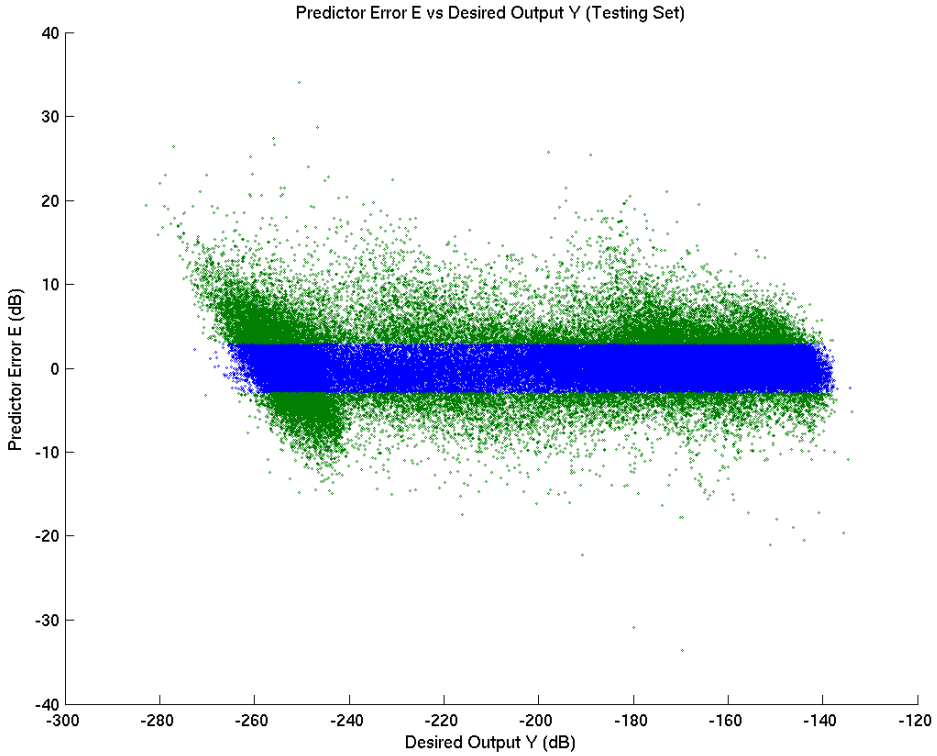
Colorado State University
Center for Geosciences/Atmospheric Research (CG/AR)
Quarterly Report No. 7
by T.H. Vonder Haar and Collaborators

Reporting period: October 1 – December 31, 2007

Cooperative Agreement #W911NF-06-2-0015



This is a plot of the prediction error vs. actual transmission loss values, from the work of Prof. Azimi's graduate student, Michael McCarron. Please see their report under the Remote Sensing of Battlespace Parameters Theme.

Overview

The main activity program-wide has been on projects that have continuing graduate students. Under the Hydrometeorology theme, both of Pierre Julien's students are making good progress, although James Halgren is the only one currently supported by CG/AR.

A CIRA postdoctoral fellow, Yoo-Jeong Noh, accepted a research position working within the Clouds, Icing, and Aerosols Effects theme. The official appointment start date was February 1, however, Yoo-Jeong has already begun analyzing the characteristics of wintertime midlevel mixed-phase clouds, using the observations from C3VP/CLEX-10. Both she and Curtis Seaman have had close interactions with the experiment team and participated in the first post-field campaign workshop. Curtis presented early results to our colleagues at NRL/Monterey.

Presentations and interactions at BACIMO 2007 were the focus of researchers under the Environmental Modeling and Assimilation research theme. In addition, Milija Zupanski produced new results with the WRF model, looking at Hurricane Katrina.

Work has continued on topics under the Remote Sensing of Battlespace Parameters, primarily that of Stan Kidder and Professor Azimi and his graduate student. Michael McCarron is continuing to make good progress on his thesis research and provides a detailed report herein.

Work on publications and submissions to relevant conferences continues across all the research themes.

