AFSC Remote Sensing Workshop: Abstracts List

Warts and All: The Current State of the University of Alaska's Near Real Time Satellite Imagery and Derived Products Available to the Alaska Wildland Fire Community

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Sharon Alden, Heidi Strader, and Jenn Jenkins (Alaska Interagency Coordination Center)

The Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks receives data from a number of polar-orbiting weather satellites. Data from these satellites are used to generate imagery and other derived products (such as the "hotspots" product) that are delivered in near real time to users such as the National Weather Service and Alaska Fire Service.

While there have been many successes over this 13-year-long collaboration, both the quantity and quality of GINA's imagery available at Alaska Fire Service and the Alaska Interagency Coordination Center (AICC) could be improved. Challenges have primarily been rooted in logistical issues that have hindered the ability of fire managers to fully access GINA's imagery.

Examples of GINA's imagery and products currently available at AICC will be presented, with emphasis on the strengths and shortcomings of the imagery. The goal of this talk is to spark a discussion with the assembled experts and stakeholders that guides and prioritizes future enhancements to services.

Use of New NASA Technologies for Pre-, Active, and Post-Fire Applications

E. Natasha Stavros, Science Applications Software Engineer (Jet Propulsion Laboratory, California Institute of Technology)
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Increasing wildfire size, frequency, and severity, and impacts on a growing wildland urban interface create a need for new technological approaches to study and understand the role of fire in ecological systems (i.e., fire ecology). In November 2015, JPL hosted a study inviting participants from the US Forest Service, National Center for Atmospheric Research (NCAR), and NASA to develop an application traceability matrix relating informational data products useful for pre-, active, and post-fire applications to different platforms that could provide these estimates. Both airborne and spaceborne platforms were considered. In this talk, we will present results from airborne campaigns that have been used for fire applications, present ongoing activities that have the potential for extrapolation to boreal regions with the extensive airborne campaigns as part of the NASA Artic-Boreal Vulnerability Experiment (ABoVE). Specific results will be presented from airborne campaigns over large extents of California. The results derive from use of technologies such as a hyper spectral visual to shortwave infrared Airborne Visual/Infrared Imaging Spectrometer (AVIRIS), high spatial resolution multi-band thermal infrared imaging (MASTER), coupled spectrometer and Light Detection and Ranging (LiDAR) on the Airborne Snow Observatory (ASO), and the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR). This talk will highlight the use of LiDAR to provide 3-dimensional forest structure and biomass, AVIRIS to provide information on forest composition, chemistry, condition, and quantification of fire severity, MASTER to provide very high-resolution fire intensity, evapotranspiration and water-use efficiency maps, ASO to provide forest structure, and UAVSAR to provide estimates of change detection and soil moisture. Because these technologies are either not yet available from satellite, or with limited extent on satellites, research is being conducted to assess their full utility for fire ecology. Although many of these technologies are limited to airborne campaigns currently, that is not true for many of them in the near future. The second part of this talk will focus on describing some of the upcoming missions, specifically NISAR, what the Applications Plan is, how the flight project intends to work with the applications communities, and different information that can be derived (i.e., canopy structure, biomass, change detection, inundation, and fuel moisture) to advance the applications utility of NISAR data. Missions like NISAR have the potential to change the fire management landscape by providing

information that is otherwise limited to cloud-free, well-lit (i.e., day time acquisition) areas of the world.

S-NPP/VIIRS and Landsat-8/OLI global active fire data sets

Wilfrid Schroeder, University of Maryland

Two spatially-refined active fire data sets have been developed using global multispectral data from the Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite (S-NPP/VIIRS) and Landsat-8 Operational Land Imager (OLI). The S-NPP/VIIRS 375 m resolution fire detection and characterization product supplements the baseline 750 m fire product, which was built on and therefore provides continuity to the MODIS 1 km resolution *Fire and Thermal Anomalies* product (MOD14/MYD14). Similar to its coarser resolution siblings, the VIIRS 375 m fire product carries many of the same base layers, including a full-blown fire mask, sub-pixel fire radiative power (FRP) retrievals and file attributes. However, the higher 375 m spatial resolution results in significantly greater response over smaller/lower intensity fires and thermal anomalies, while also delivering improved mapping of larger fire perimeters. Compared to the coincident VIIRS 750 m global fire data, the 375 m product detects, on average, 3x (+20x) more daytime (nighttime) fire pixels of which »45% (»80%) are unique to the product (i.e., show no match in the 750 m data set). Complementing those data, the Landsat-8/OLI global active product delivers 30 m resolution day and (on-demand) nighttime fire detection information albeit at much reduced temporal resolution (16-day nominal interval). The OLI 30 m fire data is the first of its kind to be implemented operationally in support of fire management applications in the U.S. A growing network of Landsat-class instruments which includes ESA's 20 m resolution Sentinel-2a/b Multispectral Instrument (MSI) and other commercial assets (e.g., Digital Globe's Worldview 3&4) have the potential to transform the way those data are used in routine operations, specially at high latitude regions where observation frequency is improved as a result of satellite orbit convergence. Exploring these refined satellite fire products, we demonstrate new data applications supporting routine wildfire mapping and coupled weather-fire behavior modeling.

Short-term Prediction Research and Transition (SPoRT) Center Datasets and Products for Wildland Fire Potential and Prediction

Christopher Schultz and Anita LeRoy, SPoRT

Leading up to a wildfire event, land surface and vegetation health are two key components to identifying locations ripe for wildfire occurrence. NASA's Earth Science Division has a number of polar-orbiting satellites that measure land cover characteristics, precipitation, and can even identify active fires and burn scars. These data can contribute to the prediction and monitoring of wildfire occurrence in Alaska through direct use for situational awareness or by integration into modeling tools. This information can provide both short term (0-24 hours) and longer term information valuable to those monitoring for wildfire occurrence. NASA's Soil Moisture Active Passive (SMAP) satellite and the Evaporative Stress Index are vital sources of information on ground moisture and vegetation health. Synthetic Aperture Radar (SAR) measurements, such as those available from the European Space Agency's Sentinel missions, and other high-resolution sensors, such as Landsat-8 can provide additional detail on vegetation stress, active fires and burn scar extent. The Global Precipitation Mission (GPM) provides useful satellite-based precipitation types and rates. The Short-term Prediction Research and Transition (SPoRT) Center at NASA's Marshall Space Flight Center works to transition all of these datasets to operational partners. Additionally, SPoRT currently runs a real-time, high-resolution land surface model based off the NASA-developed Land Information System (LIS), which has capabilities for integrating SMAP and GPM to track land surface, soil and vegetation characteristics for situational awareness and can decipher trends in the land surface characteristics on longer time scales (months, years).

NASA SPoRT and the Earth Science Office at MSFC also has a long standing history of working with ground based and space based lightning for monitoring thunderstorm activity. This includes engineering of instrumentation, intercomparision of lightning datasets from different instruments, development of algorithms to monitor lightning activity and training for end users to maximize the use of the lightning data in the operational framework.

Recently, NASA SPoRT has combined its land surface and lightning expertise to start developing an approach to identify the potential for lightning-initiated fires in real-time. In a small study of 87 lightning-initiated wildfire cases (5300 flashes) statistically significant land surface parameters and lightning characteristics were observed to separate fire starting flashes from non-fire starters. Both the 0-10 cm relative soil moisture content and green vegetation fraction were the two SPoRT-LIS parameters which demonstrated the most utility in identifying lightning flashes which initiate wildfires. Furthermore, the peak magnitude of negative cloud-to-ground flashes were statically different than non-fire starting flashes. For positive flashes, the peak magnitudes were similar, and the underlying land surface that determined if a fire start occurred.

This presentation focuses on specific examples of these datasets and products and demonstrates their utility in the short term prediction and identification of wildfire potential.

Potential Fire Risk (12)

Can remotely sensed data (e.g., daily snow extent, others) estimate spring soil moisture and surface and subsurface fuel moisture and fuel conditions, and thus provide critical inputs for fuel moisture indices used to predict fire danger and risk?

Assessing Fuel Moisture in Boreal and Arctic Ecosystems with Active and Passive Microwave Satellite Imagery

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Kyle McDonald (City University of New York)

In Alaska and Canada, the Canadian Forest Fire Danger Rating System (CFFDRS) is used to estimate moisture in the organic soil layers of the ground from the surface (nominally 1.2 cm) down to deeper, more compact organic layers of the duff horizons (10-20 cm depth). The moisture status of the organic soil is a key driver of the potential for wildfire and NASA's Soil Moisture Active Passive (SMAP) satellite sensor has potential to provide complementary data to CFFDRS. As a weather-based point source system, CFFDRS has inherent limitations that could be greatly improved with synoptic moisture information from a satellite sensor at high repeat frequency, such as SMAP. Research is underway to assess the utility of the L-band 36 km resolution SMAP moisture products for organic layer fuel moisture monitoring in boreal and Arctic ecosystems for fire danger prediction including: a) comparison to the broadscale network of weather-based CFFDRS fuel moisture estimates; b) soil moisture databases; c) the Canadian Land Data Assimilation System (CaLDAS) modeled root zone and near-surface soil moisture; and d) the actual occurrence of wildfire. In addition, a comparison of the passive SMAP data with high-resolution SAR imagery is being evaluated to: a) address the impact of scene heterogeneity and surface water on SMAP results; and b) investigate methods for downscaling SMAP to a finer resolution (0.2 to 3 km) soil moisture product through development of hydrological modeling and integration of high resolution SAR data from Sentinel-1 and/or PalSAR-2. The overall investigation will yield a more complete understanding of the relationship between field measurements, the CFFDRS Fire Weather Index, CaLDAS moisture models, SAR and SMAP soil moisture. A key goal of this project is the development of a refined assessment of fire danger for boreal and Arctic regions. With 2 day repeat, synoptic coverage, and an observation-based enhancement to the weather-based CFFDRS codes, SMAP has potential to provide essential, complementary data to the weather data that provides the basis for current fire danger and behavior assessment system used in Alaska and Canada. The outcomes of this project will be valuable for fire management and prediction across the vast region where weather-based information is scarce. While the research is focused on improving modeling of fire danger to understand spatial and temporal patterns of organic soil moisture in HNL ecosystems, something that has not been able to be monitored synoptically before now, the impact of this research extends beyond fire decision-making into needs for ecosystem modeling and monitoring climate change impacts.

