Air Sensors 2018
Deliberating Performance Targets for Air Quality Sensors

Field performance and calibration practice for low cost ozone sensor

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1. Current state of sensor technology

Background

Traditional compliance monitor/equipment

- High price and maintenance cost;
- High precision but requires professionals.
- Regional/local air quality instead of personal info.

"Professional" sensing technologies

- Lower cost and small, compact, easy to deploy;
- Good performance in certain applications with different data quality objective.

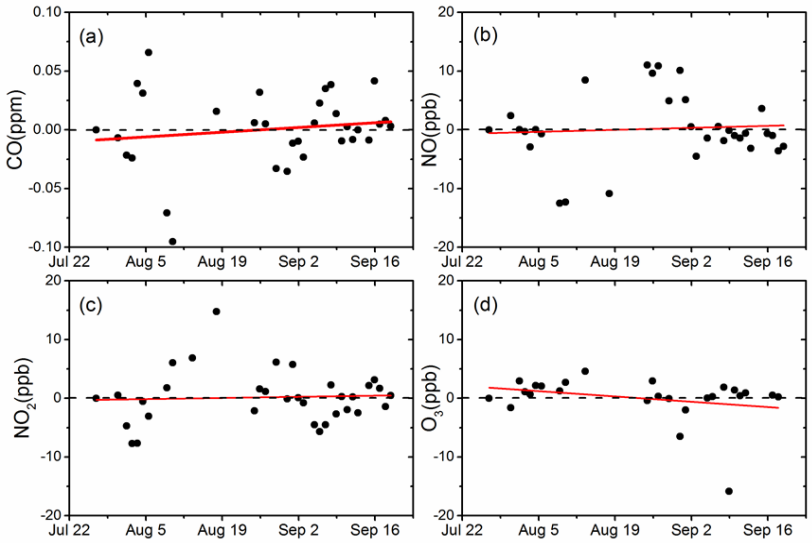
Consumer sensors (low cost sensors)

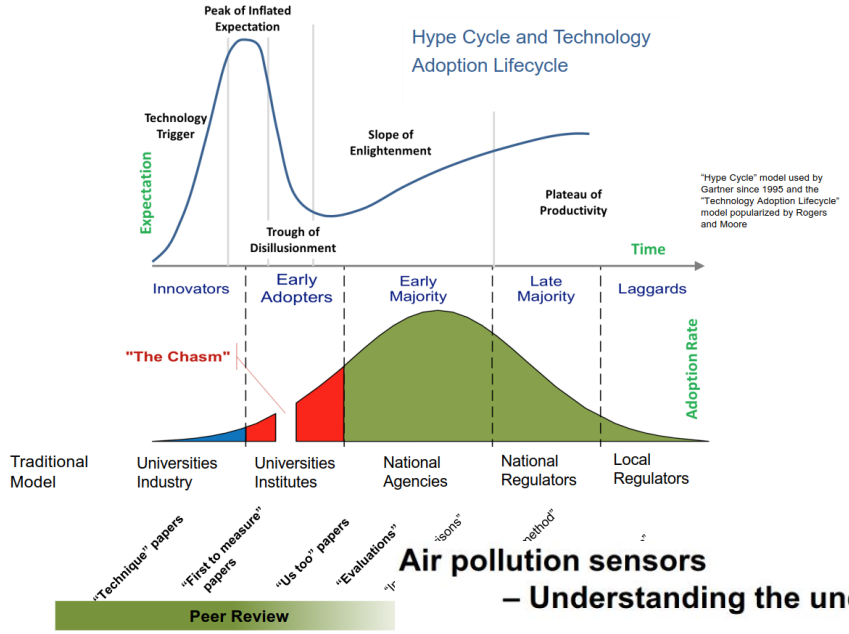
- Cheap and small for personal and family usage;
- Indication purpose, not scientifically reliable.

