

# **Resolving Air Flow over Elevated Terrain to Improve Dispersion Modelling for Sour Gas Flares**

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**ARC Project No.: CEM – 9254-2005**

**March 31, 2006**



## Acknowledgements

The authors would like to acknowledge the contribution to the performance of this project and the preparation of this final report by:

- Spectrasyne Ltd., UK, in collecting SO<sub>2</sub> plume measurements with their mobile DIAL unit and reporting of the measurement results,
- IROC Systems Corp. in supplying the mobile meteorological equipment and satellite communications and interpreting and reported the weather data,
- RWDI Inc. in performing the SO<sub>2</sub> plume dispersion modelling and the interpretation and reporting of the plume dispersion results.

The authors also acknowledge the assistance and guidance from the Air Issues Steering Committee and the project facilitation services of Petroleum Technology Alliance of Canada (PTAC).

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## Executive Summary

Flaring of natural gas containing hydrogen sulphide may occur during well testing and both Alberta and B.C. have ambient air quality guidelines for maximum permissible concentrations of sulphur dioxide (SO<sub>2</sub>) at ground level during sour gas flaring. Numerical dispersion models are often used to predict ground level SO<sub>2</sub> in the vicinity of a flare and to identify any situations of flare operation, terrain or weather conditions that might lead to ambient SO<sub>2</sub> concentrations above the guidelines.

The objective of this project was to perform a combination of plume dispersion modelling and Differential Absorption Lidar (DIAL) tracking of an SO<sub>2</sub> plume to resolve issues around dispersion modelling of atmospheric flows, especially when the plume approaches elevated terrain. DIAL measurements of the plume trajectory and behaviour as it approaches a hill would be collected under real atmospheric conditions and compared with numerically predicted plume dispersion and behaviour.

A field test program was completed at an operating sour gas processing plant in Alberta over a six-day period in September 2005. DIAL profiles of SO<sub>2</sub> concentration in the plume from a tail gas incinerator stack were measured along the top of a ridge located about 1.5 km downwind of the stack. The profiles were typically from measured ground level to an elevation of 200 meters and between 50 and 1500 meters from the location of the DIAL unit. A mobile meteorological station was set up to measure wind speed and direction at the top of the ridge. A mobile satellite communications unit was located at the site, enabling real-time plume dispersion modelling to occur during the DIAL measurements.

Based on the DIAL measurements, during the majority of the test period the main part of the plume was higher than 20 meters above the ridge downwind of the incinerator stack. During light winds from the west, the plume followed the valley in a southwest direction rather than crossing over the ridge. The plume was often highly fragmented with a portion following the valley and a portion crossing the ridge, even at higher wind speeds. The CALMET/CALPUFF dispersion model system used in this study used a standard prediction of one-hour average, ground level concentrations of SO<sub>2</sub>. This complicated the direct comparison of the DIAL measurements with the plume dispersion results. The dispersion model predictions of the plume position generally agreed with the DIAL measurements.

Based on the results of this study, further comparison of the collected DIAL data and plume dispersion predictions is recommended. The dispersion model should be run for time steps of 10 minutes instead of 1 hour with output of the vertical as well as ground level SO<sub>2</sub> concentration profiles. This may require modification of the dispersion model to output the predicted SO<sub>2</sub> concentration contours throughout the elevation of the plume to enable direct comparison to the DIAL measured SO<sub>2</sub> concentration profiles. Software development is also recommended to more easily output and analyse the large number of DIAL scans collected during the test period, including a means to average several scans over a one hour period to compare with the one hour average predicted by plume dispersion modelling.

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# Resolving Air Flow over Elevated Terrain to Improve Dispersion Modelling for Sour Gas Flares

## 1. Background

Sour gas is flared during well testing, as a means to dispose of sour solution gas, and for emergency purposes at compressor stations and gas processing plants. Both Alberta and B.C. have ambient air quality guidelines for SO<sub>2</sub> and H<sub>2</sub>S that cannot be exceeded during sour gas flaring. Dispersion models are often used to identify any situations of flare operation, terrain or weather conditions that might lead to ambient SO<sub>2</sub> and/or H<sub>2</sub>S concentrations above the guidelines. For well test flaring, either truck mounted or stationary SO<sub>2</sub> and H<sub>2</sub>S monitoring equipment may be required in the area around a flare to confirm that ambient guidelines are not exceeded. For emergency flaring at sour gas facilities, the application of the model predictions may result in flaring restriction (e.g., time of day, wind direction, duration).

Natural gas exploration and development is proceeding in rugged and remote areas of Alberta and B.C. Well test flares are often located in valleys amid mountainous terrain. Accurate dispersion modelling in such complex terrain depends on the model's assumptions regarding air flow over elevated terrain features. The key uncertainty relative to the models is the height of the plume above the ground as it passes over the elevated terrain feature. The uncertainty component is critical for night-time conditions, as the models often assume direct impingement in these situations; potentially leading to gross over predictions.

Differential Absorption Lidar (DIAL) is a laser based remote measurement method that can track and profile SO<sub>2</sub> plumes from sour gas flares. The method was demonstrated in Alberta during 2003 in a Canadian Association of Petroleum Producers (CAPP) and Environment Canada sponsored project. The comparison of DIAL measurements of a well test flare plume with dispersion modelling predictions demonstrated the potential of the method to generate valuable data for dispersion model validation (Chambers, 2003). DIAL measurements could be a valuable tool to investigate the accuracy of predictions of plume behaviour with current plume dispersion models. Chambers (2003) recommended further testing to resolve plume flow over an adjacent hill by comparing measurements of the plume position with dispersion model predictions.

## 2. Objective

The objective of this project was to perform a combination of dispersion modelling and DIAL tracking of an SO<sub>2</sub> plume to resolve issues around dispersion modelling of atmospheric flows over elevated terrain. The proposed testing would be performed at an operating site in Alberta. DIAL measurements of the plume trajectory and behaviour as it approaches a hill would be collected under real atmospheric conditions and compared with numerically predicted plume dispersion and behaviour. The anticipated result would be recommendations on the accuracy of current predictive models and suggestions for improvements to better predict flow over complex terrain. These improvements would increase the confidence in the dispersion models for the companies using them, regulators that sanction their use and the public who are concerned with air quality resulting from industrial activity. A secondary objective was to investigate the

potential of DIAL as a tool for tracking H<sub>2</sub>S plumes from inefficient flares or accidental sour gas releases.

### 3. DIAL Field Measurements

For the direct measurement of the SO<sub>2</sub> plume position, Spectrasyne Ltd., UK, ([www.spectrasyne.ltd.uk](http://www.spectrasyne.ltd.uk)) was contracted to bring their mobile DIAL unit and operating team to Alberta.

DIAL is a laser-based optical method that can measure the concentration of a gas species at a remote point in the atmosphere. The DIAL method uses a pulsed laser operating at two wavelengths, one strongly absorbed by the gas species of interest and one weakly absorbed. A system of mirrors and lenses is used to direct the laser pulses toward the target gas volume and collect light back-scattered from particles and aerosols in the atmosphere. The pulse time and light absorption information from the return signals enables calculation of a gas concentration distribution along the length of the light path.

The ultra-violet laser on the Spectrasyne DIAL unit was used for the SO<sub>2</sub> measurements during this study. With the scanning telescope/mirror system on the Spectrasyne DIAL unit, a vertical plane in the atmosphere was measured to locate the plume and to measure the SO<sub>2</sub> concentration profile in the scan plane. Previous work with the DIAL in Alberta (Chambers, 2003) demonstrated the ability of the DIAL method to measure SO<sub>2</sub> at concentrations down to 10's of parts per billion at distances up to 2 km from the DIAL unit. Figure 1 is a photograph of the DIAL unit showing the steering telescope system at the rear of the unit. The DIAL unit includes a retractable 14 meter weather tower to collect data on air temperature and wind speed and direction that correspond with the DIAL measured gas concentrations.



