Learning Global Variations in Outdoor $PM_{2.5}$ Concentrations with Satellite Images

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Introduction

- Fine particulate matter ($PM_{2.5}$) kills millions annually with economic impacts measured in billions of dollars
- Cost-effective methods for estimating air pollution are needed to support pollution mitigation and health research
- Traditional geostatistical models for predicting exposures rely on detailed geographic information (e.g. traffic, land use) that are not always available
- Alternatively, this geographic information can be captured through satellite imagery

Methods

- 20,000 annual average measurements among 6000 global sites (spanning 2010-2016) were compiled from the WHO and grouped into ~156 x 156km geohash cells

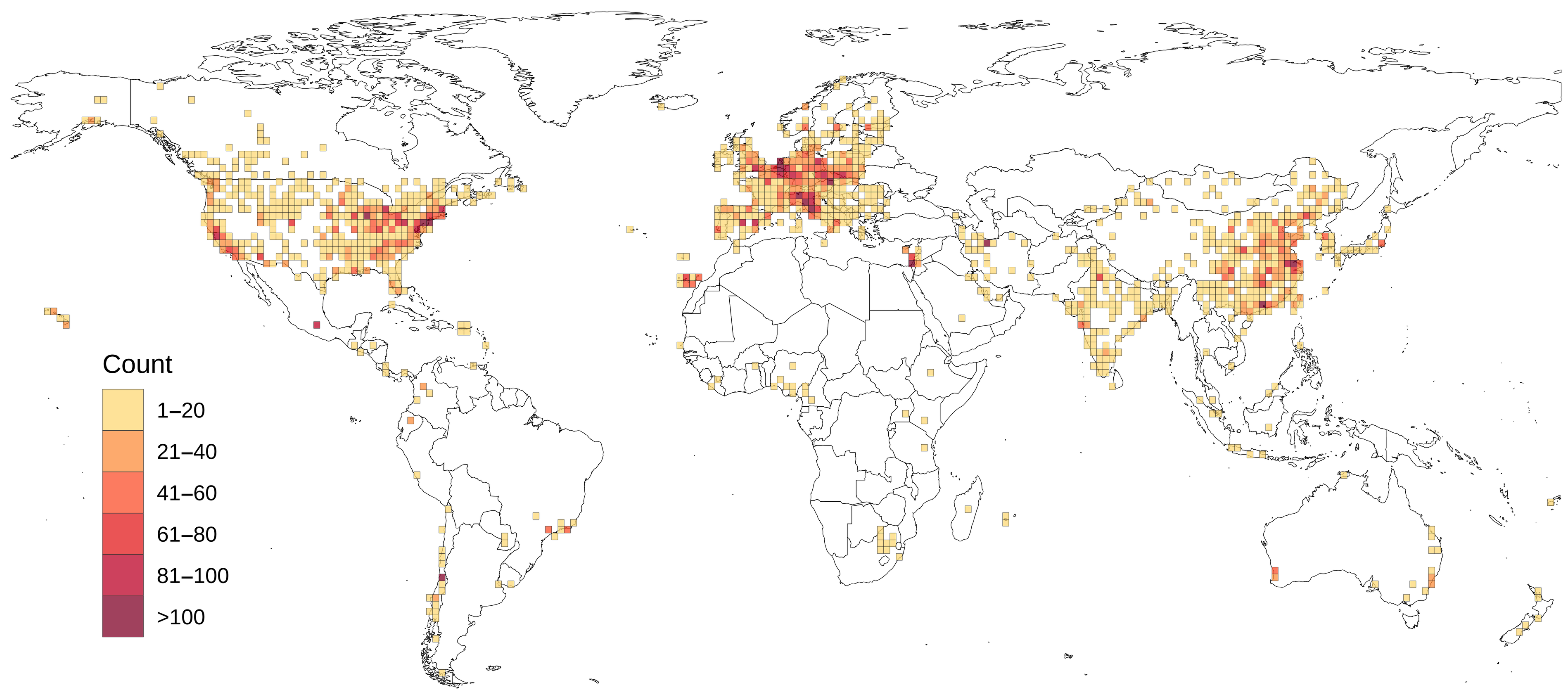

Figure 1: *Locations of global $PM_{2.5}$ monitoring sites grouped into 1200 geohash cells.*

- Zoom level 13 to 16 satellite images centred on measurement sites were downloaded from Google static maps

