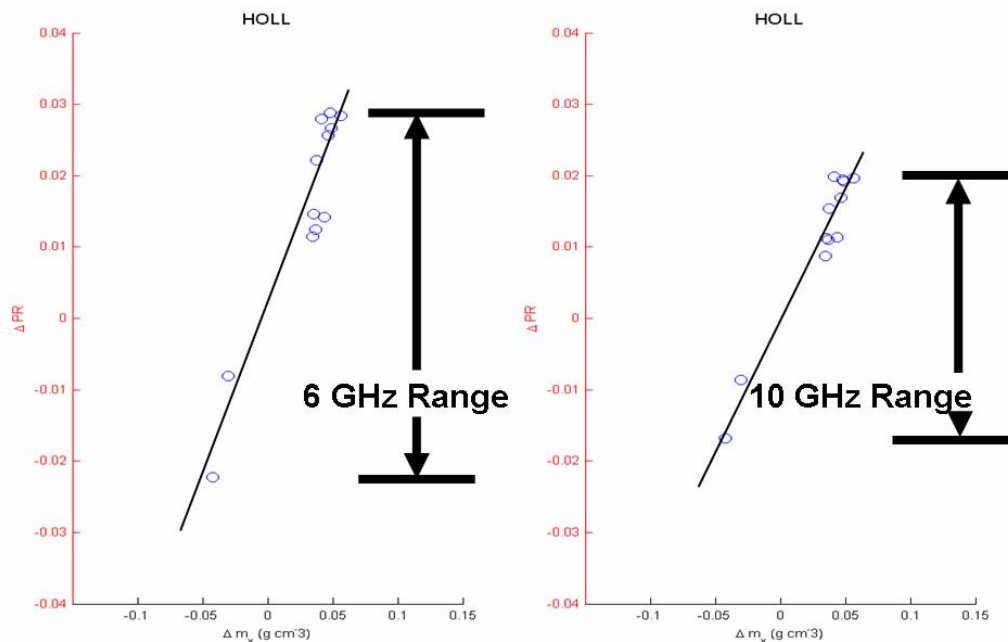


**Colorado State University**  
**Center for Geosciences/Atmospheric Research (CG/AR)**  
**Quarterly Report No. 3**  
**by T.H. Vonder Haar and Collaborators**

**Reporting period: October 1-December 31, 2006**

**Cooperative Agreement #W911NF-06-2-0015**

*[Note: This new 5-year Cooperative Agreement became effective May 1, 2006. It overlaps a previous Cooperative Agreement, #DAAD19-02-2-0005, which ends with a no-cost extension April 30, 2007. The same technical contents are being submitted to satisfy the requirements of both Cooperative Agreements. Some changes in theme area titles have been made to reflect the refined emphasis of the program.]*



*Results from WindSat indicate that the 6 GHz signal is 43% more sensitive than the 10 GHz signal strength (Rapp, 2006). In the figure above, results are shown for polarization ratio (PR) tendencies as compared to USAF AGRMET soil moisture tendencies for WindSat 6 and 10 GHz data at Holland, Oklahoma, for September 2003.*

*(This work is summarized in the quad chart in the **Hydrometeorology** section.)*

## Overview

This period was very busy with significant progress accomplished in all major research theme areas. Research highlights include:

**Hydrometeorology Theme Area:** Collaborations continued between Dr. Tarendra Lakhankar and Ms. Cindy Combs on the soil moisture in-situ validation and geospatial statistical analysis. Highlights of their collaborative work are shown in this report. Mr. Dustin Rapp successfully defended his masters degree research in December and will continue on to publish his results. James Halgren began his Ph.D work targeting needed updates to the TREX model. Additionally, Seema Shah has finished updating the TREX user's manual documenting all recent upgrades to the TREX model.

**Clouds, Icing, and Aerosols Effects Theme Area:** The long awaited tenth installment of the CG/AR's Cloud Layer Experiment (CLEX-10) began on October 31<sup>st</sup>. CLEX-10 is collaborating with the Canadian CloudSat/CALIPSO Project (C3VP) to study mid-level mixed phase clouds and is being run over the Southern Ontario region of Canada. Dr. Larry Carey, Mr. Adam Kankiewicz, and Mr. Curtis Seaman served as CLEX flight scientists during the first two intensive observation periods of C3VP. Early results have exceeded expectations with detailed observation notes presented in this report. The final two intensive observation periods of C3VP will be run in January and February of 2007 (respectively).

**Environmental Modeling and Assimilation Theme Area:** 4DVAR GOES Sounder and WindSat soil moisture experiments have been successfully initiated and reported on by Dr. Manajit Sengupta and Mr. Scott Longmore in this report. Collaborations with NCAR/MMM on WRF-Var data assimilation activities are continuing, with plans for a third joint CSU/CIRA-NCAR/MMM data assimilation workshop to be held in February. Drs. Milija and Dusanka Zupanski and Steven Fletcher continue to work on the implementation of Maximum Likelihood Ensemble Filter (MLEF) interface with the Weather Research Forecast (WRF) model. Significant progress on microphysical parameterization upgrades to both RAMS and RAMDAS and WRF are also detailed in this statement.

**Urban and Boundary Layer Environment Theme Area:** Mr. David M. Stokowski details work on look-up-table and neural network replacement for the Mahrer-Pielke longwave radiative flux divergence parameterization. Early results suggest between 20-50% improvements over the base parameterization scheme when run in the RAMS modeling environment. Mr. Giovanni Leoncini completed work on an incompressible version of RAMS, and is currently testing it against general analytical solutions. Giovanni's lookup table development work within RAMS has suffered some setbacks. He details results of recent model runs and identifies solutions he hopes will improve his results in this report.

**Remote Sensing of Battlespace Parameters Theme Area:** Dr. Stanley Kidder helped initiate and maintain real-time GOES imagery for CLEX-10/C3VP field operations. Stan's conclusion is that the CloudSat and CALIPSO satellites are ideal for the study of mid-level mixed phase clouds and that they will help improve cloud phase detection and characterization using visible

and infrared satellite data. These findings were presented by Stan at the Fall Meeting of the AGU. John Forsythe reports on continuing upgrades to CG/AR's C1DOE data assimilation code. Recent modifications include the addition of GOES imager radiances as an optional input and compatibility with all operational GOES satellites. Prof. Mahmood R. Azimi-Sadjadi reports on continued development of the Transmission Loss (TL) acoustic prediction system and its preparation for integration into the ARL's Acoustic Battlefield Aid (ABFA) environment. Recent upgrades to the TL prediction system, including the generation of high frequency (up to 300Hz) data sets and the training of new neural networks are well documented in this report.

Further highlights, including multiple conference and journal paper submissions, conference presentations and collaborative interactions that occurred during this reporting period are detailed in this report.