Loretta Wilson
Program Assistant II

For more information on the DoD Center for Geosciences/Atmospheric Research at Colorado State University, please access our web page at http://www1.cira.colostate.edu/GeoSci/overview.htm

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)
- Andy Jones, Laura Fowler, Steven Fletcher, Manajit Sengupta, Scott Longmore, Tarendra Lakhankar, and Curtis Seaman with Dale Barker, Hans Huang, Qingnong Xiao, Jenny Sun, and Zhiquan Liu
- Large and small group interactions at the Annual Review, held at CSU/Fort Collins, including:

  Tom Vonder Haar, Ken Eis, Loretta Wilson, et al. with DoD Review Panel and invited attendees

  Adam Kankiewicz with Pam Clark (ARL) and Ted Tsui (NRL)

  Stan Kidder and Jeff Jorgeson (ERDC)

  John Forsythe with Ted Tsui (NRL)

  Pierre Julien and James Halgren with Jeff Jorgeson (ERDC)

  Sonia Kreidenweis with Ron Pinnick (ARL)
- Steven Fletcher with Profs. Nancy Nichols and Alan O'Neil (Data Assimilation Research Centre, UK)
- Steven Fletcher with Dr. Amos Lawless (Department of Mathematics at the University of Reading) and Dr. Eric Andersson (ECMWF)
- Tom Vonder Haar with Patricia Phoebus, Joe Turk, Jerry Schmidt, Nancy Baker and Craig Bishop (NRL)

- Tom Vonder Haar with Philip Durkee (NPS)
- Mahmood Azimi with Mike Mungiole, Alan Wetmore, John Noble, Pam Clark, Sandra Collier and Dave Marlin (ARL)
- Curtis Seaman with Nancy Baker and others (NRL)
- Andy Jones and Steve Fletcher with Dale Barker (NCAR); Dennis Garvey, Jim Cogan, Alan Wetmore (ARL); Tim Nobis (AFWA)

Research Theme: Hydrometeorology

Administrative

None this period.

Research activity and/or results

Dr. Andrew Jones, Theme Leader
There was no reportable activity during this quarter.

Prof. Pierre Julien, James Halgren, and Seema Shah-Fairbank
Seema presented a preliminary proposal to her committee on November 12 and was encouraged to continue with her research. She has been performing a detailed analysis of the Modified Einstein Procedure for calculating total sediment load. She has developed a procedure for determining the fraction of total load in suspension and the fraction of total load measured based on the Rouse concentration profile and the logarithmic velocity profile. The procedure has been calibrated using river data from the Enoree, Middle Rio Grande and Mississippi Rivers.

James has continued work on the soil moisture code for the hydrologic model TREX. He is making progress towards the integration of a sub-surface flow module for watershed modeling. This component will improve the applicability of the model for long-term simulations.

Travel

None this period.

Technology transfer

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

Equipment/systems status

The newly purchased workstation in Julien's group received warranty service to resolve problems with spontaneous shutdowns. Presently, all systems are fully operable.

Research Theme: Clouds, Icing, and Aerosols Effects

Administrative

In early October, Yoo-Jeong Noh accepted the offer of the new Research Scientist II position established in the area of satellite remote sensing and microwave radiative transfer. She joins the clouds, radiation, and precipitation group of researchers at CIRA, working on CG/AR environmental studies. Although Dr. Noh's new appointment officially begins February 1, 2008, she began looking at data from the recent C3VP/CLEX-10 field program this past summer. We are pleased that she has chosen to join our research efforts.