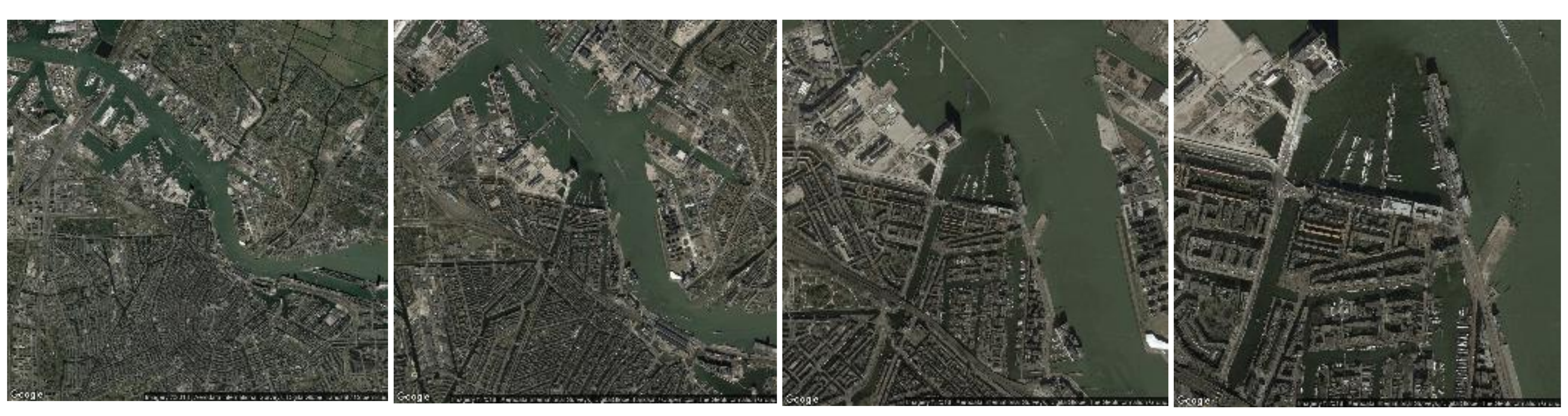

Figure 2: *From left to right, respectively: zoom level 13 (10 x 10km) through 16 (1.5 x 1.5km)*

- Data were randomly split into disjoint training (80%), validation (10%), and test sets (10%) by geohash cells
- Categorical (10 balanced classes split evenly by deciles of $PM_{2.5}$ distribution) and continuous models were developed
- Optimal configuration consisted of zoom level 13 images and an Xception base initialized with ImageNet weights
- Model performance was compared to "gold standard" DIMAQ geostatistical model from the Global Burden of Disease Study