**Figure 1: Rear of DIAL Mobile Unit Showing Telescope System**

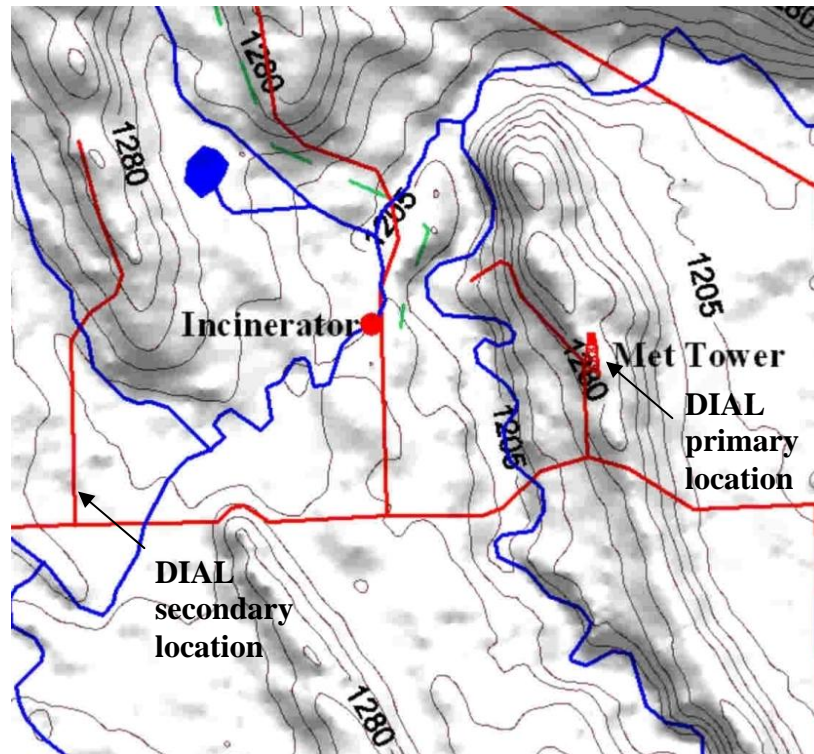
The following summarizes information on the test locations, measurements completed and other data collected.

### **3.1 Field Test Site**

The main interest for this study was to investigate the behaviour of a plume when approaching a ridge. When approaching an elevation gain, the plume could stay at a constant elevation above ground (i.e. rise over the ridge), impact on the ground or travel an intermediate path. Current plume dispersion models include factors for predicting how the plume course will interact with elevated terrain. The Spectrasyne DIAL unit method is a particularly sensitive tool for locating and tracking SO<sub>2</sub> plumes. To meet the objective of these tests, a site was required that had an existing SO<sub>2</sub> source and an elevation gain downwind of the SO<sub>2</sub> source.

With the assistance of the Air Issues Steering Committee, a gas processing plant site that had a ridge downwind of the plant in the direction of the prevailing winds was located. The plant processed sour gas and included a tail gas incinerator to convert any un-recovered H<sub>2</sub>S to SO<sub>2</sub>. There was also adequate road access on the ridge to enable location of the DIAL on the ridge.

Figure 2 is a contour map of the area selected for the study showing the ridge located east of the tail gas incinerator stack for the gas processing plant. Also indicated is the location of a meteorological station and the adjacent mobile DIAL unit used during the testing. The DIAL unit was located primarily at two locations on the east ridge with the laser scans collected south of the unit along the top of the ridge. DIAL measurements were also collected at one location west of the plant on a day when the wind was from the east.



**Figure 2: Contour Map Showing Ridge East of Tail Gas Incinerator Stack**

### 3.2 Weather Data

During the period of the plume measurements, IROC Systems Corp. ([www.iroccorp.com](http://www.iroccorp.com)) operated a portable meteorological station to collect wind speed and direction data and other atmospheric data required for the plume dispersion modelling. The wind speed and direction instruments were located on an 18 meter (60 ft.) tall portable tower located on the top of the ridge (Figure 2). IROC Systems Corp. also supplied a mobile satellite communications unit to transmit the weather data directly to RWDI Inc. for direct input into real-time plume dispersion modelling, as discussed in Section 4.

In addition to the IROC system, the DIAL unit also collected wind speed and direction information from a 14 meter high tower built into the DIAL unit.

Figure 3 is a photograph of the DIAL unit, mobile weather tower and satellite communications unit installed on the ridge east of the gas plant. This was the location for most of the measurements during the study.



**Figure 3: Mobile DIAL Unit and Weather Station Located at Site**

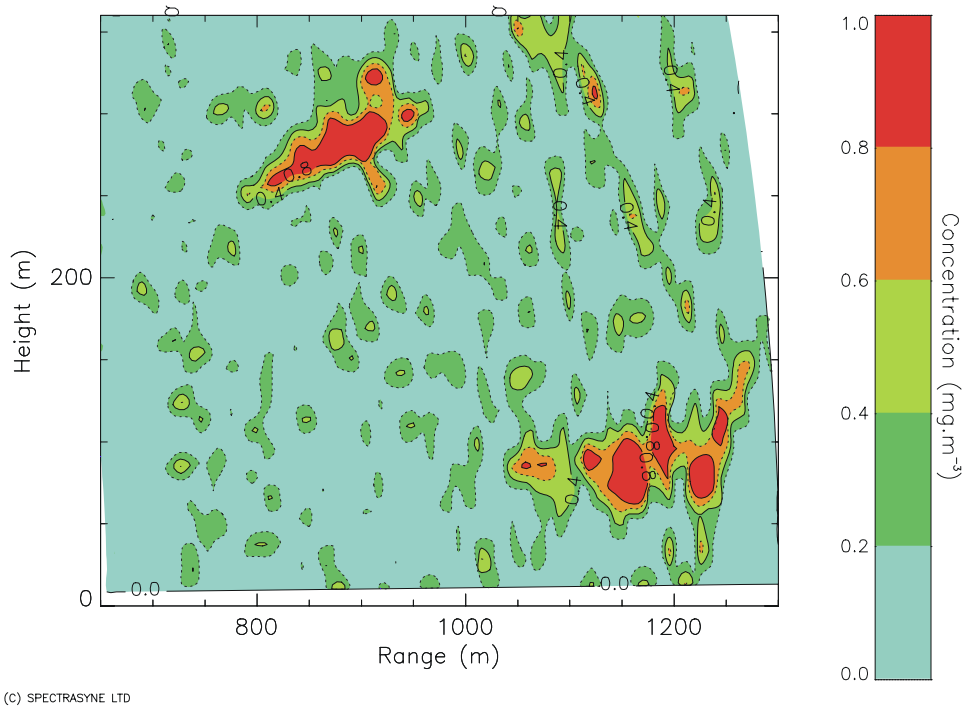
### **3.3 DIAL Measurement of the Plume**

DIAL measurements of the SO<sub>2</sub> plume from the tail gas incinerator were collected over a period of six days, from September 19 to 24, 2005. During most of this period the DIAL was located on the top of the ridge just east of the plant scanning in a south direction along the top of the ridge. On the first day of testing, the wind direction was initially from the north and swung from the east. With the east wind the DIAL was moved to a location southwest of the plant. The two primary locations are shown in Figure 2.

