

Grey Literature Review: Internet Published Cancer Maps

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Executive Summary

The following report outlines the results of a grey literature review that investigated cancer atlases published on the internet and publically available between 01/01/2010 and 01/05/2016. The review identified 33 cancer maps meeting that criteria.

The maps identified came from all over the world, and covered a range of geographies and resolutions from global, to national or state maps. The smallest area within these maps varied significantly and ranged from entire countries to states, counties and smaller area estimates. Publishers of these cancer maps were predominantly non-for-profit organisations who often generated and published them in partnership with another research or government organisation.

The type of measures included in the identified maps were an informative aspect of the review, as we found large variation across the different maps. Age standardised incidence rates per 100,000 population was the most commonly reported measure for cancer incidence (n=21). Cancer counts, standardised incidence ratios and relative excess risk were also used (n=4, n= 3, n=2, respectively). For mortality, age standardised death rates per 100,000 (n=8), death counts (n=3), mortality ratios (n=2) and relative excess risk (n=2) were used. Many of the maps used more than one measure, for example reporting crude counts was often accompanied by a measure of age standardised rates. Although spatial smoothing has an inherently appealing purpose for maps, it was not widely utilised, and among those that did, (n=4), three used the BYM (Besag, York and Mollié) model.

The interactive capabilities of the cancer maps ranged from static documents or infographics (n=10), to interactive web interfaces (n=23). The sophistication of the identified maps notably increased over time of initial publication. The visualisation platforms and technologies used to render and publish maps with interactive capabilities included InstantAtlas (n=7), Environmental Systems Research Institute (ESRI) based products (n=2), custom built (n=10), and d3.js + leaflet (n=1) which was identified as an emerging and increasingly popular visualisation tool.

Almost half the cancer atlases (45%, n=15) included some sort of uncertainty measure within or alongside the map. Most commonly the uncertainty used was error bars or confidence/credible intervals (n=10). Boxplots (n=3), indicating statistical significance (n=2) or noting areas of small sample size (n=2) were also reported in a small number of maps and some maps reported more than one type of measure.

Overall, the review provides a detailed overview of the current landscape and practices used to generate publically available cancer atlases. It is hoped that this review will provide a valuable resource and inspiration to guide the design of the Australian National Cancer Atlas.

Please see the accompanying excel file for details on all atlases identified in this review.

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List of Abbreviations

AUS	Australia
BYM	Besag, York and Mollié
CAN	Canada
CAR	Conditional Autoregressive
CI	Confidence interval
DSR	Directly Standardised Rate
EC	European Commission,
ESRI	Environmental Systems Research Institute
EU	European Union
GIS	Geographic Information System
NFP	Not-for-profit
NCI	National Cancer Institute
NIH	National Institute of Health
NRW	North Rhine-Westphalia
SIR	Standardised Incidence Ratio
SMR	Standardised Mortality Ratio
UK	United Kingdom
US	United States

1. Introduction

Maps are effective and powerful tools for communicating geographical variation in health and disease. They enable non-expert decision-makers to visualise the data and access the outputs of often sophisticated geospatial statistical analyses. Both the statistical methods and visualisation techniques used to generate these maps are highly varied, with differences depending on the disease being mapped, the intended message or audience and the person or organisation publishing the material.

Improvements in statistical methods, data visualisation and geographical information system (GIS) techniques, as well as interactive web technologies, has enabled health and disease maps to increase in popularity and utility. Disease and health maps are now commonly used by governments, not-for-profit organisations, and research institutions to enable the use of statistical outputs in decision making, and raise community awareness around target issues. Depending on the data and technology used to generate the maps, their interactive capabilities range from simple downloadable pdf documents to dynamic and interactive web interfaces.

Cancer maps are commonly published on the internet rather than in academic peer-reviewed journals, due to their powerful use as a communication tool for non-academic audiences. Therefore, in order to provide an overview of the current practices used to generate these cancer maps, we conducted a grey literature review of cancer atlases published on the internet and available between 01/01/2010 and 01/05/2016. While many of the themes and issues are applicable to the wider field of disease mapping this report focuses exclusively on cancer mapping.

2. Methods

Research Question: What cancer maps are currently available to the public via the internet, and what methodologies and technologies have been used to generate them?

Aim: To summarise the cancer atlases available publicly on the internet in terms of: geography covered, publishing organisation, data date range & publication date, resolution, reported measure, statistical methods, inclusion of uncertainty, interactivity features and additional functionality, technology platform used, and smoothing methods.

2.1 Search Description

The Google search engine was used for all searches, and no other search engines were explored for this study. The search was conducted between October 2015 and January 2016, and then updated in May 2016. Searches were restricted to pages with publication dates between 01/01/2010 to 01/05/2016. Only English search terms were used, however atlases that were identified in the searches but are not published in English were still recorded and data extracted where possible. Searches were not restricted by country, and were conducted from Australia.

The following list details the final search strings. These strings were developed through an iterative process of trialling and refining searches until the desired specificity was reached. See Appendix A for a full description of the search protocol and Appendix B for details of the trialled search strings and their associated hits.

Within these search strings, we used the context-specific terms of “allintitle” (which requires all the search terms to be in the title) and “intitle” (which requires only the first search term to be in the title and the rest anywhere in the document). hits containing in their title campus, kinase, kinases and concept were excluded. Kinase and kinases refer to a protein enzymes often the focus of research when investigating the biology of cancer.

1. intitle: spatial AND epidemiology AND cancer AND map OR mapping OR atlas - campus
2. allintitle: cancer AND map OR mapping OR atlas -campus -kinase -kinases -concept
3. allintitle: spatial AND cancer AND statistics
4. allintitle: spatial OR geographic AND cancer AND variation OR distribution
5. allintitle: spatial AND epidemiology AND cancer AND map OR mapping OR atlas - campus
6. intitle: cancer AND atlas

Pages were selected for data extraction if they met the following criteria:

- contained a visual geographical map of cancer incidence, risk, mortality or counts (either pdf, static image or interactive web interface).
- accessible without a password or log in.

- published or updated on or after the 1st of January 2010.

A full search protocol can be found in Appendix A.

3. Summary Findings

Grey literature searches identified 33 Cancer Atlases which were publicly available on the internet, published between 1/1/2010 and 01/05/2016, which met the eligibility criteria defined in Chapter 2. Three of the identified atlases were not published in English, however the details of these maps were extracted where they could be determined. A database detailing all identified atlases is provided as a supplement to this report.

3.1 Geographical Coverage

Identified cancer atlases covered geographies from all around the world: 4 were global, 3 from Australia (AUS), 11 from the United States (US), 2 from Canada (CAN), 7 from the United Kingdom (UK), 2 from Spain, 1 from Switzerland, 1 from Germany, 1 from Norway, and 1 covering the European Union. Not all maps had a national focus and 10 covered a region or state rather than an entire nation. The states covered were Pennsylvania (US), New Hampshire (US), Cape Cod (US), Missouri (US), South Australia (AUS), Queensland (AUS), Ontario (CAN), Valencia (Spain), Florida (US), New York State (US) and Arizona (US).

3.2 Publishers

The majority of atlases were published by non-commercial organisations, including not-for-profits (NFPs), government, research organisations, advocacy groups or a partnership between an NFP & government. Only one map was published by a commercial entity, in this case a media organisation.

3.3 Reported Measures

The majority of maps identified reported age adjusted rates of either incidence, mortality or both. A few reported survival measures. Table 3.1 shows the different reported measures and how often they were used. Many maps reported more than one measure therefore the '*Number of publications*' does not add to 33.

Table 3.1: Different reported measures used in cancer atlases

Type of report measure	Number of publications
Incidence	Total – 27
Counts (cancer cases)	5
% of cases in population	1
Crude incidence rates per 100,000	2 *
Directly age standardised incidence rates (DSR) per 100,000 or SIR (Standardised Incidence Ratio)	24
Projected cancer incidence DSR per 100,000 (2020 – 2030)	1
Relative risk (Smoothed SIRs)	3
Mortality	Total - 14
Counts (number of deaths)	3
Crude mortality rates per 100,000	1
Directly age standardised death rates (DSR) per 100,000 or standardised mortality rate (SMR)	8
Relative Mortality Rate or Mortality Ratio	2
Mortality Probability (Excess Risk) *	1
Survival	Total - 6
Age adjusted survival rates (defined as the percentage of people still alive after one year, three years and five years, following a diagnosis of cancer.)	3
Smoothed RER (Relative Excess Risk)	2
Age Adjusted % of people still alive after 1, 3, or 5 yrs.	1
Other	Total - 2
Relative Risk Standard Deviation (RRSD)	1
Prevalence **	1

*Reported alongside the age adjusted rates.

**Further details of the methods used to generate this measure could not be found.

3.4 Number of Geographical Areas

Table 3.2 shows the number of geographical areas reported within each map, and where possible, the total population. The number of geographical areas mapped ranged from 10 to over 3,000.

Table 3.2: Geographical resolution of cancer atlases

Atlas Title	Total area mapped	No. of areas in map	Total Map population* (in year)
All Ireland Cancer Atlas 1995- 2007	National (Northern Ireland + Republic of Ireland)	3,500 (Electoral Divisions)	~ 6.15 million
Breast Cancer Mortality in Canada	National (CAN)	Could not be determined	~ 38 million
Globocan 2012: Estimated Cancer Incidence, Mortality and Prevalence	Global	>100	~ 7,080 million
The Cancer Atlas	Global	>100	~ 7, 080 million
Global Cancer Map	Global	>100	~ 7, 080 million
Spatio-temporal atlas of mortality in Comunitat Valenciana	State (Valencia, Spain)	>50	~ 0.80 million
United States Cancer Statistics: An Interactive Cancer Statistics Website	National (US)	50	~ 314.1 million (2012)
MapNH Health (Projected)	State (New Hampshire, US)	23 (health services area)	n/a
Pennsylvania Cancer Atlas	State (Pennsylvania, US)	63	~ 12.7 million (2011)
NCI Geoviewer NIH GIS Resources for Cancer Research	National (US)	3,141	~ 314.1 million (2012)
Longer Lives Healthier Lives	National (England)	>150	~ 53.5 million
Lung Cancer Map - Global Lung Cancer Coalition	Global	>100	~ 7, 080 million (2012)
Environmental Facilities and Cancer Mapping	State (New York, US)	30 - 40	~ 19.31 million (2009)
An Atlas of Cancer in South Australia	State (South Australia, AUS)	117	~ 1.65 million (2009)
Bowel Cancer Australia Atlas	National (AUS)	565	~ 23.13 million (2013)
Epidemiologisches krebregister Nordrhein-Westfalen	State (NRW, Germany)	>40	
Helseatlas - Dagkirurgi, 2011 - 2013 (Skulderkirurgi)	National (Norway)	18	
Cancer Incidence in Switzerland	National (Switzerland)	10	~ 8 million (2012)
Age Adjusted Invasive Cancer Incidence Rate: All Sites: 2011 (experimental dashboard)	State (Missouri)	>100	~ 6 million (2011)
CINA+ Online Cancer in North America	National (US)	58	~ 314.1 million (2014)
The Environment and Health Atlas of England and Wales	National (England & Wales)	>1,500	~ 56.6 million (2014)
UK Cancer e-atlas NCIN	National (UK)	~175	~ 63.26 million (2011)
Map of Cancer Mortality Rates in Spain	National (Spain)	Could not be determined	~ 46.16 million (2008)
The Florida Prostate Cancer Atlas	State (Florida, US)	67	~ 18.17 million (2007)
Atlas of Cancer in Queensland	State (Queensland, AUS)	478	~ 4.43 million (2008)
Atlas of Childhood Cancer in Ontario	State (Ontario, US)	60	
Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997	European Union	1,278 - level II of the EC statistical services.**	~ 450 million (1997)
National Cancer Registry of Ireland - Cancer Atlas	National (Ireland)	~26 (UK counties)	~ 4.6 million (2012)

Geographic Variation in Primary Liver and Gallbladder Cancer	National (UK)	~25	~ 60.25 million (2006)
Cancer Atlases of UK and Ireland	National (UK & Ireland)	>50 (UK counties)	~ 64.7 million (2000)
Cancer Mortality Maps (US)	National (US)	3,144 (US counties)	~ 263.1 million (1994)
Cape Cod Breast Cancer Atlas	State (Cape Cod, US)	>50 (Census blocks)	

Abbreviations: AUS=Australia, CAN=Canada, EC= European Commission, NRW=North Rhine-Westphalia, popns=populations, UK=United Kingdom, US=United States

* Area populations obtained from <http://healthierlives.phe.org.uk/topic/mortality/comparisons#are//par/E92000001/ati/102/pat/102>
<http://healthierlives.phe.org.uk/topic/mortality/comparisons#are//par/E92000001/ati/102/pat/102>

<https://www.census.gov/quickfacts/map/PST045215/33011,33003,2300> <https://www.census.gov/quickfacts/map/PST045215/33011,33003,2300>

** Areas conform to level II of the European Commission (EC) statistical services, with finer subdivision where population numbers are sufficient enough. 47 of the 1,278 areas have less than a population of 100,000.

