

Quantifying Climate-driven Changes in Toxic Air Pollution from Wildfires

From Knowledge
to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal
Program



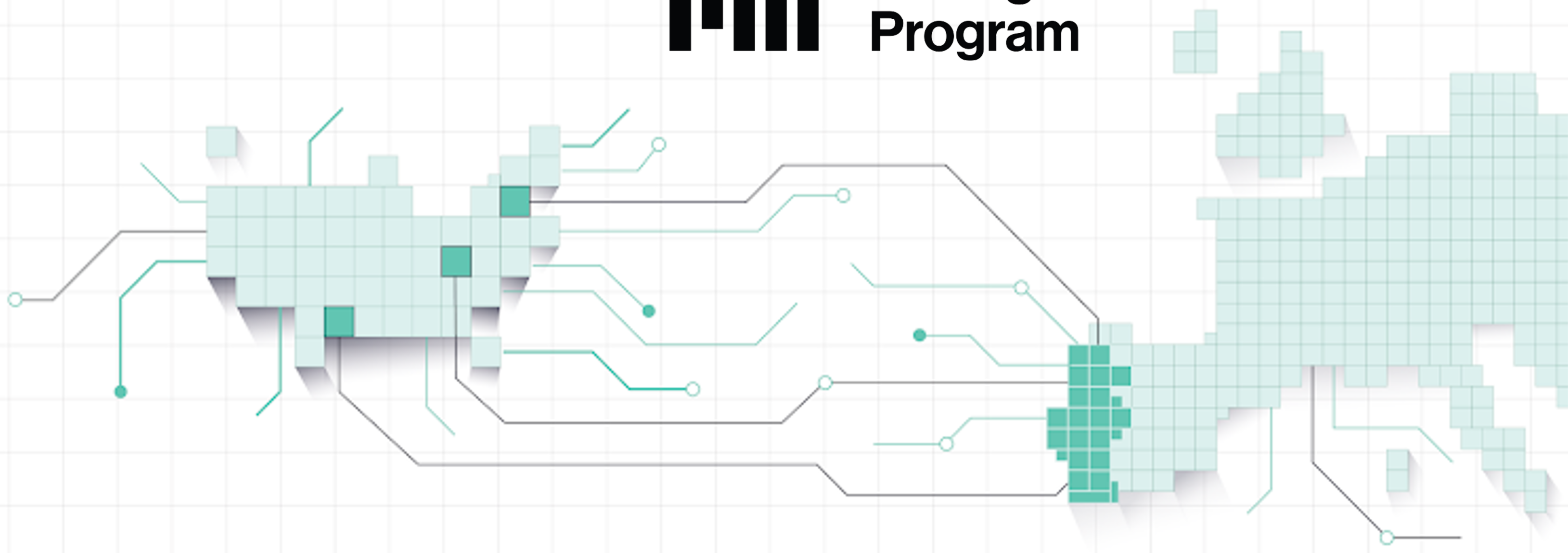
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Climate Science and Climate Change

Introduction

Wildfires are expected to become more frequent and intense in many parts of the world as the climate warms. This has important implications for fire-prone regions such as Portugal. Among these concerns is the potential impact on human health, as wildfire smoke contains a complex mixture of harmful pollutants. This includes the emission of mercury (Hg) and polycyclic aromatic hydrocarbons (PAHs). Hg can bioaccumulate in aquatic food webs and pose neurotoxicological risks to humans, while PAHs are known to cause cancer. To better understand the impacts of fires on exposure to toxic species, we can use an atmospheric model to simulate the emissions, transport, and chemistry of Hg and PAHs under current and future environmental conditions.

