

**Colorado State University**  
**Center for Geosciences/Atmospheric Research (CG/AR)**  
**Quarterly Report No. 5**  
**by T.H. Vonder Haar and Collaborators**

**Reporting period: April 1-June 30, 2003**

**Cooperative Agreement #DAAD19-02-2-0005**

**Overview**

*[Note: For this reporting period, the same technical contents will be submitted under Cooperative Agreements #DAAD19-01-2-0018 and DAAD19-02-2-0005. At the request of the Army Research Laboratory Contracts Office, the new CA began May 8, 2002, overlapping the previous CA by 5 months. By design, the Center for Geosciences/Atmospheric Research activities are phasing into the new CA as they phase out of the previous CA (now to end September 30, 2003).*

CIRA is now ingesting both CDFS II and the AGRMET data from AFWA. This is allowing us to run comparisons (CDFS II) and to begin closer collaborations in the AGRMET arena with George Gayno's group.

CASC2D-SED has been modified to allow dynamic elevation changes that more realistically account for the sediment transport in subsequent runs of this hydrology channel model.

Dr. D. Zupanski has completed a significant model experiment that has objectively shown that advanced data assimilation techniques can overcome intrinsic model errors. This is a significant contribution and will help justify future community expenditures on data assimilation.

We have begun the data analysis of the first dual Doppler lidar data collection that was collected during the Joint Urban 2003 experiment in Oklahoma City in June.

Ben Ruston's land surface microwave emissivity work is progressing well and he will be traveling to NRL to assist the Navy in a collaboration to improve temperature profiling during the next quarter.

Computer modeling of the Salt Lake City air flows is showing that advanced meso-scale models can be used to determine dispersion patterns in regions of complex terrain. This work will resume when we garner more computer resources and go to a higher resolution topography data set.

We are working on our first detailed technical collaboration with UPOS. Dr. Kidder (CG/AR) and Dr Mike Kelly (UPOS) are working on the installation of Kidder's 3.9 micron CI albedo algorithm at AFWA.

*Mr. Kenneth E. Eis*

For more information on the DoD Center for Geosciences/Atmospheric Research at Colorado State University, please access our web page at <http://www.cira.colostate.edu>

**Colorado State University  
Center for Geosciences/Atmospheric Research  
Scientific Interactions December 2001 to Present**

- Tom Vonder Haar, Ken Eis, et al. with BGen. Johnson, USAF/XOW
- Ken Eis attended NRL Annual Program Review
- Ken Eis briefed AFMC Wright-Patterson AFB Sensor Directorate
- Ken Eis participated in the ARL/CISD Technical Assessment Board (TAB) Review – Dennis Thompson, Bruce Hicks, Eugenia Kalnay, Jon Mercurio, Jim Gantt, N. Radhakrishnan, Dan McMorrow, Bob Dumais, Dennis Garvey, Don Hooch, and Doug Brown
- Ken Eis, Tom Vonder Haar, Stan Kidder, Don Reinke, John Forsythe and Cindy Combs with Drs. John Zapotocny, AFWA and Ed Hume, UPOS/JHU
- Large and small group interactions at the Annual Review, held at ARL/Adelphi, including:
  - Tom Vonder Haar, Ken Eis, et al. with DoD Review Panel and invited attendees
  - Dr. Azimi with Mike Mungiole, Pam Clark, Alan Wetmore, Doug Brown, John Zapotocny, and other attendees briefly
  - John Davis, Sonia Kriedenweis and Robert Banta met with Pam Clark, Kris Gurton, David Ligon, Steven Hill, J. Pendleton, Ronald Pinnick, Alan Wetmore, D. Garvey, G. Videen, and Donald Hooke (via conference call), ARL, Atmospheric Effects Branch
  - Rob Newsom, Adam Kankiewicz, Capt. Jones, Ben Ruston and John Davis with Dennis Garvey, David Ligon, John Noble, Young Yee, Edward Vidal, Jimmy Yarbrough
  - John Forsythe with Larry Carey, Larry Key, John Zapotocny, and Pat Phoebus
  - Andy Jones with Nathaniel Winstead, Richard Gasparovic, Louis Butler, Frank Minaldo, Pam Clark, Gary McWilliams, Alan Wetmore, and Pat Phoebus
  - Jim Jones with Frank Garcia, John Zapotocny, Jon Mercurio, Doug Brown, Pat Phoebus, Young Yee, and Vince Larson
  - Pierre Julien with Doug Brown, Frank Garcia, John Zapotocny, and Roger Smith
  - Stan Kidder with Ed Hume, Dan McMorrow, and Mike Kelly, UPOS
  - Sonia Kreidenweis with Doug Brown and Pat Phoebus
  - Vincent Larson with Walter Bach, ARO
  - Tim Nobis with Robert Banta, NOAA/ETL, Col. Key, and Pat Phoebus
  - Roger Pielke, Sr. with Jon Mercurio

Jorge Ramirez with Doug Brown, John Zapotocny, Roger Smith, and Vincent Larson

Tomi Vukicevic with Jon Mercurio, Pat Phoebus, and Dr. Mango

Loretta Wilson with Doug Brown, Linda Duchow, staff of the BED office and some interactions with the Review Panel

Milija Zupanski with Doug Brown, Pat Phoebus, John Zapotocny, Leander Page, Vincent Larson, and Robert Banta

- Christian Carrico with Dr. Doug Lowenthal and others, NRL
- Ken Eis, Don Reinke and Capt. James Jones with Col. Benson and staff, AFWA
- Tim Nobis with Dr. Jimmy Adegoke, University of Missouri-Kansas City
- Tomi Vukicevic with Dr. N. Baker and COAMPS modeling group, NRL
- Mr. Gary McWilliams (ARL) visited Andy Jones regarding the NPOESS IPO/ARL soil moisture work
- Mr. George Gayno (AFWA) visited Andy Jones and John Forsythe regarding the USAF AFWA AGRMET data usage in the CG/AR work
- John Forsythe and Ken Eis with Maj. Ed Bensman, AFCCC
- Roger Pielke, Tomislava Vukicevic and others with participants of the Forum on Modeling the Atmospheric Boundary Layer

## Research Theme: Hydrometeorology

### Administrative

No actions during this period.

