

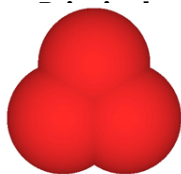
Observational Analysis To Improve Understanding of Ozone Formation in San Antonio, Texas

**Final Technical Report for 2018
Professional Services Contract**

**Metropolitan Health District
City of San Antonio, Texas**

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**Prepared by
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OThree Chemistry
Research and Service
LLC

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1.0 Purpose

Conduct graphical analysis of ambient chemical and meteorological data monitored in TCEQ Region 13 for period 2012 to 2015 for the purpose of improving the understanding of ambient ozone formation and trends leading to exceeding the USEPA Federal Ozone Standard and thus requiring local planning for potential new controls on emissions. Characterize exceedance and non-exceedance days and identify the associated ambient conditions and identifiable processes for each class. Compare to other Texas locations and known causal mechanisms. Develop additional testable hypotheses and needed sources of data. Describe how the underlying observational data led to the regulatory requirements and identify uncertainties in finding appropriately effective regulations. (Contract)

1.1 Approach

The purpose of this work is to provide an improved understanding of how atmospheric ozone is being formed and transported within TCEQ Region 13 for the purpose of taking actions to reduce the ozone below the current USEPA Federal Ozone Standard.

Even though ozone is also a natural component of the atmosphere and necessary for life on earth, ground level ozone is harmful to humans and is regulated by the USEPA at increasing lower and lower atmospheric levels, a process that requires monitoring the air in cities to assess its status and then trying to reduce ozone to 'safe levels' by reducing 'emissions'.

While the general formation mechanisms for ozone are understood, the **processes actually at work in a given or specific environment are complex and involve many elements of urban life and activity**. Emissions of known precursors to ozone formation : (1) oxides of nitrogen created as a side-effect of using air as an oxidizer in combustion sources leading to conversion of N_2 to NO and NO_2 -- together called NO_x , and (2) emission of volatile organic compounds (VOCs) used as fuels or used in organically-derived product production, are the ingredients needed to make O_3 . Emissions of both of these types of gasses are integral to modern urban life--especially in transportation and power production. Together with the "necessary" meteorological conditions (e.g. low dilution), these emissions are a "sufficient condition" to form O_3 in sunlight.

What to monitor, what to reduce, and how much are major State and Federal decisions that need effective answers. Such reductions can also be costly. Power plants emit significant NO_x and require "scrubbers" to remove it. Cars have catalytic converters to further oxidize the residual VOCs from the partly combusted fuel. Atmospheric circulation dilutes emissions but also carries it to other locations while also reacting to make O_3 along the way. Economic development may be delayed (or done elsewhere !).

From the mid-1970's, increasing complex computational tools have been developed--some requiring a decade to build--to simulate the atmospheric circulation, mixing, and transport and the NO_x and VOC chemistry to '**predict**' under a given set of circumstances what '**controls**' are needed for precursors to achieve the USEPA Federal O_3 standard. Further, these have been integrated into the legal requirements to met the USEPA standards. The data needed to '**operate**' such models has become complex and at the same time less

detailed (e.g. annual averaged) and often 'stale' (currently using emission inventories over a decade old with various "adjustments"). Thus, rather than making a prediction of a future condition, (like the weather models do), the regulatory ozone model has been reduced to predicting 'ratios' under the assumption that these billion dollar models are better at predicting 'changes' than they are at predicting likely future 'states'. A major problem with the application of such models is the fundamental issue of "compensating errors" among different process in the model such that the testing of the model for accuracy is flawed by one major process in the model having component predictions that are too high, while another major process in the model has component predictions that are too low. When the processes are combined with other model process, and the model is operated, the model then predicts the "right answer" but "for the wrong reasons". It is extremely difficult to determine if this is the case at any application, however, a limited examination of the TCEQ model for 2012 has been included herein and results suggests that such process are at work in the TCEQ model. In addition, using actual 'fuel-based' emissions tools, new ambient and modeling research by NOAA and NASA are also suggesting that the current EPA model system likely has a significant NOx emission magnitude error too high. This is still under investigation.

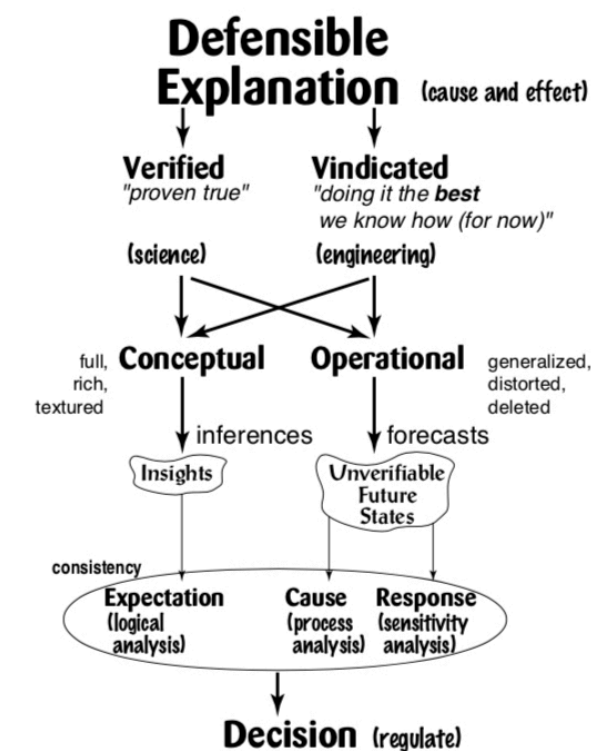
For these reasons and others, a more complex application of "scientific explanations", "conceptual explanations", "observational data analysis", and "operational explanations" analyses have been used to seek solutions to particular air quality problems. Such a method was highly successful in Houston, TX in the early 2000's and led to a very different alternative solution that was much less costly and more successful than the strictly 'follow EPA's model guidelines' approach.

One name given to this approach is "Defensible Explanation" and its structure is shown in Figure 1. An important element in this approach is a form of "engineering" where the decision maker must make a "vindication" argument as part of the defense to proceed with regulation. A vindication argument is that the decision maker is "doing the best we know how (for now) and if anyone else knows any better way to do it, defend it." But the real benefit of the "Defensible Explanation" is the use of science, engineering, inferential analysis, forecasts, and seeking consistency among these as what to 'regulate' to most likely achieve the goal of good air quality at the lowest costs.

This work was a bottom up, process-based, site-by-site, hour-by-hour, year-by-year analysis of 1-h ozone, wind data, and other available observational (e.g., CO, NO_x, and VOC) data available for the period 2012 , 2015, and 2016 for San Antonio monitors, including the non-regulatory monitors. Beyond the monitored 1-h ozone, the 8-h average ozone values were computed for every day and compared. The 8-h ozone values are the result of many processes with multiple causes (there are over 82,000 different combinations). These 'regulatory' values are useful to see if you are getting what the regulators want, but are far removed from how outcomes got that way.

A major goal was to find the differences among the exceedance days and sites and the non-exceedance days (both for all days 1-h ozone > 100 and all days 8-h ozone > 70 ppb). To look for associations among observations to see if certain conditions are associated with ozone violations. Then reason from these associations to estimate the likely causes of exceedances.

Figure 1.



Harvey Jeffries, UNC

1.2 Deliverables

1. Production and Delivery of Detail Plots and Tables of Ozone, Winds, NO_x, CO:
Equinox to Equinox (months 04–10) Daily Plotting O₃ and Winds by Month
Includes specifically designed plots and data transformations “see the data differently”
Selection of 4-day Focus Periods and Plotting of each period and repeated plots types for focus periods. Compare San Antonio and Houston periods, especially August 2015.
2. Investigate similarity and differences among years 2012, 2015, and 2016:
Compare distributions, patterns, wind conditions, ozone formation and other elements among the years. Focus is to understand the meteorological and chemical differences among the modeled 2012 year meteorology and ozone production in later years.
3. Investigate and prepose hypothesis to explain the yearly variation in number of 8-h Ozone Exceedances at the San Antonio Regulatory Monitors.

2.0 Summary of Findings

2.1 Rotating Wind Flows

1. 500-mb Upper Air Stations show low wind speed rotations across Texas. See Figure 4.
2. Geostrophic forcing by large-scale High and Low pressure systems are similar for San Antonio and Houston (and El Paso <prior study>). See Figure 5.
3. San Antonio monitor site 1-H winds form hodograms nearly identical to Houston's hodograms from 1998 to 2016. But on a few days in 2012 and 2015, the San Antonio BULL and SANW monitors produced a previously unseen hodogram condition of a 2Q flow back over itself in a reversal straight line. The origins of this condition are still under investigations but may be related to San Antonio's terrain compared to Houston's. See Figures 7, 8, and 11.
4. San Antonio and Houston's QX_PIE charts are very similar for 2012, 2015, and 2016, but differ by year. See Figure 11.
5. San Antonio's SANW 2015 monitor on 2015-08-27 showed indications of significant nighttime O31H transport with elevated ozone values as high as 55 ppb. These were 2Q flow conditions. See Figure 12.
6. Comparison of rotating winds and exceedances for TCEQ's CAMx **model** of 2012 at 4-km grid for the Houston H03H and CLIN sites showed that the model predicts 6 more exceedance days at H03H and 7 more exceedance days at CLIN than were observed at the sites. The H03H site errors were for 1Q and 2Q winds and the CLIN site errors were for 3Q and 4Q winds. More work will be done on the San Antonio model and obs data next month. See section 3.3.6.1.
7. Radial QXW_ROSE plots for BULL showing the number of days with morning winds from each octet (45 degrees) and the associated 'nQ' for the day, reveal that the vast majority of the '8X' and '9X' ozone exceedances come from the W-NW and NW-N morning directions. At SANW the vast majority of '8X' exceedances from '4Q' days from with NW-N morning directions. This is true for 2012, 2015, and 2016. See Figure 15.
8. Timeseries QXW_WOCT plots for BULL and SANW show April to Nov distribution of '8X' and '9X' have morning winds that are clustered from W-NW to N but most **non**-exceedance days have morning winds from SE-S. This is true for 2012 and 2015. See Figure 16 and 17.
9. Scatter plots O3TD_SCAT for O31H and O38H at BULL and SANW show April to November scatter plot for Morning Transport Distance, km. In 2012, the travel distances for O31H > 100 ppb were < 50 km and the same for O38H > 70 ppb; In 2015, the travel distances for O31H > 100 ppb were < 12 km. See Figures 18-23.

2.2 Reactive Source Areas

The low frequency of producing O_3 as demonstrated by the small ratio of 8X or 9X days compared to the much larger number of 3Q or 4Q 'necessary' conditions days for making O_3 , implies that there is a limit on the "sufficient" causes of 8X or 9X O_3 levels, that is, the reactive ingredients are not available often enough under 3/4Q conditions to result in more X's. The 'sufficient' causes must be NO/NO_x and VOCs (that are not dispersed by 1Q or 2Q winds). Further the strength of the NO_x source is highly repeatable as morning and evening traffic (and heavy duty trucks) The NO_x is a by-product of this activity. VOCs on the other hand are mostly used as liquid, transported as liquid, and volatilized to a gas as a side effect. We know from the use of the IR camera that VOCs can easily be 'vented' and not even recognize as such. Virtually none of this mass is reported. Even if it were, it would be small annually and usually neglected. Small plumes of VOC can be less than a kilometer wide, and can travel significant distances with little dispersion. It is common in both Houston and in San Antonio monitors to see 1-h wide 15 to 35 ppb increases and decreases in measured O_3 . See Figure 25. This implies that the sources of these VOC are narrow and likely stochastic in time and thus difficult to identify.

The fact that so many exceedances at BULL originate from the W-NW in 2012, from the NW-N in 2015, and this direction is the only one at 3Q for 2016, can be taken to suggest that a VOC source may be moving around in the area west of BULL. The 2012 and 2015 SANW data suggest that the source is more N and more NE of SANW which puts it close to where BULL is "pointing" also.

2.3 Windowed Timeseries

Figures 24 to 30 provide the specialized $O_3 \times H$ _UVDD plots that display ozone timeseries data and wind data. The plot displays both $O_3 1H$ and $O_3 8H$ levels for the day, provides the 1-H wind speed, and shows the displacement trajectory and 'nQ' value for each day.

The tables beginning on page 44 provide the critical data about the top 10 highest ranked $O_3 8H$ days. The tables (eg, BULL_20xx_TP10_1Y_STAT3) provide critically important data about the 10 highest exceedances. In section 3.4 starting on page 44, at top of page a $O_3 \times H$ _UVDD plot for the entire month in which an exceedance appeared in the table is provided; below the UVDD plot is provided the site measured NO and NO_2 1-H data that is aligned with the time base of the UVDD plot. The full month of 1-H data shows the significant variation in MET and chemical data. The month data are used to select out 4 day time windowed periods to investigate further. These show that the variability in NO_x is not strongly correlated with O_3 .

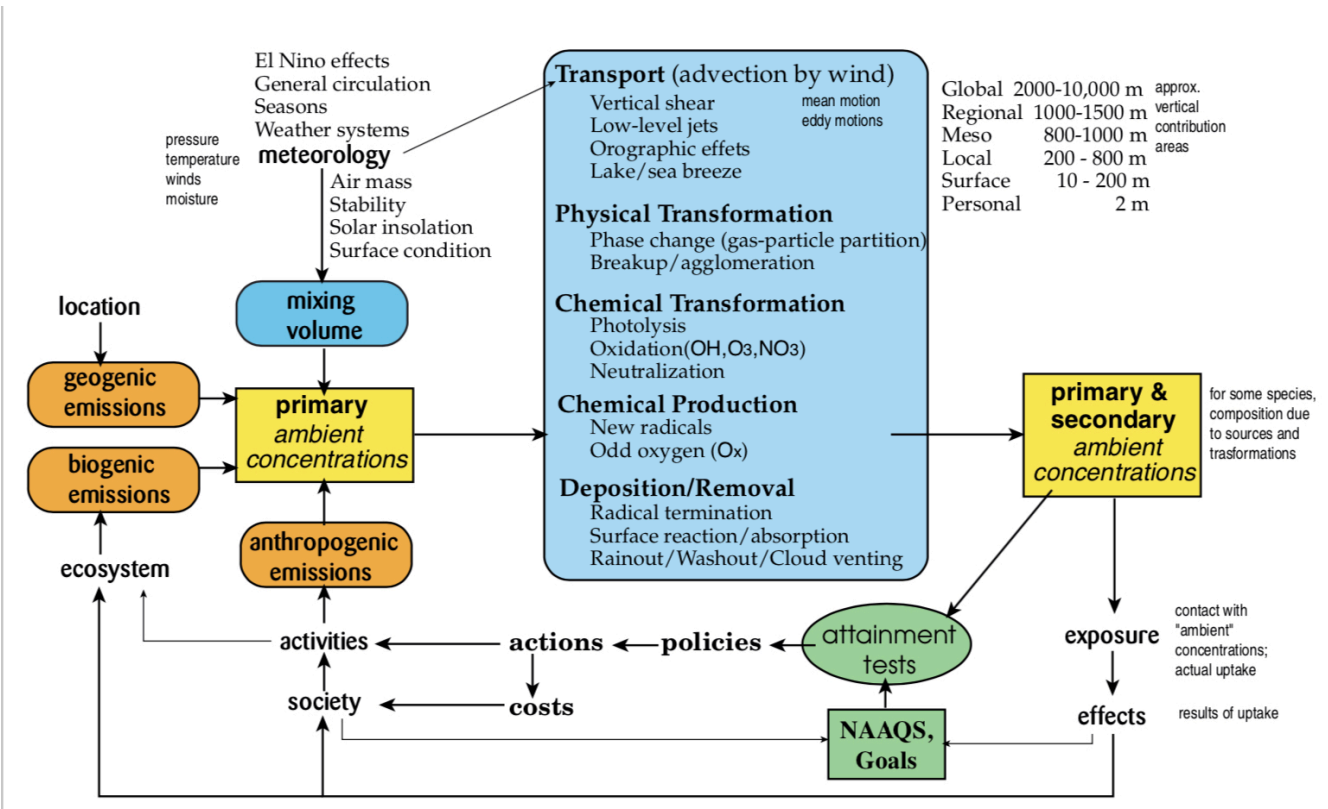
2.4 Need an IR Camera To Look for 'small' VOC Sources.

The application of the IR camera that can 'see' invisible VOC plumes was a major turning point in the Houston 2004 SIP formulation and led to more than a decade of decreasing O_3 .

3.0 Background and Conceptual Frameworks

3.1 Atmospheric Chemistry Concepts

Figure 1. Air Quality Conceptual Model



Solving air quality problems requires understanding a large number of scientific, engineering, and societal concepts. Figure 1 is a relatively high-level ‘conceptual model’ connecting ‘emissions’ with ‘health effects’, and to ‘policies to remediate’ their impacts.

The case of near-surface ozone (O_3) is unique: it is not directly emitted, but is formed entirely in the atmosphere via two major processes. The first source is above 20 km in the atmosphere in which the short wavelength incoming solar radiation is absorbed by oxygen in the atmosphere and two 'atomic $O\cdot$ ' are formed that combine with O_2 to form $2 O_3$. This is the 'earth's ozone layer' that absorbs the short-wave UV light that could otherwise cause DNA rupture if it reached the surface. The second source--and the one we are concerned with here--is at the surface where anthropogenically-sourced nitrogen dioxide (NO_2) is photolyze by sunlight ($NO_2 + h\nu \mapsto O\cdot + NO$), which is followed immediately by $O\cdot + O_2 \mapsto O_3$. Therefore, surface NO_x is one of the 'sufficient' ingredients to form tropospheric O_3 . Note that the NO formed can be re-cycled back to NO_2 by " $RO_2\cdot$ " and $HO_2\cdot$ radicals, where 'R' is some type of partly 'oxidized volatile organic compound' (VOC). Therefore VOC also a 'sufficient' ingredient to form tropospheric O_3 . While the NO can be recycled back to NO_2 multiple times (4-6) to make $O\cdot$, which then yields O_3 , the process will also make more " RO_2 " radicals from VOCs needed to convert the NO back to NO_2 .

What this means, is that there is no 1-to-1 relationship among ozone precursors and O_3 . This is well illustrated in one of EPA's first ozone models shown in Figure 2.

Figure 2. EPA's Empirical Kinetic Model Approach (EKMA/OZIP)

(<https://www3.epa.gov/scram001/userg/other/ozipr.pdf>) (<https://www.shodor.org/ekma>)

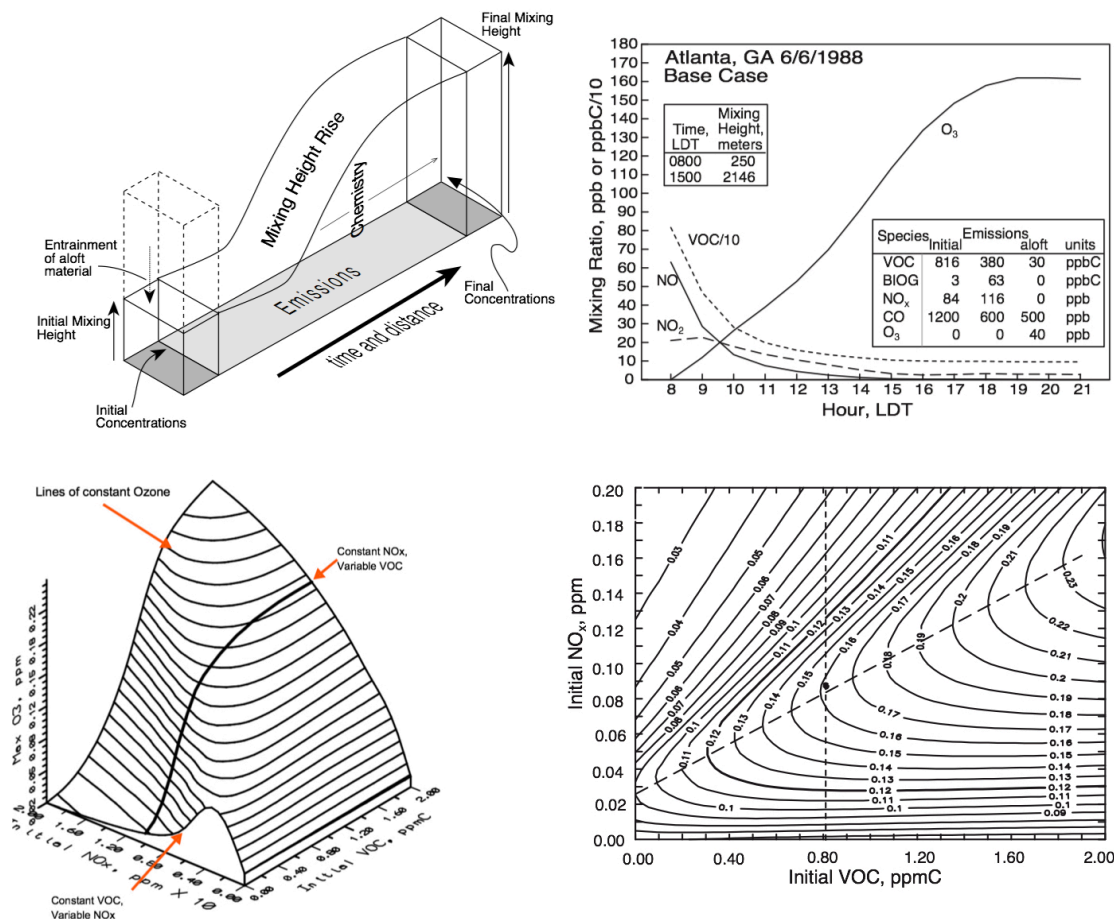


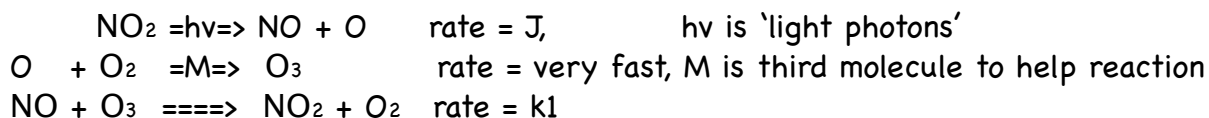
Figure 2 shows concepts from an early EPA meteorologically-simple (but chemical complex) model of relationships among NO_x, VOCs, and O₃ that was used to compute controls before the EPA had complex Eulerian photochemical models that are multicellular, layered models (and the fast, large memory computers to run them) like CAMx used by TCEQ and EPA today.

Clearly the 'meteorology' was of necessity highly simplified in this model and it only had one cell to hold the chemicals. The 'meteorology' moves the one cell over the 'emissions inventory' and the cell grows in height as the surface heats up from solar radiation, diluting the chemicals in the cell. Tables of 'initial mixing heights' and 'final mixing heights' were published by EPA for different cities. The mixing height curves shapes were based on EPA measurement work in real city atmospheres and were 'normalized' to shape, with initial and final heights determining the total dilution. Likewise, city emissions were 'estimated' and published. This model is still used all over the world to make O₃ predictions in cities for smaller nations.

The plot on the top right shows outputs for a single set of conditions model run in Atlanta, GA for 6/6/1988.

Looking at the concentration lines for NO, NO₂, VOC and O₃, one can see that the 'rising mixing height' rapidly diluted the initial amounts even while emissions were adding to the well-mixed box. On the other hand, so much O₃ is being chemically produced that the O₃ increased to over 180 ppb while the 'precursors' were being diluted to values lower

than 10 ppb. **Dilution actually permits higher O₃ to be produced!** It turns out that the controlling factor is not the actual NO_x concentrations, but the changing **ratio** of NO₂ to NO. This is because NO is oxidized to NO₂ by organic radicals and the subsequently photolysis of NO₂ makes back NO and creates O₃ and this can happen many times before NO₂ is finally lost to nitric acid (HNO₃) which does not photolyze. If the ratio NO₂ to NO exceeds about 10, the O₃ will likely exceed 80 ppb. The following three equations show how simple this part of the process is.



An overall relationship of these three reactions is (where [] means concentration, eg, ppb)

$$[\text{NO}][\text{O}_3]/[\text{NO}_2] = J/k_1$$

That is, the rate of loss of O₃ over the rate of production of O₃ is dominated by the inverse ratio of [NO₂]/[NO]. This can reach a 'photo-stationary state' in only a few minutes in urban atmospheres. Researchers in Tianjin, China have used measured average city ambient measurements to show this relationship in two compact plots in Figure 3.

Figure 3. Ambient City Relationship between O₃, NO, and NO₂ in China

(https://aaqr.org/files/article/1089/4_AAQR-10-07-OA-0055_128-139.pdf) (Han, et.al, Aerosol and Air Quality Research, 11: 128-139, 2011)

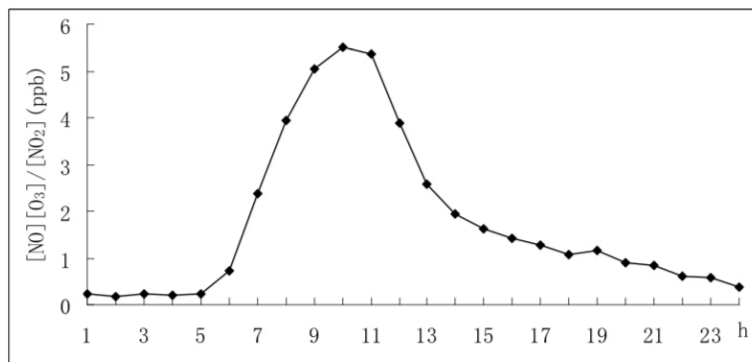
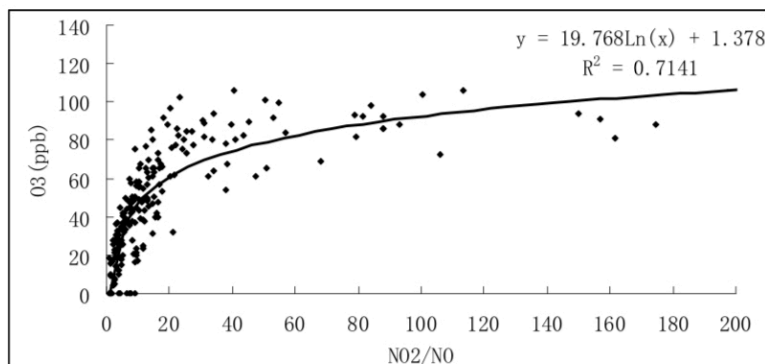


Fig. 3. Daily variation of mean values of J_1/k_3 (ppb).



The 'factors' that are keeping the [NO₂]/[NO] ratio high are the organically-derived HO₂ and RO₂ radicals from the reacting VOCs via photolysis or •OH radical attack on them.

These urban data show that the highest production rate of O₃ occurs between 08 AM and 11 AM, which is very similar to the ambient data in Houston and San Antonio. Further, even as the NO mixing ratios are driven down, O₃ can remain above 80 ppb.

What often happens later in urban centers, however, is that the evening traffic emits fresh NO that--in the declining light--reacts with atmospheric O₃ to 'recreate evening' NO₂. that does not photolyze. If there is not enough fresh NO, to exceed the evening O₃, the residual O₃ will 'carry over' during the night. Otherwise, in big traffic cities, evening O₃ approaches very low values via "NO_x titration". If, however, winds are blowing from a daytime higher O₃ area, residual O₃ can be blown onto the monitor site and fresh NO blow away and O₃ will remain higher during the night. This is one signal that some "ozone transport" is occurring at the site.

Now, return to Figure 1 and examine the two plots at the bottom. These illustrate the results of running the model over and over with different amounts of NO_x and VOCs. The 3-D plot on the left is the same as the 2-D 'isopleth' on the right. Several surprising elements show up:

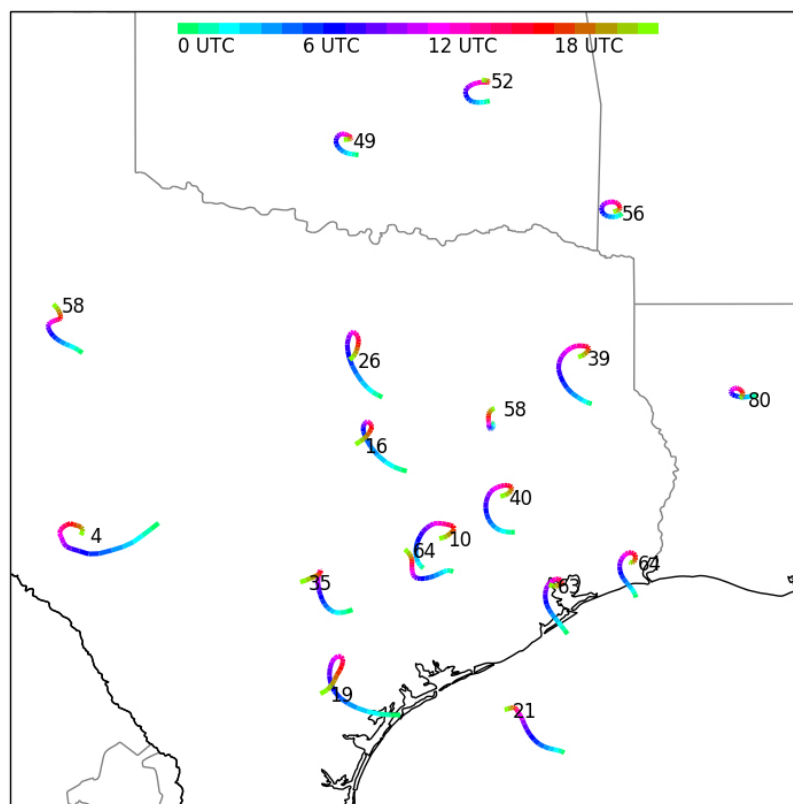
- 1) Final peak O₃ at first **increases** with increasing initial NO_x, but above a "ridgeline" increasing NO_x leads to **decreasing** O₃. This is because higher levels of NO_x can rapidly remove •OH radicals to make HNO₃ instead of NO₂ and fail to react with VOCs.
- 2) Final peak O₃ can only **increase** with **increasing** initial VOCs.
- 3) After some point, adding more initial VOCs increases O₃ less and less.
- 4) Which reactant to control to reduce O₃ depends very much on where you start.
 - In some cities, large-scale reduction of VOCs does little to reduce O₃.
These are NO_x-limited. (They are "below the ridgeline").
 - In other cities, large scale reduction of NO_x can actually increase O₃.
These are VOC-limited. (They are "above the ridgeline").
 - Before 2000, Houston once argued that this was their case!

