

# Basal and squamous cell carcinoma risks for golfers: an assessment of the influence of tee time for latitudes in the Northern and Southern hemispheres

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**Keywords:** Skin Cancer; Ultraviolet; Golf; UV exposure

**Abstract**

This study investigates the influence of tee time to determine the relative basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) risk for weekly single round competition golfers located in the Northern and Southern latitude ranges between 25°, 35°, 45° and 55°. A comparative risk methodology, employing annual erythemally effective ultraviolet (UVE) exposure calculations was used to determine BCC and SCC risk factors for golfers using a regular weekly tee time. Relative risk was found to be proportional to golf tee time with mid morning tee times generally presenting the greatest risk in each latitude range. The greatest contribution toward the risk of developing basal and squamous cell carcinoma was found to occur for golfers beginning weekly rounds mid to late morning, with specific risk factors of 1.47 (BCC) and 1.98 (SCC) in the Northern hemisphere compared with similar maximum risk factors of 1.51 (BCC) and 2.08 (SCC) in the Southern hemisphere occurring at comparable morning tee times. Differences in annual UVE exposure between the golfer and non-golfer were the largest determinant of BCC and SCC risk. Generally, these risks were found to decrease with lower latitude although contribution toward overall risk was influenced strongly by the global time zone of each studied golf course site.

## 1. Introduction

Although a significant number of ultraviolet (UV) radiation studies have been conducted to investigate the exposure influence of various physical parameters, there currently remains limited information available to characterize the impact of personal behavior on exposure and subsequent skin cancer risk (1,2,3,4,5). Many studies have detailed personal UV exposures for a range of situations (6,7,8). However for the golfing population group, being placed by necessity in the sun for extended periods of time, there remains limited information on exposure and the related skin cancer risk (9,10). To characterize UV exposure risk for a range of expected conditions, UV irradiance models have been used to provide a reasonable first approximation which can be applied to describe the likely exposures for a range of outdoor activities (11,12,13), including golf, provided the exposure of the individual is expressed relative to the ambient exposure. In doing this, the factors that influence the UV exposure episodes at any latitude must first be summarized and presented relative to existing numerical techniques that have been used to determine relative skin cancer risk.

Considering a cloud free sky, in which the UV irradiance follows a normal distribution with the time of day, exposures received before and after solar noon will be lower than exposures received during the peak noon period, followed by irradiance reductions caused by absorption by stratospheric ozone, air and atmospheric particulates, the local altitude and slight variations in the earth sun distance caused by the earth's elliptical solar orbit (14,15,16,17). The timing and total duration of any playing round has the most significant influence on the total UV exposure received. Whereas, the UV irradiance ( $\text{Wm}^{-2}$ ) changes rapidly with the movement of the sun, peaking at solar noon, the total UV exposure ( $\text{Jm}^{-2}$ ) is dependent upon the variation of the irradiance in the playing interval and the length of the playing interval itself. The rate at which the peak UV irradiance is reached and the height of the daily UV irradiance curve varies also with latitude and season (18,19). These variations will affect skin cancer distributions for golfers as is the case with other population groups which show an increase in incidence with decreasing latitude (20,21,22). Discriminate atmospheric absorption of UVB (280 nm to 320 nm) and UVA (320 nm to 400 nm) wavelengths for different solar elevations has further implications for erythemally effective UV, which for humans is positively associated with shorter wavelength UVB than UVA radiation (23). This has been investigated previously with variation in latitude (24), although not specifically for golfers. Variations between stratospheric ozone concentrations

in northern and southern latitudes further influence erythema exposure differences between the Southern and Northern hemisphere (25). The implications for golfers are that erythemally effective ultraviolet (UVE) exposures vary considerably with latitude and at different rates in the Northern and Southern hemispheres due to the strong dependence of the erythema response to short wavelength UVB radiation and stratospheric ozone concentrations.

Erythemally effective UV has previously been correlated with relative keratinocyte carcinoma risk, where the risk of developing keratinocyte carcinoma has been shown to be dependent upon the annual UVE exposure and the age of the individual (26). By making relative comparisons, the dependence on the age of the individual can be removed (27,28). This technique was recently applied to calculate relative basal and squamous cell carcinoma risk for golfers in southern Queensland compared to office workers (10). For this research, variations in the annual UVE exposure and the associated relative skin cancer risk is calculated for single round weekly golfers playing in different latitudes in both the Southern and Northern hemispheres. As such, this research is the first global simulation study developed to investigate the influence of personal behavior in a range of different ambient climates for a potentially high risk population group.

