Colorado State University
Center for Geosciences/Atmospheric Research (CG/AR)
Quarterly Report No. 10
by T.H. Vonder Haar and Collaborators

Reporting period: July 1 – September 30, 2008

Cooperative Agreement #W911NF-06-2-0015

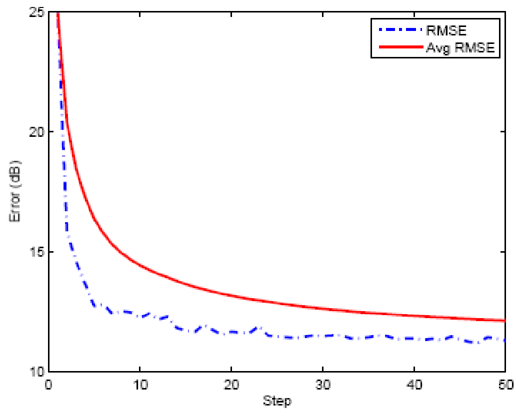


Figure 1: RMSE of Wavelet Network with 20 Neurons

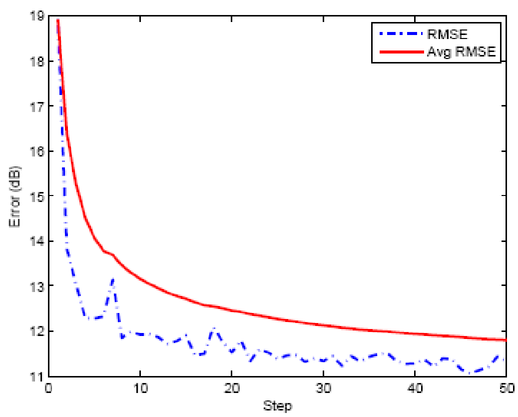


Figure 2: RMSE of Wavelet Network with 50 Neurons

Figures depicting the training curves that illustrate the leveling off of the error as the number of iteration cycles increase, from the research of Prof. Azimi and his graduates students. See the Remote Sensing of Battlespace Parameters research theme for the full discussion.

Overview

Four new masters students came onboard and did some early summer work before starting their first academic semesters in mid-August. One new student under the advisement of Prof. Cotton and three students under the advisement of Prof. Vonder Haar. Several visitors to CG/AR were hosted or met by Dr. Andy Jones during this period.

Hydrometeorology – Andy Jones began activities related to support for the NPOESS MIS Performance Team (MPT) land team. This involves significant coordination between the Army Research Laboratory, the Navy Research Lab, and the US Army Corps of Engineers. Additionally, a Computer Science graduate student did some work during the summer on improving the performance of the TREX model. That work resulted in significant optimization improvements to the TREX model performance.

Clouds, Icing, and Aerosols Effects – Yoo-Jeong Noh analyzed aircraft measurements from the Canadian CloudSat/CALIPSO Validation Project and the 10th Cloud Layer Experiment (C3VP/CLEX-10) over southern Ontario to investigate the characteristics of wintertime midlevel mixed-phase clouds. In collaboration with Dr. Steve Miller, a database of reflectance ratios in the near-IR channels was created using a radiative transfer model. That database information will be used to improve detection of mixed-phase clouds. Dr. Noh also participated in the Precipitation Detection Working Group meeting of the 2008 Precipitation Measurement Mission (PMM) Science Team Meeting. This meeting was held at Fort Collins, CO, August 4-7. Dr. Noh also participated in a NOAA/NESDIS Science Symposium, hosted by Oregon State University, Aug. 12-13. In addition, Dr. Miller and Ms. Combs used a solar-lunar illuminance model to create data sets to assist in the quantitative use of the NPOESS VIIRS day/night capabilities. This data set included an orbital analysis of the future NPP VIIRS sensor at three potential time slots (530, 930, 1330).

Environmental Modeling and Assimilation - Dr. Cotton's aerosol/cloud interaction project began with a new masters student, Geoffrey Krall, starting this fall semester. His work will focus on the western Pacific typhoons that can be impacted by dust aerosols originating from China. Curtis Seaman continued his 4DVAR RAMDAS experiments for his PhD advanced data assimilation research objectives. The MLEF-WRF system was interfaced to the NCEP observational operator. Dr. Fletcher worked on the implementation of the 4-DVAR hybrid lognormal-normal statistics using the Lorenz 1963 model. The outcome of that work is to demonstrate that the moisture variables in cloud resolving data assimilation are incorrect, and that theoretical bias adjustments can improve the subsequent data assimilation analysis. Scott Longmore also began activities to expand the CG/AR data assimilation work to the NCEP Grid point Statistical Interpolarion (GSI) interfaces, and the Earth Systems Modeling Framework (ESMF). This will facilitate our research interactions with future planned changes to the USAF/Army WRF-Var system.

