Can a neural network learn about physics?

Using Explainable AI to Understand Heavy Rainfall Predictions.

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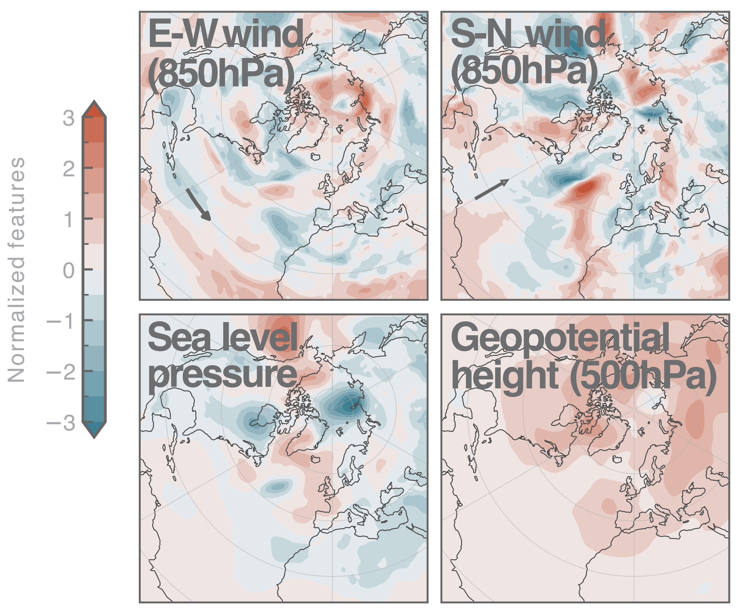
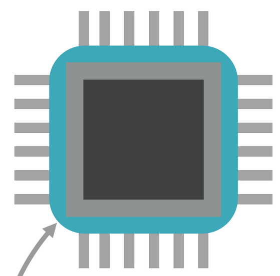
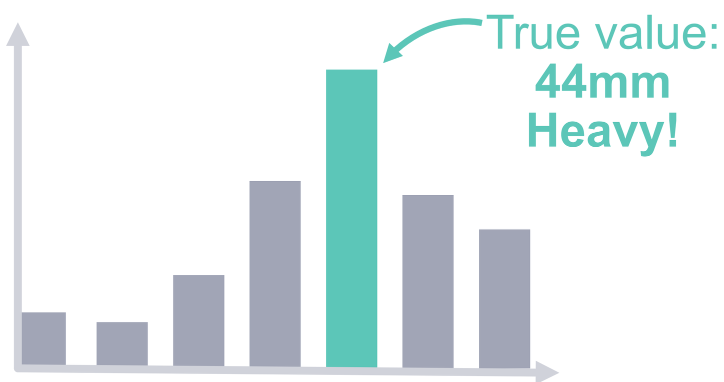
Introduction

1 A neural network **can** predict heavy rainfall events





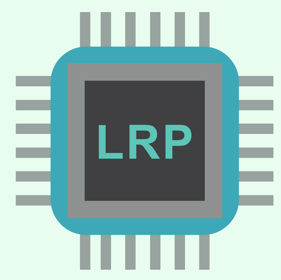
Convolutional neural network with 5 convolution layers.



The NN predicts very high probability of heavy rainfall in **4 days** (2016-08-09).

