G
U
R
M
E

Air Pollution Monitoring

Dr. Sarath Guttikunda
@ Desert Research Institute, Reno, USA & UrbanEmissions.Info

WMO
OMM

GURME

Why do we Monitor?

- Compliance
- Trends in ambient pollution
- Spatial and temporal analysis
- Hot spot analysis
- Model verification
- General issues
  - Uses of data
  - Variability among monitor types
  - Spatial representativeness

WMO
OMM

G
U
R
M
E

… and Forecasting


Air pollution forecasting in the offing in India-Pune-Cities-The Times of India - Mozilla Firefox

http://timesofindia.indiatimes.com/Pune/Air_pollution_forecasting_in_the_offing_in_India/articleshow/3802992.cms

THE TIMES OF INDIA Pune

Home | Cities | India | World | Indians Abroad | Business | Cricket | Sports | Health/Sci | Infotech | Education | Earth | Opinion | Entertainment | Lifestyle | Classifieds

Ahmedabad | Bangalore | Chandigarh | Chennai | Delhi | Goa | Hyderabad | Jaipur | Kolkata | Lucknow | Mumbai | Nagpur | Patna | Pune | Thiru'puram

Air pollution forecasting in the offing in India

7 Dec 2008, 0001 hrs IST, Prasad Kulkarni, TNN

PUNE: Air quality forecasting will begin in the country in the near future. Scientists at the city-based Indian Institute of Tropical Meteorology (IITM) are working on a model for predicting air pollution levels. This will help the public better manage their health and welfare, the scientists said.

"The model termed as the atmospheric chemical transport model will be used to predict air pollution levels in various parts of the country. It will make short-term predictions (viz for the next 48 hours) possible," Gufran Beig, head of the urban air pollution and transport modelling group which is developing the model, told TOI. "To start with, predictions for central and western

More Pune
- Brain Stroke: Deceptive symptoms cause high mortality rate
- Campaign to highlight violence against women
- 'Theatre is a quest for identity'
- 'I take a story and make it my own'

Other News
- Sheila Dikshit set to be Delhi CM for third time
- Maharashtra CM Chavan brings in new faces to cabinet
- LeT mastermind behind Mumbai attacks held: Report
- Fight terror or face aid cut: US lawmaker to Pakistan

Latest News
- French police arrest suspected new Basque ETA chief
- US military jet crashes into San Diego neighbourhood
- French Muslim graves damaged, third time in 2 years
- Greek youths occupy consulate office in Berlin

WMO
OMM

GURME

Type of Monitoring

Forecasting Data Sources	Parameters	Time Resolution	Real-time availability	Cost/ Resources
Written records of episodes	~PM	-	-	Low
Meteorological Data				
Visibility	~PM	Hourly Daily	Yes	Low
Reports of smoke/haze	~PM	Varies	Possible	Low
Satellite images	~PM	Hourly Daily	Yes	Low
Air Quality Data				
Surface				
Continuous	PM, O_3, CO, NO_2, NO_x, SO_2, and more	Hourly	Possible	Moderate
Samplers	PM, O_3, CO, NO_2, NO_x, SO_2, and more	Typically Daily	No	Moderate
Passive samplers	PM, O_3, CO, NO_2, NO_x, SO_2, and more	Integrated	No	Low
Upper-Air				
Ozonesonde	O_3	Periodic	No	High
Aircraft	PM, O_3, CO, NO_2, NO_x, SO_2, and more	Episodic	No	Very high
LIDAR	PM, O_3, CO, others	Hourly	Yes	Very high

WMO OMM

G
U
R
M
E

Monitors

WMO
OMM

Typical Continuous Gas Monitors

- Ambient air is continuously drawn into the monitor, pre-treated (e.g. particles, hydrocarbons, and/or H_2S removed), and measured either directly or via chemical reaction using a spectroscopic method
- Direct measurement

  CO: gas filter correlation

  SO_2: UV fluoresence

  O_3: UV photometric
- After reaction with O_3

  NO_2: by difference (NO_x-NO) using chemiluminescence and catalytic converter

GURME

Typical Particle Monitoring

- Filter sampler for 24-hr (daily) PM mass
  - Single channel or sequential
- Continuous (hourly) monitors
  - Tapered Element Oscillating Microbalance (TEOM)
  - Beta Attenuation Monitors (BAM)

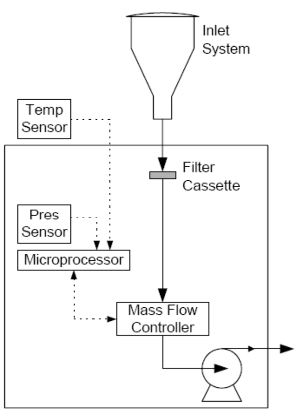
WMO
OMM

GURME

Daily Filter Samplers

Filter Sampler

- Ambient air is drawn through inlet (to remove larger particles)
- Material collects on the filter; filter is later analyzed for mass or chemical species
- Problems
  - Potential loss of volatile material
  - Not available for short time intervals
  - Not available in real time



