EVALUATING METEOROLOGICAL MONITORING SITES USING SIGMA-THETA

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During the 2002 NUMUG meeting, one presentation discussed using Sigma-Theta measurements to determine if trees and tower structures were impacting wind data. The Tennessee Valley Authority (TVA) used this approach to examine its meteorological monitoring sites.

This presentation addresses the results of TVA's evaluation for each of its nuclear plants sites and validates the use of the Sigma-Theta methodology. In general, the evaluation confirmed conditions already known. However, it identified a previously unidentified anomalous condition at Browns Ferry Nuclear Plant—for a narrow range of wind directions, the Sigma-Theta values were not as expected. This presentation examines the anomaly and identifies a probable cause.

A 2002 NUMUG presentation discussed using Sigma-Theta measurements to determine if trees and tower structures were impacting wind data (*The Impact of Nearby Structures and Trees on Sigma Theta Measurements*, by Tom Bellinger). The Tennessee Valley Authority (TVA) used this approach to perform an evaluation of the meteorological monitoring sites for its nuclear plants.

Methodology for Sigma-Theta Evaluation

TVA has collected meteorological data (including horizontal wind direction deviation) at its three nuclear plant sites (Browns Ferry, Sequoyah, and Watts Bar) since 1972-73. Unfortunately, TVA's wind direction deviation (i.e., sigma) calculations changed in 1989 (Table 1), so sigma data prior to then were not directly usable in the evaluation. Further, because of physical changes near the meteorological towers, measurements during earlier years are not comparable to measurements during later years. Finally, a current "snapshot" was desired to help determine if any action was necessary concerning the current monitoring program. Therefore, the TVA based the Sigma-Theta evaluation on the most recent six complete years of data (1997-2002).

Table 1
Horizontal Wind Direction Deviation Calculations

Sigma-Y (replaced in 1989)

a. Calculate Standard Deviation for 5-minute intervals.
b. Calculate hourly Sigma-Y based on arithmetic average of 12 5-minute Values.

Hourly Sigma-Theta

a. Calculate hourly Sigma-Theta based on 720 WD readings.

15-minute Sigma-Theta

a. Each 15-miutes, calculate Sigma-Theta based on 180 WD readings each.
b. Calculate hourly Sigma-Theta based on root-mean-square of the four 15-minute Sigma-Thetas.

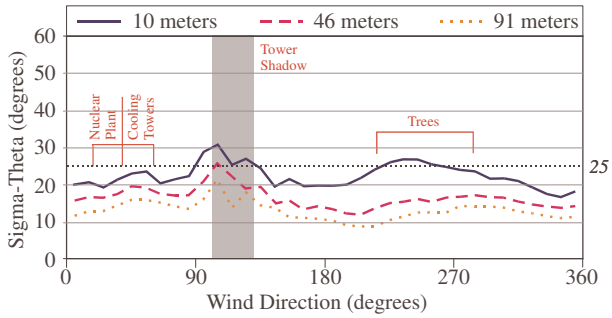
Preliminary Evaluation

In performing this evaluation, TVA used only the hourly values based on the 15-minute Sigma-Thetas. The 15-minute Sigma-Theta values best reflect the actual windflow impacts on the meteorological tower, because they minimize changes resulting from wind shifts. After obtaining all valid hourly values, the evaluation data set was prepared as follows:

- Eliminated values during wind speeds less than 5 miles per hour to avoid the wide swings in wind direction associated with calm and near-calm conditions.
- Sorted remaining values into10-degree sectors based on the simultaneous wind direction.
- Calculated annual average values for each 10-degree sector.

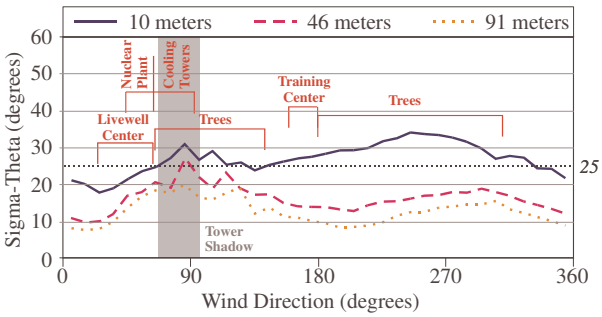
The annual average Sigma-Theta values were plotted on a graph which identifies features and obstructions that were expected to impact the measurements. An arbitrary 25-degree limit was used as a cut-off for analysis.