An overview of twenty years of research at the Faculty of Forestry and Environmental Management, University of New Brunswick, Canada on fuel moisture estimation using optical, thermal infrared and radar remote sensing in boreal forests in Alberta, the Northwest Territories, and Alaska

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This paper presents an overview of 20 years of research at the Faculty of Forestry and Environmental Management, University of New Brunswick, Canada, on fuel moisture estimation using optical, thermal infrared and radar remote sensing in the boreal forests of Alberta, the Northwest Territories, and Alaska. In collaboration with Canadian Forest Service (CFS), the first studies tested the use of NOAA-AVHRR NDVI and surface temperature images over the boreal forests of the Northwest Territories and Alberta. Over the boreal forests in the Northwest Territories, we observed that mean surface temperature values increased as ignition dates approached and high fire weather index (FWI) areas corresponded to high surface temperature values (Oldford et al. 2003). A modelling approach showed that FWI was related to the ratio between actual and potential evapotranspirations estimated from NOAA-AVHRR images (Strickland et al. 2001). Over boreal forests in Alberta, significant relationships were established between the drought code (DC) and NOAA-AVHRR NDVI and surface temperature images, Satellite-based DC estimations were more reliable than weather station-based DC in the detection of fire starts (Oldford et al. 2006). More recently, SAR images from ERS-1 C-VV (Leblon et al. 2002) and RADSARSAT-1 C-HH (Abbott et al. 2007) were tested over forests in the Northwest Territories for the estimation of fuel moisture codes such as DC and FWI. Relationships with foliar moisture content (FMC) were also established. These studies also showed that biomass and canopy had an influence on the moisture code or FMC estimation. Finally, over a chronosequence of Alaskan boreal black spruce ecosystems (recent burns, regenerating forests dominated by shrubs, open canopied and moderately dense forest cover), RADARSAT-2 and ALOS-PALSAR polarimetric images were tested to assess DC variations (Bourgeau-Chavez et al. 2013 a, Bourgeau-Chavez 2013). Several polarimetric variables from a multi-date RADARSAT-2 C-band image sequence that were acquired across a range of soil moisture conditions were used to develop empirical algorithms to estimate volumetric soil moisture maps over the Alaskan boreal test area (Bourgeau-Chavez et al. 2013b). A mean error of 6.7 % between observed and estimated values was achieved through a regression model that used the C-VH backscatter intensity, the maximum of degree of polarization (dmax) and the maximum of the completely unpolarised component (Unpolmax) as independent variables. The model also showed improvement from 27% to 33% in the accuracy of the soil volumetric moisture content retrieval by comparison with a model that used only single polarized C-HH data. By providing information on surface roughness and/or biomass, dmax appeared to be helpful for extracting surface soil moisture from SAR data. So far, only empirical relationships have been established and a more deterministic approach still needs to be developed. The various studies were funded by NSERC. RADARSAT-1 and-2 images were provided by the Canadian Space Agency.

Lightning Distribution and Wildland Fire Occurrence in Alaska tundra

Jiaying He, Tatiana Loboda (University of Maryland)

Wildland fires can cause dramatic changes in vegetation, soil and water properties of ecosystems in a short period of time, leading to strong impacts on ecosystem functions and services. Though wildland fires are relatively rare in Alaskan tundra ecosystems compared to forest regions, they release vast below-ground carbon stores, affect biogeochemical cycles and alter biophysical properties, leading to consequences from local to global. Recent studies indicate that small fires are quite common and climate warming has the potential to increase wildland fire frequency and area burned in the tundra biome in future. However, the drivers and mechanisms of wildland fire occurrence and spread in Alaskan tundra area are still poorly understood. To enhance the understanding of wildland fire activities in Alaskan tundra, this study aims to explore the interactions between lightning and wildland fire as well as the mechanisms of lightning activities, utilizing remote sensing data and circulation models. In this study we build quantitative relationships between lightning as recorded by the Alaska Lightning Detection Network and ignition points for wildfires in Noatak Nature Preserve during the large fire season of 2010 extracted from the Moderate Resolution Imaging Spectroradiometer (MODIS) active fire detection data. We further examine the spatiotemporal distribution patterns of lightning and fires, and the potential relationship between those patterns with a focus on understanding the factors, derived from MODIS observations of the atmospheric column, and atmospheric processes that drive the lightning activities and distribution in Alaskan tundra. Finally, we quantify fuel state that supports lightning-based ignition using 1km Daymet meteorology and the Canadian

Forest Fire Danger Rating System weather indices. The results of the analysis are combined in a spatially-explicit fire ignition model that delivers daily wall-to-wall projections of ignition probability for Alaskan tundra ecosystems.

LANDFIRE Remap: opportunities for incorporating new remotely sensed data into vegetation and fuels characterization across Alaska

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The LANDFIRE program has produced and distributed consistent and comprehensive vegetation, fuels, and fuel regime data across the United States for over 10 years. LANDFIRE data are used for strategic wildfire and natural resource management planning, tactical wildfire incident response, and a diverse array of other ecological applications. LANDFIRE data are regularly updated, from the circa 2001 base layer, to account for vegetation and fuel changes in response to landscape disturbance and vegetation succession. LANDFIRE is now embarking on its first ever update to the base vegetation and fuel layers. The LANDFIRE Remap effort will utilize newly available field data and remotely sensed data sources to create more current versions of the LANDFIRE data layers, from which future updates can be based. Improvements are being made to the product legends, mapping methods, and input data sources, and collaborations with partner organizations are being created or enhanced.

To prepare for the LANDFIRE Remap, a series of prototyping efforts are ongoing to test different product definitions, algorithms, and ancillary data sets. The prototyping work in CONUS is currently wrapping up with a production kickoff anticipated in early 2017. Prototyping activities in Alaska are now being defined and started. One of the specific collaborations being pursued, as part of LANDFIRE Remap prototyping in Alaska, is with the ABoVE program. The goal is to integrate as many of the ABoVE data sets and processes as are applicable into the LANDFIRE base layers to improve quality and currency. Other remotely sensed datasets being evaluated include Landsat, Sentinel, airborne and spaceborne lidar, and synthetic aperture radar. Given the paucity of field data in large parts of Alaska, and the complexity of some ecosystems, the hope is that more recently available remotely sensed datasets will provide valuable information on which to base the new LANDFIRE layers.

The LANDFIRE Remap effort is expected to take 3-4 years and will produce data for all 50 states and associated insular areas. More information about the Remap prototyping and production efforts can be found on the program website at www.landfire.gov.

Improving fuel characterization and maps useful for emissions modeling

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Michael Billmire, Research Scientist (Michigan Tech Research Institute)
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In developing new approaches to mapping fire emissions, data on the heterogeneity of fuels and variability in fuel loading is a fundamental factor to be considered. For regionally specific approaches to emissions modeling, fuels classification maps are valuable tools to account for landscape heterogeneity. Underlying fuel classifications, however, is variability in fuel loadings that is not acknowledged, much less quantified. The best practice for producing emissions estimates from data with inherent spatial variability is to represent the underlying uncertainty in the base fuels map. This measure of uncertainty can then be used in understanding the reliability of the fuel-loading estimates and also to evaluate how that uncertainty translates to variability in emissions estimates. The goal of the JFSP-funded project is to develop a geospatial database of fuels that enables best practices modeling of national- and regional-scale emissions. Best practices include fuel layers that characterize variability of fuel loading for a specific type, and that have been validated by field sampling. The presentation will review progress on our efforts to characterize the distributions of fuel loadings by strata for standard FCCS fuelbeds of the Contiguous US and Alaska. The presentation will also review the sensitivity analyses underway to quantify fuel loading impacts on emission estimates, and the information system we will be building to help serve out the complex fuel loading data. The value of and status of advanced methods for quantifying fuel loadings will also be reviewed, as planed within the Fire and Smoke Model Evaluation Experiment (FASMEE). We envision a set of data that will have value to emissions modeling at regional scales and that will provide a statistically accurate characterization of representative fuelbeds and loadings for national emissions inventories and other broad-scale applications.

Improving Remote Sensing Capability for Assessing Wildfire Effects in North American Boreal Peatlands

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William de Groot, Chelene Hanes (Canadian Forest Service)
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Wildfire is a natural disturbance factor in high northern latitude (HNL) ecosystems occurring primarily through lightning ignitions. However, there is evidence that frequency of wildfire in both boreal and arctic landscapes is increasing with climate change. Higher temperatures and reduced precipitation is leading to widespread seasonal drying in some HNL landscapes, thereby increasing wildfire hazard. In 2014 Northwest Territories (NWT) Canada had a record breaking year of wildfire, burning over 3.4 million hectares of upland forests, peatlands, and even emergent wetlands. Fire activity occurred across seasons (spring, summer, and fall) in the Taiga Shield and Boreal Plains ecozones. Similar large fire years have occurred in boreal Alaska in 2004 and 2015. Under NASA ABoVE and other efforts, North American boreal peatlands of Alaska and Canada are the focus of both field and remote sensing studies to better understand their vulnerability and resiliency to wildfire. Landsat and radar satellite imagery is being used to develop remote sensing algorithms specific to peatlands to map and monitor not only burn severity but also organic soil moisture, peatland type (e.g. bog vs. fen) and biomass form (herbaceous, shrub, forest dominated). Through integration with CanFIRE (a carbon emissions and fire effects model), this spatial information allows for better quantification of the landscape heterogeneity of peatlands and fire effects, thus providing new insights to landscape scale changes and allowing improved understanding of the implications of increasing wildfire in HNL ecosystems. This presentation will focus on results from several current and previous NASA-funded projects focused on characterizing wildfire vulnerability and resiliency in North American boreal peatlands.

