Deforestation control and its potential air quality co-benefits: South American wildfire emissions reductions

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Introduction

GOAL
- To determine the potential air quality co-benefit brought about by effective deforestation control measures in Northern South America (and subsequent reduction 1 deforestation_related fires).

MOTIVATION
- Biomass burning emissions are a key source of air pollutants in Northern South America, home to more than 160 million people
- Most green house gas emissions in South America come from land use change, which is mainly driven by deforestation of the tropical forest.
- Climate policy commitments in the region include measures to drastically decrease the uncontrolled deforestation of the tropical rainforests.
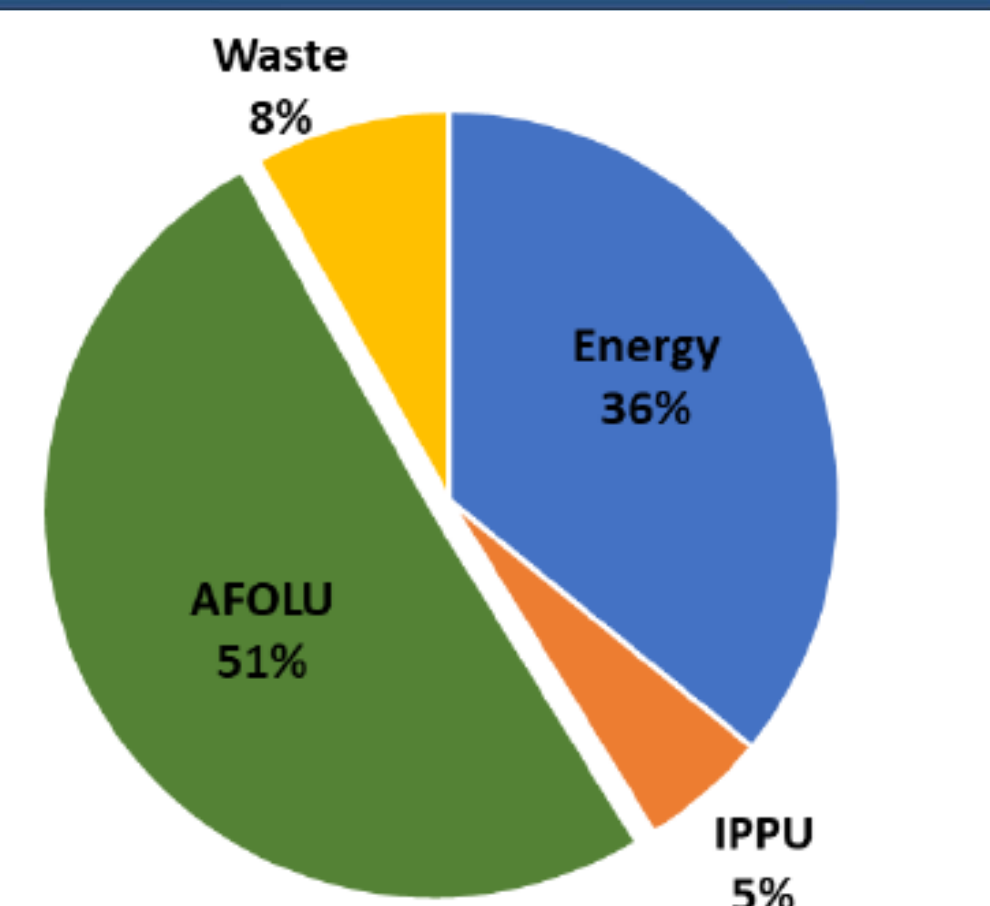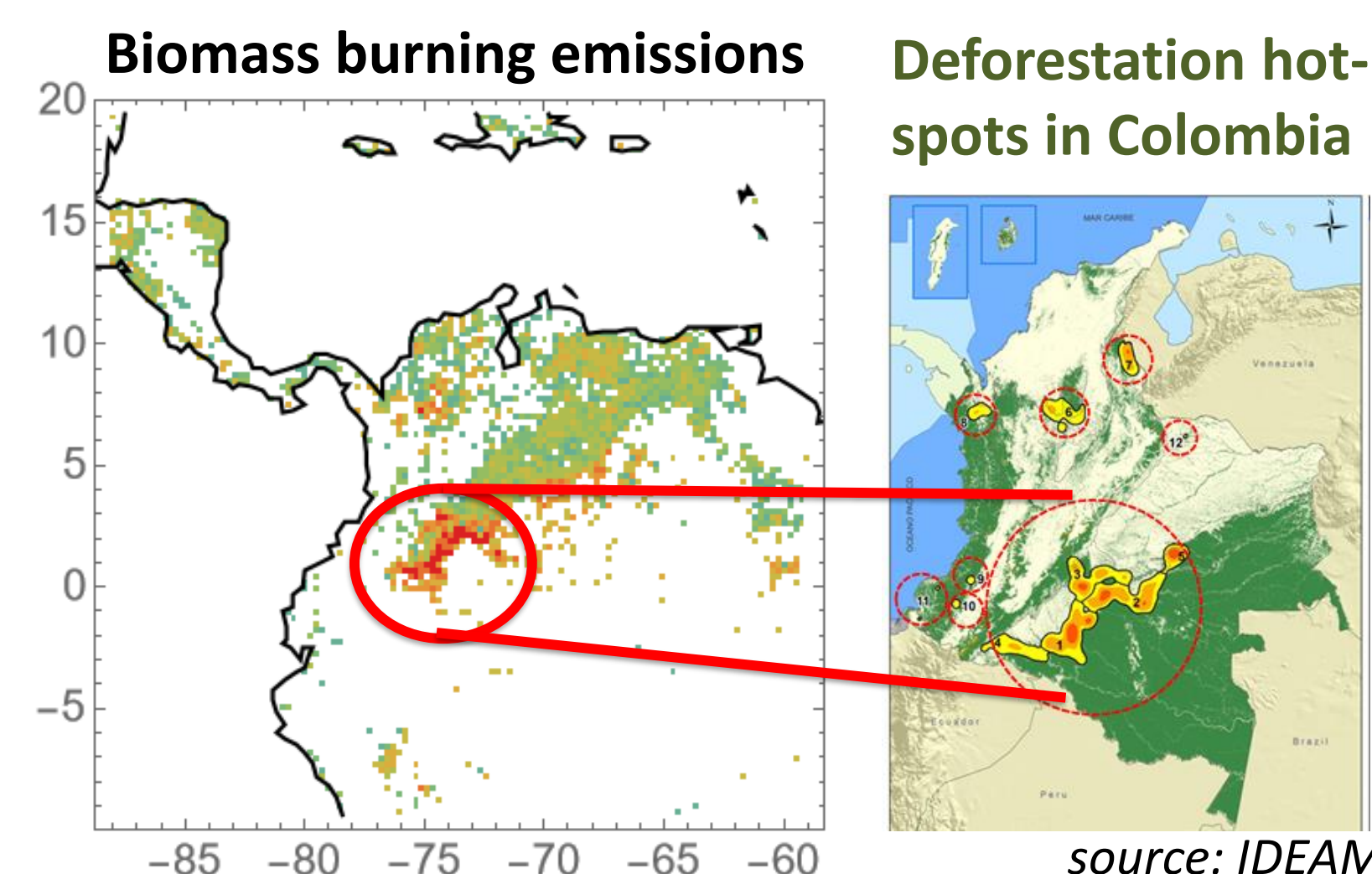

