Dermatology Practical & Conceptual

Climate, Seasons, and Skin Cancer: A 16-Year Retrospective Study of Trends in New Zealand

Sharad P Paul[1,2,3], Suresh Lama[1], Mahsa Mohaghegh[1], Allanah Knight[2]

1 Auckland University of Technology, Auckland, New Zealand
2 Skin Surgery Clinic, Auckland, New Zealand
3 School of Medicine, University of Queensland, Brisbane, Australia

Key words: Skin cancer, Basal cell carcinoma, Squamous cell carcinoma, Melanoma, Climate

Citation: Paul SP, Lama S, Mohaghegh M, Knight A. Climate, Seasons and Skin Cancer: A 16-Year Retrospective Study of Trends in New Zealand. *Dermatol Pract Concept*. 2026;16(3):7139. DOI: https://doi.org/10.5826/dpc.1603a7139

Accepted: February 25, 2026; **Published:** July 2026

Copyright: ©2026 Paul et al. This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (BY-NC-4.0), https://creativecommons.org/licenses/by-nc/4.0/, which permits unrestricted noncommercial use, distribution, and reproduction in any medium, provided the original authors and source are credited.

Funding: None.

Competing Interests: None.

Authorship: All authors have contributed significantly to this publication.

Corresponding Author: Sharad P Paul, MD, Professor, Auckland University of Technology, Auckland, New Zealand. ORCID: 0000-0001-9601-9109. E-mail: sharad@sharadpaul.com

ABSTRACT

Introduction: Skin cancer remains a major public health concern in New Zealand, where high ultraviolet (UV) radiation and a predominantly fair-skinned population contribute to some of the world's highest incidence rates. While national prevalence has recently been documented, less is known about how skin cancer incidence fluctuates across months, seasons, and years, or how these temporal patterns relate to short-term environmental factors such as UV index, temperature, and rainfall.

Objectives: This study aimed to quantify seasonal and long-term trends in basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and malignant melanoma (MM) diagnosed between 2009 and 2024 and to examine their associations with environmental conditions.

Methods: A retrospective analysis of 24,653 biopsy-confirmed cases was conducted using clinical records from a New Zealand skin cancer clinic over a 16-year period. Monthly incidence rates were modelled with negative-binomial regression incorporating Fourier terms to test for seasonality and long-term temporal trends were evaluated. Lagged Pearson correlations (0–6 months) were calculated to assess associations between cancer incidence and environmental variables (UV, temperature, rainfall).

Results: BCC and SCC showed significant seasonal peaks in late summer and early autumn, demonstrating a delayed but consistent rise following peak UV exposure over summer months, while MM displayed minimal or inconsistent seasonality. These results may help public health advice and prevention measures..

Conclusions: This 16-year analysis highlights distinct seasonal and long-term temporal dimensions in skin cancer incidence within New Zealand's high-UV environment, with clear increases in non-melanoma skin cancer incidence (but not melanoma incidence) following summer months.

Introduction

Skin cancer, including melanoma (MM) and nonmelanoma forms such as basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), represents the most common cancer group in New Zealand and imposes a substantial healthcare and economic burden [1]. New Zealand's high incidence reflects the combination of relatively high ambient ultraviolet (UV) radiation, outdoor lifestyles, and a predominantly fair-skinned population [2]. In such populations, UV exposure is a major risk factor for keratinocyte cancers and melanomas [3].

Northern hemisphere studies demonstrate seasonal fluctuations in skin cancer diagnoses, typically peaking in months following maximum UV exposure [4,5]. However, the extent to which these patterns occur in southern hemisphere settings, including New Zealand, remains incompletely understood. Monthly or seasonal trends in biopsy-confirmed BCC, SCC, and MM have not been quantified using clinic-level datasets. Furthermore, the influence of short-term environmental variability such as UV index, temperature, and rainfall on detection patterns has not been studied in New Zealand.

This study analyzed more than 24,000 biopsy-confirmed skin cancers diagnosed at the Skin Surgery Clinic, a major skin cancer services provider, between 2009 and 2024. To minimize potential bias related to fluctuations in clinic attendance, including COVID-19-related disruptions, cancer detection rates were analyzed as a proportion of total clinic attendances as opposed to total numbers.

Seasonality and interannual variability in BCC, SCC, and MM detection rates were evaluated using negative-binomial regression with Fourier terms. Long-term trends and lagged correlations with environmental variables, including UV index, rainfall, and temperature, were assessed to determine short-term environmental influences. The study aimed to characterize seasonal variation and long-term trends to inform prevention strategies, public awareness campaigns, and clinical resource planning in New Zealand.