Hydrological and phenological monitoring of wildfire potential in boreal and taiga wetlands: remote sensing approaches

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Regionally, the boreal forest of North America contains between 10-30% wetland area, often as a mosaic alongside upland forest. These wetland complexes vary widely in their vegetation structure and susceptibility to wildfire, ranging from treeless sedge fens to forested black spruce bogs. During large fire years featuring widespread and persistent drought, the rate of hydrological response of these wetland types varies by wetland type. Moreover, contrasting vegetation structure among wetland types in both the surface and the overstory leads to variable flammability via deciduous phenology. Here we outline a method of monitoring flammability across the range of boreal wetlands via remote sensing techniques and applications of the Canadian Fire Weather Index system. In order to discriminate between the various wetland types, we describe the use of integrated remote sensing and forest inventory data products in order to predict the distribution of sedge-dominated (fens) and moss-dominated (bogs) surface fuels and their respective abundance of larch and spruce tree cover. With this spatial knowledge of the distribution of sedge wetlands, a simple MODIS-based NDVI monitoring scheme currently used in the Canadian Wildland Fire Information System (CWFIS) for sedge wetland greenup and senescence is shown. The gap-filling scheme used to produce nowcasts of sedge wetland greenup is also shown. In order to distinguish between flammable (i.e. cured) sedge wetlands with high and low water tables, a reanalysis of historic water table measurements across western Canadian non-permafrost wetlands is used to predict water table depths using the Drought Code of the Canadian Fire Weather Index system. We show how a simple Drought Code scheme by wetland type can effectively map areas where low water tables allow for sufficiently dry surface fuels to carry fire spread. Lastly, a case study of this framework in a fire management context is shown during the drought-driven fires of 2015 in Wood Buffalo National Park, Alberta. This ecologically-informed monitoring framework allows for an improved estimation of fire spread potential in areas of abundant wetland cover, and offers a contribution towards improved modelling of smoke emissions, carbon loss, and overwintering fire potential in these often data-limited and remote areas of North America.

Burn, grow, repeat: Toward an improved understanding of causes and consequences of shortened fire return intervals in northwest boreal forests

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The boreal region of Alaska and Canada is warming approximately twice as fast the global average, and above-average temperatures and prolonged drought over the last half century are thought to have increased regional fire frequency in recent decades. Over the past 11 years Alaska has seen the largest (2004), second largest (2015), third largest (2005), and sixth largest fire years (2009) since 1940, and observed increases in area burned in Canada during the last four decades are linked with warming summer season temperatures and attributed to human-induced climate changes. Changes in wildfire frequency have been identified as a "tipping element" likely to seriously impact boreal forest and woodland integrity. To the surprise and concern of fire and resource managers some of these fires burned across fire scars from the previous decade or decades (i.e., were much more frequent "reburns"), an uncharacteristic phenomenon in boreal forests. This dynamic is significant in terms of management - past fires serve as fire breaks that are factored into active fire planning for protection of life, infrastructure, and resources - and ecology, because changes in fire frequency and severity can alter successional trajectories, species composition, critical wildlife habitat, and long-term carbon balance. However, there are few studies in northwest boreal forests that provide information on the weather, climate, and fuels factors associated with short-interval fires, or on their ecological impacts. We use geospatial datasets of fire history, land cover and fuels, weather, climate, fire danger indices, and fire progression from MODIS/VIIRs to address the following questions: 1) Under what climatic, weather, topographic, and vegetation (fuels) conditions do fires reburn recently burned areas? 2) What characteristics allow older fires to act as fuel breaks for new fires? 3) Is fire behavior or fire severity different in reburned areas? 4) What are the effects of changing fire regimes on northwest boreal ecosystem processes such as carbon storage, stand dynamics, vegetation biomass and composition, wildlife habitat, and subsistence? Project results provide improved understanding of potential changes in fire regimes and fuels that impact ecology and management of northern boreal forests.

Synoptic-scale fire weather conditions in Alaska

Hiroshi Hayasaka (Fire Science Division, NPO Hokkaido Institute of Hydro-climate)
Hiroshi L. Tanaka (Center for Computational Sciences, University of Tsukuba)
Peter A. Bieniek (International Arctic Research Center, University of Alaska Fairbanks)

Recent concurrent widespread fires in Alaska are evaluated to assess their associated synoptic-scale weather conditions. Several periods of high fire activity from 2003 to 2015 were identified using Moderate Resolution Imaging

Spectroradiometer (MODIS) hotspot data by considering the number of daily hotspots and their continuity. Fire weather conditions during the top six periods of high fire activity in the fire years of 2004, 2005, 2009, and 2015 were analyzed using upper level (500 hPa) and near surface level (1000 hPa) atmospheric reanalysis data. The top four fire-periods occurred under similar unique high-pressure fire weather conditions related to Rossby wave breaking (RWB). Following the ignition of wildfires, fire weather conditions related to RWB events typically result in two hotspot peaks occurring before and after high-pressure systems move from south to north across Alaska. A ridge in the Gulf of Alaska resulted in southwesterly wind during the first hotspot peak. After the high-pressure system moved north under RWB conditions, the Beaufort Sea High developed and resulted in relatively strong easterly wind in Interior Alaska and a second (largest) hotspot peak during each fire period. Low-pressure-related fire weather conditions occurring under cyclogenesis in the Arctic also resulted in high fire activity under southwesterly wind with a single large hot-spot peak.

Deciduous trees are a large and overlooked sink for snowmelt water in the boreal forest

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The terrestrial water cycle contains large uncertainties that impact our understanding of water budgets and climate dynamics. Water storage is a key uncertainty in the boreal water budget, with tree water storage often ignored. The goal of this study is to quantify tree water content during the snowmelt and growing season periods for Alaskan and western Canadian boreal forests. Deciduous trees reached saturation between snowmelt and leaf-out, taking up 21–25% of the available snowmelt water, while coniferous trees removed <1%. We found that deciduous trees removed 17.8–20.9 billion m3 of snowmelt water, which is equivalent to 8.7–10.2% of the Yukon River's annual discharge. Deciduous trees transpired 2–12% (0.4–2.2 billion m3) of the absorbed snowmelt water immediately after leaf-out, increasing favorable conditions for atmospheric convection, and an additional 10–30% (2.0–5.2 billion m3) between leaf-out and mid-summer. By 2100, boreal deciduous tree area is expected to increase by 1–15%, potentially resulting in an additional 0.3–3 billion m3 of snowmelt water removed from the soil per year. This study is the first to show that deciduous tree water uptake of snowmelt water represents a large but overlooked aspect of the water balance in boreal watersheds. The water content of deciduous vegetation may have impacts for understanding fire dynamics in the boreal forest.

Effects of weather and climate on forest fire behaviour: Case study of Northern boreal forest in Republic of Sakha (Yakutia), Russia

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Natalia Serditova, Professor, Faculty of Geography and Geoecology (Tver State University)

Modern climate change in the northern regions, including Russia, has been greater than in most of the rest of the world. Climate change is projected to be even greater in the future and the changes even faster than in the past. Study area, Yakutia has unique geographic and climate characteristics that makes the examination of climate change and its implications urgent and very important. In republic, climate changes over the past 40 years are in part responsible for the rise in economic losses from extreme weather events, stresses on water supply, worsening air quality and related health and economic effects. Extreme events and rising temperatures are becoming more damaging as recent strong summer forest fires and thawing permafrost have demonstrated. This research is devoted to evaluation of the relative role of different weather conditions in explaining occurrence and burned area for Sakha Republic in historical period (1955-2014) and preparation predictions of future forest fire risk. Other study goals are (2) assessment of historical trends of forest fires, (3) determine which part of the republic had highest forest fire rick in the past and how this risk will be

changed under influence of climate change and (4) examine how climate conditions varied historically and how they can change between present and 2100 according to the predictions from set of modern climate models. Six different climate models were used to predict future climate changes which effects on number and the area of forest fires, extent of their impact on forest ecosystems in the republic. This study used GIS environment to map the present and future climate change variables across Yakutia and historical spatial distribution of forest fires. Information from 85 meteorological stations was selected to interpolate temperature and precipitation data for the entire of the Sakha Republic. Interpolation of climate data and forest fires statistics had done using Kriging method. Predicted climate data based on tested climate models shows increase of temperature during forest fire season. But this increase is not the same for all area, as maps present more changes of temperature is for western part of the study area. Western part of republic, which had the highest fire risk in the past, will have the most risk based on predicted data.

APRFC Produced QPE and QPF grids

Arleen Lunsford (NOAA/NWS/APRFC)

The Alaska-Pacific River Forecast Center (APRFC) produces Quantitative Precipitation Estimation (QPE) grids for synoptic 6-hour periods and for the 12Z-12Z (4am-4am AKDT) 24-hour period daily during the open water season, generally late April through early November. The QPE grids are also produced during the cold season, with grids produced daily Monday through Friday (excluding holidays), and the grids for Saturday and Sunday are produced on Monday. The APRFC also produces 6-hour Quantitative Precipitation Forecast (QPF) grids out to 7 days.

This presentation will describe the input data and the programs used in producing these grids, as well as some of the factors to be aware of when using these grids. We will also discuss why the grids are produced when they are, as well as other gridded products currently produced at the APRFC, and products that might be available in the future.

Near Real-Time Fire Behavior (7)

Which remotely sensed data are best and most timely for fire detection, plume tracking of fire emissions, fire behavior modeling, mapping of flaming fronts, fire intensity, active fire perimeters, and response for ongoing fires?

High-Resolution Rapid Refresh with Smoke (HRRR-smoke) modeling system for experimental smoke forecast guidance

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B. Pierce (Advanced Satellite Products Branch, Center for Satellite Applications and Research, NOAA/NESDIS)
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S. Benjamin (NOAA ESRL/GSD)

Wildfires can have a huge impact on air quality and visibility over large parts of the contiguous US and Alaska. In this talk we describe a fully coupled meteorology-chemistry modeling system (HRRR-Smoke) run in real time for the CONUS and Alaska domains. The HRRR-Smoke modeling system uses fire radiative power (FRP) data measured by the Visible

Infrared Imaging Radiometer Suite (VIIRS) sensor on the Suomi National Polar-orbiting Partnership satellite. Using the FRP data the model predicts fire emissions, fire size and plume rise.