Mercury (Hg) cycling

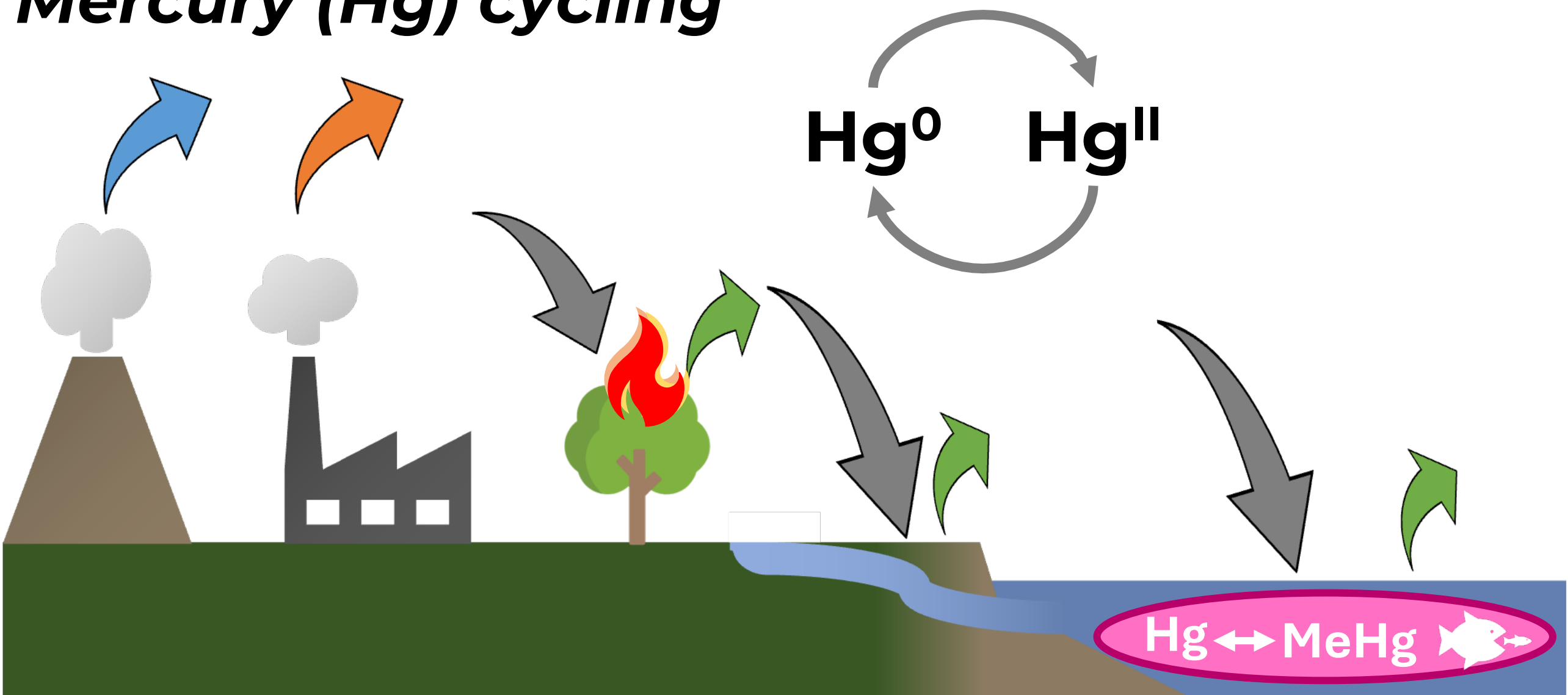


Figure 1: The environmental cycling of Hg depends on both modern day emissions and the reemission of historical pollution. Hg poses risks to the environment and humans through the bioaccumulation of methyl-Hg (MeHg) in aquatic ecosystems.

