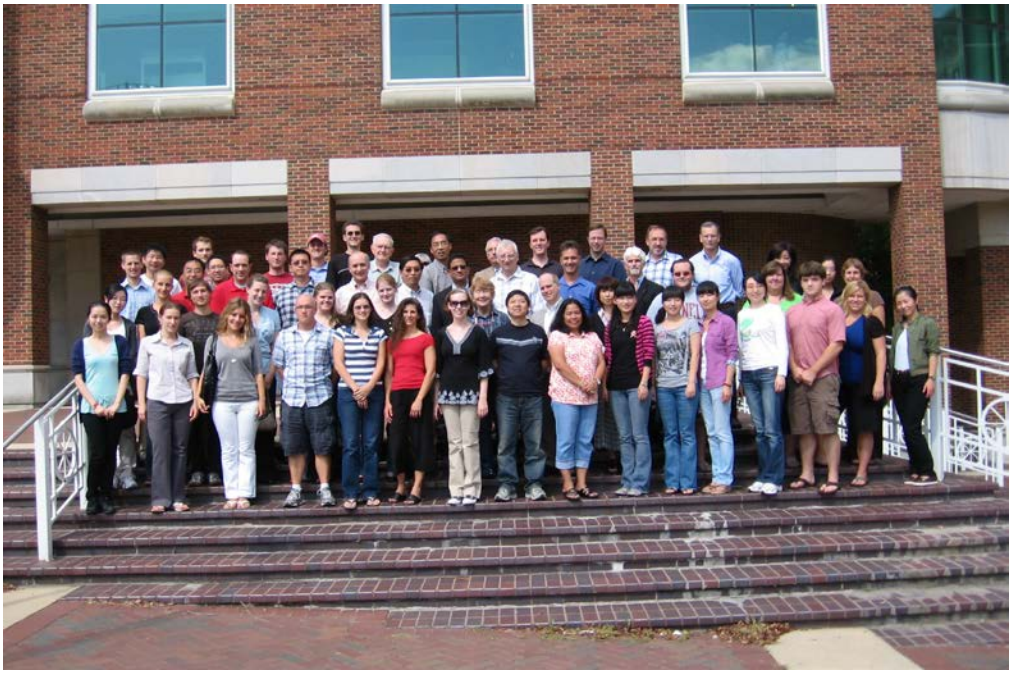
# Department of Atmospheric and Oceanic Science

Self-Study



Covering the Period:
January, 2003 – December, 2010

Tenure track and research faculty:
Dale Allen, Phillip Arkin , Hugo Berbery, Antonio Busalacchi, Timothy Canty, James Carton (Chair), Gennady Chepurin, Russell Dickerson, Semyon Grodsky, Robert Hudson, Kayo Ide, Eugenia Kalnay, ZhanQing Li, Takemasa Miyoshi, Ragu Murtugudde, Sumant Nigam, Rachel Pinker, Alfredo Ruiz-Barradas, Ross Salawitch, Jeffrey Stehr, Kostantine Vinnikov, Ning Zeng, Da-Lin Zhang, and Qunan Zheng

## Table of Contents

## 1. Introduction

The Department of Atmospheric and Oceanic Science (AOSC) has grown over the past few decades from a research center in an institute to one of the top ten graduate programs in the United States. This self-study describes challenges and contributions to this growth, emphasizing what has happened during the eight years since the Department's last review. During these years AOSC has undergone many changes including a change of name (Meteorology to AOSC); the loss of two academic faculty and the gain of four; the rapid expansion of data assimilation, air chemistry, and earth system science; the development of the new MSquare Earth System Science Interdisciplinary Center (ESSIC) and NOAA facilities; the creation of a professional MS degree; and the submission of a plan for an undergraduate major. Productivity has been outstanding within the graduate program, highlighted by the fact that of the 133 Ph.D.s produced since the Department began 40% have been awarded since 2002 (**Fig. 1**).

AOSC is one of three environmental science units, along with Geology and ESSIC, within the new College of Computer, Mathematical, and Natural Sciences (CMNS). This self-study by the AOSC Internal Review Committee[1] was initiated at the request of Prof. S. Halperin, Dean of CMNS in August 2010 to document the changes in AOSC since 2002 and to prepare for the upcoming External Review. This Internal Review Committee has based its self-study on information from several sources. Financial information was gathered from the Department, from the College, and from University archives. Information about students comes from Department archives, while information about the faculty was solicited directly. Information about courses and evaluations comes from University websites. To understand individual and group assessments and issues, the Internal Review Committee circulated questionnaires to the teaching faculty, research faculty and postdocs, graduate students, and the business/office staff. The Internal Review Committee also held meetings to promote broader discussion and offered to have confidential discussions with anyone from the groups at AOSC. Many comparisons to other departments of meteorology, atmospheric, and/or oceanic science are based on statistics from the 50 atmospheric and oceanic science graduate programs covered in the recently released report of the National Research Council (AOS-NRC). Finally we note that because of the close connections and overlapping missions shared by AOSC and ESSIC[2], for many comparisons we describe the combined activities of these two units.

This self-study is organized into seven sections; Introduction, Teaching and Advising, Research, Faculty Profiles, National Reputation, Service, and Future Plans; with supporting data provided in associated Appendices.

### 1.1 Mission Statement

The goal of the Department of Atmospheric and Oceanic Science is to advance the understanding of the atmosphere, oceans, and their climate interactions through basic and applied research, graduate and undergraduate education, and service. The Department

---

[1] The IRC consists of: Tony Busalacchi, James Carton, Russell Dickerson, Kayo Ide, Ning Zeng, Cathy Sabol, Jeff Stehr, and June Sherer.

[2] ESSIC (www.essic.umd.edu) is a joint center between AOSC, Geology, and Geography together with the Earth Sciences Directorate at NASA Goddard Space Flight Center (GSFC). Most AOSC Academic faculty have joint appointments in ESSIC.

works closely with surrounding government laboratories in fulfillment of its research and educational missions.

**1.2 Background and History**

The origins of the present AOSC can be traced back to the beginning of computational geophysical fluid dynamics in the United States. In the late-1960s, the Director of the Institute for Fluid Dynamics at UMD, Monroe Martin, hired a small group of meteorologists to develop a meteorological specialization within the Institute. During the 1970s this specialization gradually grew in numbers of faculty and began graduating M.S. and Ph.D. students under the umbrella of the Institute. By the time of the first Department external review in 1982, the Department of Meteorology had nine academic faculty covering areas of atmospheric physics and dynamics and basic fluid dynamics, a base (State) budget of $1.2M (2008 Dollars) and a small MS/Ph.D. program. In the 1980s a further expansion occurred bringing the academic faculty number up to twelve, and shifting the academic focus of the Department toward expanding the Ph.D. program. At this time the graduate program had 16 Ph.D. students and 29 MS students and was awarding 1-2 Ph.D.s per year (**Fig. 1**). This decade also saw the creation of the joint UMD-NOAA Cooperative Institute for Climate Studies (CICS) which brought a number of NOAA researchers to campus.

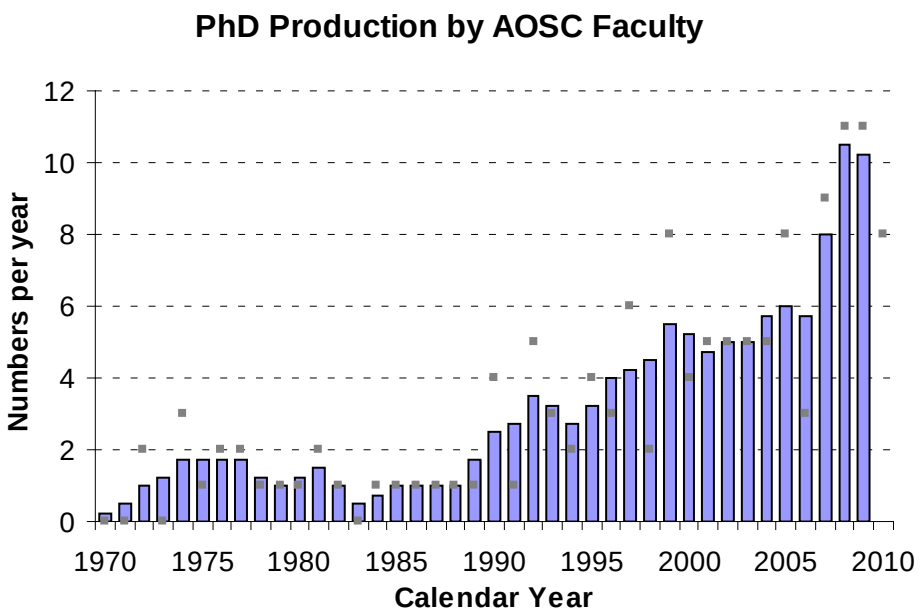



**Figure 1** Annual Ph.D. production (boxes), and smoothed with a three year triangular filter (bars) since 1970. Department faculty produced one Ph.D. prior to 1970.

During the 1990s the Department underwent more change, including the creation of the joint UMD-NASA Joint Center for Earth System Science (JCESS) and the departure of the Center for Ocean, Land, Atmosphere Interactions. Indeed, more than half of the current academic faculty were hired since the 1999 hiring of Eugenia Kalnay and Zhanqing Li. Under Antonio Busalacchi's leadership JCESS became the basis for ESSIC. ESSIC was formed as a joint center among AOSC, Geology, and Geography and the Earth Sciences Directorate at NASA Goddard Space Flight Center (GSFC). ESSIC

was soon joined by CICS, which shifted from AOSC to ESSIC in 2001. The shift of CICS was followed by a rapid expansion of its size and scope.

### 1.2.1 2003 External Review

The most recent external review of the Department was carried out in early 2003 based on material collected in late-2002. At that time the External Review Committee report summarized the future of the Department in very optimistic terms: "*We believe that the Department is emerging among the top tier of climate science departments in this country. And we're optimistic and even a bit envious of the Department's future prospects that accrue from its inherent strengths and its unique location in the Washington DC area*." The report went on to identify eight recommendations for the further progress of the Department. Here we summarize these (the full recommendations are included in **Appendix 1**) with an indication of how the Department has responded:

1. *The Department needs a continually updated implementation plan with specifics on priorities for hiring of academic and research faculty, laboratory renovation, and space allocation.* In response the Department has developed several strategic/implementation plans, the latest of which is contained in **Appendix 2**.
2. *The Department should aggressively pursue opportunities to expand research and academic relationships with NOAA and NASA.* Since 2003 the Department has followed this advice single-mindedly. Department faculty members have played a critical role in the development of the new NOAA science center on the MSquare Research Park, future home of NCEP as well as significant portions of NESDIS. Recent Department faculty hires (Salawitch, Ide, and Liang) were carried out in collaboration with NASA GSFC, NASA HQ, and NOAA NCEP, and this year NESDIS and NCEP are collaborating on a new hire in the area of data assimilation. Retired NOAA employee Vern Kousky has been teaching our highly successful graduate course in synoptic meteorology (AOSC 600). The recently developed Professional MS degree program and the undergraduate major were both built to exploit the resources, and designed to address the needs, of the government labs. Finally we note the creation of an Earth System Science Graduate Fellowship supported by NASA GSFC.
3. *The Department should immediately develop plans for the possible collocation with NOAA on the University of Maryland campus.* The agreement on the co-location of NOAA was signed in 2007. We currently expect occupancy in late-2012. In 2007 a Memorandum of Understanding was signed with NOAA spelling out areas of cooperation in numerical weather, climate, and ocean prediction, and earth system science research.
4. *Additional steps could be taken to enhance the positions of research faculty. Ways of generating some institutional support for research faculty should be considered. Any plan to enhance the status, security and compensation of research staff will require a strategic plan.* In response some additional opportunities have been made available. The University has created a 'safety net' for senior research scientists. AOSC has created the ½ time position of Assistant Director of Undergraduate Studies. Our hope is that development of the Master of Professional Studies program will provide additional opportunities, however this remains an area where we need to make additional progress.

5. *The Department should take a more proactive role in expanding its contributions to the general education of UMD undergraduates.* In response AOSC has greatly increased the number of undergraduates attending its service courses (discussed later). AOSC also has developed a plan to create an undergraduate major. This plan will be being voted on, by the University Senate, this fall.
6. *The Department, in concert with the College, should develop and pursue a plan to attract, foster, and recruit qualified students from traditionally under-represented groups into its graduate program.* The Department still lacks a plan. However, since the 2003 External Review our graduation rates for certain under-represented groups have climbed. 30% of recent PhD graduates are women.
7. *The external review pointed out the joint interest in paleo-climate between the Department and Geology and suggested that it would be natural to teach joint courses and recruit students in this area.* The area of paleoclimate has received a major boost with the hiring of Michael Evans into Geology and ESSIC, with an Affiliate appointment in AOSC. Ning Zeng has become an Affiliate of Geology. Certain Geology faculty with an interest in paleo-climate regularly attend AOSC seminars.
8. *The Department should change its name to a name that reflects the breadth of expertise and teaching and research interests of its faculty*. In 2006 the Department name was changed from Meteorology to Atmospheric and Oceanic Science.

**1.2.2 Recent Developments**

There have been a number of important changes since the 2003 External Review which we summarize here.

1. *Faculty Changes.* Academic faculty (tenure and tenure-track) members Owen Thompson and Daniel Kirk-Davidoff have departed and Robert Hudson has shifted to a half-time position, while Sumant Nigam (2003), Ross Salawitch (2007) and Kayo Ide (2008) have joined the Department. Professor Xin-Zhong Liang will join us from his current position at University of Illinois in January 2011. We are in the process of completing a search for an assistant professor in the area of data assimilation. A number of AOSC research faculty have left since 2003. These include: Ming Cai (FSU), Andrew Dessler (Texas A&M), Bruce Doddridge (NASA/LaRC), Menglin Jin (San Jose State), Istvan Laszlo (NOAA), Ken Pickering (NASA/GSFC), Gene Rasmusson (retired), and Roxana Wajsowicz (retired). We consider it a sign of health for the Department when research faculty go on to tenure track positions at other universities or to highly-ranked civil service positions (e.g., B. Doddridge is a Branch Head at NASA/LaRC). A smaller number of research scientists have been hired including Alfredo Ruiz-Barradas, Jeff Stehr, Takemasa Miyoshi, Dale Allen, and Tim Canty, while many others are active in AOSC, but are paid through ESSIC. In 2009 all academic faculty with one exception, who were not previously in ESSIC, became joint AOSC/ESSIC appointments.
2. *Facilities upgrades.* As a result of rearrangements of space within the Computer and Space Sciences building the air chemistry laboratory has gotten a complete upgrade. This laboratory has moved to a larger, newly renovated space on the fourth floor of Computer and Space Sciences building and now includes a roof-top laboratory for remote sensing and ground truth for satellite observations.

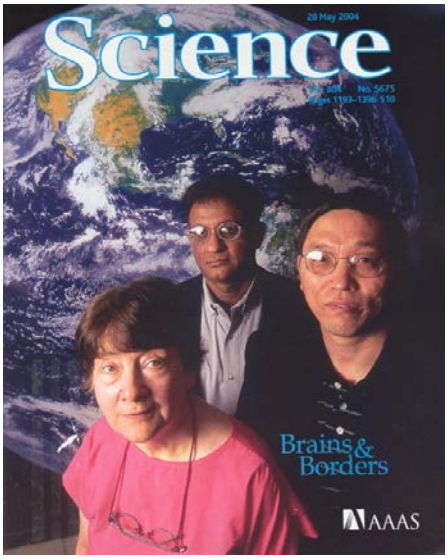
3. *Growth of ESSIC and the MSquare facilities*. ESSIC has grown dramatically, both financially and in the number of scientists, since the last review. ESSIC now numbers 98 people (including most of the AOSC faculty who now have split appointments in ESSIC). CICS has been replaced by the expanded Cooperative Institute for Climate and Satellites (retaining the acronym CICS). CICS is now a multi-institutional organization led by UMD and the University of North Carolina System through North Carolina State University. Other partners include: Princeton University, Howard University, UC Irvine, Columbia University, City University of New York, Duke, University of Miami, Oregon State University, Colorado State University and Remote Sensing Systems. ESSIC and CICS are now housed in a new building next to the future site of NCEP and NESDIS.
4. *Development of the Academic Program.* Both the MS/Ph.D. programs and the undergraduate instruction have expanded. For example, Ph.D. graduation rates have increased from 4.7/yr (1996-2002) to 7/yr (2003-2009) with even greater numbers in the past few years. Over the same time period the number of undergraduates taught increased from 130 seats/yr to 364 seats/yr (and is at 1,100 seats/yr for this past year). A new Masters of Professional Studies in Atmospheric and Oceanic Science has been approved and implemented, while a plan for an undergraduate major in Atmospheric and Oceanic Science has been submitted to the University.

