III – Collaboration in Education and Training

Introduction

Patrick Parrish

The WMO Global Campus Initiative is first and foremost about finding new ways to collaborate. Collaboration brings greater capacity, but also a greater number of perspectives and insights to serve innovations. The volume brings together chapters focused on a number of ways to use groups of collaborative partners to foster innovation.

- D'Amen and Menalled offer a report on the development and delivery of a virtual workshop involving DRR partners from national meteorological and hydrological services and disaster response agencies.
- Jacobs describes how three European countries with language and geographic affinities work together to address their learning requirements in operational meteorology, generating a great savings in time and effort.
- Mamaeva et al. describe an interdisciplinary and cross-border collaboration to address workplace requirements for sustainable shore development in the transboundary coastal zone of the eastern Baltic region.
- Smith et al. provide the story of an international and intercontinental collaboration to design and develop a series of self-directed training resources on forecasting uncertainty with ensemble prediction system products.
- Mamaeva et al. highlight the benefits of collaborative and cooperation between a hydrological university and national hydrological and meteorological service to ensure that university graduates gain important practical skills during their studies.
- Jacobs describes the challenges and significant benefits of adapting existing educational resources on radar meteorology to a new country and climate regime, and making these adaptations available to the international community.

1. Developing and Implementing a Virtual Workshop on "Meteorology in the framework of Disaster Risk Reduction: Interaction between National Meteorological and Hydrological Services and decision makers"

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Abstract

This paper describes a virtual workshop approach for the promotion of effective coordination between national meteorological and hydrological services (NMHSs) and decision makers for the issuance of early warnings for disaster risk reduction and management in Argentina. The "Virtual Workshop" was developed by the Argentinean National Meteorological Service (SMN). Its development and implementation followed the guidelines of the World Meteorological Organization (WMO) regarding the role of national meteorological and hydrological services in the reduction of disaster risk, based on the Hyogo Framework for Action 2005-2015 and the Sendai Framework for the Reduction of Disaster Risk 2015-2030. The steps in offering the virtual workshop are summarised, and its applicability to civil protection for disaster risk reduction at national and sub-national levels is demonstrated. Incorporating country-specific participatory tools that ensure fluid communication among participants will enhance the global applicability of the virtual workshop format as a new and powerful tool to raise the awareness of disaster risk reduction among the NMHSs and emergency agencies.

Keywords: Virtual Workshop, Disaster Risk Reduction, National Meteorological and Hydrological Services. Emergency Agencies.

Introduction

In 2017, the Argentinean National Meteorological Service developed the virtual workshop on *Meteorology in the framework of Disaster Risk Reduction: Interaction between National Meteorological and Hydrological Services and decision makers*. The workshop was targeted at the national meteorological and hydrological services (NMHSs) and emergency agencies of the Regional Association III (South America) of the World Meteorological Organization (WMO). Its main objective was to strengthen coordination among different institutions involved in disaster risk management in the region by promoting effective sharing of meteorological information among different users for Disaster Risk Reduction (DRR). To this end, the Argentinean National Meteorological Service created an office to integrate the social sciences dimensions of disaster risk management in its operations to enable it properly orient decision makers in relevant national institutions involved in the dynamics of DRR, such as Civil Protection and Defence.

The "Virtual Workshop" followed the WMO guidelines regarding the role that the National Meteorological and Hydrological Services should play in disaster management, based on the Hyogo Framework for Action 2005-2015 and the Sendai Framework for the Reduction of Disaster Risk 2015-2030. The workshop promoted the coordination of NMHSs in the Region in all aspects of disaster risk management with regard to the process of issuing early warnings. To benefit maximally from the Virtual Workshop, the user needs to learn how to use the official meteorological information. In addition, there should be good collaboration between NMHSs and emergency agencies of each country.

The following shares the experience and lessons learnt from a four-week Virtual Workshop, which could be useful for other countries improving their DRR processes or intending to incorporate its dynamics in their operations. It describes the main steps involved in the development of the workshop platform.

Virtual Workshop Design

The Virtual Workshop was executed in five steps.

The first step was the constitution of a working team in each country. The working team was composed of three members: one each from the partner NMHSs, the National Civil Protection and the Local Civil Protection in each country in WMO Region III. The tasks proposed to be carried out were properly articulated and shared among the members of the team. This was to promote collaborative work among representatives of different government agencies that are involved in different aspects of risk management. Each country was given a time limit within which to clarify the tasks and make a presentation of one PowerPoint presentation. In addition, the Argentinian team, using guiding questions, facilitated forum discussions among different countries. A unique aspect of the workshop was that the Argentinean team worked as tutors and at the same time as participants, having previously performed the same tasks that were requested of the others teams. This not only enhanced the clarity of the tasks that were to be accomplished, but also enabled the Argentinean National Meteorological Service to share its work experience with the National Civil Protection and Provincial Civil Defense.

To kick-start the Virtual Workshop, in the second step a presentation was made in a workshop for the tutors in which it was proposed that each participant would make a presentation on the activities of his or her place of work. Each presentation was to focus on the mission, competences and the structure of the institution to which the participant belonged. The presentation was also to stress the working relationships that existed between each NMHS and the emergency agencies, such as National Civil Protection and Provincial Civil Defence, operating in each country, as well as their organigrams. The purpose of the approach, which included the contextualization of the various institutions involved in disaster risk reduction in each country, was to share experiences among the WMO Regional Association III (RA-III) countries. It was also to share information on the status of legislation that regulates state intervention in disaster risk management among different agencies in different countries. The outcome from the second step was a comprehensive document that reflected different aspects of the national early warning systems in the same PPT document. (See Figure 1.1)

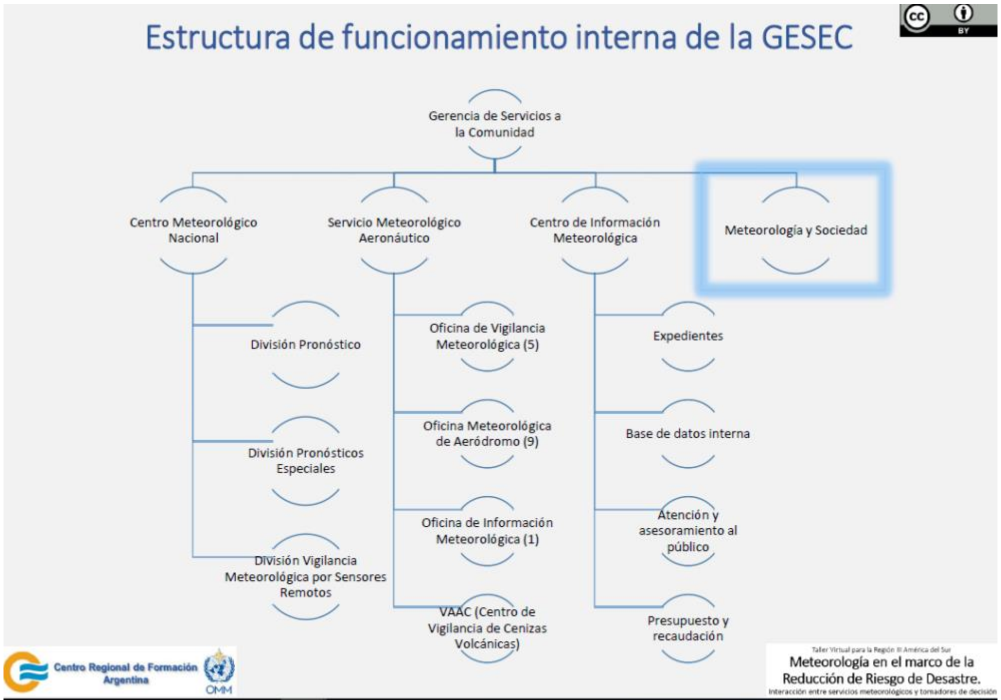

Figure 1.1. Virtual Workshop. One of the outcomes of STEP 2

In the third step that followed the initial presentation, each team was asked to collect information on the forecast products that could be used in integrated risk management and generate a flow chart for the channels of communication that each institution had in place. From these materials, the participants in the Civil Protection agency from each country prepared a chart that associated each forecast product from the NMHSs with actions (internal and external) that the agency implemented (see Figure 1.2). This was done to explore potential synergies among the different Defence and Civil Protection Agencies in their use of meteorological information and different forecast products in their own activities. It was also to show how the NMHSs incorporate the perspective of the emergency agencies in the construction of forecast products and verify the extent to which meteorological information produced focus on the forecast users. In addition, the exercise at this stage provided some information on the next steps to improve the users' comprehension about meteorological information, with emphasis on the need for coordination among the participants from different agencies. Thus, the virtual workshop was not only an opportunity to share and exchange experiences, but also a concrete way to share work experiences from a DRR perspective.

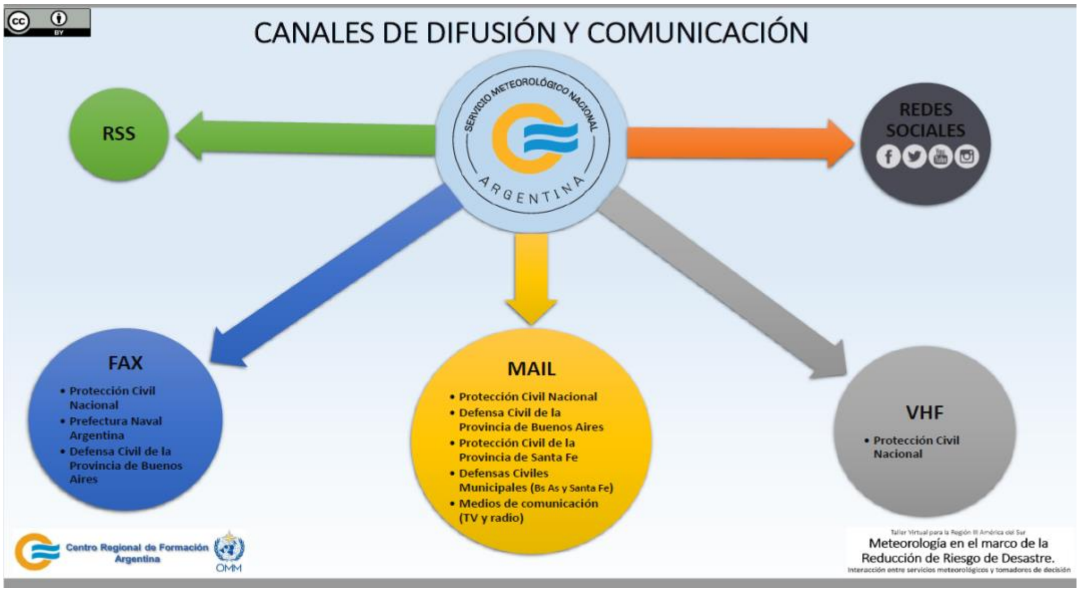

Figure 1.2. Virtual Workshop. One of the outcomes of STEP 3

The fourth step involved an activity that integrated what had been produced in previous steps. Each team was asked to select a high impact meteorological event that had happened in its country and for which there was adequate information preserved. Members of the NMHS in each team then reconstructed the forecasts that were issued for the event while members of Civil and Defence Protection Agencies detailed the actions taken based on the information provided at different times. In this way, the participants had to reconstruct what had happened in the event and then analyze the products that were issued by the NMHSs and the actions that were later implemented by the Civil and Defence Protection Agencies. This task once again required joint work among members of different institutions. While the meteorologists had to make a brief description of the event and recover the various forecasts issued by the NMHSs, members of emergency agencies had to recover their files related to the forms of organization and intervention they made during the event. Then, they had to link that information with the different components of DRR. In this way, the forecasts at different meteorological scales and products issued by the NMHSs were associated. (See Figure 1.3)

