Understanding changes to extreme rainfall

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Heavy rainfall events that only last a few hours or less are associated with flash flooding, which poses a significant challenge to public safety, infrastructure, and the economy. Such events are of growing concern as greenhouse gas-induced global warming will increase the level of moisture in the atmosphere, causing heavier rainfall events. New research is, therefore, trying to understand how changes to atmospheric moisture and circulation dynamics will combine to amplify or weaken regional increases in extreme precipitation events which cause flash floods. This knowledge can be used to provide a better basis for climate change adaptation planning.

The INTENSE Project

INTENSE (INTElligent use of climate models for adaptation to non-Stationary hydrological Extremes) is a large, 5 year research project (€2m) funded by the European Research Council. It is the first project to examine sub-daily precipitation extremes, enabling substantial advances to be made in observing current and past changes. It will also provide a physical understanding of processes relating to precipitation extremes necessary for improved regional prediction of change.

INTENSE is leading the global research effort in this area as a Global Energy and Water Exchanges (GEWEX) Hydroclimatology Panel Cross-Cutting project on sub-daily precipitation extremes, with a large number of international collaborators and partners. Begun in 2014, it is comprehensively analysing the response of precipitation extremes to global warming by:

- Constructing a new global sub-daily precipitation dataset;
- Using this and high-resolution climate modelling to quantify the nature and drivers of global precipitation extremes across multiple timescales;
- Examining the influence of local thermodynamics and large-scale atmospheric circulation modes on observed precipitation extremes; and
- Using these to identify climate model deficiencies in the representation of precipitation extremes.

Data collection, quality and indices

Sub-daily rainfall extremes are particularly important as causes of urban flooding, but compared with heavy rainfall on timescales of a day or longer these events have been studied relatively little in most regions. Records of sub-daily rainfall are not as extensive, either in time or space, as those for daily rainfall totals. Such data is most commonly available from the 1990s onwards, given advances in rain gauges and electronic recording devices/telemetry. Further, sub-daily rainfall data is much harder to get access to than daily data because many organisations do not make the former freely available.

The INTENSE project is focussing on collecting gauge-based rainfall data only as it gives the most accurate representation of the amount of water reaching the ground. Many sub-daily