## 2. Materials and Methods

### 2.1 Estimates of annual UVE exposure

The duration of any round of golf is an important consideration that needs to be taken into account in determining the annual UVE exposure. This has been accounted for in past research to determine annual exposures (28,29,30,31,32). The methodology of Vishvakarman and Wong (28) is modified for this research that assumes an annual UVE exposure is accrued by the summation of exposures received during normal working days in which the individual spends 1.5 hours traveling to, from and at work daily, and receives between 4 to 6 hours exposure during weekends and annual leave periods. These are estimates of the UVE exposure received on days during which golf is not played. For golfers, annual UVE exposures are dependent upon daily UVE exposures received on work days, UVE exposures received on weekend and leave days during which golf is not played, and UVE exposures received on days during which golf is played. A simple approximation of the annual UVE exposure can be calculated assuming golf is only played during a weekly 9-hole round (10):

$$E_A = \sum_{d=1}^{d=246} E_n(d) + \sum_{d=1}^{d=119} E_w(d) + \sum_{d=1}^{d=52} E_g(d) \quad (1)$$

where  $E_A$  is the annual UVE exposure of the golfer,  $E_n(d)$  is the UVE exposure received on each of the normal working days in the year,  $E_w(d)$  is the UVE exposure received on each of the weekend and leave days, and  $E_g(d)$  is the UVE exposure for the golfer received on each of the weekly days on which golf is played and received in addition to normal working day UVE exposures. The equation can be modified to determine the UVE exposure received by a weekly golfer that plays an 18 hole round each weekend such that  $E_g(d)$  represents the UVE exposure received on golf days which make up part of the entire 365 day year and are not received in addition to UVE exposures represented by normal working days as had been determined previously (10):

$$E_A = \sum_{d=1}^{d=246} E_n(d) + \sum_{d=1}^{d=67} E_w(d) + \sum_{d=1}^{d=52} E_g(d) \quad (2)$$

Annual UVE exposures presented in this research are determined for weekly single 18 hole round golfers where  $E_w(d)$  is the UVE exposure received on recreational days and weekends where the total daily UVE exposure time on leave or recreational days is taken to be 6 hours and on non golfing weekend days the daily exposure is taken to be 4 hours. The exposure interval for working days,  $E_n(d)$  was fixed at 1.5 hours daily. Additionally, the exposure duration for the golfer,  $E_g(d)$  was set to 4.5 hours based on playing periods listed previously (10). Annual UVE exposures (equation 2) were determined by summation of daily UVE exposures for golf playing days, normal working days and weekend and recreational days.

UVE exposures were determined by application of a horizontal plane UV exposure model (33). The model used employs calculation of the direct and diffuse UV irradiance for input parameters including, latitude, altitude, SZA, ozone concentration, albedo and air and particulate density. The direct UV irradiance modeled at the earth's surface is based on Rundel's (34) formulation of the Green, Cross and Smith (35) and Schippnick and Green (36) improvement to the original Green, Sawada and Shettle (37) semi-empirical UV irradiance model. The horizontal plane diffuse UV irradiance model is based on the equations of Green, Cross and Smith (35) and employs the radiative transfer calculations of Braslau and Dave (38) and Dave and Halpern (39) for diffuse UV reaching the terrestrial surface. The model was used to determine daily UVE exposure for each day of the year for golf course locations situated in the approximate latitudes 25°, 35°, 45° and 55° for both the northern and southern hemispheres (Figure 1). These sites were Blue Shark, Bahamas (25°N, 77°W), Augusta National, Georgia (33°N, 82°W), Bordeaux, France (45°N, 1°W), St Andrews, Scotland (56°N, 3°W), Coral Cove, Queensland (25°S, 152°E), Royal Adelaide, South Australia (35°S, 139°E), North Otago, New Zealand (45°S, 171°E), and Ushuaia, Argentina (55°S, 68°W).

#### FIGURE 1

In applying the horizontal plane UV model, altitude was set at sea level which approximates the altitude of the studied golf course sites. Air and particulate densities were left at their default values (34,35,36,37). Surface albedo was set at 0.02 in order to represent the UV albedo of a grass surface (40). Daily ozone concentrations in Dobson units (DU) for each golf course location were input for the period December 2008 through to November 2009 and were obtained from the Ozone Mapping Instrument (OMI) data set available on the OMI website (41) (Figure 2).

## 2.2 Variation with exposure time

The starting time determined for each daily exposure period was set at 8:00 am for normal working days, recreational and weekend days. This time was chosen as it covers a middle daily solar zenith angle (SZA) range and represents a likely practical time for an individual to begin their daily outdoor exposure. Daily UVE exposures received on golf days were calculated for a set of varying tee times calculated in half hourly increments ranging from 6:00 am to 1:00 pm. Golf day exposures were calculated for each tee time and repeated each week. This enabled annual UVE exposure estimates to be determined based upon the assumption that a weekly golfer controls their chosen tee time and regularly plays at the same time during the year.

