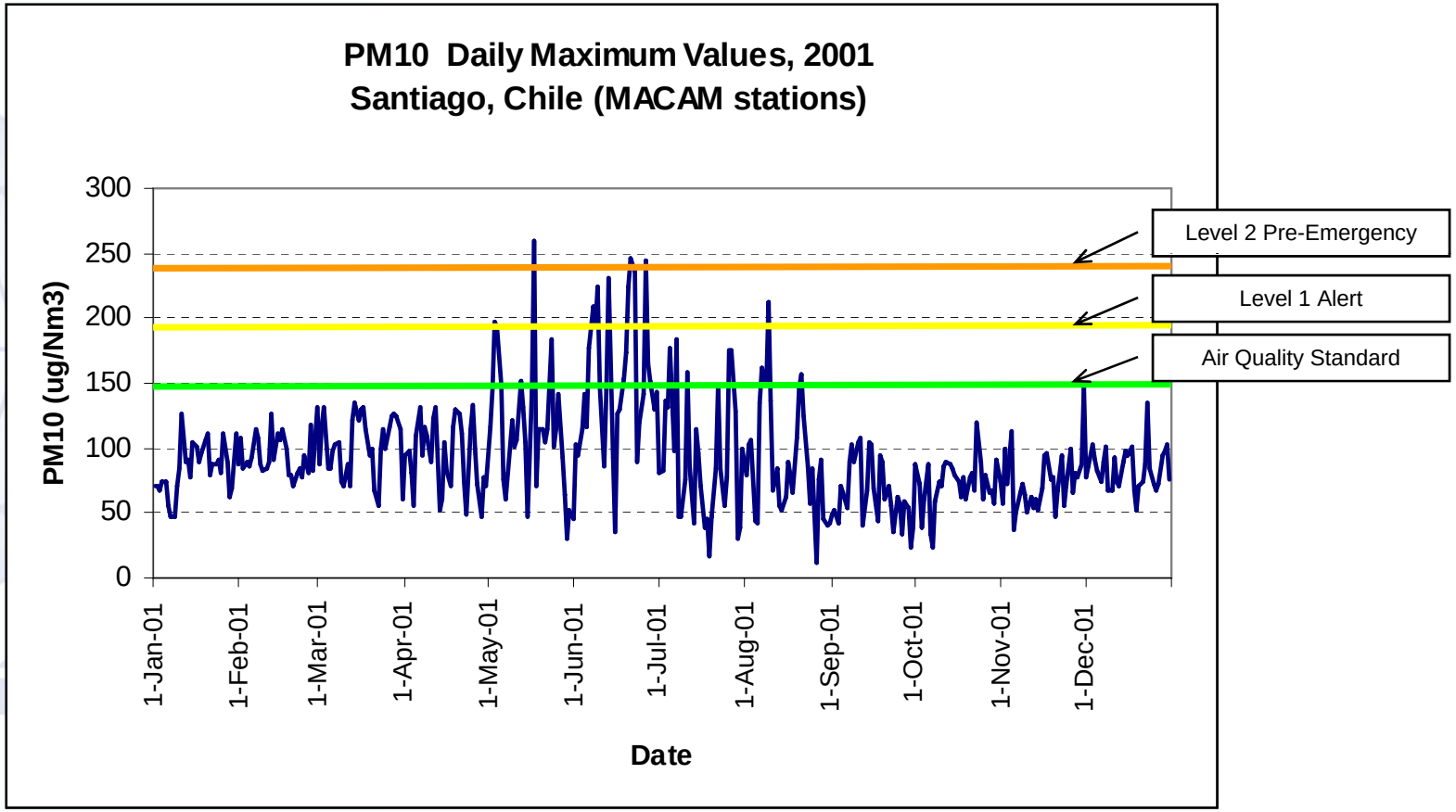
AREP
GAW

WMO
OMM

AQ Forecasting

What Are We Forecasting – Averaging Time (3 of 3)



Ulriksen and Merino (2003)

AREP
GAW

What Are We Forecasting – Spatial Scale (1 of 2)