Objectives

This study aimed to quantify long-term trends in basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and malignant melanoma (MM) diagnosed between 2009 and 2024 and to examine their associations with seasonal and environmental conditions.

Methods

Study Design and Data Source

This study analyzed patient records from the Skin Surgery Clinic in New Zealand, covering the years 2009 to 2024. Departmental ethics approval was attained through Auckland University of Technology. All data were irreversibly anonymized prior to analysis, with no individual identification possible, and the Auckland University of Technology departmental committee determined that further formal ethics approval was not required for this study. The dataset contained 57,455 clinical records, including demographics (age, sex), pathology-confirmed diagnosis, and date of clinic visit. The environmental and weather pattern data required for this study i.e., UV index, rainfall, and temperature, were obtained from the National Institute of Water and Atmospheric Research (NIWA), a New Zealand government body that offers evidence-based analysis and advice from environmental experts.

Data Selection and Exclusion Criteria

Records were filtered to biopsy-confirmed cases of BCC, SCC, or MM. Exclusions were duplicate entries, same patients at follow-up visits, or incomplete records (e.g., half-year datasets). After cleaning, 24,653 usable cases were included in this analysis. Covid-19-affected years were excluded from primary calculations to avoid bias; nonetheless, data points and figures during the Covid-19 years were interpreted in the light of pandemic effects.

Statistical Modeling

Monthly incidence rates were calculated as the proportion of cancer cases relative to total patients per month, with 95% confidence intervals (CI). All analyses were performed using Python version 3.12.4. The principal libraries used were NumPy, pandas, SciPy, statsmodels, patsy, openpyxl, and Matplotlib. To test seasonality, the count data with simple seasonal terms were modeled using Poisson model. Since the data varied more than Poisson model allows, negative binomial regression models with Fourier terms (sine and cosine components) were chosen to account for overdispersion. Seasonality was modeled using Fourier sine and cosine terms to generate smooth annual cycles, with the number of term pairs determining the resolution of seasonal patterns. Long-term trends were also characterized. Environmental associations were evaluated using Pearson correlation analyses, both contemporaneous and with lags of 0–6 months.

Results

Average Seasonal Incidence Pattern of Melanoma and Nonmelanoma Skin Cancer (2009–2025)

Figure 1 illustrates the seasonal average rates of detection for basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and malignant melanoma (MM) from 2009 to 2024. Rates shown are average rates with 95% confidence intervals. The highest seasonal average rates were: BCC 8.6% (95%

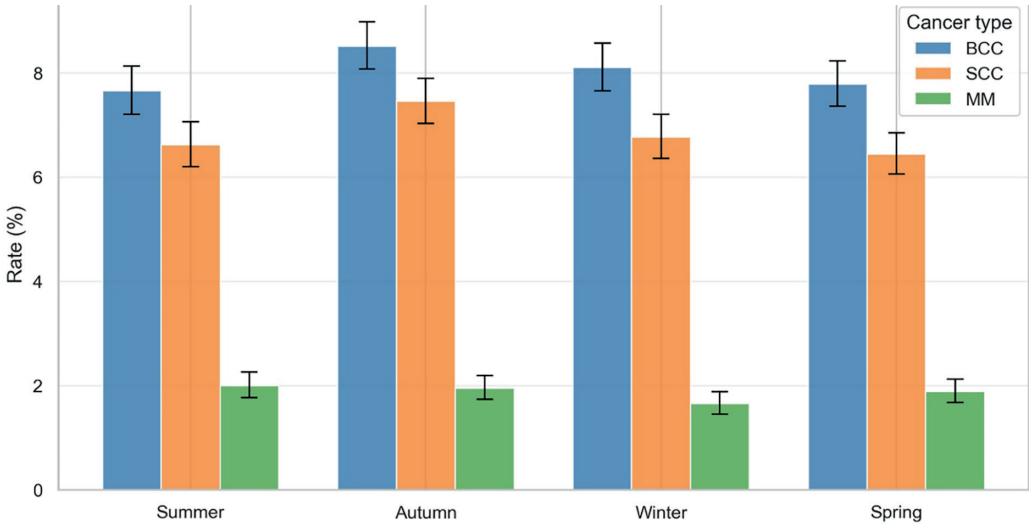

Figure 1. Average seasonal detection rates of basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma (MM), 2009–2024.