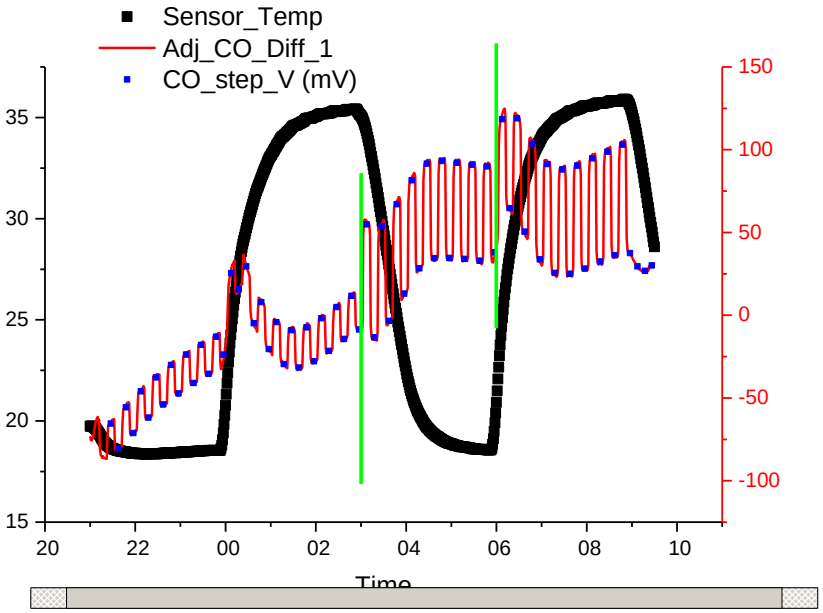
1. Current state of sensor technology

Realities and challenges

- **Sensors have 3 dimension of factors**
  - Concentration, Temp, RH
- **while conventional monitors have only 1 dimension of factor**
  - Concentration only
- **Drift has been a concern.**
  - Drift correction is important!







Air pollution sensors
– Understanding the uncertainties

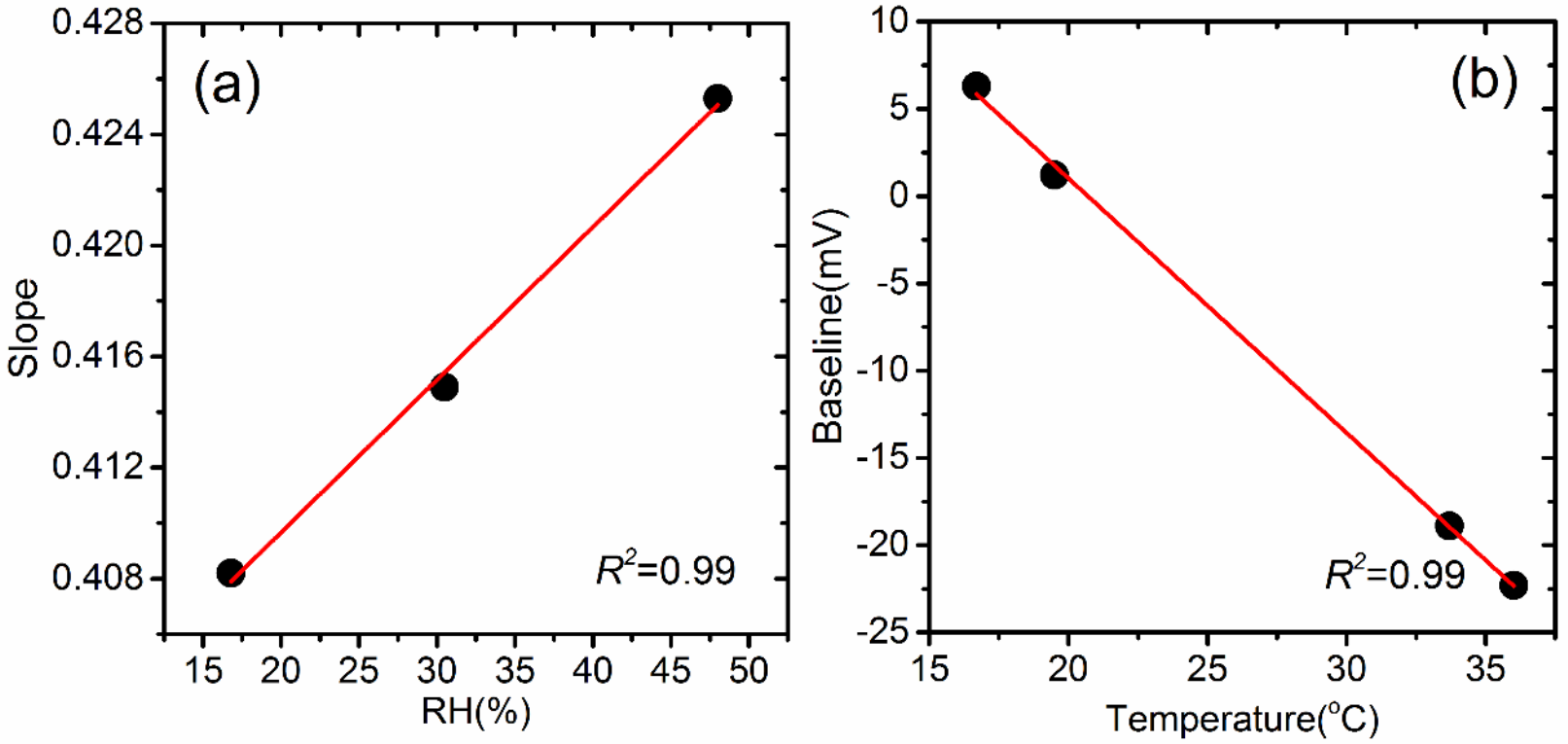
Credit to: **Alastair C Lewis**, Peter M Edwards, James D Lee, Marvin Shaw, Mat J Evans, Sarah J Moller, Katie Smith.

