Active Learning for Air Quality Station Deployment

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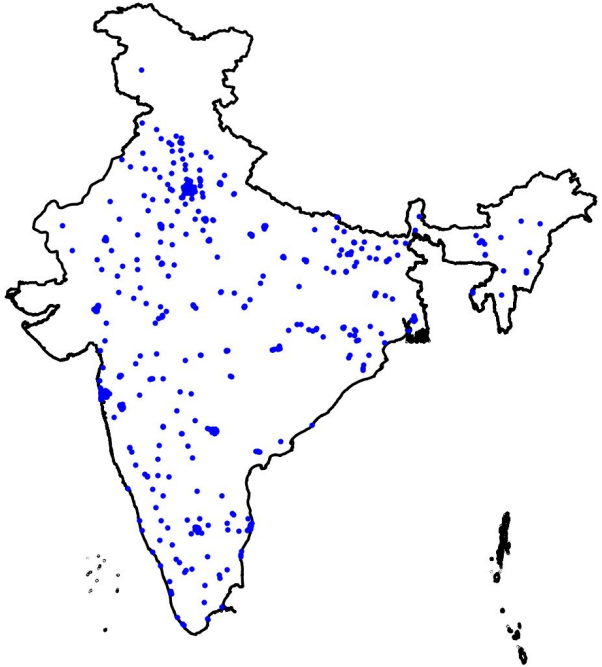
Motivation



- Air pollution kills 70 lakh people every year[1]
- 17 lakh fatalities occur in India alone
- We can only improve it if we can measure it.
- Current monitors: 558, Demand: 4000[2]

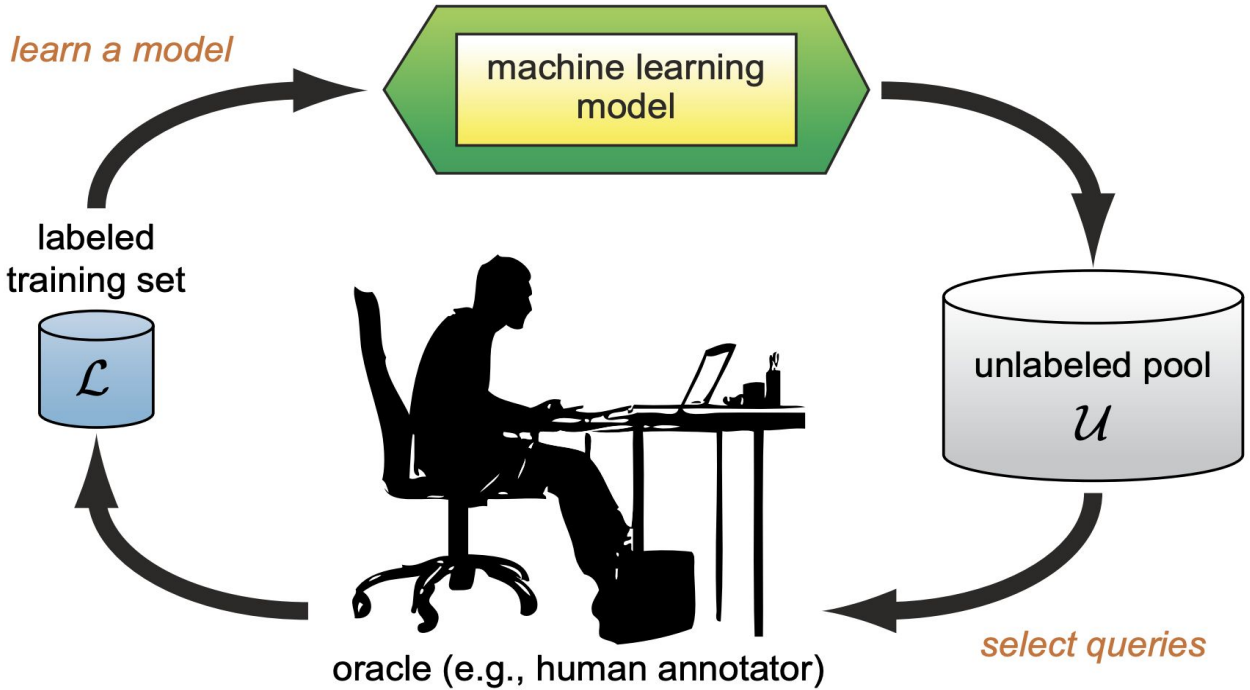
Methodology

- **Earlier**: Active learning focused on classification
- **Now**: We predict continuous values (pollution levels)
- Need to model both **predictions** and **uncertainty**
- **Neural Processes** provide both:

  → Pollution estimate

  → Confidence at each location
- Use uncertainty to guide next sensor placement

Methodology I - Active Learning



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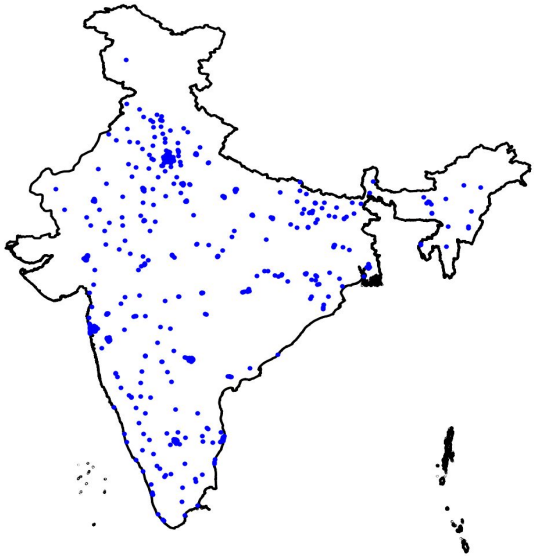
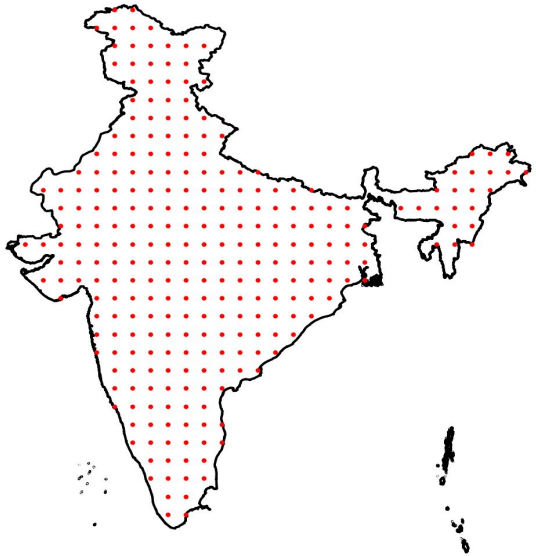
Active Learning Search Grid