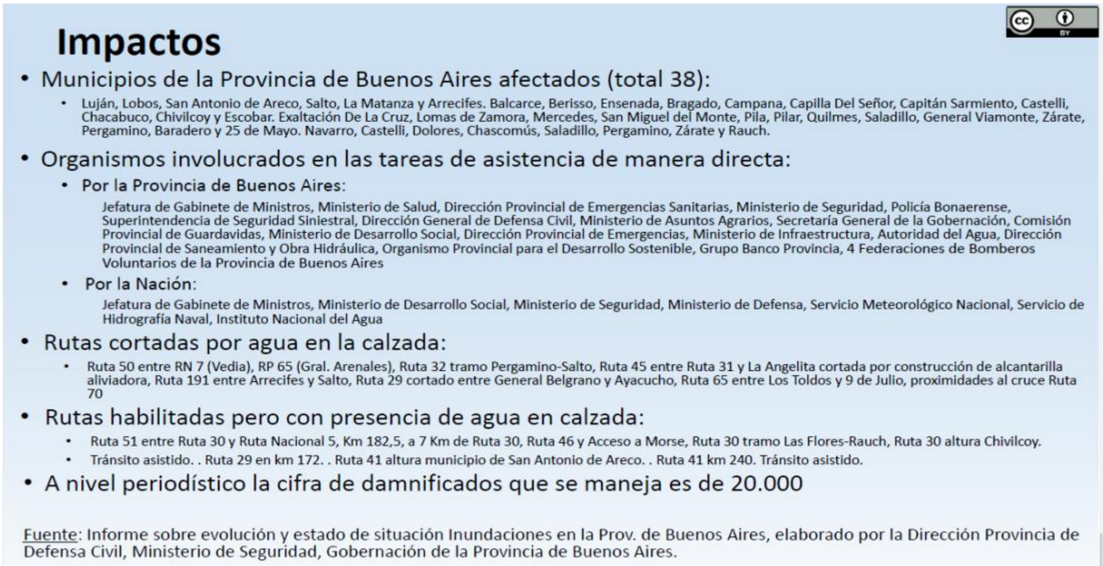

Figure 1.3. Virtual Workshop. One of the outcomes of STEP 4

This activity allowed practitioners to put into practice one of the central tenets of DRR by not only focusing on the response, but also strengthening the implementation of actions in the stages before and after a meteorological event. Thus, it contributed to the review of the guidance elaborated in the WMO guidelines on the role of NMHSs in DRR. There were also interactions among different institutions in carrying out the task. This aspect of the Virtual Workshop consolidated the previous tasks and enabled further understanding of the theoretical basis for DRR. It also brought out some challenges that may be encountered in translating these aspects of DRR into practice due to complex interactions of the multiple factors contributing to disasters.

The final phase of the Virtual Workshop started with video discussions among the participants to review the content and its relevance for the first regional workshop. The purpose was to share experiences on perceptions about the process, lessons learnt and challenges, as well as concerns that could be critical inputs into future workshops in disaster risk management. At the beginning of the discussions, the most significant difficulties in integrated risk management were exposed. Common challenges mentioned during the video discussions included current legislation, the organizational structure and the imperative for intra- and inter-institutional coordination. Thus, we recommend that this strategy of video discussion should be an integral part of the workshop since it is difficult to know the opinions of participants in a purely virtual format.

In addition to the video call, an online SWOT (Strengths, Opportunities, Weaknesses and Threats) analysis of the Virtual Workshop approach was undertaken among participants to evaluate the benefits of the exchanges that took place among countries in the region and to get participants thinking about the success factors and challenges of the Workshop. Furthermore, regional challenges that could affect the future application of the workshop methodology in the region were evaluated. The SWOT analysis and feedback from participants from different countries indicated that the use of participatory tools and good interactive communication among participants are critical for the success of the Virtual Workshop for disaster management at the regional level. This workshop also made it possible to explain the importance of the development of other workshops at a regional level because they facilitate the sharing of different work experiences. In this regard, this workshop served as a forum for the exchange of experiences at a regional level between NMHSs and emergency agencies. It also fostered the sharing of theoretical material to deepen the need to focus the products of the NMHSs on specific users. Thus, the Virtual Workshop has been adopted as a new and powerful tool for DRR among the NMHSs and emergency agencies of the RA-III of the WMO.

The workshop outcomes, however, pointed out the need for advances in the generation of meteorological products and specific actions in the four components of the DRR: prevention, preparedness, response and reconstruction.

At the end of the Virtual Workshop the original materials prepared by the members of each work team were consolidated into a final document to reflect the experience of the four weeks.

Conclusion

This article demonstrates the novelty of integrating social sciences with meteorological information in disaster risk reduction and management among NMHSs through a Virtual Workshop methodology. It also shows the value of getting NMHSs and emergency agencies to work together in DRR, as practically demonstrated for RA-III of the WMO. We hope that other professionals in different Regions of WMO will find this Virtual Workshop methodology useful to enhance their approach to DRR.

Link to the final workshop report is available at the WMOLearn portal, or directly from the link provided.

2. D-A-CH cooperation: An example of efficient and well-targeted training

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Abstract

This chapter describes the reasons and strategies for the formation of the D-A-CH cooperation for training weather forecasters primarily in three Central European countries. D-A-CH is formed by the German, Austrian (including ZAMG and, starting in 2020, Austro Control, and Swiss meteorological services, with additional support from EUMETSAT. The goal is to organize one blended-learning course each year, using a multi-week online phase to cover a range of weather phenomena, and a one-week classroom phase to delve deeper into a single topic and provide more opportunities for forecasting exercises. The D-A-CH cooperation, by sharing of resources and alternating leadership in the training development and delivery, is expected to generate substantial savings to the participating meteorological services—up to 15 weeks of personnel time for the service acting as the course lead, and up to19 weeks of savings for those not leading in that year.

Challenge for services

Enabling forecasters to do their jobs according to rapidly changing requirements is a continuous challenge for training. Forecasters do not need only scientific competence but also the ability for putting manifold information into a complete and logical conceptual model of significant weather developments, even under time pressure, and to issue forecast products that are tailored to the needs of individual customers. Forecaster training has to be offered regularly because each service has to fulfill international ISO- and WMO standards.

Opportunities and challenges of international cooperation

Although several services have powerful resources to overcome these challenges, each service needs help from others. Many training projects and institutions offer high quality training material about many different topics, as well as trainers and technicians with high-level expertise and a modern and powerful infrastructure. However, several challenges still remain. Forecasters have to cover different regions with different climates, and forecast products must be tailored to the demands of customers in different countries and industries. The technical equipment and facilities at different locations have to be taken into account in the training process. The biggest challenge of meeting international needs is the diversity of the work force itself, with different background knowledge and cultures. Often many different languages are the first languages of the participants in international training seminars. Because translation often cannot be offered many courses have to be delivered in English, yielding a reduction of the learning in some cases.

Why D-A-CH courses?

Despite these challenges, international cooperation is an important resource for forecaster training. However, it makes sense to define regions of similar conditions and similar working techniques. For decades, a close partnership has existed between the weather services of Germany, Austria and Switzerland (D-A-CH). Analogous to the successful cooperation of NOMEK (Nordic Meteorological Competency Training), the three directors of these services met in 2016 and decided to extend D-A-CH cooperation to include forecaster training because the requirements and forecasting techniques are rather similar within the D-A-CH community and because this co-operation would lead to a win-win situation due to its synergies.

Brief history and organizational matters

EUMETSAT is also very interested in forecasters' training in Middle Europe, especially in the usage of the new satellite products of Meteosat, 3rd Generation, whose launch is scheduled for 2021. In order to ensure training of as many forecasters as possible, EUMETSAT has agreed to provide financial support for travel.

In June 2017, the D-A-CH expert team met for the first time in Langen (with members from ZAMG, Meteo Suisse, DWD-training center and DWD-Central Forecasting Unit, EUMETSAT). Austro Control, responsible for Austrian air navigation, will join D-A-CH in 2020. During this meeting, the target group (forecasters with existing knowledge of synoptic meteorology), the learning objectives, the learning platform and the forecasting timescale (very short range forecasting and nowcasting) were fixed. The group decided to offer a blended seminar (an online phase followed by a classroom phase). The general course structure, the tasks and the responsibilities of the participating services and milestones were drafted.

Although satellite products will be an important part the course content, it will include all aspects of routine work. However, products of the Meteosat, 3rd Generation (MTG) satellite will play an increasing role as the launch time of MTG approaches. The training will serve up to 20 forecasters in the classroom and additional participants during the online part.

The spoken language will be German since forecasters from Austria, Germany and Switzerland are being targeted. Because considerable amount of high quality training material already exists in English, and in order to be flexible to training requirements from other WMO-member countries, the expert team decided to use training material in English. This will ensure training materials can be offered to a broader community as well as integrated easily into D-A-CH courses.

In October 2017, the team met again in Langen and discussed how to organize their work and responsibilities. For each topic, one leading service will coordinate the corresponding online part (for example, reviewing the content and contacting trainers) and the classroom Phase (Figure 2.1). The responsible trainer in the training unit will make decisions about the teaching methods.

In January 2018, the group met in Vienna. The training topics, the course schedule and milestones with responsible people were specified. EUMETCAL agreed to organize the course platform.

In December 2018, the expert team worked on the training development plan (TDP), and documents regarding the Enabling Skills (NWP, radar, satellite) were used in order to train in accordance to the WMO guidance. However, due to organizational reasons, the first course schedule was postponed by about six months. Figure 2.1 reveals the final schedule for the classroom phases and the lead service for each year.

During an online meeting in February 2019 open points were clarified, such as budget, experts for training, cooperation with Austro Control, and the time for course announcement.

Training concept

A course will be offered every year. Each online phase covers all course topics for that year’s course: (a) cyclones, fronts, strong precipitation, b) fog, stratus, drizzle and freezing drizzle, c) summer convection. From 2020 onwards d) Foehn winds, orographic induced waves, and turbulence will be added. Each topic will last two weeks (2x3 hours working time, including overview of the topic and self-guided and interactive learning, and ending with an evaluation of the learning success).

One of these topics in 2019, cyclones, fronts and strong precipitation) will provide preparation for the classroom phase. It is not practical to cover all topics during a classroom phase of only one week. Longer forecasters’ absence cannot be managed by the services. On the other hand, forecasters need also regular training in the other topics in order to handle all high-impact weather situations during the year.

The online phase on Summer Convection will be delivered in three steps. In the first step, the physical background of all relevant structures of summer convection and their identification will be explained. With this knowledge the forecaster decides about the suitable conceptual model (on life cycle and weather impact) in order to gain valuable hints to severe convection, such as region and probable time period, as early as possible. For instance, typical features of hodographs (vertical wind shear), radar signatures (such as radar echo in a bow form) and the probable weather impact (such as hail or heavy wind gusts) are discussed. In the second step the applications during the different forecast timeframes—6-24, 2-6 hours (early warning), and up to 2 hours (nowcasting)—will l be demonstrated. These applications include how and when to apply the different data sources for the identified forecasting problem. The last step contains practice and homework.

In preparing the classroom phase (18-22 November 2019 in Vienna) different categories of fronts (such as cold fronts, split fronts, warm fronts and frontal substructures) and special subspecies will be considered in respect to physics, 3-D-structure, and identification in satellite images. Regarding rapid cyclogenesis and different kinds of occlusions, also the 3-D-view, characteristics of rapid cyclogenesis, life cycle and diagnosis using satellite products will be discussed. In connection to the topic, “Strong precipitation,” typical weather situations and their regional variations will be considered, with emphasis on using radar products and of NWP forecasts. In the final step, the warning process will play an important role. Case studies will be used frequently for demonstration purposes and interactive exercises will be included.

During the classroom phase emphasis will be given to a single topic. Figure 2.1 contains the preliminary schedule, topic, leading institute and the location of the classroom phase.

18-22-November 2019	**Autumn 2020**	**Spring 2021**	**Spring 2022 (TBD.)**
Cyclones, fronts, strong precipitation, Lead: ZAMG, @ Wien	Fog, stratus, drizzle, Lead :MCH, @ Zürich	Summer convection, Lead: DWD, @ Langen	Waves, Foehn, Turbulence, Icing., Lead: Austro Control, @ Wien

Figure 2.1. Time period, leading institute and venue of classroom parts

The main goal of the classroom phase will be to take an active learning approach. More than 50% of the time consists of group work and presentations by the participants. Only nine hours of the week are reserved for presentations by the trainers. During the breaks further discussing and exchanging of experiences and ideas are expected.