At the location on the east ridge, the DIAL scans through the plume were about 1.5 km downwind of the tail gas incinerator stack. At this distance from the source of the plume, even small changes in the wind direction would result in large horizontal shifts in the plume position. A five degree shift in wind direction would shift the centreline of the plume by about 130 meters. At the typical wind speed of 6 m/s during the tests, any change at the incinerator stack would take about four minutes to travel to the DIAL scan plane. Due to the large shifts in plume position caused by wind changes and the action of turbulence in dispersing the plume, in many cases the DIAL scans did not encompass the whole plume. Also the interaction of the wind with

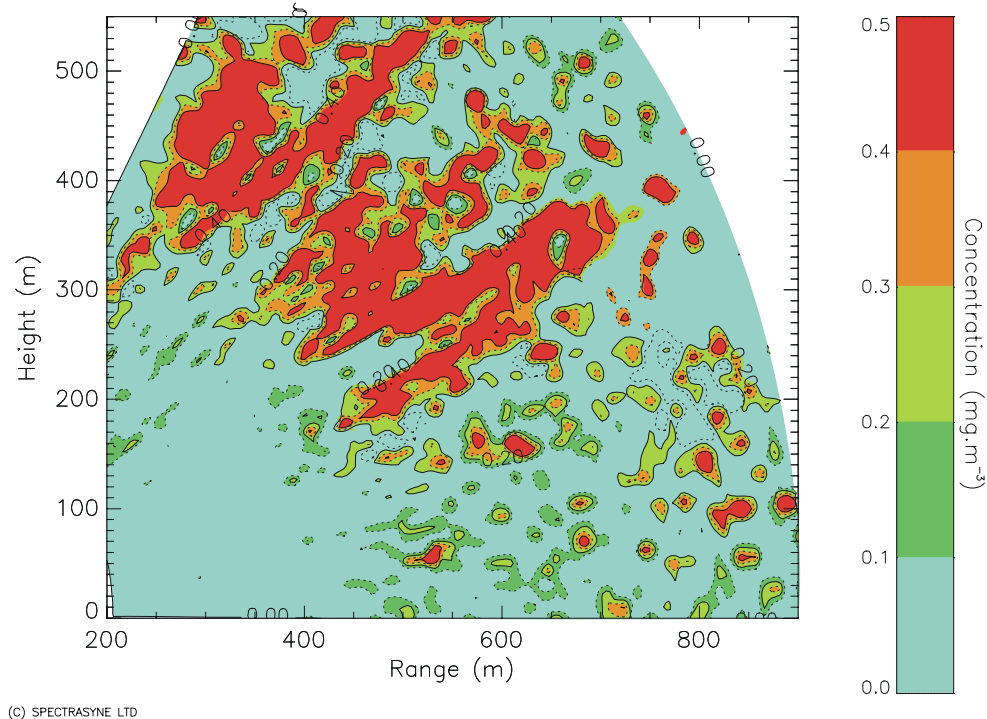
the complex terrain also tended to split the plume into a portion following the valley in a direction southeast of the plant and a portion that went over the ridge. This tendency was especially evident at wind speeds below 3 m/s (11 km/h) when, even with wind at the top of the ridge directly from the west, the stack plume was found to follow the valley in a south east direction.

Figure 4 and Figure 5 are two examples of two dimensional profiles of SO<sub>2</sub> concentration measured with the DIAL during this test program. The horizontal axis is the distance from the mobile DIAL unit and the vertical scale is elevation above ground level. DIAL measurements of plumes, both in this and previous studies, indicate that plumes generally consist of pockets of high gas concentration as opposed to an evenly distributed gas concentration. Figure 4 is an example of a highly fragmented plume with widely dispersed pockets of higher concentration SO<sub>2</sub>. Figure 5 is a much more consolidated plume with some pockets of SO<sub>2</sub> concentration in the order of 0.3 mg/m<sup>3</sup> (100 ppb) reaching ground level in this case. These figures also illustrate the ability of the DIAL unit to measure SO<sub>2</sub> remotely at distances in the order of 1200 meters.



**Figure 4: Plume Fragments near Ridge Top (Sept. 20 13:54)**





**Figure 5: Part of Plume Reaching Ridge (Sept. 20, 11:55)**

Section 5 includes a discussion of the comparison between DIAL measurements of the SO<sub>2</sub> plume position and predictions from plume dispersion modelling.

#### 4. Plume Dispersion Modelling

For this study, real-time dispersion modelling was done during the field studies to help guide the DIAL SO<sub>2</sub> plume measurements and to give an immediate impression of the comparison between model predictions and DIAL measurements of the plume position. Real-time dispersion modelling was made possible by the use of the IROC mobile satellite communications system and the Plume-RT system developed by RWDI Inc. Further plume dispersion modelling was also performed after the testing had been completed.

The Plume-RT (Plume Real-Time) system is an on-line interface developed by RWDI Inc. ([www.rwdi.com](http://www.rwdi.com)) that uses US EPA approved air dispersion models (accepted by Alberta and British Columbia regulatory bodies). This is done with proven meteorological technology to produce current hour and twenty-four hour forecasted predictions of SO<sub>2</sub> concentrations over a predefined domain.

These predictions aid decision-makers, field operators, and regulators in managing and mitigating risks associated with planned and accidental atmospheric release events from well test flaring, incineration activities, and drilling operations.

Features of the Plume-RT system include:

- The Plume-RT system uses US EPA approved CALMET (a diagnostic three dimensional meteorological model) and CALPUFF (a transport and dispersion model) to predict ground-level SO<sub>2</sub> concentrations.
- Access to regional weather forecasts that are updated every three hours through the Internet.
- The system provides continuous, automated dispersion predictions on an hourly basis, and 24-hour forecasts.
- Real-time access to onsite meteorological stations via satellite, cell phone or other communications technology provides reliable access to remote, stand-alone meteorological stations.
- Ability to define numerous discrete receptors to monitor SO<sub>2</sub> concentrations at specific locations such as:
  - landowners
  - monitoring sites
  - environmentally sensitive areas
  - command centers
  - road block
  - campgrounds
  - other points of interest
- Results are displayed to the client, via a secure web interface as a series of reports including:
  - animations of ground-level SO<sub>2</sub> concentrations;
  - maximum SO<sub>2</sub> concentration contour plots;
  - frequency distribution plots;
  - criteria exceedance tables; and
  - time-series graphs.

CALMET is a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modelling domain and provides representative realistic estimates of wind flow accounting for complex terrain features (Earth Tech, 2000a). The CALMET model used the ground station meteorological data provided by IROC via the Internet and the NAM (formally ETA) and RUC meteorological upper air data available from NOAA. The upper air data is extrapolated to a point on the gridded terrain called a pseudo-station. This station was placed near the highest terrain point within the meteorological modelling domain. From this point CALMET uses the three dimensional terrain to “drape” the meteorology and produce wind fields and temperature fields for the domain. The local weather station or other “real-time” meteorological information can be used to adjust the wind fields to what is being observed locally.

CALPUFF is a transport and dispersion model that advects “puffs” of material emitted from modelled sources, simulating dispersion and transformation processes along the way (Earth Tech, 2000b). A web-based interface inputs the source characteristics as gas composition, stack location, stacks height and inside diameter, flow rate, and elevation for the flare stack.

