

Research

Exploring the role of national weather services in climate change knowledge and communication: an international survey

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Abstract

This study investigates the roles, perspectives, and communication strategies of National Meteorological Services (NMS) concerning climate monitoring, climate change projections, and the attribution of meteorological phenomena to climate variations. Using a survey distributed to 131 of the 193 National Meteorological Services affiliated with the World Meteorological Organization, we explore how these entities contribute to and communicate about the science of climate change. The survey targeted their involvement in observing and recording climate data, making climate projections, attributing specific weather events to climate change, and their methods of communicating these issues to the public and government officials. Responses were received from 44 countries, reflecting diverse levels of economic development and capabilities in handling, and disseminating complex climate information. The results show a strong engagement in traditional meteorological tasks, with a varied approach to the scientific study of climate change effects and public communication strategies. This study highlights the critical role of NMS in climate change research and underscores the challenges they face in effectively communicating complex climate information, which is crucial for public understanding and policymaking.

1 Introduction

The collection and maintenance of weather and climate data are primarily performed by the National Meteorological Service (NMS) of each country. These services are tasked with analyzing daily meteorological data, which, over time, reveals both natural and human-induced variations in climate. The historical data series that scientists rely on, along with the measuring tools such as stations, radars, and satellites, are integral components of the infrastructure provided by national or supranational meteorological organizations. Frequently, these services are also responsible for distinguishing anthropogenic climate change from natural climate variability. Embedded within state structures, these meteorological services primarily serve as vital sources of information for politicians and government bodies [2].

The systematic observation of weather began with the publication of various astronomical calendars in the fifteenth and sixteenth centuries. These observations were fueled by advancements in astronomical studies and their application in astro-meteorology. In Europe, meteorological data extracted from the astronomical calendars of several universities, such as Cracow in Poland and Ingolstadt in Germany, have enabled researchers to determine the climatic characteristics

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of these regions [13]. Similarly, in Japan, systematic records of weather-related events have been maintained since the fifteenth century, documenting phenomena such as the blooming of cherry trees and the freezing of lakes [9].

National Weather Services are the modern inheritors of a tradition characterized by rigorous, methodical, and scientific observation [11]. The extensive data and knowledge they have accumulated over time establish their authority in studying historical climate patterns as well as their evolution. More recently, particularly in the latter half of the twentieth century, these services have also taken on responsibilities for studying human-induced climate variations and projecting future climate scenarios. Since 1950, the World Meteorological Organization (WMO), an agency of the United Nations, has coordinated the National Meteorological Services of various countries [3].

The most significant milestone in international coordination for raising awareness of climate change and the imperative for action occurred at the United Nations Scientific Conference in Stockholm, Sweden, in June 1972. Often referred to as the First Climate Summit, this conference resulted in the adoption of a declaration of principles focused on the conservation and enhancement of the human environment, along with an action plan that included recommendations for controlling pollutants. This declaration was the first to call for government action in the battle against climate change [6].

The decade of the 1970s ended with the First World Conference on Climate of the World Meteorological Organization (WMO) [23], with a declaration that “called on the governments of the world to monitor and anticipate potential changes in the climate, caused by the human being, that could be adverse for humanity” [23]. The World Climate Program (WCP) was established under the joint responsibility of the WMO, the United Nations Environment Program (UNEP) and the International Council for Sciences (ICSU).

In 1988, the United Nations General Assembly established the Intergovernmental Panel on Climate Change (IPCC) through Resolution 43/53 on December 6 [17]. The IPCC was mandated to gather scientific knowledge on climate change, assess its potential environmental and socioeconomic impacts, and develop viable response strategies for consideration in future international climate conventions.

The role of the National Meteorological Services in understanding the meteorology and climate of their respective countries is well recognized [8]. However, their contributions to attributing climate change and making climate projections are less well known. Moreover, there is limited literature on the international variations in the work conducted by each NMS at the national level. In an era where combating climate change has become a global priority [18]. There is a growing effort developing climate services like the Global Framework for Climate Services [5], it is equally important to understand the role these services play in communicating about climate change.

