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A review of resources for geographic variables

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Summary

The purpose of this report is to provide an overview of some of the main small area geographical variables available in Britain. These variables could potentially be linked to data from the British Birth Cohort Studies and other longitudinal studies in order to provide contextual information to supplement the rich and detailed information already held on individual cohort members. For example, data on air pollution levels in different areas could be included in models that aim to explain variations in respiratory function for individuals in mid-life, based on experiences and exposures during childhood. The report begins with a brief discussion of how geographical variables can be defined and conceptualised and then provides more detail on variables on three main topics: 1) the census (and area deprivation), 2) air pollution, 3) climatic data.

Overview of geographical variables

Geographical variables are defined as variables that provide information about the characteristics of a place, instead of just the location of that place. One example would be a rural-urban identifier, which may have a number of classes, from the most urban metropolitan centres to the most remote rural areas. Another example might be an unemployment rate for an area. Such data can be constructed at a range of spatial scales, but for many applications local-area data are preferred – ward level unemployment rates would usually be preferable to district or regional unemployment rates (Boyle et al 2004).

Geographical variables can be derived from the longitudinal datasets themselves and also be derived from external sources. The former might be based on questions that were asked about the neighbourhood in which a person lived, or the data may be created from averaging the characteristics of respondents in the survey who all lived within the same area. The latter may be from population censuses, social surveys or administrative sources. Ideally the geographical variables are updated regularly at about the same time as the cohort study. While the information on neighbourhoods from the longitudinal surveys proper is simultaneous with the time of the survey, the information from external sources may not be collected or measured at the same time or period. For example, the 1970 cohort study collected data from 1970 and repeated at 1975, 1980, 1996, 2000, 2004 and 2006. UK population census data was only collected every ten years at the first year of a decade (e.g. 1971, 1981 etc).

There is a significant amount of geographical data available at the local scale in the United Kingdom. The most important source of geographical data is the decennial population census, last conducted in 2011 and available at local areas down to the Output Area level (on average a few hundred people). However, the temporal mismatch between the collection of census data and the collection of data from members of the cohort studies is a potential problem as characteristics of area can change. The development of a set of Neighbourhood Statistics (http://www.neighbourhood.statistics.gov.uk/) is designed to provide updates for a number of key local-area variables between censuses. It also includes variables not available in the population census, mainly derived from different parts of local government,

including police, education, social services and health data. Neighbourhood Statistics are being developed separately in England and Wales, in Scotland and in Northern Ireland.

Another important source of small-area data is the NOMIS system (National Online Manpower Information System: http://www.nomisweb.co.uk/). NOMIS is run by the University of Durham on behalf of the Office for National Statistics (ONS). NOMIS provides a wide range of government statistical information on the UK labour market including employment, unemployment, earnings, Labour Force Survey and jobcentre plus vacancies.

Information is available at the local level for a range of environmental variables, through the work of such organisations as the Ordnance Survey, the Geological Survey, the Department for Environment, Food and Rural Affairs, and the Meteorological Office. It is also possible to derive local-area information from maps. An additional source of data in rural areas is the survey of rural facilities conducted every few years by the Countryside Agency, which provides data on rural transport and accessibility to shops and services. Local information on school examination performance is also collected and published. Many other forms of local information are collected for a range of different purposes by different organisations.

In the following sections of this report we will focus on providing a more detailed description of census data, air pollution data and climate data.

Population census

Population censuses are the only survey which by law requires everyone in the country to participate. Therefore the census provides the most comprehensive and detailed information on demographic, housing and socioeconomic conditions of the population. In addition to population data, the UK census includes information on many themes, including birthplace, ethnic group, religion, household structure, housing, economic activity, migration, limiting long-term illness, car use, educational qualifications, occupation, industry, social class and travel to work.

So far the census in the UK has been taken every ten years since 1801 apart from 1941. However, use of the census data longitudinally is often hampered by issues like changes in the questions asked and the definitions and classification used; changes in tabulations; and changes in the boundaries of areas for which published data are provided.

