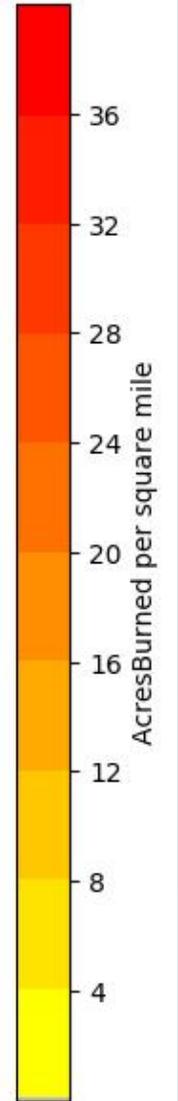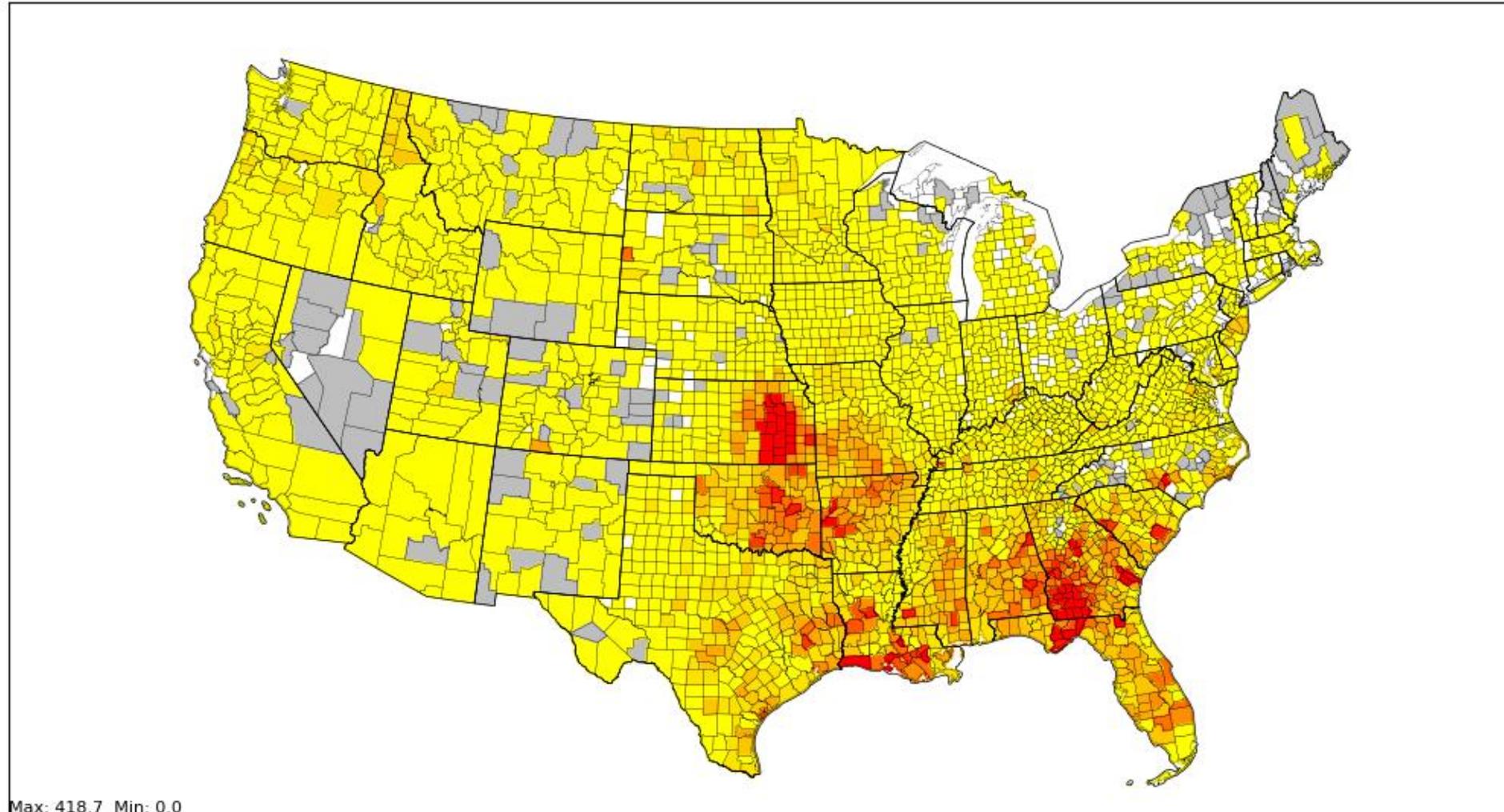# Diurnal profiles for Prescribed burns: Review, Recommended Updates and Next Steps

JEFF VUKOVICH (USEPA)

CMAS CONFERENCE 2020

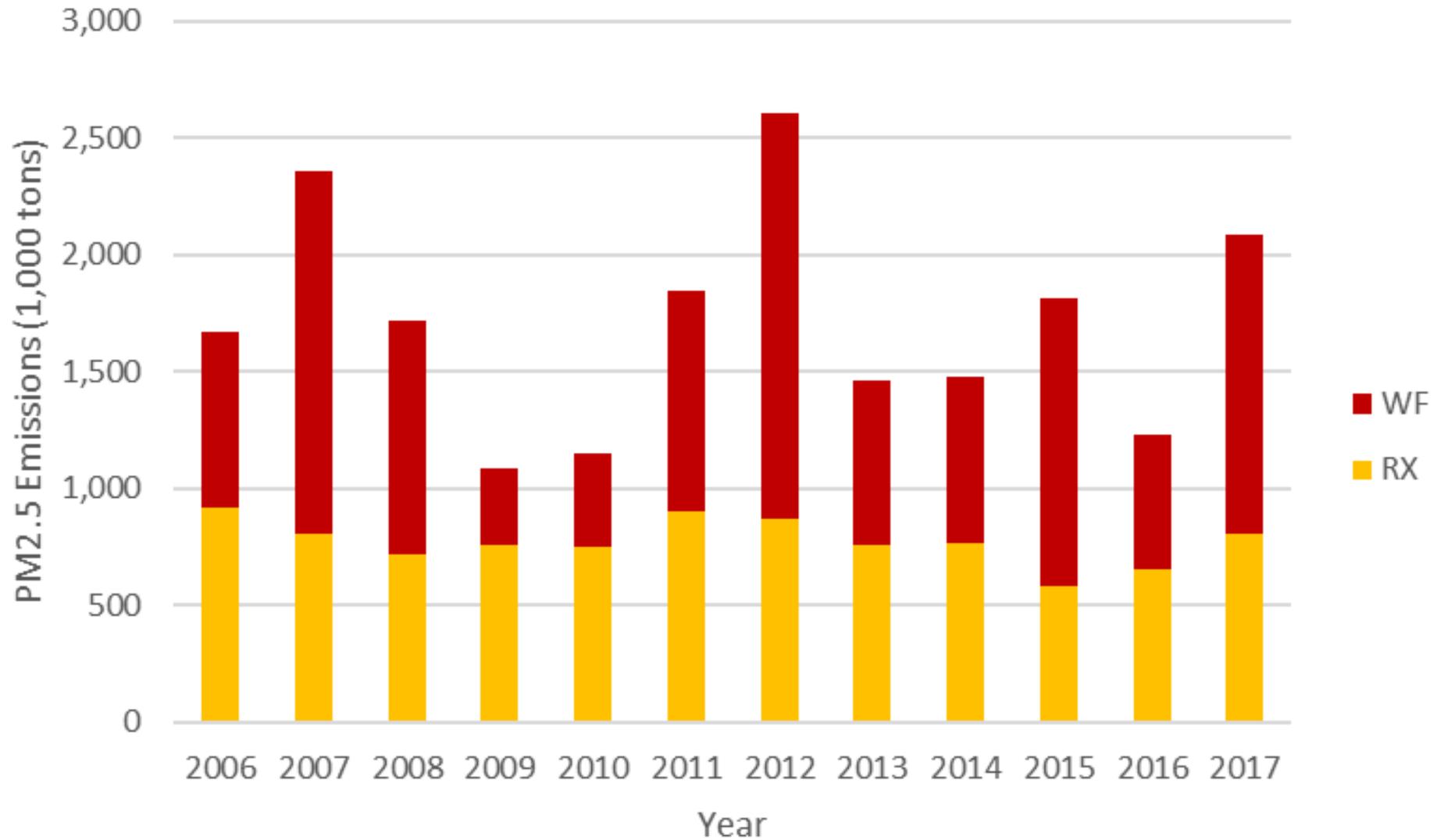## Prescribed burns: county acres burned per square mile

Acres Burned Density: prescribed_fire 2016 v1 inventory
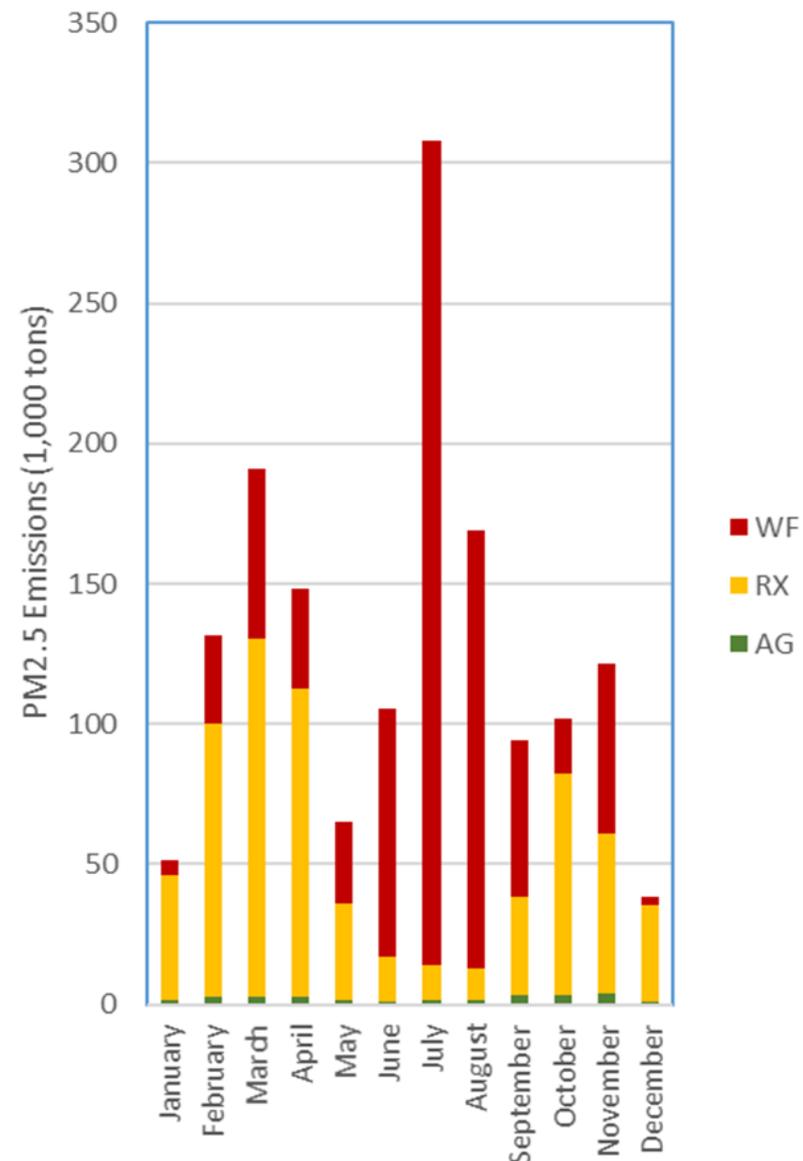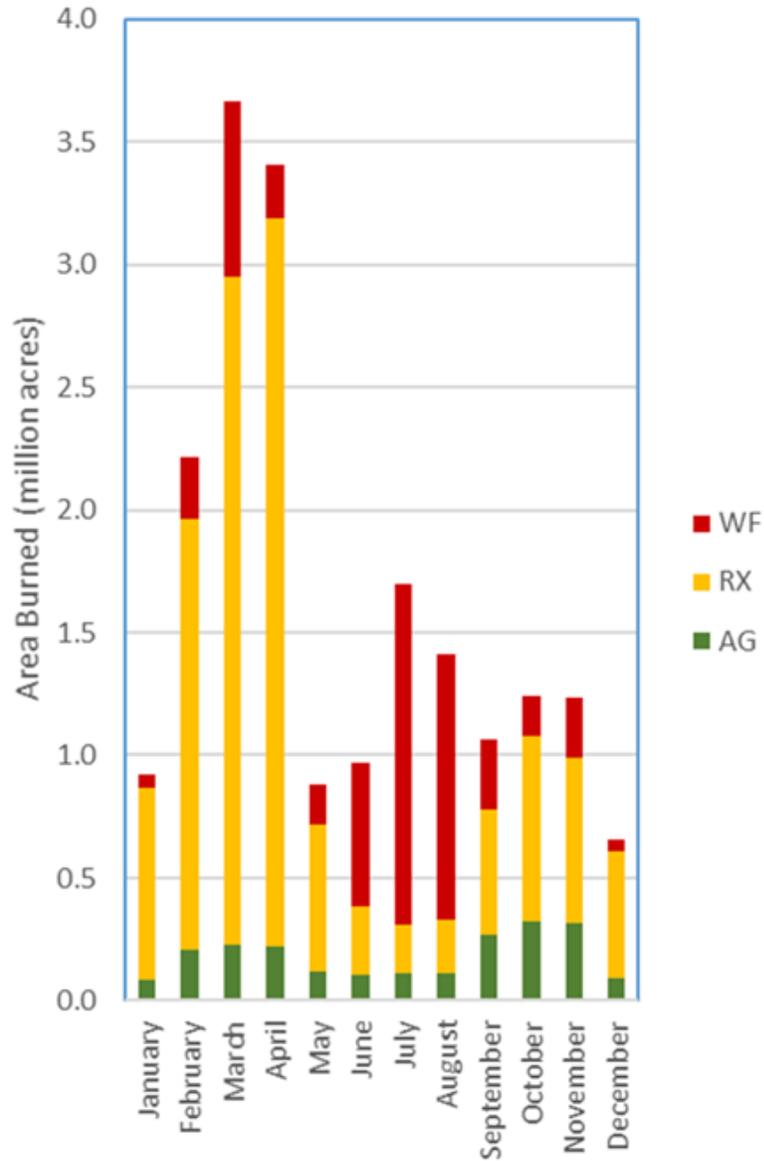
Max: 418.7 Min: 0.0

HOW MUCH?
Prescribed burns: ~600K+ tons of PM2.5 per year in USA

WF=Wildfires
RX = Prescribed fires

WHEN?
## Prescribed burns: High and low National activity months for 2016

WF=Wildfires
RX = Prescribed fires
AG = Agricultural fires

Information in National Emissions Inventory for fires: Recent Changes to Source Classification Codes (SCCs)

- Pre-2014NEI
  - All wildfire emissions in one SCC; all prescribed burns emissions in one SCC
  - Included all three phases: **flaming, smoldering during flaming and residual smoldering**

- 2014NEI, 2016v1 and 2017NEI
  - Wildfire and prescribed burns both broken up into two different SCCs
    - One SCC for flaming and smoldering emissions during flaming phase
      - 2810001002 (Wildfires) and **2811015002 (Prescribed burns)**
    - One SCC for **residual smoldering** phase (after flaming has ended)
      - 2810001001 (Wildfires) and **2811015001 (Prescribed burns)**
    - The emissions for these phases taken from output from BlueSky-Framework

- Prescribed fires are treated as DAY-specific
  - Vast majority of prescribed fires last one day
  - Diurnal profiles are typically assigned by SCC

BLUESKY FRAMEWORK
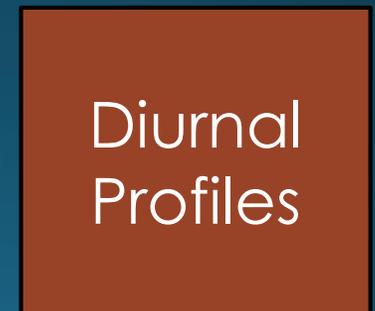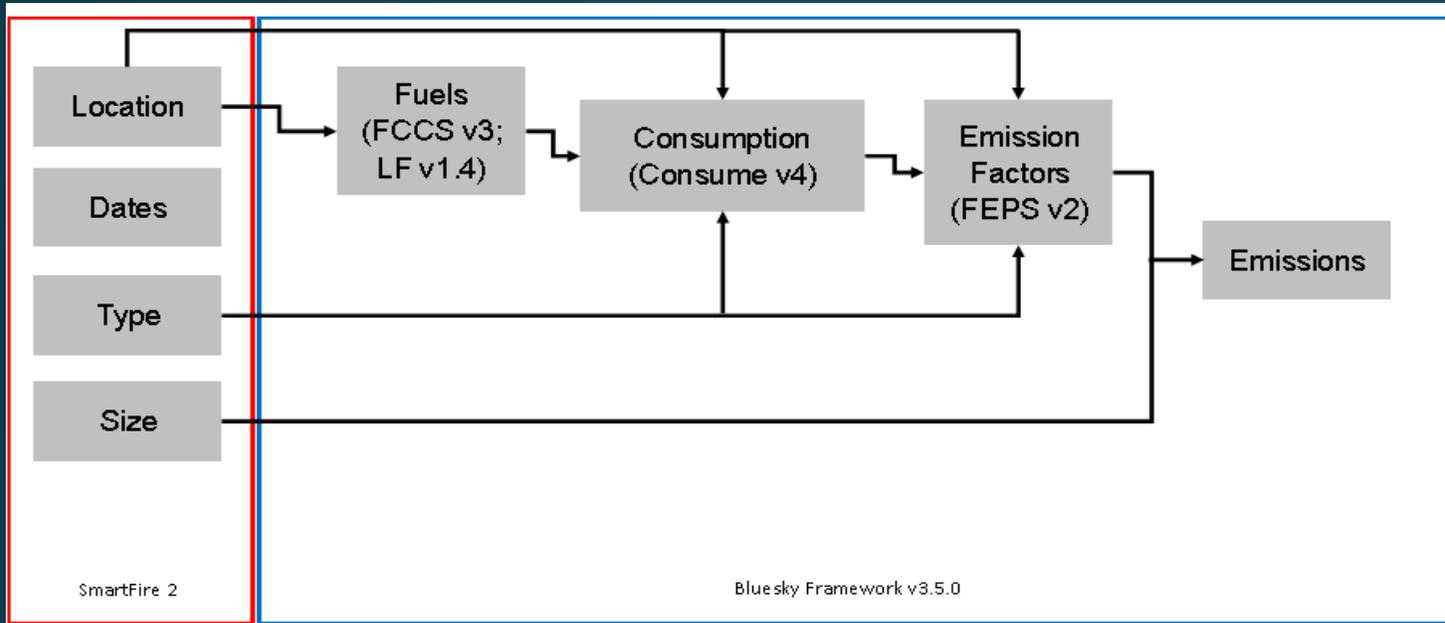
US Prescribed fires: Current profiles by state were derived from FEPS (Pace 2002)

Diurnal Profile: Prescribed fires
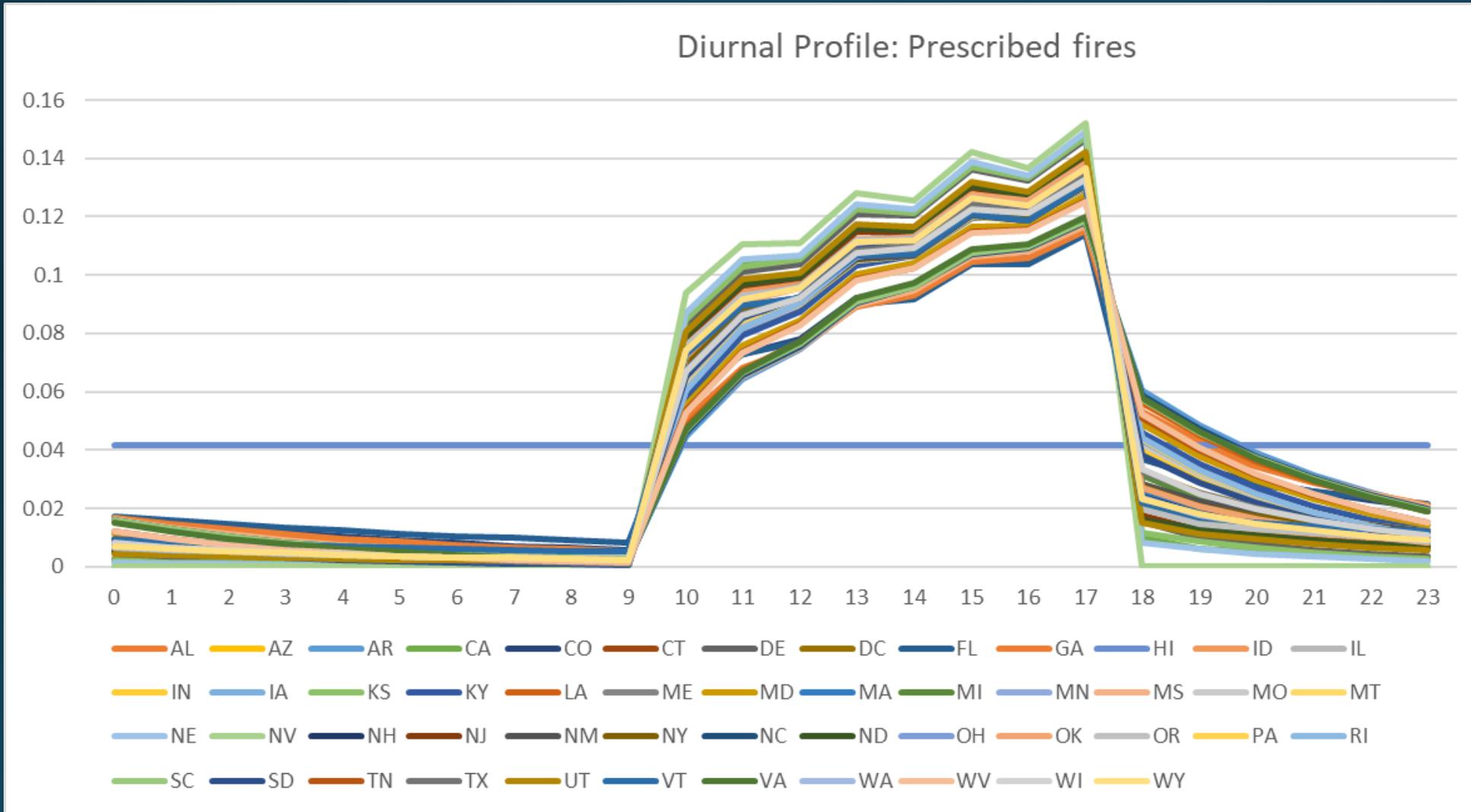
X-axis= hours Local Standard Time (LST)

Y-axis = Fraction of emissions assigned to this hour

- AK, HI flat profile
- Rest of the states have similar shape

KEY ASSUMPTION: ALL PHASES OF FIRE EMISSIONS ARE IN ONE SCC

What does Bluesky use for diurnal profiles for flaming and residual smoldering now?