### 1.2.3 Department Demographics and Diversity

The Department contains 14 research faculty, 13 academic faculty (one half-time), 2.5 state-funded staff and 2.5 soft-funded staff. One additional academic faculty member is expected in January, and a search is on for two more (one split with ESSIC). For comparison the median size of academic faculty of AOS-NRC departments is 18.9. The median combined number of academic plus research faculty for the AOS-NRC group is 33.

The AOSC academic faculty has been lauded by the AAAS for its international outlook and diversity (see **Fig. 2**). We include three women (26%) and one member of an under-represented minority group (9%). For comparison, the medians of the AOS-NRC group are 15% and 2%. In region of origin our current academic faculty includes: one person of South American background, one of European, one of Middle Eastern, two of south Asian, four of east Asian background, and four born in the United States. Members of our academic faculty are at advanced stages of their careers compared to other departments of atmospheric and oceanic science, with 11 Full Professors, one Associate Professor, and one Assistant Professor. In contrast, 6 of the 14 members of the research faculty are at the Assistant level.

**Figure 2** May 2004 cover of *Science* showing AOSC faculty members Eugenia Kalnay, Sumant Nigam, and Zhanqing Li.




Between 2003 and 2010 the Department graduated 60 Ph.D.s. This includes all students primarily advised by AOSC faculty, some of whom were officially enrolled in other programs at UMd. Of these, 30% are women and 13% are members of an under-represented minority group (for comparison the median under-represented minority representation in the AOS-NRC group is 4%). In region of origin, 39% of the students are from the United States, 46% from Asia, 6% from Europe, and 9% from Central or South America.

### 1.3 Organization and Administration

The Chair is appointed to a fixed term of office, ordinarily for five years, by the Dean. The current Chair, James Carton, was appointed in 2007. The Chair consults with staff through frequent formal and informal meetings (the offices are adjacent). The Chair holds faculty meetings approximately every two months through the academic year to address substantive issues. AOSC administrative services consists of an Administrative Assistant (Tammy Paolino), Graduate Secretary (Tammy Hendershot, currently halftime; her other halftime assignment is with Astronomy at UMd), Director of Administrative Services (who also oversees Geology, June Sherer), financial coordinator (Sonja Junek) and business manager (Bernadette Gatewood, halftime) **(Fig. 3)**. The academic aspects of AOSC are managed by a series of faculty committees**.** Membership in the faculty committees is assigned annually by the Chair. In particular, overall responsibility for the graduate program is the responsibility of the Graduate Director (Dalin Zhang) who also serves as Associate Chair, while Admissions is overseen by the Chair of the Admissions Committee (Sumant Nigam). Further information including current committee membership is provided in **Appendix 3**.

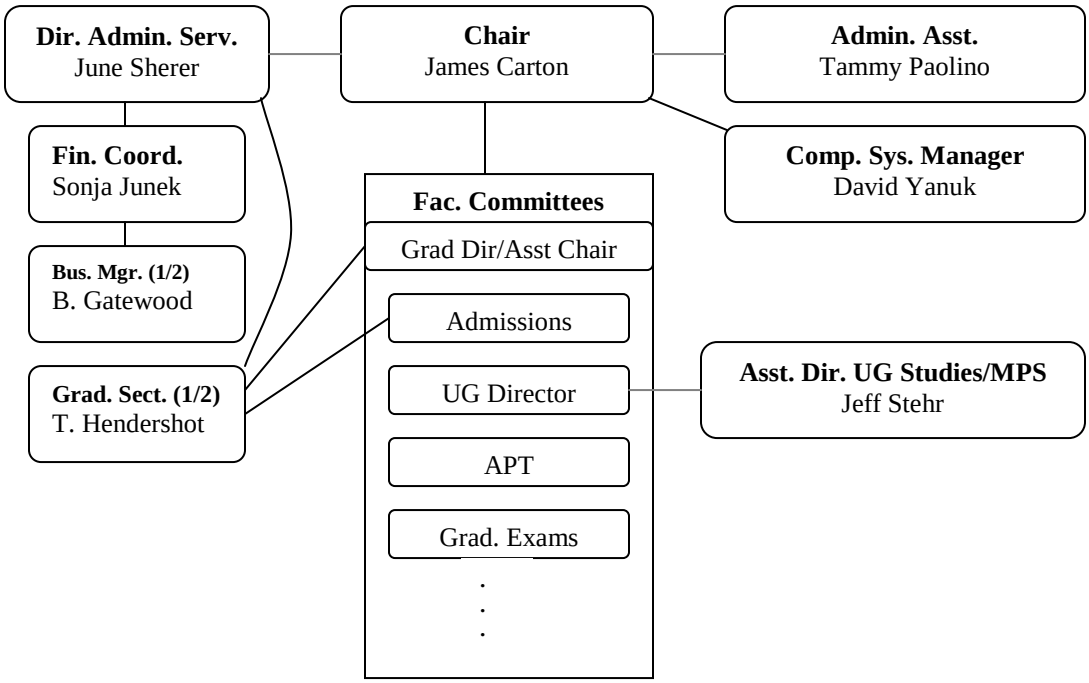



**Figure 3** Organization and administration of AOSC. The Department administration is the responsibility of the Department Chair who reports to the Dean of CMNS. All administrative services are overseen by June Sherer, who also oversees business services in Geology. Several of the faculty committees interact with the graduate secretary. The position of Assistant Director of Undergraduate Studies, which would provide half-time support to a research scientist who has taken an active role in prior classroom instruction, is being developed in anticipation of an undergraduate degree program.

### 1.4 Physical and Computational Infrastructure

AOSC has a total space allocation of 21,043 $ft^2$ (www.facilities.umd.edu). Most of this space is in the Computer and Space Sciences (CSS) building (16,400 $ft^2$), divided into 75 rooms, including 36 faculty offices (6,046 $ft^2$) and 1,460 $ft^2$ open lab space. Of this space, 9,970 $ft^2$ is contained on the second and third floors of the CSS West Wing while 6,430 $ft^2$ is in the older main building. Of the latter, 1,700 $ft^2$ is occupied by the recently renovated air chemistry laboratory. A fifth of the AOSC space (4,643 $ft^2$) is in nearby (next door to CSS) Jull Hall. Two offices in the third floor of the CSS building have been modified with enhanced cooling to allow us to house our computer servers nearby. *However these rooms continue to have episodes of overheating due to building cooling issues*. Another large room on the third floor holds a combined department library and State Climatologist's Office. The Department has a conference room that can comfortably accommodate 12 to 15 people. We are seeking a space where we can hold meetings of 30 people for moderate sized seminars and dissertation defenses, etc.. The developing undergraduate major will add additional demands on available space. Rearrangements of space as a result of the new physical sciences complex may offer opportunities in this regard.

AOSC maintains a Central Computing Core facility that provides web hosting, email, user account services, printing services as well as computational platforms and a central

Network Attached Storage cluster for high density file serving. The storage cluster currently has a storage capacity of over 400 TB, including a new 196TB disk-based backup system (added in response to the loss of a number of disks due to power failures of the uninterruptable power supplies during last winter's snowstorms). The Central Computing Core is accessible from client desktops via a 1Gbps Local Area Network as well as a campus-wide wireless network for general-purpose Internet traffic. The campus maintains a communications backbone consisting of two internal 10Gbps links with a 2Gps and a 10Gps link to the outside world. AOSC maintains two fully equipped student computational labs with 35 client seats running Windows and linux, which serve a dual purpose (the instructional program and student research). The larger of these is currently being upgraded to dual-boot Windows/MACOS computers. AOSC also maintains a number of computational servers for general use while individual research groups maintain currently four linux-based Beowulf clusters. Computational facilities are maintained by one fulltime systems administrator (David Yanuk) and a very capable student assistant (Jose Caceres). Individual scientists including students generally use laptops or desktop linux boxes, the latter of which are maintained by our IT department.

**1.5 Department Finances**

**Tables 1** and **2** summarize the income and expenses for the past five years for AOSC. The primary sources of funds to support the operation of the Department and pay academic salaries are: State budget support and Designated Research Initiative Funding (DRIF) associated with contracts and grants. The major expenses are for faculty and staff salaries, teaching assistants, and operating expenses. In **Table 2** we examine finances in FY2010 in more detail. During this past year administrative costs were $8,938 per faculty (research plus academic) or 9% of the faculty salary costs while IT costs were $5,432 per faculty. Adding administrative and IT costs together gives a total administrative plus IT cost per faculty of $14,370 per faculty or 15% of the annual faculty salaries. *We would like to hear the Committee's views of the reasonableness of the ratio of State-to-outside support, while acknowledging that we are in an era of restrained budgets.*

The IT infrastructure is supported partly by DRIF and partly by charges to users of the computer system. The major IT expense is for salaries, with smaller but variable expenses for hardware and software licensing. For example, in FY2010 IT salaries were $153,879, of which $100,454 was covered by computer fees to users based on usage. In FY2011 we are installing a $30,000 disk backup system partly supported by user fees, as well as a computer laboratory upgrade.

**Table 1** Summary of income and expenses for the recent six fiscal years (in $thousands). Grant funding is discussed more completely in Section 5.2

| | FY2005 | FY2006 | FY2007 | FY2008 | FY2009 | FY2010 |
|---|---|---|---|---|---|---|
| **Research Awards** | | | | | | |
| AOSC Contracts/Grants | $4,222 | $4,676 | $3,413 | $4,463 | $4,121 | $3,958 |
| ESSIC Contracts/Grants | $6,063 | $7,038 | $7,418 | $9,880 | $8,258 | $18,173 |
| **AOSC Income** | | | | | | |
| DRIF Income from C/G | $206 | $187 | $215 | $253 | $202 | $232 |
| AOSC State Budget contribution | $1,129 | $1,184 | $1,189 | $1,341 | $1,348 | $1,258 |
| Other (including IT charges) | $174 | $168 | $166 | $158 | $161 | $212 |
| **AOSC Expenses** | | | | | | |
| Faculty salaries | $967 | $1,032 | $1,000 | $1,049 | $1,084 | $1,113 |
| Staff salaries including IT | $334 | $386 | $404 | $440 | $435 | $420 |
| TAs | $19.62 | $24.19 | $28.86 | $51.07 | $60.98 | $85.51 |
| Operating | $95.49 | $91.48 | $87.41 | $93.68 | $88.84 | $62.28 |

**Table 2** Expense ratios detailing administrative (Admin) and information technology (IT) costs relative to faculty costs for FY2010. Percentages are computed comparing the annual salaries.

| | |
|---|---|
| Admin $/ # of Tenure-track Faculty | $26,798 |
| Admin + IT $/ # of Tenure-track Faculty | $43,084 |
| Admin $ / Tenure-track Faculty $ | 18% |
| Admin + IT $ / Tenure-track Faculty $ | 29% |
| Admin $/(# of Research and Tenure-track Faculty) | $8,938 |
| Admin + IT $/(# of Research +Tenure-track Faculty) | $14,370 |
| Admin $ / Tenure Track + Research $ | 9% |
| Admin + IT $ / Tenure Track + Research $ | 15% |

AOSC is too small to provide stable statistics on faculty salaries. However, the median AOSC 12-month professorial salary of $147 K/yr is somewhat below the peer average of $177 K/yr (based on information collected by Texas A&M for schools such as UNC, Univ. Ill, and UC Berkley for the year 2009, www.tamu.edu/oisp/faculty-reports/aaude-faculty-salary-fall-2009.pdf). A comparison of salaries versus time since Ph.D. within CMNS suggests that AOSC salaries are generally in line with those of other units within our College. Student Graduate Research Assistantship stipends are provided in **Table 3**. Comparison suggests that our stipends are in line with those offered by other departments within our College.

**Table 3** Student Stipends for FY2010 (12mo). Numbers are shown for two other departments within CMNS for comparison.

| | **AOSC** | **Geology** | **Chem/Biochem** |
|---|---|---|---|
| GRA Step 1 | $24,347 | $23,301 | $22,779 |
| GRA Step 3 | $25,742 | $25,915 | $24,212 |
| TA Step 1 | $18,882 | | |
| TA Step 3 | $20,194 | | |

## 2. Teaching and Advising

### 2.1 Graduate Education

AOSC offers three graduate degree programs, a non-thesis MS, a Master of Professional Studies, and a Ph.D.[3]. The non-thesis MS and Ph.D. programs share many aspects including Admissions and the Comprehensive Examination. The non-thesis MS requires 30 semester hours of coursework and a passing grade for the Comprehensive Examination that covers: 1) atmospheric and oceanic dynamics, 2) atmospheric physics and chemistry, and 3) climate and earth system science. Course offerings are presented in **Appendix 4**. Students typically complete the MS degree within two years (**Fig. 4**).

The Ph.D. program also has a 30 semester hour coursework requirement along with a requirement to pass the Comprehensive Examination at the Ph.D. level. Recently a popular new option as been added to the Comprehensive Examination for career scientists who are returning to complete their Ph.D., which allows these students to bypass the written portion of the exam and focus on their area of specialization. All Ph.D. students must also pass a Specialty Examination that includes a dissertation prospectus.

On average, it has taken students less than 1.5 years to pass the Ph.D. Qualifying Examination, 3.8 years to advance to candidacy, and then an additional 2 years to complete the Ph.D. program (median: 5.7 yrs, mean: 5.8 yrs) (**Fig. 4**). For most of these students, this 5.8 year program length (**Fig. 4**) includes the semesters required to complete the minimum 27-credit graduate-level courses and 3 research credits to meet the Master degree requirements.

This 5.8 year time to degree is affected by the enrollment of about 15% part-time students, many of whom are full-time employees of nearby federal agencies such as NASA, NOAA, and EPA. As a result of their other commitments, most of these students progress more slowly than full time students. Nonetheless, they provide valuable links to these research centers. Moreover, they have received research training in these research centers prior to being admitted into our program, which benefits the Department. For the full-time students the average time to degree is under 5 years. The time to degree is also lengthened due to some students who switched their research fields. Despite our relatively short time to degree relative to other science departments we feel there is still room to reduce this time.

[3] www.gradschool.umd.edu/catalog/programs/aosc.htm

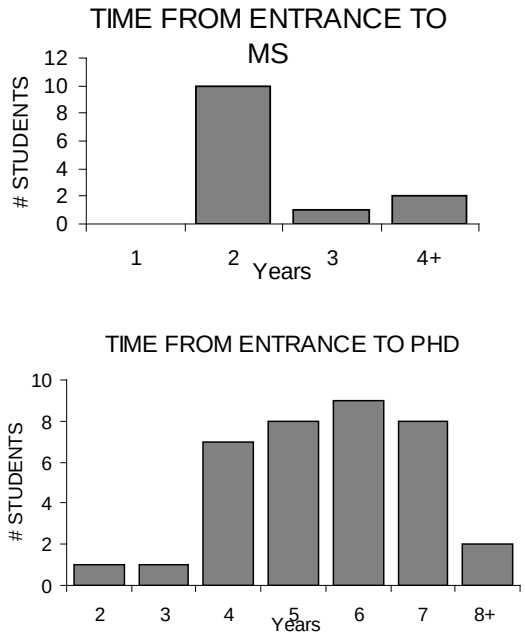



**Figure 4** Histograms of time from entrance until degree for the MS and Ph.D. program based on data from 2005-2009. The MS data excludes students who continued for a Ph.D.. MS recipients who took longer than two years had unusual situations including in one case the birth of a child and in another a full time job. Of the two Ph.D. recipients who took longer than 7 years the one suffered from a serious illness and the other had extensive family responsibilities and a fulltime job.

The Master of Professional Studies in Atmospheric and Oceanic Science is a new program, authorized in 2009, designed for working meteorologists, oceanographers and environmental scientists who would like to extend their education in atmospheric and oceanic science and related fields. Professional Masters students are likely to be taking courses on a part-time basis. The program includes three Certificate programs in 1) Computational Methods in Atmospheric and Oceanic Science, 2) General Atmospheric and Oceanic Science, and 3) Air Quality Science and Technology and a ten-course Master of Professional Studies. Each certificate requires the successful completion of four courses. The program is specifically designed to benefit employees of the NOAA facility that will soon move to the MSquare campus. So far, the number of students who have enrolled is just a few per year. However, the program has not yet been widely promoted. We expect enrollment to increase substantially once the delayed arrival of NOAA at the MSquare campus (currently expected in 2012) facility is occupied.

Plans are also developing for an international exchange program at the graduate student level, with the University of Reading, in the area of data assimilation. The exchange program will allow students from the two Universities to spend 1-2 semesters at the other location, giving those students international experience and allowing them to exploit UMd's proximity to NOAA and NASA laboratories as well as the proximity of Reading to ECMWF.

