

# On the Potential of Optimal Transport in Geospatial Data Science

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# Gap between prediction & optimization research

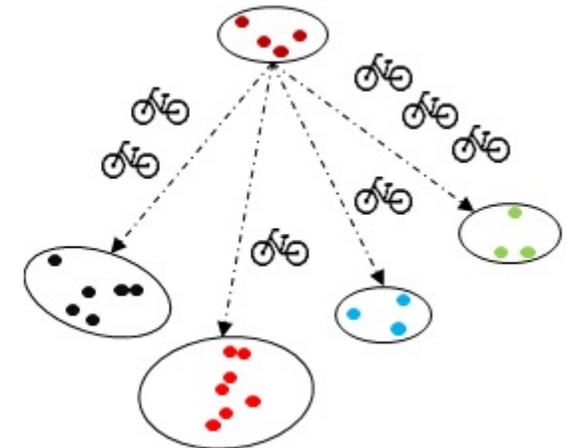
## Demand prediction

e.g., bike sharing demand



## Optimizing operations

e.g., bike relocation

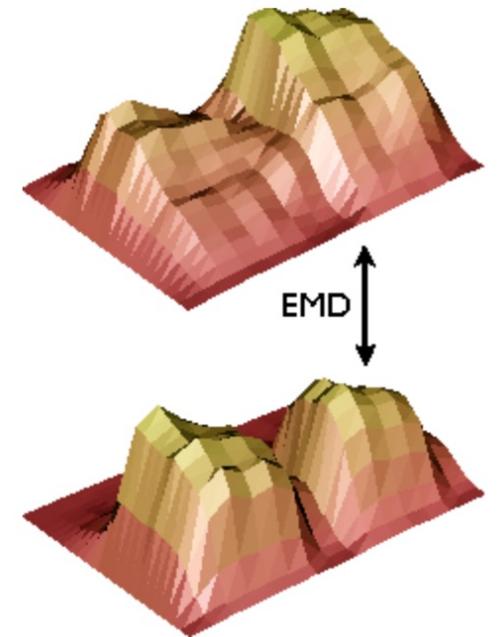


→ How much do good prediction improve operations?

→ How to measure the impact of prediction errors, e.g. in terms of CO<sub>2</sub> emissions?