1.1 Objectives

The National Meteorological Services are tasked with collecting meteorological data and maintaining the climate records that form the basis for studying climate change. In some instances, they are also responsible for preparing climate projections and attributing specific phenomena to climate change. We are keen to understand their perspectives on current climate and climate change knowledge, their projections, and their attributions of ongoing phenomena. Additionally, we are interested in exploring how they communicate this information to the public both within their respective countries and on an international scale.

The specific objectives are the following:

Understand the role of National Meteorological Services in monitoring climate, projecting climate change, and attributing meteorological phenomena to these climate variations.

Explore the perspectives of National Meteorological Services on the communication of climate change information.

2 Methodology

The volume and complexity of climate information, including projections and data related to mitigation and adaptation, are rapidly increasing. This creates a paradox where more accessible information simultaneously becomes less comprehensible and digestible for the global population, which varies greatly in levels of education and access to information [12]. In this context, understanding weather and climate and effectively communicating scientific knowledge about climate change becomes crucial. It is essential to make this information understandable to the general public to prevent misinterpretations and combat misinformation. We focus on the National Meteorological Services as key providers and verifiers of weather and climate information. Our research methodology involves surveying public communication

officials from as many National Meteorological Services (NMS) as possible. While we recognize that the information provided by these officials may not fully reflect the actual data, research, or modeling activities of the NMS, our focus is specifically on what is conveyed to the public, rather than on the technical aspects of the NMS operations.

The target group for our survey includes the 193 National Meteorological Services (NMSs) of the member states and territories affiliated with the World Meteorological Organization. To reach them, we utilized the contact lists available on the WMO website [21], ensuring that only those NMSs with active links and available contact methods (either email or a contact form) were included. As a result, invitations to participate in the survey were sent to 131 of the 193 NMSs, accounting for 67.8% of the total.

NMSs are governmental entities in their respective countries, and their activities are legally defined and constrained. Therefore, the survey was designed to be completed by any official who received it. The questions focused on exploring the role of each NMS in monitoring climate change, making future climate projections, attributing current events to climate change, and communicating these issues to the public. The survey was developed and validated with the assistance of staff responsible for the WMO's Public Meteorological Services.

The survey was distributed in a Google questionnaire format, chosen for its compatibility with the majority of operating systems and hardware. This format ensures accessibility for NMSs across countries with varying levels of technological capabilities. The survey was conducted in English to maintain consistency. It was initially launched in February 2023, and a follow-up reminder was sent to the same contacts two weeks later.

3 Results

We received responses from the Meteorological Services of 44 countries, representing 34% of our sample and 23% of all countries with an NMS. These responses came from countries across five continents (Fig. 1).

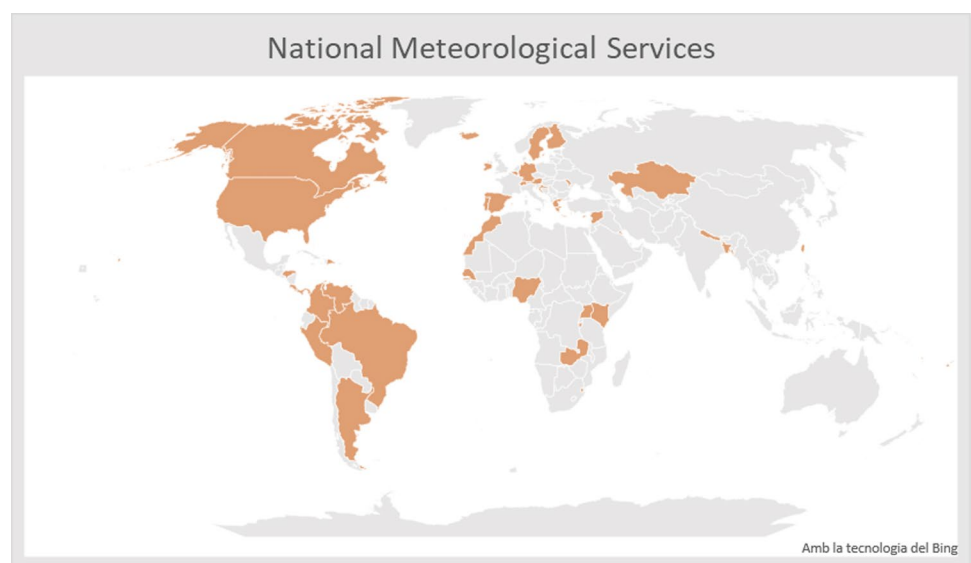
In analyzing the origins of the received responses, we noted participation from NMSs across all income levels as classified by the World Bank [19]. We received responses from 43.7% of high-income countries of the Organization for Economic Cooperation and Development (OECD), 14.5% from high-income non-OECD countries, 17% from upper-middle-income countries, 21.5% from lower-middle-income countries, and 10% from low-income countries. It is important to note that the World Bank's classification includes a total of 215 countries and territories, which differs from the WMO's list of 193.

