TVA Nowcast Aids for Emergency Preparedness

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Meteorological support for TVA Nuclear Emergency Preparedness must be responsive to releases from various heights by obtaining data collected at multiple levels. TVA maintains a tall tower at each site to obtain the required data. Since the data availability from these onsite meteorological tower is normally very high (>98%), TVA does not operate backup sensors or towers. However, it is conceivable to have a partial or total meteorological system outage during an emergency. To address this possibility, TVA has developed a set of Nowcast Aids that provide alternative estimates of the necessary meteorological variables and confidence associated with the estimated values. These Nowcast Aids are designed to use reference variables to establish the estimated values.

This presentation discusses the need for Nowcast Aids, how the Nowcast Aids were developed, and provides examples of use.

Meteorological tower data must be available at all times for estimating the dispersion and transport characteristics of releases from nuclear power facilities.

- Real-time accurate data can be crucial to making correct protective action recommendations in the event of an accidental release.

- ANS-3.11-2005 (ANS-3.11), "*Determining Meteorological Information at Nuclear Facilities*", requires "a valid, accurate, and representative meteorological data base" to be utilized in evaluating environmental impacts and consequences of radiological releases (both routine and accidental). Modeling applications often need values for every data point and time.

Routine data collection is not expected to provide values at every data point for all times, and even backup and redundant measurement systems cannot guarantee a 100% data availability. Therefore, another approach is sometimes necessary. The Nowcast Aids methodology provides a means to substitute suitable data values when they cannot be obtained by other means.

Background and History

NRC Regulatory Guide 1.23 (RG-1.23), "*Onsite Meteorological Programs*," (published in 1972) requires each nuclear plant to collect meteorological data to support plant operations. RG-1.23 specified that the maintenance program shall ensure a 90% data recovery rate and indicated that redundant sensors would be acceptable if necessary to achieve this recovery rate. During the middle-to-late 1970's, the Tennessee Valley Authority (TVA) developed a meteorological program for each of its nuclear plants that consists of a single meteorological tower at each plant site, dedicated local maintenance personnel, and extensive data validation support to ensure data quality. This approach not only met the 90% data recovery requirement, but often achieved data recovery rates of 98% or greater.

In 1980, following the Three-Mile-Island accident, NRC issued NUREG-0654, "*Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*," which established tighter criteria for meteorological monitoring programs. Specifically, NUREG-0654 required that equipment shall be available for

"continuously assessing" the impact of a release--essentially 100% data availability. Since a 100% data availability rate would be impossible to achieve using a single set of meteorological sensors on one tower, NUREG-0654 required both primary and backup meteorological measurements systems.

TVA evaluated establishing a backup measurements system but decided against it because of the need to establish data relationships between the primary and backup data values. Further, it would be too costly to upgrade its existing system for only a slight gain in data availability. Instead, TVA developed Nowcast Aids to substitute replacement values from existing sources whenever actual measurements were unavailable. Because of differences in accuracy, each Nowcast Aid was assigned a confidence level as a measure of its representativeness.

TVA's Nowcast Aids were developed during 1982-1983 to reflect the specific information required by the computer model used for dose assessment. During 1984-1985, the Nowcast Aids were evaluated by NRC in the Watts Bar Nuclear Plant emergency appraisal and determined to be acceptable. In 1986, the Nowcast Aids were consolidated into a procedure format for ease of use.

During 1989-1991, the Nowcast Aids were updated to incorporate additional analysis, fill some gaps in the reference variables, customize some variables based on regional weather conditions, and provide a more user-friendly format. With only minor changes since then (primarily editorial), these Nowcast Aids are still in use.

General Information about Nowcast Aids

Meteorological support for the Radiological Emergency Plan (REP) must be responsive to releases from various heights. Data for such support are normally taken from the onsite meteorological tower. Wind speed/direction and temperature for each plant are measured at approximately 91 m, 46 m, and 10 m. Stability class (based on the $\Delta T/\Delta Z$ method) is determined based on temperature differences between two levels.

The specific data required for REP applications depend on the release type. Releases are classified as ground-level or elevated releases based on the release point and the possible influence of building wake effects.

Release Point	Building Wake Effect?	Release Type	Data Required
Lower than height of adjacent solid structures	*N/A*	ground-level	• 46 m wind direction/speed • 46-10 m stability class
Above height of adjacent solid structures *	No	elevated *	• 46 or 91 m wind direction/speed *(whichever is closer to plume height)* • 91-46 m stability class
	Yes	ground-level *	• 46 m wind direction/speed • 46-10 m stability class
Stack	*N/A*	elevated	• 91 m wind direction/speed • 91-46 m stability class

* A release is elevated if the effluent exit velocity is 5 or more times greater than the 46 m wind speed. Otherwise, it is a ground-level release.