National Centre for Atmospheric Science
Wolfson Atmospheric Chemistry Laboratories, University of York, Heslington, York, UK.

1. Current state of sensor technology

Realities and challenges

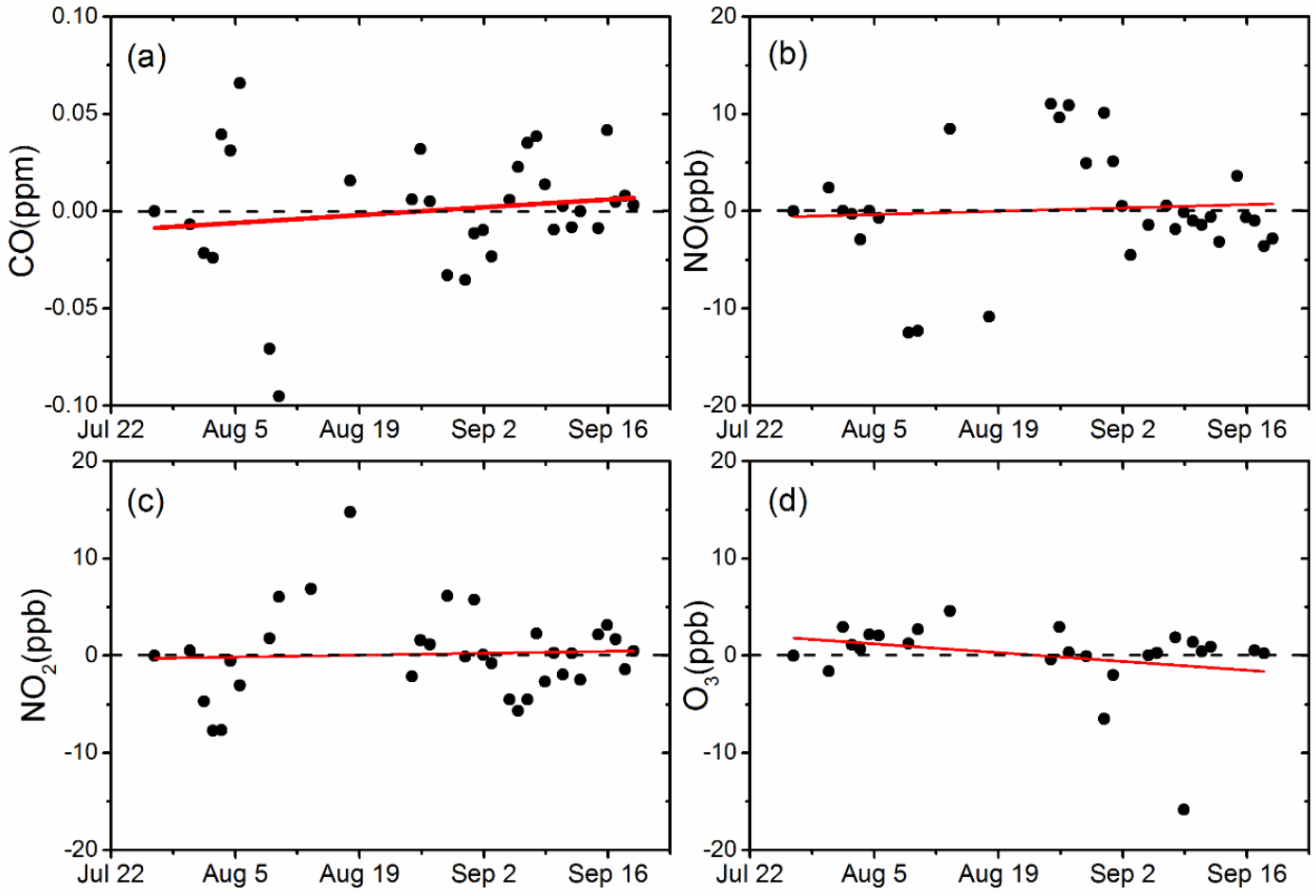
Laboratory results show strong relation between temperature/RH and response



1. Current state of sensor technology

Realities and challenges

Drift of sensor signals



2. Current state of sensor usage practice

Existing QAQC/calibration methods

Methods	Comments
Laboratory gas calibration (zero/span or multiple point)	• Laboratory calibration may not be sufficient for sensor field deployment; • Can't be used with temp and RH impact.
On-site side by side learning and calibration;	• High quality research grade reference instruments are required; • Good for researchers and agencies, but potentially dangerous when actual measurements are out of range; • Frequent calibration are required.
On-site nearby station comparison for learning and calibration;	• Not recommended but very commonly used, especially in mainland now.
On-the-fly mobile platform driving through (one point check);	• Not recommended but as last resort; also only in case when DQI is loose
Artificial intelligence/Machine learning.	• Fancy but not magic; Performance on how long you train the data and if the range of T/RH/C is covered for prediction
Long term deployment of sensor network calibration (not single point data assurance).	• For smart city or grid based measurements to identify hot spots, but not recommended for close-to-reference DQI.

