

**ENVIRONMENTAL FLUID DYNAMICS PROGRAM****ANNUAL REPORT 2002 \***

**Ira A. Fulton School of Engineering  
Arizona State University  
Tempe, Arizona**

**Vision and Mission of the EFD Program**

The mission of the Environmental Fluid Dynamics (EFD) Program is to bring together researchers from Arizona State University (ASU), other domestic and international academic institutions, local industry, and state and federal institutions to initiate new research activities and enhance ongoing research at ASU pertinent to environmental transport processes. The emphasis is on collaborative and multidisciplinary research of immediate societal impact. In addition, the program facilitates single investigator research by providing infrastructure support, which includes: maintenance of state-of-the-art laboratory facilities; organization of seminars, discussion groups and workshops; arranging the visits of prominent scientists and scholars; and the initiation of new research thrusts. The current broad research thrusts include: modeling of environmental flows (short- and long-term forecasting of oceans and atmosphere); air pollution dispersion; fluid-structure interactions (for example, flow around buildings and vehicles, and wave forcing on platforms); health and epidemiological implications of environmental transports; atmospheric dispersion, especially the dynamics of aerosols and toxic releases; indoor air quality and building ventilation; prediction and remediation of natural hazards; and socio-economic and public policy issues of ecosystem management. In addition, efforts are made to initiate research involving micro- and nano-scale fluid mechanics as applied to environmental, biological and industrial flows. Both fundamental and applied research are emphasized.

**Multidisciplinary Activities**

Considerable efforts were directed during the past year to enhance collaboration between researchers from different colleges at ASU in addressing problems related to atmospheric and oceanic transport processes. These include:

- (i) hosting a multidisciplinary seminar series covering a wide variety of topics related to environmental flows;
- (ii) inviting eminent scholars and faculty from different ASU colleges to deliver seminars in this series,  
so that their research expertise and interests can be better understood; as well informing them of EFD's research activities.
- (iii) organizing meetings of clusters of investigators in responding to various RFP's;
- (iv) involvement of dedicated graduate students and post-doctoral fellows from various departments in EFD research projects and coordinating their activities through the EFD office;

- (v) maintaining a cadre of post-doctoral and senior researchers, some of them shared between other research centers such as the Center of Environmental Studies.
- (vi) initiating a new thrust on modeling and fundamental research on urban flows, in particular, those of rapidly expanding urban regions.
- (vii) maintaining close cooperation with the NSF-funded Long Term Ecological Research (LTER) Program of the Center for Environmental Studies, and the remote sensing group of the Department of Geological Sciences.
- (viii) Maintaining close cooperation with state agencies, such as Arizona Department of Environmental Quality and Arizona Department of Transportation.

Concurrent with the thrusts of the Vice President for Research's (VPR) Office, most of the efforts were focused on enhancing ASU's strengths in the area of urban fluid dynamics. This included contributing to ASU's GP2100 project and to the Consortium of Rapidly Expanding Urban Regions (CSRUR) and urban sustainability initiative. As the program is concerned with fluid dynamics of pollution dispersion, major efforts are underway to collaborate with other groups of complementary expertise. An internal research thrust on urban air pollution was started and is continuing, which is highly opportune given Phoenix's location in a complex terrain airshed beleaguered by serious air pollution problems. Ties with the Urban Security groups of the Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL), Defense Threat Reduction Agency (DTRA), Army Research Office (ARO), Inv. Cientificas y Technologicas Sonora, University of Rome, and Beijing Environmental Information Center, China are continuing. By intensifying both fundamental and applied research on urban pollution and redirecting some of the internal resources, it was possible to compete for several grants in the air pollution arena. The inter-governmental agreement signed with the Arizona Department of Environmental Quality (ADEQ) is continuing and has been highly useful. Applied research on airflow and dispersion has resulted in exciting new opportunities, including funding from the Arizona Department of Transportation (ADOT) and the Department of Energy Laboratories (Lawrence Livermore National Laboratory). Other sponsors of the EFD program are the National Science Foundation (NSF; Polar Programs; Fluid Mechanics; Atmospheric Chemistry; Atmospheric Sciences), the Office of Naval Research (ONR), Army Research Office (ARO), the Southwest Center for Environmental Research and Policy (SCERP), Arizona Public Services Company, the California Air Resources Board (CARB), and the Air Force Office of Scientific Research (AFOSR).

In addition to air related research, the program pursued the area of water and marine resources, in particular, physical oceanography, wetlands, river transports and riparian ecosystems. The U.S. Office of Naval Research (ONR) continued to fund our work on ocean waves and their interaction with large objects. Several proposals were submitted to ONR to initiate work on mixing induced by

topographic features and wakes in stratified fluids (the former is pending and the latter was approved in 2003). The following are some highlights of the EFD program in 2002:

- ADEQ awarded a contract to conduct flow, ozone and socio-economic modeling work in support of 8-hour ozone boundary designations for the U.S. EPA.
- A new ONR grant was approved to conduct research on underwater vehicles, such as submarines moving in the oceanic thermocline.
- EFD researchers presented and defended their work in 3 public (stake holder) meetings with regard to 8-hour ozone boundary designations.
- ADEQ awarded a grant to start a major modeling partnership between ASU and ADEQ by instituting a joint ASU/ADEQ modeling center.
- Through a DURIP (Defense University Research Initiative Program) grant a Doppler Lidar was purchased (PI. R. Calhoun). This is the first such Lidar to be purchased by a university.
- Under the intergovernmental Service Agreement signed between the Arizona Department of Environmental Quality and EFD, three new projects were funded.
- A new multiyear grant was awarded by the Office of Naval Research dealing with mine burial in coastal environments.
- A major grant was awarded by the Department of Army to participate in the Joint-Urban 2003 field experiment led by the US Department of Homeland Security.
- Professor Joseph Zehnder spearheaded the effort of starting an Atmospheric Sciences Certificate Program at ASU. This is a multidepartmental certificate program approved by the graduate college. Initiation of this program followed the admission of ASU to the University Corporation of Atmospheric Research (UCAR) in 2000; EFD played a major role in both of these activities.
- Collaborative work with colleagues from the Mathematics department (Professors Nicolaenko and Mahalov) continued on problems related to stratospheric turbulence. A major three year grant was received from the AFSOR to carry out this work.
- The multidisciplinary “Ecosystems Engineering Seminar” was continued, featuring invited distinguished seminar speakers. The multidisciplinary research funding from VPR’s Office is used for this activity. Each semester, nearly twenty students from the Departments of Chemical Engineering, Civil and Environmental Engineering, Mechanical and Aerospace Engineering, Mathematics, Planning, Chemistry and Geography register for this course. The Faculty attendance for this seminar series is also encouraging. This seminar is cross-listed as MAE 591/CEE 591/CHE 591/MAT 591. It is also used as a platform to invite distinguished speakers recommended by the university administration or to invite prospective faculty candidates. The mailing list for the seminar series includes state agencies and local industry, and participation of individuals from these organizations is not a rarity. A listing of the 2002 Ecosystem Engineering Seminars as well as details on general Environmental Fluid Dynamics seminars is given later. The former is also being used as the capstone seminar for the Atmospheric Certificate course.
- The EFD laboratory is being used as a showcase for prospective undergraduate and graduate

