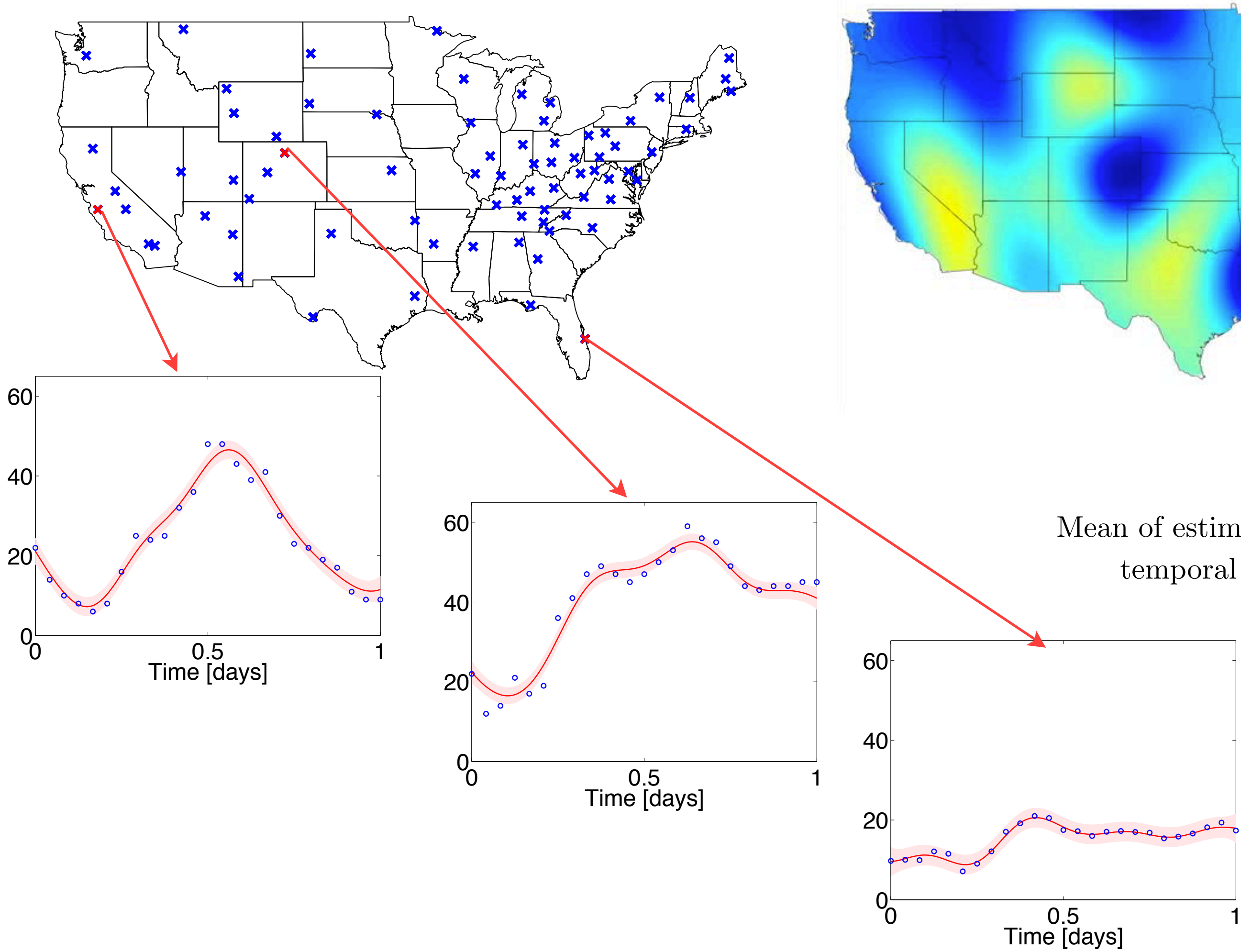
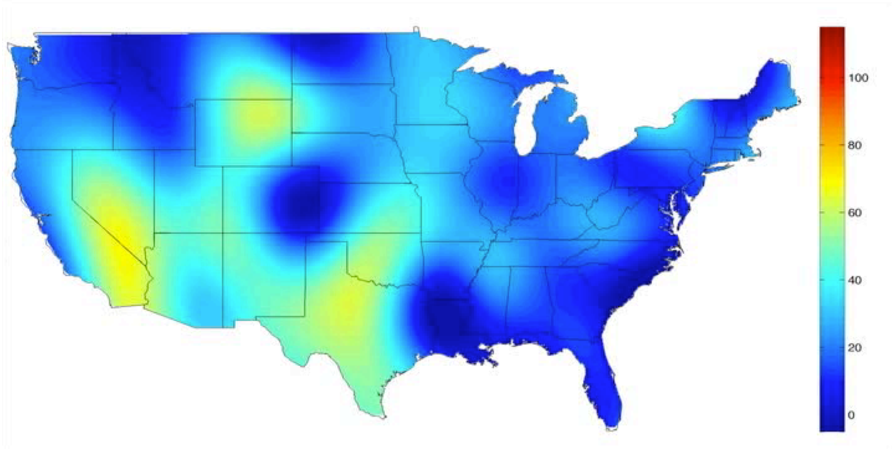
A Platform for Air Quality Forecast

Fabio Ramos
Infact Analytics, National ICT Australia
fabio.ramos@nicta.com.au

Ozone forecast





Mean of estimated spatial-
temporal process

Current Approaches

Simple empirical models: fast, easy to use, but inaccurate

Advanced, physically-based approaches: accurate in specific locations, computationally expensive, not very adaptable to other environments

Statistical approaches: provides uncertainty on the predictions, learns complex spatial-temporal patterns, computationally expensive, difficult to implement

A Bayesian Approach to Air Pollution Forecast

infact analytics

NICTA

Prior belief

Likelihood function

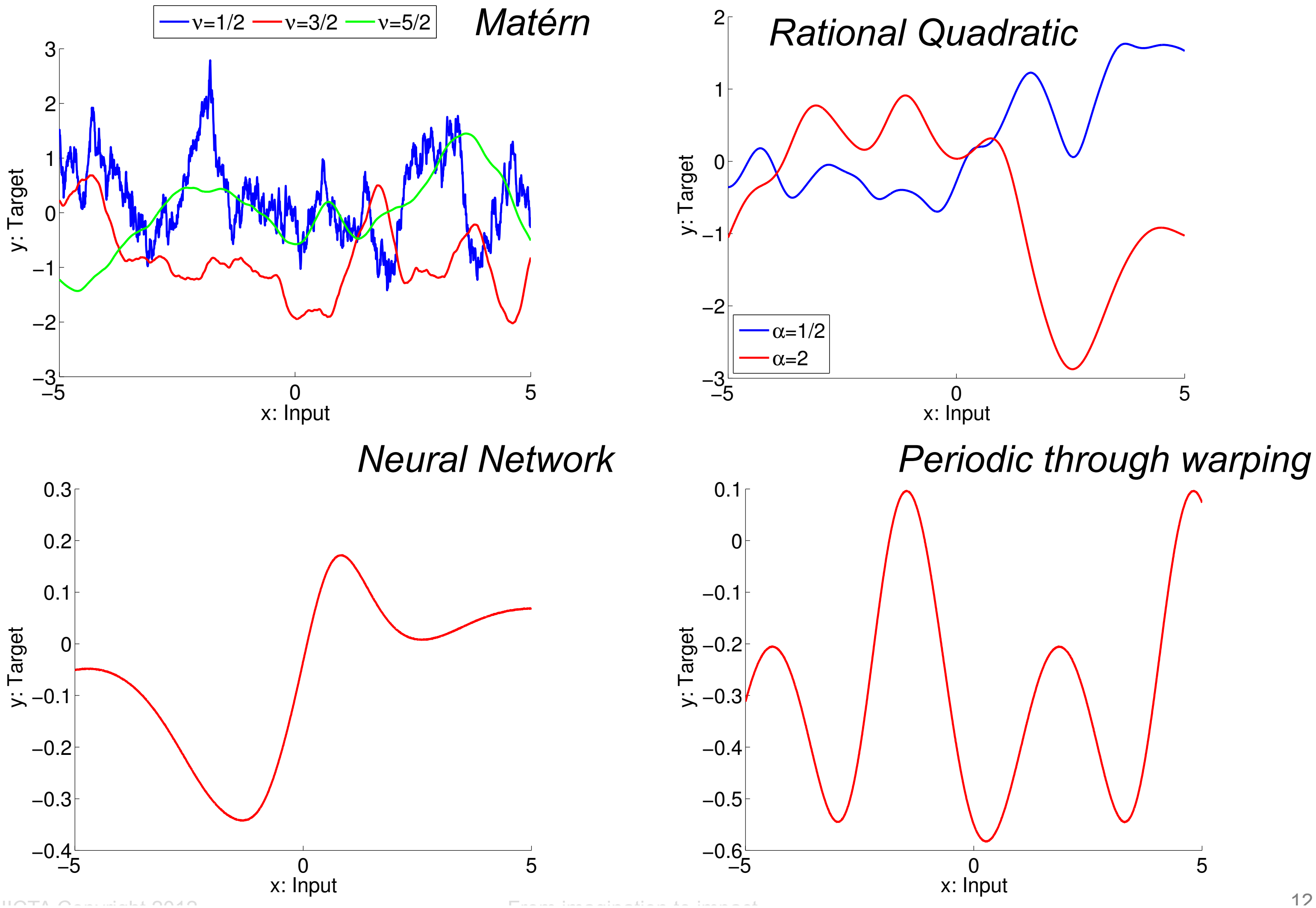
$$P(m|\mathbf{d}) = \frac{P(m)P(\mathbf{d}|m)}{\int_m P(m)P(\mathbf{d}|m)dm}$$

Posterior Belief

A Bayesian approach allows us to:

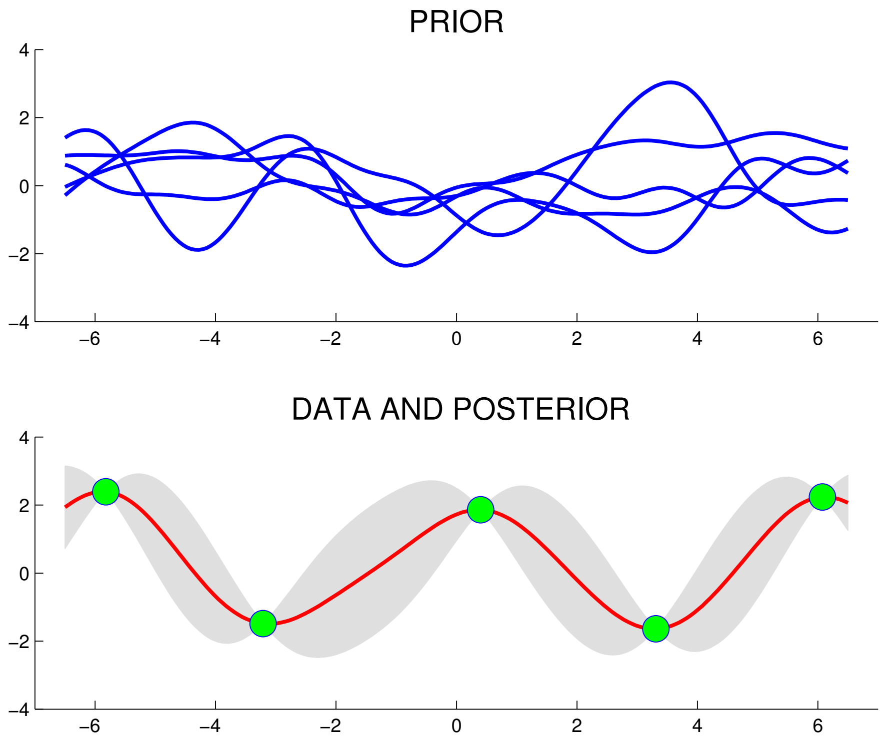
- Quantify risk – probability distribution over possible models
- Use all available data – data fusion
- Update our hypothesis with new data
- Improve decision support