Figure 1. 2030 GHG emissions in Colombia by sector under no-policy scenario. AFOLU accounts for more than 50%.

Methods

1. Area of study

- We focus on the northern part of South America
- The domain is home to some 160 million people
- The amazon rainforest is the main biome in the region, together with the grasslands of the Orinoco river basin

Figure 2. FIRMS hot-spots in Northern South America, and the location of high deforestation-rate zones in Colombia. Most fires in forested areas are linked to deforestation activities

2. WRF-Chem model configuration and experimental design
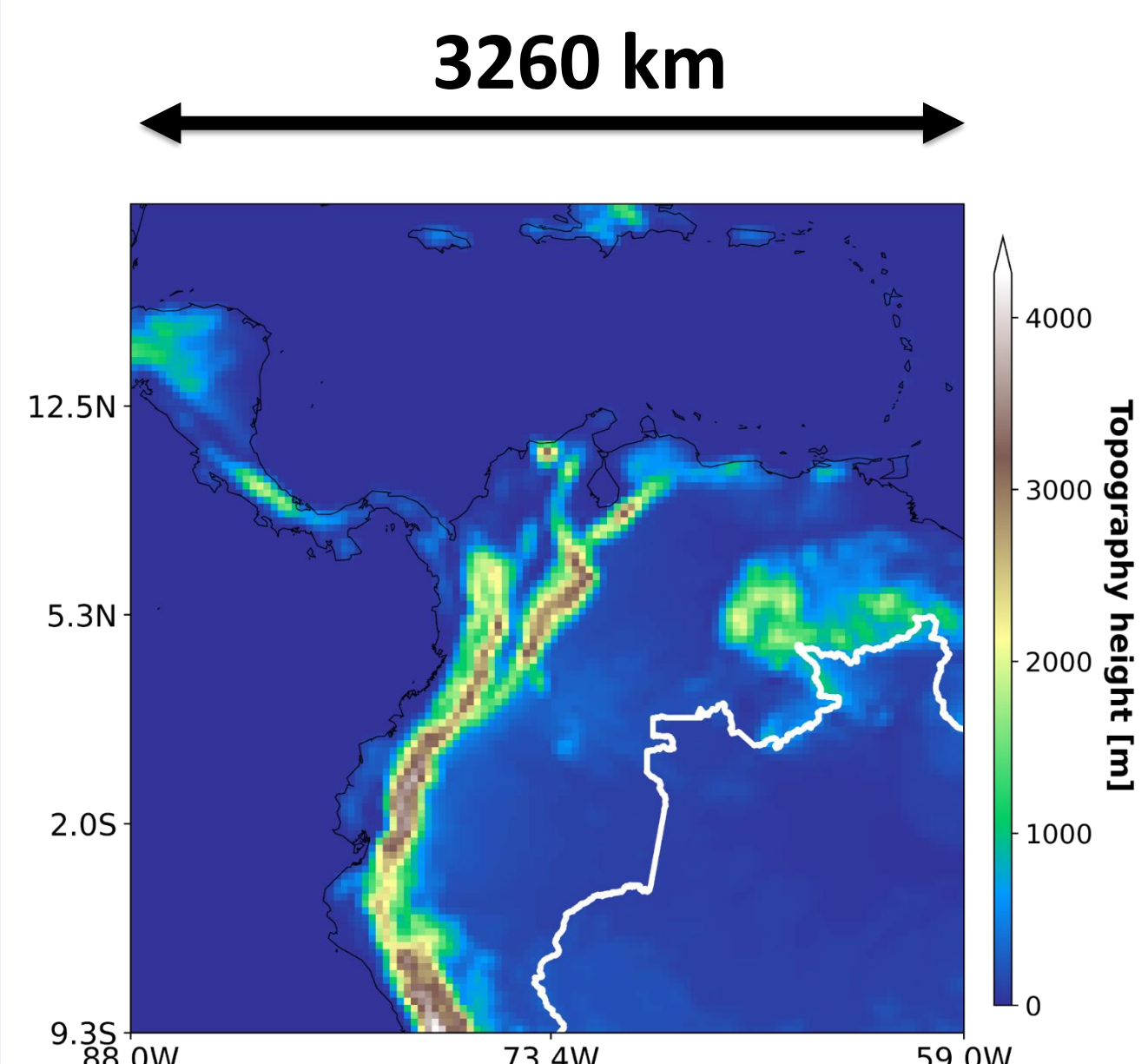
3260 km

The WRF-Chem model was set up in a 3260 km x 3260 km domain in Northern South America

We carried out one year simulations for year 2018 for the following cases:

Control	Base	Only Forests
No BB emissions	All BB emissions	Only BB emissions from forests

- To quantify emissions uncertainty, we utilized two biomass burning emission inventories: FINNv1.5 and GFEDv4
- For the FINN emissions "only forests" the emissions from forests were defined as those from GENVEG categories 3 = tropical forest, 4 = temperate forest, 5 = boreal forest, and 6 = temperate evergreen forests
- For the GFED emission inventory "only forests" was defined as the category *deforestation*

Physics Options	
Microphysics	Lin et al (1983)
LSM	Noah LSM
Cumulus	Grell-Devenyi
Radiation	RRTMG

Chemistry Options	
Aerosols	MADE-VBS
Gas phase Chem.	RACM

Boundary Conditions	
Chemistry	CAM-Chem
Meteorology	FNL (1° x 1°)

Emissions	
Anthorpog.	EDGAR 4.3.1 + Loca
Biogenic	MEGAN
Biomass burning	FINN v 1.5