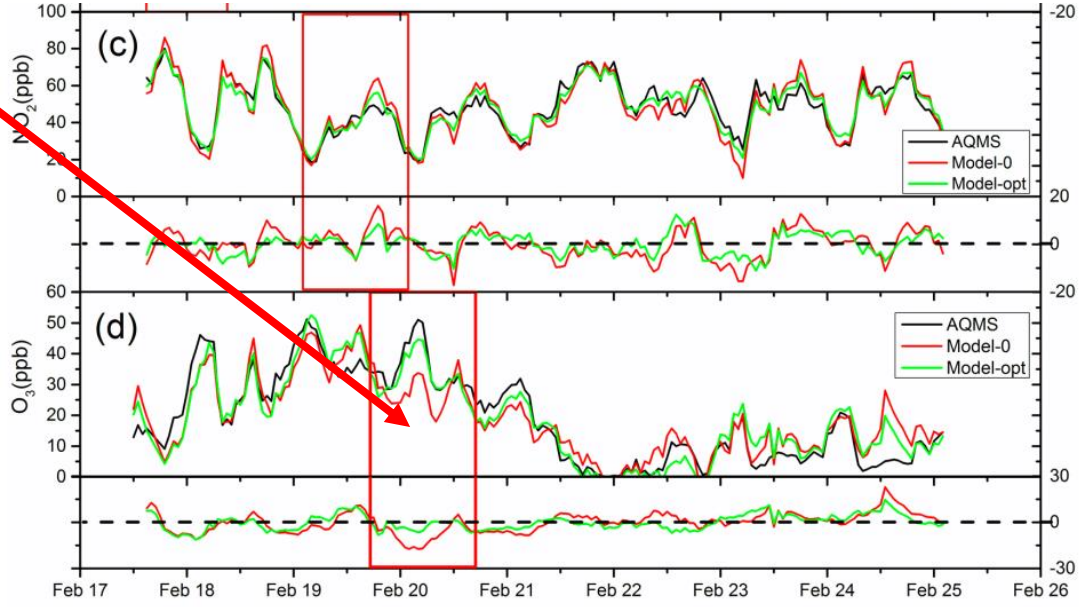
- Various calibration algorithms:
  - -Linear regression, Multiple linear regression, Machine learning…
  - -Questions on data integrity because of proprietary algorithms

3. Application and QAQC/calibration recommendation

ONE week short measurement

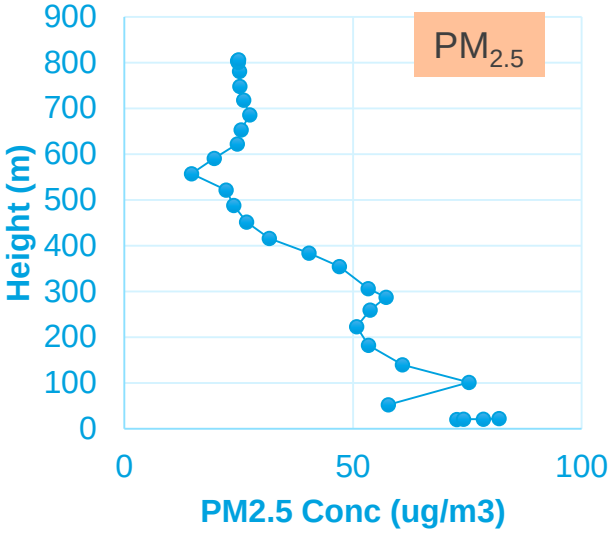
- **In general, a short period of side by side comparison shows good agreement, but with cases of drift due to the impact from temperature and humidity, as red boxes show.**

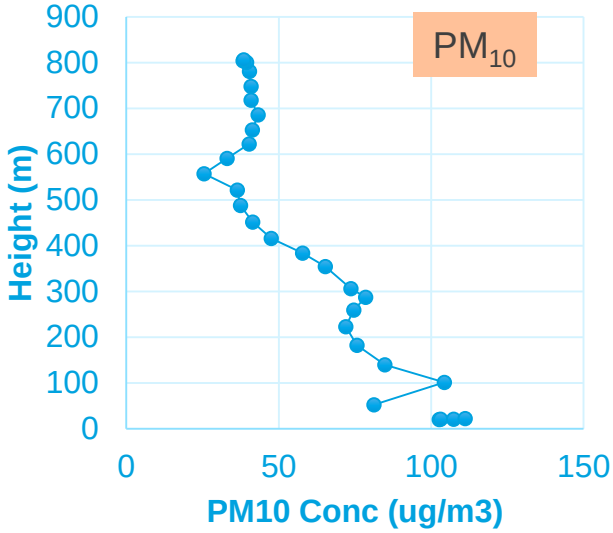
Mini Air Station (MAS)