D-A-CH cooperation in the context to the international training community

Many services have asked for forecaster training, in particular developing skills for using radar, satellite, NWP products and high-impact Weather. Too often this training is developed at different training institutes independently from each other, leading to duplication of effort. We hope that the synergy of our D-A-CH seminars will help to improve this situation.

Although the international courses under the umbrella of EUMETCAL and EUMeTrain, two other broader European cooperative training programmes, are frequently offered, the D-A-CH-courses will be tailored to the needs of Middle European countries and to the climate of the middle latitudes, equivalent to NOMEK courses for the Nordic European countries, and SEEMET courses for southeast Europe. The expert team plans to open these courses and resources also to the WMO Global Campus community. We support increased communication and cooperation among different training institutes, and the D-A-CH cooperation could be seen as an additional step forward in this direction.

Estimated benefits for each D-A-CH member

Synergy makes it possible that the D-A-CH-group can offer a new course every year: a) four topics during the online phases using interactive training methods and assessments, b) one week in the classroom focused on one topic in order to go deeper into practice and to encourage students to do project work and to exchange experiences and expertise.

In addition to the central benefits (improving the service's image, learning from each other, having more highly skilled forecasters issuing better forecasting products, and the final consequence of protecting people) the benefit due to reduced effort can be remarkable. Even using existing training material, the total training workload of all services is quite high (estimated to be 28 weeks). However, through the cooperation of D-A-CH members, personnel costs for each service is reduced by about 15 to 19 weeks. Table 1 summarizes the amount of work (estimated working time in weeks and without interruption during one year).

Table 1: Estimation of personal resources and of saving for each service (Austro Control [from 2020], DWD, Meteoswiss, ZAMG) per year

Activity	Working time for all (4) services [in weeks]	Working time per service [in weeks]	Savings for each service [in weeks]
Meetings (preparation and evaluation)	4	1	0 (Services work synchronously)
Online phase (e.g., development,	4 x 3 =12	3	9 (Services work mainly

monitoring, evaluation)			asynchronously)
Classroom phase (e.g., development, organization, delivery, travel and stay, evaluation)	6 +3 x 2 =12	2 (not leading) 6 (leading)	10 (not leading) 6 (leading)
Sum	28	6 (not leading) 10 (leading)	19 (not leading) 15 (leading)

Each year the D-A-CH team will arrange one face-to-face and one online meeting. The preparation, the meetings itself, the evaluation and minutes need about one week working time for each service. The work load will not differ significantly from service to service, yielding equal benefit for each service because they are working synchronously. A significant benefit comes during the online phase. The workload estimations for each topic is three weeks. The total work load for all services can be estimated at twelve weeks. Because each service concentrates mainly on one topic (equivalent to working asynchronously) the benefit for each service results in nine weeks savings of effort.

During the classroom phase, the estimated workload for all services is similar to the online phase (twelve weeks). If a service is not leading a topic, however, the work is limited to two weeks: to travel, to deliver some lectures and to monitor the participants' progress. However, the classroom phase's organization and conception creates a work load for the leading service of about six weeks.

Table 1 reveals a total work load for all co-operating weather services combined of 28 weeks, equivalent to 78 k€ (according to German conditions). However, the workload distribution among the D-A-CH partners yields a significant savings for each service. Each fourth year, when the service has the lead, the saving is about 15 weeks (equivalent to about 42 k€), and during the next three years not leading, up to 19 weeks savings is achieved (equivalent to about 53 k€).

An additional benefit comes from working with EUMETSAT, which covers the forecasters' travel costs, equal to about 4 k€ for each service. The total benefit per year and for each service amounts to about 46 k€ (leading service) and 57 k€ (not leading service).

As more course development processes are established and course materials are reused, it is likely that personnel cost savings will decrease. However, this co-operation will certainly remain reasonable for many years.

These numbers cover only the savings of personnel resources and travel costs. It is more difficult to quantify the benefits of an improved image, more skilled trainers, forecasters and training managers, and protecting people.

Conclusions

- The benefit from the cooperation of D-A-CH countries greatly exceeds the investment for each service;

- D-A-CH can be seen as a model for cooperation in other regions of the world. They could also be seen as a resource for bigger training bodies like EUMETCAL, and even the WMO Global Campus, by using and offering training expertise, material, resources and facilities;

- More forecasters can be trained yielding better forecast products with positive impacts to many people.

3. Transboundary Partnerships for Capacity Development and Effective Coastal Zone Management

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Abstract

This chapter reports on an on-going initiative to promote sustainable use and management of transboundary coastal zone resources through effective collaboration among experts in the region, with emphasis on the Eastern Gulf of Finland that encompasses the Russian and Finish cross-border areas. A consortium of experts have been put in place and it has developed a three-year project (Getting Ready for the Cross-Border Challenges: Capacity Building in Sustainable Shore Use – GET READY), with the objective of developing an innovative, skilled and well-educated workforce in the cross-border area. The partnerships that will be established will promote skills development and life-long learning by providing problem-oriented training based on the "case-study method", implementing interdisciplinary approaches, and using e-learning. It will also foster cooperation between businesses and enterprises, educational institutions and scientific and research institutions by establishing joint educational activities, preparing development plans and encouraging innovation in the cross-border area for the sustainable development of the transboundary coastal zone.

Keywords: collaboration, international collaboration, transboundary collaboration, sustainable shore use, coastal zone management, emerging content areas, case study strategies

Introduction

Sustainable use and effective management of the coastal zone cannot be implemented without strong cross-border cooperation involving common approaches and a shared understanding of strategies, technological decisions and scientific progress. This is only possible through the joint efforts of a highly qualified workforce, who have the necessary knowledge and professional competencies in a variety of areas, including coastal zone management, climate change adaptation and applied hydrology. So, professional education and training of students, professionals and decision makers becomes a priority for the region. This can be realized by developing and running educational and training programmes for a wide range of audiences, based on the accumulated experience and the best practices of stakeholders involved in developing the coastal zone.

This chapter reports on a partnership-building initiative at the international level that is intended to serve as an example of what can be achieved if environmental risks of a coastal region are tackled through collaborative efforts among institutions and experts. The focus is the cross-border region of the Eastern Gulf of Finland.

The challenge

In the coastal zone of the Eastern Gulf of Finland (EGoF), both on the Russian and Finnish sides, new ports have been constructed as part of the rapid development of the coastal infrastructure. The operation of the ports ensures intensification of the exchange of goods, raw materials and intellectual information between the countries of the eastern and western Baltic, which is a prerequisite for sustainable development of the Baltic region as a whole. At the same time, the coastal zone of the EGoF is recognized as a valuable natural ecosystem, which is highly sensitive to the impacts of global warming. Development of the "coastal technosphere" in the EGoF is accompanied by number of environmental risks, including those occurring at a transboundary level: transformation of natural coastal landscapes, decreasing of species diversity in biological communities, fragmentation of the integrated terrestrial and marine biotopes, stress-effects of noise, thermo-pollution, appearance of alien species, among others. The challenge is ensuring the sustainable development of the coastal region in the face of its environmental problems and the need for its rapid development of economic growth.

Overview of the project

An international consortium of partner organizations from Finland and Russia (see the authors' affiliation) was created. It brought together research institutes (carrying out scientific research and development), businesses (dealing with production and implementing innovations driven by science) and universities (providing a qualified working force via education and training programmes). There are comparative advantages for all involved parties with such diverse backgrounds and experiences that contributed to the effectiveness and sustainability of the international partnership. They include:

- Businesses using the educational and scientific capabilities of leading universities and research institutes to enhance their products and services.

- Universities and research institutes ensuring that their research, development and educational activities address the needs of businesses.

All the members of the consortium recognise that education and training are the basis for sustainable development.

Eco-Express-Service LLC takes the leading role in the consortium for managing collaborative efforts aimed at developing and using the scientific, industrial and intellectual potential of Finland and Russia in the cross-border region. The three-year project developed by the consortium, "Getting Ready for the Cross-Border Challenges: Capacity Building in Sustainable Shore Use" (referred to as GET READY), was awarded for funding as part of the Cross-Border-Cooperation Programme 2014-2020 "South-East Finland - Russia" (https://www.sefrcbc.fi/) within the thematic objective, "Support to education, research, technological development and innovations".

In the preparatory stage, the partners agreed upon the management system and defined the communication and information flows. Also a visibility and communication plan was agreed to that will provide transparency and a wide dissemination of the project's results. A Project Steering Committee, composed of external environmental experts from local authorities, was appointed to provide guidance on how to maximize the usefulness of the outcomes of the project for society and other stakeholders. The consortium also approved a detailed project working plan, which contained progress indicators and reporting procedures.

The primary objective of GET READY is to develop an innovative, skilled and well-educated workforce in the cross-border area. The wider objective is to increase the readiness of the cross-border region to overcome existing and expected challenges by sharing examples of the best practices and applying innovative solutions for the sustainable use of the coastal zone.

Roles of the partners

GET READY involves a variety of activities, including a work package on education and training. The members of the consortium are motivated and recognize the benefits that will be realized by carrying out the activities in the project plan. The following is a summary of the contributions that will be made by each of the partners to the success of the work package. (See Figure 3.1)

The universities and institutions that are part of the GET READY consortium are expected to develop and implement the professional educational and training programmes of the project. Also, there will be the involvement of a specially created Russian-Finnish Centre for Education, Research and Innovations in Coastal Zone Management. The establishment of this centre will be coordinated by Eco-Express-Service LLC (EES), which is a private company with extensive experience in monitoring and implementing large hydrotechnical and dredging projects in the Baltic Sea (e.g. Ust-Lugaharbor and Bronka port**).** EES conducts research and develops know-how in the field of ecofriendly engineering. It is interested in developing cooperation with scientists and educators around the region based on the understanding that sustainable development can be only provided by collaborative efforts.

The State Hydrological Institute (SHI) of Roshydromet is the leading Russian research institute for the study of surface water resources. Its research activities include (a) assessing the impact of climate change on natural conditions, hydrological characteristics and water resources, (b) creating and developing technologies for the maintenance of databases, and (c) developing automated technologies for data collecting and processing. In addition, SHI participates in international activities through organizations such as WMO and UNESCO. It launched the WMO International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) in 2009. SHI will contribute to GET READY by carrying out a training needs analysis and then running development courses on applied hydrology, water resources, training for trainers and management.

The Department of Ecological Safety and Sustainable Development of Regions at the St Petersburg State University (SPbSU) is an important component of the partnership dealing with "science-business-education and training". The Department will develop new curricula, use methodical approaches to stakeholder training, and prepare teaching materials and manuals. Participation in the project will intensify the exchange of scientific information and best practices with Finnish partners. As a result of the exchange of information, a database will be compiled of best practices in the field of sustainable coastal management for use in the educational process at SPbSU.

Kotka Maritime Research Centre (KMRC) is an international research centre doing interdisciplinary applied research to improve maritime safety, prevent accidents and protect the marine environment. The expertise of its staff is built upon the joint research done at the University of Helsinki, Aalto University, University of Turku and the South-Eastern Finland University of Applied Sciences (XAMK). The role of KMRC in GET READY is to study the possibilities for digitizing environmental management tools for ports in EGoF. This will involve analyzing, classifying and summarizing existing digital tools and data to promote the digitalization of environmental management systems used in ports. Additionally, a workshop and two short training courses will be organized in cooperation with XAMK.

University of Turku (UTU) is a multidisciplinary research and education organization. In GET READY, the Brahea Centre at UTU will focus on research and education covering maritime transport and logistics, regional development and environmental management in the Baltic Sea region. The development and planning of training programmes, with a focus on new and innovative learning approaches, is at the core of the education and development activities of the Brahea Centre. GET READY will provide opportunities for UTU's researchers and education experts to further develop the multidisciplinary knowledge base and provide advanced training on integrated coastal zone management and marine spatial planning. In this way, UTU will contribute to the societal interaction and regional development of the Gulf of Finland.

