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1 Planetary health in action: developing a heatwave vulnerability tool for primary care

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26 Abstract 250 words

27 Background: Heatwaves are becoming longer and more frequent. Despite the availability of
28 open environmental data, little is operable and formatted for primary care use.

29 Aim: Create a user-friendly online mapping tool to assess the vulnerability of communities to
30 heatwaves for use by primary care practitioners. This study questioned *what* knowledge
31 needed to be deployed, *who* needed to participate and *how* the knowledge should be shared.

32 Design and Setting: A participatory action-research project based on knowledge mobilization in
33 France as part of the Green Data for Health Challenge.

34 Method: Knowledge was summarized on the factors most affecting heatwave vulnerability in a
35 collaborative process, enabling a consensus on data variables and mobilised content for the
36 online tool. Purposive sampling included primary care stakeholders with Regional Health
37 Agencies (ARS), Public Health France, and data scientists.

38 Results and Conclusion Nineteen participants participated in ten co-construction workshops, a
39 brainstorming carousel strategy and five weekly co-design meetings between December 2022
40 and June 2023. The heatwave vulnerability variable was constructed using surface temperature,
41 social deprivation, vegetation coverage, and presence of air conditioning equipment. Identified
42 experts mobilized data on the national composite indicator at the communal level for heatwave
43 morbidity. There is no standard platform for sharing environmental data in France. This co-
44 creation study offers a new approach to incorporating environmental data on heatwaves into
45 primary care consultations. We demonstrate the importance of knowledge mobilisation in
46 primary care to bridge the research-practice gap. Integrating primary care records with
47 environmental data may promote broader applications for planetary health research.

48

49 Keywords (MeSH – 6): primary health care, general practice, environmental health, mapping,
50 extreme heat

51 HOW THIS FITS IN

52 Heatwaves are becoming longer and more frequent, and the cause of an estimated 33'000
53 deaths in France 2014-2022. Primary care clinicians must be aware of the risks, yet heatwave
54 vulnerability tools are often directed at urban planners. We present action-research project
55 that developed an online tool for GPs in France to assess heatwave vulnerability. This is an
56 example of applying environmental data for clinical primary care, opening the door for other
57 uses for planetary health.

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74 *Background*

75 Planetary health can be defined as *‘the health of human civilization and the state of the natural*
76 *systems on which it depends’* in a transdisciplinary, solutions-oriented social movement (1). An

77 estimated 23% of global deaths can be attributed to the environment (2). The

78 Intergovernmental Panel on Climate Change (IPCC) estimates that the average global

79 temperature increased by 1.09°C, comparing 2011-2020 to the pre-industrial period (1850-

80 1900)(3). Regardless of emission scenarios, global warming could reach +1.5°C by the 2030s.

81 This overall temperature increase results in significant local temperature differences. In Europe,

82 the average surface temperature has risen by 2.2°C since the pre-industrial era (1850-1900),

83 twice the global average. This leads to longer, more intense and more frequent heatwaves,

84 alongside extreme weather events such as droughts and wildfires (3). A heatwave is a

85 prolonged period of exceptionally hot weather compared to the typical conditions for that time

86 of year, often accompanied by elevated humidity. Heatwaves caused an estimated additional

87 33,000 deaths in France during the summers 2014-2022 (4, 5,6)). Three heatwaves occurred in

88 2022, leading to heatwave alerts in 69 French departments, covering 77.8% of the population.

89

90 The World Health Organization (WHO) and IPCC emphasize the need for a holistic and cross-

91 sectoral approach to address climate change challenges (3). The Physiological Society

92 consensus statement, Roadmap for Global Heat Resilience, reinforces the need for enhanced

93 collaboration with transdisciplinary approaches by creating networks to facilitate the exchange

94 of ideas and practices for heat resilience and facilitate knowledge sharing (7). A first step is to

95 identify vulnerable populations and target local-scale interventions, with an important role for

96 local actors including healthcare professionals (8). There is a lack of knowledge among doctors

97 regarding planetary health, the effects of climate change and heat (9). Sixty-eight percent of

98 surveyed French general practitioners (GPs) were unaware of heatwave recommendations

99 (10). Only 20% of doctors reported monitoring high-risk patients more frequently during
100 heatwaves. Despite 93% of GPs believing they play an important role in informing their patients
101 about environmental risks, only 55% felt capable (11).

