Summary of Single-Column Model Intensive Observation Period Workshop at Annual Atmospheric Radiation Measurement Science Team Meeting

D. A. Randall
Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

R. T. Cederwall
Lawrence Livermore National Laboratory
Livermore, California

Objectives

1. Review recently completed winter single-column model (SCM) intensive observation period (IOP), including data collected and delivery schedule to Atmospheric Radiation Measurement (ARM) Science Team.
2. Evaluate adequacy of measurements (valued-added data) available from recent and future SCM IOPs.
3. Recommend changes and additions to ARM observation strategies, external data acquisition, and data algorithms to enhance SCM efforts in ARM.
4. Increase the interaction among SCM investigators and facilitate interaction with and guidance of the ARM infrastructure support of SCM activities within ARM.

Recommendations

- Initially focus on a single derived quantity (horizontal divergence) that is critical to SCM and implement best possible approach for it.
- Consult experts on best objective analysis approaches for observations.
- Incorporate all wind data into an objective analysis scheme (i.e., initially Barnes) and then calculate divergence.
- Study previous observation simulation system experiments (OSSEs) (i.e., Bill Frank, Pennsylvania State University [PSU]) and conduct OSSEs as necessary to evaluate data network.
- Implement additional "boundary" facilities and investigate possible interim capabilities for upcoming SCM IOPs.
- Improve resolution of wind profiles observed in lowest 1 km, using data sources such as towers of opportunity, doppler sodar, and doppler radar.
- Have SCM Science Team members visit Lawrence Livermore National Laboratory (LLNL) to work with infrastructure on evaluation of measurement algorithms.
- Form an SCM Working Group, with workshop participants as a starting point for group membership, and establish initial communication via a group e-mail list.
- Conduct an SCM workshop in June 1994 (San Diego or San Francisco), with SCM IOP data made available to SCM members well in advance of the workshop.

Background and Discussion

Winter SCM IOP

The winter SCM IOP was conducted from January 21 to February 11, 1994. Weather conditions sampled included

various levels of cloudiness with rain, drizzle, and snow, as well as cold, clearing days. Sounding data recovery rates for the three boundary facilities (BFs) and the Central Facility (CF) ranged from 76% to 97%. Better data recovery is possible since much of the missing data is stored in raw form on floppies. Some remaining QA problems will need to be resolved during reprocessing of the sounding data.

Surface meteorological data are available from eight Cloud and Radiation Testbed (CART) surface meteorological observation station (SMOS) locations, Kansas State University network locations, Oklahoma Mesonet stations, and selected National Weather Service (NWS) stations. Surface flux data were collected at 11 CART energy balance Bowen ratio (EBBR) stations. Wind data from the National Oceanic and Atmospheric Administration (NOAA) 404-Mhz profilers (seven within the southern Great Plains [SGP] site domain) have been obtained for the IOP, along with gridded fields from the NOAA Forecast System Laboratory (FSL) Mesoscale Analysis and Prediction System (MAPS) model and the National Meteorological Center (NMC) ETA model.

Data observed at CART and some data from external sources will be delivered by the end of March, with additional external data and derived measurements from CART and external data sources becoming available during April and May.

The next SCM IOP is planned for April 11 to May 1, 1994. This IOP will be conducted simultaneously with the Remote Cloud Sensing IOP and several collaborative campaigns such as ARM unmanned aerospace vehicle (UAV) and verification of the origins of rotation in tornadoes experiment (VORTEX). This period will be rich with cloud and radiation data not normally available for the SCM IOP.

The summer SCM IOP (in approximately July 1994) appeared to be in doubt. Near the end of the workshop, we were able to obtain confirmation that the summer IOP had not been canceled; however, it will compete for resources (people) who are also needed to implement the remaining extended facilities. The confusion over whether there would be a summer IOP points to the need for better communication between the infrastructure and the Science Team. The formation of a working group (see discussion item #4) should help in this regard.

Current Measurement Algorithms for SCM Measurements

Sounding data from three BFs and the CF are being used to create slab-averaged state variables (temperature, relative humidity, and horizontal winds), advective tendencies of these quantities, and horizontal divergence. The three BFs form a triangle with approximately 250-km sides. Slab-averaged variables also use data from the CF. Divergence and tendencies are obtained by a surface integral around the triangle, using normal fluxes calculated from the sounding data for layers bounded by preselected constant pressure surfaces.

There are 39 layers, each 25 hPa thick. A triangle is the minimal arrangement for such calculations, and such a procedure is known to produce rather noisy results. Profiler wind data are also used in the above algorithm to estimate horizontal divergence for height-based layers of constant 250-m thickness.

As discussed below, more BFs are needed, as well as less noisy algorithms. Site-averaged values for surface meteorological and flux variables are currently obtained using a simple arithmetic scheme. An active area of ARM research is the fusion of point observations into single values representative of a large, heterogeneous area (Doran and Coulter). Their work will produce algorithms that make use of surface characteristics and submodels. There is now a Surface Flux Working Group with whom we should interact regarding lower boundary conditions for SCMs.

Adequacy of Observations/Algorithms and Additional Data/Algorithm Needs

Most of the workshop discussion related to the issues of what additional observations were needed and how best to process the data into representative measurements for use in SCMs. The mismatch of time and space scales between each of the various observations and between observations and model scales was at the heart of the discussions.

Sampling of the three-dimensional CART SGP domain with CART instrumentation is not adequate at this time. However, several data sources from outside ARM can help fill this gap. The difficulty is in fusing this information into the SCM measurements desired. Objective analysis schemes can be used to incorporate all available data into an algorithm via the resulting gridded data set. Care must be taken to account for the scales represented by the various data sources; i.e., in time, hourly consensus profiler winds versus sounding winds that are more instantaneous at a given level during the ascent. Some control over this can be exercised by filtering the observations. Although gridded fields from models have specific scales implied, driving SCMs with results from other models is not a satisfactory solution for most workshop participants.

