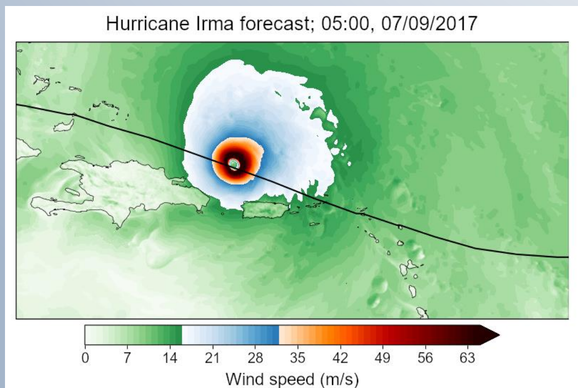
European Climate Prediction system

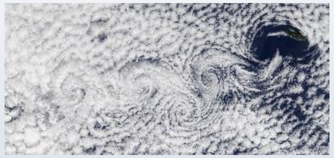
Outer-European domain simulations

The Caribbean is impacted by tropical cyclones, which can cause serious damage through high winds, heavy rain and storm surges. EUCP has investigated how effective high-resolution, convection-permitting climate models can be at simulating these dangerous phenomena. These are the latest generation of climate models covering specific regions with more spatial detail than earlier models

The models were able to simulate winds from Hurricane Irma accurately, with a well-defined structure and following the hurricane's observed path. Although hurricane activity shows a lot of natural variability, the models indicate a tendency towards higher maximum rainfall levels under future climate warming. Policies and planning for flooding, landslides and other impacts of hurricanes will need to take account of these projected changes.



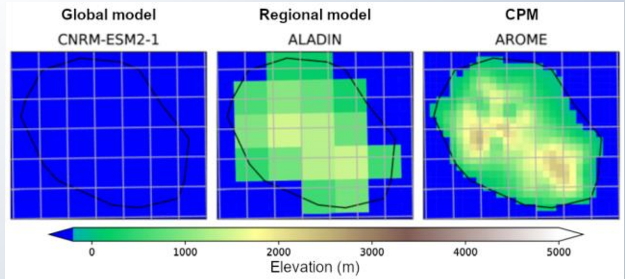
The weather and climate of the **Canary Islands** and **Madeira** are difficult to simulate owing to their small size and high mountains. This terrain can trigger extreme rainfall, as well as complex trains of atmospheric vortices. EUCP has used very high-resolution climate models to investigate this system.



The team found that higher-resolution models were able to resolve the vortex trains, as well as simulating the islands' rainfall in much greater detail than lower-resolution models. In the EUCP projections, the region is set to see less rainfall overall under climate change, however Madeira may see greater autumn rainfall. This is useful information for future water management and climate impact policy.

The island of **la Réunion** in the Indian Ocean has a steep, volcanic topography, producing complicated patterns of climatic conditions. This setting means that high-resolution modelling is particularly valuable for exploring how the island's climate may change.

EUCP's simulations show that global-scale models do not resolve the island at all, while higher-resolution models, in contrast, can pick out the islands two main volcanoes.



The high-resolution model can also simulate tropical cyclones in much greater detail. The simulations indicate that the island's surface temperature is set to increase under climate change, while maximum river flow could increase by 30%, increasing flood risk.

Policymakers can use these findings to justify effective policies to reduce the impact of climate change, while the results are also useful to scientists engaged in modelling the complicated climates around small islands.

Outer-European domain simulations

A new generation of climate models known as 'convection permitting models' (CPMS) are providing a step change in our ability to simulate changes in high-impact weather extremes.

Providing new regional climate projections using these models is at the heart of EUCP. Our scientists have generated the first multi-model ensemble of CPM simulations, covering the European continent as well as some of the EU's outermost regions These new high-resolution projections offer better information about future extreme weather events such as storms, informing efforts to adapt to them and reduce their impact.

What are Convection-Permitting Models?

Convection-Permitting Models (CPMs) are very high-resolution climate models, using a grid size usually of 5 km or less. This allows them to simulate atmospheric convection, a key process in many extreme weather events such as extreme windstorms, extreme rainfall and tropical cyclones.

These high-resolution simulations also have specific advantages for simulating important detail relevant for Europe's outermost regions, such as cyclones and extreme rainfall. This report describes the advancements EUCP has made in generating and applying these cutting-edge simulations in the outermost regions, focussing on three areas: La Réunion, the Caribbean, and the Canary Islands and Madeira.

