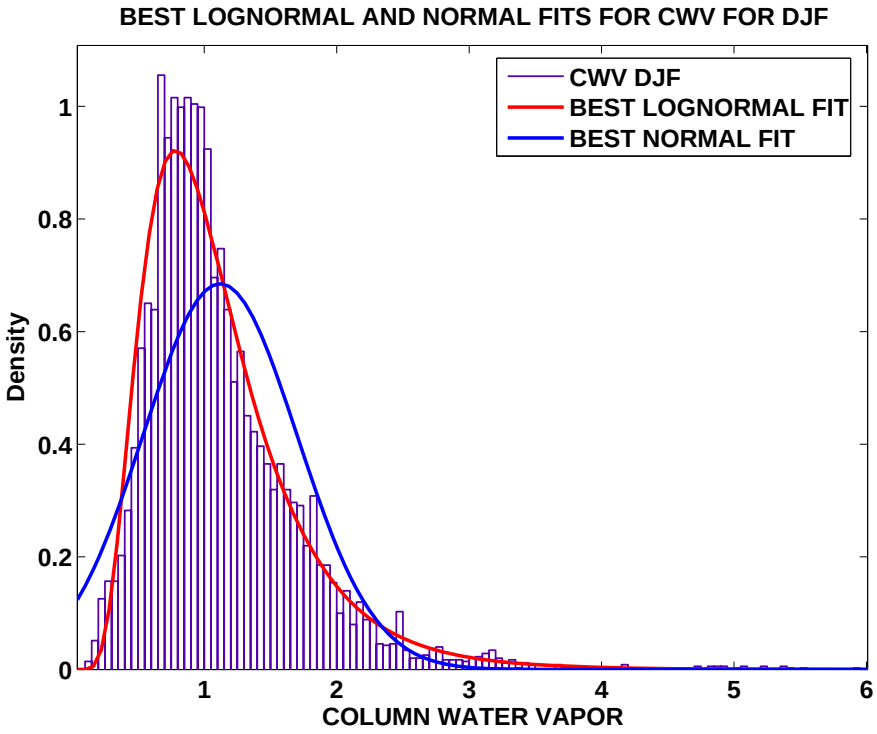
Colorado State University
Center for Geosciences/Atmospheric Research (CG/AR)
Quarterly Report No. 9
by T.H. Vonder Haar and Collaborators

Reporting period: April 1 – June 30, 2008

Cooperative Agreement #W911NF-06-2-0015



Observational results from the ARM site column water vapor in the winter months (DJF) for 1997-2000, when a status cloud was present in the observations. These results demonstrate the lognormal nature of many hydrometeorological variables, and why the extension of our data assimilation techniques to "real" non-Gaussian distributions is essential for future operational performance improvements for variables of high DoD interest (such as water vapor and clouds).

From the work of Dr. Steven Fletcher, in the Environmental Modeling and Assimilation research theme.

Overview

This performance period marked a transition period at CG/AR with new projects restarting after funding interruptions in the previous year. Several projects were restarted, but overall activity levels were reduced from nominal levels. With the new year's funding in hand, progress was made on several fronts, including the Clouds, Icing, and Aerosols Effects, Environmental Modeling and Assimilation, and Remote Sensing of Battlespace Parameters theme areas; the other theme areas were more quiescent during this period.

In the Clouds theme area, Dr. Noh emphasized data exploitation of the Canadian/CloudSat/CALIPSO Validation Project and the 10th Cloud Layer Experiment (C3VP/CLEX-10) data sets over southern Ontario. This included unique aircraft measurements such as the airborne radar data (35 GHz) and more detailed cloud layer information from CloudSat in conjunction with the CALIPSO data sets. The emphasis is on mixed-phase cloud cases with supercooled liquid water near cloud top. These clouds are aviation hazards, and the research toward understanding and remotely estimating their properties is a goal of Dr. Noh's work. Ms. Combs and Dr. Miller began new work on the VIIRS Day/Night spectral response at night using specialized satellite navigation and viewing geometry software from the U.S. Naval Observatory. The goal of that work is a quantitative exploitation of the new night time capabilities of the NPOESS VIIRS sensor for low light (lunar illuminated) conditions on the battlefield.

