Colorado State University
Center for Geosciences/Atmospheric Research (CG/AR)
Quarterly Report No. 7
by T.H. Vonder Haar and Collaborators

Reporting period: October 1 - December 31, 2003

Cooperative Agreement #DAAD19-02-2-0005

Overview

Dr. Andy Jones reports progress in microwave sensing of hydrometeorological parameters. Also under the Hydrometeorology theme, chemical transport is being added to CASC2D hydrological model.

Work has begun on the transmittance at visible and infrared wavelengths of mixed-phase clouds.

Researchers in the N-Dimensional Data Assimilation and Fusion theme report that data assimilation into atmospheric models is advancing on several fronts. The new Ensemble Kahlman collaborative effort between CG/AR and WSMR got underway with researcher visits to Whites Sands and Fort Collins.

Dr. Kidder's work on thin cirrus algorithm collaboration continues.

Ben Ruston successfully defended his Ph.D. research on microwave land emissivities and was offered a postdoctoral position at the Navy Research Laboratory, Monterey in order to continue his work.

Pielke's group added options for treatment of pressure gradients to RAMS 4.3 and the coupling of the RAMS mesoscale model with the Town Energy Balance (TEB) urban parameterization scheme was completed.

Dr. Stan Kidder

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 Hoock, 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
- Adam Kankiewicz with Dr. Jason Nachamkin (NRL)
- Ben Ruston with Dr. Nancy Baker and data assimilation group at NRL
- Andy Jones, Tomi Vukicevic, Ken Eis, John Forsythe, Adam Kankiewicz, and Tim Nobis attended the BACIMO 2003 Conference and had numerous interactions with researchers from the Army, Navy and Air Force labs, as well as other participants
- Milija Zupanski with Patrick Haines, ARL/WSMR and Chatt Williamson, ARL/Adelphi

Research Theme: Hydrometeorology

Administrative

None this period.

Research activity and/or results

Dr. Andrew Jones
Extensive work was performed with the 1DVAR microwave water vapor profiling algorithm and emissivity retrievals. The system has been optimized to improve computational performance more than 15%. Additional science improvements are being made to update the microwave emissivity model to the latest version of the NOAA Weng emissivity model.

A standalone Microwave Emissivity Model (MEM) DPEAS application was also created for intercomparisons purposes. The MEM is feed AGRMET model data.

Timings of the new 2D Discrete Backus-Gilbert (DBG) method show that the speed improvements are at least twice as fast if not more. Alternate methods are currently being explored for the generalized singular value decomposition (GSVD) improvements due to the Stoygrn formulization of the instrument noise versus the resolution enhancement. This is currently being worked on. Planning for implementation of the new 2D DBG method using real observational data sets is underway.

Prototype DMSP SSMIS data are now being been obtained from FNMOC in near real time. This is exercising the CIRA SSMIS data processing algorithms. Considerable work remains to use the full data feeds which should become available in about 1 year (after the full SSMIS Cal/Val phase).

Prof. Pierre Julien
The CASC2D hydrological model is being expanded to add chemical transport and mass transfer/transformation processes to the basic framework. Model implementation of hydrologic and hydraulic transport processes have been extensively revised to permit coupling with chemical transport modules. Testing of model overland and channel flow routing algorithms is underway. We anticipate that flow routing algorithm testing will be completed during the upcoming quarter. Review and revisions of model sediment transport processes has also underway. We anticipate this review and all revision to sediment transport algorithms will also be completed during the upcoming quarter.

Once the revisions to all flow routing and sediment transport algorithms have been tested, chemical transport and mass transfer/transformation (fate) modules will be added to the model. A diagram of chemical transport and fate processes is presented in Figure 1.

