Washington Group International

Integrated Engineering, Construction, and Management Solutions

Comparison of Consequence Analysis Results from Two Methods of Processing Site Meteorological Data

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Role of Meteorological Data in Consequence Analysis

- Input to atmospheric transport & dispersion calculations
- Support statistical treatment of consequences (e.g., 95th percentile)

Atmospheric Transport & Dispersion

- Gaussian Plume χ/Q Model (radiological analysis)

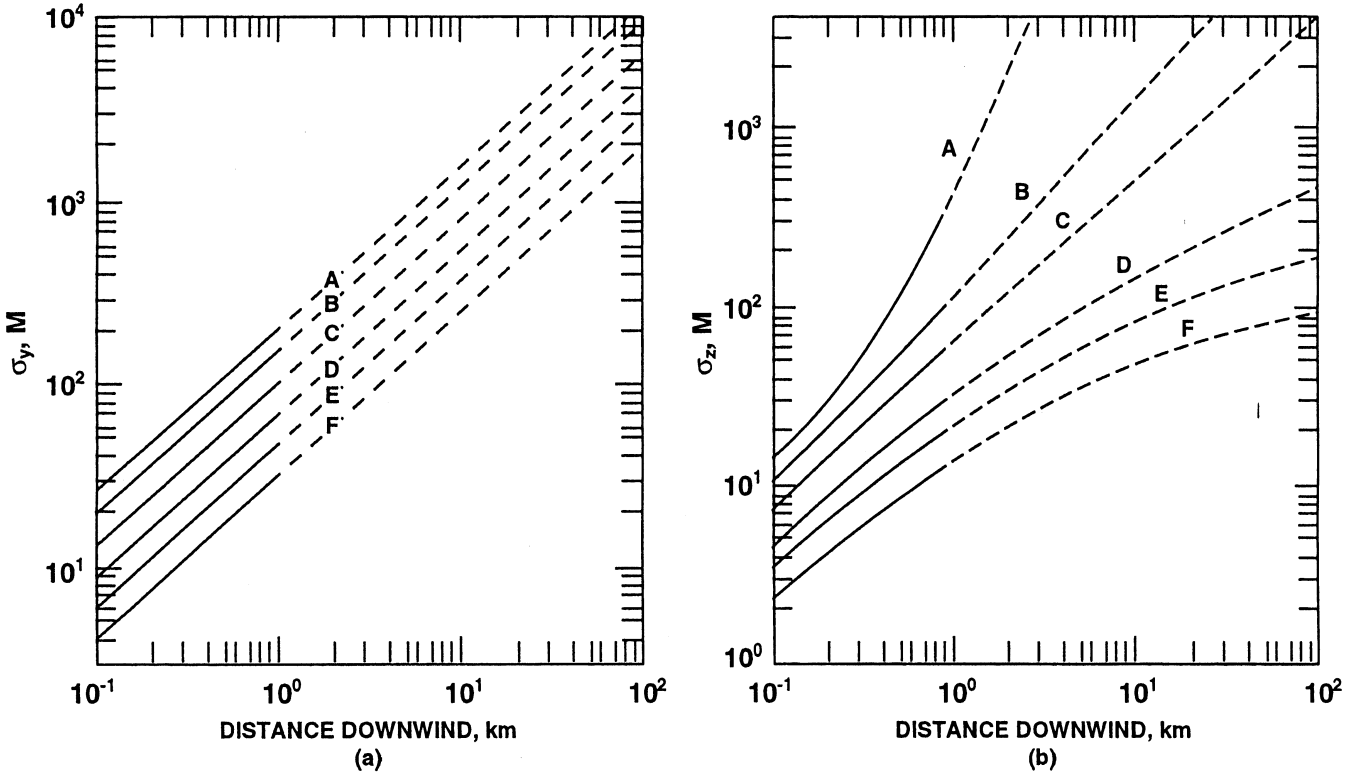
$$\chi(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

  - χ is time integrated atmospheric concentration [Ci-s/m3]
  - Q is source term release [Ci]
  - x is downwind distance relative to source [m]
  - y is horizontal (crosswind) distance relative to plume centerline [m]
  - z is vertical distance relative to ground [m]
  - H is effective release height relative to ground [m]
  - σ_y is the horizontal dispersion coefficient (function of x) [m]
  - σ_z is the vertical dispersion coefficient (function of x) [m]
  - u is the average wind speed (typically at 10 m elev. or stack height) [m]

