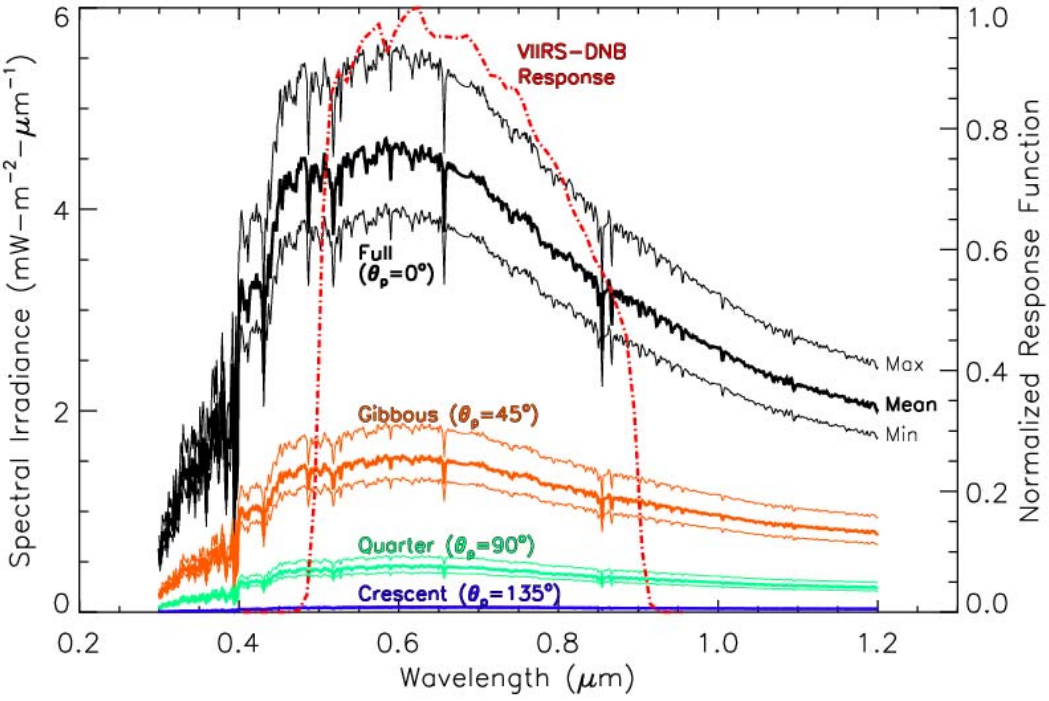
Colorado State University
Center for Geosciences/Atmospheric Research (CG/AR)
Quarterly Report No. 8
by T.H. Vonder Haar and Collaborators

Reporting period: January 1 – March 31, 2008

Cooperative Agreement #W911NF-06-2-0015



Example of lunar spectral irradiance as a function of lunar phase, showing high variability. From the work of Steven D. Miller – see the detailed description under the Clouds, Icing, and Aerosols Effects theme.

Overview

Research continued in several areas while we began planning the focus for the new research year (beginning May 1) on the heels of the Federal FY08 appropriation. Other areas saw activity primarily in the dissemination of results via conference presentations and publications. In particular, CG/AR results were presented at the AMS Annual Meeting and associated conferences in January, which were well attended again this year.

In addition to the continuing dissertation work of PhD student Curtis Seaman, the Clouds, Icing, and Aerosols Effects theme saw steady progress of the analyses of the characteristics of wintertime midlevel mixed-phase clouds, performed by Yoo-Jeong Noh, using the observations from C3VP/CLEX-10. Steve Miller's nighttime applications is continuing strong here at CIRA with some assistance by Cindy Combs.

Steven Fletcher's work continued under the Environmental Modeling and Assimilation theme. Curtis Seaman's dissertation work has crossed into this theme area and is detailed in this section.

Work has continued on topics under the Remote Sensing of Battlespace Parameters, primarily that of Stan Kidder and Professor Azimi and his graduate students. January saw the addition of a new GRA to work with Michael McCarron and then continue in either this topic or a new DoD-relevant area after Mr. McCarron graduates. A recent masters graduate under Prof. Vonder Haar began working on a special project dealing with total precipitable water, under the supervision and mentoring of John Forsythe.

