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Sharing skills and needs between providers and users of climate information to create climate services: lessons from the Northern Adriatic case study

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SUMMARY The need to cope with the expected impacts of climate change on socio-ecological systems calls for a closer dialogue between climate scientists and the community of climate information users (e.g. decision makers belonging to public institutions). We describe an interactive process designed to bridge this gap by establishing a two-way communication, based on mutual learning. We analyse the need of climate information for the integrated assessment of climate change impacts on the coastal zone of the Northern Adriatic Sea, which is considered to be particularly vulnerable to several climate-related phenomena, e.g. heavy rainfall events, pluvial flood, and sea-level rise, causing potentially high damages to coastal eco-systems and urban areas (e.g. acqua alta in the Venice Lagoon). A participatory process is designed engaging representatives from both the scientific and local stakeholders communities, and facilitated by a boundary organization, embodied by the Euro-Mediterranean Center on Climate Change.

Keywords: decision making, climate products, climate services, risk assessment, Northern Adriatic, participatory process, CLIM-RUN.

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1. INTRODUCTION

The growing evidence in support of anthropogenic influence on Earth's climate, and the need to cope with the expected impacts of climate change on socio-ecological systems call for a closer dialogue between climate scientists, and the large community of climate information users. Attempts to bridge the gap between climate information providers and end-users paved the way to the development of climate services (Buontempo et al., 2014).

The research described here is focused on an interactive process facilitated by the Euro-Mediterranean Center on Climate Change (CMCC) to close the gap between climate information providers, i.e. climate scientists, and climate information users. Here we chose to focus on decision makers belonging to public institutions, because of the growing relevance of climate impacts on society, under the assumption that decision makers working in local administrations, with mandates related to Integrated Coastal Zone Management (ICZM), must take into consideration climate change (IPCC, 2014).

Many programs on climate services were designed with the goal of providing a benefit for society. To address the needs of disaster relief organizations and national decision-makers, climate scientists have started providing climate information, including (among others) forecasts for the coming season, short-term and long-term projections, and environmental monitoring to reduce risks and impacts of climate on society (Vaughan and Dessai, 2014). Some examples are the World Climate Data and Monitoring Programme (WCDMP) of the WMO[1], the UK MetOffice PRECIS (Providing Regional Climates for Impacts Studies) system[2], the International Federation of Red

[1] http://www.wmo.int/pages/prog/wcp/wcdmp/index_en.php

[2] http://www.metoffice.gov.uk/services/climate-services/international/precis last accessed February 2016

Cross and Red Crescent Societies (IFRC) Seasonal Forecast Email Notification System[3], and UKCIP climate change scenarios (for UK). In order to increase effectiveness and usability of outcomes of climate research, some researchers have engaged with the potential end-users: the co-production of climate services increases possible use of the information (Vaughan and Dessai, 2014).

Information useful for decision making could integrate physical climate information with other specific information, according to the local specificities and the institutional mandates, e.g. land-use planning, disaster risk reduction, climate change adaptation, etc. (Asrar et al., 2012). Moreover, societies will benefit from climate services, if given in a timely and effective manner, because these, e.g., will give warnings on risks and impacts of climate change, support adaptation planning, sustainable development, water resources management, human health, weather risk management (Asrar et al., 2012; Scott et al., 2011). Climate research, in fact, can address specific needs arising from users, for example, the increase in climate knowledge and the improvement of its applicability can help us decrease impacts and risks associated with climate variability and change (Lyon et al., 2014). Forecasts of climate events, which are based on the understanding of the physical mechanisms, could, therefore, be used for decision making and prevention, if the consequences on the environment and on society are investigated, as is proven by interdisciplinary research stemming from climate research on the El Niño-Southern Oscillation, and its impacts on society: a transformation is in progress, which will bring change in institutions and in the way they act (Zebiak et al., 2014). Therefore, climate services need to deliver information appropriate for the specific mandate of end-users, e.g. including information on caveats, uncertainties, and complexities (Krauss and von Storch, 2012).

Climate information is already being used in decision making. This is the case, for example, of the climate products developed by the International Research Institute for

[3] https://ifrc-notify.iri.columbia.edu/

Climate and Society (IRI), who has cooperated with end-users to improve the usability of climate info for decision making (Barnston and Tippett, 2014). Significant effort is devoted to improve products to meet decision makers' needs, however, not all requests can be addressed: often the request is for temporal or spatial scales which cannot be delivered (Barnston and Tippett, 2014). Moreover, climate information is not always adequate to support decision making, thus there is the need to understand how to bridge the gap between providers of climate knowledge, i.e. climate researchers, and users of climate knowledge, e.g. decision makers (McNie, 2013). Bridging this gap means designing a two-way communication, so that mutual learning occurs: on the one hand, end-users will have the opportunity to discuss about their mandate while learning about how the use of climate services could improve their work, thus end-users' information needs will be assessed; on the other, climate scientists will learn how to communicate their research outcomes, so that end-users will be able to integrate this information in their decision making system (McNie, 2013).

