DRAFT "Other Test Method" OTM 33A (Ver. 1.3)

Geospatial Measurement of Air Pollution-Remote Emissions Quantification-Direct Assessment (GMAP-REQ-DA)

1. Scope and Application

1.1 Geospatial measurement of air pollution (GMAP) is a general term referring to the use of fast-response instruments and precise global positioning systems (GPS) in mobile formats to spatiotemporally-resolve air pollution patterns in a variety of use scenarios. General "mobile measurement" or GMAP applications can utilize many different instrumentation and mobility schemes to investigate numerous air quality questions on a range of spatial scales.[1] Other Test Method 33(OTM 33), "Geospatial Measurement of Air Pollution-Remote Emissions Quantification" (GMAP-REQ), describes a subset of GMAP approaches that use ground-based vehicles to improve understanding of air pollution sources at local scales. OTM 33 GMAP-REQ is typically based on two primary operational modes, (1) mapping surveys to detect and locate source emissions and (2) source measurement and/or characterization procedures to assess near source concentrations and source mass emission rates.[1]

OTM 33 provides a general prescription for GMAP-REQ. Specific sub-methods of OTM 33 describe variations in application and use scenarios that may employ different emissions detection and/or source characterization schemes. The sub-method of OTM 33 detail the method requirements (MRs), performance metrics (PMs), method quality indicators (MQIs) and typical application scenarios for the described approach.

This document describes sub-method OTM 33A, a GMAP-REQ approach called "direct assessment" (DA). OTM 33A (GMAP-REQ-DA) is used for mobile assessment of emissions from near-field, ground-level point sources and is designed to be a rapidly executed inspection approach. OTM 33A allows detection and assessment of source emissions without use of deployed equipment or site-specific modeling.

1.2 OTM 33A describes use of instrumented, ground-based vehicles to acquire information on air pollutant sources located near the driving route and to estimate emissions in some cases using a “direct assessment” approach (GMAP-REQ-DA). OTM 33A is applicable to characterization of non-extended (small in spatial extent) sources located in close proximity (generally between 20 m and 200 m) of the driving route.

1.3 OTM 33A is used for one or more of the following three source assessment modes(SAMs): (1)concentration mapping(CM) used to find the location of unknown sources and/or to assess the relative contributions of source emissions to local air shed concentrations,(2) source characterization (SC) used to improve understanding of known or discovered source emissions through direct GMAP observation or through GMAP-facilitated acquisition of secondary measures (e.g. whole air canister grab samples), (3)emissions quantification (EQ) used to measure (or estimate) source emission strength.

1.4 OTM 33A is applicable to emissions detection and characterization of near ground-level fugitive, vented, and area source emissions of limited spatial extent as well as general mobile inspection applications in a wide variety of scenarios. This sub-method may be applied for source emission rate assessment for specific applications (e.g. upstream oil and gas production activities and industrial fugitive emissions) that fall within the use prescriptions of OTM 33A.

2. Summary of the Method

2.1 Principle of GMAP-REQ-DA. Under OTM 33A, a mobile inspection vehicle is fitted with requisite instrumentation specified here and in controlling quality assurance procedures to allow acquisition and analysis of spatially and temporally resolved emissions information from areas around sources of air pollutants including: gas phase criteria pollutants, volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and greenhouse gases (GHGs).

2.1.1 The acquisition and analysis of geospatially resolved mobile and stationary air quality data under OTM 33A can be performed for a number of applications within sub-method and project-specific quality assurance use limitations. These applications may include: (1) emission source detection and location, (2) emission source and local air shed characterization, and (3) emission source mass emission rate determination.

2.1.2 OTM 33A generally includes any near-field emission source location mapping and source emission strength inverse estimate scheme that employs a single point measurement executed from a mobile platform and that does not require site-specific modeling or on-site measures, such as release of tracer gas for atmospheric dispersion normalization. The GMAP-REQ-DA approach is generally useful for applications where: (1) emission source locations may be unknown, (2) the sources are relatively small with emission points near ground level, (3) direct (on-site) measurements may not easily be achieved or where remote (off-site) measurements may be beneficial, and (4) rapid deployments from mobile platforms are desired. In general, GMAP-REQ-DA approaches are very useful for surveying large areas or facilities to locate emissions source points and provide rapid, first-level source characterization and source mass emission rate assessment.

2.1.3 Project-related quality assurance documentation should define OTM 33A implementation in the context of the data quality objectives (DQOs) of the specific deployment. The implementation of OTM 33A for a given project includes an analysis of the required equipment and performance metrics, use limitations, data uncertainty, and QA measures in the context of the specific application.

2.2 Application of GMAP-REQ-DA

2.2.1 See OTM 33, sections 2.2.1 through 2.2.8 for discussion regarding detection and assessment of sources with mobile measurement approaches and the general differences between remote measurements and traditional ambient and direct source sampling.

2.2.2 OTM 33A applications typically include a combination of concentration mapping (CM) activities used to locate sources followed by execution of specialized stationary or mobile measurements conducted from remote vantage points (20 m to 200 m distant). These source assessment modes (SAMs) include source characterization (SC) and/or emission quantification (EQ) activities and are designed to provide first-level assessment information about the source(s) in support of more traditional direct (on-site) source measurement activities. Figure 2-1 illustrates a typical OTM 33A application in oil and gas production fields.

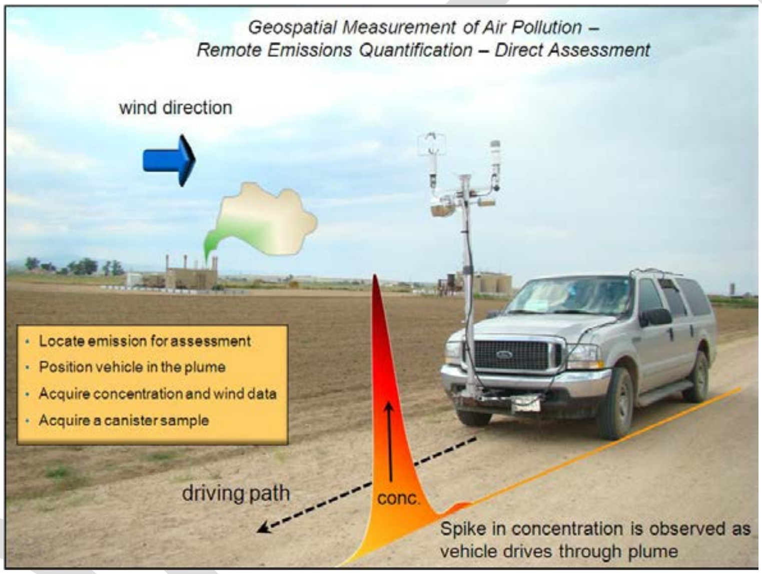

Figure 2-1. Illustration of a GMAP-REQ-DA application

2.2.3 Concentration mapping (CM) refers to the use of mobile sampling platforms to determine spatially-resolved concentrations around one or more known air pollution sources or to investigate an area or facility in an attempt to discover unknown emissions sources. The spatial scale of CM can range from tens of meters for an application like landfill-surface hotspot mapping to tens of kilometers for a city-wide leak survey of natural gas distribution networks.

Figure 2-2 provides an example of a CM application where a GMAP-REQ vehicle fitted with a UV spectrometer performs a mobile survey for fugitive benzene emissions. A facility can use such surveys to augment leak detection and repair programs by directing inspection crews to important areas for further investigation.

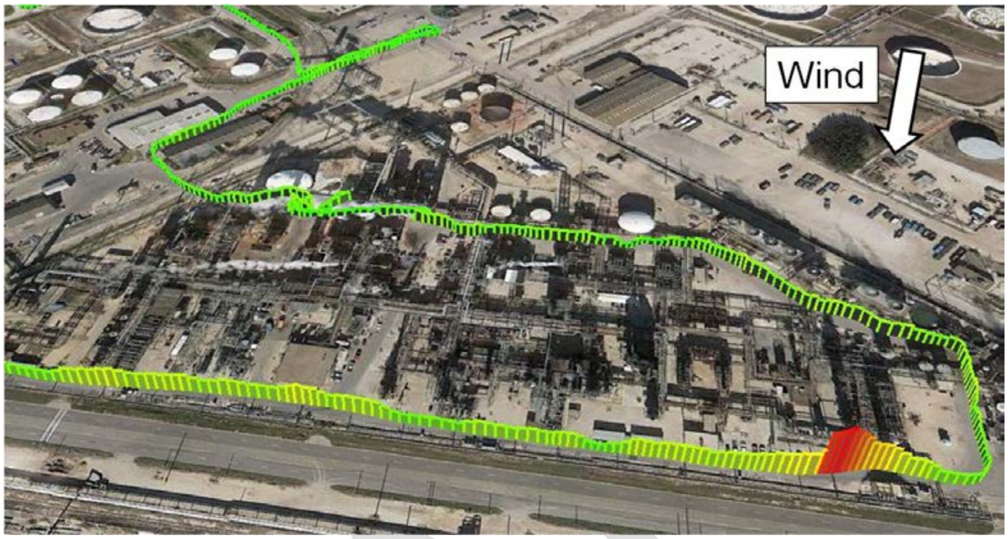

Figure 2-2. GMAP-REQ-DA concentration mapping survey of an industrial facility. Red points indicate elevated benzene levels

Figure 2-3 shows a slightly larger CM survey application conducted in the industrial sector of a city for the purpose of locating previously unknown sources of emissions. In this case the GMAP-REQ survey discovers a large and repeatable hydrogen sulfide (H_2S) emission. This emission source was then further investigated with a traditional on-site inspection approaches and corrective actions were taken.

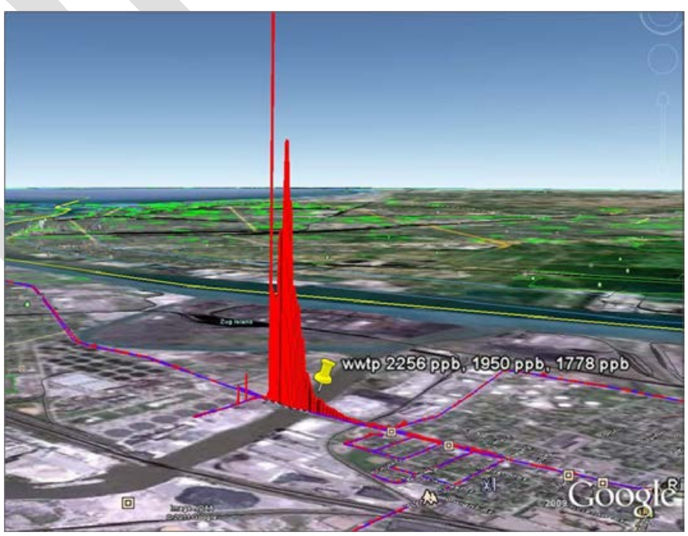

Figure 2-3. Example of a larger-scale OTM 33A concentration mapping survey for H_2S

2.2.4 After or as part of the CM survey, some form of source characterization (SC) activity may be performed to provide additional information on the detected emissions. This can involve repeated mobile transects or mapping upwind and downwind of the source to help identify source location and potential background interferences. SC may also involve acquisition of other data forms such as infrared camera images or canister grab samples to develop additional information on the source. For some SC functions, it is typical to use the real-time signal from the concentration measurement instrument (CMI) to position the vehicle in the emission plume at a safe and appropriate downwind observing location for acquisition of auxiliary data.

2.2.5 Source assessment modes that attempt to determine the mass emission rate of the source can be executed under OTM 33A in suitable scenarios. Emission Quantification (EQ) can be accomplished from mobile or stationary positions. For a typical stationary EQ measurement, the vehicle is placed downwind of the source (using the real time CMI data), the engine of the vehicle is turned off to reduce exhaust interference, and a series of 15 to 20-minute observations following a prescribed set of data acquisition protocols are executed [e.g. (OTM 33A Appendix E)].

2.2.6 Emission quantification (EQ) data analysis of measured compounds is accomplished by combining time-resolved concentration and wind measurements (and potentially vehicle motion data and other information such as source distance) with a suitable inverse source emission strength estimation algorithm while applying data acceptance QA requirements. An example of one possible observation and EQ scheme, called point source Gaussian (PSG) is presented in Figure 2-4. In this EQ approach, the GMAP vehicle is stationary and is placed at an appropriate downwind observing location where concentration data and wind field information are acquired for a 15 minute to 20 minute time period (for a single EQ measurement). In this approach, variations in wind direction move the plume around the observation location in three dimensions (Figure 2-4A). Using a PSG data analysis computer program, the acquired concentration data is binned by wind angle (Figure 2-4B) and the combined information is used to estimate the emission source mass emission rate using a procedure based on a point source assumption and Gaussian plume dispersion tables(further described Section 12 and Appendix F). Other inverse source mass emission rate algorithms based on stationary or mobile observations are possible.

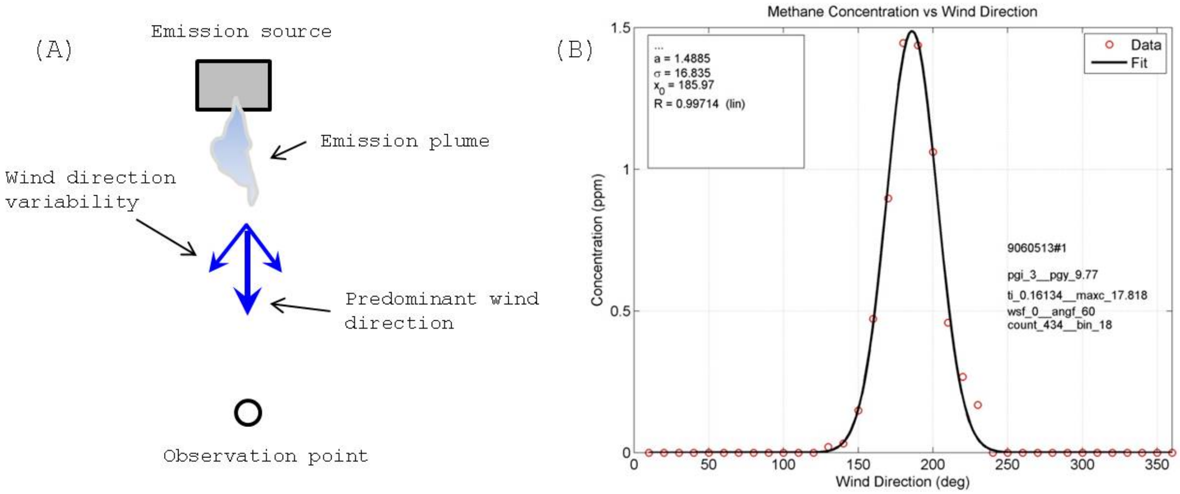

Figure 2-4. (A) Illustration of a stationary EQ observation and (B) a resultant time-integrated, angle-resolved data file and Gaussian fit.

2.2.7 OTM 33A can include post-acquisition source characterization functions such as assessment of co-emitted pollutants by evacuated canister acquisition with ratio calculation (or other approach). These post-acquisition functions must employ proper acquisition and laboratory analysis QA protocols specified in the PSQAP.

2.2.8 OTM 33A (GMAP-REQ-DA) applications typically use near-real time concentration measurements, data from GPS, sonic anemometers, and meteorological measurements that are automatically recorded by a control computer to locate sources and calculate emission rates and other source characterization information. Ideally, real-time data quality indicators on plume position and data acquisition integrity are provided to the operator at the time of measurement via a user interface. Auxiliary information, such as infrared camera observations, source distance measurements, site photographs, chain of custody forms and field notes are typically acquired as part of the measurement protocol. Particular attention is paid to potential non-target sources and wind-field obstructions that can affect measurement accuracy. The overall source configuration (e.g. size, emission points, and temporal variability) and the results of repeat measurements must be taken into account when forming conclusions based on the data.

3. Definitions and Acronyms used in OTM 33A

3.1 OTM 33 definitions. Refer to OTM 33 Sections 3.1 through 3.32 for descriptions of the following general GMAP-REQ terms that are also applicable to OTM 33A:

OTM 33 Section 3.1: Geospatial measurement of air pollution (GMAP)

OTM 33 Section 3.2: Remote emissions quantification (REQ)

OTM 33 Section 3.3: Specific sub-methods

OTM 33 Section 3.4: Source assessment modes (SAMs)

OTM 33 Section 3.5: Concentration mapping (CM)

OTM 33 Section 3.6: Source characterization (SC)

OTM 33 Section 3.7: Emissions quantification (EQ)

OTM 33 Section 3.8: Quality assurance (QA)

OTM 33 Section 3.9: Method requirements (MRs)

OTM 33 Section 3.10: Performance metrics (PMs)

OTM 33 Section 3.11: Project-specific quality assurance plan(PSQAP)

OTM 33 Section 3.12: Data quality objectives (DQOs)

OTM 33 Section 3.13: Method quality indicators (MQIs)

OTM 33 Section 3.14: Method interference

OTM 33 Section 3.15: Near-field obstruction (NFO)

OTM 33 Section 3.16: GMAP Vehicle

OTM 33 Section 3.17: Global positioning system (GPS)

OTM 33 Section 3.18: Concentration measurement instrument (CMI)

OTM 33 Section 3.19: Meteorological instrument (MI)

OTM 33 Section 3.20: Accuracy

OTM 33 Section 3.21: Precision

OTM 33 Section 3.22: Data completeness

OTM 33 Section 3.23: Data representativeness

OTM 33 Section 3.24: Detection limit (DL)

OTM 33 Section 3.25: Quantitation limit (QL)

OTM 33 Section 3.26: Dynamic range

OTM 33 Section 3.27: Operational robustness

OTM 33 Section 3.28: Auxiliary equipment

OTM 33 Section 3.29: Sampling system

OTM 33 Section 3.30: Control system

OTM 33 Section 3.31: Temporal resolution

OTM 33 Section 3.32: Spatial resolution

3.2 Direct Assessment (DA), as in GMAP-REQ-DA, the subject of OTM 33A, generally refers to any near-field emission source location mapping and sources emission strength inverse estimate scheme that employs a single point measurement executed from a mobile platform and which does not require site-specific modeling or on-site measures, such as release of tracer gas for atmospheric normalization.

3.3 Controlled release is a QA validation tool that allows testing of EQ algorithms to be used under OTM 33A. A simulated source emission is created by releasing a compound at a known rate and the GMAP-REQ-DA SAMs such as EQ are applied to determine information from the simulated emission.

3.4 Point source Gaussian (PSG) is one possible EQ algorithm used under OTM 33A that is based on single point stationary observation of a source and processing of concentration and wind field data using a Gaussian approximation and dispersion look-up tables.

3.5 Backwards Lagrangian stochastic (bLs) is one possible EQ algorithm that is based on single point stationary observation of a source and processing of time-integrated concentration and wind field data using the bLs algorithm.

3.6 Single point transect (SPT) is an example of one possible EQ algorithm used under OTM 33A that is based on single point mobile (drive-by) assessment of near field sources.

3.7 Atmospheric stability indicator (ASI) is a measure of the atmospheric conditions used in the PSG algorithm that is determined from an average of the turbulence intensity ($TI = u'/U$), measured by the 3D-sonic anemometer and the standard deviation in 2-D wind direction ($\sigma\theta$), acquired by the compact met station. The ASI ranges from 1 ($TI > 0.205$, $\sigma\theta > 27.5°$) to 7 ($TI < 0.08$, $\sigma\theta < 7.5°$), roughly corresponding to Pasquill stability classes A-D, in steps of one unit with equal increments ($TI = 0.025$, $\sigma\theta = 4.0°$) defining each step. Note that nighttime Pasquill stability classes E and F are not represented here.

4. Interferences

4.1 OTM 33 Method Interferences. Refer to OTM 33 Sections 4.1 through 4.8 for general descriptions of the following GMAP-REQ inferences also applicable to OTM 33A:

OTM 33 Section 4.1: Planning for interferences.

OTM 33 Section 4.2: Requisite meteorology interference.

OTM 33 Section 4.3: Roadway access.

OTM 33 Section 4.4: Non-target source interference.

OTM 33 Section 4.5: CMI performance interference.

OTM 33 Section 4.6: Source configuration interference.

OTM 33 Section 4.7: Wind flow obstruction interference.

OTM 33 Section 4.8: Other measurement instrument interferences.

4.2 Requisite meteorology interference in CM applications. As explained in OTM 33 Section 2.2.3 (Figure 2-2) and OTM 33 Section 4.2, a necessary condition for successful identification of source emissions during concentration mapping is that the plume is transported to the driving path so the that CMI can detect the emissions. For OTM 33A CM applications, insufficient wind speed (approaching 1 m/s or below) coupled with unstable atmospheric conditions (approaching ASI 1) is not conducive to advection of the plume. In these cases, sources even in close proximity to the driving route may not be detected or effectively observed. Additionally, improper wind direction with respect to the driving path prevents successful CM operation.

4.3 Interference by NFO in CM applications. For OTM 33A, wind flow obstruction interference by objects near the source or driving route can affect CM results. As explained in OTM 33 Section 4.2, a necessary condition for successful identification of source emissions during concentration mapping is that the plume is transported to the driving path so the that CMI can detect the emission. Even when favorable wind conditions exist, near-field obstructions such as hedges, trees, building, and fences can lower the efficacy of OTM 33A CM applications by adding dispersive elements reducing detectable plume concentrations. NFOs can potentially reduce the concentration of target compounds to a level below the detection capability of the CMI or redirect the plume vertically to a location above the inlet of the mobile sampling system. For applications like landfill surface emissions or underground pipeline leak surveys, the ground itself can be an obstruction, diverting and/or dispersing emissions along underground channels. The GMAP-REQ system design (i.e. close-coupling inlet ports to ground surface for underground leak applications) can ameliorate some ground interferences. The GMAP-REQ system design, PSQAP, and operating procedure should account for NFOs in an application-specific context.

4.4 Requisite meteorology inference in SC and EQ applications. In a similar manner to CM (section 4.2), characterization or quantification of source emissions under OTM 33A can be adversely affected by lack of required meteorological parameters. Many EQ approaches (including the

OTM33A PSG approach) rely on a determination of a representative concentration profile from the source at the downwind observing location. Depending on the inverse algorithms utilized, non-optimal atmospheric and wind conditions can lead to uncertainty in the emissions assessment.

Figure 4-1 (top-down view) and 4-2 (side view) illustrate two common method interferences caused by non-optimal meteorological parameters. Figure 4-1(A) shows an ideal case of a proper alignment of the GMAP vehicle position and predominant wind direction; whereas 4-1(B) shows a non-optimal alignment where the predominate wind direction changed significantly during measurement. The primary effect is to lower the number of useable measurements of the source which can adversely affect the representativeness of the time-integrated profile. The direction of EQ bias can be either positive (overestimate) or negative (underestimate) depending on the statistics of the distribution and the inverse algorithms utilized.