2 We want to know if the decision is **based on physically meaningful signals**.

Step 1: identify which areas influence the predictions



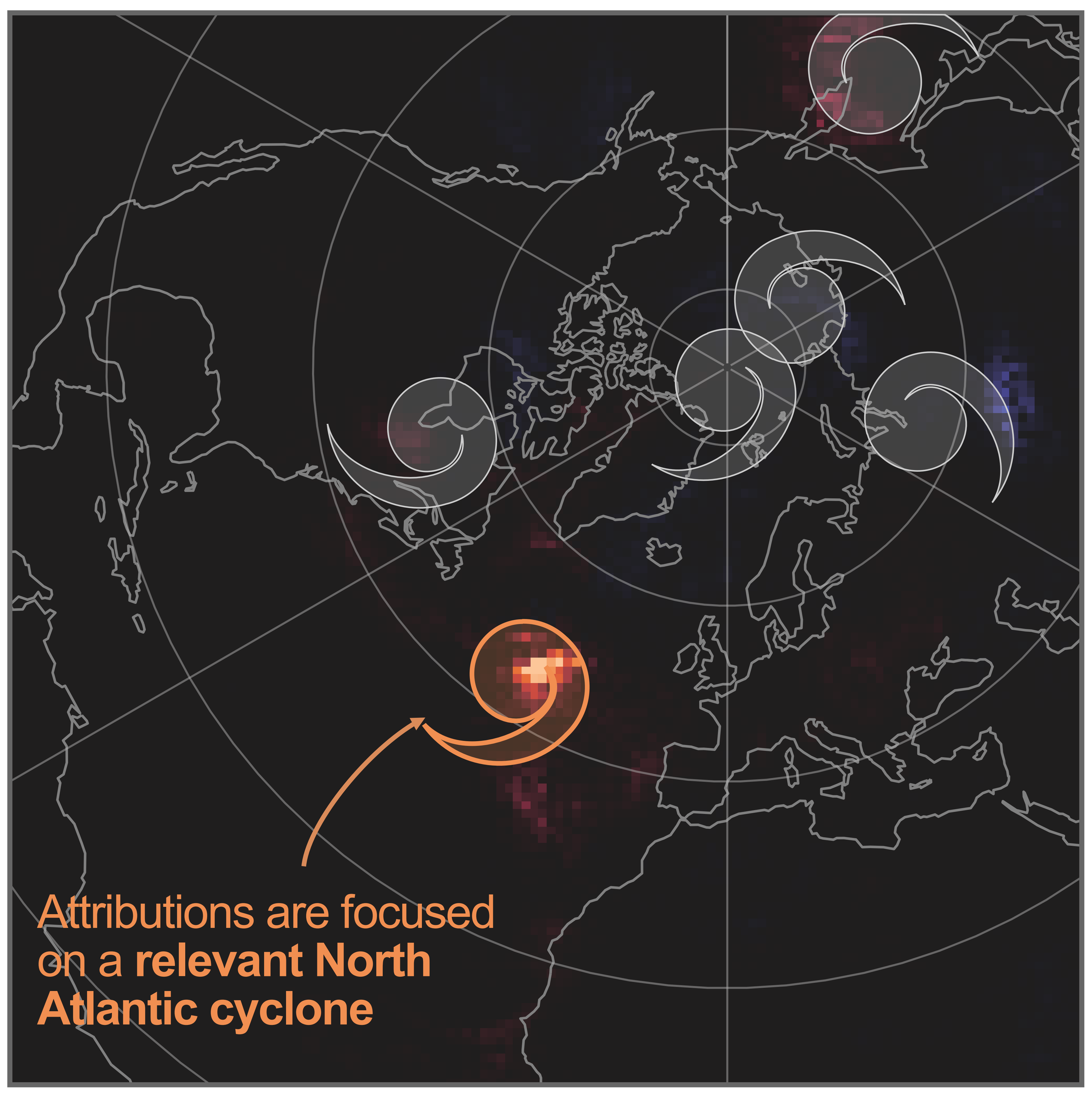
Layer-wise Relevance Propagation is used to determine which pixels contributes to the prediction with **attribution maps**.

