CUNY GRADUATE CENTER
EARTH AND ENVIRONMENTAL SCIENCES PHD PROGRAM
EES 79903
Biosphere-Atmospheric Interactions
2016 Fall

Class Hours: 4:15-6:15 PM on Monday
Class Location: Graduate Center Campus
3 credits, no exam, but 5 homework, a term paper of a research project and a presentation, and reading research papers

Instructor: Prof. Chuixiang (Tree) Yi
Office: E-222, Science Building at Queens College
Office Hours: Monday after class or by appointment
Email: cyi@qc.cuny.edu
Work Phone: 718-997-3366

Course Description:

The biosphere has changed with Earth's climate, but the biosphere also is a major regulator of atmospheric chemistry and climate. Interactions between atmosphere and biosphere are determinants of feedbacks in earth climate system through the cycling of energy, water, trace gases and other chemical elements. This course will focus on concepts and principles of atmosphere-biosphere interactions that are important for understanding hydrology, ecology and other geosciences, and environmental issues and anthropogenic disturbance of earth climate system.

Goal of Course:

Is to provide students with a basic understanding the role of terrestrial biosphere in climate systems and be knowledgeable about cycling processes of energy, water and greenhouse gases and able to identify environmental problems and suggest solutions that are related to anthropogenic carbon pollution.

Rational: This advanced course is designed to provide students with core concepts and principles of the tightly coupled biosphere-atmosphere interactions and the role of land in the climate system. It also will provide students opportunities to participate in a research project on environmental issues with the integration of knowledge they have learned in early stages of their major.

The Objectives of EES 79903

The objectives of this course are to provide students with an understanding of the role of the terrestrial biosphere in the climate systems and experiential learning of how to do climate-related research. The topics covered by this course are: (1) the first and second laws of thermodynamics; (2) basic turbulence theory and eddy-flux measurements; (3) terrestrial biomes and climatology; (4) photosynthesis and respiration; (5)

evapotranspiration and water budget; (6) global warming, extreme weather, disturbance of ecosystems; and (7) the structure of a research paper.

The Outcome of EES 79903

At the end of this course, students are expected to be knowledgeable about global change issues, such as climate controls of carbon, water, energy, and nutrient cycling from leaf to globe, as well as global and regional water-food-energy security in a changing climate. The students are expected to be able to identify environmental problems and suggest solutions based on understanding of reciprocal relationship between biosphere and atmosphere.

Reference Textbooks:

1. Terrestrial Biosphere-Atmosphere Fluxes, by R. Monson and D. Baldocchi,2014
2. Terrestrial Hydrometeorology, by W. James Shuttleworth. 2012.
3. Plant Physiological Ecology, by H. Lambers, F.S. Chapin III, T.L. Pons, 1998.

Course Assessment:

Homework	25% (5 sets each 5)
In-class presentation	25%
Term paper	35%
Participation	15%

Course Schedule:

Week 1: Lecture topic: Research method - from hypothesis, deduction, validation to a scientific law; the first law of thermodynamics, second law of thermodynamics, and entropy and the directions of natural processes of energy and mass transports. *Exercise:* Reading syllabus, and investigating research topics as well as associated references listed in the syllabus for the purpose of selecting a research project for this class.

Week 2: Lecture topic: Biomes and climates, eight major terrestrial biomes in the world, characteristics of their climate, vegetation diversity, location, production, and Holdridge's life triangle. *Exercise:* Still investigating research topics as well as associated references listed in the syllabus, consulting with the instructor on your research topic. The homework #1 is assigned and due in a week.

Week 3: Lecture topic: Turbulence, laminar flow and turbulent flow, turbulence properties, Reynolds number, kinematic viscosity, eddy viscosity, energy cascade, and Kolmogorov's turbulence theory. *Exercise:* The homework #2 is assigned as a research proposal, which includes a research title, research goals, research questions, what data you are planning to use, and reference list. Homework #2 is due in two weeks.

