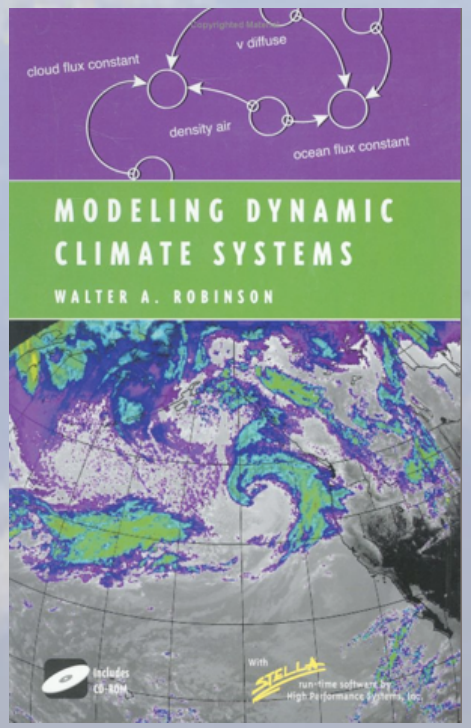
Systems Modeling with STELLA

Linear Steady State System

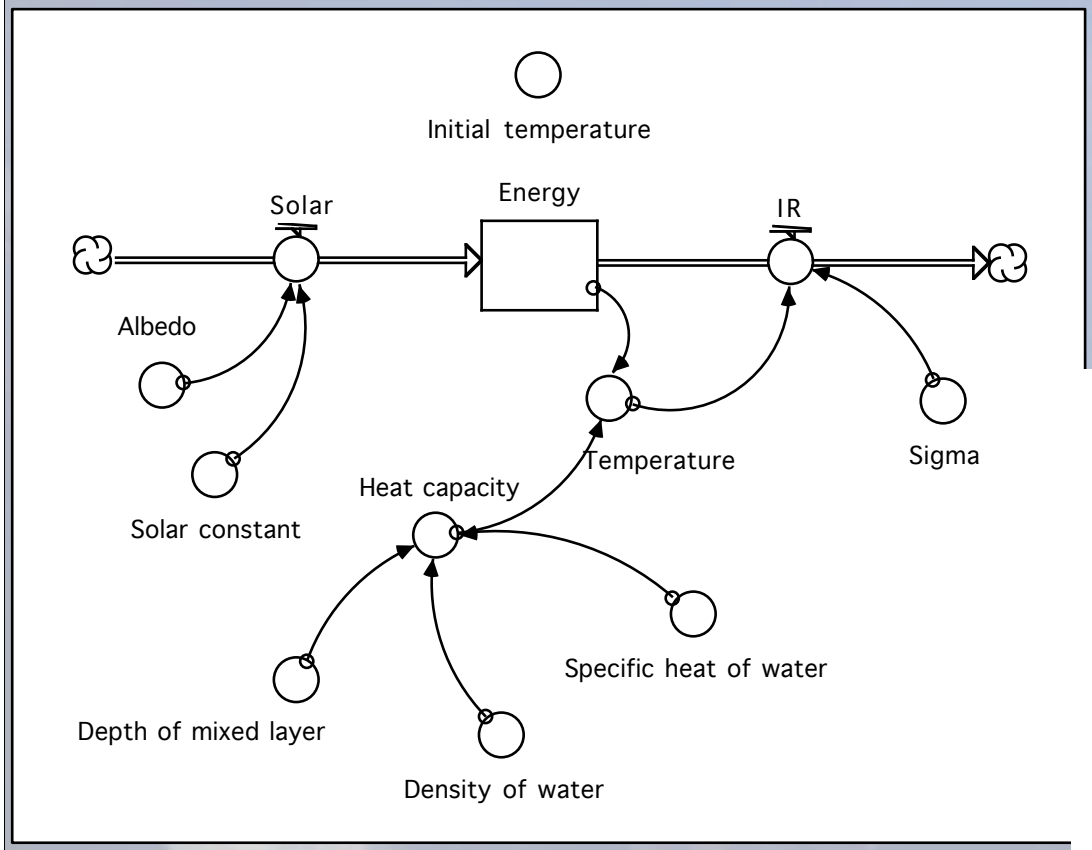


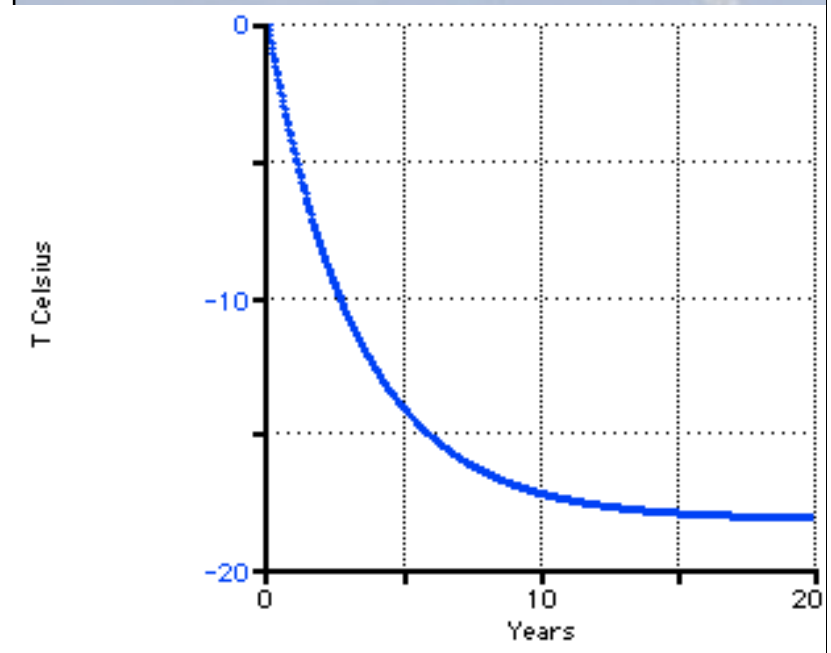
Nonlinear System



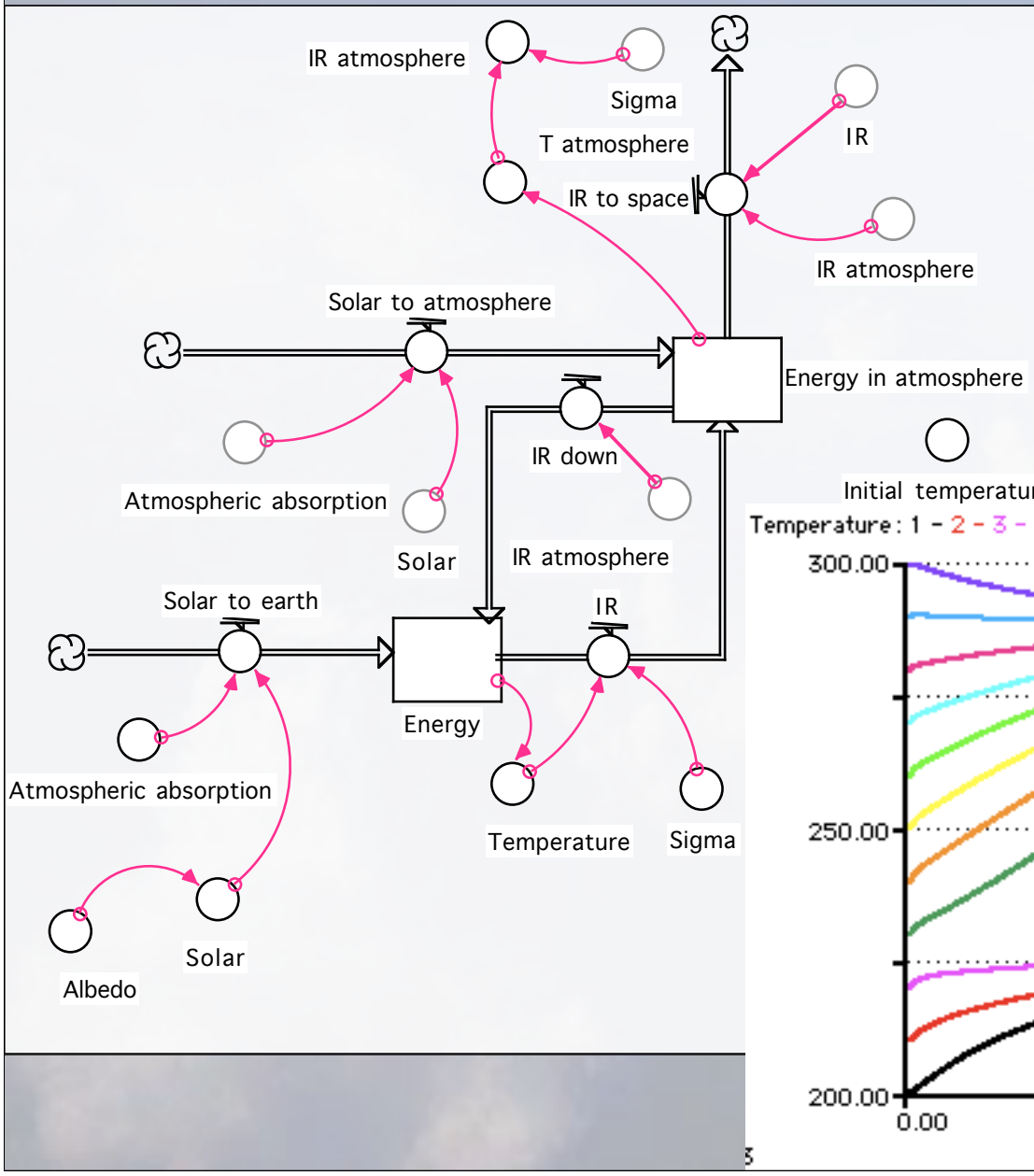


No Atmosphere STELLA Model

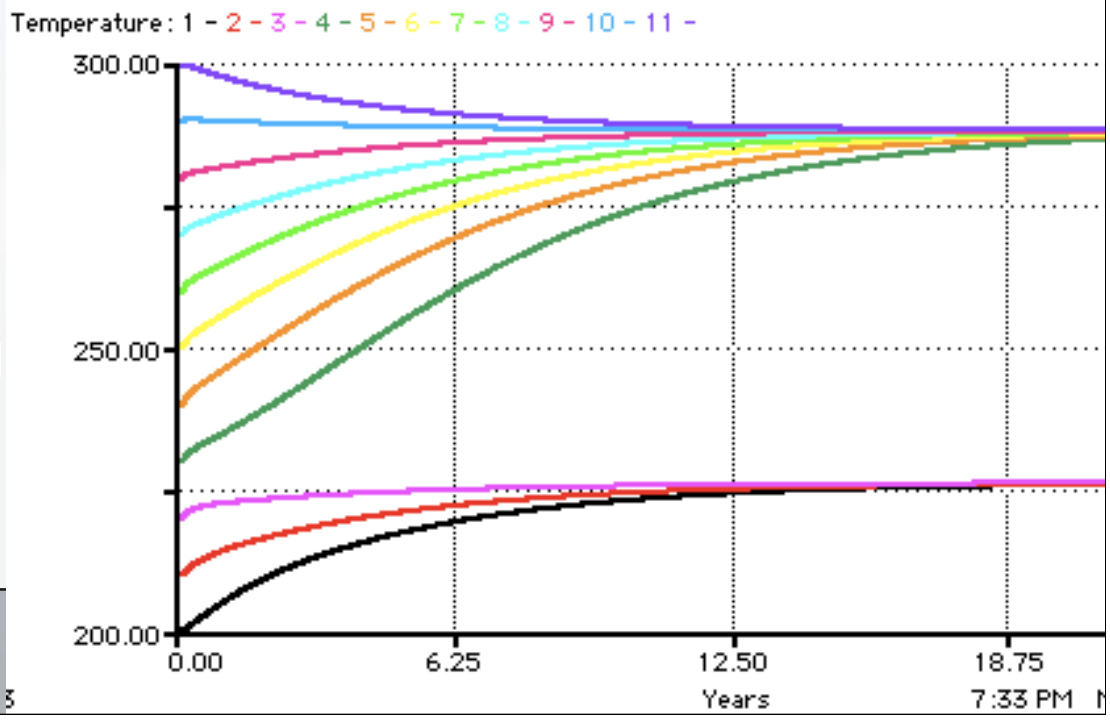




One-Layer Atmosphere STELLA Model



Run #	Initial temperature
1	200
2	210
3	220
4	230
5	240
6	250
7	260
8	270
9	280
10	290
