Tracing PAH Origins in the Arctic: A Sector-Region Source Apportionment Approach with GLEMOS

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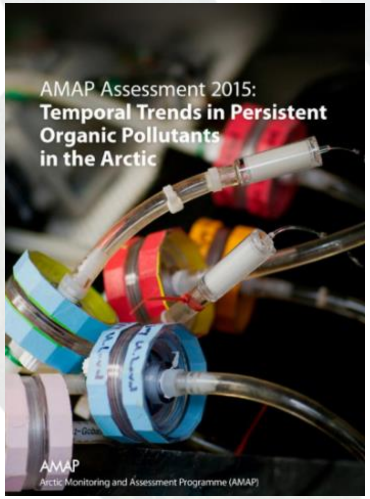
Motivation & Context

- **PAHs** - Known for their toxicity, persistence, and potential carcinogenicity.

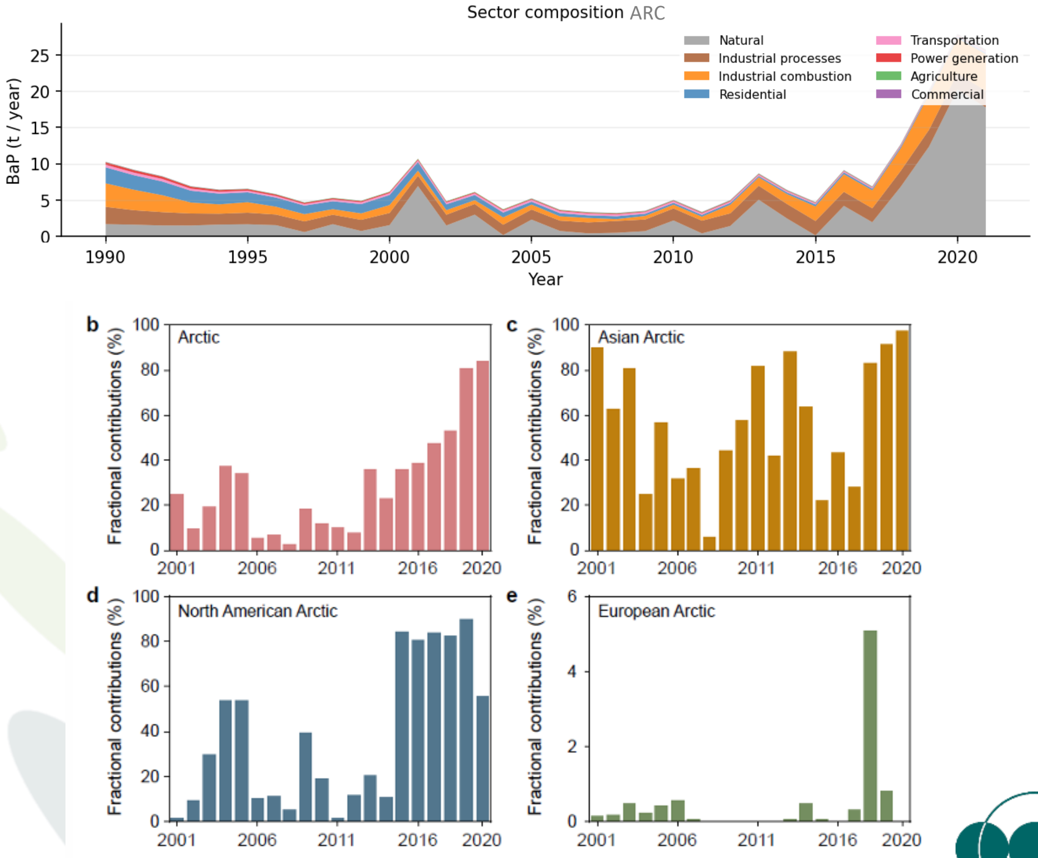
Why PAHs in the Arctic matter?

long-range transport + climate sensitivity = receptor region for distant emission sources



- Observational networks in the Arctic are sparse
- Scarce modelling studies focus on specific source-region attribution

Recent increase in wildfire emissions estimates

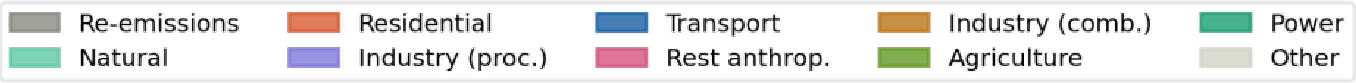


Song et al. 2023

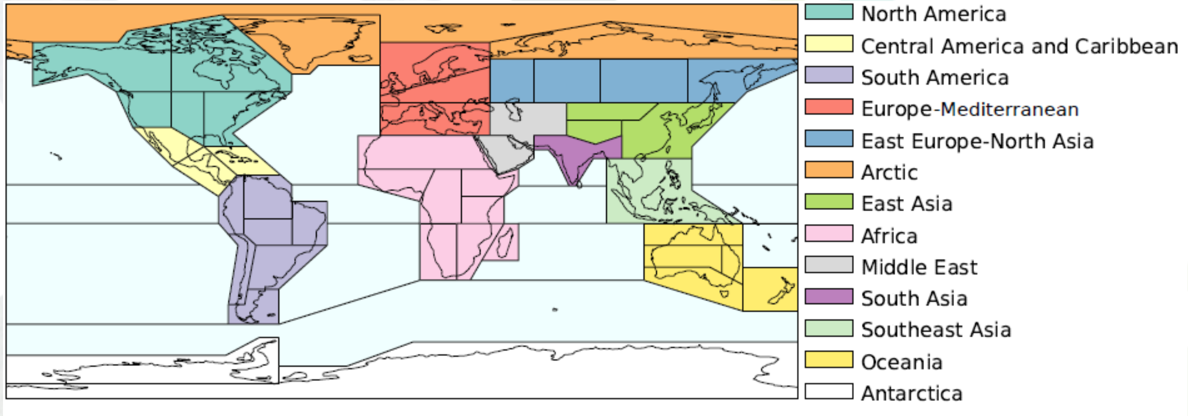
Knowledge gap: which sectors and regions are the dominant contributors?