Priors over functions



Bayesian modelling

$$\textit{posterior} \propto \textit{prior} \times \textit{likelihood}$$



- A prior over the weights induces a prior over functions
  - e.g. smooth functions
  - Closeness in input space → closeness in output space

Automatic Parameter Estimation

Given a set of samples

$$X = [\mathbf{x}_0, \ldots, \mathbf{x}_{N-1}]^T$$
$$\mathbf{y} = [y_0, \ldots, y_{N-1}]^T$$

Choose a covariance function

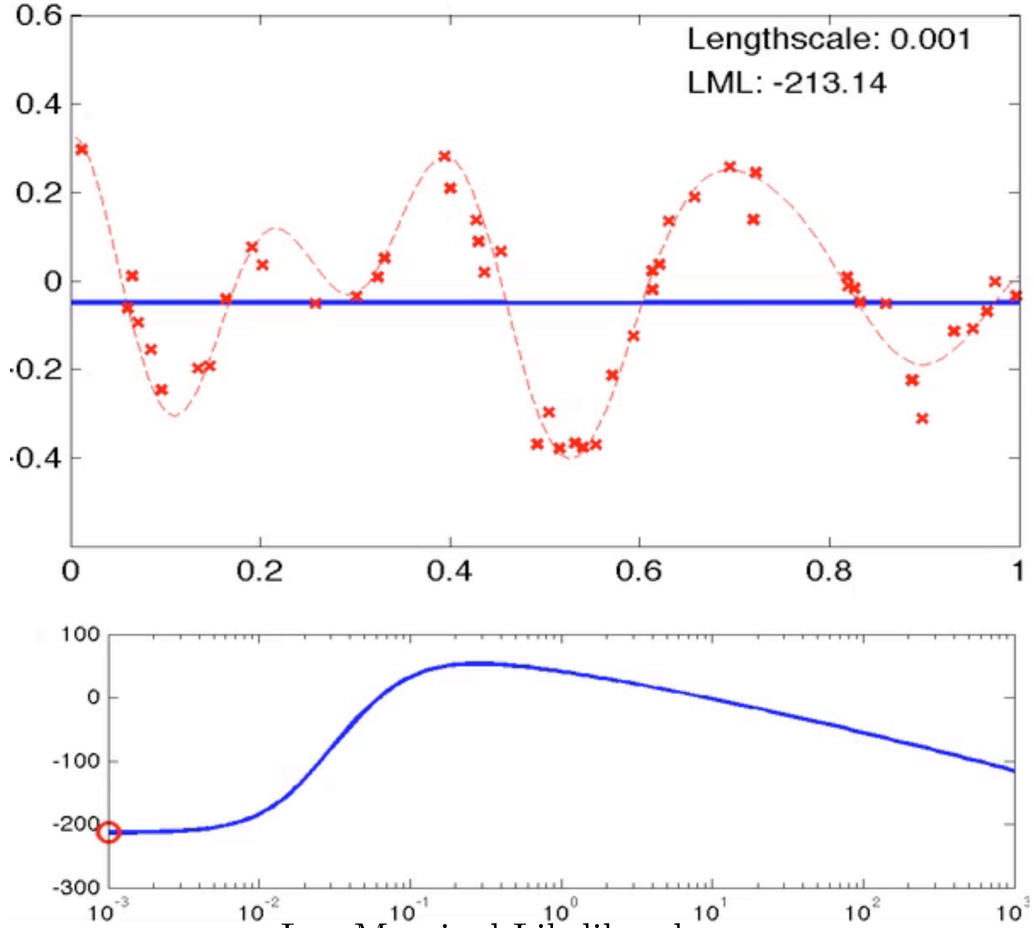
$$k(\mathbf{x}_i, \mathbf{x}_j \mid \theta)$$