*Mr. Adam Kankiewicz*

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 May 2006 to Present**

- Sonia Kreidenweis and Kelley Johnson with Doug Westphal, Piotr Flatau, and Marcin Witek (NRL/Monterey)
- Tom Vonder Haar and others with Mr. Robert Brown (ARL)
- Tom Vonder Haar and CG/AR researchers with Dr. James Cogan (ARL)
- Milija Zupanski and others with Jeff Tilley (UND)
- Andy Jones and Cindy Combs with Gary McWilliams (ARL) and Li Li (NRL)
- Steven Fletcher with Carolyn Reynolds (NRL), Dale Barker (NCAR), Brian Ancell (Univ. Washington), Ron Errico and others (NASA Goddard), and international colleagues
- Stan Kidder with Arlin Krueger (Univ. Maryland-Baltimore County)
- Steven Fletcher with Clarke Amerault (NRL)

## Research Theme: Hydrometeorology

### Administrative

Dustin Rapp successfully defended his masters research on December 19. He will finalize his thesis and work on submitting publications of his research on an hourly basis while he also seeks post-degree employment.

### Research activity and/or results

**Dr. Andrew Jones** (with some summary of the entire group)

Several AMS conference papers were finalized and submitted. Two technical reports previously mentioned were finalized as well.

Collaborations continued between Dr. Tarendra Lakhankar and Ms. Cindy Combs on the soil moisture in situ validation and geospatial statistical analysis. This work is defining necessary correlation length scales for the advanced 4DVAR soil moisture assimilation experiments. We anticipate additional technical reports and conference papers on those new results shortly.

### **Cynthia Combs**

Pulled out AGRMET sectors for five more Oklahoma Mesonet sites. Made several plots comparing AGRMET soil moisture and precipitation with in situ data from each site. Analyzed results. Also revisited the Mud Lake, LA site comparison, checking for rain fall discrepancies between AGRMET and in situ.

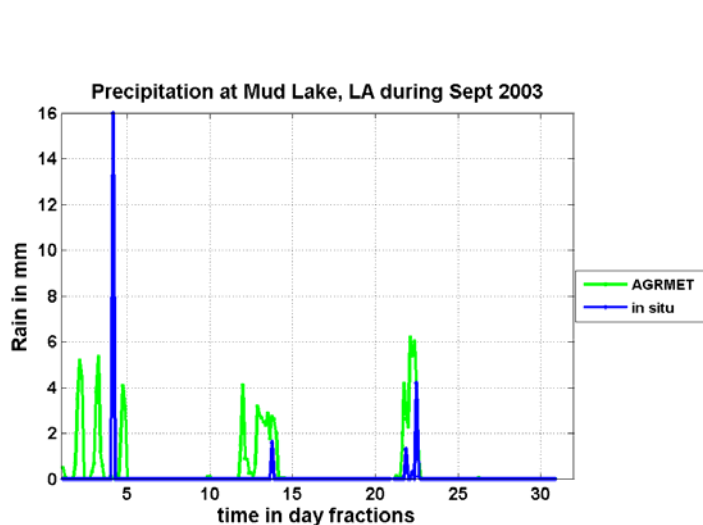


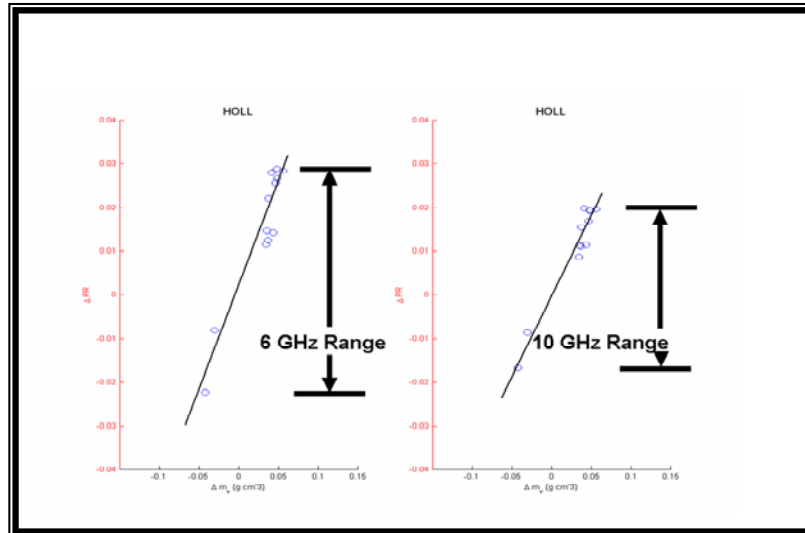
Figure 1. Precipitation Comparison between in situ and AGRMET at Mud Lake, LA during September 2003.

From the above analysis, wrote extended abstract for the AMS Hydrology conference. Also wrote rough draft of technical paper; still need Tarendra's contribution from his Krigging work.

## CG/AR HYDROMETEOROLOGY

### RESEARCH QUESTION/OBJECTIVE

- Passive microwave measurement of soil moisture using WindSat
- Emphasis on determining 6 GHz vs. +++10 GHz signal strength.
- Results indicate that 6 GHz exhibits a 43% stronger soil moisture signal



### RESEARCH APPROACH/METHOD

- Normalized Polarization Ratio (PR) differences relationships vs. USAF AFWA AGRMET soil moisture tendencies
- PRs are derived from horizontal and vertical polarization radiances from low frequency microwave radiometer data
- This approach mitigates radiative transfer model error biases

### RESEARCH STATUS

- MS Thesis results by Dustin Rapp
- Rapp completed degree requirements
- Work has identified radiative transfer model errors that need improvement for soil moisture retrieval requirements
- However, the work has also demonstrated a strong soil moisture signal when RFI and other effects are mitigated successfully

Met with Tarendra and Andy about the Krigging work. Made suggestions to Tarendra about his site selection filter. Provided data plots of OK Mesonet soil moisture measurements to Tarendra to aid in site selection.

Attended telecon with Army colleagues, including George Mason. Discussed AMS extended abstract and comparison results.

### **Prof. Pierre Julien, James Halgren, and Seema Shah**

James Halgren defined the research scope for his PhD research: Extend the TREX model to accommodate long-term modeling. He will be examining approaches to bridge the gaps between hydrologic events using a conceptual groundwater model coupled to the physically based TREX surface water model.

During the past several months Seema Shah has significantly updated the TREX users manual in response to numerous inquiries regarding both CASC-2D and TREX over the past quarter. TREX has also recently been utilized in a classroom setting at Colorado State University to show rainfall and infiltration simulation. The program as placed on the web has also proven to be a useful tool for many students in other countries including Slovenia, China, South Korea and Taiwan. Seema and Mark have provided some technical support, code guidance, and other assistance to these users.

In collaboration with Seema and James, Mark Velleux is compiling a version of the TREX code with a snow melt model based on solar radiation flux, an extension of work completed by Dohyuk Kang last year.

### **Travel**

None this period.

### **Technology transfer**

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

### **Equipment/systems status**

Using the budget approved in September, a new linux workstation was selected, purchased, and configured for use in running the TREX model and derivatives. The workstation arrived in November and configuration was complete just prior to Christmas. This new workstation should have a 5 year useful life-span. The operating system of the new workstation will be Linux based to take advantage of significant development tools freely available in that environment and also the improved management of the multiple core processors and large RAM. Specifications for the new machine are summarized as follows: a) Two dual-core AMD opteron 280 processors (four total processors); b) Gigabytes RAM; c) 150 Gigabyte mirrored modeling disk with fast read/write; d) 750 Gigabyte mirrored storage disk; and e) Dual head monitor card.