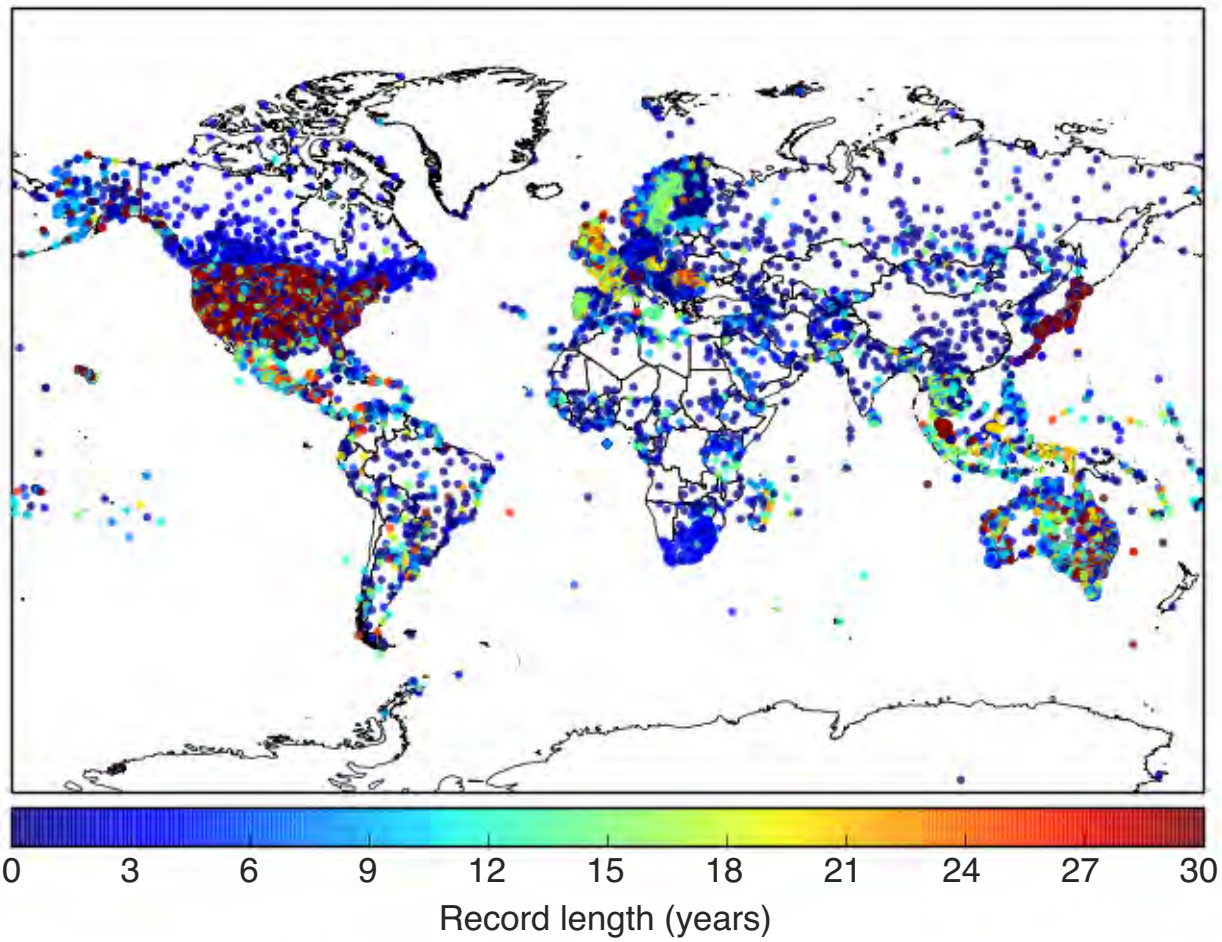


Figure 1: *Location of rainfall stations collected by INTENSE and their record length in number of years*

rainfall datasets exist that cover a large proportion of the globe but are not based on gauged observations. For example, satellite datasets such as GPM record precipitation every 3 hours. Global gridded precipitation datasets also exist, such as MSWEP based on merged gauged, satellite and reanalysis data products, but these are coarse at 3hr and 0.25°. Radar and merged rainfall measurements are limited in usefulness, particularly for the aims of INTENSE which focus on extreme rainfall, as they are yet to be fully validated by observations as no global sub-daily gauge dataset exists.

We have collected data from 22,644 stations globally (just under half of these are from the UK Met Office's Integrated Surface Database). However, even where we have data, it may not be adequate for the analysis of extreme events – for example, undocumented gauge breakdowns may be recorded as periods without rain, daily totals may be erroneously recorded as hourly values or mechanical failure of the rain gauges may produce erroneous extreme events. Furthermore, changes such as gauge location, site characteristics, or equipment type may introduce inhomogeneities in climatic series. The detection of such errors is important for the evaluation of extreme events and for the assessment of longer term variability and trends. We are therefore developing an automated quality control programme for global sub-daily data that will be applied to the station records to produce a high-quality global dataset.

We are using the data collected to produce a set of sub-daily extreme rainfall indices describing monthly maxima, frequencies over thresholds and the diurnal cycle, which will be made freely available to all users and will be very useful for understanding current patterns of extreme rainfall and for the validation of climate

model outputs at sub-daily scales. Additional work will use the new dataset to validate new precipitation satellite products from NASA and explore options for combining the gauge and satellite data to produce a gridded global sub-daily dataset.

The dataset collected by INTENSE is a platform for future development by the larger scientific community and policy makers. In particular, we are working to find a global organisation who will maintain and update the dataset. This will require a tremendous amount of effort as licences will need to be negotiated and secured to make the data itself available to researchers to further scientific understanding.

Scaling of intense rainfall with temperature

Climate models suggest that rainfall will intensify under global warming as the physics of a warmer atmosphere are capable of holding more moisture. We expect that rainfall intensities will increase with temperature according to the Clausius–Clapeyron (CC) relation (a rate of ~6-7% $°C^{-1}$), although precipitation data for some parts of the world show larger (super-Clausius-Clapeyron) rates of change for short-duration (hourly and shorter) extremes. Historical records of UK hourly summer (June-August) rainfall show CC scaling. Our work will examine the new global dataset to see how precipitation extremes scale with temperature change and moisture availability globally.

