

## SPATIAL AND TEMPORAL MODELING OF INDIVIDUALS LIFE TIME EXPOSURE TO ULTRAVIOLET B RADIATION

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### BACKGROUND

Several studies have indicated that the development of Multiple Sclerosis (MS) is directly correlated to Ultraviolet B radiation (UVB) exposure. It is widely hypothesized that reduced Vitamin D exposure – especially during the first fifteen years of life may be associated with a higher risk of MS. Early papers reported that the frequency of MS was greater between 45 and 64 degrees latitude – than at lower latitudes (Kurtzke 1977). These reports were organized geographically by Kurtzke (1980) in a map that revealed bands of higher prevalence in Northern and Central Europe as well as North America and parts of Southern New Zealand and Australia (John F. Kurtzke 1980). There are two main shortcomings with the latitude correlation. First, the use of single latitude for assignment of UV-B exposure disregards the role of life history, and particularly the role of UV-B exposure at key points in patient history (Hammond, English et al. 2000; van der Mei, Ponsonby et al. 2003; Alberto Ascherio 2007; Sloka, Pryse-Phillips et al. 2008; Beretich and Beretich 2009). It also fails to account for the increasing mobility of western populations (Beretich and Beretich 2009). Second, latitude correlations do not measure actual UV-B exposure. Notable exceptions include recent use of satellite data to determine average UV-B exposure at latitude (Sloka, Pryse-Phillips et al. 2008; Beretich and Beretich 2009). Ebers (2009) called for calculation of actual UV exposure (Ebers 2009).

Static flow maps are useful in depicting movement over space and time and are often used to show the migration of people or animals, in transportation planning, and more recently, for GPS tracking. Techniques used with static flow applications include flow vector, flow density and OD matrices maps (Tobler 1987; Rae 2009; Jo Wood, Jason Dykes et al. 2010). The large amount of geospatial data available within the computer era brings with it new challenges related to visualization. A good map visualizes data so as to minimize clutter and allow clear interpretation; however large volumes of data make this task more difficult. A common solution to this issue involves aggregating the data in such a way that general trends in movement are preserved. Various aggregation techniques can be used for this purpose, including aggregating trajectories with the same location or attributes. In addition, several techniques exist to enable the visualization of large numbers of trajectories at the individual level. This paper builds upon these techniques to describe a method for visualizing the spatially and temporally varied lifetime trajectories of thousands of MS patients of Caucasian descent.

### OBJECTIVES

Although the depiction of individual patient movements from birth to final place of residence was the primary goal of this research, the accumulative UV exposure for each patient at each place of residence was also captured. There were several challenges involved in mapping and visualizing the large spatial and temporal data sets utilized within this study. First, the large amount of data required additional computer processing time, thereby reducing the options for data visualization and manipulation. Second, grouping by common attribute was not possible due to the dynamic and independent nature of the patient data, making data management and visualization much more complex. As a result, the spatial and temporal components of each year's calculation of cumulative UV exposure had to be tightly linked at the individual patient level. Finally, the use of a static map limited the space available to visualize both the spatial and the temporal dimensions of the data. The fact that there were few common attributes amongst the trajectories made this even more pronounced, as it prevented the aggregation of much of the data.

### METHODS

#### *Data*

The UV data was obtained using the NASA Total Ozone Mapping Spectrometer (TOMS) data set. TOMS data consists of several data sets collected by NASA satellites during the period 1979 to 2005 (excluding 1994-95). This study will use TOMS' Eurythmical UV data as it provides a record of UV values reflected from the earth's surface. The raw data is collected and recorded daily and covers the world's surface with 180 cells longitude, 288 cells latitude and a cell dimension of 1X1.25. The TOMS data UV values consist of 3 digit values which need to be converted in order to obtain the actual UV value for each location. As

the TOMS data does not provide UV values for all locations within the study, a value of 999 (e.g. missing data) has been assigned to these areas.