102

103 How can we apply environmental data to primary healthcare? Huge amounts of environmental
104 data are already available, often with easy and free access. Internationally, various databases
105 exist: the New Jersey Environmental Public Health Tracking (EPHT) Network in the United States
106 (12) and, in Europe, the Environmental and Health Information System (13). There are
107 numerous public open databases for the French territory, such as Public Health France GeoData
108 “GEODES”(14) and Interregional health informatics system “SIRsÉ”(15). However, these
109 datasets are often independent and isolated, leading to a lack of standardization and
110 interoperability, and not intended for use by clinicians (16,17). These challenges in using
111 environmental data led to the development of an initiative to share environmental data for
112 health, known as the Green Data for Health, led by the fourth National Environmental Health
113 Plan of the French government (18). We describe this knowledge mobilisation (KM) process:
114 how to optimise the use of knowledge and how to disseminate and apply this research to a
115 concrete action in practice (19).

116 The aim of this study was to create a user-friendly online mapping tool to assess the
117 vulnerability of communities to heatwaves for use by primary care practitioners.

118

119 **Methods**

120 *Context*

121 The action-research took place December 2022-June 2023 in France. The study was based on
122 participatory methods in KM (19,20) within the context of a “Green Data for Health Challenge”

123 launched by the French government in October 2022 to produce new tools to better mobilise
124 environmental data for health use (18). The challenge included a national call to action survey,
125 from which our project was selected. The study is reported in line with the Checklist for
126 Assessing Quality in Action research (21).

127 *Recruitment*

128 The emphasis was on collective making in co-design with the end users. The project stems from
129 a “bottom up” model: the initial idea was submitted by the GP and public health team (KG, PBB,
130 FC, GM), who are both researchers and participants in this participatory project. Early
131 engagement from academics and clinical stakeholders are prerequisites to achieve impact in
132 KM (22). The initial researchers and the facilitator were all experienced in co-creation. Further
133 participants were included during the iterative process. Maximum variation purposive sampling
134 involved selecting participants with different roles to actively contribute to the design process,
135 ensuring variability between primary care, public health, data scientist and technical roles.
136 Workshops were virtual video meetings considering the participants geographical location.

137 *Preparation*

138 A literature review in December 2022 using Pubmed and Medline on heatwaves, morbidity and
139 mortality and risk factors guided the co-creation workshops (Supplementary Data). The
140 carousel strategy (23), kickstarted the process and identified four questions to address (Box 1).

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Box 1: Four questions identified to address during knowledge mobilisation (KM)

1. *What data is available to measure the impact of heatwaves on human morbidity and mortality pertinent to primary care use?*
2. *Which indicators are available to model the vulnerability of the French population to heatwaves?*
3. *What team members and roles are needed to co-create this tool online?*
4. *What platform is best to share this tool to reach primary care stakeholders in France and how do we evaluate the use?*

Action

There was a constraint of a 2-month “tool production” window April-May 2023. We incorporated a creative co-design in an iterative, collaborative process to generate solutions and design the mapping tool. Weekly co-creation workshops permitted iterative feedback to define the format and content of the online tool within this short timeframe. The challenge facilitator provided momentum and initiated interdisciplinary contacts.

National data sources from metropolitan France were used. The commune is the smallest administrative unit, usually covering a small area (mean 14.9km²) but with a variable population size (range 500 -to large cities). Population size in each of the 95 metropolitan departments ranges from 76000- >2 million (25).

