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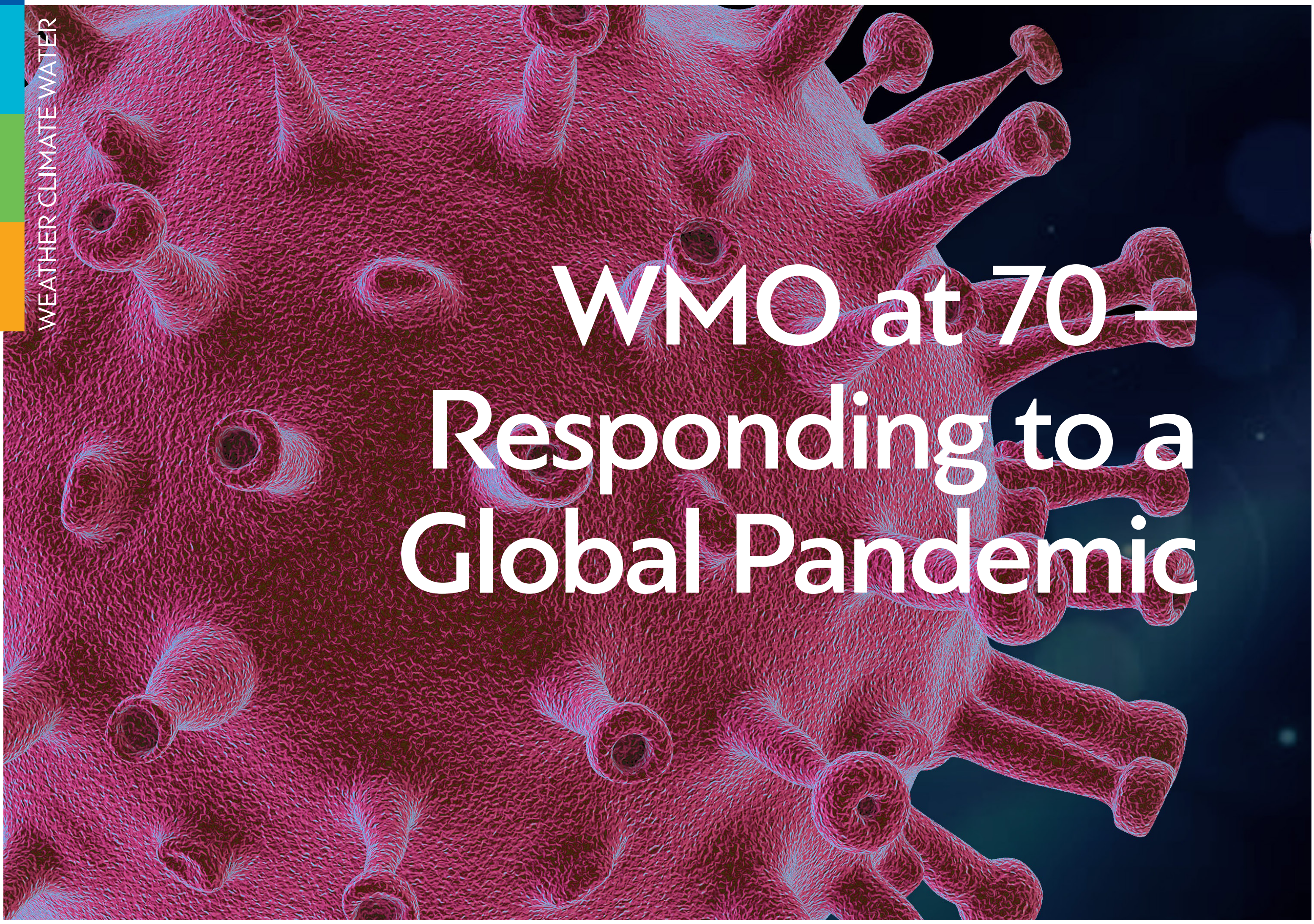
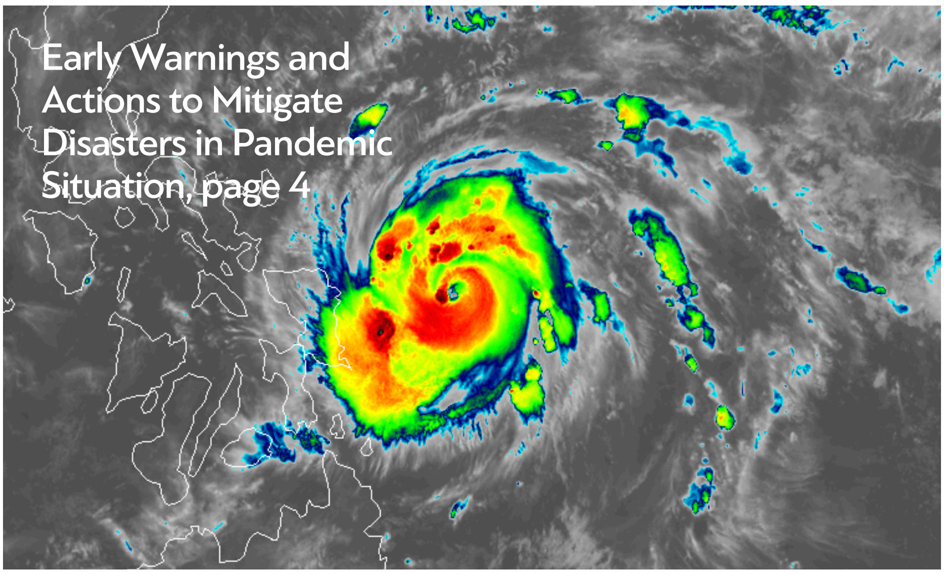
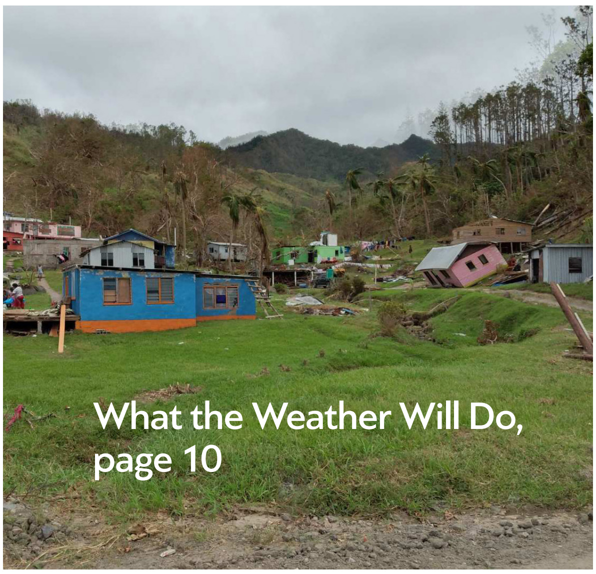
WEATHER CLIMATE WATER



WMO at 70 – Responding to a Global Pandemic



Early Warnings and Actions to Mitigate Disasters in Pandemic Situation, page 4



What the Weather Will Do, page 10

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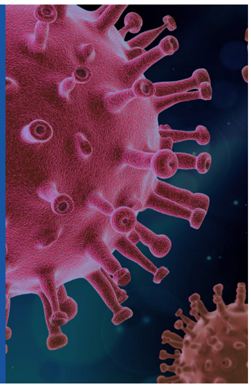
Contents

"A framework for research linking weather, climate and COVID-19" was published in *Nature* Communication on 12 November. It reports on the outcomes of the international and interdisciplinary virtual symposium on **Climatological, Meteorological and Environmental (CME) factors in the COVID-19 pandemic** held from 4 to 6 August by WMO. The symposium attracted over 400 participants with interdisciplinary background from 72 countries to assess and review the current understanding, forecasting, and communication challenges related to climatic, meteorological and environmental influences on SARS-CoV-2 and COVID-19. Read the article at www.nature.com/articles/s41467-020-19546-7



Foreword
WMO Secretary-General
Professor Petteri Taalas

At the beginning of 2020, I looked forward to the 70th year of WMO as a new beginning. The WMO Community had several notable achievements to celebrate: a new Earth System approach, a new governance structure that would broaden the participation of all Members in the core work of the Organization and streamline processes, and a new management structure in the Secretariat. The year ahead looked promising as we set about to deliver on the WMO Vision for 2030, "a world where all nations, especially the most vulnerable, are more resilient to the socioeconomic consequences of extreme weather, climate, water and other environmental events; and underpin their sustainable development through the best possible services, whether over land, at sea or in the air."

But already in January, there was news about a virus. Then in February, the situation took a turn for the worse as one country after another recorded outbreaks of COVID-19. Daily reports on the escalating number of victims increased concerns. Everyone became more cautious, but no one expected the full-scale restrictions that would be imposed as of March to slow down COVID-19 outbreaks. WMO immediately implemented the recommendations of the Swiss Government with deep-rooted concern for the health of Secretariat staff and for that of the entire WMO Community around the world. Despite the COVID-19 crisis, the WMO Community would be called upon to continue to provide early warning of weather, climate and water-related hazards and to coordinate with emergency services to mitigate disaster risks.

It was relatively easy for most Secretariat staff to switch to working from home, so only a skeleton crew remained to provide essential services at our headquarters in Geneva. However, National Meteorological and Hydrological Services had many adjustments to make to maintain operational services during the lockdown. Some fared better than others, but with the support of their colleagues in other services, all continued to perform their essential 24/7 functions despite the pandemic.

The impacts of the lockdown were most felt in the WMO Integrated Global Observing System, the backbone for all weather and climate services and products provided by WMO Member to their citizens. Aircraft-based observations, which make significant contributions to upper-air monitoring of the atmosphere, dropped by 75% to 80%. Surface-based weather observations declined, especially in Africa and parts of Central and South America where many stations are manual.

Analysis of the available data indicates that despite the lockdown measures CO_2 will continue to accumulate in the atmosphere in 2020 and greenhouse gas concentrations will continue to rise with just a slight decrease in the rate of this increase. Therefore, the demand for improved services from WMO will continue to grow.

WMO's 70th year was one of crisis. This issue of the WMO Bulletin highlights some of the challenges and solutions being implemented during the crisis. It demonstrates how family bonds in the WMO Community grow stronger in times of crisis. How we are stronger together at 70, than any of us could be standing alone. Together, we look forward to another 70 years to further advancement in science and research, observations and data sharing, and weather, climate and hydrology product and service provision to serve the public good.

Petteri Taalas
Secretary-General
World Meteorological Organization

Early Warnings and Actions to Mitigate Disasters in Pandemic Situation

By Cyrille Honoré and Sylvie Castonguay, WMO Secretariat

The COVID-19 pandemic is impacting all sectors and activities across our societies, and there is no exception for meteorologists, hydrologists and their organizations. In such a dire situation, should National Meteorological and Hydrological Services (NMHSs) be given special assistance to keep performing their duties 24/7, 365 days a year similarly to other critical infrastructures and services? Yes, without doubt. The reason: climate change and weather, climate and water-related hazards, and their associated risks to lives and property, have not stopped for the COVID-19 pandemic!

Since the beginning of 2020, no region has been left untouched by natural hazards and many countries have faced the challenge of protecting populations from extreme events during the pandemic. In April, Severe Tropical Cyclone Harold caused widespread destruction in the Solomon Islands, Vanuatu, Fiji and Tonga. In May, Tropical Cyclone Amphan ravaged parts of India and Bangladesh – a country that in July experienced its worst monsoon flooding in a decade. The 2020 Atlantic hurricane season exhausted the regular list of storm names and moved on to the letters of the Greek alphabet for the second time on record. There have been floods across the African continent and other regions. Europe experienced a summer of heatwaves. Wildfires and drought in Australia, Russia and the United States captured headlines. The impacts are severe, especially among those most vulnerable people – refugees, internally displaced people, the poor – who are also hard-hit by COVID-19.

Fully aware of their core mandate and responsibility to serve the common good, our colleagues in NMHSs around the world are doing their best to maintain critical services to society as well as national early warning systems and to support national resilience-building efforts. From a business continuity perspective, COVID-19 has placed different activity areas across the hydrometeorological and early warning system value chain at risk – from observation (hazard monitoring) and forecasting to the issuance of warnings and their dissemination in support to early action decision-making.

WMO survey of Members

In early spring, the WMO Secretariat launched a global survey across all the NMHSs of its 193 Members to assess the impacts of the COVID-19 crisis on their operations and identify areas where potential support would be needed. More than 140 responses were received from 126 Members. One thing was immediately apparent: COVID-19 mitigation measures, such as lockdown and travel restrictions, had varied impacts on NMHSs, depending primarily on their resources, status and recognition.

The WMO World Meteorological Centres (WMCs), most of the WMO Regional Specialized Meteorological Centres (RSMCs) and the members of the Coordination Group for Meteorological Satellites (CGMS) were well-organized and had the resources to ensure that their regional or global service delivery commitments would not be compromised by COVID-19 restrictions. The continuity in service that they are providing is evidence of the relevance of the WMO supportive frameworks and of the importance of activities established and carried out under the Global Data Processing and Forecasting System (GDPFS), the Severe Weather

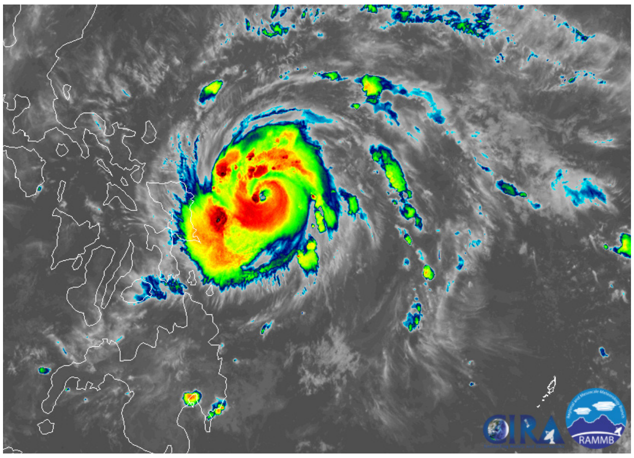
Forecasting Programme (SWFP), the Flash Flood Guidance System (FFGS) and various other projects.

At the national level, less than 10% of respondents reported serious concerns or impacts. Some 30% stated they were well-prepared for such events and at least 55% stated that they had the situation in control. Teleworking arrangements had been implemented by almost 3 out of 4 respondent NMHSs at different levels and in varied proportions. But teleworking is not always an option for tasks such as the maintenance of the observation networks, IT operations, and forecasting and warnings. In order to maintain operational staff in their offices even in limited numbers, specific arrangements were made to comply with health authority's guidelines, but travel authorizations and derogations to general restrictions were necessary in a number of cases. Less than 60% of the responding NMHSs stated that their governments recognized that they offered an essential service and should, therefore, benefit from the same exceptions and practical support as other essential services.

From a user perspective, preparedness and early actions in response to hazard warnings could not be carried out as usual in this unprecedented situation. Evacuations, sheltering and the prepositioning of response resources had to comply with health and pandemic mitigation guidelines. Additional shelters had to be identified to minimize contamination in overcrowded buildings. Existing evacuation routes had to be adapted. Re-assessment of the necessary lead-time to safely evacuate people at risk were needed. While these are not in the mandate of NMHSs, the information and warnings they provide support decision-making by National Disaster Management Organizations (NDMOs) on these matters as the case study below demonstrates.

Case study: Typhoon Vongfong landfall in the Philippines

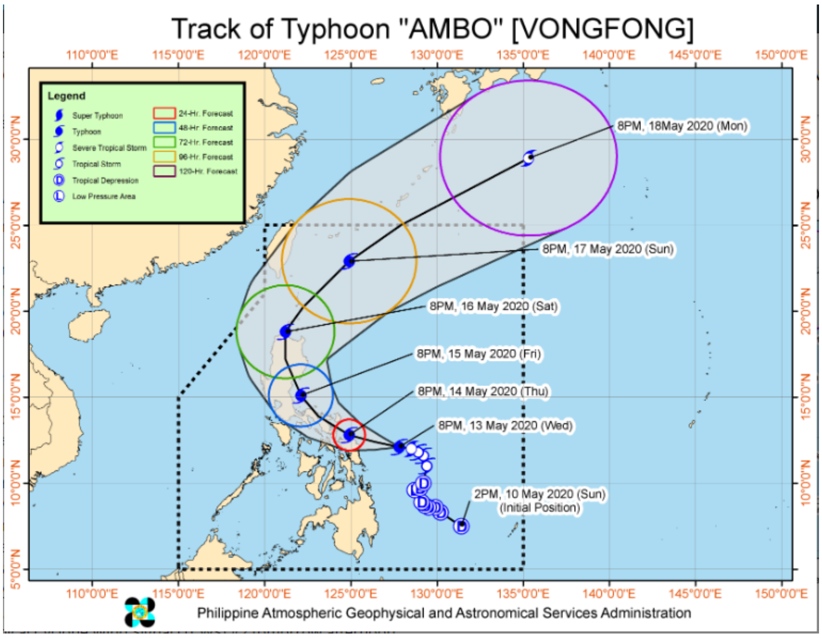
Typhoon Vongfong (named Ambo in the Philippines) made initial landfall on 14 May in San Policarpo, Eastern Samar, Philippines. The Category 3 typhoon brought destructive winds and intense rainfall as it moved northwest towards mainland Luzon and Metro Manila, a major COVID-19 hotspot. Large parts of the country were under movement restrictions and lockdowns, which put strain on emergency response efforts.



Himawari 8 satellite image of Typhoon AMBO intensifying over the Philippines on 13 May 1540 UTC

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) provided early information of the pending threat four days before landfall and named the Tropical Depression that had developed east of Mindanao "AMBO" on 10 May. (The international name, Vongfong, was attributed by WMO Regional Specialized Meteorological Centre for Tropical Cyclones in Tokyo when the system developed into a Tropical Storm.) The National Disaster Risk Reduction and Management Council (NDRRMC) convened a Pre-Disaster Risk Assessment meeting on 11 May, three days ahead of the typhoon's first landfall. They worked with telecommunication companies to disseminate emergency alert messages via mobile phones to people in the affected areas and regional emergency operations centres were activated. The Department of Social Welfare and Development readied standby funds and stockpiled family food packs, and other food and non-food items amounting to US$ 23.4 million (PhP1.18 billion).

The Department of Health advised local government authorities to allot wider spaces in evacuation centres to ensure adequate physical distancing: families to be evacuated were to observe minimum health standards, which included wearing face masks, proper hygiene and cough etiquette. The NDRRMC also urged local authorities to explore alternative evacuation centres, since schools could not be used as many



Eight-day rack of Typhoon AMBO from 10-18 May 2020

had been designated as quarantine facilities for COVID-19 patients. Further to its initial warning and contributions, PAGASA monitored the evolution of the typhoon and provided continuous weather updates throughout the event.

Local officials pointed to the double challenge of keeping their residents safe from COVID-19 and the typhoon, noting the difficulty of maintaining physical distancing in temporary shelters. Several local governments decreed that evacuation centres were only to be filled to half their usual capacity to prevent the spread of the coronavirus disease. The Catholic Church offered the use of its church buildings and chapels as additional shelters and some shopping malls did the same.

This led to the pre-emptive evacuation of 46 812 families or 182 916 persons, almost one-third of the total of 140 147 families or 578 571 persons who were affected in the country.

Essential services

Governments, emergency services and public attention are focused on the pandemic situation. Meteorologists and hydrologists, therefore, need to be pro-active and anticipate beyond existing institutional arrangements and national warning policies concerning the issuing of official warnings. Specific notifications and strong relationships with national stakeholders do make a difference in early preparation and action to mitigate the impacts of hazardous events, as shown in the Philippines case.

More than ever, there is a critical demand for early, actionable warnings and advisory services. Clarity on possible impacts, taking forecast uncertainty into account, and as much accuracy as possible on chronology and localization allow early targeted action to save lives and limit damages. The combination of these types of requirements is the classical challenge that the WMO community has been confronted with for decades. It is the driver to our continued efforts in research, Earth system understanding, monitoring and forecasting, and sharing science and technological progress across all WMO Members in a cooperative spirit. In this time of pandemic, the challenge is even bigger for most NMHSs, but they need to remain vigilant and dedicated to the provision of essential services for the common good.

