Machine Learning as a tool for positive impact :
case studies from climate change

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Tackling Climate Change with Machine Learning

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www.climatechange.ai

Solar Geoengineering

+ **Understanding and improving aerosols: design** — Long-Term

+ **Understanding and improving aerosols: modeling**

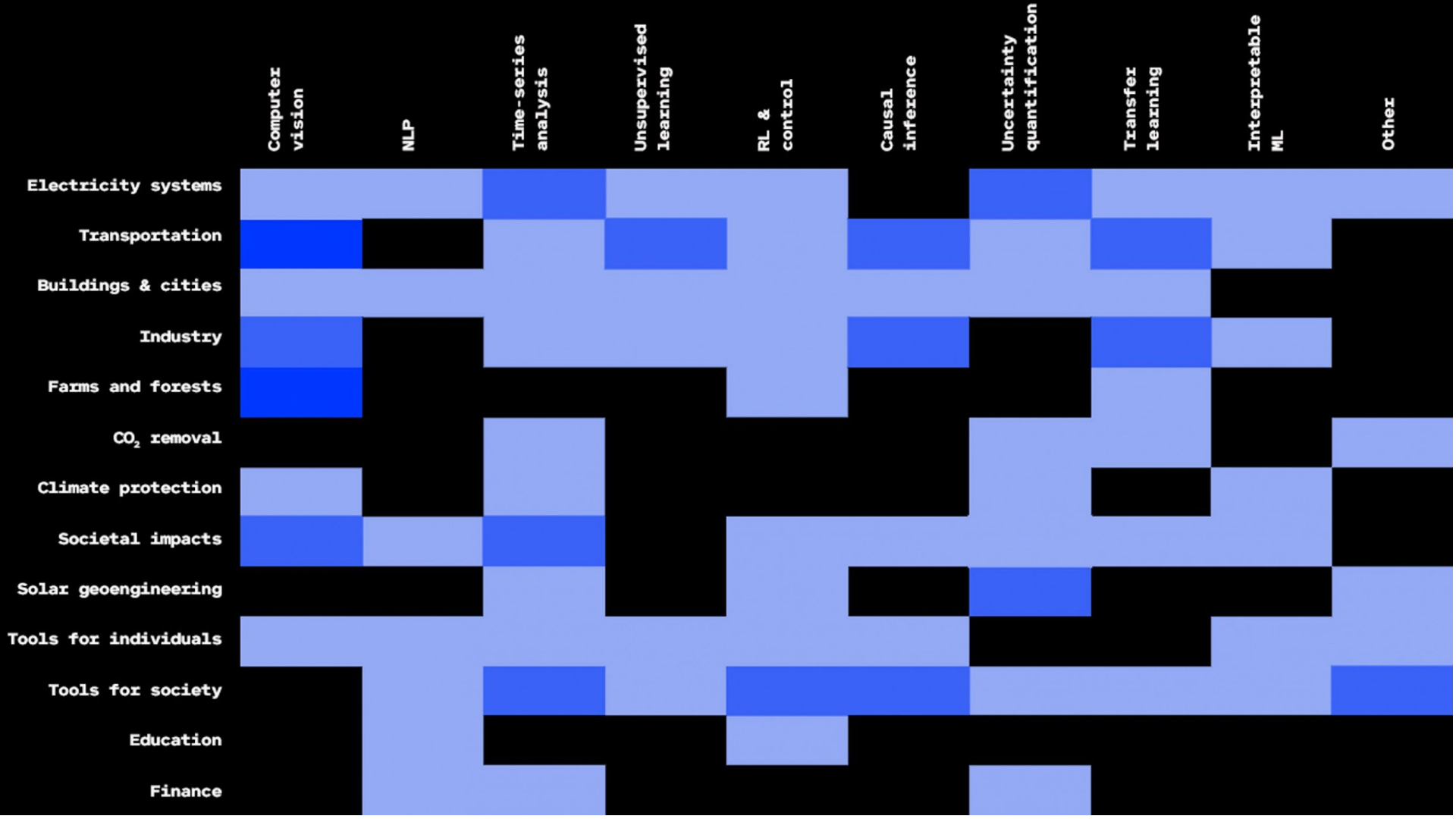
+ **Engineering a planetary control system** — High Leverage, Long-Term, Uncertain Impact

