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ORIGINAL ARTICLE

Spatially explicit analyses of environmental and health data to determine past, emerging and future threats to child health

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Background: Dire forecasts predict that an increasingly hostile environment globally will increase the threats to human health. Infants and young children are especially at risk because children are particularly vulnerable to climate-related stressors. The childhood diseases most affected, the breadth and magnitude of future health problems and the time frame over which these problems will manifest remain largely unknown.

Objectives: To review the possibility that spacially explicit analyses can be used to determine how climate change has affected children's health to date and whether these analyses can be used for future projections.

Methods: As an example of whether these objectives can be achieved, all available Australian environmental and health databases were reviewed.

Results: Environmental and health data in Australia have been collected for up to 30 years for the same spatial areas at 'Statistical Area level 1' (SA1) scale. SA1s are defined as having a population of between 200 and 800 people and collectively they cover the whole of Australia without gaps or overlap. Although the SA1 environmental and health data have been collected separately, they can be merged to allow detailed statistical analyses that can determine how climate change has affected the health of children.

Conclusions: The availability of environmental and health datasets that share the same precise spatial coordinates provides a pathway whereby past and emerging effects on child health can be measured and predicted into the future. Given that the future health and well-being of children is one of society's greatest concerns, this information is urgently needed.

Key words: child health; climate change; geospatial.

What is already known on this topic

1 Although children are expected to bear the health burden of climate change, little is known about how climate change has affected children to date.
2 We need accurate measurements to show how climate change and environmental degradation has affected children's health so far, and how it will affect child health in the future.

What this paper adds

1 Provided that environmental and health data are collected longitudinally for the same spatially explicit areas, the effects of climate change on child health can be determined.
2 Spatial modelling is required to detect emerging health problems and predict how these problems will increase without adequate mitigation.
3 Nations that collect spatially explicit environmental and health data can do world-leading research on climate change and child health.

Background

Children will bear the highest health burden from climate change

The greatest threat to child health in the future will come from environmental degradation, including anthropogenic climate disruption and the associated increases in ambient temperature, as well as deteriorating air quality, increases in heatwave frequency and magnitude, more frequent severe weather events, changes in the ranges of infectious diseases and their hosts and higher incidence and severity of zoonotic diseases.[1–4] These issues are expected to degrade child health in many ways, with several studies over the last 30 years confirming that aspects of climate change are already increasing infant mortality and disease prevalence during childhood. However, this information is fragmentary, such that we still have only a vague picture of which childhood diseases will be affected by environmental change, as well as the magnitude and timescale of these anticipated effects.[3] Given that one of the greatest concerns young people have today

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is how climate change will affect them, their children and their grandchildren,[5] research that can provide reliable insights should be one of our greatest research priorities.

Environmental damage and its effects on child health

The major damage to our planet already done by humans[6] is severely compromising not only natural ecosystems, but human rights, health, well-being and wealth. This damage is reflected in the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC AR6) published in August 2021[7]; the IPPC AR6 underlines the dire future facing our planet's environmental health and gives strong warnings about the likely implications for human health. Despite these issues being presented at the Paris Climate Change meeting in 2015,[8] there has been no discernible reduction in global greenhouse-gas emissions. Some of most reliable data on CO_2 emissions comes from the Commonwealth Scientific and Industrial Research Organisation's Cape Grim environmental station[9] located in the north-west of Tasmania. Cape Grim samples perhaps the freshest air on the planet, as the incoming air has travelled across the vast Southern Ocean with no cities or civilisations for tens of thousands of kilometres upwind. As of August 2021, the rate of increase of CO_2 concentration since 2015 has not deviated from the prior rate of increase or from the effects of COVID-19 (Fig. 1).[9] With no discernible reduction in emissions, and global population growth continuing at the same rate for the last two decades at over 80 million/year[10] with no sign of slowing, the future of the planet and of the health of children in the future is of grave concern. Unless immediate action is taken to curb emissions, we may not be able to avoid passing the 'tipping point'[11] where the global environment continues to deteriorate even if fossil-fuel emissions stop.