Gaussian Plume Model

Pasquill – Gifford (P-G) Stability Categories: A through F

Dispersion Coefficients for Gaussian Models



Statistical Treatment of Consequences

- DOE-STD-3009-94, CN3 (2006) – Appendix A
  - 95th percentile consequence result ⇔ evaluation guideline
  - Regulatory Position 3 of NRC Reg. Guide 1.145
    - ≥ 1 year of meteorological data (wind speed, P-G stability)
    - χ/Q distribution of results (Gaussian plume model)
    - 95th percentile - χ/Q exceed by 5% of results

Atmospheric Turbulence

- Two Sources
  - Mechanical Turbulence
    - Wake flows
    - Surface roughness elements
    - Wind shear
  - Buoyancy Turbulence
- Scale of Turbulent Eddies
  - Larger Scale (thermals, building wakes)
  - Smaller Scale (surface roughness, wind shear)
- Influence of Wind Speed
  - low wind speed & intense sunshine ►buoyancy turbulence
  - high wind speed ► mechanical turbulence

P-G Atmospheric Stability Categories

- Measure of Turbulence Intensity
  - Class A ►most unstable
  - Class D ►neutral stability
  - Class F ►most stable
- Project Prairie Grass
- Correlated to Other Meteorological Data

P-G Atmospheric Stability Determination Methods

- Vertical Temperature Difference (VTD) [NRC, 2007]
- Turner Method [EPA, 2000]
  - time of day, wind speed, cloudiness, & ceiling height
- Solar Radiation Delta-T (SRDT) [EPA, 2000]
  - solar radiation, VTD, & wind speed
- Wind Direction (WD) Fluctuation Data [EPA, 2000]
  - standard deviation of wind elevation angle & wind speed
  - standard deviation of wind direction & wind speed

Vertical Temperature Difference Method

- ΔT_{100m} - VTD over 100 m

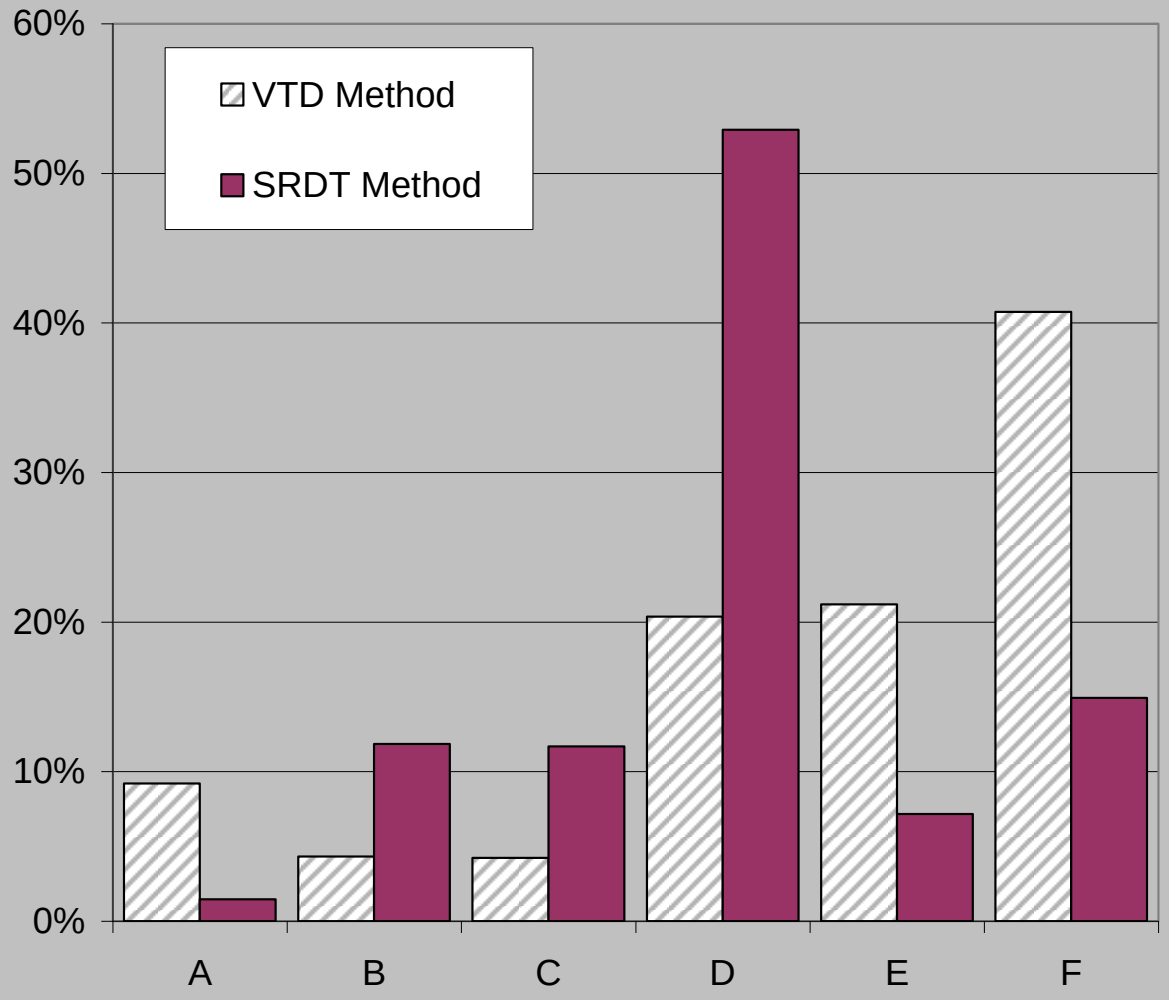
Stability Classification	P-G Category	Criterion (°C/100 m)
Extremely unstable	A	$\Delta T_{100m} \leq -1.9$
Moderately unstable	B	$-1.9 < \Delta T_{100m} \leq -1.7$
Slightly unstable	C	$-1.7 < \Delta T_{100m} \leq -1.5$
Neutral	D	$-1.5 < \Delta T_{100m} \leq -0.5$
Moderately stable	E	$-0.5 < \Delta T_{100m} \leq 1.5$
Extremely stable	F	$1.5 < \Delta T_{100m} \leq 4.0$

