Assessing the frequency and height of wintertime radiation inversions over Richmond

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Executive summary

Tasman District Council (TDC) is developing a comprehensive airshed modelling capability in order to more effectively manage the air quality issues under their jurisdiction. To complement and inform this capability the TDC have created a database of 25,000 digital images recording the air directly over Richmond over a 16 month period. These images have been visually analysed following a detailed protocol using manual, subjective methods. The visual image analysis shows that smoke events are more likely in autumn and winter and associated with mainly zonal regime Kidson Types. Mixing heights in winter are reduced to under 150m and are much less variable than other seasons.

Further quantitative methods relying on image intensity software have been developed and compared with the subjective results, in order to see if the analysis of images for air quality or meteorological purposes may be successfully automated. The results show promising developments in using automatic image analysis.

The results obtained in this study were consistent with the common understanding of the dispersion conditions in this urban area:

- Smoke events were more frequent in winter (~30%) than in summer.
- In summer there were 0% of foggy/smoky days
- Orchard fires could be responsible for the unexpectedly high frequency of smoke events in February and March

By correlating the Kidson weather types with the estimates of smoke events it was possible to demonstrate that:

- There is a ~30% possibility of a smoke event when the synoptic condition corresponds to the types H, TNW or HNW.
- There is less than 10% probability of a smoke event when the synoptic condition corresponds to the types SW, HW, HSE, HE or TSW
- No smoke event was ever observed when the synoptic condition type R was reported.

An estimate of the atmospheric mixing height for the smoke events was obtained. This estimate is consistent with the expected seasonal variation of the mixing height.

- The estimated mixing height during the smoke events in winter (June to August) is below 150m while for the fall (March to May) is above 150m.
- The mixing heights obtained in this study cannot be directly compared to other estimates because they are dependent on the ability of the user to identify the NPI plume and estimate its base or top height.
- However, the conclusion that during the smoke events in winter the mixing height seems of similar height throughout the season could be verified using other tools such as radiosondes or modelling exercises.

The automatic image analysis successfully detected differences in light intensity between smoke and non-smoke events intermittently throughout the average day. Even though this is not ideal, it indicates that the automatic analysis of digital images can provide objective information about the presence of a smoke layer. To further develop this method, a more comprehensive set up will be required, including a more advanced digital camera.

Thus, the image database enabled the development of relationships between the images' information and meteorological characteristics, which can inform air quality management decisions. The use of visual image analysis can be complemented by a quantitative analysis to enhance the value of this time consuming activity.

1 Introduction

Tasman District Council (TDC) holds a comprehensive database of images of the lower atmosphere over Richmond, potentially capturing important information about the meteorological conditions during episodes of poor air quality. A method has been devised to determine the frequency and height of radiation inversion layers by analysing the images for visible layers of smoke. The stability of the atmosphere may also be identified through the rise and dispersion of visible plumes. Characterising the atmosphere through this media serves as a complementary method to advanced dispersion modelling undertaken to inform about the air quality of the area, and may also add a further tool for evaluating the modelled meteorological data which drives airshed modelling.

Visibility was first defined for meteorological purposes as a quantity to be estimated by a human observer, and observations made in that way are widely used. However, the estimation of visibility is affected by many subjective and physical factors. From an air quality perspective, visibility is often treated as an effect of poor air quality. In fact, nitrogen oxides and atmospheric aerosols have an impact changing the transparency of the atmosphere and thus changing the perceived visibility.

In New Zealand, the Ministry for the Environment published a study in 2000 identifying areas of "high risk of degraded visibility" (MfE, 2000). As shown in Figure 1-1, this study identified Auckland and Christchurch as the areas with the biggest risk of degraded visibility. However, this study showed some inconsistencies such as the low index attributed to the Nelson-Richmond area. This area experiences significant degradation of visibility during the winter season.

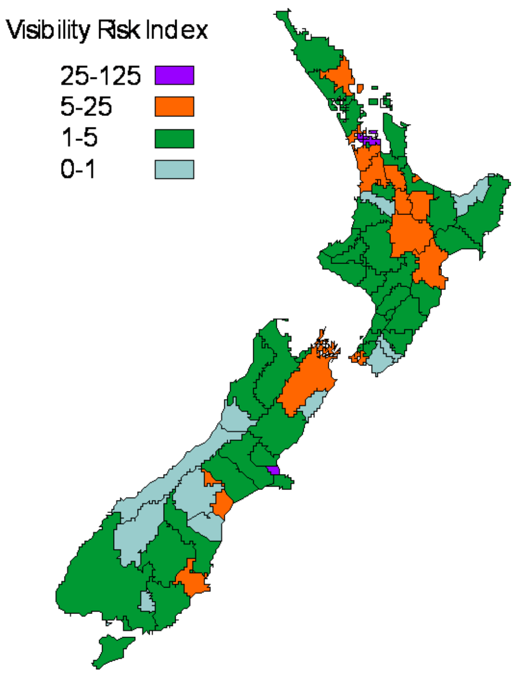


Figure 1-1: New Zealand map of visibility risk. From MfE (2000).

Visibility measurements have been used in many places for air quality management since early in the 20th century. In Australia, there is official documentation of visibility measurements in the Melbourne area since the 1950s. In New Zealand, the largest dataset of visibility imagery has been developed by Auckland Council (formerly Auckland Regional Council). This dataset has been used to explore the phenomenon of a brown haze that is visible in Auckland during still winter days. However, because of the labour intensive task of visually analysing the images, digital imagery has only been sparsely used to quantify air quality parameters.

Tasman District Council (TDC) deployed a visibility camera with a slightly different objective from those set in Auckland. Instead of directly quantifying the air quality recorded in the images, the objective of this study was to obtain information about the frequency and strength of atmospheric inversion events, to inform the modelling capability being developed for the Tasman area. To this end, traditional, manual visual analyses of images was applied, but an automated quantitative method was also developed and tested to see if similar future analyses could be undertaken with minimum resources. This report summarises the methods and results from both analyses, focusing on the seasonal variation of atmospheric inversion events in Richmond and on the efficacy and reliability of the automated approach.

2 Objectives

The main objective of the work reported here is to:

Estimate the monthly and seasonal frequency, height and intensity of inversion events in the Richmond area, based on the analysis of digital images.

To achieve this objective, the following partial objectives were set:

- Develop a validated dataset of digital images.
- Characterise the digital images by visual inspection.
- Quantify the digital images through automatic image analysis.
- Analyse the relationships between the time of the year and the synoptic conditions, and the estimates of inversion obtained from the visual and quantitative analysis.

The original work plan for the project consisted of four phases necessary to deliver a dataset of the frequency and characteristics of atmospheric inversions over Richmond, related to pollutant dispersion. They were:

- a review of the meteorology and air quality of Richmond for the period covered by the database;
- a review of the library of images;
- analysis of the images, to derive from them objective measures of the recorded inversion layers; and
- a final report documenting the procedure for obtaining objective measures, for future reference.

3 Data

3.1 Digital Images

A total of more than 25000 digital images, captured by Tasman District Council between May 2007 and September 2008, were used in this study. Figure 3-1 shows the approximate location of the camera and its field of view. The camera was set up to automatically capture a full resolution image every 30 minutes during daytime hours (between 05:00 and 20:00) and to send the images to NIWA servers for storage.