Dr. Fletcher made significant progress on extending his non-Gaussian DA theories to 4DVAR methods. His emphasis at this time is a Hybrid approach that can intermix normal variables with other probability distributed variables such as lognormal variables. New data analysis is showing that many cloud variables have lognormal statistical properties. Dr. Fletcher's new methodology treats these variables in a way that prevents statistical artifacts from distorting the performance of our operational data assimilation systems which currently rely on variable transform methods to approximate this solution. This work is foundational to addressing the non-Gaussian variable problem from a more robust theoretical perspective.

Dr. Azimi's group made generalization improvements to the Operationally Adaptive TL Prediction System (OAR-TAP). The software was delivered to ARL. They continued to develop an information theoretic performance measure, whose goal is to allow neural networks to be trained so that the mutual information between the network's output and desired value generated by the model can be maximized. Dr. Ostashev continued work developing an algorithm for estimation of source coordinates taking into account the atmospheric refraction of sound waves due to atmospheric profile structure. He has also started to study the effects of atmospheric turbulence, and a variety of error sources in the ability to accurately determine the source coordinates. Both activities have obvious implications toward more accurate and computational efficient sound propagation effects for military use.

Dr. Andrew Jones
Deputy Recipient Program Manager

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)
- CG/AR researchers and graduate students with James Cogan (ARL/WSMR)
- Steve Miller and Andy Jones with Michael Wynne (Secretary of the Air Force

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
Pradeep Srinivasa, a graduate student recommended by CSU Computer Science Professor Sanjay Rajopadhye, was partially supported by CG/AR during the summer to work on parallelizing the TREX code.

James Halgren and Seema Shah-Fairbank remain actively associated with CG/AR, although currently funded on other projects in their department. A brief research summary was presented during the informal CG/AR Research Progress Meeting held on June 12. Their research progress is summarized below:

Seema is currently preparing her final draft of her dissertation. She has been performing a detailed analysis of the Modified Einstein Procedure (MEP) for calculating total sediment load. She has developed a procedure which simplifies the total load calculation based on data measured using a depth-integrated sampler and extrapolating to determine the unmeasured load. Her procedure has been validated using data from various streams and rivers within the United States where total load is calculated using a depth integrated sampler and Helley Smith bedload sampler. Her study shows that the simplified MEP will be applicable in sand bed rivers with a u^*/ω (shear velocity/fall velocity) is greater than 5. In addition, when compared to previous MEP programs the accuracy has increased. Finally, as river depth increases less flow depth needs to be measured to show good relationship between the measured data set and the theoretical results.

James continues to develop a sub-surface flow algorithm for long-term simulation with the CASC2D-TREX model. He is working on preparing his research proposal including preliminary research results.

Pierre, James and Pradeep met with Jim Cogan during his CSU visit in June to discuss future directions for the modeling research at CSU; several potential applications and collaboration opportunities were identified.

Travel

None this period.

Technology transfer

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

Equipment/systems status

The programming workstation in the Julien group required replacement of its power supply and is now operational.

Research Theme: Clouds, Icing, and Aerosols Effects

Administrative

None this period.

Research activity and/or results

Yoo-Jeong Noh

Wintertime midlevel mixed-phase clouds

- 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 (Version 2 aircraft 1D data released in March) during the C3VP/CLEX10 field experiment, the detailed structures of midlevel mixed-phase clouds have been analyzed including vertical distributions of ice/ liquid and temperatures, and particle sizes. Also, we started to analyze airborne radar data (35 GHz) that arrived at CIRA at the end of May, together with CloudSat data in order to detect more detailed cloud layers.