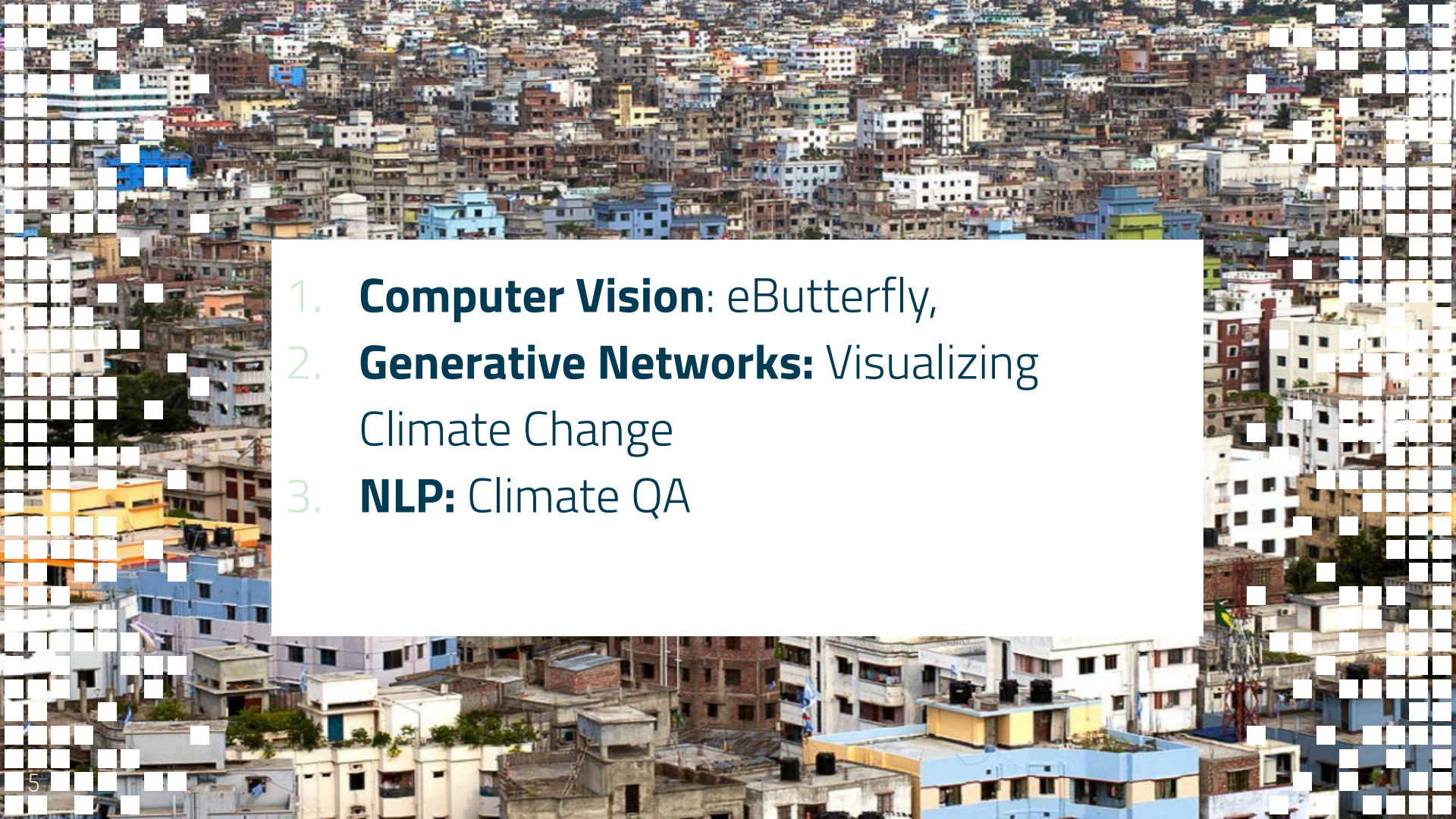
+ **Modeling impacts** — Long-Term

Individual Action

+ **Understanding personal carbon footprint**

+ **Facilitating behavior change** — High Leverage

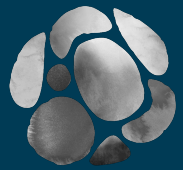

Computer vision
NLP
Time-series analysis
Unsupervised learning
RL & control
Causal inference
Uncertainty quantification
Transfer learning
Interpretable ML
Other
Electricity systems
Transportation
Buildings & cities
Industry
Farms and forests
CO_2 removal
Climate protection
Societal impacts
Solar geoengineering
Tools for individuals
Tools for society
Education
Finance



1. **Computer Vision**: eButterfly,
2. **Generative Networks:** Visualizing Climate Change
3. **NLP:** Climate QA