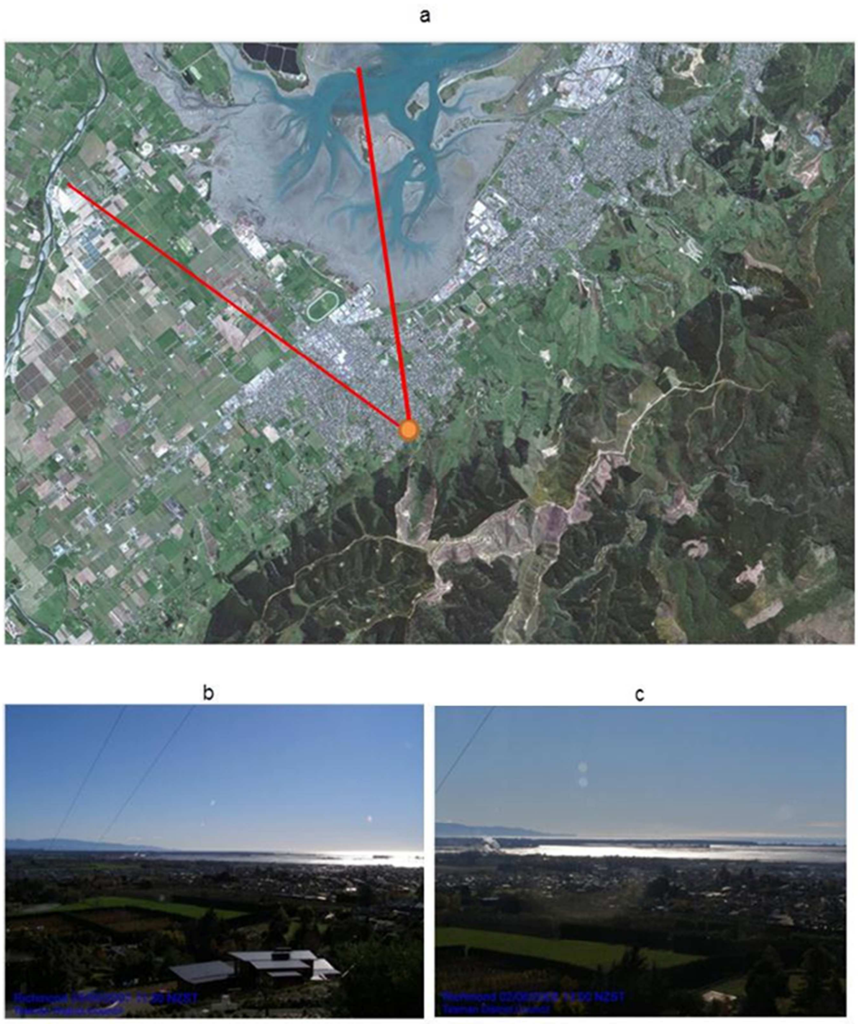


Figure 3-1: Image capture system details. Approximate location of the automatic image capture system and two sample images showing the different field of views used in this study.

As a result of early optimisations of the system, for the last 14 months the camera had the field of view shown in Figure 3-1(c). This change did not compromise the overall objectives of the project but made the visual analysis more complex as not all the targets or reference elements were visible for all the images. One limitation of the system was the lack of a radiometer at the site to accurately quantify the light intensity, and to manually control the exposure of the images. (See Lim et al (2004) and Raina et al (2005) for details.) However, the *autoexposure* function used on the camera partially compensates for this by 'evening out' the light level in the images.

The image capture system worked well during the 16 months of this campaign, but there were still some technical issues that prevented a 100% of image capture. Table 3-1 shows the percentage of data that is available for each month as a percentage of the total number of hours between 05:00 and 20:00.

Table 3-1: Image availability. Percentage of daylight hours (05:00 to 20:00) that have image available for the data capture period between May 2007 and September 2008.

Month	Coverage	Month	Coverage
May-07[1]	100%	Feb-08	100%
Jun-07	100%	Mar-08	100%
Jul-07	100%	Apr-08	52%
Aug-07	49%	May-08	77%
Sep-07	84%	Jun-08	95%
Oct-07	100%	Jul-08	42%
Nov-07	100%	Aug-08	70%
Dec-07	100%	Sep-08[1]	100%
Jan-08	100%		

3.2 Summary of AQ and Met data In the Richmond area

3.2.1 Air quality

A detailed analysis of the air quality of Richmond during the campaign was not undertaken. The campaign spanned the winters of 2007 and 2008, which exceeded the National Air Quality Standard's 24hr average concentration limit for PM_{10} 21 and 20 times, respectively.

3.2.2 Meteorology

Meteorological data recorded at the nearby Nelson Airport was examined for the period. Of the measurements available the most relevant to air quality were the wind speed and direction, which drive the dispersion of air pollutants and temperature. In an area where air pollutant emissions are dominated by domestic heating, the minimum temperature may give an indication of the likelihood of increased emissions. Temperatures during the campaign period ranged from -3^{o}C to 28^{o}C with a mean of 13^{o}C.

A wind rose displaying the frequency of wind speed and direction is shown in Figure 3-2

[1] The percentage in the set-up and decommissioning months was based on the total hours that the system was in place.