Graduate student mentoring occurs primarily through interactions with the individual student's advisor(s). In the past few years the weekly department seminar has been used to give students enhanced exposure to visiting scientists. All graduate students are expected to attend department weekly seminars and to meet with the speaker for a student-only session after the lecture (this is quite popular with both speakers and students). Typically 1-2 students are invited to go out to lunch with the faculty and the speaker. A number of other lecture series are also available to Department members,

including weekly ESSIC, CSCAMM, and Atmospheric Chemistry brownbags. The AMS lecture series held in the US Senate buildings offers additional opportunities. To give students exposure to the national scientific community, virtually all advanced graduate students participate in national meetings such as the annual AMS or AGU meetings. To give students more teaching experience, the students run exhibits as part of Maryland Day and conduct various other volunteer activities. They also typically work as a TA for a semester during their stay at UMD, although this is not required. One student works as the Assistant State Climatologist, a position that involves constant interaction with the public.

Another important mechanism by which graduate students become involved in the life of the Department is through the graduate student organization known as METOGRADS. Illustrative METOGRADS activities are: arrangements for grad student visits to nearby government labs once or twice a semester; participation in the annual National Weather Service open-house; hosting activities at the annual Maryland Day festival (30,000 visitors tour the University campus); hosting booths at the first USA Science & Engineering Festival on the Mall; providing help to the British Embassy workshop on environmental science; providing help to the Joint Centers for Satellite Data Assimilation annual workshop; giving lectures at local middle and high schools. METOGRADS also arranges weekly seminars by, and for, students.

Formal feedback from the graduate students on the quality of the program comes in two forms: course evaluations and exit interviews. The results indicate that they are satisfied with the general design of the courses. The standard University evaluations of course teaching, given below, show the mean scores ranging from 3.22 to 3.64 for “Syllabi, Homework and Tests”, and 3.05 to 3.66 for “Overall, I would rate this course as...,”, for both graduate courses (ignoring Spr08 due to sampling). A comparative analysis was conducted by the CMNS Associate Dean, Paul Smith, who found AOSC course evaluations to be on par with those of the rest of the College.

**Table 4** Graduate course evaluations averaged over all graduate courses (each course weighted equally regardless of enrollment, out of 4.0). The set of questions changed in 2007, but we have attempted to connect three questions. Lower values in Spring 2008 were the result of poor scores for one course with four respondents.

| | FY05 | | FY06 | | FY07 | | FY08 | | FY09 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spr | Fall | Spr | Fall | Spr | Fall | Spr | Fall | Spr | Fall |
| The instructor's handling of the course/well-prepared | 3.46 | 3.41 | 3.58 | 3.38 | 3.4 | 3.18 | 2.94 | 3.43 | 3.69 | 3.42 |
| The instructor’s respect towards students | 3.69 | 3.74 | 3.89 | 3.75 | 3.72 | 3.41 | 3.48 | 3.68 | 3.79 | 3.61 |
| Overall, I would rate the instructor as/effective teacher | 3.48 | 3.29 | 3.66 | 3.23 | 3.45 | 3.09 | 2.65 | 3.32 | 3.05 | 3.23 |
| Syllabi, homework, and tests were appropriate | 3.39 | 3.5 | 3.64 | 3.22 | 3.32 | | | | | |
| Aproachability of the instructor | 3.72 | 3.58 | 3.61 | 3.31 | 3.5 | | | | | |
| Overall, I would rate the | 3.48 | 3.29 | 3.66 | 3.23 | 3.45 | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| instructor as | | | | | | | | | | |
| Overall, I would rate this course as | 3.22 | 3.12 | 3.56 | 3.22 | 3.28 | | | | | |

Overall supervision of the graduate program is the responsibility of the Graduate Director (Da-Lin Zhang). Information about courses, requirements, deadlines, etc is also provided by the Graduate Secretary, Tammy Hendershot. One problem we face is that this critical position is currently underfunded -- Hendershot presently splits her time between AOSC (afternoon) and Astronomy (morning).

### 2.1.1 Admissions

As of fall 2010 the Department had 68 graduate students in various stages of progress (including several for whom AOSC faculty provide support and advising but the students are actually enrolled in other programs such as Applied Mathematics and Scientific Computation, Chemical Physics, Marine Environmental Estuarine Studies, Chemical Engineering, and Chemistry & Biochemistry). Here we provide a brief statistical overview of admissions and the current student body based on information gathered for the five year period 2005-2009 (**Table 5**). This period contains two academic years, 2006 and 2007, which are unusual due to historically low admissions in turn partly due to changes in visa regulations for foreign graduate students. The increase in 2008 is the result of a particularly dynamic Admissions Committee Chair, Sumant Nigam.

The data in **Table 5** reveal that AOSC receives around 80 applications per year and attracts a new class of 13-16 students each fall (we typically have 0-2 spring admits). Support is provided by a combination of Graduate Research Assistantships, Teaching Assistantships, and some University Fellowship funding. In addition GSFC funds the first year of one graduate assistantship in Earth Science each year. Focusing on the 2009 admissions season, the most common colleges and universities among applicants include Nanjing (8), Millersville (6), Penn State (4), and Cornell (3). In order to improve our ability to attract top foreign students, we have recently instituted a program where we allow the Graduate Director, Da-Lin Zhang, who makes regular trips to China, to interview and make tentative offers of admission to Chinese applicants. We would like to expand this to include other countries, exploiting the international connections of our faculty.

**Table 5** Graduate student statistics including admissions for the years 2005-2009. Undergraduate grades are not provided because of the difficulty in interpreting foreign grading.

| | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|
| **Applicants** | 82 | 76 | 79 | 76 | 80 |
| **Median QGRE** | 780 | 745 | 780 | 770 | 770 |
| **New Students** | 13 | 7 | 9 | 13 | 16 |
| **Total Students** | 60 | 64 | 64 | 58 | 60 |
| **Ph.D.s granted** | 5 | 2 | 9 | 11 | 11 |
| **Terminal MS** | 0 | 2 | 3 | 3 | 3 |

To understand the funding arrangements for our graduate students we examined the support for the 60 students in 2009. Of these 60, 28 were supported on full GRAs, two received ½ GRAs, two were supported as hourly students, and two as faculty research

assistants. Most of the remaining 26 were working fulltime or in transition (e.g. in the process of graduating or shifting to a postgraduate job).

### 2.1.2 Ph.D. Graduate Outcomes

AOSC students successfully compete for national fellowships such as the NASA Earth Science Fellowships at a rate of 1-2 per year and are typically able to publish at least one paper in a refereed journal prior to graduation. But perhaps the best measure of Ph.D. graduate outcomes is through examination of the employment profiles of the 60 Ph.D. graduates since 2003 (**Appendix 5)**. Of these, 19 have gone to work at NOAA laboratories, 8 have gone to work at NASA laboratories (most of whom went to GSFC), 19 went into university research positions (including 5 at UMD). Of this group eight have become assistant professors (Choi at Pusan in Korea; Yang at National Central University in Taiwan; Danforth at University of Vermont; Sun at George Mason University; Taubman at Appalachian State University; Karnauskas at Woods Hole Oceanographic Institution; Kieu at Vietnam National University; and Wang at Nanjing University). The remainder went to a wide variety of jobs including foreign weather services, private companies, and other government laboratories. Most graduated with degrees from AOSC, but 10 who were advised by AOSC faculty received their degrees from related departments (AMSC, CHPH, CHEM, ENCH, or MEES). All graduates were able to secure employment and all remained in their field of science after graduating. One recent graduate, Megan Linkin who has gone to work in the reinsurance industry, was recently profiled in the New York Times (www.nytimes.com/2010/12/02/nyregion/02entry.html) as an example of an innovative career path.

### 2.1.3 Results of Graduate Student Surveys

Cathy Sabol, head of the graduate student organization METOGRADS, received 14 student responses to the student questionnaire (full responses provided in **Appendix 8**). Here is a summary of the responses written by Ms. Sabol.

**Courses**

- The main concern about the courses was the standardization of AOSC620 (Physics and Chemistry of the Atmosphere I). There were many comments about how the course seems to focus on different material depending on the professor that is teaching it. There was mention of an overlap of material with 621 (Physics and Chemistry of the Atmosphere II) as well.
- Most students acknowledged that the courses were difficult, but found them to be the appropriate level.
- Many students commented that taking AOSC652 (Analysis Methods in Atmospheric and Oceanic Science) in the first year would have been helpful. The reasoning is that much time during the first summer is spent learning how to use the computer system and learning whatever programming language is to be used, instead of beginning research immediately.
- A few students mentioned that they would like to see more application in the courses rather than focusing on mathematical manipulation, particularly in AOSC610 (Dynamics of the Atmosphere and Ocean I).

**Qualifying and Specialty Exams**

- Many students commented that the qualifying exam was too detail-oriented and should focus more on broader topics. A couple of students thought that the qualifying exams tested basic understanding well enough.
- A few students felt that the written exam is being given too close to finals and that more time should be given to prepare.
- A few students stated that they find the written portion of the qualifying exam to be a duplication of the final exams for the courses. A couple of students suggested having a general exam with questions covering all topics and not splitting the exam into courses.
- Those that mentioned the specialty exam thought that it is adequate.

**Advising**

- Most of the students stated that they have had a good personal experience when it comes to advising. A couple of students mentioned that they were initially dissatisfied with the advising, but the situation has changed.
- Many students commented that the advising situation seems to be advisor dependent, with advisors varying in how involved they are.
- A few students mentioned that they appreciated that their advisors allowed them to focus on coursework in the first year, while a couple of other students mentioned that they wish they had more direction in their first year and wanted to begin research sooner.

**Jobs**

- Many students appreciate the amount of job announcements received in emails. Even if they are not currently searching for jobs, it gives them a better understanding of what is available.
- Many students feel that the meet-the-speaker sessions are a good addition to the Department seminar series and help give more information about the job market.
- A couple of students suggested that meeting with recent graduates or having some sort of panel session consisting of professionals in different fields would be a good way to get students more informed.

**Reduction of time to obtain Ph.D.**

- Many students believe that the time to acquire the degree is advisor and subspecialty dependent.
- A few students suggested that reducing the amount of side projects not directly relating to the thesis would help reduce the time.
- A couple of students suggested enforcing the student seminars and giving yearly updates on research would keep students on track.
- A couple of students stressed that the quality of research needs to be maintained when reducing the time working on a thesis.

**Attitude of the department towards research**

- Of the surveys received, the students unanimously said that the department has a positive attitude towards research. Many agreed that the department is a stimulating environment, while a couple of students do not believe this is the case, mainly due to the computing facilities.
- Many students are pleased with the seminar series and how much research they are exposed to. AOSC680 (Introduction to Earth System Science) was another source of exposure mentioned. A couple of students also appreciated faculty

seminars so students are aware of what research is being done within the Department.

- Many students appreciate the amount of connections that the faculty has and the collaborations available to them. A couple cited that as one of the main reasons for choosing to study here.
- A couple of students are concerned that research and teaching are not balanced enough. They feel that some professors are too focused on their research or have too much to do, which negatively impacts the students who take their courses.

**Computing facilities**

- Many students feel that the computing facilities are in need of an update. Some say that the facilities are sufficient, but a couple of these people say that they will become outdated quickly.
- Many students felt that the network interruptions were very disruptive, though some say that this has improved this semester, possibly because of the addition of Jose Caceres (student assistant to David Yanuk).

**Teaching Assistantships**

- Most of those that responded felt that it was a rewarding experience.
- Those that commented on the supervision of the TAs thought that it was adequate.

**Off-site supervision**

- Two students felt the communication could be better, while one student felt that there was good communication.

**Cost of living in College Park**

- The students agree that the cost of living is quite high in College Park and the surrounding areas, though none of the students commented that the cost of living was high enough to negatively impact academic activities.
- A few students believe that the stipend is sufficient, while the same number felt it should be higher. A few students also stated that they are tight on money and would like the stipend to be higher, but are aware that there are limited funds.
- A few students are concerned about the safety of the area and as a result live in more expensive communities that are farther away.

**Improving the quality of the Department and additional comments**

- While most of the comments for these two questions were stated elsewhere in the survey, the two items that were stressed the most were improving the computing facilities and restructuring the core courses.

## 2.2 Undergraduate Education

One of the recommendations of the 2003 External Review was to expand our contributions to undergraduate education. Currently AOSC participates in the UMD undergraduate program through the Physical Sciences degree program run by the Physics Department, through the Atmospheric Science track within Physics, and through several minor options. At the introductory level AOSC collaborates with Geology and Geography in one course: *AOSC123 Causes and Implications of Global Change* and offers another: *AOSC200 Weather and Climate* and an associated laboratory course (**Table 6**, lefthand column). In addition, as part of its commitments to these degree programs AOSC offers eight three-credit undergraduate courses at the 300-400 level.

**Table 6** (left) Current and (right) proposed modifications to AOSC undergraduate courses associated with the introduction of the AOSC undergraduate major[4]. The AOSC Major will result in the modification of several courses, replacement of one, co-teaching of one, and creation of two three-credit courses. Most changes are associated with the need to provide courses fulfilling Civil Service and AMS requirements.

| AOSC Course # | Title of Current Courses | Title New Courses (result of new UG major) |
|---|---|---|
| 123 | Global change | *Unchanged* |
| 200 | Weather and climate | *Unchanged* |
| 201 | Weather and climate lab (1credit) | *Unchanged* |
| 345 | Cycles in the earth system | *Unchanged* |
| 375 | Introduction to the blue ocean | *Unchanged* |
| 400 | The atmosphere | Physical Meteorology of the Atmosphere |
| 401 | Global environment | *Subsumed into new AOSC 433* |
| 424 | Remote sensing of the atmosphere and oceans | *Unchanged* |
| 431 | Atmos. physics and thermodynamics | Atmospheric Thermodynamics |
| 432 | Large scale atmos dynamics | Dynamics of the Atmosphere and Ocean I |
| 433 | | Climate Dynamics of the Atmosphere and Ocean II |
| 434 | Air pollution | *Unchanged* |
| 470 | | Synoptic Meteorology *(co-taught with AOSC600)* |
| 493 | | Senior Research Project I |
| 494 | | Department seminar (1credit) |
| 498 | | Senior Research Project II |
| 499 | Special problems in atmospheric science | *Unchanged* |

Enrollments in AOSC courses have risen dramatically in recent years from less than 400/yr in 2003 to in excess of 1,100/yr (**Fig. 5**). Much of this rise has been in the introductory courses, which satisfy various University requirements. In contrast, enrollments in a number of our 300-400 level courses still have room for expansion. Surprisingly considering its location, University of Maryland offers no introductory undergraduate course in oceanography. To fill this gap AOSC would like to complement the atmospherically focused AOSC200 with: AOSC2XX: *The Ocean Planet*. We are currently attempting to obtain the resources for development of this course.

[4] Current course descriptions are available at: www.umd.edu/catalog/index.cfm/show/content.chapter/c/50

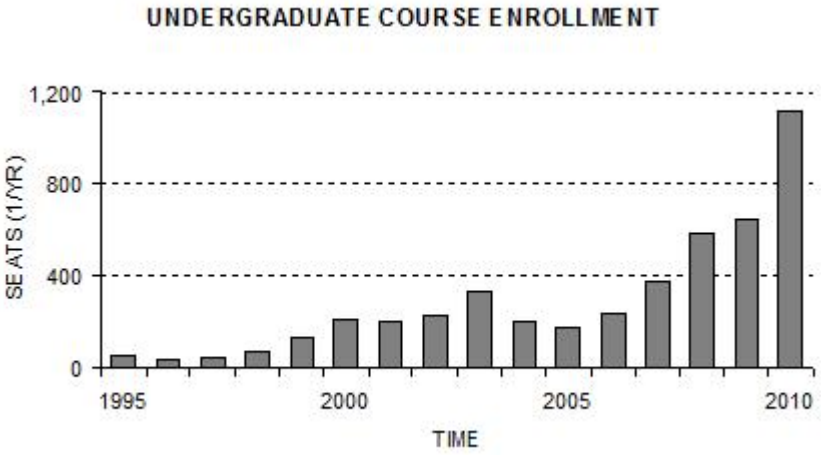



**Figure 5** Annual undergraduate enrollment in AOSC courses (normalized to a standard 3 credit course). Much of the growth in undergraduate enrollment since 2005 is the result of enrollment expansion in introductory courses, notably AOSC200.

As discussed above, the University has a voluntary course evaluation system. In **Table 7** we provide a brief summary of evaluation scores for the past six semesters since the University changed its rating system in 2007. These ratings are generally at a par with those in other departments in this college. An AOSC faculty member, Dan Kirk-Davidoff, won the Dean's teaching award for 2007.

