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Introduction

This informal letter report has four objectives: (1) to illustrate the concept of the linear response model and explain how the models will be implemented in the Rooftop Unit Comparison Calculator (RTUCC), (2) demonstrate how this response data can be extracted from EnergyPlus runs, (3) justify a simplified representation method, and (4) document the supporting EnergyPlus runs and post-processing analysis.

The RTUCC uses a binned-weather analysis to estimate building loads and predict a corresponding air conditioning system's energy use. A fundamental part of this analysis is a linear model (see Figure 1) that is used to represent the buildings thermal response to outdoor temperature and its internal loads.

The linear response model predicts the thermal load on a building's cooling system as affected by the temperature differential between the outdoor and indoor temperature. This response reflects the nature of the physical building and its internal loads.

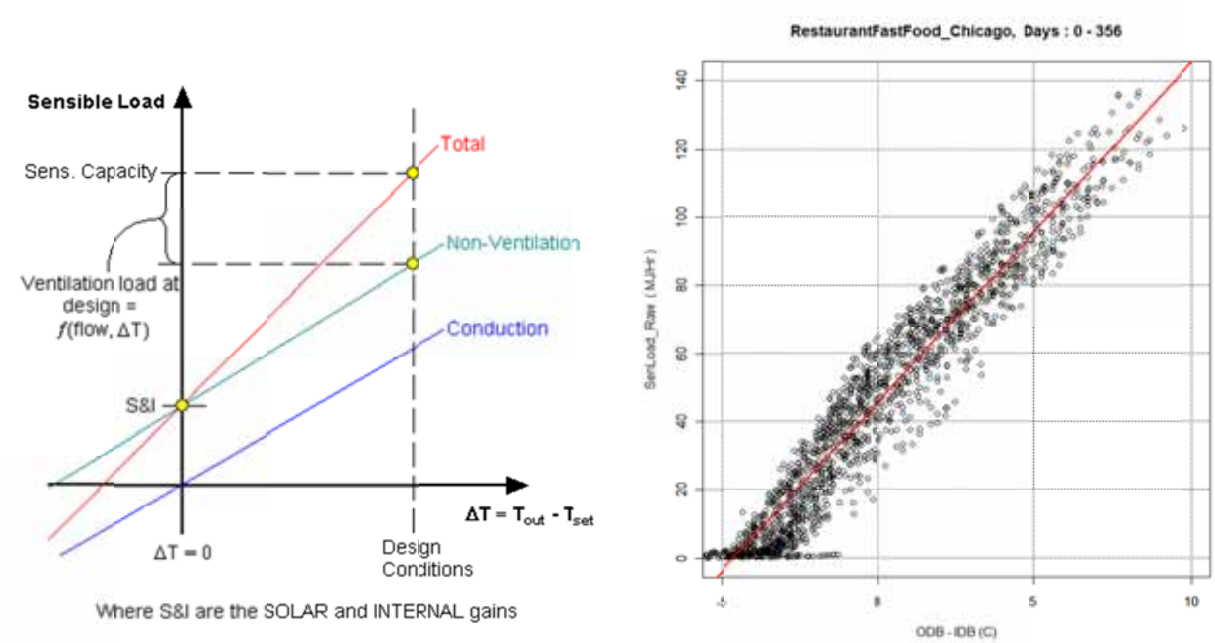


Figure 1. Load-line concept drawing and corresponding example EnergyPlus data.

The analysis in this report serves to establish the slope and intercept of the load line (see red lines in Figure 1). This is done by modeling the aggregate sensible load as a linear function of the indoor-outdoor temperature differential.

These response models are shown in this report to be approximately independent of the weather data driving the EnergyPlus runs. This means that one response model can be used to represent one building type at a variety of locations. Hotter climates will have more operation hours at higher delta-T, but the slope and the intercept will be similar to those seen in cooler climates.

Implementation of the response model in the RTU CC is done by using the model to do a simple calculation of the S&I fraction as affected by the cities design temperature. The S&I fraction is defined in the RTU CC as follows:

$$S\,\&\,I \equiv \frac{F(\Delta T = 0)}{F(\Delta T = T_{design} - T_{set})}$$

In words, this equation says the S&I fraction in the RTU CC is defined to be the ratio of the load at neutral conditions (when outdoor temperature equals the indoor setpoint) to the load at design conditions. At neutral conditions, the load is primarily caused by solar and internal effects (this is the motivation for the S&I name). A particular building design operating in a cooler climate will have a higher S&I fraction than the same building running in a hot climate. One response model, for one building type, predicts a different S&I fraction for each climate, depending on its design temperature. As expected, internal loads are a larger fraction of the design load in cooler climates.

The S&I fraction can also be thought of as a mechanism to scale the response model to match the capacity of the unit, being simulated in the RTU CC, at the cities design conditions. This scaling process preserves the ratio between the slope and intercept of the response model.

An implicit assumption in this approach is that the response model scales simply with building size. “Simple scaling” means that the two parameters in the model, the slope and the intercept, both scale at the same rate as the building size increases or decreases. Improvements on this assumption could possibly be incorporated by considering that internal loads and ventilation loads may scale with floor area and that the conduction loads may scale with external envelope area. The geometry of the building could be used to establish different scaling factors for the two model parameters.

Ideally a sensible-load model is preferred. Sensible models best reflect how a DX system works to remove sensible loads as dictated by a sensible thermostat. It will be shown in this report that total-load models make reasonable substitutes for the preferred sensible models, especially with building simulations where the sensible loads are not available.

An additional characterization of the building is done by modeling the ventilation-sensible-load line. The slope of this line can be compared to the slope of the total-sensible-load line. The ratio of the two slopes (ventilation-sensible-load slope / total-sensible-load slope) is a good indicator of the factional contribution of ventilation in the load line. If the ratio is 0.6, that means 60% of the temperature-dependent response is attributable to ventilation. This ratio is the third parameter that will be used to characterize a building type. This parameter (for a type of building), and a city’s design conditions, will be used in the RTUCC to establish default ventilation rates.

Summary of Findings

- Variations between response models, by building type, is significant enough to justify a representative model for each building type.
- A building response model developed in Chicago is sufficient for representing similar buildings in different climate zones.
- Total and sensible load models both produce similar results in calculating S&I fractions.
- Models can be developed without turning off setback or ventilation in the building. IDF input modifications are only needed to change reporting variables.

	Building Type	Slope (MJ/HrC)	Intercept (MJ/Hr)	I/S (C)	Slope (KBTU/HrF)	Intercept (KBTU/Hr)	I/S (F)	Ventilation Fraction	Assumed VF
1	Apartment-Midrise	12.3	128.3	10.4	6.5	121.6	18.7	NA	0.30
2	Apartment-Highrise								
3	Healthcare-Hospital	55.8	1370.0	24.6	29.4	1298.5	44.2	NA	0.80
4	Healthcare-Outpatient	41.8	704.0	16.8	22.0	667.3	30.3	0.05	0.25
5	Hotel-Small								
6	Hotel-Large	149.5	1313.0	8.8	78.7	1244.5	15.8	0.96	0.60
7	Office-Small	3.5	43.4	12.5	1.8	41.1	22.6	0.32	------
8	Office-Medium	33.7	382.0	11.3	17.7	362.1	20.4	0.50	------
9	Office-Large	410.0	4250.0	10.4	215.9	4028.2	18.7	0.69	------
10	Restaurant-FastFood	10.0	45.8	4.6	5.2	43.4	8.3	0.76	------
11	Restaurant-SitDown	17.7	98.0	5.6	9.3	92.9	10.0	0.79	------
12	Retail-StandAlone	26.5	245.4	9.3	14.0	232.6	16.7	0.63	------
13	Retail-StripMall	35.4	187.2	5.3	18.6	177.4	9.5	0.40	------
14	School-Primary	63.5	718.0	11.3	33.4	680.5	20.4	0.61	------
15	School-Secondary	95.0	779.0	8.2	50.0	738.4	14.8	0.13	0.40
16	Warehouse	7.1	5.7	0.8	3.7	5.4	1.4	0.21	------

Table 1 Summary of Run Results: "Slope" and "Intercept" columns are shown in both Metric and English units. The "I/S" columns are the ratio of the intercept to the slope and are an indicator of the degree of internal loading in the structure (high for Hospital, low for warehouse). The "Ventilation Fraction" column is the fraction of the slope in the load model that is attributable to ventilation. The "Assumed" column indicates a ventilation-fraction value that is currently being used in the RTUCC in substitution of the run result. The slope

As of the time of this writing, five of the ventilation levels are intended for future review (see yellow cells). These values were either not extractable from this initial EnergyPlus analysis or the determined values were considered significantly different from intuitively expected levels. The RTUCC is not sensitive to the ventilation-fraction values. The load slope and load intercept are more critical. The ventilation-fraction values that are actually used in the RTUCC are show in the far right column, "Assumed VF".

EnergyPlus Output and Post Processing

The hourly report (the csv file produced by EnergyPlus) is post processed using R, a statistics analysis language. R scripts are run for each building to scan in the csv file and analyze the hourly record.

IDF Files

In support of the ASHRAE Standard 90.1 Committee, PNNL developed a suite of 16 prototype building models in EnergyPlus. There are 17 different models for each of the building types. Each model complies with the prescriptive requirements of Standard 90.1, 2004 in each of the 17 DOE climate zones.

The 2004 versions of the IDF input files, representing various building types, were obtained from this PNNL network location:

\\korea\comstd\ASHRAE189.1

Here is an example folder path to a specific building type (OfficeMedium):
\\korea\comstd\ASHRAE189.1\OfficeMedium\189.1.std2009\input.nobackup

Example filename: ASHRAE30pct_OfficeMedium_STD2004_Chicago.idf

(Note: at the time of this writing, the restaurant IDF file was unintentionally a 2010 version.)

Output Variables

Loads

DXCOIL.DX.Coil.Sensible.Cooling.Energy.J..Hourly. (DX only, gross sensible cooling by system)
DXCOIL.DX.Coil.Total.Cooling.Energy.J..Hourly. (DX only, gross total (=S+L) cooling)
Air.Loop.Total.Cooling.Coil.Energy.J..Hourly. (Includes both DX and Chiller, gross total (=S+L) cooling)

Zone.Sys.Sensible.Cooling.Energy..J..Hourly. (Net sensible cooling, after economizer and reheat, delivered to zones. Includes sensible cooling delivered to zone when coils are off, such as economizer.)

Air.Loop.Total.Heating.Coil.Energy.J..Hourly. (Heating done by system. Includes reheat.)

Ventilation

Zone.Mechanical.Ventilation.Mass.Flow.Rate..kg.s..Hourly.
Zone.Mechanical.Ventilation.Volume.Flow.Rate.Current.Density..m3.s..Hourly.
Zone.Mechanical.Ventilation.Cooling.Load.Increase..J..Hourly.

Indoor Air

Zone.Mean.Air.Temperature..C..Hourly.
Zone.Mean.Air.Humidity.Ratio....Hourly.

Outdoor Air

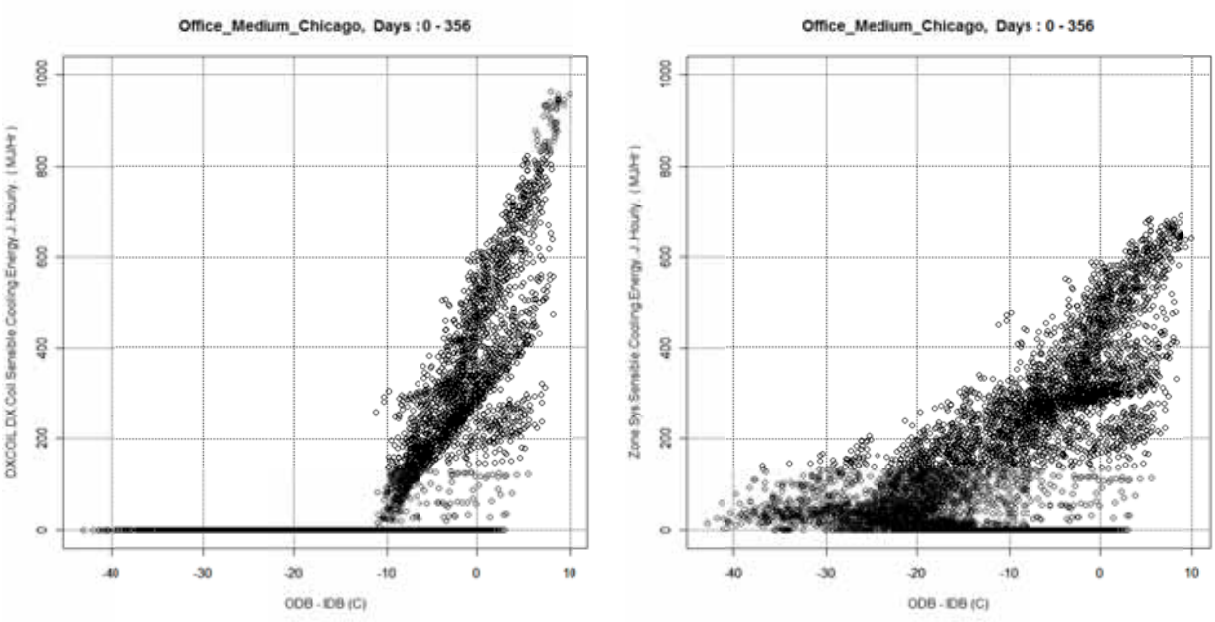
Environment.Outdoor.Dry.Bulb..C..Hourly.
Environment.Outdoor.Wet.Bulb..C..Hourly.

Environment.Outdoor.Barometric.Pressure..Pa..Hourly.
Environment.Outdoor.Air.Density..kg.m3..Hourly.