students. The EFD program coordinated numerous student and faculty visits, and each year the laboratory entertains hundreds of visitors.

- Professor Julian Hunt (Lord Hunt of Chesterton), former Chief Executive of the U.K. Meteorological Office and currently a Professor of Space and Climate Physics at the University College in London, continued to be a part of the visiting faculty attached to the EFD program. Under his leadership, major mathematical modeling efforts pertinent to urban flows were started and they continue to flourish.
- The Energy Management Laboratory continued to host the Industrial Assessment Center (IAC), one of 26 such Centers across the country sponsored by the US Department of Energy. The IAC provides free assessments of small and medium-sized manufacturing plants throughout Arizona and in the Las Vegas area, and makes recommendations on energy efficiency, waste reduction, and productivity improvement. A similar project was the Rebuild America Project (RAP), led by the Arizona State Energy Office. A major undertaking here was an analysis of the energy efficiency of schools, in collaboration with the Arizona Schools Facilities Board. Presently, the data gathered from the Mesa School District are being analyzed to determine the most cost-effective energy measures that can be taken by these, and other, schools. Finally, a major initiative was launched in 2002 involving biochemical sensors, in collaboration with Tony Garcia (Bioengineering), Mark Hayes (Chemistry & Biochemistry), and Ron Calhoun (MAE & EFD). Our part involves the simulation of the motions of small particles and molecules in a confined geometry, as is encountered in many types of biochemical sensors.
- Research Professor Iossif Lozovatsky participated in an international oceanic measurement program, with partial financial support from the Office of Naval Research and in collaboration with Russian Oceanographers. The third expedition in this series was carried out in April 2002, covering a transect across the Atlantic.

### **Associated Faculty**

A number of regular and adjunct faculty members from the Departments of Civil Engineering (CE), Mechanical & Aerospace Engineering (MAE), Chemical and Materials Engineering (CME), Geography (GEO), and Mathematics (MAT) have been closely involved in the proposal development and research efforts of the EFD Program. The faculty who submitted proposals during 2001 and their affiliations are: J. Anderson (MAE), D. Boyer (MAE), P. Phelan (MAE), K. Squires (MAE), I. Lozovatsky (MAE), A. Mahalov (MAT), B. Nicolaenko (MAT), G. Raupp (CBME), S. Voropayev (MAE), D. Smith, (MAE), J. Zehnder (GEO), A. Dillner (CEE), R. Calhoun (MAE), J. Allen (CME), and S.M. Lee (CE).

In addition, a large multidisciplinary IGERT proposal was submitted entitled "IGERT: Urban Atmospheres: Observations, Modeling and Management." The faculty involved were H.J.S. Fernando (MAE/EFD), V. Burrows (CME), H. Campbell (PAF), G. Raupp (CME), and J. Zehnder (GEOG). A full proposal was invited, but due to limited submission requirements, the ASU administration recommended that a full proposal should not be submitted.

Post-doctoral fellows, faculty associates and numerous visiting scientists contributed immensely to the program. The EFD program maintains a cadre of research scientists, post-doctoral fellows and visiting researchers to maintain its long-term research viability and international presence in numerous research activities. Listings of these activities are given below.

### **EFD Research Scientists in 2002**

Dr. I. Lozovatsky (Research Professor)	Dr. S. Voropayev (Research Professor)	Dr. D. Smith (Research Associate Professor)
Dr. Sang-Mi Lee (Assistant Research Professor)	Dr. S. Grossman-Clarke (Post-Doctoral Fellow)	Dr. F. Tse (Post-Doctoral Fellow)
Dr. Jae-Jin Kim (Post-Doctoral Fellow)	Dr. Andjelka Srdic (Assistant Research Professor)	Dr. Olga Alexandrova (Faculty Research Associate)
Dr. Binson Joseph (Post-Doctoral Fellow)	Dr. Gordon Moore (Faculty Research Associate)	Dr. James Anderson (Senior Research Associate)
Dr. Sergey Smirnov (Post-Doctoral Research Associate)	Dr. Xin Hua (Faculty Research Associate)	Dr. Eric Strang (Faculty Research Associate)

### **Visitors to EFD in 2002 (more than one month)**

<b>VISITOR</b>	<b>AFFILIATION</b>	<b>DATE(S)</b>
Andrey Ksenofontov	Russian Academy of Sciences	Jan 02 – April 02
Jong-Jin Baik	Kwanju Institute of Science and Technology, Korea	Jan 02 – Feb 02
Paolo Monti	University of Rome, Italy	Jan 02
Andrew Mills	Illinois Institute of Technology	May 02 – Aug 02
Walter Giori	University of Rome, Italy	Aug 02 – Dec 02
JCR Hunt	University College, London	Dec 02
Tomasz Kowalewski	IPPT/PAN, Poland	Jan 02
Peter Baines	CSIRO, Australia	Feb 02

### **EFD Students 2002**

A listing of students who were supported by EFD-related projects and the Ph.D. and M.S. degrees completed under the auspices of the EFD program are listed below.

