ENVIRONMENTAL RESEARCH LABORATORIES

AIR RESOURCES LABORATORY

ATMOSPHERIC TURBULENCE AND DIFFUSION DIVISION

OAK RIDGE, TENNESSEE, U.S.A.

1992 ANNUAL REPORT

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ATDD Contribution File No. 93/6

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PREFACE

The following is a compilation of summaries of research contributions produced during the calendar year 1992 by the Atmospheric Turbulence and Diffusion Division of the National Oceanic and Atmospheric Administration's Air Resources Laboratory. In some cases, the contributions were published during the year. In other cases, the manuscripts are pending publication, and hence cannot be considered "final." In all cases, copies of the papers are generally available from the appropriate author(s). The research reported in this document was performed under agreements between the National Oceanic and Atmospheric Administration and the following agencies: U.S. Department of Energy, U.S. Environmental Protection Agency, U.S. National Park Service, U.S. Department of Defense (Air Force and Army), and the National Aeronautics and Space Administration.

Rayford P. Hosker, Jr., Director
Atmospheric Turbulence and Diffusion Division

CONTENTS

ATMOSPHERIC TURBULENCE AND DIFFUSION DIVISION
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BACKGROUND

The Atmospheric Turbulence and Diffusion Division (well known in the atmospheric dispersion community as the Atmospheric Turbulence and Diffusion Laboratory, ATDL) is one of several field facilities of NOAA's Air Resources Laboratory, headquartered in Silver Spring, Maryland. The laboratory conducts research on matters of atmospheric diffusion and turbulent exchange, concerning air quality. ATDD focuses attention on the physics of the lower atmosphere, with special emphasis on the processes contributing to atmospheric transport, dispersion, and deposition, and on the development of predictive capabilities using the results of this research. Research is directed toward issues of national and global importance, related to the missions of NOAA, DOE, and to DOE's Oak Ridge Operations Office. The research is divided into six major projects, as follow: plume transport and diffusion in the planetary boundary layer, complex topography, canopy micrometeorology, dry deposition, emergency preparedness, and physical (wind-tunnel) modeling. The objectives of this laboratory's research are three fold: (1) to develop better methods for describing atmospheric transport, diffusion, and deposition in numerical simulations, (2) to extend the applicability of these techniques to non-ideal situations such as non-stationary conditions, complex terrain, and dense vegetation, and (3) to develop and test improved numerical models incorporating these new methods.

Research programs are undertaken with the assistance of personnel of the Energy/Environment Systems Division of Oak Ridge Institute of Science and Education (ORISE), and in close collaboration with scientists from the Oak Ridge National Laboratory and various other organizations, universities, government agencies, and private research institutions operating in our area of expertise.

The laboratory is located at 456 South Illinois Avenue, Oak Ridge, Tennessee, with a permanent field station set up some five miles away, adjacent to Oak Ridge National Laboratory's Walker Branch Watershed experimental area.

PERSONNEL (calendar year 1992)

Administrative

R. P.	Hosker, Jr., Ph.D.	Director
B. S.	Johnson	Administrative Officer

Administrative Support

L.	Chambers, B.A.* **	Library Technician
S. D.	Conger	Divisional Secretary
R. A.	Green* **	Administrative Assistant
K. L.	Hill, B.S.*	Word Processor
C. L.	Kitzmiller* **	Student Aide
O. H.	Pearson**	Procurement Clerk
W. S.	Sheffield* **	Purchasing and Travel Assistant
K. M.	Kelley	Student Aide
J. L.	Duncan	Student Aide

Scientific and Engineering

D. L.	Auble, B.S.	Instrument Design and Development
D. D.	Baldocchi, Ph.D.	Canopy Micrometeorology, Dry Deposition
K. R.	Birdwell, B.S.*	Meteorological Computer Specialist
T. L.	Crawford, Ph.D.	Atmospheric Chemistry and Modeling
R. J.	Dobosy, Ph.D.*	Dispersion Modeling
R. M.	Eckman, Ph.D.	Turbulence and Dispersion
M. E.	Hall, B.S.*	Field Engineer and Field Site Manager
J. A.	Herwehe, M.S.	Dispersion Modeling
R. P.	Hosker, Ph.D.	Dispersion and Deposition
D. R.	Matt, Ph.D.	Dry Deposition and Atmosphere-Surface Exchange
R. T.	McMillen, M.S.	Dry Deposition and Field Programs
T. P.	Meyers, Ph.D.	Turbulent Exchange and Modeling
C. J.	Nappo, Ph.D.	Turbulence and Dispersion
W. R.	Pendergrass, M.S.	Emergency Preparedness Manager
J. W.	Przybylowicz, Ph.D.*	Dispersion Modeling
K. S.	Rao, Ph.D.	Turbulence and Dispersion
J. R.	White, B.S.*	Physical Modeling and Particle Studies
J. D.	Womack, M.S.*	Dry Deposition and Atmospheric Chemistry

Personnel (continued)

Technical Support

J.	Gholston*	Instrumentation, Shop
D. J.	Hunter, III* **	Data Analysis
R. M.	Mayhew*	Machining, Shop
L. C.	Satterfield, B.S.*	Computing, Dry Deposition
J. L.	Sharp	Instrumentation, Shop, Communication
J.	Wynn, B.A.*	Climatological and Dry Deposition Data Management

Visiting Scientist(s)

S. A.	Collineau, Ph.D. Candidate[1]	Canopy Micrometeorology
A. H.	Luhar[2]	Atmospheric Dispersion Modeling in Complex Terrain
C. A.	Vogel, Ph.D.[3]	Boundary Layer Turbulence

* Appointment through ORAU
** Part-time Appointment
*** Appointment through Analysas
**** Appointment through TRESP
1 On leave from INRA (National Institute of Agronomic Research), Paris, France
2 NRC Post-Doctoral Fellowship from Cambridge University
3 DOE Global Change Distinguished Postdoctoral Fellow

FOREWORD

Purpose

Existing techniques for estimating atmospheric dispersion depend largely on the results of the numerous diffusion experiments conducted during the 1950s and early 1960s. Consequently, most contemporary parameterizations of atmospheric dispersion rates apply only in steady-state conditions and idealized terrain. However, current theories and recent experiments are forcing a reconsideration of these results. Extension to the natural situation in which conditions are continually changing and where the surface is neither flat nor uniform is a complicated process. This laboratory has played a leading role in the development of many of the relationships currently popular for use in dispersion models. This role has evolved into a continuing effort to modify the steady-state formulations developed over the last several decades, in order to simulate atmospheric transport, diffusion, and deposition in situations that are not constrained by temporal stationarity or spatial uniformity.

Historical Foundation

Concern about the consequences of accidents involving atmospheric releases of hazardous chemicals is certainly not new; such concern underlies much of the long history of research into atmospheric dispersion. The subject of emergency response and preparedness was recognized as an issue of importance by those involved even in the earliest studies of nuclear fission and atomic energy. Much of this early work was conducted at Oak Ridge, where a combination of terrain and resource availability had led to its selection as the principal site of the Manhattan Project. The fear of an accident, and the potential repercussions, were high in the list of factors that had to be considered in the choice of the Oak Ridge location, and in the detailed location of each plant on the Oak Ridge reservation. As work of the Atomic Energy Commission progressed, and as other plants were set up at locations distributed across the nation, meteorological support became standard. At some places, the meteorological support was established as an in-house activity, but at other locations the U.S. Weather Bureau was called on.

At Oak Ridge, it was the U.S. Weather Bureau that was asked to provide the meteorological services required to support the three local installations. As time progressed, the Weather Bureau evolved into the Environmental Science Services Administration, and at this time the operation at Oak Ridge became the Atmospheric Turbulence and Diffusion Laboratory, under the direction of Dr. F. A. Gifford. Later, ESSA was changed to NOAA (the National Oceanic and Atmospheric Administration), and the ATDL became the Atmospheric Turbulence and Diffusion Division of NOAA's Air Resources Laboratory. A principal contribution of the early activity was the now-famous document ORO-99, a detailed review of the local atmospheric conditions. Scrutiny of this document reveals that the basis for much of the existing Gaussian-plume modeling capability was outlined first in ORO-99; the models were developed in the scientific papers that followed the publication of ORO-99.

In its early years of operation, this laboratory operated a network of meteorological stations arranged to meet the needs of government facilities in the Oak Ridge area. This was, perhaps, the first operational remote telemetering network of its kind. Output from the meteorological stations was collected by ATDD, and served as a basis for the initiation of much of the research and the development of many of the models for which ATDD became best known. After nearly two decades of operating this network, funding for it was terminated, and the network was reluctantly withdrawn. Research on atmospheric dispersion continued, but without the practical focus that had been provided by the direct association with warning systems.

Recent events have concentrated public attention on matters of atmospheric releases and related emergencies. The magnitude of potential problems became apparent following a series of major disasters, such as the Bhopal, India accident. The recognition of a need for an improved, coordinated activity related to atmospheric emergencies has resulted in the identification of this laboratory as DOE's main advisor in this region and in this area of expertise. This clearly-specified role provides a re-sharpened focus on the dispersion research for which this laboratory is noted.

