Co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe

Impact of revised canopy model on BVOC emissions and ozone in EMEP

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TFMM, Beld, 5th-7th May 2025

UNECE

Convention on Long-range Transboundary Air Pollution

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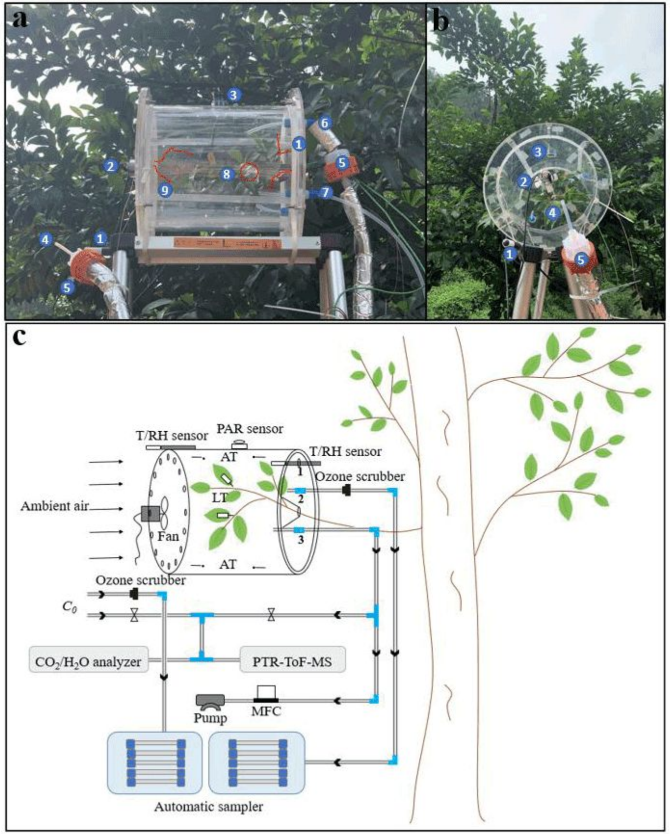
BVOC Temperature Dependence



- Species specific emission factors are typically derived from chamber or cuvette measurements
  - These measurements are needed to isolate emission factors but modify the environment
- Guenther et al., 1993 algorithm is based on leaf temperature
- CMIP6 intercomparison found variability between canopy processes and emission factors (Do et al., 2025)
- Here a simple canopy model is developed for leaf temperature for BVOC emissions in EMEP

Zheng et al., 2022

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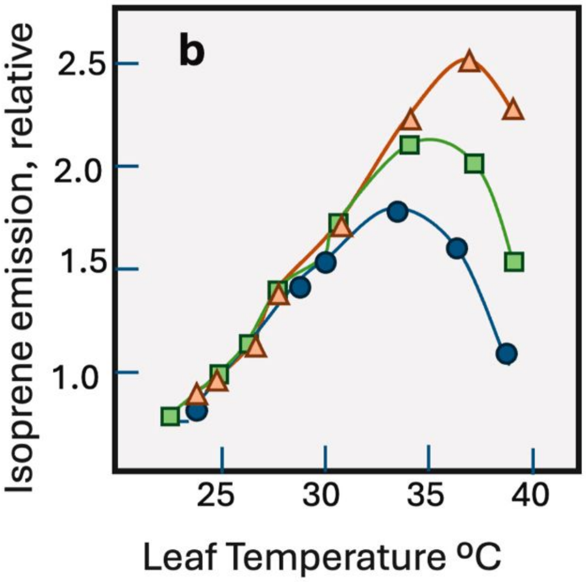
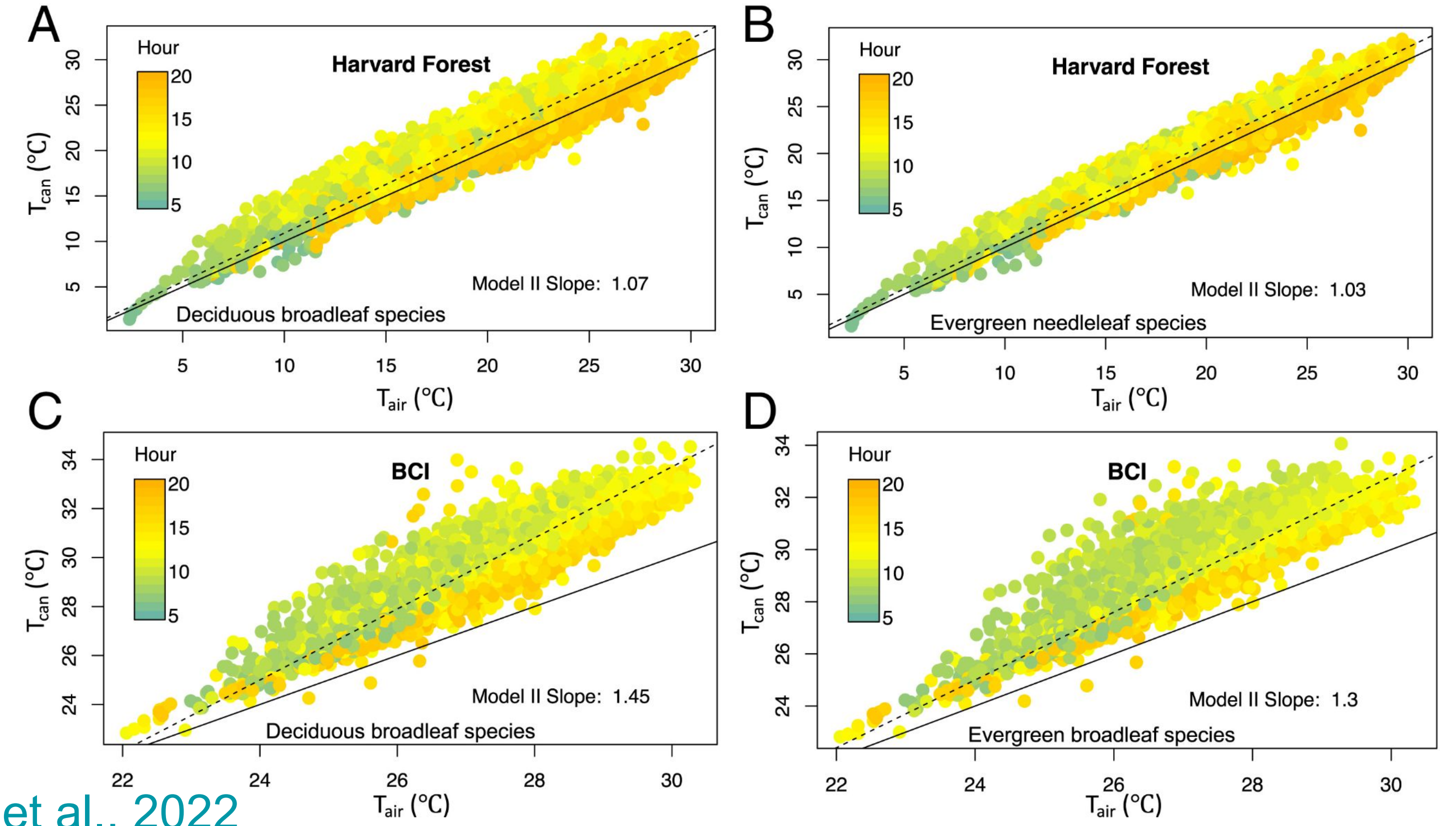
Why does it matter?



