George Mason University  
Graduate Course Approval/Inventory Form

Please complete this form and attach a copy of the syllabus for new courses. Forward it as an email attachment to the Secretary of the Graduate Council. A printed copy of the form with signatures should be brought to the Graduate Council Meeting. Complete the Coordinator Form on page 2, if changes in this course will affect other units.

Please indicate:  ____X__ NEW  ____ MODIFY  ____ DELETE

Local Unit:  SCS  Graduate Council Approval Date: 

Course Abbreviation:  EOS  Course Number:  855

Full Course Title:  Introduction to Mesoscale Atmospheric Modeling

Abbreviated Course Title (24 characters max.):  Into. to Mesoscale Modeling

Credit hours:  3  Program of Record:  ESS Ph.D. and CSI Ph.D.

Repeatable for Credit?  ___ D=Yes, not within same term  ___ T=Yes, within the same term  ___ X N=Cannot be repeated for credit

Activity Code (please indicate):  X__ Lecture (LEC)  ___ Lab (LAB)  ___

Recitation (RCT)  ___ Studio (STU)  ___ Internship (INT)  ___ Independent Study (IND)

Catalog Credit Format  3: 3: 0  Course Level:  GF(500-600)  GA(700+)  X____

Maximum Enrollment:  10  For NEW courses, first term to be offered:  S05

Prerequisites or corequisites:  Permission of instructor

Catalog Description (35 words or less):  Introduction to the physical and numerical modeling issues involved in mesoscale atmospheric flows. These flows involve time and space scales associated with the diurnal cycle, the atmospheric inertial mode, thermal and mechanical forcing due to mesoscale terrain inhomogeneities, mesoscale precipitation systems, and downscale energy transfer from the synoptic scale to the mesoscale due to nonlinear flow interactions.

For MODIFIED or DELETED courses as appropriate:

Last term offered:  Previous Course Abbreviation:  Previous number:

Description of modification:
APPROVAL SIGNATURES:
Submitted by: ________________________________ email:
________________________________________

Department/Program: ________________________________ Date:
________________________________________

College Committee: ________________________________ Date:
________________________________________

Graduate Council Representative: ________________________________ Date:
________________________________________
GEORGE MASON UNIVERSITY
Course Coordination Form

Approval from other units:

Please list those units outside of your own who may be affected by this new, modified, or deleted course. Each of these units must approve this change prior to its being submitted to the Graduate Council for approval.

<table>
<thead>
<tr>
<th>Unit:</th>
<th>Head of Unit’s Signature:</th>
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Graduate Council approval: ______________________________ Date: __________________

Graduate Council representative: ______________________________ Date: __________________

Provost Office representative: ______________________________ Date: __________________
Course proposal to the Graduate Council
by
The School of Computational Sciences

1. CATALOG DESCRIPTION

EOS 855 Introduction to Mesoscale Atmospheric Modeling

Prerequisites: Permission of instructor.

Catalog description:

Introduction to the physical and numerical modeling issues involved mesoscale atmospheric flows that possess various mesoscale time and space scales arising from the diurnal cycle, the atmospheric inertial mode, thermal and mechanical forcing due to mesoscale terrain inhomogeneities, mesoscale precipitation systems, and downscale energy transfer from the synoptic scale to the mesoscale due to nonlinear flow interactions.

2. COURSE JUSTIFICATION

Course objectives: Mesoscale can be defined as having a temporal and a horizontal spatial scale smaller than the conventional rawinsonde network (about ~300km), but significantly larger than individual cumulus clouds. This implies that the horizontal scale is on the order of a few kilometers to several hundred kilometers or so, with a time scale of about 1 to 48 hours. As a somewhat arbitrary middle region of the atmospheric energy spectrum between local-scale to global scale, the mesoscale can be classified into three spatial decades as suggested by Orlanski (1975): the meso-γ scale (2-20 km), the meso-β scale (20-200 km), and the meso-α scale (200-2000 km).

