1 Introduction to Remote Sensing and Modeling Applications to Wildland Fires

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Abstract Wildland fire is one of the most disastrous natural hazards threatening life and properties. The rapid growth of wildland-urban interface since last century has increased the complexity of fire management. It is important to exploit new technologies for fire risk assessment, fuel management, wildland fire detection, fire behavior modeling, smoke emissions estimation, and analysis of fire impacts on air quality. This book contains 23 chapters, covering various topics related wildland fires, including satellite remote sensing applications for fire detection and monitoring, fire behavior simulation, smoke emissions and monitoring, and fuel managements. It can be used as a reference book for graduate students and researchers interested in wildland fire study.

Keywords Wildland fires, Remote sensing, Fire behavior model, Air quality, Fire management

Wildland fire is one of major natural hazards. For the last century, North American forest communities have been vitally concerned with wildland fires. They have tried to eliminate wildland fires entirely, to reduce fire intensity, to thin and burn, and even to return to a more naturally occurring wildland fire regime. Urban and suburban growth through the 20th century has dramatically increased the association of housing and people with wildlands, increasing the complexity of fuel management and fire fighting activities. Since topography, climate, ecosystems, and development patterns are all so different in east and west, it is time for a focused look at these issues from an eastern perspective. The EastFIRE conference brings together researchers, subject matter experts, technicians, vendors, and decision makers to share information on using remote sensing (RS), decision support systems and simulation to better manage wildland fire in the eastern United States. Planned

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products of this conference will capture the significant outcomes for determining future plans of action.

The core of this book arose from the EastFIRE conference held at George Mason university May 11 – 13, 2005 (http://eastfire.gmu.edu/workshop). The primary objectives of the conference are: ① Develop bridging approaches that link ecology and the physical sciences at local, landscape, state, and regional scales for wildland fire in the east. ② Suggest decision support views of integrated data for policy makers and front-line decision-makers. ③ Share information on new technologies and techniques which address eastern states fire management issues. ④ Create new understanding of the challenges ahead for eastern states wildland fire management and how RS might better address them. ⑤ Create appreciation for geographic scale issues in wildland fire management and rehabilitation in the east, and descriptions of experiences in applying RS and simulation modeling to these issues. The Conference would accelerate coalescence of scientists and managers around a strategy aimed at providing timely, cost effective, and technically appropriate fire related information to the broad and diverse fire community of the Eastern United States. We believe that the conference was largely successful in providing that acceleration. Over 111 papers were delivered at the conference covering, by over 100 authors representing a diverse area of public and private institutions. Based on session chairs' suggestions, the EastFIRE conference editorial board selected 28 tentative chapters for the book.

We proposed five sessions: ① research needs and programs; ② fire-atmosphere, ③ fire-RS; ④ fire-modeling, and ⑤ Fuels and impacts. This book can be use a reference book for graduate and under graduate students. This book includes 23 chapters in total.

In Chapter 2, Dr. William T. Sommers discusses "Wildland Fire and Eastern states diversity" (Sommers, 2010), provides an introduction of wildland fires in the Eastern United States. Much of wildland fire management, research and resource allocation in the United States is focused on the Western states, while the Eastern states are different from the west in terms of ecosystems, climate, land use, and demographics etc., it is necessary to study the characteristics of wildland fires in the eastern states so as to meet the diverse needs of eastern fire managements.

In Chapter 3, Dr. John A. Stanturf and Dr. Michael C. Wimberly analyze demographic trends in the Eastern United States and the impacts on fire management (Stanturf et al., 2010). The changing demographics and growing wildland urban interface (WUI) of the Eastern United States were characterized, and the implications for the land manager of the expansion of dense human settlements into fire-affected forests were discussed. To improve the capability of fire risk estimation and fire monitoring, land managers and policy makers need to exploit new approaches, such as RS and geographic information systems, to monitor land use change and update the WUI.

Dr. LeRoy Spayd provides an overview of NOAA's fire weather, climate and air quality forecast products and services in Chapter 4 (Spayd, 2010). NOAA's national weather service's (NWS) fire weather program provides timely fire weather data and forecasts, which are critical to wildland firefighting and resource management. NWS climate services provide data products of major drought indicators, as well as services for drought monitoring and prediction. For air quality forecast, NOAA and the environmental protection agency (EPA) have teamed together to develop a national air quality forecasting (AQF) system.

Dr. Douglas G. Fox, Dr. Allen R. Riebau, and Dr. Pete Lahm review wildland fire and air quality management in Chapter 5 (Fox et al., 2010). Wildland fire and smoke can make significant contribution to air pollution. Smoke emissions from fires that are not "natural", such as prescribed fire and agricultural burning, need to be planned, managed, and mitigated in the same way as other air pollution sources. US regional Haze rule and national ambient air quality standard for particulate material are described, as well as recommendations for strategic and tactical planning, operations and evaluation of smoke management activities.