- BVOC emissions increase exponentially with temperature
  - Exponential up to approximately 30°C for isoprene and light dependent monoterpenes
- Leaf temperatures can be more than ± 10° C than the air temperature
- Implemented in MEGAN (Guenther et al., 2012) and BEIS BVOC (Bash et al., 2016) models

Sharkey et al., 2026

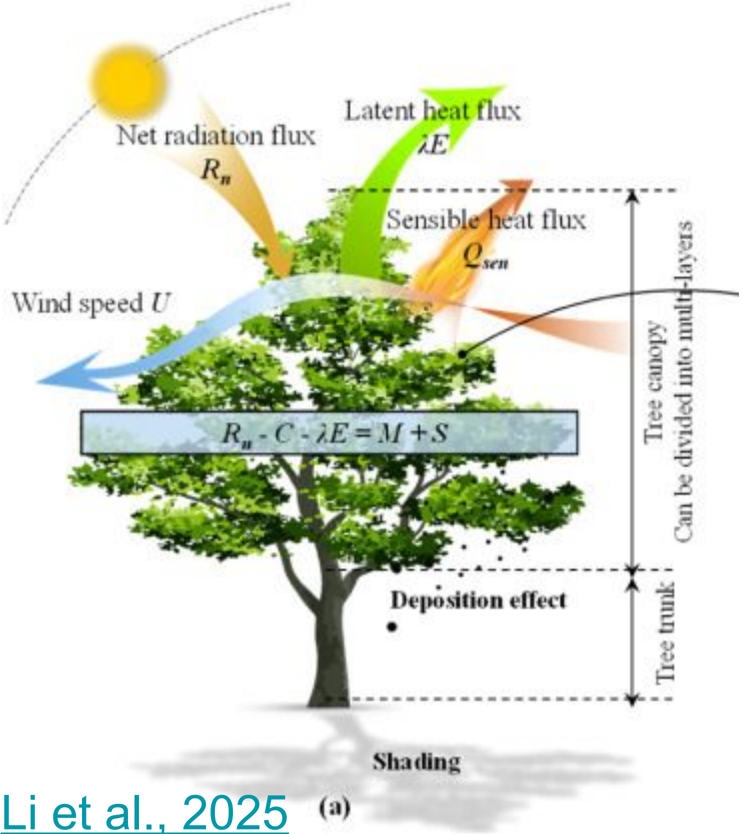
Leaf Temperature Versus Air Temperature



Still et al., 2022

Leaf Temperature Estimates

- Estimated from the surface energy balance
  - MEGAN utilizes its own surface energy balance
  - BEIS coupled to meteorological model
- Highly dependent on land use
  - Small differences in parameterizations can result in large differences in estimates
- This work takes an intermediate approach and applies the intrinsic biophysical mechanism (IBM) proposed by Lee et al., 2011
  - CTM: aerodynamic resistance and land use
  - Meteorological model: Bowen ratio, and incoming solar radiation