Electricity Consumption

Air Loop DX Cooling Coil Electric Consumption (compressor and condenser fan)
Air Loop Fan Electric Consumption (fans: not sure if this is all fans or just the evaporator)

Post Processing in R



These two plots contrast the two sensible-load report variables. In the left plot, DXCOIL.DX.Coil.Sensible is an aggregate (sum) of all the air-loop (system) sensible coil loads (energy removed by coils). The right, Zone.Sys.Sensible, is an aggregate (sum) of all the sensible cooling delivered to the zones. The zone result (right) includes all sensible cooling delivered to the zone, even when the compressor is off. There is likely economizer cooling (compressor off) in the zone aggregate.

It is difficult to assess with certainty if these loads are net after the re-heat. However, descriptions in the EnergyPlus Input/Output reference lead the reader to assume the zone report (right plot) is a net effect (net cooling delivered to the zone, after reheat and economizing). The air-loop report (left plot) is strictly the output of the cooling coil (gross) needed to satisfy the thermostatic control. The air-loop cooling is the gross coil cooling needed to satisfy all sensible loads, including reheat. The two plots above support this interpretation, the right plot shows lower peak values in hot weather (because they are net) and more cooling in cool weather (because of economizing).

Annual sums for two plots above: Coil Loads = 9.13654e+11 (J), Zone Cooling = 1.208048e+12 (J)

The air-loop (or system) variable best reflects how hard the system has to work to satisfy all the loads. For this reason, this, or related system variables, will be the basis for developing response models.

In the analysis that follows, load variables are used as follows:

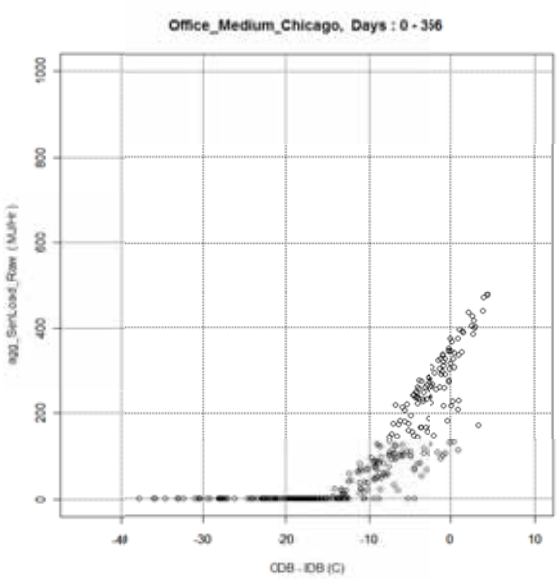
DXCOIL.DX.Coil.Sensible.Cooling.Energy is used whenever there is only DX cooling. Note that sensible coil load analysis is not possible in EnergyPlus if there is no DX cooling. System (Air.Loop) variables, such as Air.Loop.Total.Cooling.Coil, only have total (=S+L) versions.

DXCOIL.DX.Coil.Total.Cooling.Energy and Air.Loop.Total.Cooling.Coil.Energy are equivalent if there is only DX cooling. If there is both DX and chiller, the DXCOIL.DX.Coil.Total will provide the DX portion of the total (=S+L) cooling. If there is both DX and chiller, the Air.Loop.Total variable will provide a sum of the DX and chiller coil cooling.

In the R modeling of the loads, a "bottom scraping" approach is used to subset the hourly data. This removes zero-value or near-zero value loads before regression is done. (Zero level loads are clearly visible in the raw load plot on the previous page.) The idea here is that zeros should not contribute to the regression; the model should reflect the loads presented to and processed by the system. Including zeros in the regressions inappropriately lowers the predictions of the load model. The default scraping mode (**GEZ**), is to **E**xclude **Z**ero-value loads and any load data occurring at temperatures lower than the lowest **G**reater-than-**Z**ero load. An alternate approach (**GM**) is used on some buildings that produce a large number of near-zero loads. The GM approach accepts all data that is **G**reater than a minimum value as establish as a fraction of the **M**aximum hourly load. In this approach, the tolerance for ground clutter (near-zero values) can be varied to see at what level their effect stops. The lowest tolerance that eliminates the effect is used.

Loads are aggregated (summed) with similar systems or zones. For example, the Medium Office building has three DX systems supporting three air loops. These are summed to produce an aggregate DX load.

Indoor temperature is calculated as an average of the zone temperatures. These are not weighted by zone size, only a simple average. For some buildings unconditioned zones may be excluded from the average. For example, the Fast Food Restaurant building has an unconditioned attic zone that basically floats at the outdoor temperature; this is excluded from the temperature average.



Ventilation loads are calculated (in R post processing) for any zone reporting mechanical ventilation. Standard ASHRAE algorithms are used to calculate sensible and total ventilation loads. The calculation uses indoor and outdoor psychrometric conditions and reported hourly air-mass flows. Ventilations loads are calculated at the zone level and then aggregated to produce a building sum.

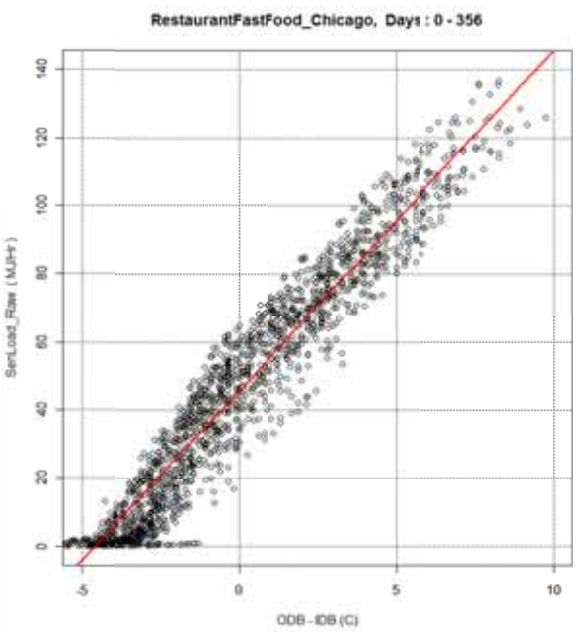
The option of producing daily average loads was considered. The plot at the left (Figure 2) shows daily average loads for the DXCOIL.DX plot above. This plot includes the zero-value points in the daily average, this inclusion reduces the slope. This approach was not used in the end mainly because the hourly approach

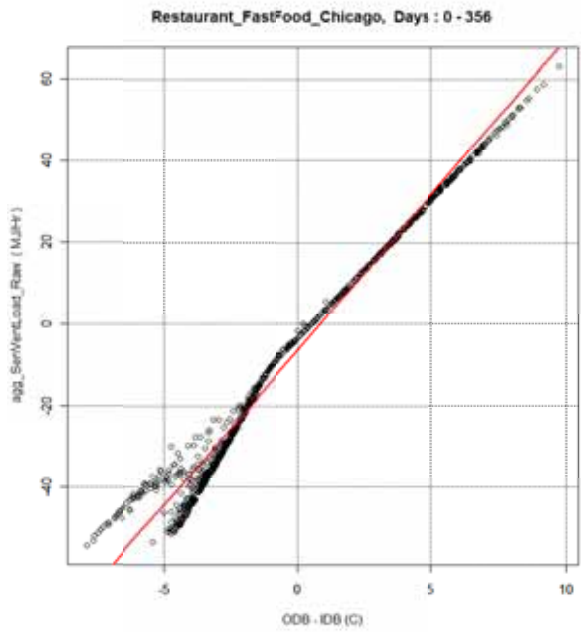
offered more control over excluding the near-zero value points. Also, with the hourly approach, it is clearer to the reader which points have been excluded.

The following sections have the detailed post processing results that are in support of the findings.

Restaurant-FastFood-Chicago

Sensible Load





Intercept = 45.8 +/- 0.2

Slope = 9.97 +/- 0.07

Slope = 7.61 +/- 0.03

Slope Fraction = 7.61/9.97 = 0.76

Chicago DT = 7.5	SI Fraction = 0.38
SanFran DT = 0.8	SI Fraction = 0.86
Phoenix DT = 18.0	SI Fraction = 0.20

The post-processing analysis output for this first example run is explained here in detail. Most of the following runs will show a similar output. Differences are noted.

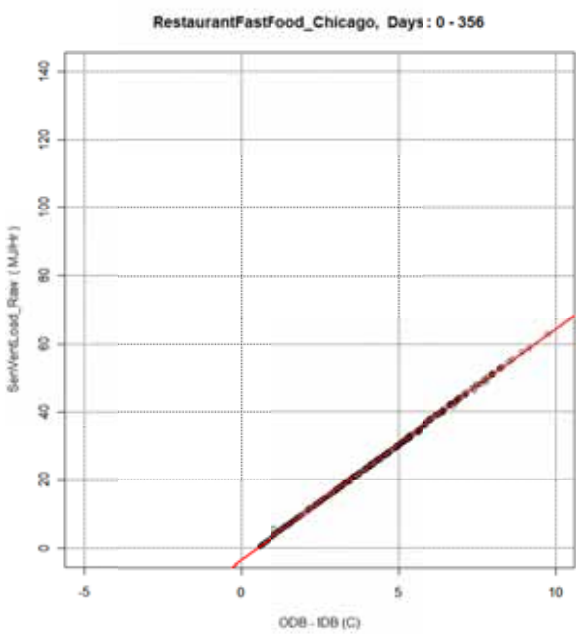
There are two plots shown. The sum of the sensible-coil loads (left) and the sum of the sensible-ventilation loads (right). Both plots are as a function of the outdoor-indoor temperature differential. Both plot show a linear-model line in red. The plot title identifies the building type and any special adaptations done to the IDF input file. The title also identifies the range of days included in the plot.

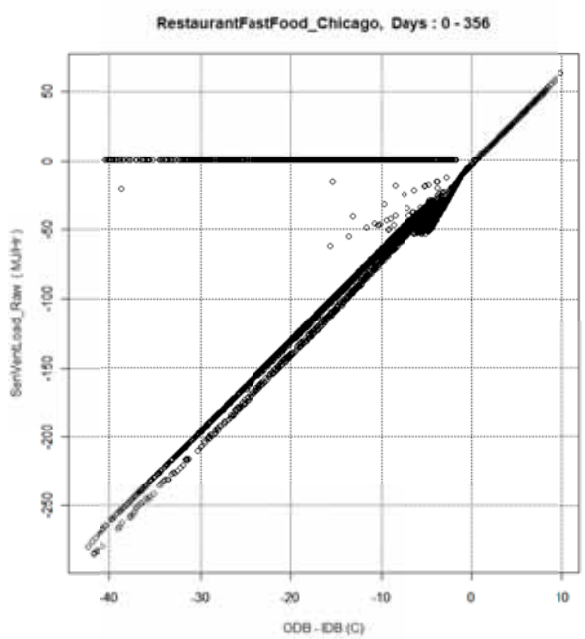
Slope and intercept are reported for the coil-load model. Only slope is reported for the ventilation model (generally ventilation models have a zero or a nearly zero intercept). The slope and intercept form the main part of coil-load response model. This is then used to calculate the S&I fraction as defined in the equation in the introduction (this is done for three example cities; see turquoise highlight). For this case, the fraction of response due to ventilation is 7.61/9.97 = 0.763. This is shown after the ventilation slope, under the ventilation plot. This slope fraction is the third parameter needed for the building response signature (all three parts shown in yellow highlight).

Here is an example call to the scripted R plotting functions that are used to plot the data and produce the regression model.:

```
Scan(blnReScan = TRUE, strMainDirectory="Restaurant_FastFood_Chicago", strSubDirectory="")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenLoad_Raw", "GM", strUnits="MJ/Hr", ymin_fraction=0.00, strFitMode="T", myYlim=c(0,140), myXlim=c(-10,10))
PlotVsTemp("DT", "CR", c(0,356), "agg_SenVentLoad_Raw", "LF", strUnits="MJ/Hr", ymin_fraction=0.00, strFitMode="T", blnNoIntercept="T")
```