Any partial or total meteorological system outage (which includes both missing and invalid data) during an emergency will require an alternative source for the necessary variables. The Nowcast Aids provide procedures for estimating required values.

Reference variables (i.e., some piece or pieces of available information) are used to establish estimated values. Reference variables include earlier values of the variables to be estimated, other onsite data, offsite data (e.g., National Weather Service [NWS]), and time of day and month. Not all reference variables are used for each procedure. Priorities for substitution have been established for each missing parameter. They are arranged in order of effectiveness, with the most effective listed first.

Procedures are provided for estimating missing values of the following variables at each site:

91-46 meter stability class	**91 meter wind direction**	**91 meter wind speed**
46-10 meter stability class	**46 meter wind direction**	**46 meter wind speed**

Development of Nowcast Aids

Three key principles were followed in developing Nowcast Aids.

1. **Nowcast Aids must be quick.** The data collection cycle for the REP program is 15-minutes. In that time, the meteorologist must review the observed data and provide valid data for use, the dose assessment analysis must be performed, and the results must be released for follow-up actions. Consequently, if any meteorological data values are unacceptable, the meteorologist has only a few minutes to obtain suitable replacement values.

2. **Nowcast Aids must be simple.** The data collection program is very reliable, so Nowcast Aids are rarely needed, and the meteorologists do not get much practice in this aspect of REP support. Therefore, the Nowcast Aids have to be designed so that they can be used with minimal instructions using no more than a hand calculator.

3. **One or more Nowcast Aids must be available at all times.** It has to be assumed that data are going to be unavailable due to catastrophic failure of the data collection or communication system (i.e., no data of any kind are available). Therefore, at least one Nowcast Aid for each variable has to be based on reference values that can be determined at any time (e.g., time of day).

There are five types of TVA Nowcast Aids:

	Type of Nowcast Aid	Description	Examples
1.	Persistence	Persistence assumes that there is no significant change in a variable over a short period of time (up to 4 hours).	Wind Direction Wind Speed

	Type of Nowcast Aid	Description	Examples
2.	Inter-Level and Other Site Comparisons	Comparisons are based on differences between the 'missing' variable and concurrent observations, either at a different level on the same tower, or at a nearby location (e.g., NWS station).	Stability Class • other layers • other locations Wind Direction • other levels • other locations Wind Speed • other levels • other locations
3.	Power Law Exponents	Power law exponents apply to different wind speed levels and are presumed to persist for up to four hours. With the power law exponent from an earlier observation, and an observed wind speed for at least one other tower level, the wind speed for a missing level can be estimated.	Wind Speed
4.	Geostrophic Wind Methodology **	Geostrophic wind aids are determined based on sea-level pressure observations from four NWS stations surrounding the plant. The Nowcast values are based on the relationship of the 'missing' variable to the geostrophic wind.	Wind Direction Wind Speed
5.	Average Values	Average values based on the time of day have been calculated for each variable and are used as default values if none of the other procedures can be used.	Stability class • by wind speed, cloud ceiling, & time-of-day • by time-of-day Wind Direction • by time-of-day • by weather conditions Wind Speed • by time-of-day

** The geostrophic wind results from a balance between the Coriolis force and the pressure gradient force that causes the wind to blow parallel to isobars of pressure. The pressure field is determined from differences between simultaneous observations at surrounding NWS stations.

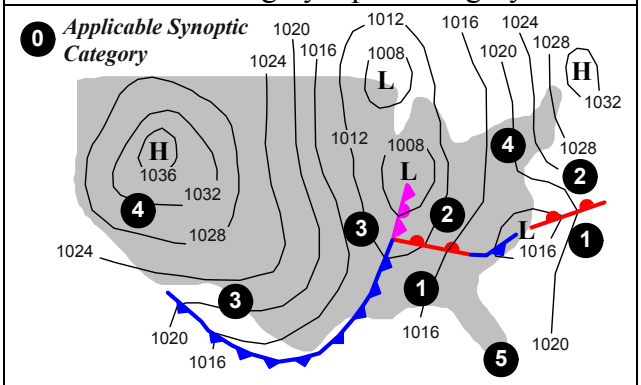
The following precision limits are assumed for using Nowcast Aids:

- Wind direction - ± 45 degrees (± 2 sectors).
- Wind speed - ± 2.2 m/s (± 5 mph).
- Stability class - ± 1 Pasquill category.