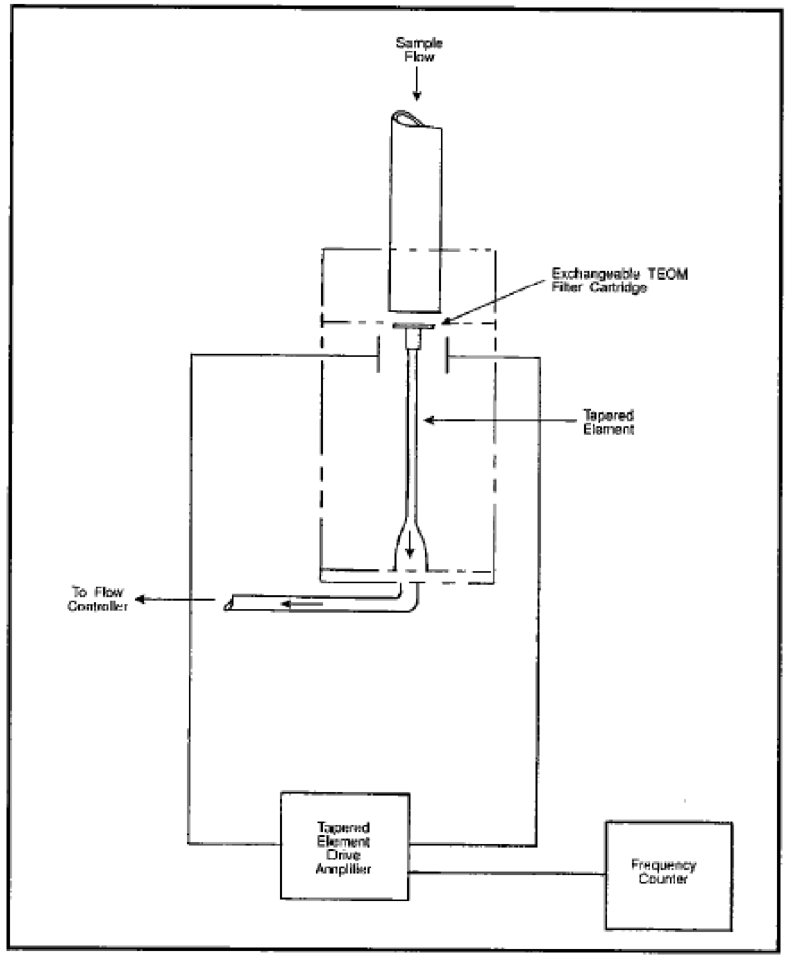
WMO OMM

G
U
R
M
E

Continuous Particle Monitors (1 of 2)

Tapered Element Oscillating Microbalance (TEOM)

- Determines mass by variation in frequency of filter element on an oscillating arm
- Differential mass for each hour
- Problems
  - Negative mass values due to volatilization
  - Volatilizing nitrates and carbon species, particularly during cold weather or high humidity causes underestimation of PM mass



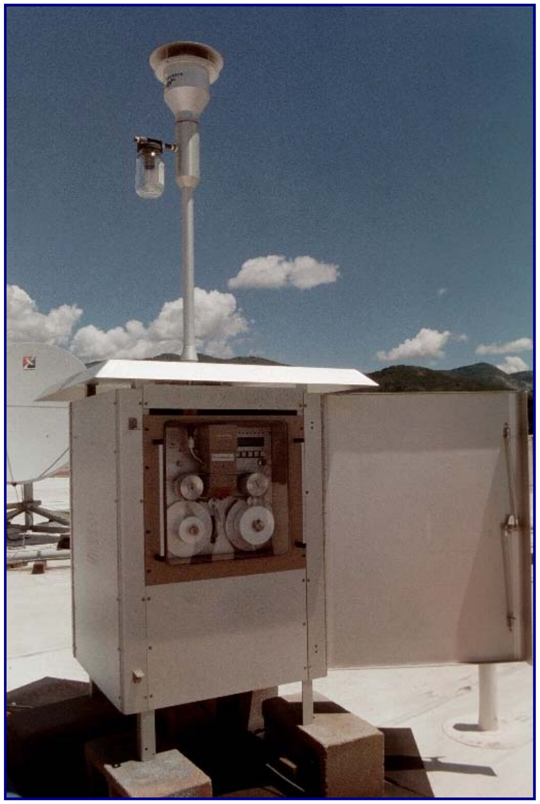
WMO
OMM

GURME

Continuous Particle Monitors (2 of 2)

Beta Attenuation Monitor (BAM)

- Mass of PM collects on a filter and is exposed to beta ray, the attenuation of which is proportional to the mass on the filter
- Problems
  - PM species attenuate beta rays differently
  - Relative humidity (RH) can influence calculation of PM mass from attenuation data causing under or overestimation of PM mass during periods of fluctuating RH values



WMO OMM

G U R M E

$PM_{2.5}$ Federal Reference Method (FRM)

WMO
OMM

G
U
R
M
E

Speciation Monitors (EPA speciation network)

Mass Aerosol Sampling System (MASS)
URG Corporation, Raleigh, NC

Reference Ambient Air Sampler (RAAS)
Andersen Instruments, Smyrna, GA

Spiral Aerosol Speciation Sampler (SASS)
Met One Instruments, Grants Pass, OR

Interagency Monitoring of Protected Visual Environments (IMPROVE) Sampler
Air Resource Specialists, Ft. Collins, CO

G
U
R
M
E

Other Speciation Monitors

Partisol 2300 Speciation Sampler
Rupprecht & Patashnick, Albany, NY

Dual Channel
Sequential Filter Sampler
and Sequential Gas Sampler
Desert Research Institute, Reno, NV

Dichotomous Virtual Impactor
Andersen Instruments, Smyrna, GA

Paired Minivols
Airmetrics, Inc., Springfield, OR

WMO
OMM

I. Inlets . . . *Fine Particle Inlets*

Type	Cut Point (d_{50})	Slope ($\sqrt{d_{84}/d_{16}}$)	Flow Rate
Harvard sharp cut impactor	2.5 µm	1.02	4 L/min
R&P sharp cut cyclone	2.5 µm	1.23	5 L/min
GRT sharp cut cyclone	2.5 µm	1.24	6.8 L/min
Harvard sharp cut impactor	2.5 µm	1.06	10 L/min
URG cyclone	2.5 µm	1.32	10 L/min
EPA WINS impactor	2.48 µm	1.18	16.7 L/min
BGI sharp cut cyclone	2.5 µm	1.19	16.7 L/min
URG cyclone	2.5 µm	1.35	16.7 L/min
Harvard sharp cut impactor	2.5 µm	1.25	20 L/min
Andersen/AIHL cyclone	2.7 µm	1.16	24 L/min
IMPROVE cyclone	2.3 µm	1.18	28 L/min
Bendix/Sensidyne 240 cyclone	2.5 µm	1.7	113 L/min

