# INTERACTIONS OF BIOSPHERE AND ATMOSPHERE WITHIN LONGLEAF PINE RESTORATION AREAS

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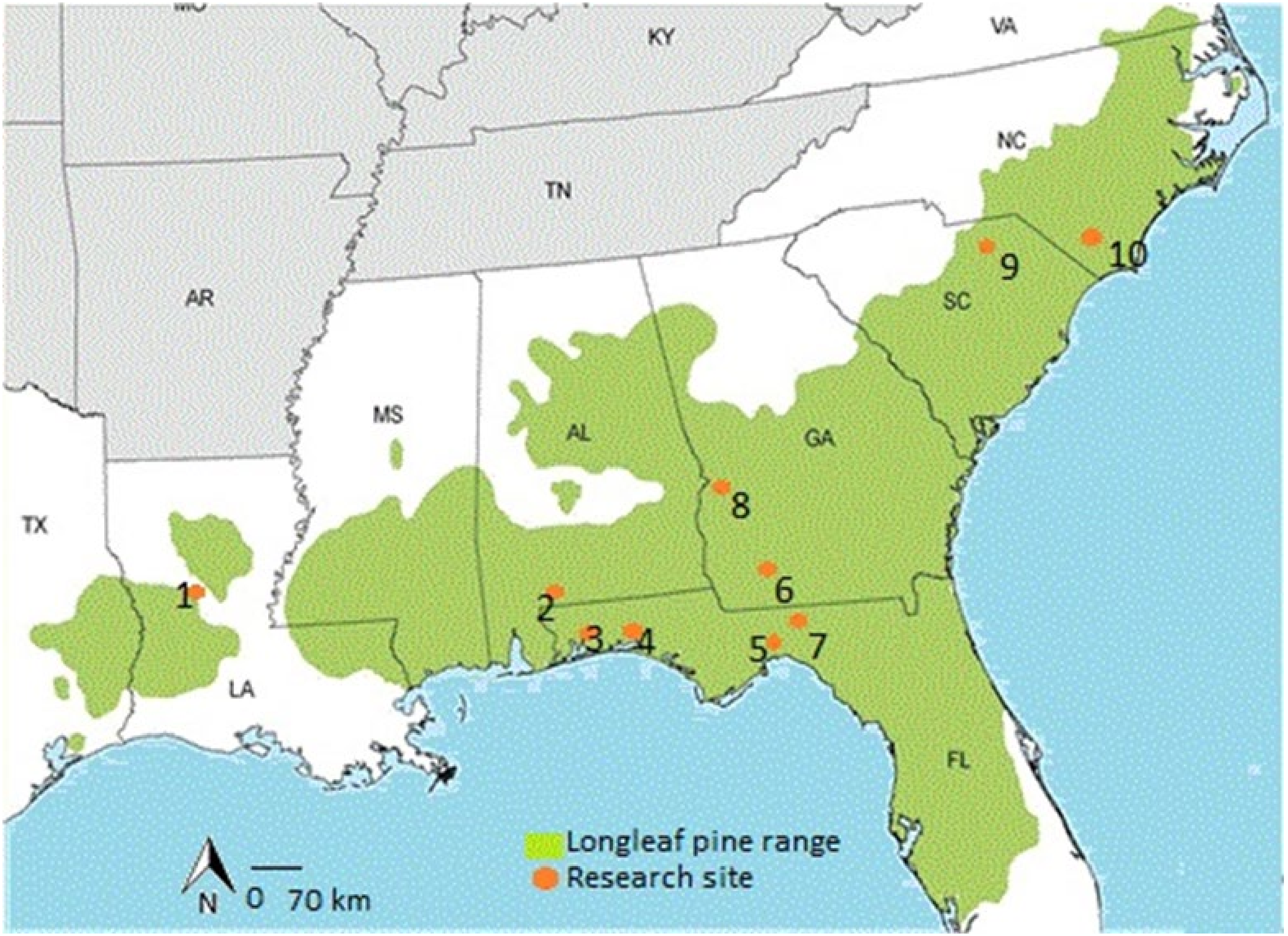
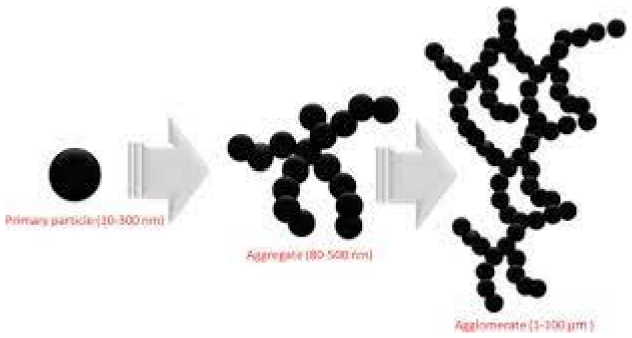
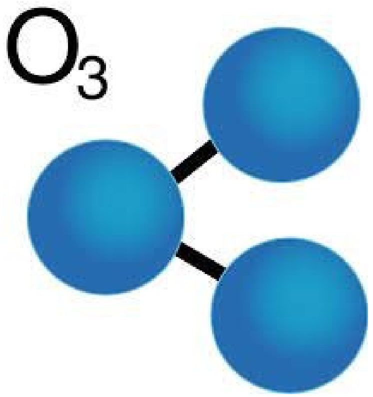
This forest ecosystem is listed as a critically endangered ecosystem


MO
KY
VA
NC
TN
AR
SC
MS
AL
GA
TX
LA
FL
1
2
3
4
5
6
7
8
9
10
Longleaf pine range
Research site
N
0 70 km

- Forests and the atmosphere exchange energy, matter, and momentum, because forests affect fluxes in carbon dioxide ($CO_2$), water, and latent or sensible heat.
- Black carbon has a warming impact on climate which is 460–1500 times stronger than $CO_2$ per unit of mass.
- Elevated atmospheric $CO_2$ and $O_3$ affect plant photosynthesis and growth to varying degrees , and may modify community species composition and soil ecological processes .
- The depletion of ozone in springtime is found to cause surface temperature and precipitation anomalies



