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# Challenges for developing national climate services – Poland and Norway

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ABSTRACT

This contribution discusses the challenges for developing national climate services in two countries with high fossil fuel production – Poland (coal) and Norway (oil and gas). Both countries, Poland and Norway, have highly developed weather services, but largely differ on climate services. Since empirical and dynamical downscaling of climate models started in Norway over 20 years ago and meteorological and hydrological institutions in Oslo and Bergen have been collaborating on tailoring and disseminating downscaled climate projections to the Norwegian society, climate services are now well developed in Norway. The Norwegian Centre for Climate Services (NCCS) was established in 2011. In contrast, climate services in Poland, in the international understanding, do not exist. Actually, Poland is not an exception, as compared to other Central and Eastern European countries, many of which neither have their national climate services, nor are really interested in European climate services disseminated via common EU initiatives. It is worth posing a question – can Poland learn from Norway as regards climate services? This contribution is based on results of the CHASE-PL (Climate change impact assessment for selected sectors in Poland) project, carried out in the framework of the Polish – Norwegian Research Programme. The information generated within the Polish-Norwegian CHASE-PL project that is being broadly disseminated in Poland can be considered as a substitute for information delivered in other countries by climate services.

## Practical Implications

This contribution, based on results of the Polish-Norwegian CHASE-PL (Climate change impact assessment for selected sectors in Poland) project, discusses the challenges for developing national climate services in Poland and Norway. Even if these countries are giants of fossil fuel production (coal in Poland, oil and gas in Norway), their attitudes to climate services are largely different. Well-developed climate services exist in Norway, while in Poland they are non-existent. In fact, there is no Polish equivalent for the term "climate services".

Actually, Poland is not an exception in the region. Many other Central and Eastern European countries neither have their national climate services, nor are interested in relevant EU initiatives. In Poland, the "inconvenient truth" about the anthropogenic climate change is very inconvenient. Poland is neither a member nor a cooperating state of the European Centre for Medium-Range Weather Forecasts (ECMWF). Likewise, it is not a member of the EU's JPI (Joint Programming Initiative) Climate.

Availability of information on climate change, both observed and projected for the future is essential for building climate change awareness among Poles. Yet, there is no way for an interested citizen to learn about climate change by an easy access to a long time series of historical data from Poland.

There could be potential interest in climate projections in several sectors in Poland. Seasonal or sub-seasonal forecast of a heat wave or of a cold wave could help health and communal services be prepared. In Poland, cold wave in winter is still a major killer – even in the warming climate. Indeed, people (often – homeless and/or abusing alcohol) freeze to death. The number of fatalities due to hypothermia in Poland, in 2009 and 2010, respectively, was 238 and 333. Heat waves, that occur more frequently with the warming, cause increase in mortality (e.g. over a thousand additional deaths in 10 large towns in Poland, related to heat waves in 1994). Climate information could be used in health sector, building industry, agriculture and forestry, flood risk reduction, as well as water and sewage sector. Foresters are now planting forests to be

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harvested in the second half of the 21st century – a common horizon of climate modelling.

In contrast to Poland, climate services in Norway have been vigorously developing. The Norwegian Centre for Climate Services (NCCS) was established in 2011 with the main mission to provide the society with information relevant to climate change adaptation. Among the products of the NCCS are comprehensive datasets, design values for present and future climate, climate assessment reports, “climate profiles” for counties, “tailoring” of climate products, user interfaces: phone service, meetings, as well as the web portal www.klimaservicesenter.no, etc. Downscaled climate projections are tailored and disseminated, on a regular basis, to the Norwegian society. The Centre recommends a 20–40% increase in design rainfall values towards the end of this century. The NCCS addresses their activity to various users' categories, including governmental institutions and authorities at various levels, from national to municipality, as well as stakeholders in the area of roads, railways, coastal infrastructure etc.; sectors/industries, e.g.: energy, buildings, health, primary industries; and climate impact and adaptation research community. All general NCCS's services are free of charge for the users.

Indeed, an organized collaboration between climatologists and impact scientists, perhaps modelled on the Norwegian example, could be an idea for disseminating information for climate adaptation in Poland. In a way, results of the CHASE-PL project, carried out in 2014–2017 under the framework of the Polish – Norwegian Research Programme, can be regarded as a useful initiative *in lieu* of climate services that do not exist in Poland.

The deliverables of this project include a geoportal as well as a book with information on climate change and its impacts on selected sectors in Poland, published in two language versions, English and Polish. The Polish version of the book is available for free on internet. In addition, results of the CHASE-PL project have found their way to several publications in peer reviewed, scientific, periodicals of international standing.

The CHASE-PL project reviewed change detection in observed temperature, precipitation, and snow cover in Poland. Observed impacts of heat waves on human mortality in large Polish towns were also examined. Climate projections for the territory of Poland were produced via downscaling of EURO-CORDEX-based results of climate models. Future climate changes (temperature, precipitation and snow cover) for two future time horizons and for two Representative Concentration Pathways (RCP) were examined. Based on climatic projections, large-scale impacts on water resources, biota, and agrosystems in the basins of two main rivers, the Vistula and the Odra (covering 88% of the area of Poland) were examined. This was a large and pioneering task, since model-based analysis for the whole river basins of the Vistula and the Odra (including areas in neighbor countries) had not been conducted in Poland before. This was achieved via multi-site calibration and validation of the hydrological SWAT (Soil & Water Assessment Tool) model, identification of in-stream and riparian ecosystems water needs, and scenario-based analysis of impact on ecosystems (in-stream ecosystems and wetlands) and agricultural production. In addition, meso-scale models for two medium-sized lowland catchments were used for sediment and nutrient load assessments and projections.

The CHASE-PL project linked strengths of both participating countries, exemplified by Norway's traditions and achievements in climate science and Poland's experience in climate impact science. Norwegian experts provided common climatic foundations by producing downscaled projections, while Polish experts took the lead in impact analysis.

It is trusted that results of the CHASE-PL project contribute, in a considerable way, to increase of understanding of climate change impacts in selected sectors in Poland. They extend the state-of-the-art of the detection of change, as well as projection of climate change and its impacts, and interpretation of uncertainty. The CHASE-PL project contributed to reduction of the information gap on climate change impacts among the policy-makers, stakeholders and the broad Polish society.