Modeled annual ambient UVE exposures were weighted to neck and forearm site exposure ratios (ER) of 0.5 and 0.3 respectively (10). Here the ER represents the fraction of ambient UV received by each of the neck and forearm body sites. Neck and forearm ER information is assumed to be the same for the golfer and non golfer in this simulation. This is done purposefully to investigate the exclusive influence of tee time on annual UVE exposure and subsequent skin cancer risk.

### *Calculation of keratinocyte carcinoma risk*

The additional exposures received by playing golf contribute to the risk of developing keratinocyte carcinoma. The additional contribution to the risk is provided as a power law (26):

$$\text{Risk} \propto (\text{age})^{\alpha} \times (\text{annual UV dose})^{\beta} \quad (3)$$

where  $\alpha$  is the age exponent constant and  $\beta$  is the biological amplification factor (BAF) of 1.4 for basal cell carcinoma (BCC) and 2.5 for squamous cell carcinoma (SCC) (26). For a golfing population group that receives an annual UVE exposure,  $E_A(b)$  compared to a reference population group that receives an annual UVE exposure relative to the same body site,  $E_o(b)$  the previous equation allows the additional contribution to be calculated as:

$$\left[ \frac{E_A(b)}{E_o(b)} \right]^{\beta} \quad (4)$$

where the dependence on age is removed in the ratio when comparing individuals of different annual UVE exposures that are of the same age. The relative comparison allows exposure risk to be calculated for both BCC and SCC. These risks are presented for a single round player in each 25°, 35°, 45° and 55° latitude range where the reference individual's golfing days were replaced by weekend days to determine the reference individual's total annual UVE exposure,  $E_o(b)$ . The reference individual represents a working non-golfer.

For the first presented simulation (Table 1), the golfer is assumed to start their 18 hole round at 8:00 am for each round in the year, except for cases in winter at high latitudes where golf tee times were postponed when needed to meet minimum conditions for daylight for periods when the sun was located below the horizon at 8:00 am. Similarly, for latitudes and times of year during which the weekly golfer finishes their round after daylight, tee times were rescheduled earlier in the day by the minimum time required to end each round in daylight.

### 3. Results

#### 3.1 Daily clear sky plots and variation with season and latitude

Figure 3 shows the modeled daily erythemally effective ambient UV for each 25°, 35°, 45° and 55° approximate latitude for each golf course site in both the Northern and Southern hemispheres. The model is for cloud free cases only.

FIGURE 2

FIGURE 3

The choice of date for the beginning of three weeks annual leave during which an individual will be exposed to the ambient UVE plotted above is dependent on the location and habits of individual workers. For this study it was assumed that Southern hemisphere workers took three weeks annual leave from 22 December 2008 to 9 January 2009. This is a typical pattern for workers using their annual leave for summer vacation. For Northern hemisphere workers, annual leave was determined for 22 June to 10 July. Both periods of annual leave occur immediately after each respective summer solstice occurring on 21 June and 21 December. Weekend days occurring during periods of annual leave were assumed to result in 4 hours daily personal



exposure as per regular weekend day exposure calculations. It is further assumed for the purposes of this study that no immediate travel is taken during leave periods.

### **3.2 Annual UVE exposures of weekly single round golfers**

Table 1 lists the annual erythemally effective UV received at each of the eight golf course sites for a weekly single round golfer teeing off at 8:00 am in comparison to a reference individual's UVE exposure. Annual UVE exposure is expressed in units of standard erythema dose (SED) where 1 SED is taken to represent  $100 \text{ Jm}^{-2}$  of erythemally effective UV. In the table, annual ambient UVE exposure is the annual UVE exposure received for a cloudless sky. This has been calculated daily by application of the horizontal plane UV irradiance model for each of the listed golf course sites (Figure 3). Personal exposures for the reference individual and the golfer were calculated by application of equation 2 where golf days,  $E_g(d)$ , were substituted with weekend days  $E_w(d)$  for the non-golfer. Note that in calculating relative skin cancer risk, the ER of each body site is not needed provided the ER of the golfer and non-golfer is assumed to be the same. ER information for the neck and forearm are however listed in the table as reference approximations for individuals located at each studied golf course site. Differences between the reference individual and the golfer are due to variation in exposure time and SZA at the time of each daily exposure event in both annual UVE exposure intervals. For a single round golfer playing an 18 hole round once per week at 8:00 am there is an increased risk of both BCC and SCC development.

TABLE 1

### **3.3 The influence of tee time on skin cancer risk**

The SCC and BCC risk due to variation in tee time is presented in Figures 4 and 5 respectively. Here, the calculated basal and squamous cell carcinoma risk does not vary depending upon body site as the risk is calculated as the relative ratio of the golfer to the reference individual who are both assumed to experience the same relative ratio of annual UVE exposure to respective forearm and neck sites.