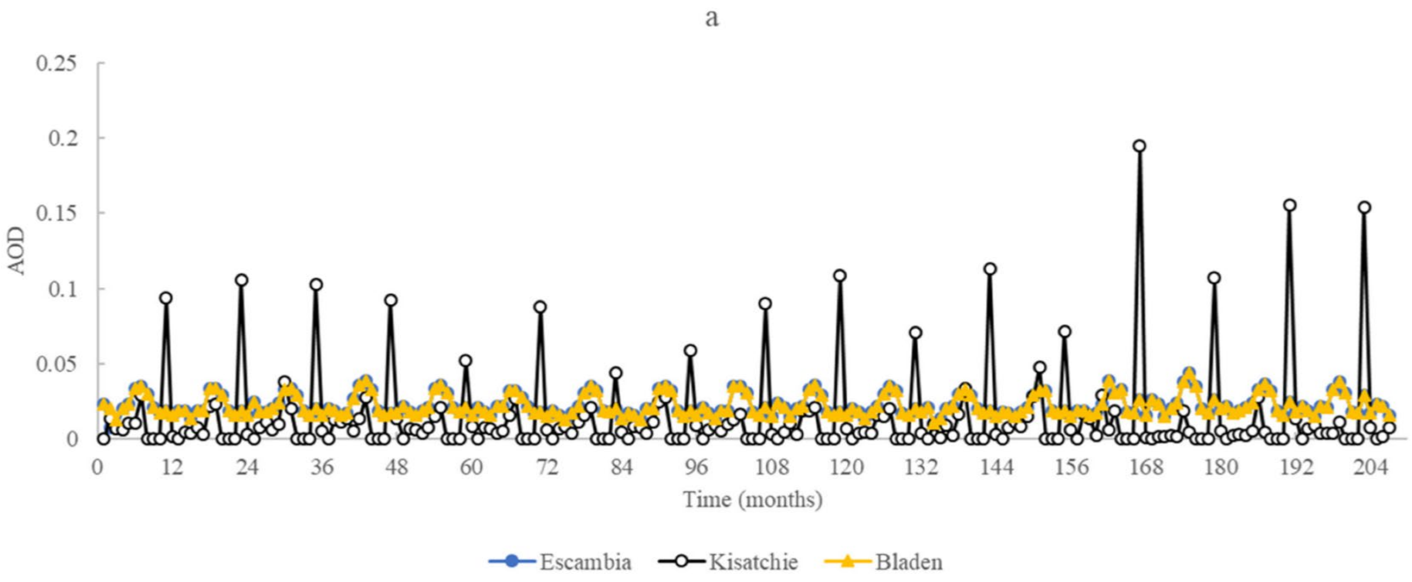
# Methods

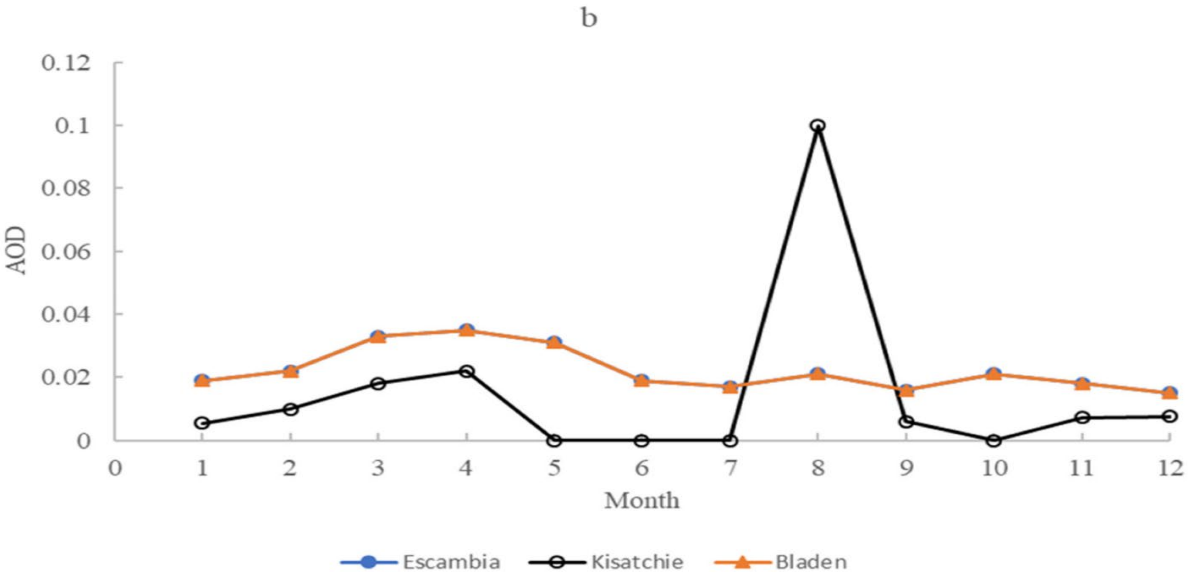
- The Moderate-resolution imaging spectroradiometer (MODIS) data can provide day-scale information on Earth's surface and atmosphere with a spatial resolution of 0.5–1.0 km. In this study, some parameters related to aerosols and gases were retrieved from MODIS data. These data have been broadly tested with ground monitoring data.

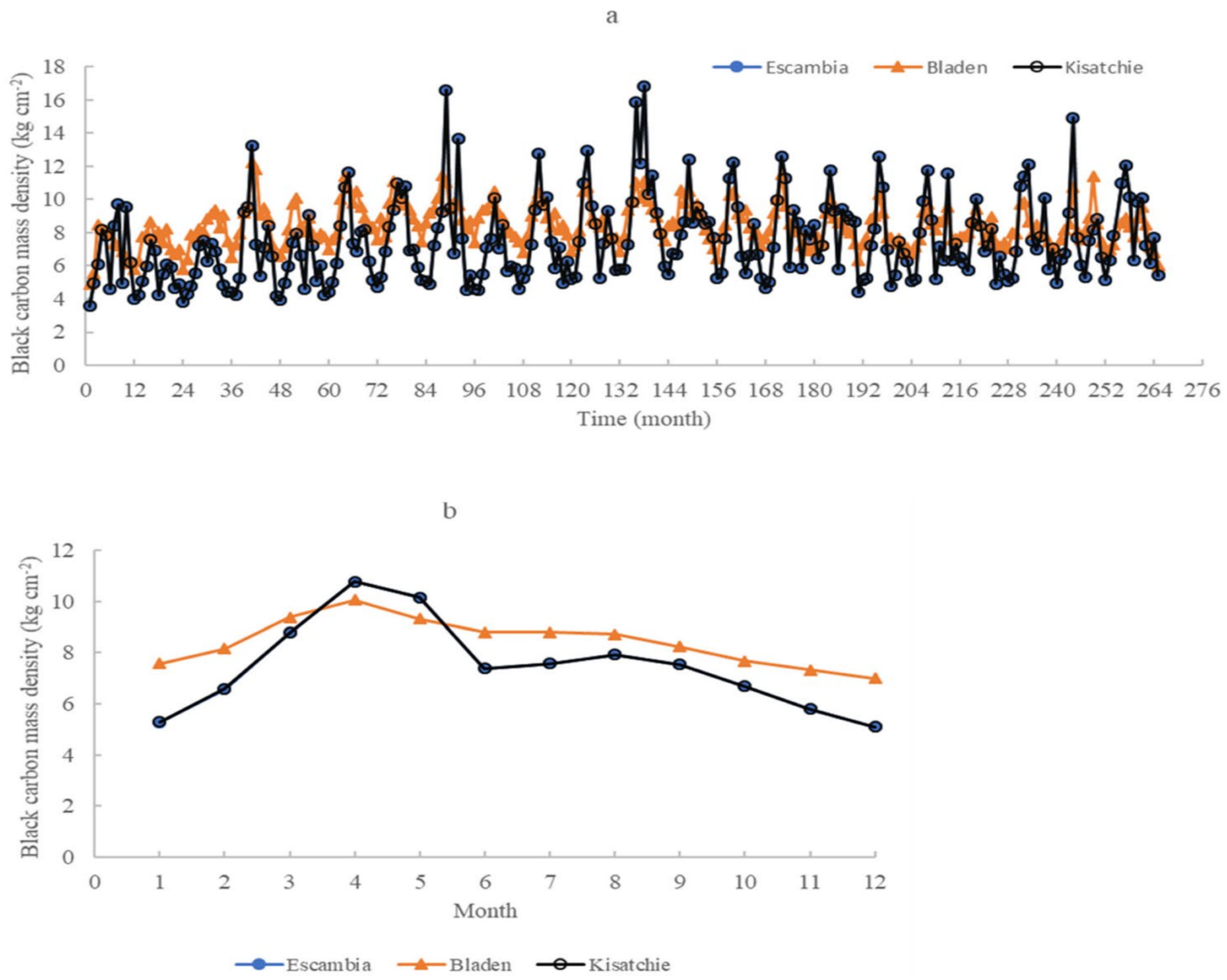
- All data in this study were downloaded from multiple satellites and derived from products at NASA EarthData (**https://www.earthdata.nasa.gov/** )