Ambient temperature increase has already caused major damage to the global environment and ecosystems,[4] and is expected to be one of the strongest factors affecting the health of children.[5–7,12] Increased temperature is expected to reduce the diversity of the global microbiome, which will in turn damage all other global ecosystems.[8] The impact of these problems will be substantial – global temperatures are anticipated to increase by at least 2°C over the next 50 years[4,9] and for parts of Australia to between 1.5°C and 2.5°C for 2030–2059[10] and 1.75°C and 4.5°C by end of this century.[4] The most troubling data regarding temperature come from a recent study in Africa suggesting that over the last 30 years, the largest impact on infant mortality is from increases in ambient temperature.[12] Although the drivers of this relationship are not clear, the magnitude of the relationship (increase of ~20 deaths/1000 children/°C) should raise serious concerns for the rest of the world.

Heat waves are also a threat to children's health, with the greatest effects likely to be seen in low- and middle-income countries. But increases in child health problems during heatwaves have even been reported in high-income communities including South Australia where increases in admissions and child mortality were observed,[13] and in California where there were increases in early and preterm births.[14]

Air pollution also erodes child health, with satellite-derived data showing that a 10 μg/m^3 increase in PM2.5 concentration is associated with a 9% (95% confidence interval: 4–14) rise in infant mortality in 30 sub-Saharan countries, with 22% of deaths in this age group (449 000 deaths in 2015) attributed

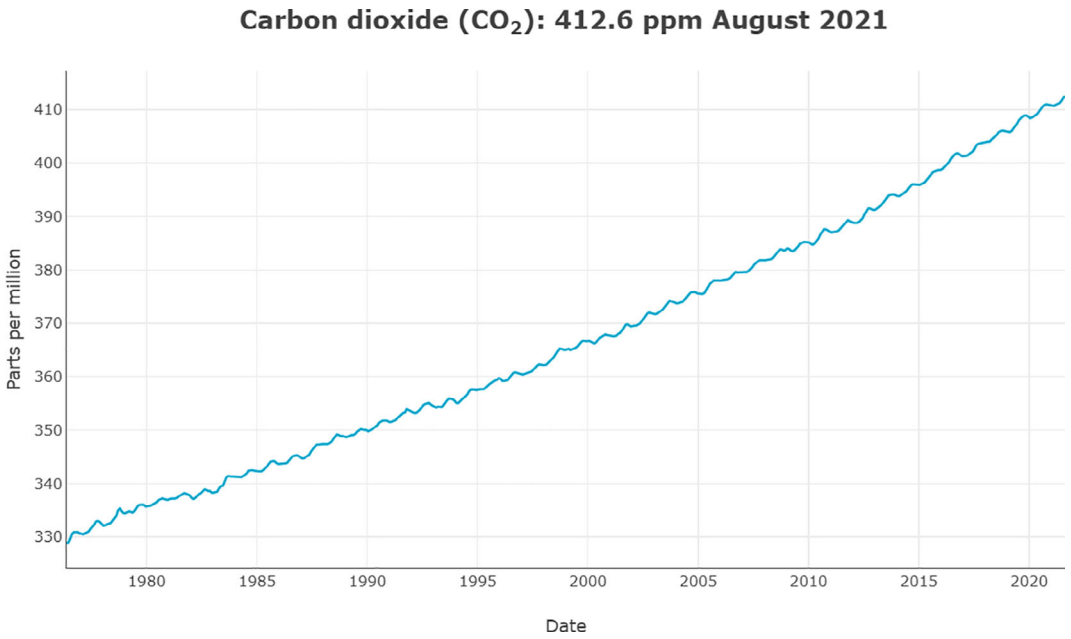

Fig 1 Atmospheric carbon dioxide concentration from the Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) sampling station at Cape Grim, located in the north-west of Tasmania.[9] No obvious deviation in concentration is evident after the Paris Climate Change meeting or from the effects of COVID-19 from early 2020 onwards. (Graph obtained from CSIRO, with permission.)