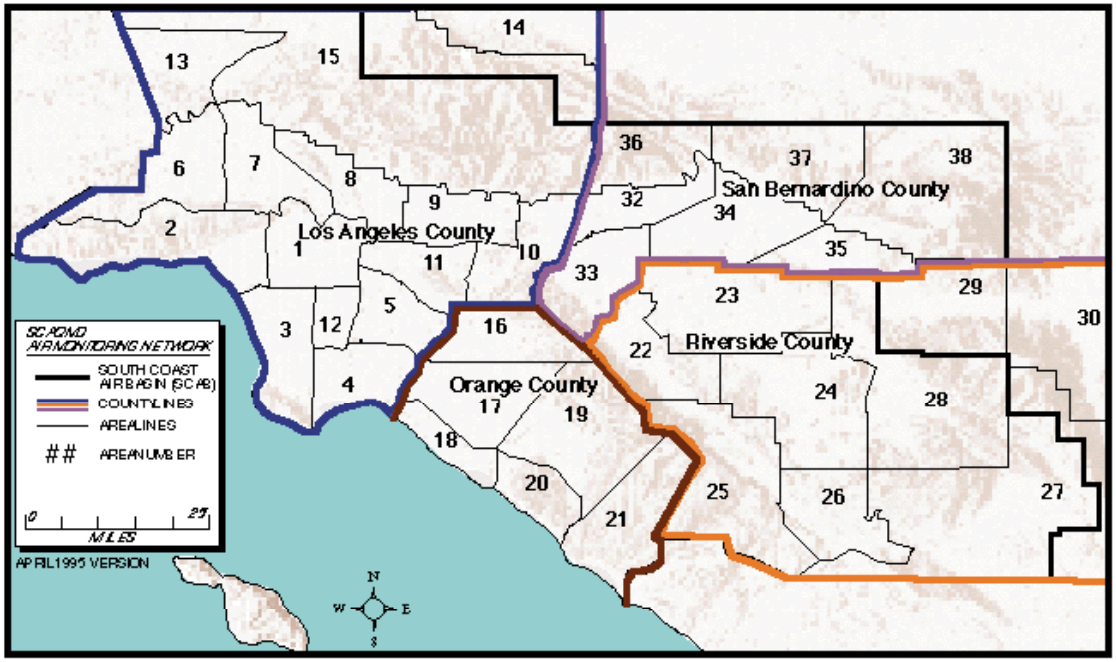
- Scales
  - Regional or mesoscale (10 km – 400 km)
  - Urban or sub-regional (10 km)
  - Neighborhood or single site (< 5 km)
  - Forecast scale needs to match local air quality scale
- Forecast zone
  - Several may exist in an area
  - Areas with complex terrain, meteorology, and emission patterns are subject to multiple forecast zones
- Metrics
  - Maximum of all sites in forecast zone
  - Multi-site average
  - Others

WMO
OMM

AREP
GAW

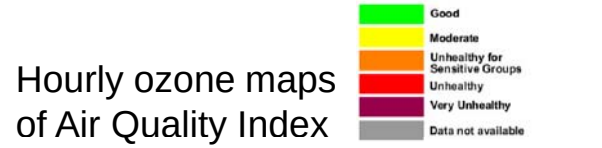
What Are We Forecasting – Spatial Scale (2 of 2)