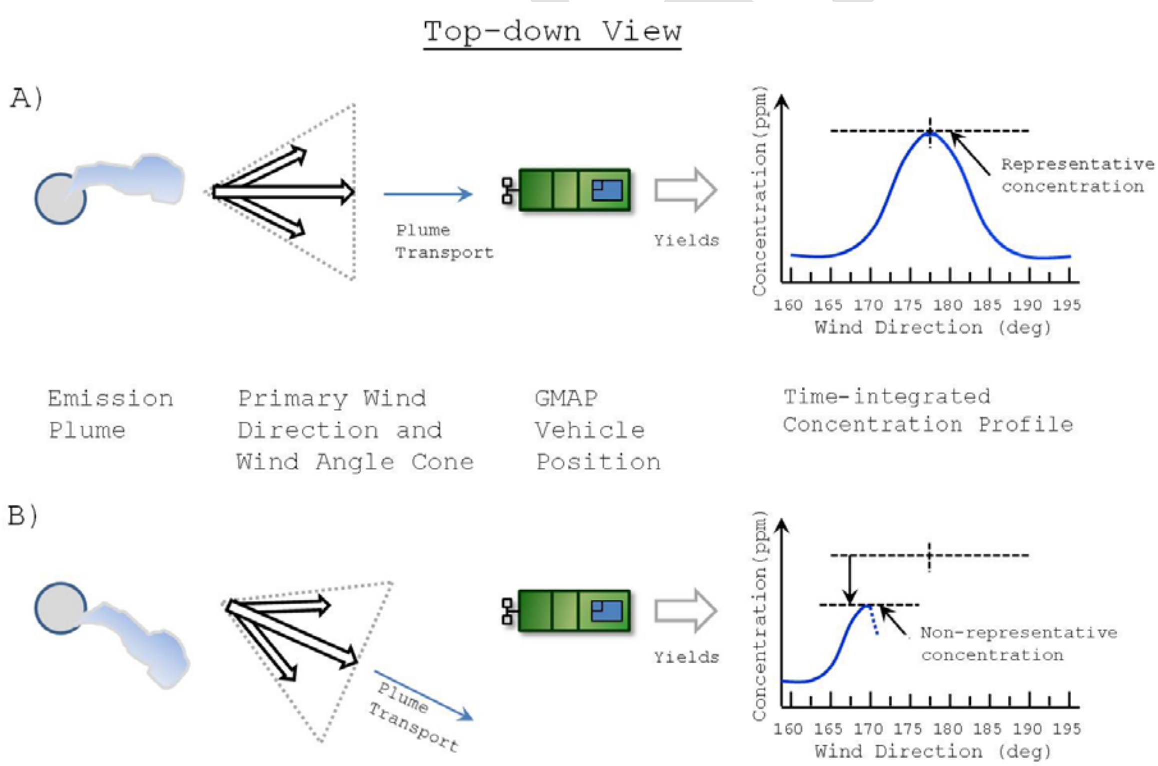

Figure 4-1. (A) Meteorological parameters acceptable yielding a representative time-integrated concentration profile; (B) Primary wind direction not aligned with GMAP vehicle position providing the potential for a non-representative concentration profile.

Figure 4-2 illustrates the effects of insufficient plume advection on SC or EQ assessments. With proper transport, Fig. 4-2 (A), a representative concentration profile can be obtained. If wind speed is too low, coupled with atmospheric-induced plume rise, Fig. 4-2 (B), the sampling point may be located below the time-integrated centroid of the plume leading to an underestimation of source emission strength using most inverse algorithms. The effect is exacerbated by increasing source height above the ground.

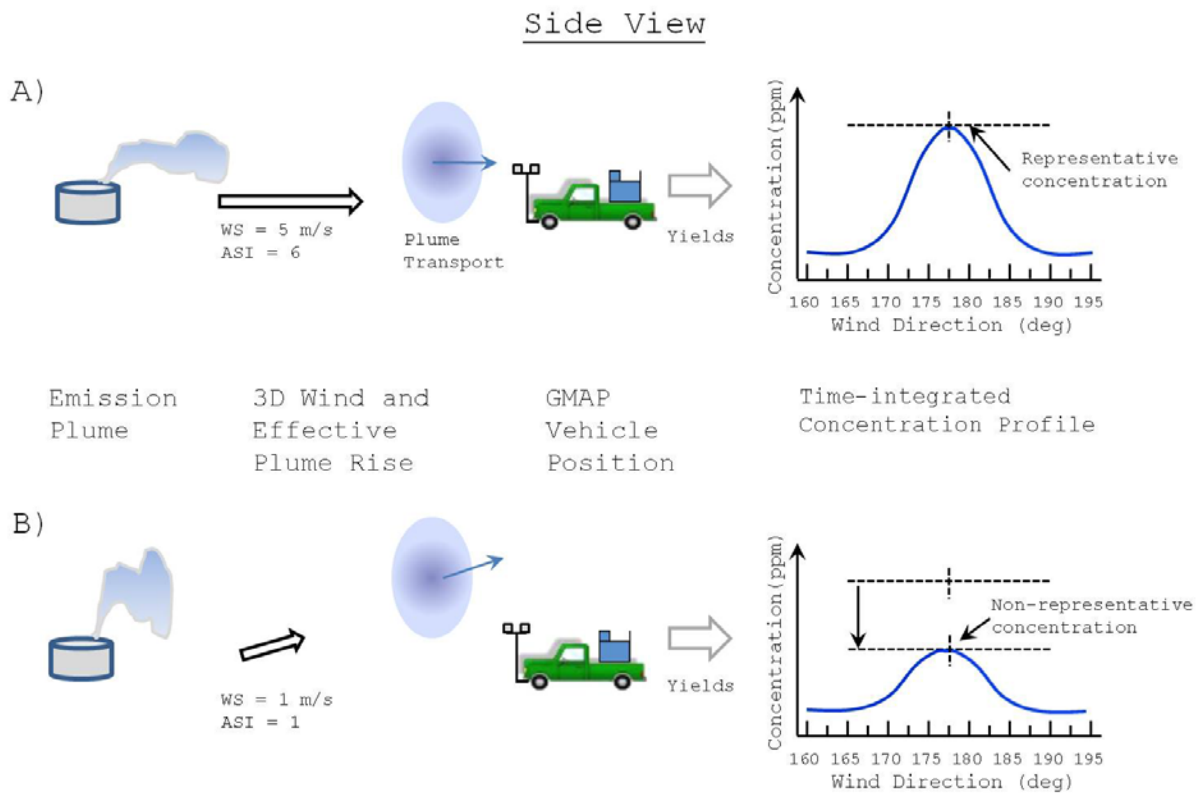

Figure 4-2. (A) Meteorological conditions are acceptable yielding a representative time-integrated concentration profile. (B)Wind speed too low, coupled with plume rise leading to a non-representative concentration profile.

4.5 Interference by NFOs on SC and EQ applications. The presence of near-field obstructions can prevent the application of or affect the accuracy of OTM 33A source characterization and emission quantification schemes. Most if not all OTM 33A SC and EQ applications assume that the remote observation (the acquired data) of the emitted plume is representative of the actual emission. NFOs can produce non-representative concentration profiles by affecting wind flow patterns which enhance or reduce measured concentrations in comparison to the unobstructed case. Some EQ algorithms (like PSG) assume that the emitted plumes evolve by ground-level unobstructed Gaussian dispersion, and departure from this condition leads to errors in the emission estimate.

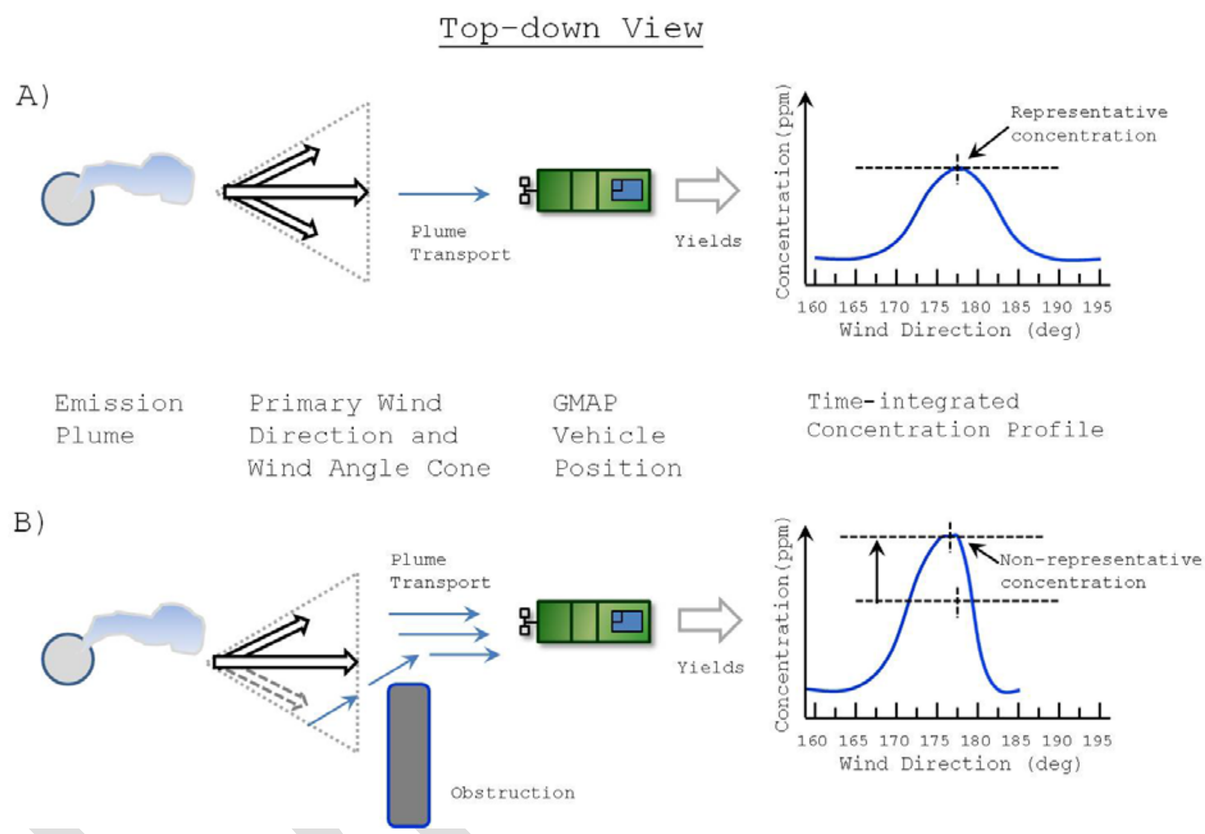

Figure 4-3 (A) Unobstructed transport yielding a representative time-integrated concentration profile. (B)Flow is channeled by obstructing enhancing concentrations, leading to an overestimate of emissions.

Figure 4-3 (top-down view) and 4-4 (side view) illustrate two common method interferences caused by NFOs. Figure 4-3(A) shows a properly aligned vehicle position and an unobstructed plume transport yielding a representative concentration profile. Figure 4-3(B) shows a case where a near-field obstruction channels flow to the observation point enhancing measured concentrations, leading to a higher than normal assessment of source mass emission rate.

Figure 4-4 illustrates the effects of a NFO directing the plume upwards. This can lead to underestimation of source mass emission rate (in a similar manner to Fig. 4-2(B) or an overestimation if obstruction and wind characteristics produce recirculating vortices (downwash) behind the obstruction in the observation area. The latter effect can be somewhat mitigated by assuring minimum standoff distances from the obstruction.

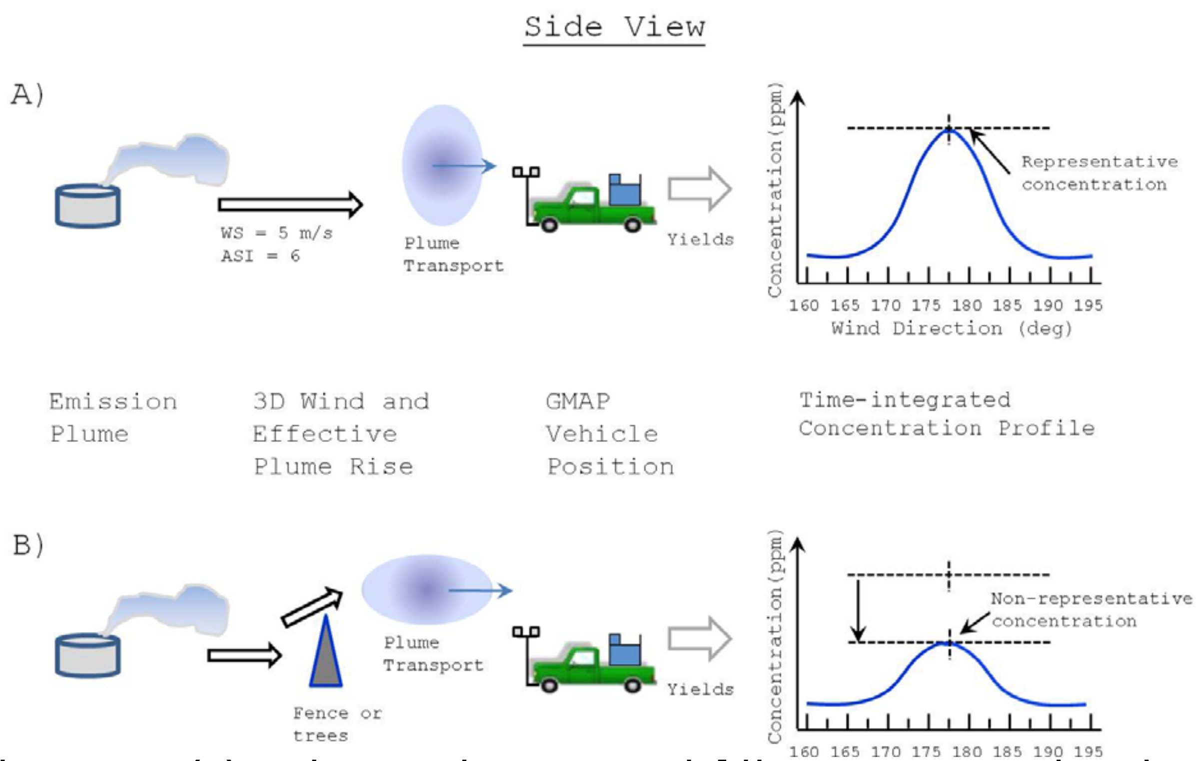

Figure 4-4. (A) Unobstructed transport yielding a representative time-integrated concentration profile. (B) An NFO (e.g. fence, trees, and structures) directs the plume upwards causing a non-representative concentration profile.

4.6 Improper vehicle orientation. Figure 4-5 illustrates method interference caused by improper vehicle orientation (side-view). In a similar manner to method interference by NFOs (Section 4.5), the accuracy of the PSG EQ can be impacted by the non-representative concentration profiles created by channeled (or obstructed) wind flow from the body of the GMAP vehicle. The effects of this condition are difficult to predict and can result in positive or negative EQ biases. This interference can be avoided through proper vehicle positioning to maximize free-flow of the plume to the sampling probe and meteorological instruments.

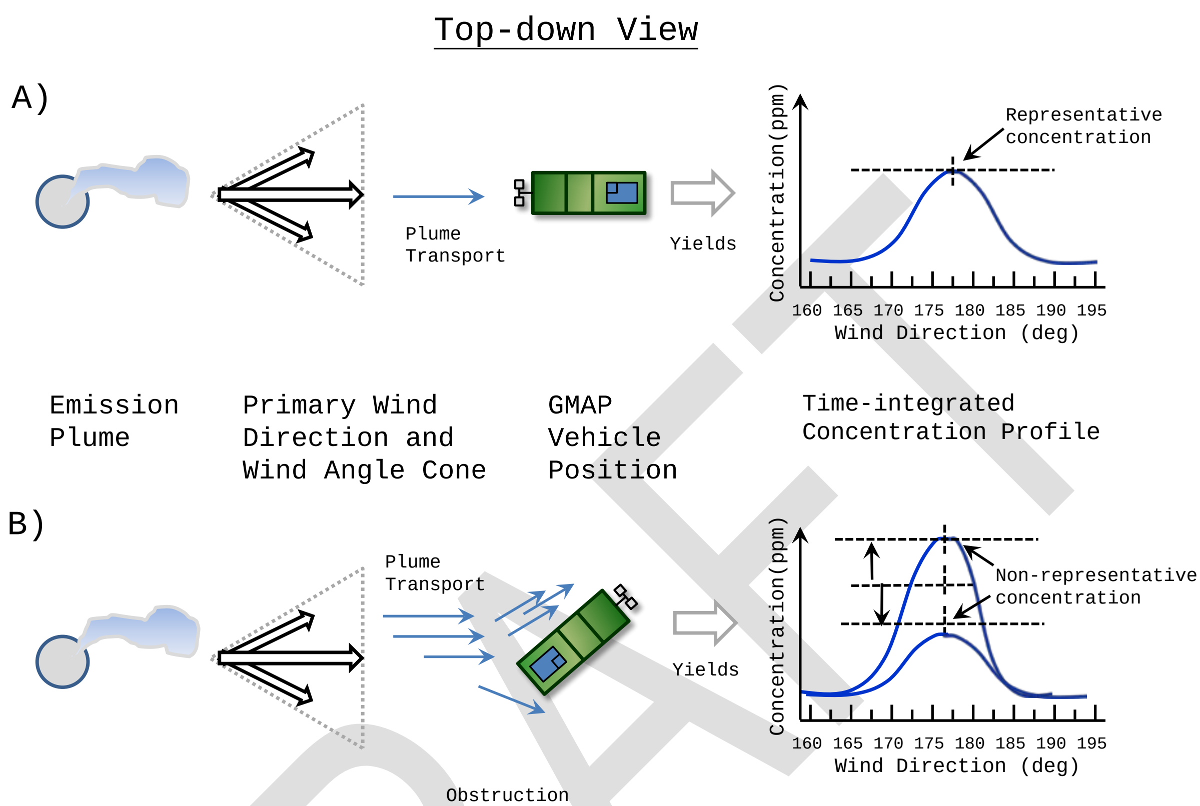

Figure 4-5. (A) Unobstructed transport yielding a representative time-integrated concentration profile (proper vehicle positioning). (B) Obstructed wind flow created by improper vehicle positioning causing a non-representative concentration profile.

4.7 Surrounding topography interferences. Whereas NFOs located between the source and sampling location can cause EQ biases by directly impacting wind flow to the sampling instruments, larger scale surrounding topographies can also affect results. Figure 4-6(A) illustrates an ideal sampling case with generally few obstructions and low surrounding topographies. This scenario is conducive to good plume transport to an available observing location under favorable meteorological conditions. Figure 4-6(B) shows an unfavorable condition where the surrounding tall trees could impact free plume transport to any observing location. The effects of surrounding topography as shown in Figure 4-6(B) on PSG EQ performance has not been systematically studied but a small number of controlled release experiments indicated significant potential impact so this scenario is not recommended for OTM 33A EQ by PSG at this time.

Figure 4-6. (A) Acceptable surrounding topography (B) unacceptable surrounding topography.

4.8 Non-representative temporal sampling. The OTM 33A PSG EQ method assumes acquisition of a representative plume concentration measurement. Ideally this means that the source plume overlaps the sampling probe many times during the nominal 20 minute sampling period. A 20 minute (+/- 5 minutes) sampling period is used since it is long enough to allow representative sampling but short enough to typically capture a representative “snapshot” of the ever changing atmospheric transport conditions. A very short sampling time period (a few minutes) may capture only one or two particularly strong or weak plume-probe overlap states and is therefore subject to higher levels of potential EQ assessment bias. Non-representative temporal sampling can also occur as a result of wind direction method interference [Figure 4-1(B)] where an initially well-centered predominate wind direction changes shortly after initiation of sampling period, becoming a non-optimal observation. Method quality indicators (described Section 9) can help inform representative plume sampling by assessing the number of plume counts above background and plume centering data.

4.9 Source elevation interference. In similar condition to Figure 4-2(B), if the source is significantly elevated with respect to the sampling probe height, the plume center will pass over the probe leading to large underestimation of the source emission strength. As described in Section 8.6.6, wake flow effects around tanks (downwash)can help move the plume towards ground level in some cases to aid in plume-probe overlap but emissions from even moderate height stacks cannot be effectively sampled with OTM 33A.

Alternatively, the emission source may be well below the sampling probe as in the case a ground pipeline leak observed from close distances under high winds. Here it is possible for the plume to move below the sampling probe (low bias). In other atmospheric conditions, plume ground reflection effects can occur increasing observed concretions (high bias). The utilized EQ approach (inverse algorithm) can take into account these effects. The simple PSG EQ calculation provided here as an example assumes that the sampling probe (nominally 2.7 m above ground level) and the source are at similar heights and ignores these effects.

4.10 Source distance interference. The source to observation sampling distances for OTM 33A is recommended to be 20 m to 200 m. Measurements that are too close to sources like tanks can exhibit assessment bias due to recirculated air flow (downwash). Measurements in excess of 150 m become difficult due to plume transport issues. For the OTM 33A PSG approach, the distance to the source is used in the EQ calculation so uncertainties in this parameter directly affect assessment accuracy. This is particular problem when multiple sources at varying distance may be simultaneously measured. In this scenario, the distance to the closest source should usually be used for inspection applications (producing a low estimate).

4.11 Multiple source method interference. The OTM 33A PSG approach assumes a single source gaussian plume transport. Multiple sources that are spatially separated can be measured individually through proper downwind positioning. In some cases (such as an oil and gas well pad), the PSG EQ assessment will consist of a composite plume of multiple closely-spaced sources. In addition to source distance uncertainty (Section 4.10), this effect is believed to cause a general underestimation in combined source mass emission rate since the PSG calculation assumes a single source (smallest possible plume size). The average concentration of the Gaussian does carry contributions from all observed sources in the angular observation window.

4.12 Unknown source interference: The OTM 33A PSG approach requires a knowledge of the source location. For sources like oil and gas production pads, it helpful to confirm source locations using an infrared camera. In cases where the suspected source is distant (e.g >150 m) and the source cannot be confirmed, the potential exists for an unidentified proximate source (e.g. unknown pipeline leak) to be located in the near field and impact the measurement. An investigation of the plume width and time-resolved concentration profile can help identify unknown proximate sources. Source that are very close to the observation will exhibit sharply varying concentration profiles since the plume is spatially undispersed.

4.13 Other method interferences. Other interfaces to CM, SC, and EQ applications described in OTM 33, such as from malfunctioning instrumentation, are also applicable to OTM 33A. The importance, effect, identification, and mitigation of potential method interferences should be described in acquisition DQIs, MQIs, analysis procedures, and the PSQAP.

5. Safety.

5.1 General sub-method safety. This sub-method does not purport to address all safety issues or procedures needed when executing OTM 33A (GMAP-REQ-DA) applications. Precautions typical of air sampling field projects are required. Each user-developed equipment design and application prescription may have specific safety considerations. Each field location may have site-specific safety factors that must be taken into consideration such as special hazards associated with sources under study. It is important that approach-specific and site-specific hazards be understood. Integrated safety planning and equipment check procedures can help ensure safe operations. The following safety planning and preparation steps are recommended:

- Project-specific safety planning
- GMAP vehicle preparation and safety checks
- Power system preparation and safety checks
- Vehicle fixture set up and safety checks
- Auxiliary equipment set up and safety checks

5.2 OTM 33 safety. Refer to OTM 33 Sections 5.2 through 5.6 for general descriptions of the safety considerations associated with OTM 33 mobile measurement applications that are also applicable to OTM 33A.

OTM 33 Section 5.2: Project-specific safety planning.

OTM 33 Section 5.3: GMAP vehicle preparation and safety checks.

OTM 33 Section 5.4: Power system preparation and operation.

OTM 33 Section 5.5: Vehicle fixture preparation and safety checks.

OTM 33 Section 5.6: Auxiliary equipment set up and safety checks.

In addition to general OTM 33 mobile measurement safety considerations, the following sections provide example safety points commonly associated with OTM 33A. These example safety considerations are based on EPA GMAP-REQ-DA example systems described in Appendices A and B to this method. This base GMAP system design includes a vehicle-mounted sampling mast with meteorological and GPS instrumentation mounted to the mast. Primary method safety points include considerations for driving the vehicle with the sampling mast deployed, how to safely execute the method from mobile and stationary observation locations, and a discussion of necessary safety equipment and personal protective equipment for field personnel.