A comparison method is considered acceptable if the results were within precision limits at least 90 percent of the time. A comparison method is unacceptable if the results were within precision limits less than 50 percent of the time (*unless no alternative method was available*). If the results were between these two limits, the comparison method was acceptable, but confidence limits were specified as less than 90 percent.

To determine if the comparison method was improved by further subdivision, the results were classified by season and/or synoptic category (see box to right). The confidence limit was calculated for each subdivision. If the confidence limits for the subdivisions did not differ greatly, it was assumed that no significant improvement was possible by using the subdivisions.

Determining Synoptic Category



The following guidelines are used to identify the appropriate Synoptic Category:

1. Warm sector of an extratropical cyclone with cyclonic curvature of surface isobars.
2. Ahead of the warm front in the region of cyclonic curvature of the surface isobars.
3. Behind the cold front in the region of cyclonic curvature of the surface isobars.
4. Under a polar high in a region of anticyclomic curvature of the surface isobars.
5. In the vicinity of a subtropical ridge.

Based on NUREG/CR-3882, "A Method to Characterize Local Meteorology at Nuclear Facilities for Application to Emergency Response Needs"

Using Nowcast Aids

The Nowcast Aids contain a separate section for each variable. The first page of each section is a table of contents that lists the reference variables and identifies the procedures for estimating the missing variable. The procedures are arranged in the order of effectiveness with the most effective listed first.

To estimate a missing variable, the user turns to the appropriate section and reads down the list to the first variable(s) that is (are) available. The user then turns to the applicable procedure and follows the instructions to obtain an estimated value of the missing variable.

Preferably, a Nowcast Aid will satisfy the precision limits at least 90 percent of the time (90 percent confidence limit). If the 90 percent confidence level has been attained, only the Nowcast value is given in the procedure. If the 90 percent confidence level has not been attained, the expected percent of success (the actual confidence level) is given. These confidence factors (± values and confidence levels) are provided as the estimated (Nowcast) value. The data users can then interpret their information based on the reliability of the meteorological data.

Examples of Applying Precision Limits	
Nowcast Conditions	Estimated Value (and confidence level).
Historical wind direction is within 37º of the reference value 90 percent of the time (*37º is within the ± 45º precision limit*).	**Nowcast value ± 37º** (90 percent or better confidence is assumed)
Historical wind speed is within 5.4 mph of the reference value 90 percent of the time, but is within 3.8 mph of the reference value 75 percent of the time (*5.4 mph exceeds the 5 mph precision limit while 3.8 mph is within the precision limi*t).	**Nowcast value ± 3.8 mph, 75%**

Nowcast Aids Examples

Example A: On the Sequoyah (SQN) meteorological tower, no temperature data (and hence no ΔTs) and no 10-m wind speed data are available.

Determine low-level (46-9 m) Pasquill stability class for SQN.

Step 1: Determine which reference data are available by reading down the reference variable list for SQN 46-9 Stability Class.

Reference Variable(s)	Availability Status
SQN 91-9 m stability class	*Not available*, SQN has no temperature data.
SQN 91-46 m stability class	*Not available*, SQN has no temperature data.
SQN 10-m wind speed, ceiling height, time of day	*Not available*, SQN has no 10-m WS data.
Watts Bar (WBN) 91-10 m stability class	Available.
WBN 46-10 m stability class	Available.
WBN 91-46 m stability class	Available.
Time of day	Always available.

Step 2: Identify the specific reference variable to be used.

None of the SQN variables are available because there is no ΔT information or 10-m WS from SQN. All of the WBN variables are available, and the time of day is always known.

Since the variables are listed in decreasing order of effectiveness, the highest available reference variable (**WBN 91-10 m stability class**) should be used.

Step 3: Go to the specific table for the **WBN 91-10 m Stability Class** and determine the Nowcast value that applies.

Watts Bar 91-10 m Stability Class	Sequoyah 46-9 m Stability Class

A.....A ± 1
B.....A ± 1, 80%
C.....A ± 1, 86%
D.....D ± 1, 74%
E.....E ± 1
F.....F ± 1
G.....G ± 1

Step 4: Based on the current **WBN 91-10 m Stability Class**, nowcast the SQN 46-9 m Stability Class (and include confidence limits if applicable).

