Strengthening Application of the Ventilation Climate Information System (VCIS) for Multiple-Scale Planning, Documentation, and Risk Assessment

A proposal in response to the Joint Fire Science Program's Announcement for Proposals, Task 2 of 2003-4, supporting Task 1 of 2003-1.

Principal Investigator(s): Dr. Sue A. Ferguson and Dr. Narasimhan Larkin
USDA-FS, Pacific Northwest Research Station
400 North 34th Street, Suite, 201, Seattle, WA 98103
Tel. 206-732-7828 Fax. 206-732-7801
E-mail: sferguson@fs.fed.us, larkin@fs.fed.us

Collaborators: Jim Russell, USDA-FS Region 6; Deirdre M. Dether, USDA-FS Region 4; Marcus Schmidt, BLM-CO; Paula Seamon, The Nature Conservancy; Kevin Hiers, Jackson Guard, Eglin Air Force Base

Abstract: The Ventilation Climate Information System (VCIS) was completed with Joint Fire Science Program support in 2000 under a 1998-2000 project called, "Assessing Values of Air Quality and Visibility at Risk from Wildland Fires." It is a twice-daily, 30-year database of surface wind, mixing height, and ventilation potential for the United States at about 5km spatial resolution with an interactive web user interface that allows access to the data and ancillary information in forms of maps and graphs. While VCIS performs well as a regional and national assessment tool, users have suggested a number of ways that it can be improved to better meet such needs as documentation for the National Environmental Policy Act (NEPA), programmatic and project planning, and risk assessment at multiple scales. Because VCIS continues to be one of few landscape tools for evaluating and documenting the probability of potential smoke impacts, we propose making the user-identified improvements to the data and web-access system, create on-line tutorials for specific project tasks such as documentation, planning, and assessment at local to regional scales, and develop lesson plans and workshops to facilitate training.

______________________12/30/02	______________________12/30/02
Dr. Edward DePuit, Program Manager	Dr. Sue A. Ferguson, Principal Investigator
Managing Natural Disturbance Program	

Introduction

1) *Justification*. This project addresses Task 2 of the Joint Fire Science Program's Announcement for Proposals, 2003-4, "Produce readily understandable and useable information synthesis…" Also, this project provides a baseline climate scenario of potential smoke impacts for Task 1 of the Joint Fire Science Program's Announcement for Proposals, 2003-1, "Interactions between climate, fire regimes, and fire management."

It builds from The Ventilation Climate Information System (VCIS) that was completed with Joint Fire Science Program support in 2000 under a project called, "Assessing Values of Air Quality and Visibility at Risk from Wildland Fires," and links with the National Fire Plan Project, 01.PNWA.2, "Estimating Natural and Anthropogenic Sources of Visibility Impairment and Regional Haze from Prescribed and Wildland Fires."

Air quality and visibility remain critically at risk from wildland fires, especially with the increased use of prescribed fire, the increased threat of wildfire, and the encroaching urban interface. Many managers are postponing fuel treatment or choosing more expensive non-burn alternatives because of unknown or perceived risk to air quality and visibility.

While it is possible to assess risk from individual units or events with smoke dispersion models, these tools are designed for operational predictions, evaluating case studies, or limited to planning only worst-case scenarios (Breyfogle and Ferguson 1996; Ferguson et al. 2001). Also, states and Regional Planning Organizations (RPOs) are developing photochemical grid modeling exercises to simulate current and potential future effects of wildland fires on regional haze and visibility but these efforts are on coarse spatial scales and do not define the probability of optional scenarios (Tonneson et al. 2001). Until the Ventilation Climate Information System (VCIS) was developed in 2000 (Ferguson 2000, Ferguson et al. 2001, 2002a, 2002b, and In press), there were no tools that helped local and regional land managers determine or illustrate the relative risk of smoke impacts from a user-defined fuel treatment location or at a particular time of year.

Ventilation indexes are used by a number of states to regulate outdoor burning. Therefore, a climate summary of the index at a given location typically is well understood and accepted by air regulators (e.g., Wade 1989; Utah Administrative Code 2001). Also, it is a very simple index to derive, allowing many burn managers to estimate its value preceding and during wildland fire operations. Therefore, it is a relatively easy index for land managers, fire operations, and others to understand and use.