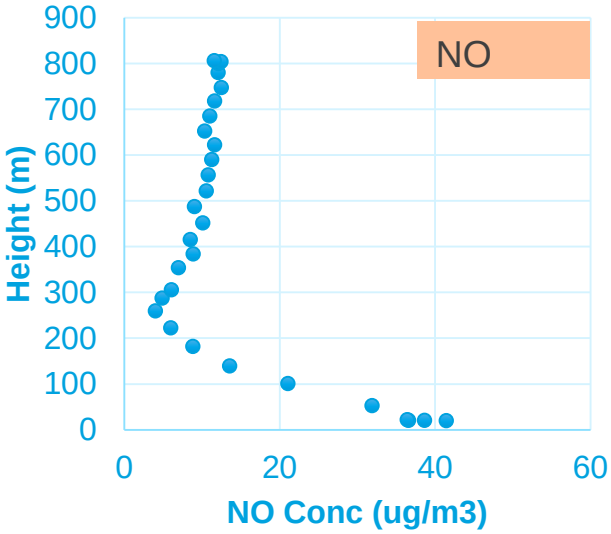


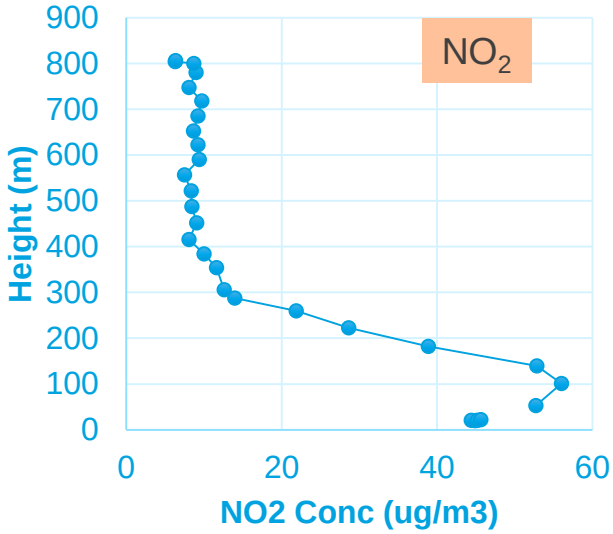
3. Application and QAQC/calibration recommendation

Intensive campaign in Shanghai from 0 to 1000 m







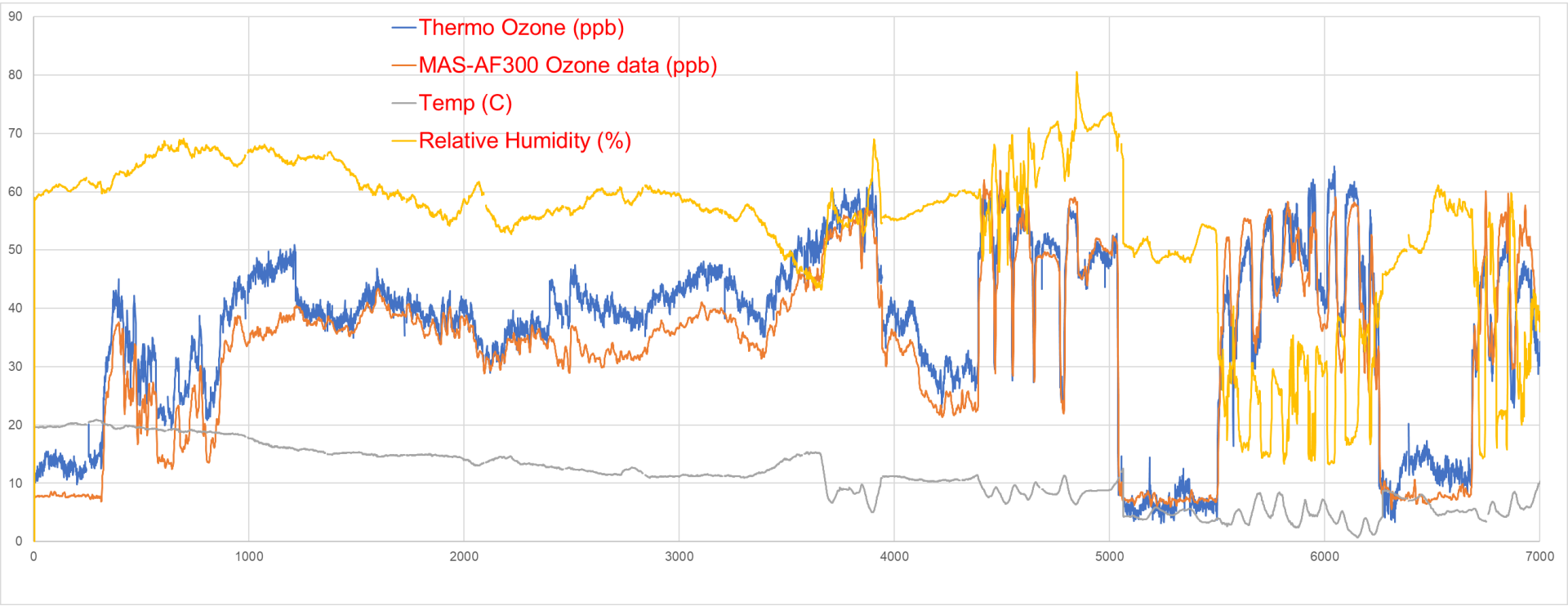


MAS sensors and Thermo analyzers on board of tethered balloon with 200 kg payload in Shanghai, led by Shanghai Environmental Monitoring Center