Flaming example profile

Residual smoldering example profile
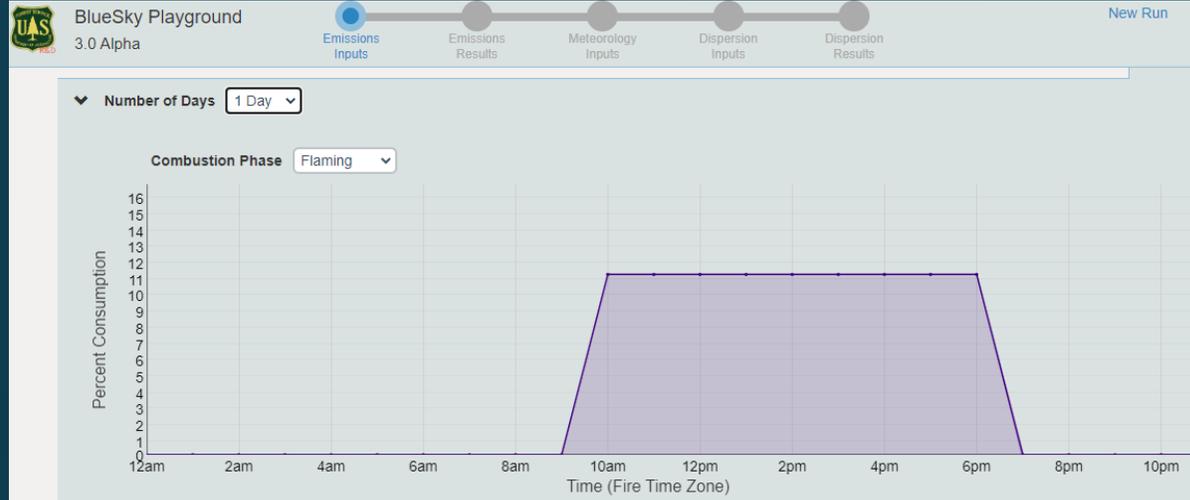
Flaming phase lasts 8 hours in this example

Residual smoldering dependent on flaming profile

Residual smoldering begins during first hour of fire and reaches maximum and end of flaming phase

NEED SEPARATE PROFILES: ONE FOR FLAMING AND ONE FOR RESIDUAL SMOLDERING

US Prescribed fires: Focusing on current GA, FL and KS profiles

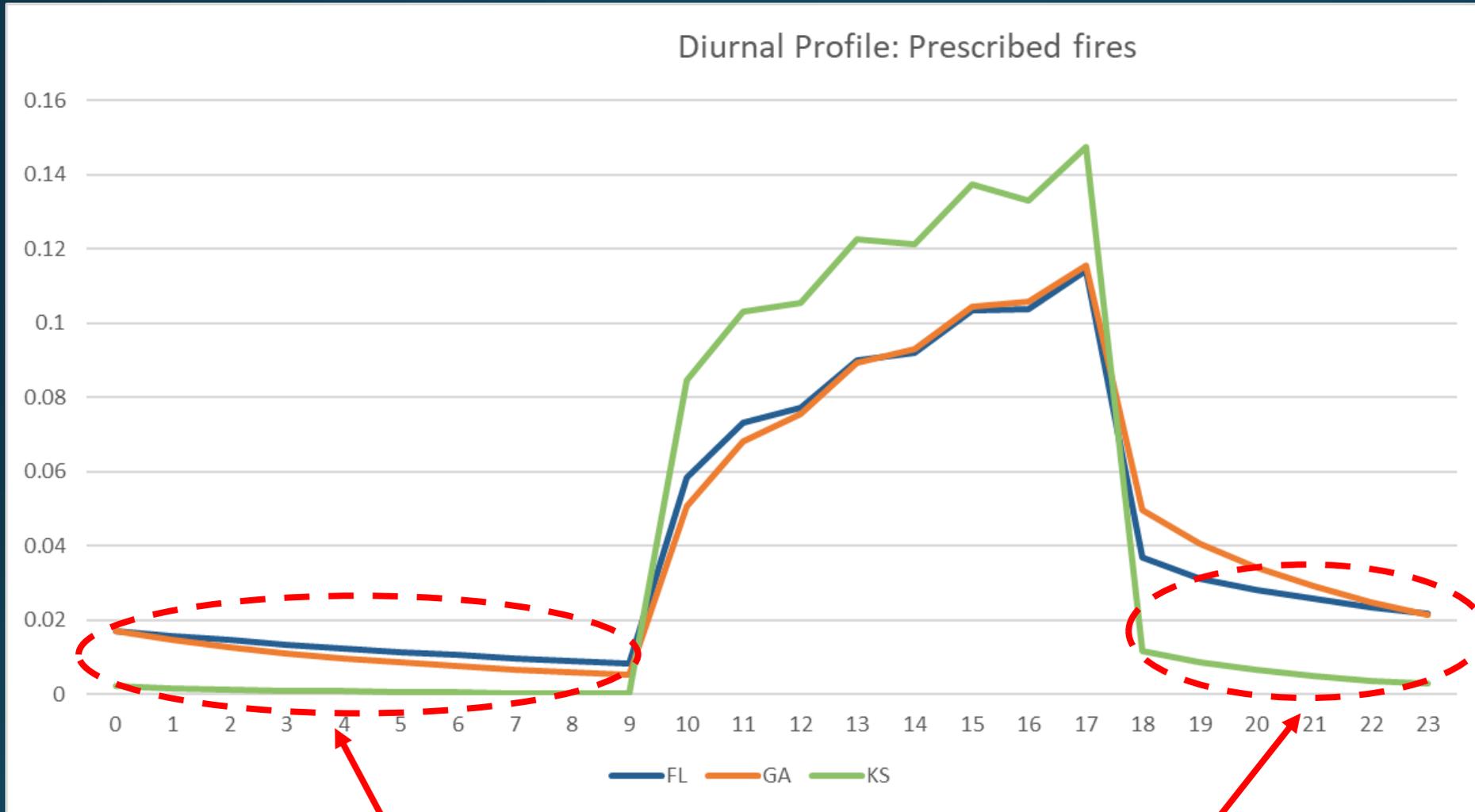Diurnal Profile: Prescribed fires

Legend: FL, GA, KS

X-axis= hours (LST)

Y-axis = Fraction of emissions assigned to this hour

GA, FL, KS ~ 4-5M acres burned/year

Profiles assume fire flaming phase starts 10-11 LST and ends 17-18 LST; 7 hour duration

Residual smoldering starts 10-11 LST and reaches max at 17-18 LST

Residual smoldering emissions only (tails of profiles)

What other available data may help inform a diurnal profile for the "flaming" phase of prescribed burns?

- Prescribed burn activity datasets obtained from Florida(2017) and Georgia (2016-17)
  - Start and ending times
  - Acres burned
  - Confirm months of high activity
- Hazard Mapping System (HMS) satellite detects used in inventory development
  - Geostationary satellite detects best for common burn times/profile development
  - Weed out wildfire detects somehow
- **Goals of this work were to find out more about the following for flaming profile**
  - Most common start and ending times
  - Average duration
  - Possible shape of curve
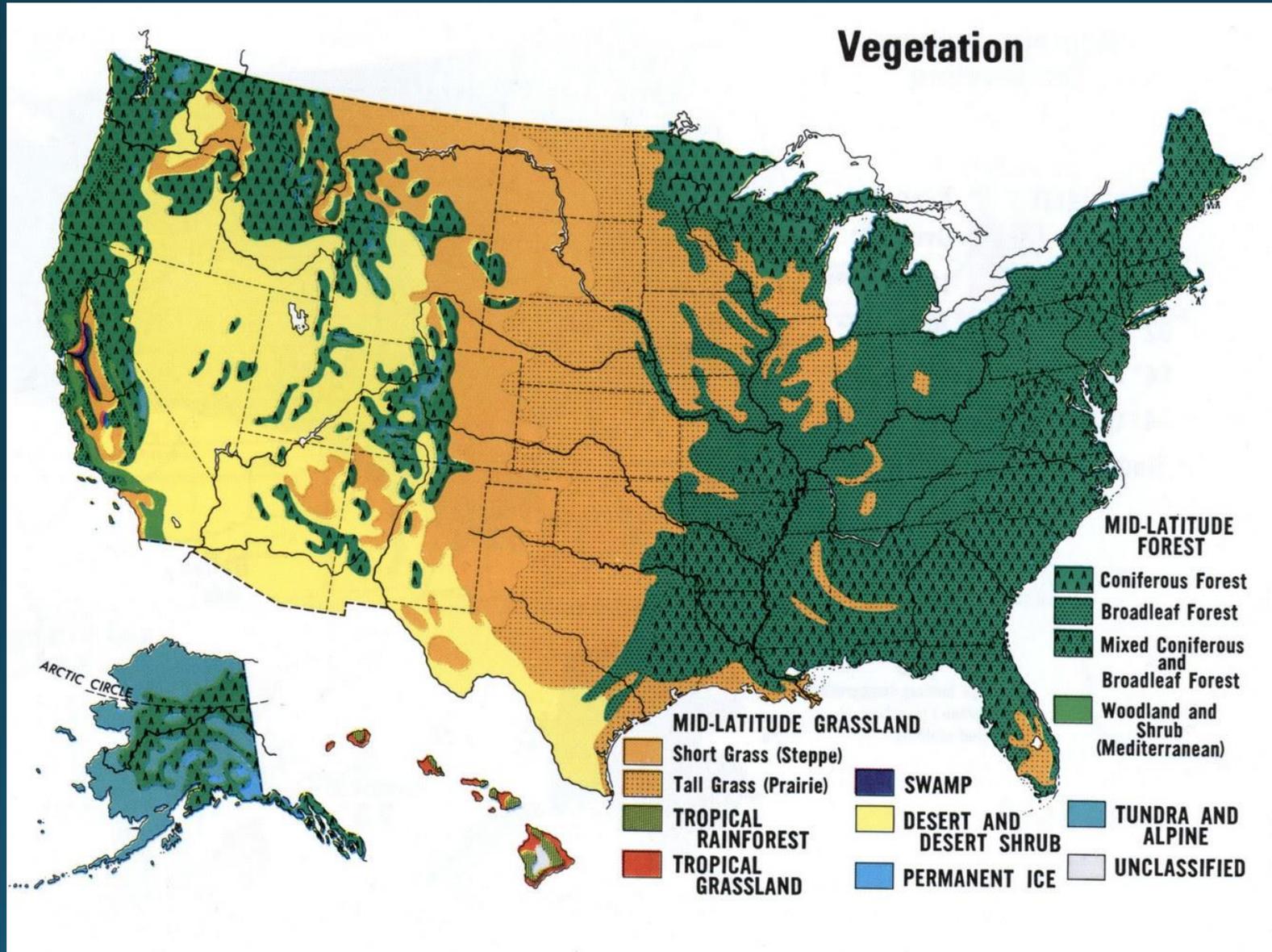 - Do any of the above change during the year? By region/state?

Findings from FL and GA permit databases

State	Georgia	Georgia	Florida	Florida
Activity Level	**High Activity**	Low Activity	**High Activity**	Low Activity
Months	**Jan-Apr, Nov, Dec**	May-Oct	**Jan-Mar, Nov, Dec**	Apr-Oct
Most acres burned fire size	**25-500 acres**	25-500 acres	**100-500 acres**	100-500 acres
Avg Duration	**7 to 8**	8 to 9	**8 to 9**	10 to 11
Most common Duration (hours)	7	8 and 9	8	9 and 10
Most common Starting Hour	10	10	**9 and 10**	9 and 10
Most common Ending Hour	18	19	**18 and 19**	22
Duration-Fire Size Correlation	**Mixed**	Mixed	**Yes**	Yes

# Filtering Hazard Mapping System (HMS) satellite detects

- Hazard Mapping System (HMS) satellite detects used in inventory development
  - Geostationary satellite detects best for common burn times/profile development
  - Examined 2016-2019 detects
  - **GOES satellite detects only**
  - GOES-13 retired around end of 2017
  - **GOES-16 (GOES-R series) online around end of 2017**
    - **Fire Detection and Characterization (FDC) methodology = very large increase in # of detects**
- Find all county-day combinations where wildfire emissions occurred in inventory
  - Remove GOES detects for all wildfire county-days
- Group detects by state/region/high-low activity months
- **GOAL #1: Find most common flaming hours and perhaps find shape of diurnal profile**
- **GOAL #2: Use common flaming profile to estimate residual smoldering profile**

Vegetation in CONUS: High-level look at varying fuels for fires

Vegetation

MID-LATITUDE FOREST
- Coniferous Forest
- Broadleaf Forest
- Mixed Coniferous and Broadleaf Forest
- Woodland and Shrub (Mediterranean)

MID-LATITUDE GRASSLAND
- Short Grass (Steppe)
- Tall Grass (Prairie)
- SWAMP
- TROPICAL RAINFOREST
- DESERT AND DESERT SHRUB
- TUNDRA AND ALPINE
- TROPICAL GRASSLAND
- PERMANENT ICE
- UNCLASSIFIED

Examine detects summed by Regions for Flaming profile analysis

- **Allows for examination of different levels of activity, fuels and climates by region**

- **Also examined Flint Hills counties only**
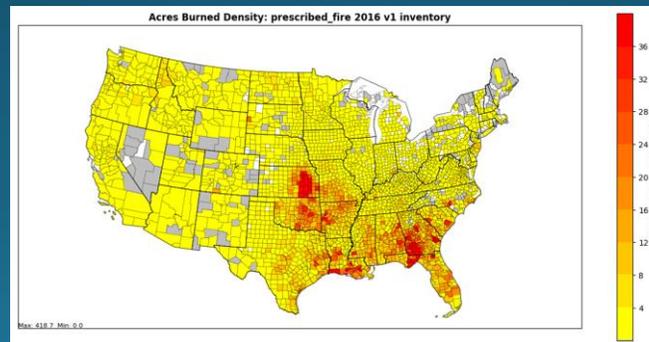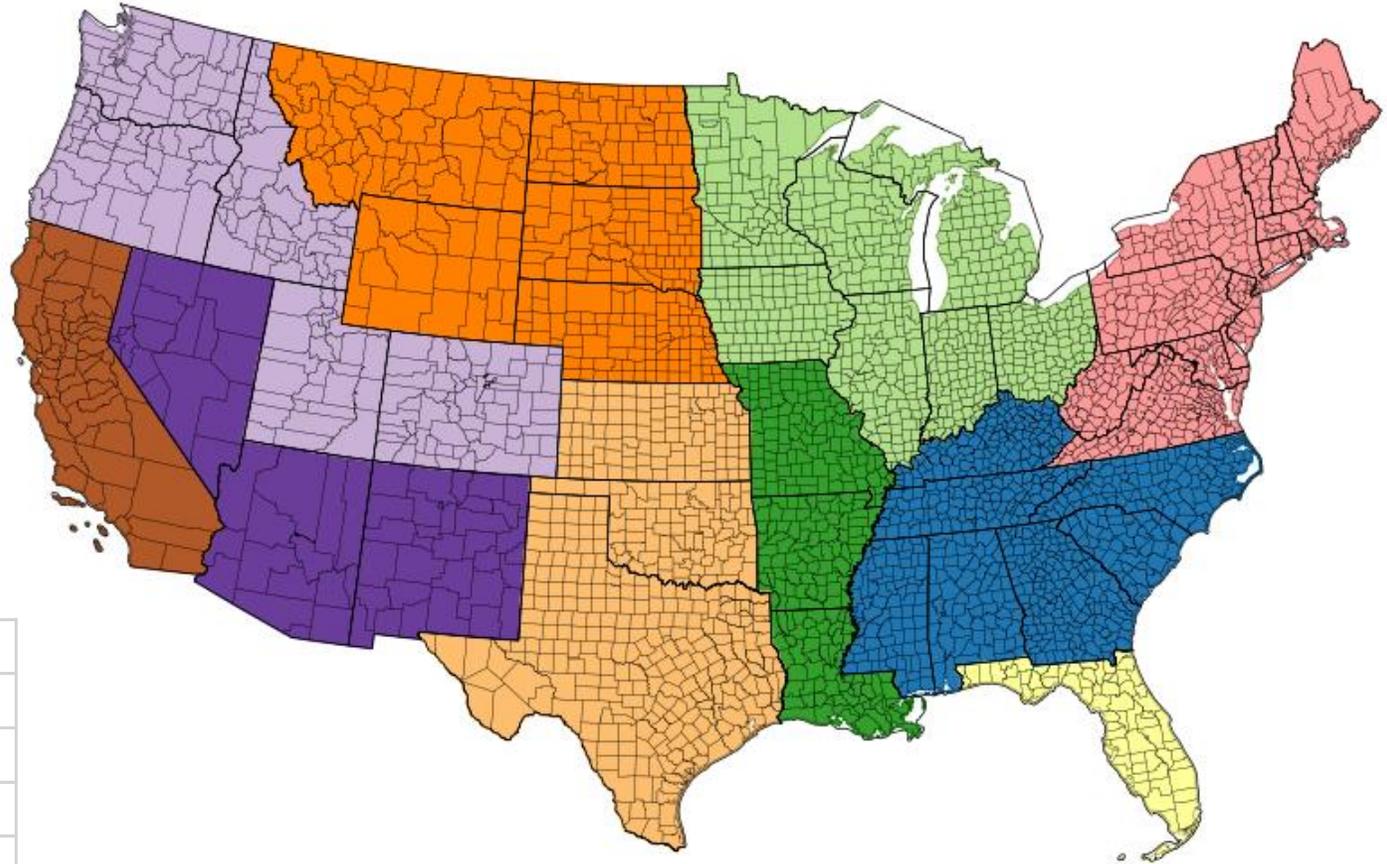
Region	States
SEminusFL	NC, SC,GA,AL,MS,TN,KY
Glakes	OH,MI,IN,IL,WI,IA,MN
LA_AR_MO	LA,AR,MO
NEast	VA,MD,DE,WV,PA,NY,RI,NH,ME,CT,VT
Nplains	NE,SD,ND,WY,MT
SPlains	TX,OK,KS
WestMix	UT,CO,WA,ID,OR
WestShrub	AZ,NM,NV
FL	FL
CA	CA

Acres Burned Density: prescribed_fire 2016 v1 inventory

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Number of HMS Detect Occurrences during daylight hours by Region 2016-2019 HIGH and LOW activity periods *

Region	HIGH months	HIGH	LOW	StateIDs
SPlains	Jan-Apr, Nov,Dec	115073	50398	TX,OK,KS
SEminusFL	Jan-Apr, Nov,Dec	114732	62715	NC, SC,GA,AL,MS,TN,KY
FL	**Jan-Mar, Nov, Dec**	82550	41084	FL
GA	Jan-Apr, Nov,Dec	58140	18581	GA
LA_AR_MO	Jan-Apr, Nov,Dec	57380	58271	LA,AR,MO
GLakes	Jan-Apr, Nov,Dec	20409	8596	OH,MI,IN,IL,WI,IA,MN
NPlains	Jan-Apr, Nov,Dec	11559	11133	NE,SD,ND,WY,MT
WestMix	Jan-Apr, Nov,Dec	8286	8131	UT,CO,WA,ID,OR
CA	Jan-Apr, Nov,Dec	6464	12246	CA
WestShrub	**Jan-Mar, Nov, Dec**	4626	3257	AZ,NM,NV
NEast	Jan-Apr, Nov,Dec	4043	3218	VA,MD,DE,WV,PA,NY,RI,NH,ME,CT,VT

CONFIRMS REGIONS OF HIGH ACTIVITY

* Wildfires detects removed

Looking for common diurnal profile shapes for prescribed fires

Possible Flaming Profiles
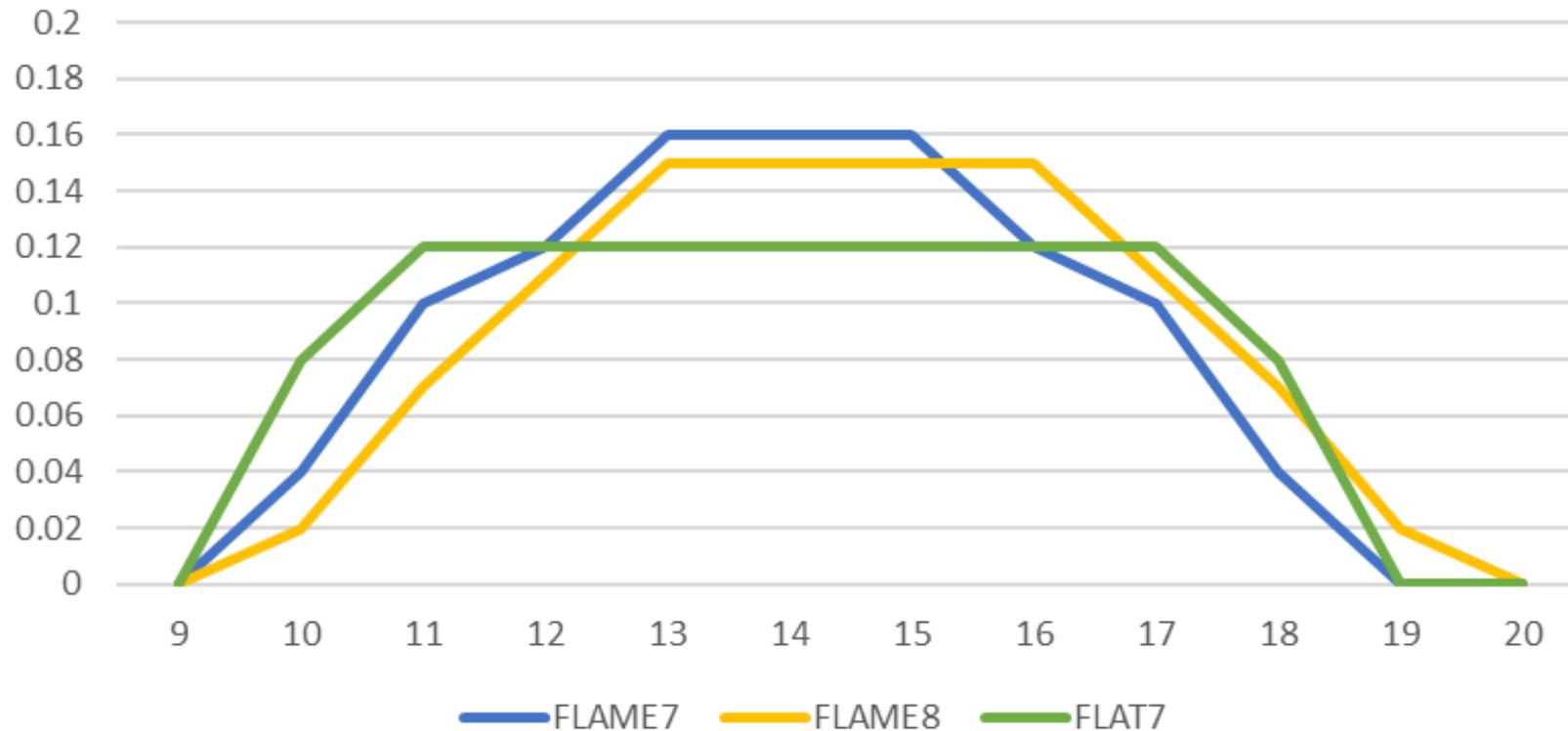
FLAME7
- **92% in 7 hours**
- **72% in 5 hours**

FLAME8
- **96% in 8 hours**
- **82% in 6 hours**

FLAT7
- **84% in 7 hours**
- **Constant consumption for 7 hrs**

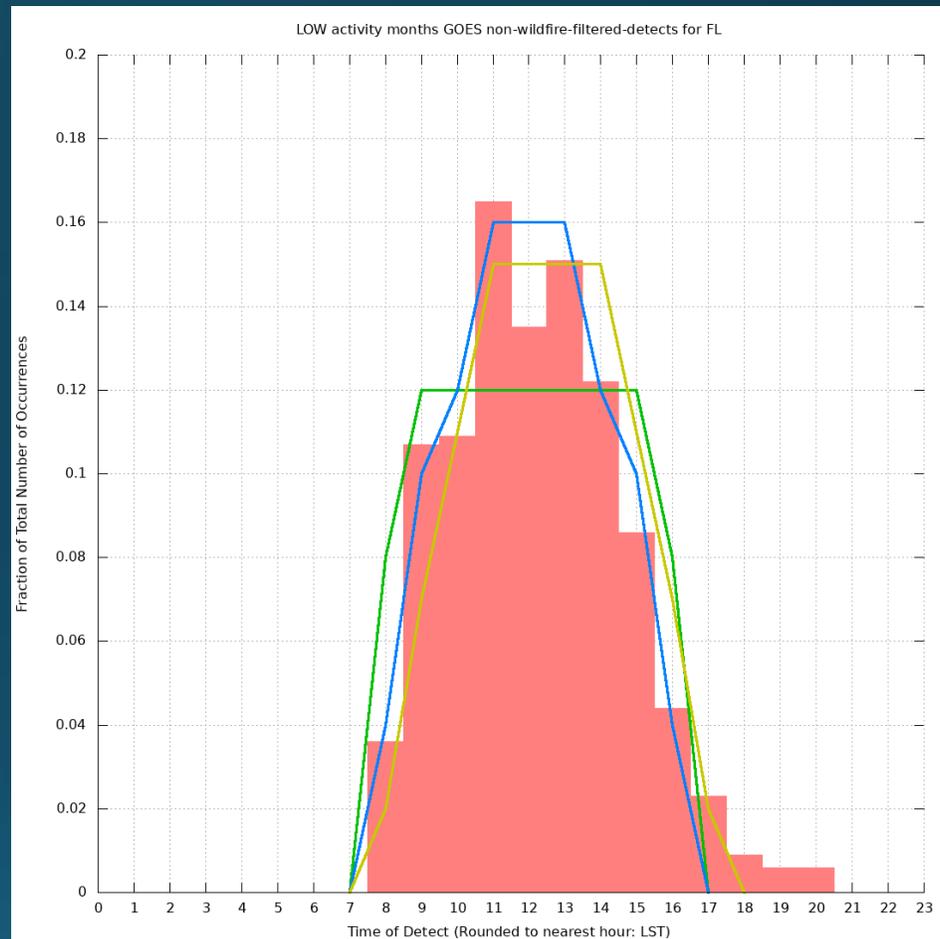**PROFILES CAN BE SHIFTED LEFT OR RIGHT AN HOUR DEPENDING ON FINDINGS**

HIGH
Florida only detects
LOW

HIGH activity months GOES non-wildfire-filtered-detects for FL

LOW activity months GOES non-wildfire-filtered-detects for FL
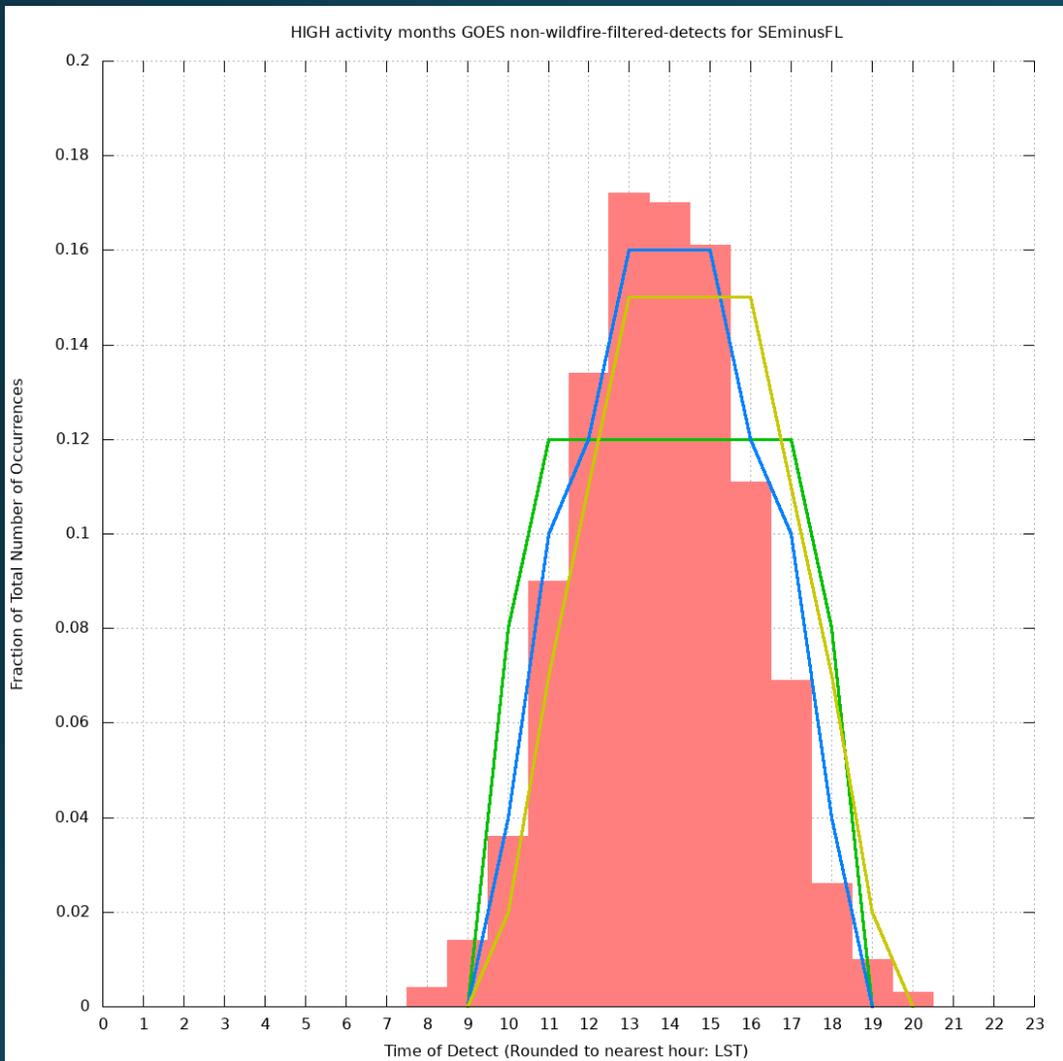
Fraction of Total Occurrences

