Source Apportionment 101

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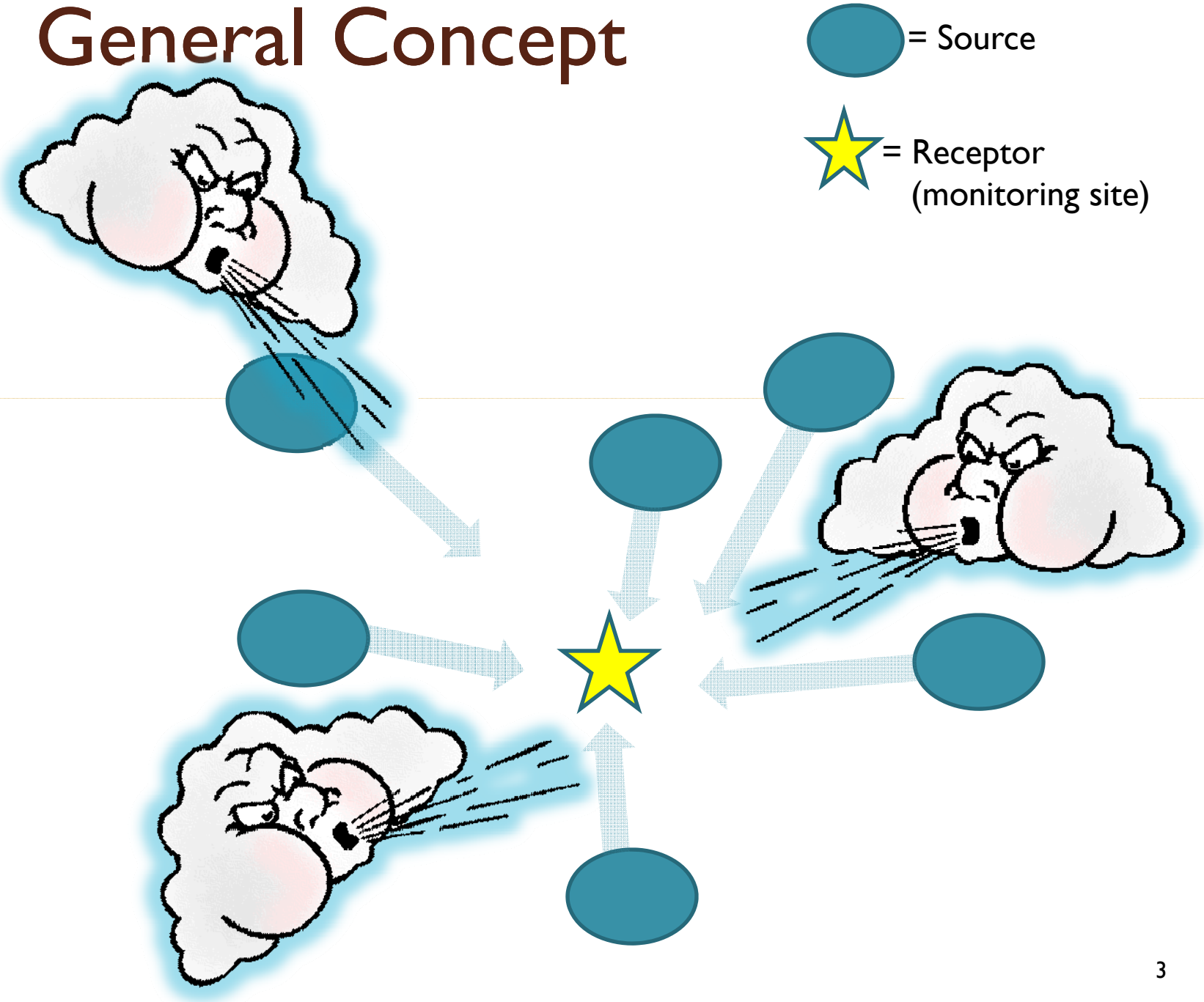
What is Source Apportionment?

- Collection of techniques to provide information regarding how much a source (usually a generalized category) contributes to the overall pollutant concentration at receptor (usually a monitoring site)
- Can be both qualitative and quantitative
- Can be used for various pollutants
- Not a "magic bullet"

General Concept



Examples of Source Apportionment Techniques/Tools

- Qualitative
  - Wind/Pollution Roses
  - Wind Trajectories (e.g. HYSPLIT)
- Quantitative
  - Chemical Mass Balance (CMB)
  - Factor Analytic Techniques
    - Positive Matrix Factorization (PMF)
    - UNMIX
  - Non Parametric Regression (Kernel Smoothing)
  - Source Tagging using Deterministic Models (e.g. CMAQ)

Chemical Mass Balance

- Chemical Mass Balance (CMB)
  - X=PC+E
    - X: Vector of the ambient data (usually a suite of species concentrations)
      - This is measured (e.g. CSN (PM2.5), PAMS (VOC), etc.)
    - P: Matrix of the "known" source profiles
      - This is known or measured (e.g. EPA's SPECIATE database)
    - C: Vector of the individual source contributions (usually something like total PM2.5 or total VOC)
      - This is what is being solved for
    - E: Error vector
      - This is the difference between what the model predicts and what was observed in the ambient data