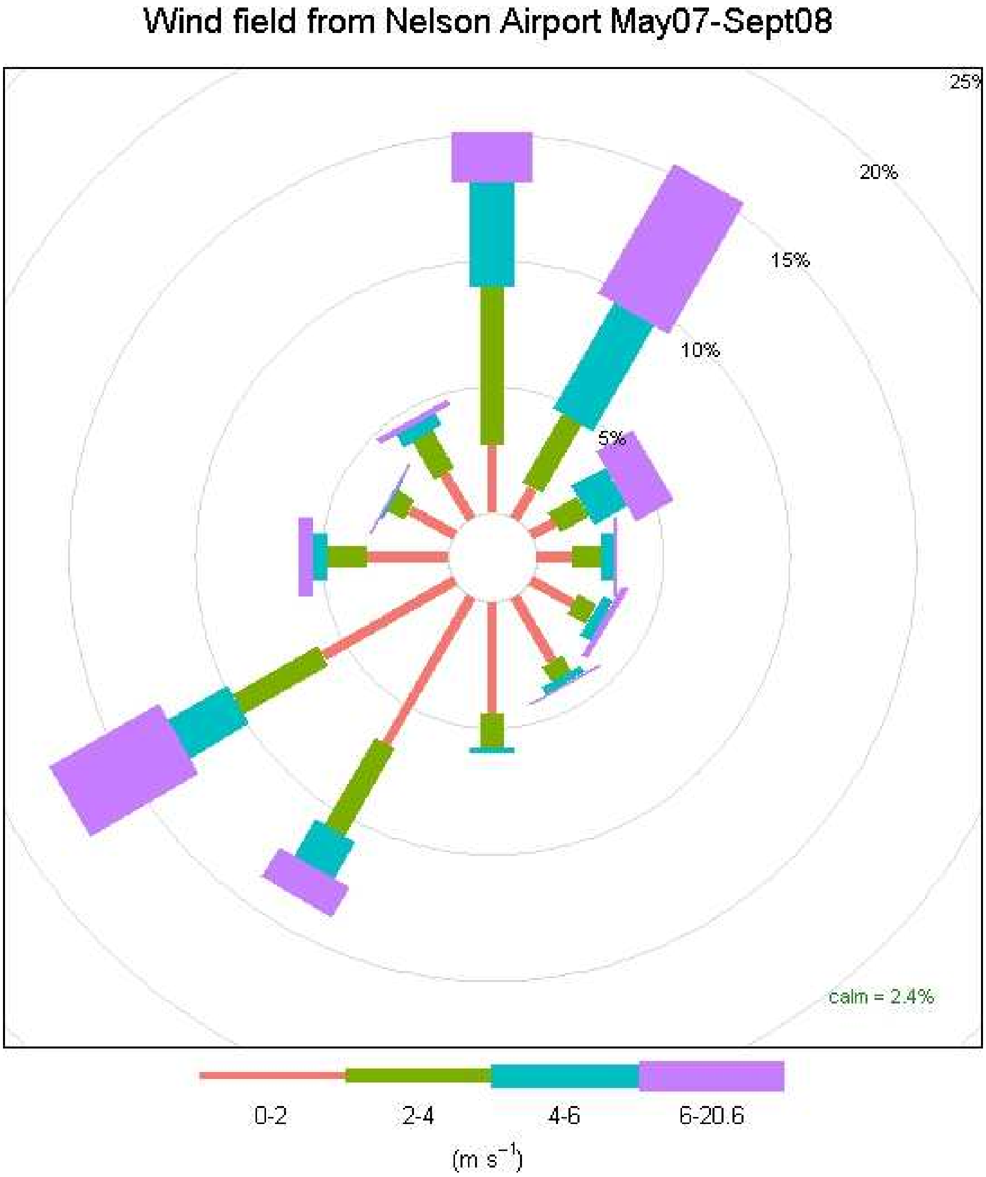


Figure 3-2: Wind rose from Nelson Airport: May 2007 to September 2008

3.2.3 Synoptic Weather Types

Synoptic weather conditions set the broad stage for meteorological processes at more local scales. The full range of synoptic conditions experienced by New Zealand have been codified into Kidson Types (Kidson, 2000), which allow a consistent description of the general air flows over the country. The twelve types fall into three regimes: 'Trough', with troughs over and east of the country; 'Zonal', which has intense anticyclones to the north/northwest and strong westerlies to the south, and; 'Blocking' which has anticyclones to the south and east. Although 'Zonal' types occur less frequently in summer, there is no strong seasonal pattern to the regimes.

In terms of expected weather patterns, the regimes serve to indicate where departures from average conditions may be expected, as seen in table 3-2.

Table 3-2: Regimes based on Kidson types and their associations with weather conditions**.**

Regime	Effects on Temperature	Effects on Precipitation
Trough	Below normal in the south	Significantly above normal in all districts
Zonal	Above normal in the south	Below normal in the north and east
Blocking	Above normal on the west coast	Above in the north and east and below on the West Coast

The Kidson Weather Types are reported twice daily by NIWA at 00Z and 12Z hrs and are used in this study to explore the relationships between the information obtained by the image analysis and the meteorology of the area. This is to enable the generalisation of the conclusions of the image analysis.

4 Method

In line with the objectives set for this study, the method used to analyse the images consisted of three steps.

1. **Visual image analysis**. This corresponds to the manual analysis of the images aimed at identifying visible smoke layers that can be related to inversion events. The result of this step was a comprehensive database with detailed information of each individual image that showed a discernible smoke layer over Richmond.

2. **Automatic image analysis**. This corresponds to automatically assigning a *value* to each image that is related to its colour and brightness with the aim to develop a quantitative alternative to the labour intensive visual analysis. Quantifying each image should make it more comparable with classic ambient measurements. The result of this step was to enhance the previous database with quantitative information of each captured image.

3. **Analysis of Relationships**. This final step aimed at characterising the relationships between the frequencies of occurrence of smoke events in Richmond and the seasonal variability of weather patterns. It also served to evaluate the efficacy of the automatic analysis compared to the visual method.

4.1 Visual Image Analysis

The main objective of this analysis was to extract *subjective* information about the smoke events occurring in Richmond, based on the available images. The information required to be extracted from the images included:

- Presence of smoke layer.
- Estimate of the height of the smoke layer.
- Visibility of the plume from Nelson Pine Industries' (NPI) stack.
- Estimate of the height of the mixing layer based on NPI's plume.

Tasman District Council staff was tasked with the visual inspection of the images following the procedure summarised below and attached in Appendix A1.

Identify the image as useful or not

As this analysis is primarily subjective, it is not possible to strictly define what is a useful image and what is not. Nevertheless, Figure 4-1 illustrates the differences between what was considered useful and not. The main criterion corresponded to the presence of visible layers of smoke or fog and/or visible plumes from the stacks.

Useful image

Not useful image

Figure 4-1: Example of useful images. Sample of a useful and a not useful image, according to the protocol implemented for Tasman District Council's visual analysis of the images.

Estimate the height of the smoke layer in the residential parts of Richmond

Using local landmarks as points of reference with known heights provided by TDC, the depth of the smoke/fog layer in the residential parts of Richmond was estimated. It is worth noting that because there were changes in the orientation of the camera, the field of view of the images changed during the period of analysis. This meant that not all the points of interest were visible in all the images. However, the smoke layer heights estimates obtained from this analysis were not dependent on single points and were always used as a composite estimate from at least three points. Estimating the height of the smoke layer gave an indication of the inversion layer height.

Stability class

The plume from the Nelson Pine Industries plant was used to classify the stability of the lower atmosphere by exploration of the stack plume in terms of its shape, location and evolution (see Appendix A – Stability classification for details). An estimate of the mixing height was also obtained from the plume when possible.

Other purposes

Finally, each image was flagged for purposes outside this project, such as identifying orchard fires in the area.

4.2 Automatic Image Analysis

To convert the digital images into numeric information, a LabView® routine was implemented. This routine extracted the colour information of all the pixels in the image as light intensity for the pixel and the **red**, **green** and **blue** channels. Appendix B gives a detailed explanation of the use of this software to convert a set of images into a set of quantitative measures.

Through this process, four values were obtained for each image, representing the average light intensity of the whole image and the light intensity of the red, green and blue channels. The light intensity gives an indication of whether smoke is present in the atmosphere.

A secondary method based on *blob analysis*[2] was explored but was deemed unsuitable because of the large variability in sharpness of the images and the change in field of vision that occurred partway through the campaign.

4.3 Analysis of Relationships

The results of the visual image analysis were used to determine the frequency of smoke events over Richmond and give an indication of the stability, in relation to the time of day and season. This is documented in section 5.1.

The synoptic characterisation in terms of the Kidson weather types was also incorporated into the database. However, as indicated before, the Kidson weather type information is available twice during the day while the image record contains information for 30 half-hours each day. This meant that to incorporate the Kidson weather type information, the half-hourly information was first converted to daily information by flagging all days that have **any** image considered **useful**. The relationship between the frequency of smoke events and synoptic conditions was then analysed (See section 5.2)

Analysis of mixing height estimates in relation to season is discussed in section 5.3

In section 5.4, the light intensity values from the automatic image analysis were compared with the results from the subjective visual analysis, to see if the images manually defined as useful represented a definable/discernible/discrete subset of the quantitative data.

5 Results

5.1 Frequency of smoke events

One of the main objectives of this study was to estimate the frequency of occurrence of visible smoke layers over Richmond (smoke event). Figure 5-1 shows the fraction of images that show a smoke event as a percentage of the number of images assessed using the manual method described in Appendix A. As expected, the frequency of smoke events is

[2] Blob analysis refers to the method by which certain features in an image are automatically identified. This is very useful for face recognition or object tracking but it requires very sharp images and it is not appropriate for hazy conditions like those observed when a smoke layer is present in an image.

highest during the winter months (about 30%) and the lowest during summer when the values drop to zero.

February and March (months 2 and 3) present a somewhat surprisingly high frequency of smoke events (~10%). The reason for this is unclear because the image database does not record any fire event in those months and it is still possible that cold nights forced residents to light up fires or that orchard fires outside the field of view of the camera were active at the time.

