J12.2 A CONSORTIUM FOR COMPREHENSIVE MESOSCALE WEATHER ANALYSIS AND FORECASTING TO MONITOR FIRE THREAT AND SUPPORT FIRE MANAGEMENT OPERATIONS

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1. INTRODUCTION

Given fuel loads and fuel energy potential are weather dependent, higher resolution weather and climatologic intelligence, beyond that currently available to fire managers, will improve predictions of fire behavior and fire season severity. The USDA Forest Service Rocky Mountain Center (RMC) is a new entity, established in June 2002, that provides 24/7 mesoscale meteorological analysis and forecasting for the Interior West of USA: http://www.fs.fed.us/rmc/. RMC is currently a collaborative effort between the Forest Service Rocky Mountain Research Station (RMRS) and NOAA's Forecast Systems Laboratory (FSL). RMC is one of five regional mesoscale modeling centers sponsored by the US Forest Service under the Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) initiative. A strategic goal of RMC (and of FCAMMS as a whole) is the development of customized local weather modeling capabilities, which are supported by local users under consortium charters. The primary focus of RMC is to provide weather products tailored to the specific needs of fire application operations and management planning.

Forecasting of the regional (mesoscale) weather including stability and wind flow pattern is an important aspect of the fire operations and fire management efforts during the active season. Accurate prediction of meteorological conditions from 24 to 60 hours into the future is critical for fighting wildland fires, and making go/no-go decisions about prescribed burns. Future values of atmospheric parameters such as temperature, humidity, wind speed, and wind direction as well as fuel moisture need be considered in order to properly assess immediate fire danger, and allocate fire-fighting resources. Knowing with a high degree of certainty how future wind fields and atmospheric stability might change over a region is also indispensable for evaluation of smoke dispersion from prescribed burns. The latter is critical for air quality management and mitigation of the smoke impact on public health. The safety of fire fighters is another vital management issue, which calls for reliable and accurate local weather forecast.

2. METHOD

The RMC delivers spatially explicit up-to-date hourly information about *current* and *future* values of weather elements such as *air temperature, relative humidity, precipitation, cloud cover, wind speed and wind direction*, as well as several *fire indices* (i.e. Ventilation, Haines, Fosberg, and Ketch-Byrum). Weather elements are provided over a large domain completely or partially covering 12 states of the Interior Western USA (i.e. ID, MT, ND, SD, NV, UT, WY, NE, CO, AZ, NM, TX). Analysis and predictions are produced at 12-km resolution for the main domain, and at 4-km resolution for two nested sub-domains within the main domain covering the CO-WY and AZ-NM Rocky Mountain and the Southwest and Geographical Area Coordination Centers (GACCs) respectively. GACCs are interagency command posts for managing fire fighting resources,. Weather forecast extends 48 hours into the future for the main domain, and 24 hours for the two sub-domains. In addition, RMC provides real-time smoke dispersion forecast for selected active fires.

Weather analysis and forecasting are performed using the Local Analysis and Prediction System (LAPS) supported by FSL in Boulder, CO. LAPS consists of two main components. The analysis module of LAPS assimilates thousands of meteorological observations every hour and interpolates them to a continuous 3-D grid of certain resolution. The analysis produces a consistent mass-balanced 3-D data field of cloud cover, temperature, water vapor, wind speed and wind direction. This field is passed to the predictive component of LAPS, the MM5 Community Mesoscale Model, which performs the temporal integration and produces weather forecast. MM5 is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate 3-D mesoscale atmospheric circulation. It was jointly developed by researchers at the Pennsylvania State University and the National Center for Atmospheric Research. The model is run twice per day for each one of the three domains. Forecasts of smoke dispersion are produced by the *BlueSky* Modeling System through collaboration with the Northwest Regional Modeling Consortium. *BlueSky* uses meteorological forecast data fields for input that are provided by RMC. Results from LAPS analysis and weather forecast as well as smoke impact predictions are displayed in real time at the RMC Website.