Two aspects need to be taken into account: (1) improving models, e.g. increasing predictive skill and reducing uncertainty, and (2) understanding end-users' needs, which could drive climate research. Within the climate research community there is discussion on how to improve knowledge produced, this could improve the application and dissemination of existing predictions, and bring new prediction methodology in operation (Graham et al., 2011). In this respect, an important coordinating role and guidance for the development and provision of climate services has been played by several sovranational initiatives and networks, such as (among others) the UN-led Global Framework for Climate Services (GFCS), the IRI-led Climate Services Partnership (CSP), the European Climate Services Partnership (ECSP), the European Climate Observations, Modelling and Services - 2 (ECOMS2), and the EU JPI-Climate.

There is a gap between knowledge production and use, to bridge this gap some have designed participatory processes to understand how decision makers use science (Kirchhoff et al., 2013). Participatory processes might also lead to improvement in dissemination and in understanding of the climate information by end-users, thus enable decision making based on climate information (Peterson and Broad, 2010). However, it must be taken into consideration that norms and goals, which lie outside the participatory process itself, might guide the decision making subverting the activity (Peterson and Broad, 2010).

The main objective of this research is to analyse the need for climate information and the effectiveness of climate services for the integrated assessment of climate change impacts on the coastal zone of the Northern Adriatic Sea. This geographical area is an interesting example of Mediterranean coastal zone, including various fragile ecosystems such as coastal wetlands and lagoons, and high value cultural and socio-economic locations (e.g., the city of Venice). The Northern Adriatic coastal zone is considered to be particularly vulnerable to several climate-related phenomena, including, among others, heavy rainfall events, pluvial flood, sea level rise, in turn causing potentially high damages to coastal eco-systems and urban areas (e.g., 'acqua alta', in the Venice Lagoon).

The research reported in this article (conducted within the framework of the EU-funded project Climate Local Information in the Mediterranean region Responding to User Needs project, CLIM-RUN) focuses on the set up of a participatory process designed to understand end-users' needs, engaging representatives from both the scientific (including climate and risk assessment experts) and local stakeholders communities working on ICZM. The process was facilitated by the CMCC acting as a "boundary organization", i.e. an organization that assists the interaction between science producers and users, following the definition reported in Kirchhoff et al. (Kirchhoff et al., 2013) and coherent with other literature (see for example (Orlove et al., 2011; R. J. Swart, 2009)). This interaction could be beneficial for improving climate information, and for identifying new climate data addressing end-users' needs (Lemos et al., 2014).

Other researchers involved in the CLIM-RUN project explored different sectors: tourism, energy, and wild fires. Stakeholders engaged to represent these sectors, i.e. potential users of related climate information, were coming both from the public and from the private sectors (see other articles published, e.g. (Koutroulis et al., 2015) and (Bedia et al., 2012)).

The paper is structured as follows. The applied methodology and results from three different workshops and an online questionnaire are described in section 2. In section 3 the usefulness of the opinions of stakeholders to the creation of climate services is discussed . Finally, conclusions and recommendations are provided in section 4.

2. METHODS AND RESULTS OF THE INTERACTIVE PROCESS

To achieve the objectives outlined in the previous section, a participatory process was set up, involving experts from the climate science and risk assessment communities engaged in the CLIM-RUN project (hereafter simply referred to as the researchers), and end-users of climate information and risk assessments (hereafter simply referred to as the stakeholders) (N. Rousset et al., 2014). While researchers were selected from the CLIM-RUN partnership, stakeholders were selected among representatives of those public institutions having a specific mandate for ICZM. The geographical area taken into account is the coastline of the two Italian regions of Veneto and Friuli Venezia Giulia (Northern Adriatic Sea). The definition of ICZM used is that found in the EU Protocol on Integrated Coastal Zone Management in the Mediterranean[4] (European Union, 2009). Sectors of reference therefore include all

[4] Article 2 (f): 'integrated coastal zone management' means a dynamic process for the sustainable management and use of coastal zones, taking into account at the same time the fragility of coastal

those public offices that have a mandate according to the above definition, which are identified in the EU Recommendation[5] (European Union, 2002).

Following this definition a list of 63 offices was compiled and used to perform a stakeholder analysis. The offices were ordered in a table according to the geographical scale of their mandate. To ensure the choice of the most representative and significant authorities for each geographical scale a rank was performed by researchers, who have been chosen because of their knowledge both in climate science and on ICZM. They scored the relative importance of each authority in a table using votes from 1 (the least relevant) to 5 (the most relevant), considering five specific attributes (i.e. importance, influence, effects, relevance, attitude) (N. Rousset et al., 2014). The authorities with the highest votes were selected and invited to participate in the CLIM-RUN project.

