Analysis of drought effects on VOC emissions in Asia using GEMS products

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Introduction

- **Drought** is known to increase **biogenic volatile organic compound (BVOC) emissions** through enhancing plant water stress. However, the current chemical transport models generally do not reflect this phenomenon. Specifically, they use the **activity factor for soil moisture (γ_{SM})** constant or increasing as the soil moisture increases.

$$E = E_0 \times \gamma_T \times \gamma_P \times \gamma_{LAI} \times \gamma_{Age} \times \gamma_{SM} \times \rho$$

(E: BVOC emission rate, E_0: emission factor, γ: emission activity factor, T: temperature, P: photosynthetic photon flux density, LAI: leaf area index, Age: leaf age, ρ: loss and production within the plant canopy)

- Observed **formaldehyde and glyoxal VCDs** can provide information on VOCs emissions.
- In this study, we assessed the change of glyoxal and formaldehyde VCDs with drought intensity utilizing GEMS observation. We exclude the biomass burning emission effect to deduce a relationship between soil moisture and HCHO and CHOCHO VCDs produced from biogenic emissions.

Method

Data

Data	Resolution	Period	Description
GEOS-FP data assimilated meteorology	0.25°× 0.3125°	2020/8–2023/9	Temperature (temperature 2 m above displacement height)
			Soil moisture (root soil wetness, a wetness at the depth of 0.1-1 m)
Offline MEGAN			Isoprene biogenic emission
GEMS V2.0 HCHO	~3.5 km × 8 km		formaldehyde vertical column densities (VCDs)
GEMS V2.0 CHOCHO	~14 km × 32 km		glyoxal vertical column densities (VCDs)
GFED4			Biomass burning emission
Leaf Area Index (LAI)	0.25° ×0.25°	1981–2015	Global Monthly Mean Leaf Area Index Climatology processed from MODIS and AVHRR measurements (Mao, J., and B. Yan., 2019)

Spatial and temporal co-location

- Spatial co-location: all variables are re-gridded into **0.25°×0.3125°** resolutions.
- Temporal co-location: all variables except LAI are **daily averaged**.

