An Integrated Data Assimilation and Sounding System

W. F. Dabberdt, C. Martin, H. L. Cole, J. Dudhia, T. Horst,
Y. H. Kuo, S. Oncley, and J. van Baelen
National Center for Atmospheric Research[a]
Boulder, CO 80307-3000

K. S. Gage, W. Ecklund, D. Carter, R. Strauch, and E. R. Westwater
National Oceanic and Atmospheric Administration Environmental Research Laboratories
Boulder, CO 80303

H. Revercomb and W. L. Smith
University of Wisconsin
Madison, WI 53706

Overview

The Integrated Data Assimilation and Sounding System (IDASS) provides high-resolution tropospheric structure through the use of atmospheric measurements and a dynamic mesoscale model. The measurement system (Integrated Sounding System, or ISS) is developed around a suite of in situ and active and passive remote sensors which individually satisfy certain needs, but which together function in a complementary mode. ISS subsystems may include: multiple-frequency UHF wind profiler(s) with a radio acoustic sounding system (RASS); a Navaid-based sounding system; a surface meteorological station; a microwave profiler (MWR); a high-resolution infrared sounder; and a laser ceilometer. The ISS operates as an integrated system. Important aspects of the system are the synergistic interaction of data streams from the individual instruments and the application of real-time and post facto data assimilation, as well as the mechanical integration that provides a central data acquisition, processing, display and communications capability in the field for research studies.

Measurements from the in situ and remote sensing instruments are coupled with a state-of-the-art mesoscale modeling system. In the mesoscale data assimilation process, the model solution is relaxed toward the available observations so that it is consistent with the measurements. Over regions where there are no observations, the evolution of the model fields is constrained by model dynamics and physics. The end product is a highly resolved four-dimensional meteorological data set (including three components of wind, temperature, humidity, cloud water, and integrated moisture).

The mesoscale data assimilation scheme is the Newtonian nudging technique. During the data assimilation period, observations of wind, temperature, and humidity are used to nudge (or relax) the time dependent model variables to the observed values. We are using the Penn State/NCAR mesoscale model (MM4), which includes parameterizations of surface and planetary boundary-layer processes, convective and nonconvective clouds, and radiation. A comprehensive data analysis system is coupled with the model, allowing real-data experimentation.

ISS Measurement/Design Study

A preliminary evaluation of the ISS was undertaken in conjunction with the Winter Icing and Storms Program (WISP) conducted during the period January - March 1991 on the Front Range in northeastern Colorado. Existing observing systems were collocated near Platteville, Colorado, to simulate an ISS facility. A network of radiosonde stations and wind profilers provided data to simulate an ISS network to evaluate the data assimilation/modeling and to undertake sensitivity tests for the purpose of optimizing ISS design and observing network requirements (e.g., horizontal, vertical, and temporal resolution).

(a) The National Center for Atmospheric Research (NCAR) is sponsored by the National Science Foundation.

The ad hoc ISS at Platteville (elevation 1.5 km MSL) included the following instrumentation: NCAR atmospheric surface turbulent exchange research (ASTER) facility; National Oceanic and Atmosphere Administration/Wave Propagation Laboratory (NOAA/WPL) 50-MHz wind profiler with RASS; NOAA Unisys demonstration network 404-MHz Doppler wind profiler with RASS; NOAA/Aeronomy Laboratory 915-MHz Doppler wind profiler with RASS; RemTech phased array Doppler wind profiling sodar; NCAR CLASS radiosonde system; several NOAA/WPL and Jet Propulsion Laboratory (JPL) microwave radiometers; University of Wisconsin high-resolution interferometer sounder; and a Vaisala laser ceilometer. In addition, a nine-station portable automated mesonet (PAM-II) (surface winds and state variables) micronetwork with 5-km station spacing was centered at the Platteville site. Other instrumentation available to the IDASS development through the WISP-1991 program included approximately 75 surface meteorological stations, four Doppler weather radars, six CLASS systems, an assortment of radiometers and profilers, and the University of Wyoming King Air research aircraft.

