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**RELATING INCOMING UV RADIATIONS TO MELANOMA CASES IN THE
COUNTRY OF NEW ZEALAND**

By

Madeline Paige Eversoll

AN UNDERGRADUATE THESIS

Presented to the Faculty of
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Under the Supervision of
Christine Haney
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INTRODUCTION

The role that the atmosphere upholds provides an important service that interconnects all areas of the Earth's system. Since the industrial revolution, the atmosphere has been impacted by harmful emissions that were capable of producing a phenomenon known as the ozone hole. The ozone hole is located on the southern pole above Antarctica and has been influencing the southern hemisphere countries with smaller ozone concentrations and higher UV irradiances. Under such exposures, the atmosphere can greatly influence the health of living organisms. Humans in particular are impacted by the ozone hole, specifically to populations residing in southern hemisphere countries. One country that is of primary concern is New Zealand.

The purpose of this study is to look at how incoming ultraviolet rays might have an impact on skin cancer occurrences for the country of New Zealand. Looking at the atmospheric conditions and assessing how it can be related to areas like public health, can show how interconnected the environment can be with the welfare of human beings. If such connections can be made, relationships between melanoma toward UV and ozone can show how effective the Montreal protocol was in prohibiting the emissions of chlorofluorocarbons (CFCs). According to Chemistry Climate Model Projections, if it weren't for the Montreal protocol 67% of the ozone would be lost by 2065. (Bodeker, 2007)¹ The depletion of the ozone can show how humans are capable of changing the atmosphere. Before addressing the thesis approach, it will be best to describe the background of the ozone, how it connects to the southern hemisphere, the incidence rates of melanoma, and defining melanoma.

The ozone layer protects all living things from the harmful ultraviolet rays and has been a mechanism to make the planet a more habitable place to live in. Chemically, the ozone consists of three oxygen atoms with about 90% within an atmospheric layer known as the stratosphere. The stratosphere is about 10-15 km above the Earth's surface and is the first layer of the atmosphere that blocks harmful UV radiations. (Nasa Ozone Watch, 2013)² During the 1920s, humans have been capable of changing the concentrations of the ozone by emitting harmful chemicals like chlorofluorocarbons (CFCs). The main uses of chlorofluorocarbons include coolants for refrigerants/air conditioners, aerosol propellants, electronic cleaning solvents, and blowing agents. (SEDAC- Thematic Guide on Ozone Depletion, 1997)³ By around 1985, it was

discovered that CFCs have contributed to the break down of the ozone layer above Antarctica.

The primary cause for the ozone hole being located mostly at the poles is due to the presence of polar stratospheric clouds. Polar stratospheric clouds provide surfaces for chemical reactions to occur and appear at the South Pole during high latitude winters. Such chemical reactions involve the chemical element chlorine that is supplied by CFCs. When chlorine attaches to the polar stratospheric clouds, it is converted from relatively nonreactive forms to other forms that are highly reactive with the ozone, leading to ozone depletion. (University of Cambridge Centre for Atmospheric Science- The Ozone Hole Tour, 1998)⁴

With the ozone depleted by the CFCs, it has resulted in having the poles more exposed to the intense ultraviolet rays. The UV rays that are most dangerous would be UV-B rays because of their short wavelengths. In the southern hemisphere, countries like New Zealand are close to Antarctica and have been under the influence of thin ozone concentrations. During the summer months in the southern hemisphere from December to March, around half of the ozone hole vanishes. (Rough Guide to Climate Change, 2008)⁵ The summertime UV levels over New Zealand are approximately 40% or higher than at comparable latitudes in the Northern hemisphere. The cause of having high UV levels over New Zealand is due to it having less polluted air, lower ozone levels, and the sun being slightly closer to the Earth in December than in June. (UV Radiation and its effects- NIWA UV Workshop, 2010)⁶ This position of the earth being close to the sun is known as the perihelion and it is caused by the earth's orbit being oval shaped rather than a circle. Under such conditions, it can be assumed that intense solar radiation can have detrimental health impacts for the southern hemisphere.

Since the atmosphere of New Zealand receives high amounts of UV radiations, it would be important to look at how this can impact the public health of New Zealand. New Zealand along with Australia has one of the highest incidents rates of skin cancer in the World. In 2009, melanoma was the fourth most common cancer with 2,212 registered cases. (NZ Cancer Society, 2012)⁷ According to the Skin Cancer Foundation, melanoma is the most dangerous form of skin cancer that develops. Melanoma occurs when the DNA of skin cells is damaged, which is most likely caused by ultraviolet

radiation. The damaged DNA triggers mutations that lead the cells to multiply rapidly and form malignant tumors. These tumors originate from the pigment-producing cells called melanocytes that are located in the basal layer of the epidermis. The chances of getting melanoma increases by having light skin tone, having many moles, having red or blond hair, living in sunny climates/high altitudes, spending lots of time in high levels of sunlight, having skin that freckles rather than tans, or having a family history of melanoma. (Skin Cancer Foundation, 2013)⁸ Once an individual is diagnosed with melanoma they experience symptoms such as pain, nausea, fatigue, or death if the melanoma spreads to other parts of the body. It is best to catch melanoma at its earliest stage before it spreads to other parts of the body where it can become fatal. The survival rate for melanoma changes based upon the size of the tumor and how far it has spread into the body. From Stage I, there is an average of 90% chance of survival for 5 years and 82% chance of survival for 10 years. The stage 4 is the most severe stage with a 15-20% survival for 5 years or 10-15% for 10 years. (American Cancer Society, 2012)⁹

The basis of the thesis is to prove the hypothesis that if there is an increase in incidence rates for melanoma then the UV radiations are high with low ozone levels. The National Institute of Atmospheric Research (NIWA) is a research institute for New Zealand that provides data under the field of Environmental Science. NIWA will provide the data for ozone and incoming UV radiations. Such data is available through a downloadable computer program called *UV Atlas*. The melanoma incidence rates will be provided by the New Zealand's Cancer Registry (NZCR), which is a population based register of all primary malignant diseases diagnosed in New Zealand. NZCR's website provides downloadable excel documents that show historical data of cancer registrations from 1948-2008. In addition to the analysis of the data, a survey was conducted between Dunedin, New Zealand and Lincoln, United State. The purpose of the survey is to see if the knowledge of melanoma and the sun safety behavior are different between the two locations. This along with the background of the survey takers will also be taken into consideration (age, gender, ethnic background, etc.).

There have been several assessments that have looked at New Zealand in terms of its unique atmospheric conditions and how melanoma has impacted the public health of New Zealand. The literature review will provide what the National Institute of Atmospheric Research has discovered with the ozone and UV radiations for New

Zealand, what the New Zealand Cancer Registry shows for melanoma rates, and the implications of New Zealand's Cancer Registry under the Cancer Registry Act.

LITERATURE REVIEW

■ **NIWA UV Workshop Overview- NIWA Information Series No. 77 2010**

The NIWA Institute for New Zealand has provided several journals pertaining to areas like UV Radiation, photochemical sciences, and photo biological sciences. Among the journals, one is a collaborative report entitled *UV Radiation and its effects- an update 2010*⁶, which describes a NIWA UV workshop that took place in Queenstown from 7-9 May, 2010. The UV workshop was a forum for discussion among groups involved with all aspects of the causes and effects of changes in UV radiation. During the workshop, a range of topics were presented and focused on areas such as UV radiation variability /causes, UV radiation Impacts on human health, and UV radiation Impacts on plants/animals/physical environments.

