Temporal Comparison of Atmospheric Stability Classification Methods

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Acknowledgement of Data

- Calvert Cliffs
  - Richard Conatser
- Nine Mile Point
  - Tom Galletta

Basis of Problem

- Pilgrim Station was experiencing some problems with the upper-level temperature indication used to derive delta-T on its primary tower
- *Question*: Can Pilgrim substitute data from its backup tower, or another estimate of stability class, to meet data recovery goals?
- *Proposed Solution*: Compare various estimates of stability class to determine suitability for substitution

Stability Class Determination

- Safety Guide 23 recognizes two methods for determining stability class
  - Delta-temperature between two levels of a tower reflects potential for *vertical* mixing based on adiabatic lapse rate
  - Sigma theta, or variability of wind direction fluctuations, reflects potential for *horizontal* mixing
  - Which is better? Should they compare?

Delta-T Method

- Employed by most plants as their primary method for determining stability class
- Most plants measure temperature differential between sensors at the top of the tower, and at the standard height of 10 meters ("bottom" of tower)
- Some plants have temperature sensor at midpoint, and can derive multiple delta-T values (Top-Bottom, Middle-Bottom)

Sigma Theta Method

- Based on the standard deviation of the wind direction obtained over the same period of time used to determine average wind direction, usually 15 minutes (NUREG-0654)
- Useful for determining stability class for "short" towers, where conditions are measured at a single level (10 meters)
- Many plant use a 10-meter tower with single-level instruments as their backup tower

Pasquill Gifford Stability Class

Stability Classification	Pasquill Category	Delta-T deg.C/100m	Sigma-theta degrees
Extremely unstable	A	<-1.9	>22.5
Moderately unstable	B	-1.9 to -1.7	17.5 to 22.5
Slightly unstable	C	-1.7 to -1.5	12.5 to 17.5
Neutral	D	-1.5 to -0.5	7.5 to 12.5
Slightly stable	E	-0.5 to 1.5	3.8 to 7.5
Moderately stable	F	1.5 to 4.0	2.1 to 3.8
Extremely stable	G	>4.0	<2.1

Dispersion X/Q Equation

$$\frac{X}{Q}=\frac{1}{2\pi\sigma_y\sigma_z\bar{u}}\bullet\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\bullet\left(\exp\left[-\frac{(z-h)^2}{2\sigma_z^2}\right]+\exp\left[-\frac{(z+h)^2}{2\sigma_z^2}\right]\right)$$

Horizontal Dispersion Component

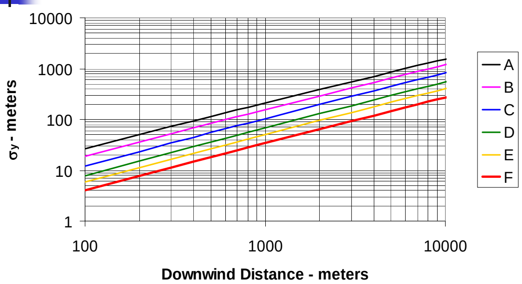
Vertical Dispersion Component, Including Reflection

y = distance from release point

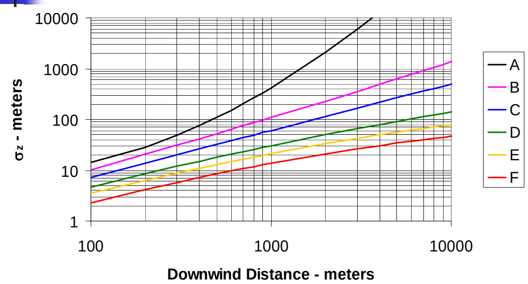
z = terrain height above ground at distance 'y'

h = elevation of release point above ground

Horizontal Dispersion Coefficient



Vertical Dispersion Coefficient



Ground-Level Release X/Q

Wind Speed = 5 m/s (~11 mph)