Classification of drought periods

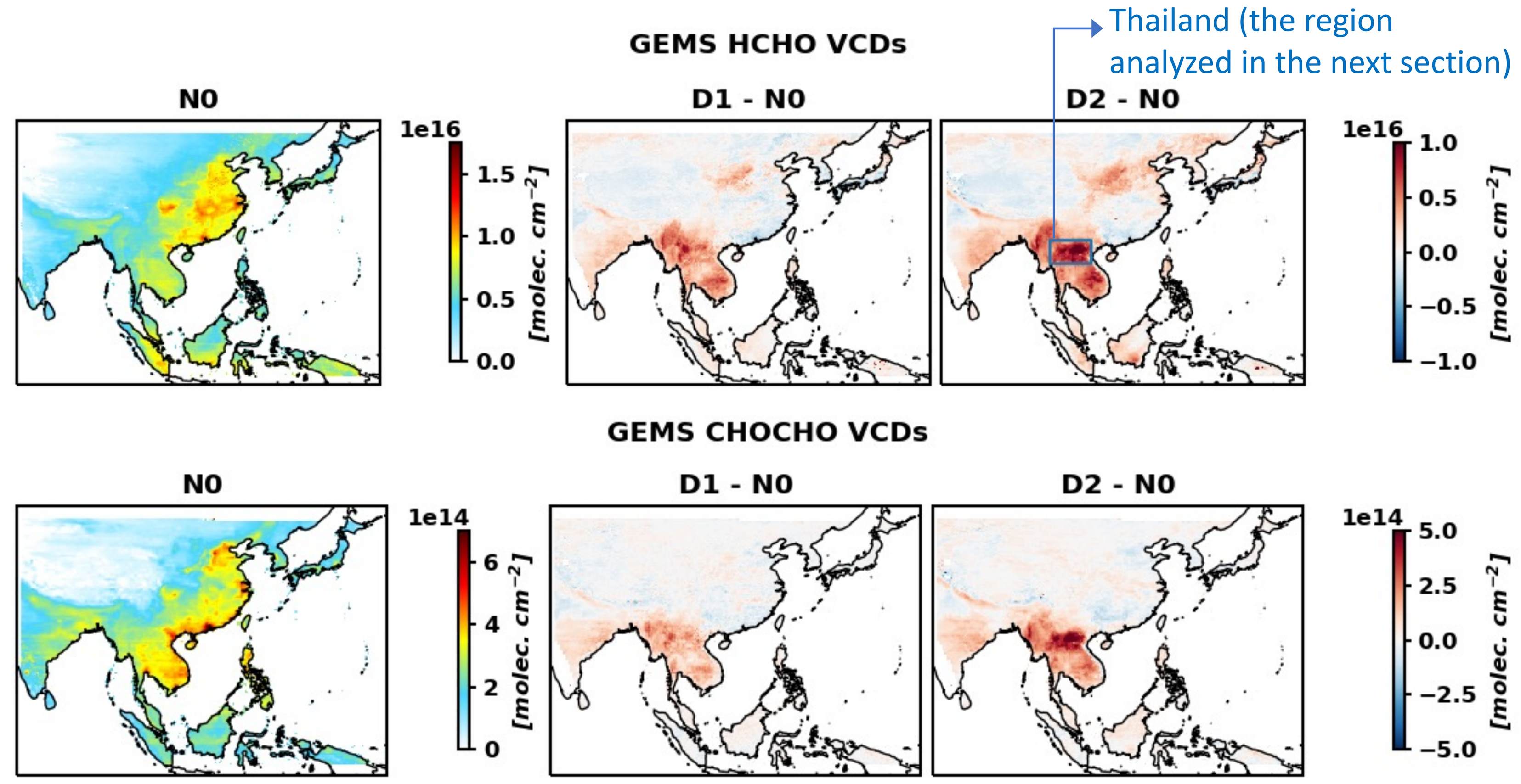
- We use the percentile of **soil moisture data** for each grid to classify drought periods (N0: non-drought, D1: mild drought, D2: extreme drought).

Percentile of the soil moisture

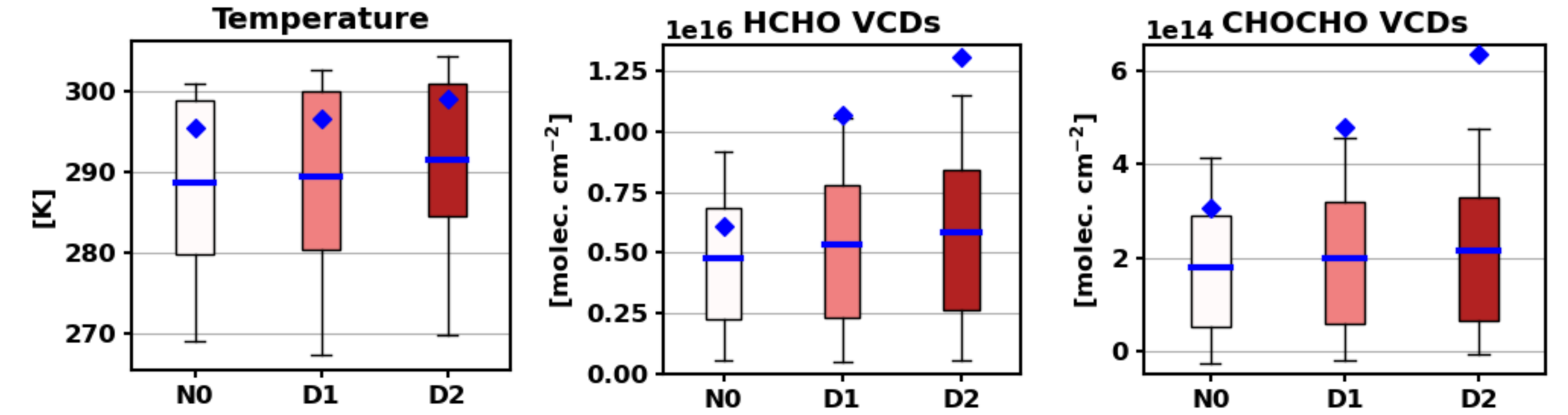
0th – 10th	10th – 20th	20th – 100th
D2	D1	N0
extreme drought	mild drought	non-drought