Research activity and/or results

Yoo-Jeong Noh

The main objective is to analyze the characteristics of wintertime midlevel mixed-phase clouds by using satellite and aircraft observations during the Canadian CloudSat/CALIPSO Validation Project and the 10th Cloud Layer Experiment (C3VP/CLEX-10). These two field experiments worked together during 2006-2007 winter seasons to target A-Train (the Afternoon satellite constellation led by NASA's Aqua satellite) overpasses of winter season clouds and precipitation over the southern Ontario region of Canada and surrounding areas. The motivations of this study are as follows:

- Midlevel mixed-phase clouds such as altostratus and altocumulus are often mistyped from satellite observations as either water or ice clouds. Detailed microphysical features of these clouds are not fully understood yet sin spite of converging over 22 % over the earth's surface.
- An ability to detect mixed phase conditions and retrieve cloud properties is directly linked with civil/military aircraft safety issues and numerical climate/weather predictions.

Using aircraft measurements (Convair-580) during the C3VP/CLEX-10 field experiment, which cleared the first data quality control check, the vertical distributions of ice and liquid particles in mixed-phase clouds were analyzed. We found the existence of a supercooled liquid water layer at low temperatures (~ -20°C) above the freezing level for several mixed-phase cloud cases. A study using satellite data from various passive/active microwave sensors also started in order to investigate the sensitivity of mixed-phase clouds at these frequencies and validate the satellite retrieval products. Datasets from CloudSat CPR, AMSR-E onboard Aqua satellite, and AMSU-B onboard NOAA satellites are used. From the preliminary results, we confirmed that detecting and characterizing mixed-phase clouds need multi-frequency and multi-instrument analyses. It is also noted that intensive observations are necessary to validate satellite retrievals such as CloudSat products, as well as to improve our understanding of mixed-phase clouds and their radiative properties.

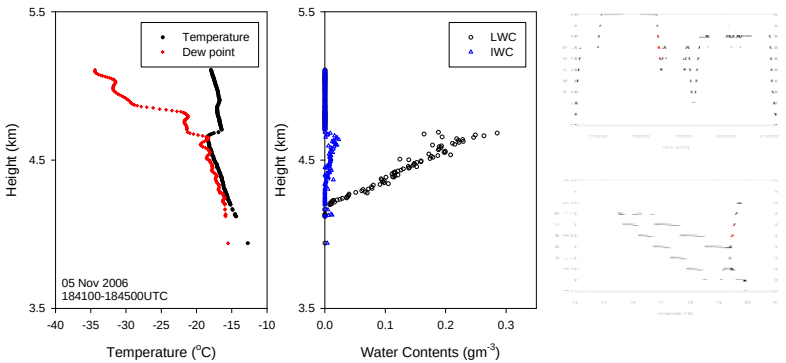
Participated in the 4th Workshop of the Canadian CloudSat/CALIPSO validation project in November and gave a presentation on the study.

Analysis of wintertime mixed-phase clouds using aircraft/satellite measurements

RESEARCH QUESTION/OBJECTIVE

- Understanding of the mixed-phase clouds is important for radar, lidar, satellite retrievals, climate/weather numerical modeling, and aviation safety issues regarding icing conditions, but their detailed microphysics are not fully understood yet.
- In this study, the characteristics of wintertime midlevel mixed-phase clouds are analyzed by using satellite and aircraft observations during the Canadian CloudSat/CALIPSO Validation Project and the 10th Cloud Layer Experiment (C3VP/CLEX10) .

Vertical profiles of temperature/dew point and liquid and ice water contents from the C3VP/CLEX10 aircraft observation 5 Nov 2006.



RESEARCH APPROACH/METHOD

- Analyzed Convair-580 measurements during the C3VP/CLEX10 field experiment for mixed-phase cloud cases.
- Investigate the sensitivity of mixed-phase clouds at satellite microwave frequencies using CloudSat, AMSR-E (Aqua satellite) and AMSU-B (NOAA satellites).
- Validate the CloudSat retrieval products using the aircraft data.

RESEARCH STATUS

- Analysis of vertical distributions of liquid/ice in mixed-phase clouds are ongoing using the aircraft data that cleared the first data quality control check. The existence of a supercooled liquid water layer above the freezing level was found for several cases.
- Intensive observations are necessary to validate satellite retrievals such as CloudSat products, as well as to improve our understanding of mixed-phase clouds and their radiative properties.
- Collaborate with Cory Wolff (NCAR) and Thomas Lee (NRL) on aircraft icing conditions.

