Evaluation of soil moisture stress parameterizations in MEGAN model against MOFLUX field data and satellite observations of formaldehyde from OMI

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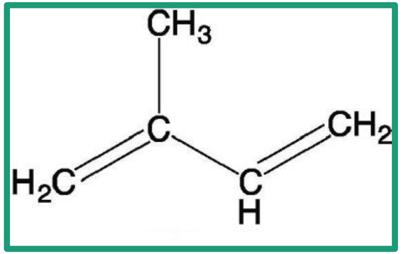
ALBERI

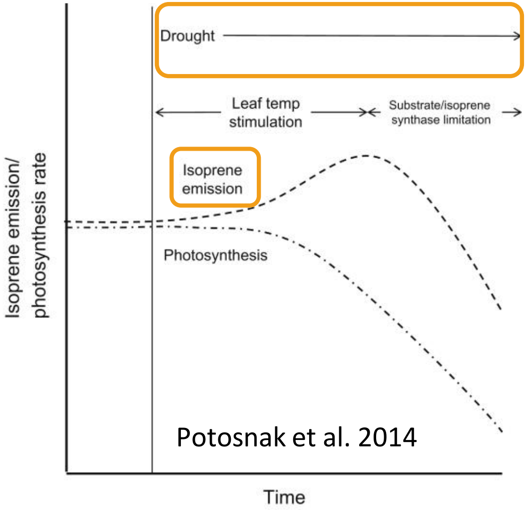
Assessing Links between Biogenic Emissions and Remotely-sensed photosynthesis Indicators

Introduction

- The research focuses on isoprene (C_5H_8) :
  - Key biogenic volatile organic compound (BVOC)
  - Emitted primarily by vegetation
  - Global annual emissions estimated at 300-700 Tg
  - Impact on air quality and climate: precursor of tropospheric O_3 (in high-NO_x), involved in the formation of secondary organic aerosols, influences methane lifetime,…



- Our focus is on the response of isoprene emissions to drought
- Extreme weather conditions such as drought events can substantially affect the emissions. There are important challenges:
  - insufficient flux measurements under drought conditions
  - the response of isoprene to drought is nonlinear and depends on the severity and duration of the drought (cf. figure)
  - different effects of drought across biomes and species (e.g. drought-adapted and drought-sensitive species)
  - biogenic emission models do not cope well at representing the response of biogenic emissions to drought



Potosnak et al. 2014

Research aims

Our goal is to evaluate the current available parameterizations of the soil moisture stress in the MEGAN biogenic emission model (Guenther et al., 2012), through the following two approaches:

→ Local and short-term approach

The parameterizations are evaluated at the Missouri site of the AmeriFlux network (referred to as MOFLUX) for which two campaigns of isoprene flux measurements were conducted during the droughts of 2011 and 2012.

→ Global or local, long-term approach

Using satellite observations of a high-yield product of isoprene oxidation, formaldehyde (HCHO), we perform a global-scale evaluation over 2005-2016.

