Linking Satellite-derived Fire Counts to Satellite-derived Weather Data in Fire Prediction Models to Forecast Extreme Fires in Siberia

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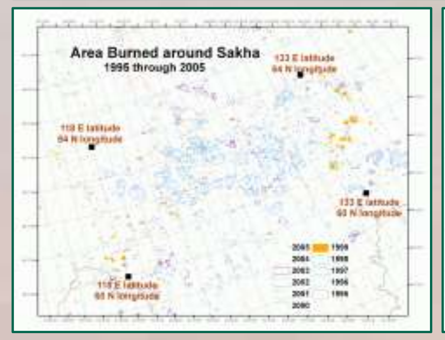
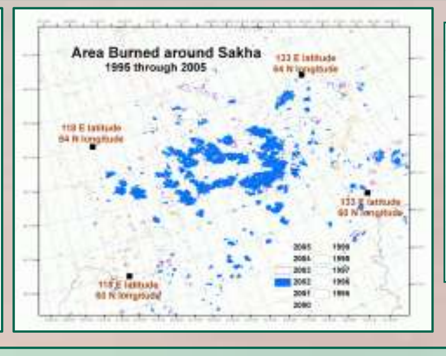
Introduction: Fire is the dominant disturbance that precipitates ecosystem change in boreal regions, and fire is largely under the control of weather and climate[1,2,3,4,5]. Boreal systems contain the largest pool of terrestrial carbon, and Russia holds 2/3 of the global boreal forests[6]. Fire frequency, fire severity, area burned, and fire season length are predicted to increase in boreal regions under current climate change scenarios[1,7]. Therefore to predict fire weather and ecosystem change, we must understand the factors that influence fire regimes and at what scale these are viable. In previous work, we demonstrated the viability of large-scale (1°) data to assess fire weather and danger[8]. Meteorological parameters influence fire danger and fire is a catalyst for ecosystem change.

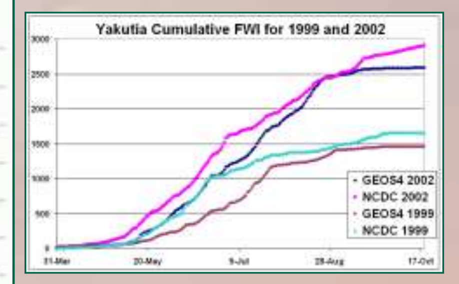
Objective: The ultimate goal of this research is to assess the viability of large-scale (1°) data to be used to assess fire weather danger and fire regimes, so such data can be more confidently used to predict future fire regimes using large-scale fire weather data, like that available from current International Panel of Climate Change (IPCC) climate change scenarios. Specifically, in this poster, we relate large-scale fire weather, area burned, and the amount of fire-induced ecosystem change.

Methodology: First, we demonstrate the similarity in NASA Langley Research Center (LaRC)-derived fire weather indices (FWI) and National Climatic Data Center (NCDC) surface station-derived FWI. Both of these are calculated using the Canadian Forest Service (CFS) FWI, which is based on local noon surface-level air temperature, relative humidity, wind speed, and daily (noon-noon) rainfall[9,10]. The large–scale (1°) LaRC product uses NASA Goddard Earth Observing System version 4 (GEOS-4) reanalysis and NASA Global Precipitation Climatology Project (GEOS-4/GPC) data to calculate FWI. CFS Natural Resources Canada uses Geographic Information Systems (GIS) to interpolate NCDC station data and calculate FWI. FWI's are compared spatially and temporally and with satellite-derived fire counts[11]. Then, the fraction of grid boxes that burn in each FWI class (very low to extreme) are quantified for the fire season from April through October for the years of 1999, 2002, and 2004. These are classified by International Geosphere-Biosphere Programme (IGBP) 1°x1° resolution vegetation types to determine and compare fire regimes in each FWI/ecosystem class. On days with fire counts, the domain total of 1°x1° grid boxes with and without daily fire counts and area burned are totalled. The fraction of 1° grid boxes with fire counts and area burned to the total number of 1° grid boxes having common FWI category and vegetation type are accumulated, and a daily mean for the burning season is calculated. The LaRC and the CFS domain extends from 50°N-80°N latitude and 70°E-170°W longitude.

