Program for Climate, Ecosystem and Fire Applications

Climate and Ecosystem Studies and Product Development for Wildland Fire and Resource Management

Annual Report

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Desert Research Institute
Division of Atmospheric Sciences

CEFA Report 05-03 December 2005

Forward

In November 2000 an Assistance Agreement 1422RAA000002 was established between the Bureau of Land Management National Office of Fire and Aviation and the Desert Research Institute (DRI). This report describes the activities at the DRI Program for Climate, Ecosystem and Fire Applications (CEFA) under this Agreement during the period 1 October 2004 - 30 September 2005. For further information regarding this report or the projects described, please contact either:

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Table of Contents

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Annual Report to the Bureau of Land Management National Office of Fire and Aviation

by
Timothy J. Brown and Beth L. Hall

Program for Climate, Ecosystem and Fire Applications
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A. INTRODUCTION

This annual report covers federal fiscal year 2005 and represents accomplishments, deliverables and activities under the Bureau of Land Management (BLM) national Office of Fire and Aviation and the Desert Research Institute (DRI) cooperative Assistance Agreement (AA) 1422RAA000002. The 5-year AA was signed by BLM and DRI during November 2000. The overall scope of the AA is climate and ecosystem studies and product development for wildland fire and resource management. Its objective is to establish and maintain a partnership between BLM and DRI that allows for product development, applied research, training, education and consultation using DRI scientific expertise in climatology, meteorology, terrestrial ecology and fire management "expertise" from BLM and other land management agencies. The deliverables under this AA are intended to have high interagency value in addition to specific BLM agency needs. The target audience varies depending upon the product or information, but includes fire management, Predictive Services meteorologists, fuels analysts, intelligence officers, fire behavior analysts, and fire specialists. Project concepts can originate at all levels including local, state and national offices as well as at DRI.

This report describes activities and accomplishments under the AA for the period 1 October 2004 – 30 September 2005. Report sections include an overview of tasks during the year, other related activities, travel, presentations and meetings, and publications. For a brief history of the DRI Program for Climate, Ecosystem and Fire Applications (CEFA), see the annual report for federal FY2001 (CEFA Report 01-04). In May 2003 an interagency program review of CEFA was conducted for the BLM. The purpose of the review was "to clarify the program's relevance, quality and performance". The review recommended, among other things, that the CEFA program continue and that a "Stakeholder Oversight/Advisory Panel" be developed "to ensure the continuing relevance and performance of CEFA work". The National Interagency Fuels Coordination Group (NIFCG) has assumed the role of the CEFA Oversight Group.

Contributions to this report were provided by Ryan Kangas, Julide Koracin, Crystal Kolden, Greg McCurdy, Domagoj Podnar, Kelly Redmond, Hauss Reinbold, Paul Schlobohm and Tesfamichael Ghidey. The CEFA staff members are very appreciative of the agency support towards the Program, and the opportunity to work with the fire community.

B. TASK ORDERS

This section describes AA tasks specific to BLM that were in progress during federal FY2005. Administrative Task Order 1 began in the first half of calendar year 2001 and is ongoing through the AA 5-year period; Task Order 7 began in September 2001 and is in its fourth year; Task Order 9 began in summer 2002 and was completed in September 2005; Task Order 10 began in October 2002 and is in its third year; Task Orders 13 and 14 began in September 2003 and are currently in their third year. New Task Order 15 began in June 2005. Task Order 16 began May 2004 and is in its second year. Task Order 17 began in August 2004 and is in its second year.

Task Order 1: CEFA Infrastructure and Administration (Sponsor: BLM)

This task order provides for some basic infrastructure required for CEFA general operations. The primary components include:

- Salary for CEFA administration and management by Director and other program staff (partially used to allow CEFA personnel to be available on short notice as if they were agency staff).
- Readily available funds for short-term projects requested by the field in support of fire season activity.
- Travel including field visit for training and discussion, working team meetings, workshops and scientific conferences.
- Materials and supplies including computer software upgrades and license fees, computer hardware related supplies (e.g., tapes, diskettes, printer toner, etc.), and books and reference materials.
- Computer hardware upgrades (e.g., disk storage drives).
- Publication charges related to conference proceedings, report printing, and scientific journal publications.
- CEFA web administration.
- Salary for GIS, specialized computer programming and hourly student support.

Notable accomplishments for the reporting period:

CEFA was co-organizer of two Predictive Services Seasonal Assessment Workshops. The first of these was held in Sheperdstown, WV during 19-21 January 2005 (Eastern and Southern areas), and the second was held in Boulder, Colorado during 28 March – 1 April 2005 (Western States and Alaska). These workshops brought together climatologists, Predictive Services units, and fire managers from across the country to produce Geographic Area Coordination Center (GACC) seasonal fire outlook reports. For the eastern and southern area workshop, emphasis was placed on bringing together state agency representatives in addition to federal participants. The workshops are structured to foster communication between climate forecasters and fire specialists, and to enhance communication and cooperation between the representatives. Products from the workshops included a seasonal fire potential outlook, a two-page flyer providing outlook information for national fire directors and Washington, D.C. interests, and a final report. These workshops will be held again in 2006. See Lenart et al. (2005) in the publication section for workshop report references.

CEFA continues to respond to agency questions regarding climate and meteorological data. CEFA responded to 19 data requests for fire occurrence and lightning information. CEFA responded to two media requests for fire climate related information.

CEFA is now the national fire agency archive for lightning data. In conjunction with the new fire agency agreement with Vaisala, CEFA receives monthly updates of national lightning occurrence from the National Lightning Detection Network®, which is added to a national archive extending back to 1990. As part of the national agreement, fire agencies in need of lightning information can fill out a user request form at NIFC, and if approved, will be forwarded to CEFA for processing. Simple requests for data may be handled in this manner, but actual analysis of lightning data may require a separate contract depending upon the resources required.

CEFA maintains a historical archive of federal fire occurrence data for the period 1970 to the most current year. Most of the Department of Interior reports begin in 1980. In 2002, an extensive quality control (QC) analysis was done on these data, and reported in the CEFA online publications section (CEFA Report 02-04). Each year the QC process is run on the annual dataset and the archive updated correspondingly as data are made available annually from NIFC.

In August 2005 CEFA purchased a Silicon Graphics Inc. (SGI®) Altix® computing cluster in support of Fire Program Analysis (FPA) work. This system is comprised of 8 Itanium®-2 processors with 16 GB of RAM, and is used for FPA data processing as well as other CEFA project work. As required per annual basis, several software license renewals and updates were administered on the CEFA servers and desktop units.

Web administration is an ongoing process. Some new and updated CEFA products were added to the site (see tasks below). CEFA maintains an extensive website for science information delivery and outreach. The site currently consists of 1028 web pages, 106,226 graphics files, 103,335 miscellaneous files, and 5,809 web links totaling nearly 12.3 GB of information. The CEFA web site address is http://cefa.dri.edu.

Travel and publications under Task 1 are listed in separate sections near the end of this report.

Task Order 7: Web Access to RAWS Data and Products (Sponsor: BLM)

The Western Regional Climate Center (WRCC) manages this task with BLM funds utilizing the Assistance Agreement. The report in this section was provided by WRCC.

The primary project objective is to build upon recent efforts to reconstruct the internal storage and access system for RAWS data and initiate system-wide improvements. The overall objective is to provide improved access to archived RAWS data and climatology applications of these data in order to fully serve the fire agencies as a historical RAWS archive. This work officially began in August 2001, and this reporting period represents the third year of the project through the period 30 June 2005. In July 2004, another year was funded on this Task Order by BLM for the period 1 July 2004 – 30 June 2005. Statement of Work specific task elements and accomplishments during the project period included:

A) Data improvement

1. *Task element*: Data conversion. Continue reformatting of remaining RAWS station data from ASCII text to internal binary indexed format.

   Accomplishment: The primary task of converting the historical data has been completed. New stations are brought online typically within a week of receipt of first data. The one-week delay allows for verification and entry of all metadata parameters for the new station. At least 50 stations (brand new or transitioned from WIMS to ASCADS) were brought online from July 2004 through June 2005. The communications and ingest system has functioned fairly well in an automated fashion. Occasional babysitting is still needed to deal with hiccups in data flow or data processing.

2. *Task element*: Station metadata. Development of a station selector and search function.

   Accomplishment: Updating station metadata in the internal database is an ongoing process. As of this reporting period, there were 53,000 station records in the database. Approximately 100-200 new records are added each month.

3. *Task element*: Quality Control. Mark suspicious data and rehabilitate sections of flawed data as much as possible. Quantify both the quality and the reliability of the receipt of data records and files. Explore the development of a quality indicator for each datum. Where possible, attempts will be made to fill gaps in historical records, with provisions for labeling such data.

   Accomplishment: Two tools to deal with quality control issues have been developed. One tool allows a user to screen the data by setting limits. A report is then generated which displays the occurrences when the limits were exceeded. The second tool allows periods of missing data to be estimated using methods of multiple linear regression. Nearby stations, with similar data behavior, may be used to estimate for missing periods. The program also computes correlation confidence values, so that the user can determine what degree of correlation exists. The system has been redesigned to allow a much more robust and extensive set of flags. Figure 1 shows example hourly output for a RAWS site including flag values for each element based on a data quality check.

Grace Idaho

: LST : Date/Time :YYMMDDhhmm	in Precip	flg	mph Wind Speed	flg	Deg Wind Direc	flg	Deg F Av Air Temp	flg	Deg F Fuel Temp	flg	% Rel Humidty	flg	volts Battery Voltage	flg	Deg Dir MxGust	flg	mph Mx Gust Speed	flg	ly Solar Rad.	flg
0502040000	12.24	0	1	0	221	0	26	0	25	0	61	0	12.8	0	317	0	5	0	0	0
0502040100	12.24	0	1	0	75	0	27	0	24	0	54	0	12.8	0	228	0	6	0	0	0
0502040200	12.24	0	1	0	167	0	27	0	24	0	56	0	12.7	0	210	0	6	0	0	0
0502040300	12.24	0	0	0	188	0	26	0	23	0	59	0	12.7	0	189	0	4	0	0	0
0502040400	12.24	0	0	0	203	0	24	0	23	0	63	0	12.7	0	202	0	5	0	0	0
0502040500	12.24	0	0	0	301	0	24	0	23	0	64	0	12.7	0	203	0	4	0	0	0
0502040600	12.24	0	1	0	306	0	23	0	22	0	65	0	12.7	0	309	0	4	0	0	0
0502040700	12.24	0	0	0	36	0	20	0	22	0	72	0	12.6	0	319	0	4	0	0	0
0502040800	12.24	0	0	0	73	0	22	0	21	0	74	0	12.6	0	194	0	6	0	0	0
0502040900	12.24	0	0	0	194	0	30	0	21	0	59	0	13.6	0	192	0	7	0	5.247	0
0502041000	12.24	0	6	0	186	0	34	0	22	0	55	0	13.5	0	163	0	11	0	21.33	0
0502041100	12.24	0	4	0	191	0	38	0	22	0	47	0	13.4	0	199	0	12	0	32.51	0
0502041200	12.24	0	1	0	66	0	40.7	E	22.9	E	43	E	-9999	M	-9999	M	-9999	M	42.84	E
0502041300	12.24	0	5	0	131	0	42	0	25	0	42	0	13.3	0	124	0	12	0	49.37	0
0502041400	12.24	0	5	0	150	0	43	0	25	0	44	0	13.4	0	173	0	13	0	49.54	0
0502041500	12.24	0	7	0	128	0	40	0	27	0	48	0	13.4	0	136	0	12	0	44.55	0
0502041600	12.24	0	7	0	140	0	39	0	27	0	43	0	13.4	0	125	0	12	0	35.01	0
0502041700	12.24	0	6	0	137	0	37	0	28	0	51	0	13.5	0	137	0	11	0	19.35	0

Figure 1. Example data output including a quality control report. Flag codes are 0 = data okay; M = data missing; E = estimated value.

B) Product development. Develop statistical summaries and other manipulations of the observations, the simplest product being a listing of the data themselves. Products can have either textual or graphical formats.

1. *Task element*: Daily time series. The analog for this product is the Summary-of-the-Day data set from the National Climatic Data Center [http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html]. Some property, or a variety of properties, of the 24 (or 25) hourly values, is summarized for each day, and all such properties presented as a listing. For example: max and min temperature, total solar radiation, mean scalar wind speed, peak gust for the day, daily precipitation, vector mean wind direction and speed, number of hours exceeding some value (e.g., greater than 81 degrees, less than 7 percent humidity), and the like, again with user control of what is acceptable, and what is not, in terms of data availability.

   Accomplishment: This product was developed and is available for use. Hourly or sub-hourly values are utilized to produce daily averages, daily sums, or number of hours exceeding some threshold value. Missing data can be represented in a variety of ways. A number of different output formats are available.

2. *Task element*: Climate summaries. These products consist mainly of hourly and daily climatologies. Of greatest interest are measures of central tendency (averages or medians), by hour, by day, by month, or by year. Derived data sets may be developed to provide information on daily extremes (max and min temperature, wind speed and gusts, relative humidity, etc) and totals (such as precipitation and solar radiation). Parts of the requisite information are available via other products, but these are not collected in one convenient place.

   Accomplishment: The main component of the climate summaries that is most needed is the monthly time series summary and lister. This has been a difficult and complicated program to write, because there are many ways that summary data can be formed from the original values, and there is a strong need to be able to do all of them. Among many other reasons is the need to be able to debug basic problems with a given station record, and to debug other products.

3. *Task element*: Fitted frequency distributions and probabilities. These products involve the ranking of data, and provision of information on the likelihood of occurrence. In 2003-04 an empirical portion was completed, and we would like to include fitted distributions (e.g., Pearson III, normal, gamma, etc.). Some may involve joint distributions (such as wind and humidity together).

   Accomplishment: The option of fitting was deferred in order to work on other products.

4. *Task element*: Selective lister. To hold down data volume, many users only want data records from days or hours where thresholds exceed certain user-defined values, perhaps following Boolean criteria (for example, list all records with winds over 27.4 mph, or all days or hours with temperatures above 90ºF and humidity below 9.3 percent).

   Accomplishment: This option has been deferred in order to work on other products.

C) *Task element*: RAWS Advisory Group. Continue to utilize the feedback from this user group and others.

Accomplishment: This group has not provided much formal feedback in the past year. We do continue to hear from a variety of users with suggestions for improvements to products, either new products, or augmentations to existing products.

D) *Task element*: RAWS web page improvements. A web page that provides access to RAWS data seems to be functioning well, but will be improved according to user requests and internal needs [http://www.wrcc.dri.edu/wraws]. A new home page for RAWS, incorporating this page, still needs to be developed, that directs a user to data, metadata, news and existing products, other RAWS information at WRCC and elsewhere, and related agency links, including ASCADS and others. The goal remains to develop a "one-stop shopping" page that agency activities can easily link to.

Accomplishment: Major improvements were done this past year to pages that display basic metadata. Inclusion of station photos and other location information was improved to show more clearly the station setting. Links are also included to access the NWS current 7-day forecast for the station location using the new NWS 7-day point forecast.

E) *Task element*: ASCADS re-engineering. Developments in the re-engineering of ASCADS are critical to the success of the infrastructure and products of this Task Order. This task places a priority on close coordination between WRCC and BLM ASCADS redesign efforts. WRCC will work in conjunction with BLM and other NIFC agencies to insure that the system jointly developed has the proper attributes for future use and expansion.

Accomplishment: Adaptation to the requirements of secure shell connections was completed without interruption of data flow. WRCC also looked at the possibility of retrieving data from Wallops Is. during NIFC outages (periods when data was lost). As long as periods are kept minimal (a day or 2 at most), WRCC can retrieve the missing data. WRCC has yet to build the data decoders to ingest data retrieved directly from Wallops, but the need to do so is present. (Required by another project)

F) *Task element*: Lightning data. Contingent upon proprietary needs being adequately addressed, WRCC will work with NIFC personnel to offer improved internal agency access to historical archived NLDN lightning data to serve interagency requirements within the fire community.

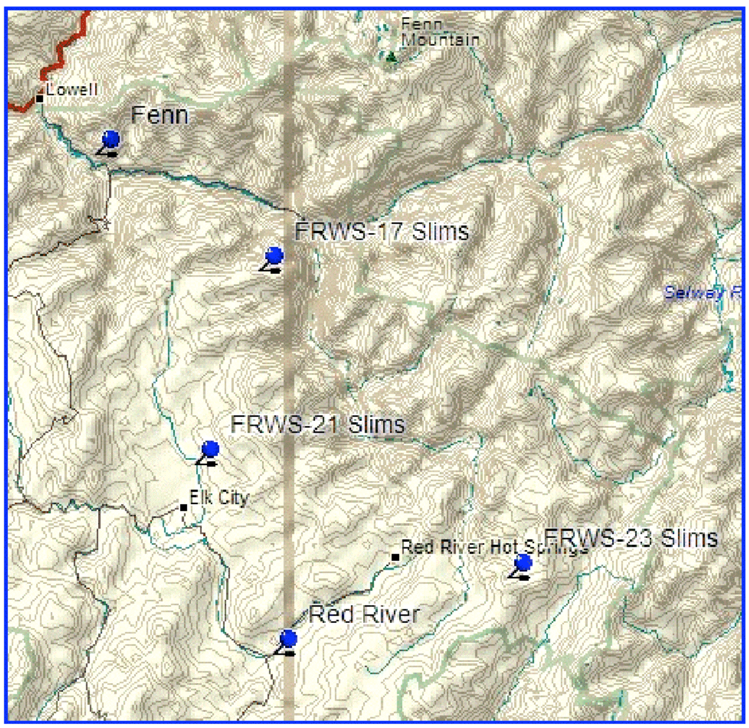
Accomplishment: Lightning data continues to be handled by the CEFA group. Concerns of copyright and valid request procedures are such that making the NLDN® lightning data part of the products distributed by WRCC is not desired at present.

G) *Task element*: Ties to ISOS and the National Cooperative Mesonet. There is increasingly widespread recognition of the need to bring together data from all the federal networks in support of the next generation of weather and climate prediction models and for addressing local and regional scale issues. In June 2004 NOAA formally initiated the Integrated Surface Observing System and associated National Cooperative Mesonet. There is great interest from many quarters in the RAWS network, and WRCC is frequently approached to help make this information more available and useful. We will be working to find ways that RAWS can play a significant role in the developing national system of atmospheric and climatic observations.