Analyzing the responses according to the United Nations Human Development Index (HDI) for 191 countries and territories of the United Nations Development Programme [16], we found that 34.8% of the responses came from countries with a very high HDI, 14.2% from countries with a high HDI, 22.7% from countries with a medium HDI, and 12.5% from countries with a low HDI.

Our study received responses from NMSs across countries at various stages of development and income, encompassing even those at the lowest economic levels (Fig. 2).

Below we present the answers to the four questions of the questionnaire sent to the National Weather Services.

Fig. 1 Geographic distribution of NMS survey responses



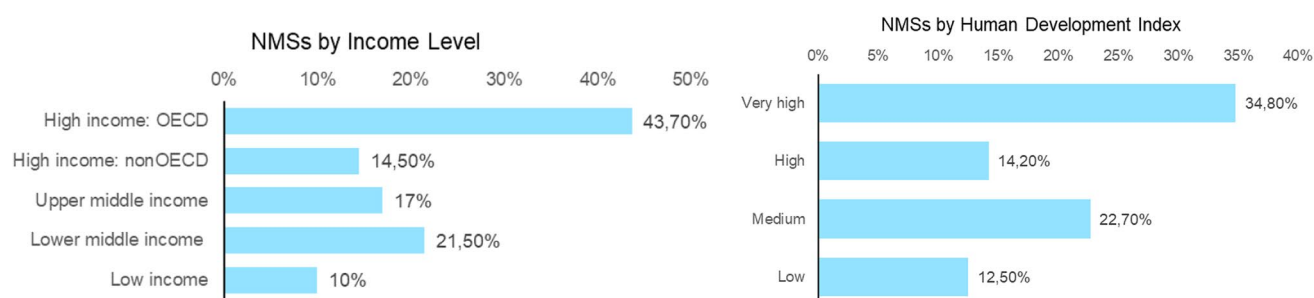


Fig. 2 Distribution of NMSs by Country, categorized by Income Level on the left and by Human Development Index on the right

3.1 Climate change monitoring

In the initial question regarding the role of NMSs in monitoring climate change, a vast majority of the respondents (90.9%) reported that they conduct observations of current weather conditions in their countries and maintain climate series (88.6%). Additionally, most are responsible for studying natural climate variations (86.4%). However, only half of the NMSs engage in studies on the impact of human activity on climate change.

Notably, five countries—Kazakhstan, Kuwait, Panama, Venezuela, and Syria—indicated that they do not maintain climate series. Furthermore, four countries—Brazil, Kazakhstan, Panama, and Canada—reported that they do not make current weather observations. However, upon reviewing these countries' websites, it appears that this information is indeed available, particularly in the case of Canada.

Additionally, six countries—Fiji, Taiwan, Venezuela, Dominica, Argentina, and Burundi—reported that they do not study natural variations in the climate (Fig. 3).

3.2 Climate change projections

In terms of the role NMSs play in preparing climate change projections, a significant majority (90.9%) generate reports on climate change within their countries. Additionally, 79.5% contribute to advancing scientific knowledge about climate change. A smaller yet still substantial majority (65.9%) of NMSs prepare reports on the impacts of climate change within their countries and model future climate scenarios. However, only 14 of the NMSs (31.8%) report on climate variations in regions outside their own countries.

