Draft Other Test Method 33: *Geospatial Measurement of Air Pollution, Remote Emissions Quantification*

This test method relates to the general practice of using instrumented, ground-based vehicles to acquire information on air pollutant sources located in proximity to the driving route. Through specific sub-methods of OTM 33, source emissions assessments ranging from near-field inspection of small fugitive releases to whole facility mass emission rate measurements can be executed.

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.

This method was submitted by the EPA’s Office of Research and Development – National Risk Managment Research Laboratory to EPA’s Office of Air Quality, Planning and Standards – Air Quality Assessment Division – Measurement Technology Group (MTG) for inclusion into the Other Test Method (OTM) category on EPA’s Emission Monitoring Center (EMC) website at: http://www.epa.gov/ttn/emc/tmethods.html#CatC/.

The posting of a test method on the OTM portion of the EMC is neither an endorsement by EPA regarding the validity of the test method nor a regulatory approval of the test method. The purpose of the OTM portion of the EMC is to promote discussion of developing emission measurement methodologies and to provide regulatory agencies, the regulated community, and the public at large with potentially helpful tools.

Other Test Methods are test methods which have not yet been subject to the Federal rulemaking process. Each of these methods, as well as the available technical documentation supporting them, have been reviewed by the EMC staff and have been found to be potentially useful to the emission measurement community. The types of technical information reviewed include field and laboratory validation studies; results of collaborative testing; articles from peer-reviewed journals; peer-review comments; and quality assurance (QA) and quality control (QC) procedures in the method itself. A table summarizing the available technical information for each method can be found at the link below. The EPA strongly encourages the submission of additional supporting field and laboratory data as well as comments in regard to these methods.

These methods may be considered for use in Federally enforceable State and local programs (e.g., Title V permits, State Implementation Plans (SIP)) provided they are subject to an EPA Regional SIP approval process or permit veto opportunity and public notice with the opportunity for comment. The methods may also be considered to be candidates to be alternative methods to meet Federal requirements under 40 CFR Parts 60, 61, and 63. However, they must be approved as alternatives under 60.8, 61.13, or 63.7(f) before a source may use them for this purpose. Consideration of a method's applicability for a particular purpose should be based on the stated applicability as well as the supporting technical information outlined in the table. The methods are available for application without EPA oversight for other non-EPA program uses including state permitting programs and scientific and engineering applications.

As many of these methods are submitted by parties outside the Agency, the EPA staff may not necessarily be the technical experts on these methods. Therefore, technical support from EPA for these methods is limited, but the table contains contact information for the developers so that you may contact them directly. Also, be aware that these methods are subject to change based on the review of additional validation studies or on public comment as a part of adoption as a Federal test method, the Title V permitting process, or inclusion in a SIP.

Method History

Version 1.2 – 11/1/2014 – Public release of draft on EMC Website.

EPA advises all potential users to review the method and all appendices carefully before application of this method.

If any end users have data, comments or suggestions related to this method, please contact Eben Thoma, EPA ORD, thoma.eben@epa.gov or Jason DeWees, EPA OAQPS, dewees.jason@epa.gov.

Additional sub-methods and supporting data can be found on EPA's EMC website @ http://www.epa.gov/ttn/emc/prelim.html

DRAFT "OTHER TEST METHOD" OTM 33 (Ver. 1.2)

Geospatial Measurement of Air Pollution, Remote Emissions Quantification (GMAP-REQ)

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.[1-39] 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.

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-methods of OTM 33 detail the method requirements (MRs), performance metrics (PMs), method quality indicators (MQIs) and typical application scenarios for the described approach. One example is a GMAP-REQ approach called "direct assessment" (DA), specified as OTM 33A. 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. Future updates to OTM 33 will include additional sub-methods that describe alternate GMAP-REQ schemes (such as tracer release, mobile flux planes, or site-specific modeling) that serve to extend the range of application of OTM 33.

1.2 OTM 33 relates to the general practice of using instrumented, ground-based vehicles to acquire information on air pollutant sources located in proximity to the driving route. Through specific sub-methods of OTM 33, source emissions assessments ranging from near-field inspection of small fugitive releases to whole facility mass emission rate measurements can be executed.

1.3 OTM 33 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 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. The specific assessment modes are determined by the technical approach and utilized equipment and are detailed in sub-methods to OTM 33 and in project-specific quality assurance documentation.

2. Summary of the Method

2.1 Principle of GMAP-REQ. Under OTM 33, a mobile inspection vehicle is fitted with requisite instrumentation as specified in the sub-method and 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, particulate matter and ultrafine particles, 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 information under OTM 33 can be performed for a wide range of purposes including but not limited to: (1)automated detection of unknown emissions as part of leak detection and repair programs within facilities or production fields, (2)periodic fence line monitoring for inspection applications,(3) gradient-type concentration mapping to investigate the impact of emission sources on the local air shed, (4)characterization of source mass emission rate and other aspects of source emissions using one of a variety of approaches amenable to the specific source characteristics and measurement objectives.

2.1.2 OTM 33 provides the general framework for GMAP-REQ whereas sub-methods and project-related quality assurance documents detail specific methodology, required equipment, use limitations, measurement uncertainty, and QA measures in the context of the application.

2.2 Application of GMAP-REQ

2.2.1 General factors to consider when planning, designing sampling equipment, and executing GMAP-REQ measurements are presented in OTM 33. Specific application details for GMAP-REQ are contained in the sub-methods and the project-specific quality assurance plans (PSQAPs).

2.2.2 In general, GMAP-REQ measurement approaches differ from traditional *ambient measurements* and *direct source measurements* in several ways. Ambient air quality measurements are primarily performed from fixed-placement monitoring stations, with the aim to determine long-term trends in air shed pollutant concentrations. Ambient air quality measurements are usually located away from sources and have well-defined instrument performance requirements with modest time resolution needs. Direct (on-site) measurement of air pollution sources refers to assessment of stack, leak, or tail pipe emissions where the location of the emission and the test procedures are well defined and under strict control. By contrast, GMAP-REQ applications are conducted in the space between traditional ambient and direct source measurements (Figure 2-1) and possess some characteristics of both. GMAP-REQ operates in the "near-source" measurement regime and presents new source diagnostic capabilities not achievable with direct source or ambient measurements. While providing new information, near source measurements cannot be as specified, controlled, or reproducible as traditional ambient and direct source measurements so additional quality assurance and interpretation approaches are required.

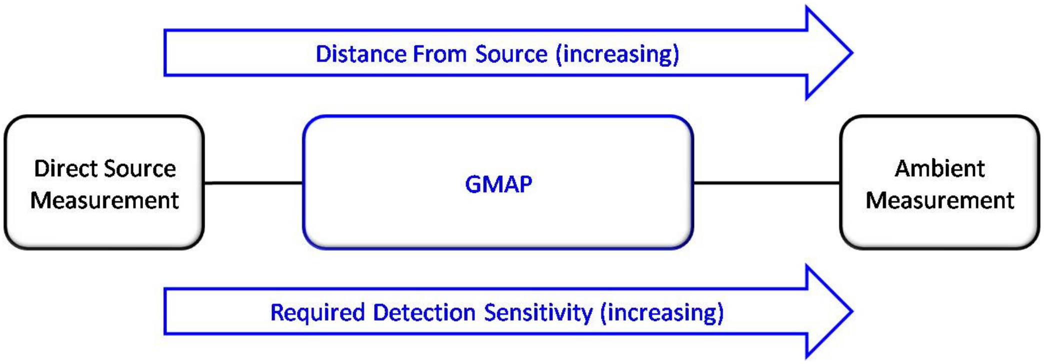

Figure 2-1. GMAP operational regime

2.2.3 GMAP-REQ measurements are affected by interference from background sources, aspects of meteorology, and other factors that can have significant impact on interpretation of data and are beyond the direct control of the operator. Figure 2-2 illustrates a typical limitation of GMAP-REQ source assessment that has no analog in traditional ambient measurement or direct source measurement methods.

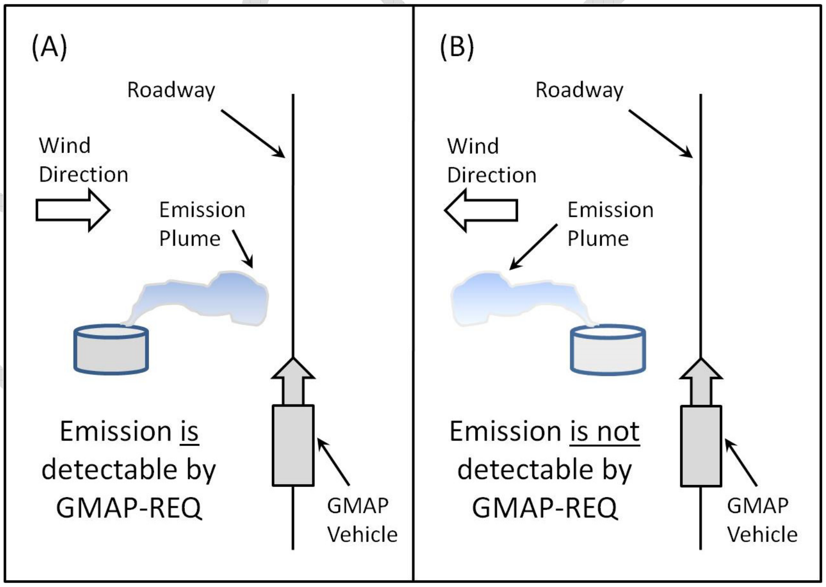

Figure 2-2. Illustration of limitations of near-source measurements: (A)wind transports the plume to GMAP route, emission is detectable; (B)plume does not cross GMAP route, emission is not detectable.