As part of the workshop overview, the introduction of the report has the main emphasis on the New Zealand/Australian region. UV radiation in the New Zealand context is one that poses unique problems. Measurements showing peak UV Index from NIWA's Lauder site (45° S, 170° E) were 40% more than corresponding latitudes in the northern hemisphere. (Mckenzie et la. 2006)¹⁰ In regards to melanoma rates, the report claims that New Zealand and Australia have the World's highest mortality rates for melanoma. One explanation as to why the mortality rates are so high is due to the fact that many New Zealanders and Australians are descended from the British Isles. The British Isle is located at much higher northern latitude where UVI values are much lower, thus making the population less adapted to high UV irradiances. Despite having the same cancer rates, New Zealand's UV irradiances are significantly lower than in Australia. Though this is puzzling, several assumptions would be Australia having better education and darker skin tones since a large proportion of Australia's European population originate from southern Europe.

With New Zealand and Australia as the context of the workshop, their unique atmospheric variables have brought about recurrent themes. Such themes include the dichotomy between harmful effects of UV radiation compared with beneficial health effects through the production of vitamin D. (Mckenzie et al. 2009)¹¹ Due to the success

of the Montreal Protocol, the period has past where UV irradiances are at its highest. Still, even with full recovery of the ozone layer that is expected to occur late in the 21st century (UNEP, 2010)¹², the summertime UV irradiances in New Zealand will remain high. This will require a continuation of protection against damaging effects of summertime UV in the foreseeable future. This projection of New Zealand's atmosphere would be an interesting research to follow up on regards to future monitoring of the UV irradiances. Linking this idea to the thesis, the analysis of the UV data might show a plateau of UV values if such high values were to stay the same.

■ **Personal Exposures to UV Radiation in New Zealand**

Ben Lily, Martin Allen, John Robinson, Richard Mckenzie, and the UV Vitamin D Team

Within the contents of the UV Workshop report, a journal called *Personal Exposures to UV radiation in New Zealand*¹³ goes about a research that has used UV dosimeter badges. The UV dosimeter badges were designed by Dr. Martin Allen from the University Canterbury and have been used in several studies that relate UV exposure to public health. (NIWA website- Personal UV Dosimeters)¹⁴

Over a span of 8 or 10 weeks, personal UV exposure to solar erythemal UV has been measured on 517 participants using UV dosimeter badges. The badges were worn on the wrist and logged exposure every 8 seconds from 6:00 AM to 10 PM with a total of 7200 measures per day or 40,000-50,000 per participant over the 8 to 10 weeks. The results show that even during the summertime, 50% of the participants had an average exposure below 000.01 during the day. In other words, exposure below 0.001 is 10,000 times less than the daily peak. On an hour by hour basis, it was common to have 10% of participants receive more than 10% of the available radiation with the remaining participants having an even lower percentage of received available UV radiation.

The research concluded that the participants seemed to be receiving a low dose of UV radiation. However, the badges used in the project resulted in several problems like data downloading issues and human errors. Further work will be required to better categorize the data based upon the lifestyle of the participants, physical characteristics, work, diet, etc. The results from this project show the counter part of the statement that UV radiation is increasing the exposure to individuals for New Zealand. From the workshop overview, it stated that UV irradiances is expected to remain high. Either the

dosimeter project has a technical error or people are changing their behavior when it comes to following sun safety procedures.

■ **The increasing incidence of melanoma: the role of MelNet**
Graham Stevens, for the melanoma Network of NZ

Although there hasn't been a report published yet in regards to analyzing the raw data of melanoma incidents rates, there have been reports that have discussed certain actions that can be taken to handle New Zealand's high melanoma occurrences. The report titled *The increasing incidence of melanoma: the role of Melnet*,¹⁵ discusses how the network Melnet can help reduce the incidence and impact of melanoma in New Zealand. Specifically, Melnet provides a forum for professionals working in areas that are related to melanoma. Within the report, it states that incidence rates in New Zealand have increased greatly over the past 50 years but is showing signs of plateauing. Even though rates seem to have stabilized, New Zealand needed to establish an effective health program that can better report and handle melanoma.

A Trans Tasman project published in 2008, proved to be a major achievement as the first international clinical melanoma guidelines. The New Zealand perspectives of the guidelines were further incorporated as the main template for service improvement for melanoma care. From the Melanoma Summit, *Melnet* was established and marked for implementation as part of the primary guidelines. The main goal of *Melnet* is to bring a collaboration of scientists, health promoters, health professionals, and policy makers in making New Zealand better prepared with melanoma. *Melnet* facilitates communication between various work areas, provides a dedicated website, mail outs, and a database. Throughout *Melnet's* various roles toward providing care for New Zealanders, the report claims that *Melnet* is well placed to face the challenge of increasing numbers of melanoma diagnosis.

■ **Review of the New Zealand Cancer Registry**
Ministry of Health

One of the initial projects that *Melnet* hopes to accomplish is to develop a National melanoma database. Being that the Ministry of Health also sponsors *Melnet* indicates that Melnet is connected to the New Zealand Cancer Registry. The New Zealand Cancer Registry (NZCR), the primary source of the thesis's melanoma rates, is

a population based register for all primary malignant diseases like melanoma. (Ministry of Health, 2013) ¹⁶ This registry excludes squamous and basal cell cancers because they are classified as non-melanoma skin cancers (NMSC).

The difference between NMSC and melanoma is the type of cell the cancer originates from. For instance, squamous cell carcinoma is a cancer that grows on the squamous cells, whereas basal cell carcinoma is a cancer that grows on the basal cells. Typically, non-melanoma skin cancers can be treated with relatively simple surgery. Both Basal cell carcinoma and squamous carcinoma grows slowly and rarely metastasizes (spreads) to other parts of the body. (Cancer.net, 2011) ¹⁷ In other words, a tumor from a cancer can be benign (noncancerous) or malignant (cancerous, meaning it can spread to other parts of the body). That is why melanoma is also called malignant melanoma because it can spread to other parts of the body.

The establishment of the NZCR started registering cancer incidences since 1948. However, due to the incomplete reporting of cancers as well as the underreporting of cancer mortality, the registry was regarded as a useless resource. As a result, the Cancer Registry Act and Regulations of 1993 had been passed. The act required mandated reporting of all malignant tumors from laboratory reports. This mandate of reporting is evident when looking at the incident rates. As highlighted by Sneyd and Cox in the NZ Medical journal entry *Control for Melanoma in New Zealand* ¹⁸, there is a “spike” in apparent incidence in 1994 and 1995 when registration became compulsory under the Cancer Registry Act 1993. This incidence of underreporting will be taken into consideration when looking at the melanoma rates for this thesis. From a personal one on one interview with Dr. Mary Jane Sneyd on March of 2012, she claimed that from 1948-1993 there’s about 40% missing data. With this in consideration, about 60% of valid data is available for 1948-1993 in addition to 100% valid data from 1993 to the most recent occurrences.

MATERIALS AND METHODS:

■ The Atmospheric Data

The approach for this thesis will involve looking at past records of the Yearly Total Clear Sky UV Dose (erythemally weighted) or $f_{UV_{ERY}}$ and total column ozone (TCO) over the country of New Zealand provided by NIWA. NIWA provides a database

program called *UV Atlas* that can be downloaded by any PC to oversee atmospheric variables like total column ozone, UV radiations, temperature, humidity, and surface pressure. Selected NIWA sites located throughout New Zealand provide such variables. The site that will be used for this analysis will be the Lauder site.