Single Site Analysis



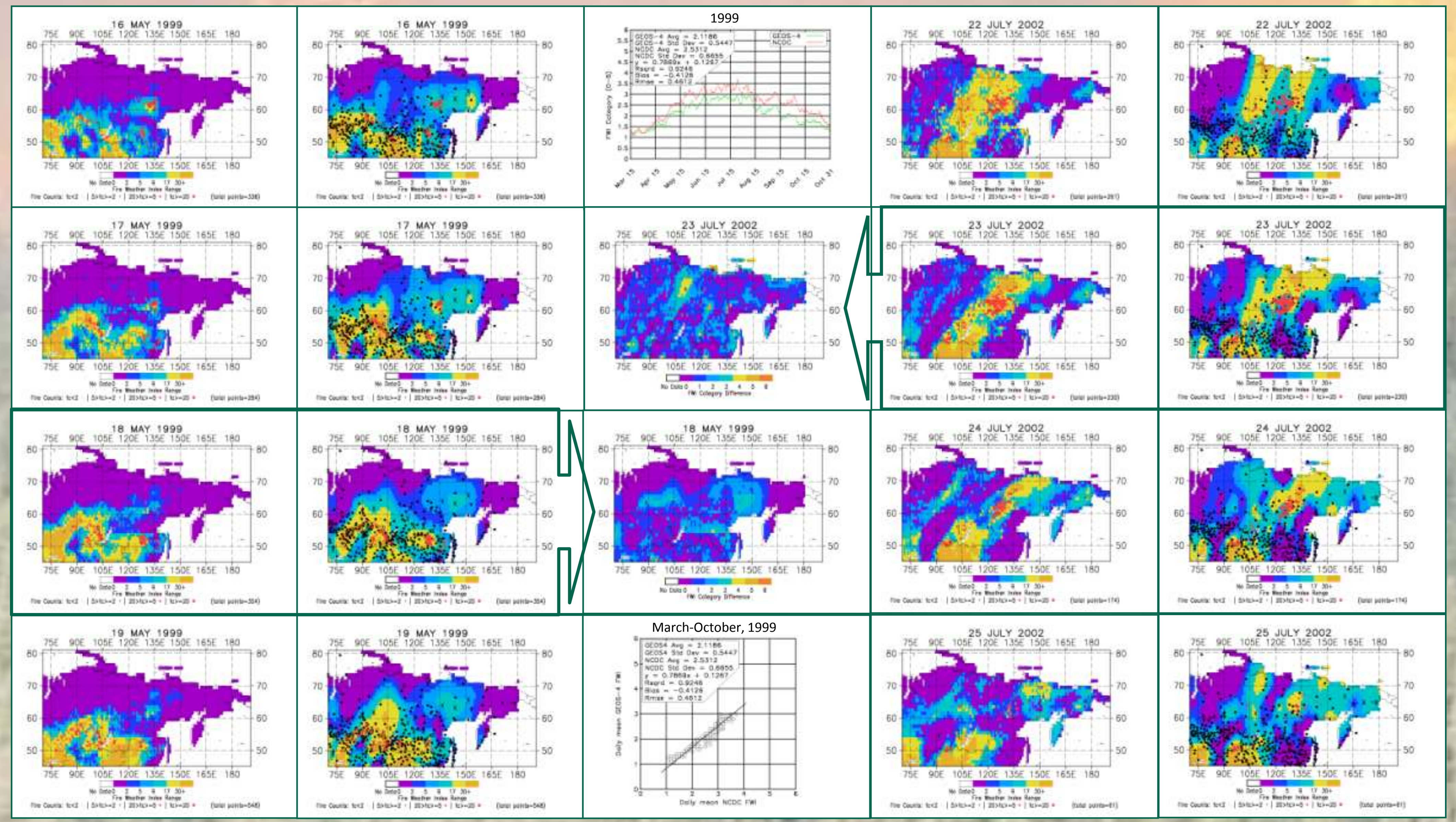




FWI Category Danger Rating	
Danger Class	FWI Range
Very Low	0-1
Low	2-4
Moderate	5-8
High	9-16
Very High	17- 29
Extreme	30 +

Comparison of a minimal fire year (1999) and an extreme fire year (2002) for the Yakutian station in the Republic of Sakha, demonstrating the ability of the FWI to capture extreme fire weather and season. The LaRC NCDC and LaRC GEOS-4/GPCP cumulative FWI are in close agreement throughout the fire season in both 1999 and 2002.