3.2 Meteorological Concepts

Figure 4. Potential For Frequent 24 Hour Rotating Winds at 30° North Latitude

(Courtesy of Prof. John Nielson-Gammon, Texas A&M University, 2018)(<https://www.youtube.com/watch?v=pBl-aKA-qAM>)

Rotating Winds in Upper Air Texas

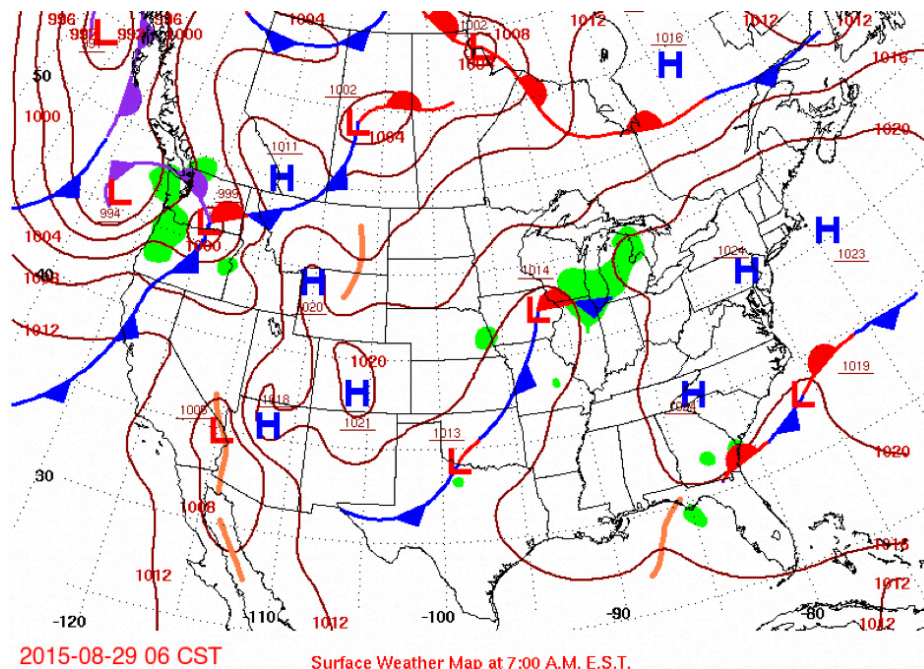
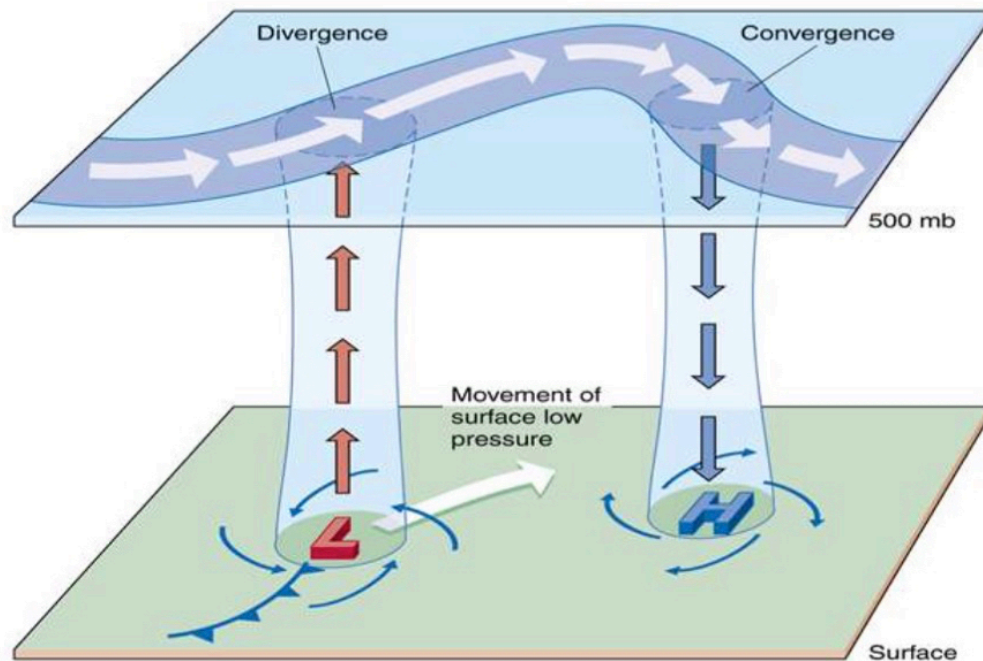


Mean 500 mb 24-H Wind Flow to Statewide Sounders during TexAQS2 for May-October days with WS < 11 km/h and the number of days used is marked.

Figure 4 shows the average measured upper winds for the conditions in the caption. The 500 mb level of atmosphere (which is near the level of non-divergence) allows for an efficient analysis of vorticity. The origin of these 'rotating winds' is the balance between the [Coriolis forcing](#) (an inertial force that acts on objects in a frame of reference that rotates with respect to the inertial frame) and large scale pressure gradient forcing ([geostrophic forcing](#)). The Coriolis force is due to the rotation of the earth and in the northern hemisphere 'deflects the moving object to the right of the counterclockwise rotation of the earth'. The effect of the Coriolis force is an apparent deflection of the path of an object that moves within a rotating coordinate system. The object does not actually deviate from its path, but it appears to do so because of the motion of the earth underneath it. The "strength" of the effect is proportional to the speed of the earth's rotation at different latitudes and it has an important impact on moving objects across the surface. **At 30° N latitude, a full apparent rotation (a circle) requires 24 hours.** To the north, the cycle time is shorter and further south is much longer (zero at equator). Houston, San Antonio, and El Paso are very near 30° N latitude. So the strongest effect is confined to Texas and Florida and the air pollution effects of this 'circular flow' are not very important in the rest of US.

The [geostrophic forcing](#) is caused by high and low pressure systems on the surface of the earth (see Figure 5). Figure 5 shows the flow around Low pressure and High pressure systems in the US and a US Weather Map for 2015-08-29 06:00 CST. The H pressure area over western NC and SC and the L pressure system over Texas and Louisiana, provide a 'geostrophic flow' from the Gulf of Mexico over much of Texas and that is very similar to the upper diagram and reinforces an ultimate SE to NW flow over Houston, (and San Antonio) TX on this day. But in the mornings, the [Coriolis forcing](#) can **oppose** this geostrophic wind and result in **reversible or looping wind trajectories**.

Figure 5. Geostrophic Flow around Low Pressure and High Pressure Systems in US.



Dr. Daewon Byun, a meteorologist (and former leader of the EPA Models3/CMEC development) also recognized this unique circulation problem when he moved to University of Houston in 2005 as he had worked on it in his graduate work at NC State. In 2005, he presented an analysis of the issue and a few of his figures are included here.

Figure 6. Byun, Kim, and Ngan Air Trajectory Tools and Theoretical Analysis.

(TexAQs II Intensive Field Study Meeting, Oct 11, 2005, and HARC H19 Report.)

Byun's full formulation of atmospheric surface flow is

Gutman and Berkofsky (1985); Byun and Arya (1990) →

$$\frac{\partial \mathbf{V}_m}{\partial t} = -\text{ADV}(\mathbf{V}_m) - f\mathbf{k} \times (\mathbf{V}_m - \mathbf{V}_{Gm}) - \left[g' \nabla \cdot \boldsymbol{\eta} - \left(\frac{gh}{2\Theta_0} \right) \nabla \cdot \boldsymbol{\Theta}_m \right] - \frac{C_d}{h} |\mathbf{V}_m| \mathbf{V}_m \quad (1)$$

[1]
[2]
[3]
[4]
[5]
[6]

[1] Local tendency

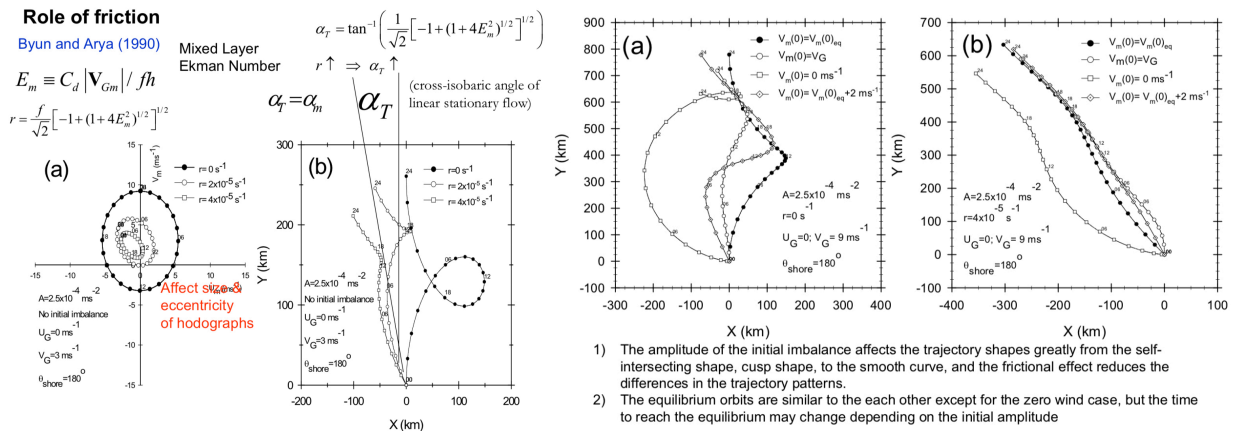
[2] Advection

[3] Coriolis forcing

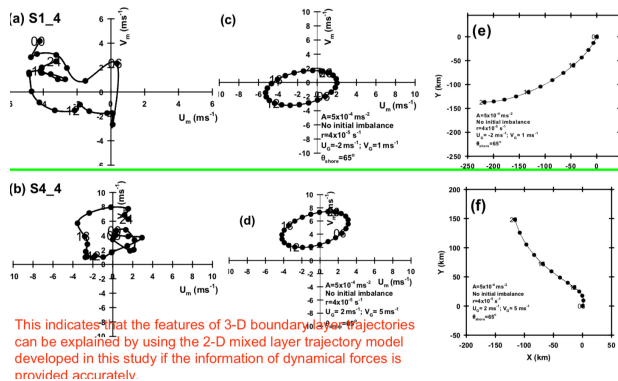
[4] Large-scale pressure gradient (or geostrophic) forcing

[5] Local thermal forcing

[6] Turbulent drag – Quadratic friction (no entrainment assumption)



Theory vs Real



Summary and Discussion

- According to the simple sensitivity test, the mixed layer trajectories have three types: 1) self-intersecting curve, 2) cusp shape and 3) smooth curve types depending on the different balance of the dynamical forces
- This classification of mixed layer trajectories is highly related with the hodograph analysis of mixed-layer wind. The size and location of the hodograph are determined by the combination of local thermal force and large-scale geostrophic force.
- Friction also plays an important role in the determination of the hodograph. Especially, it shifts the axis of hodograph center to the left of the geostrophic flow direction as the cross-isobaric angle increases and reduces the radius of the hodograph.
- The geographical feature of land and sea also has an important role since it determines the direction of land/sea breeze.

This model fully explains the shape of the surface wind trajectories across mid-Texas. The use of such 'trajectories' in ambient analysis shows that certain types are more ozone conductive than others. This concept forms the first 'classification' condition for analysis here.

3.3 Meteorological Conditions Classification Schemes

3.3.1 Monitor Site Hodograms and Derived Displacement Trajectories

Figure 7 shows wind hodograms from the BULL and SANA monitoring sites for some 2015 cases. The monitoring site is at the center of the radial plot with red circles being km/h wind speed circles and the squares and dots are at the hourly radial directions and speeds to the site observed for that hour. Color lines connect the hours. Midnight times are squares and hours are dots. The colors apply to 00–05 H, 06–11 H, 12–17 H, and 18–23 H.

In the first plot on the top left, all the winds to the site for the day came from the directions between N-NW and N at a wind speeds of 8 to 22 km/h. The 'wobble' of the locations is a refraction of the Coriolis force deflecting the wind paths.

In the first plot on the top right, in the morning, the winds to the site came from the N-NE but the wind reversed itself at about 09 H and then came to the site from the SE until midnight; this had the effect of blowing the morning air back over the site for the afternoon, reducing the 'mixing' for this site. In Texas, so far all observed O31H and O38H exceedances involve some type of 'back flow over' or 'circular flow around' the site.

Hodograms can be converted into 'displacement trajectories 'to' and 'from' the site and these are easier to understand than the ordinary hodogram.

Figure 8 shows example displacement trajectories derived from the hodograms for similar cases as those in Figure 7.

Figure 7. Hodograph Surface Circulation Representations

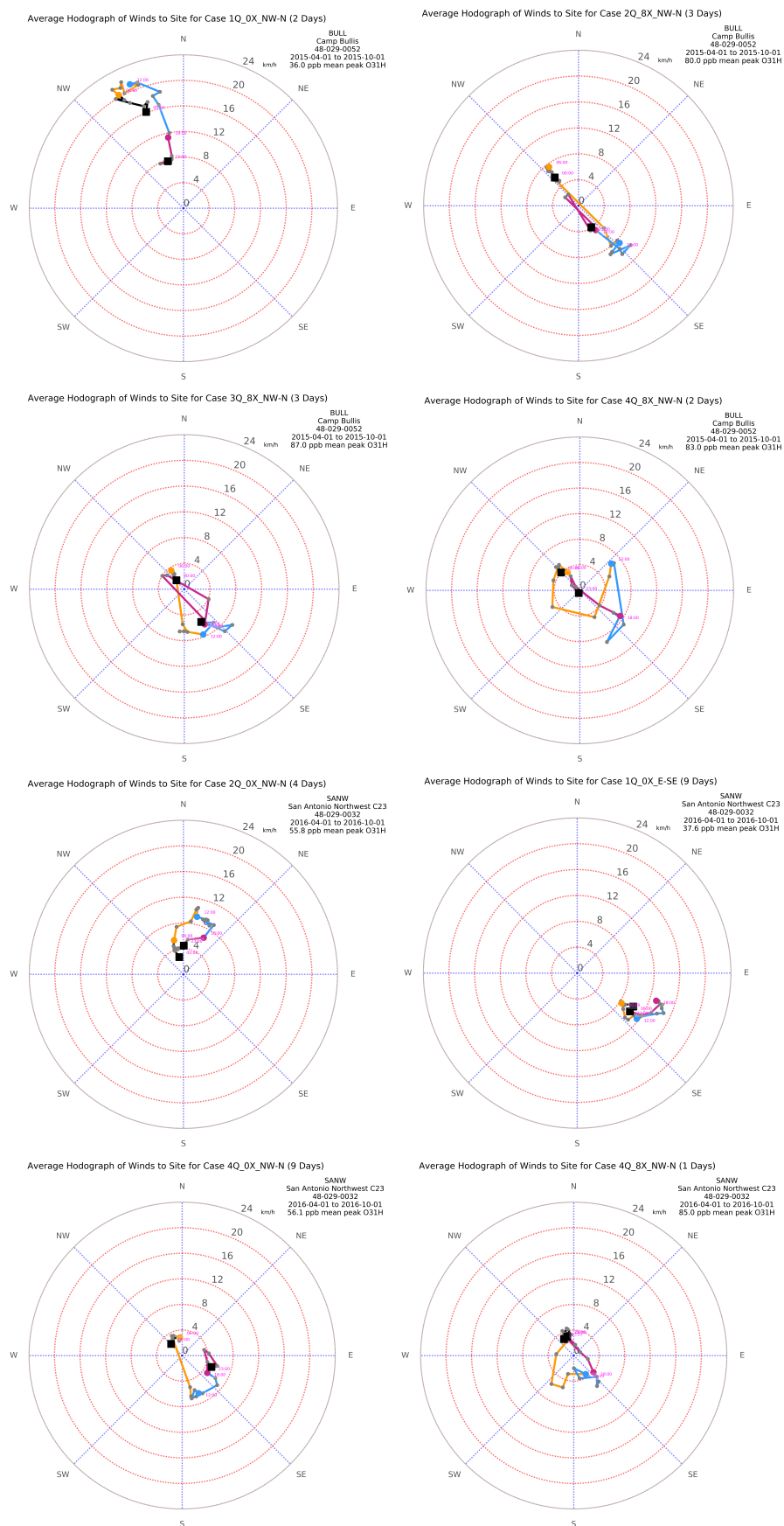
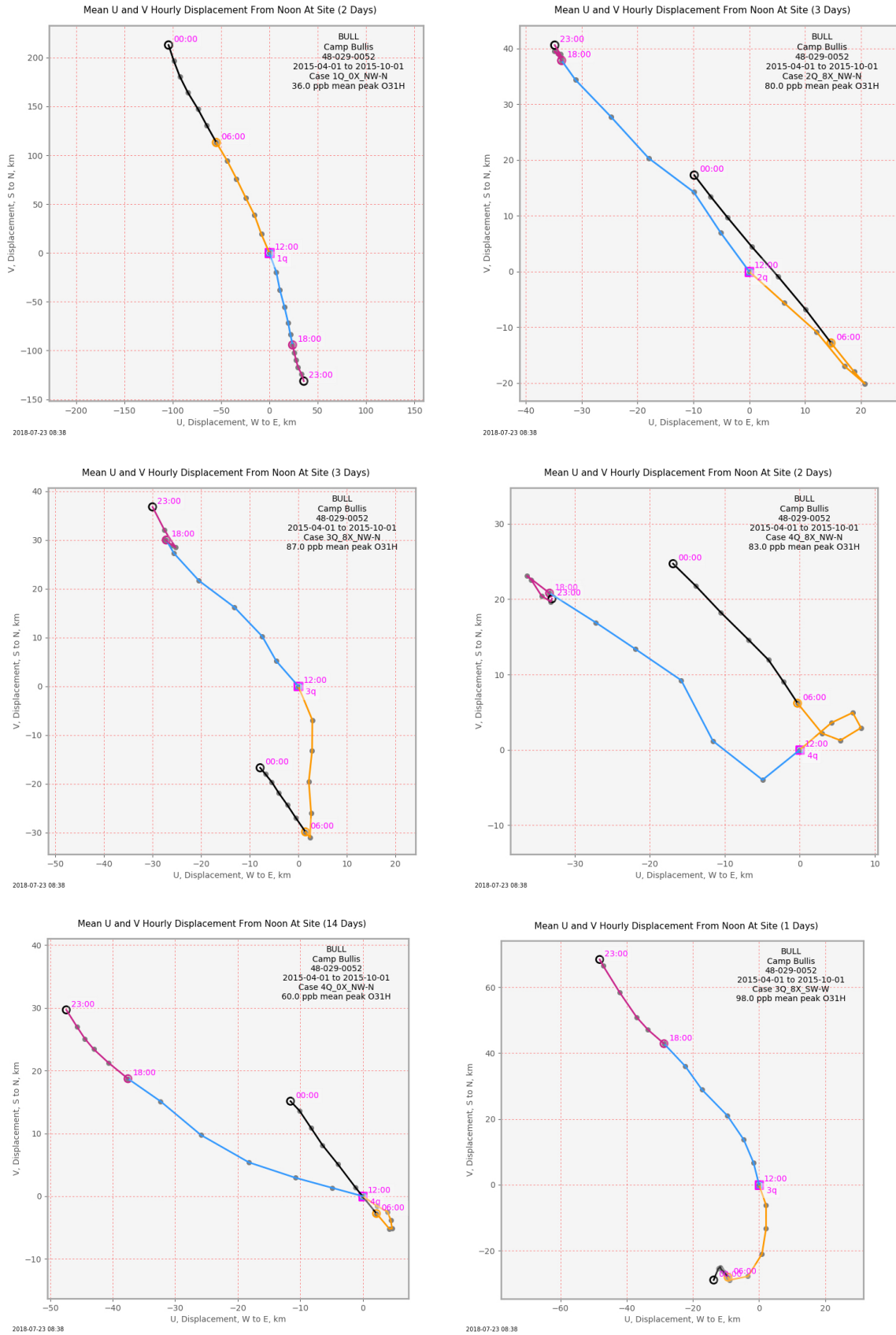


Figure 8. Displacement Surface Trajectories Representations



3.3.2 Monitor Site QX Pie Charts - How do they work?

To further classify and summarize the meteorological conditions (1Q, 2Q, 3Q, 4Q), and the ozone exceedances (0X, 1X, 8X, 9X) over monthly and annual time periods, "QX_PIE" charts are created for each site and for annual and monthly time windows. Such data were computed and appear in a special Pandas DataFrame named

site_yyyy_FL03_1D_1Y_STAT3

which is fully described in "Appendix A. Project Source Data" on page A 8. This DataFrame combines "Flow" and "Ozone" conditions for each day at site.

The 'nQ' number is a simple count of hours spent in the four wind quadrants

W-N, N-E, S-W, E-S

on each day at each site. For example, part of BULL_2015_FL03_1D_1Y_STAT3 for three days looks like :

nQ	HHInQ	WSInQ	sQatHH
3	[6,0,1,17]	[2,0,1,8]	[EESWWW WWWEEE EEEEE EEEEE]
4	[12,3,3,6]	[3,7,3,6]	[WWWWW WWSSWN NEEEEE EEWWWS]
4	[12,1,1,10]	[3,3,0,6]	[WWWWW WWWEEE ENEEEE EEWWWS]

where, in the first row example,

nQ : number of wind quadrants for day

nQ = 3 and sQ = '3Q'

HHInQ : number of hours in each Q

6 hours from W-N,

0 hours from N-E,

1 hours from S-W,

17 hours from E-S

WSInQ : average wind speed in each Q

2 km/h from W-N,

0 km/h from N-E,

1 km/h from S-W,

9 km/h from E-S

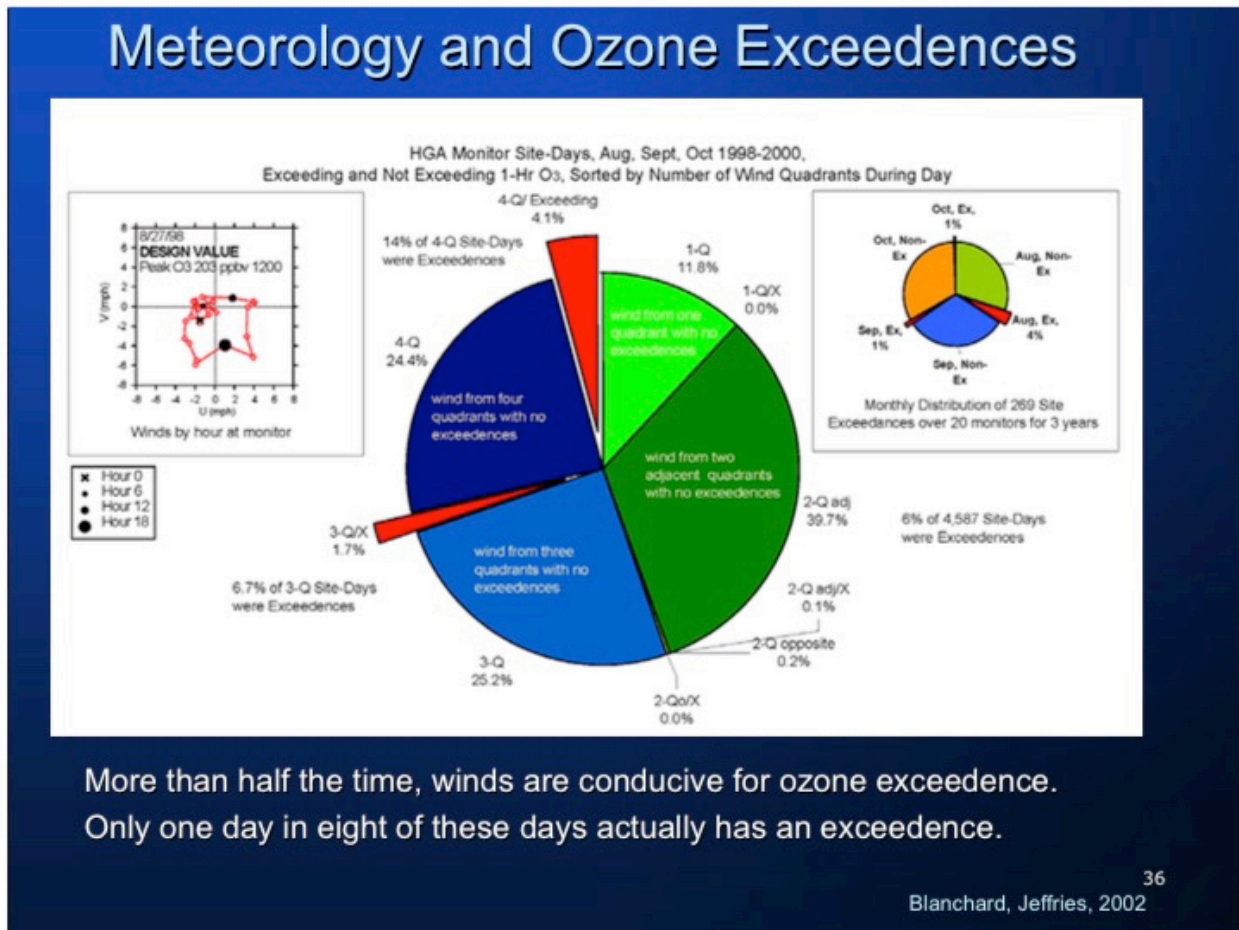
sQatHH : quadrants by hour

The QX_PIE chart combines the number of wind quadrants and the number of exceedances in an easily comparable plot.

QX_PIE charts were first created by Jeffries in 2001 when the ozone standard was 125 ppb for 1-hour.

Figure 9 shows this first QX_PIE chart. Jeffries generated an hypothesis that has been tested in Houston with nearly a 100,000 monitor hours of ozone and wind data and with changing O31H to O38H at 85, 75 and 70 ppb exceedance levels.

Figure 9. QX_PIE Plot of 1998-2000 Houston Ozone Data 1X Exceedances



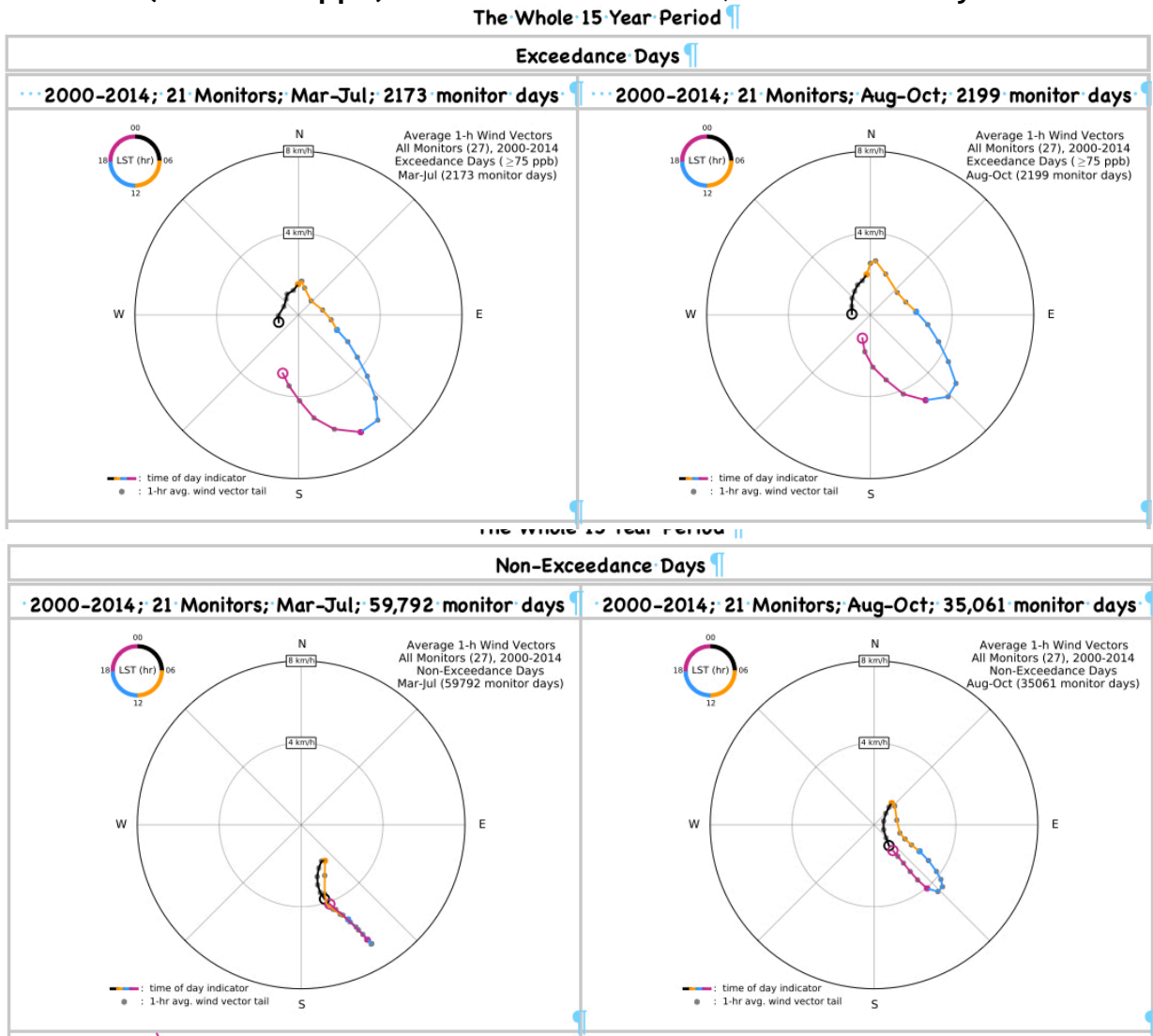
In the original 2001 to 2004 work Jeffries did in Houston, Blanchard and Jeffries, (2002) found that **all** exceedences of the **1-H 125 ppb ozone standard required** either a **3Q** or **4Q** wind at the site of violation.

Jeffries generated an empirical hypothesis that O₃1H exceedences at or above 125 ppb O₃ needed the "constraint" of dilution and time near the monitor to generate the higher concentrations; these flow conditions were associated with winds that came to the site before noon during 3Q's or 4Q's wind conditions. The 1Q and 2Q conditions for the sites in Houston did not appear to provide enough time for chemistry to work faster near the monitor than subsequent downwind dilution.

Subsequently, in Jeffries' work in Houston after the standard was changed to O₃8H and was lowered to 85 ppb (and then to 75 ppb), this analysis was repeated but using monitored data from 27 regulatory and private network ozone monitors from 2000 to 2014 at O₃8H > 75 ppb. Once again Jeffries---considering 99,225 monitor hours of data---found that **only 3Q** or **4Q** wind at the site of violation could create **8X** exceedences.

Instead of QX_PIE charts, these latter data were processed into UV03_H0D0 plots (see details in Figure 10) for both monitors in attainment and those not in attainment.

Figure 10. UVO3_HODO Plots of 2000-2014 Houston Ozone Data 8X Exceedances (O38H > 75 ppb) for 27 Monitors and 99,225 Monitor Days



The mean nQ for all exceedances of O38H 75 ppb standard for 4,372 monitor days in Houston was 4Q, but the hours spent in the S-W Q was at midnight as the Coriolis forcing closed its circle for the day.