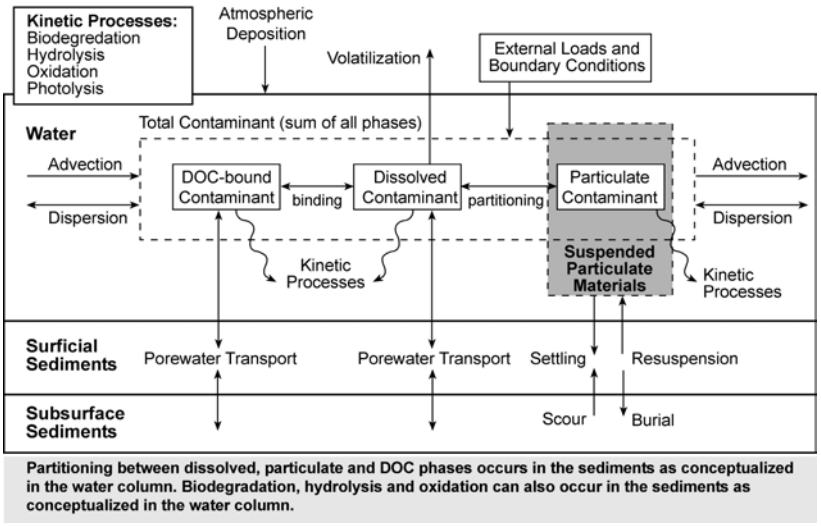


Figure 1. Chemical transport and fate processes to be added to CASC2D.

We anticipate that the chemical transport and fate processes will include advection and dispersion in channels and the overland plane, porewater transport between sediments and water in the channel network, partitioning between dissolved, bound, and particulate phases, erosion, deposition, volatilization, hydrolysis, oxidation, biodegradation, and photolysis.

All code is being developed using the ANSI standard C programming language. We expect that the final set of model source code will be portable across a range of different computing platforms and operating systems.

Prof. Jorge Ramírez

We have continued development and improvement of the hydrologic model HYDROR. In addition to continued improvement of our model, we are exploring ways of scaling up the model without loss of model accuracy. In addition to allowing more efficient application of the model to larger scales, this will also ensure a better integration with other models that operate al larger spatial scales like CASC2D-SED, and eventually RAMS. We are implementing improvements to the erosion and sediment transport components to allow for unsteady external sediment supply rates.

A manuscript titled: "*Hillslope Drainage Development with Time: A Physical Experiment*" by Raff, D.A. and J. A. Ramirez was accepted for publication in the *Journal Geomorphology*.

Travel

None this period.

Technology transfer

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

A paper and poster by D.A. Raff and J.A. Ramirez were presented at the Fall Meeting of the American Geophysical Union in San Francisco, December 8-12. The paper is titled "A Physical, Mechanistic and Fully Coupled Hillslope Hydrology Model."

Equipment/systems status

Prof. Pierre Julien
All equipment and systems (two Pentium4-based personal computers and one dual processor Itanium2-based workstation) are operational and meet present computational needs. These systems are used for numerical model development.

Research Theme: Cloud Structure, Dynamics and Climatology

Administrative

None this period.

Research activity and/or results

J. Adam Kankiewicz, CLEX Leader

Work has begun on a modeling study of the transmissivity of visible and infrared wavelengths through a mixed-phase cloud profile. As a special effort outside his new position at CSU's Natural Resource Ecology Lab, John Davis has been guiding Curtis Seaman through the MODTRAN radiation transfer code to simulate theoretical target transmittances at various locations within a mixed-phase cloud profile. A white paper on this work will be produced in early 2004.

Attended the ARM cloud properties working group meeting in Broomfield, Colorado. At this meeting, I learned more about the current state of mixed-phase cloud research. While significant work and progress is being made understanding mid-latitude and arctic mixed-phase clouds, almost nothing is known about tropical or oceanic mixed-phase clouds. I talked with various researchers about mixed-phase clouds and was able to share CLEX-results with ARM's mixed-phase cloud sub-group. I also identified possible field experiment collaborations that might benefit CIRA's mixed-phase cloud research.

The RAMS@CSU (with Ray McAnelly) and COAMPS (with Dr. Jason Nachamkin at NRL) modeling work continues. Our current focus is on the 2 Nov 2001 CLEX-9 case study. Horizontal and vertical grid nesting schemes are being tested to identify the optimal configurations needed for our simulations. The RAMS@CSU simulations show good skill out to about the 9 hour forecast. Though no cloud is produced, horizontal and vertical locations of humidity maximums match well with observed data. Jason has reported that early COAMPS simulations of the 2 NOV 2001 case fail to produce a cloud as well. He is going to try the same model simulations incorporating NAVDAS ingest to see if that improves the forecast. Work will continue on these simulations.