GEMS HCHO and CHOCHO change with drought intensity

Variation of HCHO and CHOCHO VCDs with drought intensity



blue marker: mean over Thailand, blue line: mean over Asia (the entire domain), box: 25^{th} - 75^{th} percentile over Asia, whiskers: 10^{th}, 90^{th} percentile over Asia



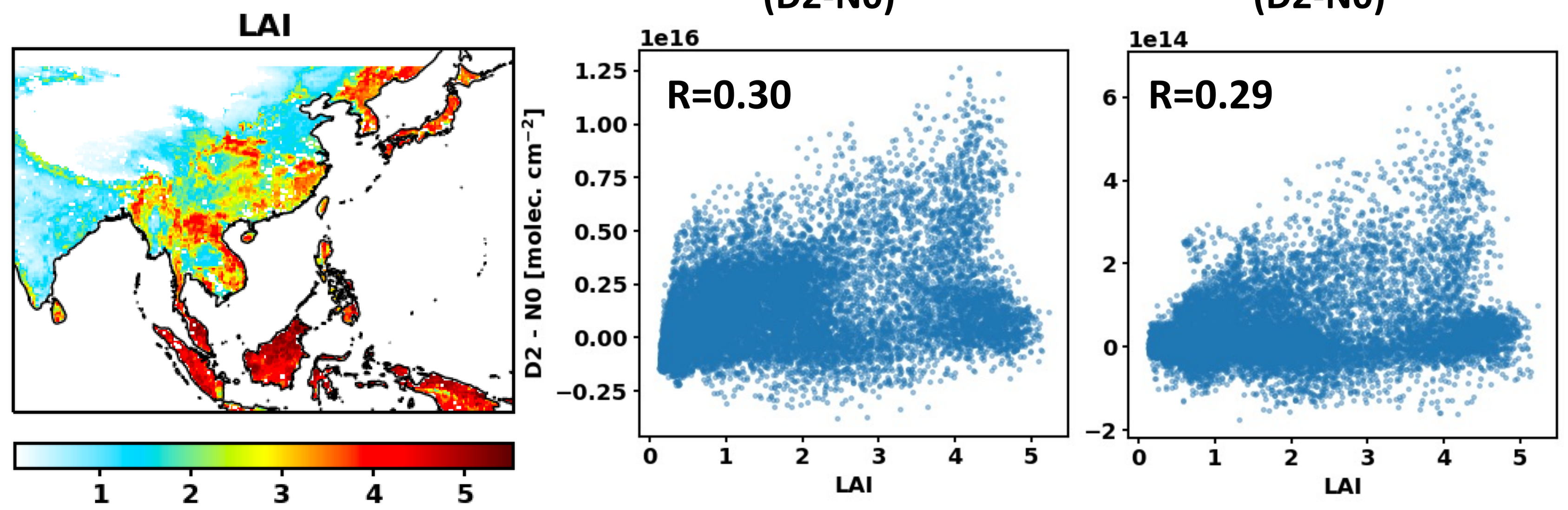
	Temperature D1	Temperature D2	HCHO D1	HCHO D2	CHOCHO D1	CHOCHO D2
Asia —	0.7 K	2.8 K	12%	20 %	12 %	23 %
Thailand ♦	1.2 K	3.6 K	75 %	114 %	55 %	106 %