Distance	Stability Class					
km	A	B	C	D	E	F
0.5	5.0E-06	1.4E-05	3.6E-05	9.8E-05	1.8E-04	4.1E-04
1	7.2E-07	3.7E-06	1.0E-05	3.0E-05	5.9E-05	1.4E-04
3	1.9E-08	4.2E-07	1.3E-06	5.2E-06	1.1E-05	2.6E-05
10	1.8E-10	3.9E-08	1.5E-07	8.3E-07	1.9E-06	5.0E-06

Elevated Release X/Q

Stack Height = 60 m, Wind Speed = 5 m/s

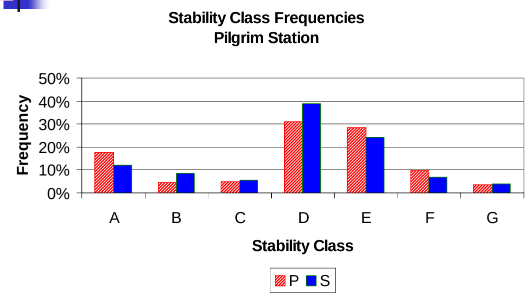
Distance	Stability Class					
km	A	B	C	D	E	F
0.5	4.3E-06	7.5E-06	6.3E-06	3.6E-07	4.2E-09	6.0E-15
1	7.1E-07	3.2E-06	6.1E-06	4.3E-06	1.1E-06	9.7E-09
3	1.9E-08	4.2E-07	1.3E-06	3.4E-06	4.0E-06	2.0E-06
10	1.8E-10	3.9E-08	1.5E-07	7.5E-07	1.5E-06	2.2E-06

Pilgrim Meteorological Towers

- Primary Tower
  - 220-ft tall, based at ~80 ft above sea level on vegetated area 270m from ocean
  - Effective height = 300 ft
  - Wind and temperature at top and 10m
- Secondary (Backup) Tower
  - 160-ft tall, based at ~20 ft above sea level in parking lot 100m from ocean
  - Effective height = 180 ft
  - Wind and temperature at top and 10m
- Hourly averages for 3-year period, yielded ~25,000 observations

Stability Class Frequencies

Pilgrim Station



Agreement Matrix

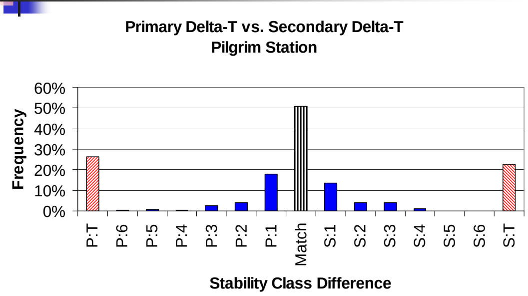
Primary	Secondary A	B	C	D	E	F	G	Total
A	1751	821	318	857	278	15	3	4043
B	240	279	128	330	71	5	0	1053
C	173	261	191	451	112	2	2	1192
D	384	481	592	5037	813	54	26	7387
E	70	66	65	2281	3657	560	127	6826
F	138	35	21	180	720	794	432	2320
G	82	25	13	99	83	179	343	824
Total	2838	1968	1328	9235	5734	1609	933	23645

Agreement Matrix Summary: Summation of Diagonals

Stability Class Difference	Primary Tow er Conservative		Secondary Tow er Conservative	
Match	12052	51.0%	12052	51.0%
1	4273	18.1%	3205	13.6%
2	982	4.2%	941	4.0%
3	570	2.4%	956	4.0%
4	118	0.5%	285	1.2%
5	163	0.7%	15	0.1%
6	82	0.3%	3	0.0%
Total	6188	26.2%	5405	22.9%