It is worth posing a question – can Poland learn from Norway as regards climate services? The authors of this paper are rather pessimistic here. Nevertheless, since Poland has neither a platform nor instruments for dialogue between climatologists and users of climate information, a project like CHASE-PL could indeed play a role and enhance a welcome change. The information generated within the CHASE-PL project can be considered as a substitute for products delivered in other countries by climate services. However, the CHASE-PL project lasted 40 months only, hence after its end in April 2017, provision of updated information is discontinued. It seems that the emergence of a full-fledged Polish climate services centre is not in sight yet.

## 1. Introduction

Despite the progress towards improved climate projections, in many countries decision makers and stakeholders are not yet fully benefiting from effective climate services in support of decision-making in climate sensitive sectors (Lúcio and Grasso, 2016), cf. Climate Services for Decision-making (brochure):http://www.gfcs-climate.org/sites/default/files/GFCS_3-fold_flyer_July2014_EN.pdf. There are limited institutional capacities and absence of effective user interfaces providing platforms for dialogue between scientists and stakeholders. In order to improve the situation, the Global Framework for Climate Services (GFCS), cf. www.gfcs-climate.org, was launched by the World Meteorological Organization (WMO) in 2009, with the aim to guide the development and application of science-based climate information and services in support of decision-making in climate sensitive sectors. The following five critical components were identified (Lúcio and Grasso, 2016): User Interface Platform; Climate Services Information System; Observations and Monitoring; Research, Modelling and Prediction; and Capacity Development.

The concept of national climate services nicely complements the mandate of the Intergovernmental Panel on Climate Change (IPCC) - a large-scale quasi-climate-service. The mandate of the IPCC is to provide policy makers with an objective assessment of the scientific, technical and socio-economic information available about climate change, its impacts and possible response options (adaptation and mitigation), via its assessment reports.

An interesting example of continental-scale information which can be used for large-scale impact assessment important for the development of adaptation strategies in European countries was provided by Van Vliet et al. (2015). They delivered a kind of climate information service for pan-European water use sectors that are vulnerable to climate change impacts, such as water management, disaster risk reduction, agriculture, energy (hydropower and cooling water use for thermoelectric power) and environment (water quality). They capitalized on robust patterns of projected future change. Their results corroborate the established knowledge on a distinct north–south divide in water projections across the continent. In the warming climate, the availability of water resources is projected to decrease in the south and to increase in the north. Hydrological extremes – floods and droughts – are on the rise over large parts of Europe. The energy sector will be affected by lower hydropower potential in most European countries and reduced cooling water availability due to higher water temperatures and reduced summer river flows. A clear hotspot of climate change impacts is emerging in the Mediterranean region, getting hotter and drier, with large impacts on agriculture and energy sectors. Results showed important impacts of climate change on European water use sectors indicating a clear need for adaptation.

Climate services are established in most industrialized countries, but they are being developed worldwide, e.g. in Peru, in the framework of a twinning project, CLIMANDES, of Peru and Switzerland (Rosas et al., 2016). Global warming will intensify the hydrological cycle, leading to increase in frequency and intensity of heavy rainfall. Fifth Assessment Report of IPCC (2013) states that a robust increase is observed in heavy rainfall in both wet and dry regimes, and that heavy rainfall events will "very likely" (> 90% probability) become more frequent up to 2100 over most of the mid-latitude landmasses. Adapting urban runoff spillway systems to present and future design values for heavy rainfall will thus significantly reduce risk of human and economic losses.

The present contribution discusses the challenges for developing national climate services in two countries – Poland and Norway, based on results of the CHASE-PL (Climate change impact assessment for selected sectors in Poland) project, carried out in the framework of the Polish – Norwegian Research Programme.

## 2. Poland and Norway – setting the scene

Poland has mostly temperate climate, in transition between oceanic climate dominating in the north and west of the country, and continental climate in the south and east. Air masses may come to Poland from all directions. Hence specificity of the climatology of Poland can be perceived as a mix of maritime, continental, polar and tropical influences. Oceanic currents are an important factor driving the climate of Poland. The inter-year variability of seasonal or monthly mean temperature can be very high. Depending on the frequency of atmospheric circulation types, monthly temperatures can largely vary between years, particularly in winter. For example, in December, the mean temperature can be lower than −4 °C (as in many places in 2010) or higher than +6 °C (as in the same places in 2015). Examination of long time series of records of daily minimum and maximum temperatures shows that daily minimum in February can be as low as −40 °C, while daily maximum can be as high as +20 °C.

Norway has a largely elongated shape and a long coastline with fjords and islands, and extends over several climatic zones. Parts of Norway have oceanic, subarctic, tundra, or continental climates. The coastal climate is mild, due to the Gulf Stream influence. The western part of the country is exposed to moist air masses from the Atlantic, with high annual precipitation exceeding 3000 mm at some locations; while in contrast there is a rain shadow in some inland areas with annual precipitation lower than 300 mm. Norway exhibits large temperature contrasts, with extreme observed temperatures ranging from −50 °C to +35 °C. Important characteristic of the country's climate is the seasonal variation in daylight, with "white nights" in June.

Both countries, Poland and Norway, possess highly developed weather services (National Meteorological Service – Institute of Meteorology and Water Management – State Research Institute, IMGW-PIB in Poland and the Norwegian Meteorological Institute – MET Norway, respectively). However, the countries largely differ on climate services that are developed in Norway but virtually do not exist in Poland.

The topical area of climate change and its impacts is recognized as very important in Norway, as well as in many countries of the European Union. The recent survey on climate change perceptions in four European countries (France, Germany, Norway and UK) showed that 48% of Norwegian people said that they are fairly worried about climate change, whereas 29% were very worried or extremely worried (Steentjes et al., 2017). Climate change does not get a comparable status in the public discourse in Poland. In general, Poles are aware of climate change, but this issue is not widely considered as a priority. It should be added that observed impacts of climate change in Poland are not dramatic and the attribution of these impacts is complex, in the context of multiple drivers. Combination of high natural variability of hydro-meteorological phenomena with significant uncertainty of future projections hinders public discussion on these natural phenomena (Kundzewicz et al., 2017e,g). The public perception is driven by the well-rooted wisdom that Poland 'sits on coal' and this is the natural primary energy source (Kundzewicz and Matczak, 2012). In contrast, the fact that Norway is heavily dependent on export of oil and gas, does not markedly shape its public perception on climate change, although it affects its rather conservative opinion on fossil fuel taxes compared to France, Germany and UK (Steentjes et al., 2017). This is perhaps so, as national energy consumption in Norway is dominated by hydropower, responsible for 96% of national electricity production (Table 1).