LST
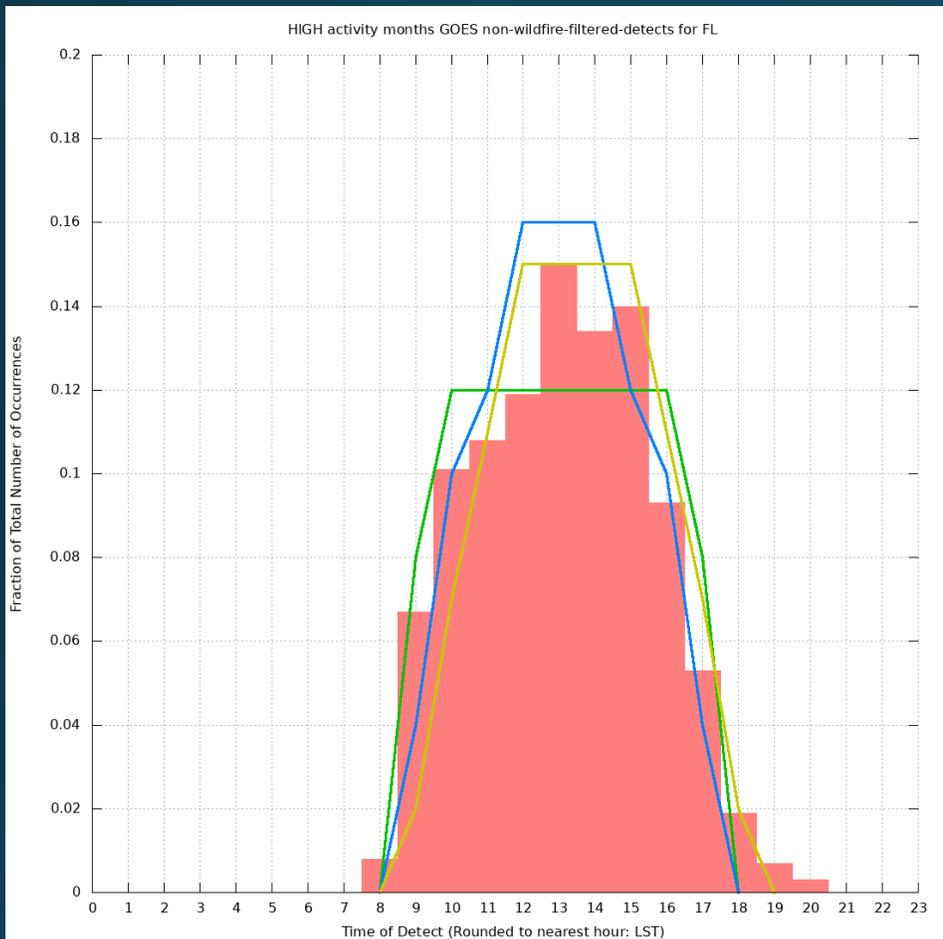
LST

- Most common start hours in permit database was 9 and 10 LST
  - detects basically suggest this as well
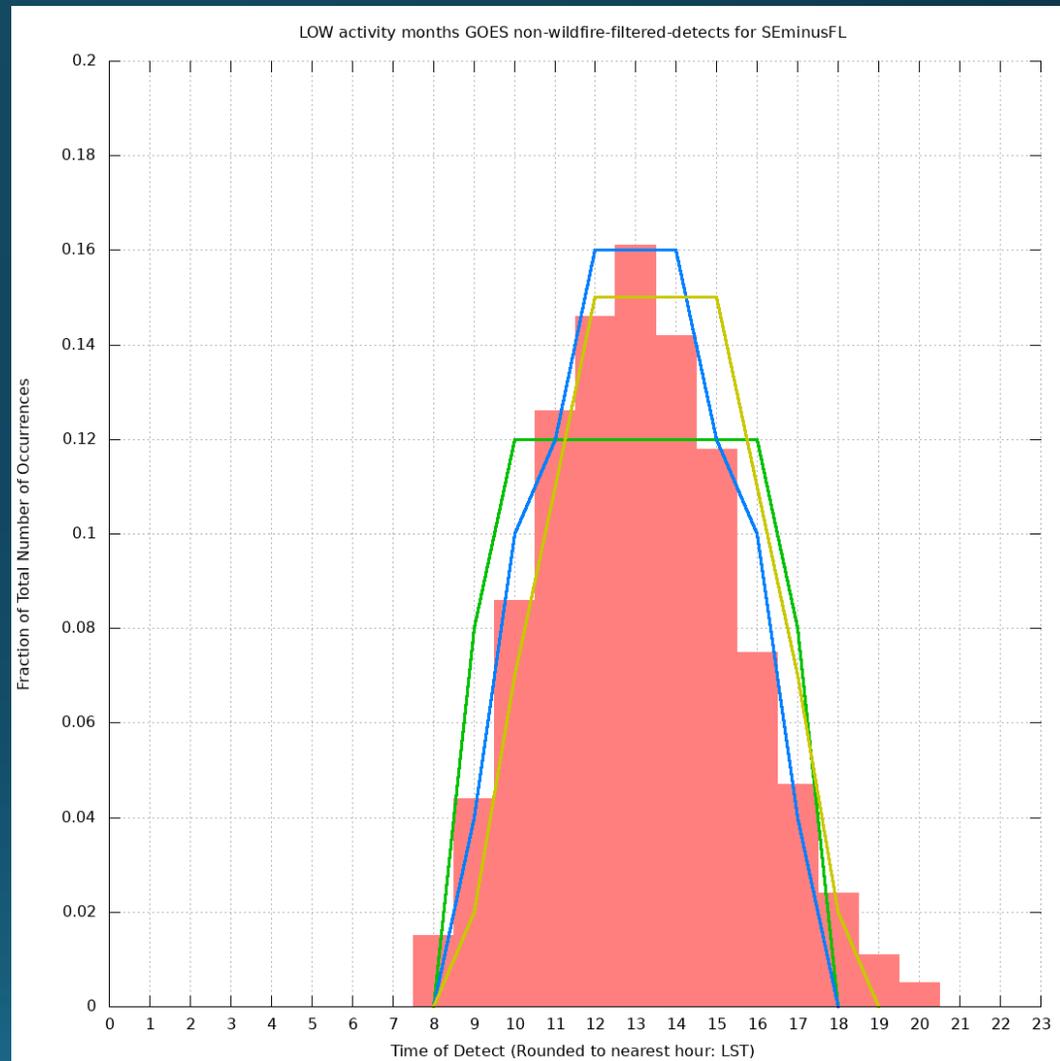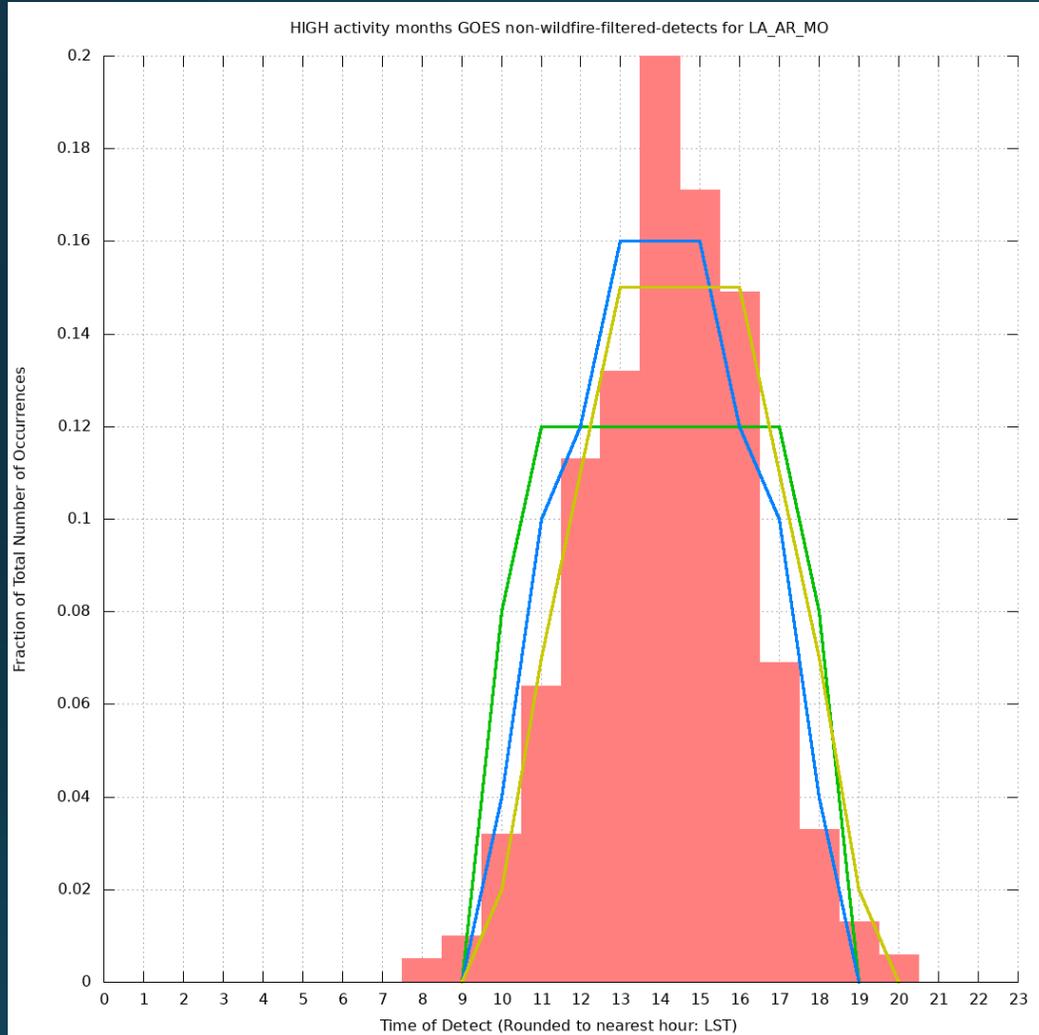- However, detects suggest a shift of one hour earlier in LOW activity profile (right) 17

HIGH activity months GOES non-wildfire-filtered-detects for SEminusFL

LOW activity months GOES non-wildfire-filtered-detects for SEminusFL

Fraction of Total Occurrences

LST   LST

- NC, SC, GA, AL, MS

HIGH   LA_AR_MO only detects   LOW

HIGH activity months GOES non-wildfire-filtered-detects for LA_AR_MO
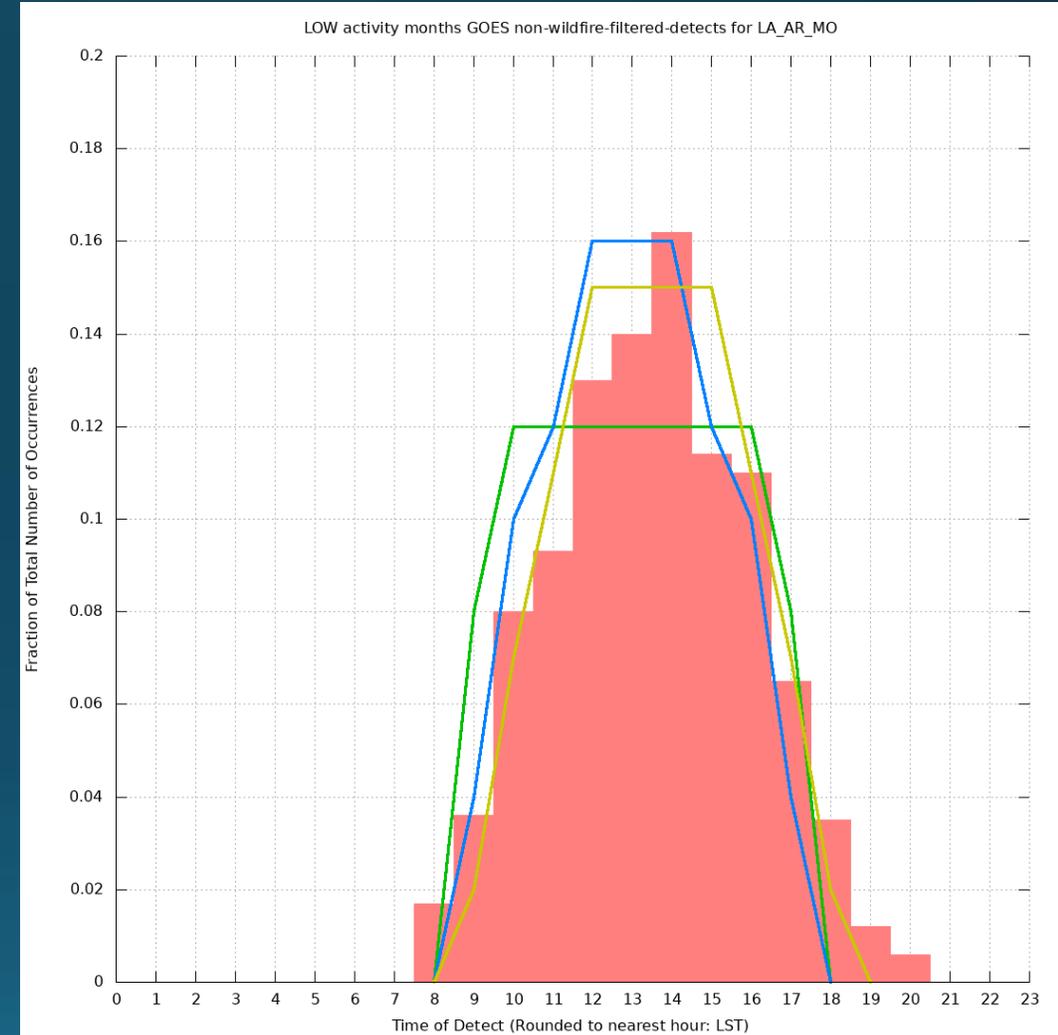
LOW activity months GOES non-wildfire-filtered-detects for LA_AR_MO

Fraction of Total Occurrences

LST   LST

- LA, AR, MO
- Similar result as Georgia and SEminusFL only detects

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HIGH   SPlains only detects   LOW

HIGH activity months GOES non-wildfire-filtered-detects for SPlains

Fraction of
Total
Occurrences
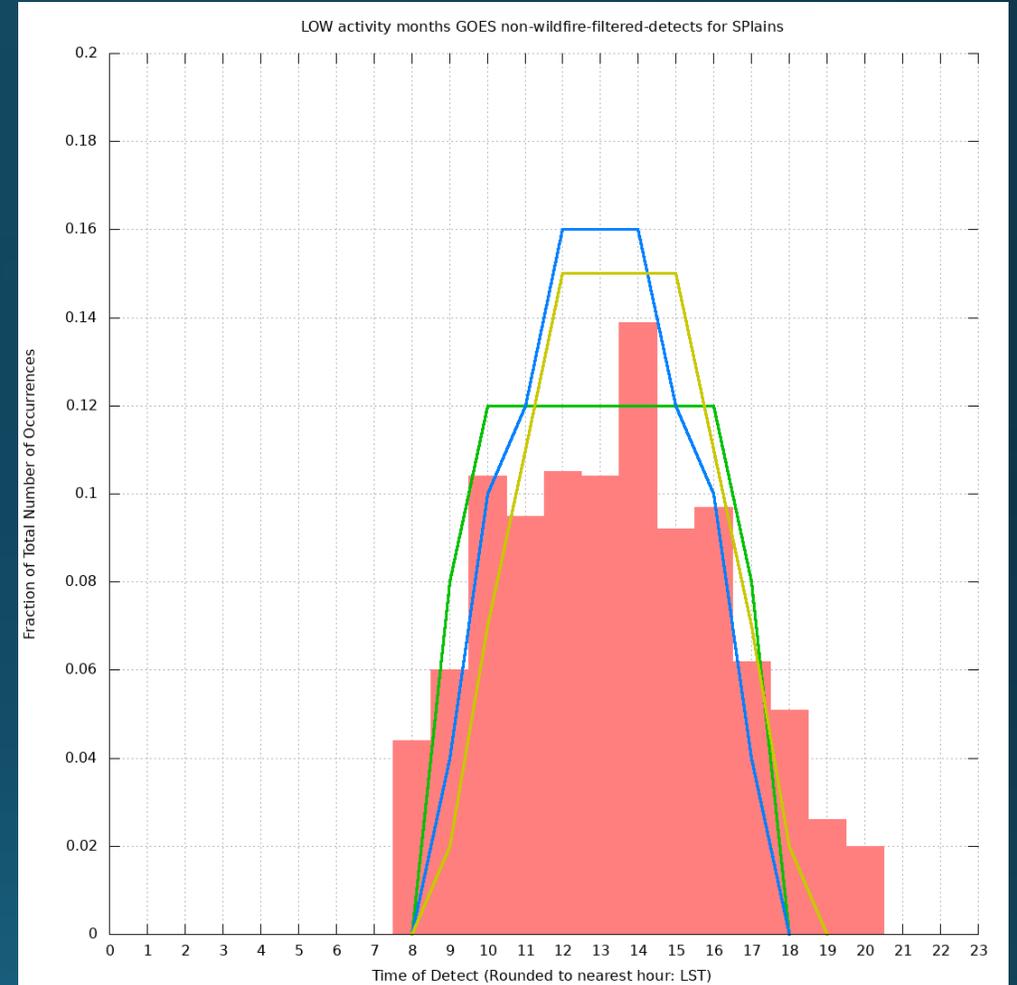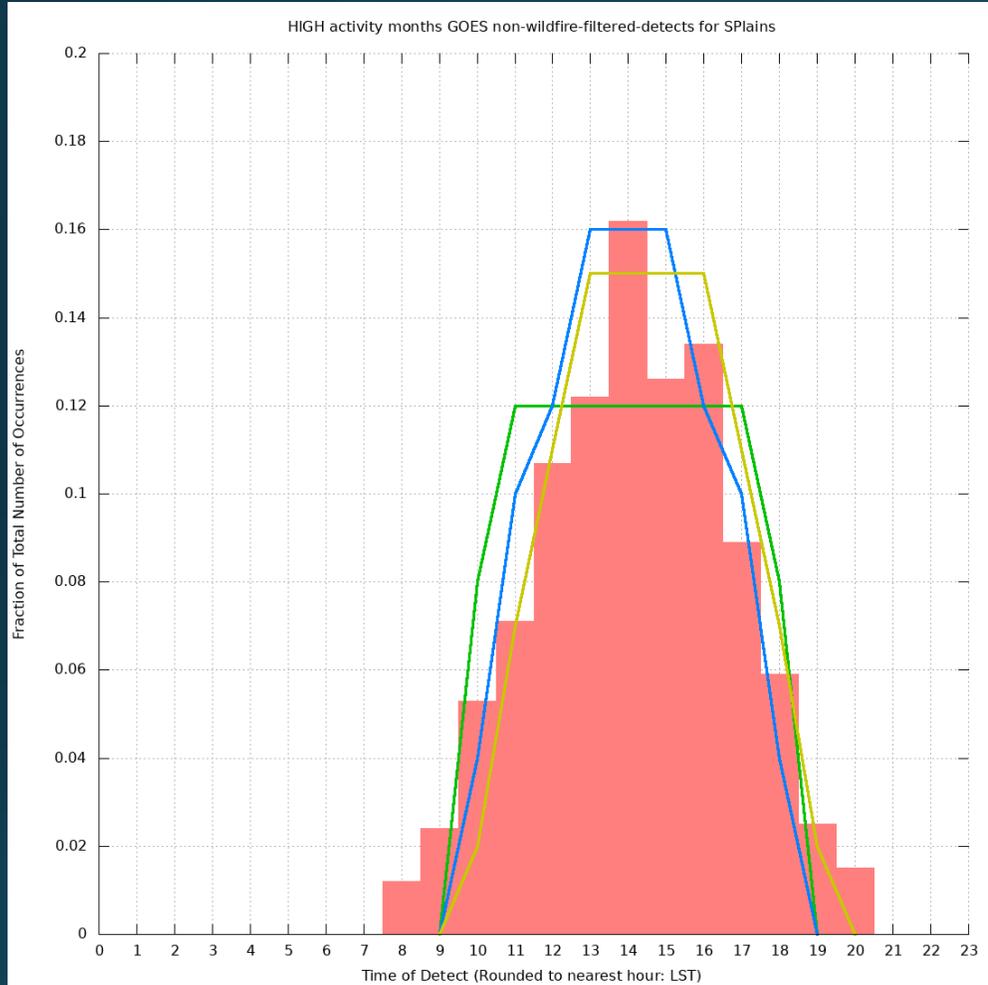
LOW activity months GOES non-wildfire-filtered-detects for SPlains
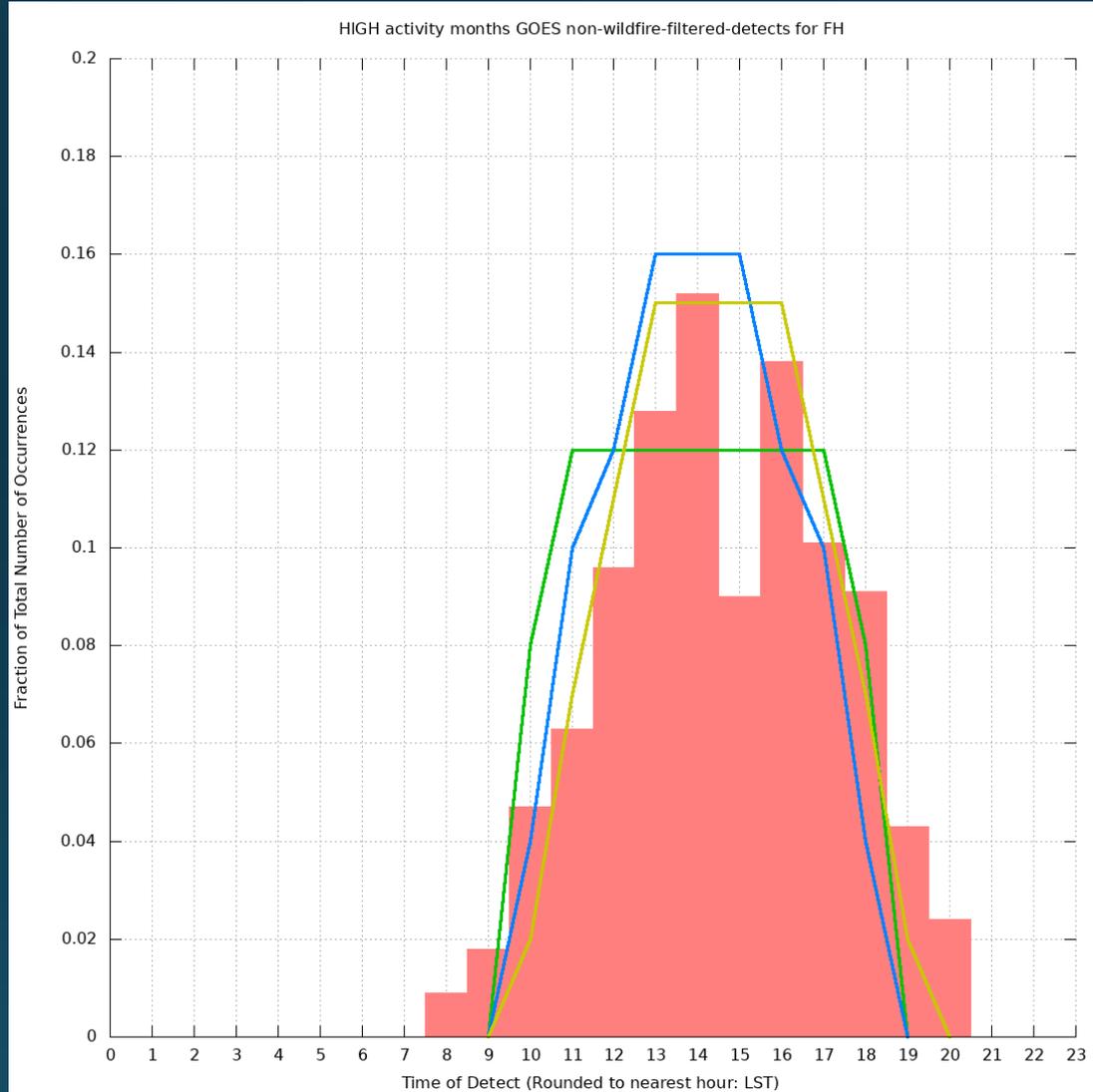
LST   LST

