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Twinning SENAMHI and MeteoSwiss to co-develop climate services for the agricultural sector in Peru

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ABSTRACT

The development and dissemination of weather and climate information is crucial to improve people's resilience and adaptability to climate variability and change. The impacts of climate variability and change are generally stronger for disadvantaged population groups due to their limited adaptive and coping capacities. For instance, smallholder farmers living in remote areas such as the southern Peruvian Andes suffer strongly from adverse weather and climatic events such as droughts or frost. The project Climandes aimed at providing high-quality climate services in support of the agricultural sector in southern Peru by implementing the guidelines of the Global Framework for Climate Services (GFCS).

In Climandes, a two-fold challenge was tackled: the co-development of climate services by building up a continuous dialogue between the information provider (in this case the Peruvian national meteorological and hydrological service (NMHS)) and potential users; and the production of climate services through international cooperation. To this end, the NMHSs of Peru (SENAMHI) and Switzerland (MeteoSwiss) worked closely together to tackle issues ranging from the treatment of climate data to ensure the provision of reliable information to establishing continuous interaction with different user groups. In this paper, we postulate that this approach of close collaboration, the so-called twinning of the two NMHSs, was key for the projects' success and contributed to strengthening the Peruvian NMHS institutionally and procedurally. This project overview guides its reader through the approach, main achievements, and conclusions regarding successes and challenges of the project, and reflects on some potential improvements for future initiatives.

Practical implications

Human livelihood is strongly affected by extreme weather and climate events. The development and dissemination of weather and climate information is thus crucial to improve people's resilience and adaptive capacity to climate variability and change. The impacts of extreme events and climate change are generally stronger for disadvantaged population groups due to their limited adaptive and coping capacities. For instance, smallholder farmers

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living in remote areas such as the southern Peruvian Andes suffer strongly from adverse weather and climatic events such as droughts or frost. In this context, the project Climandes aimed at providing high quality climate services in support of the agricultural sector in southern Peru by implementing the guidelines of the Global Framework for Climate Services (GFCS). Climandes addressed the main elements of the entire climate services value chain in a pilot setting by identifying and addressing the main capacity gaps both of the provider and the users.

In this study, we present the approach and the main results of the Climandes project. Climandes tackled a two-fold challenge by 1) implementing climate services and 2) operating in an international cooperation context. For the first challenge, wide ranges of capacities have to be in place at a national meteorological and hydrological service (NMHS). The provision of meaningful climate services entail capacities that range from systematic observations to their quality control, data analysis, and monitoring and forecast production, up to the understanding of sector and user-specific needs. For the latter, the co-development of climate services through an early engagement with users is key to ensure that climate information becomes part of the users' decision-making process. The second challenge of implementing climate services in a developing context was tackled through what we like to refer to as a twinning approach, i.e., in our case by setting up a close collaboration between the two NMHSs from Peru and Switzerland. All project outcomes have been developed together in e.g. multilateral workshops, bilateral meetings between Peruvian and Swiss experts, visits on site, and scientific exchanges. This close collaboration resulted in building shared ownership and trust between all project partners.

Climandes was conducted as a pilot project in the agricultural sector but the main findings and implications may be applied to other sectors as well. These findings encompass identifying and addressing specific gaps on both the provider and the users' side. The capacities of climate services providers can be grouped into technical capacities, which range from the observation to the production and delivery of services, human capacities, institutional capacities to enhance the policy dialogue and governmental support, as well as infrastructural capacities (not addressed in Climandes). On the user side, the awareness for the potential of climate services need to be raised. Further, a good understanding of the products should be developed. Both goals require establishing a continuous user-provider interface, or in GFCS terms a User Interface Platform (UIP). In the following, the main implications of the Climandes results and experience are listed that aid in providing more sustainable results. They can be taken as suggestions for consideration by similar projects in the field of climate services.

Enhancing the technical capacities at a NMHS:

- Climate and weather observations are the basis for any climate service and are the NMHSs' essential assets. The systematic enhancement of climatological observations through quality control and homogenization is fundamental for the production of high quality and consistent climate products.
- The observation network design determines for which regions climate services are representative, a particularly important aspect in complex terrain such as the southern Peruvian Andes. Complex terrain demands for information at high spatial resolution. The use of complementary information in addition to station observations should be considered in case an observation network is not sufficiently dense.
- A thorough validation of such additional information is essential to ensure the quality of the derived product and information.
- A systematic data management system in form of a fit-for-purpose, modern, interoperable database system including backup and redundant systems is key to allowing for the implementation of consistent climate products.
- The production of scientifically based and sector-specific climate analyses and their effective implementation are key to ensuring that climate services meet the users' needs and feed into the decision-making process.
- High quality of the weather and climate products, for example regarding accuracy, timeliness, and resolution, is the key factor to ensure the institutional credibility and reputation of the NMHS in society and politics.

Enhancing the user-provider interface:

- Identify and evaluate the key stakeholders relevant for climate services (stakeholder mapping).
- Hold an institutional policy dialogue with local, regional, and national policy-makers to determine the return on their current and future investments in climate services.
- Establish a continuous interaction mechanism with the user community e.g. through workshops targeted to directly address the identified opportunities and constraints of the use of weather and climate information. Improve the climate literacy of the target users.
- Design information tailored to the users and delivered through identified distribution systems. Establish a feedback mechanism to verify that forecasts and warnings are received and understood with the aim to improve the service continuously.
- Increase awareness in the climate community to ensure appropriate consideration of user needs for climate data and products.
- Community outreach is resource-intensive and requires enhanced capacities of technical staff in meteorological offices in peripheral regions. Particular attention must therefore be paid that these offices are endowed with sufficient human and financial capital.

Fostering human capacities:

- Develop human capacities to strengthen the technical expertise at the NMHS through formal training and a culture that supports informal learning (e.g., peer-to-peer training).
- Determine suitable learning formats that best fit your training purpose (e.g., online, classroom, or blended online and classroom training).
- Support knowledge holders and experts with a didactics center and corresponding training infrastructure.
- Search for mechanisms for keeping the expertise within the provider institution and avoid brain drain.
- The twinning approach promotes ownership and close collaboration between all project partners. Twinning encompasses the building of trust among the partners from the beginning of a project, the establishment of common goals, and the set-up of a continuous exchange throughout the project.

Striving for sustainability:

- Bring the developed prototype services into operation.
- Upscale the prototype service to a wider user community. Announce this as additional activities in the budget cycles early on in the project.
- Share lessons learnt and key experiences with other organizations and practitioners.
- Strengthen regional collaboration through regional training activities, workshops, conferences, etc., but also envisage data exchange mechanisms and technical collaborations.

1. Introduction

There is growing awareness of how weather, climate, and water resources affect a wide variety of human livelihood ranging from every day's life to the sustainable development of societies. The World Economic Forum's (WEF) Global Risks Report listed in their 2019 edition that environmental challenges such as extreme weather events, climate change mitigation and adaptation policy failures, and natural disasters are the risk of greatest concern (WEF, 2018). In 2015, the international community established new global agendas which include the combat against climate change and its impacts: 1) the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015), 2) the Agenda 2030 for Sustainable Development (UN, 2015), and 3) the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC, 2015). Building resilience is a unifying concept of these landmark frameworks for global policymaking for sustainable development, adaptation, and disaster risk management (UNFCCC, 2017). Hereby, climate services, i.e., a decision aid for governments, organizations, and individuals that are seamlessly derived from information about the past, current, and future climate (WMO, 2013), support the achievement of these three global agendas. For the Sendai Framework, weather and climate predictions on a broad range of spatial and temporal scales are a fundamental element of multi-hazard early-warning systems. Under the Paris Agreement, improved communication of scientific information on climate variability, trends, and extremes contributes to climate risk assessments and supports the promoted National Adaption Plans (NAPs), where the layout of these latter clearly relies on strong national meteorological and hydrological services (NMHSs; UNFCCC, 2012). Finally, the majority of the 17 sustainable development goals (SDGs) is climate-sensitive, again rendering climate services critical for achieving these goals. There is a need for user-tailored climate information to enable smarter decision-making. To coordinate and guide these initiatives, heads of state, governments, and scientists worked together on the Global Framework for Climate Services (GFCS) at the Third World Climate Conference (WCC-3) in 2009, to promote the availability of climate information in climate-sensitive sectors to better adapt to climate change.