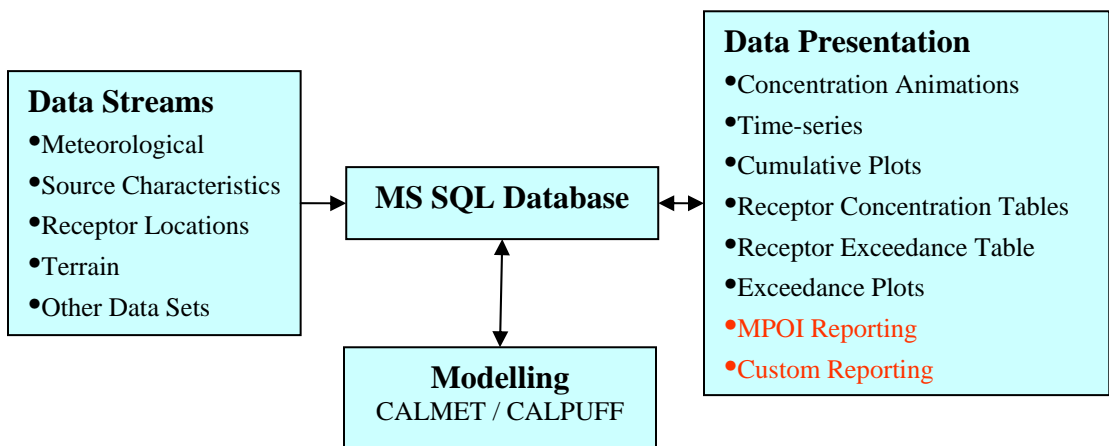
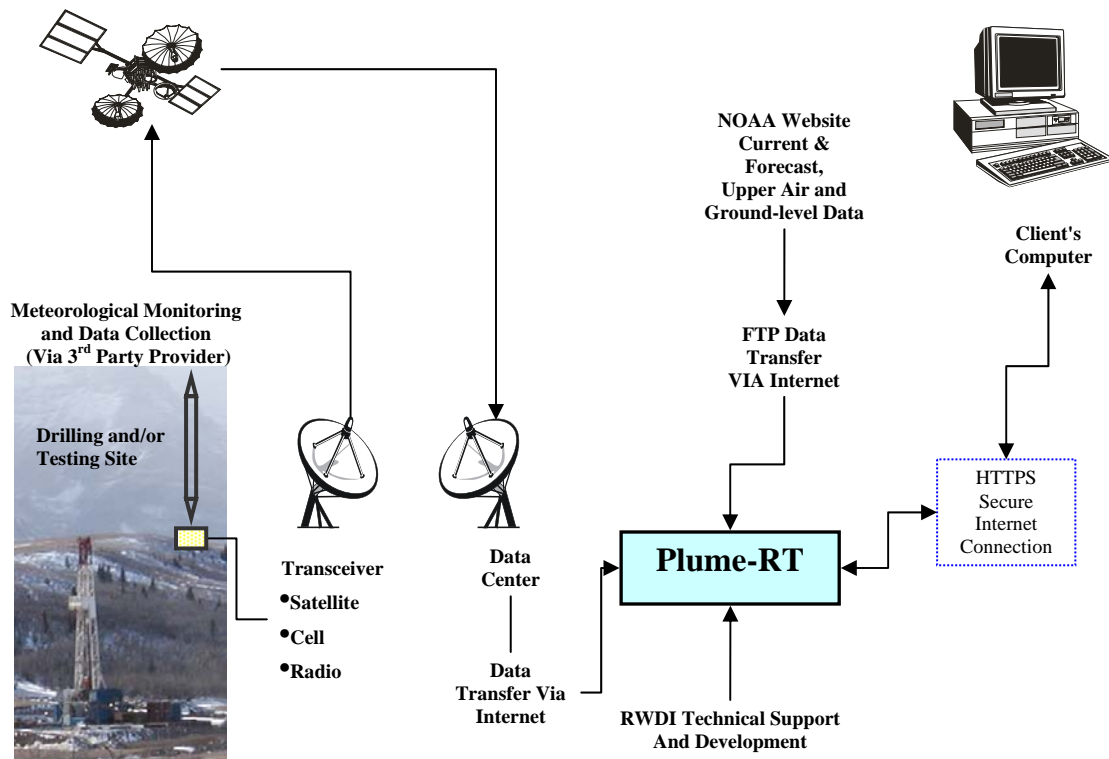


Additionally up to 10 discrete receptors can be added to specifically predict SO<sub>2</sub> ground level concentrations. The receptor grid spacing is 100 m throughout the domain. During the period of the field test, data on stack emission conditions were collected from the plant to use as input to the dispersion model.

The CALPUFF data is displayed to the client through the secured web interface as a series of reports: Animation of ground-level SO<sub>2</sub> concentrations, maximum SO<sub>2</sub> concentration contour plots, frequency distribution plots and tables, and a time-series graph for the discrete receptors. All of the data is stored in a MS SQL database and can be queried to produce customized information at the request of the client. This data can also be used to run post event modelling outside of the Plume-RT system.

The Plume-RT modelling system provides predictions of SO<sub>2</sub> concentrations based on the source conditions and meteorological conditions input into the model and assuming that a release is occurring continuously. Model results are available that represent the actual last-hour conditions as well as next-hour forecast conditions. Modelling is conducted continuously without regard to the stop/go nature of actual flaring activities. While changes to model input parameters can be incorporated into the Plume-RT modelling system, modelling results can be adjusted forward in time only. Thus, when comparing predicted values to monitored values, it is important to track and consider which input parameters are being represented in the modelling results.

During the field test the Plume-RT model was operating to supply prediction of current plume dispersion and also predicted future plume dispersion based on weather forecasts. Any measured data and modelling conditions were archived with the capability to recalculate plume dispersion predictions with different input conditions if required.



**Figure 6: Real-Time Plume Dispersion Model Configuration**

## 5. Comparison of Model Predictions and DIAL Measurements

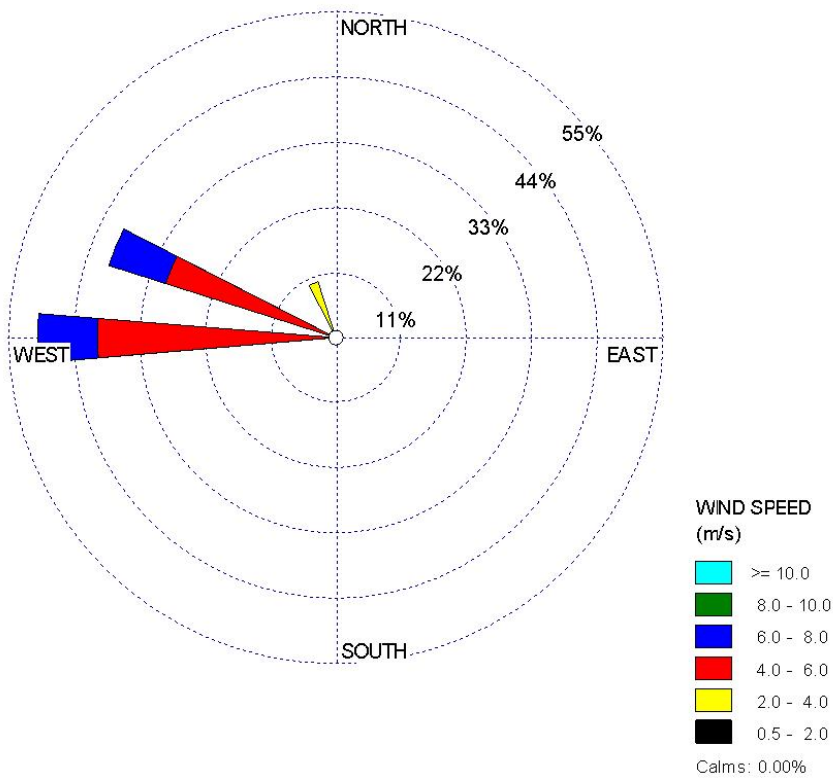
The following discusses the comparison of the predicted position of the SO<sub>2</sub> plume from the tail gas incinerator with the DIAL measured position of the plume. Comparing the predictions and DIAL measurements was not straightforward due to the differing objectives of standard plume dispersion models and the nature of DIAL plume measurements. Some of these differences are summarized in Table 1.

**Table 1: Properties of Dispersion Model vs. DIAL Measurement**

	<b>Plume Dispersion Model</b>	<b>DIAL Measurement</b>
<b>output</b>	SO <sub>2</sub> concentrations at ground level	SO <sub>2</sub> concentration profiles in a vertical slice through the plume
<b>time scale</b>	one hour average	relatively instantaneous, 5 seconds per scan line, 5 to 7 minutes per scan plane
<b>plume properties</b>	assumes evenly dispersed gas concentration	plume typically composed of pockets of higher concentration
<b>wind effects</b>	wind speed and direction changes averaged over 1 hour	scan to scan variations as a result of wind speed and direction changes

The comparison of the measurements and plume dispersion prediction will concentrate on the data collected on September 21. Based on weather predictions, it was forecast that during the early morning the meteorological conditions were likely to be conducive to plume grounding on the ridge east of the plant. The DIAL plume surveys were started at 03:45 on the morning of September 21 and continued until 12:00 in order to capture the transition from night to day and its effects on the SO<sub>2</sub> plume. About 35 measurement scans were completed during this period.