GURME

Inlets . . . *Examples of Inlets*

WINS impactor

Bendix cyclone

Airmetrics impactors

⇦ PM_{10}

$PM_{2.5}$ ⇨

Sharp cut cyclone

WMO OMM

GURME

I. Inlets . . . *PM₁₀ Inlets*

Type	Cut Point (d_{50})	Slope ($\sqrt{d_{84}/d_{16}}$)	Flow Rate
Harvard sharp cut impactor	10 µm	1.11	4 L/min
Harvard sharp cut impactor	10 µm	1.09	10 L/min
Andersen 246B impactor	10.2 µm	1.41	16.7 L/min
Harvard sharp cut impactor	10 µm	1.06	20 L/min
Andersen med-vol impactor	10 µm	1.6	113 L/min
Andersen hi-vol impactor	9.7 µm	1.4	1,133 L/min
TEI/Wedding cyclone	9.6 µm	1.37	1,133 L/min

WMO OMM

G
U
R
M
E

Inlets . . . *Examples of PM_{10} Inlets*

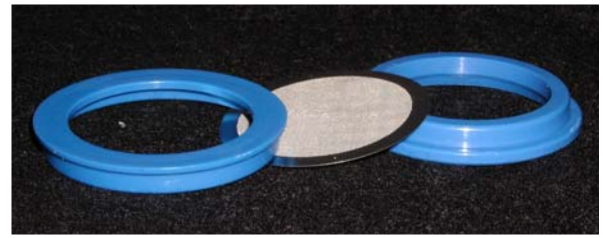
WMO
OMM

G
U
R
M
E

Filter Holders

Dichotomous sampler
polyethylene 37mm filter holder

FRM sampler
Delrin 47mm filter holder ring
with stainless steel grid



Nuclepore polycarbonate filter
holder

Savillex molded FEP filter
holder

Speciation sampler
Teflon-coated aluminum filter
holder

Sampling Substrates . . . Types of Media

Teflon membrane

- Mass and elemental analysis, sometimes ions
- Not for carbon

Quartz fiber

- Ions and carbon (after annealing)
- Not for mass or elements

Cellulose fiber

- Gas sampling with impregnates (citric acid/NH_3, triethanolamine/NO_2, sodium chloride/HNO_3, sodium carbonate/SO_2)

Nylon membrane

- Nitric acid, also adsorbs other gases (SO_2)

Etched polycarbonate

- Scanning electron microscopy, elements, mass with extensive de-charging
- Not for ions or carbon

Teflon-coated glass fiber

- Mass, ions, organic compounds (e.g., PAH)
- Not for carbon or elements

G
U
R
M
E

Optical Sensors

WMO
OMM

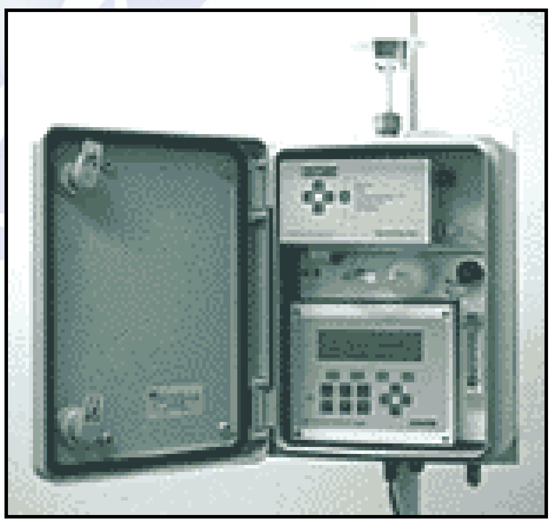
GURME

Continuous Mass Surrogates (particle scattering measurements)