The ranking methodology applied in the Northern Adriatic case allowed to reduce the number of participants to the process, identifying the most representative stakeholders to be involved. Based on the final rank, 40 offices were selected and invited to participate in the interactive process designed for the CLIM-RUN project, making sure the goal of the project was understood, and therefore the appropriate person was self-selected by each office to participate: 20 people participated (Table 1).

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ecosystems and landscapes, the diversity of activities and uses, their interactions, the maritime orientation of certain activities and uses and their impact on both the marine and land parts.

[5] Chapter III: (1) Sectors such as: fisheries and aquaculture, transport, energy, resource management, species and habitat protection, cultural heritage, employment, regional development in both rural and urban areas, tourism and recreation, industry and mining, waste management, agriculture and education; (2) cover all administrative levels; (3) analyse the interests, role and concerns of citizens, nongovernmental organisations, and the business sector; (4) identify relevant inter-regional organisations and cooperation structures, and (5) take stock of the applicable policy and legislative measures".

Table 1. List of institutions that participated

	LEVEL	INSTITUTION	1st workshop	questionnaire	2nd workshop	focus group
	Supranational	Adriatic Euro-region	1			
	National	ISPRA Venezia	1	1		
Veneto Region	Regional	Geological Survey	1	1		1
		Genio Civile di Rovigo	1	1		
		Sistema idrico integrato	1	1		
		Teolo Met Service	1	1	1	
	Independent Authorities	Magistrato alle acque di Venezia	1			
		Consorzio Venezia Nuova	1			
		Consorzio di Bonifica Delta Po	1	1		
		Consorzio di Bonifica Veneto Orientale	1	1		1
		Consorzio di Bonifica Ledra–Tagliamento			1	
		Port Authority of Venice	1			
	Provinces	Venezia: Geological Survey	1			1
	Municipalities	Venezia: Urban Sustainability	1	2	1	
		Venezia: PAES and C40			1	
		Venezia: Energy agency			1	
		Venezia: Istituzione Centro Previsioni e Segnalazioni Maree	1	1		1
Friuli Venezia Giulia Region	Regional	Civil Protection	1			
		Geological Survey	1	1	1	
		Regional Environmental Agency	2		3	
		OSMER Met Service	1	1	1	
	Parks	Marine Protected Area of Miramare	1	1	1	
		total	**20**	**13**	**11**	**4**

The interaction between researchers and stakeholders of the Northern Adriatic case study was performed at different stages of the project with appropriate tools and methods to achieve the specific goals, i.e. workshops, questionnaires, focus group, and discussions. A strong effort was made to keep all the stakeholders engaged during the process. The internet was mainly used in order to ensure communication among and between researchers and stakeholders, and to exchange informative material (e.g. e-mails, CLIM-RUN website, newsletters, brochures, presentations) useful for the project development. The interaction process between researchers and stakeholders can be summarized in three main steps:

1. First workshop held in Venice on 13 September 2011, aimed at defining climate services and understanding stakeholders' needs. This step included an online perception questionnaire designed to gain insights and details about stakeholders' needs, and the interaction carried out through e-mail exchanges as a follow-up to workshop discussion (October 2011 – May 2012). Aim of this activity was to facilitate the interaction between stakeholders and researchers.

2. Second workshop held in Trieste on 28 May 2013, aimed at presenting and discussing the preliminary climate services developed by researchers. This step included a feedback questionnaire distributed to stakeholders after the workshop, aimed at the refinement of the climate products presented.

3. Focus group held in Venice on 26 September 2013 aimed at presenting final products improved after the second workshop, discussing and assessing further needs.

The first workshop and the perception questionnaire allowed to elicit key stakeholders' needs in terms of climate variables, impacts, priority receptors, temporal and spatial resolution and scale. The workshop was divided in two main sections: (1) presentations by researchers to introduce the concept of climate services, and to present the goals of the CLIM-RUN project; (2) discussion with participants on present use and needs with respect to climate services, and definition of a road map for further consultation (Giannini et al., 2011).

The perception questionnaire was developed within CLIM-RUN in English (Goodess, 2011), and then translated into Italian and made available to stakeholders online. Some questions were added to the original format of the questionnaire, developed within the CLIM-RUN project, in order to collect opinions about derived climate parameters (i.e. climate impact and risk assessments) according to the specific objectives of the Northern Adriatic case study. The questionnaire was divided into five main sections: 1) information on institution/organization, 2) risk perception and current use, 3) perspectives on climate services,4) data requirements, 5) handling uncertainties. Thirteen out of the twenty stakeholders who participated to the first workshop answered the questionnaire.

The information collected in the first workshop and through the online questionnaire was synthesised and analysed to identify and translate stakeholders' needs in terms of climate change impacts (i.e. coastal flooding, coastal erosion, drought, salinization and water quality, hydro-geological disturbance), and priority receptors (i.e. beaches, deltas and estuaries, wetlands, hydrological systems, agricultural areas, keystone species habitats, lakes, infrastructures for tertiary sector). The perception questionnaire also allowed to obtain information about the scale and the resolution of the climate data needs: high resolution climate data with local/regional scale ranging from a medium (50 km) to a fine (1 km) and all possible temporal resolutions were required (annual, seasonal, monthly, daily, sub-daily), while the time scale mainly required ranges from past 10 to 50+ years. Regarding the time horizon, stakeholders asked for projections for the next 10 to 50 years. Only a few stakeholders asked for projections over a longer than 50-year temporal horizon.

