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Valuing climate information in context

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Developing usable climate information requires a profound understanding of the context in which information is expected to be used. However, revealing how contexts shape the use of climate information is a cumbersome task. Against this, we propose an alternative approach which focuses on understanding how prospect climate information users construct evaluative criteria to assess the use of climate information for planning and policy making.

Based on empirical observations stemming from three local governments, our research suggests that evaluative criteria respond to the same set of formal and informal normative frameworks that orient the performance of work. These normative frameworks define what counts as legitimate and desirable action. Such frameworks operate through dominant institutional narratives that shape how climate risks are interpreted, what knowledge is considered credible, and which practices are seen as appropriate. As a result, certain uses of climate information appear natural and legitimate, while others remain difficult to pursue. Connecting climate information use with political, strategic, and operational agendas is critical for its uptake, as decisions about the use of climate information often involve balancing what is politically acceptable, technically feasible, and strategically desirable. These dynamics underscore that the use of climate information does not only depend on information attributes, but it also largely depends on the social processes that allign information with norms and narratives. We argue that a more profound understanding of how assessment criteria are constructed can offer valuable insights into how prospective climate information users learn, exchange knowledge, collaborate and develop trust in climate information, which are integral components for the successful development of climate services

Climate information ("*information about past, present and future climate conditions… and the resultant implications on development, people's livelihoods and the environment*")[1] is widely recognised as essential for municipal decision-making and urban governance[2]. Yet, despite decades of investment in monitoring, modelling, and dissemination, actual uptake in planning and policy remains limited[3]. Access alone does not translate into use[4,5]. This paradox—high availability but low utilisation—frames the central problem addressed in this article.

A large body of work has explained why climate information is difficult to integrate into routine municipal processes. Cash[6] highlighted early on that climate information brings distinct complexities and caveats: uncertainty in data and projections; temporal horizons that do not match political or budgeting cycles; spatial resolutions that do not coincide with administrative boundaries; and interdependencies among risks that complicate evaluation. Subsequent studies have elaborated additional barriers, including entrenched political interests, immediate contingencies and agendas, personal and organisational experience, historical legacies, educational backgrounds, social and economic contexts, and contested framings of risk and solutions[7–21]. Collectively, this literature suggests that using climate information is an outcome of social, organisational, and political processes that structure how information is judged and mobilised.

In response, climate service producers have emphasised that climate science must be produced with the explicit end goal of being used by society[22]. This orientation has led to strong emphasis on user-centred design, engagement with end-user needs[23], ensuring comprehensibility for intended recipients[16,24], and deep attention to decision contexts[10,20,25–29]. User-need assessments consistently show heterogeneous priorities, implying that stakeholder groups value and evaluate climate information differently[30,31,].

Whilst the climate-services literature has delivered important insights into enablers and barriers influencing the use of climate information, it has largely overlooked how local stakeholders assess the contribution of climate information, and how evaluative criteria are established, contested, and stabilised in practice. We argue that more profound understanding of how assessment criteria are constructed can illuminate the processes through which prospective users learn, exchange knowledge, collaborate, and develop trust in climate information—processes that are integral to the development of usable climate services[31,32].

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Guided by this perspective, we ask: How do practitioners in local governments assess the contribution of climate information for planning, decision-making, and policy development? How are criteria justified or made legitimate? These questions underpin two goals. First, we seek to understand how practitioners' perspectives and judgements about the value of climate information are constituted within normative professional contexts. Second, we examine how particular criteria become established and shape outcomes in the use of climate information and services. We address these questions empirically in three local governments—Bilbao, San Sebastián, and Copenhagen—where climate information was used for risk estimation, policy design, communication, and project definition. In this study, we highlight the tension between long-term climate projections and the short-term municipal cycles of budgeting, procurement, and service delivery—where decisions about what is considered useful and usable are largely shaped by concerns of feasibility and legitimacy within political and operational arenas.

We draw on Practice theories to examine the normative foundations that shape judgment about the use of climate information. For Schatzki[33], practices represent "nexuses of human activity, open-ended sets of doings and sayings organised by understandings, rules, and teleoaffectivities". In essence, practices are activities that follow prescription, e.g., in a professional context practices are enacted following general expectations of how *work* should be done[34]. Professional contexts are normative: they follow their own set of implicit and explicit rules and meanings that orient what people consider appropriate, legitimate and valid, thereby providing the guidelines for assessing what is correct or incorrect (ibid).

Revealing what people actually do under prescriptive orientations is a central aspect of the study of practices[33]. The role of normativity in stabilising practices, particularly the tension between rule-following and interpretation, has long been debated in Practice theory. Wittgenstein[35] argued that rules are not self-interpreting and may be followed in divergent ways. Giddens[36] viewed rules as codified interpretations, while Schatzki[37] emphasised that their applicability and meaning are always actor-interpreted. Interpretation, as Heidegger[38] noted, presupposes background competence—a profound understanding expressed in practice[39].

Schatzki's conception of practices is strong in emphasising human agency in the interpretation of rules. Our perspective posits that the use of climate information will be oriented by established norms and principles guiding professional practice. However, within this normative framework, individuals retain a degree of flexibility, as their agency is exercised through the interpretation and application of these rules. Others have already noticed that planning for adaptation (where using climate information is an aspect of it) often requires challenging or reconfiguring norms that structure decision contexts[40–42].

The valuation of something (in this case, climate information) is attributed and assessed collectively, involving negotiation, agreement on criteria, and consensus-building under conditions of ambiguity[43,44]. For us, the establishment of criteria for assessing climate-information use is a socio-cultural process—a site of tension and ongoing re-enactment[45].

Building on this framework, we analyzed the data collected in three case studies using a Social Orders schema. Social Orders are "the nexuses that keep things hanging together in society … the arrangements… through and amid which social life transpires"[33] (p. 22). They consist of arrangements—layouts of entities (human, materials) positioned relationally, where meaning and identity define interconnections—and positions, which are relational rather than spatial, reflecting how entities fit within ongoing practices. These positions evolve through interactions, making social life dynamic and contingent.

In designing the Social Orders schema, our aim was to uncover the interests, priorities, and concerns shaping professional activities and judgments about climate-information use in planning and decision-making.