## **Research Theme: Clouds, Icing, and Aerosols Effects**

### **Administrative**

Kelley Wells has completed her CG/AR-supported work. She will, however, continue to work on the submitted manuscript reporting her results as it proceeds through the review, revision and publication process. She is pursuing her PhD degree under other funding at CSU, but continues to be under the advisement of Prof. Kreidenweis and will remain in touch with CG/AR research.

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

#### **J. Adam Kankiewicz, CLEX Leader**

Attended the final planning workshop for the C3VP field experiment and presented an overview of our planned activities for CLEX-10. The workshop went well with only a few last minute action items identified. The major news at this workshop was the announcement that the NASA Global Precipitation Mission (GPM) project would be participating in the third C3VP Intensive Operating Period (IOP). Their planned contribution will be to bring some extra ground instruments to the CARE site in January.

After a year long delay, the much anticipated C3VP field experiment finally began on Oct 31. Served as the CLEX flight scientist during the first twelve-day IOP, which was a great success from the CLEX perspective. Four of the five flight missions run by C3VP had mixed phase clouds which were sampled during A-Train satellite overpasses. The CLEX-10 contribution to IOP #1 consisted of two C3VP extension flights to sample mixed phase clouds. Will return to Ottawa in January to participate as the CLEX flight scientist during the third IOP.

The second IOP of C3VP was run from Dec 2-11. Professor Larry Carey (TAMU) was the CLEX flight scientist during this IOP. Highlights from this IOP include two dedicated CLEX flight missions and a successful nocturnal mixed phase cloud mission sampled over the CARE ground site. A summary of CLEX operations from C3VP is attached to this quarterly report.

Helped prepare CloudSat, CALIPSO and MODIS satellite data for Stan Kidder's presentation at the Fall AGU meeting. A session devoted to early results from the A-Train satellite constellation was where our work devoted to early observations of mixed phase clouds remotely sampled by the A-Train was presented. Preparations are underway for a journal manuscript submission based on our results.

#### **Curtis Seaman**

Designed and developed the latest version of the CLEX website ([www.cira.colostate.edu/clex10](http://www.cira.colostate.edu/clex10)) with assistance and input from Adam Kankiewicz, Stan Kidder and Larry Carey. This website serves as an aid to on-site operations and is the initial technology transfer point for CLEX research.

Participated in second half of IOP#1 of CLEX-10/C3VP at both Ottawa and at the CARE site. Assisted with daily forecasting, managed the daily updates to the CLEX-10 website, and gained

valuable experience as an observer during one of the flights. For IOP#2, continued with participation in the forecasting and website management duties from CSU.

Continued work with Manajit Sengupta of preparing RAMDAS to be run with GOES Sounder data. This work has involved “cleaning” the code, tracking down sources of errors and validating the corrections. While progressing slowly, this work should be concluded by the end of the next quarter.

### **Aaron Schwartz**

As a first-semester graduate student, began preliminary work on selecting a thesis topic related to arctic clouds.

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

UW-M collaborators have re-run the Nov. 11 CLEX-5 altostratocumulus case using COAMPS microphysics instead of idealized microphysics. This is a preliminary step that will allow us to simulate the CLEX-9 alto clouds, which contained ice, with more fidelity.

The status of three manuscripts (two in *J. Geophys. Res.* and one in *Mon. Wea. Rev.*) are reflected in the attached publications list.

### **Prof. Larry Carey (Texas A & M University)**

Participated in IOP#2; see attached summary of C3VP and CLEX-10 operations to date.

### **Prof. Sonia Kreidenweis and Kelley Johnson Wells**

A manuscript based on Kelley’s masters research was submitted in early November to *Atmospheric Environment* and is currently in review.

Christopher Steffen from the CIRA Boulder group, worked on researching the feasibility of compressing the Navy Aerosol Analysis and Prediction System (NAAPS) dataset. A detailed report and recommended course of action has been submitted to Prof. Kreidenweis.

### **Travel**

Adam Kankiewicz and Tom Vonder Haar traveled to Toronto, Ontario to attend the C3VP planning workshop held at Environment Canada on October 2. Dr. Vonder Haar also traveled to Ottawa prior to this meeting to check on the setup of the research aircraft and meet with scientific colleagues at that location.

Adam Kankiewicz traveled to Ottawa, Ontario to participate in IOP #1 of the CLEX-10/C3VP field campaign, October 29 - November 10.

Curtis Seaman visited the CARE site near King City, Ontario, then traveled to Ottawa, November 4-10.

### **Technology transfer**

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

Ken Eis and Stan Kidder presented two posters at the Fall Meeting of the American Geophysical Union: one on the CFLOS work by D.L. Reinke et al., and the Kankiewicz et al. work on quick look cloud data products.

### **Equipment/systems status**

No report this period.

# Summary of CLEX-10/C3VP results thus far

J. Adam Kankiewicz and Larry Carey  
January 3, 2007

## Short summary of flight operations from C3VP:

### C3VP IOP #1

31 Oct – Decent multi-layered mixed phase cloud field sampled prior/during A-Train overpass.

3 Nov – Nighttime lake-effect snow case sampled near CARE site. No mixed phase clouds present.

5 Nov – Extensive mixed phase clouds present during A-Train overpass. CLEX added 1.3 flight hours onto C3VP mission to sample clouds over CARE site.

7 Nov – Dissipating mixed-phase clouds sampled proper/during A-Train overpass. CLEX added 1.5 flight hours onto C3VP mission targeting fleeting mixed phase clouds.

9 Nov – Some mixed phase clouds remotely profiled while flying to the C3VP target region.

### C3VP IOP #2

2 Dec - Good mixed phase clouds over flown on the way to C3VP target area. Dissipating mixed phase clouds sampled after A-Train overpass.

5 Dec - Great nighttime case for mixed phase cloud sampling (unique as far as I know). Excellent remote sensing and in-situ data collected over CARE site

6 Dec - Dedicated CLEX mission over CARE site. Good mixed phase clouds sampled both in-situ and remotely.

7 Dec - Lake-effect snow case sampled near CARE site. No mixed phase clouds present.

9 Dec – A-Train overpass day run by CLEX. Complicated multilayer mixed phase sampled NE of Ottawa.

11 Dec - Some scattered mixed phase clouds remotely sensed en route to C3VP target location.

**Summary:** There have been two dedicated and two extended flight hour CLEX missions run during the first two IOP's of C3VP. Additionally, there are many mixed phase cloud cases sampled during the first two IOP's by C3VP.

### **Comments on the C3VP/CLEX-10 experiment in general:**

Overall, the working environment has been great for us. The C3VP personnel are top-notch and very dedicated to their jobs. Dave Hudak and Mengistu Wolde have been great to work with and are running a tight ship during the IOPs.

The “bang for the buck” we are getting during the C3VP IOPs is excellent. Due to the widespread occurrence of mixed phase clouds during the first two IOPs, CLEX has been able to greatly leverage its assets by gaining access to mixed phase cloud data sampled during dedicated C3VP flight hours. Our goal of obtaining mixed phase cloud data sampled during A-Train overpasses has greatly exceeded our expectations.