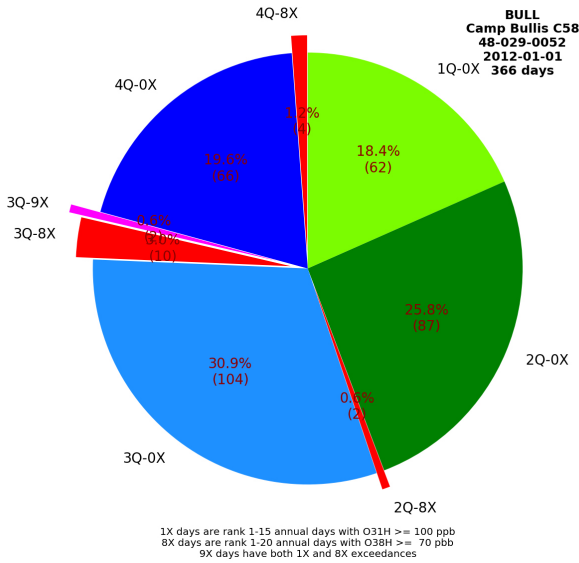
3.3.3 San Antonio Monitor Sites QX Pie Charts

Figure 11 compares QX__PIE charts for BULL and SANW monitors for 2012, 2015, and 2016. Note that there are inter-annual variations in the distribution of number of Q-days because the El Niña/La Niña bi-annual cycle of large scale flow over the US changes the geostrophic flow patterns across the whole US south.

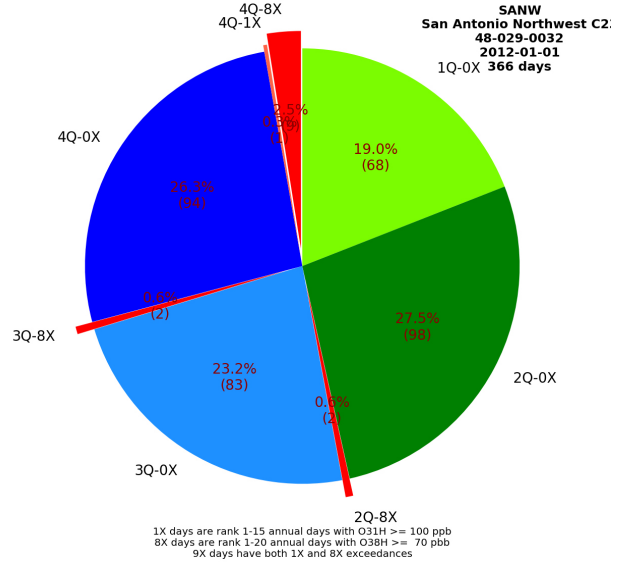
A 'surprising' feature of these QX__PIEs is that in 2012 two days had a 2Q O38H 8X (70 ppb) violation at both sites, and in 2015, both sites had a one day 2Q O38H 8X violation, but 2016 had no such violations. These will be investigated further below.

Figure 11. Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X) At San Antonio, 2012, 2015, 2016

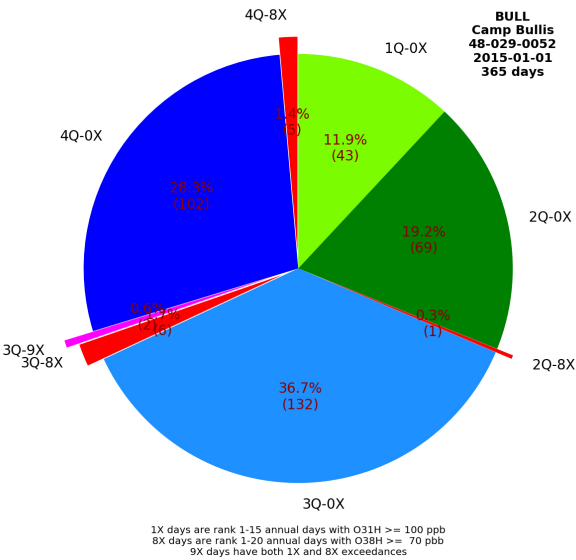
Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)



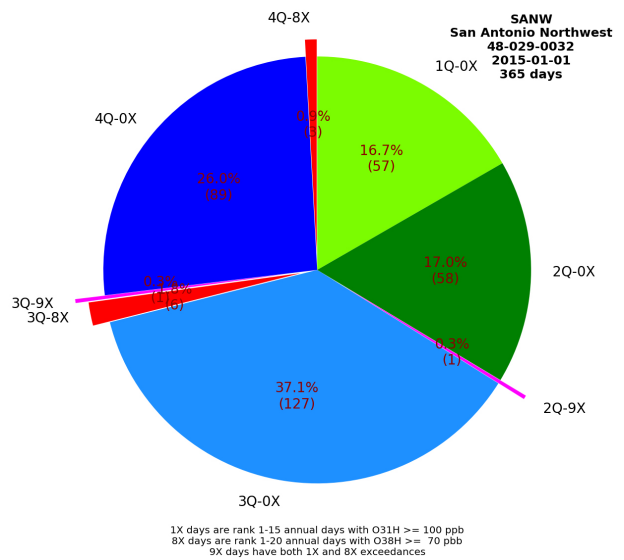
Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)



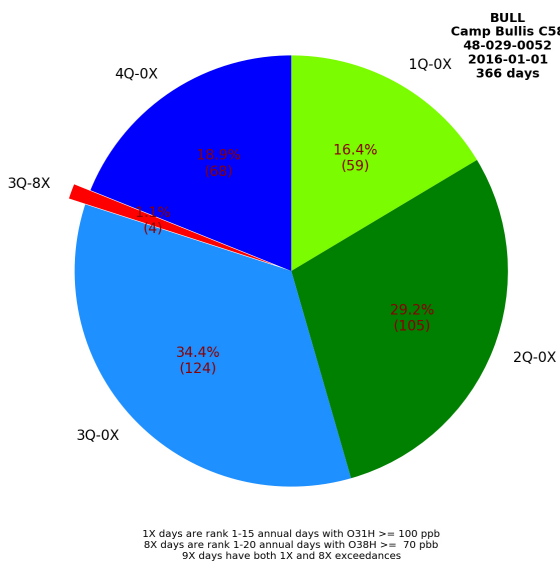
Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)



Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)



Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)



Daily Wind Quadrants (Q) and O₃ 1-H and 8-H Exceedances (X)

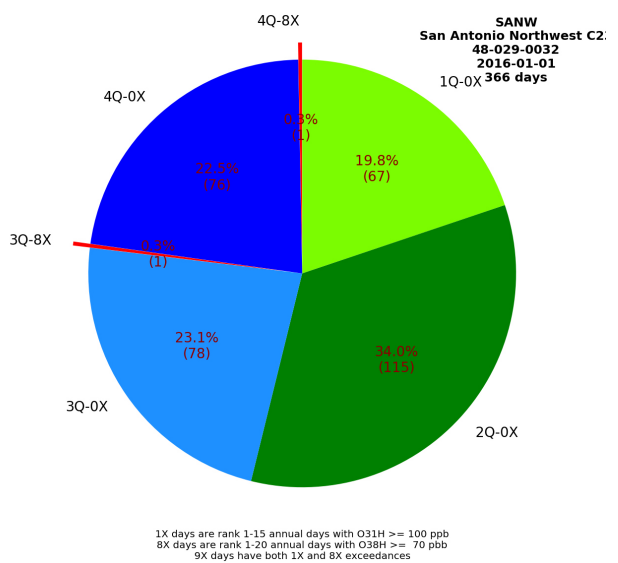


Figure 11 compares QX_PIE charts for BULL and SANW monitors for 2012 and 2015. There were more 3Q days at BULL and more 4Q days at SANW. Then in 2015, the number of days in the wedges shifted similarly at both sites, due to the large scale flow changes. Both sites exhibited one 2Q exceedance day and it was a 9X day at SANW. In 2016, the Q-day distributions at BULL are very similar to those in 2012, while the number of 2Q, 3Q wind days shifted significantly to more 2Q days. The number of all exceedances in 2016 decreased significantly compared to 2015, and there were no 2Q 8X days at either site.

3.3.4 San Antonio Monitor Sites Potential O31H Transport

In Figure 12, data from the SANW 2015 monitor are shown as O3xH_UVDD time-windowed, ozone and wind time series and at the bottom from UVO3_TRAJ for two days.

The O3xH_UVDD plot shows O31H (black lines), O38H (red bar), Wind Speed 1H (blue lines), and shows centered along the 100 ppb ozone line, the UV component displacements (color coded as the square legend box in upper left) with noon centered on the 100 ppb line. These same data in larger format is shown in the bottom plots as UVO3_TRAJ, but for one day with 'sQXW_i' value of '2Q_9X_S-SW' (2015-08-27) and a later day with '3Q_9X_S-SW' (2015-08-29). The 2015-08-27 day was rank 2 in O38H exceedance and the 2015-08-29 day was rank 1 in O38H exceedances at SANW site in 2015.

Investigating these plots for the SANW 2Q exceedance shows that this exceedance was a morning 60 km 'transport' flow from the S-SW, followed by a counter clockwise 90° turn to the NW, bring air from the E-S quadrant from the central city after 15:00 HH. As can be seen in the O3xH_UVDD plot, the flow from the S-SW was late afternoon, peaking in ozone at 14:00 HH. This appears to be 'direct transport' of O31H from the 'city' to the SE of SANW. A similar event appears to have happened on 2015-08-29 day.

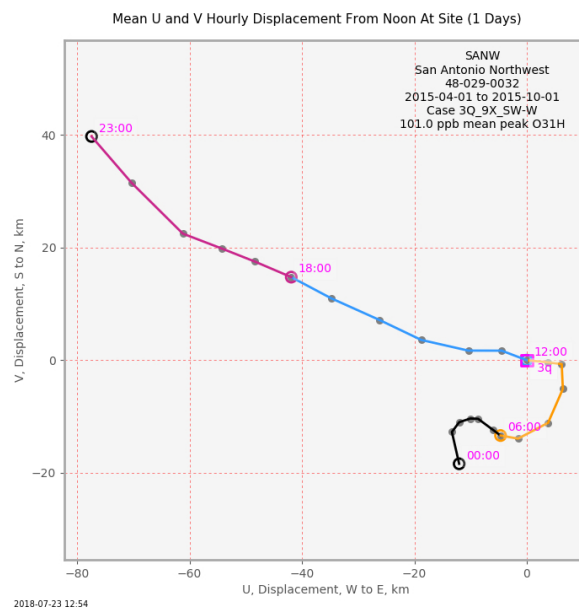
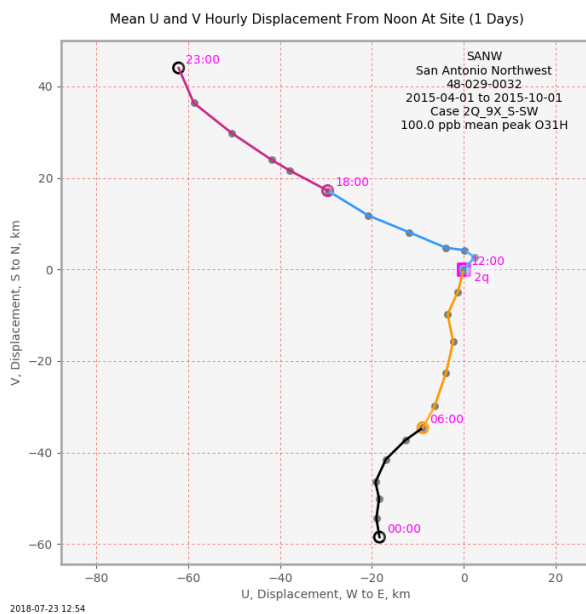
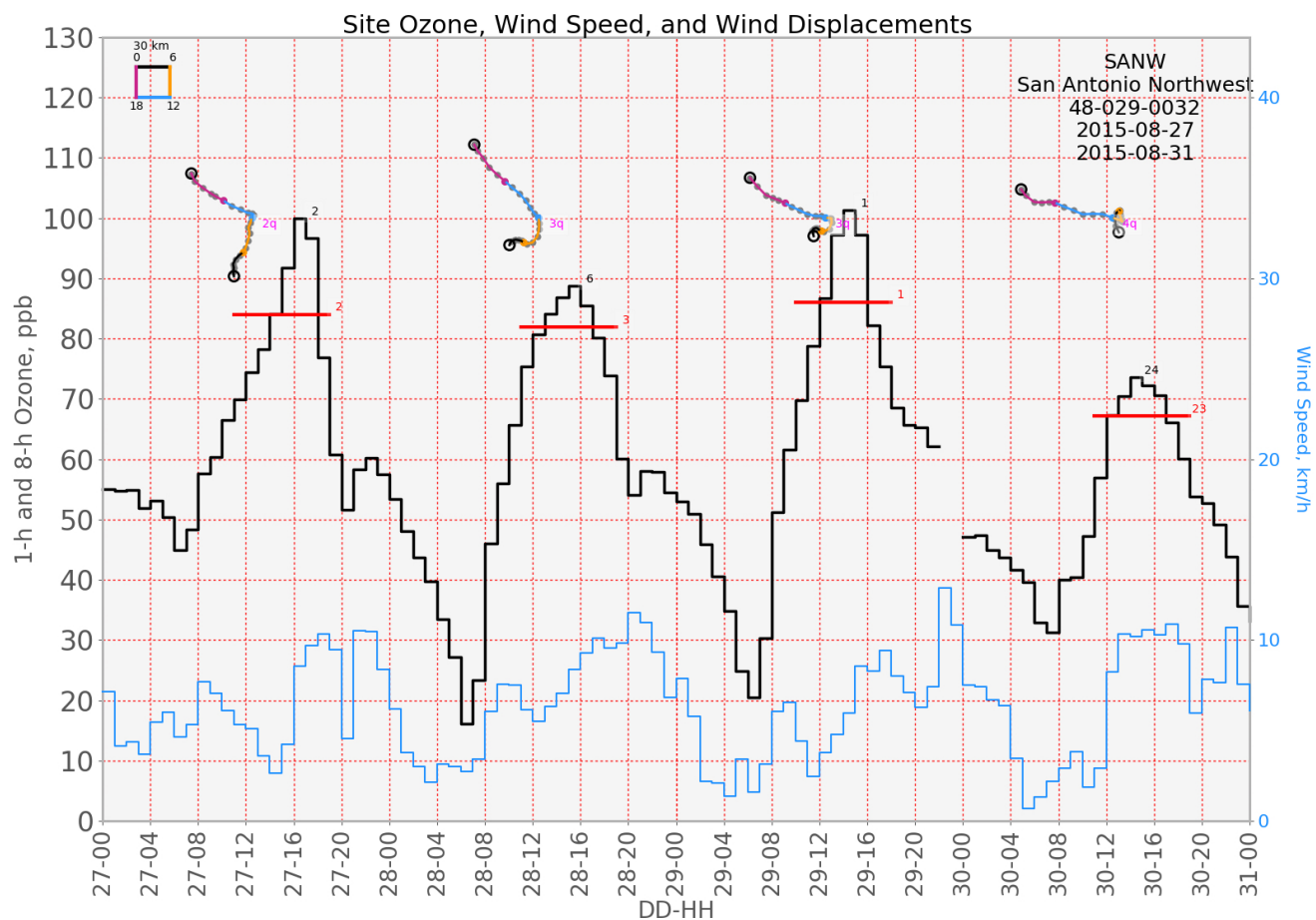
Further support for "transported" O31H is seen in the ozone levels in the time windows between 00:00 HH and 08:00 HH, which were between 55 and 45 ppb of O31H and showing little sign of any 'fresh NO' titration. Thus the next day daily chemistry started off with significant morning ozone and slow stepped ozone production until the wind shifted to come from the city and then O31H increased 15 ppb over two hours. The high 'transport' of O31H continues 18:00 to 24:00 HH and eventually the morning traffic begins to 'titrate' the O31H down to 20 ppb just before the morning sun-driven chemistry starts. This behavior appears to occur for all days shown in the plot.

The change in direction to the SANW site during the morning of 08-30, finally stopped the morning rise of ozone before 12:00 HH.

This seems to be a clear case of 'transport' of ozone itself into site and transport of local NOx away from the site. Thus the mechanism that creates O31H in Houston monitors and in most of the San Antonio, given the type of terrain, can set up a case of 8X, 9X exceedances for 2Q conditions. Note however that the distances involved are on the order of 60 km.

These conditions appear to be very infrequent, but these were the rank 1 and rank 2 8X/9X exceedances at SANW in 2015. No such conditions occurred in 2016 observations.

Figure 12. SANW Ozone 2Q Transport Example, August 2015



3.3.5 Houston QX_Pies for Comparison With San Antonio QX_Pies, 2012, 2015

Figure 13. Wind Quadrants and Ozone Exceedances At Houston, 2012, 2015

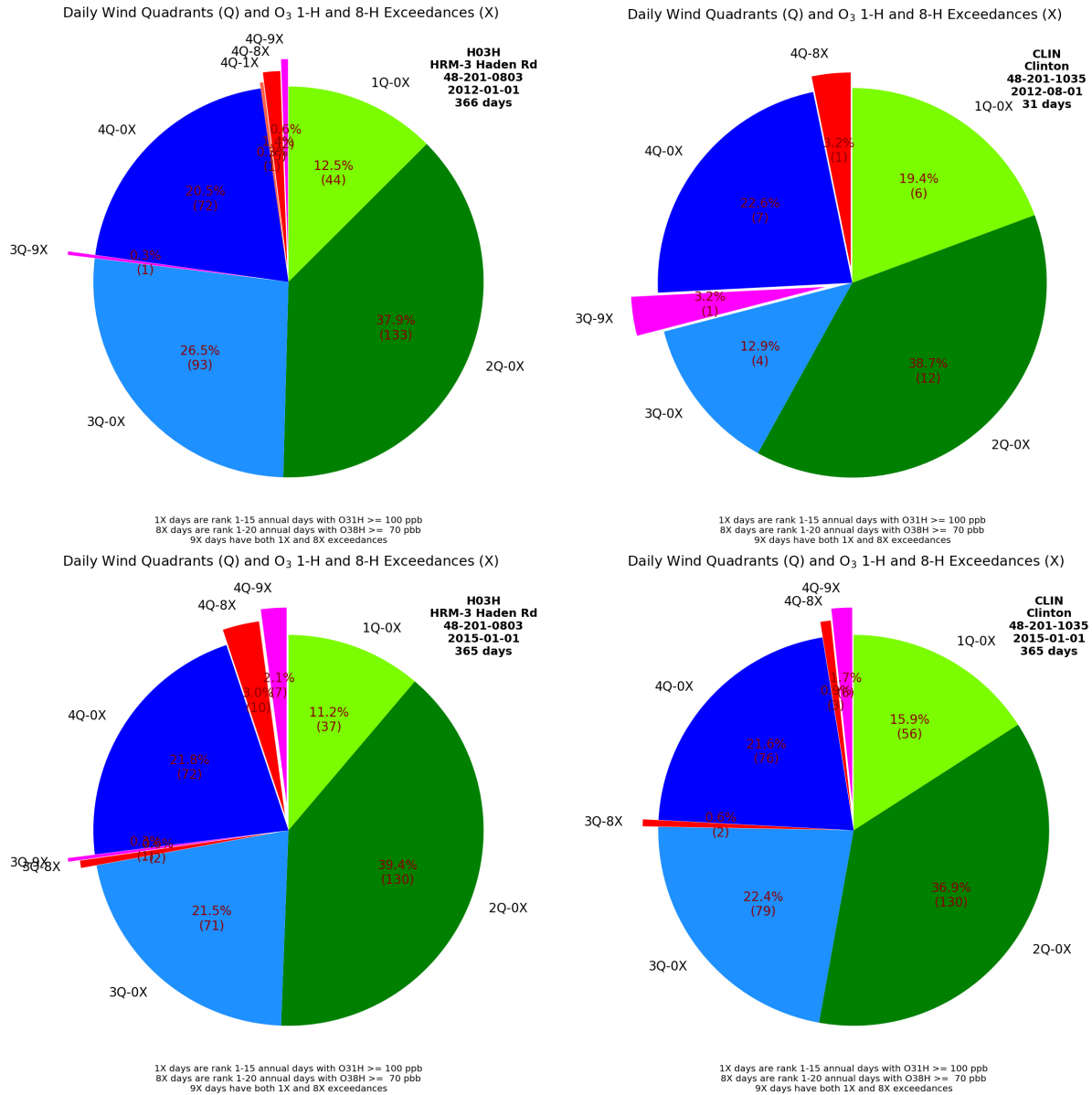


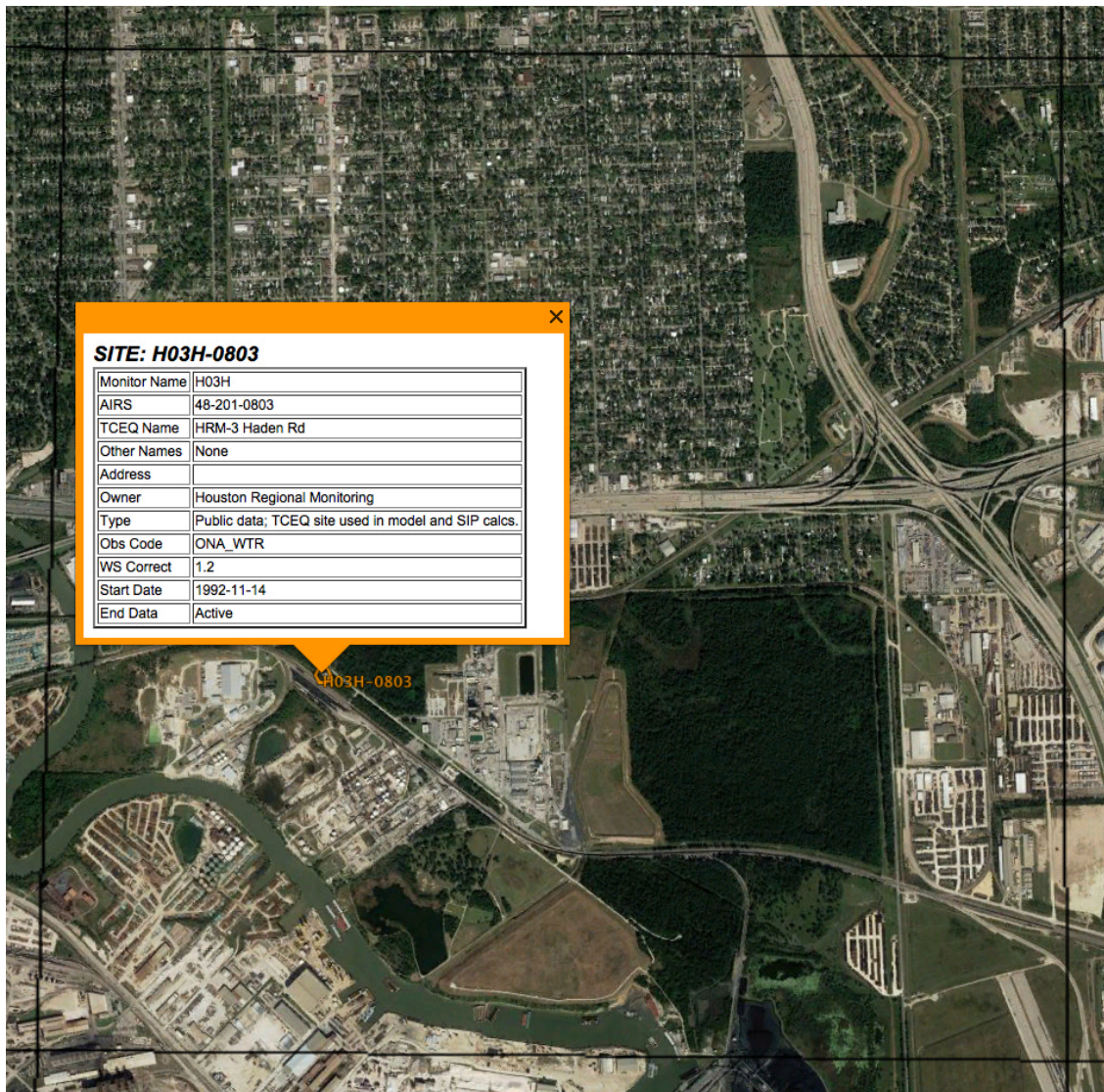
Figure 13 has QX_PIE charts for 2012 and 2015 for contrast with San Antonio in Figure 11.

3.3.6 Houston Model Predictions Compared to Houston Monitor Observations, 2012

The year 2012 was the base year of modeling by TCEQ and others (Alpine Geophysics in Houston; AACOG in San Antonio) all using the same 4-km grid and mostly the same emissions and winds. While AACOG was able to supply OThree Chemistry with model extracted predicted concentrations and winds, these were not available until early September and too late for OThree to include in this work. These will be analyzed in October 2018.

Alpine Geophysics also runs the same TCEQ model and data with a focus on the Houston area; they were able to supply the extracted model data for the sites in Houston in late August. Comparing the 'Measured' and 'Predicted' values at the Houston sites is useful in understanding the model's performance. I do not expect the San Antonio part of the grid to be much different.

Figure 14. Example Model Four Kilometer Grid and Houston H03H Monitor, 2012

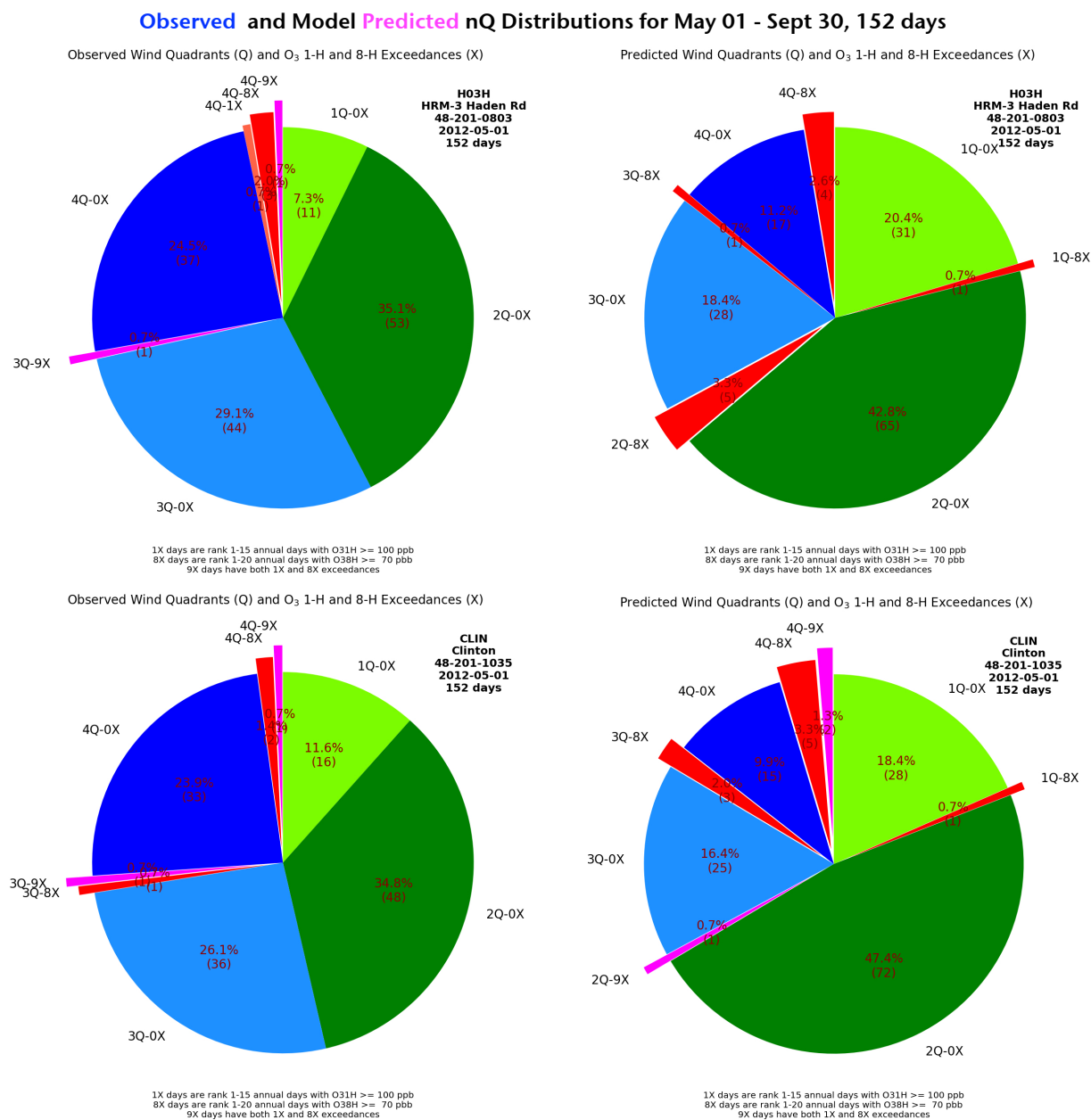


Single 4-kilometer CAMx Model Grid (black lines) containing Houston H03H TCEQ Monitor

Model predicts one set of mixing ratios for whole cell and layer.

Model predicts U- and V- components of the wind at left edge and bottom edge and layer.

Figure 15. Wind Quadrants and Ozone Exceedances At Houston, 2012



The left pies are “Observed” data and the right pies are “Predicted” data. The model was run only from May 01 to September 30, or 152 simulation days. For comparison purposes, the the observed data has also been ‘time-windowed’ to match the days and conditions simulated by the model. The model also uses a complex, nested metrological grid to simulate the U and V winds at the boundaries of the 4-km grid cells. See Figure 14.

The monitor-cell extracted model data were processed as if they were the observed AIRS measured data.

3.3.6.1 Differences For Exceedances Among Observations and Predictions

The first Obs-to-Mod agreement is that the 'winds do rotate'.

The first Obs-to-Mod disagreement is the distribution of wind nQ and nXs:

Site H03H 2012 Wind nQ and Ozone nX Errors (days)

nQ	Obs		Mod		Errors	
	nObs	nX	nObs	nX	nQ	nX
-Q	1					
1Q	11	0	32	1	21	1
2Q	53	0	70	5	38	5
3Q	45	1	29	1	-16	0
4Q	42	4	21	4	-21	0
Days	152	5	152	11	22	6

Site CLIN 2012 Wind nQ and Ozone nX Errors (days)

nQ	Obs		Mod		Errors	
	nObs	nX	nObs	nX	nQ	nX
-Q	14					
1Q	16	0	29	1	13	1
2Q	48	0	73	1	25	1
3Q	38	2	28	3	-10	1
4Q	36	3	22	7	-14	4
Days	152	5	152	12	27	7

For 2012, the model predicts :

6 more exceedance days at H03H and

7 more exceedance days at CLIN

than were observed at these sites.

The H03H nQ errors were 22 extra days with 1Q and 2Q winds.

The CLIN nQ errors were 27 extra days with 1Q and 2Q winds..

The model is showing prediction errors for all wind quadrant directions.

Further detail investigation is planned and the San Antonio model data will be included.