TSI DusTrak

Optec NGN-2

Greentek

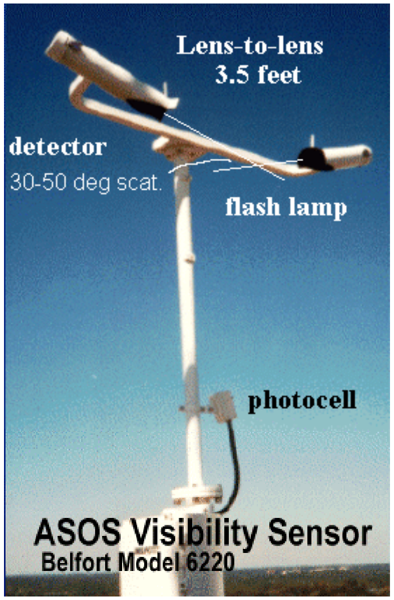


Radiance M903 nephelometer with smart heater

WMO OMM

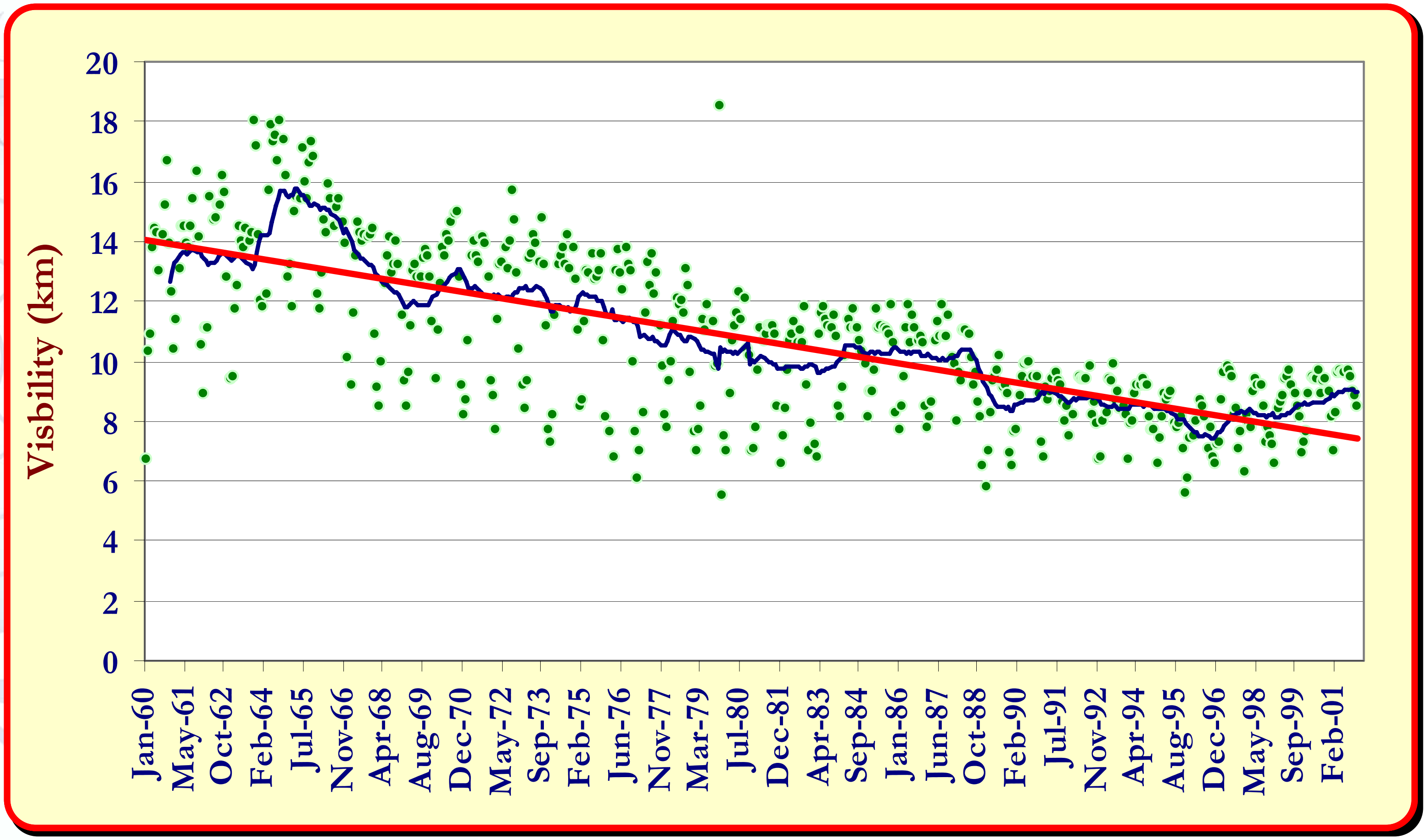
Visibility Sensors

- Nephelometers
- Transmissometer (weather visibility sensors)
- Measurements
  - Measures light scattering
  - Provides continuous data
  - Correlated with PM
  - Lower cost PM measurement



GURME

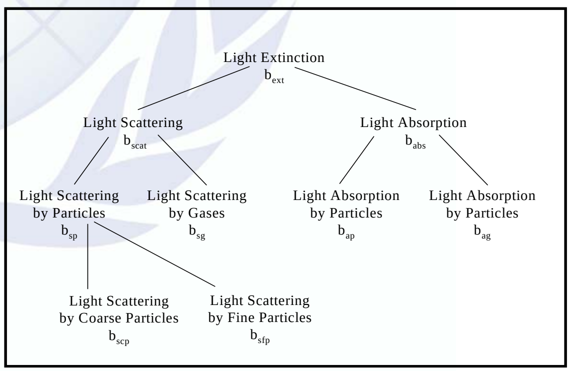
Bangkok Visibility Index

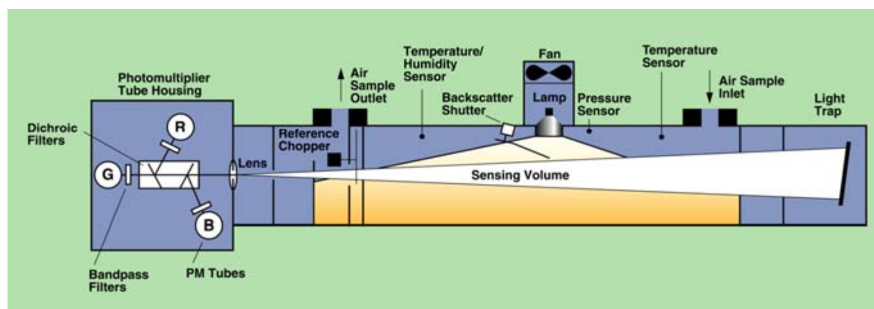


Source: Climatology Division, meteorology department, Thailand

Nephelometers

- Nephelometers
  - Measure light scatter from particles
  - Sensitive to aerosols < 2.5 µm
  - Heater dries air (removes affect of humidity)
  - Not sensitive to flow rate
  - Lower maintenance costs
- Problems
  - Sensitive to humidity
  - Carbon can absorb light and bias data





The relationship of the components of light extinction.

G
U
R
M
E

Satellite

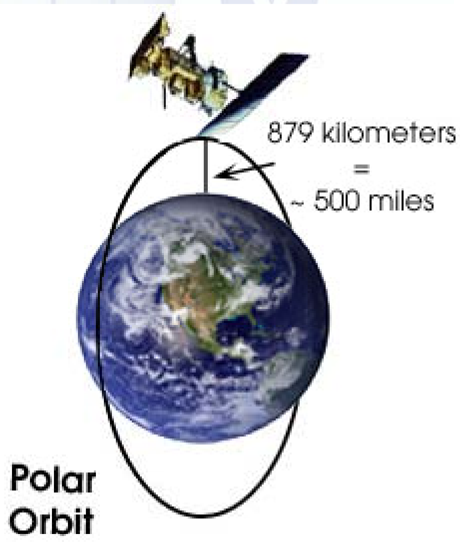
WMO
OMM

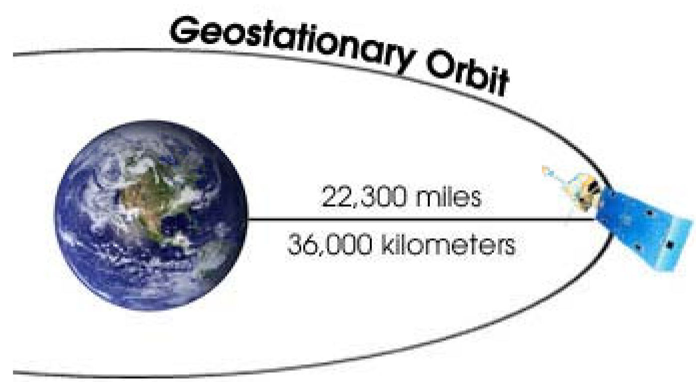
GURME

Satellite (1 of 5)