Results

1. Results

No BB emissions — $PM_{2.5} = 8.6\ \mu g/m^3$
Only forests — $PM_{2.5} = 10.7\ \mu g/m^3$
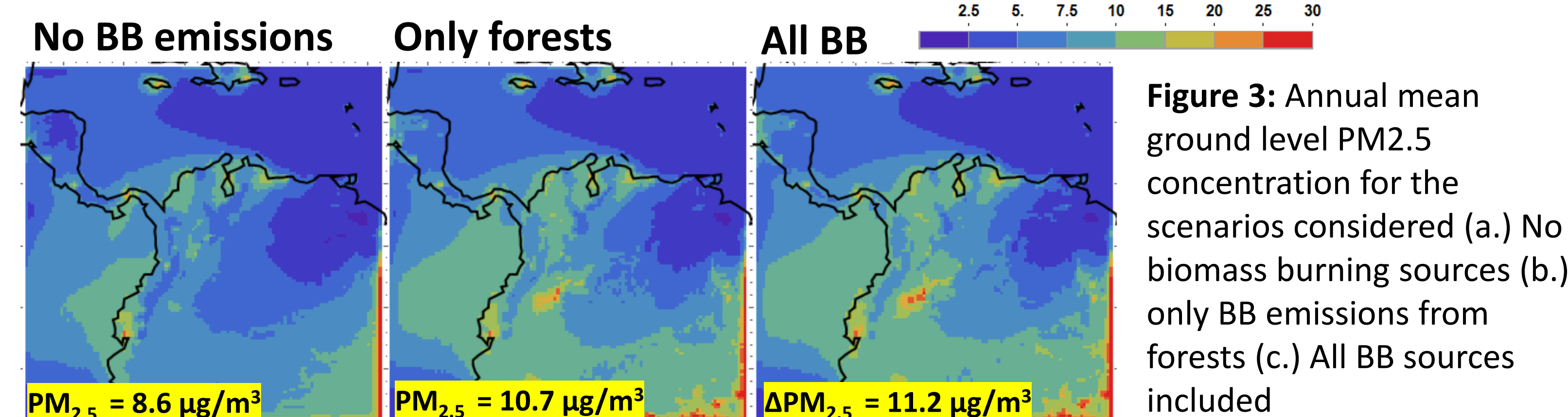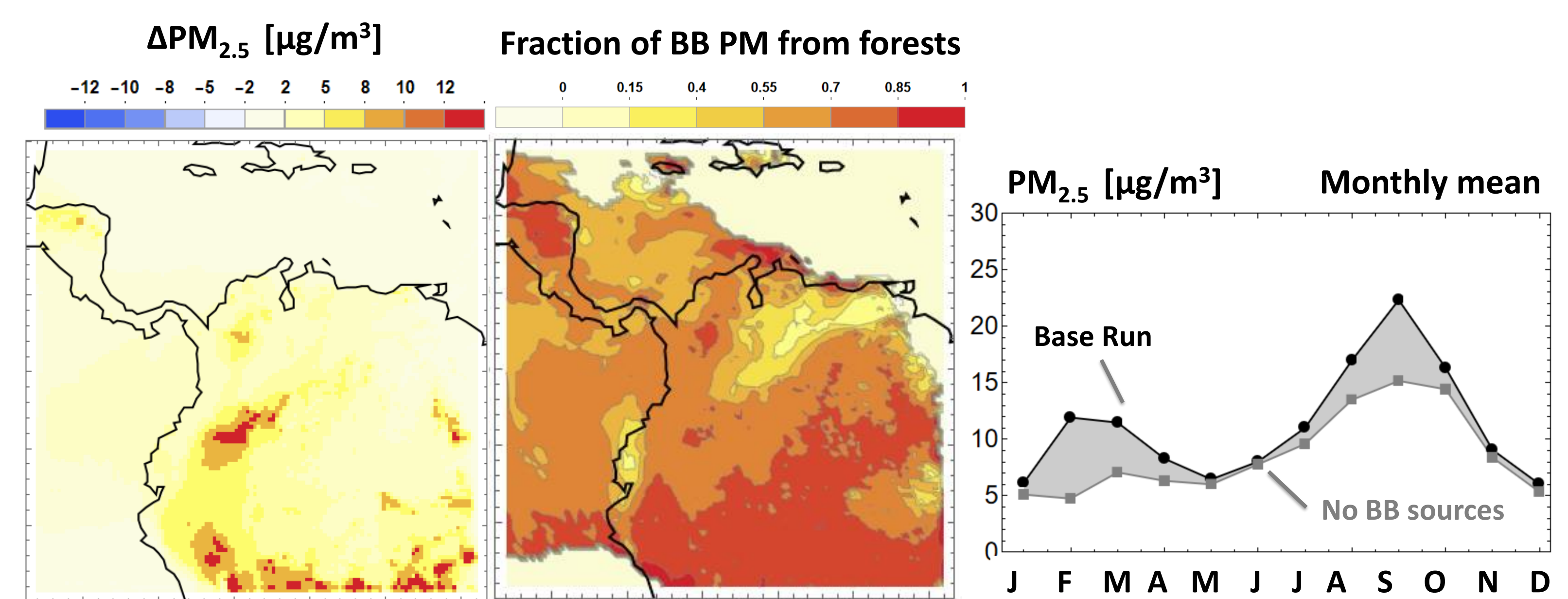**All BB** — $\Delta PM_{2.5} = 11.2\ \mu g/m^3$

Figure 3: Annual mean ground level PM2.5 concentration for the scenarios considered (a.) No biomass burning sources (b.) only BB emissions from forests (c.) All BB sources included

$\Delta PM_{2.5}$ [$\mu g/m^3$]

