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AUG 24 2012
WSU Registrar

Washington State University
MAJOR CURRICULAR CHANGE FORM - - COURSE
(Submit original signed form and ten copies to the Registrar's Office, zip 1035.)

Future Effective Date: 01/01/2013 ☑ New course ☐ Temporary course ☐ Drop service course
(effective date cannot be retroactive) ☐ There is a course fee associated with this course (see instructions)

☐ Variable credit _____ ☐ Repeat credit (cumulative maximum _____ hours)

☐ Increase credit (former credit _____) ☐ Lecture-lab ratio (former ratio _____)

☐ Number (former number _____) ☐ Prefix (former prefix _____)

☐ Crosslisting (between WSU departments) **(Must have both departmental signatures)** ☐ Cooperative listing (UI prefix and number _____)
taught by: WSU ☐ UI ☐ jointly taught ☐

☐ Conjoint listing (400/500) ☐ S, F grading

☐ Request to meet Writing in the Major [M] requirement **(Must have All-University Writing Committee Approval)**

☐ Request to meet GER in _____ **(Must have GenEd Committee Approval)** ☐ Fulfills GER lab (L) requirement

☐ Professional course **(Pharmacy & Vet Med only)** ☐ Graduate credit **(professional programs only)**

☐ Other (please list request) _____

CE	506	Theory and Measurements of Turbulent Fluxes
course prefix	course no.	title

3				CE ~~402 or~~ 502
credit	lecture hrs per week	lab hrs per week	studio hrs per week	prerequisite

Description (**20 words or less**) Introduce the fundamental concepts of turbulence and turbulent fluxes in the atmospheric surface layer, the statistical description of turbulence and turbulent fluxes, eddy covariance systems, and post-filed processing of flux data.

Instructor: Heping Liu Phone number: 335-1529 Email: heping.liu@wsu.edu
Contact: Brooke Whiting Phone number: 335-1219 Email: bwhiting@wsu.edu
Campus Zip Code: 2910

- Please attach rationale for your request, a current and complete syllabus, and explain how this impacts other units in Pullman and other branches (if applicable).
- Secure all required signatures and provide 10 copies to the Registrar's Office.

B Luhunthan 23Aug2012	Robert A Oe 8/23/12	
Chair/date	**Dean/date**	**General Education Com/date**
Chair (if crosslisted/interdisciplinary)*	**Dean (if crosslisted/interdisciplinary) ***	**Graduate Studies Com/date**
All-University Writing Com/date	**Academic Affairs Com/date**	**Senate/date**

***If the proposed change impacts or involves collaboration with other units, use the additional signature lines provided for each impacted unit and college.**

CE 506 **Theory and Measurements of Turbulent Fluxes**

There is a growing need for using the eddy covariance technique to measure turbulent fluxes of energy, water vapor, and trace gases in many research fields, such as biosphere-atmosphere interactions, air pollution, biogeochemical cycles, and environmental sciences. The purpose of this course is to provide students with theories and skills necessary to work on eddy covariance systems for different purposes. The course will give students insight into the perspectives and theories of turbulent fluxes by examining the physical processes and factors which influence flux measurements and data quality. A secondary goal of this course is to teach students to design and build a micrometeorological measurement system which includes a variety of meteorological instruments/sensors and eddy covariance sensors, and to learn the methods used to analyze the flux data and other meteorological datasets.

Theory and Measurements of Turbulent Fluxes

CE 506-Every Spring Semester

(3 Credits)

Instructor: Heping Liu; Dana 306B, heping.liu@wsu.edu, 5-1529.

Office Hours: By appointment.

Lectures: TuTh 9:10-10:25

Lecture Slides: Posted to ANGEL as available.

Prerequisites: CE402/502

Course Goal: To introduce the fundamental concepts of turbulence and turbulent fluxes in the atmospheric surface layer, the statistical description of turbulence and turbulent fluxes, eddy covariance systems, and post-filed processing of flux data. Special topics will be discussed, including the surface energy balance enclosure, uncertainty in flux measurements, and fluxes over complex terrain.

Class Activities and Evaluation

Homework: Problem sets including readings of journal articles/book chapters and data processing will be assigned weekly or so.

Exams: No midterm exam and final exam will be made.