3.3.7 Monitor Site QXW__ROSE Plots - How do they work?

The QX__PIE charts are a good first look at Qs and Xs by site, but while they indicate how many nQs are involved, they do not indicate “where from”. Another directional dimension needs to be introduced to further understand ‘source regions’ for nX violations: these are QXW__ROSE plots. A new wind direction characteristic, ‘nW’ and ‘sW’ are needed for these and other DataFrames and to associate with datetimes. These columns appear in several Pandas DataFrames named :

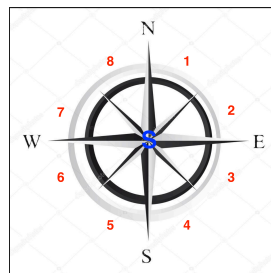
```
site_yyyy_QXWF_1D_1Y_CODES  
site_yyyy_QXWF_1D_1Y_TEXTS  
site_yyyy_QXWF_1D_1Y_STAT3  
site_yyyy_QXWF_1D_1Y_STAT4
```

that are all fully described in “Appendix A. Project Source Data” on page A 9. These DataFrames all combine elements of “Flow” and “Ozone” with conditions for each day at site.

These ‘nW’ and ‘sW’ data elements are derived from a ‘C8ta’ column in the previously partially described special Pandas DataFrame named

```
site_yyyy_FL03_1D_1Y_STAT3
```

wherein a Pandas column is calculated for each day at each monitor from the site wind data. This metric is a 4 digit shorthand way to represent the Compass Headings of each of the four 6-hour segments of the wind trajectory as belonging to one of the 45° compass octets for that segment. The compass octets are numbers, ‘nW’, between 1 and 8 that are assigned to a compass as:

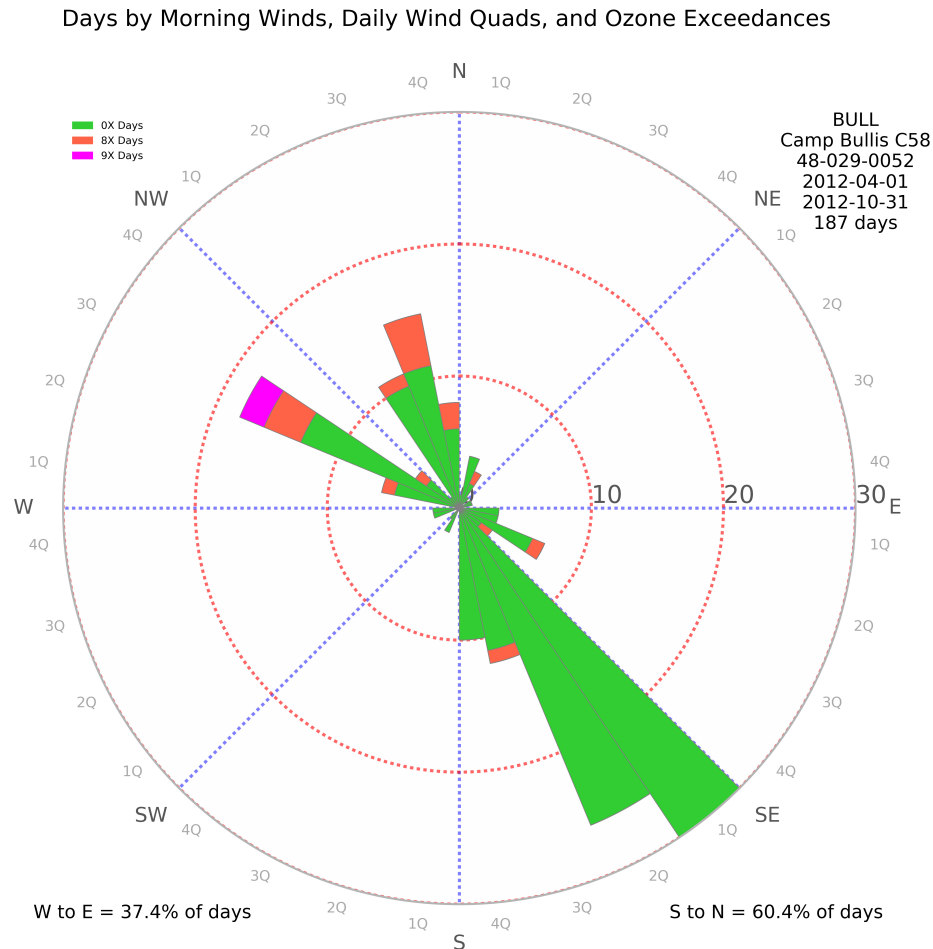


The ‘sW’ representations for labels are :

```
1 = 'N-NE ', 2 = 'NE-E ', 3 = 'E-SE ', 4 = 'SE-S ',  
5 = 'S-SW ', 6 = 'SW-W ', 7 = 'W-NW ', 8 = 'NW-N '
```

The ‘sW’ joints with ‘nQ’ and ‘nX’ to create a daily characteristic ‘sQXW’ to help further classify the morning winds.

Figure 15. Anatomy of a QXW__ROSE Plot



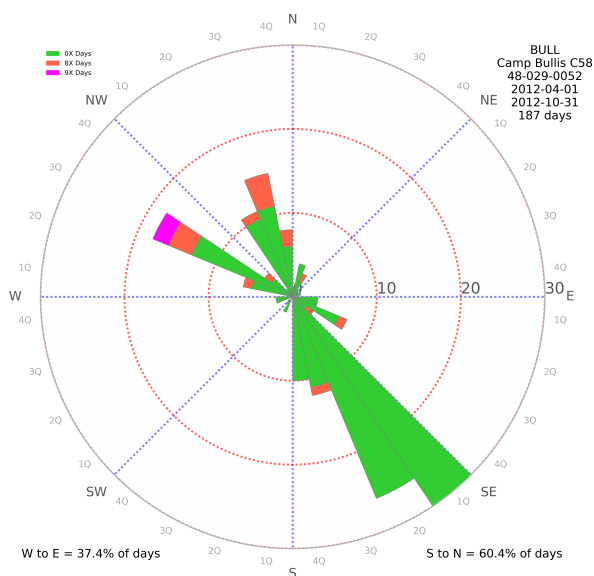
The 'rose' is laid out on a compass diagram divided (by blue lines) into (eight 45°) wedges with names that use the left and right compass points like 'N-NE' followed by 'NE-E' etc. These wedges are called 'octets'. Each octet is further divided into 4 'nQ' sub-wedges, marked on the outside radius. The nQ wedges are 11.25° used to hold a 'petal' for winds that came from the 'octet' in the morning, but the whole day was one of '1Q', '2Q', '3Q', '4Q' character. The diagram is divided into 'number of days' by red circles. The 'petals' are wedge-like that extend from the center (the site) a length proportional to the number of days with the same 'SW' and 'SQ' characteristics the labeled octets parameters. Within each of these petals the number of days with 'sX' (exceedance status) are colored (G = 'OX', R = '8X', and P = '9X' day)

For BULL for the April-October window, the site experienced winds from all octets (but only 1 day from 1Q_OX_NE-E and only 3 days from S-SW and SW-W). The majority of the wind (78 days) came as 1Q (30), 2Q (25), 3Q (13), and 4Q (10) days from SE-S and these had only one day with 8X exceedance. The majority of O38H exceedance days come from W-NW (2 9X days, 3 8X days) to NW-N (7 8X days of 3Q, 4Q, with one 2Q day.)

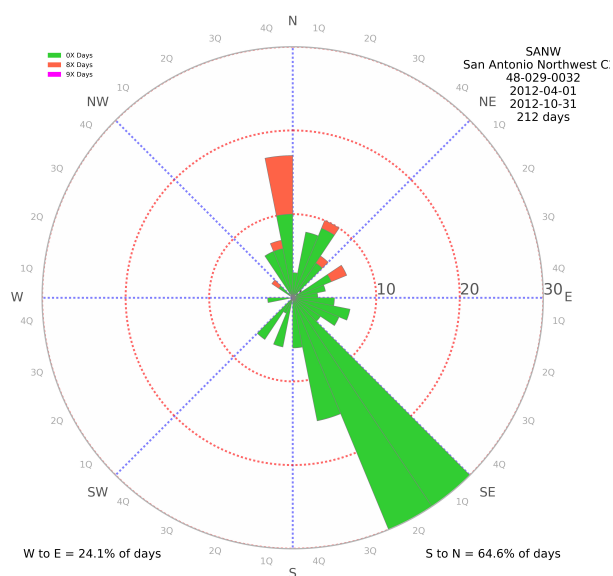
It seems clear that the "city" is not the source of the O38H production for BULL and SANW sites, but instead sources that are in the West to North quadrant of the sites are the major origins of O3 production.

Figure 15. QXW__ROSE Plots for BULL and SANW, 2012, 2015, and 2016

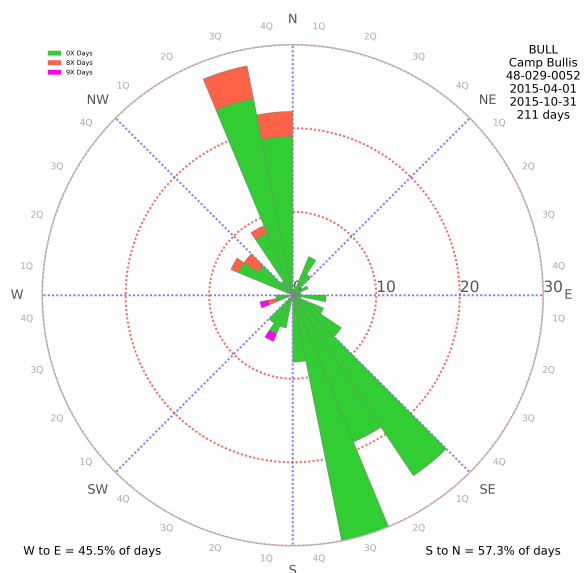
Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



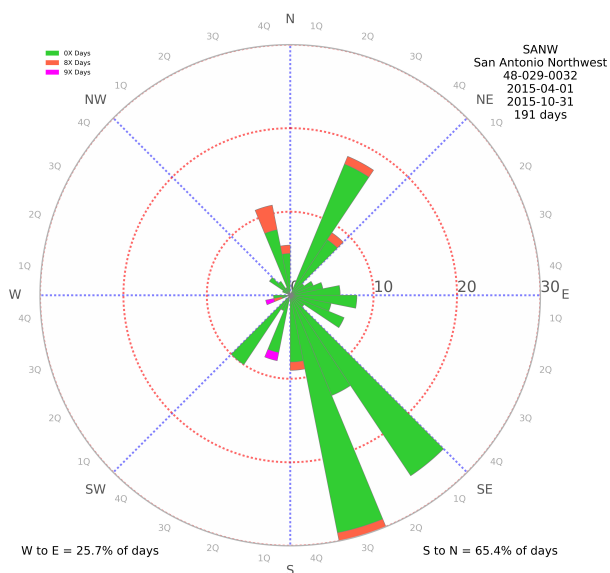
Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



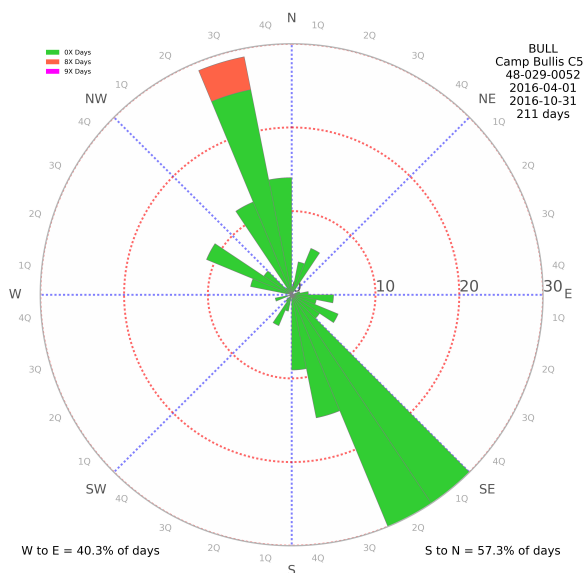
Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



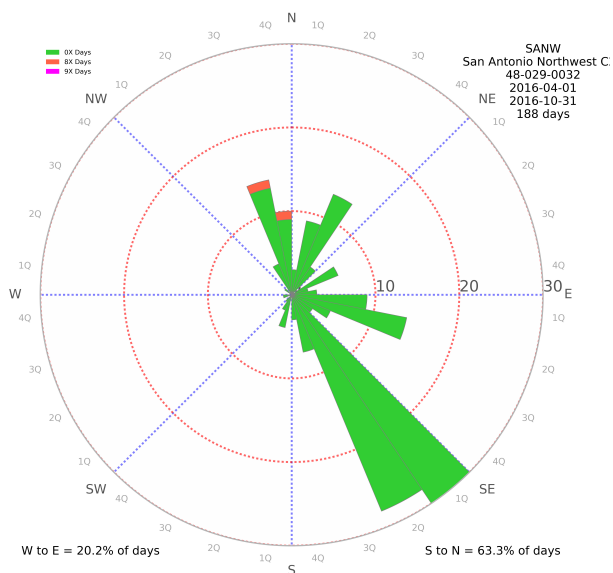
Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



Days by Morning Winds, Daily Wind Quads, and Ozone Exceedances



3.3.8 Monitor Site QXW__WOCT Plots - How do they work?

The above QXW__ROSE charts are a good tool for locating the directions for O31H precursor regions but they do not indicate “when” these happened. A temporal dimension needs to be introduced to further understand when ‘nX’ violations are happening: these are the QXW__WOCT (‘wind octet’) plots. These use the same ‘nW’ and ‘sW’ morning wind data items, but the form of the plot is temporal. Because the wind direction are ‘circular’ and ‘wraps around’ some special off-settings are need to make these time-series plots of ‘sW’ and ‘sQ’ plots.

The average morning winds to the site are computed using the first two digits of the ‘C8ta’ daily property as in the QXW__ROSE plots above; these are plotted offset on the y-axis to avoid excessive rolling over the top or bottom. These values are plotted in a time-series plot against the Date of the observation and are connected by a line to show the daily shifts in wind directions. The ‘dot’ that is plotted for the day is ‘filled’ with a gray scale color indicating wind speed in the morning (white is <5 km/h to black, which is >40 km/h). A red filled circle shows an ‘nX’ violation on that day and wind condition.

Across the top of the plot, the ‘nQ’ variable is plotted for each day with ‘1q’ and ‘2q’ days and ‘3q’ and ‘4q’ day markers.

In both the 2012 and 2015 years, in San Antonio and Houston, the vast majority of the days start out from the East to the South. As frontal passages occur due to large-scale High and Low pressure systems passing west to east across the US, the morning wind heading shifts to West to North.

Except for three days at BULL in 2012 and two days at SANW in 2015, all other ‘8X’ or ‘9X’ O38H violations happen only for ‘shifted’ morning winds at ‘3q’ and ‘4q’ conditions.

Figure 16. QXW__WOCT Plots for BULL and SANW, 2012

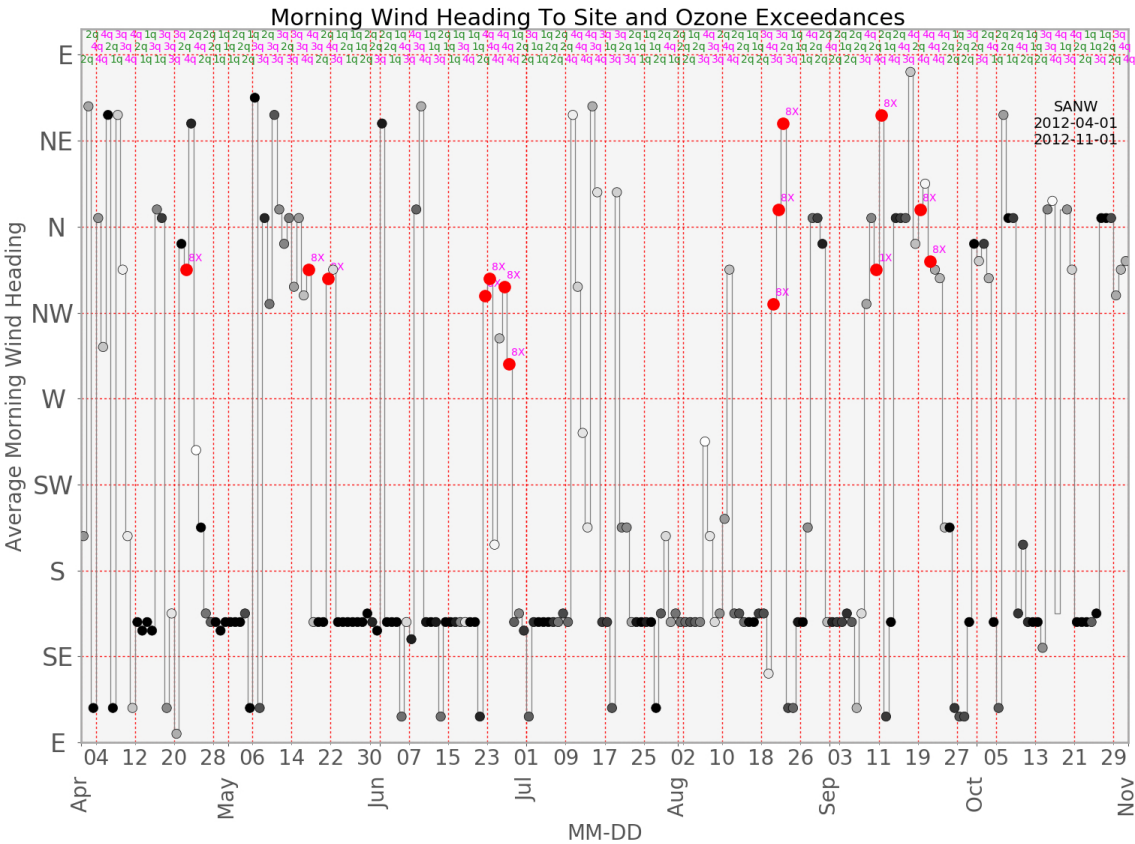
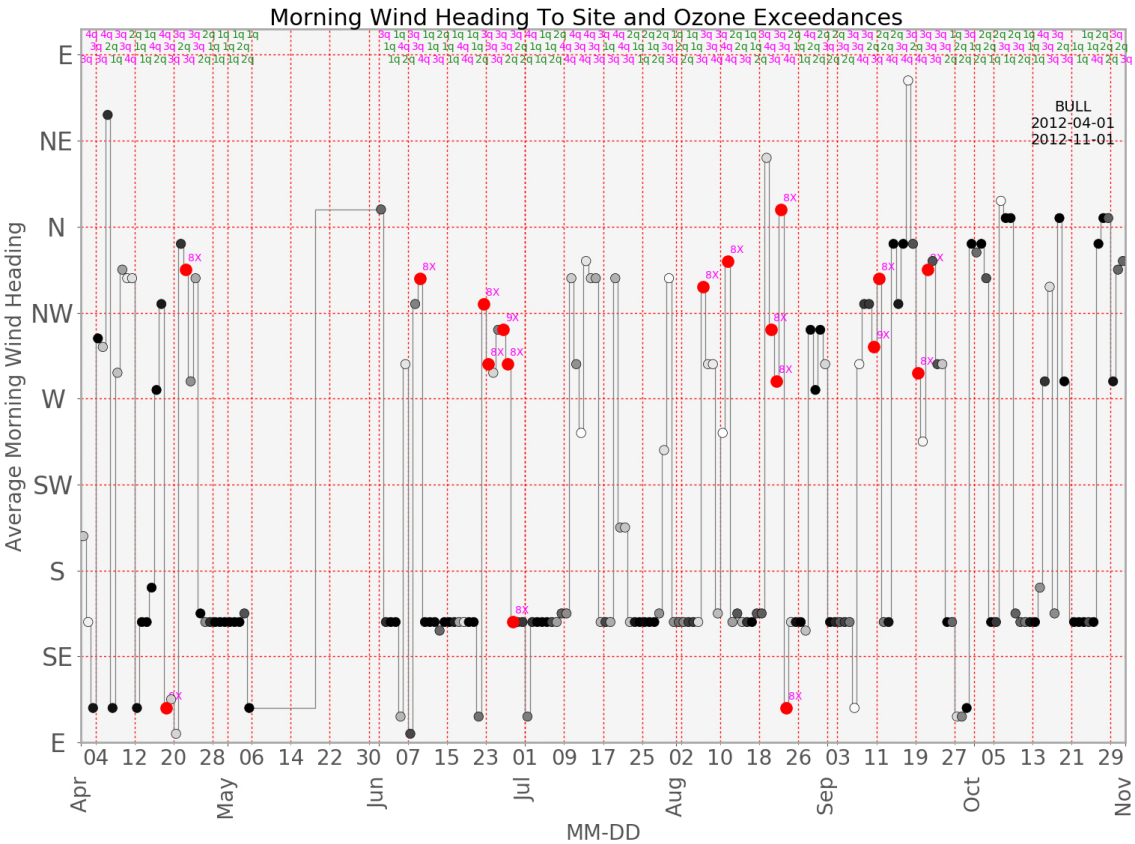
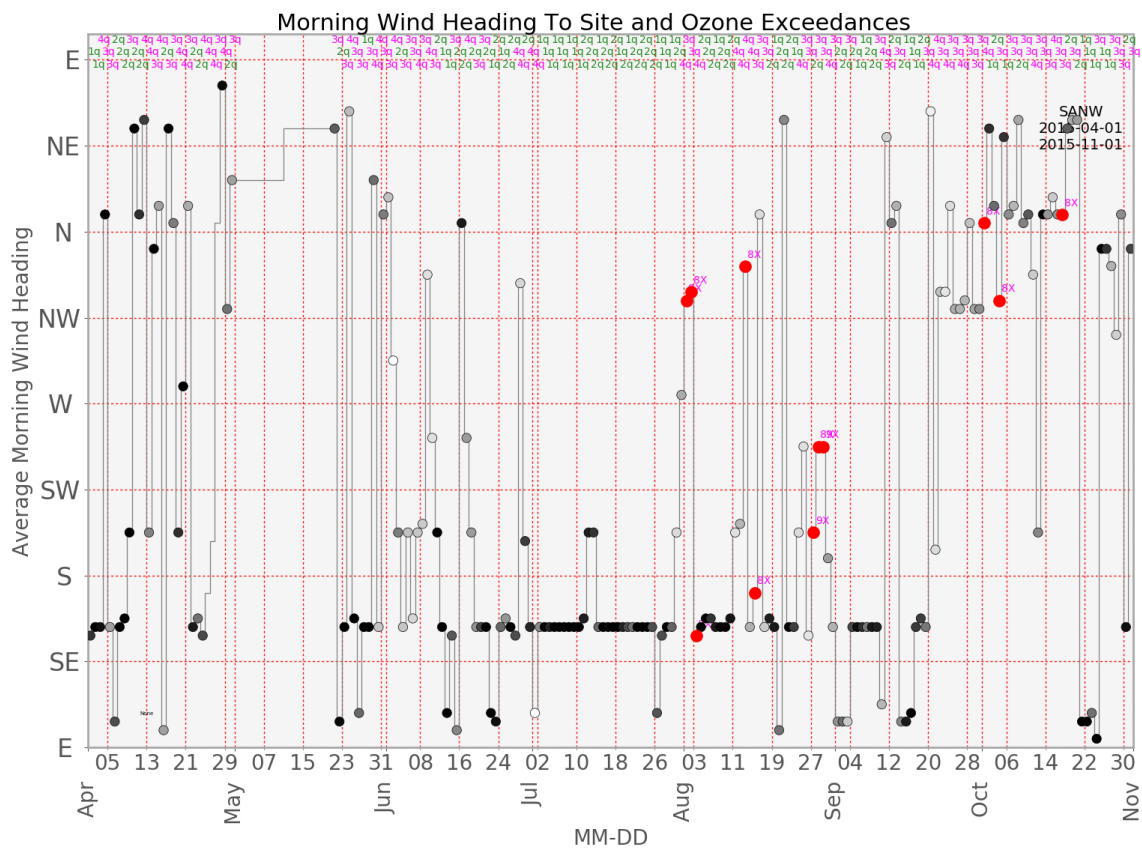
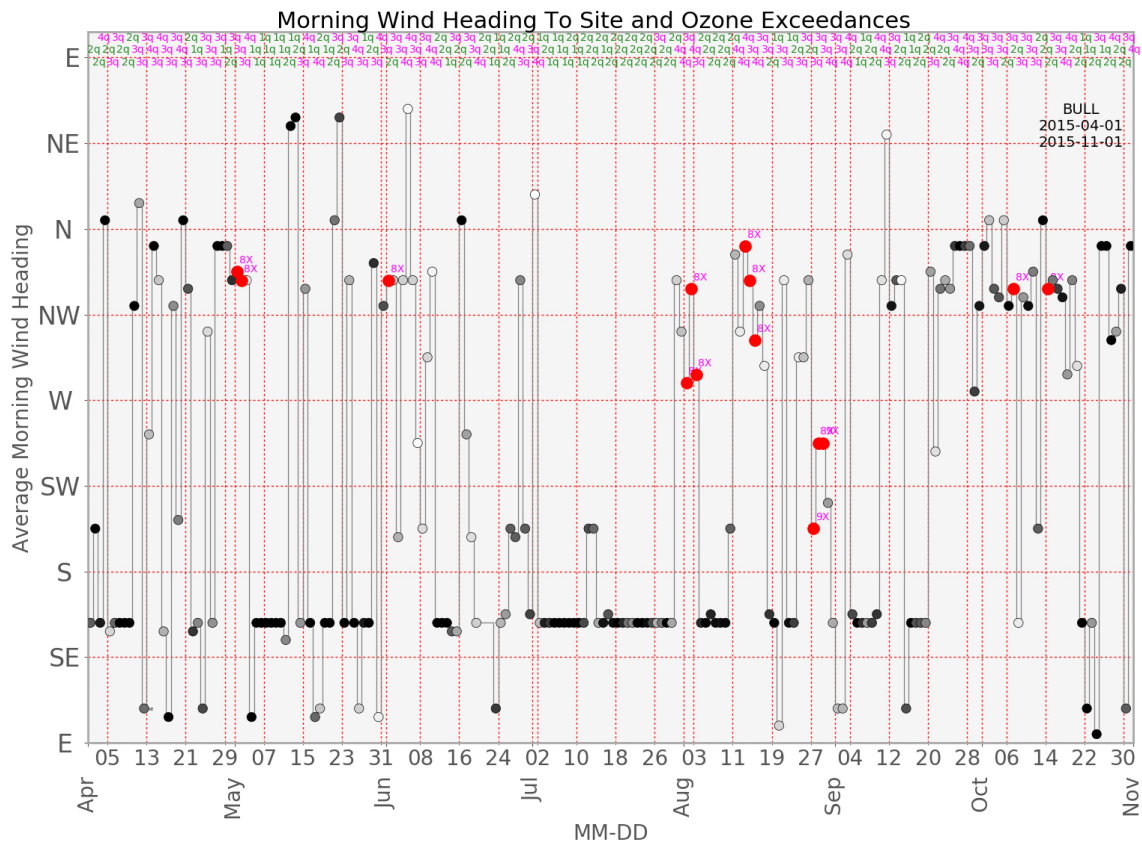


Figure 17. QXW_WOCT Plots for BULL and SANW, 2015



3.3.9 Monitor Site O3TD_SCAT Plots - How do they work?

Another way to relate winds (transport) to site ozone is to create a scatter plot of O31H and O38H ozone peak concentrations related to "Morning Transport Distance", that is, the distance the wind traveled to the site from midnight to 06:00, just before sunrise. Separate plots are made for the O31H ozone and the O38H ozone.

Furthermore, these values are classified (by color of point) as to the WOCT key associated with the wind octet direction. Finally, for those values that are above the O31H value of 100.0 ppb and above the O38H value of 70 ppb, the month and day are appended to the point to identify which days were above the criterial lines.

In addition there are COTD_SCAT and NOCD_SCAT plots as well, but these are not shown here.

Ozone values of 25 ppb to 60 ppb represent 'regional background ozone' associated with residual transported continental ozone as well as the natural background ozone arising for the natural atmospheric stratospheric ozone descending to the earth's surface from the stratosphere. The present ocean background is estimated to be between 20-40 ppb ozone.