Curtis Seaman
Prepared a poster on the mixed-phase clouds and aircraft icing conditions observed during the Canadian CloudSat CALIPSO Validation Project for BACIMO 2007, which was presented at the conference by Andy Jones and Ken Eis.

Visited the Naval Research Laboratory in Monterey and presented a seminar which included a review of the results from CLEX-9, an overview of CLEX-10, and results from the work performed by the 4DDA research theme group as it relates to his PhD research. Met with members of the data assimilation group, including Nancy Baker, Ben Ruston, and Bill Campbell to discuss current and future data assimilation research. Also met with Jim Doyle of the mesoscale modeling group to discuss modeling of mid-level clouds, and with members of the satellite group, including Tom Lee and Christian Mitrescu to discuss results from C3VP/CLEX-10, as they were preparing a paper on validation of the CloudSat cloud mask product using satellite data collected during the experiment.

Prepared and gave a talk at the 4th C3VP Workshop, the first workshop after the completion of field experiment. The presentation focused on CIRA/ CG/AR's goals for CLEX-10 and early results, including Paul DeMott's analysis of ice nuclei data and Stan Kidder's look at various cloud phase retrieval algorithms.

CG/AR has now received first cuts of the microphysical probe data. There are still some minor quality control issues with the ice particle data from the microphysical probes, but there has been sufficient data for early analysis, which is currently being performed by CIRA postdoc Yoo-J. Noh.

Prof. Sonia Kreidenweis
There was no reportable activity during this quarter.

Travel

Curtis Seaman traveled to Monterey, California, November 6-7.

Curtis Seaman and Yoo-Jeong Noh traveled to St. Hubert, Quebec, Canada, November 26-29.

Technology transfer

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

Equipment/systems status

Nothing to report for this period.

Research Theme: Environmental Modeling and Assimilation

Administrative

None this period.

Research activity and/or results

Dr. Andrew Jones, Theme Leader
Prepared and presented oral presentations at BACIMO 2007. Meeting sessions and side discussions were very productive.

Dr. Milija Zupanski
New results with the WRF model and hurricane Katrina were produced, by using 6-hour old lateral boundary conditions to reflect better the operational forecasting environment. Also, a new scheme for error covariance localization based on local domains was tested. The results show a considerable improvement of the MLEF experiment over the no-assimilation experiment. The observations are mostly at surface and over the land, thus creating a very challenging environment for data assimilation and testing the robustness of the MLEF. The manuscript representing those results is almost completed, and should be submitted for publication in the next quarter.

Dr. Steven Fletcher
Prepared and presented oral presentation at BACIMO 2007. Participation in the conference and side discussions were very beneficial to the ongoing research.

Prof. William Cotton
With the graduation of his masters student last quarter, the continuation of the research is on hold until new funding for the Center is in hand and current DoD requirements are matched with CG/AR's capabilities.

Curtis Seaman
Continues to make progress on the PhD dissertation research. Have uccessfully assimilated GOES Sounder channel 7 and 11 data and found that these channels are useful to improving the moisture analysis in the mid-troposphere. The major complication is the reanalysis data used to initialize the model is so poor (meaning the atmosphere is too dry) that the assimilation cannot recover from the poor start. At the height where a mid-level cloud is known to form, the relative humidity in the initialization has relative humidity ~ 20%. After assimilation the relative humidity is ~ 40%, which is an improvement, but not nearly enough to produce a cloud. Currently working on assimilating GOES Imager channels 3 & 4, which are analogous to the Sounder channels previously assimilated, only with higher temporal and spatial resolution.

Discussions during November's visit to the Naval Research Laboratory in Monterey, as previously identified in the Clouds, Icing, and Aerosols Effects section, fall under this research theme as well.

Travel

Andrew Jones and Steven Fletcher traveled to Boston, MA, November 5-8 and 4-8, respectively.

