Center for Geosciences/Atmospheric Research (CG/AR)
Phase III

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History and Background

The DOD Center for Geosciences was instituted in 1986 as a DOD-sponsored University Research Initiative (URI). Since then Colorado State University and the Cooperative Institute for Research in the Atmosphere have hosted three phases of this DOD-directed research. We are currently halfway through the three years of funded research comprising Phase III. The research conducted within the context of CG/AR has had to pass two tests. First it must be peer reviewed by university and governmental researchers for scientific merit. Second it is reviewed by the DOD laboratory structure for military relevance. As a result many of the research topics have been spun off as operational capabilities.

Collaborations and Management

CG/AR is managed by CIRA within the context of Colorado State University and by the Army Research Office within the DOD. CIRA, being an institute of CSU, brings multidisciplinary talents to CG/AR. This includes meteorologists, physicists, computer science specialists, engineers, hydrologists, and social scientists. Being a Joint Institute of NOAA, CIRA also brings its research activities, generally associated with NESDIS and OAR, to bear on military problems. CG/AR is currently collaborating with the Forecast Systems Laboratory, ETL, Air Force Weather Agency, University of Alaska, UPOS, Army Research Laboratory, NCAR, and CSU's Atmospheric Science Department on elements of CG/AR research. CG/AR continues to refine its research objectives so they are in line with DOD needs and so as to take advantage of successful lines of research.

Research Themes

1. Hydrometeorology - This theme focuses on precipitation amounts and rates, soil moisture, stream and overland flows as well as improved detection and forecasting of water in the atmosphere. These focus areas will directly improve our understanding of agricultural meteorology, flash flooding, and river crossing and trafficability problems that are of direct concern to Army maneuver units. CG/AR is working with UPOS/University of Alaska researchers on transferring the soil moisture algorithms to an MM-5 context.

2. Cloud Structure, Dynamics, and Climatology- This theme focuses on clouds and their structure, radiative properties, phase (ice, water or mixed), growth and decay, their extent in the vertical (cloud tops, bases and layers) and in the horizontal (cover and motion). CG/ARs research, uniquely tailored to military concerns, has focused on the complex middle cloud layers that tend to be non-precipitating in nature. Although cirrus, stratus, and rain in cummulo nimbus clouds tend to be studied in most atmospheric research projects, it's these middle layer clouds that have proven most significant to air operations in Desert Storm and

the recent Kosovo/ Serbian operations. These are the clouds, despite their benign weather consequences, that get in the way of air strikes, obscuring the air-to-ground view for intelligence gathering, strike missions, and battle damage assessments.

3. Data Assimilation and Data Fusion- This theme is significant to both civilian and military weather forecast operations. Every forecast today, whether generated by a numerical technique or by a human forecaster, starts with knowledge of the current atmosphere. Historically, the weather forecasting process has depended upon the human forecaster keeping the 4 dimensional picture developed from the limited observations of balloon soundings and surface observations in his head. He filtered bad data out with knowledge of how the atmosphere behaved. Today we have millions of times more data from satellites, radar, and ship buoy observations. This data comes in different formats, often only indirectly related to the old set of wind, temperature and humidity variables we want to forecast. Data also comes in at various times making their fusion much more difficult. Assimilating this vast array of disparate data takes a very sophisticated process beyond which any human can manage. Computer assimilation of this data has usually meant smoothing data sets, and creating relationships between satellite observational variables, such as infrared energy coming off the top of clouds and temperature that could be entered into the forecast models initial time step along with all other "temperatures" observed by other observational systems. Only in the last few years have computers and atmospheric models been able to directly assimilate these disparate data formats. Today CG/AR is working on the newest method of data assimilation called adjoint modeling. This method allows the forecast model itself to filter out bad data, reconcile different observational times, and compensate for the bias errors known to be generated by the observational instruments. Combat weather forecasting needs this method as much as civilian and peacetime operations since most of the areas where the forecast is needed are also areas where no conventional surface observations are available. Satellite- remotely sensed information can only be fully exploited with methods like the adjoint process.

