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The Institute of Atmospheric Sciences (IAS) was established at the School of Mines in 1959 and has an active research program. Students in the Department of Atmospheric Sciences are encouraged to participate in IAS research. Such participation gives the student an excellent background for a career in atmospheric sciences/meteorology.

For a background on the Institute and its current areas of research, follow the links:

Who we are and what we do
Numerical Cloud Modeling
Armored Research Aircraft
Upper Missouri River Basin Pilot Program
Weather Radar Research
Evaluation of Weather Modification Activities
Radiative Transfer and Remote Sensing
Mesoscale Studies
Land Surface Process Studies
Biogeochemistry
Future Research Efforts

Publications

Our research scientists have had papers published in many scientific journals, and have presented papers at many conferences, both nationally and internationally. Check out the list of publications.

Our History

The IAS is housed in the Mineral Industries Building on the School of Mines campus. The recent collocation of the National Weather Service's Rapid City Weather Forecast Office on the School of Mines campus affords another opportunity for access to real-time weather data. The IAS is connected to a campus network with a port to the Internet, providing access to the large computers of the National Center for Atmospheric Research (NCAR), and other computer systems belonging to agencies sponsoring research projects as well as national/international electronic mail. Several personal computers are available for use exclusively by the IAS. Research facilities available to IAS staff members and students include an armored T-28 research aircraft which collects data inside hailstorms and thunderstorms, a computer-based synoptic laboratory, and x-ray diffraction and air pollutant monitoring instrumentation.

The EROS Data Center near Sioux Falls, SD is the nation's repository for land surface remote sensing data. A growing land surface process research effort has led to increasing interactions, including stationing of an EROS employee within the IAS.

Originally, the primary emphasis of the IAS research program was on weather modification. The IAS carried out large-scale field research programs in weather modification for several federal agencies. Simultaneously, the IAS developed strong capabilities in such fields as numerical modeling of convective clouds, radar data analysis and processing, and precipitation physics. Studies of air quality and air pollution problems, mesoscale-cloud interactions, thunderstorm electrification and lightning, radiative transfer processes, and remote sensing have been developed in more recent years.

Many of the IAS research programs are carried out in cooperation with other scientific groups. IAS staff, including graduate research assistants, have participated in the National Hail Research Experiment (NHRE), the Thunderstorm Research International Project (TRIP), the Severe Environmental Storms and Mesoscale Experiment (SESAME), the Cooperative Convective Precipitation Experiment (CCOPE), the Grossversuch IV program in Switzerland, the High Plains Cooperative Program (HIPLEX) of the Bureau of Reclamation, the Alberta Hail Project, the Cooperative Huntsville Meteorological Experiment (COHMEX), the North Dakota Thunderstorm Project (NDTP), the Convective and Precipitation/Electrification (CaPE) experiment, and the North Dakota Tracer Experiment (NDTE). IAS scientists are cooperating with local and national agencies in development of methodology and its practical application to air quality source apportionment of urban areas and surface and subsurface mining activities. IAS scientists are involved in joint research efforts together with scientists from the National Center for Atmospheric Research (NCAR), Colorado State University (CSU), National Aeronautics and Space Administration (NASA), Illinois State Water Survey, University of North Dakota, and SRI International.

Additional information about our radar analysis software package IRAS can be found by clicking on the underlined words.

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Development of Numerical Cloud Models

Numerical cloud models run on computers have been an important research tool for IAS scientists for 25 years. Several types of models are used to simulate the formation and development of convective clouds under various atmospheric conditions. The more advanced models are capable of simulating the response of the clouds to ambient winds, surface heating by the sun, and temperature and moisture perturbations in the lower atmosphere. Condensation, the coalescence of cloud droplets into raindrops, the freezing of cloud droplets to form ice crystals, and the formation of snow and hail are simulated. A model to include atmospheric electrical effects, including lightning and the production of nitrogen oxide by lightning, has been developed. The models have been used to further our understanding of cloud and precipitation processes and have been applied to several atmospheric situations such as: (1) the spread of excess water vapor and heat from electric power plants and their effect on severe storms; (2) the transport and diffusion of carbon black dust and its effect on cloud-scale convection; (3) cloud mergers and their effect on precipitation; (4) the development of hailstorms and the evolution of hailstone distributions; (5) cloud seeding by silver iodide or dry ice particles or hygroscopic particles and their effect on rainfall and hailfall from various types of clouds; (6) the electrification of clouds and storm systems; (7) the effects of atmospheric pollutants, such as sulfur dioxide, on the acidity of clouds and precipitation; and (8) the formation of downdrafts and strong horizontal wind shear conditions (microbursts) at the earth's surface. The results of model runs are compared with observations made by the Institute's armored T-28 aircraft, other research aircraft, and radar and ground instrumentation.