Average change of variables during D1 and D2 compared to N0

- Cause of HCHO and CHOCHO VCD increase during drought
  - Increase of **temperature**
    →accelerated oxidation reactions producing HCHO and CHOCHO from precursors
    →increase of biogenic emission
  - Decrease of **soil moisture**
    →increase of biogenic emission due to enhanced plant water stress
    →increase of biomass burning emissions

Regional differences of HCHO and CHOCHO responses to drought

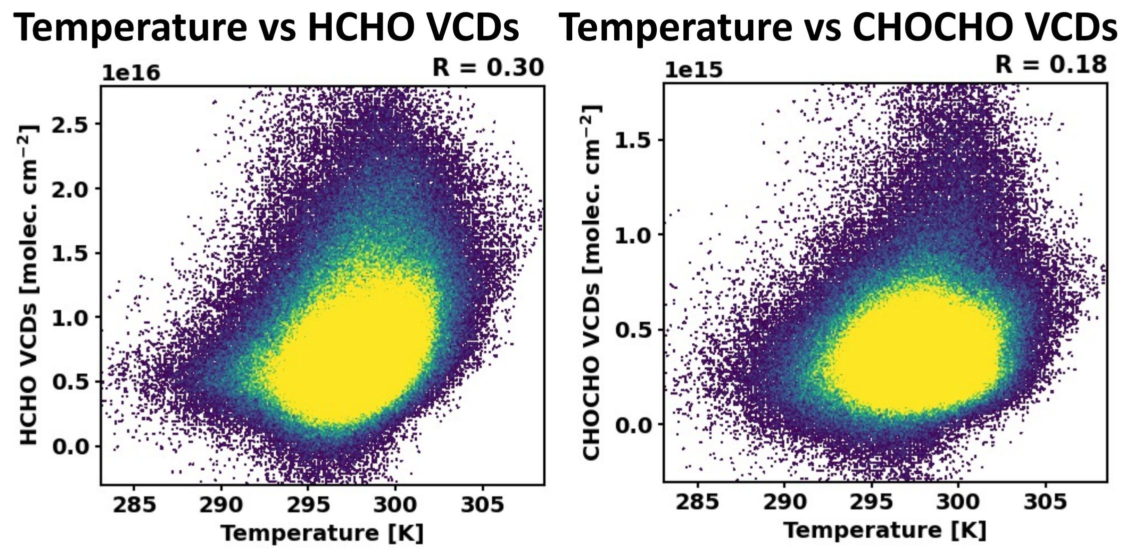
LAI = leaf area/ground area [m²/m²]



Regions showing significant increases in HCHO and CHOCHO VCDs during drought tend to have high LAI, suggesting that these increases are related to vegetation.