Fraction of BB PM from forests

$PM_{2.5}$ [$\mu g/m^3$] **Monthly mean**

Base Run

No BB sources

J F M A M J J A S O N D

- The contribution of BB emissions from forests to $PM_{2.5}$ is significant (2.1 µg/m³ annual mean).
- There are two peaks in activity (Feb-Mar and Sep-Oct)
- According to the FINN emission inventory, most of the $\Delta PM_{2.5}$ attributable to BB comes from forests

3. Estimated impact on mortality: short- and long-term exposure

- We utilized a concentration response function to estimate the impact on all-cause mortality associated to short- and long-term exposure to $PM_{2.5}$ attributable to BB from forests
- Our estimates indicate some +5000 excess deaths that could be avoided by effective deforestation related fire control
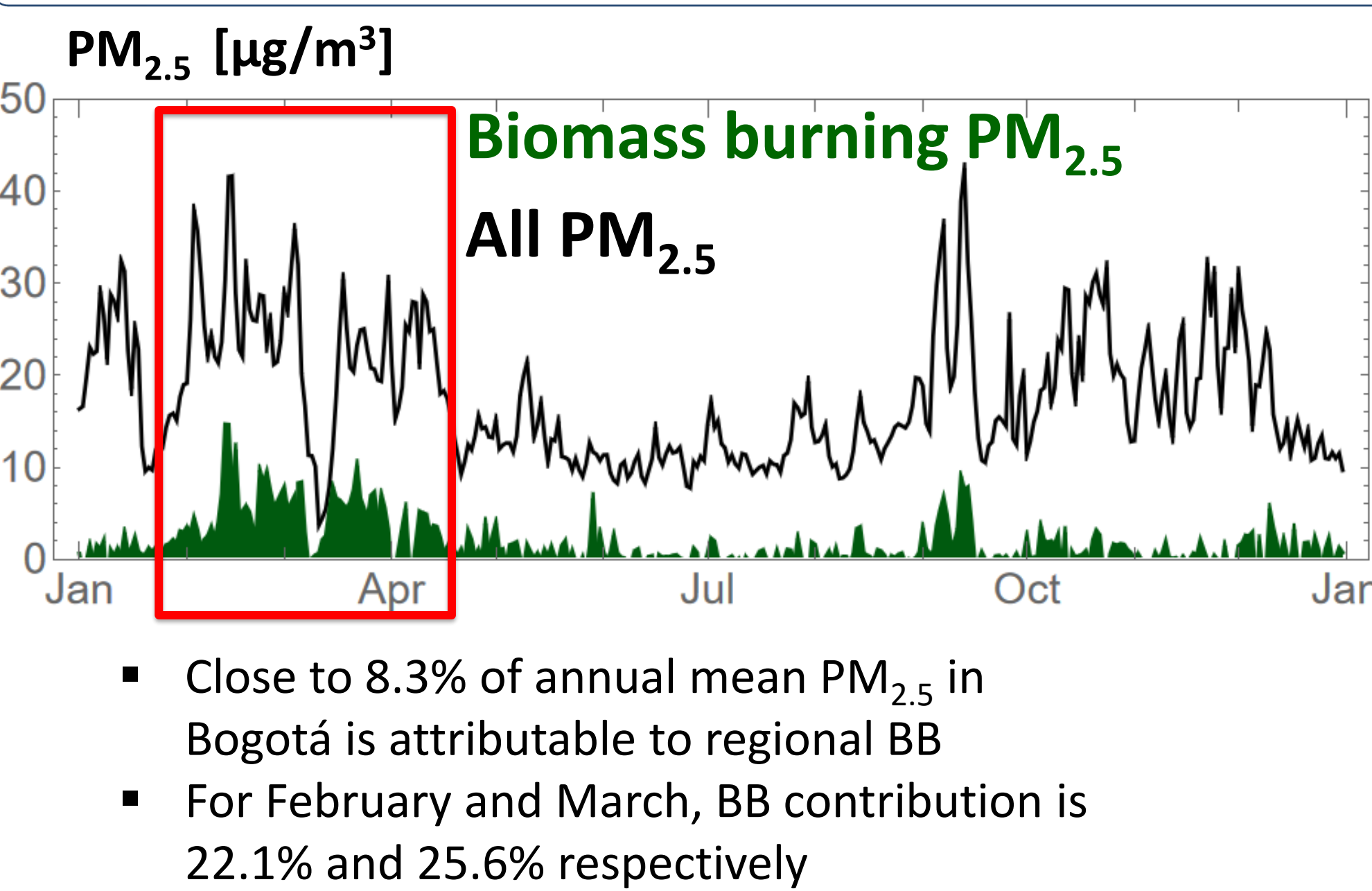
$$\Delta y = y_0 (1 - e^{-\beta\ \Delta PM_{2.5}})$$