In the last ten years, the laboratory has also become heavily involved in studies of air-surface exchange of atmospheric trace gases and particles. Much of this work has been part of the National Acid Precipitation Assessment Program, with the primary focus on dry deposition. More recently, however, attention is being given to the net exchange of pollutants essential to more general studies of global tropospheric chemistry and climate change. The work couples with the dispersion studies mentioned above, since the surface exchange constitutes the areal source and sink function needed in dispersion models.

Work on the theory and modeling of atmospheric dispersion and deposition has received support from several federal sponsors, including the Nuclear Regulatory Commission, the Environmental Protection Agency, the National Park Service, the Army Research Office, the National Aeronautics and Space Administration, and the Air Force, among others. Projects typically involve developing new simulations, and updating existing models on the basis of recent experimental and theoretical results. Special studies may require other methods; for example, for the National Park Service, studies are being conducted of the flow around monuments and specimens of materials used in construction. All studies of this kind complement ongoing NOAA and DOE studies.

APPROACH

ATDD activities are divided into four major areas and into six major projects as follow.

Diffusion

A. **Dispersion and PBL Studies**. This work is extending contemporary understanding of transport and dispersion in the lower atmosphere to non-stationary conditions and is providing improved methods to estimate atmospheric plume dispersion. Current activities focus on the role of sporadic nocturnal turbulence as a mechanism for accelerating dispersion at night, and on the consequences of releases of dense and/or chemically reactive pollutants.

B. **Complex Topography**. As part of the DOE's ASCOT program, this laboratory is conducting a coordinated program of field studies, theoretical investigations, and numerical modeling involving sites of various complexities to extend existing parameterizations for pollutant transport and dispersion to non-simple terrain.

Turbulent Exchange

C. **Canopy Micrometeorology**. Atmospheric transport, diffusion, and deposition of airborne materials are influenced by the roughness and thermal characteristics of the underlying surface. In the case of vegetated surfaces, biological factors also come into play. This research effort is designed to identify and quantify the interactions involved in above- and within-canopy transport, dispersion, and deposition, and in canopy-atmosphere exchanges of materials and energy. Such information will be used to include physical and biological surface effects in numerical models.

D. **Dry Deposition**. The dry exchange of airborne trace gases and particles at the surface has been identified as a major issue by the National Acid Precipitation Assessment Program. A "CORE" network of three research sites has been set up under joint DOE, NOAA, and EPA sponsorship. These sites are intended to provide reference data for a more extensive network of routine air-concentration and meteorological monitoring stations now established as "CORE/satellite" stations. Parameterizations developed in this program will be used to interpret data obtained in field applications of the "concentration monitoring" approach to dry deposition monitoring. Recent interest in global climate change and the so-called "greenhouse gases" is resulting in increased emphasis on trace gases such as carbon dioxide and methane, as well as the previously studied pollutants.

Emergency Preparedness

E. **Emergency Preparedness Activities**. A special independent effort concentrates on matters related to emergency preparedness in the jurisdiction of the Oak Ridge Operations Office of DOE. The focus of the ATDD/ORO emergency preparedness activity is on near-field planning and rapid response to accidental releases. Close collaboration with the existing DOE/LLNL Atmospheric Release Advisory Capability (ARAC) is seen as a necessary feature of the system, but has yet to be fully implemented. In concept, the local operation concentrates on the near field and rapid response, whereas ARAC is maintained in a stand-by mode, ready for rapid utilization if a large release occurs or if additional resources are needed to handle local problems.

Physical Modeling

F. **Physical Modeling**. Contemporary mathematical models of plume dispersion are not yet adequate to calculate concentrations of pollutants when the plume is affected by hills or buildings. Small scale models immersed in the flow of a wind tunnel or water channel (i.e., fluid models) can frequently be used to simulate transport and diffusion in a timely and relatively inexpensive manner. A wind tunnel is available for modeling studies in conjunction with ATDD programs. This program supports each of the preceding major components, and also receives independent support for intensive studies of dispersion around and deposition to obstacles.

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: On the Use of the Inferential Technique to Estimate Dry Deposition of SO_2.

Author(s): D. R. Matt and T. P. Meyers

Status: *Atmospheric Environment* 27A(4):493-501 (1993).

SUMMARY

Inferred dry deposition rates of SO_2 determined using concentrations from a continuously operated chemical monitor are compared to results obtained from weekly averages, a protocol that is currently employed in many dry deposition networks. Results from two years of data were compared to evaluate any seasonal differences in the uncertainty using a weekly sampling protocol. In general, a weekly sampling protocol was found to underestimate the flux by 40% during the growing season when the diurnal cycle of estimated deposition velocity was found to correlate with measured hourly concentrations. For leafless forest conditions, no consistent correlation was found. This result is a 20% underestimate of the flux on an annual basis.

ATDD Contribution File No. 92/1

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Fast Response Instrumentation for Methane Flux Measurements: II. Emission Rates From a Landfill

Author(s): T. P. Meyers*, D. C. Hovde, A. C. Stanton, and D. R. Matt*

Status: To be published in *Journal of Atmospheric Chemistry*.

SUMMARY

We describe a fast response methane sensor based on the absorption of radiation generated with a near-infrared InGaAsP diode laser. The sensor uses an open path absorption region 0.5 m long; multiple pass optics provide an optical path of 50 m. High frequency wavelength modulation methods give stable signals with detection sensitivity (S/N=1, 1 Hz bandwidth) for methane of 65 ppb at atmospheric pressure and room temperature. Improvements in the optical stability are expected to lower the current detection limit. We used the new sensor to measure, by eddy correlation, the CH_4 flux from a clay-capped sanitary landfill. Simultaneously we measured the flux of CO_2 and H_2O. From seven half-hourly periods of data collected after a rainstorm on November 23, 1991, the average flux of CH_4 was 17 mmol $m^{-2}hr^{-1}$ (6400 mg CH_4 m^{-2} d^{-1}) with a coefficient of variation of 25%. This measurement may under-represent the flux by 15% due to roll-off of the sensor response at high frequency. The landfill was also a source of CO_2 with an average flux of 8.1 mmol $m^{-2}hr^{-1}$ (8550 mg $CO_2m^{-2}d^{-1}$) and a coefficient of variation of 26%. A spectral analysis of the data collected from the CH_4, CO_2, and H_2O sensors showed a strong similarity in the turbulent transfer mechanisms.

*NOAA/ATDD

ATDD Contribution File No. 92/2

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Trace Gas Exchange Above the Floor of a Deciduous Forest II. SO_2 and O_3 Deposition

Author(s): T. P. Meyers and D. D. Baldocchi

Status: *Journal of Geophysical Research* 98(D7):12631-12638 (1993).

SUMMARY

The pollutant uptake capacity of the surface beneath forest canopies is poorly understood. In this study we show that the eddy correlation method can be applied within a canopy. Direct measurements of SO_2 and O_3 deposition to the forest floor of two deciduous forests were made with the eddy correlation method. For dry periods the surface uptake resistance for SO_2 was on the order of 700 s m^{-1}. When the soil and litter were moist, the SO_2 surface uptake resistance was small, resulting in deposition velocities at the forest floor that were about 2 times greater than during dry periods. SO_2 deposition to the forest floor constitutes between 20 and 30% of total uptake to the forest ecosystem when the surface is moist. Soil surface uptake resistances for O_3 were about 2000 s m^{-1} for both wet and dry periods.

*NOAA/ATDD

ATDD Contribution File No. 92/3

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A National Critical Loads Framework for Atmospheric Deposition Effects Assessment: III. Deposition Characterized[1]

Author(s): B. B. Hicks*, R. T. McMillen*, R. S. Turner, G. R. Holdren, Jr., and T. C. Strickland

Status: *Environmental Management* 17(3):343-353 (1993).

SUMMARY

Methods are discussed for describing patterns of current wet and dry deposition under various scenarios. It is proposed that total deposition data across an area of interest are the most relevant in the context of critical loads of acidic deposition, and that the total (i.e., wet plus dry) deposition will vary greatly with the location, the season, and the characteristics of individual subregions. Wet and dry deposition are proposed to differ in such fundamental ways that they must be considered separately. Both wet and dry deposition rates are controlled by the presence of the chemical species in question in the air (at altitudes of typically several kilometers in the case of wet deposition, and in air near the surface for dry). The great differences in the processes involved, lead to the conclusion that it is better to measure wet and dry deposition separately and combine these quantifications to produce "total deposition" estimates than to attempt to derive total deposition directly. A number of options for making estimates of total deposition to be used in critical loads assessment scenarios are discussed for wet deposition (buckets and source receptor models) and for dry deposition (throughfall, micrometeorology, surrogate surfaces and collection vessels, inference from concentrations, dry-wet ratios, and source-receptor models).