- SBDART model sensitivity tests under various mixed-phase cloud conditions

For mixed-phase cloud cases with supercooled liquid water near cloud top (temperatures <~ -20°C), Dr. Steven Miller and I have worked on testing an ability to detect mixed-phase cloud conditions of Near-IR channels under various solar/satellite geometry and cloud conditions by using SBDART (Santa Barbara DISORT Atmospheric Radiative Transfer, Ricchiazzi et al. (1998)) model. Our goal is to make a mixed phase cloud database (or lookup table) of reflectance ratios at Near-IR (currently focusing on 1.62 and 2.25μm that are GOES-R ABI channels), based on different radiative characteristics of liquid and ice particles at different wavelengths. Simulated results have been analyzed for varying surfaces, atmospheric soundings, aerosol models, solar/sensor zenith angles, and azimuth angles as well as different cloud layer inputs such as various optical thicknesses of liquid/ice and particle sizes.

Analysis of snow clouds

- Build the *a-priori* database of clouds over the Great Lakes region in developing a Bayesian snowfall retrieval algorithm.

We are working on building the *a-priori* database using MWRT3 (a microwave radiative transfer model, Liu (2004) and Noh et al. (2006)) simulations with inputs from CloudSat data, NEXRAD radar data, and aircraft measurements during C3VP/CLEX10. Simulations of brightness temperatures using snowfall profiles from CloudSat were completed and are ongoing for NEXRAD snowfall profiles.

Curtis Seaman

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

Dr. Steven Miller and Cynthia Combs
With the assistance of CDR John Fergurson (NOAA Environmental Satellite Program Executive Office) we have obtained two-line-elements (satellite ephemeris) predicted for the NPOESS constellation (0530 local time descending node and 1330 local time ascending node). With the assistance of orbital prediction software from Dr. Stan Kidder, we have begun running multiple months of orbital simulations. The latitude/longitude/time for these simulations is used as input to a lunar geometry prediction software (Solar/Lunar Almanac Core (SLAC), U.S. Naval Observatory). Dr. John Bangert of the U.S. Naval Observatory provided updated SLAC software (version 1.1.2), allowing us to run the simulations during the timeframe of NPOESS and up to the year 2050. These simulations will be used to conduct a study on 'lunar availability' during nighttime passes of the NPOESS constellation as a function of latitude, season, and particular NPOESS orbit. Also considered will be the removal of the 0930/2130 orbit. The European MetOp satellite will provide coverage in this orbit, but does not include the Day/Night Band required for nighttime low-light applications. This will result in a mid-evening gap in temporal coverage. The purpose of this paper is to quantify both the available coverage and the lost coverage due to the NPOESS program re-structure.

Provided VIIRS Day/Night Band spectral response function to Cristian Mitrescu (PI of NightApps on the NRL side) in preparation for radiative transfer look-up table generation. A nighttime cloud mask, classification, and property retrieval capability will be enabled via the quantified lunar spectral irradiance data being produced in this project. The look-up tables predict multi-spectral cloud reflectance for the specific band-pass of the Day/Night Band. These values will be compared against actual reflectance to relate measurements to optical properties. For nighttime retrievals, the measured upwelling irradiance (assumed isotropic) must be normalized by the cosine (zenith angle) weighted downwelling lunar irradiance. The theoretical paper mentioned in item (1) above provides the basic downwelling lunar irradiance information required to do this calculation.

Participated in the 1-day informal CG/AR research progress meeting held in June.

Travel

As reported in the January-March report, Yoo-Jeong Noh traveled to Steamboat Springs, Colorado, March 31 - April 3.

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
Contacted Pam Clark and Mr. Bob Dumais (ARL) regarding Army data assimilation research needs. Also invited Mr. John Eylander (AFWA) to Fort Collins for additional discussions. Additional collaboration meetings with ARL and AFWA are scheduled for August.

Presented a CG/AR overview to Secretary of the Air Force Wynne, who visited CSU on May 29.

Dr. Steven Fletcher
Discussed their respective preconditioners with Mr. Mike Fisher at the European Center for Medium Range Forecasting and Dr. Tony Weaver at CERFACS in France for use in the WRF-VAR system. Mike Fisher has agreed that the formulation used there could be adapted to the WRF-VAR system which is to be used by the US Air Force.