2. 1. Local Analysis and Prediction System (LAPS)

The Local Analysis and Prediction System was developed as a versatile assimilation system for local forecast offices. LAPS is a UNIX-based software designed to accept various sources of regional data. i.e. from satellite, mesonet, profiler, radar, aircraft, etc., and provide high-resolution analyses on a wide range of computing platforms. LAPS uses a two stage approach

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to analysis: a) a data combination step where numeric information from many platforms is combined to satisfy basic geometric constraints through a combination of successive correction methods and variationally applied splines; and b) a dynamic adjustment step that forces fundamental equations of thermodynamics, motion and continuity to be satisfied within the domain to a desired degree of accuracy.

A unique component of LAPS is the cloud analysis, which provides users with a complete description of the cloud environment including cloud bases, tops, coverage, liquid and ice distribution. In 1999, the LAPS cloud scheme was extended to a complete analysis of Water In All Phases (WIAP) with the aim to provide model initial conditions with a complete description of the water environment and the motions and thermodynamics that sustain them. The process utilizes multi-spectral satellite data from GOES, radar, aircraft, surface reports, and the LAPS temperature analysis to derive a 3-D estimate of cloud coverage. Additional step is the retrieval of cloud microphysical data using a version of the Smith-Feddes model.

LAPS detailed analysis of cloud fields is perfect for generating initial conditions for numerical forecast models because the fields represent a state that contains water and ice components of clouds, the vertical and horizontal motions that sustain them, and a balance condition that ensures a smooth model start. The model is initiated with a completely mature cloud water, ice, and precipitation. This "hot-start" initialization has significantly improved forecast accuracy in the first few hours.

The high-resolution analysis and forecasting system developed for fire support is applicable to other problems as well. Thus, a version of LAPS is now being applied to a US ARMY Parachute Drop System to provide high-resolution 3-D wind analyses for complex terrain.

2. 2. Mesoscale model: MM5

RMC currently uses the MM5 mesoscale model jointly developed by researched from the Pennsylvania State University and National Center for Atmospheric Research in Boulder CO (Grell et al. 1995). MM5 was chosen because it is employed by other FCAMMS centers, which were established before the Rocky Mountain Center. RMC has borrowed from the experience of NOAA FSL and other FCAMMS (particularly the Northwest Regional Modeling Consortium).

The 2002 fire season was the first real-time demonstration of the RMC capability to support the fire community with information products delivered to users in the field posted through the World Wide Web (visit http://www.fs.fed.us/rmc/). Several important upgrades to the model post-processing and display utilities were developed for the 2003 fire season. Perhaps the most unique aspect of the current modeling system is the initialization method, which accommodates active clouds and precipitation processes (Schultz and Albers, 2001; Shaw et al. 2001). Known as the "hot start" this method is an extension of the well-established LAPS analysis package (Albers et al 1996; Albers 1995; Birkenheuer 1999) that collects and processes local datasets for use in regional modeling systems. The method facilitates more accurate predictions of precipitation in the first several hours of model forecasts. While the "Hot Start" initialization has been most extensively tested in MM5, it is also implemented for the new Weather Research and Forecasting model (WRF) (Michalakes et al. 2001), which will be adopted by RMC once operationally proven.

3. RMC IMPLEMENTATION

3. 1. MM5

The RMC has implemented version 3.5 of MM5 with minor modifications made by FSL to accommodate the presence of hydrometeors in the initial conditions from the LAPS diabatic initialization. All three RMC model domains use the following suite of physics: Schultz microphysics, the MRF (Hong-Pan) boundary layer scheme, the rapid radiative transfer model (RRTM), Dudhia's short-wave radiation package, and the OSU land-surface model (LSM). The F1 (12-km) domain also utilizes the latest version of the Kain-Fritsch convective parameterization of shallow cumulus cloud processes. FSL has modified this scheme to allow feedback of parameterized condensate to the resolved grid. All three domains are initialized using LAPS for the atmospheric variables and an NCEP Eta forecast of soil moisture and temperature for the land surface model. The F1 domain is initialized twice per day at 0950 UTC and 2150 UTC using the 0900 UTC and 2100 UTC LAPS analyses, respectively. The F1 domain forecast extends 48-hours. The soil temperature and moisture fields, and the lateral boundary conditions are provided from the operational NCEP Eta runs at 0600 UTC and 1800 UTC. The F2 (Rocky Mountain GACC, 4-km resolution) and F3 (Southwest GACC, 4-km) domains are run twice daily starting at 0000 UTC and 1200 UTC and forecast extends 24 hours. Since the F1 domain forecast is completed before the start of F2/F3 runs, the latter domains use lateral boundary conditions from the F1 forecast making them effectively 1-way nested grids of the F1 domain, but utilizing the updated initial conditions from a later LAPS analysis. This scheme of staggered initialization times between the 12-km and 4-km domains evolved as researchers interacted with the operational clients.