Step 2: compare with known physical drivers

Heavy rainfall in Western Norway is mainly caused by **North Atlantic cyclones.**

This neural network uses cyclones to predict heavy rainfall events in Western Norway

3 Case study of a used cyclone



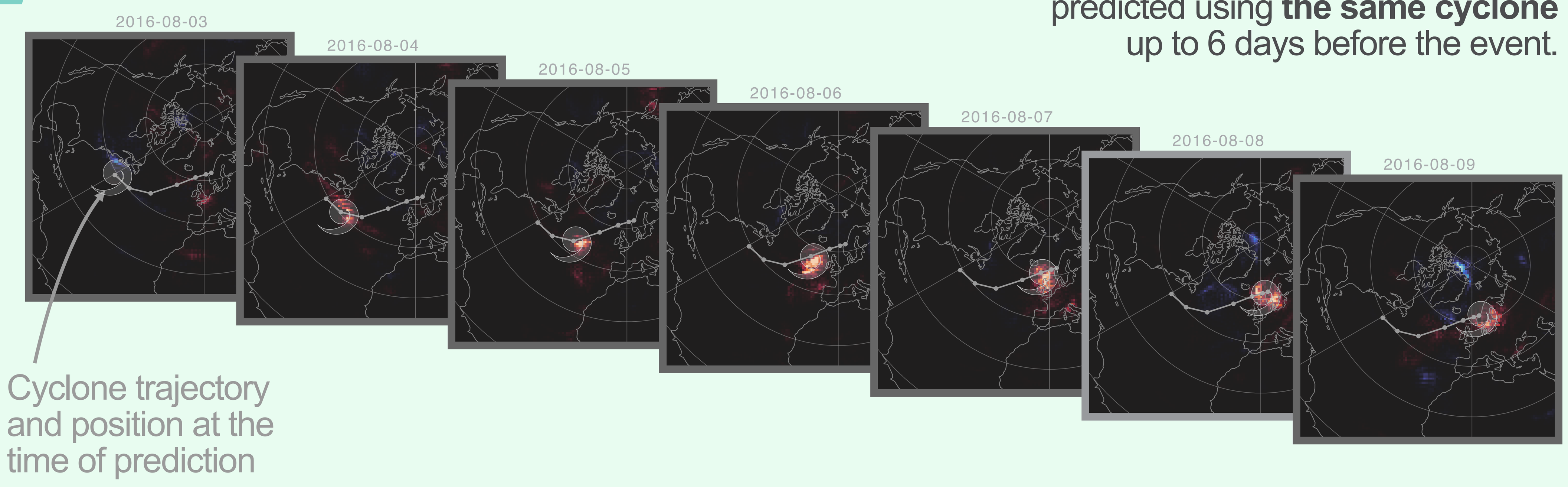
August 9th, 2016 heavy rainfall event predicted 4 days earlier (August 5th, 2016).

LRP attribution map:
Contribution of pixels to prediction
Negative Positive

Cyclones detected with the Melbourne algorithm:

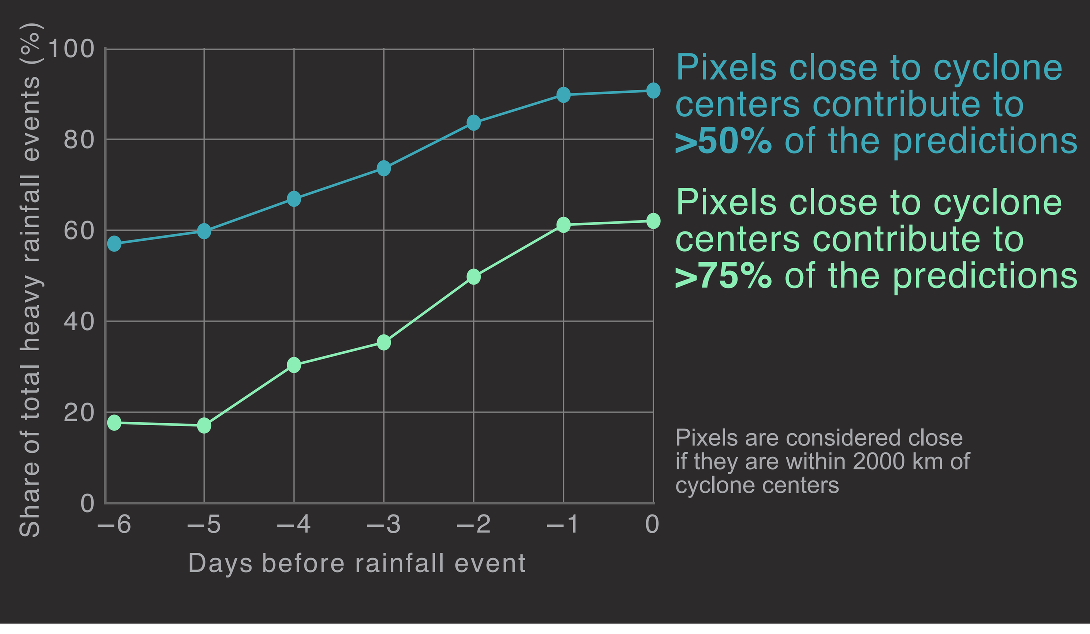
4 Is it consistent across lead times?