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)
- Yoo-Jeong Noh and Curtis Seaman with David Hudak (Environment Canada)

Research Theme: Hydrometeorology

Administrative

None this period.

Research activity and/or results

Dr. Andrew Jones, Theme Leader
There was no reportable research activity during this quarter. Most work involved travel and related presentations and publications.

Prof. Pierre Julien, James Halgren, and Seema Shah-Fairbank
Although not directly supported during this time period, both Seema and James gave presentations of CG/AR-supported research at the AGU Hydrology Days conference held at CSU at the end of March. Seema presented preliminary results from her analysis of the Modified Einstein Procedure for calculating total sediment load using river data from a USGS publication on measured total sediment load. James presented a brief summary of his graphical methods for interpreting the TREX model results. In conjunction with this conference, both graduate student participated in a research colloquium sponsored the CSU Vice President for Research. The Global Water Colloquium was a joint effort of the Colorado Water Resources Research Institute, the CSU Civil Engineering Department, and the CSU Department of Forest, Rangeland, Watershed Stewardship. Both the conference and the colloquium offered opportunities to connect with other researchers and to explore future collaboration opportunities.

Travel

Andy Jones traveled to New Orleans, LA January 20-24 for the AMS Annual Meeting. He traveled to Camp Springs, MD February 25-27 for the Satellite Algorithm Testbed Workshop, and to Adelphi, MD March 25-27 for the WIDA Workshop at ARL.

Technology transfer

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

Equipment/systems status

At 1.5 years old, the new programming workstation in the Julien group was sent for warranty repair of the motherboard to finally resolve problems with spontaneous shutdowns. Other systems are performing adequately for continued service.

Research Theme: Clouds, Icing, and Aerosols Effects

Administrative

None this period.

Research activity and/or results

Yoo-Jeong Noh

Wintertime midlevel mixed-phase clouds

- Investigate the characteristics and microphysics of wintertime midlevel mixed-phase clouds that are often mistyped and not fully understood yet in satellite retrievals and numerical climate/weather models.
- Analyze aircraft measurements during the Canadian CloudSat/CALIPSO Validation Project and the 10th Cloud Layer Experiment (C3VP/CLEX-10) over the southern Ontario and surrounding areas.

Using aircraft measurements (Convair-580) during the C3VP/CLEX-10 field experiment, the microphysics of midlevel mixed-phase clouds is studied such as vertical distributions of ice/ liquid and temperatures, and particle sizes. Newly quality-controlled aircraft 1D data (Ver. 2) was released in March with improved ice water contents, but 2D probe data release has been delayed. Mixed-phase cloud cases with supercooled liquid water at low temperatures (<~ -20°C) at cloud top were re-examined using the new version data. CALIPSO lidar data analysis is also ongoing together with CloudSat CPR data to more clearly detect the supercooled liquid water layers. These satellite products are compared with the aircraft measurements.

Analysis of snow clouds

- Analyze aircraft data of snow cases during C3VP/CLEX-10.
- Build the *a-priori* database of clouds over the Great Lakes region in developing a Bayesian snowfall retrieval algorithm.

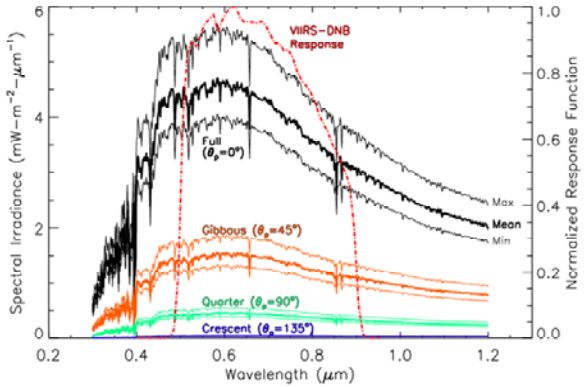
Snow precipitating cases are investigated by utilizing rich and intensive data sets during C3VP/CLEX-10. Aircraft measurements of ice/liquid water have been used as input of a radiative transfer model to generate the *a-priori* database of the Bayesian snowfall retrieval algorithm, together with CloudSat data. Analyses of the detailed microphysics of snow clouds also started to improve our understanding of wintertime non-precipitating and precipitating cloud structures. A study of the cloud microphysics during a transition period between non-precipitating and precipitating stages is going on.