**Table 7** Student evaluations of AOSC undergraduate courses beginning fall, 2007. Scores are out of a maximum of 4 points.

| | 2007 | | 2008 | | 2009 | 2010 |
|---|---|---|---|---|---|---|
| | fall | spr | fall | spr | fall | spr |
| I learned a lot from this course. | 2.91 | 2.85 | 2.67 | 2.58 | 2.87 | 2.96 |
| Overall, this instructor was an effective teacher. | 2.78 | 2.81 | 2.75 | 2.61 | 2.73 | 3.15 |

However, our major initiative at the undergraduate level is to offer a full undergraduate degree program in Atmospheric and Oceanic Science designed to exploit our unique location in the Washington DC area through involvement of students in internships and of government researchers in teaching (**Appendix 6**). As the only Department of Atmospheric and Oceanic Science in the State of Maryland, the objective of our proposed undergraduate program is to provide a degree path for Maryland students interested in this branch of environmental science. The program will provide intensive training in junior and senior years, building on basic coursework in mathematics, physics, and chemistry in freshman and sophomore years (and accommodating transfers from Community Colleges). Graduates of this degree program may easily satisfy the General Services Administration requirements for certification as 'meteorologist' and 'oceanographer' and can build on this major to acquire appropriate background to teach earth system science at the high school level. By providing this opportunity for Maryland students to pursue interests in meteorology, physical oceanography, or global climate without leaving the State, the proposed major addresses the UMD mission to remain "…the school of choice for the most talented students in Maryland and for outstanding out-of-state students".

The program requires two new undergraduate courses, AOSC493 and AOSC498 (**Table 6 righthand**). Of these AOSC493 will be taught by untenured faculty, and AOSC498 represents the senior 2nd semester research experience. Two issues are raised.

1) Our lack of Teaching Assistantship funding. We do not expect this to be a problem initially, but there currently is no mechanism for obtaining TA support from the University as course demand increases. Our expectation is that expansion of the Professional MS degree program will fund the required TAs.
2) The need to ensure that the AOSC undergraduate major contributes positively to the graduate and research missions of the Department.

→ *We are extremely interested in the External Review Committee's views on our plans for this new major and how to make it function effectively within a graduate/research oriented department.*

## 3. Research

### 3.1 Major Research Thrusts

The combined AOSC/ESSIC research enterprise broadly addresses the physics, dynamics, and chemistry of the atmosphere and ocean and their interactions which control climate variability and change (see: *Strategic Plan*, **Appendix 2**). Specific areas of Department concentration include: observational and modeling studies of atmospheric chemistry, aerosols and mesoscale meteorology; data assimilation and its application to a variety of problems in meteorology and oceanography; radiative balance of the earth system; seasonal to centennial climate including: diagnostics, modeling, physical and biogeochemical oceanography; air-sea and air-land interactions; carbon cycle and ecosystems. Here we provide some overview and describe some developments in research since the 2003 External review as well as indications of future research.

**Atmospheric Chemistry and Aerosols**

Atmospheric chemistry research within AOSC is focused on quantification of the effect of human activity on atmospheric ozone and aerosols. Interestingly, human pollution leads to higher levels of tropospheric ozone ("bad ozone" that is harmful to human health and agriculture) and, at the same time, pollution also leads to reduced levels of stratospheric ozone ("good ozone" because of protection from harmful solar ultra-violet radiation). Aerosols, particularly small size particles produced via combustion, pose a significant health risk, especially for children and the elderly. Aerosols also exert a profound influence on clouds, precipitation, and the radiative forcing of climate. We study the effects of atmospheric aerosols as they pertain to issues such as human health and climate, ranging from in situ observations conducted from ground and airborne platforms to analysis of global satellite data. The Department has added faculty members Dale Allen, Ross Salawitch, and Timothy Canty with expertise in remote sensing and theory (numerical modeling) to complement the traditional strength in experimentation and observation.

Research interest on atmospheric ozone spans scales ranging from local to global, from the surface to the stratosphere. Our local work on tropospheric ozone is conducted under support from the Maryland Department of the Environment, though the Regional Atmospheric Measurement Modeling and Prediction Program (RAMMPP). The goal is to provide policy-relevant science needed to improve air and water quality over the

eastern US. Research is conducted using UMD instrumentation that flies on a Cessna 402B aircraft. The aircraft data are essential for proper quantification of transport efficiency and pathways of pollutants into and out of the mid-Atlantic region. Our analysis of ground based and satellite observations has shown that air quality models overestimate the abundance of nitrogen oxides in urban areas and underestimate this quantity in rural areas. This has a profound impact for proper quantification of future routes for achieving particular air quality standards for surface ozone. We have also quantified, based on an analysis of surface ozone data collected over several decades, the impact of climate change on air quality. This work showed that the so-called climate penalty factor has been ameliorated, somewhat, by the large reduction of nitrogen oxide emission from power plants that began around year 2002. We routinely take part in tropospheric aircraft field campaigns that range from Middle America to East Asia; NASA will support UMD participation in DISCOVER-AQ in 2011. UMD is known for research on convection – a process that can transform local air pollution problems into global atmospheric chemistry and climate problems – and for quantifying the efficiency of nitrogen oxide production by lightning. ISI ranked UMD in the top 20 institutions, world-wide, for citations on Air Pollution.

Our global work in atmospheric ozone is conducted primarily via participation in NASA field campaigns and membership in the NASA Aura Science Team. We participated in NASA TC4 (Tropical Composition, Cloud and Climate Coupling) mission (summer 2007, San Jose, Costa Rica) and the NASA ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites) mission (spring and summer 2008, Fairbanks, Alaska and Cold Lake, Canada). Our analysis of the TC4 and ARCTAS data has led to the realization that satellite observations of bromine monoxide (BrO), an important catalyst for removal of ozone, have likely been misinterpreted for the past decade. A study using ground-based, aircraft, and satellite data shows many satellite BrO "hotspots" previously attributed to high latitude surface release of inorganic bromine (with resulting BrO resident in the troposphere) are likely, instead, due to tropical release of organic bromine (with resulting BrO resident in the lower stratosphere). Proper understanding of the effects of halogens on ozone requires that the tropospheric and stratospheric contributions to the satellite burden be properly quantified. We are helping NASA plan the next field campaign, the Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC$^4$RS), that will deploy in Thailand during summer 2012.

We also have a long-standing interest in quantifying the effects of anthropogenic halocarbons on the ozone layer. Recent highlights include co-authorship on a chapter in the WMO/UNEP 2010 Ozone Assessment Report, co-authorship on a chapter in the SPARC Chemistry-Climate Model Validation Activity (CCMVal) report, and leadership (as well as co-authorship of the report) for the SPARC report entitled SPARC reports on The Role of Halogen Chemistry in Polar Stratospheric Ozone.

AOSC and ESSIC have led two major US-China collaborative projects focused on aerosols since 2004: the East Asian Study of Tropospheric Aerosols, a Regional International Experiment (EAST-AIRE) and the East Asian Study of Tropospheric Aerosols and Impact on Regional Climate (EAST-AIRC). Accomplishments include: 1) establishment of three instrument-intensive stations measuring aerosol, cloud and radiation quantities in polluted regions of eastern China, 2) a network of 25 stations

measuring aerosol optical depth (AOD) and particle size, and 3) ground-based and airborne campaigns measuring the physical and chemical properties of aerosols and precursor gases. For the first time in history, American meteorological instruments flew on Chinese aircraft. In 2008, a major field experiment took place in China, including deployment of DOE Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF), as illustrated below. The experiment was carried out at four locations, representing distinct environmental/meteorological conditions throughout China. The projects provided unprecedented measurements that led to two special issues of *Journal of Geophysical Research*, totaling more than 60 papers, documenting the improved understanding of the effect of human activity on aerosols and climate. The experiments also showcase the potential for cooperation between the US and China for jointly addressing global climate change. Breakthroughs include: the first nation-wide *in situ* observations of aerosol radiative forcing; identification of mechanisms for the transport and transformation of air pollutants; improvement of NASA remote sensing of aerosol products.

**Oceanography and Air Sea Interactions**

Ocean research continues to be developing very rapidly, driven by a combination of expanding data sets, improvements to computer power. The areas of most rapid development are those which address the ocean's role in the earth's climate and its capacity for change. The Washington DC area is a wonderful location to carry out such research because of the presence of data providers such as the National Oceanographic Data Center for *in situ* observations and NASA and NOAA for satellite observations, large computer modeling activities at NASA and NOAA, extensive seasonal forecasting activities in both organizations, and comprehensive research in meteorology and land surface processes for which the ocean plays a role. The Department's academic commitment to oceanography has expanded since the 2003 review through the hire of Kayo Ide as well as the expansion of ESSIC and CICS. This area shares large overlaps with Climate Analysis and Modeling and Data Assimilation. Important themes for research in this area include:

- *Tropical climate variability*. AOSC and ESSIC faculty have extensive, long-term observational and modeling research activities directed towards understanding the nature and causes of climate variability in the tropics and their relationship to air-sea interactions. Examples of current research include: examination of the role of salinity changes on ENSO forecasting; the nature of decadal variability in the tropical Indian sector; and connections between seasonal and decadal variability in the Atlantic.
- *The Chesapeake Bay Forecasting System* (CBFS) at ESSIC. The CBFS is an applied project in earth system science. It combines component models into a regional climate system for use in the analysis of current conditions and prediction of future changes. Individual component models include estuarine circulation and biogeochemical/ecosystem models, models of terrestrial processes, and surface meteorology. The types of applications envisioned include: predicting the consequences of severe flooding, changes in crop distributions, anthropogenic climate change, or simply whether warm weather will lead to an abundance of sea nettles.

- *Remote sensing of the Oceans*. AOSC and ESSIC scientists continue to conduct research using a number of satellite remote sensing tools including ocean color, SST, vector winds, and sea level, primarily focusing on using the satellite data sets to examine ocean processes (level 3 data). One exciting area of research is in understanding the potential applications of the passive microwave Aquarius sea surface salinity sensor (due to be launched in 2012). A number of AOSC/ESSIC scientists are exploring applications of remote sensing of ocean sea level and SST. Still others are working with ocean color to address issues such as longterm trends in ocean biological production. One funded effort is examining the archive of active remote sensing of surface winds in an attempt to construct a consistent multidecadal record (because of changes in satellite technology wind estimates from different satellites are not currently comparable!).

The future of research in this area within AOSC/ESSIC is very bright. Tremendous opportunities are available for collaborative research both within AOSC/ESSIC and with the neighboring government laboratories, while the number of interesting scientific problems continues to grow. One concern is that oceanography research at UMD does not attract as much attention as it should partly because it is distributed across several units (discussed in Section 3.1.2).

**Data Assimilation**

Data assimilation is the process of using observations as constraints to improve the accuracy of numerical simulation. Although first developed for application to numerical weather prediction, data assimilation can be applied to other components of the earth system such as physical and chemical oceanography and hydrology. The exponential growth in the number and types of environmental observations as well in the increasing sophistication of numerical simulations has given increasing importance to the role of data assimilation for environmental research. Within the United States, although the Weather and Chaos interdisciplinary group created at UMCP in 2000 had made a mark, there were essentially no academic centers of excellence required to produce the young researchers who will develop data assimilation technology. In response to this need, taking advantage of our location in the Washington DC area, and with the support of our colleagues at NASA and NOAA, the department has made a substantial commitment of new resources in this area since 2003. This has resulted in one new academic faculty hire (Kayo Ide), while a second academic faculty search is underway now. This growing commitment to data assimilation research has accompanied a number of new research efforts.

- Local Ensemble Transform Kalman Filter (LETKF), a development of scientists within AOSC in collaboration with IPST (www.weatherchaos.umd.edu), the LETKF is both a sophisticated sequential ensemble assimilation algorithm and a piece of FORTRAN code allowing rapid implementation of this algorithm in different physical systems. Since its publication in 2007 the LETKF has found many applications both within the United States and abroad and has become a key piece of technology upon which other AOSC research activities are developing.

  Examples of leading edge applications of the LETKF are the new advanced ocean data assimilation that has been shown to give more accurate results than the standard 3D-Var; a system for simultaneous assimilation of atmospheric variables

and AIRS CO2 that holds the promise of improving estimates of surface fluxes; a new advanced data assimilation for the atmosphere of Mars, and a regional LETKF/WRF model for hurricane prediction.

- AOSC and ESSIC are World centers of research in the reanalysis of climate systems. Indeed, the five most highly cited papers from AOSC in the past eight years for which department faculty are at least 3rd author are all associated with climate reanalyses in one form or other. The associated research efforts are expanding to cover the full 20th century and to include high latitude and biogeochemical processes.
- Data assimilation for carbon inventory. On the atmospheric side this work builds on our understanding of the circulation of the atmosphere to track the sources and sinks of atmospheric $CO_2$. On the ocean side two distinct research efforts have developed to track the physical and biological mechanisms by which $CO_2$ is sequestered in the ocean by adding data assimilation to coupled physical-biogeochemical models. This work will leverage off of a faculty member's involvement in the OCO-2 and GOSAT programs, and another faculty member's development of a model of the global carbon cycle.
- Lagrangian Data Assimilation (LaDA). By assimilation positions along the trajectories of trackable tracers, the LaDA effectively extracts underlying flow dynamics with a small number of observations. So far this method has mainly been applied to ocean monitoring and observing system design. It is now considered for the improvement of hurricane forecasts and deployment strategy of a small number of atmospheric balloons by the NOAA WISODM group.

**Climate analysis and modeling research**

Climate analysis and modeling research seeks to advance understanding of the functioning of the climate system from statistical and dynamical analysis of observational data sets, and from numerical modeling of ocean-atmosphere-land-cryosphere interactions. Climate analysis has recently focused on differentiating natural variability from anthropogenic climate change, spurring detection of the global warming fingerprints in surface temperature and hydroclimate as well as diagnosis of the structure and mechanisms of recurrent seasonal and interannual variability in present-day and future climates. Notable examples of the latter include the intriguing seasonal-cycles in the eastern tropical Pacific and Atlantic basins with coldest SSTs in the Northern summer/fall, and the well-known large-scale patterns of interannual variability: El Niño Southern Oscillation, North Atlantic Oscillation, North Pacific Oscillation, and Pacific Decadal variability. Another mode of natural climate variability that is of interest in the context of detection of anthropogenic climate change is the Atlantic Multidecadal Oscillation (AMO), an oscillation in North Atlantic SSTs with a 5-8 decade period and exerts considerable influence on North American hydroclimate. AOSC and ESSIC efforts in climate analysis and modeling are focused around the following themes:

- *Hydroclimate variability, droughts, desertification:* Analysis of atmospheric and terrestrial water-balance has led to reassessment of the role of local land-atmosphere interaction (e.g., evapotranspiration) in generation of warm-season hydroclimate variability; models had indicated a much larger role. The greater role for moisture transports, indicated from observational analysis, provides a

basis for investigation of the contributions of the Pacific and Atlantic basins in generating multi-year droughts over North America and desertification over Sahel. The impact of expanded deserts on the larger-scale circulation is also being analyzed; for example, influence of the expanded Thar desert on South Asian summer monsoon. The influence of absorbing aerosols on monsoon hydroclimate is also actively being investigated in AOSC.

- *Climate teleconnections:* Teleconnections describes the climate links between geographically separated regions; often, oppositely-signed variations in sea-level pressure and circulation. AOSC efforts have advanced dynamical understanding of the prominent wintertime teleconnections (e.g., the North Atlantic and North Pacific Oscillations) and their links to regional climate, including Arctic sea ice. The surface (and subsurface) structure of the AMO and its contribution in generating regional trends in surface air temperature and precipitation is the focus of current efforts, which should help in improved characterization of the anthropogenic signal.
- *Arctic sea ice variability and decline:* A key goal of AOSC efforts is to obtain a clarified footprint of the anthropogenic influence on Arctic sea ice; the influence cannot be the full signal as some sectors show decline while others build-up, indicating impact of the decadal climate fluctuations. The separation of natural variability and the anthropogenic signal will help answer pressing questions: For instance, is the sea ice decline from global warming being offset or aided by natural variability? Might the decline be steeper in the out-years in the flip-phase of decadal variability? Are Arctic summer sea ice variations potentially predictable on decadal-multidecadal timescales?
- *Climate model assessment*: Assessment of the 20$^{th}$ century climate simulations produced by the leading US modeling centers (NCAR, GFDL, and GISS) is a recurring theme of AOSC efforts. The simulations are scrutinized to assess the realism of the recurrent circulation and hydroclimate variability patterns over North America, surface winds over tropical oceans, winter teleconnections, South Asian summer monsoon, and ocean-atmosphere interaction over the Pacific and Atlantic basins, among others.
- *Population and Climate Change:* A pioneering new project is underway in collaboration with the School of Public Policy and the JGCRI, with the goal of fully coupling Human Models to climate Earth System Models. Such a model will represent the important feedbacks that take place in the real human-environmental interactions and allow the exploration of different scenarios dependent on policy changes and adaptation measures. It will allow the exploration of different scenarios dependent on the mechanisms of mesoscale weather and contribute to further improvements of the mesoscale NWP capabilities.
- *Carbon and Climate* AOSC faculty members have developed an earth system model of the global carbon cycle and have taken a leadership role in the scientific dialogue surrounding addressing climate change by the sequestration of rapidly growing trees, and are participating in the validation and analysis of data collected by GOSAT instrument. Several AOSC members co-authored the NASA White Paper that provided the scientific justification for the re-build and re-launch of OCO, following the Feb 2009 launch accident. This White Paper, which was

reviewed by the National Academy of Sciences, appeared to be instrument in the decision to proceed with OCO-2.