2.2.4 GMAP-REQ systems in general rely on a combination of multiple data forms (location, concentration, wind information, etc.) to provide the necessary information for source detection, location determination, and source mass emission rate assessment. GMAP-REQ air pollutant measurement instrumentation needs near ambient-level detection sensitivity with sufficient dynamic range, and physically robust packages suitable for mobile applications. Relatively high time resolution instruments must be used for data to be acquired at roadway speeds. Since multiple data forms (e.g. concentration, wind direction, position) work in concert, time synchronization of GMAP-REQ data elements to one second-level precision is usually needed.

2.2.5 As opposed to direct (on-site) source measurements, remote source measurements can frequently include superposition of multiple upwind source emissions points (Figure 2-3). GMAP-REQ measurements of combined-source emissions plumes can provide important information on groups of sources but the result must be interpreted appropriately. Repeat measurements under different wind conditions and auxiliary data and site information can aid in interpretation of results.

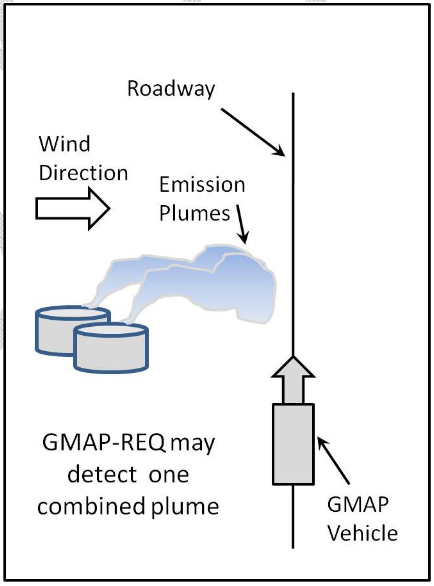

Figure 2-3. Illustration of superposition of multiple source emission plumes detected by GMAP-REQ.

2.2.6 Depending on the GMAP-REQ technical approach, the physical configuration of the source can produce use limitations for the method. For example, if the emissions point is significantly elevated from ground level (e.g. a tall stack), the plume may detached from ground level and not intersect the sampling inlet of the passing GMAP vehicle. Potential GMAP-REQ approaches which utilize extended sampling approaches in the vertical plane, such as mobile solar occultation flux[21,25,26] would successfully intersect an elevated plume.

2.2.7 In contrast to many forms of direct source measurements, the temporal emission profile of the source can have a serious impact on results when using OTM 33 remote measurement approaches. For example, if the emission from the source is periodic in time, it may not be detected during a single drive-by inspection under favorable wind conditions.

2.2.8 Factors that may affect OTM 33 data quality and interpretation of results, such as site specific method interferences and special source properties are described in the PSQAP. Quality assurance planning also includes the technical details of the sub-method and factors associated with the specific equipment utilized. Development and use of MQIs and/or data quality indicators (DQIs) are particularly important for remote measurement approaches. Post-acquisition data analysis quality assurance procedures and data inter-comparisons are important in OTM 33 applications since test conditions are not as controllable as in application of traditional direct source and ambient measurements.

3. Definitions and Acronyms used in OTM 33

3.1 Geospatial measurement of air pollution (GMAP) refers to the family of mobile measurement approaches for air pollution assessment.

3.2 Remote emissions quantification (REQ), as in GMAP-REQ refers to a subset of general GMAP approaches related to detection and assessment of emissions from near-field air pollution sources, the subject of OTM 33.

3.3 Specific sub-methods of OTM 33 provide application prescriptions [method requirements (MRs) and system performance metrics (PMs)], quality assurance information [method quality indicators (MQIs)], and use limitations for a given GMAP-REQ technical approach.

3.4 Source assessment modes (SAMs) refers to the three primary aspects of the GMAP-REQ method: concentration mapping (CM), source characterization (SC), and emissions quantification (EQ), which are explained below. The specific assessment functions are determined by the technical approach and utilized equipment and are detailed in sub-methods to OTM 33 and in project-specific quality assurance plans (PSQAP) and associated equipment design documentation.

3.5 Concentration mapping (CM) refers to the procedures for measuring and recording the concentration of target analytes along the driving route (in the survey area) for the purposes of finding the location of unknown sources and/or to assess the relative contributions of source emissions to local air shed concentrations.

3.6 Source characterization (SC) refers to any GMAP-REQ procedure that aims to improve understanding of the location, variability and or composition of known or discovered source emissions, either through direct GMAP observation or through GMAP-facilitated acquisition of secondary measures (e.g. Infrared camera video, canister grab samples, etc.).

3.7 Emissions quantification (EQ) is any technical approach used to measure (or estimate) source mass emission rate, usually from a remote vantage point, the details of which are contained in the sub-methods of OTM 33.

3.8 Quality assurance (QA) is a general term referring to any activity designed to ensure the method, procedures, or analysis is conducted properly so that the data resulting from the field activities will be of known certainty or quality.

3.9 Method requirements (MRs) represent the general requirements for OTM 33 (GMAP-REQ) as well as specific application prescriptions and use limitations detailed in the sub-methods to OTM 33.

3.10 Performance metrics (PMs) refer to general data acquisition capability requirements for GMAP-REQ with details on any specific equipment design, data acquisition, and analysis procedures detailed in sub-methods to OTM 33, in the PSQAP, and in GMAP-REQ system designs.

3.11 Project-specific quality assurance plan (PSQAP)refers to additional planning details that include but are not limited to: equipment design and operating procedures, pre-deployment instrument testing, instrument calibration frequency, driving route planning, analysis of interferences and method applicability, and QA of auxiliary data for a particular OTM 33 sampling effort.

3.12 Data quality objectives (DQOs) refers to data acquisition and analysis needs (level of certainly, error tolerance, etc.) to achieve the goals or decision points for a specific project. The DQOs are discussed in the PSQAP for a particular application.

3.13 Method quality indicators (MQIs) for OTM 33 and sub-methods form the quality assurance foundation for the successful acquisition and analysis of GMAP-REQ data of known quality. For the purposes of OTM 33 applications, the term “data quality indicator (DQI)”is used interchangeably with MQI.

3.14 Method interference refers to any factor or condition that negatively impacts the execution of the method. Ideally, quality assurance tests, calibration procedures, and MQIs can provide the ability to detect and assess method interferences.

3.15 Near-field obstruction (NFO) is a method interference for GMAP-REQ applications that refers to the effects of objects (such as buildings, shrubs, trees, etc.) on wind flow patterns near sources. Depending on the sub-method technical approach, NFOs can negatively impact one or more SAMs.

3.16 GMAP vehicle refers to the instrumented mobile platform used for acquisition of OTM 33 GMAP-REQ data. The GMAP vehicles will have different designs that are based on the prescriptions of the sub-method.

3.17 Global positioning system (GPS) is a GMAP instrument used to determine the time-resolved spatial position of the GMAP vehicle during driving and stationary observations.

3.18 Concentration measurement instrument (CMI) refers to the device(s) used to determine the concentration of the target analyte (air pollutant or GHG of interest).

3.19 Meteorological instrument (MI) refers to the device(s) used to acquire wind speed, wind direction, temperature, atmospheric pressure, and other atmospheric properties necessary for execution of the specific GMAP-REQ application.

3.20 Accuracy: Each GMAP-REQ instrument has a measurement accuracy that is generally determined by comparing a measured value to a known standard, and is usually assessed in terms of percent bias using the following equation:

$$\left[1-\left(\frac{\text{Measurement}}{\text{Standard}}\right)\right]\times 100=\%Bias \qquad \text{Eq. 3-1}$$

The accuracy of GMAP-REQ instruments such as CMIs and meteorological equipment is determined using a combination of manufacturer’s testing and certification, pre-deployment laboratory testing, and in-field accuracy data quality testing. In-field testing of instrument performance is important in order to determine the effects of mechanical vibration, and temperature and background variation encountered in the specific application.

3.21 Precision: The precision of a measurement system can be evaluated by making replicate measurements of the safe parameter and assessing the variations of the results. Precision can be assessed in terms of relative percent difference (RPD), or relative standard deviation (RSD) and should be conducted under field conditions.

3.22 Data completeness is expressed as a percentage of the number of valid measurements compared to the total number of measurements taken. For OTM 33 applications, data completeness is affected by instrument performance and by external factors.

3.23 Data representativeness refers to how well the acquired data represents the actual population or parameter that was intended to be studied. The project-specific requirements for data completeness and representativeness must be well understood for each OTM-33 application so appropriate conclusions based on the observations can be formed.

3.24 Detection limit (DL) generally refers to the minimum concentration at which a CMI can detect the target analyte so as to produce useful information for one or more OTM 33 SAMs. The DL can be defined in the sub-method to OTM 33 but is generally considered to be any appropriately sustained signal that exceeds three times the standard deviation (3σ) of the measured baseline noise (with no source signal present)registered by the CMI for the application. The DL should be established in the mobile format (e.g. in the presence of mechanical vibration, temperature variation, and interfering backgrounds).