In the atmosphere, mesoscale energy is distributed over a variety of flow modes, including internal gravity waves, mean mesoscale circulations, and mesoscale eddies. Flow dynamics are also quite variable and complex on the mesoscale. For example, mesoscale flows may be hydrostatic or nonhydrostatic. Nonhydrostatic motions may contain significant features on scales ranging from several meters to several tens of kilometers with time scales of minutes to many hours. Hydrostatic motions, in which the
nonhydrostatic motions are embedded, have motion scales orders of magnitude larger than the nonhydrostatic motions.

Over mesoscale travel times and distances, density stratification in the atmosphere plays an important role in flow dynamics and dispersion of pollutants. For example, a large number of processes such as flow over orography, rising convective elements, shear instability, and frontal systems, can generate internal gravity waves due to the presence of density stratification. Internal gravity waves are propagating mesoscale atmospheric free oscillations. They can transport both momentum and energy over long distances. They are the simplest and most fundamental motions on the mesoscale, and are almost always present in the density-stratified free atmosphere. These waves can influence the atmospheric dispersion of pollutants in several ways. Their presence may result in mesoscale fluctuations or oscillating variations in wind speed and direction depending upon the direction of propagation of the wave relative to the mean wind. Such periodic variations in wind direction may cause plume meander. These waves can also trigger flow instabilities such as Kelvin-Helmholtz instability and convective instability, which produce isolated patches of turbulence, even in the interior of stably stratified fluids. Thus, gravity waves can also influence the dispersion of pollutants by increasing turbulence intensity levels through these flow instabilities.

The presence of flow shear further complicates the flow dynamics and the dispersion of pollutants over mesoscale travel times and distances. Many flow instabilities occur partly as a result of the presence of flow shear, which may enhance turbulent diffusion by increasing turbulence intensities. For example, at night under stable conditions, the formation of a nocturnal surface inversion due to longwave radiational cooling decouples the nocturnal boundary layer from the remainder of the well-mixed daytime planetary boundary layer. In the nocturnal boundary layer, the wind speed decreases and the wind direction backs due to the new force balance between the pressure gradient force, the Coriolis force, and a weakened friction force. These changes in the wind direction and speed may result in pollutants at different levels being advected at different speeds (speed shear) or in different directions (directional shear). When morning arrives and the unstable daytime planetary boundary layer begins to grow, the shear-distorted pollutants mix in the vertical. Vertical turbulent mixing acts to reduce vertical wind shear and shear enhanced dispersion. Nevertheless, vertical shear will still be present mainly due to surface friction and baroclinicity, and its interaction with vertical diffusion results in simultaneous mixing.

Thermal and mechanical forcing due to mesoscale terrain inhomogeneities can generate mesoscale flow inhomogeneities such as sea breeze, land breeze, urban heat island, and mountain-valley circulations. Moist processes can generate cumulus-scale convection, squall lines, mesoscale convective complexes, mesoscale cellular convection, tropical cyclones, and mesoscale rainbands. Synoptic-scale wave-wave interactions may produce higher wavenumber circulations or flow features. This wide range of mesoscale circulations and their associated mesoscale vertical ascents and descents can have a significant impact on the dispersion of pollutants. In addition, large-scale baroclinicity and large-scale vertical motions affect the local structure and the dynamics of planetary
boundary layer. Latitude affects both the inertial period and diurnal forcing. Time of day affects the dynamics of the boundary layer, while time of year affects the diurnal forcing.

In summary, mesoscale atmospheric flows commonly possess various mesoscale time and space scales arising from the diurnal cycle, the atmospheric inertial mode, thermal and mechanical forcing due to mesoscale terrain inhomogeneities, mesoscale precipitation systems, and downscale energy transfer from the synoptic scale to the mesoscale due to nonlinear flow interactions. Even for horizontally homogeneous flows over flat, uniform terrain, mesoscale frequencies such as the diurnal heating cycle and formation of a nocturnal low-level jet will usually be present. The transport and diffusion of atmospheric pollutants can be affected by this wide range of flow scales through variations in the mean transport wind, differential advection due to vertical and horizontal wind shear, and vertical mixing.