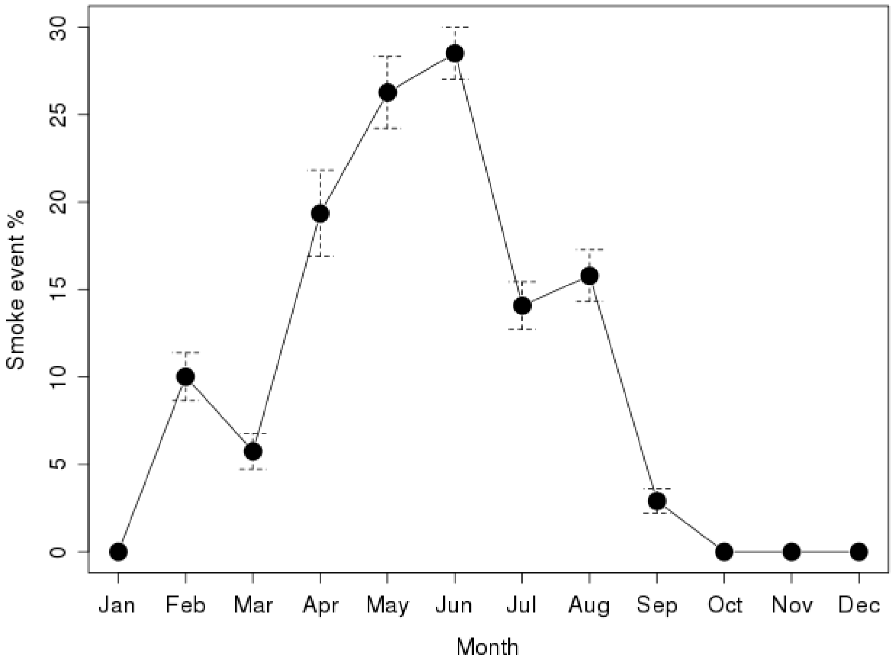


Figure 5-1: Estimated monthly frequency of smoke events. The error bars indicate the 95% confidence interval of the mean based on the half-hourly images.

The large number of images makes it possible to also quantify the frequency of smoke events as a function of the hour of the day. Figure 5-2 shows the diurnal variation of the frequency of smoke events in the images, separated by season (Summer: December to February; Autumn: March to May; Winter: June to August; Spring: September to November).

As shown in Figure 5-2, between 07:00 and 17:00 the frequency of events is relatively uniform and varies primarily with season. During the Autumn-Winter season, the frequency of smoke events is between 20% and 30% while during the Spring-Summer season the frequency is below 5%. This indicates that burning, or smoke generation is on-going throughout the day in Richmond during these seasons. The rest of the day (before 07:00 and after 17:00) the frequency of smoke events is reduced probably due to insufficient light in the image to identify any smoke layer. There is a slight increase at 8:00 (in autumn and winter) and at 17:00 (autumn only), which may be resulting from the use of the auto-exposure function in the digital camera.

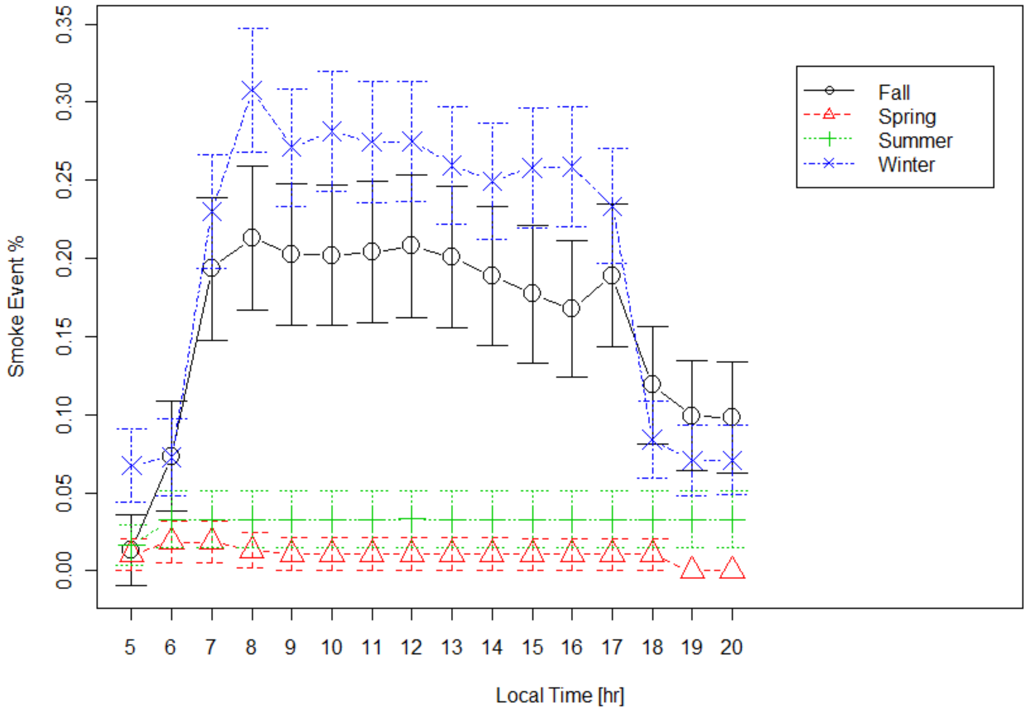


Figure 5-2: Diurnal and seasonal variation of the frequency of smoke events The seasons considered were Summer: December to February; Autumn: March to May; Winter: June to August and Spring: September to November. The error bars correspond to the 95% confidence interval of the respective averages.

5.2 Weather type frequencies

In order to generalise the findings from the analysis of the digital images, the relationships between the frequency of *smoke events* and the Kidson weather types was explored.

Figure 5-3 shows that five Kidson weather types show a frequency of smoke events higher than 20%.

- **H**. Zonal type characterised by an anticyclonic system over the country associated with light winds and low atmospheric dispersion. According to this analysis there is a 29% chance of a smoke event with this weather type. This type covers 23% of the smoke events observed during this period.

- **TNW**. Trough type characterised by cyclonic circulation over the country with north to northwest winds. According to this analysis there is a 28% chance of a smoke event with this weather type. This type covers 12% of the smoke events observed during this period.

- **HNW**. Zonal type characterised by an anticyclonic circulation with southwest winds. According to this analysis there is a 28% chance of a smoke event with this weather type. This type covers 13% of the smoke events observed during this period.

- **W**. Zonal type characterised by an anticyclonic system to the west of the country and associated with westerly winds. According to this analysis there is a 24% chance of a smoke event with this weather type. This type covers 4% of the smoke events observed during this period.
- **NE**. Blocking type characterised by an anticyclonic system to the north east and associated with northeast winds. According to this analysis there is a 20% chance of a smoke event with this weather type. This type covers 8% of the smoke events observed during this period.

These results are consistent with the common understanding of the dispersion conditions in Richmond in that anticyclonic systems are associated with poor dispersion conditions in the area and therefore are expected to be related to more frequent smoke events.