Accomplishment: The utilization of RAWS data as part of an Integrated Surface Observing System (ISOS), spanning all federal agencies, has been promoted in a variety of venues. The ISOS concept has advanced only modestly within NOAA during the last year because of budgetary constraints.

H) *Task element*: Emergency response. At the discretion of the Administrative Representative, emergent situations may require a rapid response to develop a new capability or focus on special stations or situations. Examples from the past few years included special pages produced by WRCC being rapidly produced for the Cerro Grande Fire, the World Trade Center, the Columbia Recovery, and the Rodeo-Chedeski Fire, and a large number of blazes in the summers of 2002 and 2003.

Accomplishment: In May 2005, WRCC was asked to include stations that would be deployed on Caribbean Islands in the coming summer months. The needed web pages were created and stations added as they were deployed. Following is a link directly to access these stations: [http://www.wrcc.dri.edu/wraws/prF.html]. Figure 2 provides an example of developing a "quick response" map for access to station data. Figure 3 shows example output for one of the stations (Slims) on the Figure 2 map.



Map Courtesy of DeLorme Topo USA

Figure 2. Example WRCC "quick response" map for the Slims fire. Blue pin locations are clickable to obtain climatology information.

FRWS-21 Slims #2 Idaho

Monthly Summary for

August, 2003

Day of Month	Day of Year	Total Solar Rad. ly.	Wind Ave. V. mph	Wind Dir. Deg	Wind Max. mph	Air Temperature Mean Deg. Fahrenheit	Air Temperature Max	Air Temperature Min	Fuel Temperature Mean Deg. Fahrenheit	Fuel Temperature Max	Fuel Temperature Min	Humidity Mean Percent	Humidity Max	Humidity Min	Dew Point Deg. Fahrenheit	Wet Bulb	Total Precip. inches
1	213																
2	214				8.0		88	58		92	57		93	21			
3	215		0.5	287	11.0	60	73	55	61	82	52	89	99	57	57	58	0.11
4	216				15.0		86	49		97	48		99	23			
5	217	423	1.1	40	22.0	61	89	45	63	101	44	79	99	25	52	55	0.57
6	218	386	1.4	8	11.0	62	80	52	65	90	52	84	99	49	57	59	0.04
7	219				10.0		84	47		95	45		99	37			
8	220				12.0		93	46		105	42		99	13			
9	221		1.3	359	17.0	70	96	44	73	109	43	48	95	8	41	53	0.00
10	222				25.0		95	44		106	42		86	7			
11	223	512	1.2	16	12.0	63	87	43	66	100	41	53	82	25	43	51	0.00
12	224	493	1.0	342	11.0	62	86	42	65	94	41	60	93	27	45	51	0.00
13	225	611	1.3	26	12.0	65	89	46	69	100	44	53	90	25	45	53	0.00
14	226	574	1.2	359	13.0	67	94	40	69	105	38	50	91	18	43	52	0.00

Figure 3. Example output for one of the stations in Figure 2.

<u>WRCC web usage</u>

Web usage continued as in past years with well over 250,000 accesses from participating agencies. This number is suspected to be low as it represents only those users accessing the web from locations that identify them as from participating agencies as opposed to private or contract service providers.

Task Order 9: Development of U.S. Operational Fire Danger 15-Day Forecasts (Sponsor: USDA Forest Service)

One of the primary objectives of Predictive Services at the National Interagency Coordination Center (NICC) is to provide relevant information about weather, climate and fuels for decision-making and planning for resource allocations and the determination of national preparedness levels. Prediction needs of weather, climate and fuels include short-term (1-2 days), medium-term (3-10 days), and long-term (30-90 days) forecasts. Operational daily forecasts from NWS provide much of the needed weather and climate forecast information for these periods, and there are also a number of experimental climate forecasts available that offer monthly and seasonal climate predictions. Forecasts of vegetation and fuel conditions at these various time scales are much more difficult to generate. Indices from NFDRS are often projected forward (e.g., via Fire Family Plus) as an indicator of future fire danger and then related to fire business, especially in terms of severity potential and resource demands. In order to predict preparedness levels and assess resource demands on daily and longer time scales at the national level, information needs include forecasts of weather, climate, fire danger, fire severity and fire potential along with how these factors relate to the various aspects of fire business. This project addresses a component of these needs - forecasts of weather and fire danger as an aid in assessing national preparedness levels and resource allocations.

The overall goal of the project is to develop a prototype system for producing operational forecasts of fire danger on a daily basis out to fifteen days. It incorporates national needs at NICC with operational forecast products produced by NWS. Techniques developed at the Missoula Fire Sciences Laboratory (MFSL) were used for producing national gridded predictions of ERC using fuel model G (ERC-G) by inputting NCEP/NWS Global Forecast System (GFS) model forecasts of temperature, relative humidity, wind, cloud cover and precipitation into NFDRS algorithms. To facilitate the standardized ERC concept, an ERC-G gridded national climatology was produced by MFSL. National maps of standardized ERC-G are currently produced by CEFA on an experimental and operational basis for use at NICC and the GACCs. Fifteen-day forecasts have been chosen for the prototype in part based upon information requests for preparedness level planning requirements at NICC and by GACC Predictive Services. The GFS model has been chosen for the prototype as an NCEP/NWS operational product meeting the 15-day requirement. This project is a collaborative effort with MFSL and NICC.

One of the needed components for producing a gridded ERC-G forecast is a gridded climatology of ERC-G. This climatology provides the mean and standard deviation information necessary to produce standardized values. A daily 8 km ERC-G grid was produced at the University of Montana, Numerical Terradynamic Simulation Group (NTSG) under direction of MFSL. The Daymet model provided the underlying high-resolution climatology of daily surface temperature, precipitation, humidity and radiation over complex terrain using both a digital elevation model, and daily observations of minimum and maximum temperatures and precipitation from ground-based meteorological stations. The calculation of ERC requires fuel moisture, state of the weather and precipitation duration. These values had to be estimated for input into the model. Woody and herbaceous fuel moisture was estimated from NDVI data. NFDRS state of the weather was estimated utilizing a cloud cover condition based on solar radiation provided by Daymet. Precipitation duration was estimated using a combination of climate class and season. Details of the methods are provided in Hall et al (2003; see publication list). The ERC-G climatology was calculated on a daily 8 km grid for the period 1982-1997. These 8km grids were then averaged to match the available GFS forecast grids of 1 and 2.5 degrees.

In December 2003, the project was extended and additional task elements were developed primarily to perform a validation of the algorithms used to produce the standardized ERC values. Also, the development of ensemble forecasts was also extended over to another year. Please refer to the 2003 and 2004 annual reports for previous task accomplishments. Work in the final portion of the extension was focused on adjusting both the Daymet climatology values and the GFS forecast values to better fit the RAWS distributions. This is described in more detail in CEFA Report 05-02, December 2005.

Product monitoring during the 2004 fire season revealed a potential forecast problem, particularly in southern California, where a large negative standardized value was appearing on a persistent basis. Analysis of this pattern indicated that there was a variance bias in Daymet leading to large standardized values. In other words, the distribution of Daymet temperature and relative humidity values was dissimilar to RAWS. Further investigation also showed variance bias in the GFS forecast values.

Figure 4 shows boxplots of RAWS and Daymet for a single grid point in southern California. The left most boxplot is unadjusted Daymet, the center boxplot RAWS, and the right boxplot adjusted Daymet based on a modified method utilized in remote sensing to "stretch" distributions. In this method, the 1st and 3rd quartiles (25th and 75th percentiles) are determined from both RAWS and Daymet, and used in an algorithm that adjusts the Daymet distribution to better match that of RAWS. The method typically uses the maximum and minimum data values for both the original and unadjusted datasets, but improved distribution adjustments were realized by utilizing quartiles for the Daymet data. In some cases, the adjusted maximum or minimum exceeded the original RAWS distribution; in this case, these values were reset to the corresponding RAWS maximum or minimum value. This method was also applied to the GFS forecasts. See the CEFA Report 05-02 for details of the algorithm.

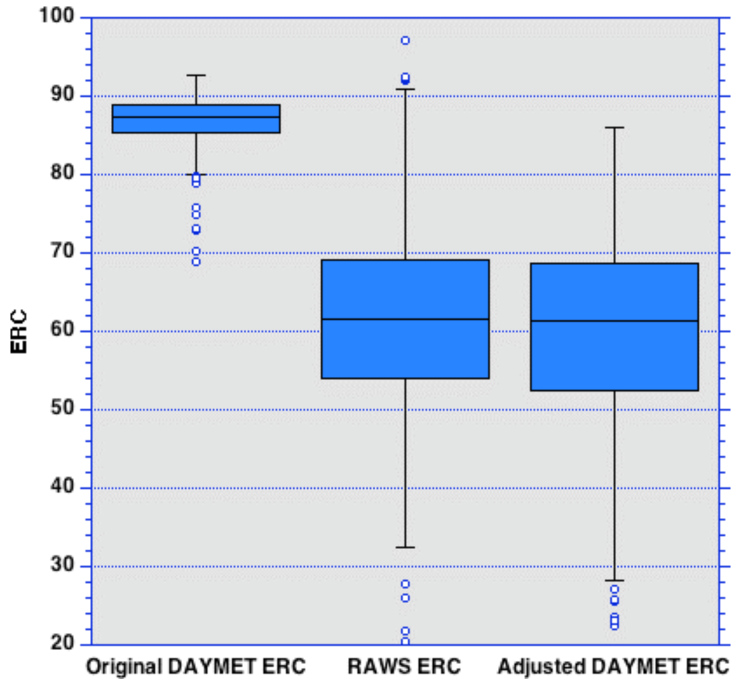


Figure 4. Box plots showing the distribution of August daily ERC values for unadjusted DAYMET, RAWS and adjusted DAYMET at the 120ºW, 35ºN grid cell located near the coast of southern California.

The boxplots in Figure 4 clearly show that Daymet ERC for this grid cell has much less spread in its distribution compared to RAWS, and has a large high bias (median value of approximately 88 compared to 62 for RAWS). The adjusted distribution more closely matches RAWS in terms of spread and median value, though it does lack a few outlying values in the upper end of the distribution.

While Daymet adjustments could be undertaken in grid cells that have corresponding RAWS, there are many locations where RAWS is not available to utilize in this process. Thus, sufficient adjustments of climatology bias and distribution are not available at all grid cell locations. In the future it would be desirable to produce a new ERC climatology that reduces mean and variance biases such that the distribution everywhere is more comparable to observed and expected surface observations.

<u>Product examples</u>

Three primary forecast maps are updated daily; these include actual ERC-G (Figure 5a), standardized ERC-G (Figure 5b) and ERC-G anomaly (Figure 5c). For these example maps, the color scale legend is shown at the bottom of each map, and the “block” appearance represents the unsmoothed model grid. Fifteen-day forecasts are available on the CEFA web site [http://www.cefa.dri.edu/data/NatlERC/natlErc.html].

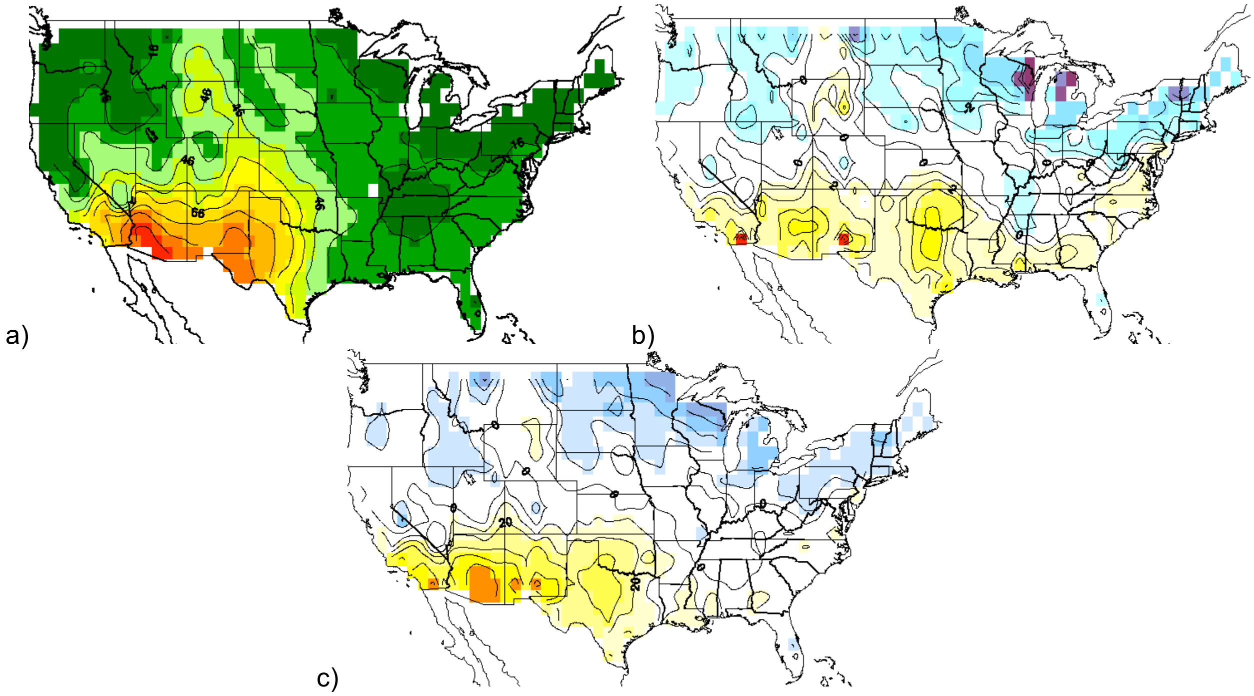


Figure 5. Example maps of ERC-G a) forecast values, b) standardized values and c) anomaly values.

Deliverables

Two primary operational products are available for fire management at NICC and regional levels: 1) GFS 15-day forecasts of standardized, actual and anomaly ERC-G for the contiguous U.S.; and 2) GFS 10-day ensemble forecasts of standardized ERC-G.

Task Order 10: Operations of the CEFA Operational Forecast Facility (Sponsor: CANSAC)

In May 2004, the California and Nevada Smoke and Air Committee (CANSAC) dedicated its facilities at DRI and began product generation. For an overview of CANSAC, please see the CEFA FY03 annual report (CEFA 03-02). The CANSAC web site [http://www.cefa.dri.edu/COFF/coffframe.php] contains a description of the facilities and products. Agency membership as of the end of September 2005 included USDA Forest Service Region 5, USDA Forest Service Pacific Southwest Research Station, Bureau of Land Management (California and Nevada State Offices), U.S. Fish and Wildlife Service, National Park Service, California Department of Forestry and Fire Protection, California Air Resources Board, and San Joaquin Valley Air Pollution Control District. CANSAC organizational structure includes the Board of Directors (BOD), Operational Applications Group (OAG) and the Technical Advisory Group (TAG). General deliverables from the CANSAC project include:

1) Meteorological model forecast output as defined by OAG.
2) Web based application products as defined by OAG.
3) Reports and/or presentations describing the functions and operations of CANSAC.

1. Current personnel

Primary CEFA-CANSAC personnel include Julide Koracin (operations and development manager), Domagoj Podnar (systems administration), Hauss Reinbold (post-processing, graphics and web support), Beth Hall (OAG liaison) and Tesfamichael Ghidey (Ph.D. graduate student) under the project administrative direction of Dr. Tim Brown.

2. Production of operational forecasts

The official CANSAC dedication meeting was held at DRI on 19 May 2004. Real-time product generation began officially on 1 June 2004, and is now an ongoing process. Forecasts are generated twice daily based upon NCEP 00 and 12 UTC Eta model initializations. New products and updates are developed and maintained under the guidance of the OAG. The product web page is [http://www.cefa.dri.edu/COFF/cansac_output.htm].

3. Assessment of 2005 products

From the very beginning of real-time production, OAG has been providing feedback on the usability of the products. This feedback has been in the form of email memos to CEFA and conversations with CEFA personnel. It would be desirable to establish a formal process of product assessment and documentation of this information. However, from a qualitative perspective OAG and the CANSAC communities have provided verbal and email reports, and are pleased with the products.

4. Project Deliverables

The project deliverables include a suite of fire weather forecast products identified by OAG. Products fall into four categories: 1) fire weather; 2) smoke dispersion and transport; 3) fire danger; and 4) fire behavior. Of these four, only fire weather has been developed and in a full production mode. Prototype fire danger forecast maps of energy release component, burning index, spread component and ignition component were introduced in the summer of 2005. These are based upon work undertaken at the USFS PNW station. Smoke products from the Bluesky system are anticipated for implementation by the end of 2005. Prototype fire behavior products are anticipated by summer 2006.

Below are samples of current products available from the CANSAC system. All products provided by the system are finalized by OAG for content and appearance. Figure 6 shows an example forecast map of color shaded surface temperature, wind speed and direction barbs, and contoured sea level pressure for the 36 km domain. Figure 7 shows an example forecast map of wind vectors and color shaded wind speed for the northwest quadrant of the 4 km domain. Figure 8 shows an example forecast map of energy release component. Figure 9 shows an example forecast map of color shaded ventilation index and wind barbs.