Met with Dr. Vince Larson on October 10 at CSU to discuss notes about an early draft of our CLEX-related BAMS article that is being finalized. Work with both Vince and Prof. Larry Carey (TAMU) on the BAMS article continues.

The archiving of Cloud Depiction and Forecast System (CDFS II) World-Wide Merged Cloud Analysis (WWMCA) (both bogused and unbogused data) onto DVD media continues at CIRA. One year of CDFS II data has been successfully archived at CIRA!

I am providing MODIS data and technical support to both Vincent Wong and Amanda Falcone (graduate students in Dr. Azimi's group).

John Forsythe
Met with Matt Nielsen (new masters student advised by T. Vonder Haar) several times to introduce him to scientific programming and microwave remote sensing. Provided him with the microwave radiative transfer model from the Microwave Optimal Estimation package. Though his graduate research assistanceship is supported by other funding, Matt's research topic will involve remote sensing of clouds and is relevant to CG/AR.

Completed contribution to CHANCES/MODIS journal paper and provided to Don Reinke.

Continued development of the Microwave Optimal Estimation retrieval within the DPEAS system. Investigated errors in the temperature retrieval via a 13000 point matchup dataset obtained from NCDC. Validation of the retrieval with this data continues.

Travel

Adam Kankiewicz traveled to the ARM Cloud Working Group Meeting in Broomfield, Colorado, October 28-30.

Technology transfer

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

Equipment/systems status

John Forsythe
System functioning nominally.

Research Theme: N-Dimensional Data Assimilation and Fusion

Administrative

None this period.

Research activity and/or results

Dr. Tomislava Vukicevic
Worked on stability of Regional Atmospheric Modeling and Data Assimilation System software. This involved testing for cases with all cloud microphysics included. The software is not yet quite stable. More testing is ongoing.

Dr. Milija Zupanski
Development of a simple 1-dimensional ensemble Kalman filter (EnKF) algorithm, and its installment on the Army high-performance computers (HPC) started. At this point, the algorithm employs a 1-dimensional Korteweg-de Vries-Burgers model and simulated observations produced in a twin experiment. The initial development and testing on the CIRA Linux PC cluster is almost completed, but porting of the code to the Army HPC is still waiting the security clearance for the computer account.

Related to the start-up EnKF collaboration with ARL, two visitors came to CIRA/Fort Collins, December 18-19: Patrick Haines of ARL/WSMR, and Chatt Williamson of ARL/Adelphi. With the assistance of Dusanka Zupanski, the visitors are introduced to practical aspects of including model errors in NWP model.

Dr. Dusanka Zupanski
The issues of ensemble data assimilation were further examined with Milija Zupanski. During the visit of Patrick Haines and Chatt Williamson, we discussed the specific problems related to linking the microscale models with the ensemble data assimilation algorithm.

Dr. Manajit Sengupta
Upgrade to the observational operator being used for data assimilation to RAMDAS, started during the previous quarter, was continued into this period. Preparation for a new data assimilation experiment was made, which involved obtaining and processing satellite data to make it compatible for the new experiment. A preliminary comparison of clouds generated using the RAMS model was made using ground-based radar data from the Atmospheric Radiation Measurement (ARM) Program site located in Oklahoma.

Travel

Tomi Vukicevic and Manajit Sengupta traveled to the ARM Cloud Working Group Meeting in Broomfield, Colorado, October 28-29.

Dr. Milija Zupanski traveled to White Sands Missile Range, New Mexico, November 19-20, as an initial organizational effort for the EnKF-related collaboration with ARL.

Technology transfer

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

Research Theme: Boundary Layer Atmospheric Chemistry and Aerosols

Administrative

Postdoctoral researcher Laurent Labonnote resigned his position in November 2003 to accept a research position in France.

Research activity and/or results

Profs. Sonia Kreidenweis and Graeme Stephens, Dr. Laurent Labonnote, and Laura Sample
Laura Sample continued to research methods for combined lidar/radiometer retrievals.

Laurent Labonnote completed his CG/AR-funded research. He is preparing a manuscript for publication, but it has not been submitted as of this report date.

Travel

None this period.

Technology transfer

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

Equipment/systems status

No report this period.