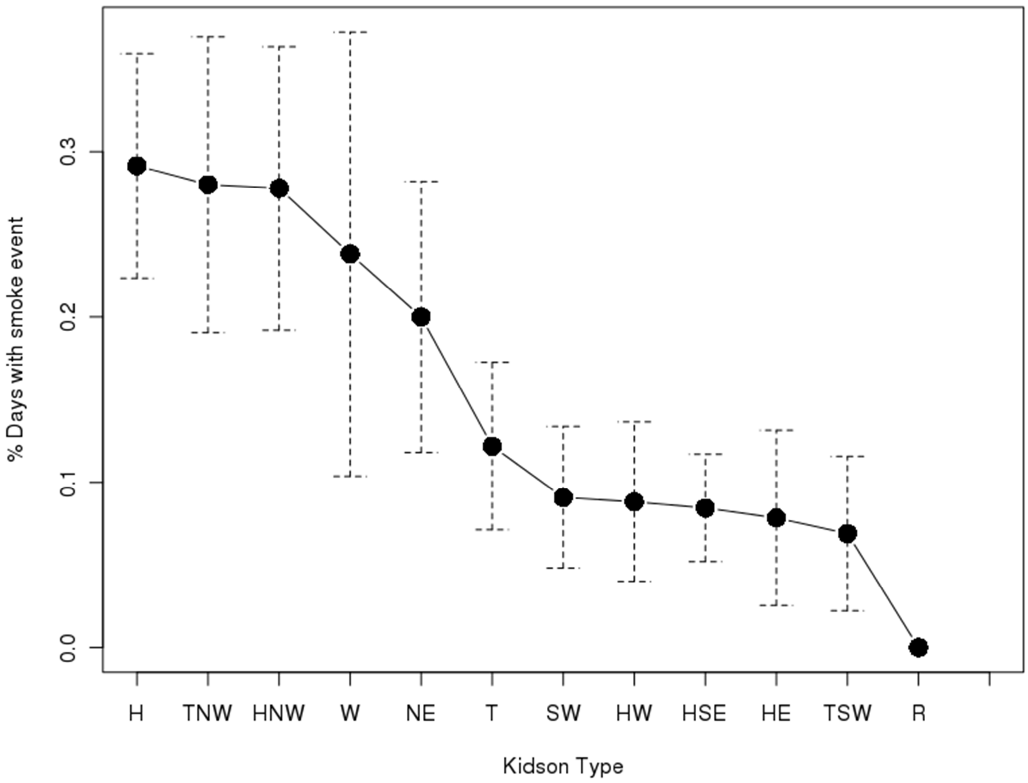
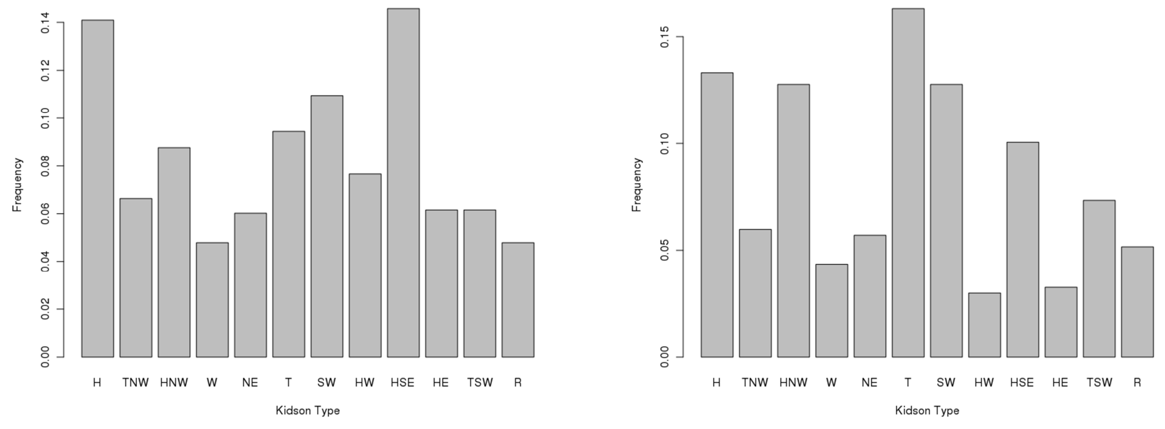


Figure 5-3: Frequency of smoke event by Kidson weather type. Fraction of days with each Kidson weather type that presented a smoke event. The error bars indicate the 95% confidence interval of the frequency. Note that for type R no smoke events were recorded and therefore the error bar is not visible.

To put the smoke event frequencies into context Figure 5-4 shows the frequencies of the Kidson types for the whole period (16 month campaign) and for the winter months only (June to August). From this figure it is apparent that the most common weather type in winter (T) is only associated with a small frequency of smoke events (~10%) while one of the more uncommon weather types (TNW) is associated with a much higher frequency of smoke events (28%).



Whole period Winter (June to August)

Figure 5-4: Frequency of Kidson weather types. Total and winter-only frequency of Kidson weather types.

5.3 Mixing height estimates

The presence of a smoke layer in Richmond is the effect of a reduced dispersion capacity of the lower atmosphere in the area. This dispersion capacity can also be described by the depth of the mixing height.

By using the plume from the Nelson Pine Industries' (NPI) stack as an indicator of the mixing height around the area, the visual analysis described in Appendix A was able to produce a time series of estimated mixing height.

However, because of the relative subjectivity of this approach, the estimates here presented must be taken only as indicative and not an accurate description of the depth of the mixing layer. Nevertheless, the diurnal and seasonal variation of these estimates can be used to describe the variations of the depth of the mixing layer.

Figure 5-5 shows the monthly variability of the estimated mixing height at the site of the NPI stack in Richmond. As expected, the estimated mixing height appears significantly higher during the summer months and very low for the winter months. Also, the size of the error bars suggests that the estimated mixing height in summer has a much larger variability than during winter. However, because during summer there are 70% fewer smoke events, the statistics from January to March are less robust than for the winter months.

Nevertheless, this analysis suggests that the mixing height during winter in Richmond is about five times smaller than during summer and that between the months of June to August, smoke events are associated with a relatively similar mixing height estimated as less than 150m.

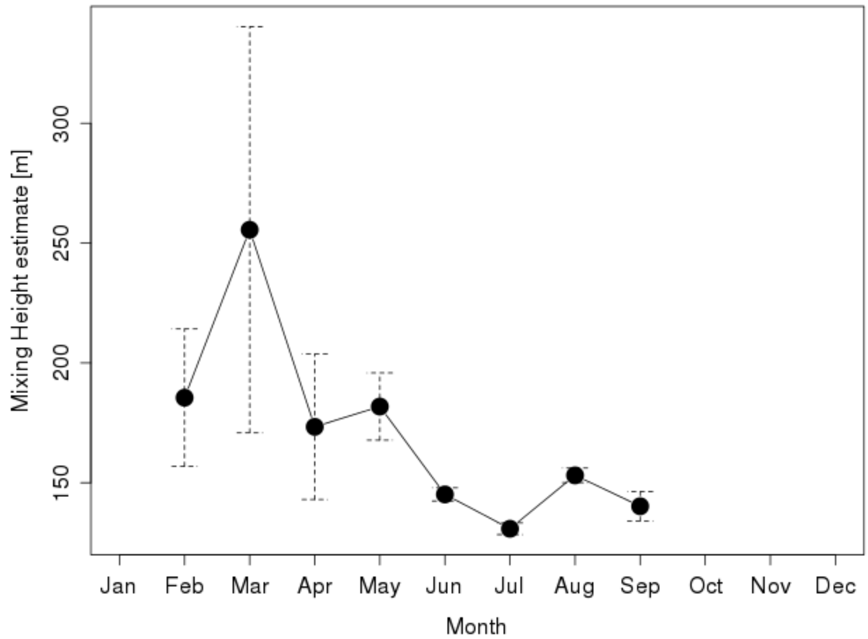


Figure 5-5: Monthly average of the mixing height. Monthly average estimated mixing height based on the NPI stack plume for the months that there were images available. The error bars correspond to the 95% confidence interval around the mean.

5.4 Quantitative analysis

Although the camera deployment was not optimised for quantitative analysis (as mentioned in 3.1), useful information was still derived from the images by analysing the image intensity. Figure 5-6 shows the annual variation of the total image intensity which reflects the variation in total sunlight between winter and summer.