3.5 Smoothing

Of the atlases identified, only four reported spatial smoothing and one used temporal smoothing (that is, smoothing by calendar year, but no spatial smoothing), 22 did not use any form of smoothing within their methods, and seven had insufficient information available to determine whether smoothing was used. Of the cancer atlases with smoothing models, three used the BYM (Besag, York and Mollié) model (Table 3.3). This model incorporates a spatially structured component, commonly incorporating adjacent areas using a conditional autoregressive (CAR) prior, as well as an unstructured component. Further details on these methods can be seen in the associated report: *Spatial Modelling Methods*.

Table 3.3: Spatial smoothing methods

Cancer map	Smoothing	Reference
<i>The Environment and Health Atlas of England and Wales</i> http://www.envhealthatlas.co.uk/eha/Breast/	BYM	Besag et al. (1991)
<i>All Ireland Cancer Atlas 1995- 2007</i> http://www.ncri.ie/publications/cancer-atlases	BYM	Besag et al. (1991)
<i>Atlas of Cancer in Queensland</i> https://cancerqld.org.au/research/queensland-cancer-statistics/queensland-cancer-atlas/	BYM (incidence) Poisson piecewise with BYM components (survival)	Besag et al. (1991) Fairley et al. (2008)
<i>Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997</i> http://www.iarc.fr/en/publications/pdfs-online/epi/sp159/AtlasCancerMortalityEU-10.pdf	<i>Examined regional variation by:</i> 1. Poisson-gamma model (one unstructured random effect, no spatial structure) 2. Multilevel model with 3 geographic hierarchies (again, no spatial structure was included)	Pennello et al. (1999) Similar to Langford et al. (1999)

4. Visualisation Methods

There are a range of methods and approaches used to visualise and publish the generated cancer maps on the internet making them accessible to a public audience. Visualisation platforms are rapidly changing as GIS technologies, graphic design tools, and interactive web capabilities continue to develop. These changes are giving rise to mapping and design tools that can generate customised and interactive web based maps. The skills required to generate sophisticated and professional outputs using these emerging platforms and tools vary.

The development of tools and technologies for generating visual cancer and disease maps has progressed rapidly. Even in the six year period that this grey literature review covers, the visualisation approaches used have evolved. Early maps are predominantly static pdfs or non-interactive infographics while products have slowly grown in design aesthetics and interactive capabilities. It is very common in the most recently published maps to have fully interactive web interfaces where users can select features such as the population sample, geographical resolution, cancer of interest, as well as other outcome measures.

The section below provides a brief overview of the technology platforms used to generate the maps identified in this review, and briefly introduces some emerging technologies for developing both cancer and disease maps. Further discussion on these platforms, their interactive features and technical skill requirements can be found in the associated third report: *Communicating statistical outputs through maps*.

4.1 Platforms and Tools

Interactive features available through different platforms or tools range from no interactivity, such as in a static pdf or infographic, to highly interactive where the audience is given the option to customise the map by selecting features such as the population of interest, the cancer of interest, resolution, other demographic variables (e.g. race, age, socio-economic status) and/or compare multiple maps at once.

Table 4.1: Platforms used for visualising cancer maps

Technology Platform	Number of Atlases using platform	Further Details
Pdf or infographic	10	n/a
InstantAtlas	7	http://www.instantatlas.com/
Googlemaps based platform	2	n/a
ESRI ArcMap (Part of the ESRI ArcGIS Desktop suite)	2	http://www.esri.com/software/arcgis
Custom built	5	These custom built maps use a range of JavaScript libraries, mapping services and HTML5/CSS frameworks
Custom built - D3.js	2	D3.js - https://d3js.org/
Custom built - D3.js + leaflet	1	Leaflet - http://leafletjs.com/
Custom built – interface with google api	2	

Platforms or tools could be classified into three categories: 1) an infographic or downloadable pdf available on a webpage, 2) a visualisation platform customised interactive product built on an existing GIS or data visualisation platform or tool such as google maps, ESRI, or ArcMap 9.3, Instant Atlas or 3) a custom built web product using tools such as d3.js + leaflet (see Report 3 for a detailed description of d3.js and leaflet). Table 4.1 shows a breakdown of the different platforms identified within the review.

4.2 Communicating Uncertainty to Non-Expert Users

Cancer atlases were considered to report uncertainty if they included a measure of uncertainty either within or alongside the map. Maps that only reported uncertainty within the supplementary material were not included, as these were not considered to be attempts to communicate with a non-expert audience.

Close to half of the atlases identified (45%, n=15) included some measure of uncertainty. The dominant measure was the inclusion of credible or confidence intervals (CIs). CIs were either visualised by including their bounds in a supplementary graph of estimates vs regions, or reported numerically through CI upper and lower bounds noted in a data table or appearing through a tool tip function (n = 10). Additional methods of including uncertainty were: boxplots, distributions, reporting statistical significance of the difference between subregions and the overall map, an indication of regions where observations or populations were below a defined limit, and a highly novel measure of relative risk standard deviation (seen only in one map).

Table 4.2 shows the uncertainty measures used and a sample of thumbnails show the range of visualisation design approaches. Uncertainty communication methods are further discussed in Report 3.

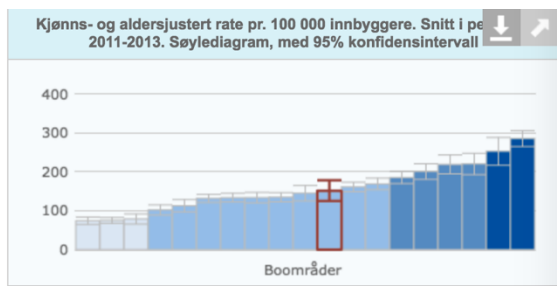
Table 4.2: Measures used to quantify and report uncertainty in cancer maps

Type of uncertainty measure	Number of atlases this appears in
Confidence or Credible Interval	10
Indication of regions with small sample or population sizes	2
Boxplots or interquartile ranges	3
Frequency distributions	1
Relative Risk Standard Deviation	1
Statistically significantly different to state average or national average	2
Bayesian methods	3

4.2.1 Confidence Intervals

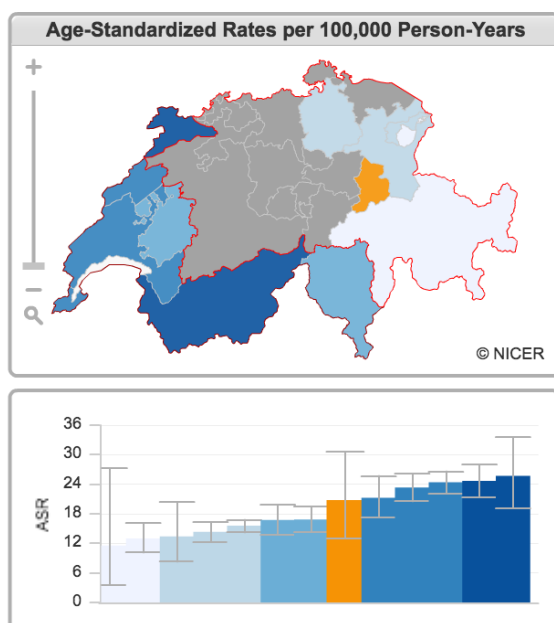
The *Norwegian Cancer Atlas* shown in Figure 4.1 and the *Cancer Incidence in Switzerland* in Figure 4.2, both include confidence intervals in a supplementary graph of estimate vs region.

Figure 4.1: Norwegian Cancer Atlas – Error Bars



URL: <http://www.helse-nord.no/helseatlas/atlas.html>
(link is no longer active.)

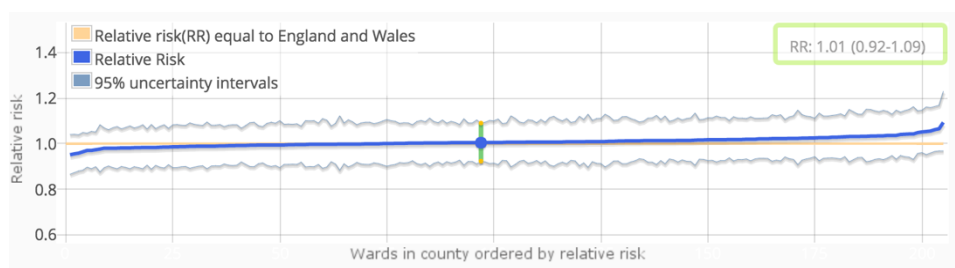
Figure 4.2: Cancer Incidence in Switzerland



URL: <http://www.nicer.org/NicerReportFiles2015-2/EN/report/atlas.html?&geog=0>

The *Environmental Health Atlas of the UK*, shown in Figure 4.3, shows a slight variant in design, with the confidence intervals shown as bounds around the Relative Risk estimates.

Figure 4.3: Environmental Health Atlas of the UK



URL: <http://www.envhealthatlas.co.uk/eha/Breast/>

Many maps also reported the upper and lower bounds of the confidence intervals in a data table embedded within the map dashboard. Figure 4.4 shows an example from the *Pennsylvania Cancer Atlas*. A unique feature of this particular data table is its interactivity.

Each column of this table can be sorted in ascending or descending order by clicking on the column heading. Although not necessarily interpretable for a non-expert audience, this is an interesting and potentially valuable feature for a more experienced user.