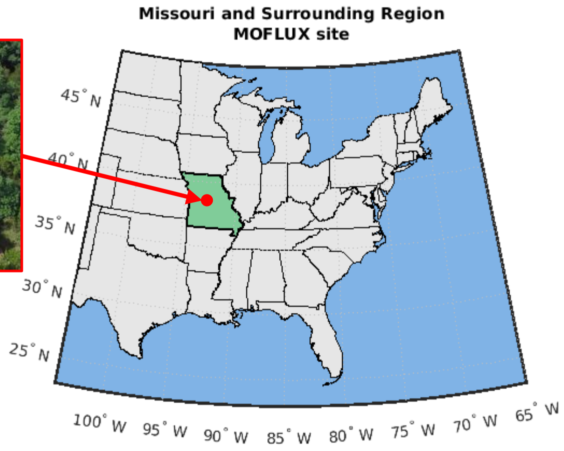
Study area: MOFLUX

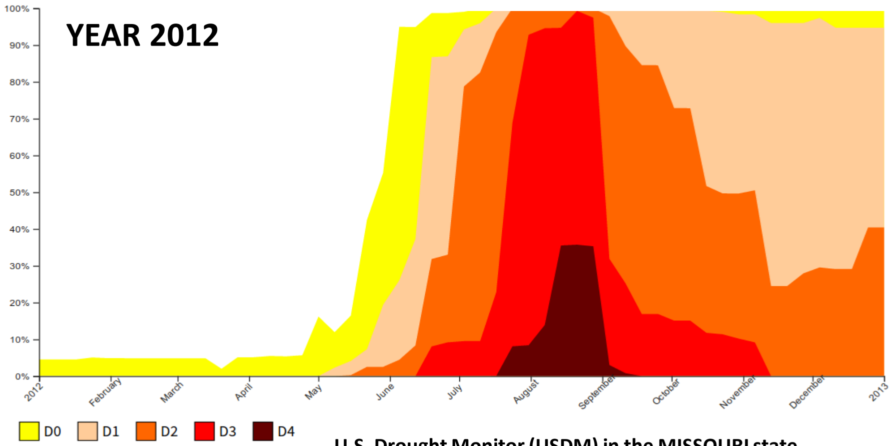
- Central U.S. Forest (38.74°N, 92.2°W) in the Missouri State
- Part ot AmeriFlux Network (US-MOz)
- Vegetation:
  Deciduous Broadleaf Forests dominated by oaks
- “Isoprene volcano”:
  this region exhibits very high isoprene emissions
- Drought-prone area

Two campaigns provide isoprene flux measurements during drought events :

- 2011: mild drought stress
  Measurements description : Potosnak et al. (2014)
- 2012: severe drought stress
  Measurements description: Seco et al. (2015)

Image Credit: Jeffrey Wood (PI)





D0 - Abnormally Dry;
D1 - Moderate Drought;
D2 - Severe Drought;
D3 - Extreme Drought;
D4 - Exceptional Drought

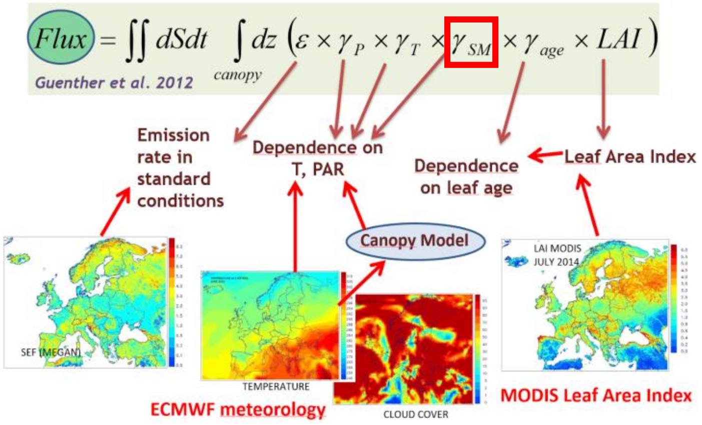
U.S. Drought Monitor (USDM) in the MISSOURI state

In August, about 30% of the Missouri state suffered from exceptional drought conditions.

Source: https://www.drought.gov/

Modelling the effect of drought in MEGAN-MOHYCAN

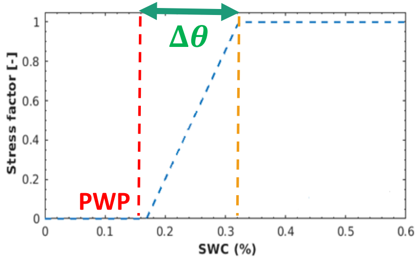
❖ Biogenic emission model MEGAN-MOHYCAN (Guenther et al., 2012; Müller et al., 2008)

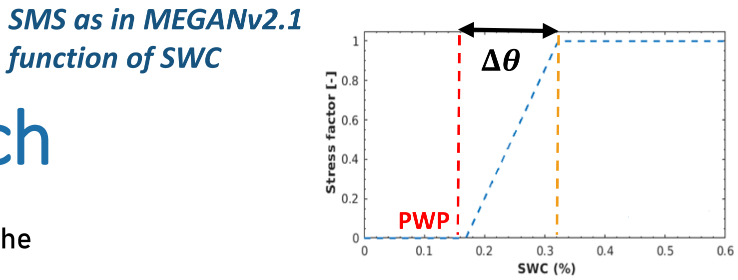


❖ The soil moisture stress (SMS) function, denoted by γ_{SM}.