Smaller countries, such as Dominica, are solely responsible for producing reports for their own nation, while others like Fiji mention in their responses that they lack the capacity to conduct this research independently but collaborate with international partners. Additionally, several NMSs highlight in their open-ended responses that they provide advisory services to their respective governments on adapting to climate change (Fig. 4).

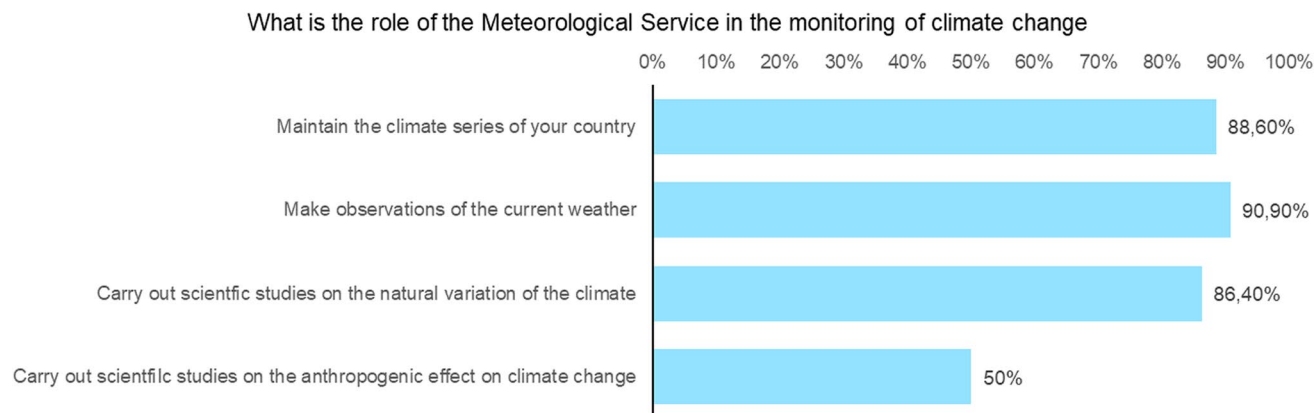


Fig. 3 Role of NMSs in climate monitoring

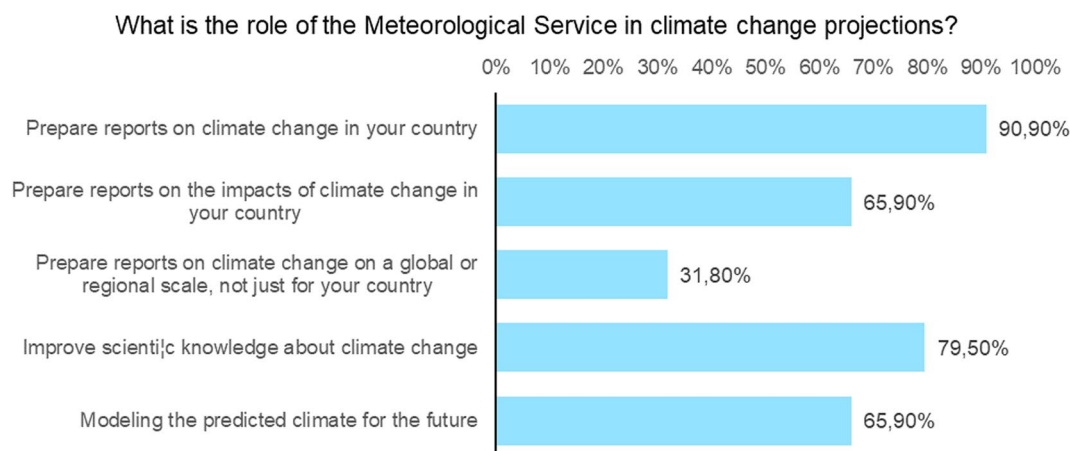


Fig. 4 Role of NMSs in climate projections

3.3 Attribution of weather events to climate change

The role of NMSs in attributing weather events to climate change—that is, in distinguishing to what extent a weather event is a result of natural variability or a manifestation of ongoing climate change that has become part of the new normal—varies significantly. A majority of NMSs (75%) report that they engage in adaptation and mitigation efforts in response to observed changes in weather and climate. Additionally, 61.4% of NMSs identify which events can be attributed to climate change and take appropriate emergency actions. However, only 59.1% specifically determine which events are due to climate change and which are not (Fig. 5).