Methods

The Methods section draws extensively on text published in the main author's doctoral thesis[46]. Our methodology follows a qualitative approach based on in-depth analysis of case studies through interviews in three cases: the cities of Bilbao, San Sebastian, and Copenhagen. The selection of the case studies was guided by their participation in ongoing projects[1] focused on the development and application of climate information in urban decision-making. These initiatives provided a context in which municipal actors had already engaged with climate data, information, tools, and services, making the cities particularly relevant for examining how climate information is interpreted and used in policy and planning processes.

Our case selection, therefore, follows a purposive strategy aimed at studying contexts where the interaction between climate information and urban governance could be observed in practice. The selected cities had accumulated several years of engagement with climate information through project-based collaborations between researchers, climate service providers, and municipal administrations. This allowed us to investigate how such information is integrated into local decision-making processes.

Literature review

Literature for this research was identified through targeted searches in Web of Science, Scopus, and Google Scholar using combinations of keywords including "use of science in policy," "climate information usability," "science–policy interface," and "urban climate change." The search focused on studies examining how scientific knowledge is interpreted and used in climate governance and urban adaptation contexts. Publications were included if they addressed interactions between climate information and decision-making processes in policy or planning settings. The initial corpus of literature was subsequently expanded through backward and forward snowballing from key articles, as well as through relevant publications identified through prior research and participation in academic and practitioner workshops focused on climate services and urban climate governance.

Prior to fieldwork, secondary sources—including climate data, adaptation plans, legal decrees, and other relevant documents—were analyzed (see Supplementary Tables 2 and 3). From the literature review, theoretical themes were organized into 23 thematic areas (Supplementary Table 4), which informed the development of theoretical codes for labeling key aspects in the reviewed material. These thematic areas were then translated into broad questions for semi-structured interviews, ensuring alignment with theoretical foundations. Each question was linked to its theoretical basis and tracked in Excel to maintain transparency and support subsequent analysis. During fieldwork, this framework guided the interview process.

Data collection

We conducted 34 qualitative, semi-structured interviews between 2018 and 2019 with municipal officials responsible for planning, sustainability, and crisis management, as well as researchers, meteorological office staff, consultants, and one NGO. These stakeholders were selected for their roles in providing, translating, and communicating climate information (see Supplementary Table 1 and Supplementary Figs. 1 and 2). Interviews, lasting 90–120 min, were guided by 15 thematic questions designed to elicit reflections on practices and decision-making related to climate information.

Contact to interviewees was established through prior project involvement and expanded via snowball sampling. Exhaustion point (redundancy in interviewees' answers) was reached after approximately five interviews in each city. Multiple stakeholders were interviewed to minimize bias, and no significant contradictions emerged.

Data analysis

Interviews were transcribed and analysed using in-vivo coding[47], which foregrounds participants' own language and aids in identifying recurrent themes and boundaries[48]. We linked the initially designed theoretical codes (Supplementary Table 4) to different sections of the transcribed interviews. Coding delineated municipal officials' activities and their interconnections. As new topics emerged from the interviews, new codes were created. The final list of codes listed in Supplementary Table 4 was compared to existing literature to situate findings within a broader theoretical context[49].

We analysed the data using a Social Orders framework, pre-defined in the conceptual framework. Guided by this approach, we systematically reviewed all data segments to identify activities revealing actor relationships and actions related to climate information use. Segments were coded using three Social Orders variables: arrangements, strategies, and positions.

Actors were characterised by how they established agreements to using climate information. The schema draws on Corbin and Strauss[34] and comprised three variables:

- Arrangements: The agreements established to reach specific outcomes related to the performance of work, and have to do with the use of resources, technologies, time, etc. These arrangements "are always temporary and subject to re-negotiation"[34] (p. 13).
- The strategies of interaction by which arrangements in the planning and decision-making context are made. Strategies emerge "previous the work starts and during the arrangement-making process" (ibid)
- Position refers to the stance assumed by each participant toward both the work and the process of working things out[33]. It reflects an actor's perception and influence within the arrangements being made. In our framework, we focus on the position each actor assumes regarding the use of climate information in urban planning and their perceived capacity to shape decision-making processes.

After developing the Social Orders scheme, we identified three relational dynamics connecting social relations, as described by Schatzki[33]: causality, spatiality, and prefiguration.

It is important to notice, however, that in Schatzki's Social Orders Scheme, a fourth relational dynamic—intentionality—is discussed alongside causality, spatiality, and prefiguration. While actors' intentions to steer the use of climate information were evident in principle, the interview data referred to intentionality in very general terms. This made it difficult to isolate specific intentions from other relational dynamics and to link them concretely to observed practices. As a result, intentionality remained too opaque for systematic analysis. Therefore, we decided to focus on the other three relations (causality, spatiality, and prefiguration), which provided more explicit and detailed accounts of how persuasion and other efforts unfolded in practice.

- Causal relations occur when one entity's actions or experiences influence another's response.
- Spatiality highlights that entities occupy physical and relational positions within arrangements, with activities distributed, sequenced, and nested in space.
- Finally, prefiguration refers to how the current state of social affairs constrains and enables future activity.

Social Order Schemes were generated for each city individually to capture the context-specific evaluative criteria shaping the use of climate information.

We report on our findings supported by quotations from our interviews, which are coded respectively indicating city, actor and interview line (e.g. *B (for Bilbao) A (first interview) 41 (line of interview in the transcription)*).

Next, the Results section draws substantially on the primary author's doctoral dissertation[46]. All quotations presented therein are verbatim transcriptions of interviews conducted in relation to the three cities examined in this study[46].

Results

Bilbao, the regenerated city

As field work was undertaken, Bilbao was revising and updating its territorial planning instruments and appraising opportunities to integrate climate information into their territorial planning instruments: e.g., identifying areas prone to be affected by urban heat islands, floods, sea-level rise and drought; as well as discussing the promotion of green infrastructure.

In 1990, Bilbao underwent a major urban transformation aimed at revitalising and decontaminating large industrial wastelands and brownfield sites (areas heavily polluted with chemicals which were spread throughout the bay during flood events). The transformation was widely regarded as a success in terms of urban planning and execution, and it thereby became a dominant narrative within the municipality that has shaped its principles and values guiding urban development ever since.