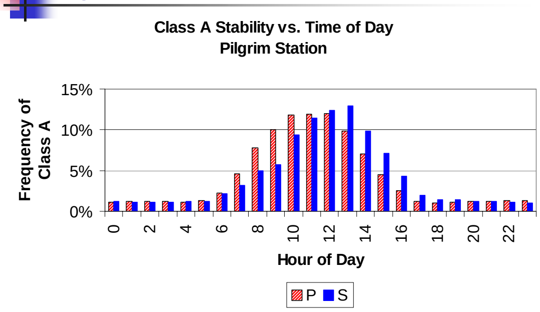
Agreement Graph

Pilgrim Delta-T Primary:Secondary

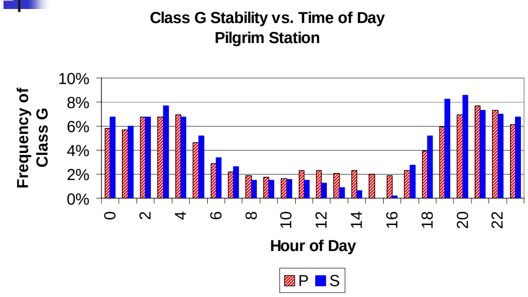


Class A Hour Distribution

Pilgrim Station



Class G Hour Distribution
Pilgrim Station



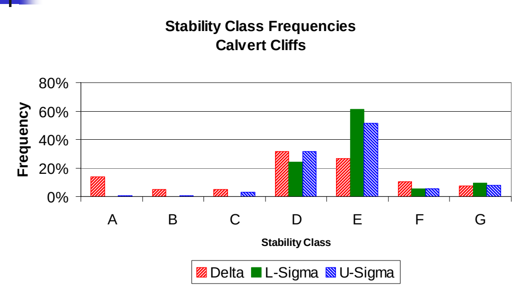
Is Pilgrim Unique?

- Need to obtain sigma theta information, which isn't available at Pilgrim
- Obtain data from other 'coastal' sites
  - Calvert Cliffs
  - Nine Mile Point
- Perform similar types of evaluations
  - Comparison Matrices
  - Time-of-day distributions

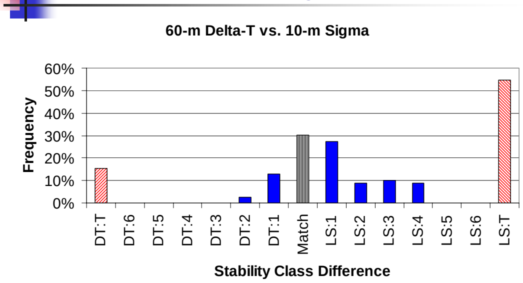
Calvert Cliffs Data

- Obtained from single tower, with instruments at 10m and 60m
- Hourly averages for 3-year period: 2000, 2001, 2002, yielded ~25,000 observations
- Calvert Cliffs adjusts stability class based on guidance in EPA-454/R-99-005, "Meteorological Monitoring Guidelines For Regulatory Modeling Applications."
- However, I used "raw" data categorized by Safety Guide 23 guidance… I had to process data

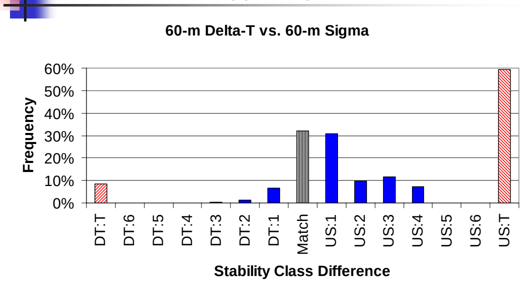
Stability Class Frequencies
Calvert Cliffs



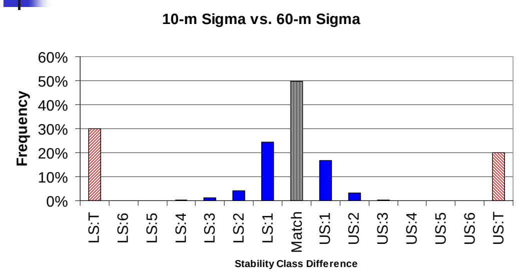
Agreement Graph
Calvert Delta-T:Lower Sigma Theta



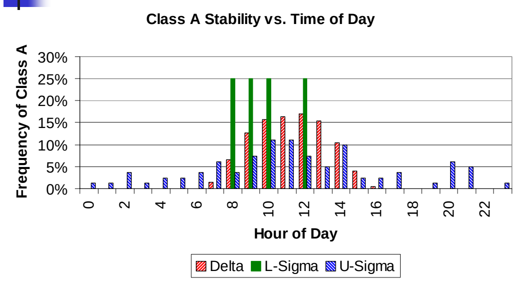
Agreement Graph
Calvert Delta-T:Upper Sigma Theta