Objectives

- Quantify sectoral contributions to Arctic PAH burden

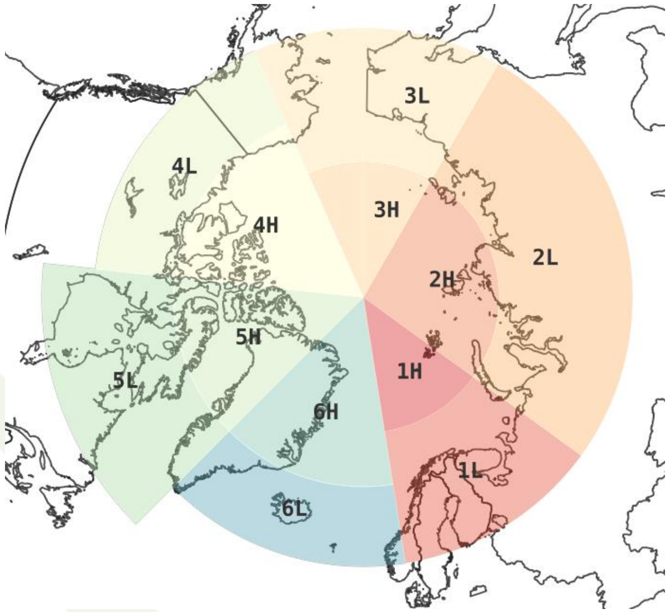


- Identify key source regions



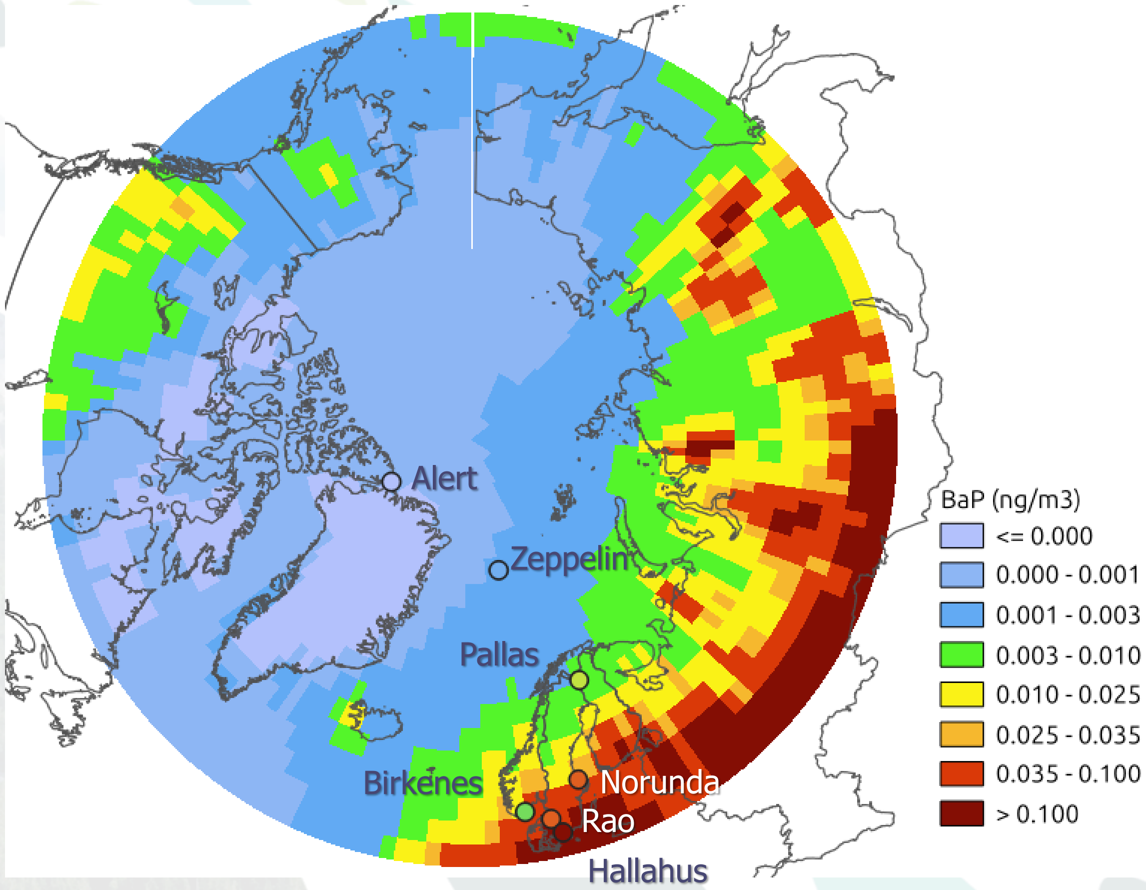
- **GLEMOS model:** Multi-scale, multi-pollutant chemical transport model
- Global 3x3 degrees Source receptor matrix simulations of 15 PAH

GEMS: Global Emission Modeling System – inventory by Southern University of Science and Technology (SUSTech) and Peking University (PKU) https://gems.sustech .edu.cn/home

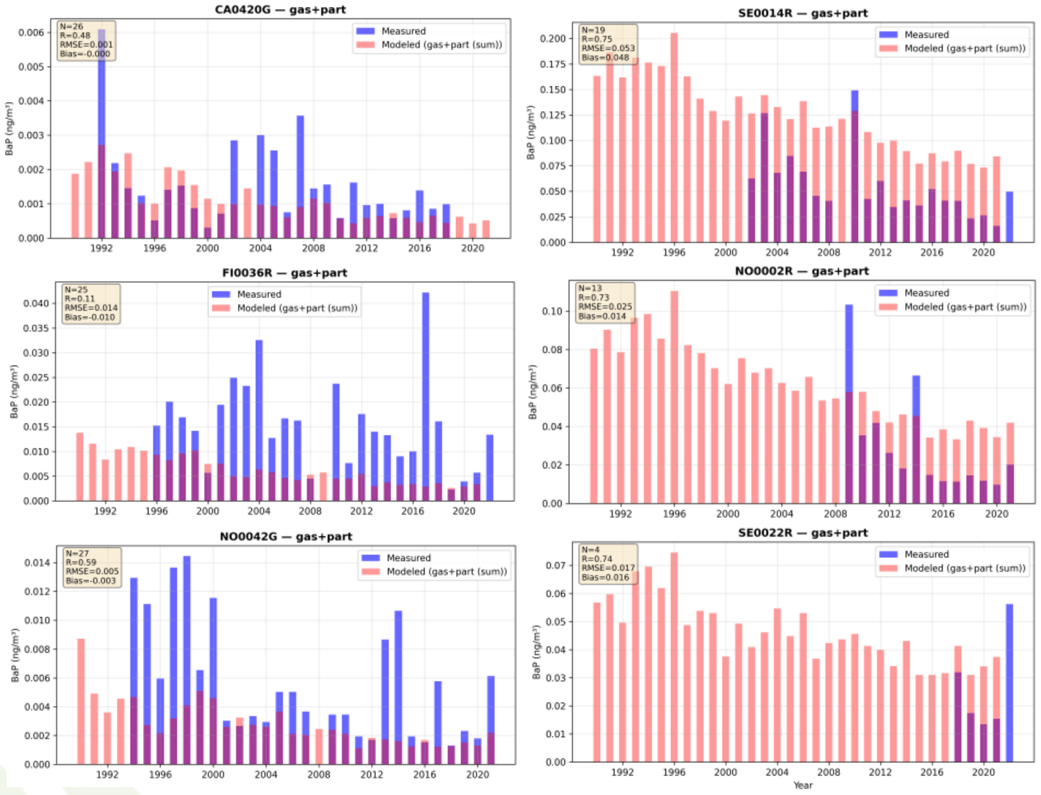


Measurements vs. GLEMOS model output

- High Arctic
  - Canada
  - Norway
  - Finland
- Low Arctic
  - Norway
  - Sweden