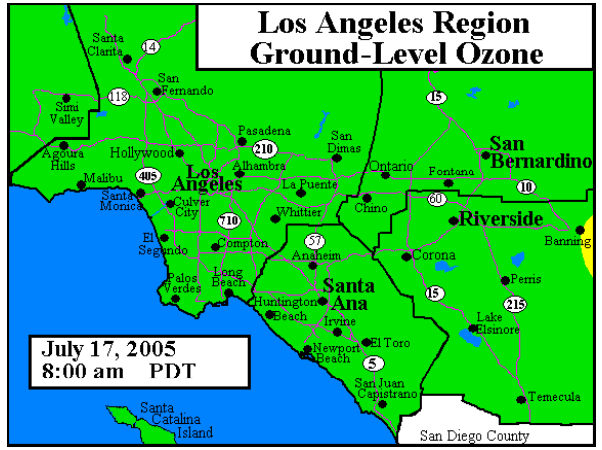
Local forecast regions

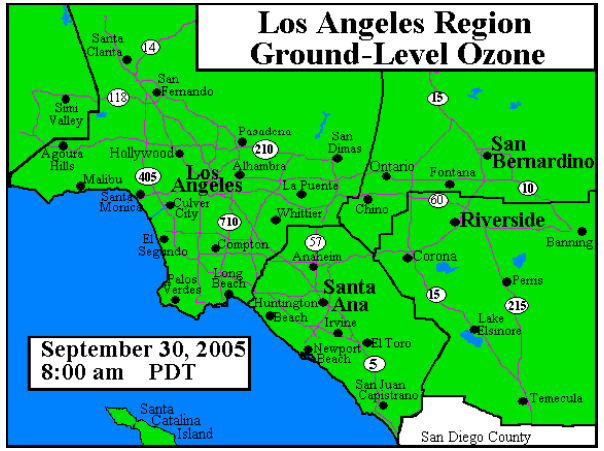


Los Angles, California, USA Forecast Regions

Hourly ozone maps of Air Quality Index







WMO
OMM

AREP
GAW

Summary

- Pollutants of concern
  - Major (ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide)
  - Toxics
- Toxics are difficult to forecast because of uncertainties in emissions and their chemical change in the atmosphere
- What are we forecasting?
  - Units of measure
  - Averaging time
  - Spatial scale

WMO
OMM

AREP
GAW

Protect Public Health

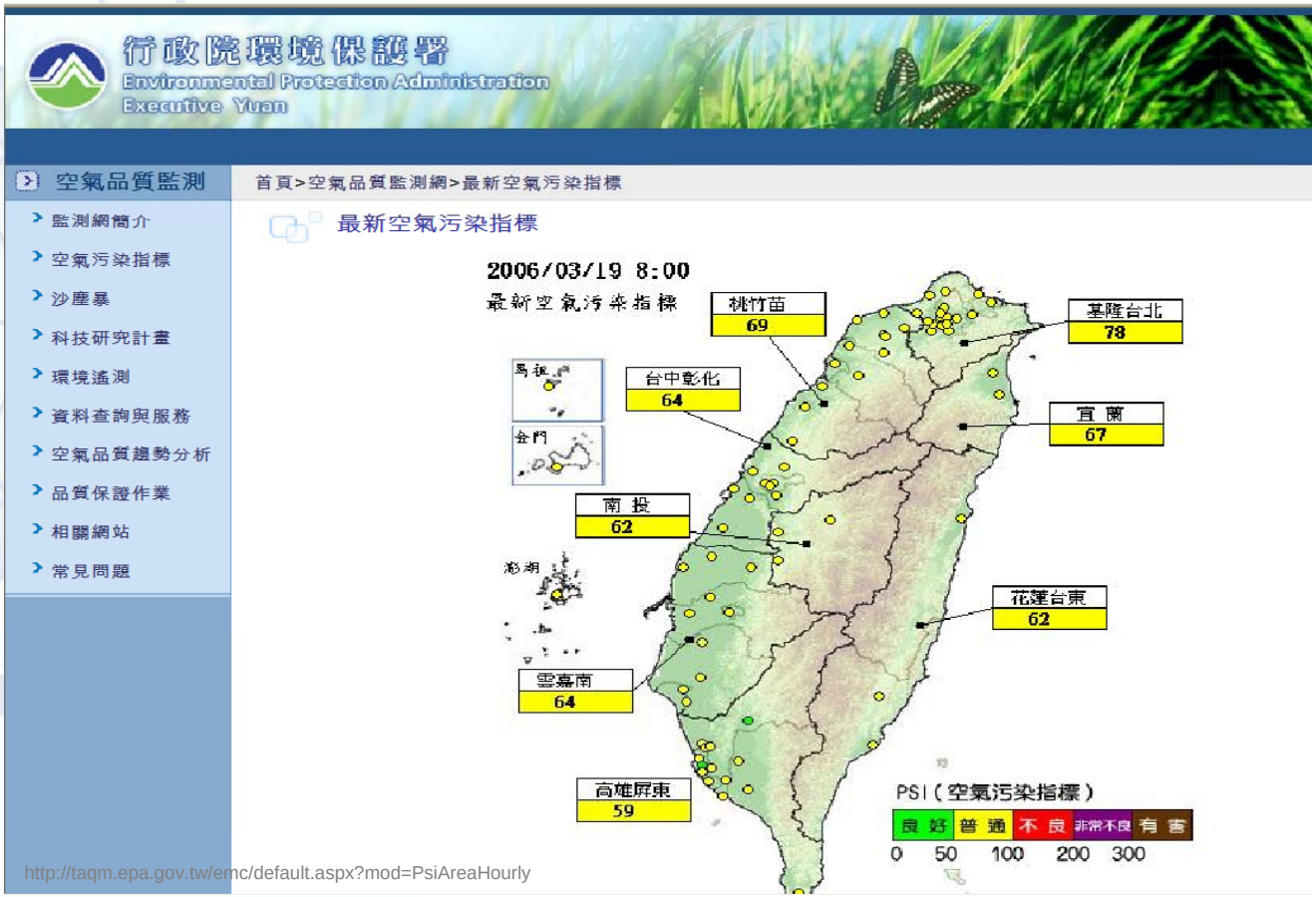
- Forecast allows the public to plan
  - Activities to avoid exposure to unhealthy air
  - Outdoor activities
  - Health and medical care
- Forecasts are used by
  - Air quality agencies (communications office)
  - Media (television, newspaper, radio, and web)
  - Public (general and sensitive individuals)
  - Schools (scheduling outdoor activities)
- Critical forecast issues
  - Timeliness (when do users need it)
  - Localized forecasts
  - Multi-day (one-to-five day) forecasts are useful
  - Easy-to-understand format