Prepared poster for presentation at the AMS Symposium on Recent Developments in Atmospheric Applications of Radar and Lidar/88th Annual Meeting. Also prepared invited presentation for the 2nd International Workshop on Space-Based Snowfall Measurements.

A Lunar Spectral Irradiance Database for NPOESS-VIIRS Day/Night Band Nighttime Applications

RESEARCH QUESTION/OBJECTIVE

- **The NPOESS VIIRS Day/Night Band provides calibrated measurements of nocturnal visible light (both natural and artificial sources).**
- **Moonlight reflectance measured by the DNB can be related to the physical properties of the cloud/surface media.**
- **Calculation of reflectance requires knowledge of the input moonlight—a highly variable quantity .**
- **This research provides a means to specifying the lunar irradiance on any night, at any time.**



Examples of lunar spectral irradiance as a function of lunar phase, showing high variability.

RESEARCH APPROACH/METHOD

- **Develop lunar phase function and lunar spectral albedo model datasets**
- **Refine model for sun/earth/moon geometry prediction**
- **Apply radiative transfer principles to compute top-of-atmosphere down-welling lunar irradiance for exact geometry.**
- **Provide a "standard geometry" solution that can be scaled to current geometry.**

RESEARCH STATUS

- **Completed initial lunar irradiance model**
- **Presented results at 2008 AMS Annual Meeting in New Orleans**
- **Submitted write up on the technique to IEEE/TGRS**
- **Developed software to interpolate a standard-geometry table for use by operational application developers.**

Curtis Seaman
PhD research work has been to perform assimilation experiments; please see the input in the Environmental Modeling and Data Assimilation section.

Prepared and presented poster at the AMS 12th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS) at the 88th Annual Meeting.

Met with Dave Hudak (Environment Canada), who visited CIRA on March 25. Dr. Hudak discussed the status of the aircraft data from CLEX-10, and showed some preliminary results. Most aircraft probe data has been quality controlled to a level 2 state, except the ice water content from the 2D imaging probes, which is still being processed. The data quality looks very high at this point.

Dr. Steven Miller
The period was spent finalizing research on lunar spectral irradiance prediction in preparation for the Visible/Infrared Imager/Radiometer Suite (VIIRS) Day/Night Band (DNB) to fly on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) constellation members (to be previewed on the NPOESS Preparatory Project (NPP) in the early 2010 timeframe). The VIIRS-DNB will be the first nighttime visible-band sensor to provide a calibrated measure of reflected moonlight. In order to calculate the reflectance of a scene (cloud or surface), one must know the magnitude of down-welling incoming light. Reflectance properties may then be related to physical/optical properties of the media. The highly variable nature of moonlight as a function of the sun/earth/moon geometry (e.g., changes in lunar phase, variable earth/sun and earth/moon distances due to elliptical orbits, etc.) make specification of the down-welling radiation challenging. This work provides developers with a tool for specifying this quantity as a function of date and time. The data are provided at 1-nanonmeter spectral resolution to accommodate convolution with various sensor response functions (SRF). This convolution has been done for the specific SRF of the VIIRS-DNB.

Cindy Combs assisted in developing interpolation codes necessary to convert the standard-geometry lunar irradiance results into current-geometry results (as a function of date/time) using time-dependent scaling factors. Redundant codes were written in IDL and FORTRAN-90. In the coming months she will assist in the assessment of moonlight availability for the NPOESS orbits.

Submitted lunar spectral irradiance paper to IEEE-TGRS in March. The paper will include supplemental materials allowing for the research community to work with an approximate (interpolated from standard geometry) solution to the down-welling lunar irradiance (spectral, or convolved with the VIIRS-DNB SRF).

Travel

Steve Miller and Curtis Seaman traveled to New Orleans, Louisiana, January 20-24. Yoo-Jeong Noh traveled January 21-24 (travel funded by the CIRA postdoc project).

Yoo-Jeong Noh traveled to Steamboat Springs, Colorado, March 31 - April 3.