Week 4: Lecture topic: K-theory, Prandtl's mixing-length theory, logarithmic layer, velocity-squared law, and problems of applying classic theories to vegetation layer. *Exercise:* Still working on homework #2.

Week 5: Lecture topic: Eddy-covariance techniques, turbulent flux of CO_2, H_2O and heat, stable atmospheric boundary layer (ABL), unstable ABL, roughness sublayer, energy-closure problems in eddy-flux measurements, advection issues in eddy-flux measurements, katabatic flow, and issues and solutions. *Exercise:* Discussing and obtaining data (e. g. FLUXNET data) with the instructor. Homework #3 is assigned and due in a week.

Week 6: Lecture topic: Land-surface energy budget, Wien's law, Stefan-Boltzmann law, Planck law, albedo, greenhouse effect, sensible-heat flux, latent-heat flux, disturbances of land use and land cover on surface energy budget. *Exercise:* Reading reference papers associated with your research, discussing your research with the instructor.

Week 7: Lecture topic: Land-surface water budget, ideal gas law, vapor pressure and saturated vapor pressure, water-holding capacity of air , global warming and extreme weather, and climate-carbon feedbacks. *Exercise:* Reading reference papers associated with your research, discussing your research with the instructor. Homework #4 is assigned and due in a week.

Week 8: Lecture topic: Photosynthesis and respiration, the history of photosynthesis discovery, bioenergetics and the laws of thermodynamics, ATP – energy currency of the cell, oxidation-reduction reactions, autotrophs, heterotrophs, pigments, chlorophyll, chloroplast – a glucose factor, xylem, phloem, cuticle, mesophyll cell, bundle sheath cell epidermis, spongy mesophyll cell, guard cell, stomatal control of CO_2 in and H_2O out by opening and closing dynamics. *Exercise:* Working on your research, discussing your research with the instructor.

Week 9: Lecture topic: Photosynthesis and respiration, overview of photosynthesis (light-reaction in thylakoids – split water, release O_2, produce ATP and form NADPH; the dark-reaction in stroma, formation of sugar from CO_2 using ATP and NADPH), photosystem II, photophosphorylation, electron transfer chain, ATP produced between lumen and stroma by pumping proton, photosystem I, high energy electrons uploaded in NADPH in photosystem I, noncyclic electron flow, and cyclic electron flow, and the Z scheme, rubisco, RuBP and RuMP, three stages of Calvin cycle –carboxylation-reduction-regeneration, carbon math. *Exercise:* Working on your research, consulting your research with the instructor. Homework #5 is delivered and due in two weeks.

Week 10: Lecture topic: Photosynthesis and respiration, the dependence of photosynthetic rate on environmental conditions: light intensity, temperature, CO_2 and O_2 concentration. Light use efficiency, light compensation point, dark respiration rate, the difference in photosynthesis between single leaf and whole canopy, photorespiration under low CO_2 and water stress conditions, C4 plants physically separate light reaction in mesophyll and dark reaction in bundle-sheath cell (separating rubisco and O_2), difference of photo-efficiency between C3 and C4 plants, CAM plants separates light reaction and dark reaction by day and night. *Exercise:* Discussing your initial research results and problems with the instructor.

Week 11: Lecture topic: Photosynthetic modeling, Farquhar-von Caemmerer-Berry Model, Michaelis-Menten enzyme kinetics, quasi-steady-state assumption, competitive inhibition between photorespiration and carbon-fixation, the enzyme specificity factor, carboxylation rate, oxygenation rate, RuBP limitation, Rubisco limitation, CO_2 limitation, discussion on Farquhar model. *Exercise:* Discussing your initial research results and problems with the instructor.

Week 12: Lecture topic: Photosynthetic modeling, stomata opening dynamic model, water use efficiency, plant respiration, soil respiration, autotrophic respiration, heterotrophic respiration, Q10, Arrhenius function, soli respiration modeling, leaf Q10 and biome Q10, the sensitivities of terrestrial biome carbon storage to increasing of atmospheric CO2 and warming temperature. *Exercise:* Discussing your research paper and presentation with the instructor.