Watts Bar Nuclear Plant



- 10-meter values are generally less than 25 degrees.
- Values above 25 degrees are due to identifiable causes.

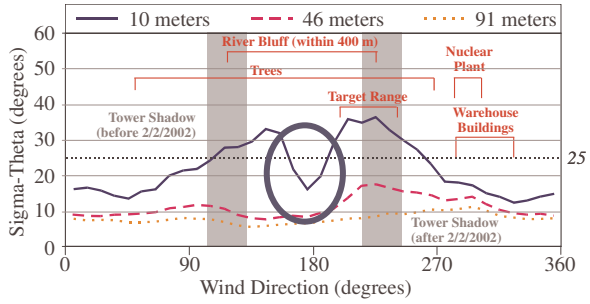
Sequoyah Nuclear Plant



- More cases with 10-meter values above 25 degrees.
- Values above 25 degrees still due to identifiable causes.

For both Watts Bar and Sequoyah, the Sigma-Theta curves are generally consistent with the location and type of obstructions. However, for Browns Ferry, there a dip in the 10-meter Sigma-Theta curve for 150-210 degrees that is not consistent with obstructions.

Browns Ferry Nuclear Plant



- Some high cases, but most are below 25 degrees.
- Most values above 25 degrees due to identifiable causes.

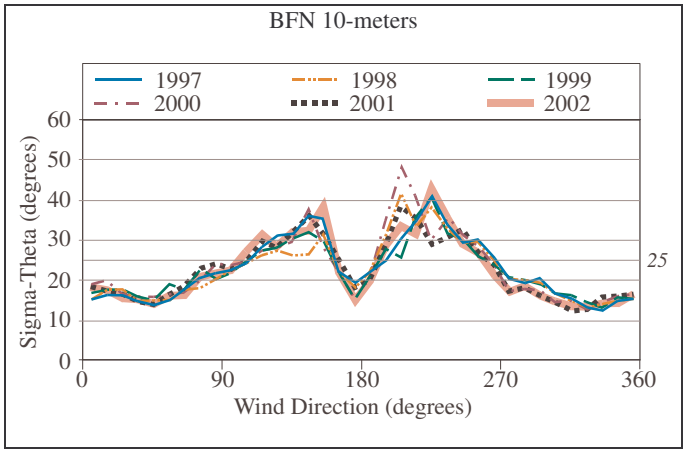
Why is there a dip in 10-meter Sigma-Theta? (Dip is not consistent with obstructions.)

The remainder of this paper with involve answering this question.

Detailed Analysis

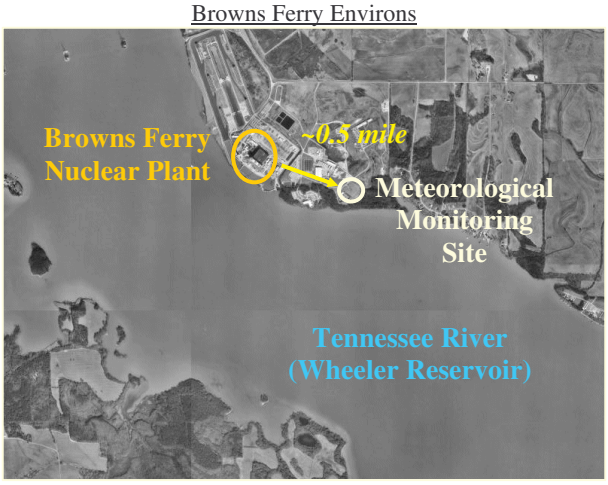
STEP 1—Examine the data on a year-by-year basis to determine if the Sigma-Theta dip is consistent over time or due to a recent change. As can be seen, although there are some differences in other parts of the curve over the years, the dip is extremely consistent.

Therefore, the dip is likely due to a persistent feature of the meteorological monitoring site and not a transient condition.