### Research activity and/or results

#### **Dr. Andrew Jones**

Submitted two journal papers:

Vukicevic, T., T. Greenwald, M. Zupanski, D. Zupanski, T. Vonder Haar, and A. S. Jones, 2003: Mesoscale cloud state estimation from visible and infrared satellite radiance. *Mon. Wea. Rev.*

Jones, A. S., T. Vukicevic, and T. H. Vonder Haar, 2003: A microwave satellite observational operator for variational data assimilation of soil moisture. *J. Hydrometeorology*.

The USAF AFWA AGRMET data sets have now been decoded. This data will be used as first guess information for the soil moisture data assimilation work. Below is an example of the USAF operational product after having been read into the DPEAS data processing system at CIRA and remapped to a global projection:

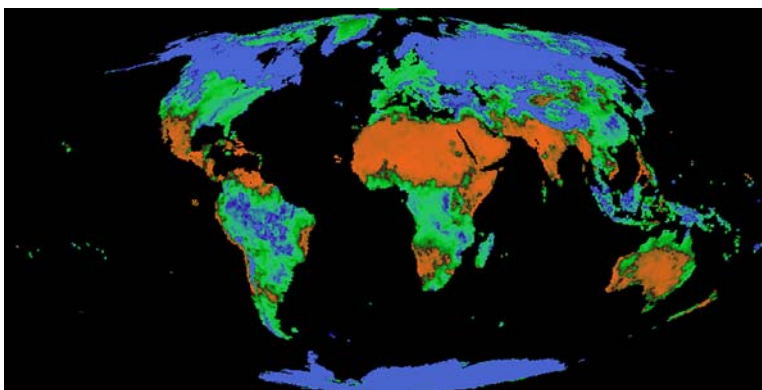


Figure 1: USAF AFWA AGRMET model output for global soil moisture content 0-10 cm for March 26, 2003. red is dry, green is moderate moisture, and blue is wet or snow covered.

Phil Stephens has now completed a portion of the 2D Backus-Gilbert (BG) work. That work is now being extended to the new advanced algorithms. A publication work plan was outlined during his visit to CIRA in May.

#### **Prof. Pierre Julien and Dr. Rosalia Rojas**

The hydrological model CASC2D-SED has been changed to account for local time stepping (LTS) in channels. The benefits of using an LTS approach over more traditional global time stepping method is a reduced computer run time among others. A base flow can be accounted for as initial condition in CASC2D-SED as well allowing the rainfall-runoff simulation to start

from a condition different than dry. Finally, the code has been modified to vary dynamically the terrain elevation, as erosional and depositional processes occur within the watershed.

The paper entitled “Washload Erosion Modeling with CASC2D-SED” by Rosalia Rojas and Pierre Y. Julien has been submitted for publication to the *Journal of Hydraulic Engineering* (ASCE) for its publication.

#### **Dr. Jorge A. Ramírez**

We have continued development and improvement of the hydrologic model HYDROR. Our model has demonstrated its ability for the prediction of the hydrologic and geomorphic responses of hillslopes to precipitation and other perturbations (e.g., land use changes). This potential is of great importance in addressing issues of erosion and sediment transport, contaminant transport, trafficability, etc. There is a need for continued integration across scales, in particular with the objective of providing physically-based parameterizations for larger-scale hydrologic models like CASC2D-SED, or those used in mesoscale atmospheric models like RAMS. Our model is especially well-suited to providing the basis for those developments. In addition to continued improvement of our model, integration across scales is of importance. Therefore, we are continuing to explore how this integration may be best carried out, in particular integration with other models that operate at larger spatial scales like CASC2D-SED, and eventually RAMS.

A manuscript titled: “Hillslope Drainage Development with Time: A Physical Experiment” was submitted for publication.

#### **Travel**

Dr. Andrew Jones attended the WRF-LSM WG14 Workshop in Boulder, CO, June 18.

Prof. Pierre Julien traveled to Billings, MT, June 2-3 (travel funded by another source).

#### **Dr. Andrew Jones**

Mr. Gary McWilliams (ARL) visited regarding the NPOESS IPO/ARL soil moisture work on May 27.

Mr. George Gayno (AFWA) visited regarding the USAF AFWA AGRMET data usage in the CGAR work on June 17.

#### **Prof. Pierre Julien and Dr. Rosalia Rojas**

Two presentations were given at the 9<sup>th</sup> Billings Land Reclamation Symposium and 20<sup>th</sup> Annual Meeting of American Society of Mining & Reclamation, June 3–6, and can be viewed via the website:

“Waste Piles Physical Characterization,” in the workshop on Assessing the Toxicity Potential of Mine Waste Piles, June 1.

<http://www.billingslandreclamationsymposium.org/workshops.htm#2>

“Fate and Transport of Metals and Sediment in Surface Water,” June 3.  
[http://www.billingslandreclamationsymposium.org/technical\\_sessions.htm](http://www.billingslandreclamationsymposium.org/technical_sessions.htm)

**Equipment/systems status**

A specific request for a new computer system has been made by Pierre Julien; Ken Eis is working on the details.

## **Research Theme: Cloud Structure, Dynamics and Climatology**

### **Administrative**

Dr. John M. Davis submitted his letter of resignation to CIRA, effective on July 11, 2003 in order to pursue other interests. Mr. Adam Kankiewicz will assume the role of CLEX project leader.