Predict the value of $f(\mathbf{x}_*)$

Mean $\mu(f(\mathbf{x}_*))$

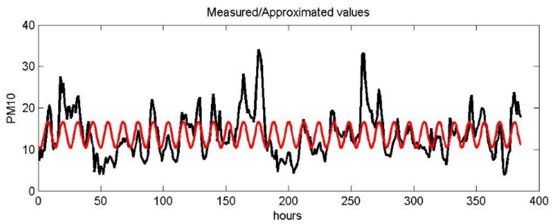
Variance $\sigma(f(\mathbf{x}_*))$

Regression

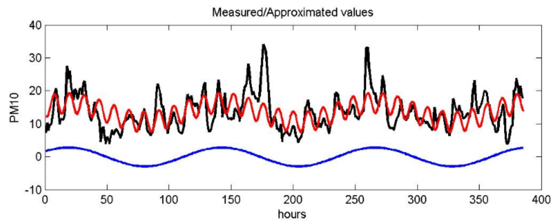


Log Marginal Likelihood

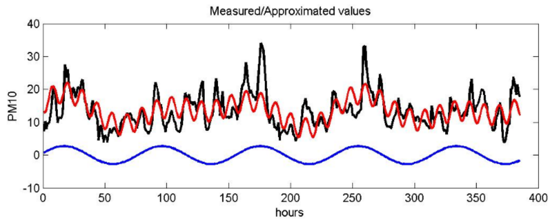
Learning Temporal Patterns



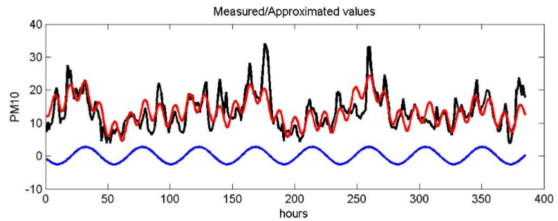
(a) Period of 12 hours



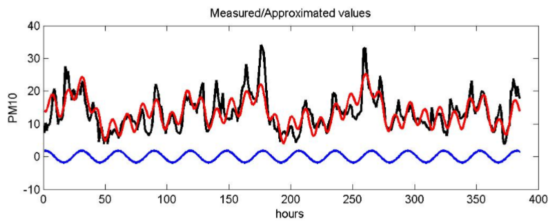
(b) Period of 123 hours



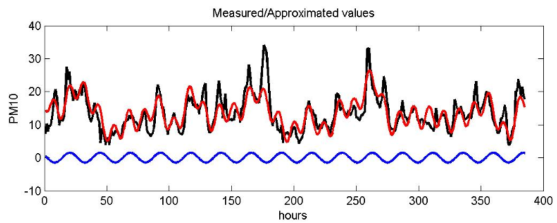
(c) Period of 79 hours



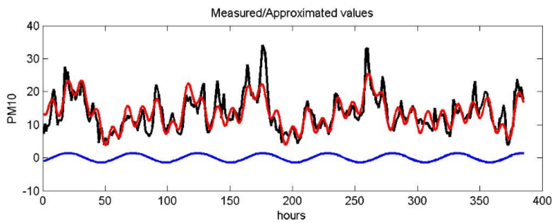