FIGURE 4

FIGURE 5

It was assumed for the purposes of this study that the golfer played their single weekly round on the same golf course each week. Although this assumption is a simplification to the likely behavior of a weekly single round golfer, the influence of latitude and global time zones is apparent in Figures 4 and 5.

### 3.4 Differences in Annual UVE Exposure

Table 2 lists the modeled annual UVE exposure for the non-golfer  $E_o$ , and the golfer beginning their weekly round from either 6:00 am to 1:00 pm,  $E_A$ . The difference in exposure between the golfer and the non-golfer is provided in Table 3 for each of the studied golf course sites. Table 3 lists the difference in annual UVE exposure received by a golfer as a percentage of the non-golfer's annual UVE exposure. Here the exposure difference is effectively weighted to the reference individual's exposure as expressed by the relative risks plotted in Figures 4 and 5.

TABLE 2

TABLE 3

There are several trends apparent in the results presented in Table 3. Firstly, the difference in exposure tends to increase with increasing latitude for mid morning tee times. This is caused by the higher diurnal elevation of the sun in low latitude locations where a golfer beginning their round mid morning in a low latitude location experiences a much higher solar elevation than does a golfer located at higher latitudes. The increased range in solar elevation also results in their being a shift in the peak exposure difference tee time from late to mid morning at golf course sites located in progressively lower latitudes. Peak differences evident in Table 3 change for example from tee times of 11:00 am (Bordeaux) to 10:00 am (Blue Shark) in the Northern hemisphere and from 11:30 am (Ushuaia) to 9:30 am (Coral Cove) in the Southern hemisphere. The effect can be understood by considering an individual venturing outdoors at 8:00 am in a low latitude location effectively exposing themselves to UVE in a period when the sun can quickly reach a high elevation compared to an afternoon golfer that begins their round after the peak daily UV

irradiance and experiences a period of solar elevation that falls relatively quickly compared to locations at high latitude. In high latitudes, solar elevations experience less variation so that for these cases, beginning a round after the peak daily UV irradiance will result in a lower exposure difference being observed.

## **4. Discussion**

### **4.1 Risk Comparisons**

Immediately obvious in comparison between Figures 4 and 5 is the lower relative risk for the development of BCC. This is a direct result of the BAF exponent applied to equation 4 of 1.4 for BCC compared to 2.5 for SCC. This factor represents the lower likelihood of the development of BCC with increasing annual UVE exposure in comparison to SCC. The greatest BCC relative risk for the Northern hemisphere golfer was determined for a beginning tee time of 11:00 am at 1.47 (Bordeaux) compared to the greatest BCC risk of 1.51 for beginning tee times of 11:00 am and 11:30 am for the Southern hemisphere golfer (Ushuaia). A similar pattern in relative risk was determined for the development of SCC with the greatest risk being 1.98 for a tee time of 11:00 am in the Northern hemisphere (Bordeaux) and 2.08 for tee times of 11:00 am and 11:30 am in the Southern hemisphere (Ushuaia).

From the results presented in Figures 4 and 5 it appears that the relative cancer risk tends to be higher for locations of higher latitude except for the St Andrews golf course site. This is best explained by considering equation 4, which shows the largest determinant for relative skin cancer risk to be the ratio of exposure between the reference individual and the golfer. For locations of high latitude, exposures that begin for the normal working day and weekend periods at 8:00 am may occur before sunrise. Thus, a nil exposure may be accumulated during times when golf is not played. However, as the golfer cannot begin a round until daylight, the exposure received by a golfer over a 4.5 hour period will often be greater than that experienced by a non golfer venturing outside for 8 hours during weekend periods and 1.5 hours on normal working days during which the sun is not above the horizon.

## 4.2 Time Zone Considerations

The start of the working day and weekend period of 8:00 am for the non-golfer were influenced by the global time zone of the individual's location. For Ushuaia for example, located at 68° west of Greenwich, the astronomical time for 8:00 am (locally) will occur approximately 4.5 hours after the equivalent universal, or Greenwich mean time (GMT) of 8:00 am, where 4.5 hours is determined as the quotient of Ushuaia's longitude and 15° for each hour in difference from GMT. Thus, a local time of 8:00 am in Ushuaia corresponds astronomically to a time of 12:30 pm GMT. The global time zone of Ushuaia however is placed at GMT – 3 hours for civil reasons and not GMT – 4.5. A non-golfer beginning their day at 8:00 am locally begins their day at 11:00 am GMT, a total of 1.5 hours before the sun reaches an astronomical 8:00 am local time. This places the non-golfer in the dark for longer than the golfer who is delayed in time until the sun peaks above the horizon. This further influences the annual UVE exposure difference between the golfer and non-golfer for the purposes of calculating relative risk (equation 4).