Results

Classification accuracy: 33.7%
One-off classification accuracy: 65.7%

Test set SD: 23.82 μg/m^3
Regression RMSE: 13.01 μg/m^3

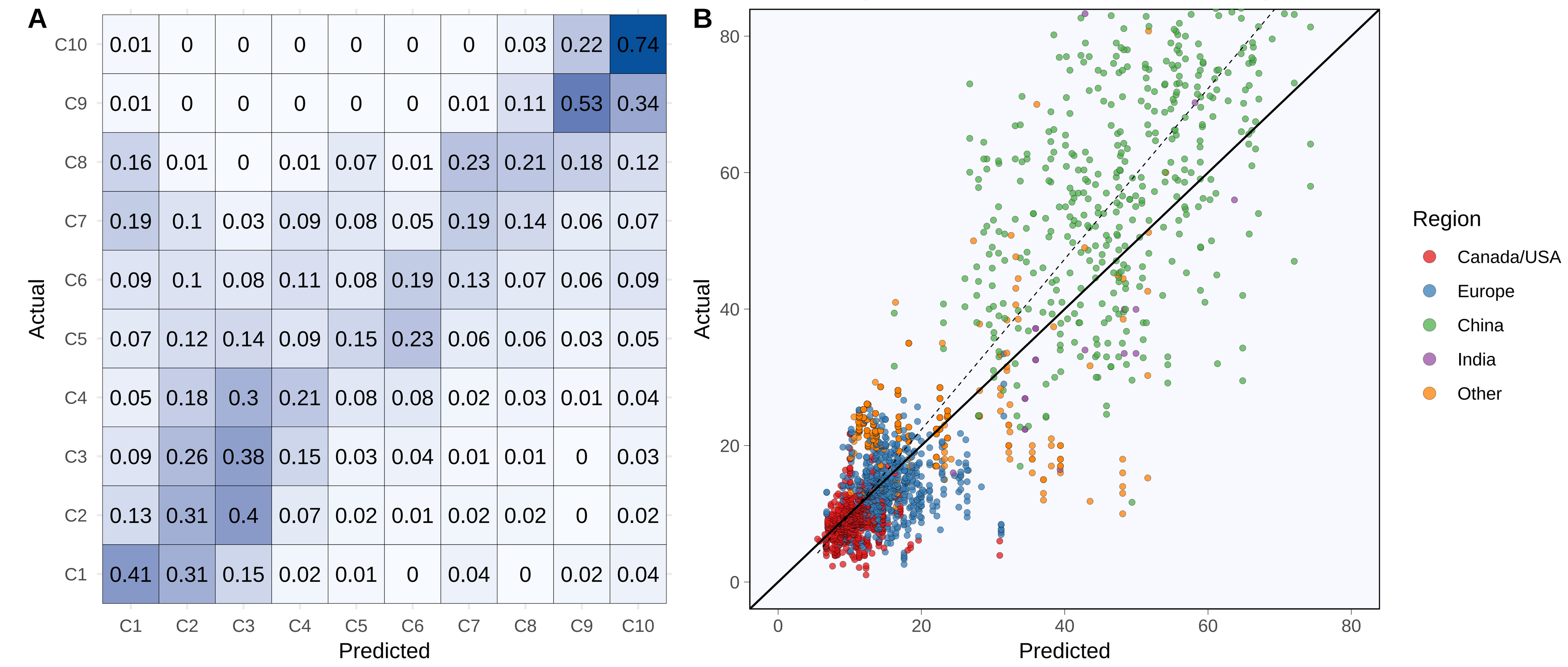

Figure 3: *Measured versus predicted $PM_{2.5}$ concentrations (C1: low; C10: high) in the test set*