*NOAA/ATDD

ATDD Contribution File No. 92/4

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Deposition of Gaseous Sulfur Compounds to Vegetation

Author(s): D. D. Baldocchi

Status: Presented at the Workshop on Sulfur Nutrition and Assimilation in Higher Plants: Physiological Functions and Environmental Significance, April 21-25, 1992, Garmisch-Partenkirchen, Germany, and published in *Sulfur Nutrition and Assimilation in Higher Plants: Physiological Functions and Environmental Significance,* L. J. De Kok et al., eds., pp. 271-293, SPB Academic Publishing bv, The Hague, The Netherlands (1993).

SUMMARY

Micrometeorological methods are used to measure and model sulfur deposition fluxes to plant canopies. The goals of this paper are to discuss experimental methods that are used to measure S concentrations and fluxes, to review the literature on field measurements of S deposition, to discuss the physical, biological, and chemical processes that control S deposition fluxes over vegetation, and to describe how these fluxes are modeled.

The predominant pathway for gaseous S uptake to dry vegetation is via turbulent transfer through the atmospheric surface boundary layer and molecular diffusion through the leaf's laminar boundary layer and the stomata. The soil surface is a significant, but weaker sink for sulfur. The appreciable solubility of SO_2 causes its uptake to be enhanced greatly in the presence of moisture on leaves and in the soil. The aqueous uptake of SO_2, however, causes the pH of a solution to decrease, which in turn produces a reduction in the solubility of SO_2.

Three classes of models have been developed to compute deposition fluxes. Big-leaf resistance models are the simplest and are used routinely; calculated flux densities are inversely proportional to the sum of resistance exerted by the turbulent boundary layer, the laminar boundary layer and the canopy surface. Multi-layer Eulerian and Lagrangian models provide a way of scaling SO_2 fluxes to leaves up to the canopy scale. These models can describe the controlling abiotic factors better. Hence, they yield more accurate estimates of deposition fluxes.

ATDD Contribution File No. 92/5

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: The Wavelet Transform In Data Analysis: Basics and Application

Author(s): S. Collineau

Status: To be published as a NOAA Technical Memorandum ERL/ARL.

SUMMARY

In the past years, numerous studies of the atmospheric surface layer involving high frequency measurements have shown the importance of intermittency in turbulent transfers. The wavelet transform, as a time-frequency representation of signals, is more likely to cope with intermittent signals than the Fourier transform. In general, the wavelet transform can be very helpful in dealing with edge-detection, band-pass filtering, and time-scale determination from turbulence measurements or any intermittent data. In this report, the basics and properties of the wavelet transform are presented. In addition, it is shown that Fast Wavelet Transform algorithms are available for particular wavelets to implement real-time processing of data. Examples are presented for turbulence data in the atmospheric surface layer over a pine forest.

ATDD Contribution File No. 92/6

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Gravity-Wave-Generated Turbulence In The Stable Boundary Layer Over Complex Terrain

Author(s): C. J. Nappo

Status: Presented at the Sixth Conference On Mountain Meteorology and included in the *Tenth Symposium On Turbulence And Diffusion*, September 29-October 2, 1992, Portland OR, pp. J64-J67, AMS, Boston, MA (1992).

SUMMARY

It is well know that mountains can generate atmospheric gravity waves which in turn vertically propagate momentum and energy into the middle and upper atmospheres. The dissipation of these waves, for example through the saturation process, results in levels of turbulence much greater than would be expected on the basis of local atmospheric stability. There are no reasons to suppose that these same phenomena do not also occur over terrain features in the stably-stratified planetary boundary layer (PBL); only the scales will be different. The turbulent stresses produced by ridges and hills a few tens of meters high will be quite small compared with those produced by mountain ranges; however, on the PBL scale this turbulence will be significant. Conventional PBL theory does not account for wave-generated-turbulence, and it is to be expected that the applications of these theories in complex terrain regions will be inaccurate.

This paper evaluates the magnitudes of wave-generated-turbulence produced over two-dimensional ridges and three-dimensional hills, and these results are compared with frictional stress values for typical PBL conditions. It will be shown that at low wind speeds, wave drag is significantly greater than friction drag. The parameterizations of these wave effects in mesoscale models are discussed.

ATDD Contribution File No. 92/7

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Airborne Measurements of Mass, Momentum, and Energy Fluxes for the Boardman-Arm Regional Flux Experiment - 1991 Preliminary Data Release and Appendix

Author(s): T. L. Crawford, R. J. Dobosy, and K. R. Birdwell

Status: NOAA Technical Memorandum ERL/ARL - 202, 57 pp. (1992).

SUMMARY

During 2-19 June 1991, the Atmospheric Turbulence and Diffusion Division of NOAA measured flux densities of mass, momentum, and energy from an airplane in support of DOE's Atmospheric Radiation Measurement (ARM) program. Over 507 horizontal flux transects were completed, along with 24 vertical atmospheric profiles, during 93 flight hours. Flux transects passed over both irrigated farmland and steppe. Of these transects, 274 were flown at low level over a specified instrumented path; 75 were flown in an "asterisk" formation (various headings centered on a flux tower); 42 were flown normal to the usual instrumented path, and 116 were flown to define vertical flux divergence. Fluxes were measured both day and night over a wide range of weather conditions.

This report describes the variations in wind, radiation, and surface temperature along with exchange of mass (CO_2, H_2O, and O_3), momentum, and energy as observed along the transects. Airborne measurements are compared with those from flux towers in wheat, corn, and steppe. In general, the measurements correspond well. The largest difference occurs at the steppe tower, with stronger heat fluxes reported by the tower. This discrepancy increases as heat flux increases. The cause may be a significant vertical flux divergence or an inconsistent specification of the mean state.

ATDD Contribution File No. 92/8

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Dry Deposition of SO_2 on Limestone and Marble: Role of Humidity and Surface Moisture

Author(s): E. C. Spiker, V. J. Comer, R. P. Hosker, Jr.*, and S. I. Sherwood

Status: Presented at and included in the *Proceedings of the 7th International Congress on Deterioration and Conservation of Stone*, Lisbon, Portugal, pp. 397-406, June 15-18 (1992).

SUMMARY

The dry deposition of gaseous pollutants on stone and other materials is influenced by atmospheric processes, the chemical characteristics of the deposited species, and the characteristics of the specific material. Previous studies have shown the importance of relative humidity and surface moisture, as well as the acid buffering capacity of a material's surface for increased SO_2 deposition. Utilizing a specially designed environmental chamber, this study quantifies the relationship among relative humidity, surface moisture, and SO_2 deposition to limestone and marble. Results indicate that SO_2 deposition on clean Salem limestone and Shelburne marble increases exponentially with relative humidity. Deposition on the limestone at 80% relative humidity was about 26 times greater than deposition on the marble. The trends indicate there would be little deposition on the limestone and marble below about 20% and 60% relative humidity, respectively. SO_2 deposition appears to be proportional to the surface area of the stone wetted by absorbed water. SO_2 deposition on structures may be strongly influenced by factors which control surface moisture, including stone type, porosity, surface finish and roughness, insolation, and the presence of hygroscopic contamination.

*NOAA/ATDD

ATDD Contribution File No. 92/9

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Recommended Meteorological Measurement Network for the Oak Ridge Y-12 Plant

Author(s): R. M. Eckman

Status: Released to U.S. Department of Energy, April (1992).

SUMMARY

Beginning in October 1989, the Atmospheric Turbulence and Diffusion Division (ATDD) conducted a meteorological site survey of the Oak Ridge Reservation. The data collection program continued for roughly one year, with occasional periods of intensive supplementary study such as the DOE ASCOT study in March 1990. The purpose of the meteorological site survey was to examine the meteorological conditions (specifically wind fields over the Oak Ridge Reservation), identify topographical influences, and provide DOE/OR with a recommendation of supplemental meteorological monitoring for the Oak Ridge Reservation to resolve the local flow field for emergency management applications.

The final Oak Ridge Site Survey report (Eckman et al., 1992) was delivered to DOE/ORO in February 1992. At the time, DOE/OR requested that ATDD re-evaluate the Oak Ridge Site Survey to provide "site-specific" recommendations instead of the "reservation-wide" system detailed in the Site Survey Report. This document provides a summary of the analysis of near-field flow conditions associated with the Y-12 facility. Potential trajectories are evaluated for releases from the ORNL facility with respect to the most probable wind conditions. This analysis, coupled with the results of the Oak Ridge Site Survey, provides recommendations for supplemental meteorological monitoring specific to the Y-12 facility. An additional eight monitoring sites are recommended, as well as the addition of an upper-air measurement capability using a Doppler Sodar.

ATDD Contribution File No. 92/10

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Atmosphere-Surface Exchange of Mercury in a Forest: Results of Modeling and Gradient Approaches

Author(s): S. E. Lindberg, T. P. Meyers*, G. E Taylor, Jr., and W. H. Schroeder

Status: *Journal of Geophysical Research* 97(D2):2519-1528 (1992).