**Table 1**
Electricity and heat sources in Poland and Norway for 2014, after International Energy Agency (IEA). Data from: https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=POLAND&product=ElectricityandHeat https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=NORWAY&product=ElectricityandHeat.

| | Poland | Norway |
|---|---|---|
| Electricity production (GW h) | 159 059 | 142 327 |
| Coal | 131 551 | 157 |
| Oil and gas | 6 922 | 2 629 |
| Hydroenergy | 2 734 | 136 636 |
| Wind | 7 676 | 2 216 |
| Waste and solar | 57 | 361 |
| Biofuels | 9 677 | 25 |
| Other sources | 142 | 303 |
| Heat production (TJ) | 276 887 | 26 026 |
| Coal | 241 174 | 241 |
| Oil and gas | 19 819 | 888 |
| Waste | 351 | 12 885 |
| Biofuels | 14 258 | 3 408 |
| Other sources | 1 285 | 8 604 |

Hydropower includes production from pumped storage plants. Much of heat in Norway comes from electrical heating (counted in electricity production).

## 3. Climate services in Poland and Norway

High-quality weather services are of crucial importance for warning the society on forecasted extreme weather. Similarly, dedicated climate services are crucial for adapting infrastructure to present and future extreme climatic events. Additionally, both weather and climate services should provide easily accessible information to the public. Climate services in Poland, in the international understanding, do not exist. On a funny note, there does not even exist a Polish equivalent for the term "climate services" that an average Pole with university education would understand.

There is no way for an interested citizen to learn about climate change by an easy access to a long time series of historical weather data at stations in Poland. As Potsdam (Germany) is not very far from Western Poland, the www.klima-potsdam.de portal, that provides long time series of observations (daily values since 1893) free of charge to everyone, serves many Poles (also scientists) being a convenient source of useful long-term climate information.

Jury is out yet on whether seasonal forecasts belong (or do not belong) to the general concept of weather services or climate services. Perhaps they occupy a border zone. However, there could be, potentially, considerable demand for seasonal forecasts in Poland. This agrees with a finding by Vaughan et al. (2016) who present community perspective on research priorities for climate services. They reveal considerable interest in advancing the skill of forecasts at sub-seasonal-to-seasonal scales that are found to be more broadly useful to decision makers and stakeholders at large than the more remote information at the end-of-century timescale.

Seasonal or sub-seasonal forecast of a heat wave or of a cold wave could help broad public and health and communal services be prepared. In Poland, cold wave in winter is still a major killer – even if the climate has been warming, a colder winter weather kills many people who freeze to death (often – homeless and/or abusing alcohol). Government Security Centre reported of 238 and 333 deaths due to hypothermia in Poland, in 2009 and 2010, respectively (Anonymous, 2013). Heat waves, that occur more frequently in the warming climate, cause increase in mortality. For instance, Graczyk et al. (2017b) estimated that 1186 additional deaths occurred in 10 large towns in Poland, related to heat waves in the summer of 1994.

There could be potential interest in climate projections in several sectors of Polish economy. Especially, such information could be used in building industry (in order to accommodate warmer winters and heavier and more frequent heat waves and heavy precipitation), agriculture and forestry, flood risk reduction, as well as water and sewage sector. Trees grow for many years, so that foresters are now planting forests to be harvested in the second half of the 21st century – a common horizon of climate modelling. Urban runoff spillway systems should be designed to last several decades. In some circumstances, consideration of climate change impact, risks and adaptation is formally requested, e.g. if a utility company applies for a loan from an international bank.

Availability of information on climate change, both observed until recently and projected for the future is essential for building climate change awareness in the Polish nation. Some historical climate information, without disclosing the numbers (that are generally not made available for free to broad public by the IMGW-PIB), used to be posted in the www.imgw.pl portal (cf. Fig. 1). It clearly illustrated the ongoing warming. There are many colder spots in the upper part of the "carpet" corresponding to the past years and many warmer spots that occur more recently, in the lower part of Fig. 1. Now, this useful product, prepared by Professor Halina Lorenc at IMGW-PIB, is not continued anymore.

There have been many scientific publications (articles in periodicals and reports) as well as some books on climate change in Poland but, typically, they are not available for free and hence are not accessible to broad public. It is worthy of mentioning, that there exists a very useful, and well maintained, Polish web portal on climate science, www.naukaoklimacie.pl, where broad public (including pupils and students) can find competent and objective information on climate change. Feedbacks and interactions between the portal leaders and the audience are possible, e.g. in the form of scientifically backed reactions to emerging myths and misconceptions.

Actually, Poland is not an exception, as compared to other Central and Eastern European countries. Many such countries neither have their national climate services centres, nor are really interested in European climate services disseminated via common EU initiatives, such as the CLIPC project, cf. http://www.clipc.eu/ or the recently launched Copernicus Climate Change Service (C3S, https://climate.copernicus.eu/). Poland, a country of many climate change sceptics[1], is really far behind many EU countries in this context due to several reasons, such as the lack of awareness on climate change (both among the society in general, and among decision-makers and even scientists), different culture and tradition, as well as philosophy of climate data sharing. The latter is slowly improving, but still commercial, non-research, users have to pay prohibitively high sums for access to meteorological or climatic data. A step in the right direction was the launching of a new website by IMGW-PIB, with free access to their data: https://dane.imgw.pl/ in January 2017. It is far from being perfect (for example it is difficult to download data for a longer period and for many stations) but still it is a major positive change as for Polish conditions.