WMO
OMM

AREP
GAW

Protect Public Health (Example)

Taiwan EPA web site showing current and forecasted air quality conditions



WMO
OMM

Operate Emissions Reduction Programs (1 of 2)

- Types of programs
  - Voluntary (not required)—sometimes called “Action Day Programs”
  - Mandatory (required)

- Forecast needed for
  - Advanced planning to prepare for communication and taking action
  - Notification of stakeholders
- Critical forecast issues
  - Participation depends on forecast timeliness and accuracy
  - Emissions are affected (may affect forecast verification)

AREP
GAW

Operate Emissions Reduction Programs (2 of 2)

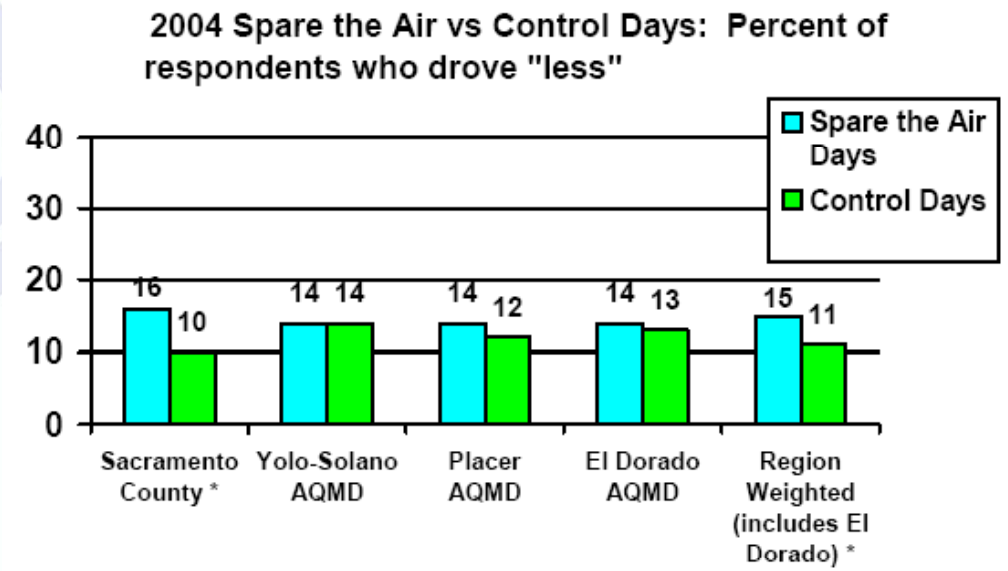
- Voluntary emissions reduction program
  - Spare The Air (STA) Program (Action Day) in Sacramento, California, USA
  - Objective – Seeks public involvement to voluntarily reduce emissions on forecasted Spare The Air Days
- How are forecasts used
  - Spare The Air Day is triggered by a one-day forecast
  - On Spare The Air Days
    - Notify the public by television, public service announcements, radio, newspaper, fax, and web
    - Ask the public to reduce emission-producing activities
      - Reduce driving by carpooling (several people in one vehicle) and taking public transit
      - Reduce use of paints, solvents, etc.