Using Spatiotemporal Features for Butterfly Classification

MARTA SKRETA, SASHA LUCCIONI, DAVID ROLNICK



espace pour la vie montréal
insectarium

Climate Change and Butterflies

BUTTERFLIES

Temperature/weather impact

Indirect via habitat loss

ECOSYSTEM

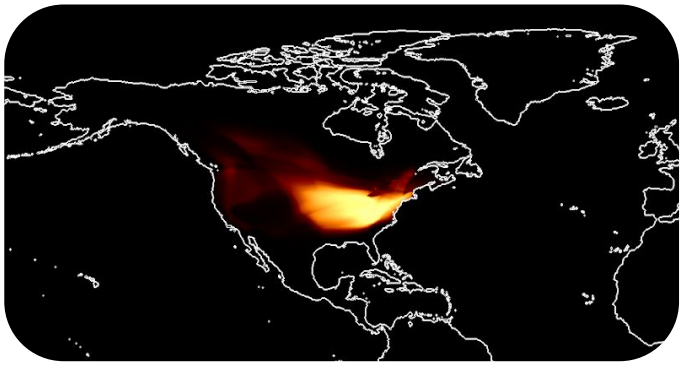
Predators of butterflies/caterpillars

Plants that butterflies pollinate

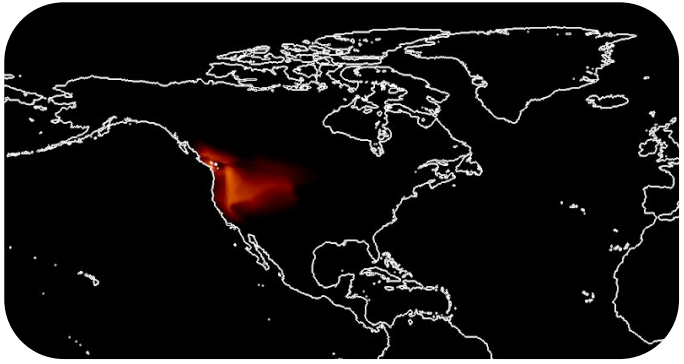
eButterfly project

- **> 400,000 observations** in North America by **citizen scientists**
- **> 600 species**
- **Difficult to label** images by hand
- **Machine learning** can be useful

S. cybele



S. zerene



Can we use **WHERE** and **WHEN** the image was taken to improve classification?

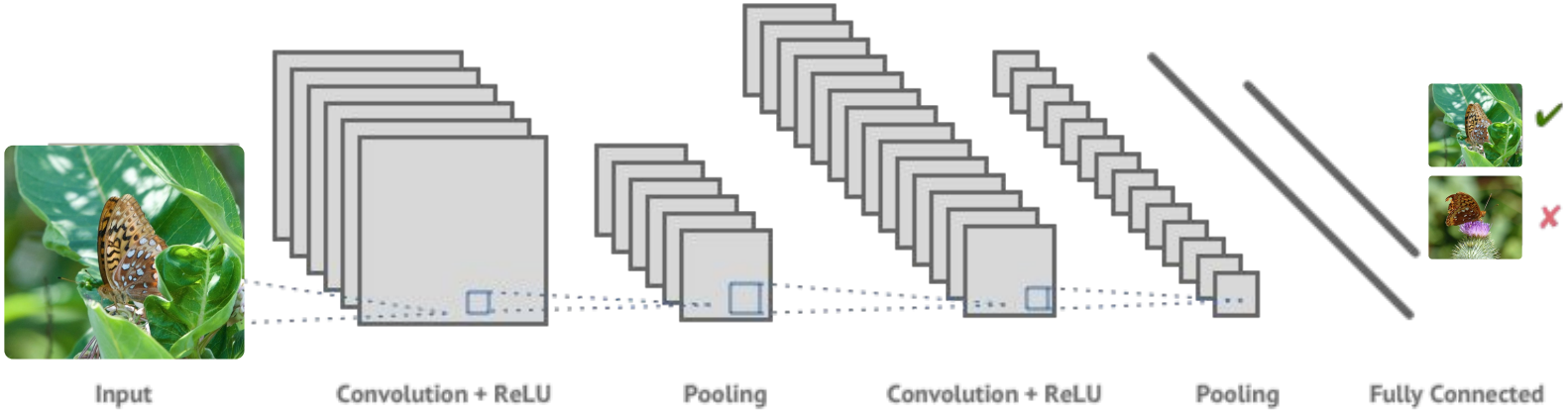
Related work

- Networks **trained** on images and geo-coordinates **together**[1]
  - Assumption that test sample has location
  - Can't learn from spatiotemporal information that doesn't have image
- **Bayesian approach:**

  Train image and spatiotemporal **models separately, combine them at test time**[2]
  - Successfully used to classify birds & other animals
- Image-only classifiers have been built for butterfly identification[3]

[1] Chu et al. Geo-aware networks for fine-grained recognition. ICCV 2019
[2] Aodha et al. Presence-only geographical priors for fine-grained image classification. ICCV 2019
[3] Kantor et al. Guided attention for fine-grained and hierarchical classification. 2020

Encoding images



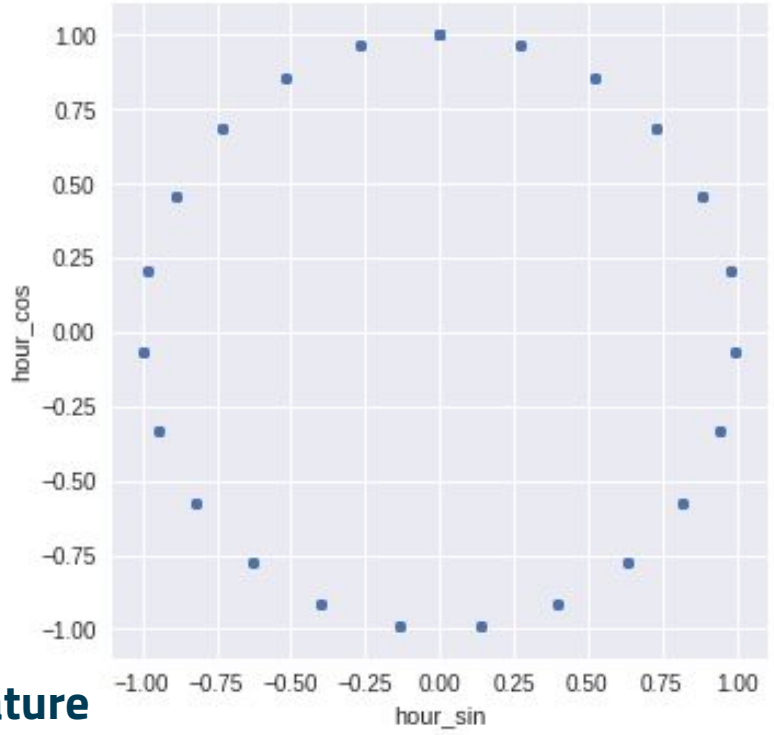
We used a **Convolutional Neural Network** for detecting both high-level and fine-grained features on the images.