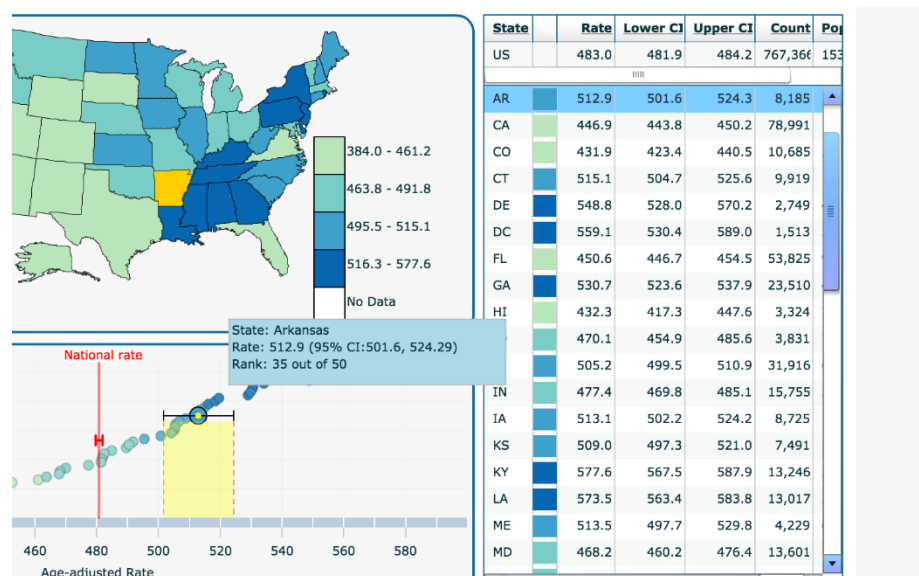
Figure 4.4: Pennsylvania Cancer Atlas

Data Table	Glossary		Further Info			
County	Rate	Lower CI	Upper CI	Count	Population	
Pike	30.6	25.5	36.6	133	392,536	
Lancaster	52.7	50.6	54.9	2,360	4,170,699	
Somerset	50.1	45.7	55	475	719,153	
Cumberland	52.7	49.7	55.9	1,131	1,905,492	
Centre	52.1	47.6	56.9	502	1,214,956	
Lehigh	55.7	53.2	58.4	1,843	2,779,260	
Chester	56.2	53.8	58.7	2,015	3,797,562	
Montgomery	57.1	55.4	58.8	4,390	6,638,731	
Bedford	52.3	46.3	58.8	287	446,092	
Erie	56.1	53.4	59	1,546	2,533,719	
Franklin	55.4	51.5	59.6	762	1,155,851	
Beaver	56.4	53.3	59.7	1,247	1,654,797	
Greene	52.5	45.8	60	225	366,432	
Columbia	54.2	48.8	60.2	373	580,126	
Bradford	54.3	48.8	60.3	363	563,934	
Fulton	47.3	36.6	60.4	68	129,490	

URL: <http://www.geovista.psu.edu/grants/CDC/>

The CDC's *United States Cancer Statistics: An Interactive Cancer Atlas* (Figure 4.5) expanded the CI visualisations shown above through the use of a tool-tip function. The tool tip function connects the map and the age-adjusted rate vs region graph. When a region of the map is selected, a visualisation of the CI appears on top of the point estimate within this graph, and in addition, a small box appears above the mouse symbol which reports the numeric CI boundaries. A unique feature of this map not found in any others is that the axis of the Rate vs Region are flipped, with the age-adjusted rate shown on the x axis. All other cancer maps show the rate on the y axis.

Figure 4.5: United States Cancer Statistics: An Interactive Cancer Atlas



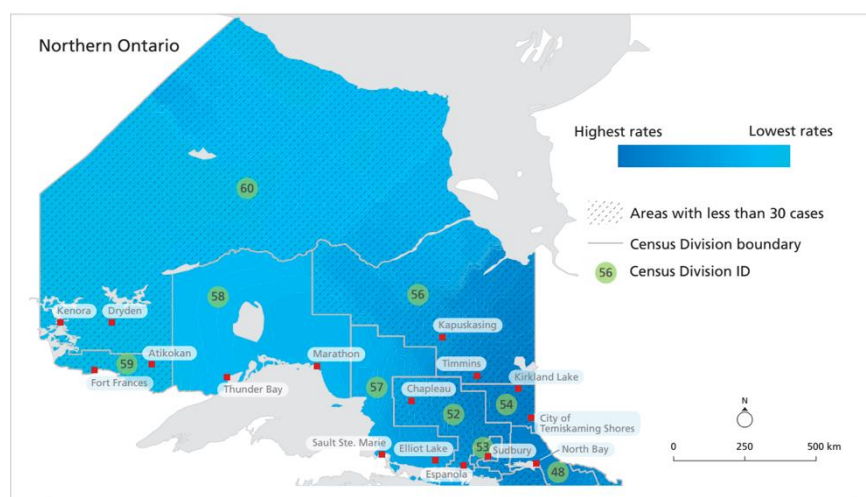
URL: https://nccd.cdc.gov/DCPC_INCA/

4.2.2 Small Sample Sizes

A small sample or small population size within a region can influence the confidence and certainty of cancer related estimates in that region. If a population in a region is small, but has a high number of cancer cases, it is difficult to determine if the high incidence is due to chance, or is a true reflection of a high cancer incidence rate within that region. The same applies for small populations that have low cancer measures.

While reporting sample or population size is not a quantified measure of uncertainty, small sample or population size can be a source of uncertainty, and can be informative as an indirect indicator of areas that should be interpreted with caution. A small number of maps (n=2), highlighted regions where observation or population sizes were small, and therefore estimates were less reliable. Figure 4.6 provides an example of one such map.

Figure 4.6: Atlas of Childhood Cancer in Ontario



URL: http://www.pogo.ca/wp-content/uploads/2015/02/POGO_CC-Atlas-3-Incidence_Feb-2015.pdf

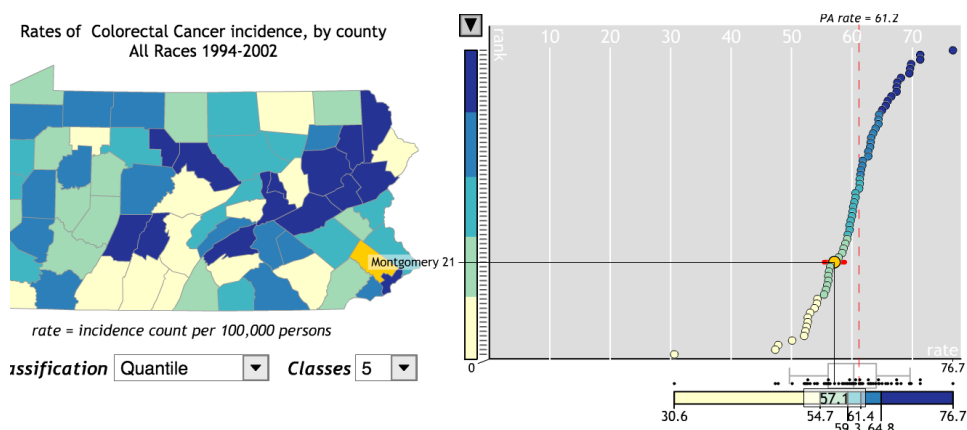
4.2.3 Boxplots

Although box plots show the spread of the total estimates, they are not a direct measure of uncertainty. However they can give an indication of the variance of the data, which is an important source of uncertainty.

Figure 4.7 shows a boxplot for the overall map used in the *Pennsylvania Cancer Atlas*, where each data point represents a region within the map. See the subtle box plot under the scatterplot (bottom right corner). This gives a summary of how closely the estimates bunch together around the median.

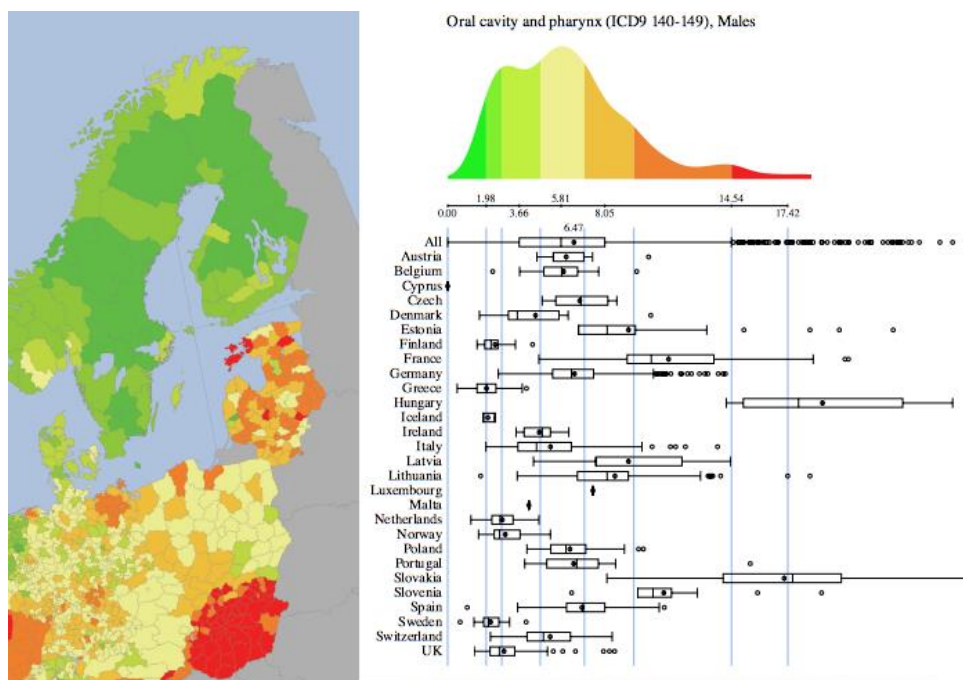
Figure 4.8 *The Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997*, shows a boxplot for each country, where each data point represents one region in that country. In this way, the collection of boxplots can inform the user when comparing between countries. The boxplots make the spread of the estimates more transparent. Again not a measure of uncertainty but an informative source of uncertainty. This is particularly appropriate for this EU map as it covers a very large geographical region and each country within that region has used data from different sources and of different quality to generate the estimates.

Figure 4.7: Pennsylvania Cancer Atlas



Insert URL: <http://www.geovista.psu.edu/grants/CDC/>

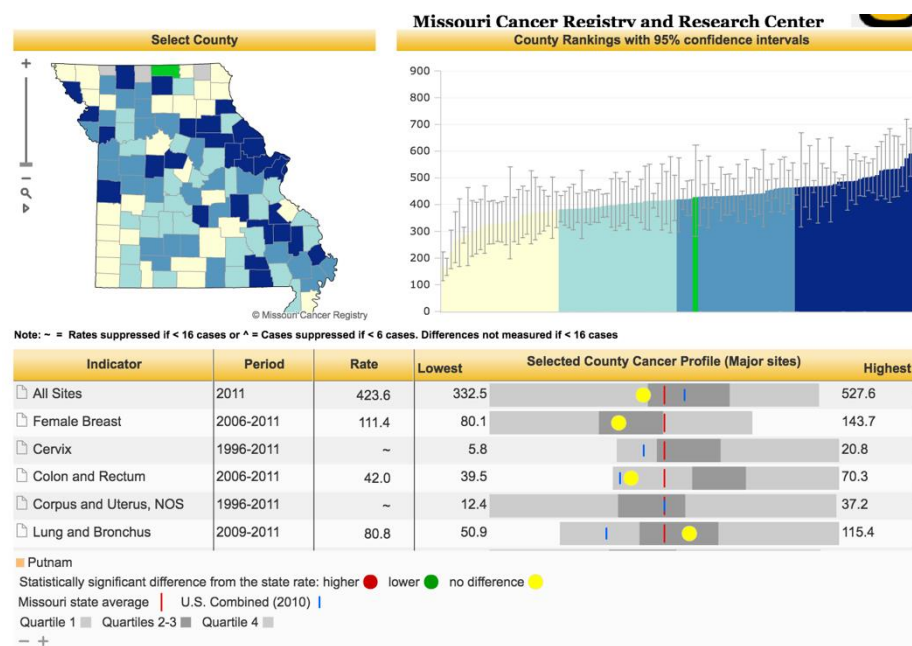
Figure 4.8: Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997



URL: <http://www.iarc.fr/en/publications/pdfs-online/epi/sp159/AtlasCancerMortalityEU-10.pdf>

Figure 4.9 shows a third example of the use of a box plot. The cancer map from the *Missouri Cancer Registry and Research Center* uses a slightly different visual design to show the interquartile ranges of the data and embeds the visualisation within the data table that accompanies the map. The column furthest to the right in the data table (bottom right quadrant of the dashboard) includes a graphic of the interquartile range of the estimates for each cancer. An interesting addition to this graphic representation of the boxplot is inclusion of simple glyphs (yellow, red or green spots) on top of the shaded boxplot which appears when the mouse hovers over a region on the map. These glyphs indicate if the incidence rate for that region is statistically significantly different to the state average.