Figure 18. O3TD__SCAT Plots for BULL 2012

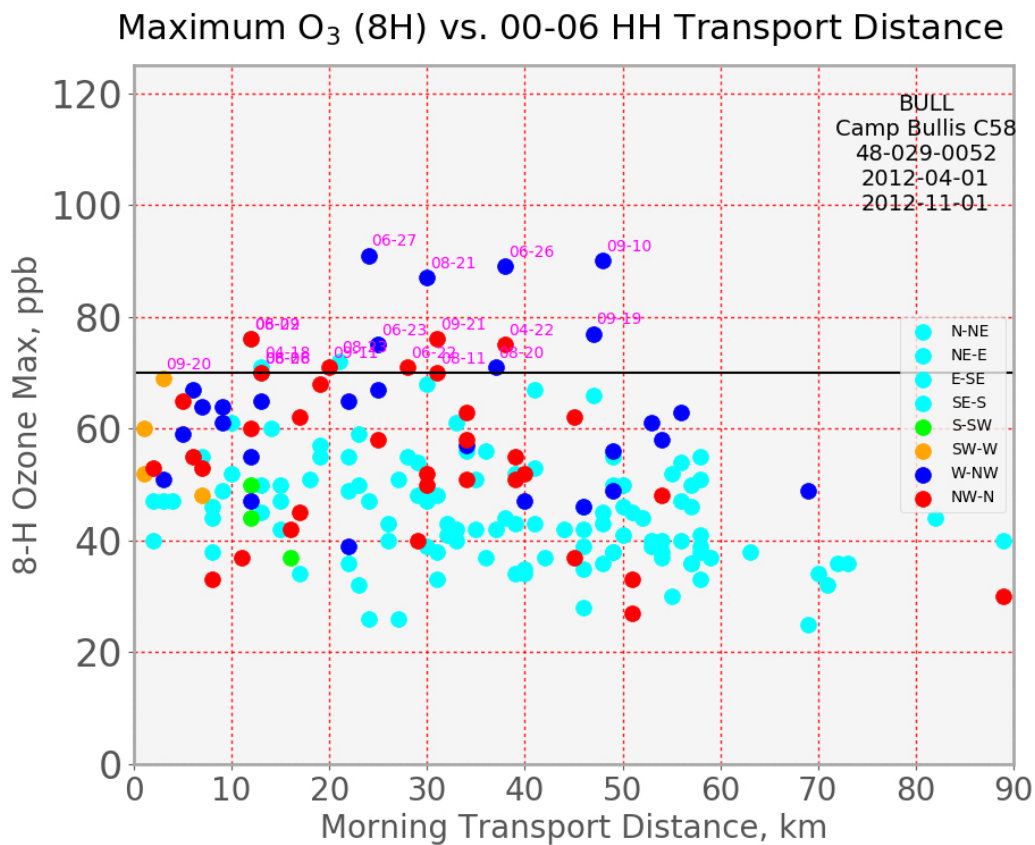
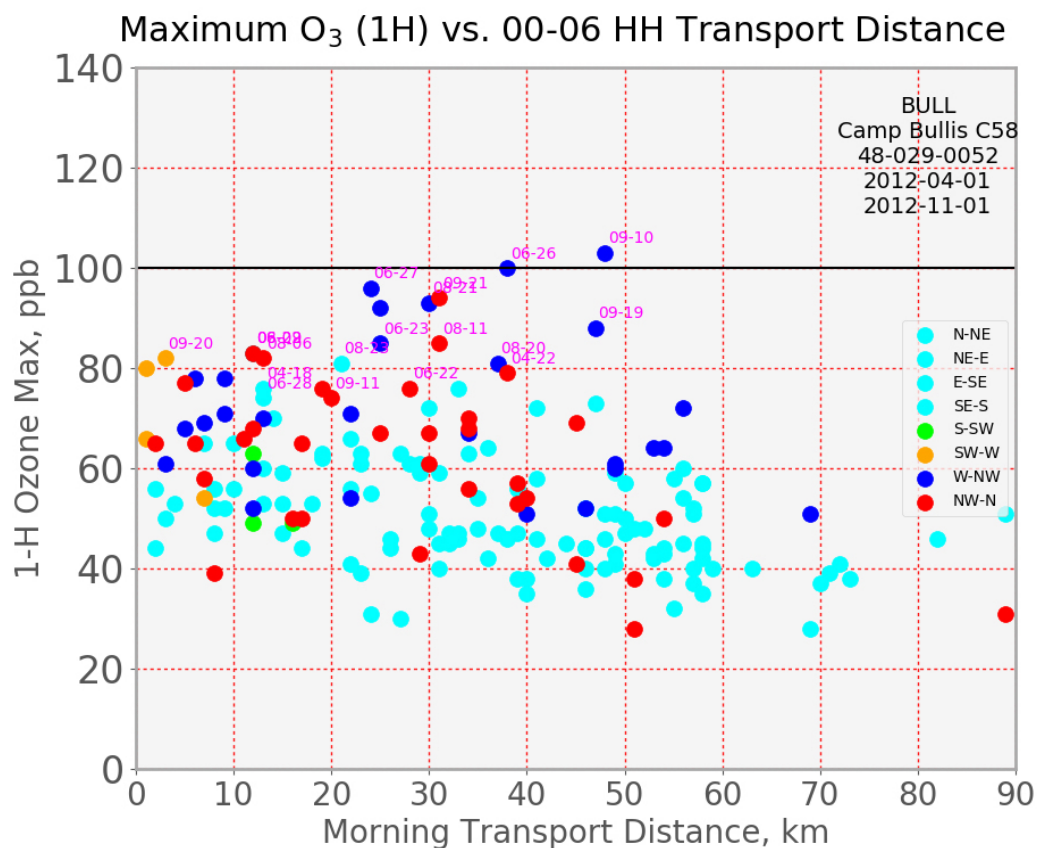


Figure 19. O3TD__SCAT Plots for SANW 2012

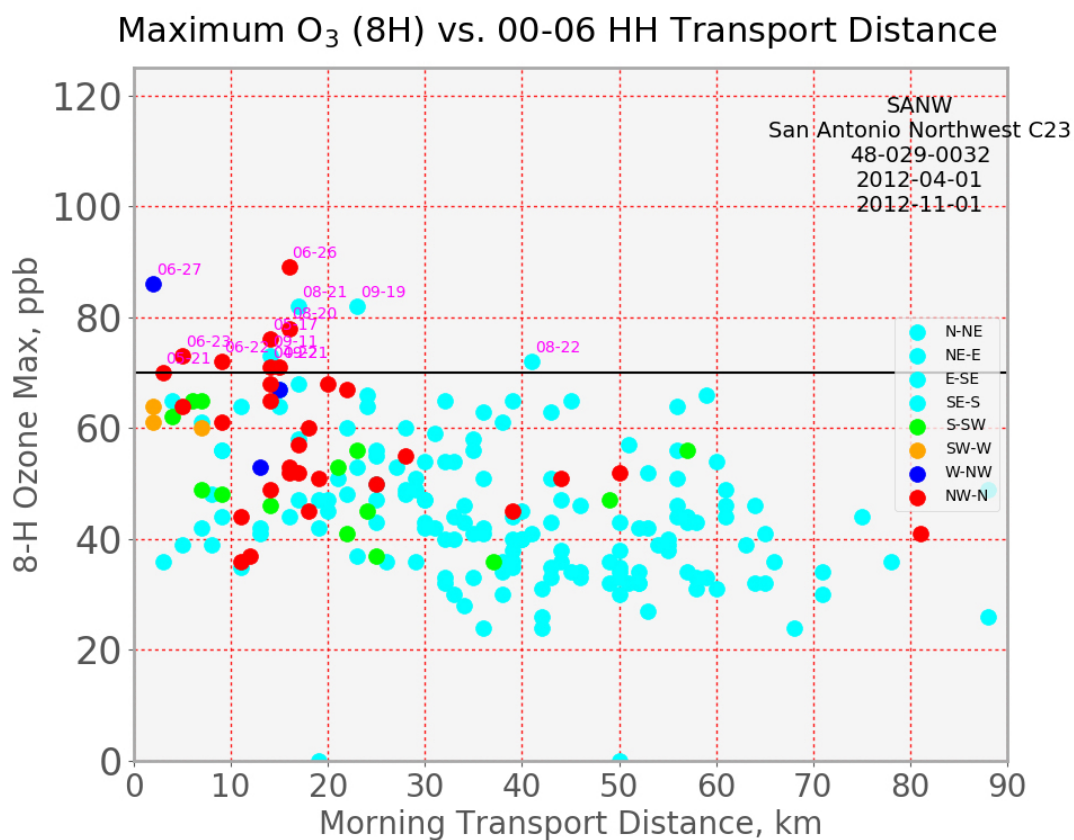
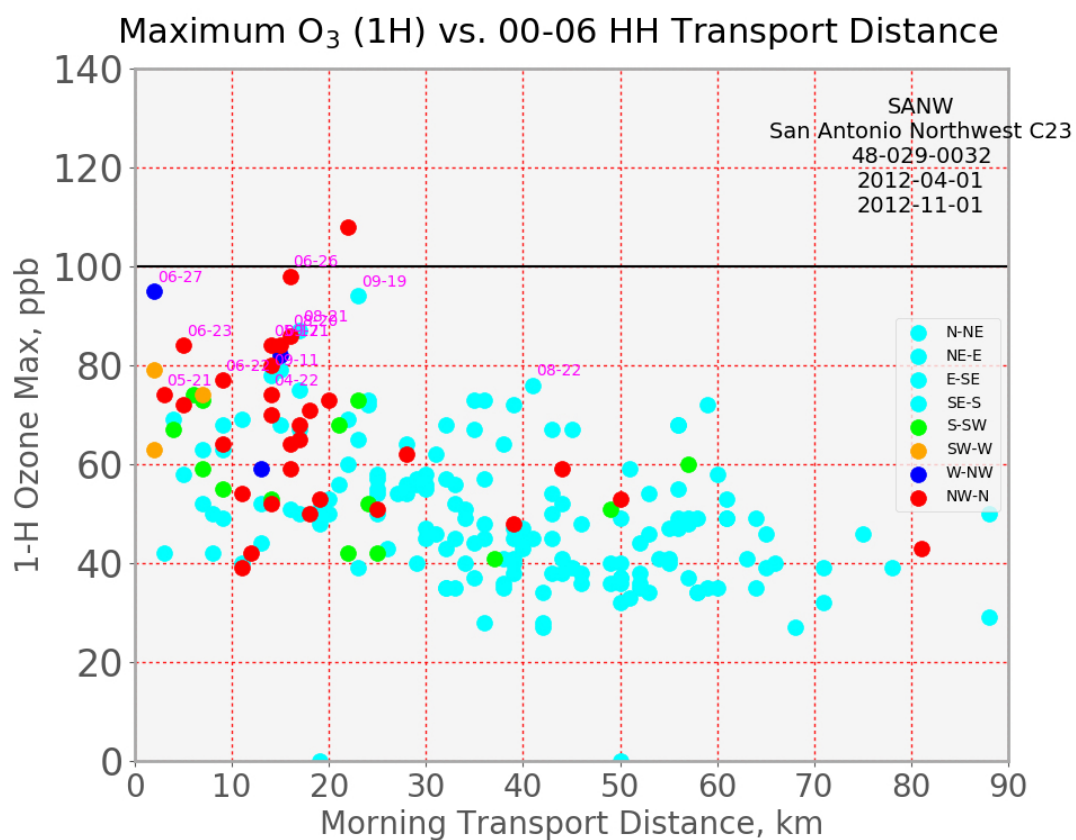


Figure 20. O3TD__SCAT O31H and O38H Plots for BULL, 2015

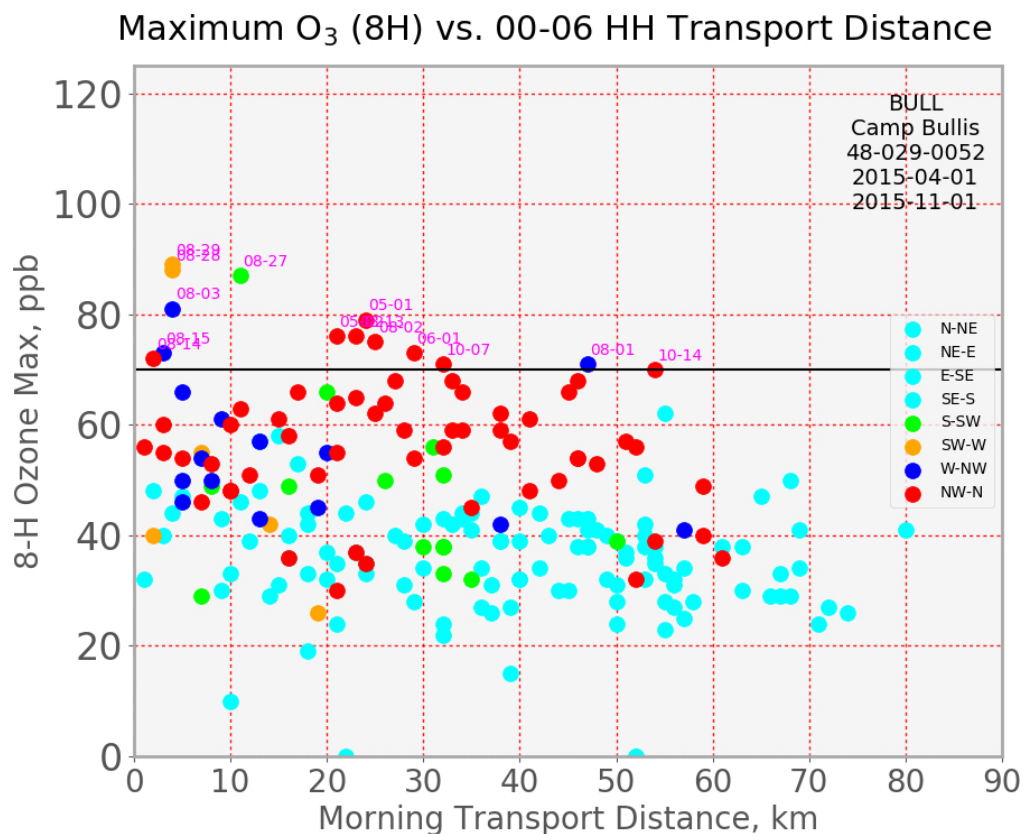
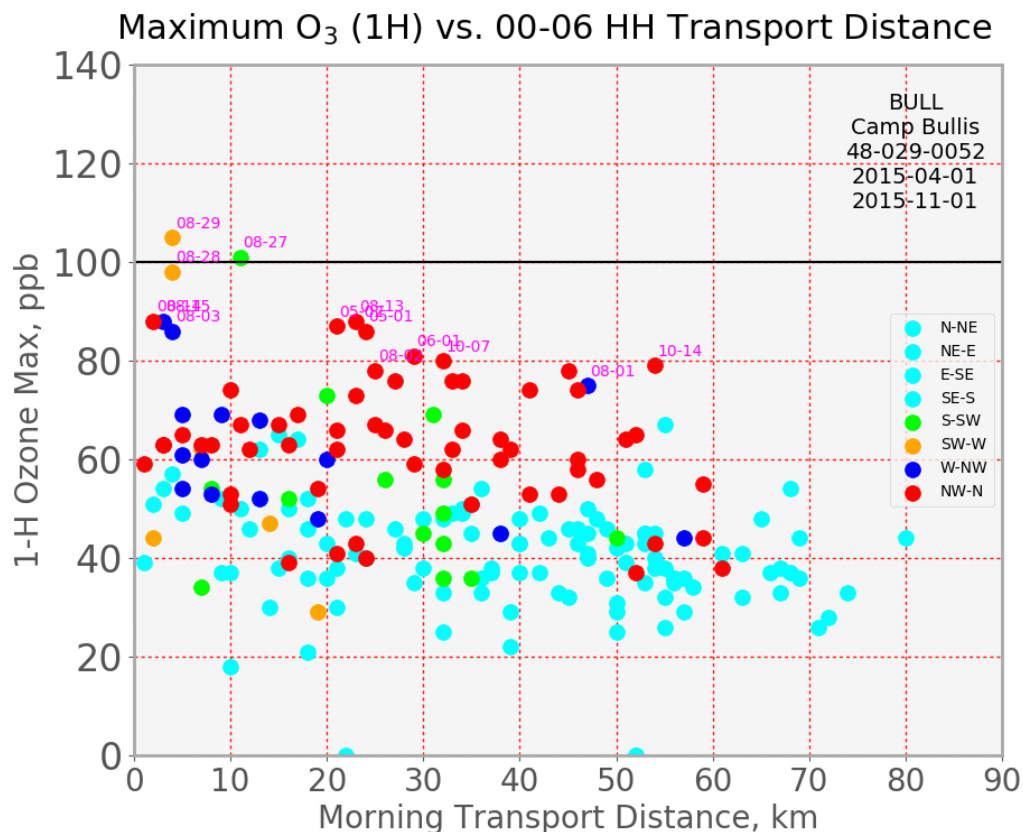


Figure 21. O3TD__SCAT O31H and O38H Plots for SANW, 2015

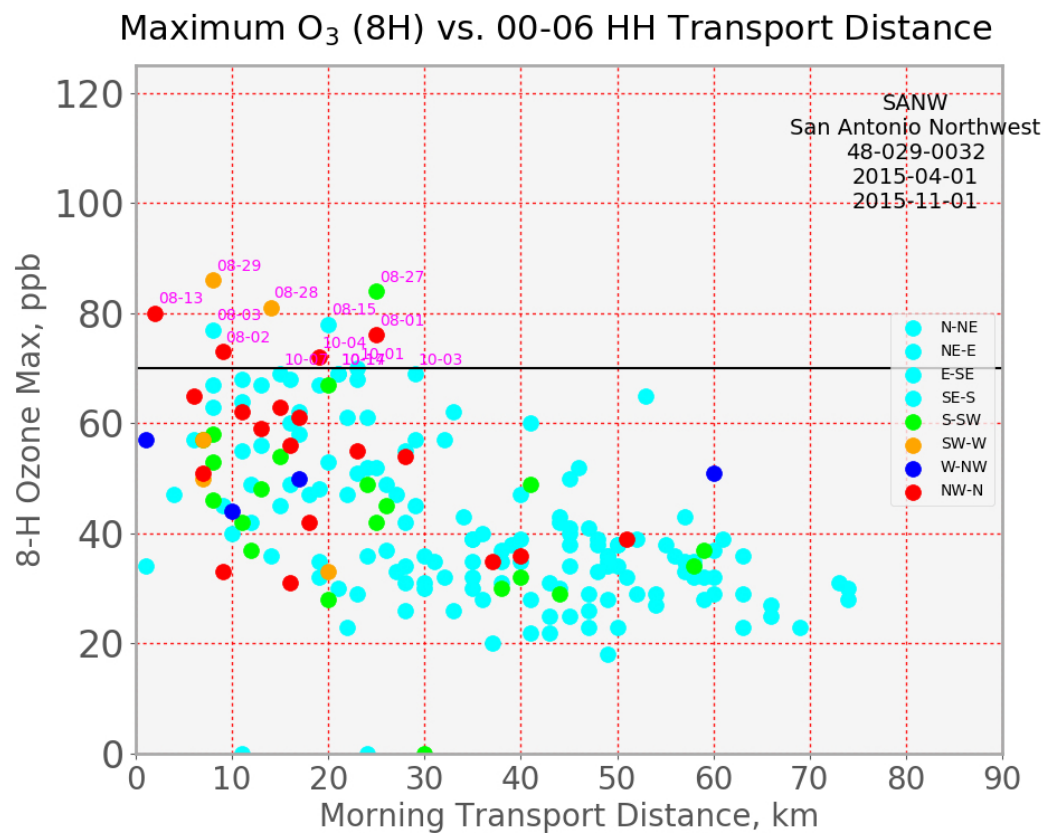
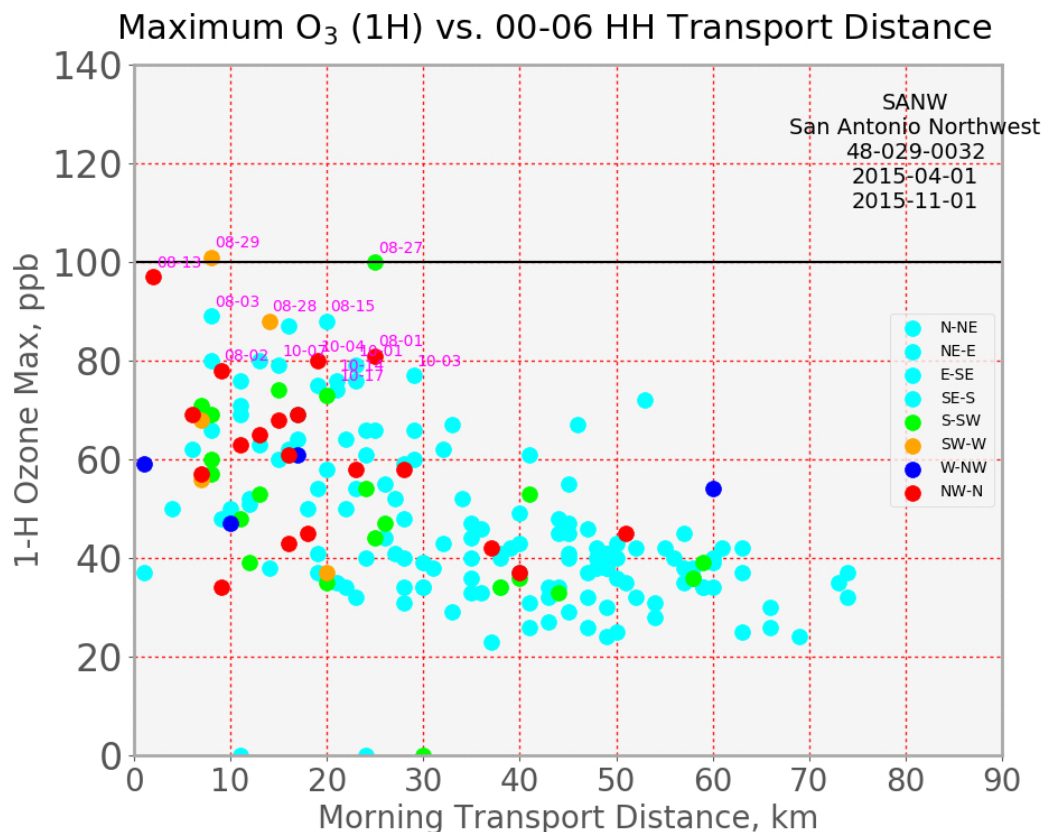


Figure 22. O3TD__SCAT O31H and O38H Plots for BULL, 2016

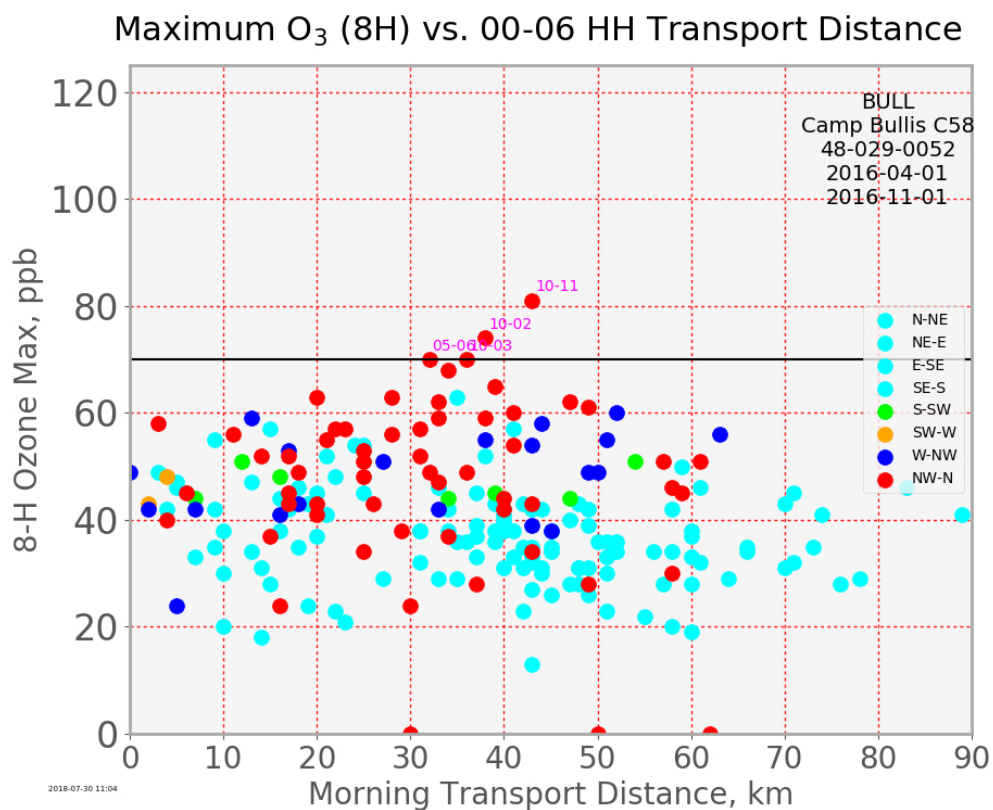
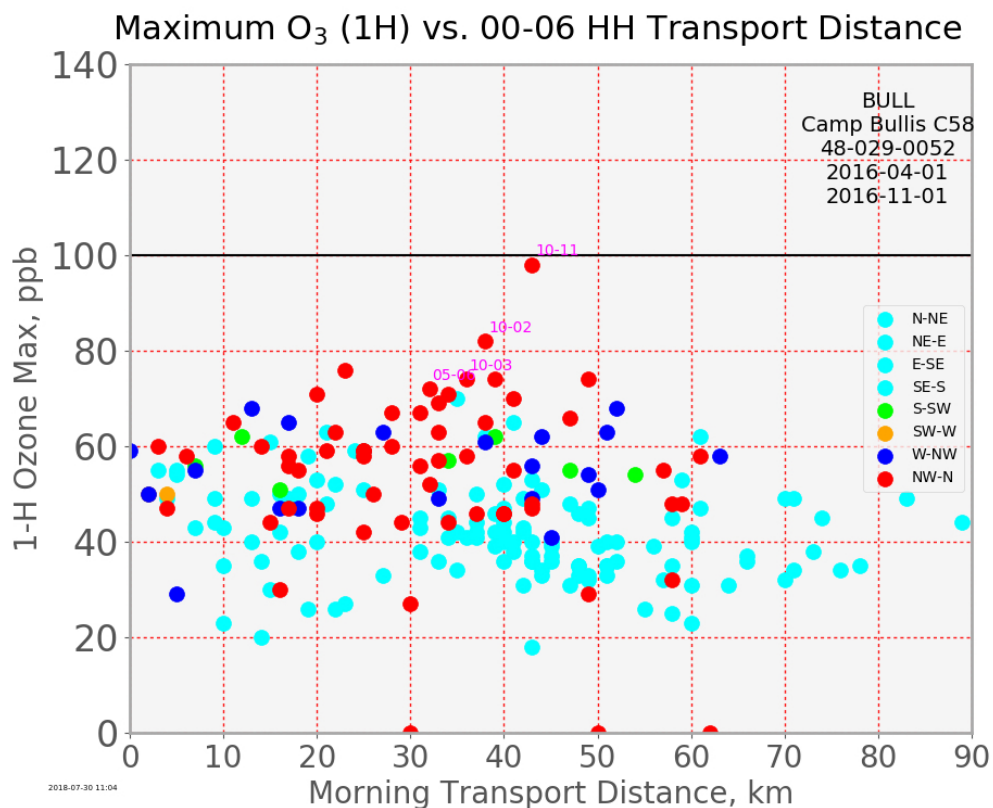
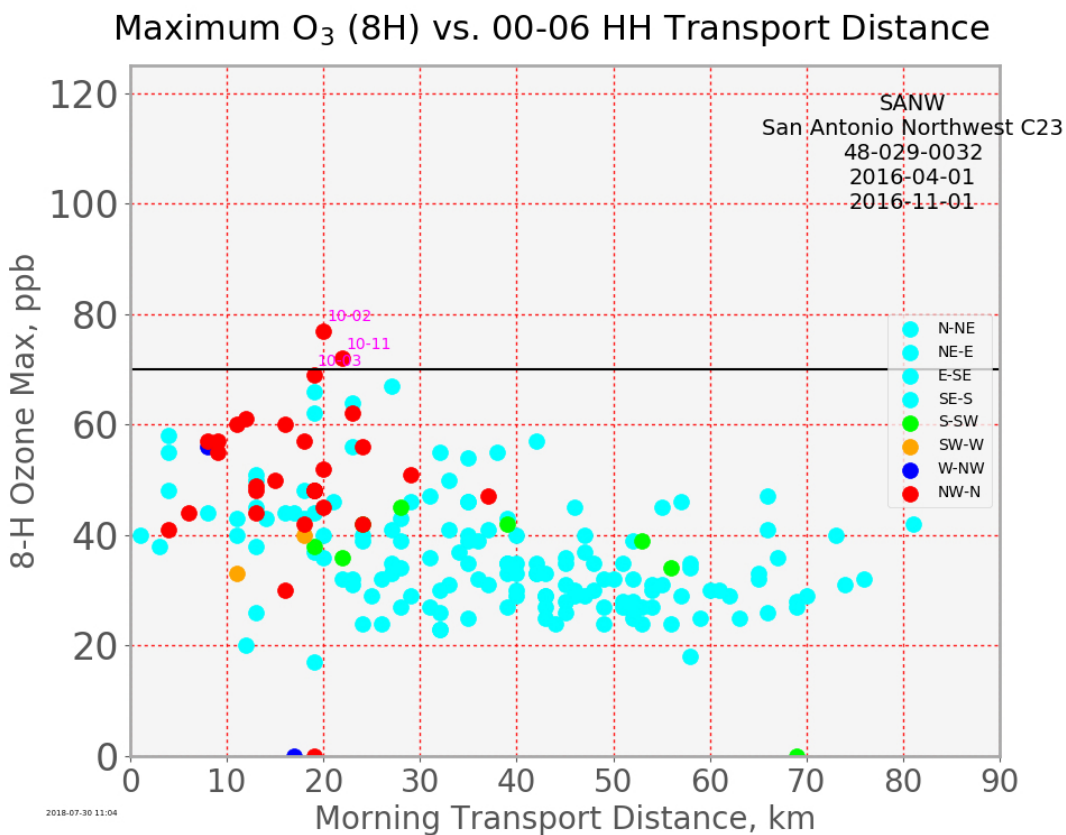
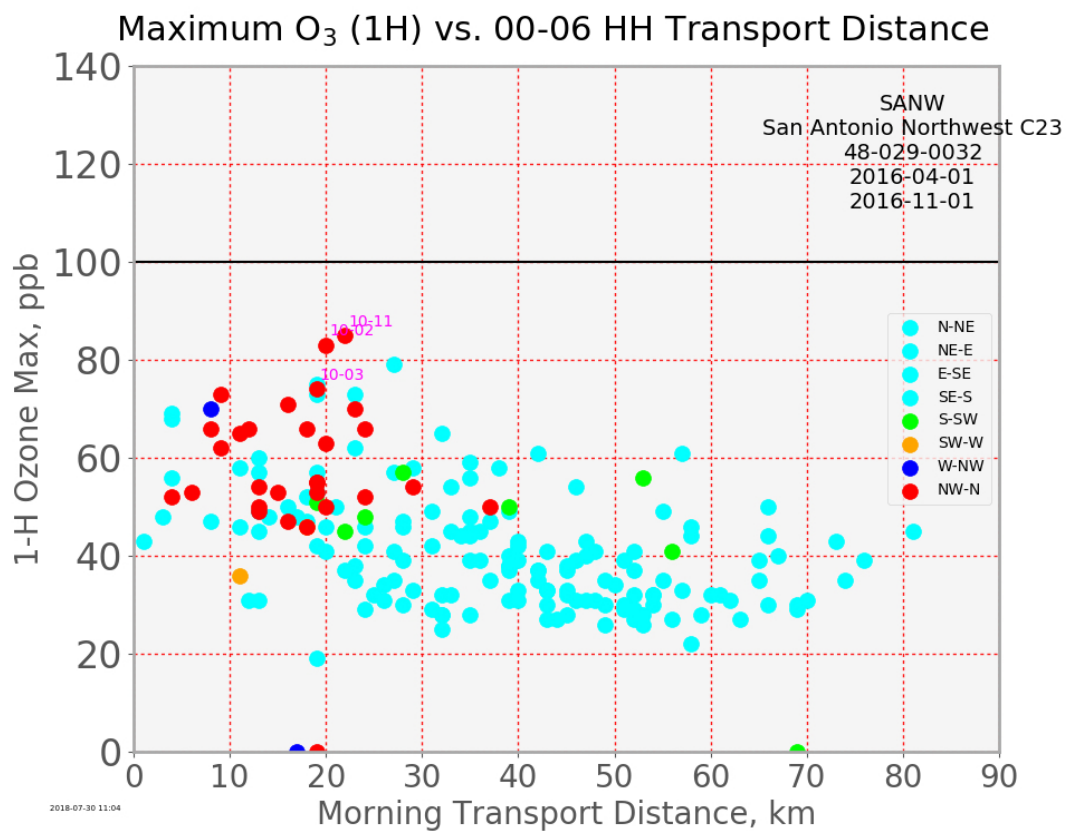