■ Statistical Analysis with Partial Correlation

So the *UV Atlas* program will provide the UV_{ERY} , dose and TCO from 1978-2005. Once the data is obtained a time series graph will be created showing the UV_{ERY} and TCO data. Additionally, another time series graph will be created to compare the UV_{ERY} with the melanoma occurrences. To determine if variables are related rather than by chance the Partial Correlation Test will be used. The Partial Correlation test will provide the correlation coefficient (r) and the p-value (p). The correlation coefficient is a number between -1 and 1 that determines whether two paired sets of data are related. The closer to 1 the more 'confidence' there is of a positive linear correlation and the closer to -1 the more 'confidence' there is of a negative linear correlation (Fenton, 2012)¹⁹. The p-value is a measure of statistical significance, which shows the probability of an event occurring due to chance alone. The higher the p-value, the higher the probability that the event being observed is due by chance and the lower the p-value the lower the probability that the event is due by chance. In other words, p-values of either 0.05 or 0.01 are used as a cutoff value, even though this value is arbitrary. Results larger than the cutoff are considered to occur by chance, while results smaller than the cutoff value are likely to have occurred because of a real explanation. (University of Michigan-Public Health, 2010)²⁰

Originally, the Pearson Correlation test was used, which included the year variable with the two datasets. As a result, the year variable greatly impacted the correlation coefficient and the p-value. The purpose is to look at just the relationship between UV_{ERY} and TCO; UV_{ERY} and melanoma occurrences. When suspecting that the relationship between two variables is impacted by other variables, the partial correlation is used to correct the influence by different covariates. (Altman, 1991)²¹

■ Explanation of UV_{ERY}

The reason why UV_{ERY} is selected is because it shows the skin damaging UV radiation. Unlike the UV Index, the UV_{ERY} shows the intensity of the UV radiations as

W/m^2 whereas the UV Index is based on a scale from 1-11+. The UV Index is derived from the UV_{ERY} by multiplying the UV_{ERY} value by 0.4 to get the UV Index value. For example, a UV_{ERY} value on an average of 15 minutes is $200 \text{ W/m}^2 \times 0.04 = 8$ UV index. UV_{ERY} is derived from a mathematical equation and is calculated by multiplying the wavelength times the erythral weighting function. (Relationship between UVB and erythemally weighted radiation- McKenzie 2004)²² Since the UV_{ERY} is derived from the UV Index, it is the most accurate in regards to UV radiations and its impact on biological health, especially for humans.

Erythemally Weighted Radiation Formula

$$\text{UV}_{\text{ERY}} = \int I(\lambda) w(\lambda)$$

λ is the wavelength in nanometers

$I(\lambda)$ is the irradiance in Wm^2 derived from the wavelength

$w(\lambda)$ is the erythral weighting function.

■ Cancer Data

The cancer data will be provided by New Zealand's Cancer Registry (NZCR), the NZCR is a population based register of all primary malignant diseases diagnosed in New Zealand. NZCR's website provides downloadable excel documents that show historical data from 1948-2008. This historical data shows the total deaths and registrations for each cancer type. This data will provide registrations of melanoma occurrences both by total count on an annual basis and age standardized rates. Since melanoma is a disease it would be best to look at the age standardized rates because it takes into account the young and old proportions of the diseased population. Age standardized rates is calculated by dividing the number of incidences by the actual local population in a particular age group multiplied by the standard population for that particular age group and summing across the relevant age groups. (London Health Observatory, 1990)²³ When rates are age standardized, it shows how the differences in rates over time do not reflect variations in age structure of the population. This is significant when looking at cancer rates because cancer is a disease that predominately impacts the elderly. So when cancer rates are not age standardized, a higher rate in one country is likely to reflect the fact that it has a greater proportion of older people.

(Cancer Research UK Glossary, 2009)²⁴ Throughout the course of the thesis, melanoma occurrences will be referred to as MEL_{ASR}.

■ Deficiencies of Cancer Data

Due to the fact that mandatory reporting of cancer occurrences started from 1994 with 40% of the data missing from 1948-1993, it will be the goal of this thesis to use to the best of our knowledge what can be determined with the data available. Also, to keep in mind that 60% of actual data available is sufficient enough for the thesis analysis.

■ Surveys

To make the thesis more applied beyond reviewing material, surveys were conducted to assess melanoma awareness and behavior for Dunedin, New Zealand and Lincoln, Nebraska. Reasons why such comparisons are being used is that it would determine if people living in Dunedin, New Zealand would have a higher awareness of melanoma versus people living in Lincoln, United States. A total of 100 surveys were used with 50 in Dunedin, NZ and 50 in Lincoln, US.

■ Surveys- Background Questions

Other questions in the survey ask about the background of the survey respondents. The background questions are different between Dunedin and Lincoln due to different ethnic groups of the area. New Zealand's demographics mainly consists of the following ethnic groups: White/Caucasian, Maori, Asian, and Pacific Islander. North America's demographics are slightly different by excluding Maori and Pacific Islander. North America's demographics include: White/Caucasian, Hispanic, African American, and Asian. Since the background information doesn't pertain to the goal of whether or not New Zealanders are more aware (knowledgeable) of or exhibit preventable behavior with melanoma, no statistical analysis will be required. The background questions will be regarded as percentages that show a general overview of the ethnicity, age, and gender of the participants. (i.e. 45% of Dunedin participants were female, 25% of Lincoln participants were African American). This will be shown as a pie chart in the results section. The background questions are shown below:

Q1: What's your gender?

☐ Female ☐ Male

Q2: What is your Age?

___ OR DOB __/__/____ day/month/year

Q3.1: What is your ethnic background?

(For Dunedin)

☐ White/Caucasian ☐ Maori ☐ Asian ☐ Pacific Islander ☐ Other

Q3.2: What is your ethnic background?

(For Lincoln)

☐ White/Caucasian ☐ Hispanic ☐ African American ☐ Asian ☐ Other

■ **Surveys- Knowledge Questions**

To determine if there is a difference in awareness, several statistical analysis approaches will be used with the knowledge-based questions. A knowledge-based question is a question that requires a correct answer. The Statistic Department for UNL offered statistical analysis assistance to determine if the results were statistically significant. Below are the three knowledge-based questions:

Q4: To your best knowledge, what is melanoma?