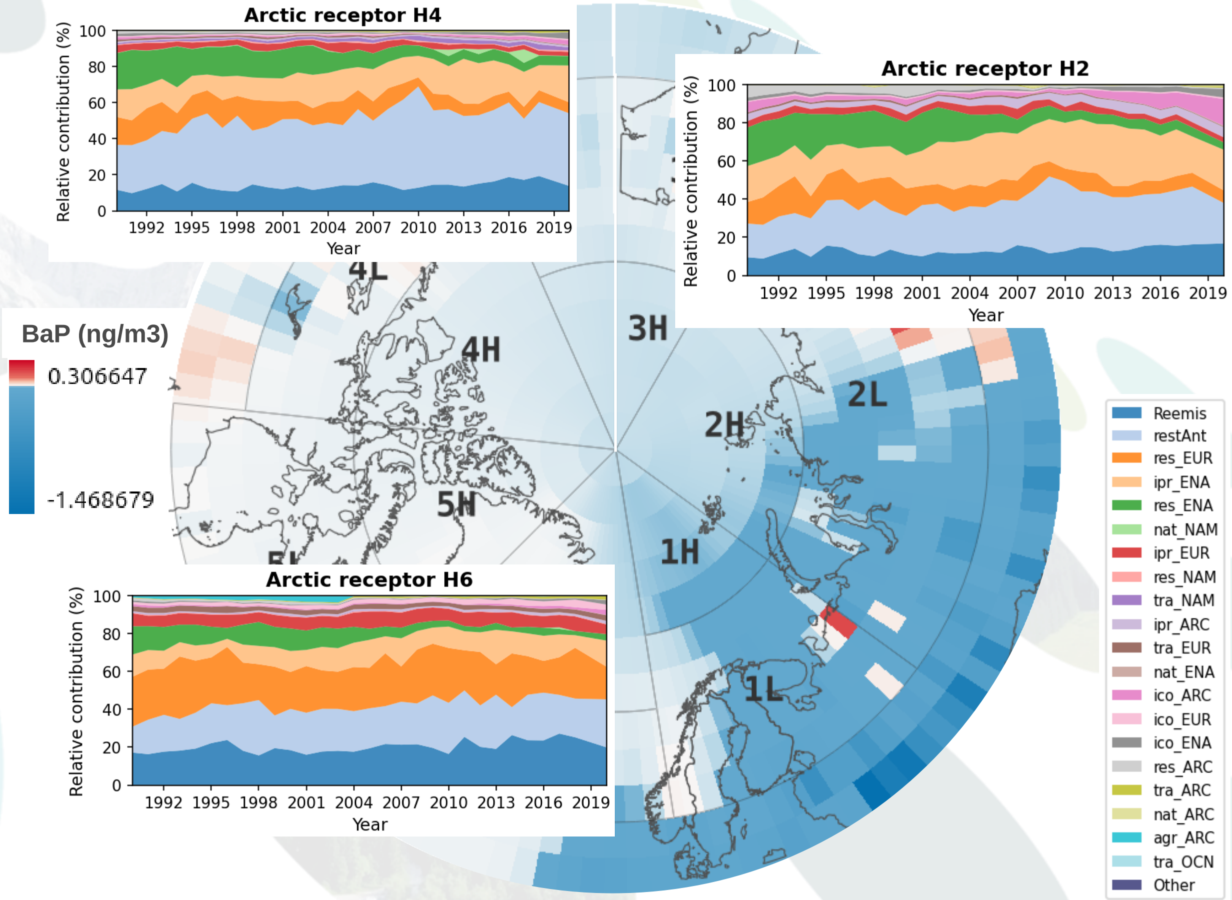


2018 BaP average air concentration

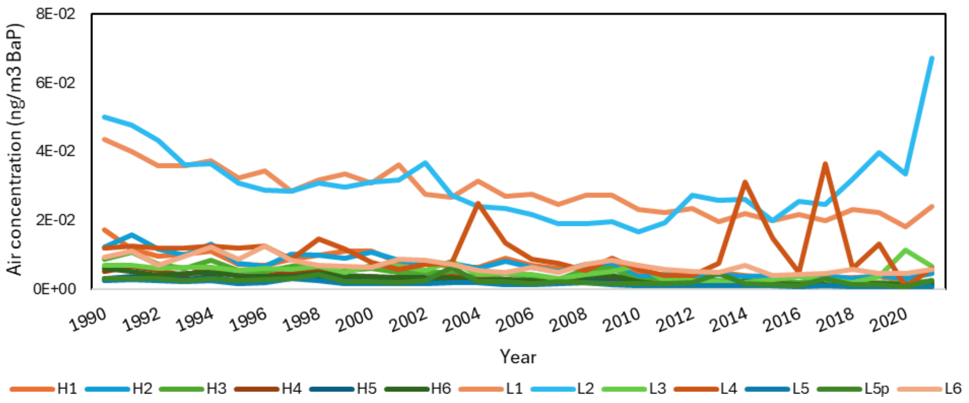


Results: Findings – BaP example

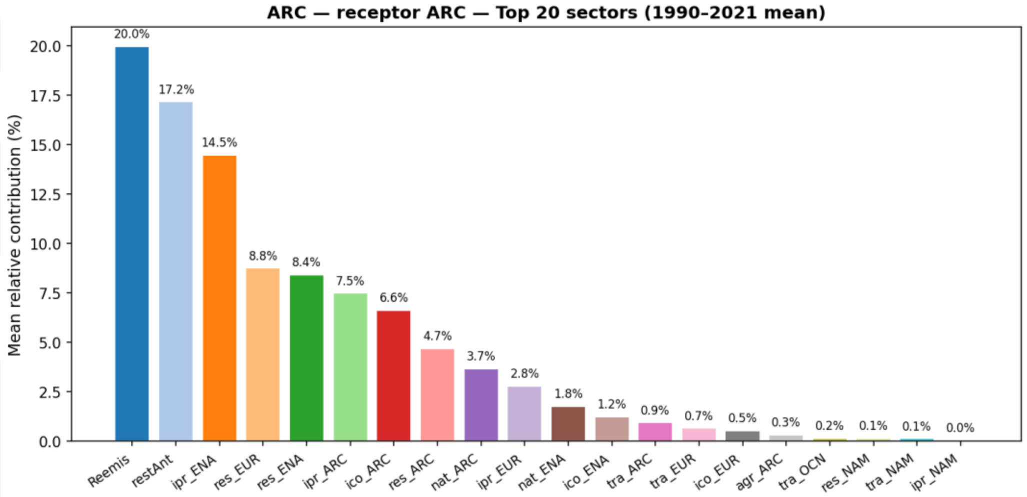
Difference in BaP air concentration from 1990 to 2021