Figure 4.9: Missouri Cancer Registry and Research Center



URL:

<http://mcriaweb.col.missouri.edu/IAS/dataviews/report?reportId=13&viewId=3&geoReportId=62&geoId=1&geoSubsetId=>

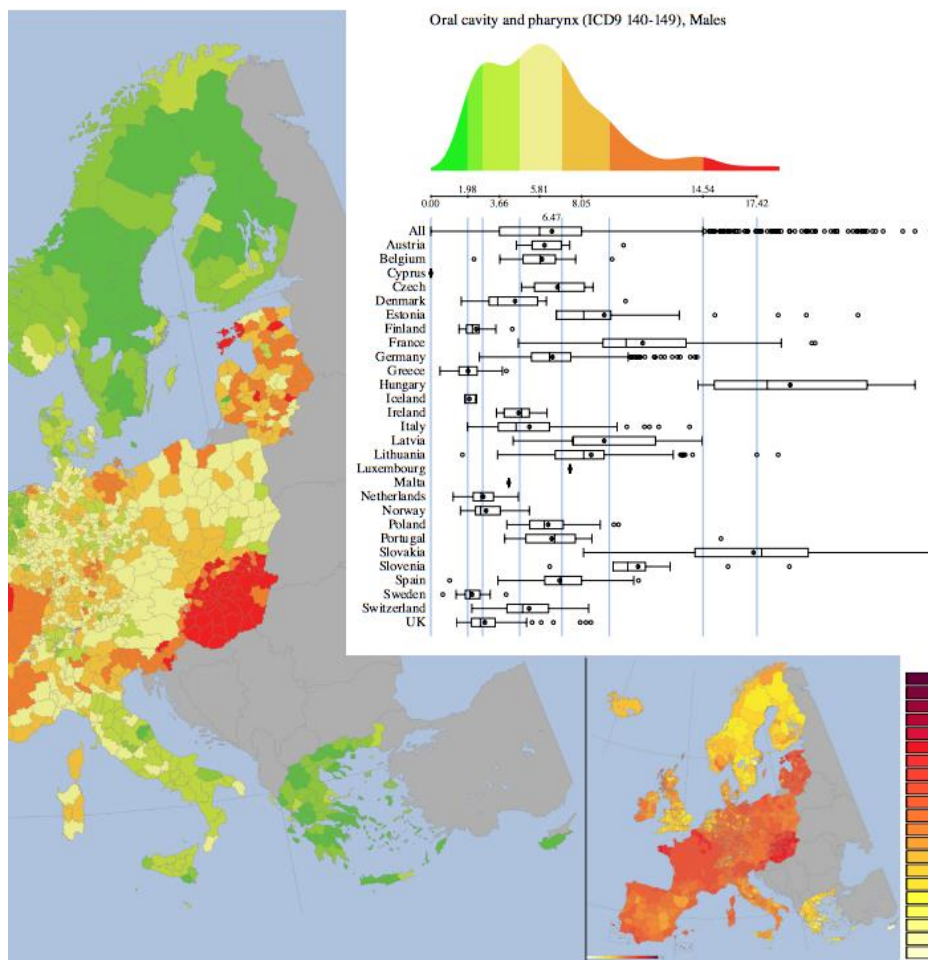
4.2.4 Relative Risk Standard Deviation

The *Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997*, seen in Figure 4.10, included a unique measure of uncertainty not seen in any other map. Additional to the main map that shows the cancer incidence rate, a bivariate map (bottom right corner) covering the same region, shows the standard deviation of the relative risk. This provides an estimate of the level of uncertainty in the relative risk within specific areas; this is similar in intent to the confidence intervals – areas with high standard deviation would also have a wider confidence interval.

4.2.5 Statistical Significance

A small number of maps (n=3) indicated when the difference between the estimate for a specific region was statistically significantly different from the overall average. Figure 4.9 shows one example of this.

Figure 4.10: Atlas of Cancer Mortality in the European Union and the European Economic Area 1993-1997



URL: <http://www.iarc.fr/en/publications/pdfs-online/epi/sp159/AtlasCancerMortalityEU-10.pdf>

5. Cancer Maps

The following section shows nine maps selected from the 33 identified in the grey literature review and briefly discusses their pros and cons (from the admittedly subjective perspective of the authors of this report). Each of the maps have been selected because they contain a design or interactive feature(s) that can provide inspiration for the design of the future National Cancer Atlas. The six InstantAtlas maps are summarized into one example, as their features and functionalities are very similar and are highly defined by the InstantAtlas platform.

Table 5.1: Cancer map examples

	Map title	Reason for selection	Programming details & skills required to build
5.1	InstantAtlas	Popular platform used by a range of organisations	InstantAtlas platform - Minimal technical skill requirements. No JavaScript, html, CSS or other programming skills required.
5.2	Pennsylvania Cancer Atlas (Built using the GeoVista Visualisation platform)	Layout design, feature for comparing two maps, fast interactivity, all dashboard products interconnected. data table is sortable.	GeoVista platform – Unknown skill requirements, further investigation of the GeoVista platform required. (final product is rendered in flash).
5.3	The Environmental Health Atlas of England and Wales	Layout design, overall feel, high density display, comparison of data products in dashboard.	Custom built using d3.js + leaflet.
5.4	CINA+ Online Cancer in North America	Interesting layout for comparison of two maps, clean design, interesting pop-ups for drilling into data, interesting area comparison functions.	Custom built using JavaScript. Built from scratch!!
5.5	NIH – GIS Resources for Cancer Research	Many capabilities for interactive customisation. Design is a little dated and clunky. Print function is a nice feature. Designed as a tool for researchers, or other stakeholders that would use a visualisation of this data, rather than for the general public.	ESRI ArcMap
5.6	MapNH Health	Projected future estimates is an interesting report measure. Nice example of changing map resolutions (State>county>small area)	Custom built using D3.js +JavaScript + GIS capabilities.
5.7	United States Cancer Statistics: An Interactive Cancer Atlas	Clean design with nice interactive features. Relatively quick to update. One of the nicest Instant Atlas examples.	InstantAtlas - Minimal technical skill requirements. No JavaScript, html, CSS or other programming skills required.
5.8	Longer Live	Interesting layout and visual design	Custom Built using JavaScript + Google maps api.
5.9	PRI: Cancer Global Footprint	Related stories in the ribbon at the very bottom of the page is a nice way to add links to related information and stories.	Custom built with JavaScript + modest maps + mapbox.

5.1 Instant Atlas Examples

URL: <http://www.instantatlas.com/>

Publisher: Varied

Reason for Selection: Popular platform used by a range of organisations

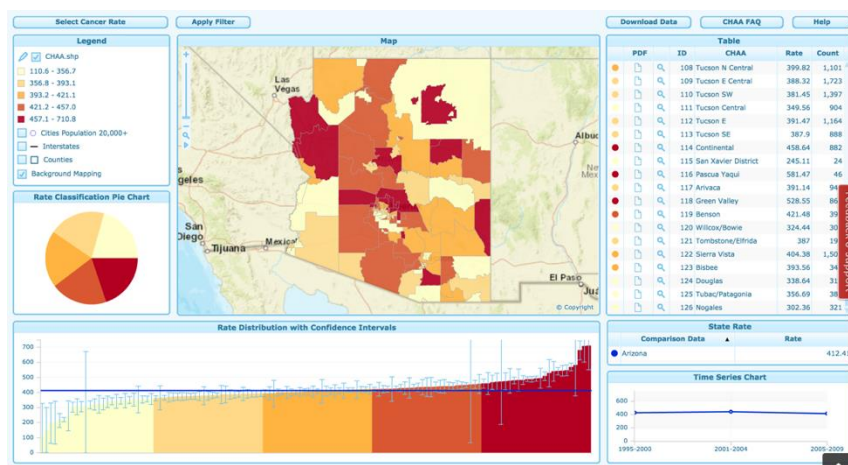
Skill level required: No JavaScript, html, CSS or other programming skills required.

InstantAtlas' Dashboard Builder enables the creation of highly interactive dashboards that includes a range of charts, tables and maps. The platform has a very low barrier to entry and no html or javascript knowledge is required. Users upload the data as a csv file, select a dashboard layout and then add the additional panels within the dashboard by choosing from a selection of widgets. Colours and legend options are also customisable.

Further info about the dashboard builder: [https://help.instantatlas.com/dashboard-builder-overview/](https://help.instantatlas.com/dashboard-builder/dashboard-builder-overview/)

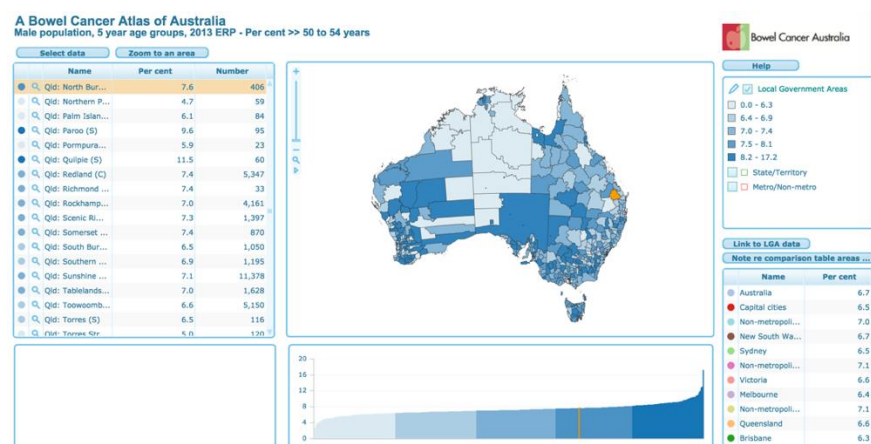
Figures 5.1 to 5.6 provide examples of cancer maps generated through the InstantAtlas platform. They clearly demonstrate the recognisable 'style' of this platform and demonstrate what can be achieved by using InstantAtlas.