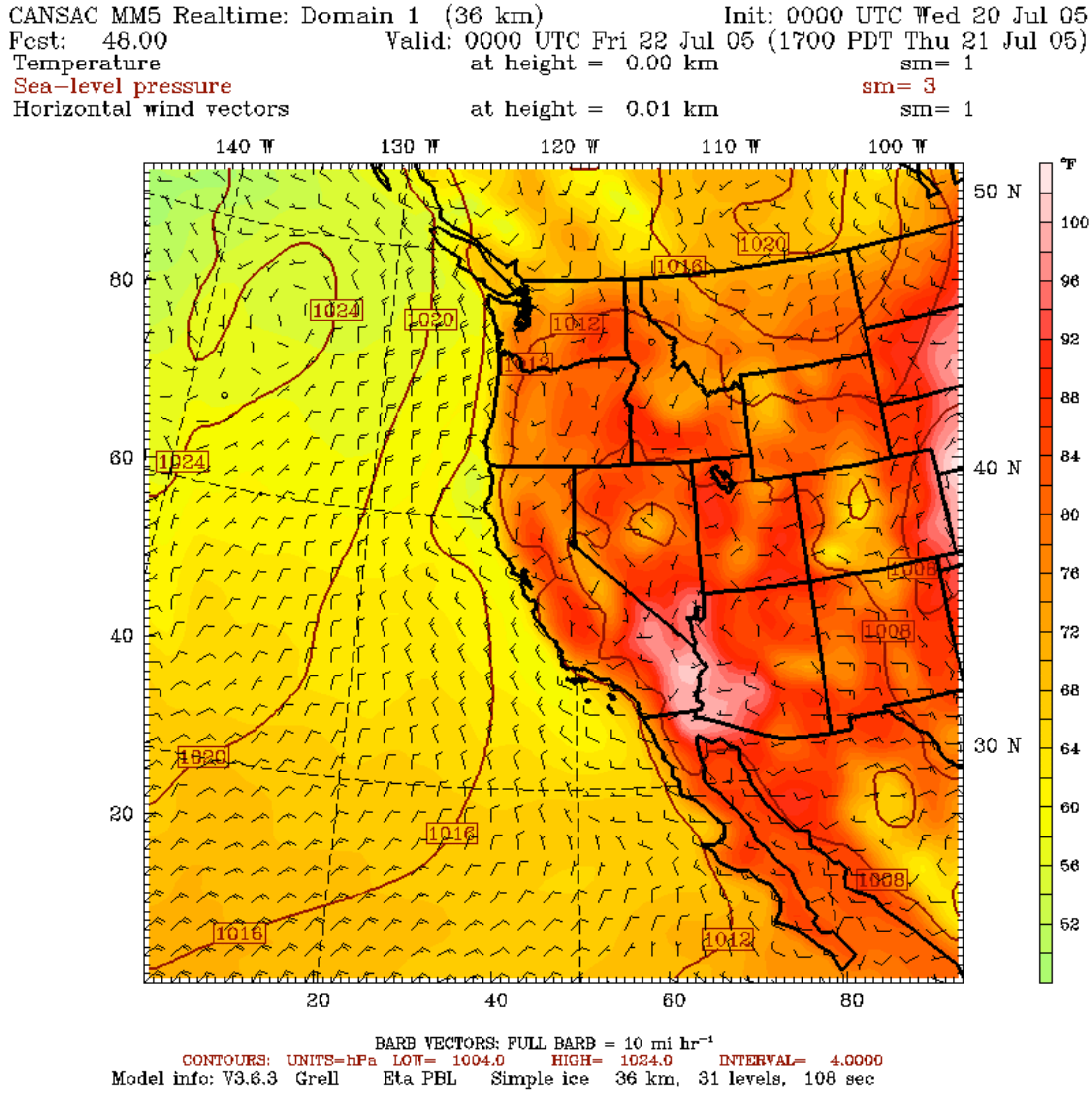


Figure 6. Example forecast map of surface temperature (color scale on right), sea level pressure (contours) and wind as shown by wind barbs indicating speed and direction.

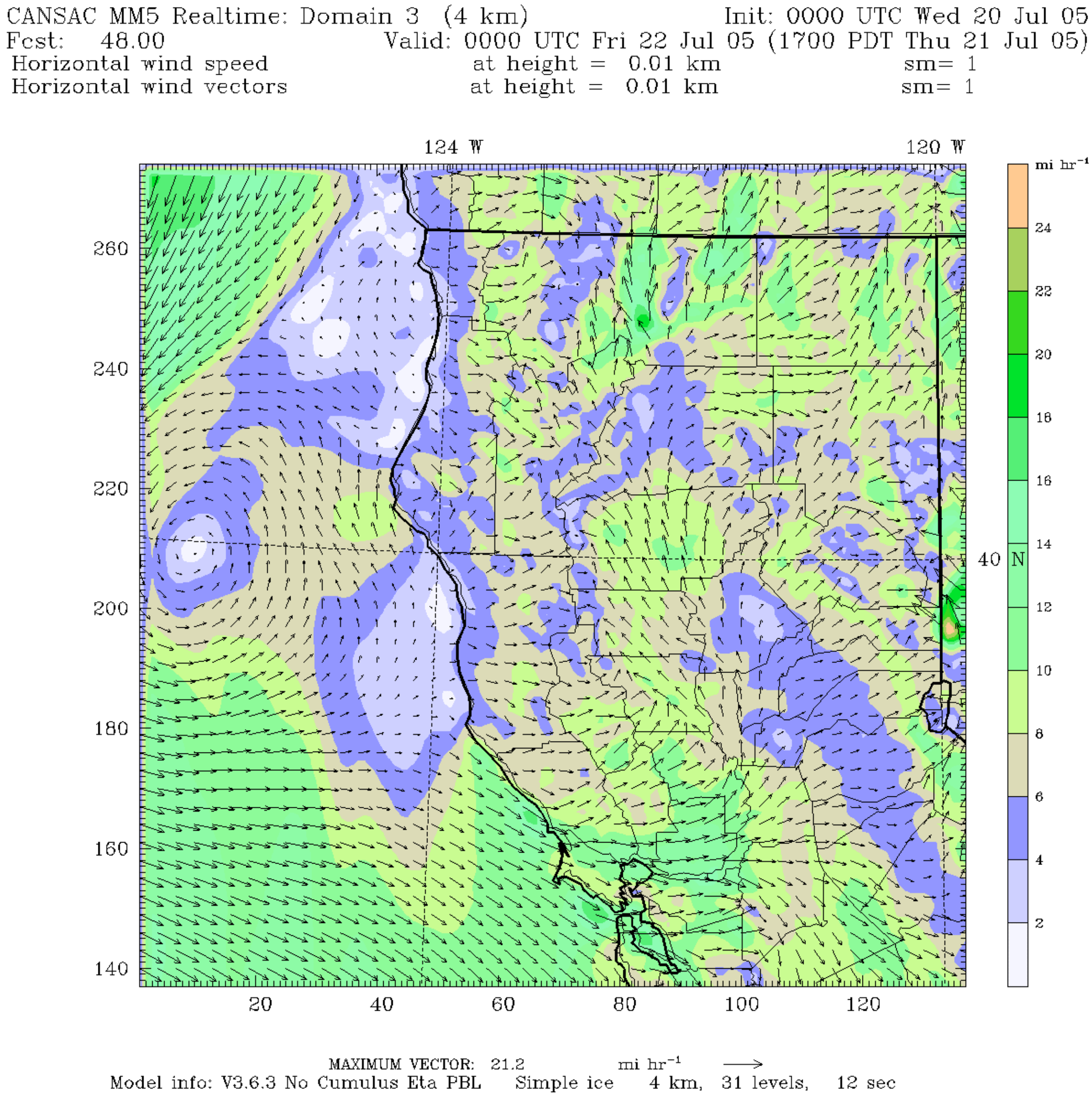


Figure 7. Example map of forecast wind speed (color bar at right) and wind direction (arrows) for the northwest quadrant of the CANSAC 4 km domain. These quadrant maps provide the highest detail for a particular meteorological variable.

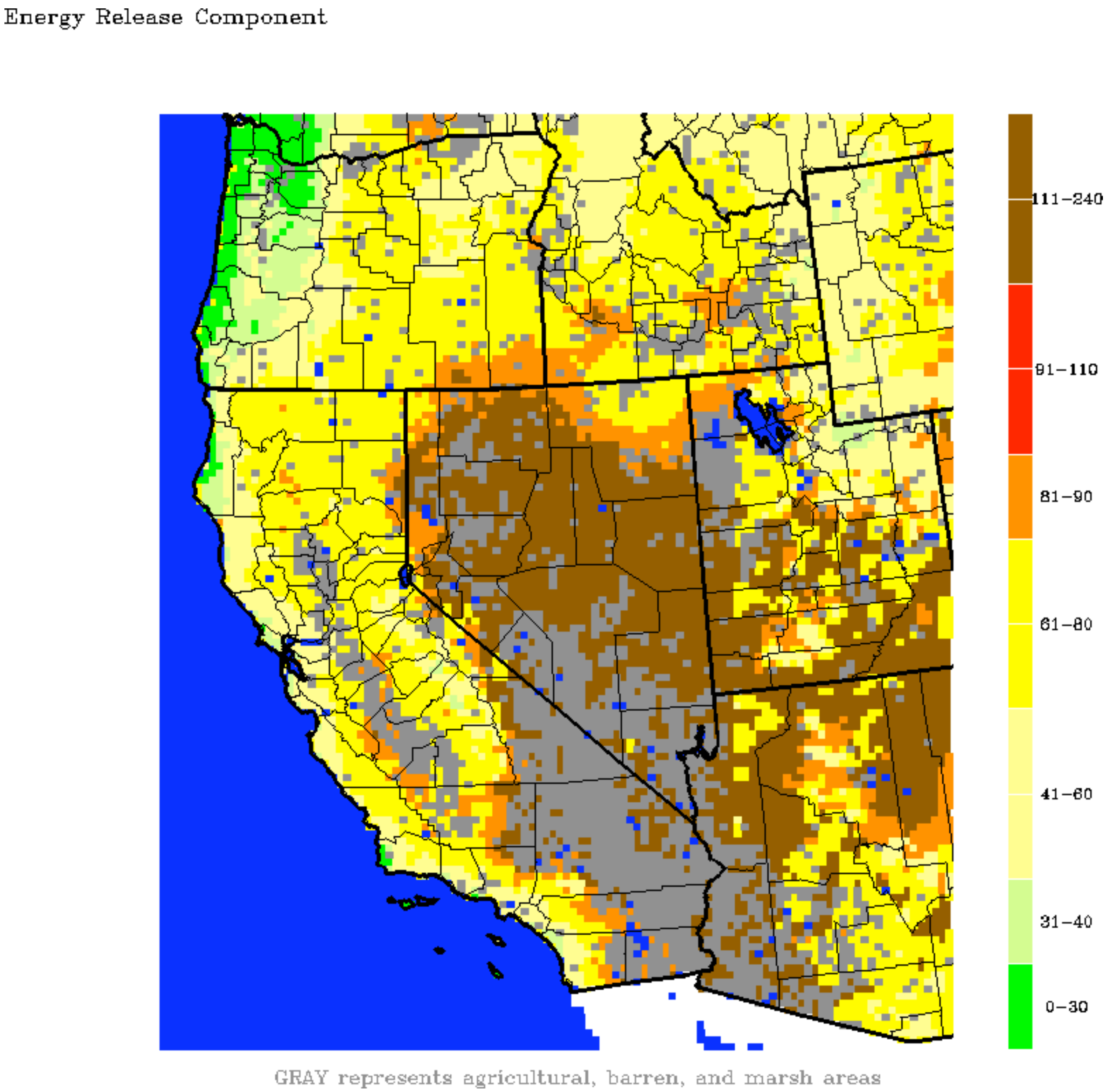


Figure 8. Example forecast map of NFDRS energy release component (ERC).
Color scale denotes ERC range value.

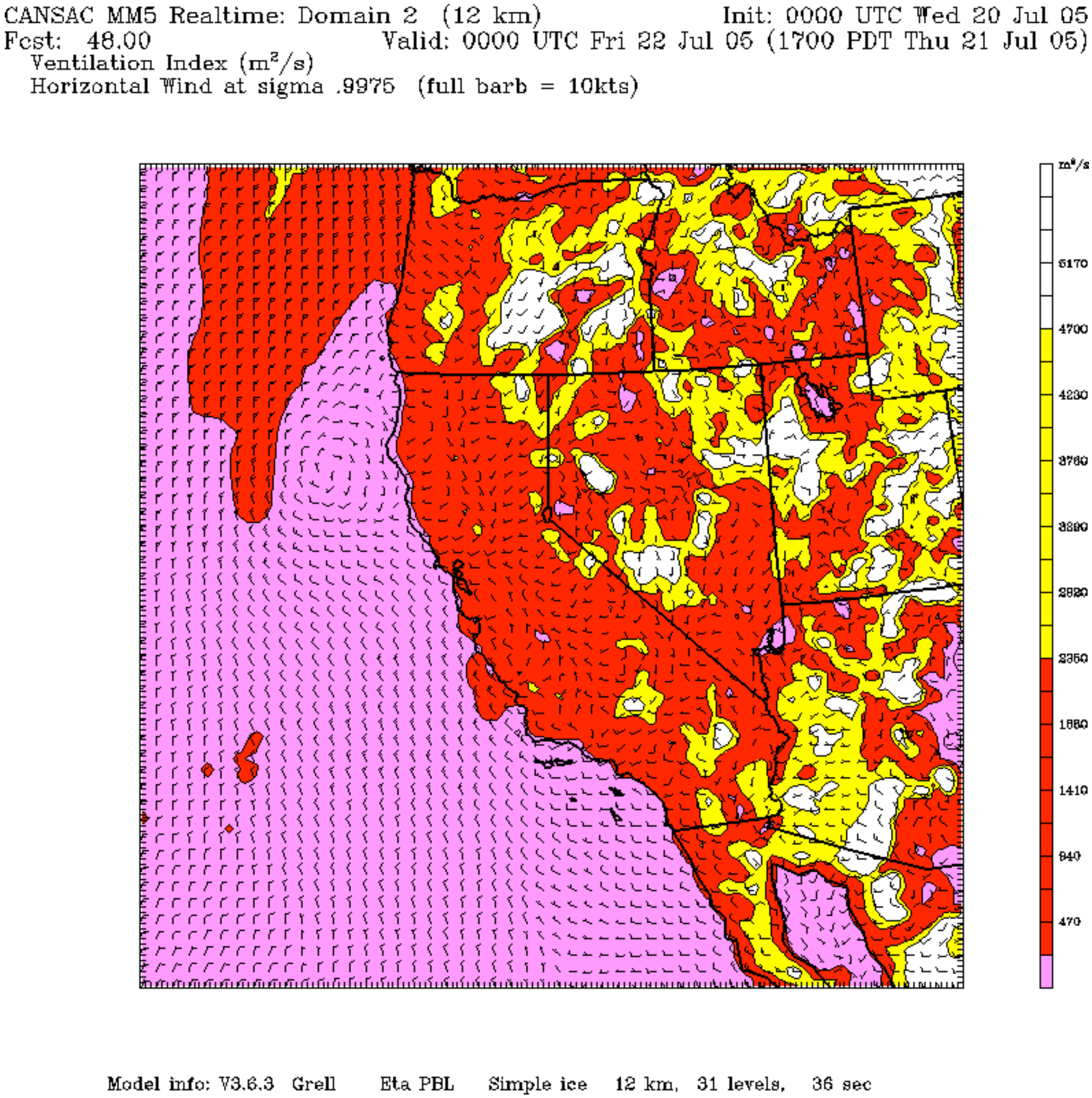


Figure 9. Example forecast map of the ventilation index. Color bar at right gives index values. Wind barbs are also shown on the map.

5. FY06 Work Plan

The major elements of the CANSAC project work plan in FY06 include continuation of real-time products and product development per OAG recommendations, further development of the real-time verification system, implementation of the Bluesky system, refine NFDRS products as appropriate, develop prototype fire behavior products and capitalize on relevant research opportunities as they become available. The real-time verification system updates will include time series of forecasts versus station and sounding observations. The Bluesky system will initially provide forecast maps of PM concentrations based on wildfires from 209 reports, and prescribed burn concentrations based upon inputs from burn plans. Fire behavior products will be output of MM5 wind field grids for input into FARSITE and FlamMap.

Task Order 13: Understanding Drought for Interagency Fuels and Fire Business (Sponsor: National Interagency Fuels Coordination Group)

Task Order 13 began 1 September 2003 with the hiring of Master's graduate student Ryan Kangas and is intended to be a multi-year project. The specific task elements for this year's project phase are provided below, but the ultimate goals of the project are to 1) provide an understanding of drought as an impact on fire and fuels management, and 2) assess the predictability of drought from seasonal to multi-year scales for strategic planning and budgeting.

Specific task elements for the first year of the project included:

1) Determine spatial extent of drought. For SPI indices, a statistical method will be developed to determine the spatial extent of drought. Once a satisfactory method is developed, analysis will be undertaken to determine the spatial scales of drought for various SPI thresholds (e.g., -2.0 for the 12-month SPI).
2) Determine temporal extent of drought. Once spatial drought has been identified, how often these events occur will be analyzed. This will be done for several SPI time-scales.
3) Relate drought information to vegetation. A high spatial resolution national fuel map will be analyzed in relation to the spatial extent of drought determined in task element 2). This analysis will provide information on where and how often various vegetation types may have been impacted by drought. This is not meant to be a definitive study on the relation between drought and vegetation, but is intended to provide some fundamental background on potential impacts that can be applied to future projects to assess drought for fuels management and budget planning.
4) Prepare report. A report describing these results will be prepared at the end of the project. The project is also anticipated to be a Master's thesis, and will be published as such and as a scientific journal manuscript.

The primary purpose of this study was to examine the spatial and temporal characteristics of drought and pluvial (anomalously wet) events utilizing a monthly U.S. high-resolution spatial precipitation dataset. This information is important to understand the characteristics of historical dry and wet periods, which in turn is proxy information on what fuel conditions may have been like during these periods, and subsequently provides insight into possible climate scenarios for strategic planning and potential treatment outcomes (at least based on historical occurrence). Fourteen indices comprising the Standardized Precipitation Index (SPI) and the Palmer Drought Severity Index (PDSI) were computed monthly on a 4 km grid for the contiguous U.S. based on PRISM (Parameter-elevation Regression on Independent Slopes Model) precipitation data for the period 1895-2003. Each month for each year had 451,709 grid points for which multiplied by 14 indices yielded over 8.2 billion grid point calculations.

The Palmer index is based on the concept of anomalies in the supply and demand of the water balance equation. The calculations involved in the PDSI are quite complex as 68 terms are involved in creating the final output. The inputs include precipitation, temperature, evapotranspiration, soil moisture and latitude. The data are standardized to account for regional differences; therefore, the index should be a similar representation for differing areas even though the actual rainfall deficiencies vary. The SPI is a probability-based indicator of drought in that it is essentially a standardized transform of the probability of the observed precipitation, or a statistical z-score representing the precipitation deficit over a specific time scale relative to the climatology. Standardizing the precipitation allows the index to be used as a comparison of drought severity across different hydrologic regimes. Positive values for either index refer to wet conditions and negative values refer to dry conditions.