11	300



EV 211

Human Impacts on Biogeochemical Cycles

Some Key Questions:

- What is a model?
- How is feedback incorporated?
- What is the sensitivity of different variables?
- How do we evaluate the quality of data?
- Why do some systems display complex behavior?
- Are we living in the Anthropocene?

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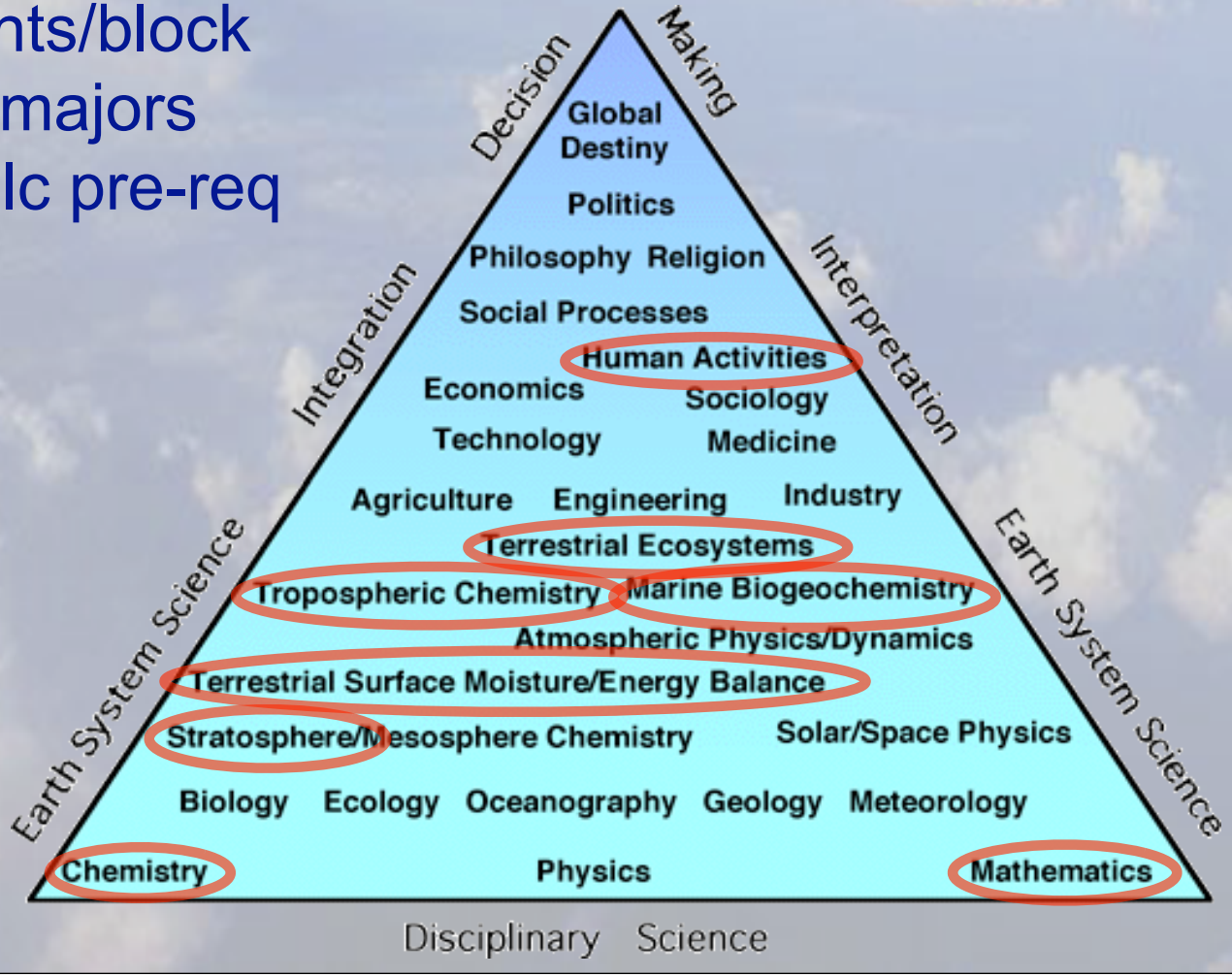
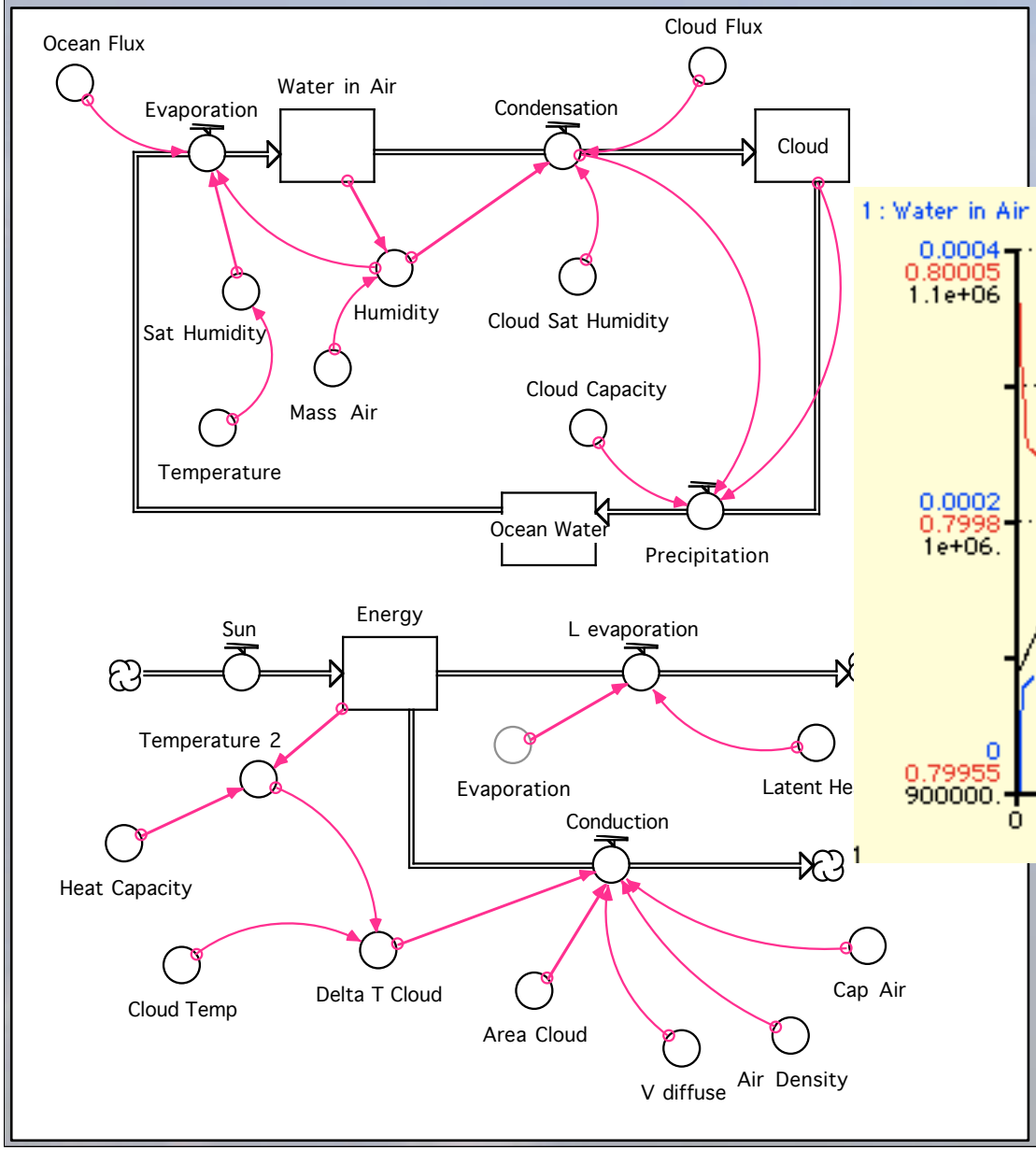
EV 211