WMO Members, Working Together in Good Times and Bad

By Gavin Iley, WMO Secretariat

The ongoing global pandemic has demonstrated that WMO is much more than the official scientific body of the United Nations on the global climate, weather and water – it is a family that pulls together when times get hard. The WMO Secretariat's initial survey to assess the impacts of COVID-19 restrictions on its Members' operational capability contained a few supplementary questions, the responses to which highlighted that fact. One question asked, "Would your National Meteorological and Hydrological Service (NMHS) be able to provide support to other NMHS's if needed during the pandemic?" Overwhelmingly, the response was "Yes!"

And they were true to their promise. When Cyclone Amphan formed in the Bay of Bengal in the middle of the first wave of the COVID-19 pandemic, the Chinese Meteorological Administration (CMA) reached out to their colleagues in the Bangladesh Meteorological Department (BMD) to offer additional modelling support. Following an earthquake in late March in Croatia, which damaged some of the key Croatian Meteorological and Hydrological Service (DHMZ) infrastructure, the European Centre for Medium-Range Forecasting (ECMWF), supported by European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), successfully backed up the DHMZ production capability thereby ensuring continuity of service in the months that followed.

The willingness and enthusiasm of WMO Members to lend a helping hand and support their colleagues did not just arise with the pandemic. The esprit de corps in WMO has been nurtured and strengthened throughout the 70-year history of the Organization and existed already in its predecessor, the International Meteorological Organization. The family approach flows throughout WMO and is clearly visible in all areas of its work.

Bilateral and multilateral support

In times of need, help is always at hand. This was apparent during and after Cyclone Idai in 2019 when several NMHSs provided support to their colleagues in Mozambique. During the Ebola crisis in West Africa when the Sierra Leone Meteorological Department (SLMD) came under unprecedented strain, colleagues from the Nigeria Meteorological Agency (NMA) stepped in to provide web-based support to ensure that services to the local authorities and population were maintained. Following the devastating earthquake in Haiti in 2010, MeteoFrance established a dedicated forecasting service for their Haitian colleagues to ensure that vital forecasts and warnings remained available throughout the response and recovery phase. These bilateral partnerships are one example of how the WMO family works together and there are many more.

At the multilateral level, Ireland, the United Kingdom (UK) and the United States of America (USA) have a formal collaboration mechanism that activates when a tropical storm has the potential to threaten Irish and UK waters. Ahead of their respective Tropical Cyclone seasons, Members come together by region to ensure that collective response, mitigation and mutual support plans remain suitable for the season ahead. At the more operational level, World Meteorological Centres (WMCs), Regional Forecast Support Centres and the network of Regional Specialized Meteorological Centres (RSMC) provide analysis and guidance down from one level to the other and synthesize these for their national level colleagues.

Support for humanitarian efforts

Members also work together to support wider crisis response. In the northern hemisphere winter of 2015/2016, thousands of refugees fled from Syria to Western Europe – a distance of over 1 000 kilometres. WMO Members from across Europe, particularly those in South East Europe, came together to provide United Nations relief agencies with weather forecasts and information that was critical to their response mechanisms. But probably more important was the very specific local knowledge they could share on the likely impacts on the ground of the forecast conditions. This additional insight would have been more difficult to come by without their expertise and local knowledge.

A further example is the ARISTOTLE Partnership through which NMHSs in Europe, in partnership with colleagues in the geophysical science area, provide the European Commission's Emergency Response and Coordination Centre (ERCC) with a dedicated 24/7 Multi-Hazard Emergency Response Service.

In addition, the WMO family supports several national and regional forecast-based finance and early action initiatives. To do this, they work in partnership with governmental and non-governmental organizations as well as United Nations agencies to ensure that decision-makers and local communities receive impact-based severe weather advice in time to act. For example, the Bangladesh Meteorological Department (BMD) and the National Flood Forecasting and Warning Centre provided technical support to the United Nations Humanitarian Country Team (including OCHA, WFP, FAO, UNFPA, etc.) and the Bangladesh Red Crescent Society to successfully conduct anticipatory action during the 2020 monsoon floods. This enabled the United Nations to release US$ 5.2 million of Central Emergency Response Funds (CERF) in record time, thereby supporting those in desperate need.

NMHSs also come together with experts from other technical disciplines in Regional Climate Outlook Forum (RCOF) to produce consensus seasonal forecast statements. These help governments and development partners to plan risk mitigation actions in advance of events and thereby reduce the risks that crisis situations develop.

Invest in both partnerships and services

These are just a few examples of the many areas of collaboration and close cooperation in the WMO family. This cooperation enhances the provision of authoritative weather, climate and water-related information to the public and to policy and other decision-makers responsible for ensuring that vital services are maintained, and people are kept safe no matter what the challenge.

What makes this collaboration work? What are its key characteristics? And more importantly, how does one maintain the formal and sometimes informal support and collaboration architecture?

One common essential characteristic is the equal investment of both time and energy in creating and maintaining partnerships and services. In our complex world, every institution has its own vision statement, goals and strategic plans. As these are rarely the same, every partner will have a slightly different "view" on the world, which will influence their engagements and partnerships. Therefore, clear and transparent communication channels have to be established. Over time, with renewed contact and exchanges, personal relationships develop, and trust is built. Thus, partners feel freer to air their ideas and solutions are found to assist each other to move forward together. But the primary ingredient remains an equal investment in developing partnerships and service delivery.

The development of sustainable partnerships can be a difficult challenge at the best of times – it is an even greater challenge during the COVID-19 crisis. We no longer meet in person and there are fewer opportunities to build relationships through informal conversations over a coffee or a cold drink. There are no quiet discussions in the margins of a meeting to work out issues, thus no chance to explain what you "actually" mean when you make a formal statement on behalf your organization during an official meeting. In the COVID world, everything is arranged ahead of time, Teams, Webex and other video conferencing platforms are the order of the day (I've currently got 10 conference call "apps" installed on my phone). The building of strong ties requires harder work and even more time – maybe the time saved from travelling around the world on "planes, trains and automobiles"?

With the WMO Secretariat as facilitator, WMO Members have worked together through good and bad times. Naturally, like in any partnership, there have been arguments and disagreements. However, over the last 70 years our community has continued to move forward, advancing science and producing better and more timely services. One of the most significant achievements of this family is the principle by which observational data of all Members is freely shared to feed the data hungry global weather forecasting machine.

As we continue to move forward, the development of the Global Multi-Hazard Alert System (GMAS) will add authoritative warnings into this expanding information goldmine. Our colleagues in the United Nations and humanitarian agencies are incorporating ever more impact-based hydrometeorological information in their decision-making architecture and WMO is maintaining momentum on developing better products to assist them. The WMO Coordination Mechanism (WCM) will ensure that the expertise and insight of our meteorological family are readily available to serve the United Nations and humanitarian efforts.

However, as we look forward to the next 70 years, we can see a world in which climate change has increased hydrometeorological risks and made populations ever more vulnerable. Therefore, it is more important than ever that the WMO family "rolls up its sleeves" to deliver the services and advice that will help to save lives and protect livelihoods. In looking back on this article and reflecting on my own 30+ years working in the hydrometeorological arena, I have every confidence that our WMO family will be more than equal to this challenge.

What the Weather Will Do

40th Anniversary of the WMO Tropical Cyclone Programme

This article is based on WMO Bulletin interviews with Prime Minister Frank Bainimarama of Fiji, Mr Jone Usamate, Minister of Infrastructure and Meteorological Services of Fiji, and Mr Cyrille Honoré, Chief, WMO Disaster Risk Reduction and Public Services.

"The increasing ferocity of tropical cyclones due to climate change presents the greatest ever threat to Fiji's development. These disasters can shave off years of Fiji's economic growth and, if left unmitigated, will blow us entirely off course from the aims of the 2030 Sustainable Development Agenda," said the Fijian Prime Minister Frank Bainimarama in an interview with WMO. Tropical cyclones (typhoons and hurricanes are the same phenomena named differently in different regions) are among the most frequent, frightening and life-threatening of natural phenomena. They can generate winds that ravage harvests and tear apart homes and infrastructure, deadly storm surges and torrential downpours that trigger floods and coastal inundations.

Fijian Prime Minister Frank Bainimarama

Over the past 50 years, 1 942 disasters have been attributed to tropical cyclones, which killed 779 324 people and caused US$ 1 407.6 billion in economic losses – an average of 43 deaths and US$ 78 million in damages every day. The WMO Tropical Cyclone Programme, which celebrates 40 years in 2020, has facilitated research, coordination and communication to improve tropical cyclone forecasts and early warning systems. Its main focus over recent years has been on improving impact-based multi-hazard early warning. The importance of that work was highlighted in a series of interviews earlier this year, following Tropical Cyclone Harold in Fiji.

Mitigating cyclone risks during lockdown

When Tropical Cyclone Harold hit the small-island state of Fiji in April 2020, Covid-19 restrictions were in place. Jone Usamate, Fiji's Minister for Infrastructure and Meteorological Services, told the Bulletin, "COVID-19 is having an impact on our ability to plan and mitigate the impact of disasters. When Cyclone Harold happened, COVID-19 restricted movement. It restricted our ability to go out and assist people." He could see the benefit of further improvement in early warnings to provide more lead-time to emergency services in times of crisis such as the COVID-19 pandemic.

"Numerical Weather Prediction has benefited tremendously from advances in science and technology, especially satellites and the advanced capacity of super computers. Today, the accuracy of a tropical cyclone tracking forecast with a three-day lead-time is comparable to that of the two-day lead-time 20 years ago" explained Cyrille Honoré, Chief, WMO Disaster Risk Reduction and Public Services.

Tropical Cyclone Harold caused extensive damages in Fiji


Fiji's Minister for Infrastructure and Meteorological Services

The gains in Numerical Weather Prediction are particularly suitable for severe weather forecasting in tropical and sub-tropical regions, but they are extremely computationally intensive and can only be supported by a few leading Severe Weather Forecasting Centres. Thus, WMO devised a Cascading Forecasting Process for World Meteorological Centres (WMCs) to make global-scale products available to Regional Specialized Meteorological Centres (RSMCs) who integrate and synthesize these to provide daily short-range and medium-range forecast guidance products for hazardous weather conditions and weather-related hazards to NMHSs in their geographic region. Participating NMHSs have improved their ability to forecast severe weather events and to issue effective severe weather warnings to disaster managers and civil protection authorities in their respective countries. Their lead-time for issuing early warnings is up by 3 to 5 days.

As part of the Cascading Process, NMHSs conduct near real-time verifications and evaluations, based on observations of meteorological parameters collected at local meteorological stations and information gathered on the impacts of the severe weather phenomena, to feedback information to the WMCs. This permits a constant honing and refining of WMCs' products.

"The work to improve cyclone forecasting is vital because it gives us a lifesaving window of opportunity to prepare for a storm's arrival, allowing relevant authorities to make accurate and timely predictions for better informed decisions," said Prime Minister Bainimarama. "This allows for better management of related risks and supports clear messaging of critical information to the public. It also ensures the better management of scarce resources and enables better planning before, during and after disasters. I'm confident this work will help save Fijian lives. It will help manage and minimize risks and help build resilient communities, filled with families who know what to expect and how to effectively respond to tropical cyclones."

Impact-based early warnings

"During Tropical Cyclone Harold, people were prepared for the cyclone, but not really prepared for the storm surges and the coastal inundation. So, it is obvious that we need to improve the way that we teach people and get the message across to them," said Minister Usamate. "When you explain a disaster, or potential disaster in terms of its impacts, it drives the message home. People realize it's going to affect my life, my plantation, our homes. They understand intensely and that compels them to change their behaviour, to take on the right behaviour." He further noted, "We also need to work in partnership with other bodies in the country to make sure that we have face-to-face

interaction so that people are trained on how to deal with these disaster issues."

Early warning is a major element of disaster risk reduction. They can prevent loss of life and reduce the economic and material impacts of hazardous events, mitigating disasters. But to be effective, early warning systems need to actively involve the people and communities at risk, facilitate public education and awareness of risks, disseminate messages and warnings efficiently and ensure that there is a constant state of preparedness and that early action is enabled. Impact-based multi-hazard early warning services translate hazard warnings into sector and location-specific impacts, and develops responses to mitigate those impacts in advance of hazards. In an effort to move forward together, the National Meteorological and Hydrological Services (NMHSs) that have adopted this approach are assisting other NHMSs to do the same.

Mr Honoré explains, "Impact-based forecasting and warnings require the processing and integration of large amounts of information to tailor the services and warnings to the specificities and needs of people at risk, including small communities. It implies the development of technical capacities, skills and competencies, and their sustained implementation."

One of the most common challenges, however, "is developing strong technical and institutional partnerships nationwide." NHMSs must complement the forecasts and warnings developed through the Cascading Process with country-specific information – such as topography, flood and landslide hazard maps, population demographics and geo-located critical infrastructure and other vulnerability and exposures – to produce impact-based forecasts and risk-informed warnings. They must also participate in preparatory work with other government agencies in order to rapidly identify populations at risk, exposed assets, physical and social vulnerabilities and to support the quantification of impacts for early action.

Dissemination

"We need to make sure that forecasts are given in a language that people understand not in terms of only English and iTaukei, but also the choice of words, removal of scientific terms. At the same time, we need to make sure that we use the right mediums. Newspapers obviously don't work for rural areas. Radio works, but face-to-face interactions have proven to be the best. And that is something that we need to do," said Minister Usamate.

It is essential that disaster management plans include evacuation strategies that are well-practiced and tested.

NMHSs need to disseminate clear and consistent early warnings quickly and effectively down to the last mile. There are ever more communications tools at hand to do so: websites, mobile phone apps and SMS, radio, television, Facebook, Twitter, WhatsApp, etc. They should know which tool is best for reaching which audience.

Preparedness and response

It is essential that people understand the risks, respect the national warning service and know how to react to warning messages. Education and preparedness programmes play a key role. It is also essential that disaster management plans include evacuation strategies that are well practised and tested. People should be well informed on options for safe behaviour to reduce risks and protect their health, know available evacuation routes and safe areas and know how best to avoid damage to and loss of property.

There are many key actors that should be included in preparedness and response initiatives if they are to reach the last mile. National and local disaster management agencies should take the lead in coordinated scientific and technical agencies such as NMHSs, health authorities, ocean observing organizations and geophysical agencies; military and civil authorities; humanitarian and relief organizations such as United Nations agencies, the Red Cross and non-governmental organizations; community-based and grassroots organizations; the list goes on, in planning and coordinating. Schools, universities, the informal education sector, and media organizations can play important roles in informing and educating the public.

"We have a good mechanism in Fiji. We have the national disaster management council that works with all the parties. We have a cluster system, groupings where we have government, non-governmental organizations and even our development partners.

Fiji NDMO

So, the framework, the arrangement of the natural disaster management consultant committees, is already there. We just need to make sure that it works well and that it continues to be on its toes whenever a potential disaster appears on the horizon," explained Minister Usamate.

WMO Tropical Cyclone Programme

Impact-based forecasting and risk-informed early warning services facilitate the understanding of tropical cyclones risks and, coupled with preparedness initiatives, permit individuals to make decisions to mitigate impacts and save lives.

"We'll always be needing assistance from World Meteorological Organization to improve the way we do things here and also to assist in capacity building, providing us access to best practice around the world so that we can do our best to prepare our people in our country for potential natural disasters in the future," stated Minister Usamate.

At the end of 2020, WMO will release updated guidelines for NMHSs to develop and implement impact-based forecasting. The publication will highlight best practices and the lessons learnt by countries that have implemented the approach. Mr Honoré points to the new tool as a reference for NMHSs. It will assist in their efforts to enhance their warning services thus enable early action and better preparation for hazardous events and potential disasters.

Impacts of COVID-19 Restrictions on Observations and Monitoring

By Lars Peter Riishojgaard, WMO Secretariat

The ongoing COVID-19 crisis is impacting a broad range of activities in fields that are far from the immediate and obvious concerns related to public health. WMO activities in the areas of weather, climate and water are among them. Earlier in the year, during the first COVID-19 restrictions, the media devoted considerable attention to the potential effect on our activities. Now, a few months down the road and well into a second wave of COVID-19 and related restriction in many countries, this article provides a brief overview of the main impact on the observing systems and some – mostly speculative – discussion of the potential downstream repercussions on the quality of products and services.

Aircraft-based observations

The most immediate and dramatic impact has been a rapid and decline in the overall availability of aircraft-based observations (See Figure 1). Commercial aircraft measure wind speed and atmospheric temperature every few seconds as a matter of routine. They do this for their own avionics, not for meteorological purposes. However, a growing number of commercial airlines are making a subset of these measurements available to the WMO community in near-real-time for operational purposes via their participation in the WMO Aircraft-Based Observing System (ABOS), one of the important networks under the WMO Integrated Observing System (WIGOS) umbrella. Over a two-week period during the early part of the crisis – late February and early March – the overall number of aircraft-based observations received by global numerical weather prediction (NWP) centres reduced to around 15% of the numbers typically received. Beyond this number, very large geographic variations in the impact were seen. Over Europe, with most national borders closed and therefore only a small minority of the flights being operated, the supply of aircraft observations essentially ground to a halt. Over the United States of America (US), on the other hand, many domestic flights continued operating. The availability of observations, therefore, stabilized at around 50% of the pre-COVID number.

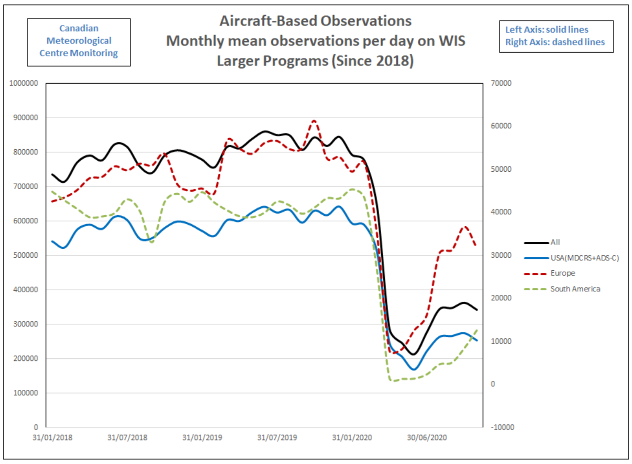


Figure 1: Monthly mean observations per day on larger WMO Information System (WIS) programs since 2018

Aircraft-based measurements provide profiles of meteorological variables – primarily temperature and wind speed and direction – during the ascent and descent phases of the flights. These observations complement the upper air soundings made by the radiosonde network, and are of particularly high value to NWP since, generally speaking, coincident profiles of wind and temperature tend to noticeably improve NWP skill (i.e. the quality of the resulting weather prediction). In addition to the ascent/descent profile measurements, commercial aircraft provide observations during level flight at cruising altitude. These flight-level observations are especially valuable over the ocean and in the Southern Hemisphere and

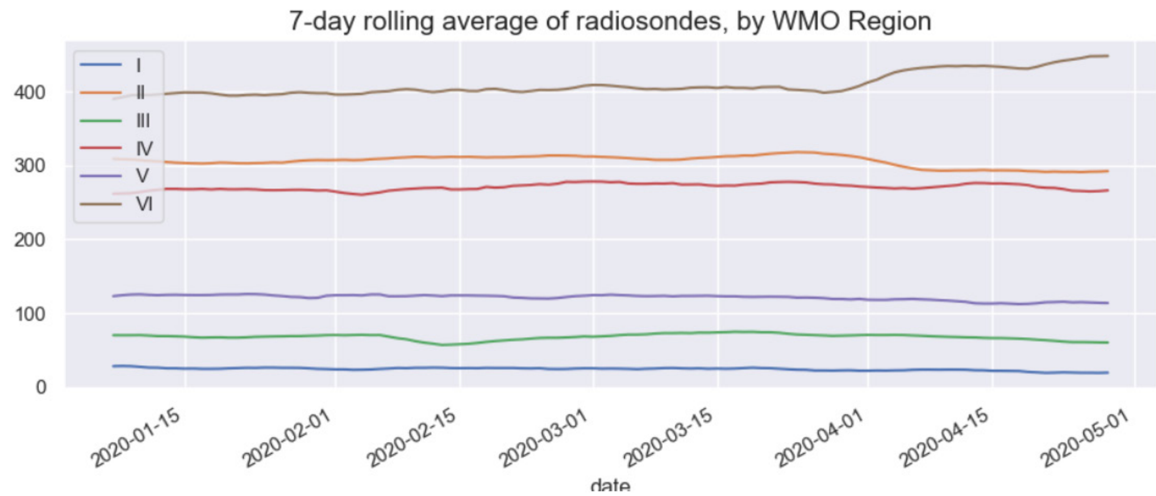


Figure 2: 7-day rolling average of radiosondes by WMO Region

other areas where in situ observations tend to be scarce. The observations provided by ABOS have a very significant beneficial impact on NWP skill.