**Cloud and Radiation Budget Studies**

The radiation budget of the earth-atmosphere system plays a fundamental role in the thermal condition of the atmosphere and the oceans, shaping the main characteristics of the earth's climate. The irradiance at the earth's surface is especially important to understand climate processes, as the earth's surface transforms about 50% of the solar radiation absorbed by the Earth System. Our present understanding of the radiation distribution both in the horizontal and in the vertical is not sufficient to address many outstanding issues in present climate. The need for accurate information on radiative fluxes for assessment of the sensitivity of atmospheric radiation and clouds to climate change, and to better model the hydrological cycle were recognized by the scientific community.

AOSC has been heavily involved in research on surface radiative budgets focusing on development of algorithms for deriving radiation budgets using methods of remote sensing. These algorithms are intended for applications at global scale with special attention in challenging areas such as high elevations, high latitudes, and high aerosol impacts.

- *Surface Radiation Budget Model* A long-standing association with NASA Langley is ongoing on the implementation of the Global Energy and Water Cycle Experiment Surface Radiation Budget (SRB) model at LaRC as developed at UMD. Cooperation with NOAA/NESDIS was instrumental in the operational implementation of the SRB model in support of the GEWEX Continental Scale International Project and the GEWEX Americas Prediction Project (GAPP), and contributed to the development of the new initiative on Land Data Assimilation (LDAS) activity at GSFC and NCEP.
- *International Collaborations* AOSC maintains many national and international collaborations to monitor the earth’s radiation budget including:
  > Indian Institute of Tropical Meteorology in the study of aerosols over the Indian continent.
  > University of Ilorin, Nigeria and the Aerosol Robotics Network at GSFC for long-term aerosol observations in sub-Sahel Africa.
  > Ben Gurion University on better characterization of the drought index.
  > Dr. E. Dutton from NOAA/ARL is in the framework of the Science Panel of the WCRP Baseline Surface Radiation Network since 1996.
  > Collaboration on the total energy budget of the tropical Atlantic Ocean with RSMAS/University of Miami, Texas A&M University, and the Institut Francais de Recherche Pour l'Exploitation de la Mer (IFREMER). The UMD role is to provide expertise on the radiative flux components.
  > CLIVAR High Latitude Working Group on improving the understanding of the energy budget at high latitudes
  > MEASURES program to develop consistent Earth System Data Records for the global terrestrial water cycle.
  > Institute of Tibetan Plateau Research (Chinese Academy of Sciences, Beijing) on issues of high elevations. Collaboration is ongoing with the Working Group

on Radiative Fluxes for GOES-R, with CeRES, Chiba, Japan on radiative flux research and the SKYNET aerosol network.

**Mesoscale Meteorology and Extreme Weather**

Mesoscale meteorology is the study of weather systems that are often too small to be resolved by conventional upper-air observations but much greater than typical cumulus clouds. Mesoscale weather systems include squall lines, mesoscale convective complexes, tropical cyclones, frontal rainbands, mountain waves, and other severe storms. Because of the lack of high-resolution observations, all numerical weather prediction models have great difficulties in predicting their initiation, subsequent evolution and dissipation as well as the associated precipitation. Thus, our mesoscale research has been directed to simulating the inner-core structures and evolution of these weather systems using the Weather Research and Forecast (WRF) mesoscale model at progressively higher resolutions. The model outputs are then diagnosed to examine the mechanisms by which they develop; test different theories, hypotheses and model physical representations; and finally interpret, to the extent possible, the observed behaviors of these weather systems and their pertinent small-scale circulations.

Improving the understanding and prediction of hurricanes and tropical cyclogenesis has recently attracted considerable attention in mesoscale meteorological research, since the hurricane is one of the most dangerous natural hazards to the human society and environment, e.g., Hurricane Katrina (2005). Although there has been continuing improvements in forecasting hurricane track and landfall location, virtually little progress has been seen in intensity forecast during the past two decades. Our early modeling work was the first to demonstrate that many inner-core structures of hurricanes, such as the eye, eyewall, spiral rainbands, polygonal eyewalls, and the eyewall replacement cycle, can be reproduced using high-resolution cloud-resolving models. We have developed diagnostic tools, such as the potential vorticity inversion algorithm, to examine the interaction of various flow elements in determining the intensity and structures of hurricanes. Based on the numerical model analyses, we developed a new linear theory of the mixed vortex-Rossby-gravity waves in tropical storms, and a nonlinear analytical model for hurricane intensity, given the time dependence of vertical motion. ISI ranked UMD in the top 17 institutions world-wide for citations on tropical storm (see esi-topics.com/tropical/inst/c1a.html).

In addition, we have started data assimilation and predictability studies using the WRF-LETKF system (see: Data Assimilation). Our ongoing work focuses on understanding and improving the forecast of tropical cyclone lifecycle evolution and intensity in collaboration with field-campaign projects that deployed intensive observations for tropical cyclones. Better use of both atmospheric and oceanic observations through the LETKF would help improve our knowledge on the mechanisms of mesoscale weather and contribute to further improvements of the mesoscale NWP capabilities.

### 3.1.1 ESSIC and CICS

ESSIC is a joint center between AOSC, Geology, and Geography together with the Earth Sciences Directorate at NASA GSFC. The links to AOSC are strong in that all AOSC academic faculty (with one exception) also have partial appointments in ESSIC. ESSIC also administers the Cooperative Institute for Climate and Satellites (CICS,

essic.umd.edu/cics) which is a joint center with NOAA NCEP and NESDIS. The goal of ESSIC is to enhance understanding of how the atmosphere-ocean-land- biosphere components of the Earth interact as a coupled system and the influence of human activities on this system. The manner in which this research is accomplished is via analyses of in situ and remotely sensed observations together with component and coupled ocean-atmosphere-land models. Together this provides a foundation for understanding and forecasting changes in the global environment and regional implications. ESSIC research is separated into four Theme areas:

Theme 1 – Climate Variability and Change. Theme 1 research is oriented toward understanding, monitoring, and predicting the physical processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time scales.

Theme 2 - Atmospheric Composition and Processes. Theme 2 research is oriented toward understanding, monitoring, and predicting the interrelationships of changes in atmospheric composition, climate, ozone-layer depletion, and surface-level chemical and radiative exposure.

Theme 3 - Global Carbon Cycle (Terrestrial and Marine Ecosystems; Land Use/Cover Change). Theme 3 research is oriented toward understanding, monitoring, and predicting the global carbon cycle, including the role and variability of terrestrial and marine ecosystems, land use, and land cover.

Theme 4 - Global Water Cycle. Theme 4 research is oriented toward understanding, monitoring and predicting the global water cycle, including precipitation, evaporation, storage and transport, on time scales from weeks to centuries.

CICS is formed through a national consortium of academic, non-profit and community organizations with leadership UMD and the North Carolina State University. CICS activities are carried out at two centers. The first joins the UMD with the Center for Satellite Applications and Research in NOAA NESDIS and with the Climate Prediction Center in NOAA NCEP. CICS conducts its research under three themes.

Theme 1 - Climate and Satellite Research and Applications - Development of new observing systems, or new climate observables from current systems;

Theme 2 - Climate and Satellite Observations and Monitoring - Development and improvement of climate observables from current systems

Theme 3 - Climate Research and Modeling - Research component that brings together climate observables, modeling and validation in a comprehensive integrated whole.

### 3.1.2 Collaborations with Other USM and External Organizations

In addition to its close relationship with ESSIC/CICS AOSC has growing collaborations with a number of units within the University of Maryland System (USM) and with nearby government laboratories.

**USM Collaborations:** collaborations have been fostered by the fact that all of the tenure faculty hired since 2003 have had joint appointments (Nigam: AOSC/ESSIC, Salawitch: AOSC/CHEM/ESSIC, Ide: AOSC/IPST/ESSIC/CSCAMM, Liang: AOSC/ESSIC). Many faculty also have affiliate appointments and are advising students in other units including Chemical Physics, Applied Mathematics and Scientific Computation,

Chemistry and Biochemistry, Engineering, and the program in Marine Environmental Estuarine Studies. AOSC treats all graduate students equally (e.g. space, computer facilities) regardless of their academic home. A collaboration is developing with the School of Public Policy on the topic of interactions between population and climate.

In addition to the ocean-related research carried out in AOSC and ESSIC (as well as the cross-campus Marine Environmental Estuarine Studies program [MEES], bioscience, Geology, and Chemistry) there is extensive ocean-related expertise, particularly in near-shore environments, in the two marine laboratories of University of Maryland Center for Environmental Studies (UMCES www.umces.edu): Horn Point Marine Laboratory, and Chesapeake Biological Laboratory. The UMCES laboratories currently participate in graduate education through MEES and run popular teacher training and student internship programs in the summer. An effort was begun in 2006 to coordinate USM ocean research activities, one result of which was the creation of a website: ocean.umd.edu, and initiation of discussions regarding creation of an umbrella University of Maryland Institute of Oceanography. However, these ideas remain undeveloped. *We would deeply appreciate any advice the External Review Committee may have regarding improvements in coordinating ocean-related research and teaching within the University of Maryland System.*

**Nearby Government Laboratory Collaborations**
As highlighted by the 2003 External Review, AOSC recognizes that its most irreplaceable asset is its location in the Washington DC area, which provides Department faculty and students with easy access to an enormous range of resources. Among government laboratories, AOSC maintains the most numerous and comprehensive interconnections with NASA GSFC Earth Sciences Division and the NOAA NCEP and NESDIS laboratories. These collaborations are maintained partly through ESSIC and CICS, but also through many shared student advising and research activities. Other local laboratories that AOSC has strong links to include: NIST, EPA and NOAA Air Resources Laboratory; NOAA National Oceanographic Data Center and Laboratory for Satellite Altimetry; DOE Joint Global Change Research Institute; and JHU Applied Physics Laboratory.

Recently AOSC has received inquiries from local companies involved in satellite research, notably Lockheed Martin and Ball Aerospace. In addition to providing employment opportunities for graduating students, development of such connections offers the possibility of diversifying our funding base and offering opportunities to expand connections to UMD engineering.

**4. Faculty Profiles**
In addition to the core faculty listed below, AOSC has an active group of Adjunct and Affiliate faculty (Christopher Brown, Rita Colwell, Bruce Doddridge (NASA), Michael Evans, Wayne Higgins, Michael King, Vernon Kousky, William K. M. Lau, Kenneth Pickering, Eric A Smith, Anne Thompson, and Louis Uccellini). Volunteer Norm Canfield runs the AOSC library.

**Dale Allen**
Assistant Research Scientist

www.researcherid.com/rid/F-7168-2010
Dale's research is focused on the impact of atmospheric transport and trace gas and aerosol emissions on tropospheric photochemistry, air quality, and climate. As part of his research he has developed specialized algorithms for the solution of constituent continuity equations and for the specification of lightning-NO emissions within atmospheric chemistry and transport models (CTMs). He has also investigated the impact of natural and anthropogenic emissions on global tropospheric photochemistry and air quality with a focus on the eastern United States and eastern Asia. He has served as the principal investigator on several NSF and NASA research projects and is currently a member of the Global Modeling Initiative Science Team. He has also provided modeling and technical expertise to the Maryland Department of the Environment during their preparation of State Implementation Plans for ozone and particulate matter. He is currently the primary research advisor for four University of Maryland graduate students. Before coming to Maryland in 1995, Dr. Allen worked as a research assistant in the Atmospheric Chemistry and Dynamics Branch at NASA-GSFC from 1987-1995. While in that position, he played a major role in the development of NASA's stratospheric chemistry and transport model.

**Phil Arkin**
Senior Research Scientist
www.researcherid.com/rid/F-5808-2010
Phil Arkin is the Director of the Cooperative Institute for Climate Studies (CICS). He is also Deputy Director of ESSIC & a Senior Research Scientist specializing in observation and analysis of precipitation, including how precipitation responds to and affects various aspects of the Earth System. Previously, Phil worked as a research scientist and manager at NOAA for more then 20 years. He has a doctorate in meteorology from the University of Maryland. (www.essic.umd.edu/~parkin/parkin.html)

**Hugo Berbery**
Research Professor
www.researcherid.com/rid/F-4560-2010
Monsoon systems have a profound effect on agriculture and water resources, and as such they affect more than half of the world population. Although the Asian Monsoon is the most prominent system, the climates of North and South America exhibit tropical/subtropical features that are identified as monsoon regimes. My research interest focuses on understanding the mesoscale nature of the American monsoons circulations, including the role of low-level jets that supply moisture for precipitation to develop. I am also interested in advancing the understanding of how the monsoon precipitation may modulate the hydrology of large basins in North America and in particular the La Plata basin in South America.

The biophysical properties of the land cover/vegetation (e.g., surface albedo, surface roughness, leaf area index, stomatal resistance, and others) affect the land surface-atmosphere exchange of momentum, heat, moisture, and other gaseous/aerosol materials. The land surface states may influence the atmosphere through land-atmosphere feedbacks in the same manner that ocean conditions modulate the atmospheric states in seasonal and longer time scales. I have focused my recent research in understanding how soil moisture anomalies may affect the onset of the monsoon in South America. In a more general

sense I have been looking at how land cover changes may affect the climate and hydrology of large basins, and in collaboration with remote sensing experts we are looking into alternative ways of representing the surface conditions in regional models based on ecosystem functional types.

**Tony Busalacchi**
Professor, ESSIC Director
Antonio J. Busalacchi received his Ph.D. degree in oceanography from Florida State University in 1982. He has studied tropical ocean circulation and its role in the coupled climate system. His research in these areas has supported a range of international and national research programs dealing with global change and climate, particularly as affected by the oceans. In 1999 he was appointed Co-Chairman of the Scientific Steering Group for the World Climate Research Programme (WCRP) on Climate Variability and Predictability (CLIVAR). Previously, he served as Chairman of both the Climate Research Committee and the Committee on Earth Science and Application: Ensuring the Climate Measurements from NPOESS and GOES-R for the National Academy of Science/National Research Council (NAS/NRC). In 2008 he was elected as Chairman of the Joint Scientific Committee for the WCRP. Presently, he serves as Chair, NAS/NRC Board on Atmospheric Sciences and Climate, Co-Chair NAS/NRC Committee on National Security Implications of Climate Change for US Naval Forces, Member, NAS/NRC America's Climate Choices: Panel on Advancing the Science of Climate Change, Member, NAS/NRC Committee on Earth Studies, Member, IOM/NRC Committee on the Effect of Climate Change on Indoor Air Quality and Public Health, and Chair, NOAA's Climate Working Group.

In 1982 Busalacchi began his professional career at the NASA GSFC. In 1991, he was appointed as Chief of the GSFC Laboratory for Hydrospheric Processes, and was responsible for research in the oceanic, cryospheric, and hydrologic sciences. In year 2000, he was selected as the founding director of the Earth System Science Interdisciplinary Center (ESSIC) at the University of Maryland and appointed to the faculty as Professor in the Department of Meteorology. Professor Busalacchi has received numerous awards and honors. Among these, in 1991, he was the recipient of the prestigious Arthur S. Flemming Award, as one of five outstanding young scientists in the entire Federal Government. In 1995 he was selected as Alumnus of the Year at Florida State University, in 1997 he was the H. Burr Steinbach Visiting Scholar at Woods Hole Oceanographic Institution, in 1999 he was awarded the GSFC Excellence in Outreach Award and that same year chosen by President Clinton to receive the Presidential Rank Meritorious Executive Award. He is a Fellow of the American Meteorological Society (AMS), the American Geophysical Union (AGU), and in 2006 was selected by the AMS to be the Walter Orr Roberts Interdisciplinary Science Lecturer.
(http://essic.umd.edu/~tonyb/tonyb.html)

**Timothy Canty**
Assistant Research Scientist
www.researcherid.com/rid/F-2631-2010
One of our major research efforts is the use of photochemical models to reconcile atmospheric observations and theory with the aim of developing a better understanding of the chemical and physical processes the control atmospheric ozone. As part of the

Salawitch research team, I have worked extensively with photochemical models to analyze measurements from satellite (MLS, POAM, Aura MLS, SAGE III), balloon-based (FIRS-2, BOH, SLS), and aircraft (ER-2, DC-8) instruments. These models have been used to validate observations of Aura MLS OH and $HO_2$ (Canty *et al.*, 2006, Pickett *et al*., 2006, 2007) using measured $HO_x$ precursors ($H_2O$, $O_3$, $CH_4$, $N_2O$, and CO) from the satellite and balloon platforms. Aside from validating MLS observations, this work has resolved a long-standing disagreement between measured and modeled OH measurements, the "$HO_x$ dilemma", while highlighting the continued discrepancy between observed $O_3$ and model simulations, the "Ozone deficit problem".