The South-Eastern Finland University of Applied Sciences (XAMK) is renowned for its research, development and innovation activities aimed at fostering sustainable regional development and well-being, improving regional economic competitiveness, and promoting national and international innovations. Participation in a cross-border cooperation project supports the fulfillment of these goals. In addition, such cooperation enables knowledge sharing between project partners and their respective regions, and gives opportunities to make new contacts and develop stakeholder relations. During the project, the expertise of the research personnel will also be enhanced. The envisaged knowledge sharing between partners and regions is vital for fruitful co-operation now and in the future.

The Finnish Environment Institute (SYKE) is both a research institute and a centre for environmental expertise. SYKE is committed to protecting the environment and applying cross-disciplinary research to problem-solving. As a result, SYKE contributes to policy formulation and implementation at local, national, EU and international levels and is experienced in a range of policy fields, including biodiversity, waste, climate and water. For GET READY, SYKE will focus on: (a) improving skills in marine and coastal planning and (b) improving skills in preparing and using inventories and assessing coastal and underwater biotopes (like wetlands, mollusks settlements, fish spawning places and nurseries) and the impacts of human activities on those biotopes. Through GET READY, SYKE will strengthen its networking with Russian organizations that work for improving the environmental status of Gulf of Finland.

Concluding remarks

The benefits of establishing an innovative, skilled and well-educated workforce in the cross-border area of Finland and Russia for sustainable development, that could be replicated in many WMO Regions, include:

- Promoting skills development and life-long learning by providing problem-oriented training based on the "case-study method", implementing interdisciplinary approaches, and using e-learning facilitated by different institutions (SPbSU, KMRC, UTU, XAMK);

- Fostering cooperation between businesses and enterprises, educational institutions and scientific and research institutions by establishing joint educational activities, preparing development plans and encouraging innovation (EES, SHI, SYKE).

Figure 3.1. The kick-off meeting of the GET READY project partners with the Managing Authority of the Cross-Border-Cooperation Programme on 12 March 2019 in Lappeenranta, Finland. GET READY is an international consortium of scientific and research institutions, universities and the private sector working together to support education, sustainable development and innovations.

4. Multi-partner Innovations in Forecast Uncertainty Training

Andrea Smith and Bryan Guarente, The COMET Program, University Corporation for Atmospheric Research; Francis Wu and Stephen Kerr, Meteorological Service of Canada

Abstract

The COMET Program and Meteorological Service of Canada (MSC) recently collaborated with numerical weather prediction experts from EUMETCAL (an education & training program within the European Meteorological Services Network, EUMETNET) to create the online curriculum *Forecast Uncertainty: EPS Products, Interpretation, and Communication.* The curriculum was inspired by 2014-2016 EUMETCAL training priority areas of understanding

Ensemble Prediction Systems (EPS) and their output, forecasting high impact weather, and effectively communicating probabilistic information. MSC's multi-year cooperative agreement with COMET was an ideal vehicle for creating easily-accessible lessons that would benefit many global partners.

The curriculum was designed by COMET and MSC staff, with EUMETCAL and other agencies contributing NWP expertise and ensemble datasets. This effort represented a unique partnership between separate funding agencies (MSC) and those providing in-kind expertise and products (EUMETCAL and others). The overarching goal was to create an online EPS and probabilistic communication curriculum that could be successfully used by *any* NMHS (national meteorological and hydrological service) forecaster.

To achieve this goal, the series was designed with the following features:

- NWP Expert Group determination of common EPS map and chart types
- Use of generic, conceptualized EPS products in addition to exposure to specialized and/or region-specific products
- A primer on the fundamentals of EPS functionality and statistics, for beginners and NMHS staff in the process of implementing EPS
- Case studies that span several meteorological phenomena, several geographic regions, and several different forecast and communication processes

The result is a well-rounded, seven-lesson treatment of EPS products, how to interpret them, how to communicate about them, and how to integrate them into the forecast and service delivery process. The series is highly rated by MetEd users, and available in English, Spanish and French for global accessibility.

Introduction

Numerical weather prediction (NWP) developers created ensemble prediction systems (EPS) over 35 years ago, and the meteorological community first transitioned their output into operational use in 1992. Since then, EPS have become commonplace in some National Hydrometeorological Services (NMHS) and within the private forecasting sector. However, many NMHS have yet to adopt EPS, or are still in the process of implementing their usage.

EPS are sophisticated NWP systems that produce many outcomes. Instead of running an NWP model once, as with deterministic model runs, scientists run a model many times using slightly different conditions or physics packages, or use a combination of many different models. As such, EPS allow us to envision multiple possible forecast outcomes and determine likelihoods of those outcomes, providing a more detailed level of service to decision makers and the public.

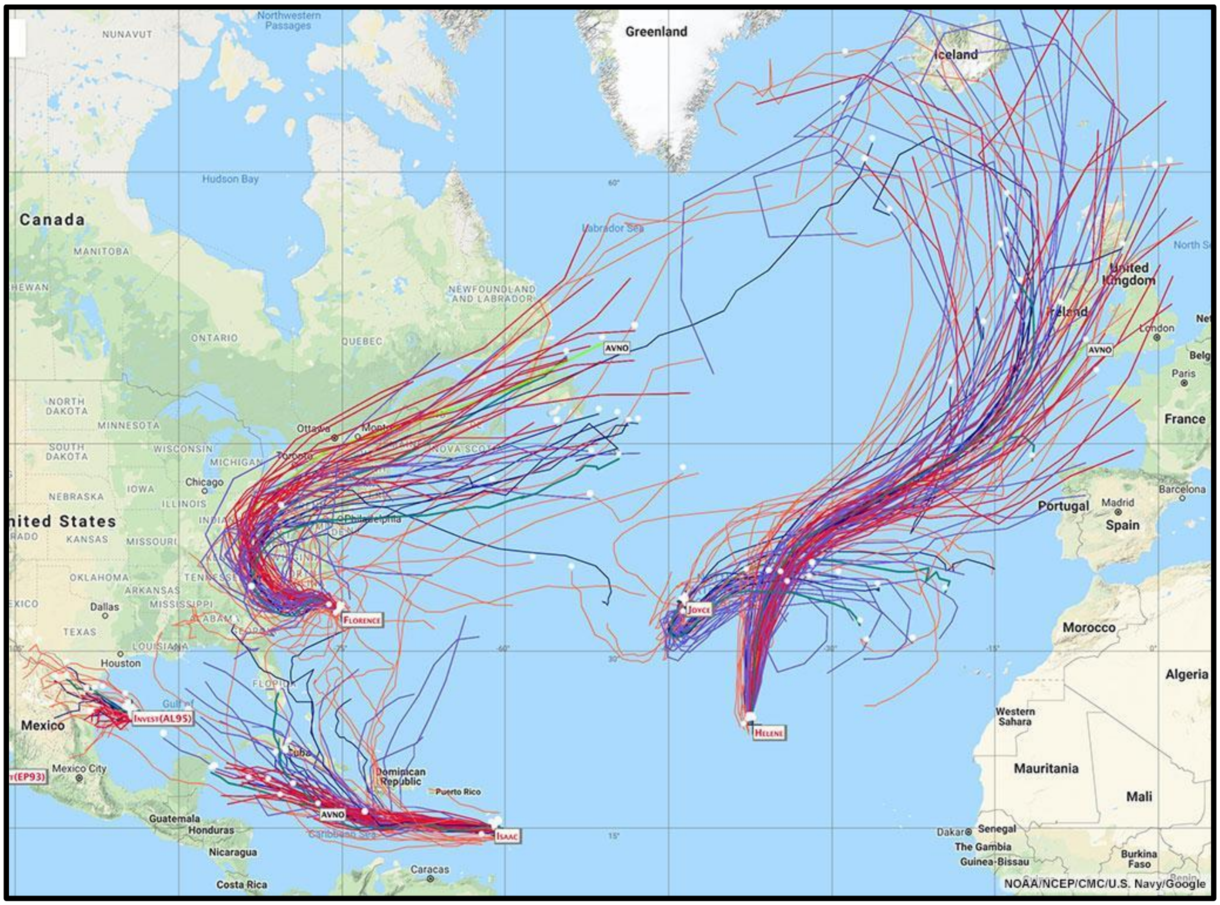


Figure 4.1. Ensemble storm tracks from several different global EPS for 2018 September 13th 12Z model runs.

Some EPS have ten or fewer "members", or individual model run solutions, while others may contain more than sixty. As one can imagine, tens of possible individual solutions for dozens of different weather variables creates a very large dataset. Interpreting these possible solutions and efficiently integrating them into the forecast process requires different statistical approaches. The most likely solution, and specific thresholds of concern, such as the probability of temperature below freezing, are two common examples of EPS statistics. These statistical approaches have varying levels of complexity, and each has limitations that a forecaster must understand if he or she is to accurately use the products and then communicate the uncertainty to stakeholders. For NMHS offices that previously issued deterministic, single-value forecasts, the transition to utilizing this large and specialized amount of EPS output can be daunting, to say the least.

To address the looming training needs associated with EPS implementation, the Meteorological Service of Canada (MSC), EUMETCAL (an education & training program within the European Meteorological Services Network, EUMETNET), and other partners convened an NWP working group to brainstorm training options that would serve not only the NMHS represented by the group, but any NMHS that would be adopting EPS usage over the next decade or two.

The working group met several times in person and virtually between 2015 and 2017. The group's initial efforts included cataloging existing EPS training, outlining common learning objectives or competencies typically required upon EPS implementation, and discussing funding vehicles.

After much discussion and assessment, the team prioritized the following learning objectives (LOs):

1. Recognize key differences between deterministic and probabilistic modeling approaches

2. Interpret common EPS product charts and maps, and understand the statistical approaches used to create them

3. Evaluate NWP and EPS product strengths and weaknesses with respect to the forecast scenario and end-user information needed

4. Integrate EPS information with other meteorological observations and model output in the forecast process

5. Effectively communicate probabilistic forecast information to end users

Existing materials among the various NMHS represented did not adequately meet all of these objectives, and much of the existing training was too agency-specific or region-specific to be applicable to various users. Additionally, reaching the broadest possible audience in a cost- and time-effective way was a top priority for the group. Thus, the working group selected the creation of new EPS and communication distance learning materials in partnership with MSC and The COMET® Program. The remainder of this article further describes the *Forecast Uncertainty: EPS Products, Interpretation, and Communication Series* curriculum and instructional design, the materials delivered, their effectiveness, and recommendations for future multi-institute training collaborations of this nature.

Organizational Collaboration

COMET has produced geoscience training for over 30 years, and houses over 600 lessons across 20 different topic areas on its freely-available MetEd website. MetEd has over 600,000 registered users and is widely accessed by NMHS staff, educators, and geoscience stakeholders.

MSC and COMET have partnered for over 20 years through a cooperative agreement within which COMET provides instructional design and scientific support service to create learning materials with MSC subject matter experts. These materials are then published on MetEd, and many are translated to French. COMET also translates many of the lessons to Spanish to reach the widest audience possible.

The working group agreed to harness MSC-COMET's successful and longstanding training collaboration to create EPS and communication materials that would be accessible by all NMHS and the public. MSC provided cooperative agreement funding for COMET and MSC training, scientific and development staff time, while various working group member agencies provided in-kind contributions of subject matter expertise and meteorological data/products for case studies. The following list highlights in-kind contributors:

- Agencia Estatal de Meteorología (AEMET), subject matter expertise and data/products
- Deutscher Wetterdienst (DWD), subject matter expertise and data/products
- Finnish Meteorological Institute (FMI), subject matter expertise and reviews
- European Center for Medium Range Weather Forecasting (ECMWF), subject matter expertise and data/products
- Latvian Environment, Geology and Meteorology Center (LVĢMC), subject matter expertise and reviews
- Met Éireann, subject matter expertise and reviews
- Swedish Meteorological and Hydrological Institute (SMHI), subject matter expertise and reviews
- United Kingdom Meteorological Office (UKMET), subject matter expertise and reviews
- University of Manchester, subject matter expertise and reviews
- United States National Weather Service (NWS), subject matter expertise and data/products

These institutions contributed to one or more case study, best practice or theory-based lessons, or provided case event details and refined how technical and meteorological concepts were presented. The next section outlines the training series objectives and instructional approaches.