Classified as a mega diverse country, Peru is among the most vulnerable countries in Latin America with regard to climate variability and change (MINAM, 2010). Severe droughts such as the one occurring at the end of 2016 in the Andes, causing bush fires and yield losses, endanger the livelihoods of agricultural communities. Torrential rainfalls that often occur at the northern coast during strong canonical El Niño events, and e.g. the coastal El Niño in January to March 2017 (e.g., Ramírez and Briones, 2017; Rodríguez-Morata et al., 2019), threaten infrastructure and the population in general. Glacier retreat in the Andes will likely intensify problems related to water shortages (Rabatel et al., 2013; Salzmann et al., 2013). Further, many of these adverse climate conditions are projected to worsen in the future (e.g., Minveille and Garreaud, 2011; Neukom et al., 2015; Magrin et al., 2014). For Peru, a study estimated an average annual economic loss caused by climate change to be 7.3 to 8.6 percent of the country's gross domestic product (GDP) by 2050 for the most extreme climate scenario (Vargas, 2009). By the end of the 21st century, these economic losses could reach up to 20% of Peru's GDP if no effective measures to mitigate climate change are taken (Vargas, 2009). The agricultural sector is particularly at risk and losses could reach up to 33% of the sector's GDP (BID and CEPAL, 2014). The Peruvian government recognized these challenges and developed a National Strategy on Climate Change in 2015 (MINAM, 2015).

The impact of climate variability and change is not distributed equally; it is generally greater for disadvantaged population groups (IPCC, 2014). In the Andean highlands, this higher vulnerability is the product of the high exposure of the region to environmental hazards and the low socio-economic capacities of the population. Especially in tropical regions, climate warming leads to adverse impacts in the form of yield losses (e.g., Schleussner et al., 2016), a threat that could be reduced if the global temperature increase was kept at 1.5 °C (IPCC 2018). Due to missing coping strategies, minor harvest may directly translate into long-term impacts on the livelihoods of farmers and their families and a single event can push people into poverty and reverse long-lasting development progresses. Improved climate risk management through climate services is a key component for increasing the resilience of vulnerable populations. However, availability alone is not sufficient; too often climate and weather information does not reach the target community in a meaningful and understandable form (Carr and Onzere, 2017).

In 2012, the Global Program Climate Change and Environment (GPCCE) of the Swiss Agency for Development and Cooperation (SDC) launched Climandes (Servicios climáticos para el desarrollo) as one of the eight priority projects for the implementation of the GFCS. This cooperation project between the national meteorological and hydrological services (NMHSs) of Peru (SENAMHI) and Switzerland (MeteoSwiss) aimed at developing user-tailored climate services with emphasis on subsistence farming in the Peruvian highlands. The overall goal of Climandes was to support SENAMHI in the implementation of the core elements necessary for the consistent provision of climate services. The first phase (2012–2015, e.g., Rosas et al., 2016) dealt with quality control and homogenization of climate data and targeted training. Further, SENAMHI established a broad communication strategy through the creation of a specialized network of journalists, diverse climate fora, and the collation of a user database. A demand study revealed current needs regarding climate and weather information, and showed that there is a high interest in forecasts at the seasonal scale (Rosas et al., 2016), which shaped the direction of the second phase of the project.

The present paper reports on the main results achieved in the second phase of Climandes (2016–2019). Section 2 describes the projects' approach to implement GFCS, to tackle the challenge of international cooperation, and to ensure the sustainability of the projects' results, and briefly presents the project set-up. The main results are presented in Section 3. The paper ends with a summary and conclusion, and an outlook to potential future initiatives.

2. Implementation of the GFCS through twinning

In this section, the two-fold challenge of implementing GFCS in the form of an international cooperation project is described. By two-fold we refer to the co-development of climate services in a developing context. The GFCS officially started in concomitance with the kick-off of the Climandes project in 2012. The relatively recent constitution of the framework is indicative of the fact that high-quality climate services are not yet established in most countries and NMHSs. In 2011, this was also true for Switzerland as there was no national implementation of the GFCS at that time. Meanwhile, a National Center for Climate Services (NCCS) was established in Switzerland in 2015 that develops and coordinates climate services for diverse sectors (www.nccs.ch).

The challenges in international cooperation are well known and generally have their origin in a combination of institutional, technical, human, and infrastructural shortcomings and needs, which often makes focusing on the project tasks difficult. In addition, cultural differences that come with most international cooperation settings require particular attention. In order to address these challenges, a twinning arrangement between SENAMHI and MeteoSwiss was set up.

2.1. GFCS implementation: an interdisciplinary and inter-institutional challenge

The GFCS aims to improve the availability, quality, and access to climate services in order to better deal with climate-related risks in five priority areas, including agriculture and food security (WMO, 2011). Further, it recognized that developing countries and countries with emerging economies often have limited capabilities for providing weather and climate services and are, therefore, given a high priority in the implementation of the framework. In order for an NMHS to become fit for GFCS purposes, a wide range of capacities has to be in place. Fig. 1 illustrates the required elements to deliver meaningful services ranging from systematic observations to their analyses and use in forecast production, up to sector and user-specific understanding of the users' needs. In order to disentangle the different complexities, the GFCS structures the necessary capacities into the five pillars: observations, forecasting,

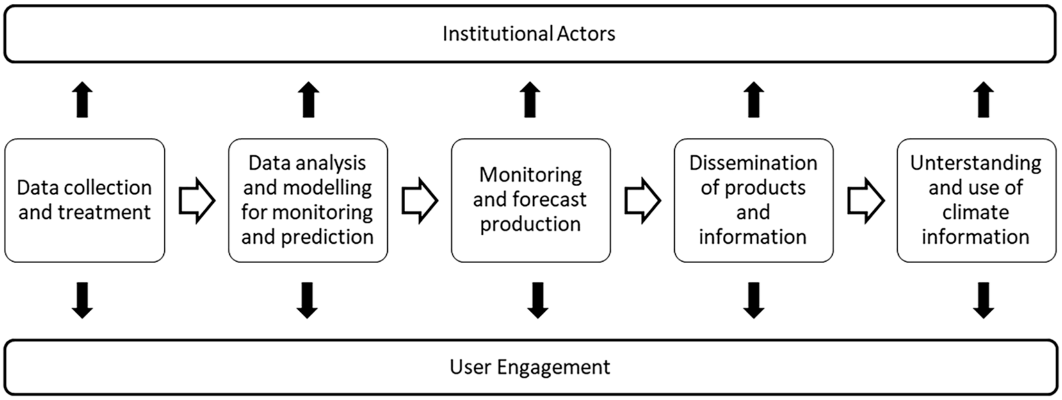

Fig. 1. The climate services value chain.
Adapted from Worldbank (2014)

information dissemination, user interface, and an all-encompassing capacity development pillar[1].

It is well recognized that there is a large gap to be closed between climate service providers and users. For this reason, the GFCS introduced the concept of the User Interface Platform (UIP) to improve the fit of climate services to the users' needs. However, a recent review of the framework concluded that the purpose and functioning of a UIP is not well understood by many climate service producers and users' (Gerlak et al., 2017). In this paper, we present the pathway chosen by Climandes to address this lack of understanding and contribute to bridging this gap by promoting an improved interaction between users and providers.

2.2. Co-production of climate services

Climate information is only valuable if it reaches its destination and is used for decision-making. A widespread integration into decision-making requires the early engagement of users in the development and dissemination of climate services, i.e., the co-design of the service. This encompasses the collection of specific requirements to tailor the climate product to the users' needs, appropriate communication channels for data and product transmission, and regular user-provider interactions. Consequently, the implementation of climate services must build on a multidisciplinary approach to combine expertise and to set-up a dialogue between natural and social sciences that contributes to a variety of complementary actions.

The demand study performed towards the end of the first phase of Climandes revealed user requirements related to the accuracy, resolution, and timeliness of the provided information, and highlighted the need for predictions at the seasonal scale (Rosas et al., 2016). This exchange with the users thereby determined an important technical focus of the projects' second phase. Further, we learned that user engagement should be more systematic. Therefore, users were engaged from the beginning and throughout the whole second phase of Climandes (e.g., Rossa et al., 2020).