Technology transfer

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

Equipment/systems status

No report this period.

Research Theme: Urban and Boundary Layer Environment

Administrative

None this period.

Research activity and/or results

There was no reportable research activity during this quarter.

Travel

None this period.

Technology transfer

None this period.

Equipment/systems status

No report this period.

Research Theme: Remote Sensing of Battlespace Parameters

Administrative

A new graduate student was approved to join Prof. Azimi's research efforts, to begin in January.

Research activity and/or results

Dr. Stanley Kidder
Continued work to develop satellite products for the battlespace; the main focus is in validating cloud products using CloudSat and CALIPSO data.

John Forsythe
In early October, submitted the extended abstract for the oral presentation which was made in September at the EUMETSAT/15th AMS Satellite Meteorology and Oceanography Conference.

No active development on C1DOE this quarter. GPS/GOES Sounder/AMSU and SSM/I near real-time total precipitable water ingest continues to function well (runs every six hours).

Prof. Mahmood R. Azimi-Sadjadi and Michael McCarron
Focused on continuing to improve the performance of the Operationally and Environmentally Adaptive (OEA) transmission loss (TL) prediction system along with the development and implementation of the new wavelet-based prediction system. A new synthetic dataset was also generated using the parabolic equation (PE) model for acoustic transmission to evaluate the Environmentally Adaptive (EA) TL prediction system for sources with low elevation (0 to 5m) on both moving average filtered and non-filtered data. This dataset was used to measure the EA and combined OEA systems' performance in the low source height region, and to start the training of an EA system using filtered data. This retrained EA system will be incorporated into the OEA system to improve performance on the moving-average filtered data. Statistical analysis was done on the combined OEA system to determine the effects of outliers (testing set samples which produce largely erroneous TL predictions) on the overall system's performance. This analysis leads to the idea of using a more appropriate measure for training of the neural networks in the OEA system to improve performance on these outliers.

PE Model Dataset

The new PE model dataset uses the extended parameter ranges for all parameters except source elevation which is restricted to 0-5m corresponding to ground sources. This range is of critical importance as many sources of interest are close to the ground. The EA system was combined with the Operationally Adaptive (OA) system to improve performance in this critical region but only a slight performance gain was achieved. This is due to the EA system being trained on non-filtered data while the OA system was trained on filtered data. The filtering was originally introduced to help combat some of the nonlinear effects associated with the extended parameter ranges, but also had a large enough effect on the data in the original ranges to reduce the performance of the EA system.

The new PE model dataset consists of 167,000 samples which are sampled uniformly along each dimension in the input space except horizontal separation which has forty samples for every one sample of the other parameters. This dataset is smaller than the PE model dataset used to develop the OA system which contains 275,000 samples, resulting in training, validation, and testing sets of size ~55,600 as opposed to ~91,600 samples. These set sizes may not be large enough to retrain the EA system on filtered data, but are enough to examine the performance of the already trained EA system on both types of data. New samples are still being generated and added to the new PE model dataset to bring the number of samples to 275,000. These additional samples can be used later to improve the performance of any EA system trained with the current number of data samples.

EA System Performance

Figures 1 and 2 show the performance of the EA system as a function of source height on the new PE model data using the filtered and non-filtered versions respectively. These figures were generated using only the samples which fall within the EA system's parameter range, about 45,000 samples out of the 167,000 total samples.