#### **EFD Graduate Students**

Rodolfo Rodriguez (CME), Dragan Zajic (MAE), John Holeman (MAE), Marko Princevac (MAE), John Rotter (MAE), Sean Riley (MAE), Firat Testik (MAE), Jason Porter (MAE), Cristian Dumitrescu (MAE), Zhihe Zhao (MAE), Hemanth Gokula (MAE), Charity Coury (CHE), Jamshed Ghoush (MATH), Bong-Sik Kim (MATH)

#### **M.S./Ph.D. Degrees completed by EFD students**

<b>FACULTY NAME</b>	<b>CANDIDATE</b>	<b>DEGREE</b>	<b>THESIS</b>
Patrick Phelan	CA Flores Padilla	M.S.	Analysis of Industrial Electricity

			Consumption for the USA and for the Mexican Border States Maquiladoras
Don Boyer	Sergey Smirnov	Ph.D.	Jets and Wakes in Stratified Fluids

### **EFD Undergraduate Students**

Richard Montenegro, Martin Weeden, Tracey Doyle, Gerardo Brigido

### **Chapters in Books 2002**

Boyer, D.L., Srdic-Mitrovic, A.N., 2002. Laboratory experiments of continuously stratified flows past obstacles, environmental stratified flows, Editor: Roger Grimshaw, Kluwer Academic Publishers, 193-225.

Fernando, H.J.S. "Stratified Turbulence, 2002 " In: Environmental Stratified Flows, Ed. Roger Grimshaw, Kluwer Academic Publishers, 163-193.

### **Conference Presentations 2002**

G. B. Delgado, M. Princevac, and H.J.S. Fernando, Flows in Complex Terrain: The Generation of Anabatic Flow on Simple Slopes, Poster Presentation, Building a Vision for Higher Education in Science, Technology, Engineering and Math, 19 –21 September 2002 in Albuquerque, NM

Alexandrova, O.; Anderson, J. R.; Boyer, D. L.; Fernando, H. J. S., Nocturnal temporal and vertical variations of the concentration of pollutants induced by thermally driven circulation within the Salt Lake Valley, 27th General Assembly of the European Geophysical Society, Nice, France, April 2002.

P. Bhattacharya, P.E. Phelan, "Modeling the Behavior of  $F_1$ -ATPase Biomolecular Motors Using Brownian Dynamics Simulation," BioDevice Interface Science and Technology Workshop, Scottsdale, Arizona, September 7 - 9 (2002).

P. Bhattacharya, P.E. Phelan, "Understanding the Behavior of an  $F_1$ -ATPase Biomolecular Motor Using Brownian Dynamics Simulation," US-Japan Nanotherm Seminar: Nanoscale Thermal Science and Engineering, Berkeley, California, June 24 - 26 (2002).

W.P. Brown, B.J. Foucault, A. Mahalov, B. Nicolaenko, F.H. Ruggiero and J. Werne, "Atmospheric Propagation, Adaptive Optics, and Turbulence Characterization Studies for the Airborne Laser, DoD High Performance Computing Modernization Program," (HPCMP) Conference, Austin, Texas, June 10-13, (2002).

A. Vuppu, S. Saha, A. Garcia, P.E. Phelan, M. Hayes, & R. Calhoun, "Paramagnetic Particle Microsphere Chains in Fixed and Rotating Magnetic Fields," small Talk2002, San Diego, California, July 28 – 31 (2002).

A. Vuppu, S. Saha, A. Garcia, P.E. Phelan, M. Hayes, R. Calhoun, & K. Booksh, "Lock-In Amplifier Detection Using Dynamically Patterned Microrotors," BioDevice Interface Science and Technology Workshop, Scottsdale, Arizona, September 7 – 9 (2002).

C. Flores, P.E. Phelan, J.I. Mou, & H. Bryan, "A Comparison of Industrial Energy Consumption Among Manufacturers in the Border Region," Border Energy Forum IX, Saltillo, Mexico, Oct 23 – 25 (2002).

M. A. Carroll, T. D. Thornberry, C. Campbell, S. Hengel, G. Yip, L. Yageman, E. Fortner, J. Abrams,

- A. J. Hogg P. B. Shepson, K. Ford, J. W. Grossenbacher, S. B. Bertman, M. R. Pippin, M. Marchewka, Y. He, X. Zhou, and G. Huang, L. G. Huey, D. J. Tanner, S. Sjostedt, and D. B. Slusher, J. O. Allen, A. E. Delia, D. W. Toohey, D. R. Worsnop, J. Moody, M. Lilly, "Reactive Oxidized Nitrogen Partitioning and Ozone Production Efficiencies during the PROPHET Summer 2000 and Summer 2001 Measurements Intensives," American Geophysical Union Meeting, December, 2002, San Francisco, CA.
- J. O. Allen, D. A. Gonzales, A. E. Delia, J. L. Jimenez, K. A. Smith, M. Canagaratna, J. T. Jayne, D. R. Worsnop, "Speciated Fine Particle Deposition to a Forest Canopy Measured by Eddy-Correlation Mass Spectrometry," American Geophysical Union Meeting, December, 2002, San Francisco, CA.
- A. E. Delia, R. M. Garland, D. W. Toohey, J. O. Allen, D. R. Worsnop, "Investigation of Remote Continental Aerosols at PROPHET 2001," Twenty-first Annual Conference of the American Association of Aerosol Research, October, 2002, Research Triangle Park, NC.
- J. O. Allen, C. A. Tyree, J. L. Jimenez, A. E. Delia, K. A. Smith, M. Canagaratna, J. T. Jayne, D. R. Worsnop, "Deposition of Particulate Species Measured by Eddy-Correlation Mass Spectrometry," American Chemical Society 224th National Meeting, August 2002, Boston, MA.
- Zehnder, J.A. 2002: Numerical Forecasts of the Diurnal Temperature Cycle in an Arid Urban Environment with MM5. 4th Symposium on the Urban Environment, , American Meteorological Society, 20 -24 May, 2002. Norfolk Virginia.
- Zehnder, J.A. Raymond, D.J., 2002: The Genesis of Tropical Storm Lorena. 25th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, 29 April - 3 May 2002, San Diego California.
- Lee, S.M., Grossman-Clarke, S., Fernando, H.J.S., 2002: Application of Models-3/CMAQ to El Paso airshed, Models-3 Users' Workshop, 21-23 October, Research Triangle Park, North Carolina.
- Lee, S.M., Sinesi, M., Princevac, M., Zajic, D., Fernando, H.J.S., Anderson, J., 2002: A numerical study on the spatial and temporal variation of ozone within the Phoenix valley, 6<sup>th</sup> Annual George Mason University Transport and Dispersion Modeling Workshop. 10-11 July, Fairfax, Virginia.
- Lee, S.M., Sinesi, M. Princevac, M. , Zajic, D., Fernando, H.J.S., Anderson, J. 2002: A study on vertical distribution of ozone in the PBL of the Phoenix valley, p.13-14, 12<sup>th</sup> Joint conference on air pollution meteorology with the Air and Waste Management Association, 20-24 May, Norfolk, Virginia, USA.
- Ellis, A.W., Fernando, H. J. S., Lee, S. M. ,2002: Climatological analysis of lower atmospheric particulates within a Bi-National airshed: Douglas, AZ-Agua Prieta, SON, the 98<sup>th</sup> Annual Meeting of the Association of American Geographers, Los Angeles, CA, USA.
- Grossman-Clarke, S., Hope, D. , Lee, S.M. , Fernando, H.J.S. , Hyde, P.G. , Stefanov, W. L. , Grimm, N. B. 2002: Modeling temporal and spatial characteristics of nitrogen dry deposition in the Phoenix metropolitan area, American Geophysical Union 2002 Fall meeting. 6-10 December, San Francisco, CA.
- Zajic, D., Princevac, M., Kim, J., Fernando, H.J.S., 2002: American Meteorological Society, Flow and Turbulence Surrounding a Building Cluster, Fourth Symposium on the Urban Environment 2002, 20—24 May, Norfolk, VA.
- Brown, M., Pardyjak, E., Zajic, D. Princevac, M., Biltoft, C., 2002, The MUST Field Experiment: Mean and Turbulent Wind Fields at the Upstream Edge of a Building Array American Meteorological Society, Fourth Symposium on the Urban Environment 2002, 20—24 May, Norfolk, VA.