Figure 5.1: Arizona Cancer Rates by Community Health Analysis Areas



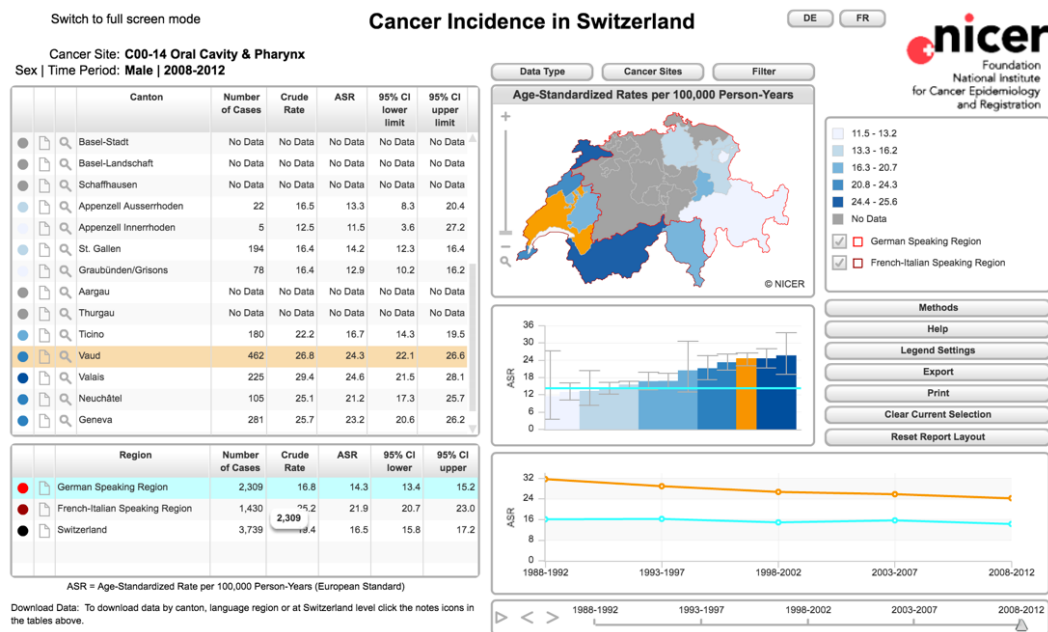
URL: <http://www.azdhs.gov/preparedness/public-health-statistics/cancer-registry/chaa/index.php>

Figure 5.2: Bowel Cancer Atlas of Australia



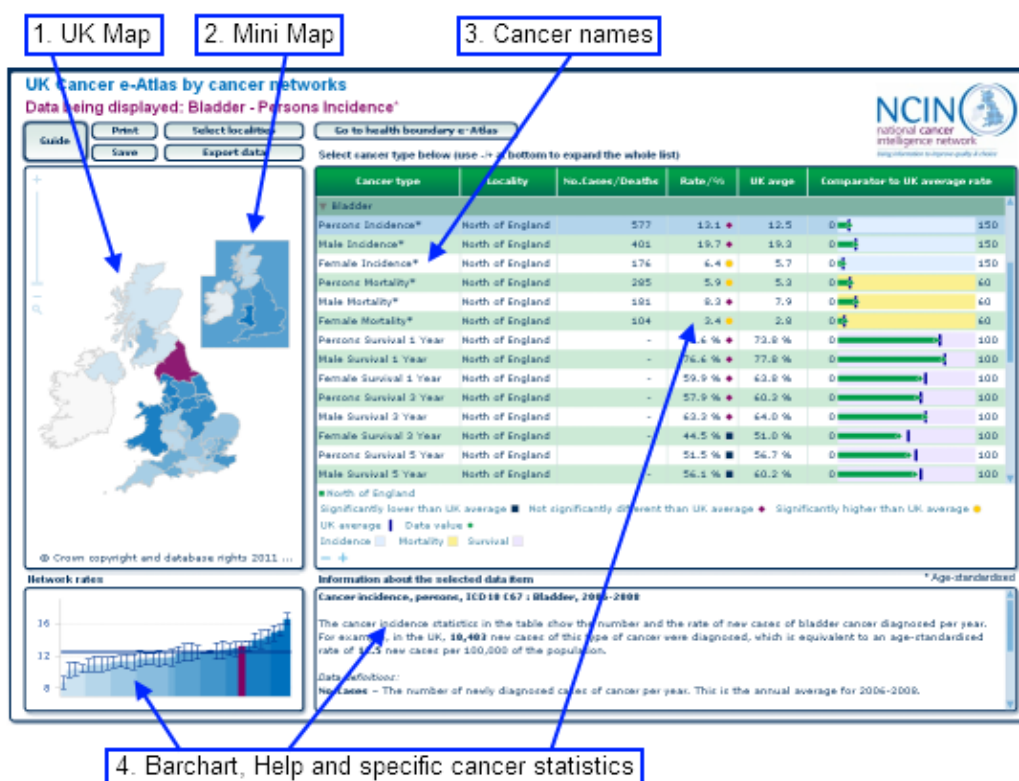
URL: <http://www.bowelcanceratlas.org/>

Figure 5.3: Cancer Incidence in Switzerland



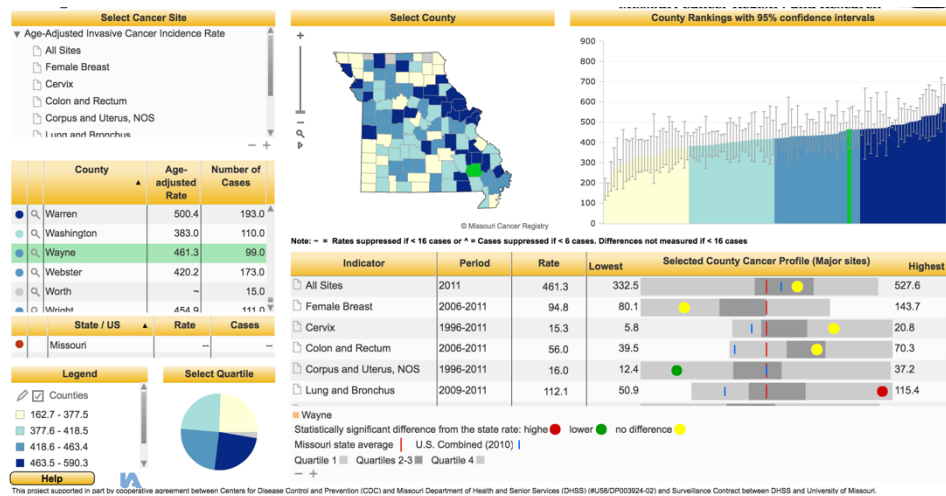
URL: <http://www.nicer.org/NicerReportFiles2015-2/EN/report/atlas.html?&geog=0>

Figure 5.4: UK Cancer eAtlas | NCIN



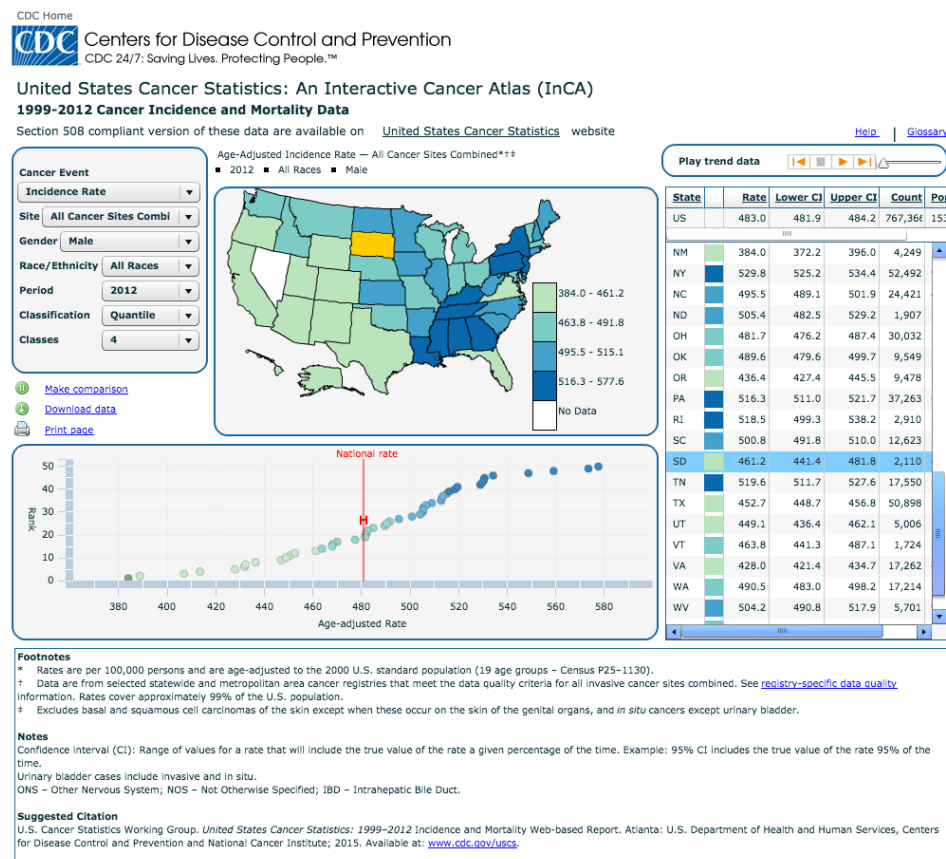
URL: http://www.ncin.org.uk/cancer_information_tools/eatlas/

Figure 5.5: Age-Adjusted Invasive Cancer Incidence Rate (Missouri Cancer Registry and Research Center)



URL: <http://mcriaweb.col.missouri.edu/IAS/dataviews/report?reportId=13&viewId=3&geoReportId=62&geoId=1&geoSubsetId=>

Figure 5.6: United Cancer Statistics: An Interactive Cancer Atlas (InCA)



URL: https://nccd.cdc.gov/DCPC_INCA/

PROS

- Minimal programming skills required to build an interactive dashboard.
- Minimal modelling skills required to generate age adjusted estimates.
- Hosting and embedding on an existing website is relatively simple.
- Subscription costs significantly lower than hiring personnel or consultants to building a custom interface.
- All panels in the dashboard are interlinked.

CONS

- Overall design feels 'dated' - however this is improving.
- Layout and design options are limited.
- Slow to load. Both initially loading the webpage and also when exploring the map by selecting population, cancer type or other variables.
- Very poor labels (non-intuitive)
- Uncertainty visualisation options limited (CIs appear to be the only option)

5.2 Pennsylvania Cancer Atlas

URL: <http://www.geovista.psu.edu/grants/CDC/>

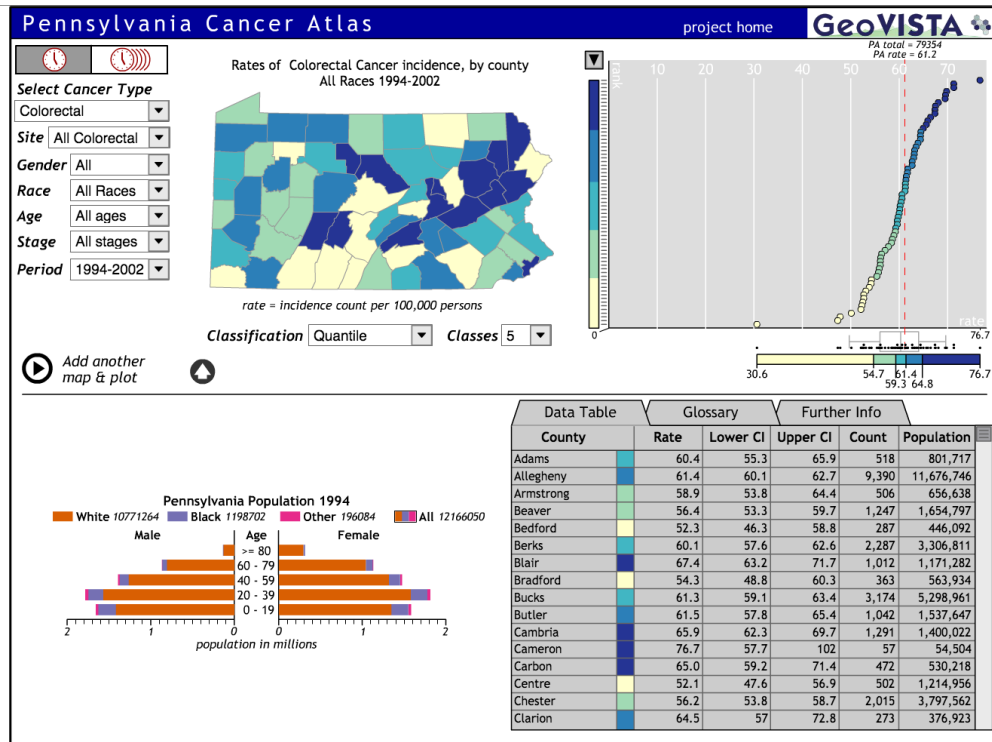
Publisher: Penn State Health Medical Center

Reason for Selection: Layout design, comparison of two maps, fast interactivity, all dashboard products interconnected. data table is sortable.