### **Research activity and/or results**

#### **Dr. John M. Davis, CLEX Leader**

Preliminary results concerning the retrieval of the optical properties of mid-level, mixed-phase clouds have been obtained. The technique utilized measurement of the spectral radiances in the 18, 12 and 8-micron regions obtained from the interferometric data collected at North Platte, NE during CLEX9, coupled with modeled radiances from clouds in the same regions using microphysical distributions measured by the UWKA as input into the MODTRAN v4.2 radiance and transmittance model. The results consisted of 10-micron optical depths, which were found to be highly correlated with the liquid water path as measured by the NOAA/ETL ground based microwave radiometer located next to the interferometer site. Retrieval of optical depth due to ice was less conclusive likely due to the extremely small water contents attributable to the ice. The method can be extrapolated to find the visible or IR target contrast that are used by DoD weapon systems. The results also indicate that while the liquid water portion of mid-level, mixed-phase clouds may comprise only 20% of the cloud vertical structure, the total optical depth is almost entirely due to the liquid portion, which is counterintuitive to what might be expected if the cloud structure is viewed from radar imagery, where the image is totally dominated by backscatter from the ice. The findings for the Oct. 14<sup>th</sup> and Nov. 2<sup>nd</sup> cloud cases have been documented for inclusion in the upcoming article on CLEX, which is in preparation for publication in the Bulletin of the American Meteorological Society.

#### **John Forsythe**

Visited the Air Force Combat Climatology Center (AFCCC) in Asheville, NC, May 12-16 with Ken Eis. Presented briefings to AFCCC staff including Col. Dave Urbanski on "CHANCES Regional Products" and "Smart Climatology Possibilities." Hosted Maj. Ed Bensman; our goal was to secure advocacy for these efforts. We received very positive feedback from Maj. Bensman about our presentations.

Modularized a portion the microwave optimal retrieval software which retrieves temperature, moisture, clouds, and emissivity from AMSU, SSM/T-2, and SSMIS in the future. The retrieval is now installed into the DPEAS system. In the process of installing the necessary pipelines for the first guesses required to start real-time processing.

Met with George Gayno of AFWA and learned about the AGRMET land surface model. Will use these fields in the OE retrieval as first guesses and as comparison points.

Wrote a work plan to complete the journal paper "Development of Regional Cloud Statistics from the CHANCES Satellite Database and Comparison with MODIS Cloud Mask" with Reinke

et al. My portion of work involves analyzing the difference between the MODIS and CHANCES results. Continued coding work to extract the various MODIS cloud tests.

**J. Adam Kankiewicz**

Provided both Jim Jones and Curtis Seaman with GOES IR satellite data in support of their MS degree work. All CLEX-9 visible and infrared satellite data has been retrieved, processed and archived at CIRA.

Provided IDL visualization help to Cindy Combs and the conditional climatology work she is working on.

The archiving of Cloud Depiction and Forecast System (CDFS II) data (both bogused and unbogused data) onto DVD media continues at CIRA. CDFS-II sample climatologies have been provided to Ken Eis, Don Reinke and John Forsythe for use during recently given presentations at AFWA and AFCCC.

The abstract titled "Comparison between the new CDFS-II WWMCA product and the CHANCES and MODIS global cloud products" has been accepted for a poster presentation at the 2003 BACIMO conference. I have obtained all of the needed MODIS (both Terra and Aqua-based) data for this project. The necessary data processing for this project is almost completed.

Collaboration with Larry Carey on the CLEX overview journal article continues. Graphs, figures and text needed in the article are being polished up for a final draft.

FORTRAN and IDL code that is used to produce the CHANCES Regional Products has been passed onto me from Don Reinke and is being used to generate data needed for my BACIMO conference poster.

### **Cynthia Combs**

#### CHANCES Regional Products

Ran Wind Regime programs using winds from the NCEP grid box west of Baghdad, Iraq for January-February, 2000-2001 for several hours. These results were compared to the results for Baghdad during the same time periods. Some differences between cloud frequencies and number of cases per wind regime were seen.

Wrote an abstract for submission to the BACIMO conference in Monterey entitled, Wind Stratified Cloud Products from Combined Satellite Cloud Observations and Model Output Fields. Assisted in the production of briefing slides for the AFCCC presentation.

### **Matt Rogers**

Continued work with CLEX-9 data and picking case studies suitable for research involving SLD retrieval. Discussed radar/lidar retrieval techniques with John Davis, made radar data requests to data contacts.

**Vincent E. Larson (University of Wisconsin-Milwaukee)**

Submitted to *Journal of the Atmospheric Sciences* a revised version of “Prognostic equations for cloud fraction and liquid water, and their relation to probability density functions.” This manuscript discusses the theory behind prognostic cloud schemes such as Tiedtke’s scheme, which is used by ECMWF. The theory should be useful for parameterizing clouds such as the mid-level clouds studied in the CLEX field experiment. I have begun planning to write a modeling section of a collaborative manuscript on CLEX. The manuscript will be submitted to *Bulletin of the American Meteorological Society*. I have continued modeling altocumulus clouds. I have been attempting to adapt the new Weather and Research Forecast (WRF) model to simulate altocumulus clouds. Progress has been hampered by bugs in the code, but I have been working with the lead developer of the model dynamical code, Dr. William Skamarock, to track down the bugs.

**Dr. Larry D. Carey and Mr. Larry Belcher (North Carolina State University)**

Contoured frequency by altitude diagrams (CFAD) provided the ability to assess the bulk statistics of the WCR radar data collected during CLEX-9. An automated filter was also used to only include radar data from level flight legs (i.e., rejection of data when aircraft roll exceeded  $0.5^\circ$ ). In an effort to further investigate the variability of WCR data, CFAD’s were constructed (from the same data set as described above) for each case day during CLEX-9.