The final patient data set was comprised of 3311 patients and close to 12500 individual trajectories encompassing movements from place of origin to final residence. The trajectory for each patient will typically include several moves, with a final residence of BC, Canada. Table 1 shows the table after the accumulative UV exposure and age was calculated.

In order to prepare the study data for analysis, a UV value was assigned to each year of each patient's life. This was done by first identifying and geocoding each unique location within the patient movement dataset and then assigning a UV value to each unique location on each of the earth surfaces created from the satellite data. In years where no satellite data was available, an average surface was created from which to extract the UV data. The result was a UV reference table providing a UV value for each unique location and each year included in the study. The reference table was used to assign the correct UV value to the patient movement table based on time and location. In order to be able to tightly link individual patients and their individual moves to their corresponding accumulative UV exposure levels and age, a unique identifier was created for each patient and each movement.

ID	MOVE_SEQUENCE	YEAR	City	Prov	Country	BirthPlace	Age	UVMove	CumUV
2	1	1945	VANCOUVER	BRITISH COLUMBIA	CANADA	Y	23	1986	1986
2	2	1968	TORONTO	ONTARIO	CANADA	N	24	110	2096
2	3	1969	VANCOUVER	BRITISH COLUMBIA	CANADA	N	35	946	3042
2	4	1980	PARIS		FRANCE	N	36	69	3111
2	5	1981	VANCOUVER	BRITISH COLUMBIA	CANADA	N	60	2067	5178

Table 1. Shows the patient table with calculated age and cumulative UV (red columns).

## VISUALIZATION

In order to visualize the data, a series of 3D curved trajectories was created over a 2d surface plane of the world. ArcScene was used to visualize this data. An average UV surface was created from the NASA TOMS dataset to serve as the 2D plane surface over which the 3D trajectories were displayed. The surface was overlaid with a top layer containing world continents and countries. Using 3D trajectories helped to overcome the problem of shorter and longer trajectories occluding on the same space, as the height difference was used to differentiate the starting point. Patient age and total cumulative UV exposure, were also assigned for each location using the unique identifier assigned to each patient movement. For example, the birthplace of a patient who did not move in the first 20 years of life was assigned an attribute of 20 for age and an accumulative UV exposure of 20 years. This was done in order to show gradual increases in accumulative UV as the patient aged. Line and point data with different heights and colors were used to visualize gradual increases in accumulative UV exposure with age.

### Creating 3D Trajectories

Using ESRI ArcGIS, 3D trajectories were created by first creating straight lines between the origin and destination of each patient move (shapefiles). One hundred evenly spaced points were then created along each line, regardless of the length. This was done in order to limit the number of points that would be created. After converting the shapefiles to ASCII type files, each point was assigned a height(Z) value, using a Log formula in which the origin and destination points received a zero value (i.e. no height) and the remaining points were given gradually increasing heights so as to create a smooth curve. The points were then rejoined to create the 3D trajectory line (Fig 1).