❖ There are two parameterizations available, g2 and g3, available in MEGANv2.1 and v3, respectively.

❖ MEGAN-MOHYCAN is driven by local variables (hourly air temperature and PPFD, daily LAI).

MEGANv2.1 (g2) (Guenther et al., 2012)	MEGANv3 (g3) (Jiang et al., 2018)
Function of: - Soil Water Content (SWC) - Permanent wilting point (PWP) 	Function of : - Maximum rate of carboxylation (V_{cmax}) (photosynthetic parameter) - Soil water stress function (β_t) $\gamma_{SM} = \begin{cases} 1 & \beta_t > 0.6 \\ V_{cmax}/\alpha & \beta_t = 0.6 \\ 0 & \beta_t < 0.6 \end{cases}$
Parameter: $\Delta\theta = 0.04$	Parameter: $\alpha = 37$
Inputs (SWC and PWP) from either 1) Satellite-based GLEAMv3.5b dataset (Martens et al., 2017) 2) In situ AmeriFlux observations	Inputs from the Community Land Model (CLM4.5)

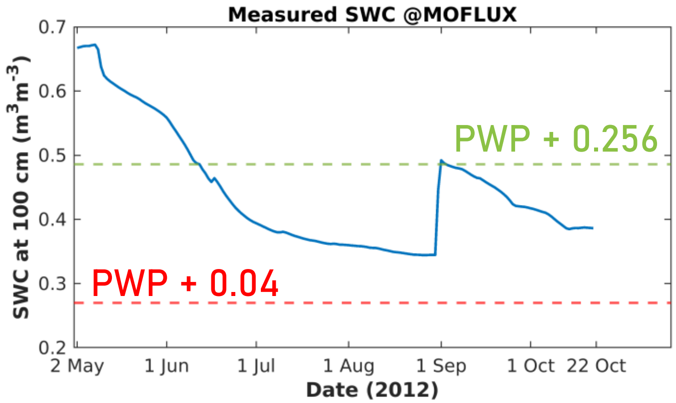


Optimization for the local approach

- g3 was calibrated based on the MOFLUX site (Jiang et al., 2018). This is not the case of g2.

- In 2012, when the SMS is expected to have the biggest impact, the parameterization g2 using locally measured 100-cm SWC and the local PWP (=0.23) implies $\gamma_{SM} = 1$. This happens because the SWC never drops below PWP + 0.04.

- Optimization of the parameter $\Delta\theta$ in g2 was performed by minimizing the Root-Mean Square Error in both years between the MOFLUX data and modelled isoprene fluxes calculated using either local observations or GLEAM.