3.25 Quantitation limit (QL) generally refers to the minimum concentration at which a CMI can produce a quality measurement of the target analyte for use in one or more OTM 33 SAMs. The QL can be defined in the sub-method to OTM 33 but is generally considered to be any appropriately sustained signal that exceeds six times the standard deviation (6σ) of the measured baseline noise (with no source signal present)registered by the CMI for the application. The QL should be established in the mobile format (e.g. in the presence of mechanical vibration, temperature variation, and interfering backgrounds).

3.26 Dynamic range generally refers to the measurement range of a CMI. GMAP-REQ applications frequently require CMIs with large dynamic ranges as the system must function at ambient levels and in close proximity to emission sources. For example, methane concentrations near oil and gas production sites can range from ambient ($\cong$ 1.8 ppm) to > 100 ppm if in close proximity to the source.

3.27 Operational robustness refers to the ability of GMAP-REQ instrumentation to successfully operate in mobile applications that are subject to temperature variations, mechanical vibrations, and other stresses not typically encountered in traditional ambient or direct source measurement applications.

3.28 Auxiliary equipment refers to any supporting instrumentation or equipment that assists in execution of a specific GMAP application; such as laser range finders, infrared video and standard photographic cameras, mass flow controllers, hand-held GPS, secondary meteorological stations, sampling masts, battery or inverter power systems, etc.

3.29 Sampling system refers to the necessary infrastructure for acquisition of OTM 33 data for a specific application. The sampling system can include requirements for mounting equipment and air inlets away from the body of the vehicle (i.e. mast system) along with prescriptions for acquisition of auxiliary data such as grab samples.

3.30 Control system refers to the necessary data acquisition hardware and software needed to acquire time-synchronized mobile data and execute auxiliary measures from the various instrumentation associated with a given OTM 33 approach.

3.31 Temporal resolution (or time-resolution) refers to the data acquisition temporal frequency for GMAP-REQ instruments. For some systems, this includes both the instrument measurement speed and the time required to refresh the instrument sampling system (e.g. change-over of sampling cell volume).

3.32 Spatial resolution refers to the data density as function of position for mobile applications and is determined by a combination of system temporal resolution and GMAP vehicle speed.

4. Interferences

4.1 Planning for interferences. In contrast to traditional direct source or ambient air quality measurements, OTM 33 applications are inherently less prescribed and are affected by external factors (interferences) to a greater degree. The effect of any potential interference will depend in part on technical aspects of the utilized measurement approach, detailed in the specific sub-method. In addition to interference assessment and use limitations described in the MRs and MQIs of the sub-method, PSQAPs should anticipate interferences on a site-specific basis. For example, the general meteorological conditions, roadway access, distances from potential sources, possible presence of interfering sources, physical dimensions of sources (height, width), and interfering species, should all be considered in pre-deployment planning and in the formulation of measurement goals and DQOs.

4.2 Requisite meteorology interference. A primary interfering condition preventing successful application of any OTM 33 approach is noncompliance with requisite meteorological conditions at(and potentially before) the time of measurement. Each sub-method of OTM 33 will specify individual meteorological requirements.

For CM applications, the measured pollutant concentration level and its spatial variability may look very different depending on atmospheric boundary layer height and ambient wind speed. If atmospheric conditions change during an extended mobile mapping survey, comparisons of intra-survey results can be complicated. For GMAP-REQ source emissions measurements, atmospheric conditions must allow the emission plume from the source to be carried to the observation location with reasonable transport properties. If the wind speed is too low on a bright sunny day (Pasquill-Gifford stability class A), the emission plume evolves vertically and there may be too little advected transport to a distant observing location. By contrast, on a morning with stagnant wind conditions, the emission plume may build into the local air shed raising concentrations uniformly, making it difficult to decipher the source location or its instantaneous contribution during a CM or EQ application. Favorable meteorology includes stable atmospheric conditions with moderate and steady wind speeds and directions.

4.3 Roadway access. Most OTM 33 applications rely on roadway access in the survey area (upwind and downwind of the source). The lack of sufficient roadway access at acceptable distances from the source interferes with the execution of GMAP-REQ approaches.

For CM applications, the survey area should include sufficient range to illustrate changes in concentration. If the measurement objective is to assess gradients in concentration moving away from the source, roadway access must be conducive to executing the planned transects. For SC and EQ applications, the basic premise is usually to characterize the source by moving the CMI around the source. Verifying upwind concentrations and successful positioning in and through the downwind plume are important aspects of source characterization. For some envisioned GMAP-REQ applications such as tracer correlation, there is a minimum observation distance required for assessing large area sources so roadway access of both proper orientation (with respect to wind) and stand-off distance from the source are needed. Additionally, the traffic patterns of available roadways will affect the safe operational conditions for the survey (min-max highway and secondary road speeds, congested traffic, etc.).

4.4 Non-target source interference. OTM 33 applications use mobile CMI(s) to determine spatially and temporally resolved concentrations of one or more target analytes in a survey area or in a specific spatial relation (i.e. downwind) of a source under observation. Any contribution to target analyte concentration that did not originate from the source under observation constitutes a non-target source interference. This category of interference can include (1) slowly varying background concentrations and contributions from very distant sources, (2) near-field non-target sources, or (3) self-contamination from the GMAP sampling vehicle. The degree to which non-target sources affect a particular OTM 33 application depends on a number factors but becomes more complicated in cases where mobile source emissions (either from the sampling vehicle itself or other vehicles on the road) represent potential non-target source interferences. Analysis of the potential for non-target source inferences along with prescriptions for identifying and removing said interferences in post processing must be developed using a combination of method requirements(MRs), PSQAP, and system performance metrics (PMs) for the specific GMAP-REQ vehicle and instrumentation package utilized. For example, GMAP measurements focusing on assessment of mobile source emissions may employ electrical-powered vehicles to eliminate the potential for self-contamination.

4.5 CMI performance interference. The CMIs used in OTM 33 applications can vary from relatively simple gas-phase sensors to more complex instrumentation for assessment of particulate matter concentration and size distributions. The performance of the CMI is a key factor in achieving DQOs for any OTM 33 project. Method interference can be caused by performance failures of the CMI or improper use of a CMI for an application for which it is not appropriate. As part of proper PSQAP procedures, the performance metrics (PM) of the GMAP vehicle and instrumentation packages must be fully understood in an application-specific context.

Many aspects of CMI performance should be considered in the process of instrument selection and system design including detection limit, quantitation limit, dynamic range, accuracy, precision, time resolution, and robustness to mechanical vibration and temperatures changes. With regard to CMI-induced method interferences, a very important factor is the ability of the CMI to discriminate the target analyte and potentially interfering non-target species that may be present in the encountered air matrix (further described in Section 9).

4.6 Source configuration interference. In general, each OTM 33 sub-method is designed to assess a specific source configuration. For example, OTM 33A (GMAP-REQ-DA) is used for mobile assessment of emissions from near-field, near ground-level point sources. Emissions from heights that exceed 25 ft from ground level are difficult to accurately assess using OTM 33A since, depending on observation distance, the centroid of the plume may have a high probability of passing over the sampling probe. Other GMAP-REQ approaches have different use prescriptions and use limitations. The physical properties of the sources should be considered in the PSQAP and the formulation of DQOs for the project.

4.7 Wind flow obstruction inference. Some GMAP-REQ approaches rely on characterization of wind flow fields for EQ determination.

Near-field obstructions (NFOs) such as trees, shrubs, fences, etc. can impact the accuracy of emissions assessment calculations. For some CM applications, NFOs can limit the ability to detect emissions.

4.8 Other measurement instrument interferences. In addition to interferences associated with CMI operation or application, other GMAP-REQ instrumentation must be well characterized, properly installed and operated, and appropriate for the intended purpose. Method interference can occur from improperly aligned or calibrated GMAP-REQ instrumentation. For example, a low quality GPS may produce unacceptable levels of data drop-out interfering with CM applications.

5. Safety.

5.1 General method safety. This method does not purport to address all safety issues or procedures needed when executing OTM 33 (GMAP-REQ) applications. Precautions typical of air sampling field projects are required. Each GMAP-REQ sub-method includes general safe operation requirements. 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 site-specific hazards be understood in the context of the particular sub-method. 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 Project-specific safety planning. Safety planning is a critical aspect of any field measurement campaign and it is recommended that a project-specific safety plan be generated for OTM 33 applications. Acquisition of OTM 33 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 33 is a mobile method, the single greatest safety hazard is likely related to vehicle accidents so minimizing driver distraction is critical. 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.

As part of pre-deployment planning activities, it is critical that information on the locations of nearest emergency services is investigated and communicated to the sampling crew. A GPS navigation system is also useful to find the nearest emergency service or hospital. In some remote locations, such as remote oil and gas fields, it is important to identify emergency response procedures prior to deployments.

Some GMAP-REQ applications require use of compressed gas cylinders for tracer releases and for calibration of equipment. 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 and other hazardous materials be understood and obeyed. It is also critical that health and safety aspects regarding the use of gas cylinders (e.g. https://www.osha.gov/SLTC/compressedgasequipment/) for tracer or calibration functions be included in the site-specific safety plan. In particular, use of acetylene as a tracer gas has several important specific safety requirements due to its flammable and unstable nature. For large tracer 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 need to be followed.