Polycyclic Aromatic Hydrocarbon (PAH) cycling

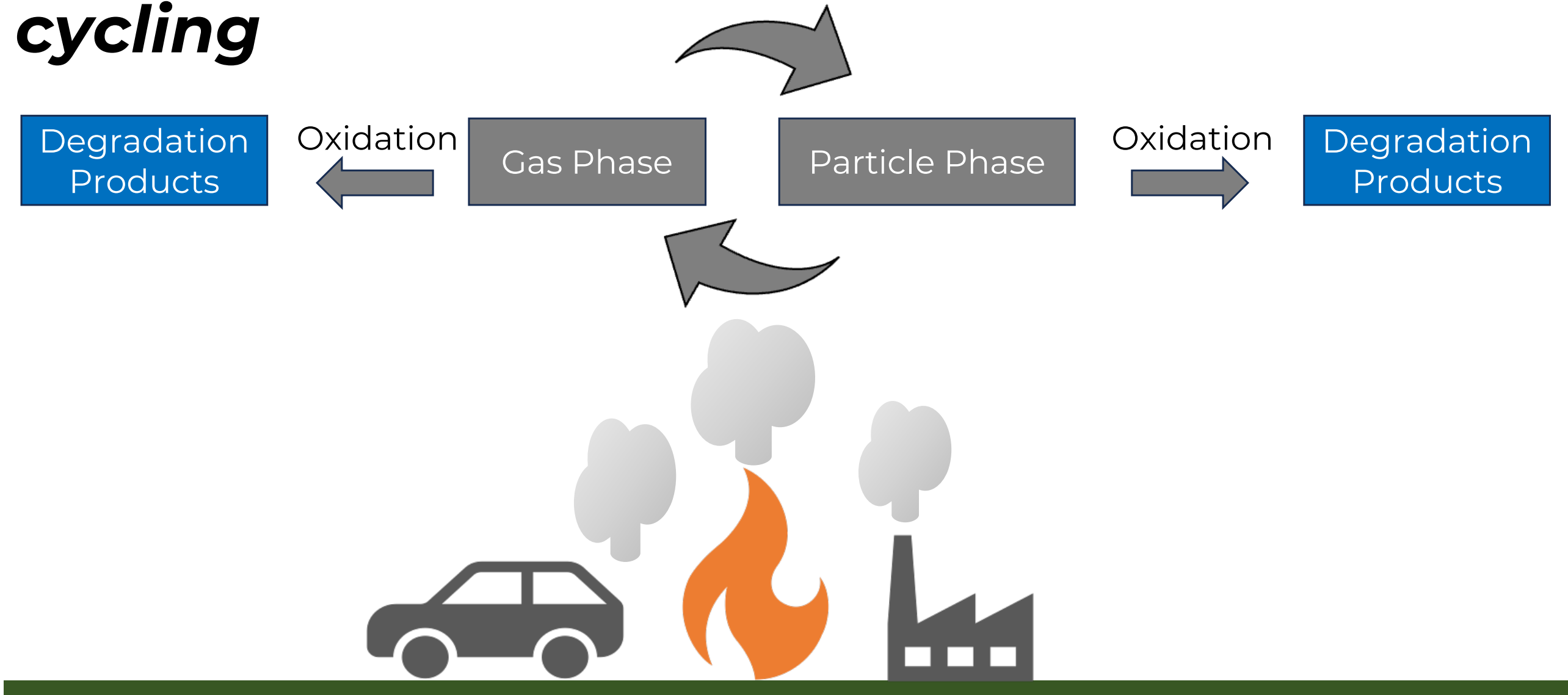


Figure 2: PAHs are emitted from incomplete combustion, and in the atmosphere partition between the gas and particle phases and undergo chemical reactions to form degradation products. PAHs are carcinogenic, and inhalation provides a pathway for human exposure.

How do we estimate future wildfire toxic emissions?

Future wildfire emissions will depend on future climatic conditions, which depend on future human activity (Figure 3). Climate scientists have devised an array of future storylines of future human activity and economic development (Shared Socioeconomic Pathways, or SSPs). These assumptions are used to drive simulations of climate models that predict future environmental conditions based on the SSPs, including the activity of wildfires. Finally, we estimate wildfire emissions of PAHs and Hg by scaling simulated wildfire activity by literature-derived ratios of Hg and PAHs emitted for a given amount of biomass burned.