Li et al., 2025

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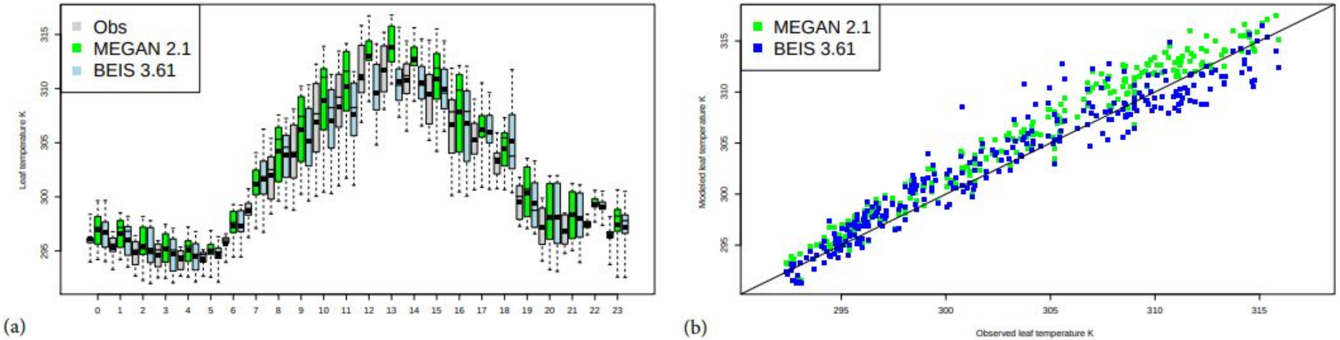
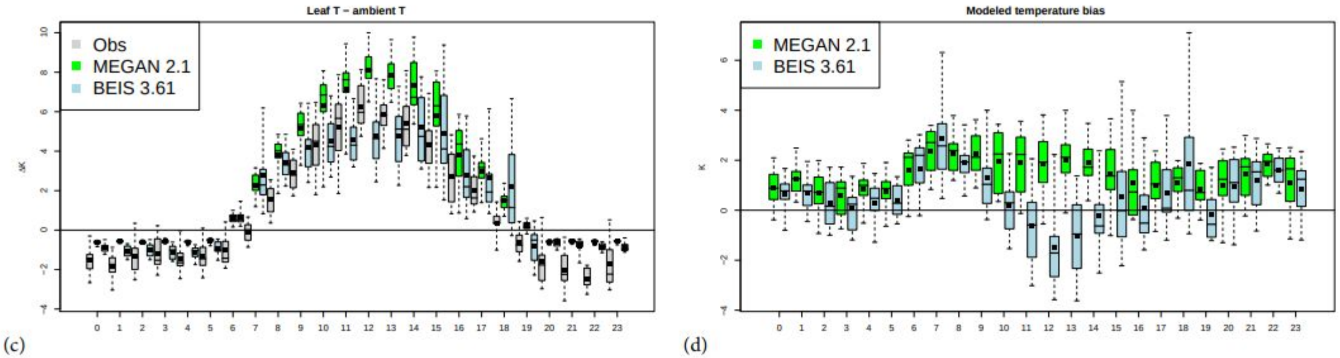
MEGAN and BEIS



Bash et al., 2016



Modeled from observations over a managed grass field at Duke Forest, NC, USA

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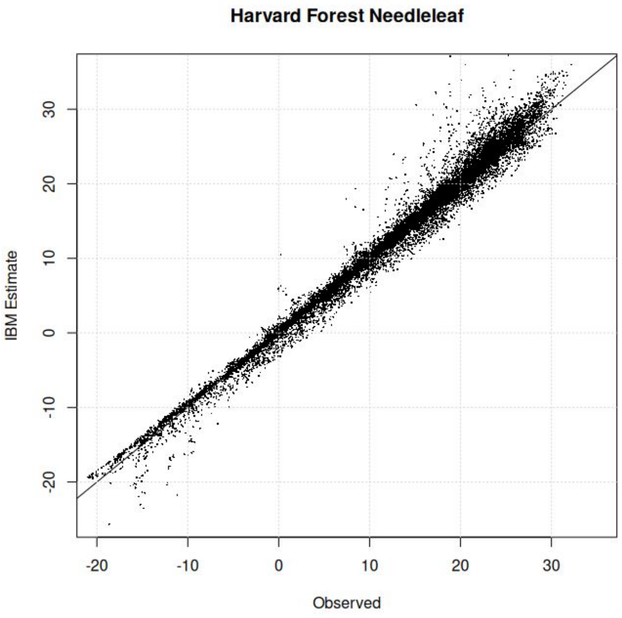
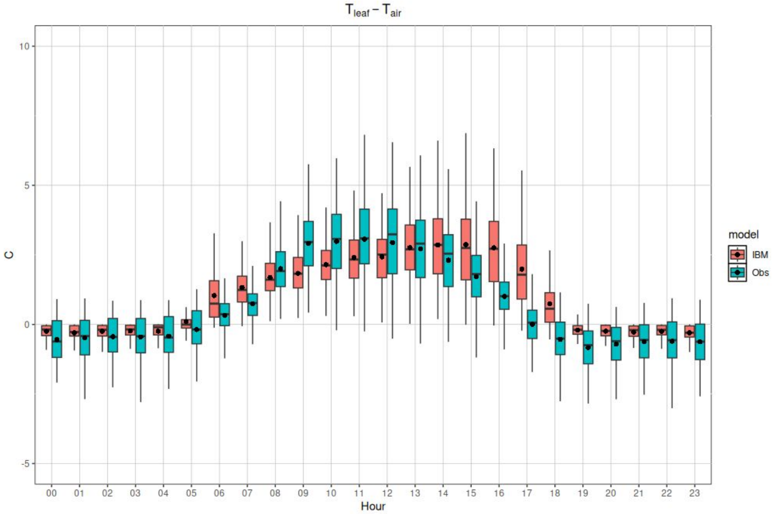
Evaluation of IBM Leaf Temperature Estimates