(d) Period of 45 hours



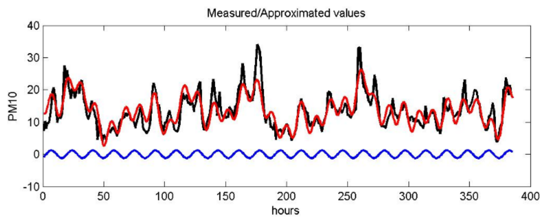
(e) Period of 29 hours



(f) Period of 24 hours

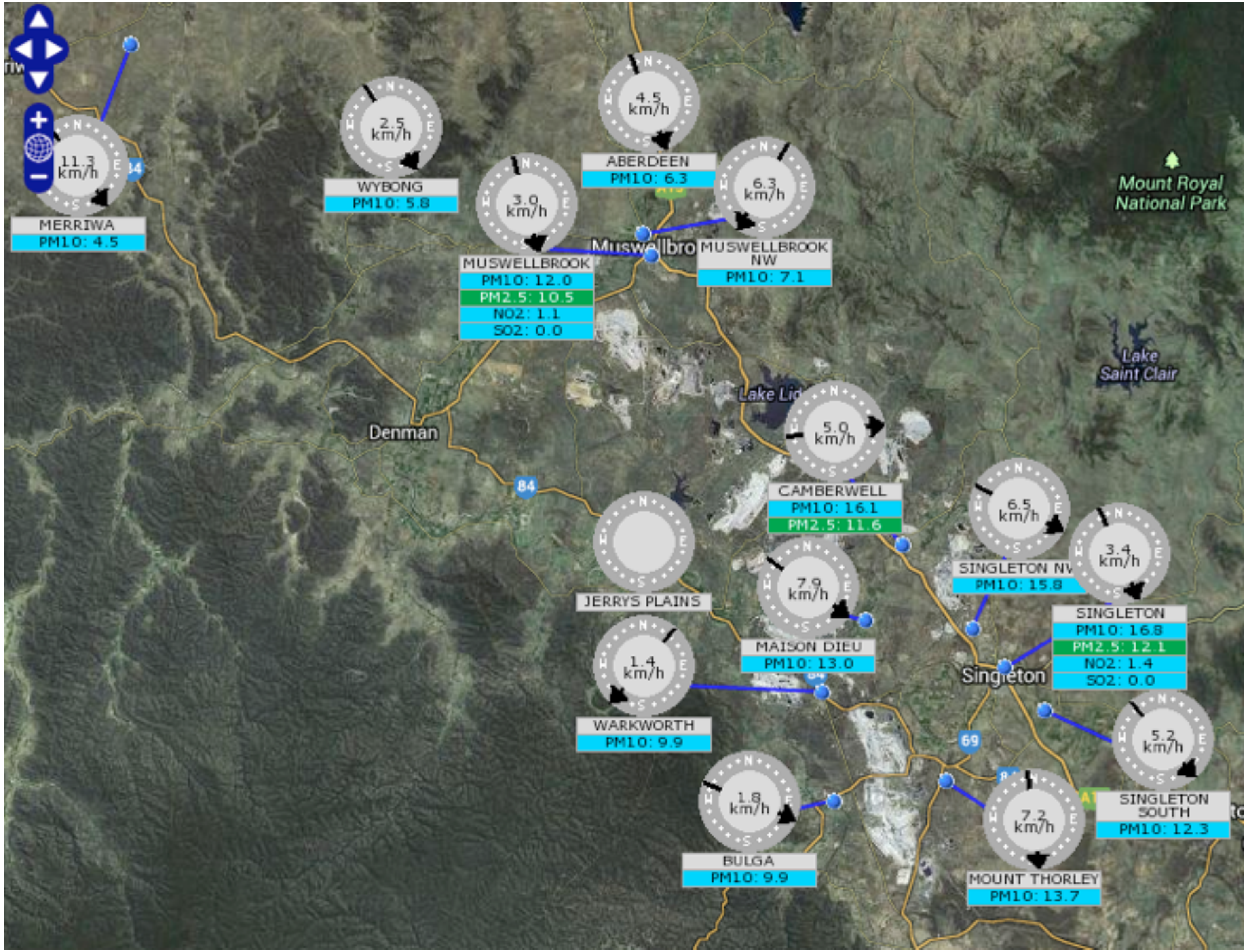


(g) Period of 52 hours



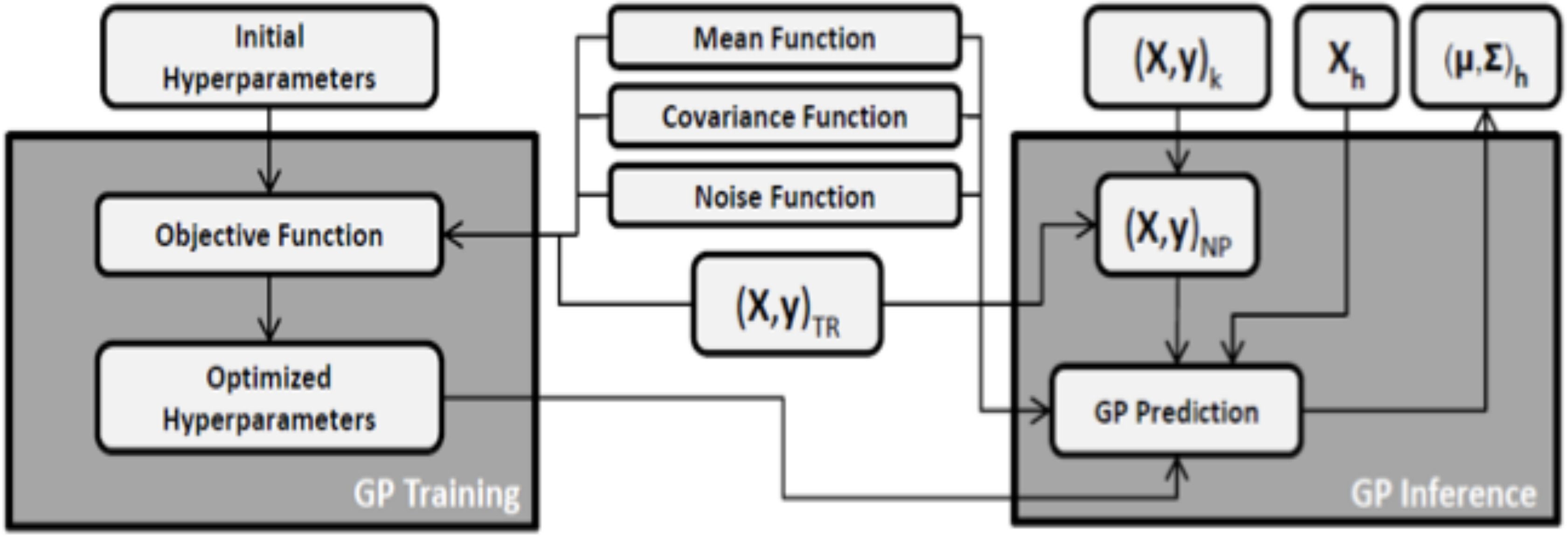
(h) Period of 17 hours

Case Study - Hunter Valley



First Approach: Separate Models

Body Level One

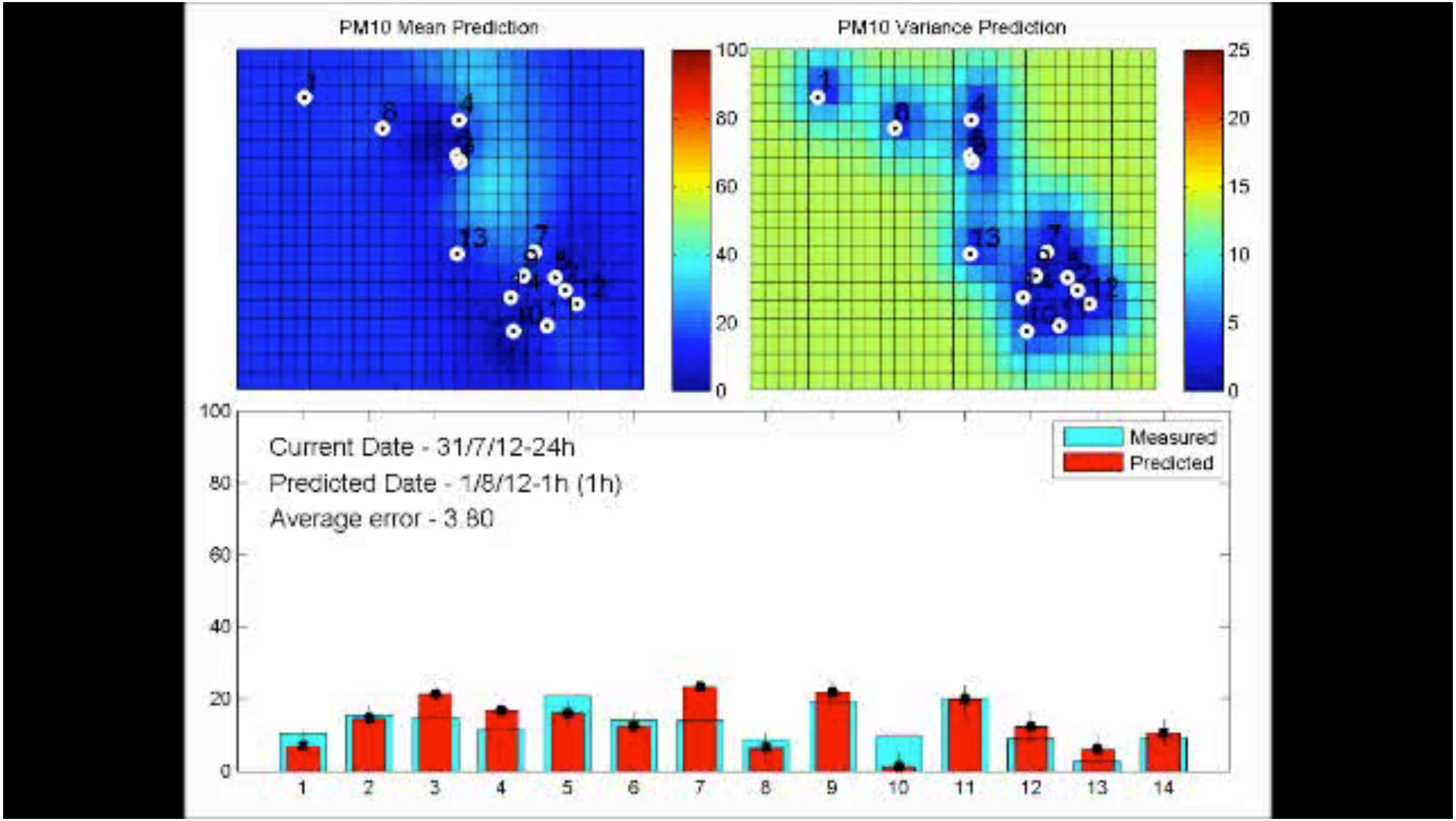


From space and time to PM10

From space and time to PM2.5

From space, time, and PM10 to PM2.5

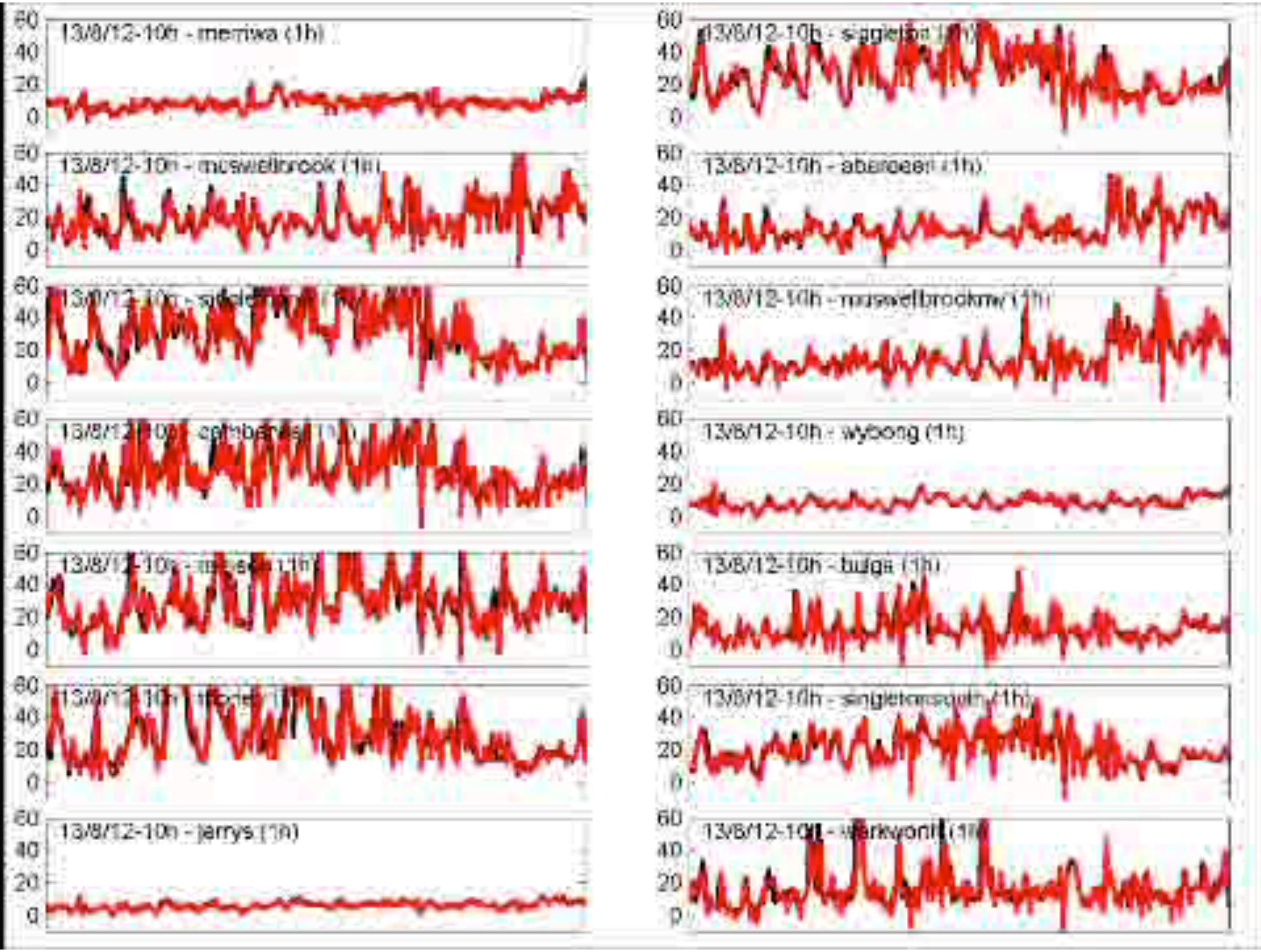
PM10 1-hour prediction



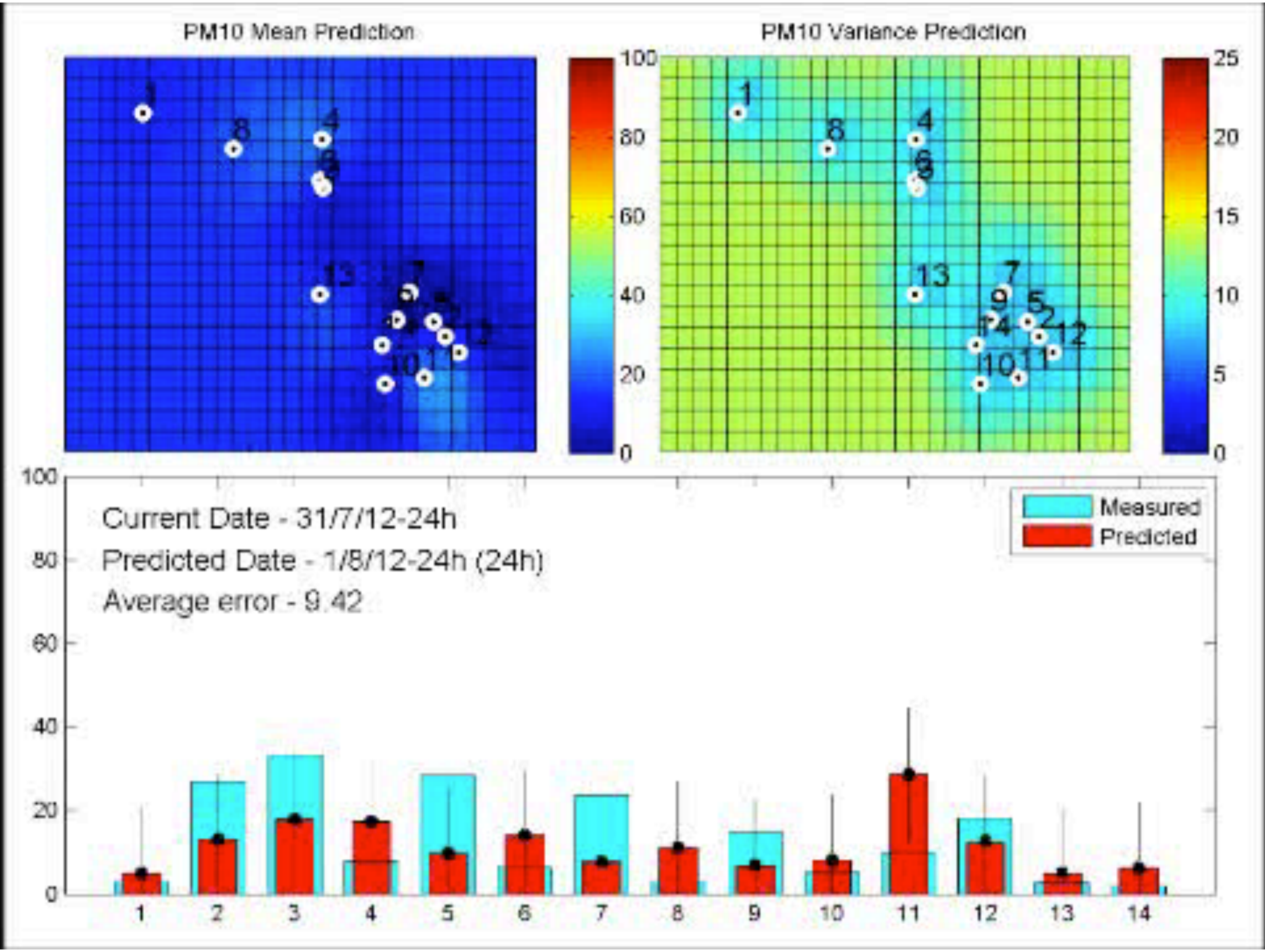