Figure 23. O3TD__SCAT O31H and O38H Plots for SANW, 2016



3.4 Chemical Conditions Classification Schemes

3.4.1 Monitor Site Top 10 O38H Days at BULL and SANW, 2012, 2015, 2016

/BULL_2012_TP10_1Y_STAT3

	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2012-06-27	11	91.06	96.25	1.06	5.86	264	2Q_8X_W-NW	S2N	W-NW	24	1	7487	G,-,-,-	-6.18	7.28	9.55
2	2012-09-10	11	90.94	103.61	1.14	26.98	16	3Q_9X_W-NW	S2N	W-NW	48	1	7688	-,-,-,-	-3.16	5.18	6.07
3	2012-06-26	11	89.95	100.26	1.11	18.73	55	3Q_9X_W-NW	E2W	W-NW	38	2	7878	-,-,-,-	-4.91	3.99	6.33
4	2012-08-21	10	87.94	93.97	1.07	19.62	50	3Q_8X_W-NW	E2W	W-NW	30	1	7266	-,-,-,-	-9.12	1.82	9.30
5	2012-09-19	11	77.39	88.11	1.14	23.87	31	4Q_8X_W-NW	W2E	W-NW	47	5	7384	-,-,V,-	-1.23	2.01	2.35
6	2012-08-22	11	76.75	83.03	1.08	11.07	151	3Q_8X_N-NE	E2W	N-NE	12	1	1277	-,-,-,-	-10.38	-0.06	10.38
7	2012-09-21	11	76.32	94.32	1.24	32.95	6	3Q_8X_NW-N	S2N	NW-N	31	3	8583	-,-,V,-	-1.85	4.17	4.57
8	2012-06-09	11	76.22	83.10	1.09	6.73	247	4Q_8X_NW-N	S2N	NW-N	12	1	8487	G,-,-,-	-5.40	7.35	9.12
9	2012-04-22	11	75.12	79.66	1.06	11.23	150	3Q_8X_NW-N	S2N	NW-N	38	1	8583	-,-,-,-	-1.83	6.06	6.33
10	2012-06-23	9	75.03	85.19	1.14	16.77	72	3Q_8X_W-NW	E2W	W-NW	25	3	7477	B,-,-,-	-5.92	3.96	7.12

/SANW_2012_TP10_1Y_STAT3

	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2012-06-26	11	89.40	98.06	1.10	6.18	241	4Q_8X_NW-N	E2W	NW-N	16	1	8378	-,-,-,-	-6.61	1.57	6.79
2	2012-06-27	12	86.33	95.96	1.11	16.78	57	4Q_8X_W-NW	S2N	W-NW	2	1	7477	G,-,-,-	-7.95	5.64	9.75
3	2012-09-19	11	82.19	94.37	1.15	28.96	8	4Q_8X_N-NE	E2W	N-NE	23	4	1217	-,-,-,-	-0.28	1.30	1.33
4	2012-08-21	11	82.17	87.12	1.06	10.08	152	3Q_8X_N-NE	E2W	N-NE	17	1	1276	-,-,-,-	-8.74	1.76	8.91
5	2012-08-20	11	78.18	86.82	1.11	17.09	54	3Q_8X_NW-N	E2W	NW-N	16	3	8177	-,-,-,-	-4.19	2.79	5.03
6	2012-05-17	11	76.45	84.83	1.11	12.78	106	4Q_8X_NW-N	S2N	NW-N	14	2	8588	-,-,-,-	-2.13	5.09	5.52
7	2012-06-23	9	73.64	84.64	1.15	15.93	64	4Q_8X_NW-N	E2W	NW-N	5	3	8477	-,-,-,-	-5.49	2.76	6.15
8	2012-09-11	11	73.50	78.74	1.07	9.14	170	2Q_8X_NE-E	E2W	NE-E	14	1	2377	-,-,-,-	-6.87	4.19	8.05
9	2012-06-22	11	72.88	77.29	1.06	3.90	309	4Q_8X_NW-N	E2W	NW-N	9	1	8277	-,-,-,-	-10.04	0.32	10.05
10	2012-08-22	11	72.20	76.30	1.06	7.68	202	2Q_8X_NE-E	E2W	NE-E	41	1	2267	-,-,-,-	-9.95	-0.47	9.96

/BULL_2015_TP10_1Y_STAT3

	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2015-08-29	10	89.38	105.84	1.18	34.21	2	3Q_9X_SW-W	S2N	SW-W	4	3	6588	-,-,-,-	-2.73	4.99	5.69
2	2015-08-28	11	88.73	98.93	1.11	21.74	27	3Q_8X_SW-W	S2N	SW-W	4	1	6588	-,-,-,-	-3.85	7.02	8.01
3	2015-08-27	11	87.45	101.63	1.16	25.35	12	3Q_9X_S-SW	S2N	S-SW	11	1	5588	-,-,-,-	-1.99	5.55	5.90
4	2015-08-03	10	81.03	86.19	1.06	10.51	145	3Q_8X_W-NW	E2W	W-NW	4	1	7378	G,-,-,-	-8.37	4.16	9.34
5	2015-05-01	11	79.83	86.36	1.08	17.83	59	3Q_8X_NW-N	S2N	NW-N	24	1	8584	-,-,V,-	-1.81	5.78	6.06
6	2015-05-02	10	76.45	87.72	1.15	15.73	80	3Q_8X_NW-N	S2N	NW-N	21	1	8478	-,-,-,-	-5.73	7.89	9.75
7	2015-08-13	11	76.07	88.98	1.17	28.33	8	4Q_8X_NW-N	N2S	NW-N	23	1	8875	-,-,-,-	-4.53	0.32	4.54
8	2015-08-02	11	75.18	78.96	1.05	7.36	205	4Q_8X_NW-N	E2W	NW-N	25	3	8372	-,-,-,-	-5.58	3.64	6.66
9	2015-08-15	11	73.77	88.52	1.20	33.36	3	4Q_8X_W-NW	N2S	W-NW	3	6	7746	-,-,V,-	0.85	-0.46	0.96

/SANW_2015_TP10_1Y_STAT3

	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2015-08-29	10	86.09	101.33	1.18	31.53	4	3Q_9X_SW-W	E2W	SW-W	8	3	6577	-,-,-,-	-5.16	2.02	5.54
2	2015-08-27	11	84.03	100.00	1.19	30.06	5	2Q_9X_S-SW	S2N	S-SW	25	3	5577	-,-,-,-	-3.26	3.38	4.70
3	2015-08-28	11	81.93	88.75	1.08	13.40	81	3Q_8X_SW-W	S2N	SW-W	14	1	6588	-,-,-,-	-4.37	6.03	7.45
4	2015-08-13	12	80.02	97.51	1.22	28.70	7	4Q_8X_NW-N	E2W	NW-N	2	4	8678	-B,G,-	-7.42	1.45	7.56
5	2015-08-15	12	78.59	88.93	1.13	23.77	13	3Q_8X_SE-S	E2W	SE-S	20	6	4857	G,-,-,-	-2.07	-1.68	2.67
6	2015-05-02	10	78.53	84.19	1.07	10.52	129	-Q_-X_X-XX	X2X	X-XX	0	0	9999	-,-,-,-	nan	nan	nan
7	2015-08-03	10	77.43	89.74	1.16	14.98	65	4Q_8X_SE-S	E2W	SE-S	8	1	4377	G,-,-,-	-8.37	1.74	8.55
8	2015-08-01	10	76.51	81.26	1.06	9.36	152	3Q_8X_NW-N	E2W	NW-N	25	1	8267	-,-,-,-	-8.11	-1.52	8.25
9	2015-05-01	12	75.91	78.82	1.04	4.97	244	-Q_-X_X-XX	X2X	X-XX	0	0	9999	-,-,-,-	nan	nan	nan

/BULL_2016_TP10_1Y_STAT3

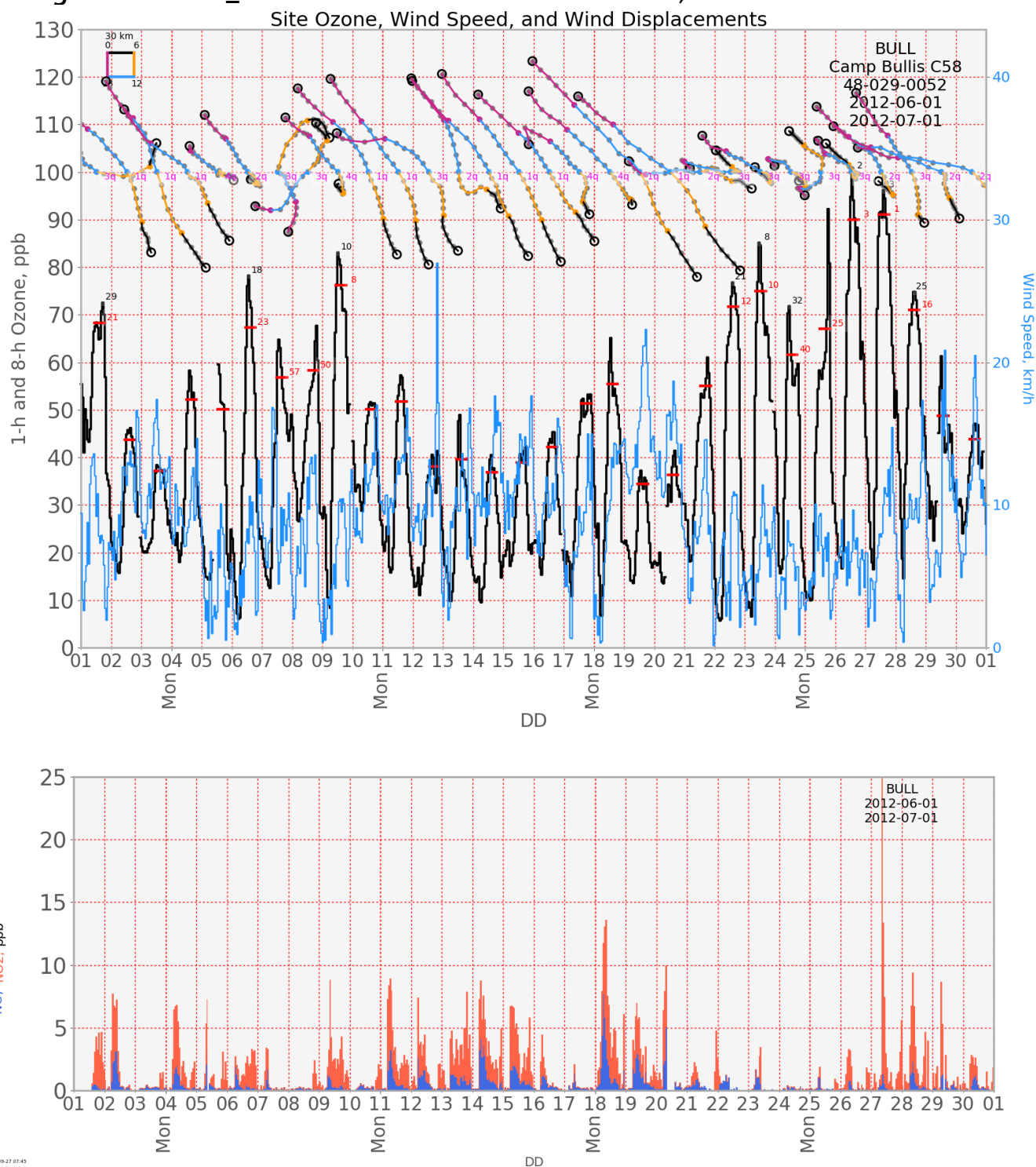
	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2016-10-11	10	81.67	98.73	1.21	38.49	4	3Q_8X_NW-N	S2N	NW-N	43	2	8584	-,-,-,-	-1.67	4.61	4.90
2	2016-10-02	10	74.48	82.15	1.10	21.01	27	3Q_8X_NW-N	N2S	NW-N	38	5	8784	B,B,+,-	-2.06	2.92	3.58
3	2016-10-03	10	70.72	74.60	1.05	12.47	123	3Q_8X_NW-N	S2N	NW-N	36	2	8488	-,-,-,-	-4.42	5.55	7.09
4	2016-05-06	11	70.26	72.76	1.04	3.99	312	3Q_8X_NW-N	E2W	NW-N	32	1	8377	-,-,-,-	-7.99	4.07	8.96
5	2016-04-23	11	68.58	71.98	1.05	8.63	205	2Q_0X_NW-N	E2W	NW-N	34	2	8478	B,-,-,-	-7.67	2.99	8.23
6	2016-04-08	11	65.31	74.69	1.14	15.65	79	4Q_0X_NW-N	E2W	NW-N	39	1	8278	-,-,V,-	-13.61	0.65	13.63
7	2016-04-04	11	63.69	71.46	1.12	14.87	91	3Q_0X_NW-N	S2N	NW-N	20	1	8583	-,-,-,-	-0.49	7.44	7.46
8	2016-04-05	11	63.58	67.48	1.06	8.00	216	3Q_0X_NW-N	S2N	NW-N	28	1	8588	-,-,-,-	-4.97	11.38	12.42
9	2016-05-13	10	63.33	70.55	1.11	14.70	93	3Q_0X_N-NE	E2W	N-NE	35	1	1388	-,-,-,-	-5.59	5.36	7.75

/SANW_2016_TP10_1Y_STAT3

	Date	Hr8HWin	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2016-10-02	10	77.19	83.44	1.08	18.91	28	3Q_8X_NW-N	E2W	NW-N	20	4	8274	-,-,-,-	-2.98	0.21	2.99
2	2016-05-05	12	74.22	85.80	1.16	19.33	26	-Q_-X_X-XX	X2X	X-XX	0	0	9999	-,-,-,-	nan	nan	nan
3	2016-10-11	10	72.68	85.78	1.18	26.72	8	4Q_8X_NW-N	S2N	NW-N	22	3	8585	-,-,-,-	-1.43	3.56	3.84
4	2016-05-06	11	72.39	77.10	1.07	8.15	176	-Q_-X_X-XX	X2X	X-XX	0	0	9999	-,-,-,-	nan	nan	nan
5	2016-04-23	11	69.75	75.18	1.08	9.39	140	-Q_-X_X-XX	X2X	X-XX	0	0	9999	-,-,-,-	-6.68	2.05	6.99
6	2016-10-03	11	69.44	74.03	1.07	8.10	178	3Q_0X_NW-N	E2W	NW-N	19	1	8377	-,-,-,-	-5.07	3.43	6.12
7	2016-10-10	11	67.41	79.72	1.18	28.99	6	3Q_0X_N-NE	E2W	N-NE	27	5	1266	-,-,-,-	-2.06	-0.03	2.06
8	2016-04-08	13	66.86	75.86	1.13	12.32	93	3Q_0X_N-NE	E2W	N-NE	19	1	1167	-,-,-,-	-11.45	-0.75	11.48
9	2016-09-03	10	64.95	73.19	1.13	16.87	38	4Q_0X_N-NE	E2W	N-NE	23	1	1377	-,-,-,-	-4.75	2.94	5.59
10	2016-06-07	11	62.72	70.82	1.13	19.76	21	3Q_0X_NW-N	E2W	NW-N	23	2	8167	-,-,-,-	-5.71	-2.15	6.10