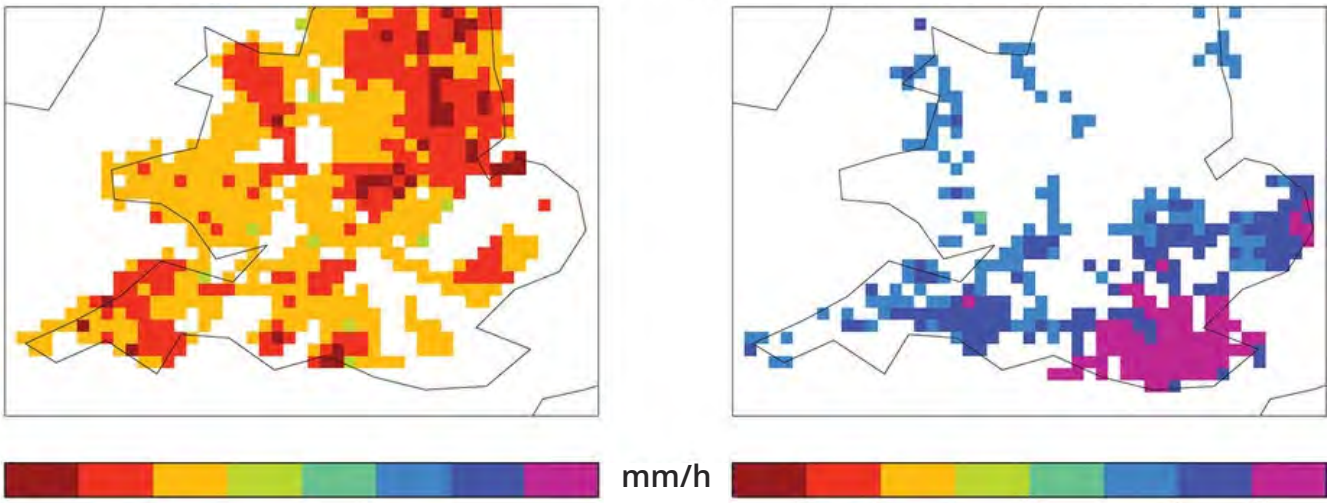
Trends in extreme rainfall

We have produced the first analyses of trends in sub-daily rainfall records over the US. These show that hourly and daily seasonal maxima have significantly increased over the last 6 decades. The percentage of stations showing significant increasing annual maximum precipitation trends was generally higher for daily compared to hourly extremes. However,

DIFFERENCE BETWEEN MODELLED AND OBSERVED HEAVY SUMMER RAINFALL (HOURLY)