ΔT	BDLF	NDLF
NMB	-29%	34%
RMSE	1.74 C	1.48 C
R	0.446	0.400

Data from Still et al., 2022

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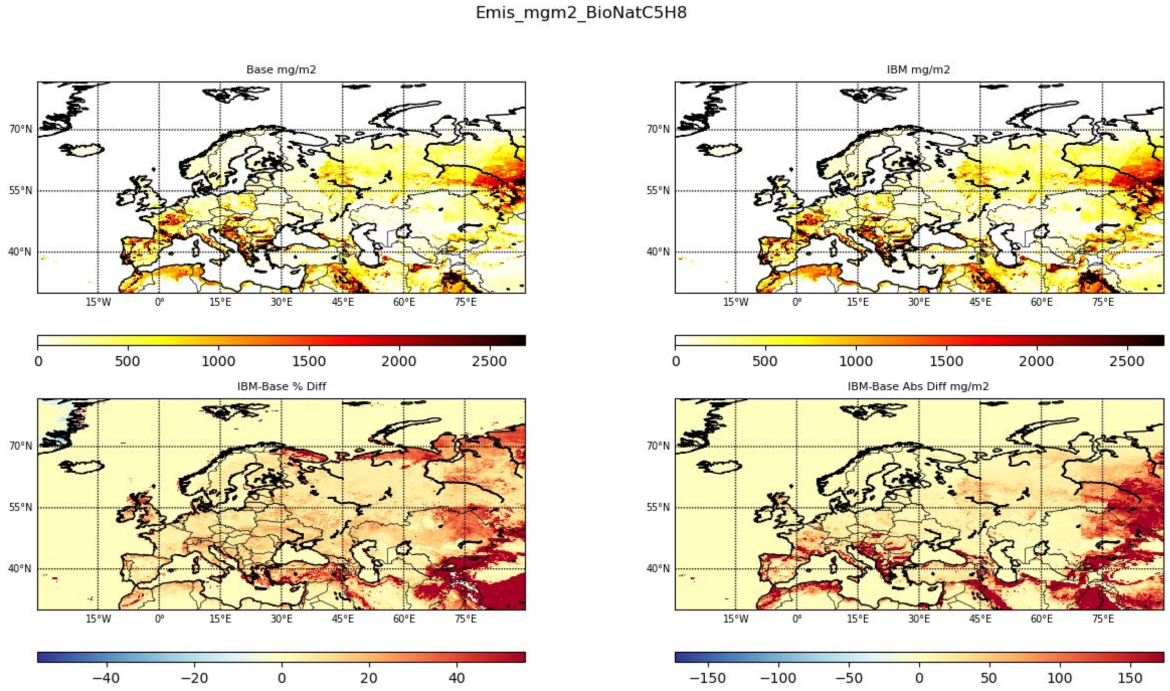
Leaf Temperature Impact on Isoprene Emissions

- Isoprene emissions increased approximately 16% in the domain
  - Largest absolute increases predominantly in the Mediterranean and warm climates
- Monoterpene emissions increase by approximately 4%
  - Smaller absolute change due to nighttime radiative cooling
- Global differences are larger as the largest isoprene emitting regions are outside of Europe



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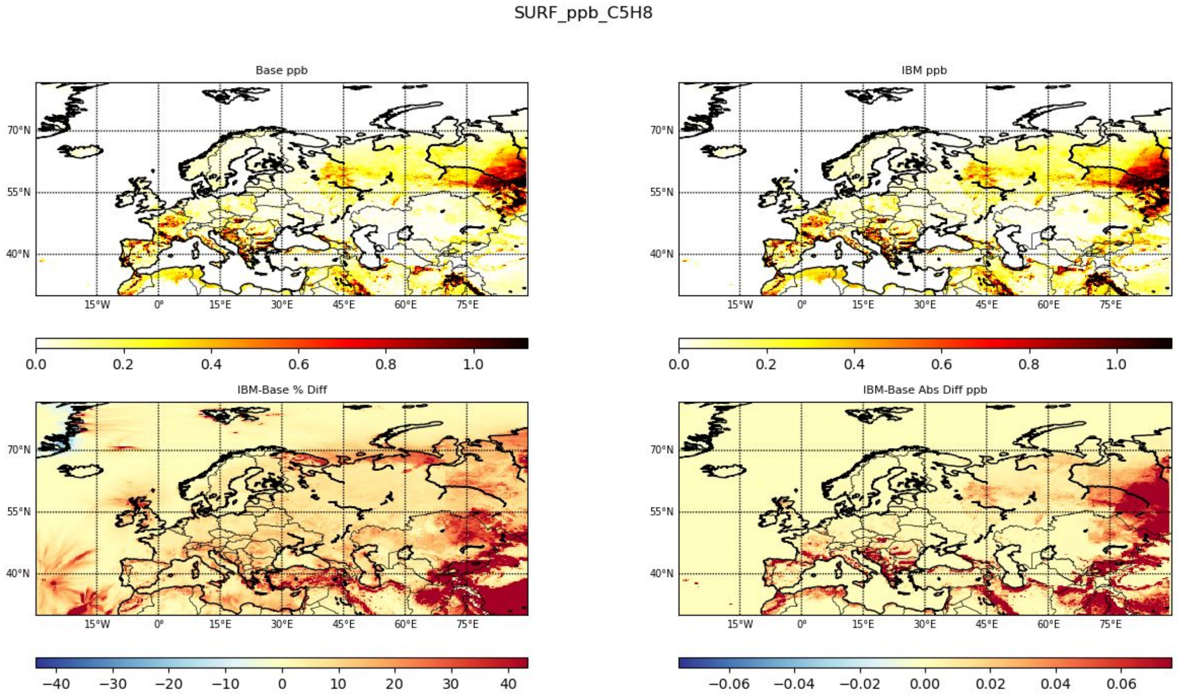
Leaf Temperature Impact on Isoprene Concentrations