5.3 GMAP vehicle preparation and safety checks. The execution of safe and effective GMAP-REQ measurements starts with proper vehicle preparation. This preparation involves configuration of special components unique to mobile measurements such as the battery supply, instruments, and mast systems, but it also includes basic preparation of the sampling vehicle. General elements of safe vehicle preparation and operation begin with checks on vehicle performance and components including for example:

- Suitability of vehicle for expected terrain
- Tire condition, air pressure, spare tire and jack
- Engine condition, belts, components, fluid levels
- Windshield wipers, headlamps, signals, mirrors, hazard lights

In addition to general elements of preparation, a mobile measurement vehicle requires special preparation for attaching components, the details of which can vary based on equipment design and measurement application but can include:

- Installation of a front or rear mounted trailer hitch
- Connection of mast systems or attachment of external gear
- Removal of rear seats to make room for equipment

- Installation of auxiliary battery systems
- Installation of permanent instrument rack systems
- Securing temporary battery and instrument systems
- Installation of a power inverter and or charging system
- Transport racks for calibration check or tracer gas cylinders

It is important to ensure that special equipment carried in or attached to the GMAP-REQ measurement vehicles is secured properly so it does not shift during driving and that it is sufficiently designed to operate at driving speed. It is critical to understand overhead clearance limitations from tree branches, power lines, and bridges. The GMAP-REQ vehicle should be equipped with tools, traffic safety cones and flares, orange safety vests for operators, a fire extinguisher, first aid kit, and a spill kit. A cell phone with GPS capability helps ensure safe field studies by allowing communication to first responders and determination of nearest medical facilities in the case of emergency.

5.4 Power system preparation and operation

OTM 33 applications of any form require electrical power to operate CMI, MI, GPS, and other instrumentation. Some GMAP-REQ system designs can utilize power from an inverter system hooked to the vehicle engine or from an electrical output of a vehicle battery supply in the case of hybrid powered vehicles. Another option is to power the instruments from stand-alone battery systems. Many mobile measurement applications involve stationary measurements with the vehicle placed in an optimal observing location. To facilitate operation from stationary locations, battery systems are used so that the primary instrumentation can seamlessly operate with the GMAP vehicles engine turned off. The specific power system requirements and operational procedures will depend on the application and system design and should be discussed in project-specific safety planning documentation.

5.5 Vehicle fixture preparation and safety checks. Most OTM 33 applications require special fixtures to be attached to the body of the sampling vehicle. Some GMAP-REQ applications require a vehicle-mounted mast system whereas some sub-methods require a minimal amount of attachments such as a magnetically mounted GPS antenna or a roof-rack mounted compact meteorological station. It is critical that required fixtures mounted to the vehicle be properly engineered, installed, and maintained and that proper safety checks on installation and operation are followed. System design features and special considerations or hazards should be discussed in project-specific safety planning documentation.

5.6 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 cylinder transport and storage, tracer release gear, and combustible or toxic gas personal safety monitors, etc.

6. Equipment and Supplies.

The equipment and supplies needed for execution of OTM 33 will vary based on the specific requirements of the sub-method. General examples of OTM 33 GMAP-REQ equipment are described here.

6.1 GMAP system design overview examples

Section 6.1 provides illustrations of GMAP-REQ systems for a simple mobile measurement application (6.1.1) and a more complex application (6.1.2).

6.1.1 Simple GMAP-REQ application.

For simple GMAP-REQ applications, where the source assessment modes are limited primarily to emission detection and location by concentration mapping (CM), components such as a sampling mast are not required. For simple applications, GMAP system components may consist of only the GMAP vehicle, concentration measurement instrument (CMI), sampling line, and GPS (Figure 6-1).

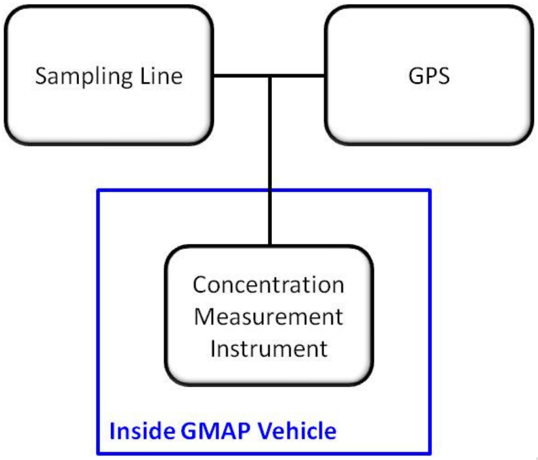

Figure 6-1. Basic GMAP components for source detection and location

The CMI represents acquisition of any target air pollutant concentration parameter. In most cases, the CMI will deliver air pollutant concentrations but it could represent particle size distribution measurements for example. The CMI is usually powered through an inverter system connected to the GMAP vehicle engine or by an auxiliary battery system. The sampling line must extend outside of the GMAP vehicle cabin in order to sample outside air and the GPS system must be of high enough performance to meet the DQOs of the project. If mapping is executed, a method for synchronizing the position and concentration data is required. The time resolution and measurement performance of the instruments must be sufficient to meet the DQOs for the project.

6.1.2 More complex GMAP-REQ application. In more sophisticated OTM 33 applications, such as remote emissions assessment, the required equipment set increases. Two examples of required equipment are schematically represented in Figure 6-2, OTM 33A (GMAP-REQ-DA) and a future method called tracer correlation (GMAP-REQ-TC) that uses a measured release of tracer gas to execute large area source emission assessment. For GMAP-REQ-DA, characterization of wind fields at the point of concentration measurement are important so a 3D sonic anemometer and a mast system to position the sampling instruments away from the body of the GMAP vehicle are recommended. For GMAP-REQ-TC applications, high-resolution stationary measurements with mast-based wind field and concentration data are less critical so a subset of equipment (indicated by blue dots) is required. The reason for this is that the atmospheric dispersion information needed for source assessment calculations are contained in the tracer release and recovery data for the TC approach. Likewise, tracer release data are not required for the GMAP-REQ-DA approach allowing an assessment to be made without site access and eliminating the need for tracer release equipment.

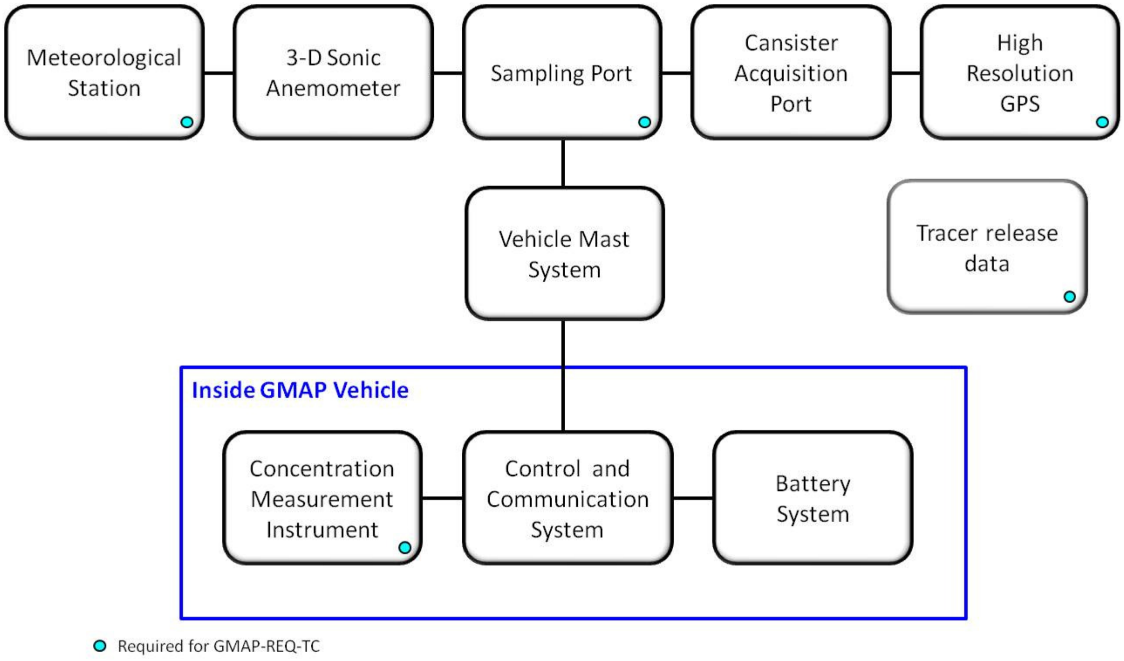

Figure 6-2. Schematic representation components for a GMAP-REQ-DA and a GMAP-REQ-TC application (subset indicated by blue dot)

6.2 Sampling equipment examples.

6.2.1 GMAP-REQ sampling vehicles. All OTM 33 embodiments are based on mobile platforms. In principle, any movable form (such as a trailer), can be used for specially-located stationary measurements. In general, OTM 33 applications require significant mobility so a preferred method is to equip a powered vehicle with requisite instrumentation. A sports utility vehicle (SUV) is frequently utilized for both interior space reasons and since rough roads are encountered with many GMAP-REQ applications. Concentration mapping in city environments with paved roadways can be accomplished very effectively using automobile-based GMAP platforms. With very complicated mobile measurement systems, a utility van or bus-type platform may be required. GMAP-REQ applications executed off-road or actually on the source emission surface (such as on a landfill), may require four wheel drive or specially-configured all-terrain vehicles (ATVs). Vehicles with front or rear-mounted trailer hitches are useful for mounting the GMAP mast systems and other components. If an auxiliary battery systems for instrument power is utilized, weight and space capacity of the vehicle must be considered.