12km model – radar difference, JJA

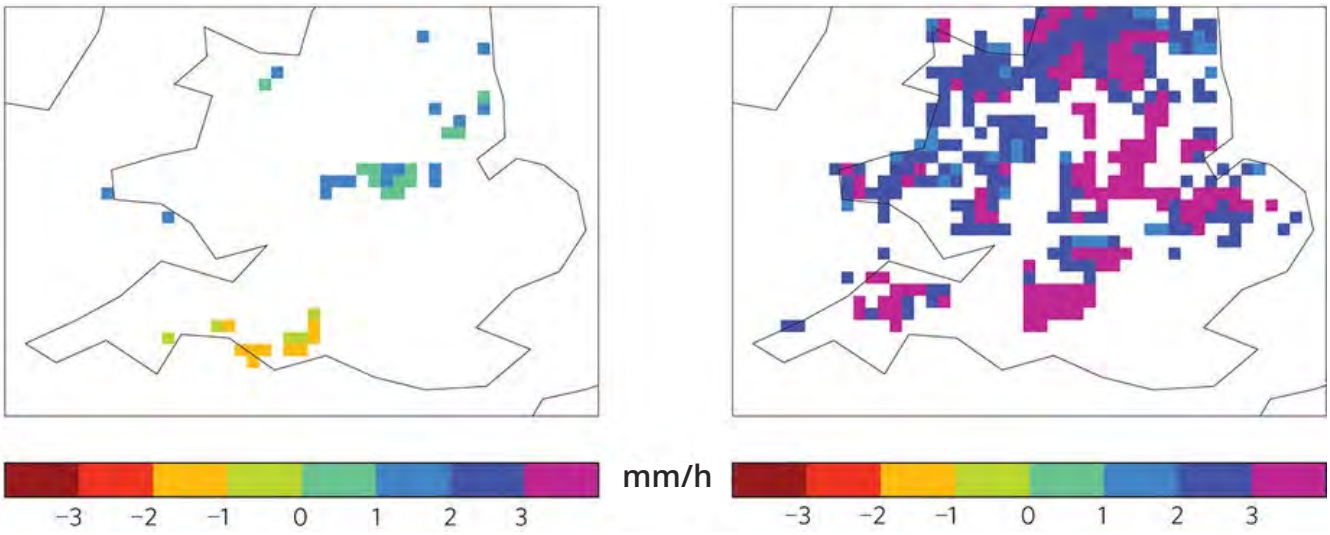
1.5km model – radar difference, JJA



CHANGE IN HEAVY SUMMER RAINFALL (HOURLY)

12km future change (2100 – present-day), JJA

1.5km future change (2100 – present-day), JJA



strong evidence points to more widespread increases in the magnitude and frequency of hourly extremes during winter compared to daily extremes. This work is now being extended to examine trends globally and how these relate to global mean temperature change. Our work has indicated, though, that one of the challenges of assessing changes in historical rainfall extremes is their relatively large natural variability, in part due to their dependence on large-scale atmospheric patterns such as El Niño.

Climate modelling

Climate models are the main tools used by scientists to obtain projections of future climate from which estimates of future impacts on society are subsequently derived. Although they have a high degree of skill in simulating many features of our climate they also have a number of known weaknesses and so there are large uncertainties in regional patterns of change, making the development of efficient

adaptation strategies for flooding more difficult. One major weakness is that the grids they operate on are not fine enough to incorporate surface features that influence local climate or to represent the convective storms that produce intense summer rainfall.

Working with our partners at the UK Met Office Hadley Centre we adapted a weather-forecast resolution model to study potential changes in hourly rainfall associated with climate change. This model, unlike coarser resolution climate models, is able to realistically represent hourly rainfall, allowing us to make future projections with some confidence. In Nature Climate Change in 2014, together with the UK Met Office Hadley Centre, we published the first evidence that summer downpours could become heavier over the UK with climate change. While we expect summers to become drier overall by 2100, our results indicate heavier summer downpours in the future, with almost 5 times more events exceeding 28mm in 1 hour (associated with flash flooding) by 2100 than there are currently. The model also shows increases in hourly rainfall intensities in winter, consistent with projections from a coarser 12km-resolution model and previous studies at the daily timescale. The results represent the first step towards building a complete picture of how rainfall may change as our climate warms.

This work has led to the inclusion of several very-high resolution model simulations in the UK's next set of official climate change projections (UKCP18). We have now also extended this work to compare our results with the results from other international modelling centres to build up a picture of how the results from these very high-resolution models differ from those coarser resolution models generally used to create national climate scenarios used for climate adaptation. We have also extended our work within INTENSE to examine larger model domains – building towards very high-resolution global model runs.

Putting science into practice

Changes to future rainfall intensities will impact sewer flooding and so our initial work has been applied in the UK water industry. Using our high-resolution observations and model simulations and working with UK Water Industry Research, we have developed better guidance on estimates of change in rainfall intensities (uplifts) affecting water and sewerage companies, offering the potential for their application in both flooding and pollution analyses and in investment planning. INTENSE will be able to use its high-quality observations from around the globe to provide relevant stakeholders with the most reliable return period estimates for different rainfall intensities, and so contribute to a better understanding of current flood risk. Our high-quality data could also be used to better understand how river catchments respond to intense rainfall events – for example, we have produced a high resolution gridded dataset of hourly rainfall for the UK which will be freely available to hydrologists and other practitioners. The project's advances in data provision and scientific understanding will, therefore, facilitate knowledge to help make people, business and infrastructure more resilient to flooding from intense rainfall in the future.