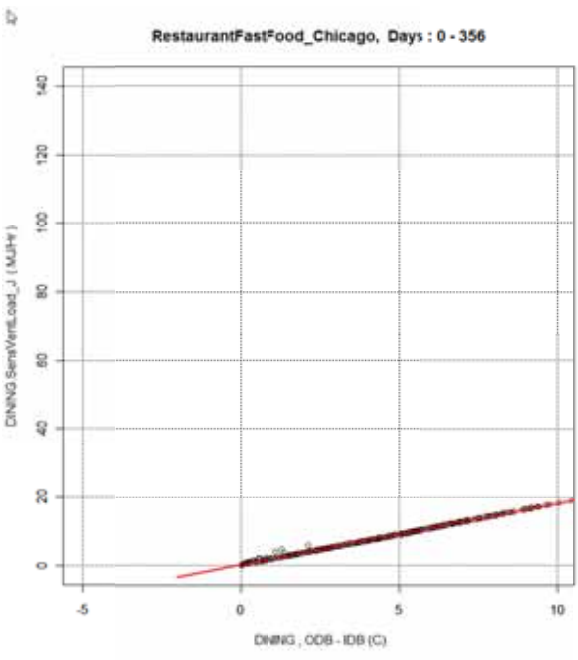
Sensible Ventilation Load

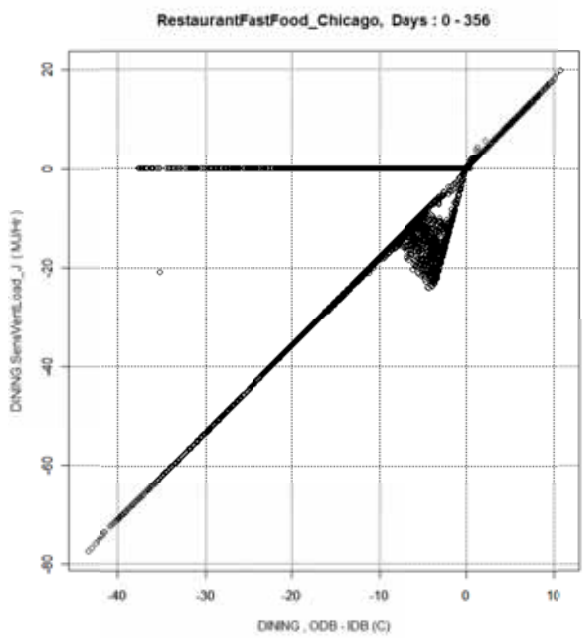




Slope = 6.8

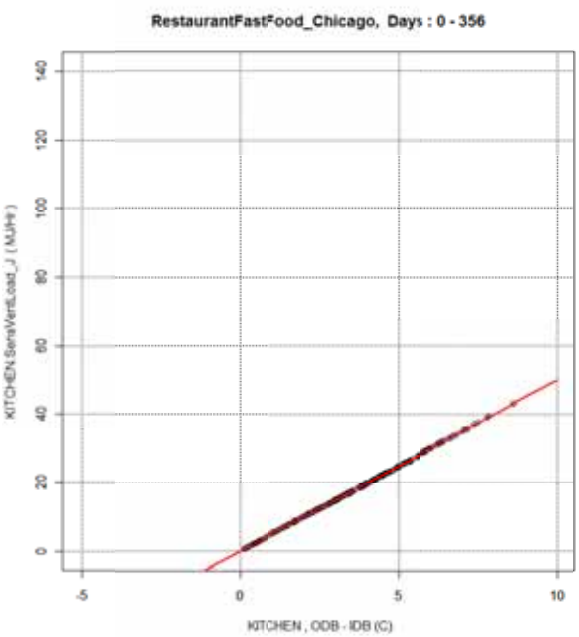
Left plot shows the aggregate ventilation load for both kitchen and dining zones. The inside temperature is a simple average of the two zone temperature. Raw plot on the right also includes loads less than or equal to zero. This is shown here for comparison to the following two individual-zone plots. This demonstrates the model slope for aggregate zone plot is equal to the sum of the two individual-zone model slopes (1.8 + 5.0 = 6.8). The right side plot shows the raw, unfiltered, load data.

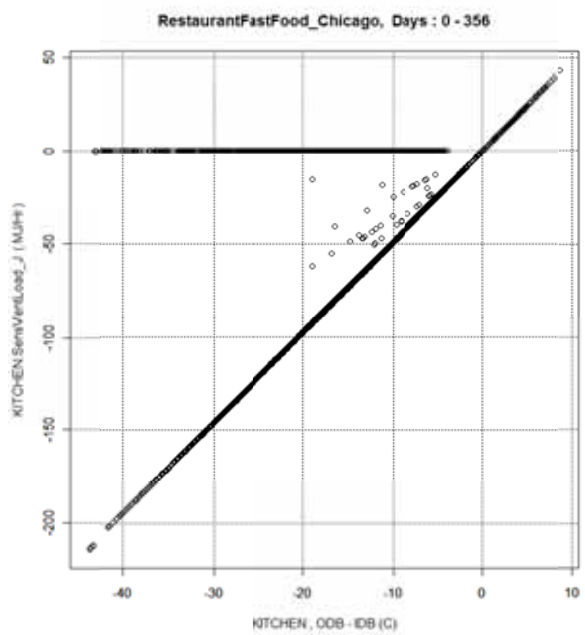




Slope = 1.8

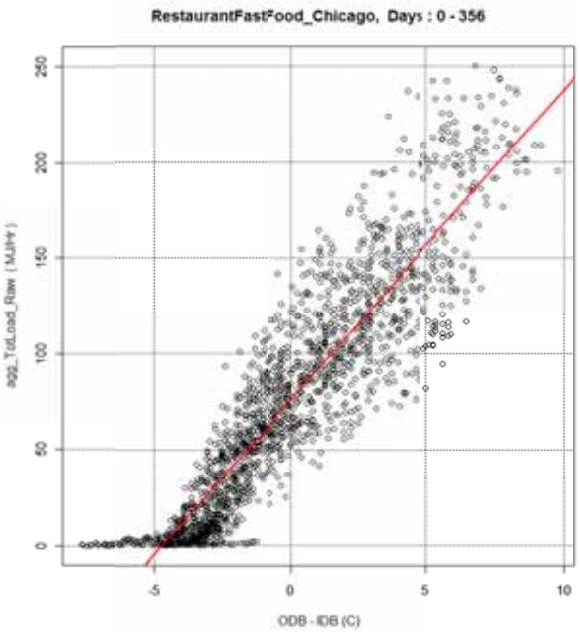
Plots above and below show single zone ventilation load plot. These plots are show to demonstrate that the sum of the two zone slopes is equal to the slope in the aggregate plot (1.8 + 5.0 = 6.8).

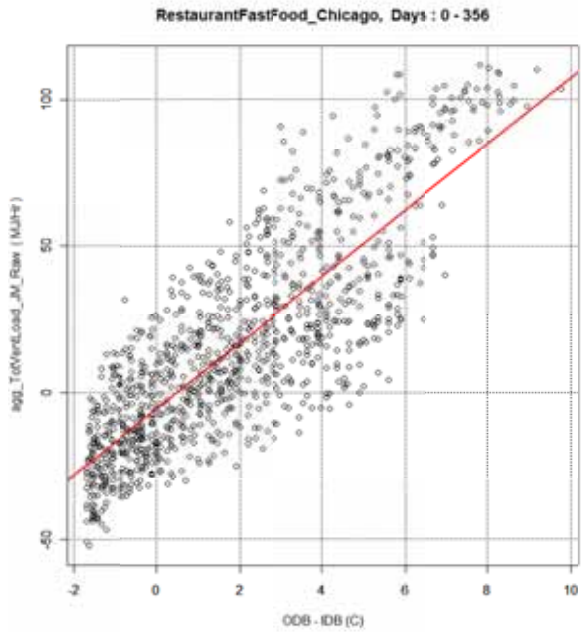




Slope = 5.0

Total (=sensible+latent) Loads





Intercept = 76.28

Slope = 16.16

Chicago DT = 7.5 SI Fraction = 0.39

SanFran DT = 0.8 SI Fraction = 0.86

Phoenix DT = 18 SI Fraction = 0.21

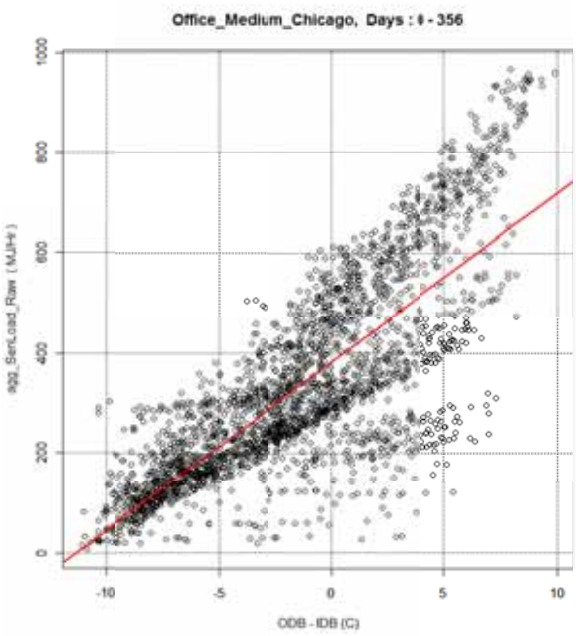
Slope = 11.31; Fraction is 11.31/16.16 = 0.70

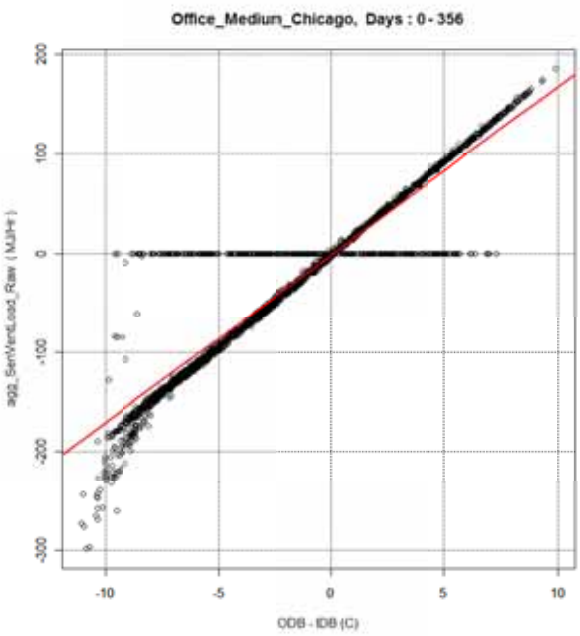
These total (sensible + latent) load plots illustrate how the response model (from total loads) produces S&I fraction calculations very similar to those resulting from the sensible analysis. This also demonstrates that the percentage of the ventilation line is similar to that in the sensible analysis. This result justifies using the total load data for those buildings that do not have DX cooling systems.

Office-Medium-Chicago

Sensible Loads

Chicago Weather





Intercept = 382 +/- 2

Slope = 33.7 +/- 0.5

Slope = 16.91 +/- 0.13; Fraction = 0.50

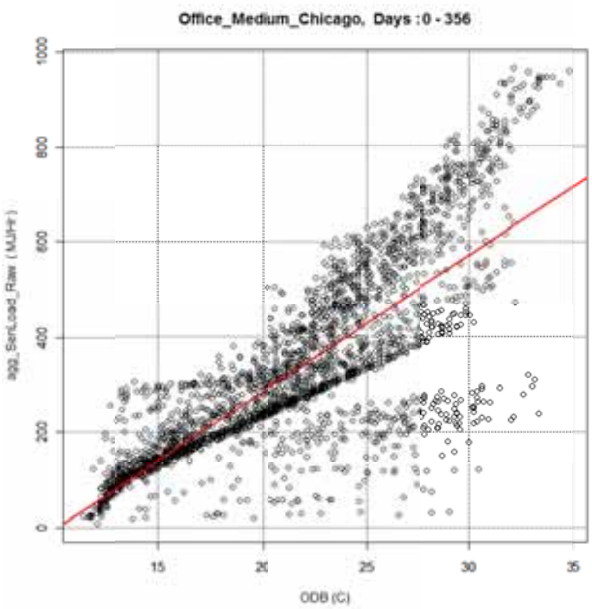
Chicago DT = 7.5 SI Fraction = 0.6

SanFran DT = 0.8 SI Fraction = 0.94

Phoenix DT = 18 SI Fraction = 0.39

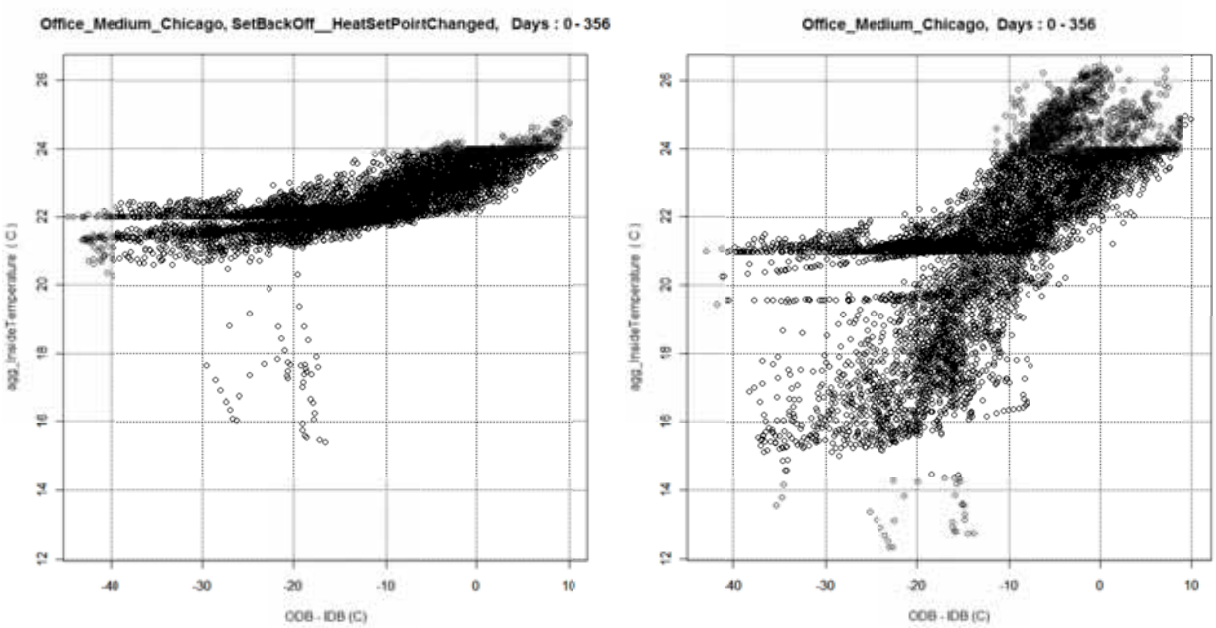
This is the baseline case: the Chicago version of the Medium Office building, run with Chicago weather. This case will be compared to other cases where the Medium-Office-Chicago building is run with different weather data. It will also be compared to a different city version of the Medium-Office building run with the corresponding weather data.

Simple Outdoor Temperature Plot



This Medium-Office-Chicago plot uses the raw Outdoor DryBulb (ODB) temperature, not the ΔT that is based on the aggregate zone temperature as is used in previous plots. Correlation levels are similar; some parts of the data appear more tightly correlated. The ΔT plot offers independence from thermostat setpoint and setback.