- Polar-orbiting or geostationary
- Visible imagery
- Aerosol optical depth

- Advantage
  - Data available from around the world
- Disadvantage
  - No direct pollutant measurements
  - Only works during daylight and when skies are cloud-free
  - No vertical resolution





Images courtesy of University of Wisconsin, Madison

G
U
R
M
E

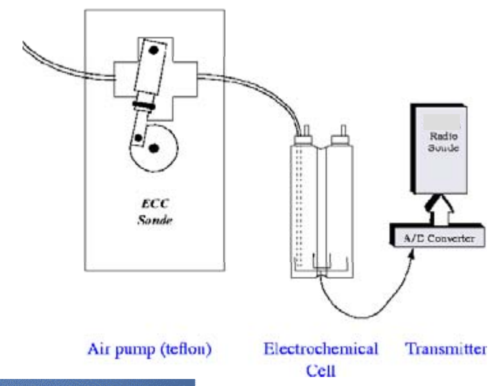
Ground Based

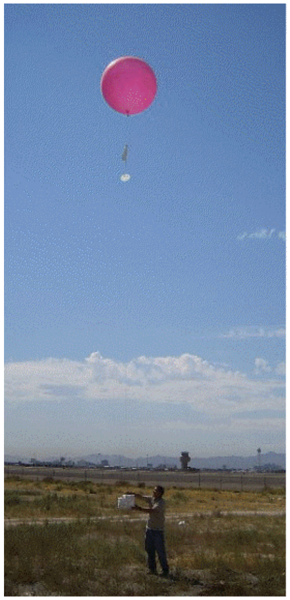
WMO
OMM

GURME

Ozonesonde

- Sensor attached to a radiosonde
- Measures vertical profile of ozone
- Examines aloft ozone conditions
- Problems for forecasting
  - Expensive
  - Very sparse, non-routine networks