During the study it was recognized that analyzing pluvial periods was just as important as analyzing drought periods for fuels management. The sections below summarize the key results of the study. One general result is that the definition of a drought or pluvial in terms of index magnitude can dramatically affect the size, duration and location of the event. This is important in the context of fuels management, because a needed study is to quantify vegetation stress and growth in relation to these different indices. This is also important for seasonal prediction of vegetation particularly in the context of specific treatment activities. For example, for a given precipitation index, a relevant question is how much dry or wet impacts a given fuel treatment (e.g., prescribed burning)? Another general finding is that utilizing a higher-resolution gridded dataset indeed provides information often masked by a coarser spatial size such as a climate division or even a large grid (see Figure 10 below). This is important to fire and fuels management as efforts are made to generate gridded maps and GIS layers for agency analyses and planning.

1. Spatial extent of drought

Key findings regarding analyzing the spatial extent of the precipitation indices include:

1. The largest drought and pluvial areas tend to occur during the winter season.
2. The largest drought and pluvial areas occur at shorter timescales (i.e., 1- and 3-months), and conversely, longer period drought and pluvials occur over smaller areas.
3. Drought and pluvial have similar spatial patterns.
4. The largest drought and pluvial areas tend to occur in the Midwest compared to other areas.
5. The majority of extreme index values have occurred in the western portion of the U.S. (see Figure 11 below).

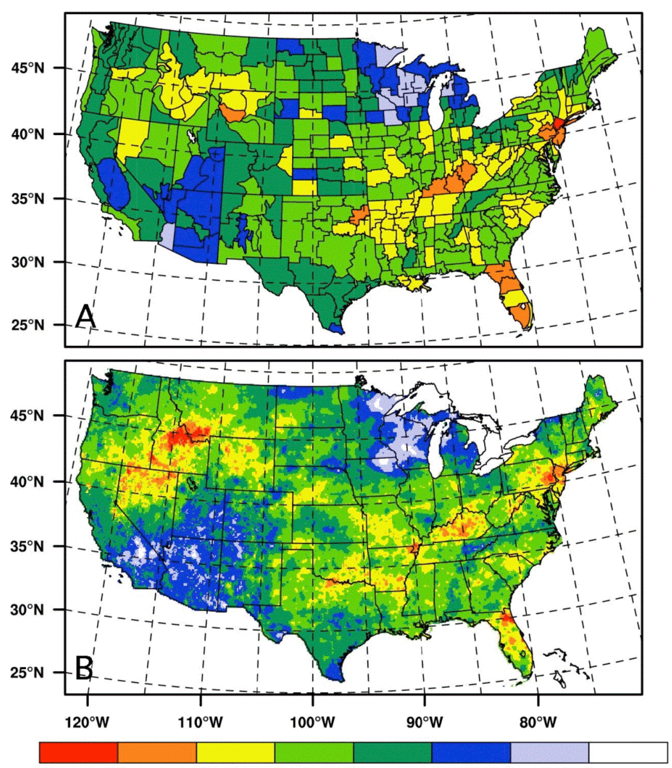


Figure 10. 1-month SPI for July 1999 showing (A) index values based on climate divisions and (B) index values based on PRISM data. Color scale denotes SPI index value.

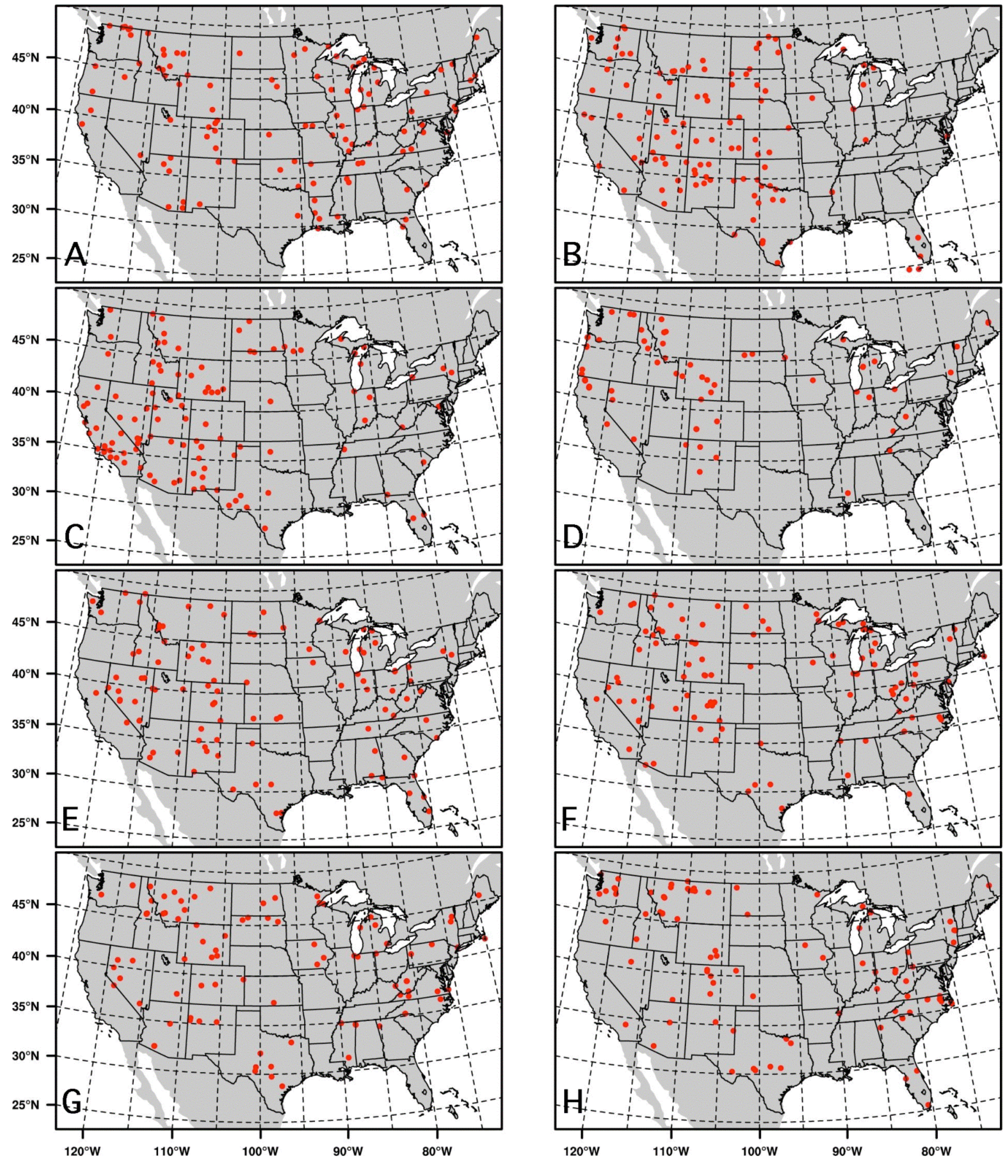


Figure 11. Maps showing the locations (solid dot symbol) of the most extreme annual dry values for the 1895–2003 period for (A) 1-month SPI, (B) 3-month SPI, (C) 6-month SPI, (D) PDSI, (E) 12-month SPI, (F) 24-month SPI, (G) 36-month SPI, and (H) 72-month SPI.

2. Temporal extent of drought

Key findings regarding analyzing the temporal extent of the precipitation indices include:

1. All timescales show considerable interannual variability (see Figures 12 and 13 below).
2. Longer timescale indices (e.g., 48- and 72-month) best highlight the longer-term drought and pluvial events (e.g., droughts during the 1930s and 1950s).
3. Up to around 1970, there was a greater tendency for dry events over the U.S. as a whole; since 1970 the pattern has been primarily wet. This is especially highlighted in plot H in Figures 12 and 13 below.

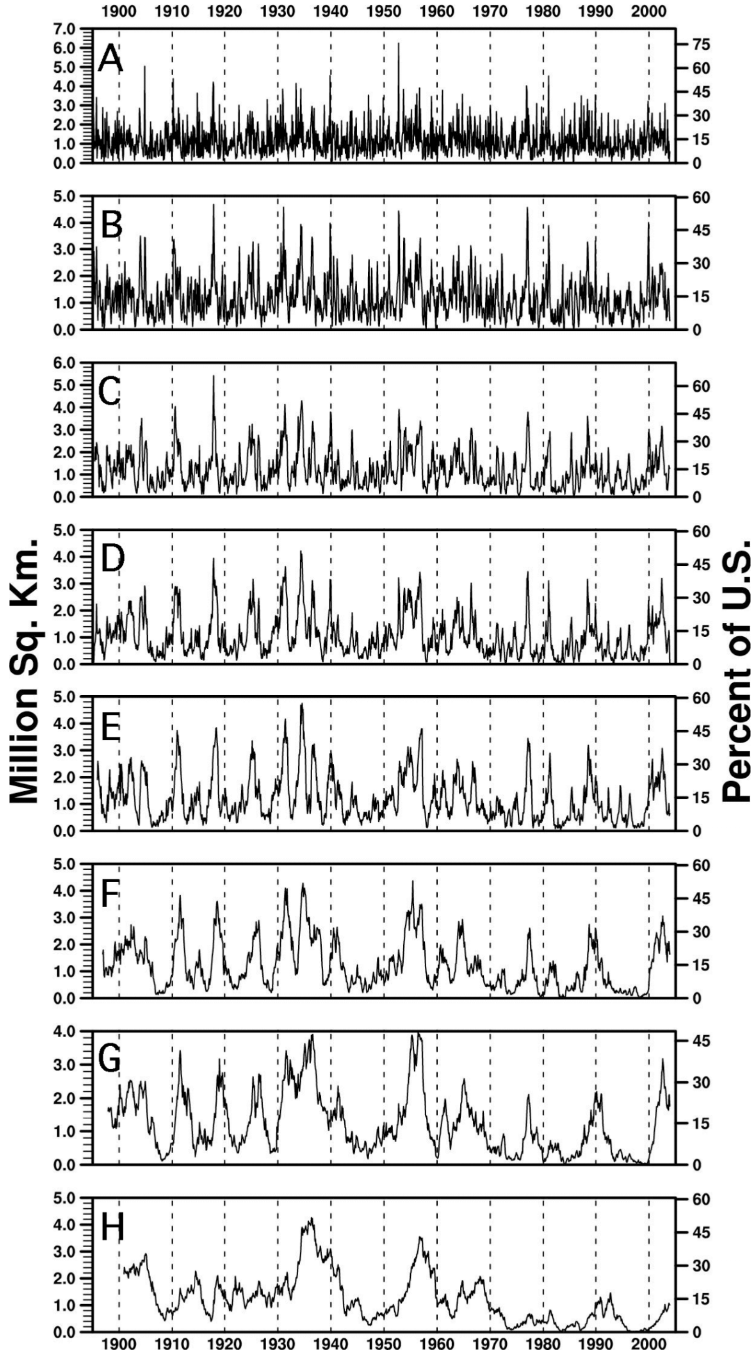


Figure 12. Monthly time series plots representing the total drought area (in millions km^2) for eight drought indices with the corresponding percentage of area given on the right axis for (A) 1-month SPI, (B) 3-month SPI, (C) 6-month SPI, (D) PDSI, (E) 12-month SPI, (F) 24-month SPI, (G) 36-month SPI and (H) 72-month SPI. Note that different scales are used as needed to highlight individual plot features rather than a direct comparison of the indices.

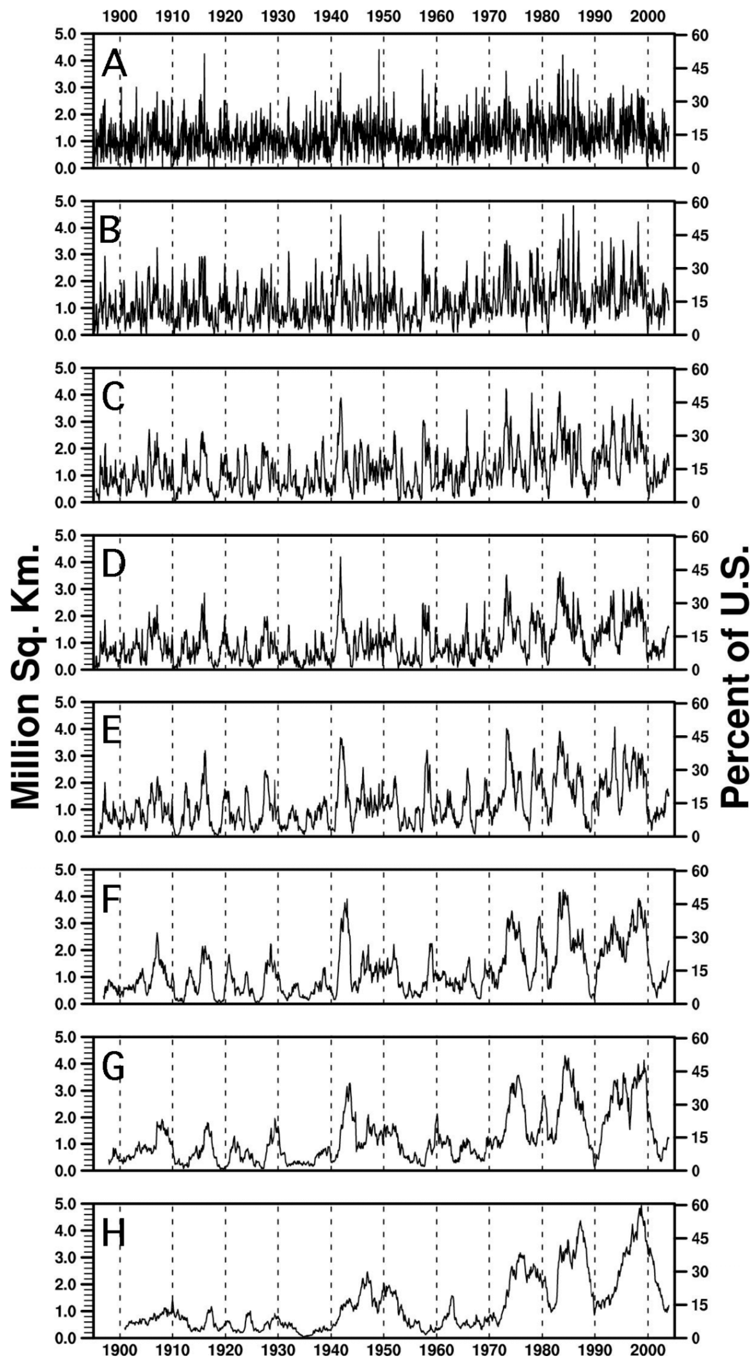


Figure 13. Monthly time series plots representing the total pluvial area (in millions km^2) for eight drought indices with the corresponding percentage of area given on the right axis for (A) 1-month SPI, (B) 3-month SPI, (C) 6-month SPI, (D) PDSI, (E) 12-month SPI, (F) 24-month SPI, (G) 36-month SPI and (H) 72-month SPI. Note that different scales are used as needed to highlight individual plot features rather than a direct comparison of the indices.

3. Vegetation

In brief, this component of the project did not come to full fruition. Attempts were made to establish a quantitative relationship between spatial drought characteristics and a current fuel model map. It was desired to determine if any vegetation types were especially susceptible to short- or long-term spatial scale drought. Or in lieu of finding a specific relationship, perhaps be able to describe drought characteristics in terms of vegetation. For example, indicate drought characteristics of different fuel models given historical precipitation patterns overlain on a fuel model map. No specific relationship was discovered, and describing fuel models in the context of drought did not prove to be effective either. The examination of spatial drought statistics showed that only a portion of the Midwest was more susceptible to drought than other portions of the country, and this only on the short-time scales (e.g., 1- and 3-months). Hence, there is no necessarily preferred area for drought to occur, though perhaps less so along the coasts compared to the interior.

Thus much of the project emphasis was placed on analyzing the spatial and temporal characteristics of drought and pluvial regimes. An analyst or decision-maker can readily examine the various maps produced in the study, and relate this information to their particular area of interest and vegetation type. It would be desirable in a future study to better quantify the relationship between precipitation and vegetation type for the various fuel models. There remains an interesting question of just how much drought or how much moisture affects fuel treatment implementation and fire potential.

4. Prepare report

As of this report writing, a Master's thesis was nearing completion describing all of the relevant project results. The thesis is also being prepared as a journal paper for submission to the *International Journal of Climatology*. Thus, the thesis and paper should be finished nearly simultaneously. Completion is anticipated in December 2005.

Deliverables

The primary deliverables for this reporting period include 1) the development of a historical high-spatial resolution database of drought index data for the U.S.; and 2) an analysis of this dataset to summarize the spatial and temporal characteristics of drought and pluvial regimes. It is anticipated that 1) this information will provide important insight into a basic understanding of historical precipitation information that can be used for fuels management, and 2) this information will be beneficial in the development of prediction models for drought and pluvial events.

Future work

The next phase of the project will focus on utilizing gridded datasets for developing climatologies of fire danger, growing season indices and green-up. It is desired to provide a dataset that can be used in analyses for a variety of fuels management questions ranging from prediction for treatment planning to air quality issues related to prescribed burning.

Specific task elements for the FY06 SOW include:

1. Develop North American Regional Reanalysis (NARR) climatology. Using gridding methods for NFDRS previously developed at the Missoula Fire Lab and from the Task Order 9 project of producing gridded national forecasts of standardized ERC, a daily climatology of ERC for NARR data period (1979-2005) will be developed. Relevant climatology information from NARR will also be extracted and a database generated in association with task elements 1) and 2) in Task Order 14 in conjunction with the escaped burns and fuels management business thresholds, respectively, and task element 3) below.
2. Analysis of gridded NARR data. Once the climatology has been developed, statistical analysis will be undertaken to examine temporal and spatial patterns of the relevant variables including ERC and soil moisture. The purpose of this analysis is to provide

quantitative information to fuel and fire managers regarding regional variability and patterns of climate factors directly impacting fuels during the past 25-year period. This information will be useful for strategic fuels management planning.