The analysis of the UWKA in-situ data also provided insight into the statistical characteristics of the clouds sampled during CLEX-9. The distribution of liquid water content (LWC) from the DMT-100, Gerber PVM, and FSSP-100 were investigated, while that of ice water content (IWC) from the PMS 2D-C probe was also investigated. Observations of LWC show peak values up to  $1 \text{ g m}^{-3}$  with average values at or slightly below  $0.1 \text{ g m}^{-3}$ . Values of IWC rarely exceeded  $0.5 \text{ g m}^{-3}$  and exhibited average values near  $0.1 \text{ g m}^{-3}$ . The distribution of LWC and IWC within the clouds is consistent with previous work showing larger values of LWC (IWC) near cloud top (in the middle to lower portions of the cloud).

A power-law relationship between IWC and Z (i.e.,  $\text{IWC} = aZ^b$ ) from particle size spectra was also investigated. Analysis of in-situ data yielded an average  $a = 0.0103$  and  $b = 0.555$ . The mean values of “a” (“b”) are in good agreement with coefficients inferred from individual cases, which range from 0.005 to 0.018 (0.428 to 0.612). WCR reflectivity observations will be utilized in these Z-IWC equations to infer cloud-scale structure of IWC, statistical behavior of IWC as a function of temperature and distance from cloud top, horizontal and vertical homogeneity of IWC and the relationship of these properties to the in-situ identified all liquid or mixed-phase generating cells at cloud top.

Spectral analysis was conducted using the SSA (Singular Spectrum Analysis) toolkit (Ghil et al., 2002) to retrieve the periodic behavior of FSSP concentration, Gerber PVM LWC, and WCR reflectivity signals along flight tracks. The analyses indicate that the FSSP, PVM, and WCR data oscillates with 3-5 and 1-2 km (with occasional sub-kilometer signal) periods. These periods were found to be statistically significant in each case. The reasonable agreement found here confirms the connection between the liquid layer at cloud top and the enhanced ice region lower in the cloud, occurring in clusters throughout the cloud.

Each of the analyses discussed above were incorporated into a paper entitled “MM-Wave Radar Structure and Microphysical Characteristics of Mixed Phase Altocumulus Clouds” to be presented at the upcoming AMS 31<sup>st</sup> radar conference on August 6 in Seattle, WA.

### **Travel**

Ken Eis and John Forsythe traveled to Asheville, NC, May 12-16.

### **Technology transfer**

[See also the section under the Technology Transition and Interactions research theme].

#### **John Forsythe**

Presented Maj. Ed Bensman with the latest NASA Water Vapor Project (NVAP) CD-ROM containing sample animations, images and scientific results. AFCCC was previously unaware of this valuable 12-year climatology of global water vapor.

### **Equipment/systems status**

#### **John Forsythe**

Upgraded to CVF version 6.6b Fortran compiler.

Matt Rogers

Suitable for research at hand.

#### **J. Adam Kankiewicz**

Everything is running well.

## **Research Theme: N-Dimensional Data Assimilation and Fusion**

### **Administrative**

Dr. Vukicevic (with the other selection committee members) concluded selection of the candidate for research scientist position in the area of satellite remote sensing modeling and assimilation.

### **Research activity and/or results**

#### **Dr. Tomislava Vukicevic**

Attended technical meetings with Dr. N. Baker and COAMPS modeling group at NRL in Monterey in early April. The purpose was to define collaborative project between CIRA's data assimilation research group and NRL on cloud data assimilation using GOES observations.

Finished study on 4DVAR assimilation of GOES IR and VIS radiances for a case of liquid continental stratus cloud. Results show that these observations have strong influence on the cloud forecast with RAMS due to 4D dynamical links between the model cloud and the associated atmospheric environment. These results strongly suggest that 4D data assimilation procedure is necessary to extract useful information from the cloudy radiance satellite observations.

Submitted manuscript to MWR on “Mesoscale cloud state estimation from visible and infrared satellite radiances”, authors: T. Vukicevic, T. Greenwald, M. Zupanski, D. Zupanski, T. Vonder Haar and A. Jones.

Helped revise manuscript to appear in MWR on “Adjoint analysis of an observational operator for cloudy visible and infrared radiance assimilation,” authors: T. Greenwald, T. Vukicevic, L. Grasso and T. Vonder Haar.

Helped revise manuscript to appear in J. Hydrometeorology on “A microwave satellite observational operator for variational data assimilation of soil moisture,” authors: A. Jones, T. Vukicevic and T. Vonder Haar.

#### **Dr. Dusanka Zupanski**

Data assimilation experiments employing RAMDAS were performed to estimate model error of the RAMS model. The results indicate that the advanced data assimilation systems, such as RAMDAS, can successfully use observations to estimate and correct model error. Some interesting features of the model error were observed. Model error of the RAMS model has a strong systematic component along the horizontal boundaries, as well as a fast moving component throughout the model domain. The fast moving component of the model error was previously noticed in the data assimilation experiments employing Eta model (Zupanski et al. 2002). A manuscript reporting these results is being prepared.

A theoretical development to include model error estimation into the ensemble data assimilation technique has been carried out. Currently, only preliminary experiments are being performed,

employing a simple one-dimensional model. The experimental results indicate that model error estimation can be successfully achieved. A manuscript reporting these results is under preparation.

Dr. Milija Zupanski

Begun 4DVAR experiments to be used to publish RAMDAS results in Monthly Weather Review. The paper will be an overview of the RAMDAS system, presenting basic features and performance of the system. A paper on the Ensemble Data Assimilation with Hessian Preconditioning is submitted for publication to the Journal of Numerical Linear Algebra with Applications. This paper presents first theoretical results of the impact of preconditioning in ensemble data assimilation.