In terms of mitigation steps, various WMO Members and their Global Data-Processing and Forecasting System Centres (GDPFS), including World Meteorological Centres (WMCs), have tried to compensate the lack of ABO by introducing additional observational data into their forecasting systems. For examples, some NMHSs, in particular in Europe, have launched additional radiosondes beyond their regularly scheduled twice-daily flights (see Figure 2), and wind measurements data from ESA's Aeolus/ADM research satellite are now being assimilated routinely by some centres. At least two private companies made additional data freely available to certain NWP centres during the peak of the crisis in the spring of 2020. Those observations are normally available only on a commercial basis, namely so-called TAMDAR aircraft observations and a set of GPS Radio Occultation (GPSRO) soundings obtained by a constellation of small satellites operated by SPIRE Inc.

Other parts of the observing system

Beyond ABOS, other observing systems were impacted, albeit to a much smaller extent at least at the global level. Many NMHSs around the globe have had to implement shut-downs or work from home policies. Especially in the developing world, where a significant number of observing stations still rely on human intervention for reading instruments and/or for encoding and transmitting observational data, an impact could be seen (see Figure 3 below).

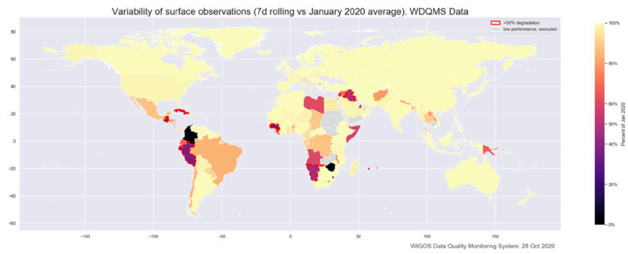


Figure 3: Variability of surface observations (7-day rolling vs January 2020 average)

The marine observing systems have also been impacted by the crisis (see Figure 4), especially as concerns observations made by ships participating in the WMO Voluntary Observing Ship (VOS) Programme. These now seem to have stabilized at around 80% of pre-COVID levels. Shipping traffic has generally suffered less than air traffic during the crisis but the indirect impact due to COVID-19 related restrictions has nevertheless been felt. It has been difficult for Port Meteorological Officers to visit ships to repair or calibrate measurement equipment, and this is believed to be among the primary reasons for the decrease in the number of observations.

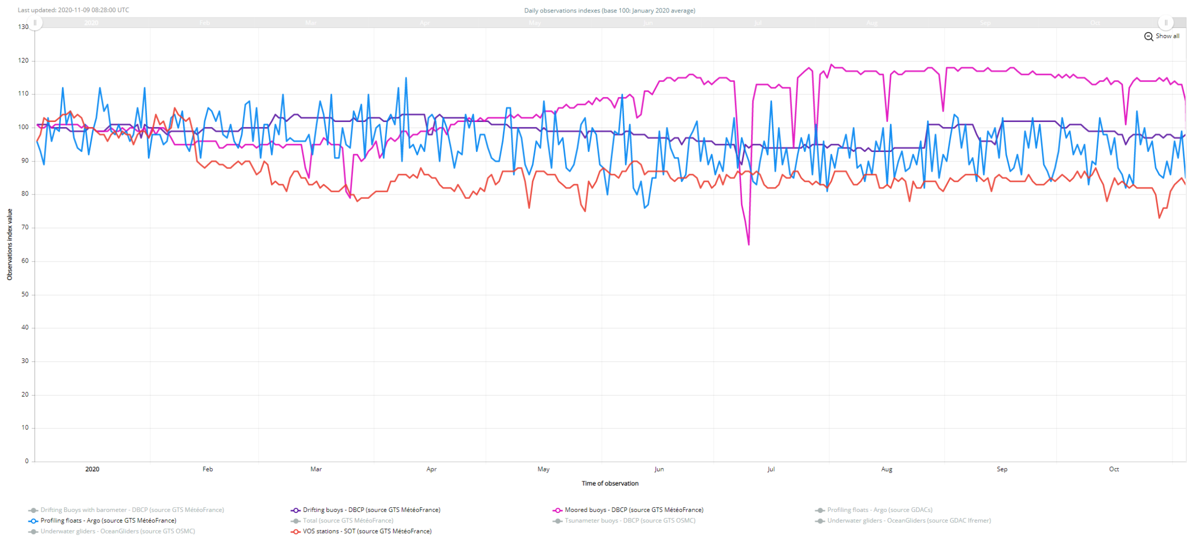


Figure 4: Daily observations

Most other marine observing systems – such as drifters, moored buoys and ARGO floats – are highly automated and autonomous and thus less susceptible to short-term COVID-19 impacts. Drifters and floats will need to be replaced over time, and moorings will need to be regularly maintained, so over a longer period of time the impact could well become substantial. Most drifters and floats are manufactured by relatively small companies, some of which may not survive an extended period without customer orders. Lost opportunities to visit moorings may result in losing the mooring altogether and, since lost ship time is a resource that cannot be easily recovered once the crisis is past, it may take years to recover any backlog that might develop as a result of an extended crisis.

Generally speaking, automated and autonomous systems have performed better during this crisis than systems relying on direct, routine human actions. Satellite systems would thus be expected to have very good initial resilience to crises of the type generated by COVID-19. Satellite systems are fully automated and autonomous, they typically have operational lifetimes of several years, and the operational systems that form the backbone of the space-based component of WIGOS are typically designed with some form of operational back-up capability in orbit. As long as program development and implementation efforts on the ground can continue rapidly enough for the system to be replenished as needed, the space-based component of the system should be able to continue to deliver its observations in spite of COVID-19. And in fact, the flow of satellite observations, which currently dominate the mix of observations both by data volume and by contribution to skill, has continued largely unaffected by the current crisis.

End-user applications

In terms of the effect on end-user applications of the reduced observational capabilities, the best tools for assessing this are provided by the global NWP systems operated by a number of WMO Members under the auspices of the GDPFS. All such systems include methodologies for attributing forecast skill to specific observation types and/or locations. However, one complicating factor is that the ranking of the importance of each observation type in terms of its impact on NWP skill may differ between NWP forecasting systems.

The European Centre for Medium-Range Weather Forecasts (ECMWF), a WMC, reports that aircraft-based observations (ABO) are second only to satellite data in terms of their impacts on forecasts. They represent 13% of the impact of all observations used at ECMWF averaged over 2019. For the Met Office in the United Kingdom and for the Fleet Numerical Meteorology and Oceanography Center (FNMOC) of the US Navy, the impacts on their respective global models represent 8% and 9% for the same period (2019). This provides a reasonable basis for expecting that a significant lack of ABO would adversely affect forecast performance. The decrease in the number of ABO during the pandemic is very clearly evident from time series plots, such as the one shown in Figure 1, but due to day to day variability in atmospheric conditions and in forecast quality, it is not nearly as simple to demonstrate unequivocally the impact of this decrease on forecast performance. Forecast performance varies from one day to another due to factors beyond just the number and quality of observations that are available, primarily the prevailing types and spatial scales of weather phenomena on a given day.

However, in a background, controlled data denial experiment carried out for a time period prior to the Covid-19 pandemic, the impact can be assessed quantitatively, and this may help yield some insight. ECMWF thus executed an ABO data denial experiment in 2019 by running a series of forecasts, using all available observations except ABO. The forecast quality was compared to the quality of forecasts made using all available data. The result showed that wind and temperature forecasts for the northern hemisphere are the main quantities negatively affected by the loss of ABO. The decrease in skill was found to be most significant during the first 24 hours of forecast range, and it persisted up to a range of 7 days. This altitude level is significant since it also happens to be near the maximum intensity of the polar jet stream, which plays an essential role in the steering of major weather systems. More detailed results can be found here.

Scientists from several WMCs (Bureau of Meteorology of Australia (BoM), ECMWF, National Centres for Environmental Prediction (NCEP) and the Met Office) are currently working on assessing and analyzing the impact of the reduction in different types of observations during the pandemic period. The initial hypothesis is that there may indeed be an impact, and anecdotal evidence of some impact on short-range forecast quality has been reported. However, the factors listed in the previous paragraph are making it difficult to detect an unambiguous signal. At the recent Session of its Technical Advisory Committee in October, ECMWF reported that it had seen "no clear degradation in forecast performance despite the loss of observations due to COVID-19." Additional information will be released as it becomes available.

Lessons learnt

In summary, the COVID-19 crisis has clearly had an impact on the availability of observational data, and this impact has been very significant for some components, less so for others. While the overall effect of this on end-user products is still under investigation, some lessons can already be drawn out.

Lesson number one is that automated systems tend to be highly resilient to this type of crisis. Lesson two is that a given level of forecast skill can be attained via different mixes of observations. It has been gratifying to see various entities from both the public and private sector step in to offer additional observations to the modelling community in order to mitigate the effect of the loss of data caused by the crisis. And the most important lesson: the crisis has provided a reminder of the danger of over-reliance on observations of opportunity, such as aircraft-based observations. While these data are unquestionably highly valuable for NWP, the COVID crisis has shown that their availability is determined entirely by commercial and operational constraints of the airlines that provide them, factors that are entirely beyond the control of WMO and the NMHSs of its Members.

As the use of observations of opportunity continues to grow, it will be crucial to maintain a certain level of investment in core observations that are made for the sole and specific purpose of underpinning the weather, climate, water and environmental services provided by all Members under WMO auspices. If nothing else, the crisis has clearly demonstrated the immense value of operational robustness, a quality that is inherent in an observing system consisting of many and diverse components operated by a broad group of entities from different sectors and different nations.

Sustaining Engagement in an Online Course for Trainers

By Patrick Parrish, WMO Secretariat

Note: This article is adapted from a chapter in the upcoming publication, WMO Global Campus Innovations

The urgent response to the COVID-19 pandemic, with the need to reduce in-person events, has required rapid conversion to distance learning delivery options to maintain capacity development goals. However, the WMO Education and Training Office (ETR) recognized the value of distance learning long before the recent dramatic changes to workplaces.

The First World Meteorological Congress in 1951 adopted Resolution 10 authorizing "WMO to participate in the United Nation Programme of Technical Assistance for Economic Development of Underdeveloped Countries." Thus, developing the competencies of Members to promote common, high-level service delivery standards has been a cornerstone of the work of WMO throughout its first 70 years. Capacity development to enhance the knowledge and skills of staff members in the National Meteorological and Hydrological Services (NMHSs) is one of the key activities of WMO technical department. Over the last decades, ETR courses to train trainers and the adoption of distance learning have permitted WMO to extend the reach and depth of its capacity development.

The importance of training trainers

The WMO Executive Council (EC) began designating Regional Training Centres (RTCs) in the 1960s to identify, then support, local centres to offer learning opportunities for developing core qualifications and to enhance service delivery. RTCs ensured that Members in developing countries had training opportunities that aligned with their expectations, in local languages and in closer geographic proximity. The train-the-trainer courses were developed to help RTCs and to support national trainers. The early courses aimed to share the latest scientific and technical knowledge so that regional and national training would be in line with international standards in science and services.

However, as instructional technologies evolved and competency-based approaches to teaching were demonstrated as the most effective for developing operational knowledge and skills, a new emphasis arose for the courses for trainers. In the early 2000s, the courses became targeted to helping trainers develop a working knowledge of practices that included the application of cognitive and constructivist learning principles, as well as competency-based approaches for improving learning outcomes. Learners would actively practice new skills in addition to receiving the required background information. These courses involved an average of 20 to 25 participants attending a two-week residence course.

In 2014, after codification of these learning principles in the WMO Competency Requirements for Education and Training Providers (WMO-No. 1209) and publication of the WMO Guidelines for Trainers based on the competency framework (WMO-No. 1114), closer alignment and more complete coverage of the competencies was expected. Developing training competency is related to more deliberate consideration in making the decisions required for effective training design. This required a longer course, one that offered practice in carrying out the entire training planning process, which was not feasible in classroom mode due to limited time, logistics and cost. It also suggested the need to reach more participants, with new trainers taking on that role each year.

Motivation to deliver training online

Going online meant that we could reach more in the training community. This is partly due to the elimination of a physical location and travel costs. But online learning also simplifies delivery in other languages because facilitators can be located anywhere, and second language facilitators and learners can take more time to read and compose responses, sometimes using machine translation as an aid. There are many motivations for increasing distance learning (DL) approaches including:

- increased reach and equal opportunity
- greater sustainability of learning through broader impacts and opportunities for longer-term interaction with learners
- lower costs and lessened disruption to work due to travel
- opportunities for early intervention prior to training events and ongoing connection afterwards, during application of new knowledge and skills on the job
- aids to evaluating the impacts of training
- facilitating the dissemination of learning to others through, for example, preservation of learning resources
- flexibility for learners and trainers who need to meet family and work responsibilities
- higher relevance through immediate connection to the learners' job environment
- increased empowerment and independence of learners, which build skills for lifelong learning.

Starting with the first online course, the average number of students earning certificates of completion increased to 37 per offering—a 60% increase—at a cost reduction of at least 85%. In the nine offerings conducted from 2014 to 2019, in English, Russian, French and Spanish (with the aid of WMO RTCs), a total of 333 certificates of completion were granted. When one considers that each of these 333 participants directly impacts the learning of many others in the training they offer, we can assume that 1000s will have benefited from the improved training practices.

As will be shown, the course has quite rigorous requirements for certificates of completion. This is contrary to the assumptions of many that online approaches cannot be as rigorous as classroom learning. And while many expected that it would be difficult to sustain engagement in a comprehensive online course, especially in regions with challenges to Internet access, the number of completions has been quite gratifying. The most recent offering, the 2020 WMO Online Course on Education and Training Innovations, linked to an upcoming Global Campus publication, while different in format and content, covered much of the same ground. Over 100 certificates of completion were issued for the course, which was in many ways even more demanding than prior courses.

A final motivation for going online was to promote the use of online learning and new online tools for engaging learners, such as discussion forums, simulations, games and various media. The course has exposed many more trainers to the possibilities of online learning, and provided many examples of active learning approaches, which has influenced their training practices in general. More online training translates to meeting more WMO Members' capacity development needs. Indeed, the annual statistics from RTCs show that online learning has nearly doubled in recent years, from 600 students in 2014/2015 to 1128 students in 2016/2017. As the testimony of RTC staff has confirmed, part of this increase can be attributed to exposure to the WMO Online Course for Trainers.

The usual fears associated with converting a classroom experience to an online environment were felt—losing engagement, lower knowledge and skill gain, lower enrollments, etc. But none of these fears turned out to be justified. In fact, by redesigning the course from scratch as an online experience, we gained in each of these areas.

Format of the course

The WMO Online Course for Trainers is almost entirely asynchronous, meaning it does not rely on facilitators and participants being online at the same time. They access the course website, view resources, contribute to discussions and participate in activities at times available to them. This not only provides significant flexibility for participants and facilitators to fit the course into their schedules, but it allows the course to be run with students in any time zone. While the offerings usually focus on one or two regions, participants come from nearly all regions for some. Language is a stronger boundary than geography. The 2018 French-language course attracted participants and facilitators from five WMO regions, and the 2020 English-language course had participants from all six WMO regions.

One down-side with the asynchronous approach is that participants and, especially, their managers, may give the course less attention than a residence course. While the participant nomination form asks that the Permanent Representative to WMO agree to a 6 to 8 hour per week work release during the course, our experience is that only about 50% receive this time. Most simply fit the course into their personal time, after-hours and on weekends. Many also respond that 8 hours is not enough time to complete the work, partly due to it not being in their mother-tongue. Nonetheless, most do complete the course.

The course has evolved and improved over time. The 2019 edition took a narrower focus on blended learning while the 2020 edition focused on innovations in education and training. The last full competency-based versions of the course (2017 and 2018) were offered in 9 one-week units, grouped into 3 modules, with two breaks of at least one week between modules (allowing for holidays and time to catch up on assignments). A Pre-Course preparatory orientation session of about two weeks is also offered as an ice breaker, allowing participants and facilitators to get to know one another—establishing important social engagement and commitment.

The course units are mapped to the WMO competency framework for education and training providers (WMO-No. 1209). Like with all competency-based training, course completion indicates that participants have had practice and feedback on applying the underlying skills and demonstrated that they have acquired the required background knowledge, full competence is within their reach.

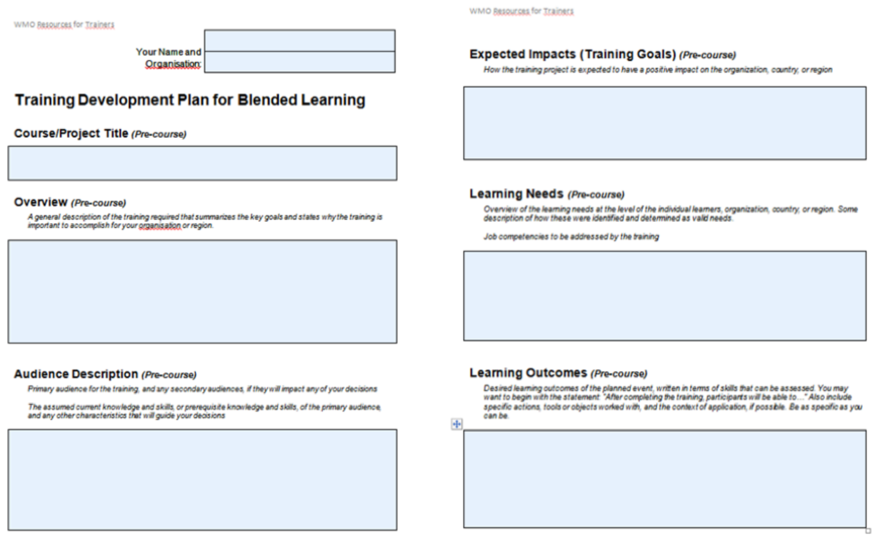
Engagement strategies

A weeks-long online course requires careful design to maintain the engagement of participants. While many are concerned that distance learning inevitably leads to high dropout rates, the WMO Online Course for Trainers has over a 75% completion rate. Furthermore, the majority of the remaining 25% leave the course in the first few weeks, or do not start at all. While no thorough analysis has been conducted to determine the primary reasons for leaving or not starting, the number who leave before or during the first weeks indicates that the format is unexpected by some of those who register. Even though clearly described in announcements, some may be curious to see what the course looks like before deciding not to learn online. After the first 2 weeks, the percentage of those that do not finish is very small, less than 10%, often due to conflicts with work assignments. Nonetheless, this 10% gained from their partial participation and no investment was lost in the offering.

How does the course keep an average of 37 participants engaged without once meeting in person? It takes several factors working together:

Relevance - Engagement begins by offering relevant content and learning activities. Learners need to value what they are learning and know that it can positively impact their work performance. From the start of the course, we introduce the WMO Competency Requirements for Education and Training Providers, and learners self-assess their current level of competence. This stimulates their curiosity and expectation for reward.

Materials are also designed for those new to the study of training as a discipline as participants are often assigned to the training based on their operational expertise or education level. While many complex topics are taught, such as needs assessment processes, learning assessment and the design of practical learning activities, the writing and discussion are kept to a level and length that avoid overwhelming learners with too much jargon and information. In


WMO Resources for Trainers

Your Name and Organisation:

Training Development Plan for Blended Learning

Course/Project Title *(Pre-course)*

Overview *(Pre-course)*

A general description of the training required that summarizes the key goals and states why the training is important to accomplish for your organisation or region.