Research Theme: Derivation of Battlespace Parameters

Administrative

Steve Saleeby will be assisting with the Cotton work by taking over for Gustavo Carrio in the implementation of the PDF turbulent closure model in RAMS.

Research activity and/or results

Dr. Stanley Kidder
Worked on the thin cirrus detection problem and continued work with Mike Kelly of UPOS to implement the 3.9 μm algorithm at AFWA. Also started a parallel effort to extend the algorithm to the daytime using 1.6 μm data, which is currently available on some of the NOAA satellites and on the new Meteosat Second Generation.

Benjamin Ruston
On December 10, Benjamin Ruston successfully defended his PhD research on microwave land emissivities. The dissertation is entitled "Characteristics of Summertime Microwave Land Emissivity over the Conterminous United States." The work has direct and indirect impacts on cloud retrievals and detection, rainfall quantification over land, land surface temperature, and atmospheric sounding of temperature and moisture. At microwave frequencies the atmosphere is semi-transparent. Consequently, a satellite radiance measurement contains a large fraction of energy from the Earth's surface. This research characterizes microwave surface emissivity and its associated error over the summertime Conterminous United States (CONUS) during 2000 – 2002 for use with various remote sensing applications and data assimilation systems. It is found that the microwave emissivity errors are dominated by the error in the land surface temperature. The microwave emissivity error is generally better than one and a half percent, and the retrieved emissivity varies by less than five percent about a summertime mean value for a given location.

Recent accomplishments by Ruston at CG/AR include retrieving Land Surface Temperatures (LST), microwave emissivities, and cloud fraction from June through August for three years beginning in 2000. Microwave emissivities were retrieved from three Special Sensor Microwave Imagers (SSM/I) for the entire CONUS domain and nine month time period. Two Advanced Microwave Sounding Units A (AMSU-A) were used to retrieve microwave emissivity over the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains (SGP) site in northern Oklahoma for July and August for three years beginning in 2000. The AMSU emissivities over the ARM-SGP site were used in a one-dimensional variational retrieval, which has been developed at the Naval Research Laboratory (NRL) at Monterey, CA by Dr. Nancy Baker. The dissertation work included collaboration with NRL where the AMSU emissivities were used to deduce their impact on temperature and moisture profiles focusing on the lowest atmospheric levels. This collaboration is a benchmark study that has established the feasibility of satellite microwave retrievals of temperature and moisture over land.

Figure 1 shows histograms of emissivities from SSM/I channels 1, 2, 6, and 7 at 19V, 19H, 85V, and 85H GHz respectively over the nine-month study period. These histograms of the microwave land emissivities have several common features. The microwave emissivity is

greater at the vertical polarization because the surface is a less efficient reflector of radiation in this polarized state. The increase in vegetative cover and its lushness increases scattering and minimizes the polarization difference between the channels. In heavily forested areas, the microwave emissivity polarization difference at 19 GHz is similar to that at 85 GHz. Bare ground areas show the vertically polarized emissivity value is about 0.04 greater than the horizontal at 19 GHz while this difference converges towards zero by 85 GHz. In bare ground areas the 19 GHz channels have a greater contribution from the ground, while as frequency increases very little ground cover is needed to effectively obscure the polarized signal from the ground. Lastly, the width of the histogram of emissivities is greater for the horizontal polarizations, because of the greater variability in the scattering efficiency of horizontal waves.