Measurements from 5-6 March were used in an initial IDASS test. During this period, 50- and 915-MHz profiler winds (Figure 1) indicate NW flow in the boundary layer through much of the period with backing to W, and then NW flow followed by sharp backing at the end to NE flow. The flow aloft is W and WSW through much of the period, but veers to NW flow for about 6 h toward day's end. Profiles of water vapor mixing ratio from the 3-h CLASS radiosondes indicate significant drying generally persists throughout the day with the exception of a moisture infusion around 12 GMT.

Data Assimilation Sensitivity Studies

An initial series of four-dimensional data assimilation experiments has been completed using various subsets of the WISP/ARM-91 data base. These experiments were conducted to assess the sensitivity of the model results to the type and density of assimilated observations. Using

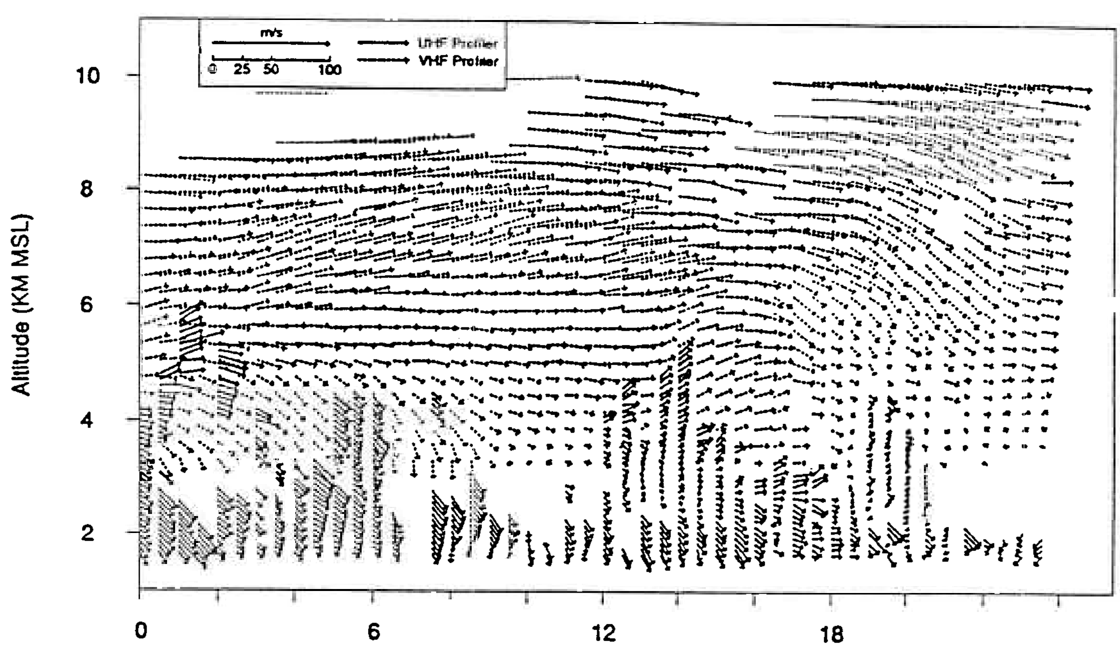

Figure 1. Time-height cross section of winds from 50- and 915-MHz Doppler wind profilers, 6 March 1991, Platteville, Colorado.

the hydrostatic version of the MM4 model, these experiments have focused on the sensitivity of model simulations of precipitable water and water vapor mixing ratio (discussed here) and temperature and winds (not discussed). Table 1 summarizes the simulation experiments that have been conducted for the test period 5-6 March 1991; future tests will assimilate other variables and other observing periods as well as apply the new nonhydrostatic version of MM4. Referring to the table, "NWS" refers to assimilation of conventional upper-air data from the synoptic network of the National Weather Service, and "WISP" refers to special upper-air data available only during the WISP/ARM experiment. Numbers in parentheses denote the number of WISP upper-air stations actually used in a particular assimilation experiment. In all cases, model results apply to and are compared with observations at the Platteville site. When the number of assimilated stations is less than six, upper-air data from Platteville have not been assimilated in the model.

