Climate Change and Associated Fire Potential for the southeastern United States in the 21st Century

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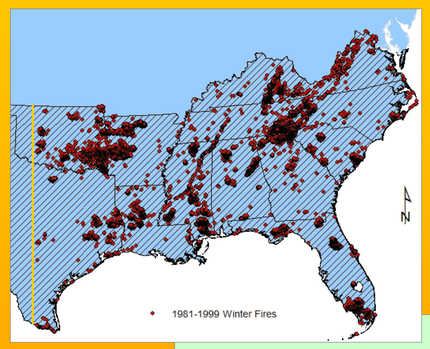
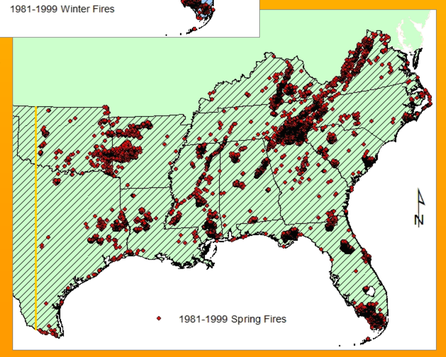
Introduction

Wildfires – fueled by dry weather, high winds, and ample fuels – can burn acres of land and introduce large amounts of particulate matter into the atmosphere. Meteorology plays a central role in the onset, spatial expanse, and duration of such forest fires and the by-products they produce. Such weather phenomena as high temperatures, low humidity, and strong horizontal winds are ingredients conducive to forest fire development and spread. Climate projections of the 21st Century have suggested increasing temperature and prolonged periods of droughts across the southeastern U.S.

Motivation

This study aimed to address the potential for forest fire activity in the southeastern U.S. – given its abundance of forested landscape – during the 21st Century. In a projected warmer and generally drier climate, it was hypothesized that conditions conducive to wildfire development will be more widespread than at present. This type of scenario implies a possible upward trend in forest land burned and in the atmospheric pollutants that these fires create, placing the burden on forest fire management services to improve upon their mitigation practices for the sake of human and environmental health.





Forest fire locations from 1981-1999 in the study domain during the winter (top) and spring (bottom) seasons. Orange lines designate the western extent of the study domain.

Data

❖ Daily and 3-hour timestep data from two pairs of GCM/RCM simulations (CRCM-CCSM & WRFG-CCSM) were used from the North American Regional Climate Change Assessment Program (NARCCAP) for this study during both the late-20th (historical; 1981-1999) and the mid-21st Centuries (future; 2051-2069) for the winter (JFM) and spring (AMJ) seasons.
❖ Frequency, locations, area burned, and onset dates of forest fires in the study domain from the Fire Program Analysis (FPA) System of the National Interagency Fire Center (NIFC) during the historical period.

Methods

❖ **500-hPa geopotential heights & variances analyses**
Determine meridional changes in heights and height variances for each 19-year period

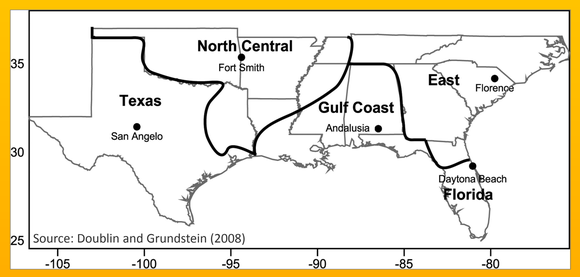
❖ **Seasonal analyses of convective & total precipitation**
Ratio of mean seasonal totals of convective and total precipitation amounts averaged over the Southeast

❖ **Monthly values of Haines Index**
- Use 950-hPa and 850-hPa temperature and 850-hPa specific humidity (for 850-hPa dew point depression calculation)
- Ranges from 2 (low "large" fire risk) to 6 (high risk)

❖ **Monthly values of Keetch-Byram Drought Index**
- Use mean annual rainfall, daily maximum temperature, and daily rainfall
- Ranges from 0 (soil saturation) to 800 (absolute soil moisture depletion)

❖ **Sequences of low relative humidity days**
- Derived critical RH thresholds based on months of high fire activity using daily average temperature and dew point from NCDC
- Mean probabilities and mean lengths of low-RH day sequences

❖ **Regional analyses & statistical testing**
- Five regions in the Southeast with similar soil-moisture properties
- Pearson's correlation coefficient and matched-pairs difference of means Student *t* test



Five soil-moisture deficit regions and cooperative locations used in this study.

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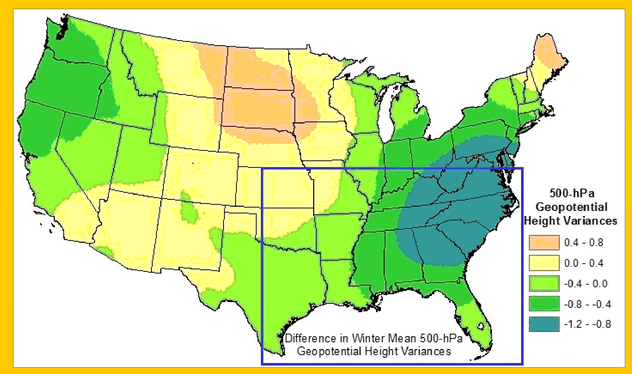
Winter Results & Conclusions