3.4.2 Monitor Site O3xH_UVDD Plots at BULL and SANW, 2012, 2015, 2016

Figure 24. O3xH_UVDD O3xH and Wind Plots for BULL, 2012-06+30d



08-09-27 07:45

Figure 25. O3xH_UVDD O3xH and Wind Plots for BULL, 2012-06-24+4d

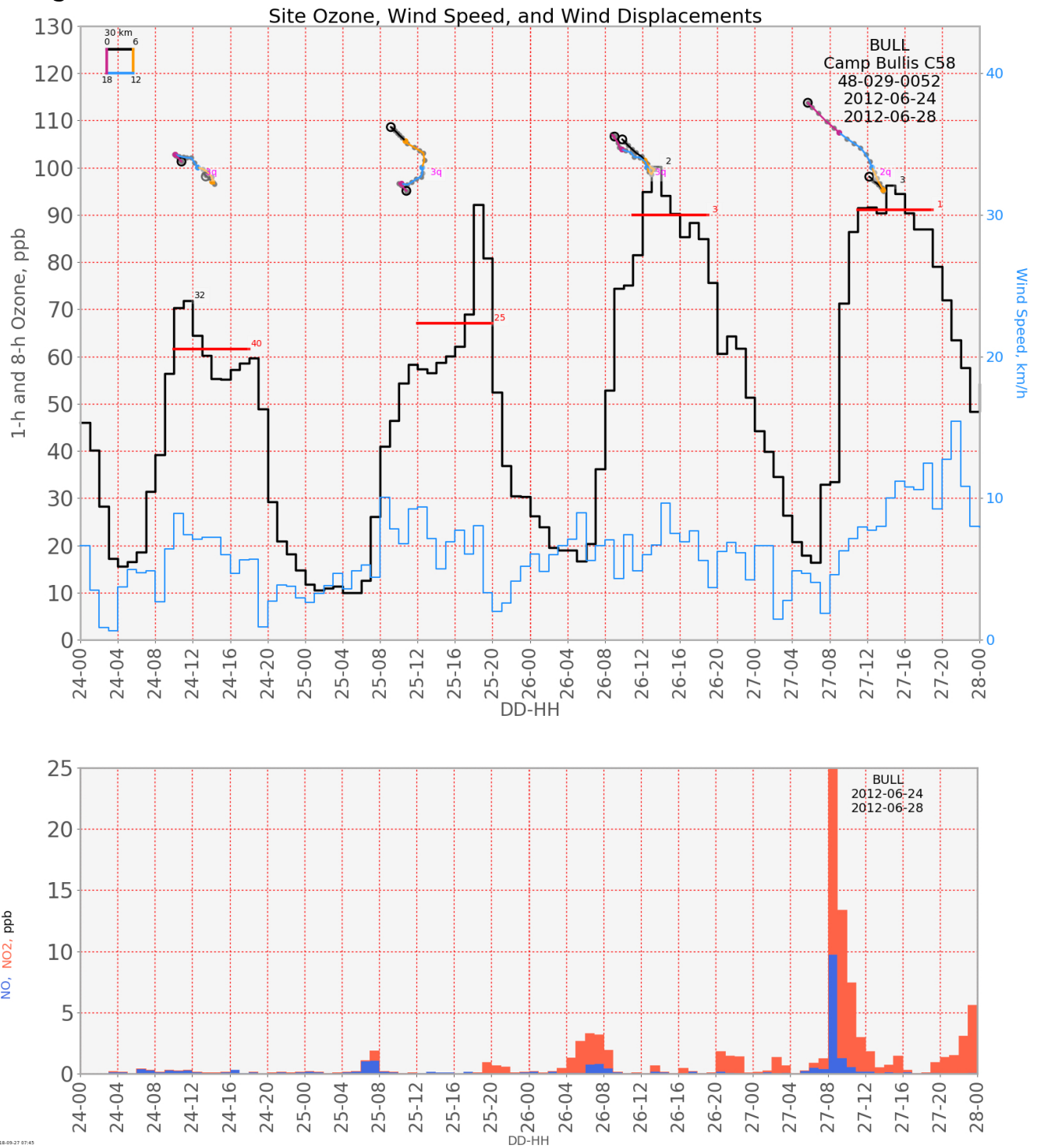


Figure 26. O3xH_UVDD O3xH and Wind Plots for BULL, 2012-09-01+30d

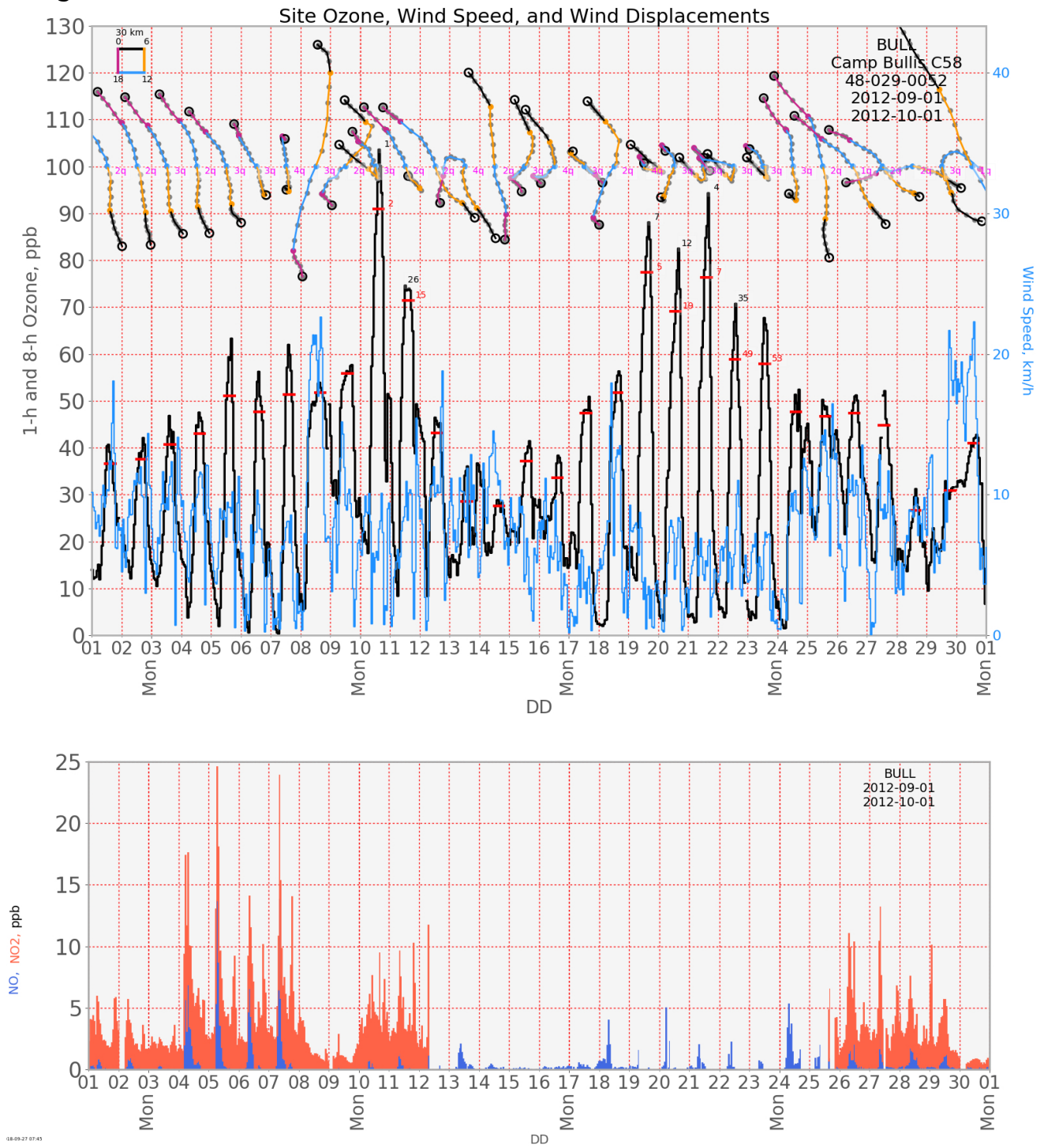


Figure 27. O3xH_UVDD O3xH and Wind Plots for BULL, 2012-09-10+4d

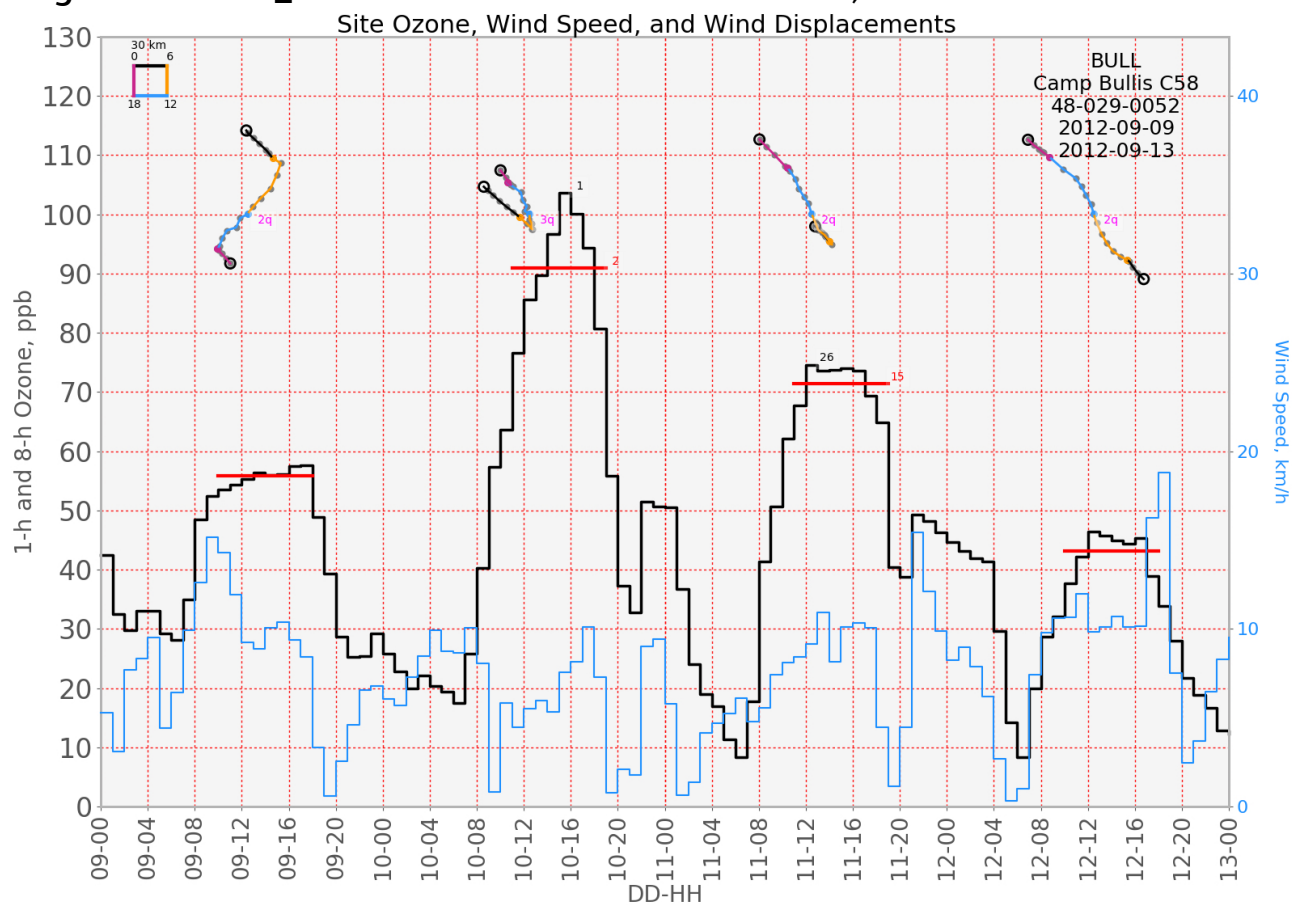


Figure 28. O3xH_UVDD O3xH and Wind Plots for BULL, 2012-09-18+4d

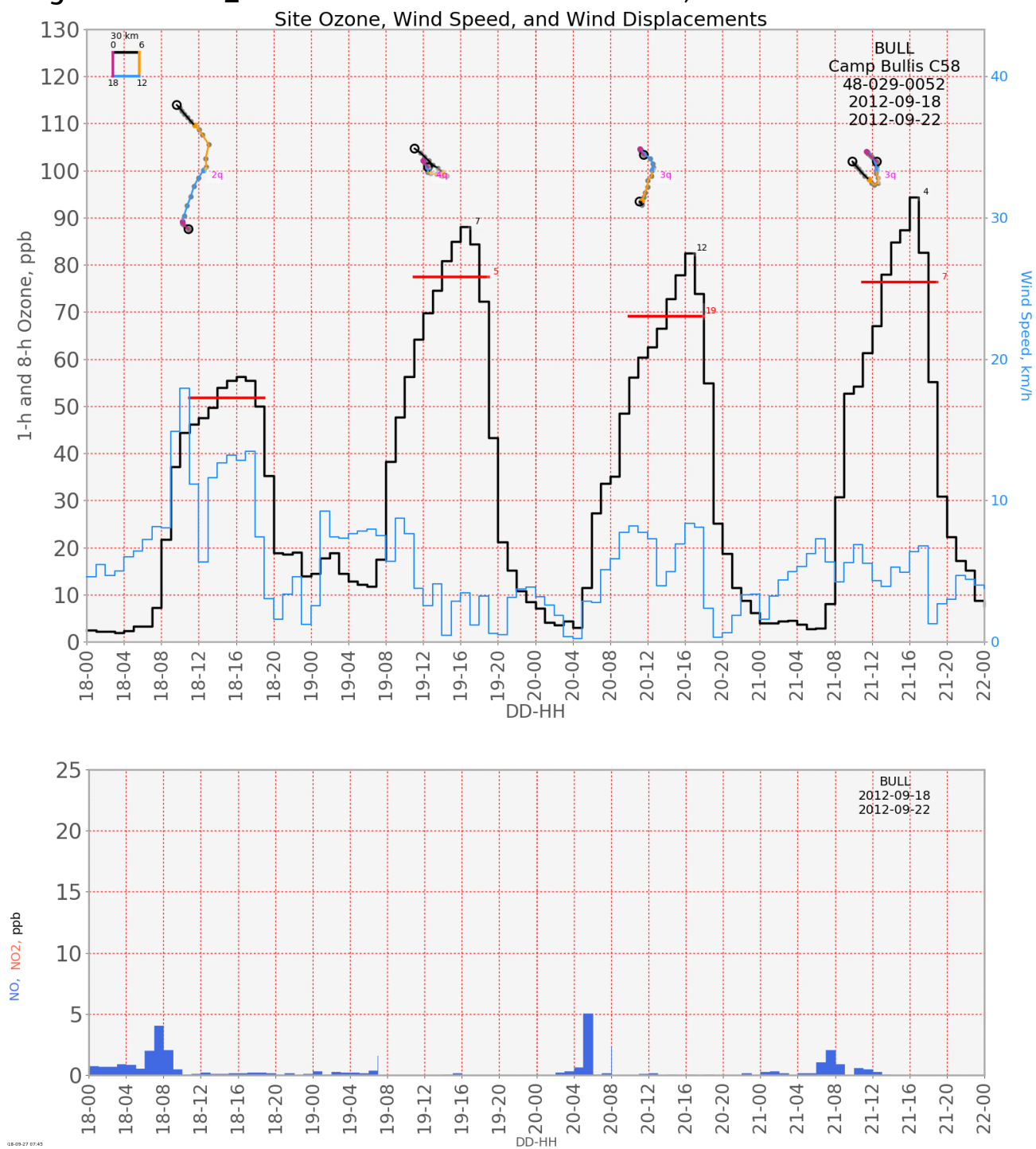


Figure 29. O3xH_UVDD O3xH and Wind Plots for BULL, 2015-08+31d

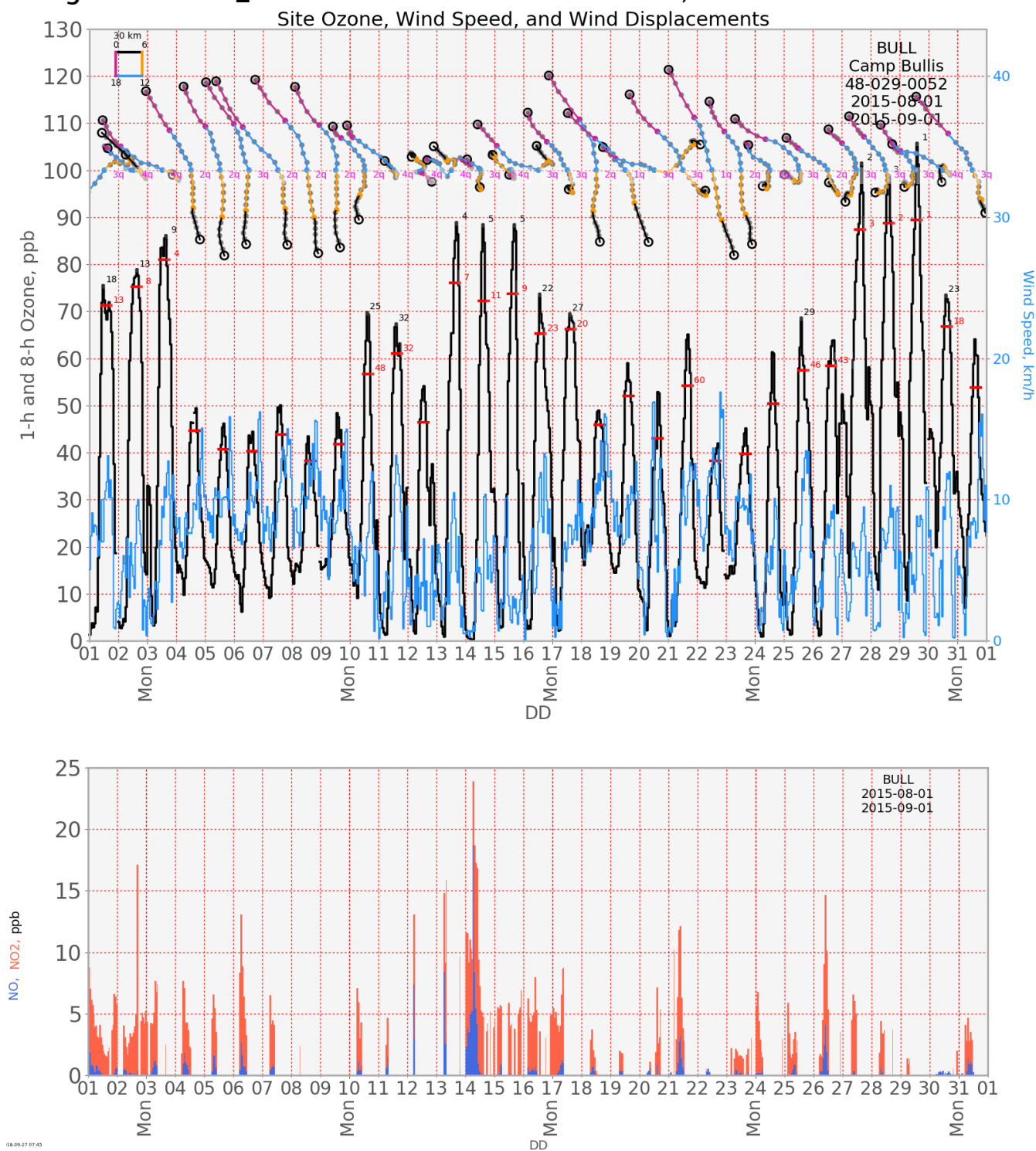


Figure 30. O3xH_UVDD O3xH and Wind Plots for BULL, 2015-08-12 + 4d

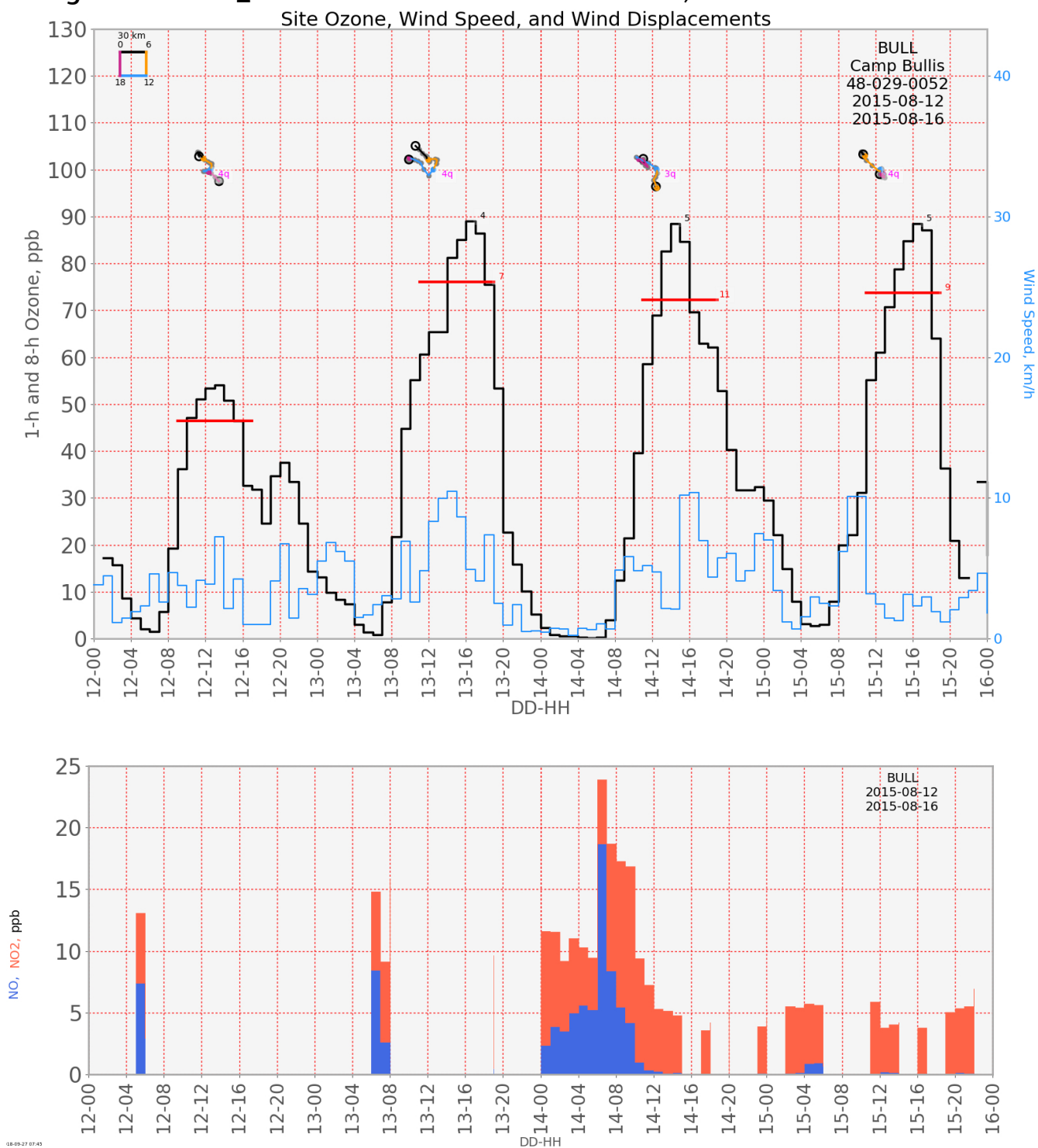
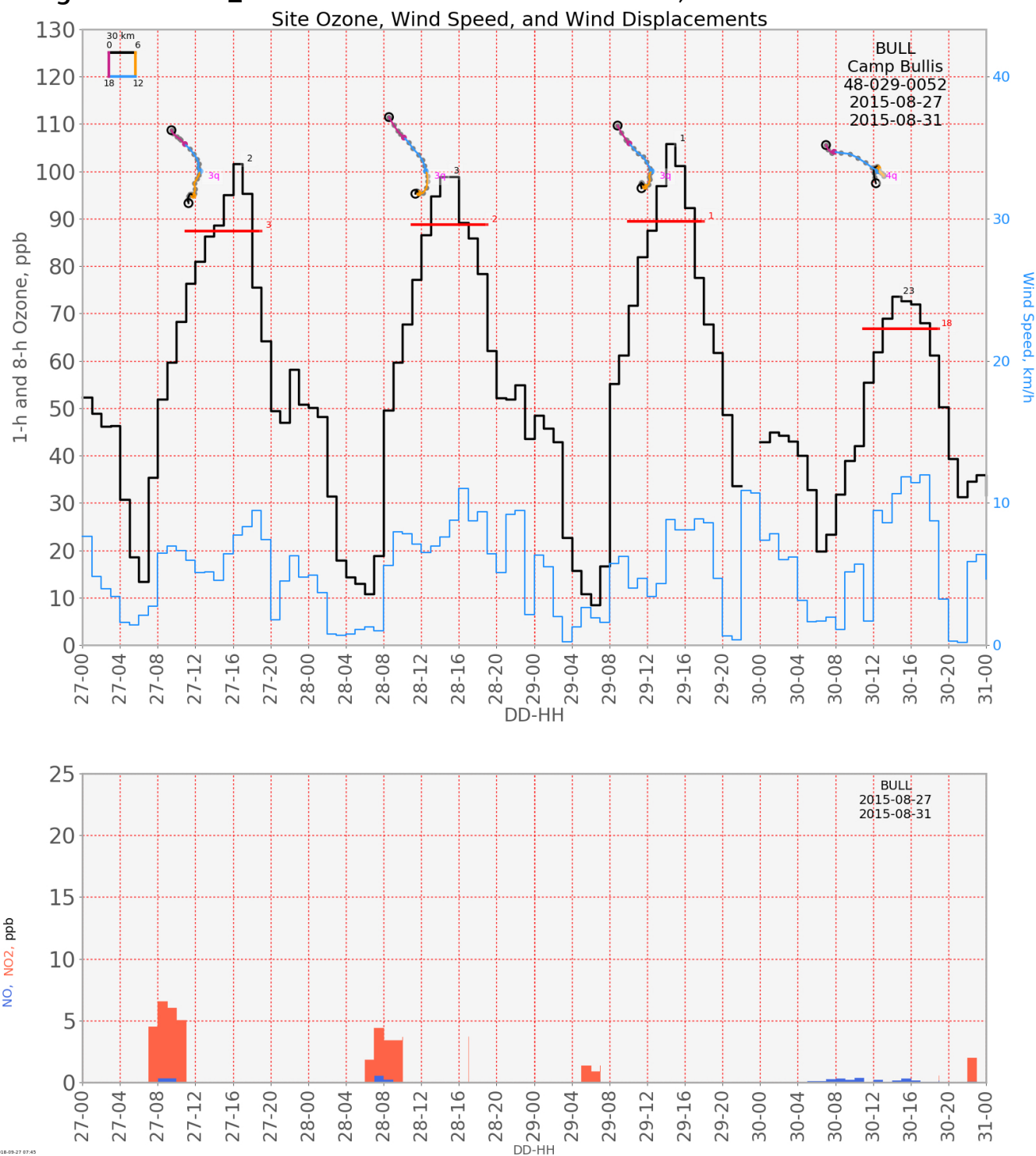


Figure 31. O3xH_UVDD O3xH and Wind Plots for BULL, 2015-08-27 + 4d



Appendix A. Project Source Data

Site Metadata Table For San Antonio Study

San Antonio Area 21 Monitor Sites Data Available at Site = 1

Site	AIRS	TCEQ Name	O3	NOx	CO	AVOC	WD	SR	T	P	Rain	tot obs
MCRH	48-021-0684	CAPCOG McKinney Roughs C684	1	0	0	0	1	0	1	0	0	3
SANW	48-029-0032	San Antonio Northwest C23	1	1	0	0	1	0	1	0	0	4
SEAL	48-029-0051	San Antonio Seale A140	0	0	0	0	1	0	1	0	0	2
BULL	48-029-0052	Camp Bullis C58	1	1	0	0	1	1	1	0	0	5
PECV	48-029-0055	CPS Pecan Valley C678	1	1	1	0	1	0	1	0	0	5
CALA	48-029-0059	Calaveras Lake C59	1	1	0	0	1	0	1	0	0	4
ELMC	48-029-0501	Elm Creek Elementary C501	1	0	0	0	1	0	1	0	1	4
FORA	48-029-0502	Fair Oaks Ranch C502	1	0	0	0	1	0	1	0	1	4
HEMS	48-029-0622	Heritage Middle School C622	1	1	1	0	1	0	1	0	1	6
PALO	48-029-0676	Palo Alto C676	0	0	0	0	1	0	1	0	0	2
OLDH	48-029-0677	Old Highway 90 C677	0	0	0	0	1	0	1	0	0	2
I35N	48-029-1069	IH 35 C1069	0	1	0	0	1	0	1	0	0	3
BVES	48-091-0503	Bulverde Elementary C503	1	0	0	0	1	0	1	0	0	3
GARD	48-091-0505	City of Garden Ridge C505	1	0	0	0	0	0	0	0	0	1
NBAP	48-187-0504	New Braunfels Airport C504	1	0	0	0	0	0	0	0	0	1
SOLC	48-187-0506	Seguin Outdoor Learning Center C506	1	0	0	0	0	0	0	0	0	1
SMSR	48-209-1675	CAPCOG San Marcos Staples Road C1675	1	0	0	0	1	0	1	0	0	3
CCWT	48-355-0025	Corpus Christi West C4	1	0	0	0	1	1	1	0	0	4
CCTU	48-355-0026	Corpus Christi Tuloso C21	1	0	0	0	1	0	1	0	0	3
FLHB	48-493-1038	Floresville Hospital Blvd C1038	0	1	0	1	1	0	0	0	0	3
KARN	48-493-1070	Karnes County C1079	0	1	0	1	1	0	0	0	0	3
tot sites			15	8	2	2	18	2	16	0	3	92

Total of 92 data streams distributed across 21 monitor sites.
Data from 2012, 2015, and 2016

Types and Names Patterns of DataFrames Used in San Antonio Analysis

PRIMARY TYPE	SITE CODE	YEAR	SUB-TYPE	Hierarchical Index	TIME STEP	EXTENT	SORTED BY	INDEX	START TIME	END TIME	DAYS	COLUMN DATA	Example DataFrame Name
OBS2	SSSS	2012, 2015, 2016	INOR		1H	(1Y)		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	AIRS Data	SSSS_201X_INOR_1H_OBS2
			WIND		1H	(1Y)		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	AIRS Data	SSSS_201X_WIND_1H_OBS2
			SOLR		1H	(1Y)		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	AIRS Data	SSSS_201X_SOLR_1H_OBS2
			TEMP		1H	(1Y)		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	AIRS Data	SSSS_201X_TEMP_1H_OBS2
STAT2	SSSS	2012, 2015, 2016	MAXC		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	NO, NO3, CO, VOCC	SSSS_201X_MAXC_1D_1V_STAT2
			O38H		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	pkO31H, pkO38H, timings, ranks	SSSS_201X_O38H_1D_1V_STAT2
STAT3	SSSS	2012, 2015, 2016	FLO3		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	wind flows, O3 parameters	SSSS_201X_FLO3_1D_1V_STAT3
			FLO3		1D	JM		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-10-31	90	wind flows, O3 parameters	SSSS_201X_FLO3_1D_JM_STAT3
			FLO3		1D	AO		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-10-31	214	wind flows, O3 parameters	SSSS_201X_FLO3_1D_AO_STAT3
			FLO3		1D	ND		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-12-31	61	wind flows, O3 parameters	SSSS_201X_FLO3_1D_ND_STAT3
SORT3	SSSS	2012, 2015, 2016	FLO3		1D	1Y	O38H	yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	wind flows, O3 parameters, sorted	SSSS_201X_FLO3_1D_1V_SORT3
STAT3	SSSS	2012, 2015, 2016	QXWF		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	Quads, Exceed, morn Wind, net Flow	SSSS_201X_QXWF_1D_1V_STAT3
	SSSS	2012, 2015, 2016	QXWF		1D	AO		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-10-31	214	Quads, Exceed, morn Wind, net Flow	SSSS_201X_QXWF_1D_AO_STAT3
STAT4	SSSS	2012, 2015, 2016	QXWF	sQXW_j	1D	1Y	clustered	yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	Quads, Exceed, morn Wind, net Flow	SSSS_201X_QXWF_1D_1V_STAT4
CODES	SSSS	2012, 2015, 2016	QXWF		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	number codes for Q, X, W, F vars	SSSS_201X_QXWF_1D_1V_CODES
			QXWF		1D	AO		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-10-31	214	number codes for Q, X, W, F vars	SSSS_201X_QXWF_1D_AO_CODES
TEXT	SSSS	2012, 2015, 2016	QXWF		1D	1Y		yyyy-mm-dd hh:mm	YYYY-01-01	YYYY-12-31	365	text codes for Q, X, W, F numbers	SSSS_201X_QXWF_1D_1V_TEXTS
			QXWF		1D	AO		yyyy-mm-dd hh:mm	YYYY-04-01	YYYY-10-31	214	text codes for Q, X, W, F numbers	SSSS_201X_QXWF_1D_AO_TEXTS
CNTS3	SSSS	2012, 2015, 2016	QWX_	sQ (1Q,2Q,3Q,4Q)		1Y	counted	sW (N-NE to NW-N)				nX (0X,1X,8X,9X)	SSSS_201X_QWX_1V_CNTS3
TOTL3	SSSS	2012, 2015, 2016	QWX_			1Y	counted	sQ (1Q,2Q,3Q,4Q)				nX (0X,1X,8X,9X)	SSSS_201X_QWX_1V_TOTL3
MISS3	SSSS	2012, 2015, 2016	QWX_			1Y	counted					sQ,sW,sX	SSSS_201X_QWX_1V_MISS3
STAT4	SSSS	2012, 2015, 2016	UVO3	sQXW_j		1Y	clustered	hour 0-24	0	23	unique	mean O3, Ua, Va, WSt for cluster	SSSS_201X_UVO3_1V_STAT4
				sQXW_j		AO	clustered	hour 0-24	0	23	unique	mean O3, Ua, Va, WSt for cluster	SSSS_201X_UVO3_AO_STAT4
CNTS4	SSSS	2012, 2015, 2016	UVO3	sQXW_j		1Y	series					number of days in sQXW_j cluster	SSSS_201X_UVO3_1V_CNTS4
						AO	series					number of days in sQXW_j cluster	SSSS_201X_UVO3_AO_CNTS4
STAT5	SSSS	2012, 2015, 2016	UVO3_14QU	sQXW_j		1Y	clustered		0	23	unique	means pkO31H, pkO38H, d06, Days in sQXW_j cluster	SSSS_201X_QXO3_14QU_1V_STAT5
			UVO3_14QU	sQXW_j		AO	clustered		0	23	unique	means pkO31H, pkO38H, d06, Days in sQXW_j cluster	SSSS_201X_QXO3_14QU_1V_STAT5

Key To Types and Names

Symbols	Definitions
INOR	inorganic species measured by TCEQ and reported to AIRS. Includes O3, NO, NO2, CO hourly data averaged from 5 min data
O31H	symbol used for ozone reported as one hour average of 5 minute data
O38H	symbol used for highest daily 8-hour averaged 1-hour ozone data with at least 6 hours of 1-h O3 data in 8-h window
Q	Number (1, 2, 3, 4) wind quadrants (W-N, N-E, E-S, S-W) during 00 HH to 23 HH at a site, 10 meter wind measurement reported as average 1-H heading
X	Number (0, 1, 8, 9) that codes the type of ozone exceedance at site measuring ozone 1-H data; 0 == no exceedance [0X], 1 == exceedance of 99.9 ppb 1-H ozone measurement, but not 69.9 ppb 8-H ozone measurement [1X]; 8 == exceedance of 69.9 ppb 8-H ozone measurement, but not 99.9 ppb 1-H ozone measurement [8X]; 9 == exceedance of both 69.9 ppb 8-H ozone measurement, and 99.9 ppb 1-H ozone measurement [9X];
W	codes for compass wind octets eg, 1 = N-NE, 2 = NE-E, 3 = E-SE, 4 = SE-S, 5 = S-SW, 6 = SW-W, 7 = W-NW, 8 = NW-N
F	codes for daily total wind flow : N2S, S2N, W2E, E2W

AIRS Data and Pandas DataFrames

Source(s))	DataFrame
AIRS DATA	_INOR_1H_OBS2
	_WIND_1H_OBS2
	_SOLR_1H_OBS2
	_TEMP_1H_OBS2
INOR OBS2	_MAXC_1D_1Y_STAT2
	_O38H_1D_1Y_STAT2
WIND_1H_OBS2 & O38H_1D_1Y_STAT2	_FL03_1D_1Y_STAT3
FL03_1D_1Y_STAT3	_FL03_1D_1Y_SORT3
	_QXWF_1D_1Y_CODES
QXWF_1D_1Y_CODES	_QXWF_1D_1Y_TEXTS
FL03_1D_1Y_STAT3 & QXWF_1D_1Y_CODES	_QWX__1Y_CNTS3, _QWX__1Y_TOTL3, _QWX__1Y_MISS3
FL03_1D_1Y_STAT3 & QXWF_1D_1Y_TEXTS	_QXWF_1Y_STAT3
QXWF_1Y_STAT3	_QXWF_1Y_STAT4
QXWF_1Y_STAT4	_QXO3_14QU_1Y_STAT5, _QXO3_34QS_1Y_STAT5
O38H_1D_1Y_STAT2 & QXWF_1D_1Y_STAT3 & WIND_1H_1Y_OBS2	_TP10_1Y_STAT3

Definitions of Index and Data Columns in Pandas DataFrames

NB: 'SSSS' is the four letter site name assigned to each site (see **Site Metadata Table**)

Pandas DataSets are by year and indicated below as 201X where X=2, 5, or 6

SSSS_201X_INOR_1H_OBS2

DateTime - index column using ISO 8601 format : yyyy-mm-dd hh:mm:ss

O3 - data column, units ppb, averaged 5-minute data over 1-hour

NO - data column, units ppb, averaged 5-minute data over 1-hour

NO2 - data column, units ppb, averaged 5-minute data over 1-hour

other data columns similar, see 'Site Metadata Table'

SSSS_201X_WIND_1H_OBS2

DateTime - index column using ISO 8601 format : yyyy-mm-dd hh:mm:ss

WSt - data column, wind speed TO site, units km/h,
averaged 5-minute data over 1-hour

WDt - data column, wind direction TO site, units degrees from N,
averaged 5-minute data over 1-hour

Ua - data column, west to east projected component of the
wind vector away from site, units km/h,
averaged 5-minute data over 1-hour

Va - data column, south to north projected component of the
wind vector away from site, units km/h,

Uad - data column, head-to-tail vector sum displacement away from site,
units are km

Vad - data column, head-to-tail vector sum displacement away from site,
units are km

Uadz - data column, Uad adjusted to 0.0 km displacement from site at noon,
resulting in displacement TO site before 12:00 and AWAY from site after,
units are km

Vadz - data column, Vad adjusted to 0.0 km displacement from site at noon.
resulting in displacement TO site before 12:00 and AWAY from site after,
units are km

SSSS_201X_SOLR_1H_OBS2 and SSSS_201X_TEMP_1H_OBS2

DateTime - index column using ISO 8601 format : yyyy-mm-dd hh:mm:ss

SITE - data column, incident solar radiation to site in ly/min

10 meter air temperature at site in deg F
averaged 5-minute data over 1-hour

SSSS_201X_O38H_1D_1Y_STAT2

DateTime - index column using ISO 8601 format : yyyy-mm-dd 12:00:00

i.e., single row in DataFrame per day

Cnt - data column, number of hours of data in 8-h window,
must be > 5

O31H_min1 - data column, O31H minimum ppb before 06:00 LST

O31H_min1_hr - data column, hour of O31H minimum before 06:00 LST

O31H_min8 - data column, O31H minimum ppb during 8-h max time window

O31H_min8_hr - data column, hour of O31H_min8

O31H_max8 - data column, O31H maximum ppb during 8-h max time window

O31H_max8_hr - data column, hour of O31H_max8

O31H_max8_rk - data column, serial rank 1 to 364 of O31H_max8

O31H_rng8 - data column, (O31H_max8 - O31H_min8), ppb

O31H_rng8_rk - data column, serial rank 1 to 364 of O31H_rng8

O38H - data column, O38H average ppb during
8-h time window with the highest O38H value
computed by EPA algorithm from 6, 7, or 8 O31H values;
less than 6 hours of O31H values during the highest
O38H time window results in 'missing' or NAN values

O38H_str8_hr - data column, hour of start of max 8-h time window

O38H_rk - data column, serial rank 1 to 364 of O38H

ratio1H8H - data column, (O31H_max8 / O38H), unitless

nX - data column, exceedance numerical code for day
0 : O31H < 100 ppb; O38H < 70 ppb
1 : O31H ≥ 100 ppb; O38H < 70 ppb
8 : O31H < 100 ppb; O38H ≥ 70 ppb
9 : O31H ≥ 100 ppb; O38H ≥ 70 ppb

SSSS_201X_FLO3_1D_1Y_STAT3 and SSSS_201X_FLO3_1D_1Y_SORT3

DateTime - index column using ISO 8601 format : yyyy-mm-dd 12:00:00

Flow - data column: longest direction of wind flow for day:

one of W2E, E2W, N2S, S2N; midnight to next midnight

dW2E - West to East distance for daily displacement bounding box

dS2N - South to North distance for daily displacement bounding box

dBBx - longest diagonal distance of daily displacement bounding box

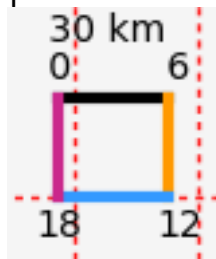
d06 - 00 H to 06 H displacement distance by wind, km, BLACK

NB: d06 is also referred to as "morning travel distance" in many plots

d12 - 06 H to 12 H displacement distance by wind, km, GOLD

d18 - 12 H to 18 H displacement distance by wind, km, BLUE

d24 - 18 H to 24 H displacement distance by wind, km, PURPLE

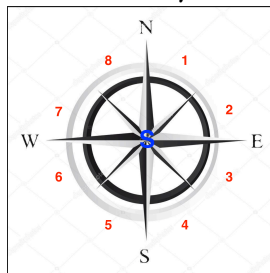


C8ta - aggregated 4 digit number where each digit is a 'compass octet' giving the average 00-06 H and 06-12 H 'heading' 'to' the site and average 12-18 H and 18-24 H 'heading' 'away' from the site.

'compass octets' are:

1 = 'N-NE', 2 = 'NE-E', 3 = 'E-SE', 4 = 'SE-S',

5 = 'S-SW', 6 = 'SW-W', 7 = 'W-NW', 8 = 'NW-N'



wCROS - four letter code to indicate if later 6-h wind displacements crosses over a previous wind displacement path (path order K,G,B,P)

code example : '-,-,-' no cross-over of previous by later paths

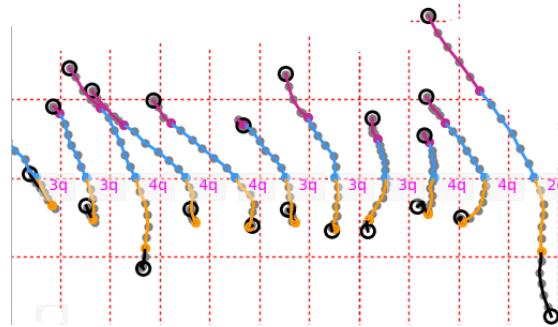
'G,-,-' 06-12 path (Gold) cross-over of 00-06 path

'-,B,G,-' 12-18 path (Blue) cross-over of 06-12 path

hrSite - number of hours the 1H wind displacements were within 5 km of site

SSSS_201X_FLO3_1D_1Y_STAT3 and SSSS_201X_FLO3_1D_1Y_SORT3, continued.

nQ - single digit code from list [1, 2, 3, 4] that gives the number of wind quadrants directions the wind to/from the site for the whole 24 h day.



HHinQ - total number of hours (0-24) wind was in each Q in order of [W, N, S, E] quadrants directions the wind came to the site for the whole 24 h day.

code example : '[10,1,0,13]' is 10 h from W, 1 h from N,
0 h from S, 13 h from E

WSinQ - mean wind speed in each Q, km/h

sQatHH - Q for each hour, eg [WWWWWW WVEEEE EEEEE EENWWE]

nX - data column, exceedance numerical code for day
same as 'nX' in SSSS_201X_O38H_1D_1Y_STAT2

pkO31H - data column, peak (or max) O31H for the day
same as 'O31H_max8' in SSSS_201X_O38H_1D_1Y_STAT2

rkO31H - data column, exceedance numerical code for day
same as 'O31H_max8_rk' in SSSS_201X_O38H_1D_1Y_STAT2

pkO38H - data column, peak (or max) O38H for the day
same as 'O38H' in SSSS_201X_O38H_1D_1Y_STAT2

rkO38H - data column, exceedance numerical code for day
same as 'O38H_rk' in SSSS_201X_O38H_1D_1Y_STAT2

SSSS_201X_QXWF_1D_1Y_CODES

- DateTime - index column using ISO 8601 format : yyyy-mm-dd 12:00:00
- nQ - numerical code for number of wind quadrants for day: 1,2,3,4
 - sQ - character code for number of wind quadrants for day: 1Q,2Q,3Q,4Q
 - nX - numerical code for type of O3xH exceedance for day: 0,1,8,9
 - sX - character code for type of O3xH exceedance for day: 0X,1X,8X,9X
 - nW - numerical code for morning wind-heading from `C8ta`: eg: 84, 54
 - sW - character code for morning wind-heading from `C8ta`: eg: NW-N, S-SW
 - nF - numerical code for dominate wind flow for day: 1,2,3,4
 - sF - character code for dominate wind flow for day: W2E, N2S, S2N, E2W

SSSS_201X_QXWF_1D_1Y_TEXTS

- DateTime - index column using ISO 8601 format : yyyy-mm-dd 12:00:00
- nQXWF - numerical combination code number of wind quadrants for day:,
O3 exceedance, morning wind heading, daily dominate flow
 - sQX - character code for number of wind quadrants for day and
O3 exceedance codes
 - sQXW - character code for number of wind quadrants for day,
O3 exceedance code, morning wind heading
 - sW - character code for morning wind-heading from `C8ta`, eg: NW-N
 - sF - character code for dominate wind flow for day: eg: S2N

NB: `SSSS_201X_QXWF_1D_1Y_STAT3` is build from columns of previous DataFrames to provide a 1-day resolution collection over 1-year of chemical and metrological attributes for the purpose of “aggregating” similar days in the second MultiIndex’ed (i.e., hierarchical indices) `SSSS_201X_QXWF_1D_1Y_STAT4` data frame, which is indexed first by `sQXW` and then by `DateTime` for the days that meet the criteria of the given `sQXW` category, thus “clustering” similar meteorological and ozone days for inspection and plotting or averaging. Except for the addition of the top order index `sQXW`, plotting the data columns in these two DataFrames are the same and will not be repeated.