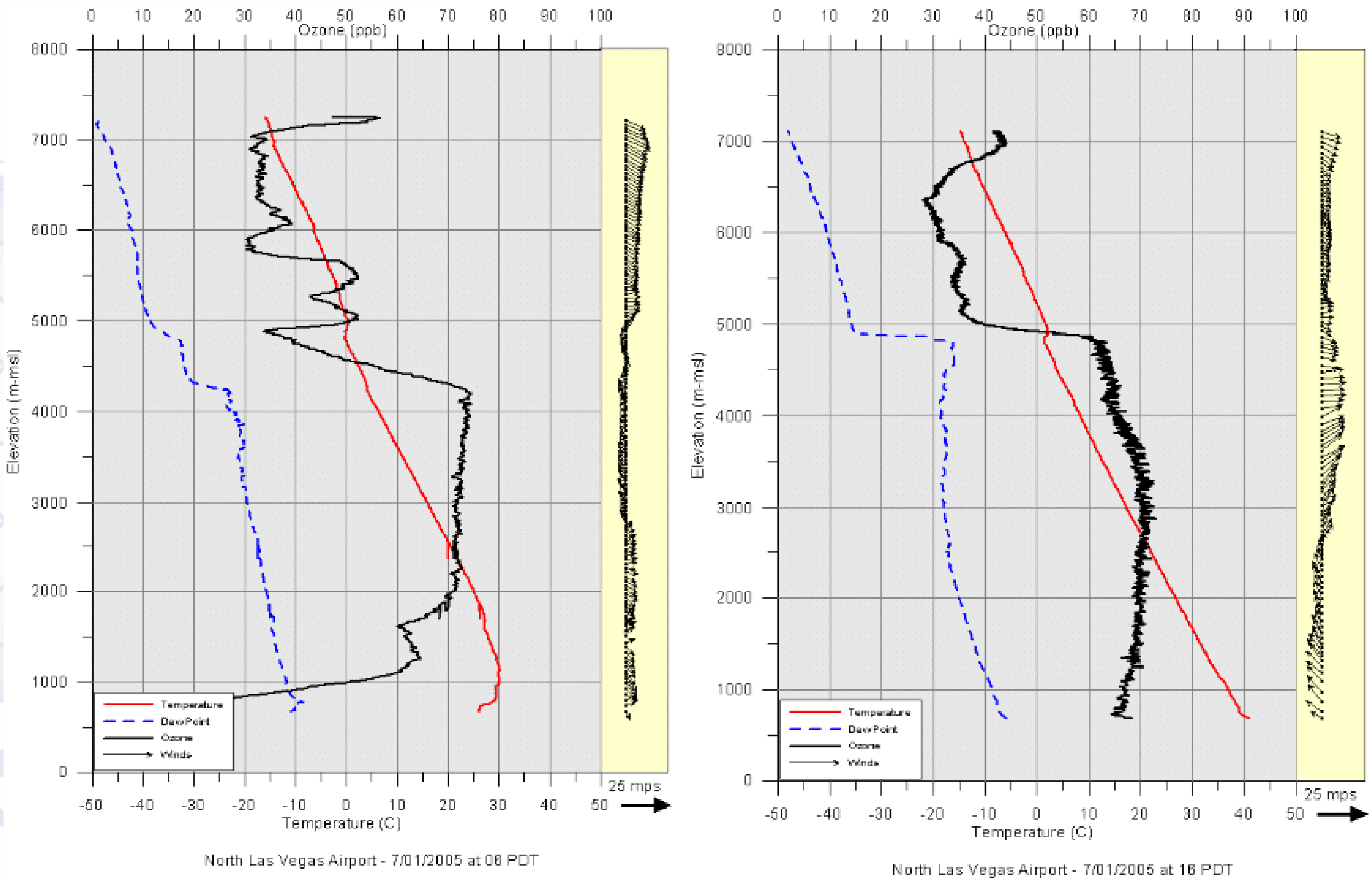


Courtesy of T&B systems

WMO
OMM

G
U
R
M
E

Ozonesonde – Example

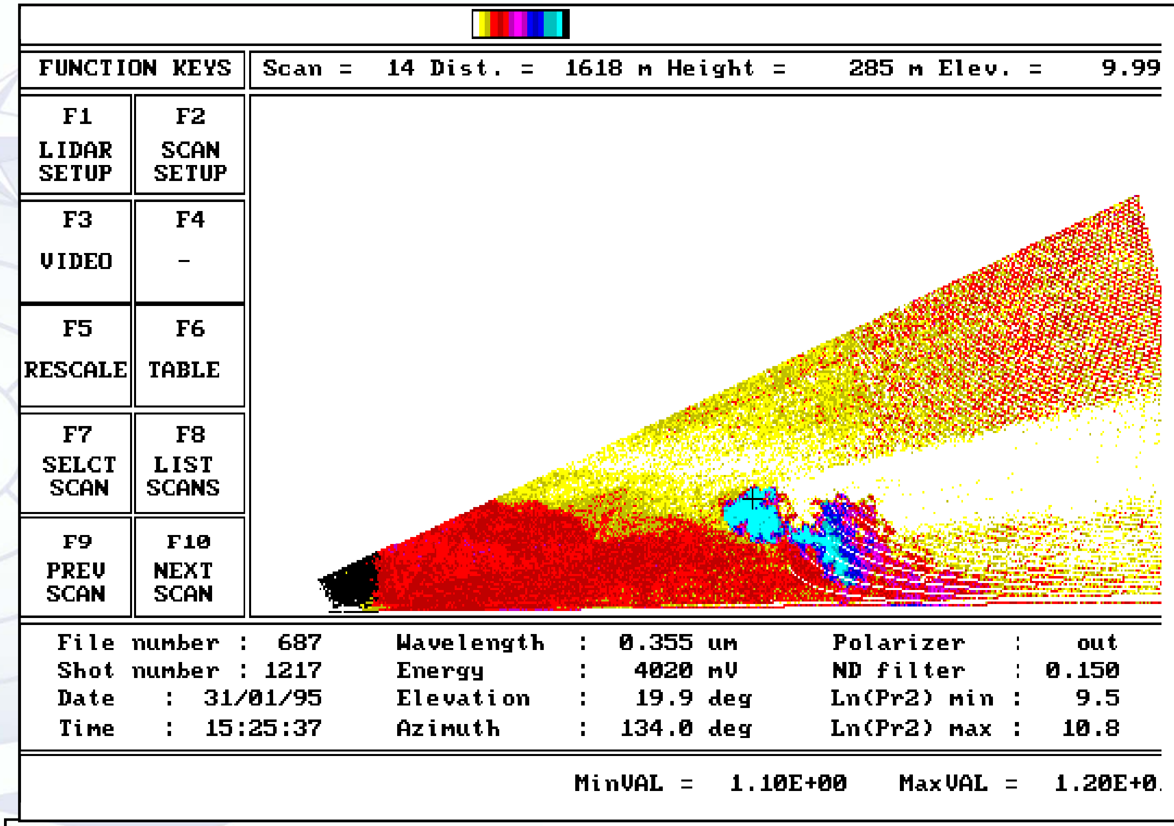


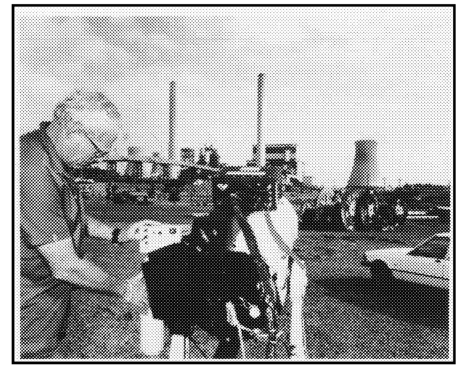
Morning (6 a.m.) and afternoon (4 p.m.) ozonezonde data showing ozone concentration (black line), temperature (red), dew point temperature (blue), and winds from Las Vegas, Nevada, USA on July 1, 2005. Courtesy of T&B systems.

WMO
OMM

GURME

Lidar





An early transportable LIDAR from CSIRO on location during a plume tracking experiment.

Cross section of a plume displayed during data acquisition obtained by LIDAR (located to the left), showing the height of the mixing layer (red) and structure in the plume (blue). If an appropriate wave-length is used, LIDAR can measure SO_2 concentration in the plume directly.