SUMMARY

We have modified recently published dry deposition models to estimate deposition velocities (V_d) for H_g in both aerosol and vapor form to forest canopy surfaces. Aerosol and total vapor phase H_g concentrations in air previously measured at Walker Branch Watershed in Tennessee have been used with model results to estimate dry deposition to a deciduous forest. The concentration data confirm that airborne H_g is dominated by vapor forms at this site and exhibits concentrations moderately above continental background levels. The modeled V_d values reflect published data which suggest that dry deposition of H_g vapor is strongly controlled by surface transport processes--notably stomatal and mesophyll resistances, the latter dominating. Weekly mean V_d values ranged from 0.006 (winter) to 0.12 (summer) cm s^{-1}. We also measured concentration gradients of H_g vapor in air above this forest to estimate air-surface exchange during short-term experiments. While the model results indicate that the canopy is a sink for H_g vapor, the concentration profiles suggest that the forest soils are a source during some periods, the combined effect of which is net H_g fluxes in the upward direction. Application of a detailed canopy turbulence model yielded soil emission rates on the order of 50 ng H_g m^{-2} h^{-1}, ≈10% of which is deposited in the canopy. Our modeled dry deposition estimates plus limited measurements of wet deposition in this area suggest that dry and wet deposition may be comparable in magnitude.

*NOAA/ATDD

ATDD Contribution File No. 92/11

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Recommended Meteorological Measurement Network for the Oak Ridge National Laboratory

Author(s): Richard M. Eckman

Status: An in-house report prepared for U.S. DOE, Oak Ridge, TN. Given to DOE, April (1992).

SUMMARY

Beginning in October 1989, the Atmospheric Turbulence and Diffusion Division (ATDD) conducted a meteorological site survey of the Oak Ridge Reservation. The data collection program continued for roughly one year, with occasional periods of intensive supplementary study such as the DOE ASCOT study in March 1990. The purpose of the meteorological site survey was to examine the meteorological conditions (specifically wind fields over the Oak Ridge Reservation), identify topographical influences, and provide DOE/OR with a recommendation of supplemental meteorological monitoring for the Oak Ridge Reservation to resolve the local flow field for emergency management applications.

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ATDD Contribution File No. 92/12

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Summary and Data of the Atmospheric Turbulence and Diffusion Division Measurement Program During the 1991 ASCOT Study

Author(s): J. R. White and M. E. Hall

Status: Internal Report for ASCOT.

SUMMARY

The report provides a descriptive summary of the objectives, methods, instrumentation, and quality control (QC) of the experiments performed by ATDD in the vicinity of DOE's Rocky Flats facility as part of the multi-laboratory 1991 ASCOT field study. These experiments were designed to determine the role major canyons in the area play in the nocturnal drainage, and to discover if that drainage contributes significantly to the nocturnal transport and diffusion. Investigated was the evolution of the cold air drainage, including depth and speed and the height of the wind speed maximum. Also investigated was the influence, if any, of the canyons' drainage flow on each other.

A tethersonde collected hourly vertical profiles of wind speed and direction, temperature, and humidity. Data was transmitted from a 10 m tower instrumented with a propeller vane, temperature and relative humidity probe, a pyranometer, and a barometric pressure sensor to a 21X data logger.

Careful QC was observed in the field and further tests and checks were performed on instruments and data upon returning to the ATDD. Data are available on IBM PC-compatible diskettes.

ATDD Contribution File No. 92/ 13

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Oak Ridge Meteorological Site Survey K-25 Facility Evaluation

Author(s): William R. Pendergrass

Status: Generated for DOE/ORO Emergency Response.

SUMMARY

Beginning in October 1989, the Atmospheric Turbulence and Diffusion Division conducted a meteorological site survey of the Oak Ridge Reservation. The data collection program continued for roughly one year, with occasional periods of intensive supplementary study such as the DOE ASCOT study in March 1990. The purpose of the meteorological site survey was to examine the meteorological conditions -- specifically wind fields -- over the Oak Ridge Reservation, identify topographical influences, and provide DOE/ORO with a recommendation of supplemental meteorological monitoring for the Oak Ridge Reservation to resolve the local flow field for emergency management applications.

The final Oak Ridge Site Survey report (Eckman et al., 1992) was delivered to DOE/ORO in February 1992. At that time, DOE/ORO requested that ATDD re-evaluate the Oak Ridge Site Survey to provide "site-specific" recommendations instead of the "reservation-wide" system detailed in the Site Survey Report. This document provides a summary of the analysis of near-field flow conditions associated with the K-25 facility. Potential trajectories are evaluated for releases from the K-25 facilities with respect to the most probable wind conditions. This analysis, coupled with the results of the Oak Ridge Site Survey, provides recommendations for supplemental meteorological monitoring specific to the K-25 facility. An additional six monitoring sites are recommended, as well as the addition of an upper-air measurement capability using a Doppler Sodar.

ATDD Contribution File No. 92/14

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: An Episode of Wave-Generated Turbulence in the Stable Planetary Boundary Layer

Author(s): C. J. Nappo*, R. M. Eckman*, and R. L. Coulter

Status: Presented at and included in the Preprint Volume of the *Tenth Symposium on Turbulence and Diffusion*, September 29-October 2 1992, Boston, MA, pp. 118-122, AMS, Boston MA (1992).

SUMMARY

Gravity waves and turbulence are often observed to exist simultaneously in the stable planetary boundary layer (PBL). It is believed that outbreaks of turbulence in the upper regions of the stable PBL are due to gravity waves. The stability of gravity waves, which directly relates to the wave-turbulence coupling mechanism has been studied by Chimonas (1992), and Fua *et al* (1976, 1982). In these studies, an internal gravity wave modulates the value of the local Richardson number, Ri, so that during portions of the wave cycle Ri is less than its critical value (0.25), and kinetic energy is transferred from the wave to the turbulence. Another mechanism for turbulence generation is the development of unstable Kelvin-Helmholtz waves at a critical level where $0 < Ri < 0.25$. In this case, the wave propagates horizontally in the direction along which Ri attains its minimum positive value below 0.25, and the wave phase velocity is equal to the component of the mean wind speed along this direction. Because the wave is unstable, its amplitude increases with time, and eventually breaks down into turbulence. This type of PBL instability has been observed. Episodes of sudden, sporadic breakdowns of PBL stability seem to be associated with wave disturbances; however, it is possible that other mechanisms can produce breakdowns of the PBL.

This paper reports on an episode of apparent wave instability and associated turbulence. It is argued that an unstable Kelvin-Helmholtz wave developed at a critical level about 300 m above the ground, and after several oscillations the wave collapsed into turbulence restricted to a layer between 100 m and 300 m AGL, and persisted for about 90 minutes. Because the turbulence outbreak is not observed near the ground surface, one might incorrectly assume that the PBL was stable throughout its depth. There is no reason to believe that these types of elevated disturbances are uncommon, and they may have a significant effect on turbulence and dispersion in the stable PBL.

*NOAA/ATDD

ATDD Contribution File No. 92/15

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A Boundary Layer Parameterization for Global Dispersion Models

Author(s): C. J. Nappo* and H. Van Dop

Status: In press: *Journal of Geophysical Research*.

SUMMARY

A simple parameterization of the diurnally varying planetary boundary layer (PBL) is developed for use in global scale dispersion and air chemistry models. The parameterization captures the essential features of the convective and stable boundary layers, and includes the effects of surface and volumetric sources of pollutants and trace gases. Initial tests are performed with a one-dimensional model. These tests show that the parameterization is mass conserving and gives realistic results. The volumetric source term can be used to model photochemical production of ozone in the convective PBL, and the surface source term can be used to model emissions such as radon or methane.

*NOAA/ATDD

ATDD Contribution File No. 92/16

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: The Boardman Regional Flux Experiment

Author(s): J. C. Doran, F. J. Barnes, R. L. Coulter, T. L. Crawford*, D. D. Baldocchi*, L. Balick, D. R. Cook, D. Cooper, R. J. Dobosy*, W. A. Dugas, L. Fritschen, R. L. Hart, L. Hipps, J. M. Hubbe, W. Gao, R. Hicks, R. R. Kirkham, K. E. Kunkel, T. J. Martin, T. P. Meyers*, W. Porch, J. D. Shannon, W. J. Shaw, E. Swiatek, and C. D. Whiteman

Status: *Bulletin of The American Meteorological Society* 73(11):pp 1785-1795 (1992).

SUMMARY

A field campaign was carried out near Boardman, Oregon to study the effects of subgrid-scale variability of sensible and latent heat fluxes on surface boundary-layer properties. The experiment involved three U. S. Department of Energy laboratories, one National Oceanic and Atmospheric Administration laboratory, and several universities. The experiment was conducted in a region of severe contrasts in adjacent surface types that accentuated the response of the atmosphere to variable surface forcing. Large values of sensible-heat flux and low values of latent-heat flux characterized a sagebrush steppe area; significantly smaller sensible-heat fluxes and much larger latent-heat fluxes were associated with extensive tracts of irrigated farmland to the north, east, and west of the steppe. Data were obtained from an array of surface flux stations, remote-sensing devices, an instrumented aircraft, and soil and vegetation measurements. The data will be used to address the problem of extrapolating from a limited number of local measurements to area-averaged values of fluxes suitable for use in global climate models.