Source: www.sparetheair.com

WMO
OMM

How Are Forecasts Used? (1 of 4)

1. Evaluate voluntary program results
   - Compare driving habits on STA and non-STA (control) days
   - Evaluate reduction in driving
   - Calculate reduction in emissions

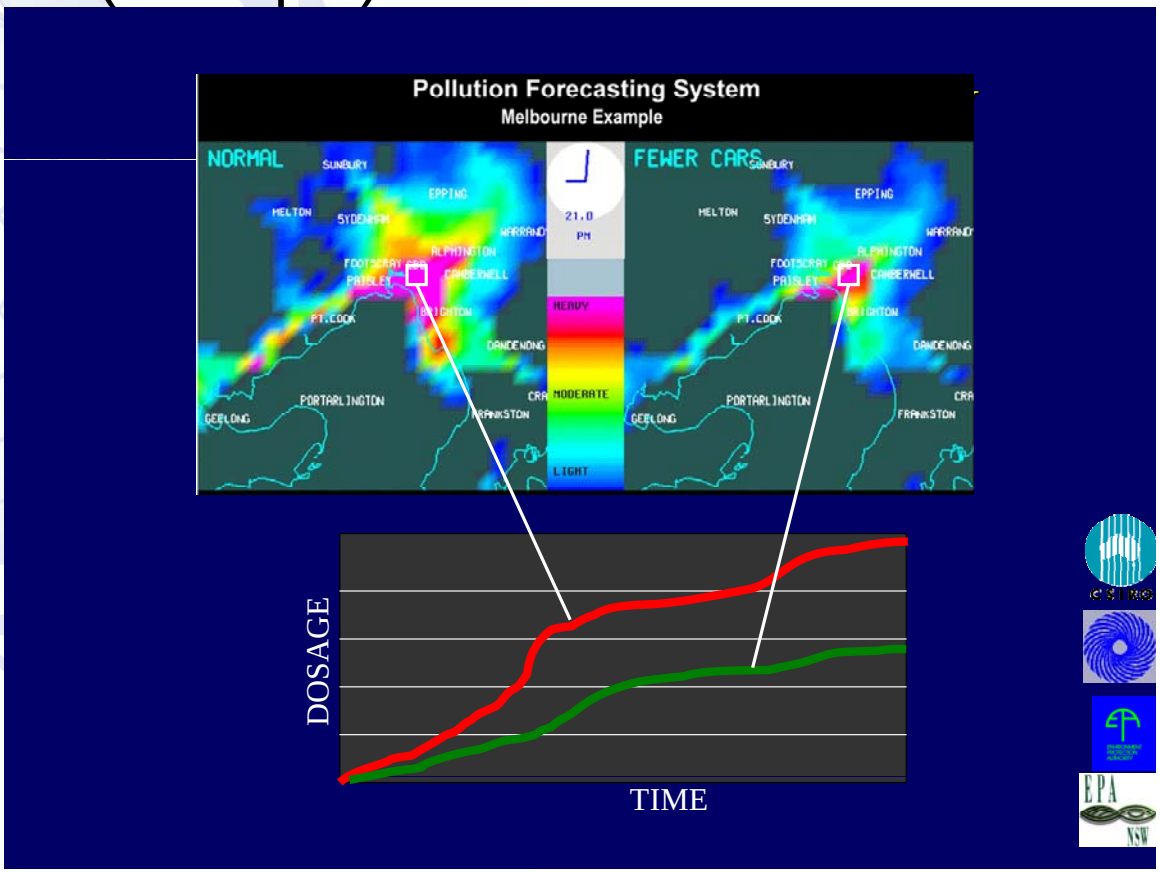


Source: http://www.cleanerairpartnership.org/images/Final%20Evaluatio&ir%20Campaign.pdf

AREP
GAW

How Are Forecasts Used? (2 of 4)

2. Operate mandatory emissions reduction programs (example)



"Green" Scenario – on days of forecast high pollution, develop a forecast with reduced traffic that could result from public warnings, to show the improvement of air quality: Melbourne on a high smog day and with a 25% reduction in traffic.

WMO
OMM

AREP
GAW

How Are Forecasts Used? (3 of 4)

3. Conduct special sampling
   - Several types of programs
     - Localized special monitoring
     - Regional monitoring
     - Field studies
   - Forecast are needed for
     - Advanced planning to prepare monitoring or equipment (aircraft, samplers, other sensors)
     - Sampled pre-episode conditions (day before high air quality concentrations)
   - Critical forecast issues
     - Obtaining detailed forecast
     - Allowing sufficient time to prepare monitoring equipment and personnel

How Are Forecasts Used? (4 of 4)

4. Conduct special sampling (example)

Winds and air pollution forecasts are used in the design of day-by-day sampling strategies in major studies providing data for impact assessments for new industries or expansions of industrial facilities. The photo is from a study of power stations in the Latrobe Valley of Victoria