J. Adam Kankiewicz

Work on the 2 Nov 2001 CLEX-9 4DVAR case has been halted. The lack of nested grid capabilities within the RAMDAS system has limited the domain size and resolution of modeled case studies resulting in unrealistic mid-level cloud simulations.

Met with Ray McAnelly from Bill Cotton's research group to discuss the feasibility of running a post-event RAMS (V4.3) simulation on the 2 Nov 2001 CLEX-9 case. Ray indicated that this simulation work could begin when the necessary computer resources are reserved.

### **Travel**

Dr. Tomislava Vukicevic traveled to Monterey, CA, April 1-3.

### **Technology transfer**

[See also the section under the Technology Transition and Interactions research theme].

Dr. Tomislava Vukicevic

Gave seminar at ECMWF on the CIRA-CG/AR data assimilation research on June 5.

## **Research Theme: Chemistry, Aerosols and Visibility**

### **Administrative**

Prospective graduate student Laura Sample, completing her B.S. in Meteorology at Texas A&M, was recruited, and accepted an offer of admission to the CSU graduate program in Atmospheric Sciences. She will begin working on research in July 2003 and will begin coursework in Fall 2003, with Prof. Kreidenweis serving as her academic adviser.

### **Research activity and/or results**

#### **Prof. Sonia Kreidenweis and Graeme Stephens, and Dr. Laurent Labonnote**

During this quarter, the research emphasis of postdoctoral fellow Dr. Laurent Labonnote shifted to questions related to the retrieval of particle information from CloudSat/MODIS instruments. Although the exact instrumentation configuration is unique to CloudSat/MODIS, some of the same retrieval issues will occur with other proposed DoD remote sensing configurations, and thus the study undertaken to investigate questions of retrieval accuracy will be of use to future programs. The study completed in the second quarter of 2003 has specifically addressed retrievals of cloud parameters for layered-cloud situations, and follow-on work during the coming months will extend this to aerosol size and composition ranges. In the completed work, the sensitivity of the retrieved cloud optical thickness and effective radius was examined as a function of location in the cloud and the wavelength used in the algorithm. The goal of this work is to develop guidelines to determine in which part of the layer the retrieval sensitivity is highest for a given effective radius and wavelength. It was found that the retrieved cloud effective radius and consequently the retrieved optical thickness are strong functions of the chosen wavelength. This is due to variations in sensitivity in different locations within the cloud for different wavelengths. Consequently, if we imagine an altitude-dependent variation of the actual effective radius within the cloud, using different wavelengths to retrieve optical parameters will generate different results. This sensitivity thus limits the accuracy of the retrievals. We expect similar sensitivities to occur in aerosol retrievals, but will address this question specifically in continuing work in 2003.

#### **Dr. Rob Newsom and Dr. Yelena Pichugina**

Research has progressed on the structure and dynamics of stably stratified nocturnal boundary layers through the analysis of the CASES-99 data set. Several collaborative studies are currently in progress.

Reviews from a paper entitled "Review of near-surface flow dynamics in the neutral planetary boundary-layer from a CASES'99 case study" by Drobinski et al. have been received and the paper has been conditionally accepted for publication in the Journal of the Atmospheric Sciences. This paper examines linearly organized low-speed streaks observed by Doppler lidar during the CASES-99 field experiment. We have been working with the first author to provide additional analysis of the lidar data to satisfy the reviewers.

Reviews from a second paper entitled "Retrieval of Microscale Flow Structures from High Resolution Doppler Lidar using an Adjoint model" by Chai et al. have been

received and the paper has been conditionally accepted for publication in the Journal of the Atmospheric Sciences. In this paper, Doppler lidar data from the CASES-99 field program is used in a 4DVAR algorithm to retrieve all three components of the wind field, as well as the pressure and potential temperature fields. We have been working with the first author to address the reviewers' criticisms. Also during this period, we have been preparing two journal articles which describe and apply our own 4DVAR algorithm for wind and temperature retrieval from Doppler lidar data. These articles will be submitted to the Journal of Atmospheric and Oceanic Technology.

Toward the end of this quarter, efforts focused on preparing for the Joint Urban (JU2003) dispersion field experiment in Oklahoma City. The experiment is scheduled to run from the end of June to the end of July, 2003. Modifications were made to existing code used for display and analysis of lidar data. The modifications were necessary to ingest the CTI data format.

### **Travel**

Dr. Newsom drove to Oklahoma City on June 26 to participate in the Joint Urban (JU2003) dispersion field experiment.

### **Technology transfer**

[See also the section under the Technology Transition and Interactions research theme].

### **Equipment/systems status**

No report during this period.

## **Research Theme: Remote Sensing of Battlespace Parameters**

### **Administrative**

#### **Prof. Mahmood R. Azimi-Sadjadi**

GRA appointments were completed for a new Ph.D. student, Vincent Wong, who will start August 1, 2003, and for a new masters student, Ms. Amanda Falcone, who will start August 15, 2003.

### **Research activity and/or results**

#### **Dr. Stanley Kidder**

This quarter I worked with Mike Kelly of UPOS to implement my cirrus detection scheme at AFWA. Mike visited AFWA and is in the process of getting some AFWA GOES data. I shipped Mike some code to calculate the 3.9  $\mu\text{m}$  albedo, which is one component of the cirrus detection.