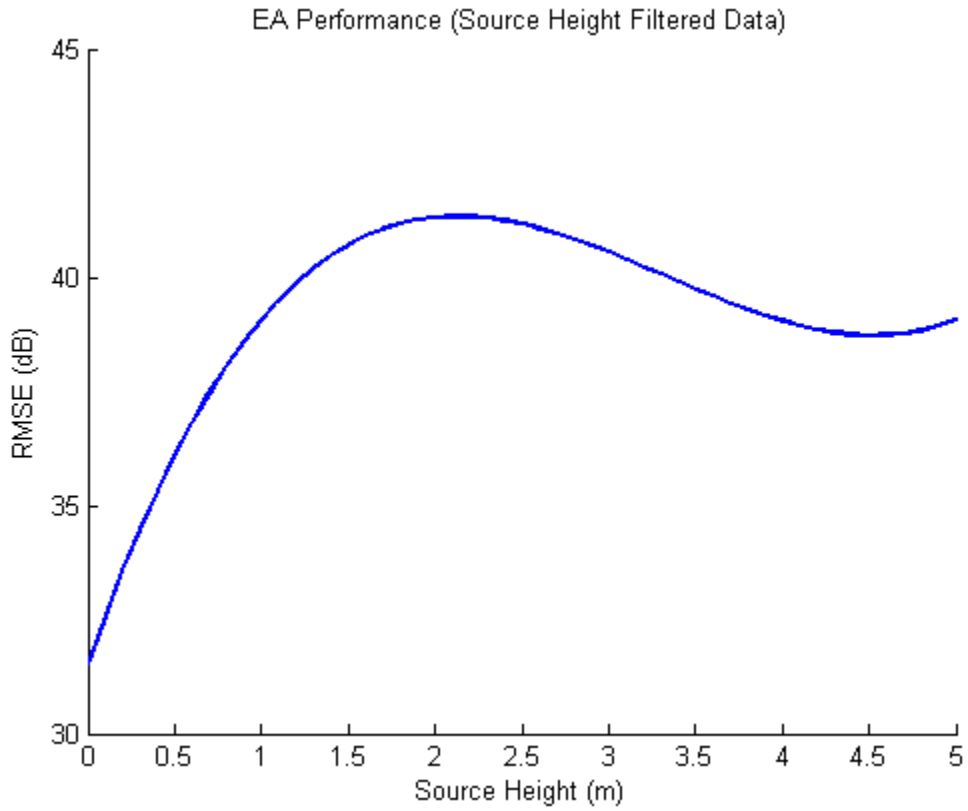


Figure 1. Plot of the root-mean-square error of the EA system as a function of source height on filtered data. The RMS error on the filtered dataset was 35dB.