WMO OMM

G
U
R
M
E

Aircraft

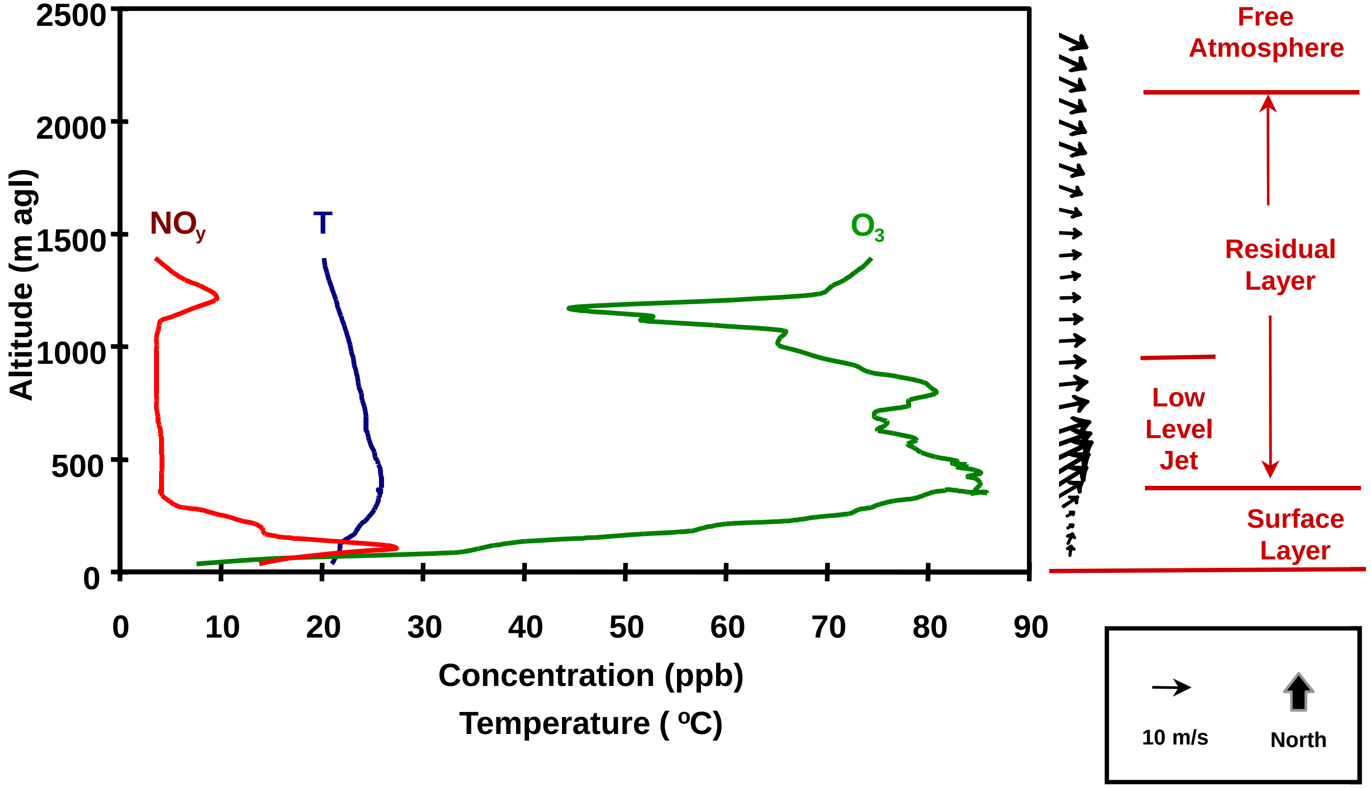
WMO
OMM

Aircraft

- Provide multi-pollutant monitoring
- Able to fly in area of concern
- Useful for monitoring aloft carryover, transport of pollution, and mixing processes
- Morning flights profile useful forecasting information
- Problems
  - Expensive
  - Data not available in real-time

GURME

Aircraft – Example



Aircraft measurement of ozone, NO_y, temperature, and winds provide aloft information about the air quality conditions in the nocturnal low-level jet. In this example, aircraft data collected near Gettysburg, Pennsylvania, USA on August 1, 1995, at 0600 EST showed a nocturnal jet that transported air pollution over several hundred kilometers during the overnight hours. This aloft pollution mixed to the surface during the late morning hours.

WMO
OMM

G
U
R
M
E

How many are enough?