- Isoprene concentrations increased by approximately 17%
- Isoprene emissions increases largely follow the change in emissions
- Much smaller impact in terpene emissions (~1%) and concentrations
  - Isoprene is only emitted during the daytime
  - Terpene is temperature dependent and impacted by nighttime radiative cooling



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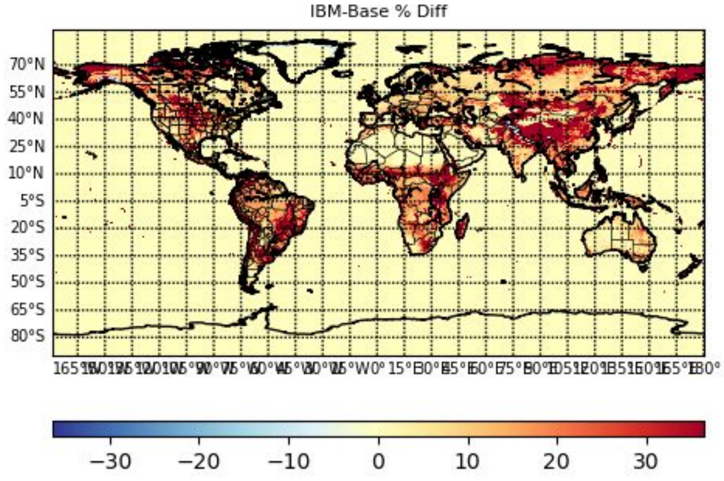
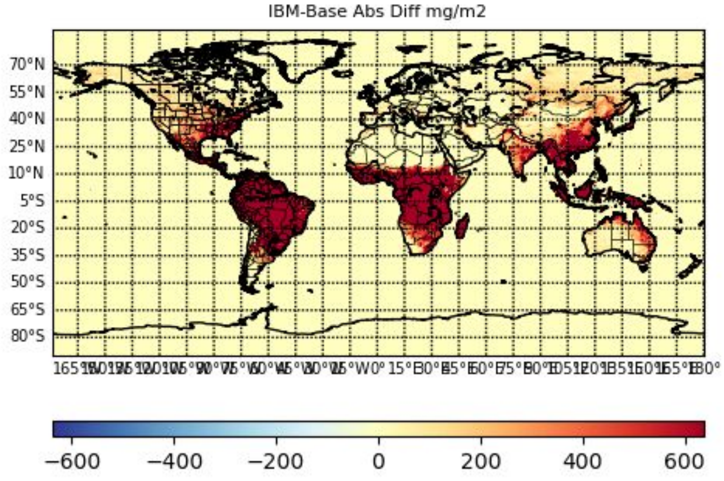
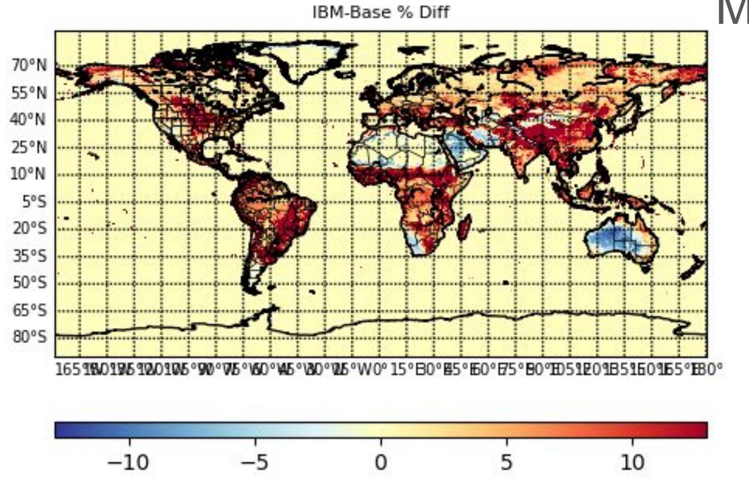
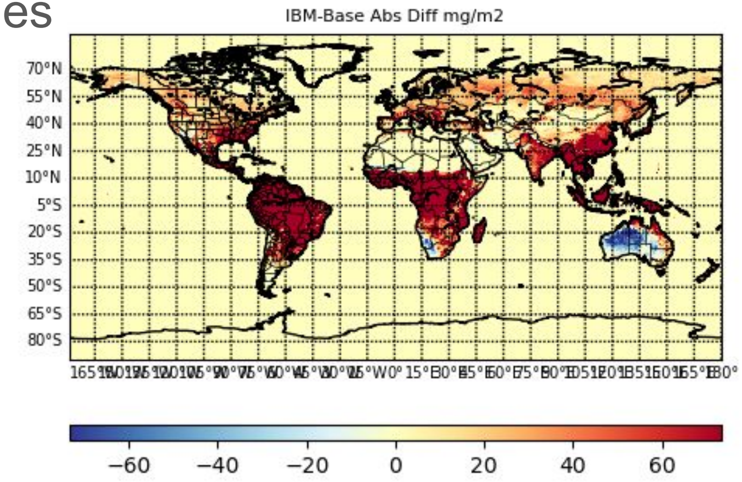
Isoprene