Technology transfer

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

Dr. Noh presented “Snowfall observation and retrieval using passive/active microwave data” at the request of conference organizers of the 2nd International Workshop on Space-Based Snowfall Measurements, held in Steamboat Springs, March 31 through April 4.

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
There was no reportable research activity during this quarter. Most work involved travel and related presentations and publications.

Dr. Steven Fletcher
Worked on the preconditioner for the WRF-VAR system at NCAR in collaboration with Dale Barker, Thomas Auligne and Rizvi Syed. We have recently been working on the possibility of using the preconditioner at ECMWF which is also an EOF-based system, along with the conjugate gradient optimization scheme which is used in both institutions.

Worked also on the hybrid lognormal – normal 4D VAR system with a publication under second review at the Quarterly Journal of the Royal Meteorological Society. As part of this work, I have been deriving the adjoint equations for the Lorenz 1963 system of non-linear differential equations to eventually implement the hybrid system to demonstrate the positive impact this new approach has.

Curtis Seaman
Continues to make progress on the PhD dissertation research and performed the following assimilation experiments:

- GOES Sounder channels 7 & 11 for one observation time (45 min assimilation period). Results from this experiment were shown at the American Meteorological Society Annual Meeting in New Orleans, LA (detailed below).
- GOES Imager channels 3 & 4 for one observation time (45 min assimilation period).

Results from these experiments have been far from producing the correct cloud (i.e. mid-level altocumulus cloud from the 2 Nov 2001 case study of CLEX-9). Both cases produce surface fog and an extremely dry mid-troposphere. Reasons for this are still being explored.

Numerous bugs were cleared out of the RAMDAS code to allow for assimilation of GOES Imager data, as the default set-up of the code is for Sounder data only. Tests are currently being performed to see if the code can handle both Imager and Sounder data assimilated at the same time.

Previous researchers have played around with surface skin temperature debiasing in RAMDAS. Some of the attempts to remove bias have proved fatal to the system; others have proved necessary for the system to minimize. The surface temperature clearly has a large impact on the quality of the assimilation in the cases where “atmospheric window” channels are used.

Numerous attempts have been made to perform a 45 min assimilation using three Imager observations (15 min apart). In this case, it appears as though the minimization produces an unphysical solution causing RAMS to fail. Reasons for this are also being explored.

Travel

Andy Jones and Curtis Seaman traveled to New Orleans, LA January 20-24 for the AMS Annual Meeting.

Andy Jones traveled to Camp Springs, MD February 25-27 for the Satellite Algorithm Testbed Workshop, and to Adelphi, MD March 25-27 for the WIDA Workshop at ARL.

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

The subaward with the University of Colorado to add the ongoing acoustic effort of Dr. Vladimir Ostashev officially began January 1. Masters candidate (Tom Vonder Haar, adviser) Jason (Brant) Dodson began working on CG/AR half-time in January, as a hourly research assistant.

Research activity and/or results

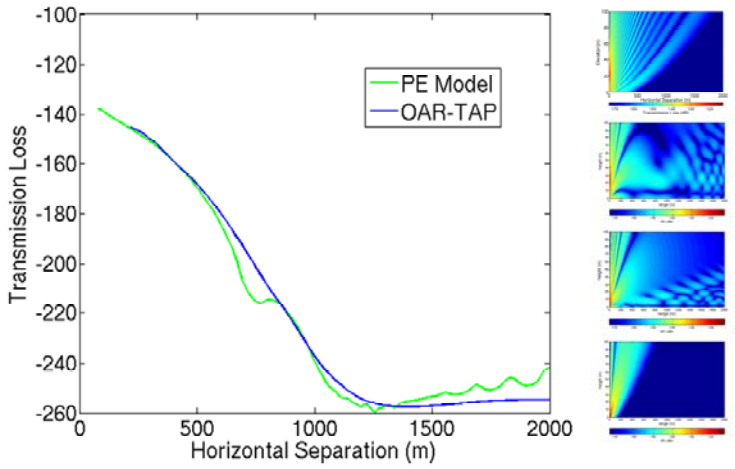
Dr. Stanley Kidder
Continued work to develop satellite products for the battlespace; the main focus is in validating cloud products using CloudSat and CALIPSO data. started analyzing GEOPROF-LIDAR product, which combines CloudSat and CALIPSO data in an algorithm from Jay Mace and Qiuqing Zhang of the University of Utah. The algorithm produces the geometric top and bottom of up to five layers of clouds. These data were combined with the ECMWF-AUX product and the MODIS-AUX product to yield a one-month (July 2006) data set with the following parameters for each CloudSat ray:

1. The date and time of the observation (Date_Time)
2. Latitude of the observation (Latitude)
3. Longitude of the observation (Longitude)
4. Surface elevation at the location of the observation (DEM_elevation)
5. The number of cloud layers (CloudLayers, 0-5)
6. Quality flags (Data_quality)
7. Height of the base of each layer (LayerBase)
8. Height of the top of each layer (LayerTop)
9. Information flags at cloud base (FlagBase)
10. Information flags at cloud top (FlagTop)
11. Surface pressure at each observation (Surface_pressure, from ECMWF field)
12. Skin temperature at each observation (Skin_temperature, from ECMWF field)
13. Temperature at 2 m (Temperature_2m, from ECMWF field)
14. Temperature at cloud base (T_Base, interpolated from ECMWF data)
15. Temperature at cloud top (T_Top, interpolated from ECMWF data)
16. Pressure at cloud base (P_Base, interpolated from ECMWF data)
17. Pressure at cloud top (P_Top, interpolated from ECMWF data)
18. MODIS Cloud Mask (Cloud_Mask)
19. MODIS 3.7 μm brightness temperature (BTM12)
20. MODIS 8.5 μm brightness temperature (BTM14)
21. MODIS 10.7 μm brightness temperature (BTM15)
22. MODIS 12.0 μm brightness temperature (BTM16)
23. MODIS 0.41 μm reflectance (RefM1)
24. MODIS 0.67 μm reflectance (RefM5)
25. MODIS 1.38 μm reflectance (RefM9)
26. MODIS 1.6 μm reflectance (RefM10)
27. Solar zenith angle (Solar_zenith)

Near Real-Time Atmospheric Acoustic Transmission Loss Prediction

RESEARCH QUESTION/OBJECTIVE

- **Goal: Accurately and quickly (near real-time) predict transmission loss (TL) in different atmospheric, environmental and operational conditions.**
- **Ability is key to providing *real-time battlefield awareness* of the acoustic environment.**
- **Must be accurate for a wide range of conditions.**



RESEARCH APPROACH/METHOD

- **A bank of operationally adaptive (OA) and environmentally adaptive (EA) predictors along with a performance-aware fusion system to approximate the PE Model.**
- **Develop learning methods that exploit mutual information between the desired PE model and actual predictor outputs.**
- **Wavelet-Based multi-resolution function approximation.**

RESEARCH STATUS

- **New information theoretic performance measure proposed.**
- **The system is being redeveloped for a wider range of atmospheric, environmental, and operational conditions.**
- **Two TL prediction systems have been developed:**
  - **EAR-TAP**
  - **OAR-TAP – Expanded range of operation.**

28. Solar azimuth angle (Solar_azimuth)
29. Sensor zenith angle (Sensor_zenith)
30. Sensor azimuth angle (Sensor_azimuth)
31. VIIRS Cloud Phase (CP)

These data will be compared with other cloud products, specifically International Satellite Cloud Climatology (ISCCP) products and Middle East products constructed at CG/AR from Meteosat Second Generation data.

Brant Dodson and John Forsythe
Began investigation of relationship of cloud vertical structure to total precipitable water (TPW) anomalies. Hypothesis is that understanding the amount of integrated moisture in the atmosphere and whether it is extremely dry or wet will be a strong predictor of cloud occurrence and in particular cloud base, number of layers, and total thickness. These cloud properties have high impact on DoD operations but are traditionally very difficult to obtain via satellite measurements in data-denied regions. The TPW anomaly was generated at CIRA for NOAA, a near-real time display of the CONUS is available at http://amsu.cira.colostate.edu/gpstpw. In this study, the 6-hourly anomaly product for January – April, 2007 is being compared to the CloudSat/CALIPSO cloud mask products. Initial results indicate a strong relationship between positive TPW anomalies and cloud vertical structure. In dry conditions, the relationship is still under study and is less clear. A challenge is understanding the error in CloudSat/CALIPSO cloud retrievals in the lowest 1.2 km near the surface, where surface reflection makes the interpretation of the radar/lidar data problematical.