Series Curriculum and Design

To meet the working group objectives discussed earlier, COMET instructional designers worked with working group experts to outline the following curriculum components:

- A reference guide to the most common EPS products - fulfills LOs 2 and 3
- A "best practices" lesson on communicating forecast uncertainty - fulfills LOs 4 and 5
- Regional case studies - fulfills LOs 2 - 5

Original plans included addressing LO 1, *recognize key differences between deterministic and probabilistic modeling approaches*, within the reference guide to common EPS products.

However, it quickly became clear that the reference guide should stand alone and a separate *Introduction to EPS Theory* lesson would be more appropriate to ensure a thorough understanding of what an EPS is, how it and its output are constructed, and how it differs from and can complement deterministic output. *Introduction to EPS Theory* serves as the first lesson in the curriculum, and contains a pre-test and post-test to ensure understanding of the topics. (See Figure 4.2)

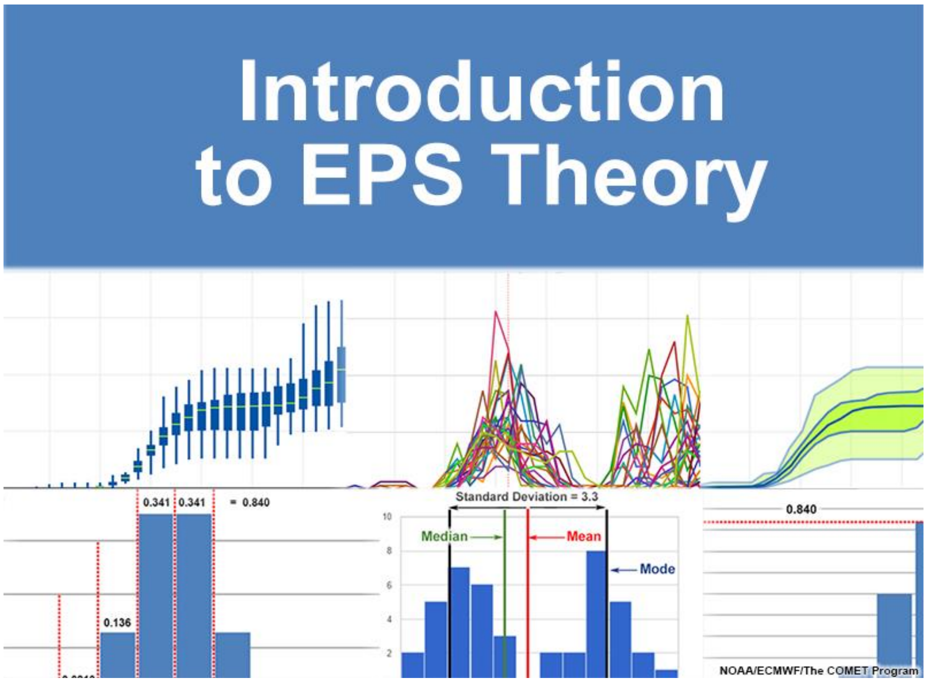


Figure 4.2. Main webpage imagery for *Introduction to EPS Theory* lesson.

The EPS Products Reference Guide fulfils LO 2, interpret common EPS product charts and maps, and understand the statistical approaches used to create them, and LO 3, evaluate NWP and EPS product strengths and weaknesses with respect to forecast scenario and end-user information needed. (See Figure 4.3)

The products chosen for the reference guide were ones familiar to all agencies represented in the working group, and ones that could be used in all regions and/or climates. A variety of point products and areal products were chosen so that both gridded and specific point forecasts could successfully be addressed:

- mean and spread
- box and whisker EPSgrams
- shaded percentile EPSgrams
- spaghetti maps
- ensemble trajectories
- plume diagrams

- probability of exceedance/occurrence
- extreme forecast index (EFI) and shift of tails (SOT)
- climatological percentiles

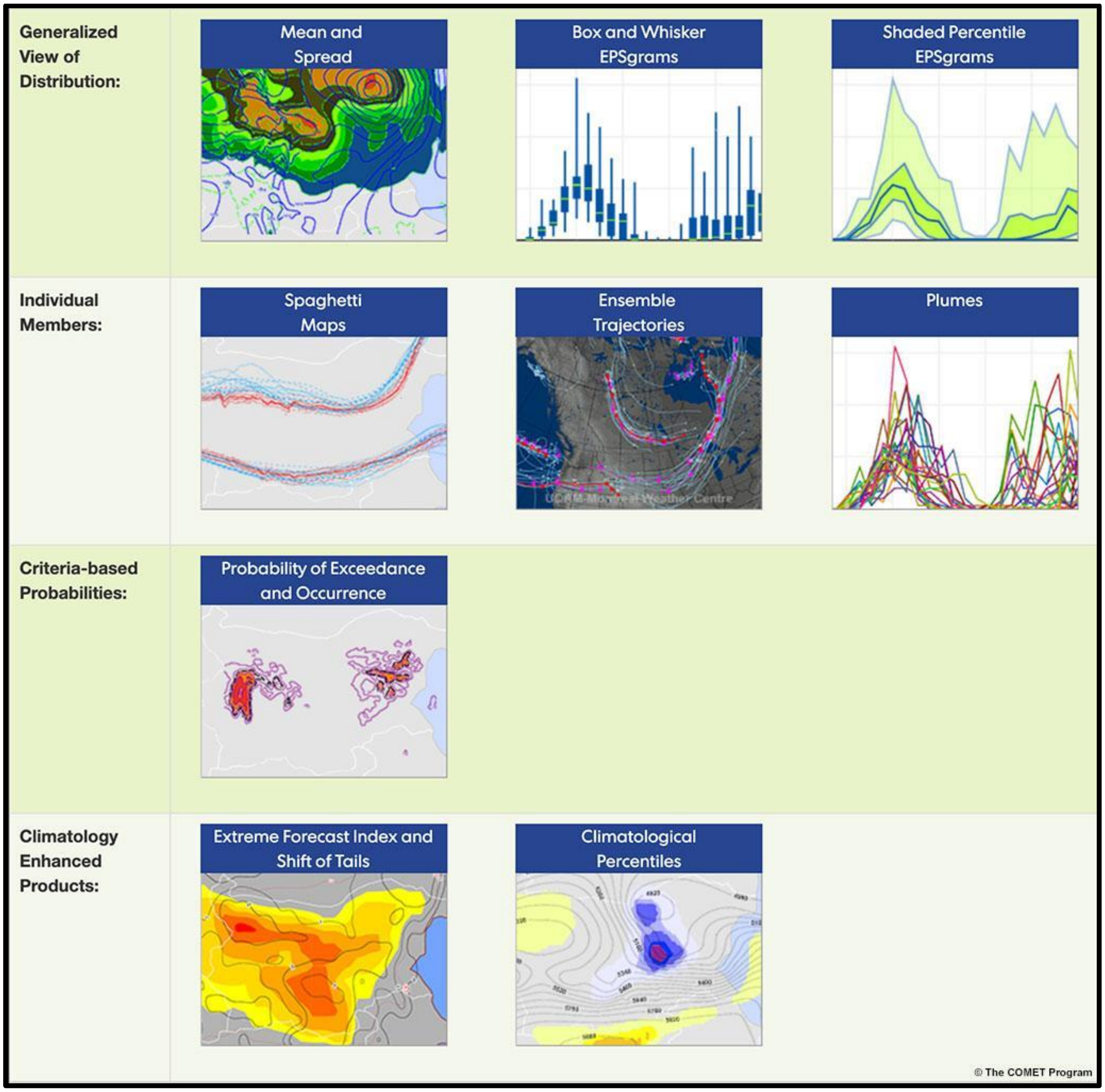


Figure 4.3. Screenshot of EPS Reference Guide webpage menu

To further ensure the EPS reference guide applied to as many NMHS as possible, EPS product imagery was generalized and idealized. Country-specific information, such as background geographical maps and NMHS-designed thresholds, was removed from the primary EPS products featured in each category, and uncomplicated statistical distributions were selected for presentation. (See Figure 4.4) This allowed learners to focus on the underlying statistical concepts and how to interpret *any* EPS product of that type.

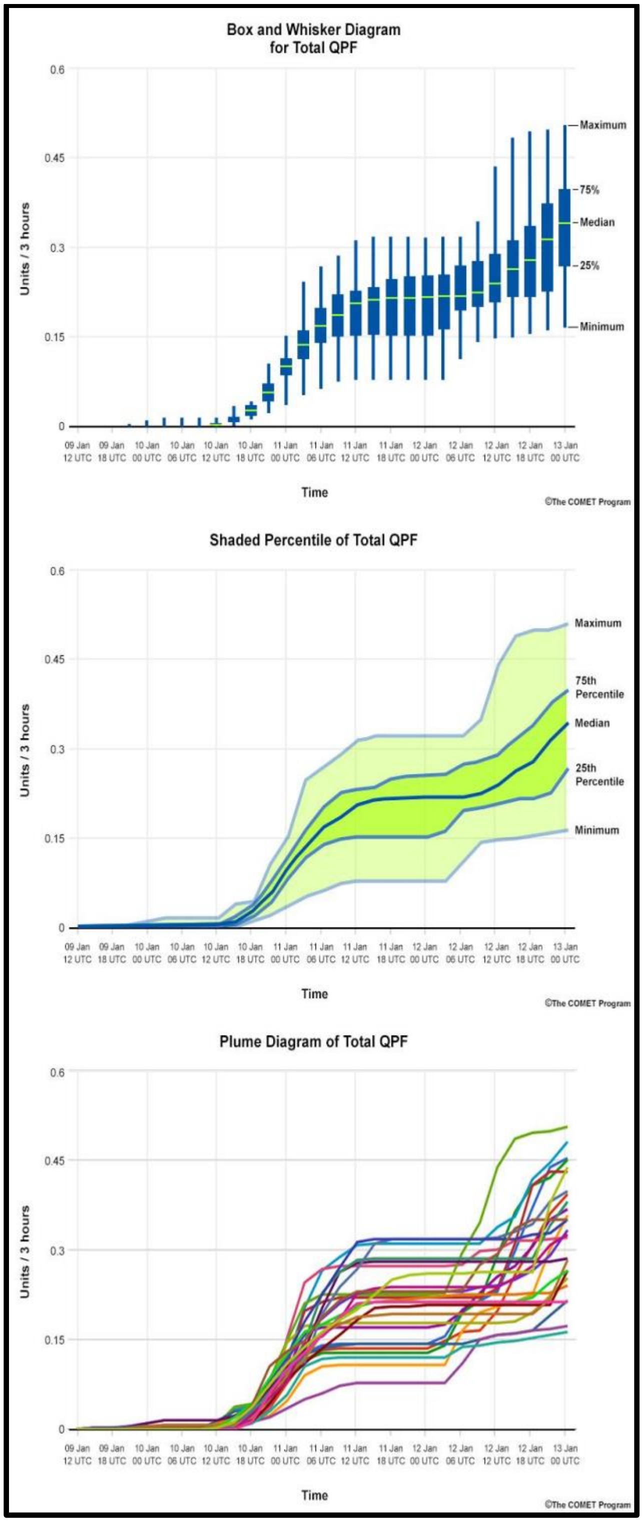


Figure 4.4. Box and whisker, shaded percentile and plume diagram EPS point forecast products, all generalized and idealized using the same dataset.

Specific, real examples from various agencies were presented in the culminating *Examples* subsection within each product type, to showcase commonalities and subtle variations. (See

Figure 4.5) By grouping the products into several common product-type applications, such as individual member types, the working group effectively created the opportunity to add more EPS products to the guide in the future.