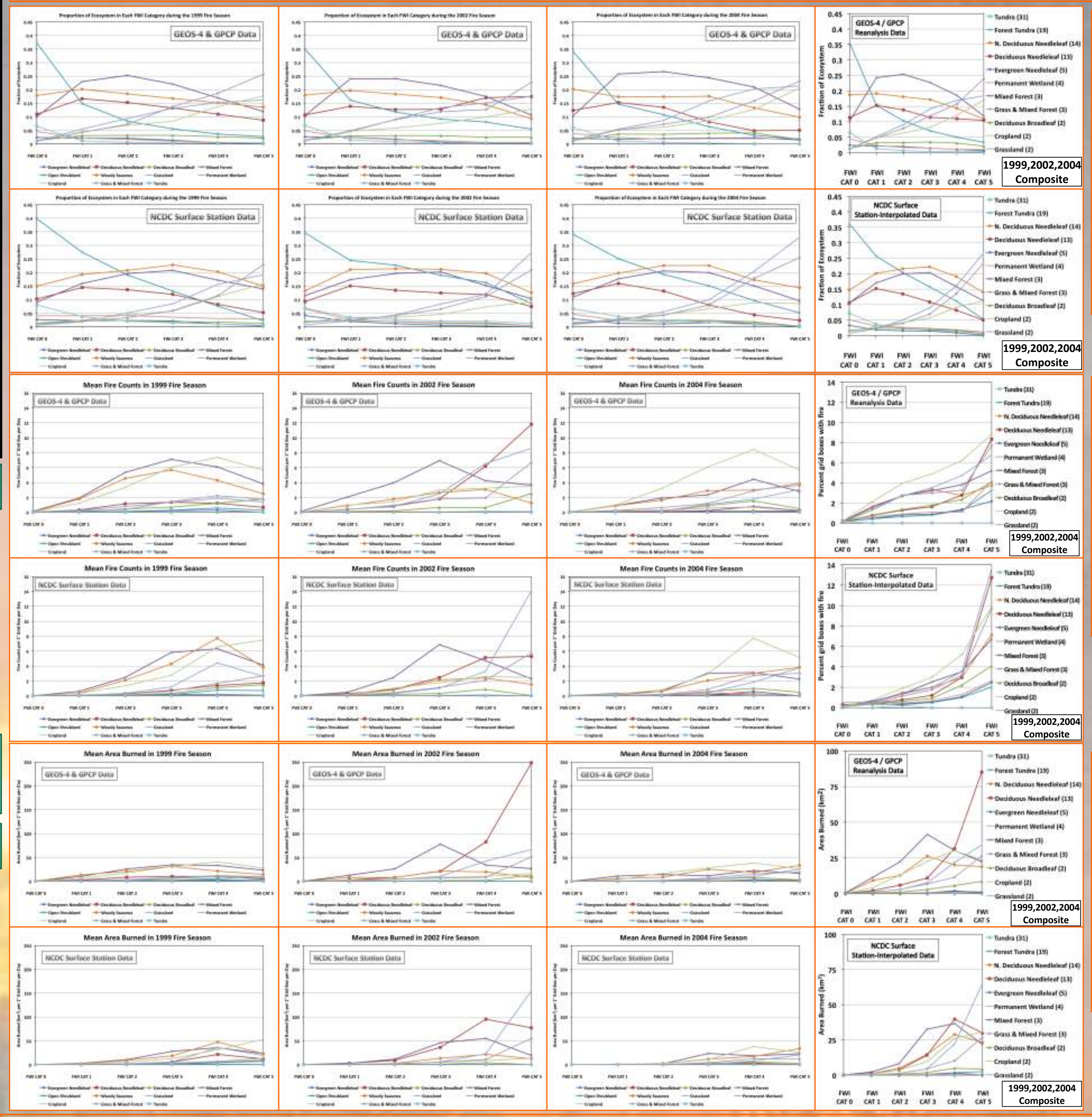
Examples of Daily Langley-derived GEOS-4/GPCP FWI and CFS-interpolated Surface FWI



CFS NCDC interpolated station data offers the detailed weather data that are available from Siberia, however one advantage of the LaRC GEOS/GPCP data are that it is spatially and temporally consistent over time. Surface station locations are overlaid on the CFS NCDC maps highlighting data availability and the distance between the stations. NCDC stations meeting the criteria of 75% of the possible reporting observations per day and 60% of the possible days in each month are indicated with black circles (total stations: 1999: 648; 2002: 635). Those not meeting the criteria but used in FWI interpolation are indicated by an "X" (not meeting criteria: 1999: 232; 2002: 209). Satellite-derived fire counts are shown in red[11].

