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FOREIGN TRIP REPORT

1. SUMMARY

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Contract No. DE-AC08-88NV10617

Support to Lawrence Livermore National Laboratory (LLNL)
Atmospheric and Geophysical Sciences Division (G-Division)
Atmospheric Release Advisory Capability (ARAC)

Trip Report Date: May 10, 1990

b. Dates of Trip: **April 28 to May 4, 1990**

Destination: **Roskilde, Denmark**

c. Succinct Statement of Purpose

The purpose of this trip was to *attend the Ninth Conference on Turbulence and Diffusion held at the Scandic Hotel in Roskilde, Denmark from April 30 to May 3, 1990*. The conference was sponsored by the American Meteorological Society and hosted by Riso National Laboratory, Roskilde, Denmark.

d. Summary of Activities, Discussions and Events

This conference addressed recent theoretical advancements of turbulence and diffusion in the atmospheric boundary layer (ABL). My activities centered on the technical sessions of the conference. Sessions addressed clouds and the marine atmospheric boundary layer, field experimental techniques, physical and numerical simulations, transport and diffusion, surface properties, general boundary layer, stratified turbulence and turbulence in complex terrain. I presented a jointly authored poster on an evaluation of the ARAC emergency response models with and without on-site sound detection and ranging systems (sodars) which measure vertical wind profiles. Several scientists commented on our work and some requested further information. In addition, there was a workshop on dispersion around groups of buildings and a tour of Riso National Laboratory.

Developments relevant to our work included work on dispersion model evaluation, especially using Monte Carlo random walk techniques, parameterizations of mixing height and turbulence from remote sensing systems such as sodars and radars, and measurements and parameterizations of enhanced turbulence around groups of buildings.

2. DETAILED TRIP REPORT

a. Detailed Statement of Purpose

The purpose of this trip was to attend the Ninth Conference on Turbulence and Diffusion held at the Scandic Hotel in Roskilde, Denmark from April 30 to May 3, 1990. The conference was sponsored by the American Meteorological Society and hosted by Riso National Laboratory of Denmark. Appendix A gives a complete itinerary.

This conference was the ninth in a biennial series originating in 1971 to address theoretical advancements of turbulence and diffusion in the atmospheric boundary layer (ABL). It provided information relevant to G-Division's research themes in numerical simulation of dispersion, atmospheric microphysics, heavy gases, and sub-grid scale climate processes. The research presented is also important to ARAC's operational dispersion models. These models are used to estimate the real-time consequences of accidental releases of radioactive material into the atmosphere for the Departments of Energy and Defense. New developments are periodically integrated into ARAC's models to maintain the state-of-the-art.

Interaction with scientists from around the world was beneficial for gaining information and understanding of research on these developments. About 200 attended from 20 countries including Canada, USA, Australia, India, Japan, China, USSR, and most of Europe. The list of pre-registered participants is provided in Appendix B.

A preprint of four-page extended abstracts was distributed at the conference. A bibliographical listing of literature acquired is provided in Appendix C.

b. Detailed Summary of Activities, Discussions and Events

Clouds and Marine Atmospheric Boundary Layer

The conference began with sessions on clouds and the marine ABL. The focus was on the formation and dissipation of turbulence in the moist ABL. Low-level marine stratocumulus (SCu) clouds that form over west coasts of continents strongly influence the earth's radiation budget. Several papers presented analyses of the First International Satellite Cloud Climatology Project Regional Experiment off the California coast in 1987. Formation and breakup of SCu is controlled by the relative amount of entrainment from evaporative cooling due to downdrafts versus the amount of condensational heating from the surface, which causes updrafts. Parameterizations of the moisture balance and small-scale turbulence for higher-order turbulence closure and large eddy simulation (LES) models were presented. Dissipation of the turbulent kinetic energy (TKE) over water was measured by several other recent experiments. Advances in measurements of the velocity variance spectrum in the inertial subrange, wind stress, drag coefficient, and surface fluxes over water were discussed.