Visualisation Platform used: GeoVista software built by Pennsylvania State University (<http://www.geovista.psu.edu/>).

Skills: unknown, further investigation of the GeoVista platform required.

Figure 5.7: Pennsylvania Cancer Atlas



URL: <http://www.geovista.psu.edu/grants/CDC/>

PROS/ INTERESTING FEATURES

- Summarises a large amount of data/information in one screen.
- Many customisation options (cancer type, gender, race, age, stage).
- Can compare two customised maps with the click of one button.
- Screen layout is clean.
- All graphs in the dashboard are integrated. Scrolling over one graph lights up linked data in other graphs.
- Columns within data table can be sorted.
- Links to 'Further Info' and 'Glossary' easy to find.
- Can show change over time.
- Having the legend show the data distribution is an interesting feature (could be enhanced if redesigned to be a clearer legend/key).
- The map is rather small within the dashboard.

CONS

- Legend is not intuitive or obvious, initially difficult to find. Numbers are difficult to interpret and it is not clear if the numbers reported are high, medium or low.
- Ability to customize number of quantiles or classes seem unnecessary.
- Population graph adds very little extra value to the overall dashboard. Difficult to relate population information to the mapped estimates (but is interactive).
- Scatter plot of estimated rates, on the top right contains a lot of wasted space.
- Difficult to find methods - even after following the 'Further Info' link.
- While there are many customisable options, the display does not 'tell a story' or pull out the key messages. For example, the user would have to view many different maps to explore if any of the variables provided (age, gender, race, etc) are related to cancer incidence.

5.3 The Environment and Health Atlas for England and Wales

URL: <http://www.envhealthatlas.co.uk/eha/Breast/>

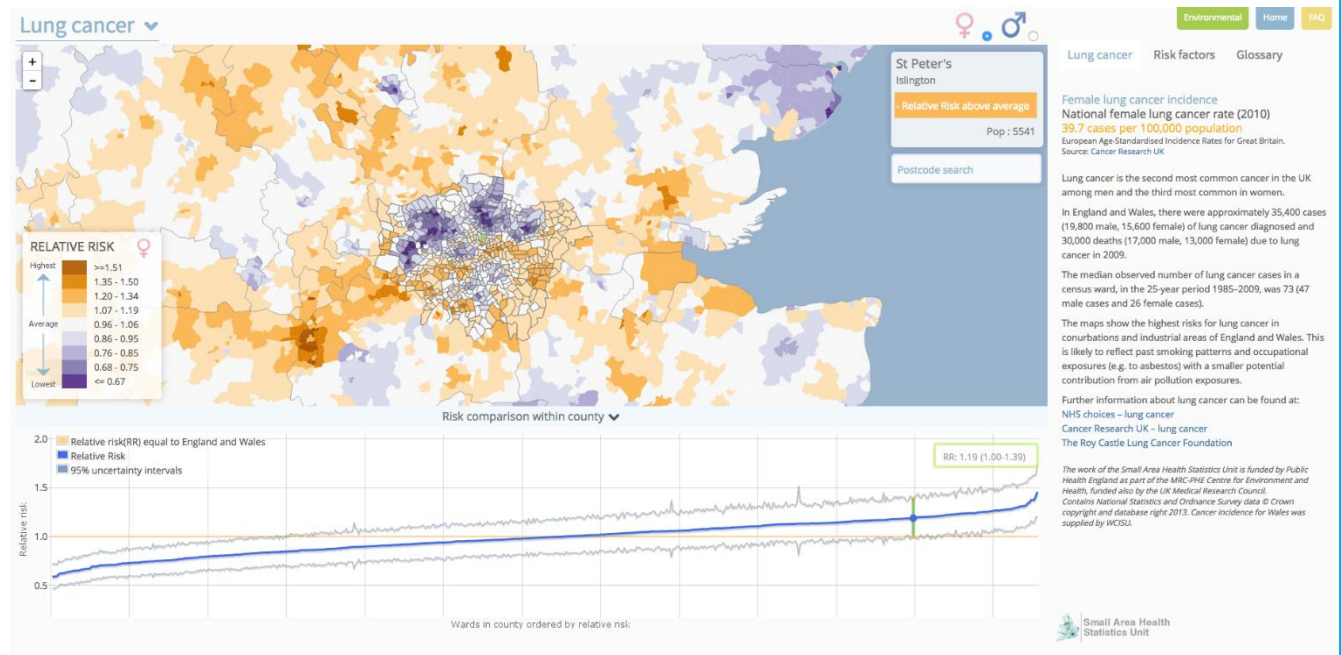
Publisher: Small Area Health Statistics Unit, RC-PHE Centre for Environment & Health, Imperial College London

Reason for Selection: Layout, multiple data displays, comparisons, high density data.

Visualisation Platform used: Custom built using d3.js + leaflet.

Skills Required: Professional level of graphic design, programming, and web development skills required.

Figure 5.8: Environmental Health Atlas of England and Wales



PROS

- Design has a clean, modern and uncluttered feel.
- Legend is intuitive, easy to find.
- Colour scheme is clear and intuitive to interpret
- Zoomable - resolution can be changed easily from counties to small area estimates by interacting with the map.
- Additional information and resources are cleanly embedded alongside the map and it tells a clear story and connects to relevant resources.
- Further information (pop-up graph) appears through exploring the map details.
- Postcode search function is simple and easy to use.
- The map is simple and easy to navigate.
- The map is the main feature of the screen.

CONS

- Although the Highest<average>lowest label and colours are clear, the numbers on the legend are not immediately intuitive.
- Graph of relative risk vs region obscures the map quite a lot. Could be re-designed more efficiently to use the space, as it feels like the map is obscured when this graph is displayed.

5.4 CINA + Online Cancer in North America

URL: <http://www.cancer-rates.info/naaccr/>

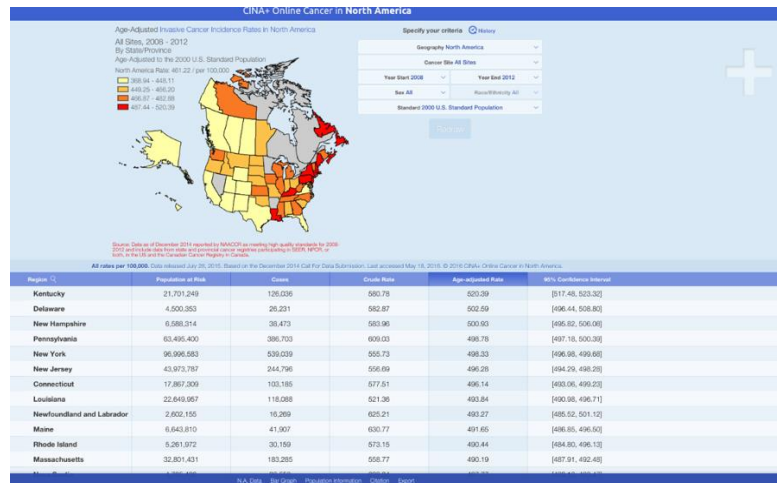
Publisher: North American Association of Central Cancer Registries

Reason for Selection: Interesting layout for comparison of two maps, clean design, interesting pop-ups for drilling into data, interesting area comparison functions.

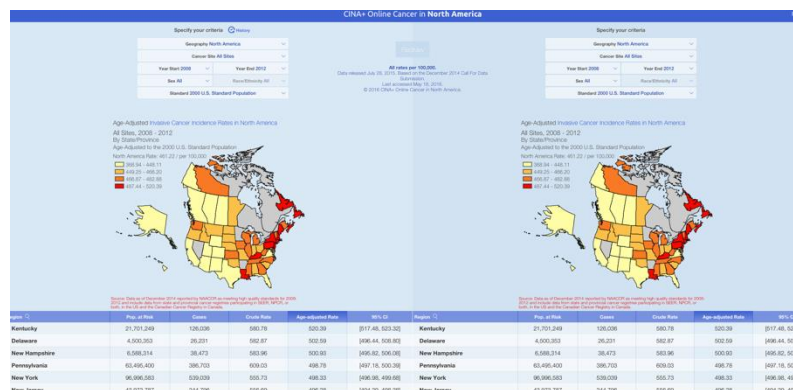
Visualisation Platform used: Custom built using Javascript

Skill Level Required to Create: Professional - coded in java from scratch!

Figure 5.9: CINA+ Online Cancer in North America



URL: <http://www.cancer-rates.info/naaccr/>



URL: <http://www.cancer-rates.info/naaccr/>

PROS

- Design has a clean, modern and uncluttered feel.
- Can add a second map for comparison.
- Very easy to customize. The variables selection and redraw functions are clear and easy to navigate.
- Ability to drill down on specific details in a particular state or compare multiple states are easy to use. Both interact with the map and the data table.
- Data table contains uncertainty information..
- Pop-up menu at the bottom enables further exploration, data export, further info, barchart, etc without taking up space.

CONS

- Legend labels are not intuitive. What do the rates provided mean? Do the colours relate to high, medium or low? Unclear if they are compared to the state average.
- Uncertainty info provided (in data table) not easily applicable to the overall map, or interpretable for a non-expert audience.
- Pop up menu at the bottom of the screen is not initially easy to find.
- Map is rather small within the dashboard

5.5 NIH - GIS Resources for Cancer Research

URL: <https://gis.cancer.gov/geoviewer/app/>

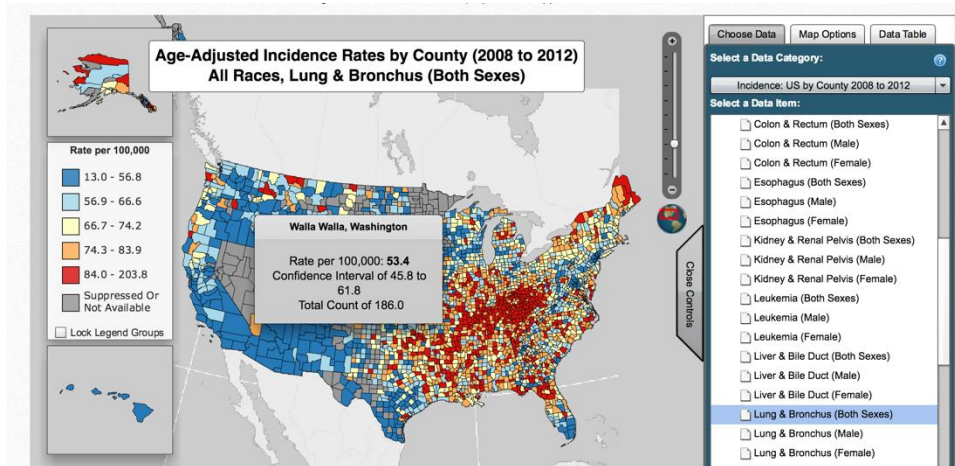
Publisher: NIH – National Cancer Institute | Geographic Information Systems for Science and Cancer Control (US)

Reason for Selection: Many capabilities for interactive customisation. Design is a little dated and clunky. Print function is a nice feature. Designed as a tool for researchers or other stakeholders that would use a visualisation of this data, rather than for the general public.

Visualisation Platform used: ESRI ArcMap

Skill Level Required: Unsure

Figure 5.10: NIH's GIS Resources for Cancer Research



PROS

- Can explore a large number of cancers, data date ranges, and other demographic variables.
- Large number of map display options (possibly too many).
- Designed more as a research support tool, rather than a communication tool for the general public
- Print map options enables users to create a map to suit their needs and export this as a pdf for their own purposes. The 'map options' tab, in the 'Controls' panel, enables design features to be customized as well (map borders, heading, number of categories, etc).
- Data table embedded in the Control tab is a nice design feature. Stops the data table from cluttering the view.