AREP
GAW

Summary

- Forecasts allow for planning (activities, exposure avoidance, health care) and action
- Forecasts are used by air quality agencies, media, public, industries, and schools
- Critical forecast issues include
  - Timeliness
  - Localized forecasts
  - Multi-day
  - Easy-to-understand format (Air Index)

WMO
OMM

AREP
GAW

Forecasting Tools and Methods (1 of 3)

- Persistence
- Climatology
- Criteria
- Statistical
  - Classification and Regression Tree (CART)
  - Regression
- Neural networks
- Numerical modeling
- Phenomenological and experience
- Predictor variables

Fewer resources, lower accuracy

More resources, potential for higher accuracy

WMO
OMM

Forecasting Tools and Methods (2 of 3)

Tool development is a function of

- Amount and quality of data (air quality and meteorological)
- Resources for development
  - Human
  - Software
  - Computing
- Resources for operations
  - Human
  - Software
  - Computing

AREP
GAW

Forecasting Tools and Methods (3 of 3)

For each tool

- What is it?
- How does it work?
- Example
- How to develop it?
- Strengths
- Limitations

WMO
OMM

AREP
GAW

Criteria

- Uses threshold values (criteria) of meteorological or air quality variables to forecast pollutant concentrations
  - For example, if temperature > 27°C and wind < 2 m/s then ozone will be in the Unhealthy AQI category
- Sometimes called “rules of thumb”
- Commonly used in many forecasting programs as a primary forecasting method or combined with other methods
- Best suited to help forecast high pollution or low pollution events, or pollution in a particular air quality index category range rather than an exact concentration

AREP
GAW

Criteria – Example

Conditions needed for high pollution by month

Month	Daily Temp Max (above °C)	Daily Temp Range (above °C)	Daily Wind Speed (below m/s)	Wind Speed 15-21 UTC (below m/s)	Prior Day's Ozone 1-hr Max (above ppb)
Apr	26	11	4	3	70
May	29	11	4	5	70
Jun	29	11	3	5	70
Jul	33	11	3	4	70
Aug	33	11	3	4	70
Sep	31	10	3	4	75
Oct	31	10	3	3	75

Lambeth, 1998

To have a high pollution day in July

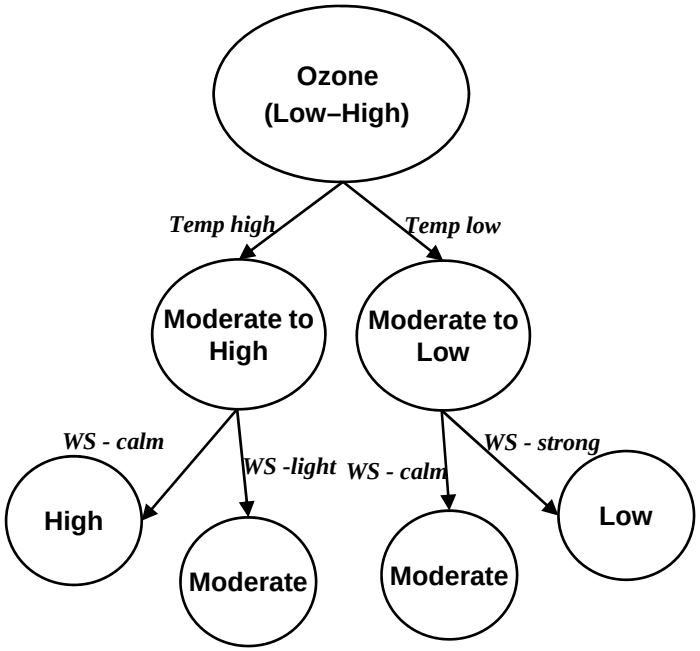
- maximum temperature must be at least 33°C,
- temperature difference between the morning low and afternoon high must be at least 11°C
- average daytime wind speed must be less than 3 m/s,
- afternoon wind speed must be less than 4 m/s, and
- the prior day's peak 1-hr ozone concentration must be at least 70 ppb.

