Downwind and Out: The Strategic Dispersion of Power Plants and Their Pollution

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Air-Quality Regulation

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The Clean Air Acts of 1963 and 1970 (and subsequent amendments):

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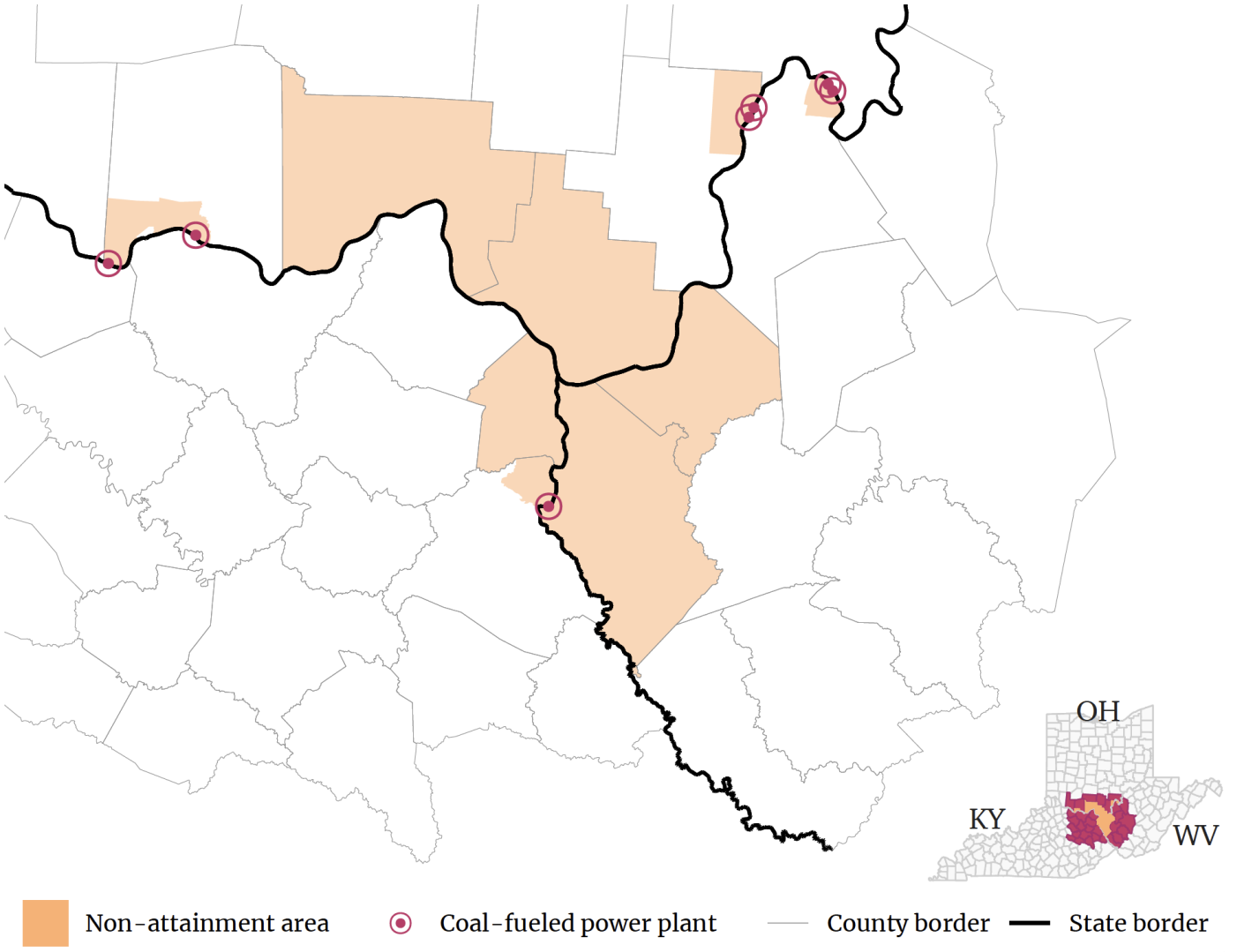
Problems:

1. Regulated units **strategically respond** to this regulatory patchwork.
2. Coal-generated air **pollution travels long distances**.

$\Longrightarrow$ Attribution, regulation, & enforcement are complicated!

An example of transport's regulatory complexity:

The Huntington-Ashland (WV-KY-OH) non-attainment area



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So what?

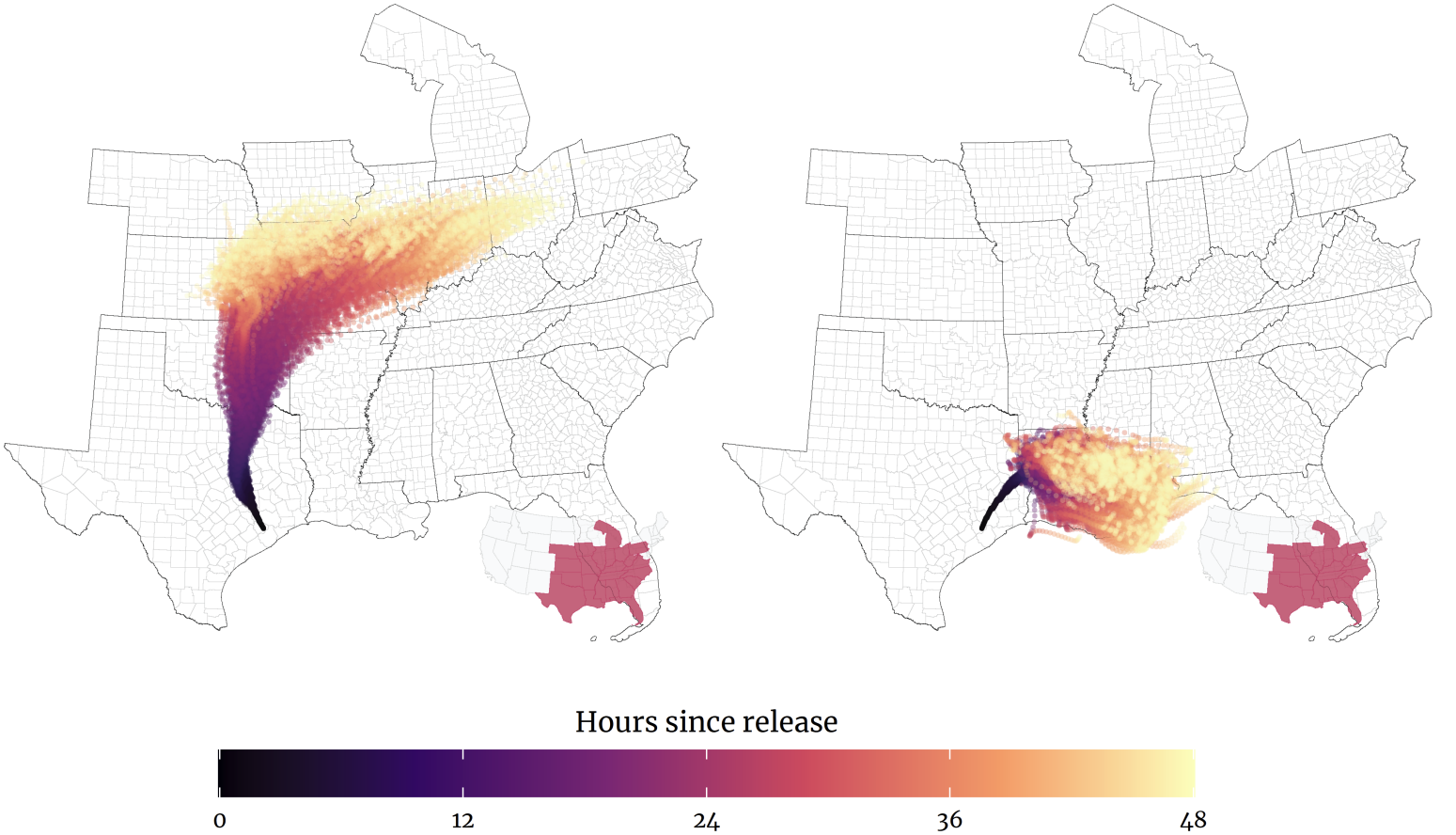
In this paper, we

- Highlight **regulatory challenges** in the current, federalist system.
- Identify **strategic responses** to regulatory oversight.
- Underscore the importance of **transport-focused regulation**.