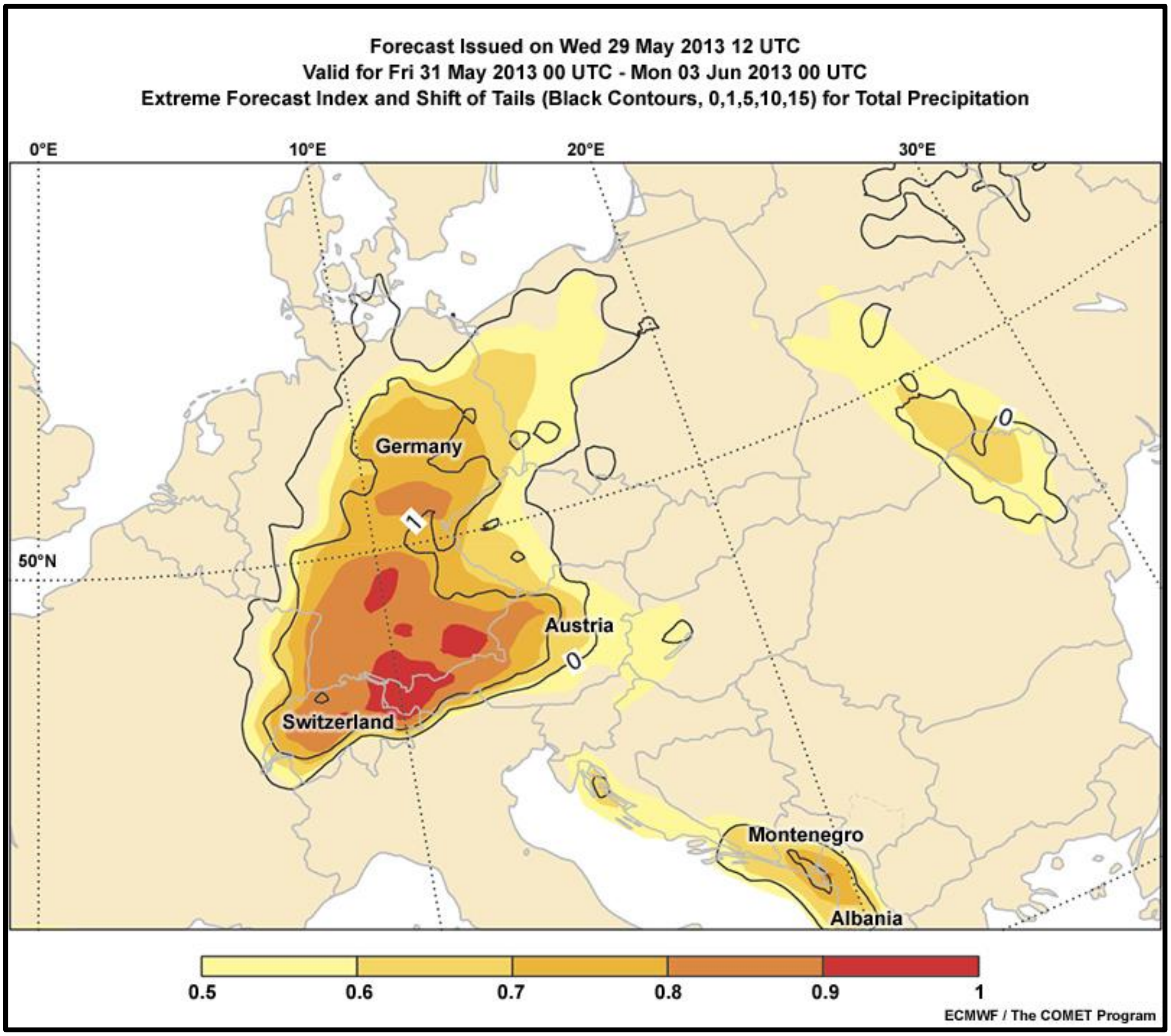


Figure 4.5. Example agency-specific product, ECMWF Extreme Forecast Index and Shift of Tails

The reference guide is listed as an optional component for curriculum completion, as learners may already be comfortable interpreting and using some of the products but not others. Considering this, learners may pick and choose which output they would like to learn or refresh their knowledge upon, effectively using it is a job aid. There is no pre-test or post-test associated with the reference guide.

The third lesson in the series, *Communicating Forecast Uncertainty*, fulfills LO 4, *integrate EPS information with other meteorological observations and model output in the forecast process,* and LO 5, *effectively communicate probabilistic forecast information to end users*. (See Figure 4.6)

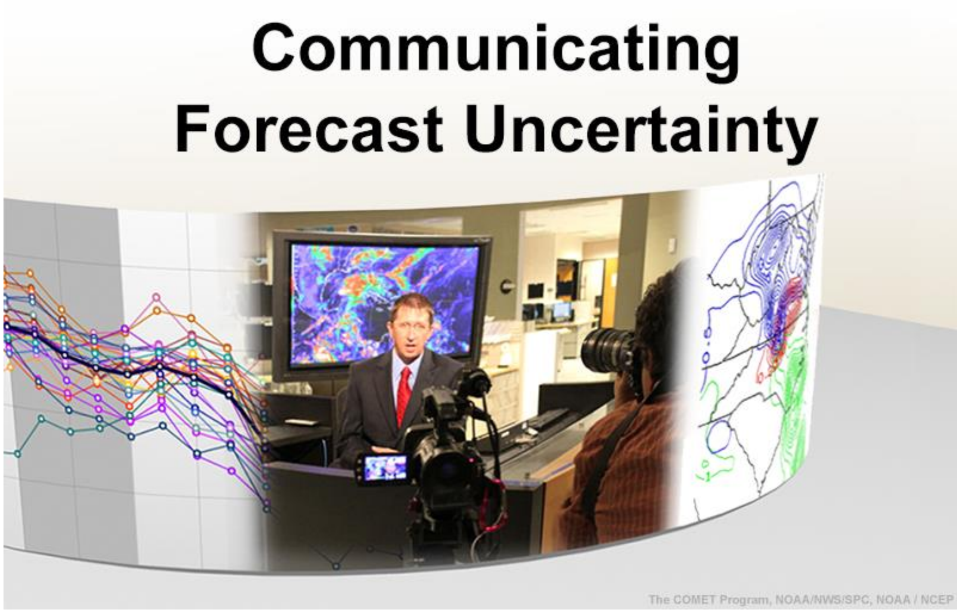


Figure 4.6. Main webpage imagery for *Communicating Forecast Uncertainty* lesson.

This lesson steps through determining various end users' forecast information needs and which EPS products are best-suited to delivering that information, and introduces a North American heavy snow event. Learners then analyze the snow event forecast situation and interpret related EPS products before receiving a primer on uncertainty communication best practices. The lesson culminates with learners applying the communication best practices to effectively communicate the forecast information to two end users with very different forecast concerns. The end user situations were selected to provide focus on either event magnitude, event timing or event impacts, or some combination of the three. Varying the end user type allowed broad representation across the common call-in or weather briefing questions a forecaster may need to be prepared to answer. One end user situation required a specific threshold amount of precipitation to make a decision. This represented a common decisionmaker need and allowed learners to practice tailoring forecast information beyond the standard available charts and map output. A pre-test and post-test accompany the lesson.

Several regional case studies constitute a capstone experience. The working group wanted learners to be able to explore a variety of weather events relevant to their region. Instructional designers in the group agreed that the case studies should represent a variety of forecast situations, from long-term to short-term, and a variety of related stakeholder concerns. Thus, four different, optional case study lessons were created: a European heavy snow event, a North American winter storm event, a German freezing rain event, and a heat wave event over the Iberian peninsula. (See Figure 4.7)

Figure 4.7. Main webpage imagery for all four case study lessons in series

The European heavy snow lesson focused on medium to short-range products and forecast processes, and concluded with ski-industry stakeholders and decision makers that had threshold-based information needs. The North American winter storm lesson presented medium- to short-range products and forecast processes, and concluded with a simulation in which learners communicate to the public via social media and must deal with their reactions. The Germany freezing rain lesson highlighted short-range products and integration of observations, and culminated with transportation-industry stakeholder communications. Finally, the Iberian peninsula heat wave lesson focused on long- to medium-range products, and concluded with issuing heat-related warnings and advisories based on likelihood of meeting local temperature thresholds. Together, these lessons offer learners practice scenarios from a variety of regions, weather types, forecast ranges and end user interaction types. Learners can complete all four lessons for a well-rounded view, or one or two that are particularly relevant to their position and/or agency.

These case studies, and the reference guide and lessons before it, were designed with case-based learning best practices in mind, and each feature multiple opportunities for learners to perform the following:

- explore new concepts and confirm their understanding with checkpoint questions,
- practice the relevant types of meteorological analysis and communication methods, and
- apply these new skills to further, novel case examples and events.

The next section discusses training series usage and reception in the NMHS community.

Series Usage Statistics and Ratings

The table below describes global usage of the series lessons' original English-language publication, as well as those translated into French or Spanish. The number of total user sessions spent in the lessons since their publication is noted, and then further broken down into the two most common user groups of NMHS and Education (primarily university faculty and students) sector.

Table 4.1. Total online lesson sessions, sessions by NMHS users, sessions by education sector users and average lesson rating for *Forecast Uncertainty: EPS Products, Interpretation, and Communication Series* lessons in English (shaded rows), and French and Spanish languages.

Lesson Title	Pub. Date	Total Sessions	NMHS Users	Education Users	Avg. Rating (out of 5)
Communicating Forecast Uncertainty	Mar. 2016	2,922	1,138	434	4 stars
Communiquer l'incertitude de la prévision	Sept. 2016	49	27	8	4 stars
Cómo comunicar la incertidumbre de las predicciones	Jul. 2018	187	40	53	4 stars
Communicating Forecast Uncertainty: European Case	Mar. 2017	392	128	44	3 stars
Cómo comunicar la incertidumbre de las predicciones, caso europeo	Aug. 2018	84	9	11	5 stars
Introduction to EPS Theory	Mar. 2017	1,388	533	268	4 stars
Introduction au SPE	Jan. 2018	34	18	10	5 stars
Teoría básica de sistemas de predicción por conjuntos (EPS)	Nov. 2017	156	22	63	4 stars

EPS Products Reference Guide	Mar. 2017	1,020	441	136	4 stars
Guide de référence des produits issus de SPE	Jan. 2018	20	12	4	No ratings
Guía de referencia para los productos de los sistemas de predicción por conjuntos (EPS)	Nov. 2017	152	43	15	No ratings
Interpreting and Communicating EPS Guidance: British Columbia Winter Storm	Mar. 2018	369	88	60	4 stars
L'interprétation et la communication de données issues d'un SPE : tempête hivernale en Colombie-Britannique	Mar. 2019	10	5	0	5 stars
Interpreting and Communicating EPS Guidance: Iberian Heat Wave	Mar. 2018	364	82	91	4 stars
Cómo interpretar y comunicar la información de guía de los sistemas EPS: ola de calor en la península ibérica	Dec. 2018	55	11	13	5 stars
Interpreting and Communicating EPS Guidance: Germany Winter Event	Mar. 2019	154	59	28	4 stars

Lessons published more recently, as expected, show less usage than those that have been available online for longer. The vast majority of lessons published received four or five out of five star ratings, consistent with most NWP trainings available on the MetEd website. Only the European heavy snow case study lesson received fewer, at three stars, primarily due to two post-test questions that initially malfunctioned (the post-test issue has since been resolved). Selected free-response feedback comments are listed below for English-language lessons.

Introduction to EPS Theory:

"Such a module on eps theories was long overdue. It's somewhat basic, but important topics were definitely included! I liked how the different forecasting interpretation methods were discussed using statistics, weather maps, graphs, and their significance to the modeling."

"As a forecaster, understanding the differences in deterministic versus probabilistic model data is invaluable. This was a good course to review and improve basic understanding of the two, as well as for learning about products I hadn't used before."

EPS Reference Guide:

"Useful information, and not too detailed."

Communicating Forecast Uncertainty:

"A useful refresher, can be applied to any meteorological service."

"Helped me to understand the two-way communication better between end users and forecaster"

"...provides good illustrations of the diversity of needs of differing user groups."

Interpreting and Communicating EPS Guidance Case Study Lessons:

"Good overview of Interpreting and Communicating EPS Guidance. Looking forward to more modules like this in the future!"

"Great use cases and examples, interaction is good, and very applicable."

"A nice way of highlighting the right selection and correct interpretation of ensemble products. Learning by doing is in this case certainly the best approach. Just make sure you know about the basics (what EPS products are around / what can you take from them) before diving in"

"Great idea, great use of data … but where do we go to get it."