The two big issues we have had to deal with include Convair instrument outages and reluctance to fly on non-C3VP mission days. Malfunctioning Convair instrumentation are promptly diagnosed and handled by the crews as best as possible (much better than I have witnessed during prior CLEX campaigns). They have flown extra technicians to help diagnose problems when possible. As for the reluctance to fly issue, we just need to press hard to get non-C3VP flight hours in. Due to our plan to fly relatively few off-C3VP flight hours, I do not expect significant problems with this area during the third IOP.

Paul DeMott and company have been very professional and great to work with during the first IOPs. There have been at least two cases of elevated ice nuclei sampled by the CSU Continuous Flow Diffusion Chamber (CFDC) during C3VP flight missions. Most of the supercooled liquid water clouds sampled have had ice water contents on the lower end of the spectrum. This is consistent with the hypothesis that ice production in mixed phase clouds can be driven by the presence of ice nuclei. Kevin Strawbridge's lidar data will also greatly compliment the results obtained by the CSU CFDC instrument.

We are currently on target for the depletion of our Convair flight hours during the next (#3) C3VP IOP. We have room in our budget for one more dedicated CLEX mission and a few C3VP add-on missions. The CARE site will be targeted by C3VP more frequently during IOP #3 (due to the added GPM ground instrumentation). This will offer CLEX excellent leverage opportunities to sample mixed phase clouds occurring over the CARE site region. Additionally, the mild winter being experienced over the C3VP region should continue enhance the occurrence of mixed phase clouds during the upcoming IOP.

## **Research Theme: Environmental Modeling and Assimilation**

### **Administrative**

Matt Masarik successfully defended his masters research in November and submitted his thesis to the University. Matt remains in Professor Schubert's group, where he will pursue a doctoral degree.

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

#### **Dr. Andrew Jones** (with some summary of the entire group)

The 4DVAR GOES Sounder experiment has been successfully started. We have not achieved progress through the first iteration cycle. Debugging continues for the 2nd iteration cycle results. To date, the preliminary results appear to be reasonable. Manajit Sengupta and Scott Longmore are performing detailed tests on the 2nd iteration cycle performance and evaluating and designing the next series of 4DVAR tests. The RAMDAS system is not considerably more robust and generalized for starting with unique initialization conditions necessary for longer-term 4DVAR GOES radiance assimilation experiments. Curtis Seaman continues to use the system and learn the various components as part of his PhD research activities.

The 4DVAR WindSat soil moisture experiment has also been successfully started, with WindSat control runs being performed for the Sep. 2003 period. Significant amounts of documentation and source code analysis has been performed. The paper by Longmore et al. (2007) discusses this progress in more detail.

Collaborations with NCAR/MMM on WRF-Var data assimilation activities are progressing. We plan to have a third joint CSU/CIRA-NCAR/MMM data assimilation workshop in February to discuss efforts for collaborations with the WRF-Var DA system. We hope to have a formal WRF-Var collaboration work plan by the end of the month. These activities will better integrate the CG/AR data assimilation efforts with the WRF operational communities.

New data assimilation efforts have been proposed with the ARL and ERDC for land surface temperature data assimilation and mitigation of land surface emissivity model errors. Those efforts will also begin to leverage our existing RAMDAS 4DVAR and C1DOE 1DVAR data assimilation experiences with our WRF data assimilation interactions.

Several new conference publications were the process of being submitted to a variety of international conferences including the Satellite Conference in The Netherlands, and the IGARSS 07 in Barcelona, Spain.

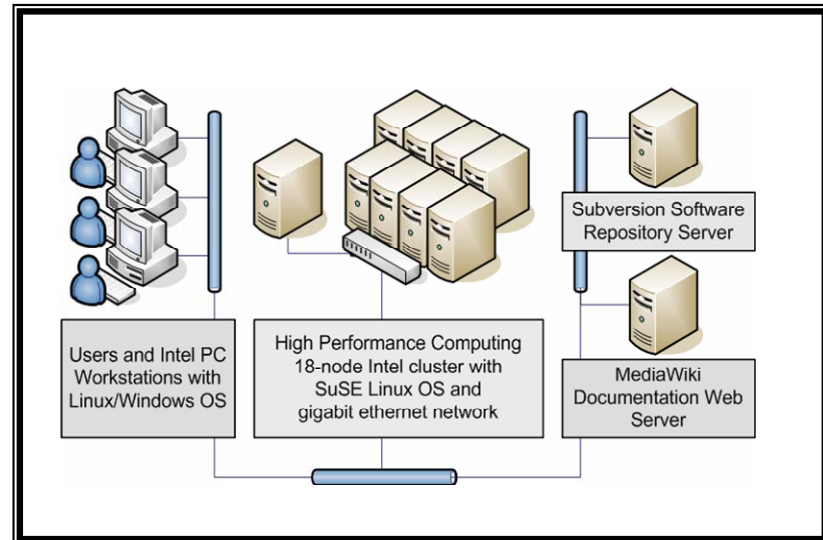
#### **Dr. Milija Zupanski**

After becoming familiar with the WRF model structure, several strategies for blending it with MLEF algorithm were evaluated. The option decided to be implemented is the one with least interaction with WRF inner structure. All of the interface programs are now separate from the model itself, allowing not only more efficient programming, but also more general approach to

## Environmental Modeling and Assimilation

### RESEARCH QUESTION/OBJECTIVE

- Coordination of advanced 4D Variational data assimilation of GOES Sounder and WindSat microwave imagery data using an advanced mesoscale atmospheric modeling system (RAMDAS)
- Build a collaborative research environment for complex scientific 4DVAR iterations
- Requires good organizational capabilities



### RESEARCH APPROACH/METHOD

- Use open standards and available tools such as Subversion for software configuration management, and Media Wiki for documentation versioning and collaboration
- Facilitate training activities
- Facilitate software debugging capabilities using Totalview debugging software

### RESEARCH STATUS

- Methodology published at AMS IIPS Conference (Longmore et al., 2007)
- New approach is facilitating the work of approximately 6 academic researchers using large advanced scientific codes and scripts
- 4DVAR data assimilation experiments continue to make good scientific progress with verifiable milestone markers

including any new model into the MLEF system. The interface programs are completed, and the work on the interface scripts is underway. In anticipation of high-dimensional, fine-resolution WRF applications, the work on error covariance localization has also started.

### **Dr. Dusanka Zupanski**

Experimented with forecast error covariance localization, which is currently considered as one of the most important issue to be solved in ensemble data assimilation approaches. Examined using a “distance” defined in terms of information measures, rather than using a geographical distance (which is commonly used). Using this new distance definition seems to be more adequate, since it depends on the actual atmospheric flow-patterns. The new definition of distance had a positive impact on covariance localization and data assimilation results.

Started familiarizing with the Weather Research and Forecasting (WRF) model and how to use it within the ensemble-based data assimilation algorithm (Maximum Likelihood Ensemble Filter, MLEF). In collaboration with M. Zupanski, we are developing an interface between the MLEF and the WRF model.

### **Dr. Steven Fletcher**

Succeeded in getting a version of the Weather and Forecasting model to work on the local Linux machine. Identified certain parts of the main model program that will allow the interface of the Maximum Likelihood Ensemble Filter, MLEF.

