Evaluating the impact of different spaceborne land cover distributions on isoprene emissions and their trends using the MEGAN model

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INTRODUCTION

The biogenic volatile organic compounds (BVOCs) are emitted at about 1100 Tg per year of which almost half is due to isoprene. Biogenic isoprene is mainly emitted by plant foliage, with trees being the major contributors. Our objective is to replace the current static land cover map of the MEGAN model in order to account for land cover and land use (LULC) changes. First, we compare the tree cover provided by three spaceborne datasets against each other and with the FAOSTAT (fao.org) database. Then, the impact of land cover changes on regional to global isoprene emissions and trends in 2001-2018 is evaluated using the MEGAN model, based on two different satellite land cover datasets.

MODEL: MEGAN-MOHYCAN

We use the MEGAN v2.1 model (Guenther et al., 2012) coupled with a multi-layer canopy model MOHYCAN (Müller et al., 2008) to estimate biogenic isoprene emissions. The standard version uses the Community Land Model (CLM4) plant functional type (PFT) map with a static representation of 16 PFTs for the year 2000.

LULC DATASETS

Three spaceborne datasets are used:

- **MODIS PFT (MCD12Q1 v006):** available with 12 PFTs (Source: lpdaac.usgs.gov)
- **HANSEN-MODIS:** MODIS PFT dataset modified to match the tree cover (TC) distributions from Hansen et al. (2013) (v1.6) available at 30m resolution. The total tree cover gain over 2000-2012 provided by Hansen et al. was implemented by assuming a linear increase over the period, extended until 2018.
- **ESA CCI-LC (v2.1.1):** The conversion from the ESA-CCI land cover clataset to PFTs follows Table S1 from Li et al. (2018) and references therein. (Source: maps.elie.ucl.ac.be/CCI/viewer/)

The subdivision of climate zones and the C3/C4 photosynthetic paths are obtained based on Table 3 from Poulter et al. (2011) with minor adjustments. The satellite datasets are compared to:

- **FAOSTAT**: based on national inventories (Source: www.fao.org)

MODEL SIMULATIONS

We perform the following three global MEGAN-MOHYCAN simulations at 0.5° resolution:

- **CTRL:** using the static CLM4 PFT maps,
- **MODIS:** using the MODIS PFT data,
- **HANSEN-MODIS:** using the HANSEN-MODIS data.

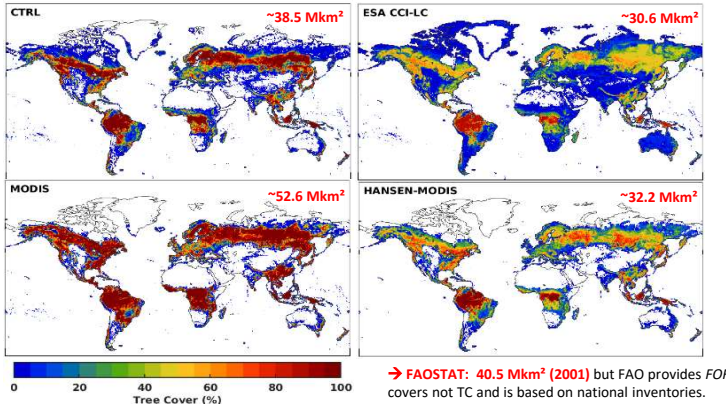
The simulations account for climate variability based on ECMWF ERA-Interim data and neglect the impact of the soil moisture stress factor and CO_2 fertilisation.

References:

- Chen et al. (2018): *Regional to global biogenic isoprene emission responses to changes in vegetation from 2000 to 2015*, JGR, 123, 3757– 3771
- Guenther et al. (2012): *The Model of Emissions of Gases and Aerosols from Nature version 2.1. (MEGAN 2.1): an extended and updated framework for modeling biogenic emissions*, Geosci. Model. Dev. 5(6), 1471-1492
- Hansen et al. (2013) :*High-Resolution Global Maps of 21st-Century Forest Cover Change*, Science Vol. 342, Issue 6160, 850-853
- Li et al. (2018): *Gross and net land cover changes in the main plant functional types derived from the annual ESA CCI land cover maps (1992-2015)*, Earth Syst. Sci. Data, 10, 219-234
- Müller et al.(2008): *Global isoprene emissions estimated using MEGAN, ECMWF analyses and a detailed canopy environment model*, Atmos. Chem. Phys., 8, 1329-134
- Poulter et al. (2011):*Plant functional type mapping for earth system models*, Geosci. Model Dev., 4, 993–1010

TREE COVER DISTRIBUTIONS AND TRENDS

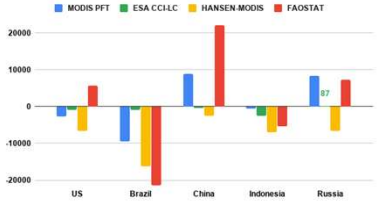
Global TC distributions (in %) and areas (in million km²) for year 2001



→ **FAOSTAT: 40.5 Mkm² (2001)** but FAO provides *FOREST* covers not TC and is based on national inventories.

