Estimating Atmospheric Visibility From Camera Images

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OBJECTIVE

Compute trustworthy estimates of atmospheric visibility on a statewide scale using images derived from a network of outdoor cameras

INTRODUCTION

- Automated Surface Observing Systems (ASOS) visibility measurements:
  - High-quality
  - Expensive, limited coverage
- Cameras are ubiquitous
  - For example: every station in the New York State Mesonet (NYSM) has a camera with a five-minute daytime sampling interval (Brotzge et al. 2020)
- Wilson Reyes (2023):
  - Convolutional neural network for comparing relative visibility of a query image against a reference image of a known visibility distance (You et al. 2018)
  - For model training and verification, ASOS distances are used as ground truth labels for Mesonet images
  - Because of the distance between the NYSM and ASOS stations, labels are noisy
- We propose an approach for human verification of ASOS-derived labels for reference images

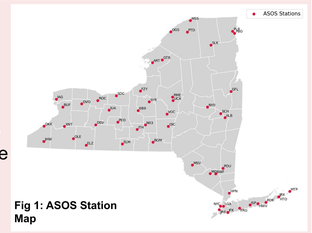


Fig 1: ASOS Station Map

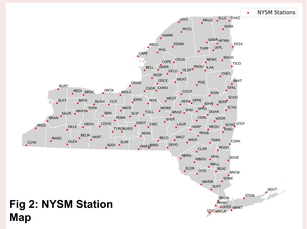
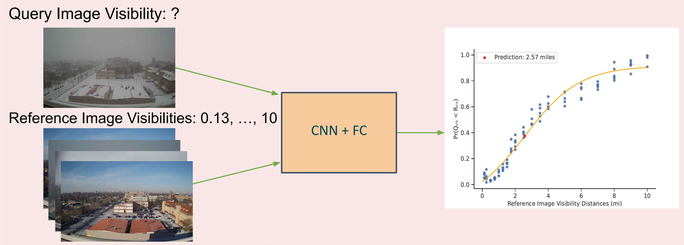


Fig 2: NYSM Station Map

DATA & METHODS

Comparative Visibility Model (Wilson Reyes 2023)



* From a limited set of labeled reference images

Fig 3: Model diagram

- Convolutional neural network (CNN) model
- Input is an image pair
  - Query: image of unknown visibility distance
  - Reference: image of known visibility distance
- Output:
  - Probability that the query image is less visible than the reference image
- Visibility distance estimation for the query image:
  - Compare the query image to a set of reference images
  - Fit a sigmoid to the resulting probabilities
  - Estimated distance is the inflection point of function

Reference Image Selection Procedure

1. Find the distance of uniquely identifiable features using satellite imagery
2. For each uniquely identifiable feature:
   a. While the number of verified images is less than 3:
      i. Sample without replacement k images that have the same ASOS-reported distance as the true feature distance
      ii. Select reference image from set if:
      - Feature is partially visible in the image
      - No obstructions are on the lens
      - The image represents a different time of day and season than the others that have been selected



Fig 4: Feature distance from Queens camera (see Fig 7)

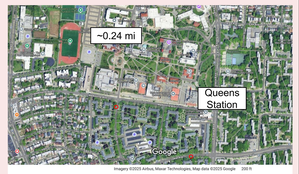


Fig 5: Feature distance from Queens camera (see Fig 8)