- *"… with the transformation …. an identity is generated, with certain values that shape urban planning dynamics, growth style…. it is a brand …. and you have to know how to follow that brand…" (GC2).*

The profound impact of the 1983 flood—a one-in-500-year event—has become embedded in the collective memory of *Bilbaínos* (BC44), reinforcing a persistent focus on flooding in urban risk management. Discourses play a pivotal role in shaping risk perception, as they delineate the repertoire of "ideas, concepts and categories through which meaning is given to social and physical phenomena"[50]. However, entrenched risk discourses in Bilbao have led to climate change being conceptualised almost exclusively through the lens of flooding.

- *"The results of the (climate change) vulnerability analysis were not surprising because … it was based on the risks of floods… there is enough culture here… the areas flooded and the risks are already known and emerge almost without work, because the same sites are being flooded every day, so it's pretty obvious…" (BB42).*

However, the prominence of large floods in the collective memory of Bilbao's residents tends to overshadow other hazards, such as heatwaves, which often remain unacknowledged, unattended, or excluded from problem framings (BC46-47, BB22).

- *"The (urban) heat island effect is less integrated in our thinking as planners and decision-makers… we are not Seville either…while floods are clearly part of our collective memory" (BB105).*

Regarding evaluative criteria, official criteria in Bilbao suggest that urban planning operates under a strict legal framework, yet the absence of specific guidelines for the use of climate information creates a normative gap.

- *"While at the European level several Directives consider climate change adaptation, given that these have not yet been made official, they are hardly usable" (BB14); "While we have heat maps for the city, these are not normative, so we are not obliged to consider them." (BB62).*

The prevailing paradigm within Bilbao's administration is the perception that official mandates possess determinative authority and constitute the exclusive framework through which municipal activities are organised.

- *"We don't do more than what URA (Water Agency) or other agencies indicate: raise the flood-protection wall, open a canal to let water flow through, etc. … it is all official and that is what we can do and do" (BB50).*

Official mandates clarify roles but can also constrain action, and their interpretation varies. While technical standards leave little ambiguity, they evolve with practice and policy windows. Rules may guide action yet lack enforcement, making compliance optional. Hence, understanding how interpretation shapes application is crucial.

Regarding the unofficial criteria emerging from this context, our research identified two dominating norms framing evaluative criteria for using climate information:

Norm 1. Requests for incremental and gradual change are accepted.

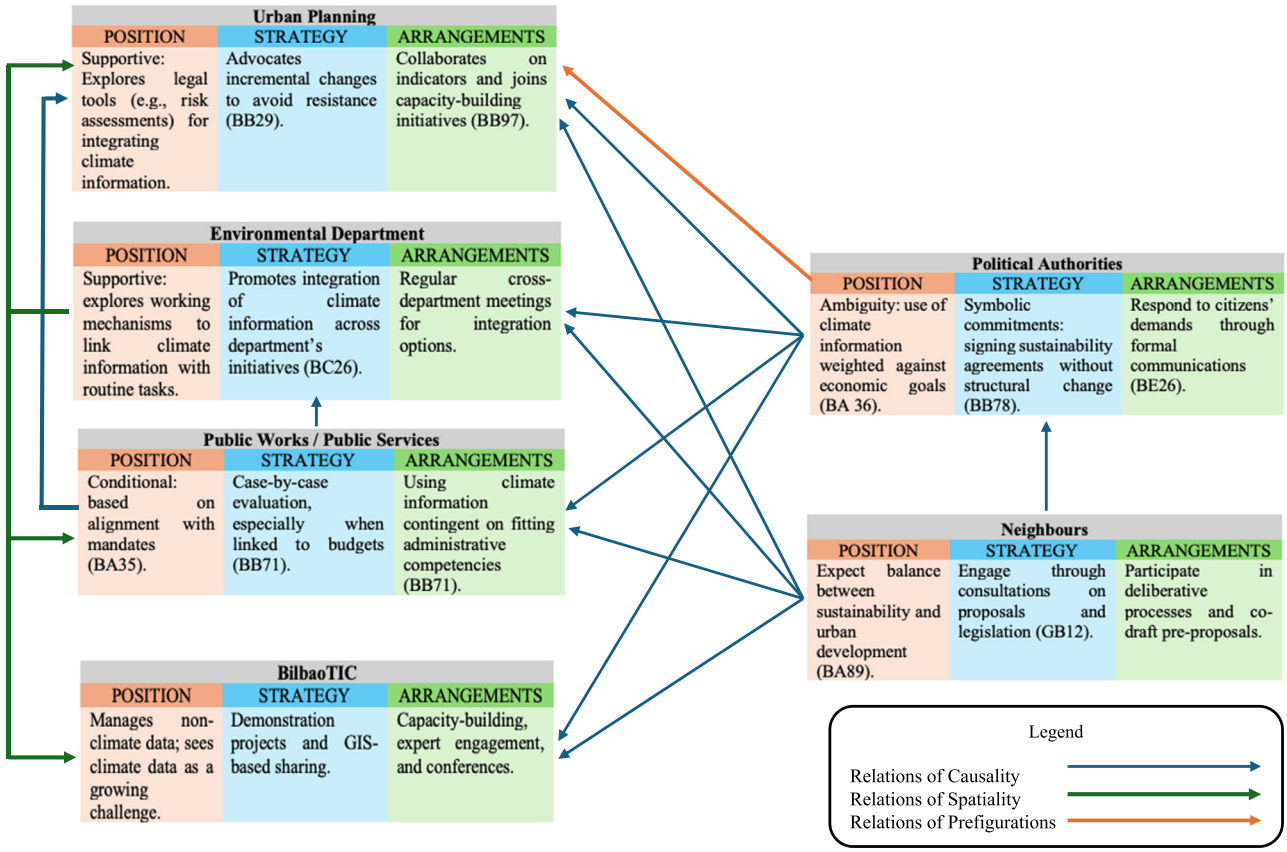


Fig. 1 | Social orders and relationships. Details of relational dynamics between entities (causality, spatiality, and prefiguration) can be found in Supplementary Tables 5, 6 and 7.

Strategy: Persuasion within limits. In Bilbao, compliance with work norms depends on formal obligations; without specific rules for using climate information, usability relies on experience-based competences. Progress under restrictive mandates involves blending norms with practical knowledge—adhering to work rhythms and avoiding rhythmic disruptions, progressing gradually, and negotiating intermediate goals.