| Indices | Unit | Time | Scale |
|---|---|---|---|
| Aerosol optical depth | unitless | October 2004–December 2021 | Daily, 0.25° |
| Single scattering albedo | $m\ m^{-1}$ | October 2004–December 2021 | Daily, 0.25° |
| Black carbon column mass density | $kg\ cm^{-2}$ | January 2000–December 2021 | Monthly, 0.5° × 0.625° |
| Dust column mass density | $kg\ cm^{-2}$ | January 2000–December 2021 | Monthly, 0.5° × 0.625° |
| Total column ozone | DU | October 2004–December 2021 | Daily, 0.25° |
| CO mole fraction in the air | ppbv | September 2002–September 2016 | Daily, 1° |
| $SO_2$ column mass density | $kg\ cm^{-2}$ | January 2000–December 2021 | Monthly, 0.5° × 0.625° |
| Albedo | $W\ W^{-1}$ | January 2000–December 2021 | Daily, 0.25° |
| Total cloud area fraction | $m^2\ m^{-2}$ | January 2000–December 2021 | Monthly, 0.5° × 0.625° |
| Sensible heat net flux | $W\ m^{-2}$ | January 2000–December 2014 | Monthly, 0.25° |
| Latent heat net flux | $W\ m^{-2}$ | January 2000–December 2014 | Monthly, 0.25° |
| Bowen ratio | $W\ W^{-1}$ | January 2000–December 2014 | Monthly, 0.25° |
| Net shortwave of surface | $W\ m^{-2}$ | January 2000–December 2021 | Monthly, 0.25° |
| Net longwave of surface | $W\ m^{-2}$ | January 2000–December 2021 | Monthly, 0.25° |

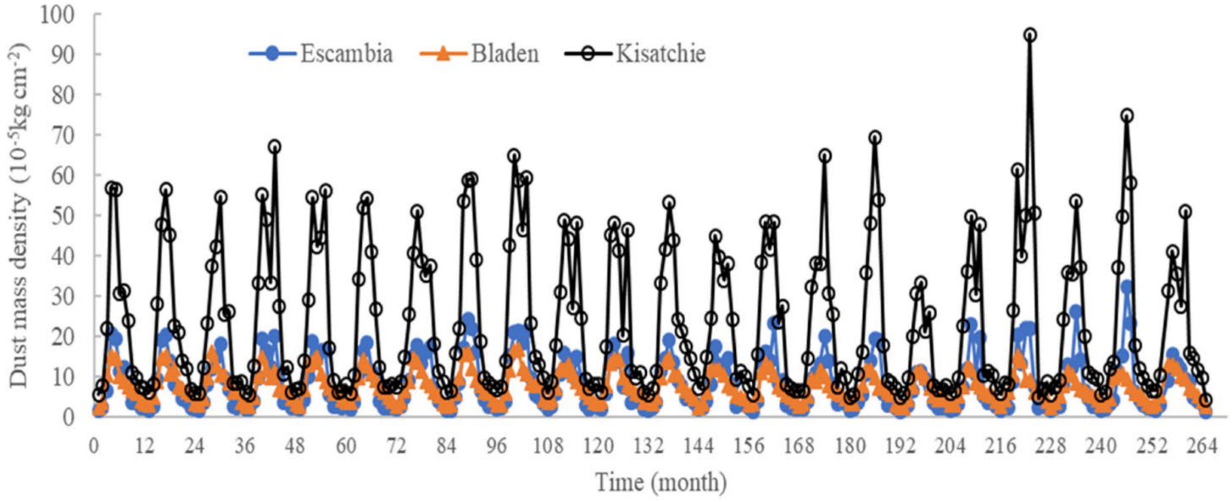
# Results


a
0.25
0.2
0.15
0.1
0.05
0
AOD
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204
Time (months)
Escambia
Kisatchie
Bladen


b
0.12
0.1
0.08
0.06
0.04
0.02
0
AOD
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
Escambia
Kisatchie
Bladen

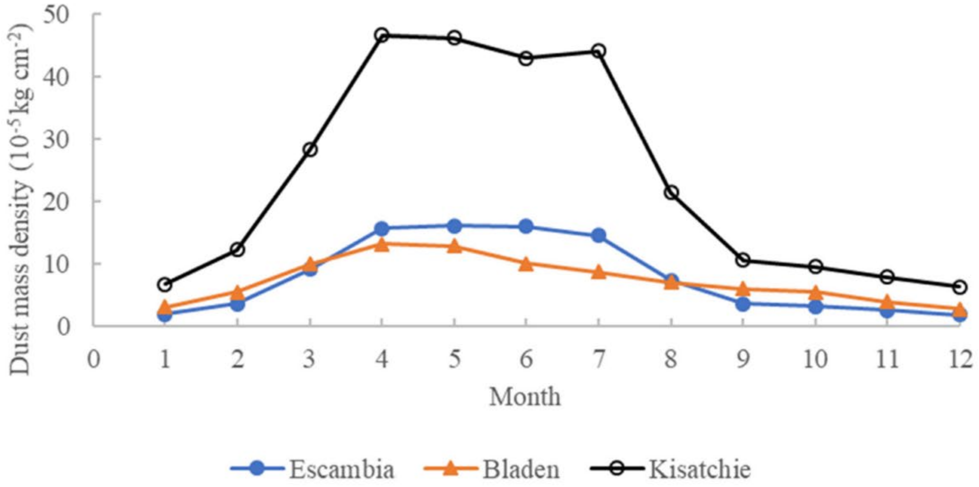

a
Escambia
Bladen
Kisatchie
Black carbon mass density (kg cm-2)
Time (month)
b
Black carbon mass density (kg cm-2)
Month
Escambia
Bladen
Kisatchie