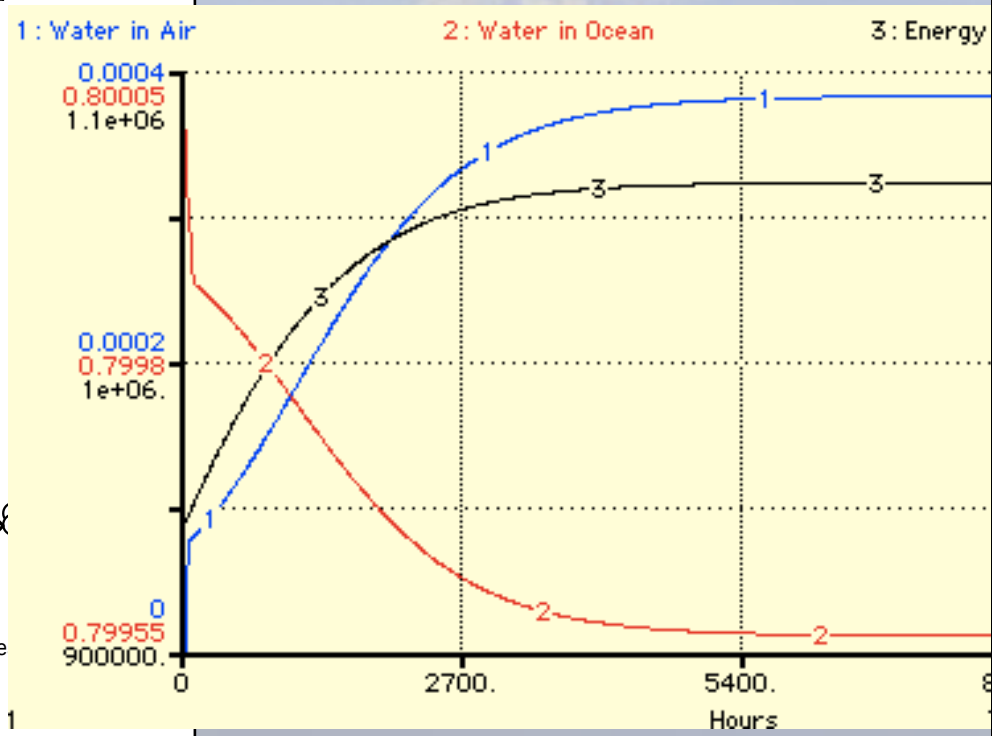
Human Impacts on Biogeochemical Cycles

- Two blocks/year
- ~16 students/block
- EV/Policy majors
- EV 128/calc pre-req

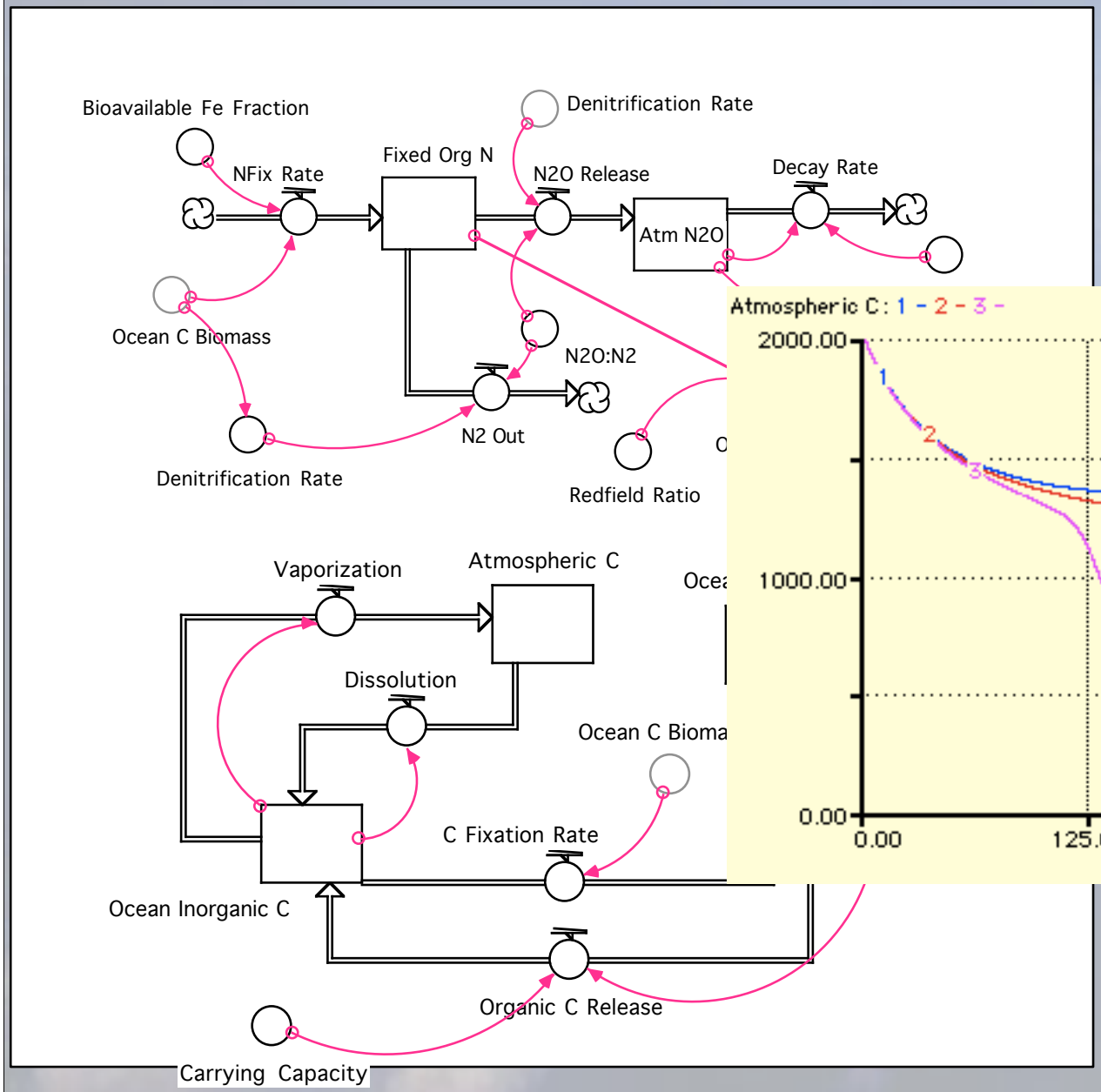


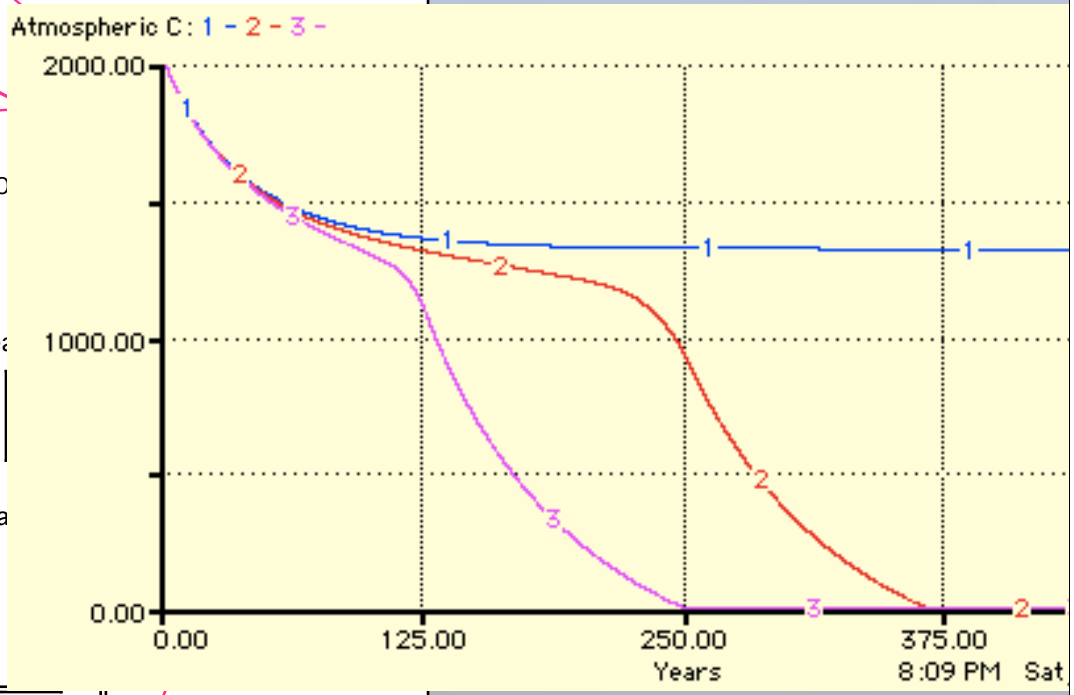
"Shoebox" Energy Balance STELLA Model





Student Final Project: Fe Fertilization





EV 431:Air
Atmospheric Physics & Chemistry

Some Key Questions:

- How do we model the weather?
- Should Colorado College move its Children's Center to a larger site closer to the interstate highway?
- Why does ozone chemistry appear to change in different regions of the atmosphere?

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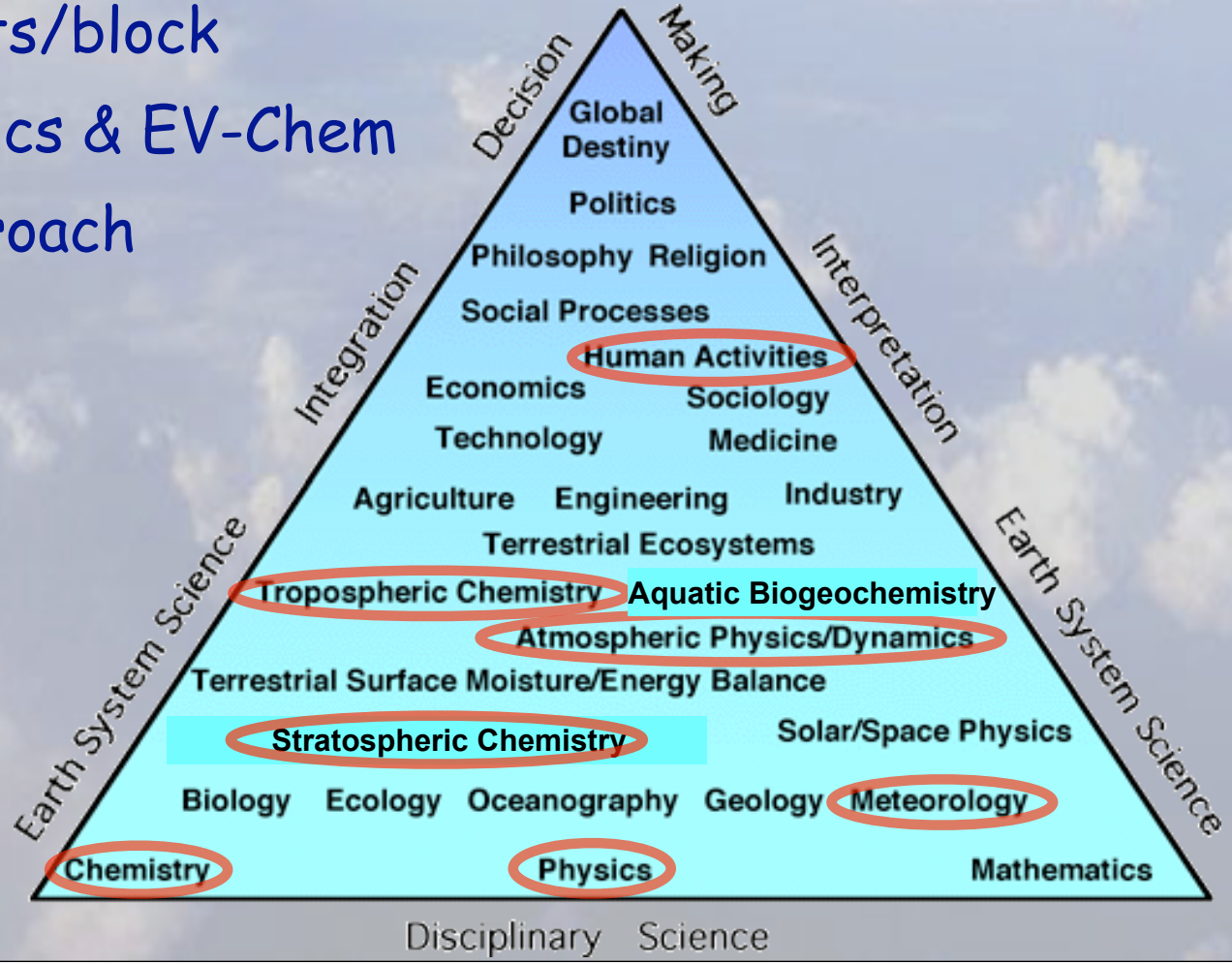
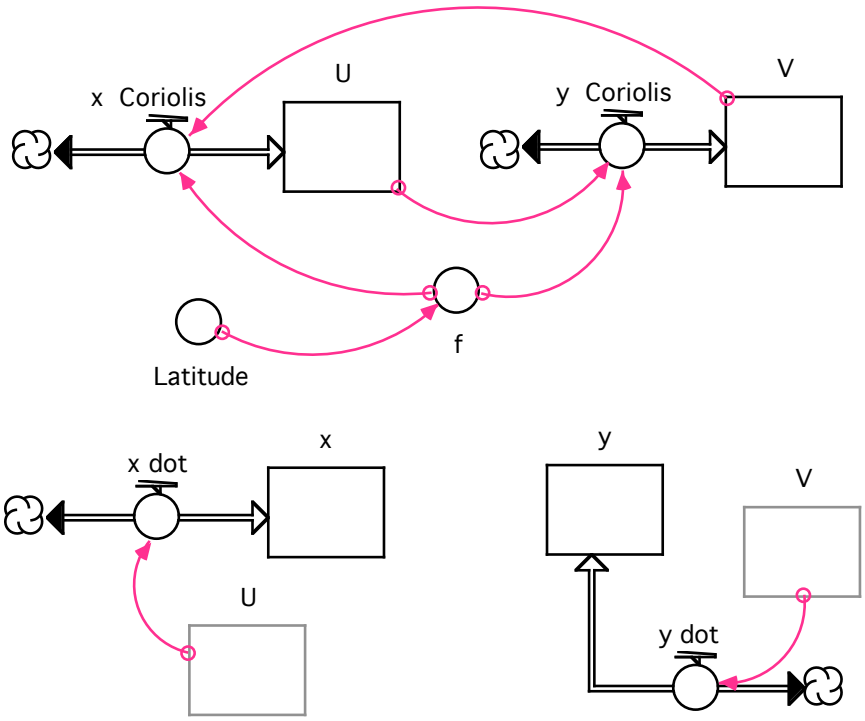
EV 431:Air
Atmospheric Physics & Chemistry