Table 1 presents selected topics in censuses from 1931 to 2001 in Britain. For example, housing tenure was first introduced in 1961, and car ownership from 1971. Employment as a topic has been included for a long time. However, the categorisation of economic activity is subject to change over different censuses.

The 1961 census was the first to be digitally processed at the time, however there were no machine-readable outputs. A selected set of 1951 and 1961 census data was transcribed and uploaded into the UK Data Service by the Great Britain historical GIS (Geographical Information System) team (GBHIS) in the University of Portsmouth (http://discover.ukdataservice.ac.uk/catalogue/?sn=4556&type=Data%20catalogue,Southall 2014). The topics include age and sex, education, housing conditions, marital status, occupations, social class and socio-economic groups.

The geographies for which the aggregate census data are published have been subject to substantial changes (Table 2). With the use of computers and geographical information systems (GIS), since 1971 the census data were digitised and released at a range of spatial scales from the local authority to the enumeration district (ED) level (or output area level from 2001).

Table 1: Selected topics in censuses 1931-2001

Topic	1931	1951	1961	1971	1981	1991	2001
Education							
Whether scholar or student		GB					
Age at which full-time education ceased		GB	GB				
School level qualifications				GB			
Scientific and technical qualifications			GB	GB	GB	GB	GB
Higher qualifications				GB	GB	GB	GB
Employment							
Activity	GB	GB	GB	GB	GB	GB	GB
Students of working age	GB	GB	GB	GB	GB	GB	GB
Working full-time or part-time		GB	GB		GB	GB	GB
Weekly hours worked			GB[3]	GB			
Employment status (employee, self-employed)	GB	GB	GB	GB	GB	GB	GB
Apprentice or trainee		GB	GB	GB	GB	GB	GB
Industry	GB	GB	GB	GB	GB	GB	GB
Address of business	GB					GB[4]	GB
Occupation	GB	GB	GB	GB	GB	GB	GB
Households							
Number of rooms	E,W	GB	GB	GB	GB	GB	GB
Number of rooms with one+ windows	S						
Sharing accommodation				GB	GB	GB	GB
Tenure of accommodation			GB	GB	GB	GB	GB

Car or vans			GB	GB	GB	GB
Household amenities						
Cooking stove	GB	GB	GB			
Kitchen sink	GB	GB	GB			
Piped water supply	GB	GB				
Hot water supply		GB	GB			
Fixed bath or shower	GB	GB	GB	GB	GB	GB
Inside WC	GB		GB	GB	GB	GB
Outside WC			GB	GB		
Central heating					GB	GB

GB: Great Britain; E: England; W: Wales; S: Scotland
Source: Norris & Mounsey 1985; Champion 1996; ONS 2004

Enumeration districts are designed for data collection purpose. Their size and shape were largely determined by the requirements of the data collection process but they also fit within the administrative boundaries current at the time. Since 2001 (1991 for Scotland), enumeration districts were abandoned as output units. Instead output areas are especially designed for census output. In 1961 the census data at the ED level were only published on users' demand so it did not cover the whole of Britain.

Table 2: Output geographies of censuses

Year	Geography			
	Enumeration district	Output area	Ward	Local authority
1951				GB
1961	Partly on demand		GB	GB
1971	GB		GB	GB
1981	GB		GB	GB
1991	E,W	S	GB	GB
2001		GB	GB	GB
2011		GB	GB	GB

Note: for Scotland pseudo postcode sectors are used instead of ward in 1981, 1991 and 2001 censuses.
Source: Denham & Rhind 1983; Coombes, M. 1995

Areal deprivation

Census data can be used to describe characteristics of an area. The most commonly used indicator for an area is perhaps the deprivation indicator, which has been used by governments allocating resources. A number of deprivation measures have been developed by government agencies or academics. From 1981 the two most commonly-used deprivation indicators constructed from the census data are the Townsend deprivation index and Carstairs deprivation index. The Townsend deprivation index is defined as the sum of four standardised percentage variables: residents in unemployment, households without cars, households who are not owner–occupiers, and households in overcrowded conditions (more than one person per room). The Carstairs deprivation index is defined in the same way but uses different variables: male residents in unemployment, residents in overcrowded households (more than one person per room), residents in households with no car, and residents in lower social classes (partly skilled and unskilled occupations).