## 4.3 Annual UVE exposure differences with tee time

Tee times where the relative skin cancer risk for the golfer are at parity with the non-golfer occur over a narrower diurnal range with decreasing latitude (Table 3). For the high latitude golf courses, only the first equivalent exposure (or risk factor 1) point is evident in the early morning tee time period between 6:00 am and 1:00 pm. Both points become apparent at golf course locations at latitudes of 35° or less (apparent as negative afternoon differences in Table 3). In low latitudes, the weekly habits of an early morning or afternoon golfer effectively reduce the likelihood of being exposed to UVE during periods of high solar elevation and peak diurnal UV irradiance, reducing the BCC and SCC risk compared to a reference non-golfer living in the same location who is assumed to receive weekend exposures beginning at 8:00 am for each weekend of the year.

The time shift in peak exposure differences corresponds with a wider range of tee time periods whereby the golfer beginning their round either early in the morning or in the afternoon can receive a lower exposure than the reference non-golfer. Lower golfer exposures are most noticeable before 7:00 am and after 12:00 pm (Coral Cove) and before 7:00 am and after 12:30 pm (Blue Shark). Tee times whereby the golfer receives a lower annual UVE exposure than the

non-golfer correspond to tee times that reduce BCC and SCC relative risk below 1 (Figures 4 and 5). Here, an early morning golfer experiences a lower UV irradiance in the period before 8:00 am. Similarly, for late tee time golfers, the UV irradiance may be lower than that received by the non-golfer who is always assumed to begin their outdoor activity at 8:00 am daily. By modeling the non-golfer's weekend exposure from 8:00 am, the risk model indicates a lower skin cancer risk for the early morning and sometimes late afternoon golfer. This assumption does not specifically indicate early morning or late afternoon golfing is necessarily good for the skin as the risk model used is relative to each local population group. In these cases risk is reduced due to the beginning exposure time parameter of the non-golfer. It would remain prudent for golfers to apply appropriate exposure reduction strategies regardless of tee time.

## 5. Conclusions

Both BCC and SCC risks for a golfer expressed relative to an individual living in the same location have been presented for eight different golf course sites located in the Northern and Southern hemispheres at approximate latitudes of 55°, 45°, 35°, and 25°. As relative risk estimates, the data presented here does not represent the overall risk for the development of the disease with respect to latitude as the development of skin cancer is very much dependent upon skin and phenotype, the individual's attitude to sun protection and their outdoor pattern of behavior. Skin cancer rates are however highest in populations of fair skin type living in high ambient ultraviolet climates. A golfer in Queensland, for example will have a higher likelihood of developing a skin cancer compared to a golfer from Scotland. Similarly a non-golfer will experience a heightened risk of developing a skin cancer due to geographical location alone. The risks will vary for each separate population group. However, within each population there are several steps that can be taken to reduce the likelihood of developing the disease, including the active use of sunscreen, shade and physically protecting the skin by the use of high ultraviolet protection factor clothing. Here, the aim of this research has been to determine what difference a golfer's weekly tee time may have on reducing the skin cancer risk inherent in different population groups separated by latitude and hemisphere. Furthermore, it needs to be kept in mind that the relative risks expressed here are calculated between individuals living in the same location. The study does not calculate comparative risks between a golfer and non-golfer living in separate latitudes.

Both BCC and SCC risk can be influenced by weekly tee time. Within each population group, risk is increased for golfers that begin their round mid to late morning between approximately 9:30 am to 11:30 am. The peak risk, influenced by weekly tee time for both types of cancer was found to shift toward earlier tee times with decreasing latitude.

The results presented in this research are the first to consider the influence of tee time and therefore can be considered a reasonable first approximation to the overall risk faced by the recreational golfing population. However, the study is limited by several assumptions. In the modeling process clear sky conditions were assumed to occur for each day of the year. For future investigations, the addition of precise climatic cloud cover data would greatly improve modeling estimates and in turn increase the accuracy of the relative risk calculations. Measurements of the

UVE exposure made under clear and cloudy conditions in each of the studied latitudes are also needed to validate the UVE exposure output generated by the model. Another point to consider is the behavior of a typical weekly single round golfer. Individual behavior is likely to vary and not all weekly competition golfers may continue playing the same course each week as was assumed for this research. Also, many club competition and weekend golfers may take several weeks off every year to recover from injuries or fatigue. Therefore, further research analysing the actual behavior of competition golfers is needed to enhance the quality of the results. An avenue for further research may also consider the playing schedule of a professional or touring golfer.