The results of the first workshop and of the perception questionnaire were summarized in a report (Giannini et al., 2011) and shared with all stakeholders and researchers, who were given the possibility to suggest improvements and integrations. On the basis of this information a table was designed to enable comparison between stakeholders' needs and researchers' capability to address these needs, within the timeline set by the CLIM-RUN project. The table was divided in two areas: one filled with information made available and shared by stakeholders, and one in which researchers identified basic climate variables to address stakeholders' needs, including information on their spatial and temporal scales. The table was focused on stakeholders' needs relative to three sectors: the hydro-climatic regime, the coastal and marine environments, and agriculture. Finally the table was passed to researchers. Based on the information contained in the table, a priority ranking was performed by researchers, who decided to focus their analysis on three key issues, i.e. extreme events, sea level rise and drought, for the development of climate products.

The following five climate products were developed:

1. short-term (2020-2050) projections of sea level rise;
2. seasonal predictions of extreme rainfall events;
3. long-term regional projections of climate extremes (including heat waves, dry spells and heavy rainfall events);
4. sea level rise inundation risk maps for the low-lying coastal areas of Veneto and Friuli-Venezia Giulia regions;
5. pluvial flood risk maps for the urban territory of the municipality of Venice.

The second workshop was organized to present and evaluate the relevance and possibility of use of these five climate products, and to improve their final format (Giannini et al., 2014). The five climate products were presented and discussed with stakeholders: three regarding climate variables; and two regarding derived risk parameters. As a conclusion of the workshop, a feedback questionnaire was distributed to stakeholders. Results of the second workshop and of the feedback questionnaire were synthesised and analysed in a report made available to researchers and stakeholders for comments and integration (Giannini et al., 2014). Eleven people participated in this workshop, and out of these three filled the questionnaire (Table 1).

Finally, in a focus group held in Venice on 26 September 2013, information sheets (http://www.climrun.eu/products/information-sheets) describing climate products were presented and discussed with stakeholders, in order to get final feedbacks about the usefulness of the products and recommendations for further developments. Four people participated in this focus group (Table 1).

In summary, stakeholders' involvement and discussion allowed, since the preliminary phases of the iterative process, to identify which were the stakeholders' needs for climate services in the Northern Adriatic coastal zone: (1) data to support land-use planning, (2) data with greater resolution and longer time series, (3) data on climate impacts and risks, (4) precipitation patterns to improve irrigation, (5) sea level rise and tides to plan ahead both agriculture and Venice defences, (6) climate variations and extreme events, (7) seasonal trend for tidal waves, and (8) hydraulic risk. Stakeholders selected extreme climate/weather events as the most important climate variables needed, because they are necessary for the development of flood early warning systems, for urban planning, and for ICZM. For this purpose detailed climate information at the regional/local scale with spatial resolution ranging from 50 km to 1 km was requested. Some stakeholders also asked to concentrate the analysis to some specific hotspots of climate change risk already considered by the Civil Protection emergency plans (e.g. hospitals, strategic infrastructures, people). Based on all needs expressed climate variables were listed in a table and climate products were designed for the Northern Adriatic case study.

Moreover, interaction between stakeholders and climate researchers highlighted the difficulty of prediction of specific climate variables (i.e. sea level rise and precipitation), and the relative concept of uncertainty in predictions. This is the case, for example, of precipitation: climate simulations do not completely agree in the predicted changes over the Northern Adriatic region. Results suggest that the Northern Adriatic lies in a 'transition' zone between those regions projected to become drier (i.e. the Southern Mediterranean) and those projected to become wetter (i.e. Central-Northern Europe).

On the other hand, the dialogue among risk experts and stakeholders allowed to select more appropriate and informative risk metrics and thresholds useful to evaluate the impact of climate change in coastal zones, informing sustainable management decisions. In fact, the participative process allowed to incorporate stakeholders' preferences and values into a structured risk assessment process (Torresan et al., 2014) allowing the simultaneous consideration of climate, environmental and socio-economic components and providing decision-makers with more transparent and reliable information about vulnerability and risk indicators and maps.

Last but not least, it is important to underline that not all the stakeholders' needs were satisfied due to lack of data, and appropriate tools to perform the analysis, e.g. the product related to the assessment of water deficit for agricultural areas was not finalized. A limit in the development of risk products was due to data gaps, e.g. lack of detailed and homogeneous information about coastal artificial protection, high-resolution laser altimetry data, presence and efficiency of urban drainage systems.