to air pollution there.[15] This problem will worsen as air pollution deteriorates, not only due to continuing release of pollutants, but also due to climate change causing air stagnation, especially in the tropics.[14] Air pollution has also been associated with increases in disease risks in children[16] and in asthma in children.[17] Air pollution increases the risk of low birthweight and preterm birth.[18]

Atmospheric carbon dioxide concentrations are likely to reach a scale that is toxic to all mammals (including humans) this century. The current global concentration of >400 ppm and still rising is well above the 250 ppm concentration that mammals have experienced over the last few hundreds of millennia. A recent study exposing pregnant mice and their newborn to concentrations of just below 900 ppm found higher tissue elastance, longer chord length and lower lung compliance in the offspring.[19] The IPCC Shared Economic Pathway 6 will approach these CO_2 concentrations and Shared Socioeconomic Pathway 8.5 will pass them by the end of this century.[20]

Environmental degradation drives poorer child health in Africa.[21] Low- and middle-income countries are likely to manifest closer links between environmental integrity and child health than high-income countries,[2] but environment in wealthy countries is still likely to be linked to health and well-being in children through such processes as access to green space and the microbiome benefits of exposure to nature.[22]

Infectious diseases: As climate change increases temperature and moves rainfall away from the Equator, the prevalence of infectious diseases will likely increase with expanding ranges of their vectors.[4] For example, Lyme disease is now found in Canada due to the increased northerly movement of its tick vectors.[23]

Other environmental factors that could affect child health by altering local environments include rainfall, humidity and the dryness index (temperature-vegetation-soil moisture dryness index), but there are few data to determine the possible effects of these; extreme weather events will affect children most likely disproportionally.[24]

Methods

Spatial studies investigating climate change and child health

The basic premise behind spatially explicit studies examining the linkages between climate change and human health is to investigate environmental variables and health impacts in the same well-defined locations. The reliability of these studies is enhanced if: (i) the area of the location is small and the number of locations is high; (ii) there is wide variation in the range of environmental variables; (iii) all variables are collected longitudinally over a timespan long enough for there to be a measurable and meaningful change in the environment; (iv) the environmental changes in the locations assessed vary among different locations; and (v) the health data collected provide an reliable record of the diseases in each location and the precise location where each individual lives.

A few countries have prospectively collected data on both environmental conditions and human health for several decades. Environmental data are collected from weather stations strategically placed across the country, as well as geostationary weather satellites – these often measure ambient temperature, extreme weather events, heatwaves, air pollution, bushfires, rainfall, humidity and the dryness index. Health data come from a variety of sources, with the best information likely to come from nationally or regionally coordinated health services.[25] These data typically include hospital presentations and admissions where each patient's address, location coordinates and comprehensive clinical details, including diagnosis and length of stay. The raw environmental and health data collection is typically the responsibility of two different government bodies and might not apply the same spatial delineations to store the information collected. However, in some cases the information has been segregated into the same spatial units (i.e. from known, well-defined areas) so that the environmental and health data for each location can be merged into one data set, and covariation in