5.3 Driving with the mast deployed.

5.3.1 Mast height. Understanding the sampling mast height including the height of all attached components is a primary factor for safe OTM 33A operation (for units fitted with a mast). The sampling mast must not exceed local roadway height restrictions or there is a danger of impacting low clearances such as bridges or power lines on main roadways. The American Association of State Highway and Transportation Officials standard for interstate highway vertical clearance is 14 feet in urban areas. However, clearance for bridges and overpasses on secondary and rural roadways may be much lower than those found on highways. In general, low hanging branches provide an effective lower operational limit of about 12 ft in rural settings and special clearance situations (such as parking garage, or shed roofs at gas stations or hotels) can be significantly lower. It is the sole responsibility of the operator of the GMAP vehicle to be aware of the height of the sampling mast components, and note all posted low clearance warnings for bridges and overpasses and all special clearance situations to ensure safe operation.

The height of the example EPA sampling mast (Appendices A and B), using the default 3-section configuration is approximately 11.5 feet. This height depends on the size of the GMAP vehicle (trailer hitch height). After installation of the mast on the vehicle, the operator must obtain an accurate measurement of the height of the tallest mast-mounted component and should record this height for reference throughout the field campaign. Note that adding or rebalancing the load in the vehicle can alter mast height. The EPA mast can accept two 1-meter extensions that can be used to extend the mast vertically for stationary measurements of elevated sources. The GMAP vehicle should never be driven with an installed mast extension as this increases the height to unsafe levels.

5.3.2 Mechanical factors. Understanding the mechanical robustness of any components attached to the vehicle is a primary factor for safe operation. It is of critical importance that the sampling mast and all of its components and any other vehicle-mounted systems be designed and attached sufficiently to tolerate the wind forces and vibrations encountered at roadway traveling speeds as well as the bumps and potholes encountered in rural road work. Mast mechanical failure or accidental detachment of a component from the mast or vehicle is highly dangerous for the sampling vehicle occupants and for other vehicles and pedestrians.

The EPA example sampling mast (Appendices A and B) is designed for quick removal of mast mounted components. Although driving can be accomplished with components in place, it is recommended to remove components for long drives at highway speeds.

5.4 Driving near overhead power lines. Overhead power lines, in particular those located on secondary roads, pose a potential electrical hazard when the measurement mast is mounted to the vehicle. Extreme caution should be taken when attempting to drive the measurement vehicle under overhead power lines. As is the case with bridges and overpasses, it is the sole responsibility of the driver of the vehicle to be aware of the height of the mounted sampling mast components and the presence of any overhead power lines, and note any posted low clearance warnings in order to determine if it is safe to drive the measurement vehicle under any power lines or other overhead structure. If the driver is unsure if sufficient overhead clearance exists, the vehicle should be stopped prior to passing under the power line structure, and the sampling mast should be removed from the vehicle before proceeding.

5.5 Execution of GMAP-REQ-DA measurements. Acquisition of OTM 33A CM (mobile) and SC, EQ (mobile or stationary) data is usually accomplished on or near public roadways. Use of a two-person crew with one person concentrating only on the driving task is highly recommended. As OTM 33A is a mobile method, the single greatest safety hazard is related to vehicle accidents and minimizing driver distractions is critical to avoiding accidents.

Use care when conducting measurements in highly congested areas or near busy intersections. Be mindful of the presence of other vehicles on the roadway. If possible, allow faster vehicles behind the measurement vehicle to pass in locations where the measurement vehicle can be safely pulled to the side of the road. Deploy hazard lights on the measurement vehicle when appropriate. Refrain from conducting stationary measurements in the vicinity of large hills or other obstructions where visibility is limited. For stationary measurements, pull the measurement vehicle as far off the road as is safely possible and deploy orange traffic cones behind the vehicle. Ensure the vehicle is in park and turned off before deployment of personnel outside of the vehicle. Field personnel outside of the vehicle should wear orange or yellow traffic safety vests and be mindful of traffic conditions. Only conduct work outside of the vehicle when it is safe to do so. Do not stop the vehicle or conduct stationary measurements on the side of busy roadways or roadways with narrow shoulders.

5.6 Safety equipment. The following are examples of safety equipment that should be present in the GMAP vehicle:

- ABC 10 lb. fire extinguisher
- First aid kit
- Orange traffic cones
- Traffic flares
- GPS (for rapid location of emergency services)
- Cell phone

In addition to the safety equipment referenced above, the following personal protective equipment (PPE) should be used by field personnel during data acquisition activities:

- Steel-toe work boots
- Safety glasses
- Traffic safety vest
- Other personal protective equipment (such as sunscreen)
- Combustible or toxic gas safety monitor (if needed)

5.7 Auxiliary equipment set up and safety checks. In addition to equipment attached to or carried in the GMAP vehicle, it is important that auxiliary equipment be designed, maintained, and operated properly. Auxiliary equipment can include support trailers for gas cylinders and transport and storage, and controlled gas release gear. It is critical that U.S. Department of Transportation rules (e.g. http://ntl.bts.gov /DOCS/hmtg.html)with regard to transporting compressed gas cylinders be understood and obeyed. It is critical that health and safety aspects regarding the use of gas cylinders (e.g. https://www.osha.gov/SLTC/ compressedgasequipment/)for controlled gas release or calibration functions be included in the site-specific safety plan. For large gas release applications, it is important to understand local and state permitting requirements and potential National Environmental Policy Act (e.g. http://www.epa.gov/compliance/nepa/analysis)requirements that may need to be followed.

6. Equipment and Supplies

6.1 General equipment requirements for OTM 33A. The equipment and supplies needed for execution of OTM 33a will vary based on the application and GMAP vehicle design. Refer to OTM 33 Sections 6.1 through 6.3 for general descriptions of design details and equipment needed for GMAP-REQ mobile measurement applications. These descriptions are also applicable to OTM 33A.

OTM 33 Section 6.1: GMAP System design overview examples.

OTM 33 Section 6.1.1: Simple GMAP-REQ application.

OTM 33 Section 6.1.2: More complicated GMAP-REQ application.

OTM 33 Section 6.2: Sampling equipment examples.

OTM 33 Section 6.2.1: GMAP-REQ sampling vehicles.

OTM 33 Section 6.2.2: Global positioning system (GPS).

OTM 33 Section 6.2.3: Concentration measurement instrument (CMI).

OTM 33 Section 6.2.4: Control and communication system.

OTM 33 Section 6.2.5: Instrument power system.

OTM 33 Section 6.2.6: Sampling system.

OTM 33 Section 6.2.7: Meteorological instruments.

OTM 33 Section 6.2.8: 3-D ultrasonic anemometer.

OTM 33 Section 6.2.9: Auxiliary equipment.

OTM 33 Section 6.3: Supplies.

6.2 General equipment requirements for OTM 33A. OTM 33A applications typically require all equipment elements described in OTM 33 sections 6.2.1 through 6.2.9. Since stationary measurements can be conducted under OTM 33A, a battery power system (not an inverter system) is typically utilized to power instrumentation allowing the GMAP vehicle's engine to be turned off during sampling.

OTM 33A source characterization activities frequently involve acquisition of evacuated canisters so design provisions for effective execution of this sampling is recommended. This would include considerations such as connecting the canister near the CMI's sampling probe, remote solenoid trigger and automated recording of the time of canister draw, and time-synchronization of the canister and CMI so in-plume acquisitions are easily accomplished.

For OTM 33A, auxiliary equipment can include gas and associated flow measurement gear for controlled releases to allow GMAP system and EQ inverse emission estimate verification testing. Gas releases (as a tracer) is not part of OTM 33A method application.

6.3 Equipment and design examples for OTM 33A. Appendices A and B to this method provide examples of GMAP-REQ-DA systems and hardware and control designs developed by EPA. Appendix C to this method provides software control code written in LabView™ software (National Instruments Inc., Austin, TX USA). Appendix D provides the software user interface manual. Appendix E provides the field data acquisition SOP. Appendix F1 provides analysis code for the PSG stationary emission assessment approach written in Matlab™ (Mathworks, Natick, MA USA). The equipment designs and software contained in this method and its appendices are for informational purposes only and are not method requirements. Adoption and or modification of the EPA GMAP-REQ engineering designs, software, or protocols are the sole responsibility of the user. Deployment and safe-use of this method, engineering examples, or variations thereof is the sole responsibility of the user. No engineering or software design performance or safe-use guarantees are given or implied.

6.3.1 General performance requirements. GMAP-REQ vehicle and equipment designs will depend on the DQOs of the project, the target analytes, the sampled air matrix, and specifics of the measurement application. See OTM 33 for general information on CMI and other instrumentation performance guidelines.

6.3.2 GMAP vehicle performance. The requirements for GMAP vehicle performance are application-specific and potential design elements are described in OTM 33 and in this method and its appendices. A primary performance factor to consider is related to the requirements of the utilized SAM. If stationary measurements are required, battery power operation for the instruments is likely necessary as the vehicle's engine will be turned off during sampling. If the target analyte is a compound emitted by mobile sources, electrical-powered vehicles can also help prevent self-contamination of the data by the GMAP vehicle's exhaust. If the roadways to be traveled in survey operations are very rough, four-wheel drive may be necessary. Other considerations include mast and other equipment connection capability, and interior room for instruments and equipment.

6.3.3 GMAP system control. OTM 33A applications require time synchronization of data by a control computer with master clock or by a controlling CMI to a precession 1 Hz or better. Temporal deconvolution of CMI or other data with native time-resolutions below 1 Hz must be specified as part of data analysis procedures. The GPS time stamp is the recommended time standard for the master clock.

6.3.4 Time-resolution. For OTM 33A applications, a CMI measurement time-resolution (including sampling cell turn over time) of 1 Hz or better is desirable for most CM, SC, and EQ technical approaches. CMI measurement time resolution less than about 0.2 Hz makes interpretation of mobile data difficult and may cause issues with dome SC and EQ schemes. The target measurement time-resolution of basic metrology and GPS data should be 1 Hz. Measurement time resolution of advanced wind-field measurements can exceed 10 Hz as per requirements of the technical approach.

6.3.5 CMI analyte measurement performance. The DQOs for the project along with application-specific information such as encountered air matrix components and expected near-source concentration levels will determine the CMI's performance requirements. The performance of the CMI with regard to potential analytical interferences and its detection sensitivity, accuracy, and precision for target analyte measurement in the encountered air matrix must be well-characterized (see OTM 33 Section 9.4).

For OTM 33A applications, the general requirement for CMI analyte measurement performance is in-field accuracy (in the presence of interfering analytes) within +/- 10% of actual. The required detection sensitivity (or quantitation limit) of the CMI is determined by the DQOs of the project in the context of encountered field target source signals. Weak sources signals or stringent source detection DQOs will require higher performance CMIs. Real-world CMI sensitivity and stability evaluations should be conducted in actual field conditions with measurements of precision and accuracy executed in areas free of source signal. Sustained in-plume target source signals (minus non-target source background) should ideally exceed six (6) times the standard deviation in CMI-measured baseline (background) data for confident measures. Procedures for evaluating and removing CMI baseline drift must be developed if required.

6.4 Supplies. Supplies required for execution of OTM 33A can include but are not limited to: primary instrumentation and auxiliary equipment for maintenance and calibration, gas cylinders, tubing, general cleaning supplies, vehicle maintenance and operation-related materials, safety-first aid related supplies, notebooks, pens, calculators, and digital media supplies.

7.0 Reagents and Standards

OTM 33 and 33A field applications are typically executed using air quality and meteorological instrumentation that do not require laboratory reagents or standards other than compressed-gas calibration cylinders for quality assurance of the CMI. If a particular OTM 33A project has other specific laboratory reagent requirements, these requirements must be specified in the in the PSQAP.

For CMI verification, compressed gas standards and procedures must be specified to allow in-field calibration testing of instrumentation at prescribed frequencies and performance tolerances necessary to meet data quality objectives for the application or project.

8. Field Data Acquisition and Sample Collection

8.1 General requirements for OTM 33. Refer to OTM 33 Sections 8.1 through 8.6 for a description of general field data acquisition and sample collection requirements for GMAP-REQ activities that also apply to OTM 33A (GMAP-REQ-DA):

OTM 33 Section 8.1: *Lab. sample collection, preservation, storage.*

OTM 33 Section 8.2: *Field data acquisition.*

OTM 33 Section 8.3: *Preparation for field activities.*

OTM 33 Section 8.3.1: *Site and source knowledge.*

OTM 33 Section 8.3.2: *Planning and equipment preparation.*

OTM 33 Section 8.3.3: *Project and quality assurance planning.*

OTM 33 Section 8.3.4: *Safety planning for OTM 33.*

OTM 33 Section 8.3.5: *GMAP vehicle and instrument system design.*

OTM 33 Section 8.3.6: *GMAP vehicle preparation.*

OTM 33 Section 8.4: *Pre-deployment and in-field system testing.*

OTM 33 Section 8.5: *Execution of data acquisition.*

OTM 33 Section 8.5: *Data archiving and chain of custody.*

OTM 33 Section 8.6: *Data archiving and chain of custody.*

OTM 33 Section 8.6.1: *Chain of custody forms.*

OTM 33 Section 8.6.2: *Field data package.*

OTM 33 Section 8.6.3: *Daily checklist.*

OTM 33 Section 8.6.4: *Time synchronization.*

OTM 33 Section 8.6.5: *Data archiving practices:*

8.2 General requirements for OTM 33A. In addition to the general requirements for OTM 33, OTM 33A has field data acquisition and sample collection requirements based on the measurement objective, SAMs employed, and utilized equipment. Each application will involve measurement instrumentation with specific use and calibration protocols that should be covered in the PSQAP. Planned deployments may have site-specific elements that require special execution, and safety procedures should also be part of pre-deployment planning. The following sections outline general procedures and examples of execution of OTM 33A SAMs (CM, SC, and EQ) in typical application scenarios. These sections expand the overview discussion of OTM 33A found in Section 2.

8.3 General execution sequence for OTM 33A. Execution of OTM 33A involves planning, equipment design, set up, field testing, and data analysis. OTM 33A field testing involves execution of SAMs such as CM (Section 8.4), SC (Section 8.5), and EQ (Section 8.6). These can be accomplished separately or in combination and a typical application involves some element of all three. In general, execution of OTM 33A involves the following steps:

- Planning and pre-deployment testing.
- Daily planning, set up, and equipment checks
- Execution of application-specific SAMs.

- Execution of in-field DQI checks.
- Completion of daily measurements.
- Post-acquisition data analysis and comparisons.

8.3.1 Planning and pre-deployment testing. The first step in execution of OTM 33A involves quality assurance and safety planning, equipment selection, and preparation, and pre-deployment testing of GMAP-equipment for CM, SC, and EQ activities (described elsewhere in OTM 33 Sections 5, 6, 8, and 9 and in this method). Planning and equipment development activities are accomplished prior to field deployment.

8.3.2 Daily planning, set up, and equipment checks. During field deployment, it is important to conduct daily planning and equipment preparation prior to acquisition of data. Instrument and equipment startup, calibration, and operational checks should be conducted as per SOPs and the PSQAP. It is recommended to review daily route planning and safety factors (locations of nearest emergency rooms in survey area, special hazards, etc.) prior to sampling. Use of an operations checklist to prepare for the day's work is recommended. Final set up and safety checks of mast systems and other components are ideally accomplished after driving to the measurement location, just prior to the start of data acquisition.

8.3.3 Execution of application-specific SAMs. As per PSQAP, and applicable SOPs, execute the data acquisition plan in the survey area. Some form of CM survey (Section 8.4) is usually the first OTM 33A SAM that is executed and is in some cases followed by periodic execution of SC (Section 8.5)and EQ(Section 8.6) functions along with collection of auxiliary data. The process of conducting CM surveys with potential execution of other SAMs is repeated throughout the sampling day as per the PSQAP.

8.3.4 Execution of in-field DQI checks. As part of daily operation, in times between execution of SAMs, conduct in-field CMI calibration checks and DQI checks of meteorological instruments and other equipment as specified in the PSQAP (reference OTM 33 Section 9 for examples).

8.3.5 Completion of daily measurements. After completion of field sampling for the day, conduct concluding calibration and equipment checks and remove and stow equipment as specified in operational protocols and PSQAP. Take care of chain of custody and other data records, archive back-up data, and perform time-synchronization checks. See OTM 33 Section 8.6 for a list of elements to consider. Development of a checklist is recommended.

8.3.6 Post-acquisition data analysis and comparisons. As per the SAM technical approach and PSQAP, conduct post acquisition data analysis and available secondary QA cross-comparisons of data (e.g. OTM 33 Section 9.4.6). Conduct summary QA analysis of analyzed data sets and address any deviations in procedure from the PSQAP.

8.4 Considerations for CM execution. Concentration mapping (CM)is an SAM that uses GMAP sampling platforms to establish spatially-resolved concentrations around one or more known air pollution sources or to investigate a large area in an attempt to discover unknown emission sources or understand air shed pollutant variability. General CM can be thought of as a survey operation where typically many kilometers are driven. General CM may differ from mapping activities that precede or are part of OTM 33A SC and EQ exercises which are executed at smaller spatial scales (sub-kilometer). Examples of GMAP-REQ-CM surveys are presented in Figures 2-2 and 2-3 with additional examples provided here. General CM surveys may not require precise wind field measurements so they can be executed with a minimum amount of equipment (OTM 33 Section 6.1.1) whereas CM surveys supporting SC and EQ functions may use more complicated equipment designs (OTM 33 Section 6.1.2).

8.4.1 Route planning and CM execution. Execution of CM surveys must consider route planning designed to address potential method interferences. Some aspects of mitigating interferences are associated with post-processing data analysis techniques but there are also important field planning procedures regarding route execution that should be considered.

8.4.2 Non-target sources and replicate CM surveys. Method interferences from non-target sources can affect CM survey interpretation and the execution of multiple successive (close in time) transects (or routes) can provide important insight into the nature of specific evaluated concentrations and their relationship to the target source. A particularly challenging example of non-target source interference from a general GMAP-CM survey application is shown in Figure 8-1 where local air shed impact of highway emissions is under study.[2] In this case non-target interferences from vehicle emissions on secondary roads in close proximity to the GMAP survey vehicle can mask the target source. In the lower left (southwest) of Figure 8.1, non-target source interferences encountered on a congested secondary road dominate signal levels preventing observation of the target source (the highway). Less traveled neighborhood roads in the northeast provide a better opportunity to understand the concentration gradients from the highway (repeatable replicate measurements). Also shown, just north of the highway, is a non-target source signal from a single proximate vehicle passing by that would not be replicated in a repeat survey.

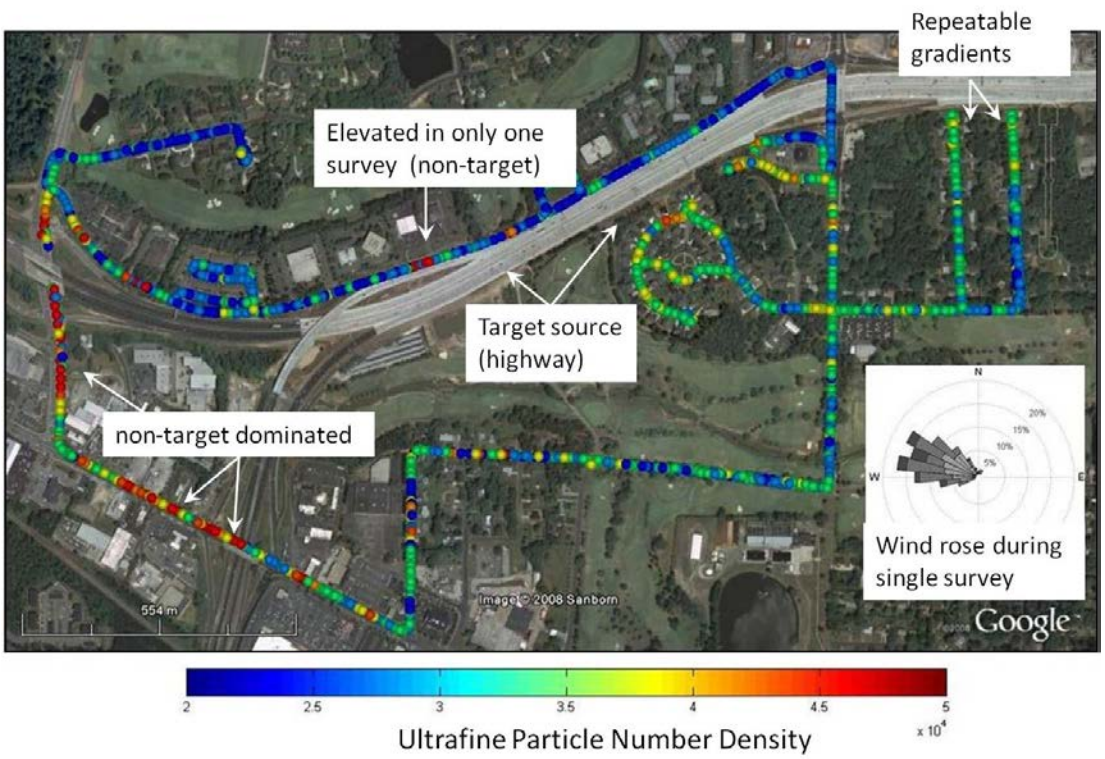

Figure 8-1. CM of ultrafine particles near a highway. Replicate measurements can help to understand non-target source interference.

Although the above example is from a general GMAP-CM survey, similar complexity can be encountered in GMAP-REQ applications if the target pollutant measured is also significantly emitted from mobile sources. Replicate surveys can help decipher interferences and are also important to establish the average concentrations induced from the target source. In complicated cases, other supporting techniques such as use of a web camera to identify the source of proximate emissions and special data analysis techniques that remove local concentration spikes can also be important.[11]

8.4.3 Non-target sources and CM route design. Another example of how CM route execution can help with interpretation of results is contained in Figure 8-2. In this case a small spatial-scale CM survey (driving route indicated by gray path) is conducted in proximity to an oil and gas source. A typical sampling strategy evolves detecting the emission and establishing the predominate wind direction and drivable roadways as part of a general CM survey, followed by initiation of smaller-scale transects with aim to circumnavigate the target source. By driving around the source (both upwind and downwind), the origin of the emission can be established and the potential for non-target source interferences can in many cases be eliminated. This CM survey can be immediately useful to the operator in vehicle placement for subsequent SC and EQ source assessment applications if the GMAP system provides for rudimentary real-time mapping.

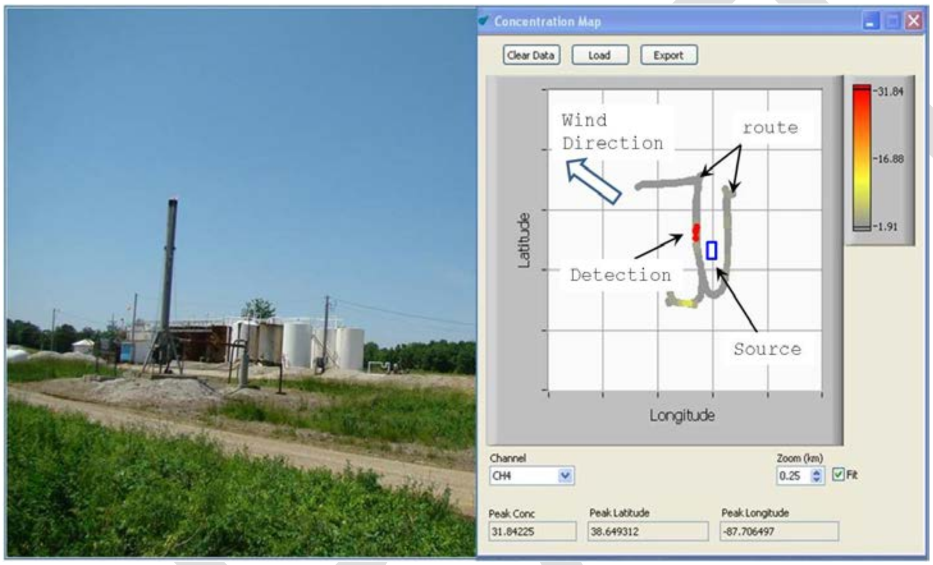

Figure 8-2. Example of a CM route surrounding a source

8.4.4 Requisite meteorology and CM route design. For GMAP-REQ-CM applications, it is important to considerer the daily meteorological conditions prior to measurement. OTM 33 Sections 2.2 and 4.2 and OTM 33A Section 4.2 describe meteorological method interferences in CM applications. Daily route planning in a survey area must consider predicted wind directions, speeds, and atmospheric stability factors. CM routes must be planned to include roadways that are predicated to be downwind of suspected sources in the survey area. Upwind route segments can also be important in interpretation of results but insufficient downwind routes generally preclude successful achievement of project DQO goals. Ideally, pre-deployment planning can identify multiple survey strategies (route combinations) that can be implemented under different encountered predominate wind directions.