We have also worked hard to communicate our research with the public more generally. We recently developed a museum exhibition, FLOOD! In which we showcased our research into extreme rainfall. We aimed to help visitors navigate their way through the arguments made in the public sphere around climate change and

extreme rainfall and provided a more detailed understanding of why flooding happens and what can be done to prevent it. Throughout the exhibition, visitors experienced what it's like during a flood with an immersive virtual reality headset, understood the role of landscapes and rainfall through an augmented reality sandbox and learnt about flood management, using a giant version of the childhood game Kerplunk. The exhibition also used puppets, real field kit that we use to obtain hydrological data and a peg board game to understand how the probability of extreme rainfall events will change in the future. The walls were covered in information boards and videos explaining the causes and types of floods, how we measure and model flooding, what climate change is, how climate change will affect flooding and what we can do to reduce flood risk, and also displayed research posters from the INTENSE project. The exhibition ran from 3rd-9th July 2017 and attracted over 1,000 visitors.

Outlook

Research within the INTENSE project is providing a greater understanding of the nature and drivers of change in heavy rainfall events worldwide, which will help us to better understand the mechanisms associated with flash flooding. In turn, this should lead to improved prediction of likely future changes and improvements in the use of climate models for adaptation.

Publications referred to in this report can be found on the INTENSE website.

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Clean energy is vital for all of Europe

In a speech, Climate Action and Energy Commissioner, Miguel Arias Cañete, highlights the clean energy transition taking place across Europe

Firstly, I would just like to outline the pace of change that we have witnessed as the clean energy transition takes hold; Secondly, I would like to say a few words about the Paris Agreement; and thirdly, I would like to talk about our Commission proposals in the Clean Energy for All Europeans Package – and how things stand at the moment.

In reality, the level of investment and new projects is moving more quickly than the gathering of statistics. The key point is that renewable energy is now cost-competitive and frequently becoming more and more cheaper than fossil fuels. With 12,5 GW of gross additional wind capacity installed in 2016[1], wind has now overtaken coal as the second main source of energy in Europe (after gas) and the EU remains the second largest market for wind power (after China).

Figures for 2016 from the renewables agency, IRENA, show that the level of power capacity from renewables continues to increase, with a global increase of 9% last year, relative to 2015. In Europe, the level of growth in 2016 was around 5% and this is in good part because the EU is already doing more than others. Per capita,

the EU has installed 4 times more renewable power than the rest of the world (0.8 kW/capita versus 0.2 kW/capita) – and twice as much as China (0.4 kW/capita).

In total, the renewables sector in Europe employs over 1 million people, attracts more investments than many other sectors, and has reduced our fossil fuels imports bill by €16 bn since 2005. On top of that, whereas in the past we used to see a clear link between energy consumption and GDP growth – with any rise in GDP only possible with an increase in energy consumption. In recent years we have managed to fully decouple these 2 elements. Whereas GDP grew by some 10% from 2005 to 2015, primary energy consumption decreased by almost 11% in the same period. The signal is clear – cleaner energy and economic growth can go hand in hand. In short, this is not just a transition, we are truly undergoing a clean energy revolution. Our job as policymakers is to see how we can steer and accelerate this process most efficiently by creating the right regulatory and enabling framework.

This brings me nicely on to my second point – the most important global achievement – the ratification of the Paris Agreement. The Paris Agreement was a remarkable, perhaps unique exercise in collective responsibility to slow down global warming to well under 2 degrees; 195 parties working together to establish the most efficient vehicle for fighting climate change. Sealed by the EU ratification of the deal, the moment that this accord came into force was one of the most fulfilling moments of my political career. This is why, I will do whatever it takes to defend and implement it.

Of course, the EU deeply regrets the unilateral decision of President Trump to withdraw the USA from the Paris Agreement. In our response, we have made clear that the 29 articles of this accord are not up for renegotiation. The Agreement is ratified. It is fit for purpose. It is here to stay. I was touched by the stance taken by many cities around the world and the number of green-coloured town halls that were pictured on social media. Perhaps this is a good chance to acknowledge the role that can be played by cities and local authorities in this contest. A good instrument to make this happen is the Global Covenant of Mayors, which should become fully operational in the course of this year.