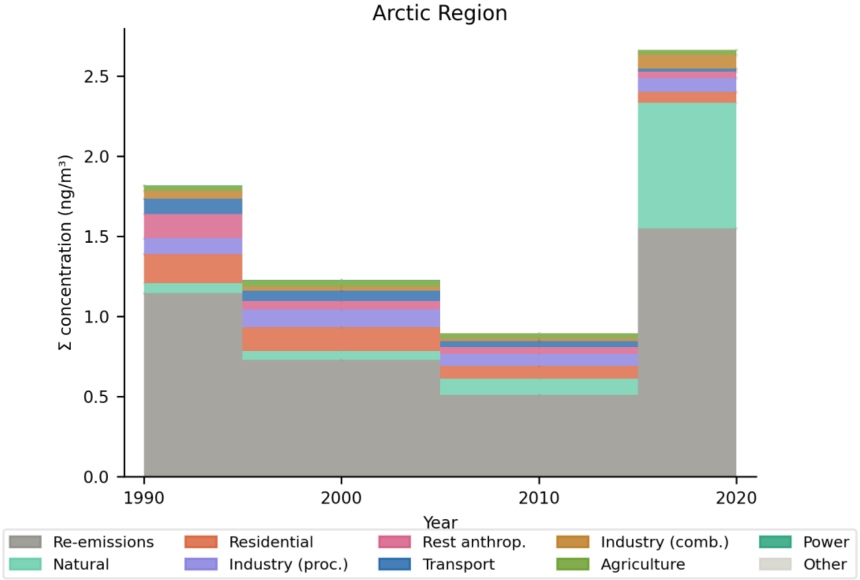
Arctic Subregions BaP air concentration



Sector-region mean BaP source attribution

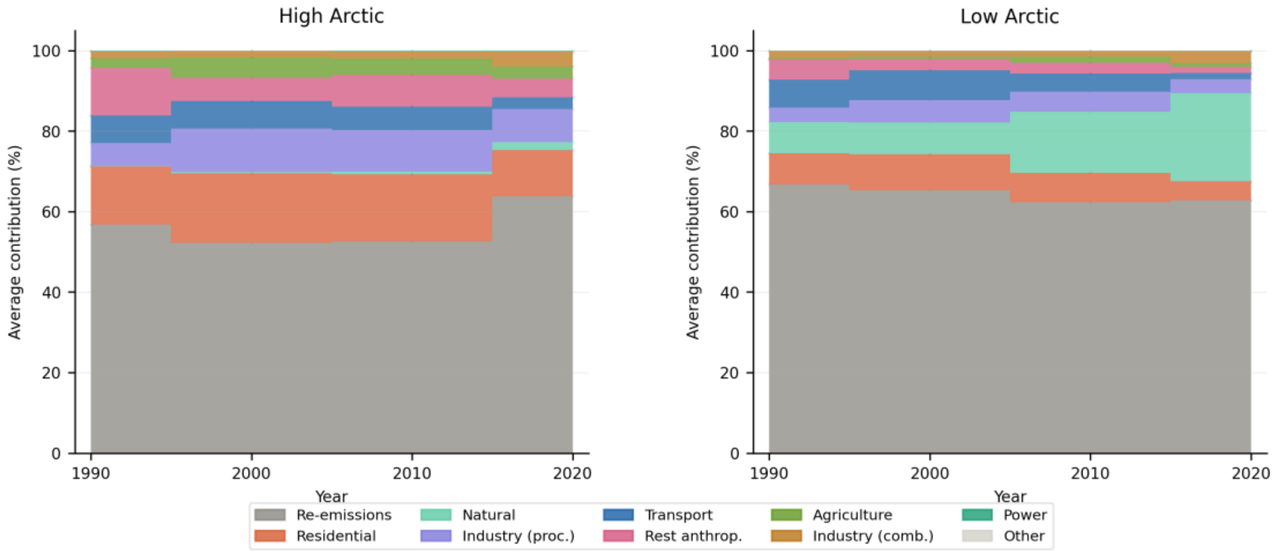


Results I: Sectoral contributions



Key Sectoral Shifts

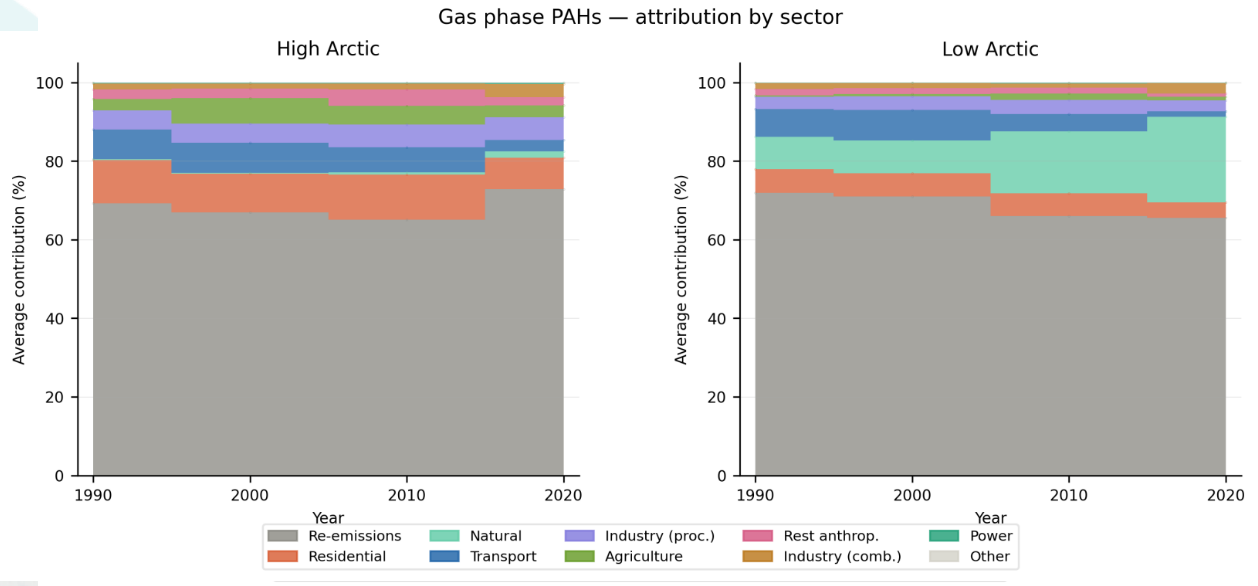
- Residential combustion remains a dominant source throughout the period but shows a gradual decline in Low Arctic
- Transport and Agriculture show a decreasing trend
- Industrial combustion has slightly increased its contribution over time
- Natural emissions show the most significant increase, particularly in the Low Arctic

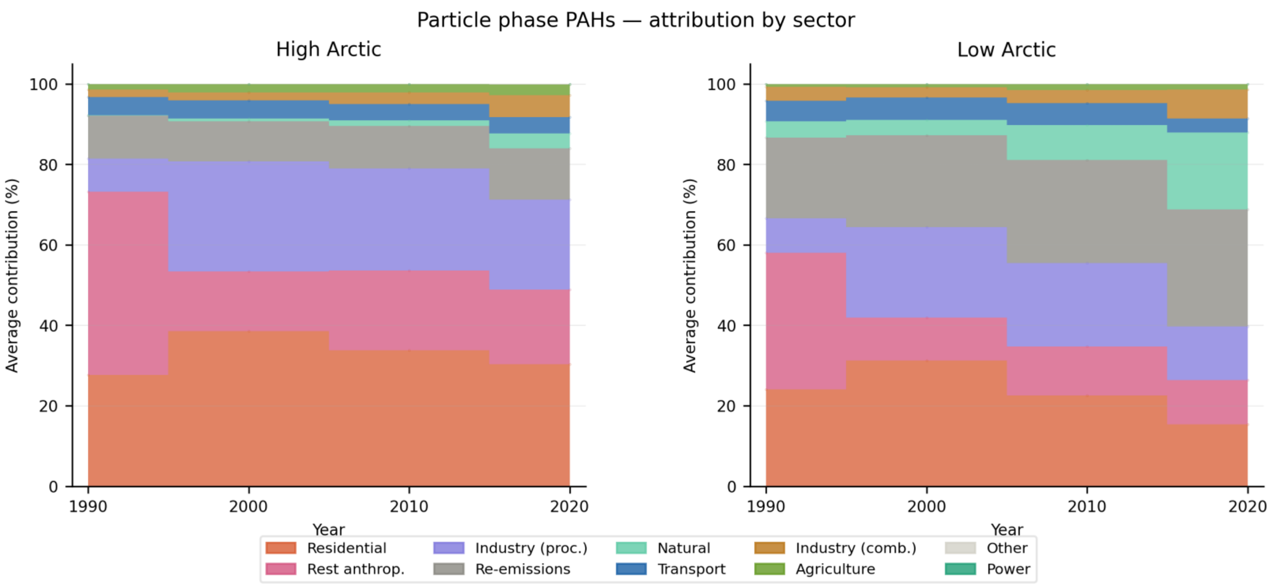


Overall Trend

- Arctic PAH burden shows a general decrease over the first two decades, followed by a notable increase toward 2020, driven largely by the growing role of natural emissions (re-emission and wildfires).