- *"We are holding each other at our rhythms…" (BA71); "… what is expected is to be able to solve things little by little" (BC8); "… as long as we can within our capacity" (BA71); "… small steps are being taken, which have emerged little by little…" (BB18).*

Following this norm, urban heat island studies were integrated into the Urban General Plan through incremental steps, enabling inclusion in official risk maps without disturbing existing procedures.

- *"… the heat island areas are not official, but (the directors) have accepted them because…. they were only two areas…" (BB70). "These are pilot cases to see how far we can go…" (BB19). "…we have included a series of things that represent a small step within the city council" (BB81).*

Norm 2. Work in line with existing methodologies:

Strategy: Linking climate risk with existing indicator system. Bilbao applies what resembles disclosure-based transparency policies (transparently reflecting progress)[51]. Here, using indicators provide useful means to deliver accountability and for communication, narrative building, and process standardization—making them a promising mechanism for operationalizing climate information.

- *"… (we want to) … create indicators that allow data to be taken automatically without too much effort" (BC7); "…our "daily war" is about the indicators that we have the capacity to act as a municipality…" (BC37)" "…if (climate information) supports our indicators, then we can use it…" (BA111).*

The Social Orders schema developed for Bilbao examines how climate information comes to be used through the actions of specific actors who seek to demonstrate its added value and mobilise support through concrete initiatives. Figure 1 depicts actor relationships in terms of causality, spatiality, and prefiguration. The schema highlights the dominant influence of political authorities, represented as the primary source of causal and prefigurative relations shaping municipal action. This configuration reflects the requirement for municipal departments to align their activities with political priorities. At the same time, neighbours are shown to exert influence on both political authorities and municipal departments, underscoring the importance of citizen acceptability in urban climate policy. Relations of spatiality—connecting activities across departments—are evident only among municipal actors and are led by the Environmental Department, which seeks to establish collaboration to embed sustainability criteria within projects developed by Urban Planning, Public Works, and Bilbao TIC.

San Sebastián: articulating efforts, policies, and cross-sectoral policy coherence

San Sebastián is recognised as one of Europe's most active cities in sustainability, with a strong coastal identity shaped by activities such as surfing and sailing. Climate risk is primarily water-related, focusing on Urumea River flooding, sea-level rise, and severe storms ("Galernas") affecting beaches. The city integrated climate considerations into its Partial Territorial Plan (PTP), expanding flood-prone zones to curb urban sprawl in line with the guidelines provided by the Water Agency (URA). A key milestone occurred in 2014 when San Sebastián committed to the EU Covenant of Mayors, requiring an adaptation plan. In 2017, the city adopted its Climate

Change Adaptation Plan and Vulnerability Assessment, aiming to establish a Community of Practice (CoP)—a cross-departmental structure to support implementation. All climate-related actions, including mitigation and adaptation, are coordinated under the Klima2050 Strategy, which sets out 31 adaptation measures to be achieved by 2050.

San Sebastian's evaluative criteria are explored in the context of participation in the community of practice to implement Klima2050. Successfully executing Klima2050 requires resolving policy contradictions, aligning various urban plans, and ensuring that cross-sectoral collaboration is not hindered by conflicting departmental functions or overlapping responsibilities.

Regarding the official evaluative criteria, political authorities have endorsed the use of climate information, but agreements on its application are negotiated at the technical level, with each municipal department determining how climate information informs decisions. Administrative competencies are central to implementing Klima2050 since they shape how priorities are established, determining what is considered important and where attention is focused, based on sector, functions, and responsibilities.

- *"…. water issues… is more the responsibility of the Department of Urban Services and Maintenance. We can give our opinion, but the execution is not ours…" (DA6)*
- *"…Climate projections do not influence investments… upgrading T10 and T25 years… does not happen, because the investments are made in large things such as changing damaged water collectors… the useful life of a collector is 100 years more or less… a parameter of 100 years is used so every 100 years we make it all new" (DC22-23).*

In turn, the unofficial criteria suggest that although Klima2050 is an official mandate, it does not automatically harmonize the diverse competencies within municipal services. Efforts to align departmental administrative responsibilities under a unified framework can provoke conflict, as such measures may be perceived as encroachment on other departments' domains.

- *"…there are always other departments that are more difficult to work with …. they see that our collaboration (implies) more work to them and see that the work is more of supervision than of co-creation and they don't like that…" (DE29).*

Allocating tasks and responsibilities based on strategic assessments of departmental competencies and expertise is one way to overcome conflicts (DE15).

- *"… this depended a lot on the pertinent administrations of each department, so we analysed the organization chart and evaluated which departments could be involved…" (DE15).*
- *"In the adaptation commission, we were invited because we handle the basic information of the city…" (DD28).*

The results showed that many technical, resource, and administrative requirements for Klima2050 were already part of routine departmental work. Where additional needs arose, such as new studies or assessments, extra budgets were allocated for outsourcing (DE17).

Collaboration built also on prior sustainability initiatives, such as Agenda21 (DE7), which had already established mutual understanding and shared norms for effective cooperation.

- *"… the water agenda, comes from Agenda 21, and we already meet once a year to discuss (with) the Water Agency… we have other shared projects… then that collaboration is already taking place…" (DE11).*

Four norms that enabled reaching a common orientation to implement Klima2050.

Norm 1. Follow the leaders. Wenger[52] maintains that a common orientation is central to building Communities of Practice (CoPs), and a common orientation rests on shared sources of coherence.

Strategy: Leading cities like Copenhagen, Vancouver, and Toronto were considered benchmarks for climate action. Their successful initiatives, such as green roof ordinances and community engagement, aligned with the goals outlined in the Klima2050 strategy. These cities provide a tangible example of the resources and expertise needed to achieve similar goals, providing a normative corpus that guided expectations of urban development in general, and the goals of Klima2050 more specifically.

- *"…Copenhagen has solved many problems, they have a very interesting plan… they are the benchmark… Vancouver and Toronto have the whole theme of green roofs, they have an ordinance… they do it very well…" (DE60). "… Copenhagen has an outstanding economic approach; here it would be more difficult to promote it…. I think there are cultural differences… we are not at that point…" (DE61).*

Norm 2. Mutual trust is the base for coordination.

Strategy: Since the CoP bestows departments with the full ownership and responsibility over project implementation (DD28-29; DA5), the principle of "managing with flexibility and pragmatism" becomes prominent to highlighting respect for the attributions, functions, experience and expertise of other departments. Normative criteria are built around the trust that responds to the perceived procedural and technical saliency displayed by the departments' expertise, and which is acknowledged as the best way possible of doing things.