CI:8.2–9.1) in autumn; SCC, 7.5% (95% CI:7.1–8.0) in autumn, and MM, 2% in summer (95% CI:1.8–2.3) and in autumn (95% CI:1.7–2.2). Both BCC and SCC exhibited clear and statistically significant seasonal fluctuation (P=0.017 for BCC, P=0.002 for SCC), with the highest detection during autumn (following the summer period) and the lowest detection in spring to early summer. Fourier-based negative binomial regression revealed that for BCC and SCC, the predicted peak is approximately April (autumn) and the minimum about October (spring), providing an indication of several-month lag between peak summer ultraviolet (UV) exposure and subsequent detection of cancer. This lagged pattern concurs with existing research that discloses nonmelanoma skin cancers happen months after maximum UV exposure due to biological latency and clinical delay in presentation. On the other hand, MM did not demonstrate statistically seasonality (P=0.189). Overall, these results highlight that nonmelanoma skin cancers have a regular annual pattern, while melanoma detection shows no seasonal variation.

Interannual Variability in Seasonal Patterns

Figure 2 presents month-by-month incidence trends for BCC, SCC, and MM for each year between 2009 and 2024. Although overall seasonal fluctuation is evident in most years, particularly for BCC and SCC, the shape and timing of the pattern do not remain constant over the course of the study. During certain years, detection rates were highest during late summer or early autumn (i.e., February–April), corresponding to the overall pattern in the mean monthly incidence pattern, with a clear April peak when data were pooled across all years. During other years, peaks were earlier or later, and some years only had moderate or irregular seasonal variation. The size of seasonal maxima also varied extremely, with some years exhibiting steep late-summer peaks and others rather flat distributions.

Notably, 2020 and 2021 present clear anomalies, with abrupt peaks followed by steep declines. This could be explained by service disruptions due to COVID-19 pandemic lockdowns. Interannual variability indicates that, even while a steady seasonal signal is seen when data are averaged, seasonal trends are not replicated in a consistent way each year. These irregularities are assumed to reflect the effect of year-to-year variation in exogenous drivers, including availability of health services (e.g., clinic appointments, holiday closure), public engagement in seeking diagnosis, and environmental/UV variation. However, broad seasonal trends emerge when data are aggregated over large spatial regions, even if the precise timing, magnitude, and peak shape may show some variation across years [4,5].

Long-Term Trends in Skin Cancer Incidence

Figure 3 displays the yearly detection rates of BCC, SCC, and MM for the period 2009-2024. There was a steady decline for the nonmelanoma skin cancer excision rates. BCC fell from 16.3% in 2009 to 5.7% in 2024, while SCC fell from 10.9% to 4.0%. International reviews emphasize preventability and public health measures but do not show sustained global declines in keratinocyte cancer incidence [3,4], seasonal detection patterns may reflect awareness and service factors such as earlier detection and topical treatments, meaning that excisional biopsies were not needed (because our study was based on biopsy-proven skin cancers for accuracy) rather than long-term incidence changes.

In contrast, MM rates were comparatively steady, fluctuating between 1.3% and 2.7% throughout among clinic

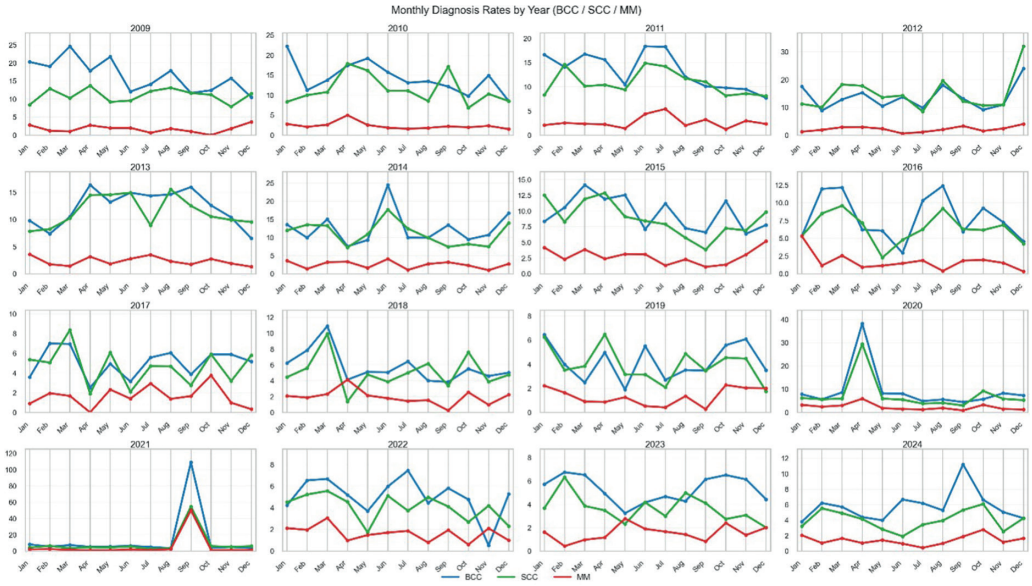

Figure 2. Year-by-year monthly incidence patterns of basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma (MM) excisions from 2009 to 2024.