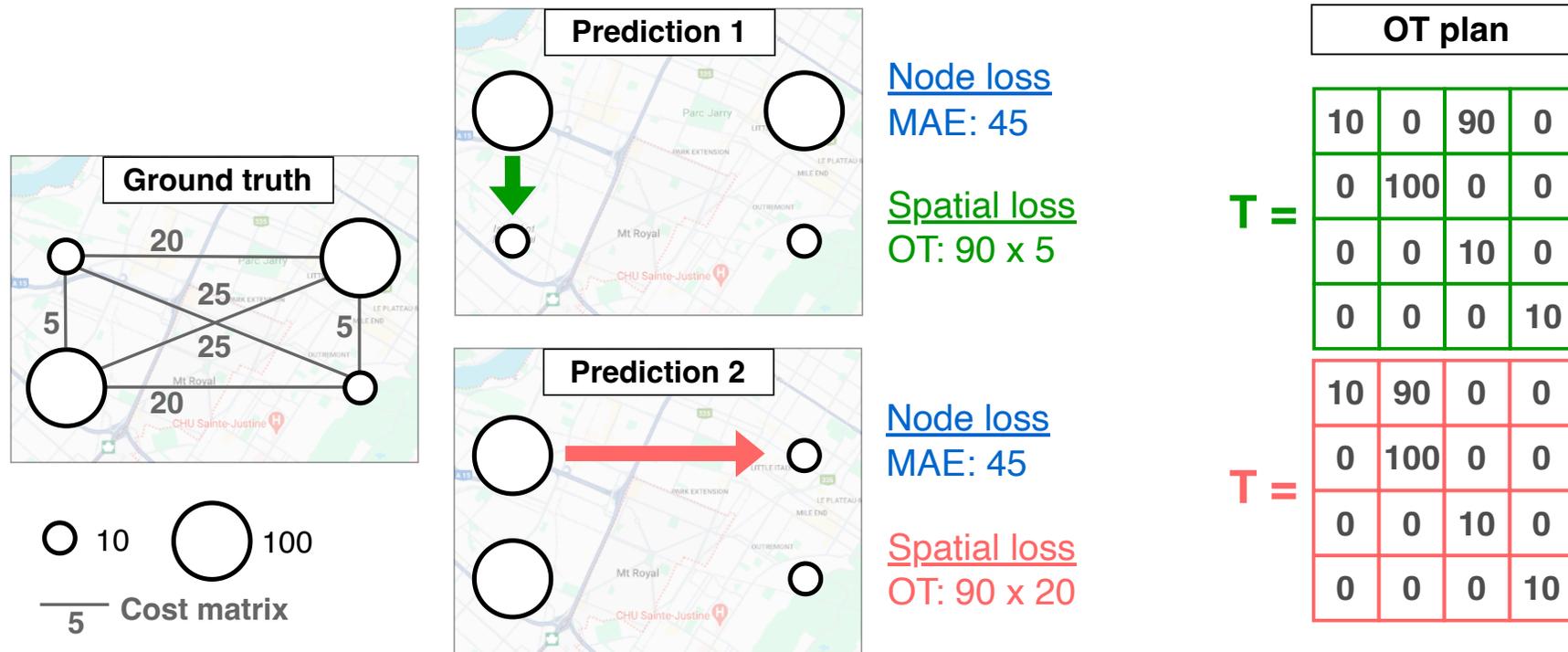
# Optimal Transport as a spatial metric

- Standard metrics (e.g., MSE) ignore the spatial distribution
- **Aim:**  
**Spatial evaluation metric & loss function that measures the discrepancy between true and predicted distribution**
- Optimal Transport theory:  
Minimal cost of moving mass from an initial distribution to a target distribution



# OT for evaluating spatiotemporal predictions

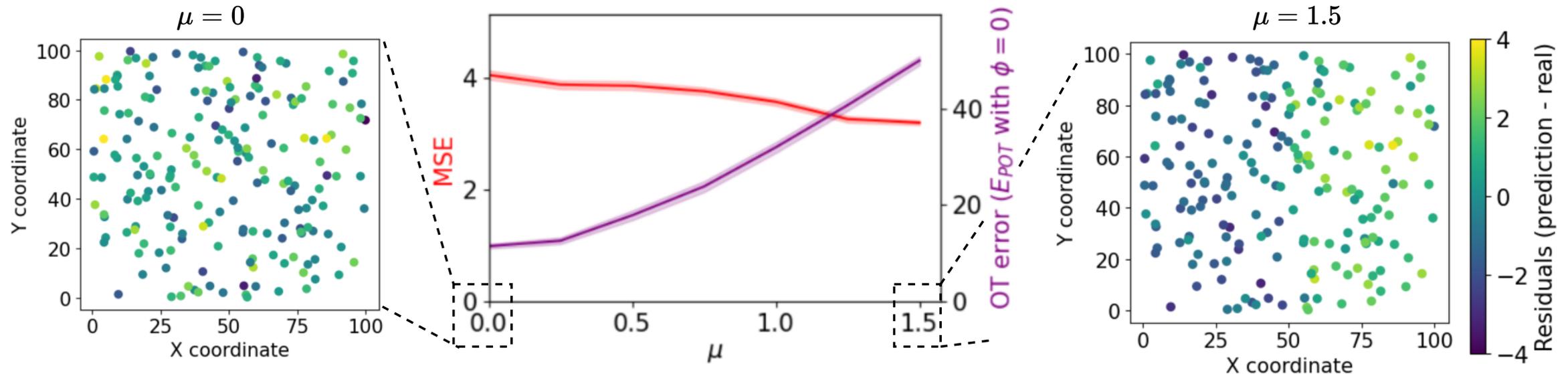
- Linear programming to compute the optimal transport plan T
- T shows how the mass is redistributed with minimal cost



# Results – synthetic data

**Synthetic data:** Residuals drawn from  $N(\mu, \sigma)$  for  $x < 50$  and from  $N(-\mu, \sigma)$  for  $x > 50$

→ The larger  $\mu$ , the larger the difference in the residuals, and the higher the transportation cost!



## Results – training with OT-based loss

- OT cost is found via linear programming
  - LP is not differentiable
  - Sinkhorn algorithm was developed for efficiently approximating OT [1]
- Training with Sinkhorn loss reduces the OT error

Application	Loss function	MSE	$E_{OT}$
Bike sharing demand	OT (Sinkhorn) loss	1.26	135.7
	MSE loss	1.24	161.5
Charging station occupancy	OT (Sinkhorn) loss	0.35	30.7
	MSE loss	0.34	32.7

# Conclusion

- OT is a promising tool to evaluate and improve spatiotemporal predictions
  - Climate change pathway: OT costs have a direct relation to CO<sub>2</sub> emissions
  - Generally applicable, e.g. for
    - Traffic forecasting
    - Power demand forecasting
    - Wildfire spread prediction
  - Further work is needed to assess the potential of OT for specific applications
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