Because there is no other climate database that focuses on ventilation, we believe that VCIS can not only be a useful decision and planning tool, but it can function to help describe current climate conditions for determining smoke impact from which alternative fuel treatments or climate conditions can be based. Also, because components of the ventilation index are generated from observations, it can be used to assess the ability of large-scale models to predict those values that affect regional haze and visibility.

In addition to several obvious attributes, VCIS includes the very unique ability of considering local, nighttime inversion potential in its calculation of ventilation index. This attribute is unavailable in any other derivation of ventilation index and is poorly handled by numeric meteorological models.

While VCIS has proven to be of great value in assessing and demonstrating potential risk, it fails to provide some basic tools that would greatly assist documenting NEPA requirements, demonstrating alternatives in smoke management planning, and finer-scale local assessments.

2) *Objectives*. The principle objective is to improve the Ventilation Climate Information System (VCIS 2000) so that it becomes more useful to a wider variety of land managers and becomes easier to understand and apply – VCIS 2004.

This improvement includes:

- Add statistics that allow users to better determine the frequency of exceeding or limiting threshold values of surface wind, mixing height, and/or ventilation index and better anticipate or plan for alternative scenarios.
- Generally improve the quality and accuracy of all supporting data layers.
- Improve the export functionality to help use VCIS data in cumulative risk assessments, public meetings, and local project development
- Develop ventilation information at 30-meter resolution over selected areas to allow overlays with local-level data and capture the influence of small-scale terrain features.
- Modify the VCIS web interface to improve ease-of-use.
- Create access to the raw data so users can group or display information in alternative ways for help in assessing relative risk between locally-defined airshed or from one basin to another.
- Improve metadata of GIS products to facilitation documentation.

An additional objective is to improve the understanding and use of VCIS 2004. This objective includes:

- Create an on-line tutorial for navigating through VCIS and accessing products for selected tasks, such as creating visuals for a public meeting, developing a smoke management plan, or NEPA documentation.
- Create a 1-hour lesson plan for presenting at meetings, workshops, and training sessions.
- Create a ½-day workshop that walks users through creating necessary documentation and assessment from VCIS.

3) *Background*. The Ventilation Climate Information System (VCIS) was developed in 2000 as a result of a two-year project funded in 1998 by the Joint Fire Science Program, "Assessing Values of Air Quality and Visibility at Risk from Wildland Fires." While other products have focused on modeling (e.g., estimating emissions and global carbon budgets, determining air chemistry and regional haze potential, or predicting impacts under specified weather conditions by simulating smoke dispersion), only VCIS provides information on the probability of smoke intrusion based on lengthy patterns of climate. This attribute has made VCIS a popular tool among smoke management specialists in many public agencies throughout the United States and it is gaining attention in other parts of the world.

VCIS 2000 is at http://www.fs.fed.us/pnw/fera/vent (Fig.1).
Please be patient. Our office moved in late autumn 2002 and the computing systems are undergoing a general overhaul during January 2003 that may cause VCIS to be unavailable at times.

Figure 1. The VCIS 2000 home page at http://www.fs.fed.us/pnw/fera/vent.

VCIS 2000 continues to be one of few tools of its kind that allows assessments of risk from smoke impacts and planning for mitigation of smoke impacts from fuel treatment projects. Its Geographic Information System (GIS) format also makes it suitable for importing, overlaying, and integrating with other land-based products.

Currently, VCIS 2000 is running on a MS-Windows web server with the ESRI ArcInfo Internet Map Server (ArcIMS) and a 16-processor linux cluster database server. Users access the information through the web server where maps of monthly mean meteorological values (surface wind, mixing height, and ventilation index) can be overlain with terrain contours, rivers, lakes, state and county boundaries, cities, federal land ownerships, wilderness areas, hospitals, schools, roads, airports, and/or railroads. Whenever detailed information is requested for a single point through the “get stats” button, the request is ported to the linux cluster where over 100 GB of data are interrogated and summarized into graphical plots. The process requires only a few seconds to complete.