Eric R. Pardyjak, Michael J. Brown, Matthew A. Nelson, Dragan Zajic, Marko Princevac, Christopher Biltoft, and J.C. Klewicki, Buildings Effects On Thermal Stratification During The MUST Trials, American Meteorological Society, Fourth Symposium on the Urban Environment 2002, 20—24 May 2002 in Norfolk, VA.

M. Princevac, P. Monti, H.J.S. Fernando, T.A. Kowalewski, E.R. Pardyjak, Turbulence and mixing in the nocturnal boundary layer over a slope - VTMX field program results, 10th Conference on Mountain Meteorology 13—21 June 2002 in Park City, UT.

M. Princevac, A. Mills and H.J.S. Fernando, Destruction of Cold Pools in Complex Terrain Air Basins, American Physical Society, 2002 Division of Fluid Dynamics, Dallas, November 2002.

Lozovatsky, I.D., Fernando, H.J.S, Morozov, E.G., 2002: "Topographically induced Mixing in the Eastern Atlantic," *Eos, Transactions*, AGU, **83**(4), OS354.

Roget, E., Figueroa, M., Lozovatsky, I., 2002: "The dissipation rate in the wind-induced Ekman boundary layer", *Geophys. Res. Abstracts*, **4**, 27<sup>th</sup> EGS Gen Assembly, Nice, France.

Figueroa, M, Roget, E., Pierra, J., Lozovatsky, I., 2002: "Wavelet denoising of the dissipation measurements in the upper ocean", *Geophys. Res. Abstracts*, **4**, 27<sup>th</sup> EGS Gen Assembly, Nice, France.

Allen, J. O., Tyree, C. A., Jimenez, J. L., Delia, A. E., Smith, K. A., Canagaratna, M., Jayne, J. T., Worsnop, D. R., "Deposition of Particulate Species Measured by Eddy-Correlation Mass Spectrometry," American Chemical Society 224th National Meeting, Boston, MA, August 2002.

### Journal Papers 2002

Zehnder, J.A. 2002: Simple modifications to improve fifth-generation Pennsylvania State University-National Center for Atmospheric Research mesoscale model performance for the Phoenix, Arizona metropolitan area. *J.Appl.Met.*, **41**, 971-979.

Lee, S. M., Fernando, H.J.S., Princevac, M., Zajic, D., Sinesi, M., McCulley, J. Anderson, J. 2002: Transport and Diffusion of Ozone in the Nocturnal and Morning PBL of the Phoenix Valley, *Environmental Fluid Mechanics*.

Monti, P. Fernando, H.J.S., Princevac, M., Chan, W.C., Kowalewski, T.A., Pardyjak, E.R., 2002: Observations of Flow and Turbulence in the Nocturnal Boundary Layer Over a Slope, *Journal of the Atmospheric Sciences*, Vol 59 (17), 2513-2534.

Voropayev, S.I., Smirnov, S.A., Filippov, I.A., Brandt, A. (2002) Mushroom-like currents in a stratified shear flow. *Izvestiya, Russian Academy of Sciences. Atmospheric and Oceanic Physics*, 38(2), 212-216. 2.

Voropayev, S.I., Smirnov, S.A., Filippov, I.A., Boyer, D.L. (2002) Stratified wakes generated by a point momentum source. *Izvestiya, Russian Academy of Sciences. Atmospheric and Oceanic Physics*, 38(3), 358-364.

Kaya, D., Phelan, P.E., Chau, D.S., Ibrahim Sarac, H., 2002: "Energy Conservation in Compressed-Air Systems," *International Journal of Energy Research* 26, pp. 837 - 849.

Lozovatsky, I. D., Fernando, H.J.S., 2002: "Turbulent mixing on a shallow shelf of the Black Sea", *J. Phys. Oceanogr.*, 32(3), 945-956.

Lozovatsky, I.D., Morozov, E.G, Fernando, H.J.S., 2002: "Spatial decay of energy density of internal tides", *JGR-Oceans*(under revision).