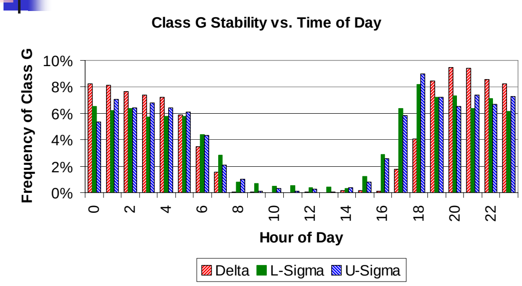
Agreement Graph
Calvert Lower Sigma Theta:Upper Sigma Theta



Class A Hour Distribution
Calvert Cliffs



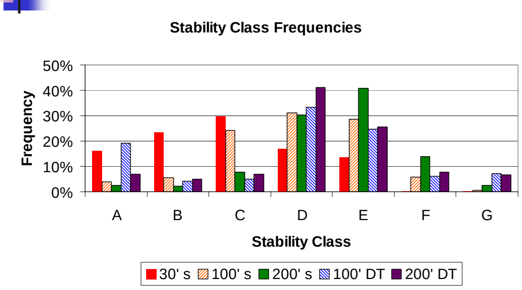
Class G Hour Distribution
Calvert Cliffs



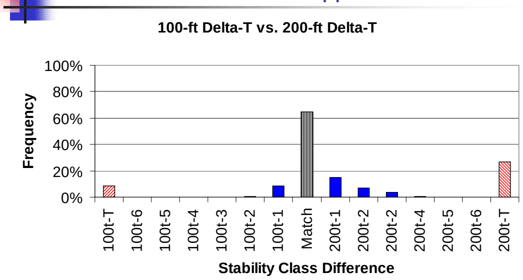
Nine Mile Point Data

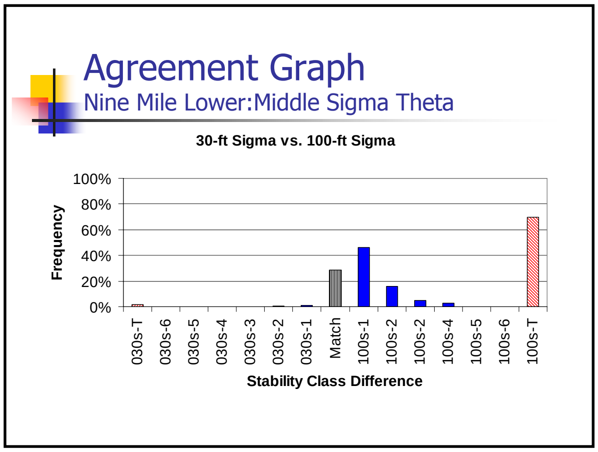
- Obtained from single tower, with instruments at 30ft, 100ft, and 200ft
- 15-min averages for 2-year period: 2001, 2002, yielded ~70,000 observations
- Used 'processed' 15-minute stability class data categorized by Safety Guide 23 guidance… I used what Nine Mile provided

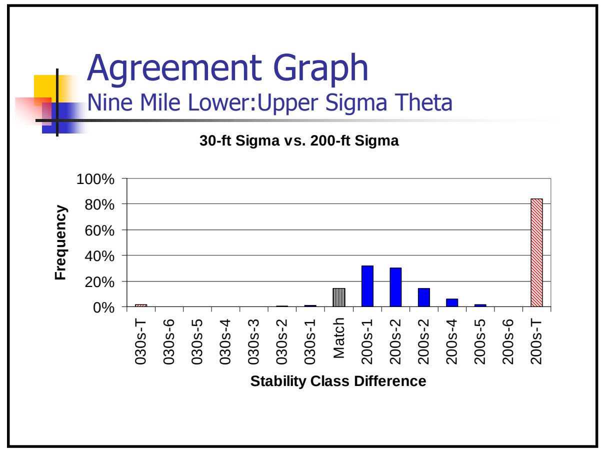
Stability Class Frequencies
Nine Mile Point