Poland has neither a platform nor instruments for dialogue between climatologists and users of climate information, except for the web portal www.naukaoklimacie.pl. So, projects like CHASE-PL could indeed play an important role and contribute to a change in the appropriate good direction. However, probably, the emergence of the Polish climate services centre is not in sight yet.

In contrast, there have been considerable achievements at the Norwegian end, where climate services have been vigorously developed. Empirical and dynamical downscaling of general circulation models started in Norway over 20 years ago. Meteorological and hydrological institutions in Oslo and Bergen have been closely collaborating on tailoring and disseminating downscaled climate projections to the Norwegian society. To facilitate this, the "Norwegian Centre for Climate Services (NCCS)" was established in 2011 as a cooperation platform between meteorologists (Norwegian Meteorological Institute – MET Norway and Bjerknes Centre for Climate Research – BCCR) and hydrologists (Norwegian Water Resources and Energy Directorate – NVE). The NCCS is led by MET Norway, and is partly financed by the Norwegian Ministry of Climate and Environment. The main mission of NCCS is to provide decision makers in Norway with information relevant for climate adaptation in a changing climate. Among the products of the NCCS are comprehensive datasets for past, present and future climate, design values for present and future climate, climate assessment reports, "climate profiles" for counties, "tailoring" of climate products, user interfaces: phone service, meetings, as well as the web portal www.klimaservicesenter.no, etc. All general NCCS's services are free of charge for the users.

In Norway, high intensity rainfall during a few hours is causing large damages on infrastructure and buildings. During 2008–2014 there were 105 000 insurance claims on damages caused by water intrusion from the outside, at a cost of ca. 450 M€ (NOU, 2015). The Norwegian society would thus significantly profit from urban sewage systems better designed to handle heavy rainfall in present and future climate. NCCS is therefore providing updated information on design values for heavy rainfall in present and future climate, expressed as Intensity-Duration-Frequency (IDF) statistics. The information is presented by maps (Fig. 2) as well as by graphs and tables at the NCCS web-site. NCCS recommends a 20–40% increase in design rainfall values towards the end of this century (Hanssen-Bauer et al., 2017).

Noting that we need to plan for future climate, but in some ways we are not even properly adapted to the present climate variability, the NCCS collects and disseminates information on observed and projected climate. The results are presented on the NCCS website as well as in assessment reports on past and future climate in Norway. The report "*Climate in Norway 2100*" (Hanssen-Bauer et al., 2017) is a condensed English version of the Norwegian report "*Klima i Norge 2100*" (Hanssen-Bauer et al., 2015). These reports provide an updated scientific basis for climate adaptation in Norway, and cover several variables (temperature, precipitation, wind, snow, runoff, flooding, drought, sea level, etc.). The focus is on future climate, but the causes of climate change and variability, as well as the development of the climate in Norway since the last glaciation, and particularly during the instrumental age, are briefly described. Projected climate change through the 21st century is described under various assumptions for future emissions of greenhouse gases. Most of the estimates are based on global climate projections from the Fifth Assessment Report of the IPCC (IPCC, 2013). Emphasis is placed on changes up to the middle and the end of the 21st century. Climate projections are influenced by uncertainties, and this topic is thoroughly discussed in the report.

The NCCS addresses their activity to various users' categories. Among them are governmental institutions and authorities at various levels, from national to municipality, as well as stakeholders in the area of roads, railways, coastal infrastructure etc.; sectors/industries, e.g.:

[1] http://www.pewglobal.org/2015/11/05/global-concern-about-climate-change-broad-support-for-limiting-emissions/