As the atmospheric boundary layer increases and wind speeds decrease, ground-level detection of near-field sources becomes more difficult so CM routes that are in closer proximity to suspected sources are favored. For low wind speed conditions (1 m/s to 3 m/s sustained) and low ASI (1 to 3 units), general metrological requirements for successful CM applications imply downwind uncongested roadway segments in the 10 m to 100 m distance range from the source. For higher wind speeds and ASIs, advection of the plume is improved and routes that are in the 10 m to 200 m distance range are generally acceptable. These meteorological and route distance guidelines are for open-area measurements and also depend on CMI performance, target analyte background levels, non–target source interferences, NFO interferences and the magnitude and physical geometry of the source emission. CM applications conducted in urban canyon environments, forested areas or in micro-scale applications (e.g. on a landfill surface) will have project-specific meteorological requirements.

8.4.5 Atmospheric interferences and CM route design. Figure 8-3 illustrates a very large scale CM survey investigating NO_2 concentrations in the San Francisco Bay area. The lowest concentrations observed were on the order of 5 ppbv (blue markers) whereas the higher concentrations (red markers) are on the order of 35 ppb. In this case the upwind leg of the measurement (to the west) shows lower NO_2 levels compared to the downwind leg.

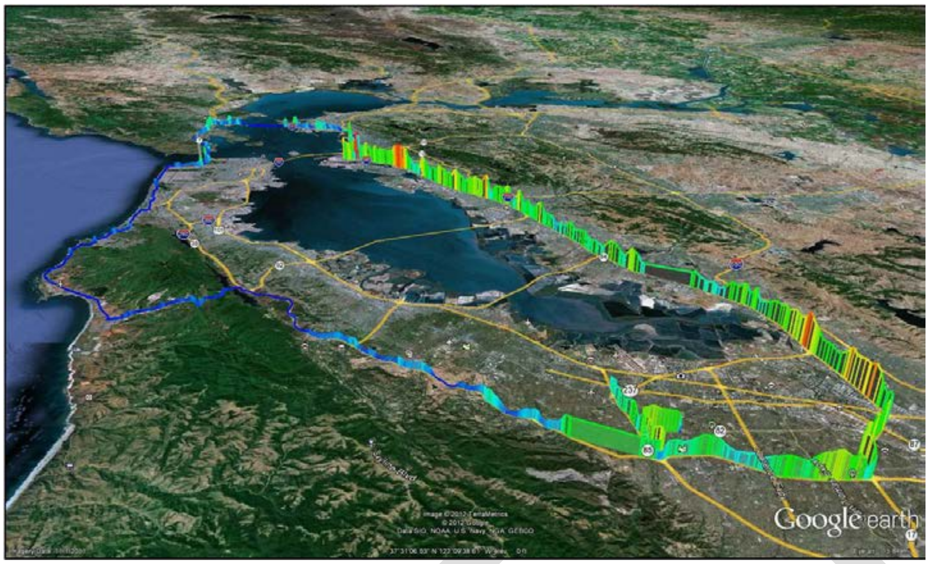

Figure 8-3. Example large scale survey of NO_2 in SF Bay area

To draw useful conclusions from this type of survey it is important to understand variations in local source contributions and the effects of atmospheric changes during the route. In this case, it is likely that some of the observed variation can be ascribed to differences in vehicle traffic and other upwind local NO_2 sources at various points on the route. However, for this long survey (multiple hours), local atmospheric conditions (wind speed and boundary layer) can change and can greatly affect local concentrations. This speaks to the general need for repeat measurements, conducted potentially at different times of day with different starting locations and traveling directions. Additionally, survey route lengths should be kept to limited duration so that atmospheric conditions during each individual survey are as similar as possible. It also points out the importance of understanding meteorological conditions throughout long mapping surveys and the potential use of auxiliary meteorological data to evaluate atmospheric changes.

Figure 8-4. Further illustrates the point that GMAP applications produce concentration measurements that are a function of both the strength of nearby sources and the encountered meteorology. In this figure carbon monoxide (CO) measurements from a GMAP survey near a highway are shown on three different days with differing wind speeds and directions. On Friday, under stagnant conditions, CO concentrations in the neighborhood are uniformly elevated at levels approximately twice as high as on Thursday with steady winds directly from the target source (the highway just to the north) under similar traffic conditions. For CM application, meteorological conditions during and prior to measurements can be a dominate factor determining near source concentrations and must be factored into conclusions.

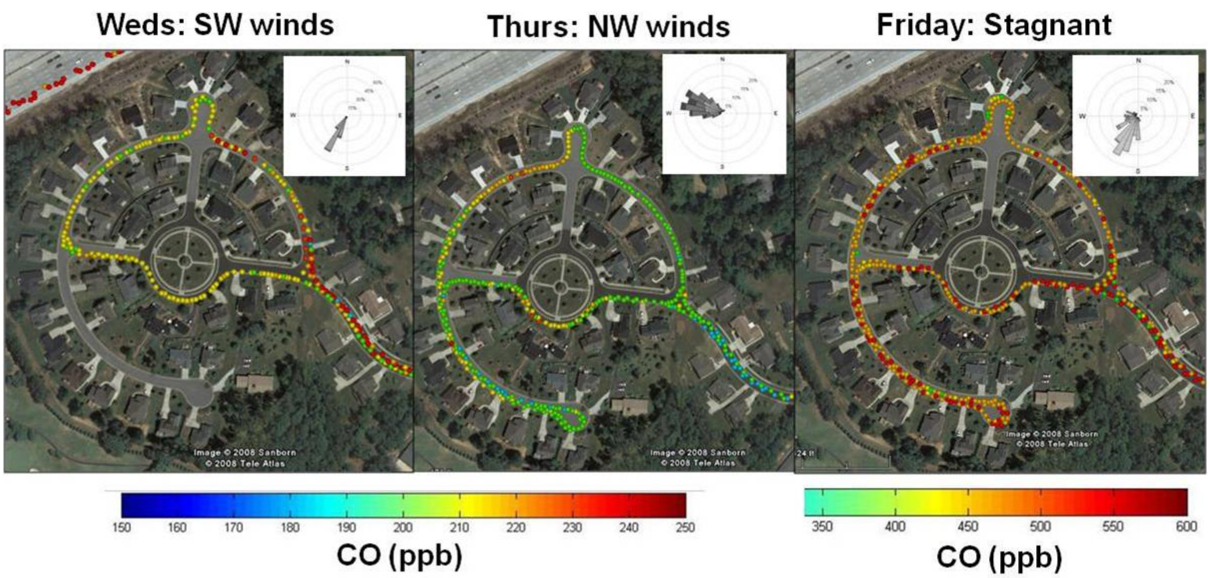

Figure 8-4. Example of day to day near source concentration variability

8.4.6 Procedures for CM execution. Procedures for CM execution must reflect planning, equipment design and preparation, field execution, quality assurance and analysis elements described in Section 8.3 and contained references. OTM 33A CM applications can be conducted as stand-alone or in support of SC and EQ SAMs. As application details can vary, procedures for CM execution should be detailed in equipment-specific SOPs and the PSQAP.

8.5 Considerations for SC execution. The OTM 33A source characterization (SC) function includes any data collection and analysis activities that supports CM (source discovery) and/or EQ (source mass emission rate) assessment procedures. SC activities include but are not limited to: special repeat CM transects to investigate source temporal or plume atmospheric transport, acquisition of evacuated canister data to determine the identify of emitted compounds not measured directly by the CMI, and collection of auxiliary data, such as site photos and infrared camera videos to help identify source emissions. Some example considerations for execution of SC functions are contained below.

8.5.1 Source verification and temporal stability. Performance of replicate drive-by transects in proximity to a near-field source can be an important SC tool in areas with elevated backgrounds or when sources are potentially temporally variable. If the source is not detected on subsequent transects under similar meteorological conditions, it may be the case that the source is transient in nature (a very important determination) or that the signal was a CMI artifact, non-target source, or background interference. Repeat transects that confirm near-field signal provide confidence in the overall OTM 33A assessment.

Figure 8-5 shows an example of repeat near-source transects near an oil and gas production pad with the turn-around points for the drive-by noted by vertical dashed lines. In this case, emissions from the nearby production pad are superimposed on a near-by interfering methane source (a livestock operation). The distant non-target source provides a slow-varying background CH_4 signal ranging from about 2.0 ppm to 2.5 ppm. The near-field production pad (24 m from roadway) signal manifests as sharp spikes in concentration as the GMAP vehicle passes ranging to 6.5 ppm. Through execution of multiple transects, understanding of target and non-target sources can be gained. This repeated SC drive-by also provides information on best observing locations for potential subsequent stationary EQ functions.

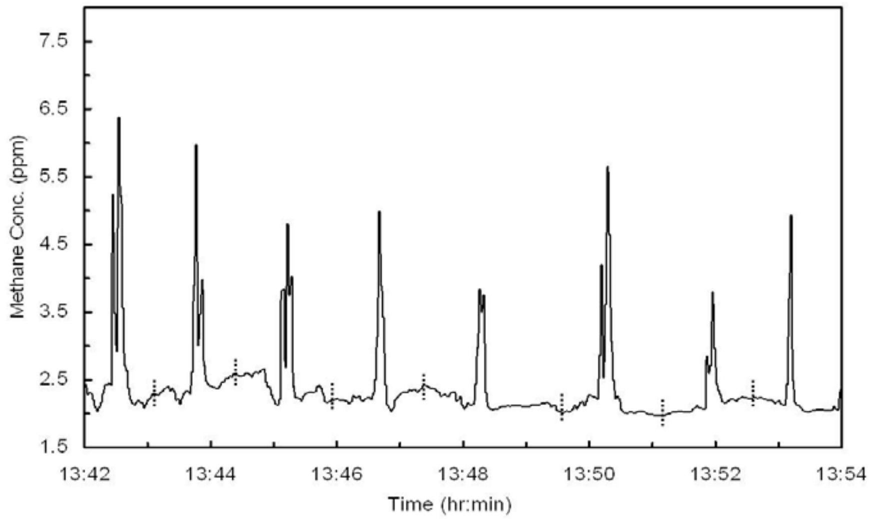

Figure 8-5. Example of SC by repeat transects in a complex background.

Additionally the SC activity of Figure 8-5 provides information on the temporal stability of the source. In this case the source is judged to be relatively constant with the observed peak height variations likely a consequence of changing overlap of the small plume with the GMAP sampling probe. This is an important determination for observation of a source like an oil and gas production pad which can exhibit periodic short term increases in emissions during separator dumps of condensate to atmospheric storage tanks. A single drive-by observation may catch the operation in a short-term peak emission state potentially producing a biased interpretation of results. Here the repeat measurements indicate a sustained emission and close inspection of the bifurcated plume shape even suggests the presence of multiple sources on the pad (to be confirmed with auxiliary SC measurements).

8.5.2 Understanding downwind source concentrations. Understanding source transport and downwind concentrations under varying atmospheric conditions can be an important aspect of SC. Figure 8-6 shows an example of two transects acquired under similar wind speeds, directions, and distances downwind from a landfill source, with the emissions of CH_4 assumed to be relatively constant in time. The later transect (11:52 AM) shows the effect of increasing boundary layer height on both local background CH_4 levels and the plume transport from the landfill. Conclusions regarding source impact should be based on repeat measurements with meteorological conditions including boundary layer height changes considered.

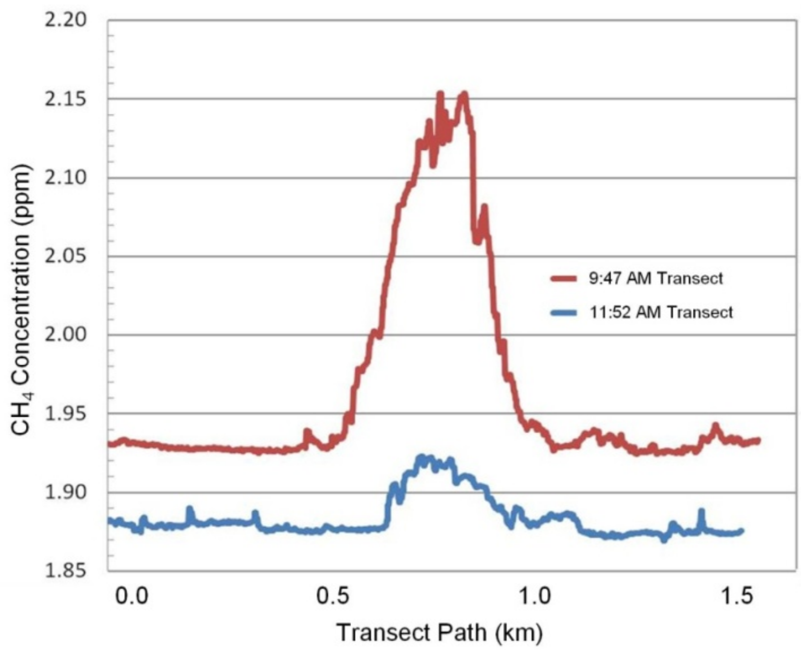

Figure 8-6. SC by repeat transects under different conditions.

8.5.3 Collection of canister samples. In many cases, real-time concentration measurements produced by the CMI provide data on only one of many compounds emitted by a source. Acquisition of an air "grab sample" with subsequent laboratory analysis can be an important SAM and can also be useful for quality assurance comparisons of the CMI (see OTM 33 Section 9.4.6) and as a diagnostic for identifying non-target source interferences. A grab-sample is usually an evacuated air sampling canister set up for with an approximate 30-45 second draw. Other types of short duration air sampling such as Tedlar™ bags, flasks, or pumped sorbent tubes are possible. Using the real-time CMI signal as an indicator of emission plume overlap, a properly designed canister acquisition system can allow effective sample collection through solenoid valve trigger either by the user or an automated control system.

Canister-derived, in-plume concentrations can be used in conjunction with the CMI signal to extend SC analysis in a number of ways ranging from simple identification of co-emitted species to extension of EQ source emission estimates to non-CMI compounds through ratio calculations. It is important to note that use of a CMI signal level as a surrogate for other species assumes that the canister acquired compounds and the target analyte are co-emitted (originate from the same source)and that the transport properties of the compounds are similar. While it is relatively easy to decipher background concentration of the target analyte measured by the CMI using the mobile nature of the GMAP approach, canister grab samples do not provide this ability so background levels of species are important to consider in many cases. An example of canister acquisition SC functions is contained in reference 3 which is reproduced in Appendix H1.

Successful sample acquisition canisters (or other sampling system) for SC functions is part of GMAP equipment system design and are described in OTM 33A Section 6.2.6 and in Appendix A and B. Design considerations include but are not limited to:

- Secure placement of the canister near the CMI sampling port.
- The ability to trigger the canister at desired CMI levels.
- The ability to read and record the internal pressure of the canister before and after sampling.
- The ability to record the exact start time and duration of acquisition so that synchronization with the CMI is possible.
- A knowledge of any CMI sampling time delays that must be compensated for in final time synchronization.

It is critical that the preparation (cleaning), set up, storage and shipping requirements for the canister (or other sampling system) be known and followed. These procedures may depend on the analytical series that is that being used. It is also critical that proper laboratory analytical procedures are followed. Examples of preparation and analysis

SOPs for a particular analytical series are contained in Appendices G1-G3.

8.5.4 Acquisition of auxiliary data. Important SC functions include acquisition of auxiliary data such as site photos and infrared camera videos which can assist in documenting the identity or state of a source (e.g. an open hatch or other malfunction) and also provide information on the presence of potential interfering non-target sources or other method inferences such as flow obstructions. Due to the remote (off-site) nature of OTM 33A, the suspected source is often too distant for effective viewing. Any auxiliary data should be time and date stamped and recorded in logs. Cameras with built-in GPS help in linking auxiliary SC data with mobile measurement results.

8.5.5 Procedures for SC execution. Procedures for SC execution must reflect planning, equipment design and preparation, field execution, quality assurance and analysis elements described in Section 8.3 and contained references. OTM 33A SC applications can be conducted as stand-alone or in support of CM and EQ SAMs. As applications details can vary, procedures for SC execution should be detailed in equipment-specific SOPs and the PSQAP.

8.6 Considerations for EQ execution. In a broad sense, OTM 33A EQ can refer to any near-field source emission strength estimate scheme that can be executed using a point measurement from a mobile platform and does not require on-site measures (such as tracer gas release for atmospheric normalization). In general OTM 33A EQ approaches are most useful in cases where the source of interest is relatively small and near ground level, where site access may not be available, and where rapid deployments are desired. OTM 33A is useful for canvassing large areas to locate emissions and provide rapid off-site emission assessment in support of more accurate on-site direct source measurements.

OTM 33A EQ can in theory be accomplished using both stationary observations and in-motion transect approaches (e.g. reference 4, reproduced in Appendix H2) using a variety of source mass emission rate estimation data processing schemes. This method describes one stationary measurement and inverse source emission strength estimate approach called point source Gaussian (PSG). Other EQ approaches based on mobile or stationary measures and other source mass emission rate estimation algorithms may become part of OTM 33A with proper description, validation, and quality assurance procedures.

As an overview, the PSG EQ measurement is typically initiated by positioning the vehicle in the plume using the near-real time concentration measurements provided by the CMI. Data from the CMI, GPS, 3D sonic anemometer, and meteorological instruments are automatically recorded by a control computer and saved as a time-stamped file for analysis in real-time or post acquisition calculation of estimated source emission rates. Ideally, real-time data quality indicators on plume position and acquisition integrity are provided via the user interface. Auxiliary information, such as infrared camera observations, source to distance measurements, site photographs, and chain of custody forms and notes are acquired / completed during the 15 to 20 minute EQ acquisition from the off-site observation location. Particular attention should be paid to wind-field obstructions and source configurations (e.g. number, size, and height of emission points, source temporal variability, etc.) that should be taken into account when assessing emission uncertainty and the representativeness of results. Measurement should be repeated several times if possible to help understand measurement uncertainty and source variability.

The PSG EQ approach, is illustrated in Figure 2-1, with typical deployment scenarios discussed in Section 8.6.4. The PSG approach is described in brief in Sections 2.2.5 and 2.2.6 and in reference 3 (reproduced in Appendix H1) with field execution further detailed in this Section and QA considerations and data analysis procedures discussed in Sections 9 and 10 respectively. Execution of the PSG EQ source assessment mode generally consists of the following steps:

8.6.1 OTM 33A Preparation. Conduct all pre-deployment and in-field planning, equipment preparation, and instrument calibration, as per SOPs and PSQAP (see section 8.1 through 8.3).

8.6.2 SAMs preceding EQ. Use CM and SC SAMs to locate and preliminarily characterize the emission source. Information such as the identity, location, and distance of the source and the presence of potential interfering sources, other method interferences, and safety hazards should be established if possible. Ensure that the meteorological conditions and site configuration is conducive to EQ execution. Ideally, wind speeds should exceed 2.0 m/s sustained and ASI should be 3 or greater. Successful measurements can be made at lower wind speeds and ASIs if the source is proximate. Distant sources (100 m to 200 m) and slightly elevated sources (3 m to 7 m) are difficult to measure under low wind speed and ASI conditions (low bias as in Figure 4-2). If the source is deemed measurable by EQ and if a safe and appropriate observation location exists, proceed to step 8.6.3.

8.6.3 Execution steps for EQ.

8.6.3.1 Position the GMAP vehicle at the determined downwind observing location with front-mounted mast system facing toward the source location (into the wind). Use real-time concentration information from the CMI to assist in fine-tuning the observation position. Position the vehicle so as to minimize obstructions in the line of sight to the source or near the vehicle as possible.

8.6.3.2 Put the vehicle in park, apply emergency brake, and turn the engine off. Implement required safety procedures (traffic vests, cones, hazard lights, etc.) and use caution exiting the vehicle.

8.6.3.3 Rotate the vehicle mast system so that the probe inlet and 3-D sonic anemometer's 180 degree axis are pointing at the suspected source. Record mast bearing and measure and record distance to the source using a high quality laser range finder or other means. Input required data elements and file names into control software and begin EQ data acquisition. Record supporting SAMs like additional site photos or infrared camera videos if possible from the off-site observing location during EQ acquisition.

8.6.3.4 Conduct a 15 to 20 minute stationary EQ observation. If the control software allows (similar to that described in Appendices C and D), observe the preliminary CMI analyte concentration measurement versus wind angle binning as the data becomes available. Since the 3D-sonic anemometer's 180 degree axis is pointing at the suspected source, the preliminary binning graph should appear similar to that shown Figure 8-7 (ideal case).

Frequently, this in-field DQI will deviate from Figure 8-7. Under low wind speed conditions, air parcels with elevated concentrations will impact from off-angle vectors. This is usually not a fundamental problem as data density in these bins is low and these off-axis values are removed in the data analysis step. Other deviations from Figure 8-7 may indicate potential presence of multiple sources (especially in the case of two distinct Gaussian profiles) or the presence (confirmation) of significant near-field obstructions which de-correlate the CMI and wind data.

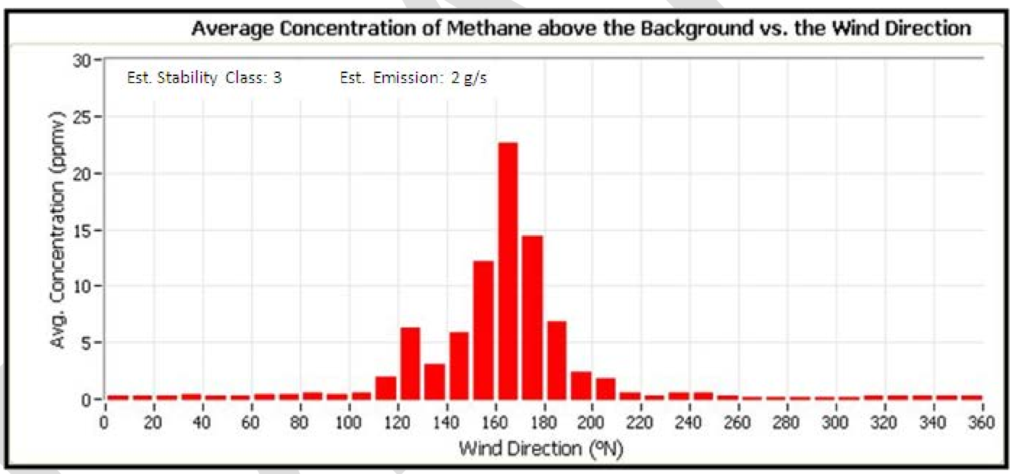

Figure 8-7: Example of real time CMI reading versus wind direction graph as an in-field DQI for PSG measurements.

