The Benefits, Challenges, and Pitfalls of Substituting Invalid or Missing Onsite Meteorological Data Using Secondary Sources

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Common Causes of Bad Data

- Sensor failures
- Tower interference
- Aspirator issues (motor, alignment, dirt)
- Snow & ice
- Power failures
- Calibrations/calibration mistakes
- I&C Scheduling (secondary)

Key Parameters

- Wind direction
- Wind speed
- Temperature
- Stability:
  - Differential temperature (ΔT)
  - Standard deviation of wind direction (Sigma)

Data Review Rules of Thumb

- These are general meteorological data review techniques and are not intended to be absolute.
- Use as a basis to flag data for further interrogation or to start the mental process of noting trends. EXCEL spreadsheet works great!
- A and B refer to primary and secondary sensors (avoid “backup” term).

Wind Directions

- Quick scan – no negatives, >360s, or directions stuck on a number for 4 hours?
- Are they consistent with each other (A,B) and between levels (i.e. 10 and 60 meters):
  - within ±10° for same level and ±20° for different level with wind speeds >5 mph. Speeds <5 mph, no direction comparison can be made.
  - at night with ΔT >3.0°F, note that directions can be >30° different between levels (inversion). Verify all was OK before sunset.

Wind Directions (cont'd)

- If there are consistently differences in wind directions (multiple days in a row):
  - vane sensors sometimes have potentiometer failures and the vane appears to be working correctly but the output reads in one quadrant – i.e. 0-90° or 270-360°.
  - misalignment during calibration or tower has a twist – more common than you think, particularly with elevators.

Wind Speeds

- Quick scan – no negatives, >50 mph, or speeds stuck on a number for 4 hours?
- Are they consistent with each other (A,B) and between levels (i.e. 10 and 60 meters):
  - within ±1.0 mph for same level and wind speeds consistently higher at 60- versus 10-meter level.
  - at night with ΔT >3.0°F, speeds can actually be lower at upper levels (inversion). Verify all OK before sunset.

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Wind Speeds (cont'd)

- 0.0 mph during the day and more than 4 hours in a row at night are possible indications of sensor bearing failure – watch the trend.
- During snow or ice storms – Speeds stuck on 0.0 are indication of frozen sensor (heater failed) or cups packed with snow/ice.
- Wind speeds consistently lower at upper level during the day – at least 1 cup may be missing or sonic sensor is failing (bent, birds).

Wind Speeds (cont'd)

- Pay attention to the amount of 0.0 mph (calm) readings you are getting.
- If they appear to be increasing in frequency or you have more than 10% calms in a week, you may have a siting (trees) or sensor problem (threshold).
- Big impacts on dose assessment down the road.

Temperatures

- Quick scan – no out of the ordinary extremes or values stuck for 4 hours.
- Are they within ±1.0°F with each other (A,B):
  - if consistently different, could be aspirator issues, water ingestion, cracked cabling, etc.
- Look for rapid changes (>5°F/hour) outside of sunrise/sunset periods. If any observed:
  - check to see if rain was recorded that hour. OK.
  - if no rain, note a problem may be starting.

Delta-T (ΔT)

- If problems are occurring in the temperature data, they will likely also be occurring here.
- In general, ΔT should be negative during the day and positive at night.
- Windy (>10 mph) and cloudy at night will keep ΔT around -1.0°F to +1.0°F.

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Delta-T (ΔT) (cont'd)

- ΔT can be >+10.0°F on clear and calm nights.
- ΔT <-3.0°F per 50 meter separation can occur for brief periods <u>only</u> and is not common due to overturning (similar to lakes).
- A and B ΔTs should be within ±0.5°F:
  - exception is near sunrise and sunset periods when ΔTs are changing rapidly.

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Temperature Aspirator Failure

- Most common issue with temperature system. Determined by voltage change flag.
- Invalidate temperature and ΔT? Not so fast.
- Data are actually still valid:
  - at night when solar insolation is minimum.
  - daytime with wind speed >7 mph (natural aspiration).
  - use caution not to bias the data set by only using night delta-Ts over extended period.

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How do I Know Data are Good?

- Performing the previous data review steps regularly will give you a good idea.
- For suspect data, watch the trends over a few days (or hours in obvious cases).
- Get a second opinion from a coworker/I&C.
- Finally, “when in doubt, 9 it out.”