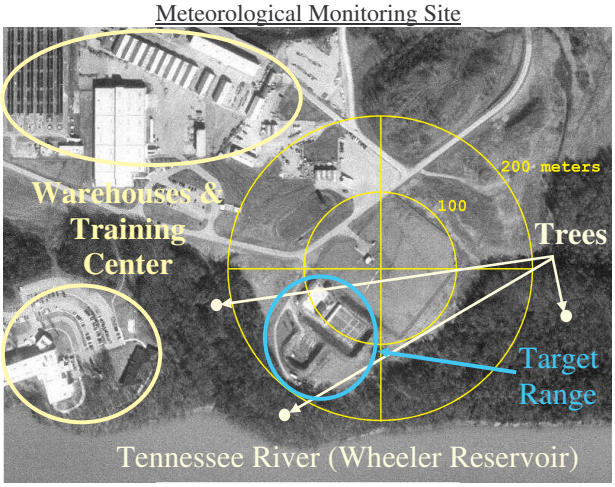


STEP 2—Examine the plant environs and monitoring site vicinity to attempt identification of relevant characteristics.

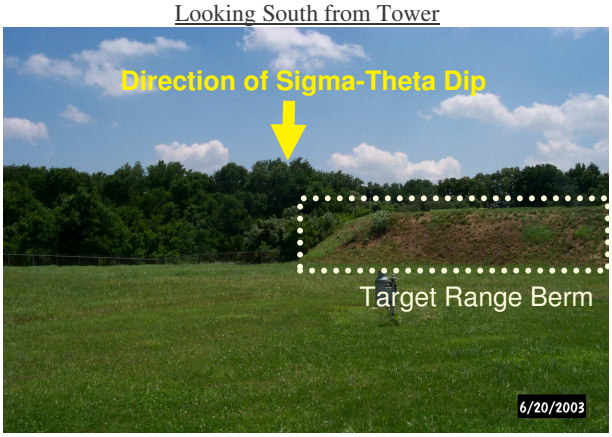
Browns Ferry Environs



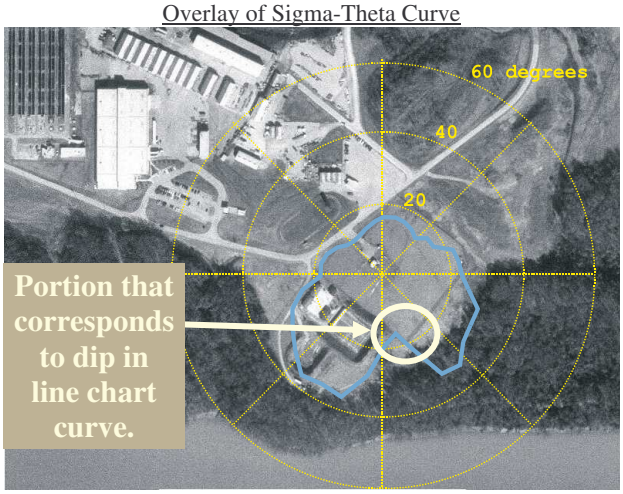
Meteorological Monitoring Site



Looking South from Tower



Overlay of Sigma-Theta Curve

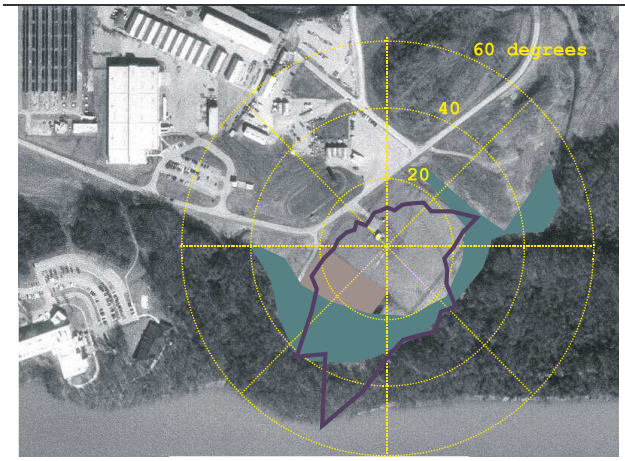


STEP 3—Based on an examination of the visual information, the reason for dip in Sigma-Theta curve is not apparent. Since a number of changes have occurred that might impact sigma measurements (Table 2), it is necessary to determine if the dip in curve has always existed, and if not, when the change occurred.