4. Chemistry, Aerosols and Visibility- This theme will allow researchers to exploit new satellite information to solve one of the oldest problems facing military operations. Fog, smoke and haze are the nemeses of military planners, pilots, tank drivers, and ship captains. Although haze and sandstorms have been observed since the early days of satellites, it is only recently that the chemical and physical attributes of this “haze” have been measurable from space. CG/AR is exploring the remote measurement of the thickness of this haze (optical depth) that will be invaluable to satellite and high altitude reconnaissance systems. The chemistry itself will someday be determined with the generation of spacecraft soon to be launched such as TERRA.

5. Remote Sensing of Battlespace Parameters- This theme encompasses several different technologies that will be exploited by military (and civilian) operations using newly developed remote sensing technologies such as LIDAR and multi-channel high-resolution satellite data. One of the major areas being explored by this theme is the need to better understand the complexities of the nocturnal boundary layer. During the night the lowest layers of the atmosphere stratify when the mixing caused by solar heating is absent. Low-level winds, and intermittent turbulence caused by viscosity breakdowns and other non-linear

effects develop during the night. These phenomena are of more than academic interest. Without a full understanding of these phenomena, our ability to predict chemical weapons dispersion patterns is compromised. This was clearly illustrated at Kamasia, Iraq at the end of Desert Storm. An Iraqi munitions depot was destroyed by U.S. troops. Only after the fact was it learned that some of the munitions were chemical shells and missile warheads. In order to determine which troops had been exposed a low-level wind and toxic chemical depression analysis was conducted. Unfortunately, the analysis failed because of lack of knowledge about the complex processes that transported the chemicals during the night.

Current Research Activities

In the last year 9 graduate students and 2 undergraduate students have been supported by CG/AR funding doing research on the previously described theme areas. In addition 23 professional researchers have also been working on CG/AR theme areas. Two major field programs CLEX-5 (Complex Cloud Layer Experiment #5) and CASES-99 (Cooperative Atmosphere Surface Exchange Study)) have been planned and will be executed in the fall of 1999. CLEX-5 will collect mid-level cloud information associated with research theme #2. CG/AR is funding a newly developed scanning LIDAR deployment to the CASES-99 operations area in central Kansas explicitly to measure the 3-dimensional aspects of the nighttime turbulence for research theme 5.

32 scientific papers have been published or are being currently reviewed for publication with CG/AR funding.

Although the research has just started and results are typically loaded at the end of projects life, CG/AR has already completed a variety of technology transfer activities to the DOD. These include:

- Held short courses on the use of CASC2D the hydrology model being run by the Army Corp of Engineers to forecast river heights. This model was used to predict the flood stage of the Sava River as heavy units of NATO forces first entered Bosnia several years ago.

- Running hydrological model at 10-meter resolution in small Colorado watershed to test high-resolution model and improve computational efficiencies.

- Coordinating with the Army Corp of Engineers to run CASC2D on the Army's super computer. This will allow the model to run over an entire theatre of operational-scale region thus improving its utility to Army operations.

- Began producing a CHANCES-97 data base product. This cloud database is a global 5-km, hourly data set for the 1997 El Nino year. In conjunction with the CHANCES-95 data set it will allow military planners and acquisition managers to use a much higher fidelity data set of cloud cover information for a variety of decisions. Additionally the CHANCES-95 data set was transferred to CD-ROM thus expanding its potential users in the DOD by a factor of 100. Now you can exploit the data on a standard PC and don't need a workstation with 8-mm tape drivers.

- Cloud Drift Winds (CDW) analysis is being transferred to the Air Force Weather Agency (AFWA) in the coming months. CDW is a method using two weather satellites to measure both wind speed and direction by using clouds as tracers in the atmosphere. Older techniques using single satellites with multiple image sequences suffer from a poor specification of the cloud height in the atmosphere. CDW in a stereo technique that uses the parallax displacement of the cloud elements as opposed to the radiometric approximation of the older methods to determine height. The Navy, Air Force, and our NATO allies are all considering the implications of this method as well as NOAA. Continued improvements to the techniques, including an automated cloud feature identification scheme are very close to implementation

- New microwave dependent methods for measuring cloud liquid water over land will be transferred to AFWA within the next 10 months. This measurement will provide forecasting models access for the first time to this portion of the water budget in the atmosphere thus improving rain and cloud characterizations and forecasts.