CPCB Sensors



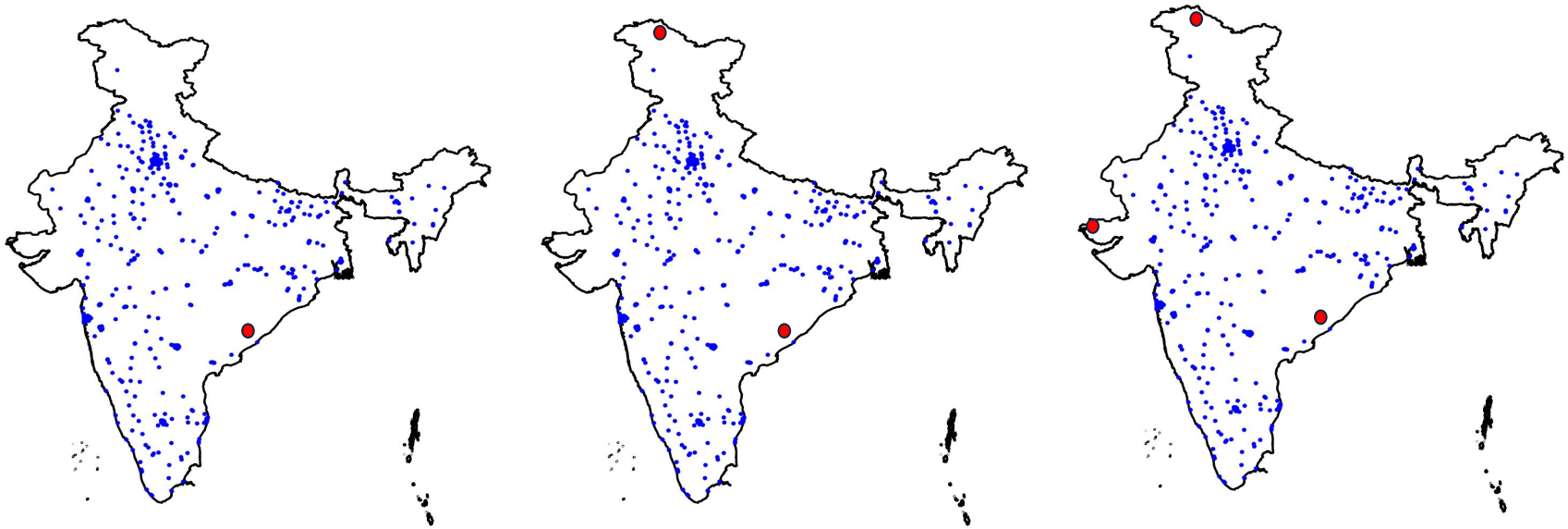
Active Learning Pool Points



Where to place the next sensor?

Methodology II - Active Learning

- **Heuristic method**
  - Context Distance: Install sensor at a location farthest from the existing sensors



Methodology II - Active Learning

- **Acquisition Strategy**
  - Entropy

$$x^* = \arg\max_{x \in Pool} \mathcal{H}(x|\boldsymbol{x}_{tr}, \boldsymbol{y}_{tr})$$
$$= \arg\max_{x \in Pool} \frac{1}{2}\log\left(2\pi e\sigma_x^2\right)$$

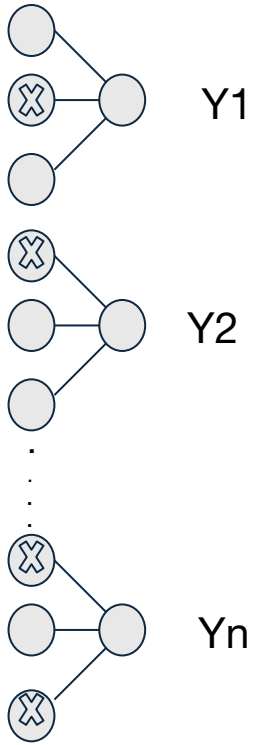
Methodology II - Active Learning

- **Acquisition Strategy**
  - Mutual Information

$$x^* = \arg\max_{x \in Pool} \left(\mathcal{H}(\boldsymbol{x}_s | \boldsymbol{x}_{tr}, \boldsymbol{y}_{tr}) - \mathcal{H}(\boldsymbol{x}_s | \boldsymbol{x}_{tr}, \boldsymbol{y}_{tr}, x, y) \right)$$

How to get uncertainty from neural networks?