2.3. Twinning: shared responsibilities and ownership

In international cooperation projects, trust between the partners is vital to building bridges across cultural and societal differences. Trust is built and maintained through constant dialogue (Lewicki et al., 2003). In Climandes, all activities were carried out in close collaboration of the two NMHSs and their partners; starting with the definition of the project objectives in the official project document, the joint planning of detailed tasks and elaboration of milestones, up to the implementation of the practical results. This cooperation took place in various formats. They encompass multidisciplinary workshops in Peru, bilateral online meetings in biweekly to monthly time intervals, scientific exchanges fostering on-the-job-training, as well as the joint work on specific tasks such as working documents, training material, code, or the user consultation, to mention a few. Further, the project team was strengthened through annual face-to-face steering meetings during which project achievements and failures were evaluated and adaptive measures were defined. These evaluation meetings were led by an external moderator, which enabled "constructive and civil discussions" as Gray and Stites (2013) describe it. The moderator often functioned as a facilitator, promoting the mutual understanding between the Peruvian and Swiss project members by explaining different political and governmental constraints faced in Peru, and was key for reflecting the Peruvian context and international programs within the framework of WMO. The common understanding of and the agreement on management processes, as well as the jointly written bilingual annual reports further helped establishing a strong project partnership.

As mentioned, the core characteristic of the Climandes twinning approach consisted in setting up a genuine and sufficiently close collaboration to find and implement viable solutions to real-world problems. In this relationship, the NMHSs were proceeding together with the benefit of having access to experience of the more seasoned twinning partner, thereby allowing both to grow. For example, at the start of the project there was not much experience in providing climate services to sector-specific user groups in either of the meteorological services.

2.4. Sustainability and regionalization

Sustainability and regionalization are two key concepts in international cooperation for very clear-cut reasons. Firstly, project achievements should remain in place after the project ends. Sounding simple, it is quite ambitious, as it requires the entire process chain to be adequately staffed and operational without the project funding and support. This actually implies that the service provider transforms from having basic processes and capacities to having trained specialists on the staff list, possibly on additional funds. Climandes ensured that all project activities went along with targeted training, in form of courses, internships, and on-the-job training. Further, the shared responsibility that came with the twinning approach strongly promoted ownership at the target-twinning partner. The acquisition of new funds in turn requires new government mandates and a stronger institutional position. This asks for a specific policy dialogue fueled by a targeted stakeholder engagement raising the awareness for the returns of public investments. To this end, a study estimating the socio-economic benefits (SEB) of enhanced access to weather and climate information (see Rossa et al.,

[1] https://gfcs.wmo.int/components-of-gfcs (accessed 11.12.2019)

2020) was shared and discussed with the Ministry of Economy and Finance (MEF) and other relevant governmental and non-governmental institutions. In addition, strategic alliances were established with institutions such as the Peruvian Ministry of Development and Social Inclusion (MIDIS) or the Regional Council of Climate Change in Cusco (CORECC). These alliances enabled the continuous dissemination of weather and climate information through already existing facilities. Further, and highly important, the long duration of the project (two phases each lasting three years) enabled the establishment of a real partnership and the continuity of the project achievements.

Secondly, from the perspectives of international cooperation agencies it is not feasible to fund the replication of bilateral interventions performed in one country on a one-by-one basis in neighboring countries. Rather a scaling up mechanism has to be envisaged through which the results and capacities built within the original intervention are spread into the region. Building on results of Climandes-1 it was possible to target various activities in Climandes-2 to promote regionalization, such as providing training courses to the South American region through the Regional Training Center (RTC). Further, the awareness of the specific climate related problems and possible adaptation strategies in the Andean region was raised through sharing lessons learnt and key results of the Climandes project with selected key stakeholders at the regional scale (Fig. 2). This is particularly important, as there is a lack of adequate communication on experiences in the co-design and co-production of climate services outside the WMO community: "Many users and implementers seek more success stories and lessons learned that help provide the proper rationale and guidance for climate service activities. Better GFCS communication and Monitoring and Evaluation (M&E) can help this cause." (Gerlak et al., 2017).

2.5. Project set up and goals

Climandes was conducted in two distinct phases, the first (Climandes-1) lasting from August 2012 to December 2015, the second (Climandes-2) from January 2016 to March 2019. Climandes-1 focused on improving the educational level in meteorology and climatology and on enhancing the quality of climate observations, both key factors for providing meaningful climate information (for details see Rosas et al., 2016). Climandes-2 extended the projects' scope to include a more systematic interaction with users and policy makers. This included the identification and evaluation of key stakeholders and users relevant for climate services (stakeholder mapping) as well as regular exchanges (i.e. business breakfast, policy events, field visits) with local, regional, and national policy-makers to help them understand the return on their current and future investments in climate services. In addition, it focused on applied research on specific climate topics relevant for the agricultural sector including the application of seasonal forecasts and its verification in the southern Peruvian Andes. Fig. 3 shows the logical framework of the Climandes project. The overall goal was to enable the staff at SENAMHI to be in position to co-develop and sustain user-tailored climate services for all climate-sensitive sectors (Module 1). Therefore, capacity development at the academic and professional level, as well as education and training of different user groups was an overarching activity (Module 2). To raise awareness of what a strong NMHS does to provide socio-economic benefits requires active exchange at the political, societal, and community level (Module 3). The efforts were concentrated in the pilot regions Cusco and Puno of the Andean highlands (see Fig. 4) with focus on smallholder farming, since small-scale agriculture plays an essential role in sustaining food security, jobs, and income in rural areas of developing countries and countries with emerging economies.

3. Results

In this section, the main project results are summarized. Section 3.6 gives special consideration to actions that promote sustainability of the

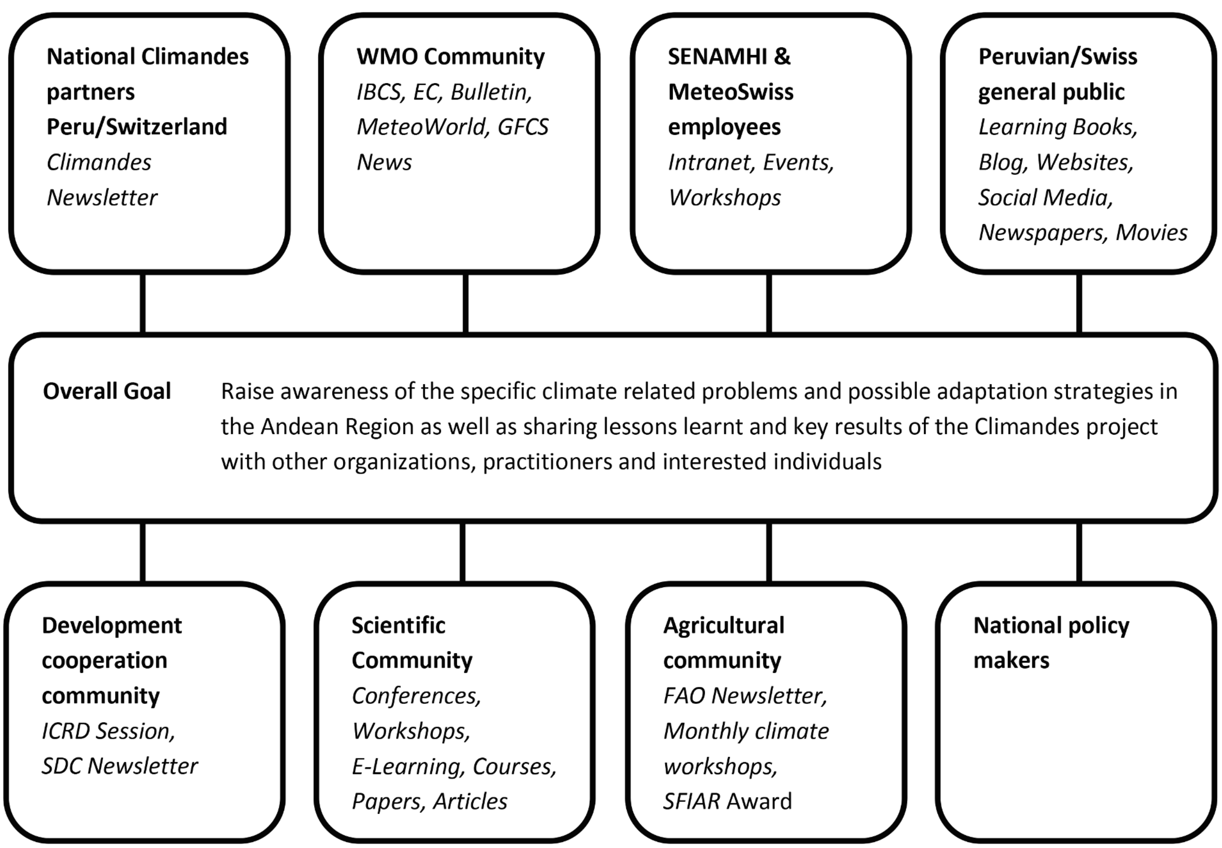

Fig. 2. Communication strategy to enhance the regionalization of projects' results.