3. DISCUSSION ON CLIMATE PRODUCTS: HOW NEEDS HAVE BEEN ADDRESSED

Generally speaking all the stakeholders who agreed to participate in the interactive process designed for the CLIM-RUN project showed interest in the area of climate services, willingness to learn, and share opinions. They followed all the stages very carefully and asked questions for clarification. Moreover, they not only declared since the beginning the availability to keep cooperating, but also shared thoughts and ideas for the development of climate services, because they are aware of their need for climate information. Ultimately they confirmed the need for an early engagement with the end-users community is key when trying to develop climate services. In the paragraphs that follow we will discuss some elements identified during the CLIM-RUN project useful for the design of climate services.

Even if the attention of the stakeholders was high throughout the whole duration of the project, the degree of direct participation to the organized workshops decreased: it ranged from the 20 stakeholders who attended the first workshop, to the three who answered the questionnaire presented in the second workshop. The decrease in participation was expected, because of several reasons, e.g. the decrease in funding available to public authorities in Italy implies a reduced possibility of participating to tasks and initiatives other than the daily duties, and the length and timing of the project interfered with other activities planned within the offices. More generally, a decrease in stakeholders' presence is observed in many participatory processes.

The first goal was to learn about stakeholders' needs. Stakeholders involved have been asking, throughout the whole participative process set up for CLIM-RUN, for strong and clear science outcomes, upon which to base decision making. Availability of information to understand climate impacts and risks could improve, for example, urban planning and climate change adaptation projects. Also, some thoughts were shared on data access and dissemination: a repository could be created where to download data from.

Moreover, stakeholders suggested decision makers and politicians need some capacity building, which could enable them to access and understand climate information. When designing capacity building special attention needs to be paid to how climate scientists address and represent the uncertainty concept, and how end-users understand it. Too many details regarding uncertainty are not useful, i.e. a simplification could make its use more effective. Some stakeholders, in fact, suggested a good/medium/bad type scale could be more effective and usable. Another option to communicate uncertainty, which is already in use, is defining several alternative climate scenarios, which would describe possible climate futures.

This brings another need: the development of organizations specifically designed to enable information exchange between climate scientists and end-users, i.e.

organizations devoted to translate climate information into products, that in turn can be integrated by end-users in the information they use to fulfil their mandate. These organizations could also help deliver the data in understandable formats, i.e. those that end-users are familiar with, and/or enable them to use other formats, perhaps through the development of ad hoc software and tools, the design of indices, the definition of thresholds, etc. Also best practices and lessons learned should be identified, including some considerations on what would happen if no action is taken. The interaction process described above is sketched in Figure 1.

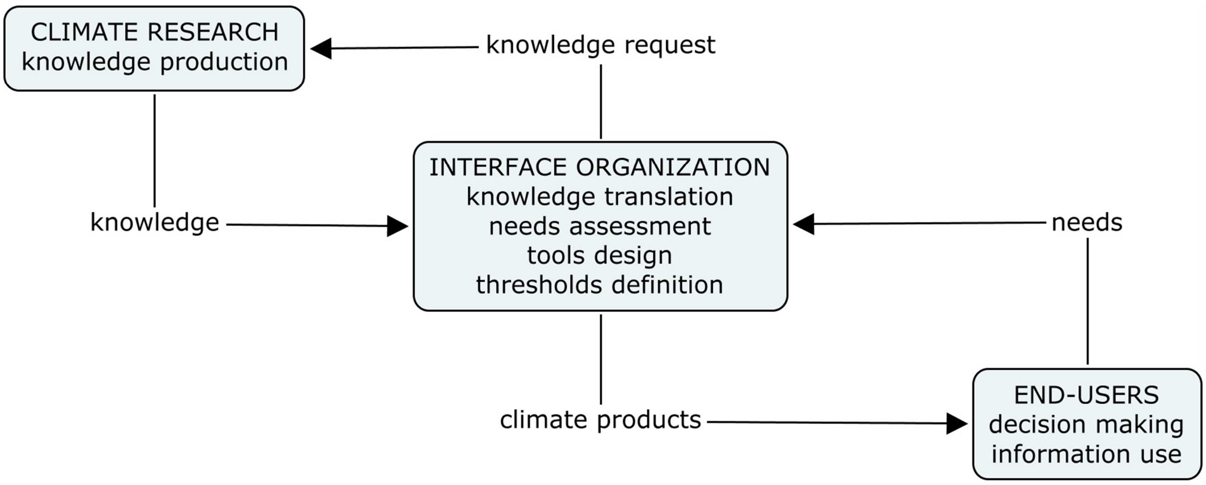

Figure 1 Interaction process

Based on the outcomes of the first workshop, three climate products addressing some of the highest priority needs identified by local stakeholders engaged in the Northern Adriatic case study were selected. Specifically, climate experts decided to focus on:

1. short-term (2020-2050) projections of sea level rise;
2. seasonal forecast of extreme rainfall events;

3. long-term regional projections of climate extremes (including heat waves, dry spells and heavy rainfall events).