The wind was from the west, carrying the plume towards the ridge. At a height of 14.5 m above the ridge the wind speed was 5 to 6.5 m/s (18 to 23 km/h) as measured by the meteorological station on the DIAL unit. Figure 7 gives the wind pattern for the period of 03:00 to 12:00 on September 21 as measured by IROC Systems from their portable meteorological station.

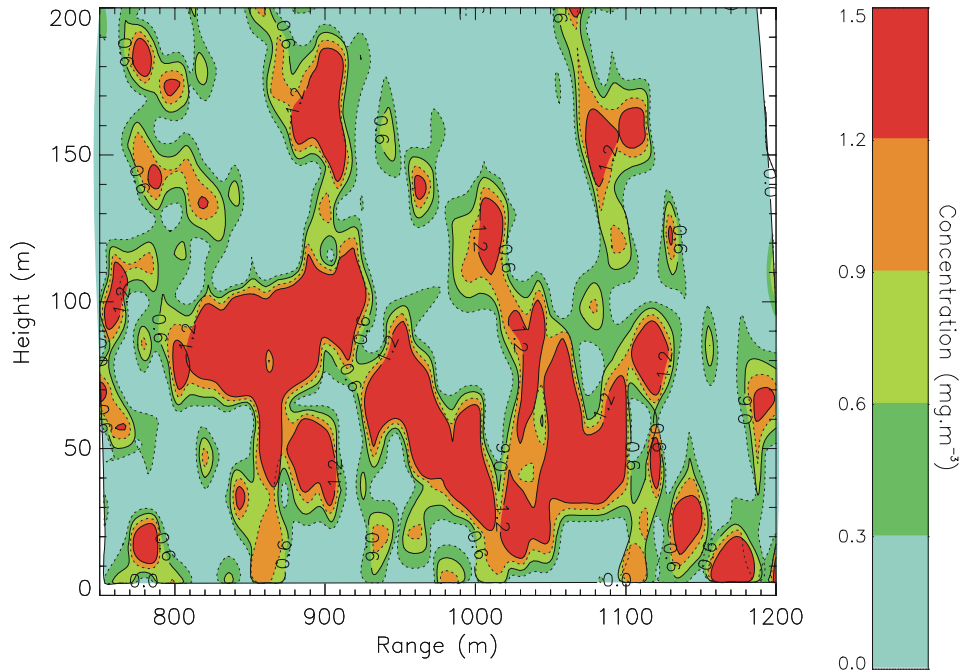


**Figure 7: Wind Pattern on Sept. 21 from 03:00 to 12:00**

In the majority of the DIAL scans, the base of the main plume was found to be 50 meters or more above the ridge. Only on one occasion early in the day was the base of the main plume seen to approach the ridge at heights less than 20 meters. Figure 8 (time 04:44) shows this scan. In a number of scans small fragments of the plume were seen at or near ground level but the major portion of the plume started 50 m above the ground.

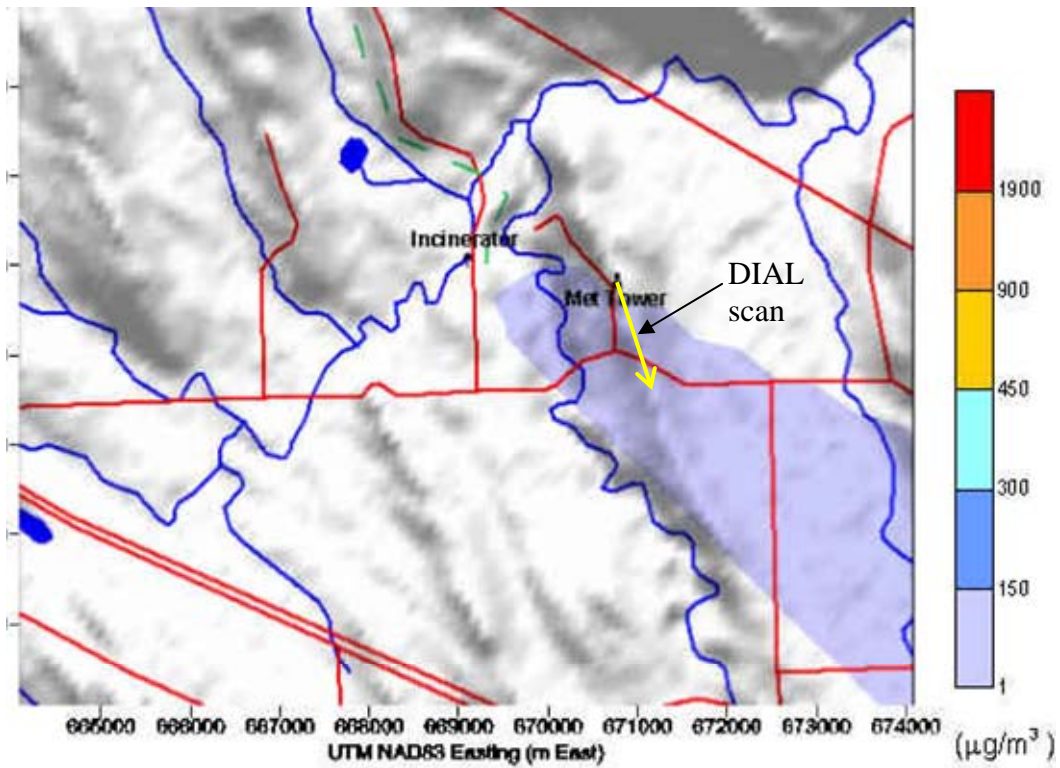
Figure 8 shows the DIAL cross-section of SO<sub>2</sub> concentrations through the plume taken at 04:44 in the morning. In this scan a significant portion of the plume is less than 50 meters above the level of the top of the ridge but the majority of the plume is higher than 20 meters. Pockets of the plume with relatively high SO<sub>2</sub> concentration (in the order of 1.5 mg/m<sup>3</sup>) were indicated near ground level.

Figure 9 shows the plume dispersion model of predicted one-hour ground level SO<sub>2</sub> concentrations for September 21 at 05:00. The predicted plume was in the same vicinity as the DIAL measured plume. One hour average ground concentrations were predicted to be less than 0.15 mg/m<sup>3</sup>.



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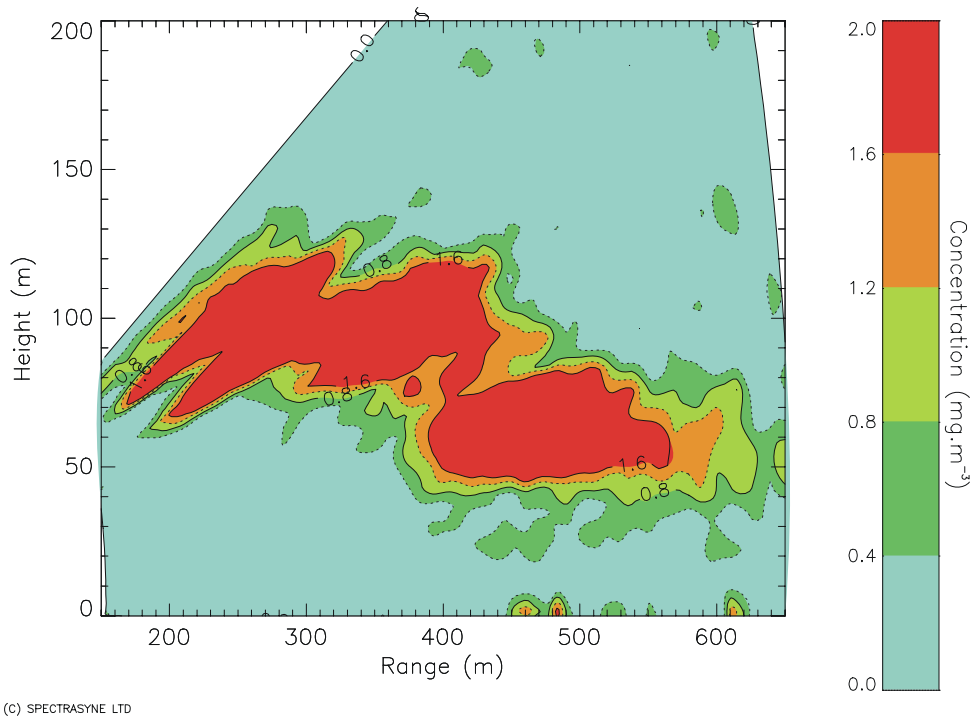
**Figure 8: Part of Plume Reaching Ridge (Sept. 21, 04:44)**