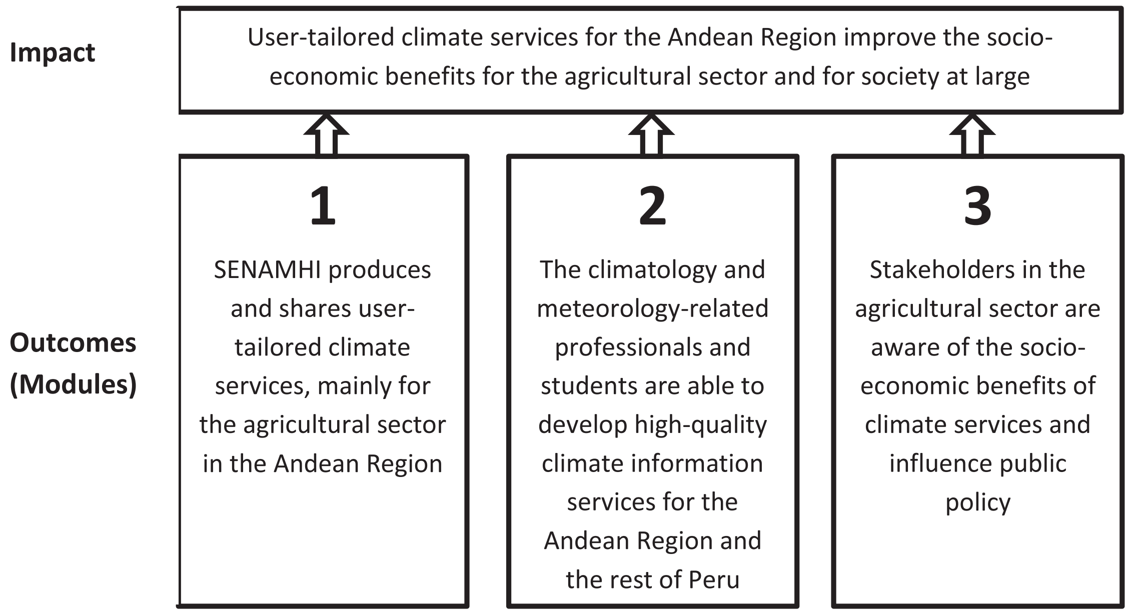

Fig. 3. Logical framework of the second phase of the Climandes project.

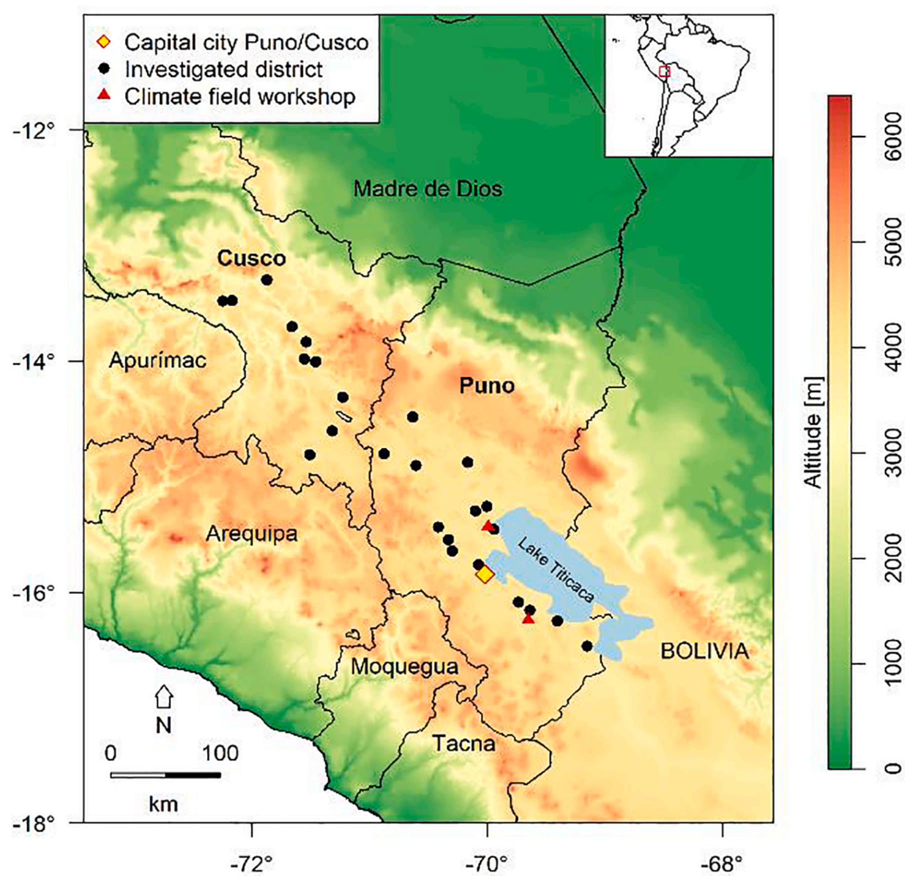

Fig. 4. Investigated districts and workshop locations in the pilot region Puno and Cusco.

results beyond the project's lifetime as well as their spreading to the entire Andean region.

3.1. User interface platform UIP

Through the conceptualization and implementation of a User Interface Platform (UIP), Climandes contributed to a deeper and more practical understanding of the role of this key GFCS element (e.g., Gerlak et al., 2017) and thereby helped shaping the implementation of the GFCS. We proposed a two-stage approach to implement the UIP. The first stage provided a vulnerability survey in the Puno and Cusco region involving more than 1′100 smallholder farmers (Fig. 4). These results helped to understand the socio-economic vulnerability of the target population including the characterization of key hazards (in terms of exposure and sensitivity) as well as socio-economic characteristics (adaptive and coping capacities) and other vulnerability factors such as gender, socio-economic status, income inequalities, etc. On the other hand, the survey helped to identify key constraints to the utilization of weather and climate information (e.g. lack of acceptance, accessibility, comprehension and accuracy), understand cultural aspects (e.g. local indigenous knowledge), and choose appropriate communication channels (e.g. radio stations, mobile phone distribution).

The second stage involved a series of field workshops in order to address and overcome the identified key constraints. This workshop series took place over the growing season 2017/18 in two pilot communities and was accompanied by monitoring and evaluation activities. Barriers constraining the use of meteorological and climatological information were directly addressed through targeted activities. The results of the inquiries point out that user participation in form of a community outreach leads to a greater credibility of the NMHS, a more positive perception of the accuracy of the information provided and an enhanced consideration in daily production activities (Fig. 5). Despite the "pilot character" of the intervention, we provide a first proof-of-concept that the GFCS User Interface Platform is a suitable vehicle to bridge the gap between the weather and climate information user and provider communities. To obtain more detailed results on the intervention, please refer to MeteoSwiss, 2018 and Rossa et al. (2020).

The dissemination of the information was improved via the broadcast of weather and climate forecasts and warnings through local radio stations, extended to other regions and communication channels, e.g. SMS and WhatsApp. Responding to another urgent identified need, the transmissions were translated to Aymara and Quechua. These enhanced information channels for weather forecasts, advisories, and warnings to reach rural communities improve the preparedness towards favorable or adverse weather or climate events. In addition, SENAMHI gathered information on bio-indicators used by the communities to attribute and link to specific meteorological and climatic events; for example, the position and height of the so-called "Lik'ichu" bird's nest, an indicator that can be associated with seasonal drought conditions. These indicators were documented in a book titled 'Willay', using the Quechua expression for reading natural signs (Willay – Measuring the weather without instruments). Communicating weather and climate information along with such traditional knowledge served as a fruitful entry point for the acceptance of SENAMHI's services. On the other hand, the elaboration of three schoolbooks "Popularización de Meteorología" for the regular basic education of pre-school, primary, and secondary as well as a guide on meteorology (Baigorria and Romero, 2019) was key. Teachers and meteorologists designed the books for rural school teachers in the Andes, with the aim to promote meteorology in a fun way.