Mini Projects: Students should discuss project proposals with instructor/advisors, identify specific datasets related to the topic, write an abstract, and email me by February 21. The instructor can also provide datasets which were collected in the past field campaigns, if requested. Their effort will be documented with a 15 to 20-page report. The report format should follow the requirements set by Journal of Geophysical Research-Atmospheres (www.agu.org). Due date for the first draft is April 12. You will receive my comments on your first draft in a few days for your revisions. Due date for the final report is May 1.

Suggested (not required) Topics for Mini Projects

1. Unclosure issues of the surface energy balance
2. The surface energy budget over different underlying surfaces
3. Horizontal advection of heat, moisture, and CO_2
4. Turbulence over hills and complex terrain
5. Critique of flux correction
6. Characteristics of turbulence in and above vegetation canopy
7. Spectral analysis and wavelet

8. Flux measurement methods (eddy covariance, Bowen ratio/energy balance, relaxed eddy accumulation, flux gradient, etc.)
9. CO_2 exchange of crops, forest, grasslands, water, etc.
10. Large eddy simulation (LES) of mean and turbulent flows
11. Methods to calculate soil heat fluxes
12. Applications of eddy covariance methods to other tracer gases
13. Turbulent fluxes in the nocturnal/stable boundary layer

Evaluation:

Class Participation	10%
Homework	20%
EC system buildup	20%
Field participation	10%
Mini Project	40%

Note: All homework/projects should be printed out. Handwriting is not accepted.

Schedule:

1. **Introduction to atmospheric boundary layer (ABL) (1.5 weeks)**
   - Surface forcings that affect the characteristics of ABL
   - Diurnal variations and vertical structure of ABL
   - What is turbulence? Its characteristics and mechanisms that generate it?
   - Turbulence and stabilities

   Practice: *Journal article reading and discussion*

2. **Turbulence, Turbulent Flows, and Governing Equations (2 weeks)**
   - Taylor hypothesis
   - mean and turbulent parts
   - basic statistical methods
   - Reynolds decomposition, variance, covariance, turbulence intensity, turbulence kinetic energy (TKE), Richardson number, turbulent transport and flux
   - Equation of State, Conservation of Mass (continuity equation), Conservation of momentum, conservation of moisture, conservation of a scalar quantity

   Practice: *Using real data and software (IGOR or FORTRAN or MATLAB) to calculate these statistics; In-class excises/homework/journal article reading/discussion.*

3. **Eddy covariance systems (1.5-week lectures + 2-week lab practice)**
   - Sonic anemometers
   - Closed-path and open-path gas analyzers
   - Other sensors (temperature, wind, humidity, pressure, soil heat fluxes, soil moisture/temperature, etc)
   - Datalogger
   - LoggerNet

Primary References

Stull, R. B., 1988. *An Introduction to Boundary Layer Meteorology*, Kluwer Academic Publishers, Boston, MA.

Kaimal, J.C., and J.J. Finnigan, 1994. *Atmospheric Boundary Layer Flows*, Oxford University Press, 302 pp.

Foken, T. 2008. *Micrometeorology*, Springer-Verlag Heidelberg ISBN: 978-3-540-74665-2, 308pp.

Lee X, W Massman, B Law, 2004. *Handbook of Micrometeorology: A Guide for Surface Flux Measurement and Analysis*. Kluwer Academic Publishers, Dordrecht.

STUDENTS WITH DISABILITIES: Reasonable accommodations are available for students with a documented disability. If you have a disability and may need accommodations to fully participate in this class, please visit the Access Center (AC). All accommodations MUST be approved through the AC (Washington Building Room 217). Please stop by or call 509-335-3417 to make an appointment with a disability specialist.

Academic Integrity:

- All members of the University community share responsibility for maintaining and promoting the principles of truth and academic honesty.
- The Office of Student Standards and Accountability has a policy defining academic dishonesty and the procedures to follow if dishonesty occurs. This information can be found at www.conduct.wsu.edu.
- Cheating or plagiarism in any form will not be tolerated. Cheating includes, but is not limited to, copying work or allowing your work to be copied. Plagiarism includes resubmitting previously graded homework from a previous semester, even if it was your own work.
- If academic dishonesty has occurred on any homework, test or other assignment, the incident will be reported to the Office of Student Standards and Accountability and the student(s) involved will receive no credit (a score of zero) for that particular material.
- A second incident of cheating may result in dismissal from the university.

SAFETY: Safety is a shared responsibility in which each member of the University community has a personal role. Each of us should know the appropriate actions to take when an emergency arises. For emergency preparedness, students are strongly encouraged to visit http://oem.wsu.edu/emergencies. Everyone is also encouraged to visit the WSU ALERT site http://safetyplan.wsu.edu for information about emergencies & the communication resources WSU will use during emergencies.