An example of **the transport problem** for coal emissions

Plant 3470, January 2005

Plant 3470, July 2005



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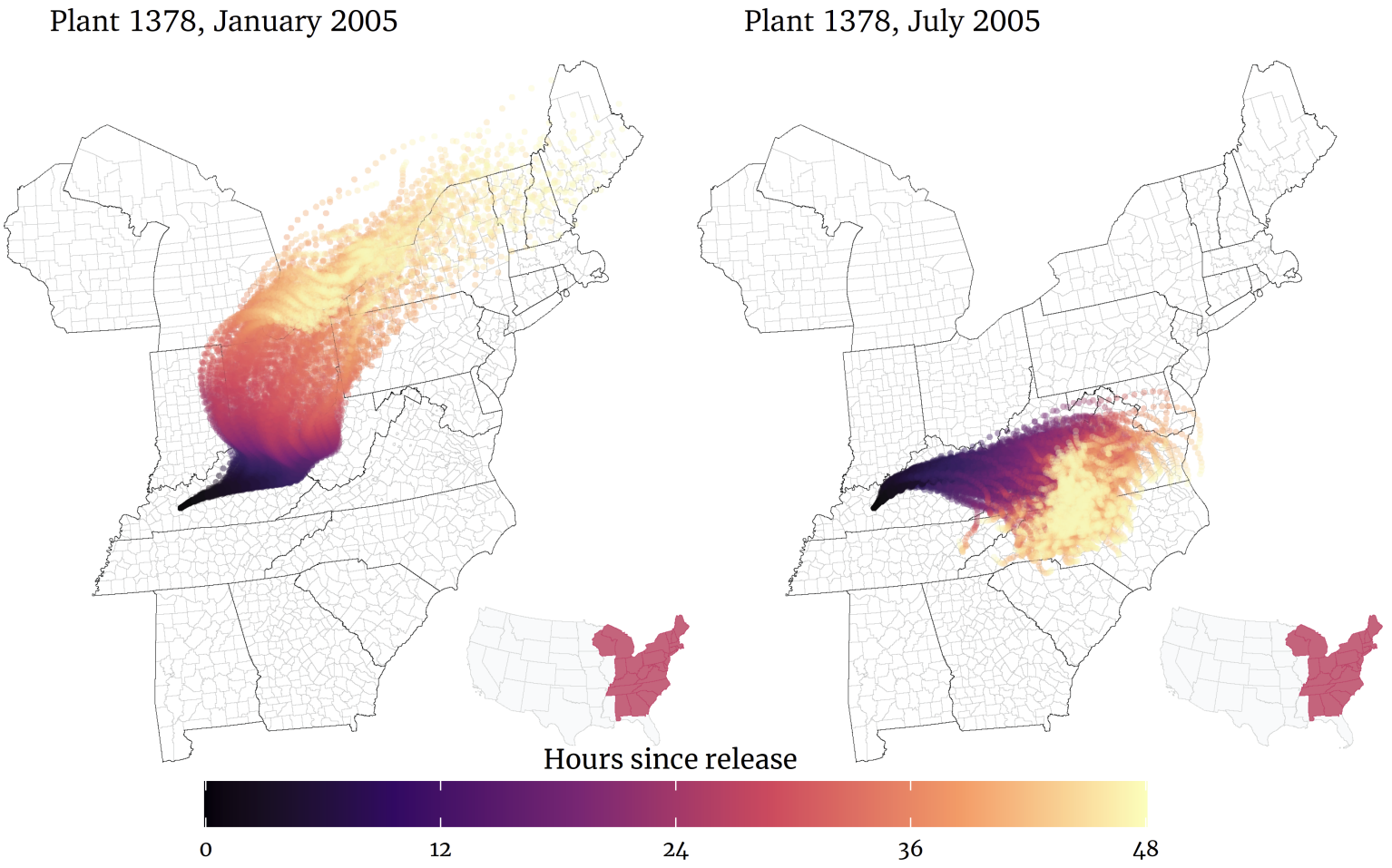

Literature

In general, our work is related to three strands of literature:

[1] Strategy and the CAA

- Downwind siting for polluters as a strategy (*e.g.* Monogan III et al. (2017))
- Strategic abatement decisions (*e.g.* Zou, 2020)
- Strategic *monitor* placement (*e.g.* Grainger et al., 2018)
- Strategic monitoring (*e.g.* Mu, Rubin, and Zou, 2021)

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[1] Strategy and the CAA

[2] The problems of pollution transfer

- Tessum et al. (2017)
- Sergi et al. (2020)
- Wang et al. (2020)

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[2] The problems of pollution transfer

[3] The pollution-haven hypothesis

- Cole (2004)
- Levinson (2008)
- Millimet and Roy (2015)
- (Among many others)

The Geography of Power Plants

Data Sources

Generator Data:

- EPA **CAMD** (Clean Air Markets Division)🦆
- EPA **eGRID** (Emissions & Generation Integrated Database)