Through all these efforts, Climandes exposed the producers of climate information to the complex suite of components along a value chain that must be present to ensure that information is relevant, credible, and timely, and that it meets the needs, supports existing decision protocols, and fits the economic and cultural constraints and contexts in which decisions are embedded. Such experiences were new for both NMHSs SENAMHI and MeteoSwiss, and while the detailed user needs identified from the southern Peruvian Andes cannot directly be translated to Switzerland, the process and the general concept are universal.

3.2. Enhanced data basis

In remote and topographically complex areas such as the southern Peruvian Andes, the sparseness and low quality of the available climate observations hinder the development of accurate climate information such as climate monitoring and the assessment of climate trends, extremes, or variability. Therefore, the efforts of the first project phase described in Rosas et al. (2016) continued in the second phase under the leadership of SENAMHI. SENAMHI digitized the original data sheets of 196 stations and integrated metadata of eight automatic stations into the WMO metadata database OSCAR Surface (WMO, 2017). The quality control rules established in Climandes-1 for manual observations were extended to automatic stations, taking into account the higher measurement frequency and additional variables. Then, a working group consisting of database experts from both NMHSs conceptually designed a state-of-the-art database architecture for SENAMHI, which is fundamental to treat meteorological data systematically.

Global re-analyses could potentially be used to fill the gaps in the data basis in remote and data sparse areas. However, Imfeld et al. (2019) showed that many of the global re-analyses available at that time (ERA-Interim, NCEP/NCAR, Merra, JRA-55, ERA-20C, CERA-20C, and 20CRv2) only poorly represent seasonal precipitation patterns in the southern Andes of Peru, and thus do not solve the problem of data scarcity in this region. This underlines the importance of adequate measurement devices and observer training to ensure reliable observations, regular station maintenance, and continuous quality control. In Climandes, an important step to improve data coverage was taken by developing a gridded dataset based on state-of-the-art methods by combining satellite and station observations. The daily temperature and precipitation dataset named PISCO (Peruvian Interpolated data of SENAMHI's Climatological and Hydrological Observations, e.g., Huerta et al., 2018; Aybar et al., 2019) is freely available at 0.1° resolution (e.g., http://iridl.ldeo.columbia.edu/SOURCES/.SENAMHI/.HSR/.PISCO/), which is in line with the Peruvian open government data policy (e.g., Resolución ministerial, N° 034–2014-MINAM, Artículo 2°). In contrast, access to other datasets such as station observations is not as straightforward despite the mentioned law.

3.3. Seasonal forecast quality assessment

It is widely known that forecasts without measures of uncertainty and skill induce a false sense of determinism and correctness, eventually leading to a loss of credibility in the forecast provider (e.g., the fable of "the boy who cried wolf" by Aesop[2], e.g. Roulston and Smith, 2004; LeClerc and Joslyn, 2015). Therefore, Climandes complemented the existing seasonal forecast system at SENAMHI with information on skill and uncertainty.

SENAMHI issues its operational seasonal forecasts based on the Climate Predictability Tool (CPT), a statistical tool developed by the International Research Institute for Climate and Society (IRI; e.g., Mason and Tippett, 2016), using large scale atmospheric variables from the preceding months as predictors. Seasonal forecasts are produced at station level as tercile probability forecast, i.e. indicating the probabilities of the upcoming season being in the lower, middle, or upper third of the climatology. Before dissemination, experts modify the forecasts based on a consensus discussion taking into account graphical information from dynamical ensemble forecasts and the evolution of relevant atmospheric parameters and sea surface temperatures up to the current date. Prior to Climandes, the final forecast product adopted a deterministic form by revealing only the dominant category, and therefore appeared to be certain and correct. Through Climandes, SENAMHI generated hindcasts (re-forecasts for past time periods) of the CPT model for Puno and Cusco based on objectively selected predictors in order to gain knowledge on the forecasts' skill. Based on this prototype, SENAMHI developed a seasonal forecast product that includes the probability of the dominant category and skill information on station basis for the whole country (Fig. 6).

In addition, SENAMHI and other NMHSs in South America expressed interest in complementing their seasonal forecast system with

[2] e.g. Wikipedia: https://en.wikipedia.org/wiki/The_Boy_Who_Cried_Wolf [accessed on 26.03.2019]

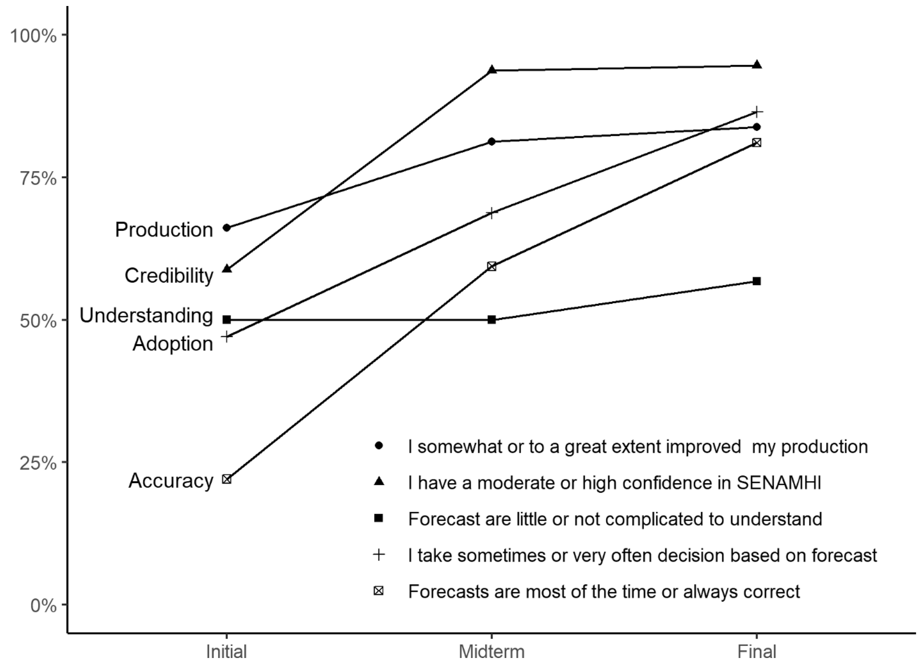

Fig. 5. We conducted a series of monthly climate field workshops in two agricultural communities in Puno during the growing season 2017/18. Over the workshop series, we repeatedly tracked specific indicators reflecting farmers' acceptance, comprehension and perceived accuracy of the information provided through a structured questionnaire after the initial (n = 68), midterm (n = 32) and final workshop (n = 37). The results demonstrate some perceived benefits of our intervention.