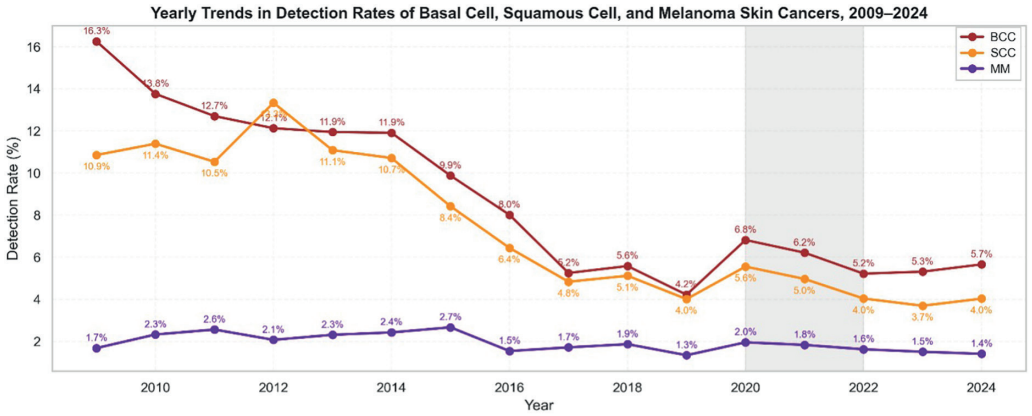

Figure 3. Yearly trends in skin cancer excision rates of BCC, SCC, and MM.

attendees. The incidence of melanoma shifted more slowly over time. The temporary rise in BCC (6.8%) and SCC (5.6%) specifically in 2020, followed by a gentle decline, was most likely an effect of diagnostic delays caused by the initial COVID-19 pandemic lockdown. The long-term trend indicates a relatively steady melanoma incidence.

Correlation with Environmental Factors

Figure 4 shows monthly skin cancer detection rates (BCC, SCC and MM) overlaid with UV index, temperature, and rainfall (top, center, and bottom panels) aggregated across June–May, seasonal years (2009–2024), UV index, and temperature peak in December–January, whereas BCC and SCC have their highest values in February–March, consistent with a short lag of 1–2 months after peak sun exposure. The magnitude of this late-summer increase is modest and varied across months. Melanoma remained low, with only a slight midsummer rise, and no consistent phase relationship with any environmental series. Rainfall is maximal in winter and minimal in late summer, yet cancer rates do not track this pattern. Overall, the comparison of pooled monthly and seasonal averages indicate limited same-month alignment and support a correlation with post-summer exposure or detection lag for BCC and SCC. Figures 5–6 present the quantitative lag correlation analysis for the same variables. Correlations in temperature and detection rate were positive but small, with maximal two-to-three-month lags for BCC and SCC ($r \approx 0.12–0.16$). Correlations with the UV index were somewhat more positive for SCC ($r \approx 0.16$ at 2–3 months) and BCC ($r \approx 0.10–0.12$ at 3–4 months). Melanoma correlations were weak, and negative after four months, with no relation in the short term. Rainfall correlations oscillated