`SSSS_201X_QXWF_1D_1Y_STAT3`

- `DateTime` - index column using ISO 8601 format : yyyy-mm-dd 12:00:00
- `nQXWF` - numerical combination code number of wind quadrants for day:,
O3 exceedance, morning wind heading, daily dominate flow
- `sQX` - character code for number of wind quadrants for day and
O3 exceedance codes
- `sQXW` - character code for number of wind quadrants for day,
O3 exceedance code, morning wind heading
- `sW` - character code for morning wind-heading from ‘C8ta’, eg: NW-N
- `sF` - character code for dominate wind flow for day: eg: S2N
- `d06` - 00 H to 06 H displacement distance by wind, km, BLACK
NB: d06 is also referred to as “morning travel distance” in many plots
- `C8ta` - aggregated 4 digit number where each digit is a ‘compass octet’ giving the
average 00-06 H and 06-12 H ‘heading’ ‘to’ the site and
average 12-18 H and 18-24 H ‘heading’ ‘away’ from the site.
- `wCROS` - four letter code to indicate if later 6-h wind displacements crosses over a
previous wind displacement path
- `hrSite` - number of hours the 1H wind displacements were within 5 km of site
- `nQ` - numerical code for number of wind quadrants for day: 1,2,3,4
- `HHinQ` - total number of hours (0-24) wind was in each Q in order of [W, N, S, E]
- `WSinQ` - mean wind speed in each Q, km/h
- `sQatHH` - Q for each hour, eg [WWWWWW WWEEEE EEEEE EENWWE]

SSSS_201X_QXWF_1D_1Y_STAT4

sQXW - index column describing number of wind quadrants for day,
 O3 exceedance code, morning wind heading,
 e.g., '1Q_OX_E-SE' aggregates all days that are "straight-line",
 do not have an ozone exceedance, and have morning winds
 from E-SE

DateTime - index column using ISO 8601 format : yyyy-mm-dd 12:00:00

Other 'data columns' are the same as those in SSSS_201X_QXWF_1D_1Y_STAT3.

Example DataFrames Created Directly From AIRS Files

(NB: these are 'truncated' in DateTime for illustration purposes)

/BULL_2015_INOR_1H_OBS2

	O3	NO	NO2
DateTime			
2015-06-01 00:00:00	2.16	0.13	nan
2015-06-01 01:00:00	2.12	0.18	nan
2015-06-01 02:00:00	1.36	0.14	0.07
2015-06-01 03:00:00	1.11	0.30	nan
2015-06-01 04:00:00	1.18	0.29	nan
2015-06-01 05:00:00	0.93	0.27	nan
2015-06-01 06:00:00	3.23	1.20	0.09
2015-06-01 07:00:00	16.53	0.55	0.54
2015-06-01 08:00:00	35.55	1.46	5.33
2015-06-01 09:00:00	47.75	1.42	7.79

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/BULL_2015_SOLR_1H_OBS2

	BULL
DateTime	
2015-06-01 00:00:00	0.00
2015-06-01 01:00:00	0.00
2015-06-01 02:00:00	0.00
2015-06-01 03:00:00	0.00
2015-06-01 04:00:00	0.00
2015-06-01 05:00:00	9.17
2015-06-01 06:00:00	145.00
2015-06-01 07:00:00	400.00
2015-06-01 08:00:00	708.33
2015-06-01 09:00:00	999.17

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/BULL_2015_TEMP_1H_OBS2

	BULL
DateTime	
2015-06-01 00:00:00	64.49
2015-06-01 01:00:00	63.55
2015-06-01 02:00:00	62.47
2015-06-01 03:00:00	62.18
2015-06-01 04:00:00	61.77
2015-06-01 05:00:00	61.14
2015-06-01 06:00:00	62.08
2015-06-01 07:00:00	69.26
2015-06-01 08:00:00	75.50
2015-06-01 09:00:00	78.37

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DataFrames Created Directly From AIRS Files and Further Processed

WSt and WDt are loaded directly from AIRS Files; other columns are computed.

/BULL_2015_WIND_1H_OBS2

	WSt	WDt	Ua	Va	Uad	Vad	Uadz	Vadz
DateTime								
2015-06-01 00:00:00	5.28	322.21	3.23	-4.17	3.23	-4.17	-4.71	2.50
2015-06-01 01:00:00	4.17	327.50	2.24	-3.51	5.47	-7.68	-2.47	-1.02
2015-06-01 02:00:00	3.42	325.14	1.95	-2.80	7.42	-10.49	-0.52	-3.82
2015-06-01 03:00:00	5.27	319.80	3.40	-4.02	10.82	-14.51	2.88	-7.85
2015-06-01 04:00:00	4.90	323.46	2.92	-3.94	13.74	-18.45	5.80	-11.78
2015-06-01 05:00:00	5.50	325.83	3.09	-4.55	16.83	-23.00	8.89	-16.34
2015-06-01 06:00:00	6.37	321.39	3.97	-4.98	20.81	-27.98	12.87	-21.32
2015-06-01 07:00:00	3.16	319.62	2.05	-2.41	22.86	-30.39	14.92	-23.72
2015-06-01 08:00:00	3.50	139.95	-2.25	2.68	20.60	-27.71	12.66	-21.05
2015-06-01 09:00:00	5.31	143.48	-3.16	4.27	17.44	-23.44	9.50	-16.77

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DataFrames Created From Existing DataFrames and Further Processed

Data Loaded From INOR_1H_OBS2 and Further Processed

to produce O38H_1D_1Y_STAT2.

Index resolution is 1D and extent is 1Y

O31H parameters are extracted from INOR_1H_OBS2 DataFrame.

All O38H parameters are computed and added for each day using EPA algorithms.

/BULL_2015_O38H_1D_1Y_STAT2

	Cnt	O31H_min1	O31H_min1_hr	O31H_min8	O31H_min8_hr	O31H_max8	O31H_max8_hr	O31H_max8_rk	O31H_rng8	O31H_rng8_rk	O38H	O38H_str8_hr	O38H_rk	ratio1H8H	nX
2015-06-01 12:00:00	8	0.93	5	72.69	11	81.04	13	10	8.36	179	73.01	11	10	1.11	8
2015-06-02 12:00:00	8	1.04	5	56.08	10	67.42	12	34	11.34	127	63.84	10	26	1.06	0
2015-06-03 12:00:00	8	4.57	3	46.32	11	52.82	13	95	6.50	231	49.58	11	80	1.07	0
2015-06-04 12:00:00	8	2.00	5	45.33	11	51.94	15	104	6.62	227	48.28	11	92	1.08	0
2015-06-05 12:00:00	8	1.49	5	44.66	12	51.56	17	105	6.91	221	48.38	12	90	1.07	0
2015-06-06 12:00:00	8	0.49	5	45.16	11	53.02	16	92	7.86	190	48.96	11	83	1.08	0
2015-06-07 12:00:00	8	2.16	5	35.93	10	44.30	14	168	8.37	178	40.24	10	153	1.10	0
2015-06-08 12:00:00	8	5.02	5	39.20	11	54.35	17	80	15.15	83	49.20	11	82	1.10	0
2015-06-09 12:00:00	8	0.93	5	53.35	12	69.28	17	28	15.93	78	61.50	12	30	1.13	0
2015-06-10 12:00:00	8	1.17	5	44.77	11	63.49	15	49	18.72	48	55.55	11	54	1.14	0

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Data Loaded From WIND_1H_OBS2 and from O38H_1D_1Y_STAT2
and further processed to produce
FL03_1D_1Y_STAT3, and FL03_1D_1Y_SORT3.
Index resolution is 1D and extent is 1Y

/BULL_2015_FLO3_1D_1Y_STAT3

Flow_Ozone	Flow	dW2E	dS2N	dBBx	d06	d12	d18	d24	C8ta	wCROS	hrSite	nQ	HHlnQ	WSlnQ	sQatHH	nX	pkO31H	rkO31H	pkO38H	rkO38H
2015-06-01 12:00:00	S2N	48	68	83	29	24	52	4	8484	-,-,-,-	3	2	[12,0,0,12]	[3,0,0,7]	[WWWWWWW WWEEEE EEEEE EEWWWW]	8	81	10	73	10
2015-06-02 12:00:00	S2N	33	89	95	11	32	53	6	8487	-,-,-,-	1	3	[10,1,0,13]	[1,0,0,7]	[WWWWWWW WWEEEE EEEEE EENWWE]	0	67	34	63	26
2015-06-03 12:00:00	S2N	62	154	166	16	54	60	38	5488	-,-,-,-	1	3	[1,0,5,18]	[0,0,6,7]	[EEEWSS SSSEEE EEEEE EEEEE]	0	52	95	49	80
2015-06-04 12:00:00	S2N	81	100	129	10	34	63	35	8478	-,-,-,-	1	4	[4,2,2,16]	[2,1,6,7]	[ENWWNW WEESSE EEEEE EEEEE]	0	51	104	48	92
2015-06-05 12:00:00	S2N	79	97	125	2	39	66	21	2478	-,-,-,-	1	4	[2,3,3,16]	[0,0,5,7]	[EENNNW ESSSEE EEEEE EEEEEW]	0	51	105	48	90
2015-06-06 12:00:00	S2N	44	78	90	10	35	53	1	8484	G,-,-,-	1	3	[11,0,1,12]	[1,0,6,7]	[WWWWWWW WEESEE EEEEE EEWWWW]	0	53	92	48	83
2015-06-07 12:00:00	S2N	41	120	127	2	39	51	37	6588	-,-,-,-	1	3	[4,0,4,16]	[0,0,6,7]	[EESWWW WESESE EEEEE EEEEE]	0	44	168	40	153
2015-06-08 12:00:00	S2N	15	86	87	8	34	30	15	5588	-,-,-,-	2	3	[1,0,11,12]	[0,0,4,4]	[EESSWE SSSSS EEEEE EEESES]	0	54	80	49	82
2015-06-09 12:00:00	S2N	14	61	63	9	27	27	6	7588	-,-,-,-	2	4	[5,1,10,8]	[1,1,3,4]	[SSSWWW WSSSES SEEEEE EESNNW]	0	69	28	61	30
2015-06-10 12:00:00	S2N	46	96	106	3	38	52	24	8588	-,-,-,-	1	4	[5,1,5,13]	[1,1,7,6]	[WWENWW WSSSS EEEEE EEEEE]	0	63	49	55	54

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/BULL_2015_FLO3_1D_1Y_SORT3

Flow_Ozone	Flow	dW2E	dS2N	dBBx	d06	d12	d18	d24	C8ta	wCROS	hrSite	nQ	HHlnQ	WSlnQ	sQatHH	nX	pkO31H	rkO31H	pkO38H	rkO38H
2015-06-01 12:00:00	S2N	48	68	83	29	24	52	4	8484	-,-,-,-	3	2	[12,0,0,12]	[3,0,0,7]	[WWWWWWW WWEEEE EEEEE EEWWWW]	8	81	10	73	10

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Data Loaded From FL03_1D_1Y_STAT3

and further processed to produce

_QXWF_1D_1Y_CODES and _QXWF_1D_1Y_TEXTS

Index resolution is 1D and extent is 1Y

/BULL_2015_QXWF_1D_1Y_CODES

	nQ	sQ	nX	sX	nW	sW	nF	sF
2015-06-01 12:00:00	2	2Q	8	8X	84	NW-N	3	S2N
2015-06-02 12:00:00	3	3Q	0	0X	84	NW-N	3	S2N
2015-06-03 12:00:00	3	3Q	0	0X	54	S-SW	3	S2N
2015-06-04 12:00:00	4	4Q	0	0X	84	NW-N	3	S2N
2015-06-05 12:00:00	4	4Q	0	0X	24	NE-E	3	S2N
2015-06-06 12:00:00	3	3Q	0	0X	84	NW-N	3	S2N
2015-06-07 12:00:00	3	3Q	0	0X	65	SW-W	3	S2N
2015-06-08 12:00:00	3	3Q	0	0X	55	S-SW	3	S2N
2015-06-09 12:00:00	4	4Q	0	0X	75	W-NW	3	S2N
2015-06-10 12:00:00	4	4Q	0	0X	85	NW-N	3	S2N

...

/BULL_2015_QXWF_1D_1Y_TEXTS

	nQXWF	sQX	sQXW	sW	sF
2015-06-01 12:00:00	2883	2Q_8X	2Q_8X_NW-N	NW-N	S2N
2015-06-02 12:00:00	3083	3Q_0X	3Q_0X_NW-N	NW-N	S2N
2015-06-03 12:00:00	3053	3Q_0X	3Q_0X_S-SW	S-SW	S2N
2015-06-04 12:00:00	4083	4Q_0X	4Q_0X_NW-N	NW-N	S2N
2015-06-05 12:00:00	4023	4Q_0X	4Q_0X_NE-E	NE-E	S2N
2015-06-06 12:00:00	3083	3Q_0X	3Q_0X_NW-N	NW-N	S2N
2015-06-07 12:00:00	3063	3Q_0X	3Q_0X_SW-W	SW-W	S2N
2015-06-08 12:00:00	3053	3Q_0X	3Q_0X_S-SW	S-SW	S2N
2015-06-09 12:00:00	4073	4Q_0X	4Q_0X_W-NW	W-NW	S2N
2015-06-10 12:00:00	4083	4Q_0X	4Q_0X_NW-N	NW-N	S2N

Data Loaded From FL03_1D_1Y_STAT3 and _QXWF_1D_1Y_CODES

and further processed to produce

_QXW_1D_1Y_CNT3 and _QXW_1D_1Y_TOTL3

Index is sQ by sW and extent is 1Y or (AO)

Columns are sX

/BULL_2015_QWX_1Y_CNTS3

	sX	0X	1X	8X	9X	Sum
sQ	sW					
1Q	N-NE	1	0	0	0	1
	NE-E	1	0	0	0	1
	E-SE	6	0	0	0	6
	SE-S	31	0	0	0	31
	S-SW	0	0	0	0	0
	SW-W	0	0	0	0	0
	W-NW	0	0	0	0	0
	NW-N	4	0	0	0	4
2Q	N-NE	13	0	0	0	13
	NE-E	3	0	0	0	3

/BULL_2015_QWX_1Y_TOTL3

sX	0X	1X	8X	9X	Sum
sQ					
1Q	43	0	0	0	43
2Q	126	0	3	0	129
3Q	115	0	6	2	123
4Q	62	0	3	0	65
Sum	346	0	12	2	360

Data Loaded From FL03_1D_1Y_STAT3 and _QXWF_1D_1Y_TEXTS

and further processed to produce

_QXWF_1D_1Y_STAT3

Index resolution is 1D and extent is 1Y or (AO)

and

MultiIndex _QXWF_1D_1Y_STAT4 and _QXWF_34Q_AO_STAT4 (sorted)

MultiIndex is by sQXW and

then by DT at resolution 1D and extent is 1Y or (AO)

/BULL_2015_QXWF_1D_1Y_STAT3

	nQXWF	sQX	sQXW	sW	sF	d06	C8ta	wCROS	hrSite	WSInQ	sQatHH	pkO31H	rkO31H	pkO38H	rkO38H
2015-06-01 12:00:00	2883	2Q_8X	2Q_8X_NW-N	NW-N	S2N	29	8484	-,-,-,-	3	[3,0,0,7]	[WWWWWWW WVEEEE EEEEE EEWWWW]	81	10	73	10
2015-06-02 12:00:00	3083	3Q_0X	3Q_0X_NW-N	NW-N	S2N	11	8487	-,-,-,-	1	[1,0,0,7]	[WWWWWWW WVEEEE EEEEE EENWWW]	67	34	63	26
2015-06-03 12:00:00	3053	3Q_0X	3Q_0X_S-SW	S-SW	S2N	16	5488	-,-,-,-	1	[0,0,6,7]	[EEEWSS SSSEEE EEEEE EEEEE]	52	95	49	80
2015-06-04 12:00:00	4083	4Q_0X	4Q_0X_NW-N	NW-N	S2N	10	8478	-,-,-,-	1	[2,1,6,7]	[ENWWNW WEESSE EEEEE EEEEE]	51	104	48	92
2015-06-05 12:00:00	4023	4Q_0X	4Q_0X_NE-E	NE-E	S2N	2	2478	-,-,-,-	1	[0,0,5,7]	[EENNNW ESSSEE EEEEE EEEEE]	51	105	48	90
2015-06-06 12:00:00	3083	3Q_0X	3Q_0X_NW-N	NW-N	S2N	10	8484	G,-,-,-	1	[1,0,6,7]	[WWWWWWW WEESEE EEEEE EEWWWW]	53	92	48	83
2015-06-07 12:00:00	3063	3Q_0X	3Q_0X_SW-W	SW-W	S2N	2	6588	-,-,-,-	1	[0,0,6,7]	[EESWWW WESESE EEEEE EEEEE]	44	168	40	153
2015-06-08 12:00:00	3053	3Q_0X	3Q_0X_S-SW	S-SW	S2N	8	5588	-,-,-,-	2	[0,0,4,4]	[EESWWE SSSSSS EEEEE EEESES]	54	80	49	82
2015-06-09 12:00:00	4073	4Q_0X	4Q_0X_W-NW	W-NW	S2N	9	7588	-,-,-,-	2	[1,1,3,4]	[SSSWWW WSSSES SESEEE EESNWN]	69	28	61	30
2015-06-10 12:00:00	4083	4Q_0X	4Q_0X_NW-N	NW-N	S2N	3	8588	-,-,-,-	1	[1,1,7,6]	[WWENWW WSSSSS EEEEE EEEEE]	63	49	55	54

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/BULL_2015_QXWF_1D_1Y_STAT4

		nQXWF	sQX	sQXW	sW	sF	d06	C8ta	wCROS	hrSite	WSInQ	sQatHH	pkO31H	rkO31H	pkO38H	rkO38H
1Q_-X_SE-S	2015-06-22 12:00:00	9999	1Q_-X	1Q_-X_SE-S	SE-S	E2W	52	4477	-,-,-,-	1	[0,0,0,8]	[EEEEEE EEEEE EEEEE EEEEE]	0	363	0	363
1Q_0X_E-SE	2015-01-31 12:00:00	1032	1Q_0X	1Q_0X_E-SE	E-SE	E2W	54	3378	-,-,-,-	1	[0,0,0,7]	[EEEEEE EEEEE EEEEE EEEEE]	28	323	25	315
	2015-05-04 12:00:00	1032	1Q_0X	1Q_0X_E-SE	E-SE	E2W	65	3378	-,-,-,-	1	[0,0,0,13]	[EEEEEE EEEEE EEEEE EEEEE]	48	129	47	97
	2015-06-23 12:00:00	1033	1Q_0X	1Q_0X_E-SE	E-SE	S2N	39	3487	-,-,-,-	1	[0,0,0,8]	[EEEEEE EEEEE EEEEE EEEEE]	22	341	15	353
	2015-09-15 12:00:00	1033	1Q_0X	1Q_0X_E-SE	E-SE	S2N	35	3488	-,-,-,-	1	[0,0,0,9]	[EEEEEE EEEEE EEEEE EEEEE]	45	152	41	142
	2015-10-22 12:00:00	1033	1Q_0X	1Q_0X_E-SE	E-SE	S2N	74	3488	-,-,-,-	1	[0,0,0,12]	[EEEEEE EEEEE EEEEE EEEEE]	33	279	26	305
	2015-11-04 12:00:00	1033	1Q_0X	1Q_0X_E-SE	E-SE	S2N	32	3488	-,-,-,-	1	[0,0,0,8]	[EEEEEE EEEEE EEEEE EEEEE]	43	184	36	203
1Q_0X_N-NE	2015-02-27 12:00:00	1011	1Q_0X	1Q_0X_N-NE	N-NE	N2S	88	1255	-,-,-,-	1	[0,15,0,0]	[NNNNNN NNNNNN NNNNNN NNNNNN]	34	275	33	240
1Q_0X_NE-E	2015-05-12 12:00:00	1022	1Q_0X	1Q_0X_NE-E	NE-E	E2W	68	2266	-,-,-,-	1	[0,10,0,0]	[NNNNNN NNNNNN NNNNNN NNNNNN]	37	241	29	279
1Q_0X_NW-N	2015-01-15 12:00:00	1081	1Q_0X	1Q_0X_NW-N	NW-N	N2S	35	8844	-,-,-,-	1	[8,0,0,0]	[WWWWWWW WWWWWW WWWWWW WWWWWW]	32	289	31	264

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/BULL_2015_QXWF_34Q_AO_STAT4

		nQXWF	sQX	sQXW	sW	sF	d06	C8ta	wCROS	hrSite	WSInQ	sQatHH	pkO31H	rkO31H	pkO38H	rkO38H
4Q_8X_W-NW	2015-08-15 12:00:00	4871	4Q_8X	4Q_8X_W-NW	W-NW	N2S	3	7746	-,-,-,V,-	6	[3,1,1,3]	[EEEWVVV WNNWWW SWSWWW ENWVVE]	88	5	73	9
4Q_8X_NW-N	2015-08-02 12:00:00	4882	4Q_8X	4Q_8X_NW-N	NW-N	E2W	25	8372	-,-,-,-	3	[3,3,0,6]	[WWWWWWW WVEEEE ENEEEE EEWVWS]	78	13	75	8
	2015-08-13 12:00:00	4881	4Q_8X	4Q_8X_NW-N	NW-N	N2S	23	8875	-,-,-,-	1	[3,7,3,6]	[WWWWWWW WWSSWN NNEEEE EEWVWS]	88	4	76	7
4Q_0X_W-NW	2015-06-09 12:00:00	4073	4Q_0X	4Q_0X_W-NW	W-NW	S2N	9	7588	-,-,-,-	2	[1,1,3,4]	[SSSWWW WSSSES SESEEE EESNWN]	69	28	61	30
	2015-07-31 12:00:00	4071	4Q_0X	4Q_0X_W-NW	W-NW	N2S	13	7843	-,-,-,-	1	[4,9,1,3]	[ESWWWWW WWWWWN NNNWWW WWWWWW]	52	93	43	125
	2015-08-12 12:00:00	4071	4Q_0X	4Q_0X_W-NW	W-NW	N2S	5	7853	-,-,-,-	6	[2,5,4,2]	[EEEWVVV WNNWWW NNESWW WWWWWW]	54	83	46	101
	2015-10-18 12:00:00	4072	4Q_0X	4Q_0X_W-NW	W-NW	E2W	20	7378	-,-,-,-	1	[3,7,0,6]	[WWWWWWW WNNNEE EEEEE EEESEE]	60	58	55	52
	2015-10-27 12:00:00	4074	4Q_0X	4Q_0X_W-NW	W-NW	W2E	57	7724	-,-,-,V,-	1	[6,1,7,0]	[WWWWWWW WWWWSS SSSSSS SENWWW]	44	162	41	140
	2015-04-13 12:00:00	4064	4Q_0X	4Q_0X_SW-W	SW-W	W2E	14	6614	-,-,-,-	1	[3,0,5,4]	[EESSSS SSSSSS SESSSS SNWWW]	47	136	42	135
4Q_0X_SW-W	2015-09-21 12:00:00	4062	4Q_0X	4Q_0X_SW-W	SW-W	E2W	7	6477	G,-,-,-	1	[1,0,2,6]	[EESSSW WVEEEE EEEEE EEEENW]	62	54	55	55

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Data Loaded From QXWF_1D_1Y_STAT3
and further processed to produce
TP10_1Y_STAT3

/BULL_2015_TP10_1Y_STAT3

	Date	Hr8HWIn	O38H	O31H	1Hto8H	1HChgIn8H	ChgRnk	sQXW	sF	sW	d06	hrSite	C8ta	wCROS	Um	Vm	Sm
Rank8h																	
1	2015-08-29	10	89.38	105.84	1.18	34.21	2	3Q_9X_SW-W	S2N	SW-W	4	3	6588	-,-,-,-	-2.73	4.99	5.69
2	2015-08-28	11	88.73	98.93	1.11	21.74	27	3Q_8X_SW-W	S2N	SW-W	4	1	6588	-,-,-,-	-3.85	7.02	8.01
3	2015-08-27	11	87.45	101.63	1.16	25.35	12	3Q_9X_S-SW	S2N	S-SW	11	1	5588	-,-,-,-	-1.99	5.55	5.90
4	2015-08-03	10	81.03	86.19	1.06	10.51	145	3Q_8X_W-NW	E2W	W-NW	4	1	7378	G,-,-,-	-8.37	4.16	9.34
5	2015-05-01	11	79.83	86.36	1.08	17.83	59	3Q_8X_NW-N	S2N	NW-N	24	1	8584	-,-,V,-	-1.81	5.78	6.06
6	2015-05-02	10	76.45	87.72	1.15	15.73	80	3Q_8X_NW-N	S2N	NW-N	21	1	8478	-,-,-,-	-5.73	7.89	9.75
7	2015-08-13	11	76.07	88.98	1.17	28.33	8	4Q_8X_NW-N	N2S	NW-N	23	1	8875	-,-,-,-	-4.53	0.32	4.54
8	2015-08-02	11	75.18	78.96	1.05	7.36	205	4Q_8X_NW-N	E2W	NW-N	25	3	8372	-,-,-,-	-5.58	3.64	6.66
9	2015-08-15	11	73.77	88.52	1.20	33.36	3	4Q_8X_W-NW	N2S	W-NW	3	6	7746	-,-,V,-	0.85	-0.46	0.96
10	2015-06-01	11	73.01	81.04	1.11	8.36	179	2Q_8X_NW-N	S2N	NW-N	29	3	8484	-,-,-,-	-4.69	6.66	8.15

Data Loaded From _QXWF_1D_1Y_STAT4 and _INOR_1H_OBS2 and _WIND_1H_OBS2
and further processed to produce
_UVO3_1Y_STAT4 and _UVO3_1Y_CNTS4 or other time-window, eg _AO_
MultiIndex is by sQXW_i and
then by HH at resolution 1H and compute average over days

/BULL_2012_UVO3_AO_STAT4

		O3	Ua	Va	WSt
sQXW_i	HH				
1Q_0X_E-SE	0	38.08	-7.91	8.57	11.84
	1	40.36	-8.67	6.63	11.12
	2	39.75	-8.16	6.78	10.76
	3	37.15	-7.78	5.80	9.72
	4	35.96	-5.57	5.36	7.75
	5	28.68	-3.74	5.25	6.54
	6	26.99	-4.06	4.26	5.89
	7	25.55	-4.14	5.88	7.27
	8	28.25	-3.49	8.30	9.16
	9	32.89	-4.50	9.11	10.34
	10	39.94	-4.36	10.26	11.16
	11	47.11	-5.05	8.87	10.23
	12	55.13	-6.53	9.68	11.77
	13	56.38	-7.09	9.33	11.92
	14	55.79	-7.12	9.54	12.27
	15	53.77	-7.70	9.54	12.35
	16	50.55	-7.74	8.96	11.97
	17	50.87	-8.88	8.84	12.79
	18	47.10	-10.00	9.20	13.69
	19	43.38	-12.07	8.66	14.94
	20	42.49	-11.74	8.62	14.67
	21	40.42	-10.32	8.39	13.35
	22	12.71	-9.23	8.05	12.31
	23	36.75	-7.63	5.63	9.63
1Q_0X_N-NE	0	14.62	-3.99	-18.94	19.36
	1	15.06	-3.61	-18.64	18.98
	2	16.38	-2.74	-17.12	17.34
	3	16.52	-3.72	-18.50	18.87
	4	16.46	-2.59	-17.13	17.33
	5	17.41	-4.60	-17.33	17.93
	6	17.61	-3.55	-17.13	17.49
	7	18.70	-5.17	-18.63	19.34
	8	20.03	-5.97	-18.95	19.86
	9	21.54	-6.89	-18.35	19.60
	10	22.98	-5.57	-18.39	19.21
	11	25.47	-6.14	-17.94	18.96
	12	27.08	-4.10	-14.59	15.15
	13	29.09	-5.97	-13.42	14.69
	14	30.09	-5.94	-13.19	14.47
	15	30.57	-5.01	-10.20	11.36

/BULL_2012_UVO3_AO_CNTS4

```
sQXW_i
1Q_0X_E-SE      3
1Q_0X_N-NE      1
1Q_0X_NW-N      1
1Q_0X_SE-S      42
2Q_0X_E-SE      3
2Q_0X_N-NE      4
2Q_0X_NE-E      1
2Q_0X_NW-N     10
2Q_0X_SE-S     26
2Q_0X_W-NW      5
2Q_8X_NW-N      1
2Q_8X_W-NW      1
3Q_0X_E-SE      6
3Q_0X_N-NE      2
3Q_0X_NE-E      1
3Q_0X_NW-N     11
3Q_0X_S-SW      1
3Q_0X_SE-S     11
3Q_0X_SW-W      2
3Q_0X_W-NW     13
3Q_8X_E-SE      1
3Q_8X_N-NE      1
3Q_8X_NW-N      4
3Q_8X_SE-S      1
3Q_8X_W-NW      3
3Q_9X_W-NW      2
4Q_0X_E-SE      2
4Q_0X_N-NE      1
4Q_0X_NW-N      6
4Q_0X_S-SW      1
4Q_0X_SE-S     10
4Q_0X_SW-W      2
4Q_0X_W-NW      3
4Q_8X_E-SE      1
4Q_8X_NW-N      2
4Q_8X_W-NW      1
dtype: int16
```


Data Loaded From _QXWF_1D_1Y_STAT4 and _INOR_1H_OBS2 and _WIND_1H_OBS2
and further processed to produce
_UV03_14QU_1Y_STAT5 or other time-window, eg _A0_
Index is by sQXW_i and columns are 'mean' values over 'Days'

/BULL_2012_QX03_14QU_AO_STAT5

	pkO31H	pkO38H	d06	Days
sQXW_i				
1Q_0X_E-SE	57.00	51.67	50.67	3
1Q_0X_N-NE	32.00	31.00	107.00	1
1Q_0X_NW-N	42.00	40.00	105.00	1
1Q_0X_SE-S	44.38	40.52	52.24	42
2Q_0X_E-SE	48.00	41.67	20.00	3
2Q_0X_N-NE	47.00	42.75	52.50	4
2Q_0X_NE-E	72.00	67.00	41.00	1
2Q_0X_NW-N	50.60	46.90	40.70	10
2Q_0X_SE-S	53.77	47.96	33.65	26
2Q_0X_W-NW	62.80	56.40	45.20	5
2Q_8X_NW-N	74.00	71.00	20.00	1
2Q_8X_W-NW	96.00	91.00	24.00	1
3Q_0X_E-SE	53.50	48.17	26.33	6
3Q_0X_N-NE	58.00	54.00	16.00	2
3Q_0X_NE-E	50.00	47.00	3.00	1
3Q_0X_NW-N	60.09	52.45	22.55	11
3Q_0X_S-SW	56.00	47.00	12.00	2
3Q_0X_SE-S	48.64	41.45	24.00	11
3Q_0X_SW-W	68.00	58.50	5.00	2
3Q_0X_W-NW	66.38	57.15	26.85	13
3Q_8X_E-SE	76.00	71.00	13.00	1
3Q_8X_N-NE	83.00	76.00	12.00	1
3Q_8X_NW-N	82.75	73.00	27.50	4
3Q_8X_SE-S	74.00	70.00	13.00	1
3Q_8X_W-NW	86.33	77.67	30.67	3
3Q_9X_W-NW	101.50	89.50	43.00	2
4Q_0X_E-SE	51.50	45.00	20.50	2
4Q_0X_N-NE	56.00	46.00	8.00	1
4Q_0X_NW-N	60.83	49.00	22.33	6
4Q_0X_S-SW	49.00	37.00	16.00	1
4Q_0X_SE-S	52.40	44.00	30.90	10
4Q_0X_SW-W	73.00	56.00	1.00	2
4Q_0X_W-NW	63.00	55.00	6.67	3
4Q_8X_E-SE	81.00	72.00	21.00	1
4Q_8X_NW-N	84.00	73.00	21.50	2
4Q_8X_W-NW	88.00	77.00	47.00	1