High resolution numerical models for smoke transport in plumes from wildland fires are discussed by Dr. Philip Cunningham and Dr. Scott L. Goodrick in Chapter 6 (Cunningham et al., 2010). It is a critical problem to predict the impacts of wildland fires and prescribed burnings on air quality, especially in the Eastern United States where wildfire-prone regions are often located near populated areas. While various models are available for modeling the air quality impacts of smoke from wildland fires, it is of particular interest, to explore the fundamental dynamics of buoyant plumes arising from intense heat sources to assess the utility and accuracy of the models and identify situations in which these models may have significant errors. The details of a high-resolution large-eddy simulation (LES) model are described, and the basic time-averaged properties of the simulated plumes and their dependence on the heat source strength and the ambient wind are analyzed.

Weather is one of key factors leading to extreme wildfire behavior, and may have significant impact on fire intensity. In Florida, sea-breeze circulations are frequently observed to have a significant impact on fire behavior, but the interaction between wildfires and the sea-breeze is still poorly understood. In Chapter 7, Dr. Deborah E. Hanley, Dr. Philip Cunningham, and Dr. Scott L. Goodrick conduct insight analysis based on radar observations and numerical simulations to explore the interaction between a buoyant plume and a density current (Hanley et al., 2010).

In Chapter 8, Dr. Gary L. Achtemeier, Dr. Yongqiang Liu, and Dr. Scott L. Goodrick review efforts in investigating the air quality impacts of prescribed fires in the southern United States (Achtemeier et al., 2010). Tools for smoke transport and the regional air quality modeling of prescribed burns, SHRMC-4S and Daysmoke, are described. SHRMC-4S is a framework for smoke and air quality modeling focused on prescribed fires in the southern United States. Daysmoke is a plume model that incorporates a human factor to assist land managers in prescribed burning. Applications of SHRMC-4S and Daysmoke are illustrated with case studies.

As one of the major natural disasters, wildland fires release large amount of particulate matter (PM) and ozone precursors that adversely affect regional air quality. Emissions from wildland fires can cause severe environmental consequences. Dr. Yongqiang Liu, Dr. John J. Qu, Dr. Wanting Wang, and Dr. Xianjun Hao discuss calculation and analysis of fire emissions (Liu et al., 2010) in Chapter 9. Approaches for fire emission calculation and techniques for fuel and fire properties estimation are reviewed briefly. Uncertainty in fire emission estimation is analyzed. And future works for fire emission research are discussed.

Foliar phenology significantly influences the exchange of mass, energy and momentum between the Earth's surface and its atmosphere (Jolly, 2010). In Chapter 10, Dr. Jolly presents a phenology monitoring system that combines satellite-derived vegetation indices from the advanced very high resolution radiometer (AVHRR) and surface weather data (Jolly, 2010). It is the first of its kind to integrate RS and surface weather-based models to determine green up dates and green factors. The system provides friendly web-based user interface that is suitable for use by land managers and general public.

In Chapter 11, Dr. Bill Millinor, Dr. Hugh Devine, and Dr. Elizabeth Eastman present the development of a comprehensive database that can be used to crosswalk formation-level vegetation maps to NFFL fuel-model maps (Millinor, 2010). Fuel type and fuel load are critical to the performance of fire behavior models. Current fire models reply heavily on national fire fuel laboratory (NFFL) fuel-classification procedures. It is found that there was a one-to-one relationship between vegetation type and NFFL fuel models for mid-Atlantic Eastern United States forests. This chapter investigates the vegetation type-fuel model relationship in eight additional Northeastern national parks, with focus on the development of a comprehensive database.

Although the primary objective of the tropical rainfall measuring mission (TRMM) is to improve observations and understanding of the tropical rainfall variability, the visible infrared scanner (VIRS) on board TRMM has the capability of producing continuous global fire data set over tropics and subtropics. In Chapter 12, Dr. Yimin Ji and Dr. Erich Stocker summarize the algorithm for detecting land fires with TRMM/VIRS measurements, and discuss the diurnal and seasonal cycles of land fires based on TRMM fire products (Ji et al., 2010).

In Chapter 13, Dr. John Hom, Dr. Kenneth Clark, Dr. Yude Pan, Dr. Steve Van Tuyl, Dr. Nick Skowronski and Dr. Warren Heilman introduce an interdisciplinary research program to enhance fire research in New Jersey and the Eastern coastal plain. Research products and applications of the program are described, including network of observation towers, mesoscale fire weather modeling and validation, vegetation mapping by RS and validation, and estimation of forest productivity and fuel dynamics.

Dead fuel load is one of the major factors associated with wildfire risk, but there is still little data available for local and regional applications. For better quantification of wildland fire risks, it is critically important to develop the capability to estimate dead fuel load and investigate uncertainties of the estimates.

In Chapter 14, Dr. Michael J. Gavazzi, Dr. Steven G. McNulty, Dr. Johnny L. Boggs, Dr. Sara E. Strickland, and Dr. David C. Chojnacky compare dead fuel load estimates across six North Carolina forest communities with different management objectives and assess the accuracy of NFDRS dead fuel load estimates for these forest types (Gavazzi et al., 2010).