M. Farge, A. Azzalini, A. Mahalov, B. Nicolaenko, K.-L. Tse, G. Pellegrino and K. Schneider, 2002: "Vortex Tubes in Shear-Stratified Turbulence," Special Issue on Tubes, Sheets and Singularities in Fluid Dynamics, Kluwer Academic Publishers, p. 21-32.

A. Babin, A. Mahalov and B. Nicolaenko, 2002: "Fast Singular Oscillating Limits of Stably Stratified Three-Dimensional Euler and Navier-Stokes Equations and Ageostrophic Wave Fronts," In the Monograph Large-Scale Atmosphere-Ocean Dynamics, Cambridge University Press, p. 126-201.

Kaya, D., Phelan, P.E., Chau, D.S., & Ibrahim Sarac, H., "Energy Conservation in Compressed-Air Systems," *International Journal of Energy Research*, 26, pp. 837 – 849, 2002.

### Teaching Activities

The EFD program is a key contributor to the interdisciplinary graduate education in environmental sciences/engineering at ASU. The course "Ecosystem Engineering Seminar," cross-listed as MAE 591, CHE 591, CEE 591, MAT 591 was offered in both Spring and Fall 2002. This is a weekly one-hour seminar presentation by a specialist in the environmental science/engineering area. Speakers of this seminar series and their discussion topics are given below. We plan to continue this course for the next several years. In addition, a special EFD seminar series is conducted on every Friday, the details of which are given following the Ecosystems seminar listing.

### Ecosystem Engineering Seminars in 2002

	<b>SPEAKER</b>	<b>AFFILIATION</b>	<b>TITLE</b>
1/16/02	Jonathan Fink	ASU-OVPR	AN UPDATE ON ASU'S ATTEMPTS TO ESTABLISH PHOENIX AS AN URBAN ENVIRONMENTAL RESEARCH LABORATORY
1/23/02	Steven R. Hanna	George Mason University	MODELING ATMOSPHERIC TRANSPORT AND DISPERSION OF CHEMICAL AND BIOLOGICAL AGENTS FROM TERRORIST ATTACKS
1/30/02	Robert Gall	NCAR	OVERVIEW OF THE U.S. WEATHER RESEARCH PROGRAM
2/6/02	Michael P. Austin	Arizona Division of Emergency Management	DISASTER AND EMERGENCY RESPONSE IN ARIZONA: A PROGRAMMATIC APPROACH
2/13/02	Andrew Ellis	ASU-GEO	PHYSICAL AND SOCIAL CONSIDERATIONS IN ANALYZING HIGH PM EPISODES WITHIN THE DOUGLAS, AZ-AGUA PRIETA, SON AIRSHED
2/20/02	Harvey Bryan	ASU-ARCH	ENVIRONMENTAL RATING SYSTEMS FOR BUILDINGS
2/27/02	J. Christopher Doran	Pacific Northwest National Laboratory	AN OVERVIEW OF THE PHOENIX 2001 SUNRISE EXPERIMENT

3/6/02	Peter Hyde	AZ ADEQ	UNDERSTANDING AIR POLLUTION PHENOMENA THROUGH THE APPLICATION OF ATMOSPHERIC SCIENCE
3/20/02	Greg Huey	Georgia Tech	MEASUREMENTS OF ATMOSPHERIC SPECIES IN REMOTE ENVIRONMENTS
3/27/02	Robert M. Banta	NOAA	URBAN AIR POLLUTION AND OTHER CONTAMINANTS
4/3/02	JCR Hunt	University College, London	DEVELOPMENTS IN SOME CONCEPTS AND THEORY OF MESOSCALE MODELLING
4/10/02	Jordan Peccia	ASU-CE	GERMICIDAL EFFECT OF UV RADIATION ON AIRBORNE MICROORGANISMS
4/17/02	Joseph Zehnder	ASU-GEO	MODELING OF THE URBAN CLIMATE USING THE PSUN/NCAR MESOSCALE MODEL (MM5)
4/24/02	Tony Brazel	ASU-GEO	CENTRAL ARIZONA CLIMATE THROUGH THE LENS OF GEOGRAPHICAL SCALE
8/28/02	Greg Raupp	ASU-CME	SECURE AND IMMUNE FUNCTIONING FACILITIES
9/4/02	Peter Hyde	AZ ADEQ	URBAN PLUME TRANSPORT AND EFFECTS ON THE ECOSYSTEM
9/11/02	Patrick Paul	Snell & Wilmer, L.L.P., Legal Offices	AN OVERVIEW OF U.S. ENVIRONMENTAL REGULATIONS
9/18/02	Pat Cupell	AZ DOT	AIR AWARE
9/25/02	Ira Domsy	AZ ADEQ	AIR POLLUTION CONTROL AND AIR QUALITY IN THE STATE OF ARIZONA
10/2/02	James Anderson	ASU-MAE	DESERT DUST – A NOT-SO-NATURAL AGENT OF CLIMATE CHANGE
10/9/02	Cathy Arthur	Maricopa Assoc. of Governments	URBAN LAND USE, TRANSPORTATION AND AIR QUALITY MODELING
10/16/02	Michael Brown	LANL	URBAN DISPERSION MODELING FOR CHEM-BIO TERRORIST ATTACK VULNERABILITY ASSESSMENTS IN U.S. CITIES
10/23/02	Ray Quay	City of Phoenix	APPLICATION OF FUTURE ANALYSIS TO PUBLIC LAND USE POLICY
10/30/02	Martin Leach	LLNL	THERMALLY DRIVEN CIRCULATION AND EFFECTS ON ATMOSPHERIC DISPERSION
11/6/02	Rory MacArthur	Chevron Products Co.	FUELS-RELEVANT TECHNICAL ADVOCACY IN AIR QUALITY ISSUES
11/13/02	Rita Walton	MAG	SOCIOECONOMIC MODELING AT MAG
11/20/02	Rob Newsom	Colorado State Univ.	INITIALIZING A LARGE EDDY SIMULATION USING COHERENT DOPPLER LIDAR DATA
12/4/02	Braden Allenby	Univ. of Virginia	EARTH SYSTEMS ENGINEERING AND