Encoding Date and Time

We transform cyclical data into two dimensions using a sine and cosine transformation.

$$x_{sin} = \sin\left(\frac{2*\pi*x}{\max(x)}\right)$$

$$x_{cos} = \cos\left(\frac{2*\pi*x}{\max(x)}\right)$$



We found that this helps the network **learn feature representations** and **improves accuracy**

TRAIN TIME

Image, **I**

ResNet-50 CNN

P(y|**I**)

(lat, lon, date)

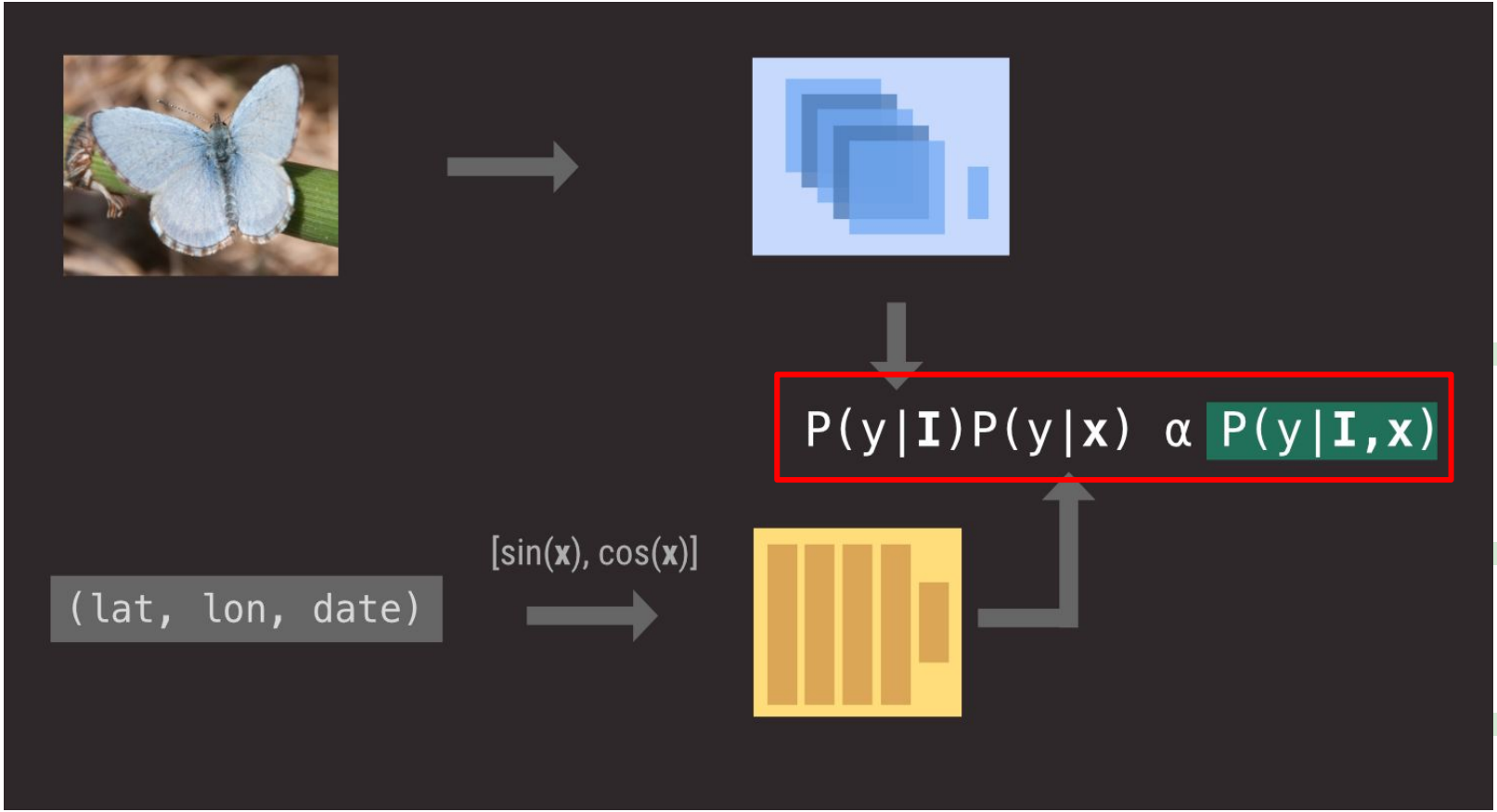
Spatiotemporal features, **x**

[sin(**x**), cos(**x**)]

Spatiotemporal encoder

P(y|**x**)

TEST TIME



Accuracy	Image only	**Image + (Lat, Lon, Date)**
Top 1, Micro	84.56	**86.53**
Top 1, Macro	59.87	**65.65**
Top 3, Micro	93.84	**95.38**
Top 3, Macro	77.53	**83.74**

