A Comparison of Ammonia Emission Rates from an Agricultural Area Source Using Dispersion Modeling: Gaussian versus Backward-Lagrangian Stochastic

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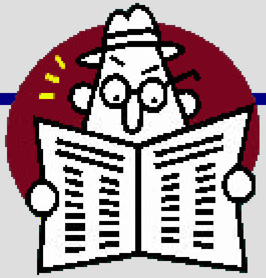
Introduction

- Impact of engineering and science on regulatory policy
  - It is ***crucial*** to understand how scientific data affects the environment as well as the industry in the surrounding world.
- Objective analysis in lieu of subjective opinion
  - Sound science and engineering ***must*** be the core of regulatory decision making in order to construct appropriate regulatory policy
- Ammonia
  - Secondary $PM_{2.5}$ formation
  - Effects Screening Levels
- Emission Rate Determination
  - Back-calculate with a dispersion model



Objective

1. Evaluate the results of two dispersion models to back-calculate the emission rate of ammonia from an area source
   - Industrial Source Complex – Short Term V3
   - Windtrax 1.0 – R1.4.2

ISC-ST3 Background

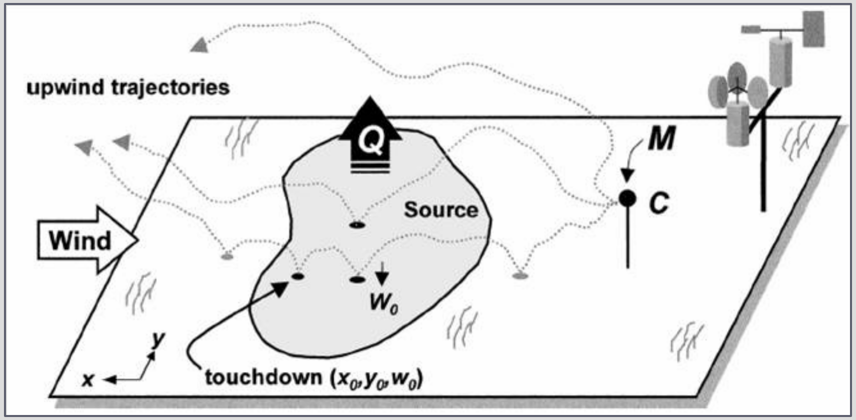
- Gaussian Plume Model

$$C_{10} = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{\exp\left(-\frac{1}{2}\frac{(z-H)^2}{\sigma_z^2}\right) + \exp\left(-\frac{1}{2}\frac{(z+H)^2}{\sigma_z^2}\right)\right\}$$

  - Assumptions:
    - Continuous emissions
    - Conservation of mass
    - Steady-state conditions
    - Normal distribution of crosswind and vertical pollutant concentrations
    - Constant wind vector field for the hourly time period

WindTrax 1.0 Background

- Backward Lagrangian Stochastic (bLS) Model
  - Based on the forward LS model
  - Simulates individual parcels of air to predict where the parcel reaching the receptor originated from
  - WindTrax - accounts for particle impact and subsequent reflection



(From Flesch, et al, 2004)

WindTrax 1.0 Background (cont.)

- bLS Model (cont)
  - Uses the particle impact information to define the ratio of the modeled concentration to the emission rate

$$(C/Q)_{sim} = \frac{1}{N}\Sigma\left|\frac{2}{w_0}\right|$$

  - Basis – fundamental diffusion and subsequent Lagrangian models
  - Underlying Lagrangian assumptions:
    - Only applicable to linearly reactive species
    - Occurring chemical reactions are independent of particle displacements and particle collision frequency

WindTrax 1.0 Background (cont.)