#### **Benjamin Ruston**

My doctoral research involves obtaining better estimates of means and variance of microwave land emissivity for use in temperature and moisture profiling algorithms. The focus for this reporting period was directed towards minimizing the error in the Land Surface Temperature (LST). I have shown that the error in the microwave land emissivity is dominated by the error from the LST. Using a database of fractional vegetation cover of 13 types (Land Data Assimilation System – LDAS [NASA]), and a spectral reflectance database (ASTER spectral library [JPL]) to create an atlas of emissivity values for use in an infrared retrieval of skin temperature. GOES data from channels 2 and 4 (3.9 & 10.7 micron) are used to create a cloud mask following a method set forth by Jedlovec and Laws, 2003 (*12th Conf. on Sat Met & Ocean*, AMS, Long Beach, CA). Profiles of temperature and moisture from either the Rapid Update Cycle (RUC [NCEP]) or Navy Operation Global Atmospheric Prediction System (NOGAPS [DoD]) are used with a correlated k-distribution infrared radiative transfer code to calculate the LST from the GOES channel 4 (10.7 micron) brightness temperature data. The cloud mask, LST retrieval, and microwave emissivity retrieval have been performed over the CONUS region for July and August of 2001 with processing over the entire study period June–August of 2000, 2001, and 2002 to be completed by the end of July 2003.

Diagnostics of the retrieval technique continue to be performed. The land emissivity shows characteristic signatures resulting from the volumetric scattering by the vegetative cover. The more vegetated the area the lower the polarization difference, and the more consistent the emissivity spectrally. Barren ground shows both a larger polarization difference, and a larger spectral dependence. Rain auto-correlations above 20 GHz are very weak. The greatest rain auto-correlation is  $-0.4$ , which occurs over bare ground at 19.35 GHz. Error budgets have been created for the retrieved infrared land surface temperature and microwave emissivity. A goal of the research is to bring the errors for both to one percent.

The goal of this research is to improve the statistics on land emissivity in the microwave spectrum. This will allow passive microwave radiance assimilation into the numerical weather

models. The weather models currently use passive microwave radiances over the ocean only for total column water vapor and temperature profiling, attempts at moisture profiling are now beginning as well. Relationships linking microwave radiances less than 20 GHz to soil moisture have been developed but are not being used operationally by the modeling community. Future goals of this research are to apply the observational knowledge of the emissivity covariance and frequency cross-correlation to observational operators, which link the radiances to weather model variables using radiative transfer. These observational operational will allow the numerical weather models to ingest the satellite radiances directly into the model.

The proposal for a project this summer (August 11-22) at NRL-Monterey has been accepted and preparations for a collaborative project with the Naval Research Laboratory (NRL) Marine Meteorology Division in Monterey has begun. The project will retrieve temperature profiles over the Southern Great Plain ARM site using a functional form of emissivity by local zenith (which I developed), along with a NRL/Monterey-developed temperature profiling algorithm. The retrieval employs data from the NOAA-Advanced Microwave Sounding Unit (AMSU) instrument. Data has been collected for the study period of July and August 2001, July and August of 2000 and 2002 will be added to make the statistics over the study region more robust. Retrievals of land emissivity at AMSU frequencies and zenith angles have begun. The 1DVAR temperature retrieval from NRL-Monterey's Dr. Nancy Baker has been obtained.

**Prof. Roger Pielke, Sr., Dr. Adrian Marroquin, Maj. Tim Nobis and Giovanni Leoncini**

The attempt to publish the paper by Marroquin and Pielke in the Earth Interactions Journal of the AMS/AGU has been difficult and slow, not only because of the lack of reasonable scientific interaction with the reviewers and editor, but the request by the referees to include a considerable number of high-resolution simulations of other cases. This request demands large amounts of computer resources that we do not have available at this time. We have chosen, therefore, to submit the paper to Weather and Forecasting without the figure animations (available in the Earth Interactions version, which we will make available on our web site). This journal was selected because the paper is intended to demonstrate that RAMS, with proper initial and boundary conditions, in high resolution, is capable of producing reasonable short-term results useful to forecasters in case of pollutant dispersion events.

The Local Analysis and Prediction System (LAPS) developed at FSL has been installed on the CIRA cluster to provide initial and boundary conditions for high resolution RAMS simulations. The purpose is to be able to ingest large number of heterogeneous field observations (profilers, raobs, metars, radar, satellite, etc.) to generate balanced three-dimensional fields used to run the model. The target case of the LAPS test was the 15 October 2000 from the Vertical Mixing and Transport experiment (VTMX) over Salt Lake City, Utah.

A 12-h simulation with LAPS analysis (4 km grid spacing) for initial/boundary conditions (every 3 h) was successful. The RAMS output forecast agrees very well with the analyses (accurate simulations of the wind reversal and drainage flow develop were produced fine) with additional small scale vertical eddies where the drainage flow interacts with the valley-floor flow from the south-east (reversed flow) along the foothills to the east of SLC.

The drainage flow that starts at about 03Z, however, lacks strength due poor observations over high terrain east of Salt Lake City. These results can be improved if hourly LAPS analyses were used in conjunction with radar data to define the boundary conditions. The temporal resolution of the LAPS analyses should have an impact in capturing more accurately the evolution of the internal (innermost grid) flow features which are small in time and space.

In a previous simulation in which RAMS was initialized with LAPS data at 00Z and with boundary conditions from the Rapid Update Cycle (RUC, 40 km), the simulations did not provide an acceptable forecast due the coarseness of the RUC grid. Due to the proximity of the boundaries to the innermost grid (250 m grid spacing covering 15 k x 15 km around Salt lake City), the flow began to be dominated by the information from the boundaries. These results show that the initial and boundary conditions for high resolution simulations have to be chosen carefully in order to provide the model with realistic data.