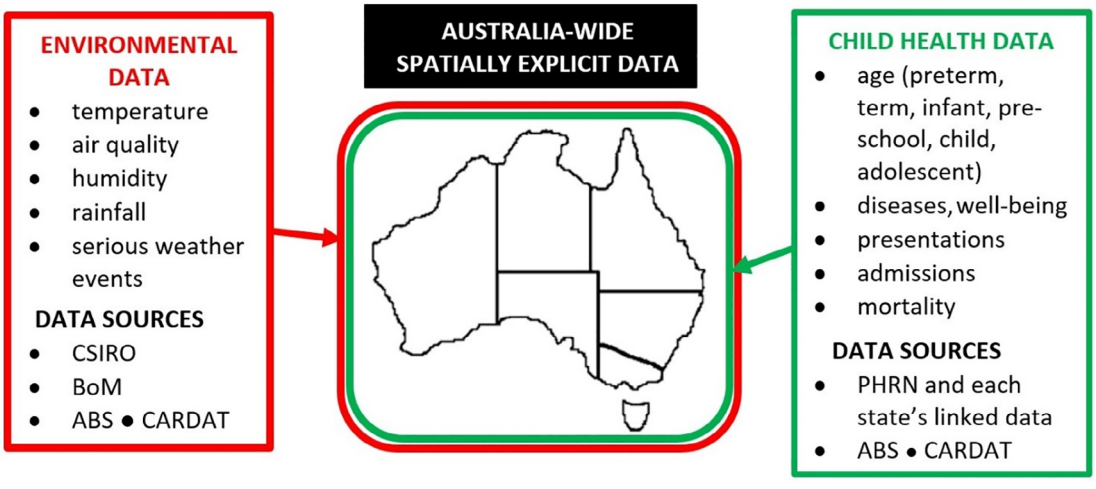

Fig 2 Data sets available at the spatial scale of Statistical Area level 1 can be used for climate change and child health research. ABS, Australian Bureau of Statistics; BoM, Bureau of Meteorology; CARDAT, Centre for Air pollution, Energy and Health Research Data and Analysis Technology; CSIRO, Commonwealth Scientific and Industrial Research Organisation; PHRN, Population Health Research Network.

environmental and health variables can be identified. Since climate change is not uniform for different locations,[26] climate variables can be examined for their relationships with specific diseases, provided a multivariate approach is used to account for the collinearity in most environmental variables. Given the organisation and expense required to assemble detailed data sets over several decades, few countries have suitable data sets available.

Results

Australia as an example nation with environment and health data collected in the same defined locations

Nationwide, spatially explicit data on environment and health have been collected for over 30 years in several broad locations, but for over a decade across the whole country. As summarised in Figure 2, Australia's environmental agencies: the Commonwealth Scientific and Industrial Research Organisation,[27] Bureau of Meteorology,[27] Australian Bureau of Statistics[28] and the Centre for Air pollution, Energy and Health Research Data and Analysis Technology,[29] have collected extensive, Australia-wide, spatially explicit environmental data on the most important aspects of climate change (including temperature, air pollution, humidity, rainfall, serious weather events and bushfires), and each Australian state has collected health data overseen by the Population Health Research Network[25] (including hospital presentations and admissions, mortality, birth, preterm delivery, birthweight, diagnosis, age, clinical information and coordinates of home addresses) from the same spatial locations. The spatial areas 'Statistical Area level 1' (SA1) are defined as: 'SA1s have generally been designed as the smallest unit for the release of data from the Australian Bureau of Statistics' Census of Population and Housing. SA1s have a population of between 200 and 800 people with an average population size of approximately 400 people'.[30] There are 57 523 SA1s that cover the whole of Australia without gaps or overlaps. SA1 data can be spatially merged so that the effects of environmental change on child health can be determined for each location or region in Australia.

Discussion

Climate change research opportunities in Australia – past, emerging and future

Australia is in an ideal position to be able to determine the physical diseases and mental health issues in children who have already been affected by climate change. In states such as Western Australia, where spatially explicit health data go back for over 30 years,[25] the opportunity is available to establish a reliable overview of the effects of climate change on child health and well-being. Such a comprehensive analysis has not been done anywhere at such a fine scale. For Australia, analyses can be done for at least 10 years for the whole country at an SA1 level. Given that climate change will exert the greatest threat to children's health in coming years,[31,32] ongoing monitoring of the Australia-wide data will allow the emerging effect of climate change on child health to be monitored, providing information that has the potential to be used in mitigation strategies. Future predictions of disease burdens can also be modelled using forward projections of climate and population demography.

Conclusion

In summary, we still have a poor grasp of how climate change has affected children's health. Spatial analyses provide the opportunity to assess how environmental change has already affected children's health and well-being over the last few decades, and ongoing monitoring will allow monitoring of the changes in disease characteristics and burden. Since the data sets for these analyses are already available and will be continued into the foreseeable future, this valuable information can be relatively easily and economically derived.

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Little Red Riding Hood by Kara Thomson (12y) from Book Covers exhibition, Children's Hospital at Westmead