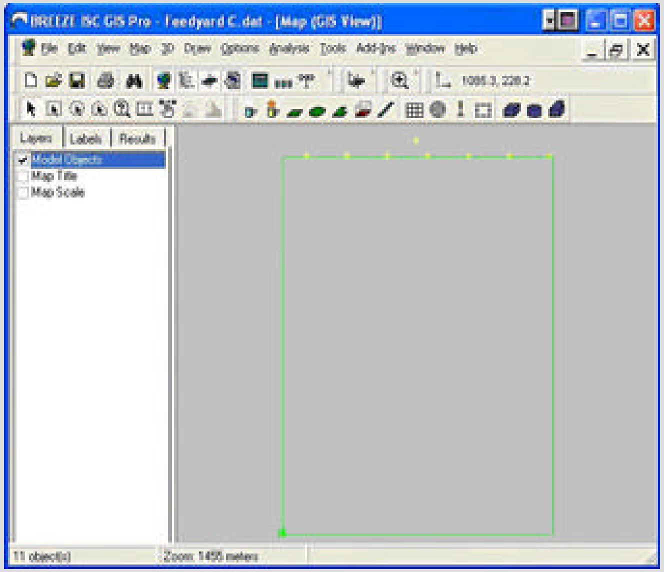
- bLS Model (cont)
  - Simplification of the basic diffusion equations
  - Assumptions
    - Moving coordinate system – particle velocity = wind speed
    - Vertical advective transport significantly less than the vertical turbulent dispersion
    - Horizontal concentration gradients – negligible to the overall system mass balance
    - Wind sheer is negligible
    - Spatially uniform emission rate
    - Horizontally homogenous flow
  - Gaussian equation is a specific solution to the Lagrangian equation (Lamb and Seinfeld, 1973)

Modeling Inputs

- Identical meteorological data for each time period
- Concentration Data
- Meteorological Data
  - Wind Speed
  - Wind Direction
  - Stability Class – SRDT Method (utilizes the surface layer wind speed, daytime solar radiation measurements, and nighttime vertical temperature gradients)
- Pasquill-Gifford stability parameter definitions

Results and Discussion

- ISC-ST3 (Gaussian Plume)
  - EPA approved model for short term dispersion modeling
  - Assumes a constant wind vector field
  - Use a random ER to predict pollutant concentrations at each of the downwind receptors
  - Scale to determine ER necessary to achieve the measured concentration at each receptor
  - Run the model with the average of these ER