a

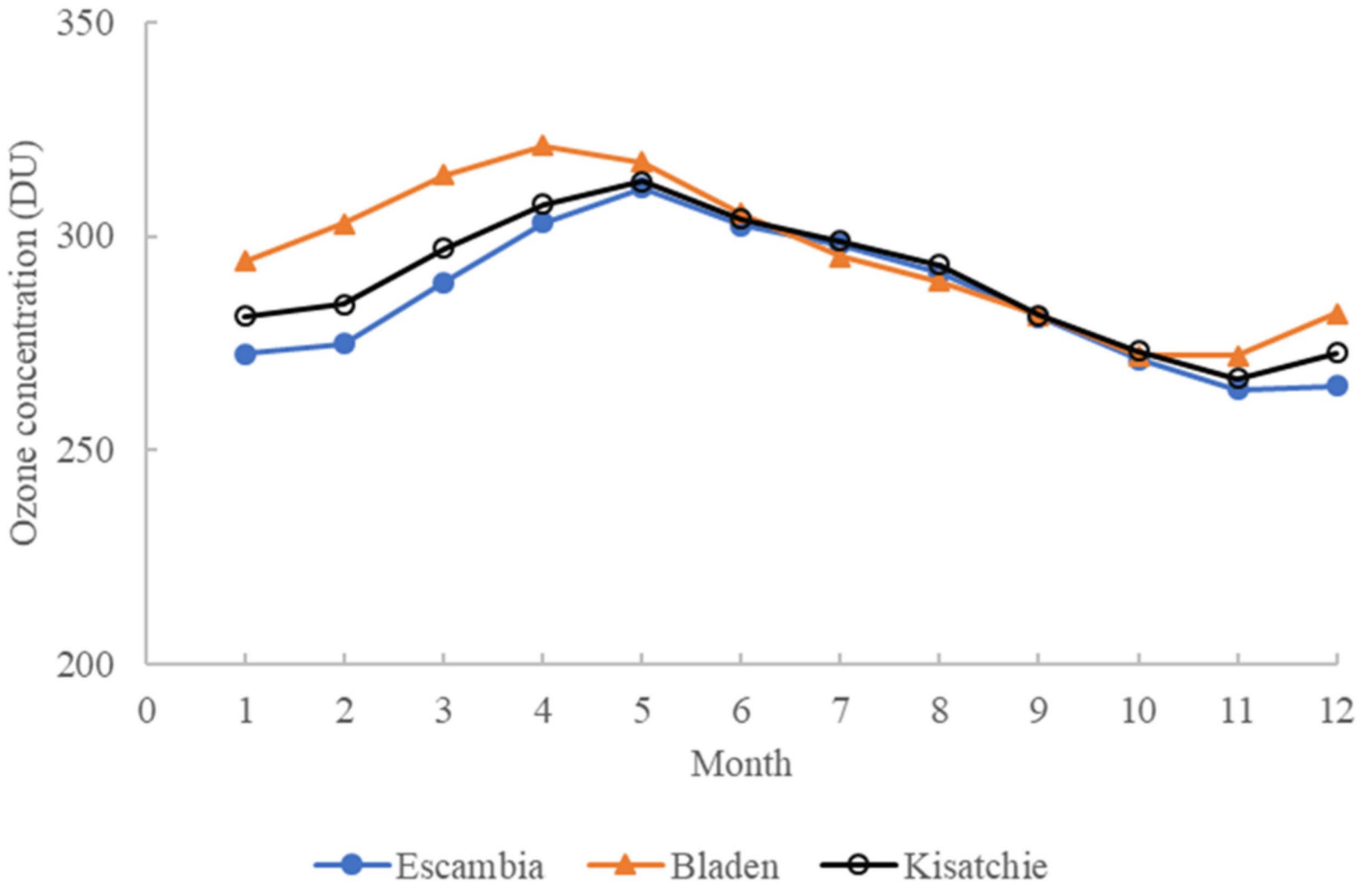


Escambia
Bladen
Kisatchie
Dust mass density ($10^{-5}$kg cm$^{-2}$)
Time (month)