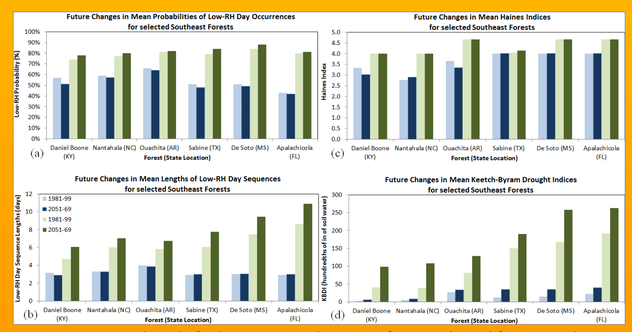
❖ Future changes in precipitation and low-level atmospheric moisture content observed to be closely tied with alterations in the major storm tracks found in the Southeast.
❖ The entire study domain exhibited an environment characteristic of a generally warmer climate annually in the future period given significantly higher 500-hPa geopotential heights throughout the Southeast.
❖ Significantly lower 500-hPa geopotential height variances in the future winter period – especially in the eastern half of the domain – offered evidence of poleward shifting wintertime storm tracks across the Southeast and fewer MLC occurrences across the domain in general.
❖ Based on the findings from the fire potential indices, much of the southern half of the study domain (i.e., the Deep South, Gulf Coast, Florida, and Texas) exhibited generally higher fire risk in the future winter period. The results for these indices offered evidence of increasing potential for fire ignition – but not necessarily growth – across the southern half of the domain in the winter season.



Differences in mean 500-hPa geopotential height variances for the winter season.

Changing Forest Characteristics

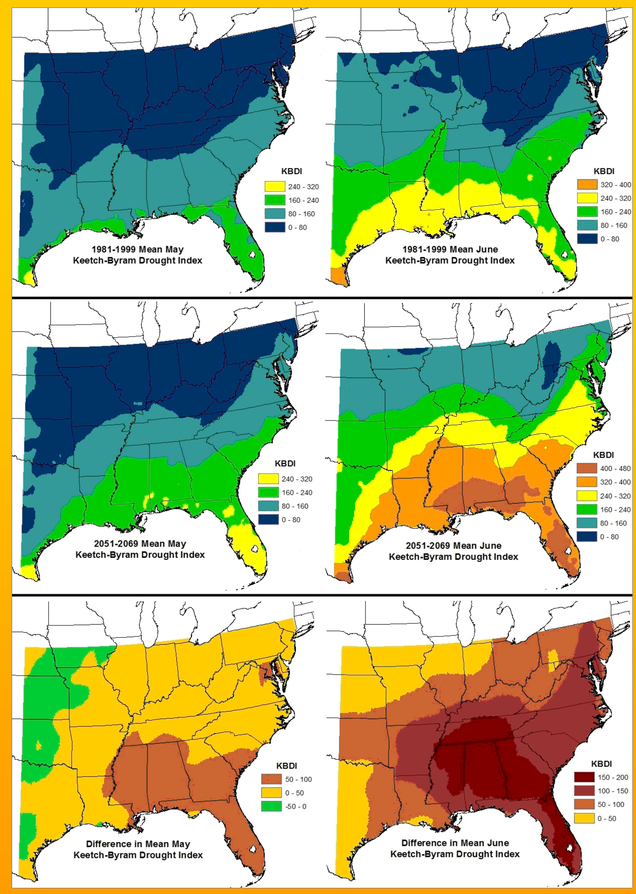
❖ **Temperature has also been projected to contribute to considerable landscape and tree species changes in the 21st Century.**
❖ Northward advancements in forest regimes and shifting growing seasons reflect the projected increase in temperatures over the next century and offer evidence of changing forest dynamics throughout the Southeast.



Statistics and study findings at point locations for six selected forests in the Southeast during the historical and future winter and spring seasons.

Spring Results & Conclusions

❖ Future changes in precipitation and low-level atmospheric moisture content observed to be more closely tied with low-level atmospheric stability than with alterations in the major storm tracks in the Southeast.
❖ The entire study domain exhibited an environment characteristic of a generally warmer climate annually in the future period given significantly higher 500-hPa geopotential heights throughout the Southeast.
❖ Even more so than the winter season, the results of the fire indices suggested that the southern half of the domain exhibited increasing fire potential in the future spring season. Higher HI values in the spring versus the winter season implied greater "large" fire risk during this season given the positive correlation between HI and both total area burned and mean fire size in the domain.
❖ The most compelling results in this study appeared to be associated with the KBDI and RH analyses for the spring season. Mean daily KBDI values of over 450 – values typical of late summer – were observed for June in the future period in the Deep South and Florida, implying greater fire risk in these areas. These increases in KBDI suggested enhanced drought and associated fire potential throughout the Southeast, and especially so in the Deep South and Florida, in the future spring period because KBDI and both total area burned and mean fire size for the domain exhibited some of the strongest correlations in this study, where KBDI explained over 40% of the variances in both of these fire statistics in the domain.



Mean Keetch-Byram Drought Index (KBDI) in May 1981-1999 (top), *May 2051-2069* (center), *and difference in May KBDI* (bottom).

Mean Keetch-Byram Drought Index (KBDI) in June 1981-1999 (top), *June 2051-2069* (center), *and difference in June KBDI* (bottom).