3. Burn/air quality windows. Burn windows based upon fire environment (weather and fuel moisture) thresholds are determined for every prescribed burn event. However, for many locations, air quality standards must also be considered for a go/no-go burn decision. An air quality district or agency typically makes this decision based upon criteria that they have established. There are numerous instances when the fire environment and air quality burn windows do not sufficiently overlap, leading to missed target goal opportunities among other frustrations. This task element will initially focus on the southeastern U.S. for which a climatology of fire environment and air quality burn windows will be computed utilizing the gridded NARR data, station data and agency threshold input. This information will be provided to the agencies and assessed in terms of its effectiveness as a decision-support tool in burn planning.

Task Order 14: Role of Climate in Prescribed Fire (Sponsor: BLM)

Task Order 14 began in January of 2004 with the hiring of Master's graduate student Crystal Kolden, and was extended through FY05. Ms. Kolden completed her Master's thesis in May 2005 and was hired as a temporary research assistant to pursue further studies under Task 14. Her Master's thesis work highlighted results of a survey undertaken during the first part of this project. The survey examined the utilization of climatology information for prescribed fire. During summer 2005, Ms. Kolden did not work on the project while working as a seasonal Forest Service firefighter.

In the CEFA FY04 report, the survey questions were provided and some preliminary results discussed. However, since that report approximately 50 additional respondents were contacted nationally. Primary survey results were given at an EastFIRE conference presentation at George Mason University in May 2005, and are discussed below.

Thirty-one questions were asked about what types of weather and climate indices fire managers use for prescribed fire purposes, how long the review process is for prescribed fire plans, if fire managers are measuring on-site fuel moistures, what some of the primary obstacles are to completing prescribed burns, and what the primary cause of escaped fires has been for their unit. The University of Nevada-Reno Human Subjects Board approved the survey for implementation. The survey was given to 192 prescribed fire managers throughout the United States of which 32 represented the eastern and southern areas. All five of the primary federal land management agencies that utilize prescribed fire were included (BIA, BLM, FWS, NPS, and USFS), as well as numerous state agency personnel. Additionally, each of the 11 Geographic Areas designated by the National Interagency Coordination Center were represented.

Two survey questions were used to specifically assess whether or not respondents were using climate information in their prescribed fire programs. First, it was asked what the top influences are on how respondents set their targets for burning each year. For combined national results, funding was the top influence for 41% of the respondents, while issues such as resource availability or timber sale activity influenced 23% of the respondents. In terms of the role of climate only 2% of the respondents felt that climate information or seasonal climate forecasts were the top influence on their target planning, and only 17% of respondents felt that climate information or seasonal climate forecasts were one of the top three influences for setting annual targets (Figure 14).

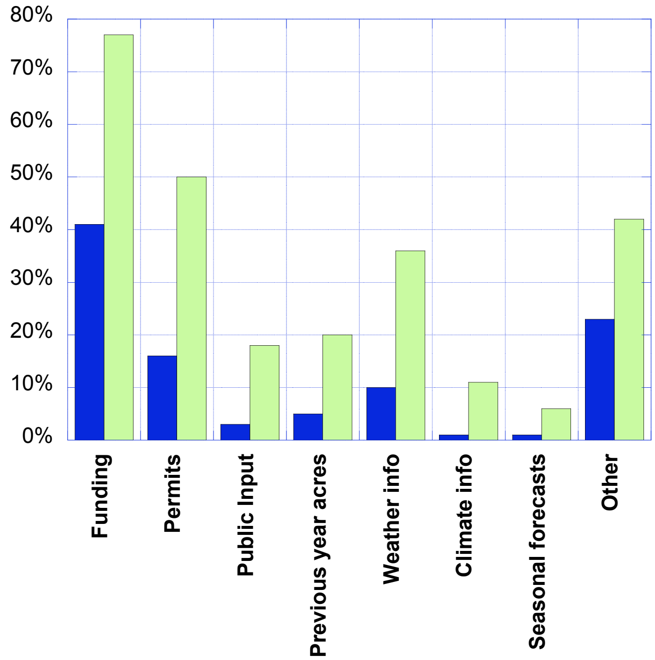


Figure 14. The top influence (solid blue) and top three influences (light green) on how respondents set their annual acreage targets by percent of respondents.

The second question that assessed whether or not prescribed fire managers utilize climate information asked respondents if they do or do not use a series of data sources, tools, and indices that track weather and climate and impacts on fuel conditions. These included Remote Automated Weather Stations (RAWS), seasonal climate forecasts, National Weather Service forecasts, Keetch-Byrum Drought Index (KBDI), Palmer Drought Indices, the US Drought Monitor, FireFamilyPlus, etc. While most respondents indicated that they use RAWS data (93%) and the National Weather Service forecasts (93%), other tools that better indicate climate anomalies are not used as widely. KBDI (33%) and the Palmer indices (27%) are used by less than a third of respondents to assess conditions for prescribed fire, while 51% use historical weather data, and less than half utilize the FireFamilyPlus software program (44%). Low use rates for these and other indices indicate that prescribed fire managers are primarily taking into account weather influences on prescribed fire use, and not climate influences.

The low use rate of climate information may stem from the constraints felt by many respondents on when they can utilize prescribed fire. Many noted that they are unable to utilize optimal burning windows due to air quality regulations, conflicts with Threatened and Endangered (T&E) Species requirements, a shortage of qualified personnel and resources, and the perceived wildfire threat in other parts of the country affecting local willingness to put fire on the landscape. Distinct differences between eastern and western managers were evident in terms of their constraints, and smoke management was a local constraint felt by all agency respondents in specific airsheds such as southern California's San Joaquin Valley, the Missoula area in western Montana, the Carolina plains, and near the National Parks with the highest tourism rates.

The influence of the National Fire Plan and follow-up directives such as the Healthy Forests Initiative were easily detected when respondents were asked what their two primary objectives for prescribed burns are. Hazardous Fuels Reduction was the top answer, with 93% of respondents indicating that this is one of their top two objectives. Additionally, 45% of respondents chose Ecosystem Restoration as one of their top two objectives, while 27% said they burned for Habitat Improvement (Figure 15).

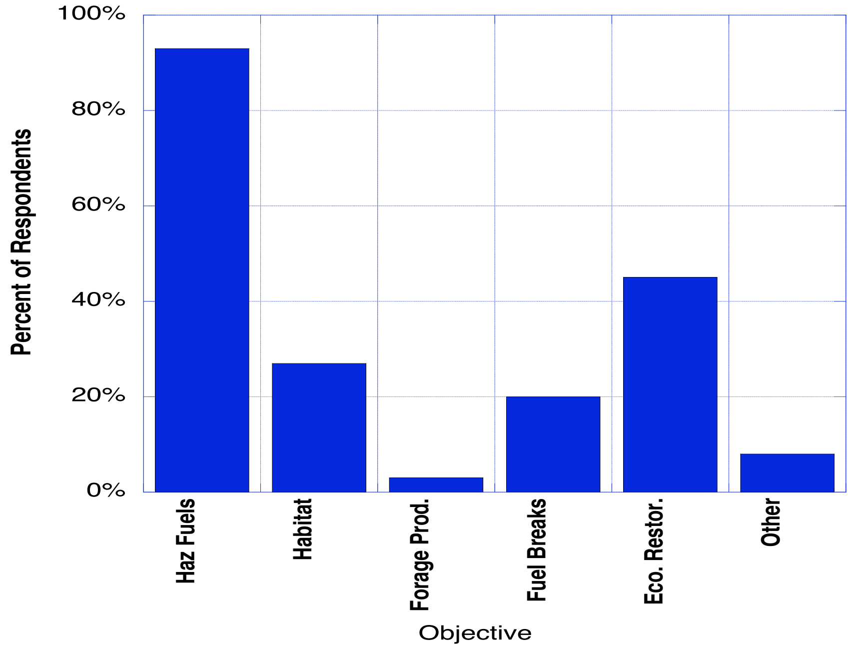


Figure 15. Percent of respondents indicating their top two primary objectives for prescribed fire use.

The respondents from the Eastern Area and Southern Area regions differed from western fire managers in several distinct ways. Many of these respondents noted that the majority of fire management tools are built for western fire managers and are not useful for eastern ecosystems. Additionally, one of the primary obstacles to eastern fire managers completing prescribed fire is the loss of personnel and funding to the western wildfire season during months when prescribed fire use might actually be optimal in the eastern US. Prescribed fire managers in the East are completing an average of 93% of their acres using broadcast or underburning, compared to only 59% in the West. Eastern managers have far fewer RAWS units available, and only 78% of respondents use RAWS, while 100% use NWS forecasts. KBDI is widely used by eastern managers (81%), while the Palmer Indices are not (13%). Problems with fuel models and lack of data in the East may be one reason why only 22% of eastern respondents use FireFamilyPlus software. While eastern managers also have an emphasis on hazardous fuels for prescribed fire objectives (94%), there is a greater emphasis on ecosystem restoration among the eastern managers, as 72% had this as one of their top two objectives. Overall, eastern managers complete far more acres of prescribed fire each year with seemingly fewer tools.

The primary objectives of this project's second year are to develop a prototype system for forecasting and displaying prescribed fire prescription thresholds, developing an escaped burn index for northern California, generating prescribed fire meteorological threshold and maps, and developing educational material for fire management on the use of climate information for prescribed burning. The ultimate project goal is to have an improved understanding of the role of climate in prescribed fire use, fire use and overall fuels management, and to use this knowledge to help agencies establish effective burn policy and meet management objectives.

During the project's second year, specific task elements included:

1. Climatological threshold tables and maps. Generate climatological tables and maps of prescribed fire thresholds based on survey information for the California-Great Basin region. This information will include descriptive summaries of basic meteorological elements (e.g., temperature, relative humidity, wind), and daily or weekly probabilities of threshold combinations being within prescription.
2. Prototype prescribed fire threshold forecast and display system. Utilizing prescribed fire threshold information from the user surveys and collected burn plans associated with the survey in the California-Great Basin region, develop a color-coded graphical forecast system that displays when combinations of meteorological and fire danger thresholds are within prescription, near the boundaries of prescription, or outside of prescription. Initially, NCEP model output will be utilized for the forecasts, but it is anticipated to tie this component into California and Nevada Predictive Services. The initial system will be for 10-day forecasts.
3. Develop escape burn index. Northern California Predictive Services (NCPS) believes that they have identified certain meteorological conditions (dryness factors in combination with wind) that can lead to an escaped burn. They have requested that an index be developed and tested, in anticipation of providing a useful prediction tool for escape burn probabilities. Interest in identifying climate/weather related escaped burn was also noted from the survey results. A statistical regression equation will be used to develop the index.
4. Develop education material. Results from the survey suggest for many fire managers a basic understanding of climate in relation to prescribed fire is lacking, and in many cases noted as desirable to have. One or two articles will be prepared for the publications *Fire Management Notes* and *Wildfire* to discuss and train on the relevant issues. This component is meant to provide a fire community outreach and educational element of the project. A small report will be prepared for NWCG providing recommendations on how climate information should be better integrated in training courses and programs.
5. Prepare report. A report describing these results will be prepared at the end of the project. The project is also anticipated to be a Master's thesis, and will be published as such, though it will focus more on the survey and associated data analysis.

<u>1. Climatological thresholds and maps</u>

The analysis of climatological thresholds is being separated into two components – prescribed fire burn window occurrence and escaped prescribed fire climate thresholds (also a component of task element 3). Utilizing data from the survey conducted in the first and second years of this task order, a series of prescribed burning window optimization tables were developed for a specific site within the study region of California and the Great Basin. In the development of prototype tables, data for some RAWS were analyzed for historical burn window occurrence.

Figure 16 shows an example of the average number of days meeting prescribed burn thresholds for a RAWS site. The monthly curve shows that August has the most number of days for which the thresholds are typically met.

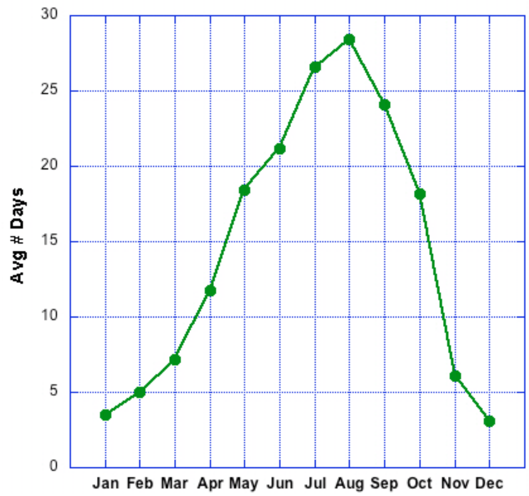


Figure 16. Historical analysis of burn window patterns reveals that for the window parameters prescribed, August has the highest average number of days when the burn window "opened".

Escaped prescribed fire events in California and the Great Basin were analyzed for climatological patterns of occurrence to determine the low ends of the climatological thresholds for prescribed fire use. Large escaped prescribed fires in southern Nevada were strongly correlated to drought conditions (based on Palmer-Z index) on a monthly scale, while escaped fires in much of California and western Nevada were strongly correlated to pluvial conditions (based on PDSI) on an annual scale. Large escaped prescribed fires (>200ha) were then assessed separately and found to occur under significantly high pluvial conditions of the 6 to 9 month time period inherent in the PDSI, and when fire danger levels were primarily average or below average. From these findings, work is continuing to develop maps for prescribed fire use based on drought conditions.

2. Prototype prescribed fire threshold forecast and display system

In conjunction with the prototype historical graphs developed under task element 1, a prototype for an interactive prescribed fire forecast system was developed. This system will allow the user to enter the parameters of a potential burn window, as well as the RAWS most closely associated with the site, and the month in which the manager would like to conduct the burn. The system calculates historical occurrence of the burn window. It is planned to experiment utilizing MOS outputs based upon model output from the Global Forecast Model (GFS) that are used to create a 10-day forecast of whether or not the window is predicted to occur. Additionally, it calculates the fire danger indices based on past dates of window occurrence, and determines if predicted fire danger levels are below, near or above the levels seen historically given the burn window. Figure 17 shows an example output from the prototype system.

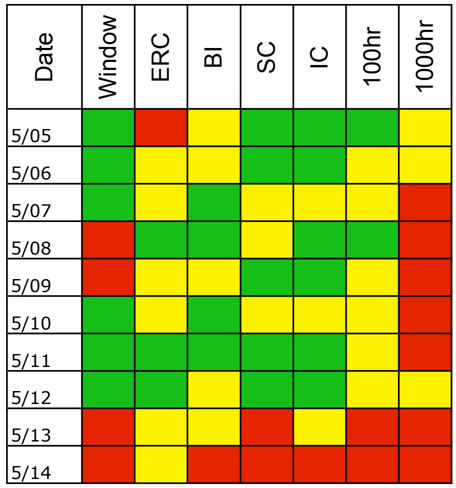


Figure 17. Example output table for the prototype prescribed fire threshold forecast and display system.

<u>3. Develop escape burn index</u>

The work in task elements 1 and 2, and results from the prescribed fire survey completed in FY04, indicated that most escaped prescribed fires in the northern California region occur in early fall (September and October). A preliminary hypothesis was developed that east wind events contributed to escaped prescribed fire occurrence. This was in agreement with the theory of forecasters at the Northern California Predictive Services unit. A preliminary analysis was undertaken to develop a statistical regression equation to describe the relationship between east wind events and escaped fire occurrence in northern California. A list of escaped prescribed fires for northern California was acquired from the Northern California Predictive Services unit and compared to the list of escaped fires generated from the escaped fire analysis in task element 1. Most of the escapes on the list did not match the database-generated list, indicating potential problems in data reporting for escaped prescribed fires. A reanalysis of the escaped prescribed fire list will be necessary to determine those dates that the escapes actually occurred on. Work on this element is anticipated to continue into FY06.

<u>4. Develop educational material</u>

A PowerPoint presentation covering various aspects of the results was developed and presented at several conferences in 2005, and is available to managers on the CEFA website. Several posters were also presented to scientists and managers at conferences in 2004 and 2005, including the Wildland Fire 2005 conference and other management-oriented meetings. An article intended for *Fire Management Today, Wildfire*, or similar management-focused journals is in development and review. Additionally, a peer-reviewed journal article for the *International Journal of Wildland Fire* is in development.

<u>5. Prepare report</u>

A Master’s thesis was completed and published in May 2005. A report describing the complete results of the Task Order will be completed at its termination.

<u>Deliverables</u>

The specific deliverables for this project phase are:

1) Reports describing the survey analysis results, the prototype system, the escape burn index, and climatological threshold maps and tables.
2) Outreach articles and presentations.
3) Web-based maps and tables providing climatological threshold information.

The escape burn index element of the project phase is anticipated to be completed in FY06 due to minimal work on this project during summer 2005.

Future work

The project is ongoing in FY06. In addition to completing the escaped burn index, refining the burn window prototype system and preparing educational material, new task elements include:

1. Climate-fuels management business thresholds. Build a database of prescribed fire events that includes date, location, management objectives and fuel model. The southeastern U.S. will be one of the focus areas, however data from other locations will be collected. It is of interest to collect data from each of the five federal fire agencies. NIFCG may provide guidance as to specific locations of interest. This is not meant to be a comprehensive database at this time, but a sufficient one to relate burns and climate conditions and build upon with the addition of other locations. Once the database is constructed, the burn information will be correlated with several climate indices to determine the background climate conditions leading up to and at the time of the initial burn. This effectively establishes a climate index directly related to fuels management business by management objective and fuel model.
2. Climate-Wildland Fire Use survey. Similar to the prescribed fire survey undertaken as previous work on this project, a formal fire use survey will be developed and implemented nationally directed towards the fire use community. Survey questions will focus on climate data and information issues relevant to planning and implementation of fire use activity.

Task Order 15: Development of Model Output Statistic Products for the Predictive Services Group (Sponsor: National Predictive Services Group)

Task Order 15 is for the period June 1, 2005 through September 30, 2006. This project logically follows Task Order 11 that produced RAWS model output statistic (MOS) data for California and Rocky Mountain Predictive Services in support of the 7-day fire potential product. In Task Order 15, the original MOS project has been expanded to include The Northern Rockies, the Western Great Basin, the Southwest and the Southern area Predictive Services group areas. In August 2005 a modification of this Task Order was developed to provide partial support for the Eastern area Predictive Services. Further funds are anticipated in FY06 to complete the Eastern area and Alaska.

