AERMOD Sensitivity Analysis With Onsite Meteorological Data

NYSDEC

EPA/State/Local Modelers Workshop

Denver, CO June 10-12, 2008


Syracuse Airport Met Tower
Onondaga On-Site Met Tower
0 0.5 1 2 3 4
Kilometers

Data Collected for Remediation Study Near Onondaga Lake to Model Toxics From Area Sources

- Collected 10m data of wind speed (threshold at 0.15 m/s), wind direction, temperature, delta-T (2-10m), and net radiation (2m).

- Initially proposed to use partial onsite data with Syracuse cloud cover. We recommended use of R_n (day) plus Ri_b (night) method instead.

- Modeling of area source showed very large impacts using Rn-Ri_b method versus cloud cover (CC) results. The former maxima were associated with winds <0.5m/s, Zm & L=1m, nighttime cases, while the CC method impacts had higher Zm and L values.

- A review of the meteorological data indicated larger variability in Zm (and low L) during days associated with the Ri_b method impacts: in some hours calculated Zm was 1m, but a value 100 times higher was assigned by AERMET interpolation from adjacent non-stable hours.

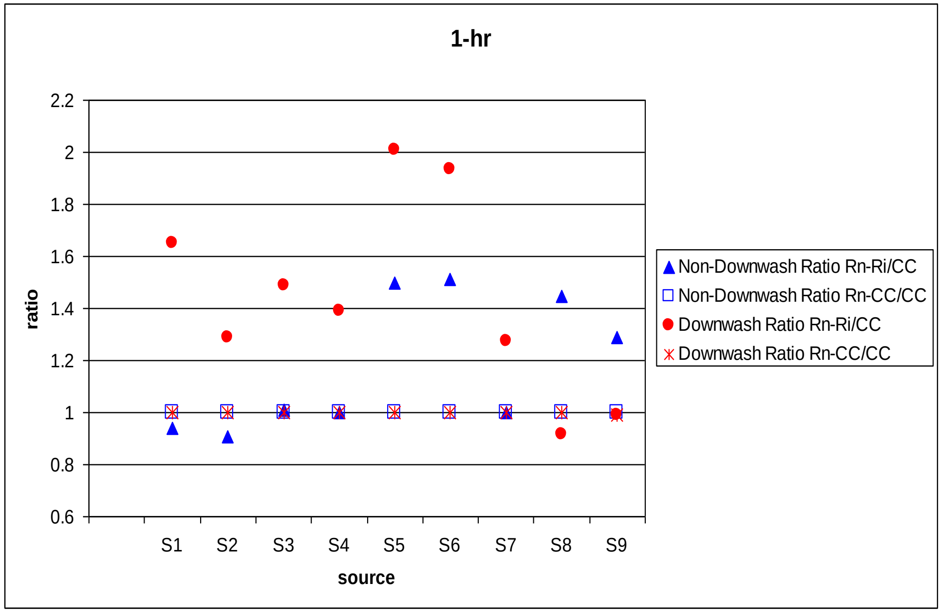
- Prompted an evaluation of the Ri_b method and expanded to a full range of point sources as well.