The HRRR-Smoke model is run in real time since the summer of 2016 on a 3km horizontal grid resolution over the CONUS and Alaska domains by NOAA/ESRL Global Systems Division (GSD). The model simulates advection and mixing of fine particulate matter (PM2.5 or smoke) emitted by calculated fire emissions. The fire emissions include both smoldering and flaming fractions. Fire plume rise is parameterized in an online mode during the model integration.

The HRRR-Smoke real-time runs use meteorological fields for initial and lateral boundary conditions from the experimental real-time HRRR(X) numerical weather prediction model also run at NOAA/ESRL/GSD. The model is initialized every 6 hours (00, 06, 12 and 18 UTC) daily using newly generated meteorological fields and FRP data obtained during the previous 24 hours. The model then produces a meteorology and smoke forecast for the next 36 hours. The smoke fields are cycled from one forecast to the next one. Predicted near-surface and vertically integrated smoke concentrations are visualized online on a web-site: http://rapidrefresh.noaa.gov/HRRRsmoke/

In this talk, we discuss the major components of the HRRR-Smoke modeling system and its potential applications for air quality forecasting.

Verification of the Experimental High Resolution Rapid Refresh in Alaska using the USArray Transportable Array Network

Taylor A. McCorkle, John D. Horel (University of Utah)

Alaska's expansive size, dynamic weather, and abundance of remote regions make it the ideal location for innovative atmospheric and environmental observation platforms. In 2015, EarthScope began deploying its USArray Transportable Array (TA) stations across the state of Alaska at an average spacing of 85 km. The USArray was originally designed as an in-situ seismic monitoring network, but later was retrofitted with atmospheric sensors to expand the platform's scientific reach. This high resolution network, known for its research quality instruments and measurements, allows for a rich dataset of pressure observations to be taken across Alaska. These TA observations will be used in an effort to validate an experimental version of the High Resolution Rapid Refresh (HRRR) being run in Alaska by the National Oceanic and Atmospheric Association's (NOAA) Earth System Research Laboratory (ESRL). The experimental Alaska HRRR is a 3 km convection-permitting model that is initialized every 3 hours and produces hourly forecast grids out to 36 hours. The verification process will use data collected during the 2015-2016 cold season (October – March) and focuses on how the HRRR handles rapidly intensifying surface lows and storm tracks. Point verification of the HRRR with TA and National Weather Service stations in western Alaska will serve to quantify the HRRR's ability to forecast the strength and location of surface pressure centers in the state of Alaska. In addition to validating the HRRR's surface pressure forecasts, the model will likely be compared to satellite imagery. The satellite data will be used to verify the HRRR's ability to model cloud cover, which will be useful not only in the cold season, but as a parameter for fire weather forecasting.

Applications of Chinese FY series meteorological satellites in boreal forest fire management

Fengjun Zhao (Research Institute of Forest Ecology, Environment & Protection, Chinese Academy of Forestry)
Yongqiang Liu (Center for Forest Disturbance Science, USDA Forest Service)

Wildfire is a major forest disturbance in the forests in northeastern China. Fires in this region have extraordinary environmental and social impacts because it's location close to densely populated regions in China and other northeastern Asian countries. This study describes the applications of Chinese satellite products in forest fire management in northeastern China. China has launched a total of 14 Fengyun (FY) (Chinese words meaning wind and cloud) meteorological satellites since 1988, seven for each of polar-orbiting and geostationary types. Half of them are in service currently. Besides weather, FW satellites provide extensive products for forest fire management, including fuel classification, fire detection, fire spread and smoke transport monitoring, damage estimate, and post-fire recovering assessment. Fuels are classified based on FY NDVI products combined with techniques such as principal component analysis and GIS. Fire detection and monitoring is the most important application of FY products. The catastrophic fires occurred in the Daxinganlin Mountains region in May, 2006, for example, were monitored by the FY satellite remote sensing throughout the entire burning period, providing the information necessary for planning and implementing fire suppression. The time resolution of the FY polar-orbiting satellite products has continued to increase, from one hour in 1997 with FY-2A/B to about one minute now and near future with FY-4A/B, leading to dramatic increase in the capacity of fire detection and monitoring. Meanwhile, the FY geostationary satellite products improved from one hour with normal scan to 6 minutes with region rapid scan, increasing the accuracy in estimating burned areas, fire intensity, and smoke. Nine more satellites will be added to the FY series from 2016-2011, which will provide more powerful remote sensing products for fire management in the boreal forests in China.

Challenges and Opportunities: Using the University of Alaska's Near Real Time Satellite Imagery to Support Alaska Wildland Fire Community

Eric Stevens, Jay Cable, Carl Dierking, Jiang Zhu, Tom Heinrichs, Dayne Broderson (UAF/GINA)

The Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks receives data from a number of polar-orbiting weather satellites. Data from these satellites are used to generate imagery and other products that are delivered in near real time to users such as the National Weather Service and Alaska Fire Service. Examples of satellite imagery useful in monitoring and forecasting weather that impacts the behavior of wildfires in Alaska will be presented, with a special emphasis on newer multispectral products. Plans for the future will also be addressed, including a description of some of the challenges that must be overcome if these satellite products are to be of maximum benefit to Alaska's wildfire community.

VIIRS Imagery Applications for Fire Weather Monitoring

Curtis J. Seaman and Steven D. Miller
CIRA, Colorado State University, Fort Collins, CO

The Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (NPP) satellite has been producing high-quality imagery since its launch in October 2011. Additional VIIRS instruments will be launched on subsequent JPSS satellites (1-4). The 22 bands on VIIRS include 5 high-resolution imagery channels (~375 m resolution at nadir), 16 moderate resolution channels (~750 m resolution), and the Day/Night Band (~742 m resolution), which collectively range in wavelength from 0.412 μm to 12.01 μm. These channels offer a wide range of imagery applications that are useful for monitoring the fire weather environment. For example, VIIRS has 5 bands in the near and shortwave IR that useful for detecting hot spots. The Day/Night Band is sensitive to the light emissions from fires at night, as well as the smoke (given sufficient moonlight). In addition to these individual VIIRS bands, there are many multispectral applications including red-green-blue (RGB) composites of these channels that are useful for detecting fires, smoke, vegetation health, snow and ice coverage, and even flooding. Specific RGB applications include: True Color for detecting/monitoring smoke; Natural Color for detecting snow cover, vegetation health and burn scars; the Fire Temperature RGB composite for monitoring fire activity; and the Snow/Cloud Discriminator product, which utilizes the Day/Night Band to improve the discrimination of snow and clouds at night. An introduction to these RGB composites and an overview of these applications will be discussed.

Improved operational approaches to high and low-intensity fire detection in Alaska using the VIIRS I-band Fire Detection Algorithm for High Latitudes (VIFDAHL)

Christine F. Waigl, Martin Stuefer, Anupma Prakash (Geophysical Institute, UAF)
Charles Ichoku (NASA Goddard Space Flight Center, Greenbelt, MD)

Fire products from Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) provide near real-time information for wildfire detection, monitoring, and characterization. Using data acquired during Alaska's 2015 extreme fire season, we analyzed the performance of the MODIS-based MOD14/MYD14, and the more recent VIIRS I-band operational active fire products. A comparison with the fire perimeter and properties data published by the Alaska Interagency Coordination Center (AICC) shows that both MODIS and VIIRS fire products successfully detect all fires larger than approximately 1000 hectares. For smaller fires, the VIIRS I-band product offers higher detection likelihood, but overall still misses one fifth of the fire events. To map both low- and high-intensity burn areas in Alaska, we developed the VIIRS I-band Fire Detection Algorithm for High Latitudes (VIFDAHL), which we applied to selected study regions of known Alaskan boreal forest fires. VIFDAHL more accurately captures the fire spread, can differentiate well between low- and high-intensity fires, and can detect 20-70% more low-burning fire pixels compared to the MODIS and VIIRS global fire products. It also offers avenues to further fire characterization via sub-pixel temperature and fractional active fire area retrieval.

Near real-time estimation of burned area in boreal forest using VIIRS 375 m active fire product

Patricia Oliva (Department of Geographical Sciences, University of Maryland, College Park)

Every year, thousands of hectares of boreal forest are affected by fires, causing significant ecological and economic consequences, and associated climatological effects as a result of fire emissions. In recent decades, burned area estimates generated from satellite data have provided systematic global information for ecological analysis of fire impacts, climate and carbon cycle models, and fire regimes studies, among many others. However, many of the operational products are delivered with a time lapse which ranges from weeks to months. There is an urgent need of near real-time burned area estimations to assess the impacts of fire, estimate smoke plume transport, and biomass burning emissions. The enhanced characteristics of the Visible Infrared Imaging Radiometer Suite (VIIRS) 375 m on board the Suomi National Polar-orbiting Partnership (S-NPP) make possible the use of near real-time active fire detection data for burned area estimation. The VIIRS 375 m active fire detection product offers higher sensitivity to smaller and low-intensity fires. In addition, the higher frequency of image acquisitions due to VIIRS long swath makes possible to obtain more than four acquisitions per day in high latitudes (> 40 degrees). The reception of multiple images per day allows the monitoring of fire growth and burned area estimation. In this study, consecutive VIIRS 375 m active fire detections were aggregated to produce the VIIRS 375 m burned area (BA) estimation over Canada, Russia, and Alaska. The accuracy of the BA estimations was assessed by comparison with Landsat-8 supervised burned area classification. The results showed good agreement with the reference fire perimeters proving that the VIIRS 375 m BA estimations can be used for near real-time assessments of fire effects.