- New weather products are being created such as fog, cirrus cloud and ice cloud images from the recently launched Advanced Microwave Sounding Unit (AMSU) data. This sensor on NOAA's newest TIROS satellite was first exploited by CSU scientists after launch. These products, which are fed back into NOAA's production system, are used by civilian and military forecasters.

- Of interest to the DOD is development of a total optical depth algorithm that can measure haze and smoke from the geostationary satellite, which covers 90 percent of the Earth. This near real-time capability will be transferred to AFWA in the near future for prototype testing. Values derived from this product can be used to make analytic corrections to high flying aircraft and satellite reconnaissance systems to better improve our understanding of military, agricultural and industrial activities being undertaken by potential adversaries.

- A new cloud base analysis will soon be tested by AFWA. CG/AR developed an improved method of blending surface and satellite measurements to determine cloud bases and thickness. Cloud base height is critical to air safety and for ground attack planning. This new method, which improves the accuracy of the old statistical nearest neighbor method, uses satellite cloud typing to spread the sparse surface observations in a more meteorologically consistent manner.

- A new neural network-based cloud typing method has been developed and is about to be transferred to the Army, Navy and Air Force. Although neural networks have been used before to type clouds, this new method uses temporal adjustment (first time ever used in a neural network setting). This adjustment compensates for variations in cloud images as the sun's illumination angle changes.

- An advanced retrieval algorithm that yields the atmospheric profile similar to the conventional balloon soundings is ready for transition for operational use with the DOD. This Beysian retrieval combines historical knowledge of the atmospheric profiles with the

satellite sounder data from the military sounder sensor. This provides a more accurate understanding of the vertical profile used in numerical weather forecasting and is particularly critical in regions were conventional balloon soundings are not available such as over a battlefield or ocean areas.

- CG/AR staff have given several seminars at DOD locations including White Sands Missile Range, Adelphi, Maryland (Army Research Lab) and the Naval Research Lab (Monterey, CA)

- CG/AR staff is leading an effort to improve collaboration between the Army Integrated Weather Effects Decision Aid (IWEDA) and NOAA's Local Data Acquisition and Dissemination System (LDADS) programs. These two computer display systems both convert basic weather data into a decision assistance system. The Army IWEDA provides assistance to the battlefield commander by determining specific weather imports on specific friendly and enemy weapon systems. LDADS provide more generic support to emergency management in the civilian community as an adjunct to the NOAA NWS's Advanced Weather Interactive Processing System (AWIPS). This sharing of technologies offers improvement potential for both systems.

CG/AR Response to New Defense Challenges

The Weather Web, part of the DOD's Smart SensorWeb initiative, was reviewed by Capt Martin in the keynote address of this BACIMO Conference. It highlights some of the environmental shortfalls critical to the DOD. CG/AR is working on some of these shortfalls. Also note that CG/AR's activities rely on satellite-based and modeling solutions that all work effectively over denied areas as follows:

1. **Analysis of data - blending divergent data types by weighting need quantification** – CG/AR's current work on dynamic data assimilation with prognostic and adjoint modeling does this quantification using explicit error covariance matrices for each sensor type. Currently CG/AR is working on direct ingest of SSM/I, and infrared imagery into forecast models using this method.
2. **Fusion of disparate day types** – Again, our 4DDA and Adjoint Modeling research is addressing this problem.
3. **Provide User-accessible data products** – CG/AR is in the process of transitioning several algorithms (see current research activities above) that will be accessible from anywhere in the battle space. Products that depend upon direct broadcast data streams (geostationary or polar tactical readouts) such as these products can be generated anywhere with a pc and a small antenna.
4. **Soil moisture and temperature** – CG/AR has solved this problem at the theoretical level from satellite observations and a sophisticated model running in a diagnostic mode. The only research required is a validation for signals from deeper regions of the soil.
5. **Obscurants smoke, cloud layers, precipitation** – CG/AR is working on optical depth measurements over land that quantifies smoke and other aerosols. CG/AR is also collaborating with the CloudSat program to directly measure cloud layers from satellite as well as providing AFWA a cloud layer (and base) algorithm this summer.

6. Volumetric 3-D winds – CG/AR has developed a high resolution winds measurement method combined with a thermal winds modeling that provides this data in a variety of circumstances.

Note- all of the above activities are the subject of specific papers presented at this BACIMO conference.