- TX, OK and KS includes Flint Hills grasslands
- Does shift an hour earlier like regions to the east

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Flint Hills KS counties only

HIGH activity months GOES non-wildfire-filtered-detects for FH

Y-axis: Fraction of Total Number of Occurrences
X-axis: Time of Detect (Rounded to nearest hour: LST)

Fraction of Total Occurrences

LST

- NEI has a SCC specifically for Flint Hills grassland fires that occur late Feb-early May
- Filtered detects for Flint Hills counties for these months (17000+ detects)
- This SCC has no separate residual smoldering emissions component
- KDHE has provided feedback
  - Typical start time 10 LST
  - Backfires first
  - Headfires 12-15 LST
  - Do have few fires starting in early evening
  - Lean towards FLAME8 (yellow) profile as best fit

Recommendations (except Flint Hills)

- **For Prescribed fires use FLAME7 profile SHAPE**
- Vary start hour by HIGH and LOW season and by region based on HMS analysis
- 3 profiles: one each beginning at 8, 9 and 10 LST
- Residual profile based on FLAME7 in **RED**
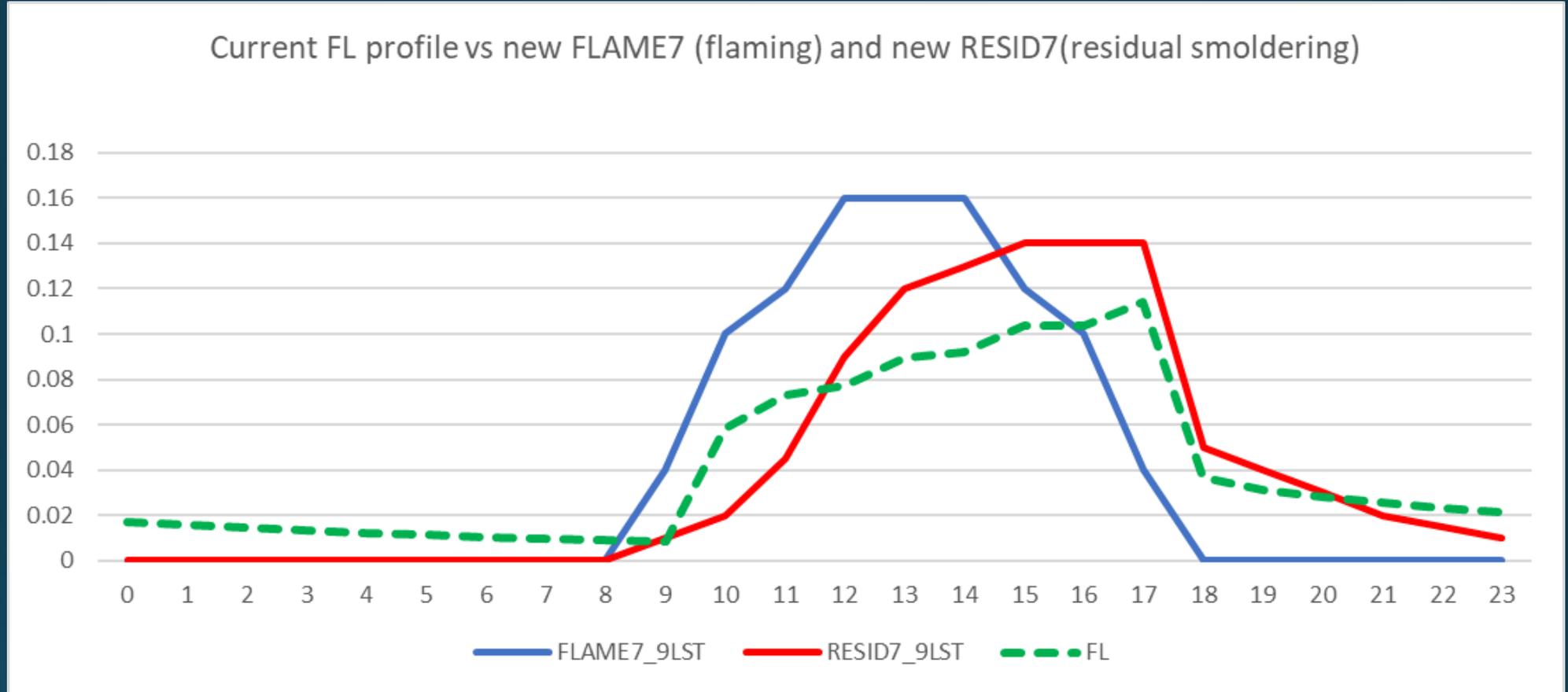
Start Hour by Region and by season (LST)

Residual profile based on FLAME7

Region	States	HIGH	LOW
FL	FL	9	**8**
CA	CA	9	9
WestShrub	AZ,NM,NV	9	9
LA_AR_MO	LA,AR,MO	10	9
NEast	VA,MD,DE,WV,PA,NY,RI,NH,ME,CT,VT	10	9
SEminusFL	NC, SC,GA,AL,MS,TN,KY	10	9
SPlains	TX,OK,KS	10	9
WestMix	UT,CO,WA,ID,OR	10	9
Glakes	OH,MI,IN,IL,WI,IA,MN	10	**10**
Nplains	NE,SD,ND,WY,MT	10	**10**
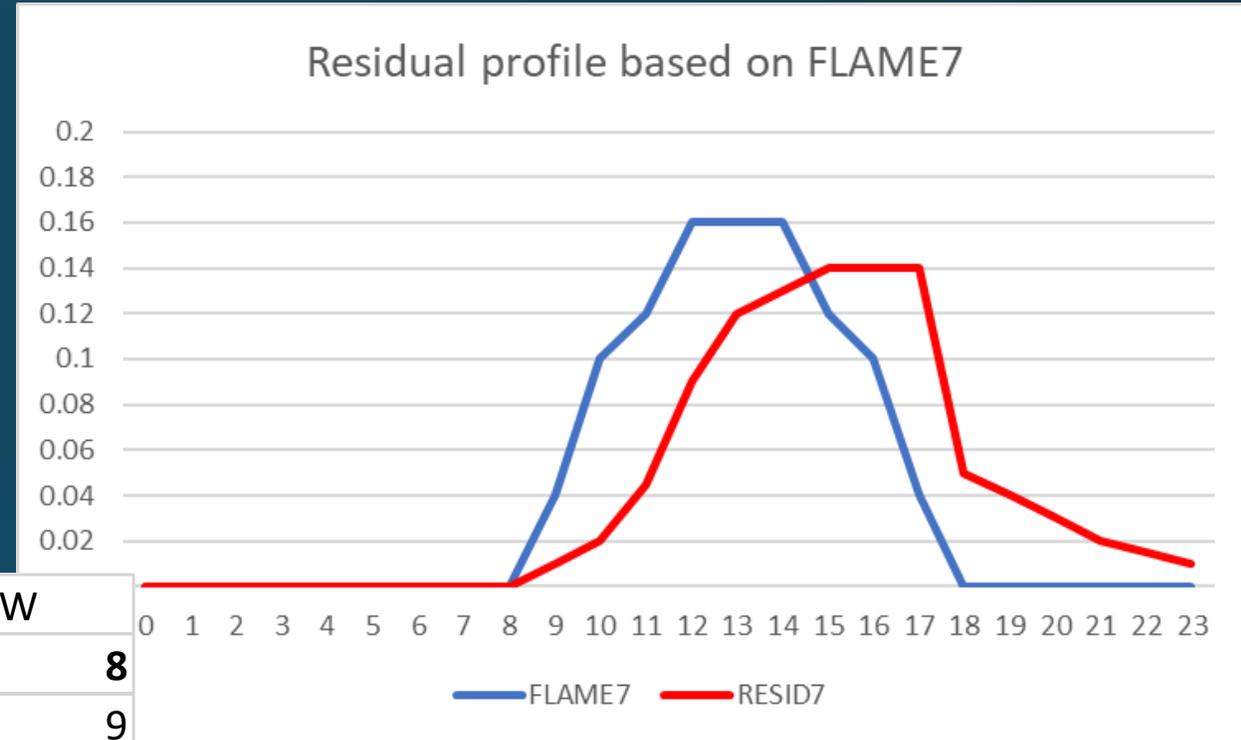
- **Alaska: Use NPlains profile**
- **Hawaii: Use Florida profile**

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Summary of changes due to recommendations

Current FL profile vs new FLAME7 (flaming) and new RESID7(residual smoldering)
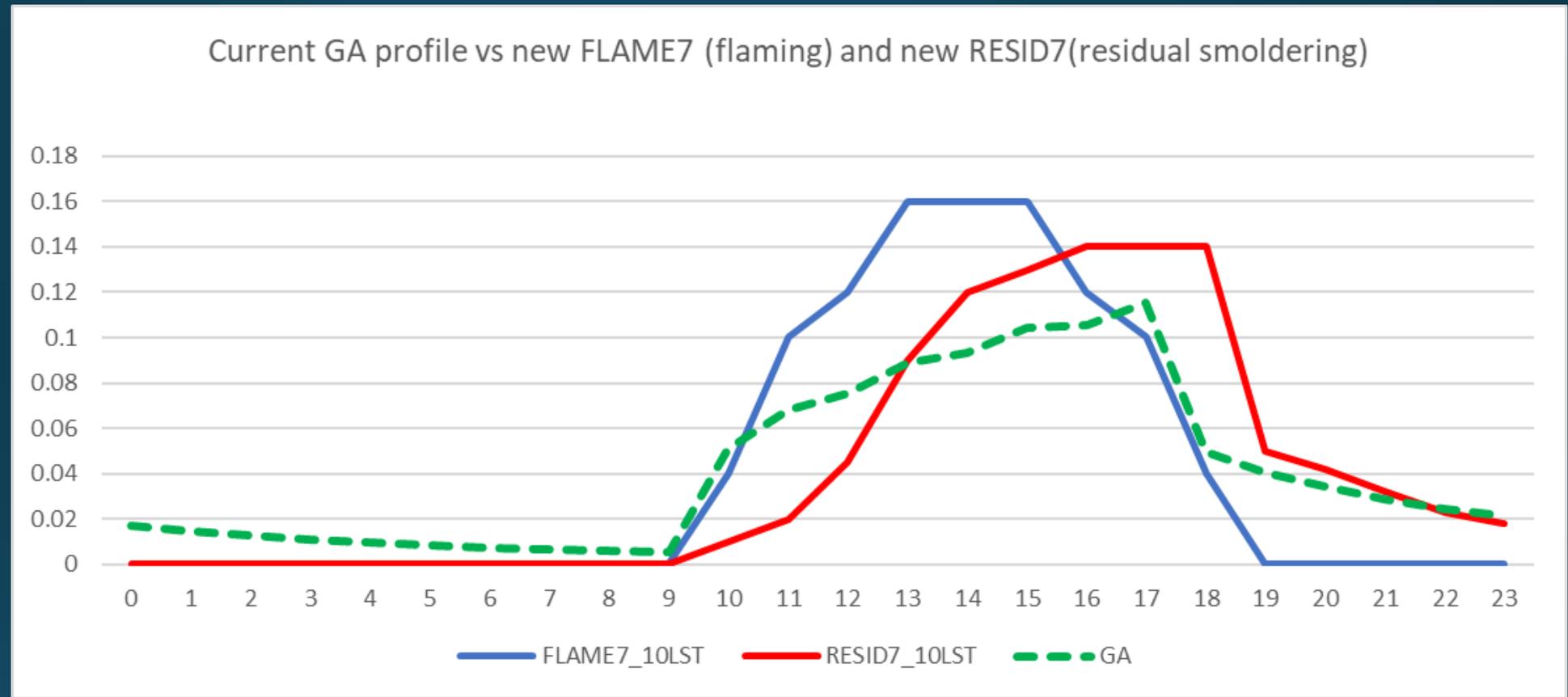
Current
New Flaming
New Residual

Legend: FLAME7_9LST, RESID7_9LST, FL

- Note recommended profile starts one hour earlier; this is for high activity months
- More emissions allocated in late morning and middle of day and no emissions at all until 9 LST in recommended profiles.
- Other states that have similar comparisons are: CA, AZ, NM, NV for high activity months

Summary of changes due to recommendations(2)

Current GA profile vs new FLAME7 (flaming) and new RESID7(residual smoldering)

Current
New Flaming
New Residual

- Note recommended profile starts at same hour; this is for high activity months
- More emissions allocated in late morning and middle of day and no emissions at all until 10 LST in recommended profiles.
- This profile difference will also occur in most other states except FL, CA, AZ, NM and NV for high activity months

Summary of changes due to recommended changes
Flint Hills only

Current
New

Current Flint Hills KS Grasslands ONLY profile vs new FLAME8 (yellow)

FLAME8_10LST — KS
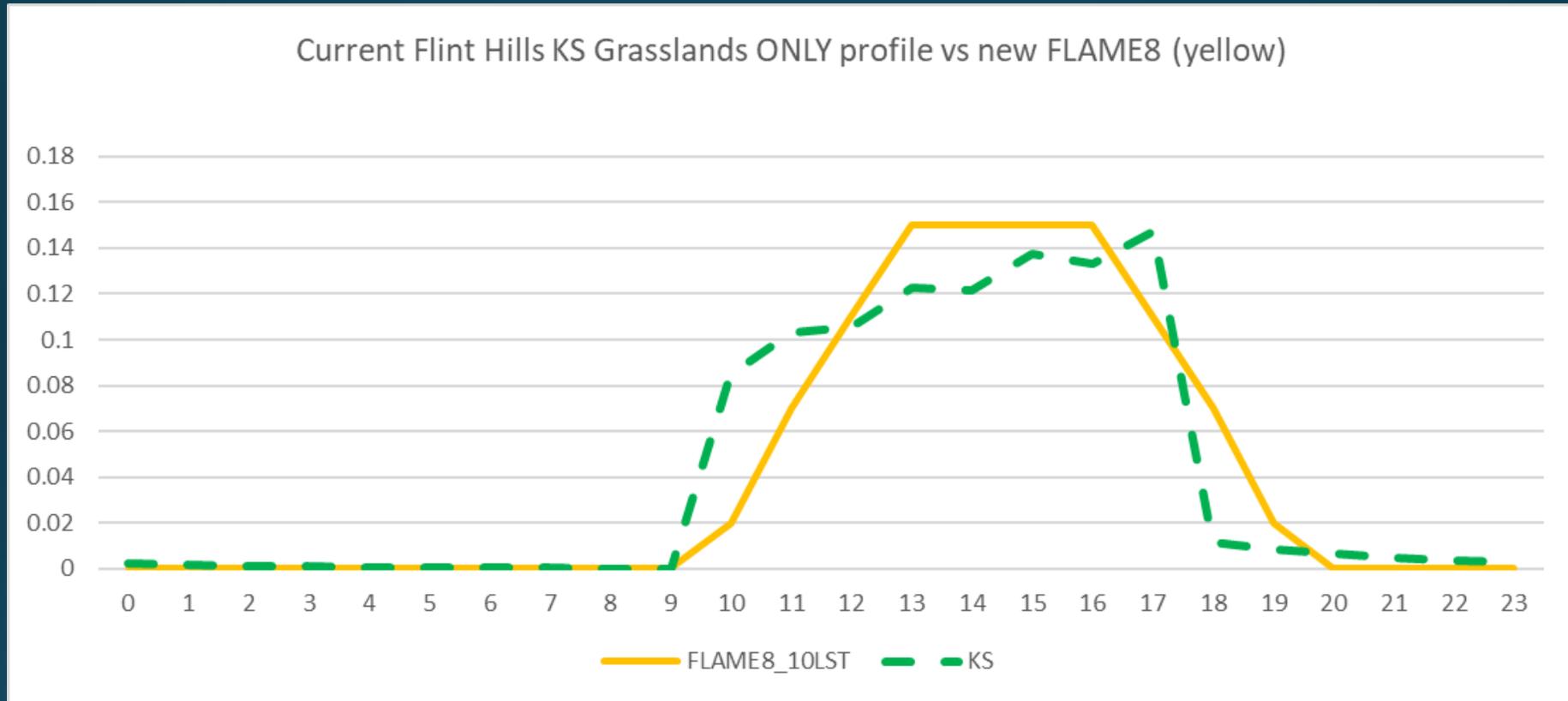
- Note recommended profile starts at same hour; Flint Hills months (Feb-May)
- More emissions allocated in middle of day and some evening hours in recommended profiles
- No emissions at all until 10 LST in recommended profiles.
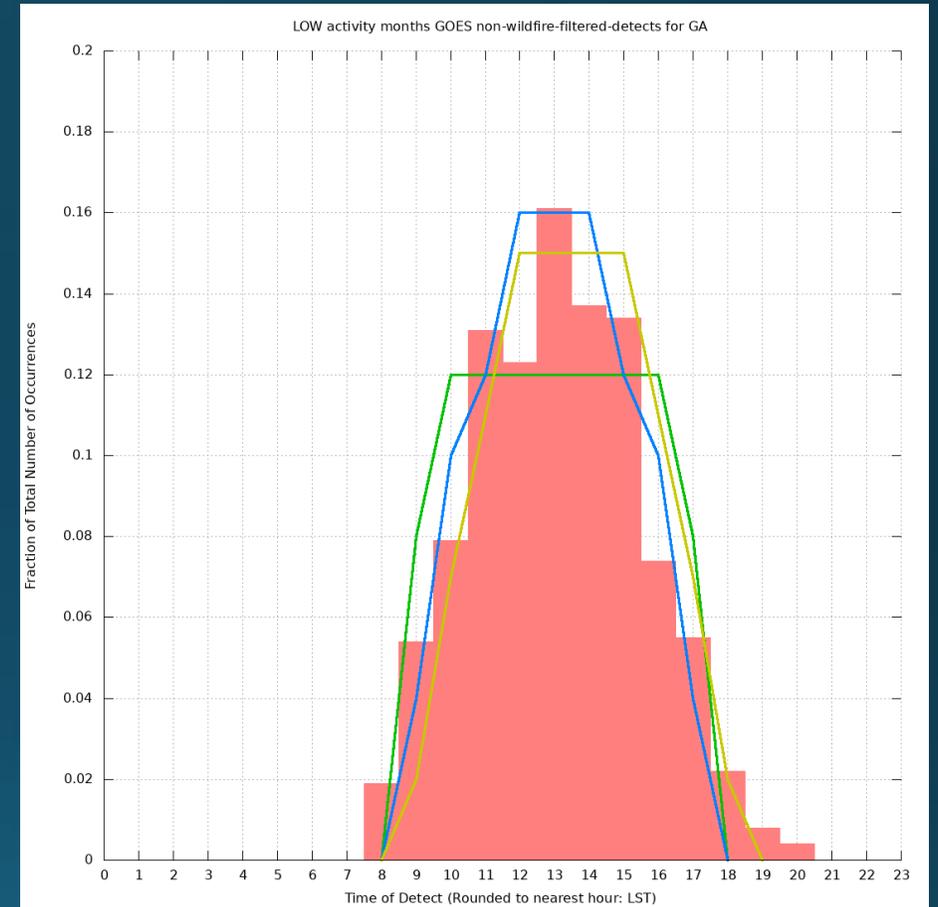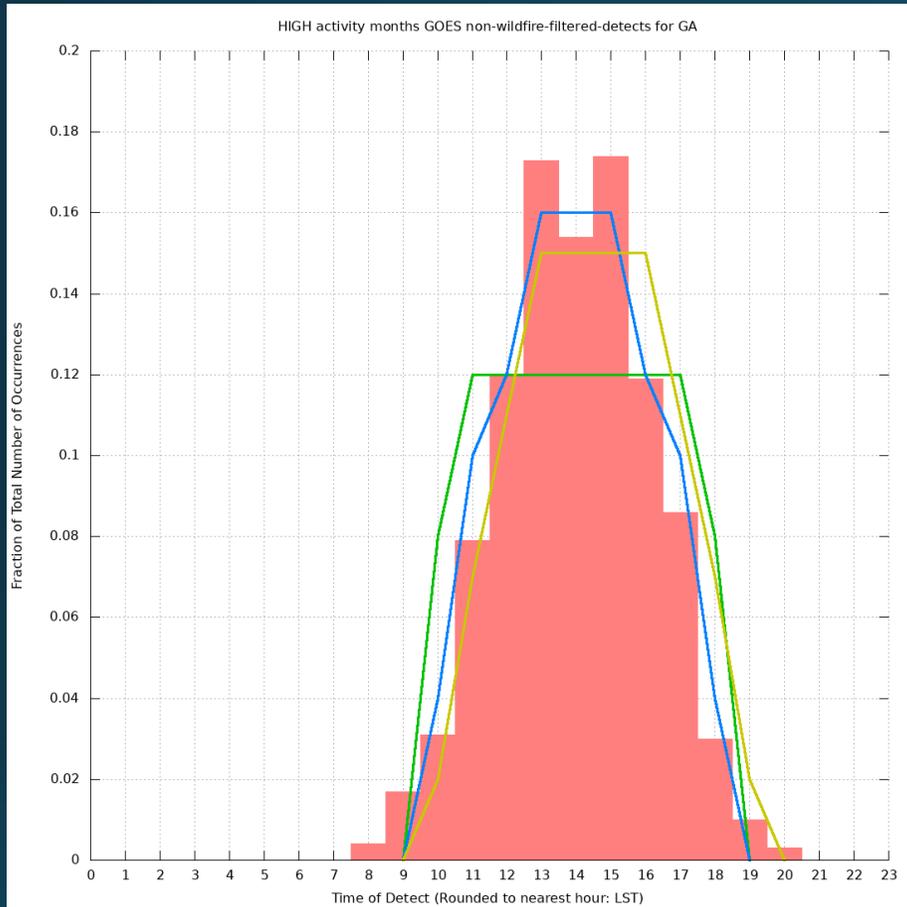
Access to new diurnal profile data and possible future enhancements

- New SMOKE-ready diurnal profiles for Prescribed Fires and cross-reference files are located at:
  - ftp://newftp.epa.gov/Air/emismod/diurnal_Rxfires/