The third column shows the daily time series and scatter plot of the mean domain GEOS-4 reanalysis and NCDC interpolated FWI for 1999, and the difference in FWI category absolute error between GEOS-4 reanalysis and NCDC interpolated FWI for 18 May 1999 and 23 July 2002. For all three years, approximately 74% of the cells contain 1 category FWI difference or less; about 18% of the cells are 2 categories different; and around 7% of the cell are 3 categories different.

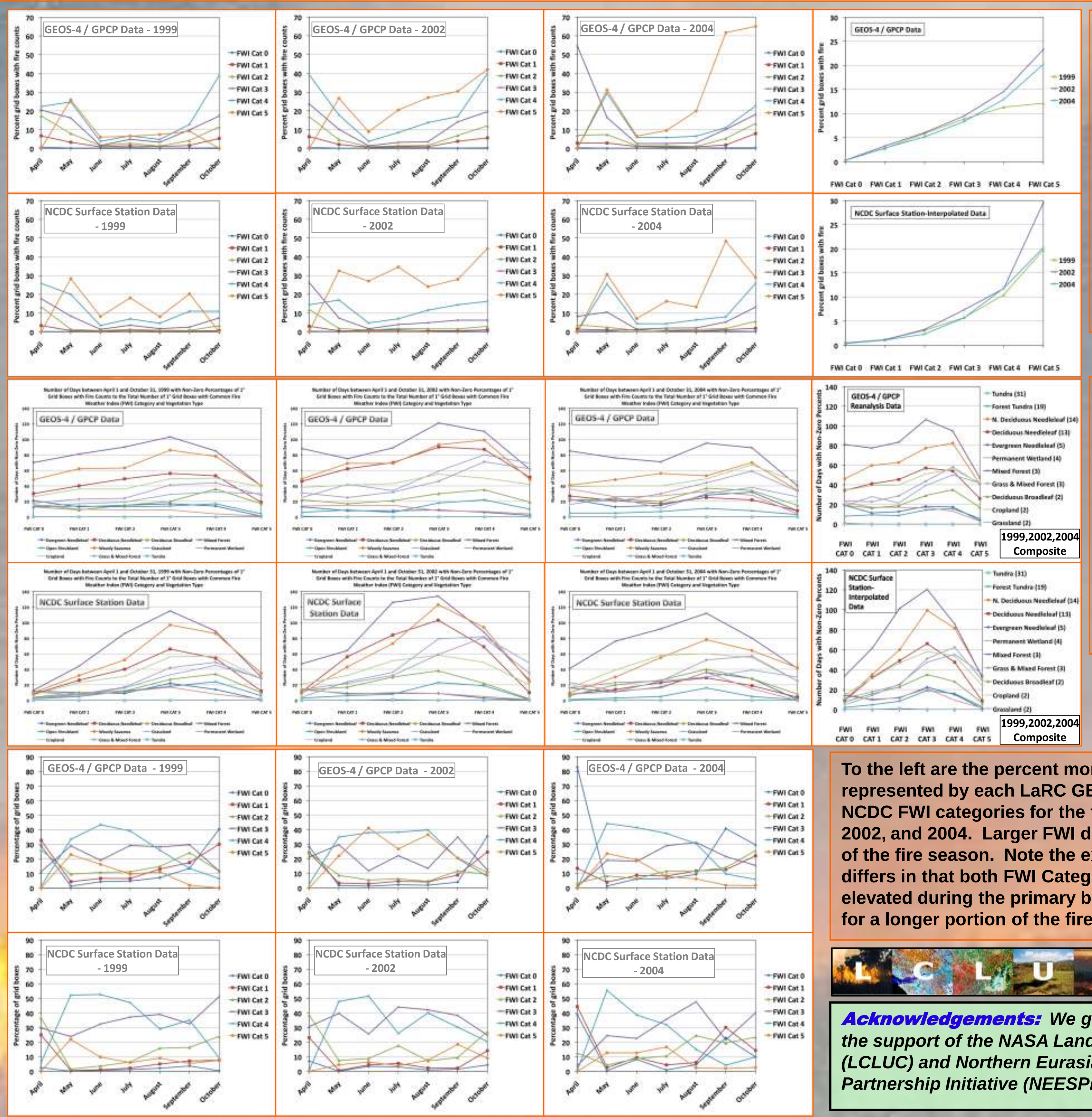
LaRC GEOS-4/GPCP-derived and CFS NCDC-interpolated FWI Fraction of 1° Grid Box Comparison