The simulation, weather forecasting, and atmospheric dispersion of the mesoscale atmospheric processes require combining detailed physical knowledge of the atmosphere at mesoscale with numerical methods appropriate for the computation of the discretized equations governing these processes. In This course, students will be required to build a basic atmospheric simulation model incrementally as the course proceeds. The course will include and review the seminal journal papers in the field; it will also expose students to contemporary research.

**Course necessity:** This course provides key underpinnings for graduate research in mesoscale atmospheric simulation for weather prediction and/or atmospheric dispersion. This is the only CSI course that addresses the issues associated with high fidelity, high resolution modeling of the atmosphere at limited mesoscale temporal and spatial scales. Understanding these issues is important for any scientist wishing to engage in research in mesoscale atmospheric processes and their modeling.

**Course relationship to Graduate Programs:** The proposed course supports several existing degree programs, including the Computational Sciences and Informatics, the Earth Observing and Remote Sensing, and Computational Fluid Dynamics. The proposed interdisciplinary course will provide essential content to students in those degree programs with an academic focus on computational mesoscale atmospheric sciences. This type of integration between Earth Observing and Remote Sensing and computational sciences is directly relevant to the degree requirements for these programs.

**Course relationship to existing courses:** This course complements, extends and integrates material in EOS: 854 Planetary Boundary Layer. The course is primarily tailored towards students interested in undertaking research in Atmospheric Sciences.

3. **APPROVAL HISTORY**  NA

4. **SCHEDULING AND PROPOSED INSTRUCTORS**

   **Time of initial offering:** Spring 05
**Proposed instructors:** Dr. Zafer Boybeyi

**Tentative syllabus:** See attached syllabus

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**Sample Student Syllabus**

**New Course:** EOS 855: Introduction to Mesoscale Atmospheric Modeling (3:3:0)

**Lectures:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction to Physics &amp; Mathematics of Atmospheric Modeling</td>
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<tr>
<td>2</td>
<td>Governing Equations / Numerical Discretization</td>
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<tr>
<td>3</td>
<td>Wave Motion in the Atmosphere / Introduction to Advection Solvers</td>
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<tr>
<td>4</td>
<td>Inclusion of Moisture – Microphysics / Operator Splitting</td>
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<tr>
<td>5</td>
<td>Cumulus Parameterizations &amp; Scale Analysis</td>
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<tr>
<td>6</td>
<td>Air-Surface &amp; PBL Representations / Explicit and Implicit methods</td>
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<tr>
<td>7</td>
<td>Atmospheric Turbulence and its representation</td>
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<tr>
<td>8</td>
<td>Atmospheric Radiation Parameterization / Initial &amp; Boundary Conditions</td>
</tr>
<tr>
<td>9</td>
<td>Mesoscale Atmospheric Circulations &amp; Simulation Models</td>
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<tr>
<td>10</td>
<td>Cloud-scale Atmospheric Circulations &amp; Simulation Models</td>
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<tr>
<td>11</td>
<td>Multiscale Models/DNS, LES, and Mesoscale Models</td>
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<tr>
<td>12</td>
<td>Special Topic: Urban Effects</td>
</tr>
<tr>
<td>13</td>
<td>Special Topic: Mesoscale Atmospheric Dispersion</td>
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<tr>
<td>14</td>
<td>Special Topic: Atmospheric Chemistry</td>
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<tr>
<td>15</td>
<td>Model Evaluation</td>
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**Required Text:**
G. J. Haltiner & R. T. Williams: Numerical Prediction and Dynamic Meteorology

**OTHER REFERENCES**
J. R. Holton: An Introduction to Dynamic Meteorology (Second Edition)
R. A. Pielke: Mesoscale Meteorological Modeling

**Grading:**
- Class Assignments: 25%
- Midterm Exam: 20%
- Reading/Presentation: 25%
- Final Exam: 30%