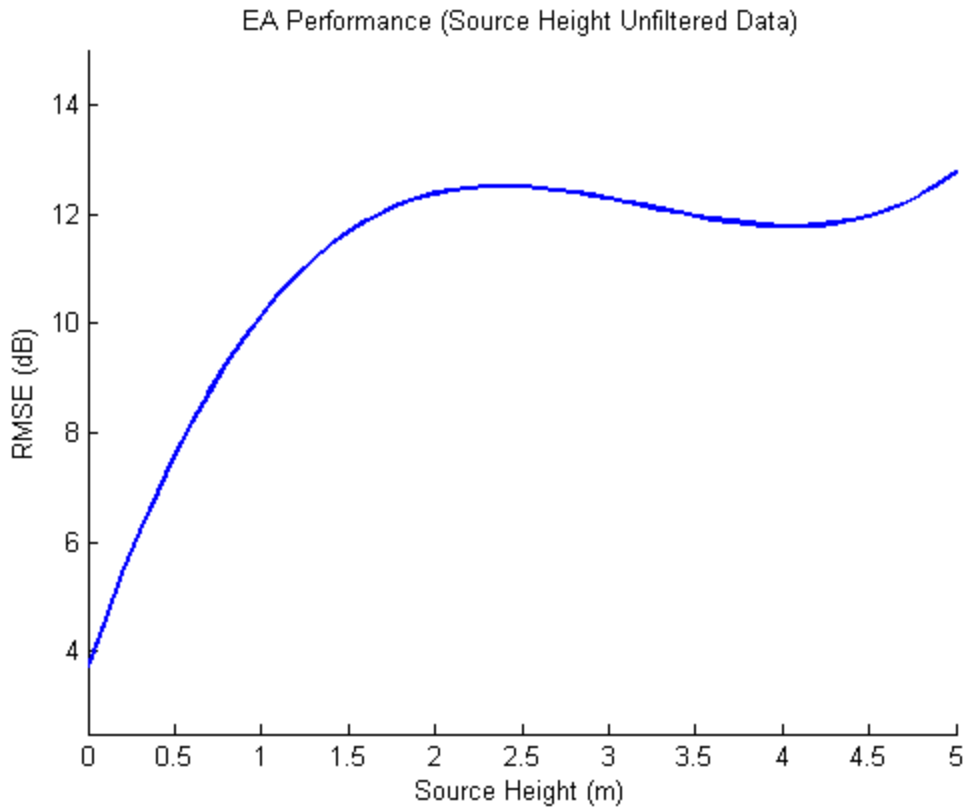


Figure 2. Plot of the root-mean-square error of the EA system as a function of source height on unfiltered data. The RMS error on the unfiltered dataset was 10dB.

It is clear from Figures 1 and 2 that the EA system needs to be retrained to perform well on the filtered data, and contribute more to the combined OEA system. The performance on the filtered data is significantly worse than the performance on the unfiltered data, ~35dB RMS error vs. ~10dB RMS error. Retraining the EA system will also allow the incorporation of some of the extended ranges such as frequency, and horizontal separation, which will also improve the performance over the current EA system.

Statistical Analysis of Combined OEA TL Prediction System

Figure 3 is a plot of prediction error versus actual TL (PE model) value for the combined OEA system on all samples in the testing set. The blue section contains non-outlier samples while the green section contains outliers. The outliers have a large contribution to the overall root-mean-square (RMS) error of the OEA system on the testing set. It is also important to notice that some outliers have very large errors, and that some regions of the TL output space have many more outliers than other regions. Both of these observations suggest that a different measure of performance for use with neural network training that penalizes these outliers more may improve the TL prediction performance.