When mapping the visual image analysis to the quantitative automatic image analysis, it is possible to show that the automatic analysis can discriminate between smoke and non-smoke periods, but not consistently throughout the daylight period. From Figure 5-7, during the early hours of the morning (before 07:00) there are clear differences in intensity between useful and not useful digital images. The categories then converge to show no differences at around 8:00. From Figure 5-2, this was when a ‘blip’ was observed in smoke events categorised by the manual visual image analysis. This indicates that during this time the auto-exposure function on the camera may be interfering with both types of analysis. The categories then diverge again in intensity until about 14:00, when they become indistinguishable using automatic image analysis until after 17:00.

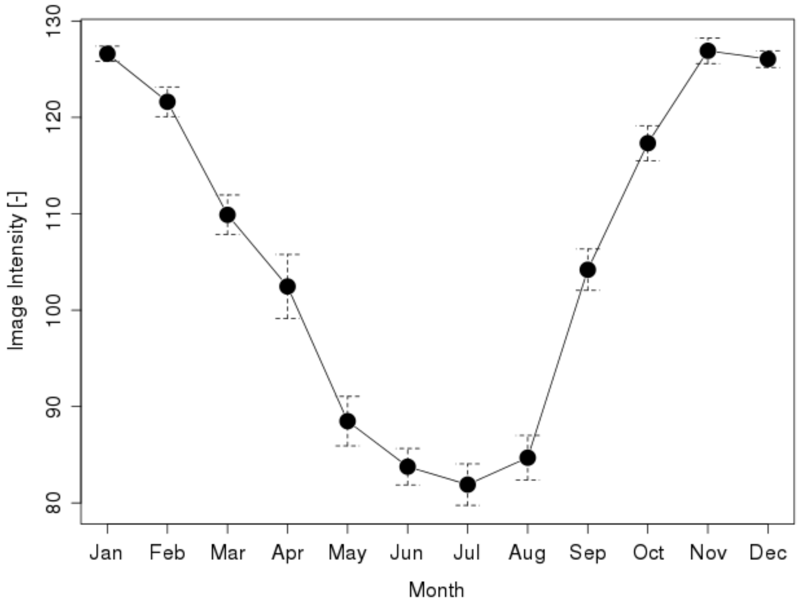


Figure 5-6: Annual variation of the average image intensity. The error bars correspond to the 95% confidence interval of the mean.

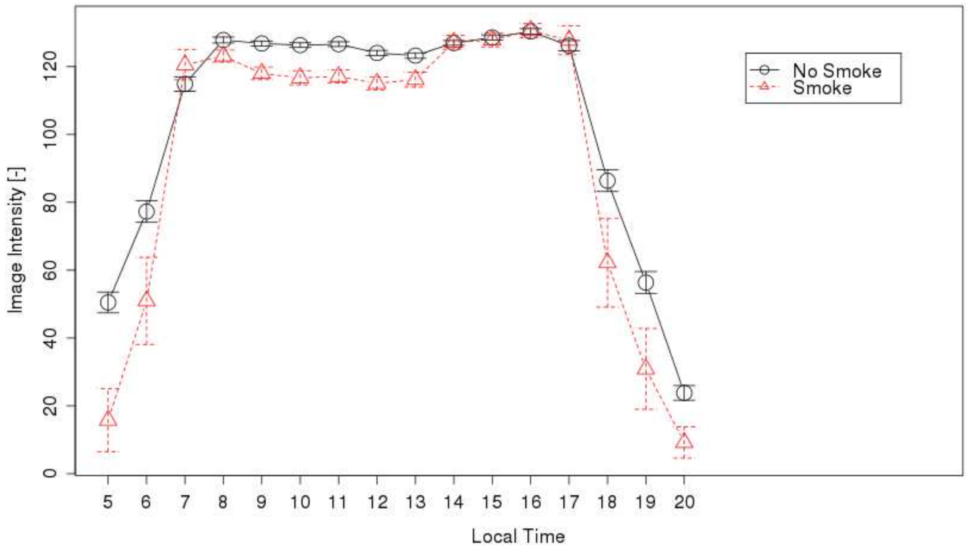


Figure 5-7: Diurnal variation of the image intensity for smoke and non-smoke events. The "Useful" label corresponds to a smoke event and the "Not Useful" label corresponds to a non-smoke event. The error bars indicate the 95% confidence interval of the mean.

6 Conclusions

The purpose of this analysis was to utilise the vast record of digital images of Richmond held by TDC in order to derive characteristics of the atmospheric inversion layer visible during days of high pollution, estimating the monthly and seasonal frequency of smoke events and the mixing height. To achieve this, a validated dataset of digital images was developed through the use of visual image analysis, and then quantified using automatic image analysis. The relationships between the time of the year, the diurnal cycle, the synoptic conditions, and the estimates of inversion obtained from the visual image analysis have been investigated, and the automatic image analysis has been evaluated against the results of the visual image analysis.

The results obtained in this study were consistent with the common understanding of the dispersion conditions in this urban area:

- Smoke events were more frequent in winter (~30%) than in summer.
- In summer there were 0% of foggy/smoky days
- Orchard fires could be responsible for the unexpectedly high frequency of smoke events in February and March

By correlating the Kidson weather types with the estimates of smoke events it was possible to demonstrate that:

- There is a ~30% possibility of a smoke event when the synoptic condition corresponds to the types H, TNW or HNW.
- There is less than 10% probability of a smoke event when the synoptic condition corresponds to the types SW, HW, HSE, HE or TSW
- No smoke event was ever observed when the synoptic condition type R was reported.

An estimate of the atmospheric mixing height for the smoke events was obtained. This estimate is consistent with the expected seasonal variation of the mixing height.

- The estimated mixing height during the smoke events in winter (June to August) is below 150m while for the fall (March to May) is above 150m.
- The mixing heights obtained in this study cannot be directly compared to other estimates because they are dependent on the ability of the user to identify the NPI plume and estimate its base or top height.
- However, the conclusion that during the smoke events in winter the mixing height seems of similar height throughout the season could be verified using other tools such as radiosondes or modelling exercises.

The automatic image analysis successfully detected differences in light intensity between smoke and non-smoke events intermittently throughout the average day. Even though this is not ideal, it indicates that the automatic analysis of digital images can provide objective information about the presence of a smoke layer. To further develop this method, a more comprehensive set up will be required, including a more advanced digital camera.

In conclusion, the analysis of digital images to provide information about the dispersive conditions of the local atmosphere is a valuable tool that provides important supplementary information to enable the effective management of air quality. Automatic analysis shows great promise in allowing a reliable and timely analysis of digital images.

7 Acknowledgements

The time and effort from the staff at Tasman District Council who performed the visual analysis of the images is greatly appreciated.

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Appendix A Briefing to TDC staff about visual analysis of images

Objective

To identify days and hours in that day when a suppressed mixing layer is present (inversion) and to quantify the height of that layer.

Procedure

1. Identify the image as useful or not
2. Estimate the height of the mixing layer in the residential parts of Richmond
3. Classify the stability of the upper layer by exploration of the stack plume and estimate the mixing height when the plume allows it
4. Flag the image for other purposes

Detailed procedure

Usefulness of the images

The main criterion corresponds to the presence of visible layers of "smog" and visible plumes from the stacks.

The analysis is primarily subjective and therefore clear definitions of what is visible and what's not are not possible. As examples, however, Figure 1 would be useful while Figure 2 would not be useful.

It is recommended to look at the images from around 7:00 until 9:00 before make a decision regarding the full day.