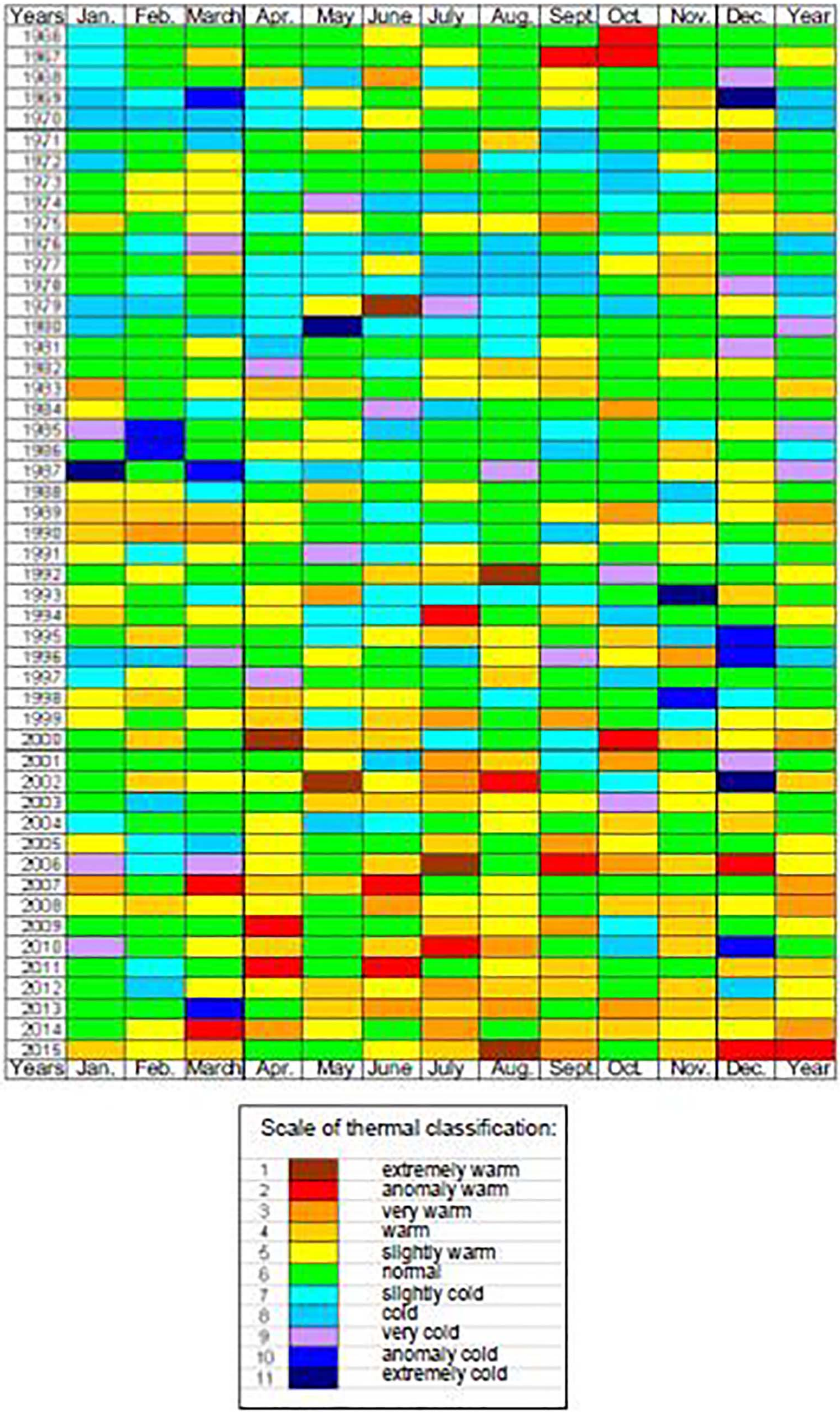


**Fig. 1.** Thermal classification of months (columns) and years (rows) for the meteorological station Warszawa-Okęcie, after Professor Halina Lorenc, with regard to the reference period 1971–2000.

energy, buildings, health, primary industries; and climate impact research community, dealing with physical systems, ecosystems, and the society. The NCCS bridges such separate entities as climatologists' knowledge and decision-makers' information needs, being also a bridge between science and management; between observations and model calculations, between past and future climate, between different scales in time and space, as well as between different institutions, directorates and ministries.

Interaction between scientists and decision-makers, and stakeholders at large, indeed requires an intermediary. Different users

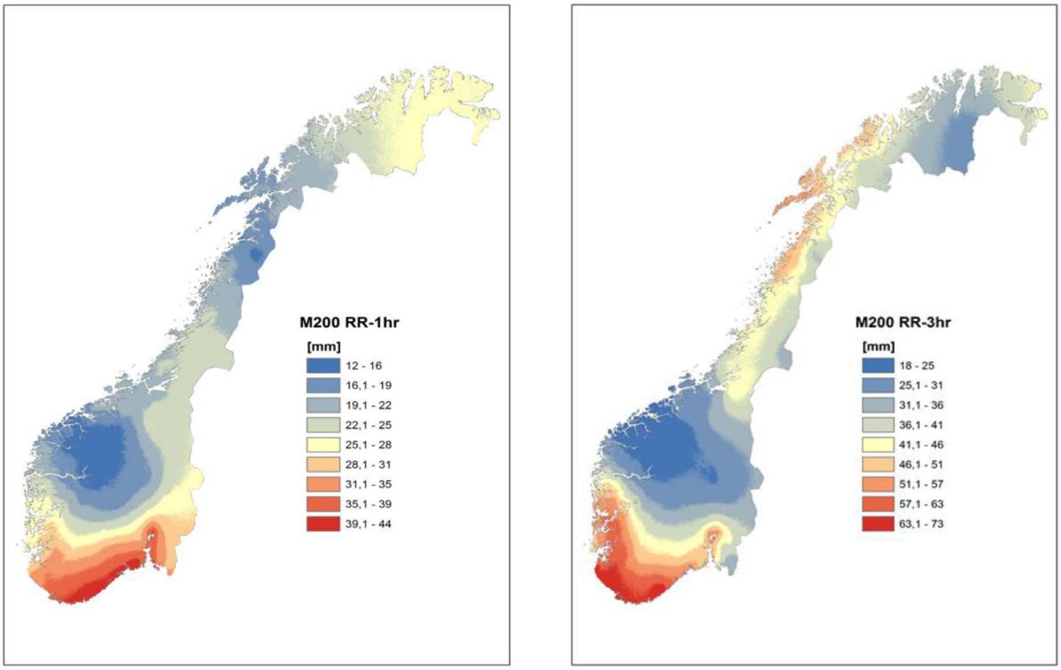


**Fig. 2.** Norwegian design values for heavy rainfall (mm) of duration of 1 and 3 h and return period 200 years.

declare different needs, some of which cannot be fulfilled. Typically, an engineer requests a single, crisp number of a parameter, to design a structure, while scientists provide a range of projections, with identification of uncertainty around the central value. A municipality planner needs e.g. a map showing flood-risk zones, in order to answer a practical question – how close to a river dwelling building areas can be allowed. A climate impact researcher may need detailed, consistent, and robust climate projections of a number of variables or indices (that in some cases cannot be provided) to design climate change adaptation.

Indeed, an organized collaboration between climatologists and impact scientists, e.g. hydrologists, perhaps modelled on the Norwegian example, could be an idea for disseminating background data for climate adaptation in Poland. Can collaboration between Poland and Norway, as evidenced at the example of the CHASE-PL project, help establish a Polish climate service centre (Kundzewicz et al., 2017b)?

## 4. CHASE-PL project – a proxy for climate services

Results of the CHASE-PL project, carried out in 2014–2017 under the framework of the Polish – Norwegian Research Programme can be regarded as a useful initiative *in lieu* of climate services that do not exist in Poland.

The information generated within the project that is being broadly disseminated can make a difference in Poland. The deliverables of this project include the geoportal with information on climate change and its impacts on selected sectors in Poland, as well as a book on climate change and its impacts on selected sectors (water resources, ecosystems, agriculture, health), published in two language versions, English and Polish (Kundzewicz et al., 2017c,d). The Polish version is available for free on internet. Both products fill an important gap.

The geoportal (http://climateimpact.sggw.pl), being an interactive web-mapping system, laureate of the 2nd prize in the Polish contest “Internet Map of the Year 2016/2017” [2], presents the following topics:

- Gridded and station-based observed climate products for the area of Poland for the period 1951–2013 (cf. Fig. 3);
- Temperature and precipitation projections from an ensemble of bias-adjusted EURO-CORDEX regional climate models and CMIP5 general circulation models for two future horizons: 2021–2050 and 2071–2100;
- Projections of climate change impacts on hydrology (and some other sectors such as riverine ecosystems, wetlands and agrosystems).