Airborne hyperspectral remote sensing in the real-time detection and management of wildfire

Keshav Dev Singh, Postdoctoral Employee (College of Agricultural and Environmental Sciences, University of California, Davis)

Hyperspectral airborne remote sensing has capable sensors for the early detection of boreal or arctic wildfire even before visible symptoms become apparent. It integrates conventional imaging and spectroscopy knowledge to attain both spectral and spatial information from an object. Imaging spectroscopy provides detailed signatures (such as reflectance) of the biological samples due to interaction between the electromagnetic radiation and contact material. It is a powerful tool in studies of wildfire triggering due to abilities to assess woodland health via reflectance profiling. I am studying various wildfire sites in California (e.g. Davis-Sacramento area: Boys Fire, Willow Fire, Bell Fire, Willow Fire; Eldorado National Forest: Mokelumne Fire, Emerald Fire; Napa valley: Creek Fire; Yuba City: Butte Fire) to characterize relationship between field composition and abiotic stress induced by different factors. The abiotic stresses are due to drought (water deficit), excessive errosion, extreme temperatures, salinity (sodicity) and hydrocrabon presence. For this study, the hyperspectral data of referred field sites are acquired using an airborne "true push-broom" hyperspectral camera [OCI Imager (OCI-UAV-D1000), BaySpec Inc.; 116 bands from 470-980nm] mounted on a drone (S1000 Premium Octocopter). The acquired images are generally affected by solar light intensity, source-sensor geometry, and scattering, so a ground-based spectrometer is used for continuous white calibration of these datasets. The bi-directional reflectance was corrected using radiative transfer based Hapke's model, which addresses non-linear factors arises due to multiple scattering. The stresses negatively impact growth, development, and yields of green woodland. The narrowband/hyperspectral indices shows that it is possible to pinpoint the areas covered by abiotic stress (drought, and other deficiencies) on woodland prior to fire spread over whole field. It prevents surrounding areas from being threatened, smokey or fire outbreaks. It also reduces the time, cost of fire retardant and poisonousness in our biosphere. The whole study shows that the airborne remote sensing technology has major importance in the real-time detection and management of wildfire for suppression.

Post-Fire Effects (15)

Can we improve analytical methods for remotely sensed data to assess fire severity, consumption/CO2 balance, active-layer changes, and successional trajectories of high latitude vegetation communities?

An Overview of the 2017 Airborne Campaign for NASA's Arctic Boreal Vulnerability Experiment (ABoVE)

C. Miller, S. Goetz, P. Griffith, H. Margolis, E. Kasischke and the ABoVE Science Team

ABoVE envisions major airborne campaigns in 2017 and 2019 with the potential for less comprehensive bridging activities in 2018. Airborne research during the 2017 ABoVE airborne campaign (AAC) will link field-based, process-level studies with geospatial data products derived from satellite remote sensing, spanning the critical intermediate space and time scales that are essential for a comprehensive understanding of scaling issues across the ABoVE Study Domain and extrapolation to the pan-Arctic. The impacts of fire on the Arctic-boreal landscape are a central feature of the 2017 AAC. ABoVE aircraft and field teams will explore fires spanning a broad range of landscapes, burn intensities, and burn histories in Alaska and northwestern Canada, with particular emphasis on areas burned in the Northwest Territories during 2014 and Alaska during 2015. We will also conduct extensive measurements over the ~1200 km^2 2007 Anaktuvuk River fire scar on the North Slope, in the Yukon-Kuskokwim Delta, and on the Seward Peninsula.

The observing strategy involves Foundational Measurements made with the NASA facility instruments UAVSAR (L-band SAR), AirMOSS (P-band SAR), LVIS (full waveform lidar) and AVIRIS-NG (VIS-SWIR spectral imaging). These will provide domain-wide sampling and coverage of ABoVE field sites. Additional measurements will be made by AirSWOT (Ka-band radar) and CFIS (solar induced fluorescence) with an emphasis on higher resolution coverage over specific field sites or portions of the experimental domain. The strategy will seek to leverage complementary NASA airborne activities such as ICEBridge and SnowEx, pre-launch airborne acquisitions for NISAR, HyspIRi and ASCENDS, as well as activities sponsored by partner agencies. Coordination with ongoing or planned Canadian airborne remote sensing (eg lidar-based boreal forest inventories) is key to this approach.

A USFS-NASA partnership to leverage advanced remote sensing technologies for forest inventory

Hans-Erik Andersen, Chad Babcock, Robert Pattison, Bruce Cook, Doug Morton, and Andrew Finley

Abstract: The boreal forests of interior Alaska cover approximately 110 million acres, and appear to be changing rapidly in response to warming temperatures. The status and trends of these forests are poorly understood due in part to the lack of a comprehensive inventory. In 2014 the United States Forest Service's Forest Inventory and Analysis (FIA) program in conjunction with the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center carried out a pilot test of an interior Alaska inventory design. The pilot inventoried the forests of the Tanana Valley State Forest (TVSF) and the Tetlin National Wildlife Refuge (TNWR) in the Tanana River Valley of interior Alaska, covering 2.5 million acres. In order to increase the precision of the inventory estimates, the relatively sparse FIA field plot sample collected in Tanana Valley State Forest and Tetlin NWR was augmented with sampled airborne remotely-sensed data acquired with the G-LiHT (Goddard-Lidar/Hyperspectral/Thermal) system to increase the precision of inventory parameter estimates. G-LiHT is a portable, airborne imaging system, developed at NASA-Goddard Space Flight Center, that simultaneously maps the composition, structure, and function of terrestrial ecosystems using lidar, imaging spectroscopy, and thermal imaging. G-LiHT provides high-resolution (~1 m) data that is well suited for studying tree-level ecosystem dynamics, including assessment of forest health and productivity of forest stands and individual trees. In addition G-LiHT data support local-scale mapping and regional-scale sampling of plant biomass, photosynthesis, and disturbance. The data is accurately georeferenced and can be matched very precisely with field plot data that are georeferenced using high-accuracy (dual-frequency, GLONASS-enabled) GPS.

Rapid response tools and datasets for post-fire modeling in Boreal and Arctic Environments

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W. J. Elliot and P. R. Robichaud (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station)

Preparation is a key component to utilizing Earth Observations and process-based models in order to support post-wildfire mitigation. Post-fire flooding and erosion can pose a serious threat to life, property and municipal water supplies. Increased runoff and sediment delivery due to the loss of surface cover and fire-induced changes in soil properties are of great concern to resource managers. Remediation plans and treatments must be developed and implemented before the first major storms in order to be effective. One of the primary sources of information for making remediation decisions is a soil burn severity map derived from Earth Observation data (typically Landsat) that reflects fire induced changes in vegetation and soil properties. Slope, soils, land cover and climate are also important parameters that need to be considered. Spatially-explicit process-based models can account for these parameters, but they are under-utilized relative to simpler, lumped models because they are both difficult to set up and require spatially-explicit inputs (digital elevation models, soils, and land cover). Our goal is to make process-based models more accessible by preparing spatial inputs before a wild fire, so that datasets can be rapidly combined with soil burn severity maps and formatted for model use. We have built an open source online database (http://geodjango.mtri.org/geowepp /) for the continental United States that allows users to upload soil burn severity maps into the database. The soil burn severity map is then rapidly combined with land cover and soil datasets in order to generate the spatial model inputs needed for hydrological modelling of burn scars. We believe our database could be expanded internationally to support other countries that face post-fire hazards.

This summer we worked with the University of Alberta to model potential erosion from the Fort McMurray fire. We utilized Lidar based DEM, Canadian weather data, Canadian Soil Landscape data, pre and post-fire Landsat imagery, and the Alberta Biodiversity Monitoring Institute land cover map in our modeling. We were able to demonstrate that process based models could be rapidly applied for modeling post-fire effects in Canada. The datasets and modeling developed for the Fort McMurray fire will be refined and utilized under a new NASA SMAP program to help improve Canadian Forest

Fire Danger Rating System predictions with SMAP soil moisture data. Data fusion techniques will be used to combine modeled predictions of soil moisture with SMAP observations with the goal of improving the spatial resolution of SMAP.

Evaluating characterization of fire extent and fire spread in boreal and tundra fires of North America from coarse and moderate resolution MODIS and VIIRS data

Tatiana Loboda, Kelley O'Neal, Varada Shevade, Khashayar Dehkordi (University of Maryland College Park)

Satellite observations of fire occurrence, extent, and spread have become a routine source of information for fire scientists and managers worldwide. In remote regions of arctic and boreal zones, satellite observations frequently represent the primary and at times the only source of information about fire occurrence. While a large suite of observations have been shown to provide beneficial and important information about fire occurrence, coarse and moderate resolution data from polar orbiting satellites in optical and thermal ranges of the electromagnetic spectrum provide the most widely-used observations that characterize on-going burning processes and consistent estimates of fire-affected areas. The reliance of the global community on active fire detections and burned area estimates delivered from the Moderate Resolution Imaging Spectroradiometer (MODIS) raises concerns about the continuity of the data record beyond the lifetime of this mission. The Visible Infrared Imaging Radiometer Suite (VIIRS) operated by National Oceanic and Atmospheric Administration (NOAA) represents the future of satellite fire monitoring within US-designed and operated missions. While some advancements have been introduced into the VIIRS fire detection capabilities, including enhanced spatial resolution of spectral bands aimed at active fire detection, the reduced number of orbital overpasses (only one VIIRS instrument is currently in orbit compared to two MODIS instruments) and other differences in data acquisition open the potential for substantial differences in future fire monitoring and mapping capacity and long-term record compatibility between MODIS and VIIRS observations. This study aims to assess and quantify the differences in characterization of on-going burning processes (including in time of detection, spatial fidelity and extent of fire detection coverage, fire spread rate, and fire radiative power) and post-fire extent within fire events (i.e. burned area mapping) in boreal forests and tundra regions of North America delivered by the MODIS Terra and Aqua collection 6 and VIIRS 750m and 375m active fire products and derived burned area maps. Since VIIRS standard data suite does not include burned area estimates, we used VIIRS and MODIS collection 6 surface reflectance products to generate an annual burned area record using the Regionally Adapted Burned Area algorithm developed specifically for high northern latitudes. Our initial results indicate that despite higher spatial resolution of VIIRS observations, the MODIS record (even from a single satellite) delivers a more comprehensive coverage of on-going burning within the large fire events of the 2014 fire season in the Northwest Territories, Canada. However, while substantial differences in fire characterization exist between the satellite data, there is strong potential for calibration of the data records (particularly for the burned area and fire radiative power estimates) for the two instruments necessary to achieve a consistent long-term record of fire occurrence in the high northern latitudes that would support long-term scientific studies and management decision-making processes.