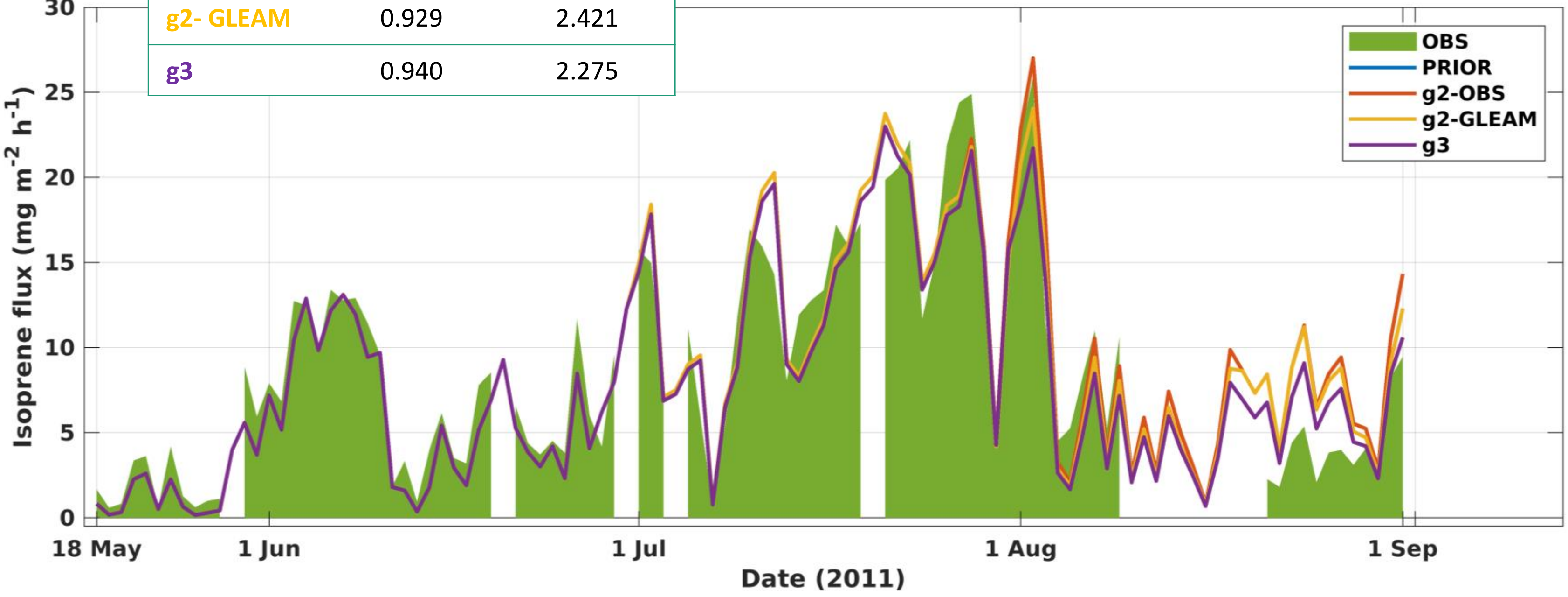


Inputs in g2	SWC	PWP (Units: m^3/m^3)	OPTIMIZED $\Delta\theta$
Observations (AmeriFlux US-Moz)	100-cm	0.23 (Seco et al., 2015)	**0.256**
GLEAMv3.5b (0.25° × 0.25°) (Mertens et al., 2017)	Root-zone	0.169 (IGBP-DIS)	**0.124**

Comparison with isoprene flux measurements in 2011

OBS	Isoprene flux measurements from Potosnak et al. (2014)
PRIOR	MEGAN-MOHYCAN model driven by locally-observed variables with $\gamma_{SM} = 1$.
g2-OBS	PRIOR + *daily* SMS function (g2 with observed soil properties and $\Delta\theta = 0.256$)
g2-GLEAM	PRIOR + *daily* SMS function (g2 with soil properties from GLEAM and $\Delta\theta = 0.124$)
g3	PRIOR + *monthly* SMS function (g3 with soil properties from CLM4.5)