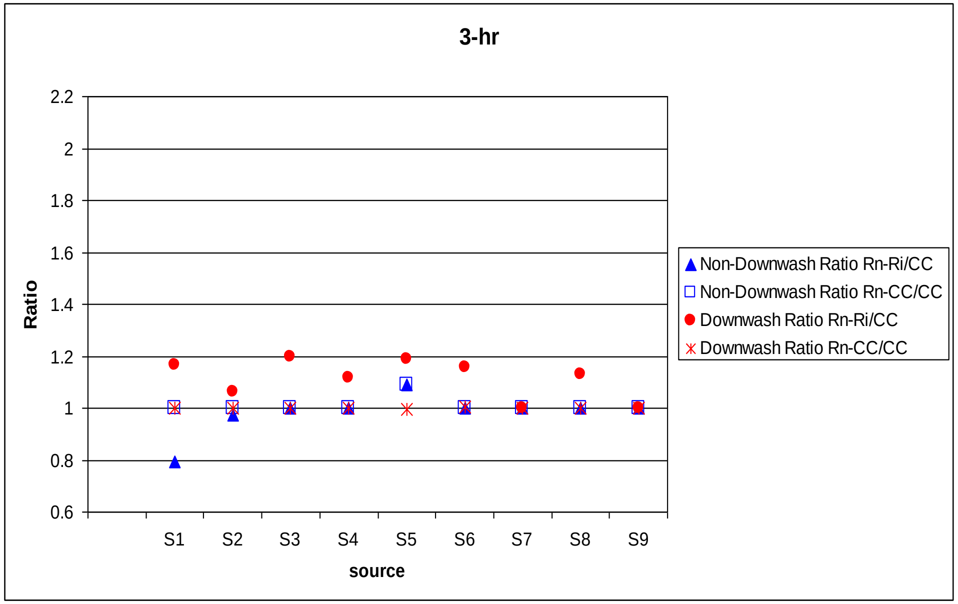
Source Emission Data

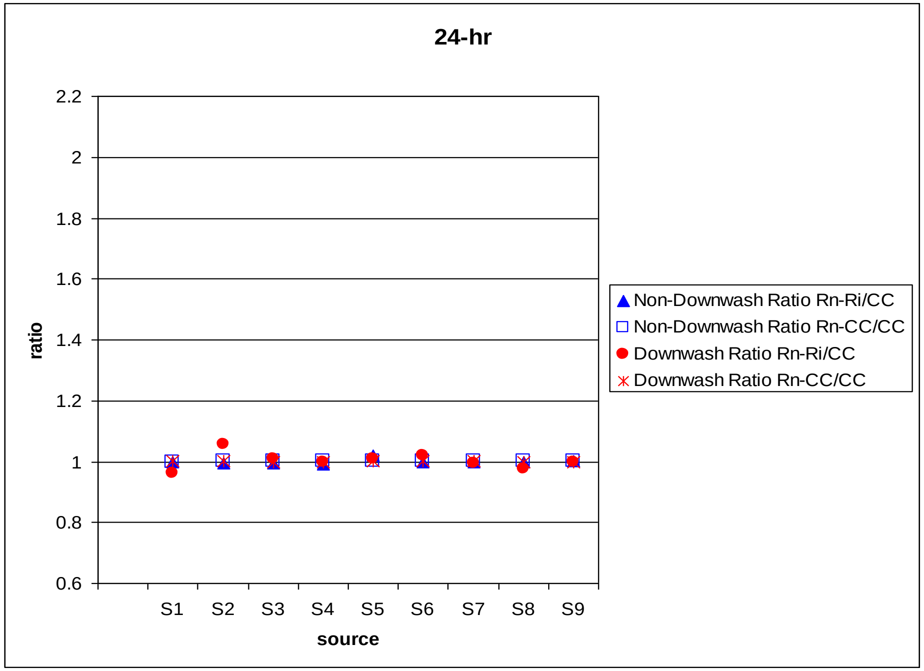
Source No.	Stack Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)	Building Dimensions (m)
S1	10	300	2.5	0.5	8x10x10
S2	10	350	2.5	1.0	10x20x20
S3	25	350	5	2.5	20x30x30
S4	25	400	5	2.5	22x30x30
S5	50	450	5	2.5	40x50x50
S6	50	450	10	5.0	40x50x50
S7	50	550	5	5.0	45x50x50
S8	75	450	10	5.0	50x60x60
S9	75	600	10	5.0	55x60x60
Area	0	250m x 250m			NA
S10	2	293	0.1	0.1	NA