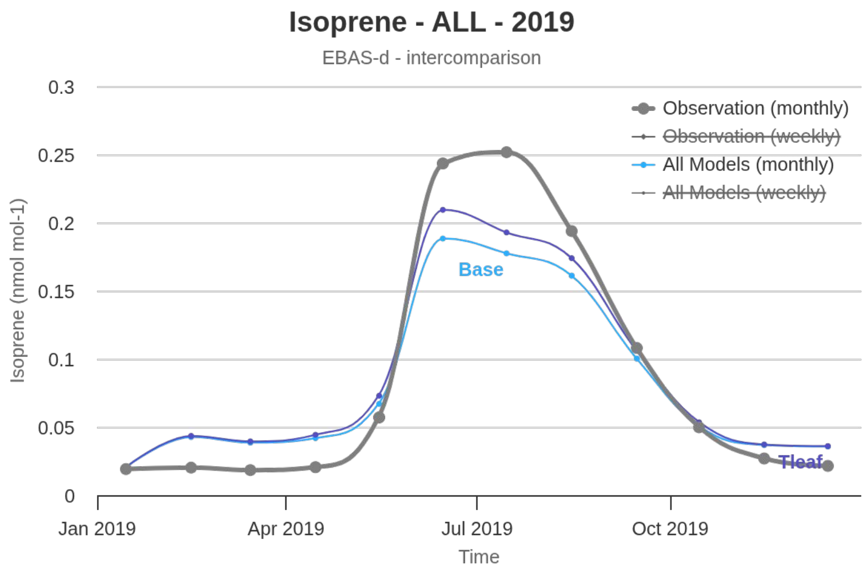


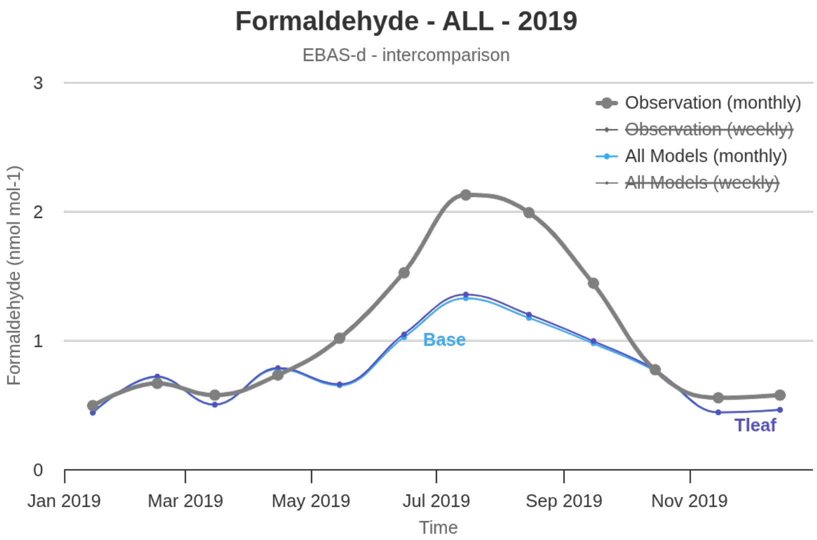
Monoterpenes





Evaluation of isoprene and formaldehyde





	NMB		RMSE		R	
Isoprene	2.3%	9.3%	0.21 ppb	0.21 ppb	0.41	0.43
HCHO	-25.5%	-24.4%	0.77 ppb	0.76 ppb	0.53	0.54