Worked on a better detail description of the probability model to describe 4 dimensional variational data assimilation. This would then enable us to introduce more cloud and mesoscale observations which do not currently conform to the Gaussian assumption and constraint used in assimilation systems. Worked on code to demonstrate the impacts of this new formulation in a 4D sense with the Lorenz 1963 chaotic model (with a positive definite variable) which has to be assimilated.

Investigating also the impacts if certain forced assumptions are made on lognormal random variables, which some moisture variables in the atmosphere are. The first is the assumption that the difference between two lognormal variables is a lognormal variable. As you can see from Figre 1, this is not true but is used quite oftern in assimilation systems. The second assumption been investigated – with the help of Dr. Manajit Sengupta, using ARM data collected over 4 year in Oklahoma when stratus clouds were present in the observations – is to do with the force Gaussian assumption. Using the associated column water vapor for the situation described above, when seasonally adjusted, was better described by a lognormal distribution than a Gaussian. This is an important variable which needs to be assimilated correctly if it is to be used in cloud prediction (see Figure 2).

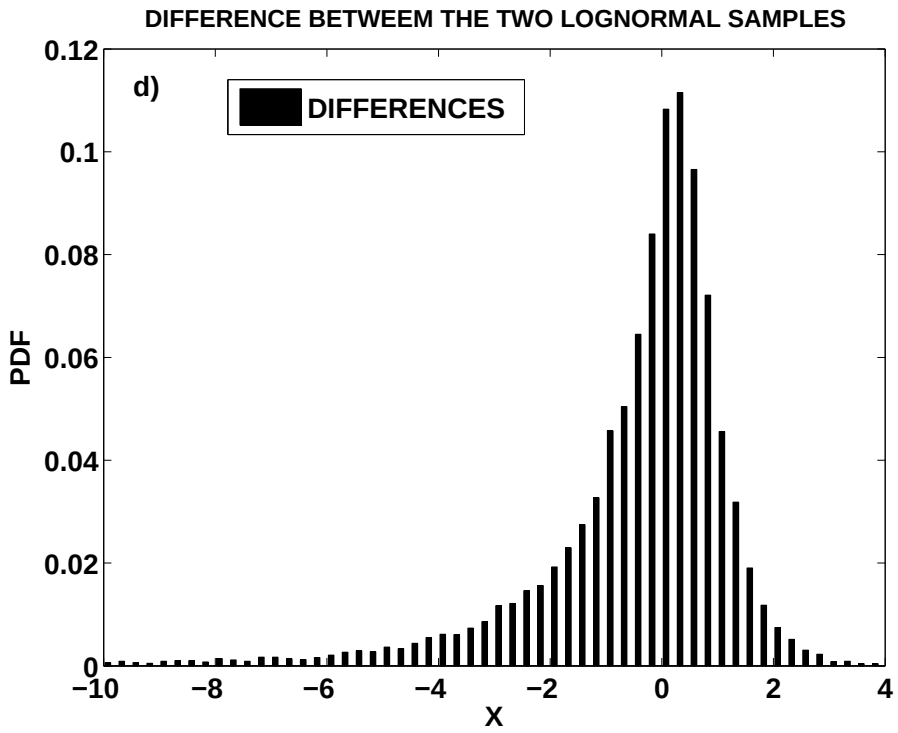


Figure 1. Plot of the difference between two random lognormal samples, with sample size of 20,000.