At this time, VCIS 2000 can be used for many types of **programmatic planning** by displaying maps of monthly mean values of wind, mixing height, or ventilation index (Fig. 2), which can be overlain with maps of sensitive receptors, political, or geographic features. The mapped features allow visualization and assessment of ventilation potential and impacts as patterns change across the landscape and month by month. Maps generated in VCIS 2000 can be imported into ArcInfo projects at the user’s home PC. This is a useful function when trying to assess cumulative risk of wildland fire; using VCIS maps to help demonstrate the values of air quality and visibility at risk overlain on other maps that may be available at one’s home office, such as wildland-urban interface, fuel condition, etc. Also, it allows titles or other attributes to be added to improve the quality of maps for demonstration, display, or publication. The import function is not straightforward, however, and some of the VCIS 2000 data layers are not independent of the display device. While maps can be stepped through time to see the month-to-month variation of patterns, it is difficult to compare information from one month to another without tedious steps to interrogate points, create prints of each, or create multiple open windows. Finally, because the mapped information must group data into color scales for display, subtle differences between regions are difficult to observe in VCIS 2000.

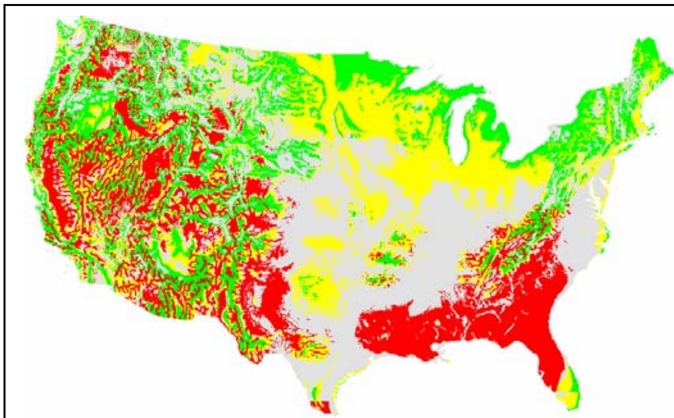

Figure 2. Monthly mean maps of ventilation index classifications for morning in October. Red represents potentially poor ventilation conditions, yellow is marginal, green is fair, and gray is good.

This feature is desired when trying to determine the relative risk of potential smoke impacts among defined airsheds or from one basin to another.

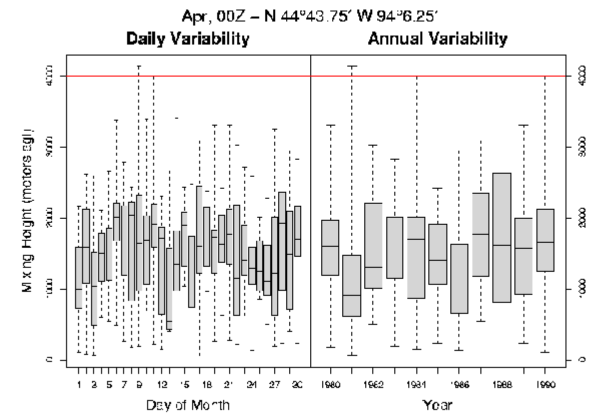

Figure 3. Box plot of afternoon mixing height in April at a point in Minnesota. The horizontal red line shows the 4000 m correction for belowground mixing height values in the afternoon.

More detailed information is available for **project-level planning** as data from individual points on the landscape are readily available from the VCIS 2000 interactive website. The frequencies of exact values of surface wind, mixing height, or ventilation index are shown. The frequency of wind speed and direction are shown in polar plots (wind roses) for each month. Mixing height and ventilation index values are box plots (median, minimum, maximum, 25th percentile, and 75th percentile) showing frequencies of values on any given day and the variability within a month from year to year (Fig. 3). While it is easy to acquire these data for any point, any value, and any time period, many users would like to see variability across an entire year at once rather than having to step through each month one at a time. This helps to determine, for example, whether projects planned in spring may have better or worse ventilation potential than those planned in the fall. Also, while wind roses and box plots are useful in showing data values, it is difficult to extract the frequency of limiting or exceeding threshold values from them. For example, if a project is planned at a site, which is 2000 meters above sea level, users may want to know how often the mixing height is above 4000 meters and at what time of year these conditions are most likely to occur. While the visual patterns of box plot show such values, quantitative information about threshold frequencies are difficult to derive from VCIS 2000 without stepping through several months and times and visually extracting the information.