Audience Description *(Pre-course)*

Primary audience for the training, and any secondary audiences, if they will impact any of your decisions

The assumed current knowledge and skills, or prerequisite knowledge and skills, of the primary audience, and any other characteristics that will guide your decisions

WMO Resources for Trainers

Expected Impacts (Training Goals) *(Pre-course)*

How the training project is expected to have a positive impact on the organization, country, or region

Learning Needs *(Pre-course)*

Overview of the learning needs at the level of the individual learners, organization, country, or region. Some description of how these were identified and determined as valid needs.

Job competencies to be addressed by the training

Learning Outcomes *(Pre-course)*

Desired learning outcomes of the planned event, written in terms of skills that can be assessed. You may want to begin with the statement: "After completing the training, participants will be able to…" Also include specific actions, tools or objects worked with, and the context of application, if possible. Be as specific as you can be.

Figure 1: Pages one and two of the Training Development Plan template used in 2019

addition, much of the content is provided in the form of worksheets and other take aways that can be used on the job. In other words, some content is embedded in tools for application.

Project-based learning - The activity that has most relevance is the creation of a Training Development Plan (TDP), based on a template provided at the start of the course. This assignment is the glue that ties the course together. The sections of the Plan correspond directly to the WMO Competencies, or subcomponents of them. (See Figure 1) While many will never have planned training using the method, all have had to make similar training decisions. Participants are asked to choose a training project in which they have been, are currently, or will soon be involved. The Plan is developed incrementally based on content and skills acquired in each unit and improved through continuous individual feedback from Coaches.

The TDP scope and length make this is a big assignment – often 10 to 20 pages long. However, the incremental production and feedback makes it manageable for nearly all participants. To aid understanding of what is expected, example TDPs from past projects are shared for guidance, and a grading rubric describing expectations for each section is indicated. While the TDP is challenging, this challenge is one of the most successful engagement strategies. Effort that offers meaningful rewards is the first secret of engagement and motivation to follow through on lengthy tasks. The frequent reports that participants adopt the TDP into their work practice after the course demonstrates the relevance and reward.

Additional active learning approaches - The TDP project is just one active learning approach used in the course. Many people think of online learning as downloadable readings and recorded lectures, with occasional testing and opportunities for questions and answers, but such an approach would not exploit the potential of distance learning for teaching skills and knowledge and for sustaining engagement. Nearly any classroom activity can be replicated in some form online.

While the WMO Course for Trainers has both required and optional in-depth readings, these are not entirely passive. The readings often include reflection questions that become topics for discussion forums, examples to help ground the readings in practice, and accompanying worksheets or templates to help design instruction during and after the course. Each of the nine units includes at least one targeted activity that provides an opportunity for feedback to participants. A few popular examples include:

- Stories of most powerful learning experiences: At the start of the course, one "ice-breaker" activity asks each participant to share a powerful personal learning experience—either from a formal learning programme or an informal experience. This helps learners think critically about how we learn best.

- Visual presentation redesign: In a unit on design processes, with one part focused on visual design principles, participants follow guidelines to share a redesign of one of their instructional slide presentations, or a single complex slide from it.

- Using an online training simulation: After viewing an online weather forecast simulation (using a tool developed at EUMETSAT), participants are given a limited time to make a forecast decision using a variety of products.

- Sharing evaluation examples: Participants share and discuss surveys or other methods they have used to gain feedback from participants in their courses.

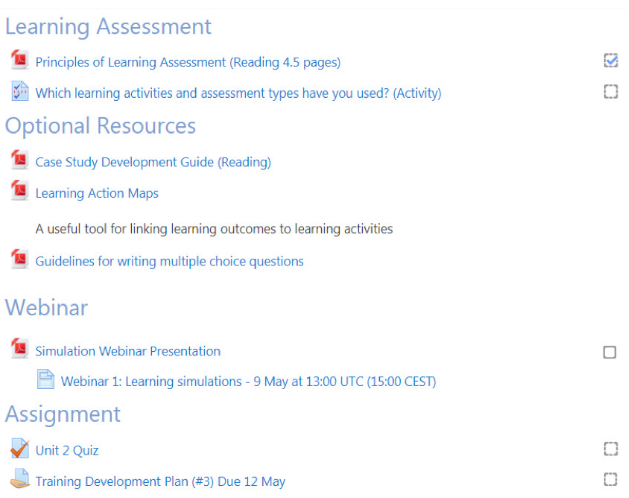


Figure 2: A portion of Unit 2 contents in the 2019 Online Course for Trainers

Clear and coherent design - The 9-unit course naturally contains many resources and activities, and its clear organization is critical to avoid confusion and intimidation. Moodle, the popular open-source virtual learning environment used to offer the course, allows the units to be displayed one unit at a time, but also offers a high-level overview of the entire course. Clicking on a unit reveals all resources and requirements for that unit/week. This tidy structure aids learners in their weekly planning.

Each unit is designed to be completed in approximately 6 to 8 hours and contains no more than 6 or 7 readings and activities, in addition to course project work. To clarify requirements, a unit introduction is made via a forum post or online video each week. This introduction links what is being learned from week to week and provides clear guidance on the unit requirements. While containing varied activities, each unit has a repeating basic structure.

The Moodle environment offers completion tracking so that learners have a visual indicator of their progress within a unit. Module summaries are offered at three points in the course to help learners feel a growing sense of achievement in what they have accomplished.

Recognition of Incremental Achievement

Regular structures provide a rhythm for learning, and a key element of that rhythm is regular recognition of achievements. So, in addition to check boxes for completion of each section, each unit offers a final quiz. The quizzes are not difficult, and are not a critical assessment element, but they demand that learners attend to all the course content. They can be retaken until a passing score is achieved, which motivates the learner to review content they missed or did not understand. Upon passing the Unit Quiz, the learner earns a digital badge for the unit. The nine badges are important incentives.

Figure 3: An example unit open badge

The Open Badge initiative promotes the use of such "micro-credentials," a new trend in life-long learning for continuing professional development. Open, digital badges provide a more rigorous designation of accomplishment than certificates of attendance. Standards have been developed to allow badges to be collected from various training providers and to be

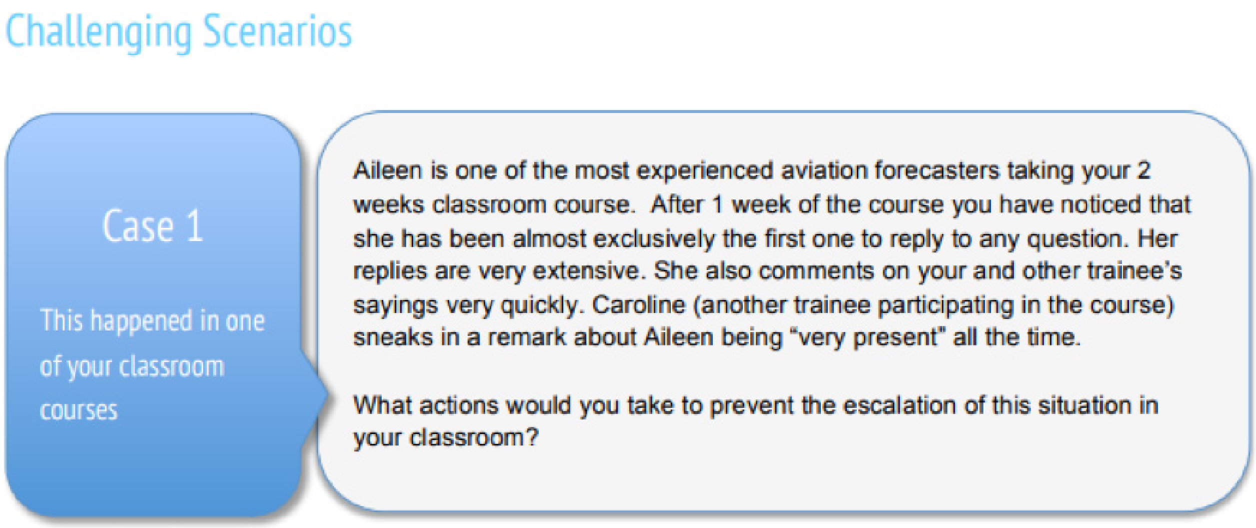


Figure 4: A scenario for discussion in the Facilitator's Gym

stored in a personal "backpack" with metadata that describe how the badge was earned. The "backpack" can be used to provide evidence of skill development to managers and future employers. Open badges are a form of "gamification" of learning, that is the use of motivational methods found in games in non-gaming environments.

Regular communication and feedback

Online study can be lonely, especially for extroverted people. The course audience (all of whom are trainers) are often highly sociable by nature. Overcoming this potential downside of distance learning requires regular and open communication. If communication is too limited or too formal, distance is magnified. To bridge what is called the "transactional distance," communication should be plentiful, welcoming, stimulating and helpful as well as respectful of time constraints.

From the beginning, principles of good online communication are taught, demonstrated and practised. Each week there can be 100s of posts and responses to the unit discussion forums, beyond the assigned work. Course participants and facilitators appreciate the opportunity to interact with peers from other institutions and countries with similar professional responsibilities.

Each forum post generates an email to participants. Because this can become overwhelming, there is an option to receive a daily digest of posts in a single email, or to only read the forum posts when visiting the course website. To keep the discussions from becoming confusing, separate forums are used for general questions about the course (grading, schedules, etc.) and topic-oriented forums. In addition, some activities are operated as separate discussions with their own rules and structures. For example, the Facilitator's Gym is a specialized forum in which participants suggest solutions to the problematic behaviours of students they might encounter in their courses. Each person reads a scenario of a problem situation, and then offers a solution a teacher might use. The solutions of other participants only become visible once a participant has submitted theirs.

The most important form of communication is feedback on performance in learning assignments. Without this critical communication, learning is diminished. Regular and timely feedback in a course this size requires quite a few facilitators. Thankfully, ETR has gathered a regular pool of volunteer facilitators with expertise that they enjoy sharing. The course has at times had as many as 20 active facilitators due to the number of participants and the emphasis on responding to forum posts within 24 hours. They are critical for the forums and course project – the TDP – that requires careful review and feedback. WMO has a Guide for Facilitators that helps those new to the role to prepare for the challenge of teaching online and providing good feedback and support. Grading rubrics for assignments are also provided.

Long-term impacts

A community of practice of trainers in WMO disciplines has formed over the years as a result of the course. Some stay in contact and join in other activities, for example, through the CALMet Community, which is closely aligned with the WMO Global Campus. Up to half of the volunteer facilitators are past course participants and all facilitators are part of the CALMet Community. Becoming a facilitator helps past participants to expand their knowledge and skills as a trainer and to offer their services to the international community. In this way, the course is continually renewed – new participants bring new questions and ideas, new facilitators bring new viewpoints. The course, with the social venue it offers for training professionals, has become a catalyst for growing the profession.

Another highly valuable outcome of the course is the WMO Trainer Resources Portal. All resources, worksheets, templates and examples used in the course over the years are now available on the Portal for anyone to access at any time, and for use in local courses.

Conclusion

The WMO courses for trainers have always strived to embrace new technologies and contemporary approaches to training practices. Just as WMO encourages the use of the most up-to-date technologies and procedures in service delivery among Members, it also encourages the adoption of contemporary educational technologies and techniques that have demonstrated effective outcomes and increased impacts for universities and professional training institutions. This is now paying off even more than expected, offering WMO advance preparation for the rapid transition to alternative delivery methods demanded by the current pandemic. The upcoming publication, WMO Global Campus Innovations, will highlight many additional approaches used by Members for their education and training initiatives.

Response of Carbon Dioxide and Air Quality to the Reduction in Emissions Due to the COVID-19 Restrictions

By Alex Vermeulen[1], Jocelyn Turnbull[2], Vincent-Henri Peuch[3], Oksana Tarasova[4] and Claudia Volosciuk[4]

Humanity is going through a health and a related economic crisis due to COVID-19. The impacts of the measures taken by governments are far and wide. The restrictions imposed on population mobility and commercial activities have resulted in changes in anthropogenic emissions and in the atmospheric chemical composition. These changes were especially pronounced in urban areas and observable in air pollutants as well as in greenhouse gases.

The potential connections between air pollution, the virus and the disease are of great interest to the WMO Global Atmosphere Watch (GAW), as well as the opportunity to observe an unprecedented, transient and complex change in anthropogenic emissions in most parts of the world. The GAW community has initiated studies on the impacts of the crisis on atmospheric composition on the global, regional, national and urban scales. The global and regional studies are based on the global network of satellite observations and numerical modelling and data assimilation, while smaller scale studies are largely driven by direct analysis of in situ observations.

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2 Co-chair of WMO GAW Steering Committee of Integrated Global Greenhouse Gas Information System and member of WMO GAW SAG on Greenhouse Gases, GNS Science, New Zealand; and University of Colorado, USA

3 Co-chair of WMO GAW SAG Applications, Copernicus Atmosphere Monitoring Service, ECMWF

4 WMO Secretariat

Carbon dioxide

Carbon dioxide (CO_2) is a long-lived greenhouse gas that accumulates in the atmosphere. When CO_2 sources and sinks are in net balance, concentrations of CO_2 will have a small variability. That was case over the 14 000 years that preceded the industrial era, which started around 1750 AD. Emissions from burning fossil fuels and changing land uses have led to an increase in CO_2 in the atmosphere from the pre-industrial level of 280 parts per million (ppm) to current levels that are over 410 ppm (this means 410 CO_2 molecules per million of air molecules or 0.041% of all air molecules).

The latest analysis of observations from GAW, supported by the Scientific Advisory Group on Greenhouse Gases and the World Data Centre on Greenhouse Gases, shows that globally averaged surface mole fractions (the measure of concentration) calculated from this in-situ network for CO_2, methane (CH_4) and nitrous oxide (N_2O) reached new highs in 2019, with CO_2 at 410.5±0.2 ppm, CH_4 at 1877±2 parts per billion (ppb) and N_2O at 332.0±0.1 ppb. These values constitute increases over the pre-industrial level of 148%, 260% and 123% respectively [WMO2019]. Concentrations of these main greenhouse gases continued to rise in 2019 and 2020. Data from all global locations, including flagship observatories – GAW Global stations Mauna Loa (Hawaii) and Cape Grim (Tasmania) – indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2020 (see Figure 1). More information on greenhouse gas trends are available

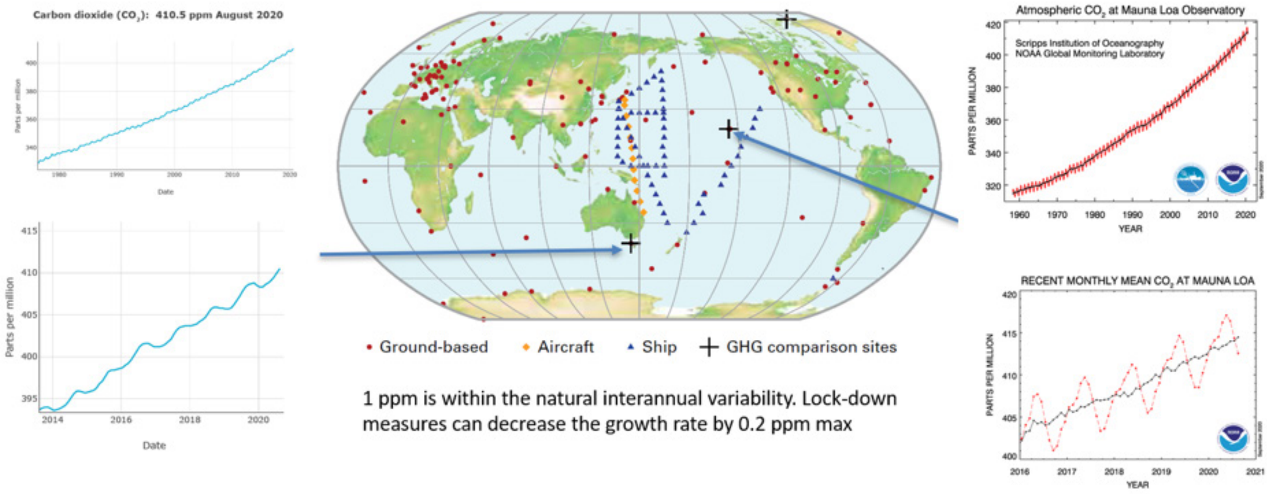

Figure 1: Monthly mean CO_2 mole fraction in ppm at (left) at Cape Grim observatory and (right) at Mauna Loa observatory. The dashed red line represents the monthly mean values, centred on the middle of each month. The black line represents the same, after correction for the average seasonal cycle. Sources: capegrim.csiro.au/ and www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html

in the WMO Greenhouse Gas Bulletin and the United in Science report [WMO2020].

Despite efforts to reduce per capita emissions as agreed in the Kyoto Protocol and the 2015 Paris Climate Agreement, emissions of CO_2 have increased globally year-by-year to about 1% in the last decade [GCP2019]. The additional CO_2 emissions have resulted in an increase in atmospheric CO_2 that is between 2 and 3 ppm per year [WMO2019] in that period. This variability of about 1 ppm in the atmospheric growth rate is almost entirely due to variability in the uptake of CO_2 by ecosystems and oceans. These two sinks together take up roughly 50% of human emissions [GCP2019].

The Global Carbon Project [GCP2020] has analysed the reduction of economic activities due to the COVID-19 lockdown in the major economies of the world. They estimated that, during the draconian period of the restrictions, daily emissions may have reduced by up to 17% globally. As the duration and severity of lockdown measures remain unclear, prediction of the total annual emission reduction over 2020 is very uncertain. The GCP estimates this annual reduction at between 4.2% and 7.5%. This is the kind of emission reduction rate needed from year-to-year in the coming 30 years to reach the Paris Agreement target of limiting climate warming to $1.5^{\circ C}$. This implies that the annual global increase in CO_2 (typically 2 to 3 ppm) will shrink by 4.2%-7.5% (that is by 0.08 to 0.23 ppm and transient up to a factor of two higher), well within the 1 ppm natural interannual variability. A similar conclusion was drawn by CarbonBrief [CB2020] and the Integrated Carbon Observation System [ICOS2020a].

The global atmospheric CO_2 signal is the integration of all natural and anthropogenic fluxes into and out of the atmosphere that have been well mixed by turbulent mixing and atmospheric transport. The GAW global network of surface stations can resolve global changes of atmospheric CO_2 over a year within 0.1 ppm of precision. Satellite observations cannot yet reach this precision for the global mean. When in situ measurements are made closer to particular sources and sinks, individual signals can be stronger but are also entangled, and in most cases the natural signal shows the highest variability with strong diurnal and seasonal variations, while fossil fuel emissions are relatively consistent. This makes it hard to detect changes on the order of 10% to 20% on timescales of a year or less. In several cities and regions around the world, measurements are now being made of the radioactive isotope Carbon-14 in CO_2 to enable the separation of fossil fuel sources of CO_2 from ecosystem sources and sinks regardless of how variable the latter are. However, these Carbon-14 measurements are rare and it takes a lot of time to analyse discrete samples in the lab. Most high precision CO_2 measurements are performed by continuously measuring in situ instruments in networks that are designed to receive the integrated signal of all sources and sinks.

To determine changes in the fossil fuel signal when there is high natural CO_2 variability requires long time series to generate robust statistics and complex data modelling using data assimilation techniques. Emissions changes of the order of 10% to 20% are hard to quantify with certainty unless one measures within about 10 km of the fossil fuel emission sources. An example of significant changes in emissions that can be measured directly within cities (such as proposed in the WMO IG³IS program framework) is shown by ICOS [ICOS2020b] where reductions in emissions of up to 75% were measured in the city centres of Basel, Florence, Helsinki, Heraklion, London and Pesaro, using so called eddy covariance techniques that directly measure vertical exchange fluxes within a circumference of several kilometres from the measurement point (Figure 2).