**EFD Seminars in 2002**

<b>DATE</b>	<b>SPEAKER</b>	<b>AFFILIATION</b>	<b>TITLE</b>
1/1/02	Vince C. Wong	University of Oklahoma	PARAMETERIZATION AND A NEW UNIVERSAL SCALING LAW IN TURBULENT FLOWS
1/18/02	Jong-Jin Baik	Seoul National University, Korea	SOME DYNAMICAL ASPECTS OF URBAN METEOROLOGY
1/25/02	David R. Bright	National Weather Service	SHORT-TERM MESOSCALE ENSEMBLE FORECASTS OF PRECIPITATION FOR ARIZONA DURING THE MONSOON
1/31/02	Owen R. Cote	Air Force Research Laboratory	AIRBORNE MEASUREMENTS OF REFRACTIVE TURBULENCE AND CLEAR AIR TURBULENCE IN STABLE STRATIFICATION: SPECTRA, BUDGETS AND THE PREDICTION PROBLEM
2/8/02	Firat Testik	ASU-MAE/EFD	THE BEHAVIOR OF CYLINDRICAL OBJECTS ON A SANDY SLOPE UNDER SHOALING WAVES
2/15/02	Rodolfo V. Rodriguez	ASU-MAE/EFD	DISPERSION EXPERIMENTS IN A MIXING ZONE DUE TO SHEAR FLOW AND OSCILLATING MOTION
2/22/02	Iossif Lozovatsky	ASU-MAE/EFD	SPATIAL DECAY OF TIDAL INTERNAL WAVES NEAR SUBMARINE RIDGES
3/1/02	Susanne Grossman-Clarke	ASU-MAE/EFD	NUMERICAL SIMULATIONS OF CARBON MONOXIDE IN THE PHOENIX METROPOLITAN AREA USING ADMS-URBAN
3/8/02	Dragan Zajic	ASU-MAE/EFD	FLOW AND TURBULENCE SURROUNDING A BUILDING CLUSTER
3/11/02	Robert Radcliffe Long	Johns Hopkins University	KOLMOGOROV THEORY OF ENERGY SPECTRUM: A CRITICAL LOOK
3/22/02	Marko Princevac	ASU-MAE/EFD	STUDY OF KATABATIC FLOWS
3/29/02	Frank Jacobitz	University of California, Riverside	DIRECT NUMERICAL SIMULATIONS OF TURBULENT STRATIFIED SHEAR FLOW
4/5/02	Francis Dalaudier	Service d'Aeronomie du CNRS, France	COORDINATED RADAR-BALLOON MEASUREMENTS DURING THE MUTSI CAMPAIGN
4/12/02	Sang-Mi Lee	ASU-CE/EFD	A NUMERICAL STUDY ON THE SPATIAL AND TEMPORAL VARIATION OF OZONE IN THE PHOENIX VALLEY
4/12/02	Nail K. Yamaleev	NASA Langley Research Center	INSIGHT INTO THE ACCURACY OF ADAPTIVE GRID METHODS FOR CAPTURED SHOCKS
4/19/02	Jae-Jin Kim	ASU-MAE/EFD	A CFD MODEL FOR SIMULATING URBAN FLOW AND DISPERSION
4/26/02	Zhihe Zhao	ASU-MAE/EFD	A STUDY OF SCOUR AROUND MINES

4/29/02	Robert D. Bornstein	San Jose State University	MM5 MODELING OF METEOROLOGICAL CONDITIONS DURING A 1997 SOUTHERN CALIFORNIA AIR QUALITY STUDY (SCOS97) OZONE EPISODE
5/17/02	John A.T. Bye	University of Melbourne, Australia	THE GENERATION OF WIND WAVES IN CIRCULAR TANKS
7/25/02	Daoyi Chen	University of Manchester, UK	TURBULENCE STRUCTURES AND POLLUTANT RELEASE/TRAPPING AT A ROUGH-BED IN OSCILLATORY FLOWS
8/30/02	Ronald Calhoun	ASU-MAE/EFD	AN INTRODUCTION OF ASU's LIDAR
9/6/02	Andjelka Srdic	ASU-MAE/EFD	IMPACT OF THE BOUNDARY TURBULENCE ON A LARGE SCALE COASTAL FLOW
9/13/02	Dragan Zajic	ASU-MAE/EFD	A STUDY OF FLOW IN THE FIRST URBAN CANYON
9/20/02	Rodolfo Vazquez Rodriguez	ASU-MAE/EFD	CONCENTRATION AND VELOCITY GRADIENTS AROUND THE MIXING ZONE CREATED BY TRAFFIC MOTION IN HIGHWAYS
9/27/02	Zhihe Zhao	ASU-MAE/EFD	A STUDY OF SCOUR AROUND MINES IN SHOALING WATERS
10/4/02	Binson Joseph	ASU-MATH	TURBULENCE VARIABILITY AND SCALABILITY IN A MODEL TROPOPAUSE
10/11/02	Firat Testik	ASU-MAE	LABORATORY STUDY OF TILTED ROTATING CONVECTION
10/14/02	Vitalii Sheremet	Woods Hole Oceanographic Inst.	NUMERICAL SIMULATIONS ON IMMERSSED BOUNDARY TECHNIQUE
10/18/02	Hemanth Gokula	ASU-CFD Resch. Group	EVALUATION OF METEOROLOGICAL MODELS, MM5 AND HOTMAC, USING PAFEX-I DATA
10/25/02	Sang-Mi Lee	ASU-CEE/EFD	THE APPLICATION OF LIDAR DATA
10/31/02	Daniel Cooper	LANL	DEVELOPMENT OF AN ATMOSPHERIC SMALL SCALE TURBULENCE PREDICTION CODE
11/1/02	Kwang-Leung Tse	ASU-MATH	COMPLEX DYNAMICS IN A SHORT TAYLOR-COUPETTE ANNULUS
11/8/02	John Lopez	ASU-MATH	FLOW ON MULTI-SLOPES: HYDRAULIC JUMP
11/15/02	Cristian Dumitrescu	ASU-EFD	A WAVELET APPROACH FOR TURBULENCE: COHERENT VORTEX SIMULATION (CVS)