Solar Radiation Delta-T Method

DAYTIME				
Wind Speed (m/s)	Solar Radiation (W/m^2)			
	≥ 925	925 - 675	675 - 175	< 175
< 2	A	A	B	D
2 - 3	A	B	C	D
3 - 5	B	B	C	D
5 - 6	C	C	D	D
≥ 6	C	D	D	D

NIGHTTIME		
Wind Speed (m/s)	Vertical Temperature Gradient	
	< 0	≥ 0
< 2.0	E	F
2.0 - 2.5	D	E
≥ 2.5	D	D

Sample Data Processing Results



CONSEQUENCE CALCULATIONS

- MACCS2 Code
  - Transport & dispersion of radioactive material
  - Internal & external doses
- Current Application
  - 1 Ci ground release of ^{239}Pu
  - No buoyancy
  - No building wake
  - Tadmor-Gur dispersion coefficients
  - Deposition velocity of 1 cm/s
  - Stratified random sampling (24 samples / day)

Consequence Results

- Ratio of results

Receptor Distance (km)	Ratio of MACCS2 Consequence Results (ΔT_z based meteorological data / SRDT based meteorological data)	
	Mean	95th Percentile
0.1	1.53	1.13
6	1.78	1.16
8	1.85	1.23
9	1.87	1.28
10 - 12	~1.9	~1.4
Note: Ratio values for distances between 0.1 and 6 km range from 1.00 to 1.18.		

Concluding Remarks (continued)

- P-G Stability Category Distribution
  - VTD method: peak at stability class F
  - SRTD method: peak at stability class D
- MACCS2 Consequence Results
  - Greater variation on mean versus 95th percentile results
  - Variation increases with downwind distance
- Context
  - Site specific results
  - One year of meteorological data

Concluding Remarks (continued)

P-G Stability Category	Test Site		Site 1	Site 2	Site 3
	VDT	SRDT	VDT	SRDT / WD	WD
A	9%	1%	20%	3%	26%
B	4%	12%	5%	17%	15%
C	4%	12%	5%	18%	18%
D	20%	53%	17%	50%	22%
E	21%	7%	22%	9%	16%
F	41%	15%	32%	3%	3%