6.2.2 Global positioning system (GPS). All OTM 33 embodiments require a GPS system to precisely determine the time-dependent location of GMAP vehicle during mapping and stationary measurements. A GPS system that provides a continual update of latitude and longitude coordinates and time-stamp at 1 Hz rates is typical. Data from the GPS is integrated with readings from the CMI and other instruments simultaneously acquired through a control data-acquisition system, which could stand alone or be part of the CMI's function. A high-resolution GPS system with a dedicated antenna is recommended for most GMAP applications to ensure robust signal under varying conditions.

6.2.3 Concentration Measurement Instrument (CMI). OTM 33 applications rely on highly time-revolved (around 1 Hz) concentration measurement of a pollutant or surrogate compound and potentially one or more tracer gasses. As detailed in subsequent sections, the CMI must be accurate, precise, and time-synchronized with the wind-field and other measurements to be most useful. In oil and gas applications for example, methane (CH_4) concentration measurements can be utilized as a surrogate to other emissions (e.g. volatile organic compounds) since CH_4 is emitted from most oil and gas sources as a consistent fraction and instrumentation is available to measure CH_4 with high precision in real time. For tracer correlation measurements, it is particularly useful for a single instrument to simultaneously measure the compound of interest and the tracer gas to facilitate time alignment of the data.

6.2.4 Control and communication system. OTM 33 equipment implementation designs usually include some type of computer control system to synchronously record information from the GPS, CMI, and other equipment. For some applications, it is possible that the primary CMI may also serve as the coordinating data acquisition computer eliminating the need for a separate control computer system. For many remote emissions quantification approaches that include auxiliary data acquisition (such as in-plume canister grab samples)the data acquisition, control, and time synchronization needs may demand specially designed instrument and sampling flow control systems using a dedicated control computer. This is especially true for GMAP systems which operate at high data acquisition speeds (i.e. > 5 Hz). Although usually not a primary requirement, a communication system based on wireless modem is useful for relaying data and acquiring information in the field.

6.2.5 Instrument power system.

For some OTM 33 sub-methods, the GMAP vehicle is fitted with a battery supply that operates the instrument packages and allows data acquisition with the vehicle engine turned off to prevent inadvertent contamination of the gas being sampled from the engine exhaust. For concentration mapping applications where self-contamination of sampling by the GMAP vehicle's exhaust is less of an issue (due to motion and target compound type), it is possible to operate equipment using an inverter system connected to the engine of the vehicle or off of the battery supply of a hybrid electric vehicle. If a dedicated GMAP vehicle is utilized, a battery system consisting of six to nine deep cycle marine (lead-acid) batteries and charger system can be permanently installed in the unit. For non-dedicated vehicles, a modular power pack based on lithium polymer battery technology can be utilized.

6.2.6 Sampling system. All OTM 33 applications require some form of sampling system to transport the sampled air stream to the CMI within the prescriptions of the sub-method and instrumentation requirements. For many remote emissions assessment applications, it is desirable to have the sampling port located near the other instruments and positioned away from the body of the vehicle for unobstructed wind flow. Some OTM 33 sub-methods require a vehicle mast system. Figure 6-3 shows an example of a GMAP vehicle fitted with a forward-mounted mast system that fixes the measurement equipment at a collocated position, at the front of the vehicle in this case. The purpose of the mast is to provide a modular support system for the instruments and ports positioned away from the body of the vehicle to allow representative wind flow for stationary source observation. A mast system is not necessarily required for other GMAP-REQ applications.

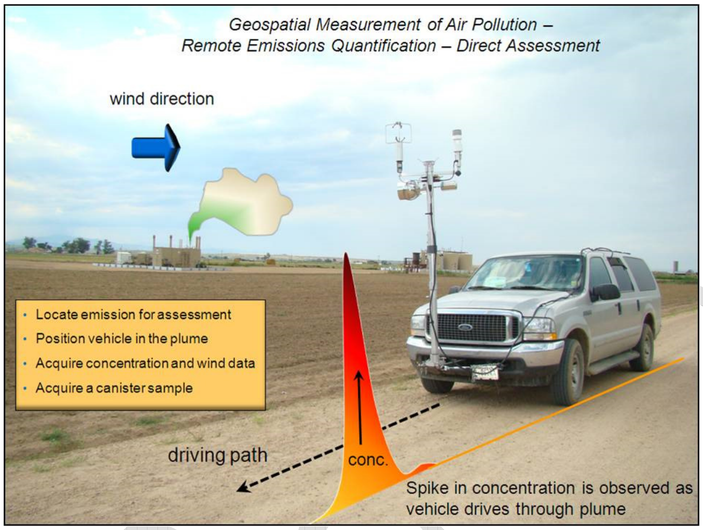

Figure 6-3. Example of front-mounted mast system

A sampling port (or air inlet) is part of the sampling system and delivers the air stream to the CMI for analysis. For some applications, the sampling port is located on the sampling mast as it is often desirable to have the inlet located near the other instruments and positioned away from the body of the vehicle for improved wind flow. For simple mapping applications, the sampling inlet could be as simple as a tube hanging out of the vehicles window.

For many OTM 33 applications, real-time concentration measurements by the CMI may provide information on only one of the many compounds present in the emission plume. Acquisition of a grab-sample, (usually an evacuated canister with an approximate 30-45 second draw) with subsequent laboratory analysis can provide both concentration and supporting emission estimation information for other specific compounds present in the plume (through ratio approaches with real-time measured compounds). The canister acquisition system allows the air sample to be acquired while in the emission plume by triggering an inlet solenoid at an optimal time as determined by the real-time concentration measurement. A canister acquisition system is usually associated with the sampling port and is many times fixed to the sampling mast. Figure 6-3 shows two canisters mounted to the sampling mast.

6.2.7 Meteorological Instruments. Some OTM 33 sub-methods require onboard meteorological measurements. A compact meteorological station with auto-north function records ambient temperature, atmospheric pressure and 2-D wind speed and direction. These data are needed for remote emission assessment calculations and also to provide real-time information to the operator on the wind direction to aid in locating the upwind source. A meteorological station is not necessarily required for basic GMAP-CM and stationary measurement applications.

6.2.8 3-D ultrasonic anemometer. Some OTM 33 embodiments require an onboard 3-D ultrasonic anemometer to provide high-resolution wind field and turbulence information used in sources emissions calculations.

6.2.9 Auxiliary Equipment. Depending on the application, auxiliary equipment can be required for executing the GMAP-REQ approaches. Equipment such as a laser range finder to help determine the distance from the suspected source to the observations point; a digital camera to take site photos; and safety gear such as orange vests, traffic cones, first aid kits, and fire extinguisher are necessary. An infrared camera fitted with a long-range optic is also useful to help establish the location of the emission sources. To execute some GMAP-REQ approaches, one or more tracer gases must be released from the source location. This operation requires tracer gas cylinders and supplies, flow measurement and control gear, tubing, a scale to weight cylinders and related safety equipment.

6.3 Supplies. Supplies required for execution of OTM 33 are specified in the sub-methods and 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 field applications are typically executed using air quality and meteorological instrumentation that does not require laboratory reagents or standards other than compressed-gas calibration check cylinders for quality assurance of the CMI. If a particular OTM 33 application has other specific laboratory reagent requirements, these requirements must be specified in the sub-methods and/or 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 Laboratory sample collection, preservation, and storage. OTM 33 field applications are typically executed using air quality and meteorological instrumentation that 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 sub-methods to OTM 33 and PSQAPs.

8.2 Field data acquisition. Data are acquired under OTM 33 GMAP-REQ sub-methods using mobile platforms in order to conduct one or more of the following source assessment modes (SAMs): concentration mapping (CM), source characterization (SC), and/or emissions quantification

(EQ). Data acquisition details are determined by source characteristics, the SAM technical approach, and by utilized equipment and are described in sub-methods to OTM 33 and in PSQAPs.

8.3 Preparation for field activities. For all OTM 33 sub-methods and applications, successful field data acquisition requires site and source knowledge, quality assurance and safety planning, and proper equipment preparation activities.

8.3.1 Site and source knowledge. A critical aspect of mobile monitoring applications is an understanding of the sources to be investigated which includes knowledge of the target compounds to be measured by the CMI, potential analytical inferences, potential non-target source interferences, site layouts with respect to available driving routes and potential sources to be measured, and factors that may affect execution of SAMs (e.g. area meteorology, obstructions, traffic congestion, etc.). Site and source knowledge should be obtained prior field activities to and serve as an input for proper project, quality assurance, and safety planning.

8.3.2 Planning and equipment preparation. The details of planning will vary based on sub-method and application but should involve the following elements:

- Project and quality assurance planning
- safety planning
- GMAP vehicle and instrumentation system design
- GMAP vehicle and system preparation
- Power system preparation
- Instrumentation pre-deployment checks

8.3.3 Project and quality assurance planning. For any environmental measurement exercise, it is important to conduct project and quality assurance planning so that the effort has the best chance of success. The U.S. EPA provides significant resources to assist in quality assurance planing (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 data quality objectives (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 of the GMAP-REQ measurement equipment and SAMs can be confidently analyzed to ensure that useful data can be produced before measurements are made. During project execution, it is important to perform pre-deployment and in-process quality assurance checks to make sure that equipment and procedures are working so that the acquired information is of value and of known quality. Using source and site knowledge and prescriptions of a given OTM 33 sub-method as a guide, the details of the definition, development, and application of the above quality assurance elements form the basis for the PSQAP.