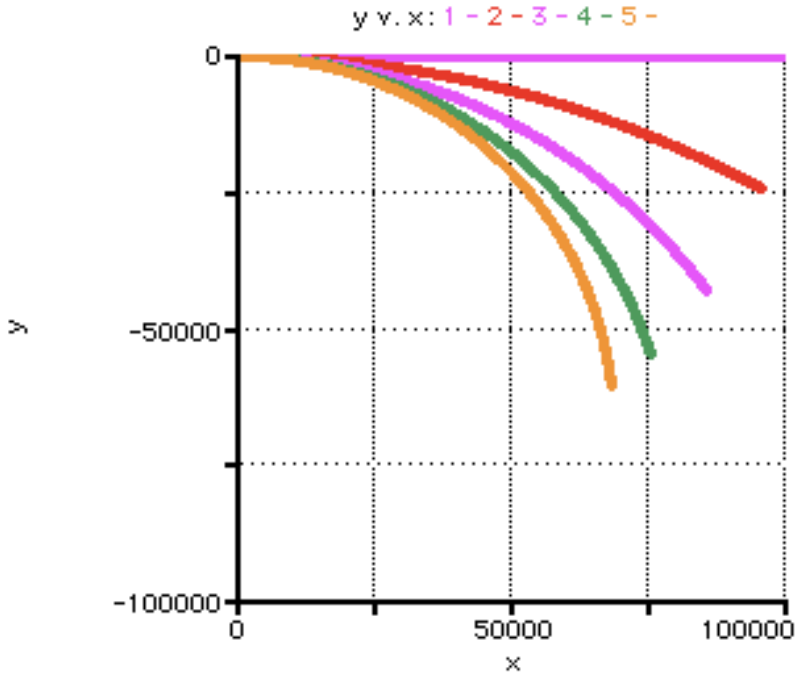
- 1 block/year
- ~20 students/block
- EV,EV-Physics & EV-Chem
- POGIL Approach



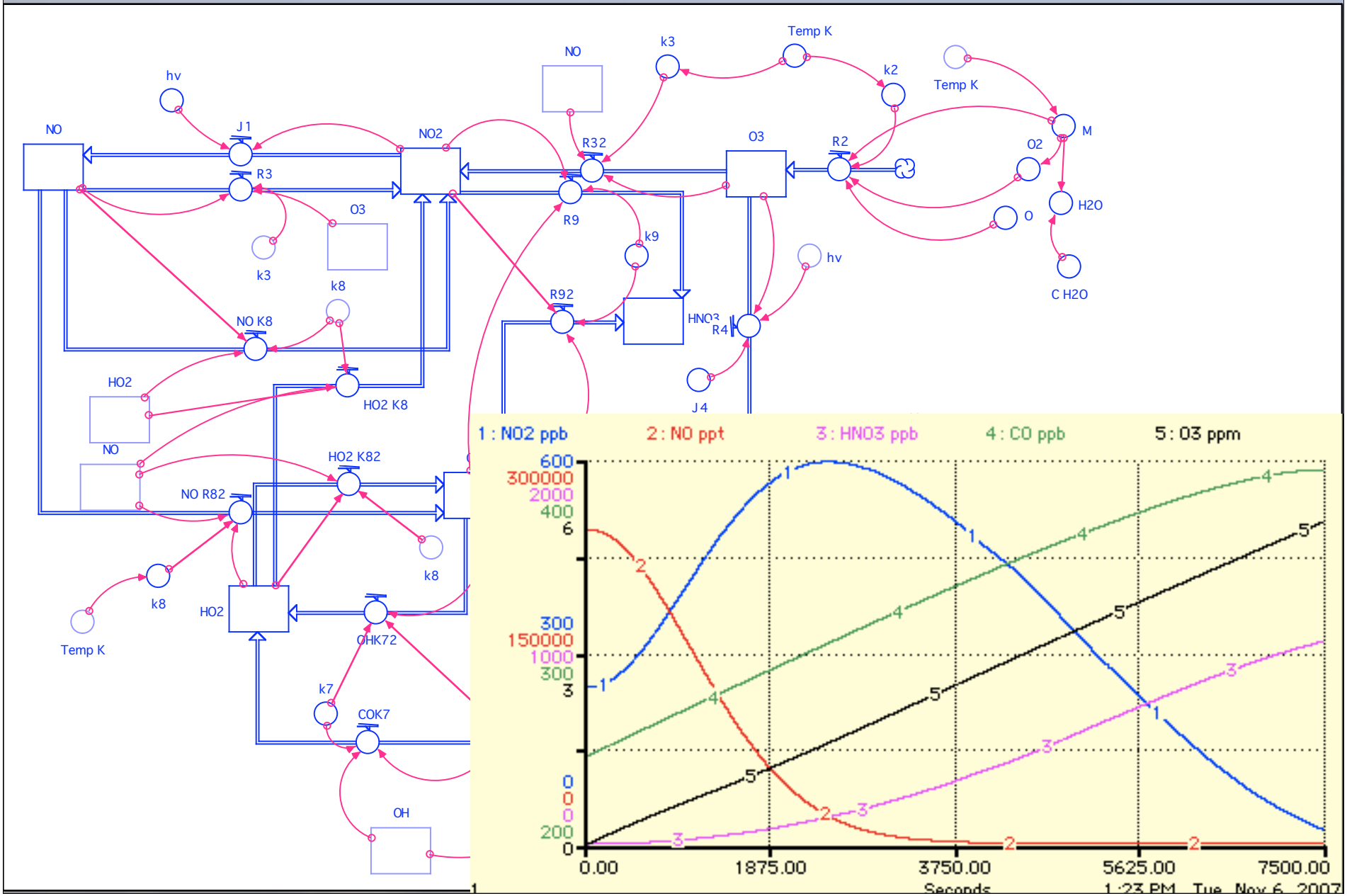
Atmospheric Dynamics STELLA Model



Run #	Latitude
1	0.00
2	20.0
3	40.0
4	60.0
5	90.0



Atmospheric Chemistry STELLA Model



What's Next?