*NOAA/ATDD

ATDD Contribution File No. 92/17

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: An Assessment of the Dispersion Models in the MARSS System at the Kennedy Space Center

Author(s): R. P. Hosker, Jr.*, K. S. Rao*, R. M. Eckman*, J. T. McQueen, and G. E. Start

Status: This is an in-house document prepared for NASA, and published as NOAA Technical Memo ERL/ARL - 205, 91 pp. (1993).

SUMMARY

This report is an assessment of the Ocean Breeze/Dry Gulch (OB/DG) and Local Meteorological Puff (LOMPUFF) dispersion models presently available for use within the Meteorological and Range Safety Support (MARSS) system at NASA's Kennedy Space Center (KSC). Improvements in the modeling of both regional scale wind fields and effluent dispersion, combined with recent rapid advances in computer technology, have brought about the need to re-evaluate the use of the OB/DG dispersion model. The key question is whether significant improvements (better accuracy, applicability over a wider range of effluent and atmospheric conditions) are possible, given the present state of dispersion modeling.

The review team considered the source and wind characteristics at KSC and the dispersion data available. It then examined KSC capabilities for regional scale modeling (present and near-future), and meteorological data collection. The various components of the dispersion models (OB/DG and LOMPUFF) available at KSC were studied in detail to identify strengths and weaknesses. Possible alternate models were discussed briefly, and recommendations for future modeling and model testing at KSC were provided.

The OB/DG model is both limited in applicability and outdated, and it is recommended that it be replaced with a more capable model. Also, a comprehensive transport and dispersion experiment is recommended, to replace the limited OB data set with data obtained over a much wider range of time, meteorological conditions, and source locations, so that the new model (and expected future improved models) can be properly tested. At NASA's request, a comprehensive "straw man" experimental plan and cost estimate was developed during the review process as an Appendix to this report.

*NOAA/ATDD

ATDD Contribution File No. 92/18

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Analysis of Tethered Balloon-Borne Measurements in Mexico City, September 1990 and February 1991

Author(s): W. M. Porch, W. E. Clements and J. A. Herwehe*

Status: LA-UR-92-1295, Los Alamos National Laboratory, Los Alamos, NM. Report is intended for internal referencing at Los Alamos Laboratory only.

SUMMARY

Tethered balloon-borne meteorological and pollution (ozone) instrumentation was used to determine vertical profiles of characteristics important to understanding pollution evolution in the Mexico City air basin. The principal feature derived from the temperature (and humidity at times) profiles is the mixing height. The mixing height is strongly related to pollution concentrations in Mexico City. The wind profiles showed nocturnal jets associated with nighttime ground based inversions, which may be due to topographic induced slope flows from the surrounding mountains.

*NOAA/ATDD

ATDD Contribution File No. 92/19

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A Wavelet Decomposition of Single-Particle Diffusion

Author(s): R. M. Eckman

Status: Published in the Preprint Volume of the *Tenth Symposium on Turbulence and Diffusion*, September 29- October 2, 1992, Portland OR, AMS, Boston, MA, pp. 110-113 (1992).

SUMMARY

The wavelet transform is a recent mathematical development that has received considerable attention in the mathematics literature (*e.g.*, Grossman and Morlet, 1984; Daubechies, 1988, 1990) and is starting to be used in the analysis of turbulence (*e.g.*, Mahrt, 1991; Meneveau, 1991; Farge, 1992). This transform decomposes a time series into coefficients that are localized both in scale (analogous to the frequency in the Fourier decomposition) and in time. Fourier coefficients, in contrast, are localized in scale but not in time. The time-localization properties of the wavelet transform make it particularly useful for investigating intermittent and nonstationary phenomena.

The wavelet transform may be a useful tool in the study of atmospheric diffusion because atmospheric turbulence is often nonstationary and intermittent, and turbulent diffusion is itself fundamentally a nonstationary process. This paper takes an initial step in the application of the wavelet decomposition to atmospheric diffusion by applying the transform to single-particle diffusion.

ATDD Contribution File No. 92/20

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Spatial Variability of the Wind Over Moderately Complex Terrain

Author(s): R. M Eckman, R. J. Dobosy, and K. S. Rao

Status: Presented and included in the Preprint Volume of the *Tenth Symposium on Turbulence and Diffusion*, September 29-October 2, 1992, Portland, OR, AMS, Boston, MA, pp. (J4)84-(J4)87 (1992).

SUMMARY

The wind fields used in atmospheric dispersion models are often obtained by interpolation among a few wind measurement sites near the pollutant source. But in complex terrain, the spatial variability of the wind makes it difficult to estimate how many measurement sites are required to adequately represent the wind field and to determine where these sites should be located. This spatial variability can result both from differences in terrain elevation (*e.g.*, hill-top versus valley-bottom winds) and from horizontal variations at the same elevations (*e.g.*, differences between the winds at two hilltops). Decision makers often have little objective information about this spatial variability, so the design of many wind measurement networks is by default based on budgetary and logistical factors.

We have been investigating a number of analysis techniques that may be useful in characterizing the wind's spatial variability in complex terrain. This paper describes a preliminary application of some of these techniques to a set of wind data taken over a region of moderately complex terrain near Oak Ridge, Tennessee. We expect that these analysis techniques--with further refinements--will be useful in assessing how many wind measurement sites are necessary to provide a reasonable estimate of pollutant transport over a given region of complex terrain.

ATDD Contribution File No. 92/21

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Detection of Turbulent Coherent Motions in a Forest Canopy Part I: Wavelet Analysis

Author(s): S. Collineau

Status: To be published in *Boundary-Layer Meteorology*.

SUMMARY

Turbulence measurements performed at high frequencies yield data revealing intermittent and multi-scale processes. Analyzing time series of turbulent variables thus requires extensive numerical treatment, able, for instance, to perform pattern recognition. This is particularly important in the case of the atmospheric surface layer and specifically in the vicinity of plant canopies, where large-scale coherent motions have been recognized to play a major role in the dynamics of turbulent transport processes. In this first paper, we examine the ability of the recently developed wavelet transform to extract information on turbulence structure from time series of wind velocities and scalars. It is introduced as a local transform performing a time-frequency representation of a given signal by a specific wavelet function; unlike the Fourier transform, it is well adapted to studying non-stationary signals. After the principles and the most relevant mathematical properties of wavelet functions and transform are given, we present various applications of relevance for our purpose: determination of time-scale, data reconstruction, filtering, and edge detection. Several wavelet functions are intercompared, using simple artificially generated data presenting large-scale features similar to those observed over plant canopies. Their respective behavior in the time-frequency domain leads to assign each a specific range of applications.

ATDD Contribution File No. 92/22

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Detection of Turbulent Coherent Motions in a Forest Canopy, Part II: Time-Scales and Conditional Averages

Author(s): S. Collineau* and Y. Brunet

Status: To be published in *Boundary-Layer Meteorology.*

SUMMARY

Turbulent exchanges between plant canopies and the atmosphere are known to be strongly affected by intermittent coherent motions, which appear in time traces of turbulent variables as periodic, large-amplitude excursions from the mean. Detecting these features requires objective and powerful signal analysis techniques. We investigate here the possibilities offered by the recently developed wavelet transform, presented in a companion paper. For this purpose, a set of data acquired in a 13.5 m high pine forest in southwestern France was used, which provided time series of wind velocities and air temperature recorded at two levels simultaneously, under moderately unstable conditions.

Firstly, a duration scale of the active part of coherent motions was estimated from the wavelet variance. Then, we focused on the detection of large-scale features; several wavelet functions were tested, and the results compared with those obtained from more classical conditioning sampling methods such as VITA and WAG. A mean interval of 26-30 s between contiguous coherent motions was obtained; the features extracted from the various traces and ensemble-averaged over 30 min periods appeared very similar throughout the four hours of data studied. They provided a dynamic description of the ejection-sweep process, readily observable at both levels. An alternate Reynolds decomposition of the instantaneous turbulent fields, using the conditionally averaged signals, allowed the relative importance of large and small-scale contributions to momentum and heat fluxes to be estimated. The results were found to be in good agreement with comparable studies.

*NOAA/ATDD

ATDD Contribution File No. 92/23

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Lagrangian Particle Model Simulations of Atmospheric Dispersion in Nocturnal Drainage Flow

Author(s): A. K. Luhar and K. S. Rao*

Status: Presented at and included in the Preprint Volume of the *Tenth Symposium on Turbulence and Diffusion*, September 29-October 2, 1992, Boston, MA, pp. (J7)192-(J7)197, AMS, Boston, MA (1992).