3.4 Climate change communication

The overwhelming majority of National Meteorological Services (90.9%) communicate with the public about climate change. However, the meteorological services of Bangladesh, Colombia, Croatia, and the Dominican Republic, they did not check this option.

Additionally, a significant majority (81.8%) of NMSs report that they inform their respective governments about observed climate changes and future projections. Similarly, 79.5% of NMSs communicate about anticipated climate projections (Fig. 6).

Fig. 5 Role of NMSs in attributing events to climate change

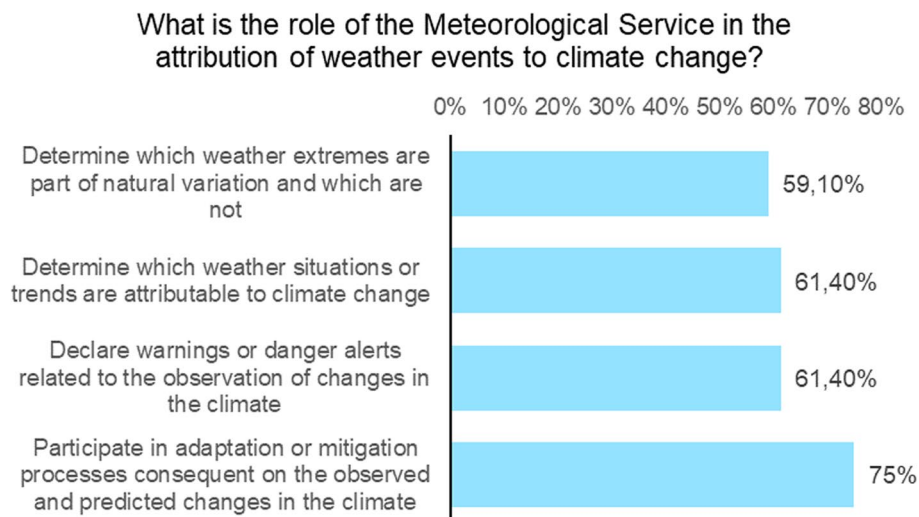
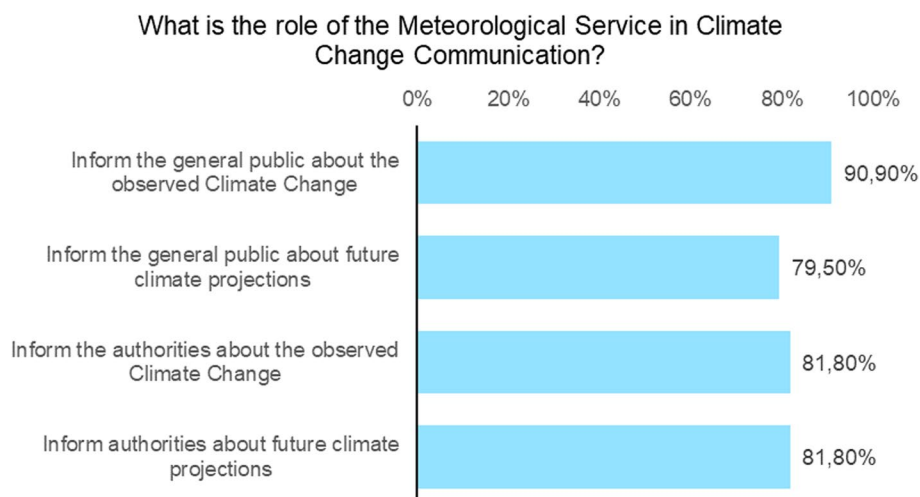


Fig. 6 Role of NMSs in climate change communication



4 Discussion and conclusions

From our survey, it is evident that most National Meteorological Services concentrate primarily on traditional meteorological tasks, such as operating weather observation networks and recording and maintaining climate data. Direct scientific engagement in studying the effects of climate change attributable to human activities is less prevalent among NMSs. Only 50% of the surveyed NMSs consider this as part of their responsibilities. In their open-ended responses, some NMSs mention their roles in coordinating or collaborating with other entities engaged in these types of studies.