The same heavy rainfall event is predicted using **the same cyclone** up to 6 days before the event.

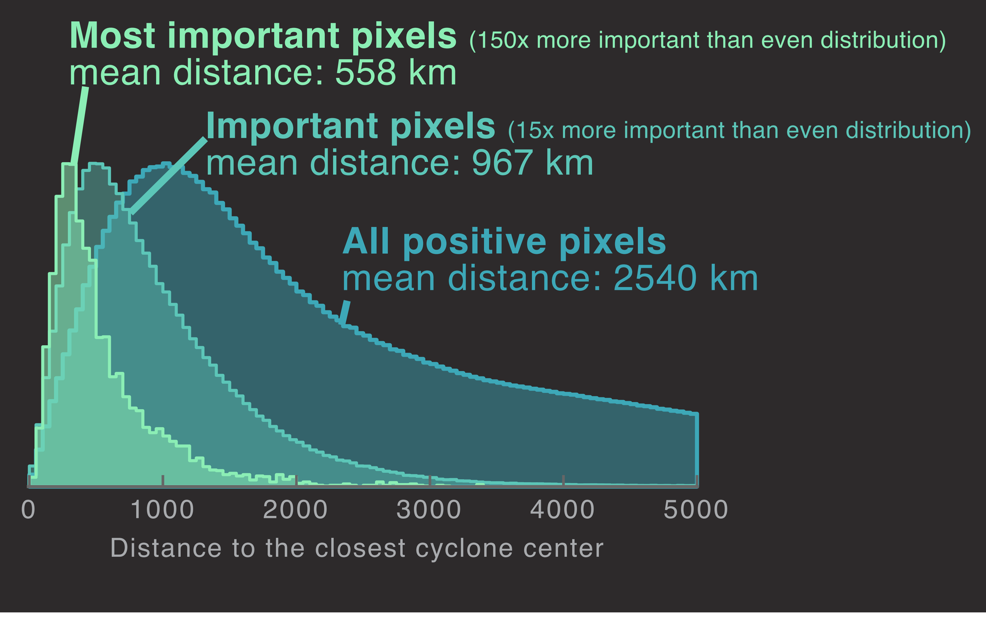


5 Is it generalizable to all predictions?

Are pixels around cyclones enough to explain the predictions?



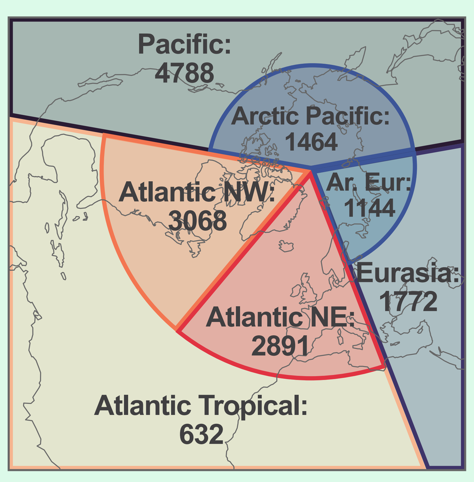
Are the strongest pixels closest to cyclone centers?