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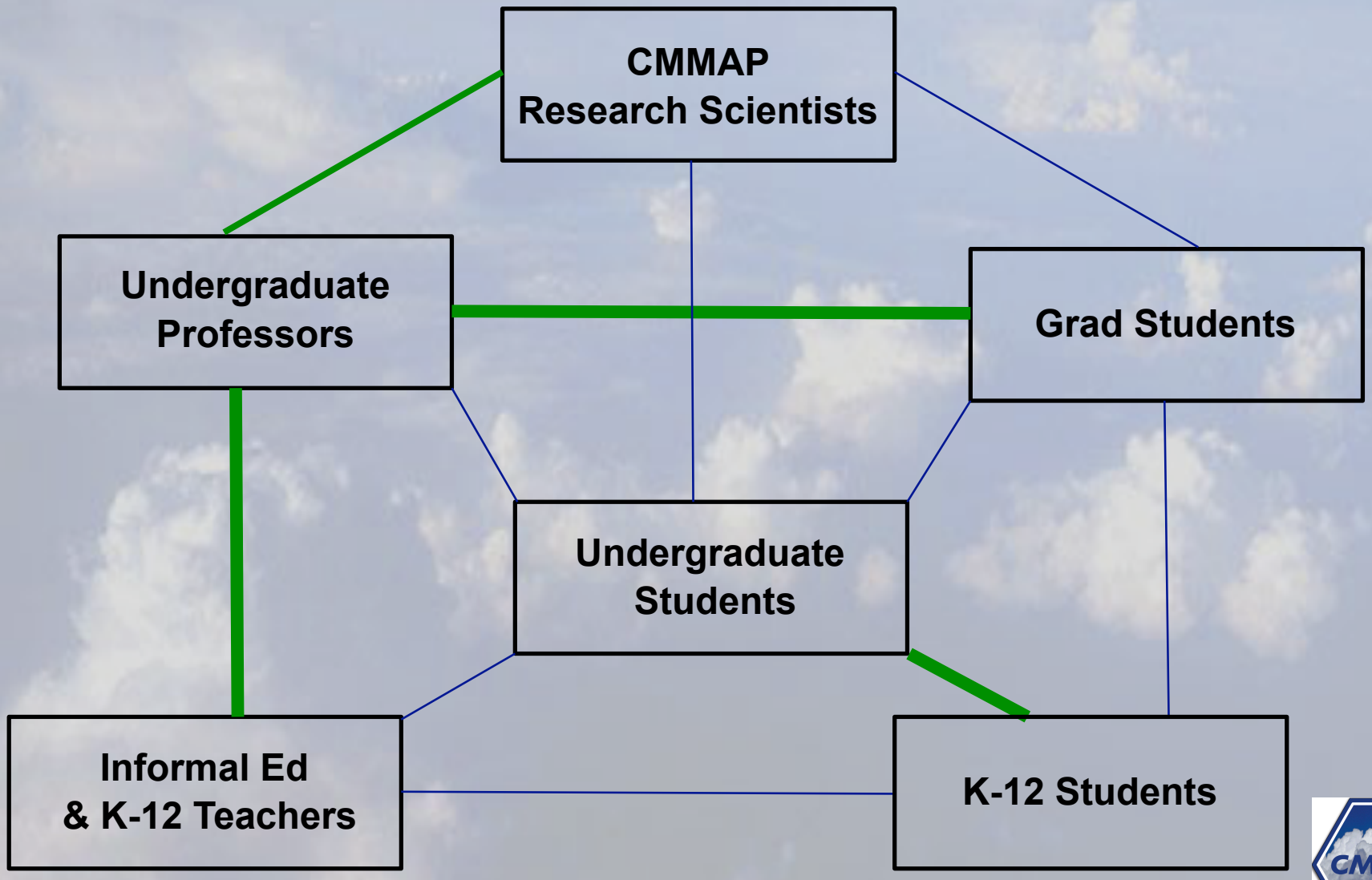
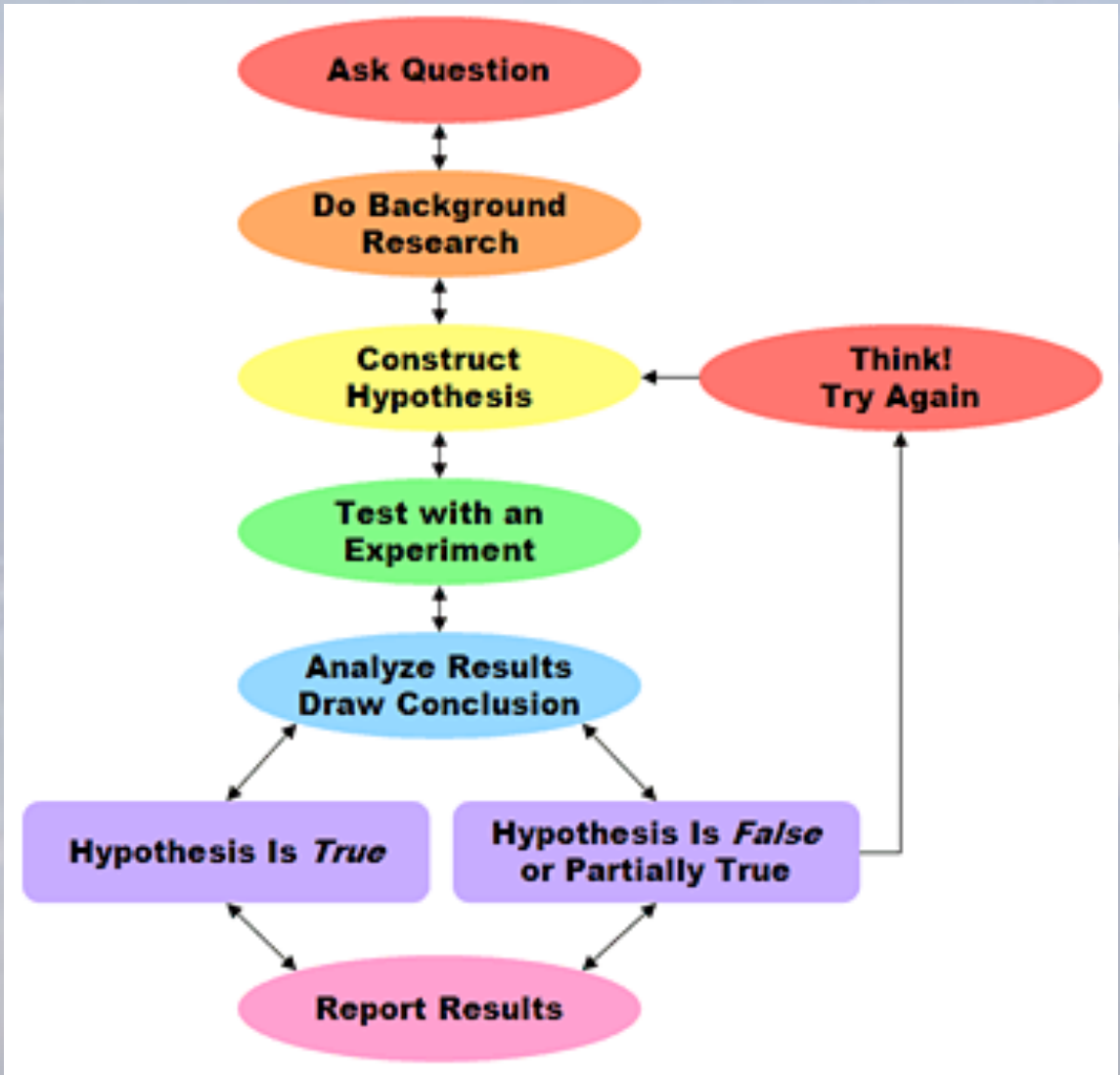
Strengthen Ties with Leverage

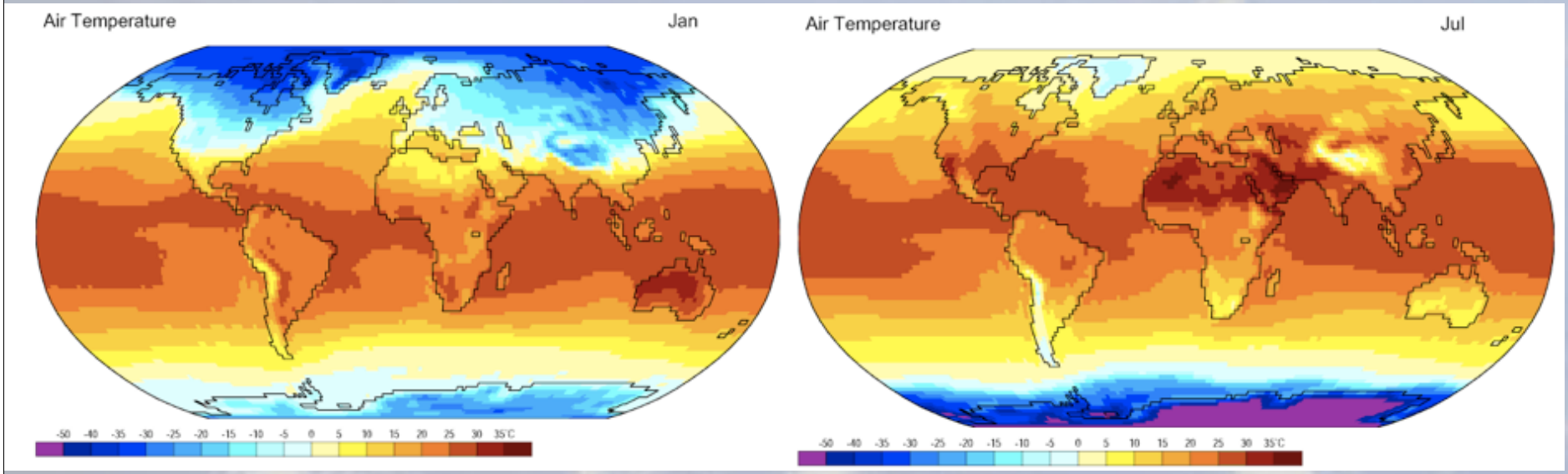


Teach science as we **do** science



POGIL MODELS

Below is the average global surface temperature for January and July (averaged from 1959 – 1997). Purples are the coldest temperatures and reds are the warmest.