Micro accuracy: total correct/total number samples

Macro accuracy: average of species accuracies

Project takeaways

```
input:::Danaus plexippus
-----top 5 closest species-----
Danaus plexippus
Limenitis archippus
Papilio polyxenes
Papilio glaucus
Vanessa virginiensis
```

- The system we developed is already **deployed** on the **eButterfly website** and in a **mobile application**
- We helped **citizen science,** facilitating tracking butterfly biodiversity in North America
- We **improved existing approaches** in fine-grained image classification by leveraging geospatial information *(NeurIPS 2020 workshop)*

ButterflAI

Mila

espace pour la vie montréal insectarium

Visualizing Climate Change with Generative Models

SASHA LUCCIONI, VICTOR SCHMIDT, YOSHUA BENGIO....

- Historically, climate change has been an issue around which it is **hard to mobilize collective action**
- Researchers studying this phenomenon have systematically observed that climate change communication arises from:
  - messages that are **emotionally charged** and **personally relevant**
  - images in particular
- Many of the traditional forms of communication that are used by experts to communicate to the public are often based on **scientific reports**
- These can fail to communicate the **urgency** and **importance** of this monumental phenomenon

- The aim of this project is to use **Artificial Intelligence** to create a **tool** to **raise awareness** with regards to the impacts of climate change.
- We focus our work on 3 common and visually striking climate-related extreme events: **floods, wildfires, smog**
- The goal is to create a website allowing users to query an address, of which we can fetch a first-person picture using Google StreetView and transform this image
- By showing people what those events look like, we aim at creating **empathy** towards regions and the **motivation** to **change behaviors**

Two-step Generative Approach

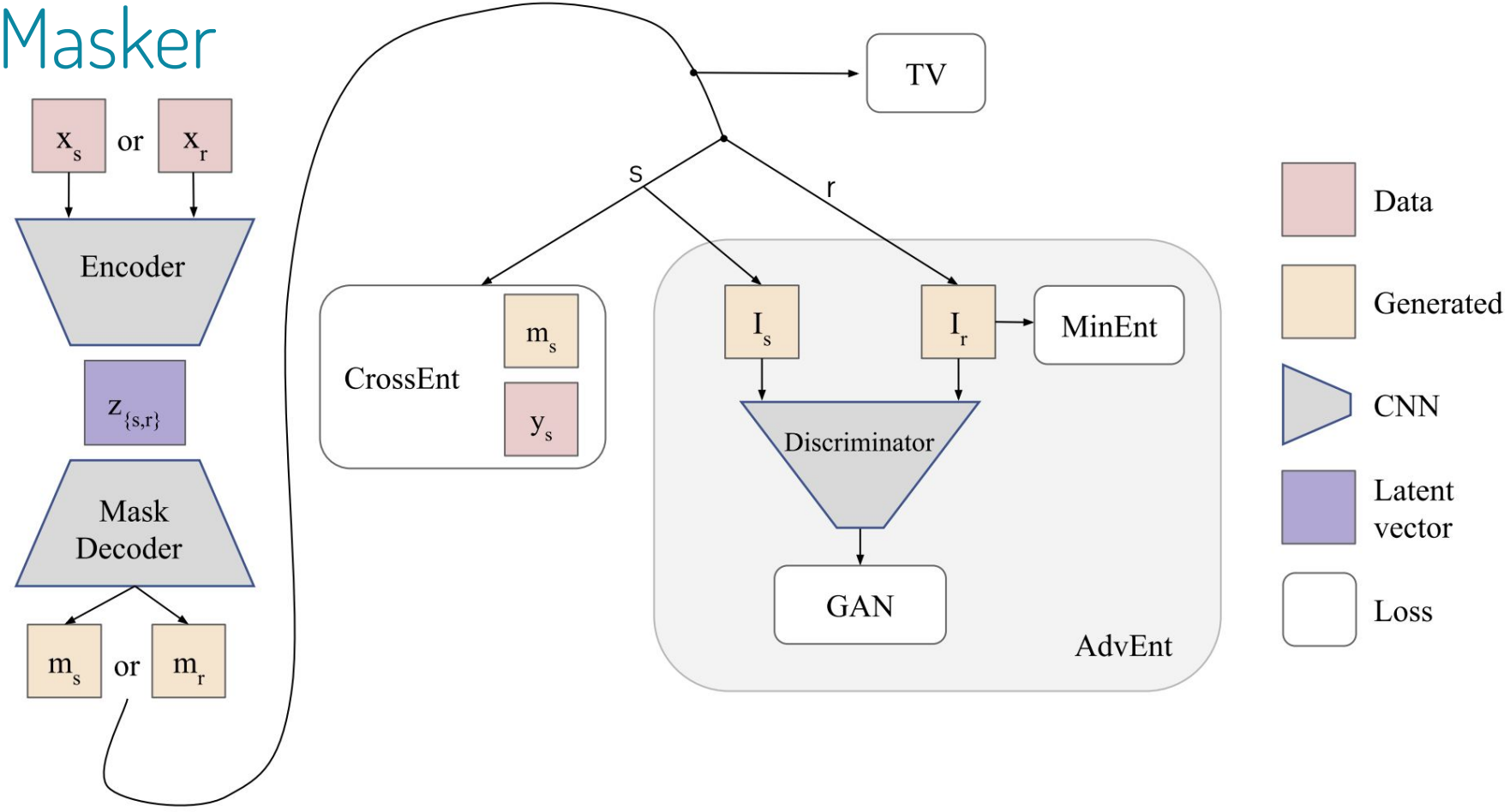
- We started with representing **floods**
- We adopted a two-step generative approach:
  - a model producing a binary mask in charge of describing where the water should go,
  - a model focusing solely on rendering realistic water given a mask and an image
- This is due to the fact that floods only affect part of the image (the ground), and leave buildings and sky intact.