Week 13: Lecture topic: Drought indexes, dryness index, standardized precipitation evapotranspiration index (SPEI), Palmer drought severity indices (PDSI), shifting of dryness control boundary and vegetation vulnerability, Land warming and drying, extreme climates and the carbon cycle, carbon-climate feedback. *Exercise:* Discussing your research paper and presentation with the instructor.

Week 14: Presentations:

This is a research-related course. The research projects are FLUXNET-data based. Students can focus on any one of the following potential research topics or your own research topic that is related to course lectures.

Research topics:
(1) Effects of climate change on terrestrial ecosystems' water use efficiency (WUE)
References:
CN13 →Claesson J and Nycander J 2013 Combined effect of global warming and increased CO2-concentration on vegetation growth in water-limited conditions Ecological Modelling 256 23-30, DOI: 10.1016/j.ecolmodel.2013.02.007.
BWB86 → Ball, J. T., I. E. Woodrow, and J. A. Berry, 1986: A model predicting stomatal conductance and its contribution to the control of photosynthesis under different environmental conditions. Progress in Photosynthesis Research, J. Biggins, Ed., Vol. 4, Martin Nijhoff, 221–224.

Ideas → using fluxnet hourly and monthly data to study the predictions of equation (4) in CN13 with different climate condition or vegetation type, or derive new formulae by combining formulations of BWB86 and CN13, or ideas from yourselves

(2) Tree mortality in a changing climate

References:

A10 →Allen et al. - 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests Forest Ecology and Management 259 (4) 660–684, doi:10.1016/j.foreco.2009.09.001

A15 →Allen et al. 2015. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. Ecosphere 6:art129. http://dx.doi.org/10.1890/ES15-00203.1

HY15 → Huang and Yi et al. 2015 Tipping point of a conifer forest ecosystem under severe drought, Environ. Res. Lett. 10 024011 doi:10.1088/1748-9326/10/2/024011 (2015).

K15 → Kolb, T. 2015, A new drought tipping point for conifer mortality, Environ. Res. Lett. 10 (2015) 031002, doi:10.1088/1748-9326/10/3/031002.

Ideas → This is a review-papers-based project. Try to answer following questions: how and what are the ways of each forest biome dying in a changing climate? Drought, fire, and barkbeetles,…? Which forest biome is the most fragile? …….

(3) Inter-annual variability of net ecosystem-atmosphere exchanges (NEE) of CO2 across biomes and continents

References:

Y10 → Yi, C. et al. (2010) climate control of terrestrial carbon exchange across biomes and continents, Environmental Research Letters, 5, doi: 10.1088/1748-9326/5/3/034007.

K13 →Keenan, T. F. et al. Increase in forest water-use efficiency as atmospheric carbon dioxide concentrations rise, Nature, 499, 324–327, 2013.

R13 →von Randow et al.(2013) Inter-annual variability of carbon and water fluxes in Amazonian forest, Cerrado and pasture sites, as simulated by terrestrial biosphere models, Agricultural And Forest Meteorology. 182–183.

Ideas → using similar methods as K13/R13 used to study interannual variability of NEE of CO2 from fluxnet data, especially using fluxnet data to produce a figure like Figure 3 in K13.

(4) Climate extremes and carbon cycle

References:

Y15 → Yi, C., E. Pendall & P. Ciais, Focus on extreme events and the carbon cycle. Environ. Res. Lett. 10 070201 doi:10.1088/1748-9326/10/7/070201 (2015).

Y12 →Yi, C. et al. 2012, Climate extremes and grassland potential productivity, Environmental Research Letters, 7, 035703 (6pp) doi:10.1088/1748-9326/7/3/035703, 2012.

You can download Y15 and rest 26 papers in this specific issue from the link below
http://iopscience.iop.org/1748-9326/focus/Extreme%20Events%20and%20the%20Carbon%20Cycle

Ideas → using perfect-deficit approach as described in Y12 to study climate control NEE of CO2 from fluxnet data, or review papers on extreme weather/climate as well as relationships to global warming.