Data collection and analysis of the knowledge mobilisation process

Data collection included online transcriptions and field notes from ten preparatory reunions, a group brainstorming carousel session and five co-creation workshops, totalling 23 hours of observation. The co-researchers used a “memoing” technique, operational memos described observations, rationale and actions and analytical memos explored hypotheses and relationships (24). Summaries were circulated using an online data-sharing forum called Slack,

170 allowing modifications and comments. The co-researchers (as both participants and
171 researchers) maintained a reflexive position.

172 *Funding and ethics*

173 The facilitator, experts and data scientists were provided by the challenge. No extra funding
174 was available. This study was performed in accordance with the Declaration of Helsinki and all
175 participants provided informed consent to participate in the Data Challenge.

176

177 **Results**

178 Table 1 demonstrates participant characteristics. There was overlap between the roles, e.g. GP
179 researcher but also future user. This co-creation group addressed four questions in the
180 development process. Responses are discussed below with examples from the data collected
181 from the workshops (Table 2).

182 **1. What data is available to measure the impact of heatwaves on human morbidity and** 183 **mortality pertinent to primary care use?**

184 Quantifying heat-related mortality and morbidity is complex. Because heat has multiple effects
185 on health, it is not possible to identify heat-attributable deaths in real-time based on a
186 predefined single cause of death (4). When mapping small numbers of cases on small
187 geographic units there is a risk of overestimating spatial heterogeneity, leading to significant
188 variations induced by statistical noise. Death certificates are not always reliable. Public Health
189 France monitors the impact of heatwaves and provides mortality data at the departmental level
190 (GEODES)(14). Mortality data at the communal level is not available.

191 The discussions identified the lack of heatwave-related morbidity data. Therefore, a Public
192 Health France epidemiologist was recruited to the following workshop. We identified the public
193 health need for a national composite indicator at the communal level for heatwave morbidity:

194 based on the number of emergency department visits and emergency GP visits for
195 hyperthermia, heatstroke, dehydration, and hyponatremia. (Figure 1). This “iCanicule” indicator
196 was produced by Public Health France.

197

198 **2. Which indicators are available to model the vulnerability of the French population to**
199 **heatwaves?**

200 A literature review elicited numerous factors that influence population vulnerability to
201 heatwaves. The workshop identified the need to recruit an expert epidemiologist. The
202 discussions reached a consensus that apart from temperature, four further factors should be
203 included: urbanisation, vegetation coverage, air conditioning and socio-economic status (Table
204 3). The choice of a communal-level resolution was influenced by data availability. The
205 construction of the indicators is explained in further detail in the data paper (26).

206 There are numerous sources of land and air temperatures. We reached a consensus to use
207 satellite-related daily mean temperature at the communal level (34).

208 There is a protective effect of vegetation (27). The integration of the proportion of artificial and
209 non-vegetated surfaces (Corine Land Cover) incorporates this effect in the vulnerability index
210 calculation (28).

211 Access to air-conditioned space is linked to heatwave vulnerability (29). French data on the
212 presence of an air-conditioning unit is available by commune (30).

213 The link between heatwaves and social deprivation is known (31,32). Data on unemployment
214 rates, education attainment and poverty rates are available at the communal level (15). We
215 used a French social deprivation score, FDep, correlated with the total mortality rate (33).

216

217 **3. What team members and roles are needed to co-create this tool online?**

218 An iterative approach was used: The co-researchers recognised the need to break the project
219 down into multiple stages and recruit specific roles. Purposive sampling included data
220 scientists, geomericians, and statisticians (Table 1). Interactions took place through one hour
221 weekly remote meetings over five weeks using the software programme Slack. At each meeting
222 there was a systematic sharing of progress before setting the goals to be achieved for the
223 following week. Each team member was assigned a specific task to complete in the coming
224 week on a voluntary basis (Table 2).