8.6.3.5 Repeat the 15 to 20 minute stationary observation (step 8.6.3.4) and record as a separate data file. Reposition the GMAP vehicle prior to measurement and record the new source distance if needed. Repeat the measurement a number of times as per PSQAP or operator decision. Generally, the number of recommended repeat measurements is proportional to the importance of the acquired data, temporal characteristics (emission constancy) of the source under study, and the measurement accuracy objectives. The number of repeat measurements should be increased if site-specific factors that could produce method interference are present. For example, if NFOs exist, multiple repeat measurements can help inform the extent and impact of method interferences.

8.6.3.6 Conduct additional SAMs such as an in-plume canister acquisition, additional site photos, infrared camera videos, or transect measurements as needed to support the EQ function. The canister data may be used to assess co-emitted pollutants not directly measured by the CMI, such as volatile organic compounds (VOCs) or hazardous air pollutants (HAPs). The canister data can also help with interpretation of non-target source interferences, in source identification, and in QA of the CMI in some cases.

8.6.3.7 Complete data acquisition sequence by recording and archiving data files and chain of custody forms, etc. Prepare vehicle for next CM survey by stowing safety equipment and securing mast system for road travel as per SOPs.

8.6.4 Example EQ application scenarios. Figures 8-8 and 8-9 provide examples of EQ application scenarios (illustrations only). In Figure 8-8, CM and SC SAMs have determined that an emission is originating from an open thief hatch on top of the left condensate tank. In this case, an infrared camera is available to the GMAP personnel and the source is close enough to the roadway so that off-site video observation confirms the location of the source and the absence of any major competing emission points (i.e. separator to the left). The site is also close enough to the road to confirm the cause of the emission (open thief hatch). In this case, the distance from the observation point to the source (50 m) is easily measured and is certain. The emission point is modestly elevated (approximately 4 m) but under moderate wind speeds, the EQ is reasonable. See Section 8.6.5 for a discussion of wake flow around tanks.

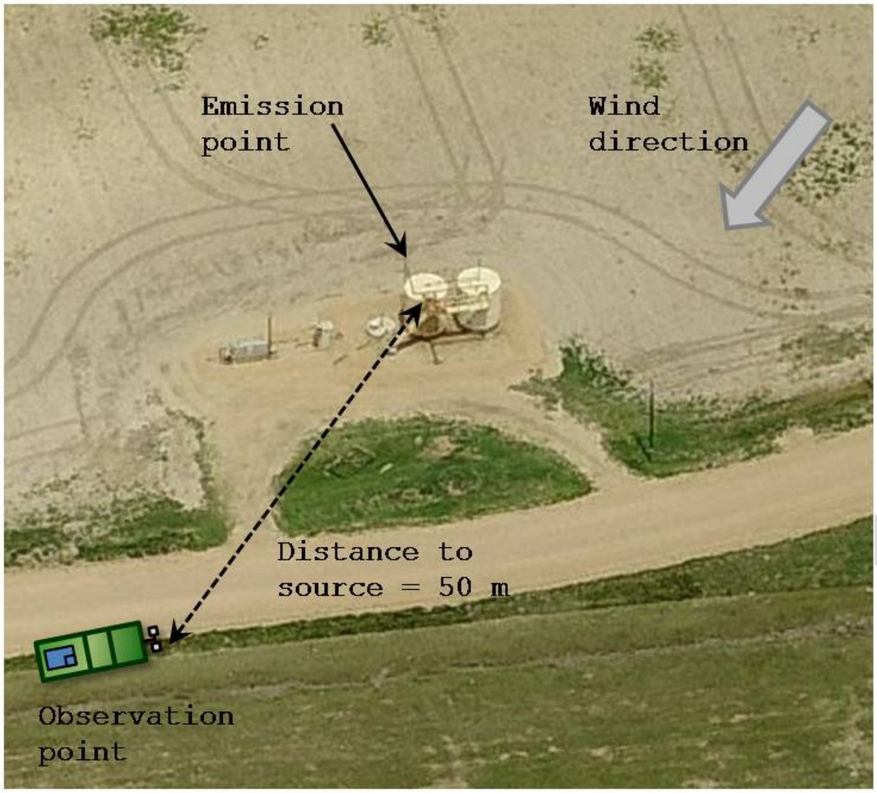

Image Source: BingMaps ©2013 Microsoft Corp. Pictometry, Bird's Eye (© 2012 Pictometry International Corp.)

Figure 8-8. Example EQ application of a known source location.

In this case acquired canisters can support source assignment as they would be expected to exhibit a high C2+ to CH_4 ratio as the emission originates from the head space of a natural gas liquids atmospheric storage tank. A significant measurement variable here would be the potential for EQ sampling during a separator dump process which may last seconds to a few minutes and occur potentially once or more each hour. During the separator dump, flash emissions occur where entrained gas can become liberated creating a much higher than normal short-term emission event (see Figure 8-10 and associated discussion). Tracking of this type of short term emission is important and repeat measurements can help to identify instantaneous and short term emissions scenarios

Figure 8-9 shows an example of EQ application in a more complicated and uncertain scenario. In this case CM and SC functions have identified an emission originating from due west (left side of figure) based on a knowledge of wind direction. In this case the operator may observe that the lateral size of the plume is somewhat increased and the in-plume concentration variation is possibly decreased in comparison to cases where the emission is proximate to the observation location (as in Figure 8-5). These factors are indicative of an evolved plume originating from a distant source. By combining knowledge of wind direction, plume dynamics, and visual siting of the equipment in the field, the emission is ascribed to the potential sources noted in Figure 8-9. In this case the operator does not have an infrared camera or the distance is too great to observe the emission directly (as confirmation). The operator must therefore determine a potential source distance range and (in this case about 140 m to 165 m) and PSG calculation would include this uncertainty. If there is no way to inform the source identity, inspection applications should likely use the closest distance (providing the lowest source emission estimate) An in-plume canister in this case may help to inform the actual source of emissions. For example, in an oil and gas field with significant condensate production, a canister result which indicated a very large percentage (>90%) of CH_4 compared to other product-related VOCs (after background correction) would point to the northern most potential source (a well-head) as the likely emission source.

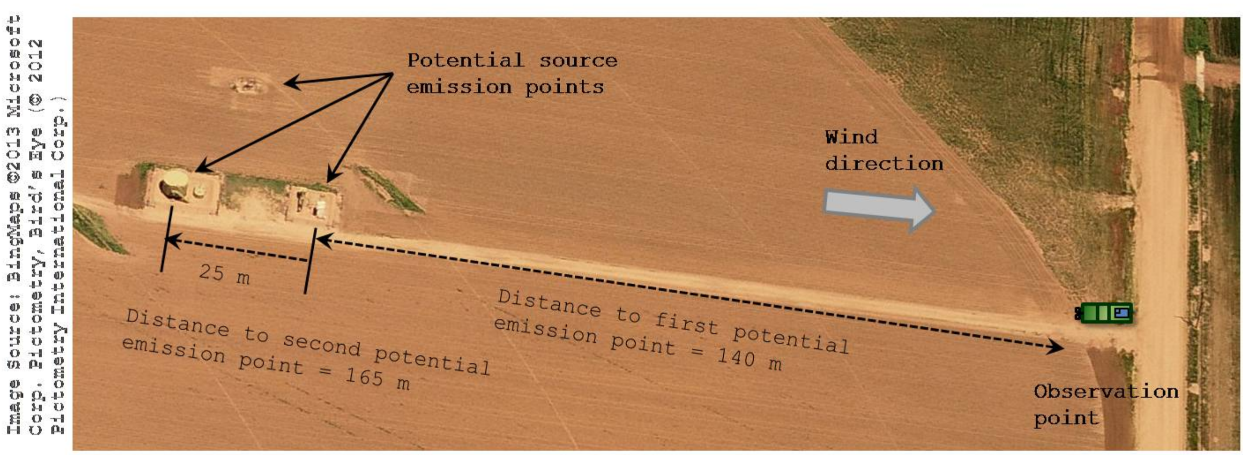

Figure 8-9. Example EQ application in a more complicated scenario

8.6.5 Source variability and repeat measurements. OTM 33A EQ activities fundamentally produce a snapshot measure of emissions that represent a specific 15 to 20 minute observation time period. Use of these instantaneous emission rate measurements to form conclusions about longer-term emissions of a source (e.g. yearly emissions) can be subject to profound error and any such attempts must take into account source specific information in the uncertainty analysis. The reason for this is that many fugitive and area sources that are measured by remote assessment methods under OTM 33 are known to exhibit significant temporal emission variability and can be affected by atmospheric conditions and seasonal effects. As examples, landfill emissions can be affected by changes in atmospheric pressure, waste water pond emissions can depend on wind speeds and the state of microbial populations, and atmospheric storage tank breathing emissions can be affected by ambient temperature and solar factors so may differ in winter and summer and diurnally.

As an example of source variability in OTM 33A EQ assessment, Figure 8-10 shows the results of repeated field measurements of CH_4 emissions from two different kinds of atmospheric storage tanks over a 5 day period. At site A, vented emissions of CH_4 from a waste water tank are found to be relatively repeatable so a small number of measurements are representative of emissions under these conditions (time of day, season, etc). At Site B measurements are first conducted during a malfunction (open thief hatch) and a large amount of variability is evident. Short-term flash emissions associated with separator dumps to the storage tank likely contribute to this variability. Later in the Site B measurement series, the open thief hatch is closed and measured emission rates decreased significantly as a result. In this particular case, a single measurement conducted during a flash emission with the hatch open produces a worst-case emission scenario that may be relatively accurate for the encountered condition but would not be representative of typical emissions throughout the year.

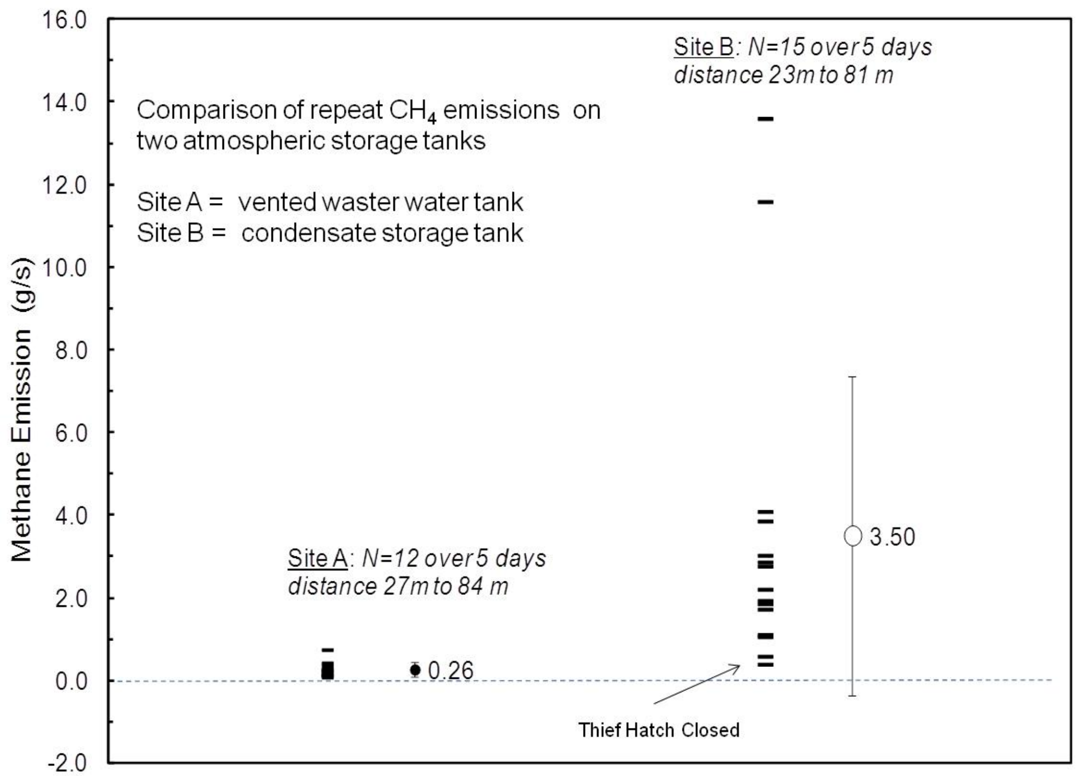

Figure 8-10. Examples of repeat EQ measurements on two different sources. The dashes represent individual measurements for Site A (N=12) and Site B (N=15) and the closed (0.26 g/s) and open (3.50 g/s) circles are site averages with error bars indicating ± 1σ.

8.6.6 Considerations for more complex sources. Many times source emissions originate from elevated positions or from multiple sources. The OTM 33A PSG EQ approach can provide source mass emission rate emission assessment in a wide variety of cases but an understanding of the assumptions and limitations of the approach are important. As an example, consider Figure 8-11 which shows a steady-state computational fluid dynamic (CFD) simulation of the near-field transport of emissions from the top of a 5 m tank under 4 m/s wind speeds and stable atmospheric conditions. Also shown is the approximate size of the GMAP vehicle and its sampling mast. Due to wake flow effects, emissions originating from the top of the tank can be pulled down by the wake resulting in significant spatial overlap of the plume centroid and the mast sampling inlet, making measurement of the elevated emissions more tractable. The plume is also dispersed in the horizontal direction making location of the plume somewhat easier as well. As wind speeds decrease and as the tank height increases, this plume downwash effect becomes less impactful and the method interferences pictured in Figure 4.2 (B) begin to dominate. For most cases, this will lead to an underestimate of emissions (a low bound estimate).

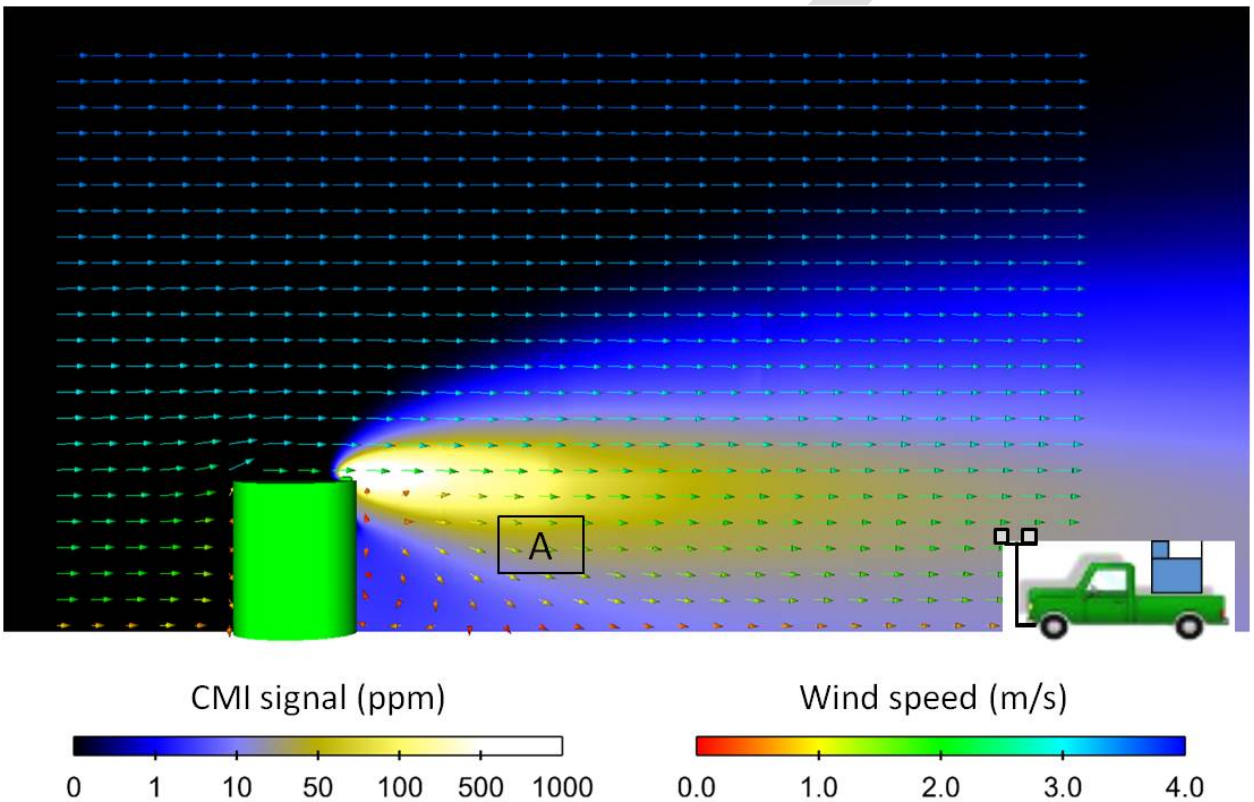

Figure 8-11. CFD model of wind vectors (arrows) and CMI readings (cloud shading originating from tank).

For near tank (or other obstruction) measurements such as this, it is important to stand-off from the tank by at least 5 diameters if possible to avoid potential recirculation effects that could cause over estimation of emissions. Position “A” in Figure 8-11, for example, would be too close to the tank for optimal measurement. Repeat measurements from multiple observation points can help alleviate this concern, the presence of which may also be evident in meteorological data comparisons (unstable wind direction and 3-D sonic anemometer data near tank in comparison with stand-off location).

Figures 8-12 and 8-13 show steady-state CFD simulations of more complex emission scenarios where the presence of multiple tanks affect the propagated wind field originating behind the tanks. In Figure 8-12, the emission originates from one tank and in Figure 8-13, the same total emission level is emitted by six tanks. At position “A” in each figure, the CMI signal for the single tank emission case is about a factor of two larger than multi-tank case. It is expected that the multi-tank case would show lower instantaneous concentration peaks but also fewer background-level excursions with a very wide apparent plume width. In both cases, the PSG approach would calculate a mean center point concentration and use this in the emission estimate with the default assumption of a single point Gaussian dispersion from the center tank. Since the plume width in the PSG lookup table (Section 12 and Appendix F1) is much smaller than the observed values, this factor will lead to an underestimate of emissions for both cases.

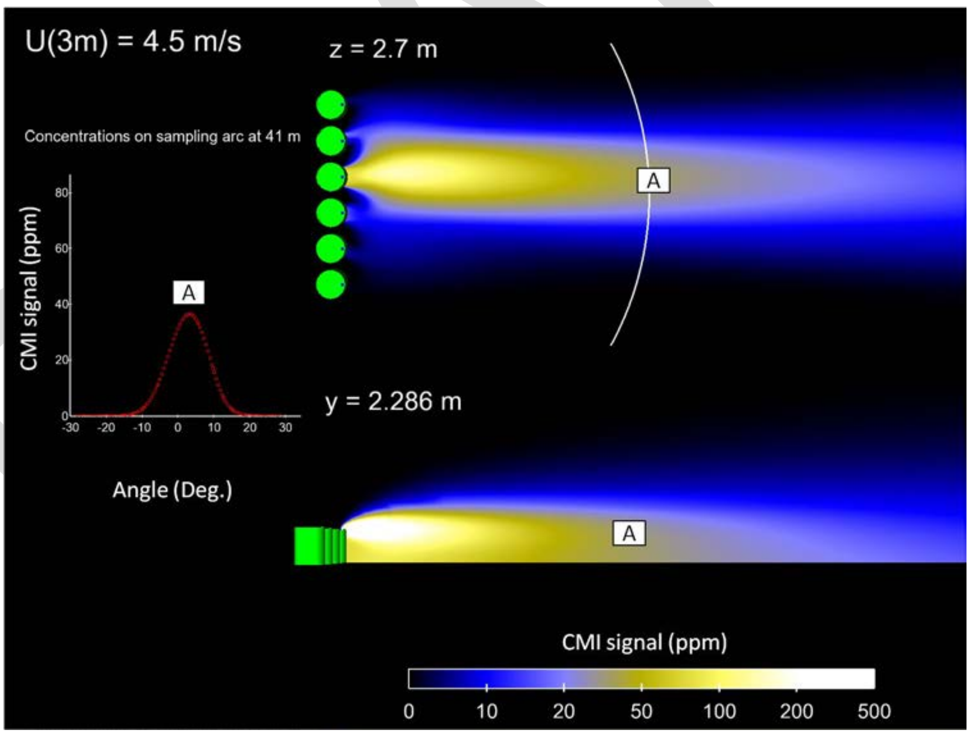

Figure 8-12: CFD simulation of one unit emission from the center tank.

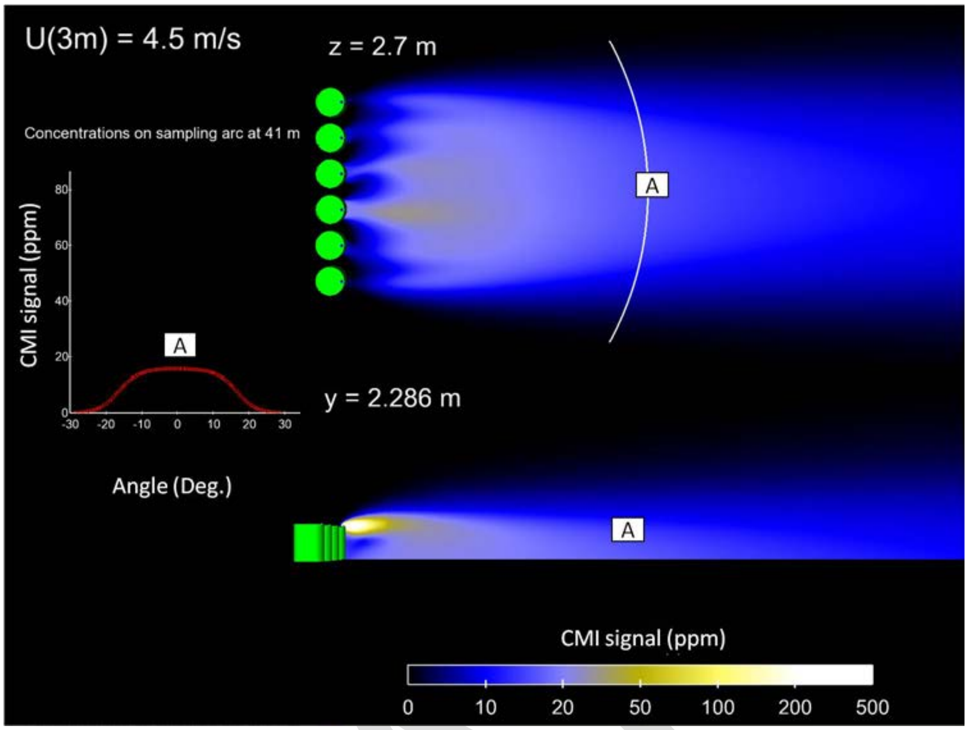

Figure 8-13: CFD simulation of 1/6 unit emission from 6 tanks.

8.7 Background considerations for an example application

This section discusses background signals from potentially interfering sources for an example measurement application, assessment of methane emissions from oil and gas production pads. Note that other OTM 33A applications will have different background concerns that should be described in the project specific quality assurance plan (PSQAP).

For methane measurements from near-ground level proximate sources, at least three background factors should be considered.

(1) Potential for interference from mobile sources

(2) Potential for interference from nearby methane sources

(3) Potential for interference from far away methane sources

It is important to note that some sophisticated CMIs can measure compounds in addition to the methane (such as ethane) or can measure the ratio of carbon isotopes (13C/12C) to assist in discriminating the methane emitted from oil and natural gas production facilities with biogenic sources. These capabilities are extremely helpful for large stand-off distance applications (such as airborne transects) but are not usually required for typical near-field assessment as in OTM 33A, due to the proximity of the source as described below.