MC Dropout



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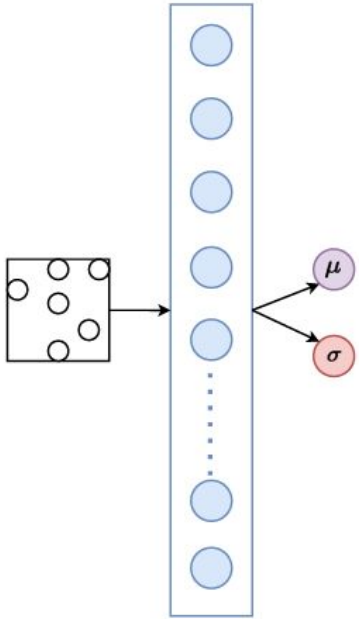
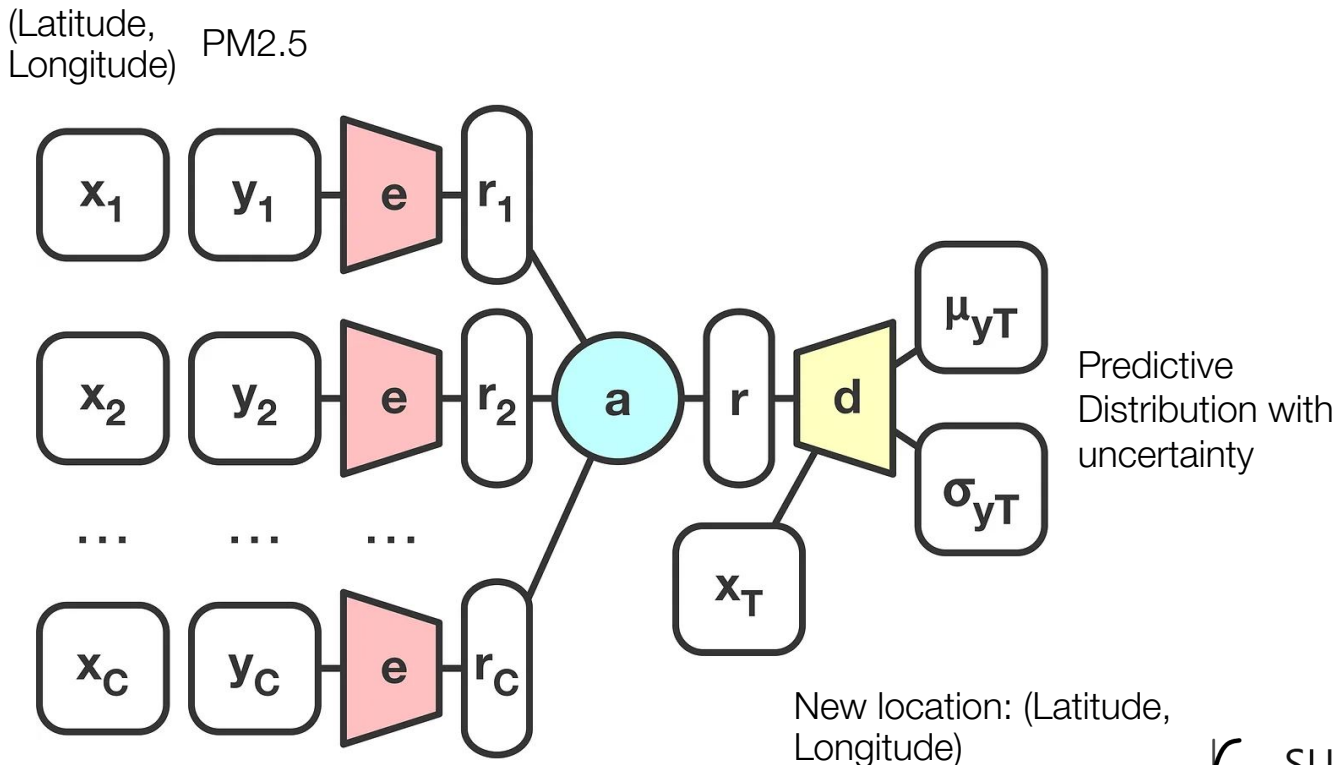
Gaussian MLP