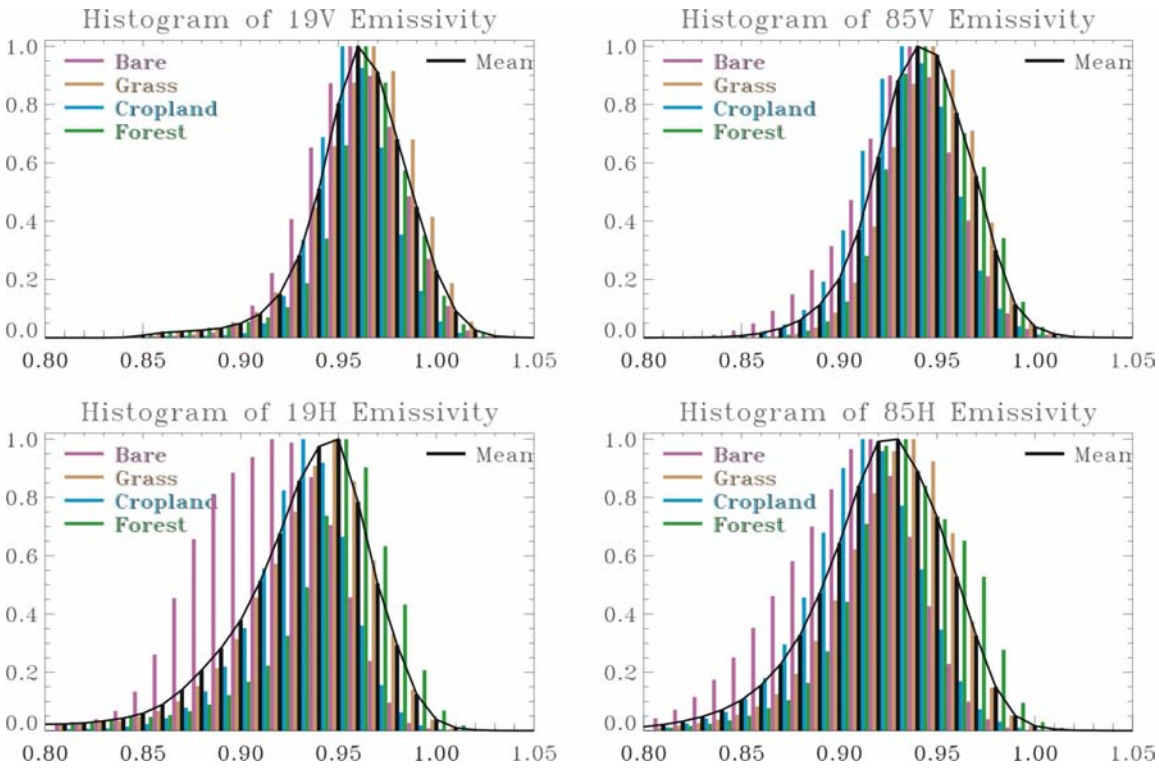


Figure 1: Histograms of emissivities over the course of a nine-month study period (June through August of 2000, 2001, and 2002) over the conterminous United States. The histograms are for SSM/I channels 1, 2, 6, and 7 which correspond to frequencies of 19V, 19H, 85V, and 85H GHz respectively.

The AMSU emissivities retrieved were used in a one-dimensional variational retrieval of temperature and moisture. The Root Mean Square (RMS) difference between the retrieved profiles and collocated radiosondes was found for 63 retrieval cases. The RMS was found for three sets of temperature and moisture profiles. The first profiles are the original temperature and moisture profiles given to the retrieval, called the *a priori* profiles. The second set of profiles are retrieved profiles of temperature and moisture which used AMSU emissivities and land surface temperatures computed at CG/AR as the first guess microwave emissivity and land surface temperature. The third set of profiles are retrieved profiles of temperature and moisture which used a fixed microwave emissivity of 0.90 and the NOGAPS original land surface temperature as first guess to their respective parameters in the variational retrieval. It was found

that in the lowest atmospheric levels the retrieved AMSU emissivities provided an improved estimate of temperature performing better than both *a priori* and the fixed emissivity case. The retrieved AMSU emissivities did not perform significantly better than the *a priori* with regard to moisture, but the fixed emissivity case on average degraded the lower atmospheric moisture estimate from the *a priori* estimate. This study has found that a well-defined microwave surface emissivity will have significant impact on surface temperature, and a correlated impact on the temperature and moisture in the lower atmosphere. An estimate of microwave land emissivity, its variability, and its error will provide various remote sensing applications and data assimilation systems with the information necessary to improve performance over land areas.