Most Recent Activities:

- 1) The effort to ingest VTMX data into LAPS is now underway. The Doppler radar ingest represents a challenge from the LAPS coding standpoint. At FSL tests are now being conducted to establish the path for such data ingest.
- 2) One of the most important aspects of RAMS high resolution simulations is the use of high resolution terrain (terrain resolution should be in fair agreement with the model grid spacing). A mosaic of 6 terrain tiles, 1 deg x 1 deg, (3-s data, 93 m) has been assembled around Salt Lake City area. Just recently, July 2, Bob Walko from ASTER modified the program mktopo.f to produce terrain files compatible with RAMS tile format. Now it is feasible to generate a complete dataset of 3s (93 m) terrain data over the United States in tile form using USGS raw data. To initiate this effort, a test will be conducted with 3-s data over the Salt Lake City area.
- 3) Software is now being tested to interpolate RAMS output to generate ppi data that can be then correlated to the corresponding lidar data from the field (VTMX).
- 4) Parallel to the terrain resolution problem, the effort to ingest other surface data at high resolution are now being considered for LAPS. This effort will involve the addition of a land surface model (LSM). At the present time LAPS is provided with a simple LSM that computes surface variables (skin temp, soil moisture) based mostly on precipitation. We have three possible LSM models; LDAS from NASA, the RUC-LSM from FSL, and the GEMTM developed and tested at CSU using the RAMS software. Preliminary work showed that the RUC-LSM and LDAS will involve considerable effort to implement in LAPS. Efforts are now underway to install the GEMTM into LAPS.

#### **Maj. Tim Nobis**

A number of events occurred during this period. My research focus has officially shifted from Oklahoma City to Washington, D.C. The goal of my research (to study urban impacts on dispersion forecasting) remains the same. The switch was made to facilitate timing as it became obvious I would not have access to the URBAN03 database in time to complete my degree. Instead, I will use a dispersion database collected in Washington, D.C. in 1984. This database

has the advantage of covering an entire year and was collected in a variety of weather so as to maximize modeling possibilities.

Attended and participated in a CSU/ARL sponsored modeling forum held here at in Fort Collins. Several modeling groups were represented and presentations were made followed by discussions on shortfalls of several aspects of mesoscale modeling. The information gained here was very valuable.

Analyzed the release/collection methodology and post processing of the tracer releases done in Washington, D.C. during 1984: concluded that the data is good enough for my purposes. Spent a great deal of my time working to couple the Urban parameterization known as the Town Energy Balance (TEB) model to the Regional Atmospheric Modeling System (RAMS). This is the key first step in my modeling efforts.

Met with Dr. Jim Adegoke from the Department of Geosciences, University of Missouri-Kansas City to discuss the coupling of TEB and RAMS. Dr. Adegoke is attempting to obtain city morphology data that will be fed into the coupled system. I am going to do the coupling and in return receive morphology data for the Washington, D.C. area. The transfer is expected in late August.

### **Giovanni Leoncini**

Resumed research after the Ph.D. qualifying exam and I first set up all the software to run the model and view results since my operative system had been updated. I had a meeting with Dr. Dalu and we decided not to compute the Laplacian of the Exner function, but to work on the geopotential as defined in Dalu et al. 2003. In order to obtain an equation for the Laplacian closer to the analytical results of Dalu et al. 2003, and therefore making the interpretation and comparison of results interpretation much easier. This should be possible multiplying the Exner function times theta or a function of theta.

I am designing a modeling experiment to study the mesoscale feedbacks into the larger scale. With this aim I read quite a few papers, and I am studying Chris Castro's methodology to evaluate its usefulness for my purposes. I also contacted Liou's research group in order to evaluate the sensitivity of their radiation routine compared to the two already implemented in RAMS.

Attended the CSU/ARL modeling forum, which was extremely useful and informative.

### **Prof. William Cotton, Russell Chibe, and Gustavo Carrio**

Russell Chibe completed his M.S. thesis research, which examined the RAMS model's ability to forecast fog, this past semester. Russell successfully defended his M.S. thesis on June 19, and also passed his final examination. For the remainder of the summer, he will write a paper based on his research, which will be submitted to a professional journal yet to be determined.

### Implementation of the PDF boundary layer model.

The PDF-based parameterization designed by Golaz (2002) is a single-column model, designed as a stand-alone scheme. The original PDF model configuration, structure and initialization modules has been modified by Dr. Gustavo Carrió to allow:

- a) compatibility with RAMS computational architecture,
- b) step by step communication with the dynamic model,
- c) and an easy adaptability to future improvements being made by the author of the original model, such as reduction in the number of degrees of freedom (higher-order turbulent moments) that will lead to an increased computational efficiency.

A series of preliminary tests have been performed to compare results of for trade-wind cumulus clouds (BOMEX) and cumulus over land (ARM). In order to isolate the performance of the new modules, a code that simulates RAMS has been designed to evaluate them before the actual implementation into RAMS.

In addition, Hongli Jiang has been interfacing the PDF model with RAMS bulk microphysics parameterization.

In the end of July, Chris Golaz will visit to share his simplifications to the scheme that will permit more efficient computations with the model when installed in RAMS or COAMPS. He will present a special seminar at CIRA during his visit.

### **Travel**

None during this period.

### **Technology transfer**

[See also the section under the Technology Transition and Interactions research theme].

Dr. William Cotton attended the Forum on Modeling the Atmospheric Boundary Layer on May 19-23 in Fort Collins, CO and made a series of presentations on RAMS microphysics, turbulence closures, radiation scheme, and boundary layer cloud prediction.

The following paper has recently been published:

- K. Saitwal, M.R. Azimi-Sadjadi, and D. Reinke,
1. "A Multi-Channel Temporally Adaptive System For Continuous Cloud Classification From Satellite Imagery,
  2. " *IEEE Trans. on Geoscience and Remote Sensing-Part II*, Vol. 41, pp. 1098-1104, May 2003.