Data

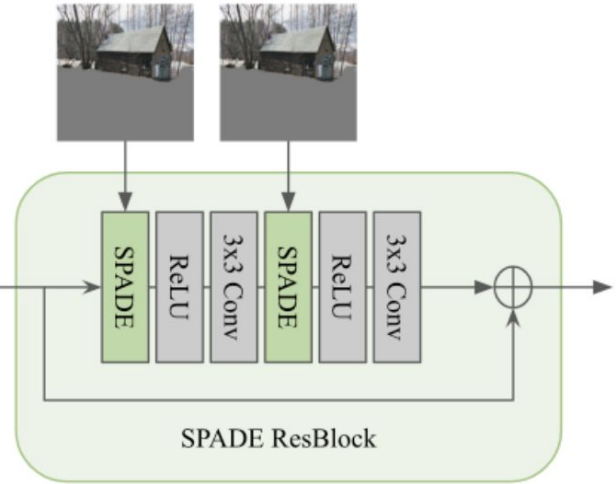
- Our **real dataset** is a collection of images from various sources, mainly collected from Street View and Cityscapes
- We selected images representative of urban, suburban and rural areas for a total of 2900 images.
- Our **simulated dataset** is collected from a 1km2 world custom created using Unity3D.

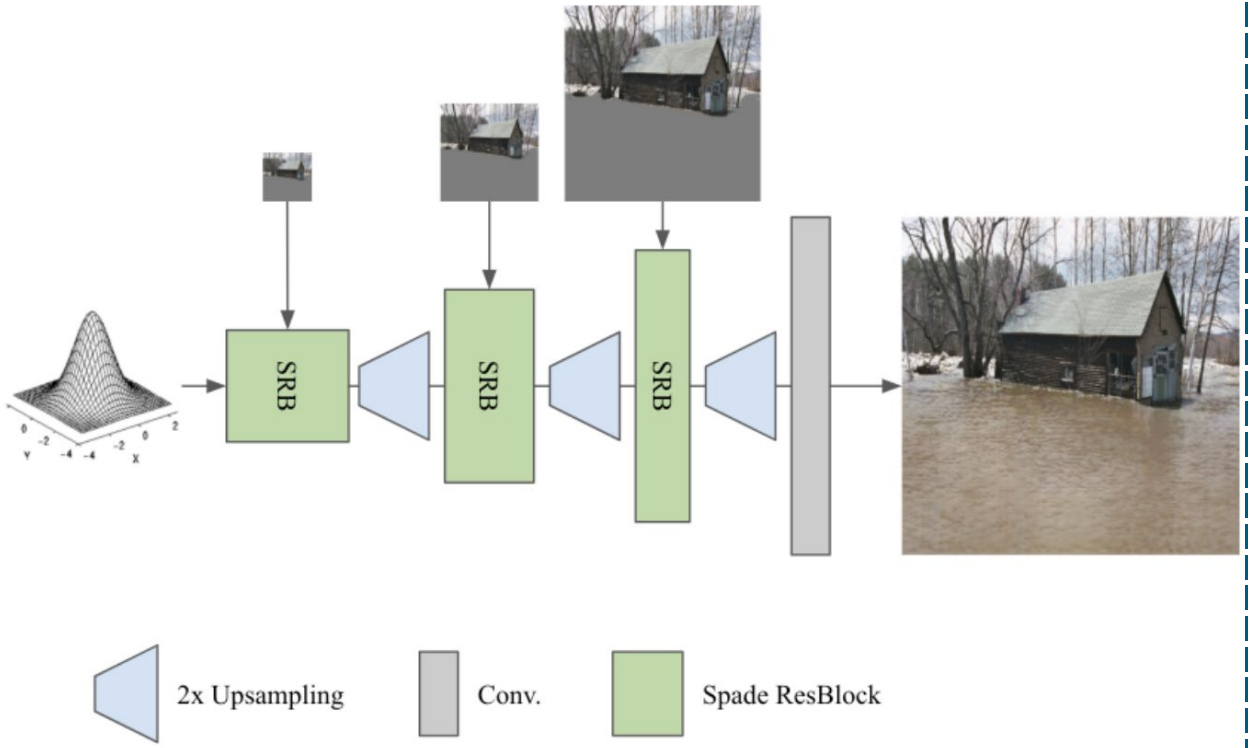
Generative Adversarial Networks

Masker


x_s
or
x_r
Encoder
$z_{\{s,r\}}$
Mask Decoder
m_s
or
m_r
TV
s
r
CrossEnt
m_s
y_s
I_s
I_r
MinEnt
Discriminator
GAN
AdvEnt
Data
Generated
CNN
Latent vector
Loss