- *"The plan was discussed very openly … so, the result is mixed … it is a set of (collective visions) of several departments and people… urgent actions …. are prioritized… concrete planning, with times and budgets … It is a plan that had to respond to a series of requirements from many areas, departments… internal and external needs …" (DA8).*

Awareness of contribution pathways enables participants to recognise how routine tasks support the collective enterprise, imbuing everyday work with new significance and clarifying its role in achieving shared goals.

- *"The agents identify themselves with that model … then they themselves in their areas think about how to work, because there is a collective end… conviction helps… (they are) transformed into active agents… they all have different influences, some political, others economic, some are more reticent…" (DB19).*

Norm 3. Weave climate information within accepted methodologies and professional practices.

Strategy: High temperatures were assessed using health and social indicators from San Sebastian's Vulnerability Assessment, such as age, poverty, and mortality. This approach generated new categories (e.g., "elderly" and "living alone" under higher risk) that influence how climate risk is understood and managed, anchoring the use of climate information in sectoral knowledge and widely accepted methodologies, enabling municipal officials to interpret climate challenges through their sectoral expertise.

Norm 4. Make progress visible.

Strategy: To demonstrate progress, Klima2050 was divided into shorter timeframes with partial goals.

- *"… the Project by Project (approach) is super important, because the general view allows you to raise awareness… when it comes to seeing results, you have to specify projects … because we all need … concrete actions …" (DE54); "… The risk study considers the year 2100, but (even) 2050 was already difficult-; … an action plan for 2023 (was created)" (DE96); "… It is difficult to quantify the costs of the projects… So, (we)…*

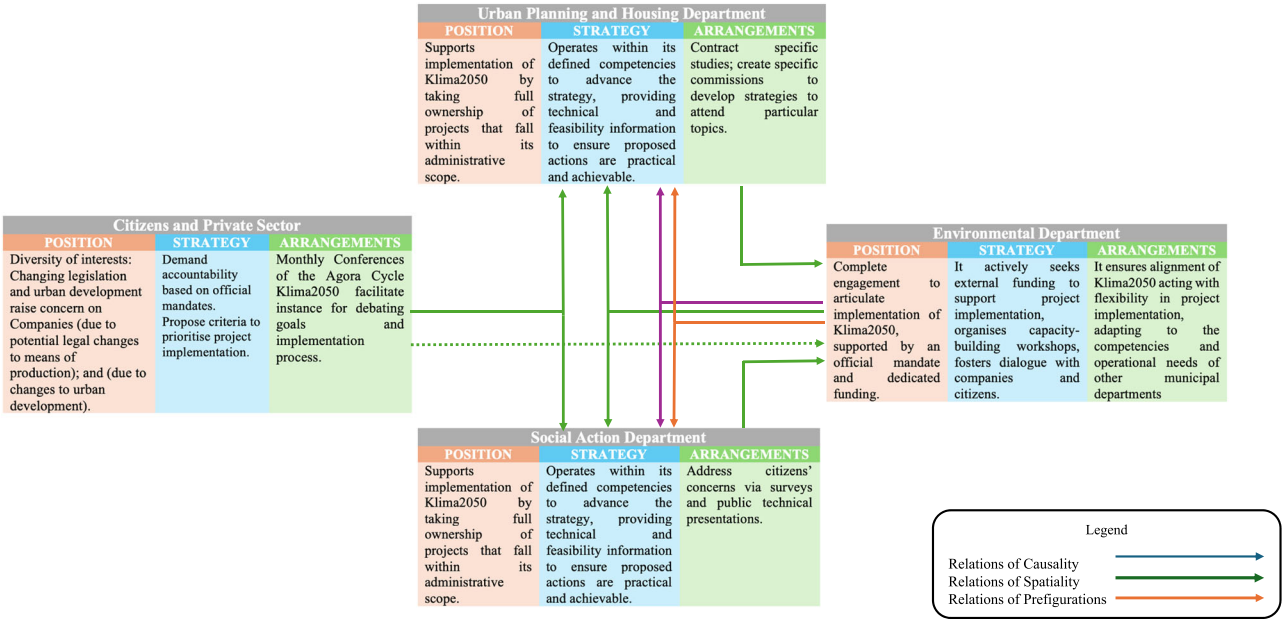


Fig. 2 | Social orders and relationships. Details of relational dynamics between entities (causality, spatiality, and prefiguration) can be found in Supplementary Tables 8, 9 and 10.

integrated budget ranges… from actions with no cost to actions that have a significant cost…" (DE98).

Norm 5. Provide an enabling environment.

To encourage participation, central coordination efforts focused on clearly communicating the added value of joining the Klima2050 CoP. This included facilitating additional funding for ongoing projects, identifying relevant opportunities for departments, and providing access to capacity building schemes (DE17, DE52).

- *"… when it comes to convincing people to participate …. there has to be a win-win; that is, this has to also help them with the work they do in their department …." (DE52).*

- *"…. for that, we try to find different… ways of financing projects that can benefit … parts of the plan they manage" (DE17); "we are trying to attract European funding… we have participated without funding but as beneficiaries… (thus) we get a lot of information that otherwise would have been expensive …" (DE103-104).*

The Social Orders schema for San Sebastián examines how a shared orientation is constituted within the community of practice. Figure 2 shows actor relationships in terms of causality, spatiality, and prefiguration, revealing no dominant position among municipal departments and reflecting the collaborative governance underpinning Klima2050. While the Mayor plays a decisive role in initiating the programme, its functioning depends on collective commitment and a division of work based on departmental expertise. Causal relations are evident where the Environmental Department requests information from other departments to support implementation, while the Citizens' Council demands accountability regarding progress. In terms of prefiguration, the Environmental Department facilitates implementation by securing funding and extending departmental networks through participation in international projects. Spatial relations emerge from the Environmental Department's role in coordinating activities and articulating departmental contributions towards achieving Klima2050's goals.