Analysis of the available data demonstrates that a reduction of emissions in the order of 4% to 7% globally does not mean that CO_2 in the atmosphere will go down. In fact, CO_2 will continue to accumulate in the atmosphere and concentrations will continue to rise with just a slight decrease in the rate of this increase. Discerning the change will be difficult because of the superimposed and larger natural variability.

Only when the net emission of CO_2 comes close to zero, can one expect the net uptake by ecosystems and ocean to start to slightly reduce CO_2 levels in the atmosphere. But even then, most of the CO_2 already added to the atmosphere will remain there for several centuries and take part in the warming of our climate.

Air quality

The reduction in economic activity and population mobility has contributed to localized improvements in air quality. The lifetime of air pollutants in the atmosphere is shorter than for greenhouse gases. Therefore, impacts of emission reductions on air pollutants are more localized and can be seen much

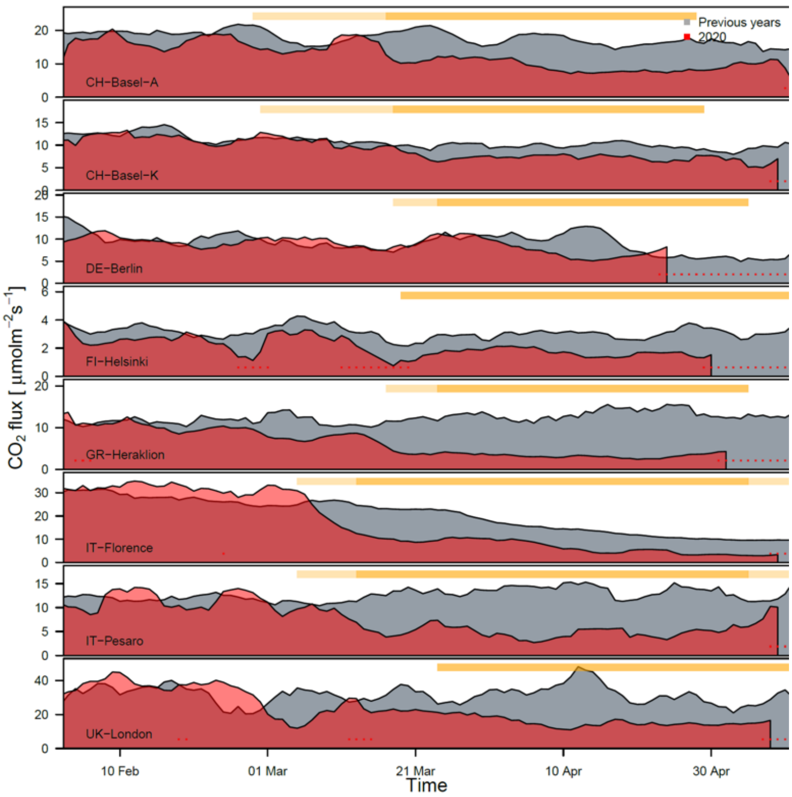

Figure 2: Average daily emissions from 5 February to 6 May 2020 (red area) and average of the previous years during the same period (grey area). The dark-orange horizontal bars cover the periods of official lockdown while the light-orange bars indicate periods of partial lockdown or general restrictions (e.g. schools closed, personal contact reductions, mobility constraints). Source: ICOS2020b

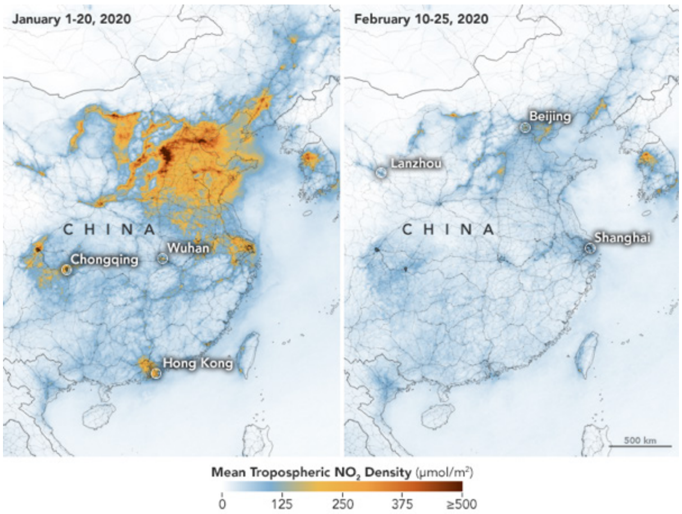

Figure 3: Mean tropospheric NO_2 density, comparison between January and February 2020. Source: NASA2020

faster in atmospheric concentrations. Reduced levels of nitrogen dioxide (NO_2) have been observed from satellite during the lockdown in many parts of the world, including for instance China (Figure 4; NASA2020) and Italy (Figure 3, CAMS2020). Yet, air quality is partly determined by emissions and partly by changes in the weather. While stagnation leads to an accumulation of pollutants near to sources, wind, vertical mixing and rain contribute to their dispersion. To disentangle the effects of weather from those of reduced emissions, detailed analyses are required. In some parts of Europe, the detection of a statistically robust trend is yet more challenging, as shown below for some of the capitals in Northwestern Europe. Weather-related episodes of high (between weeks 3 and 4; week 6) and low NO_2 surface concentrations are the main features that can be seen (Figure 5; CAMS2020). Several methods have been developed to try to delineate the effects of weather and emissions changes by estimating what would have been the spring of 2020 under "business as usual" conditions using, in particular, Machine Learning techniques (see [Barré2020]).

Many scientists are investigating the impacts of COVID-19 lockdown measures on air quality as well as the impact of air pollution levels and other environmental factors on the outcome and spread of the disease. A survey among the GAW community collected 86 responses, the majority of which addresses the impact of lockdown measures on pollution and greenhouse gas levels. A dedicated urban scale study is led by the WMO GAW Urban Research Meteorology and Environment (GURME) Scientific Advisory Group. This activity is also supported by work on anthropogenic emissions themselves and on the changes that can be deduced from publicly available activity data such as transport/mobility or energy statistics (see for instance for Europe [Guevara2020]).

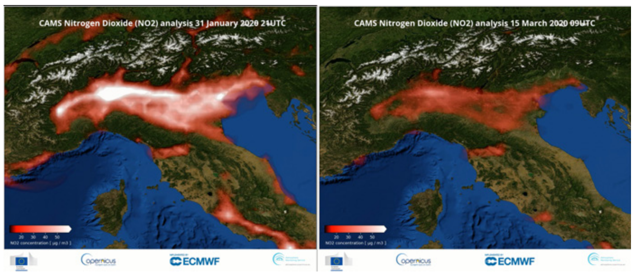

Figure 4: Surface concentrations of NO_2 over northern Italy, comparison between 31 January and 15 March 2020. Source: CAMS2020; ECMWF

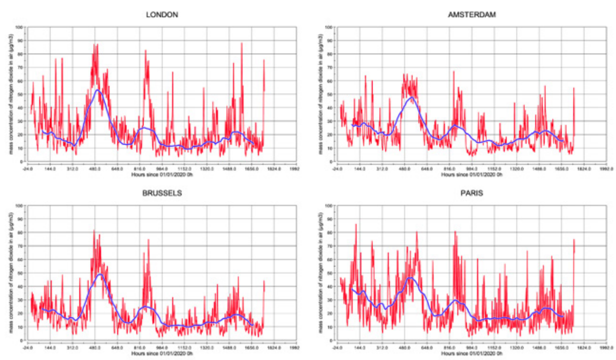

Figure 5: Time series of NO_2 surface concentrations in northwestern European capitals [CAMS2020].

The Copernicus Atmosphere Monitoring Service (CAMS) provides daily analyses of hourly concentrations of regulatory air pollutants. These can serve as "ground truth" to assess quantitatively, and in more details, the changes in concentrations identified by satellites and attributed to the effects of COVID-19 measures across the world. CAMS has created a COVID-19 resource to quickly provide robust data [Peuch2020].

The WMO Research Board has established a task team on COVID-19 in consultation with the World Health Organization (WHO) through the WMO/WHO Joint Office. The Task Team supported the organization of the international virtual Symposium on the Impact of Climatological, Meteorological and Environmental Factors on the COVID-19 Pandemic on 4–6 August and the outcomes of the Symposium were presented to the WMO Executive Council in September.

The temporary emission reductions are no substitute for climate action or air quality policies. Long-term efforts and commitments are required to reach net-zero greenhouse gas emissions and cleaner air.

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Stranded at Sea during COVID-19 Restrictions

By Robert Hausen, Christian Rohleder, Julia Fruntke and Gertrud Nöth, all staff at Deutscher Wetterdienst (DWD), supported by information taken from the Alfred Wegener Institute (AWI) press release of 24 April 2020

The crew, staff and researchers on the RV Polarstern, a German research vessel, found themselves stranded aboard a ship drifting in the ice in the Arctic in March when COVID-19 restrictions made scheduled changes of staff virtually impossible. Two staff from Deutscher Wetterdienst (DWD), Robert Hausen, a meteorologist, and Christian Rohleder, a weather technician, were aboard. This is their story.

Robert Hausen (left) and Christian Rohleder (right) in front of RV Polarstern (09 April)

Polarstern never leaves port without its shipboard DWD weather station, and that was the case on 5 November 2019 when the research icebreaker set-off from Tromsø, Norway. The MOSAiC[1] expedition called for five exchanges of crew, scientists and DWD meteorological staff on an over 13-month journey.

Picture-perfect weather after the storm: the two Twin Otters landed close to the Polarstern to pick up scientists who couldn't stay longer for personal reasons (22 April).

"As a long-standing partner of the Alfred Wegener Institute (AWI), we are delighted to support this unique expedition from the meteorological side by seconding our experienced colleagues on board the ship," said Prof. Dr Gerhard Adrian, President of the DWD, who is also the President of the World Meteorological Organization (WMO). "The expedition will promote weather and climate research around the world by contributing valuable insights into physical processes in the Arctic, which are becoming increasingly important in the ongoing climate change."

Fully packed daily routines

During MOSAiC expeditions, the RV Polarstern drifts with the ice in an area where data for weather forecasts are scarce. The data needed for onboard meteorological briefings reach the ship through very low bandwidth connections with polar-orbiting

1 Multidisciplinary Drifting Observatory for the Study of Arctic Climate

Changeover in the weather station office: meteorologist Julia Wenzel (DWD) hands over control to Robert Hausen (02 March).

communication satellites. The shipboard weather station has a reception antenna to receive near real-time images from meteorological satellites in polar orbit. Moreover, data obtained from onboard radiosonde ascents are indispensable for the expedition's weather forecasts.

The role of the onboard meteorologist is to provide the captain, cruise leader and helicopter crew with weather forecasts to ensure safe and efficient operation of the expedition. The weather technician is responsible for the station's meteorological sensors and daily radiosonde launches and assists the onboard meteorologists with the collection, processing and preparation of meteorological data.

"For the weather station staff, it means getting up early, every day, without exception," reports Hausen. "Producing the morning reports, meeting with the captain, chief scientist and pilot, continuously monitoring the weather, viewing and interpreting the latest satellite and model data, providing meteorological advice for all activities on the ice, preparing the presentation for the evening meeting, updating the weather reports in the evening," is his telegram-style description of the working day aboard the Polarstern. Hausen continues, "This can only be achieved thanks to the work of our weather technician on board, and thanks to the many colleagues back home at the DWD, who provide further data that help us to produce weather forecasts onboard all-day round, in particular for flying operations."

In the white-out of the Arctic: Robert Hausen (left) (10 March).

Specifically, it is the aeronautical meteorological briefings for the crew of the on-board helicopter that take the most time and effort. They cover weather conditions for take-offs and landings as well as the conditions during flights over the ice. Key elements are cloud-base height, visibility and the risk of icing as well as the assessment of weather conditions regarding possible white-out situations – how well the helicopter pilot can see the horizon line during the flight and/or identify the topography of the snow surface.

Scientists in sea fog on the floe (23 March) (top right). Always present: a camera team from the German film and television production company UFA, here interviewing Robert Hausen (left) on the ice floe (23 March) (bottom right). Without meteorological advice, flights of the on-board helicopter, which busily transported equipment and measuring devices to the floe, would have been impossible (25 March) (right).

The weather technician's daily schedule is similarly packed. "The first task in the morning is to check that the meteorological sensors on board work properly. This means getting out of the weather station office up on deck in all wind and weather," explains Rohleder. "The meteorologist then immediately needs the weather data for the morning briefing. Apart from the weather observations we take on board, we receive most of the data from the DWD's offices in Offenbach or Hamburg. All observations must be transmitted regularly, every three hours. In addition, there are the radiosonde ascents, which are carried out four times a day and in special weather situations as often as eight times a day. It may even happen that we launch an additional weather balloon before a helicopter takes off in order to get a data update and keep the pilots informed about the weather during their flight. Later, I support the meteorologist again for the evening meeting, which reviews the past day's weather but is mainly aimed at discussing what the weather will be like on the next day. And for that we need up-to-date data."

The AWI Helmholtz Centre for Polar and Marine Research provides all the sensors on board RV Polarstern; however, maintenance, minor repairs or the replacement of defective sensors are the weather technician's job. Major repairs, especially on the ship's mast, are carried out in co-operation with the electronic engineers on board.

Stranded on board

Hausen and Rohleder were in the third of the five planned expedition legs. They set out from Tromsø aboard the Russian icebreaker Kapitan Dranitsyn on 27 January 2020 but took over four weeks to reach

Robert Hausen (sitting left in the front) with the helicopter team on the floe (09 April).

Polarstern. "Immediately after we put to sea, we encountered our first delay. Heavy storms raging in the Barents Sea forced us to wait in a fjord for about a week for better weather. After a short passage into open water, we set off on an arduous journey through often multi-year ice north of Franz Josef Land on 7 February. The distance to RV Polarstern, which was drifting a little north of 88 °North, was over 600 kilometres. On some days, the ice pressure acting on the ship was so great that we made only a few kilometres and we began to doubt if we would ever get there. We reached our final position for the exchange on 28 February – about two weeks later than planned," explained Hausen.

"We had just about settled in on the Polarstern when the COVID-19 pandemic took on an incredible dynamic with an ever-increasing number of infections, deaths and restrictions within a very short time," said Hausen. “Pictures of the deserted inner cities of Berlin, London, Rome, Madrid or New York, etc. seemed so surreal. I couldn’t believe it, had no idea what to think of it. Then we watched the speech by our Federal Chancellor Angela Merkel [on 18 March] here on board. Afterwards, several crisis meetings were convened during which option after option for staff rotations to replace those on board were ruled out – partly because our runway was insufficiently developed due to the dynamics of the ice, partly because of the stringent restrictions imposed due to the COVID-19 crisis. By the middle of March, it was clear to us that we would not be able to return in April and probably not in May either – if MOSAiC was going to be continued. At first, that was quite a shock!” The original plan was for team 3 to return to Germany on 5 April.

AWI Professor Torsten Kanzow, then cruise leader on the Polarstern, commented, “People with families tried, as much as possible, to stay in touch with their loved ones at home via satellite telephone and e-mail. As cruise leader, I collected the worries and concerns of the people on board and reported them to the project coordination team and the AWI. This way, we regained a bit of security in planning.”

Seven staff were finally flown out on 22 April – personal circumstances left them with no choice but to discontinue their work in the project. But that brought challenges for the DWD staff. "A week before the two Twin Otters were to fly out from Station Nord on Greenland, originally planned for 19 April, we supplied the pilots and the AWI logistics team with detailed, daily updated forecasts. In addition to our own data, we received TAFs [Terminal Aerodrome Forecasts] from Station Nord and sent them back METARs [METeorological Aerodrome Reports] and Polarstern Airfield Forecasts (PAFs)," said Hausen. "But instead of moving on as expected, a bad weather system persisted from one day to the next and from model run to model run. Two to three days before the 22nd, there were signs that the flight could eventually become possible on that day. But white-out conditions persisted until the eve of 22 April. Marking the runway on the ice floe at a length of more than 400 metres was only possible the very morning. The weather played along and so the two Twin Otters took off from Station Nord in Greenland, with which we were in constant contact, and landed close to the Polarstern a little more than two hours later."

Portrait of Christian Rohleder (12 April).

Research activities on the ice floe continued with great enthusiasm despite all the challenges and the participants' concerns. From 25 March onward, the work was done in the endless sunlight of the Polar Day. Nearly the entire third team stayed and continued their tasks with undiminished devotion.

When the team members realized that they would probably be on board for two months longer, they reacted quite differently. "Some people on board were so totally absorbed in their daily scientific work even after such a long time that they'd rather not leave at all. Others would have liked to be back with their families today rather than tomorrow. My colleague Christian Rohleder and I continued our work as always, as a team and highly motivated. We had to accept the situation as it was, there was simply no alternative," said Hausen. "Our physical well-being was well cared for and the food was varied and tasted great. After work, we had plenty of leisure opportunities, such as the fitness room or the sauna, or playing water polo, table tennis or table football." But the situation did eventually get to them, "After a few months, we slowly started to feel physically and, above all, mentally exhausted. Moreover, we felt that the situation at home could change abruptly at any time. This was probably one of the most difficult things we had to cope with, that is learning to deal with uncertainty."

"We watched the daily COVID-19 updates in the news with great concern," said Rohleder. "No one could predict how the crisis would develop. The only thing we knew for sure was that we on board could not fall ill with COVID-19 – but what about our families back home? This question became a top priority for me on 31 March when my daughter told me via WhatsApp that she had the virus. As a nurse, she was at high risk from the very beginning, but now it was certain. During the next ten days or so, she struggled with the symptoms. Even after that, she repeatedly tested positive for the virus and, in the end, her quarantine lasted 45 days! You just feel helpless, so far away and nervously waiting for information from Bremerhaven on what was going to happen with the expedition."

Alternative resupply plan: rendez-vous at sea off Spitsbergen

The Polarstern crew exchange between the third and fourth team of the expedition was originally planned to take place mainly by air. The idea was to build a runway

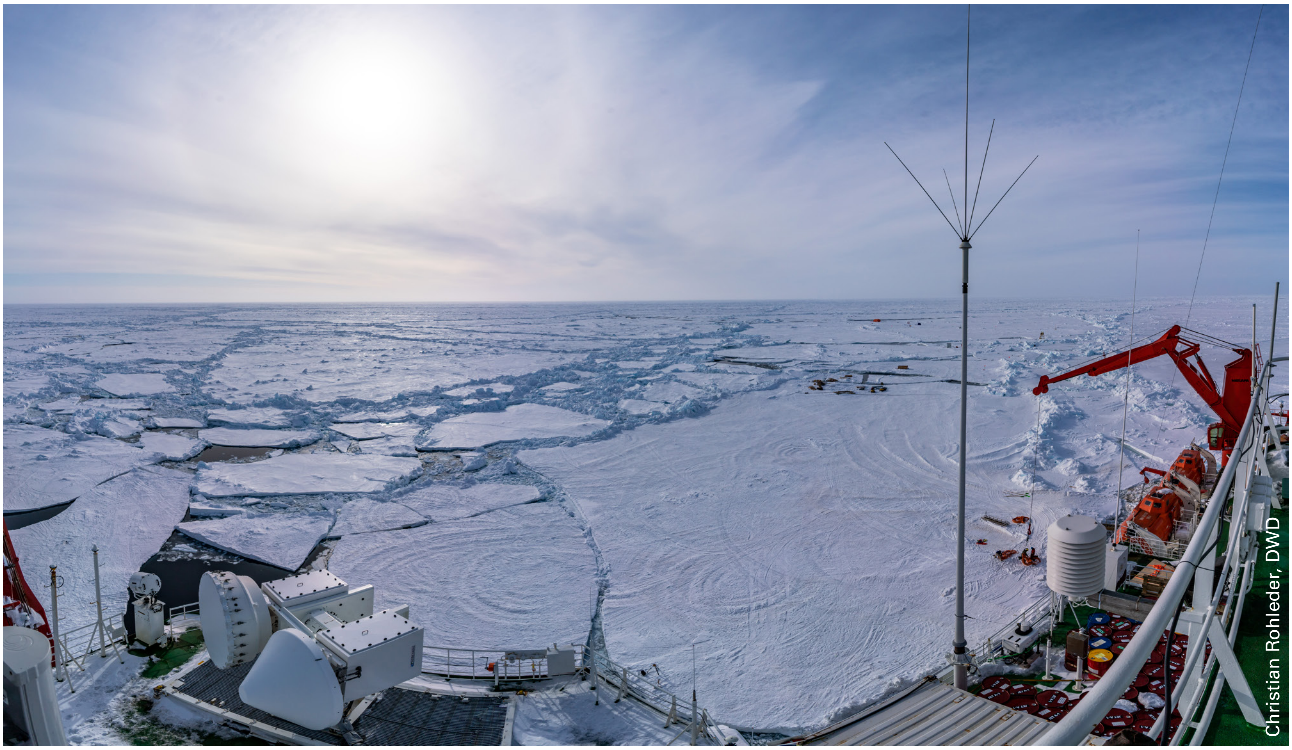
The Polarstern received occasional visits from polar bears (23 April).

on the ice floe where the Polarstern was docking. The aircraft for the transport of staff and material to and from the Polarstern were to take off and land in Longyearbyen on Spitsbergen. This plan, however, was thwarted by the COVID-19 pandemic and by the dynamics of the ice floe. Finally, new, alternative resupply plans, developed with the support of the German Federal Ministry of Education and Research (BMBF), the German Research Foundation (DFG) and the partners of the German Research Fleet, as well as the dedicated work of MOSAiC team three made it possible to continue the expedition into its next phase.