The results presented in this research are applicable to other similar outdoor activities in which grass is assumed to be the predominant ground cover. For this research, body postures for the golfer and reference individual were assumed to present the same body site ratios of exposure expressed relative to the ambient UV. In cases where body posture for the activity to be studied varies significantly from the reference population body posture, appropriate site exposure ratios need to be substituted to determine accurate annual exposures for each population group. Similarly, differences in the ambient environment between the activity and reference population group are needed for cases where there is expected to be a notable difference between populations. The purpose of the current study however has focused on the effect of tee time. A comparison between the tee time risk estimates provided here and weekly exposure in the sun beginning in the half hourly periods from 6:00 am to 1:00 pm can be made using the present results. As such the results presented here may be used as approximations to the risks likely to be encountered by other groups which may include, other sports or outdoor activities.

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## Tables

Table 1: Estimated Annual UVE exposure of a weekly 8:00 am single round golfer and a reference individual. Skin cancer risk is calculated relative to the reference individual for each of eight golf course sites in the Northern and Southern hemisphere. Annual UVE exposure to a neck site (n) and forearm site (f) are also listed.

Golf Course site	Latitude	Annual ambient UVE exposure (SED)	Reference individual annual UVE exposure (SED)					Weekly golfer's annual UVE exposure (SED)					Relative skin cancer risk	
			En	Ew	E <sub>o</sub>	E <sub>o</sub> (n)	E <sub>o</sub> (f)	Ew	E <sub>g</sub>	E <sub>A</sub>	E <sub>A</sub> (n)	E <sub>A</sub> (f)	SCC	BCC
St Andrews	56° N	6177	344	1228	1572	786	472	854	445	1643	822	493	1.12	1.06
Bordeaux	45° N	9596	246	1375	1622	811	487	951	543	1740	870	522	1.19	1.10
Augusta	33° N	14520	662	2398	3061	1531	918	1556	1034	3252	2265	1359	1.16	1.09
Blue Shark	25° N	17930	1055	3155	4210	2105	1263	1978	1416	4449	2225	1335	1.15	1.08
Ushuaia	55° S	7589	195	1020	1214	607	364	746	358	1299	650	390	1.18	1.10
North Otago	45° S	10400	408	1838	2246	1123	674	1275	691	2375	1188	713	1.15	1.08
Royal Adelaide	35° S	14194	716	2626	3342	1671	1003	1745	1063	3524	1762	1057	1.14	1.08
Coral Cove	25° S	18481	1218	3618	4836	2418	1451	2298	1562	5078	2539	1523	1.13	1.07

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E<sub>n</sub> - annual working day UVE exposure

E<sub>w</sub> - annual weekend and recreational day UVE exposure

E<sub>g</sub> - annual golf day UVE exposure

E<sub>o</sub> - non-golfer annual UVE exposure

E<sub>A</sub> - golfer annual UVE exposure

Table 2: Modeled annual UVE exposure for a single 18 hole round golfer playing a regular weekly round at tee times ranging from 6:00 am through to 1:00 pm.

	Longitude	Time Zone	E <sub>o</sub> (SED)	E <sub>A</sub> (SED)														
				6:00	6:30	7:00	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00
St Andrews	3° W	GMT	1572	1418	1470	1528	1587	1643	1693	1731	1755	1762	1752	1726	1686	1636	1579	1521
Bordeaux	1° W	GMT+1	1622	1438	1486	1554	1641	1740	1843	1943	2028	2092	2128	2132	2106	2050	1971	1874
Augusta	82° W	GMT-5	3061	2680	2776	2911	3074	3252	3417	3556	3656	3707	3704	3647	3543	3401	3234	3058
Blue Shark	77° W	GMT-5	4210	3657	3806	4005	4232	4449	4640	4785	4871	4890	4841	4727	4560	4356	4132	3910
Ushuaia	68° W	GMT-3	1214	1093	1128	1174	1232	1299	1370	1442	1508	1564	1605	1626	1627	1607	1568	1513
North Otago	171° E	GMT+12	2246	1994	2067	2158	2264	2375	2482	2575	2645	2685	2693	2667	2609	2525	2422	2311
Royal Adelaide	139° E	GMT+9.5	3342	2946	3057	3199	3361	3524	3668	3782	3854	3878	3852	3778	3662	3516	3353	3189
Coral Cove	152° E	GMT+10	4836	4232	4414	4640	4869	5078	5250	5367	5419	5401	5314	5167	4973	4752	4520	4309

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E<sub>o</sub> - non-golfer annual UVE exposure

E<sub>A</sub> - golfer annual UVE exposure

Table 3: Difference in annual UVE exposure of a golfer beginning their weekly round at tee times from 6:00 am to 1:00 pm compared to a non-golfer expressed as a percentage of the non-golfer's annual UVE exposure for each of the studied golf course sites.