1) Short-term projections of sea level rise in the Northern Adriatic basin. Providing reliable climate information on expected sea-level change over the Northern Adriatic sub-basin for the upcoming decades is key for the evaluation of the impacts of extreme events that may cause flooding (e.g., “acqua alta” in Venice) of the coastal areas in the Northern Adriatic region. During the workshop in Trieste, the capability of state-of-the art numerical models in reproducing the observed sea-level anomalies in the Northern Adriatic sub-basin were illustrated. Results from regional climate projections of sea level rise in the Mediterranean basin taking into account some of the most relevant factors potentially affecting the sea level, were shown (Gualdi et al., 2012). The limitations affecting sea-level projections associated with the under-representation of specific processes by climate models (most importantly, the lack of land-ice melting) were illustrated. Also the uncertainties determined by the model-dependence of climate projections, and the need for using alternative climate change scenarios (i.e., assuming different mitigation measures) were discussed.

2) Seasonal forecasts of extreme rain events. The ability of a state-of-the-art seasonal forecast system (specifically, the CMCC Seasonal Prediction System (SPS); (Athanasiadis et al., 2014; Materia et al., 2014)) to predict the occurrence of heavy precipitation events over Europe, and more specifically over the Northern Adriatic target area was illustrated. This specific class of extremes refers to events having a 10% probability of occurrence (i.e., 1 in 10 day events). The predictive skill of the heavy rain events is quantified for the 1989-2005 period, after concatenating all seasons (specifically: DJF, MAM, JJA and SON) so as to allow a sufficiently large sample for a statistically robust evaluation. The analysis reveals that the skill displayed by the CMCC-SPS in predicting this type of events is relatively low over most of the European sector. Concerning the Northern Adriatic region, the correlation between

retrospective forecasts (i.e., forecast of the past, made to verify the predictive skill of the forecast system) and observations ranges from 0.1-0.2 over north-eastern Italy, to negative values (corresponding to no skill) over the neighbouring Slovenia and Croatia territories. These results highlights that the potential for using seasonal forecasts as a tool to predict intense precipitation events with a few months in advance is fairly limited for this region. The results presented are broadly consistent with a similar analysis performed by Eade et al. (Eade et al., 2012) using the UK Met Office system. These analogies further corroborate the indication that reliable forecasting of intense rainfall on seasonal timescales are still a challenge for state-of-the-art seasonal prediction systems (for additional details see (Bellucci et al., 2014)).

3) Long-term regional projections of climate extreme indices. Projected changes in temperature and precipitation extremes, including dryness, for the end of the 21st Century over the Euro-Mediterranean region (thus, encompassing the Northern Adriatic target area) were illustrated. Results were based on an ensemble of scenario simulations performed with the RegCM4 regional climate model, at a 50-Km spatial resolution, forced at the open boundaries using different global climate models. Specifically, three indices were selected to illustrate the expected changes in the statistics of climate extremes: a heat wave day index (HWD; number of “heat wave” days, where a heat wave is here defined when the daily maximum temperature exceeds the long term average by at least 5 degrees, for at least 5 consecutive days), a dry spell length index (CDD; maximum number of consecutive dry days, where a dry day is defined as having precipitation below 1 mm/day), and a heavy precipitation index (R95; percent of total precipitation above the 95% percentile). Regarding the CDD and R95 hydro-climatic indices, results suggest that the Northern Adriatic region lies in a ‘transition’ zone between those regions projected to become drier (i.e. the Southern Mediterranean) and those projected to become wetter (Central-Northern Europe). The model-to-model discrepancies affecting the position of this transition

zone, makes the projected changes of the above mentioned hydro-climatic indices highly uncertain over the targeted Northern Adriatic region.

Based on the results of the first workshop and the information provided by the climate products 1) and 3), two risk products were developed for the Northern Adriatic region:

4. sea level rise inundation risk maps for the low-lying coastal areas of Veneto and Friuli-Venezia Giulia regions;
5. pluvial flood risk maps for the urban territory of the municipality of Venice.

4) Sea level rise inundation risk maps for the low-lying coastal areas of Veneto and Friuli-Venezia Giulia regions. The analysis of sea level rise risk was performed with the aim to produce useful information for local stakeholders about targets and areas that are more likely to be submerged by sea level rise in the medium term scenario 2041-2050. The assessment followed the Regional Risk Assessment (RRA) approach implemented by the Decision Support System for Coastal climate change impact assessment (DESYCO) (Torresan S., ,Rizzi J., Zabeo A., Critto A., Gallina V., Furlan E., Marcomini A., 2013) considering a variety of coastal targets potentially exposed to sea level rise (e.g. beaches, wetlands, protected areas, river mouths, agricultural areas, terrestrial biological systems and urban areas) and compared different sea level rise scenarios for the investigated timeframe (i.e. 4, 15 and 27 cm) simulated by the PROTHEUS model (DellAquila et al., 2012) under the A1B emission scenario for the Adriatic Region. Resulting hazard maps showed that more than 50% of the investigated coastal area will be potentially inundated by a future sea level rise inundation (2041-2050) for all the three sea level rise scenarios considered (4cm, 15cm and 27cm). Risk maps allowed to identify that the receptors more affected by a potential sea level rise inundation are beaches and wetlands followed by agricultural areas, terrestrial biological systems and urban areas. Sea level rise risk products can support decision making and coastal management in a wide range of situations (e.g.

shoreline planning, land use and natural resources management), and can be used to mainstream climate adaptation in the definition of plans, policies and programs at the regional scale.