Remote Sensing of Battlespace Parameters – Three new masters students started in the Dept. of Atmos. Science under Prof. Vonder Haar. Dr. Stan Kidder is mentoring Kelly Howell, Mr. John Forsythe is mentoring Eric Guillot, and Dr. Steve Miller is mentoring Jessica Ram. A new research effort was started to exploit the CloudSat statistics into 2D spatial space. This will allow for the CloudSat vertical behaviors to be extrapolated into unobserved locations, thus enhancing the knowledge of cloud structures over a wider region of space than CloudSat can do directly. This work also has potential application for use within our data assimilation research activities, by providing for customized spatial statistical cloud behaviors – resulting in more realistic cloud statistical constraints.

Prof. Azimi's research group began a new acoustic transmission loss (TL) prediction system. A variety of methods are being intercompared to determine their performance characteristics. Dr. Ostashev developed an algorithm for estimation of acoustic source coordinates using aerostat-based measurements. Boundary layer interactions with the acoustic propagation is accounted for within the methodology. Two remote sensing techniques for determining integrated vertical profiles of temperature and wind velocity were proposed.

Dr. Fletcher presented a video-teleconference seminar to our DoD laboratory partners on Sep. 16 entitled "Advances in Data Assimilation". In this seminar, Dr. Fletcher presented the non-Gaussian framework, and its impact to current operational data assimilation systems. Methods for extending and customizing that method to future DoD data assimilation systems and DoD-unique variable probability distributions was also discussed.

Dr. Andrew S. 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)
- Andy Jones with Gary McWilliams (ARL)
- Andy Jones with Dr. Ye Hong (Aerospace)
- Andy Jones with Mr. John Eylander (AFWA)
- Andy Jones with Dr. White (NOAA/ESRL)
- Andy Jones and Steven Fletcher with Bob Dumais (ARL)

Research Theme: Hydrometeorology

Administrative

None this period.

Research activity and/or results

Dr. Andrew Jones, Theme Leader
Dr. Jones began activities related to support for the NPOESS MIS Performance Team (MPT) land team. Mr. Gary McWilliams (ARL) is our team lead. Numerous technical meetings and telcons were used to communicate the beginning of the MPT efforts. Creating MIS soil moisture error budget estimates is our current focus. Andy and Scott Longmore began the process of obtaining DoD HPC access for future ARL/AFWA land surface DA research activities.

Visitors hosted: Dr. Ye Hong (Aerospace), August 5 – NPOESS MIS algorithm discussions; Mr. John Eylander (AFWA), August 7 – AFWA land surface DA collaborations; and met with Dr. White (NOAA/ESRL), September 4 – NOAA Hydromet Testbed research activities.

Prof. Pierre Julien, James Halgren, and Seema Shah-Fairbank
Research in improving the performance of the model TREX was carried out over the summer in collaboration with Prof. Rajopadhye in Computer Sciences. His student Pradeep Srinavasa (funded by CG/AR) worked on finding stencil kernels in the program and translated them into alphabet programs in generated C code for an improvement of model performance. The results of this work has been a 34% performance gain in the routine "OverlandWaterRoute" and a 21% improvement in the overall running time of the application.

Travel

Andrew Jones traveled September 8-12 to New York City for soil moisture collaboration meetings at CUNY/NOAA-CREST.

Technology transfer

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

Equipment/systems status

Andy's laptop computer had a hardware failure and was replaced with a desktop system. The CIRA AMSU5 satellite data processing system was removed from the satellite data processing cluster due to hardware instabilities.

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 and investigate the characteristics of wintertime midlevel mixed-phase clouds.