WMO
OMM

AREP
GAW

Classification and Regression Tree (CART)

- CART is a statistical procedure designed to classify data into dissimilar groups.
- Similar to criteria method; however, it is objectively developed.
- CART enables a forecaster to develop a decision tree to predict pollutant concentrations based on predictor variables (usually weather) that are well correlated with pollutant concentrations



WMO
OMM

AREP
GAW

CART – How It Works (1 of 2)

The statistical software determines the predictor variables and the threshold cutoff values by

- Reading a large data set with many possible predictor variables
- Identifying the variables with the highest correlation with the pollutant
- Continuing the process of splitting the data set and growing the tree until the data in each group are sufficiently uniform

AREP
GAW

Summary

- Wide range of forecast tools
- Each type has advantages and disadvantages
- More tools result in better forecasts
- Consensus forecasting can produce better results

WMO
OMM

AREP
GAW

WMO
OMM

Section 13
Developing a Forecasting Program

Understanding Users' Needs
Understanding the Processes that Control Air Quality
Choosing Forecasting Tools
Data Types, Sources, and Issues
Forecasting Protocol
Forecast Verification

AREP
GAW

Understanding Users' Needs

- Success depends on forecast
  - Accuracy
  - Meeting the users' needs
- Three main uses (Section 5)
  - Protect public health
  - Operate emissions reduction programs
  - Conduct special monitoring
- Consider these issues
  - Size of forecast domain
  - Population affected
  - Pollutants to forecast
  - Industries to be controlled
  - Smog transport
- Process
  - Gather stakeholders
  - List of questions (next three slides)

WMO
OMM

AREP
GAW

Understanding Users' Needs – Forecast Specification Questions (1 of 3)

Who will use the forecast?

- For how many months are forecasts needed?
  - Certain season (summer and fall)
- What periods should a forecast cover?
  - Current and next day
  - 1-5 days
- Are multi-day forecasts needed for weekend/holiday periods?

WMO
OMM

AREP
GAW

Understanding Users' Needs – Forecast Specification Questions (2 of 3)

- What are the accuracy requirements?
  - Define target first
  - Make sure it is reasonable
- What area do the air quality forecasts cover?
  - Regional maximum
  - Sub-regions or monitoring sites
- Are written forecast discussions of predicted weather and air quality conditions needed?

WMO
OMM

AREP
GAW

Understanding Users' Needs – Forecast Specification Questions (3 of 3)

- How should forecasts be disseminated?
  - E-mail, fax, phone
  - Web site
- When should forecasts be issued to meet deadlines?
- Should forecasts be re-issued? If so, under what conditions?
- Should forecasts be made for specific concentrations or concentration ranges (e.g., AQI or API categories)?
- How should missed forecasts be handled?

WMO
OMM

AREP
GAW

Choosing Forecasting Tools (1 of 3)

- General guidelines
  - Start with simple tools and add complex tools later
  - Consensus approach to forecasting works best
  - Establish a reliable product (not necessarily the most accurate)
  - Persistence, time series, and climatology tools will never identify a significant change in air quality
  - Regression, CART, and neural networks require time to develop and validate, but are usually more accurate than persistence
  - Photochemical modeling can be more accurate, but requires significant resources
- Resource considerations
  - Development costs vs. operational costs
  - Time needed to forecast

AREP
GAW

Choosing Forecasting Tools (2 of 3)

- Severity of problem
  - Seasons, number of pollutants to forecast
  - Limited problem – use simple methods
  - Severe problem – use many forecasting methods

- Consensus forecasting works best
  - More tools provide a better forecast
  - Cumulative knowledge of all forecasting tools is greater than using a single tool
  - As the pollution problem becomes more complex, no single forecasting tool can reliably predict all relevant factors

WMO
OMM

AREP
GAW

Choosing Forecasting Tools (3 of 3)

- Experience
  - Some forecasting tools require extensive experience
  - Working with a local university/firms to develop tools can be beneficial
  - No tool can replace forecaster experience

WMO
OMM

AREP
GAW

Forecast Verification Overview

- Comparing forecasts to actual observations to quantify success of forecasting program
- Topics
  - Why verify air quality forecasts?
  - Schedule
  - Types of verification: categorical and discrete
  - Contingency table and examples
  - Performance targets
  - Forecast retrospective

WMO
OMM

AREP
GAW

Forecast Verification

- Why verify air quality forecasts?
  - Quantify the performance of forecasters and/or the forecast program
  - Identify trends in forecast performance over time
  - Quantify improvements from new (or changes in) forecasting methods/tools
  - Compare verification statistics to those from other agencies that forecast air pollution
  - Demonstrate the performance of forecasts to program participants, stakeholders, and the media