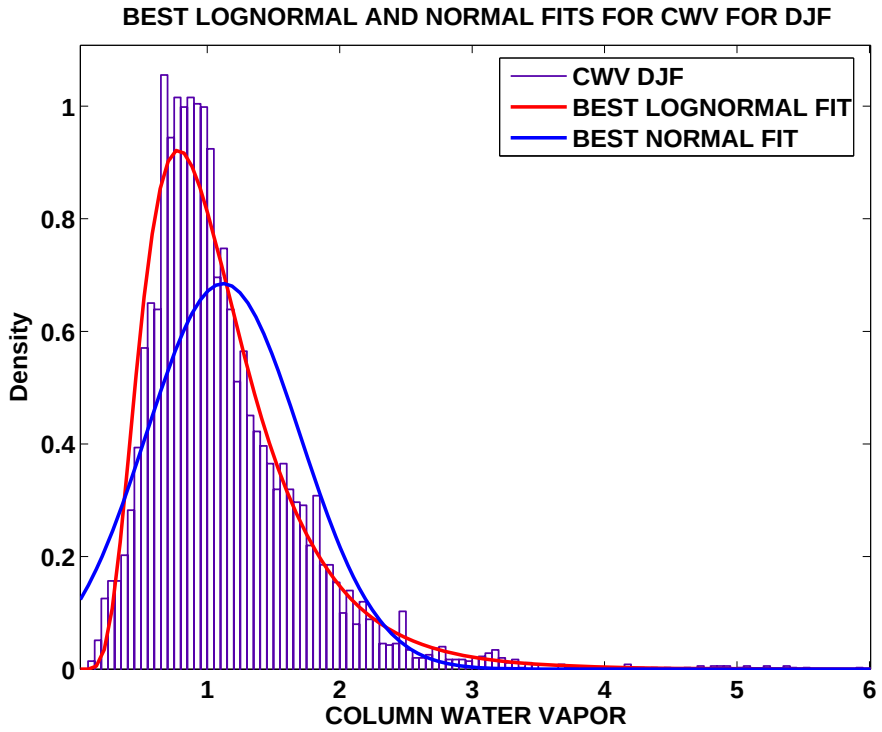


Figure 2. Plot with real data from the ARM site for column water vapor in the months of December, January and February for 1997 – 2000, when a stratus cloud was present in the observations.

Scott Longmore
Provided support to Curtis Seaman in his PhD research activities namely, resolving configuration, running, and visualization issues with RAMDAS.

Participated in the WRF Users' Workshop, held in Boulder, Colorado.

Curtis Seaman
In addition to the assimilation runs performed last quarter of the 2 November 2001 case from CLEX-9, Curtis has performed an assimilation of the water vapor sensitive channels from GOES Imager (channel 3) and GOES Sounder (channel 11), for a single observation time with 45 min. assimilation window. This is the first completed simultaneous assimilation of both GOES Imager and Sounder data.

Continued to explore assimilation of GOES Imager data with higher temporal resolution (i.e. 45 min. assimilation three observation times), and to adding more water vapor information via GOES Sounder channels 6, 10 and 12. There has been little success as of yet in these areas.

Travel

Scott Longmore commuted from Fort Collins to the WRF Users' Workshop in Boulder, June 23-27.

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

None this period.

Research activity and/or results

Dr. Stanley Kidder
Continued analysis of the GEOPROF-LIDAR product to learn how to use it to develop/validate satellite products for the battlespace.

Prof. Mahmood R. Azimi-Sadjadi, Michael McCarron and Jon Fidrych
Operationally Adaptive TL Prediction System
Generalization Improvement

- An additional Parabolic Equation (PE) model data set was generated to retrain the Environmentally Adaptive system, which contains only samples for near-ground targets (source elevation less than 5m).
  - Since the OAR-TAP system was trained over this region, it should perform well on this new data set. However, it was discovered that the OAR-TAP system did not generalize well to this new data set.
- The source of poor generalization was the validation set, which was being formed in a manner that allowed over-fitting and under-fitting problems to occur.
  - For each sample in the validation set, there was an associated sample in the training set which differed by only horizontal separation parameter (one out of the ten input parameters).
  - This results in the system being fine-tuned to the effects of horizontal separation, hence not generalizing well. At the same time, the other nine dimensions were being neglected, and not fine-tuned enough.
- This was corrected by reforming the validation set. In the new scheme, for each sample in the new validation set, no sample was allowed in the training set that differed only by horizontal separation. This corrected the poor generalization performance.
  - Table 1 shows the performance details of the OAR-TAP system's generalization ability when trained using the old validation set vs. when trained using the updated validation set. The original validation set results in a dramatic increase of error on new data. With the new validation set the error is consistent on new data.