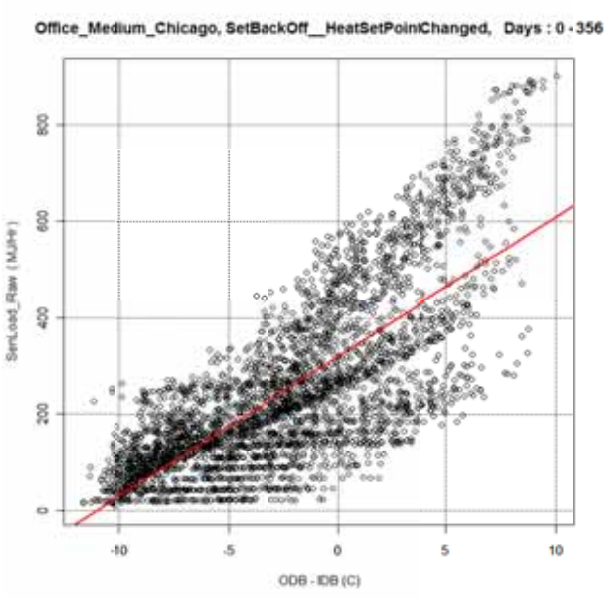
Setback Turned Off

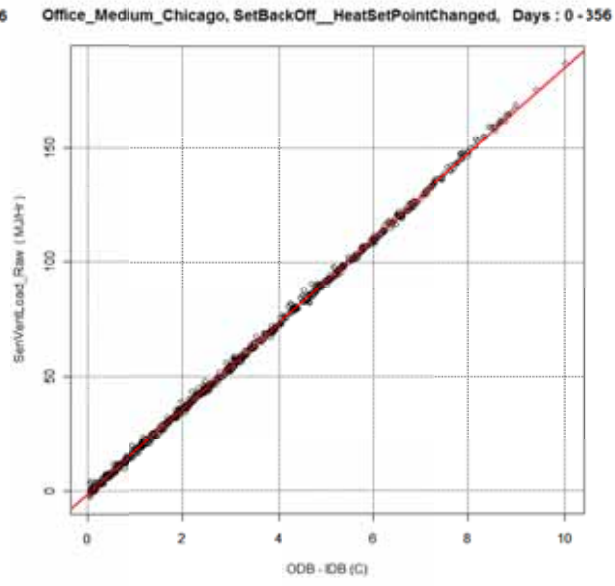


These zone-aggregated temperature plots are here to illustrate the effect of turning off setback in the IDF file. The left plot has setback turned off and has a higher winter setpoint. The right one uses setpoints and setback and corresponds to the base case Chicago run. The next page shows the impact on the cooling-load response model as caused by removing setback.

Call parameters:

PlotVsTemp("DT", "CR", c(0,356), "agg_InsideTemperature", "raw", strUnits="C", ymin_fraction=0.0, strFitMode="F", myYlim=c(12.5,26.2),myXlim=c(-43,10))





Intercept = 320.4

Slope = 28.87

Slope = 18.67; fraction = 18.67/28.87 = 0.65

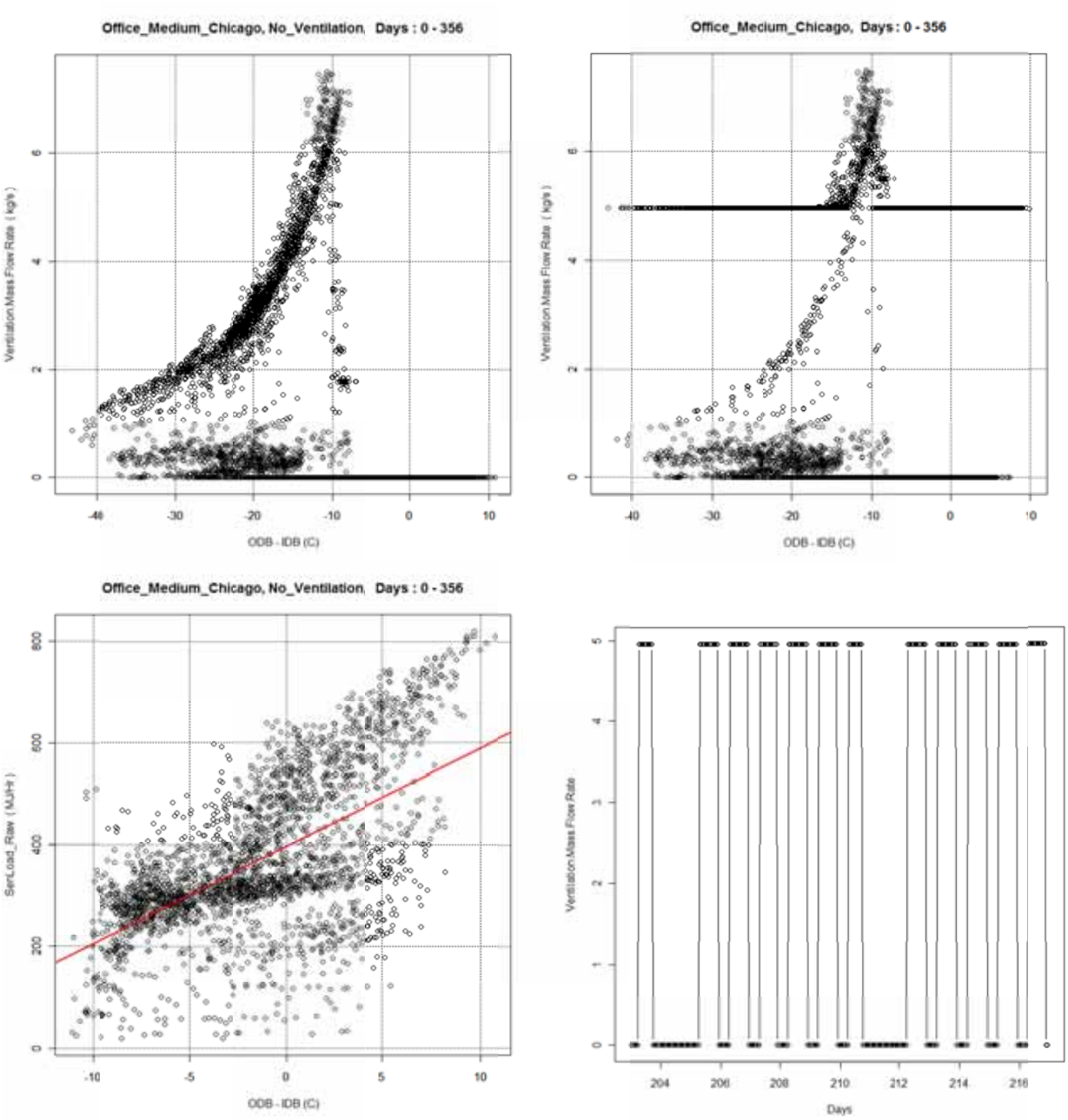
Chicago DT = 7.5 SI Fraction = 0.6

SanFran DT = 0.8 SI Fraction = 0.93

Phoenix DT = 18 SI Fraction = 0.38

In this case the setback has been turned off. Refer to previous page for illustrating temperature plot. The effect on the load model is small.

No Ventilation

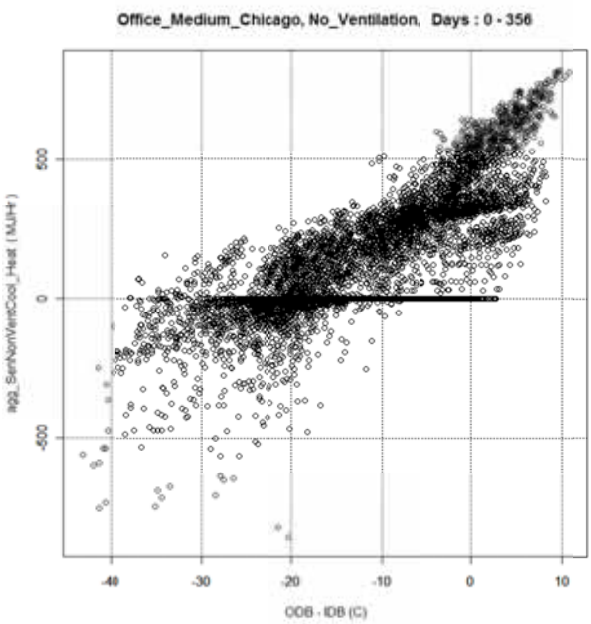


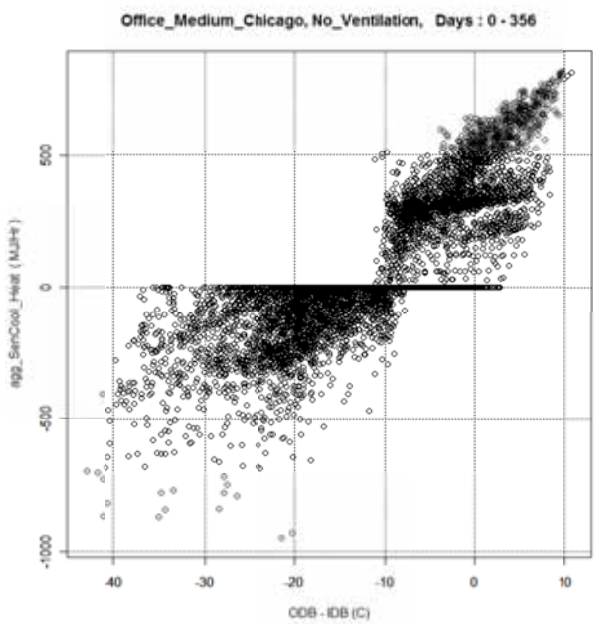
Slope = 19.19

These plots illustrate the effect of turning off mechanical ventilation in the IDF file. The two plots on the right show the base case with ventilation on (bottom right shows daily pattern). For the two plots on the left, the mechanical cooling ventilation has been effectively turned off. There appears to still be some ventilation in the heating season.

The end result of assessing ventilation levels this way is similar to when done by calculating ventilation loads in post processing. The slope (19.2) in the load line above is reasonably close that which would be

predicted by subtracting the slope of the calculated ventilation load from the slope of the ventilated load line (33.7 - 18.7 = 15.0).





The two plots above are an attempt to show the buildings heating and cooling loads on the same plot. The thought here is that, together, the heating and cooling loads might give a cleaner overall picture of the building response to outdoor temperature.

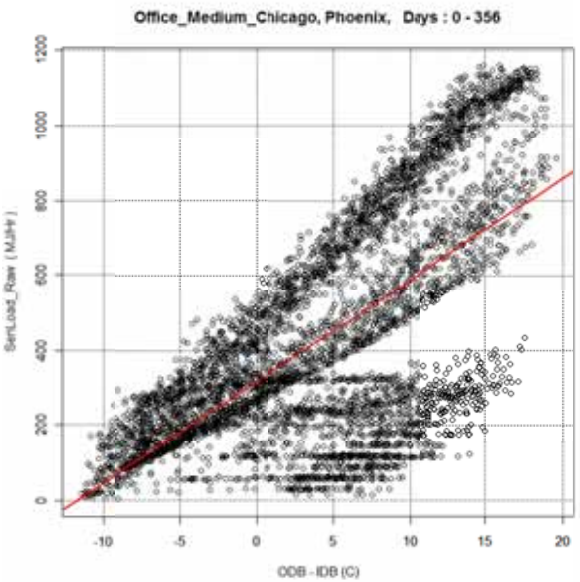
Heating loads are assigned negative values and then added to the time series of cooling loads. Both plots have the mechanical ventilation turned off in their IDF file. (Remember, this shutdown left some mechanical ventilation in the heating season.)

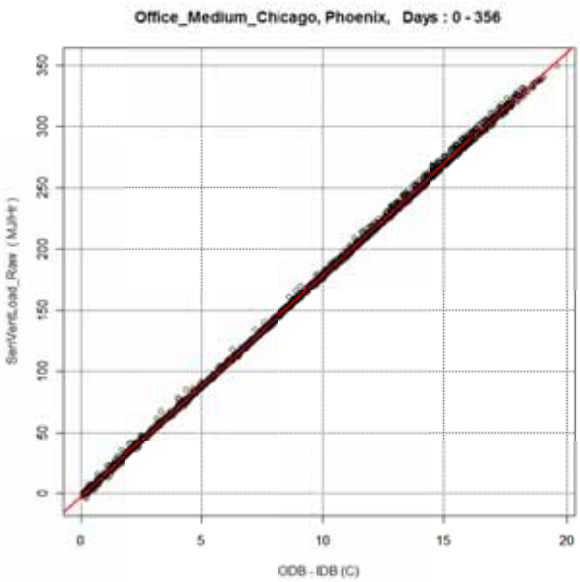
The right side plot is raw.

The left side has the calculated heating ventilation subtracted out. This tends to shift up heating load and produce a true non-ventilation load line for both heating and cooling.

This was not conclusive as to whether a cooling and heating load data would produce a better load model. The idea is only presented here for possible future reference.