The primary objectives of this project are to: 1) develop RAWS-MOS equations for all of the remaining GACCs excluding the Pacific Northwest and Eastern Great Basin areas where they have developed their own MOS equations; 2) provide operational output of RAWS-MOS forecasts via electronic transmission and web interface; and 3) continue to provide operational gridded output of GFS model fields that were determined in Task Order 11. The project will be a collaborative effort between CEFA, Southern California Predictive Services (SCPS), and each GACC that the product is being done for. Specific task elements from the original Statement of Work (SOW) include:

1) Development of RAWS-MOS equations based on GFS model output. Methods used in Task Order 11 will provide the framework for statistical regression techniques utilized in developing the equations. However, one change from the previous work is that GFS output will be transformed to a fixed predictor grid that will allow other models (e.g., Eta) to potentially be used in the MOS process. Historical GFS and RAWS data will be used for the 2001-2002 period to generate the equations. Cross-validation will be done on 2003 data. Analysis will be done for four GACCs with priority given as: 1) Northern Rockies; 2) Southwest; 3) Western Great Basin; and 4) to be determined by NPSG. The operational product will be comprised of 10-day forecasts from the GFS model. Validation on wind speed and direction, 10-hour fuel, BI and IC will be undertaken if time permits. Validation priority will be given to temperature, relative humidity, 100-hour fuel moisture, 1000-hour fuel moisture and ERC. The remaining elements will be examined in detail if project funding resources are available after the priority work is completed or new funding is available to the project. This task element requires interaction and feedback from the agencies in regards to the validation and operational testing of the equations. Specific predictand elements will include:
   - Maximum and minimum temperature, relative humidity and dew point. 00 and 12 UTC times will serve as proxy max/min model values.
   - 00 and 12 UTC wind speed and direction
   - 00 and 12 UTC 10-hour, 100-hour and 1000-hour fuel moisture.
   - 00 and 12 UTC ERC, BI, and IC
2) Development of RAWS climatologies. Climatologies will be developed for all of the predictand elements. These will be used for task element 3 below.
3) Development of value-added products from the MOS type output. Forecast tables of value-added climatology information will be provided in the product output. These will include:
   - Forecast climatological anomalies (departures from average) for each forecast period for temperature, relative humidity, dewpoint, and wind speed.
   - Forecast climatological percentiles (90^{th} or 97^{th} percentile) for each forecast period for temperature, relative humidity, dewpoint, and wind speed.
4) Prepare report. At the end of the project, a report will be prepared documenting the task element activities, products and deliverables.

This work is ongoing as of this reporting period. The Northern Rockies area was selected first for product development. Thus, accomplishments below primarily reflect this effort.

<u>1. Development of MOS equations</u>

MOS equations were developed for several elements requested by Predictive Services – maximum/minimum temperature, maximum/minimum relative humidity, maximum/minimum dew point, wind speed, wind direction, 100-hour and 1000-hour time-lag fuel moisture, the fire danger indices of ERC, BI, SC, and IC (based on fuel model G), and the Haines index for three levels (low, medium and high). The model times of 00 and 12 UTC were used for proxy maximum and minimum times, respectively. All of the other elements are for the 00 and 12 UTC times. Dew point values are based upon an algorithm calculation from forecasts of temperature and relative humidity.

The statistical software package S-Plus® was used in developing the regression equations to produce the MOS forecasts. Initially, all GFS elements were considered potential predictors. However, after considerable testing, it was determined that only a smaller subset of elements was really needed to generate satisfactory equations. The final methodology adopted was largely that developed by Terry Marsha at the Pacific Northwest Predictive Services. Mr. Marsha was consulted on several occasions regarding results of this project, and his time and support are greatly appreciated. The final set of model elements for the four nearest surrounding model grid points to the station to be considered yielded a potential total of 324 predictor variables. Analysis was done for the RAWS chosen by Northern Rockies Predictive Services as shown in Figure 4 below. After some testing, it was determined that two seasonal equations could satisfactorily represent the summer and winter seasons. An example of a typical regression equation is shown below. Given are the variable names used in the statistical software, and regression equation coefficients as determined from the equation development and diagnostics.

ERC = 0.4277*(pERC) -0.222* (pFuel1000) + 0.0588*(pMin.RH) - 0.0966(PR.Gr.1) + 0.2463*(850.temp4) - 0.3664*(850.RH.3) + 0.0137*(850.temp2) - 0.0424*(850.temp1) - 0.1113*(700.temp4) - 0.238*(850.RH.2) + 0.2153*(850.RH.1)

The MOS equations were developed on 2001 and 2002 data and cross-validated using 2003 observations. The cross-validation procedure provides correlations to determine how well the regression equation predicts a given element. A correlation of 1.0 is a perfect prediction, but is rarely achievable in this type of real-world application. Generally, correlations greater than .90 were achievable for temperature and ERC, but tended to be lower for relative humidity. Other than ERC, maximum temperature and minimum relative humidity tended to yield the highest correlations and hence the best predictability. Systematic equation assessment was only done for temperature, humidity, fuel moisture and ERC. Correlations were acceptable for most stations, but there are a few that remain problematic. An example of maximum temperature correlations is shown Figure 18.

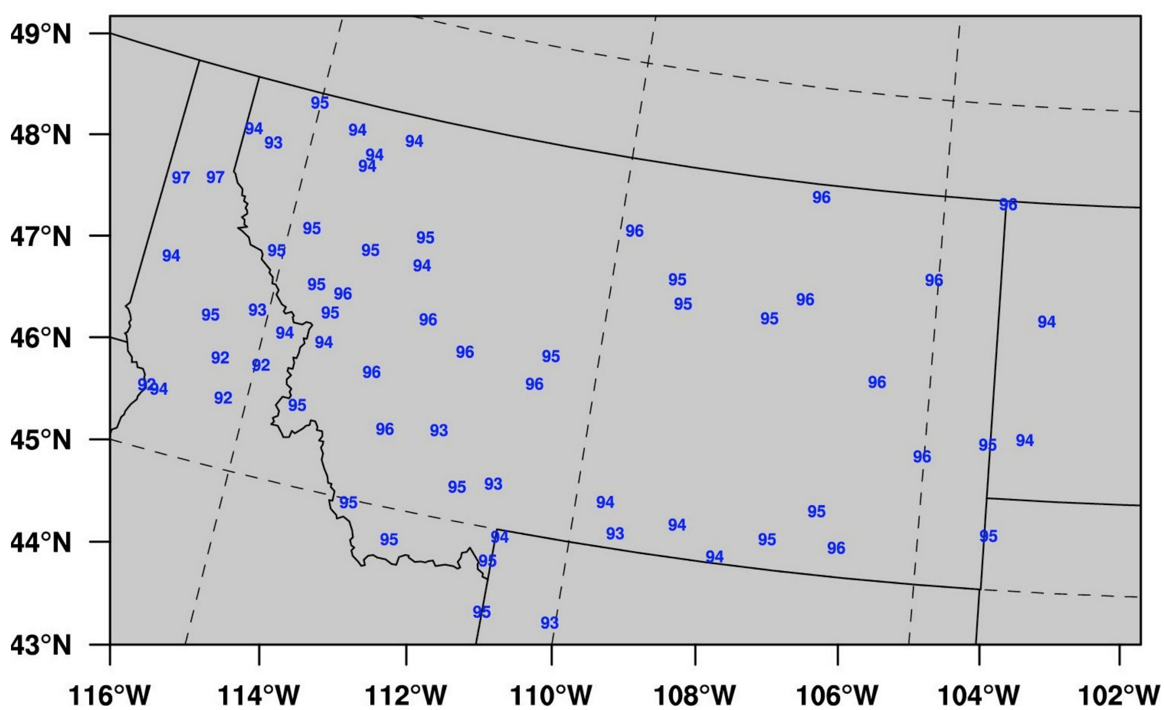


Figure 18. Cross-correlation values (times 100) for maximum temperature.

Lower atmospheric level elements of temperature and relative humidity serve as useful predictors of station temperature, relative humidity, ERC and fuel moisture. Lower-level wind serves as a useful predictor for wind speed and direction. For most cases, surface elements from the GFS model do not work well as predictors. This is primarily due to the fact the 1-degree gridded model field does not correlate well with individual RAWS given their variety of elevation, slope and aspect locations. Lower-level atmospheric fields (e.g. 925, 850 and 700 mb) serve as better predictors in part because they are smoother fields representing a generally free-air atmosphere compared to a high friction surface. It was determined in the analysis that the persistence for each predictand was also a very important predictor; for example, yesterday's value often has significant weight in predicting today's value. In order to produce operational forecasts, it then became necessary to acquire the previous day's values from WIMS. While these values could be obtained daily from WFAS, the problem emerged that not all of these stations are based on fuel model G, the preferred fuel model. Larry Bradshaw at the Missoula Fire Sciences Laboratory prepared a computer script that provided daily station output based on fuel model G. His effort in this project is greatly appreciated. This dataset along with the weather model output provides the input for the production of twice daily forecasts. Figure 19 provides an example of forecast output. The format of this table, as well as the other product tables and graphs, were determined by Predictive Services.

*Acton C	45438	-118.2	34.4	20040827	00					
Fcst Dy	08/27	08/28	08/29	08/30	08/31	09/01	09/02	09/03	09/04	09/05
Max RH (%)	61	59	52	45	46	48	73	76	72	87
Min Temp (F)	52	56	57	58	57	60	54	45	56	74
AM Dew Pt (F)	39	42	39	37	36	41	46	38	47	70
Min RH (%)	13	5	2	1	2	9	8	10	39	61
Max Temp (F)	91	94	95	95	94	91	82	86	87	83
PM Dew Pt (F)	34	14	-11	-20	-3	25	17	24	59	68
WDir	281	265	261	267	271	276	257	276	268	42
WSpd (knt)	8	8	9	10	9	9	10	4	3	4
BI	170	167	178	173	151	150	113	129	79	47
ERC	88	104	114	119	114	100	97	94	49	2
IC	90	100	100	100	100	97	97	97	54	8
SC	59	60	68	65	53	55	36	54	41	21
100-hr fuel (%)	11	10	8	8	7	8	8	8	10	13
1000-hr fuel (%)	8	8	8	8	8	8	9	9	9	9
Haines (high)	4	5	4	5	5	3	3	4	2	2
Haines (medium)	6	6	6	6	6	6	5	5	4	3
Haines (low)	5	5	5	5	5	5	5	5	4	3

Figure 19. Example forecast output from MOS equations. The first line provides the RAWS name and location information, and the model run date and time. The second line provides the forecasted date. The first column provides the abbreviated forecast element. The remaining matrix columns contain the forecast values, respectively.

Output is being produced for other elements (i.e., BI, SC, IC and Haines), but these values contain a higher-degree of uncertainty since they have not been statistically examined to the extent of the other elements.

2. Development of RAWS climatologies

This task element was a prerequisite for task element 4. For each RAWS chosen by Predictive Services, daily climatologies of temperature, relative humidity, dew point and wind speed were generated. Hourly RAWS data was acquired from the WRCC archive and processed to determine daily mean values for each weather element. This information is subsequently used in producing forecasts of anomalies (departures from average) for each weather element. A database was also generated of historical daily values that are used to produce forecast percentile values as one of the value-added products.

3. Development of value-added products

Four value-added products were included in the project based upon forecasted values from the GFS model. Forecast climatological anomalies and percentile matrices are produced for each RAWS based upon the climatology produced in task element 3. Figure 20a shows an example output matrix of anomaly forecasts, and Figure 20b shows a similar matrix except for percentiles. The value of these tables is that they provide the decision-maker with an indication of how far the forecasted value is from its climatological normal, or where it is ranked given a climatological history.

a)

*Bailey	52001	-105.5	39.4	20040827	00					
Fcst Dy	08/27	08/28	08/29	08/30	08/31	09/01	09/02	09/03	09/04	09/05
Max RH (%)	13	4	3	-12	-11	-8	-27	-28	4	-2
Min Temp (F)	-8	-13	-8	-6	-1	-2	1	2	-1	2
AM Dew Pt (F)	-4	-10	-6	-9	-4	-4	-9	-8	1	3
Min RH (%)	21	4	-5	2	2	-10	-16	-3	8	8
Max Temp (F)	-20	-11	-4	-3	-2	2	5	-2	0	0
PM Dew Pt (F)	-1	-3	-4	3	4	-5	-11	-1	11	11
WSpd (knt)	-2	-2	-2	-1	-1	-2	-1	-4	-3	-2

b)

*Bailey	52001	-105.5	39.4	20040827	00					
Fcst Dy	08/27	08/28	08/29	08/30	08/31	09/01	09/02	09/03	09/04	09/05
Max RH (%)	70	59	58	42	43	47	24	22	58	52
Min Temp (F)	33	21	29	35	53	45	56	59	49	56
AM Dew Pt (F)	60	39	49	39	55	52	35	35	63	67
Min RH (%)	92	80	64	78	78	49	29	69	85	85
Max Temp (F)	11	22	38	41	44	54	71	41	47	44
PM Dew Pt (F)	70	64	59	75	78	57	38	64	92	92
WSpd (knt)	22	22	22	37	37	22	37	4	11	22

Figure 20. Example forecast output from MOS equation for a) climatological anomalies and b) climatological percentiles. First line provides the RAWS name and location information, and the model run date and time. The second line provides the forecasted date. The first column provides the abbreviated forecast element. The remaining matrix columns contain the forecast values, respectively.

Report

A report will be prepared at the end of the project describing equation development and cross-validation results.

Deliverables

The key deliverables from this project are:

- 10-day operational forecast tables of RAWS weather and fire danger elements
- 10-day operational forecast tables of RAWS climatological anomalies
- 10-day operational forecast tables of RAWS climatological percentiles
- 10-day forecasts of Haines indices

The forecast tables of actual values are sent electronically to each of the respective Predictive Services areas that are completed. This information is then used as part of the input to construct the 7-day significant fire potential product. Figure 21 shows an example of the product from Southern California Predictive Services. The color box shows fuel dryness for each of the forecast days for each Predictive Service area (see map and legend at right). The also shows significant weather triggers and “high risk” days. A weather synopsis, fire potential discussion and CWCG preparedness level for the issue day are given in text format.

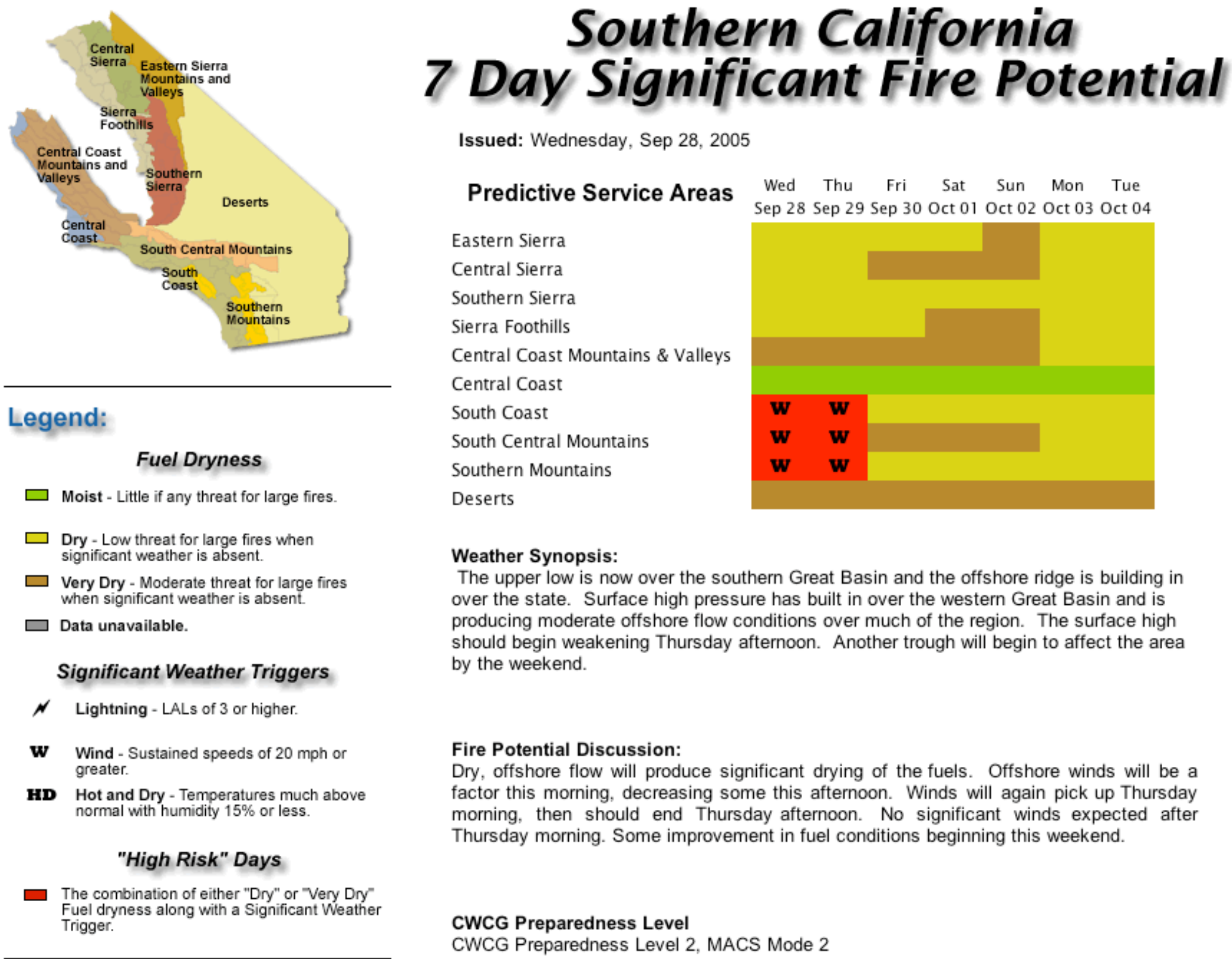


Figure 21. Example output from the Predictive Services 7-day significant fire potential product.

Future work

This project will continue through all of FY06. The lifetime of the project is through September 2010, so that any new equations can be developed as needed or problematic RAWS equations addressed. It may also be possible to develop and refine new regression indices during this period, such as the Canadian Fire Weather Index.

Task Order 16: Real-time Drought Assessment for Rangelands (Sponsor: BLM)

The Western Regional Climate Center (WRCC) manages this task with BLM funds utilizing the Assistance Agreement. The report in this section was provided by WRCC.