Results I: Sectoral contributions





	High Arctic	Low Arctic
Dominant sector	Residential (throughout)	Natural & Industrial (rising)
Trend	Residential prevalence stable	Shift toward natural sources

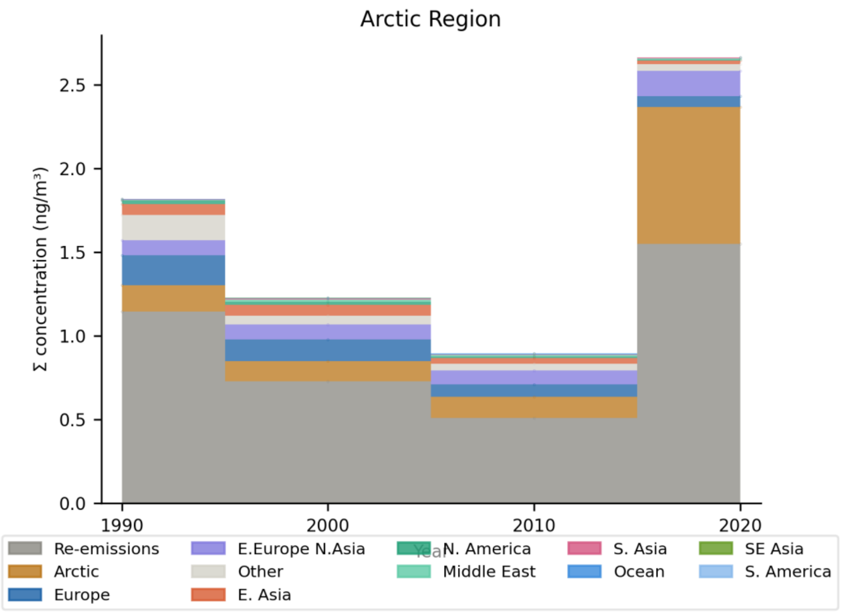
Gas vs. Particulate Phase PAH

Re-emission is more prominent in the **gas phase**. Re-emission is more relevant for these lighter compounds due to their volatility, and represents a growing natural source signal.

Transport contribution decreases specifically in the gas phase

Common to both phases: increase in Natural sources; increase in Industrial combustion

Results II — Regional Contributions

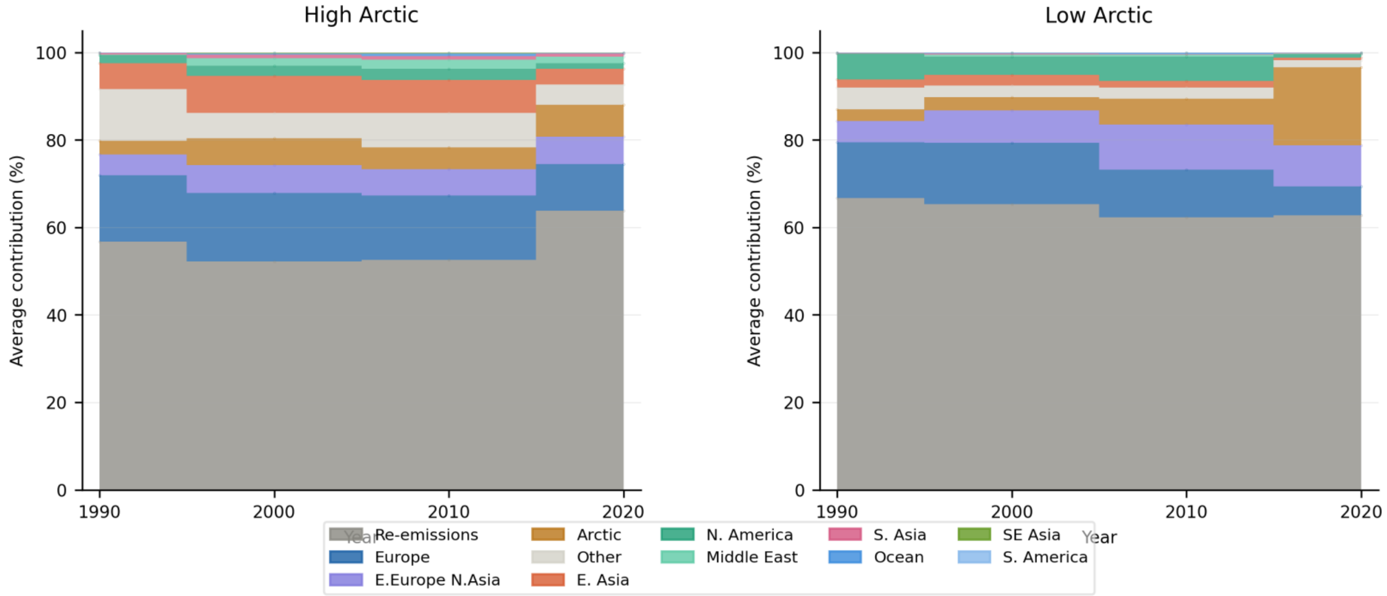


Key Regional Shifts

- Europe (EUR), North America (NAM) and East Asia (EAS) show an overall decrease in relative contribution, though EUR remains steadily present especially in the High Arctic
- The Arctic region (ARC) contribution has grown substantially, most notably in the Low Arctic
- East Asia maintains relevance particularly for High Arctic PAHs

Overall Trend

- The period is marked by a shift in dominant source regions, with the Arctic region itself becoming increasingly important in recent years