#030

Devine, Lisa

From: Wherland, Scot
Sent: Wednesday, October 10, 2012 9:59 AM
To: Devine, Lisa
Subject: FW: Catalog agenda #30 CE 506
Attachments: CE 506 Syllabus-flux.doc

Lisa,
Here is the final syllabus for CE 506 to forward to Grad Studies.
Scot

Scot Wherland
Professor of Chemistry
Boeing Science/Math Education
Distinguished Professor Voice: 509.335.3360
Department of Chemistry FAX: 509.335.8867
Washington State University Office: Fulmer 151
Pullman, WA 99164-4630 Email: scot_wherland@wsu.edu

From: Liu, Heping
Sent: Monday, October 08, 2012 10:45 AM
To: Wherland, Scot
Cc: Whiting, Brooke Erin
Subject: RE: Catalog agenda #30 CE 506

Dear Dr. Wherland,

I'm glad to know that your committee discussed my CE506. I made some changes to the syllabus (please see the attachment). I do feel that it is difficult to evaluate students' participation objectively, so I deleted this part and adjusted grading scores. Hopefully, these changes work with you. I added the grading scale to make it clear to students.

As for the change in Academic Integrity, I replaced mine with what I found in the syllabus template from the university website. If you would like, please change it back for this part, or please let me know if you would like me to change it back. Thanks you!

Heping

From: Wherland, Scot
Sent: Thursday, October 04, 2012 3:42 PM
To: Liu, Heping
Subject: RE: Catalog agenda #30 CE 506

Prof. Liu,
We met today and passed CE 506 provisionally. Please send me another syllabus with a description of how you will evaluate participation for the 10% class participation, and also please give a grading scale. This can be

quite simple (90 to 100% =A, 80-89% =B or whatever, and you can indicate that, for example this is the lowest grade a student would receive).
Also, your academic integrity statement was more specific the first time, but either one is ok. When I get the syllabus I will send it to the Registrar and the proposal will go on to Grad Studies.

Scot Wherland
Professor of Chemistry
Boeing Science/Math Education
Distinguished Professor Voice: 509.335.3360
Department of Chemistry FAX: 509.335.8867
Washington State University Office: Fulmer 151
Pullman, WA 99164-4630 Email: scot_wherland@wsu.edu

From: Liu, Heping
Sent: Friday, September 28, 2012 10:31 AM
To: Wherland, Scot
Cc: Whiting, Brooke Erin
Subject: RE: Catalog agenda #30 CE 506

Hello Dr. Wherland,

Thanks for your comments on the syllabus for this new course. I made some changes accordingly. Please see the attached file for a new version. I added a "Learning Outcomes" section. I deleted the field trip section since it is uncertain. I made it clear that the lab practice will be occurring during lecture hours. Also I changed the format in line with the template, based on my understanding. My LAR colleagues made some suggestions too. One thing was that we changed the course title to be more general so as to attract non-LAR students. Could you please make a quick view to see if it looks okay to you? Please let me know if more changes are needed. Really appreciate!

Heping

Heping Liu, Ph. D.
Associate Professor
Laboratory for Atmospheric Research
Department of Civil and Environmental Engineering
Washington State University
Pullman, WA 99164-2910

Phone: 509-335-1529; Fax: 509-335-7632
heping.liu@wsu.edu
http://lar.wsu.edu

From: Wherland, Scot
Sent: Thursday, September 20, 2012 7:51 AM
To: Liu, Heping
Cc: Whiting, Brooke Erin
Subject: Catalog agenda #30 CE 506

Prof. Liu,
Catalog has received your request to establish CE 506. There are a few issues I can anticipate.

1. The syllabus does not quite meet the current requirements, please see http://dev.ugr.wsu.edu/faculty/syllabustemplate.html . In particular, specific "Learning Outcomes" are now required.
2. The syllabus refers to "Field Trips" and lab work is described. It is not clear from the syllabus whether these will occur during lecture time or if they are in addition to lecture time. If they are in addition to lecture time they either need to be in the time schedule for the course as lab time, or you will need to add "Field trips required" to the course description and give a specific schedule the first day of class. If the lab time is outside of lecture and adds up to enough hours (45 for the semester) then the course credits should include this, for example "2-3" would mean 2 hours of lecture and 3 hours of lab per week. It does not seem that this is the case, but hours outside lecture need to be described.