☐ A type of skin cancer ☐ A type of bacteria ☐ A heart condition
☐ A Bronchial disorder ☐ A mole on the skin ☐ None of the above

Q5: Which of the following do you think are risk factors for melanoma? That is, what do you think increases your chances of getting melanoma? (Check all that apply)

☐ Getting lots of sunburns ☐ Pesticides on fruits/veges ☐ Having many moles
☐ Lack of exercise ☐ Having red or blonde hair ☐ Being overweight or obese
☐ A family history of heart disease ☐ Having skin that freckles rather than tans

Q6: When do you think it is necessary to protect yourself from the sun in Dunedin or Lincoln? (Check only one answer)

☐ Summertime (6 AM-10 AM) ☐ Wintertime (6 AM-10 AM)

- ☐ Summertime (10 AM-4 PM) ☐ Wintertime (10 AM-4 PM)
- ☐ Summertime (4 PM-10 PM) ☐ Wintertime (4 PM- 10 PM)

* Correct Answers- Q1: Type of Skin Cancer, Q2: Getting lots of sunburns, having red or blonde hair, having many moles, having skin that freckles rather than tans, Q3: Summertime (10AM-4PM)*

Question 4 and 6 require just one answer. With a small sample of 50 surveys, the Fischer's exact test is the most appropriate statistical method to use. The Fischer's Exact Test sums the probability of each response to determine if the probability of getting a correct answer is higher for Dunedin versus Lincoln. For question 5, there are multiple correct answers or check all that apply and requires the t-value statistics approach. The t-value statistics approach compares the average number of correct responses for Dunedin, NZ and Lincoln, NE. In general, the t-value statistic approach is a more robust test and performs better with smaller sample sizes. The results from the statistical analysis will show the p-value, which will determine whether or not the results are significant. The lower the p-value the more significant the relationship is to determine if the respondents from New Zealand are more aware of melanoma than Respondents in the U.S.

■ Surveys- Behavior Questions

For the behavioral questions, the Fischer's Exact Test will be used. Having the most preventative behavior as the correct answer will allow the Fisher exact test to determine if there is significance in the responses between the two locations. Selecting the answer that follows the most precautionous choice in terms of skin cancer safety will provide a conclusion on which area follows the most preventative behavior. For example, the most preventative answer in Question 7 would be combining sunscreen with other alternatives and for Question 8 it would be to visit the doctor. The questions are listed below.

Q7: What would do you do to protect yourself from the sun?

- ☐ Use only Sunscreen ☐ Stay in the shade as much as possible
- ☐ Combine sunscreen with other alternatives (i.e. sunhat, sunglasses, clothes with more coverage etc.)

Q8: What would you do if you noticed a new mole or a changing skin lesion?

☐ Visit the doctor ☐ Watch over it yourself but don't take immediate action ☐ Ignore it

■ Statistical Analysis Help

The University of Nebraska's Statistics Department has provided the results for the Pearson Correlation test, the Fisher's Exact Test, and the t-value statistics test using the Statistical Analysis Software (SAS).

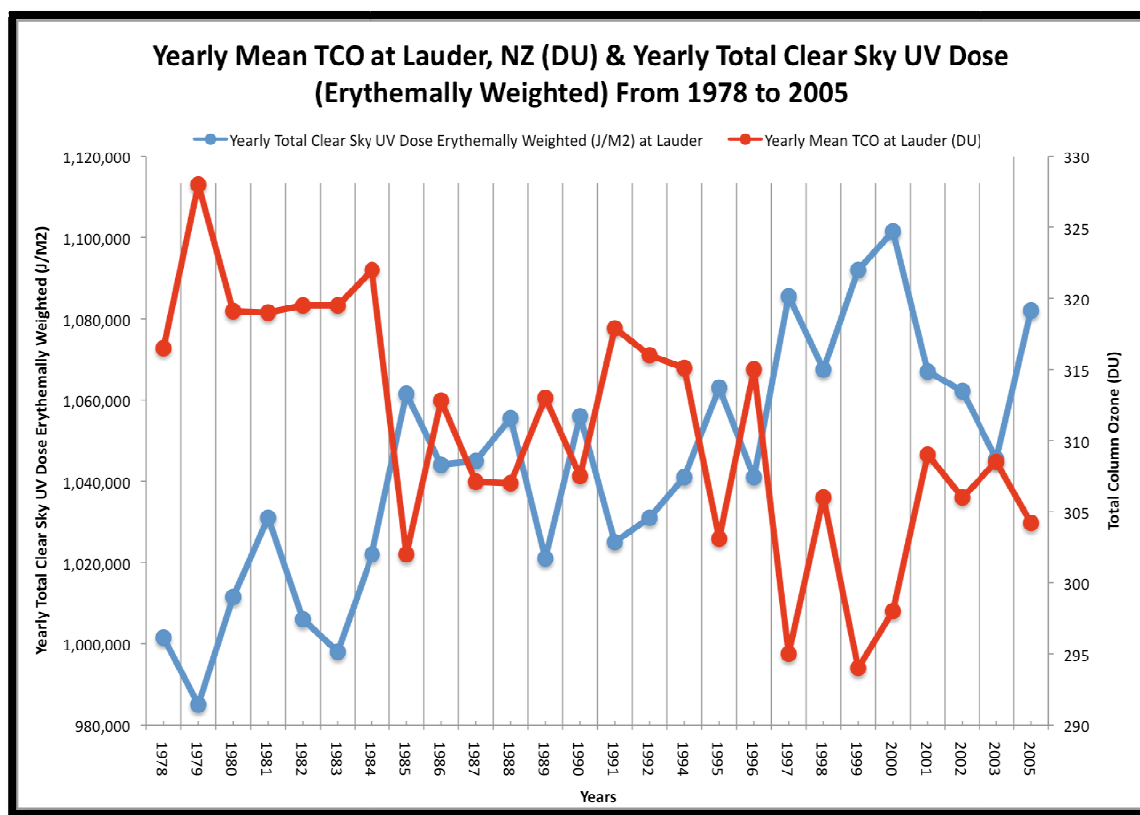
RESULTS:**■ Comparing TCO with UV_{ERY}**

By using the UV Atlas program, the (TCO) was graphed with UV_{ERY} Dose, by using a double y-axis format. The available year range that UV Atlas can provide is from 1978 to 2005 and is taken from the Lauder site in New Zealand (location shown in picture below with marker A). Lauder has been known as one of the major sites that retrieves atmospheric data, which is why it has been selected for the thesis analysis.



**Map of New Zealand with Lauder Site Indicated by
Geographical Location Otago, New Zealand, Australia and Oceania.
Coordinates: 45° 3' 0" South, 169° 40' 0" East**

Starting out with the yearly total clear sky UV_{ERY} dose on the left y-axis in comparison to the total column ozone on the right y-axis with the years 1978 -2005 on the x-axis, Graph 1 is produced.



Graph 1: Total Column Ozone compared to Yearly Total Clear Sky UV_{ERY} dose.