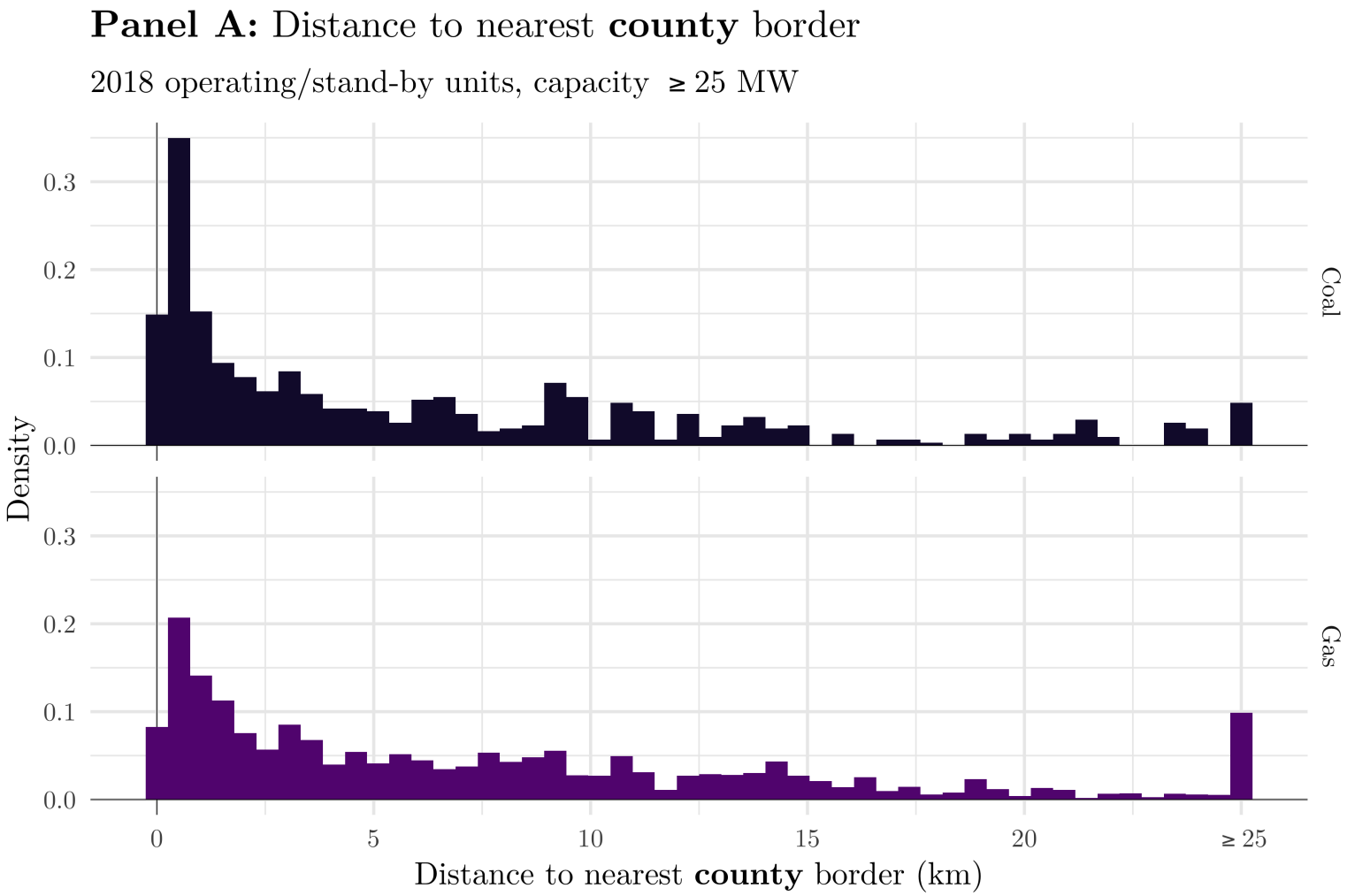
Geography:

- US Census Bureau **TIGER/Line** and **cartographic boundary** shapefiles for county, state, and water features
- EPA's **Greenbook NAYRO** for county non-attainment histories

Meteorology: NOAA's **NARR** (North American Regional Reanalysis)

- Historic wind patterns by pressure levels.
- 32km $\times$ 32km grid cells across contigous US

🦆 We gratefully acknowledge assistance from EPA via their EmPOWER Air Data Challenge.