PM10 1-hour prediction

infact analytics

NICTA

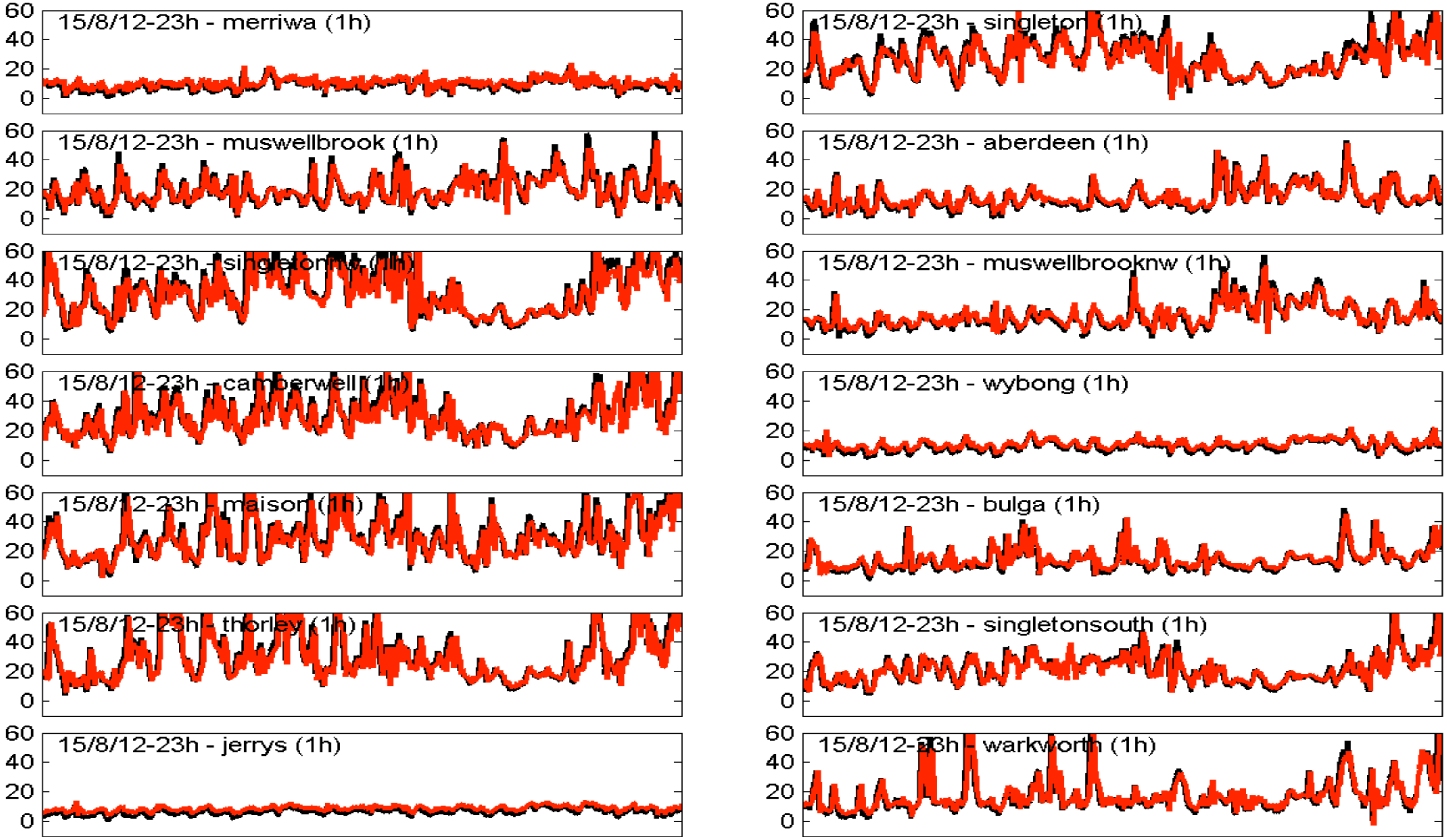


PM10 24-hour prediction



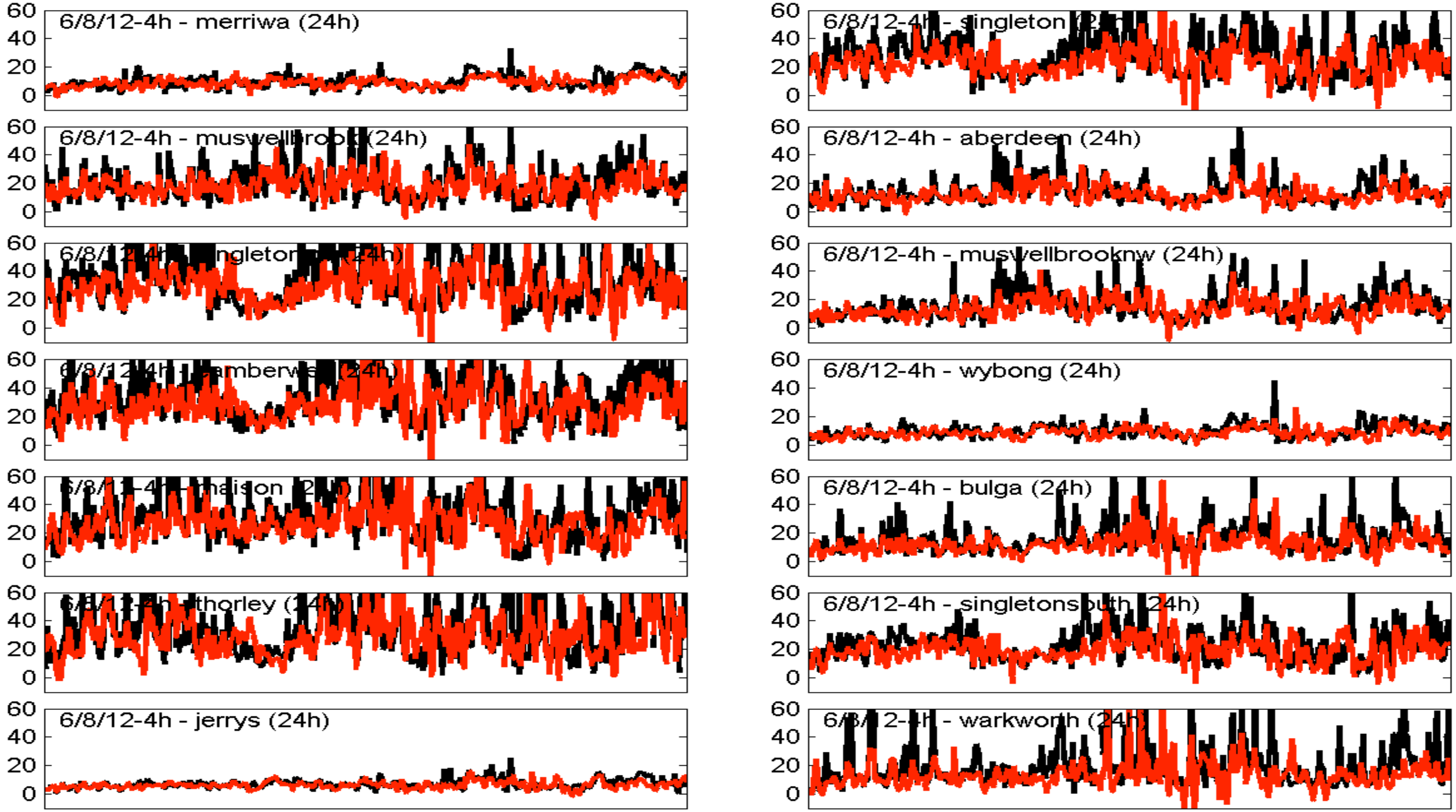
Experimental Results

- **PM10 – 1h individual sensor prediction**



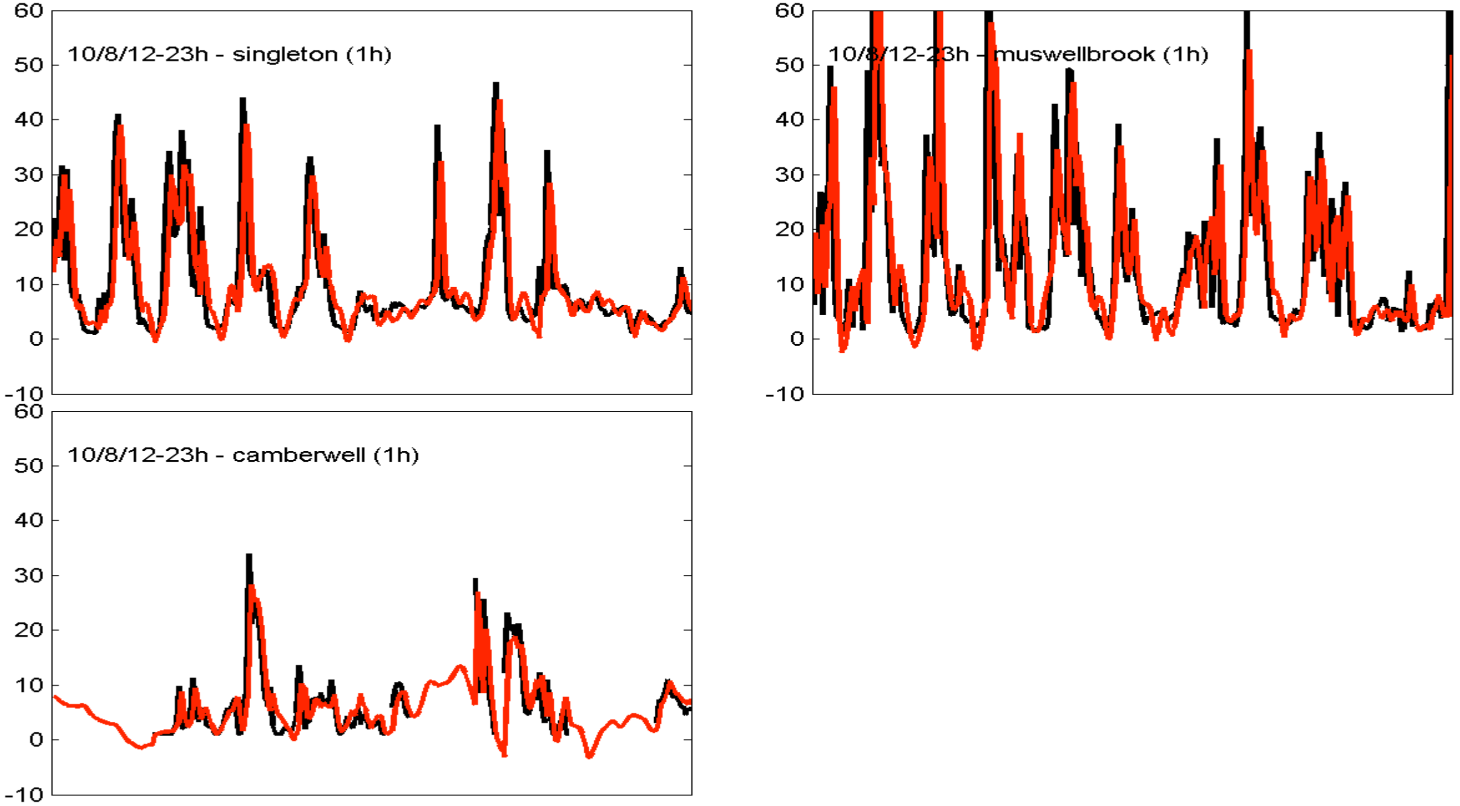
Experimental Results

- **PM10 – 24h individual sensor prediction**



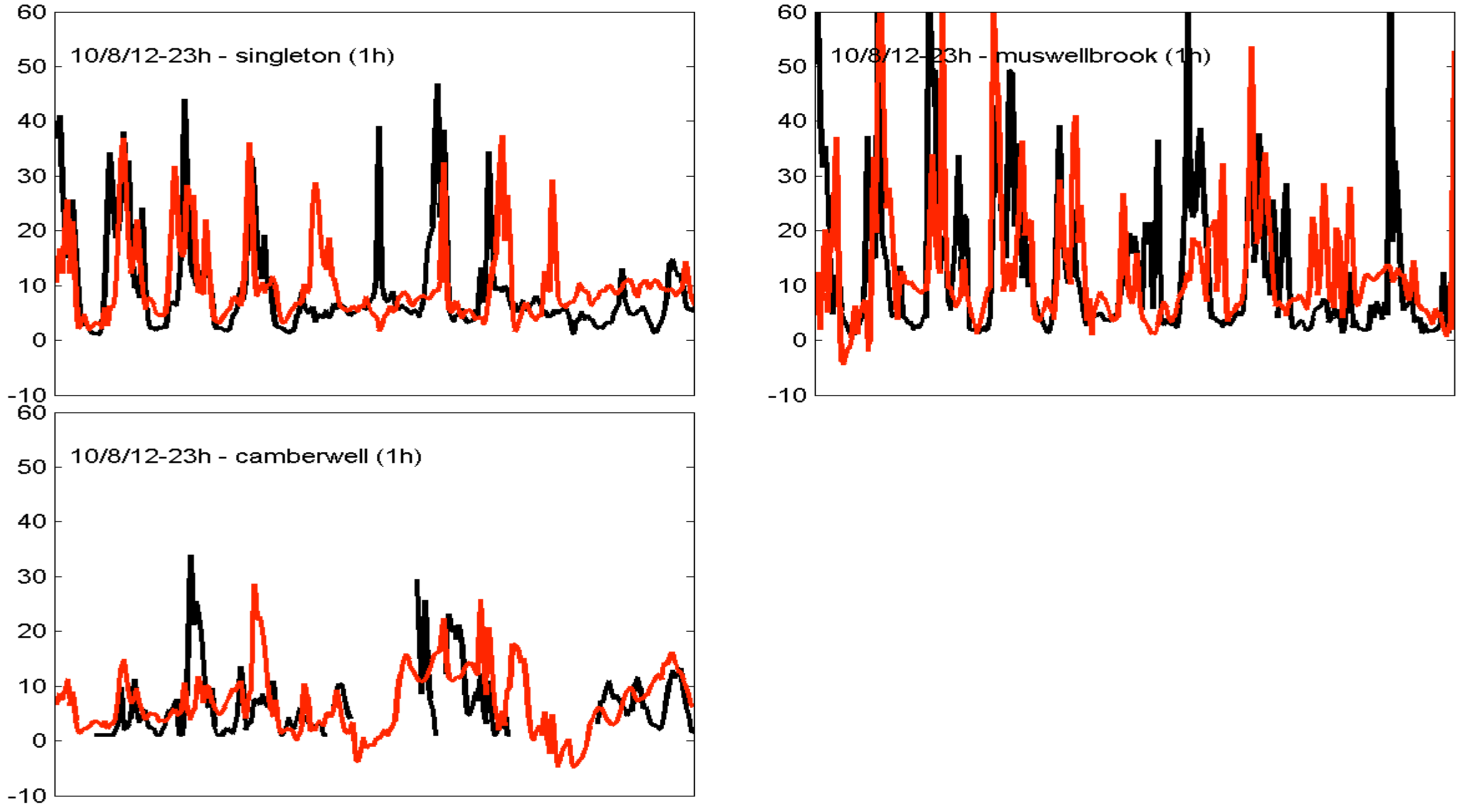
Experimental Results

- **PM2.5 – 1h individual sensor prediction**

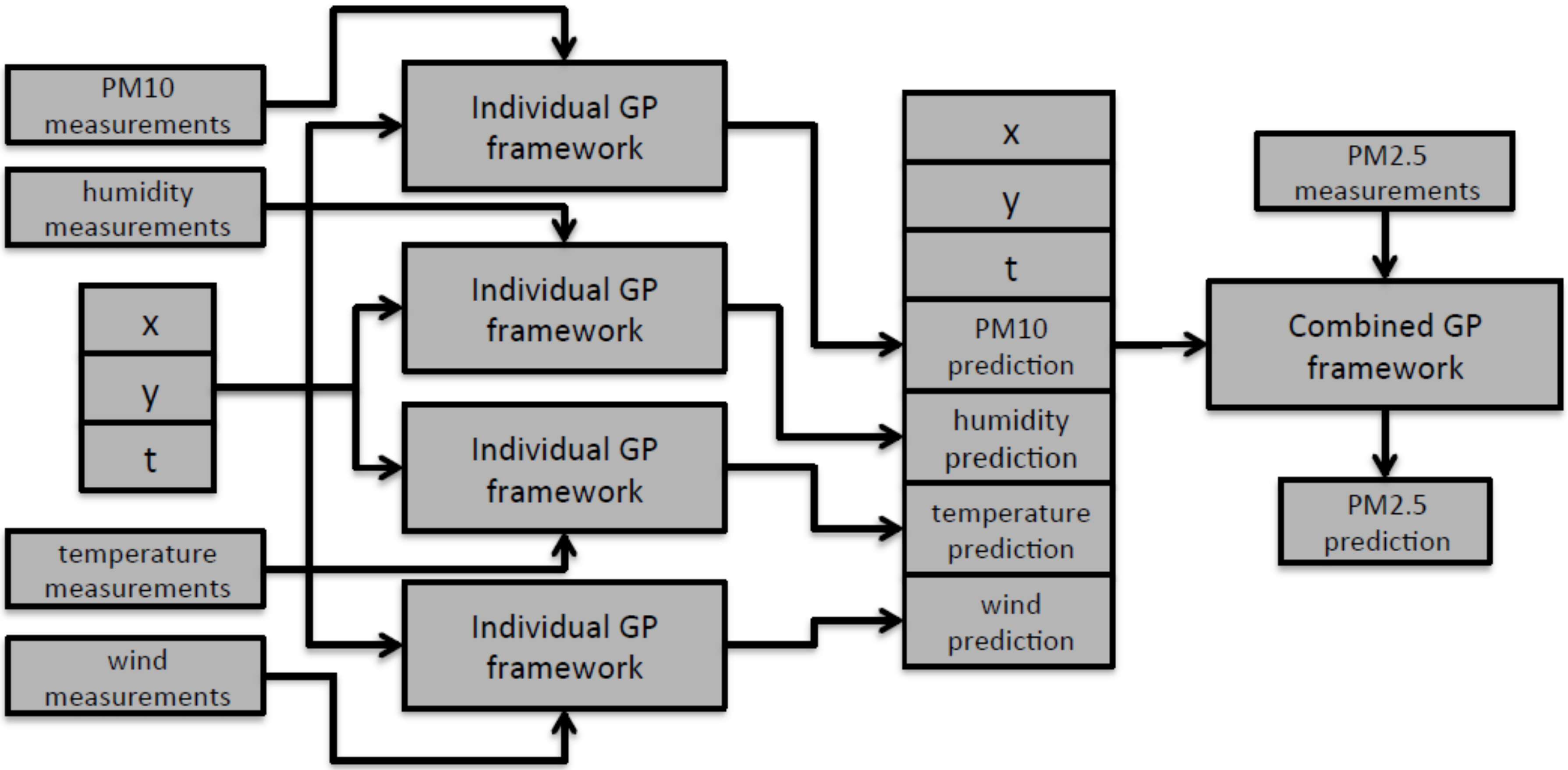


Experimental Results