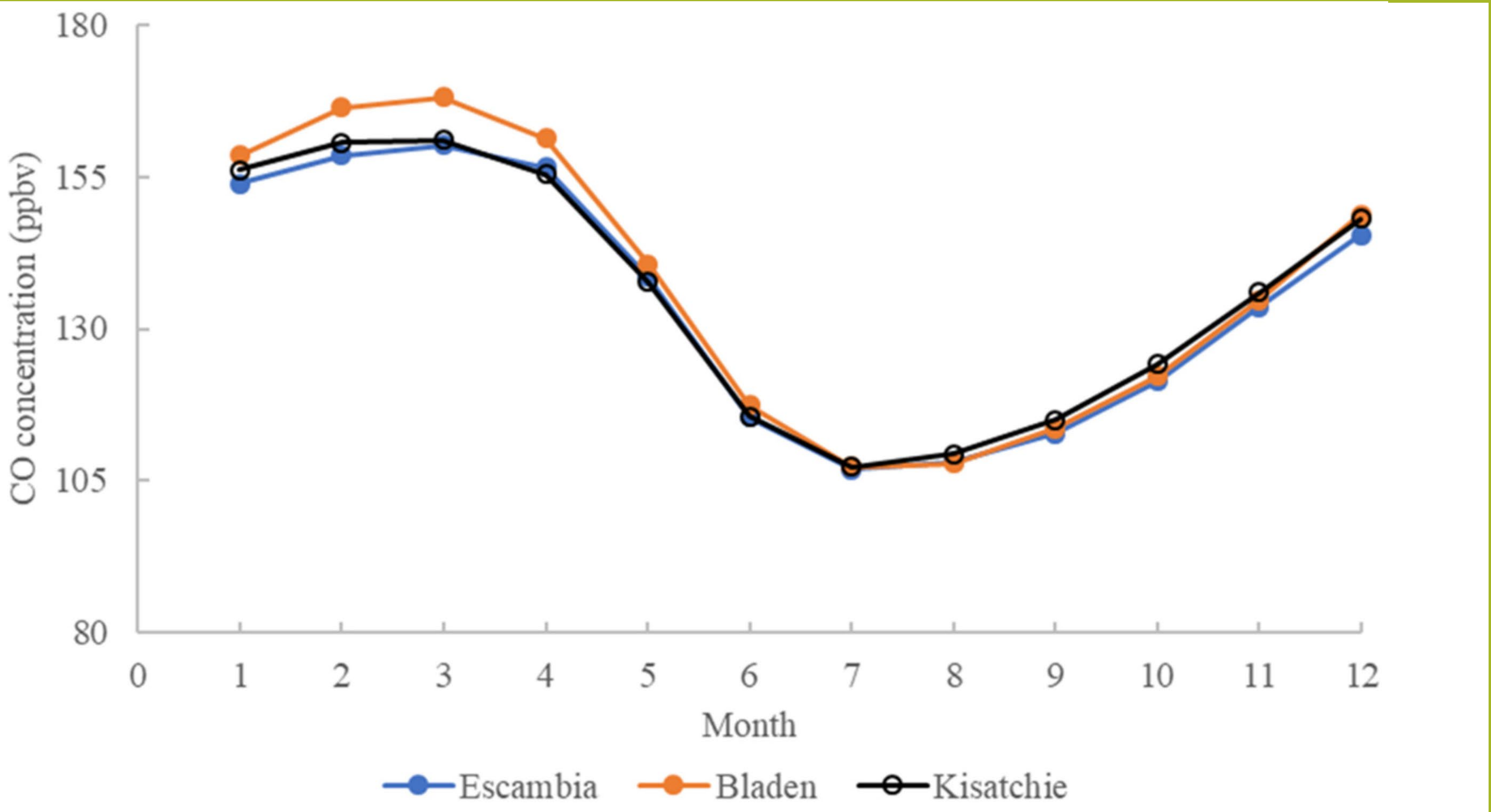

b



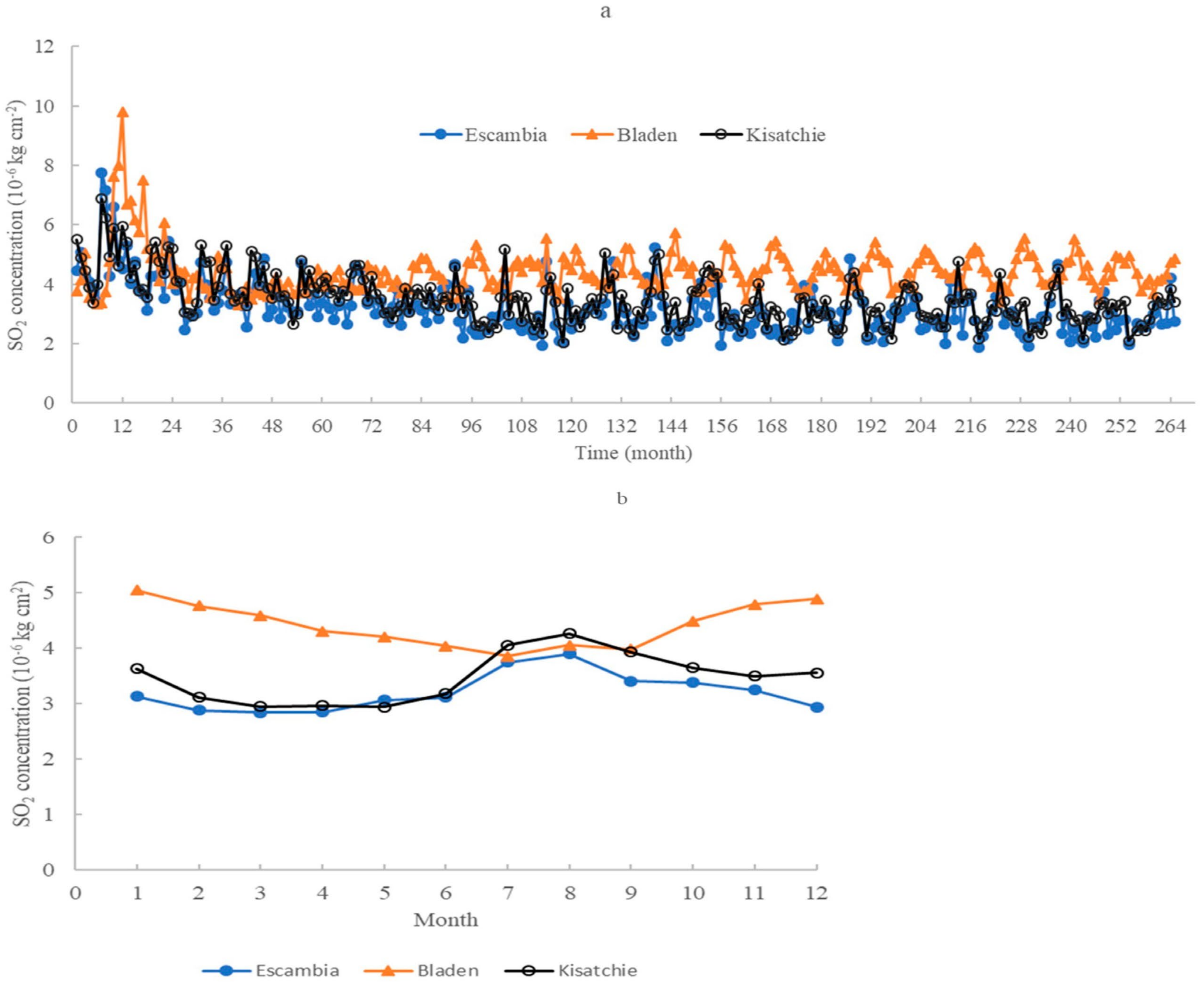
Dust mass density ($10^{-5}$kg cm$^{-2}$)
Month
Escambia
Bladen
Kisatchie



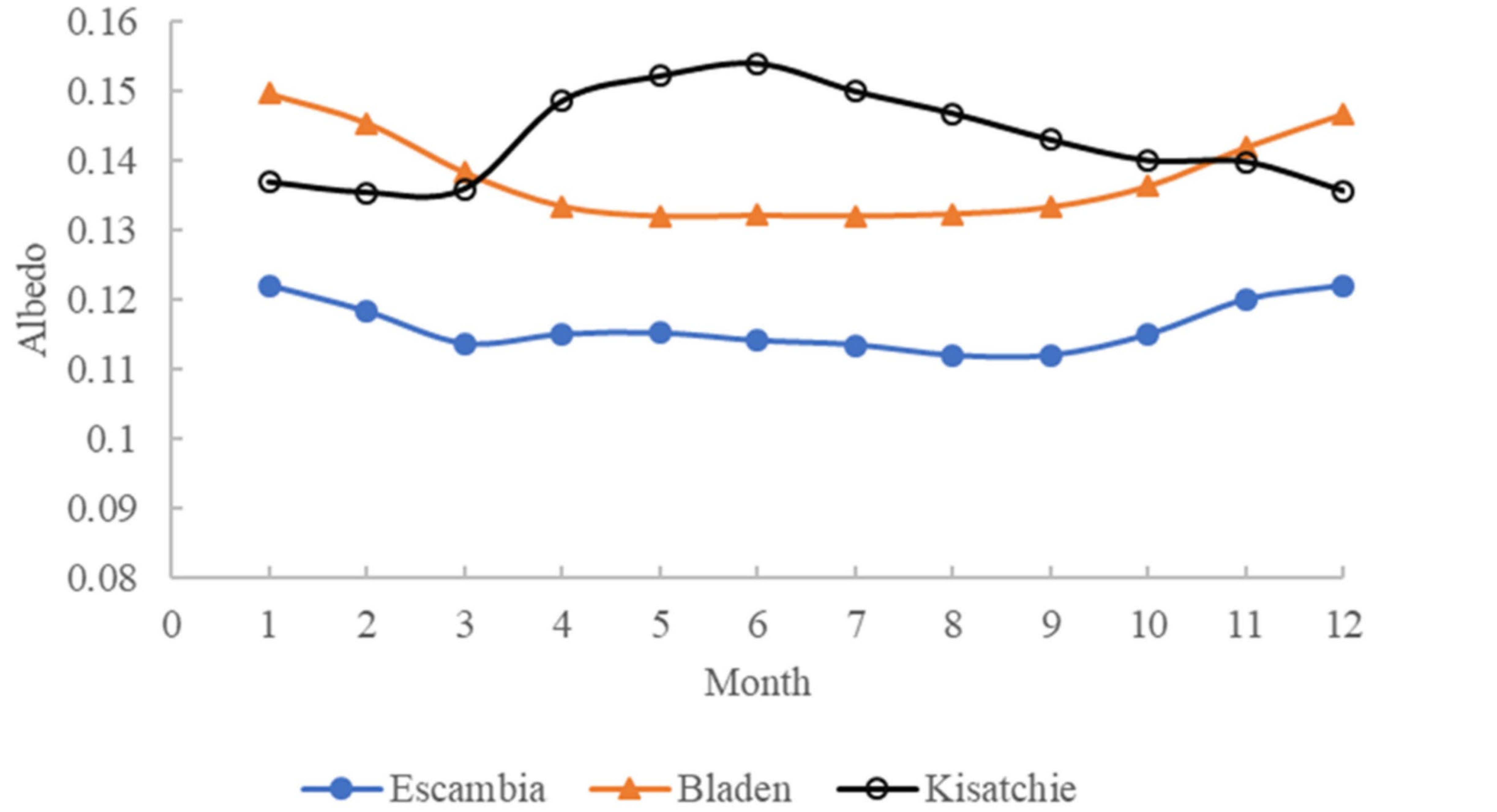
350
300
250
200
Ozone concentration (DU)
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Escambia
Bladen
Kisatchie