(5) Study NEE differences between the warm part and cold part of the land that is divided by 16oC latitudinal belt
References:
Y14 →Yi, C., S. Wei & G. Hendrey, Warming climate extends dryness-controlled areas of terrestrial carbon sequestration. Sci. Rep. 4, 5472; DOI:10.1038/srep05472 (2014).

Ideas → You can learn where the warm/cold part of the land is from Y2014 and then study NEE differences from fluxnet data, or ideas from yourselves

(6) Instability analysis of canopy flow over complex terrain
References:
Y09 →Yi, C., Instability analysis of terrain-induced canopy flows, Journal of the Atmospheric Sciences, 66, 2134-2142, doi:10.1175/2009JAS3005.1, 2009.
CY12 →Chen, H., and C. Yi, Optimal control of katabatic flows within canopies, Quarterly Journal of the Royal Meteorological Society, DOI:10.1002/qj.1904, 2012
Y08 →Yi, C., Momentum transfer within canopies, Journal of Applied Meteorology and Climatology, 47, 262-275, doi:10.1175/2007JAMC1667.1, 2008.

Ideas → Using instability analysis approach described in Y2009 conduct instability analysis for the governing equations (1a) and (1b) in C12. This is a theoretical study (no data are required to use).

(7) Review of global warming, climate extremes, terrestrial carbon cycling
References:
Y15 → Yi, C., E. Pendall & P. Ciais, Focus on extreme events and the carbon cycle. Environ. Res. Lett. 10 070201 doi:10.1088/1748-9326/10/7/070201 (2015).
Y14 →Yi, C., S. Wei & G. Hendrey, Warming climate extends dryness-controlled areas of terrestrial carbon sequestration. Sci. Rep. 4, 5472; DOI:10.1038/srep05472 (2014).
Y12 →Yi, C., et al., Climate extremes and grassland potential productivity, Environmental Research Letters, 7, 035703 (6pp) doi:10.1088/1748-9326/7/3/035703, 2012.
CN13 →Claesson J and Nycander J 2013 Combined effect of global warming and increased CO2-concentration on vegetation growth in water-limited conditions Ecological Modelling 256 23-30, DOI: 10.1016/j.ecolmodel.2013.02.007.

B03 →Baldocchi DD (2003) Assessing the eddy covariance technique for evaluating carbon dioxide exchange rates of ecosystems: Past, present and future. Global Change Biology 9, 479-492.

Ideas → This requires writing a review report on issues about climate change and carbon cycles whatever you are interested (no research requested).

Structure and contents of research paper:

Title (& your affiliation)	Keep it interesting and short
Abstract (& key words)	Summarize four aspects in 300 words: (1) what issues (or problems) you are studying? (2) what approach (method) you used in your research? (3) what are your results; and (4) what are conclusions and implication? Please do not just copy from a main body!
Introduction	An essential part is what research problems you want to study and what is your research goal, including literature review.
Data & Method	Describe what data and method you used.
Results	Explain the major findings from the data analysis
Conclusions	Summarize major content and draw common themes
References	List cited papers by the format of the first paper.

Term Paper → at least 15 pages with double space (Font 12 in Time New Roman) with Figures, tables and references. The format and structure of term paper is required to follow the format of one of scientific journal papers you cited.

Presentation will be graded by the following criteria:
Gain points:
1. Your story is interesting (e. g. if more students ask questions on your talk during question time, indicating your talk more interesting; otherwise…)
2. Your research questions are clearly presented.
3. There is a focus in your talk rather than many aspects or too general.
4. Figures/Tables/Results not from yourself are cited as (authors, year) in your slides.
5. Figures/tables/analysis results from yourself are very much appreciated.

Loss points:
1. Reading rather than talking (i.e. write all words on slides and then read).
2. No eye contacts with audiences.
3. Focus is not clear.
4. Research questions are not clear or too broad/general.
5. Copy/paste from web.

Classroom Etiquette: Please turn off your phone before class begins.