REFERENCE IMAGES

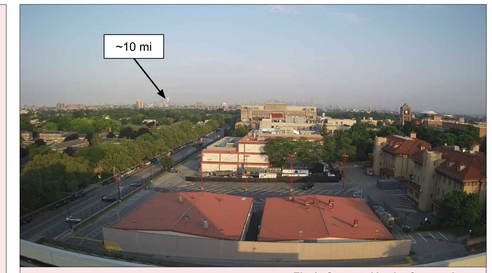


Fig 6: Queens 10 mi reference image

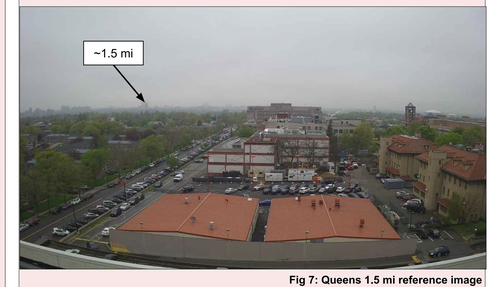


Fig 7: Queens 1.5 mi reference image



Fig 8: Queens 0.25 mi reference image

RESULTS: CASE STUDIES

CASE 1: Wildfire Smoke

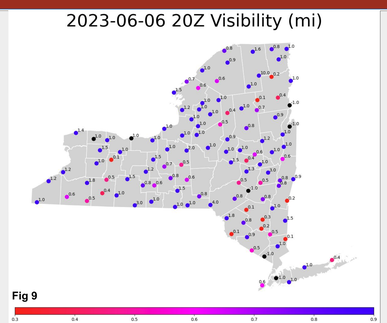


Fig 9

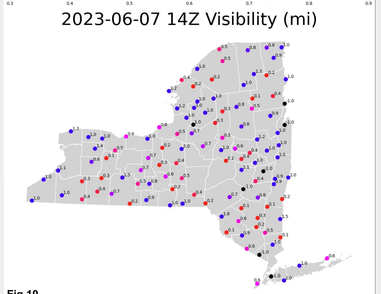


Fig 10

CASE 2: Winter Weather

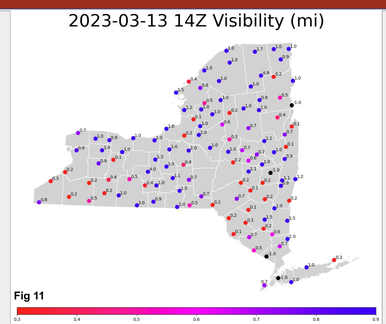


Fig 11

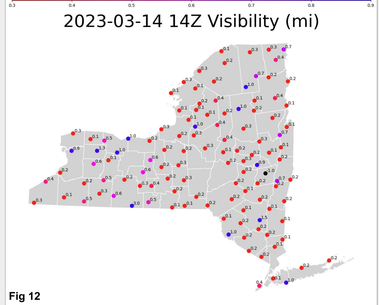


Fig 12

CASE 3: Clear Skies

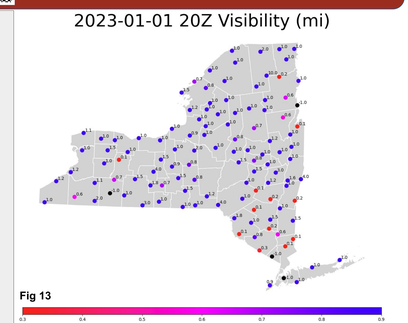


Fig 13

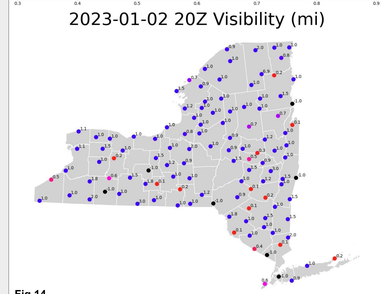


Fig 14

CONCLUSION

- Most stations responded well to changes in visibility
- Few stations could not be represented due to pairing issues
- Few stations had consistently low estimates, despite clear conditions
  - Stations with ambiguous features or lack of depth in the field of view

Future Work

- Implement a real-time visibility distance dashboard
- Automatic reference image selection
- Automatic correction of ASOS-derived labels

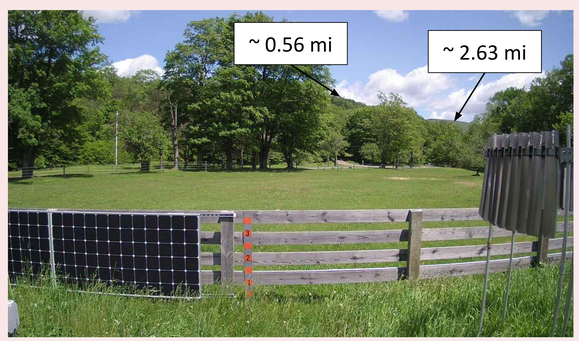


Fig 15: Camera image from NYSM Claryville station

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