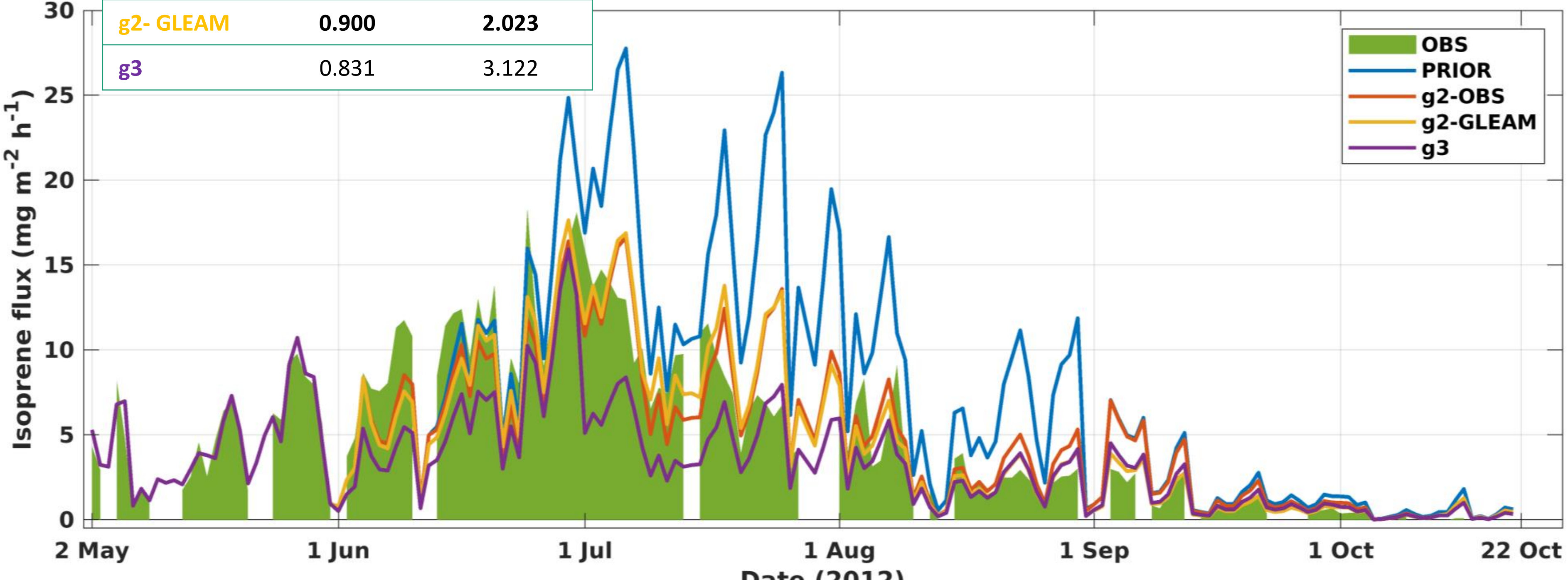
CASE	r^2	RMSE
PRIOR	0.925	2.515
g2- OBS	0.925	2.515
g2- GLEAM	0.929	2.421
g3	0.940	2.275



Comparison with isoprene flux measurements in 2012

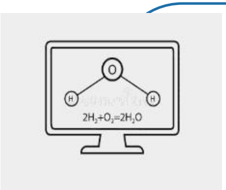
CASE	r^2	RMSE
PRIOR	0.758	4.981
g2- OBS	0.879	2.189
g2- GLEAM	**0.900**	**2.023**
g3	0.831	3.122

OBS	Isoprene flux measurements from Seco et al. (2015)
PRIOR	MEGAN-MOHYCAN model driven by locally-observed variables with $\gamma_{SM} = 1$.
g2-OBS	PRIOR + *daily* SMS function (g2 with observed soil properties and $\Delta\theta = 0.256$)
g2-GLEAM	PRIOR + *daily* SMS function (g2 with soil properties from GLEAMv3.5b and $\Delta\theta = 0.124$)
g3	PRIOR + *monthly* SMS function (g3 with soil properties from CLM4.5)



HCHO columns: Model and observations

OMI HCHO
(Observations)
(De Smedt et al. 2018)
http://www.qa4ecv.eu



MAGRITTEv1.1
(Regional chemistry-transport model)
(Müller et al., 2019; Stavrakou et al., 2018)