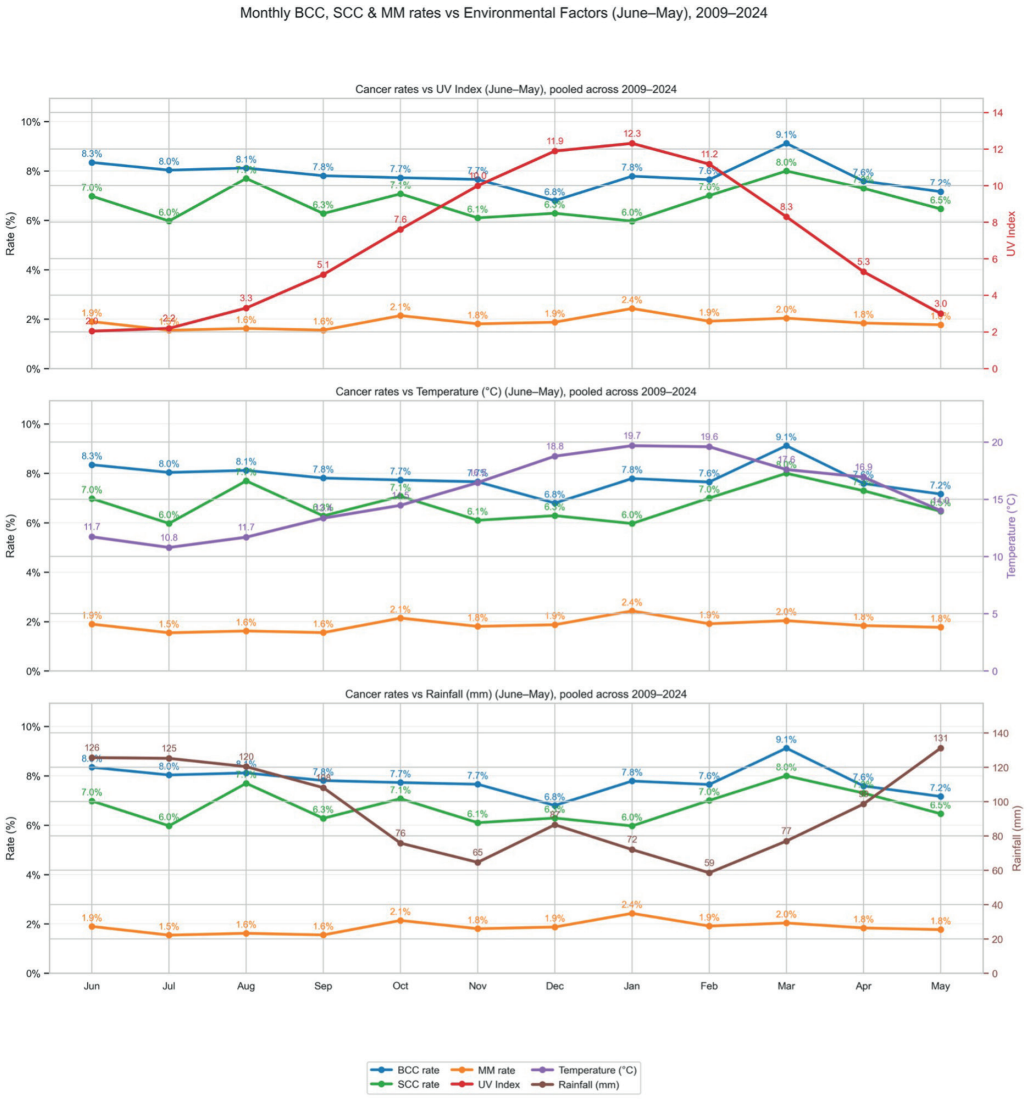

Figure 4. Figure. Monthly BCC, SCC, and MM rates (2009–2024) plotted against environmental factors (UV index, temperature, and rainfall) across the seasonal year (June–May).

around zero with alternating signs, and no pattern emerged across the cancer types. These findings indicate that month-by-month variations in temperature, UV, and rainfall have little correspondence with rates of skin cancer diagnosis. The minimal positive lag with UV and temperature may corroborate the observation that cumulative ultraviolet exposure rather than short-term environmental variability is the key driver of incidence [3,6].

Discussion

This study identified seasonal patterns for basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), with incidence peaks during late summer and early autumn, while malignant melanoma (MM) exhibited weaker seasonality. These results are consistent with evidence that cumulative ultraviolet (UV) exposure and subsequent biological latency lead to delayed clinical presentation of nonmelanoma skin cancers[4]. Comparable seasonal variations and short-term UV effects have also been reported across European and North American populations [5,7,8], but such data had been lacking in the southern hemisphere. Given that New Zealand experiences some of the highest ambient UV radiation levels globally [2], behavioral changes such as increased outdoor exposure during summer months can influence seasonal diagnosis rates.

Beyond seasonality, long-term analysis revealed a sustained decline in BCC and SCC excision rates between 2009 and 2024, with reductions in skin cancer surgery rates of approximately 65% and 60%, respectively. The observed moderation in nonmelanoma incidence may partly reflect the cumulative impact of strengthened public health campaigns leading to sun protection behaviors such as sunscreen use and shade seeking, better primary care skin cancer