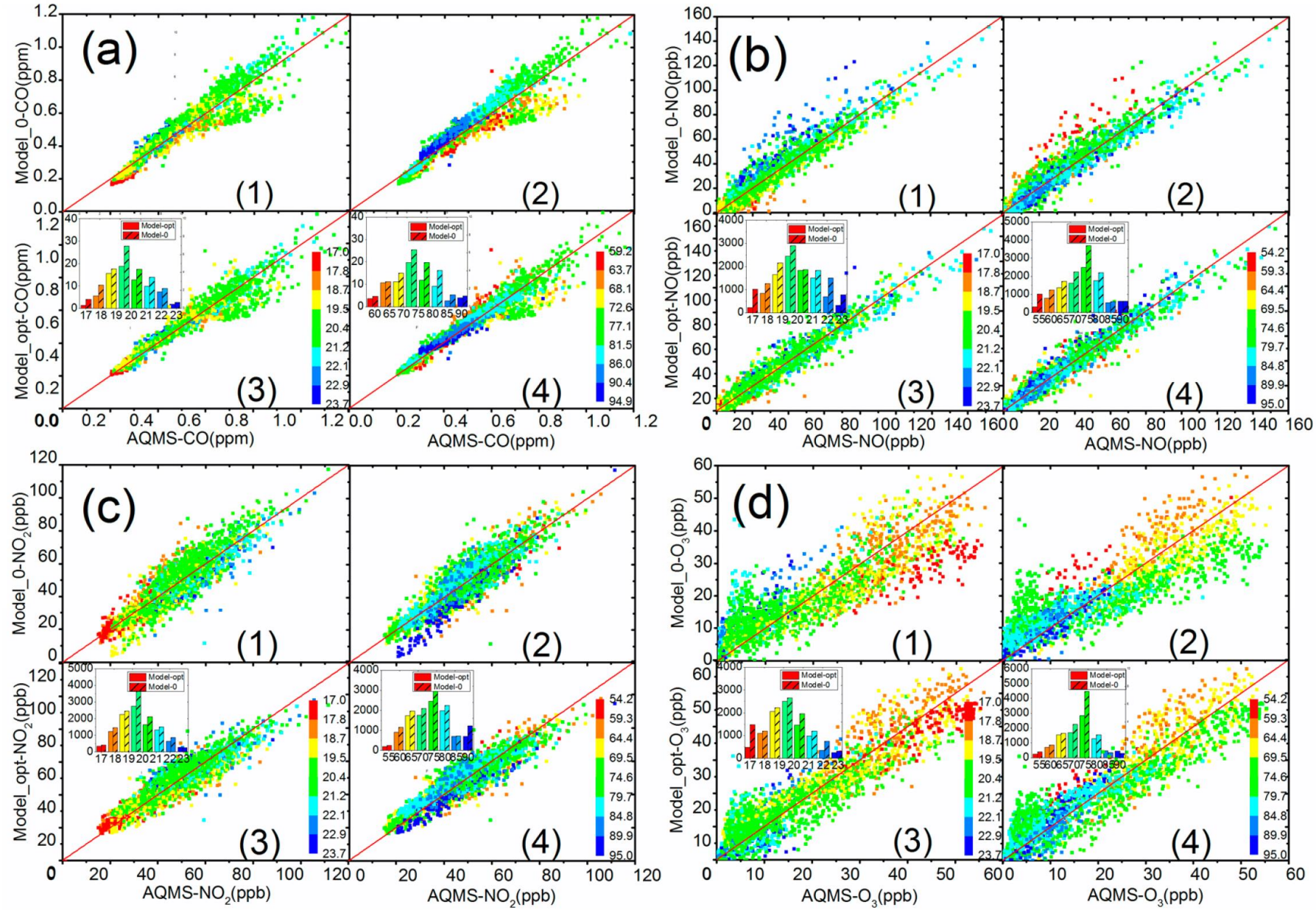
3. Application and QAQC/calibration recommendation

Intensive campaign in Shanghai from 0 to 1000 m

- **Impact of extreme and fast temperature (0-20 C) and humidity (80-15%) changes can be a problem.**
- **Baseline and sensitivity drift correction in MAS sensor system.**