Phoenix Weather





Intercept = 317.07

Slope = 27.06

Chicago DT = 7.5 SI Fraction = 0.61

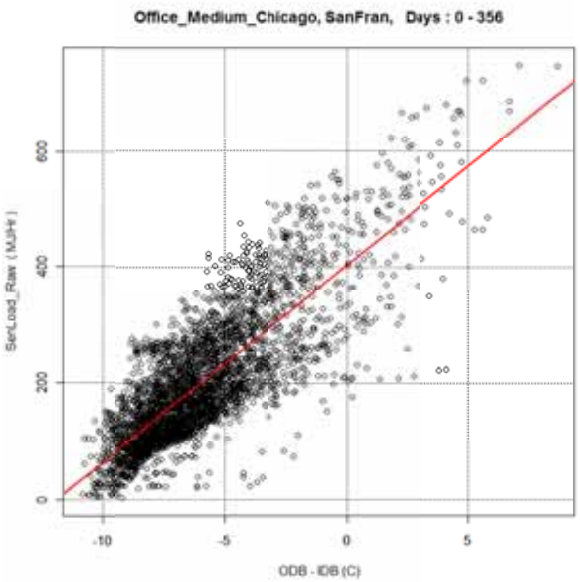
SanFran DT = 0.8 SI Fraction = 0.94

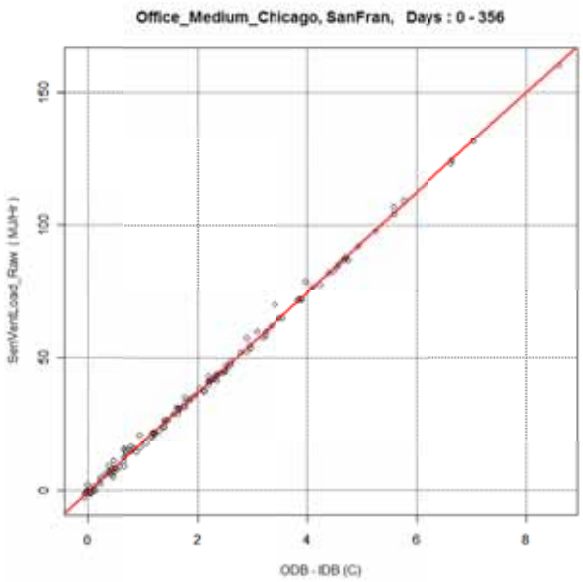
Phoenix DT = 18 SI Fraction = 0.39

Slope = 18.13; Fraction = 18.13/27.06 = 0.67

This run simulates the Office-Medium-Chicago building with Phoenix weather. A significant part of the data is at higher temperatures (Chicago is mostly below a 10 degree differential). However, the S&I calculations for the three cities are very similar to that when simulated with Chicago weather.

San Francisco Weather





Intercept = 403.86

Slope = 34.05

Chicago DT = 7.5 SI Fraction = 0.61

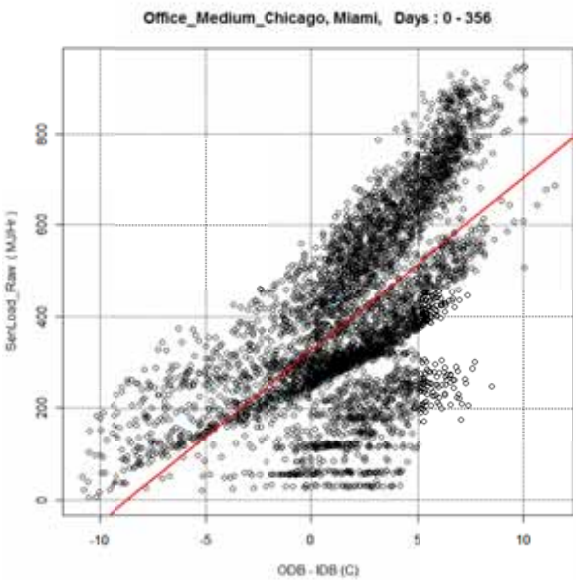
SanFran DT = 0.8 SI Fraction = 0.94

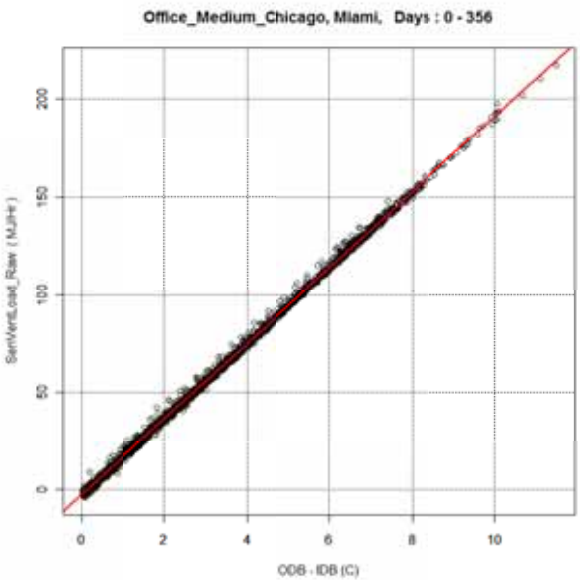
Phoenix DT = 18 SI Fraction = 0.40

Slope = 18.84; Fraction = 18.84/34.05 = 0.55

This run simulates the Office-Medium-Chicago building with San Francisco weather. Notice that most of the data is at outdoor temperatures below the setpoint. However, the S&I results are very similar to when simulated with Chicago weather.

Miami Weather





Intercept = 326.55

Slope = 37.66

Chicago DT = 7.5 SI Fraction = 0.54

SanFran DT = 0.8 SI Fraction = 0.92

Phoenix DT = 18 SI Fraction = 0.33

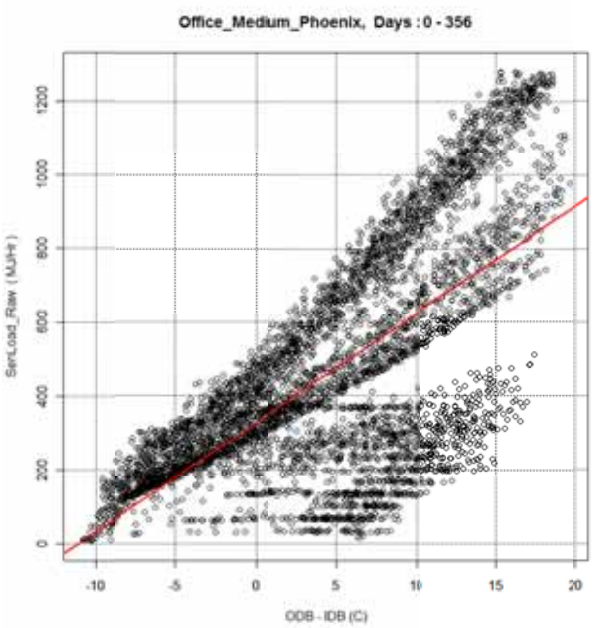
Slope = 19.38; Fraction = 19.38/37.66 = 0.51

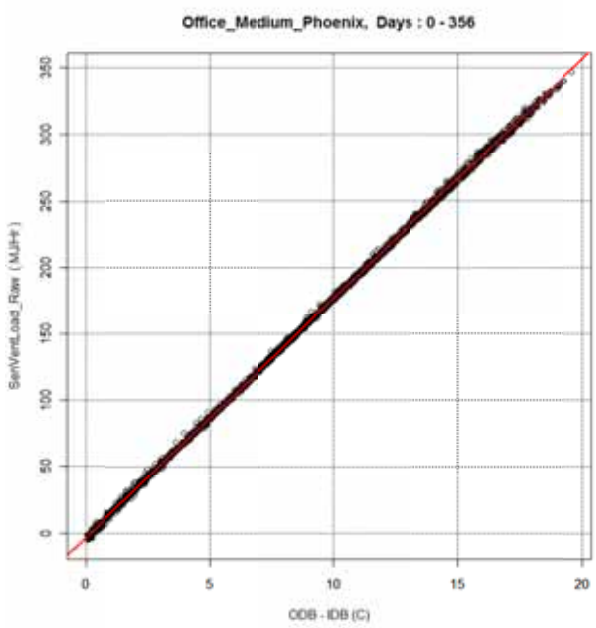
This run simulates the Office-Medium-Chicago building with Miami weather. Notice that most of the data is at outdoor temperatures cooler than Phoenix, a similar overall range to Chicago, but with much more of the data at deltas above setpoint (delta=0). However, the S&I results are lower but still reasonably similar to when simulated with Chicago weather.

Office-Medium-Phoenix

Sensible Loads

Phoenix Weather





Intercept = 327.65
Slope = 29.45
Chicago DT = 7.5 SI Fraction = 0.6
SanFran DT = 0.8 SI Fraction = 0.93
Phoenix DT = 18 SI Fraction = 0.38

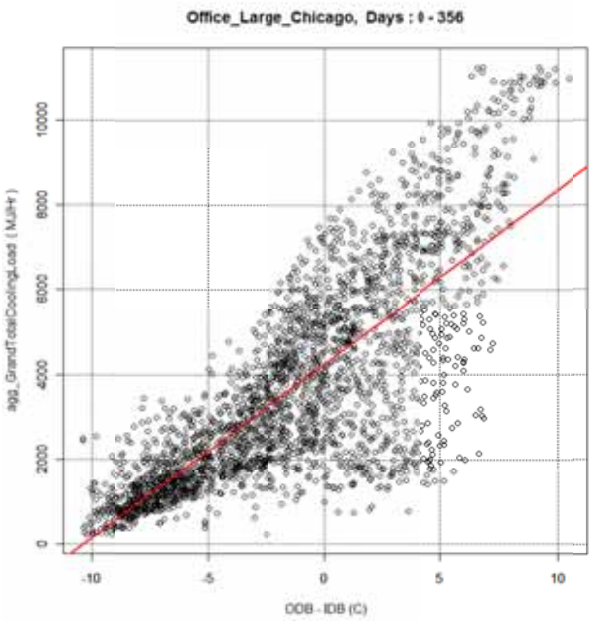
Slope = 18.01; Fraction = 18.01/29.45 = 0.61

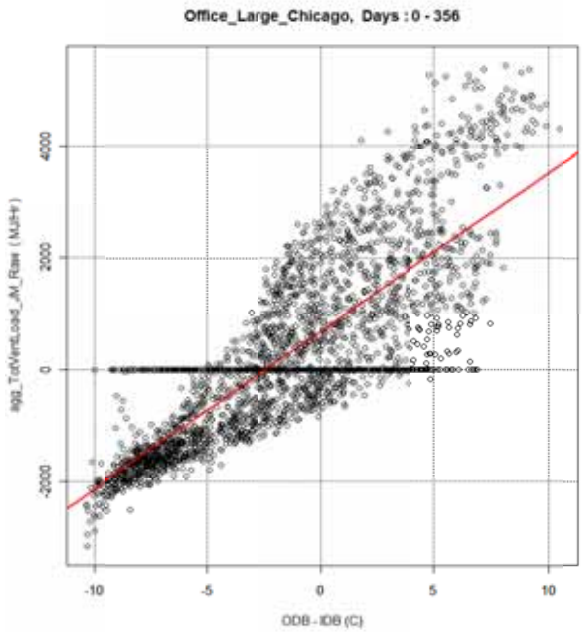
This result shows the Medium-Office-Phoenix (Phoenix version) of the Medium Office building simulated with Phoenix weather. Notice the S&I results are very similar to the Chicago version simulated with Chicago weather.

Office-Large-Chicago

Total Loads

Chicago Weather





Intercept = 4250 +/- 30

Slope = 410 +/- 6

Slope = 283 +/- 4; Fraction=0.69

Chicago DT = 7.5 SI Fraction = 0.58

SanFran DT = 0.8 SI Fraction = 0.93

Phoenix DT = 18 SI Fraction = 0.37

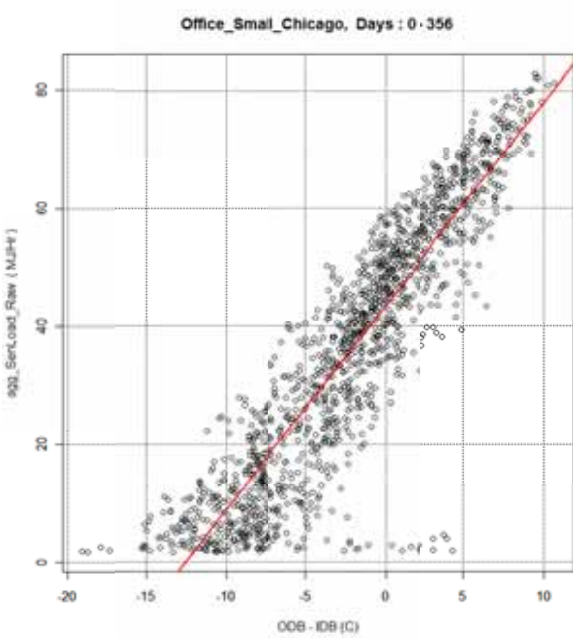
Large Office building uses chillers, no DX, so this model was based on total loads. S&I calculations are still very similar to the results for the Medium Office building.