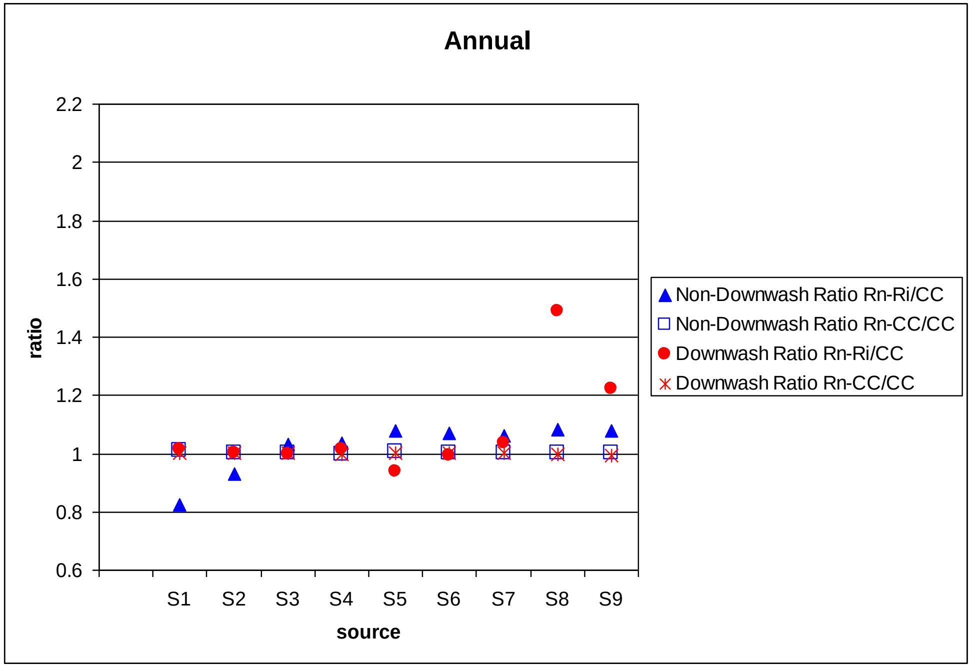
AERMET and AERMOD Setup

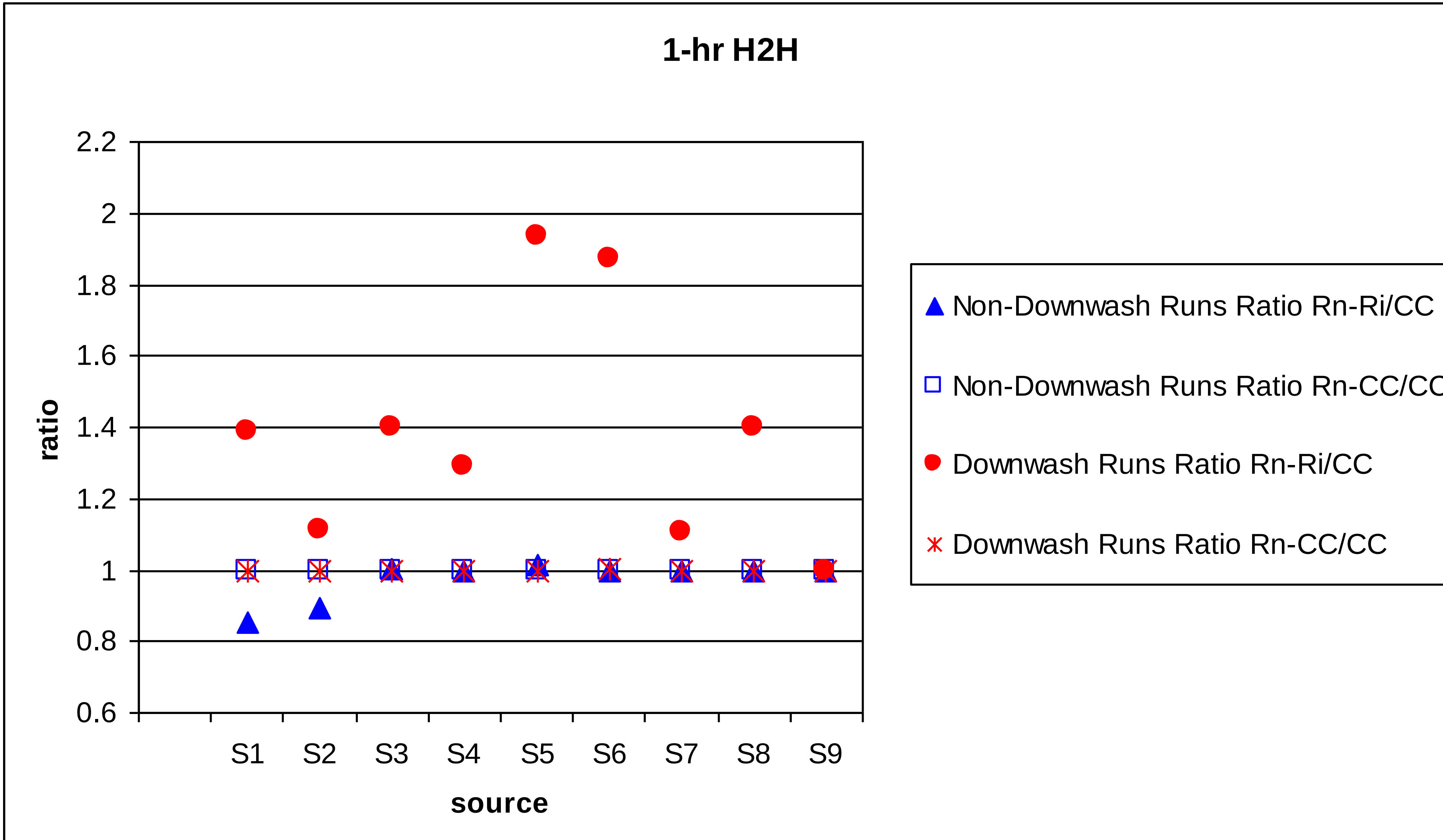
- Three met data sets were produced from 2006 data by combining onsite data and Syracuse cloud cover:
  - 1) all onsite data with Rn-Ri_b method,
  - 2) onsite data, but Syracuse cloud cover (assume no Rn or Ri_b),
  - 3) onsite data with Rn (day), but Syracuse cloud cover at night.
- Unit emission rate, with a polar grid from 100m to 8km, with denser increment (100m) within 1km.
- Land use around the met tower determined by latest AERSURFACE.