$\beta_{24h} = 0.68\ \%/10\mu g m^{-3}$
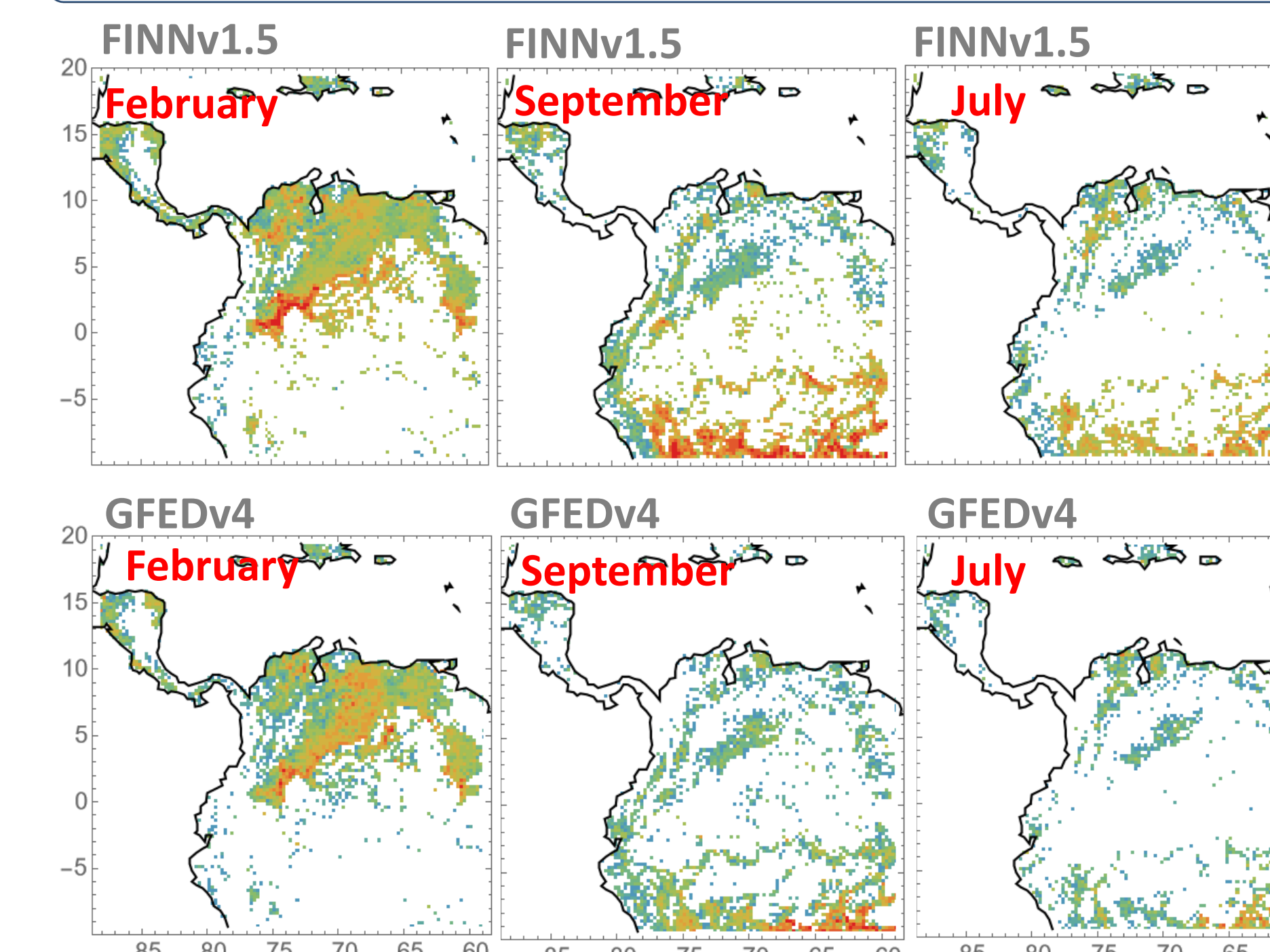$\beta_{long-term} = 8.0\ \%/10\mu g m^{-3}$