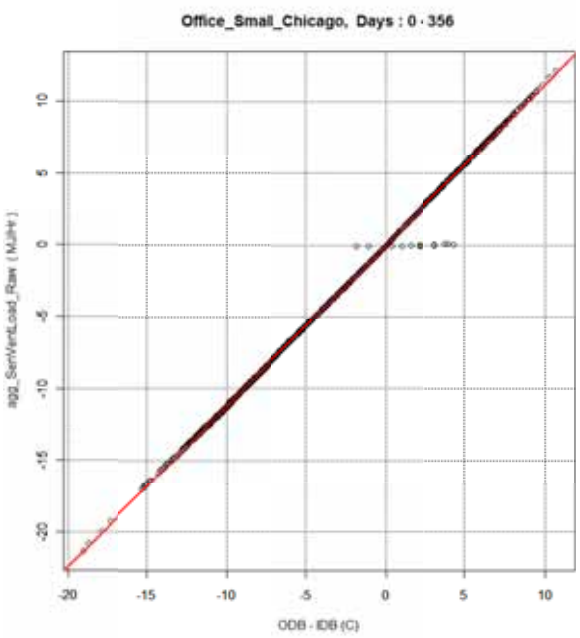
```
Scan(blnReScan = TRUE, strMainDirectory="Office_Large_Chicago", strSubDirectory="")
PlotVsTemp("DT", "CR", c(0,356), "agg_GrandTotalCoolingLoad", "GM", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
PlotVsTemp("DT", "CR", c(0,356), "agg_TotVentLoad_JM_Raw", "LF", strUnits="MJ/Hr", ymin_fraction=0.00, strFitMode="T", blnNoIntercept="F")
```

Office-Small-Chicago

Sensible Loads

Chicago Weather





Intercept = 43.4 +/- 0.3
Slope = 3.46 +/- 0.04

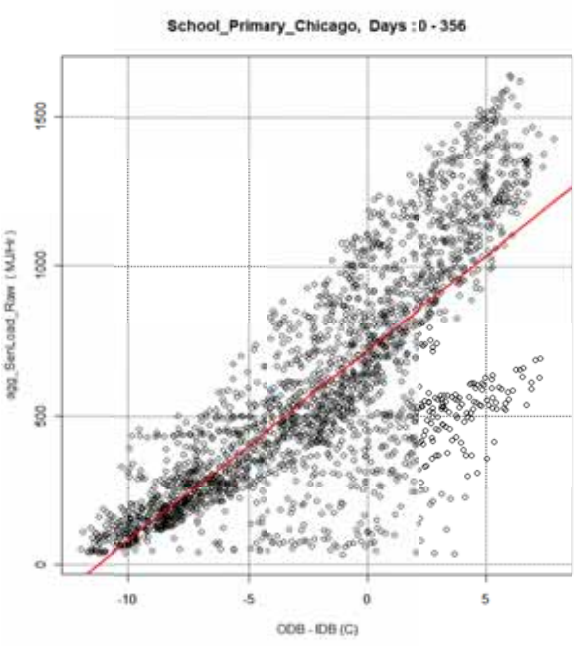
Slope = 1.120 +/- 0.001, Fraction = 0.32

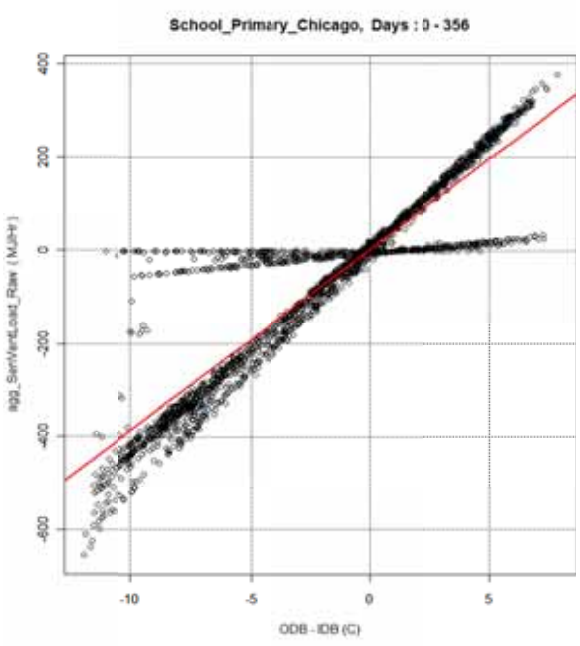
Chicago DT = 7.5 SI Factor = 0.63
SanFran DT = 0.8 SI Factor = 0.94
Phoenix DT = 18 SI Factor = 0.41

School-Primary-Chicago

Sensible Loads

Chicago Weather





Intercept = 718 +/- 5
Slope = 63.5 +/- 1.0

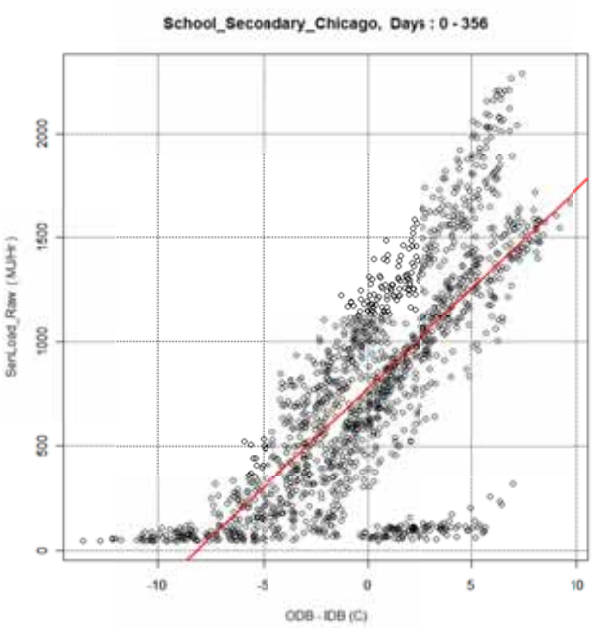
Slope = 38.8 +/- 0.3 Fraction = 0.61

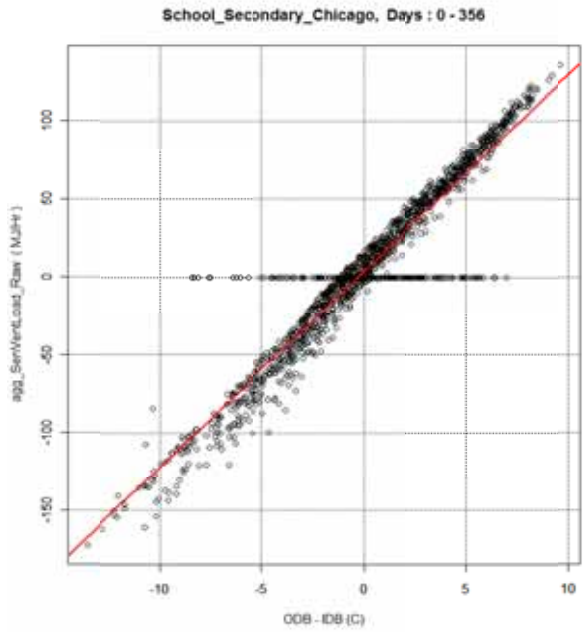
Chicago DT = 7.5 SI Factor = 0.6
SanFran DT = 0.8 SI Factor = 0.94
Phoenix DT = 18 SI Factor = 0.39

School-Secondary-Chicago

Sensible Loads

Chicago Weather





Intercept = 779 +/- 9
Slope = 95 +/- 2
Chicago DT = 7.5 SI Fraction = 0.52
SanFran DT = 0.8 SI Fraction = 0.91
Phoenix DT = 18 SI Fraction = 0.31

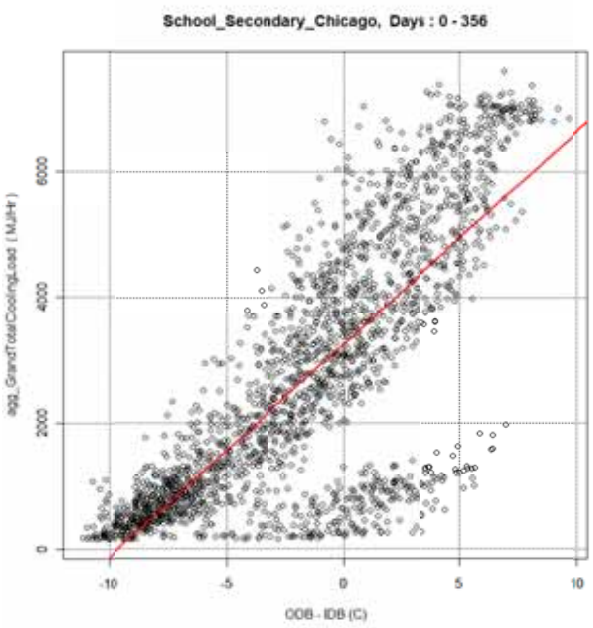
Slope = 12.62 +/- 0.10; Fraction = 0.13

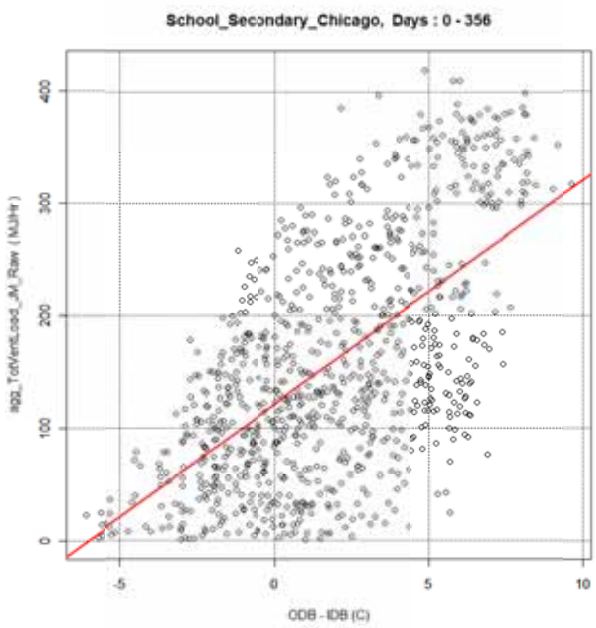
The School-Secondary building uses both DX and chiller. This sensible model is based on the DX systems in the building.

```
Scan(blnReScan = TRUE, strMainDirectory="School_Secondary_Chicago", strSubDirectory="")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenLoad_Raw", "GM", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenVentLoad_Raw", "LF", strUnits="MJ/Hr", ymin_fraction=0.00, strFitMode="T", blnNoIntercept="F")
```

Total Loads

Chicago Weather





Intercept = 3255.74
Slope = 339.14
Chicago DT = 7.5 SI Fraction = 0.56
SanFran DT = 0.8 SI Fraction = 0.93
Phoenix DT = 18 SI Fraction = 0.35

Slope = 20.04; Fraction = 20/339 = 0.06

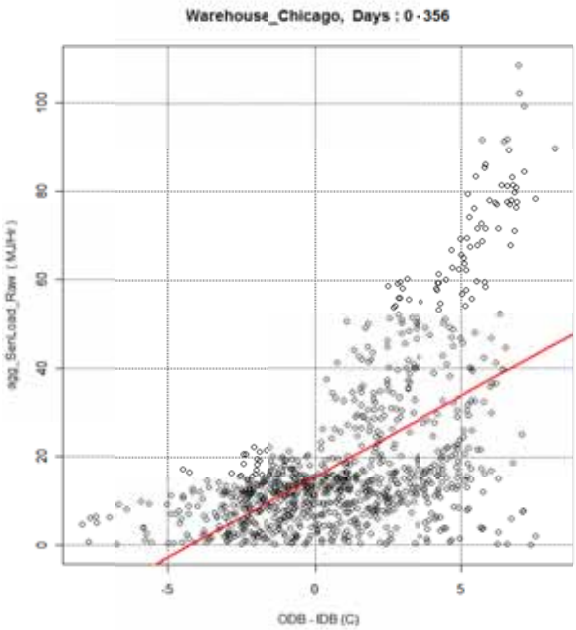
The School-Secondary building uses both DX and chiller. This total (=S+L) model is based on both the DX and chiller systems in the building. The S&I predictions are similar to those based only on the DX systems.

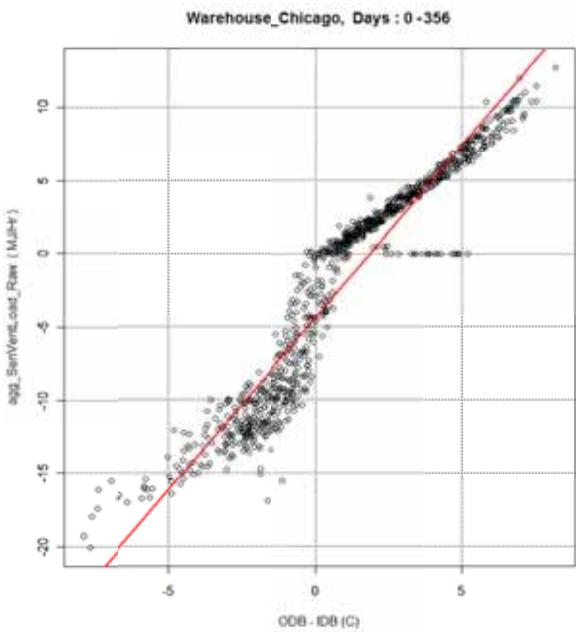
```
PlotVsTemp("DT", "CR", c(0,356), "agg_GrandTotalCoolingLoad", "GM", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
PlotVsTemp("DT", "CR", c(0,356), "agg_TotVentLoad_JM_Raw", "GM", strUnits="MJ/Hr", ymin_fraction=0.0, strFitMode="T", blnNoIntercept=F)
```

Warehouse

Sensible Loads

Chicago Weather



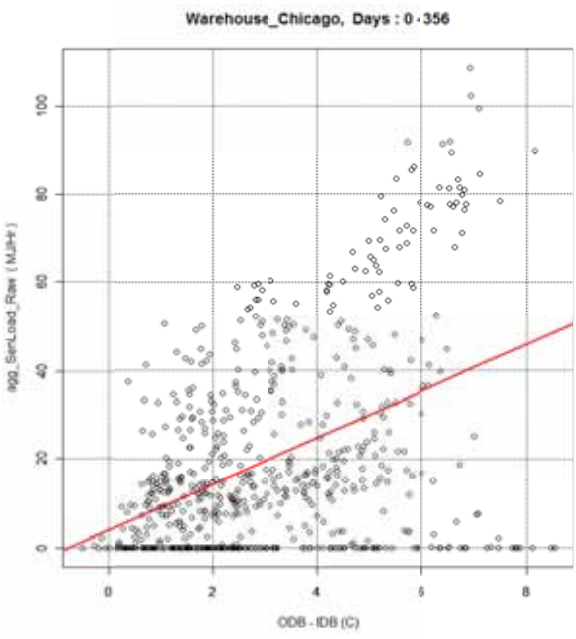


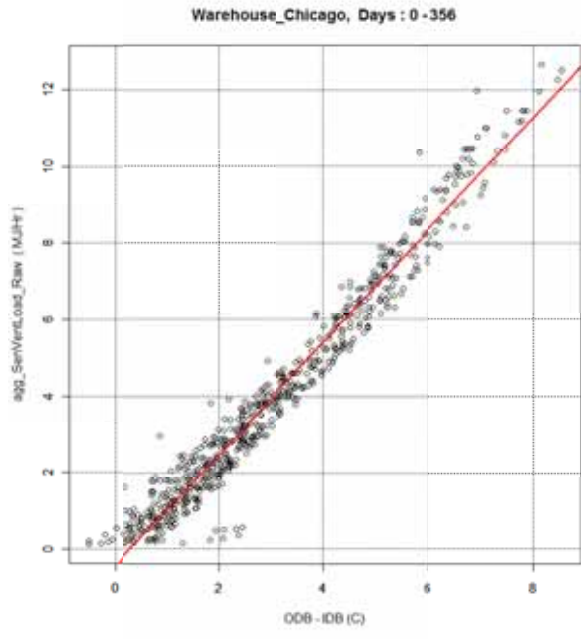
Intercept = 15.5 +/- 0.5
Slope = 3.68 +/- 0.16

Slope = 2.35 +/- 0.02 Fraction = 0.64

Chicago DT = 7.5 SI Factor = 0.36
SanFran DT = 0.8 SI Factor = 0.84
Phoenix DT = 18 SI Factor = 0.19

This initial analysis shows strong economizer effects for the Warehouse building type. So it was re-analyzed to use only hours where the ventilation load is positive.