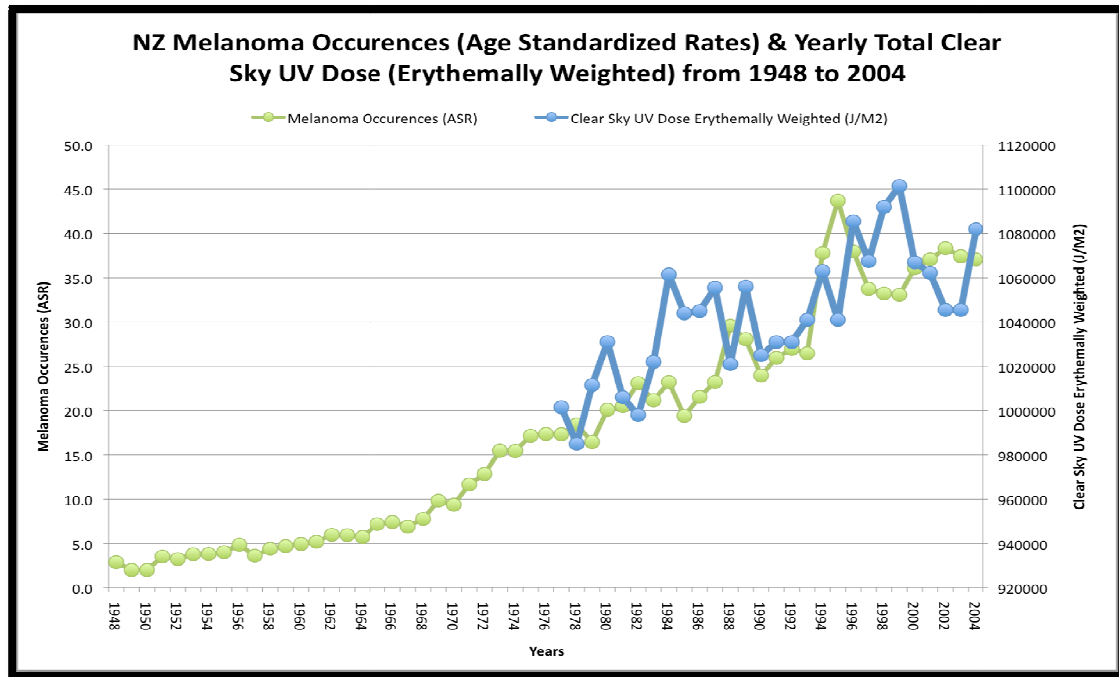
To determine if there is a relationship between the UV_{ERY} Dose and TCO the Pearson partial correlation test is used. The following p-values (p) and correlation coefficients (r) for TCO and UV_{ERY} are listed in Table 1.

Table 1. P-value (p) and Correlation Coefficient (r) of TCO and UV_{ERY}

Partial Correlation Test	TCO		UV _{ERY}	
UV _{ERY}	r	-0.864843	r	1.00000
	p	<0.0001	p	1.00000
TCO	r	1.00000	r	-0.864843
	p	1.00000	p	<0.0001

■ Comparing UV_{ERY} to MEL_{ASR} .

A double y-axis graph is used to compare the UV_{ERY} to MEL_{ASR} . Since the available UV_{ERY} values start in 1997, the range from 1997-2004 will be used to compare UV_{ERY} to the MEL_{ASR} . This is shown in Graph 2 below.



Graph 2 Melanoma Occurrences (ASR) and Yearly Total Clear Sky UV_{ERY} Dose (Erythemally Weighted) (J/m^2)

To determine if there is a relationship between MEL_{ASR} and UV_{ERY} dose is significant, the Pearson partial correlation test is used. As used before with the TCO and UV_{ERY} data comparison, the Pearson partial correlation test will provide the p-value and correlation coefficient between the MEL_{ASR} and UV_{ERY} Dose from 1978-2005. The results are shown below.

Table 2. Correlation Coefficient (r) and P-value (p) of MEL_{ASR} and UV_{ERY}

Partial Correlation Test	ASR		UV_{ERY}	
MEL_{ASR}	r	1.00000	r	-0.055734
	p	1.00000	p	0.7825
UV_{ERY}	r	-0.055734	r	1.00000

	p	0.7825	p	1.00000
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■ Survey Data Fisher's Exact Test:

Using the Fisher's Exact Test with Questions 4,6,7,8 the following p-values are produced:

Question	Answer used as indicator	P-value (Dunedin vs. Lincoln)
Q4: To your best knowledge, what is melanoma?	A type of skin cancer.	0.4357
Q6: When do you think it is necessary to protect yourself from the sun in Dunedin or Lincoln?	Summertime 10AM-4PM	0.2036
Q7: What would do you do to protect yourself from the sun?	Combine sunscreen with other alternatives (i.e. sunhat, sunglasses, clothes with more coverage etc.)	0.3798
Q8: What would you do if you noticed a new mole or a changing skin lesion?	Visit the doctor	0.3355

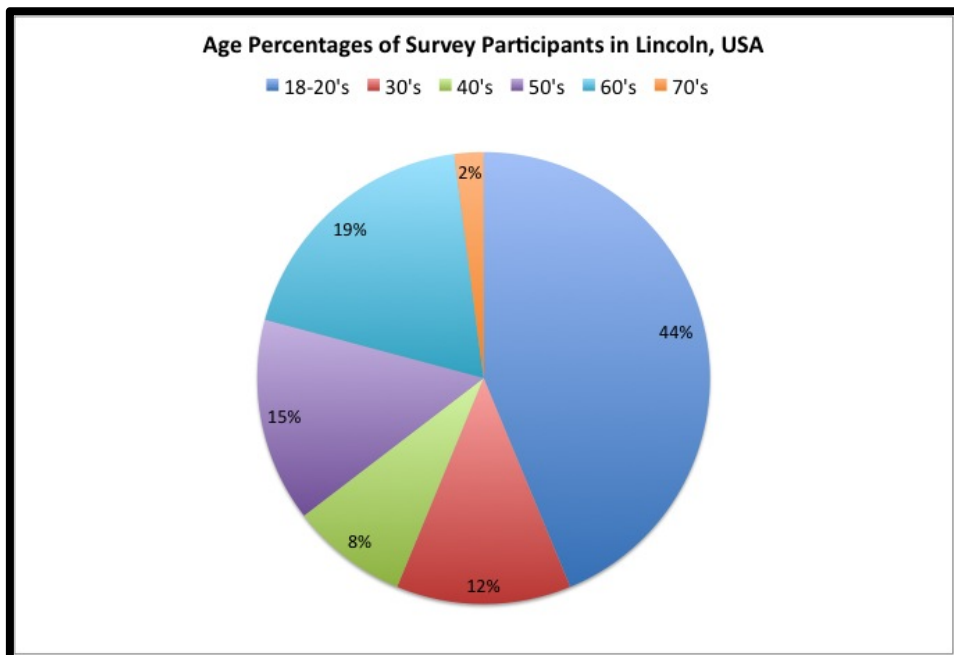
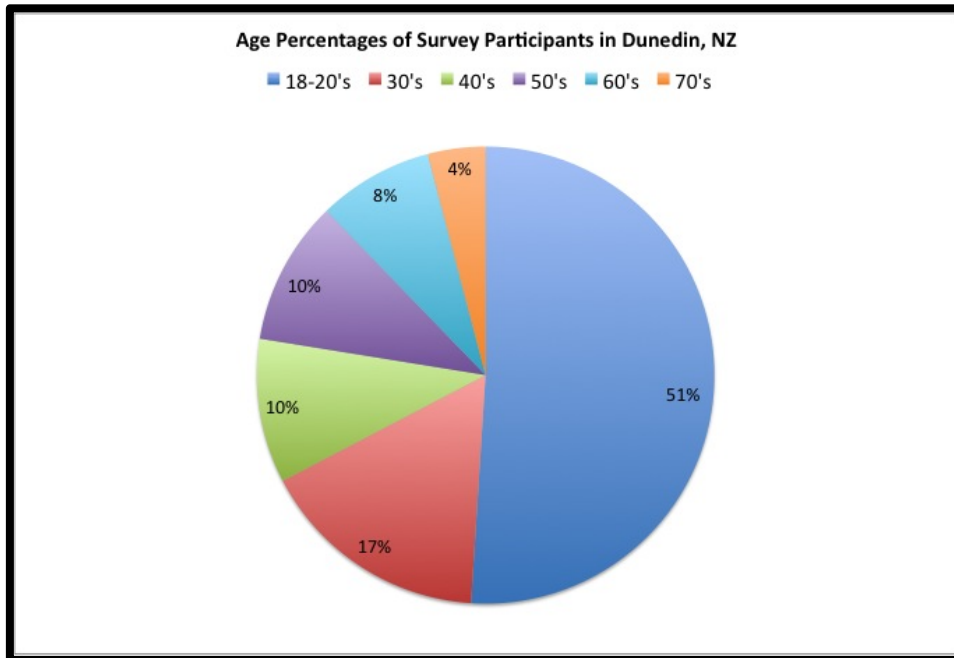
■ Survey Data T-value statistics test:

Using the t-value statistics test for the multiple answers questions, the following p-values are produced.