Due to lack of data availability, Townsend or Carstairs deprivation scores cannot be constructed from the census data before 1971. However, it is possible to model areal deprivation using one or two variables from the census because of the high degree of spatial correlation between the component parts of an index such as Townsend or Carstairs. Table 3 lists relevant census variables which can be used in the definition of areal deprivation. For example we can use unemployment rates to indicate local deprivation levels from 1931.

Details on other deprivation indexes can be found in Senior (2001). There have been criticisms of deprivation measures. For example, car ownership is not essential for urban residents due to parking constraints, while in rural areas car ownership is vital for residents to access services. Therefore, car ownership is not necessarily an indicator of deprivation and its importance varies across urban and rural areas. Use of census data based deprivation indicators has also been criticised because the census is decennial and the deprivation index does not measure the current situation, but instead measures a situation in the past. The use of available non-census data for small areas is increasingly adopted for central governments in the UK in producing deprivation index. The Index of Multiple Deprivation (IMD) has used seven domains: income; employment; health and disability; education, skills and training; housing; and geographical access to services from administrative records. IMD has been updated regularly over past decades.

Table 3: Deprivation indicator from census

Deprivation indicator	Description	Note
Unemployment	% as total economically active	1931 onward
Overcrowding	% of households with over 1 person per room	1931 onwards
Renters	% of households socially or privately rented;	1961 onwards
No car	% of households with no car or van	1971 onwards

Low social class	% in social class 4 (partly skilled) and 5 (unskilled)	1951, 1971 for males
Lacking household amenities	% of households without exclusive use of all amenities asked about that year	1951: hot water, stove, sink, water closet, and bath; 1971: hot water, fixed bath, and inside water closet; 2001: bath, water, and toilet;
Lacking higher education	% of all persons lacking higher level qualifications	1951: terminated education at age 20 or over (most likely age category at which degree obtained; 1971: holding a degree or equivalent ; 2001: level 4 or 5 out of five degree level qualification

Source: Murray et al 2012

ONS area classification

The Office for National Statistics (ONS), the successor of Office of Population and Census Survey (OPCS) has created areal classifications or typologies using the census data since 1971 (Webber and Craig 1978). The classification serves as general-purpose incorporating a range of demographic, employment, socio-economic, household, and housing characteristics. The classification is structured in a nested hierarchy where there are different levels of clusters and users can choose which level of clusters they prefer to use. These classifications are usually available at local authority, health authority, electoral ward, or ED/OA levels (ONS, 2007; Vickers & Rees, 2007).

Although the classification was updated in 1981, 1991, 1999 and 2001 these classifications were not entirely comparable because different sets of census variables, and different methodologies were used. In addition geographical boundaries have been changed over years, for example, local authority boundaries have been adjusted due to restructure in 1996. As a result caution needs to be taken when using the classifications. The 11-group OPCS classification based on local authorities is widely used and listed here in Table 4. It is also feasible to further aggregate the OPCS classification into a 7-group and a 4-group categorisation.

Table 4: OPCS classification of local authorities 1971

code	District type
1	Inner London
2	Outer London
3	Principal metropolitan districts
4	Other metropolitan districts
5	Large non metropolitan cities
6	Small non metropolitan cities
7	Districts with Industrial areas
8	Districts with New Towns
9	Resorts, ports and retirement districts
10	Urban & mixed urban/rural districts
11	Remoter mainly rural districts

Note: This classification was updated by Champion 2005 and Simpson & Jivraj 2013 for 2011 local authority (http://www.ethnicity.ac.uk/census/districtclass/index.html). Paul Boyle also involved in update of this classification.
Source: Webber & Craig 1978

Area level classification has also been taken at ward and output area level at different censuses. Again these classifications are not fully comparable over time due to different variables used and boundary changes. Table 5 presents the 2001 ward classification and its hierarchical system.