225

226 **4. What platform is best to share this tool to reach primary care stakeholders in France and** 227 **how do we evaluate the use?**

228 There is no standardized platform for online tools for primary care in France. The open access
229 heat vulnerability indicator map and iCanicule indicator was made available on SIRSé.fr on
230 5/06/2023 (15). The link was shared via GP networks. Initial feedback was obtained from one
231 focus group of users in March 2024 to test the site with ten GPs from two multidisciplinary
232 practices in the south of France. It was facilitated by one of the authors (KG) with a simple
233 interview guide with open-ended questions about their experiences with managing heat-
234 related illnesses and opinion of the mapping tool and relevance to medical practice. Feedback
235 included that the site at a national level was informative, and coherent to compare between
236 departments, but less useful at the local scale. The map scale was only at communal level, and
237 *“needed to be more precise, at the street level”*. The GPs were interested in more precise
238 morbidity and mortality data, which is not yet available, and the relation to other clinical data.
239 Other doctors suggested that mapping other environmental variables, not only heatwaves and
240 heatwave vulnerability, could be useful to better understand the specific risks in each territory.
241 Further in-depth interviews and focus groups and formal qualitative analysis could explore the

242 impact of this mapping tool on medical practice. Further quantitative evaluation will include the
243 number of users.

244

245 **Discussion**

246 Summary

247 An online mapping tool for heatwave vulnerability was successfully developed that incorporates
248 variables for surface temperature, social deprivation, vegetation coverage, and air conditioning
249 equipment (26). It was developed with and for primary care stakeholders in a collaborative
250 process with Regional Health Agencies (ARS), Public Health France (SPF), and data scientists.
251 Knowledge was synthesised on the factors most affecting heatwave vulnerability, enabling a
252 consensus for the choice of indicators and mobilised content for the online tool (15).

253 This co-creation study offers a new approach to including environmental data on heatwaves into
254 the primary care consultation, going beyond sparse existing educational interventions for
255 patients and primary care professionals. This study questioned *what* knowledge needed to be
256 deployed, *who* needed to participate and *how* the knowledge should be shared. Responses to
257 these questions were elicited through co-creation workshops and online discussions.

258

259 Strengths and limitations

260 Mapping tools provide a quick visual summary to improve understanding of heatwave
261 vulnerability. Our tool enables comparisons at a small communal scale. Due to the iterative
262 process and purposive sampling, the co-construction team was varied, with data science and
263 cartography experts. KM encouraged collaboration, flexibility and pragmatism and objectives
264 evolved according to methodological constraints. The difficulties in KM are well-known, notably
265 the challenges and time constraints in bringing stakeholders together (22). All workshops were

266 online, however facilitation and online software programs maintained momentum and
267 encouraged team participation.

268 The research methodology chosen was the most feasible with the time constraints and resources
269 available. Other possible methods include systematic literature review or Delphi consensus.

270

271 Comparison with existing literature

272 Our heatwave vulnerability tool was based on previous studies using a mapping tool (37). The
273 city of New York have published an online interactive index for each neighbourhood including
274 the average daily temperature during heatwaves, access to air-conditioned space, the rate of
275 green spaces, the percentage of inhabitants living below the threshold of poverty and the
276 percentage of black residents. (38)

277 Population density is a significant exposure factor. It is directly correlated with urbanization
278 and the "urban heat island" effect (39). Surface temperature, theoretically higher in more
279 urbanized areas, directly represents this phenomenon. A European Lancet report identifies two
280 indicators: 1. vulnerability to heat exposure that includes : percentage of adults >65 years old,
281 live in urban areas and have a chronic disease (diabetes, cardiovascular, respiratory or kidney
282 disease) and 2. exposure of vulnerable populations to heatwaves, defined as people >65 years
283 and infants <1 year (40).

284 The final selection of indicators was based on data availability. We did not integrate individual
285 risk factors for heat mortality identified by epidemiological studies (41–43). For example, the
286 standardised prevalence of people treated for chronic conditions is only published at the
287 departmental level. Additionally, data on ethnicity and race cannot be collected in France (44).

288 We constructed a composite index using equal weights for each indicator, as in previous studies
289 modelling heatwave vulnerability (38). However, this does not allow indicators to be weighted
290 to their probable impact, which requires additional study.