To help assess values of air quality and visibility at risk from wildland fire on a national scale, VCIS data were aggregated into regional airsheds throughout the country (Fig. 4). The summarized information showed, for instance, that the southeastern U.S. has the greatest risk to air quality and visibility from wildland fire because it has the highest density of sensitive receptors and experiences frequent, widespread, poor to marginal ventilation conditions. (Ferguson, et al., In press). Aggregating values like this is not possible through the VCIS 2000 website but users would like to see patterns of difference between smaller airsheds or between one basin or valley and another.

Figure 4. Regional airshed boundaries within which aggregated ventilation climate information from VCIS 2000 was used to assess relative risk to air quality and visibility within the 48 U.S. states.

VCIS 2000 has been taught at RX410 courses in Florida, California, and

Oregon, an RX300 course at the Great Basin Training Center, and at smoke model training in Montana. In addition, it has been presented at several meteorology and fire ecology conferences (2002 Fire Conference; 4th Symposium on Fire and Forest Meteorology, 2001; Applied Climate Conferences, 2000, 2002). It was used to help develop smoke management plans in the Boise National Forest, in Colorado for fire and fuels planning, and during the 2002 fire season to help determine potential long-term smoke impacts resulting from the Biscuit wildfire in southwestern Oregon. We believe that with broader, more innovative training opportunities VCIS 2004 can become even more widely used than it is today.

Material and Methods

Since the VCIS project began in 1998, the Fire and Environmental Research Applications (FERA) team in Seattle has grown substantially. This affords a great depth of atmospheric, air quality, and climate science, computational science, statistics, geospatial analysis, synthesis and integration, and technology transfer. We plan to tap into this wealth of skill and talent to complete the technical elements of the VCIS upgrade. In addition, because VCIS 2000 has been available for over two years, there is a cadre of users whose experience in applying VCIS to real problems has fostered intelligent and critical recommendations.

We propose beginning the project by hosting a day-long workshop with our collaborators and other potential users to go over the details of the existing VCIS 2000 and make collaborative decisions on desired changes, which include form, content, and function. We hope that an additional outcome of the workshop will be a draft of timelines for products and reviews. It is anticipated that new components of VCIS will become available about every quarter, at which time, a notice of the change and recommended review questions will be disseminated to all collaborators and posted on the website. Another workshop of collaborators and interested reviewers is planned in the 2nd year of the project to help develop and review prototypes of on-line tutorials and curricula.

We propose upgrading our existing web server and cluster database server to handle new software that has become available since VCIS 2000 went on line two years ago and build capacity to generate very fine-resolution data. All of the technical development will be accomplished within FERA at the Seattle Forestry Sciences Laboratory and through a small contract with ESRI, manufacturer of ArcIMS as we have found that VCIS functions often test the limit of this tool. Because VCIS is available from the public Internet, collaborators and other users from all agencies will have ready access to the products as they develop.

While the basic science behind VCIS has been reviewed by peers and tested against known theory and observations, we propose improving the determination of mixing height when observed values map below the height of surrounding terrain. Currently this value is only approximated at 4000 meters above ground level in the afternoons and 1000 meters above ground level in the mornings, which are annual averages of observed mixing heights. The approximation tends to skew the frequency statistics and makes resulting patterns difficult to explain. By calculating and spatially interpolate the planetary boundary level twice daily from radiosonde observations, the upper limit of mixing is more accurately defined.

Unfortunately, processing and data volume will limit downscaling VCIS information to small domains. We propose selecting 3 areas for downscaling VCIS that coincide with significant burn activity and/or smoke management problems, 2 in the west and one in the southeast, to be determined by consensus with our collaborators. The downscale domains will have information generated at 30 m spatial resolution. Other areas throughout the U.S., including Alaska and Hawaii, will continue to have the improved VCIS 2004 functionality at the current spatial resolution of about 5 km.