Such a single, global coalition of cities is important for a range of reasons, but I will mention only one: cities and regions can inspire each other and learn from each other's best practices. In other words: our cities can team up with cities in other continents to jump over the fossil age.

As European Commissioner responsible also for Climate Action, I will work relentlessly to forge news partnerships around the world, from the world's biggest economies to the most vulnerable developing countries, supporting and helping them to adapt and mitigate climate change, a good example of this renewed partnership is China.

But first and foremost – and that brings me on to the third point I would like to cover – we, the EU, are putting in place our own ambitious domestic energy and climate change policies and setting the conditions right to steer the necessary investment in the clean energy transition thanks to the Clean Energy Package.

Clean energy for all

I see the Clean Energy for all Europeans package as the way of cementing the EU's Paris Agreement commitments into our rulebook.

The key here is creating the optimal conditions for energy transition, not only by setting the necessary regulatory framework, but also, by driving the necessary investments – both public

Climate Action and Energy Commissioner, Miguel Arias Cañete

and private – to support this transition. This time the commission took a different approach by going beyond regulation, and by developing, at the same time, the enabling instruments and support measures that would be needed to reduce greenhouse gas emissions by at least 40%, to achieve an energy efficiency target of 30% and to reach the level of at least 27% of renewable in our final energy consumption.

I would like to highlight a few elements, starting with Energy Efficiency, the most mature file, at least in Council. I would like to be clear: energy efficiency is not a slogan, it is one of the most cost effective ways to support the transition to a low carbon economy and a key policy to implement the Paris Agreement. Besides, it is also an effective way to create investment opportunities, growth and employment domestically. According to our estimates, the 30% energy efficiency target will increase Europe's GDP of €70 billion, create about 400,000 new jobs – especially among SMEs – and reduce our gas imports by 12% by 2030.

Moreover, the binding nature of the target will provide additional certainty to the investors. Many industry representatives are fully in line with an ambitious binding target, to have more predictability. After the productive discussions that we had in Malta at the occasion of the informal Energy Council, I am happy to see more and more Member states moving in our direction.

But ambition is not only about the target, it is also about the requirement for Member States to make annual savings of 1.5%, foreseen by article 7. This is a core provision, since through it we achieve about half of all the savings of the directive.

How can we explain to our citizens that undergoing energy transition and combatting climate change is more important than ever, and yet we lower the existing requirements? This makes no sense. Of course, I recognise the need for more flexibility, notably as far as renewables are concerned, but this should not lead to the creation of loopholes in the legislation and should not be at the expenses of the level of ambition.

If that will be the case, I would rather be in favour of giving ourselves more time, to work out a better compromise. Another key point is the need to improve the energy performance of buildings, given that this accounts for 40% of Europe's energy consumption and 36% of CO_2 emissions.

Significantly accelerating the rate of building renovation has the potential to help more families move out of energy poverty, and to improve the quality of life for many – as well as stimulating jobs, in particular for local SMEs. In this context, our proposal for pre-cabling and charging points for electric vehicles in new and existing buildings – and the recent mobility package – should help to address one of the key bottlenecks holding back electric vehicle growth in Europe. On this specific issue, I regret that as far as charging points are concerned the council compromise will reduce the level of ambition by more than 95% compared to the Commission original proposal. I look favourably at the work ongoing in the European Parliament and I hope that we will be able to bring back a certain level of ambition here.

"In total, the renewables sector in Europe employs over 1 million people, attracts more investments than many other sectors, and has reduced our fossil fuels imports bill by €16 billion since 2005. On top of that, whereas in the past we used to see a clear link between energy consumption and GDP growth – with any rise in GDP only possible with an increase in energy consumption."

Also because by the end of the year we will adopt the post 2020 emission standards for cars and vans and, there, we are considering options to set a dedicated target for zero and/or low emission vehicles. And of course the availability of charging infrastructure is going to be essential for the penetration of these vehicles into the market.

I attach a lot of importance to two main elements: first, preserving the consistency between the different proposals of the Package and second, ensure that the legislation that we will adopt will be enforceable. ■

This is an edited version of a speech by the Commissioner that can be found here:
http://europa.eu/rapid/press-release_SPEECH-17-1721_en.htm

Miguel Arias Cañete
Commissioner for Climate Action and Energy
European Commission
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