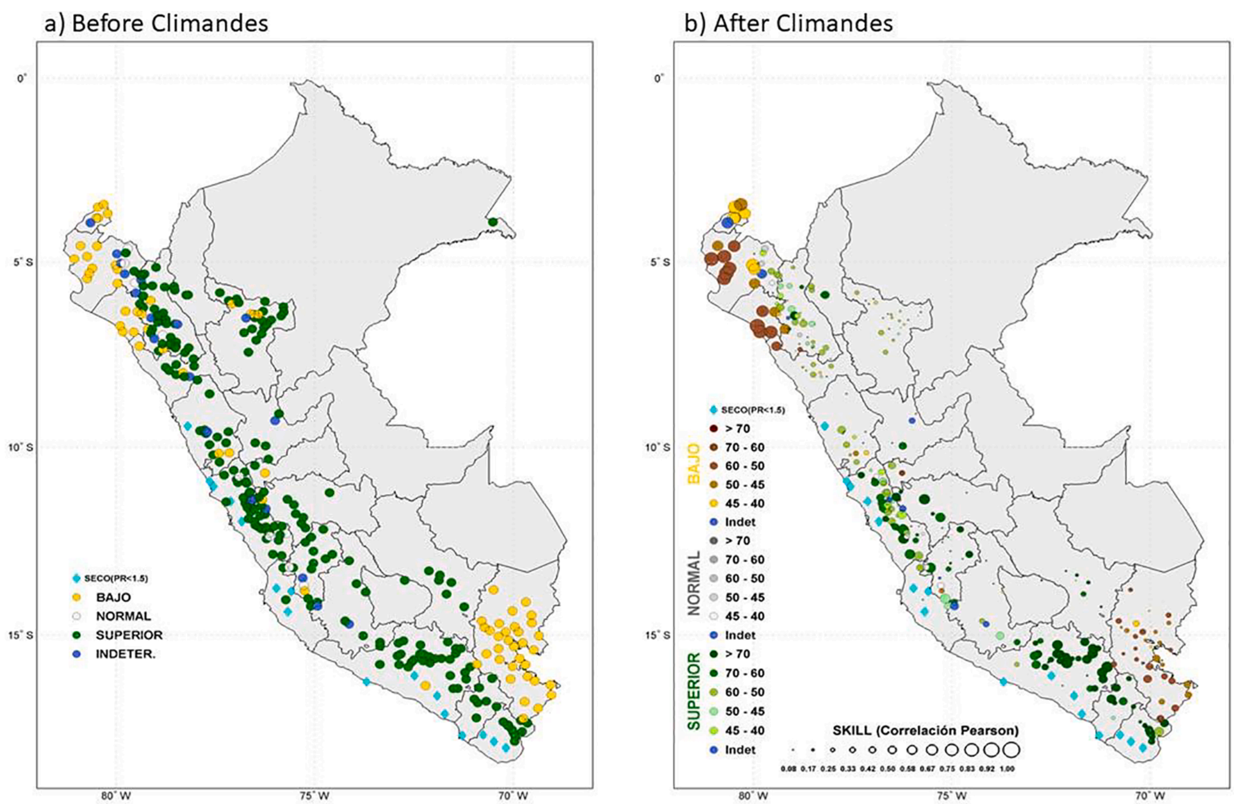

Fig. 6. SENAMHI's seasonal forecast product before (left) and after (right) Climandes. While the product before Climandes appears as a deterministic true forecast, the seasonal forecasts after Climandes include information on skill and uncertainty.

dynamical ensemble forecasts such as System 5 (SEAS5) issued by the European Centre for Medium Range Weather Forecasting (ECMWF) (e.g., Molteni et al., 2011; Johnson et al., 2019). Amongst other advantages, dynamical predictions avoid the often lengthy and subjective selection of the predictors in statistical forecasts, and ensure physical consistency of the forecasted parameters and across countries. Furthermore, state of the art dynamical seasonal forecasts do include external forcing trends such as the increasing CO2 levels and hence implicitly include climate change, which has been shown to also improve forecast performance (Doblas-Reyes et al., 2006). In Climandes, we found that SEAS5 mostly outperforms the seasonal forecasts issued by SENAMHI in Puno and Cusco (Fig. 7), for both temperature and precipitation, a result that highlights the potential of dynamical models in the region. However, the skill of seasonal precipitation prediction is still quite low in the

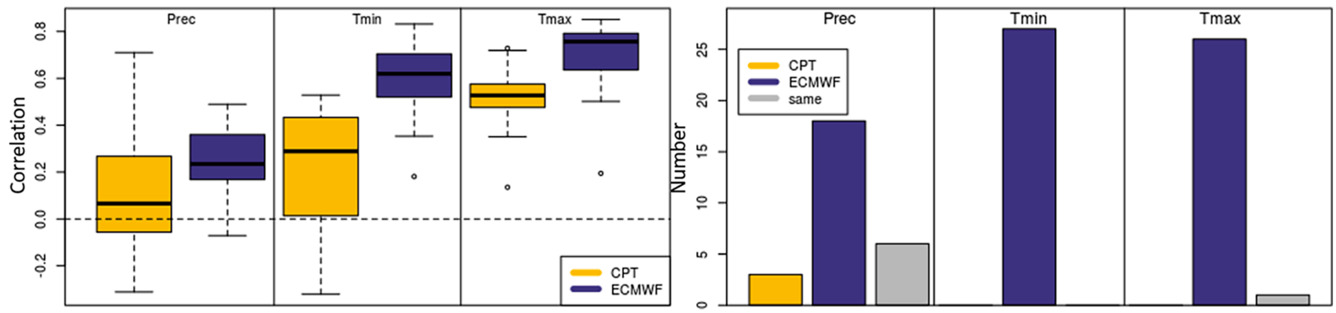

Fig. 7. Comparison of CPT and ECMWF SEAS5 forecasts. Left) Boxplots of correlations for 27 stations in the study area. b) Barplots indicating the number of stations for CPT (yellow) and ECMWF (blue) where the correlation of the respective model is higher by at least 0.05. Grey bars show the number of stations where the skill of CPT and ECMWF have a similar correlation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

two pilot regions and does not provide much benefit compared to purely climatological information. This contrasts to prediction skill found in the tropics during austral summer, i.e., in the regions and season of most pronounced influence of the El Niño Southern Oscillation (ENSO) (Gubler et al., 2020), where skill reaches the usefulness range (Ziervogel et al., 2005) even for small-scale applications.

3.4. User-tailored climate indices

In the case of low prediction performance and as a general advice for evaluating options for adaptation and planning, a good knowledge of the current climate and its variability is key and often more reliable than seasonal forecasts. This includes climatological information on extremes, variability, and trends. For these reasons, Climandes focused on using seasonal forecasts as an entry point to climatological discussions, and provided in-depth analyses of the past and current climate variability of specifically developed climate indices for agriculture.

For example, the annual trends of pre-defined climate change indices (e.g., Expert Team on Climate Change Detection and Indices (ETCCDI; Karl et al., 1999; Peterson et al., 2001)) employed during the first project phase were extended to user-tailored indices at sub-annual timescales, e. g., during the growing season. While the annual precipitation sums in the southern Peruvian Andes have increased over the last 50 years, substantial seasonal differences are present (Imfeld et al., 2020). The observed precipitation decrease in austral spring for instance supports the farmers' impressions of decreased water availability during the sowing season. This has impacts on sowing dates, thereby affecting the growing cycle of the crops. Further, the decreasing precipitation in austral spring goes along with less cloud cover and hence an increase of the outgoing longwave radiation. Therefore, despite the observed general warming in the region (e.g., Rosas et al., 2016), minimal night temperatures and hence frost risk remained almost constant in the last decades.

As agriculture in the Andes is mainly rain-fed, the project put a special focus on the climatological analysis of precipitation and droughts, starting with a mapping of precipitation and dry spell characteristics over the Peruvian Andes for an estimate of the spatial distribution of precipitation/drought hazard probability (Domínguez-Castro et al., 2018). Further, we showed that the onset of the rainy season has a large inter-annual variability ranging from August up to February , but no significant trend over the last 50 years. This stands in contrast to the farmers' perception of climate change being responsible for delayed rainy seasons. It is suspected that this perception relate more likely to a general precipitation decrease during austral spring, as mentioned above.

Further, agrometeorological drought indices were evaluated regarding their applicability to define the beginning, the end, and the intensity of an agricultural drought for relevant crops such as quinoa or potatoes. These analyses led to the selection of a set of drought monitoring indices based on station observations and / or satellite data, which are implemented operationally at SENAMHI: e.g., the Crop Water Requirement Satisfaction Index (WRSI), the Vegetation Health Index (VHI), the Aridity Anomaly Index (AAI), as well as the Standard Precipitation Index (SPI).

3.5. Capacity development

Human capacity development is the overarching activity embedded in the GFCS concept. While training was provided through a variety of activities throughout the project, i.e., primarily through on-the-job training through twinning, this section focuses on the formal development of capacities provided through the Regional Training Centre (RTC) of Peru.

With the aim of supporting the RTC Peru and therewith fostering the regionalization of the offered training, Climandes introduced and established e-learning, provided short-term blended training courses, and facilitated contacts to international experts supporting the training activities (see Garcia et al., 2020). Within the first phase of Climandes, the University of Berne developed e-learning material for basic climatological training. First experiences revealed a variety of barriers hindering the usage of the provided material, for example, the lack of human resources and training regarding the implementation of e-learning at the RTC. To overcome these barriers and identify the specific needs regarding e-learning, we conducted a workshop at the beginning of the second phase with the aim to develop an e-learning strategy for the RTC. Through the workshop, opportunities and strengths as well as weaknesses and possible threats regarding e-learning were identified. Further, the participants gained first experiences with a variety of e-learning activities. As a result, SENAMHI introduced the concept of blended training and planned and organized a variety of blended training courses. A parallel training development course for Latin America by WMO supported these efforts through enhancing didactical knowledge and enabling a detailed conceptual elaboration of a specific training development plan.