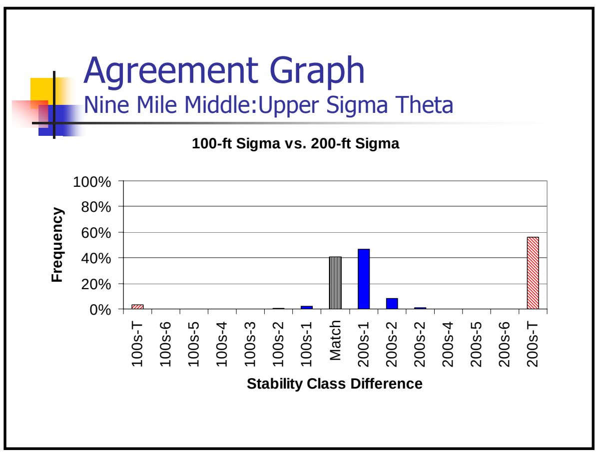


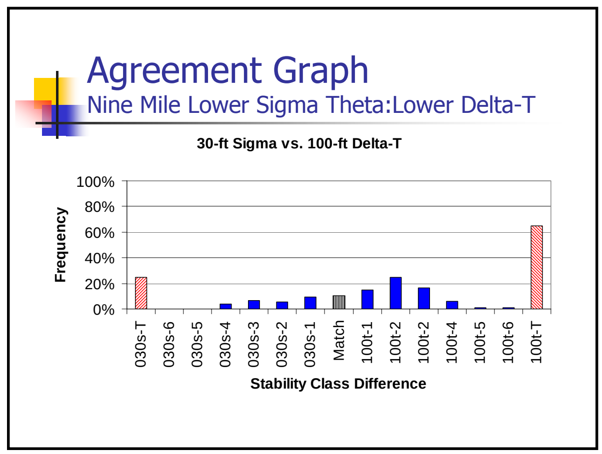
Agreement Graph
Nine Mile Lower Delta-T:Upper Delta-T

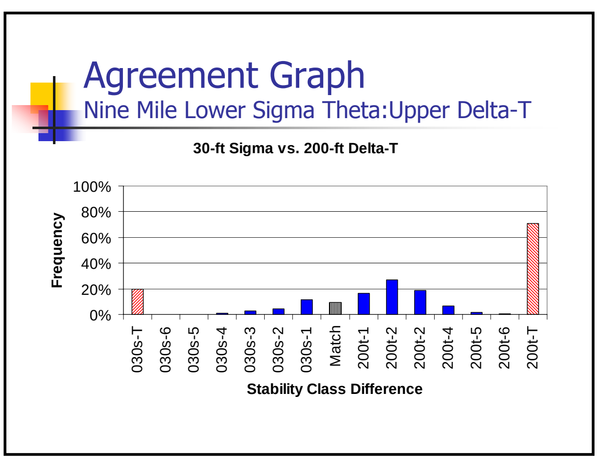


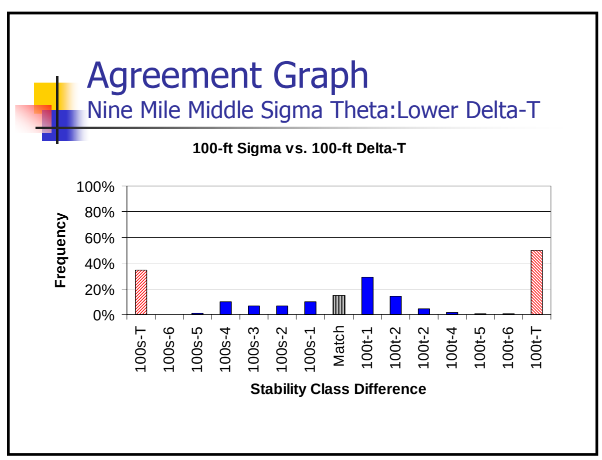

Agreement Graph
Nine Mile Lower:Middle Sigma Theta
30-ft Sigma vs. 100-ft Sigma
Frequency
100%
80%
60%
40%
20%
0%
030s-T 030s-6 030s-5 030s-4 030s-3 030s-2 030s-1 Match 100s-1 100s-2 100s-2 100s-4 100s-5 100s-6 100s-T
Stability Class Difference