The ratings and free-response comments suggest that the lessons are useful to a broad variety of learners in the community and cover topics that are generally relevant to forecasters' processes and duties.

Discussion and Summary

Overall, the *Forecast Uncertainty: EPS Products, Interpretation, and Communication Series* provided lessons that were relevant to a variety of NMHS, educational and other users in the community. The curriculum design required that key, core EPS and communication principles be mastered while allowing flexibility with regard to which region, weather and climate type, and forecasting role learners would like to practice within the case lessons. Common EPS products, their interpretation, and communication best practices were covered in the core required lessons, and many opportunities to practice integrating the underlying concepts were provided via the case studies, achieving the original goals of the working group. Average learning, as shown via total pre-test and post-test scores ranged from 13% to 21% improvement, and lesson ratings and commentary suggested a broadly applicable, informative learning experience for learners.

Table 4.2. Mean pre-test and post-test scores for required and optional lessons/lesson groups in series. Case study lessons were grouped to allow a more meaningful sample size from which pre-test and post-test scores could be calculated, as the lessons are designed similarly and only a fraction of users using the lesson complete the tests.

Lesson Title	Mean pre-test Score	Mean post-test Score
Communicating Forecast Uncertainty	69%	82%
Introduction to EPS Theory	64%	81%
EPS Products Reference Guide	N/A	N/A
Interpreting and Communicating EPS Guidance Case Event Lessons	53%	74%

The working group format with broad representation from multiple NMHS proved valuable in determining common learning objectives and common EPS products that would be relevant to learners across the globe. The funding mechanism from one agency, supplemented by in-kind contributions of case study material and expertise from other agencies worked well for all partners. MSC was able to assist in the production of several well-received training opportunities that benefited their forecasters and met the goals of their cooperative agreement, while keeping their development and review time to a minimum, representing a cost savings over recent production efforts. Other working group agencies benefited by helping to create learning materials relevant to their forecasters and regions, and from having MSC and COMET organize and manage the training development efforts, which represented a time and cost savings and avoided individual contracts. The working group approach also provided valuable networking opportunities to all involved, and allowed members to gain knowledge of how other NMHS are conducting the forecast process with respect to NWP and EPS.

The development of these lessons took several years from working group inception to publication of the final case-based lesson. Case study construction, including gathering of case event data and visualization of products from previous events, was particularly time-consuming. A recommendation for others creating similar case-based learning materials is to decide on the number and type of cases as early as possible, so that case data can be easily archived by a number of parties in the following corresponding season.

Communication with such a large contributing group was sometimes challenging, even with advanced web conferencing capabilities. Face-to-face working sessions are suggested whenever possible, including convening group meetings after-hours at larger conferences where most contributors will already be present.

5. Collaborative efforts to increase efficiency and leverage expertise in hydrology

Maria Mamaeva, State Hydrological Institute of Roshydromet (SHI); Galina Pryakhina and Mikhail Georgievsky, St. Petersburg State University, Institute for Earth Sciences (SPbSU), Department of Land Hydrology

Abstract

The paper highlights the benefits of collaboration and cooperation between a university (St.Petersburg State University) and an operational service (National Hydrological and Meteorological Service in the Russian Federation) in hydrology that could be replicated in many WMO Regions. Tangible results from its implementation, as presented, indicate that graduates from the University acquired practical skills from associating with the hydrological and meteorological service. In this regard, they work better as hydrologists, weather forecasters, climatologists or scientists than their counterparts that did not go through the collaborative training scheme. Some plans for future upgrading of the project for universal application are discussed.

Keywords: hydrology, collaboration and cooperation

Introduction

Hydrometeorology (including hydrology, oceanography and climatology) is very knowledge-intensive and depends on innovations and technologies driven by universities, scientific institutions, businesses and industries. In addition, researchers in the field are expected to be able to communicate their scientific results to a wide range of stakeholders and to manage projects and people. This requires very close collaboration between all parties involved in collecting and processing hydrometeorological data, making forecasts, and developing the science and technologies that underpin hydrometeorology. However, over the years, there has been little or no collaboration between academic institutions and operational organizations in the area of hydrometeorology. This often leads to poor practical skills for graduates from universities who eventually work as hydrologists, weather forecasters, climatologists or scientists.

To address this challenge, the National Hydrological and Meteorological Service in the Russian Federation (Roshydromet) provides its facilities, equipment and expertise to academicians and university students. For example, the State Hydrological Institute of Roshydromet (SHI), being the central federal scientific institution for the comprehensive study of natural waters, signed a cooperation agreement with St. Petersburg State University (SPbSU) which covers many joint activities. The closest, long-term and fruitful cooperation within the framework of the agreement is carried out by the Department of Land Hydrology of the Institute of Earth Sciences at SPbSU (hereafter referred to as the Department).

The collaboration programme

The Department was founded in 1918 and was the instigator of higher hydrological education in the country. At the time of its creation, the Department was a part of the Petrograd Geographical Institute, but was in 1925 joined to Leningrad University (now SPbSU). The era of cooperation between the SHI and the Department began when Prof.V.G. Glushkov, as the director of SHI, became head of the Department for five years after its creation. He was one of the founders of the world-famous soviet hydrological school and has a bay of the Northern Island of Novaya Zemlya named after him.

Currently, the Department has a "Hydrometeorology" programme that leads to a Bachelors or Masters degree. Two new Masters' programmes have been launched. They are (i) "Hazardous hydrological phenomena: from monitoring to decision-making" (2017) and (ii) "Hydrosphere and atmosphere: modeling and forecast" (2018). Typically, the Department has about 5-10 Masters' students per year. Also, graduates of the Department have the opportunity to apply for a PhD as part of the "Geography" programme and choose a topic under the guidance of a member of staff. Every year, 2–3 PhD level students are supervised by the Department staff members.

One of the distinctive features of the teaching process of the Department is an individualized approach to teaching and supervising the students because of their small number (about 5 to 6 undergraduate students). Also, there is emphasis on developing scientific analysis skills and the ability to do research. Over the past 20 years, the Department has trained more than 150 specialists, half of whom are currently working as hydrologists in various organizations, including, of course, SHI.

Beneficial collaboration initiatives

The collaboration between the Department and SHI has resulted in the following joint activities:

- Typically, 1–2 PhD students at SHI run specialized training sessions for undergraduates in the Department. This helps disseminate SHI knowledge and experience, whilst enabling the PhD students to become more confident in teaching and communicating science.

- Every year, 2–3 students from the Department gain experience by participating in operational and research activities at SHI.

- Every year, third year BSc undergraduates from the Department carry out laboratory work at the Marsh Station, the Main Experimental Base (MEB) of SHI, located in Illichevo village, 60 km from St. Petersburg (Russia). The facilities at the experimental base include the following laboratories: hydrophysical, hydraulic, remote sensing methods and GIS (formerly laboratory of aero-methods), as well as straight-line 140-meter and circular calibration pools and installations for metrological research. The channel laboratory was created to study the patterns of development of channel processes, the development of methods for calculating and forecasting channel deformations in the design and construction of bridges, power lines, gas and oil pipelines, water intakes and pumping stations, among other tasks. During the one-day excursion to the experimental base, students become familiar with its function and scientific activities. The SHI Valday Branch, together with the Department, organizes an annual summer school. Second year BSc undergraduates from the Department (5–8 students), along with students from other specialized universities, undergo practical training. In addition to becoming familiar with the work of the SHI Valday Branch, they observe runoff sites and the elements of the water balance.

- SHI scientists supervise the course and graduation works (BSc and MSc) of two to four students annually from the Department in the field of hydrometeorology.

- SHI specialists participate in the certification commissions of SPbSU. This helps assure educational quality and formulate directions for future topics of students' research.

- SHI specialists and staff of the Department participate in joint research projects and externally-funded activities of both organizations. This attracts post-graduate students and students of the Department to these projects and activities including field works and research.

- Students from the Department have free access to the SHI Library and Data Archive to get valuable information and materials needed for their studies. Hundreds of methodological recommendations, guidance books and regulations on hydrological collection and processing of observation data and reference materials are made available to students.

- Staff members from SHI and the Department participate in the organizing committees of scientific conferences planned by both organizations, as well as being involved in the joint organization of conferences.

- Staff members from SHI and the Department jointly publish scientific articles. In the last two years, six scientific cited articles were published.

- SHI specialists participate in the development of curricula and work programmes for disciplines associated with the Department's educational programme in "Hydrometeorology".

Discussion and conclusion

Due to the wide range of activities that are offered, SHI is attracting qualified personnel (four new members of staff employed by SHI in the last two years) and providing topics and guidance for research carried out by PhD students and young scientists. At the same time, cooperation with SHI is an extremely important and necessary feature of the educational process of the Department. Consequently, the Department holds a leading position amongst the higher educational institutions of the Russian Federation that train specialists in hydrometeorology. This collaboration allows the Department to:

- raise the educational process to a new professional level;

- keep abreast of current scientific trends and developments occurring in Russian hydrometeorology, including the use of the latest specialized equipment;

- attract students to research projects and other activities at all stages of the educational process; and

- have direct contact with a potential employer who is a leading research institution in the field of land hydrology.

The cooperation agreement has an automatic renewal clause (it is automatically extended after expiry unless otherwise decided). Thus, cooperation will continue and develop. Employees of the Department, together with specialists from SHI, are constantly searching for new ways to improve the educational process.

At present, SHI and the Department are discussing the development of a unique course for the Master-level students – managerial practice. In this course, students would become acquainted with the structure of SHI and Roshydromet and the distinctive ways in which they function. In particular, they would learn about the activities of various SHI departments, and how to implement large research projects (including preparation of tender documentation), deliver and manage research projects, work with the customers, and report and communicate results.

In 2019, SHI is celebrating its 100 years of existence. More opportunities and directions for cooperation will be explored during the anniversary conference in December 2019 due to wide participation of the academic and research staff from both SHI and the Department.

Figure 5.1. Students at the SHI experimental station.

Figure 5.2. Roshydromet (State Hydrological Institute) provides its facilities, equipment and expertise to students of Department of Land Hydrology (St. Petersburg State University).

6. Adaptation of existing training material from the international community for DWD's purposes

Wilfried Jacobs, Deutscher Wetterdienst

Abstract

Self-directed learning through online learning resources has been shown to be effective, but this is true only when the materials are developed by training experts with the required skills for working in this medium. For many organizations, such development efforts are beyond available budgets and staffing, and reuse of existing resources is the only option. However, while the reuse of quality open educational resources developed by others promises great benefits, these resources are often not designed appropriately for the organizational factors, climate, geography, and culture of those who wish to reuse them. This chapter describes the effort to adapt resources to meet local needs, while saving significant overall resources in the process.

General challenge

Forecasters at DWD and other services need both scientific and social competences in order to do their jobs successfully, even under time pressure. A forecaster has to evaluate a significant amount of individual information and integrate it to produce a forecast product of high quality that is according to the individual customer's needs. After training and an examination, forecasters receive a license that is in accordance with international ISO-norms. However, in order to keep their license, we must train the forecasters regularly. We perform evaluations at irregular time intervals by external auditors, among others, in order to check if our training is according to the WMO regulations. The big challenge for each service is to provide efficient training for many forecasters within a short time that enables them to do their job successfully. This conflict arises from the limited financial and personnel resources on one side and the competency requirements on the other side. The only solution for this conflict is e-learning as a support for training.

Another target group for the DWD's training efforts is students at the University of Applied Science for Diploma. After the Diploma, they undergo further training and examination in order to become a licensed forecaster. However, we must consider these students' lower pre-knowledge in comparison to routine forecasters that are working in shifts.

Concepts at DWD in the past and remaining challenges

For several years the DWD has promoted e-learning training not only for more efficient training in relation to personnel and finances but also for higher acceptance by the forecasters, trainers and decision makers. Efficient training means to find a compromise between a training event's length, flexibility (time, location, individual student) and effectiveness. We currently train our forecasters every third year, but it is always a challenge to do so. Moreover, our goal for the future is to train our forecasters every year.