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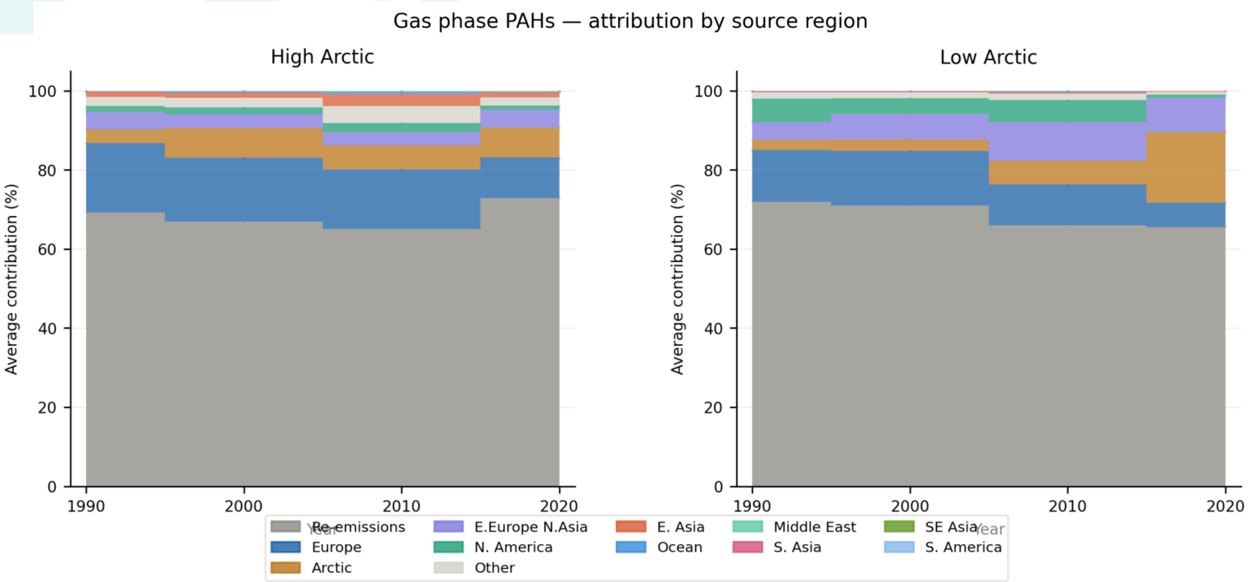
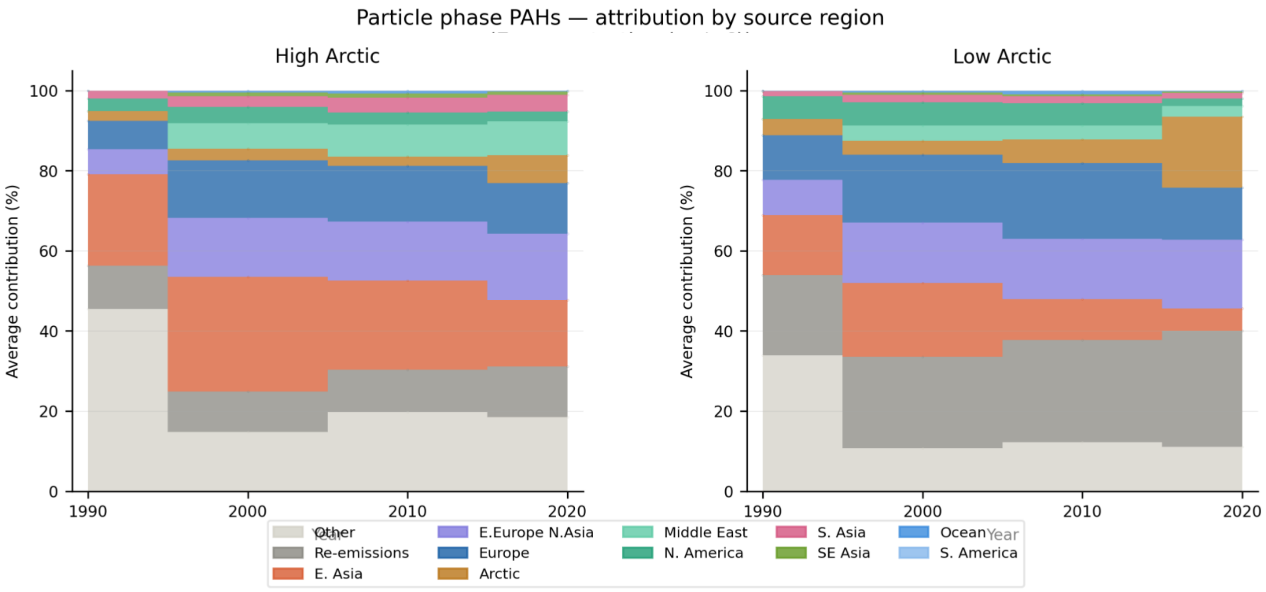
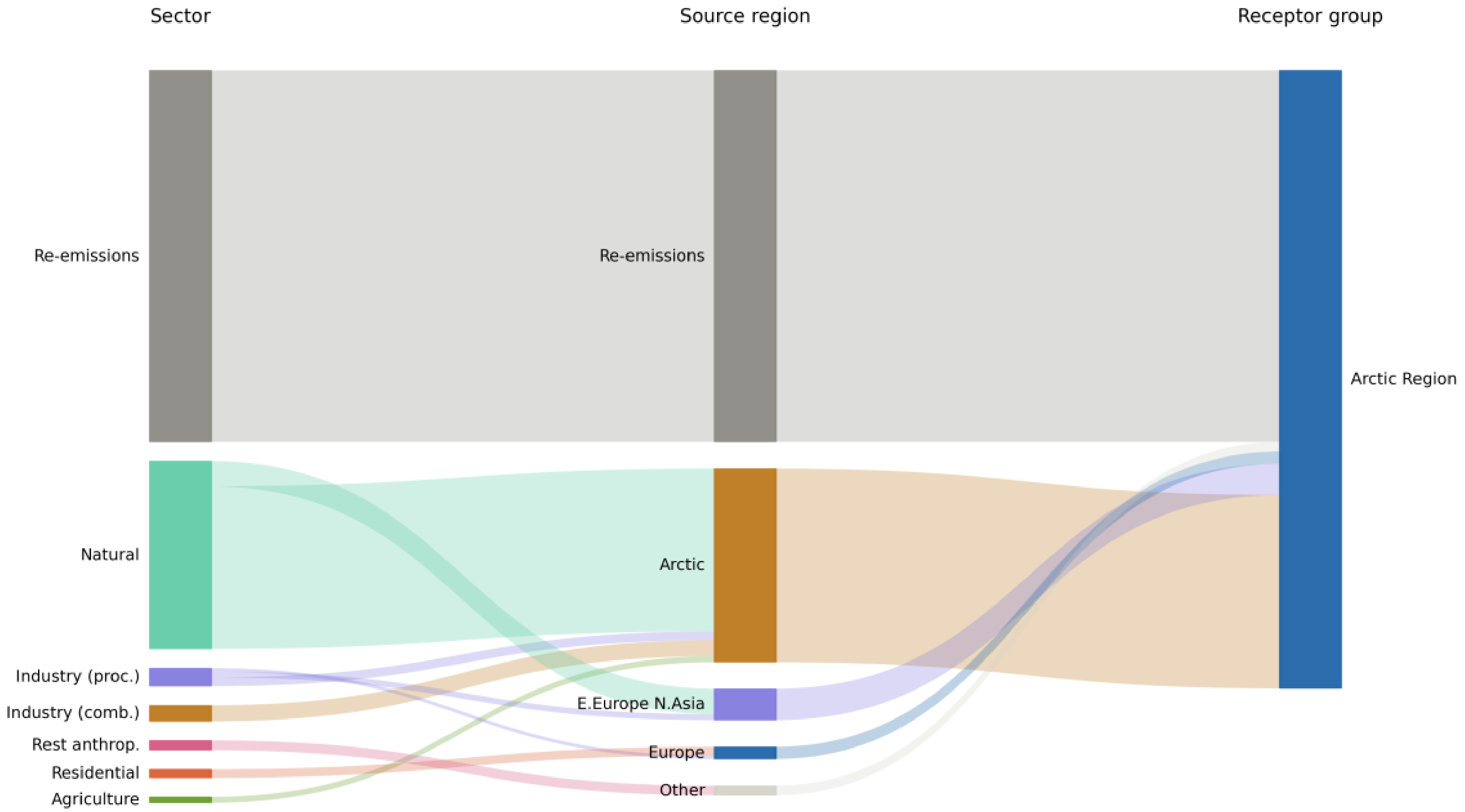