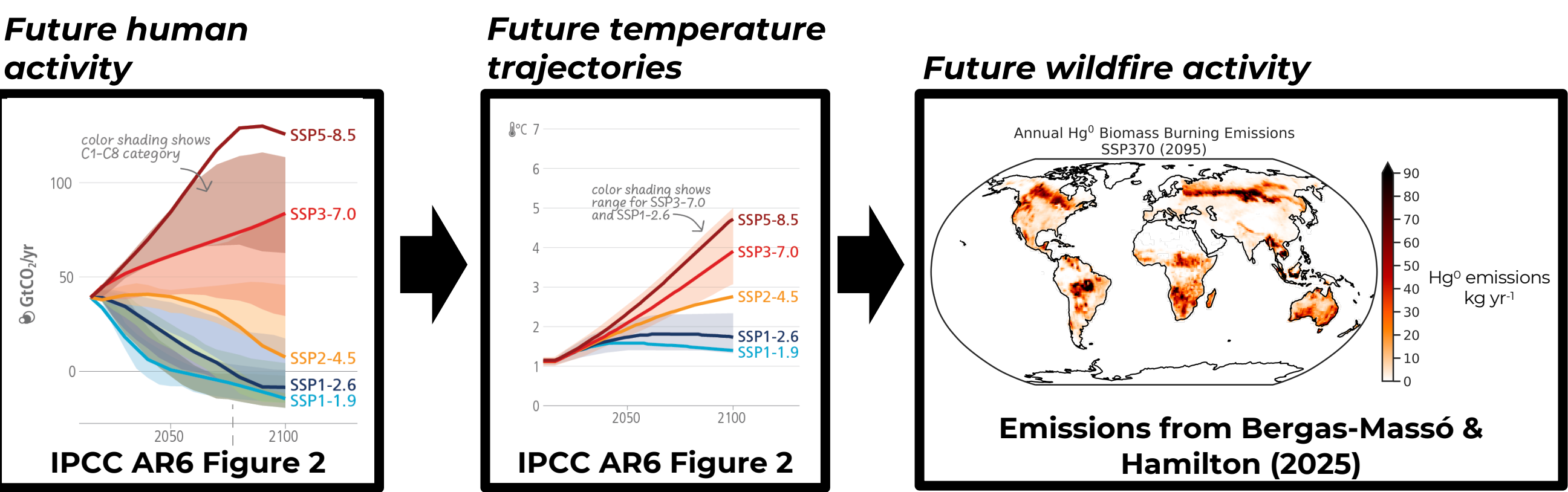


Figure 3: Estimation of future biomass burning emissions of PAHs and Hg requires assumptions about future human activity (left panel), which is used to simulate future environmental trajectories in climate models (e.g., temperature, middle panel). A subset of climate models also simulates the future wildfire activity as a function of environmental conditions, which can then be scaled by literature-derived Hg and PAH emission factors to estimate emissions (right panel).

Results

2017 PAH biomass burning emissions

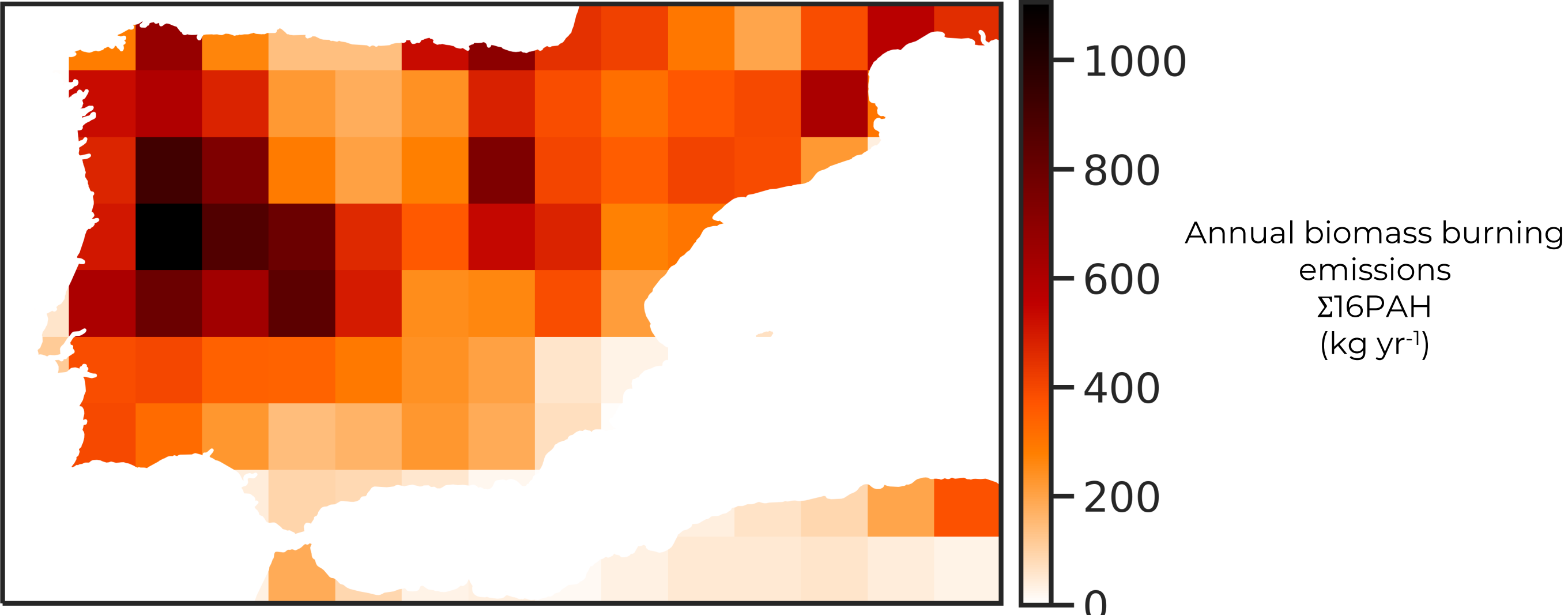


Figure 4: Annual biomass emissions of PAHs in 2017 across the Iberian Peninsula.