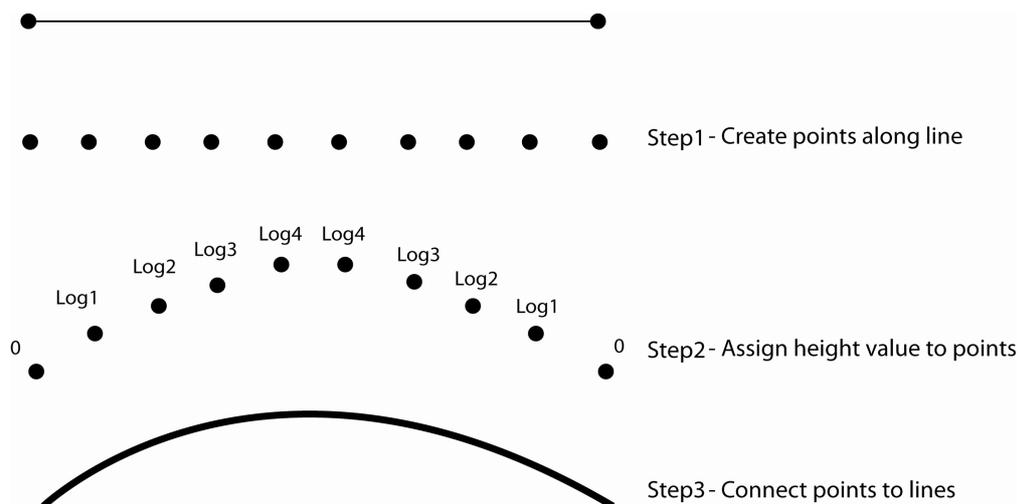


Figure1. Shows conversion of straight line to 3D Arc. Assigning a log formula value to each point allowed for the creation of a smooth curve.

Visualizing cumulative UV

Visualizing the age-related increase in accumulative UV required two steps: the first, involved the creation of vertical lines from each point of origin and destination. In creating these lines, the patient’s age at each location was used as a height value. The second step, required the creation of a point, representing accumulative UV level, at the top of each line. A graduated color scheme was used to symbolize these points. The color was based on the accumulative UV exposure at each specific location and age.(Fig 2).

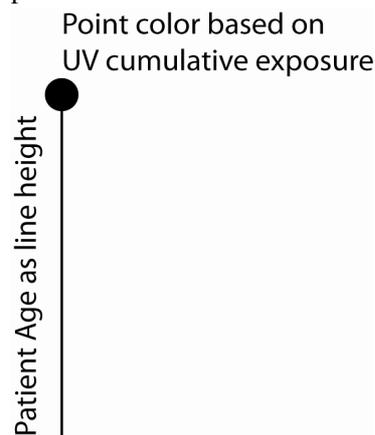


Figure 2. Represents age and cumulative UV exposure at each patient’s place of residence by assigning the height value as the patient age for both the vertical line and the point and the accumulative exposure as the color value.

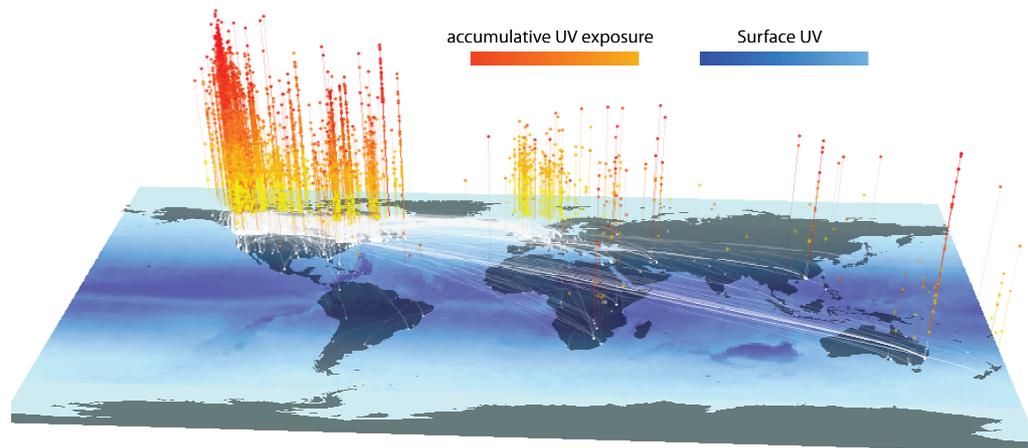
**RESULTS**

The final map (Figure 3) shows a concentration of trajectories in BC, Canada and into North America in general. The map also shows a distinct migratory trend from Europe to North America. While the global trend is quite visible, trends in migration within North America are masked by the large number of trajectories therein. However, local movements in areas of lesser concentration (e.g. South America and Africa) are more easily viewed. Visualization of the accumulative UV exposure with age provides insight into the temporal and spatial variability within the data. The large concentrations of vertical lines in Western Canada and the US indicate the spatial distribution of patients across the continent (i.e. patients are concentrated in BC). The gradual change in color from yellow to red as line height (age) increases shows clearly that accumulative UV increase with age. It also shows a concentration of patients within BC (red dots), the province of final residence for the patients. In addition, the concentration of yellow dots within North America, and to a certain extent, within Europe, indicates that most of the patients were born in one of these two continents (as they were of Caucasian decent). To determine whether critical information was lost as a result of adding the 3D temporal component to the map, a simplified map, with trajectories color coded from yellow(low UV levels) to red (high UV levels) was created (Fig 4). This map provided additional data regarding patient movement from Northern to Western Canada. This information was lost in the original map as it was masked by the 3D temporal data. The simplified map however, did