291 We demonstrate successful KM in primary care. A key facilitator of KM are integrated care
292 records; updating local information in real-time into primary care records, such as the United
293 Kingdom Clinical Practice Research Datalink (19). A French equivalent, Platform for Data in
294 Primary Care (P4DP), is currently being deployed in French primary care. The next step is to
295 integrate inter-operable environmental variables into care records, using clinical data alongside
296 the heatwave vulnerability index.

297

298 Implications for research and practice

299 Harnessing a diverse range of environmental data, not only on heatwave vulnerability, could
300 guide primary care professionals and patients. Implications for primary care practice include
301 enhancing preventive care, personalising risk assessments and targeted interventions to combat
302 health disparities and improving community health interventions, education and advocacy (45).

303 We demonstrate the importance of KM in primary care to bridge the research-practice gap.
304 However, future studies are needed to improve spatial resolution. Primary care centres are
305 grouped into territorial areas in France and are not aligned to other communal maps. Presenting
306 the information at a level politically relevant would guide healthcare professionals to perform
307 environmental health territorial diagnostics and improve patient interventions. Further studies
308 are needed to integrate environmental data directly into care records, allowing healthcare
309 professionals to better understand local heatwave vulnerability and prevent heatwave-
310 associated morbidity and mortality.

311

312 **Additional information**

313 Funding: this study was undertaken within the context of a “Green Data for Health Challenge”

314 Competing interests: the authors declare no competing interests.

315 Data availability: The datasets used and/or analysed during the current study are available from
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453 List of tables and figures:

454 Table 1: Participant characteristics

455 Table 2: Details of co-creation workshops

456 Table 3: Variables included in the vulnerability score that can influence heat wave related

457 morbidity mortality

458 *NB All variables at the “commune” level, the smallest administrative unit in France*

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462 Figure 1: Heatwave vulnerability map

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464 *1= iCanicule indicator: number of emergency department and emergency GP visits for heatwave*
465 *morbidity: based on the number of emergency department visits and emergency GP visits for*
466 *hyperthermia, heatstroke, dehydration and hyponatremia. Canicule is the French term for*
467 *heatwave.*

468

469 *2= Heatwave vulnerability Index: Composite indicator of 4 variables (FDep, Corine Land cover rate,*
470 *average summer surface temperature, rate of equipment of residential buildings with air*
471 *conditioning)*

472 *Available at: sirse.atlasante.fr [\(12\)](#)*

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Workshop	Time	Discussions/ tasks:
Carrousel	4h	In 4 parts: <ol style="list-style-type: none"> 1. Pitch – define objectives and questions to address. 2. Subject pertinence and generalisability 3. Method Feasibility: identify the needs, tools, software, personnel. 4. Data availability and data quality: identifying potential issues in advance.
Workshop 1	1h	Discussion on indicators, source Decision to use France communes as mapping scale.
Workshop 2	1h	Temperature data extraction, decision to use satellite data. Inclusion of data on buildings equipped with air conditioners. How to deal with missing data from the sociological variable FDep? How to take into account vegetation land cover?
Workshop 3	1h	Satellite temperature data extraction
Workshop 4	1h	Corine Land Cover, calculation of Z scores
Workshop 5	1h	Calculation of final score

Table 2 Details of co-creation workshops

Role	Gender	Age Range
Practice coordinator + future user	M	30-44
General Practitioner, clinical and academic roles, + future user	M	30-44
	F	30-44
	F	30-44
General practitioner trainees + future user	F	18-30
	M	18-30
Public Health Doctors	M	30-44
Data scientist	F	18-30
	F	18-30
	F	18-30
	F	18-30
Data Analyst	F	18-30
	F	18-30
Facilitator, epidemiologist	M	30-44
Geometrician	F	18-30
Regional Health department sanitary engineer and project leader	F	45-60

Project leader for the national mapping tool AtlasSanté	F	30-44
Health geographer	F	30-44
	M	30-44