Methodology II - Neural processes



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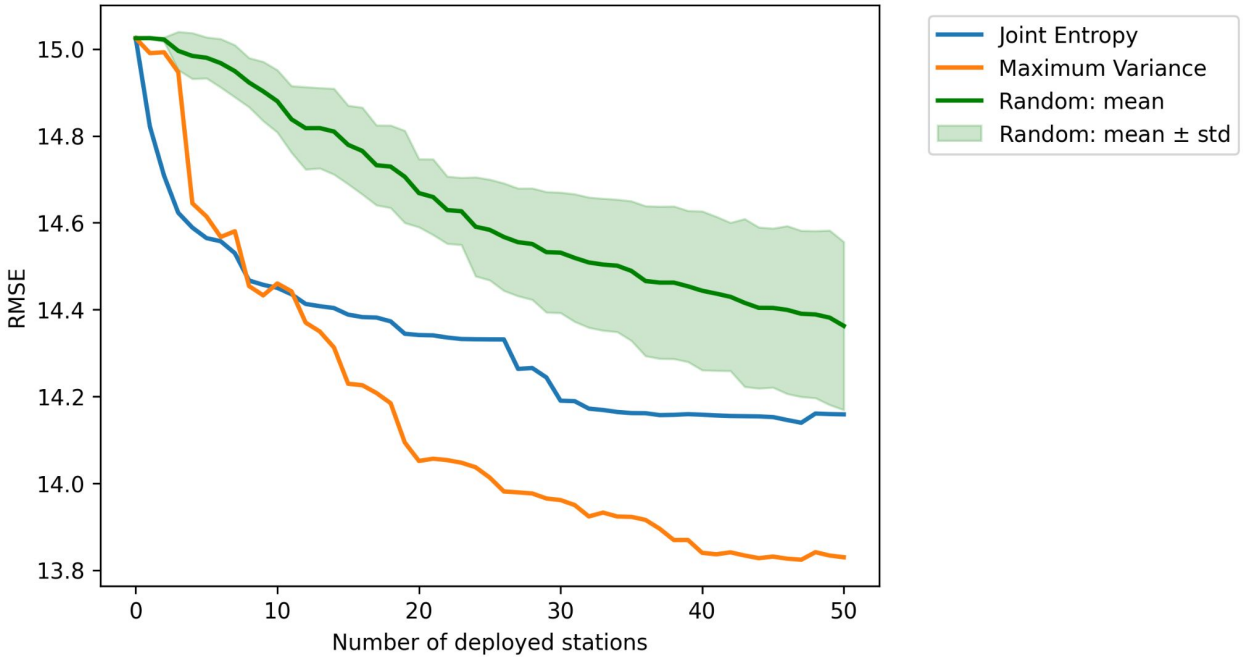
Active Learning Setup

- Satellite-derived PM2.5 monthly data from WUSTL
- Spatial resolution: 0.1 degree
- Timespan: 1998 to 2022 (25 years)

Active Learning Results



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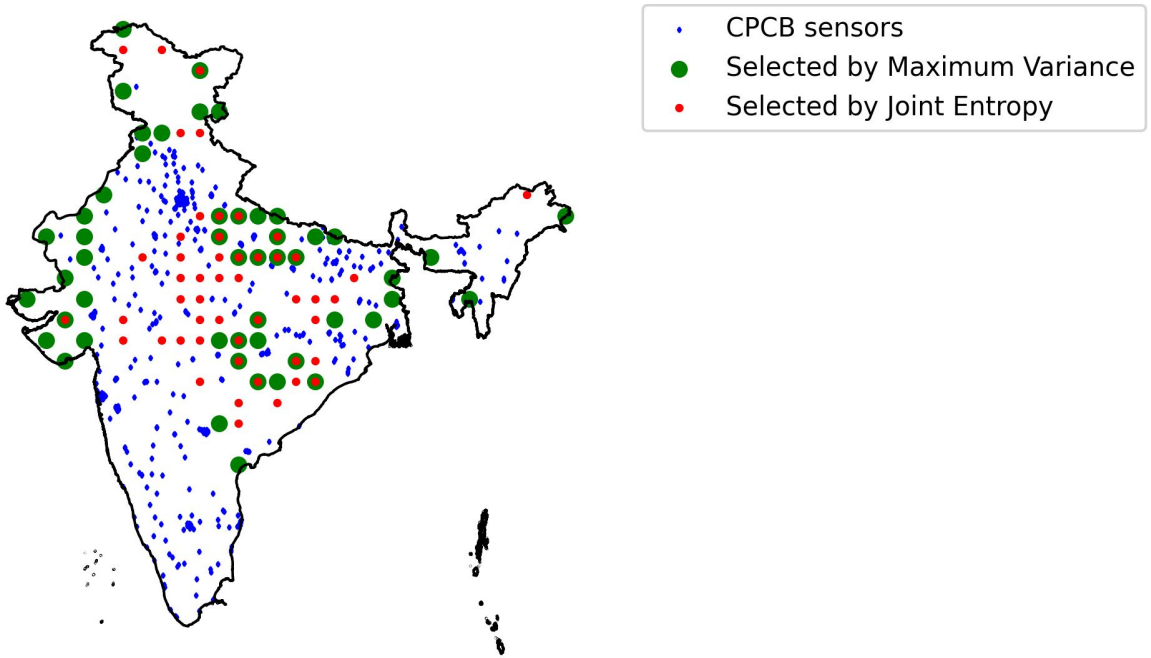
Active Learning Results