	High Arctic	Low Arctic
Notable feature	East Asia higher contribution	Strong rise of Arctic contribution
Regional trend	EUR steady but declining	EUR decreasing; ARC increasing

	Gas Phase	Particulate Phase
High Arctic	EUR > ARC > ENA dominant	East Asia dominant, followed by ENA, EUR
Key difference	Re-emission amplifies local/regional sources	Long-range transport from Asia more evident
Common trend	Arctic contribution increasing	East Asia contribution declining

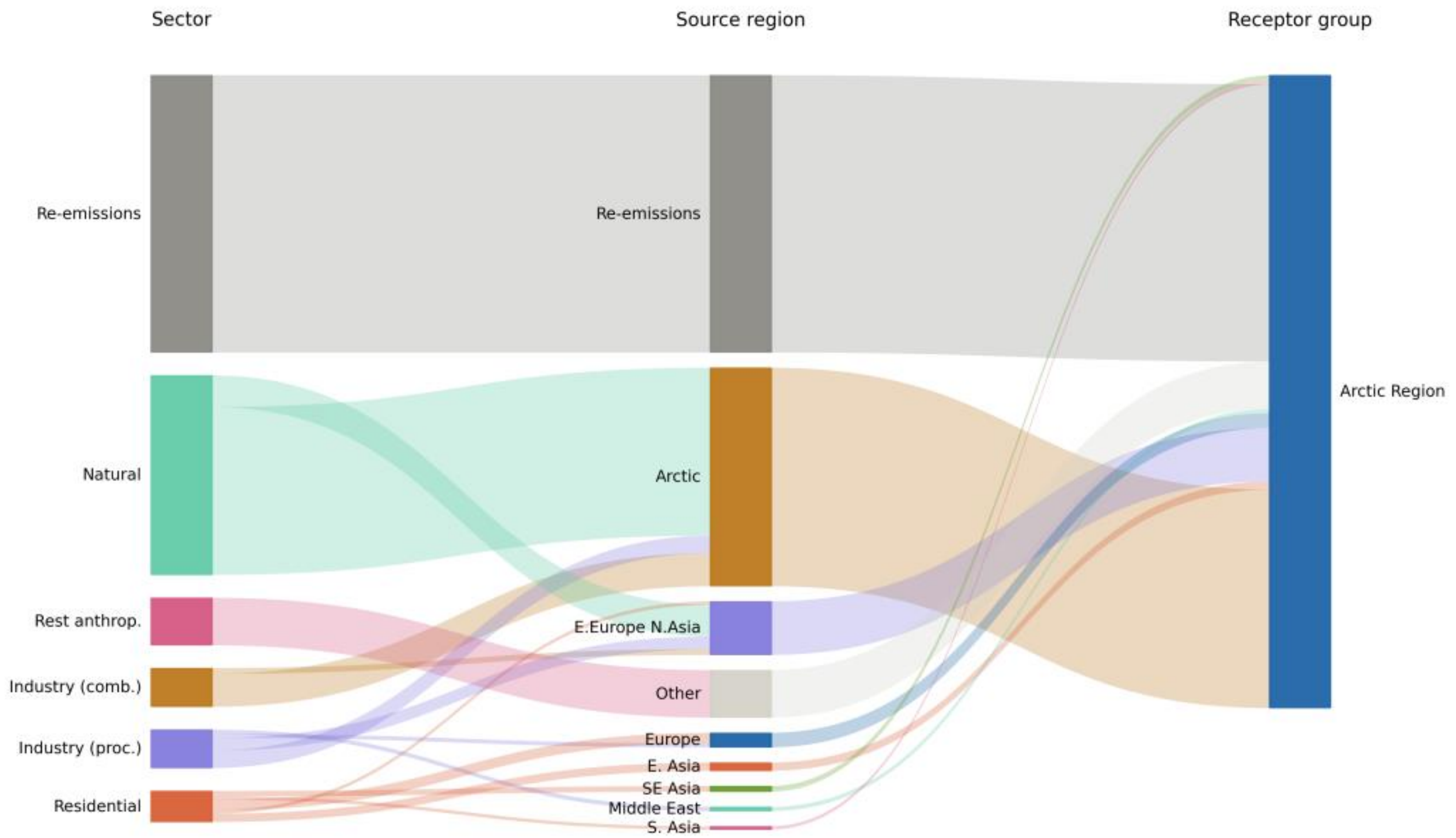
Results III — Combined Sector-Region View



Contribution to Arctic Air concentration of each sector per region

- 1990: Res> Ipr>Trp; EUR, ARC>ENA,
- 2000: Res> Ipr> Tra; EUR>ARC> ENA
- 2010: Nat, Res, Ipr> ; ARC> ENA, EUR
- 2020: Nat>> Ipr, Ico; ARC>> ENA> EUR

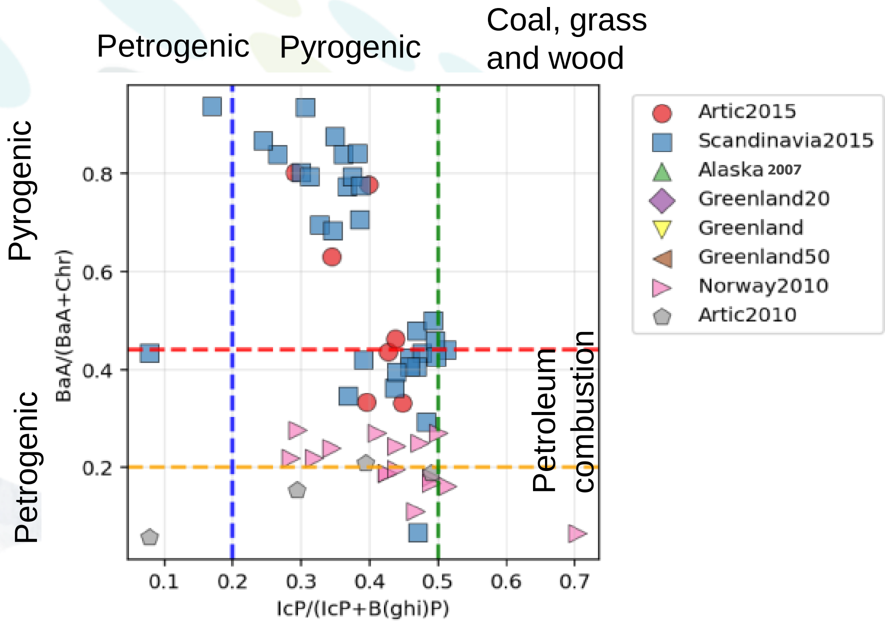
Results III — Combined Sector-Region View