Panel A: Distance to nearest **county** border
2018 operating/stand-by units, capacity ≥ 25 MW
Density
0.0
0.1
0.2
0.3
Coal
Gas
0
5
10
15
20
≥ 25
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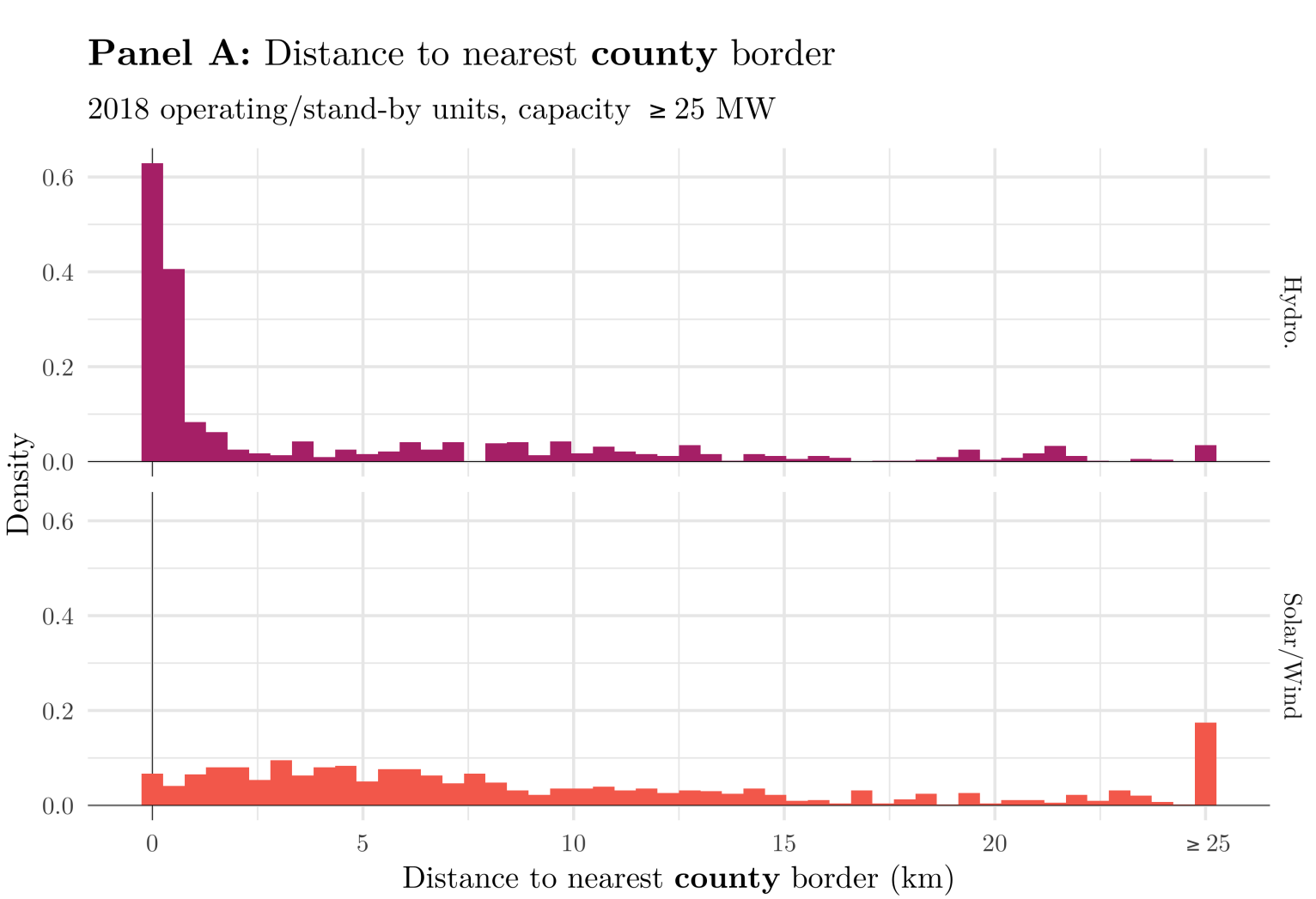
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Density
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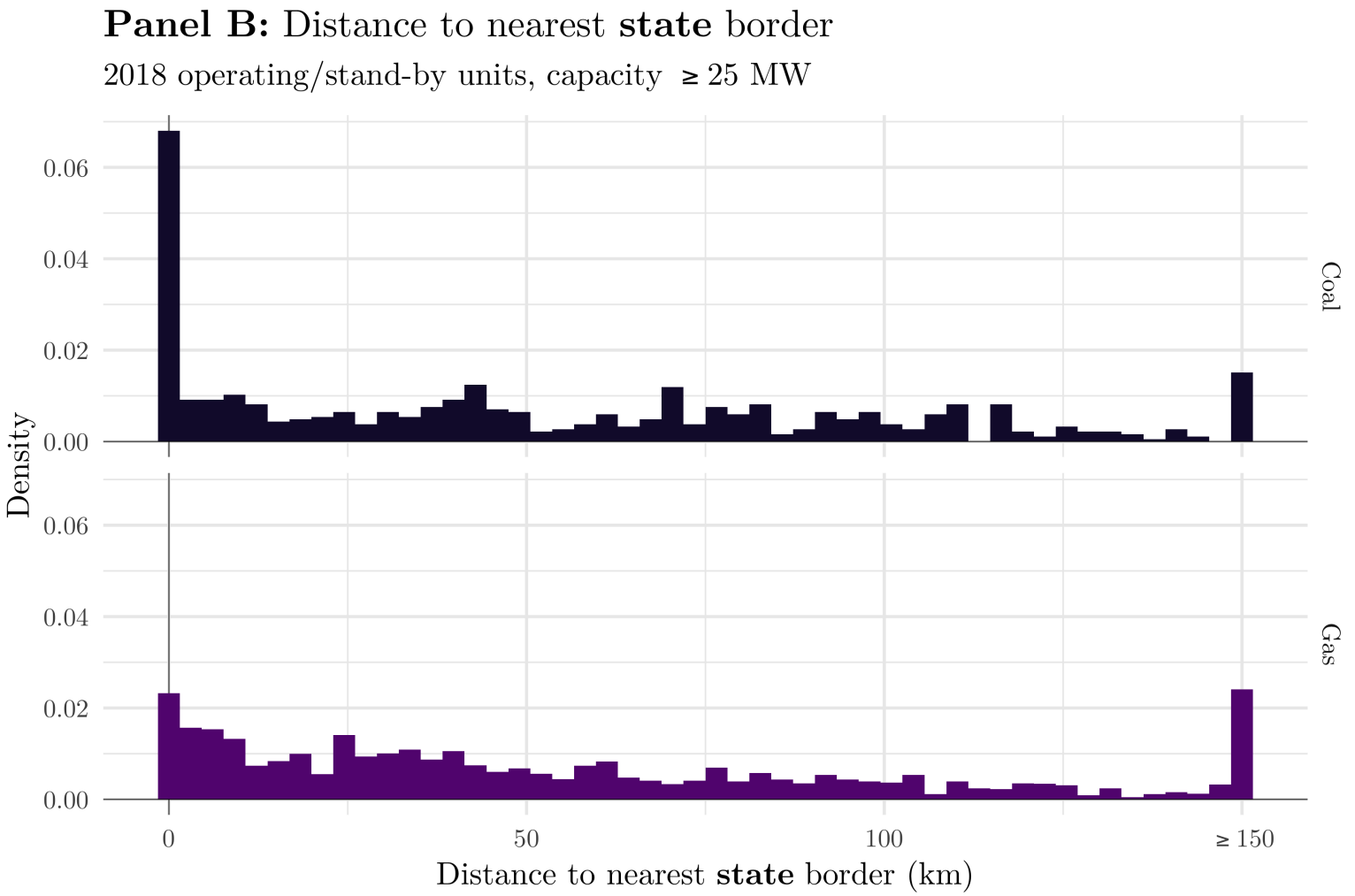
0.4
0.2
0.0
Hydro.
Solar/Wind
0
5
10
15
20
≥ 25
Distance to nearest county border (km)