Marketing research firms have been involved in the creation of small-area classifications based on census, administrative and commercial data, also called geo-demographic classification. A few examples are ACORN (http://acorn.caci.co.uk/), Mosaic (http://www.experian.co.uk/business-strategies/mosaic-uk.html) and CAMEO (http://www.callcredit.co.uk/). It may be argued to be unwise to use commercial geo-demographic systems like ACORN for research purposes, when the precise method of calculation of the classification is not released for reasons of commercial confidentiality.

Table 5: ONS three-level ward level classification, 2001

Supergroup name	Supergroup	Group name	Group	Subgroup name	Subgroup
Industrial Hinterlands	1	Industrial Areas	1.1	Industrial Areas A	1.1.1
				Industrial Areas B	1.1.2
		Out of Town Housing	1.2	Out of Town Housing	1.2.3
Traditional Manufacturing	2	Built-up Manufacturing	2.3	Built-up Manufacturing	2.3.4
		Transitional Economies	2.4	Transitional Economies A	2.4.5
				Transitional Economies B	2.4.6
Built-up Areas	3	Built-up Areas	3.5	Built-up Areas A	3.5.7
				Built-up Areas B	3.5.8
Prospering Metropolitan	4	Prospering Metropolitan	4.6	Prospering Metropolitan A	4.6.9
				Prospering Metropolitan B	4.6.10
Student Communities	5	Student Communities	5.7	Student Communities A	5.7.11
				Student Communities B	5.7.12
				Student Communities C	5.7.13
Multicultural Metropolitan	6	Multicultural Areas	6.8	Multicultural Areas	6.8.14
		Inner City Multicultural	6.9	Inner City Multicultural	6.9.15
Suburbs and Small Towns	7	Suburbs	7.10	Suburbs A	7.10.16
				Suburbs B	7.10.17
		Prospering	7.11	Prospering Suburbs	7.11.18

		Suburbs			
		Commuter Suburbs	7.12	Commuter Suburbs A	7.12.19
				Commuter Suburbs B	7.12.20
Coastal and Countryside	8	Countryside	8.13	Countryside A	8.13.21
				Countryside B	8.13.22
		Senior Communities	8.14	Senior Communities	8.14.23
		Out of Town Manufacturing	8.15	Out of Town Manufacturing	8.15.24
		Northern Ireland Countryside	8.16	Northern Ireland Countryside	8.16.25
Accessible Countryside	9	Accessible Countryside	9.17	Accessible Countryside	9.17.26

Source: http://www.ons.gov.uk/ons/guide-method/census/census-2001/news-archive/2004-2006/area-classifications-for-wards-and-health-authorities/index.html

Air pollution

In 1961 the UK established the world's first co-ordinated national air pollution monitoring network, called the National Survey. It monitored black smoke (BS) and sulphur dioxide (SO2) at around 1200 sites in the UK. The past decades have witnessed the change in pollution sources from industrial to traffic. Therefore focus has shifted progressively to the monitoring of pollutants generated from vehicular emissions, which include ozone, nitrogen dioxide and fine particulate matter. In 1987, the UK established an automatic urban monitoring network, to monitor compliance with the emerging EC Directive limit values on air quality (Gulliver et al 2011; Morris et al 2007).

In 1992, the then Department of Environment established an Enhanced Urban Network (EUN), and in 1995, all statutory and other urban monitoring was integrated into one comprehensive programme. In the following five years, over 50 local authority sites were integrated into the resulting network, including 14 of the London Air Quality Monitoring Network sites. In 1998, the previously separate UK urban and rural automatic networks were combined to form the current Automatic Urban and Rural Network (AURN). The AURN is the most important and comprehensive automatic national monitoring network in the country, which is made up of 127 sites across the UK.