Some Real-Time Examples for Key Parameters

Wind Speed

Wind Direction

Delta-T

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Questionable Data?

MO	DAY	HR	T10A	T10B	WD60	WD10	WS60	WS10
1	8	5	51.8	51.7	159	155	5.1	3.0
1	8	6	51.9	51.8	144	155	7.6	3.9
1	8	7	51.9	51.8	150	156	6.8	3.4
1	8	8	51.8	51.7	143	155	6.7	3.4
1	8	9	51.7	51.5	154	155	7.4	4.4
1	8	10	52.0	51.7	155	155	6.4	4.3
1	8	11	52.9	52.2	143	155	9.6	5.5
1	8	12	54.0	53.1	148	156	8.6	4.8

10M Direction Invalid

MO	DAY	HR	T10A	T10B	WD60	WD10	WS60	WS10
1	8	5	51.8	51.7	159	155	5.1	3.0
1	8	6	51.9	51.8	144	155	7.6	3.9
1	8	7	51.9	51.8	150	156	6.8	3.4
1	8	8	51.8	51.7	143	155	6.7	3.4
1	8	9	51.7	51.5	154	155	7.4	4.4
1	8	10	52.0	51.7	155	155	6.4	4.3
1	8	11	52.9	52.2	143	155	9.6	5.5
1	8	12	54.0	53.1	148	156	8.6	4.8

Questionable Data?

MO	DY	TM	T60	T10	WD60	WD10	WS60	WS10	PCPN
2	16	17	35.3	34.6	326	312	12.7	6.7	0.17
2	16	18	34.6	33.9	329	313	12.9	7.2	0.19
2	16	19	33.6	32.9	345	338	12.5	7.8	0.07
2	16	20	32.0	31.3	335	329	0.7	8.7	0
2	16	21	30.8	30.0	336	329	0.3	8.1	0
2	16	22	30.2	29.4	346	342	0.3	0.3	0
2	30	23	29.9	29.1	349	344	0.3	0.3	0
2	30	24	29.5	28.7	353	343	0.3	0.3	0

Wind Speed-Snow/Frzng Rain

MO	DY	TM	T60	T10	WD60	WD10	WS60	WS10	PCPN
2	16	17	35.3	34.6	326	312	12.7	6.7	0.17
2	16	18	34.6	33.9	329	313	12.9	7.2	0.19
2	16	19	33.6	32.9	345	338	12.5	7.8	0.07
2	16	20	32.0	31.3	335	329	0.7	8.7	0
2	16	21	30.8	30.0	336	329	0.3	8.1	0
2	16	22	30.2	29.4	346	342	0.3	0.3	0
2	30	23	29.9	29.1	349	344	0.3	0.3	0
2	30	24	29.5	28.7	353	343	0.3	0.3	0

Calm Wind χ /Q Impacts

- Impact of calm winds on downwind χ /Qs is significant.
- A 5% increase in calms could increase your downwind χ /Qs by 100%!

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Questionable Data?

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
3	30	5	53.5	53.6	53.6	53.8	0.10	0.25
3	30	6	55.0	55.1	54.7	55.0	-0.25	-0.08
3	30	7	55.6	55.8	55.6	55.9	-0.08	0.09
3	30	8	55.9	56.0	55.4	55.7	-0.47	-0.24
3	30	9	58.0	58.1	57.3	59.3	-0.67	1.27
3	30	10	62.4	62.4	61.4	70.1	-1.00	7.65
3	30	11	65.4	65.4	64.1	71.9	-1.33	6.51
3	30	12	68.5	68.5	67.3	70.5	-1.17	1.92

Temperature and ΔT Invalid

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
3	30	5	53.5	53.6	53.6	53.8	0.10	0.25
3	30	6	55.0	55.1	54.7	55.0	-0.25	-0.08
3	30	7	55.6	55.8	55.6	55.9	-0.08	0.09
3	30	8	55.9	56.0	55.4	55.7	-0.47	-0.24
3	30	9	58.0	58.1	57.3	59.3	-0.67	1.27
3	30	10	62.4	62.4	61.4	70.1	-1.00	7.65
3	30	11	65.4	65.4	64.1	71.9	-1.33	6.51
3	30	12	68.5	68.5	67.3	70.5	-1.17	1.92

ΔT Night and Day Extremes

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Questionable Night ΔT?