Copenhagen: integrating long term blue-green urban planning

In 1990, Copenhagen set a goal to make its harbour swimmable, requiring major upgrades to meet EU water quality standards. Later, climate projections warned of heavier rainfall and flood risks, with potential damages of DKK 16 billion over 100 years. A severe cloudburst in 2011 caused DKK 6 billion in losses, accelerating action. The city responded with the Cloudburst Management Plan (CBMP)—a 20-year programme integrating climate projections and hydrological models to guide 300 projects focused on green-blue-grey solutions for surface catchment areas for water treatment and flood control. While this approach is considered more cost-effective[53] and demonstrate immediate action (CB9), this ambitious initiative demands balancing financial viability, political priorities, and public expectations while ensuring effective risk reduction and broader social, environmental, and economic benefits. Given its high cost and long-term horizon, sustaining CBMP's legitimacy is critical: *"it will take several decades to implement the plan even under the most optimistic circumstances, and it remains to be seen as to whether the political awareness will remain high if the frequency of extreme precipitation becomes relatively low at some future point in time"*[54] (p. 83).

Copenhagen's CBMP relies on climate projections and hydrological models to design flood protection against extreme rainfall. In this context, Copenhagen's use of climate information is explored through the implementation of the CBMP.

- *"Climate information is important for the plan as a round level… "It makes sense to use climate information as guidance, but not as the only thing… You settle dimensions … we do not make specific calculations in each project because we do it for the entire (CBMP) plan… our projects are connected; they are not stand-alone projects" (CA46).*

  Regarding official evaluative criteria, climate change adaptation in Denmark is embedded in national laws and strategies[53], which mandate municipal adaptation plans and support sectors such as water. The CBMP operates under a shared governance model shaped by multiple legal obligations, requiring alignment of stakeholder interests (see Supplementary Fig. 2). While the Adaptation Department holds supra-municipal authority for CBMP implementation, all projects must comply with environmental standards enforced by the Environmental Department. Environmental permits are a central requirement and often determine project feasibility.
- *"… handling of rainwater cannot conflict with our environmental goals…" (CE8); "if you want to use parks in the city which are protected by law for preservation… you find conflicts against adaptation*

projects…" (CE12); "you cannot just… lower the terrain to retain water…" (CE13).

Implementing the CBMP highlights the need to navigate complex regulatory frameworks and ensuring that climate adaptation remains legally compliant and environmentally responsible.

Regarding unofficial criteria, a key challenge in implementing the CBMP is its novelty, requiring municipal officials to learn through experience and maintain a solutions-oriented approach. Success depends on strong collaboration, which is valued culturally for enabling efficient action and fostering positive interactions.

- *"…the (CBMP) plan is a common driver so that we can also start working together… so when new roads have to be constructed, or new parks have to be created, we all know that we can coordinate things…" (CE57).*

  Collaboration is acknowledged as a requirement for coordinating resources more efficiently:
- *"When you go and see that funding is limited, we have to mainstream the investment and see the window of opportunity… (if) one month you dig it all up to put in new pipes and then three months later install electric installations and then 2 years later we take it all up again because we need to do something else… so we need to coordinate" (CE53)*

Collaboration is central to resolve institutional, legal and technical barriers and to resolve unexpected problems linked to specific contexts:

- *"…for example, the EU (flood directive) says you are not allowed to intervene in protected areas … So, if you (want to set up) a dike, you cannot just do it here or there, even though if people are under risk… so that's why we keep on meeting up… the city, the utilities, you start learning things all the time" (CE56).*

These observations indicate that implementing the CBMP relies on both planned collaborations and those that evolve during execution. As a result, iterative processes—such as trial and error, conflict resolution, problem-solving, and the design of new procedures—are integral to its implementation.

Four norms that facilitated implementation of the CBMP.

Norm 1. Value-adding solutions

Strategy: CBMP implementation reframes flood risk into a value-enhancing asset for the city. Added value has been strongly branded as part of Copenhagen's image, and the city brands itself as a frontrunner in urban innovation, quality of life and economic development.

- *"The Copenhagen brand is much about how we have been working… a double vision of making things attractive… And that is the brand: we don't only solve the problem; we also find the opportunity at the same time. (What) it is called the added benefit" (CA5).*
- *"… so not only handling water in a concrete basin but also doing it on the surface and showing that we added value to greening the city… and the citizens could see…" (CB20).*

Norm 2. "No-regret"

Strategy: The CBMP emphasizes the integration of green solutions, framing it as an opportunity to enhance liveability while protecting the city against extreme precipitation.

- *"…even without climate change, who would be against having a green park?" (CA9)*

Greening the city enhances also the flexibility for implementing future upgrades in infrastructure.

- *"… (in) areas that need to do upgrade… you can bring green into the city, so you can use climate change as the driver to make a more liveable city, and instead of just planting a tree, you plant it because it gives shade, is nice, is cool… people are willing to put money on it" (CE31).*

  Norm 3. "Never-ever approach"

  Strategy: Set clear thresholds -impacts such as those provoked by the 2011 rainfall are not tolerable, they go beyond an accepted threshold-. The approach addresses questions of acceptable flood frequency and water levels, resulting in standards such as allowing sewer discharge to reach ground level once every 10 years and permitting water levels to exceed ground level by 10 cm once every 100 years (CE26).

  Norm 4. "Caring for everyone"

  Strategy: Decision-making under the CBMP balanced financial estimates with social equity considerations. Because impact assessments cannot fully capture non-monetary vulnerabilities[55], safety for all citizens was prioritised—even at the cost of over-investment in some areas. Progress was made visible by aligning financial sustainability with equity goals -underscoring the importance of visible, community-level benefits for advancing climate initiatives-, reinforced through political support and tangible local improvements.
- *That was a political signal…" (CE30); "… what really makes (the CBMP) acceptable… are the local improvements…" (CA10); "… showing that we added value to greening the city… and the citizens could see it and it generated great enthusiasm…" (CB20). "…all these things come up and there is a multi-criteria element behind the decisions (CE57).*

The Social Orders schema developed for Copenhagen examines how climate information is embedded in the implementation of the CBMP. The causal relations reveal reciprocal dependencies between political, adaptation, and environmental actors in the implementation of the CBMP. The Adaptation Department supplies salient scientific climate information to politicians, enabling political buy-in, while political endorsement authorises implementation, subject to security and technical requirements. The Environmental Department further shapes implementation by enforcing environmental standards, requiring the Adaptation Department to adjust technical project components accordingly.