In the end, the changeover took place at sea with the German research vessels Sonne and Maria S. Merian. Both ships had returned to Germany shortly before because of the restrictions imposed to mitigate the pandemic, so they departed together from Bremerhaven. RV Polarstern left the ice floe in mid-May to meet the Sonne and Maria S. Merian in calm waters off Spitsbergen at the end of May. "But again, the plan was shaken up when we had to fight through compact multi-year ice and only rarely found larger ice-free areas. The exchange, about 100 people altogether, and the reprovision of freight and supplies, finally took place in the Isfjord near Longyearbyen," reported Hausen. The RV Polarstern then returned to the ice floe to continue its Arctic expedition. Several measuring instruments had been left on the ice so observations could continue autonomously when Polarstern veered south for the exchange, but others had been dismantled and had to be put back into the ice.

Extensive safety guidelines, prepared in close coordination with the German and Norwegian health authorities, had made the resupply and exchange possible. The fourth expedition team underwent controlled quarantine measures for 14 days in Germany before their departure and were tested repeatedly for the coronavirus during that time.

It was then decided that there would be only one further exchange of staff because of the delay in this exchange. Irrespective of this, the expedition ended in mid-October as scheduled.



Shortly before leaving for Spitsbergen: equipment is collected from the floe and hoisted aboard. Next to the railing, you can see one of the two weather screens, both of which belong to the DWD as part of the weather station's equipment (14 May).

Finally home

Team three was finally on their way back home. After a somewhat rough crossing to the coast of Norway, the passage got calmer. "At first, doing nothing was a great pleasure, but then the only wish was to get home," added Hausen. The entire team arrived safely in Bremerhaven on 15 June. From there, they returned directly home to their families.

When Rohleder arrived in Bremerhaven, his primary wish was a smooth journey home by train. "It was so strange and unfamiliar to see people with mouth and nose protections on the street or to sit behind a protective partition in the taxi to the train station," he reported. Robert Hausen shared the same impressions, before concluding, “My family picked me up at the station. To finally see them again after five months was an overwhelming feeling for me. But what remains in the end is the memory of an exciting, unforgettable time that had its ups and downs, but with the positive aspects prevailing clearly. Once you have got to know and love the Polar regions, you will be fascinated forever.”

About the persons:

Robert Hausen, graduate meteorologist, employed at the DWD since 1 November 2009. He worked twice at Neumayer Station in Antarctica as a forecasting meteorologist for the DROnning Maud Land Air Network (DROMLAN). He also served as an on-board meteorologist on the German research vessels Meteor and Polarstern.

Christian Rohleder, weather technician, has been working at the DWD for 33 years. Until 1990, he was a member of the Meteorological Service (MD) of the former German Democratic Republic, which was integrated into the DWD in the course of Germany's reunification. He took part in numerous missions on the research vessels Meteor and Polarstern.

Climate Services Ecosystems in times of COVID-19

By Lisa Goddard[1], Carmen González Romero[1], Ángel G. Muñoz[1], Nachiketa Acharya[1], Shamsuddin Ahmed[2], Walter Baethgen[1], Benno Blumenthal[1], Mélody Braun[1], Diego Campos[3], Xandre Chourio[1], Rémi Cousin[1], Catalina Cortés[3], Ashley Curtis[1], John del Corral[1], Dannie Dinh[1], Tufa Dinku[1], Francesco Fiondella[1], John Furlow[1], Alan García-López[4], Diana C. Giraldo[5], Rosario Gómez[4], Amanda Grossi[1], Kinfe Hailemariam[6], James Hansen[1], Quamrul Hassan[2], Lam Hoang[8], Pamela Jordan[1], Geneva List[1], Md. Abdul Mannan[2], Simon J. Mason[1], Jeimmy Melo[9], Carlos Navarro-Racines[5], Ousmane Ndiaye[10], Trung Nguyen-Quang[7], Thang Nguyen-Van[7], Juan Pablo Oliva[4], Daniel Osgood[1], Diego Pons[1], Steven D. Prager[5], Mónica Hernandez Quevedo[4], Andrew W. Robertson[1], Julián Ramirez-Villegas[5], José Franklyn Ruiz[9], Oscar Rojas[11], Lena Schubmann[12], Fetene Teshome[6], Madeleine Thomson[13,1], Jacquelyn Turner[1], Sylwia Trzaska[1], Khiem Van Mai[8], Audrey Vadillo[1], José Miguel Vicencio[3], Thang Vu-Van[7] (on behalf of the ACToday project)

Faced with the greatest public health crisis of our time, people must work together and learn from each other to overcome the complex challenges facing our communities, countries, and the world. Climate-related hazards are one of those challenges; they exacerbate already challenging public health conditions and impact not just people, but also the infrastructure, trade, and community support on which society depends. Through "Adapting Agriculture to Climate Today, for Tomorrow" (ACToday), the first of Columbia University's Columbia World Projects, proactive interactions in six developing countries help identify and create the local climate service ecosystems needed to address food security, agricultural sustainability, and nutrition goals.

In times of crisis and uncertainty, such as the current global pandemic of COVID-19, the preparation for climate impacts often turns toward reaction and response. However, climate risks remain unabated despite the COVID crisis; systems that make it easier for already-stressed decision-makers to understand and manage climate risks – and opportunities – are critical. Together, society must prepare for and manage the challenges that it can anticipate in order to be more resilient to those it cannot, and climate services ecosystems can help in this regard.

ACToday

ACToday was launched in 2017 and has been supporting decision-makers to combat hunger in six developing countries that are particularly dependent on agriculture and vulnerable to the effects of climate variability and change: Bangladesh, Colombia, Ethiopia, Guatemala, Senegal, and Vietnam. Led by Columbia's International Research Institute for Climate and Society (IRI), and

1 International Research Institute for Climate and Society (IRI). The Earth Institute at Columbia University
2 Bangladesh Meteorological Department (BMD), Bangladesh
3 Dirección Meteorológica de Chile (DMC), Chile
4 Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH), Guatemala
5 International Center for Tropical Agriculture (CIAT), Colombia
6 National Meteorological Agency (NMA), Ethiopia
7 Vietnam Institute of Meteorology, Hydrology and Climate Change (IMHEN), Vietnam
8 National Center for Hydro-Meteorological Forecasting, Vietnam Meteorological and Hydrological Administration, Vietnam
9 Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Colombia
10 Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), Sénégal
11 Food and Agriculture Organization (FAO), Italy
12 World Food Programme (WFP), Guatemala Country Office, Guatemala
13 Wellcome Trust, London NW1 2BE, UK

in close collaboration with national and international organizations, ACToday strengthens local climate services to meet national needs in the areas of food security, sustainable agriculture, nutrition, and beyond.

Collectively, climate services increase the resilience of vulnerable countries to floods, droughts and other climate-related risks [Vaughan and Dessai, 2014; Vaughan et al, 2017]. Climate services engage a range of expert and stakeholder communities to co-produce and tailor information to specific decision-making contexts, which builds the capacity of all involved, supports economic development, and allows governments to adapt to climate change and variability. Climate services typically address the climate-related needs of the present to near-term future through a better understanding of climate risks, as well as the actions that can be taken to prepare, plan, and thrive, especially in times of crises. Following the language of "Four Pillars of Climate Services" (Figure 1), the importance of good-quality climate information (generation) put into sectoral terms (translation) are both well recognized as essential features of effective climate services. The translated information then needs to be communicated/disseminated to the intended beneficiaries (transfer) in an appropriate format and level of quality to facilitate effective use. The format and quality also dictate use. In order to support appropriate use, the effective co-development and transfer of information, products, and tools for decision-makers must remain a high priority for subnational, national and international climate services.

Effective climate services require co-development to ensure that limited resources are dedicated to bringing the most promising solutions to the most pressing needs. Hence, after concrete demands are identified with partners, ACToday catalyzes the generation, translation, transfer and use of tailored tools to support Sustainable Development Goal #2: Zero Hunger. Some of the co-developed climate services involve approaches such as:

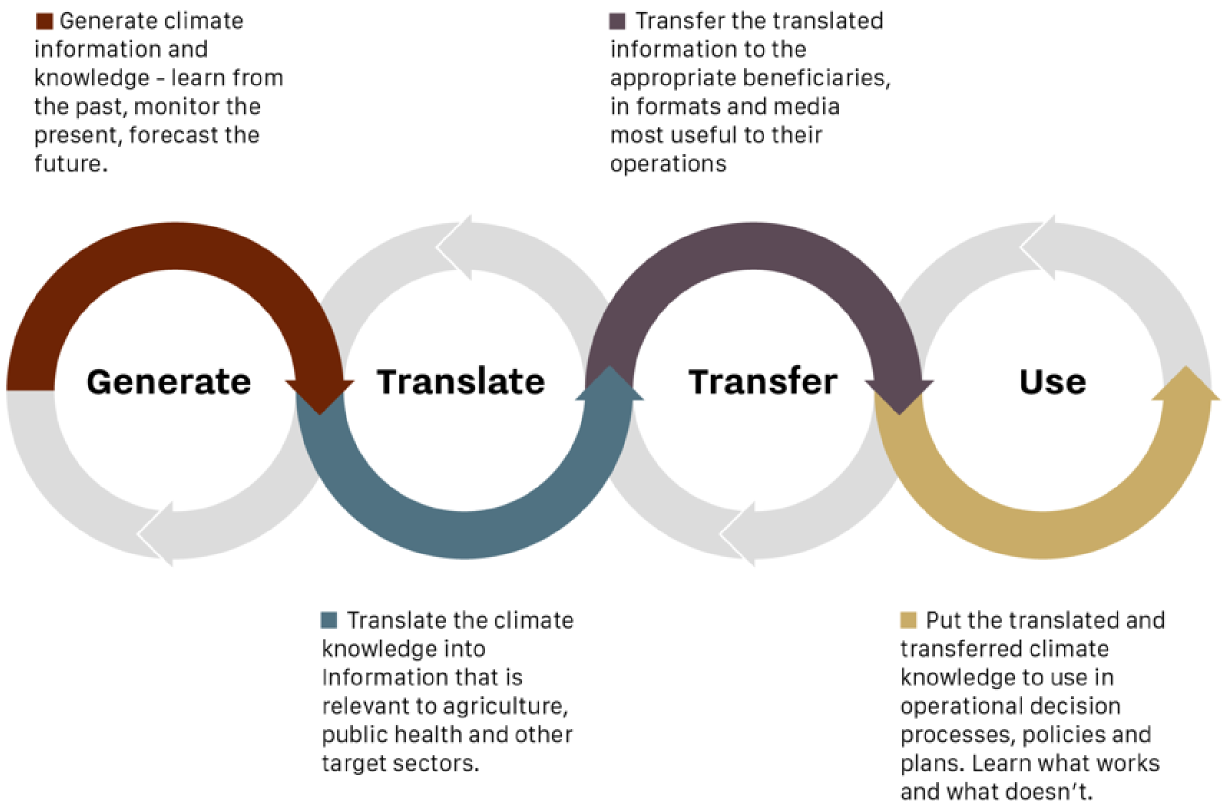


Figure 1. The Four Pillars of Climate Services: generation, translation, transfer and use. Credits: IRI

- The Enhancing National Climate Services (ENACTS) initiative to provide context to climate-related hazards via a better understanding of past and present climate conditions in the countries, through the use of quality-controlled, high-resolution climate data [Dinku et al., 2017, Nyade et al., 2012; Ouedraogo et al. 2018]

- Next Generation of climate forecasts (NextGen), using tools such as IRI's Climate Predictability Tool (CPT) to provide objective, tailored predictions at multiple timescales, including sub-seasonal and seasonal, in a variety of formats and for different variables of interest, such as rainfall, temperatures, crop yields, vegetation health indices, acute undernutrition and others [Gonzalez Romero et al., 2020; Mason et al., 2020; Muñoz et al., 2019, 2020; Pons et al., 2020]

- Local Technical Agroclimatic Committees (Mesas Técnicas Agroclimáticas (MTAs), in Latin America), two-way discussion spaces between decision-makers and national meteorological services to assess current climate conditions, analyze forecasts and produce targeted recommendations for different cropping systems, to reduce climate-related risks [Loboguerrero et al., 2018; Giraldo et al., 2020]

- AclímateColombia: a climate services platform for agriculture that facilitates the generation, translation, and transfer of ACToday-enabled, state-of-the-art NextGen forecasts to deliver agricultural advisory for multiple crops and locations in Colombia and Ethiopia [Sotelo et al., 2020; Fernandes et al., 2020]

- Complementary financial instruments, such as index-based insurance and forecast-based financing, to help transfer climate-related financial risks.

Through ACToday and its partners, these and other climate services are often discussed in Climate Outlook Fora around the world (e.g., CACOF, CariCOF, SASCOF, GHACOF).

Most of the climate services co-generated through ACToday in the different countries use the IRI's Data Library [Blummenthal et al., 2014], a powerful infrastructure that permits the users to access, visualize and perform calculations on a wide variety of datasets. Results are then communicated visually through continuously updated websites called Maprooms, where the information is tailored to target audiences and thus help to ensure that understandable and usable information are generated with the climate services.

To guarantee the long-term sustainability of these initiatives during and after the project, ACToday initiated a series of in-country Climate Services Academies with targeted educational and capacity building efforts for strengthening foundational climate knowledge (see two examples online in Bangladesh and Colombia). The Academies also support the development of the National Frameworks for Climate Services (NFCS) in the six countries. Furthermore, ACToday has implemented a Monitoring and Evaluation strategy to facilitate reproducibility and scalability of these and other solutions into different regions and countries.

An in-country ACToday Academy for Climate Services in Bangladesh, with targeted educational and capacity building efforts for strengthening foundational climate knowledge.

Support to local, national and international partners as they build or strengthen their climate services is just a part of the puzzle. Non-climate-related hazards, such as market volatility, also play an important role when dealing with food security. Furthermore, climate services with a very limited focus, for example, the generation of climate forecasts for the sole purpose of crop-yield prediction in one region of a country, miss potential opportunities, as those same forecasts may be applicable to other socio-economic sectors. Accordingly, ACToday has strived to co-develop an ecosystem of climate services that can share common solutions across different sectors, and that can identify links to, and potential interactions with, non-climate-related solutions.

Climate-Services Ecosystems

Climate services (Figure 1) can offer a powerful set of synthesized data, tools and solutions to support decision-makers with the information they need. However, if implemented in isolation – or with only one purpose in mind – opportunities are missed, the service may not be sustained or may conflict with parallel efforts. Coordinated efforts are needed to avoid unproductive replication of efforts, recognizing that some redundancy is beneficial. A healthy overlap of interventions can lead to integration and sharing of climate services that are useful and valuable for multiple sectors. For example, the development of strategies that can target multiple timescales (e.g., using the "Ready-Set-Go" approach [Braman et al., 2013; Goddard et al., 2014]), have shown considerable benefits to local partners in the ACToday countries.

Climate-services ecosystems can be defined (slightly modifying the business-perspective definition of Vargo and Akaka (2012)) as relatively self-contained, self-adjusting systems of resource-integrating actors connected by shared institutional goals, and mutual-value creation through exchange of climate services. In other words, a climate services ecosystem involves interactions between different sectors sharing the same or similar climate services, which enhances resilience to crises, and lends efficiency and value by optimally orchestrating the available solutions. These ecosystems tend to be more robust to climate impacts than a collection of climate services focused on certain applications or just one sector, because shocks to one part of the ecosystem are redistributed and dampened through the entire network.

In line with the climate services ecosystems definition, ACToday has taken full advantage of the implementation of ENACTS, NextGen and the Academies, to mention a few. These solutions are available not only to the food security and agricultural sectors, but also to the water-resource management, health, energy, and disaster risk reduction and management sectors. The presence of the climate-services ecosystems developed by ACToday is also helping the project countries to fight COVID-19-related impacts on society – as well as impacts in other sectors of society that depend on reliable climate information and climate-risk transfer mechanisms.

An unwelcome stressor: COVID-19

Food insecurity is not going away during the present COVID-19 pandemic; instead, the insecurity has worsened.

The pandemic sparked fears of impending economic crisis and recession [Nicola et al., 2020]. The preventive measures to control the spread of the virus led to a reduced workforce across all economic sectors. In the agriculture sector, this health crisis led to a drop in commodity prices of up to 25% in some markets [WBG, 2020], which reduced income levels for farmers. Between 30% to 50% of farmers in the regions where ACToday is being implemented are experiencing lower income as well as less access to food and agricultural inputs [CCAFS, 2020]. Disruptions of labour inputs and supply chains, more strict border controls, trade restrictions, lower demand and exchange-rate pressure also impacted emerging markets and developing economies. For example, according to the United Nations Office for the Coordination of Humanitarian Affairs, in Central America, the reduction of remittances due to COVID-19 has made Central Americans more vulnerable to food insecurity and has put many at risk of extreme poverty [OCHA, 2020].

COVID-19 has certainly exacerbated society's vulnerability, but those negative impacts can be offset, or at least lessened, through climate-services ecosystems. For example, NextGen climate forecasts are being used by Guatemala's and Colombia's MTAs to develop concrete recommendations for farmer associations, especially smallholder farmers, to guide the implementation of sound strategies during the present crisis (see some examples here). Guatemala, conjointly with the World Food Programme, is developing an index-based insurance program to provide a safety net for the most-impacted segments of the population. In Bangladesh, research on floods and training on index insurance are being developed to inform the creation and validation of flood-index

In Guatemala, ACToday supports the translation and use of climate information through the development of agroclimatic round tables (MTAs in Spanish), bringing climate services providers closer to farmers and other users.

products in a year in which the country is facing the biggest floods in the past decade.

Complementary forecast-based financing mechanisms (Figure 2 below) are also being explored in Guatemala's Dry Corridor, to help distribute resources in preparation for adverse climate-related events, once critical quantitative thresholds are crossed in the forecast with a specified level of confidence. Some good news in this regard is that these interventions are unlikely to be needed this year, given the current La Niña conditions, expected to extend through the rest of 2020.

The NextGen seasonal forecast indicates that the *postrera* planting season is expected to receive above-normal rainfall in multiple locations of Central America, where staple crops are mainly rain-fed.

In Senegal, early communication of above-normal rainfall forecasts has given hope to many sectors to cope with the adverse effects of the pandemic and created a good "mindset" of investment in the farming community. In Vietnam, ACToday efforts with international partners, leaders in the Ministry of Agriculture, and the meteorological service, are helping modify policies and practices to facilitate the

In Vietnam, ACToday works with international partners, leaders in the Ministry of Agriculture, and the meteorological service, to help modify policies and practices to facilitate the use of climate services and decrease the impact on food security.