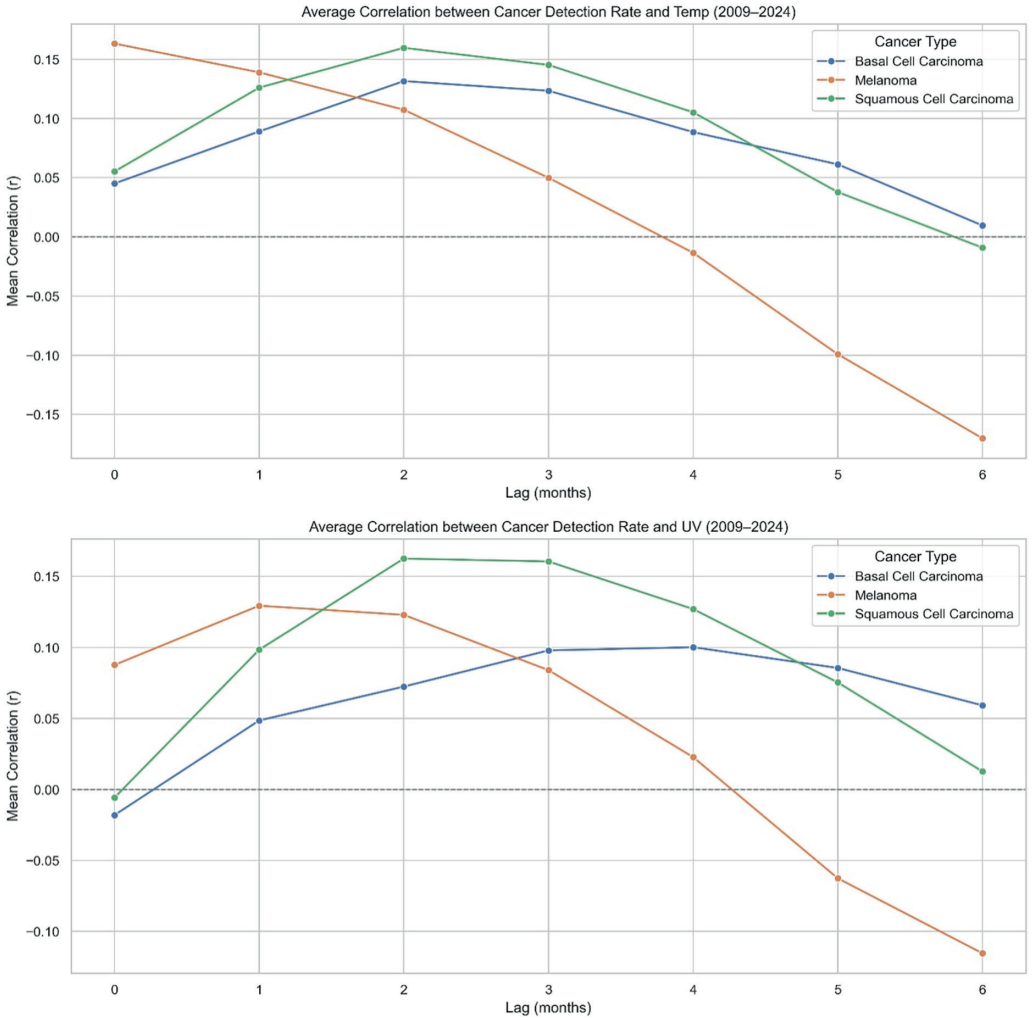

Figure 5. Average lag correlation plots (0–6 months) between temperature, UV, and skin cancer rates. Panels illustrate Pearson correlation coefficients at different lags for BCC, SCC, and MM.

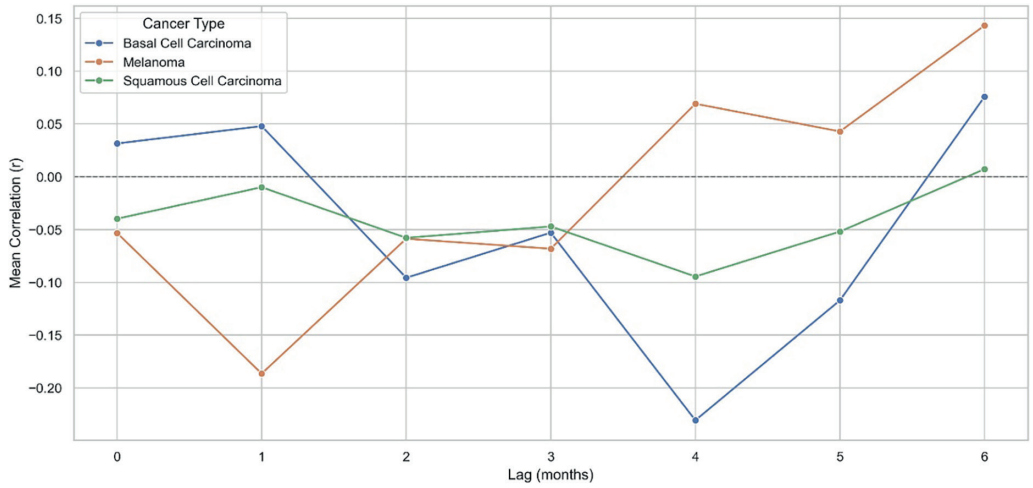

Figure 6. Average lag correlation plots (0–6 months) rainfall and skin cancer rates. Panels illustrate Pearson correlation coefficients at different lags for BCC, SCC, and MM.

management leading to improved early detection, chemoprevention, and topical treatments [3,9,10]. The significant decline in 2020 likely resulted due to the COVID-19 pandemic, when dermatological screening and elective procedures were limited, followed by a gradual return to baseline detection levels once healthcare services resumed [11,12].