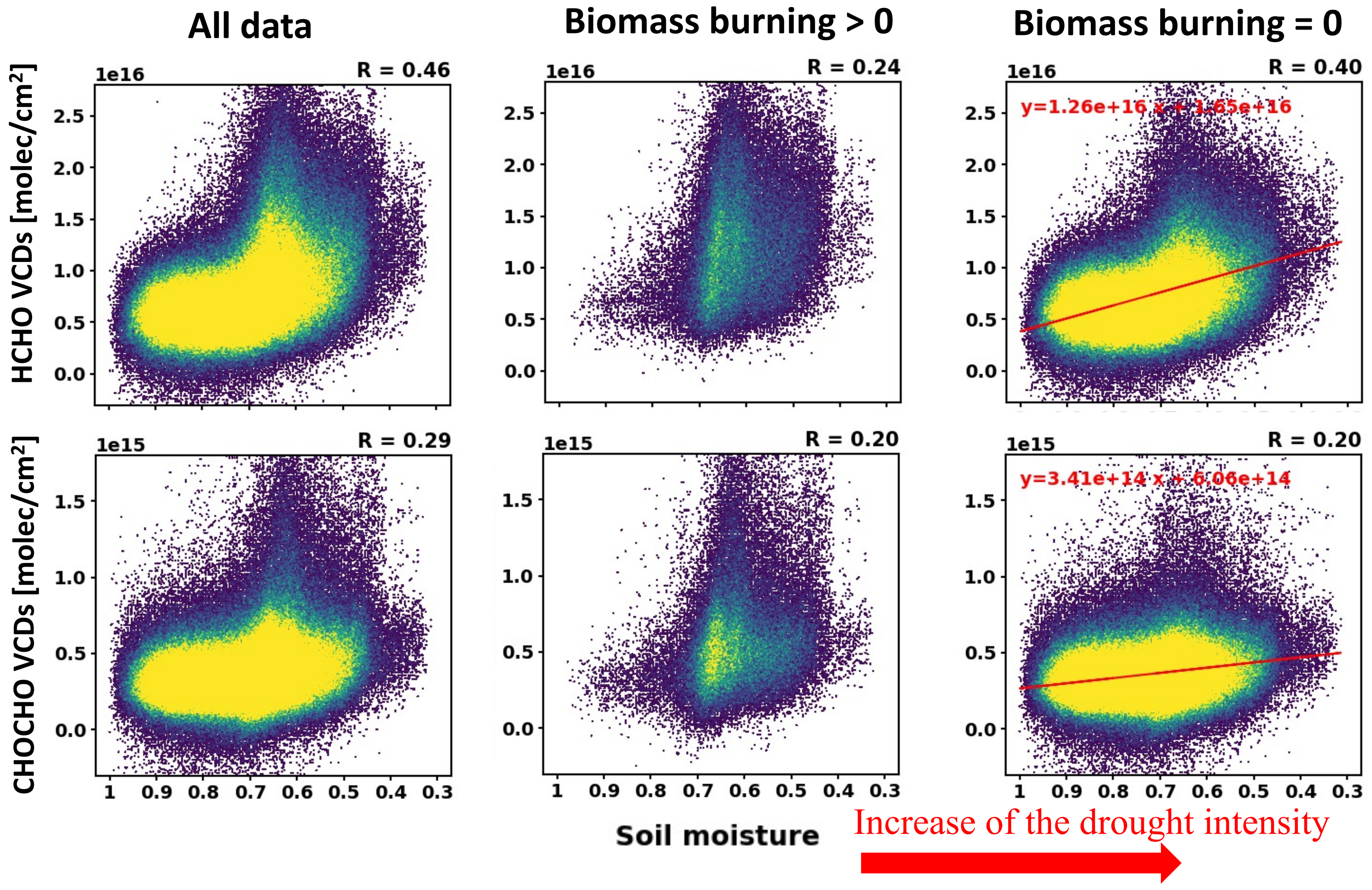
Relationship between soil moisture and VOC concentration

Relationship between temperature and VOC concentration



- **Analyzed domain**
  Thailand (17.6-22.5° N, 96.9-105.5°E; significant response to drought)
- **Biogenic emission criteria**
  grids that represent monthly biogenic isoprene > 1.5×10^{-10} kgC/m²/s.

Relationship between soil moisture and VOC concentration



Conclusion

- Both HCHO and CHOCHO VCDs increase as the drought intensifies, which could be combined effects of temperature and soil moisture change. Thailand exhibited the most significant response of HCHO VCDs, with average increases of 75% during D1 and 114% increase during D2 compared to N0.
- Regions showing significant response to drought tend to have high LAI.
- Temperature and drought intensity showed positive correlations with HCHO and CHOCHO VCDs. We excluded grids with positive daily biomass burning emissions to deduce a relationship between soil moisture and HCHO and CHOCHO VCDs produced from biogenic emissions.
- Using the relationship between VOC concentration and biogenic emissions from the model simulation, we could further examine the relationship between biogenic emissions and drought intensity.

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links to Ha et al., 2024, EGUsphere [preprint]