Figure 2 compares MWR measurements of precipitable water on 6 March with modeled values from Experiments C

Table 1. ARM/WISP-91 simulation experiments, 5-6 March 1991.

Exp	Mesh (km)	Period (hr)	4DDA (?)	Model Type	Assimilated Variables
A	40	36	no	H	
B	40	36	yes	H	NWS:V,T,q
C*	20	24	no	H	
D*	20	24	yes	H	WISP(6):V,T,PW
E*	20	24	yes	H	WISP(5)†:V,T,PW
F*	20	24	yes	H	WISP(5)†:V,T,q
G*	20	24	yes	H	WISP(3)†:V,T,PW

* initialized with results of B
† Platteville soundings excluded
H Hydrostatic MM4
NH Nonhydrostatic MM4

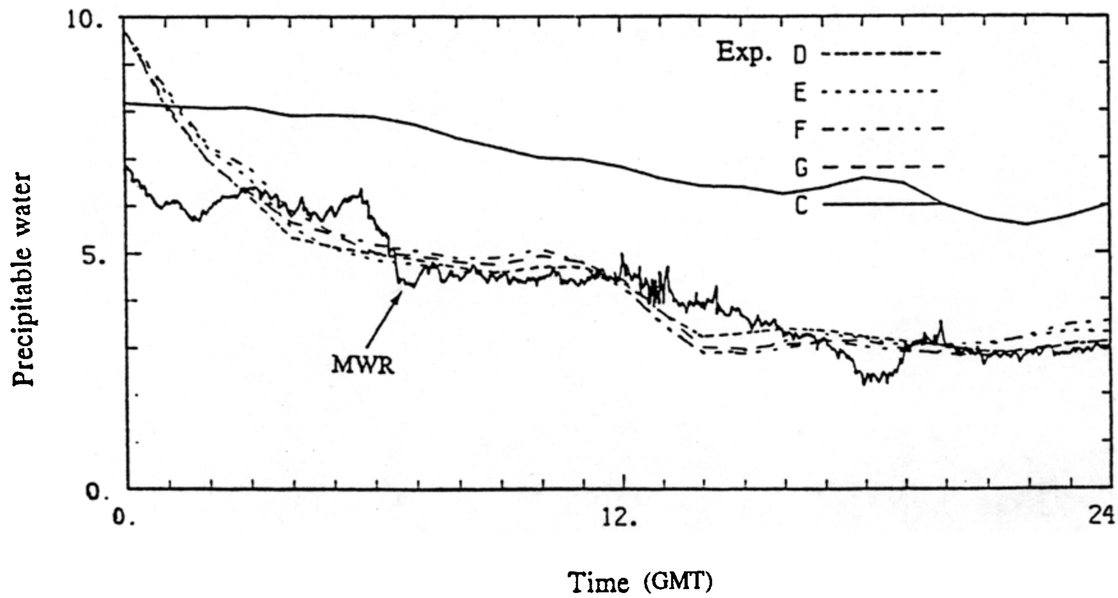

Figure 2. Observed and modeled precipitable water, 6 March 1991, at Platteville, Colorado.

(no assimilation) and D - G (varying forms of assimilation). Several conclusions are readily apparent: without assimilation, the model captures the general trend but demonstrates a positive bias of about 0.5 cm. The results with assimilated data indicate very good agreement in all cases with the observations except for the very beginning of the period. The simulated fields are virtually insensitive to the number of observing sites and to the type of water measurement assimilated. There appears to be a small-scale phase difference between observations and modeled values.

Of course, these results are very limited and need to be extended to include other weather regimes; other seasons and locations; and other combinations of station spacing, sampling frequency, and data types. In conducting these additional experiments, we will be seeking to improve the design of individual integrated sounding systems and ISS networks.

Acknowledgments

The authors wish to acknowledge Ms. Mary Ann Pykkonen for production of the manuscript and Ms. Anne-Leslie Barrett for creation of the illustrations.