Climate-scale predictability and variability of Alaska wildfires

Climate Physics Journal Club/IARC REU
June 12, 2019

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Wildfire is part of the boreal system

Alaska NSF EPSCoR
Recent fires/lightning
Interior Alaska fire season is driven by extremes

- Most fires burn in Interior Alaska
- Extreme years with area burned exceeding 1 million acres have big impacts
Boreal forest

 Existing
 Under threat (from logging, mining, road building, or hydroelectric development)
 Deforested and degraded boreal biome

Other biomes
Permanent ice cover
Tundra
Temperate forest
Greenland
Desert and dry shrub
Mediterranean shrub and woodland
Tropical forest

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Why does wildfire happen?

Interior Alaska has a ”continental climate”

- Drier in Interior and Arctic
- Highest temperature range in the Interior

Data: GHCN
Lightning started wildfires responsible for most area burned

- Major fires of 2015 started by lightning
- Most area burned each year is due to lightning ignitions
- Forecasting lightning is a challenge!

See: A. Sampath poster on predicting seasonal fire danger
Research motivated by what fire managers need

- Wildfires are managed by different agencies across Alaska (AICC)
- Many fire danger related decisions are based on the “Canadian Fire Weather Index”

- Alaska fire managers actively partner with researchers
- One of the easiest groups of managers to do research with!
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CFFDRS key fire danger rating system for Alaska

BUI Trends, 1994-2015
PSAs AK01E, AK01W, AK02, AK03N, AK03S, AK04, AK05, AK07, AK09, AK14

2013 2015 Avg
2004 2005 2009
Recent climate-fire projects

- **Extreme fire season climate attribution**
- **Army ranges fire danger projections (USACE)**
- Lightning forecasts/projections (NOAA)
- Seasonal forecasts of fire danger (NOAA)
- Fire Index inter-comparison (USGS/CASC)
- High-resolution dynamical downscaling for Fairbanks region (DOD SERDP)
- Fire and Ice (NSF EPSCoR)
Climate data: Reanalysis and GCMs

• Reanalysis: observations (weather stations and satellite) ingested into a model
  – ERA-Interim (1979-present)

• General circulation model (GCM): used for seasonal forecasts and future climate projections
  – IPCC/CMIP5: GFDL and CCSM (next 100 years)
  – NMME: CFSv2 (next 6-9 months)
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http://www.ucl.ac.uk/earth-planetary-institute/research/polar-environmental-change
Downscale reanalysis and GCM data to include more local detail

- WRF has more detailed terrain
- Reanalysis has broader high elevation areas
- Can better resolve mesoscale features

Completed Downscaled Products:
- ERA-Interim (observations): 1979-2015
- GFDL-CM3 and NCAR-CCSM4 (CMIP5 future scenario) RCP8.5: 1970-2100

Bieniek et al. (2016)

Data available on request from SNAP
• FWI can be computed in station, reanalysis and GCM data
• Downscaled data have been used in Alaska for climate assessment of BUI (e.g. Partain et al. 2016)
• Validation and bias correction is necessary to capture index thresholds (e.g. BUI = 80)
Extreme fire seasons more likely due to climate change

• Pre-Industrial (no human influence) Alaska summer climate was cooler and drier than the present based on GCM model estimates
• Risk of a large fire season like 2015 is 34%-60% more likely due to human-induced climate change
Army range usage dictated by fire danger

- U.S. Army Alaska uses CFFDRS to determine training range usage
- Want long-term projections of CFFDRS
- Higher BUI than present in May-Jun projected by 2071-2100, uncertain change after Jun
Lightning is a key driver of Alaska area burned: can we predict it in advance?

- 1986-present data is available
- Not homogeneous due to network changes
- Gridded strike counts compared to downscaled reanalysis
Most lightning strikes in Interior Alaska
Jun-Jul

- Most lightning strikes in June and July
- Weaker activity in May and August
More convective precipitation = more lightning strikes

- Interior seasonal lightning strikes correlated with area average convective precipitation
- Can we use seasonal model predictions of convective precipitation as an index of lightning?

Convective precipitation from Alaska 20km WRF downscaled ERA-Interim 1982-2015 [Bieniek et al. 2016]
Climate drivers of lightning

- Convective precipitation correlated with seasonal lightning
- Regression models of weekly lightning developed for each PSA. Predictors from reanalysis: Convective Precipitation, 850-500hPa dT, dewpoint, temperature, 500hPa height
- Modelled lightning captures much of the observed variability at the seasonal scale
Interior Jun-Jul Lightning Projections

- No trend in historical lightning strike counts
- Lightning project to increase by 2100.
- Variability is driven mostly convective precipitation estimates
Forecasts of Fire Likelihood

Products Needed
1. Forecasts of BUI
2. Forecasts of Ignition

Tools: Seasonal Ensemble Forecasts
1. Operational forecasts available
2. Create above products from forecasts
Seasonal Forecasts of Climate: CFSv2

March Start Seasonal Forecasts

1982-2018

1 April - 30 September
Forecasts of T, P, humidity, and winds

26 to 120 forecasts are made at NOAA to comprise ensemble

Use forecast data to calculate Fire Weather Indices
Ensembles provide possible outcomes
Tanana Valley West 2015 BUI Forecast: bias correction

[Graph showing the buildup index (BUI) for Tanana Valley West 2015 over time from April 1 to October 1, with lines indicating observed, ensemble mean, uncorrected ensemble mean, +1sigma, and -1sigma]

[Akila Sampath]
CFS has skill for temperature in a few years based on the March outlook

- **BUI skill** less than 0.4 in most seasons and PSAs
- **Highest Precipitation forecast skill** for Lower Yukon PSA
- **2004-5 and 2007** had relatively good skill for temperature

![Figure 10: Skill score distributions of summer (JJA) of 10 boreal forest PSAs for the period of 1994-2017 for the summer season (a) temperature, (b) precipitation, (c) buildup index (BUI). Less than or equal to 0.1 indicates no forecast skill and 1 corresponds to perfect skill score. Sampath et al. (2019 in prep)](image)
Seasonal lightning predictability fairly low with CFSv2

- 1-3 month lead forecasts of lightning predictor variables have relatively low correlation with observed reanalysis
- Forecast skill improves as the lead time decreases

Interior Alaska 1986-2015 CFSv2 hindcast correlation with observations

<table>
<thead>
<tr>
<th>CFS Forecast</th>
<th>Lightning</th>
<th>Convective Precip</th>
<th>850-500 dT</th>
<th>Dewpoint 2m Temp</th>
<th>500h</th>
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<tbody>
<tr>
<td>March</td>
<td>-0.08</td>
<td>0.14</td>
<td>0.18</td>
<td>0.13</td>
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<td>April</td>
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<td>0.33</td>
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<tr>
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<td>0.10</td>
<td>0.13</td>
<td>0.06</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Uses the same weekly regression models as for GCM projections
Summary

- Multiple climate-fire projects are ongoing at IARC/UAF
  - Dynamical Downscaling
  - Seasonal forecasting of CFFDRS, lightning
  - Long-term climate projections
- Fire danger is projected to increase in the future
- Forecast model skill limits seasonal prediction