If the image is useful, a note should be made about the date and in general, all the images for that day should be analysed.

Figure 1 – Useful image

Figure 2 – Not useful image

Mixing height estimate in residential areas

Tasman District Council has information about the tall buildings in the area and also the height of the stacks visible in the images. As shown in Figure 3, in general, the features "poking" out of the mixing layer are tall trees and therefore those should be used to estimate the height of the layer. The height should be marked when the tree (or tall object) is no longer "hazy" (see Figure 3).

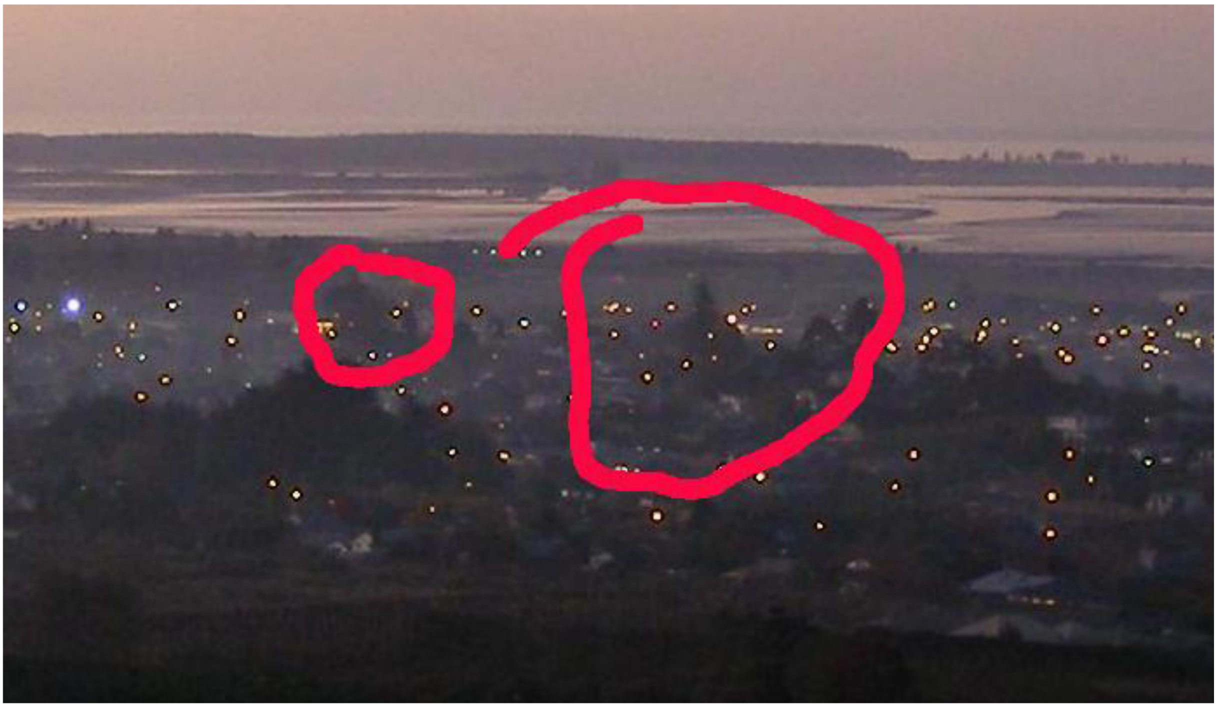

Figure 3 – Residential mixing height

Take between 3 and 5 "spot" heights for each image but some images may be only possible to take 1 or 2 heights.

Stability classification

The dispersion of the plume from the stacks to the west of Richmond are very useful to gain information about the stability of the atmosphere in certain periods.
There are several possible situations:

1. The plume looks very "thin" and it moves only horizontally (no vertical spread of the plume.
   This corresponds to a **STABLE** situation where the plume is being injected **INSIDE** the inversion layer but above the surface layer.
2. The plume looks "fat" but does not "spread" downward.
   This corresponds to a **STABLE** situation with the plume being injected **ABOVE** the inversion layer.
3. The plume seems very large and points upward.
   This corresponds to a **UNSTABLE** situation and if there is a haze layer at the surface (identified before), the layer above it is very unstable and well mixed.
4. The plume "turns" higher up.
   This corresponds to a **NEUTRAL** condition where the layer near the surface is moving in one direction but the layer above is moving in another direction. The most relevant information in these situations corresponds to the height of the change in direction of the plume
5. The plume (or part of it) seems to "wash down" from the stack.
   This corresponds to a **STABLE** condition where the plume is being injected **BELOW** the inversion layer and mixed downward. These periods are when we can get more accurate information about the mixing height. The information required is the height of the **TOP** of the "surface cloud" close to the stack

Other issues

Once the analysis has been done for the image, explore it for "anomalous" conditions such as orchard fires or other black/gray clouds and note any of those features in the register. This information is not directly useful for this project but it would be beneficial for TDC to have.

The register

For each image it is necessary to fill the following information (as structured in the "ImageRegistry" file:

Date and time	Useful	Mixing height 1	Mixing height 2	Mixing height 3	Mixing height 4	Mixing height 5	Stability	Injection of plume	Mixing height from stacks	Other issues
05/23/07 01:30 p.m.	y						Unstable	Below	150	

Appendix B User guide of the Image Analysis Software

A stand alone “image quantification tool” was developed to aid the analysis of digital images for this project. This tool can be used to quantify **any** set of images that are in the appropriate format (Joint Photographic Experts Group **JPG**).
The software was developed by NIWA and it is released under the Creative Commons Attribution 2.5 license (http://creativecommons.org/licenses/by/2.5/) to be used for and by anyone in any situation.

INSTALLATION

The software is provided with an automatic installer that guides the user in installing the required libraries for the program to work.
The installation process is relatively simple and only requires the user to have administrative rights and to open the installer and follow the instructions.
Once the installation has finished, the Image Quantification Tool can be found in the **START** menu under **Programs>NIWA_JPG Quant>JPG_Quant**.

EXECUTION

Once the software is installed and started, the user is presented with the main interface (Figure B-1) where the basic instructions to run the software can be found.
The first step in using the software is to select the folder where the images to be quantified are located. As highlighted in Figure B-1, the user is required to click on the “browse” icon in order to select the appropriate folder.
Figure Figure B-2 shows the window prompt to select the appropriate folder by browsing to the right location and then selecting the “Current Folder” button. When the folder selection process is finished, the software returns to the main interface screen and the user is able to select **OK** to begin the quantification process (Figure B-3).
While the software is working an indicative progress bar is presented in the main interface window that gives information about how much of the process has been completed and how much is remaining.
When the progress bar reaches the right side of the window and the **OK** button is no longer “greyed out”, the software has finished and the user can choose to repeat the process (replacing the resulting file) or select a different folder and repeating the process for a different set of images or to exit the software by clicking **STOP** (Figure B-4).
The output of this software is saved in a text file called “**image_data.txt**” on the same folder where the images were and it has the structure described in Table B-1.

Table B-1: Image data file. Sample structure of the data stored in the output file of the image quantification tool.

