Multiresolution Feature Analysis and other Techniques for Understanding and Modeling Turbulence in Stable Atmospheres -- Abstract of Plans and Progress through September 2001

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I Introduction

This abstract summarizes the work being done on DOE's VTMX project at Stanford University's Environmental Fluid Mechanics Laboratory (EFML). The goal of our work is to use observations and numerical simulations to define observable patterns of atmospheric motion that could be related to occurrences of vertical mixing in stable, urban atmospheres, especially in regions of complex topography. As the work has progressed, it has become apparent that before we can reach our goal, we must first obtain as much observational data as possible, put those data in common formats and analyze them. We also decided that we were not the only ones who might benefit by having access to the data archive that we were assembling, so we have worked to make the information available to others.

Most of this abstract describes the progress that has been made at the EFML. Our accomplishments fall naturally into three categories: 1) Acquisition, processing and distribution of information from the October, 2000 VTMX field study in the Salt Lake City area, 2) Preliminary analyses of those data, and 3) efforts to reproduce relevant atmospheric behavior through numerical simulation. These discussions include the enumeration of the scientific questions that we are trying to answer. We conclude with a brief discussion of how we plan to continue the studies described herein.

II Data Acquisition, Processing and Distribution

Routinely distributed meteorological information (e.g. weather maps, satellite images etc.) and many special observations from the October 2000 VTMX study (e.g. using profilers, sodars, tethersondes) in the Salt Lake City area have been gathered together from the world wide web and VTMX participants. The resulting archive has been written to CD-ROMs, 32 of which have so far been distributed to VTMX participants. The consolidated data have been processed, reformatted and organized so that data collected within about 30 minutes are filed together. The purpose of this data consolidation has been two-fold. First, we believe that the archive will be of use to all VTMX participants by providing easily accessible information that can be used for interpreting their own observations, thereby helping them answer the scientific questions of interest to the whole community. The second purpose is to provide us with as much of the available data as possible, and in the formats required for our objective analysis and numerical simulation efforts, which are described further below.

The planned uses described in following sections have shaped the processing and formatting of the data that we have collected from other participants. For example, some data have been averaged so that the time and space scales represented by the different kinds of data are more consistent with one another, and with our planned analyses. The data processing methods and the formats of the data are described on the CD-ROM that has been distributed. The actual source code for processing the data from different sources has also been included.

III Data Analysis

We have begun objective analysis of the combined data to generate three-dimensional meteorological fields that can serve as a basis for determining preferred flow patterns, their scaling and how they relate to turbulent mixing events. There are many important scientific questions that depend on the understanding of flow patterns and their interrelationships. They include: *How do drainage flows down slopes, canyons, and valleys interact with and contribute to the buildup of cold pools or other stratified layers? How do the convergent and divergent flow patterns that develop as a result of thermal and terrain forcing contribute to organized vertical motions?*

The objective analyses derived from the consolidated data will also be used to define the initial and boundary conditions for model (ARPS) simulations in the Jordan Narrows area, as discussed in the next section. This area was chosen because the topography is conducive to several interesting kinds of flow. First, there is the larger scale, channeled flow in the Salt Lake and Utah Lake areas with its frequent diurnal reversal. Embedded within that larger flow are 1) the smaller scale channeling through the Jordan Narrows, 2) the flow over the ridges of the Traverse Mountains, and finally 3) the interaction of those flow features with canyon flows to and from the Wasatch Mountains. These special features are expected to produce (both in the field and in the simulations) very interesting flow features for study, such as hydraulic jumps, bores, wave initiation and Bernoulli effects in confluent flows through the Narrows and over the ridges.

IV Numerical Simulations

Some encouraging initial ARPS simulations have already been completed. Improvements and modifications of the model are under way. The observed data will be used to verify that the changes that we are planning, really do improve the model's ability to simulate observed atmospheric behavior. This phase of our study is directed at answering scientific questions like the following: *How do the convergent and divergent flow patterns in the Salt Lake Valley (from thermal and terrain forcing) generate organized vertical velocities? What insights can be provided by detailed simulations? To what extent can large eddy simulations*

(LES) be used to improve parameterizations of vertical exchange processes in stable conditions for use in larger scale models?

In order to make sure that we take full advantage of ARPS capabilities, we have established relationships with others doing related work. For example, Prof. Ming Xue, the principal architect of ARPS, recently spent three days at our laboratory working with us to address the questions that we are trying to answer with the ARPS model. We have also started working with those at the University of Utah (Prof. Horel, Lacey Holland and Carol Ciliberti) who are using the ADAS meteorological preprocessig system for ARPS. We have arranged to exchange meteorological analyses with them.

V Plans

Our long term goal is to study the flows at the highest resolution possible. Ultimately, this will include numerical simulations that can be compared with the measured data in the Jordan Narrows and perhaps other areas. By "simulating the data," We intend to do virtual experiments and sample the simulations in exactly the ways that the real atmosphere was measured, i.e. "simulate the data." If we are able to successfully do this, and the virtual and real experimental data are well correlated, then we can assert that the simulations accurately describe the atmospheric behaviors. The simulations will then be used to understand the flow physics. We can use our simulated "virtual experiments" to investigate the role of synoptic and mesoscale forcing on smaller scale processes in the stable boundary layer. In essence, we will use the simulations to extend resolution to smaller scales, integrating the simulation results with observations to provide a picture of the scaling of atmospheric motion over a wide spectrum of wavelengths.

In order to accomplish the goals outlined above, we are modifying ARPS to use advanced subfilter-scale models for large-eddy simulation over rough boundaries and have added a module to predict topographic shading of solar radiation. The terrain shading module provides more realistic heat flux estimates in the deeper valleys in the VTMX region. In addition we plan to make extensive use of ARPS nesting capabilities to relate the fine and large scales.

In the near future, we plan to compile another CD that includes all the data possible and the necessary computer programs for obtaining objective, three-dimensional analyses of those data.

Finally, it should be noted that are activities to date have put us in contact with most of the other VTMX organizations and most of them have already collaborated with us by making their data readily available, and by answering our questions. We are very grateful for the cooperation, but more importantly, we expect that it will lead to greater collaboration in the future.