Eight mixed-phase cases were selected during C3VP/CLEX10 field experiment based on the flight summary report. For each case, satellite and aircraft data were processed focused on the vertical structure of the clouds and their microphysics. For the aircraft measurements, we have collaborated with David Hudak and Peter Rodriguez of EC (Environment Canada) and continue to analyze the detailed structures of midlevel mixed-phase clouds by utilizing various data sets. The data used in this study and some related issues are as follows:

- o CloudSat (Level 2 CPR reflectivity and Cloud classification data)
- o CALIPSO (Level1 532nm and 1064nm backscatter)
- o MODIS images
- o Aircraft measurements
  - ▪ 1D data (V2 released in March 2008) – Temperatures and LWC/IWC data
  - ▪ 2D probe data (particle size info) and airborne lidar data are still under calibration.
  - ▪ EC folks started to recalibrate airborne radar data (35 GHz) due to the geolocation inconsistency.

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

Regarding icing problems, Dr. Steven Miller and I have worked on building a database of reflectance ratios (currently 1.62 and 2.25μm) in Near-IR channels to detect mixed-phase clouds with supercooled liquid water near cloud top (temperatures <~ -20°C) by using a radiative transfer model, SBDART (Ricchiazzi et al., 1998). The basic structure of the database is completed. Below are the options used in SBDART simulations.

- Idealized two layered clouds (liquid top and ice below)
- Over ocean and vegetation surfaces
- Liquid effective radius: 6, 8, 10, 12, 15, and 20 μm when ice=30 μm
- Ice effective particle size: 30, 50, 70, 100, and 120 μm when liquid=8 μm
- Sensor/Solar zenith angle: 0-80°
- Sensor azimuth angle: 0-170°
- Total optical thickness and liquid optical thickness are varying from 0 to 30.

The important features of the database under various geometry and cloud conditions and the impact of each variable on reflectance ratio have been analyzed. Also, comparisons with pure ice/liquid or ice-topped clouds have been done to clarify the mixed-phase condition with supercooled liquid water by combining different channels.

Dr. Noh joined the precipitation detection working group meeting of the 2008 PMM Science Team Meeting, held in Fort Collins, August 4-7. She also gave a presentation on her work combining satellite and model information for snowfall retrieval at the 5th Annual NESDIS Cooperative Institute CoRP Science Symposium, hosted by Oregon State University, August 12 and 13.

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
Using the previously developed and installed code for Stan Kidder's satellite subpoints, the IDL code for swath locations, the Solar-Lunar Almanac Core (SLAC) model, and the Lunar Irradiance code, produced data sets containing location, time, lunar phase, lunar irradiance, moon phase angle, and the altitude, azimuth, and illuminance for both sun and moon for the year 2011. This information was calculated for every 300 km of the satellite swath at one minute intervals during the orbits for each of three potential NPOESS satellites (530, 930, 1330).

Travel

Dr. Noh traveled to Corvallis, Oregon, August 11-14 to attend the 5th Annual NESDIS Cooperative Institute CoRP Science Symposium (funded by NOAA).

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

A new masters student under Prof. Cotton was accepted into the graduate program in the Department of Atmospheric Science and began working on the project prior to the beginning of the Fall semester.

Research activity and/or results

Dr. Andrew Jones, Theme Leader

Dr. Jones coordinated DA research activities, including support for Curtis Seaman PhD research activities using the 4DVAR RAMDAS system, and planned for future NCAR, ARL, and AFWA DA collaborations through a series of meetings, visits, and presentations. Worked with Steven Fletcher on communicating his new non-Gaussian DA research to our DoD sponsors. Coordinated planning for the CG/AR VTC seminar series. Andy and Adam Carheden began the process of obtaining DOE HPC access for environmental DA research activities.

Met with visitors Drs. Alberta Carrassi and Stephane Annitsem from the Royal Meteorological Institute August 20 and discussed data assimilation error modeling aspects and plans with the future WRF-Var work.

Dr. Milija Zupanski

The MLEF-WRF system was interfaced with the NCEP observation operator, opening the possibility to assimilate operational observations.

The manuscript "Ensemble Data Assimilation with the Weather Research and Forecasting (WRF) Model: The Hurricane Katrina Case" submitted to *Journal of Geophysical Research* was revised during this period.

Dr. Steven Fletcher

Worked on the implementation of the four dimensional variational system with hybrid lognormal-normal statistics into the Lorenz 1963 model. It is from these results that we can demonstrate that the impact of transforming a non-Gaussian variable into a lognormal variables results in a bias and we shall see how this bias is propagated in the model. The outcome from this work is to demonstrate that the moisture variables in meso-scale and cloud resolving data assimilation are incorrect and to see the impact of this on the analysis.