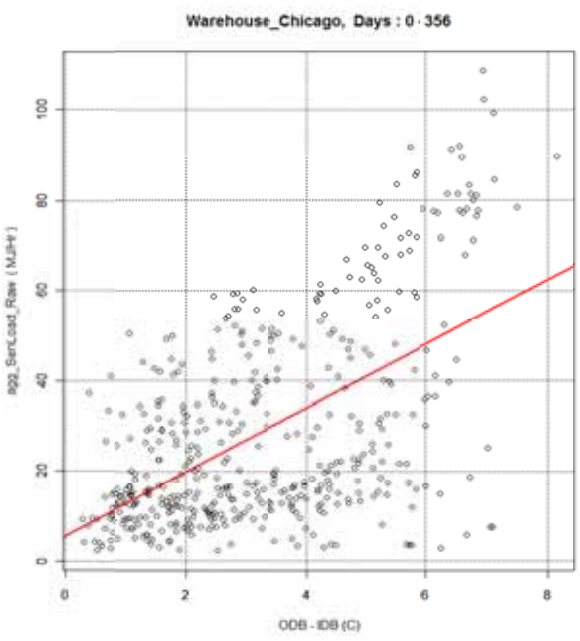


Intercept = 3.8 +/- 1.5
Slope = 5.3 +/- 0.4

Slope = 1.47 +/- 0.01 Fraction = 0.28

Chicago DT = 7.5 SI Factor = 0.09
SanFran DT = 0.8 SI Factor = 0.48
Phoenix DT = 18 SI Factor = 0.04

Here negative ventilation loads are excluded. This is done by filtering on the ventilation load data and then using the resulting set of hours in the sensible load plot. This still left some zero-load points. These were excluded in one more level of filtering as shown on the next page. The results on the next page are used in the RTU CC.



(Ventilation graph is the same as on previous page)

Intercept = 5.7 +/- 1.7
Slope = 7.1 +/- 0.5

Slope = 1.47 +/- 0.01 Fraction = 0.21

Chicago DT = 7.5 SI Factor = 0.10
SanFran DT = 0.8 SI Factor = 0.51
Phoenix DT = 18 SI Factor = 0.04

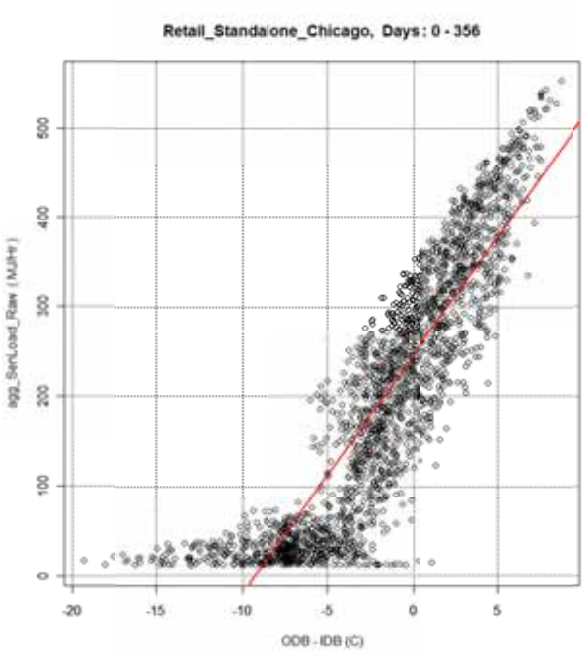
Note the order of the following summary of calls. The ventilation load data is processed first. That acts to produce the subsetting vector which is applied in the next two command.

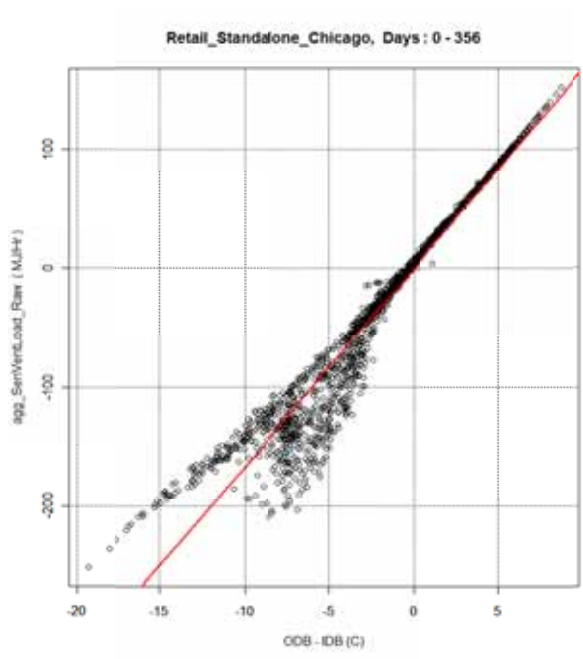
```
Scan(blnReScan = TRUE, strMainDirectory="Warehouse_Chicago", strSubDirectory="")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenVentLoad_Raw", "GM", strUnits="MJ/Hr", ymin_fraction=0.01, strFitMode="T", blnNoIntercept="F")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenLoad_Raw", "LF", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
PlotVsTemp("DT", "CR", c(0,356), "agg_SenLoad_Raw", "LFGM", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
```

Retail-Standalone

Sensible Loads

Chicago Weather





Intercept = 245.4 +/- 1.5
Slope = 26.5 +/- 0.3

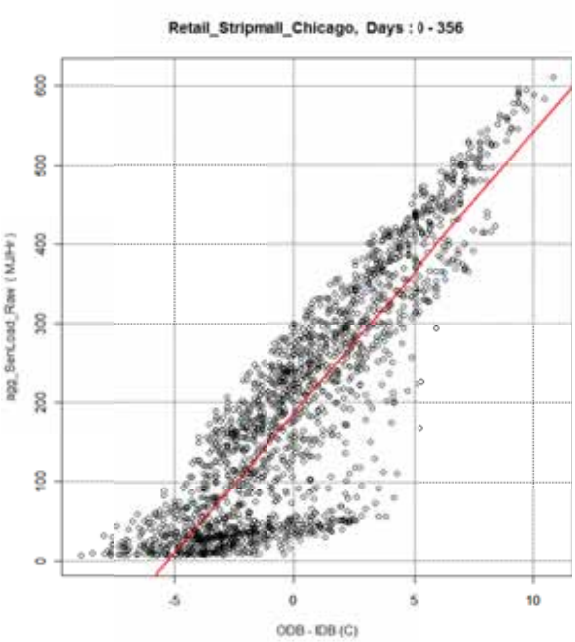
Slope = 16.69 +/- 0.09 Fraction = 0.63

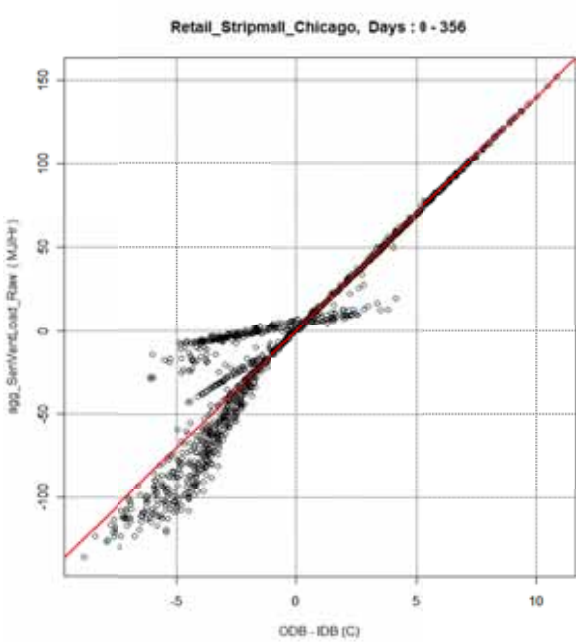
Chicago DT = 7.5 SI Factor = 0.55
SanFran DT = 0.8 SI Factor = 0.92
Phoenix DT = 18 SI Factor = 0.34

Retail-Stripmall

Sensible Loads

Chicago Weather





Intercept = 187.2 +/- 1.6
Slope = 35.4 +/- 0.4

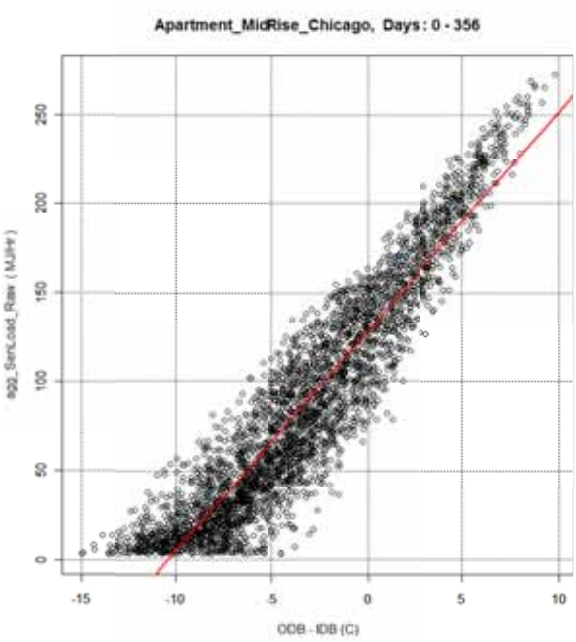
Slope = 14.00 +/- 0.09 Fraction = 0.40

Chicago DT = 7.5 SI Factor = 0.41
SanFran DT = 0.8 SI Factor = 0.87
Phoenix DT = 18 SI Factor = 0.23

Apartment-Midrise

Sensible Loads

Chicago Weather



(Mechanical ventilation not reported.)

Intercept = 128.3 +/- 0.5
Slope = 12.32 +/- 0.08

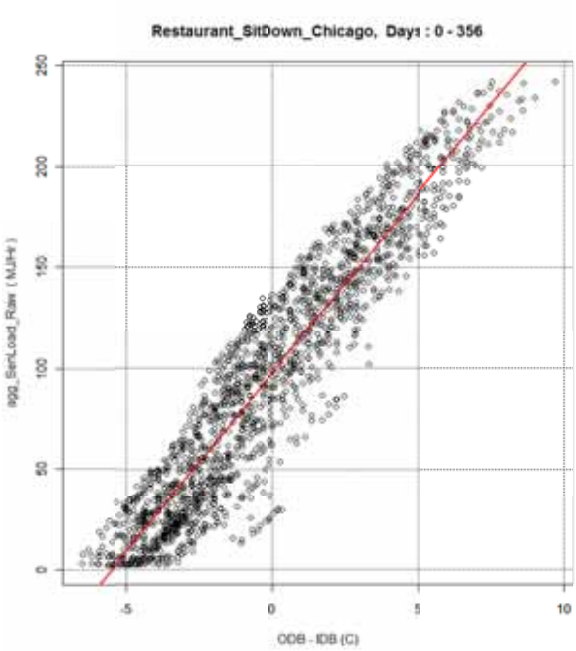
Fraction = 0.0 (assumed)

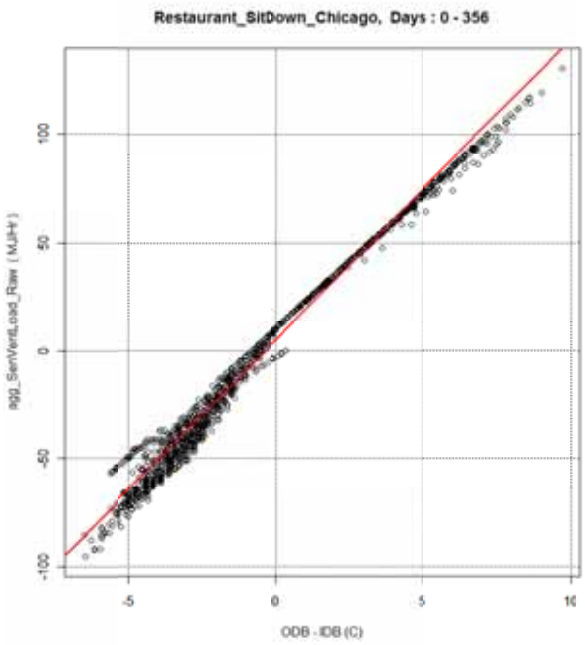
Chicago DT = 7.5 SI Factor = 0.58
SanFran DT = 0.8 SI Factor = 0.93
Phoenix DT = 18 SI Factor = 0.37