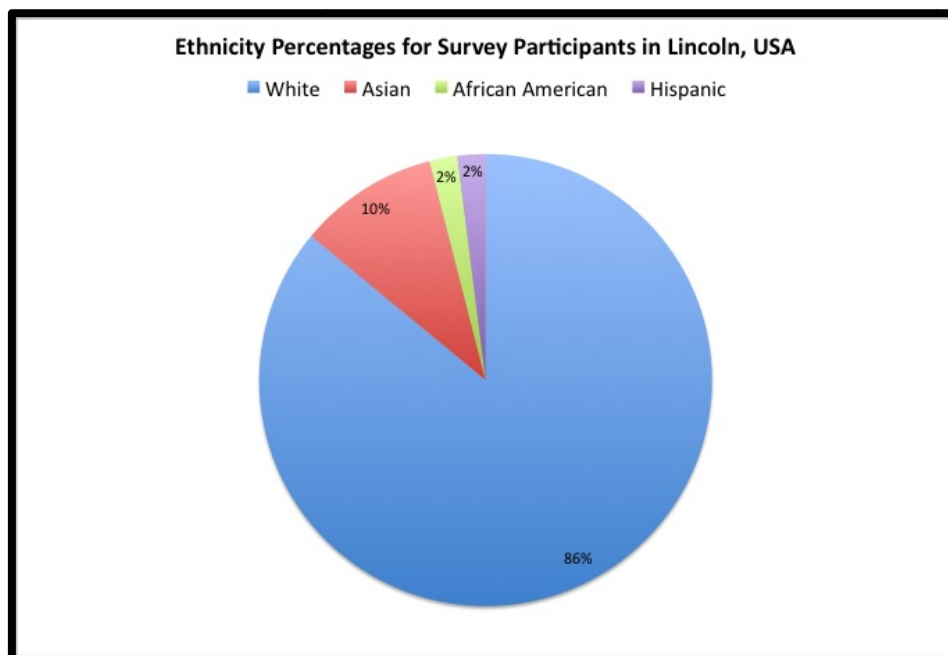
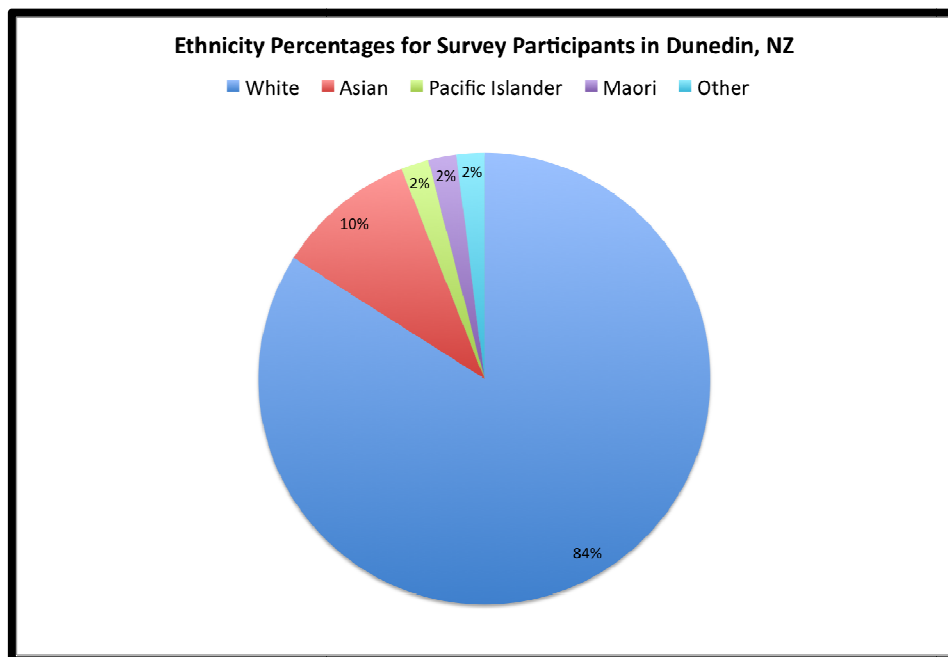
Question	Answers used as indicators	P-value (Dunedin vs. Lincoln)
Q5: Which of the following do you think are risk factors for melanoma? That is, what do you think increases your chances of getting melanoma? (Check all that apply) <input type="checkbox"/>	Getting lots of sunburns, having red or blonde hair, having many moles, having skin that freckles rather than tans	0.9252

■ Pie Chart Representations for Background of Survey Participants

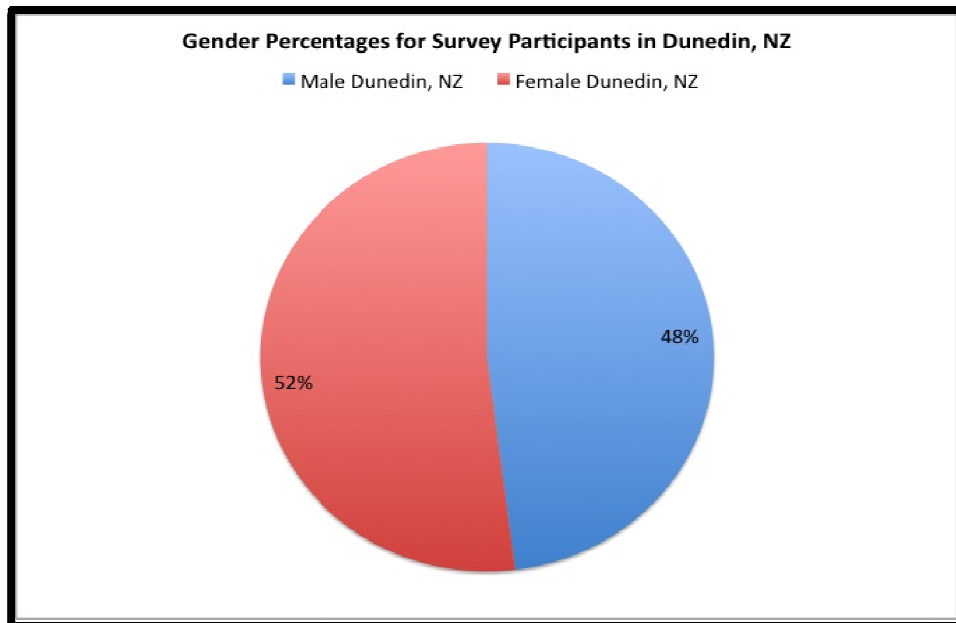
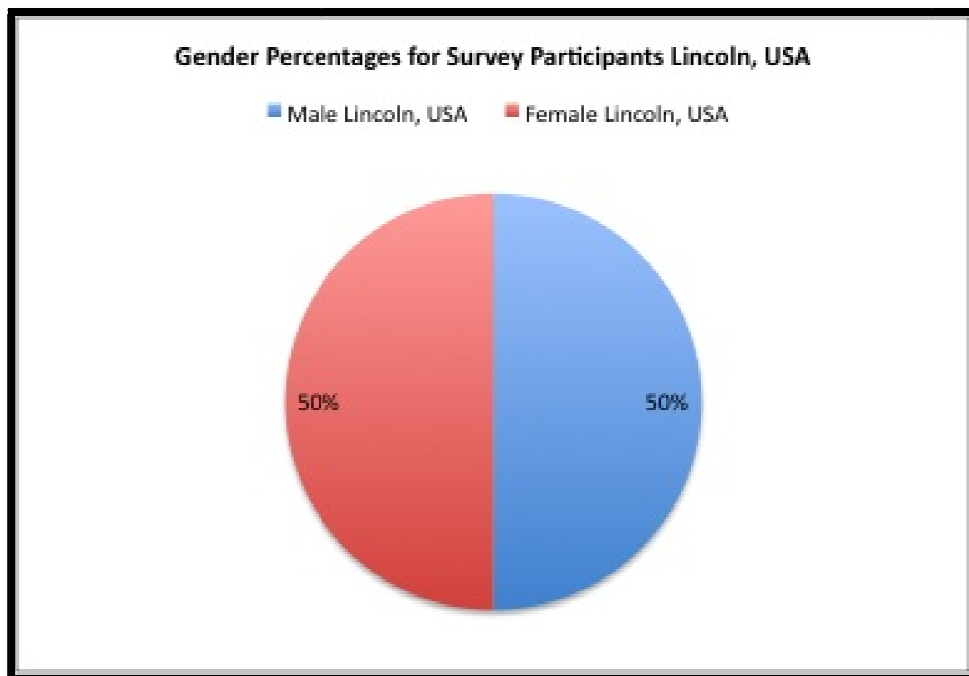
Age Percentages:



Ethnicity Percentages:

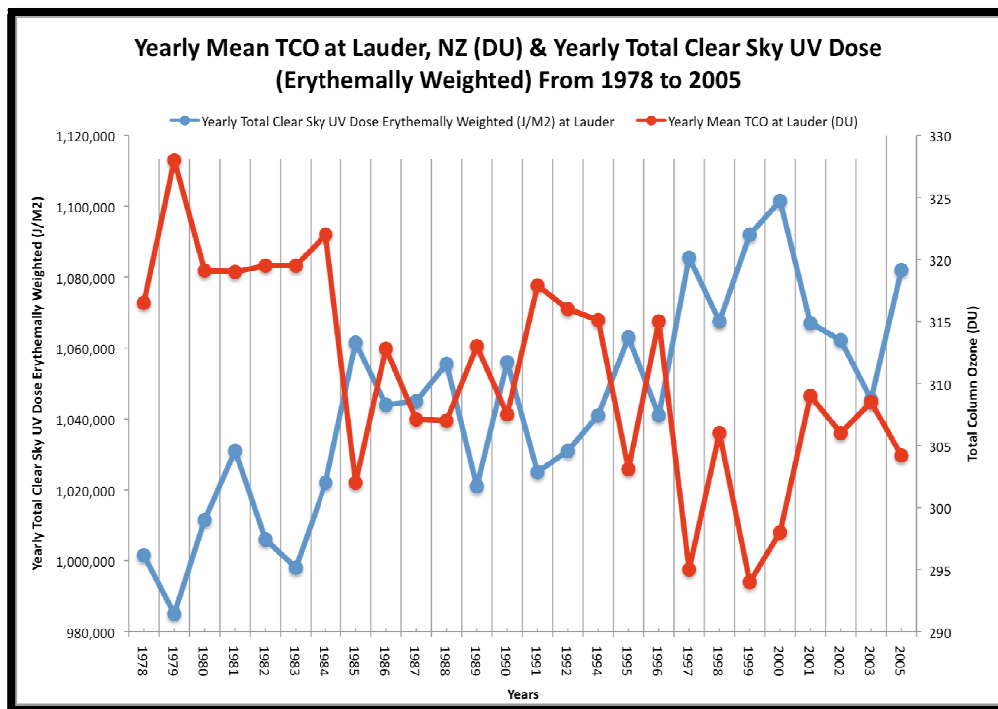


Gender Percentages



■ DISCUSSION:

Assessing the results based upon the Pearson partial correlation test there is a significance with dataset 1 for TCO and UV_{ERY} . Looking at table 1, a correlation coefficient of -0.864843 indicates that there is a strong negative correlation relationship because its closer to -1. This shows that as TCO increases the UV_{ERY} decreases significantly and it is not by chance. A negative correlation also means that the variables have a strong inverse relationship.



Graph 1: Total Column Ozone compared to Yearly Total Clear Sky UV_{ERY} dose.

By determining that the relationship is significant between the TCO and UV_{ERY} , it validates how such variables have impacted each other from 1976-2005 as shown in Graph 1. This inverse relationship seems apparent from the beginning to the end segments of the graph. At the beginning of the graph, 1976-1984 shows that the TCO is higher than the UV_{ERY} values and is during the time before the ozone hole was discovered in 1985. Then once the ozone hole was discovered in 1985 there seems to be a fluctuation of TCO and UV_{ERY} without a clear separation of the two variables. Then from 1997 to 2005, the TCO is lower than the UV_{ERY} through the remainder of the

graph.

In order for the ozone to properly protect the biosphere, the ozone must be higher than the UV_{ERY} values. Atmospheric Scientist Dr. Richard McKenzie states that because of the success of the Montreal Protocol on protection of the ozone layer, we have probably now passed the period where UV irradiances are highest. However, even after a full recovery, summertime UV irradiances in New Zealand will remain high compared with corresponding latitudes in the northern hemisphere. (UNEP, 2010)²⁵, This would mean that the end segment of the graph will continue to have high UV_{ERY} values than the TCO value until the end of the century.

When comparing the UV_{ERY} with the MEL_{ASR} , there are some deficiencies due to data availability of MEL_{ASR} . As mentioned before, the full reporting of melanoma occurrences started in 1994 with 1948-1994 having about 40% of its data missing. It is the purpose of this thesis to use data that is only available through the New Zealand Cancer Registry. There are statistical approaches that can take missing data into account. However, only the upfront values of ASR are available with no access on how the New Zealand Cancer Registry calculated the ASR. Data like how many people were effected by melanoma in each age range (i.e. 0-10 years old, 11-20 years old) and the total population overall in that age group are needed to determine how the ASR was calculated. Since that is not available, the statistical method that helps take into account the missing data cannot be achieved. The years that have 60% of data available and have been used to compare to UV_{ERY} are from 1978-1994 since the UV_{ERY} data availability starts from 1978-2005. So with full reporting of melanoma to UV_{ERY} , the years available are from 1994-2005, which isn't sufficient in determining a relationship. There needs to be a wider range of years of data available in order to accurately determine if melanoma occurrences are related to UV Radiations.

By using what is only available for this thesis, a Pearson partial correlation test was still implemented to determine the significance between UV_{ERY} and MEL_{ASR} from 1978-2005. As a result, the correlation coefficient (r) was -0.055734 and the p-value was 0.7825. This means that the variables are not significant because any r-value close to 0 is considered insignificant and -0.055734 is very close to 0. Also, since the p-value is 0.7825 it indicates that about 78% of the data is probably due by chance and not by a

relationship. Several things can be considered to explain why the relationships of the variables have turned out to be insignificant. Several assumptions would be as time has progressed methods of detection have become more effective. Also, keeping in mind that this data comparison is not adequate due to the short range. Longer term data can provide valid connections since data generally tends to fluctuate drastically for shorter year ranges.