Melanoma showed a comparatively stable pattern throughout the study period, fluctuating mildly but showing no consistent upward trend. There is a global observation that melanoma incidence has plateaued in many developed nations after earlier decades of increase, largely due to improved diagnostic completeness and saturation of awareness programs [13]. A recent article from the UK suggested a theory, albeit scientifically unproven, that ultraviolet radiation is not the major cause of melanoma mortality [14]. However, if UV index is used as a measure, the overlay figures (Figure 4) visually seem to support this finding, showing that melanoma incidence remains largely decoupled from short-term UV, temperature, and rainfall cycles, in contrast to the seasonal alignment observed clearly for BCC and SCC.

Correlation analyses between environmental variables (UV, temperature, rainfall) and monthly incidence provided limited evidence of short-term influence. Weak and inconsistent lagged associations across cancer types support the view that cumulative lifetime UV dose rather than monthly fluctuations determines overall risk [6]. The overlay plots confirm that these environmental variables exhibit statistically weak seasonal cycles relative to cancer incidence, underscoring that short-term weather variation plays little measurable role in detection patterns. Similar findings were reported by Weller et al. [14], who identified ultraviolet radiation, rising temperature, individual behavior, occupation, and air pollution as possible influences on skin cancer rates and highlighted substantial complexity and uncertainty in the evidence base. Additionally, pandemic-related service interruptions and changes in clinic attendance likely weakened short-term associations by reducing and delaying diagnostic activity [16-18]. Ultraviolet exposure remains the principal environmental driver of nonmelanoma skin cancer risk; its carcinogenic effects are largely cumulative, with measurable impacts emerging over longer timescales rather than month-to-month fluctuations [19-21]. Dika et al. in their comprehensive review of BCC mention that in addition to genetic factors (mainly the sonic hedgehog pathway along with additional signaling molecules) that contribute to BCC predisposition, UV radiation (particularly when acute and intermittent) is considered the major environmental risk factor for a higher lifetime BCC risk [22].

Our study used data from a large clinic in one city, so the findings may not generalize nationally; attendance-driven service access could also bias detection rates. We did not model cumulative UV doses, and environmental covariates were limited to UV indices, temperature, and rainfall, leaving important factors (e.g., individual behavior, occupation, sun protection) unmeasured. Future work can incorporate cumulative UV dose and behavioral exposure, broaden environmental covariates, and strengthen time-lag modeling.

Conclusion

In summary, this 16-year retrospective analysis identified two dominant temporal patterns of skin cancer incidence in New Zealand. Firstly, BCC and SCC (but not melanoma) exhibited a consistent seasonal pattern, with peak incidence occurring in late summer and early autumn, likely reflecting a delay between lesion onset and clinical presentation. Secondly, trends for the long term showed continued declines in rates of SCC and BCC surgery through 2009 to 2024, possibly reflecting better sun protection and chemoprevention, with a largely flat melanoma trend where such chemoprevention or topical treatments are not typically used.

Weak short-term correlations between other environmental variables (temperature, rain) and skin cancer incidence portends that cumulative exposure to UV rather than transient climatic fluctuation remains the primary environmental risk determinant for skin cancer risk. These findings add to the public health knowledge in the field.

References

1. Paul S, Chen, Mohaghegh M. Analysis of Prevalence, Socioeconomic and Disease Trends of Non-Melanoma Skin Cancer in New Zealand from 2008 to 2022. *J. Epidemiol. Glob. Health*. 2024;14(3):1012-1021. DOI:10.1007/s44197-024-00250-4
2. McKenzie RL, Aucamp PJ, Bais AF, Björn LO, Ilyas M. Changes in biologically active ultraviolet radiation reaching the Earth's surface. *Photochem. Photobiol. Sci.* 2007;6(3):218-231. DOI:10.1039/b700017k
3. Garbe C, Forsea AM, Amaral T, et al. Skin cancers are the most frequent cancers in fair-skinned populations, but we can prevent them. *Eur. J. Cancer*. 2024; 204:114074. DOI: 10.1016/j.ejca.2024.114074
4. Bianconi F, Masanotti GM, Liso A, La Rosa F, Duca E, Stracci F. Seasonal variation in skin cancer diagnosis. *Front. Public Health*. 2016; 4:78. DOI:10.3389/fpubh.2016.00078
5. Samia AM, Nenow J. Seasonal variation in the diagnosis of skin cancers from 1983 to 2017 in Greenville, North Carolina. *Cureus*. 2022;14(3): e23254. DOI:10.7759/cureus.23254
6. Wu S, Han J, Vleugels RA, et al. Cumulative ultraviolet radiation flux in adulthood and risk of incident skin cancers in women. *Br. J. Cancer*. 2014;110(7):1855-1861. DOI:10.1038/bjc.2014.4.3
7. Singh S, Sharma A, Mahajan VK. Seasonal variation in diagnosis of cutaneous invasive melanoma and squamous cell carcinoma. *J. Dermatol. Dermatol. Surg*. 2022;26(2):103-109. DOI: 10.1016/j.jdds.2022.04.007