SUMMARY

The Lagrangian particle (also known as the random-walk) modeling technique is being increasingly applied to simulate atmospheric dispersion of pollutants, especially in complex turbulent flows where many other techniques, such as similarity theory and gradient-transfer theory, are inappropriate or invalid. This technique models dispersion by stochastically simulating the motions of individual fluid particles. Much of the previous work using Lagrangian particle modeling has focused on convective boundary layers over flat, horizontally homogeneous terrain.

In this paper, we describe a three-dimensional Lagrangian particle model of dispersion in Gaussian inhomogeneous turbulence. This model was developed to simulate dispersion in three-dimensional drainage flows in complex terrain. High ground-level concentrations of pollutants are expected to occur in these flows. The performance of the model has been tested using the U.S. Department of Energy's ASCOT (Atmospheric Studies in Complex Terrain) tracer data bases collected during the 1984 field study in the Brush Creek Valley in western Colorado and the 1991 field study near the Rocky Flats Plant northwest of Denver. Both field experiments took place in complex terrain where nocturnal drainage flows were observed.

*NOAA/ATDD

ATDD Contribution File No. 92/24

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Random-Walk Model Studies of Turbulent Dispersion in Katabatic Flows

Author(s): A. K. Luhar and K. S. Rao*

Status: Presented at and included in the Preprint Volume of the *Tenth Symposium on Turbulence and Diffusion*, September 29-October 2, 1992, Boston, MA, pp. 322-325, AMS, Boston, MA (1992).

SUMMARY

The random-walk modeling technique is being increasingly used to study atmospheric dispersion of pollutants. This technique, which models dispersion by simulating the motions of individual fluid elements (or particles), is particularly suited to study dispersion in complex turbulent flows where other techniques, such as the similarity theory and gradient-transfer theory, are inappropriate or invalid. In this paper we discuss the characteristics of dispersion in two-dimensional katabatic flows over a uniform, sloping terrain and simulate this dispersion using the random-walk modeling approach.

*NOAA/ATDD

ATDD Contribution File No. 92/25

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Kinematics of Turbulent Diffusion from a Continuous Source

Author(s): R. M. Eckman

Status: To be published in *Journal of Fluid Mechanics*.

SUMMARY

A kinematic description of diffusion from a continuous source in stationary, homogenous turbulence is presented. This description is used to show how plume diffusion measurements depend on the time interval over which the diffusion is sampled and averaged (*i.e.*, the sampling time). It is shown that time averaging can be applied to either the absolute or relative diffusion of a plume. Absolute diffusion is affected by the sampling time only when the output or spatial configuration of the source varies with time. The sampling-time effects that are familiar to diffusion researchers actually correspond to time-average relative diffusion. This time-average relative diffusion is related to the separation with time of two marked fluid particles having a specified initial separation. Unlike other forms of two-particle diffusion that have been considered, these marked particles are not released simultaneously into the flow. The diffusion of these particles is shown to be determined by the autocovariance of their relative velocity. Kolmogorov's similarity hypotheses are used to obtain information about this two-particle diffusion in the inertial subrange.

ATDD Contribution File No. 92/26

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A History of the Atmospheric Turbulence and Diffusion Division -- 1948 -June 1992

Author(s): R. A. Green

Status: An ATDD in-house document.

SUMMARY

This paper discusses the history of the Atmospheric Turbulence and Diffusion Division (ATDD) of the Air Resources Laboratory, Environmental Research Laboratories, National Oceanic and Atmospheric Administration, from its inception in 1948 as a United States Weather Bureau Research Station to its evolution as an applied atmospheric physics research division of today.

ATDD Contribution File No. 92/27

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Analysis of Wind Data Intercomparison Between Erie, PA and Ashtabula, OH

Author(s): J. R. White and J. Przybylowicz

Status: Prepared for U. S. DOE, Oak Ridge, TN (1992).

SUMMARY

Wind data from the Erie, Pennsylvania Airport and Ashtabula, OH were analyzed for December 1988 and the first three months (January, February, and March) of 1989. The data for Ashtabula were measured at the 10 m (33 ft) and 30 m (98 ft) levels on a temporary meteorological tower erected at the site. The data for Erie were taken by the National Weather Service at about 6 m (20 ft) above ground level at the Erie Airport.

ATDD Contribution File No. 92/28

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A Laboratory Approach to Configuration-Dependent Dry Deposition to Structures

Author(s): R. P. Hosker, Jr.*, E. A. Smith, J. R. White*, and S. I. Sherwood

Status: To be published as a NOAA Technical Memorandum.

SUMMARY

Variability in deterioration over the surface of a building or structure is often large. Some observed effects are due to weather-related damage, but others are due to the action of pollutants transferred from the atmosphere to the building materials. This transfer occurs through wet or dry deposition. The first step in dry deposition requires turbulent transfer of the pollutants from the air to the vicinity of the receptor surface; this depends on the efficiency of local atmospheric mixing, although the actual transfer and uptake by the surface depend on surface physical characteristics, chemical affinities of the pollutants and receptor material, and possibly biological activity on the surface. Local atmospheric mixing depends partially on the aerodynamics of the building configuration.

This report describes a laboratory study of the variability of the dry deposition process as it is influenced by aerodynamic effects. In the study, a white naphthalene coating was uniformly applied over the surface of a matte black painted model building or building component. The model was then placed in a simulated turbulent boundary layer flow in a wind tunnel, and the naphthalene coating began to sublime away. Regions where the mass transfer was greater sublimed faster, and appeared as dark areas sooner than regions of slower mass transfer. The technique reveals zones where pollutants are transferred most efficiently to the receptor surface, identifying areas that are potentially most at risk from pollutant-induced damage, although the actual uptake by the surface will depend on the pollutant species and the surface type and condition. A rack for field studies of material exposure, an equestrian statue, and architectural columns were modeled. Flow visualizations (smoke, small soap bubbles) were also performed.

*NOAA/ATDD

ATDD Contribution File No. 92/29

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: The Effectiveness of Stationary Automobiles as Shelters in Accidental Releases of Toxic Materials

Author(s): R. J. Engelmann, W. R. Pendergrass*, J. R. White*, and M. E. Hall*

Status: *Atmospheric Environment* 26(A):3119-3125 (1992).

SUMMARY

The protection offered to occupants of stationary automobiles against airborne gases and respirable particles, such as might result from an accidental release, was measured and found to be substantial. For the four autos tested with the air conditioning (AC) system on and in recirculate position, the equilibrium ratios of inside/outside concentrations (I/O) for 2-μm diameter particles were less than 0.2, and some ratios were as small as 0.014. With both the AC compressor and the system fan off, the I/O for five autos ranged from 0.04 to 0.18. These low ratios are primarily a result of deposition within the autos. However, three of the five autos had substantially higher I/O ratios when the AC fan was on than when off, indicating that for some autos the AC caused significant added intake of outside air. Air exchange rates for the five stationary autos were on the order of 0.5 h^{-1} with AC off, and 2.5 h^{-1} with AC on.

*NOAA/ATDD

ATDD Contribution File No. 92/30

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: The Spatial and Temporal Variability of Heat, Water Vapor, Carbon Dioxide, and Momentum Air-Sea Exchange in a Coastal Environment

Author(s): T. L. Crawford*, R. T. McMillen*, T. P. Meyers*, and B. B. Hicks

Status: To be published in the *Journal of Geophysical Research, Atmosphere*.

SUMMARY

The spatial and temporal variability of heat, moisture, momentum, and CO_2 turbulent fluxes in a coastal environment were assessed using simultaneous eddy correlation measurements from a tower, a boat, and an aircraft platform. The flux tower was operated on the windward beach of Florida's Bahia Honda Key, while the boat was stationed upwind between 1 and 15 km offshore. The airplane flew transects 10 to 20 m above the ocean surface, along flight paths extending from the tower to 40 km offshore. Dissolved CO_2 in the coastal waters and atmospheric CO_2 concentrations were continuously measured throughout the experiment. The results indicate good agreement among the different sensing systems and demonstrate that air-to-sea trace gas, momentum, and energy flux density measurements are achievable from both a boat and an aircraft. Further, the observations emphasize the complex temporal and spatial trends possible in a coastal region. The observed 10 W m^{-2} sensible heat flux was time-invariant but did vary spatially with surface temperature, which was strongly correlated with ocean depth. The 100 to 200 W m^{-2} evaporative moisture flux dominated energy exchange and varied both in space and in time. No consistent diurnal variation was observed, but the spatial trend also followed surface temperature. As expected, momentum flux scaled with wind speed. CO_2 exchange showed large spatial and temporal variance. Spatially, the surface temperature warmed as the shore was approached and CO_2 was apparently driven off. Temporally, CO_2 exchange varied greatly, as did ΔpCO_2 which ranged from +50 to -100 ppm.

*NOAA/ATDD

ATDD Contribution File No. 92/31

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Correcting Airborne Flux Measurements for Aircraft Speed Variation

Author(s): T. L. Crawford*, R. T. McMillen*, R. J. Dobosy*, and I. MacPherson

Status: To be published in *Boundary-Layer Meteorology*.