The geoportal is available in two language versions; Polish and English. The purpose of making processed climate data, and in particular information based on the newest generation of climate change projections for the area of Poland, available is to encourage their use in all disciplines of research where climate change is an important driver. Since most of the maps are available at high, 5 km, resolution, the portal can also be useful for adaptation planning at local government level. A recent comprehensive survey carried out within another Polish-Norwegian project (PolCitClim) revealed that local government authorities in Poland, in contrast to Norway, are faced with the lack of climate impact scenario data at the spatial scale that would be most relevant for them (Swianiewicz, 2017). The geoportal that allows quick browsing of over 1500 maps using a time slider can also be used as an educational tool at high school and university level. Finally, it builds upon the massive amounts of research data and information produced within the CHASE-PL project, that are available for download in open research data repositories (Berezowski et al., 2016; Mezghani et al., 2017a,b; Piniewski et al., 2017c). It is our strong belief that free and easy access to processed historical data and projected hydro-meteorological information allows for critical and rigid comparison of different approaches to the assessment of climate change impact.

Another major product of the CHASE-PL project is a book compiling all major results achieved during the project (Kundzewicz et al., 2017c,d). In the book, change detection in observed climate of Poland was carried out for a range of variables of particular relevance and interest. Graczyk et al. (2017a) reviewed changes in temperature, Pinskwar et al. (2017) – changes in precipitation, while Szwed et al. (2017) – changes in snow cover.

Projections of climate variability and change for Poland were also produced, following the results of the EURO-CORDEX initiative (Jacob

[2] http://kartografia.pwr.edu.pl/Joomla_SKP/index.php?option = com_content&view = article&id = 219:wyniki-konkursu-internetowa-mapa-roku-20162017&catid = 45:internetowa-mapa-roku&Itemid = 111

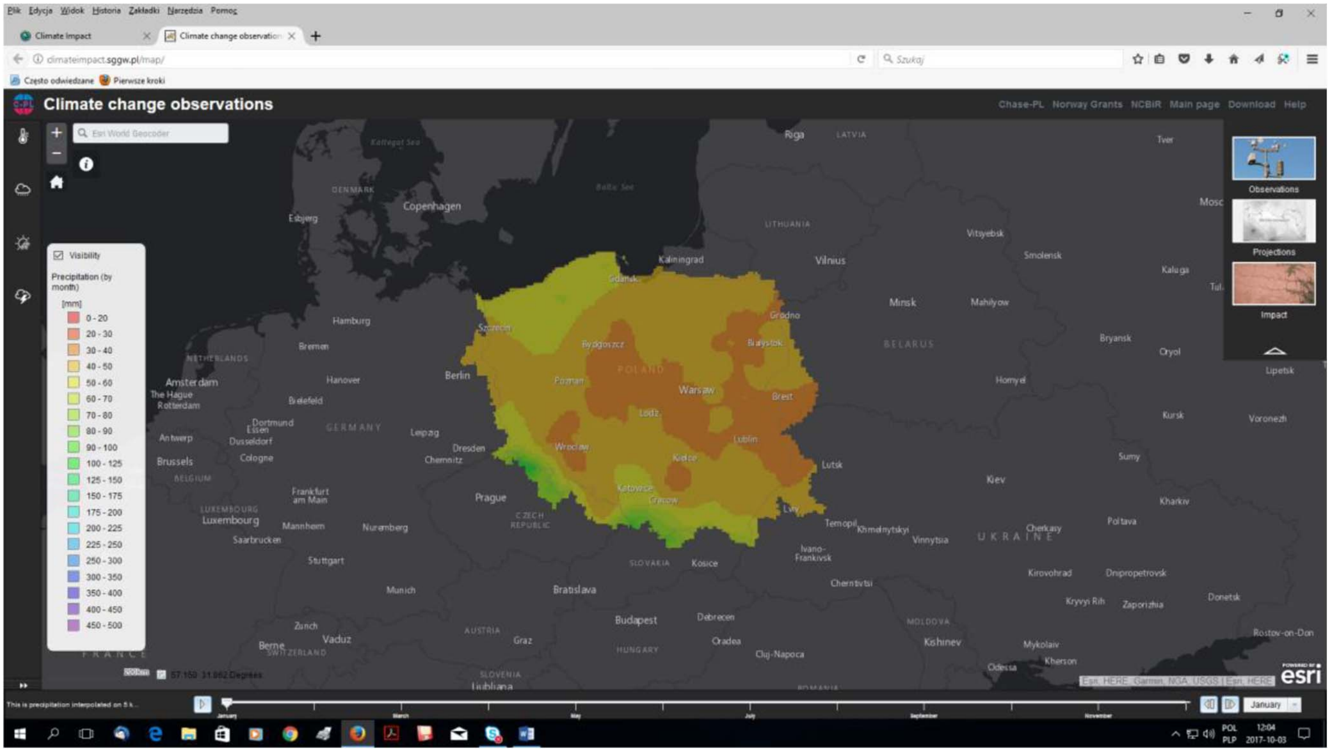


**Fig. 3.** Gridded and station-based observed January precipitation for the area of Poland for the period 1951–2013. A PrintScreen view from the geoportal (http://climateimpact.sggw.pl/map/).

et al., 2014) and compared with the reference period. This was achieved via downscaling of General Circulation Models (GCMs) climate projections for the territory of Poland. Indeed, input of Norwegian experts was dominant there – Mezghani et al. (respectively 2017a and 2017b) examined future climate changes (temperature, precipitation and snow cover) for two future time horizons and for two Representative Concentration Pattern (RCP) emission scenarios (cf., IPCC, 2013) and discussed methodology of projections.

Large-scale climate change impacts in the basins of two main rivers, the Vistula and the Odra (covering 88% of the area of Poland), were examined, where the impacts on water resources, biota, and agrosystems were considered. This was a large and pioneering task, since model-based analysis for the whole river basins of the Vistula and the Odra had not been conducted in Poland before. This was achieved in the CHASE-PL project via multi-site calibration and validation of the hydrological SWAT (Soil & Water Assessment Tool) model, identification of in-stream and riparian ecosystems' water needs, scenario-based analysis of impact of climate change on ecosystems and agricultural production. In addition, two meso-scale models, for two medium-sized lowland catchments, the Upper Narew and the Barycz (which are sub-catchments of the Vistula and the Odra basins, respectively) were calibrated and used for sediment, nitrogen and phosphorus load assessments and projections.