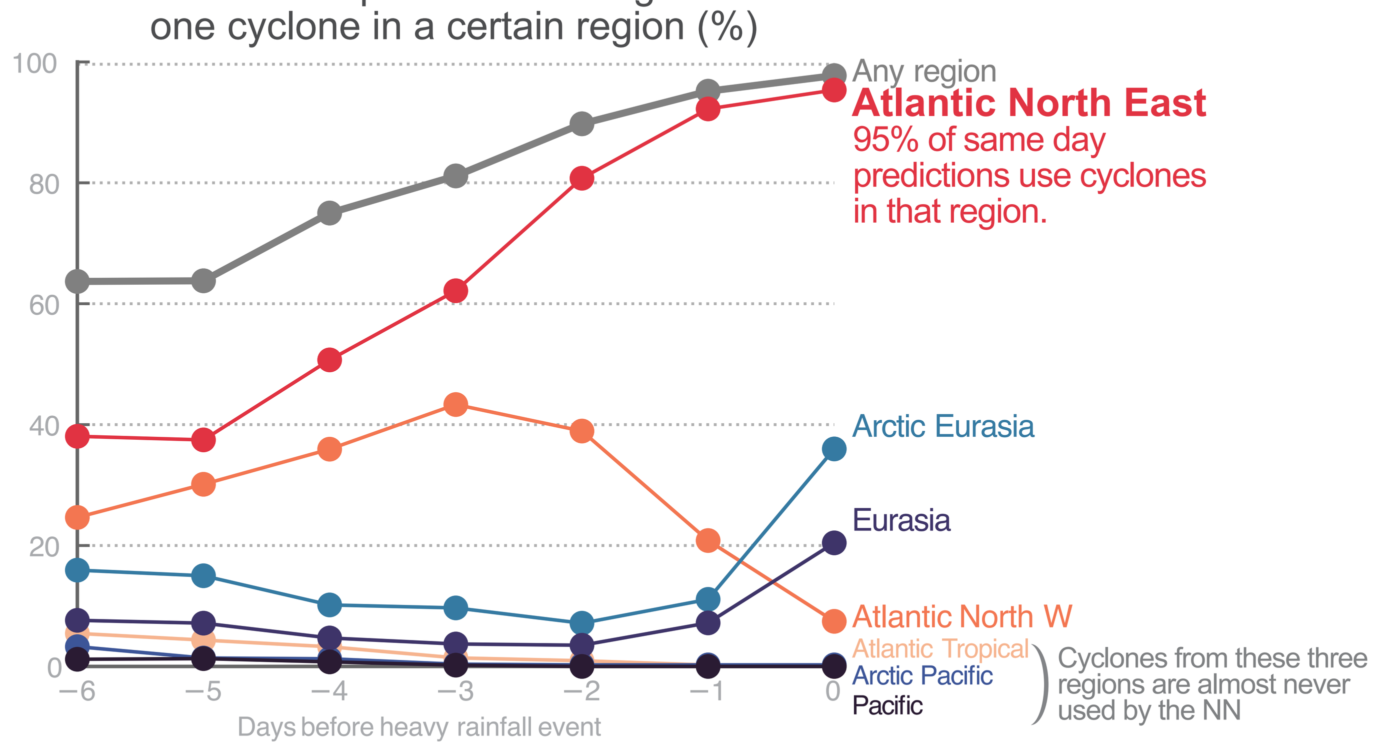
The neural network focuses on North Atlantic cyclones

6 Where are the cyclones used by the neural network?

Regions studied and total number of cyclones per region.



A cyclone is considered **"used by the NN"** if 30% of all attributions are within 2000km of its center.



Conclusion and perspectives

1. We show the ability of a neural network to learn about physics: here our network correctly learned the physical importance of **North Atlantic cyclones** for heavy rainfall in Western Norway.

2. Heavy rainfall in Western Norway is an "easy" case, as there is **one main physical driver,** but can a similar network learn physics in other, more complex situations?

3. This is a proof of concept on a simple neural network. We can build on this work to create **physical benchmarks** for more advanced AI weather prediction models, like *Pangu*, *GraphCast* or *AIFS*.

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