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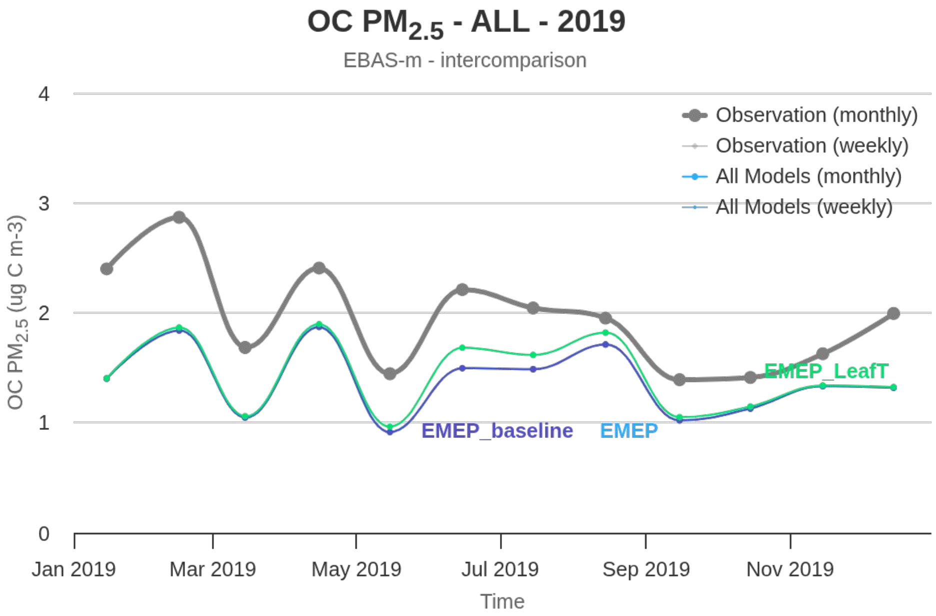
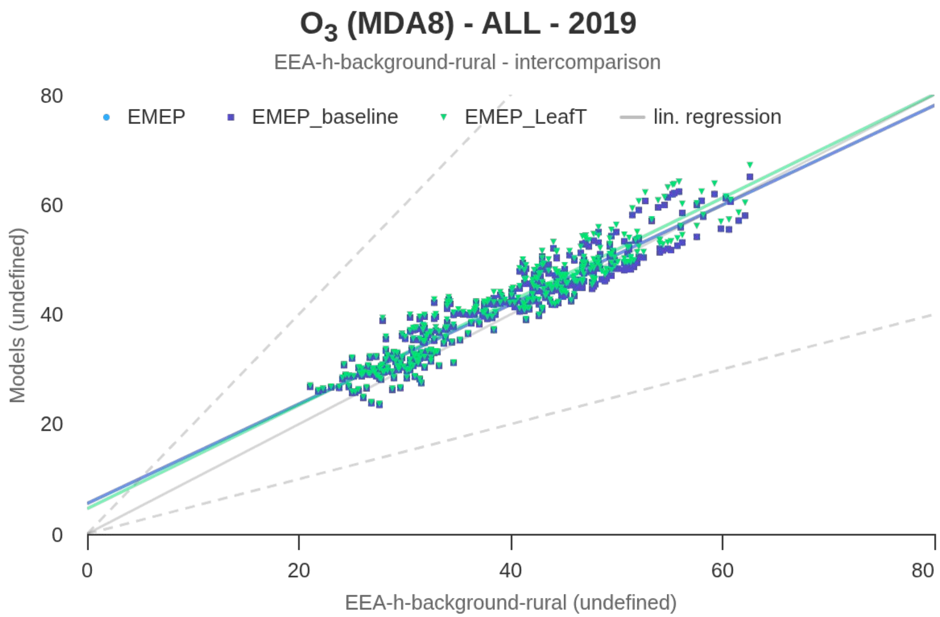
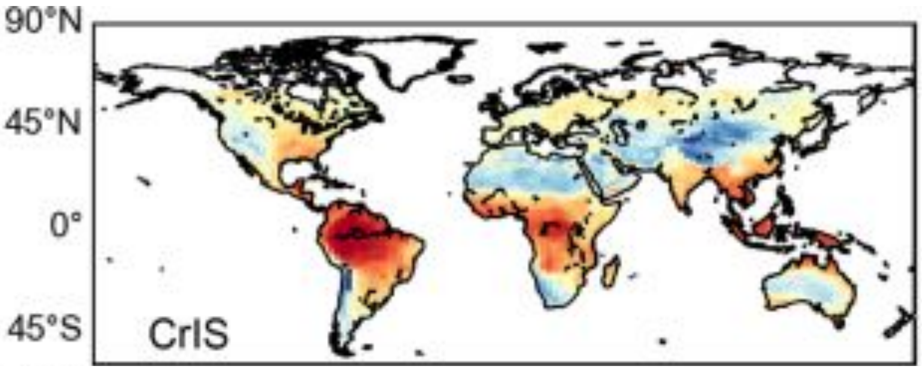
Evaluation of $PM_{2.5}$ and Ozone