The primary purpose of the project is to provide local predictions of plant-growth capability and disseminating this information via the WRCC web site. The project utilizes two primary components: real-time meteorological data from WRCC and rangeland plant modeling. The project period was 1 May 2004 – 30 September 2005. The original Statement of Work (SOW) task elements included:

1. *Task element*: Develop a system to automatically parameterize an Agricultural Research Service (ARS) plant growth model using daily weather data available at

WRCC and typical soil and plant characteristics that would be provided by the ARS and BLM.

Accomplishment: The application allows the user to specify the soil and plant characteristics of any RAWS location via a web form (see [http://www.wrcc.dri.edu/cgi-bin/wea_rangetekc.pl?idihsb]). For locations with known characteristics, the user may retrieve a description and enter or alter the characteristics for the specific site. An example of these descriptions may be found at [http://www.wrcc.dri.edu/cgi-bin/wea_rangetekd.pl?idihsb].

2. *Task element*: Develop a web-based user interface allowing an on-line user to select: weather information from a geographical area showing station locations; typical plant characteristics for at least five rangeland communities (to be determined); and at least five soil types (to be determined) from a list of typical soil types.

   Accomplishment: The user interface allows selection of any RAWS station. The interface is part of the general RAWS access provided by WRCC. Access to the product is on the station list of applications and labeled as "Rangetek". Currently, the product is undergoing review and approval. An example of the application interface can be found at [http://www.wrcc.dri.edu/cgi-bin/wea_rangetek.pl?idihsb]. Karl Gebhardt and Kyle Fend from BLM are providing site specific descriptions of soil and plant characteristics for each RAWS location for user reference (see [http://www.wrcc.dri.edu/cgi-bin/wea_rangetekd.pl?idihsb]).

3. *Task element*: Develop numeric and graphical displays of the model's output.

   Accomplishment: Once the user has executed a 'run', the output is shown in tabular form. Figure 22 provides an example output table for Horse Butte, Idaho. Column headings in blue lettering can be mouse clicked to obtain a time series graph of the data. Each element may be graphed individually, or multiple elements may be graphed. Figure 23 is an example graph of the Horse Butte, Idaho computed potential evapotranspiration.

Date	Year	Day of Year	Day of Run	Max T (C)	Min T (C)	Precip (cm)	Snow (cm)	Solar Rad (ly)	PEt (cm)	Transpiration effect	Energy limited P Soil Evap	Daily Transpiration (cm)	Actual Evap	Yield index	Cum Yield index	Cum Pot. Trans	Cum Trans	Drainage (cm)	Soil Water 1 (cm)	Soil Water 2 (cm)	Soil Water 3 (cm)
08/01/2004	2004	214	1	35.56	16.67	0.00	0.00	629.69	0.85	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
08/02/2004	2004	215	2	30.56	16.67	0.00	0.00	462.14	0.60	0.02	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
08/03/2004	2004	216	3	31.11	15.00	0.00	0.00	741.85	0.96	0.03	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
08/04/2004	2004	217	4	33.33	12.22	0.00	0.00	734.11	0.95	0.03	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
08/05/2004	2004	218	5	31.11	16.11	0.00	0.00	671.49	0.88	0.03	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00

Figure 22. Example table of Rangetek calculated output for Horse Butte, Idaho.

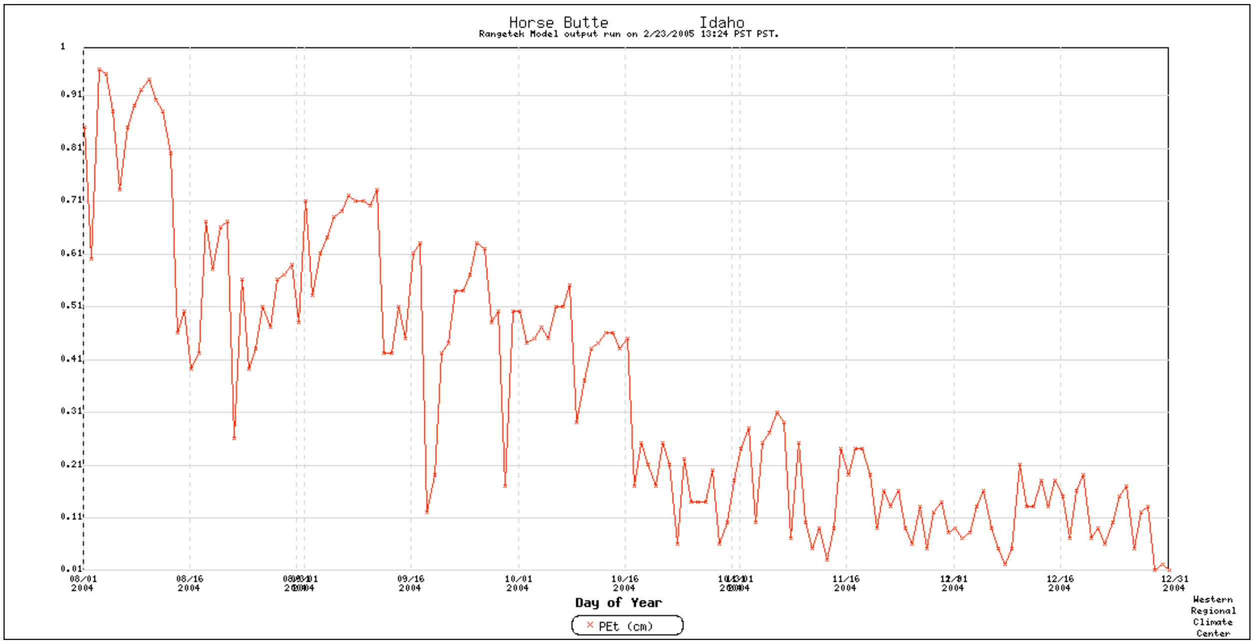


Figure 23. Example graph of potential evapotranspiration from Rangetek calculated output for Horse Butte, Idaho.

4. _Task element_: Develop flexibility in the system that will allow generated weather information to provide simulated output for lower, normal, and higher-than-normal precipitation.

   Accomplishment: The work on allowing input of lower, normal and higher-than-normal precipitation has been delayed due to dealing with other issues such as data incompleteness and bad or missing data.

5. _Task element_: Work with representatives from the ARS, BLM, and NIFC to develop recommendations for refinement of the system.

   Accomplishment: Refinement of the system continues through ARS providing more site descriptions and evaluation of the results. It is expected that the product will be ready for general use in early spring of 2005.

In June 2005, the Task Order was amended to include the following task elements:

1. _Task element_: Continue to development and improvement of the system to automatically parameterize an ARS plant growth model using daily weather data available at WRCC and typical soil and plant characteristics that would be provided by the ARS and BLM.

   Accomplishment: Profiles of RAWS sites continue to be added to the web pages. Sites without existing profiles may be added by user input. Currently 11 sites have listed parameter descriptions.

2. _Task element_: Continue to development and improvement of the web-based user interface allowing an on-line user to select: weather information from a geographical area showing station locations; typical plant characteristics for at least five rangeland

communities (to be determined); and at least five soil types (to be determined) from a list of typical soil types.

Accomplishment: The web-based interface is currently available at [http://www.raws.dri.edu/rangetek.html]. Once it has passed review it will be available through the standard RAWS interface as an application for each station.

3. *Task element*: Continue development of numeric and graphical displays of the model's output based on ARS user input.

   Accomplishment: The numeric and graphical displays continue to be developed. These tools have also been valuable in finding and correcting data and programming errors.

Task Order 17: RAWS Data Quality Check and Estimation (Sponsor: FPA/Interagency)

A new fire planning analysis process is being developed to assess the fire program needs of local fire agency units using an interagency approach. The first module of the Fire Program Analysis System (FPA) was implemented in October 2004. Critical to this effort is the availability of high quality weather data. The primary sources of these data are the archives in the USDA-managed National Interagency Fire Management Integrated Database (NIFMID; daily) and the Western Regional Climate Center (WRCC; hourly). Neither of these archives applies a rigorous data quality filter to the original data, nor do they provide estimated values for missing fields. To optimize the performance of FPA, a process of data quality checking and estimation is necessary.

This project is a collaborative effort between the CEFA, WRCC and the five federal wildland fire agencies (BLM, BIA, FWS, NPS, USFS) as coordinated by the FPA national program office. Howard Roose from BLM is the FPA Business Team Lead and is CEFA's project coordinator. Two primary objectives were identified for the first phase of the project:

Objective 1. Provide data analysis for four prototype (Alaska, central Oregon, portion of California, Mississippi) areas by 30 September 2004. The priority will be assuring data quality for the 1300-hr observations for stations provided by the agencies.

Objective 2. Develop a prototype of a complete hourly archive for all federal fire agency fire weather stations containing QC'd original observations and, where needed, estimated data. Develop a prototype process that may be applied operationally in the future to meet agency needs (e.g. daily, annually) for maintaining dataset currency. Provide this archive and process at the WRCC for agency use.

The project has been divided into phases of which phase I addresses four prototype areas and the building of the necessary computing hardware and software infrastructure, phase II focuses on estimation validation and incorporating all FPA weather stations, and the phase III emphasis will be on building a data delivery system and a quasi real-time update system. The phase I project period was scheduled to be 1 August 2004 through 30 September 2005. However, due to data and computing resource issues, and an overall late start on the project, phase I carried over into FY05.

PHASE I

Specific project task elements for phase I included:

1) Utilize lists of weather stations provided by participating agencies. This may include manual and non-satellite telemetered automatic fire weather stations as well as the more common RAWS. Create a working set of existing period of record data for these stations. This working set will be manipulated into the final clean dataset without compromising either source archive (NIFMID and WRCC). Station identification records will be matched with physical installation location to develop a complete site record.
2) Write and implement software code to perform an assessment of the data for impossible and unlikely values in order to establish the overall quality of the dataset and the resulting workload required to provide a complete quality record. It is anticipated that much of this code can be adapted from previous efforts mentioned earlier. Data will be categorized as Acceptable, Questionable, or Impossible, according to criteria defined in Brown et al (2002). For example, it is unreasonable to expect a relative humidity value of less than 0% or greater than 100%.
3) Acceptable data can be used as is. Impossible data is outside the realm of possibility and will be marked as missing. Further analysis is necessary to determine if Questionable data is actually Acceptable or Impossible. An example would be 24 consecutive hours of unchanging temperature, which is possible, but unlikely. Depending on the amount of Questionable data and the complexity of its analysis, this task can be intensive and impose a significant impact on the timetable of this project. For this reason, the assessment in this task and its projected impact on the project schedule will be reported prior to proceeding to task four. If necessary, the agencies will determine criteria for limiting the scope of this analysis in order to produce as much station data as possible within the schedule.
4) To produce a complete data set, missing data will be estimated. At a minimum, data will be estimated for the 1300-hour (daily) observation, where gaps exist. Hourly data will be addressed if time allows. Estimates will be made for state of the weather, dry-bulb temperature, relative humidity, wind direction, wind speed, 24-hour maximum temperature, 24-hour minimum temperature, 24-hour maximum relative humidity, 24-hour minimum relative humidity, precipitation duration, and precipitation amount.
5) Write and implement software code to place the complete dataset in data file formats required for agency use, including weather observation data transfer format (.fwx or .fw9) and text (comma delimited) files. The .fwx/.fw9 formats allows observations to be input into pcHA and Fire Family Plus.
6) Write a final report documenting the processes used, criteria employed, and descriptions of the confidence the agencies can place in the estimated data.

Some of these task elements were reported on in the CEFA FY04 annual report. Thus, only updates or new information from FY05 is reported below.

Develop agency weather station list

A list of weather stations for four prototype regions was provided by FPA in September 2004. The four regions included Alaska, California, Oregon and Mississippi. There were 206 stations in the original list. Only 117 of those could be processed during this first phase. The primary reason why a station had to be excluded from the analysis was because the matching station data could not be identified or located within the WRCC RAWS database. The WRCC database uses a 4-character identifier code for each RAWS station. This WRCC code is used to download the historical weather data for each station. Without the code, correlations could not be computed between the hourly RAWS and the daily data available in NIFMID that were necessary for estimating missing data.

Perform QC analysis

Coarse data quality assessment was performed on all available prototype RAWS using similar criteria as that found in CEFA Report #02-01 *Quality control of California RAWS historical data* (Brown 2002). Checks were made on temperature, relative humidity, wind speed, wind direction and precipitation. Changes from the California RAWS project allowed for potential climatological differences from state to state for maximum and minimum temperature value limits and precipitation amount. Climatological data from the WRCC was used to identify reasonable value limits for these parameters.

The original intention was to do hand-checks on data that was considered to be questionable, but not impossible. Because of the large amount of data, and limited time to deliver the products, this task element was removed during the project period. Therefore, all data that was *not* originally considered to be acceptable was flagged for future estimation. Ideally, if the originally questionable value was reasonable, then the estimated value would have been similar to the original value so removing these from the original dataset should not have posed a problem.

Perform data estimation

Estimation of missing or non-acceptable observations was made for temperature, relative humidity, wind speed, wind direction, and precipitation for every hour since each station was first made active. All estimations depended upon the existence of good atmospheric data at a nearby location to each station for the hour of interest. Since all surface weather stations are susceptible to periods of inactivity or data collection errors, there was a desire to identify an atmospheric data set that was known to have no gaps. The National Centers for Environmental Prediction (NCEP) / National Center for Atmospheric Research (NCAR) reanalysis data set meets this requirement. Data was acquired from three different data sets within reanalysis: surface level, pressure level, and flux. The surface and pressure level data set is at a 2.5 degree spatial resolution and the flux data is on a T62 Gaussian grid (approximately 1.875 degrees in the east-west direction and 1.9 degrees in the north-south direction). All datasets were at a 6-hourly temporal resolution.

A stepwise multiple regression routine was used to determine which reanalysis variables had the strongest correlation to the RAWS variable being estimated. There were originally 554 predictor variables considered in each regression analysis. These included the 48 possible pressure level variables, the 8 surface variables and 4 flux variables from reanalysis for the nine grid cells surrounding and including the RAWS location. This also included RAWS persistence of all 7 RAWS variables (temperature, humidity, speed, direction, precipitation, *u* and *v* vector components of the wind) for both the previous hour and the current hour from yesterday. The statistical software package S-Plus was programmed and used to perform the statistical analysis.

Output from S-Plus included equations and regression coefficients for each variable. Unique equations were collected for each station, for each of the 7 RAWS variables, for two seasons in the year (May through October; November through April), and for 4 time periods throughout the day (00-05 UTC, 06-11 UTC, 12-17 UTC, and 18-23 UTC). Therefore, each RAWS station had 56 equations associated with it that were used to compute any missing RAWS observation since the station was made active through 2003. Since there were 117 stations processed, this means that there were 6,552 equations ultimately produced.

In addition to missing RAWS observations being estimated through various equations, the hourly state of the weather was also computed based upon a combination of data from the reanalysis dataset and the RAWS values (either estimated or observed). Reanalysis total cloud cover along with RAWS relative humidity, temperature, and precipitation was used to assign one of the 10 categories of state of the weather. The algorithms used for each category do not compare directly with the definitions from NIFMID. This was to adjust for the unique distributions of values from the reanalysis data. Several analyses were performed to adjust the estimation algorithms so that the distribution of each estimated state of the weather category was similar to the distribution of actual state of the weather values for that station in NIFMID. Several stations in California were used for this frequency distribution analysis of the state of the weather in developing the state of the weather algorithms.

Prepare report

A report on phase I was prepared (CEFA Report 05-01) and made available on the CEFA publications web site [http://cefa.dri.edu/Publications/publications_home.php].

Deliverables

Data for each station was available via DRI's anonymous FTP site. Notification of the data availability was made to Howard Roose and Susan Weber. The anonymous FTP site is cleaned out on a regular basis, so current access to the data is by request at no cost. Data was provided in 3 separate text/ASCII formats. Data files ending with an .fw9 extension consisted of all hourly data in the 1998 WIMS data format. Files ending with an .fwx extension consisted of the once-daily values for 1300 LT in the 1972 WIMS data format. The third data file format has a .dat extension and was comma delimited including all values and flags indicating whether (1) the value was the original, good observation, (2) the value was estimated, or (3) the value was made missing because the algorithm failed after 20 hours OR the estimation was physically unreasonable (e.g., relative humidity well above 100%).

PHASE II

In this phase, proposed to cover a project period 1 April – 30 September 2005, two new objectives to meet both the short- and long-term needs of FPA were identified:

Objective 1. Provide data analysis for a comprehensive list of RAWS as agreed to and prioritized by the participating agencies. Data will include both RAWS and manual stations.

Objective 2. Perform a statistical validation analysis of the estimation process. This is necessary to ensure that the best estimates are made available, and that a scientific process has been undertaken in generating the final product.

Specific project task elements for phase II include:

1. Develop working dataset based upon lists of weather stations provided by participating agencies. This may include manual and non-satellite telemetered automatic fire weather stations as well as the more common RAWS (Remote Automatic Weather Stations). Create a working set of existing period of record data for these stations. This working set will be manipulated into the final clean dataset without compromising either source archive (NIFMID and WRCC). It will be necessary to match agency provided station identification information with WRCC archive identification information to develop a complete RAWS record for data

processing. In order of priority, RAWS data will be processed first followed with the manual stations. Processing priority will be given to stations that can be readily obtained from the WRCC archive and matched with the agency list. It is expected that a sizable fraction of the stations will not be readily accessible due to lack of ID numbers or difficulty in matching the station data, and hence problematic to process in a timely manner. The prioritization is necessary in order to process as many stations as possible given the FPA March 1, 2005 deadline.