Sit-down Restaurant

Sensible Loads

Chicago Weather





Intercept = 98.0 +/- 0.5
Slope = 17.65 +/- 0.14

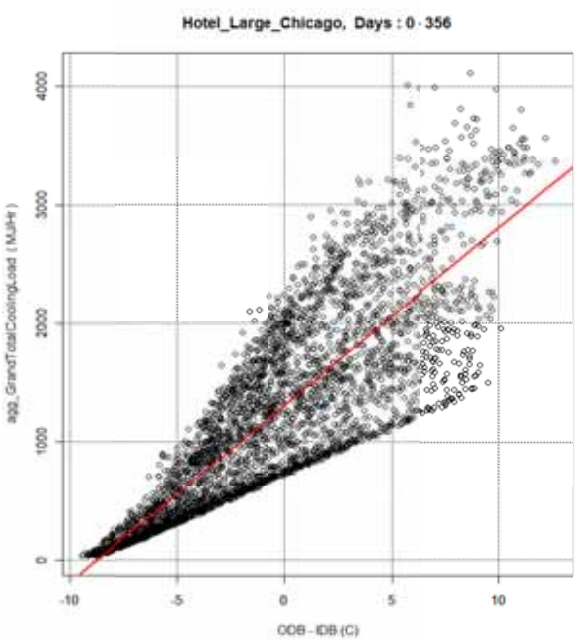
Slope = 13.88 +/- 0.04 Fraction = 0.79

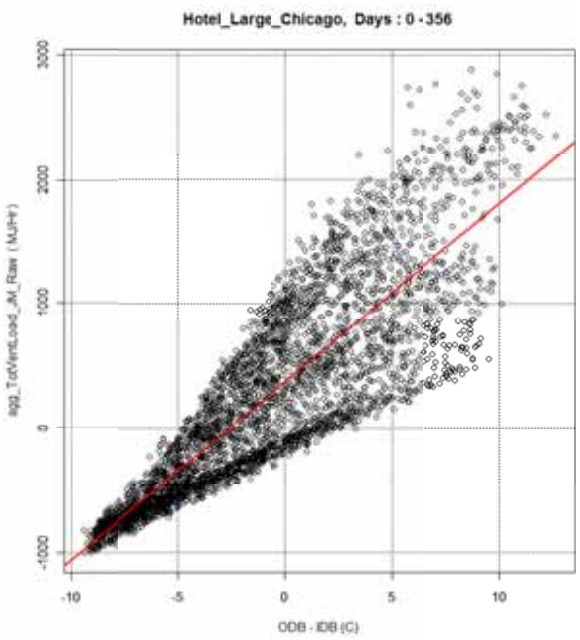
Chicago DT = 7.5 SI Factor = 0.43
SanFran DT = 0.8 SI Factor = 0.88
Phoenix DT = 18 SI Factor = 0.24

Hotel-Large

Total Loads

Chicago Weather





Intercept = 1313 +/- 7
Slope = 149.5 +/- 1.4

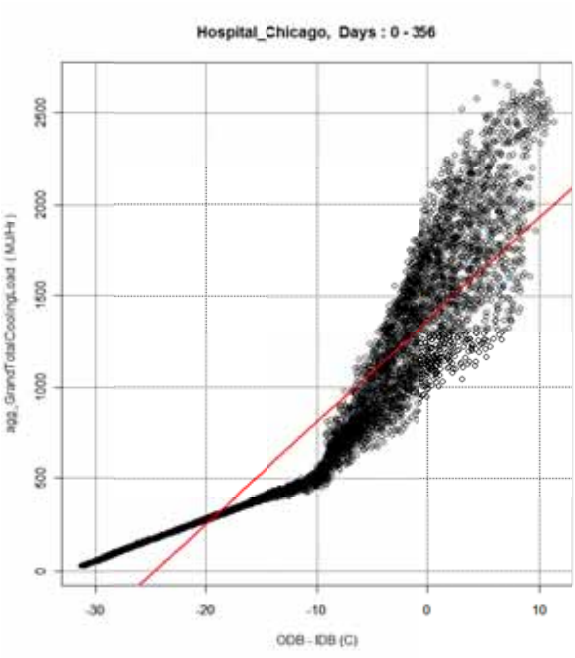
Slope = 143.3 +/- 1.3 Fraction = 0.96

Chicago DT = 7.5 SI Factor = 0.54
SanFran DT = 0.8 SI Factor = 0.92
Phoenix DT = 18 SI Factor = 0.3

HealthCare-Hospital

Total Loads

Chicago Weather



(ventilation loads not reported)

Intercept = 1370 +/- 4
Slope = 55.8 +/- 0.3

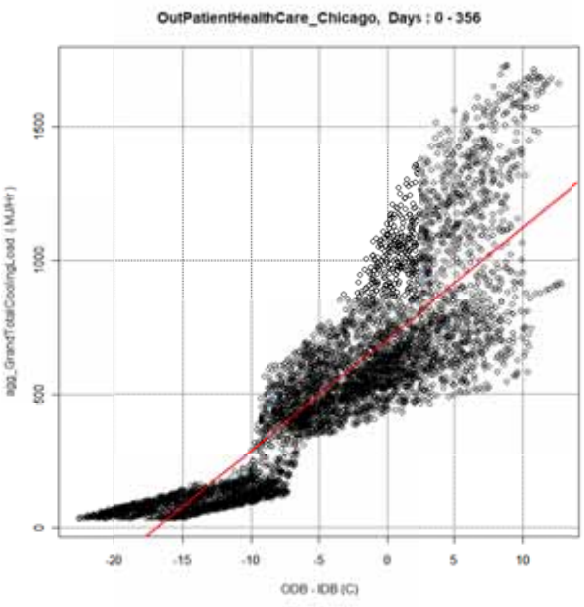
Fraction (assumed) = 0.70

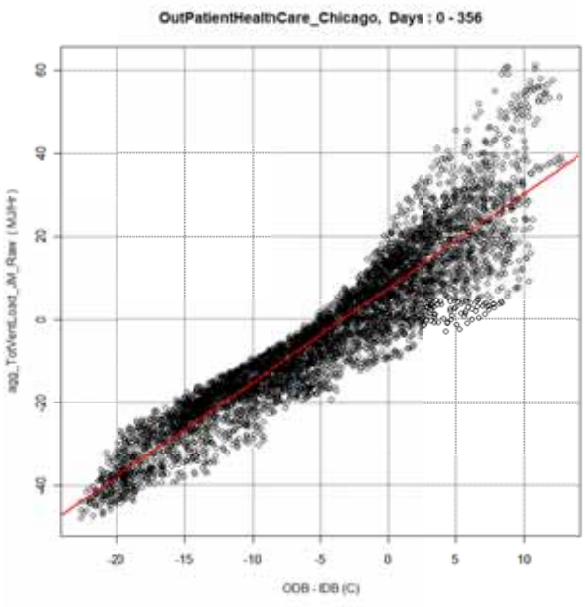
Chicago DT = 7.5 SI Factor = 0.77
SanFran DT = 0.8 SI Factor = 0.97
Phoenix DT = 18 SI Factor = 0.58

HealthCare-Outpatient

Total Loads

Chicago Weather





Intercept = 704 +/- 3
Slope = 41.8 +/- 0.3

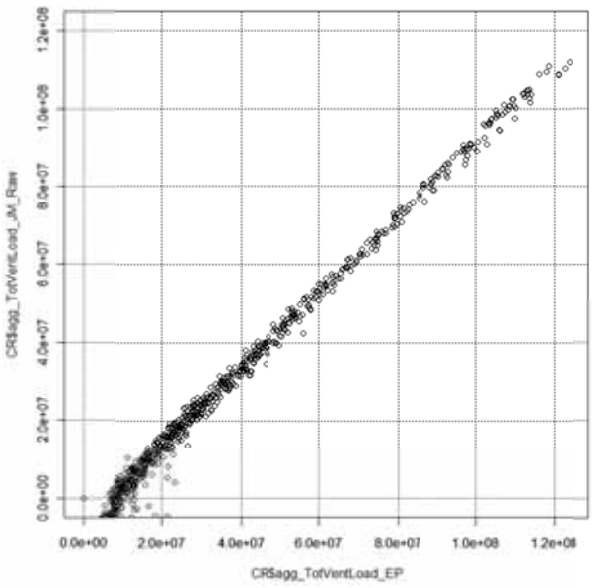
Slope = 2.270 +/- 0.011 Fraction = 0.054

Chicago DT = 7.5 SI Factor = 0.69
SanFran DT = 0.8 SI Factor = 0.96
Phoenix DT = 18 SI Factor = 0.48

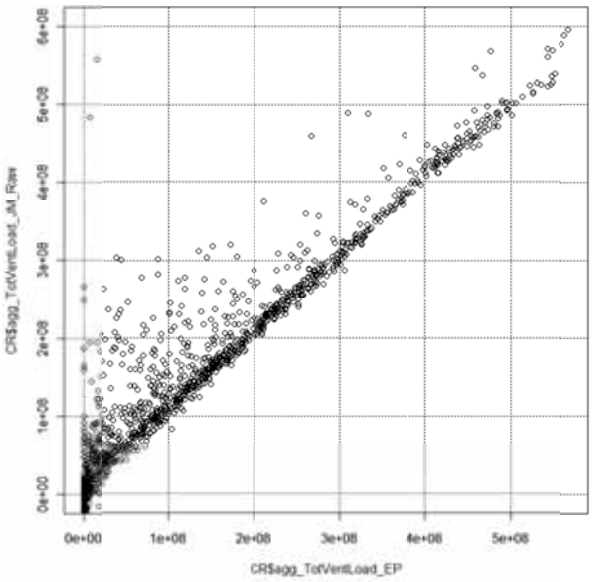
```
Scan(blnReScan = TRUE, strMainDirectory=" OutPatientHealthCare_Chicago", strSubDirectory="")
PlotVsTemp("DT", "CR", c(0,356), "agg_GrandTotalCoolingLoad", "GM", strUnits="MJ/Hr", ymin_fraction=0.02, strFitMode="T")
PlotVsTemp("DT", "CR", c(0,356), "agg_TotVentLoad_JM_Raw", "LF", strUnits="MJ/Hr", ymin_fraction=0.00, strFitMode="T", blnNoIntercept="F")
```

Check of Total Ventilation Load Calculation

Medium Office

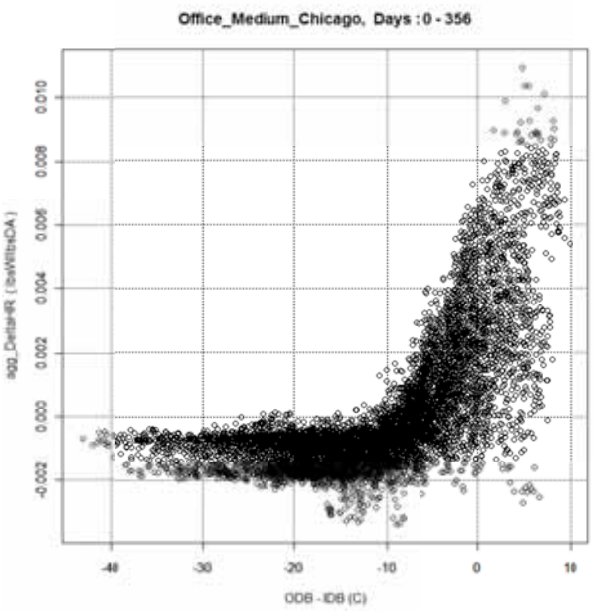


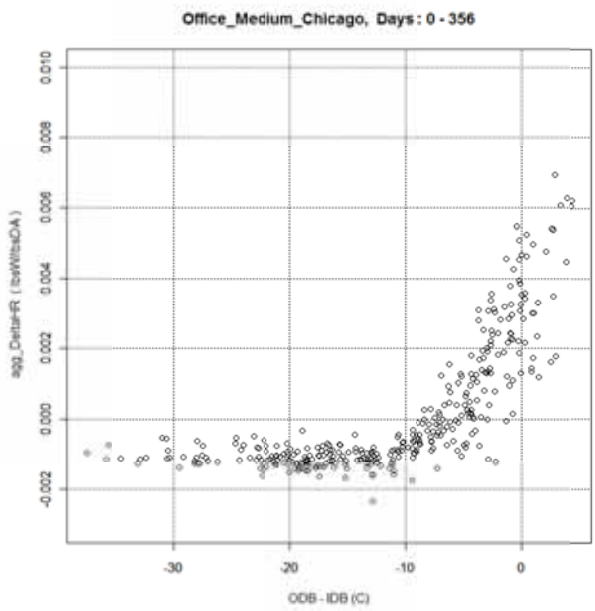
Restaurant



These plots are a comparison check between the total ventilation loads calculated in the post processing and the ventilation loads reported by EnergyPlus in the Zone.Mechanical.Ventilation.Cooling.Load.Increase variable. There is one-to-one agreement with the Restaurant data (above left). EnergyPlus documentation does not specifically specify if their variable is sensible or total; agreement here indicates it must be total. A similar sensible variable is not available in EnergyPlus.

Humidity Ratio Difference





These plots (left is raw hourly; right is daily average) of the difference between the outside and inside humidity ratio. This shows a positive difference during the summer cooling season, and a negative difference in winter. Summer cooling, and resulting dehumidification, suppresses the indoor humidity ratio. This is shown here only for future reference and for possibly developing an indoor humidity ratio model based on EnergyPlus runs.