	E <sub>0</sub> (SED)	(E <sub>A</sub> -E <sub>0</sub> ) / E <sub>0</sub> (%)														
		6:00	6:30	7:00	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00
St Andrews	1572	-10	-9	-3	1	5	8	10	12	12	11	10	7	4	0	-3
Bordeaux	1622	-11	-8	-4	1	7	14	20	25	29	31	31	30	26	22	16
Augusta	3061	-12	-9	-5	0	6	12	16	19	21	21	19	16	11	6	0
Blue Shark	4210	-13	-10	-5	1	6	10	14	16	16	15	12	8	3	-2	-7
Ushuaia	1214	-10	-7	-3	1	7	13	19	24	29	32	34	34	32	29	25
North Otago	2246	-11	-8	-4	1	6	11	15	18	20	20	19	16	12	8	3
Royal Adelaide	3342	-12	-9	-4	1	5	10	13	15	16	15	13	10	5	0	-5
Coral Cove	4836	-12	-9	-4	1	5	9	11	12	12	10	7	3	-2	-7	-11

E<sub>0</sub> - non-golfer annual UVE exposure

E<sub>A</sub> - golfer annual UVE exposure

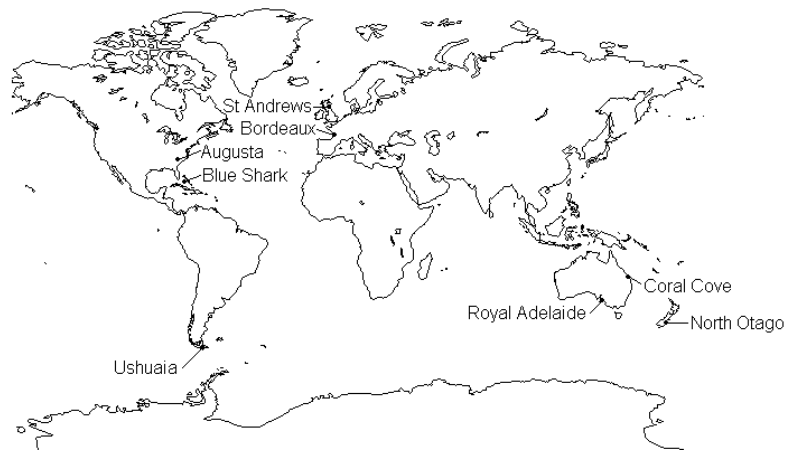
**List of Figures**

Figure 1: Locations of the golf course sites.



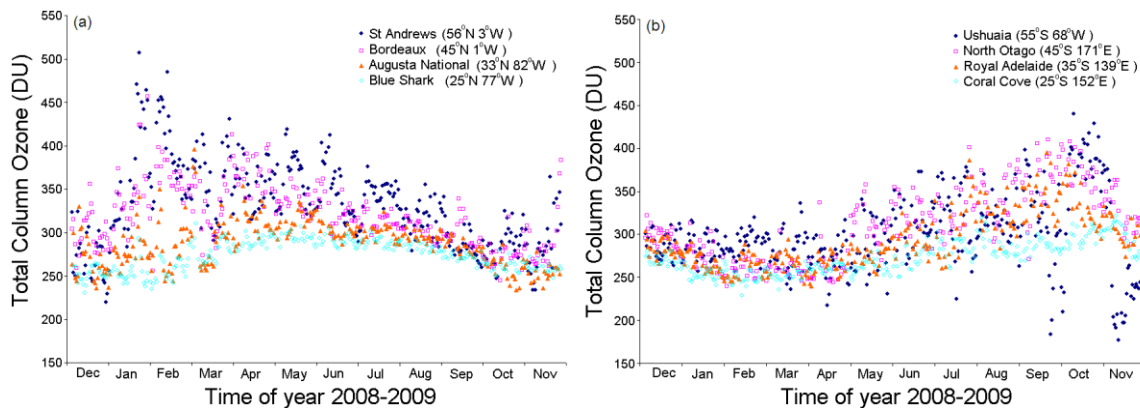


Figure 2: Total column ozone concentration for Northern (a) and Southern (b) hemisphere golf course sites (41) for the study period December 2008 to November 2009. Daily ozone concentrations were input in the horizontal plane UV exposure model to determine annual UVE exposure in each approximate latitude range 55°, 45°, 35° and 25°.