Panel B: Distance to nearest state border
2018 operating/stand-by units, capacity ≥ 25 MW
Density
0.06
0.04
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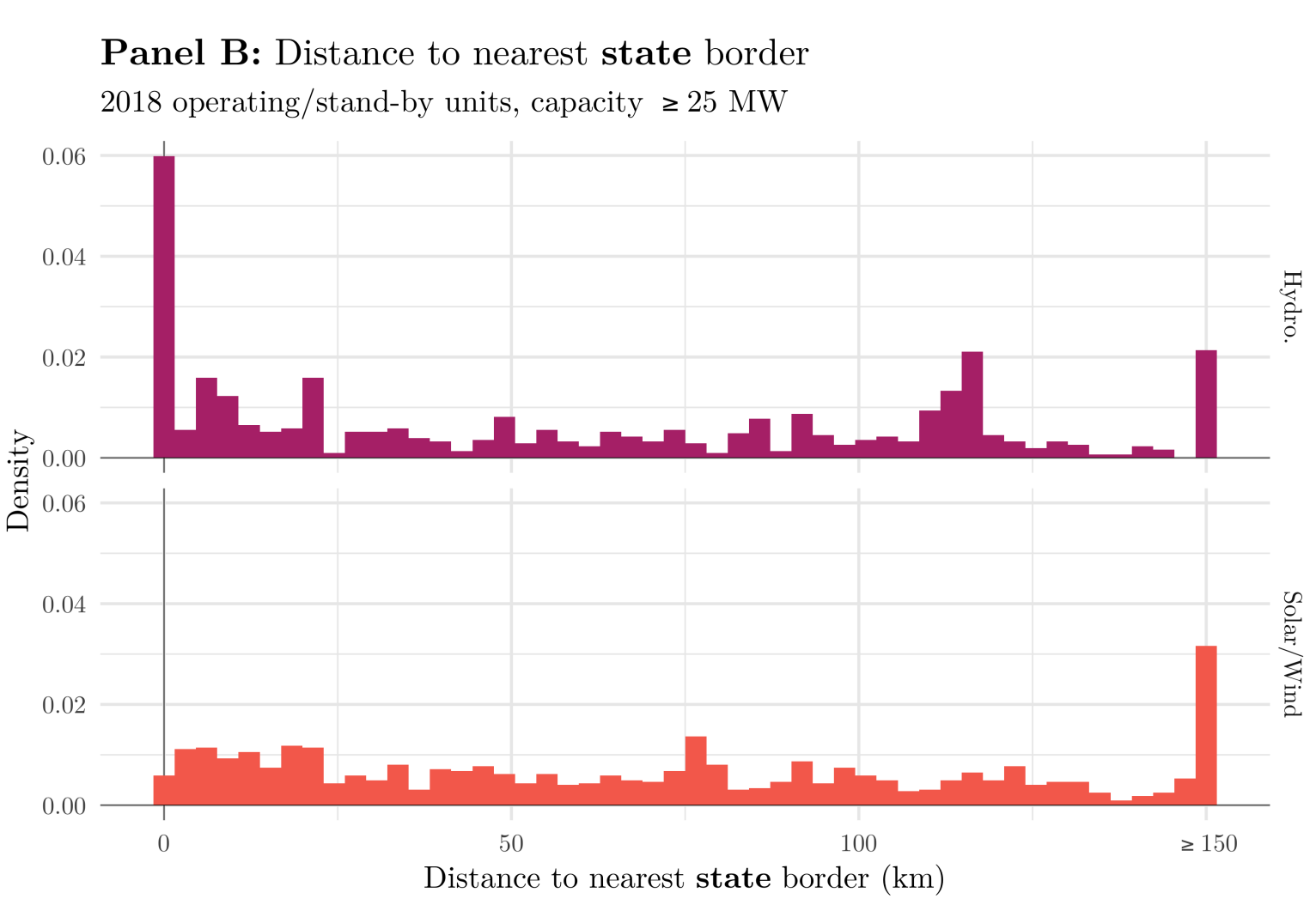
Coal
Gas
0
50
100
≥ 150
Distance to nearest state border (km)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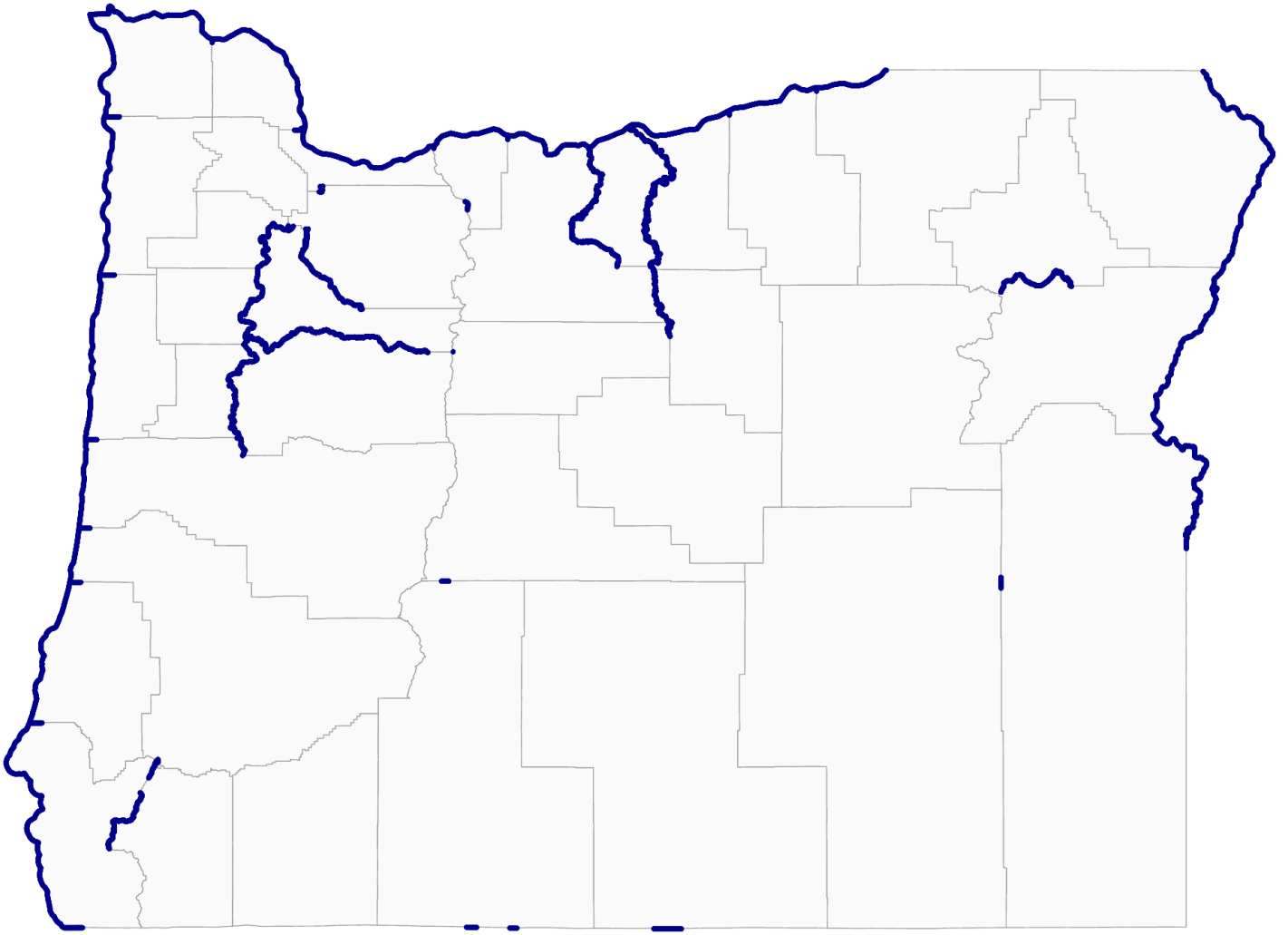
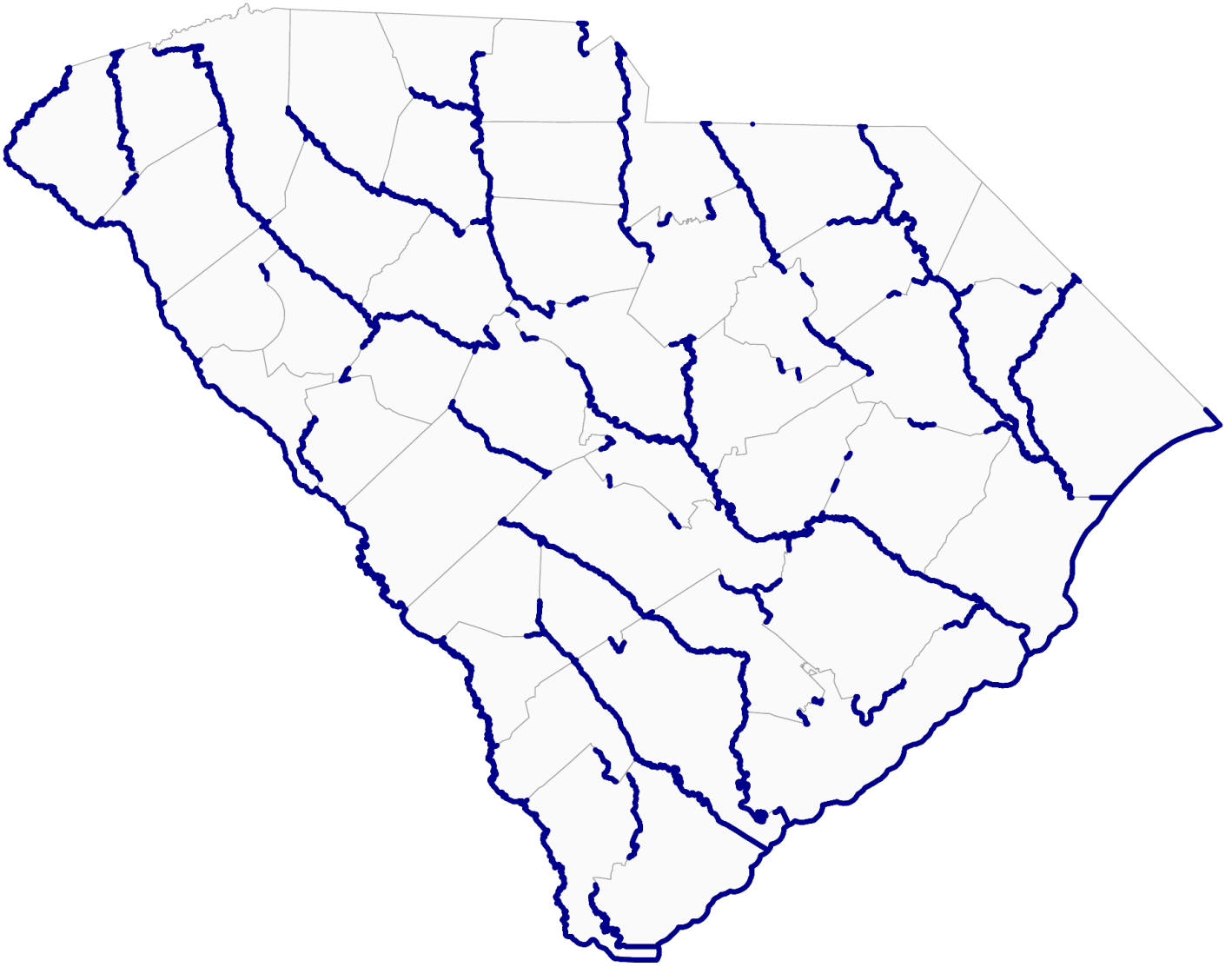
Some borders have water (Oregon)