An important achievement enabling SENAMHI to take a leading role in regional training was the installation of the online platform Moodle at SENAMHI[3]. Moodle was chosen since it is freely available and includes the most important features facilitating e-learning. Furthermore, it is used by the Education and Training Program (ETRP) by WMO, thereby facilitating the exchange of learning material with WMO. Along with its installation, a technical person at SENAMHI was trained as a platform administrator and advisor for course instructors and facilitators, thereby facilitating the use of the platform and supporting the set-up of courses. These achievements allowed SENAMHI to offer a series of blended training courses to the Andean and the larger South American region (e.

[3] http://campusvirtual.senamhi.gob.pe/

g., Garcia et al., 2020). In return, MeteoSwiss gained experience in providing online and blended training, expertise that is currently applied in forecaster training.

The blended training courses resulted in very fruitful and successful training and learning experiences, reaching participants from all countries of the Andean region and diverse countries from WMO RA III and IV, and fostering diverse additional collaborations. As a recognition for all these training activities facilitated by Climandes, SENAMHI was officially designated as the second component of the RTC-Peru by the WMO executive council in June 2018.

3.6. Sustainability and regionalization

The enhancement of human capacities was key for the sustainability of the project results. Human skills were acquired on a wide range of topics, for example, data quality and management, forecast verification, setting up a user dialog, developing training activities through e-learning, among many others. Through the guidance of MeteoSwiss, the professionals working at SENAMHI acquired new skills and were inspired to work in a multidisciplinary and scientific manner. This and the fact that all Climandes activities were developed according to SENAMHI's specific needs and were led and partly executed by professionals working in permanent positions, facilitated to turn the project activities into operational tasks being maintained by staff of SENAMHI beyond the project's end.

For example, technical innovations and the accompanying training such as the installation of the Moodle platform or the development of the open-source software package ClimIndVis[4] designed to perform climatological analyses for agriculture support the sustainability of the project results. Further, the communication channels through text messaging and WhatsApp in three languages established through Climandes are still in place, a good sign that the local population appreciates and uses the service. Then, the number of radio stations broadcasting the meteorological and climatological information has grown to four in the region of Puno in 2019. Additionally, SENAMHI now disseminates its weather and climate reports through information panels and continuous dialogue within the framework of the TAMBOS (e.g., an initiative of the Action Platforms for Social Inclusion (PAIS), which provide governmental and other services to rural areas), an indication of the importance of the established alliances. These efforts in rural areas are planned to be complemented by an online course with the aim to train decision makers through the TAMBOS platforms. This innovation, which was developed by SENAMHI in July 2020 as part of the WMO's online course "Course on Education and Training Innovations", illustrates the transformation that has taken place in the field of education, which was, before Climandes, only done in classroom formats. Further, formal achievements such as the designation of SENAMHI as part of the RTC Peru and the therewith-coming continuous support by WMO and visibility will benefit the institution in the long term.

After each of the two project phases, an extensive external review was undertaken. The second review claimed a "transformative" effect of Climandes on SENAMHI due to the success of the twinning approach. It states that the twinning provided much needed guidance and confidence in addressing complex problems that require multiple perspectives (e.g., social and economic). Interdisciplinary expertise is often lacking in NMHSs everywhere and there is limited history of NMHSs interacting with experts from other disciplines (especially the social sciences). Through the perceived benefits from the participation of experts from multiple disciplines, SENAMHI has recognized and accepted the need for inter- and transdisciplinary approaches. In fact, both NMHSs experienced firsthand that simply producing climate information does not automatically imply that it will be up taken and used by decision makers to prevent the negative impacts (or capitalize on favorable outcomes) of climate variability and change. These efforts and the supporting policy dialogue resulted in an increased consideration of SENAMHI by relevant governmental institutions (primarily the MEF) finally leading to additional government resources. Another important benefit of the twinning was access to state of the art techniques to understand the regional climate and its impact on multiple scales on the ecological and human systems considered.

A large effort was undertaken to regionalize the training and related activities by the RTC (Sect. 3.5). The conduction of a first "Data Management for Climate Services" workshop in South America enabled the establishment of expert networks and supported SENAMHI in taking leadership in its continent, thereby strengthening its visibility and role at the regional level. On the scientific level, the gained knowledge was repeatedly presented at diverse international conferences, and has been published within open-access scientific journals. Further, we organized two sessions at international conferences: "Enhancing utilization of Climate Services for strengthening livelihoods in low and middle income countries" at the International Conference on Research for Development (ICRD) in Berne, 2017, and "Co-development of weather and climate services in developing and emerging countries" at the yearly conference of the European Meteorological Society (EMS). These sessions fostered the exchange of MeteoSwiss within the international scientific community active in the implementation of climate services in international cooperation contexts, and raised the visibility of MeteoSwiss in this community.

Further, the efforts done within Climandes triggered also smaller projects such as the project DECADE (Data on climate and Extreme weather for the Central AnDEs), which was funded in the R4D (Research for Development) scheme of the Swiss Development Corporation and Swiss National Science Foundation. DECADE focused on producing a climate database and on generating a bi-national climatological atlas for the central Altiplano with partners from Bolivia, Peru, and Switzerland. Since the project partners in Peru (SENAMHI-Peru) and Switzerland (University of Bern, MeteoSwiss) were also part of Climandes, meetings were often organized back-to-back, and knowledge gained in the Climandes project was shared with the Bolivian partners (Universidad Mayor de San Andres, SENAMHI-Bolivia). Specifically, the bi-national exchange was stimulated, with Bolivian students trained in Peru and several staff exchange visits between La Paz and Lima. In addition, the regional training activities fostered informal collaborations with other meteorological services such as the Argentinean one, triggering regular exchanges and sharing of knowledge and code.

4. Summary and conclusions

4.1. Summary

Setup in 2012 as a twinning project between the Peruvian and Swiss NMHSs, Climandes was among the first examples of how to transpose the GFCS into practical solutions in an international cooperation context. The transdisciplinary project activities involved a variety of stakeholders at the regional, national, and local level with the effect that the awareness for the relevance of weather and climate services was raised in various government branches. As a result, SENAMHI was able to strengthen their procedural, technical, and human capacities while gaining visibility and credibility among the user communities involved in the pilot regions.

Hereby, the twinning approach has played a key role. It has proven to be pivotal for the successful project implementation and the ensuing results, most notably regarding aspects of sustainability and regionalization of the intervention. This approach required, and therefore triggered, a continuous dialogue, which overall brought forth mutual respect and trust during the first phase of the project, and created a base for a common understanding and vision of the second phase. The strengthening of the constant exchanges during the second phase of the project allowed finding the respective roles of each partner in the project, which in turn led to an effective collaboration. This ongoing collaboration, which encompassed all project activities, allowed all partners to present their concerns and to be taken seriously (Gray and

Stites, 2013), such that common goals could be envisioned and achieved.

An in-depth external review of the project performed by three international experts attested a 'transformative' effect of Climandes on SENAMHI, which in an international cooperation cannot be taken for granted. There was a clear progression going from phase 1 to phase 2 of the project, testifying to the effectiveness of the project. This was particularly evident for the education and training activities, the user engagement, and the policy dialogue. The added module in the second phase of the project specifically treating the user engagement gave SENAMHI a visibility at national, regional, and community level. This visibility was catalytic to raising the awareness of the importance of the role the NMHS can play in adapting to climate variability and change. This institutional strengthening improved the NMHSs' position to acquire additional projects as well as public funding for infrastructural investments. While Climandes did not deal with infrastructural capacities, it was complementary and propaedeutic to, for instance, modernization projects.