1-hr
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
ratio
S1 S2 S3 S4 S5 S6 S7 S8 S9
source
Non-Downwash Ratio Rn-Ri/CC
Non-Downwash Ratio Rn-CC/CC
Downwash Ratio Rn-Ri/CC
Downwash Ratio Rn-CC/CC

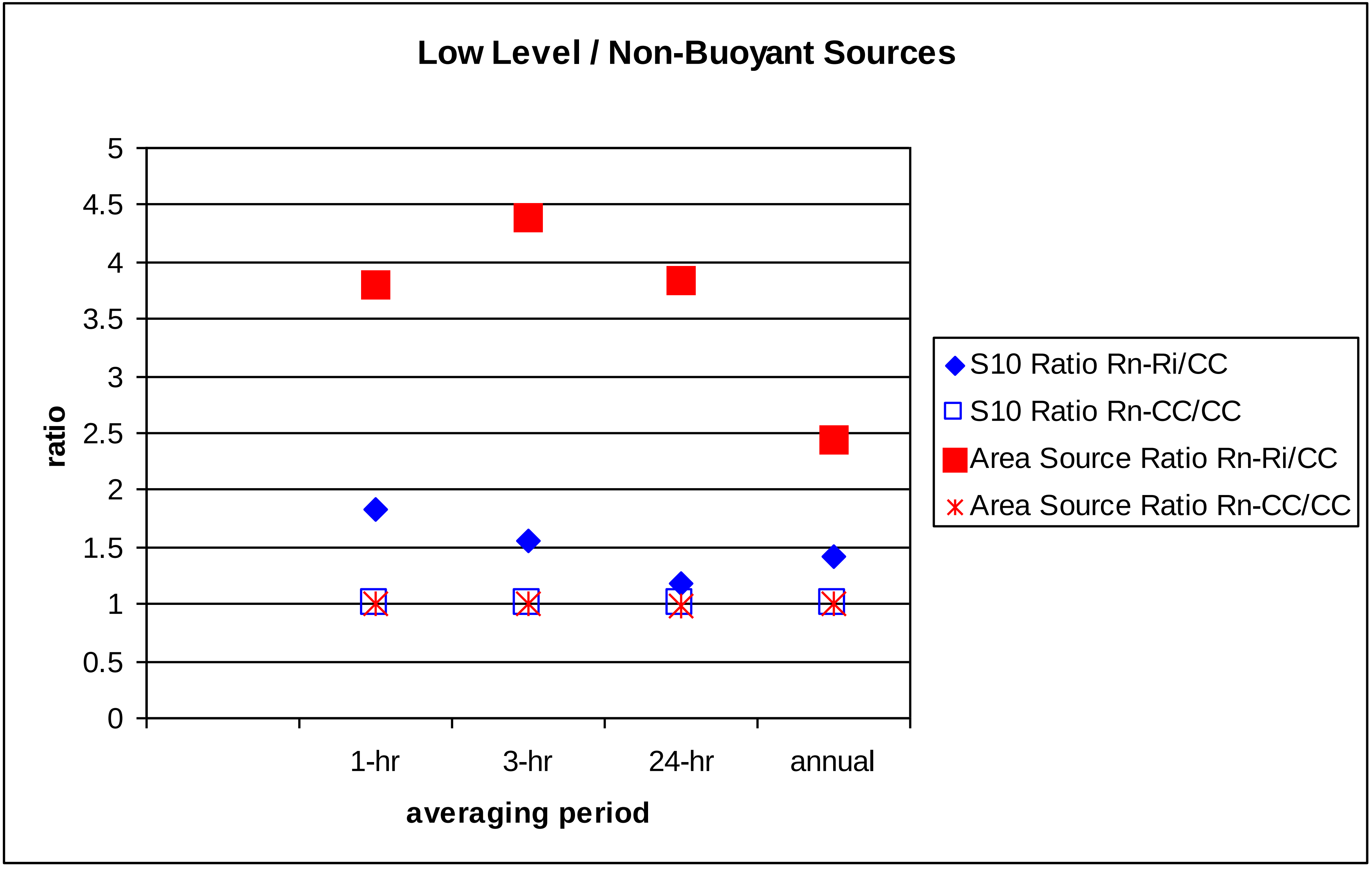

3-hr
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
Ratio
S1 S2 S3 S4 S5 S6 S7 S8 S9
source
Non-Downwash Ratio Rn-Ri/CC
Non-Downwash Ratio Rn-CC/CC
Downwash Ratio Rn-Ri/CC
Downwash Ratio Rn-CC/CC


24-hr
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
ratio
S1 S2 S3 S4 S5 S6 S7 S8 S9
source
Non-Downwash Ratio Rn-Ri/CC
Non-Downwash Ratio Rn-CC/CC
Downwash Ratio Rn-Ri/CC
Downwash Ratio Rn-CC/CC


Annual
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
ratio
S1 S2 S3 S4 S5 S6 S7 S8 S9
source
Non-Downwash Ratio Rn-Ri/CC
Non-Downwash Ratio Rn-CC/CC
Downwash Ratio Rn-Ri/CC
Downwash Ratio Rn-CC/CC



1-hr H2H
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
ratio
S1
S2
S3
S4
S5
S6
S7
S8
S9
source
Non-Downwash Runs Ratio Rn-Ri/CC
Non-Downwash Runs Ratio Rn-CC/CC
Downwash Runs Ratio Rn-Ri/CC
Downwash Runs Ratio Rn-CC/CC


Low Level / Non-Buoyant Sources
ratio
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1-hr
3-hr
24-hr
annual
averaging period
S10 Ratio Rn-Ri/CC
S10 Ratio Rn-CC/CC
Area Source Ratio Rn-Ri/CC
Area Source Ratio Rn-CC/CC

Some Observations

- The Rn-Ri_b 1 hour HSH impacts for the non-downwash cases are equivalent to the CC method, but the impacts for the downwash cases remain higher with this method.