Some borders have water (South Carolina)



Testing for strategic siting

There are two (non-exclusive) reasons plants might site near borders:

1. **"non-strategic"** inputs to production and transportation (*e.g.*, water)
2. **strategic** exporting of emissions' (external) costs (regulatory avoidance)

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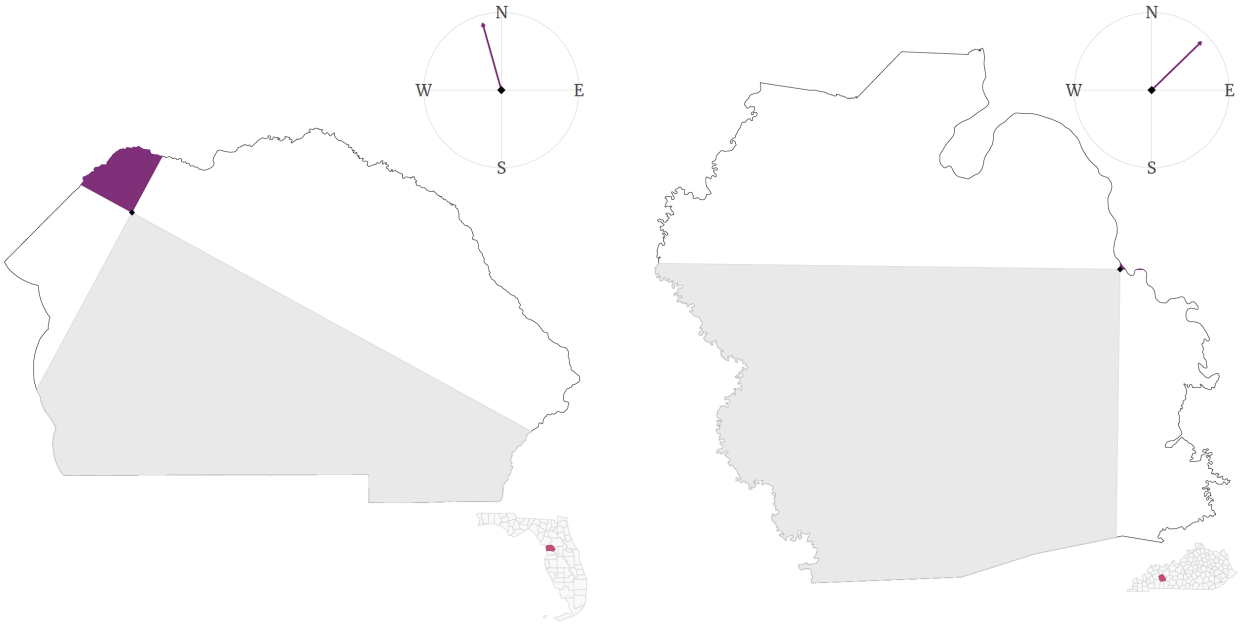
Question: Do coal-fired power plants use the ratio of upwind/downwind area within their own admin. unit to produce or transport electricity? (Unlikely.)



Strategic Siting: Identification

Main Idea: In the absence of strategy, it's a 50-50 flip whether the county's area **upwind** of the plant is larger or smaller than its **downwind** area.

- **Focus on coal-fueled plants**
  Strongest incentive to avoid regulation and/or export emissions downwind
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Identifying assumption:

There are no non-strategic, latent features used by plants use in siting decisions that also correlate w/ the ratio of upwind and downwind areas.

- Social/political/physical processes don't typically use the ratio of upwind to downwind areas within a county or state.🦆
- Nat. gas face many similar input/transmission constraints.
  This latent feature would need to be important to coal & absent from gas.

🦆 This quantity is basically an intersection between meteorologic and admin./carto. properties.

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➕ Calculate *exact* p-values. No parameteric assumptions required!

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− Major drawback: cannot capture more nuanced strategy

Strategic Siting: Main Results

	County		State	
	Coal	**Natural Gas**	**Coal**	**Natural Gas**
Count	515	1,258	515	1,258
Count *strategic*	297	612	279	575
Percent *strategic*	57.67%	48.65%	54.17%	45.71%
Fisher's exact test of H_o: downwind area $\geq$ upwind area				
Under H_o: E[Percent strategic] = 50%				
P-value	0.0003	0.8381	0.0321	0.9989

The Geography of Coal Emissions

Overview

We quantify the nature of the pollution transfer problem using **HYSPLIT**

- Particle trajectory model; heavily vetted by NOAA.
- Especially helpful for *long-distance* pollution transport modeling.
- ⬆ Coal EGU-based particles can travel long distances (*tall* stacks).

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Using HYSPLIT, we can see **where particles departing coal plants travel**

... and find the **sources** of a region's coal-based emissions.