Lower warming (SSP-245) Higher warming (SSP-370)

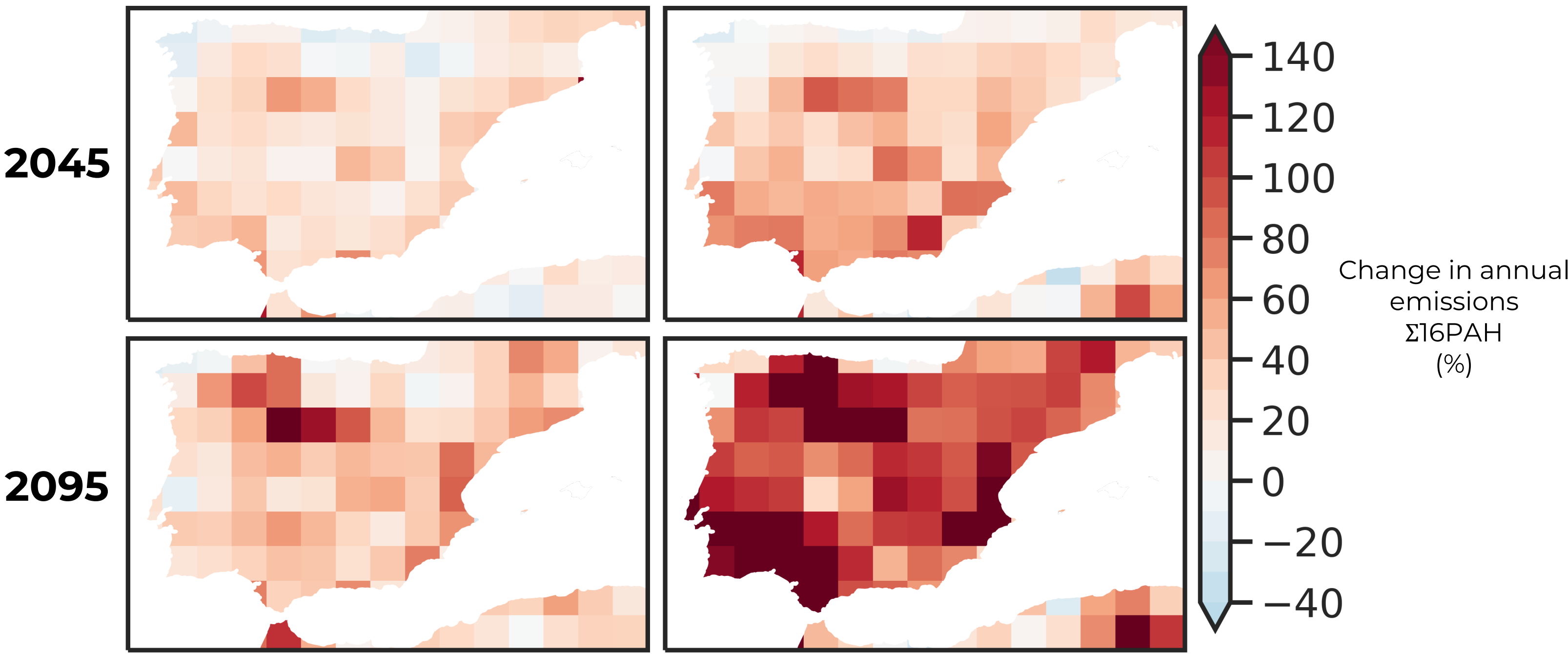


Figure 5: Difference in biomass burning emissions under lower warming (left column) and higher warming scenarios (right column) in 2045 (top row) and 2095 (bottom row) with respect to present day emissions shown in figure 4.

Conclusion: Estimates show that wildfires and their resulting emissions will increase in Portugal in the future. The magnitude of this increase depends on human choices about future activity and economic development.

Future Work

- Ongoing efforts will leverage the expertise of both the MIT and University of Aveiro teams:
- GEOS-Chem **global** chemical transport model will be used to simulate the chemical evolution and transport of future wildfire emissions of PAHs and Hg (MIT).
- **Regional** chemical transport model (e.g., WRF CHIMERE) will be used to evaluate the loss of information from coarse model (University of Aveiro).
- Annual controlled burn field campaign will help constrain model inputs and connect model output to local impacts (both teams).