Field Experimental Techniques

A second focus of the conference was on progress in instrumentation, which includes fast-response sonic anemometers, atmospheric tracers, aircraft moisture measurements, and surface-based remote sensors along with concomitant advances in data acquisition. Remote sensing systems include the use of sound (sodars), radio (conventional weather, doppler, and wind profiler radars), and light (doppler lidar using lasers). The meteorological community is approaching a point where affordable measurements of transport and diffusion are allowing more direct and sophisticated parameterizations of the ABL. An integration of a dozen such state-of-the-art remote sensing systems by Pennsylvania State University is nearly complete. Data can be simultaneously collected on the large-scale thermodynamic and wind fields as well as by small-scale turbulent cloud entrainment processes. Algorithms to determine mixing height, surface heat flux, and similarity scales for heat and momentum were presented.

Turbulence and Diffusion Modeling

Several sessions were devoted to boundary layer modeling, both physical and numerical. Papers on random walk, turbulent kinetic energy (TKE), large eddy simulation (LES), spectral, and diffusivity-dissipation (K-e) models were presented. Monte Carlo random walk models were evaluated by the Chinese and Italians with tracer experiments concentrated on low wind speed, nocturnal, stable conditions, similar to the recent work in G-Division using the DOE ASCOT data. Modeling sea-surface evaporation was another application of Monte Carlo and K-theory models. TKE models were shown to be superior to K-theory for treatment of the convective boundary layer (CBL). Sub-grid parameterization of diffusivity in the CBL and extension of LES to the stable case were the focus of recent LES work. A few papers discussed modeling flows over escarpments, dispersion in complex terrain and shoreline environments. A model evaluation study similar to our work was done by Riso and the U. S. Naval Postgraduate School. They tested new wind field sub-models in their emergency response puff model with Vandenburg AFB data.

General Boundary Layer and Surface Properties

Similarity theory, velocity spectra, surface roughness, von Karman's constant, effects of forest canopies on turbulence and gravity waves,coherent turbulent structures and stationarity, convective stucture, wind shears, mesoscale forcing, and determination of inversion and mixing heights were topics of general boundary- and surface-layer sessions. Some of the most interesting developments were with the use of sonic anemometers to analyze the cause-effect relationship between turbulent coherent structures and gravity waves above forest canopies.

Dispersion around Groups of Buildings

Julian Hunt, University of Cambridge, UK, chaired a workshop on dispersion around groups of buildings. Many of the presentations were associated with recent Commission of the European Communities (CEC) collaborations coordinated by Pat Mestayer, LMTTD, Ecole Nationale Superieure de Mecanique (ENSM), France. Participating organizations include LMTTD, Centre Scientifique de Technique du Batiment (CTSB), Riso, and DAMTP, Cambridge. The goal of the CEC group is to improve modeling of accidental releases in urban areas.

The workshop focused on parameterizing the enhanced dispersion within and around multiple buildings including complex urban areas by treating channeling effects, determining flow lifting above the buildings, and parameterizing the transition layer between the top of the buildings and the constant-flux surface layer.

Modifications to Gaussian plume, random walk, and TKE models were presented. Several wind tunnel and full-scale field experiments were conducted in several countries including one using heavy gases conducted by Riso. The three contributions from the USA (two from DOE facilities) had been withdrawn from the workshop, but Lawson from the US EPA was reinstated since he able to attend. He showed a method to quantify dispersion by analyzing video tape of smoke in the wind tunnel.

Hunt proposed that the experimental studies be coordinated to provide modelers with necess..ry parameters to develop new algorithms. However, there was little time for such interaction during this rushed 90-minute workshop because each of the 15 authors was only given 4 minutes to discuss his work! Overall, the information content of the workshop was weak because of the limited time frame and because only half the authors provided written papers for the conference preprint. A CEC conference on the topic is planned for next spring.

Tour of Riso National Laboratory

We were bussed about 5 miles to Riso on the afternoon of May 2nd. Several programs were reviewed. Riso has just begun a multi-year, multi-disciplinary modeling program to study acid deposition, deforestation, and lake eutrophication with a focus on the nitrogen cycle. Riso has just completed a wind power atlas for Europe using a three-dimensional wind flow model to extend measurements in complex terrain. The atlas as well as the Wind Atlas Analysis and Application Programme (WASP) computer code are available. Riso has modeled the transport of radioactive waste from spent nuclear fuel dumped by the British in the North Sea for decades. Another primary research area for Riso has been designing and engineering wind turbines with a goal of 7 percent wind power for Denmark by the year 2000. Currently the country has about 2,600 turbines, which produce 1.5 percent of the nation's electrical power for about 5 cents/kilowatt-hour. We toured the wind mill test station.