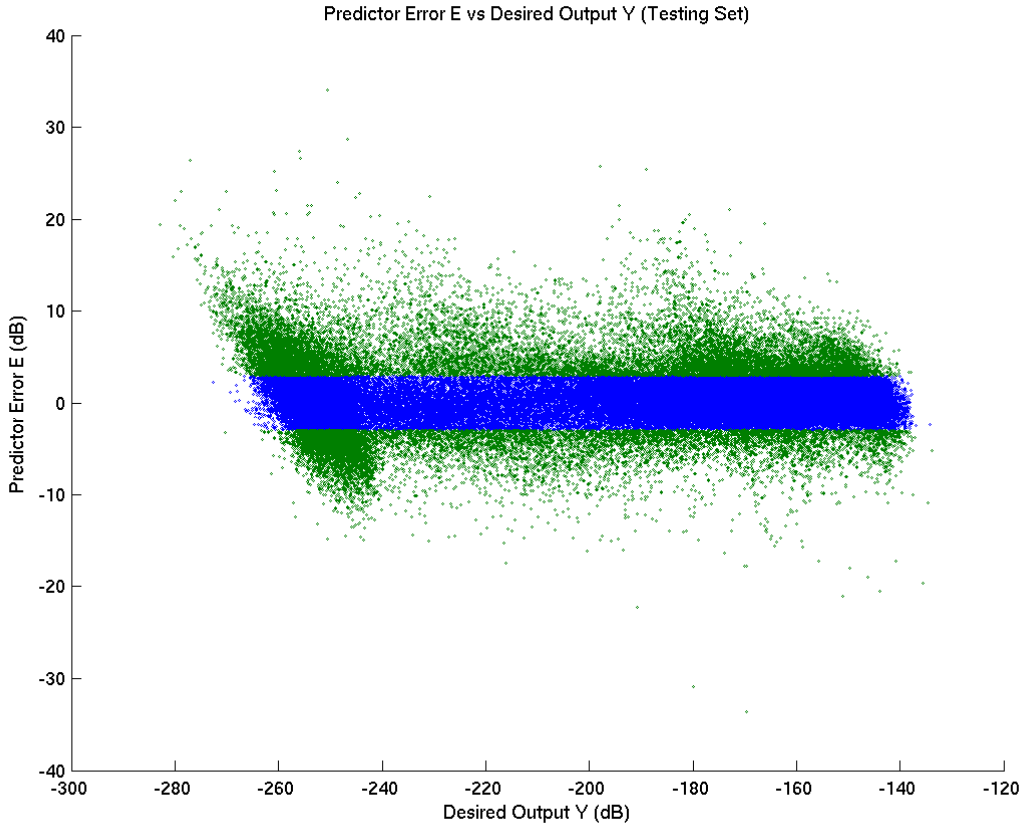


Figure 3. Plot of the prediction error vs. actual TL values.

A number of performance measures have been researched and an information theoretic measure based on the mutual information between the output of the predictor and the desired output is currently being implemented.

Multi-Scale Wavelet Based Neural Network TL Prediction System

An attempt to improve the wavelet-based TL prediction system based on single scale wavelets was made during this quarter. This modified approach uses multi-scale wavelets as activation functions for each neuron in a network with a radial basis type structure. The network implements the following function

$$g(\boldsymbol{x}) = \sum_{i=1}^{N} w_i \psi[D_i R_i(\boldsymbol{x} - \boldsymbol{t}_i)] + \bar{g}$$

where w_i are the weights, D_i is a diagonal dilation matrix, R_i is a rotation matrix**,** $\mathbf{t}_i$ are the neuron locations in the input space, N is the number of neurons, **x** is the input parameter vector, Ψ is a multi-scale wavelet, and g bar is a scalar offset. The multi-scale wavelet is formed by multiplying a number of single scale wavelets together; each evaluated using a single element of the input parameter vector. For PE model data the input parameter has 10 elements, hence 10 single scale wavelets are multiplied together to form Ψ. Each element in the diagonal dilation

matrix can be adjusted independently, allowing the scale along each dimension to be adjusted independently. The rotation matrix, R_i, is added to allow the orientation of each neuron in the input space to be adjusted.

A number of training algorithms were implemented for this network. A standard gradient descent-based algorithm was implemented but convergence of the algorithm was extremely slow due to poor rate of convergence and high computation costs. Each epoch took roughly 1 hour to calculate. This algorithm was run up to 240 epochs without convergence and with only a slight improvement in performance over an untrained network. This algorithm was optimized reducing the time per epoch to ~5 minutes. This algorithm was run for a few thousand epochs, still with no convergence and with only a slight improvement in performance. A second order Newton with Levenberg-Marquardt based optimization algorithm was implemented in an attempt to improve the rate of convergence. This algorithm was also run for a few thousand epochs with only a slightly improved rate of performance increase per epoch over the gradient descent-based algorithm.

Travel

None this period.

Technology transfer

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

Equipment/systems status

Nothing to report this period.

Research Theme: Technology Transition and Interactions

CG/AR research was represented again the BACIMO 2007 Conference, held at Boston College, Chestnut Hill Campus. Three oral presentations (Jones, et al., Fletcher, et al., and Sengupta, et al.) and one poster (Kankiewicz, et al.) were presented. This forum continues to provide our researchers with an excellent opportunity for important interactions with DoD lab and other science colleagues.

Appendix 1

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

Last Name	First Name	Department	E-mail	Specialty	Theme Area
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 Microhysics	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 Meterology/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
Miller	Steven	CIRA	miller@cira.colostate.edu	Satellite Instrumentation	Clouds, Icing, and Aerosols Effects
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

Last Name	First Name	Department	E-mail	Theme Area	Advisor	Support
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-Fairbank	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 293 publications including 76 papers in refereed journals).

Carey, L.D., J. Niu, P. Yang, J.A. Kankiewicz, V.E. Larson, and T.H. Vonder Haar, 2008: The vertical profile of liquid and ice water content in mid-latitude mixed-phase altocumulus clouds. *J. Appl. Meteor. Clim.*, (accepted pending revisions).

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).

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