Decades of Change in the Former Soviet Union: Current Assessment and New Possibilities

Amber Soja, Brian Stocks, Don Cahoon, Natasha Jurko, Alan Cantin, Bill de Groot, Elena Kukavskaya, Nadezda Tchebakova, Evgeni Ponomarev, Susan Conard Galina Ivanova, and Elena Parfenova

The Former Soviet Union (FSU) is a distinct and crucial region because it has the physical size necessary to effect regional and global climate, and it lies in the northern hemisphere upper latitudes where climate-driven change is already evident. The circumboreal zone contains the largest stock of terrestrial carbon on Earth, and Russia holds 2/3 of that carbon pool. Recent climate change data and models agree that temperature increases in Russia have been and will be among the greatest on the planet, leading to longer growing seasons, increased evapotranspiration, and increased extreme fire weather, all of which are altering fire regimes and the carbon balance in ecosystems.

Fire is an integral natural process that serves to alter landscapes and their carbon balance and is largely under the control of weather and climate. Estimating the amount of biomass burned or available fuel during fire events is challenging, particularly in remote and diverse regions, like those in Russia. Historically, we have typically assumed 25 tons of carbon per hectare (tC/ha) is emitted across boreal landscapes, however depending on the ecosystem and severity, biomass burning emissions can range from 2 to 75 tC/ha. Ecosystems in the FSU span from the tundra through the taiga to the forest-steppe, steppe and desserts and includes the extensive West Siberian lowlands, permafrost-lain forests and agricultural lands. Excluding this landscape diversity and fire severity results in inaccurate emission estimates and incorrect assumptions in the transport, deposition, and feedbacks of these emissions.

In this work, we present two beta products that will enhance long-term understanding of Russian environments. First, we will introduce a hybrid ecosystem map of the Former Soviet Union (FSU) that contains explicit estimates of fuel or biomass. Specifically, the ecosystem map is a fusion of satellite-based data, a detailed ecosystem map, and Alexeyev and Birdsey carbon storage data, which is used to build carbon databases that include the forest overstory and understory, litter, peatlands and soil organic material for the FSU. We provide a range of potential carbon consumption estimates for low-, medium- and high-severity fires that can be driven with fire weather or fire danger indices to more accurately estimate fire emissions. Additionally, a team of scientists has been working to estimate historic large-burned areas in Siberia using historic Advanced Very High Resolution Radiometer (AVHRR) Global Area Coverage data that is expected to span from 1980 through 1995. Paired with satellite-based products from Sukachev Institute of Forest, MODIS, and VIIRS, we can expect a large-fire burned area database that spans almost 40 years for Siberia.

High resolution carbon emissions estimates from boreal fires

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James Randerson (University of California, Irvine)
Elizabeth Wiggins (University of California, Irvine)
Brendan Rogers (Woods Hole Research Center)

Boreal forests and arctic tundra store approximately 35 % of global soil carbon. Many of these organic soils are vulnerable to combustion during wildfires. Carbon combustion rates are high latitude ecosystems and vary greatly depending on environmental conditions.

Several research teams associated with NASA's Arctic-Boreal Vulnerability Experiment have been conducting field measurements in recent fires in Alaska and Canada. This is resulting in a growing database of field measurements of carbon combustion in boreal and arctic ecosystems, which will increase our ability to estimate and forecast fire carbon emissions.

Effective use of these field measurements with remotely sensed and other geospatial datasets allows for spatially and temporally explicit estimates of pyrogenic carbon combustion. We explored relationships between field measurements and remotely sensed estimates of burn severity, tree cover and topography, and meteorological variables from reanalysis. A multiplicative regression model produces carbon emissions estimates with uncertainties of approximately 20 %. We combined this model with remotely sensed daily burned area maps at 500 m resolution to develop a spatially and temporally explicit carbon emissions inventory.

The model has been successfully applied in Alaska between 2001 and 2015 resulting in the Alaskan Fire Emissions Database (AKFED). We are currently expanding the model into Canada. The daily temporal resolution of the emissions combined with regional air transport models has already led to an improved understanding of emission factors. In addition, applications over the large fires years in the Northwest Territories in 2014 and in Alaska in 2015 provided critical insights in the environmental drivers of fire spread and emissions. We estimated emissions of 164 ± 32 Tg C in the Northwest Territories in 2014 and 59 ± 14 Tg C in Interior Alaska in 2015.

Our daily ignitions, burned area and carbon emissions products are of interest to land and fire managers who may benefit from spatially explicit inventories for decision-making. Our products can further provide a first step towards the inclusion of carbon accounting in fire management.

Improving remotely sensed multispectral estimations of burn severity in western boreal forests

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Marc-André Parisien, Dan K. Thompson, Ronald J. Hall, Rob S. Skakun (Canadian Forest Service)
Mike D. Flannigan (University of Alberta)

Burn severity (fire-induced changes to vegetation and soils) is assessed following wildfires to estimate ecological impacts, and to plan postfire mitigation and management. The Monitoring Trends in Burn Severity (MTBS) program provides Landsat-based remotely sensed burn severity products of the differenced Normalized Burn Ratio (dNBR) and the Relativized dNBR (RdNBR) for all large fires in the United States (including Puerto Rico). Although dNBR is a widely-adopted metric it does not accurately represent burn severity where prefire vegetative biomass is low, and in very severe burns, and thus it is often correlated to prefire imagery. The RdNBR was developed to address these limitations, but the equation can fail and may produce extreme values. Researchers have expressed longstanding concerns over modelling ecologically meaningful burn severity in the boreal forests of North America using multispectral remote sensing products, because relationships between remotely sensed burn severity and field measurements are often site-specific in northern environments. Despite known limitations, the use of Landsat-based fire severity metrics in the boreal forest persists due to their widespread availability and documented relationships to some field measures of fire severity.

The Relativized Burn Ratio (RBR) is a Landsat-based fire severity metric that presents an alternative to both dNBR and RdNBR, providing a reduced correlation to prefire imagery, while overcoming the mathematical limitations of RdNBR. We compared the relationship between field observations taken one year postfire and the three aforementioned remotely sensed measures of burn severity, collected in several fires, various ecosites, and both wetlands and uplands that burned in 2014 in the Northwest Territories and Wood Buffalo National Park (n = 51). Postfire field measurements include the Crown Fire Severity Index (CFSI), Composite Burn Index (CBI), percent overstory mortality, exposed mineral soil and organic soil depth, as well as prefire forest stand structure and composition. We produced significantly better model fits between field measurements of burn severity and RBR than with dNBR and RdNBR, suggesting that RBR may be preferable for future spatial analysis of burn severity in the boreal forest, when using multispectral imagery. Partitioning of the data by ecosite type and drainage produced different relationships between field and remotely sensed severity metrics, emphasizing the importance of the use of normalized and relativized data when quantifying burn severity across multiple fires.

As fire weather and burn rates in the boreal forest escalate under climate change, reburning over fuel-limited recently-burned areas is increasingly a reality. The successful estimation of severity in reburns where the cumulative impacts of multiple fires may be ecologically severe, but represent a small change in biomass, requires the adoption of relativized metrics of burn severity. Although new alternatives for assessing burn severity exist using other spectral satellites, UAVs, and radar, Landsat imagery provides a unique opportunity to revisit historical wildfires and a long time series. Improved models relating observed severity in northern environments to Landsat burn severity measures enable us to examine the variability in past burn severity, providing enhanced baselines from which to measure future change and guide management.

Changing fire frequency and carbon consumption in Alaskan black spruce forests

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T. Loboda (University of Maryland)
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E. Kasischke (University of Maryland)

Changes to the fire regime in the boreal forests of Alaska have included increases in burned area and fire frequency over recent decades. These fire regime changes alter carbon storage and emissions, especially in the thick organic soils of black spruce (Picea mariana) forests, but there is uncertainty in the overall vulnerability of these landscapes to burning, especially in stands that burn while they are still immature (~<60 years old). A better understanding of both the vulnerability of immature stands, and of the carbon emissions impact of immature stands burning, is needed. In the research presented here we first assessed geospatial and remote sensing datasets from 167 interior Alaskan fire events between 2002 and 2008 to analyze the relationship of fractional burned area (representative of the total burned area within a fire perimeter) with fire-free interval (a measure of fire frequency), vegetation, topography and the seasonal timing of burning. We then analyzed how fire frequency impacts carbon consumption in Alaskan boreal forests using a modeling framework. Interestingly, it was found that the fraction of burned area differed between mature forested areas and immature non-forested areas within the analysis. Results showed that considerable burning in interior boreal regions occurs in stands not yet fully recovered from earlier fire events (~20% of burned areas are in immature stands). These newly determined results were then incorporated into the modeling framework through adding an immature black spruce fuel type and associated ground-layer carbon consumption values. This alteration to the model lead to higher ground-layer carbon consumption (and thus total carbon consumed) for areas that burned in two years with high total burned area in Alaska (2004 and 2005). These new results provide insight into the fire-climate-vegetation dynamics within interior Alaskan boreal forests and can be used to both inform and validate modeling efforts to better estimate soil carbon pools and emissions in interior Alaskan boreal forests.