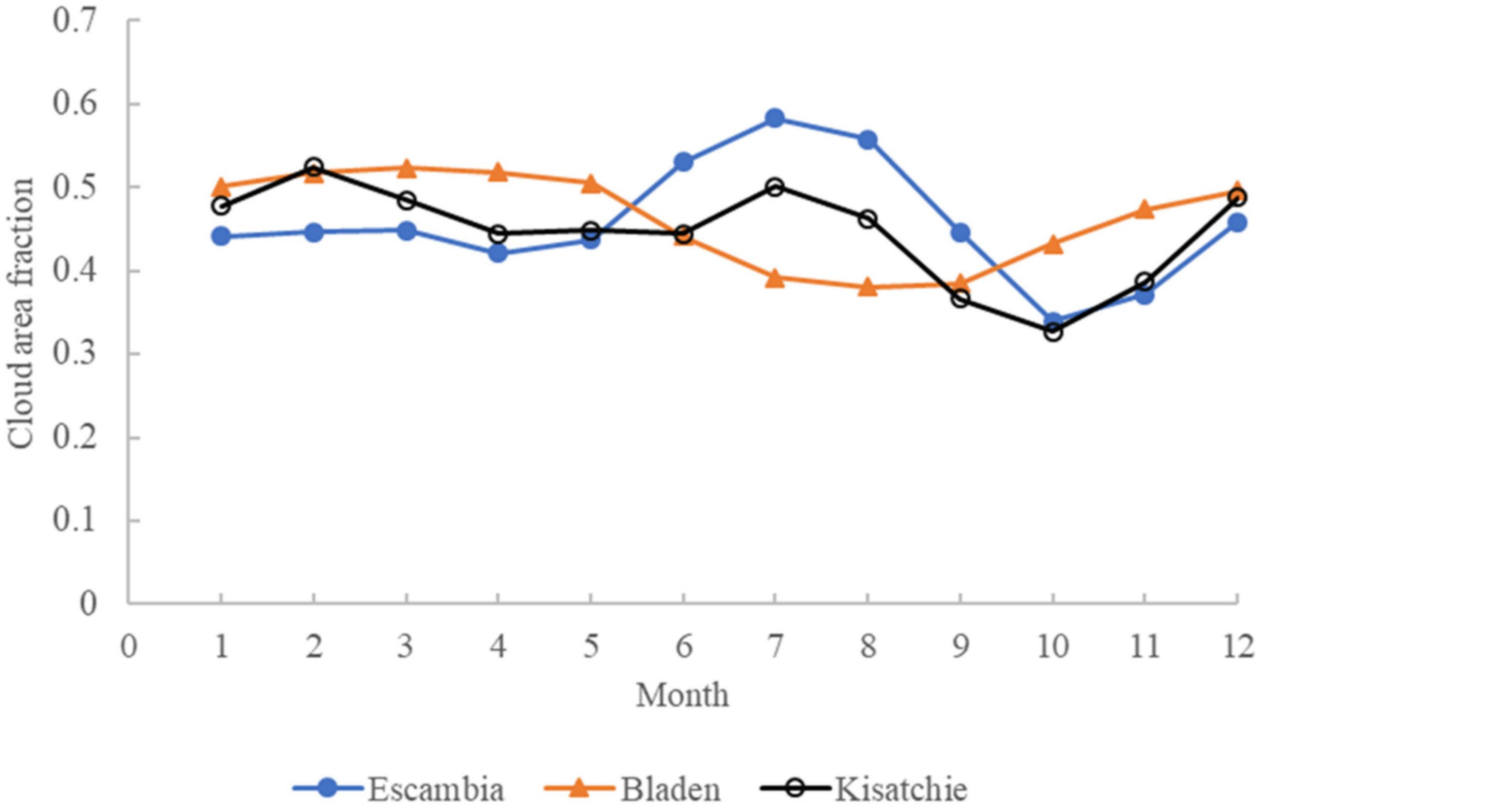


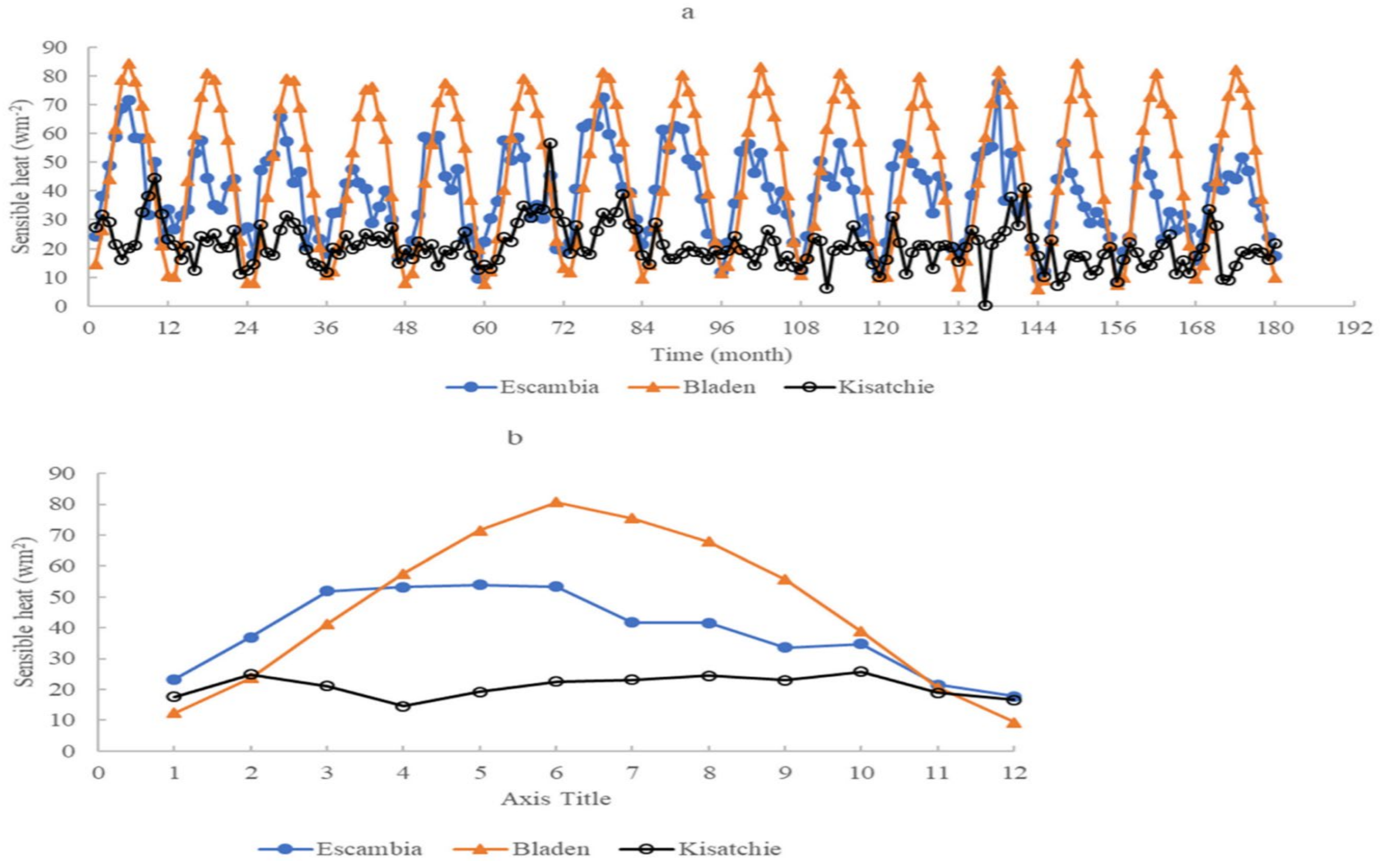
CO concentration (ppbv)
180
155
130
105
80
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Escambia
Bladen
Kisatchie