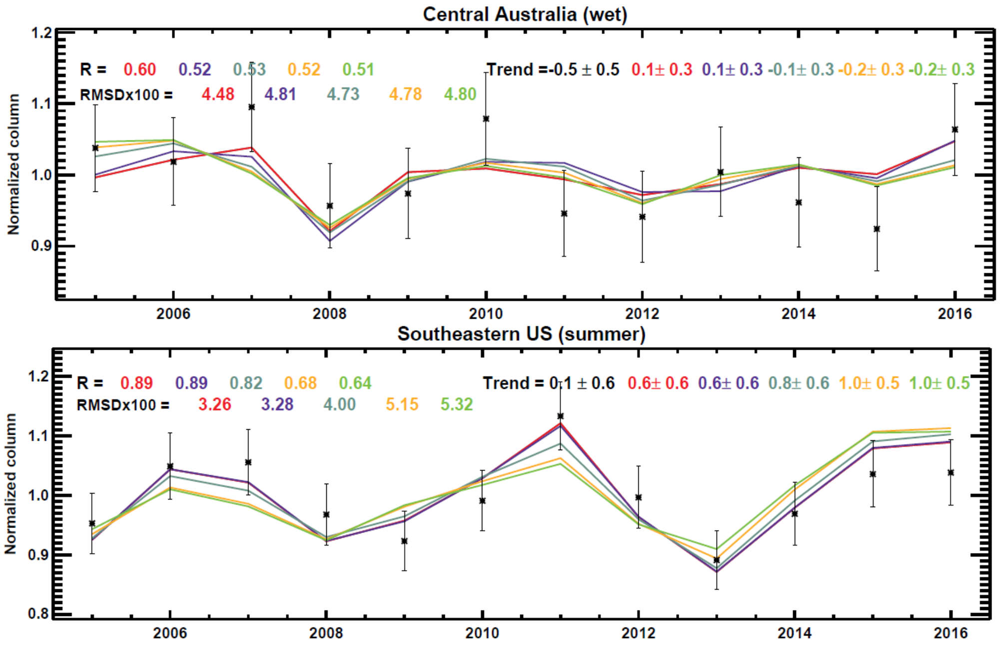
- 0.5°×0.5° over North America
- EDGARv4.3.2 and HTAPv2 (anthropogenic)
- MEGAN-MOHYCAN biogenic emissions, use the soil moisture stress with GLEAMv3.5b and $\Delta\theta$=0.04 or 0.12

Comparison of observed to modelled columns at MOFLUX *Units: ×10^{15} molec cm^{-2}*	June			July			August		
	2011	2012	Diff (%)	2011	2012	Diff (%)	2011	2012	Diff (%)
OMI HCHO	16.2	17.3	+6	21.9	17.7	-19	16.0	12.5	-22
Model ($\Delta\theta$=0.04)	16.5	17.5	+6	24.1	22.1	-8	20.1	16.0	-20
Model ($\Delta\theta$=0.12)	15.9	16.9	+6	23.0	18.5	-20	19.3	13.9	-28

The use of GLEAM with $\Delta\theta$=0.12 in MAGRITTE leads to a better overall agreement with the observed OMI changes at the MOFLUX site.

However, the use of $\Delta\theta$ higher than 0.04 in a multi-year global simulation (2005-2016) does not improve the comparison over dry regions and worsens the comparison over forested areas.

$\gamma_{SM} = 1$; γ_{SM} (with $\Delta\theta = 0.04, 0.12, 0.18, 0.24$)



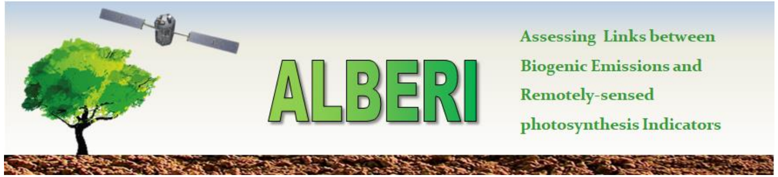
The figure shows two examples of normalized columns averaged over Central Australia during the wet season (December to February) and Southeastern US during summer (June to August).

- Observations are in black.
- The red curve is for the simulation when $\gamma_{SM} = 1$ (no stress), and with g2 using various values of the parameter .
- The correlation coefficient (R), the Root-Mean Square Deviation (RMSD) x 100, and the column trends are given inset.

Ongoing work

The work presented is part of the ALBERI project that aims at designing a better representation of the effect of drought on isoprene emissions based on remotely-sensed soil moisture data.

https://alberi.aeronomie.be/



Any comments or questions?

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