To the left are the 1999, 2002, 2004, and composite of LaRC GEOS-4/GPCP and CFS NCDC FWI categories versus their fraction of ecosystem over the domain, separated by vegetation type. The percent each vegetation type occupies within the domain is found in the parentheses. Vegetation types are listed in relation to their latitudinal positions in the domain.

To the left are the 1999, 2002, 2004, and composite of LaRC GEOS-4/GPCP and CFS NCDC FWI categories versus the mean percent of grid cells that contain fire over the domain, separated by vegetation type. Generally, percent grid cells with fire increases with increasing FWI.

To the left are the 1999, 2002, 2004, and composite of LaRC GEOS-4/GPCP and CFS NCDC FWI categories versus the mean area burned in square kilometers per 1° cell over the domain, separated by vegetation type. The mean fire counts (above) and mean area burned plots appear to be well related.



To the left are the monthly percent of grid cells that contain active fire (regardless of size) for the fire season of 1999, 2002, and 2004, in relation to the LaRC GEOS-4/GPCP and CFS NCDC FWI categories. The cumulative FWI for each year is also shown.

To the left are the 1999, 2002, 2004, and composite of LaRC GEOS-4/GPCP and CFS NCDC FWI categories versus the number of days with non-zero percent of grid cells that contain fire over the domain, separated by vegetation type.

To the left are the percent monthly grid cells represented by each LaRC GEOS-4/GPCP and CFS NCDC FWI categories for the fire season of 1999, 2002, and 2004. Larger FWI dominate in the middle of the fire season. Note the extreme fire year, 2002, differs in that both FWI Category 4 and 5 remain elevated during the primary burning season and for a longer portion of the fire season.

Background photo provided by Brian Stocks.

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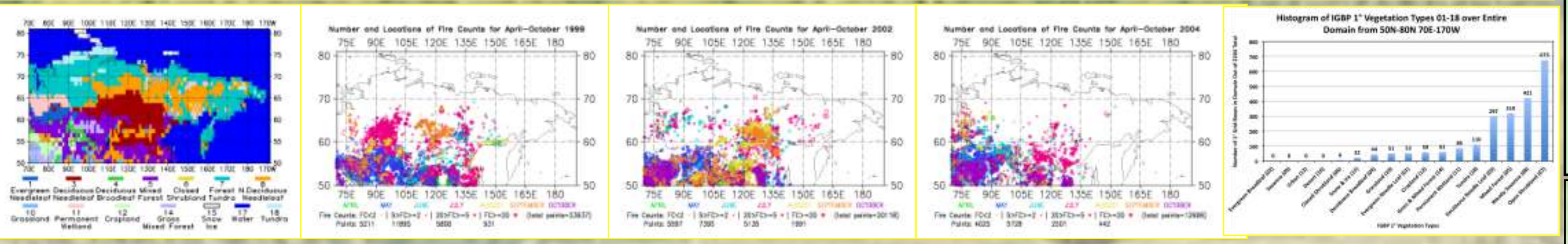
Above we compare the LaRC GEOS-4/GPCP FWI (LaRC FWI) and CFS NCDC FWI (CFS FWI) on their fraction of 1° grid boxes with satellite-derived fire counts and area burned to the total number of 1° grid boxes with a common FWI category. We separate these by vegetation type to estimate the fraction of each of the 18 IGBP ecosystems burned, which are dependent on the FWI. For the majority of the IGBP vegetation types, the patterns on the plots are similar between the LaRC FWI and the CFS FWI, although the magnitudes are not always the same. Mixed forest (05), followed by woody savanna (08), deciduous needle leaf (03), grassland (10), cropland (12), and grass & mixed forest (14) represent the majority of the burning when looking at the number of days where the fraction of 1° grid boxes for all FWI categories, all days, and all 3 years is not equal to zero. For most ecosystems, the CFS FWI peaks at category 3, while the LaRC FWI peaks at category 4. Notice how the number of days where the fraction is not equal to zero begins to decrease after category 3, while at the same time, the fraction of 1° grid boxes to total number of 1° grid boxes increases after category 3 for most vegetation types. If the CFS FWI number of days are less than the LaRC FWI, but the CFS FWI category 5 is greater than the LaRC FWI category 5, then this means the CFS FWI fraction of 1° grid boxes per day is larger than the LaRC FWI fraction of 1° grid boxes per day. LaRC FWI category 5 has more 1° grid boxes than CFS FWI, so CFS FWI has a larger fraction of cells and area burned in FWI category 5. For all 3 years, grassland (10), cropland (12), and grass & mixed forest (14) proportion of ecosystem increase with increasing FWI category, while mixed forest (05), woody savanna (08), and deciduous needle leaf (03) decrease. For all ecosystems, there is a general in-crease in mean fire counts and mean area burned with increasing FWI category, although some are more responsive than others. Cropland (12) with mean fire counts is a good example in year 2002 with the CFS FWI. Deciduous needle leaf (03) with area burned is a good example in year 2002 with the LaRC FWI. These 3 years there are few fire counts north of 65°N, where tundra (18), open shrubland (07), and woody savanna (08) dominate and the distribution of NCDC stations is small, which might explain the higher number of fraction of 1° grid boxes from LaRC FWI categories than CFS FWI categories. Perhaps this is an indication the spatial coverage of the LaRC data are an improvement over the sparsely distributed NCDC station data.