We are part of theory teams that participated in the NASA $TC^4$ (2007) and ARCTAS (2008) field campaigns. Part of our involvement was to provide a basis for estimating global fields of nitrogen, hydrogen, and bromine radicals, which lead to the catalytic destruction of ozone. Our analysis of the ground-based, aircraft, and satellite data from these field missions show that many areas of elevated total column BrO, previously attributed to high latitude surface release of inorganic bromine (with resulting BrO resident in the troposphere) are likely due to tropical release of organic bromine (with resulting BrO resident in the lower stratosphere). Proper understanding of the effects of halogens on ozone requires that the tropospheric and stratospheric contributions to the satellite burden be properly quantified. (www.atmos.umd.edu/~tcanty)

**James Carton**
Professor, AOSC Chair
www.researcherid.com/rid/C-4807-2009
James Carton received his BSE degree in electrical engineering from Princeton University in 1976, an MS in oceanography from University of Washington in 1979, and his Ph.D. in geophysical Fluid Dynamics from Princeton University in 1983. From 1983 to 1985 he was a postdoctoral fellow with Alan Robinson at Harvard University. In 1985 he joined University of Maryland as an Assistant Professor. Except for sabbatical stays at University of Wisconsin and Geophysical Fluid Dynamics Laboratory he has remained at University of Maryland, becoming a full professor in 1997 and Chair of the Department of Atmospheric and Oceanic Science in 2007.

Jim's scientific interests are directed towards understanding the ocean's role in regulating and influencing climate variability and change on seasonal to multi-decadal timescales. He has been at the forefront of research on tropical Atlantic Ocean circulation and its interactions with the overlying atmosphere. He has also played a central role in applying the technique of data assimilation to the problem of reconstructing historical changes in the climate of the global ocean (ocean reanalysis). One of the results of this work is his SODA reanalysis, which has become a standard tool of ocean climate research studies.

Among Jim's current research projects is an effort to understand the influence of water from the Atlantic on the heat budget of the Arctic Ocean and how changes in the Atlantic may influence changes in the Arctic. Jim is also interested in trying to determine the nature of long multi-decadal changes in the properties of the global ocean during the 20$^{th}$ century and their potential connection to climate. (www.atmos.umd.edu/~carton).

**Gennady Chepurin**

Assistant Research Scientist
www.researcherid.com/rid/
I received my basic training at the Moscow Physical-Technical Institute (Russia) in 1979 in ocean acoustics. During 1974-79 as a part of my training I conducted studies of the deep ocean sound channel at the Acoustic Institute of Academy of Science of USSR in Moscow as an Engineer Researcher. During 1979-94 I was working in the Marine Hydrophysical Institute (MHI) in Sevastopol. I received my Ph.D. in Oceanography in 1986 from MHI for an investigation of the synoptic variability of the open ocean. Between 1985-90 I was actively investigating tropical Atlantic Ocean circulation and climate as part of the Soviet global climate program "Razrezi" (known in the western literature as SECTIONS). My work involved understanding the propagation of Rossby Waves and their contribution to seasonal changes in the tropical Atlantic ocean. Also I was involved in the preparation and implementation of the large-scale shipboard cruises on the r/v "Academic Vernadsky" and "Mikhail Lomonosov". From 1991-95 I switched to begin looking at satellite sea level observations of the tropical Atlantic and in the Black Sea. In 1994 I joined AOSC where I have been ever since. I am investigating the global ocean climate changes and exploring ocean data assimilation in the University of Maryland. Recently my scientific interests have expanded to include ocean biogeochemistry. I'm trying to apply improved ocean state estimations to the assessment of carbon flux between ocean and atmosphere. (www.atmos.umd.edu/~chepurin)

**Russell Dickerson**
Professor
www.researcherid.com/rid/F-2857-2010
Russell R. Dickerson received his AB in 1975 from the University of Chicago and his Ph.D. in 1980 from The University of Michigan, where he studied the interaction of radiation and trace gases in the atmosphere. After graduation, he worked with Paul J. Crutzen (Nobel Laureate, 1995) in the Air Chemistry Division at NCAR and in the Abteilung Luftchemie at the Max Planck Institute in Mainz, Germany. Professor Dickerson began working in the Department of Meteorology as an Assistant Professor in 1983 as the sole atmospheric chemist. He built the program in atmospheric chemistry and air pollution to include six faculty, several post docs and more than a dozen graduate students. Research has expanded to include the interactions of weather phenomena such as thunderstorms and atmospheric chemistry, ocean-atmosphere interactions, remote sensing, the links between particulate and gaseous chemistry and global biogeochemical cycles.

His research group, composed of meteorologists, engineers, and chemists, develops analytical instruments (for species such as $NO_x$, CO, $NH_3$, aerosols, and for photolysis rate measurements) employs these instruments in the laboratory, field, and on ships and aircraft, and interprets the results in terms of photochemistry, heterogeneous processes, and atmospheric physics with the aid of numerical chemical transport and cloud models. More recently, remote sensing from satellites has been added to better extrapolate from *in situ* observations to large-scale processes and climate impacts. Among the more exciting recent discoveries are smoke pall from South Asia, rapid ozone destruction in the marine boundary layer, the impact of aerosol radiative forcing on air quality, and the dry convection as a major mechanism in inter-hemispheric transport of air pollution form China.

He has helped define, plan, and execute the Atmosphere Ocean Chemistry Experiment (AEROCE), and the Indian Ocean Experiment (INDOEX), and served as the Chief Scientist on the R/V Ronald Brown. He served on the steering committees of Center for Clouds Chemistry and Climate (C4), INDOEX, NARSTO, and BASE-ASIA. Professor Dickerson was a member of the National Academy of Sciences NRC Committee on Animal Feeding Operations and has helped write a NRC Report on the impact of agriculture on air pollution in the US. He has been a member of EPA's Scientific Advisory Committees for CO, $O_3$, NOx, SOx, and PM. He serves on the Maryland Climate Change Commission. (www.atmos.umd.edu/~russ)

**Semyon Grodsky**
Research Scientist
www.researcherid.com/rid/F-4929-2010
Semyon Grodsky has received an MA degree in physics from Moscow Institute of Physics and Technology in 1981 and a PhD in 1986 in oceanography from the Marine Hydrophysical Institute, Ukraine. He has worked on different aspects of wave dynamics, air-sea interaction, and remote sensing. He participated in five scientific cruises as a team leader and chief of expedition. In 1999 he joined AOSC. At UMD he has been studying ocean currents and winds in tropics. Since joining AOSC he has published 19 papers in peer reviewed journals. (www.atmos.umd.edu/~senya)

**Bob Hudson**
Professor
Professor Hudson joined AOSC in 1990, serving as the Chair until 1998. Prior to that, he held research positions with industry and government agencies. He teaches the following courses on a rotation basis: AOSC 621 Physical Meteorology II - Atmospheric Radiation and AOSC 200/201 Weather and Climate. He was Project Manager, Environmental Effects Project Office, NASA/Johnson Space Center (1974-1996); Head, Stratospheric Physics Branch, NASA GSFC (1976-1982); Manager, Advanced Planning and Technology Office, Earth Sciences and Applications Division, NASA/HQ (1982-1985); Head, Atmospheric Chemistry and Dynamics Branch, NASA GSFC (1985-1990). He was the President of the International Ozone Commission from 1996 to 2004. (www.atmos.umd.edu/~hudson)

**Kayo Ide**
Assistant Professor
www.researcherid.com/rid/F-8443-2010
Kayo Ide takes cross-disciplinary approach to advance understanding and improve forecast skills of geophysical systems. She focuses on development of innovative data assimilation systems with emphases on optimal use of observations. By applying mathematical and engineering techniques, she has developed the Lagrangian data assimilation method that is effective in revealing underlying dynamics with a small number of observations. So far this method has mainly been applied to ocean monitoring and observing system design. It is now being considered for the improvement of hurricane forecasts and deployment strategy of a small number of atmospheric balloons. She also works on the real-time monitoring and forecasting of the US West Coast Oceans.

Kayo Ide is also active in synergetic activities to advance data assimilation as cross-disciplinary science among geophysical, mathematical, and engineering communities. She organizes symposia at international and national levels and has acted as editor of Monthly Weather Review and Physica D. (http://www.atmos.umd.edu/~ide)

**Eugenia Kalnay**
Professor
www.researcherid.com/rid/F-4393-2010
Eugenia Kalnay received her License in Meteorology from University of Buenos Aires, 1965, Ph. D., 1971, MIT (under Jule G. Charney). In the 1980s she headed the GSFC Global and Simulation Branch (now GMAO). From 1987 to 1997, Eugenia Kalnay was the Director of the Environmental Modeling Center (EMC) of the National Centers for Environmental Prediction (NCEP), National Weather Service (NWS). During those ten years there were major improvements in the NWS models' forecast skill. Many successful projects such as the 50-year NCEP/NCAR Reanalysis (the 1996 is the most cited paper in all geosciences), Eta model and data assimilation changes associated with GCIP, seasonal and interannual dynamical predictions, ensemble forecasting, 3-D and 4-D variational data assimilation, advanced quality control, coastal ocean forecasting, were developed. EMC became a pioneer in both the fundamental science and the practical applications of numerical weather prediction.

Current research interests of Dr. Kalnay are in data assimilation, numerical weather prediction, data assimilation, predictability and ensemble forecasting, coupled ocean-atmosphere modeling and climate change. Zoltan Toth and Eugenia Kalnay introduced the breeding method for ensemble forecasting. She is also the author (with Ross Hoffman and Wesley Ebisuzaki) of other widely used ensemble methods known as Lagged Averaged Forecasting and Scaled LAF. Her book, Atmospheric Modeling, Data Assimilation and Predictability (Cambridge University Press, 2003) sold out within a year, is now on its fifth printing and was published in Chinese (2005). E. Kalnay co-founded with J. Yorke the Weather/Chaos Group at UMD. More than a dozen doctoral theses have been completed in this project.

On the occasion of receiving the 54th WMO/IMO prize, she talked in January 2010 at the NAS on “Population and Climate Change: a Proposal”, where basic facts about population growth and sustainability were reviewed, pointing out that no meaningful discussion of climate change can ignore this ‘elephant in the room’. Successful trends in non-coercive population control, and the alleged economic problems of reducing population were also discussed. She proposed that government agencies encourage development of regional population models coupled with Earth System models to study population and climate change in an objective, scientific way, while at the same time ‘desensitizing’ this taboo subject. (www.atmos.umd.edu/~ekalnay)

**Zhanqing Li**
Professor
www.researcherid.com/rid/F-4424-2010
Zhanqing Li received his B.Sc. and M.Sc. degrees from the Nanjing Institute of Meteorology, Nanjing, China, in 1983 and 1985, respectively, and the Ph.D. degree in 1991 from McGill University, Canada. After one year of postdoctoral research at the Meteorological Service of

Canada, he joined the Canada Center for Remote Sensing as a Research Scientist. In 2001, he became a full professor at the Department of Atmospheric and Oceanic Science and ESSIC, University of Maryland, College Park. During his sabbatical leave in 2008, he was a visiting professor at the University of Tokyo.

He has been engaged in numerous meteorological and interdisciplinary studies concerning cloud, radiation budget, aerosol, UV radiation, atmospheric and terrestrial environments, biomass burning,. The global radiation budget he developed from ERBE satellite data in early 1990s revolutionized the solar energy disposition. His estimate of surface absorption is 15% less, and atmospheric absorption 35% more, than the conventional values, as featured on the cover of BAMS in 1995. After another two decades of intensive studies, his estimates match closely with the modern estimates. The discrepancies partially rejuvenated the historical debate concerning the cloud absorption anomaly. His persistent and systematic pursuits played a leading role in resolving the problem that had lasted over half a century. Cloud parameters are crucial to weather and climate. His team has developed a suite of novel cloud remote sensing algorithms to maximize the utilities of passive remote sensing data to derive both the column-integrated quantities and also the profiles of cloud structure and microphysics. Prior to their studies, few had successes in using passive satellite sensor to probe the profiles of cloud properties on a global scale. As aerosol is becoming a major climate issue, he has engaged in all aspects of aerosol related studies from space-borne, airborne and ground-based observations to the investigation of aerosols' direct and indirect effects on radiation, cloud, precipitation and atmospheric circulations. He has led two major US-China joint research projects concerning Asian aerosols and climate and established close research partnerships with institutes in China. In addition to meteorological studies, he has engaged in terrestrial studies concerning land surface, biomass burning and carbon cycling. The fire monitoring, mapping and modeling (FIRE/M3) system and algorithms have been used in fire operation agencies.

His wide range of studies have been supported by various agencies such as NOAA, NASA, DOE and NDF with a total funding over $8 millions. He has authored more than 160 peer-reviewed articles in peer-reviewed journals and books with ~2700 citations and H-index of 28. Dr. Li has received numerous merit awards. He has served as editor, guest editor and associate editor in several scientific journals. (http://www.atmos.umd.edu/~zli)

**Takemasa Miyoshi**
Assistant Research Professor
www.researcherid.com/rid/C-2768-2009
Upon completing the B.S. degree in theoretical physics from the Kyoto University in 2000, Dr. Takemasa Miyoshi started his professional career as a civil servant at the Japanese Meteorological Agency (JMA). After two years at the Planning Division, Dr. Miyoshi spent about a year at the Numerical Prediction Division and developed the three-dimensional variational (3D-Var) data assimilation system from scratch for the operational nonhydrostatic regional model. In 2003, Dr. Miyoshi received a Japanese government fellowship to study at AOSC, and completed both M.S. and Ph.D. degrees on ensemble data assimilation within two years. Many studies have been published using the experimental system that Dr. Miyoshi developed for his dissertation. In 2005, Dr. Miyoshi moved back to JMA and was in charge of developing the JMA's next generation global/regional ensemble data assimilation systems. During the four years at JMA, Dr. Miyoshi came to be recognized as a leading scientist in the field of data assimilation; he was asked to give invited talks at several international conferences and to be a member of the organizing committee of the World Meteorological Organization's data assimilation

symposium in Melbourne, the most prestigious conference in the field. In 2008, Dr. Miyoshi received the Yamamoto-Syono Award from the Japanese Meteorological Society. In 2009, Dr. Miyoshi started his current position in academia as a research faculty at UMD and has been working towards his goals of advancing the science of data assimilation as well as a deep commitment to education.
(http://www.atmos.umd.edu/~miyoshi)

**Ragu Murtugudde**
Professor
Murtugudde's research focuses broadly on the role of the ocean in tropical air-sea interactions and climate at subseasonal to decadal longer time-scales including bio-physical feedbacks, ecosystem and carbon cycle responses to climate variability and change. Investigative tools include global and regional earth system models. Application of these models for regional earth system predictions focuses interactive decision-support for sustainable management of resources and human health and sustainable approaches to food, water, energy and the environment especially in developing countries.
(http://www.atmos.umd.edu/~miyoshi)

**Sumant Nigam**
Professor
www.researcherid.com/rid/A-8338-2009
Sumant Nigam is a Professor of Atmospheric and Oceanic Science at the University of Maryland, with a joint appointment in the university's Earth System Science Interdisciplinary Center. His research interests include atmospheric general circulation, climate variability and change mechanisms, tropical ocean-atmosphere interaction, and the role of natural variability in recent warming of the planet. Sumant currently serves on the Climate Research Committee of The National Academies. He has previously served as co-chair of the Climate Variability working group of NCAR's Community Climate System Model; co-chair of the US CLIVAR panel on Phenomena, Observations and Synthesis; Director of the Large-scale Dynamic Meteorology program at the US National Science Foundation; and as Editor of the Journal of Climate. Sumant is a Fellow of the American Meteorological Society. He got his M.Sc. degree in Physics from the 5-year integrated science and engineering program at IIT Kanpur in 1978, supported by the National Science Talent scholarship. He obtained his Ph.D. in geophysical fluid dynamics from Princeton University in 1984, and postdoctoral training at MIT. He was featured on the cover of SCIENCE in May 2004 in connection with a report on foreign born US scientists, titled "Brains & Borders: Many Origins, One Destination."
(http://www.atmos.umd.edu/~nigam)

**Rachel Pinker**
Professor
www.researcherid.com/rid/F-6565-2010
Rachel T. Pinker is a Professor in the Department of Atmospheric and Oceanic Science, at the University of Maryland, College Park since 1995. Her research interests are remote sensing, surface-atmosphere interactions, improving the understanding of the Radiation Budget of the Earth System. Focus of her activity is the development of methods to estimate radiation budgets parameters from remotely sensed information at scales and accuracies required for climate research applications. She collaborates closely with the

scientific community to advance research in areas such as hydrological modeling, high elevations, high latitudes, and the impact of aerosols on the radiative forcing. She has published about 120 refereed papers in scientific journals, contributed articles to encyclopedias, published several critical book reviews, presented over 200 papers at conferences and made over 100 presentations at invited workshops.