c. Traveler's Role and Participation in Discussions and Events

Determining the value of sodar data for initializing ARAC's three-dimensional, regional-scale wind field was the subject of our poster presentation on May 1. ARAC's MATHEW/ADPIC model accuracy was shown to improve by using sodar wind profiles, in comparison to using profiles from distant rawinsonde stations that provide the real-time upper air data for ARAC-supported sites. Several ARAC-supported DOE facilities are in the process of acquiring sodars, and ARAC is preparing to integrate these into the next generation site workstation in the early 1990s. Further improvements in model accuracy should be possible if additional algorithms for mixing height and turbulence were to be incorporated into the ARAC modeling system in the future.

Many scientists visited our poster, and several discussions are worth noting. Tzvi Gal-Chen, University of Oklahoma, recommended our looking into using the combined radar-sodar systems for determinating vertical thermal stratification as well as vertical velocity variation for direct parameterization of the vertical eddy diffusivity. One such system, the REMTECH Radio Acoustic Sounding System (RASS), costs about $140K. We are aware of these systems, but they are twice the cost of doppler sodar systems.

Frank Ludwig, Stanford Research Institute (SRI), was interested in our results because he and Roy Endlich worked for Pacific Gas and Electric (PG&E) on developing and evaluating the emergency response model used at the Diablo Canyon Nuclear Power Plant, where one of the two tracer studies that we used was conducted. Walt Dabberdt, National Center for Atmospheric Research (NCAR), indicated was just completing a project with Dr. Endlich for Taiwan. They have implemented SRI's potential flow puff model on an emergency response workstation. It continuously displays the real-time surface wind field. Near-in puff size is determined from a time-dependent, regression model of building-wake enhanced dispersion which was developed by Ramsdell at Pacific Northwest Laboratory. This is also the model used by the U. S. Naval Postgraduate School.

Lech Lobocki, Warsaw Technical University, Poland, was interested in obtaining the ARAC MATHEW/ADPIC models and supporting documentation for use in his nuclear power plant emergency response program. He has one sodar and five towers. Christian Sacre, Centre Scientifique et Technique du Batiment, France, wanted more complete details on the results of the Savannah STABLE study. His application was using sodar for wind energy analysis.

Brian Sawford, Commonwealth Scientific and Industrial Research Organization, Australia, echoed our concerns about extending the sodar profiles in complex terrain based on his experience with siting sodars. He later presented a paper on his 1988-89 Convective Atmospheric Dispersion Study (CADS) at the Tarong Power Station in Queensland. His data set including lidar, sodar, tower turbulence, radiosonde and gas measurements will be available in about a year.

Eugene Fedorovich, A.I. Voeikov Main Geophysical Observatory, Leningrad, suggested that we consider more complex algorithms than the power law we currently use for determining the vertical wind direction profile. He offered to send me papers by his collegues on the topic.

Guiseppe Brusasca, ENEL, Milan, who visited ARAC three years ago and uses MATHEW/ ADPIC for ENEL's emergency response, said they were just completing a joint effort with the Electricite de France (EDF) to implement a prognostic emergency response model.

d. Recommendations and Follow-up Activities

This is a useful and informative conference series in which LLNL/G-Division/ARAC should continue participation and making contributions.

General follow-up activities include maintaining contact with scientists working on algorithms that use sodar data in dispersion models, tracking progress with remote sensing systems, and following developments in dispersion model evaluation, tracer data sets and dispersion around buildings.

<u>Specific follow-up actions include the following:</u>

(1) Send Lech Lobocki, Warsaw Technical University, Poland, information on how to obtain ARAC's MATHEW/ADPIC computer codes from DOE's software library at Argonne National Laboratory.

(2) Pass the request from Christian Sacre, Centre Scientifique et Technique du Batiment, France, for further information about the Savannah STABLE study on to Al Weber at Savannah River Site.