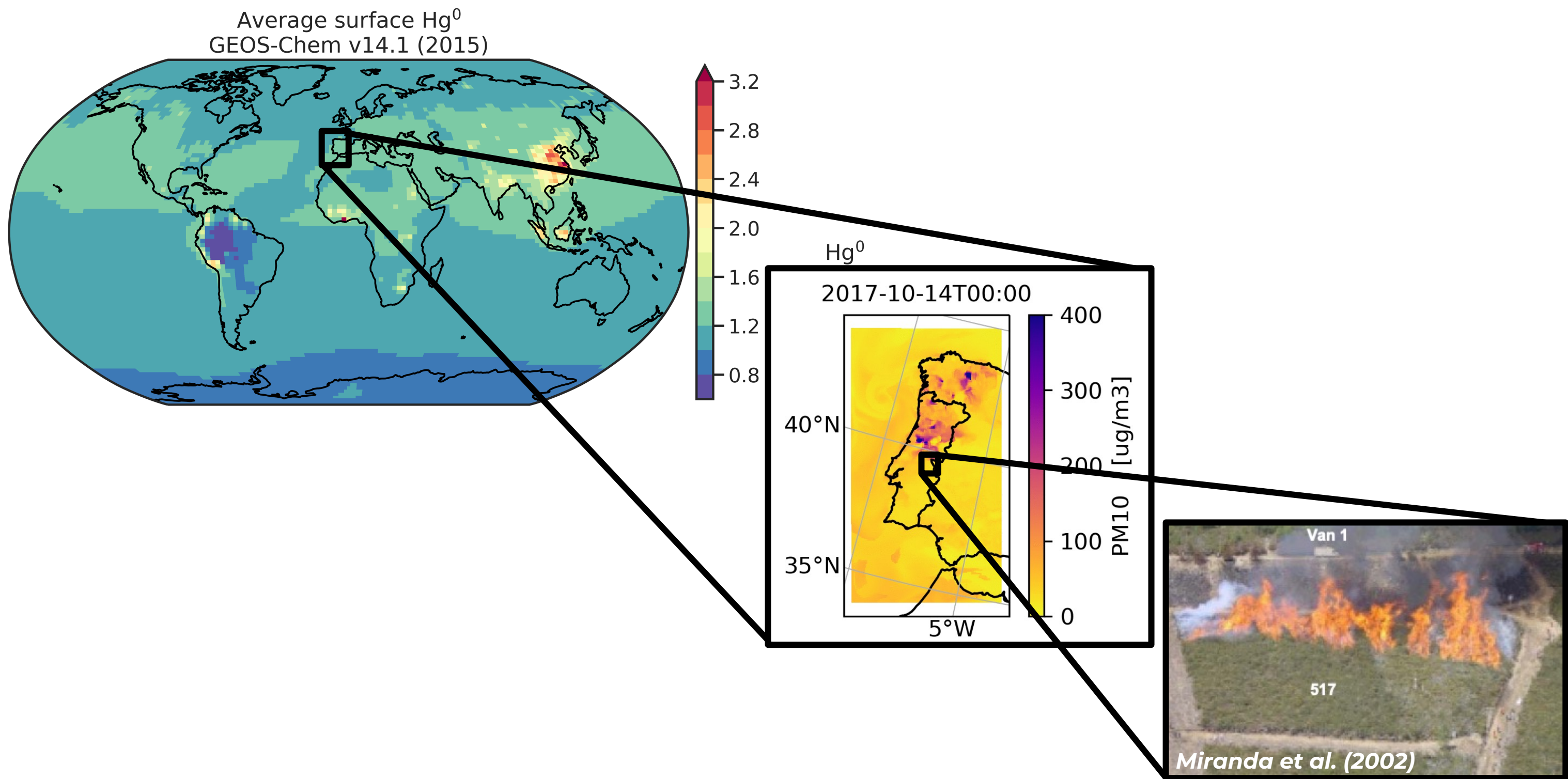


Figure 6: Future and ongoing research activity by MIT and University of Aveiro teams seeks to quantify wildfire impacts by quantifying relationships between global atmospheric models (left), regional atmospheric models (middle), and direct measurements of regionally representative wildfire emissions (right).

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