Climate change impacts on sectors in Poland were examined. Piniewski et al. (2017a) discussed climate change impacts on water resources in terms of water quantity for the Vistula and the Odra rivers and water quality for the Barycz and the Upper Narew, while Okruszko et al. (2017) delivered projections of climate change impact on water environment and wetlands in Poland. Various impacts on Poland's agricultural sector were tackled by Kundzewicz and Kozyra (2017) who discussed general climate change impact on Polish agriculture and by Piniewski et al. (2017b) who presented model-based projections of climate change impacts on spring crops until the time horizon 2050. Significant change of future abiotic conditions is revealed, which may reshape the functioning of ecosystems and agrosystems in Poland. Graczyk et al. (2017b) examined observed impacts of heat waves on human mortality in 10 large Polish towns.

Kundzewicz et al. (2017f) tackled uncertainty in climate change and climate change mitigation policy. Kundzewicz et al. (2017a) also discussed perception of climate change and its impacts in Poland and Norway, while Kundzewicz et al. (2017b) compared challenges for developing national climate services in both countries.

The CHASE-PL project linked strengths of both participating countries, exemplified by Norway's traditions and achievements in climate science and Poland's experience in climate impact science. Norwegian experts provided common climatic foundations by producing downscaled projections, while Polish experts took the lead in impact analysis. Valuable inputs were also obtained from co-authors from beyond the project (cf. Kundzewicz et al. (2017e)).

Results of the CHASE-PL project have also found their way to several publications in peer reviewed, scientific, periodicals of international standing. It is trusted that results of the CHASE-PL project contribute, in a considerable way, to increase of understanding of climate change impacts in selected sectors in Poland. They extend the state-of-the-art of the detection of change, projection of climate change and its impacts, and interpretation of uncertainty.

The CHASE-PL project enabled other researchers to use project outcomes in their own studies, as well as contributed to filling the information gap on climate change impacts among the policy-makers, stakeholders and the broad Polish society. The lessons learned from such studies can help in identifying the available adaptation strategies and rising awareness of its importance. Moreover there has been a historical, disciplinary "disconnect" between communities developing integrated water cycle and water resources assessment and modelling frameworks on the one hand, and the communities developing climate modelling frameworks on the other. The CHASE-PL project made a serious attempt to bring the activities of the hydrological and climate communities closer together (Kundzewicz et al., 2017e).

## 5. Conclusions

As noted in the present paper, even if both countries, Poland and

Norway, are giants in fossil fuel production (coal in Poland and oil and gas in Norway), their attitudes to climate services are largely different. There are well developed climate services in Norway, while in Poland they are non-existent. Actually, Poland is not an exception in the region, as many other Central and Eastern European countries neither have their national climate services, nor are interested in common EU climate-services initiatives. In contrast, climate services in Norway are vigorous – downscaled climate projections are tailored and disseminated, on a regular basis, to the Norwegian society. The Norwegian Centre for Climate Services (NCCS) was established as a cooperation platform between meteorologists and hydrologists. It is worth posing a question – can Poland learn from Norway as regards climate services?

The authors of this paper are rather pessimistic as to the response to this question. The problems in Poland are deeply rooted. It is the only "developed" European country that is not a member state or even a cooperating state of the European Centre for Medium-Range Weather Forecasts (ECMWF).[3] Likewise, Poland is not a member of the EU's JPI (Joint Programming Initiative) Climate[4], so that so it cannot receive funding for dedicated projects in the field of Climate Services (as Norway does).

At present, there is a large initiative in Poland, "Development of Urban Adaptation Plans for cities with more than 100,000 inhabitants in Poland", cf. http://44mpa.pl/wp-content/uploads/2017/02/MPA-broszura-B5_podglad.pdf. The cities, in cooperation with the Ministry of the Environment, aim at adapting them to the observed and projected climate changes. The specific task is to prepare urban adaptation plans for climate change in 44 largest Polish towns, inhabited by over 30% of Poland's population. As noted by Cortekar et al. (2016), climate change adaptation in cities do indeed need customized and flexible climate services. No doubt that Polish climate services would be very useful in such a project, aimed to improve awareness and attract stakeholders, as well as reducing risk of loss of human lives and of destruction of buildings and infrastructure.

The information generated within the CHASE-PL project that is being broadly disseminated can be considered as a substitute for information delivered in other countries by climate services. However, the CHASE-PL project lasted 40 months only, hence after termination of it, provision of updated information is discontinued.

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## References

Anonymous, 2013. Ekstremalne warunki pogodowe – zalecenia dla administracji. Biuletyn Wydziału Analiz Rządowego Centrum Bezpieczeństwa No. 1. (Oct.-Dec. 2012), 3–6.

Berezowski, T., Szcześniak, M., Kardel, I., Michałowski, R., Okruszko, T., Mezghani, A., Piniewski, M., 2016. CPLFD-GDPT5: high-resolution gridded daily precipitation and temperature data set for two largest Polish river basins. Earth Syst. Sci. Data 8, 127–139.

Cortekar, J., Bender, S., Brune, M., Groth, M., 2016. Why climate change adaptation in cities needs customised and flexible climate services. Clim. Serv. 4, 42–51. http://dx.doi.org/10.1016/j.cliser.2016.11.002.

Graczyk, D., Pińskwar, I., Choryński, A., Szwed, M., Kundzewicz, Z.W., 2017a. Changes of air temperature in Poland. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and its Impact on Selected Sectors in Poland, pp. 44–56 (Chapter 4).

Graczyk, D., Pińskwar, I., Choryński, A., Szwed, M., Kundzewicz, Z.W., 2017b. Impacts of heat waves on health in large Polish towns. In: Kundzewicz, Z.W., Hov, Ø. and Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 187–199 (Chapter 13).

Hanssen-Bauer, I. et al., 2015. Klima i Norge 2100. NCCS report no. 2/2015, 2. Opplag, 203 pp. (http://www.klimaservicesenter.no).