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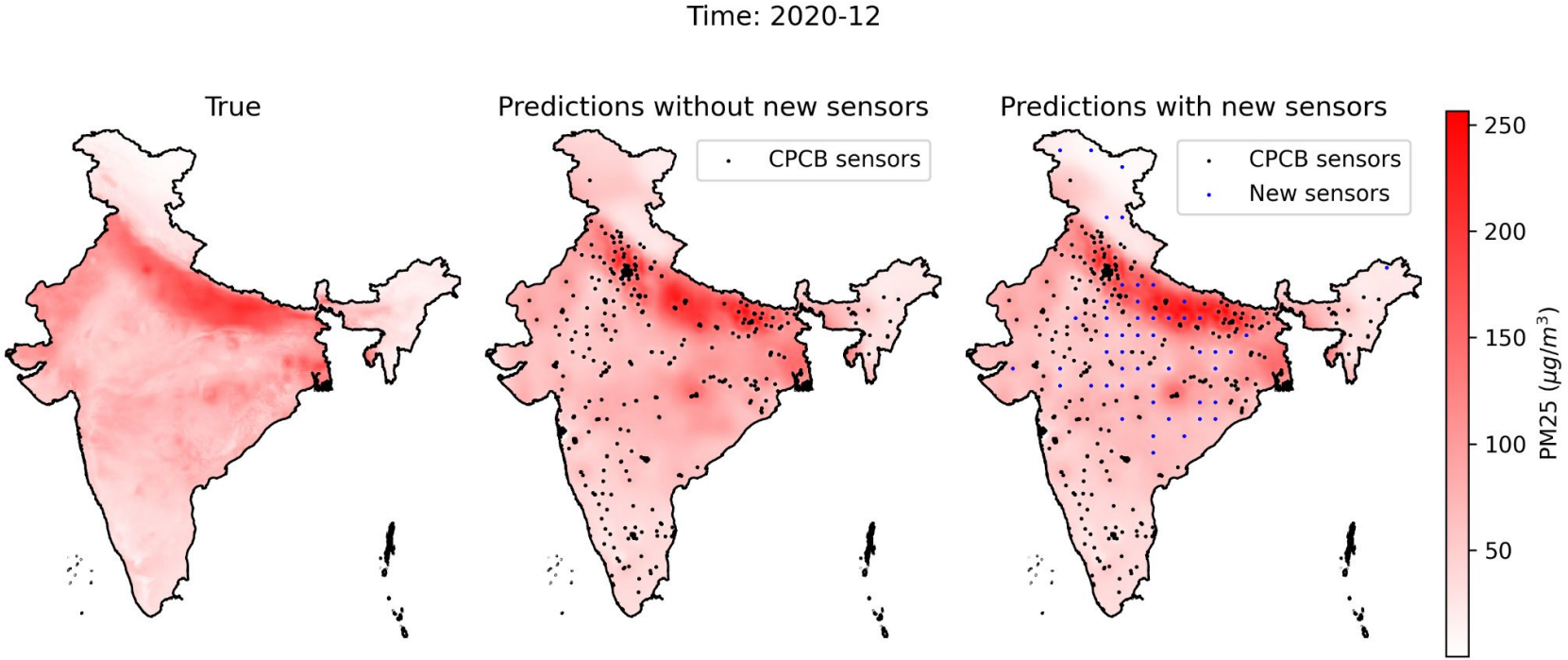
Active Learning Results



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Questions?