Investigating the surface layer CO_2 exchange at BNF under different synoptic setups

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Motivation

CO_2 being a major GHG, an accurate quantification of the CO_2 budget and the distribution of CO_2 sources/sinks is crucial for precise climate simulations. Impact of synoptic scale air mass changes via mid-latitude cyclones on near-surface CO_2 fluxes remained underexplored. Using the recently deployed BNF measurements at SE-US, we aim to eexplore CO_2, and energy exchanges between atmosphere and biosphere under varying synoptic conditions during day and night across seasons.

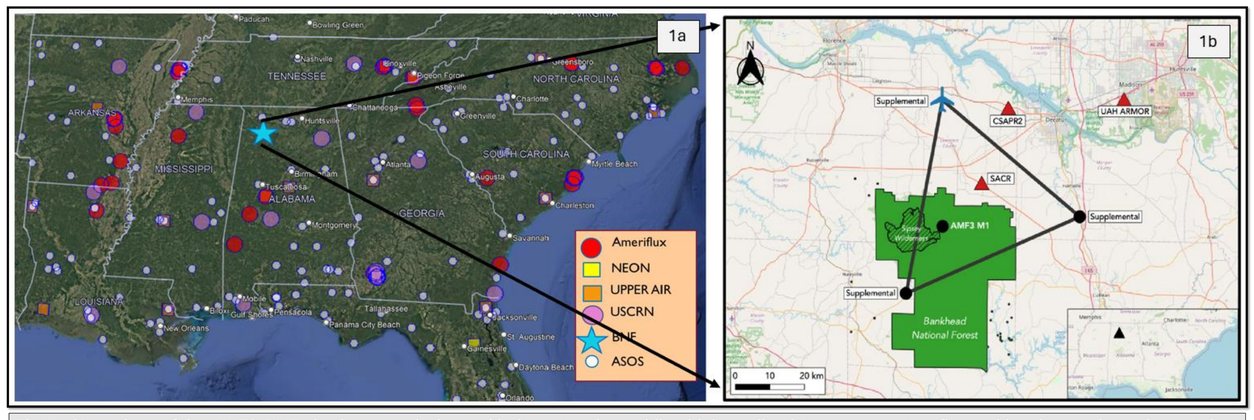


Fig 1: a)Locations of the AMF3-BNF site (cyan star) along with the network providing high-quality data on ecosystem fluxes, b) radars and supplemental site's map over BNF.

Goals

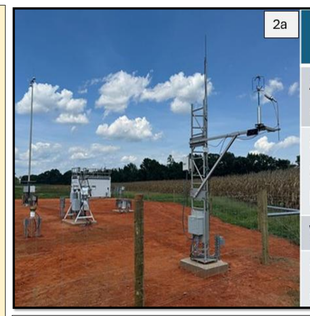
- Impact of synoptic air mass exchange on CO_2 flux variability over a vegetated forest canopy.
- How do the vertical fluxes change in the different atmospheric conditions.
- Data driven approach – To find the different synoptic categories & their distinct impact on fluxes

Instruments & Dataset

- High-quality, multi-instrument observation - 3rd Atmospheric Radiation Measurement Mobile Facility (AMF3) in north-western Alabama's Bankhead National Forest (BNF).
- Eddy Covariance (EC) measurement → 40-m tower for OCT 2024 – JAN 2025(Fall & Winter).

➢ Ultrasonic anemometer: WindMaster Pro by Gill Instruments, Ltd.

➢ Open-path CO_2 / H_2O IRGA: LI-7500 by LI-COR, Inc.



Variables	2b
Atmospheric temperature and moisture	
CO_2 flux, Sensible heat flux, Latent heat flux	
Wind speed and direction	
Cloud fraction, Radiation components	

Fig 2: a)Eddy covariance instrument at BNF atmospheric observatory in Alabama mounted on 3m tower, b) Meteorological and micro-meteorological variables.