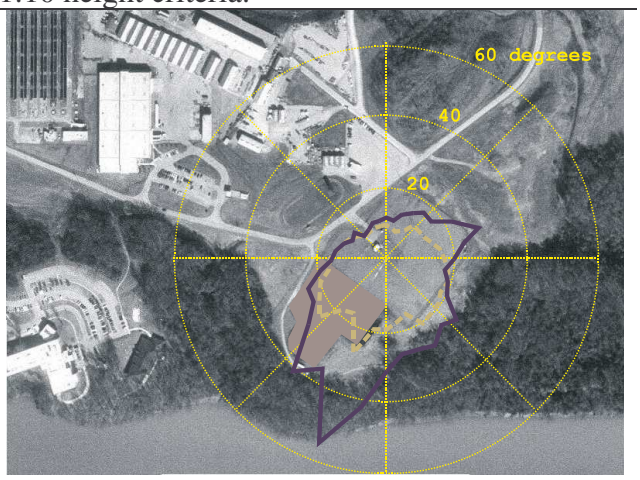
Table 2
Site Changes Impacting Sigma-Theta Measurements

- March 1973 – Start monitoring at permanent meteorological tower.
- October 1977 – Clear trees to meet 1:10 height criteria.
- July 1989 – Change sigma calculation methodology.
- April 1991 – Complete new berms around target range adjacent to meteorological tower site.
- February 2000 – Change orientation of wind sensor mounting arm (old into WNW, new into ENE).
- February 2001 – Change to ultrasonic wind sensors (included slight changes in wind sensor elevations).

Clear trees to meet 1:10 height criteria.

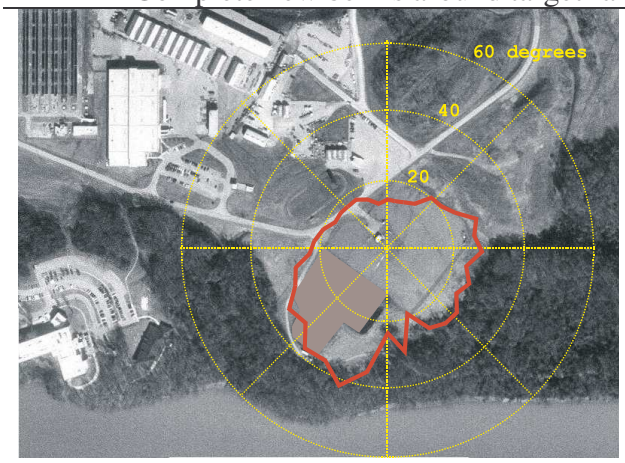


Before Trees Cut (1977- Sigma-Y)

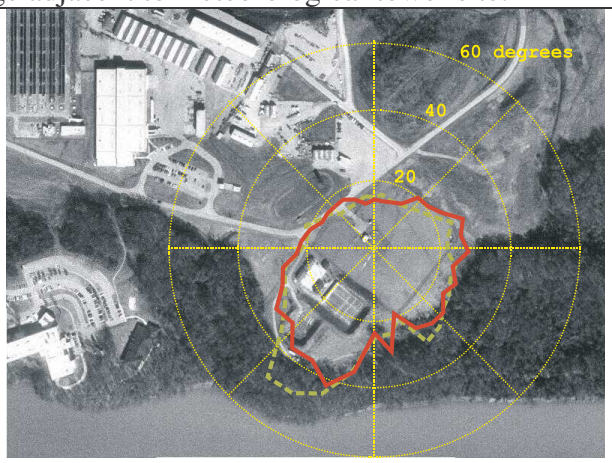


Before Trees Cut (1977- Sigma-Y)
After Trees Cut (1978 - Sigma-Y)

Complete new berms around target range adjacent to meteorological tower site.