SUMMARY

Airplane aerodynamic characteristics correlate aircraft speed with vertical wind velocity, making the time average inappropriate for estimating the ensemble average in airborne eddy-correlation flux computations. The space average, the proper form, is implemented as a time integral by a transformation of variables, which can be interpreted as a ground-speed correction to the time average. The mathematical forms are presented, and the importance of the speed correction is illustrated with airborne data. The computed correction is found to be highly variable, depending on both the turbulent flow encountered and the aircraft used. In general, the speed correction becomes more important as airplane size is reduced. For a small, single-engine Long-EZ airplane used as an example, the straight time average erred, half the time, by 12%, 10%, 20%, and 15%, respectively, for computed fluxes of momentum, heat, moisture, and CO_2. For a much heavier Twin Otter airplane also used as an example, the straight time average erred, half the time by only 1%. These errors increased with decreasing altitude for the Long-EZ and with increasing altitude for the Twin Otter.

*NOAA/ATDD

ATDD Contribution File No. 92/32

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A Comparative Study of Mass and Energy Exchange Over A Closed (Wheat) and An Open (Corn) Canopy: I. The Partitioning of Available Energy into Latent and Sensible Heat Exchange

Author(s): D. D. Baldocchi

Status: *Agricultural and Forest Meteorology* 67:191-220 (1994).

SUMMARY

Knowing how to calculate latent and sensible heat exchange rates over homogeneous canopies and under ideal conditions is insufficient today. Many contemporary environmental problems require information on evaporation and sensible heat exchange rates from a variety of landscapes and under a range of abiotic and biotic conditions; the most well-known issue involves using global and mesoscale circulation models to analyze the atmosphere's climate, chemistry, and weather and the planet's hydrology and ecology (Avissar and Pielke, 1990: Dickinson et al., 1990). Consequently, surface flux parameterization schemes for global and mesoscale circulation models must account for the processes that control evaporation over complete and incomplete canopies during day/night and wet/dry periods.

There are models that address canopy evaporation; however, most of them have some sort of deficiency. An accumulating body of literature advocates the use of simple models for calculating evaporation (see McNaughton, 1986; Jarvis and McNaughton, 1986). However, these also are not free of problems. Decisions must be made about which class of evaporation model is most appropriate for larger scale application. To do so, we must better understand the controls of surface evaporation under the wide range of conditions these models are expected to operate.

Consequently, the goals of this paper are to study the partitioning of radiant energy into latent, sensible, and soil heat exchange over a complete and partial crop canopy and to examine the biotic and abiotic processes that control evaporation during daytime and nighttime periods over these distinct canopies.

ATDD Contribution File No. 92/33

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Heat, Momentum, and Moisture Flux From an Airplane: Comparison to Tower Measurements

Author(s): T. L. Crawford, R. J. Dobosy, D. D. Baldocchi, and R. T. McMillen

Status: Presented at and included in the Preprint Volume of the *Fourth Symposium on Global Change Studies, the Seventy-third American Meteorological Society Annual Meeting,* January 17-22, 1993, Anaheim, CA, pp. 157-161, AMS, Boston, MA (1993).

SUMMARY

Eddy correlation has become a routine research method for measuring air-surface exchange of mass, momentum, and energy from fixed towers. The exchange is sampled over an upwind "footprint", the region of ground over which the measured exchange with the atmosphere occurred. Though more difficult, measurement from airplanes has become more feasible in recent years with the development of small, low-cost sensors and computers (Crawford, et al., 1990). Such moving sensors can assess spatial variations of flux along a path, while towers, placed where their footprints are within homogeneous subregions, sample temporal variations.

This paper compares the fixed monitoring system to the moving monitoring system. Although adjustments are made to relate the systems to each other, it should be noted that the systems are measuring different quantities and it would be a mistake to make detailed conclusions from these results. The field data taken at Boardman, Oregon in June, 1991, as part of the Atmospheric Radiation Measurements program of the U. S. Department of Energy (Crawford et al., 1992) are used for the comparison.

ATDD Contribution File No. 92/34

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Modeling Interactions of Carbon Dioxide, Forests, and Climate

Author(s): R. J. Luxmoore and D. D. Baldocchi*

Status: Presented at the IPCC Workshop: An International Workshop on Biotic Feedbacks in the Global Climatic System, The Woods Hole Research Center, October 25-29, 1992, Woods Hole, MA; and to be published in *Biotic Feedbacks in a Global Climate System: Will Warming Speed the Warming?*, G. M. Woodwell, ed., Oxford Univ. Press.

SUMMARY

Atmospheric CO_2 is rising, forests are responding, and climate is changing. This combination of fact(s) and premise(s) may be evaluated at a range of temporal and spatial scales with the aid of simulators describing the interrelationships between forest vegetation, litter and soil characteristics, and appropriate meteorological variables. Some insights on the effects of climate on the transfers of carbon and the converse effect of carbon transfer on climate are discussed as a basis for assessing the significance of feedbacks between vegetation and climate under conditions of rising atmospheric CO_2.

Three main classes of forest models are reviewed. These are physiologically-based models, forest succession simulators based on the JABOWA model of Botkin et al. (1972), and ecosystem-carbon budget models that use compartment transfer rates with empirically estimated coefficients. Some regression modeling approaches are also outlined. Energy budget models applied to forests and grasslands are reviewed for factors that may impact conditions in the planetary boundary layer.

*NOAA/ATDD

ATDD Contribution File No. 92/35

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: A Comparative Study of Mass and Energy Exchange Over a Closed C_3 (Wheat) and an Open C_4 (Corn) Crop Canopy: II. Canopy CO_2 Exchange and Water Use Efficiency

Author(s): D. D. Baldocchi

Status: *Agricultural and Forest Meteorology* 67:291-321 (1994).

SUMMARY

Most field crops use either the C_3 or C_4 photosynthetic pathway. Leaves of C_4 species attain greater leaf photosynthesis rates and water use efficiencies, and have lower stomatal conductances than do leaves of C_3 species (Pearcy and Ehleringer, 1984; Jones, 1983). But, do these physiological differences hold as the scale increases from leaf to field dimensions?

A growing number of researchers have used micrometeorological methods to study crop CO_2 exchange and water use efficiency (eg. Denmead, 1976; Uchijima, 1976; Dunin et al., 1989, Desjardins, 1984, 1984; Baldocchi et al., 1981; Anderson and Verma, 1986). Yet few scientists (e.g., Held et al., 1990; McGuinn and King, 1989) have used micrometeorological methods to investigate if the relative differences in C_3 and C_4 physiology hold for CO_2 exchange rates and water use efficiency of field crops.

This paper describes a study on CO_2 and water vapor exchange rates that were measured simultaneously over a closed C_3 crop (wheat: Triticum durum) and an immature C_4 crop (corn: Zea mays). The objectives of the paper are to examine the effects of environment, physiology, and phenology on the canopy flux densities of CO_2 and water vapor of a C_3 and a C_4 crop during day and night time periods. The specific question addressed here is: do physiological differences between C_3 and C_4 leaves hold as one progresses from the leaf to canopy dimensions?

ATDD Contribution File No. 92/36

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Dry Deposition of SO_2

Author(s): J. W. Erisman and D. D. Baldocchi*

Status: Presented at and included in the Proceedings of the *Workshop on Deposition*, Goteborg, Sweden, November 3 - 6, 1992.

SUMMARY

The goals of this paper are to briefly describe SO_2 sources and atmospheric chemistry, discuss experimental methods that are used to measure SO_2 dry deposition, discuss the physical, biological, and chemical, processes that control SO_2 deposition fluxes over vegetation, and describe how these fluxes are modeled. The predominant pathway for gaseous SO_2 uptake to dry vegetation is via turbulent transfer through the atmospheric surface boundary layer, and molecular diffusion through the leaf laminar boundary layer and the stomata. The soil surface is a significant, but weaker sink for sulfur, especially when frozen or covered with snow. The appreciable solubility of SO_2 causes its uptake to be enhanced greatly in the presence of moisture on leaves and the soil. The aqueous uptake of SO_2, however, causes the pH of a solution to decrease, which in turn produces a reduction in the solubility of SO_2. Neutralizing species (ammonia, inner plant species) may cancel this reduction. A method is proposed to estimate local scale dry deposition fluxes of SO_2 in Europe. The method combines long-range transport modeling results, land use and surface-specific data, and an inferential approach.

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ATDD Contribution File No. 92/37

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Re-Examination of Empirically Derived Formulas for Horizontal Diffusion from Surface Sources

Author(s): R. M. Eckman

Status: To be published in *Atmospheric Environment*.