Example B: On the Browns Ferry (BFN) meteorological tower, no wind direction data are available for any level for more than 4 hours; synoptic category is 5 ("in the vicinity of a subtropical ridge"); and one required pressure reading is missing for the Geostrophic Wind Direction method.

Determine tower top (90-m) Wind Direction for BFN.

Step 1: Determine which reference data are available by reading down the reference variable list for BFN 90-m Wind Direction.

Reference Variable(s)	Availability Status
BFN concurrent 46-m WD	*Not available*, BFN has no WD data.
BFN 90-m WD ≤ 1 hour old	*Not available*, BFN data have been unavailable for more than 4 hours.
BFN concurrent 10-m WD	*Not available*, BFN has no WD data.
BFN 90-m WD > 1 hour old, ≤ 2 hours old	*Not available*, BFN data have been unavailable for more than 4 hours.
Geostrophic WD	*Not available*, one sea-level pressure reading is missing.
BFN 90-m WD > 2 hours old, ≤ 4 hours old	*Not available*, BFN data have been unavailable for more than 4 hours.
Huntsville NWS concurrent WD	Available.
Time of day, synoptic category	Always available.

Step 2: Identify the specific reference variable to be used.

None of the BFN variables are available. At least one of the sea-level pressure readings for the Geostrophic WD is missing. Huntsville NWS data are available, and if all else fails, the meteorologist knows time of day and the synoptic category.

The highest available reference variable (**Huntsville NWS concurrent WD)** should be used.

Step 3: Go to the specific table for the **Huntsville NWS concurrent WD** and determine the Nowcast value that applies.

The table lists equations for each synoptic category. The equation for category 5 will be used.

$$WD_{90} = 27.4 + (0.9 * WD_{HSV}) \qquad \pm 29^{o},\ 50\%$$

where: WD_{90} = BFN 90-m Wind Direction
WD_{HSV} = Huntsville Wind Direction

Step 4: Based on the current **Huntsville NWS concurrent WD**, nowcast the BFN 90-m Wind Direction using the applicable equation. Inform the data users that the value is accurate to ± 29º for only 50% of the time.

Example C: On the Watts Bar (WBN) meteorological tower, the 46- and 91-m wind sensors have failed within the past hour.

Determine 46-m Wind Speed for WBN.

Step 1: Determine which reference data are available by reading down the reference variable list for WBN 46-m Wind Speed.

Reference Variable(s)	Availability Status
WBN concurrent 91-m wind speed	*Not available*, 91-m wind sensor has failed.
WBN 46-m wind speed ≤ 1 hour old	Available.
• • •	
Sixteen other combinations of variables based on persistence, power law relationships, and concurrent observations at other locations. All of these cases are less accurate than **WBN 46-m wind speed ≤ 1 hour old**.	
• • •	
Time of Day	Always available.

Step 2: Identify the specific reference variable to be used.

WBN 46-m wind speed ≤ 1 hour old is the best available reference value.

Step 3: Go to the specific table for **WBN 46-m wind speed ≤ 1 hour old** and determine the Nowcast value that applies.

The table states that the last available observation should be used unaltered and that the following confidence levels should be applied based on how long the data have been unavailable.

Time elapsed since last available observation	Confidence Level
≤ 1 hour	**± 1.3 m/s**
≤ 2 hours	± 1.9 m/s
≤ 3 hours	± 1.4 m/s, 75%
≤ 4 hours	± 1.7 m/s, 75%

Step 4: Based on the **WBN 46-m wind speed ≤ 1 hour old**, nowcast the WBN 46-m Wind Speed as equal to the last available wind speed. Inform the data users that the value is accurate to ± 1.3 m/s.

Observations about Nowcast Aids

The Nowcast Aids do accomplish the goals to be quick, simple, and always available. However, this is achieved by accepting an increasing reduction in accuracy within a few hours or during rapidly changing conditions. Consequently, the use of the Nowcast Aids is limited to the meteorologists participating in the Emergency Preparedness Program, since they are best able to determine the applicability of the Nowcast Aids.

Another benefit of the Nowcast Aids is their usefulness for preparing short-term forecasts. Since climatology was used to develop the specific time-of-day aids, the aids can be used to help prepare forecasts. The meteorologist simply uses the time-of-day values as the "first-guess" for the applicable hours, and makes adjustments to fine-tune the forecasts.

Also, Nowcast Aids are useful for filling data gaps for applications (e.g., modeling) that require continuous data.

Conclusion

Nowcast Aids are a tool than can be used in combination with other information to describe the meteorological conditions.