Implemented the hybrid distribution for lognormal and Normal variables and observations in the Lorenz 1963 model. Transforming lognormal variables and observations into their Normal counterpart then the analysis found, if not biased corrected, gives the wrong analysis state for the original variable. By using the correct distribution, we have been able to show that the analysis is more consistent with the true solution than transforming to use current data assimilation framework.

Worked on extending these ideas to a 4-dimensional framework which better uses observations but also can be added to the MLEF to make it a smoother rather than a filter.

Awaiting final clearance to access ARL’s supercomputer to start the implementation of the MLEF into the WRF model with the T-Rex observations.

The paper that was submitted to Monthly Weather Review was not accepted. However, speakers at the Adjoint workshop were invited to submit a paper for a special edition of Meteorologische Zeitschrift, which I am in the process of finishing.

### **Dr. Manajit Sengupta**

The 4D-Variational System is being comprehensively checked and I am currently carrying out an exercise to create a detailed documentation of the actual algorithms used in RAMDAS. The first version is nearly complete. This detailed exercise is helping us make the system more robust and tailor it to new data assimilation experiments in the near future; the documentation will also be placed on the RAMDAS wiki for future users of the system. This exercise is expected to end this quarter and we will be in a position to start running an experiment. Certain instability issues

with the system have been identified., which are being worked out with Scott Longmore. Curtis Seaman is also going through the system in detail using the documentation. This will enable him to set up his own experiment for his PhD dissertation research.

### **Dr. Laura Fowler**

#### RAMS

Continued testing of the latest version of the two-moment cloud microphysics parameterization to be in the forward model of the RAMS Data Assimilation System (RAMDAS). Comparison continued against the one-moment cloud scheme, using five-day experiments over the ARM-CART site with and without calls to the radiation parameterizations. The present focus is on the MPI implementation of the newest cloud scheme which is shown to produce results that are different from the ones obtained when RAMS is run on a single processor.

#### Weather Research Forecast (WRF) Model

Progress continued to be made on the implementation of the RAMS cloud microphysics in WRF, using an idealized two-dimensional squall line configuration oriented in a west to east direction. The parameterization is shown to be numerically unstable, especially for the cold phase in the version 2.1 of WRF. The same parameterization is being ported to the latest version of WRF (version 2.2) with the aim to see if positive-definite advection schemes help reduce the occurrence of unstable cloud microphysics.

### **Scott Longmore**

WindSat and other experiments; training and documentation for users on RAMDAS initialization; and tracking down issues with RAMDAS executable input/output files. Four additional control runs were run for WindSat using different soil moisture initializations. Documentation for RAMDAS initialization was created on the wiki server and an initialization training session was given in mid-November. An issue with empty output/input files was traced back to a section of code in the radiative transfer operational operator (RTMod). The code is being tested to isolated the empty output file.

Submitted a conference paper to the annual American Meteorological Society Interactive Information Processing Systems conference. Resolved a RAMDAS build issue.

### **Matt Masarik**

Worked primarily at finalizing my masters thesis. After handing in the first draft, focus was shifted to preparing my thesis defense. This presentation took place November 15th, which I successfully passed. Several appendices have been added to the final version of the thesis, as well as improvements that reflect insight gained during preparing for the defense.

### **Prof. William Cotton, Dr. William Y.Y. Cheng, and Michael Smith**

#### **Dr. William Y.Y. Cheng**

##### Interfacing of higher-order closure (HOC) parameterization

Successfully interfaced the HOC parameterization into RAMS. This version is not yet coupled to the RAMS microphysics; that work is currently underway.

### RAMS overproducing winter precipitation problem

One hypothesis is there is embedded convection within the stratiform clouds too coarse to be resolved in grid 3 at  $\Delta x = 3$  km, especially in the cases with moist southerly flow. To test this hypothesis, I implemented the latest version of the Kain-Fritsch convective parameterization scheme (CPS), taken from WRF, in RAMS. Several simulations have been run with different flow regimes both with and without the Kain-Fritsch CPS in the intermediate grid (grid 2). The purpose of using the Kain-Fritsch CPS is to parameterize unresolved convection (i.e., dry and stabilize the atmosphere) in the outer grids and letting the drying and stabilizing effect propagate into the innermost grid. As a result, the innermost grid precipitation would be reduced. Otherwise, the grid-scale resolved precipitation would be excessive. As expected, without the use of the Kain-Fritsch CPS in grid 2 caused the grid 3 precipitation to be excessive. With the use of the Kain-Fritsch CPS in grid 2, the precipitation maxima have been reduced in grid 3. However, the precipitation in grid 3 was suppressed in the entire domain. Thus, there is a trade-off in using the Kain-Fritsch CPS in the intermediate grid. These results will be reported in a paper to be submitted to the *Journal of Weather Modification*.

### **Michael Smith**

Worked on gravitational settling and wet removal schemes for the previously-implemented mineral dust and sea salt emission in the RAMS model. He plans to spend this period conducting sensitivity tests on the dust scheme, with the eventual goal of simulating dust transport and associated effects on visibility parameters throughout the Middle East.

### Travel

Steven Fletcher traveled to Obergurgl, Austria to attend the 7<sup>th</sup> International Workshop on Adjoint Applications in Dynamic Meteorology, October 4-14. Dr. Fletcher also traveled to San Francisco, CA to attend the Annual Fall Meeting of the American Geophysical Union, December 12-15.

### Technology transfer

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

The Koyama et al. (2006) paper on the GOES Sounder information content analysis was published in the December issue of *Mon. Wea. Rev.*

The MJO paper by Schubert and Masarik was published in hardcopy in December.

Steven Fletcher gave an oral presentation at the Adjoint Workshop in Austria entitled "Implications and impacts of transforming lognormal variables into Normal variables in VAR." He also gave an oral presentation of the paper "Lognormal data assimilation: Theory and Applications" at the AGU Fall meeting, co-authored by Dr. Milija Zupanski.

### Equipment/systems status

No report this period.

## **Research Theme: Urban and Boundary Layer Environment**

### **Administrative**

None this period.

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

**Prof. Roger Pielke, Sr., Maj. Tim Nobis, David M. Stokowski, and Giovanni Leoncini**

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

Continued writing on dissertation. Emphasis this quarter continued to be the morphology annex and I also worked on the literature review.

#### **David M. Stokowski**

Completed a draft of a potential journal article regarding my look-up-table work over the past year, combined with the initial work using neural networks as replacements to the Mahrer-Pielke longwave radiative flux divergence parameterization. Outlined the time gains achieved by the neural networks (between 20-50% improvements over the base parameterization), as well as accuracy achieved by the neural networks. The testing revealed that smaller neural networks (those with fewer hidden nodes) showed the best accuracy, and combined with time testing results, showed the most promise for replacement of any individual parameterization. While the look-up-table method may not be suitable for relatively simple parameterizations, it still remains to be seen what promise it could yield on more complicated code.

Am currently setting up a test to check and see the validity of a neural network replacement to the entirety of the diabatic heating within RAMS. This has involved setting up RAMS to re-run a previous set of experiments. The data has been retrieved from hourly time steps (instead of the 6-hourly data previously stored) and used to create an input data set for a neural network. My work is currently focused on preparing the data sets needed to create a neural network. Once the network is created, it will be used as a replacement for the entirety of the diabatic heating calculations. Finally, when the new code is tested for speed, it is expected that this replacement will show significant time gains over the fully functioning calculations.