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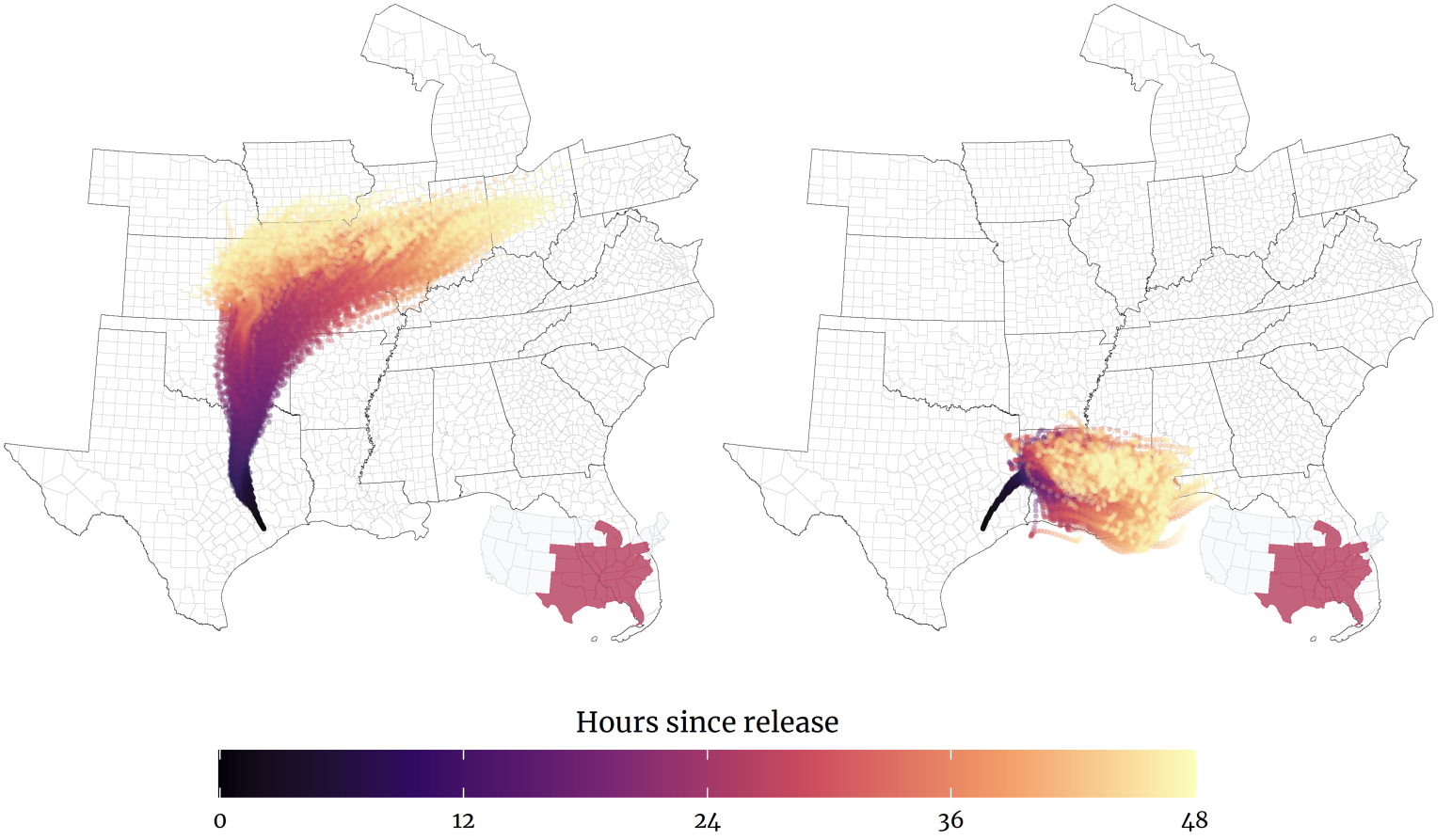
Example of HYSPLIT particle trajectories