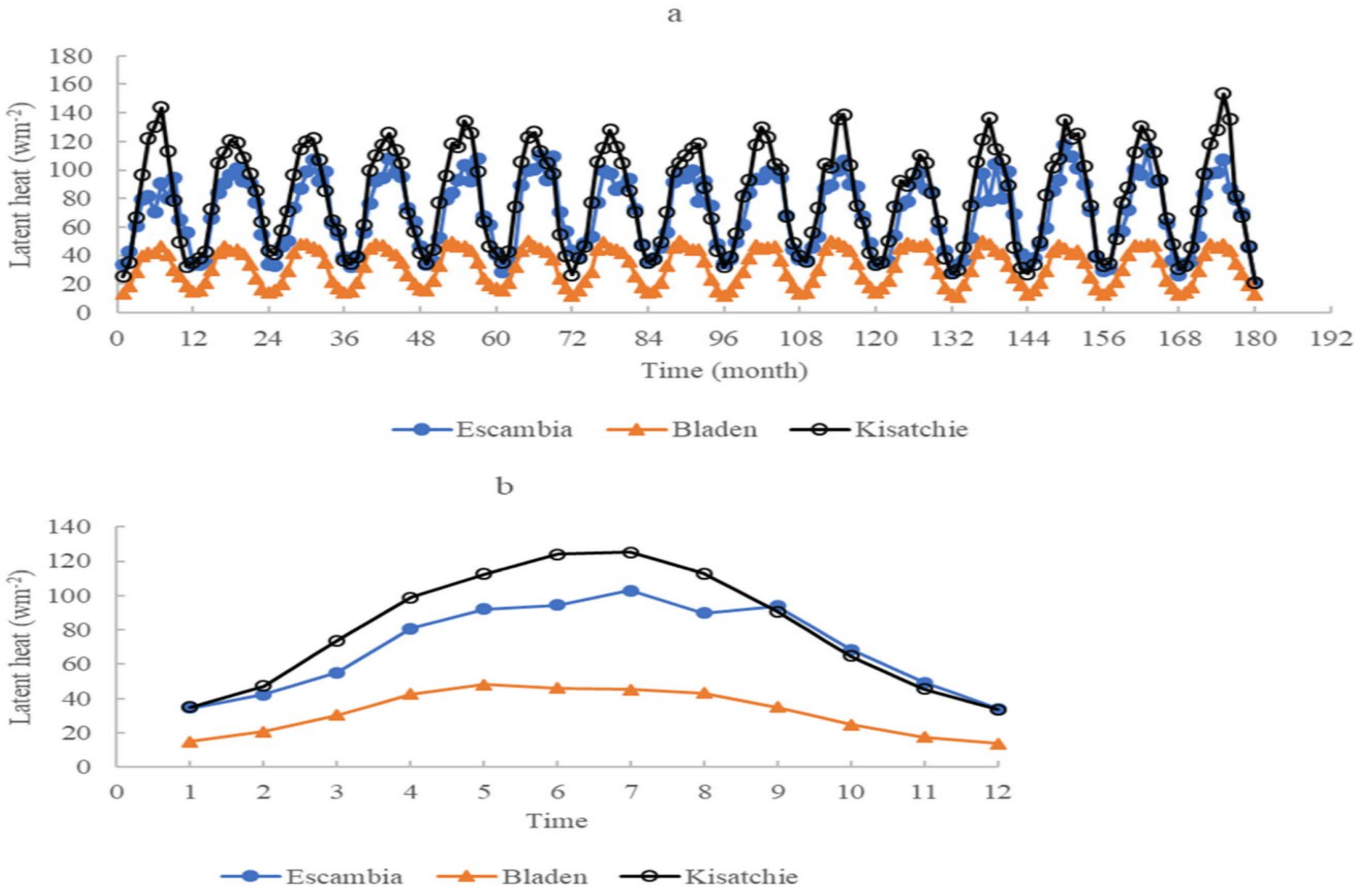


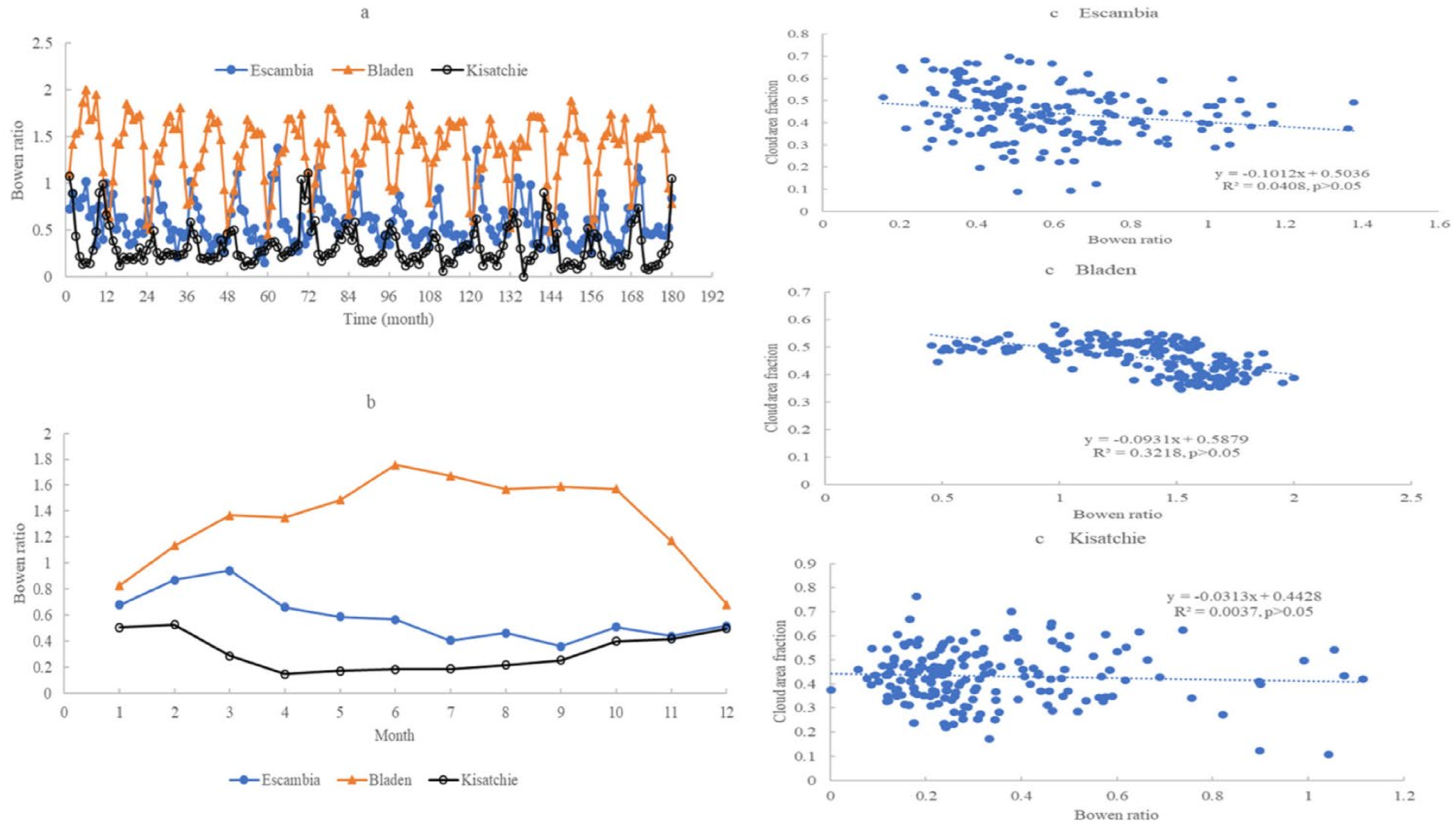
a
Escambia
Bladen
Kisatchie
SO2 concentration (10-6 kg cm-2)
0
2
4
6
8
10
12
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240 252 264
Time (month)
b
SO2 concentration (10-6 kg cm2)
0
1
2
3
4
5
6
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
Escambia
Bladen
Kisatchie