Validation Set	OA Data Set (Only Ground Sources)	New Data Set
Original	5.99dB	7.87dB
Updated	6.98dB	7.02dB

Table 1: Generalization performance in Root-Mean-Square Error (RMSE) of the OAR-TAP system from its data set to a new data set (both only near-ground sources).

Fusion System Improvement

- The function of the fusion system is to take the four preliminary predictions calculated by the OA expert TL predictors, and combine them into a final TL prediction value. This process and the overall structure of the OAR-TAP is seen in Figure 1, which shows the neural network expert predictors, the preliminary predictions, the weighting system, and the fusion center.

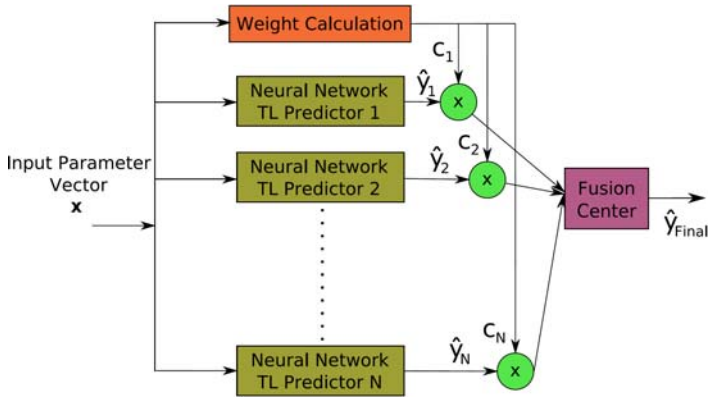


Figure 1: Previous structure of the OAR-TAP system.

  - The performance-aware weighting **(c_1, c_2, …, c_N)** multiplicatively weights each preliminary prediction based on its expected accuracy. This system was removed, instead, feeding the un-weighted preliminary predictions into the fusion neural network along with the entire input parameter vector **x**.
  - The addition of the input parameter vector gives the fusion system more information about the preliminary predictions, resulting in a more accurate fusion. This greatly improves performance of the OAR-TAP. Details of the performance of the updated OAR-TAP are shown in Table 2.

Fusion Type	RMS Error (dB)
PA-Weighting	4.57
Composite Input	3.22

Table 2: Performance of the OAR-TAP system with performance-aware (PA) vs. new composite input.

<u>Environmentally Adaptive TL Prediction System</u>

EAR-TAP Retrained

- The EAR-TAP system was retrained using the newly generated PE model data set consisting of only near-ground sources. The validation set was created using the updated method outlined above.
- Performance of this new EAR-TAP system can be seen in Table 3, which shows the values of RMS error for the latest OAR-TAP system and the newly retrained EAR-TAP system. The OAR-TAP system performs better, however, the EAR-TAP system is using an outdated fuzzy confidence-based fusion system.

System	RMSE (dB)
OAR-TAP	5.2994
EAR-TAP	5.4339

Table 3: Performance of the OAR-TAP and EAR-TAP systems for near-ground sources.

Information Theoretic Performance Measure

Continued Development

- The goal of the information theoretic performance measure is to allow neural networks to be trained so that mutual information between the network's output and the desired value generated by the PE model is maximized.
  - Calculating mutual information requires the joint distribution of the neural network's output and the desired output, which is unknown in general and must be estimated.
  - Previously the Parzen Window nonparametric density estimation method was applied, resulting in a good estimation at the cost of very high computational complexity.
- Using a truncated Edgeworth series expansion of the joint distribution looked promising. However, calculating the terms of the expansion turns out to be difficult.
- A related expansion which is easier to compute, the Gram-Charlier A series, was implemented and tested, instead.
  - Figure 2 shows the histogram of the joint distribution for a trained TL prediction system, and the estimated joint distribution using a truncated Gram-Charlier A series expansion. The series approximation did not fit the distribution well enough to train a neural network successfully.
- The Edgeworth series (asymptotic version of the Gram-C A series), should give a better fit at a lower order. Whether the accuracy will be enough to train a neural network successfully remains to be determined.