Filename	Red	Green	Blue	Total
Richmond1x20070523-1334	99.536988	102.417352	106.895091	308.849431
Richmond1x20070523-1400	80.562496	84.789433	90.317484	255.669413
Richmond1x20070523-1404	112.324713	114.295836	115.700909	342.321458
Richmond1x20070523-1416	87.201341	90.685034	96.944977	274.831352

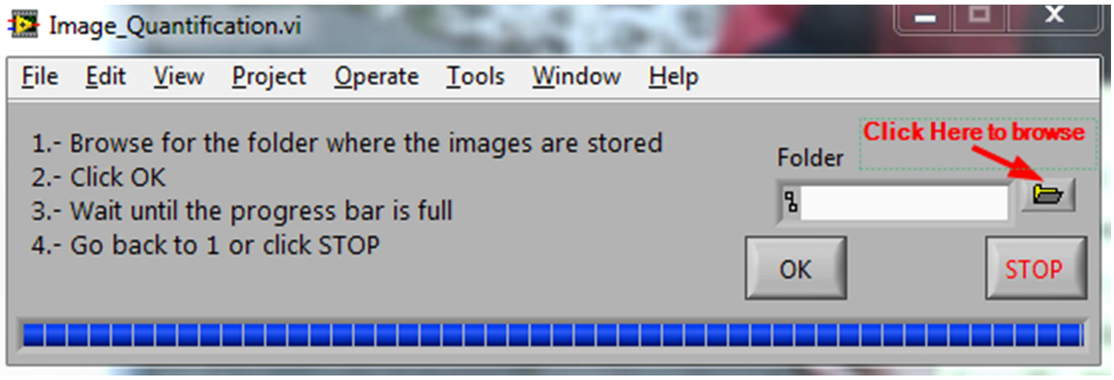

Figure B-1: Image quantification GUI. Main screen of the image quantification tool.

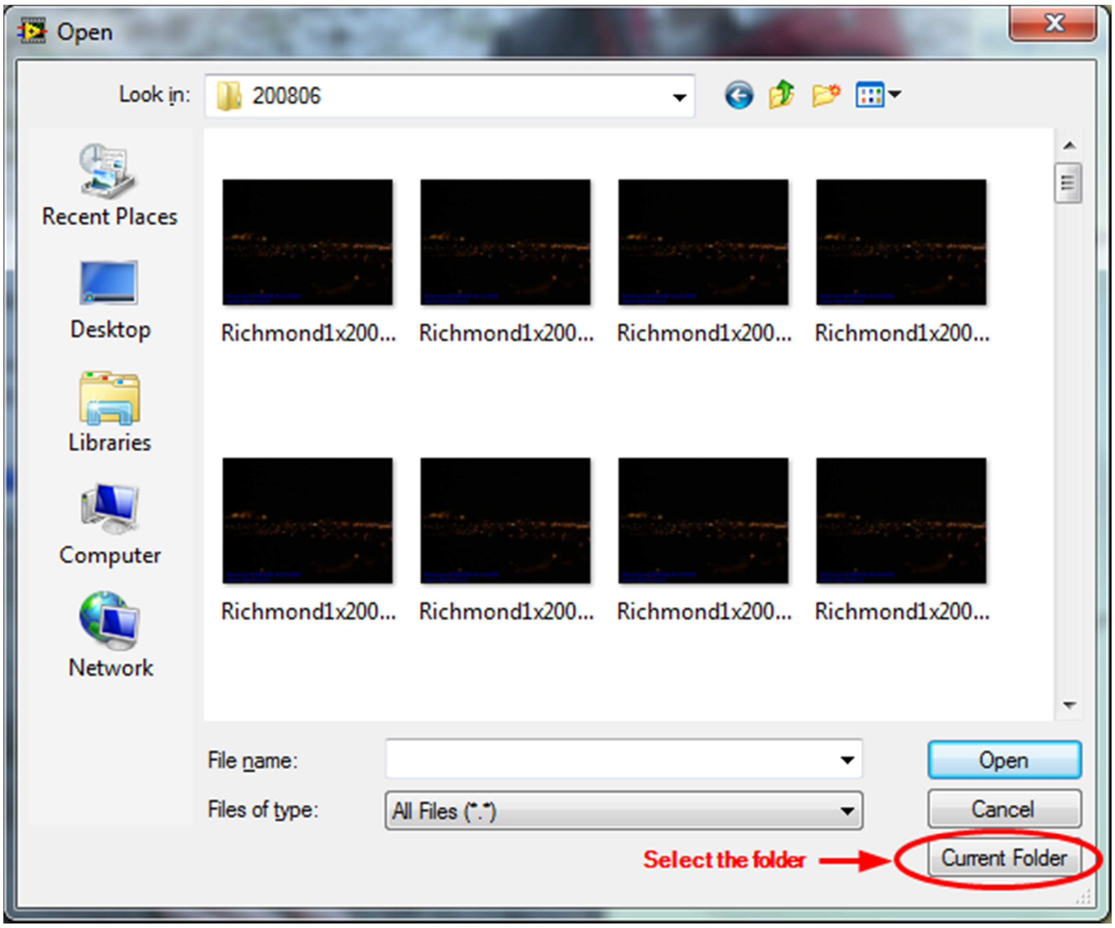

Figure B-2: File selection screen.

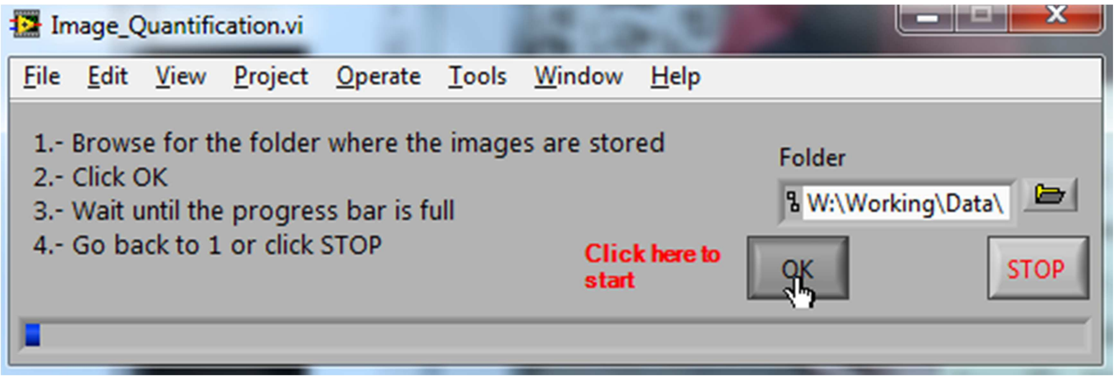

Figure B-3: Start image processing.

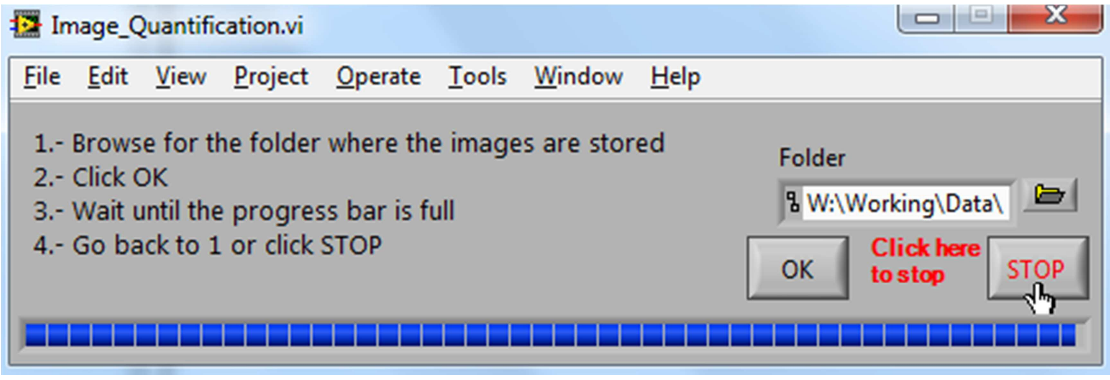

Figure B-4: Finish the program.