5) Pluvial flood risk maps for the urban territory of the municipality of Venice. The analysis of pluvial flood risk was performed with the aim to evaluate areas and targets that could be at higher risk of urban floods due to heavy rains in the future scenario 2041-2050. Data regarding the intensity of precipitation (mm/day) for the future climate scenario were provided by the Regional Climate Model (RegCM4) under the RCP 8.5 emission scenario (Giorgi et al., 2012). This choice allowed to perform a conservative estimate of risks under the worst case scenario, characterized by increasing greenhouse gas emissions over time (Riahi et al., 2011). Based on a Regional Risk Assessment approach (Landis W.G., n.d.; Pasini et al., 2012; Ronco et al., 2014) requiring the consecutive analysis of hazard, exposure, vulnerability and risks, the assessment produced a range of risk maps for commercial-industrial and residential areas and critical infrastructures. The hazard maps showed that the areas more impacted by pluvial flood events are located in the south-east littoral zone (e.g. Pellestrina and Lido) of the municipality of Venice, with the major number of potential hydraulic emergencies occurring in the autumn season. The exposure and vulnerability maps (integrating information about local land use, slope and topography, soil type and urbanization) helped to identify the spatial distribution of receptors and highlighted that most of them can be subject to potential damages due to pluvial floods events, since they are mostly characterized by relatively high and very high vulnerability classes. The final risk maps, integrating information about hazard scenarios, exposure and vulnerability, are useful to identify residential and industrial/commercial areas that could be interested by higher economic losses related to services interruption in case of pluvial flood and therefore can be used as a basis to define priorities for adaptation and risk management strategies.

The participatory process, which led to the design of the five climate products, taught us some lessons. Local communities and experts can collaborate in gathering and analysing information, building a shared formulation of the problem, and an analytical capacity to foster sustainable solutions for environmental problems. Particularly, a two-way dialogue can foster an iterative learning process, the sharing of critical reflections, and anticipatory scenario planning for climate change adaptation.

Scientists may perceive or rank risks differently from stakeholders and decision-makers due to diverse values and goals. Therefore, early stakeholders' involvement turned out to be very useful to get the right questions in terms of time scenarios, geographical scale and resolution, choice of receptors, vulnerability factors, and risk thresholds; and to develop products (risk maps and indicators) more tailored to their expectations and needs. An aspect which clearly emerged from the interaction between scientists and stakeholders was the need for climate information at very high space-time resolutions quite often beyond the reach of the climate models currently in use at climate centres. This "scale-gap" appeared to be a crucial point since the very early stages of the interaction process.

A focus on risk supports decision-making in the context of climate change: climate services are mechanisms, which produce and deliver authoritative and timely information, not only about climate variations and trends, but also about climate-related risks on built, social-human, and natural systems. Therefore, risk assessment is most effective when it is tailored to the diversity of actors involved in adaptation planning and disaster risk reduction.

Risk assessment is a complex procedure which requires the collection of multiple sources of data, including qualitative and quantitative information: a multi-disciplinary approach - integrating climate, environmental and social sciences - play an important role in the development of climate-risk knowledge, improving the process of translation of needs and the communication of results to society and decision-makers. It is also an iterative process, which evolves and matures over time: screening (first-level) risk products are useful for the evaluation of critical vulnerabilities and risks; more complex quantitative risk exercises are necessary to respond to very specific end-users' needs (e.g. how to improve the efficacy of the urban drainage systems, when and where to construct –reinforce- artificial barriers against storms and sea level rise).

4. CONCLUSIONS

In conclusion we present a table (Table 2) which summarizes highlights of what has emerged from the interaction between CLIM-RUN researchers and stakeholders. From the first row we can see that climate research can fulfil almost all needs. Therefore, early interaction between researchers and stakeholders is necessary to increase usefulness of climate products. If we then look at the row on expectations we can learn how to improve climate services: we can see what kind of broader issues need to be addressed when developing a climate service. This deals with the specific need of the stakeholders involved in the participatory process described: have climate information useful for decision making. In the last row we identify aspects which can be used to make progress faster. Some stakeholders, in fact, can provide specific knowledge, e.g. data and support.