Since it is an enormous task to obtain the best possible set of SCM measurements, given the resources available, we decided to tackle one measurement now and obtain the best practically achievable level of quality on that measurement. The highest priority SCM measurement is divergence of the horizontal wind. The current algorithm using either the sounding data or profiler data alone is not adequate. Those data, and any other wind information, can be objectively analyzed to a grid; divergence calculations can then be made from the gridded data.

We will focus initially on obtaining the best estimate possible in the near term for divergence and then tackle advective tendencies. Marty Leach volunteered to analyze the sounding and profiler winds using a Barnes scheme (a well-used approach over the years). We will also survey other objective analysis approaches and sources of objectively analyzed fields for future use in ARM. We will contact experts in this area and seek their guidance, either through informal arrangements or through more formal consulting agreements if necessary. Required implementation tasks will be undertaken by the infrastructure. Documentation of procedures, including input data and strengths and weakness of algorithms used, will increase the usefulness of ARM-developed gridded data. Vertical motion is also a critical measurement for SCMs and is often estimated from profiles of horizontal divergence. This approach, and others (i.e., using vorticity), will be evaluated for use in ARM.

Three boundary facilities are not adequate for deriving the desired SCM measurements. Adding more boundary facilities is one solution. However, some evaluation of optimal siting of sounding and/or profiling locations would give us the best chance to use our observation resources effectively. Observation system simulation experiments (OSSEs) give the information for such optimal siting strategies. Since OSSEs have been done before in situations similar to ours, we will seek the experience of others; Bill Frank at PSU was recognized as an expert in this area, and George Young has made this contact for us. Bill's initial comment is that adding a fourth sounding would markedly improve our capability. The National Center for Atmospheric Research (NCAR) has also performed OSSEs and could assist if more are required.

A related issue is the tradeoffs that would enable ARM to afford additional boundary-facility launch sites. There are several alternatives that would, in some cases, use fewer expendables and yet give better spatial coverage for SCM IOPs. Among the alternatives are shorter IOPs (14 or 18 days), fewer IOPs per year (perhaps three per year to capture the critical weather dynamics--warm season, cold season, transitional periods), fewer BF launches during non-IOP periods. The plan for sounding launches needs to be revisited, in light of the experience we gain with the early SCM IOPs and the evolving site scientific mission.

Another issue raised was the low-level jet that occurs frequently at the SGP site. Although this small-scale feature may not be resolved by climate models, it nonetheless is a strong mechanism for low-level moisture and temperature advection and must be documented if our SCM measurements are to be properly interpreted. Currently, we do not have the observations to adequately resolve the wind structure in the lowest kilometer of the boundary layer; hence, we cannot document the low-level jet as well as is required. Other sources of data would help, namely instrumenting towers of opportunity, doppler sodar, and doppler radar (NWS WSR-88D).

SCM Working Group

SCM investigators have held periodic meetings, mainly sessions at the annual Science Team meetings. Now that the SCM IOPs are under way, more frequent interaction is needed. Also, as decisions are made about data sources and processing algorithms, more interaction is needed among investigators and with the ARM infrastructure.

To provide a forum where SCM issues can be discussed and a common message given to the ARM infrastructure in terms of measurement requirements, an SCM Working Group will be formed. In that way, ARM resources can be used most effectively in support of ARM research activities. The initial membership will be drawn from participants at this workshop.

Because the second SCM IOP will soon be completed, the working group should gather in the summer to evaluate how well the SCM IOPs are meeting the SCM measurement requirements and to suggest future directions. A workshop is proposed for June 1994 in San Diego to take advantage of another ARM meeting taking place there; a day and a half should be sufficient. Data from both SCM IOPs will be available to attendees, with the winter SCM IOP data in hand well in advance of the workshop. Initial efforts at objective analysis will also be complete.

To facilitate communication among working group members, an e-mail address list—ARMSCMWG—will be implemented at Argonne National Laboratory. In this way, information can be shared rapidly within the working group. To increase interaction with the infrastructure, investigators are encouraged to visit LLNL and work with the infrastructure on evaluating the data sources and algorithms used for SCMs; the one-on-one interaction has proved valuable, as evidenced by a recent visit to LLNL by Douglas Cripe (CSU).

Participants/Organization

David Randall (moderator)
Bill Gray
Kuan-Man Xu
John Shaffer
Douglas Cripe
Colorado State University

Richard Somerville
Sam Iacobellis
Guang Zhang
Scripps Institution of Oceanography
University of California, San Diego

Ferd Baer
University of Maryland

Chris Walcek
Qi Hu
Atmospheric Sciences Research Center
SUNY Albany

Steve Krueger
University of Utah

Peter Lamb
Qin Xu
University of Oklahoma
Norman

Jennifer Simmons
University of Alaska
Fairbanks

George Young
Pennsylvania State University

Jean-Francois Louis
Marina Živković
Atmospheric and Environmental Research, Inc.

Bill Smith, Jr.
Lockheed/NASA Langley

Bernie Zak
Sandia National Laboratories

Ric Cederwall (moderator)
Marv Dickerson
Marty Leach[(a)]
Lawrence Livermore National Laboratory

Jim Kao
Los Alamos National Laboratory

Steve Ghan
C. David Whiteman
L. Ruby Leung
Pacific Northwest Laboratory

(a) Joined LLNL in April 1994 from North Carolina State.