Project planning is particularly important for remote sensing measurements of which GMAP applications are a subset. As described in Sections 2 and 4, GMAP-REQ applications have several inherent use prescriptions and method interferences that must be considered that find little analog in more traditional ambient or source measurements. Factors such as requisite meteorology, roadway access, non-target source interference, CMI performance specifications, source configuration effects, and wind flow obstruction inferences must be considered. It is critical to understand if the CMI to be used will likely have the required detection sensitivity and time-resolution necessary to execute the envisioned GMAP application and that a plan to deal with interferences (including self-vehicle pollution) is well developed. Limitations on measurements such as sustained wind speed for EQ measurements should be understood so that, based on a study of site historical meteorology, sampling times can be optimized to provide highest field measurement productivity levels.

8.3.4 Safety planning for OTM 33. Safety planning is a critical aspect of any field measurement campaign. GMAP applications can involve special safety concerns including traffic hazards. See Section 5 for further general information on OTM 33 safety. Each sub-method will further specify safety requirements for the specific application. As each field study may involve special site or source hazards, a project-specific safety plan that includes the locations of nearest emergency services should be prepared.

8.3.5 GMAP Vehicle and instrument system design. A critical part of preparation for field data acquisition activities is design and set up of the GMAP mobile measurement vehicle and associated instrumentation. The vehicle and its instrumentation systems must be designed so as to meet the DQOs for the project. Usually these factors center on the ability of the CMI to acquire information for SAMs that is of sufficient quality (high enough sensitivity and time-resolution and free from interferences) to meet the prescriptions of the sub-method in a project-specific context. These factors are further discussed in the quality control section (Section 9).

In design of the mobile instrumentation system, it is also important to consider sampling system factors, ease of instrument calibration, and the stability and operational robustness of selected components. Success in meeting DQOs for a project frequently rest on the ability of the measurement system to provide consistently high levels of data completeness. A single weak component (such as an intermittently failing GPS) can cause serious problems for a measurement campaign. A good GMAP system design includes the ability to quickly detect component failures and to replace components easily with back-up units if necessary.

8.3.6 GMAP vehicle preparation. The execution of safe and effective mobile-based measurements starts with proper vehicle preparation. This preparation involves configuration of special components unique to mobile measurements such as the battery supply, instruments and sampling mast systems, but it also includes basic preparation of the GMAP vehicle. General elements of safe vehicle preparation and power system preparation and operation are discussed in Section 5.

8.4 Pre-deployment and in-field system testing. After planning and design and fabrication exercises are complete, the system should be tested before and during field deployment. Many aspects of testing are system and application specific and should be detailed in the sub-method and PSQAP. Some equipment selection considerations and example system tests are contained in Section 9.

8.5 Execution of data acquisition. Procedures for acquiring field data under OTM 33 execution will be sub-method and PSQAP dependent. Procedures may differ depending on SAM, source types, and equipment configurations.

8.6 Data archiving and chain of custody. Regardless of specific OTM 33 sub-method or application, procedures to secure and back-up acquired data and transfer it to the analysis phase are critical. For some GMAP systems and applications, this step may be done in the field as the primary analysis may be accomplished in near real time. For many applications however, post analysis is necessary and in either case, it is important to form best practices around data archiving and screening procedures. Some elements to consider as part of sound quality assurance planning are:

8.6.1 Chain of custody forms. Create and utilize chain of custody forms for physical samples and data files.

8.6.2 Field data package. Package raw field data, field notes, and QA information in daily date-stamped folders and create back-up archives, ideally at the end of each day.

8.6.3 Daily checklist. Create and utilize a daily checklist of all data elements (physical samples, electronic data files, photo files, auxiliary measurements, field notes, daily QC checks, calibration records, and completed chain of custody forms)

8.6.4 Time synchronization. Verify time synchronization of field computers, instruments, and operator time pieces at the beginning and end of each day's work.

8.6.5 Data archiving practices: Keep raw data archives separate from processed data to avoid accidental corruption of the raw data with modified files. Use file naming conversions to ensure raw and processed data are distinguishable. Keep back-up archives in a separate physical location. Make sure media used to transfer and store files (such as USB drives) have been scanned using virus and malware protection software.

9. Quality Control

9.1 OTM 33 sub-method prescriptions and PSQAP. OTM 33 execution is based on the technical approach described in a given sub-method (e.g. OTM 33A, GMAP-REQ-DA) performed in the context of a specific application. The application details include site information (source type, target compounds, roadway configurations, potential method interferences, etc.). The application details also include the SAMs that are planned to be utilized as well as information on GMAP-REQ equipment and its performance requirements. This information forms the basis for quality assurance planning and the DQOs, MQIs (DQIs) and project descriptions/objectives that are expressed in the PSQAP.

9.2 Data acquisition and analysis quantity assurance. OTM 33 applications can have quality assurance requirements, procedures, and verifications associated with both the in-field acquisition of data and the subsequent analysis and interpretation of the data. Data acquisition quality assurance includes details on the instrumentation use and performance in addition to method prescriptions associated with remote measurement aspect (see method interference in Section 4). Data analysis quality assurance can combine and utilize data elements from several sources to help inform the quality of data and assess uncertainty. Information on both data acquisition and analysis quality assurance is application specific and is specified in the OTM 33 sub-method and PSQAP or in post-acquisition data processing analysis summaries if required.

9.3 Instrumentation quality assurance. For OTM 33 GMAP-REQ applications, there exist a number of general quality assurance considerations related to the utilized instrumentation that should be considered in the design phase of project and in pre-deployment and execution of field measurements. These general considerations are described in the remainder of Section 9.

9.4 Quality assurance for the CMI. For any OTM 33 application, the CMI performance must be well understood in the context of the application and this performance must be verified. For OTM 33 applications, CMI’s can vary from point-monitoring (cell-based) sensor systems to short open-path instruments to long-path solar occultation approaches. The utilized CMI must possess performance characteristics suitable for meeting the DQOs for the project. Use protocols must also outline a means for assessing the operational state and performance of the CMI during or after measurement. These CMI data quality indicators (DQIs) will differ based on details of the instrument utilized but must be related to the DQOs and explained in the PSQAP and related quality assurance documentation. Under OTM 33, there are several common quality considerations in selecting and utilizing CMIs.

9.4.1 CMI selection and baseline QA. As with all instrumentation, the quality assurance foundation for the CMI begins with information from the manufacture concerning the specifications, performance characteristics, environmental requirements, and operational checks for the instrument. The OTM 33 sub-method requirements and application details will provide guidance on the performance requirements (PRs) of the CMI(s). Selection of a CMI for a particular application must be based on its ability to meet the DQOs for the project under field deployment conditions. In general the following PR factors should be considered in selection of a CMI:

9.4.1.1 CMI target measurement selectivity. The CMI must be capable of measuring the target analyte without significant analytical interferences from other compounds that may be present in the local air shed to meet the DQOs of the project.

9.4.1.2 CMI quantitation limit. The CMI must be able to measure the target analyte at the minimum concentrations required by the OTM 33 sub-method and PSQAP. As the definition of minimum quantitation limit can vary based on application and DQOs, this factor is specified in the

PSAQP and is usually based around the precision of the instrument in the encountered air matrix and mobile operational state (not from a specification sheet or from testing in an ideal laboratory environment).

9.4.1.3 CMI dynamic range. Since OTM 33 applications can be performed in close proximity to sources where concentrations can be significantly elevated, it is important that the operational range (minimum and maximum measureable concentrations) and linearity of the CMI instrument be known and acceptable for concentrations that may be encountered.

9.4.1.4 CMI accuracy. For encountered operational conditions, the accuracy of the CMI for determination of the concentration of the target analyte must be known. In general terms, the accuracy of a measurement is determined by comparing a measured value to a known standard value in pre-deployment and in-field verification testing.

9.4.2 CMI initial calibration and maintenance. The initial calibration of the instrument is usually done at the manufacture’s facility and many times a certificate of calibration is available and should be saved and included in QA documentation in the PSQAP. Some manufacturers recommend periodic (i.e. yearly) factory checks of the instrument where the operational state is assessed and corrected if necessary and a new calibration certificate may be produced. A growing number of manufactures offer remote "health checks" of instruments over the internet where key hardware components can be assessed and software repaired and upgraded. Although extremely useful, remote checks are no substitute for user verification of instrument response using certified calibration gas cylinders or other accepted approach.

9.4.3 Development of a CMI SOP. Using the information provided by the manufacturer, coupled with the specific OTM 33 application, a standard operating procedure (SOP) should be developed for the CMI so that proper operating conditions, start-up, warm-up, and operation checks can be easily followed by the operator. Identifying quick DQIs that help the operator know the instrument is in working order is an important factor in SOP and PSQAP development. For example, a good DQI for a CH_4 instrument is observing background concentrations (around 1.8 ppm) in source-free areas. In addition to basic checks of functionality as part of SOP development, the user should test the response of the instrument to ensure proper operation as part of standard quality assurance procedures. In general, there are three levels of user testing which can be performed: pre-deployment testing, in-field calibration checks, and post-deployment comparisons.