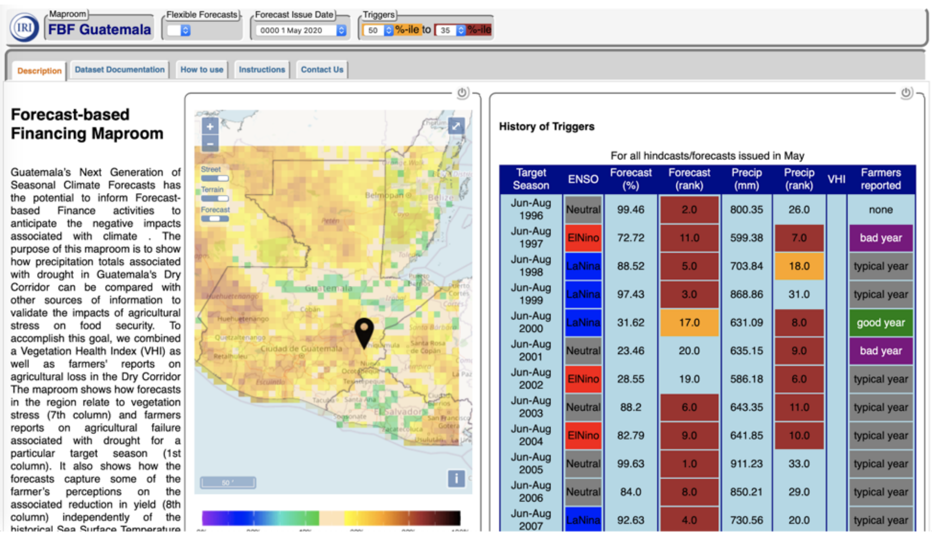
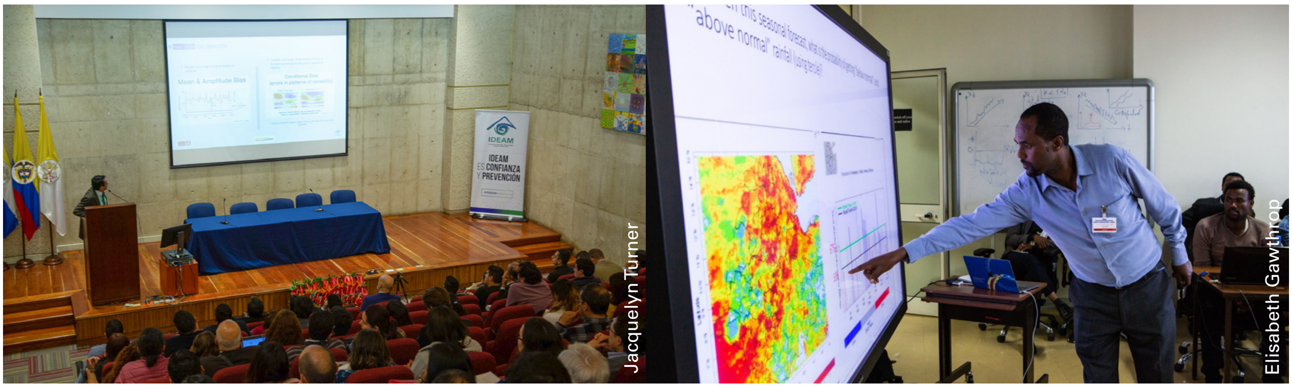


Figure 2. An example of a forecast-based financing product, being developed for Guatemala's Dry Corridor. NextGen seasonal forecasts (left) are used along with past climate and environmental information to co-identify triggers (right) that can activate funding mechanisms to help farmers fight hunger.



Both the NextGen and ENACTS initiatives provide the foundation for climate services platforms that can facilitate the generation, translation, and transfer and use of climate information to deliver agricultural advisory for multiple crops and locations. Left: the official launch of NextGen implementation by Colombia's national meteorological service, IDEAM in 2019. Right: Food-security decision-makers receive training on ENACTS in Adama, Ethiopia, 2018.

use of climate services and decrease the impact of the present pandemic on food security.

ACToday's work to catalyze national climate services ecosystems has enabled other key sectors besides agriculture to take advantage of the climate services in use by local food-security and agriculture sectors. For example, NextGen forecasts are being used by the Pan American Health Organization/World Health Organization and local health decision-makers in Central America, to identify the best course of action regarding the current dengue epidemic – the worst on record that is being exacerbated by COVID-19 and high levels of food insecurity in the region [Muñoz et al., 2020]. Similarly, in Colombia, NextGen rainfall forecasts are being used by the energy sector to decide whether the present offer of electricity is enough, or if the country will need to buy electricity in the international market to satisfy increased demand due to the extra time that the population is spending at home during COVID-19-related quarantine.

In Bangladesh, the support provided to the Bangladesh Meteorological Department (BMD) on NextGen seasonal forecasts enabled BMD to keep generating forecasts during a situation of compound risks that included COVID-19, super cyclone Amphan – one of the strongest storms ever in the Bay of Bengal – and excessive monsoon rains which triggered severe flooding and landslides, affecting millions of people. Both the cyclone and the flood impacts led to a massive pre- and post-hazard mobilization of people and resources across sectors, and a drastically increased demand on BMD to keep providing information, despite limited access to their office due to COVID-19 restrictions.

Lessons learned and the way forward

An example of climate-services development is provided by ACToday, which works with national and international partners to address local needs for climate services in the areas of food security and agriculture. Co-development of these services has been central to the engagement, use and scalability of solutions amongst the project partners. In particular, targeted capacity building, availability and access to real-time observations, objective and calibrated forecasts, well-supported dissemination platforms and discussion forums, and financial instruments allow climate services to support stakeholder needs, even during a pandemic. Climate-services ecosystems are sprouting; new climate services networks are beginning to form around the ACToday work, pushed into existence through need and opportunity. Especially in developing countries, robust funding strategies are needed to continue supporting these services. Collaboration between the public and private sectors offers one avenue for building climate services ecosystems.

The ability to scale high-quality climate services, not just to other locations but to other sectors, and the ability for these climate-service networks to organize into ecosystems is a crucial ingredient to resilience in the face of climate variability and change. This approach will help society to understand, anticipate, and manage climate risks, and increase resilience to the many other challenges we will face, both known and unknown.

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National Hydrological Services - Impacts due to the COVID-19 Pandemic

By Ramesh Tripathi and Hwirin Kim, WMO Secretariat

The COVID-19 pandemic has created a global public health emergency and placed various levels of restrictions on citizens around the world. This has also impacted the collection of Earth observation data and the delivery of important services in the sector of meteorology, hydrology and climatology. A preliminary WMO survey conducted with the focal points of National Hydrological Services (NHSs) of WMO Members scoped out COVID-19 impacts on day-to-day operational hydrological services – data collection, observation, modelling, forecasting and early warning information – as well as the measures taken to overcome these.

The 47 responses received confirmed that the NHS in developing countries are most impacted by COVID-19 restrictions. This is mainly due to the restrictions imposed on staff responsible for carrying out observations and measurements, maintenance of stations, 24/7 operation of data and forecasting centres, etc. During the first COVID lockdown, most NHS staff worked remotely from home. Very few "essential" staff were permitted into the office with protective equipment, such as face masks, and personal safety measures to follow, such as social distancing and disinfection. Even fewer went out in the field to make measurements and maintain hydrological stations.

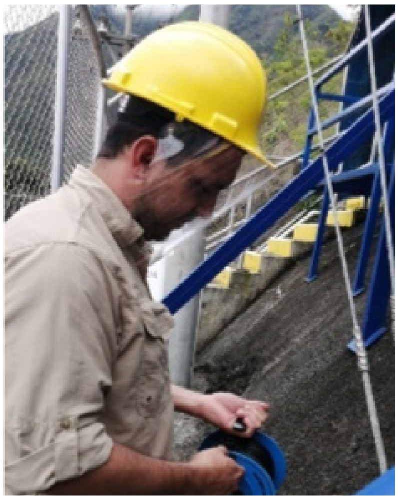
The Hydrological Advisor for Argentina, Mr Mariano Re of the National Water Institute, noted, "The development of a robust open-source hydrological system allowed us to work normally from home. When we experienced a water crisis in our main river, the Paraná, during the pandemic, several webinars and media briefings were carried out to disseminate the information." While the Hydrological Advisor of India, Mr Goverdhan Prasad, indicated that their solution was to have "Most Senior level officers working at the office, while half of the junior level officers and staff work at the office on alternate days."

Some respondents highlighted the difficulties of carrying-out urgent adjustments to data transmission and to the delivery of hydrological products when most staff are working from home. Mr Darko Borojevic, Hydrological Advisor of Bosnia and Herzegovina, stated that "Measurements in transboundary rivers were not possible. Installation of new stations and all activities related to the international projects for transboundary rivers were postponed."

Most respondents emphasized the need for technical assistance from WMO to support the timely preparation and provision of forecasts and warnings to national stakeholders and citizens. The majority requested further sharing of knowledge, while 38% requested financial assistance – about 50% expect budget cuts this year or next. Some also asked for capacity development, infrastructure support and Internet support. The sharing of knowledge concerned:

- the facilitation of transboundary hydrometeorological information sharing
- knowledge/experience sharing between different NHSs
- quality management system for the NHSs.

Field maintenance works for Pasig-Marikina River Basin, Philippines (above) and Costa Rica (below).



"WMO could provide financial support for the Internet connection, training, videoconferencing equipment, remote technical support for monitoring, improve forecasting, and the sharing experiences or solutions from other countries to mitigate COVID-19 impacts." Stated Mr Mohamed Housseini Ibrahim, Hydrological Advisor of Niger.

These initial responses will help WMO to tailor its support for NHSs during the ongoing pandemic.

WMO activities during the pandemic

WMO has continued to actively strengthen NHSs through projects, such as Flash Flood Guidance System (FFGS) and Volta Flood and Drought Management (VFDM), and initiatives, such as Climate Risk and Early Warning System (CREWS) components of Afghanistan, Burkina Faso, Chad, Dominican Republic, West Africa, Togo. These develop hydrological forecasting and early warning system and provide capacity development through e-learning and webinars. For example, one webinar highlighted progress in Integrated Riverine Flood Forecasting for the National Meteorological and Hydrological Services (NMHSs) in the Regional Association for North America, Central America and the Caribbean (RA IV) and their bilateral partners. While a first online training on riverine flood forecasting was carried out in July-August with the support of Dominican Republic's National Partner INDHRI.

In a survey of the more than 60 Members worldwide using FFGS, 42 respondents from 32 countries indicated that the real-time FFGS components functioned without any significant disturbances during the pandemic.

87% of the respondents were able to prepare and issue flash flood and dry season warnings during the COVID-19 pandemic. The WMO FFGS team is currently developing online training modules for users.

Strengthening Hydrological Services and value of preparedness

COVID-19 has significantly impacted operational hydrological services activities; however, the ways NHS and individuals are responding – the successes, challenges and lesson-learned – may provide a new pathway for responding to future multi-hazard disasters. The crisis has brought the need for, and value of, preparedness to the fore – more investment is required in preparedness to build resilience when faced with health emergencies and adapt to and mitigate the impacts climate change.

WMO Anniversaries – Dates and Facts

By Dimitar Ivanov, WMO Secretariat

There are important dates in every organization's history – dates to celebrate and to remember achievements and the people behind them. In 2020, we mark the 70th anniversary of the WMO – it is a prelude to an even more important event: the 150th year of the International Meteorological Organization (IMO) and WMO, which will be celebrated by the global meteorological community in 2023. But some question that date as the early foundational events of international cooperation in meteorology are a bit obscure and cited differently in various historic reviews.

The history of the WMO reaches back in time through its predecessor, the IMO, making it one of the oldest international organizations, probably surpassed only by the International Telecommunication Union (ITU), established in 1865 as the International Telegraph Union, and the Universal Postal Union (UPU) established in 1874. However, some sources quote the establishment of the IMO as happening in 1873 (i.e., before the UPU), while others trace it back to August 1853, when the first International Meteorological Conference was held in Brussels. Furthermore, if we follow the strict definition of an international organization as "an organization established by a treaty or other instrument governed by international law and possessing its own international legal personality," then neither date would be correct as some time was needed before the early forms of international coordination and cooperation took on the shape of an organization.

This article looks back at the history of IMO and WMO to shed light on the facts of their origin and to help us better understand the nature of this year's 70th anniversary and the coming 150th anniversary of IMO/WMO in 2023.

The International Meteorological Organization (IMO)

Regardless the exact dates of these early events, meteorology was one of the first areas where it was recognized that coordination and cooperation at international trans-boundary level would be necessary. The first networks for systematic meteorological observations were set up in several countries around 1850 as the usefulness of weather observations in practical work became more apparent. This was particularly valid in maritime activities, which were then highly dependent on ocean and sea winds and currents.

Thus, at the initiative of Lieutenant M. F. Maury, a United States navy officer, the First International Meteorological Conference was held in Brussels under the chairmanship of A. Quetelet, the first director of the Royal Belgian Observatory. The main object of the conference was to achieve a uniform system of meteorological observations at sea. Twelve delegates, mainly naval officers from nine countries – Belgium, Denmark, France, Great Britain, the Netherlands, Norway, Portugal, Sweden and the USA – attended what was later described by Sir Arthur Davis "a highly significant occasion at the time, not only because of its successful outcome from the point of view of marine meteorology, but also because it demonstrated very clearly the important benefits to be derived for meteorology from international co-operation." In this regard, there is good reason for the history of cooperation between state-led meteorological institutions to start from Brussels 1853.

It took about 20 years for the next big step, the August 1872 international meteorological conference in

Leipzig. It was a much bigger event with 52 persons in attendance. The invitation for the conference was sent to "the heads of Meteorological Institutes, other Learned Societies, as well as private scientific men and practical observers in the domain of Meteorology." A list of 26 questions that "may be proposed to discussion and possibly be answered" was sent to participants. It is not an exaggeration to say that these 26 questions formed the first agenda for the many years to come. While mostly technical, based on the pressing need for "increased uniformity in the methods of observation and publication", several questions were also posed on important institutional and cooperation matters. For instance, question 24 asked, "Is it desirable that in each country there should be established one or more Central Institutions for the direction, collection, and publication of the meteorological observations?" Then question 26 inquired, "What Regulations should be adopted in order to carry into effect the Decisions and the Objects of the Meteorological Congress?" This last question, to a certain extent, remains valid today as we strive to produce better technical and other international regulations for interoperability and standardization.

The Leipzig conference was the preparatory event for the real thing a year later: the first International Meteorological Congress, convened by the Government of Austria in Vienna in September 1873. Invitations were extended through diplomatic channels to the governments of countries that had established national Meteorological Services. Virtually all accepted and 32 delegates from 20 governments took part. [Davis]. The discussions and decisions covered many technical and organizational matters. However, as cited by Sir Arthur Davis, "Most important of all was the acceptance on all sides of the need to establish a permanent international body in order to ensure continued progress in the science of meteorology and also to ensure that all nations could reap the practical benefits that such progress would make possible. In other words, the concept of an International Meteorological Organization was born". In this citation, one should note the use of "the concept", the author does not assert that the Organization was born – not yet. The seeds had been sown and the first international "body" had been established: a Permanent Committee with seven members (Bruhns, Buys Ballot, Cantoni, Jelinek, Mohn, Scott and Wild).

There is no doubt that the Vienna Congress in 1873 was the grand opening of the international era in meteorology. What is puzzling from a historical perspective is the various interpretation of the establishment of the International Meteorological Organization. The exact act of establishment is somewhat vague but, if we remember the definition of an international organization, the attributes needed were set between 1873 and 1879 for IMO. This was a period of active work of the Permanent Committee, which met several times – in September 1874 in Utrecht, in April 1876 in London and in 1878 again in Utrecht. One of its main tasks was to prepare the Second International Meteorological Congress, which was to be held in Rome in the spring of 1879. In Utrecht in 1878, the Permanent Committee prepared the agenda and programme for the Second Congress and, most importantly, drafted the Statutes of the International Meteorological Organization, which was hoped would emerge from the Rome Congress. The Statutes, while not a formal "treaty", have been considered by some historians of meteorology as the birth date of the IMO – hence, several sources cite 1878 as its establishment year. The Second Congress, held in April 1879 in Rome, took the next key step – it adopted the Statutes of the IMO and instituted an International Meteorological Committee (IMC) consisting of nine members. Thus, some authors and historians point to the Rome Congress in 1879 as really marking the beginning of the first period of existence of IMO.

G. Svoboda, the Chief of the IMO Secretariat from 1938 to 1951 and the first Secretary-General of the WMO (1951-1955), distinguished the stages in the history of the IMO as follows:

- Preliminary conferences, 1853–1872
- Preparatory phase, 1873–1878
- First period of existence of IMO, 1879–1914
- Second period of existence of IMO, 1919–1939
- Third period of existence of IMO, 1946–1950.

After the Second Congress in Rome, the intention for future events was to keep their inter-governmental element by inviting governments to designate

The Second International Meteorological Congress took place in Rome in April 1879. A key outcome of the Congress was the establishment of the International Meteorological Committee which was the predecessor of the WMO Executive Council. The new Committee agreed that the International Meteorological Organization would function more efficiently as a non-governmental organization, and therefore, no further Congresses were convened by IMO. Instead, a system of Conferences of Directors of Meteorological Services was established on a non-governmental basis.

delegates, but things went differently. The third Congress planned for Paris never happened. Instead, IMO convened non-governmental Conferences of Directors of the Meteorological Institutes/Services. "For a period of about seventy years international co-operation in meteorology was firmly and efficiently in the hands of a [International Meteorological] Committee consisting of a group of non-governmental experts, and their co-opted successors. It was not until the creation of WMO in 1950 that the pattern of international co-operation in meteorology, started in Vienna in 1873 and in Rome in 1879 at the inter-governmental level, once more returned to that level" [Daniel].

Back to the original question of the year of establishment of the IMO. 1873? 1878? Or 1879? Many years later, the Fifth World Meteorological Congress in 1967 took a Solomonic decision with the perspective of organizing a centennial celebration of the international cooperation initiated at the First Congress in Vienna in 1873. The Resolution 11 of the Fifth Congress entitled "Celebration of IMO/WMO Centenary" stated clearly that the First International Meteorological Congress of delegates, held in Vienna in 1873, "marked the beginning of the work of the International Meteorological Organization." Congress decided that "the centenary of the creation of the International Meteorological Organization shall be celebrated by WMO in 1973 under the title "IMO/WMO Centenary Celebration". Thus, "exactly 100 years later, and in the same conference room in Vienna, the organization which was to succeed IMO held a centenary celebration attended by 210 participants, including representatives of 73 countries and 17 international organizations and in the presence of the President of Austria." [Davis]

Our generation will continue the tradition by celebrating the 150th anniversary of the IMO/WMO. It will be a grand occasion to take note of the progress made in the international cooperation in weather, climate, water and environmental practice and science and to look at the challenges that lie ahead. Over the coming decades, the community will have to shoulder greater

Celebrating 70 Years of Progress in Weather, Climate and Water

WMO has facilitated 70 years of progress in weather, climate and water observations, research and service delivery. The work of the WMO Community has helped to save lives and livelihoods and helped countless millions at home, work and play.

To mark its 70th anniversary, WMO is releasing a series of publications in 2020 with inputs from leading scientists and experts around the globe. Origin, Impact and Aftermath of WMO Resolution 40 was released in January, The Establishment of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology in June and a third on the work on the Global Atmosphere Watch will soon be released.

Some WMO Members have also contributed articles on their experiences in the Organization over the last 70 years. The WMO Community has strengthened the Earth system network of observations and data exchange, advanced science and continuously improved forecasts and warnings to help save lives and protect livelihoods.

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responsibilities in view of the formidable challenges posed by climate change, extreme weather, water resources scarcity, and environmental degradation. But we can learn from our predecessors who had their own grand challenges back when technological solutions were far less powerful than today.