Methodology & Case selection

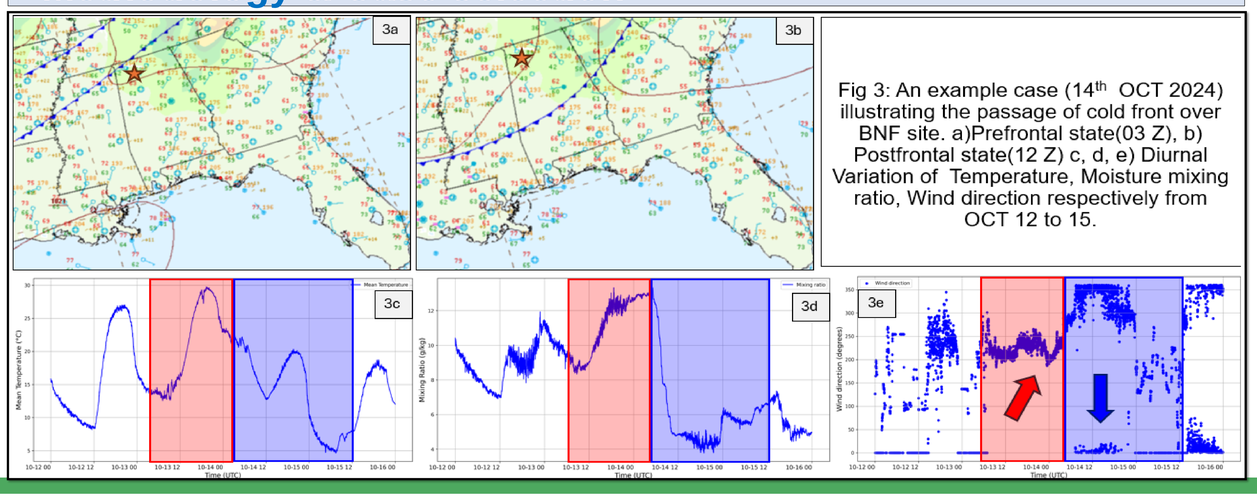


Fig 3: An example case (14th OCT 2024) illustrating the passage of cold front over BNF site. a)Prefrontal state(03 Z), b) Postfrontal state(12 Z) c, d, e) Diurnal Variation of Temperature, Moisture mixing ratio, Wind direction respectively from OCT 12 to 15.

Variables	Synoptic Classifications	Metrices
Sudden drop in temperature and mixing ratio, sudden shift in wind direction.	Frontal passages.	Daytime maximum temperature, Daytime minimum CO_2 flux.
CO_2 flux variability (near surface), CO_2 vertical variability .	Extension of Bermuda high and diverse Gulf inflow patterns.	Temperature growth rate, Dependence on Clearness Index
Increased cloudiness (Cloudiness index), Radiation, PAR.	Bermuda high present over Gulf states (Divergence blocking warm moist Gulf inflow).	Temporal variability: On synoptic timescale during a month and across seasons.

Preliminary Results

Impact of frontal passage on temperature and fluxes (H,L, CO_2).

An overview of near-surface temperature and fluxes (H, L, CO_2) on OCT 2024.

Daily representative values of met parameters and fluxes as a function of weather and season.