2. Perform QC on working dataset based upon methodology employed in Phase I. During Phase I of this project, QC software was developed and utilized for determining bad data from the RAWS in the prototype areas. The software was largely based on that developed for an earlier project of performing a QC analysis for California RAWS. This same Phase I software will be used for performing QC analysis on the Phase II list of stations.
3. To produce a complete data set, missing data will be estimated. Hourly data will first be addressed, and 1300-hour data will be generated from the completed hourly dataset. Estimates will be made for state of the weather, dry-bulb temperature, relative humidity, wind direction, wind speed, 24-hour maximum temperature, 24-hour minimum temperature, 24-hour maximum relative humidity, 24-hour minimum relative humidity, precipitation duration, and precipitation amount. Because of the time of observation inconsistencies in the NIFMID data, these data will be examined in a later project phase.
4. Implement software code to place the complete dataset in data file formats required for agency use, including weather observation data transfer formats (fwx and fw9) and text (comma delimited) files. The fwx/fw9 formats allows for the observations to be input into pcHA and Fire Family Plus.
5. Process problematic RAWS. The list of problematic stations generated in task element 1 will be assessed. It is likely that the agencies may have to provide additional station information to CEFA in order to correctly setup the station records and perform the QC and estimation processing.
6. Process manual stations. Though the concepts remain the same, the processing of manual stations will require separate computer coding and subsequent analysis for the estimation process. New computer code will be written and subsequent QC and estimation processing performed on agency listed manual stations.
7. Perform data estimation validation. An estimation process was developed in Phase I in which statistical equations were developed based on correlation relationships between each RAWS and gridded numerical weather model output. Cross-validation (statistical prediction of estimates in comparison to observed values) will be performed in order to assess the stability of statistical equations and provide for the highest correlated estimates.
8. Re-process estimates following validation testing. It is likely that the validation analysis will lead to new and improved statistical estimation equations. Once validation testing and analysis is completed, it will be necessary to re-process all of the desired station records to produce new estimates. This will generate a new FPA dataset and require subsequent distribution.
9. Write a final report documenting the processes used, criteria employed, and descriptions of the confidence the agencies can place in the estimated data.

<u>1. Develop working dataset</u>

Each of the fire planning units identified weather stations to be processed. Approximately 1,300 stations comprise the current list. Figure 24 shows locations of identified weather stations. Also shown is a color-coding of each station's data processing status as of December 2005.

2. Perform QC analysis

The same QC process was applied to all stations as was done for the prototype sites.

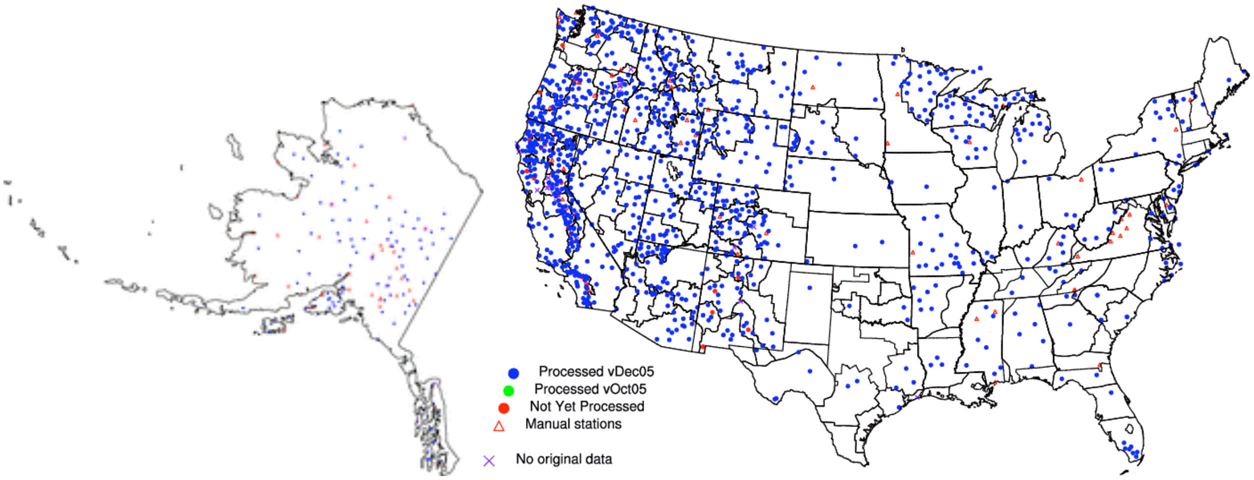


Figure 24. Locations of FPA weather stations as of December 2005.
Color coding indicates status of processing; for example, vDec05 indicates those stations were processed and updated in December 2005.

3. Data estimation

In the summer of 2005, it was decided to utilize the North American Regional Renalysis (NARR) dataset as the model output for producing estimated values. The dataset is approximately 4.5 terabytes in size, and consists of a large number of predictor variables for the surface and upper atmosphere that can potentially be used to develop an estimation equation for each station. This is a gridded dataset at a 32 km resolution. The decision to utilize NARR was made in part with an assumption that both the improved spatial resolution and additional potential predictor variables would improve the estimation results. The size of the dataset, computer hardware problems, and a delay in acquiring the data caused a substantial delay in generating the initial equations by the end of September 2005. As of this report writing, equations are being developed, but only minimal validation has been undertaken. Thus, this task element of the project has been extended into FY06 with anticipated completion in spring 2006.

4. Output data files

The same file format process is being applied to the extended list of stations as described above for deliverables.

5. Processing problematic RAWS

This task element will primarily be undertaken when the estimation equations are fully developed. However, some problematic stations may be addressed intermixed with the estimation and validation work, depending upon the station issue and input provided by FPA and field related personnel.

6. Process manual stations

This task element will be undertaken once the estimation, validation and problematic stations have been resolved and finalized.

7. Data estimation validation

This task element is a process of performing statistical assessment and subsequent improvement of the estimation equations depending upon the validation results. Each station element (i.e., temperature, relative humidity, wind, precipitation and state of the weather) is validated separately to assess their accuracy between estimated values and observed values. The statistical results will provide a level of confidence of estimates for a given weather element. The weather list in the sentence above is ordered to reflect the degree of difficulty in generating estimates. For example, it is anticipated that estimates with high confidence can be generated for temperature, but precipitation and state of the weather will be more problematic and will likely have lower confidence estimates. These latter two elements will require some research effort to determine the best methods for generating estimates. It is anticipated that the validation process will be completed in spring 2006.

8. Station re-processing

Once all of the estimation equations and validation process has been completed, the entire FPA defined dataset will be reprocessed, and the updated data made available.

9. Final report

A report on the phase II activities will be prepared once all of the processing is completed.

Future work

Phase III of the project include the following objectives:

1. Objective 1. Build a web-based delivery system and user interface for the project Phase II qc'd and estimated dataset.
2. Objective 2. Set-up the qc and estimation process in a quasi real-time mode to provide frequent updates to the database.
3. Provide a summary report on each RAWS station's percentage of good observations. This report will highlight potential areas in the US where further attention might be needed for stations that have historically had a relatively large number of problems.

OTHER ACTIVITIES

This section describes CEFA projects and activities that are not outlined in a specific Task Order, but are of relevance to BLM and interagency fire and fuels management. Brief reports are provided.

CANSAC Research and Development (Sponsor: USFS Pacific Southwest Research Station)

Though this work is being undertaken as part of Task Order 10 (CANSAC), it is a separate research contract with the USFS Pacific Southwest Research Station (PSW). This is work in progress. The background and problem statement given in the Plan of Work is as follows:

Wildland fire problems and increased emphasis on air quality by regulatory agencies in California have generated a need for high-resolution weather forecasts for both fire and smoke management. In order for the California Wildfire Agencies (CWA) to meet this need, detailed forecasts for specific areas are necessary to enhance public and firefighter safety, decrease economic losses and meet regulatory requirements. Nevada agencies are currently under less regulation than California, but they still need high-resolution forecasts and value-added products for fire management. The rapid advancements in computer technology provide new opportunities to produce the desired products at relatively low cost compared to high-end supercomputing solutions. The work will be conducted in close coordination with users who represent fire management and air quality management in California and Nevada.

The four primary objectives of this project include:

1. Develop weather model-based National Fire Danger Rating System (NFDRS) forecasts for California and Nevada, with guidance from the FIRESCOPE Weather Group.
2. Develop weather model-based air quality forecasting for California, with guidance from Forest Service Research and regional modeling consortium members.
3. Develop web site for system products generated from (1) and (2).
4. Obtain feedback from users on systems performance, analyze systems effectiveness and provide remedies for problems whenever possible.

Prototype NFDRS forecasts have been implemented on the CANSAC system based upon research and development that was undertaken at the USFS Pacific Northwest Research Station (PNW). This product, currently under testing and evaluation, provides gridded fire danger forecasts directly from MM5 model output. NFDRS indices for energy release component, burning index, spread component and ignition component are being produced for the 00 UTC forecast run. Maps are available for both the 4 and 12 km domains.

The Bluesky software system from PNW will be implemented during autumn 2005. Hourly forecasts of concentration and transport will be the initial product of the forecast package. Wildfire input will be provided from the 209 reports. A web-based form will be developed for user input of prescribed fire parameters. A separate air quality section will be developed on the CANSAC web site.

A CANSAC web site has been developed for distribution of products and information (see Task Order 10 above). All products are made available here, along with descriptive information regarding the CANSAC system and related activities.

Obtaining feedback from users on various aspects of CANSAC (e.g., system performance, product usability, etc.) is critical for the effective utilization of the CANSAC products and services. This is an ongoing process, and largely falls within the responsibility of the Operational and Applications Group (OAG) to provide the information (see Task Order 10 above). Written and verbal feedback indicates a high degree of satisfaction regarding the available products.

Aerospace Corporation

This project was commissioned by the Aerospace Corporation to study potential improvements in the accuracy of the CANSAC MM5 forecasts. WindSat data from National Polar-orbiting Operational Environmental Satellite System (NPOE-SS) are assimilated into MM5 by use of Three-Dimensional VARiational data assimilation system (3DVAR). The 3DVAR code is modified to ingest WindSat Environmental Data Records (EDR) of wind speed and direction to be input as part of the initial and boundary conditions for MM5 runs. Impact of 3DVAR assimilation into different model domain resolutions is analyzed by applying to all three domains. Results presented from an initial real-time MM5-based application of 3DVAR showed a positive response when compared with the corresponding free run weather forecast in a 48-72 hour assimilation period. The effect of 3DVAR WindSat data, which was investigated by use of MM5 outputs with and without the data showed that average air temperature deviation was slightly decreased (by 6%), however the average surface wind speed deviation was slightly increased (by 14%) compared to their corresponding statistical averages of 18 Buoy stations situated in the eastern Pacific Ocean offshore of California. However, the effect of WindSat over inland areas was insignificant.

Reaching the Ground: Developing Sustainable Partnerships between Scientists and Decision-Makers (Sponsor: NOAA Office of Global Programs)

This is a social science project in collaboration between CEFA and Dr. Barbara Morehouse at the University of Arizona. The project is CANSAC related and is also a part of CAP and CLIMAS interactions (see below), but is listed separately due to separate funding from the NOAA Office of Global Programs.

The goal of this project is to document the successful development of the California and Nevada Smoke and Air Committee (CANSAC). CANSAC is currently a consortium of nine federal, state, county and local wildland fire and air quality agencies formed to address short-term prediction issues of fire weather, fire danger, fire behavior, smoke dispersion/transport and air quality as related to wildland fire, prescribed fire and fire use. The study focus is on documenting steps and interactions in developing a sustainable partnership between scientific and decision-making communities. CANSAC provides a useful example case of a partnership between wildland fire, air quality and atmospheric science research sectors.

The structure of CANSAC is examined in part from social science theory of establishing partnerships. To date, a literature review of social science theory and findings on partnerships has been completed and synthesized. A formal survey was prepared and given to all three CANSAC groups (BOD, OAG and TAG). The purpose of the survey was to examine the structure, organizational design, availability of resources, coordination and project management, leadership, progress of project, and other general issues related to the CANSAC partnership. The questions were based upon the research literature perspective of partnership determinants and characteristics. The results of the survey indicated that CANSAC is a highly effective partnership, especially given its rather short period of existence, though most of these agencies have been working together for a number of years in other capacities. A journal paper is in preparation, and it is anticipated to be submitted in early 2006.

CAP and CLIMAS Interactions (Sponsor: NOAA Office of Global Programs)

CEFA has an established partnership with the California Applications Project (CAP; Scripps Institution of Oceanography) and the, Climate Assessment for the Southwest (CLIMAS; University of Arizona, Institute for Studies of Planet Earth) project. Both CAP and CLIMAS are NOAA Regional Integrated Science and Assessment (RISA) programs. One objective of the RISAs is to improve integration between science and users of scientific information. The CAP interactions have involved developing products jointly with California wildfire agencies. Examples include climate forecasts, the formation of CANSAC/COFF, and the California hourly fire danger project. Further CAP information can be found at: http://meteora.ucsd.edu/cap. Several of the elements in Task Order 14 are also a CAP function.

The primary collaboration with CLIMAS during this year involved co-organizing the 2005 National Seasonal Assessment Workshop (Eastern and Southern areas in January 2005 and Western States and Alaska in March 2005). These workshops brought together national, regional and state climate scientists, fire managers, and fuel and fire specialists to formally produce regional and national seasonal fire potential assessments and outlooks. This information is utilized for both national and GACC planning. Special one-page outlook reports were distributed to fire directors and fire management. Detailed reports were published describing specific aspects of each workshop. Further information regarding CLIMAS is available at: http://www.ispe.arizona.edu/climas.

Hourly Fire Danger (Sponsor: California Interagency)

Over the past couple of years and in conjunction with several California wildfire agencies, CEFA has been developing a prototype experimental system for calculating and displaying hourly fire danger in California. Using hourly RAWS from WRCC and NFDRS algorithms provided by Larry Bradshaw at MFSL, fire danger indices are computed for each fire danger rating area across the state, and an adjective fire danger class is calculated on an hourly basis. California wildfire agency personnel continue to evaluate the product as it is now being widely viewed within the state. A phase II of the project will be undertaken during FY06 that will quantitatively examine the hourly fire danger values and produce a climatology based on historical hourly fire danger. In the meantime, the current product has been widely accepted by the California wildfire agencies. Individuals continue to evaluate the system for its operational utility. The web-based maps are available at http://cefa.dri.edu/HourlyFD.

TRAVEL, PRESENTATIONS AND MEETING ACTIVITIES

This section provides brief information regarding travel, presentations and meeting activities as functions of CEFA and BLM during 1 October 2004 through 30 September 2005.

November 2-3 (Portland, OR) Tim Brown presentation at Predictive Services annual meeting.

November 9-10 (Norman, OK): Tim Brown participation in Western Governor's Association fire weather meeting.

November 18-19 (Boise, ID): Tim Brown presentation at Andrus Center conference related to the Forest Service centennial.

December 1 (Riverside, CA): Beth Hall attended Fall FIRESCOPE conference and presented overview of CEFA activities.

December 15 (Las Vegas, NV): Tim Brown and Crystal Kolden presentation of CEFA projects at the Nevada legislative reception.

January 10-12 (San Diego, CA): Tim Brown presentation at the American Meteorological Society annual meeting.

January 19-21 (Sheperdstown, WV): Tim Brown presentation and co-organizer of National Seasonal Assessment Workshop: Eastern and Southern Areas.

February 1-4 (Reno, NV): CEFA hosted and participated in joint Fire Danger/Fire Weather Working Team meetings.

February 8-9 (Boise, ID): Tim Brown participation in Western Governor's Association fire weather meeting.

March 1-3 (Fort Collins, CO): Tim Brown participation in FCAMMS/Bluesky meeting.

March 9 (Washington, D.C.): Tim Brown participation in USFS logic model workshop.

March 28-April 1 (Boulder, CO): Tim Brown presentation and co-organizer of National Seasonal Assessment Workshop: Western States and Alaska.

April 5-9 (Denver, CO): Beth Hall, Crystal Kolden, and Ryan Kangas presented at the annual Association of American Geographers.

April 12 (Boulder, CO): Tim Brown participation in Western Governor's Association fire weather meeting.

April 19-21 (Phoenix, AZ): Beth Hall and Hauss Reinbold presented at the BLM Resource Management and Tools Conference.

May 10 (Sacramento, CA): Beth Hall attended spring FIRESCOPE meeting and presented an overview of CEFA activities.

May 11-12 (Fairfax, VA): Tim Brown presentations in Eastfire Conference.

May 17-19 (College Park, MD): Tim Brown presentation at drought prediction workshop.

May 25 (Boise, ID): Tim Brown CEFA quarterly review briefing.

May 25 (Boise, ID): Beth Hall presented status of TO 17 to FPA.

June 6 (Melbourne, Australia): Tim Brown presentation at Bureau of Meteorology Bushfire Workshop.

June 7-8 (Beechworth, Australia): Tim Brown participation in Bushfire CRC Fire Manager's Research Meeting.

June 9 (Melbourne, Australia): Tim Brown presentation at Bureau of Meteorology Bushfire CRC International Perspectives of Decision-Support Systems and Fire Behavior Workshop.

June 20-23 (Savannah, GA): Tim Brown and Ryan Kangas presentations at American Meteorological Society Applied Climate meeting.

June 28-30 (Portland, OR): Tim Brown attended USFS Climate Change workshop.

August 23 (Mt. Charleston, NV): Tim Brown site visit related to virtual fire and CAVE project.

August 24 (Boise, ID): Tim Brown CEFA quarterly review briefing.

REPORTS AND PUBLICATIONS

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Kolden, C.A., and T.J. Brown, 2005: Utilization of Climate Information in Prescribed Fire. Proceedings EastFIRE Conference, George Mason University, Fairfax, VA, 11-13 May 2005, 4 pp.

Lenart, M., T. Brown, R. Ochoa, H. Hockenberry, and G. Garfin, 2005: National Seasonal Assessment Workshop: Western States and Alaska. Final Report, May 2005, 29 pp. Available at: http://www.ispe.arizona.edu/climas/conferences/NSAW/west05/NSAWwestproceedings.pdf.

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Hall, B.L., and T.J. Brown, 2005: RAWS Data Quality Check and Estimation – Phase 1. Report prepared for the Fire Program Analysis project, CEFA Report 05-01, April 2005, 16 pp.

Reinbold, H.J., J.O. Roads, T.J. Brown, 2005: Evaluation of ECPC's fire danger forecasts with RAWS observations. *International Journal of Wildland Fire*, **14**(1), 19-36.

Brown, T.J. and B.L. Hall, 2004: *Climate and Ecosystem Studies and Product Development for Wildland Fire and Resource Management*, Annual Report prepared for Bureau of Land Management, CEFA Report 04-01, December 2004, 50 pp.

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