CONS

- Slow to load
- Design feels 'dated'
- Customization through a large number of drop down menus is very clunky and can be confusing to navigate initially.
- The initial map view, on loading, is blank. Must select map details before anything appears and navigating the large list of variables is not always clear.
- User experience is not great.

5.6 MapNH Health

URL: <http://www.mapnhhealth.org/health-map?map=hsa®ion=null&ind=75&year=2020>

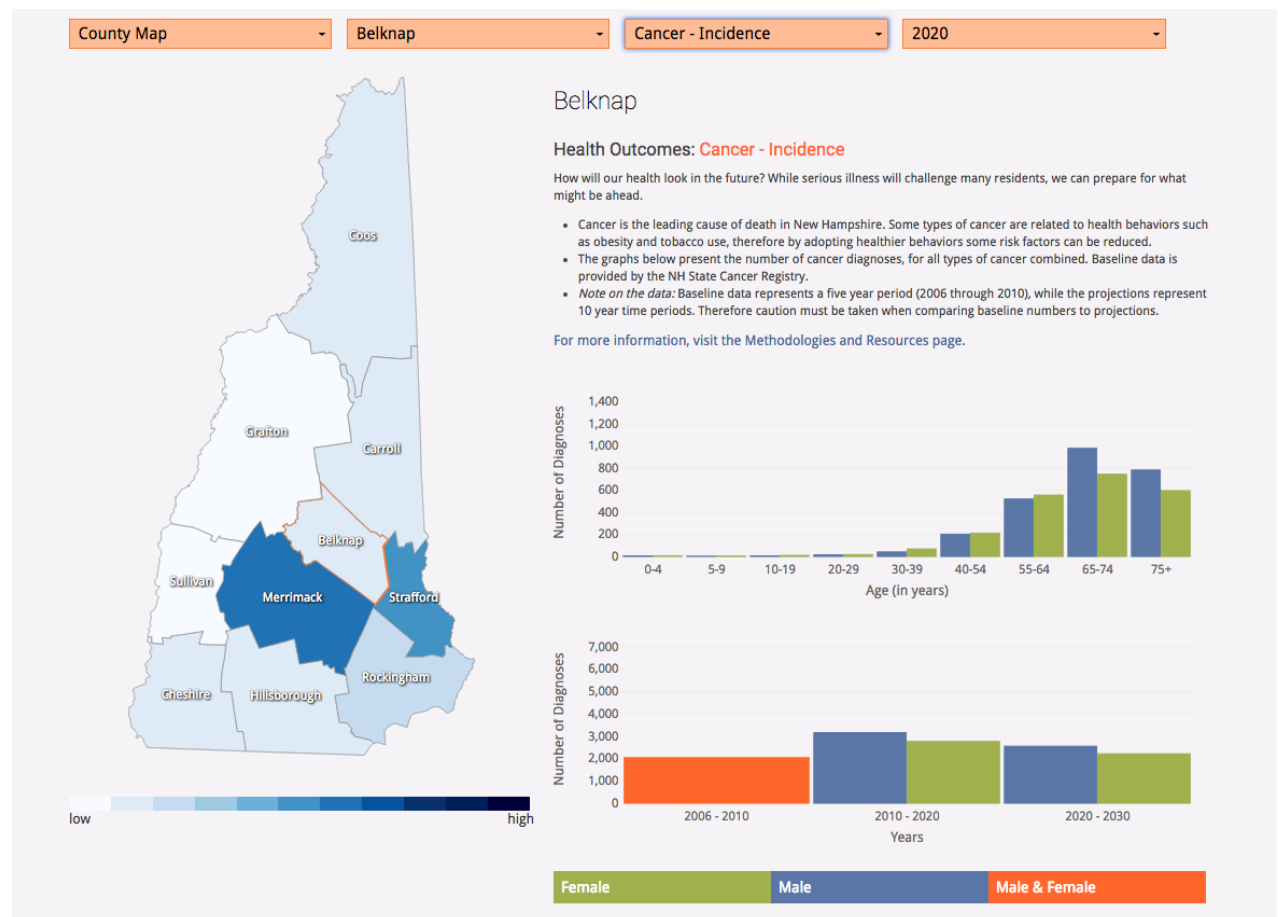
Publisher: MapNH Health

Reason for Selection: Projected estimates are interesting. Example of changing map resolutions (State>county>small area)

Visualisation Platform used: Custom Built with D3.js

Skill Level Required: Professional skill level required (D3.js +JavaScript + GIS capabilities)

Figure 5.11: MapNH Health



PROS

- Design feels uncluttered, simple and easy to navigate.
- Projected estimates are interesting.
- Legend colour scheme is clear and easy to understand.
- Accompanying graphs are clear and easy to interpret.
- Selecting resolution, region, variable, etc is easy to navigate.

CONS

- A little slow to load.
- No uncertainty information provided.
- Low and high labels on the legend. While initially easy to interpret, what do they actually mean?

5.7 United States Cancer Statistics: An Interactive Cancer Atlas (InCA)

URL: https://nccd.cdc.gov/DCPC_INCA/

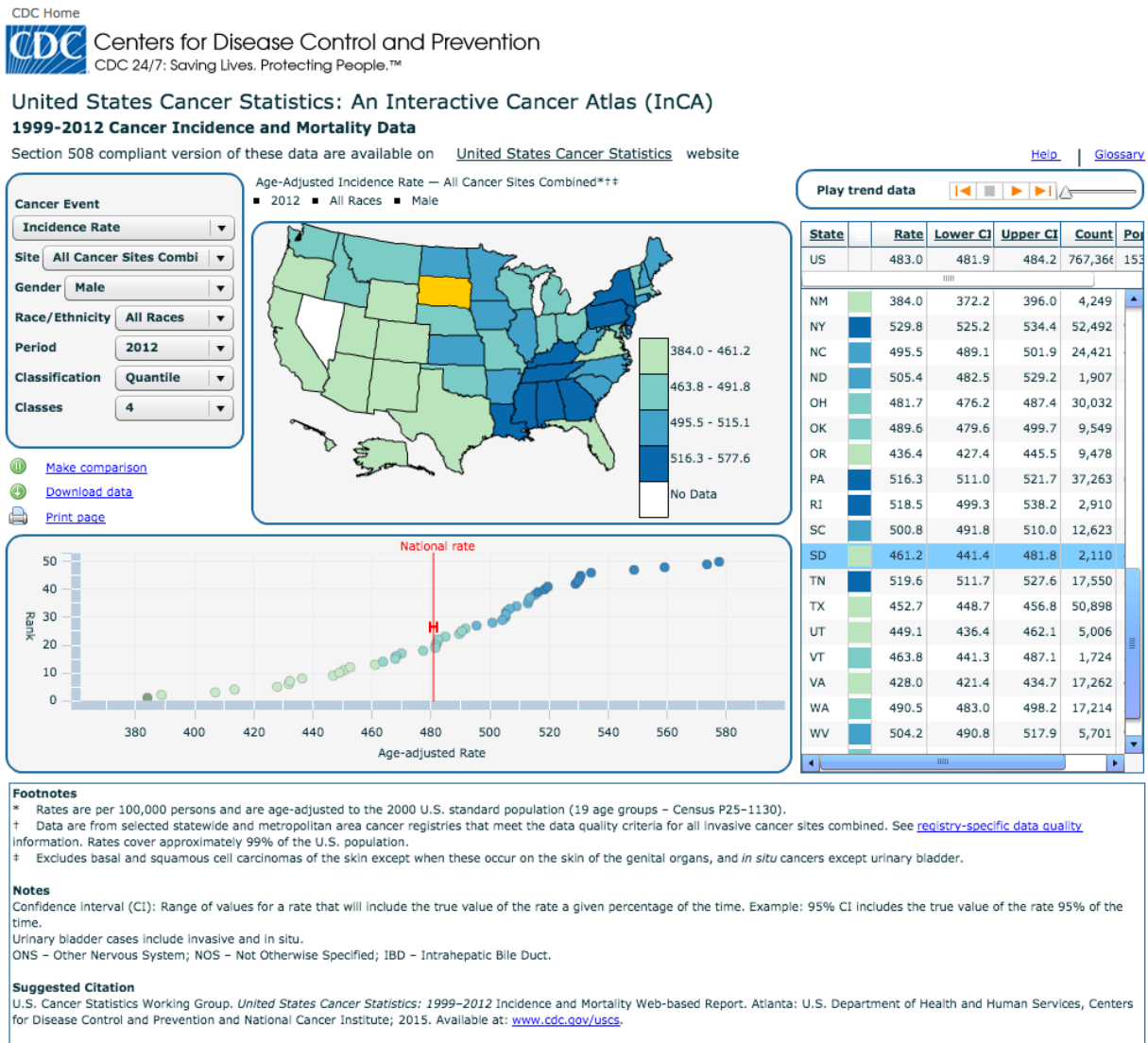
Publisher: CDC Centres for Disease Control & Prevention

Reason for Selection: Clean design with nice interactive features. Relatively quick to update. One of the nicest Instant Atlas examples.

Visualisation Platform used: InstantAtlas (see section above)

Skill Level Required: low

Figure 5.12: United States Cancer Statistics: An Interactive Cancer Atlas (InCA)



PROS

- Interconnected graphs within the dashboard work really well.
- Selecting a particular colour (risk range) on the legend will select only these sections on the map. Nice exploration feature.
- Changes to the customization panel on the top left loads a new map very quickly.
- Playing change over time is a nice feature.

CONS

- Labelling on the legend is not intuitive. Difficult to interpret if the rates provided are high or low.
- Map is rather small within the dashboard.

5.8 Longer Lives

URL: <http://healthierlives.phe.org.uk/topic/mortality>

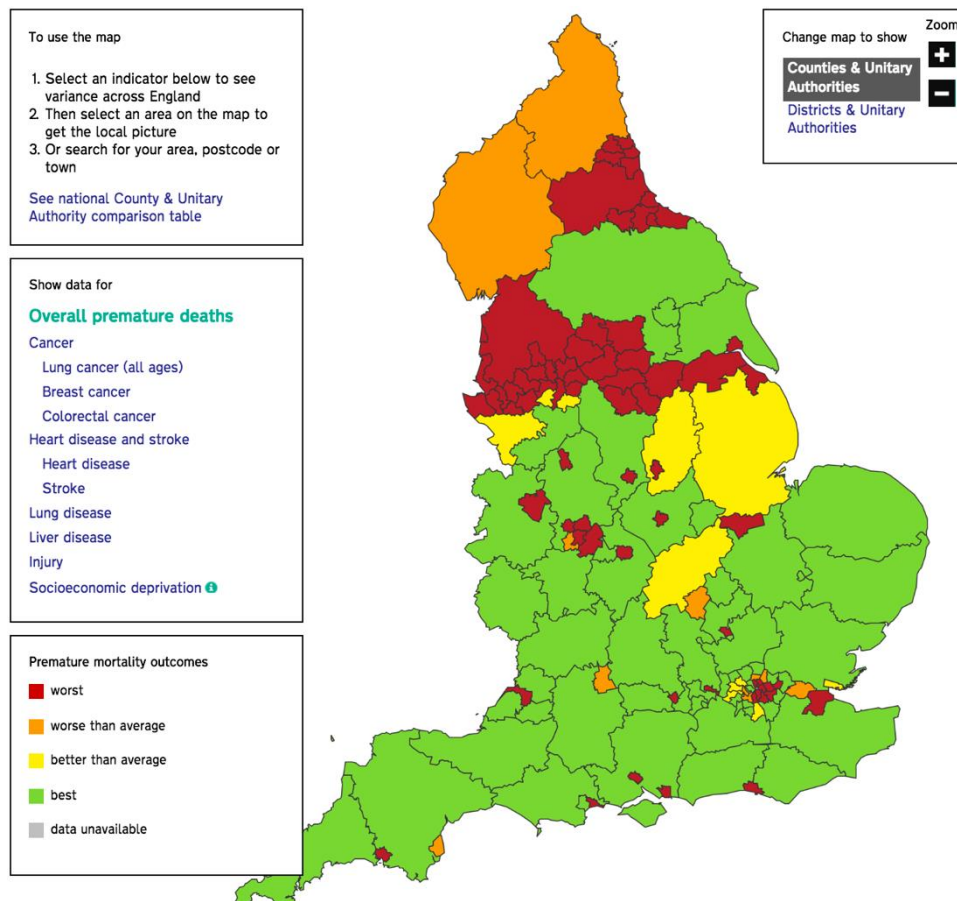
Publisher: Public Health England

Reason for Selection: Contrast in layout and visual design

Visualisation Platform used: Custom Built using JavaScript + Google maps api

Skill Level Required: Professional

Figure 5.13: Longer Lives



PROS

- Simple clean design.
- Legend labels are clear.
- Interactive features very easy to use.
- Doesn't try and be too many things.