4.2. Main findings

The most important findings of Climandes can be summarized as follows:

- Set up in a then innovative twinning arrangement between the Peruvian and Swiss national meteorological services, Climandes can be considered a best practice example of how to implement the GFCS into practical solutions at the local level. Twinning relies on a strong ownership of the target partner, an arrangement that in the case of Climandes had a transformative effect on SENAMHI. The close cooperation, fueled by the strong motivation of all partners involved, brought forth a trusted relationship that formed the basis for the success of the project.
- The policy dialogue was given progressive priority during the two phases of the project, introducing an extra outcome in phase 2 to better allocate the resources for the strongly interconnected policy and user dialogues. Therefore, the policy dialogue was strengthened at the national government level and the level of the regional governments of the two pilot regions Cusco and Puno. These efforts contributed to an increased consideration by relevant governmental institutions (e.g., the Ministry of Economy and Finance (MEF)) which resulted in additional government resources awarded to SENAMHI to sustain the user engagement and the services established in the project and prospect for a comprehensive modernization program.
- User engagement in the form of a specific user dialog was given high priority and led to the establishment of a pilot User Interface Platform (UIP). The main findings comprise that this engagement greatly enhanced the awareness and credibility of weather and climate information and increased the number of users who are prepared to include this information coming from the NMHS into their decision-making process. Setup and running the UIP clearly underscored the need of decentralized structures of the NMHSs to reach remote rural communities, who often have a culture, mentality, and language distinctly different from that of the people in the capital.
- The main impact of the user engagement consisted in the identification of the relevant weather and climate information requested by the Andean smallholder farmers, including early warnings of high-impact events such as frost, dry spells, hail, strong winds and rain, as well as snowfall. As a quick and tangible response to the outcomes of the user requirement analyses, simple yet useful new services have been implemented via local radio stations and messages sent through SMSs and WhatsApp, i.e. weather forecast, advisories, and warnings in Spanish as well as in Quechua and Aymara.
- The continued efforts to improve the quality of climate observations at SENAMHI resulted in technical capacities that allow for a continuous quality control for instance also of automatic stations, and further enable analyses on the climate in the pilot regions. In addition, the combined satellite-based remote sensing and stations observation product named PISCO (Peruvian Interpolated data of SENAMHI's Climatological and Hydrological Observations, e.g., Huerta et al., 2018; Aybar et al., 2019) now allows to monitor the Peruvian climate at unprecedented spatial resolution.
- The long-term climate trend analyses performed for the two pilot regions (e.g., Imfeld et al., 2020) showed that the perception of the farmers of the decreased water availability during austral spring, i.e., the sowing season, is in fact due to a weak decrease of precipitation occurring over the last 50 years in that season. The strong trend in maximum temperature in austral spring additionally stresses soil water availability and enhances drought risk.
- There is a high potential by complementing statistical forecasts with dynamic seasonal forecasts such as SEAS5. In Puno and Cusco, SEAS5 seasonal temperature predictions were shown to be useful for applications at the local scale and therefore benefit decisions made by smallholder farmers (Gubler et al., 2020). However, the skill of precipitation predictions, obviously very relevant for rain-fed agriculture, is low in the southern Peruvian Andes. In such cases of low prediction skill, we argue that seasonal predictions can be used as an entry point to raise the awareness of climate variability and trends, and thereby enhance adaptation.
- SENAMHI became very active in the field of education and training, to the point of becoming the second component of the WMO Regional Training Center (RTC) Peru complementing the formal education in meteorology and climatology provided by the Universidad Nacional Agraria La Molina (UNALM) in Lima. In Climandes-2, SENAMHI implemented the online learning platform Moodle and played a proactive role in disseminating specific expertise to other NMHSs and professionals in the region. A monthly briefing on seasonal forecasts between the NMHSs in the Spanish-speaking region of Latin America was introduced, strengthening the regional exchange on this high-profile topic. Most notably a much-acclaimed "Data Management for Climate Services" workshop was held in May 2018 with more than 100 professionals and students from 18 countries of the region and beyond.
- The outreach and communication activities to diverse policy makers and stakeholders at the national, regional and local level were essential for the awareness raising of the potential the NMHS can play in providing actionable information on how adapt to a changing environment. As a result, the visibility of the Climandes project and, more importantly, SENAMHI was raised significantly. Such activities are necessary and were in part integrated into the policy dialogue.
- On a practical dimension, the sustained funding from SDC was essential to make Climandes successful. It takes time to develop the personal and institutional insights to know the needs regarding all components of a climate service value chain. Moreover, processes of trust building and developing effective interdisciplinary collaboration (especially when stakeholders are involved) are difficult and time-consuming. The typical two to three year research grant would have ended before the described transformative changes within all institutions and people involved could develop.

4.3. Main challenges and lessons learnt

Climate services address the entire value chain from observations all the way to decision-making. In addition, international cooperation projects have a set of characteristic challenges, which depend on the specificities of the country under consideration. The main lessons learnt in Climandes can be summarized as follows:

- The development of climate services is an inherently transdisciplinary task and requires a continuous dialogue of developers and providers of climate products with the user communities. Having solid information on the users' needs from the very project start allows optimizing the product development and service implementation.

- Our experience made clear that community outreach is resource-intensive and requires enhanced capacities of technical staff in meteorological offices in peripheral regions. Particular attention must be paid to ensure that the NMHSs' regional centers are supplied with sufficient personal and financial resources.
- The low density of climate and weather observations in Peru remains a challenge, even more so considering that only a limited subset thereof is of sufficient quality for reliable climate analyses. In addition, systematic data quality management requires an adequate information technology infrastructure, which for the time being is not in place at SENAMHI. This constitutes an opportunity for future projects with an infrastructure component and would perfectly fit and complement the national implementation of the WMO Integrated Global Observing System (WIS2.0) standards.
- Establishing seasonal forecasts in the target regions is harder than anticipated. The limited skill of these forecasts in the pilot regions does not match up with the socio-economic structures and decision-making processes of individual smallholder farmers. However, dealing with probabilistic information advances the understanding of climate variability and raises risk awareness, and thereby supports adaptation of agricultural practice to climate change.
- Blended training was highly successful and appreciated. Especially, the level of the (costly) face-to-face course was strongly elevated through the preparatory online courses and careful selection of participants. Several elements to further improve online training were also identified, among which the sufficient allocation of time both for leading and following an online course.
- The complex administrative processes slowed down the project implementation, most notably during the first project year. There is no simple solution to this, and adapting the work plans accordingly may be a useful measure. Knowledge management in an international cooperation project is vital for the sustainability of the project results. Building human capacities is a very time and resource consuming activity. Ways should be sought to preserve this expertise within the institution, be it by an adequate staffing policy or by an appropriate documenting system, which allows knowledge transfer independently from leaving experts.
- A characteristic of the twinning setup is that it only works if the project partners are able to allocate sufficient and sufficiently dedicated human resources to the project activities. This is especially true with respect to intercultural collaboration, which places a higher demand on exchange and communication than, for instance, a purely scientific setting. On the other hand, capacity development in form of on-the-job training and access to a broad knowledge base is a clear advantage of the twinning approach, and thus caters directly to sustainable project results after the projects' end.

5. Outlook

Within the Climandes project, SENAMHI Peru and MeteoSwiss tackled a number of conceptual and technical problems. As a result, this process strengthened SENAMHI at the human, technical, and institutional level to the point that they are in position now to engage in similar projects but in a two-fold role. On the one hand, the progress made in Climandes can be consolidated and enhanced, while on the other hand, SENAMHI is able to share much of its knowledge and experiences in the Andean region. In this context, an upscaling effort of the Climandes context at the regional level would be a natural follow-on initiative.

CRediT authorship contribution statement

Stefanie Gubler: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Andrea Rossa:** Conceptualization, Writing - original draft, Writing - review & editing, Supervision. **Grinia Avalos:** Conceptualization, Supervision. **Stefan Brönnimann:** Conceptualization, Supervision. **Katy Cristobal:** Formal analysis, Investigation. **Mischa Croci-Maspoli:** Conceptualization, Supervision. **Marlene Dapozzo:** Conceptualization, Writing - review & editing, Writing - review & editing. **Andrea van der Elst:** Conceptualization. **Yury Escajadillo:** Formal analysis, Investigation. **Moritz Flubacher:** Conceptualization, Formal analysis, Investigation, Writing - original draft. **Teresa Garcia:** Conceptualization, Supervision, Writing - review & editing. **Noemi Imfeld:** Software, Formal analysis, Validation, Investigation, Writing - original draft. **Thomas Konzelmann:** Conceptualization. **Filippo Lechthaler:** Conceptualization, Formal analysis, Investigation. **Mark Liniger:** Conceptualization, Supervision. **Karim Quevedo:** Conceptualization, Supervision, Writing - review & editing. **Hugo Ramos:** Formal analysis, Investigation. **Mario Rohrer:** Conceptualization, Writing - review & editing. **Cornelia Schwierz:** Conceptualization, Supervision. **Katrin Sedlmeier:** Software, Formal analysis, Validation, Investigation, Writing - original draft. **Christoph Spirig:** Conceptualization, Supervision, Writing - original draft, Writing - review & editing. **Sara Ventura:** Project administration. **Brigitte Wüthrich:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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