9.4.4 Pre-deployment CMI testing. Understanding the performance of the CMI with regard to measurement accuracy and precision over the required response range and the potential for bias due to interfering species is important. The user should review published information from the manufacture and others regarding general performance factors for the CMI's technology class (principle of operation) and for the specific instrument if available. In addition to published information, pre-deployment testing by the user can help establish many performance aspects. The importance of testing for potentially interfering species can be complicated and its worth depends in large part on the DQOs of the project and degree to which a potential interference could cause serious measurement error affecting project conclusions.

The most common form of pre-deployment testing is to challenge the CMI over its measurement range with a series of reference standard concentrations. For gas-phase measurements, this can be done by supplying several target gas concentration to the CMI prepared from a reference cylinder mixed with a balance gas supply (typically air) using a gas standard dilution system (paired sets of mass flow controllers). Pre-deployment testing usually provides the opportunity for NIST transfer standards comparisons forming a basis for CMI quality assurance. Pre-deployment testing is usually performed in a laboratory setting and is difficult to execute on a frequent basis so in-field QA testing becomes a very important link for day to day CMI performance tracking.

9.4.5 In-field CMI calibration checks. Although operational DQIs can be very important in confirming nominal operating states of the CMI, the ability to assess measurement performance through a quick and easy in-field operation / calibration check is a critical QA tool. The nature of the check may vary based on the instrument. For example, for a particle measurement system, the insertion of a filter to remove particle concentrations in order to check zero values may be the only in-field test that can be easily performed whereas for gas CMIs, quantitative level checks are the norm. Figure 9-1 shows an example setup for a gas CMI calibration check that is very useful for low-flow rate systems. A reference gas standard in a small cylinder fitted with a two-stage regulator is presented to the CMI to establish a response. The inlet flow system to the CMI is first disconnected from the exterior sampling port and then reconnected to the calibration check system using appropriate tubing and fittings, usually with an open Tee connector in line. The redirection of flow to the CMI could also be accomplished by a valve system. Initially, the CMI samples the ambient air through the open Tee connector at a rate determined by its pumping system. The reference gas cylinder is then opened and the regulator set to a low pressure position of sufficient value to ensure excess flow is present through the open Tee. The CMI is then sampling off of this reference gas slip stream with open bypass ensuring that the CMI is not over pressurized by the compressed gas. Care must be taken to make sure that the bypass flow and exhaust from the instrument does not create a hazardous condition for the operator.

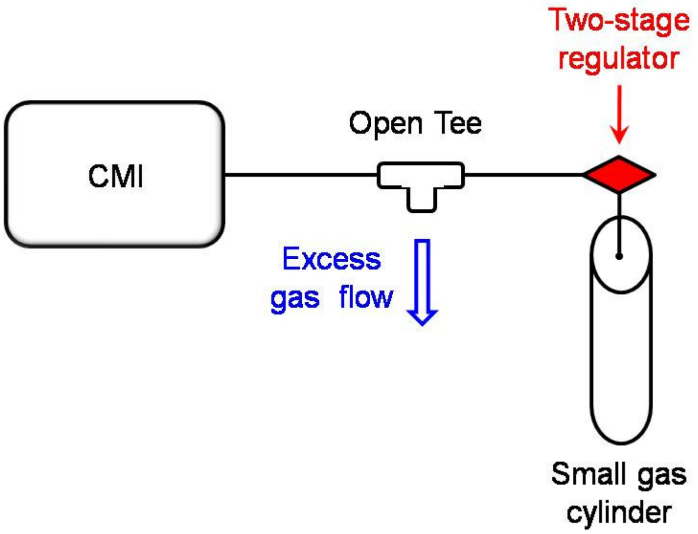

Figure 9-1. Schematic diagram of an in-field CMI test system

Although this type of DQI check does not inform bias factors for the CMI due to potential interferences in the sampling matrix, it does allow the performance of the instrument to be assessed in field operation conditions (in-motion vibration, actual operating temperatures, etc). In this way, in-field DQI checks build on the CMI's QA foundation of pre-deployment tests that may have been conducted in more controlled laboratory environments. The frequency of the in-field DQI test is determined by the project DQOs and inherent stability of the instrument. Some CMI's require full daily calibration with periodic checks and adjustments throughout the day while some more stable CMIs with good secondary DQIs checks can get by with calibration checks every couple of days. For most CMIs, the default would be pre and post test daily checks. To serve as an effective DQI, the reference gas standard should be designed to challenge the instrument at levels similar to that observed during sampling.

Figure 9-2 illustrates a typical CMI calibration check. In this case a 10 Hz CH_4 measurement system is challenged with a 20.1 ppm ± 5% CH_4 standard in balance air and the time series is recorded and analyzed. Initially the CMI is sampling the interior air of the GMAP-REQ vehicle which registers a background concentration around 1.9 ppm in this case. As the gas standard is presented to the CMI, the response rises to a stable level. In this case a 1 minute average concentration is analyzed taking care to start the average after a stable level has been reached. The average concentration is 18.99 ppm, with a standard deviation of 0.011 ppm. In this case, the instrument is reading below the standard by 5.5 % and is stable. This test can be compared with approximate background precision measurements and other measures. Assuming no adjustments are made to the calibration of the instrument, an important DQI tracking would relate to comparability of multiple assessments. In this case, if most in-field checks are around 5% below the standard then the calibration is stable and consideration of absolute accuracy should take into account potentially more accurate pre and post-deployment calibration testing.

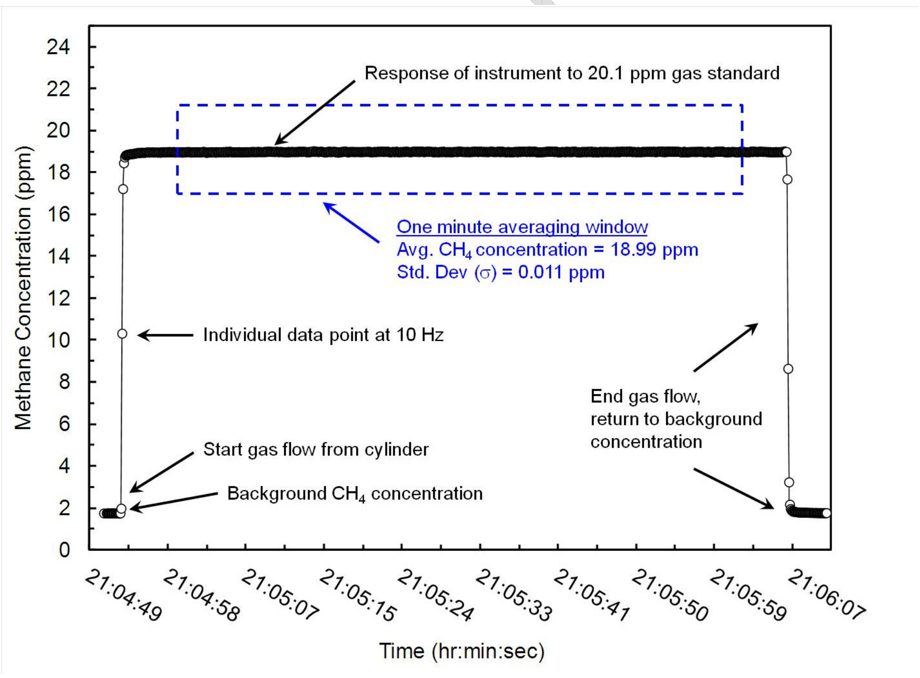

Figure 9-2. Example CMI DQI calibration challenge with gas standard

9.4.6 Post-acquisition CMI comparisons. After leaving the field, CMI comparisons with other instruments and laboratory-analyzed samples can be useful for a number of reasons such as for assessment of analytical interferences. Some CMIs, like some forms of optical absorption spectroscopy, can perform interference-free measurements with a high degree of certainty in a wide variety of encountered conditions. Some CMIs can even provide an analysis of potential interferences as part of the measurement, a valuable quality assurance tool. Many CMIs provide no traceable QA record regarding potential interferences and some are known to experience significant measurement bias in the presence of specific interfering compounds. For example, some surface film H_2S measurement systems are known to have significant response to NH_3. This may or may not be an issue depending on the particulars of the project. Proper quality assurance planning requires not only knowledge of the performance characteristics of the CMI, but also knowledge of the likely encountered composition of the air matrix. For example, agricultural H_2S sources frequently also emit much larger amounts of NH_3 so the selected CMI for this project (that intends to measure H_2S) should be one that does not exhibit NH_3 biases or the PSQAP should have procedures for assessment and mitigation of the effect of these analytical interferences.

If the CMI cannot provide a quality assurance record regarding potential analytical interferences, useful checks on the operation of the instrument in the specific air matrix can sometimes be gained through comparisons with grab samples. In this approach, the GMAP system records a real-time measurement of the target compound while a time-synchronized, co-located grab sample (e.g. an evacuated canister) is acquired. This is done when the system is located in an area of strong signal (in the plume). The canister sample is later analyzed in the laboratory for the target compounds and potentially interfering compounds as possible and the results are compared with the real-time measure to investigate potential biases. An example comparison is shown in Figure 9-3, a CH_4 measurement near an oil and gas source. In this particular case, the canister-derived methane value, agrees very well with the time-averaged determination from the CMI that includes both in-plume signal (to ≈17:52:15) and background methane signal (≈1.8 ppm) towards the end of the canister draw.