3. 2. Validation and improvements

We currently conduct a MM5 validation study, where model forecasts are being compared to spatially interpolated observations and local meteorological measurements. Preliminary results indicate that MM5 tends to underestimate surface temperature and overestimate surface relative humidity on hot summer days. This could be due to imperfections in the OSU land surface scheme, which predicts a too high latent

heat flux from the vegetation and soil. Current LSMs do not use canopy leaf area index (LAI) to scale up fluxes from leaf to canopy level and over-predict the impact

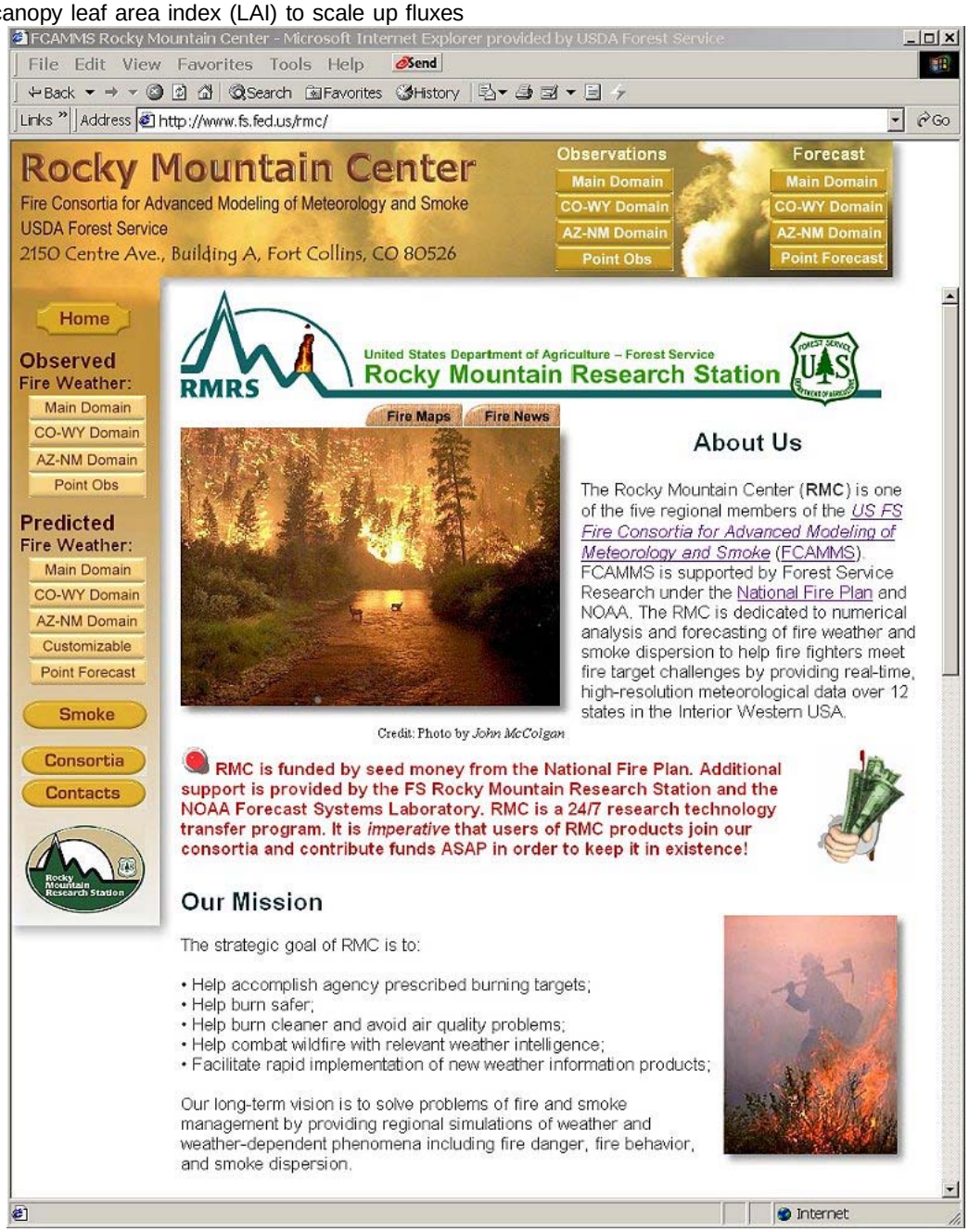

Figure 1. Official Website of the US FS Rocky Mountain Center for high-resolution modeling and forecasting of fire weather and smoke impact in the Interior Western USA.