In Chapter 15, by numerical simulations of grassland fires, Dr. William E. Mell, Dr. Joseph J. Charney, Dr. Mary Ann Jenkins, Dr. Phil Cheney, and Dr. Jim Gould review and compare FIRETEC and WFDS, two physics-based fire models capable of predicting time dependent fire behavior and fire-atmosphere interactions in 3D (Mell et al., 2010). Although these two models are still in their initial stages of development, they have the potential to provide reliable and detailed predictions of the behavior and effects of fire over a much wider range of conditions than operational models. Case studies show that FIRETEC and WFDS can produce similar results qualitatively, although there are some differences.

In WUI, since structures and vegetation are intermixed, fire behaviors are different from pure wildland. Dr. R.G. Rehm and Dr. D. D. Evans discuss the mechanisms and major features of WUI fires, and physics-based modeling of fires in WUI in Chapter 16 (Rehm et al., 2010). To build a complete and accurate model of the WUI fire, methods of fire propagation, including spread by brands, need to be quantified.

The impacts of climate change, and the associated increase in wild fire frequency and severity will very likely increase in coming years and decades. It is important to investigate the impacts of climate change and fires on ecosystem health. In Chapter 17, Dr. Steven G. McNulty, Dr. Sara E. Strickland, and Dr. Jennifer A. Moore Myers assess the climate change and fire impacts on ecosystem critical nitrogen load (Strickland et al., 2010). Change of ecosystem parameters due to drought, climate change shifts in water availability, increases aire temperature, as well as wildfires and prescribed burns, are exmined. The combined impacts of climate change and fire on critical nitrogen load are discussed.

Understanding fuel structure in a landscape and its potential influence on fire spread is helpful in fire and land management. In Chapter 18, Dr. Jacob J. LaCroix, Dr. Qinglin Li, Dr. Soung-Ryoul Ryu, Dr. Daolan Zheng, and Dr. Jiquan Chen investigate the impacts of fuels in AEI (LaCroix et al., 2010). Through simulating fire spread with landscape level edge fuel scenarios using the FARSITE model, it is found that separating AEI from other landscape elements clearly produced different projections of fire spread, fuel loading around edges plays significant role in determining the rate of fire spread and the total size of burns in the landscape. The results suggest that fuel management around edge sould be considered seriously.

Because of the interdependent nature of the variables on which sustainable forestry depends, sustainable forest management requires knowledges from multiple disciplines. In Chapter 19, Dr. Christine M. Stalling discusses integrating social and biophysical processes using SIMulating patterns and processes at Landscape scales (SIMPPLLE), which is a management tool developed to help land managers integrate the best available knowledge of vegetation change caused by disturbances, including fire, insects and disease, fire suppression, and fuel treatment. Criteria and indicators from the Montreal process, combined with modeling techniques and cooperative efforts will provide the capability to help land managers in protecting and maintaining sustainable forests.

Satellite RS has become the primary technique for wildland fire detection and monitoring. Although there exist automatic algorithms for various space-borne measurements, such as data from the geostationary operational environmental satellite (GOES), the AVHRR and the moderate resolution imaging spectroradiometer (MODIS), human element is still important for accurate fire detection and analysis. The NASA goddard space flight center (GSFC) has been collaborating with NOAA national environmental satellite, data and information service (NESDIS) to automate hazard mapping system by training neural networks to mimic the decision-making process of fire experts (Miller et al., 2010). In Chapter 20, Dr. Jerry Miller, Dr. Kirk Borne, Dr. Brian Thomas, Dr. Zhenping Huang, and Dr. Yuechen Chi describe these efforts for automated wildfire detection using artificial networks, including data reduction, architecture of neural network, traing and testing of the neural network, as well as classification and analysis.

Wildland fire is not only a natural disaster, but also an essential process for maintaining ecosystem health. Prescribed burning is an important approach for land management. It is important to analyze fire regimes and related ecological changes. In Chapter 21, Dr. Gregory J. Nowacki and Dr. Robert A. Carr compare the past and current fire regimes in the Eastern United States using GIS and remote technology, illustrate the distainct difference between the past and current fire regimes across the Eastern United States, and investigate the ecological consequences (Nowacki et al., 2010).

The prediction of fire spread behavior and burned area across landscape is very important in fire suppression planning. In Chapter 22, Dr. Zheng, Dr. LaCroix, Dr. Ryu, Dr. Chen, Dr. Hom, and Dr. Clark investigate the effects of weather, landscape structure and land management on fire spread (Zhang et al., 2010) by combining simulations with 3 models. The results demonstrate that landscape structure and fuel type composition can significantly affect fire spread behavior. Roads can remarkabley reduce burned area and thus function as fire barriers. Surface temperature and moisture conditions are the weather factors having most significant impacts on fire spread.

In the last chapter, Chapter 23, Csiszar et al. introduce the fire mapping and monitoring theme of global observation of forest cover-global observation of landcover dynamics (GOFC-GOLD) program (Csiszar et al., 2010), including GOFC-GOLD fire goals, current implementation status, and future plans. Contributory activities from US Agencies are also discussed.

Contributed by many scientists and experts from areas related to wildland fire, this book covers various topics related to wildland fire, including fire detection and monitoring, fire behavior modeling and analysis, smoke emissions and air quality, as well as fire management. It can be used as reference book, and readers can get more details from the chapters and references.

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