#### **Giovanni Leoncini**

Completed the development of the incompressible version of RAMS, and am currently testing it against a general analytical solution I computed during the summer. These features (the analytical solution and the incompressible option) will allow me to exactly simulate the Dalu et al. (2003) equations and therefore carry out the study as planned.

The lookup table development has had a significant overhaul: the first set of online tests (within RAMS) was disappointing, and not nearly as good as the offline tests reported earlier. I believe this happened because RAMS uses different parameterizations from the ones used for the North American Reanalysis which I used to build the algorithm. This caused the distribution of water vapor to be significantly different, in a statistical sense, which in turn caused the algorithm to perform poorly. So I ran RAMS for ten Septembers to develop my own climatology, and this

brought up several computing problems with the Harrington code and missing data issues with the NARR dataset. Trying to solve these issues, I significantly improved the code and with the help of the MATLAB support; was able to read and write MATLAB files from Fortran. Everything has been fixed and I was able to compute the EOFs necessary for my algorithm, however, I obtained EOFs that have negative water vapor mixing ratios, so I have to recompute them using the dewpoint.

### **Travel**

None this period

### **Technology transfer**

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

### **Equipment/systems status**

No report this period.

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

### **Administrative**

Kevin Donofrio successfully defended his masters research in November and submitted his thesis to the University. Kevin will work on submitting publications of his research on an hourly basis while he also seeks post-degree employment.

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

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

Worked on CLEX-10/CloudSat/CALIPSO. The objective was to take a first look at the CloudSat and CALIPSO data for mid-level clouds and to compare them with MODIS data. The conclusion is that CloudSat and CALIPSO have a lot to tell us about mid-level clouds worldwide and will help improve cloud detection and characterization using visible and infrared satellite data.

Maintained the real-time GOES imagery for CLEX-10 operations. [See the web site at <http://amsu.cira.colostate.edu/CLEX10/>].

Preparation of the Kidder et al. paper for the Fall Meeting of the AGU; gave the oral presentation at the meeting in San Francisco.

#### **John Forsythe**

C1DOE was modified to add GOES imager radiances as an optional input. Calibration was updated for the entire GOES series, including GOES-13 which is in a science test. The GOES imager data can now be used as input to C1DOE for land surface skin temperature, cloud detection, and cloud top temperature estimation.

Calculated satellite overpass predictions for the CLEX-10 IOPs. These were calculated for NOAA series, Aqua, Terra, ENVISAT and Metop-2. Results were added to the CLEX-10 web page and used in operations.

Wrote extended abstract for the AMS annual meeting “Extending Satellite Microwave Humidity Retrievals from Ocean to Land.” The paper will be presented in January.

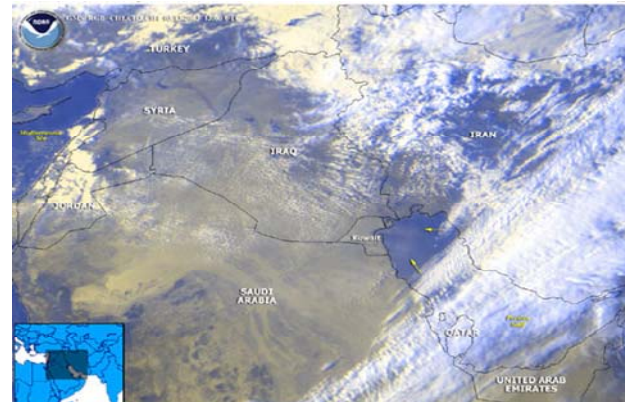
#### **Prof. Mahmood R. Azimi-Sadjadi and Michael McCarron**

Research continued on the development of the Transmission Loss (TL) prediction system in preparation for its integration into the ARL’s Acoustic Battlefield Aid (ABFA). Tasks completed include: generation of high frequency (up to 300Hz) data sets and training new neural networks to be used in TL prediction systems for the extended frequency range. These new neural networks were used to develop both an operationally adaptive (OA) and the combined environmentally adaptive (EA) and operationally adaptive TL prediction system. These new TL

## Toward Improved Prediction of Visibility Degradation by Dust in the Battlefield Environment

### RESEARCH QUESTION/OBJECTIVE

- Model the emission and transport of mineral (desert) dust
- Apply model results to an existing isotropic visibility parameter
- Examine possible impacts on visibility during military operations



Example of a 2003 dust storm over the Middle East

### RESEARCH APPROACH/METHOD

- Implementation of a dust emission scheme in the RAMS weather model
- Examine the importance of gravitational settling and rain washout on model results
- Explore the value and accuracy of a prognostic visibility parameter in the RAMS model

### RESEARCH STATUS

- **New:** Sensitivity testing on the completed dust emission module
- **Ongoing:** Modification of parameters within the dust module
- **Current Status:** Dust emission module is finished. Further testing is required before an attempt is made at prognostic forecasts.

prediction systems were developed to reduce the prediction error namely for extended source height range; they are tested and results of their performance are presented and analyzed.

The OA system has been extended to include data with a maximum frequency of 300Hz, an increase over the previous upper frequency of 230Hz. The OA system consists of three neural networks and a fusion system. Each of the three neural networks is expert network (i.e. trained) on a specific region of the input space. The input space is divided into three regions along the source height dimension, two of which are overlapping. The three regions of input space are 0-3m, 10-35m, and 25-50m. These boundaries were chosen to isolate regions of high error along with consideration of physical acoustic propagation phenomenon. The low source height region of 0-3m is a region void of ground interference, while the other regions experience ground interference. Each neural network was trained using 10 random weight initializations for 300 epochs each. The resulting neural networks were then evaluated on a validation set which consists of data not used during training. The neural network with best performance on the validation data set was kept for further use.

The OA system provided superior TL prediction results over the single back-propagation neural network (BPNN) predictor, especially when higher frequencies 230-300Hz were included. The greatest improvement in performance can be seen in the regions of 0-7m and 15-48m of source height. This can be observed in Figure 2 which is a plot of the root-mean-square error (RMSE) of the OA system as a function of source height. The increase in performance is a result of training specialized neural networks for the conditions of ground interference and no ground interference. Separating these physical phenomena, each neural network is able to better capture the underlying nonlinear mapping function.

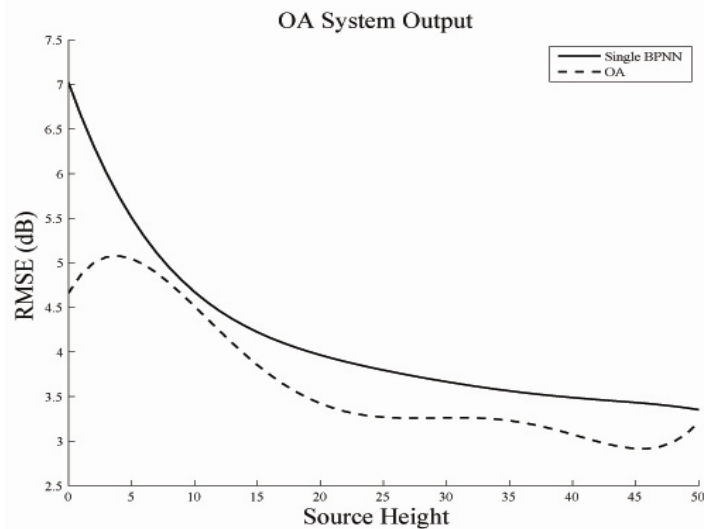


Figure 2. RMSE versus Source Height for the OA TL prediction system and single BPNN.