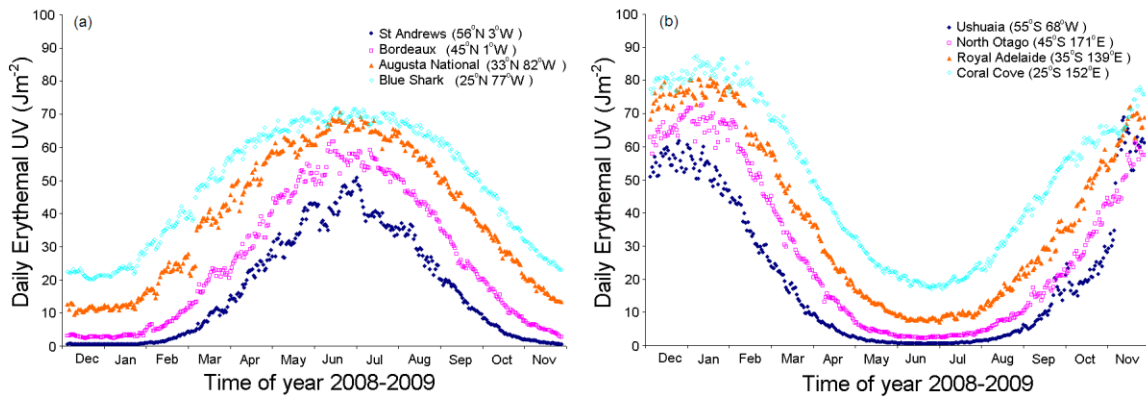


Figure 3: Modeled daily horizontal plane erythemally effective UV for Northern (a) and Southern (b) hemisphere golf course sites calculated for the period from December 2008 to November 2009.

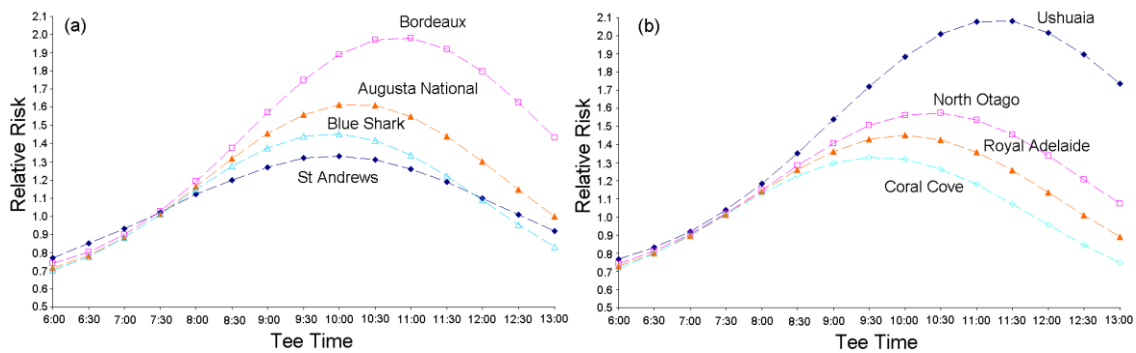


Figure 4: Modeled squamous cell carcinoma risk for Northern (a) and Southern (b) hemisphere golf course sites. The risk model is for a single weekly 18 hole round golfer using the same course and teeing off at the same approximate time each week.

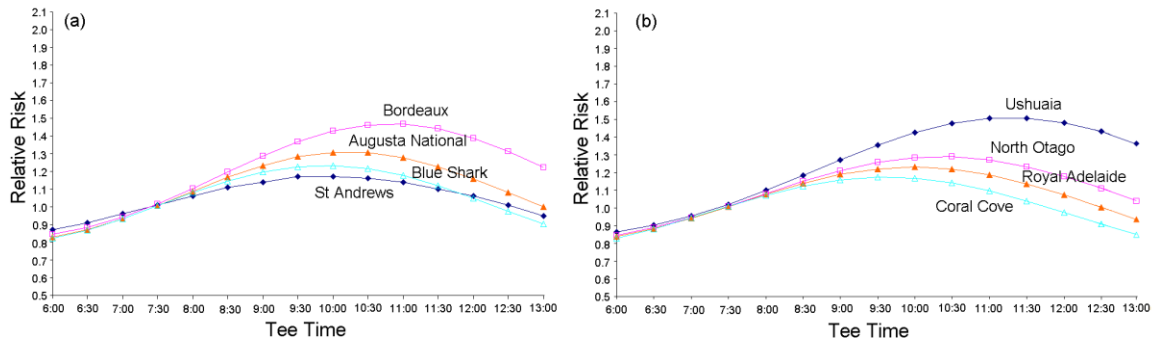


Figure 5: Modeled basal cell carcinoma risk for Northern (a) and Southern (b) hemisphere golf course sites. Risk is shown to be proportional to latitude for Southern hemisphere sites with risk increasing with increasing latitude. Variation in risk in the Northern hemisphere is also dependent upon latitude however a site's global time zone influences the exposure difference between a reference individual and a golfer that needs to play in daylight.