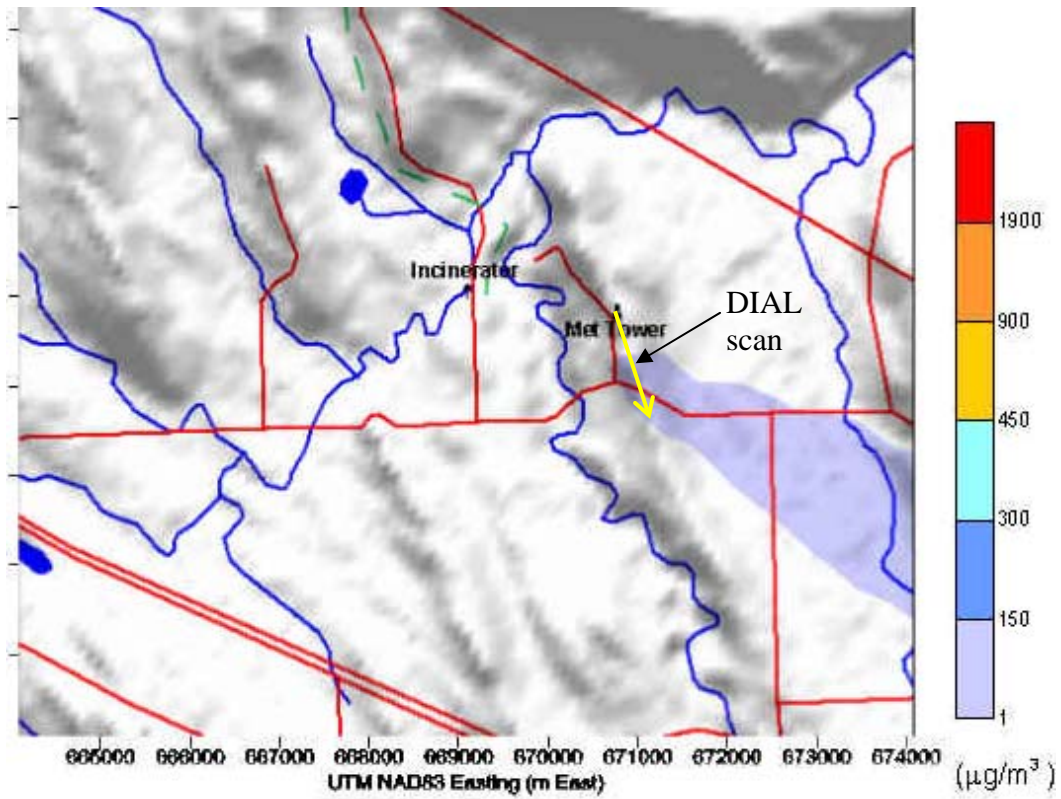
**Figure 9: Predicted Ground Level SO<sub>2</sub> Concentration on Sept. 21 05:00**

Figure 10 shows the DIAL cross section of SO<sub>2</sub> concentrations through the plume taken at 06:33 in the morning. In this scan essentially the entire plume is 40 meters or higher above the level of the top of the ridge, with only small pockets of SO<sub>2</sub> near ground level. This scan captured essentially the whole SO<sub>2</sub> plume passing over the ridge. Figure 11 is a corresponding plume dispersion model prediction of one hour ground level SO<sub>2</sub> concentrations for September 21 at 07:00. The predicted plume was in the same vicinity as the DIAL measured plume. When comparing this plume prediction with the plume prediction from two hours earlier (Figure 9), the model predicts that the plume has risen, with less SO<sub>2</sub> at ground level. The DIAL measurements would also indicate that the plume height above ground increased between 4:40 to 06:30.

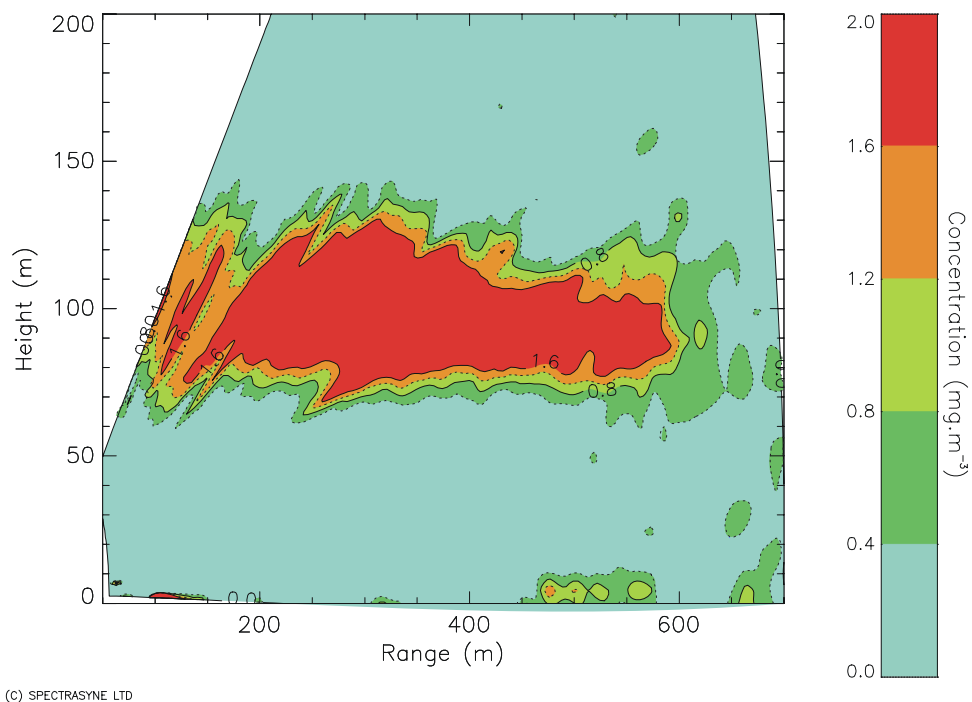
Figure 12 shows a DIAL cross section of SO<sub>2</sub> concentrations through the plume taken at 07:15 in the morning. In this scan the plume appears to have risen further with essentially the entire plume 60 meters or higher above the level of the top of the ridge. There are still small pockets of SO<sub>2</sub> near ground level. Again, this scan captured essentially the whole SO<sub>2</sub> plume passing over the ridge.