The predominant role of NMS in climate change projections primarily centers on variations in climate and meteorological variables, rather than on the impacts of these changes that are generally done by other institutions. Typically, NMSs actively inform and collaborate with relevant government departments, both domestically and internationally. NMSs from larger and more economically developed countries possess enhanced capabilities for modeling climate projections and their impacts. Importantly, a majority of NMSs report that they contribute to advancing scientific knowledge about climate change.

Regarding the attribution of extreme weather events to climate change, the scientific challenges involved—both physical and conceptual—are significant [10, 14]. The disparities in capability among National Meteorological Services become quite apparent in this area. For instance, Nepal has reported in open-ended responses that it has not yet begun climate change attribution activities, despite having a mandate to do so. Kenya has started these tasks but reports having only one meteorologist adequately trained for this complex work. Conversely, Canada has indicated that it prepares such analyses for the World Meteorological Organization and for the Bulletin of the American Meteorological Society (BAMS). Reflecting these varied capabilities, only 61.4% of NMSs report issuing alerts or warnings related to climate change impacts.

When queried about their dissemination of information to both the public and their respective governments, the majority of NMSs assert their active involvement in this endeavor. However, disparities in technical capacity become evident, particularly concerning reporting on climate projections. For instance, NOAA (the NMS of the United States of America) underscores its proactive engagement in communication efforts related to risk and vulnerability within the context of a rapidly changing climate. NOAA further emphasizes its collaborative contributions to the Intergovernmental Panel on Climate Change through partnerships with governmental agencies and academic institutions.

From the data collected, it is clear that National Meteorological Services play a crucial role in understanding historical and current climate conditions, as they establish and maintain climate databases. Future studies on climate and climate change attribution will rely heavily on this data. This effort, though conducted individually by each NMS, contributes to a shared resource accessible to the global scientific community through various World Meteorological Organization data catalogs [20].

National Meteorological Services play a crucial role in climate projections within their countries, tasked with informing their respective governments about local impacts and, in many cases, leading or collaborating with the national scientific community in studying climate projections [1, 4, 7, 15, 22]. However, the ability to make projections beyond national

borders often reflects economic disparities, influencing the human and technological capacities required for such tasks. Among the NMSs that report making international climate projections are Germany, Senegal, Iceland, Austria, Panama, Canada, the Dominican Republic, Belgium, Sweden, Morocco, Uganda, Spain, Vanuatu, and the USA. Out of these 14 countries, 8 (57.1%) belong to groups with the highest income and human development indices. When considering only the Human Development Index (HDI), this number rises to 9 of the 14 countries (64.2%). Notably, in all cases where NMSs are from countries not at the highest levels of income and HDI, their HDI values exceed their income rankings.

We can infer that despite resource constraints, many countries, particularly those with higher human development levels or facing significant vulnerabilities like Vanuatu, or those affected by persistent issues such as droughts in Uganda, Morocco, and the Dominican Republic, make concerted efforts to develop or collaborate on projections that extend beyond national boundaries.

The role of NMSs, as we have observed, is crucial in ensuring the availability of climate data and in the downscaling of future climate projections. This involvement generally extends to participating in the mitigation and adaptation processes within their respective countries, often as part of the governmental framework. The larger NMSs, which possess greater financial and scientific resources, such as NOAA in the United States or Environment Canada, sometimes even lead these efforts on a global scale.

Regarding the dissemination of knowledge to the public, the vast majority of NMSs report that they actively inform society about observed climate changes and future projections. Interestingly, this activity is reported slightly more frequently than what might be expected as mandatory reporting to their respective governments or authorities. Nevertheless, responses indicate that over 80% of NMSs consistently undertake this informative role, suggesting that this function is deeply ingrained in the majority of NMSs worldwide.

Author contributions TM, EA design, conceptualization TM, EA data acquisition TM, EA analysis and data interpretation TM Article Writing TM, EA article review All authors read and approved the final manuscript.

Data availability Data is provided within supplementary information files.

Declarations

Competing interests The authors declare no competing interests.

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