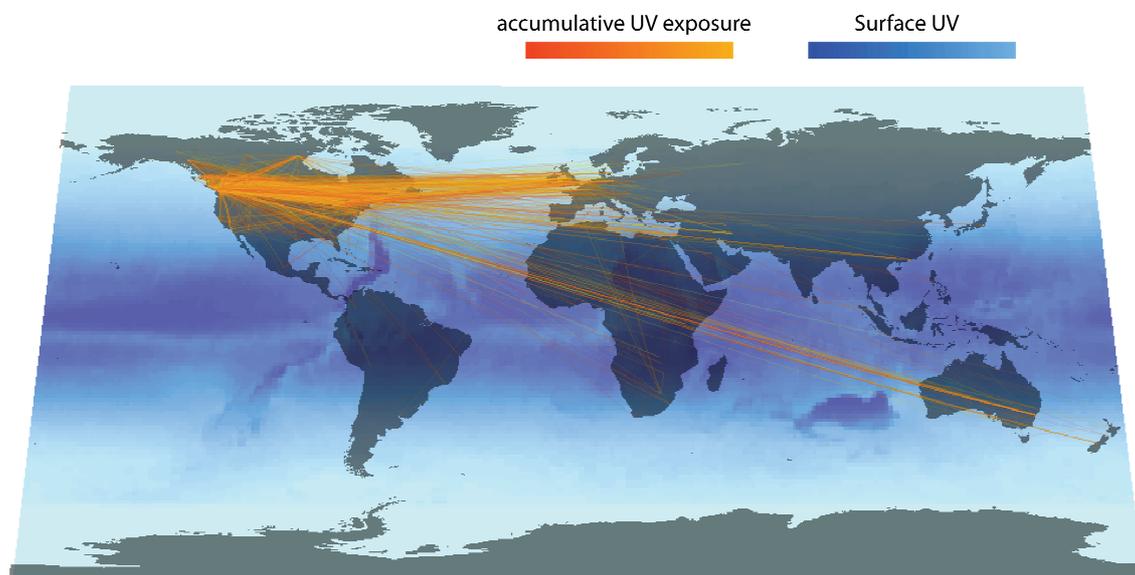
not preserve any relationships between age and increase UV accumulation. The loss of these relationships and any general trends within the data occurred because of the large number of different colored trajectories occluding on the same map space.

### CONCLUSION

The map presented in this paper enables visualization of large amounts of movement data characterized by high degrees of spatial and temporal variation. By using age to represent the height of vertical lines and a graduated color scheme to depict accumulative UV levels, temporal and spatial aspects of the data were clearly shown. The key for that was the separation between the visualization of temporal and spatial data. However, inclusion of temporal data caused some of the spatial information to be lost.



*Figure 3. Shows the final map. Adding vertical lines representing the increase in accumulative UV exposure with age provides additional insight into temporal and spatial trends within the data.*



*Figure 4. shows the simplified map with trajectories color coded by level of UV exposure. The map also shows patient movements from Northern Canada to BC. This information was masked by the vertical lines showing the increase in UV exposure with age.*

### FUTURE PLAN

Future goals include the creation of an animated map showing both patient movements and changes in cumulative UV exposure. As the study covers a large spatial area, the animation will be implemented on a continental rather than a global scale. Various visualization techniques, such as the dynamic hiding/revealing of icons at different scales and angles, will be utilized in order to more clearly show local and global patterns within the patient data.

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