A new syllabus can be sent back through me, you do not need to resubmit.

Thank you,
Scot Wherland

Scot Wherland
Professor of Chemistry
Boeing Science/Math Education
Distinguished Professor Voice: 509.335.3360
Department of Chemistry FAX: 509.335.8867
Washington State University Office: Fulmer 151
Pullman, WA 99164-4630 Email: scot_wherland@wsu.edu

REVISED

CE506: Biosphere-Atmosphere Exchange Methods
Every Spring Semester
(3 Credits)

Class hours and location: TuTh 9:10-10:25; location will be added when available.

Lab hours and location: Lab practice at ETRL 207 will occur during lecture time which will be determined in the class.

Prerequisites: CE402/502: Applied Meteorology

Instructor: Heping Liu; Dana Hall 306B; Phone number: 509-335-1529;

email: heping.liu@wsu.edu.

Office Hours: By appointment.

TA: TA information will be added when available

Course Overview: To introduce the fundamental concepts of turbulence and turbulent fluxes in the atmospheric surface layer, the statistical description of turbulence and turbulent fluxes, eddy covariance systems, and post-filed processing of flux data. Special topics will be discussed, including the surface energy balance enclosure, uncertainty in flux measurements, and fluxes over complex terrain.

Learning Outcomes: (1). a firm foundation and knowledge of turbulence structures and turbulent transfer of heat and mass in the atmospheric surface layer; knowledge of working principles of the-state-of-the-art instruments for flux measurements; knowledge of the key scientific questions related to flux theory and measurements.

(2). an ability to use statistical methods to describe turbulent fluxes;

(3). an ability to design and build up a micrometeorological measurement system which includes a variety of meteorological instruments/sensors and eddy covariance sensors;

(4). an ability to conduct processing and analysis of postfield eddy covariance data.

Materials and Resources:
Lecture PowerPoint slides/notes and journal articles for readings will be posted on Angel. Additional references include (but not required):

Stull, R. B., 1988. *An Introduction to Boundary Layer Meteorology*, Kluwer Academic Publishers, Boston, MA.

Kaimal, J.C., and J.J. Finnigan, 1994. *Atmospheric Boundary Layer Flows*, Oxford University Press, 302 pp.

Foken, T. 2008. *Micrometeorology*, Springer-Verlag Heidelberg ISBN: 978-3-540-74665-2, 308pp.

Lee X, W Massman, B Law, 2004. *Handbook of Micrometeorology: A Guide for Surface Flux Measurement and Analysis*. Kluwer Academic Publishers, Dordrecht.

Class Activities and Evaluation

Homework: Problem sets including readings of journal articles/book chapters and data processing will be assigned weekly or so.

Exams: No midterm exam and final exam will be made.

Mini Projects: Students should discuss project proposals with instructor, identify specific datasets related to the topic, write an abstract, and email me by February 21. The instructor can also provide datasets which were collected in the past field campaigns, if requested. Their effort will be documented with a 15 to 20-page report. The report format should follow the requirements set by Journal of Geophysical Research-Atmospheres (www.agu.org). Due date for the first draft is April 12. You will receive my comments on your first draft in a few days for your revisions. Due date for the final report is May 1.

Suggested (not required) Topics for Mini Projects

1) Unclosure issues of the surface energy balance
2) The surface energy budget over different underlying surfaces
3) Horizontal advection of heat, moisture, and CO_2
4) Turbulence over hills and complex terrain
5) Critique of flux correction
6) Characteristics of turbulence in and above vegetation canopy
7) Spectral analysis and wavelet
8) Flux measurement methods (eddy covariance, Bowen ratio/energy balance, relaxed eddy accumulation, flux gradient, etc.)
9) CO_2 exchange of crops, forest, grasslands, water, etc.
10) Large eddy simulation (LES) of mean and turbulent flows
11) Methods to calculate soil heat fluxes
12) Applications of eddy covariance methods to other tracer gases
13) Turbulent fluxes in the nocturnal/stable boundary layer

Evaluation Criteria:

Homework	30%
Lab practice	30%
Mini Project	40%

Note: All homework/projects should be printed out. Handwriting is not accepted.