TC trends for 2001-2015

GLOBAL: MODIS PFT: + 0.55%, ESA CCI-LC: + 0.73%, HANSEN-MODIS: -3.55% and FAOSTAT: -1.12% (forest).

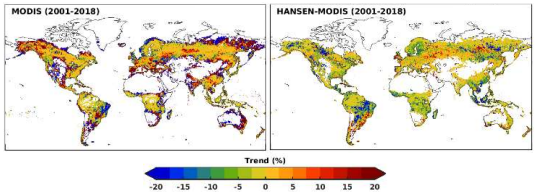


The disparities between the satellite LCLU maps are also seen at country level.

→ **MODIS PFT, ESA CCI-LC and HANSEN are very different products in terms of TC and trends.**
→ **The increasing FAO trends of US tree cover are not found in satellite-based LCLU data.**
→ **A better qualitative agreement is found for Brazil and Indonesia, with negative trends in all datasets.**
→ **In China, only MODIS displays a positive trend, but a factor of 2.5 smaller than the FAO value.**

→ **For the simulations with MEGAN, we will use either HANSEN-MODIS (constrained by the very high-resolution Hansen et al.) or MODIS-PFT, to evaluate the uncertainty associated with LULC distributions and trends.**

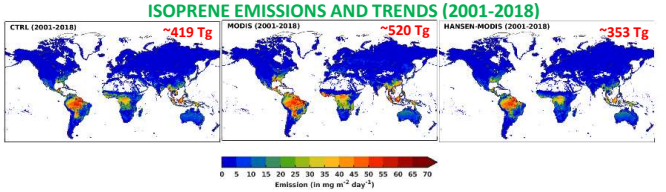
Global and zonal TC trends for 2001-2018



Units: %	MODIS	HANSEN-MODIS
Tropical	-1.5	-5.8
Temperate	2.2	-2.6
Boreal	1.7	-4.4
Global	0.5	-4.6

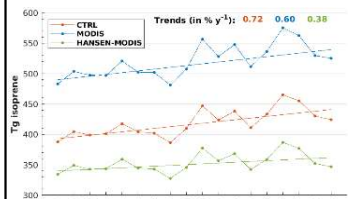
→ **Deforestation is predominant in the tropical regions, but almost a factor of 4 faster in HANSEN-MODIS than in MODIS.**
→ **Afforestation prevalent for MODIS data in the temperate and boreal regions, leading to a small positive global trend.**

ISOPRENE EMISSIONS AND TRENDS (2001-2018)



Compared to the average global isoprene emissions of CTRL (~419 Tg), MODIS global isoprene emissions are +24% higher on average, and -16% lower in the case of HANSEN-MODIS.

Global annual isoprene emission variabilities and trends



→ **Accounting for LULC results in a deceleration of the global isoprene emissions trends by ca. -2% (MODIS) and -5.5% (HANSEN-MODIS).**
→ **In MODIS, the deceleration in the global trends pertains to a negative trend (~1.5%) of the tropical trees. Tropical regions contribute for up to 80% to the global emissions.**
→ **For comparison, Chen et al. (2018) found about -1.5% trend over 2000-2015 due to LULC changes, and mean average emissions ~470 Tg.**

Mean isoprene emissions over 2001-2018

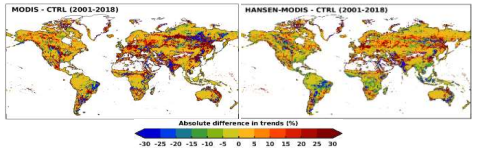
Units: Tg	CTRL	MODIS	HANSEN-MODIS
US	17	26	18
Brazil	85	112	82
China	12.5	23.5	10
Indonesia	31	33	25
Russia	6.5	8.5	7

Isoprene trends over 2001-2018 in % owing to changes in meteorology and/or LCLU

Units: %	CTRL	MODIS		HANSEN-MODIS	
	Met effect	Combined	LCLU effect	Combined	LCLU effect
US	17	17.03	+0.03	13.5	-3.5
Brazil	12	6	-6	3	-9
China	10	14	+4	2	-8
Indonesia	15	13.5	-1.5	3	-12
Russia	14	21	+7	18	+4

→ **The meteorology induces positive trends in the aforementioned regions.**
→ **Both MODIS and HANSEN-MODIS induce declining trends in Brazil and Indonesia due to LULC, and positive trends in Russia.**
→ **In US and China, the trends due to LULC are accelerated according to MODIS, and declining according to HANSEN-MODIS.**

The LULC effect on isoprene emissions trends from MODIS and HANSEN-MODIS for 2001-2018



Compared to Chen et al. (2018), stronger changes (± 25%) in certain regions. Also, no hotspot in West Africa and trends differ for SE US, SE China and South America.

CONCLUSIONS AND FUTURE WORK

Large disparities at global and regional scales in TC cover and trends entail different responses of isoprene emissions and trends. Future work will apply constraints on isoprene emissions from OMI and TROPOMI formaldehyde using the IMAGES CTM (Opacka et al. in prep.)