A combination OA/EA TL prediction system was developed using slightly modified partitions of  $u^*$  and  $c^*$  parameters from those in the original EA system along with the source height partitions used in the OA system. The partitions were modified to include the slightly increased range of the  $c^*$  parameter. The partitions of the EA system were designed to separate the data along into the stable and unstable atmospheric regimes. Combining the OA and EA division (3 for OA, 9 for EA) results in  $3 \times 9 = 27$  expert neural networks, which are trained with the same procedure described above. This OA/EA system uses a neural network version of the OA's fusion system. The neural network in the fusion system consists of 3 layers of neurons and takes the weighted outputs of each of the 27 predictors as inputs. This network takes advantage of any statistical structure in the errors of the bank of predictors.

The combined OA/EA system has improved performance over both the single BPNN and OA TL predictors, though the OA system outperforms the OA/EA system over some of the input space. The increased performance can be seen in Figure 3 which is a plot of the RMSE of the OA/EA system along with the RMSE of the OA system versus source height. The performance remained relatively the same for high source heights where the effects of ground interference are significant. This suggests that when ground interference is present the nonlinearity of the

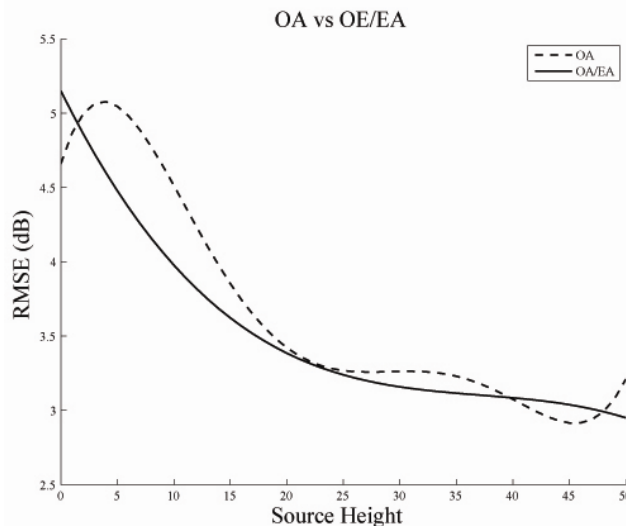


Figure 3. RMSE versus Source Height for both the OA and combined OA/EA TL prediction systems. Overall the OA/EA prediction system performs better than the OA system alone.

underlying mapping function does not change significantly between the stable and unstable atmospheric regimes. When little or no ground interference is present there is a reduction in the nonlinearity of the underlying mapping and as a result the neural networks capture the mapping more accurately. This is reflected in the improved performance in the lower source height regions. Performance of the OA and combined OA/EA systems can be seen in Figure 3 as well as Table 1, which shows the RMSE of each system on the same data sets as well as a measure of how often the TL predictions become unreliable. As can be seen, the combined OA/EA system has improved the overall accuracy of the TL prediction in both the RMSE and % outliers. However, our goal is to reduce the RMSE to less than 3dB and outliers to around 5%.

<i>Set</i>	<i>RMSE OA (dB)</i>	<i>Outliers &gt; 6dB (%)</i>	<i>RMSE EA/OA (dB)</i>	<i>Outliers &gt; 6dB (%)</i>
<i>Training</i>	3.68	9.7	3.44	8.4
<i>Validation</i>	3.77	10.3	3.59	9.1
<i>Testing</i>	3.76	10.2	3.59	9.4

Table 1: Performance of both the OA and combined OA/EA TL prediction systems.

### **Dr. John Knaff**

Azimuthal averages of mean and standard deviations of brightness temperatures from 8km 3-hourly IR imagery over tropical cyclones for the period starting in 1983 have been created.

Renewed requests have been made to obtain oceanic heat content data previously used in STIPS for 2004 and 2005.

Code continues to be developed to access these datasets and create storm relative predictor/predictant datasets.

Continued to work with B. Sampson, NRL Monterey; some of details about the logistics of how to transfer the resulting statistical model to operations at the Joint Typhoon Warning Center have been developed.

### **Travel**

Stan Kidder traveled to San Francisco, December 13-15.

### **Technology transfer**

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

Dr. Kidder gave an oral presentation of the Kidder et al. paper at the Fall Meeting of the American Geophysical Union.

### **Equipment/systems status**

No report this period.

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

Activities during this period that qualify under this heading are the publications and presentations at two major scientific conferences: the Fall Meeting of the American Geophysical Union, held in San Francisco, and the Annual Meeting and associated conferences of the American Meteorological Society, held in San Antonio. Those items have been discussed under the respective research theme area sections in this report and full references are contained in the attached publications list.

**Appendix 1**  
**CG/AR Researchers under Current Cooperative Agreement**  
**(period of performance: May 1, 2006 – April 30, 2011)**

<b>Last Name</b>	<b>First Name</b>	<b>Department</b>	<b>E-mail</b>	<b>Specialty</b>	<b>Theme Area</b>
Azimi-Sadjadi	Mahmood	Electrical Engr	azimi@engr.colostate.edu	Neural Net Studies/Acoustics	Remote Sensing of Battlespace Parameters
Carey	Lawrence	TA&MU (sub)	carey@ariel.met.tamu.edu	Radar Meteorology/Cloud Microphysics	Clouds, Icing, and Aerosols Effects
Cheng	William	Atmos Science	cheng@atmos.colostate.edu	Mesoscale Modeling	Environmental Modeling and Assimilation
Combs	Cindy	CIRA	combs@cira.colostate.edu	Satellite/Climatology	Hydrometeorology, Remote Sensing of Battlespace Parameters
Cotton	William	Atmos Science	cotton@isis.atmos.colostate.edu	Atmospheric Modeling	Environmental Modeling and Assimilation
Eis	Kenneth	CIRA	eis@cira.colostate.edu	Satellite Meteorology	Technology Transition and Interactions
Fletcher	Steven	CIRA	fletcher@cira.colostate.edu	Data Assimilation Methods	Environmental Modeling and Assimilation
Forsythe	John	CIRA	forsythe@cira.colostate.edu	Satellite Meteorology/Data Analysis	Remote Sensing of Battlespace Parameters, Clouds, Icing, and Aerosols Effects
Fowler	Laura	CIRA	fowler@cira.colostate.edu	Cloud Microphysics/Data Assimilation	Environmental Modeling and Assimilation
Jones	Andrew	CIRA	jones@cira.colostate.edu	Surface Moisture/Remote Sensing	Hydrometeorology, Environmental Modeling and Assimilation
Julien	Pierre	Civil Engr	pierre@lance.colostate.edu	Hydrology	Hydrometeorology
Kankiewicz	Adam	CIRA	kankie@cira.colostate.edu	Satellite Meteorology	Clouds, Icing, and Aerosols Effects
Kidder	Stanley	CIRA	kidder@cira.colostate.edu	Satellite Meteorology/Remote Sensing	Remote Sensing of Battlespace Parameters
Knaff	John	CIRA	knaff@cira.colostate.edu	Tropical Meteorology/Forecast Technique Development	Remote Sensing of Battlespace Parameters
Kreidenweis	Sonia	Atmos Science	soniak@aerosol.colostate.edu	Aerosols	Clouds, Icing, and Aerosols Effects
Larson	Vincent	UW-Mil (sub)	vlarson@uwm.edu	Cloud Modeling and Parameterization	Clouds, Icing, and Aerosols Effects
Longmore	Scott	CIRA	longmore@cira.colostate.edu	Modeling and Remote Sensing	Hydrometeorology/ Environmental Modeling and Assimilation
Matsumoto	Cliff	CIRA	cliff.r.matsumoto@noaa.gov	Tropical Meteorology/Hurricane Motion	Technology Transition and Interactions
Pielke	Roger	CU (sub)	pielkesr@cires.colorado.edu	Mesoscale/Regional Weather and Climate Studies	Urban and Boundary Layer Environment
Ramirez	Jorge	Civil Engr	ramirez@engr.colostate.edu	Hydrology, Hydrometeorology & Water	Hydrometeorology
Reinke	Donald	CIRA	reinke@cira.colostate.edu	Satellite Meteorology/Programming	Clouds, Icing, and Aerosols Effects
Sengupta	Manajit	CIRA	sengupta@cira.colostate.edu	Radiative Transfer	Environmental Modeling and Assimilation
Stokowski	David	CU (sub)	david.stokowski@colorado.edu	Look-up Tables	Urban and Boundary Layer Environment
Vonder Haar	Thomas	CIRA	vonderhaar@cira.colostate.edu	Satellite Meteorology	Technology Transition and Interactions
Zupanski	Dusanka	CIRA	zupanski@cira.colostate.edu	Data Assimilation Methods	Environmental Modeling and Assimilation
Zupanski	Milija	CIRA	zupanskim@cira.colostate.edu	Data Assimilation Methods	Environmental Modeling and Assimilation