excess deaths
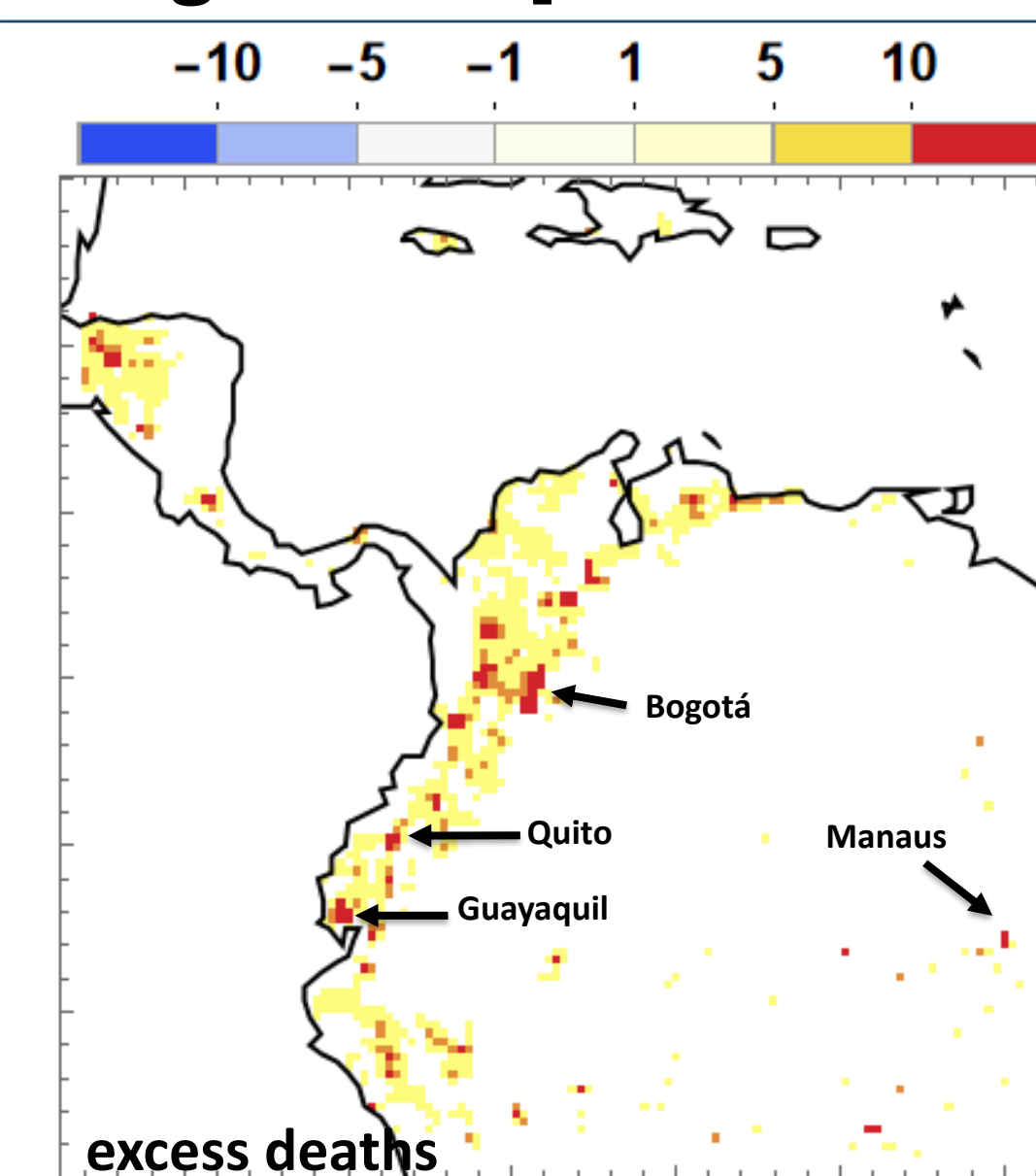
4. Biomass burning contributes substantiall $PM_{2.5}$ even in urban centers

$PM_{2.5}$ [$\mu g/m^3$]

Biomass burning $PM_{2.5}$
All $PM_{2.5}$

Jan Apr Jul Oct Jan

- Regional biomass burning emissions contribute substantially to particulate and ozone pollution in the city of Bogota
- Local emission reduction strategies could still have a large positive impact in air quality improvement

- Close to 8.3% of annual mean $PM_{2.5}$ in Bogotá is attributable to regional BB
- For February and March, BB contribution is 22.1% and 25.6% respectively

Results

Discrepancies across biomass emission inventories

FINNv1.5 February — FINNv1.5 September — FINNv1.5 July
GFEDv4 February — GFEDv4 September — GFEDv4 July

Annual mean BC emissions
- FINN v1.5: 130,000 ton_BC/yr
- GFEDv4:   68,000 ton_BC/yr

Percent of emissions from forests
- FINN v1.5: 85%
- GFEDv4:   42%

- There are large discrepancies in the total emissions from biomass burning across emission data sets
- Emission inventories give substantially different estimates of the spatial distribution and the split between emissions from grasslands vs. forests is also