**Figure 10: Whole Plume further Down Ridge (Sept. 21, 06:33)**



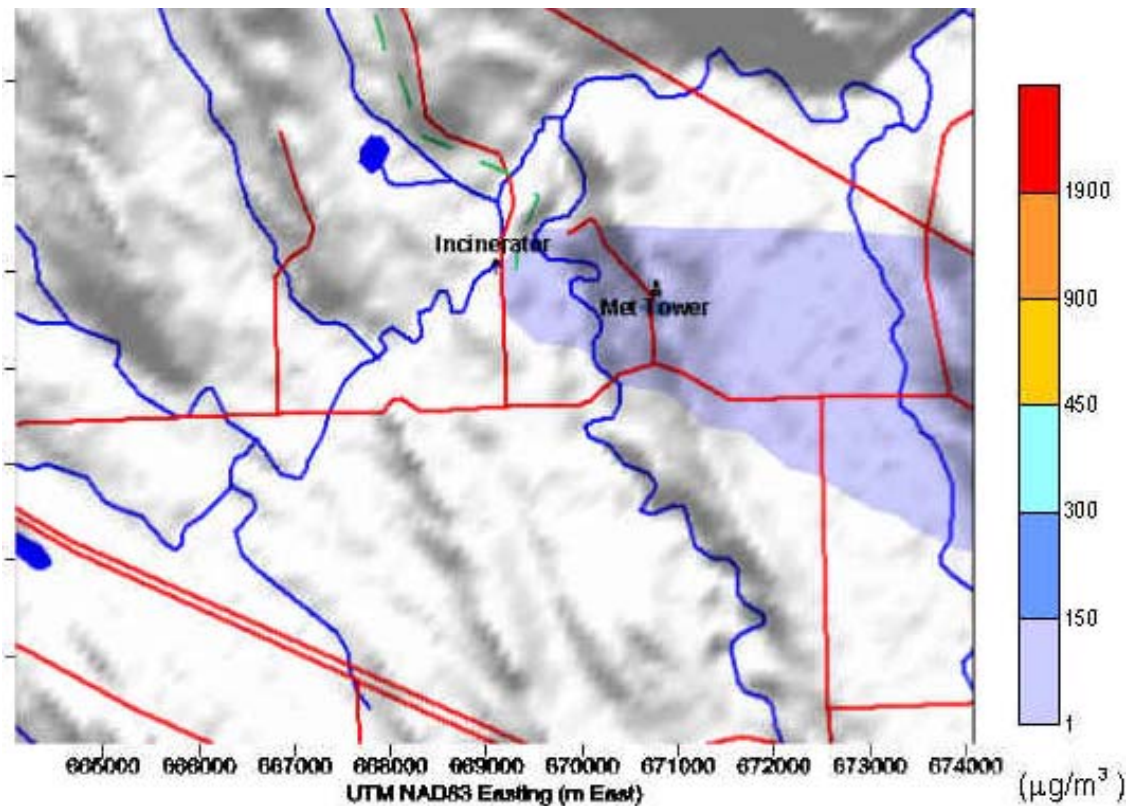
**Figure 11: Predicted Ground Level SO<sub>2</sub> Concentration on Sept. 21 07:00**



**Figure 12: Whole Plume East of Ridge (Sept. 21, 07:15)**

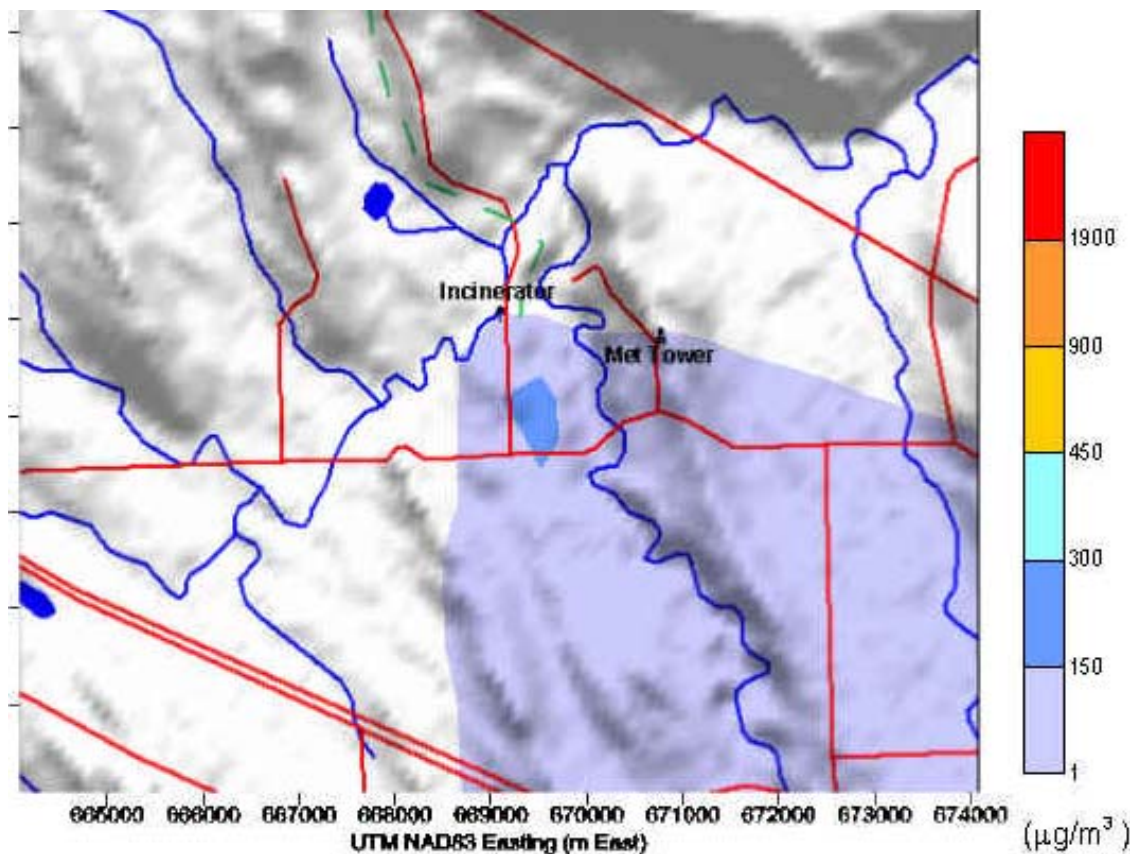


Figure 13 and Figure 14 show plume dispersion model predictions for Sept. 21 at 9:00 and later in the day at 12:00, respectively. The dispersion model predicted that ground level concentrations have increased again since 07:00 (Figure 11) and the plume was travelling in a more westerly direction. In Figure 14 the variability in wind direction increased later in the morning and the wind speed dropped, with a resulting larger spread of the ground level SO<sub>2</sub> concentrations. Even though the wind speed at the ridge top was still from the west, the model predicted the plume to travel in a south east direction following the valley. Later in the morning, DIAL scans detected only fragments of the plume directly above the ridge, with the majority of the plume following the course of the valley.



**Figure 13: Predicted Ground Level SO<sub>2</sub> Concentration on Sept. 21 09:00**





**Figure 14: Predicted Ground Level SO<sub>2</sub> Concentration on Sept. 21 12:00**

Direct comparison of plume dispersion model predictions and DIAL measurements of plume position was complicated by the different nature of the two types of data. The major differences were the relatively instantaneous nature of the DIAL measurements as compared to the one hour average prediction of the dispersion model and the focus of dispersion model output on ground level SO<sub>2</sub> concentration as opposed to the DIAL measurements through a vertical cross section of the plume.

For the measurement period that covered the transition from night to day on Sept. 21, the DIAL measurements of plume position generally agreed with the position as predicted by the dispersion model. This included the observation that with a light direct west wind at the top of the ridge, the SO<sub>2</sub> plume tended to directly follow the path of the valley towards the southeast rather than rise over the ridge to the east of the stack.

Further research is recommended to compare the DIAL measurements with plume dispersion predictions. Some software modifications may be required to the dispersion model to enable output of the predicted SO<sub>2</sub> concentrations at various levels above ground elevation. This would enable output of the predicted SO<sub>2</sub> plume concentration profile in the vertical direction for more direct comparison to the DIAL measurements of SO<sub>2</sub> cross-section concentrations. Modifications of the DIAL output may be required to more easily output and interpret the

measured SO<sub>2</sub> concentrations. This may include averaging several scans over a one hour period to compare with the one hour average predicted by plume dispersion modelling.