11/22/02	Marie Farge	Ecole Normale Superieur, France	DESTRUCTION OF COLD POOLS IN COMPLEX TERRAIN AIR BASINS
12/6/02	Marko Princevac	ASU-EFD	SUSTAINABILITY SCIENCE: RESEARCH OPPORTUNITIES AND THE EMERGENCE OF A NEW METADISCIPLINE
12/13/02	John Crittenden	Michigan Tech University	DEVELOPMENT IN URBAN METEOROLOGY AND DISPERSION MODELS

### Proposals Submitted Through the EFD Program in 2002

<b>Title</b>	<b>Investigators</b>	<b>Agency</b>
ASU/ADEQ Modeling Center	HJS Fernando (MAE/EFD)	AZ ADEQ
Microstructure, chemistry and mixing states of elemental carbon in East Asian Dust	J. Anderson (MAE) A. Dillner (CEE/CME) P. Crozier (CSSS)	NOAA
ASU Industrial Assessment Center	P. Phelan (MAE) I. MOU (IE)	DOE
Acquisition of a Stereoscopic PIV system for Flow Measurements around submerged Mines in Shoaling Waves	HJS Fernando (MAE/EFD)	ONR
Mine Burial in Coastal Environments	HJS Fernando (MAE/EFD) S. Voropayev (MAE/EFD) D. Boyer (MAE)	ONR
Dynamics of Cobbles in and near the Surf Zone	HJS Fernando (MAE/EFD) S. Voropayev (MAE/EFD) D. Boyer (MAE)	ONR
Adaptive Tracking of Atmospheric Releases	R. Calhoun (MAE) HJS Fernando (MAE/EFD)	ARO
Flow and Mixing over Shallow Seamounts: Modeling and Observation	D. Smith (MAE/EFD) I. Lozovatsky (MAE/EFD) HJS Fernando (MAE/EFD)	NSF
Numerical Modeling of Canyon Flows as influenced by Boundary Turbulence	D. Boyer (MAE) D. Smith (MAE/EFD) A. Srdic (MAE/EFD)	NSF
Multi-Scale Flow Phenomena in Complex Terrain: Mathematical Descriptions of Field Observations and Numerical Forecasts	J. Lopez (MATH) HJS Fernando (MAE/EFD) A. Mahalov (MATH) B. Nicolaenko (MATH)	NSF
An Integrated Study of Atmospheric Nutrient Deposition and Ecosystem	J. Allen (CME) N. Grimm (BIO) J. Wu (BIO)	NSF

Responses in an Urban Environment	HJS Fernando (MAE/EFD)	
Urban Fluid Mechanics: A REU Supplement	HJS Fernando (MAE/EFD)	NSF
Intelligent Geometry: Extraction, Recognition, Prediction using Spatial Data Sets	G Farin (CSE/PRSIM) G Nielson (CSE) A Razdan (VPR) J Rowe (IT) R Greeley (GEOL) H Liu (CSE) M Tocheri (ANTH) M Henderson (IS) D Collins (CFA) C Gries (PBIO) HJS Fernando (MAE/EFD)	NSF
Effects of Prescribed Burns on Air Quality in the Yuma/San Luis Area	HJS Fernando (MAE/EFD) SM Lee (CEE/EFD) J Anderson (MAE)	SCERP
A Field Study of Particulate Emissions from Major Roadways in the Phoenix Airshed	J Anderson (MAE) HJS Fernando (MAE/EFD)	NSF
Studies on Oceanic Mushroom-like Currents and other Self-Propagating Vortices	S Voropayev (MAE) HJS Fernando (MAE/EFD) D Smith (MAE)	NSF
Urban Scale Flow Modeling	SM Lee (CEE/EFD) HJS Fernando (MAE/EFD)	Univ of Houston
IGERT: Urban Atmospheres: Observations, Modeling and Management	HJS Fernando (MAE/EFD) V Burrows (CME) H Campbell (PAF) G Raupp (CME) J Zehnder (GEOG)	NSF
Chemical and Physical Characterization of Aerosol from Prescribed Agricultural Burns in the Yuma/San Luis Area	J Anderson (MAE) HJS Fernando (MAE/EFD) A Dillner (CEE/CME) J Allen (CEE/CME)	SCERP

#### Awards received through the EFD Program in 2002

<b>Title</b>	<b>Investigators</b>	<b>Agency</b>
*Coupled Physical Numerical Models of the Nonlinear Interaction Between Coastal Trapped Waves, Mean Currents & Complex Topography	D. Boyer (MAE)	NSF
*Advanced Sensor	R. Calhoun (MAE)	Lawrence Livermore

Integration into NARAC's Atmospheric Data Assimilation Program		National Lab
*Effects of Prescribed Burns on Air Quality in the Yuma/San Luis Area	HJS Fernando (MAE/EFD) SM Lee (CEE/EFD) J. Anderson (MAE)	SCERP
Individual-particle Investigations of East Asian aerosols during ACE-Asia	J. Anderson (MAE/EFD)	NSF
Studies of Mine Burial in Coastal Environments	H.J.S. Fernando (MAE/EFD) S. Voropayev (MEA/EFD) A. Srdic (MAE/EFD) D. Boyer (MAE)	ONR
Dynamics of Cobbles in the Surf Zone	H.J.S. Fernando (MAE/EFD) S. Voropayev (MAE/EFD) D. Boyer (MAE)	ONR
Specific Tasks for Douglas/Agua Prieta Airshed Modeling	J. Zehnder (GEOG) H.J.S. Fernando (MAE/EFD)	Arizona Department of Environmental Quality
Vertical Transport and Mixing in Complex Terrain Airsheds	H.J.S. Fernando (MAE/EFD) J. Anderson (MAE) D. Boyer (MAE)	DOE
Interpretation of SHEBA data using Numerical Models	D. Smith (MAE) H.J.S. Fernando (MAE/EFD)	NSF
Urban Fluid Mechanics: Thermal Circulation in Complex Terrain	H.J.S. Fernando (MAE/EFD)	NSF
Effects of Roughness and Thermal Inhomogeneities on Urban Flows	H.J.S. Fernando (MAE/EFD) D. Boyer (MAE)	ARO
Studies on Environmental Turbulent Flows: REU Supplement	H.J.S. Fernando (MAE/EFD)	NSF
Laboratory Benchmarks for the Development of Numerical Models	D Boyer (MAE) HJS Fernando (MAE/EFD) A Srdic (MAE)	ONR
Statistics and Variability of Turbulence Dynamics in the Middle Atmosphere	B Nicolaenko (MATH) A Mahalov (MATH) HJS Fernando (MAE/EFD)	AFOSR
A Field Study of Particulate Emissions from Major Roadways in the Phoenix Airshed	J Anderson (MAE) HJS Fernando (MAE/EFD)	ADOT