Revising the Quarterly Journal of the Royal Meteorological Society paper for this 4D VAR so that it now includes the model results. Also revising the work from my PhD on higher order balance conditions, which was discussed with Bob Dumais (ARL) when visiting the Research Application Lab at NCAR in Boulder, August 4 and 5.

Prof. William Cotton and Geoffrey Krall

With the new student start, research will focus on the contribution of aerosols on weather systems over North Eastern China and the western Pacific. This will be achieved by using the

Regional Atmospheric Modeling Systems (RAMS) to model storms in the Pacific Ocean under the influence of aerosols from pollution and dust storms.

Work over the summer consisted of becoming familiar with the RAMS 4.3 software and visualization software, along with the necessary background research.

With a Math and Physics background, much of Geoff's time was spent learning the material associated with a Atmospheric Science undergraduate degree: reading textbooks, professional journals, attending colloquiums, and, of course, attending classes. Since August, he has been able to run a simple simulation involving warm air bubble convective storm, and was then able to use the visualization software to analyze various parameters.

Scott Longmore
Main activities include understanding the Earth Systems Modeling Framework (ESMF), NASA Land Information System (LIS) and the NCEP Grid point Statistical Interpolation (GSI) interface documentation and technical specifications. Also started attending a High Performance Computing (Parallel Programming) class with the CSU Computer Science Department.

Other activities pertaining to CG/AR have revolved around supporting Curtis Seaman in his PhD research activities, specifically, resolving configuration, running, and visualization issues with RAMDAS.

Curtis Seaman
Completed the experiments that comprise the dissertation research. Performed assimilation of GOES Imager and Sounder data for the 2 November 2001 case from CLEX-9 with three different sets of channels: Imager channels 3 & 4; Sounder channels 7 & 11; and Imager channel 3 & Sounder channel 11 - all for a single observation time with a 45 min. assimilation window. These experiments demonstrate the utility (or lack thereof) of using infrared (IR) window and water vapor channels for an altocumulus cloud scene.

Results indicate that, with no further information given, GOES Sounder channels 7 & 11 provide more useful information than the similar channels from GOES Imager, due to differences in each channels weighting function. The Sounder channels are much more sensitive to the mid-troposphere, where the cloud formed. The temperature and humidity profiles from the Sounder-only assimilation and the water vapor-only assimilation are much closer to forming a cloud, although no cloud is formed by either assimilation.

Curtis attended and presented a poster of the results discussed above at the NOAA-funded CoRP Symposium at Oregon State University/Cooperative Institute for Oceanographic Satellite Studies (CIOSS). The symposium's focus was "combining satellites and models."

Writing of the dissertation work has begun and Curtis expects to finish in the coming months.

Travel

Andy Jones and Steven Fletcher attended NCAR/RAL and ARL WRF DA meetings in Boulder, Colorado, August 4-5, constituting in-state travel (mileage was reimbursed). Andy also attended an AFWA ACAPS meeting at the University of Colorado, Boulder on August 7.

Curtis Seaman traveled to Corvallis, Oregon, August 11-14 to attend the 5th Annual NESDIS Cooperative Institute CoRP Science Symposium (funded by NOAA).

Technology transfer

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

Equipment/systems status

Nothing to report for 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

Three new masters students were accepted into the graduate program in the Department of Atmospheric Science under Prof. Vonder Haar and began working on a special summer projects for CG/AR prior to the beginning of the Fall semester. Stan Kidder is mentoring Kelly Howell, John Forsythe is mentoring Eric Guillot and Steve Miller is mentoring Jessica Ram. Based on their interests, it is anticipated that they will work on research topics relevant to Battlespace.

A new research effort was identified and began this period titled "CloudSat Extended Statistics," led by Steve Miller.

Research activity and/or results

Dr. Stanley Kidder
Worked on the Blended Total Precipitable Water (TPW) product, which blends AMSU and SSM/I TPW over the ocean and GPS Integrated Precipitable Water (IPW) and GOES PW over land.

Dr. Steve Miller, John Forsythe, and Jessica Ram
Wrote code and completed a two year run of statistics on CloudSat data, computing cloud-type dependent correlation between local cloud top/base height and values removed from the reference point (calculated along-track of the CloudSat orbit). The statistics were broken down into the CloudSat cloud type categories, and also in terms of zonal regions. Obtained NESDIS cloud mask/type/retrieval code applicable to GOES-E and GOES-W for installation on local systems. Output from the code will include two-dimensional cloud properties, which will be coupled with the results of the CloudSat Extended Statistics work in an attempt to add third dimension to the topmost cloud layer(s) detected.