Grading Scale:

A = 90-100
B = 80-89
C = 70-79
D = 60-69
F = 0-59

Course Outline:

1) **Introduction to atmospheric boundary layer (ABL) (1.5 weeks)**
   - Surface forcings that affect the characteristics of ABL
   - Diurnal variations and vertical structure of ABL
   - What is turbulence? Its characteristics and mechanisms that generate it?
   - Turbulence and stabilities

Practice: *Journal article reading and discussion*

2) **Turbulence, Turbulent Flows, and Governing Equations (2 weeks)**
   - Taylor hypothesis
   - mean and turbulent parts
   - basic statistical methods
   - Reynolds decomposition, variance, covariance, turbulence intensity, turbulence kinetic energy (TKE), Richardson number, turbulent transport and flux
   - Equation of State, Conservation of Mass (continuity equation), Conservation of momentum, conservation of moisture, conservation of a scalar quantity

   Practice: *Using real data and software (IGOR or FORTRAN or MATLAB) to calculate these statistics; In-class excises/homework/journal article reading/discussion.*

3) **Eddy covariance systems (2-week lectures + 2.5-week lab practice)**
   - Sonic anemometers
   - Closed-path and open-path gas analyzers
   - Other sensors (temperature, wind, humidity, pressure, soil heat fluxes, soil moisture/temperature, etc)
   - Datalogger
   - LoggerNet
   - Scientific and practical considerations/issues for building a eddy covariance tower (e.g., project objectives, budget, site evaluation, choice of instruments, power, communication, site maintenance, etc)

   Practice: *build up your own eddy covariance system in lab*

4) **Postfield data processing (2-week lectures + 2-week lab practice)**
   - Data quality control
   - Stationary/ homogeneity
   - Spike and despike
   - Block average/detrending/filtering
   - Coordinate rotation/planar fit method
   - Different corrections (sonic temperature, high-frequency loss, WPL, etc)
   - Error analysis and evaluation of uncertainty of fluxes
   - Introduction of the methods used by Ameriflux and other flux communities
   - Other issues

   Practice: *step-by-step introduce (practice) to post-field data processing software, and then use real data to do practice.*

5) **Surface Energy Budget (2 weeks)**
   - Shortwave and longwave radiation
   - Radiation balance near the surface
   - Observations of radiation balance
   - Surface energy balance equation
   - Energy balance of bare surface
   - Energy balance of vegetated surface

- Energy balance of urban canopies
- Energy balance of water surfaces

Practice: *Use data we collected in the past field campaigns over different land surfaces to analyze the surface energy balance and its closure. Do literature review to compare and summarize your findings.*

6) **Fluxes over complex terrain (2 weeks)**
   - Basic concepts about turbulence over complex terrain
   - Mean flow over complex terrain
   - Turbulence
   - Advection/drainage flows and measurements

   Practice: *Journal article readings about the current understanding of theoretical and practical issues of flux measurements over complex terrain*

Policies

A. Reasonable Accommodation:

Pullman Campus Syllabus Statement: Students with Disabilities: Reasonable accommodations are available for students with a documented disability. If you have a disability and need accommodations to fully participate in this class, please either visit or call the Access Center (Washington Building 217; 509-335-3417 509-335-3417) to schedule an appointment with an Access Advisor. All accommodations MUST be approved through the Access Center.

B. Academic Integrity:

WSU expects all students to behave in a manner consistent with its high standards of scholarship and conduct. Students are expected to uphold these standards both on and off campus and acknowledge the university's authority to take disciplinary action. The purpose of these standards and processes is to educate students and protect the welfare of the community. The standards of Conduct for Students can be found at http://conduct.wsu.edu.

University instructors have the authority to intervene in all situations where students are suspected of academic dishonesty. In such instances, responsible instructors retain the authority to assign grades to students considering, from an academic standpoint, the nature of the student action. More information regarding responding to academic integrity violations can be found at: http://conduct.wsu.edu.

Feel free to contact the Office of Student Standards and Accountability (335-4532) if you would like more specific information about the process. Writing Programs (335-7959) can assist with proactive assignment design that minimizes intentional or unintentional academic dishonesty.

C. WSU Safety Statement:

Washington State University is committed to maintaining a safe environment for its faculty, staff, and students. Safety is the responsibility of every member of the campus community and individuals should know the appropriate actions to take when an emergency arises. In support of our commitment to the safety of the campus community the University has developed a Campus Safety Plan, http://safetyplan.wsu.edu. It is highly recommended that you visit this web site as well as the University emergency management web site at http://oem.wsu.edu/emergencies to become familiar with the information provided.