Assessing Boreal Forest Burn Severity using UAS-based Photogrammetric Mapping

Robert H. Fraser (Canada Centre for Mapping and Earth Observation, Natural Resources Canada)
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Wildfires are a major disturbance to boreal forests where in North America, there is often considerable variability in the severity of burns. Estimating and mapping boreal forest burn severity is important for understanding ecological response to fires, assisting rehabilitation efforts, and predicting post-fire vegetation successional patterns. Burn severity has been measured at plot scales using field techniques such as the Composite Burn Index (CBI), while a range of remotely sensed data and methods have also been applied to measure severity at landscape to regional scales. One common approach for regional-scale mapping of boreal burn severity is to quantify the empirical relationship between CBI plot values and change in the Normalized Burn Ratio (NBR) computed from Landsat satellite imagery. These relationships can then be used to convert the relative NBR spectral index into a numerical field-based rating of burn severity. Some limitations with applying this calibration approach include the subjective and qualitative nature of CBI measurements, a limited ability to measure consumption of surface organic material, and a complex mechanistic relationship between CBI's multiple, integrated measures of severity and spectral reflectance changes. Our study investigated the potential to map two simple attributes of boreal burn severity (residual green vegetation and charred organic surface) in NWT, Canada at very high (3 cm) resolution using color orthomosaics and vegetation height models derived from Unmanned Aircraft System (UAS)-based photographic surveys. These attributes were scaled to 30 m resolution Landsat pixel footprints so they could be compared to the NBR and other Landsat-based spectral vegetation indices. We found that the 30 m fractions of green vegetation and charred organic surfaces were both highly related ($R2 > 0.80$) to Landsat spectral indices and that these relationships were stronger than those between CBI and Landsat indices. Follow-on research will conduct higher resolution UAS mapping of burns to quantify more complex metrics of burn severity from which to better characterize post-burn vegetation structure. Overall, these initial results provide a proof-of-concept for using low-cost UAS photogrammetric mapping to derive key measures of boreal burn severity at landscape scales, which can be used to calibrate Landsat spectral indices for mapping severity at regional scales.

Post-fire vegetation index recovery patterns in the taiga-steppe ecotone of southern Siberia

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Wildfire disturbance in the light conifer forests of southern Siberia is a common occurrence, with an average fire return interval on the order of 50 to 100 years. In the ecotone between steppe vegetation to the south, and taiga to the north, vegetation type is determined by topographic position, with forests dominating areas of higher elevation. Wildfires can reduce the resilience of forest ecosystems, making them vulnerable to recovery failure post-fire, particularly when these occur on south-facing slopes or in areas affected by multiple fires in short succession. Remotely sensed vegetation indices are sensitive to the signal of forest loss post-fire, and can provide an estimate of the disturbed area that experiences recovery failure in the region. We apply the bfast method for detecting disturbances in southern Siberia in 2000 using remotely-sensed vegetation indices, and study the variability of post-fire recovery patterns using rgrowth. We find that a fraction of the disturbed area appears to experience recovery failure, and that the post-disturbance conditions have persisted in these sites for 1.5 decades. The loss of southern boreal forests as a result of wildfire is consistent with other studies highlighting the vulnerability of these forests globally, which is likely to offset boreal expansion to the north.

Wildfire reburn dynamics within Alaska, 1970 – 2015

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Climate is the primary driver of fire regimes in Alaskan boreal forests, where warmer and drier conditions are implicated in the contemporary trend towards larger, more severe, and more frequent fires. Resource and fire managers have also reported a contraction of reburn intervals, as a growing number of fires burn across existing fire scars in anomalously short periods of time. The deviation of reburn frequencies from historical norms can disrupt stable cycles of postfire vegetation succession, resulting in critical landscape-scale shifts in boreal forest structure, function, and species composition. To substantiate and understand reburn observations, we explored the spatial and temporal patterns of initial and reburn fires within Alaska over the past five decades. We examined fire incidence on a statewide and local level using the dataset of historical fire perimeters produced by the Alaska Interagency Coordination Center (AICC), the 2016 vegetation classification map published by the Alaska Center for Conservation Science (ACCS) (University of Alaska, Anchorage), and higher-resolution vegetation classification maps, where available, for more localized investigations in individual National Parks, National Wildlife Refuges, and ecological zones of interest. To focus on the time period of most consistent fire documentation and to exclude minor and intentional burns, we subset the perimeter dataset to non-prescribed fires that burned from 1970 to 2015 and were larger than 400 hectares. Our analysis links metrics of burn seasonality, extent, geographic location, and proportion and configuration of reburn area with coarse-level landcover categories to assess fire dynamics and trends across broad ecosystem types. Our results elucidate reburn characteristics within the context of the evolving nature of Alaskan fire regimes under altered climate conditions.

Satellite Synthetic Aperture Radar detection of soil moisture condition and associated post-fire physical and ecological changes in single and repeated burning in North American tundra

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The all-weather imaging capabilities of Synthetic Aperture Radar (SAR) satellite systems provide significantly more data looks than electro-optical systems in high northern latitudes. The extensive historical archive of ERS-1 and -2, Radarsat-1, and ALOS PALSAR image data available provides a robust dataset for both pre- and post-fire characterization of fire signatures in the Alaskan tundra. Our analysis shows that a strong statistically significant relationship between burning and increase in soil moisture immediately after the burning event and a statistically discernable change in backscatter that persists for 4-5 years (Jenkins et al. 2014). Ecologically in peer-reviewed literature this increased moisture at burn sites has been linked to the reduction in SOL depth and subsequent redistribution of moisture across a smaller duff layer leading to pooling of water on the surface (Rocha and Saver 2011). However, duff accumulation in tundra occurs extremely slowly and thus the relatively quick (5-10 year) recovery observed in SAR imagery is not likely to be related to accumulation of SOL to pre-burn layers. An alternative explanation could be presented by the subsequent considerable increase in the active layer depth allowing for more even distribution of surface moisture through the soil column. A rapid increase in vascular plant cover with the subsequent increase in evapotranspiration could present another viable alternative for the observed change in electro-magnetic radiation signature with very different ecological implications. We will summarize the initial findings from our satellite-based and in-situ analysis of soil moisture condition as a function of active layer depth and vegetation fractional composition and above ground biomass using in-situ data from four field campaigns in burned areas in the Alaskan tundra.

An Investigation of Impacts of Large Wildland Fires on Land Surface Properties in Alaska by Combing Satellite Remote Sensing and In-situ Measurements

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Wildland fire is a natural phenomenon and influential force of the Earth's climate system. During the past decades, increased large wildland fire activities, longer wildland fire durations, and longer wildfire seasons in the United States have received more and more attention because of increasing extreme weather and climate events. While there is no significant trend of fire numbers, the burned area apparently increased during the recent decade, which implies increase of large fires. Early studies have demonstrated dramatic changes of surface dynamic, radiative, vegetative, thermal and hydrological properties caused by large wildland fires and significant impacts of wildland fires on ecosystem and regional climate. Wildland fires may lead to either warming or cooling at regional scale. The net impacts of wildland fires depend on the integrated effects of many factors, such as fire emissions, changes in surface albedo, and carbon deposition. Previous studies about the climatic impacts of large wildland fires mainly focused on western region, especially in Alaska and found both positive and negative implications for climatic feedbacks. It's also important to investigate and compare the impacts of large fires over other regions.

To further understand wildland fire trends, forest recovery patterns, and fire-climate interactions, it is essential to quantitatively characterize various changes caused by wildland fires, such as atmospheric composition, cloud cover, surface albedo, soil composition and moisture etc. Providing global coverage and repetitive observations, satellite remote sensing has emerged as an advanced technique for land and climate study. The satellites of Landsat series (Landsat 1-8) have been providing continuous and consistent measurements of the earth from early 1970s to now. Landsat data have been playing important role in wildland fire study, including fuel and burned area mapping. Landsat imagery is the foundation of the LANDFIRE's vegetation and disturbance data layers. From 2000, the launch of NASA's EOS platform with a series of polar-orbiting satellites provided the opportunity for systematic observation and study of the Earth's surface and atmosphere. Especially, the Moderate-resolution Imaging Spectroradiometer (MODIS) data products are available since 2000. With plenty of products and consistent records over 15 years, MODIS has improved our understanding of global dynamics and processes occurring on the Earth's surface, and provides the potential for further investigation of fire-climate interactions.

This presentation will focus on results from our investigating land property changes in Alaska by combining using satellite remote sensing and in-situ measurements. The preliminary results include: an integrated spatiotemporal database in Alaska since 1982, including fire information, time series of land surface properties, as well as climate/weather data; post-fire land surface properties changes of burned areas spatially and temporally; and the impacts of large post-fires on regional climate in Alaska.

Wildfire Consumption of Deciduous Stands during Large Fire Years

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A shift in Alaska's fire regimes has included an increase in the severity of wildfires. Previous research suggests that the increased fire severity favors a shift towards deciduous forest stands. A vegetation shift is likely to lead to future boreal landscapes with lower flammability due to a landscape shifting from spruce to deciduous stands. How resilient are these broadleaf stands to burning during large fire years? In the study, we used Landsat imagery to map pre-fire deciduous stands and track their fate inside burned perimeters that occurred during large fire years of 2004, 2009, and 2015. We categorize deciduous stands by patch size, topographic position, and timing of wildfire to address the potential effectiveness of deciduous stands as "fire breaks" during large fire years.