Agreement Graph
Nine Mile Lower:Upper Sigma Theta
30-ft Sigma vs. 200-ft Sigma
Frequency
100%
80%
60%
40%
20%
0%
030s-T 030s-6 030s-5 030s-4 030s-3 030s-2 030s-1 Match 200s-1 200s-2 200s-2 200s-4 200s-5 200s-6 200s-T
Stability Class Difference

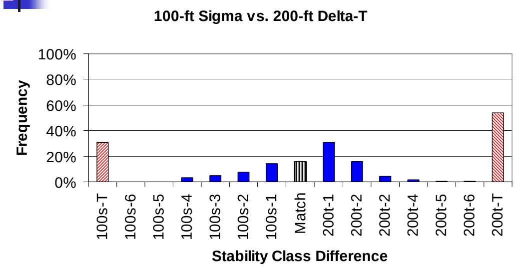

Agreement Graph
Nine Mile Middle:Upper Sigma Theta
100-ft Sigma vs. 200-ft Sigma
Frequency
100%
80%
60%
40%
20%
0%
100s-T 100s-6 100s-5 100s-4 100s-3 100s-2 100s-1 Match 200s-1 200s-2 200s-2 200s-4 200s-5 200s-6 200s-T
Stability Class Difference


Agreement Graph
Nine Mile Lower Sigma Theta:Lower Delta-T
30-ft Sigma vs. 100-ft Delta-T
Frequency
100%
80%
60%
40%
20%
0%
030s-T 030s-6 030s-5 030s-4 030s-3 030s-2 030s-1 Match 100t-1 100t-2 100t-2 100t-4 100t-5 100t-6 100t-T
Stability Class Difference

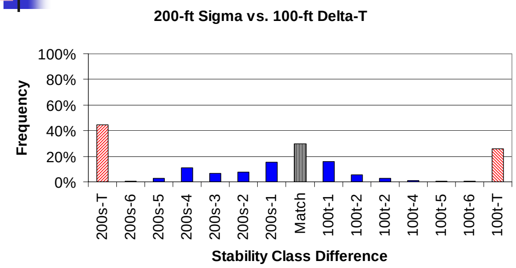

Agreement Graph
Nine Mile Lower Sigma Theta:Upper Delta-T
30-ft Sigma vs. 200-ft Delta-T
Frequency
100%
80%
60%
40%
20%
0%
030s-T 030s-6 030s-5 030s-4 030s-3 030s-2 030s-1 Match 200t-1 200t-2 200t-2 200t-4 200t-5 200t-6 200t-T
Stability Class Difference


Agreement Graph
Nine Mile Middle Sigma Theta:Lower Delta-T
100-ft Sigma vs. 100-ft Delta-T
Frequency
100%
80%
60%
40%
20%
0%
100s-T 100s-6 100s-5 100s-4 100s-3 100s-2 100s-1 Match 100t-1 100t-2 100t-2 100t-4 100t-5 100t-6 100t-T
Stability Class Difference

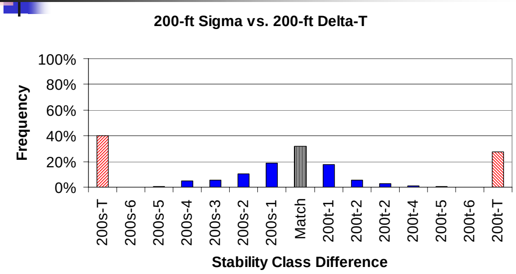
Agreement Graph
Nine Mile Middle Sigma Theta:Upper Delta-T