To downscale surface winds for VCIS 2004, we propose using a non-hydrostatic, kinematic meteorological model. (Surface winds for VCIS 2000 were generated with a hydrostatic flow model whose assumptions fail below about 5 km spatial resolution). Kinematic models are in abundance as they are used to help site wind turbines and model flow of toxic plumes in urban areas. They are an extension of fluid dynamic models in that they account for slope flows and land/sea breezes. We have experience with the Calmet kinematic model (Scire and Robe 1997), are testing others for our National Fire Plan project, BlueSky (01.PNWA.3: Ferguson et al. 2001), and plan to use the best available model. Downscaling mixing height and local inversion potential is relatively straightforward.

Web access to the raw data will use the Live Access Server, FERRET (Fig. 5), which was developed at the Pacific Marine Environmental Laboratory for viewing, selecting, and downloading spatial data sets (Hankin et al. 1992). Dr. Larkin helped develop the tool and has implemented it on one of FERA's data servers. Linking VCIS data to FERRET is straightforward but not trivial because VCIS contains such a large volume of information.

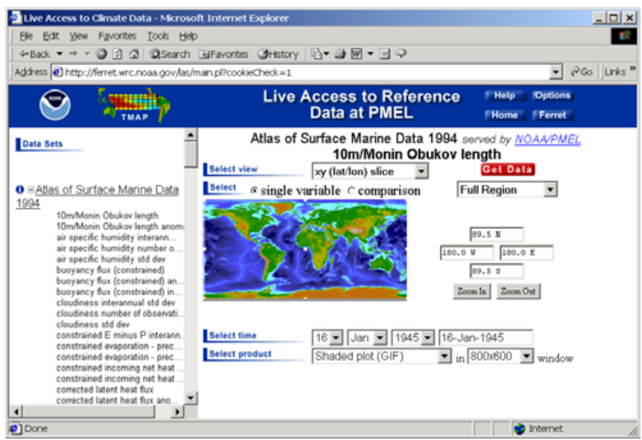

Figure 5. The Live Access Server home page, FERRET from the Pacific Marine Environmental Laboratory (http://ferret.wrc.noaa.gov/Ferret/LAS/).

Dr. Sue Ferguson, who led the successful completion of VCIS 2000, will lead the VCIS 2004 effort. She is a Research Atmospheric Scientist and leads the atmospheric science section of FERA, which includes a Research Air Quality Meteorologist, Research Physical Climatologist (Dr. Larkin), Research Meteorlogist, Computer Scientist, 4 Meteorologists, and 2 students. All of these resources, and statisticians and spatial analysts in FERA's Synthesis and Integration section will be available to work on VCIS 2004.

As co-principle investigator, Dr. Narasimhan "Sim" Larkin, brings significant climatological, statistical, and computer science knowledge to the project. He will assist Dr. Ferguson in coordinating the development of VCIS 2004, and will lead the tasks of developing web-access to the raw VCIS data and linking VCIS with National Fire Plan Project, 01.PNWA.2, "Estimating Natural and Anthropogenic Sources of Visibility Impairment and Regional Haze from Prescribed and Wildland Fires."

Our collaborators all have experience in fuels management and are in current job positions that require decisions about smoke impact from fire activities and/or coordination of fire activities to help minimize smoke impacts. In addition, they are familiar with many aspects of VCIS 2000. They will help define the additional attributes needed for VCIS 2004, guide us on the look and feel of the VCIS web-access products, and tutorials, and review user elements of the product as they become available. In addition, each of our collaborators has a leadership role in fuels management and/or mitigating smoke impacts in their region or agency. As a member of the

National Background Task Team of the Fire Emissions Joint Forum in the Western Regional Air Partnership (WRAP) and Air Quality Leader for the USDA-FS, Region Six, Jim Russell has strategic knowledge of smoke and fuels management issues across the west. Marcus Schmidt and Deirdre Dether bring critical knowledge and experience from the intermountain region, and Paula Seamon and Kevin Hiers are strong representatives of southern fuels and smoke management issues. In addition, Ms. Seamon provides perspective from private, non-governmental users. Therefore, our collaborators, each having a leadership role in their region or agency, form the central cog of a user network that spans across agencies and landscapes.