### CG/AR Graduate Students

<b>Last Name</b>	<b>First Name</b>	<b>Department</b>	<b>E-mail</b>	<b>Theme Area</b>	<b>Advisor</b>	<b>Support</b>
Donofrio	Kevin	Atmos Science	donofrio@cira.colostate.edu	Remote Sensing of Battlespace Parameters	Vonder Haar	CG/AR
Halgren	James	Civil Engr	james.halgren@colostate.edu	Hydrometeorology	Julien	CG/AR
Johnson Wells	Kelley	Atmos. Science	kcjohnso@lamar.colostate.edu	Aerosol Observations and Predictions Analysis	Kreidenweis	CG/AR
Leoncini	Giovanni	Atmos Science	leoncini@atmos.colostate.edu	Boundary Layer and Urban Studies	Pielke	CG/AR
Masarik	Matt	Atmos Science	mmasarik@atmos.colostate.edu	Environmental Modeling and Assimilation	Schubert/Vonder Haar	CG/AR
McCarron	Mike	Electrical Engr	michael.mccarron@colostate.edu	Advanced Neural Net Processing of Acoustic Data	Azimi	CG/AR
Nobis	Timothy	Atmos Science	timothy.nobis@afwa.af.mil	Boundary Layer and Urban Studies	Pielke	AFIT
Rapp	Dustin	Atmos. Science	rapp@cira.colostate.edu	Soil Moisture WindSat	Vonder Haar	CG/AR
Seaman	Curtis	Atmos Science	seaman@cira.colostate.edu	Clouds, Icing, and Aerosols Effects	Vonder Haar	CG/AR
Schwartz	Aaron	Atmos Science	schwartz@cira.colostate.edu	Clouds, Icing, and Aerosols Effects	Vonder Haar	CG/AR
Shah	Seema	Civil Engr	sshah@engr.colostate.edu	Hydrometeorology	Julien	CG/AR
Smith	Michael	Atmos Science	msmith@atmos.colostate.edu	Environmental Modeling and Assimilation	Cotton	CG/AR
Wichern	Gordon	Electrical Engr	gwichern@engr.colostate.edu	Advanced Neural Net Processing of Acoustic Data	Azimi	CG/AR

## Appendix 2

### Publications

(The following were supported under CG/AR Cooperative Agreement W911NF-06-2-0015. Readers may also want to review the publications list from the previous Cooperative Agreements, DAAD19-02-2-0005, DAAD19-01-2-0018 and DAAL01-98-2-0078. To date, CG/AR research has resulted in 282 publications including 77 papers in refereed journals).

Combs, C.L., D. Rapp, A.S. Jones, and G. Mason, 2007: Comparison of AGRMET model results with *in situ* soil moisture data. Pre-print CD-ROM, 21st Conference on Hydrology, January 14-18, San Antonio, TX (AMS).

Donofrio, K.M., 2007: A 1DVAR optimal estimation retrieval of water vapor profiles over the global oceans using spectral microwave radiances. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 165 pp.

Fletcher, S.J. and M. Zupanski, 2007: An alternative to bias correction in retrievals and direct radiances assimilation. Pre-print CD-ROM, 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), January 13-19, San Antonio, TX (AMS).

Jones, A.S., C.L. Combs, S. Longmore, T. Lakhankar, G. Mason, G. McWilliams, M. Mungiole, D. Rapp, T.H. Vonder Haar, and T. Vukicevic, 2007: NPOESS soil moisture satellite data assimilation research using WindSat data. Pre-print CD-ROM, Third Symposium on Future National Operational Environmental Satellite Systems—Strengthening Our Understanding of Weather and Climate, January 16-17, San Antonio, TX (AMS).

Kidder, S.Q. and A.S. Jones, 2006: A blended satellite total precipitable water product for operational forecasting. *J. Atmos. and Oceanic Technol.*, 24, 74-81.

Lakhankar, T., A. Jones, C. Combs, D. Rapp, M. Sengupta, and T. Vonder Haar, 2007: Analysis of large scale spatial variability of soil moisture data using a geostatistical method. IGARSS'07 (submitted).

Longmore, S., A.S. Jones, A. Carheden, and T.H. Vonder Haar, 2007: Experience and lessons learned regarding configuration and control of an advanced 4-dimensional variational satellite data assimilation system. Pre-print CD-ROM, 23rd Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, January 14-18, San Antonio, TX (AMS).

Masarik, M.T., 2007: Potential vorticity and energy aspects of the MJO through equatorial wave theory. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 86 pp.

- Pielke, Sr., R.A., G. Leoncini, T. Matsui, D. Stokowski, J.-W. Wang, T. Vukicevic, C. Castro, D. Niyogi, C.M. Kishtawal, A. Biazar, K. Doty, R.T. McNider, U. Nair, and W.K. Tao, 2006: Development of a generalized parameterization of diabatic heating for use in weather and climate models. Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, Paper No. 776.
- Rapp, D., 2007: Passive microwave measurement of soil moisture using WindSat. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 211 pp.
- Saleeby, S.M., W.Y.Y. Cheng, and W.R. Cotton, 2007: New developments in the Regional Atmospheric Modeling System suitable for simulating snowpack augmentation over complex terrain. *J. Wea. Mod.*, (submitted).