SUMMARY

Field measurements indicate that the dispersion parameter σ_y is proportional to x^p, where x is the downwind distance and the power p is generally less than unity but greater than 1/2. The conventional explanation for this less-than-linear growth is that the diffusion is undergoing a transition from the near-field to the far-field limits of Taylor's equation. An alternate explanation is presented in this paper for surface-layer releases. This explanation assumes that the less-than-linear growth of σ_y with x is due to the logarithmic wind profile. A simple roughness- and stability-dependent diffusion model based on this explanation is shown to compare well with field measurements of σ_y. In neutral conditions, the model indicates that σ_y should be proportional to $x^{0.86}$ and $z_0^{0.14}$, where z_0 is the roughness length.

ATDD Contribution File No. 92/38

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Progress Report on the Conservation Monitoring Program for the Wieliczka Salt Mine, FY 1992

Author(s): R. P. Hosker, Jr.*, R. Kozlowski, A. Hejda, L. C. Salmon, J. D. Womack*, M. E. Hall*, and H. A. Crosby

Status: Interim Report: Will not be published nor widely distributed.

SUMMARY

The Wieliczka Salt Mine, located near Krakow, Poland, was designated as a site of "outstanding universal value to mankind" under the World Heritage Convention in 1978. The Wieliczka Mine has been placed on the list of endangered World Heritage sites, in recognition of the serious threat of deterioration of the historic salt carvings therein. The carvings, created over many centuries by the miners and other sculptors, represent an impressive body of art within the mine.

The deterioration of the salt carvings is due to attack by water, some of which is transported through the air. It is know that salt develops a liquid film on its surface and begins to dissolve when the relative humidity of the surrounding air reaches approximately 76%. Protection of the mine and its artifacts may require different strategies, depending on the moisture sources.

Under a program funded by the Maria Sklodowska-Curie Joint Fund II, under the auspices of the U. S. - Polish Joint Commission, a three-year study is being carried out to perform measurements and analyses within the monument portion of the Wieliczka Salt Mine to determine the likely source or sources of moisture in the mine, and to make recommendations for the mitigation of the threat. The collaborative research groups include the National Oceanic and Atmospheric Administration (NOAA), the National Park Service (NPS), the California Institute of Technology (Caltech), and the Polish Academy of Sciences' Institute for Catalysis and Surface Chemistry (ICSC).

The study began with an intensive brief exploratory effort in February, 1992 by teams of U. S. and Polish scientists, during which instruments to monitor conditions (principally air flow, temperature, and humidity) and air pollutant concentrations were installed in key locations in the mine. These instruments will remain in place for a full year, to assess the seasonal variability of the data, and will be operated by the Polish team. The U. S. and Polish teams will work together to evaluate the information and prepare a report and recommendations for the mine authorities, so that remedial measures can be adopted.

*NOAA/ATDD

ATDD Contribution File No. 92/39

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Uncertainty in the Assessment of Atmospheric Concentrations of Toxic Contaminants From an Accidental Release

Author(s): K. S. Rao and R. P. Hosker, Jr.

Status: Presented at the Third International Workshop on Real-time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, October 25-30, 1992, Schloss Elmau, BAVARIA and published in *Radiation Protection Dosimetry,* 50(2-4):281-288 (1993).

SUMMARY

Atmospheric dispersion models are widely used to assess the risk of human exposure to toxic air contaminants resulting from an accidental release. Decisions on protective actions during emergencies are often based on dose calculations using the dispersion models. In view of the importance of such decisions, it is essential to understand and quantify the uncertainty associated with modeled concentrations. Two kinds of uncertainty, "reducible" and "inherent," are emphasized. The reducible uncertainty can be minimized through more accurate and more representative measurements and better model formulations. The inherent uncertainty arising from unmeasured or unresolvable details of the atmospheric flow leads to random fluctuations of concentrations from individual realizations about their ensemble average. When these fluctuations are large, the mean concentration alone is inadequate to predict the range and probability of the concentration levels. It is necessary to present the uncertainty in air quality models in terms of an appropriate confidence interval on the model predictions. Such methods facilitate improved decision-making based on model uncertainty and risk assessment. In this paper, we discuss the various uncertainties in the assessment of atmospheric concentrations, and illustrate some aspects of model evaluation with examples using Gaussian puff/plume models and tracer data.

ATDD Contribution File No. 92/40

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: ATDD 1991 Annual Report

Author(s): ATDD Scientific Staff

Status: To be published In House.

SUMMARY

Volume containing summaries of papers, reports, etc. written by the ATDD scientific staff during the calendar year, 1991.

ATDD Contribution File No. 92/41

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Turbulence Structure in the Atmospheric Boundary Layer -- Data and Models

Author(s): K. S. Rao

Status: Presented at and included in the *Proceedings of the First World Congress of Nonlinear Analysts,* August 19-26, Session on Atmospheric and Oceanic Sciences, Tampa, FL (1992).

SUMMARY

The atmospheric boundary layer refers to the atmospheric layer of about 2 km maximum depth next to the ground in which nearly all life on earth exists. This layer is characterized by turbulence, which plays a vital role in atmospheric dispersion and exchange processes. Considerable progress has been made over the past two decades in understanding the turbulence structure of the atmospheric boundary layer. In this paper, selected features of the convective (daytime) and stable (nighttime) boundary layers are discussed in terms of similarity theories, data, and numerical model results.

ATDD Contribution File No. 92/42

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: NOAA Air-Surface Exchange Studies Supporting U.S. Global Climate Change Research

Author(s): R. P. Hosker, Jr.

Status: Presented at and included in the Extended Abstracts of the *International Conference on Sustainable Development Strategies and Global/Regional/Local Impacts on Atmospheric Composition and Climate*, Center for Atmospheric Sciences, Indian Institute of Technology, Delhi, India, pp. 31-34 (1993).

SUMMARY

The goal of the U. S. Global Change Research Program is to improve the scientific understanding of climate change and the scientific basis for national and international policy making related to natural and anthropogenic changes in the global Earth system. Priorities include long-term documentation of the Earth system and observable changes, enhanced understanding of the controlling processes, and improved predictions using integrated models. Among the scientific questions identified are quantification of the budgets and air-surface exchanges of water, energy, and trace gas species over land (including vegetation) and sea. The National Oceanic and Atmospheric Administration (NOAA), often in collaboration with other agencies in the U. S. and other countries, has a number of programs either under way or pending that directly address these questions. This paper outlines and describes this work.

ATDD Contribution File No. 92/43

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Footprint Analysis for Scalar Flux Measurements in the Internal Boundary Layer

Author(s): K. S. Rao*, and A. K. Luhar

Status: Published in the Extended Abstracts of the *International Conference on Sustainable Development Strategies and Global/Regional/Local Impacts on Atmospheric Composition and Climate,* Center for Atmospheric Sciences, Indian Institute of Technology, Delhi, India, pp. 119-122 (1993).

SUMMARY

The term 'footprint' has been used to refer to the relative contributions of upwind area sources to the vertical scalar fluxes measured at a given point. Footprint analysis is useful for assessing the sources of greenhouse gases such as water vapor and methane, for interpreting airborne flux measurements in relation to tower data, and for determining the optimum placement of flux measurement instruments at heterogeneous sites.

In this paper, the footprints of scalar fluxes measured within the 2-D internal boundary layer downwind of a step-change surface roughness are estimated. A second-order-closure atmospheric boundary layer model is applied to determine the flow and turbulence fields under different stability conditions. These fields are used as inputs to a Lagrangian stochastic dispersion model to estimate the footprints of scalar fluxes measured at various heights at a location downwind of the surface discontinuity. The results are compared with those obtained using the assumption of horizontal homogeneity. The results indicate that footprint predictions are significantly influenced by stability, measurement height, and change in surface roughness.

*NOAA/ATDD

ATDD Contribution File No. 92/44

Publication of the Air Resources Laboratory
Atmospheric Turbulence and Diffusion Division
National Oceanic and Atmospheric Administration
1992

Title: Random-Walk Model Studies of the Transport and Diffusion of Pollutants in Katabatic Flows

Author(s): A. K. Luhar, and K. S. Rao*

Status: *Boundary-Layer Meteorology,* 66:394-412 (1993).

SUMMARY

The flow and turbulence quantities governing dispersion in katabatic flows vary with both height and down-slope distance. This variation cannot be accounted for in conventional plume dispersion models. In this study, three random-walk models of varying complexity are formulated to simulate dispersion in katabatic flows, and their strength and weaknesses are discussed. The flow and turbulence parameters required by these models are determined from a high-resolution two-dimensional katabatic flow model based on a turbulent kinetic energy closure. Random-walk model calculations have been performed for several values of source height and slope angle to examine the influence of these parameters on dispersion. Finally, we simulated the perfluorocarbon and heavy methane tracer releases for night 4 of the 1980 ASCOT field study over a nearly two-dimensional slope in Anderson Creek Valley, California. The observed peak concentrations are generally well-predicted. The effects of the pooling of the drainage air could not be taken into account in our katabatic flow model and consequently, the predicted concentrations decay much more rapidly with time than the observed values.

*NOAA/ATDD

ATDD Contribution File No. 92/45