Prof. Mahmood R. Azimi-Sadjadi, Michael McCarron and Jonathan Fidrych

- Began research and development of a new wavelet neural network acoustic transmission loss (TL) prediction system.
    - Derived expressions for determining the three parameters needed for each wavelet, namely the centers, scales, and weights.
    - Began implementation of system and checking for accuracy of training method.
- Started research of Expectation Maximization (EM) method and how it could be applied as a second method to determine the optimal parameters needed for each wavelet.
- Work continued on developing an information theoretic (IT) performance measure to improve the accuracy of currently developed TL prediction systems.
    - The purpose of this performance measure is to replace mean-square-error (MSE) as the performance measure used during training of the OAR-TAP/EAR-TAP TL neural network TL predictors.
    - The hope is that the resulting TL prediction system trained using the IT performance measure will perform better in either or both performance criteria (RMS error and/or percent outliers) than the previous systems trained with the standard MSE measure.

Wavelet Neural Network

The goal for the development of a new wavelet neural network is to improve the results obtained by the current acoustic transmission loss (TL) prediction systems as well as to decrease the complexity of the algorithms.

- The function below describes the output the wavelet neural network. The value determined by $\hat{y}$ is the predicted value for the acoustic transmission loss, w_k are the weights, φ is the wavelet function, a_k are the scales (in this case the same for all elements of vector $\mathbf{x}$), $\boldsymbol{\mu}_k$ are the centers and $\mathbf{x}$ is the sample taken from the input space.

$$\hat{y} = \sum_{k=1}^{K} w_k \phi(a_k \|\mathbf{x} - \boldsymbol{\mu}_k\|)$$

Method I

The first method that was developed for the wavelet neural networks utilized a constant non-updating scaling function and only updated the weights and centers matrices.

- However, it was determined that by using this method, the centers were updated dependent on the weights. The correct implementation would have the weights be dependent on the scales and centers. Additionally, the scales are not updated thereby restricting the amount of control we have for selecting optimal values of each of the three parameters. This in turn has shown to restrict the network from obtaining a level of error less than approximately 12dB Root-Mean-Square-Error (RMSE).
- Figure 1 and Figure 2 show the training curves that illustrate the leveling off of the error as the number of iteration cycles increase.
- In an effort to make a less complex algorithm and correct the errors found in this first method a second method was devised.

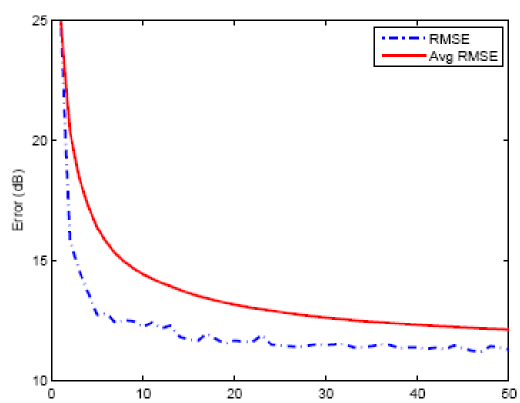
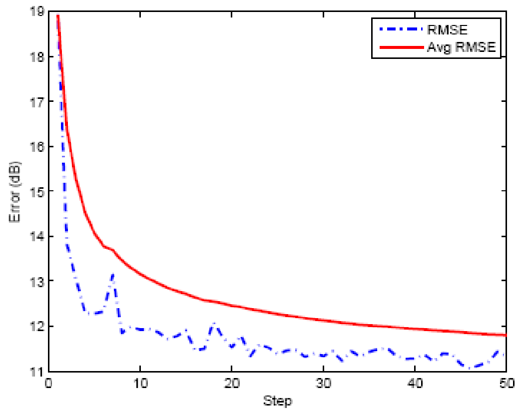


Figure 1: RMSE of Wavelet Network with 20 Neurons



- *Figure 2: RMSE of Wavelet Network with 50 Neurons*

Method II

- The second method that was developed for the wavelet neural networks utilized a method for updating the centers and scales of the wavelet activation functions. This is done through the use of the gradient descent method for each. Then the weights were found through the use of a Least Squares (LS) solution at every iteration.
  - The order of determining the parameters is important as it allows us to place the basis functions first by determining the centers and then finding the right scale parameter for each. Finally, the weights (or importance) of each basis function is determined. This will allows for a better prediction of the PE model outputs.
  - The following two expressions are used for updating the centers and scales of the wavelet activation function.