1. Compare the Equator-to-North Pole *T* gradient in January to the Equator-to-South Pole *T* gradient in July. Which is stronger? In which hemisphere is the Equator-high latitude *T* gradient *more* dependent on the choice of longitude? Why?

2. Using the set of equations in Model 1 and your answer to Model 2 Q2, describe the wind aloft (tropopause) in terms of speed, direction, and overall how wavy the flow is.

3. Would you expect any motion from the troposphere to the stratosphere (vertically) over the winter pole? Why or why not?

4. Based on your responses to the questions in Model 1 and Model 2, in their respective winters, do you expect the Arctic or the Antarctic to be more isolated from the rest of the Earth? Why?

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Using the Research Literature as an Educational Tool

- Literature vs. Textual Readings
- Literature-based exams
- POGIL literature-based exercises

Representative Papers in EV 211:

1. Overall Human Impact: Vitousek, P. M., H. A. Mooney, et al. (1997). "Human Domination of Earth's Ecosystems." Science 277(25): 494-499.

2. Hydrologic Cycle: Oki, T. and S. Kanae (2006). "Global hydrological cycles and world water resources." Science 313(5790): 1068-1072.

3. Net Primary Productivity: Haberl, H., K. H. Erb, et al. (2007). "Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems." Proceedings of the National Academy of Sciences of the United States of America 104(31): 12942-12945.

4. Nitrogen Cycle: Galloway, J. N., A. R. Townsend, et al. (2008). "Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions." Science 320(5878): 889-892.

5. Complexity: Lenton, T. M. (1998). "Gaia and natural selection." Nature 394(6692): 439-447.

6. Human Population : Tilman, D., K. G. Cassman, et al. (2002). "Agricultural sustainability and intensive production practices." Nature 418(6898): 671-677.

Earth Systems Science Education: Transdisciplinary or Multidisciplinary?

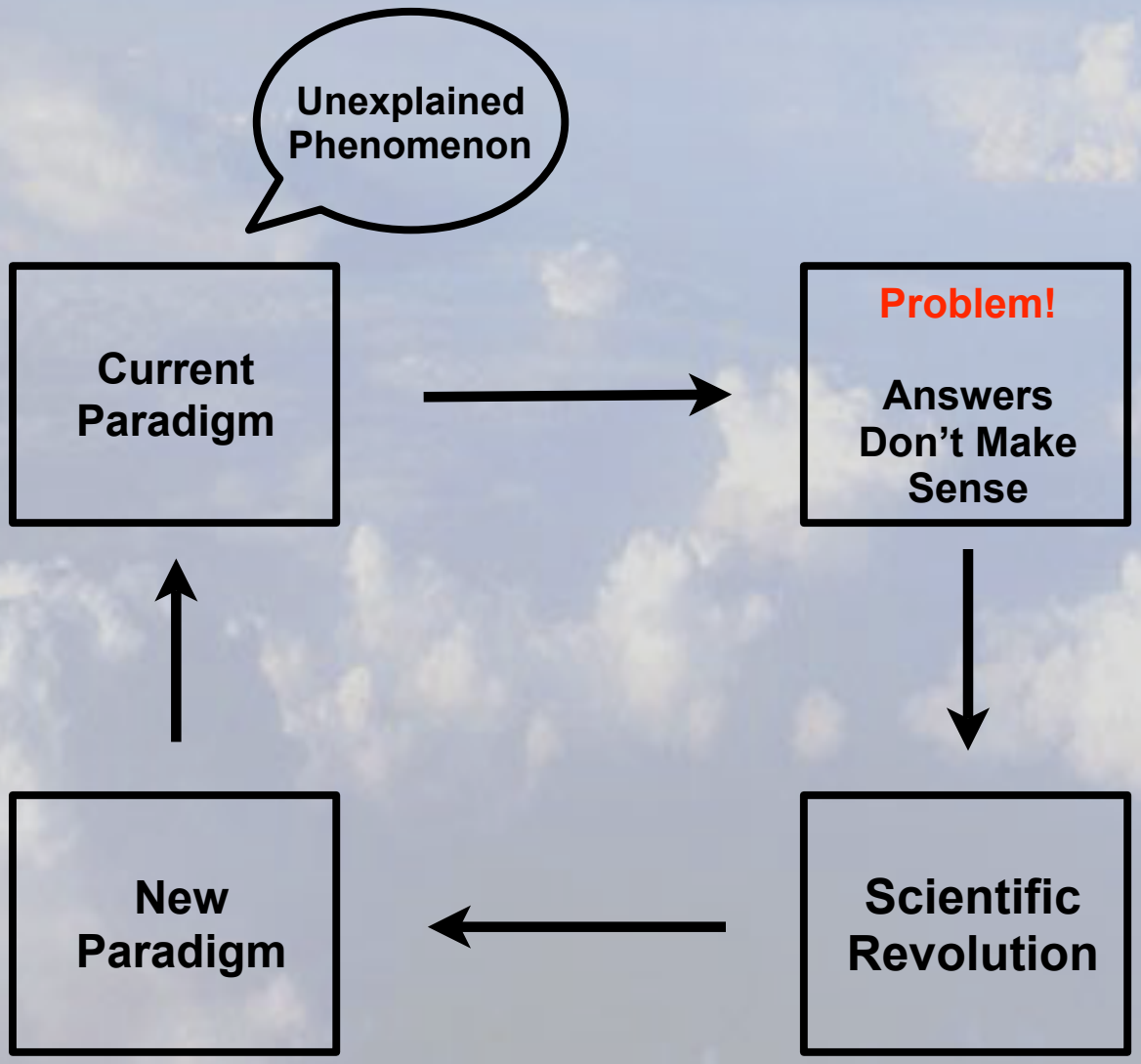
I	IT
Ethics Cognition Metacognition Motivation	Mathematics Physics Chemistry Biology Geology
WE	**ITS**
Social Processes Sociology Human Activities Philosophy Religion	Ecology Economics Meteorology Oceanography Political Science Atmospheric Science Terrestrial Biogeochemistry Aquatic Biogeochemistry