8.7.1 Potential for interference from mobile sources

In some OTM 33 applications, the target compounds being measured are also emitted by mobile sources (cars and trucks). In these cases, care must be taken to ensure that the exhaust from the OTM 33 measurement vehicle does not self-contaminate the measurement. This is done in some cases by using fully electric sampling vehicles.[2] It is also important to understand the effects of the exhaust of nearby vehicles on the sampling. Signal analysis can be complicated in these cases since local backgrounds can change rapidly near roadways and proximate vehicles can create significant spikes in concentrations. Specialized data analysis procedures for roadway measurements are many times needed make sense of these complex issues.[11]

For the example of methane measurements from oil and gas production pads, the potential for interference from mobile sources is not a great concern. It can however be a concern for measurement non-methane compounds such as benzene or general volatile organic compound sampling. Some points to consider for oil and gas applications are:

- Methane is not strongly emitted from mobile sources and in most cases, vehicle density in oil and gas fields is low. So in general, there is no issue with mobile source methane interferences as long as the CMI has no strong cross-interferences with mobile source-emitted compounds.

- The CMI instruments frequently utilized for oil and gas methane measurements employ high resolution near-infrared optical spectroscopy with extremely good accounting of potentially interfering compounds. The spectroscopic features of carbon monoxide for example (emitted from cars/trucks) is completely isolated and distinct from the target compound (methane) so it cannot it introduce bias in the methane determination. If other methane sensor systems are employed, the potential for cross-inferences should be understood.

• For vehicle designs with forward sampling (OTM 33A Appendix A), when the sampling vehicle is in motion looking for methane emissions, its exhaust at the rear of the vehicle moves away from the front mounted mast eliminating potential for “self-sampling”.

• When the sampling vehicle is stationary executing the 20 minute emissions qualification, the sampling vehicle’s engine turned off. This is accomplished by powering the instrumentation from battery systems integrated into the vehicle. If this were not the case, self-sampling of the vehicle’s exhaust could be a problem, but usually only for canister acquisitions that determine non-methane species (would still likely not affect the methane measurement for many CMIs).

8.7.2 Potential for interference from nearby methane sources

In measurement of methane emissions from oil and gas production pads, it is important to isolate the source under study from potential background sources of methane. There are two regimes of potential methane interference to consider: (1) strong point source methane signals produced by near-field sources, such as other oil and gas well pads, and (2) more dispersed background contributions caused usually by non-localized or far-field sources, such landfills and animal feeding operations discussed in Section 8.7.3.

The OTM 33A method is executed in close proximity to the well pads under study (20 m to 200 m). It is this close positioning that allows the observed well pad separated from other near-field sources. As part of the data acquisition protocol, the operator positions the vehicle at a safe and appropriate downwind observing location in the plume using the real-time signal from the CMI, parks, turns off the motor. With knowledge the prevailing wind direction and real-time methane concentration, rough triangulation of the direction of origin of the emission is readily obtained and the sampling mast and probe are rotated to point directly at the emission point. This will almost always point to an obvious (suspected) well pad source in this example application.

Ideally the operator can confirm the emission origin through use of offsite infrared imagery. The operator also takes site photos from the observation point to determine if any potential sources are located directly upwind of the source under study.

Over the twenty minute observation period, variations in wind direction will cause concentrations changes that can be spatially correlated with source under study and potential nearby sources. Figure 8-14 presents several examples of the site overheads from Google Earth™ shown with and without superimposed wind direction/ concentration roses that help point to the origin of emissions. The overhead images themselves also help us to determine potential upwind sources, but understanding of the date of the imagery is very important. Using these procedures, it is possible to confirm that a source such as neighboring well pad is spatially separated to such an extent that it does not contribute to the immediate signal (not present in the angularly-resolved PSG analysis window) and therefore does not affect the source emission rate measurement. As described in Section 8.7.3, variation in wind direction moves the source signal off of the sampling probe allowing the local background concentration to established and subtracted as part of the PSG calculation.

Figure 8-14: Overhead images with and without wind concentration roses

8.7.3 Potential for interference from far away methane sources

Distant methane sources such as landfills, animal feeding operations, or other are typically located far enough away from the well pad under study so that their contribution can be considered a relatively uniform baseline offset to the ambient background. Methane signals from far away sources are highly dispersed and do not vary with changes in wind direction as sharply as the proximate source under study. Most of the time, these source contribute < 100 ppb the methane background signal. These background signals overlap the well pad signal and become part of the analysis but usually have little effect on the well pad emission rate determination.

As the wind direction changes during the 20 minute observation period, the local background is repeatedly measured by the CMI. This occurs over and over again as the plume from the proximate well pad moves on and off of the sampling probe. In the vast majority of cases, this background is extremely stable, and this easily verified when using high precession CMIs. For a methane measurement, the PSG analysis code determines the average of the lowest 5% of the measured values and assigns this the background value and is subtracted as part of the analysis. The methane contribution from the far-field source is present in the plume and the “off plume” background data and is canceled by the background subtraction step. Figure 8-15 shows four time series from field measurements of well pads which illustrate the downwind concentration variations and “no plume” flat areas around 1.8 ppm where the local background is established. The local background value can increase in the presence of strong far field sources and also in low boundary layers (pooling conditions) but the background subtraction concept remains the same.

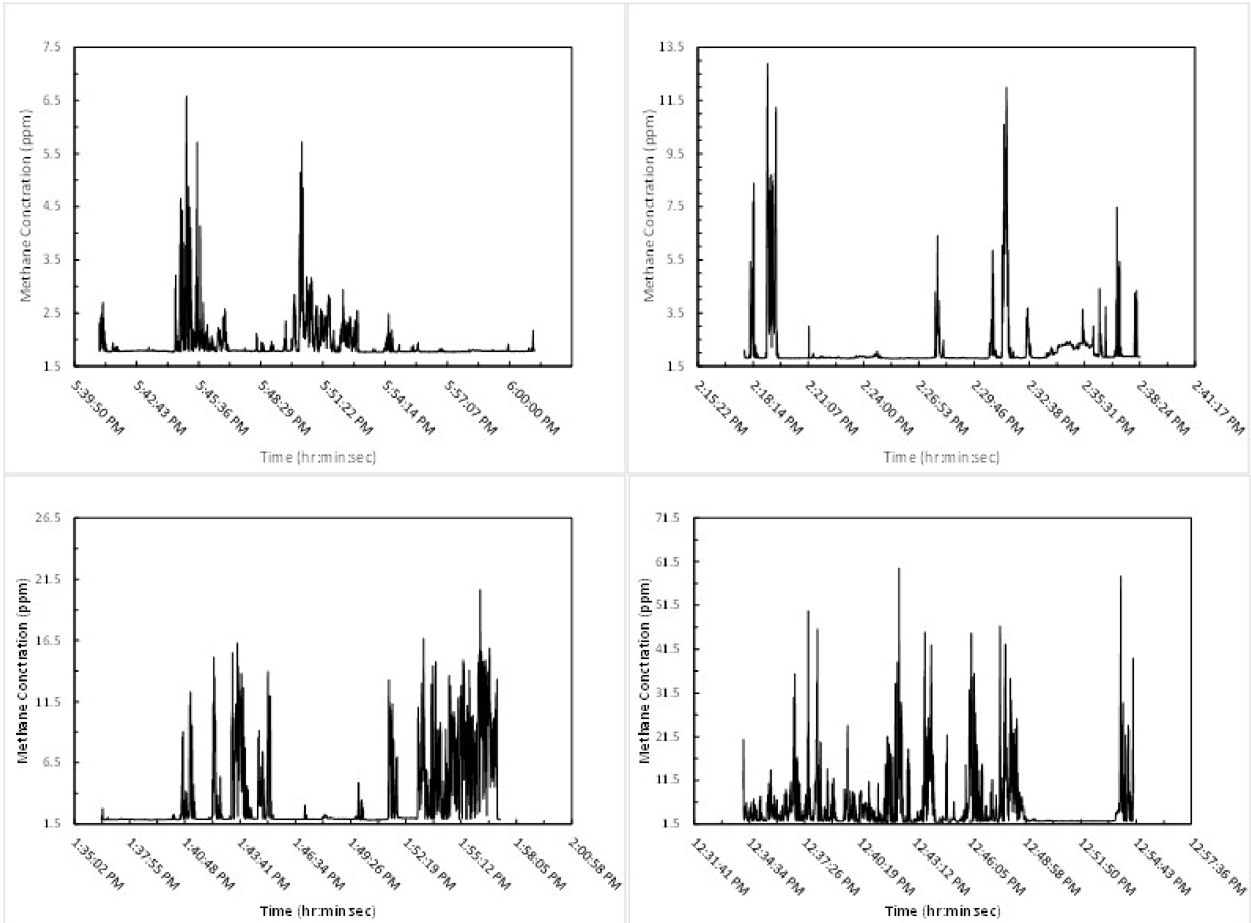

Figure 8-15: Methane time series showing flat background regions.

If the background source is close to the well pad under observation, its contribution will be more variable and this will be evident in the variance of the 5% low background determination (DQI in Column AM of PSG calculation worksheet, OTM 33A Appendix I). An example of this case is shown in Figure 8.5. Emission assessment uncertainty in these cases is somewhat higher and should be evaluated on a case by case basis. If the near field source under study generates concentrations that are large compared to the background variation, the uncertainty in emissions assessments will be minimal.

Supporting the overall point on the minimal effects of far-field background impacts is Figure 8-16 which shows field data background levels (established by the PSG approach) compared to plume signal over background for 480 OTM 33A measurements. As can been seen the background values are relatively small in comparison to the plume signal with the vast majority of cases near or at local ambient.

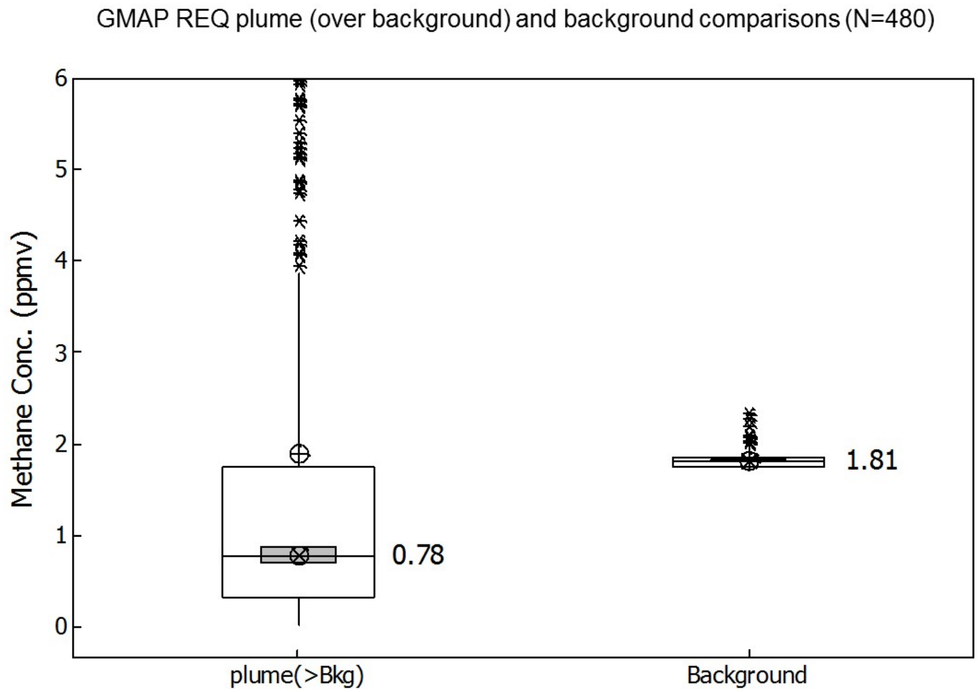

Figure 8-16: Background and in plume concentrations for 480 OTM 33 measurements.

8.8 Procedures for EQ execution. Procedures for EQ execution must reflect planning, equipment design and preparation, field execution, quality assurance and analysis elements described in Section 8.3 and contained references. OTM 33A EQ applications are typically conducted in conjunction with CM and SC SAMs. As application details can vary, procedures for EC execution should be detailed in equipment-specific SOPs and the PSQAP. See Section 8.6.3 for a discussion of EQ execution steps.

9. Quality Control.

9.1 General QA guidance for OTM 33. Refer to OTM 33 Sections 9.1 through 9.7 for a description of general quality assurance (QA) requirements for OTM 33 that also apply to OTM 33A (GMAP-REQ-DA):

OTM 33 Section 9.1: *OTM 33 sub-method prescriptions and PSQAP.*

OTM 33 Section 9.2: *Data acquisition and analysis QA*

OTM 33 Section 9.3: *Instrumentation quality assurance.*

OTM 33 Section 9.4: *Quality assurance for the CMI.*

OTM 33 Section 9.4.1: *CMI selection and baseline QA.*

OTM 33 Section 9.4.1.1: *CMI target measurement selectivity.*

OTM 33 Section 9.4.1.2: *CMI quantitation limit.*

OTM 33 Section 9.4.1.3: *CMI dynamic range.*

OTM 33 Section 9.4.1.4: *CMI accuracy.*

OTM 33 Section 9.4.2: *CMI initial calibration and maintenance.*

OTM 33 Section 9.4.3: *Development of a CMI SOP.*

OTM 33 Section 9.4.4: *Pre-deployment CMI testing.*

OTM 33 Section 9.4.5: *In-field CMI calibration checks.*

OTM 33 Section 9.4.6: *Post acquisition CMI comparisons.*

OTM 33 Section 9.5: *Quality assurance of GPS instrument.*

OTM 33 Section 9.6: *Quality assurance of meteorological inst.*

OTM 33 Section 9.6.1: *Manufacturer calibration.*

OTM 33 Section 9.6.2: *Pre-deployment quality assurance checks.*

OTM 33 Section 9.6.3: *In-field DQI checks.*

OTM 33 Section 9.6.3.1: *Operator reasonableness checks.*

OTM 33 Section 9.6.3.2: *Multiple instrument comparisons.*

OTM 33 Section 9.6.3.3: *Comparison with secondary data.*

OTM 33 Section 9.6.3.4: *Auto-north function check.*

OTM 33 Section 9.6.3.5: *Wind speed check.*

OTM 33 Section 9.6.3.6: *Post acquisition DQIs.*

OTM 33 Section 9.7: *Quality assurance of auxiliary equipment.*

9.2 General QA requirements for OTM33A. In addition to the general quality assurance guidance described in Section 9.1, OTM 33A has quality control requirements specific to the sub-method. Since OTM 33A GMAP engineering designs and field applications can vary, specific procedures for operation and calibration of utilized instrumentation and site-specific analysis of method applicability and potential interferences are required. These details should be present in a PSQAP that should also include descriptions of the overall measurement and data quality objectives (DQOs) and other considerations. The U.S. EPA provides significant resources to assist in quality assurance planning (http://www.epa.gov/QUALITY/qapps.html).

In simplified form, it is critical to understand the measurement objectives, the intended use of the data, and the measurement error tolerances for the project. It is important to understand and define the DQOs and the circumstances under which the planned measurement activities may not meet those objectives. It is important to develop in-field and analysis data quality indicators (DQIs) to help monitor operations and assess performance against DQOs. With this understanding, the necessary performance characteristics and operational considerations of the measurement equipment and SAMs can be confidently identified, evaluated, and executed.

As an example of basic deployment-specific QA considerations, Section 8.6 of this method describes a near-field direct assessment EQ approach with inverse emission estimate algorithm called PSG. Quality assurance information associated with this SAM is described subsequently. This stationary measurement EQ approach is designed for use in relatively open areas with few near-field obstructions (NFOs). Much of the validation testing of this approach was performed in open-area scenarios and under these conditions the performance of the inverse emission estimate is fairly well understood. Use of this EQ approach in a heavily wooded area where a significant number of trees separate the source and observation location or in an urban canyon environment would constitute non-standard applications of the method. The performance of the EQ approach in such scenarios is unknown and the uncertainty of the measurement would be much higher to the point that the DQOs for a specific project may not be achievable. These factors must be considered in the planning stage of the project and ways to inform measurement capability (e.g. replicate measurement, in-field validation testing, etc.) may be required.

9.3 Remote measurement QA procedures. As described in multiple sections of OTM 33 and OTM 33A, remote (off-site) measurement approaches cannot be as prescribed or controlled as direct source or ambient measurements. Remote measurement approaches possess potential method interferences (OTM 33 Section 4, OTM 33A Section 4 and Section 8) that have little analog in their traditional on-site or ambient counterparts. These potential method interferences can affect the data quality, assessment certainty, and the strength of conclusions. For this reason, remote measurement approaches must rely on a combination of pre-deployment approach validation, in-field DQIs, and post-acquisition QA analysis procedures to support measurement certainty and evaluation of data against project DQOs. This level of QA procedure builds on the QA foundation of proper operation of equipment and application of techniques as per method prescriptions and SOPs.

Example QA procedures useful for support of remote measurement approaches are contained throughout OTM 33 and OTM 33A. For example, OTM 33 Section 9 describes data comparisons between instruments and auxiliary measurements (e.g. canister to CMI), and OTM 33A Section 8 describes repeat transects under different meteorological conditions and route planning to circumnavigate sources. Auxiliary data such as site photos, co-emitted compound analysis, and secondary information about the source (range of potentially emitted compounds) can be useful. Repeat measurements can be an important tool in assessing uncertainty and supporting conclusions. In general, post-acquisition combination of data forms to support or challenge the reasonableness of conclusions is an important aspect of remote measurements. As opposed to traditional direct-source or ambient measurements, the user of remote measurements approaches has a greater degree of responsibility to use available data forms to prove that the data and conclusions are sound in the context of the specific application and its DQOs.

9.4 QA for CM applications. Several OTM 33A CM application considerations are described in Section 8 of this method. QA for CM applications includes execution of pre-deployment and in-field system testing of instrumentation as per SOPs. Post-acquisition comparison of CMI, GPS, and meteorological instrument performance is important (OTM 33, Section 9). The most important QA consideration for CM applications is ensuring high levels of data completeness which is facilitated by development and use of in-field DQI checks. Since instrumentation used in mobile applications experiences more mechanical vibrations and potentially exaggerated environmental temperature swings (compared to laboratory environments), it is important to ensure that the instruments remain within operating parameters through use of in-field DQIs.

If a CMI or GPS goes off-line during a mapping survey, it is important to detect the malfunction as soon as possible and take corrective action. GMAP system designs that allow the user to quickly verify the functional state of equipment are preferred for this reason. Development of periodic simple in-field checks, such as pausing off road, away from sources for a period of two minutes each hour to acquire stationary meteorological, GPS, and background CMI data for immediate in-field reasonableness checks (OTM 33A Section 9) and more careful post acquisition data precision and secondary data comparisons are good practices.

9.5 QA for SC applications. OTM 33A SC applications can include a range of special transect mapping and auxiliary data gathering activities including photographic records, infrared camera images, determination of observation point to source distances, and collection of evacuated canister or other physical samples. Each of these SC functions may have necessary operating and quality assurance procedure that should be specified in the PSQAP (see section 8.5). For example, for evacuated canister acquisitions, it is critical that the preparation (cleaning), set up, storage, shipping requirements, and proper laboratory analytical procedures are followed. Examples of preparation and analysis SOPs for a particular evacuated canister analytical series are contained in Appendices G1-G3.

9.6 QA for EQ applications. The OTM 33A Direct Assessment (DA) EQ approach is described in Section 8.6 of this method. OTM 33A EQ applications measure or estimate source emission strength from remote vantage points. OTM 33A EQ data analysis of measured compounds is accomplished by combining time-resolved concentration and wind measurements (and potentially vehicle motion data and other information such as source distance) with a suitable inverse source emission strength estimation algorithm, while applying data acceptance QA requirements. The current QA discussion centers on a specific stationary observation and inverse analysis approach called Point Source Gaussian (PSG) which is described in Section 2.6 and Section 8.6 of this method. Other embodiments of OTM 33A based on mobile applications or other inverse source emission strength algorithms are possible.

9.6.1 Validation of EQ approaches. One of the primary quality assurance tools for remote measurement approaches is technique performance testing using a simulated source in a realistic environment. This procedure is also called a controlled release test. These tests should be conducted with source arrangements similar to that encountered in the field and be executed under a range of atmospheric conditions and observation to source distances. The controlled release tests provide the opportunity to examine the GMAP system as a whole (e.g. combined CMI and wind field data, sampling system delay, etc.) and additionally allow important in-field and analysis DQIs to be developed and tested. A schematic diagram of a controlled release test is shown in Figure 9-1.

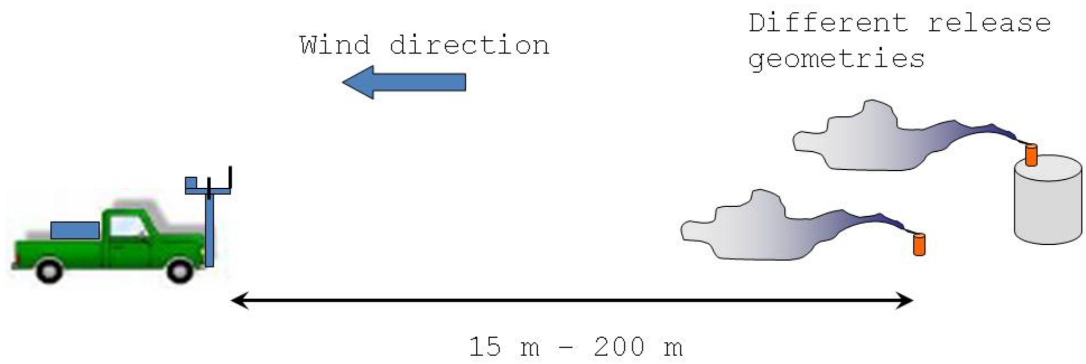

Figure 9-1. Schematic diagram of a controlled release test

The following example describes the controlled release tests conducted during the development of the PSG EQ approach. The PSG approach was initially developed for upstream oil and gas applications and is appropriate for use on relatively small, near ground level sources such as emissions from oil and gas production pads. The target analyte for oil and gas measurements is usually methane and the controlled release experiments described here were conducted using 99.9% methane high pressure cylinders as the gas supply. A gas release system was developed that could simulate a slightly dispersed emission, similar to an open condensate tank thief hatch. Figure 9-2 shows the release system that consists of an open steel bucket into which the release gas is dispersed using a simple perforated tubing arrangement. Other necessary components include the release gas cylinders, a two-stage regulator, safety equipment, teflon tubing, tools, and ideally a calibrated mass flow controller to control the release level.