- Duration of prescribed fires may be a function fire size
  - If so, how could this be implemented?
  - How important is this?
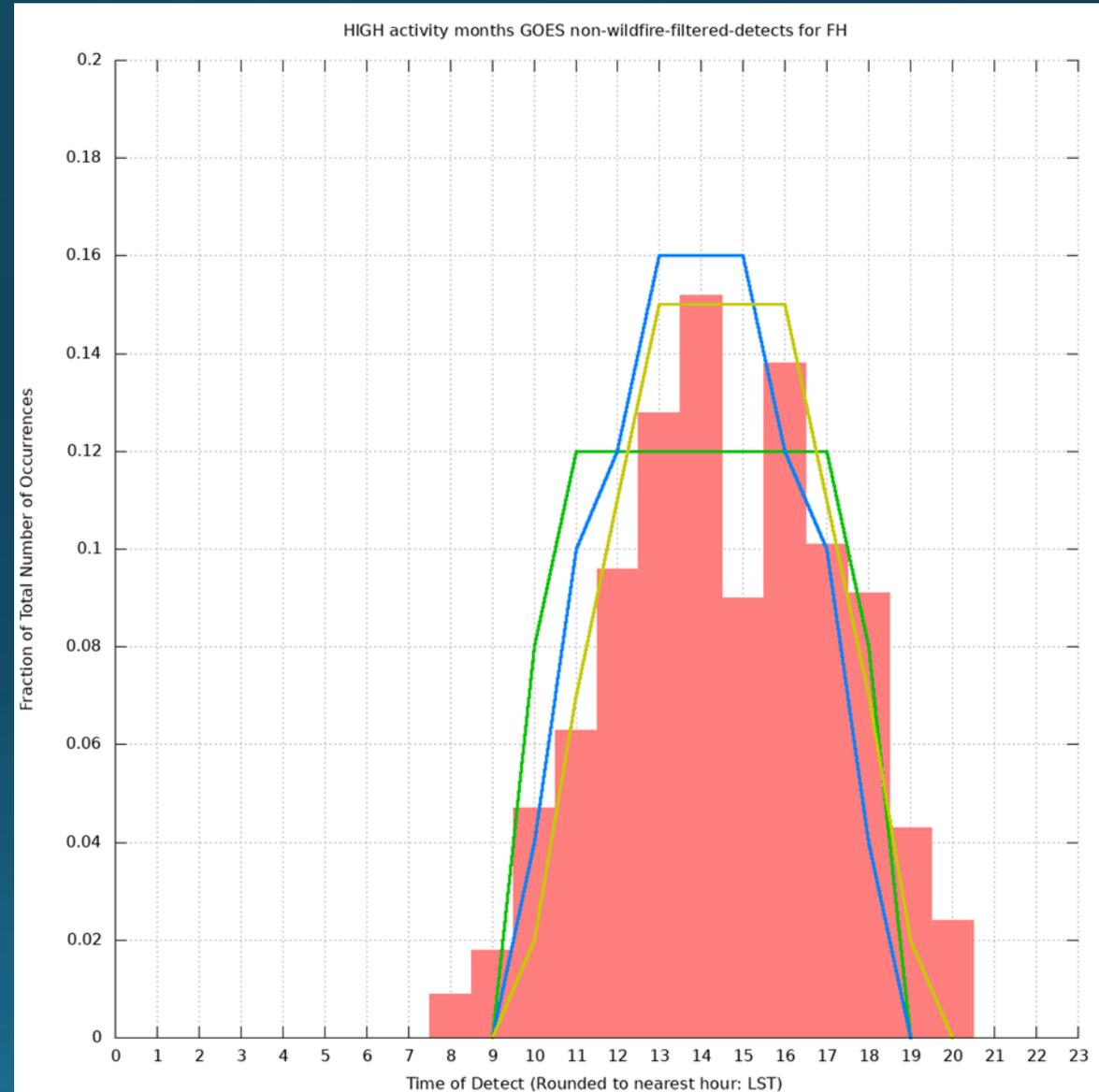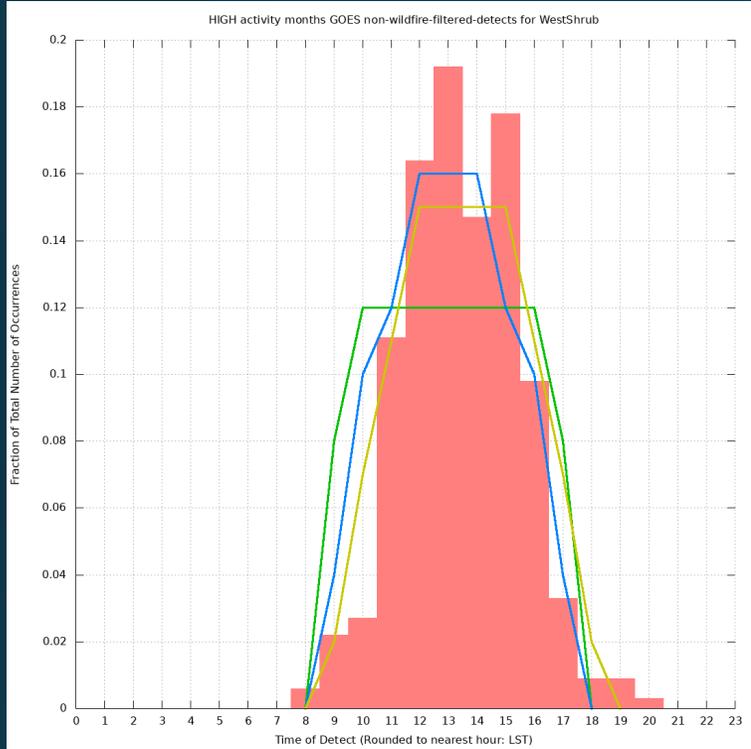- Wildfire diurnal profile update using latest GOES-R detects

EXTRA SLIDES

HIGH activity months GOES non-wildfire-filtered-detects for GA

LOW activity months GOES non-wildfire-filtered-detects for GA

All detect slides moving forward: removed night time detects and normalized to 1
Most common start hour in permit database was 10 LST which matches HIGH detect profile
However, detects suggest a shift of one hour earlier in LOW activity profile (right)
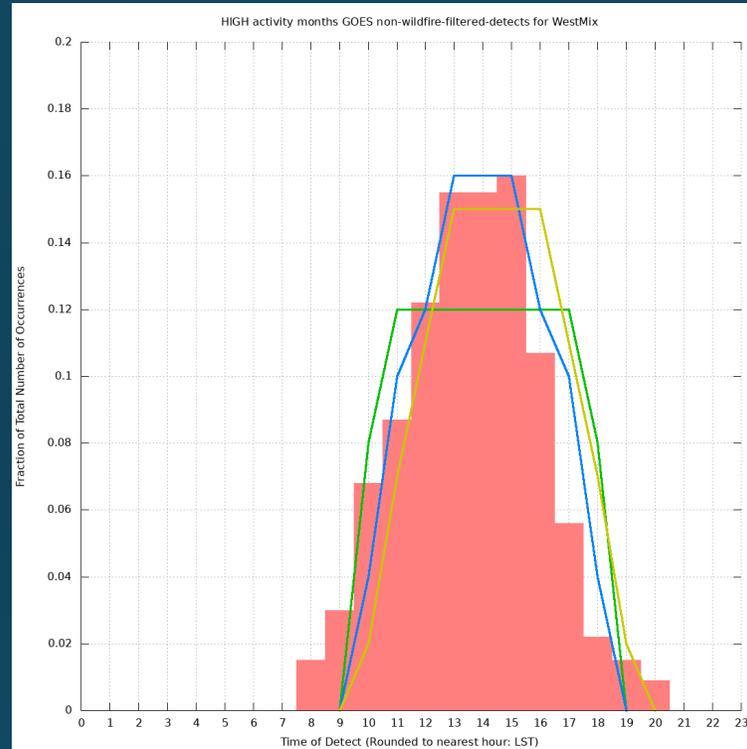
Recommendations: Flint Hills

- For Flint Hills grassland fires use FLAME8 profile SHAPE (yellow) for SCC = 2811021000
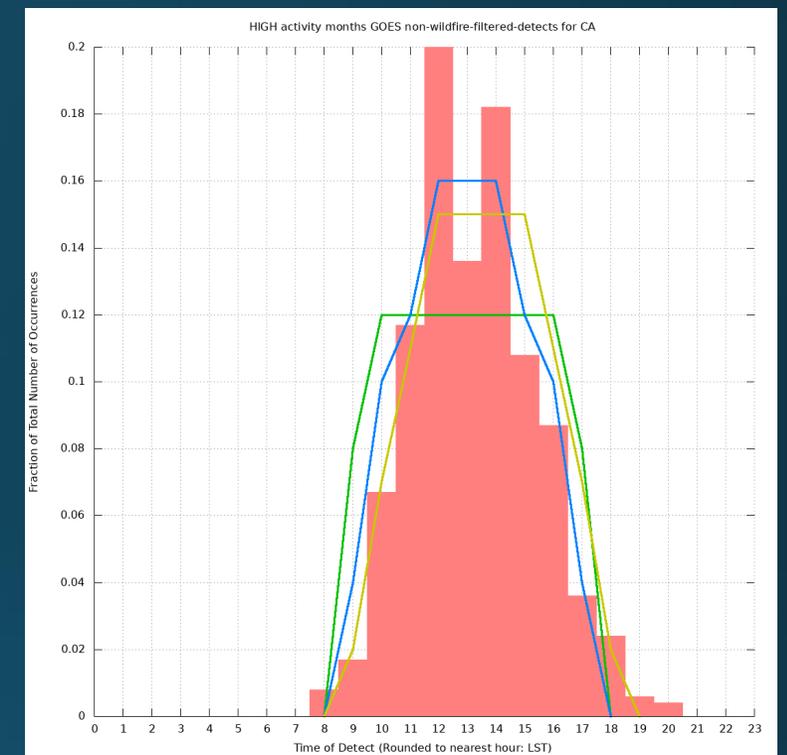- Start time of 10 LST
- No Residual profile necessary

HIGH activity months GOES non-wildfire-filtered-detects for FH

Fraction of Total Number of Occurrences

Time of Detect (Rounded to nearest hour: LST)

West Shrub HIGH

WestMix HIGH

California HIGH

HIGH activity months GOES non-wildfire-filtered-detects for WestShrub

HIGH activity months GOES non-wildfire-filtered-detects for WestMix

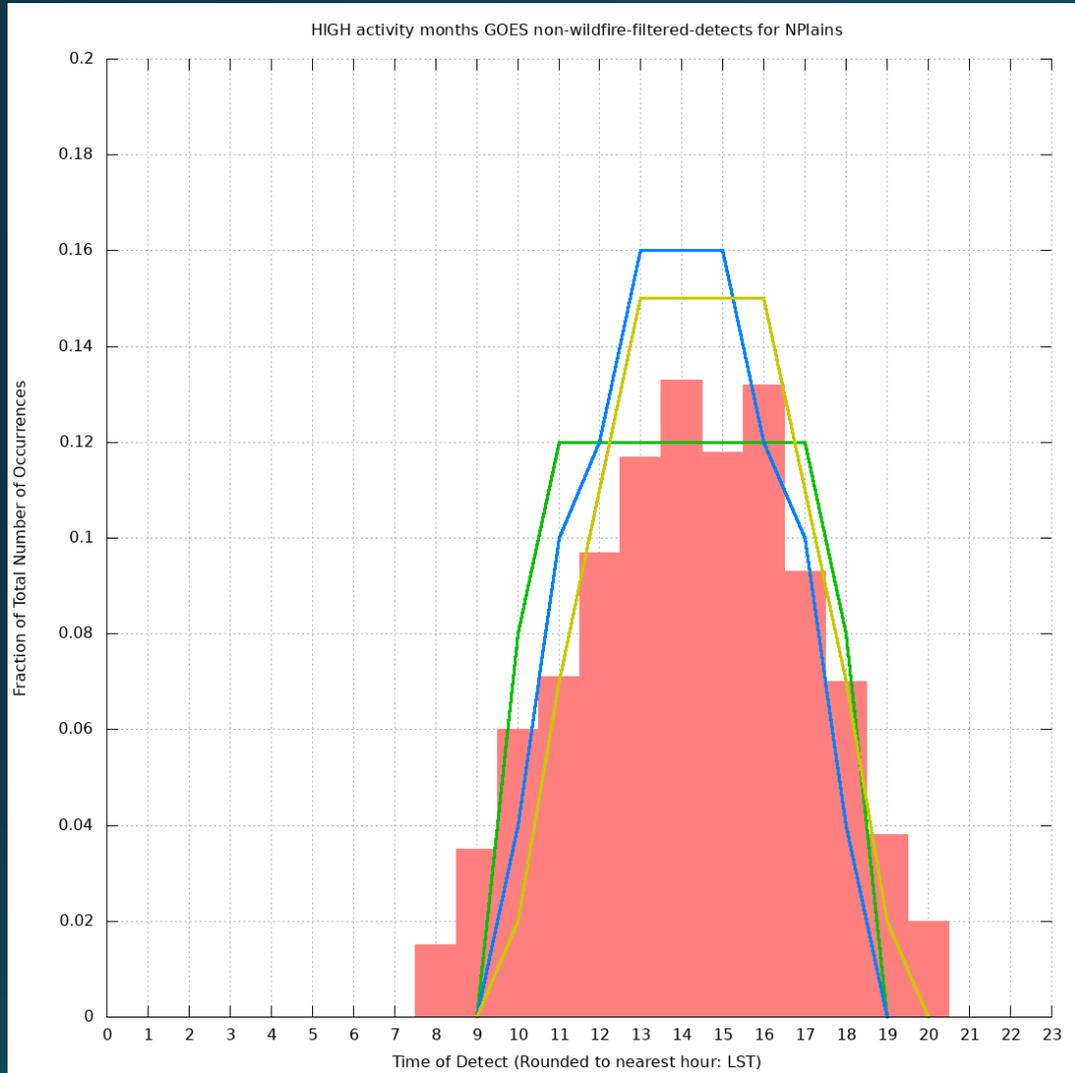HIGH activity months GOES non-wildfire-filtered-detects for CA

- AZ, NM and NV (West Shrub)
  - HIGH season pretty similar to FL with earlier start time (9LST)
- CO, UT, WA, OR (WestMix)
  - HIGH season pretty similar to SEminusFL and LA_AR_MO
- California
  - HIGH season pretty similar to FL and WestShrub

HIGH activity months GOES non-wildfire-filtered-detects for NPlains

LOW activity months GOES non-wildfire-filtered-detects for NPlains
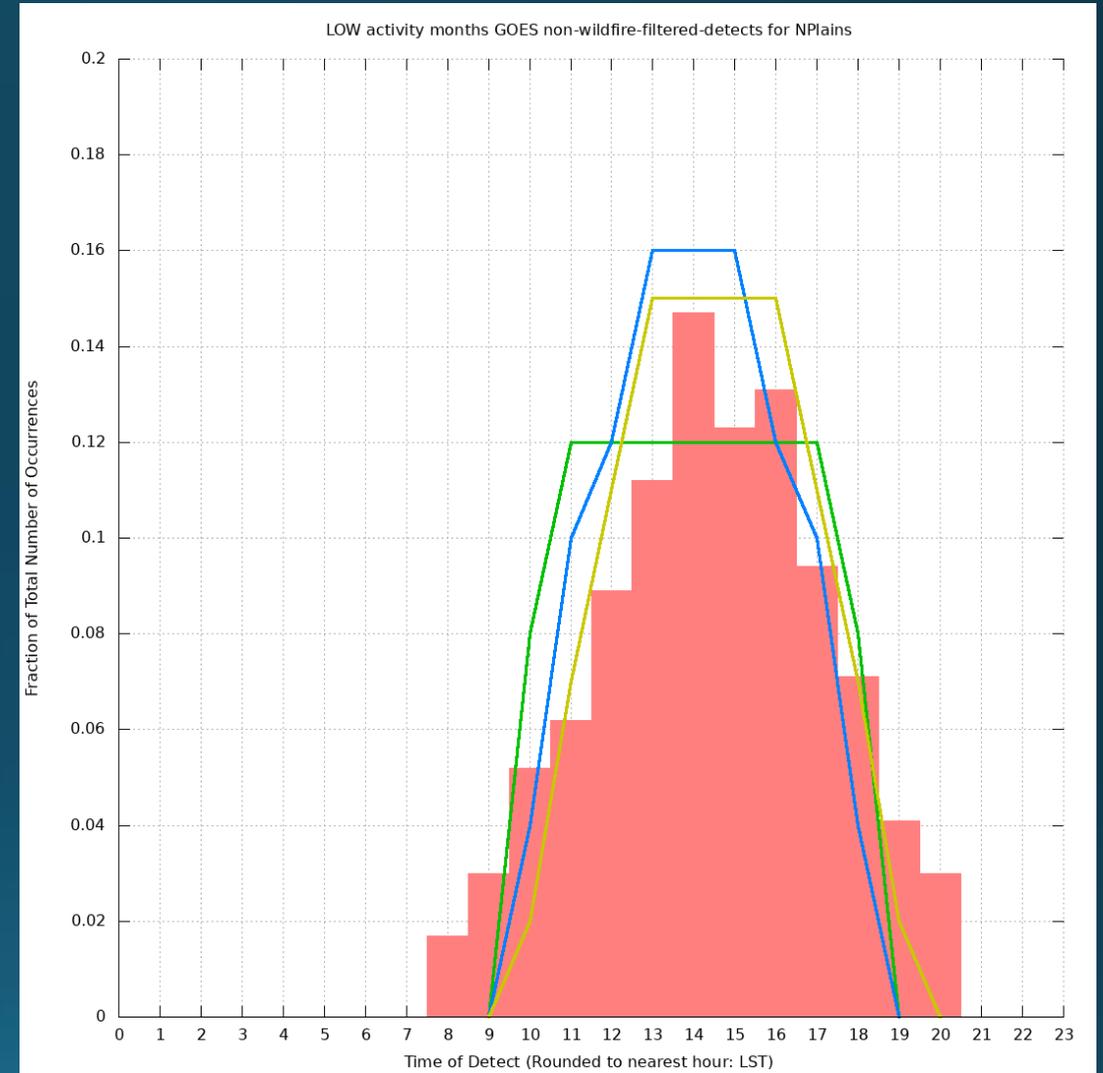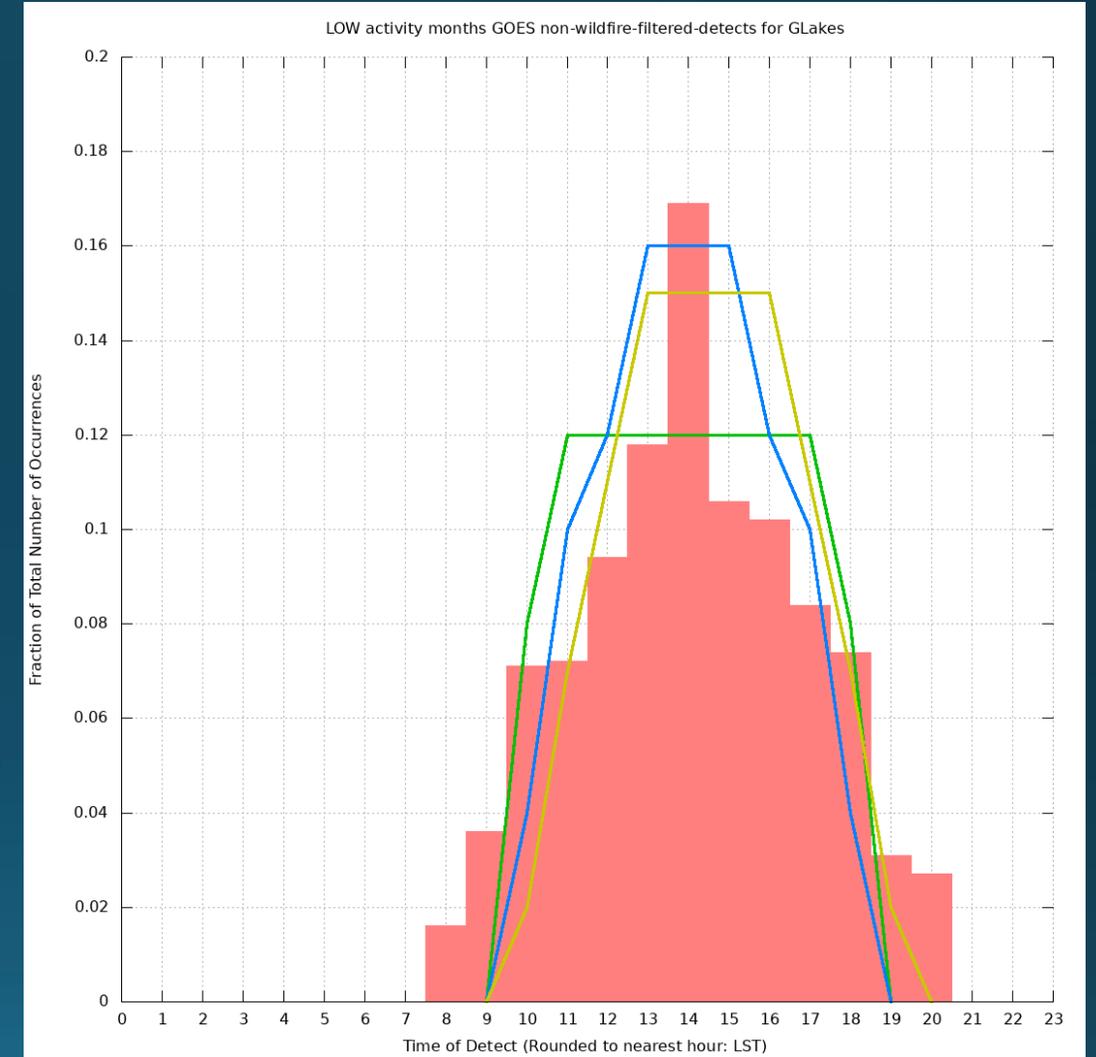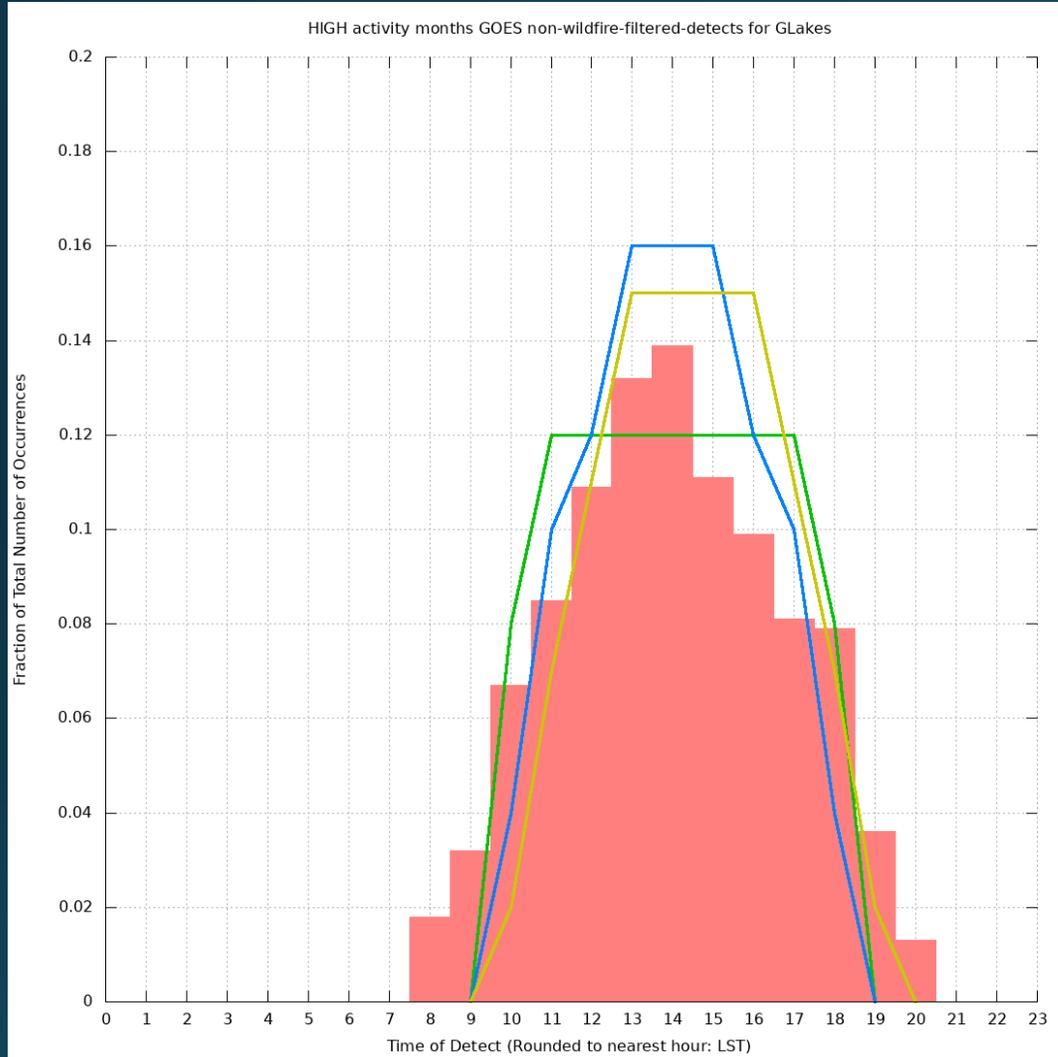
- WY, MT, ND, SD, NE
- HIGH season somewhat similar to SEminusFL and LA_AR_MO
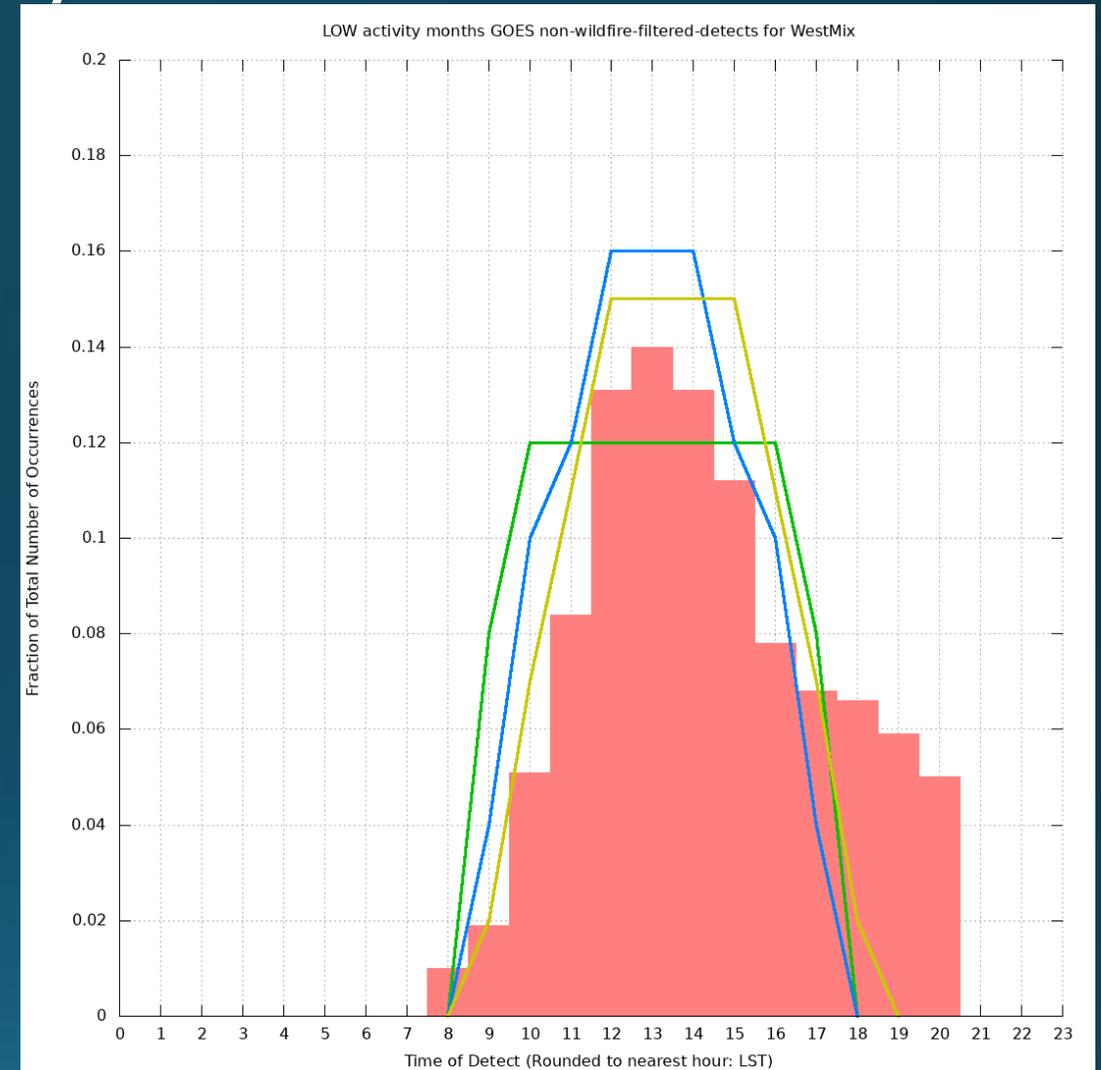- Same starting hour in HIGH and LOW seasons