To analyze the survey results, the p-values from the Fischer Exact and the t-value statistics test have been used. As previously described, the survey was broken down into three sections: background of participant, knowledge, and behavior. The p-value results that determine if people from Dunedin New Zealand were more knowledgeable of melanoma than people from Lincoln, USA show very insignificant values. The knowledge questions had p-values that include 0.4357 (what is melanoma?), 0.2036 (when do you think its necessary to protect skin from sun?) and 0.9252 (what increases your chances of getting melanoma?) For this case the higher the p-value would mean that both locations have the same level of knowledge about melanoma. One question regarding when do you think is a good time to protect the skin from the sun had some deficiencies in terms of how the participants responded, making the low p-value not completely accurate.

For example, the question asked the following:

Q6: When do you think it is necessary to protect yourself from the sun in Dunedin or Lincoln? (Check only one answer)

- ☐ Summertime (6 AM-10 AM) ☐ Wintertime (6 AM-10 AM)
- ☐ Summertime (10 AM-4 PM) ☐ Wintertime (10 AM-4 PM)
- ☐ Summertime (4 PM-10 PM) ☐ Wintertime (4 PM- 10 PM)

Several of the respondents thought that it was necessary to protect oneself from the sun throughout the year or checked more than one answer. To make sure that a total of 50 responses were taken into the analysis, the responses that selected all choices or multiple choices was changed to selecting the correct answer. This likely has caused the p-value to be lower and to make it seem like the Dunedin participants were

more knowledgeable about when to protect oneself from the sun than Lincoln participants. One way to prevent this from happening again for this survey is to reword the question by asking “When do you think the rays are most intense during the year?” This way, people will likely respond with the correct answer rather than basing it on when they should protect their skin.

Looking at the behavior questions, the p-value was based upon how people between Dunedin and Lincoln selected the answer that promoted the most preventative behavior from melanoma. The behavior questions include: What would do you do to protect yourself from the sun? What would you do if you noticed a new mole or a changing skin legion? The answers treated as the indicator for the most preventative behavior include: combining sunscreen with other alternatives (i.e. sunhat, sunglasses, clothes with more coverage etc.) and visiting the doctor when noticing a new mole or a changing skin legion. The Fischer’s Exact Test showed p-values of 0.3798 for when to protect from the sun question and 0.3355 for noticing a new mole question. These p-values are not low enough to be significant and indicate that both respondents from Dunedin and Lincoln seem to select the same responses for combining sunscreen and visiting the doctor.

One approach to take into consideration to further improve the behavior questions is distinguishing between what the respondent should do versus what the respondent would actually do. It could be assumed that the behavior questions gave the impression that the respondents should select the response that was something they ought to do versus what they would actually do. One way to fix this is to reword the question in this format: “What would you usually do to protect yourself from the sun?” and “What would you usually do if you noticed a new mole or changing skin legion?” The word “usually” would direct the respondent to answer the question as something they would normally do rather than what is considered to be the healthiest response to lower one’s risk of melanoma.

The background of the survey respondents shows some components outweighing the overall category of the background. For example, looking at the ethnic background for the locations most of the respondents were Caucasian that had 84% for Dunedin and 86% for Lincoln. In addition to the ethnic backgrounds, the age

percentages of the respondents also had components outweighing the overall category. Most of the respondents for both locations were within the ages of 18-20's that had percentages of 51% for Dunedin and 44% for Lincoln. For the gender compositions, both locations seemed balanced with females and males adequately representing the surveys in half segments. The Dunedin respondents were 50% male and 50% female, while the Lincoln respondents were 52% Female 48% male.

The city of Dunedin is known as the most popular University city in New Zealand. This could be one of the causes of why most of the survey respondents were within the ages of 18-20's. Other things that likely caused the ages to be in the youngest range would be the selection of the respondents. Without awareness, it was more comfortable to ask people who were close to my age and were students versus others that were older. This mentality likely caused my age distributions to be more toward the younger age group. Other factors that could have influenced the surveys would be the selection of the location. The locations that were selected in Lincoln included Walmart on 84th & Highway 2, the Haymarket downtown, Scooters café on 84th & Van Dorn, and South Pointe Pavilion Mall on 27th & Pine Lake. The locations that were selected in Dunedin include the University of Otago Campus, the weekly farmer's Market near the Dunedin Railway Station, and 10 blocks along George Street. Selections like cafes and the farmers market in Dunedin have been a large contributor for survey respondents. Cafes might have been an area where students were likely to congregate at. This likely caused the respondents to be mostly young in Lincoln since areas like the Haymarket had lots of coffee houses.

With the ethnicity distribution of the survey takers, one cause of having mostly white respondents would be selecting areas that have low ethnic variety. Places like the Haymarket had at least provided the best variety in ethnic backgrounds. Events that create a meeting point for a variety of backgrounds can be effective in adding variety to a survey. Also, using only the city might not have been sufficient enough in representing the country as a whole. Cities have certain demographics that don't represent the overall country. Since traveling was limited in Dunedin, only one city could be used for the survey.

To better improve the survey of the thesis one way would be to increase the number of participants beyond 100 entries. One suggestion provided by Dr Mary Jane Snyed was to start calling people over the phone to take the survey. This approach would have been effective especially for selecting respondents at random rather than approaching people in person. Conducting a survey can be a challenge and even selecting respondents that might seem comfortable to approach is not the best way to collect a well-represented survey sample. Other suggestions would be covering areas beyond the city, which was a challenge due to transportation availability and financial obstacles to allow transportation to occur like fuel usage.

SUMMARY & CONCLUSION:

Connecting atmospheric variables to areas of public health is a relationship that can show how some health risks can be beyond people's immediate control. In connection to this thesis, the unique atmospheric conditions that the country of New Zealand had along with its high occurrence of melanoma rates was a phenomenon that seemed to be significant. It was evident that the UV_{ERY} is currently higher than the total column ozone that was proven by the Pearson partial correlation test. With this in consideration, the UV_{ERY} was then compared to the Mel_{ASR} but resulted with insignificant results. Keeping in mind the deficiencies of the cancer data and not having a longer range of years to compare the UV_{ERY} to the Mel_{ASR} , such factors were likely the cause of such insignificant outputs.

The survey was used to determine if one city in New Zealand was more knowledgeable about melanoma than a city in USA. Additionally, the surveys were used to determine which location exhibited the most preventative behavior of melanoma. It resulted in having both countries very similar in their responses and doesn't support the hypothesis that New Zealand is more knowledgeable and more preventative in their behavior toward melanoma. This can either confirm that there isn't a difference in knowledge or behavior between the locations or the survey results were likely impacted by exterior factors. Such factors would include not having enough survey respondents, having a disproportion of ethnic groups or age, and only being limited to a single city parameter rather than multiple locations for each country.

There is a lot of potential to improve this research that goes beyond the boundaries of undergraduate thesis and would be adequate as a masters research opportunity. Also, as more time progresses, there would be more valid cancer data available with full reporting. This can set the basis for a reanalysis of relating melanoma occurrences with UV radiations for future research endeavors.

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