Rachel Pinker maintains extensive collaboration with major scientific institutions in the U.S. and abroad. Examples include association with NASA Langley on the implementation of the Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budge (SRB) model at LaRC, cooperates with NOAA/NESDIS, an effort that contributed to the development of the Land Data Assimilation (LDAS) activity at NASA/DAO and NOAA/NCEP, she is active in the Baseline Surface Radiation Network activity since 1996 and is a member of the Science Panel, in the Aerosol Robotics Network (AERONET) by establishing observational activity on long-term aerosol observations in sub-Sahel Africa and development of methodologies for future satellite observations. (http://www.atmos.umd.edu/~pinker)

**Alfredo Ruiz-Barradas**
Assistant Research Scientist
www.researcherid.com/rid/F-4499-2010
Alfredo Ruiz-Barradas was born in the city of Xalapa, Veracuz, Mexico on the 22 of February 1964. While living in his hometown, he got a BS degree in Atmospheric Sciences by the Universidad Veracruzana in 1987. Then he moved to Mexico City where he got an MS degree in Geophysics from the Universidad Nacional Autónoma de México (UNAM) in 1991. After completion of this degree Alfredo was hired as a research assistant by UNAM's Centro de Ciencias de la Atmósfera, a research center for the atmosphere. His job there was assisting in numerical experiments with the so called Adem's Thermodynamic Climate Model; mostly, experiments to assess and improve the model's skill at predicting monthly and seasonal precipitation over Mexico. He worked in that position for Dr. Julián Adem until August 1995, when he left to begin his doctoral studies at the University of Maryland. Alfredo got his doctoral degree in Meteorology in the spring of 2001 studying interannual climate variability in the tropical Atlantic under the advising of Dr. J. Carton and Dr. S. Nigam. He was appointed immediately as a Research Associate in the Department of Meteorology of the University of Maryland working for Dr. S. Nigam on diagnosing the role of oceans on variability of the summer precipitation over the US. This appointment ended in July 2004 when he was promoted to Assistant Research Scientist expanding his initial research to understand the structure and mechanisms of North American warm-season hydroclimate variability, and to include topics like Pacific Decadal variability as well as structure and mechanisms of tropical Atlantic variability. (http://www.atmos.umd.edu/~alfredo)

**Ross Salawitch**
Professor
www.researcherid.com/rid/B-4605-2009
Ross Salawitch is a Professor in the Departments of AOSC, Chemistry & Biochemistry, and ESSIC at UMd. He specializes in the use of computer models and observations, from a wide range of platforms, to quantify the effect of human activity on atmospheric composition with a focus on ozone depletion, air quality, and the global carbon cycle. He

is a highly cited researcher in Geosciences and a participant in assessments of the ozone layer sponsored by the WMO/UNEP as well as special reports issued by IPCC and SPARC. He has been active in many NASA Atmospheric Chemistry field campaigns, has been a member of the ATMOS, SAGE, UARS, and Aura Science Teams, and is a founding member of the Orbiting Carbon Observatory project. He has authored 136 papers in the peer reviewed literature and has an h-index of 42.

Salawitch majored in Applied and Engineering Physics at Cornell University, where he received a B.S. degree. His graduate studies occurred at Harvard University, under the joint supervision of Drs. Michael McElroy and Steven Wofsy. He received a PhD for a dissertation entitled "Antarctic Ozone: Theory and Observation". He continued at Harvard as a postdoctoral fellow and research associate. He then spent 13 years at the Jet Propulsion Laboratory and California Institute of Technology in Pasadena, rising to a level of Principal Research Scientist at JPL and serving as Visiting Faculty Associate and Lecturer at Caltech. He joined the UMd faculty in September 2007.

He has developed two courses at UMd: 1) an atmospheric chemistry course, listed at the 400 (senior) and 600 (graduate) levels within AOSC and Chemistry, that focuses on ozone depletion, air quality, the carbon cycle, and climate change; 2) a numerical methods course, listed at the 600 level, that introduces students to the use of FORTRAN, MATLAB, and IDL in a Linux environment. Recent research activities include an analysis of aircraft, ground-based, and satellite observations of bromine monoxide featured on the cover of the 16 Nov 2010 issue of *GRL*, validation and analysis of $CO_2$ measurements obtained by the Japanese GOSAT instrument, and quantitative evaluation of the coupling of climate change with both air quality and stratospheric ozone recovery. Recent community service includes membership on: the Maryland Department of the Environment Air Quality Control Advisory Council; an Advisory Committee to the town of University Park, Md for administration of a grant from the DOE Efficiency and Conservation program; and, membership on the Sustainable Maryland Certified Task Force. (www.atmos.umd.edu/~rjs)

**Jeff Stehr**
Assistant Research Scientist
www.researcherid.com/rid/F-2638-2010
Dr. Stehr's research focuses on the chemistry and physics of air pollution in the Earth's atmosphere. He employs measurements and modeling of air pollution to work on problems ranging from local air pollution to global change and long-range transport of air pollution. His research has taken him from his field site in the Beltsville Agricultural Research Center, where his students collect rainwater and filter packs, to air pollution flights in light aircraft over the Mid-Atlantic to measurement campaigns in Germany, the Maldives and China. He was one of the authors of EPA's ozone criteria document, co-wrote the most recent Maryland State Implementation Plans for ozone and fine particles, and wrote a guide to Mid-Atlantic air quality for a regional air quality planning organization. He was the lead modeler for the Maryland contribution to the air quality modeling performed for the 2007 ozone and 2008 fine particle State Implementation Plans. He has also worked to adapt commercial instruments to scientific use and to upgrade a new ammonia analyzer for fieldwork. Jeff also serves as Associate Director of the undergraduate and professional masters programs in AOSC. Before coming to

Maryland, Dr. Stehr worked for TRI Research in St. Paul, Minnesota, and got his Ph.D. from the University of Minnesota. (http://www.atmos.umd.edu/~stehr)

**Kostya Vinnikov**
Research Scientist
www.researcherid.com/rid/F-9348-2010
From 1961 to 1975 Konstantin Vinnikov worked as a Research Scientist and as a Senior Research Scientist in the Main Geophysical Observatory (Russia) on the problems of energy balance of the earth-atmosphere system, satellite and land radiation measurements, and climatic change. From 1975 to 1991 he worked as a head of the Research Laboratory on Contemporary Climate and Water Resources Changes at the State Hydrological Institute (Russia). His main scientific interests during this period were global climate change analysis, empirical study of climate sensitivity, and evaluation of the influence of the global warming on water resources and soil moisture. From 1991 to 1993 Dr. Vinnikov worked as a Visiting Senior Research Scientists at the Geophysical Fluid Dynamics Laboratory (Princeton University). He joined the Department of Meteorology (Atmospheric and Oceanic Science, now) at University of Maryland in 1993 to work on climate change, soil moisture, polar sea ice, remote sensing of atmospheric and land surface temperatures, atmospheric chemistry and other subjects. Konstantin Vinnikov has taken part in preparation of many national and international scientific reports on the problem of contemporary global warming, the IPCC reports include. He is Acting State Climatologist for Maryland.
(http://www.atmos.umd.edu/~kostya)

**Ning Zeng**
Associate Professor
www.researcherid.com/rid/A-3130-2008
Ning Zeng is an associate professor at the Department of Atmospheric and Oceanic Science and the Earth System Science Interdisciplinary Center, University of Maryland. He is also affiliated with Geology and the Maryland Energy Center. He earned a BS degree in Physics from the University of Science and Technology of China, MS degree in Astrophysics and Ph.D in Atmospheric Sciences from the University of Arizona. He worked at MIT, University of California, Los Angeles, NASA GSFC, and the Max-Planck Institute for Meteorology. His research and teaching interest includes climate change and variability from seasonal-interannual to geological timescales, carbon cycle and ecosystem, carbon sequestration and other technical solutions and policy implications of climate change. He developed the UMD Earth System Model. He serves on the US CLIVAR PPAI panel and the US Carbon Cycle Science Working Group, and is a co-chief editor of the EGU journal Earth System Dynamics.
(http://www.atmos.umd.edu/~zeng)

**Dalin Zhang**
Professor
www.researcherid.com/rid/F-2634-2010
Da-Lin Zhang received his M.S. (1981) and Ph. D. (1985) degrees from the Department of Meteorology, the Penn State University. From 1986 to 1988, he worked as a postdoctoral fellow at the National Center for Atmospheric Research (NCAR). After spending one year in the University of Toronto, he took a faculty position in the

Department of Atmospheric and Oceanic Sciences at McGill University. He joined the AOSC of University of Maryland in September 1996 as Associate Professor, and became a full professor in 1999.

Da-Lin works on the modeling and understanding of fundamental processes taking place in squall lines, mesoscale convective complexes, heavy rain- (or snow-) storms, tropical and extratropical cyclones, gravity waves, frontal circulations and topographically generated weather phenomena. His research involves simulating a variety of different severe convective systems and cyclones; examining the mesoscale structures and evolution as well as the mechanism(s) whereby they develop; testing theories, hypotheses and various model physical representations; and finally interpreting, to the extent possible, the observed behaviors of these weather systems. His research interests also include regional climate, urban heat island effects and air pollution meteorology.

Da-Lin has also contributed to the development of the nested-grid techniques for treating topography, the improvement of the planetary boundary layer, cumulus and SSiB land-surface parameterization schemes, and cloud representations in mesoscale numerical models, and the development of an observation-based algorithm for constructing hurricane vortices using the AMSU satellite data. (http://www.atmos.umd.edu/~dalin)

**Qunan Zheng**
Research Scientist
www.researcherid.com/rid/F-9025-2010
Quanan Zheng received a diploma in physics from Jilin University, China, in 1966, and a Ph.D. degree in physical oceanography from Institute of Oceanology, Chinese Academy of Sciences in 1987. He is a Senior Research Scientist at AOSC. His research interests include physical oceanography, satellite oceanography, and nonlinear wave dynamics. Dr. Zheng is also an Adjunct Senior Research Scientist of Columbia University, US, the Honorary Professor of the First Institute of Oceanography, State Oceanic Administration, China, and a Guest Chair Professor, Xiamen University. He is co-Chair of Editorial Board of *Acta Oceanonogica Sinica* (English Edition), and a member of Editorial Board of *Chinese Journal of Oceanology and Limnology* (English Edition). Dr. Zheng is a member of the American Geophysical Union, and a member of the Chinese-American Oceanic and Atmospheric Association **(**COAA**).** (http://www.atmos.umd.edu/~quanan)

**4.1 Role of Research Scientists**
Research faculty play a central role in the development of AOSC to a degree which is unusual at UMD. They include scientists with a longstanding commitment to AOSC as well as those for whom AOSC is a launching place for a research career. The interests of the research faculty broaden the subject areas and types of courses covered by AOSC. In return, the research faculty have opportunities to interact with graduate students and to develop their own research programs if they so choose. Research faculty are evaluated by the same appointment and promotion process as for the academic faculty. Their salaries are overwhelmingly supported on research grants and contracts. Although there is not the equivalent of tenure, CMNS has the following policy:

> "This mechanism described in this policy is only to be implemented if all other sources of income have been exhausted. Individuals holding the ranks of Senior

Research Scientist, Associate Research Scientist, and Assistant Research Scientists are eligible to seek short-term salary and benefits support. Funds allocated under this policy are intended to restore up to 75% of the faculty member's approved full-time, twelve month rate of pay and benefits, and may be paid for a period of six months. Extension of the arrangement for up to an additional six months may be approved upon submission of evidence that new contract or grant support is likely to be forthcoming by the end of the extension period. Funding sources for this policy will be as follows: 1/3 of the requested funds will come from the initiating unit's Designated Research Initiative Funds[5] (DRIF) or other funds; 1/3 from the College's DRIF or other funds, and 1/3 from the Graduate School's DRIF or other funds; the split however, may vary in individual circumstances. Under normal circumstances, the lack of funds in a Unit of College will not be a sufficient reason to refuse a request".

**Results of Research Faculty Survey**

As mentioned in the Introduction, the Internal Review Committee surveyed the Research faculty regarding their concerns, which is reported here. Worry about funding stability is the highest concern of the research faculty. This surpasses, though does not replace, past concerns about prestige and status relative to tenure track faculty in AOSC.

*Research faculty positions remain highly insecure, with too much time devoted to writing grant proposals.* Many research faculty find that they spend as much, if not more, time writing grant proposals as doing research. This substantial time burden erodes their productivity and increases the likelihood that they will move to a more financially stable position when the chance presents itself. To prevent this rapid turnover the Department should improve the stability of the positions. Even a small amount of state support, it is felt, would greatly reduce the uncertainty in these positions and make it more likely for these faculty to remain. In response to these concerns the university has developed a bridge funding mechanism quoted above. This was a good idea, but the documentation required to get the bridge funding as well as uncertainty as to where those dollars would come from and how they would be paid back have meant that the bridge funding mechanism is not helpful in practice.

Several ideas have been put forth to increase the stability and decrease the grant-writing burden of these positions: 1) state support 2) reduced overhead on research faculty grants when the faculty member is faced with a lapse in support, or 3) an account that could provide emergency support mentioned previously, to be filled with money from the overhead on research faculty grants. Regardless of the source, providing some greater measure of stability for research scientists would aid in the retention of talent that currently makes up half the department's faculty.

*Faculty governance remains an issue.* Finally, it should be noted that the two-tiered system of faculty appointments remains, is poorly documented, and causes some concerns for department governance. Though research faculty can attend faculty meetings and vote on many issues, they cannot vote on some, so a new tenure-track faculty member has more say in departmental governance than a research faculty member

[5] DRIF funds represent return on overhead from research grants and contracts

who has been here for decades. As a whole, the faculty get along well across all ranks, so on issues where the research faculty cannot vote due to university rules, they can address their concerns to tenure-track faculty, provided that advance notice is given of the meetings, which is not always the case. Research faculty are also divided into research professors and research scientists, with vague differences between the two. Clarifying faculty roles, writing down voting procedures and notifying the research faculty when a tenured faculty-only meeting takes place would help to clarify the roles and responsibilities of research faculty in the department and ensure that their voices are properly heard.

## 5. National Reputation

Assessing the Department's standing and impact on the broader community is complicated. Here we examine external rankings, grant funding, publications and citations, awards and presence, and student placement.

### 5.1 External Rankings and Comparisons

The National Research Council (NRC) ranked oceanography programs in 1995 and gave a single ranking of 9$^{th}$ in the country to the combination of two UMD programs: AOSC and MEES[6]. In 2008 the *Chronicle of Higher Education* released a reputational ranking of atmospheric science departments which placed AOSC 4$^{th}$ in the country. The most recent comprehensive ranking is provided by the NRC report released in October 2010, based on extensive data collected in 2005. This NRC report combined, into a single category, departments of meteorology, atmospheric science, and oceanography. Much of the comparisons below are based on examination of the data from the 50 AOS-NRC departments. We also discuss how AOSC compares to the 54 other graduate programs within UMD.

The NRC provided two summary measures based on a regression of important quantitative measures (R-Rank) and reputational surveys (S-Rank). For each they provided 95% and 5% limits. In **Fig. 5** we present the average of the rank associated with the limits for ranked 20$^{th}$ or above. Based on these overall measures, AOSC seems now to be placed comfortably in the middle of the top ten programs in meteorology, atmospheric science and oceanography. One might also ask which programs are demonstratively higher ranked such that their 5%-95% ranges do not overlap, which have ranges that do overlap, and which are demonstrably lower ranked. For the S-Rank none are higher ranked, 25 overlap and 24 are ranked lower. In **Table 7** we compare some key current AOSC statistics with similar statistics extracted from the AOS-NRC for six highly ranked programs, including three from universities frequently referred to in UMD literature as 'aspirational peers'. The comparison shows that AOSC is highly ranked among programs in this group and produces Ph.D.s at a higher rate.

[6] Marine Environmental Estuarine Studies (www.mees.umd.edu) is a multi-campus program in environmental science. The program director is Ken Paynter and is overseen by the Dean of CMNS.