Although both black smoke and sulphur dioxide were monitored from April 1961, the number and location of monitoring sites has varied over time. In the early 1970s there were more

than 1200 BS and 900 SO2 sites, followed by a gradual reduction in numbers until by 1991 there were only 285 BS sites and 202 SO2 sites. Since the early 1990s there have been further minor reductions in the total number of BS and SO2 sites. However, there has been a rapid increase in sites monitoring NO2 and PM10, reflecting the increase in traffic-related air pollution.

Data on daily average concentrations of BS and SO2 from monitoring sites can be obtained from the national air quality archive (www.airquality.co.uk). As part of the CHESS project (Chronic Health Effects on Smoke and Sulphur project, Imperial College), concentrations of BS and SO2 at 1962, 1971, 1981, and 1991 were estimated onto 1 km grids in alignment with the 10-yearly UK population census.

Air pollution dispersion models were developed to estimate annual average population exposures to PM10 (particulate matter 10 um), PM25 (particulate matter 2.5 um), NO2 (nitrogen dioxide), SO2 (sulphur dioxide), CO (carbon monoxide) and O3 (ozone) in Britain for 1994 onwards (Murrells et al 2010; Stedman 2003).

Table 6 lists availability of selected air pollutants in the UK. This underlines that prior to 1994 there is only data available on black smoke and SO2. Small Area Health Statistics Unit has also produced estimates on other pollutants from a number of projects such as the *RGI* (Ruimte in Geo-Informatie) project, and the ESCAPE *(*European Study of Cohorts for Air Pollution Effects) project. Details can be found at http://www.sahsu.org/content/sahsu-databases.

Table 6: Availability of selected air pollutants

	source		
Pollutant	AURN	NAEI	CHESS
PM25		2002-2011	
PM10		1994-2011	
Black smoke	1961*-2007		1962, 1971, 1981, 1991
CO		2001-2010	
NO2		1994-2011	
NOx		2001-2010	
O3		1994-2011	
SO2	1961*-2005	1994-2011	1962, 1971, 1981, 1991

* 1961 from April
AURN: Automatic Urban and Rural Monitoring Network
NAEI: National Atmospheric Emissions Inventory by AEA
CHESS: Chronic Health Effects on Smoke and Sulphur project

Black smoke and sulphur dioxide have been linked to the 1946 cohort study, to investigate the health effect of exposure at youth stage (Al Kanaani, et al 2012).

Climatic data

In the UK the Met Office is the national weather service responsible for weather and climate monitoring and forecasting. Around 200 synoptic *stations are evenly distributed across the UK.* These stations collect a number of meteorological elements: wind parameters, air temperatures, sunshine duration, radiation measurements, and rain measurements. Collectively these weather records comprise the best available data of the climate of the UK. Data from every available observing station in the UK are used to create best estimates of the 'true' average for the UK, its countries and regions (Alexander & Jones, 2001; Wigley & Jones, 1987).

The daily weather records from observing stations can be accessed from MIDAS (Met Office Integrated Data Archive System) (http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_ukmo-midas). MIDAS holds data from 1853 and is free for academics. Alternatively the data can be requested from Met Office (http://www.metoffice.gov.uk/). There is normally a charge from the Met Office for producing the data.

In addition to the records from individual observing stations, the Met Office also maintains several time series calculated from the station records, which are used to monitor the climate of the UK at a regional and national level. There are two main types of series - the Met Office UK Climate series and the Met Office Hadley Centre series.

The Met Office UK Climate series consists of estimated weather data at 5 km grid points, 25 km grid points and at regions (Perry & Hollis, 2005). Individual station data are employed to estimate monthly values taking into consideration factors such as topography and land use. Series are created for a wide variety of climate elements, including average maximum temperature, rainfall amount and hours of sunshine. The series generally start in 1961, however, the air temperature, rainfall and sunshine series extend further back as a result of an ongoing programme to digitise the Met Office archive of station records. The creation of the data sets is financially supported by the Department for Environment, Food and Rural Affairs (DEFRA) and they are being promoted by the UK Climate Impacts Programme (UKCIP) as part of the UK Climate Projections (UKCP09).