of soil moisture on surface evapo-transpiration. We are in a process of developing a new LSM that incorporates detailed biophysical description of vegetation-atmosphere interactions and explicitly accounts for spatial variations in canopy LAI (Nikolov & Zeller, 2003).

3. 3. Implementation Steps:

- The F2 domain, a 4-km resolution Mesoscale analysis and 4-km MM5 weather prediction window for the Rocky Mountain Area Coordination Center, was initiated in Dec 2002. This window is within the 12-km Interior West domain that extends from Canada to Mexico, and from Nevada to Kansas.
- The F3 domain, a 4-km resolution Mesoscale analysis and 4-km MM5 weather prediction window for the Southwest Area Coordination Center, was

initiated in Dec 2002. This window is also within the 12-km Interior West domain.

- RMRS has named the center the **Rocky Mountain Center** (RMC) and has launched a new, user-friendly Website at http://www.fs.fed.us/rmc/ (see Figure 1). The RMC coordinates with the NOAA Forecast Systems Laboratory to produces four 24-hr forecasts for the two 4-km windows, and three 48-hour forecasts for the 12-km domain every day. The RMC Website was integrated with the University of Utah's ROMAN point weather observation site developed for GACC predictive services.
- The computer generated point weather forecasts initiated during the Hayman fire last year, have been made easier to access and understand, and are being used by many fire managers.
- Several entities outside the two 4-km GACC windows utilize our products, i.e. the Eastern Great Plains GACC in SLC, UT, and the North Dakota GACC (http://www.ias.sdsmt.edu/RBenson/FireHome.htm) .
- The SWACC has integrated out products into their web site that serves SWACC fire managers directly: (see http://www.fs.fed.us/r3/fire/)
- A sixteen node, 32 processor Beowulf computer cluster running RedHat Linux 7.3 has been purchased, and is currently being tested and implemented by the RMC.

4. CURRENT STATUS

The RMC project for High-Resolution Fire-Weather Forecasts and Smoke Impacts is one of five FCAMMS (Fire Consortia for Advanced Modeling of Meteorology and Smoke), see http://www.fs.fed.us/fcamms/. The information product delivered by the RMC is currently being used by fire manages and incident fire meteorologists at the Rocky Mountain Area Coordination Center and the Southwest Area Coordination Center. Smoke forecast is being used by air resource managers in the Southwest Area Coordination Center.

5. FUTURE PLANS

Improved verification for 0-6 hour precipitation forecast documented for mountain regions suggests that the fire support system might be applicable to water management, urban flood control, and weather warnings. Improved accuracy of local scale precipitation forecasts would also enhance fire support. Further improvements of mountain precipitation are likely with a transition to the Weather Research and Forecast model in 2004.

Specific future plans include:

- Migrate MM5 forecasts for 12-km resolution domain from NOAA/FSL to RMRS/RMC
- Continue to add functionality and improve our user-friendly website.
- Initiate RMRS Boundary layer research and commence fire danger rating modeling research with collaborators (Nikolov and Zeller 2003)
- Establish Research cooperators for collaborative research (smoke, air quality etc.)
- Initiate EPA RPO support activities.
- Hold an Annual Workshops and establish user Sub-committees
- Establish Charters for the local modeling center
- Implement BlueSky products.
- Initiate tech-transfer with other FCAMMS centers
- Commence fire-behavior and fire-spread modeling research with collaborators
- Purchase 2nd Linux computer system for 4-km resolution model runs.
- Migrate MM5 forecasts for the 4-km windows from NOAA/FSL to RMRS/RMC
- Select new MM5 operators for two 4-km windows to supply daily model products
- Initiate upgrade from MM5 to WRF (Weather Research and Forecasting) model.

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