The dialogue between stakeholders and researchers is still at an early stage, and there are objective difficulties in clearly identifying a common ground where scientifically robust climate information can be effectively translated into a usable product by the end-users community. Concerning model-based information, most of these difficulties can be ascribed to a gap between the typical spatial and temporal scales that end-users are interested in, and the ones that the climate scientists' community is actually able to resolve with the current generation of numerical models. Specifically, end-users typically ask for spatially local (1-kilometre scale) and temporally short (days-to-weeks) information, often confusing the domain of pertinence of climate with meteorological (weather forecast) services. Seasonal-to-decadal forecast is the kind of climate product which meets more closely the requests from a large number of end-users (agriculture, tourism, energy sector, infrastructure planners, etc.) but these still suffer from a number of deficiencies/limitations. These include: low predictive skill over the extra-tropical regions (e.g., seasonal forecasts over Europe); although a few centres have recently started to provide seasonal climate forecasts at horizontal resolutions approaching the regional scale, most of the current seasonal forecasts products do still rely on coarsely resolved global models (i.e., using grids featuring O(100) Km, or coarser, mesh sizes) leading in turn to low confidence over the regional scale; very low skill in predicting precipitations, winds, solar radiation and extreme events (though the skill is strongly season-dependent) beyond a few months.

Table 2 Summary of stakeholders' feedback

climate data needed	• climate data • longer time series of observations • higher resolution • precipitation and winds • data on impacts and risks • precipitation patterns to improve irrigation
expectations	• understand climate change • acquire information on climate (variability and change) and disseminate it to public • information to improve management options • information and knowledge for land-use planning, disaster risk reduction and early warning systems
synergies between CLIM-RUN and stakeholders	• regional meteorological services (OSMER and Teolo) have provided observed data • regional agencies can do downscaling • in northern Italy a research project is trying to create a repository of daily data since 1960

For long-term climate change projections, there is a relatively high confidence on surface (ocean and air) temperatures, but the degree of uncertainty affecting trends in precipitation is still very high. Sea-level projections are severely hampered by the lack of crucial processes (most notably, the lack of ice-sheets and glaciers representation in state-of-the-art climate models), and by errors in the representation of basin-scale ocean circulation features. Current horizontal resolutions used in ocean components of global and regional general circulation models are still below the expectations of the coastal management stakeholders community. These factors concur to make sea-level change information still highly untrustworthy. In the perspective of an ever-increasing confidence in the quality of regional climate projections/predictions, fostered by several factors – including the progressive increase in the spatial resolution of state-of-the-art Earth System Models, improved representation of physical processes and the overall reduction of model systematic errors - it is legitimate to expect that the afore mentioned gaps will get narrower, and the interaction between climate scientists and stakeholders more fruitful. However, the inherently low predictability of specific, poorly constrained, climate processes will partly hamper our ability in delivering trustworthy predictions, particularly over the multi-decadal range.

The lack of integration of climate information into the decision making process, and the lack of impact and risk assessment tools, such as GIS-maps, and geospatial indicators represents another key issue. Directly related to this point, is the communication of uncertainty in model outcomes.

Uncertainties will inevitably affect any given climate information. However, nowadays a rigorous quantification of uncertainties is attainable by carefully inspecting all the corresponding sources, assisting final users in the decisional process. Thus, uncertainties should not discourage future developments of climate services, nor should be considered as an excuse for inaction. They should be rather interpreted for what they actually represent: a range of possibilities of what the future might be.

Finally, in order to support the use of climate scenarios in urban planning and facilitate decision making processes in uncertain situations, the climate risk experts are significant scientific figures and the Decision Support Systems are important tools that allow to spatially visualise the potential consequences of climate change in different natural and human systems and sectors.

The process of developing climate services to bridge the gap between providers and users of climate information is still ongoing. The growing interest, testified among others by the European Union Horizon 2020 Work Programme 2016-2017, acknowledges the need of climate services to improve climate change adaptation and, thus, increase climate resilience.

LIST OF ABBREVIATIONS

CLIM-RUN Climate Local Information in the Mediterranean region Responding to User Needs

CMCC Euro-Mediterranean Center on Climate Change

CDD consecutive dry days

CSP Climate Services Partnership

DESYCO Decision Support System for Coastal climate change impact assessment

ECSP European Climate Services Partnership

GFCS Global Framework for Climate Services

HWD heat wave day

ICZM Integrated Coastal Zone Management

IRI International Research Institute for Climate and Society

R95 heavy precipitation index

RCP representative concentration pathways

RegCM4 Regional Climate Model

RRA Regional Risk Assessment

SPS Seasonal Prediction System

AUTHORS' CONTRIBUTION

VG organized the workshops and the focus group, synthetized findings, and facilitated the interaction between stakeholders and scientists. AB acted as the principal climate researcher, and enabled exchange with the other climate researchers in the CLIM-RUN project. ST acted as principal risk expert, and enabled exchange with the other risk expert in the CLIM-RUN project. All authors read and approved the final manuscript.

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