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
9	15	18	82.1	82.3	82.4	82.8	0.31	0.50
9	15	19	73.9	74.1	80.1	80.4	6.18	6.31
9	15	20	68.9	69.1	78.6	79.0	9.77	9.91
9	15	21	65.3	65.4	77.0	77.4	11.68	11.91
9	15	22	63.5	63.7	76.7	77.0	13.20	13.39
9	15	23	61.9	62.0	76.7	77.0	14.82	14.99
9	15	24	59.1	59.2	75.8	76.1	16.74	16.85
9	16	01	57.6	57.7	74.3	74.5	16.77	16.87

This is a Valid ΔT

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
9	15	18	82.1	82.3	82.4	82.8	0.31	0.50
9	15	19	73.9	74.1	80.1	80.4	6.18	6.31
9	15	20	68.9	69.1	78.6	79.0	9.77	9.91
9	15	21	65.3	65.4	77.0	77.4	11.68	11.91
9	15	22	63.5	63.7	76.7	77.0	13.20	13.39
9	15	23	61.9	62.0	76.7	77.0	14.82	14.99
9	15	24	59.1	59.2	75.8	76.1	16.74	16.85
9	16	01	57.6	57.7	74.3	74.5	16.77	16.87

Questionable Day ΔT?

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
6	25	12	87.4	87.6	85.8	86.2	-1.57	-1.41
6	25	13	88.9	89.2	86.9	87.2	-2.06	-1.97
6	25	14	89.4	89.7	87.6	87.9	-1.85	-1.78
6	25	15	90.9	90.9	88.8	89.2	-2.12	-1.78
6	25	16	91.4	91.4	89.4	89.7	-1.99	-1.76
6	25	17	92.7	92.9	90.7	91.2	-2.06	-1.76
6	25	18	81.7	81.9	80.5	80.9	-1.13	-0.92
6	25	19	79.2	79.4	78.8	79.2	-0.40	-0.21

Valid Day ΔT

MO	DAY	HR	T10A	T10B	T60A	T60B	ΔTA	ΔTB
6	25	12	87.4	87.6	85.8	86.2	-1.57	-1.41
6	25	13	88.9	89.2	86.9	87.2	-2.06	-1.97
6	25	14	89.4	89.7	87.6	87.9	-1.85	-1.78
6	25	15	90.9	90.9	88.8	89.2	-2.12	-1.78
6	25	16	91.4	91.4	89.4	89.7	-1.99	-1.76
6	25	17	92.7	92.9	90.7	91.2	-2.06	-1.76
6	25	18	81.7	81.9	80.5	80.9	-1.13	-0.92
6	25	19	79.2	79.4	78.8	79.2	-0.40	-0.21

Tower and Conduit Interference

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Tower Interference?

MO	DY	TM	A100	B100	A60	B60	A10	B10	WD
4	30	12	13.0	13.4	12.9	13.0	10.7	10.6	**192**
4	30	13	12.3	14.6	13.0	14.9	11.9	12.4	**209**
4	30	14	16.6	10.8	16.4	11.8	14.5	9.7	**224**
4	30	15	22.3	11.9	20.5	13.3	17.9	9.8	**238**
4	30	16	19.4	9.5	17.9	10.8	15.3	7.8	**234**
4	30	17	25.8	22.4	23.1	21.1	20.2	17.1	**261**
4	30	18	16.5	13.2	14.2	11.6	12.1	8.8	**252**
4	30	19	14.7	9.3	12.4	8.4	9.7	6.1	**235**

Tower Interference – B Data Bad

MO	DY	TM	A100	B100	A60	B60	A10	B10	WD
4	30	12	13.0	13.4	12.9	13.0	10.7	10.6	192
4	30	13	12.3	14.6	13.0	14.9	11.9	12.4	209
4	30	14	16.6	10.8	16.4	11.8	14.5	9.7	224
4	30	15	22.3	11.9	20.5	13.3	17.9	9.8	238
4	30	16	19.4	9.5	17.9	10.8	15.3	7.8	234
4	30	17	25.8	22.4	23.1	21.1	20.2	17.1	261
4	30	18	16.5	13.2	14.2	11.6	12.1	8.8	252
4	30	19	14.7	9.3	12.4	8.4	9.7	6.1	235

Data Substitution

- Needed to achieve site meteorological data recovery commitments, i.e. 90% or above.
- Challenge is to locate valid data for substitution.