CONS

- Limited interactivity.
- Simple map.
- Colour scheme could be improved.

5.9 PRI : Cancer Global Footprint

URL: <http://globalcancermap.com/>

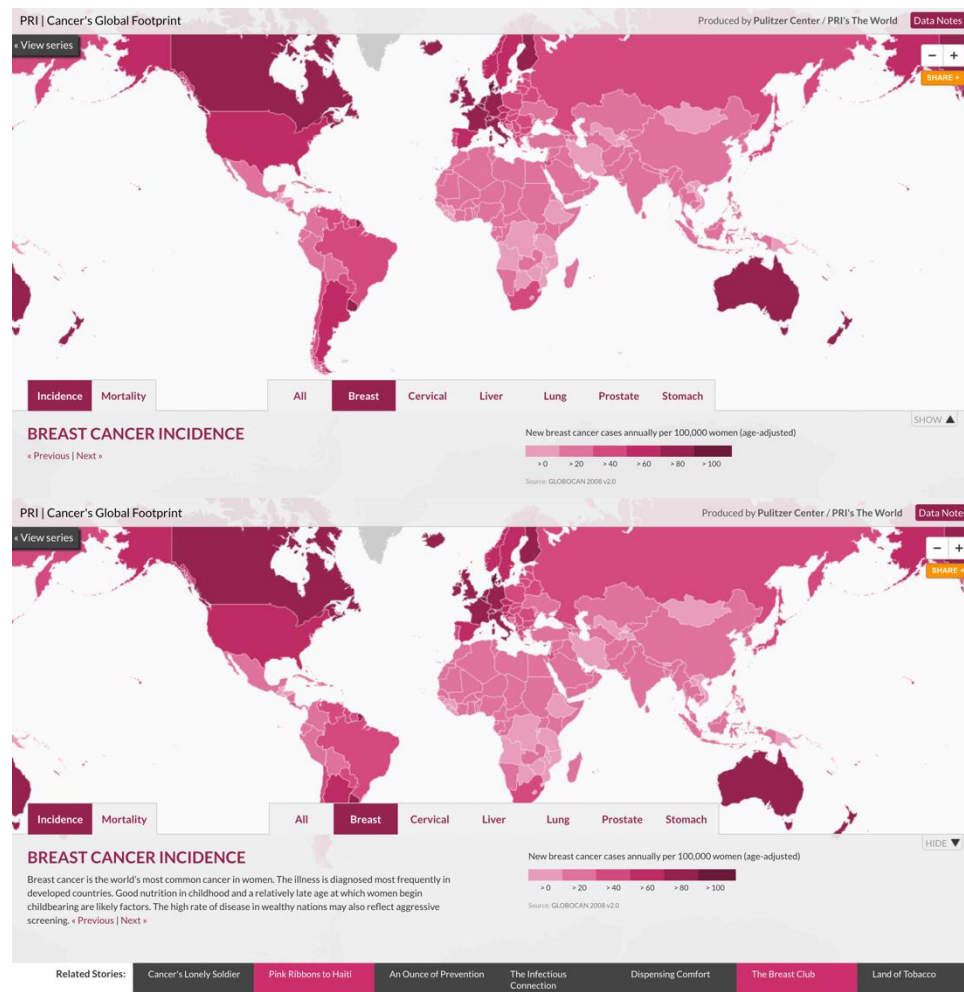
Publisher: Pulitzer Centre

Reason for Selection: Additional of related stories in the ribbon at the very bottom of the page.

Visualisation Platform used: Custom built with JavaScript + modest maps + mapbox

Skill Level Required: Professional

Figure 5.14: PRI's Cancer Global Footprint



PROS

- Clean and modern design.
- Inclusion of 'Related Stories' in the ribbon at the bottom of the screen is a nice way to include extra info, useful resources etc.
- Easily navigate between cancers.
- Legend colour scheme is easy to follow.
- Legend is easy to understand, not so easy to interpret.

CONS

- Resolution is very low, only shows estimates at the national level.
- Panel at the bottom may be better placed on the side. Would waste less space.

References

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- Langford IH, Leyland AH, Rasbash J & Goldstein H (1999). Multilevel modelling of the geographical distribution of rare diseases. *Applied Statistics*, 48:253-268.
- Pennello GA, Devesa SS & Gail MH (1999). Using a Mixed Effects Model to Estimate Geographic Variation in Cancer Rates. *Biometrics*, 55:774-781

Appendices

Appendix A: Search Protocols

Research Question: What cancer maps are currently available to the public on the internet and what methodologies and technologies have been used to generate them.

Aim: To summarise the breadth of cancer atlases published publicly on the internet in terms of: statistical methods used, outcome measures, inclusion of uncertainty, map interactivity features, available functions, access to data, availability of explanations or supporting material explaining methods and data sources, technology platform used to create the web product, country, the area of resolution, smoothing methods are used, date of the data used, date of publication, generated by (gov, research institution, university), academic publications associated with the map.

Pre-Scoping

Cancer Atlas Synonyms

Pre-Scoping Cancer Mapping Terms	Cancer map*, oncology map, geospatial health statistics, geospatial cancer statistics Health atlas, disease Atlas, health map, spatial statistics, spatial cancer statistics geographic clustering, geographic cancer variation, geographic variation, Geographic patterns of disease, spatial patterns, geographic disease distribution, atlas of disease distribution, disease distribution, bayesian cancer map*, spatial epidemiology, geospatial health data, geovisualisation, health geographics, Geographic maldistribution, disease distribution, thematic cancer map
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Search Details

Search Strings

The following list details the final search strings used to identifying cancer maps. A search testing log that outlines the testing and refinement of these search strings is detailed in Appendix B.

1. intitle: spatial AND epidemiology AND cancer AND map OR mapping OR atlas - campus
2. allintitle: cancer AND map OR mapping OR atlas -campus -kinase -kinases -concept
3. allintitle: spatial AND cancer AND statistics
4. allintitle: spatial OR geographic AND cancer AND variation OR distribution
5. allintitle: spatial AND epidemiology AND cancer AND map OR mapping OR atlas - campus
6. intitle: cancer AND atlas

Search Limits

Allintitle - restricts the results to those with all of the query words in the title. For instance, [allintitle: google search] will return only documents that have both "google" and "search" in the title. Without this limitation all the search strings listed above return in excess of 100,000,000 hits, many of which were irrelevant.

intitle - restricts the results to documents containing that word in the title. For instance, [intitle:google search] will return documents that mention the word "google" in their title, and mention the word "search" anywhere in the document (title or elsewhere).

Date - all searches were limited to pages published between 01/01/2010 and 01/05/2016

Search Engine

Google was used for all searches. No other search engines were explored.

Language

Only English was used in these searches. Searching in additional languages is outside of the resources of this project. Atlases that were identified in the searches but are not published in English were still extracted.

Eligibility Criteria

Hits were selected for data extraction if they met the following criteria:

- contained a visual geographical map of cancer incidence, mortality, survival or risk (either pdf, static image or interactive web interface).
- were accessible without a password or log in.
- were published or updated on or after the 1st of January 2010.

Appendix B: Developing and testing search strings

The table below details the search strings that were tested, number of hits and date searched.

	Search String	Database	Hits	Date	Update after 22/10/15	Hits
1a	Cancer AND map* OR Atlas		260,000,000	22/10/2015	12/05/16	126
1b	intitle:cancer AND map* OR atlas	Google	1,090,000	23/10/15	12/05/16	120,000
1c	allintitle:cancer AND map* OR atlas	Google	2,620	23/10/15		
	allintitle:cancer AND map* OR atlas - campus	Google	2,620	23/10/15		
	allintitle:cancer AND map* OR atlas - campus -kinase	Google	2,490	23/10/15		
	allintitle:cancer AND map* OR atlas - campus -kinase restricted to publications after 1/1/2010	Google	189	23/10/15		
	allintitle:cancer AND map* OR atlas - campus -kinase - kinases restricted to publications after 1/1/2010	Google	182	23/10/15	12/05/16	31
1d	allintitle:cancer AND map OR mapping OR atlas -campus -kinase -kinases	Google	7,160	23/10/15	12/05/16	122
	restricted to publications after 1/1/2010	Google	623	23/10/15		
	restricted in the past 2 yrs	Google	327	23/10/15		
	restricted to publications in the past 12 months	Google	149	23/10/15		
	restricted to publications in the past month	Google	23	23/10/15		
	restricted to publications in the past week	Google	4	23/10/15		
1e	allintitle:cancer AND map OR mapping OR atlas -campus -kinase -kinases -concept	Google	6,960	29/10/15		122

	restricted to publications after 1/1/2010	Google	625	29/10/15		
	restricted to publications after 29/10/2013	Google	333	29/10/15		
	restricted to publications after 29/10/2014 (past yr)		155			
	published in the last month (29/09/2015)		20	29/10/15		
1f	allintitle:cancer AND map OR mapping OR atlas -campus -kinase -kinases -concept	Google	7,110	23/10/15		
2	allintitle:Oncology AND map OR mapping OR atlas -campus -kinase -kinases -concept	Google	8,250	23/10/15		
3	allintitle:Spatial cancer statistics	Google	75	23/10/15		
4	allintitle:spatial OR geographic AND cancer AND variation OR distribution	Google	1,030	30/10/15		
	restricted to pages published after 01/01/2010	Google	90	29/10/15		
5	allintitle:Bayesian AND cancer AND Map OR atlas OR mapping	Google	0	23/10/15		
6	allintitle: thematic AND cancer AND Map OR atlas	Google	0	23/10/15		
7	allintitle:Spatial AND epidemiology AND cancer AND map OR mapping	Google	0	23/10/15		
	intitle:Spatial AND epidemiology AND cancer AND map OR mapping OR atlas -campus	Google	12,200	30/10/15		
	restricted to pages published after 1/1/2010	Google	1,880	23/10/15		
8	intitle:cancer AND atlas	Google	258,000	9/11/15		
	restricted to publications between	Google	39,800	9/11/15		

	01/01/2010 to 09/11/2015					
	-genome	Google	24,200	9/11/15		
9	intitle:atlas AND cancer	Google	207,000	11/11/15		
	restricted to publications between 01/01/2010 to 09/11/2015	Google	19,500	11/11/15		
	-genome	Google	18,200	11/11/15		