The simpler models can be run on the local workstations. Running the more advanced models requires access to larger computers off campus. For instance, IAS scientists and graduate research assistants access these models over the Internet on supercomputers at NCAR in Boulder, Colorado.

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Observations of Hailstorms by Armored Research Aircraft

As the northern Great Plains region is subject to frequent damaging hailstorms, hail research was an important IAS effort since its establishment. The IAS operated a T-28 research aircraft (as an National Science Foundation facility) that was armored to permit safe penetrations of hailstorms. Although the plane was retired in 2004, IAS scientists continue to study the data collected from these missions, and a project is underway to archive this data in a central location for use by the scientific community.

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Upper Missouri River Basin Pilot Project

The Upper Missouri River Basin (UMRB) Pilot Project encompasses interactive modeling and observational studies of the coupled atmosphere-surface-subsurface hydrology of the Black Hills area of South Dakota and Wyoming. This NASA sponsored project emphasizes coupled hydrologic modeling of Intermediate Scale Areas (ISA) in orographic terrain, the use of observations of differing temporal and spatial resolutions to assess ambient variability as well as model and budget uncertainties and sensitivities, intercomparison of sensors, and the transferability of models from the Black Hills ISA to other ISAs. Execution of this project is being coordinated with GEWEX Continental-Scale International Project (GCIP) activities such as the GCIP Large Scale-Northwest (LSA-NW) study. Visit the UMRB website at www.ias.sdsmt.edu/umrb for a more detailed description of the objectives and goals, and to view the maps of this location of study.

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Weather Radar Research

For many years, radar meteorologists have been trying to improve the accuracy of rainfall estimates based on weather radar observations. One approach uses a combination of radar and rain gage data. The rain gages can be thought of as providing baseline comparisons for the radar estimates of rainfall at the rain gage sites, and the radar data then fill in the areas between the gages. IAS research in this area has included studies of optimization methods for developing radar Z-R relationships and a sequential analysis procedure for making radar-rain gage comparisons in real time. Computer programs written by IAS personnel to estimate rainfall over small watersheds have been tested by the National Weather Service (NWS). Another IAS-developed program called IRAS is now widely used by NWS personnel for review and analysis of recorded NEXRAD data. The

IAS is now engaged in a study to extend a recently-developed technique of estimating convective precipitation using radar data, called the Area-Time-Integral (ATI) technique, to satellite data.

Multiple-Doppler radar data collected during several recent projects are being analyzed to determine wind fields in and around the storms. Doppler and polarimetric data were also collected during the 1987, 1989, and 1993 North Dakota projects. Multiparameter radar data from CaPE and from the hydrometeor verification projects are also being compared to T-28 observations of storm microphysics in collaboration with scientists at other universities.

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Evaluation of Weather Modification Activities

The evaluation of weather modification activities, both experimental and operational, is a perplexing problem. The natural variability of precipitation makes the effects of cloud seeding difficult to establish, and usually both physical and statistical approaches are required. IAS scientists and students have been involved in the evaluation of numerous weather modification projects. The most recent ones include HIPLEX-1, a randomized cloud seeding experiment for rain augmentation carried out in Montana, and the North Dakota Cloud Modification Program, an operational project with dual objectives of rain augmentation and hail suppression. The evaluations are based on research aircraft, weather radar, and precipitation data along with cloud model simulations. Newly-developed non-parametric statistical techniques have been applied to elucidate the seeding effects.

Recent physical studies have involved the use of gaseous tracers and also radar chaff to explore the transport and dispersion of seeding agents in convective clouds. The tracer methodology also permits the study of entrainment processes and the activation of artificial ice nuclei. Such experiments were a primary focus of the 1993 North Dakota Tracer Experiment.

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Radiative Transfer and Remote Sensing

The World Climate Research Program has placed highest priority for climate research on the cloud/radiation feedback problem. As part of this program, the International Satellite Cloud Climatology Project (ISCCP) has identified the following objectives: 1) determination of cloud cover and cloud radiative properties as a function of cloud type, 2) research on techniques for inferring the physical properties of clouds from spectral measurements, 3) improved parameterization of clouds in General Circulation Models and climate models, and 4) improved understanding of the earth's radiation budget.