Global Destiny

Transdisciplinary vs. Multidisciplinary Learning

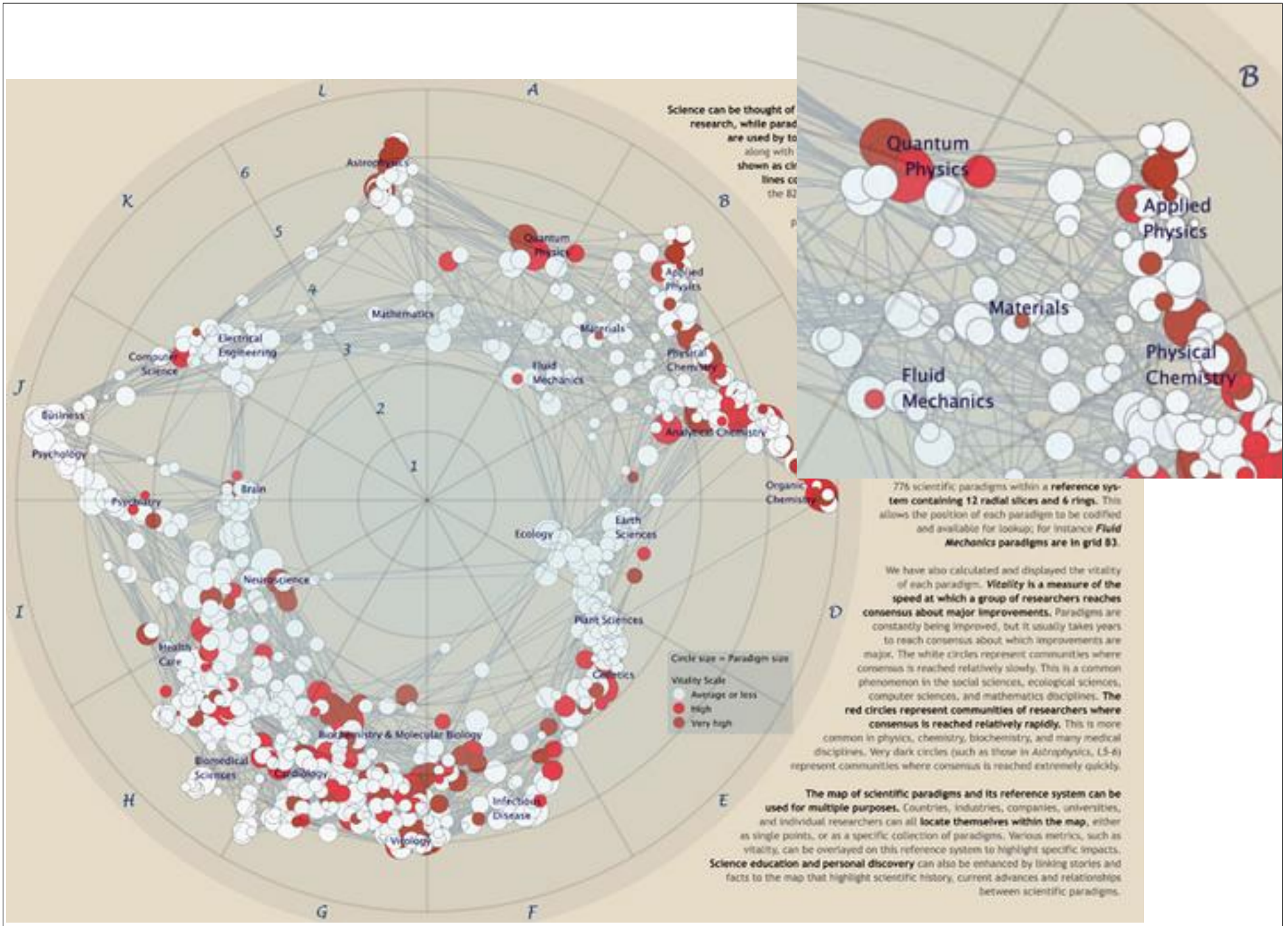
	Interior	Exterior
Individual	**What inspires me to learn?** Motivation Metacognition	**What are simple observable behaviors?** Observations Hypothesis testing
Collective	**What inspires us to learn?** Peer learning (POGIL) Science as cultural paradigm	**What are complex observable behaviors?** Human systems dynamics Earth systems dynamics

Kuhn's Scientific Paradigms



Adapted from: Thomas Kuhn, *Structure of Scientific Revolutions*

Frank and Ernest



From: http://www.visualcomplexity.com/vc/project_details.cfm?index=316&id=316&domain=

Design and implement assessments

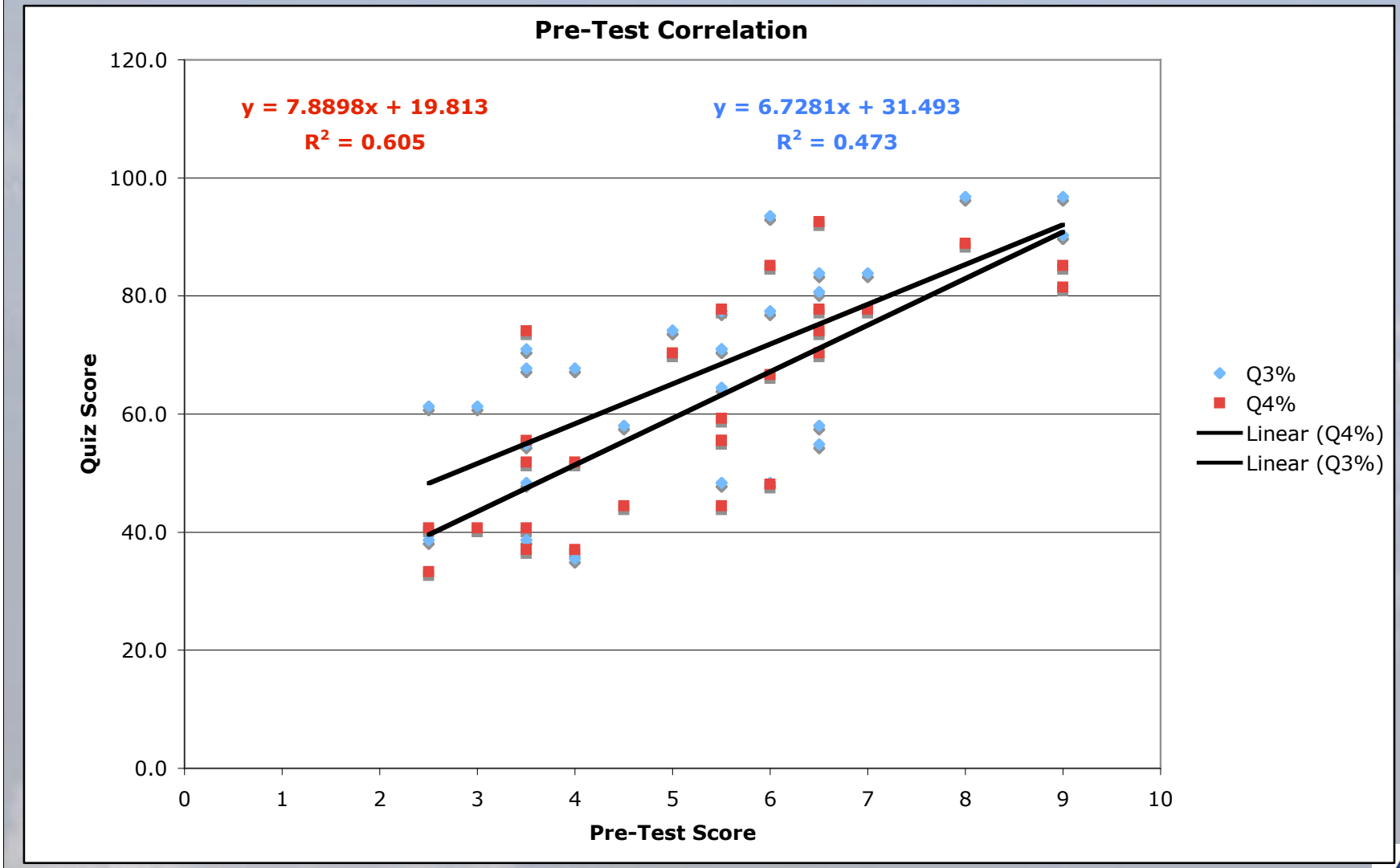
- SALG Assessment
- ACS Exams
- Project-based assignments
- POGIL
- Literature-based evaluations
- Demographic Surveys
- Tracking student interns

EV 221 assessment example

EV 211 ACS Exam Results

	Prior Chemistry	No Prior Chemistry
Conceptual Test Mean Grade	69.8%	62.5%
	p = 0.142	
Standard Test Mean Grade	67.8%	51.1%
	p = 0.009	

EV 221 assessment example



Disseminate Classes & Strategies

WHAT

- POGIL Atmospheric materials (JAMES, Web)
- Research literature-based POGIL materials
- Graduate student mentoring
- Pedagogy
- Assessment strategies and results
- Classes

HOW

- Web
- JAMES, BAMS articles
- Workshops (PKAL, CUR, SENCER)

Disseminate Classes & Strategies

PERSPECTIVE
SCIENCE VOL 323, 2 JANUARY 2009

Video Games: A Route to Large-Scale STEM Education?

Merrilea J. Mayo

Video games have enormous mass appeal, reaching audiences in the hundreds of thousands to millions. They also embed many pedagogical practices known to be effective in other environments. This article reviews the sparse but encouraging data on learning outcomes for video games in science, technology, engineering, and math (STEM) disciplines, then reviews the infrastructure obstacles to wider adoption of this new medium.

Undergraduate ESS Curriculum Development Summary

1. **Understand the mission**-inspire ESS students
2. **Identify target audience and needs**-undergrads
3. **Establish curricular goals**-ESS interest/understanding
4. **Evaluate existing curricular material**-GCC/BGC Cycles
5. **Assess students' prior knowledge**-POGIL/ACS Exams
6. **Match pedagogy to generative questions**-STELLA/POGIL
7. **Teach & evaluate with formative assessment**-POGIL
8. **Summative assessment**-SALG, Literature, ACS Exams
9. **Incorporate new findings** (go to step 3)
10. **Disseminate curriculum**

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