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HIGH activity months GOES non-wildfire-filtered-detects for GLakes
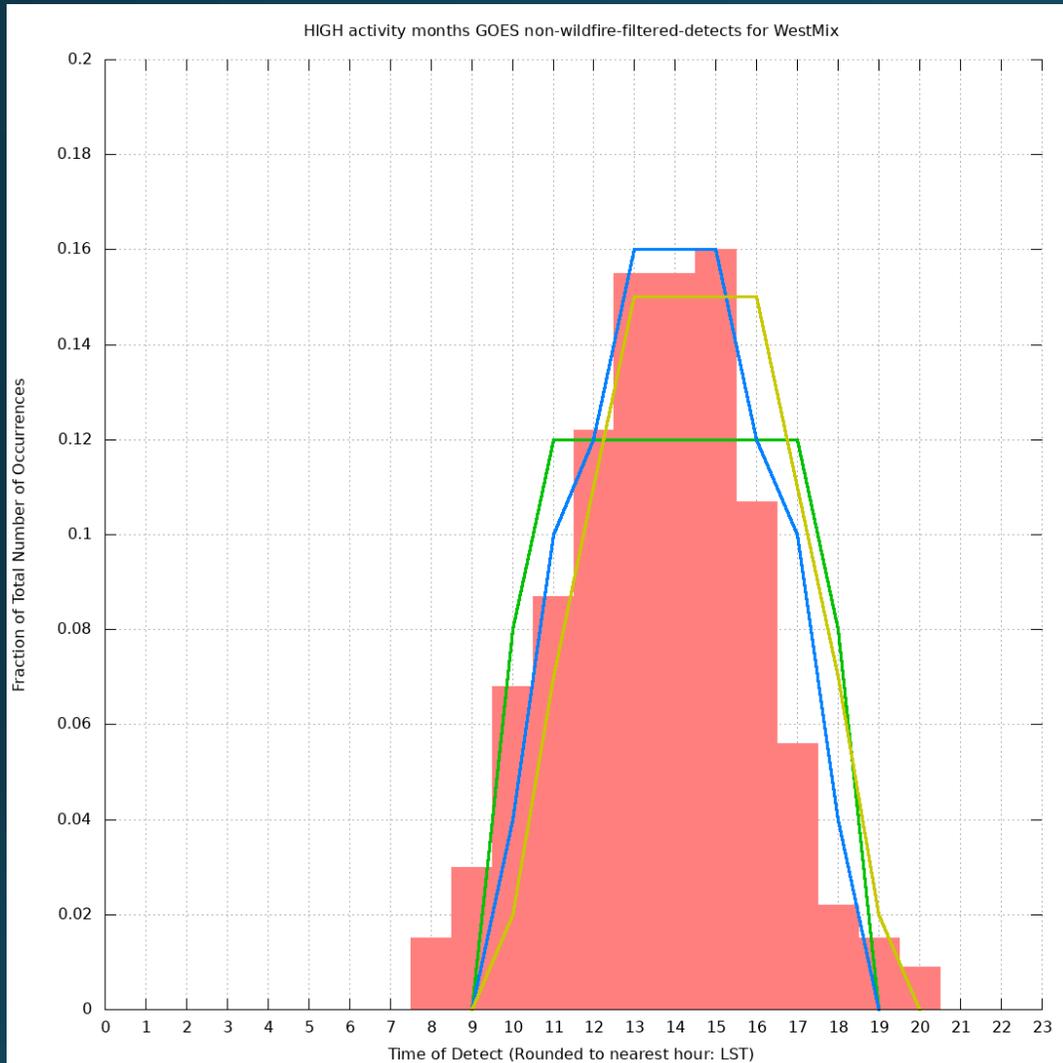

LOW activity months GOES non-wildfire-filtered-detects for GLakes

- OH, IN, IL, WI, IA, MI, MN
- HIGH season pretty similar to SEminusFL and LA_AR_MO
- Same starting hour in HIGH and LOW seasons

HIGH activity months GOES non-wildfire-filtered-detects for WestMix

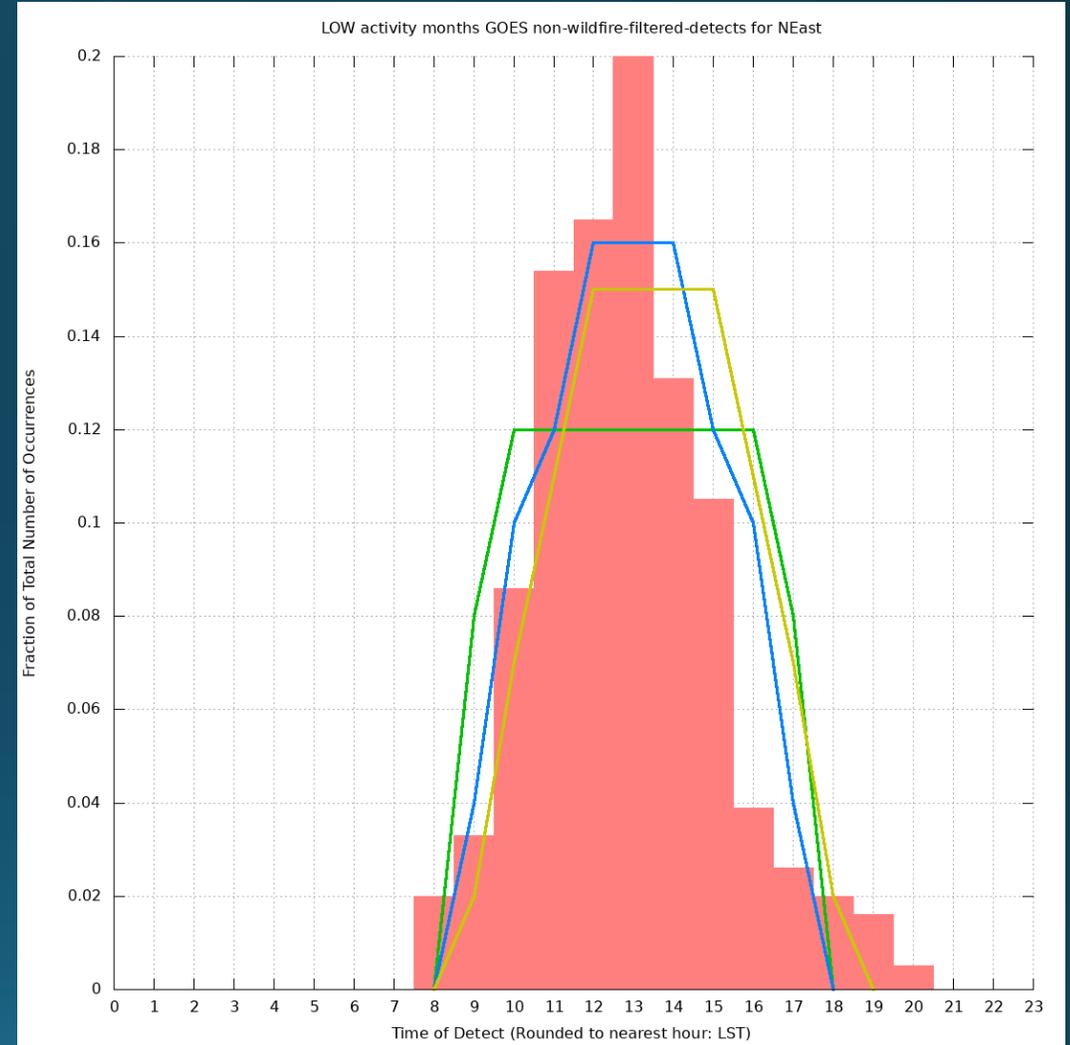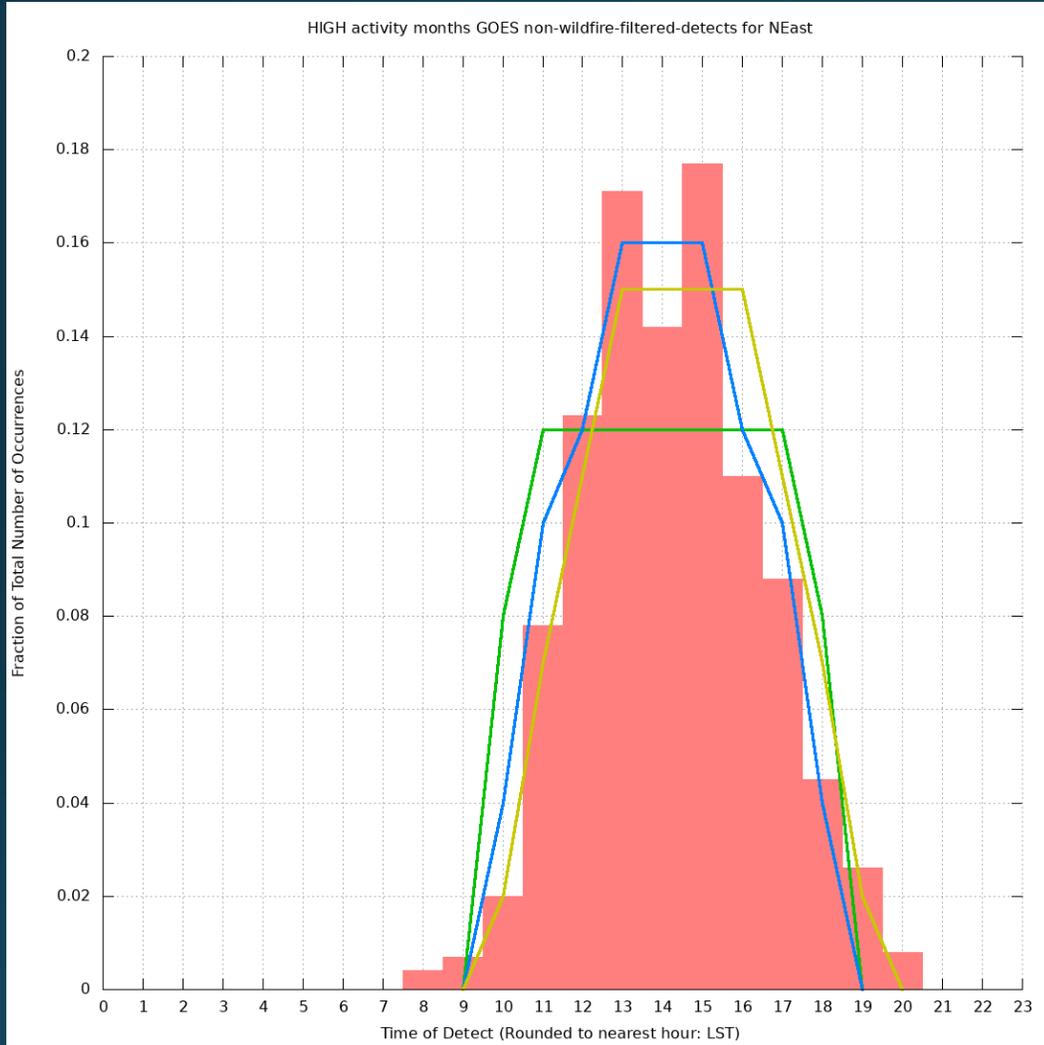LOW activity months GOES non-wildfire-filtered-detects for WestMix

- CO, UT, WA, OR
- HIGH season pretty similar to SEminusFL and LA_AR_MO
- LOW season: Shift one hour earlier; possible leftover detects that could be wildfires?

HIGH   NEast only detects   LOW

HIGH activity months GOES non-wildfire-filtered-detects for NEast

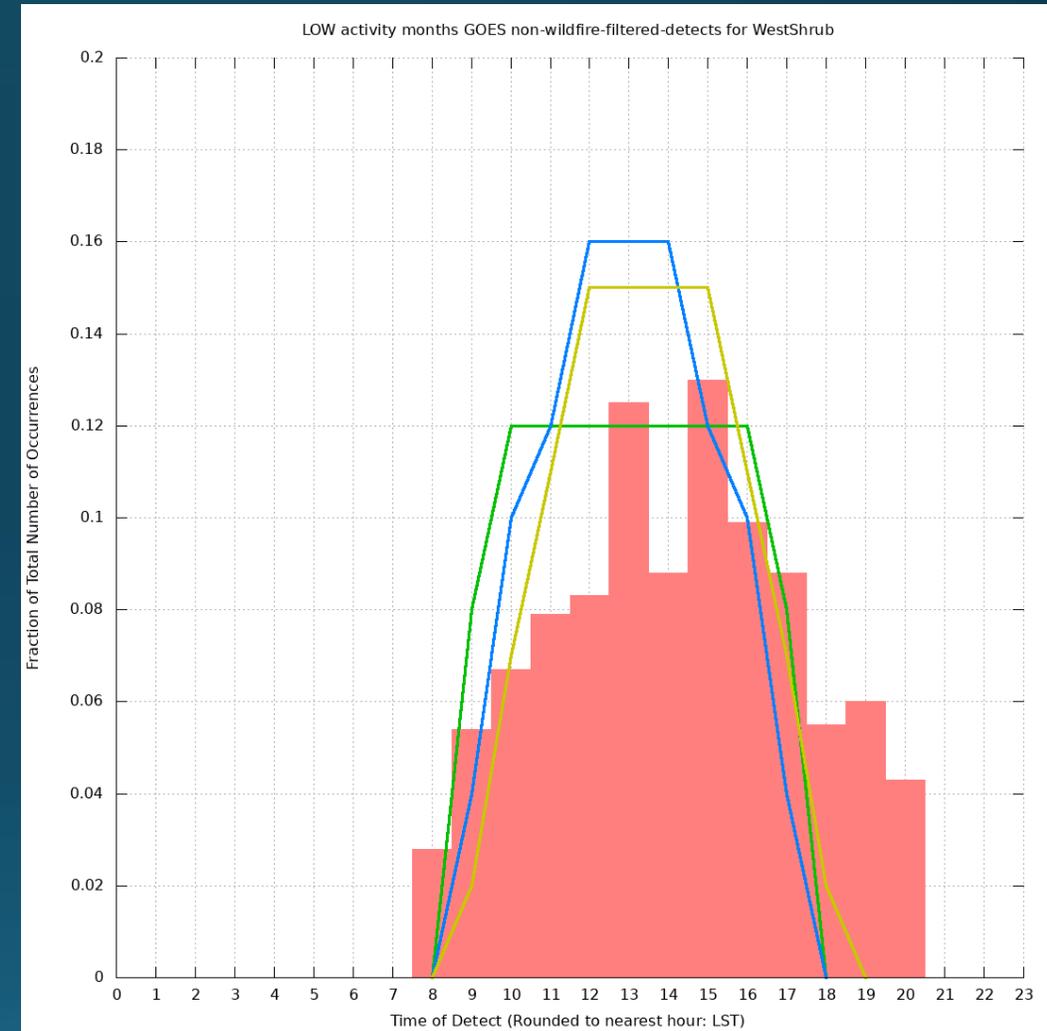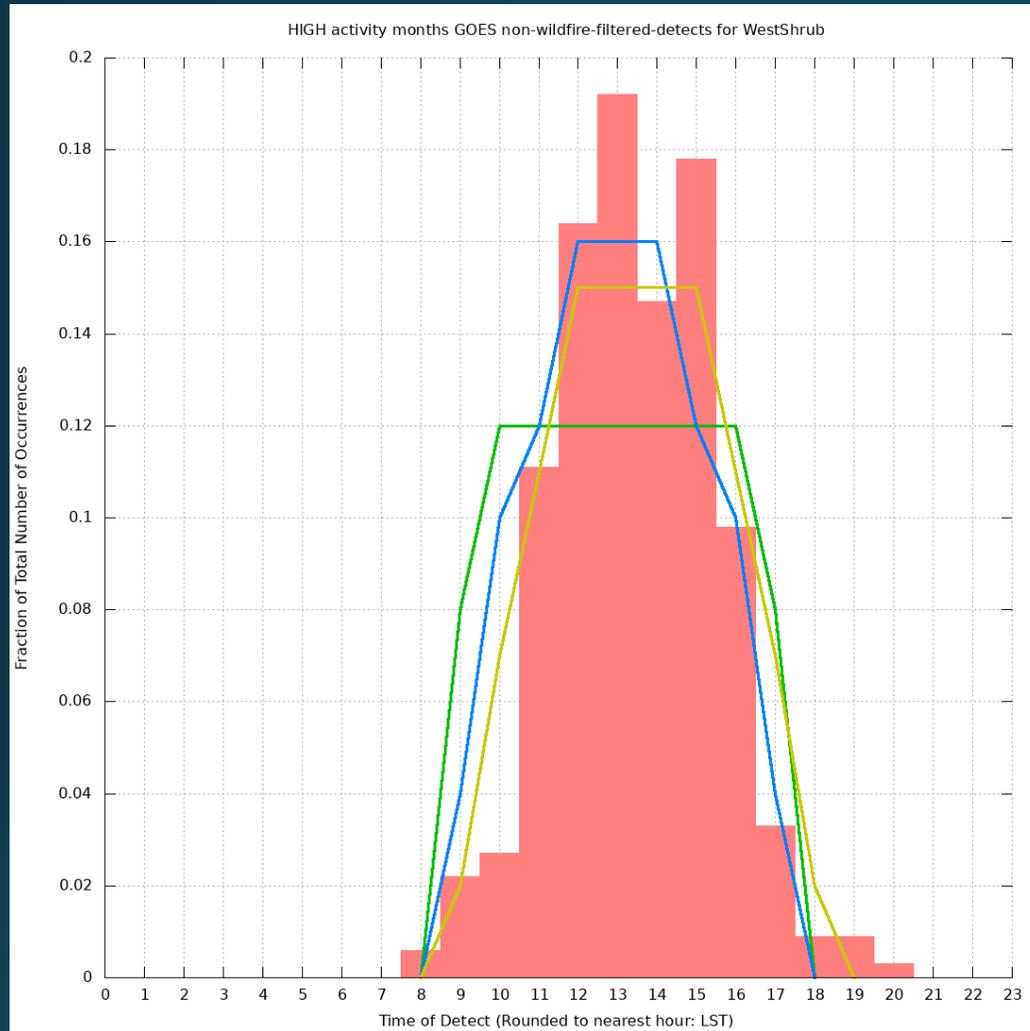LOW activity months GOES non-wildfire-filtered-detects for NEast

- VA,MD,DE,WV,PA,NY,RI,NH,ME,CT,VT
- HIGH season pretty similar to SEminusFL and LA_AR_MO
- Shift an hour earlier in LOW season; possibly shorter duration fires?

HIGH activity months GOES non-wildfire-filtered-detects for WestShrub

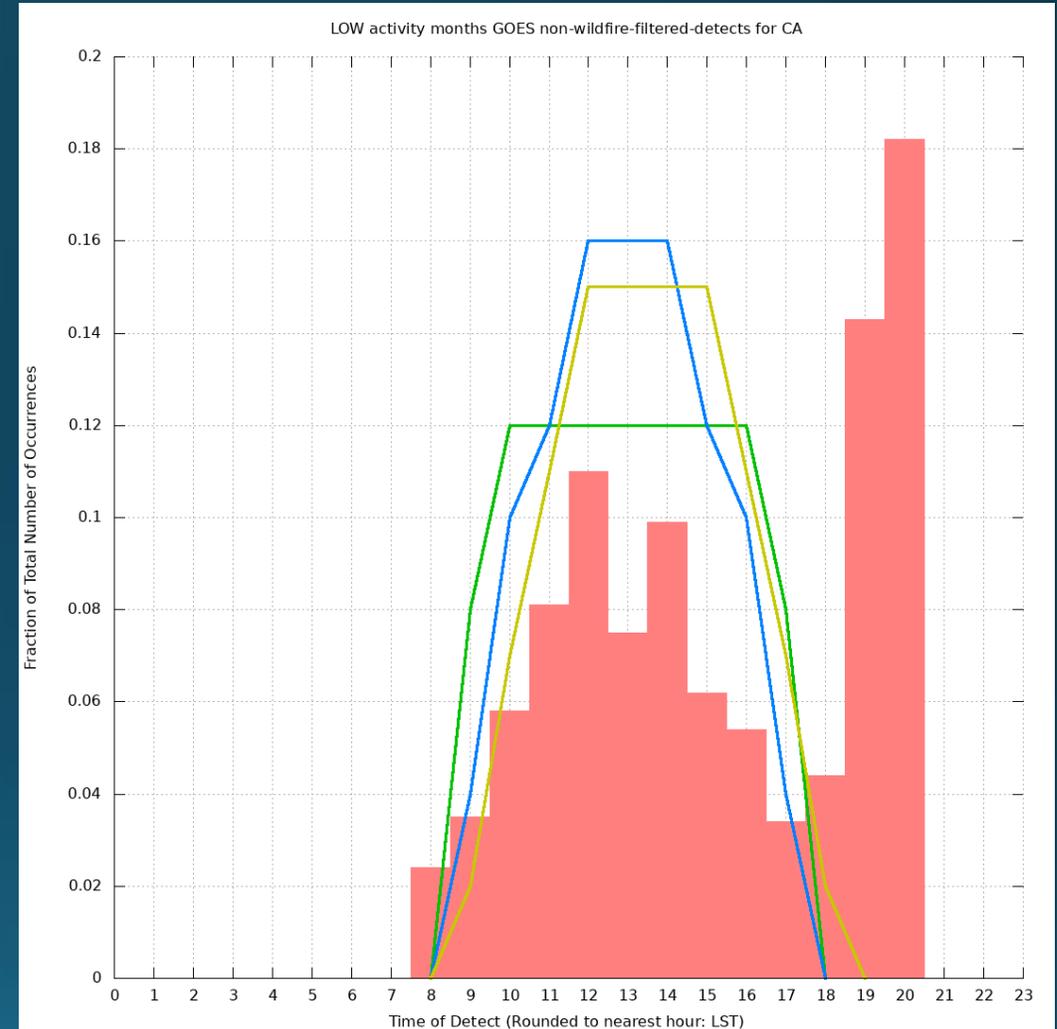LOW activity months GOES non-wildfire-filtered-detects for WestShrub
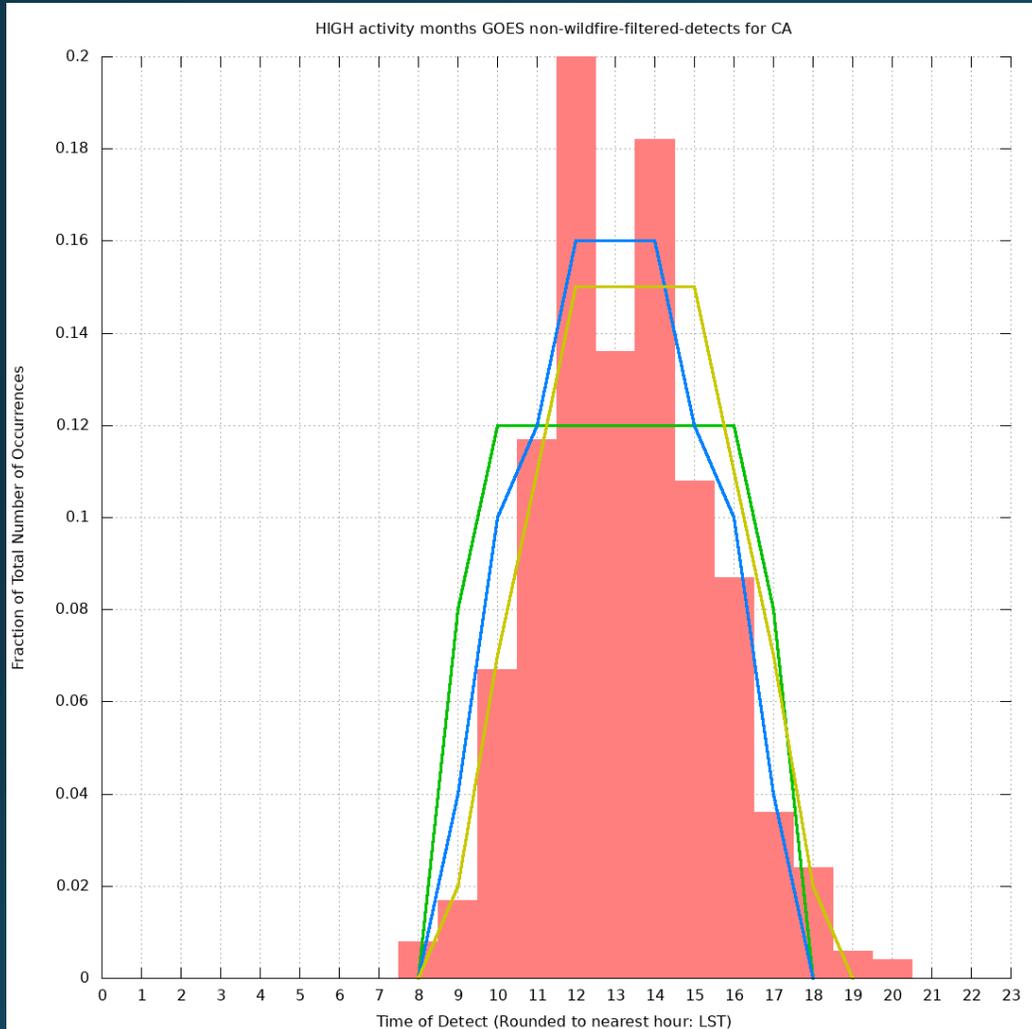
- AZ, NM and NV
- HIGH season pretty similar to FL with earlier start time (9LST)
- LOW season: No hour shift; possible leftover detects that could be wildfires?