Table 7: Summary of gridded data set availability

      1. Daily and monthly climate variables

Climate Variable	Daily Period	Monthly Period	1961-1990 Averages	1971-2000 Averages	1981-2010 Averages
Maximum air temperature	1960-2006	1914-2006	5km, 25km, Region	5km, Region	5km, Region
Minimum air temperature	1960-2006	1914-2006	5km, 25km, Region	5km, Region	5km, Region

Mean air temperature	1960-2006	1914-2006	5km, 25km, Region	5km, Region	5km, Region
Days of air frost	-	1961-2006	5km, 25km, Region	5km, Region	5km, Region
Days of ground frost	-	1961-2006	5km, 25km, Region	5km, Region	5km, Region
Sunshine duration	-	1929-2006	5km, 25km, Region	5km, Region	5km, Region
Total precipitation	Note 1	1914-2006	5km, 25km, Region	5km, Region	5km, Region
Days of rain >= 1mm	-	1961-2006	5km, 25km, Region	5km, Region	5km, Region
Days of rain >= 10mm	-	1961-2006	5km, 25km, Region	5km, Region	5km, Region
Days of sleet or snow falling	-	1971-2000	-	5km, Region	5km, Region
Days of snow lying	-	1971-2006	-	5km, Region	5km, Region
Mean wind speed	-	1969-2006	-	5km, Region	5km, Region
Mean sea-level pressure	-	1961-2006	5km, 25km, Region	5km, Region	-
Mean relative humidity	-	1961-2006	5km, 25km, Region	5km, Region	5km, Region
Mean vapour pressure	-	1961-2005	5km, 25km, Region	5km, Region	-
Mean cloud cover	-	1961-2004	5km, 25km, Region	5km, Region	-

2. Annual climate variables

Climate Variable	Period	1961-1990	1971-2000
Heating degree days	1961-2006	5km, Region	5km, Region
Cooling degree days	1961-2006	5km, Region	5km, Region
Growing degree days	1961-2006	5km, Region	5km, Region
Extreme temperature range	1961-2003	5km, Region	5km, Region
Growing season length	1961-2003	5km, Region	5km, Region
Summer heat wave duration	1961-2003	5km, Region	5km, Region
Winter heat wave duration	1961-2003	5km, Region	5km, Region
Summer cold wave duration	1961-2003	5km, Region	5km, Region
Winter cold wave duration	1961-2003	5km, Region	5km, Region
Consecutive dry days	1961-2004	5km, Region	5km, Region
Greatest 5-day precipitation	1961-2004	5km, Region	5km, Region
Rainfall intensity	1961-2004	5km, Region	5km, Region

Gridded climate data are available for daily, monthly and annual timescales, as well as long-term averages for the 1961–1990, 1971-2000, and 1981-2010 climate baseline periods. Baseline averages are also available at 25 × 25 km resolution (to match the UKCP09 climate

change projections) and as regional values (Table 7). The availability of daily and monthly data varies with different measurements. The policy for adding more gridded data, e.g. for years after 2006, is under discussion. Users can contact the Met Office Customer Centre about the provision of gridded data for recent years and any associated costs.

The [Central England Temperature series (HadCET)](#) and the [United Kingdom Precipitation series (HadUKP)](#) have been developed to study changes in our climate. They are calculated using a limited set of carefully selected stations so that the data are comparable over time (Parker & Horton, 2005).

The HadCET series are representative of an area from the south Midlands to Lancashire. Series are created for maximum, minimum and mean temperature - both daily and monthly. The HadUKP series is available for the combined area of England and Wales; five sub-regions of England and Wales; Scotland; three sub-regions of Scotland; and Northern Ireland.

Weather and climate has substantial impact on our lives. For example, hours of sunshine could indicate potential vitamin D from sunlight and amount of sunshine might also have an influence on physical activity and subjective well-being. Therefore linking weather data to cohort studies provides an opportunity to investigate potentially long-term effects of weather on people's health and well-being.

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