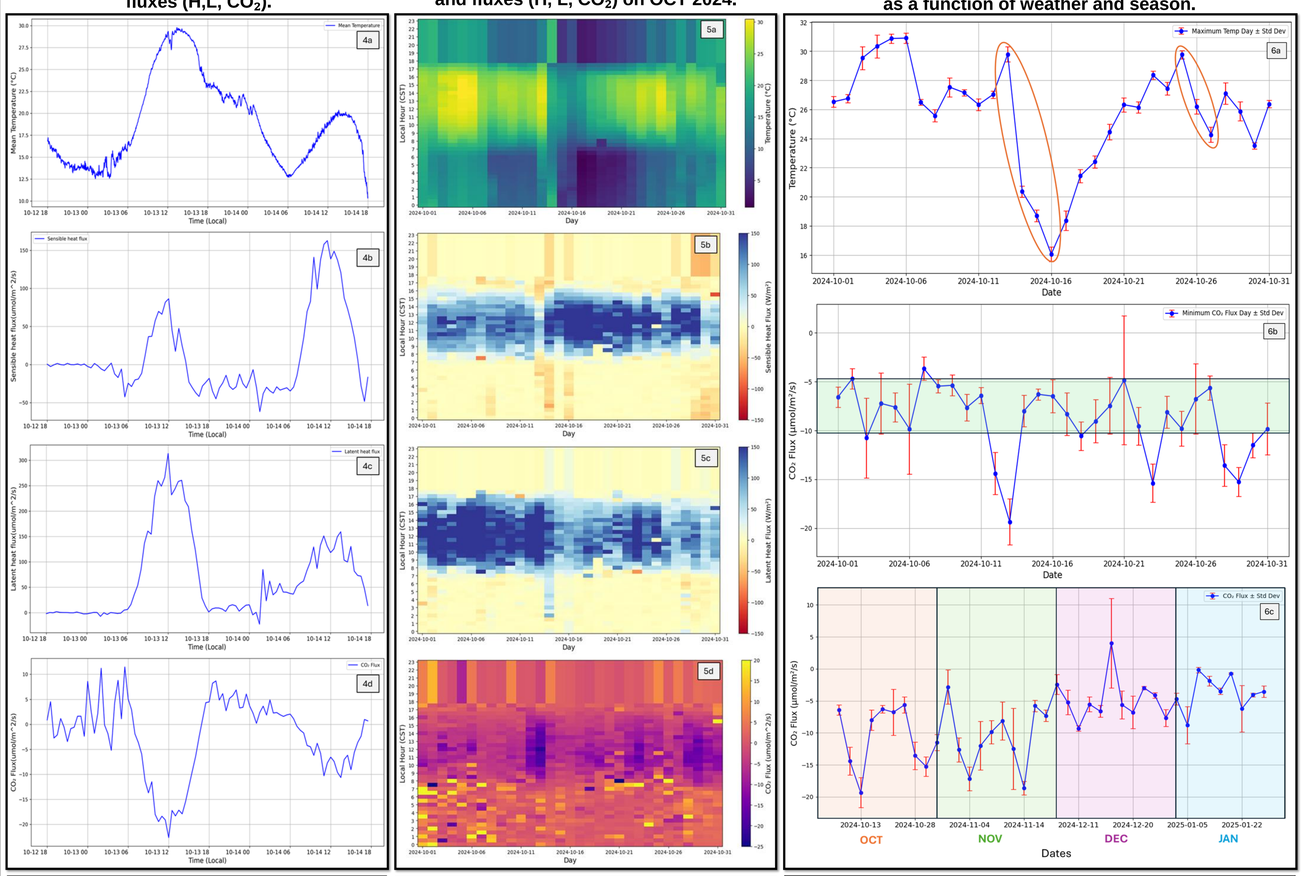


Fig 4: Diurnal variation of temperature (a), sensible heat flux (b), latent heat flux (c), and CO_2 flux observed at the BNF site from 12-14 Oct 2024 citing an excellent example of a cold front passage on 13 Oct 2024.

Fig 5: Heat-map views of diurnal and day-to-day variability in temperature, latent and sensible heat fluxes, and CO_2 flux during October 2024.

Fig 6: Day to day variability in daily daytime temperature maxima (a) and late afternoon CO_2 flux (b) during October 2024. Daytime minima of CO_2 flux during frontal events in October (c). Impact of frontal passages on CO2 fluxes (all frontal events from Oct 2024 to Jan 2025).

Summary

- Preliminary results suggest impact of the frontal passages on the CO_2 fluxes yielding significant drop in daily typical CO_2 flux (sink).
- The impact of frontal passages on fluxes showed some month-to-month variability suggesting stronger impact in fall than in winter. However, the analyses shown are preliminary and we lack measurements across all months to discern seasonal variability in frontal signatures (if any). More work needed here.

Acknowledgement

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References

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