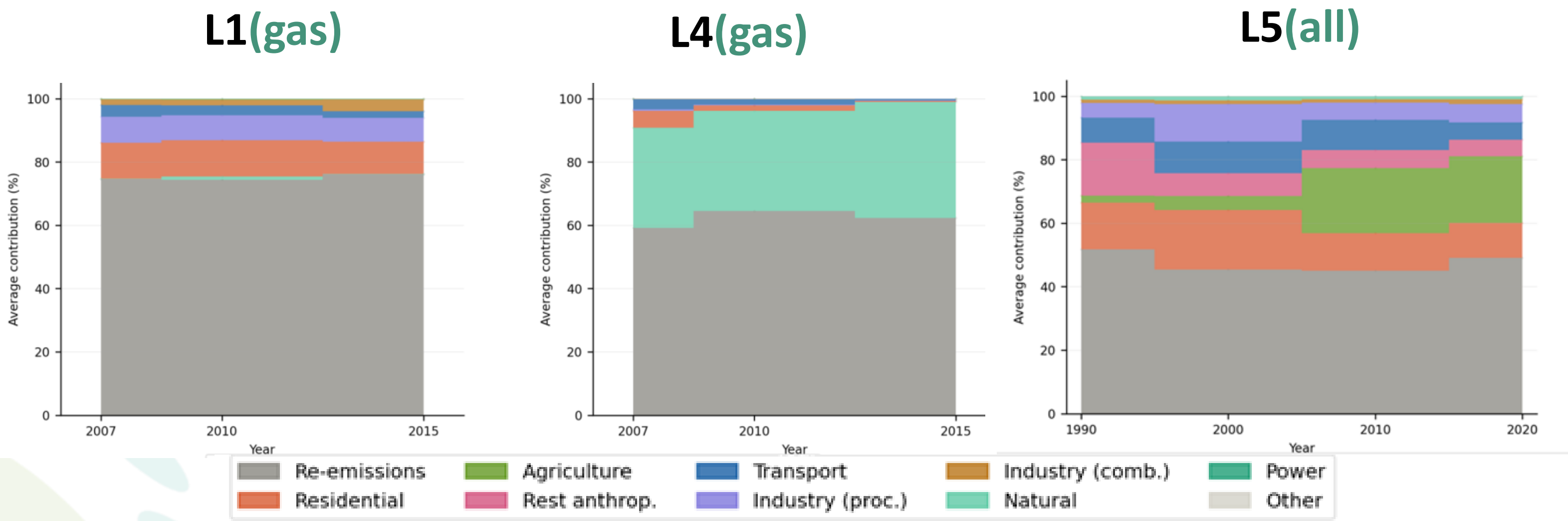


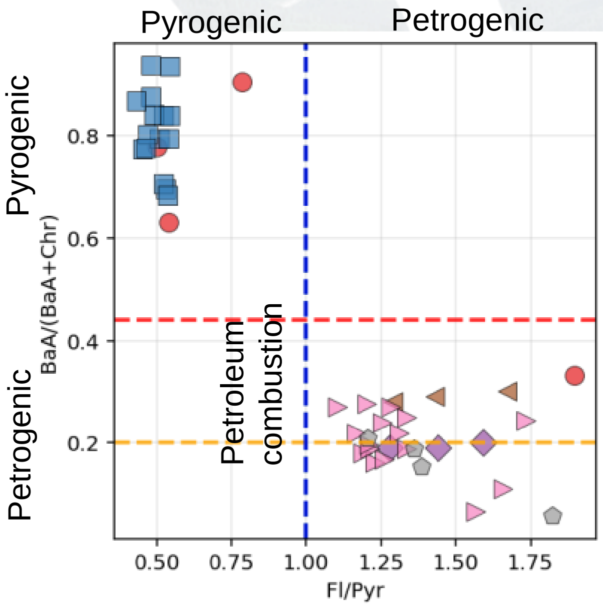
Contribution to Arctic Total deposition of each sector per region

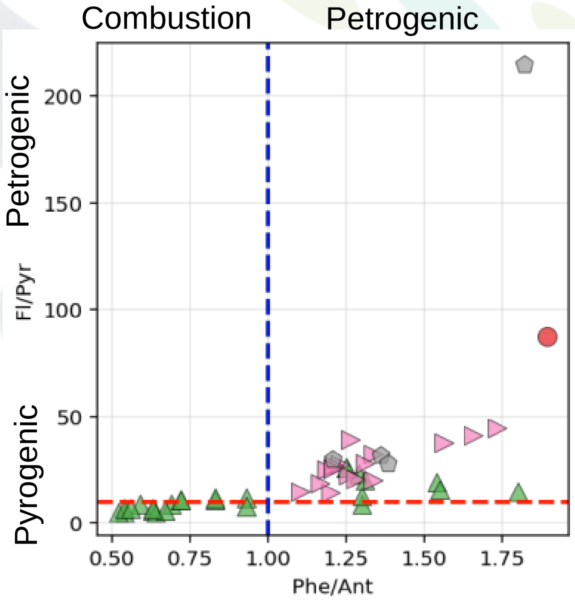
- 1990: Agr> Res> Ipr; EUR> ARC, > ENA
- 2000: Res > Ipr > Nat; ARC > ENA > EUR
- 2010: Ipr > Nat > Res; ARC > ENA > EUR
- 2020: Nat >> Ico > Ipr; ARC >> ENA > EUR

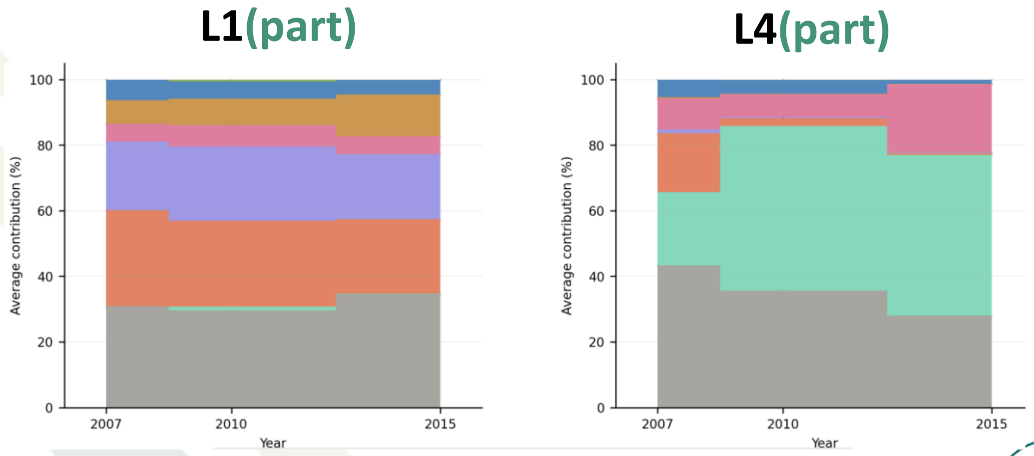
Results VI — Moss SA vs Model SA











Conclusions and perspectives

- Arctic PAH burden shows a general decrease over the first two decades (1990–2010), followed by a notable increase toward 2020, driven largely by the growing role of natural emissions particularly in the Arctic.
- A clear transition from anthropogenic to natural source dominance is observed between 1990 and 2020, in both air concentration and deposition.
- The Arctic region has shifted from a secondary to the primary source region by 2020, suggesting growing importance of local re-emission and in-Arctic processes
- The combined picture points to a feedback dynamic: as the Arctic warms, natural re-emission increases, making the Arctic itself a growing source — a finding with significant policy and climate implications
- PAH source attribution depends on available data and quality of reported emissions data for source-receptor simulations.

Thank you!

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