IGBP Vegetation Types and Fire Count Information



Vegetation types are based on the 1°x1° IGBP data over the Siberian domain. Additionally, the number and location of fire counts for the months April through October are shown for years 1999, 2000, and 2004. The histogram indicates the number of 1°grid boxes each vegetation type occupies in the Siberian domain. Note the number of vegetation types covering the domain and how much each contributed to burning as seen in the FWI figures above. The dominate vegetation type on land is open shrubland (07) [renamed "forest tundra" in some figures], followed by woody savanna (08) [renamed "northern deciduous needle leaf" in some figures], mixed forest (05), and deciduous needle leaf (03). However, mixed forest (05), followed by woody savanna (08) ["northern deciduous needle leaf"], deciduous needle leaf, (03), grassland (10), cropland (12), and grass & mixed forest (14) represent the majority of the burning when looking at the fraction of 1° grid boxes for all FWI categories, all days, and all 3 years. We provide these plots as reference to the location of the monthly fire counts to the vegetation types over our domain.

Conclusion: The ultimate goal of this research is to assess the viability of using large-scale (1°) data to analyze fire weather danger and fire regimes. Understanding the quantitative relationships between large scale weather and fire is required to assess the impact of potential future weather and climate changes to fire regimes and severity.

Specifically, in this poster, we related large-scale fire weather, area burned, and the amount of fire-induced ecosystem change. We showed large-scale meteorological data can be used to assess fire danger potential. Both the LaRC and CFS FWI showed increases in the fraction of grid boxes with fire counts and area burned with increasing FWI category, with a larger increase in the higher FWI categories for the majority of the vegetation types. Our analysis showed that a direct correlation exists between increases fire activity and increased FWI, and these are evident using large-scale meteorological data. During both normal and extreme fire season, the fraction of fire counts and area burned per 1° grid box increases with increasing FWI rating. Our analysis suggests that fires ignite and burn in many FWI categories under nominal risk conditions, but the extreme fires require sustained weather conditions that lead to FWI category 5's. This makes sense considering the time required to dry fuels (vegetation) [Soja et al., in preparation].

The fraction of ecosystems burned is dependent on the baseline dataset used to define these relationships (large-scale or surface station data). Therefore, to estimate future fire regimes, the initial relationships must be established with a similar baseline (scale and type) dataset. Before estimating future fire regions, we recognize the necessity of expanding our analyses to include additional fire seasons, regional analyses (as opposed to continental) and improve the vegetation map.

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