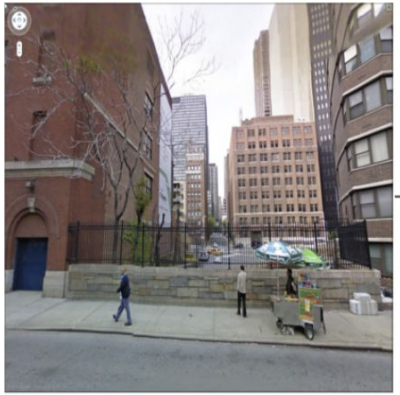
Painter


SPADE
ReLU
3x3 Conv
SPADE
ReLU
3x3 Conv
SPADE ResBlock


SRB
SRB
SRB
2x Upsampling
Conv.
Spade ResBlock

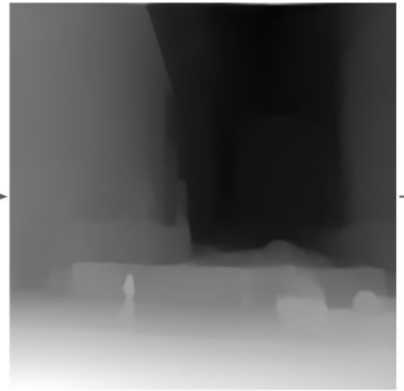
Results

Results



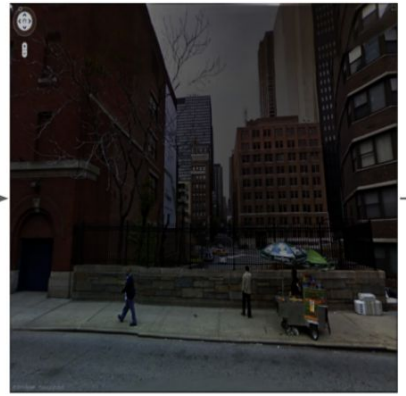
Input image

1. Infer pseudo-depth map

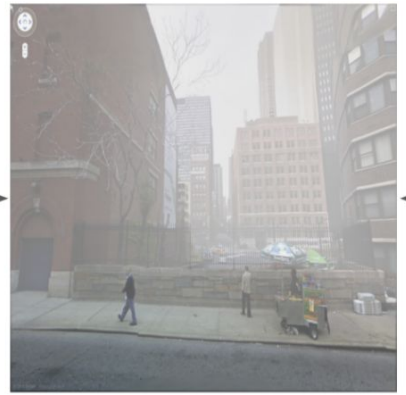


2. Compute transmission

3. Scale by airlight (0.76)



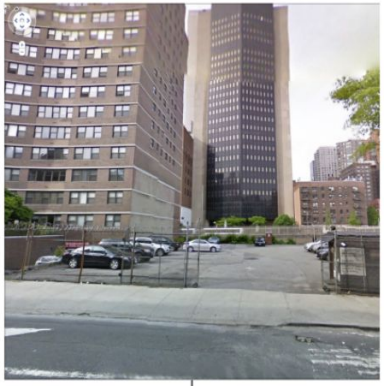
4. Compute input irradiance

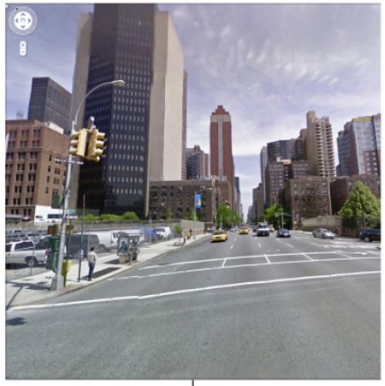


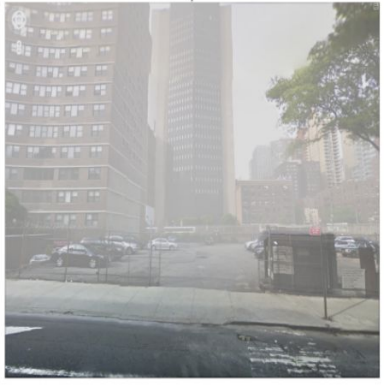
5. Weighted sum of 3 and 4

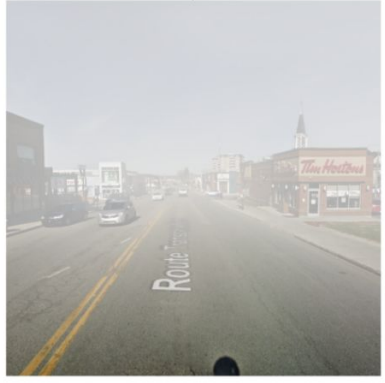
Smog

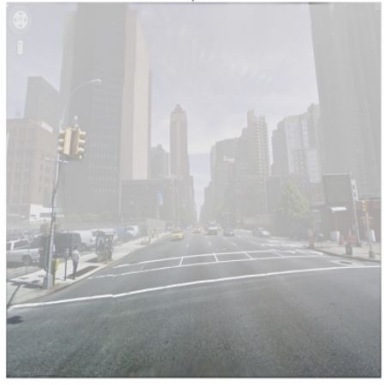
Results











Input image

1. Increase contrast