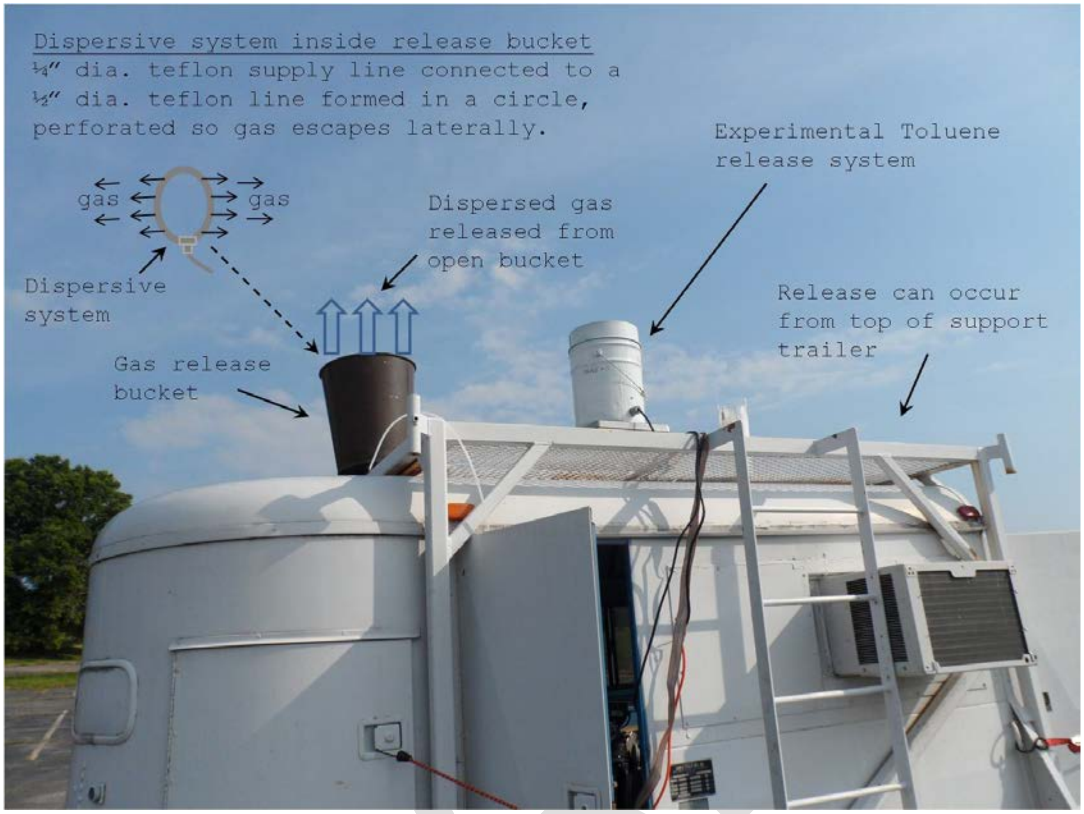

Figure 9-2. Example of one possible controlled release set up.

In Figure 9-2, the release bucket is attached to the top of a field support trailer. This is an example of one release geometry where the emissions point is elevated and the wind flow around the trailer simulates the wind flow around a condensate tank. Other release geometries include near ground-level releases (with the release bucket attached to a tripod) in complete open environments and releases near obstructions such as ground release near the base of the support trailer or other obstruction. Also shown in Figure 9-2 is an experimental release system for toluene which uses controlled vaporization of a liquid source instead of a high pressure gas supply with release rate monitored by weighing.

9.6.2   Example of controlled-release testing. This section provides an example of EQ validation testing by summarizing OTM 33A PSG controlled release test results executed from 2010 through 2013. The results are described in terms of preliminary Data Quality Indicators

(DQIs) that can assist in determination of viable method execution by identifying potential method interferences (Section 4). Alternate OTM 33A EQ techniques may have different method interferences and DQIs. Refer to the PSG data analysis section (Section 12) and OTM 33A Appendices F1 and I for details of analytical procedures, data from controlled tracer release trials, and the calculation of example (experimental) composite DQIs.

The controlled release trials presented here used single point releases from slightly dispersed, mass flow-controlled of 99.9% methane$_4$ cylinders, performed at a variety of site locations, observation distances, and under a range of atmospheric conditions (Section 9.6.1). Release rates ranged from 0.19 g/s to 1.2 g/s with the majority of values at approximately 0.6 g/s. The accuracy of the release rates were within +/- 10%. The percent error of the measured release calculated as:

-1*(nominal release rate - measured rate)/nominal release rate **Eq. 1**

The PSG controlled release trials consisted of 107 separate nominal 20 minute observations conducted over 15 deployments at seven different field sites. The trials were conducted using three different GMAP vehicles (and CMIs) and a variety of release geometries. The presented data are believed indicative of real-world field observations conducted in relatively open, obstruction-free areas with hard pan (dirt, scrub)or short grass(<0.3 m) ground cover, similar to that encountered in typical oil and gas field deployments in Western U.S States. Not included in this summary are n = 17 trials that were not indicative of the typical field applications or experienced equipment failures;[n = 7 on black asphalt parking lot surrounded by trees (Section 4.7), n = 3 observation point behind tree (Section 4.5), n= 7 either below minimum distance, observation time, or other malfunction]. The average percent error of this excluded set was -6%, (min = -99%, max = 123 %).

The 107 field-typical controlled release trials, without application of DQIs, produced an overall average accuracy value of 2% (min = -87%, max = 184%); data contained in Appendix I. Based on the data, a number of DQIs were developed to aid in determination of inaccurate PSG assessments (e.g. presence of method interferences, Section 4). Three primary DQIs were determined to be: (1) fitted peak CH_4 concentration centered within +/- 30 degrees of the source direction; (2) an average in-plume concentration greater than 0.1 ppm; and (3) a gaussian fit with an $R^2 > 0.80$. The plume centering DQI (also called Bin QA) helps to identity the upwind source interference and poor plume advection conditions. The concentration limit helps protect against insufficient plume transport and the R^2 indicator helps identify interfering sources and obstructed wind flow conditions. As a special case, the 184% overestimate is believed to be due to pooling and release under partially stagnant conditions and a trial wind variance DQI was developed for this case.

For the 107 primary controlled release trials, 74% meet the above primary DQIs. The percent error of this subset ranged from -60% to 52% with 71% of the measurements within +/- 30% of actual. Figure 9-3 shows the results of the controlled release trials for each release rate using the primary DQIs.

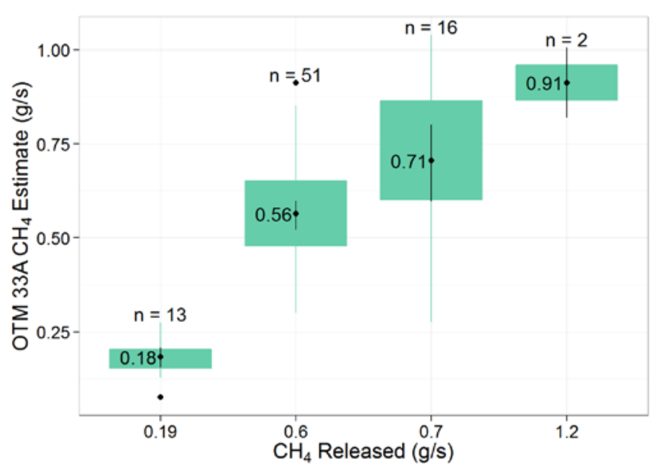

Figure 9-3. Summary of release trials by release rate for data that meets primary DQIs

In addition to the primary DQIs described above, additional DQIs and the formation of a combination of DQI (composite DQI) may be useful in determination of OTM 33A method interferences. The following discussion provides examples of additional DQIs that are part of the current version of PSG analysis. The Matlab code outputs data into a Microsoft Excel™ file (Appendix I) that contains embedded calculations to produce the individual parameter DQIs (columns CR to DW with primary DQIs contained in columns CR to DM). The composite DQI (preliminary example) is contained in column CN and is the calculated as the summation of the individual DQIs values for the parameters contained in columns CR-DM. Potentially important individual DQIs include checks for:

- Count DQI (insufficient data), check value dependent on data acquisition rate
- Low wind speed, unstable atmospheric conditions, and low CMI level (poor plume transport, underestimate potential)
- High CMI level (non-representative concentration, overestimate potential)
- Higher than normal wind speed variance (potential for stagnant pooling followed by puff flow, overestimate potential)
- Gaussian Fit DQIs (poor data quality, multiple sources or NFOs)
- Plume centering or Bin QA (off-center plumes, possible source miss-assignment/interference, or poor plume transport)
- Sig y DQI, (departure of fitted sigma and lookup table)

As seen by examining the cell calculations in Appendix I, these expanded DQIs can have progressive threshold values that may differ from the simple primary DQIs previously described. In this concept, multiple DQI flags carry a numerical value (e.g. 1, 3, 5,…) and can be added together to form a composite DQI. A high value for a composite DQI could indicate the presence of one or more method interferences. This approach, which is in draft form, can provide some practical tuning capability for in-field detection of inaccurate measurement scenarios for a particular OTM 33A application. Examples provided here are based on the controlled tracer release PSG studies and alternate OTM 33A EQ approaches would require separate analysis (release studies) and DQIs may differ. Future revisions to the DQIs are expected.

It is instructive to examine the 107 controlled release trials in terms of various experimental parameters along with the expanded DQIs. In Figures 9-4 through 9-11, the PSG emission measurement from the individual release trials are represented by the closed black data points where the error bars represent +/-1 one ASI unit and serve to illustrate the degree to which an uncertainty in atmospheric conditions can affect the data. If a data point departs significantly from the release band then the error is likely caused, at least in part, by non-atmospheric factors, such as a non-representative concentration profile. In Figure 9-4 (only), the average of all measurements that pass DQIs is shown as the right-most green square data point (PSG Avg.), with error bars representing +/- 1 standard deviation in the data. As can be seen, even though individual data points error can vary, the overall average is relatively close the nominal release value.

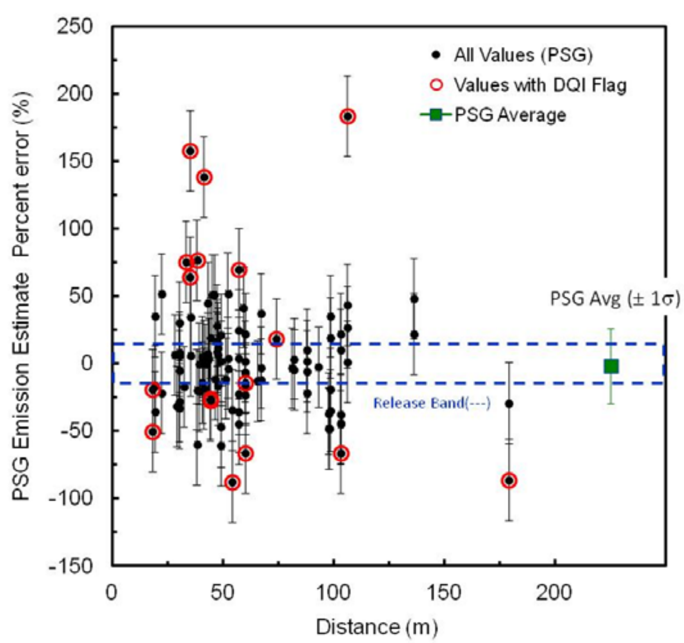

Figure 9-4. Summary of release trials by observation distance

The red-encircled data points are values that exceed the preliminary composite DQI threshold for the measurement. In Figures 9-4 through 9-10, the DQI flagged entries are those with composite DQIs equal to or greater than threshold value of 9 (appendix I). The composite DQI can help identify results with larger than normal uncertainty but in some cases also flags results with low error, close to the release band. In those cases there may off setting error factors (some creating an overestimation condition and some underestimation) which happen to cancel. This exemplifies the inherent uncertainly with rapidly-executed, single point inverse remote measurement methods and speaks to the general importance of repeat measurement in to reduced uncertainty.

In the Figures 9-5 through 9-11, the results of PSG EQ controlled release testing are plotted against various experimental parameters. By looking at the performance of the PSG analysis approach versus different parameters, some indication of bias trends can be found and the parameter range over which the controlled release experiments were conducted can be understood. Ideally this range would be similar to that encountered in the field. Figure 9-5 shows release results versus average wind speed during the measurement. The majority of results are below 4 m/s and this is due to the fact that many of the trials were conducted near EPA facilities in North Carolina where winds speeds are

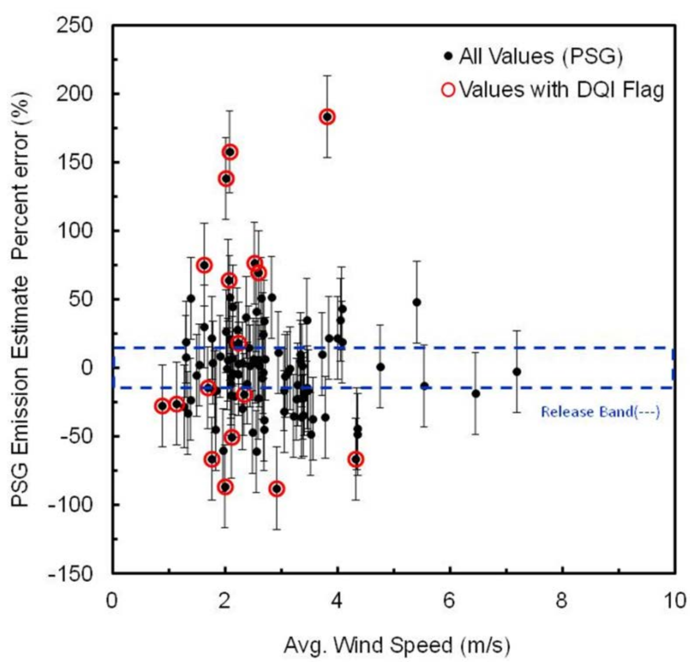

Figure 9-5. Summary of release trials by wind speed

relatively low. There is no indication that the DQI-flagged results are wind speed dependent nor does there seem to be an obvious bias trend versus the wind speed parameter. Accuracy for most remote measurement approaches are expected to improve with higher wind speeds as advected transport generally improves.

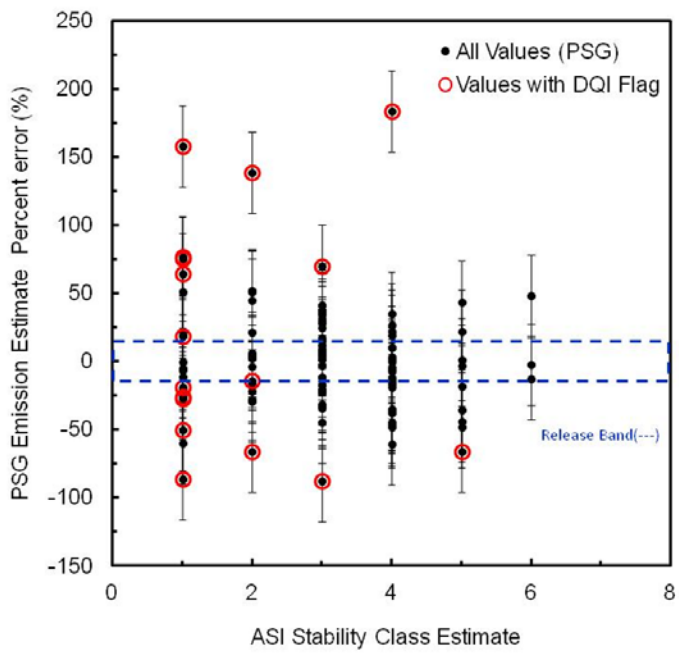

Figure 9-6. Summary of release trials by ASI

Figure 9-6 shows the PSG controlled release results versus the atmospheric stability indicator (ASI) described in Section 12 and Appendices F1 and I. Here the number of values flagged by the composite DQI increases at lower ASI values. This result is somewhat expected as less effective plume transport occurs at lower ASI values. It is possible some overestimates at low ASI could be caused by non-representative concentration profiles due stagnant wind conditions or by NFO interference which can also affect the determination of turbulent intensity and wind direction variations that form the ASI calculation.

Figures 9-7 and 9-8 show similar results as to Figure 9-6 with somewhat higher uncertainty (low bias) with decreasing effective plume transport. This is to be expected since the ASI is an average of the turbulence intensity (TI = u'/U), measured by the 3D-sonic anemometer and the standard deviation in 2-D wind direction ($\sigma\theta$), acquired by the compact met station. Again, here overestimates may be caused by non-representative concentration profiles that be created by various conditions including NFOs (Figure 4.3B), or in some cases puff-flow under highly variable wind speeds. In this case, the release gas is accumulated under stagnant conditions and then transported in mass to the observer creating higher than normal instantaneous concentrations.

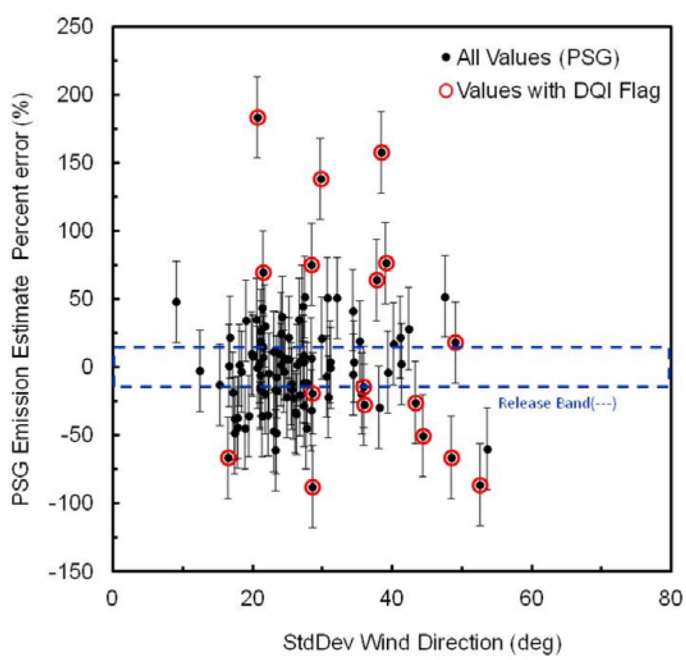

Figure 9-7. Summary of release trials by standard deviation in wind direction.

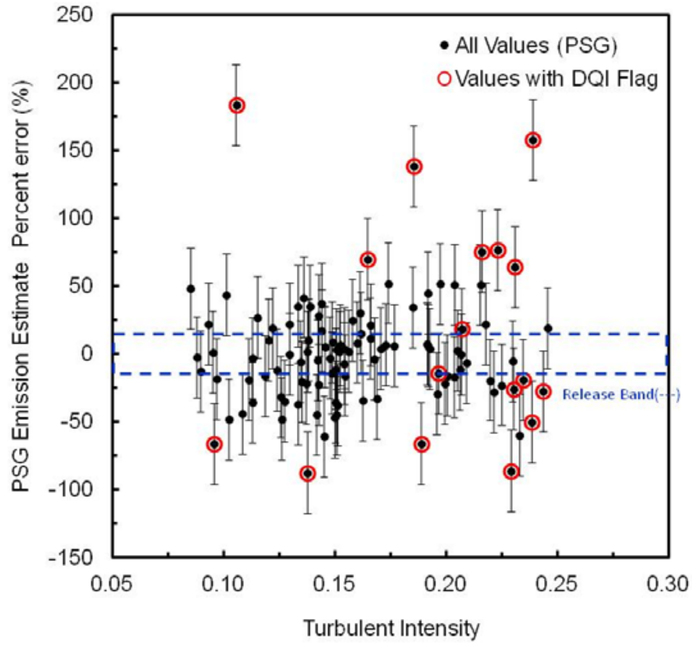

Figure 9-8. Summary of release trials by turbulent intensity

Figures 9-9 and 9-10 show release results versus the PSG-established average plume concentration (above background). The same data are displayed on two different scales (0 to 10 ppm and 0 to 2 ppm). In general, there does not seem to be a bias trend with respect to CMI data; however, the effects of insufficient plume transport under low wind speed and low ASI levels are evident in the PSG underestimates near 0.1 ppm (Figure 9-10). This is an example of lack of plume overlap with the sampling probe as in Figure 4-2B (non-representative concentration profile, low bias). The overestimates on the other hand are likely due in part to non-representative concentrations producing a high bias, some of which are due to NFOs (as in Figure 4-3B).

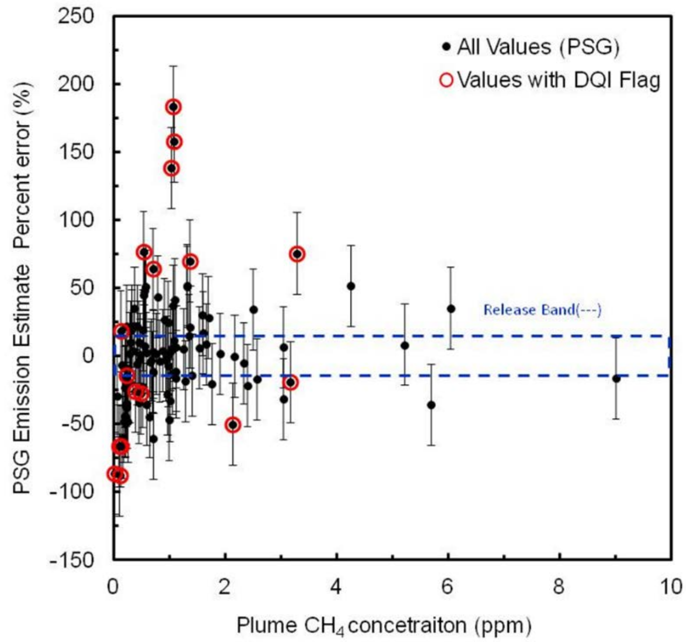

Figure 9-9. Summary of release trials by plume concentration (all values).

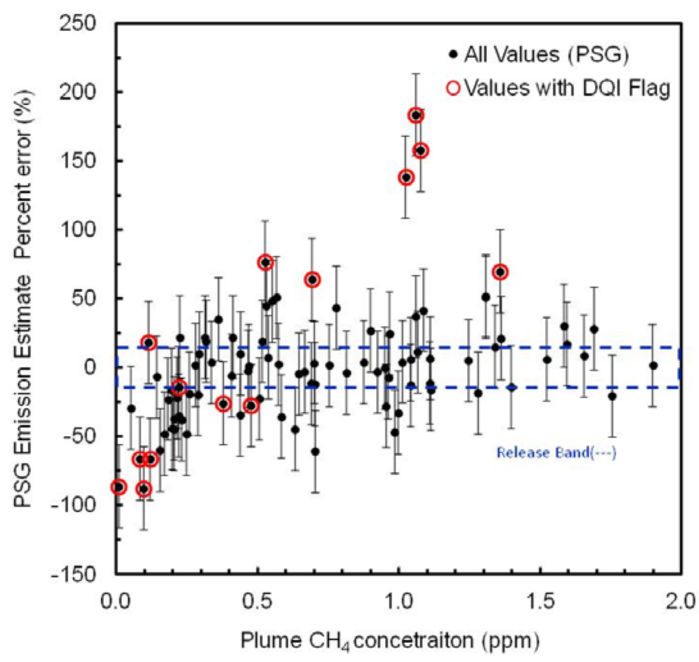

Figure 9-10. Summary of release trials by plume concentration (0 to 2 ppm).

Figure 9-11 shows the PSG emission estimates for the controlled release tests plotted against the values of the preliminary composite DQI. Figure 9-11 shows that the controlled release values that have the highest error many times have elevated composite DQIs. Since individual and the composite DQI were empirically determined based on the release results, this result is to be expected. As draft method OTM 33A evolves and is used in other applications and by other groups, it is hoped the preliminary DQIs will be become well understood and optimized to identify the most sensitive DQIs and ideally, link measurement uncertainty as the composite DQI value.

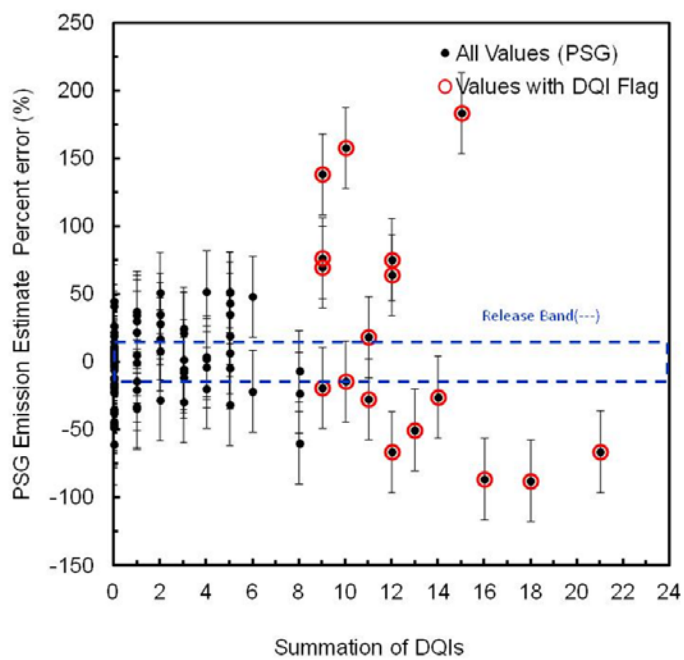

Figure 9-11. Summary of release trials by the composite DQI.