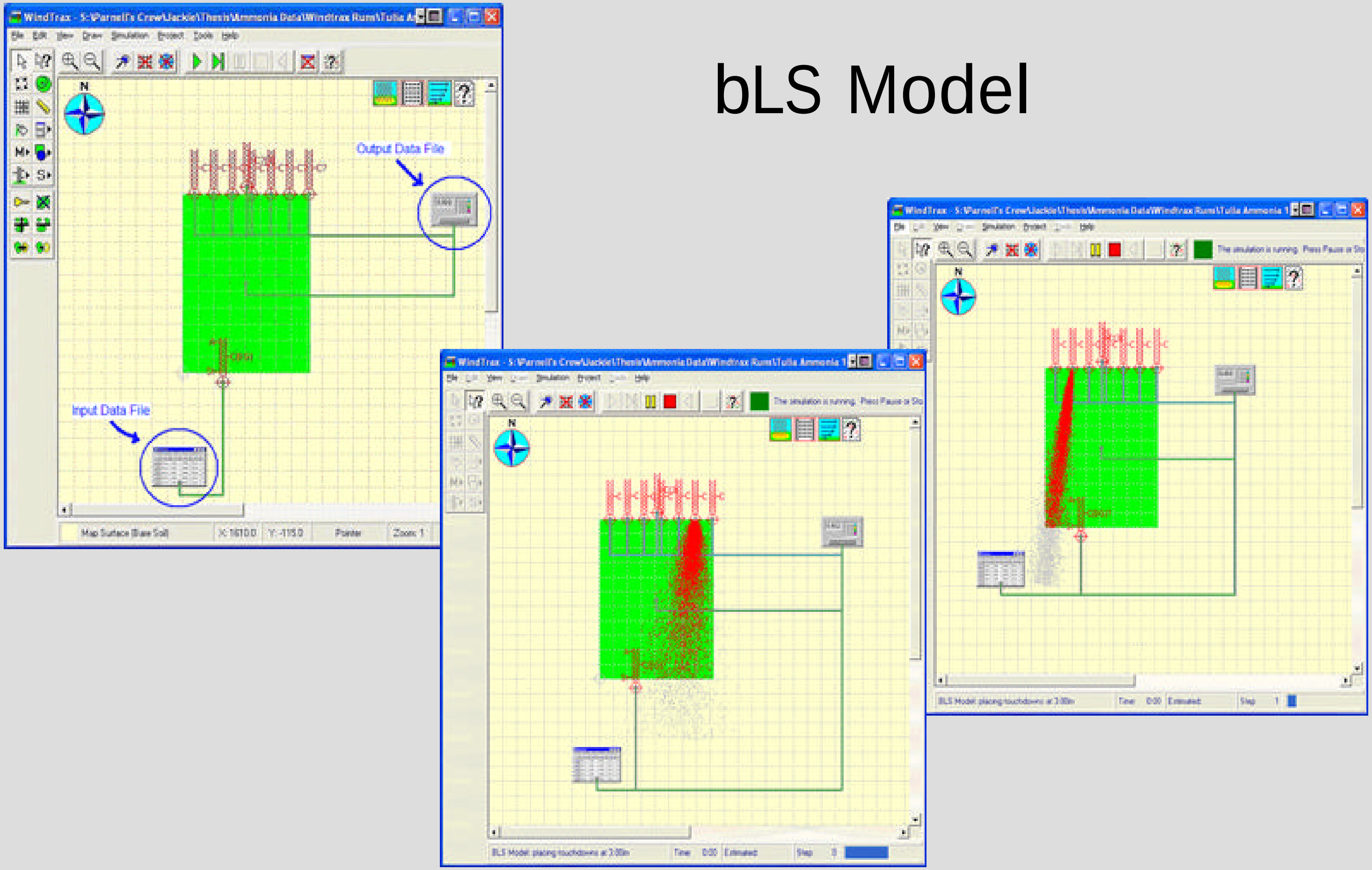


Results and Discussion

- WindTrax 1.0 (bLS Model)
  - Local dispersion model - < 1 km
  - NOT an EPA approved dispersion model
  - Ground level sources only
  - Bare ground (short vegetation) only
  - Pre-modeling tests
    - Reversibility of the model
    - Relationship between emission rate and receptor concentration
  - Requires concentration data for each hour, so the model is run like the ISC model to ensure that the equivalent data are being compared

Results and Discussion

bLS Model



Results and Discussion

- Model Comparison – Overall

	ISC ER µg/m²/s	bLS ER µg/ m²/s	Diff µg/ m²/s	Factor (bLS/ ISC)	?t (hrs)
Overall Average	6.72	68.3	61.6	10.17	5.3
Day Average	7.53	76.6	69.1	10.18	3.3
Night Average	3.98	38.5	34.5	9.68	12.0

- Factor of 10 difference in the generated emission rates based off of the *same data*?? Extremely troubling!

Results and Discussion

- Model Comparison – Select Tests

Test #	ISC ER	bLS ER	Diff	Factor (bLS/ ISC)	Day/ Night	? t	Stability Classes
	μg/m²/s	μg/ m²/s	μg/ m²/s			(hrs)	
112	1.03	103	93.1	10.06	Day	3	C, B, C
114	4.64	48.4	43.7	10.43	Night	12	All D
121	3.60	36.4	32.8	10.11	Day	7	D,D,D,D,D,D,C
122	7.62	90.9	83.2	11.93	Day	5	All D
143	7.06	56.8	49.7	8.04	Day	3	All B
144	8.14	82.2	74.0	10.09	Day	3	C, C, D
151	6.56	651	58.5	9.93	Day	3	All D
152	7.53	72.4	64.8	9.61	Day	3	C, C, B
153	11.4	113	102	9.96	Day	3	B, C, C
154	8.15	85.6	77.5	10.51	Day	3	All D
155	2.48	18.6	16.2	7.50	Night	12	D, D, D, D, E, E, E, E, E, D, D, D

Conclusions and Future Research

- ERs from the models vary by a factor of 10!
- The Gaussian equation is a specific solution to the Lagrangian equation
- Regulatory impact
  - WindTrax predicted ER used in ISC – downwind concentration would be 10 times *more* than the actual!
  - Back-calculated pollutant ERs are extremely model dependent

Thank you for your time!