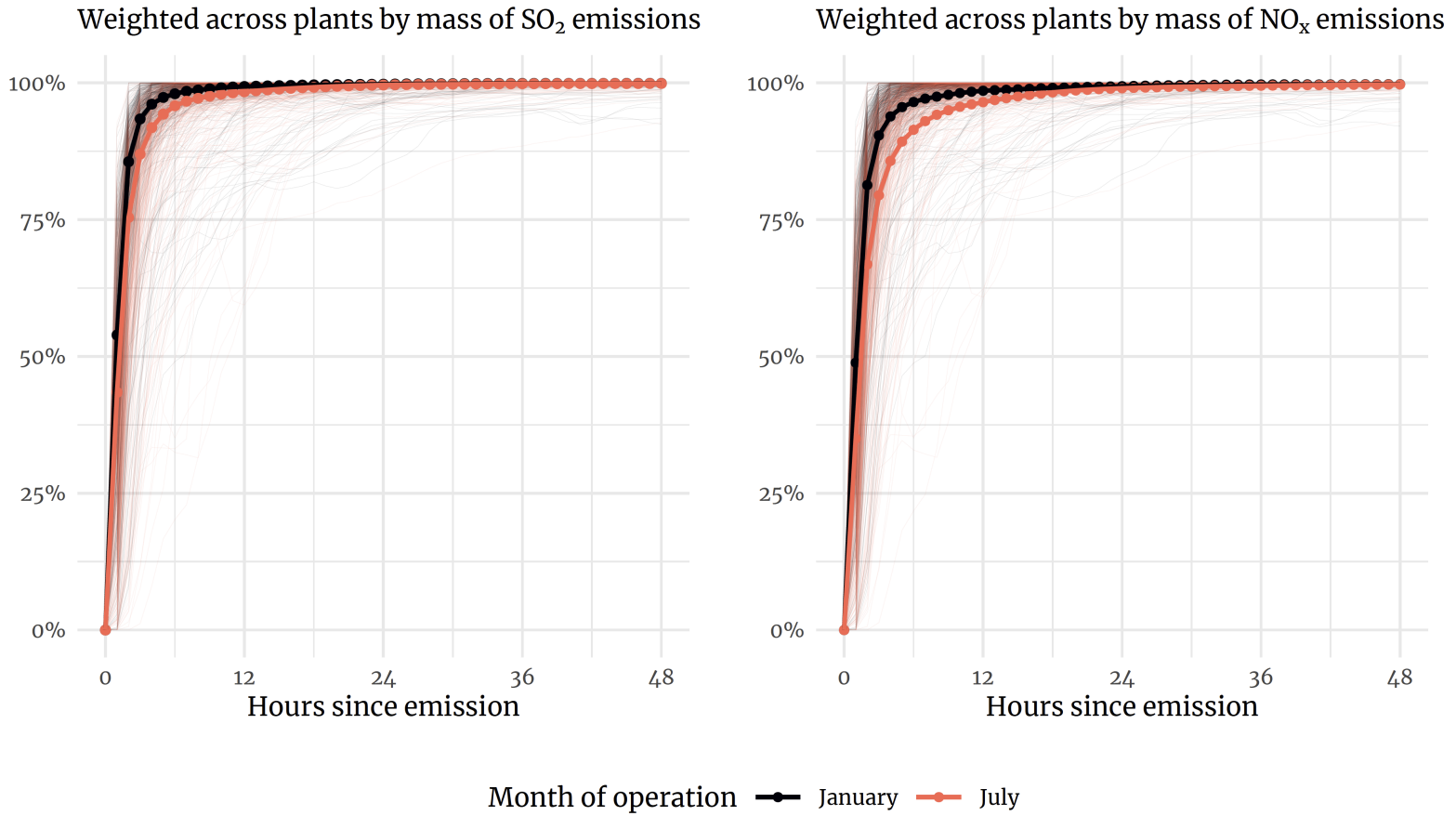
Plant 3470, January 2005

Plant 3470, July 2005



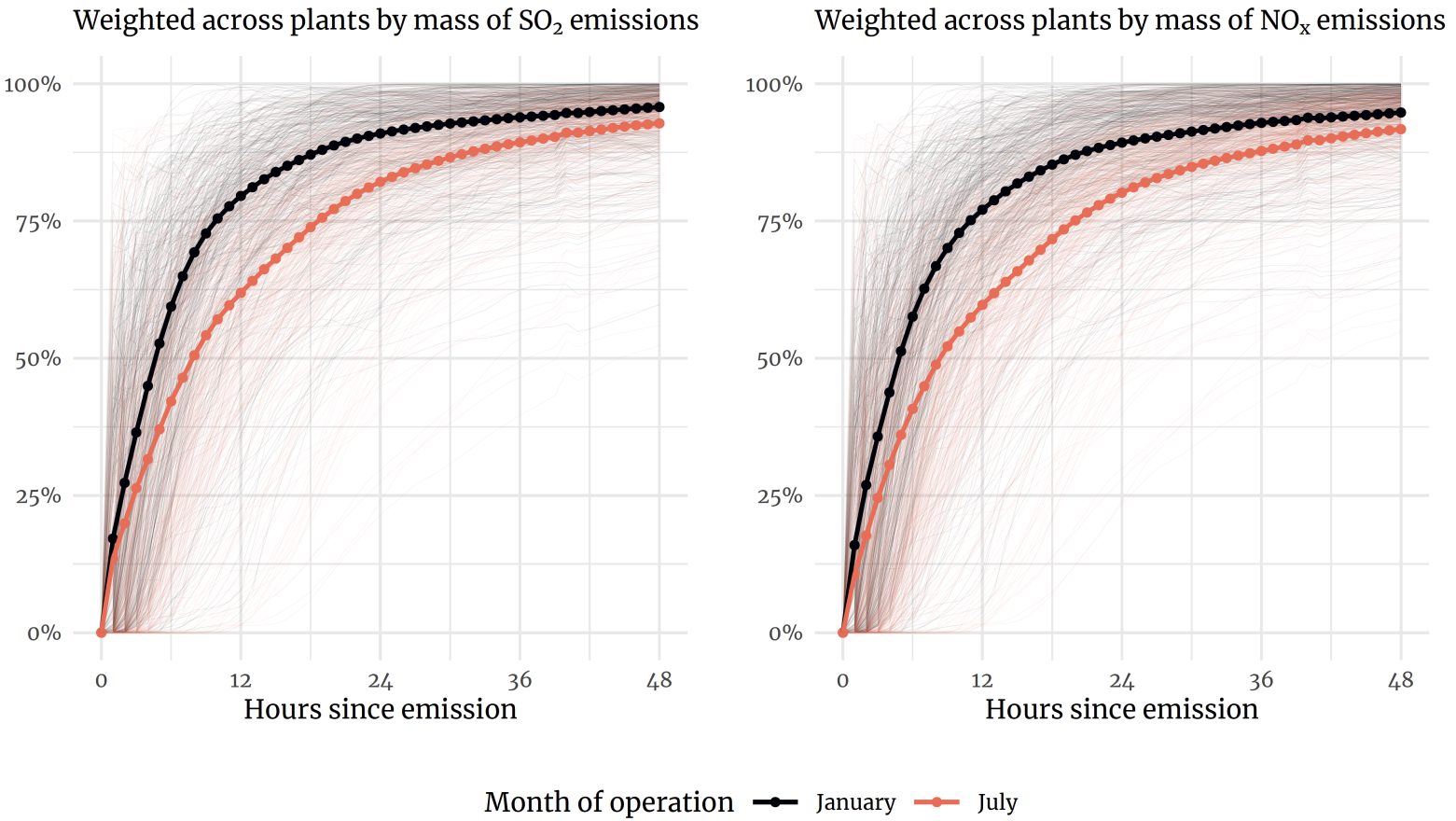
Exporting emissions

Percent of emissions outside source **county** by hours since release



Exporting emissions

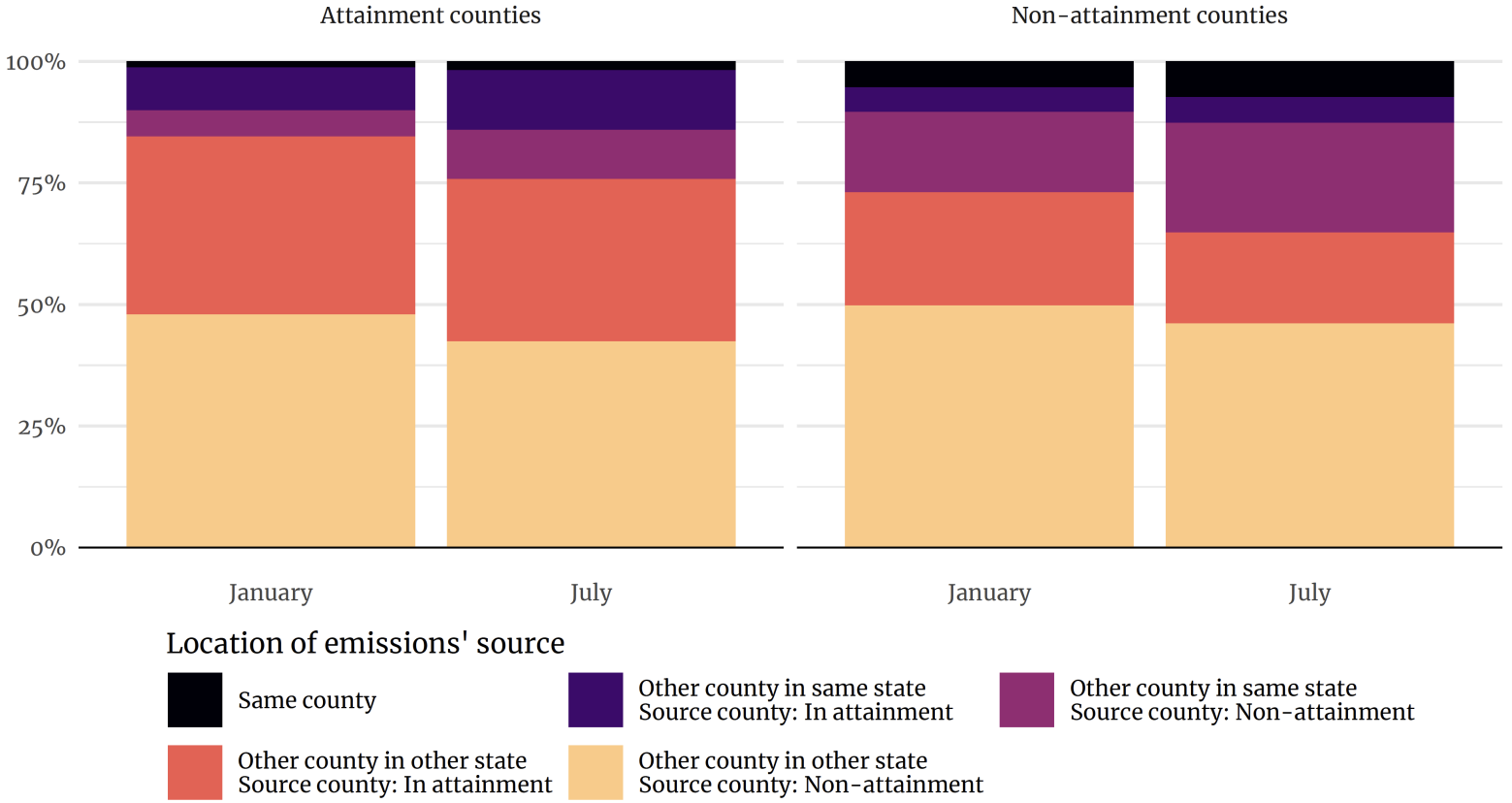
Percent of emissions outside source **state** by hours since release



Sources of local emissions

Panel A: Sources of local coal-based particles, weighted by mass of SO_2 emissions

Coal-fueled units in 2005 with capacity greater than 25 MW



Conclusions

We find

1. Many power plants in the US **sited near borders** (county and state).
2. **Coal plants strategically sited** to reduce downwind exposure.
   Nat. gas plants did not.
3. Coal plants' pollution **quickly leaves origin counties and states**.

Implications

1. Geographic dispersion of inputs complicates decentralized regulations.
2. Regulated units have strategically responded (exporting emissions).
3. Transport-based regulations will be key to internalizing costs.

Thank you!

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