In a similar manner to Figures 9-3, Figure 9-12 summarizes the 107 controlled tracer release trials by release rate at using composite DQI threshold less than or equal to 10. For this selection criteria, 90% of the data are retained and the percent error of this subset ranged from -66% to 139% with 66% of the measurements within +/- 30% of actual.

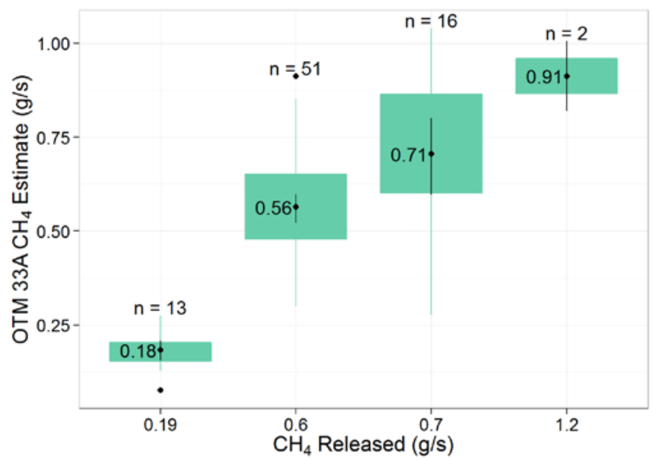

Figure 9-12. Summary of release trials by release rate for the composite DQI less than or equal to 10.

9.6.3 In-field QA for EQ applications. In-field quality assurance procedures for EQ applications begin with proper execution of operational and calibration SOPs and DQI checks of utilized equipment and instrumentation as specified in SOPs and the PSQAP. The next step in EQ quality assurance is proper field execution of the measurement method which requires considerations for correct placement and orientation of the GMAP-measurement vehicle in the source plume at a safe and appropriate downwind observing location (section 8.6). An important quality assurance step is to minimize near-field obstructions (NFOs) and produce records (photographs etc.) of the site consideration and the presence of potentially interfering NFOs for post-acquisition analysis consideration. Other important in-field QA points are described in OTM 33 Section 9 and OTM 33a Section 8.6 are:

- Develop and use quick DQI checks to verify instrument operation
- Use a quality range finder to measure source distances
- Look for potentially interfering sources
- Use real-time wind direction and concentration DQIs(Figure 8.7)
- Conduct repeat measurements
- Use proper data recording and archiving procedures
- Use sound sample collection, storage, and custody procedures

9.6.4 Post field acquisition QA for EQ. As described in OTM 33 Section 9, and OTM 33A section 8, there are a variety of post-acquisition comparisons that can be executed that ensure measurement quality including:

- Instrument to instrument comparisons
- Instrument to secondary data comparisons
- CMI to canister comparison
- Comparison of GPS to Google Earth™
- Comparison of measured source distances to Google Earth™
- Reconciliation of EQ data with knowledge of source

9.6.5 Analysis QA for EQ. See section 9.6.2 for a discussion of EQ analysis DQIs for the PSG approach based on validation studies. It is important to combine analysis QA outputs with the knowledge of the site and other SC and CM data to assist in interpretation of results.

10. Calibration and Standardization. OTM 33 and 33A field applications are typically executed using air quality and meteorological instrumentation that requires pre-deployment and in-field calibration check procedures partially outlined in the general quality assurance discussion (OTM 33 Section 9). Specific procedures and requirements for calibration and standardization will be dependent on the OTM 33A application and GMAP-REQ system design (utilized instrumentation) and should be detailed in the PSQAP.

For CMI calibration, compressed gas standards and procedures must be specified be to allow in-field verification of instrumentation at prescribed frequencies and performance tolerances necessary to meet the DQOs for the project. For meteorological instrumentation, general guidance on the calibration and standardization procedures can be found in references contained in OTM 33.

11. Laboratory Analytical Procedures. OTM 33 and 33A field applications are typically executed using air quality and meteorological instrumentation that does not require collection of laboratory samples. In some cases evacuated canister or other “grab sample” approaches may be utilized to inform source characterization, to provide comparative analysis with CMIs, or to extend source analysis to compounds not directly measured by the CMI. Collection, preservation, storage, and analytical procedures associated with field-acquired laboratory samples are detailed in the PSQAPs.

An example of evacuated canister cleaning and analytical standard operating procures is contained in Appendix G1-G3. As other examples of potential laboratory analysis, see references 5-7.

12. Data Analysis, Calculations and Documentation.

12.1 OTM 33a Data analysis and documentation procedures. OTM 33A data analysis, calculation, and documentation procedures are dependent on the data type (CM, SC, EQ, auxiliary data, or collected sample) and on the prescriptions of the utilized technical approach (e.g. PSG, bLs, or other EQ calculation and QA approaches), and on the specific documentation requirements for the project. These details should be included as part of a PSQAP. Some general considerations and examples are discussed below with suggestions on documentation contained in OTM 33.

12.2 CM data analysis considerations. First-level analysis of CM data is usually accomplished by displaying the information in a custom user map or by using a commercial product, for example Google Earth™ or a GIS platform. Examples of this type of data display are contained in Figures 2-2, 2-3, and 8-1 through 8-4 of this method. The display can be easily accomplished by loading a subset of information from the GMAP data file into Google Earth™ (or GIS platform) using the tools provided in the software. The imported file is usually in CVS text format and includes GPS latitude, longitude, and CMI data (at a minimum). Other information, such as lateral wind data can be included and some commercial mobile monitoring packages (e.g. Picarro Surveyor™, Picarro

Inc. Santa Clara CA, USA) utilize sophisticated mobile measurement display and analysis capability to aid in triangulation of detected emission points. The EPA GMAP control software (Appendix C) has a built-in transect map capability (Figure 8.2) and contains a tool to properly format the data for direct input to Google Earth™. Operational procedures for these functions are contained in Appendices D and F1.

More advanced analysis of GMAP CM data can be accomplished by plotting multiple transects in the display software or by special analysis and comparisons of transects (e.g. Figures 8-5 and 8-6) using spreadsheet type software. More advanced scientific data analysis software programs can be used to compare multiple transects and display data in multiple dimensions. These techniques can be useful for understanding interferences that may be present. Figure 12-1 shows an example of plotting multiple transacts to help identify and remove non-target interferences, in this case caused by a carbon monoxide (CO) emission from a passing vehicle. Here the large CO spikes are evident on some transect routes (or laps) and use of special processing techniques can remove these spikes.

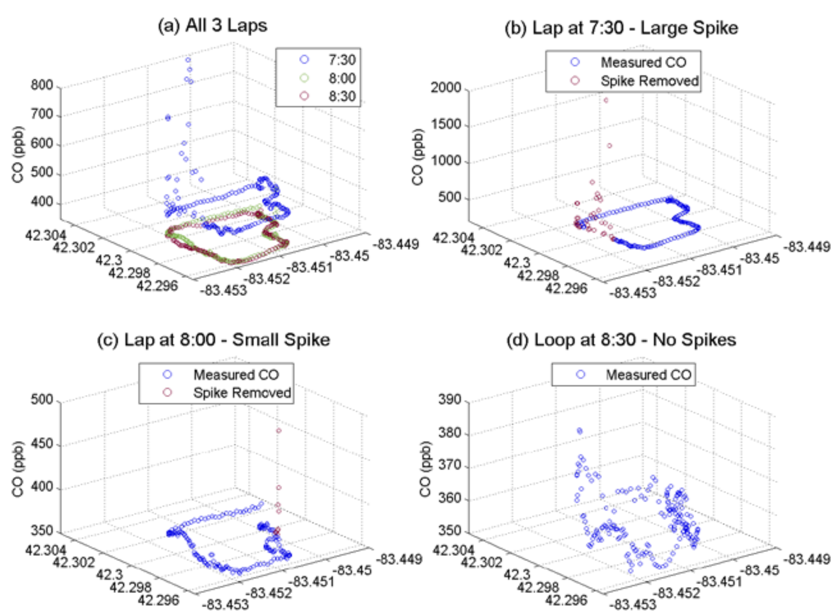

Figure 12-1. Example of multiple transect plotting to help identify and remove non-target source interferences.

12.3 SC data analysis considerations. Source characterization data analysis for OTM 33A usually pertains to special CM transect mapping, upwind-downwind comparisons, and/or to analysis of collected samples like evacuated canisters. Reference Section 8.6 for a general discussion on SC data analysis applications and Appendices G1-G3 and reference 5-7 for examples of laboratory analytical procedures.

As described in Reference 3 (Appendix H1), it is possible to utilize canister-derived concentrations in conjunction with CMI data and EQ procedures to develop an estimate of emissions for compounds not directly measured by the CMI. The procedure involves determination of the target analyte emission level (by PSG EQ for example) in addition to the average of target analyte concentrations measured by the CMI during the canister acquisition. This is followed by using the laboratory provided canister values, an estimate of other compound emissions can be gained through the following calculation:

$$F_c = [(C_c * F_o)/C_o]\ [M_c/M_o] \qquad \text{EQ-1}$$

Where:

F_c = the emissions estimate of a canister compound

C_c = the measured concentration of the canister compound

F_o = the determined EQ of the target analyte (measured by CMI)

C_o = the target analyte concentration (measured by CMI)

M_c = the molecular weight of the canister compound

M_o = the molecular weight the target analyte

The above procedure can be strengthened if it is possible to compare the integrated CMI signal from the target analyte with a canister-derived average concentration value of the safe analyte. It is also noted that this procedure does not account for background concentration of the canister compound that may be in the plume. If significant background concentrations are possible, an overestimate of emissions will likely be produced and other measures (such as an upwind canister acquisition) may be necessary to understand this factor.

12.4 EQ data analysis procedures and considerations. Emission quantification (EQ) under OTM 33A may be accomplished in principle with a variety of inverse emissions estimation schemes. Proper documentation, validation, and quality assurance procedures should be developed for each developed EQ approach. Primarily discussed here is the PSG EQ approach. The data analysis procedures for the PSG approaches along with the analytical software to execute the analysis are contained in Appendix F1 and discussed in brief below with text largely produced from Reference 3, Appendix H1. Another EQ approach, d backwards Lagrangian stochastic (bLs), is also briefly described.

As a general note, in any remote measurement approach, factors such as plume to measurement location overlap (concentration representativeness) and wind flow obstructions can complicate downwind emission assessments and limit accuracies. Some improvements in remote measurement performance can be obtained through use of site-specific configurations, released tracers, or advanced computational models, but these come with increased implementation complexity and access requirements. The near-field OTM 33A PSG approach is designed to be a rapidly deployed inspection method that uses field data acquisition and data quality indicators instead of site-specific configurations or computations to eliminate measurements with high error potential. In its current form, the technique produces a 15 to 20 minute “snap shot” measure of emissions from near ground level point sources at observation distances of approximately 20 to 200 m.

The primary assumption of the PSG EQ approach is that the fixed-position point sensor is able to obtain representative concentration profiles useful for inverse emission estimation. Representativeness implies sufficient sampling time and spatial overlap of the plume and the probe, and the lack of significant symmetry breaking processes such as concentration enhancement by channeling effects. Figure 12-2 provides an example of time and angle-resolved concentration measurements 82 m away from a 3 m elevated simulated tank emission (0.6 g/s CH_4). As wind direction shifts below ≈ 195°, the plume begins to be registered as a combination of high and low frequency events (related to vertical overlap and eddy effects).

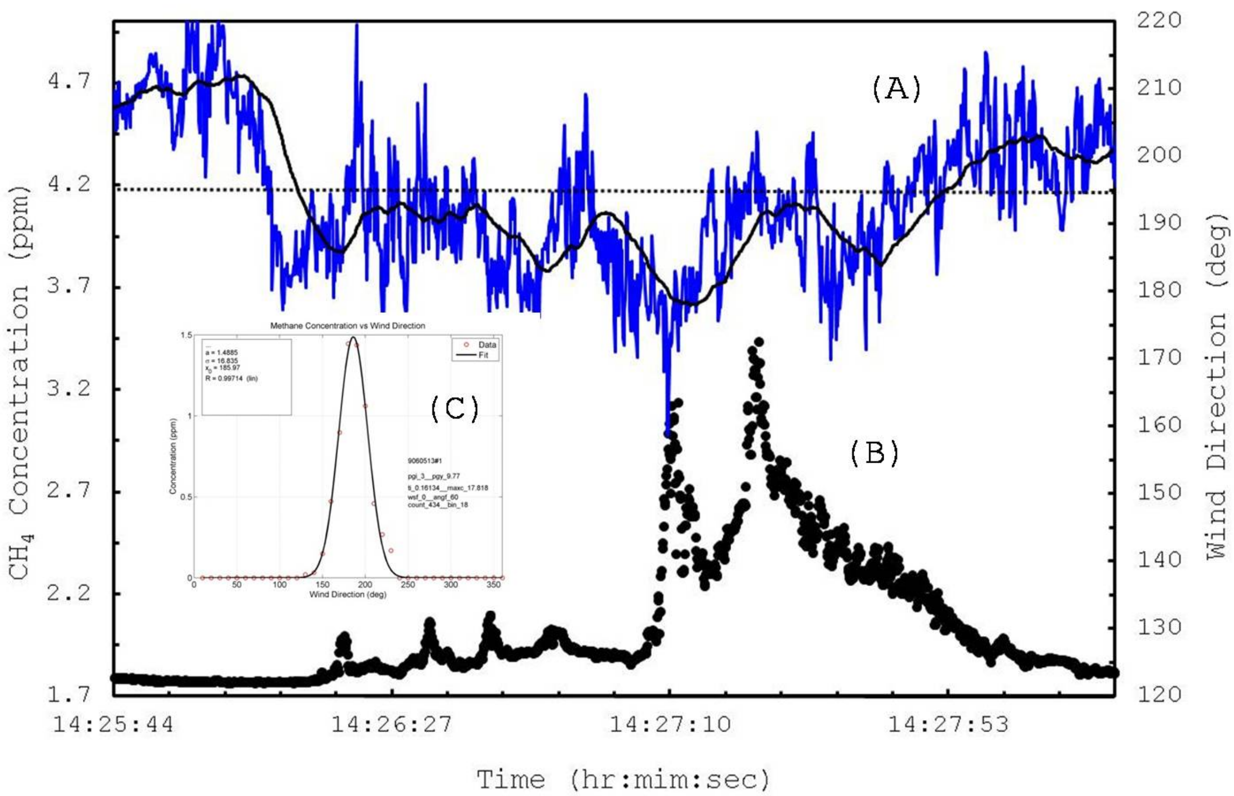

Figure 12-2. Example of simultaneous signals (A) 10 Hz CH_4 concentration data from the CMI and (B) 10 Hz wind direction with 10 second moving average, along with (C) 20-mintue integrated time average by wind direction bin. (Note that 10 Hz measurements are not required for OTM 33A PSG.)

The concentration signal returns to background levels as wind direction trends above 195 deg. If the observation point is well-centered on the emission plume, a 20 minute observation can produce numerous such events like those shown in Figure 12-2(A) and 12-2(B). Combining these events over the entire observation time allows an average concentration vs. wind direction histogram (in ten degree bins) to be constructed and analyzed [Figure 12-2(C)]. The character of the time-resolved profiles (mix of high and low frequency components)changes in complex ways based on distance to source, atmospheric dispersion, degree of wake-induced mixing, and number of sources along the observation direction. Regardless of time-resolved form, with sufficient sampling fidelity, the plume centric, time-averaged concentration carries source mass emission rate information useful for the inverse estimates. The PSG EQ approach assumes these measures can be used to produce reasonable estimates of emissions in a variety of scenarios without evoking site-dependent calculations (i.e. to yield a technique useful for rapid deployment).

Significant use limitations (also described in other sections) are related to spatial overlap of the plume to the observation point, uncertainties in source distance, and heavy obstructions affecting wind flow (trees, fences, etc.). If the height difference between the source and the observation point is too great and/or if too much plume rise exists, the measurement can lead to significant underestimation of emissions through insufficient plume overlap. If the source cannot be identified with confidence or if multiple sources (separated by distance) are present in the angular observation window, the distance utilized in the inverse calculation becomes a key driver of uncertainty. Distance limitations (around 200m) are related to approach assumptions and the necessity to have angular wind sweep generally greater than the plume size. As source size and distance increase, the use of a metered tracer gas becomes a preferred approach but at an increase in implementation burden (subject of a future OTM 33 sub-method called tracer correlation).

Emission estimates can be determined with an algorithm referred to as Point Source Gaussian (PSG), explained in detail in Appendices F1, Appendix F1-B (discontinued version) is the original version of the PSG analysis program, written in MATLAB® (MathWorks, Natick MA, USA). This program was found to have several issues regarding batch process and binning of concretions and has been replaced with updated versions in Appendices F1-F and F1-G. Appendix F1-F contains an updated version of the MATLAB® code with output features similar to F1-B. Appendix F1-G contains a PSG code written in the open source software “R” and has a streamlined output format. Each approach time-aligns the CMI measurements to correct for sampling line delay, rotates the 3-D sonic anemometer data to streamlined coordinates, and bins the CMI concentration data in ten degree increments by wind direction. The binned values are fitted to a Gaussian function to determine the variation of target analyte concentration in the crosswind direction and the peak concentration. The programs calculate a local atmospheric stability indicator (ASI) used in the PSG estimate that is determined from an average of the turbulence intensity (TI), measured by the 3D-sonic anemometer and the standard deviation in 2-D wind direction ($\sigma\theta$), acquired by the compact met station. The ASI ranges from 1 (TI > 0.205, $\sigma\theta$ > 27.5°) to 7 (TI < 0.08, $\sigma\theta$ < 7.5°), roughly corresponding to Pasquill stability classes A-D, in steps of one unit with equal increments (TI = 0.025, $\sigma\theta$ = 4.0°) defining each step.

For the PSG emission estimate, the values of horizontal (σy) and vertical (σz) dispersion are determined from an interpolated version of point source dispersion tables[8] using the measured source distance and the ASI. The PSG emission estimate (q) is a simple 2-D Gaussian integration (no reflection term) multiplied by mean wind speed (u) and the peak concentration (c) determined by the Gaussian fit: ($q = 2\pi \bullet \sigma y \bullet \sigma z \bullet u \bullet c$).

The PSG data analysis programs (Appendix F1) also prepare the CMI concentration and 3-D sonic anemometer data for input into an alternate emission estimate scheme called bLs (described in Appendix F2). The bLs approach utilizes the peak concentration and 3-D wind data in a bLs model called WindTrax.[9] The data used for the PSG and bLs approaches are pre-processed using a wind acceptance angle filter (+/- 60 degrees) to improve estimation performance by focusing on data originating from the remote source location. The bLs application using somewhat more powerful open-path CMI measurements is well-validated.[10] The use of the angle filtered, plume-oriented coordinates and concentration data in WindTrax is a nonstandard application of the model developed for this point measurement application to help reduce uncertainty due to atmospheric trending and off-axis source placement that are less of an issue when using open-path measurements with bLs.

See Section 9 of OTM 33A for a description of PSG controlled release studies that investigate the performance of the PSG approach. A basic comparison of the PSG and bLs approaches is contained in reference 3 (Appendix H1).

13. OTM 33A Method Performance.

13.1 General OTM 33 method performance. Refer to OTM 33 Sections 13.1 through 13.4 for a description of method performance requirements for OTM 33 that also apply to OTM 33A (GMAP-REQ-DA):

OTM 33 Section 13.1: *General method requirements.*

OTM 33 Section 13.2: *CMI performance requirements.*

OTM 33 Section 13.3: *Other instrumentation performance requirements.*

OTM 33 Section 13.4: *Required field and site conditions.*

13.1 CMI performance requirement. Of particular importance in OTM 33A applications is the performance of the CMI with regard to potential analytical interferences, detection sensitivity, accuracy, and precision for target analyte measurement in the encountered air matrix. These factors must be well-characterized or serious errors in EQ applications can result. This requirement includes documenting any perceived or potential data acquisition limitations (e.g. non-optimal time resolution, detection limits, etc.) of the CMI for the intended application and how these limitations may affect interpretation of results and the strength of conclusions.

13.2 Wind Field characterization. For most OTM 33A EQ applications, it is necessary to characterize the wind field for proper application of inverse source-strength emission estimate schemes. The method requirement in this regard is dictated by the technical approach, PSQAP, and DQOs for the project

13.3 Method validation and QA. OTM 33A source assessment modes should have a validation basis and sufficient QA measures to allow interpretation of the quality of and uncertainty of the measurement.

14. Pollution Prevention

[Reserved]

15. Waste Management

[Reserved]

16. References

1. U.S. EPA 2014. DRAFT "OTHER TEST METHOD" OTM 33 Geospatial Measurement of Air Pollution, Remote Emissions Quantification (GMAP-REQ), at web site *http://www.epa.gov/ttn/emc/prelim.html*
2. Hagler, G. S., E. D. Thoma, and R. W. Baldauf (2010), High-resolution mobile monitoring of carbon monoxide and ultrafine particle concentrations in a near-road environment, Journal of the Air & Waste Management Association, 60(3), 328-336.
3. Thoma, E.D, B.C. Squier, D. Olson, A.P. Eisele, J.M. DeWees, R.R. Segall, M.S. Amin, M.T. Modrak, (2012), Assessment of Methane and VOC Emissions from Select Upstream Oil and Gas Production Operations Using Remote Measurements, Interim Report on Recent Survey Studies., Proceedings of 105th Conference of the Air and Waste Management Association, San Antonio, Texas. (reproduced in OTM 33A Appendix H)
4. Thoma, E.D., B.A. Mitchell, B.C. Squier, J.M. DeWees, R.R. Segall, C.Beller, M.T. Modrak, M.S. Amin, A.B. Shah, C.W. Rella, R.L Apodaca. (2010) Detection and Quantification of Fugitive Emissions from Colorado Oil and Gas Production Operations Using Remote Monitoring, Proceedings of 103rd Annual Conference of the Air & Waste Management Association, June 22-25, 2010, Calgary, Alberta, Canada. (reproduced in OTM 33A Appendix H)

5. U.S. EPA Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS), at Web site: http://www.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf, (accessed April 12, 2013)

6. VOC analysis by PAMs Ozone Precursor method (EPA/600-R-98/161) at web site: http://www.epa.gov/ttnamti1/pams.html

7. Methane analysis with GC FID using a canister version of EPA Method 0040 (EPA530-R-01-001) at web site: http://www.epa.gov/osw/hazard/tsd/td/combust/pdfs/burn.pdf (accessed January 22, 2012) and percent level CH_4, ethane, ethene, propene, and propane by ASTM D1946/D1945.

8. Turner, D. Bruce, Workbook of Atmospheric Dispersion Estimates, An Introduction to Dispersion Modeling, 2nd Edition, Lewis Publishers, by CRC Press, Boca Raton, FL, 1994, Table 2.5, pp 2-44.

9. Windtrax 2.0 by available at http://www.thunderbeachscientific.com/ , (accessed January 6, 2012).

10. United States Environmental Protection Agency Technology Transfer Network Emission Measurement Center at web site: http://www.epa.gov/ttn/emc/prelim.html (accessed January 26, 2012).

11. Brantley, H.L., Hagler, G..W., Kimbrough, S., Williams, R.W., Mukerjee, S., Neas, L.M. (2013)Mobile Air Monitoring Data Processing Strategies and Effects on Spatial Air Pollution Trends, Atmos. Meas. Tech. Discuss., 6, 10443–10480.