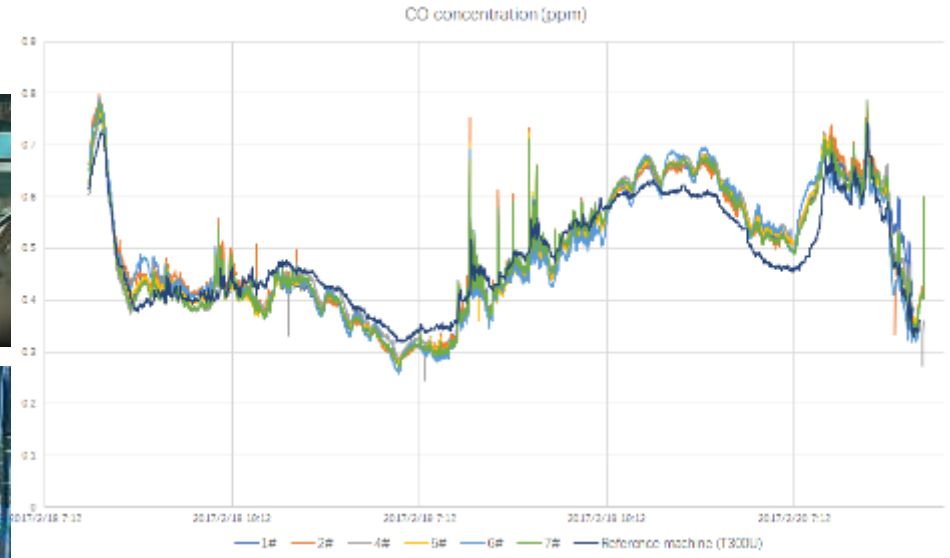
3. Application and QAQC/calibration recommendation

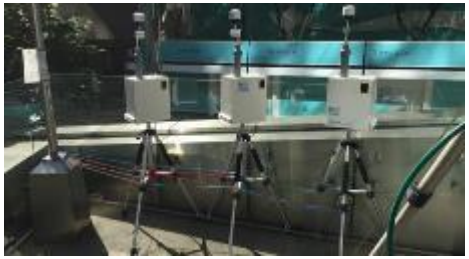


3. Application and QAQC/calibration recommendation

Inter-consistency check on multiple devices

- **Cross check on the raw data output on the multiple sensor devices;**
- **Master and slave units for quality assurance.**
- **Periodical quality control for inter-consistency check.**

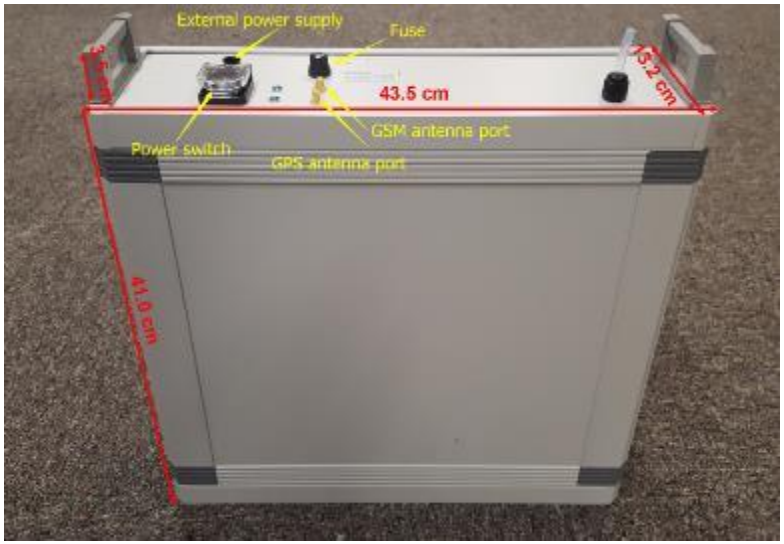




3. Application and QAQC/calibration recommendation

Mobile AIR Sensor Network (MASEN) in Hong Kong

- Bus mobile sensor platform;
- Compact and multipollutant solutions for traffic pollutants of $PM_{2.5}$, NOx (NO_2 &NO), CO, CO_2;
- GPS/ traffic speed data and real time transmission
- QAQC is very important for long term unattended operation!