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HIGH activity months GOES non-wildfire-filtered-detects for CA

LOW activity months GOES non-wildfire-filtered-detects for CA

- HIGH season pretty similar to FL and WestShrub
- LOW season: same as HIGH; possible leftover detects that could be wildfires?

EXTRA SLIDE FOR FLORIDA AND GEORGE
PERMIT DATABASE ANALYSIS

Georgia 2016 burn permit database: average statistics

Time_period	# of fires	avg_duration	total_acres_burned	% of total burned
May-Oct	18527	8.02	165076	11.62%
Nov-Apr	**53798**	**6.72**	**1255107**	**88.35%**
Nov-Apr fires ranges from 1 to 13000 acres				
Nov-Apr fires ONLY	**# of fires**	**avg_duration**	**total_acres_burned**	**% of total burned**
less than 25 acres	**40237**	**6.75**	**189516**	**15.10%**
between 25-100	**11277**	**6.48**	**557986**	**44.46%**
between 100-500	**2164**	**7.62**	**357709**	**28.50%**
greater than 500	**120**	**7.82**	**149760**	**11.93%**
May-Oct fires ranges from 1 to 1400 acres				
May-Oct fires ONLY	# of fires	avg_duration	total_acres_burned	% of total burned
less than 25 acres	16720	8.11	55176	33.42%
between 25-100	1639	7.20	75984	46.03%
between 100-500	158	7.45	24822	15.04%
greater than 500	10	7.90	9190	5.57%

Georgia has an open burning ban in most of their counties May-Sep

Recent Literature: Use of Satellite Data for Fire Diurnal Profiles
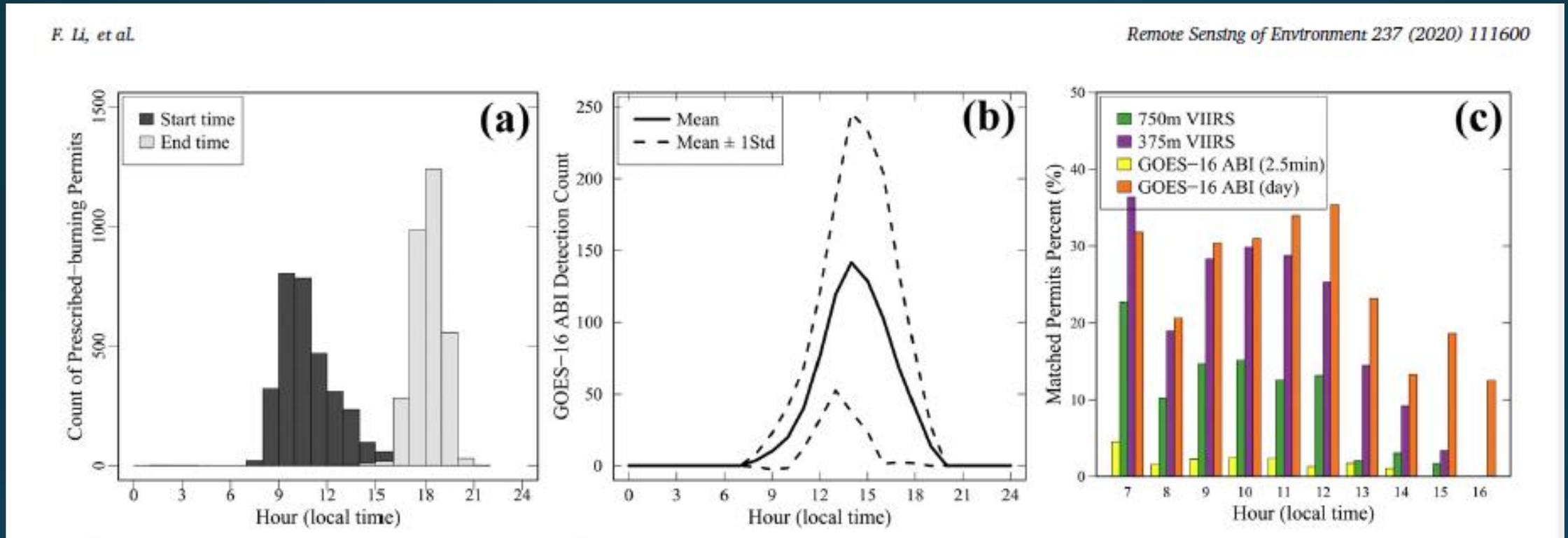
Fig. 11. The satellite active fire detections spatially matched with the prescribed-burning permits in Georgia State during the selected 25 days. (a) The number of geolocated prescribed-burning permits varying with the planned start and end burning times. (b) The diurnal profile of ABI fire detections characterized by hourly mean detection count. (c) The percent of prescribed-burning permits spatially matched with satellite active fire detections, varying with the planed begin burning times. (d), (e), and (f) are the percent of burning permits in five groups stratified by size of area planned to burn, with geolocations in each group, and spatially matched with satellite active fire detections in each group, respectively. Note the terms "2.5 min" and "day" in legend represent GOES-16 ABI fire detections observed within ± 2.5 min of VIIRS overpass time and during all day, respectively.
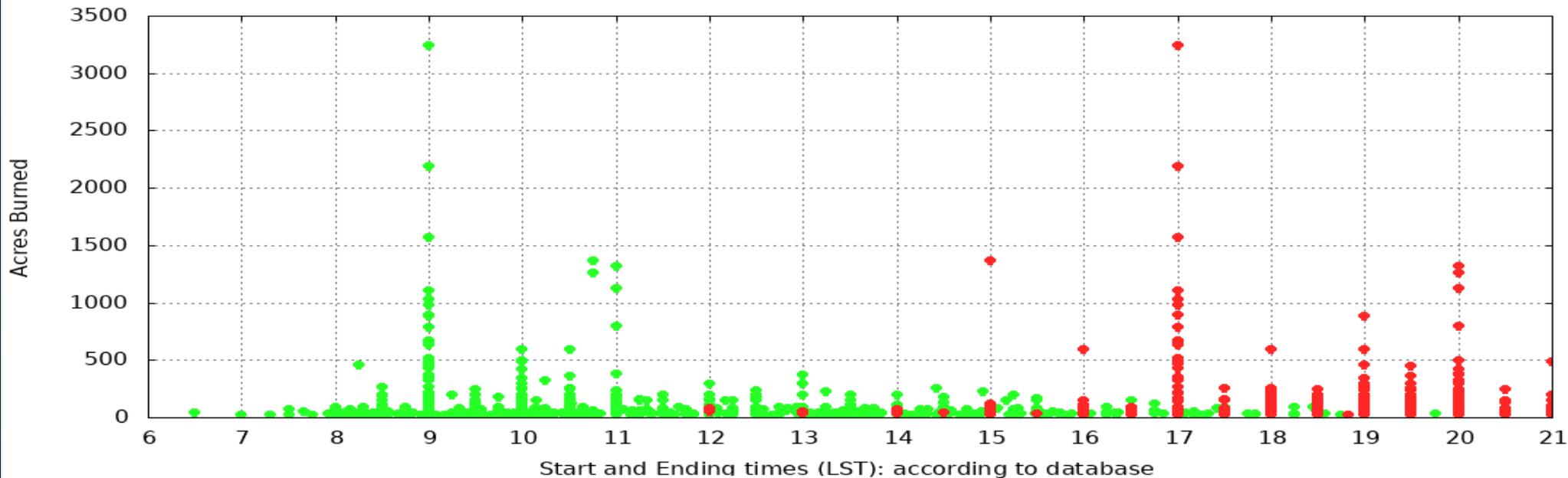
Estimation of biomass-burning emissions by fusing the fire radiative power retrievals from polar-orbiting and geostationary satellites across the conterminous USA
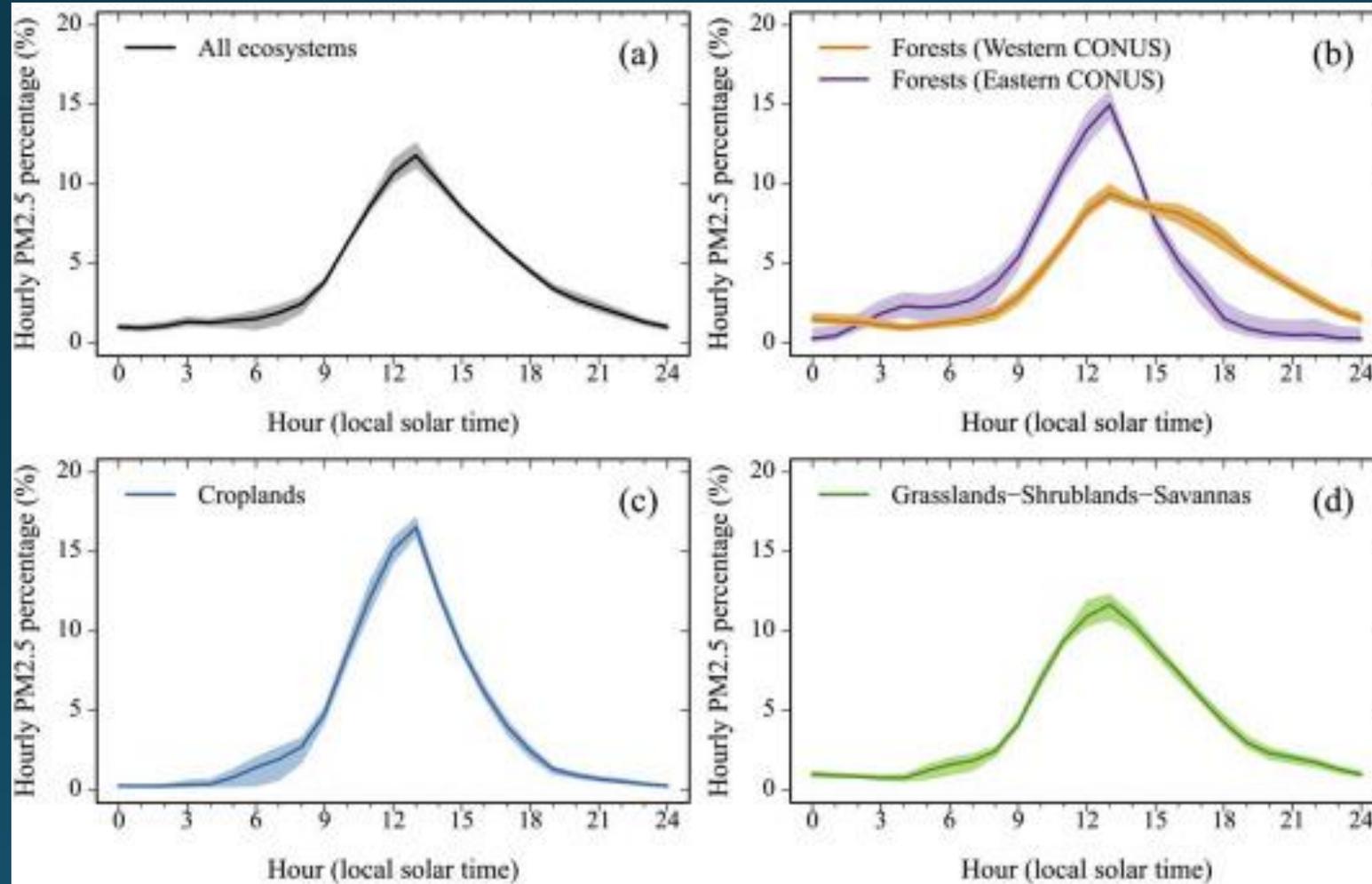
Atmospheric Environment
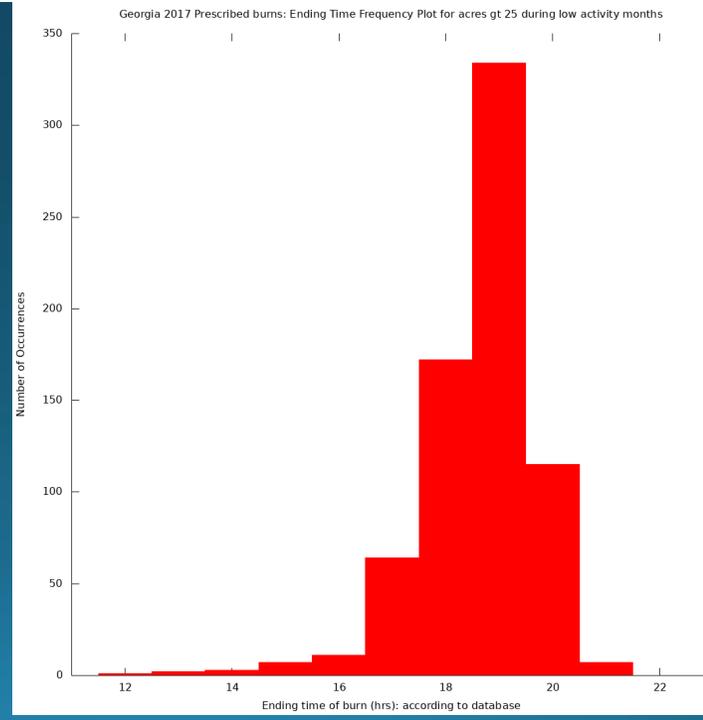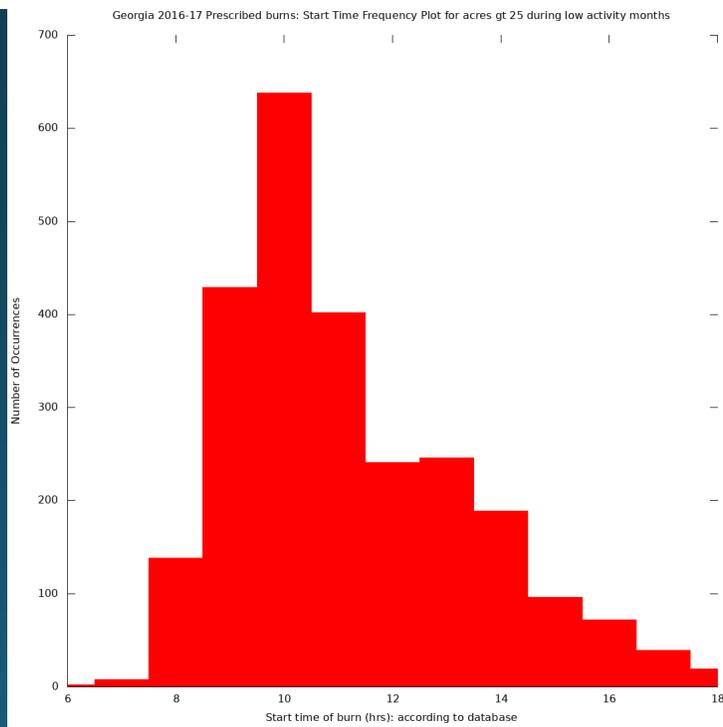Volume 211, 15 August 2019

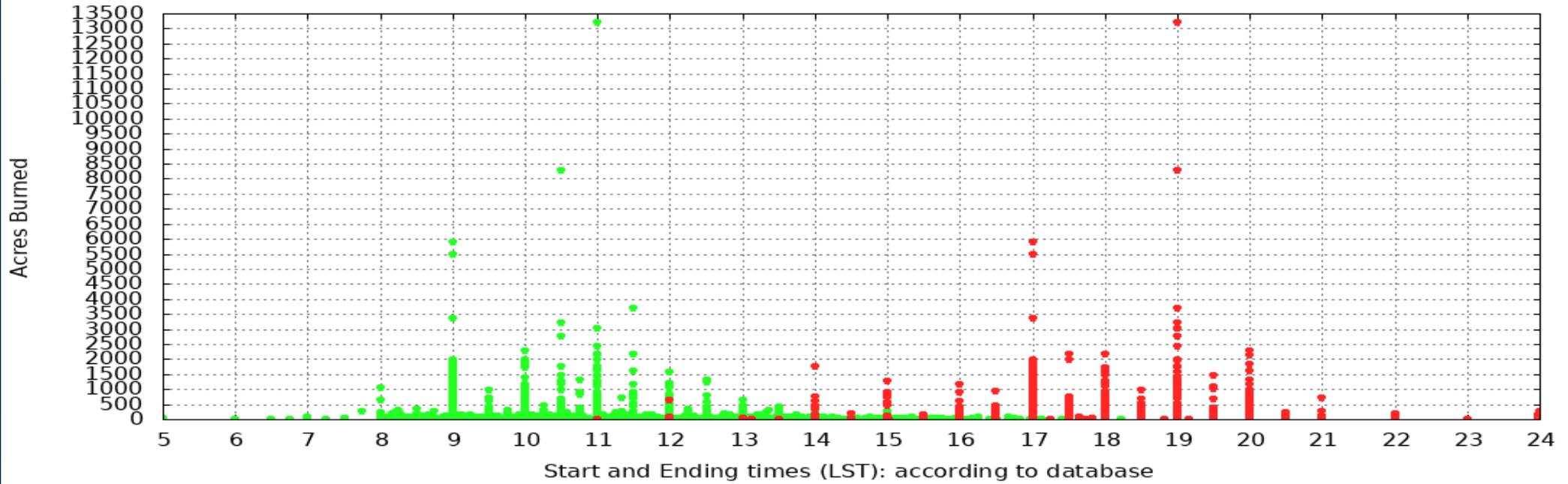Georgia Prescribed burns for low activity months 2016-17

Green= Starting
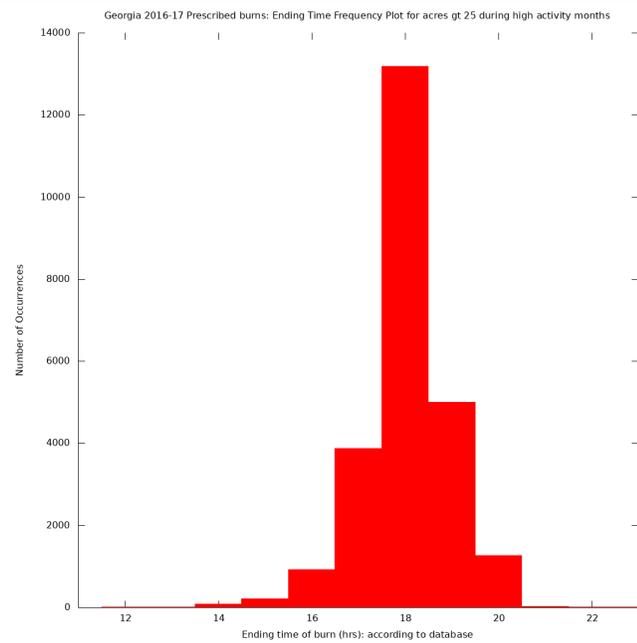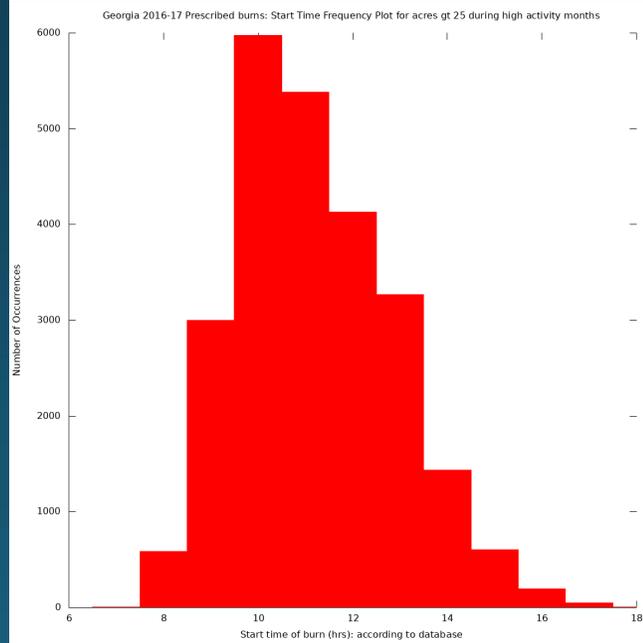**Red= Ending**

Frequency of Starting hour

Frequency of Ending hour

41

Georgia Prescribed burns for high activity months 2016-17
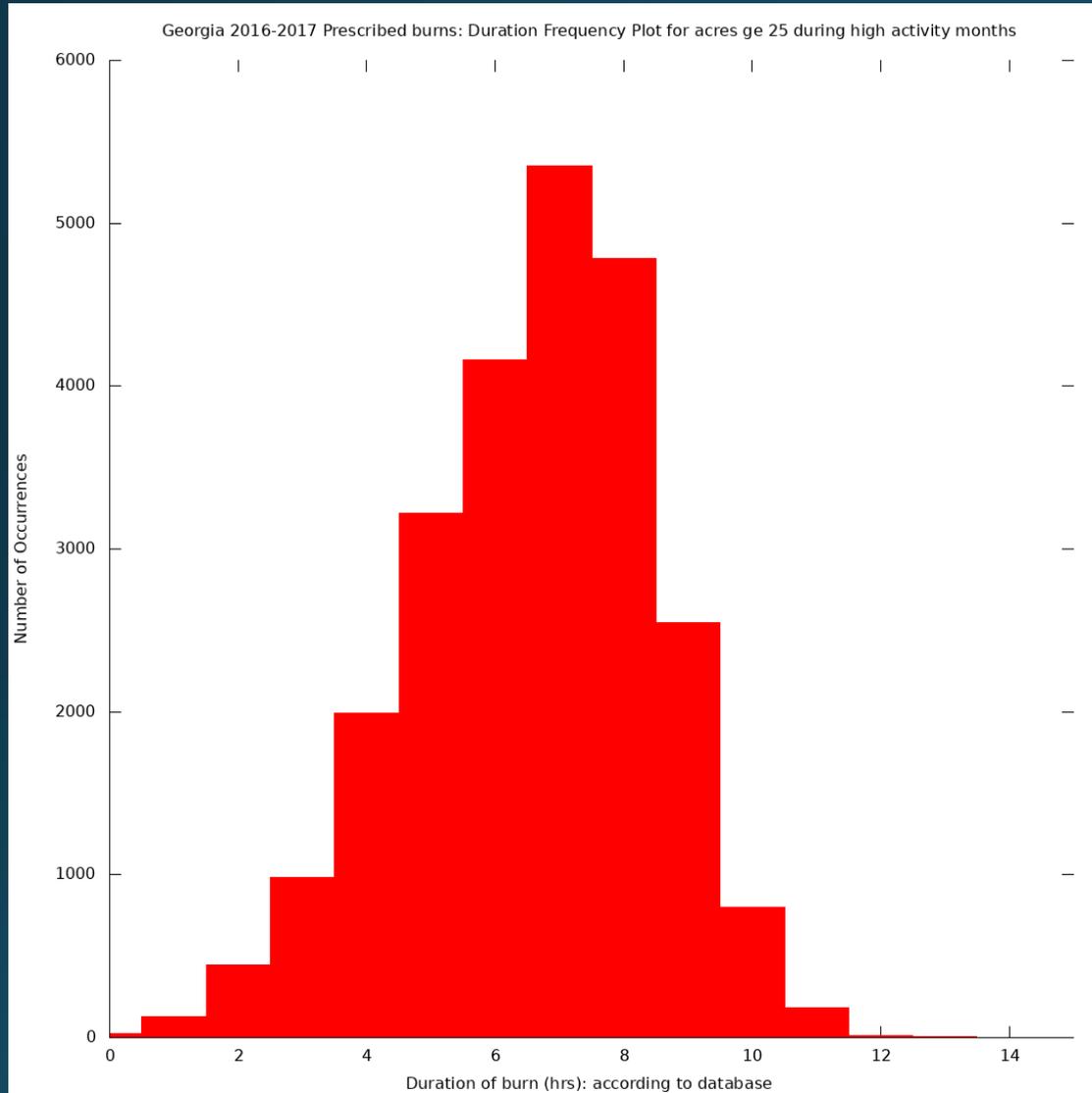
Green= Starting
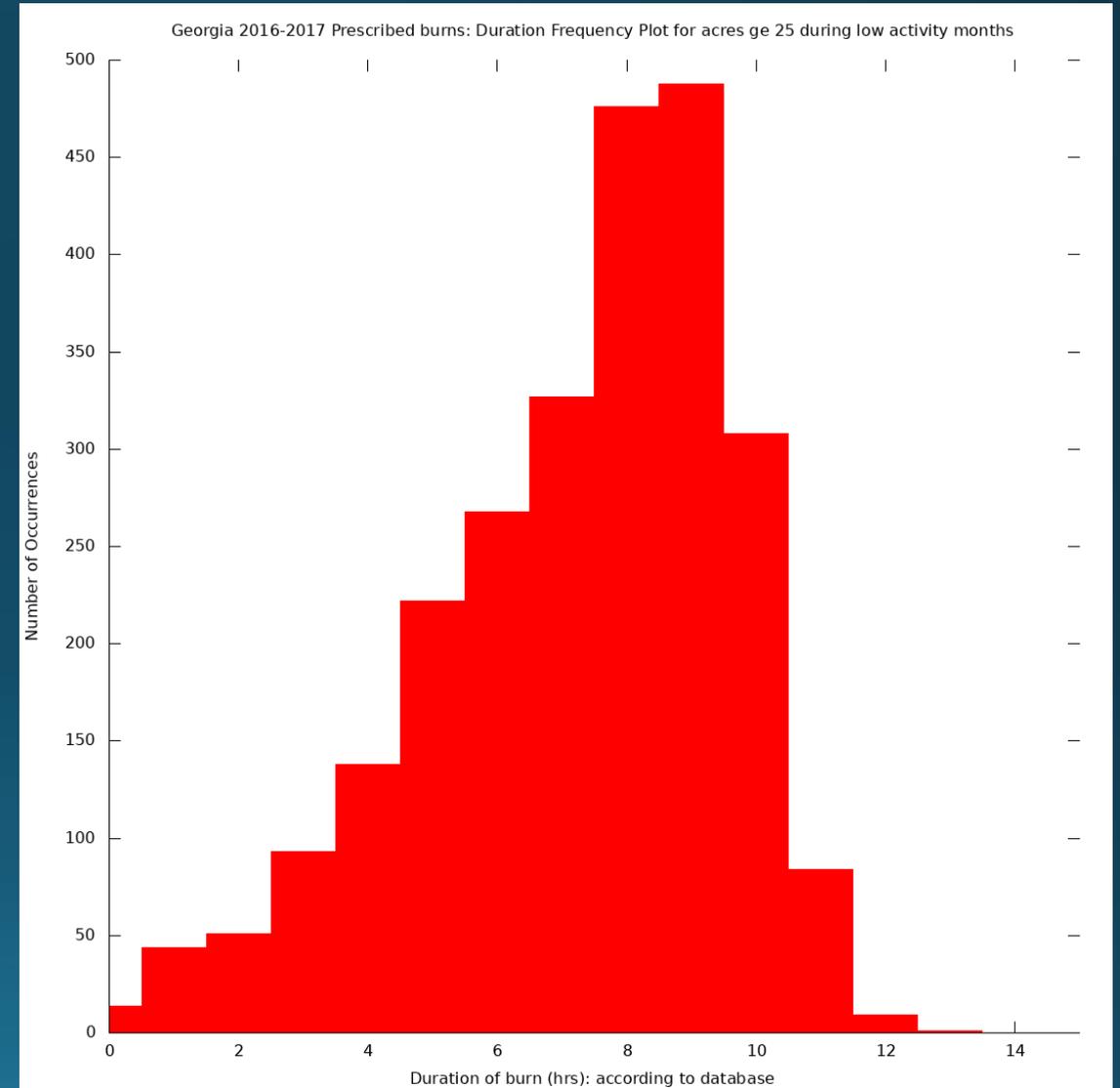Red= Ending