WMO
OMM

G
U
R
M
E

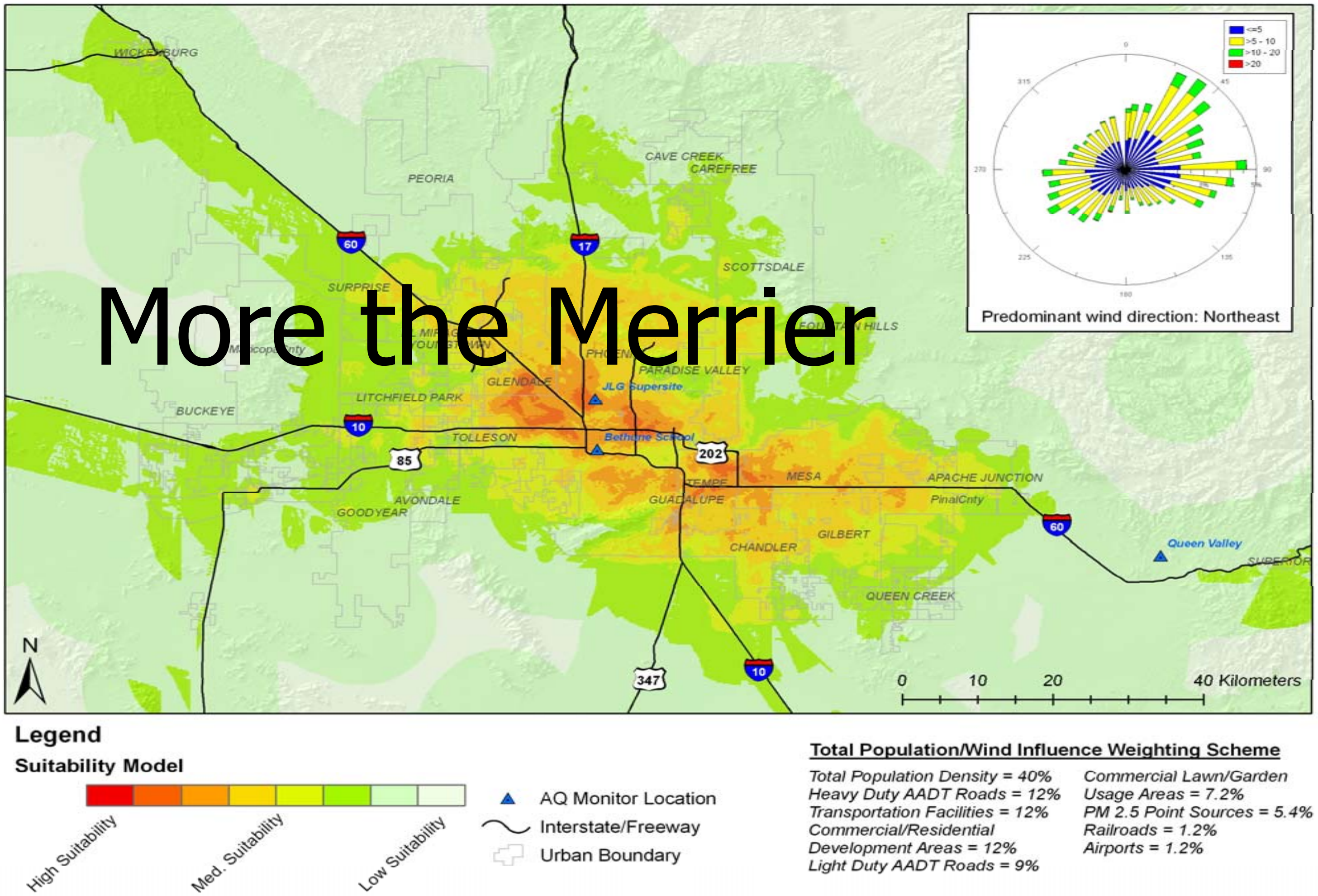
Google Earth, Delhi

WMO
OMM

GURME

Monitor Density and Location Analysis Techniques

More the Merrier

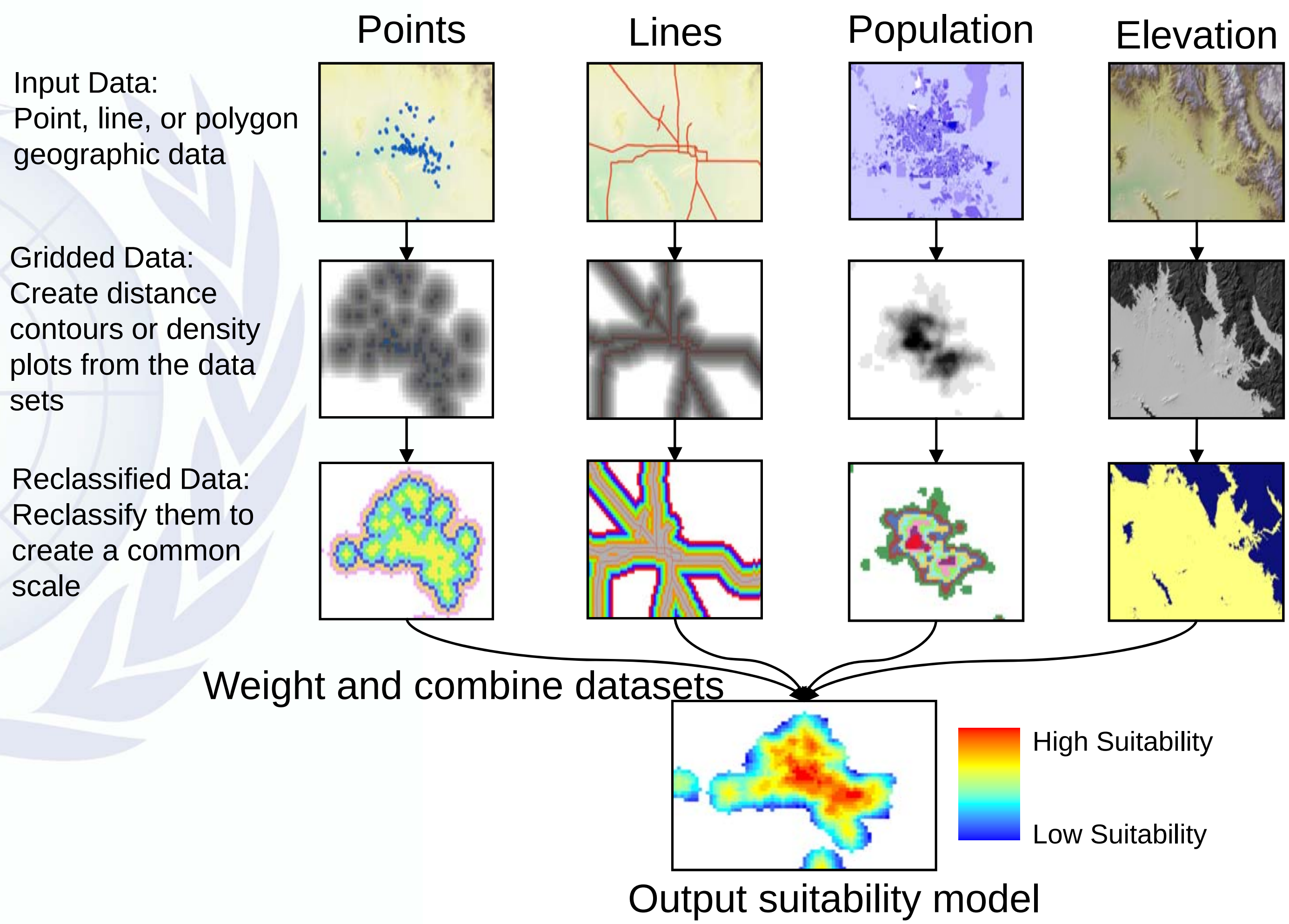


Penfold et al., 2003

WMO OMM

GURME

Monitor Density and Location Analysis Techniques



WMO
OMM

G
U
R
M
E

Google Earth, Delhi

WMO
OMM

G
U
R
M
E

Monitor Representativeness

- Representativeness
  - Do monitors measure the prevailing conditions at site, location, or region?
  - Do collocated monitors measure similar conditions (variations can exist among monitoring techniques)
  - Do closely located monitors measure similar conditions?

WMO
OMM

Data Availability

- Regional maximum differences from evolving and changing networks
  - Adding or removing sites from a network can affect overall network monitoring results
  - The same is true for sites removed from the network
- Data availability
  - Filter sampling may measure PM on different schedules (daily or every third or sixth day), which makes analysis more difficult

CPCB – Real Time Data
http://164.100.43.188/cpcbnew/movie.html

GURME

Summary

- Monitor types
  - Gas monitors
  - Particle samplers and monitors
  - Continuous – real-time, good for forecasting
  - Samplers – not real-time
  - Other
    - Visibility sensors
    - Satellite measurements
    - Ozonesondes
- General issues
  - Uses of data
  - Variability among monitor types
  - Spatial representativeness
  - Data availability

WMO
OMM

G
U
R
M
E

Thank You

Dr. Sarath Guttikunda

New Delhi, India

More details @ www.urbanemissions.info

WMO
OMM