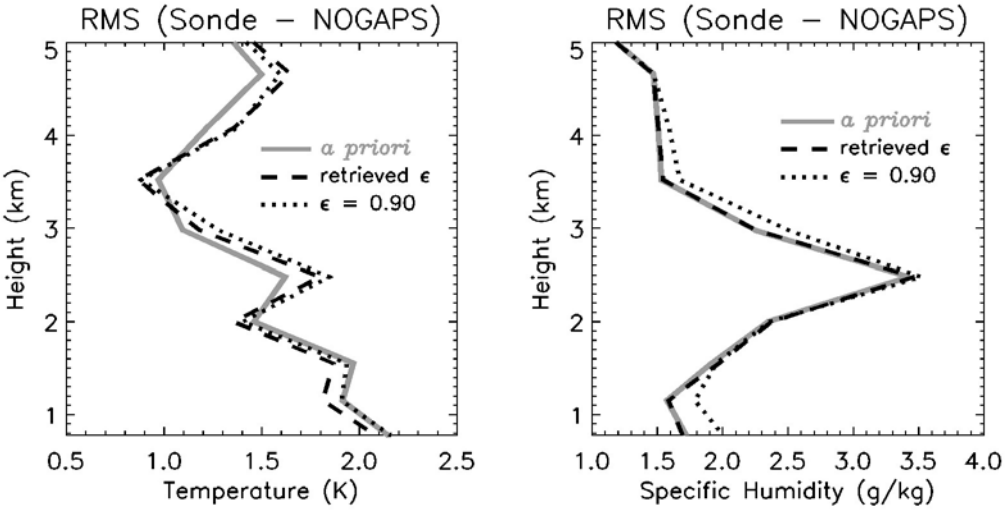


Figure 2: The Root Mean Square (RMS) error between 63 profiles of temperature and moisture from a radiosonde and three sets of NOGAPS profiles: the original NOGAPS profiles, *a priori*; variationally retrieved NOGAPS profiles beginning with a computed AMSU emissivity, retrieved ε; and variationally retrieved NOGAPS profiles beginning with a fixed microwave emissivity, ε = 0.90.

Prof. Mahmood R. Azimi-Sadjadi, Amanda Falcone, and Vincent Wong
The following paper is scheduled for publication in January, 2004.

J. Wang, M.R. Azimi-Sadjadi, D. Reinke and T. Vonder-Haar, "A Pixel-Based Temporally Adaptable Approach for Cloud Classification", to appear *IEEE Trans. on Neural Network.*

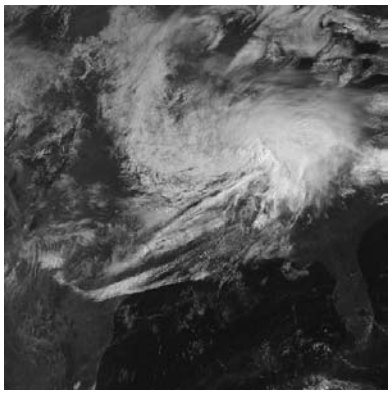
Cloud Structure

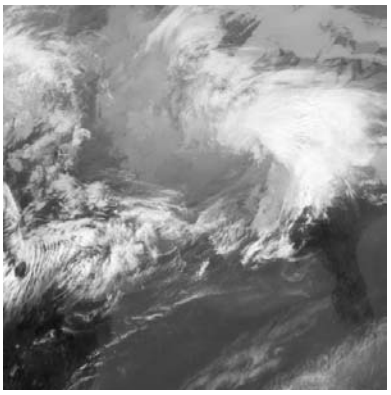
A new idea has recently been developed for use with a neural network. The satellite instrument MODIS produces a great deal of data products by use of 36 different spectral channels. These products concerning clouds are more useful than the traditional labels created for clouds for applications. Therefore, a method of utilizing the data is ideal. However, MODIS is aboard a polar-orbiting satellite, and therefore only takes data over specific areas at a frequency of 4 times daily.

The satellite instrument Meteosat is a geostationary satellite that is stationed over Saudi Arabia and the Middle East. This satellite sends data approximately every half hour. However, Meteosat records on fewer channels than MODIS and does not produce MODIS-like data. In order to have MODIS-like data for more than 4 times per day, a new idea involving MODIS and Meteosat has been proposed. The basic procedure is as follows:

- Find data products from MODIS and Meteosat that occur at approximately the same time in the day.
- Use an unsupervised neural network to create clusters of Meteosat data using the visible and infrared channels. This network will likely be a Self-Organizing Map (SOM) or unsupervised Probabilistic Neural Network (PNN). Examples of this clustering are found at the end of this section.
- After clusters are created using an unsupervised network, MODIS data (specifically the cloud mask and phase mask) will be used to label the clusters in the Meteosat images.
- A predictor will be created to determine labels for Meteosat data at times when MODIS is not available.
- The predictor will be realigned with MODIS data at each MODIS pass.
- The problems to be overcome with this new approach are as follows:
    - MODIS data products are created with 36 channels. Predicting similar products using many fewer channels requires additional information, such as the algorithms used to create the MODIS data products.
    - Neural network structures to perform the association and account for temporal changes in the data. This requires development of methods for tracking cluster centroids and assigning them to the appropriate MODIS products.