The World Meteorological Organization

With this year's 70th anniversary of WMO, the historic facts are much clearer. The birth date of the WMO is 23 March 1950 – the day of entry into force of the Convention of the World Meteorological Organization. As written in Article 35 of the Convention, "the present Convention shall come into force on the thirtieth day after the date of the deposit of the thirtieth instrument of ratification or accession." Thirty days before 23 March 1950, Iraq was the thirtieth country to deposit their instrument of accession. When the Convention came into force, WMO came into being. But again, this fact is not without an interesting history, which could be called "the history of the WMO Convention."

The main difference in the transformation of IMO into WMO is foundational. Paul Edwards gives this concise description of the non-governmental character of the IMO: "The IMO case was typical of pre-World War II scientific internationalism. For seventy-five years, the organization remained a cooperative non-governmental association of national weather services. The principle of interaction was explicitly voluntary. As a result, IMO standards and policies functioned only as recommendations, which nations were at liberty to refuse or simply ignore." Keeping the IMO business in the form of an association of weather services was a choice made after the Rome Congress in 1879. It was a pragmatic decision made to keep bureaucracy at a low level and avoid political interference in technical deliberations at a time when harmonization of methods and practices between countries would be better addressed in a purely professional discussion. After the 1920s, however, internationalization and globalization became the practice in many spheres necessitating political decision by government, such as transport and communications. IMO started to lag behind because of the voluntary nature of its decisions and resolutions. More and more meteorologists felt

Sir Nelson K. Johnson, IMO President (1946-1951), signing the Convention of the World Meteorological Organization in Washington in 1947.

that the "thing impossible" (as said by professor Wild in 1875) – to collect weather and other meteorological data from thousands of stations, scattered over the globe – could become possible if only supported by governments, including financially, and with strong and binding international regulations and standards.

Discussions on the status of the organization were a constant in the Conference of Directors meetings in 1920s and 1930s. There were two schools of thought. One preferred to keep the IMO as a non-governmental association free of politics (because, the politicians did not understand meteorology). The other saw the need to enhance the status to the inter-governmental level as some other international organization had (e.g., ITU, UPU, PICAO (predecessor of ICAO)), and to have decisions that would be binding to the Members States. In Warsaw in 1935, the Conference of Directors elected Dr. Th. Hesselberg, Director of the Norwegian Meteorological Service and a strong supporter of an improved international status for meteorology, as President of IMC. In co-operation with Mr. P. Wehrle, Director of the French Meteorological Service, he prepared the first draft of the World Meteorological Convention which, if accepted by governments, would secure official status for IMO. The Second World War postponed further development of this draft Convention, however deliberations resumed almost immediately after the war.

The Convention was one of the main items of discussion at the Washington Conference of Directors in September/October 1947. Another hot topic was the possible links of the IMO (and the future WMO) with the United Nations. The discussions were so passionate and exciting that they deserve an article of their own. Those in favour of the change claimed that "the general situation existing at the time the Statutes of the IMC were established (back in 1878) had completely changed during the twentieth

The First World Meteorological Congress took place in Paris, France in March/April 1951.

century which has witnessed the development of technology and modifications of social, economic and political conditions. The IMO should adapt to these changed conditions." Furthermore, raising the status of the organization was expected to facilitate funding by governments for the Meteorological Services, while affiliation with the UN would bring IMO greater prestige and influence as it would be officially recognized by Governments. On the other side, the opinion was that IMO had established itself as a very efficient organization and should maintain its independence. The engagement of governments and Foreign Ministries was not favoured because "the direction of the destinies of the IMO by a conference of plenipotentiaries who would not necessarily be meteorologists by profession might constitute a serious danger."

A compromise was reached when both sides agreed that the transition to the inter-governmental status, with affiliation to UN in the future, would bring benefits for Meteorological Services and for the Organization. The move in this direction would not be compromised on two conditions: the world-wide character of the organization and its independence. The inclusion in the Convention of requirements for offices and bodies to be filled by Directors of Meteorological Services safeguarded the professional representation in the Organization.

After considerable animated discussion – the Conference held 31 meetings – the Convention was voted unanimously by representatives of 31 governments in October 1947. During the interim period from 11 October 1947 until 15 March 1951, IMO was still in place, preparing the final step of the transition to WMO. The last Conference of Directors was held in Paris from15–17 March. On the last day of that Conference, IMO ceased to exist opening the path for WMO to become the international organization responsible for coordinating meteorology at the international level. Two days later the First World Meteorological Congress opened. On 20 December the same year, the United Nations General Assembly adopted Resolution 531(VI) by which WMO became a Specialized Agency of the United Nations system.

A noble purpose

The timeline and milestones of the formative years of IMO and WMO reveal a history of constant improvement and cooperation even in the most difficult times. This year's 70th anniversary of the WMO and the forthcoming marking of the 150 years of the IMO/WMO in 2023 give us a reason to look back into this rich history with its technical, scientific, political and human aspects.

The men and women who catalyzed the unprecedented global cooperation, which led to breakthroughs and developments in many other areas, and who pioneered global networking and data sharing based on common goals and needs had a strong vision of a collaborative world. The seeds of this vision, which is still present in WMO community, is apparent in the concluding remarks of Lieutenant Maury at the very first international meeting in Brussels in 1853:

"We are taking part in a proceeding to which we should vainly seek for a parallel in history. Heretofore, when naval officers of different nations met in such numbers, it was to deliberate at the cannon's mouth upon the most efficacious means of destroying the human species. Today, on the contrary, we see assembled the delegates of almost every maritime nation, for the noble purpose of serving humanity by seeking to render navigation more and more secure. I think, Gentlemen, we may congratulate ourselves with pride upon the opening of this new era."

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The Role of the Hydrometeorological Service in the Information Economy

By Charles Ewen, Met Office

As a professional technologist working within a deeply scientific domain, I have spent more time than one might expect explaining exponential growth. In the past, this has been mostly through analogy; from grains of rice on a chess board to bacteria on a petri dish. In these difficult and uncertain times, I am finding that I am having to explain this much less. Lamentably, the COVID-19 pandemic has made us all very much familiar with the consequences that exponential growth can have on our society. The issues do not appear early on, but instead, at the point at which large numbers start to double.

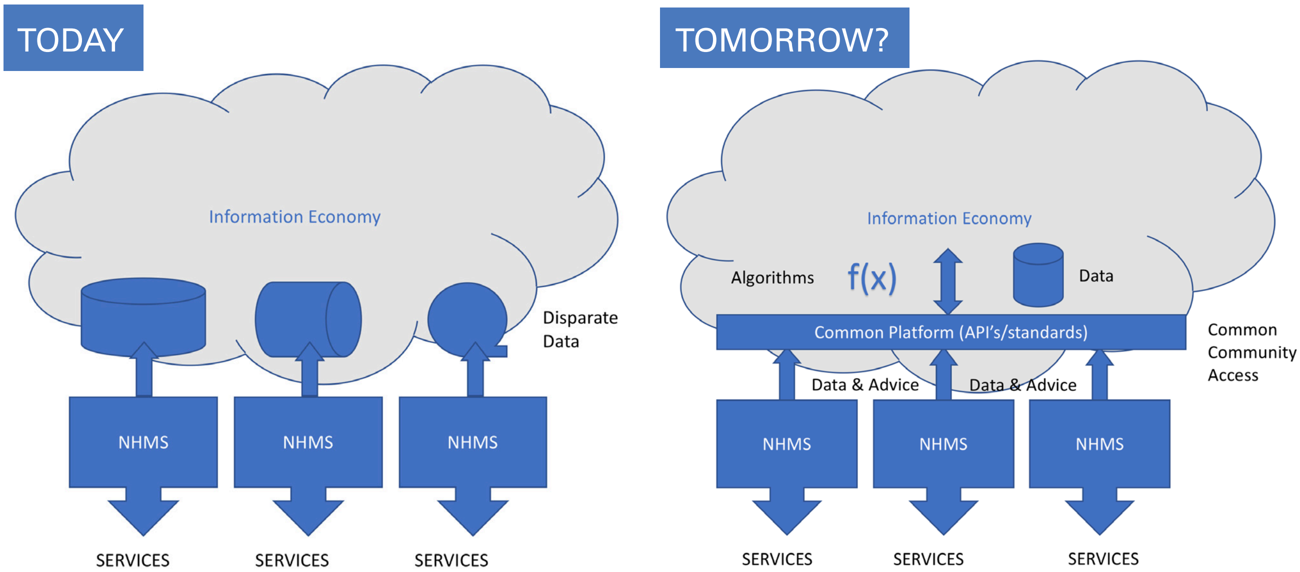
In 1965, Gordon Moore, the co-founder of Intel, wrote his seminal article for Electronics magazine. As frequently quoted, he commented upon "component cramming" – now synonymized with the number of silicon gates that can be squeezed onto a silicon wafer. But other aspects of the article were even more insightful: Moore highlighted that component cramming would lead to [exponentially growing] "complexity for minimum component costs." "Technology-driven change" is something we have all become accustomed to over the last few decades; however, it is still easy to underestimate the dramatic effect of exponential growth on large numbers.

The Rise of the Information Economy

In their insightful 2014 book, The Second Machine Age, Erik Brynjolfsson and Andrew McAfee postulated that mankind were at the cusp of an economic and social change comparable to the industrial revolution with mind, as opposed to muscle, as the theme of change. They suggested that this mind revolution would happen significantly faster than the 100 years or so that it took the Industrial Revolution to transform our world. Less than seven years on, it looks as if they were right. The companies that now dominate global earnings can attribute their spectacular growth, at least to some degree, to being in the "information" business.

At the Met Office, the Executive teams have put a considerable amount of time and effort into understanding the "Information Economy," the role that we already play, and what we might do differently to deliver the maximum public good. This has been challenging as, in many ways, organizations like the Met Office have always been in the information business. We have also been at the forefront of many of the technological implications of Moore's Law, in terms of running very highly-scaled technology platforms, complex observation platforms, and sophisticated simulations. Indeed, it is also possible to characterize applied science or operational meteorology as being in the information business, as ultimately it is all about generating new knowledge or assisting decision-making.

Another factor of the developing information economy is that as there are now more people in the information business, as well as many more in the predictions business. One of the core premises of machine learning is the development of algorithms that are able to identify patterns in datasets that represent a system. Assuming that the system will continue to behave in the future as it has done in the past, this creates a predictive capability. This is well documented elsewhere and is leading to the rapid growth of organizations that are, in some way, in the predictions business. I will refrain from commenting here upon the longer-term possibilities of machine learning augmenting sophisticated physics-based models. That debate aside, machine learning will



Today: Each NHMS pushes data of disparate approaches into the internet to be made available to the information economy. Combination of the data verbosity and complexity as well as a variety of approaches and formats makes it hard or impossible for the information economy to use. This tends to be the cumulative effect of 'the weather enterprise' approach (left). Tomorrow?: Via API's and agreed methods and standards, the NHMS community make data and advice (forecasts, warnings, etc.) available on demand. This limits the verbosity impacts over bulk push and also allows complexity to be addressed by offering a computational capability allowing user-driven processing on Public Cloud (right).

certainly have a significant impact on the end-to-end mission of helping people make better decisions. This is another example of the new ways in which National Hydrological and Meteorological Services (NMHSs) will need to interact with the information economy as distinct from the weather enterprise.

Similarly, the effect of the exponential growth on the affordable availability of high-capacity and high-capability infrastructure is also very significant. No longer is scaled infrastructure the sole privilege of those with access to, and the ability to manage, large amounts of capital. Public Cloud further accelerates technology-driven change by allowing small and medium-sized enterprises (SMEs) – and talented individuals – to access, process, combine, analyse and use vast quantities of data. This creates new possibilities for collaboration in all areas of our organizations but also demands that we make our data "useful" to these new entities. This is probably not best achieved by simply "fire-hosing" vast quantities of disparate, complex data onto the Internet.

Another challenge for the Met Office has been to re-think concepts such as "the weather value chain" and "the weather enterprise." Real-world decisions are typically not solely based upon the future state of the atmosphere, but rather the impact that this is likely to have on our everyday lives. These insights can often only be made with other data that is not weather, water, or climate-related. For many important decisions, such as investment in flood defences or choosing the safest aircraft route, weather and climate are the dominant factor, but in most cases, there are many other contributing factors. The verbosity and complexity of modern EPS (Ensemble Prediction System) simulations also mean that it is not realistic, affordable, or even possible to distribute the data within a useful timeframe. In the words of Ray Kurzwell, we have reached the "second half of the chessboard." This infers the need for an open-platform approach that facilitates integration with data and processing algorithms from other areas of the information economy. Ideally, this would include the ability to operate on all datasets at the point of generation. The

Weather and climate supercomputers at the Met Office.

more traditional notion of the widespread distribution of simulation data for exploitation by third parties (and the consequential realization of public good) does not stand up to the test of (very) big data. This potentially controversial outlook is based upon the premise that" the weather enterprise" is very rapidly being superseded by the wider "information economy."

How to think differently

All NMHSs are familiar with the wearing of many (or at least more than one) hats. With very few exceptions, Met Services are part of their domestic government and also part of an international community, orchestrated by the WMO (so that's two). Many Met Services also have research programmes and/or have global or limited-area model programmes at various geospatial and temporal scales and all run observations programmes. All also have some interaction with the private and third sectors, some at a limited scale and others at quite a large scale. This multi-faceted nature is typically long-term and slow-moving. As such, the organisation is very adept at switching context (changing hats!), and thinking, planning and acting from different perspectives. At the Met Office, we actively decided to re-imagine (think) and plan from the perspective of a "big data company within the information economy," so what did that tell us to do differently? Some of our summary findings:

1. The information economy is intrinsically global. Just like weather and climate, it does not respect geo-political boundaries and also targets local impact. Herein lies an opportunity and a major dilemma for the hydrometeorological contribution to the information economy. Today, whilst there is a strong community that has been phenomenally successful at collaboration in many areas, but it is very hard (or even impossible) to meaningfully interact with us as a single entity/capability/source of truth. This is mostly because we do not offer a single and unified method or point of access.

2. The data that we share publicly is often not suited, nor presented, in a manner that is useful to non-experts that need authoritative information to assist with real-world decision-making. These data are essentially "weather forecasts" (or climate predictions).

3. Forecasts or predictions are fundamentally different to data that describe "facts" (e.g. observations) – they are essentially "opinions." We need to know where or who they come from, when and how they were made so that we can interpret and properly use them. In the development of policies and strategies, the word "data" is an oversimplification, since the treatment of an "opinion" is very different to the treatment of a "fact" – however well-qualified it is!

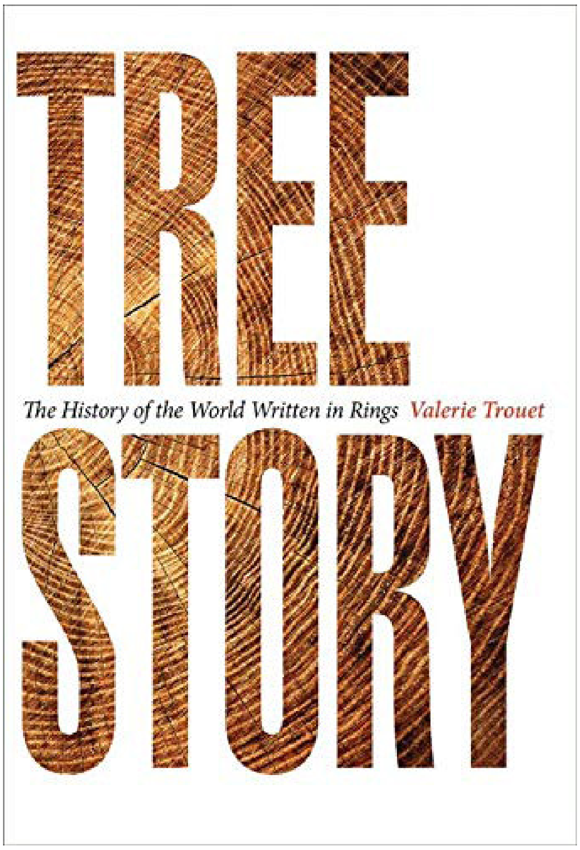
4. There are significant risks associated with treating a "prediction" as "data" in isolation and without expert hydrometeorological or climate science interpretation and advice. For significant decision-making, it is critical that expert guidance and advice is available to the information economy.

This is not the place to decompose these findings, nor to lay out how the Met Office intends to respond to this new perspective. The new Met Office purpose is "helping you make better decisions to stay safe and thrive." This seemingly innocuous change of purpose has significant implication when coupled with the realization that we need to play a central role in the rapidly developing information economy. Suffice to say that it makes collaborative structures such as the WMO, EUMETNET, EUMETSAT, and all the other organisations that we collaborate with when wearing one of our familiar hats, more relevant and important than they have ever been. It also means trying out some new hats for size in the way that we work with public, third and private sectors. This will be critical to ensure that our community continues to develop the maximum possible social value from the important work that we all undertake.

In *A sociology of our relationship to the world* (2019), Hartmut Rosa argues that society has ended up in a paradoxical state of "frenetic standstill" – where everything is constantly moving and yet nothing really ever changes. According to Rosa, this is because the rate of technological, economic and social change is now so fast that we are unable to control or manage these spheres through the slow processes of achieving consensus. It is with this caution that, as a community, we must be open to wearing some unfamiliar hats and identify the means through which our community can shift to become a core element of the emerging information economy, rather than being superseded by it.

Tree Story – The History of the World Written in Rings

Review by Michael R. van der Valk, Hydrology.nl



In 2008, an article in Science[1] argued that investments in hydrologic and other water planning need to account for anthropogenic climate change. For many involved in designing dams, dikes and water supply schemes the concept of accounting for climate change was new. In her compelling book Tree Story, Dr Valerie Trouet shows that in fact it was not new. Already in 1976, dendrochronologists[2] had used tree rings to reconstruct the Colorado River runoff record back to the year 1521. They found that the long-term average flow was more than 20% lower than the flow used for the allocation and division of the water that happened in 1922. They further found that the longest period of high flow in the 450-year record occurred in the early twentieth century, from 1907 to 1930, right when the 1922 agreement was drafted. The negotiators based their allocations on the couple of decades' data that were available at the time, but that were not representative of long-term runoff.

Notwithstanding its title, Tree Story is all about climate change and water. In the example above, tree rings were used to reconstruct the streamflow — both tree rings and streamflow are controlled by the same hydroclimatic factors, such as snowfall and evapotranspiration.

In her very accessible book, Dr Trouet tells us how dendrochronology evolved into a primary tool for studying the interactions between trees, climate, water and humans. Generally speaking, in wet years, with lots of snow and rainfall, trees grow well and form wide rings. In dry years, they suffer and form narrow rings. By counting and combining this information with other (proxy) information, climatological records (tree-ring chronologies) have been established that are precise by the year and more than 10 000 years long. "The longest continuous tree-ring record, the German oak-pine chronology, covers the past 12 650 years without skipping a single year."

In a story line that follows her career from field work in Africa to research institutions in Switzerland and USA, the reader is taken on a journey through deserts, where trees are scarce but often old, along flooding rivers and changing hydrological regimes including mega-droughts that made ancient cultures disappear,

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2 Stockton, C. W. and G.C. Jacoby. 1976. Long-term surface water supply and streamflow trends in the Upper Colorado River basin. Lake Powell Research Project Bulletin No. 18. Arlington, National Science Foundation.

to pirate ships that have benefited from a climatological optimum. Her book is not only about 'counting rings' but about the interactions between trees – including archaeological and historical wood – and the environment: the climate of past millennia, and the impact of earthquakes, sunspots and volcanoes. Trouet reveals how climate changes have impacted societies around the globe – including the Roman, Mongol and Khmer Empires, and how dendrochronology, together with hydrology and climatological teleconnections, has helped to discover these impacts. Many scales are covered: from wood cells smaller than the diameter of a strand of human hair to the winds that are triggered by the North Atlantic Oscillation. In passing we learn about the history of wood use and deforestation, big forest fires, and discover the provenance of old violins.

Tree Story is a very timely book by a key scientist; its strong messages are based on high-level science, but it reads like a rollercoaster that is funny at times. The book is excellent in its message about the importance of advances in natural science for a livable planet. It will easily be your Book of the Year.

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