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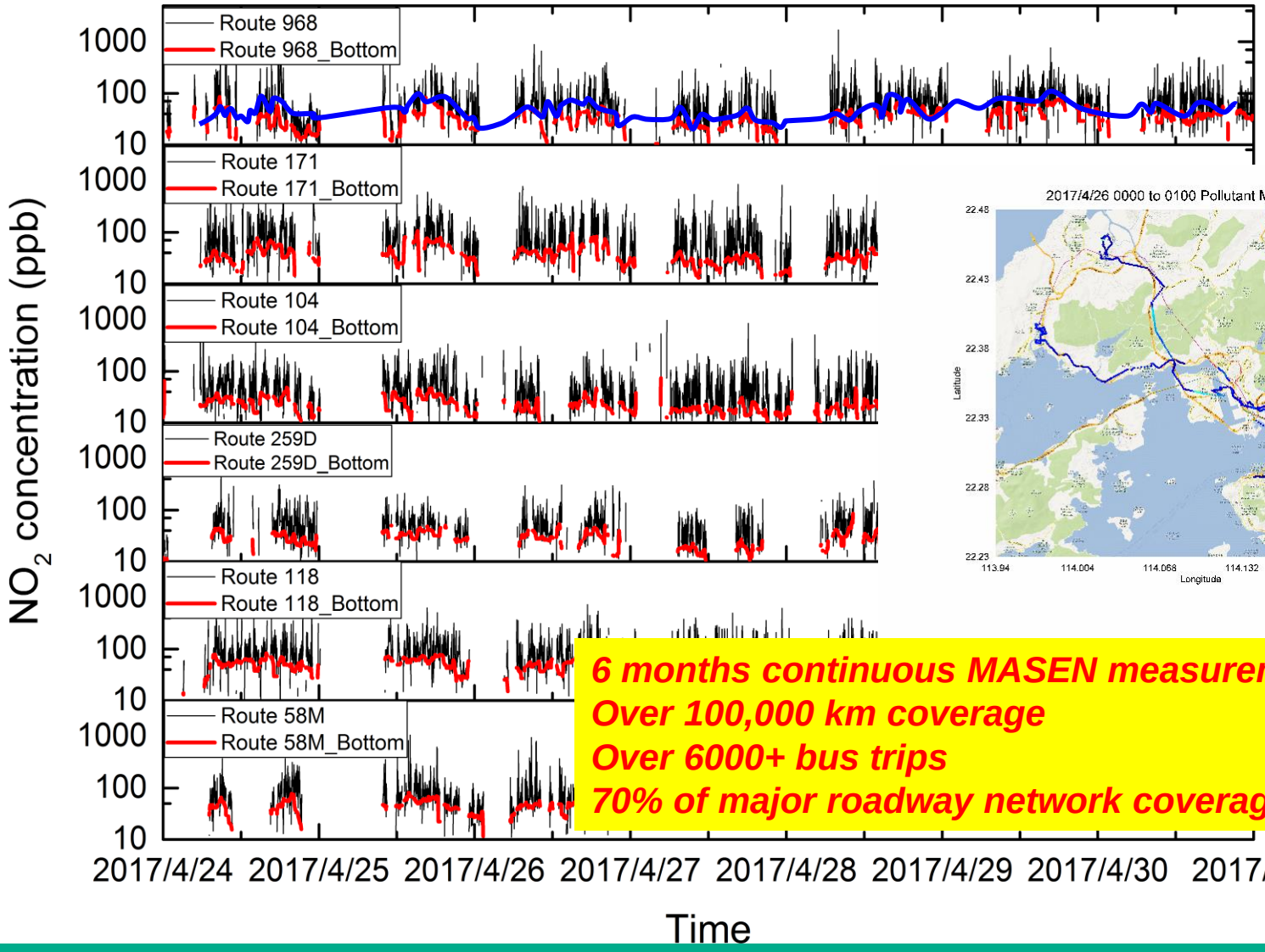
3. Application and QAQC/calibration recommendation

Mobile AIR Sensor Network (MASEN) in Hong Kong



6 months continuous MASEN measurement;
Over 100,000 km coverage
Over 6000+ bus trips
70% of major roadway network coverage in Hong Kong

3. Application and QAQC/calibration recommendation

Calibration recommendations

- Establishment of reference equipment traceability is needed
  - With existing AQMS equipment, once AQMS sites have space available, this is not a problem;

- Ad-hoc and intensive measurements (by days) calibration protocols
  1) Side by side operation for 2 days with 1 minute resolution data between sensors and AQMS for initial parameterization
  2) Side by side operation for 1 day with 1 minute resolution data between sensors and AQMS to for data validation after initialization
  3) Deployment of sensors on site to complete air monitoring tasks
  4) Zero calibration, temperature and humidity stabilization systems assist data quality assurance during operation;
  5) Deployment of sensor for next air monitoring tasks
  6) Return to AQMS sites after max 2 months operation

3. Application and QAQC/calibration recommendation

Calibration recommendations

- Intensive measurements (by weeks) calibration protocols

1) Side by side operation for 2-4 days with 1 minute resolution data between sensors and AQMS for initial parameterization
2) Side by side operation for 1-2 day with 1 minute resolution data between sensors and AQMS to for data validation after initialization
3) Deployment of sensors on site to complete air monitoring tasks
4) Zero calibration, temperature and humidity stabilization systems assist data quality assurance during operation;
5) Upon completion of the monitoring tasks, MAS return to the AQMS for data validation and post-parameterization in case of initial parameterization not sufficient to cover the variations.