Relations of spatiality emphasise the Adaptation Department's role in engaging neighbours through the provision of technical expertise and enabling technologies, thereby supporting their participation in project design. Relations of prefiguration illustrate howFig. 3 the institutional context structures action: legal decrees empower the Adaptation Department as the lead actor; neighbour endorsement can facilitate or constrain projects; geo-data software enables civic participation; and environmental permitting conditions water-management strategies.

Discussion

This article argues that the use of climate information rests on evaluative criteria that are socially constructed. Our argument posits that the uptake and evaluation of climate information is contingent on the narratives through which cities understand and present themselves. Municipal identities, including regeneration narratives (e.g. Bilbao), sustainability orientations (e.g. San Sebastián), and innovation brands (e.g. Copenhagen), delineate what counts as legitimate, desirable, and actionable practice, thereby rendering alternative framings challenging to articulate[34].

Building on the cases of Bilbao, San Sebastián and Copenhagen, we find some key recurrent patterns that illuminate how actors assemble evaluative criteria to assess the use of climate information. In all cases, climate change planning is a shared concern; however, degrees of commitment vary, shaped by political priorities, strategic agendas, and operational constraints.

Our observations suggest that evaluative criteria are constituted by official and unofficial criteria. *Official evaluative criteria* embody the set of formal and explicit rules. *Unofficial evaluative criteria* represent tacit rules (or patterns of shared expectations and assumptions)[56].

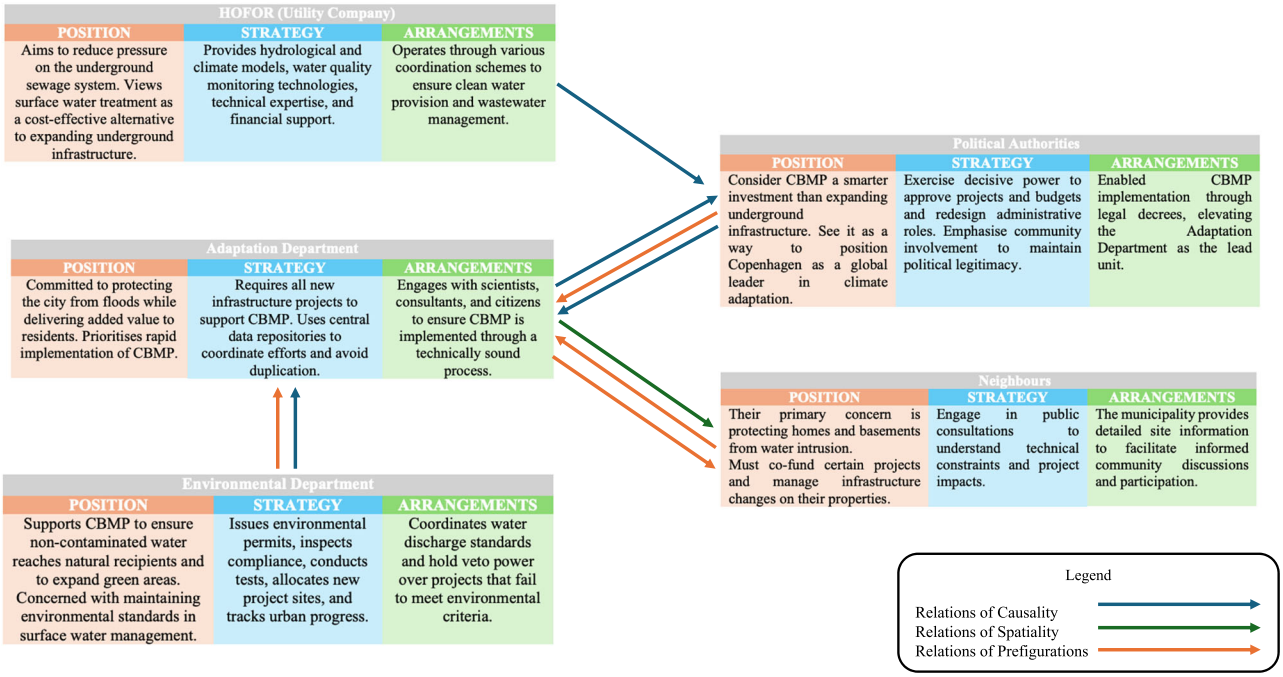


Fig. 3 | Social orders and relationships. Details of relational dynamics between entities (causality, spatiality, and prefiguration) can be found in Supplementary Tables 11–13.

Evaluative criteria become *stabilised* when judgments about appropriate actions are taken for granted, causing debates over their legitimacy to recede. Across the documented cases, our observations suggest that official evaluative criteria become stabilised by history (specific events have shaped the normative context upon which decisions are guided and assessed) and by its anchoring in legal mandates. Official criteria shape discourses that articulate what counts as good and desirable practice—Bilbao's regeneration narrative, San Sebastián's sustainability attributes, and Copenhagen's innovation brand—rendering departures from the norm nearly unthinkable. These discourses provide what Gherardi[34] calls *stabilisation by rhetorical closure*: narratives and frames specify appropriate practice (e.g. managing floods following strict standards), thereby establishing parameters of success which mediate the use of climate information.

A second stabilisation mechanism links the use of climate information to well-established technical practice. Here, methodological coherence stabilises practice through *methodological closure*: the use of climate information is anchored in established ways of calculating, planning, synchronising activities, and applying quality standards. Adhering to the methodological norm facilitates both assessing the feasibility of using climate information and identifying how climate information becomes a contribution to the flow of work.

A third stabilisation mechanism builds on legal decrees. Legal decrees reshape work coordination by jurisdiction-wide restrictions that require the re-distribution of roles, resources, and administrative competences. Here we find that the integration of climate information into urban governance varies across cities. While in all three cities reducing climate risk is mandated by legal decrees, Bilbao seeks to formalize climate information use within legal frameworks, but remains reliant on conditional support; in San Sebastián - where legal decrees support using climate information- policy coordination to avoid sectoral conflicts is required; while in Copenhagen -where using climate information is fully integrated into mandates-, preserving legitimacy amid changing conditions and priorities requires demonstrating the added value of the CBMP.

Based on our observations, our notion of stabilisation mechanisms is that evaluative criteria are sustained by norms. In turn, the use of climate information is more likely to become stabilised when claims for its use are built through strategies that render visible normative elements -meanings, values embodied in the norm-. For example, persuasion -a strategy implemented across all three cities-, built on discursive and methodological closure, thereby successfully aligning usability claims with canons of good practice. An underlying characteristic of these strategies is that across all cities, stakeholders advocating for the use of climate information had acquired sufficient practical knowledge to frame their arguments in line with normative canons.