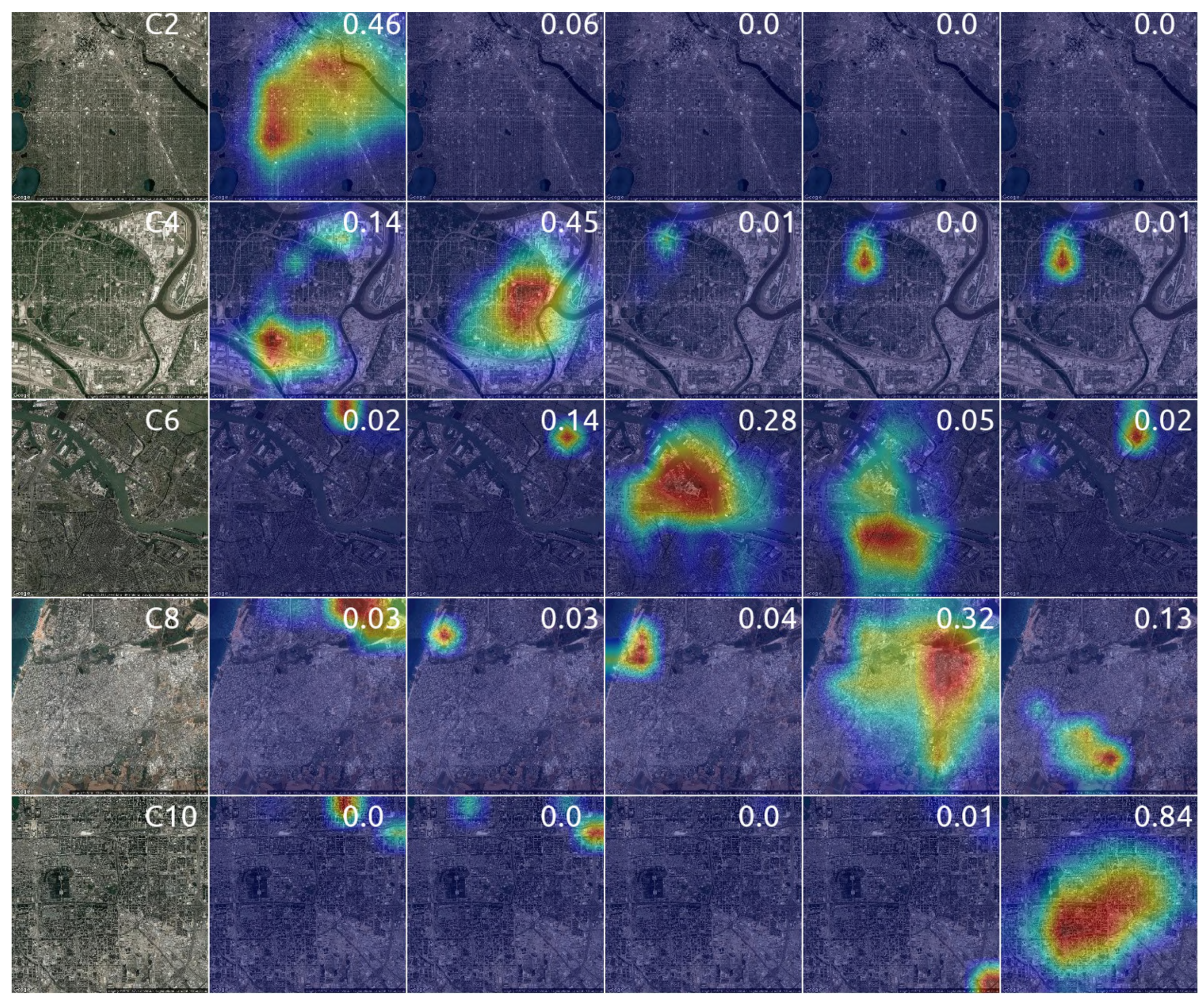

Figure 4: *Gradient-weighted class activation maps for images correctly classified by the final model. Column 1: Original Column 2-6: GRAD-CAM for classes 2, 4, 6, 8, 10, respectively. Numerical values indicate predicted probability of the image belonging to the respective class*

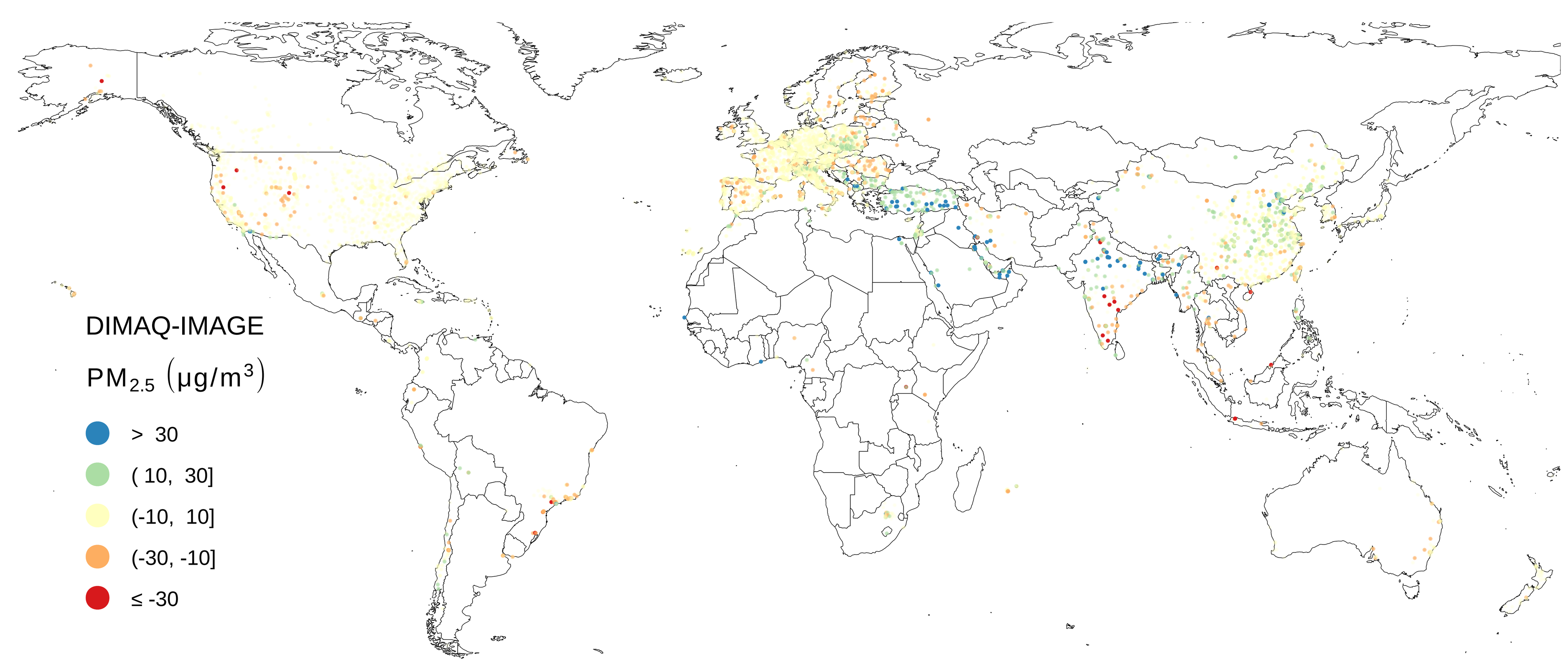

Figure 5: *Difference in predicted $PM_{2.5}$ between the IMAGE-$PM_{2.5}$ and DIMAQ models*

Discussion

- The IMAGE-$PM_{2.5}$ model offers a fast cost-effective method for estimating global variations in annual average $PM_{2.5}$
- Model could be improved with timestamped hi-res imagery
- Satellite images could serve as a predictor for other exposures

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References

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