This research is focusing on several regions (North Atlantic, North Pacific, Tropical Pacific) to test the hypothesis that the TPW anomaly is meaningful and has cloud signatures which will improve analysis of cloud base. This is a new approach not yet explored for cloud base analysis. John Forsythe is supervising/mentoring on this exploratory study.

Prof. Mahmood R. Azimi-Sadjadi, Michael McCarron and Jon Fidrych
OAR-TAP/EAR-TAP
Determined that the synthetic PE model data set, consisting of samples with the source restricted to be near the ground, being generated for the retraining of the EAR-TAP system was corrupted. The version of the PE model used to generate this data set was incompatible with the version used to generate the PE model data from which the OAR-TAP system was developed, resulting in two data sets that describe different processes, which prevents any EAR-TAP system developed with this data set from being combined with the OAR-TAP system to create a combined OAR-TAP/EAR-TAP system. The EAR-TAP system needs to be retrained since it was trained on PE model samples without a moving average filter applied across horizontal separation, while the OAR-TAP system's data had a moving average filter applied to it. To remedy the situation, the synthetic PE model data set consisting of samples with the source restricted to be near the ground along with a moving average filter, is being regenerated with the correct version of the PE model. Currently 200,000 samples have been generated, and an adequate number to retrain the EAR-TAP system (~275,000 samples) will be completed in one week.

The OAR-TAP TL prediction system has been packed and is ready for transition to the ARL. Upon retraining the EAR-TAP system, it will be incorporated into the combined OAR-TAP/EAR-TAP TL prediction system, and prepared for transition to the ARL.

Single-scale and Multi-scale Wavelet Based Neural Network TL Prediction System

The Levenberg-Marquardt algorithm was incorporated into the training of the single-scale wavelet neural network. A performance plot which shows the performance of the network on the training set vs. epoch during the training process can be seen in Figure 1. This plot shows that the network is successful in reducing error significantly in the first few epochs, but is unable to capture the fine details of the training data, resulting in sub-par performance of the trained network (18.9 RMS error on the training set, corresponding to the .06 Performance at epoch 101). Since the training method used to train this system is known to be accurate and has been successfully applied to problems of this type, it must be concluded that the approximation ability of a neural network using radially extended single-scale wavelets as activation function is not accurate enough to build an acceptable approximation to the PE model, and thus doesn't warrant further efforts.

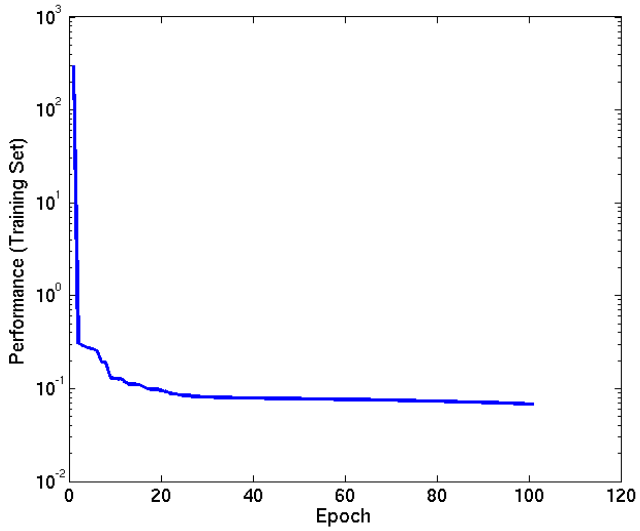


Figure 1. Performance of the single-scale wavelet neural network on the training set during training.

The Back-propagation algorithm was integrated into the training algorithm of the multi-scale wavelet based TL predictor to calculate the gradient of the predictors output with respect to the parameters of the network. This improved the computation time required for each epoch during training over calculating the gradient directly, which requires more computation and more memory. While the time between training epochs was reduced the performance of the network does not improve significantly over a reasonable amount of epochs. This suggests that a problem exists with the design of the network or the training process that causes slow convergence and is currently being researched.