We unpack these dynamics using the Social Orders scheme, tracing how evaluative criteria are socially constructed through relations of causality, spatiality, and prefiguration.

Two relations of causality -were the actions or intentions of one entity leads another entity to perform an action- were identified: political and institutional. First, regarding political causality, the three cases show that the need of political authorities to understand climate risk information in a way that resonates with political interests demanded actions from different entities to translate scientific results into politically viable narratives. The translation work needed to ensure that information showcased a broad spectrum of benefits, including social (addressing citizens' safety concerns), institutional (enhancing the city's reputation as a sustainable leader), legal (ensuring compliance with national and European regulations) and financial (demonstrating how resilient urban planning investments could yield long-term returns). Effective persuasion efforts benefited from linking social values to the use of climate information, including safety, justice, liveability, modernization, democracy, equity, and prosperity.

Second, institutional causality. In San Sebastián and Copenhagen, specialised departments—the Environmental Department and Adaptation Department—were granted supra-municipal authority to manage adaptation, as traditional institutional arrangements were insufficiently equipped to handle the complexities of Klima2050 and CBMP. Expanded autonomy enabled these departments to influence planning routines, redistribute tasks, and reallocate resources.

Regarding relations of spatiality (spatiality refers to coordination across entities), in all three cases, cross-department coordination needed to advance adaptation goals required well-planed institutional coordination mechanisms. To ensure feasible implementation of adaptation actions, these mechanisms had to be in consonance with the resources and municipal competencies of each different municipal department.

In Bilbao, the Environmental Department sought to demonstrate that consideration to climate risk was feasible by identifying projects to be

implemented by other departments that were on a planning stage. The project planning process, with its inherent flexibility to modify actions, budgets, and methodologies, was viewed as the ideal opportunity to advocate for the inclusion of resilience criteria.

In San Sebastián, Klima2050 implementation involved task distribution under the Municipal Climate Coordination Board. The distribution of tasks rested on an assessment of department's administrative competencies, resources and expertise, but it also involved ongoing discussions about the changing availability of resources needed for the plan. The case of San Sebastián emphasises the difference between prescription and practice: while roles within Klima2050 were defined by official mandates, the implementation of the plan demanded ongoing discussions about the practical limitations and options for each department to implement the plan.

In Copenhagen, coordinating the CBMP was based on a centralised data system. Every urban project in the city had to provide detailed information (including timelines, budgets, funding sources and the estimated water absorption capacity provided by the project) to a centralised data system. This system linked all projects through an automated process, ensuring streamlined coordination and data sharing across departments. This approach optimised resources and amplified impact.

Across all cases, persuasion efforts were aimed at convincing decision-makers to incorporate climate projections into planning by linking climate adaptation goals to broader political, social, and economic priorities. These observations suggest that persuasion efforts were strategically devised, and that effective persuasion relies on a deep understanding of not only regulations and administrative structures; but also, about other subjective aspects of professional working activities.

In turn, relations of Prefiguration—where one entity enables or constrains another—emerge across cases. In Bilbao, integrating climate considerations into planning required legal amendments and multi-level endorsement, demanding consensus across diverse competencies. Departments of Environment, Urban Development, and Bilbao-TIC led integration but relied on political authorities, Department of Public Works, and citizens for legitimacy. These actors serve as legitimators, and their evaluative criteria influence how climate information is assessed and applied in decision-making.

In San Sebastian, while the Environment Department played a pivotal role as a facilitator in the implementation of Klima2050, the level of participation of other departments could either catalyse or obstruct the implementation of Klima2050. The Environment Department sought to ensure a smooth implementation by ensuring all departments involved could access additional funding and external expertise needed to implement the adaptation projects. This was achieved through active participation in the preparation of national and European project proposals. The department's extensive national and international network proved instrumental in unlocking these resources and ensuring wider collaboration and support for the initiative.

In Copenhagen, Politicians have enabled the implementation of the CBMP by enacting legislation that prioritised the plan over other city projects and by designating the Adaptation Department as the lead agency. However, the Environment Department held a key veto power, as it had the final authority to grant environmental approvals for all water management projects under the CBMP. In addition, local residents also played a critical, prefigurative role, either by supporting or opposing projects proposed under the CBMP. To address this, the Adaptation Department adopted a participatory approach, providing resources that enabled citizens to participate in project design through augmented reality, visualisation and workshops.

In sum, this article set out to explore how decisions about the use of climate information in municipalities respond to context-specific evaluative criteria constructed by local stakeholders. Our findings show that these criteria are embedded in broader normative frameworks that shape how cities define legitimate and desirable forms of action. In the cases examined here, these frameworks are closely tied to the narratives through which municipalities understand and present themselves: Bilbao's regeneration trajectory, San Sebastián's sustainability orientation, and Copenhagen's innovation-driven urban identity. Such narratives function as interpretive frames that shape what counts as credible knowledge and appropriate practice, making certain uses of climate information appear natural while rendering others difficult to articulate.

In this sense, the uptake of climate information depends not only on the availability or technical quality of data, but also on how it resonates with the political priorities, strategic visions, and operational practices that define a city's sense of direction. Decisions about using climate information often involve balancing what is politically acceptable (supported by stakeholders and policy), what is technically feasible (implementable with available resources), and what is strategically desirable (aligned with long-term objectives). Climate information becomes actionable when it can be meaningfully connected to these collectively recognized agendas and narratives.

These findings highlight that improving the usability of climate services is not solely a matter of refining information products. Rather, it requires attention to the social and institutional processes through which meaning and legitimacy are constructed in urban governance. For climate service providers and risk communicators, this implies the importance of understanding how municipalities frame their development trajectories and institutional identities, and of engaging with those narratives when communicating climate risks and adaptation options. While these insights are drawn from three cases, they point to the need for future research to examine normative structures, institutional narratives, and meaning-making processes as central factors shaping the uptake and usability of climate information.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Deep-L tool to improve language and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Data availability

Available with restricted access: The data from interviews that support the findings of this study are available from Climate Service Center Germany (GERICS), but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data are, however, available upon request and with the permission of Climate Service Center Germany.

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Author contributions

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