We see blended seminars (online training monitored by a trainer, followed by a classroom phase) as a very viable training format. However, we are not able to take many forecasters out of a shift at the same time; nor do we have enough trainers for running many blended seminars, due to the costs of travelling. Therefore, we have to offer also pure online training for keeping the forecasters' licenses (after passing an online examination). Pure online training requires high pedagogical competences of trainers and of the training modules' designers.

To develop from scratch an e-learning module that is in accordance with these demands is extremely time-consuming and expensive. Highly experienced experts estimate the working time for a professional training module of one hour learning time at about 800 hours, equivalent to about 56 k€ and even 80 k€ for outsourcing (according to German conditions).

In the case of inadequate in-house personnel resources, outsourcing would be the only alternative. However, the challenge in outsourcing is the companies' limited skill in meteorology. The training target group of forecasters is relatively small compared to the target group for, for example, a commonly used software package, so outsourcing companies have not developed the relevant knowledge-base. The DWD would need to invest a lot of working time in order to guide the company accordingly, which would increase the actual costs of employing them. Therefore, the DWD will avoid developing e-learning modules from scratch.

In order to use the advantages of e-learning more efficiently the DWD has often resorted to using existing material, for example, EUMeTrain, EUMETCAL-courses, EUMETSAT, the COMET Program (COMET), libraries. Because the training material of these training bodies already exhibits high quality both in science and in design, we have used this material for e-learning in our training center and at the forecasters' working places without adaptation, due to the financial and personnel limitations that DWD experienced through 2018. However, the material often differs from the forecasters' working conditions, in terms of forecast products, region, climate and weather conditions, forecasting process, and customer needs. We see the structure and pedagogical concept as a first step to e-learning at DWD, but at the cost of lower acceptance by users and poorer learning results.

Present projects and plans

A better personnel situation since 2019 enables us to avoid this deficiency. As already pointed out, COMET offers a huge choice of excellent learning modules. We have decided to use this potential for our own purposes. We consider a learning length of not more than three hours as most appropriate, from the organizational point of view and for simplification of the adaptation process in this early phase of our project. As a first step, experts at DWD from the departments of "Basic Forecasts" and "Aviation" and of the training center reviewed COMET modules according to the following criteria (see also Table 1):

Topic and module description (as provided by COMET) → according to our requirements?

- Level (according to COMET) → target group (students, experienced forecasters)?
- Publication date → still useful, updates necessary?
- Priority according to the departments of "Basic Forecasts" and "Aviation"; and
- Comments, also pedagogical aspects.

We selected eight COMET modules for close consideration (see Table 1). We decided to start as a first step with only one module, "Radar Signatures for Severe Convective Weather," which achieved the highest ranking. Based upon the logical structure and the scientific content the new assistant for e-learning creates the adapted digital training module. We perform continuous evaluation f during adaptation of the material. We expect to optimize the entire process yielding a more efficient creating of e-learning modules. Figure 6.1 and 6.2 illustrate the structures of “Radar Signatures for Severe Convective Weather,” the COMET design and the DWD-adapted design, respectively.

Because the forecasters at DWD must fulfill the Level B2 in English (Upper Intermediate, EF-SET 51-60) we will create our material in English. We can, therefore, offer these materials to the WMO Global Campus community and weather services with a comparable climate to that of Germany.

Table 1. Selection process of COMET-modules. Italic = Selected

Topic	**Description**	**Lvl.**	**Priority Basic Forecasts**	**Priority Aviation**	**Comments**
Dynamically Forced Fog	Fog frequently forms in response to dynamically forced changes in the boundary layer. This module examines dynamically forced fog in the coastal and marine environment, focusing on advection fog, steam fog, and west coast type fog. The focus of the module is on the boundary layer evolution of air parcels as they traverse trajectories over land and water. The module also examines mesoscale effects that impact the distribution of fog and low-level stratus over short distances. A general discussion of forecast products and methodologies concludes the module.	2	2	1	Published by COMET 2005. Good for students, should be trained after "Radar Signatures for Severe Convective Weather"
Radar Signatures for Severe Convective Weather (selected)	This resource is intended for use as a job aid by operational weather forecasters in live warning situations and as a reference tool to better understand some aspects of severe thunderstorm warning events. Thumbnail images show typical representatives for sixteen radar reflectivity and velocity signatures as	*3*	*1*	*1*	Published by COMET 2010. Also according to wishes of training center. Responsible experts for scientific content:

	well as three primary severe storm types. Each signature links to content describing detection techniques and conceptual and diagnostic information to help determine storm severity. The majority of the examples shown are southern hemisphere storms in Australia; examples from the northern hemisphere are noted.				Central Forecasting Unit and the training center
NWP	1 module	1-2	1	1	**Later step**
Remote Sensing	1 self-paced distance course	2	1	1	
Synoptic	1 self-paced course	1-2	1	1	**Later step**
Aviation	3 modules	3x2	-	3x1, 1x2	**Later step**

Welcome: This resource is intended for use as a job aid by operational weather forecasters in live warning situations and as a reference tool to better understand some aspects of severe thunderstorm warning events.

Thumbnail images on this page show typical representatives for sixteen radar reflectivity and velocity signatures as well as three primary severe storm types. Each signature is seen as a proxy for thunderstorm severity, and is initially identified through pattern recognition skills.

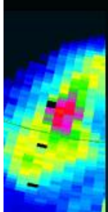
Note that the majority of the examples used are Australian. Examples from the northern hemisphere are noted within a signature's description.

Select one of the signatures; each is presented in three sections. The **Detection** section provides confidence that you have indeed identified a certain signature on your radar display. Equipped with such confidence, the **Conceptual Model** section aims to impart background knowledge on how the signature might have formed and how it relates to other processes and elements within a severe thunderstom. The **Diagnosis** section provides some guidance on how "severe" or "strong" your specific signature might be within the range of all possible signatures of its kind.

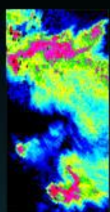
All sixteen signatures shown in this resource can be attributed to at least one of three generic storm types. Overviews of each of these storm archetypes are contained in the Storm Types Conceptual Models.

Radar Signatures Suggesting Potential Thunderstorm Severity

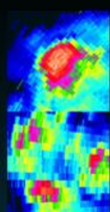
UPPER-LEVEL SIGNATURES



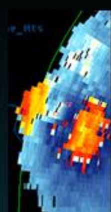
50 dBZ Echo Top Height



Anomalous Storm Propagation

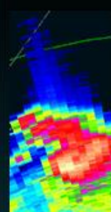


Single Cell

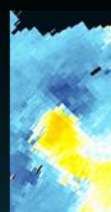


StormTop Divergence

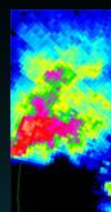
MID-LEVEL SIGNATURES



Three Body Scatter Spike



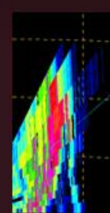
Mid-level Mesocyclone



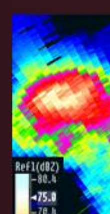
Forward Flank

MULTI-LEVEL SIGNATURES

Weak Echo Region (WER)

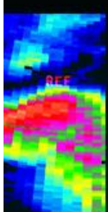


Bounded Weak Echo Region (BWER)

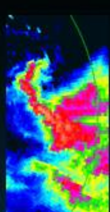


Very High Reflectivity

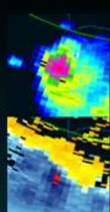
LOW-LEVEL SIGNATURES



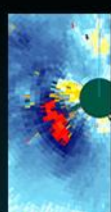
Tight Low-level Reflectivity Gradient



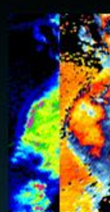
Hook Echo



Low-level Convergence



Damaging Low-level Winds



Bow Echo

Low-level Mesocyclone

RADAR SIGNATURES
for
SEVERE CONVECTIVE WEATHER

« back to signatures

50 dBZ Echo Top Height

Detection | Conceptual Model | Diagnosis | References/Addendum

Figure 6.1. Screenshots from the COMET webpage. Top: First page of the training module "Radar Signatures for Severe Convective Weather", Bottom: Headline and structure (after clicking on the image at the top left)

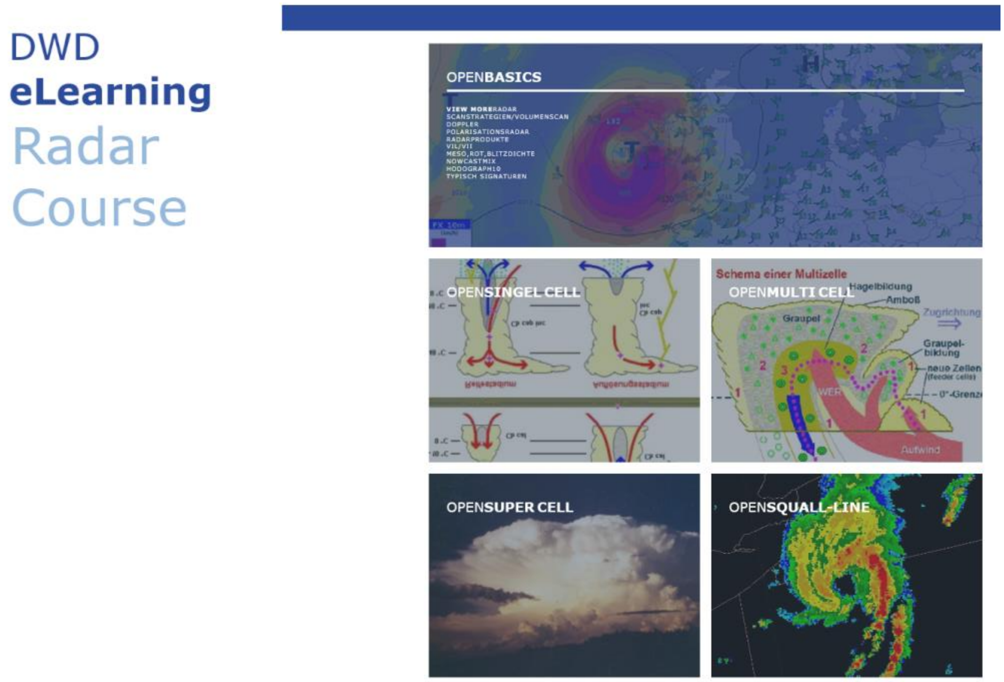


Figure 6.2. Cover page and module structure after adapting to DWD requirements. Clicking on one of the topics in black leads the student to the learning content in relation to that topic (for example, OPENBASICS opens the introductory content)

Benefit for the DWD and for the international community

Estimations by EUMETCAL and the DWD yield about 800 hours working time for developing a training module that is comparable to a COMET training module. We estimate the personnel costs to adapt COMET modules to DWD requirements at about 50 percent of this, a working time of about 400 hours because the COMET-modules reveal already advanced structure, designs, learning concept. The DWD will have only to include examples and cases utilizing locally available data products, relevant to regional climate and weather conditions, and reflecting the local working environment and practices as well as customer needs. The resulting savings from adapting existing material is equivalent to a savings of 28 k€ (according to German conditions) per each COMET module. We expect that the adaptation process will run more efficiently in future, which will further reduce personal costs).

With an operational Global Campus E-Library, the DWD could retrieve material not only from the training bodies listed above but also from the Global Campus community (while respecting copyrights). However, the opposite direction of sharing is also possible. The DWD can offer our adapted material/modules to Global Campus for usage for international training in regions with comparable conditions. It is up to these meteorological services to adapt this material according to their demands and to offer it to the training community, yielding training material for sub-areas (e.g. according to WMO-areas) and under the umbrella of Global Campus. It could make sense to include the names of all expert's involved in producing both the original and adapted materials in order to promote the exchange of experiences, knowledge and material, which could also simplify the organization of new training events by, for example, identifying experts who might be able to contribute.

This example of adapting COMET modules can give us an idea of how other services and training institutions may share training materials. If we establish close communication and cooperation throughout the international community, we could achieve even higher efficiency due to increased synergy usage. For instance, training institutes with comparable requirements can exchange training courses (or parts of them). The necessity to adapt to local requirements will thus be further reduced, yielding the benefits that we explained in this article.