8. Rommens K, Jegou D, De Backer H, Weyler J. Seasonal variation in cutaneous melanoma incidence, link with recent UV levels: a population-based study in Belgium (2006-2011). *Melanoma Res*. 2016;26(1):89-98. DOI:10.1097/CMR.0000000000000212
9. de Vries E, Coebergh JW. Cutaneous malignant melanoma in Europe. *Eur. J. Cancer*. 2004;40(16):2355-2366. DOI: 10.1016/j.ejca.2004.06.003
10. Wang R, Chen Y, Shao X, et al. Burden of skin cancer in older adults from 1990 to 2021 and modelled projection to 2050. *JAMA Dermatol*. 2025;161(7):715-722. DOI:10.1001/jamadermatol.2025.1276
11. Olsen CM, Pandeya N, et al. Impact of the COVID-19 pandemic on keratinocyte skin-cancer treatment rates in Australia. *Med. J. Aust*. 2024;220(6):285-292. DOI:10.5694/mja2.52345
12. Environmental Health Indicators NZ. Melanoma cancer registrations in New Zealand. Massey University; 2024. Accessed October 16, 2025. https://www.ehinz.ac.nz/indicators/uv-exposure/melanoma/
13. De Pinto G, Mignozzi S, La Vecchia C, Levi F, Negri E, Santucci C. Global trends in cutaneous malignant melanoma incidence and mortality. *Melanoma Res*. 2024;34(3):265-275. DOI: 10.1097/CMR.0000000000000959
14. Weller RB, Gu J. Ultraviolet radiation is not the major cause of melanoma mortality in the UK and sun exposure advice should be revised, *Br. J. Dermatol*, 2025 Mar; 192(3):548–550. DOI: 10.1093/bjd/ljae426
15. Watson TPG, Tong M, Bailie J, et al. Relationship between climate change and skin cancer. *Public Health*. 2024; 227:243-249. DOI: 10.1016/j.puhe.2023.12.003
16. Pellegrini C, Mattei A, Martorelli C, et al. The COVID-19 pandemic and its impact on skin cancer diagnosis and management. *J. Eur. Acad. Dermatol. Venereol*. 2021;35(5): e297-e299. DOI:10.1111/jdv.17159
17. Asai Y, Nguyen P, Hanna TP. Impact of the COVID-19 pandemic on skin cancer diagnosis: a population-based study. *PLoS One*. 2021;16(3): e0248492. DOI: 10.1371/journal.pone.0248492
18. Gurney J, Sarfati D, Dennett E, Koea J. The impact of the COVID-19 pandemic on cancer diagnosis and service access in New Zealand – a country pursuing COVID-19 elimination. *J. Cancer Policy*. 2021; 28:100282. DOI: 10.1016/j.jcpo.2021.100282
19. Wang H, Zhao Y, Zhang M, Chen R. Climate change and cancer: global environmental determinants of incidence. *PLOS Clim*. 2024;3(7): e0000362. DOI: 10.1371/journal.pclm.0000362
20. Tang X, Yang T, Yu D, Xiong H, Zhang S. Current insights and future perspectives of ultraviolet radiation (UV) exposure: friends and foes to the skin and beyond the skin. *Environ Int*. 2024; 185:108535. DOI: 10.1016/j.envint.2024.108535
21. Sánchez-García C, Rivas-Ruiz F, Ruiz-de-Casa A. Cumulative ultraviolet radiation and skin cancer risk: a systematic review. *Photodermatol. Photoimmunol. Photomed*. 2021;37(4): 297-309. DOI:10.1111/phpp.12656
22. Dika E, Scarfì F, Ferracin M, Broseghini E, Marcelli E, Bortolani B, Campione E, Riefolo M, Ricci C, Lambertini M. Basal Cell Carcinoma: A Comprehensive Review. *Int. J. Mol. Sci*. 2020 Aug 4;21(15):5572. DOI: 10.3390/ijms21155572