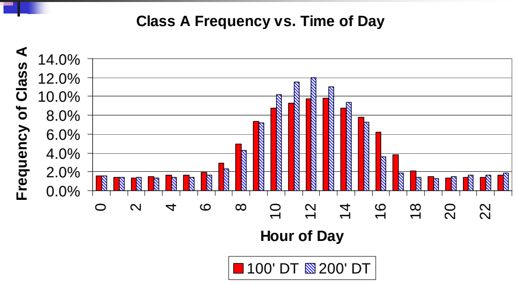
Agreement Graph
Nine Mile Upper Sigma Theta:Lower Delta-T



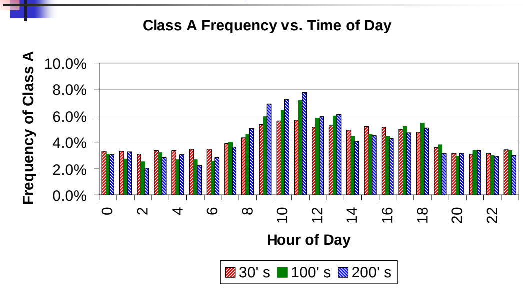
Agreement Graph
Nine Mile Upper Sigma Theta:Upper Delta-T



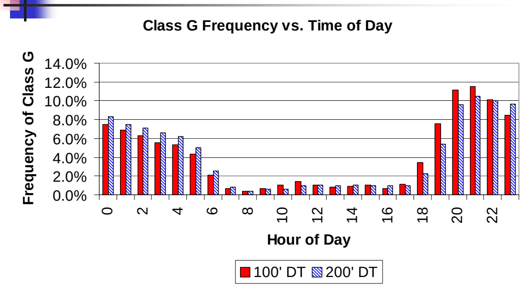
Class A Hour Distribution
Nine Mile Point: Delta-T Data



Class A Hour Distribution
Nine Mile Point: Sigma Theta Data

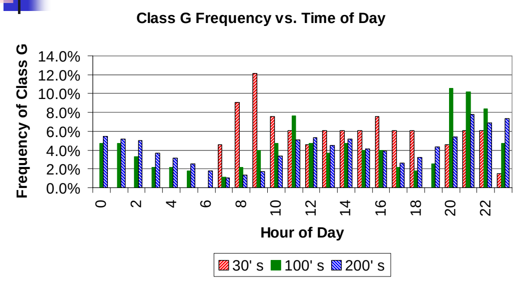


Class G Hour Distribution
Nine Mile Point: Delta-T Data



Class G Hour Distribution

Nine Mile Point: Sigma Theta Data



Summary

- Stability classes derived from delta-T do not compare well with those derived from sigma theta method… limited applicability for substitution
- Measurements at the top of the tower (delta-T and/or sigma theta) tend to yield higher stability classes

Summary – continued

- Stability classes derived from delta-T show a higher dependence on time of day… due to solar heating of the ground
- All three plants had a higher than expected frequency of class A compared to other stability classes… coastal phenomenon?

Summary – continued

- Each increase in stability class will tend to increase concentrations and resulting doses by 2 to 10 times, or maybe even more… implications to using substitute or alternate data?
- 'Adjustments' of stability class information outlined in EPA-454/R-99-005 may provide an avenue to improve comparability

Concerns - I

- If primary source of stability class is lost, is using an alternate source that could yield a stability class that is different by 2 or more classes appropriate?
- Especially of concern if primary source is delta-T, and backup is sigma theta from a short tower.
- *However, consider –*
  - Any local data is better than remote data
  - Most remote sources of data (airport, NWS) are not equipped to provide information for derivation of stability class

Concerns - II

- Is it appropriate to extrapolate stability class from a given level of a tower to a different level of a release point?
- *Consider –*
  - Stability class measured at a given level of a tower reflects conditions at that level
  - Need to match level of measurement with level of release point as much as practicable
  - Delta-T reflects vertical mixing, whereas sigma theta reflects horizontal mixing… both are needed in X/Q determination, but seldom independently measured and simultaneously applied

Concerns - III

- Which method is better… delta-T or sigma theta?
- *Consider –*
  - Safety guide 23 references both methods, so either is appropriate for regulatory compliance… does the NRC have a preference?
  - You may want to perform your own evaluation or comparison so that you are familiar with the specifics at your site, are comfortable with any differences, and understand enough to defend your approach