Deliverables

A new version of VCIS that includes:

- Improved statistics that include annual time series and probabilities of user-defined threshold values
- Query options on geographic and political data layers.
- Overlay maps of non-attainment areas and improved wilderness area data layers.
- Device-independent functions that allow greater access and export functionality.
- Ventilation information at 30-meter resolution over selected areas.
- Improved ventilation information science
- Easier to use web interface.
- Web option that allows access to the raw data.
- On-line tutorial.

Technology Transfer

- An on-line tutorial for navigating through VCIS and accessing products for selected tasks, such as creating visuals for a public meeting, developing a smoke management plan, or NEPA documentation.
- A 1-hour lesson plan for presenting at meetings, workshops, and training sessions.
- A ½-day workshop curriculum that walks users through creating necessary documentation and assessment products from VCIS 2004.
- Conference proceedings and journal articles that describe science behind development and application of VCIS 2004.

References

Breyfogle, S. and S.A. Ferguson. 1996. A User Assessment of Smoke Dispersion Models. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-379.

Ferguson, S.A., S.J. McKay, D.E. Nagel, T. Piepho, M.L. Rorig, C. Anderson, and L. Kellogg. In Press. Assessing values of air quality and visibility at risk from wildland fires. Res. Pap. PNW-RP-xxx. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Ferguson, S.A., S.J. McKay, D.E. Nagel, T. Piepho, M.L. Rorig, C. Anderson, L. Kellogg, and J. Hoadley. 2002a. The potential for smoke to ventilate from wildland fires in the United States. Abstract. In Proceedings of the 2002 Fire Conference: Managing Fire and Fuels in the Remaining Wildlands and Open Spaces of the Southwestern United States. 2-5 December 2002, San Diego, California. The Wildlife Society and The Association for Fire Ecology. 45-46.

Ferguson, S.A., S.J. McKay, D.E. Nagel, T. Piepho, M.L. Rorig, C. Anderson, and L. Kellogg. 2002b. The ventilation index climate information system (VCIS). Presented at the 13th Conference on Applied Climatology. 13-16 May 2002, Portland, Oregon. The American Meteorological Society.

Ferguson, S.A., S.J. McKay, D.E. Nagel, T. Piepho, M.L. Rorig, and C. Anderson. 2002a. The potential for smoke to ventilate from wildland fires in the United States. Abstract. In Proceedings of the Fourth Symposium on Fire and Forest Meteorology, 13-15 November 2001, Reno, Nevada, American Meteorological Society. 115.

Ferguson, S.A., J. Peterson, and A. Acheson. 2001. Automated, real-time predictions of cumulative smoke impacts from prescribed forest and agricultural fires. Fourth Symposium on Fire and Forest Meteorology, 13-15 November 2001, Reno, Nevada, American Meteorological Society. 168-175.

Ferguson, S.A. 2000. Climatology of wind and mixing height in the United States. Abstract. In Proceedings of the 12th Conference on Applied Climatology, 8-12 May 2000, Asheville, NC.

Hankin, S., J. Davison, K. O'Brien, and D.E. Harrison, 1992: FERRET A computer visualization and analysis tool for gridded data. NOAA Data Report ERL PMEL-38, 164 pp.

Scire, J. S. and F. R. Robe. 1997. Fine-scale application of the CALMET meteorological model to a complex terrain site. EarthTech, 196 Baker Avenue, Concord, MA 01742, Rep. 97-A1313. 15 pp.

Tonnesen, Gail, Zion Wang, James Lents, David Gemmill, Ralph Morris. 2001. Modeling Protocol and Quality Assurance Plan for the WRAP Visibility Modeling Project. Draft Report Prepared for: Western Regional Air Partnership Modeling Forum. http://pah.cert.ucr.edu/rmc/Modeling_Protocols/RMCprotocol.pdf

Utah Administrative Code. 2001. Emission standards: General Burning. R307-202. Michael G. Broschinsky, Administrative Code Editor, Division of Administrative Rules, PO Box 141007, Salt Lake City, Utah 84114-1007.

Wade, D.D. 1989. A Guide for prescribed fire in southern forests. National Wildfire Coordinating Group, Prescribed Fire and Fire Effects Working Team, Boise Interagency Fire Center, ATTN: Supply, 3905 Vista Avenue, Boise, ID 83705. NFES #2108. [United States Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. Tech. Pub. R8-TP 11.] 56 pp.