Sources of Substitute Data

- Secondary collocated sensors on same tower
- Secondary tower (i.e. backup tower)
- Data from different level on same tower
- Nearby plant or DOE facility tower data.
- National Weather Service (NWS)
- Farmers' Almanac (probably not!)

Secondary Collocated Sensors

- Best scenario for all parameters.
- Can see side-by-side comparison up to failure.
- Direct substitution with little concern as to whether it is representative.
- Only downside is lightning can take out both sensors at same level. Normally doesn't happen but it did in 2015.

Secondary (Backup) Tower

- Next best scenario for like parameters at similar heights.
- Do not correct data for terrain height differences – meteorology follows the terrain for the most part.
- Make sure secondary tower data is valid – these towers tend to get ignored until needed and then it is too late.

Secondary (Backup) Tower (only 10-meter)

- Direct substitution for 10-meter data on main tower except stability classification.
- For stability, no backup ΔT with one level. Only sigma available from wind direction. Can be substituted but ONLY as sigma and identified as sigma when calculating joint frequency distributions (JFDs).
- Do not substitute 10-meter secondary data for elevated levels on main tower.

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Data from Different Level but on Same Tower

- OK for wind direction in short term cases. Direct substitution.
- Ok for wind speed as long as speed correction is calculated in JFD program.
- If not corrected by JFD program, use log-wind law approximation and correct before direct substitution.

Log Wind Law

$$WS_{60m} = WS_{10m}(Height_{60m}/Height_{10m})^{0.143}$$

- For 10m WS of 8.0 mph, Calculated 60m WS would be 10.4 mph. (+30%)
- Good approximation for near neutral conditions (C,D,E) over gentle terrain.
- Not accurate for strong stable (G) or unstable (A) conditions or for over water.

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Nearby Plant or DOE facility Tower Data

- OK if site is relatively close (<50 miles) and within the same valley, plain, coastline, etc.
- Data have been validated and all bad data removed.
- Sensors meet your approved design specifications for accuracy, threshold, etc
- Do not use data from schools, TV stations , or DOT Highway system. They do not meet minimum specifications.

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National Weather Service Data

- Automated Surface Observation System (ASOS) at most stations now:
  - wind speed threshold design is 2.3 mph (Calms would increase from 1% to 23%!).
  - wind direction reported to nearest 10 degrees.
  - 2 minute average on ½ hour (plus specials).
  - no stability (sigma or ΔT).
- ASOS does not meet <u>minimum</u> Regulatory Guide1.23 or ANSI 3.11 sensor accuracies.

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National Weather Service Data

- Unfortunately, many Plant FSARs/USARs list NWS data as an approved substitution source of meteorological data.
- Bottom line: ASOS data are sufficient for airplane takeoffs and landings, but <u>NOT</u> dose assessment.

What to Use for Stability if ΔT Not Available

- Wind-direction standard deviation:
  - horizontal (sigma Θ).
  - vertical (sigma ϕ).
- Wind speed, cloud cover, time of day.
- Solar radiation/delta-T (SRDT).

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Sigma Θ History in Commercial Nuclear

- Most common method of determining stability next to delta-T (vertical).
- Simple to calculate from wind speed and direction.
- Sunny days result in uneven heating and large horizontal fluctuations.
- Many plants use it as a backup stability to delta-T.

Shortcomings

- Wind-direction meander in light winds at night results in large sigma Θ values.
- Translates into potentially large errors in dose assessment in emergency response situations.
- The NRC-approved <u>modified</u> sigma Θ routine helps by reclassifying A, B, or C stability to D or higher from sunset to sunrise based on wind speed. (Recommended)

Final Thoughts

- Substitute data only when necessary to achieve desired data recovery – i.e 90%, 95%.
- Ensure data are valid and representative.
- Avoid correcting/changing data wherever possible.
- For quality assurance, track substituted data, i.e, by color, notes, etc. Must be able to identify source of substitute data down the road.

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Questions?