- For normal point sources, all three methods produce similar if not identical maxima, with a distinct exception for the Rn-Ri_b method versus the other two for the 1 hour impacts.

- The Rn-CC method produces essentially the same maxima as the CC method for all sources→ Daytime Rn approach not dominant (see met data below), even for non-downwash elevated sources.

- For the area source, the Rn-Ri_b method produces much larger impacts than the other two methods for all averaging times. This method also produced higher impacts for the non buoyant 2m point source.

Meteorological Data Associated With Top Five 1 Hour Impacts for Select Cases

Case	$H (w/m^2)$	u_*(m/s)	w_* (m/s)	Zm(m)	L(m)	U(m/s)	Zo(m)
Area-Rn-Ri	0 to -.1	.005	0	1 to 6	1	.3 to .5	.3 to .8
Area-CC & Rn-CC	-.1 to -.4	.02	0	4 to 8	2.5	.3 to .5	.1 to.5
S5-Rn-Ri	-20 to -64	.85	0	>1500	>700	5 to 7	.5 to .7
S5-CC & Rn-CC	-30 to -64	.85	0	>1300	>600	4.5 to 7	.67
S8-Rn-Ri	-64	1.7	0	>4000	>5500	11	.67
S8-CC & Rn-CC	-64	1.7	0	>4000	>5500	11	.67
S1(DW)- Rn-Ri	-.1 to -.2	.01	0	1 to 4	1	.5 to .7	.5 to .7
S1(DW)CC&Rn-CC	-1 to -3.6	.04-.08	0	18 - 48	4 – 12	.5 to1.0	.72
S5(DW)-Rn-Ri	-.1 to -.2	.01	0	1 to 11	1	.4 to .7	.72
S5(DW)CC&Rn-CC	-2 to150	.06-.8	0 to 1.8	30/1200	7/-250	.7 - 5.5	.7/.2
S8(DW)- Rn-Ri	-2	.035	0	15 – 50	1.8	1.4	.72
S8(DW)CC&Rn-CC	-4 to 100	.06 -1	0 to 1.4	30/2400	6/-900	1.5 -8.6	.1-.72