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Variable	Source	Date stamp
<p>French Deprivation Index, FDEP</p> <p>A score that includes information on: unemployment rates and the percentage of blue collar workers in the active population 15-64 year olds, the percentage of high school graduates in the population aged 15 years and older and the median household income.</p>	INSERM, CépiDC	2015*
Mean daily surface temperature	Copernicus Climate Data Store	Mean June-July-august 2022
Percentage of primary residences equipped with an air conditioning unit	BDNB National Building Database from INSEE	2022*
<p>CORINE Land cover</p> <p>This database, created by the European Environment Agency, divides each 25-hectare square into 44 land use classes using satellite data and aerial photos.</p>	European Environment Agency's Copernicus Land Monitoring Service	2018*

Table 3: Variables included in the vulnerability score that can influence heat wave related morbi-mortality,

NB All variables at the "commune" level, the smallest administrative unit in France

*The latest available year was included.

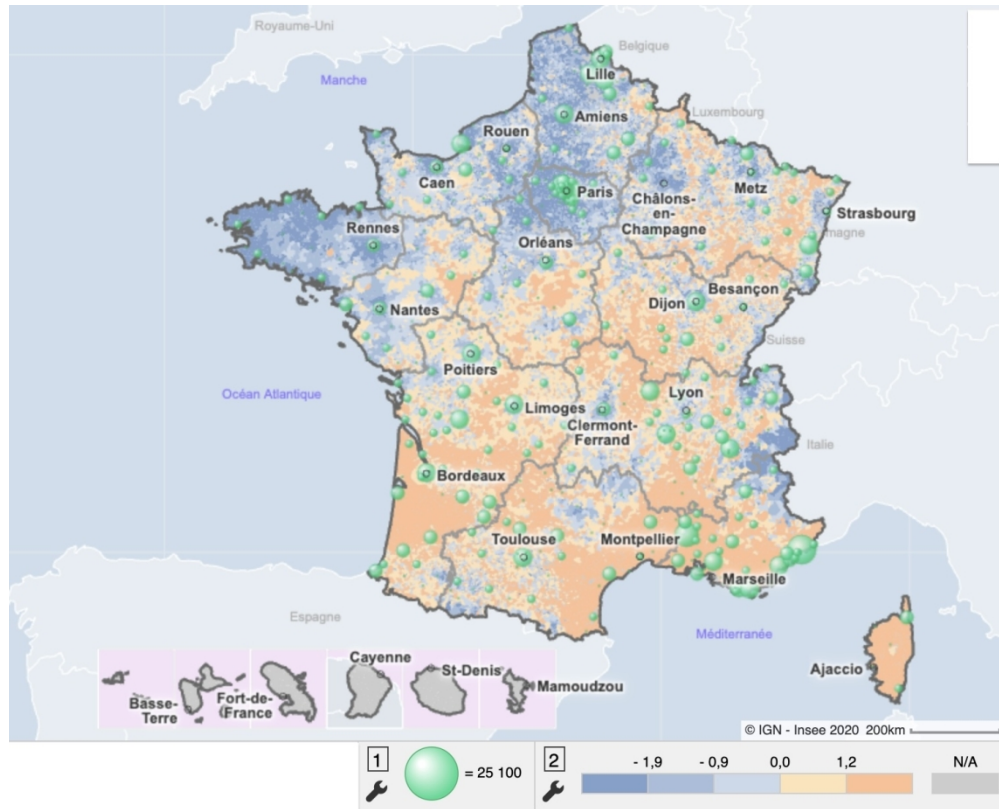


Figure 1: Heatwave vulnerability map, 1= iCanicule indicator: number of emergency department and emergency GP visits for heatwave morbidity: based on the number of emergency department visits and emergency GP visits for hyperthermia, heatstroke, dehydration and hyponatremia.
 2= Heatwave vulnerability Index: Composite indicator of 4 variables (FDEP, Corine Land cover rate, average summer surface temperature, rate of equipment of residential buildings with air conditioning)
 Available :at sirse.atlasante.fr (12)

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