After these problems are solved, the new MODIS-like data products from Meteosat should create a new way of interpreting data on a daily basis. This could lead to further developments in the way of understanding satellite data.





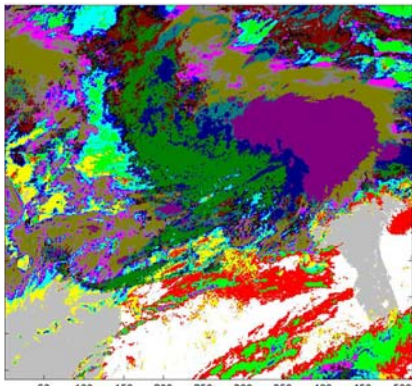


Figure 1: a) Visible Image b) Infrared Image c) Clustered image with 16 neurons

Aerosols

A simple sensitivity analysis of aerosol signal over the Arabia Peninsula as viewed by MSG-1 was performed. The result suggested that aerosol over the desert environment is not completely indistinguishable from the background. On the contrary, the signal is quite significant in the early hours of the day due to the sun-target-satellite geometry.

Successive Order of Scattering algorithm was studied in detail. It is intended to be used as the foundation model for the satellite measured radiance of the atmosphere over the desert region of the Middle East.

HSV-decomposition of an RGB-composite image of a dust storm event over the Arabian Peninsula captured by SeaFiWS was performed. The saturation component of the decomposition revealed an obvious aerosol signal. Further analysis suggested that the HSV-decomposition might amplify the aerosol signal; and the seeking of relationship between the HSV color-space and the Successive Order of Scattering algorithm was proposed.

Prof. Roger Pielke, Sr., Maj. Tim Nobis, and Giovanni Leoncini

Maj. Tim Nobis

Completed the coupling of the RAMS mesoscale model with the Town Energy Balance (TEB) urban parameterization scheme. This includes full coupling with the land surface model and the radiation scheme. Conducted numerous code testing/sensitivity runs with the coupled system using a simple NY City test case from Jul 2001. Found that the TEB model increases the simulation time by about 4% for every 10% of gridcells that have urban land class. Code seems to work well as I saw many "classic" urban heat island signatures in the simulations. Gridcell spacing must be 20 km or below in order for the parameterization to produce the best effect. Most interesting result seen was the generation of a gravity wave by the urban heat island which propagated off and impacted some developing convection several hundred miles away. Something to watch for in future simulations. Completed extensive documentation of the TEB model code, plus installed and tested a 2002 update to the code. Continued work to obtain proper land surface data files and morphology information for the Washington DC area. Should complete this by the end of Jan 04. Started the process of selecting days in 1984 for simulation. Looking for two days that correspond to the Intensive Field Campaign days of summer 1984,

plus two days in fall or winter dominated by a cold Canadian High and two days with dry frontal passages. Should also complete this by the end of Jan 04.

Giovanni Leoncini
A hydrostatic option for RAMS 4.3 has been completed adapting the RAMS 3b option that prognoses the surface pressure tendency, with w = 0 as surface boundary condition. It is currently under testing.

Ingested in RAMS 4.3 David Medvigy's code to exactly compute the Exner function tendency, which improves mass conservation. In order to accelerate execution, a few F90 changes have been made and two subroutines have been added to diagnose density and virtual temperature. This last quantity is diagnosed following an extension of Stull's derivation (Introduction to Planetary Boundary Layer Meteorology, Appendix A).

RAMS 4.3 now has the option to use the mesoscale theta to compute the horizontal Exner function gradient. This allows baroclinic vorticity generation directly.