## **Equipment/systems status**

### **Maj. Tim Nobis**

Status: Green.

### **Todd Gamber**

The Cluster is now running nicely with very few errors. However, in recent weeks, the master node had been experiencing semi-weekly crashes. In addition, four more CPU fans failed on slave nodes. These problems resulted in frequent service interruptions.

Once Ewe5's bad CPU fan was replaced from its failure during last quarter, it was reinstated not as Ewe5 but as the master node in hopes of helping the semi-weekly crashes. So far, the replaced master node is performing well. The additional failed CPU-fans were also replaced and working properly.

## **Research Theme: Technology Transition and Interactions**

In addition to the items listed in the main research theme sections, at the request of the Army Research Laboratory, CG/AR hosted the Forum on Modeling the Atmospheric Boundary Layer at the University Park Holiday Inn, Fort Collins, May 19-22. Under ARL funding, several guest experts were invited to participate. Included in this report is the provisional agenda and participant list.

## PROVISIONAL AGENDA

### Forum on Modeling the Atmospheric Boundary Layer

May 19-23, 2003  
University Park Holiday Inn  
Fort Collins, CO

Sponsored by The Army Research Laboratory and the  
DoD Center for Geosciences/Atmospheric Research

\* **Forum Format** – At this meeting we are attempting to have representation from 7 major Mesoscale modeling systems and for each of the topical areas, a representative for each of the models will be asked to present a brief (note times allocated) technical description of the manner in which the particular entity is implemented with an explanation of why this approach was used. Additional information/comments associated with a topic area may be requested. Once each model has presented its information for a particular topic, there will be an open discussion focusing on: (1) applicability of the various technique to the the Army mission; and (2) a discussion of associated research opportunities/requirements alternate techniques.

Please note that due to the ambitious scheduling, the times allotted to each model for presentation will be strictly controlled.

#### **Monday, May 19th**

1400-1700 Welcome and Forum Overview – *Dr. Jon Mercurio – ARL, Adelphi*  
*Prof. Roger Pielke, Sr., and Dr. Tomislava Vukicevic – CG/AR, CSU*

\* ARL will provide a presentation on Army requirements for meteorological information and modeling, followed by a general discussion on how the Army's needs coincide or depart from the general meteorological modeling framework.

1800-2000 *Icebreaker in the Atrium (appetizers and a cash bar)*

#### **Tuesday, May 20th**

0800-0805 Welcome and Opening Comments – *Dr. Jon Mercurio*

0805-0915 Coordinate System – *Roger Pielke, Sr., Chair*  
(generalized vertical coordinate, horizontal spatial grid, associated numerical errors) \*10 min/model

915-955 Open Discussion

- 0955-1015 *Break*
- 1015-1200 *Dynamic Core – Tomislava Vukicevic, Chair*  
(representation of advection, pressure gradient force, time derivative, conservation properties, assumptions used to derive basic model equations, such as Reynolds averaging, tradeoff between efficiency and accuracy) \*15 min/model
- 1200-1230 *Open Discussion*
- 1230-1400 *Lunch (on your own)*
- 1400-1545 *Sub-Grid Scale Fluxes – Jon Mercurio, Chair*  
(planetary boundary layer turbulence, surface layer turbulence, surface heat and moisture representations, heterogenous sub-grid scale effects) \*15 min/model
- 1545-1605 *Break*
- 1605-1650 *Open Discussion*

### **Wednesday, May 21st**

- 0800-0805 *Opening Comments – Dr. Jon Mercurio*
- 0805-0950 *Radiative Fluxes – Roger Pielke, Sr., Chair*  
(long wave, short wave; clear, partially cloudy, cloudy skies; aerosol effects)  
\* 15 min/model
- 0950-1030 *Open Discussion*
- 1030-1050 *Break*
- 1050-1200 *Initial Conditions – Tomislava Vukicevic, Chair*  
(how obtained and applied, adaptability to 4DDA) \*10 min/model
- 1200-1230 *Open Discussion (30 min.)*
- 1230-1400 *Lunch (on your own)*
- 1400-1510 *Lateral and Top Boundary Conditions/Grid Nesting – Jon Mercurio, Chair*  
(how obtained and applied) \*10 min/model
- 1510-1540 *Open Discussion*
- 1540-1600 *Break*

1600-1710 Stratiform Clouds and Precipitation – *Roger Pielke, Sr., Chair*  
(treatment, time penalty, diagnostic, prognostic) \*10 min/model

1710-1750 Open Discussion

### **Thursday, May 22nd**

0800-0805 Opening Comments – *Dr. Jon Mercurio*

0805-0915 Convective Clouds and Precipitation – *Jon Mercurio, Chair*  
(treatment, time penalty, diagnostic, prognostic) \*10 min/model

0915-0955 Open Discussion

0955-1015 *Break*

1015-1125 Procedures for Model Evaluation – *Tomislava Vukicevic, Chair*  
(comparison to ?; sensitivity of results to uncertainty of model parameterizations,  
and lateral, top and initial boundary conditions, publication of results)  
\*10 min/model

1125-1155 Open Discussion (30 min.)

1200-1330 *Lunch (on your own)*

***Note: The final three topic areas will be discussion sessions only.***

1330-1410 Ensemble Modeling – *Roger Pielke, Sr., Chair*  
(compare advantages of low and high resolution application)

1410-1450 Assimilation of Atmospheric and Land Surface Data (4DDA) – *Tomislava Vukicevic, Chair*

1450-1530 Prognostic vs. Diagnostic as a Nowcasting Approach – *Jon Mercurio, Chair*

1530-1550 *Break*

1550-1700 Breakout session to draft outline of BAMS article

### **Friday, May 23rd**

0830-1030 Summary Session

1030 Travelers depart for Denver International Airport

## Forum Participants

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