La Réunion

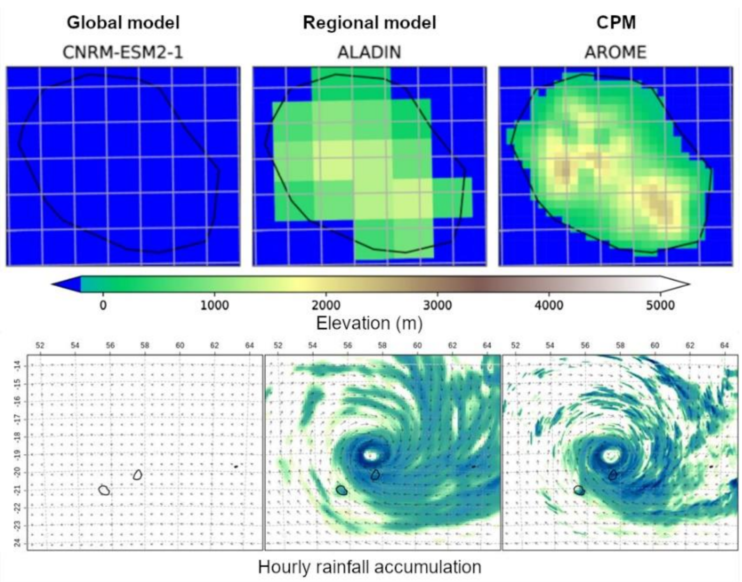
The Indian Ocean island of la Réunion is a small but densely-populated volcanic island with a particularly steep topography. The island's tropical climate is characterised by its great variability, mainly due to its imposing landscape, with the eastward half of the island being very much wetter than the western. This makes projections of climate impacts difficult, and high-resolution models are required to achieve sufficient detail.

The island of la Réunion. Credit: Airbus DS, 2014

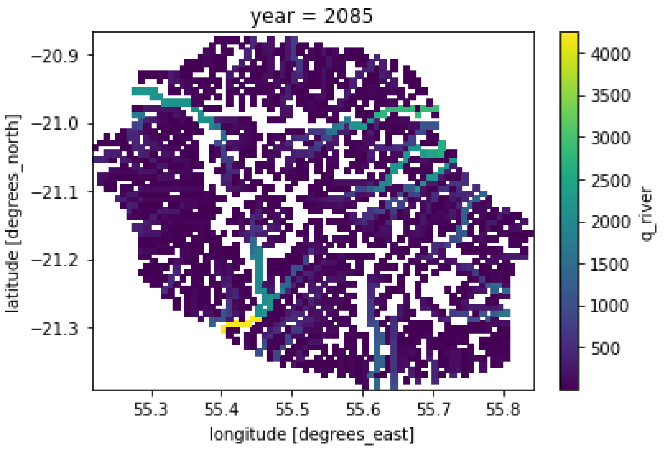
To meet this need, EUCP has run climate simulations at several resolutions to determine the benefit of the added detail, focussing on extreme rainfall and tropical cyclones. Two 20-year long simulations of Réunion's climate, one for 1991-2010 and one for 2081-2100 were used to also capture the impact of climate change.

The simulations clearly demonstrate the benefits of increased model resolution for small islands. La Réunion does not appear in the global simulations at a resolution of around 100 km. The regional model however, with a resolution of around 12 km, does resolve the island. The CPM, at a resolution of around 2.5 km, not only resolves the island's overall shape, its two principal volcanoes can be distinguished. The CPM is also able to resolve tropical cyclones in much greater detail.

EUCP also demonstrated that the improved information from these high-resolution simulations can be applied to river-flow models to provide better information about future river flow. This pilot study suggests that maximum river discharge could increase by 30%, potentially significantly increasing the risk of flooding. These results are key to informing effective climate policy, helping the island prepare for future climate impacts.



Simulations at different resolutions, showing topography (top) and hourly rainfall accumulation from a cyclone (bottom). The global model (CNRM-ESM2-1) does not resolve either properly, the regional model (ALADIN) returns some results, while the CPM (AROME) shows a much greater level of detail.