Meteorological Data Analysis

- The hours associated with the CC and Rn-CC maxima are identical, with some exceptions for lower h_s /downwash cases.
- Maxima occur under stable/neutral conditions even for higher h_s buoyant non-downwash cases. For the latter sources with downwash, some unstable conditions appear for the CC and Rn-CC methods.
- In some instances (S5 and S8 with no DW) all three methods have identical meteorology → this is forced by AERMET in strong winds where H is limited to -64w/m^2 and u_* and L are recalculated.
- The higher Rn-Ri_b maxima versus the other two methods for the area source, 2m source and S1, S5 with DW are all associated with low U(<0.5m/s), low u_*(<.01), “nighttime” cases (H=0), very low Zm(1 to 10m) and L(1m) values. The corresponding CC and Rn-CC hours have considerably higher values of these parameters.

Reasons for the Impact Differences

- The reason for the larger impacts is the Ri_b method for low winds <1.0m/s. Note: The Prof_UNL method in AERMET performed better than the Prof_LIM method with a limit on L=z/2. Large differences in low L and U (and u_*) occurred between these in very stable cases, but evaluation did not extend to U<0.5m/s.

- The low Zm values are a symptom and not the cause of the high impacts since there are some high impacts under larger Zm cases for the area source and also impacts under RN-CC method have low Zm. This confirmed by artificially setting Zm to 50m for top five 1 hours impacts (technically not valid under AERMET schemes). Got the same results.

- The cause is the very low u_* (e.g. for area sources=0.005 m/s) produced by L interpolation calculation. These produce low mechanically driven σ_w and σ_v values for dispersion coefficients.

Are low u_* values (<.01m/s) realistic?

- Convergence problems noted in initial Ri_b method evaluations with $u_* \rightarrow 0$, but with revised method under stable cases with L=1m, u_* is much larger than found here (min=.03m/s). Also, note that U_{cr} concept not used in Ri_b method.

- The low u_* is responsible for low Z_m from Venkatram's empirical formula, but data he presents shows much higher u_*(.03m/s) as $L \rightarrow 1$ asymptotically. However, none of the data extend to <0.5m/s.

- At z_r>L (cases under study), the specific M-O relationship for non-dimensional Φ_m used in AERMET does not hold. Although part of Carson and Richards equations (from Holtslag) were tested in Ri_b evaluation, it was bound by L=z/2 and did not consider the form for z_r/L>10 (i.e. β=0.8 and not 5; see references by S&B, TTTTS&B). These would produced higher u_*, all other parameters held constant.

Are low u_* values realistic (continued)?

- AERMET formulations in SBL use mechanical σ_w and σ_v which are essentially functions of u_* only and near the surface both are =C X u_* Even though σ_{wm} "residual" is related to U, it →0 near surface. It appears σ_v near the surface is also not effected by the limit placed on it's value at top of Zm and "residual limit" noted for above the mixed layer not used in SBL (with higher implied u. at this limit). These formulations result in low dispersion.

- Data reported by Panofsky (73) shows σ_w=1.3u_* holds for a wide range in stable flow beyond z/L>10 so formulation is OK, but the issue is magnitude. Wyngaard (73) indicates that even in "local z-less stratification" with large z/L, near the surface neutral formulations should still hold and reports minimum u_* =0.1m/s.

- Sutton (53) provides similar values for all but very smooth surfaces and references data showing u_*/U is constant for a given surface for 0.2<U<5m/s. In these conditions u_* is minimum 5% of U→ in our low U cases u_* should be larger (>0.02m/s).

Implications and Possible Solutions

- Large impacts for area sources could be unrealistic overestimates. Interim solution: used Rn-CC method for project at hand.

- Resetting U threshold in AERMET to 0.5m/s instead of AERMET's 0.28m/s limit for onsite data and running the area source case with Ri_b method gave same magnitude impacts. Not a solution.

- A lower limit to u_* should be established in low U-stable cases. At least near surface, can use σ_v =0.2m/s used for U threshold and combining with σ^2_v=3.6u^2_*, results in minimum u_*=0.1m/s.

- The formulation for Ri_b interpolation should be revisited for large z/L. However, the concentration data tested (e.g. CCB) either used observed σs or were for U>0.5m/s, so it will be hard to retest.