**TOTAL AWARDS - \$1,789,217**

\*denotes new

## EFD Facilities and Laboratories

The Environmental Fluid Dynamics (EFD) Laboratory at Arizona State University (ASU) is a 5000 sq. ft. state-of-the-art facility. A complete array of instrumentation is available for flow diagnostics and data analysis. This includes two- and one-component (TSI and Dantec) Laser-Doppler Velocimeters (including a Dantec fiber-optic system), (Sontek) three-component Acoustic-Doppler Velocimeters, two laser-induced fluorescence systems, three DigImage particle-tracking velocimetry systems (developed by the Cambridge Environmental Research Consultants; Dalziel 1993), two Particle-Image Velocimetry (PIV) systems including a stereoscopic, an in-house built three-component particle-tracking system, micro-scale conductivity probes, FP-07 thermistor probes, thermocouples and their monitoring systems. Also with the help of Professor T. Kowalewski (Polish Academy of Sciences), a combined whole-field velocity/temperature measurement (liquid-crystal thermographic) system has been installed, which will be a valuable tool for proposed research. A computer controlled heating/cooling system capable of producing any desired temperature cycle is available (Affinity Instruments chiller, 5-40°C range, 8GPM throughput).

EFD maintains an array of field equipment. Three instrumented trailers (acquired from a previous grant from the Arizona Department of Transportation) and one mobile laboratory (operated by the Center of Solid State Sciences) will be available in support of the fieldwork (see Figure I.1). The available instrument array is listed in the following tables.

### BALLOON SYSTEMS

<i>Quantity</i>	<i>Item</i>
3	9 m <sup>3</sup> Tether balloon
1	Regulators for helium gas
3	Winch
6	Tethersonde
3	Receiver
3	Amplifier
3	Antenna
4	DustTrak (3 suitcase and 2 environmental enclosure)
9	Aerosol sampler (Streaker)
1	1 1/8 Wrench for regulator

### TOWER (MAST) SYSTEMS

<i>Quantity</i>	<i>Item</i>
3	Sonic anemometer (Applied Technology, Metek USA-1; Campbell)
2	Tower (14m and 18m)
2	Cup anemometer
20	Thermocouples + Radiation shields
2	Data logger for cup anemometer and thermocouple OM-220
1	Pyrgeometer ( long wave )
1	Pyranometer ( short wave )
2	IR thermometer 4000.3ZL, Everest Interscience
4	Dataloggers CR, Campbell Scientific
1	Soil Heat Flux Plate HFP01SC-L
1	Net Radiometer CNR1, Kipp & Zonen
1	Krypton Hygrometer, Campbell Scientific

### Other Equipment

<i>Quantity</i>	<i>Item</i>
2	GPS Unit 76s - Garmin
4	Strobe light ( 3 white and 3 red )
1	Pocket data logger
1	Omega data logger OM-440 (back-up)
3	TEOM Instrument

Ample computer facilities (including several workstations) are available for data acquisition and

reduction, including the recently opened joint ASU-ADEQ modeling center with state-of-the-art computer facilities (funded by the Arizona Department of Environmental Quality). An impressive complement to the point and profiling instrumentation described above is the recently acquired Doppler Lidar (manufacturer: Coherent Technologies) through a (DURIP) grant from the Department of Defense (PIs: R. Calhoun and H.J.S. Fernando). Owing to its eye-safe infrared laser beam (2mJ/pulse at 400Hz) and direct measurement of aerosol backscatter, this Lidar is ideally suited to measure winds and aerosols in urban environments. Three-dimensional, roughly hemispherical regions of the atmosphere (~ 25km diameter) can be scanned within minutes. ASU is the first university to acquire a commercial Lidar of this type for research purposes. The acquisition of this Lidar has opened up new research directions for ASU researchers. Field tests have demonstrated that the new Lidar can be used to detect above ambient clouds of bio-aerosols, thus allowing new combined sensor/model approaches to civil defense of major metropolitan areas such as Phoenix.



The instrumented vehicle fleet available for the proposed field studies. Three trailers (background) are fully instrumented with TEOM and DUSTRACK instruments for aerosol measurements and retractable meteorological towers for flow measurements. The mobile laboratory (foreground) operated by the Center for Solid State Science carries numerous measurement and analysis instruments.



ASU Eye-Safe Doppler Lidar manufactured by Coherent Technologies.

## Summary

During 2002, the EFD program continued its progress with regard to research, teaching and service activities. The Energy Management Program (headed by Professor P. Phelan, MAE) was also housed within the EFD program. The CEAS allocation of funding for the program in 2002 was \$56,000 (operations budget). Numerous ASU faculty members and research associates submitted proposals and pre-proposals through the program. The awards for 2002 totaled \$1,789,217 and the expenditures were \$1,972,943. The program continued to oversee several multi-disciplinary initiatives, with participating faculty from various departments at ASU. A successful visiting faculty/scientist and post-doctoral program was in place through which, in 2002, EFD hosted 8 long-term visitors. Two excellent seminar series (Ecosystems Engineering Seminar and the EFD Seminar) were in place.

Numerous joint research publications were coordinated through the program. Steps were taken to provide infrastructure support for a first-rate graduate program; these included the offering of multi-instructor courses cross-listed between different departments. A first-rate Environmental Fluid Dynamics Laboratory accessible to the entire EFD faculty, a high-end computing support facility and a host of field experimental facilities were maintained. Service activities included organization of national and international meetings, outreach programs to local schools and consulting to several industrial outfits.

All the achievements noted in this report would not have been accomplished without the generous support of the College of Engineering and Applied Sciences, the host-department of the program (Mechanical and Aerospace Engineering) and active participation of the EFD faculty, staff and students. The EFD program wishes to thank everyone who contributed to its research, teaching and service activities. For further information, please visit our website <http://www.eas.asu.edu/~pefdhome/>.