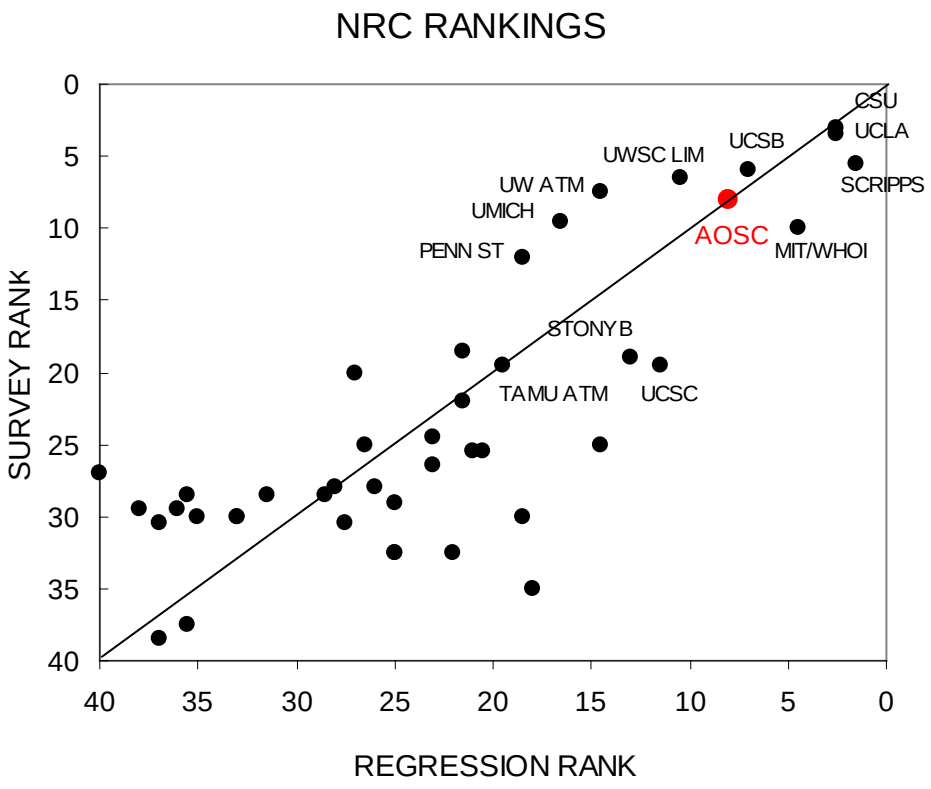



**Figure 5** Scatter diagram of average of 95% and 5% limits of Regression Rank and Survey Rank from the 2010 NRC ranking of 50 graduate programs in atmospheric and oceanic science (top 13 labeled). AOSC is marked in red.

The same survey also allows us to place our department reputation in the context of the 56 other graduate programs at UMD. While any such comparison should account for the differences in competition in each field (a nearly impossible task), we note by comparing S-Rank statistics that no UMD department is demonstrably higher ranked than AOSC and that AOSC ranks among the top handful of graduate programs at UMD.

→ *We are anxious to hear the Committee's views on what intellectual and financial developments are required for AOSC to advance further in the ranks of the elite top handful of graduate programs in atmospheric and oceanic science.*

**Table 5** Comparison of graduation statistics among AOS-NRC highly ranked schools. Asterisks indicate schools frequently referred to by UMD as aspirational peers. NRC score is the average of the R- and S-rank upper and lower limits provided by the NRC (see **Fig. 5**). Numbers were obtained from the NRC survey (collected in 2005) except for AOSC for which we use current numbers (except NRC score).

| School | NRC Score | # Tenured Faculty | Ph.D.s/yr | Median Time to Degree (yrs) |
|---|---|---|---|---|
| **UMD AOSC** | **8** | **12.5** | **8** | **5.5** |
| CSU ATMOS | 2.7 | 10 | 7.2 | 5 |
| PENN ST | 15 | 36 | 6 | 5.2 |
| UCLA* | 3.5 | 16 | 4.2 | 6.3 |
| U MICH* | 13 | 37 | 3.4 | 5.7 |
| UNC* MARINE | 28.7 | 16.9 | 2 | 7 |
| UW ATMOS | 11 | 18 | 6.6 | 6.2 |

*Aspirational Peers

**5.2 Grant Funding**

The combined AOSC and ESSIC/CICS grant and contract expenditures have climbed steadily to $14.18M/yr, an 82% increase since the 2003 External Review as a result of the increase in funding through ESSIC/CICS (**Fig. 6**). Grants and contracts *received* have increased even more rapidly to $22.13M in the current year as a result of the expansion of ESSIC. The funding of the two organizations are intertwined by the fact that a significant fraction of the funds flowing through ESSIC is associated with activities of AOSC faculty. However, the DRIF return to AOSC, reflects mainly the grants labeled as AOSC grants rather than ESSIC grants.

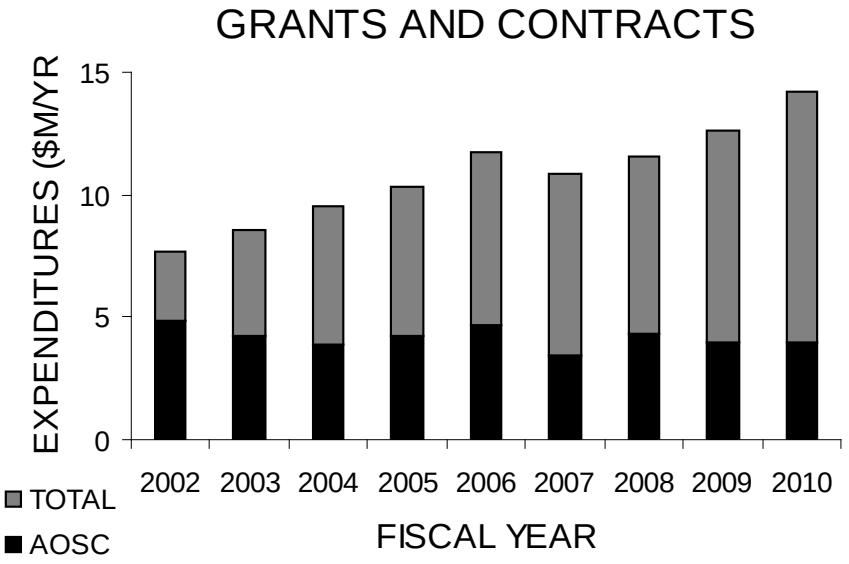


**Figure 6** Annual grants and contract expenditures for AOSC (black) and the combination of AOSC and ESSIC including CICS (grey). The five-year (2006-10) averages of the annual grants and contracts are: $4,067,640 (AOSC) and $12,182,737 (combination).

### 5.3 Publications, Citations, and Impact

In order to explore the publication rates for AOSC and ESSIC we carried out an examination of data on isiknowledge.com searching for those papers whose address was either that of AOSC or ESSIC. According to this search between 2003 and 2010 there were a total of 745 publications, or ~90/yr. Of these, 50% are in meteorology and atmospheric science journals, 27% are in multidisciplinary geoscience, 8% in oceanography and a similar number in geochemistry and geophysics (these may be associated with member of ESSIC who are not in AOSC). The funding source most frequently cited was NASA. ISI ranks UMD as among the top 20 organizations in the world in terms of numbers of citations for papers in the following subdiscipline areas: air pollution, climate dynamics, and tropical storms. Two AOSC faculty, Eugenia Kalnay and Ross Salawitch, are listed among the 32 ISI Highly Cited Researchers at UMD.

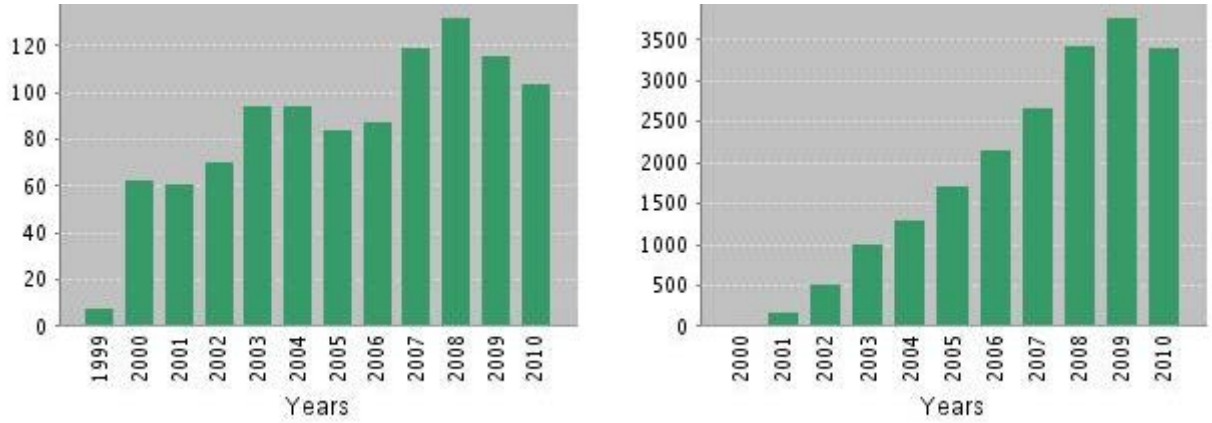



**Fig. 7** Publication statistics, number of papers (left) and number of citations (right), for all papers published between 2000-2010 found using a the combination of AOSC and ESSIC in the isiknowledge.com search window. One paper published in 2000 lists a publication date of 27 Dec 1999.

An examination of the publications listed in ISI publications shows that AOSC academic and research faculty have published an average of 87 refereed papers each year between 2003-2009. Focusing on the academic faculty, the average publication rate is 5.3 (median: 5) papers per year. The median number of citations per faculty is 2697, the median citations per paper is 30, and the median Hirsh Index is 25. The research faculty have an average publication rate of 2.1 papers per year, while the median citations per research faculty is 286 and the median Hirsch Index is 9.

### 5.4 Awards and professional presence in the community

**Major awards garnered by AOSC faculty since 2003**

- **2009 WMO International Meteorological Organization Prize:** Eugenia Kalnay
- **Foreign Member of the Academia Europaea:** Eugenia Kalnay
- **Doctor Honoris Causa, University of Buenos Aires:** Eugenia Kalnay
- **AGU Yoram Kaufman Award:** Ross Salawitch

- **Walter Orr Roberts Interdisciplinary Science Lecturer:** Antonio Busalacchi
- **Member of the Argentine Academy of Exact and Natural Sciences:** Eugenia Kalnay
- **Fellows of the American Geophysical Union**: Antony Busalacchi, Russell Dickerson, Eugenia Kalnay
- **Fellows of the American Meteorological Society:** Hugo Berbery, Antonio Busalacchi, James Carton, Sumant Nigam, and Da-Lin Zhang
- **Fellows of the American Association for the Advancement of Science:** Russell Dickerson, Eugenia Kalnay
- **2011 Leopold Leadership Fellow**: Ragu Murtugudde

**5.4.1 Scientific Community Service since 2003**

Here we provide examples of editorships, NRC committees, and major international committees:

- **Co-Chair of the Scientific Steering Group for the World Climate Research Programme on Climate Variability and Predictability** (CLIVAR). 1999-2006, Antonio Busalacchi
- **Chair of the NAS/NRC Climate Research Committee**, 2003-2008: Antonio Busalacchi
- **Chair of the NAS/NRC Committee on Earth Science and Application: Ensuring the Climate Measurements from NPOES and GOES-R**, 2007-2008: Antonio Busalacchi.
- **Chair of the Joint Scientific Committee for the World Climate Research Programme**: Antonio Busalacchi.
- **Chair of the NAS/NRC Board on Atmospheric Sciences and Climate**: Antonio Busalacchi.
- **Member of the EPA SAB Committee on Integrated Nitrogen Committee:** Russell Dickerson.
- **Member of the NAS/NRC Climate Research Committee**: Sumant Nigam
- **Member of the NAS/NRC Committee for Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs:** Russell Dickerson
- **Co-Chair, NAS/NRC Committee on National Security Implications of Climate Change on US Naval Forces,** 2009-present : Antonio Busalacchi.
- **Chair, NAS/NRC Committee on Earth Science and Application: Ensuring the Climate Measurements from NPOESS and GOES-R**, 2007-2008: Antonio Busalacchi.
- **Member, IOM/NRC Committee on the Effect of Climate Change on Indoor Air Quality and Public Health**, 2010-: Antonio Busalacchi.
- **Member, NAS/NRC Committee on the Assessment of Impediments to Interagency Cooperation on Space and Earth Science Missions,** 2009-present: Antonio Busalacchi.
- **Member, NAS/NRC Committee on America's Climate Choices: Panel on Advancing the Science of Climate Change,** 2009-2010: Antonio Busalacchi.
- **Editor of Weather and Forecasting,** 2006 - present: Da-Lin Zhang,
- **Co-Chief Editor, Advances in Atmospheric Sciences**, 2002 - 2008: Da-Lin Zhang

- **Co-Chief Editor of Earth System Dynamics**, - present: Ning Zeng
- **Co-Chair of Editorial Board of Acta Oceanonogica Sinica (English Edition):** Qunan Zheng
- **Member of Editorial Board of Chinese Journal of Oceanology and Limnology (English Edition):** Qunan Zheng

**6. University, State, and Local Service**

Here we provide examples of AOSC service contributions.

- AOSC maintains the State-funded Regional Atmospheric Measurement Modeling and Prediction Program which provides policy-relevant science to the Maryland Department's of the Environment and Natural Resources to improve air and water quality over the eastern US.
- AOSC supports the Maryland State Climatologist Office. This office provides historical and current climate information to the community either through its website (www.atmos.umd.edu/~climate) and email or by telephone. This office is currently essentially unfunded (receiving partial funding through RAMMPP) and operates on a largely volunteer basis. Incidentally, the Department has been unable to regularize the funding for the State Climatologist Office despite many attempts to obtain funding from the University and State.
- The Chesapeake Bay Forecasting System (CBFS) led by Prof. Ragu Murtugudde. The CBFS is an effort to combine models of individual components of the regional climate into a regional climate system for use in the analysis of current conditions and prediction of future changes.
- AOSC faculty member Kayo Ide also contributes to a related ocean-focused effort along the US West Coast known as the Coastal Ocean Monitoring and Forecasting. This second effort is a collaboration among scientists from UMD, JPL, and UCLA.
- Maryland Climate Change Commission membership: Russell Dickerson, Antonio Busalacchi.
- Maryland Department of the Environment Air Quality Control Advisory Council membership: Ross Salawitch

**7. Future of AOSC: Issues, Challenges, and Opportunities**

**Research** AOSC has recognized the need to focus its research enterprise both to compete within UMD and nationally, and is making an effort to concentrate on building its areas of strength, reflected in Section 3.1 Major AOSC Research Thrusts. Future extensions of our research base should satisfy four criteria: 1) exciting, forward looking science; 2) builds on current Department/University research capabilities; 3) exploits our unique location in the Washington DC area; and 4) should, with a modest enhancement of resources, lead to a World Class scientific effort. Three areas are identified in our current Strategic Plan (**Appendix 2**).

- **Marine Biogeochemical Cycles (joint with ESSIC)**
  New expertise in marine biogeochemical cycles within AOSC directly supports our goal of gathering the expertise required for Earth System Modeling as well as expands our climate-focused oceanographic research.
- **Land Surface Processes (joint with ESSIC and GEOL)**

New expertise in land surface processes directly supports our goal of gathering the expertise required for Earth System Modeling. It will allow us to link to the strong land surface groups at NASA and NOAA and provide many practical applications. We note that land surface processes are a critical component of the carbon cycle.

- **High Latitude Processes (joint with ESSIC, GSFC, and GEOL)**
  We propose a new initiative involving a cluster hire spread across three units, AOSC, ESSIC, and Geology to create a world class research academic activity targeted at the region of the planet exhibiting the most dramatic climate change. It links together meteorological, oceanographic and cryospheric science. This activity will exploit and mirror the world class remote sensing research already ongoing at nearby NASA and NOAA laboratories.

Beyond these three areas we recognize the growing need to conduct research connecting physical climate variability and change with its human dimensions. For example, Eugenia Kalnay notes that the single most important variable component in the climate system, human population, is neglected from all not included in any of current climate models. The Washington DC area is home to many of the institutions with responsibility for influencing policy in this area (e.g. IMF, USAID, and World Bank). AOSC could contribute to the development of this field in collaboration with other environmental and social science groups at UMD.

**Education** Our goals for the graduate program are straightforward -- to recruit top students and to provide an outstanding, research-oriented PhD experience. Key measures of success include the papers our students write, the jobs our graduates acquire, exit interviews from the students themselves, and the promptness with which successful students are able to progress through our program. Among the changes we foresee are a possible redesign of the Comprehensive Examination and an increase in the number of more mature students entering the program (associated with the move of NOAA to the MSquare campus). At the undergraduate level our goal is to exploit our strengths to build an outstanding undergraduate degree program as discussed above in Section 2.2.

→ *We are extremely interested to hear Review Committee's views of our choices for future directions in view of our current capabilities and the challenges/opportunities we confront*.