Chemical Mass Balance

- Assumptions
  - None of the species in ambient data react with each other
  - None of the supplied source profiles change with time
  - All potential sources are known and included in the analysis
  - Number of source categories is less than the number of species
  - Sources do not have profiles that are too similar to one another
    - There is no co-linearity among sources
  - Measurement uncertainties are random, uncorrelated and randomly distributed

Chemical Mass Balance

- Advantages
  - Run for a single sample
  - Can provide estimates for specific source categories
  - Results are easier to interpret than those from factor analytic techniques
- Limitations
  - Results are only as good as the inputs
  - Need to have a very good knowledge of the sources impacting the receptor
  - Species included in the calculations cannot react with one another in the atmosphere
  - Have to assume that the source profiles used as inputs are stable over time and space

Factor Analytic Techniques

- Positive Matrix Factorization (PMF)
  - X=GF+E
    - X: Matrix of measured species concentrations
    - G: Matrix of source contributions
      - This is solved for
    - F: Matrix of source profiles
      - This is solved for too
    - E: Matrix of random errors
      - This is the difference between what the model predicts and what was observed in the ambient data
  - Assumptions
    - Large data set for robustness
    - Not too many species less than detection limit
    - No rotational ambiguity in the final results

PMF

- Advantages
  - Does not require individual source profiles for input
    - Only requires an ambient measurement data set
- Limitations
  - Results are only as good as the inputs
  - Numerous solutions containing varying numbers of sources need to be examined
  - Requires a large data set
    - Cannot analyze a single sample as with Chemical Mass Balance
    - Usually needs at least 100 samples for more reliable result
  - Analyst needs to be able to interpret source profiles
    - Use of journal articles and experience
    - Can be very subjective
    - Other techniques such as wind trajectories can be utilized to aid in source identification
  - Usually provides generalized source categories or composites of multiple source categories

Non Parametric Regression

- Fairly new technique developed by Ron Henry at University of Southern California
- Extension of examining pollution roses
- Utilizes highly time resolved ambient data and meteorological measurements
- Provides information on more localized sources around a receptor based on wind sectors

Non Parametric Regression

- Advantages
  - Requires fewer compounds to be measured at a receptor
  - May provide more information of the impact of localized sources to the receptor than does PMF or CMB
- Limitations
  - Results are only as good as the inputs
  - Is only capable of estimating possible source contributions from localized sources
    - Has difficulty distinguishing sources if wind data does not represent local transport or if there are nearby obstructions to air flow

Policy Perspective

- Everyone would like a "magic bullet" that provides the most accurate source contribution estimates
  - Nothing like that currently exists
  - Monitoring has to be specifically tailored to a specific purpose
- Source apportionment analyses can be used as weight of evidence
  - Source permitting
  - Community complaints
  - Addressing high ambient concentrations

Policy Perspective

- Source apportionment can aid policy makers in assessing program effectiveness (e.g. control strategies)
  - Provide initial assessment of possible source categories impacting air quality
  - Provide continued assessments of possible changing source contributions due to implementation of control strategies
- Difficult to determine contributions of source subcategories (e.g. diesel or vegetative burning)
  - Not enough information in the ambient measurement data or source profiles to distinguish very similar sources

Policy Perspective

- Uncertainties associated with the results of source apportionment techniques as well as the overall generality of those results make it difficult for policy makers to target specific sources solely on the basis of statistical source apportionment tools
  - A combination of techniques provides a better picture
- Limitations in ambient monitoring technology, available monitoring data and limitations in source profile quality as well as limited resources restrict the more routine use of source apportionment techniques in policy making decisions

How can source apportionment be used to identify agricultural source influences?

- Isolate areas of ammonia contribution
- Estimate potential impacts of field burning on ambient fine particulate concentrations
- Estimate potential impacts on ambient fine particulate concentrations from overall agricultural operations
- Estimate potential impacts on ambient hydrogen sulfide concentrations from livestock operations

Applying source apportionment techniques to agricultural sources

- Be able to monitor specific pollutants from agricultural sources (e.g. hydrogen sulfide, ammonia, mercaptans, compounds unique to agricultural burning)
  - Take into account the resources needed to not only collect samples but also analyze them in a lab
- If using CMB, develop source profiles specific to agricultural sources
  - Profiles need to be chemically distinguishable from one another
- Have the "receptor" located in an area where it would mostly be influenced by agricultural sources

Applying source apportionment techniques to agricultural sources

- Collect enough data to provide source estimates across the span of several seasons
- Collect meteorological data to corroborate results
- Have a good knowledge of all potential agricultural sources that could impact ambient concentrations
  - e.g. Field burning, fertilizer use, farm equipment, livestock operations, wind blown dust from agricultural operations
  - Have a good knowledge of other non-agricultural sources within the area particularly to sources that may have similar emissions to agricultural sources

Source apportionment resources

- Chemical Mass Balance
  - http://www.epa.gov/ttn/scram/receptor_cmb.htm
- PMF
  - http://www.epa.gov/heasd/products/pmf/pmf.html
- UNMIX
  - http://www.epa.gov/heasd/products/unmix/unmix.html
- Non Parametric Regression
  - Title: Source Region Identification Using Kernel Smoothing
    Author(s): Henry, R; Norris, GA; Vedantham, R, et al.
    Source: ENVIRONMENTAL SCIENCE & TECHNOLOGY Volume: 43 Issue: 11 Pages: 4090-4097 Published: 2009