IAS scientists are cooperating in this worldwide effort. Very high resolution LANDSAT, AVIRIS and TIMS data are being used to validate and improve meteorological satellite (GOES and AVHRR) cloud and land surface retrieval schemes. Global studies of cloud and aerosol properties and their relationship to global ecosystems and the Earth's radiation budget are in progress. Other investigations involve applying satellite remote sensing and/or aircraft data to the retrieval of cloud microphysical and optical properties, including those of contrails, and participating in collaborative efforts in developing a scheme for retrieving aerosol optical depth in measurement sparse regions such as the upper Great Plains. Another important on-going study involves characterization and analysis of the extent and impacts of biomass burning associated with forest fires and deforestation, as in the Amazon rain forest.

Work is in progress to develop a Geographic Information System of the Black Hills region. The goal is to incorporate surface-based spectroradiometric, meteorological, and hydrological measurements; existing biophysical, geologic, physiographic, and hydrogeologic databases; and satellite, radar, and aircraft data into the derivation of key metrics for a coupled atmospheric-hydrologic mesoscale model, such as evapotranspiration, albedo, runoff, and radiative surface fluxes.

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Mesoscale Studies

Mesoscale weather studies are concentrating on development of models to study the airflow over topography and its effects on clouds and precipitation. In addition to fundamental studies of the physics of the effects of topography on airflow, numerical models are being used to aid in predicting the specific locations of cloud development and precipitation in the Black Hills area. Numerical studies of specific storms include heavy snowfall cases and the Rapid City flood case of 9 June 1972. The IAS is working with hydrologists in the Departments of Civil and Environmental Engineering and Geology and Geological Engineering to couple precipitation predictions with stream flow and groundwater calculations in interactive atmospheric-surface-subsurface models. A focused study on flash-flood-producing storms is under development. Numerical simulation studies are also being used to continue examination of the processes and sensitivities involved in atmospheric boundary layer forcing of the initiation of convective storms. This work has direct application to short-range forecasting of thunderstorm development. A project being carried out jointly with Illinois State Water Survey is examining the development of wind parallel bands of snow in Lake Effect Snow Storms. This work is also supported by the NSF and a field project is planned for the winter of 1997-1998.

A project involving IAS personnel and the Rapid City Office of the National Weather Service is investigating damaging wind storms, derechos, in the Northern Great Plains, with a goal of improving predictions and warnings. A corresponding numerical simulation study is in the planning stages.

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Land Surface

A growing area of work in IAS is the field of land surface process studies. Current work emphasizes remote sensing of land surface properties and fluxes and their use in atmospheric and hydrologic numerical models. Expansion of this work includes studies of ecosystem effects such as effects of forest clearing, due to forest fires and logging, or urbanization and vegetation succession. Another potential new area of study involves correlation of soil moisture anomalies on other surface parameters with the spread of disease.

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Biogeochemistry

As the earth has evolved, biological systems have evolved to play a central role in the cycling of key elements. The atmospheric components of these elemental cycles affect the trace gas composition of the earth's atmosphere. This, in turn, affects the radiation balance and the chemistry of the atmosphere in ways which may be central to the maintenance of stable chemistry and climate.

For the first time in the history of the earth, human activities are affecting key cycles on global scales. Interactions of human-caused perturbations with biological processes have affected key cycles of carbon, nitrogen, sulfur and other elements. The result may be consequences that are dramatic, unpredictable, and irreversible.

This program explores the cycling of trace gases, with special emphasis on the atmospheric transformations and biogeochemical fates of carbon, nitrogen and sulfur-containing compounds. The academic program is coupled to a research program that will provide opportunities for students to participate in field research programs to determine the fluxes of trace gas species; modeling programs to explore local and regional consequences; and remote sensing programs to link ecosystem and landscape level measurements to regional and global observations.

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Future Research Efforts

It is impossible to specify exactly the areas of research which will occupy the attention of IAS scientists in the future, but the following information may be of interest to prospective graduate students. The emphasis upon attempts to relate observations in the field to numerical models is likely to continue. Studies of atmospheric electricity and trace gas production by lightning are receiving greater emphasis. Through the use of more advanced cloud models we hope to test some of the many theories now in existence regarding the generation of thunderstorm electricity. Applied regional climatological and climate dynamic studies, as well as mesoscale analysis studies relating surface motions to cloud development and rainfall accumulations, are also planned. Some of these studies will concentrate on the weather patterns and air flow over the Black Hills, and in the Upper Missouri River basin. The rich mixture of engineering and scientific problems that will be generated by these various research activities will offer a wide range of challenges and opportunities to graduate students in atmospheric sciences/meteorology.

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