$$\mu_i(t+1) = \mu_i(t) - \frac{\lambda}{2}\frac{\partial \epsilon}{\partial \mu_i(t)}$$

$$a_i(t+1) = a_i(t) - \frac{\beta}{2}\frac{\partial \epsilon}{\partial a_i(t)}$$

  - Currently, there are several implementation issues that have not yet been resolved. It is unknown whether the gradients used for updating the centers and scales are functioning properly. The reason this is suspected is due to the fact that the error is not decreasing with each cycle through the training algorithm.
  - Once this issue is resolved and results are achieved, the next method to be investigated will be that of Expectation Maximization (EM).

<u>Information Theoretic Performance Measure</u>

- To develop an IT performance measure the goal of training needs to be modified from minimizing MSE between the network output and the desired output to minimizing conditional entropy of the desired output given the network output.
- When the conditional entropy is zero, unlike the zero MSE case, the network output may not, in general, be equal to the desired output. However, a deterministic function exists which maps the network output to the desired output due to the zero conditional entropy condition. To successfully train a network with an IT performance measure two things must be accomplished:
  - Conditional entropy must be minimized.

- A mapping $g(.)$ from the network outputs to the desired values must be found. If conditional entropy is not zero this mapping will not exist, instead a mapping is chosen which minimizes MSE.
- Previous work involved estimating the conditional entropy directly from the network output and then attempting to find a *g(.)* after training was finished. This approach has a few drawbacks due to the difficulty in accomplishing the followings.
  - Estimating conditional entropy accurately and in a computationally efficient manner directly from the training data.
  - Finding a *g(.)* which results in good generalization.
- To overcome these difficulties, work in this quarter focused on first selecting a *g(.)* and minimizing conditional entropy indirectly. Two different *g*'s were used, one parametric consisting of a piece-wise linear saw-tooth like function (SAW) and a non-parametric affine function.

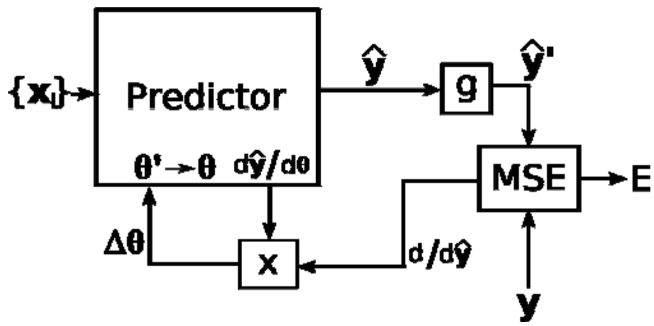


Figure X: Training with a given g.

- Figure X shows the outline of the training process. The goal is to find a parameter vector ($\boldsymbol{\theta}$) of the neural network which minimizes the MSE between the desired output ($\mathbf{y}$) and the mapped network output $g(\hat{\mathbf{y}})$ over a training set consisting of a set of input vectors $\mathbf{x}$ and associated desired outputs y. Gradient descent with adaptive learning rate and momentum term along with the backpropagation algorithm is used to find such a $\boldsymbol{\theta}$.
- Results of this training method when *g(.)* is chosen as SAW, an affine function which is fit using linear least squares (LLS) at each iteration, or the identity map (MSE) are shown in Table 1. This table presents the values for two performance criteria, RMS error and percent outliers.

Performance Measure	RMSE	Percent > 10 dB
MSE	14.89 dB	50.6 %
SAW	13.48 dB	44.7 %
LLS-Affine	12.65 dB	40.2 %

Table 1: Performance results for different performance measures for a single neural network

- These results are for a single neural network trained using the entire expanded parameter range for the operationally adaptive (OA) data set. The neural network consists of two layers. The hidden layer has 45 sigmoidal neurons and the output layer has a single linear neuron. These results for each category of performance measure are from the best performing network out of 15 different random initializations of the network's parameters.

- The SAW performance measure gives the neural network more flexibility during the training phase, while the affine performance measure adapts to the network output to further improve results. Both performance measure resulted in better performing networks than the MSE produces.

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

CG/AR hosted a video-teleconferencing seminar on September 16 with participation from DoD colleagues and CG/AR researchers. Dr. Steven Fletcher presented "Advances in Data Assimilation."

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
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