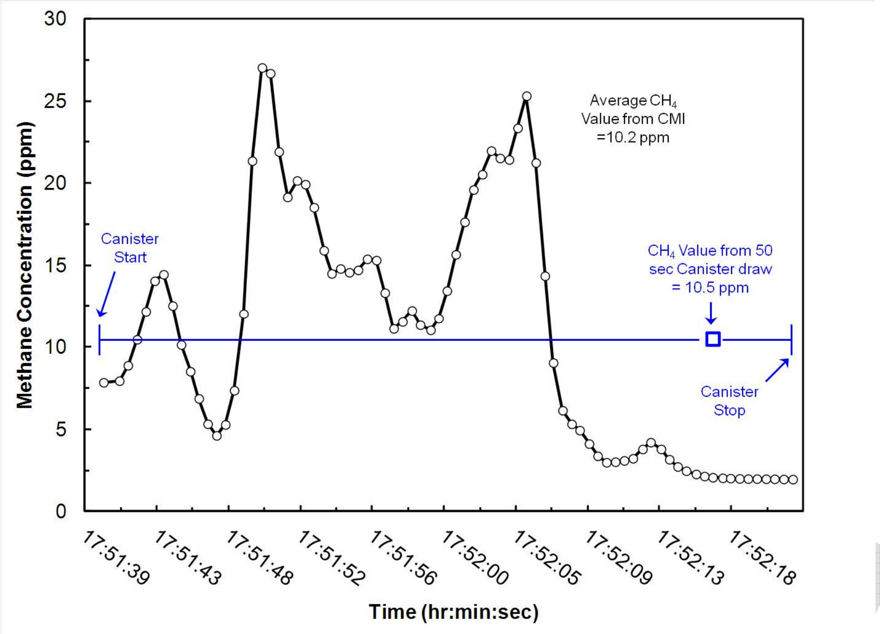

Figure 9-3. **Example comparison of CMI and canister data**

9.5 Quality assurance of the GPS instrument. For all OTM 33 applications, it is critical to have a working GPS system of known and sufficient performance capability. A GPS system provides the latitude and longitude coordinates for the GMAP vehicle and usually the master time stamp for the experiment. GPS systems can vary in performance with regard to signal reception (affecting data completeness), accuracy, precision, and time resolution. Lower-cost GPS systems (in the $100 dollar range) may experience more data drop out, lower data delivery rates, and somewhat lower accuracy and precision. The DQOs for the project will determine if a lower cost GPS system is sufficient for the application. Periodic DQI checks designed to ensure the GPS is operational become more important as the reliability of the GPS system decreases.

One operational check of the GPS is to calculate (and track) the spread of recorded latitude and longitude when the vehicle is stationary. This provides a measure of the precision of the instrument. Positional accuracy of the GPS can be found by comparing measured coordinated with geodetic survey markers (https://www.ngs.noaa.gov/NGSDataExplorer/). As a quick DQI check, the GPS-measured coordinate can be plotted on Google Earth™ in either stationary or mobile formats (as part of CM data processing). A malfunctioning GPS will exhibit data drop-out or sudden irregular deviations from a known transect road and/or the independently recorded GMAP vehicle speed during a specific test-section of a survey.

9.6 Quality assurance of meteorological instruments. Meteorological measurements can include wind speed and direction (with auto-north alignment), ambient temperature, atmospheric pressure, and relative humidity. The meteorological sensors (or combined station) must be robust enough for mobile measurements under OTM 33. For example, this may mean that certain wind measurement techniques based on mechanical actuation of a sensor (e.g. cup and vane anemometer) may not be suitable for stresses in continuous road deployments. For this reason, wind measurements based on 2-D and 3-D sonic anemometers are commonly used in GMAP applications. References 40 and 41 are resources for further understanding the differences in meteorological measurement instruments and quality factors. Quality assurance procedures including pre-deployment and in-field DQI checks for required auxiliary equipment are specified in the sub-method and PSQAP.

9.6.1 Manufacturer calibration. Meteorological instruments are primarily calibrated by the manufacturer and should be returned to the manufacturer periodically (yearly if possible) for calibration and operational checks. As with many instruments, periodic manufacturer maintenance records checks and associated calibration documents form the basis for quality assurance documentation.

9.6.2 Pre-deployment quality assurance checks. Somewhat more important than yearly calibrations are procedures for pre-deployment and in-field DQI checks of meteorological instruments. The reason for this is that under OTM 33 mobile applications, instruments experience vibrations and stresses not encountered in fixed-site deployments and as a consequence, instrument failure rates are higher. It is crucial to develop procedures to quickly and easily verify that meteorological equipment is operating properly.

The sophistication of pre-deployment tests will vary based on the facilities available to the user. The utilized meteorological equipment can be collocated and compared with a reference system if available. This approach provides a few points of comparison but will not test the operational range of the instrument. It is also possible to test the operation of the equipment by challenging it in simulated atmospheres such a wind tunnel and environmental chamber.

In most cases, the pre-deployment check of meteorological equipment can be accomplished by placing it in a suitable outdoor location and comparing readings to nearby, readily available local meteorological data such as from an airport. This provides knowledge of basic operational capability.

9.6.3 In-field DQI checks. There are several simple in-field DQI checks that can be performed in the field and can identify issues early to prevent loss of data. The quick checks of instrument performance described below require that the data from the meteorological equipment be viewable to be the operator in real time. In general, quantitative, comparative DQI checks should indicate agreement within ±10%.

9.6.3.1 Operator reasonableness check: The operator can observe current wind direction with a wind sock or other indicator and verify that it makes sense in comparison with the data provided by the meteorological equipment. Similarly, the wind speed, temperature and other parameters can be frequently checked by the operator and compared with other measures to make sure they are reasonable. Ideally, it is the reasonableness check that first identifies a malfunction and backup units can be deployed immediately (if required) so as to maximize usable data.

9.6.3.2 Multiple meteorological instrument comparison: Some GMAP-REQ system designs provide wind and temperature measures from a 3-D sonic anemometer and these readings can be compared with the primary mobile meteorological system. In general these DQI checks should indicate agreement within ±10%.

9.6.3.3 Comparison with secondary data: Using real-time weather information downloaded from the internet using a cell phone or GMAP-communication modem, wind speed, relative humidity, and temperature functions of the meteorological equipment should be periodically checked for reasonableness.

9.6.3.4 Auto-north function check: The auto-north function of the system can be checked by pointing the vehicle into the prevailing wind direction in an open area and comparing the reported wind angle from north with a compass bearing from a hand-held GPS.

9.6.3.5 Wind speed check: A rudimentary check of wind speed measurement accuracy can be accomplished by observing the output of the instrument in comparison to the speedometer of the GMAP vehicle at low driving speeds.

9.6.3.6 Post-acquisition DQIs: After leaving the field, a variety of more careful comparisons with other meteorological instruments and secondary sources of data can provide useful information regarding the operation state of the meteorological instruments during measurement.

9.7 Quality assurance of auxiliary equipment. OTM 33 applications can utilize auxiliary equipment such as tracer gas release gear, infrared cameras to locate leaks, and laser range finders to determine the distance to sources. Quality assurance procedures including pre-deployment and in-field DQI checks for required auxiliary equipment are specified in the sub-methods to OTM 33 and the PSQAPs.

10. Calibration and Standardization. OTM 33 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 (Section 9). Specific procedures and requirements for calibration and standardization will depend on the OTM 33 sub—method 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 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 40 and 41.

11. Laboratory Analytical Procedures. OTM 33 field applications are typically executed using air quality and meteorological instrumentation that that does not require collection of laboratory samples. In some cases, evacuated canister or other "grab sample" approaches may be acquired to inform source characterization, to provide comparative analysis with CMIs, or 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 sub-methods to OTM 33 and PSQAPs.

12. Data Analysis, Calculations and Documentation. Data analysis, calculation, and documentation details for OTM 33 applications are sub-method and application dependent. These procedures are specified in the sub-method and PSQAP.

13. OTM 33 Method Performance.

13.1 General method requirements. Method performance requirements are a subset of general method requirements (MRs) and are described in general here and in detail in the specific sub-method. The phrase "performance must be well-characterized (or understood)" means that through a combination of manufacturer specifications, design analysis, pre-deployment testing, and in-field calibration and evaluation procedures (on individual instruments and integrated equipment sets) the performance of the system and method for the intended application (under field conditions) is known and documented. A few examples of method requirements that should be addressed are discussed briefly below.

13.2 CMI 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. 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.

13.3 Other instrumentation performance requirements. The design and performance characteristics of other GMAP-REQ instrumentation systems as part of the GMAP vehicle platform must be understood. This requirement includes documenting any perceived or potential data system limitations (e.g. potential for self-contamination of signal due to GMAP vehicle exhaust) in the context of the intended application and how these limitations may affect interpretation of results and the strength of conclusions.

13.4 Required field and site conditions. Method limitations on data acquisition and interpretation due to operating conditions (e.g. requisite meteorology, source distance, etc.) must be understood. Factors affecting acquisition and analysis of data (e.g. interfering non-target emission sources, wind flow obstructions, etc.) must be understood. In cases where multiple interfering non-target emission sources are present, project-specific procedures are required to assess and or remove interferences. This requirement includes documenting any perceived or potential field or site limitations (e.g. lack of optimal roadway access or evaluated source heights) in the context of the intended application and how these limitations may affect interpretation of results and the strength of conclusions.

14. Pollution Prevention

[Reserved]

15. Waste Management

[Reserved]

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