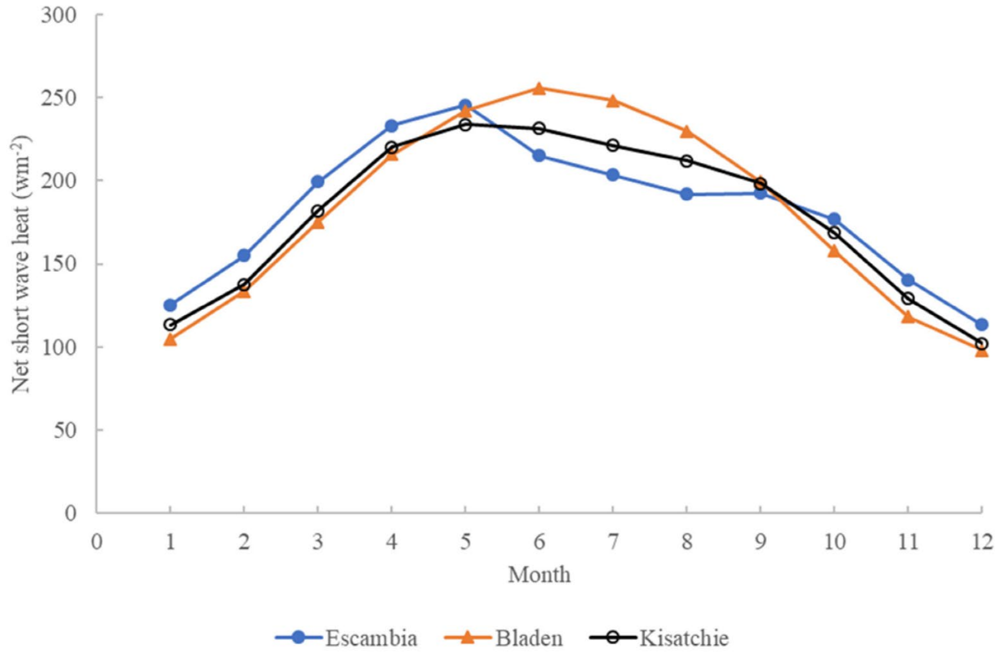

0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
Albedo
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Escambia
Bladen
Kisatchie

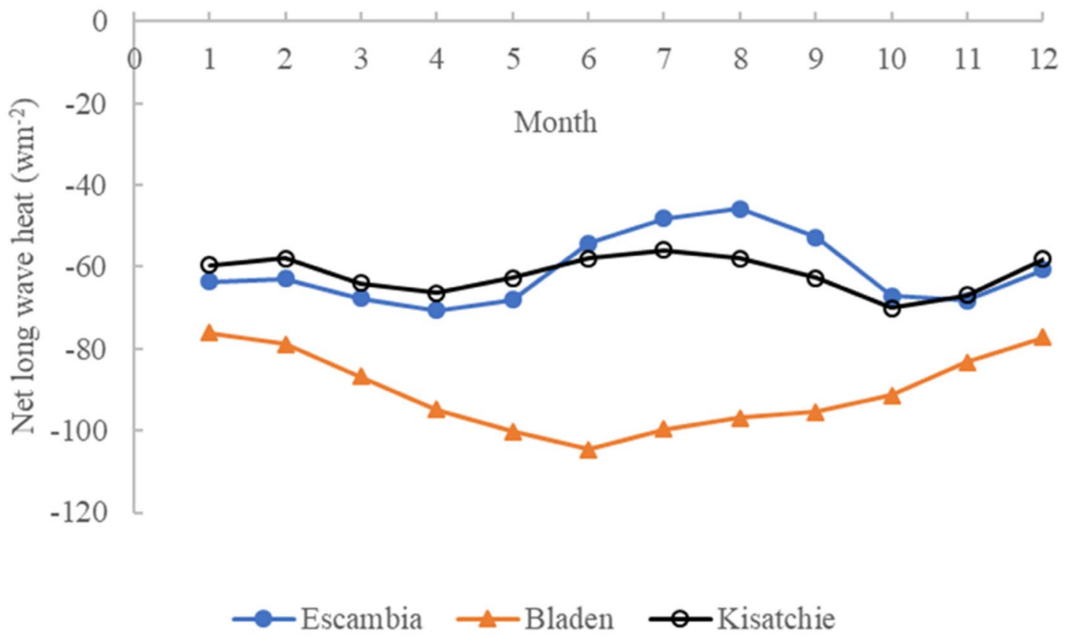

Cloud area fraction
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Escambia
Bladen
Kisatchie


a
Sensible heat (wm-2)
Time (month)
Escambia
Bladen
Kisatchie
b
Sensible heat (wm2)
Axis Title
Escambia
Bladen
Kisatchie


a
Latent heat (wm-2)
Time (month)
Escambia
Bladen
Kisatchie
b
Latent heat (wm-2)
Time
Escambia
Bladen
Kisatchie


a
Escambia
Bladen
Kisatchie
Bowen ratio
Time (month)
b
Month
c Escambia
y = -0.1012x + 0.5036
R² = 0.0408, p>0.05
Cloud area fraction
Bowen ratio
c Bladen
y = -0.0931x + 0.5879
R² = 0.3218, p>0.05
c Kisatchie
y = -0.0313x + 0.4428
R² = 0.0037, p>0.05


300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
Net short wave heat (wm⁻²)
Escambia
Bladen
Kisatchie


0
-20
-40
-60
-80
-100
-120
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
Net long wave heat (wm⁻²)
Escambia
Bladen
Kisatchie

# Conclusions

Longleaf pine forests require frequent burning to prevent their successional replacement on most sites. While the frequent burning regime will impact atmospheric conditions.

We explored remote sensing data over the past 22 years to document and compare the complex interactions of particles, gasses, and energy with the atmosphere in three areas with active longleaf pine restoration programs.

This study indicates there are spatial and temporal homogeneities (e.g., AOD and black carbon) and heterogeneities (e.g., albedo and Bowen ratio) in these interactions. Studying these biophysical interactions will be helpful for the large-scale longleaf pine forest restoration and management under climate change with multiple objectives (e.g., timber, biodiversity, air quality, climate, and public health).

Our findings provide insight into how forest restoration practices influence air quality and greenhouse gas emissions. Further research to integrate the necessary ground information is needed to clarify underlying mechanisms.