## 6. Implementation of H<sub>2</sub>S Capabilities in the DIAL Unit

During tests with the DIAL unit in Alberta in 2003 and 2004, the Spectrasyne mobile DIAL unit was not configured to measure H<sub>2</sub>S and the detection limit and range for H<sub>2</sub>S measurements was not known. Spectrasyne Ltd. was sub-contracted to evaluate the potential to measure H<sub>2</sub>S with DIAL and, if appropriate, perform any necessary optical equipment modifications to the DIAL unit that would be required to measure H<sub>2</sub>S.

High resolution spectral data was measured for H<sub>2</sub>S in the infrared wavelength range using a Bruker, high-resolution spectrometer at the Rutherford Appleton Laboratory (RAL) in the UK. To be in line with the bandwidth of the infrared laser emission from the Spectrasyne DIAL system and the H<sub>2</sub>S spectral feature bandwidth, the measured data resolution was 0.1 cm<sup>-1</sup>. The spectral features of atmospherically broadened H<sub>2</sub>S were measured between 2600 cm<sup>-1</sup> and 3300 cm<sup>-1</sup>.

The measured H<sub>2</sub>S spectra had many similar and overlapping features with the spectra for water. As water is a major component of the atmosphere, only features that do not overlap with the water spectrum are useable. Two sets of interference free absorption features for H<sub>2</sub>S were identified. However these features would only give DIAL measurements with a lower detection limit at ppm levels, which would be too high for most atmospheric measurements of H<sub>2</sub>S. Most gases that Spectrasyne measure with their DIAL have detection limits closer to ppb levels.

After analyzing the H<sub>2</sub>S spectra, Spectrasyne recommended to not proceed with trying to incorporate H<sub>2</sub>S capabilities in the current DIAL.

## 7. Fugitive Emissions from the Gas Plant Site

On one of the field test days, the wind direction and speed was not suitable to collect useable SO<sub>2</sub> plume data. The time available was used to complete an overview fugitive emissions survey of the gas processing plant. The DIAL scans were made along a plane on the south side of the plant with a northwest wind varying from 3.0 to 5.7 m/s (11 to 20 km/h). Although one survey day was not sufficient to allocate emissions to various parts of the plant in great detail or measure emissions under different wind directions, it was possible to notionally split emissions between the deep cut area and the main site.

During the fugitive emission survey on September 22, the plant throughput was about 5 million m<sup>3</sup> per day. Total site measurements of fugitive emissions of methane, C<sub>2+</sub> hydrocarbons and SO<sub>2</sub> were completed. Table 2 summarizes the emissions measured with a breakdown between the deep cut area and the main site. The mass emission values given in Table 2 and the following Table 3 are time-weighted means (TWM) of seven to ten separate DIAL scans. There typically is variation from scan to scan due to process changes and/or wind effects. Also, with the wind direction on the day of the fugitive emissions measurements there was likely some cross contamination of emissions plumes from the deep cut area and the main plant. In the case of the SO<sub>2</sub> scans in the main plant area, the variation of measured SO<sub>2</sub> flux was

large, from 1.9 to 47.3 kg/h. The SO<sub>2</sub> emissions measured from the deep cut area were likely originating from the main plant. About 75% of the methane emissions and over 70% of the C<sub>2+</sub> hydrocarbon emissions were from the deep cut area of the plant.

**Table 2: Fugitive Emissions from Plant F**

<b>Gas Plant</b>	<b>CH<sub>4</sub> Emissions (kg/h)</b>	<b>C<sub>2+</sub> Emissions (kg/h)</b>	<b>SO<sub>2</sub> (kg/h)</b>
deepcut area	58.2	72.0	0 to 7.6
main plant	18.6	30.3	1.9 to 47.3
<b>total</b>	<b>76.8</b>	<b>102</b>	<b>16.1</b>

Table 3 compares the total emissions from this site (identified as Plant F, in bold) to the results of previous DIAL surveys at gas processing plants in Alberta (Chambers 2003; Chambers 2004). The methane emissions of 76.8 kg/h for the whole site were lower than other gas plants surveyed while the 102 kg/h emissions of C<sub>2+</sub> hydrocarbons were higher than the other gas plants (after a leak repair program at Plant C). The Plant F site also had about 16 kg/h of fugitive emissions of SO<sub>2</sub> from the plant.

**Table 3: Summary of Fugitive Emissions at Alberta Gas Plants as Measured with DIAL**

<b>Gas Plant</b>	<b>Survey Year</b>	<b>Type</b>	<b>Plant Nominal Flow Rate (E6m<sup>3</sup>/d)</b>	<b>CH<sub>4</sub> Emissions (kg/h)</b>	<b>C<sub>2+</sub> Emissions (kg/h)</b>	<b>SO<sub>2</sub> (kg/h)</b>
A	2003	sour gas	1.45	8 (tanks only)	38	10
B	2003	sweet gas	3.5	104	42	-
C	2003	sour gas	10	146	342	50.4
C <sup>1</sup>	2004	sour gas	10	100 <sup>1</sup>	58.4 <sup>1</sup>	-
D	2003	sour gas	6	124	86	-
E	2004	sweet gas	-	144	41	-
<b>F</b>	<b>2005</b>	<b>sour gas</b>	<b>5</b>	<b>76.8</b>	<b>102</b>	<b>16.1</b>

<sup>1</sup> emissions measured after a focussed leak repair program

## 8. Conclusions

DIAL measurements of SO<sub>2</sub> plume concentrations and plume dispersion predictions of SO<sub>2</sub> ground level concentrations were completed over a six day period downwind of a tail gas incinerator stack at an operating gas processing plant. Conclusions from this project include:

1. Except for one occasion during the DIAL measurement period, the main part of the plume was higher than 20 meters above the downwind ridge. Any DIAL measured indications of plume impingement were only small fragments of the plume.
2. With direct westerly winds of less than 5 m/s (18 km/h) as measured at the ridge top, the plume tended to track along the valley in a southeast direction rather than go directly over the ridge that was downwind of the incinerator stack. Even in higher winds often only part of the plume went directly over the ridge, with the rest travelling along the valley.
3. Direct comparison of the dispersion model predictions of SO<sub>2</sub> concentration with the DIAL measurement of plume concentrations were complicated by the differing nature of the two methods. The standard dispersion model predictions were 1 hour average of ground level concentration while DIAL measurements are relatively instantaneous profiles of SO<sub>2</sub> concentration in a vertical slice through the plume.
4. The plume dispersion model prediction of plume position generally agreed with the DIAL measurements of plume position. Further work to examine predicted SO<sub>2</sub> concentrations at different elevations is required to confirm this observation.
5. Fugitive emissions of hydrocarbons and SO<sub>2</sub> from the processing plant were measured with the DIAL for a one day period. Measured fugitive emissions were 76.8 kg/h of methane, 102 kg/h of C<sub>2+</sub> hydrocarbons and 16.1 kg/h of SO<sub>2</sub>. The majority of the hydrocarbon emissions were from the deepcut area of the plant.
6. Remotely measuring low concentrations of H<sub>2</sub>S in the atmosphere with the Spectrasyne DIAL unit was not feasible. A spectral region could not be identified in an appropriate wavelength range that had sufficient sensitivity to enable H<sub>2</sub>S concentration measurements lower than parts per million levels.

## 9. Recommendations

The following further work is recommended based on the results of this study:

1. Modification of the dispersion model output is recommended to enable predicted SO<sub>2</sub> concentration elevation contours through the plume and the predicted wind direction and speed patterns at various elevations in the valley and above the ridge. Predicted SO<sub>2</sub> concentration changes with elevation above ground could then be more directly compared to the DIAL measurements.
2. Run the dispersion model to predict 10 or 15 minute averages rather than the standard 1 hour average to allow easier comparison with the DIAL measurements.
3. Software development is recommended to more easily output and analyse the large number of DIAL scans collected during the test period. This may include for example a method to average several scans over a one hour period to compare with the one hour average predicted by plume dispersion modelling, and compare with modelling results.

## References

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