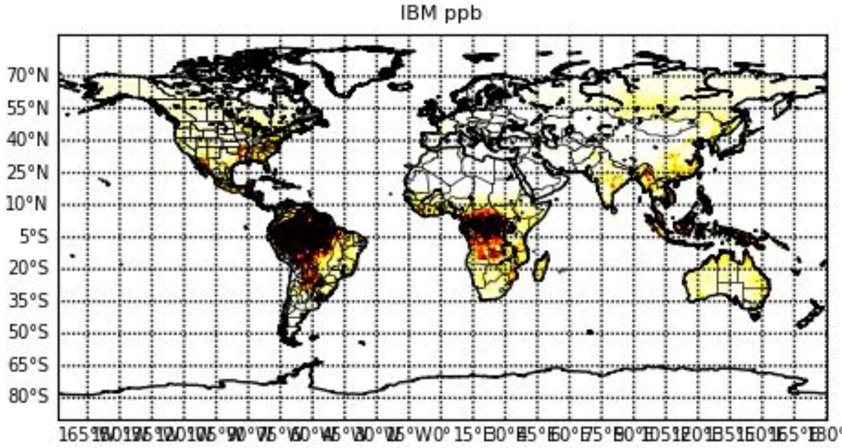




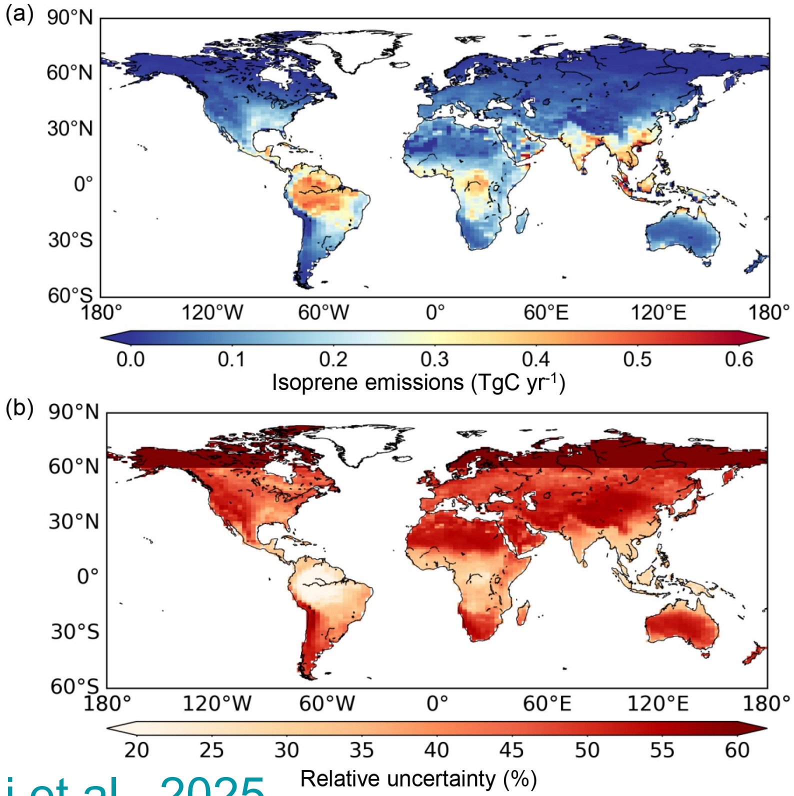
Next Steps

- Evaluation of canopy model updates
- Emission factor optimization
- Evaluation against CrIS satellite isoprene and HCHO observations
    - Characterizes concentrations in high emission regions well
    - Isoprene retrieval in Europe is near the detection limit
    - Evaluation against global simulations
- European evaluation against network observations and measurement campaigns
    - Evaluation against European observations to assess the impact in regions below the CrIS detection limit

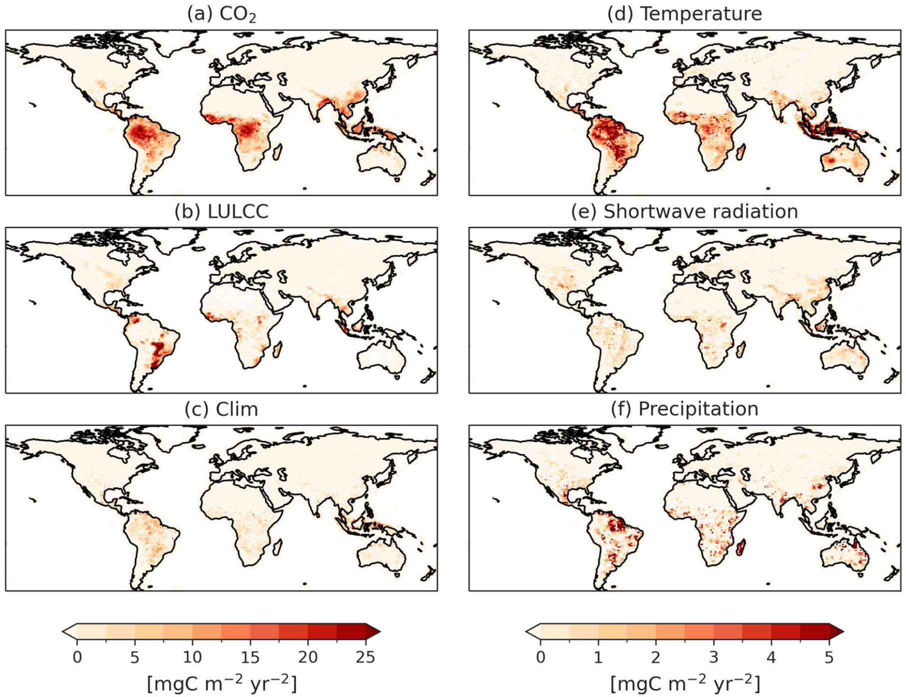




Model Variability and Satellite Observational Uncertainties



Li et al., 2025



Do et al., 2025

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Summary

- A simple leaf temperature algorithm was developed for EMEP
  - Generally increases BVOC emissions
    - Reductions in monoterpene emissions under nighttime radiative cooling in primarily semi-arid regions
  - Incrementally improves $PM_{2.5}$ OC and maximum O_3 in the summer months
  - Slight degradation in mean O_3 performance
- Evaluates well against broadleaf forest observations but overestimates temperate needleleaf
  - Sensitive to assumed leaf albedo
- Could be implemented in dry deposition parameterizations
  - Can be used to estimate dew/frost formation
  - Temperature dependences on canopy resistances

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