- **PM2.5 – 24h individual sensor prediction**

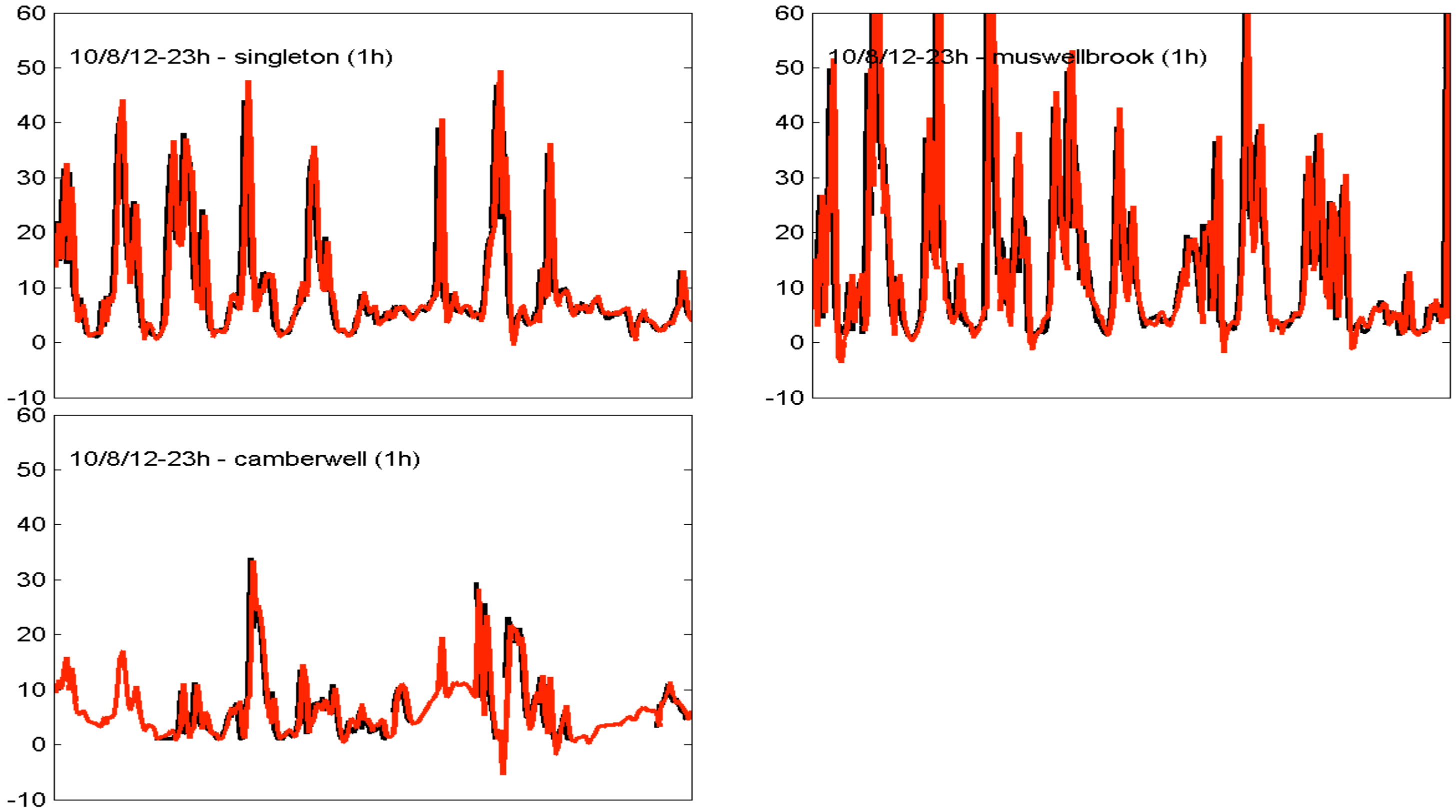


Second Approach: All Together



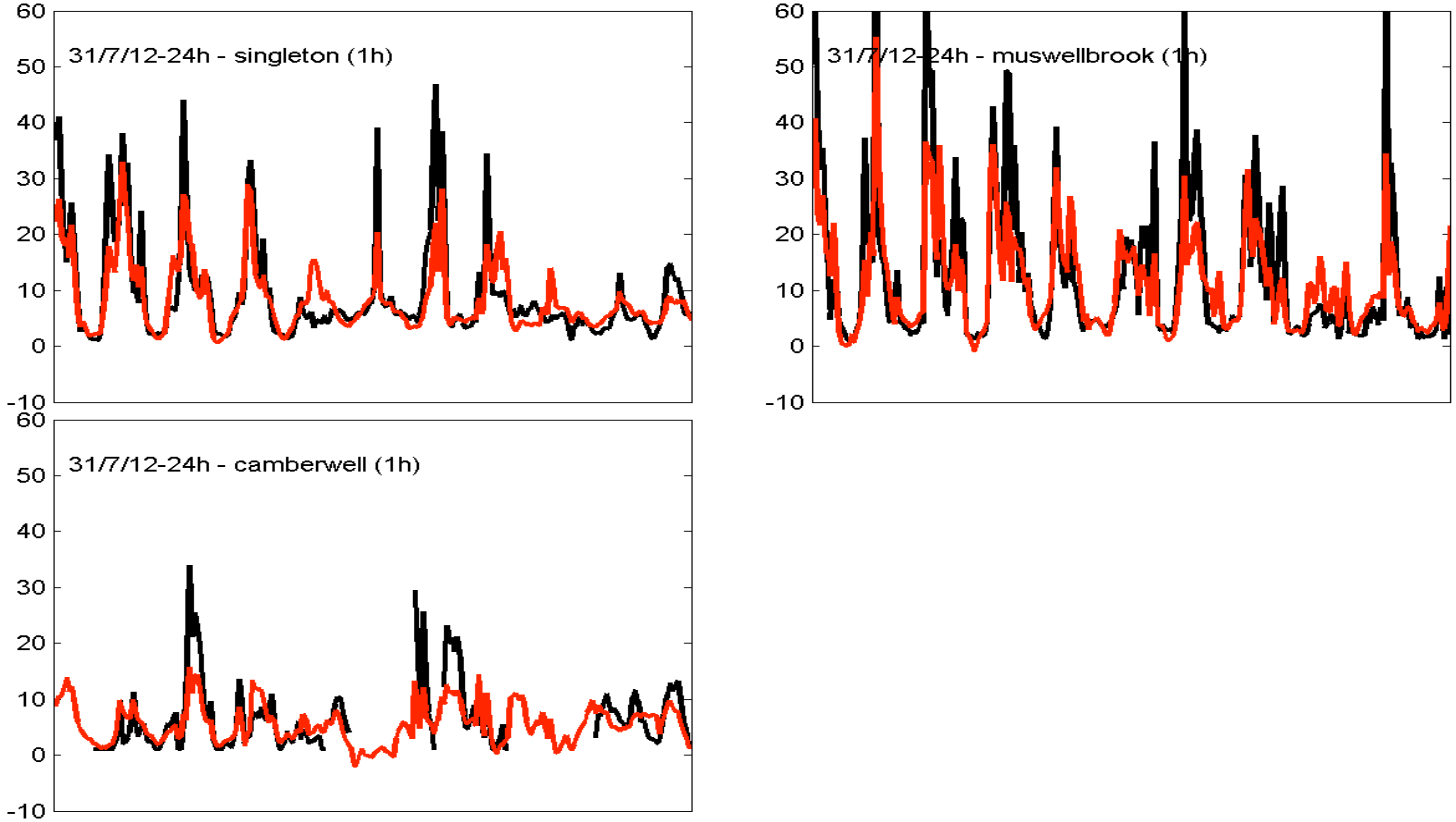
Experimental Results

- **PM2.5 + PM10 – 1h individual sensor prediction**



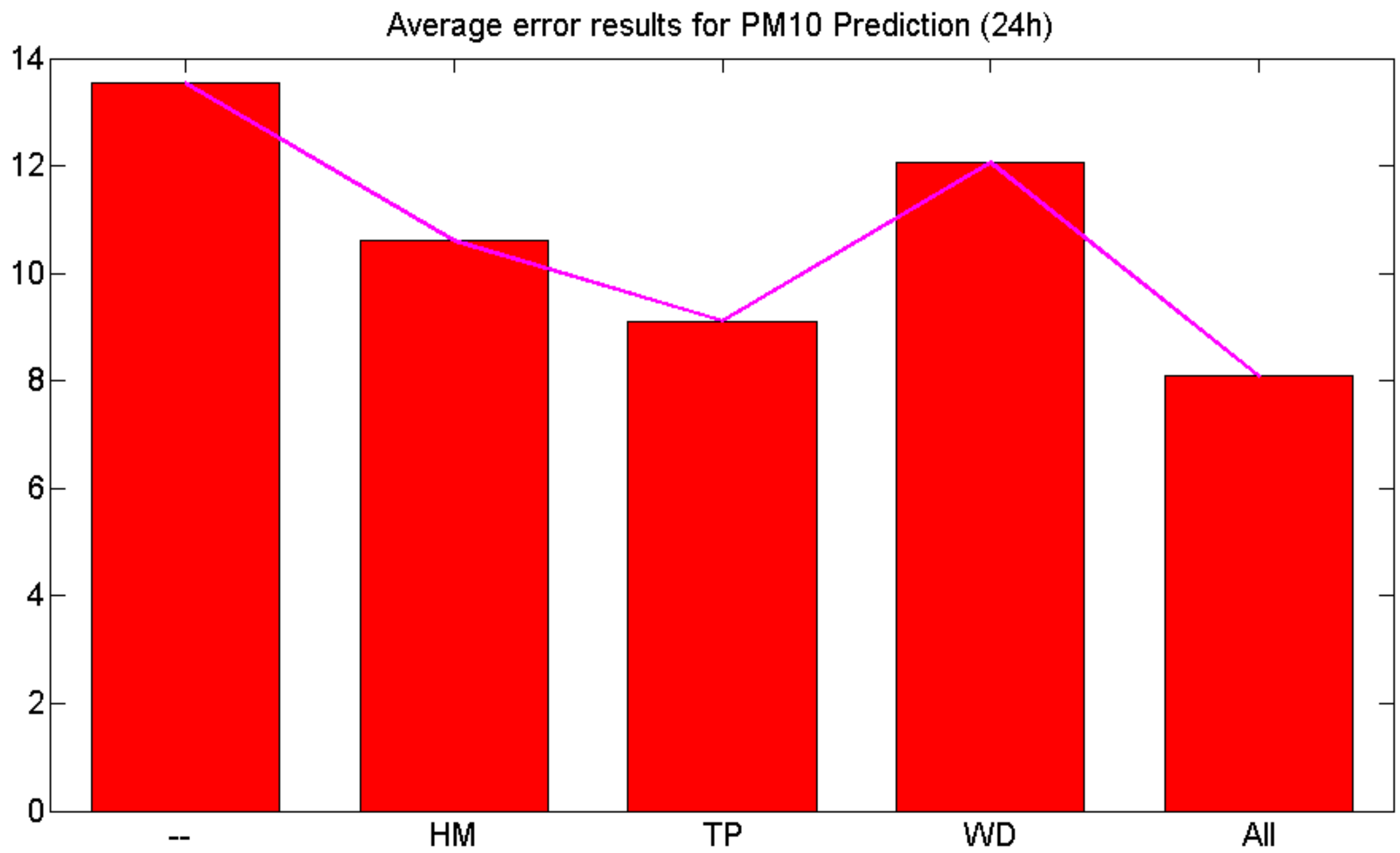
Experimental Results

- **PM2.5 + PM10 – 24h individual sensor prediction**



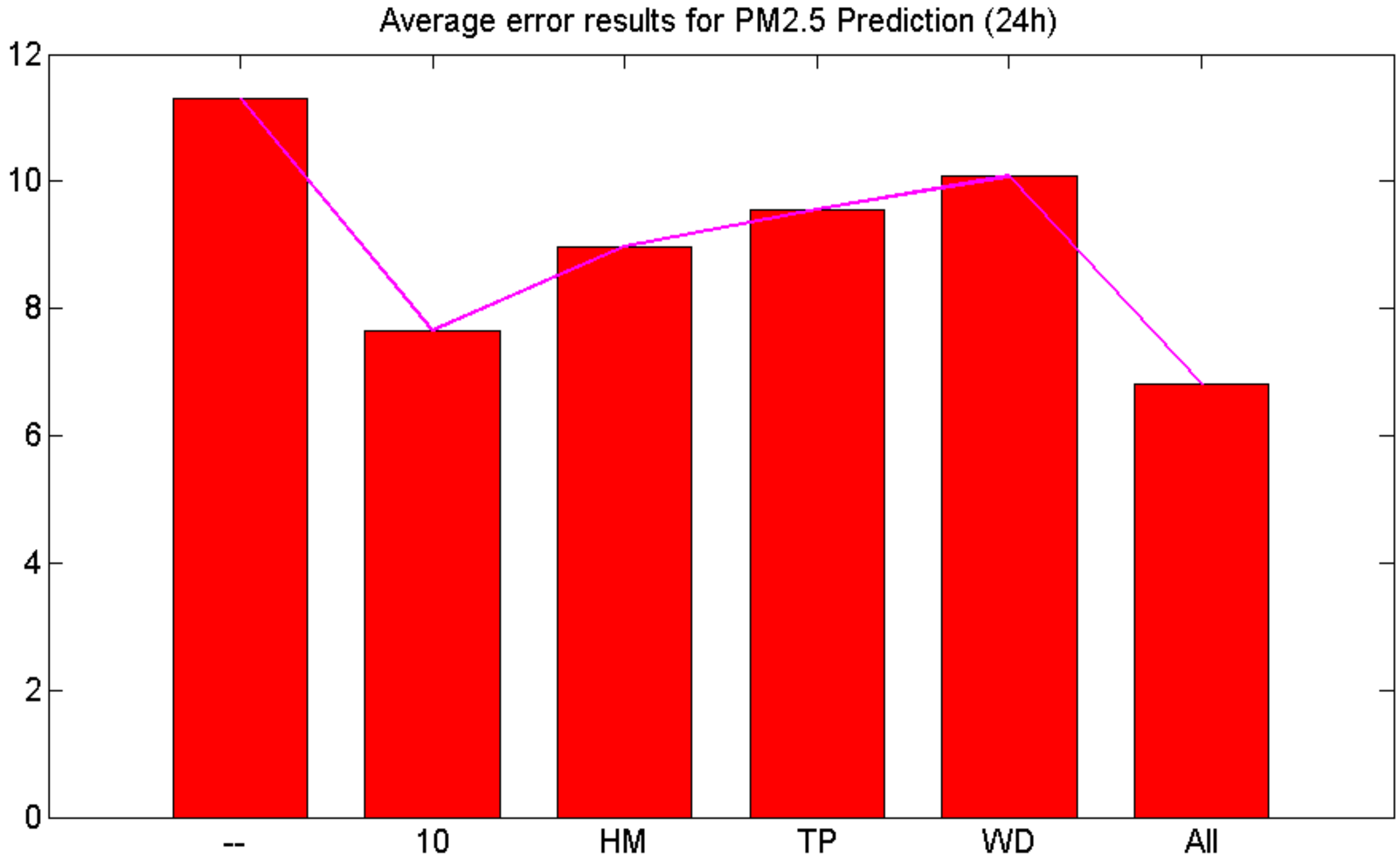
Experimental Results

- Average Errors **(PM10 – 24h)**



Experimental Results

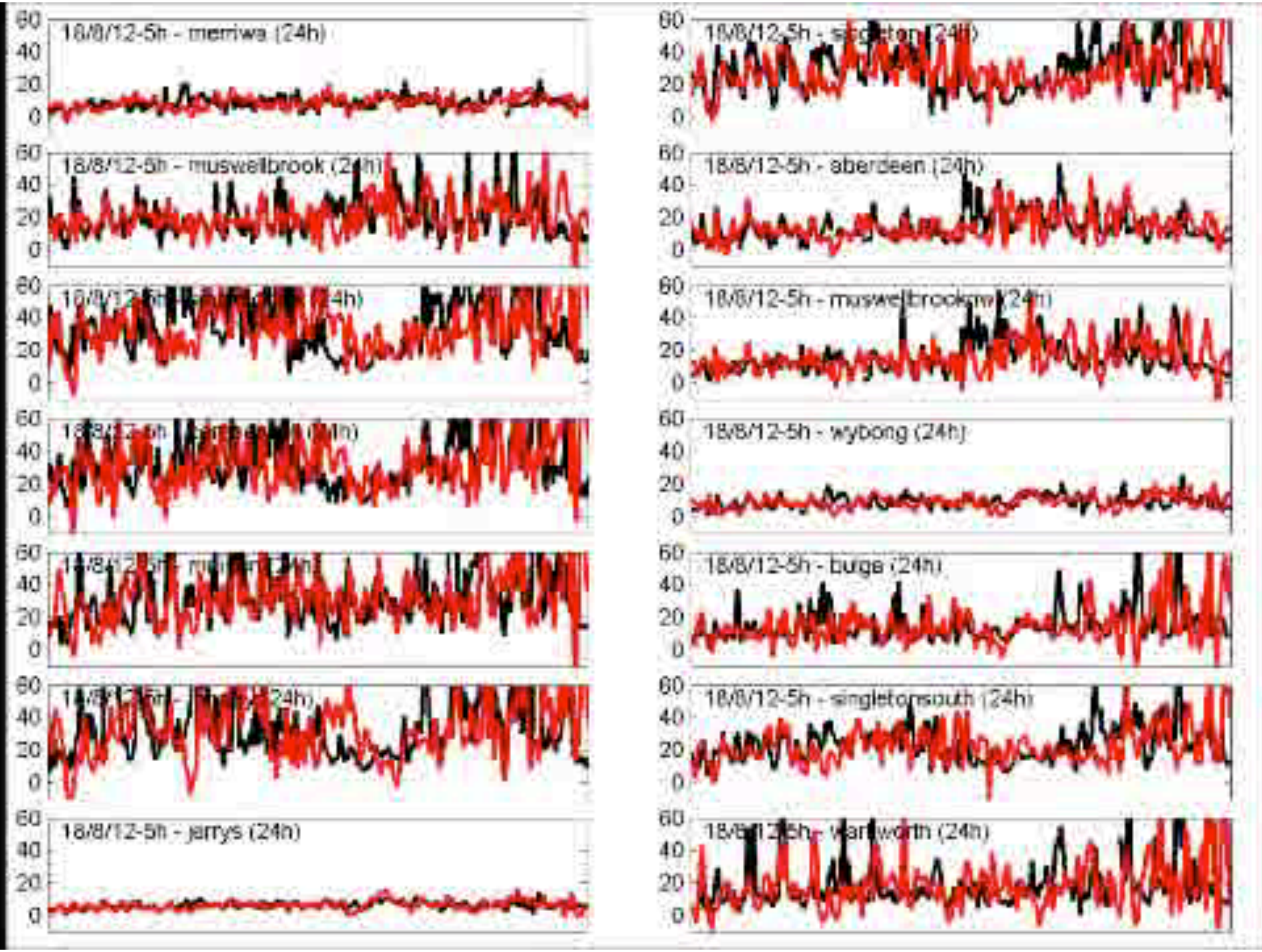
- Average Errors **(PM25 – 24h)**