I obtained a Poisson equation for the RAMS Exner function that has an interpretation analogous to that of Dalu et al. (2003), ensuring that RAMS results will be comparable to those of Dalu et al. (2003) which used a slightly different set of equations.

Prof. William Cotton, David Stokowski, Steve Saleeby, and Todd Gamber
Russell Chibe submitted a paper based on his M.S. thesis research entitled "The real-time 3-D simulation of a fog event with a cloud-resolving mesoscale forecast model" to the *Journal of Applied Meteorology*.

David Stokowski has recently finished his first semester at Colorado State University. He has gained a lot of knowledge, which will be applicable to his future work on the project. David completed coursework in Cloud Physics and Thermodynamics, Atmospheric Dynamics, Atmospheric Chemistry, and Synoptic Weather Lab. As stated in the previous update, the work David completed in Atmospheric Chemistry should be directly applicable to the project at hand. His research project entitled "Issues in Determining the Flux of Dimethylsulfide (DMS) From the Oceans to the Atmosphere" was extremely well received. The research focused on the how DMS fluxes are currently parameterized, as well as shortcomings of these parameterizations as it relates to global circulation models. David is looking forward to beginning his relationship with the Regional Atmospheric Modeling System (RAMS) during the upcoming months, as well as his continued coursework. He is enrolled in four courses for the spring semester: Atmospheric Dynamics II; Synoptic Weather Lab II; Radiation; and Cloud Microphysics. He is just now getting in touch with Jerry Harrington to start modifying his radiation code to include aerosol heating rates.

Travel

None this period.

Technology transfer

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

Equipment/systems status

- The computer used for cloud structure research (Azimi's group) was updated with more memory and a new hard drive. It is located in the Electrical and Computer Engineering Department Signal and Image Processing Lab (Engineering C209) on the Colorado State University main campus.

- Todd Gamber reports that the secondary CG/AR cluster (Cotton's group) has been running flawlessly in the past three months. We upgraded the Linux kernel version which resolved a driver conflict with the network interface. Since this upgrade, all stability issues have vanished and the cluster has had 100% uptime.

  As we have noticed in the past, we are still seeing a plateau in performance due to the architecture of RAMS. I have no recommendation as to whether the architecture in RAMS can or cannot be improved upon.

  Another hurdle we will soon be facing involves the 32-bit vs. 64-bit computer architecture. Thirty-two-bit architecture only supports 4GB of physical RAM in a computer. Our grid sizes are approaching 3GB, and only 2GB is addressable for any one process (a Linux limitation). With serious modification to the Linux kernel, we could utilize an additional gigabyte of addressable memory. However, this involves a performance hit of nearly 20% and is experimental. We will soon need a 64-bit-enabled RAMS accompanied by 64-bit computer systems and 64-bit compilers. [Editor's note: We are exploring the 64-bit issue on the primary CG/AR cluster.]

  We are also running into storage problems. This is a problem intrinsic to this type of research, but we have little/no data redundancy/backup. In some cases, our most critical data is not being backed up. As DVD recording becomes more reliable on the Linux platform, it will help alleviate problems. However, I believe a large tape backup system is needed to allow quicker and more reliable data recovery in the event of a catastrophe. I am working on a software suite which would compliment such a tape backup system nicely. Currently, I do not view our data backup system as adequate.

Research Theme: Technology Transition and Interactions

Dr. Milija Zupanski visited WSMR in November. His discussions with ARL staff were the kickoff for future transition work associated with the Army's use of ENKF-related technologies. Future transitions will include more then improved science. Data and model experiments, specifically requested by ARL will also be available.

Ben Ruston defended his dissertation on microwave land emissivities. Upon graduation Ben will be a post doc at NRL and will work to incorporate his work in the Navy's operational system. Currently microwave retrievals are performed only over the ocean. Ben's work is critical in the extension of that work over land.

We are currently working on a master-node 64-bit upgrade to a Linux cluster. We will be porting RAMS to 64-bit and run tests that will provide a benchmark on system performance of 32 vs. 64 bit system differences. Modelers are interested in the 64-bit architecture, not for any potential performance increase, but rather for the known increase in addressable RAM memory. The 4 GB memory limitation with the 32-bit code limits the size of the modeled domains to areas smaller then some of the features (specifically cloud shields, and frontal zones) under study.