Frequency of Starting hour

Frequency of Ending hour

42

GEORGIA: Frequency of fire durations (hours)
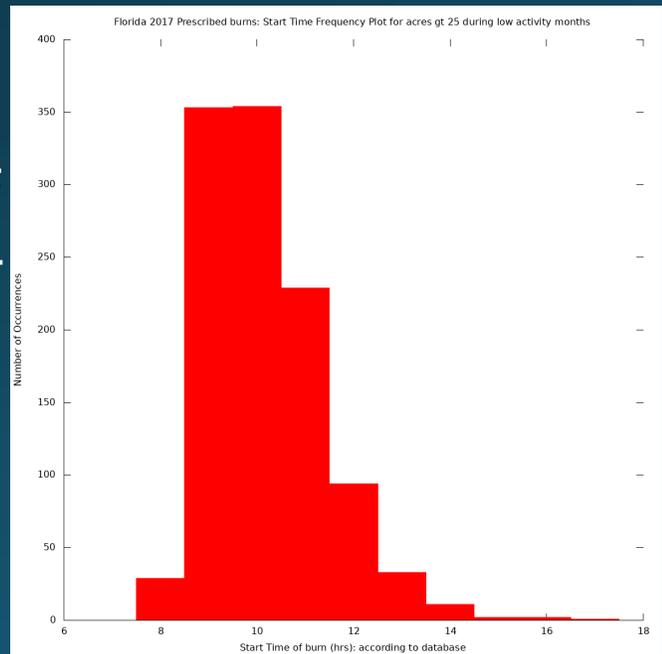High   activity months   Low activity months

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Georgia 2017 burn permit database: average statistics

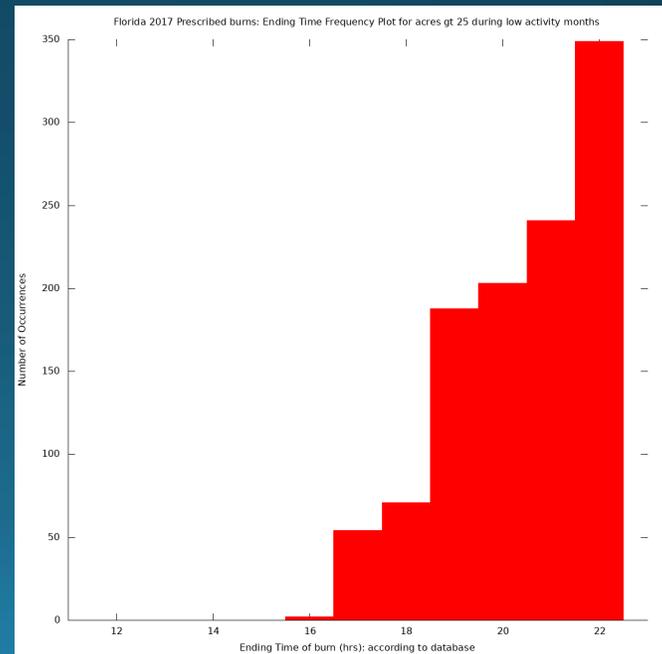| Time_period	# of fires	avg_duration	total_acres_burned	% of total burned
May-Oct	2602	7.62	75978	7.09%
Nov-Apr	**24310**	**6.58**	**995981**	**92.92%**
Nov-Apr fires ranges from 1 to 6000 acres				
Nov-Apr fires ONLY	**# of fires**	**avg_duration**	**total_acres_burned**	**% of total burned**
less than 25 acres	**13221**	**6.22**	**107090**	**10.75%**
between 25-100	**9125**	**6.88**	**451323**	**45.31%**
between 100-500	**1815**	**7.62**	**300383**	**30.16%**
greater than 500	**136**	**7.78**	**130832**	**13.14%**
May-Oct fires ranges from 1 to 3250 acres				
May-Oct fires ONLY	# of fires	avg_duration	total_acres_burned	% of total burned
less than 25 acres	1886	7.40	9883	13.01%
between 25-100	576	8.10	28633	37.69%
between 100-500	123	8.78	20090	26.44%
greater than 500	17	8.12	17394	22.89%
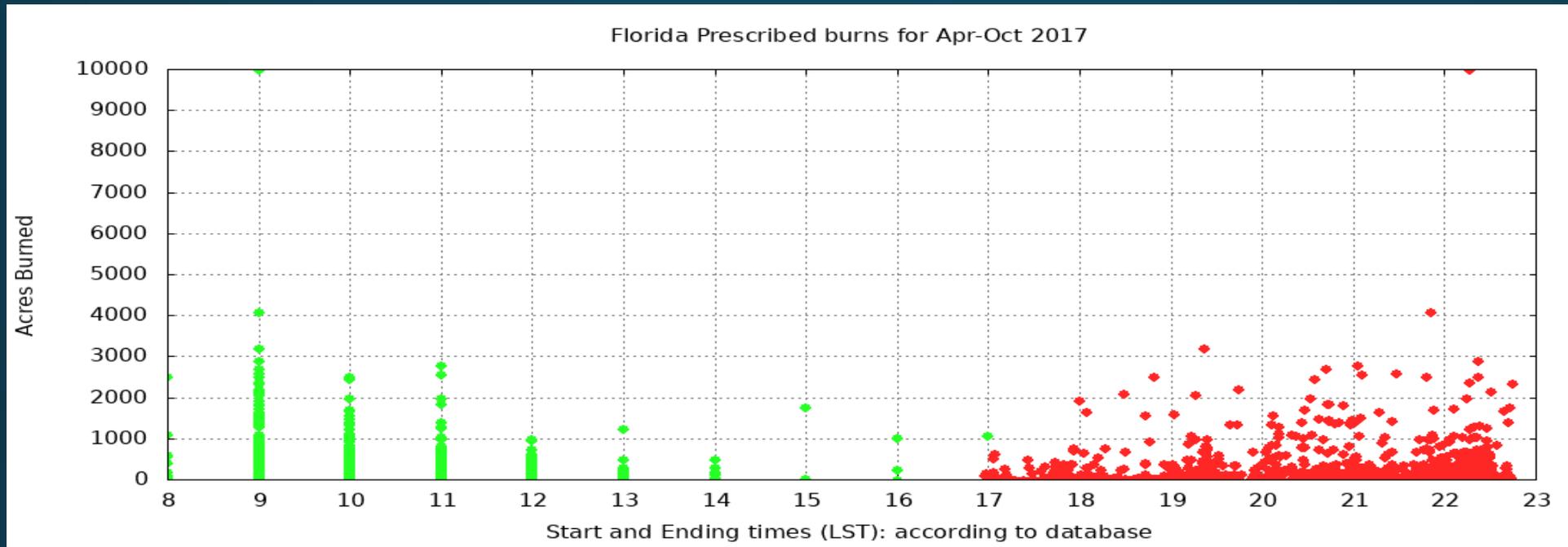
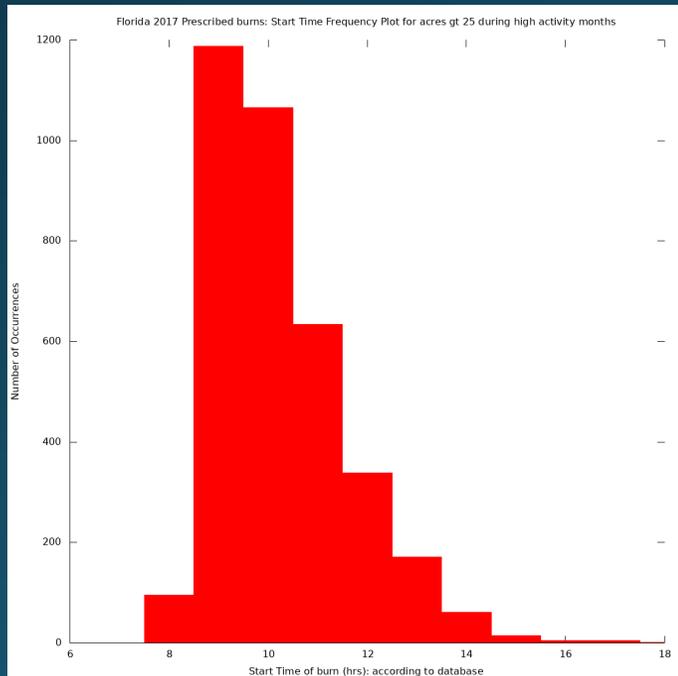Florida Prescribed burns for Apr-Oct 2017
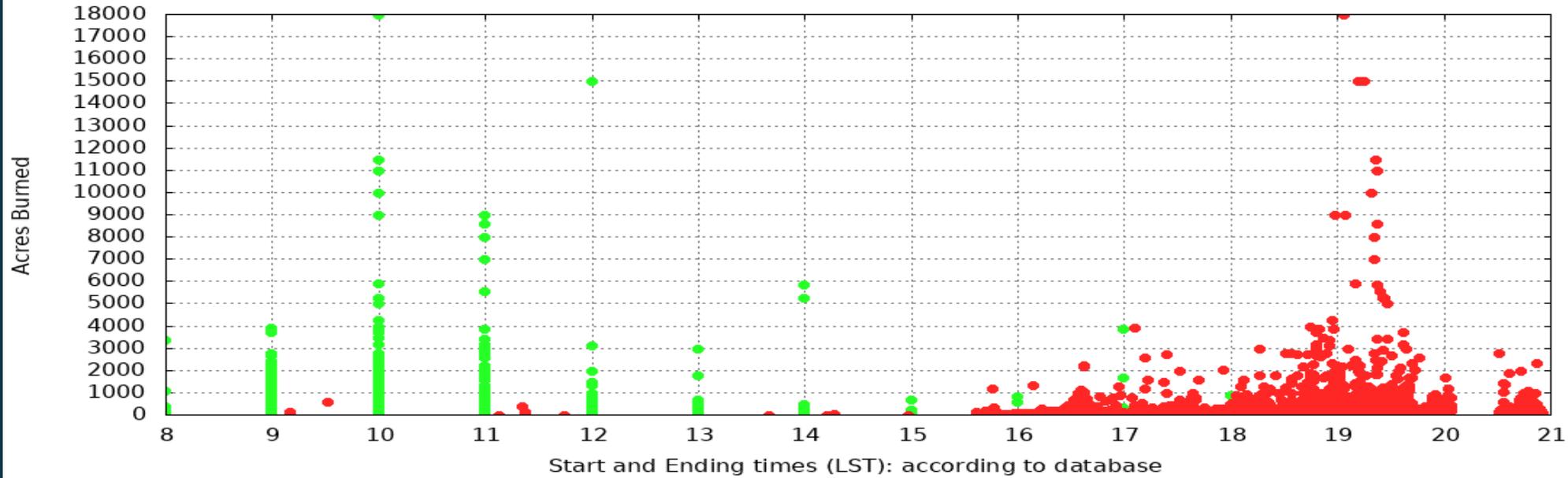
Green=
Starting
Red=
Ending

Frequency of Starting hour

Frequency of Ending hour

45

Florida Prescribed burns for Jan-Mar, Nov and Dec 2017

Green=
Starting
Red=
Ending

Frequency of Starting hour
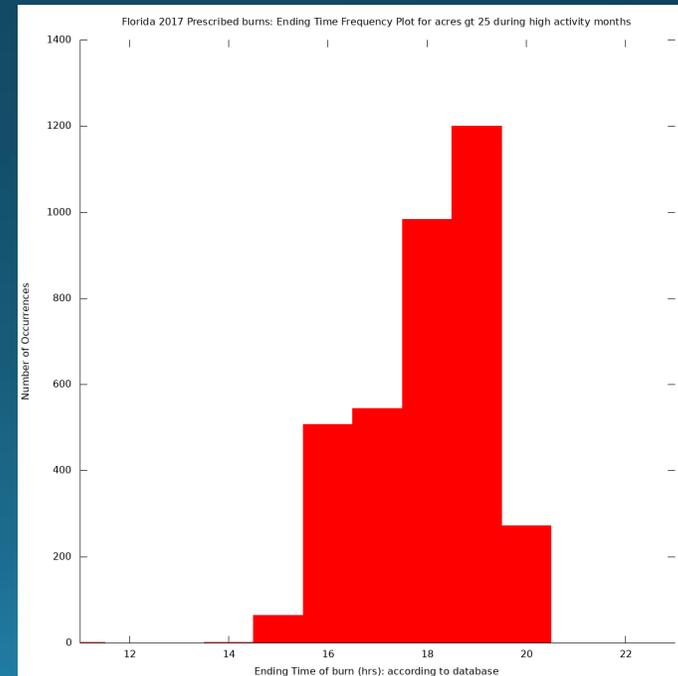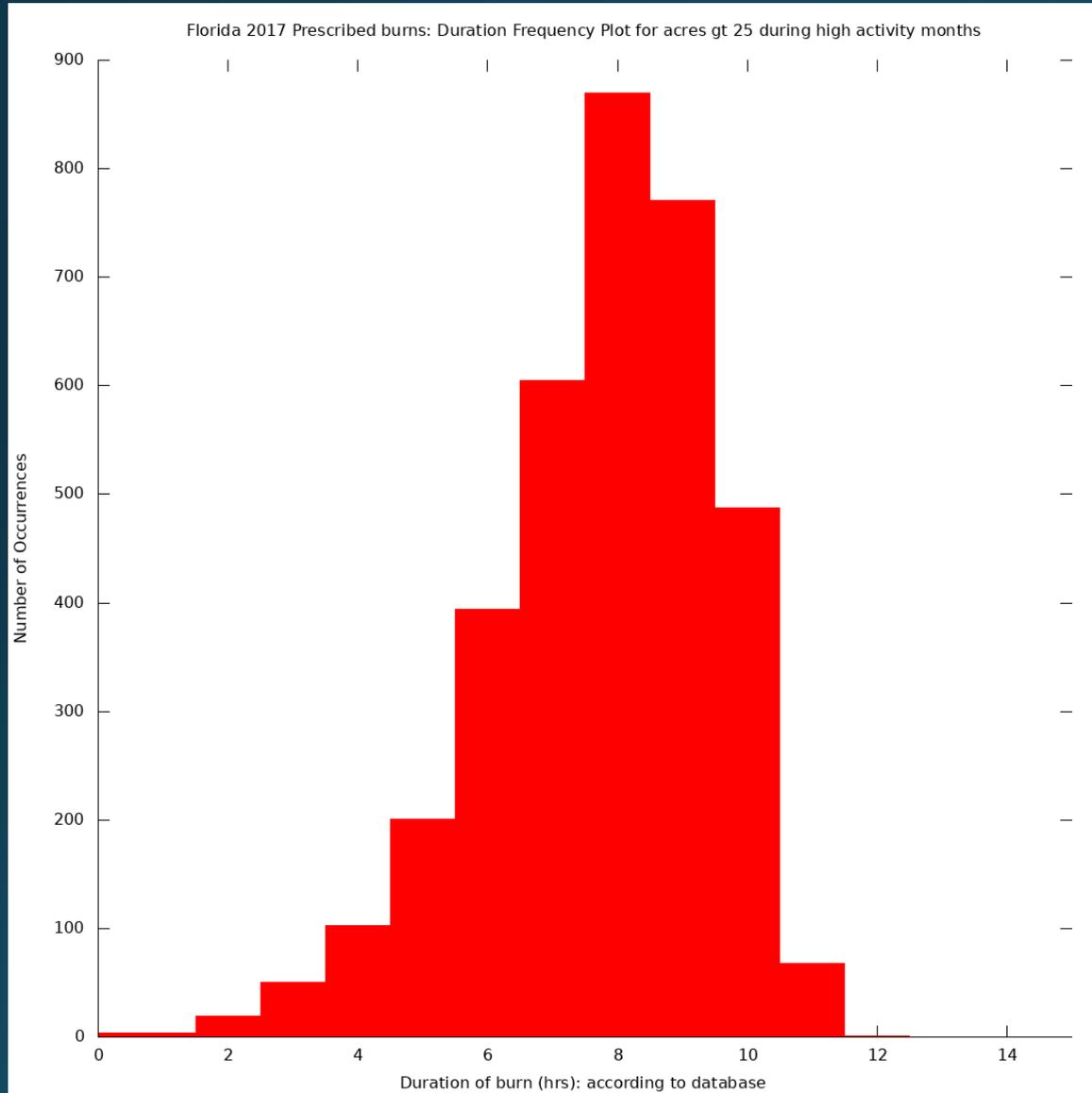
Frequency of Ending hour

46

Florida 2017 burn permit database: average statistics

Time_period	# of fires	duration_avg	total_acres_burned	% of total burned
Nov-Mar	5060	8.00	1,001,880	74.6%
Apr-Oct	1426	10.30	340,814	25.4%
Nov-March fires ranges from 1 to 18000 acres				
Nov-March fires ONLY	# of fires	duration_avg	total_acres_burned	% of total burned
less than 10 acres	936	7.20	4,680	0.5%
less than 25 acres	1603	7.40	17,633	1.8%
between 25-100	1896	8.03	113,760	11.4%
between 100-500	1203	8.66	276,690	27.6%
greater than 500	358	8.76	595,712	59.5%
Apr-Oct fires ranges from 1 to 10000 acres				
Apr-Oct fires ONLY	# of fires	duration_avg	total_acres_burned	% of total burned
less than 10 acres	223	9.13	1,115	0.3%
less than 25 acres	338	9.30	3,380	1.0%
between 25-100	473	10.55	27,434	8.0%
between 100-500	449	10.70	111,801	32.8%
greater than 500	166	10.95	198,702	58.3%

FLORIDA: Frequency of fire durations (hours)

High activity months

Low activity months

Florida 2017 Prescribed burns: Duration Frequency Plot for acres gt 25 during high activity months

Florida 2017 Prescribed burns: Duration Frequency Plot for acres gt 25 during low activity months
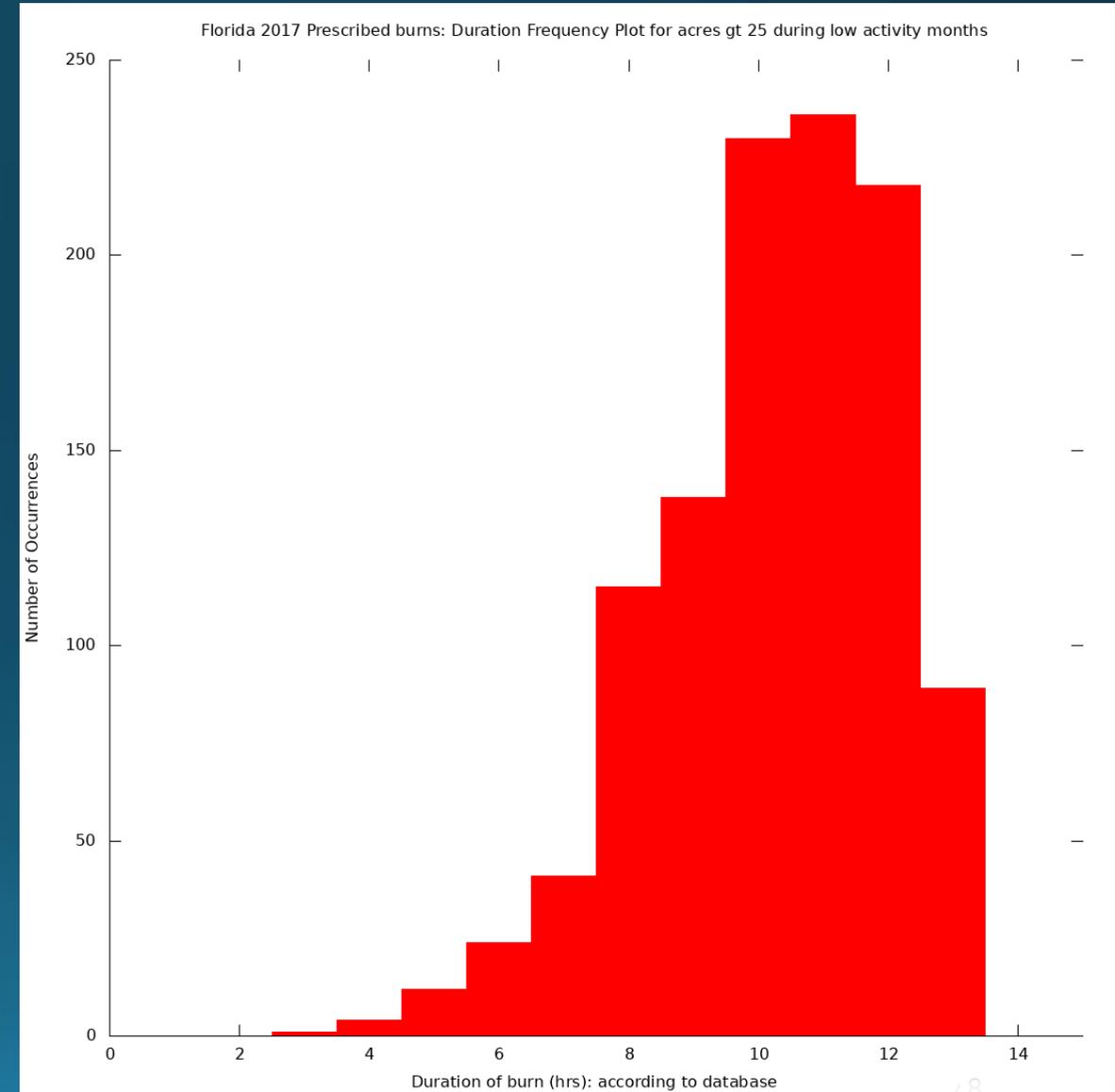
Default fire type assignment by state and month in cases where a satellite detect is only source of fire information

Default Fire Type Assignment

WF Months
- 4,5,6,7
- 5,6,7,8
- 5,6,7,8,9,10
- 6,7,8
- None