(3) Respond to Robert Walko's, Colorado State University, request for any numerical technique we might have to handle irregular domain without transforming coordinates for use with the CSU Regional Atmospheric Modeling System (RAMS) in LES configuration

APPENDIX A. FULL ITINERARY

April 28 - Air travel from San Francisco to Copenhagen, Denmark

- Note: Original TWA flight from SFO to JFK was cancelled due to a mechanical failure of the plane. I changed to a TWA flight from SFO to Heathrow and a British Airways flight from Heathrow to CPN

- Surface travel to Roskilde, Denmark, a suburb of Copenhagen

April 28 to May 3 - Stay at Scandic Hotel, Roskilde

April 29 - Roskilde-Copenhagen area

April 30 - Attend American Meteorological Society Ninth Conference on Turbulence and Diffusion at Scandic Hotel, Roskilde

- Afternoon travel to Copenhagen and Malmo, Sweden

May 1 - Attend Conference in Roskilde

May 2 - Attend Conference in Roskilde, tour Riso National Lab

May 3 - Attend Conference in Roskilde, travel to Copenhagen

May 4 - Air travel from Copenhagen to San Francisco; surface travel to home

APPENDIX B. LIST OF PERSONS CONTACTED

Pre-registered Participants for the
Ninth Symposium on Turbulence and Diffusion,
April 29 - May 3, 1990,
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APPENDIX C. BIBLIOGRAPHICAL LISTING OF LITERATURE ACQUIRED

SESSION 1: BOUNDARY LAYER CLOUDS I

Chairperson: Christopher W. Fairall, NOAA/ERL/WPL, Boulder, Colo.

POSTER SESSION P1

*Paper not available; if received in time, it will appear in back of book.

SESSION 2: BOUNDARY LAYER CLOUDS II

Chairperson: Chin-Hoh Moeng, NCAR, Boulder, Colo.

SESSION 3: MARINE/OCEANIC BOUNDARY LAYERS

Chairperson: Søren E. Larsen, Risø National Lab., Roskilde, Denmark

*Paper not available; if received in time, it will appear in back of book.

SESSION 4: FIELD EXPERIMENTAL TECHNIQUES I

Chairperson: Leif Kristensen, Risø National Lab., Roskilde, Denmark

SESSION 5: FIELD EXPERIMENTAL TECHNIQUES II

Chairperson: Hans Richner, LAPETH, Zürich, Switzerland

POSTER SESSION P2

*Paper not available; if received in time, it will appear in back of book.

*Paper not available; if received in time, it will appear in back of book.

SESSION 7: PHYSICAL/NUMERICAL SIMULATIONS I

Chairperson: Paul J. Mason, British Meteorological Office, Bracknell, U.K.

SESSION 8: PHYSICAL/NUMERICAL SIMULATIONS II

Chairperson: Willy Z. Sadeh, Colorado State Univ., Ft. Collins, Colo.

*Paper not available; if received in time, it will appear in back of book.

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SESSION 9: SURFACE PROPERTIES/SIMILARITY I

Chairperson: Paul Frenzen, Argonne National Lab., Argonne, Ill.

POSTER SESSION P3

*Paper not available; if received in time, it will appear in back of book.

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WORKSHOP ON DISPERSION AROUND GROUPS OF BUILDINGS

Chairperson: Julian C. R. Hunt, Univ. of Cambridge, Cambridge, U.K.

*Paper not available; if received in time, it will appear in back of book.

SESSION 10: SURFACE PROPERTIES/SIMILARITY II

Chairperson: Ulf Hogstrom, Uppsala Univ., Uppsala, Sweden

SESSION 11: TRANSPORT AND DIFFUSION II

Chairperson: Frans T. M. Nieuwstadt, Delft Univ. of Technology, Delft, The Netherlands

SESSION 12: GENERAL BOUNDARY LAYER I

Chairperson: Franz Fiedler, Univ. Karlsruhe, Karlsruhe, Fed. Rep. of Germany

POSTER SESSION P4

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SESSION 13: GENERAL BOUNDARY LAYER II

Chairperson: D. L. Yordanov, Bulgarian Academy of Sciences, Sofia, Bulgaria

SESSION 14: STRATIFIED TURBULENCE

Chairperson: Larry D. Mahrt, Oregon State Univ., Corvallis, Oreg.

*Paper not available; if received in time, it will appear in back of book.

*Paper not available; if received in time, it will appear in back of book.