Remotely sensing post-fire land surface changes in the Arctic using repeat airborne LiDAR

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Wildfire disturbance in northern high latitude regions is an important factor contributing to ecosystem and landscape change. The impact of fires on permafrost-influenced terrain in Boreal Forest regions is well documented; however the role of fires in initiating thermokarst development in Arctic Tundra regions is poorly understood. Rapid climate change at high latitudes has increased interest in the spatial and temporal dynamics of thermokarst and other permafrost thaw-related features in diverse disciplines including landscape ecology, hydrology, engineering, and biogeochemistry. As a result, there is an urgent need to develop new techniques and tools to observe and quantify changes to near-surface permafrost terrain. Remote sensing provides a means for documenting and quantifying many of the changes now occurring on arctic landscapes. In particular, application of multi-temporal airborne LiDAR allows for the detection of terrain subsidence caused by thermokarst. LiDAR elevation model differencing provides a direct measure of land surface elevation changes over time. In this study, we compare two airborne LiDAR datasets covering ~400 km2, acquired in the aftermath of the large and severe Anaktuvuk River tundra fire that occurred in 2007 in northern Alaska. Digital terrain models (DTMs) at 1 m spatial resolution were developed from the LiDAR datasets that were acquired two years and seven years post-fire. These datasets were differenced using the Geomorphic Change Detection tool to quantify thermokarst development in response to the tundra fire disturbance. Results show permafrost thaw subsidence (> 0.2 m) occurring across 34% of the burned tundra area studied, compared to < 1% in similar undisturbed, ice-rich tundra terrain. Ice-rich, yedoma upland terrain was most susceptible to thermokarst development following the disturbance, accounting for 50% of the areal and volumetric change detected, with some locations subsiding more than five meters in the first seven years following the disturbance. Calculation of rugosity, or surface roughness, in the two datasets showed a doubling in microtopography on average across the burned portion of the study area, with a 340% increase in yedoma upland terrain. An additional LiDAR dataset was acquired in April 2015 to document the role of thermokarst development on enhanced snow accumulation and subsequent snowmelt runoff within the burn area. Our findings will enable future vulnerability assessments of ice-rich permafrost terrain as a result of shifting disturbance regimes. Such assessments are needed to address questions focused on the impact of permafrost degradation on physical, ecological, and socio-economic processes.

Differences in wildfire induced land-surface changes between cold and warn U.S. eco-regions detected by satellite remote sensing

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Wildfires can impact the earth systems by modifying not only atmospheric radiation transfer and cloud microphysics through emitting smoke particles but also the land-air heat and water fluxes through changing land-surface properties. Both mechanisms would lead to changes in local and even regional climate. This study detected the changes in land-surface properties induced by large wildfires in the United States with a focus on the differences between cold and warm eco-regions. More than a dozen of large fires with information provided from the Monitoring Trends in Burning Severity (MTBS) dataset were examined. Satellite remote sensing tools including MODIS and Landsat were used to quantitatively evaluate the land-surface changes. The temporal changes were obtained by comparing properties of the burned area between the periods before and after a fire for both fire year and prior year. Spatial changes were obtained by comparing properties between the burned area and a nearby control area with same vegetation cover and very close albedo. The results indicate that land-surface changes are remarkable only if land coverage meets the thresholds of NDVI greater than 0.5 or LAI greater than 1. NDVI and LAI reduce by about 30-70% after burning and large changes exist over 4-10 years. Albedo is reduced by 15-25% shortly after fires, but increase from the second year due to removed vegetation. Day time temperature increases as many as 7-8 K in first 1-2 years during summer. Large changes in cold eco-regions occur mainly in winter and last longer than those in warm eco-regions. These changes and eco-region dependence provide useful guidance to the development of parameterization scheme of wildfire induced land-surface changes for simulating the climate impacts of wildfires through land-air interactions in the earth system models.

Fire-induced surface forcing of the Siberian larch forests since 2000 in the context of climate change

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The Siberian larch forests are a major component of the global boreal biome with wildfire being the most important disturbance agent. However, due to their unique characteristics and remote location, coupled with a limited record of remotely sensed datasets, we know little about the post-fire albedo dynamics in the region as well as the associated climatic impact, especially over a relatively longer temporal span. This is unfortunate as it has been suggested that the climatic effect of the fire-induced albedo change may have a pivotal role in controlling the net climatic impact of the boreal forests. Utilizing a 30-m 24-year stand age distribution map of the Siberian larch forests, combined with the MODIS albedo product and a series of climate datasets produced through the NCEP/NCAR Reanalysis project, this study quantified the fire-induced surface forcing of the Siberian larch forests over 2000-2015. The results show that the post-fire larch forests in the region has a cooling effect lasting for more than 25 years, and the magnitude of the cooling is much larger than previously expected. In contrast, the forests that remained unburned since 2000 show a considerable warming effect, which is largely attributable to the earlier snow-melt in the region. These results together indicate that wildfire may play a much bigger role in modulating the climatic impact of the Siberian larch forests than we previously thought, but this role is likely weakened by the considerable warming in the region, thus needs to be evaluated in the context of global climate change. In addition, the consistent net warming effect of the region, coupled with its large expanse, making the Siberian larch forests a significant contributor to the global warming since 2000.

Carbon exchange rate in burned black spruce forest in interior Alaska

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The Boreal black spruce forest is highly susceptible to wildfire, and postfire changes in soil temperature and substrates have the potential to shift large areas of such an ecosystem from a net sink to a net source of carbon. In this study, we examine CO_2 exchange rates (e.g., NPP and Re) in juniper haircap moss (Polytrichum juniperinum), 10-year old younger black spruce, and microbial respiration in no-vegetation conditions using an automated chamber system in a burned black spruce forest of interior Alaska during the growing season. Mean ± standard deviation microbial respiration and NEP (net ecosystem productivity) of juniper haircap moss were 0.27 ± 0.13 and 0.28 ± 0.38 $gCO_2/m^2/hr$, respectively. CO_2 exchange rates and microbial respiration showed temporal variations following fluctuation in air temperature during the fall season, suggesting the temperature sensitivity of juniper haircap moss and soil microbes after fire. During the 45-day fall period, mean NEP of P. juniperinum moss was 0.49 ± 0.28 MgC/ha following the five-year old forest fire. On the other hand, simulated microbial respiration normalized to a 10 °C temperature might be stimulated by as much as 0.40 ± 0.23 MgC/ha. These findings demonstrate that the fire-pioneer species juniper haircap moss is a net C sink in the burned black spruce forest of interior Alaska.

Environmental controls on regional trace gas variability and emission factors in Alaska

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We examined environmental controls on fire emissions and trace gas variability using three distinct conceptual models of fire emissions that draw upon different types of remote sensing information. The three approaches were derived from satellite-derived observations of active fires, satellite-derived estimates of fire radiative power, and daily emissions estimates from the Alaska Fire Emissions Database model (AKFED). In our analysis, we assessed the relative importance of different climate variables and fire weather indices in explaining the temporal variability of satellite-detected fire thermal anomalies and emissions within the state of Alaska during the summer of 2013. We evaluated the performance of each emissions model using trace gas observations from the CARVE (CRV) tower in Fox, Alaska. In our approach we used an inverse atmospheric transport model, the coupled Weather Research and Forecasting/Stochastic Time-Inverted Lagrangian Transport (WRF-STILT) model, to link the fire emissions with the trace gas observations. MISR plume observations were used to inform the injection height distribution in WRF-STILT and CRV-derived estimates of CO/CO_2 emission ratios were used to convert modeled carbon emissions into trace gas fluxes. Local climate variables had varying levels of influence on fire dynamics in interior Alaska, with vapor pressure deficit and temperature explaining the most variability. Combined use of the emissions products and WRF-STILT allowed us identify fire contributions to the CRV time series on a daily basis, and to isolate contributions from individual fires that had different temporal dynamics and interactions with atmospheric transport. Using this approach, we were able to identify individual fire contributions to emission factors calculated from CRV trace gas observations. Environmental conditions including hourly weather, soil moisture, and fractional tree cover were defined for individual fires and correlated with emission factors. The findings from this study could be used to build a dynamic emission factor model that responds to pre-existing environmental conditions.

Ecosystem Dynamics and Fate of Warm Permafrost after Tundra Wildfire and Lake Drainage on the Yukon-Kuskokwim Delta

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The Yukon-Kuskokwim Delta (YKD) encompasses the southernmost, warmest parts of the arctic tundra biome and is renowned for its high biological productivity and large subsistence-based human population. Ice-rich permafrost currently is widespread and strongly influences terrestrial and aquatic habitats, including local topography, vegetation, soil hydrology, and the water balance of lakes. Ground temperatures are near the freezing point, however, and widespread loss of permafrost is projected to occur by the end of this century. Tundra wildfire is a common ecological pulse disturbance and a potent permafrost stressor on the YKD. Permafrost-affected uplands are extensive in inland parts of the YKD and have one of the most active fire regimes in the circumpolar tundra biome. Large episodes of fire in the early 1970s and recent years have been preceded by widespread loss of upland lakes and ponds; these aquatic-terrestrial state transitions are potentially exacerbated by active-layer deepening after fire, and have secondary impacts associated with increased landscape vulnerability to fire. Here we present a suite of mapping products derived from Landsat 1–8 indicating spectral dynamics related to fire severity and ecosystem recovery, and long-term changes in surface water regime in the inland YKD (Izaviknek Uplands) since 1972. Dense time-series acquired by the Multispectral Scanner (MSS) aboard Landsat 1–3 provide foundational observations of vegetation and aquatic-terrestrial hydrologic state before and after large fires in the early 1970s at 60 meter resolution. The MSS archive has been comparatively little-used because of spectral and calibration limitations, but it is a useful resource for observing land-cover changes with a stark spectral signature such as wildfire and lake drainage. Observations by later Landsat satellites provide more detailed information on post-fire ecosystem dynamics since the mid-1980s using indices that require a short-wave infrared band (e.g., Normalized Burn Index). The landscape-scale remote sensing products presented here will inform the design of a field campaign planned for July 2017 aimed at determining impacts and trajectories of YKD vegetation, soils, and permafrost along gradients of wildfire age and intensity. Findings from field-based and remote sensing components will be used to model changes in landscape vulnerability to future fire resulting from lake drainage and post-fire shifts in vegetation and soil organic stocks. The products of this work will inform YKD resource managers and local stakeholders on the dynamics and trajectories of terrestrial and aquatic habitats and subsistence resources (e.g., berry-producing shrubs associated with permafrost soils) following tundra wildfire. This work leverages logistical and scientific synergies with ongoing research funded by NASA's Arctic Boreal Vulnerability Experiment and USFWS long-term monitoring of breeding birds that depend on upland tundra habitats.