Ongoing work

All BB — **Only forests**
Sep. — Sep.
GFED — GFED
Feb. — Feb.
GFED — GFED

- Extending the modeling domain to include the whole Amazon rain forest and to use higher spatial resolution (9km x 9km)
- Establishing a methodology to determine the fraction of fires that are directly attributable or related to deforestation activity
- Quantifying the uncertainty in health outcomes and mortality from the discrepancies in BB emission estimates from forested areas
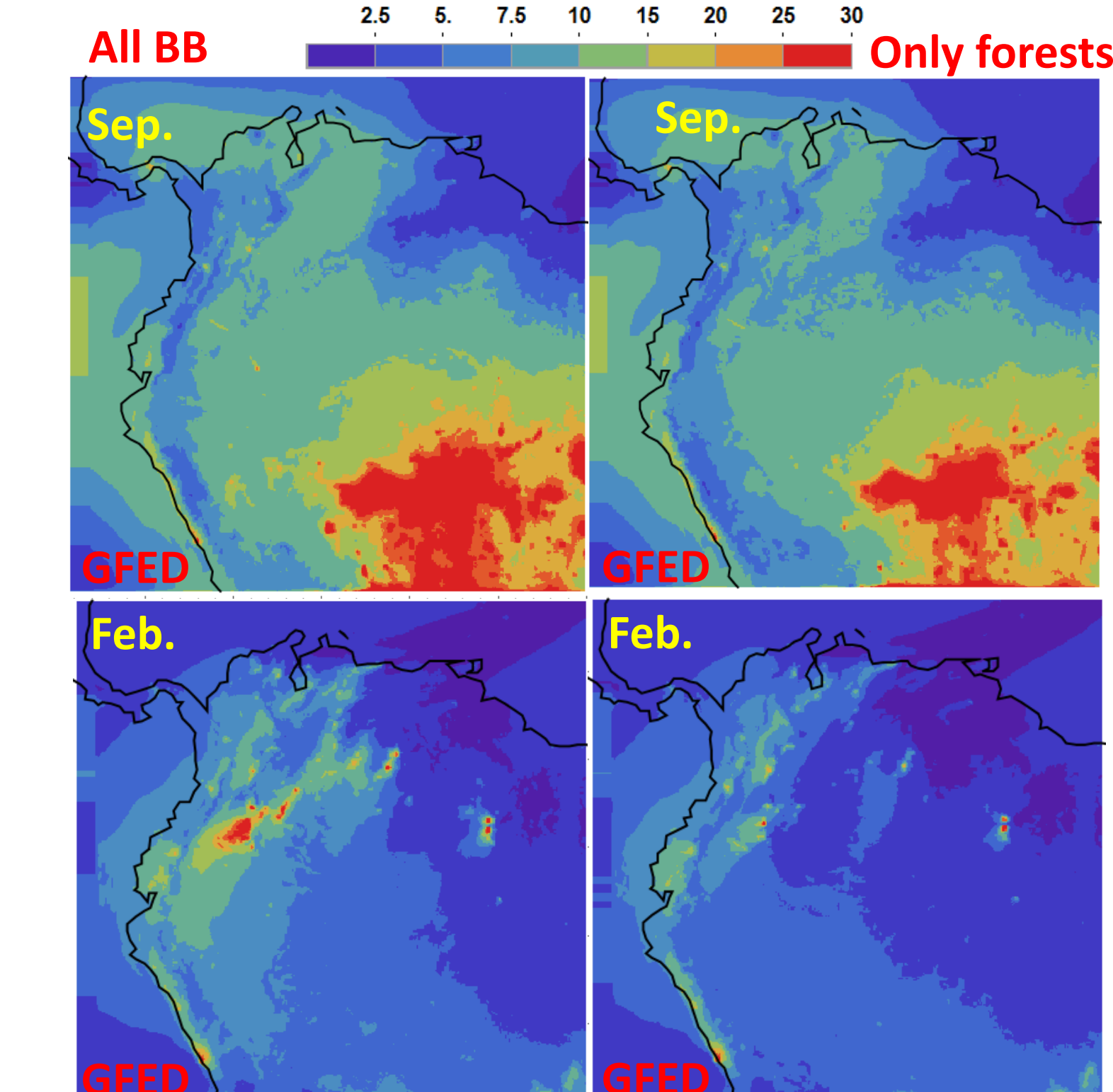
Concluding remarks

- Our work suggests that the air quality co-benefits from reducing deforestation and deforestation related fires could be substantial (despite the large uncertainty in BB emissions and in the fraction of fires directly related to deforestation).
- Despite the large differences in emission estimates across inventories, the potential air quality co-benefits of effective deforestation control are still significant
- Ongoing work is focusing on determining what fraction of fires in the tropical rainforest can be directly attributable to deforestation activities.

Acknowledgements

References

Andela, N., Morton, D. C., Schroeder, W., Chen, Y., Brando, P. M., & Randerson, J. T. (2022). Tracking and classifying Amazon fire events in near real time. Science advances, 8(30), eabd2713