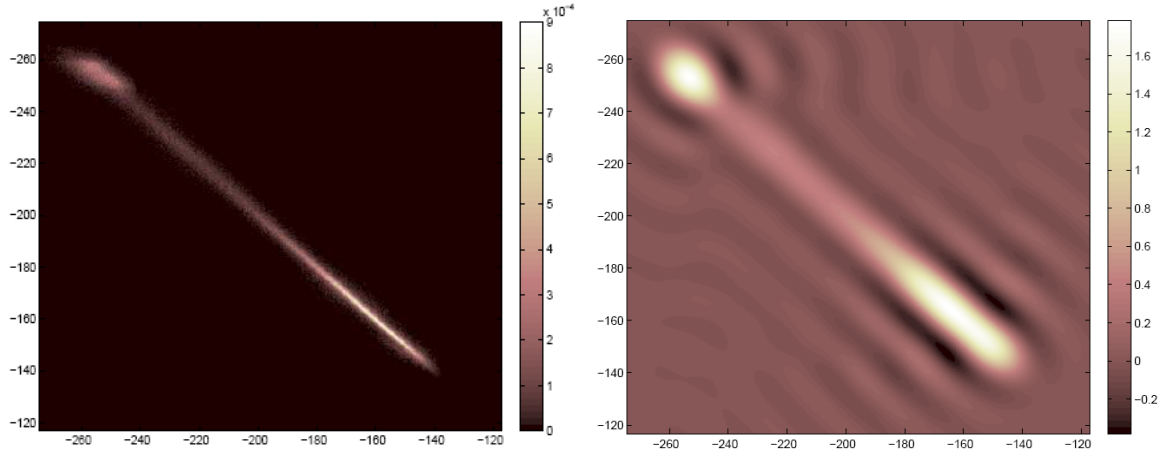


Figure 2: Joint distribution of the TL prediction and desired values: (Left) Histogram (Right) Truncated Gram-Charlier A series estimation (149th Order).

Dr. Vladimir Ostashev
Several factors limit performance of ground-based acoustic sensor arrays for source detection: absorption of sound waves in the ground, irregular terrain, sound reflections by obstacles, formation of an acoustic shadow zone in the upwind direction, and multipath sound propagation. These limitations can be overcome by suspending acoustic sensor arrays below tethered aerostats (stationary balloons). An algorithm was developed for estimation of the source coordinates which takes into account refraction of sound waves due to atmospheric stratification. In the algorithm, the source coordinates are expressed in terms of the direction of sound propagation as measured by the elevated sensor array, its coordinates, and the vertical profiles (or integrated vertical profiles) of temperature and wind velocity in the atmosphere. Using this algorithm and typical profiles of temperature and wind velocity, it is shown that sound refraction is important for accurate predictions of the source coordinates. Furthermore, two remote sensing techniques for determining the integrated vertical profiles of temperature and wind velocity were proposed.

Besides sound refraction, other factors interfere with accurate determination of the source coordinates: sound scattering by atmospheric turbulence, errors in determining the direction of signal propagation at the sensor array, and the uncertainties in the array coordinates and the vertical profiles of temperature and wind velocity. We have started to study the effects of some of these factors on determination of the source coordinates.

The results obtained were summarized in two abstracts submitted to meetings scheduled later in the year.

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

Dr. Noh presented "Snowfall observation and retrieval using passive/active microwave data" on Tuesday, April 1, at the request of conference organizers of the 2nd International Workshop on Space-Based Snowfall Measurements, held in Steamboat Springs, Colorado. (There are no official proceedings for this meeting.)

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
Fidrych	Jonathan	Electrical & Computer Engr	jonmfid@goku.engr.colostate.edu	Advanced Neural Net Processing of Acoustic Data	Azimi	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 & Computer 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 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)**.**

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).

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