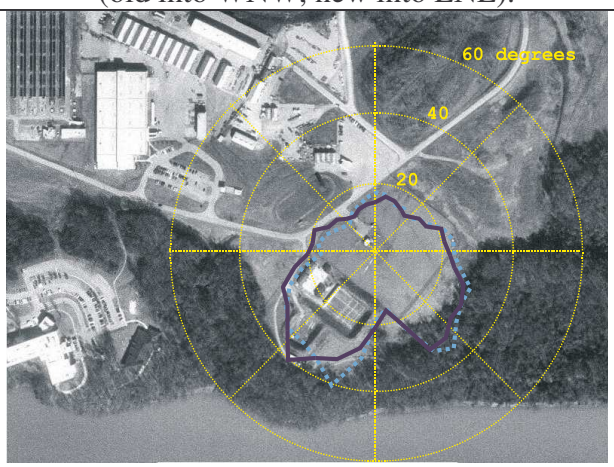


Before berm (1989-1990)



Before berm (1989-1990)
After berm (1992-1993)

Change orientation of wind sensor mounting arm
(old into WNW, new into ENE).



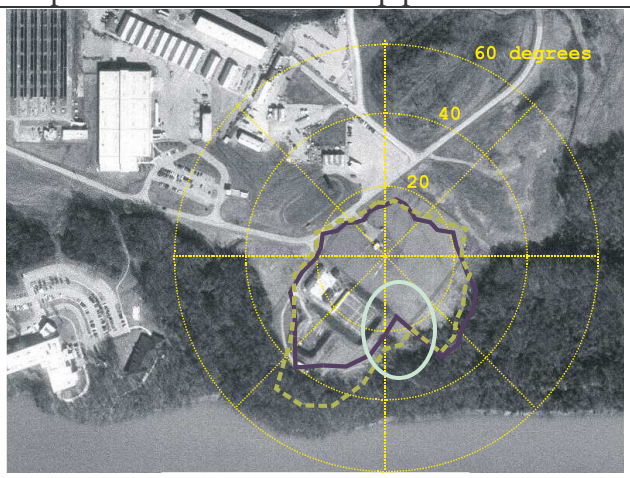
Before Re-Orientation (1997-1999) - into WNW
After Re-Orientation (2000-2002) - into ENE

Preliminary Results

[1977-1978] Changes in Sigma-Y after trees are cut shows general improvement but does not indicate dip.
[1989-1993] Dip is not apparent both before and after target range berm was built.
[1997-2002] Dip is present both before and after change in sensor orientation.

Therefore, Sigma-Theta curve changed between 1993 and 1997.

Dip not present in 1992-1993. Dip present in 1997-1999



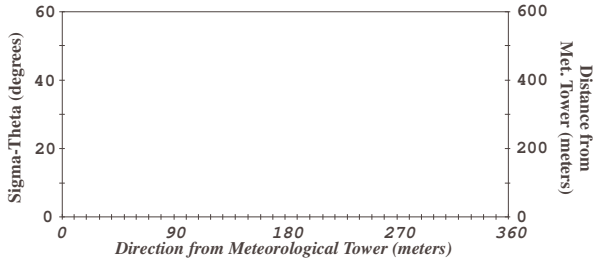
1997-1999
1992-1993

Further Analysis

While no reason is readily apparent, the dip appears to be related to narrow band of trees adjacent to river. At 1993 NUMUG meeting, a TVA presentation indicated that a temperature anomaly was partly due to the horizontal extent of a terrain feature (*Identification and Implications of a Local Temperature Anomaly, by Ken Wastrack & Norris Nielsen*).

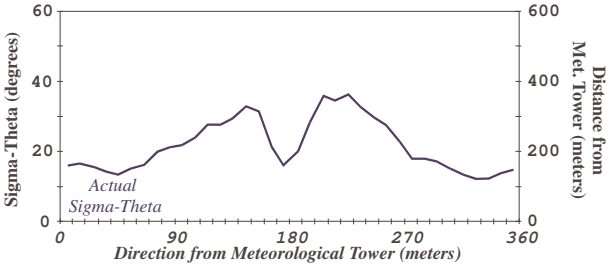
Therefore, TVA examined not only the presence of obstructions, but also their horizontal extent.