Mutual Information Performance Measures

Mutual information between two random variables can be written as the sum of the differential entropy of each random variable minus their joint differential entropy. Training a neural network can be viewed as maximizing the mutual information between two random variables that represent the network's output and the desired output. To estimate the mutual information between these two random variables the distribution of each along with their joint distribution is required. The probability density function for each distribution needs to be estimated from samples of the distributions which are generated by simulating the neural network on the training data set. One method to estimate these density functions from samples is the Parzen windowing. Using this method each evaluation of the resulting density estimation requires $O(N)$ operations (N is the number of training samples), resulting in each neural network training epoch requiring $O(N^2)$ operations for each distribution, which is impractical for this problem (N is ~100,000 in our case).

The method currently being used to develop a computationally tractable mutual information performance measure utilizes the multidimensional Edgeworth series expansion. This expansion allows the density functions required to be expressed in terms of cumulants, which are easy to compute quickly from samples. It is hoped that this mutual information measure will help the neural networks to more accurately capture the PE model mapping than MSE alone currently does.

Dr. Vladimir Ostashev
Localization of sound sources on the ground from an acoustic sensor array elevated on a tethered aerostat was considered. To improve estimation of the source coordinates, refraction of sound rays due to atmospheric stratification was taken into account. Using a geometrical acoustics approximation for a stratified moving medium, formulas for the source coordinates were derived that account for sound refraction. The source coordinates were expressed in terms of the direction of sound propagation as measured by the sensor array, its coordinates, and the vertical profiles of temperature and wind velocity. Employing these formulas and typical temperature and wind velocity profiles in the atmosphere, it was shown numerically that sound refraction is important for accurate predictions of the source coordinates.

The results obtained were summarized in a paper submitted to the refereed Journal of the Acoustical Society of America.

Travel

Brant Dodson traveled to New Orleans, LA, January 19-25 to participate in the AMS Student Conference, Annual Meeting, and associated science conferences.

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

Several papers reporting on CG/AR-related research were presented at the AMS Annual Meeting and associated conferences, held New Orleans in January. This forum provides one of the best opportunities for sharing current CG/AR research with the scientific community and it provides our researchers and graduate students with an excellent for important interactions with DoD lab and other science colleagues.

CG/AR again had a strong representation at the AGU Hydrology Days, held at Colorado State every year. In conjunction with that meeting, a science colloquium was also held, at which Prof. Julien's graduates students were able to showcase their research. Posters presented at the Global Water Colloquium, Hilton Hotel, Fort Collins, Colorado, March 25:

Halgren, J., S. Shah-Fairbank, P.Y. Julien, M. Velleux, and J. England, *Hydrology, Sediment and Contaminant Modeling.*

Shah-Fairbank, S., P.Y. Julien, and M. Remillard, Hydraulic Modeling Analysis of the Middle Rio Grande 1918-2002, Galisteo Reach, Galisteo Creek to Arroyo Tonque, New Mexico.

Presentations made at the 28th AGU Hydrology Days, Colorado State University, Fort Collins, Colorado, March 26-28:

Halgren, J., P. Julien, and M. Velleux, *Improved Graphical Representation of CASC2D-TREX Results (presentation).*

Jones, A.S., T. Lakhankar, C. Combs, S. Longmore, G. Mason, G. McWilliams, M. Sengupta, and T.H. Vonder Haar, *An NPOESS feasibility study to retrieve deep soil moisture using a temporal variational data assimilation method and WindSat data (poster).*

Lakhankar, T., A.S. Jones, T.H. Vonder Haar, *Variational data assimilation method for soil moisture estimation using active microwave data (poster).*

Lakhankar, T., A.S. Jones, C. Combs, M. Sengupta, T.H. Vonder Haar, *Geostatistical method for analysis of large scale spatial variability of soil moisture (presentation and poster).*

Shah-Fairbank, S., P.Y. Julien, and J. Guo, *Applicability of the Modified Einstein Procedure (presentation).*

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
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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 299 publications including 78 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).

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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).

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