PM10 24-hour prediction

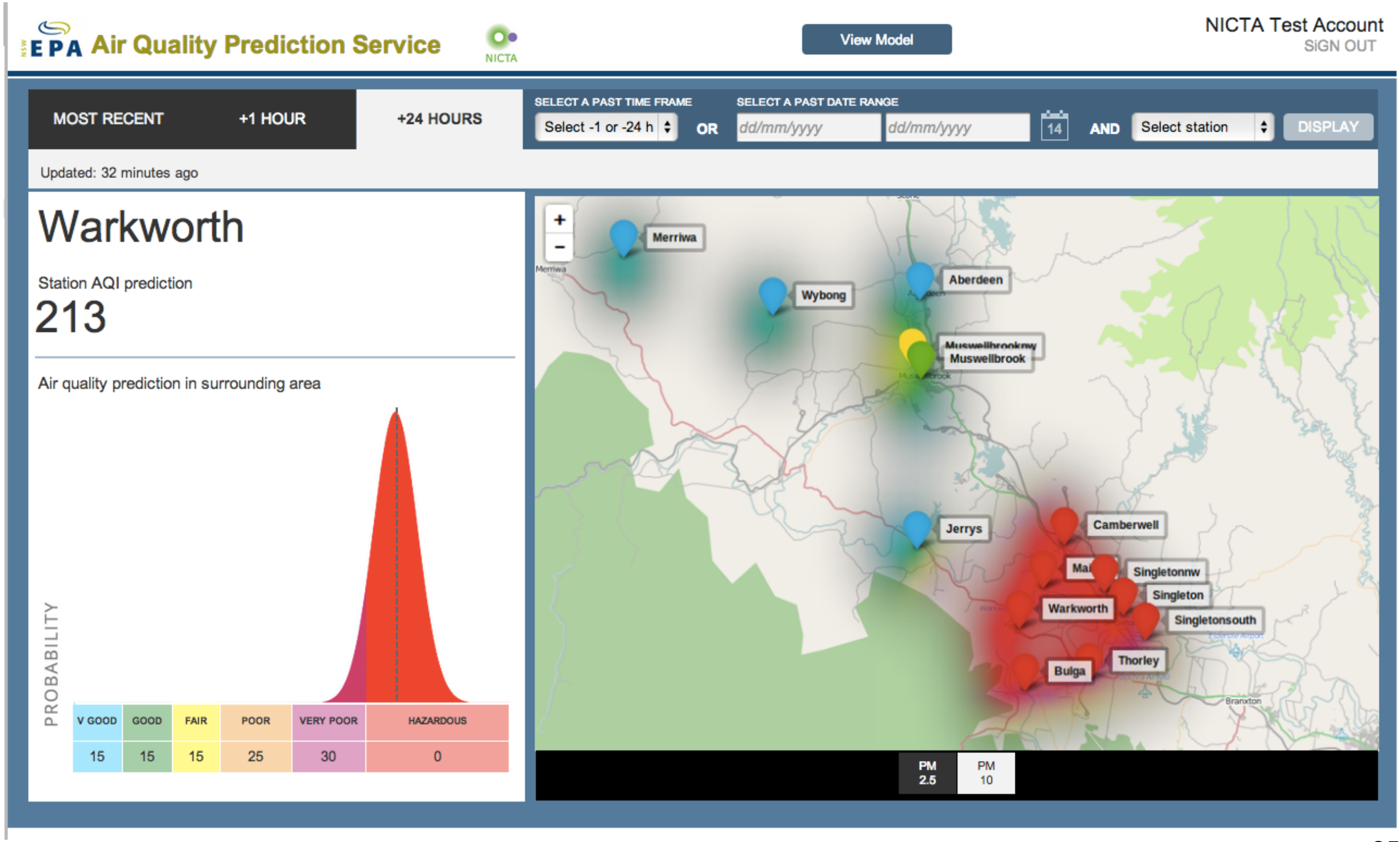
infact analytics

NICTA

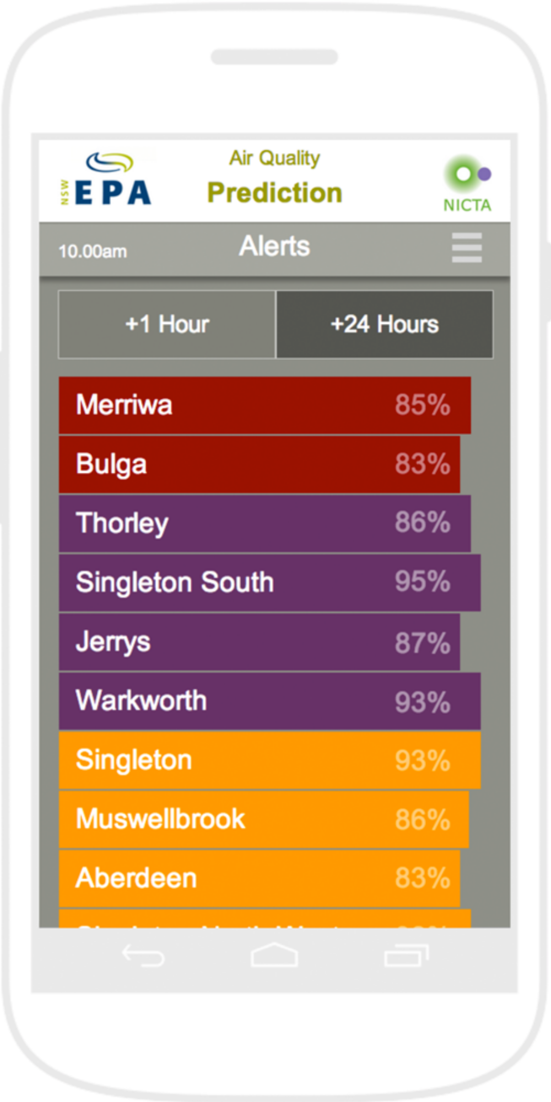


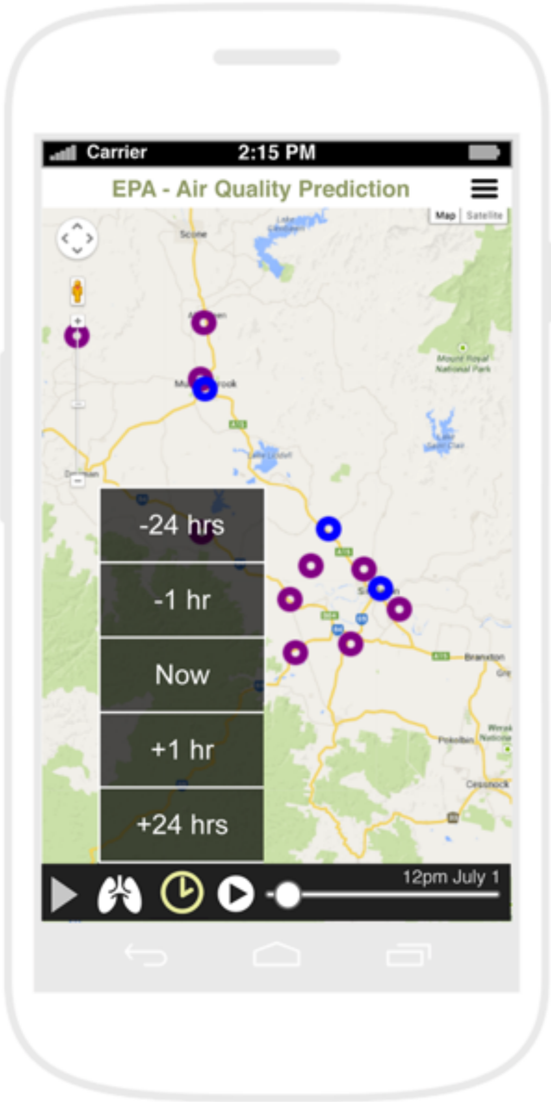
How do we make these complex algorithms easily accessible to EPAs?

Web Interface



Mobile Phone Apps

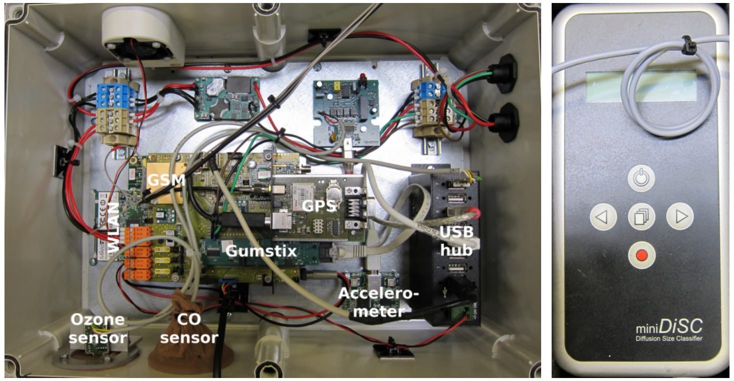




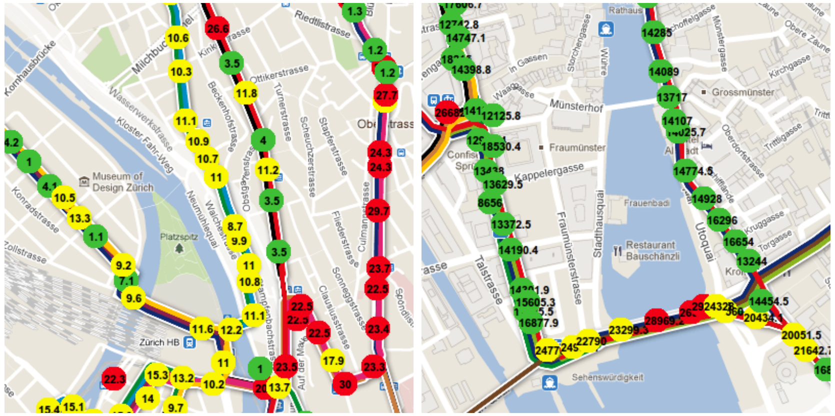
What's next in air pollution forecast?

Dynamic Monitoring: Where and When to Monitor

OpenSense Zurich Monitoring System



(a) Sensor box (b) DiSCmini



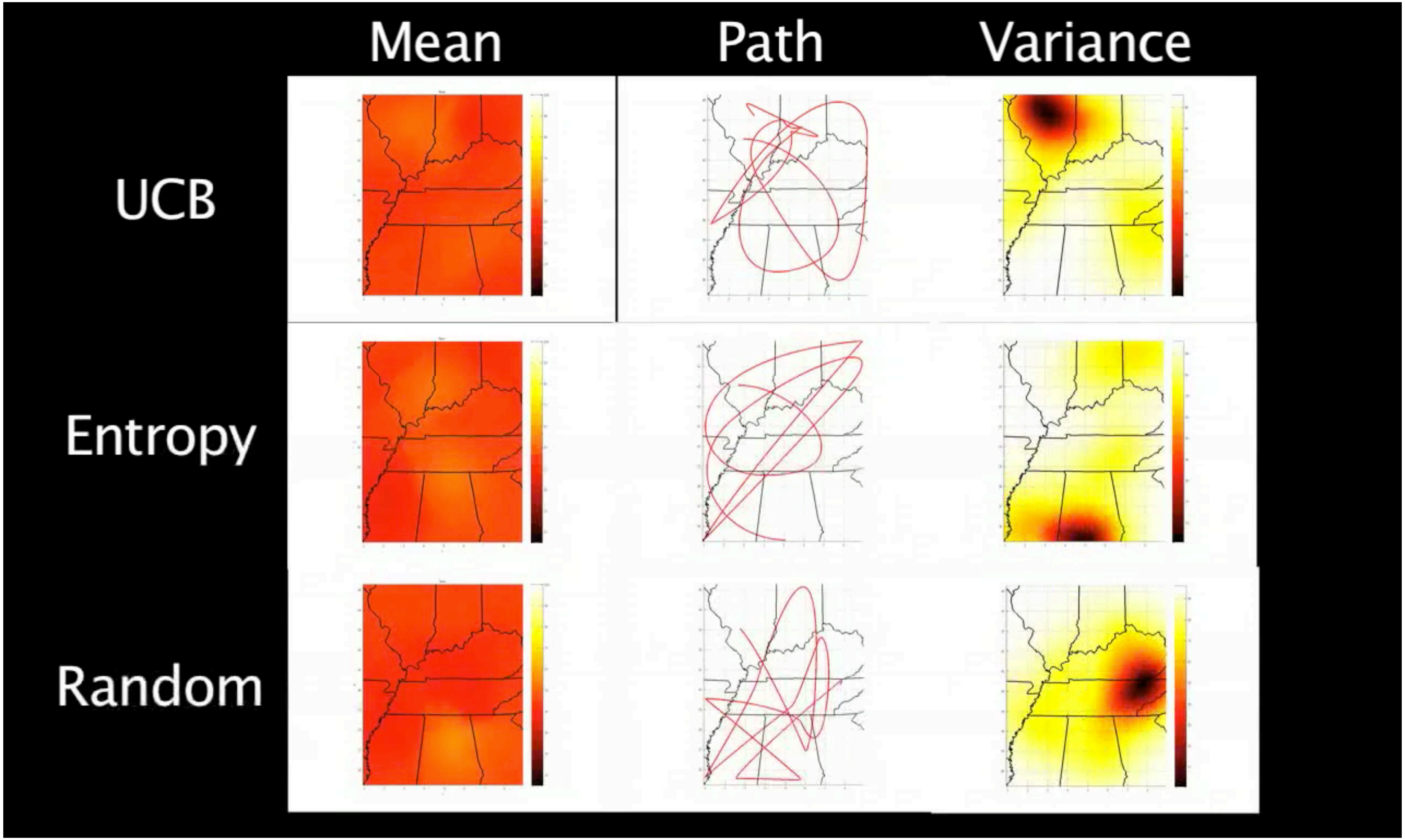
(a) Ozone (b) PM

Figure 4: Web-based interactive data browsing through the datasets of ozone and PM measurements in Zurich.

(a) Tram deployment (b) Fixed station deployment

UAVs USVs

Path Planning for Smart Monitoring



Summary

- Immense opportunities for statistical machine learning in air pollution forecast
- Assessing uncertainties is crucial
- Complex algorithms and computer systems are easily accessible through web services
- Where and when to monitor is as important as the quality of the measurements

fabio.ramos@nicta.com.au