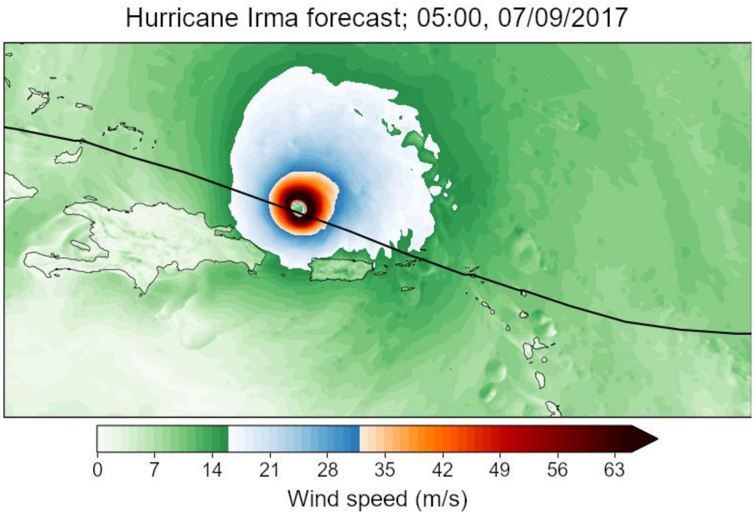
CPM projections of flow models showing river discharge for extreme flood years in future (2085) climate simulations.

The Caribbean

Hurricanes Katia, Irma and Jose in the Caribbean, September 8th, 2017. Credit: NOAA

Tropical cyclones are a serious hazard in the Caribbean region, bringing damaging winds, storm surges and heavy rainfall, which can lead to dangerous landslides and flooding. Cyclones have a complex small-scale structure, exactly the type of feature that can benefit from high-resolution modelling.

EUCP investigated the potential of using high-resolution models in this setting. Four CPMs and two lower-resolution regional climate models were used to create the simulations using a pseudo-global warming approach. This involves simulating past years with high cyclone activity and comparing them to other simulations with an artificial change added to their climatic variables, in the direction expected under climate change. This approach is necessary to overcome the high variability seen in historical cyclone activity and the issues this causes in picking out an effect of climate change in simulations. Altogether, this constitutes the first multi-model, convection-permitting climate simulation ensemble for the Caribbean.



Hourly wind speed simulation of Hurricane Irma. The observed track from IBtrACS is indicated by the black line.

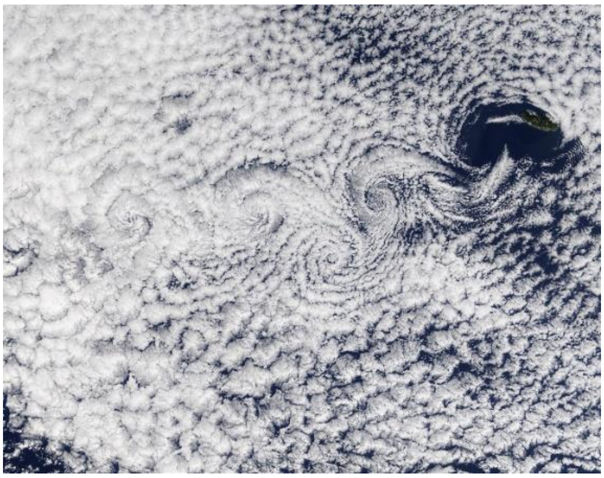
The team have used this ensemble to look at wind speed extremes, cyclone damage potential and rainfall. The ensemble can simulate winds from 2017's Hurricane Irma very well, showing a clear eye to the storm and following the hurricane's observed track accurately (see right). This shows the simulations are suitable for assessments of storm impacts.

The simulated cyclones still displayed a large degree of variability, including under pseudo-global warming. There is no guarantee from these simulations that every cyclone will become more intense under climate change, indeed most seem to weaken. However, all the models in this ensemble indicate a tendency towards higher maximum rainfall levels in future as the climate continues to warm. This could worsen impacts from flooding and land movement.

Canary Islands and Madeira

The Canary and Madeira islands in Macaronesia present significant challenges to skilful climate prediction owing to their small size and high topography, which can trigger extreme rainfall events. A notable feature of their local weather is vortex streets, caused by wind being disturbed as it passes over an island and producing a repeating line of vortices in the island's wake. EUCP set out to find out how well CPMs could resolve these features.

Like the results for la Réunion, higher-resolution models simulated rainfall over the islands more accurately and in much greater detail. Macaronesia shows a decrease in annual rainfall under climate change, however Madeira's rainfall is shown to increase in autumn. This is influenced by large-scale variability such as the North Atlantic Oscillation, so further simulations are required to confirm the result's robustness, but it is still useful in preparing effective policy to limit the impact of extreme autumn rainfall and manage water supplies.



A vortex street streaming slightly southeast of Madeira Island. Credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC

The CPM was also able to simulate the vortex street phenomena near Madeira, demonstrating the benefits of using CPMs to simulate this important process around oceanic islands.

This new capability still presents some science challenges as CPMs still require too much computing capacity to allow us to run large enough ensembles to provide uncertainty information. In EUCP we have demonstrated how individual CPM simulations like this one can be used alongside wider uncertainty information from constrained global model ensembles to provide wider uncertainty context.