AREP
GAW

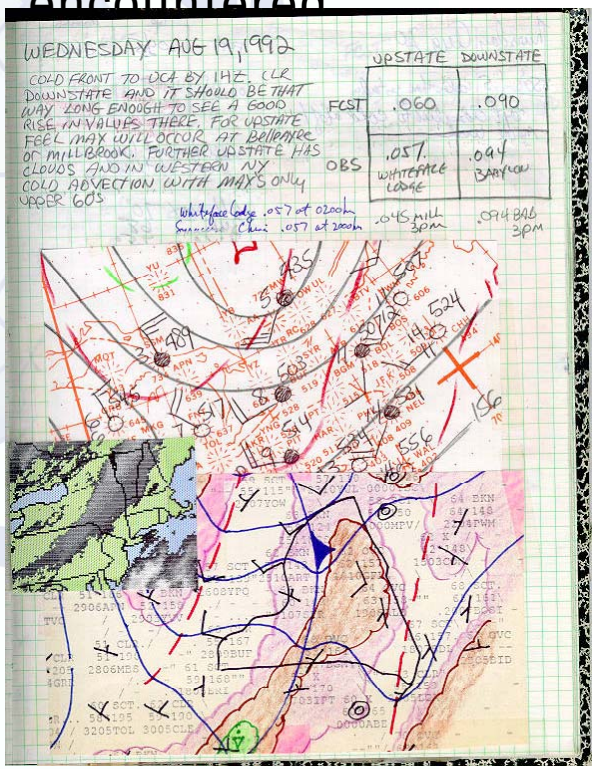
Forecast Verification Schedule (1 of 4)

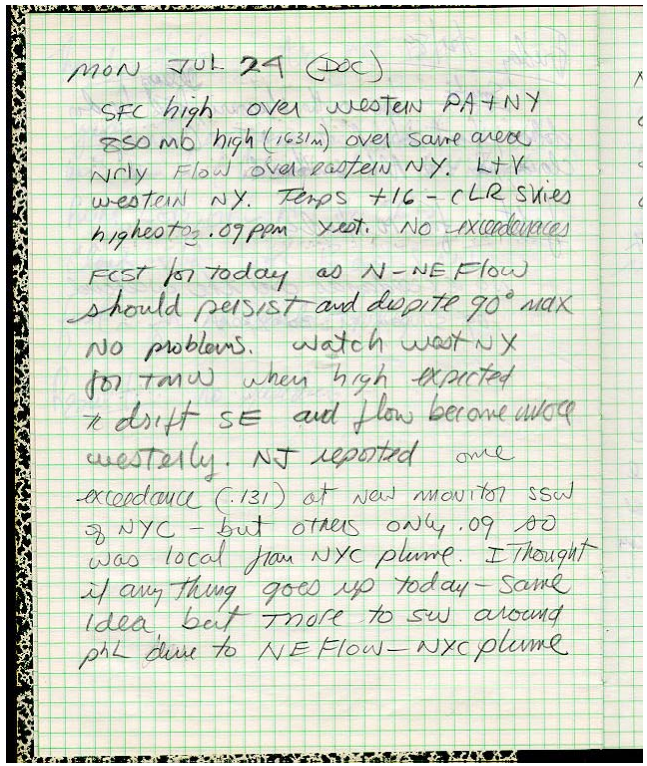
- Daily verification
  - Can identify systematic problems
  - Can identify mistaken analysis of events
  - Can identify problems with data
  - Provides opportunity for mid-season procedure corrections
- Seasonal verification
  - Identifies if model/methodology is appropriate
  - Benchmarks performance of models and forecasters

WMO
OMM

Forecast Verification Schedule (2 of 4)

- Daily
  - Each morning, review prior day observations and forecasts.
  - Keep a log book of performance and problems encountered





Courtesy of Doc Taylor, NYDEC

AREP
GAW

Summary (1 of 2)

- Understanding users' needs
  - Size of forecast domain
  - Population affected
  - Pollutants to forecast
  - Industries to be controlled
  - Smog transport
- Understanding the processes that control air quality
  - Literature reviews
  - Data analysis
- Choosing forecasting tools
  - Start with simple methods
  - Use more than one method
  - Forecaster experience is critical

WMO
OMM

AREP
GAW

Summary (2 of 2)

- Data types, sources, and issues
  - Standardize units
  - Continuously evaluate data quality
- Forecasting protocol
  - Written procedures for forecasting
  - Saves time and improves quality of forecast
- Forecast verification
  - Evaluate daily, monthly, seasonally
  - Categorical and discrete statistics
  - Set realistic goals
  - Some misses will occur

WMO
OMM