1. Start with blank frame.

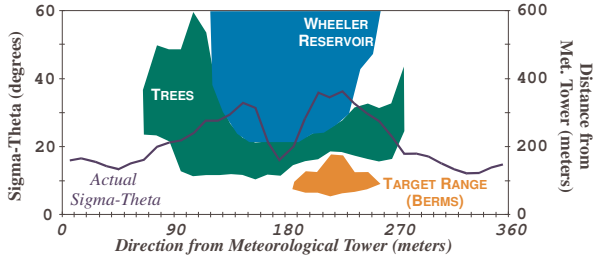


Sigma-Theta scale on left.
Distance scale on right.

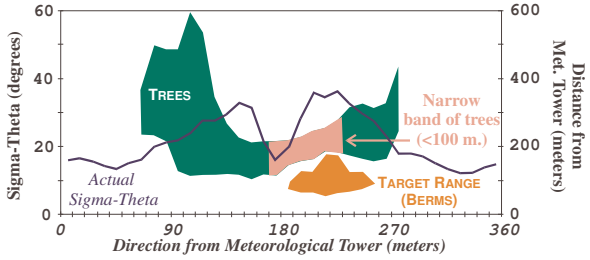
2. Add actual Sigma-Theta



3. Add reservoir, trees, and target range.

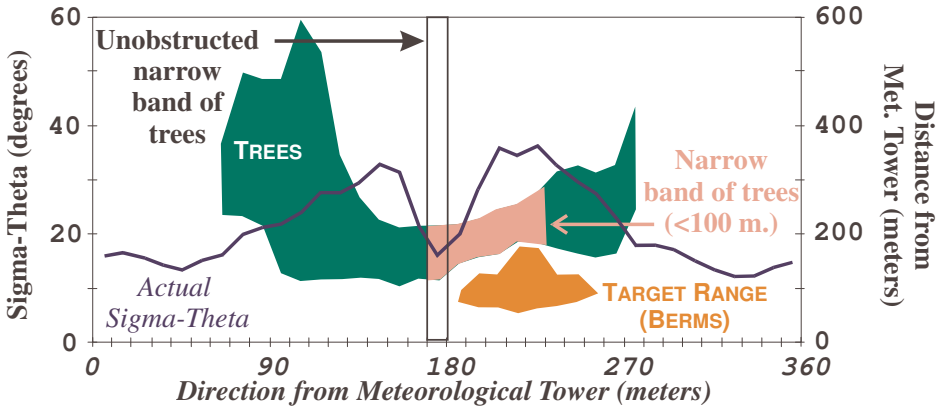


4. Show narrow band of trees (<100 m wide).



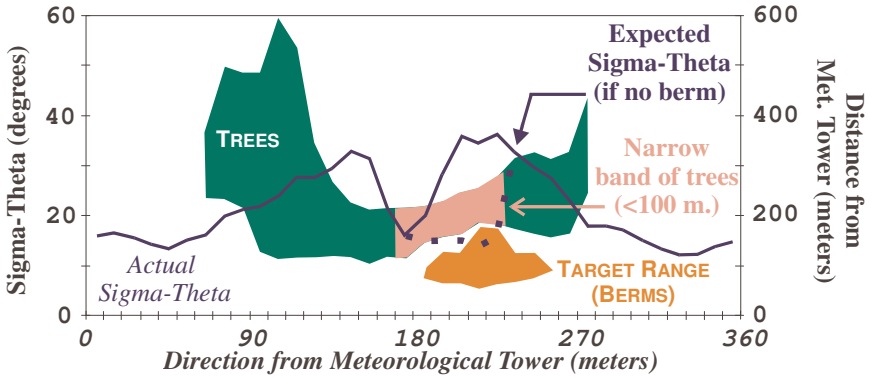
Remove reservoir to simplify

5. Examine portion of curve with dip.



Dip is related to unobstructed narrow band of trees.

What would curve look like without target range?



Expected Sigma-Theta is estimated based on tree band width.

Conclusions

The dip in Sigma-Theta curve is due to a narrow band of trees unobstructed by the target range. The dip represents relatively unobstructed wind flow.

While the tree band is narrow behind target range, Sigma-Theta values are greater from direction of target range. Consequently, even though it meets obstruction criteria, the berm still impacts measurements.

Ruckert's Law
There is nothing so small that it can't be blown out of proportion.