Hanssen-Bauer, I., Førland, E.J., Hisdal, H., Mayer, S., 2017. Climate in Norway 2100 – a knowledge base for climate adaptation. NCCS Report no. 1/2017 (http://www.klimaservicesenter.no).

IPCC, 2013. Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (Eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Jacob, D., Petersen, J., Eggert, B., Alias, A., Christensen, O.B., Bouwer, L.M., Braun, A., Colette, A., Déqué, M., Georgievski, G., Georgopoulou, E., 2014. EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg. Environ. Change 14 (2), 563–578.

Kundzewicz, Z.W., Kozyra, J., 2017. Climate change impact on Polish agriculture. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate change and its impact on selected sectors in Poland, pp. 158–171 (Chapter 11).

Kundzewicz, Z.W. Benestad, R.E., Ceglarz, A., 2017a. Perception of climate change and mitigation policy in Poland and Norway. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 216–245 (Chapter 15).

Kundzewicz, Z.W., Førland, E.J., Piniewski, M., 2017b. Challenges for developing national climate services – Can Poland learn from Norway? In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 245–255 (Chapter 16).

Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.), 2017. Climate change and its impact on selected sectors in Poland. Poznań, Poland.

Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.), 2017. Zmiany klimatu i ich skutki w wybranych sektorach w Polsce. Poznań, Poland.

Kundzewicz, Z. W., Hov, Ø., Okruszko, T., 2017e. Introduction. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 9–13 (Chapter 1).

Kundzewicz, Z.W., Hov, Ø., Piniewski, M., Krysanova, V., Benestad, R.E., Otto, I.M., 2017f. Uncertainty in climate change and its impacts. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 201–215 (Chapter 14).

Kundzewicz, Z.W., Matczak, P., 2012. Climate change regional review: Poland. WIRES Clim. Change 3 (4), 297–311.

Kundzewicz, Z.W., Painter, J., Kundzewicz, W.J., 2017g. Climate change in the media: Poland's exceptionalism. Environ. Commun. (in print).

Lúcio, F.D.F., Grasso, V., 2016. The global framework for climate services (GFCS). Clim. Serv. 2 (3), 52–53.

Mezghani, A., Parding, K.M., Dobler, A., Benestad, R.E., Haugen, J.E., Piniewski, M., 2017a. Projections of changes in temperature, precipitation and snow cover in Poland. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors In Poland, pp. 90–113 (Chapter 7).

Mezghani, A., Parding, K.M., Dobler, A., Benestad, R.E., Haugen, J.E., Kundzewicz, Z.W., 2017b. Methodology of projections. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 114–123 (Chapter 8).

NOU, 2015. Urban runoff in cities and towns: Problem and resource (In Norwegian: Overvann i byer og tettsteder: Som problem og ressurs), Official Norwegian Reports 2015: 16 (https://www.regjeringen.no/no/dokumenter/nou-2015-16/id2465332/).

Okruszko, T., O'Keeffe, J., Utratna, M., Marcinkowski, P., Szcześniak, M., Kardel, I., Kundzewicz, Z.W., Piniewski, M., 2017. Projections of climate change impact on water environment and wetlands in Poland. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 141–157 (Chapter 10).

Piniewski, M., Szcześniak, M., Kardel, I., Marcinkowski, P., Okruszko, T., Kundzewicz, Z. W., 2017a. Water resources. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 125–140 (Chapter 9).

Piniewski, M., Szcześniak, M., Marcinkowski, P., O'Keeffe, J., Okruszko, T., Nieróbca, A., Kozyra, J., Kundzewicz, Z.W., 2017b. Model-based projections of climate change impacts on spring crops until 2050. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds. ) Climate Change and Its Impact on Selected Sectors in Poland, pp. 172–186 (Chapter 12).

Piniewski, M., Szcześniak, M., Kardel, I., 2017c. CHASE-PL – Future Hydrology (CPL-FH) data set: projections of water balance and streamflow for the Vistula and Odra basins Poland. Data 2 (2), 14.

Pińskwar, I., Choryński, A., Graczyk, D., Szwed, M., Kundzewicz, Z.W., 2017. Changes in precipitation in Poland. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 57–77 (Chapter 5).

Rosas, G., Gubler, S., Oria, C., Acuña, D., Avalos, G., Begert, M., Castillo, E., Croci-

[3] http://www.ecmwf.int/en/about/who-we-are/member-states

[4] http://jpi-climate.eu/programme/membercountries

Maspoli, M., Cubas, F., Dapozzo, M., Díaz, A., van Geijtenbeek, D., Jacques, M., Konzelmann, T., Lavado, W., Matos, A., Mauchle, F., Rohrer, M., Rossa, A., Scherrer, S.C., Valdez, M., Valverde, M., Villar, G., Villegas, E., 2016. Towards implementing climate services in Peru – the project CLIMANDES. Clim. Serv. 4, 30–41. http://dx.doi.org/10.1016/j.cliser.2016.10.001.

Steentjes, K., Pidgeon, N., Poortinga, W., Corner, A., Arnold, A., Böhm, G., Mays, C., Poumadère, M., Ruddat, M., Scheer, D., Sonnberger, M., Tvinnereim, E., 2017. European perceptions of climate change: Topline findings of a survey conducted in four European countries in 2016. Cardiff University, Cardiff.

Swianiewicz, P., 2017. Gminy wobec zmian klimatu. Wspólnota 3, 50–53.

Szwed, M., Pińskwar, I., Kundzewicz, Z.W., Graczyk, D., Mezghani, A., 2017. Changes in snow cover. In: Kundzewicz, Z.W., Hov, Ø., Okruszko, T. (Eds.) Climate Change and Its Impact on Selected Sectors in Poland, pp. 78–88 (Chapter 6).

van Vliet, M.T.H., Donnelly, Ch., Strömbäck, L., Capell, R., Ludwig, F., 2015. European scale climate information services for water use sectors. J. Hydrol. 528, 503–513.

Vaughan, C., Buja, L., Kruczkiewicz, A., Goddard, L., 2016. Identifying research priorities to advance climate services. Clim. Serv. 4, 65–74. http://dx.doi.org/10.1016/j.cliser.2016.11.004.