2. Darken picture

3. Warm picture

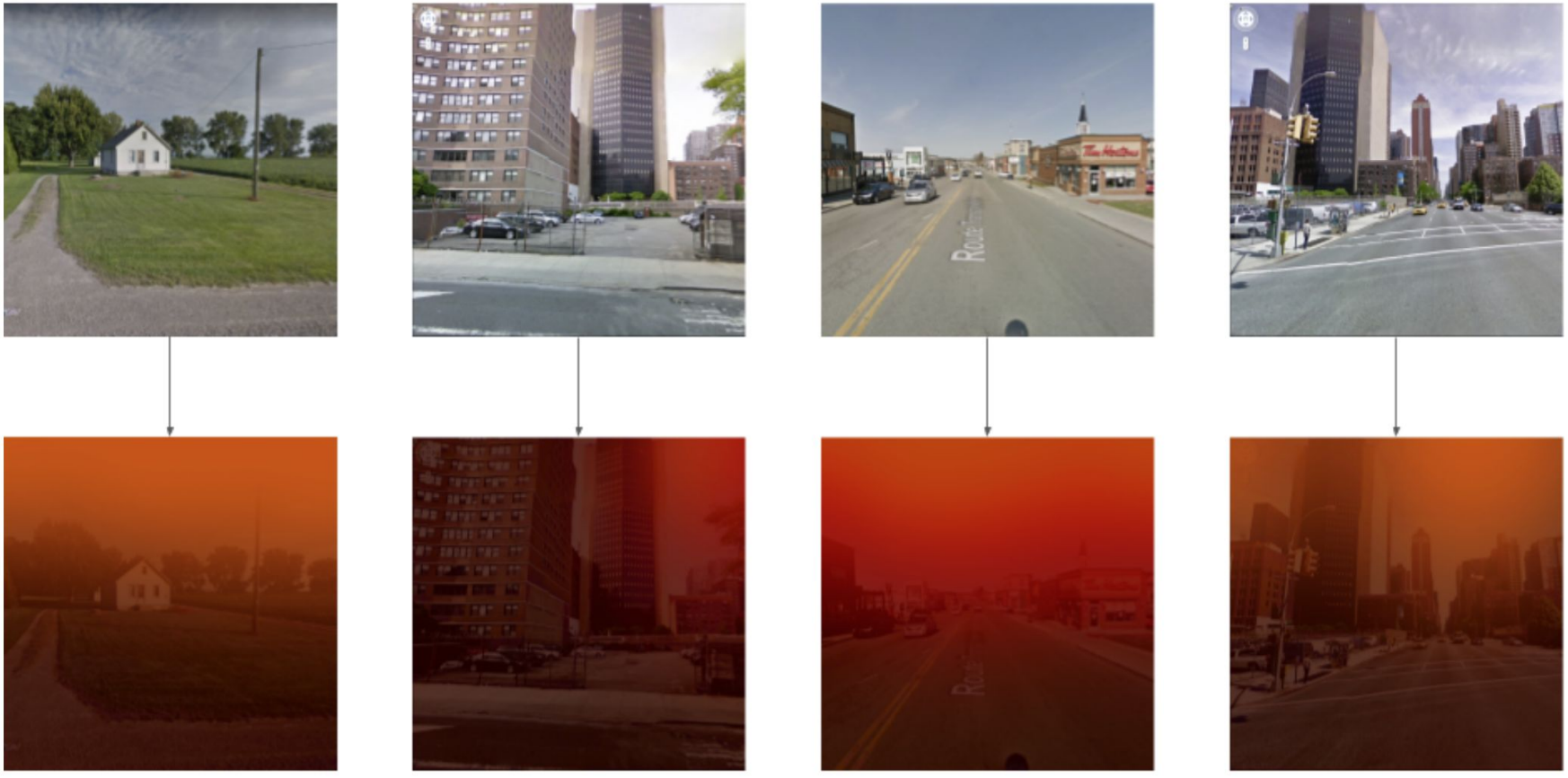
4. Segment sky

5. Increase seg map

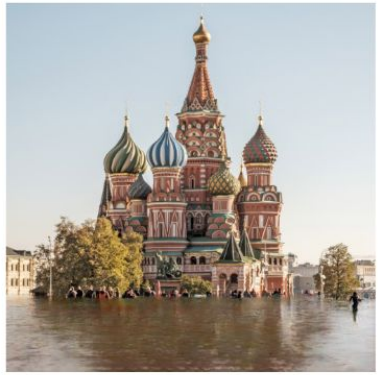
6. Add Gaussian blur

Wildfire

Results



These images
are generated by
artificial intelligence (AI)



But the environmental
disasters they portray
are very real

Can you imagine these kinds of disasters happening in your own backyard?

Scroll

These flood images are AI-generated and do not exist, but the environmental disaster they portray is very real.

This Climate Does Not Exist

Introduction

6666 Rue Saint-Urbain, Montréal, QC H2S 3H1, Canada

Try another address

Environmental Impacts

Learn more...

Your visualization

Flood

Wildfire

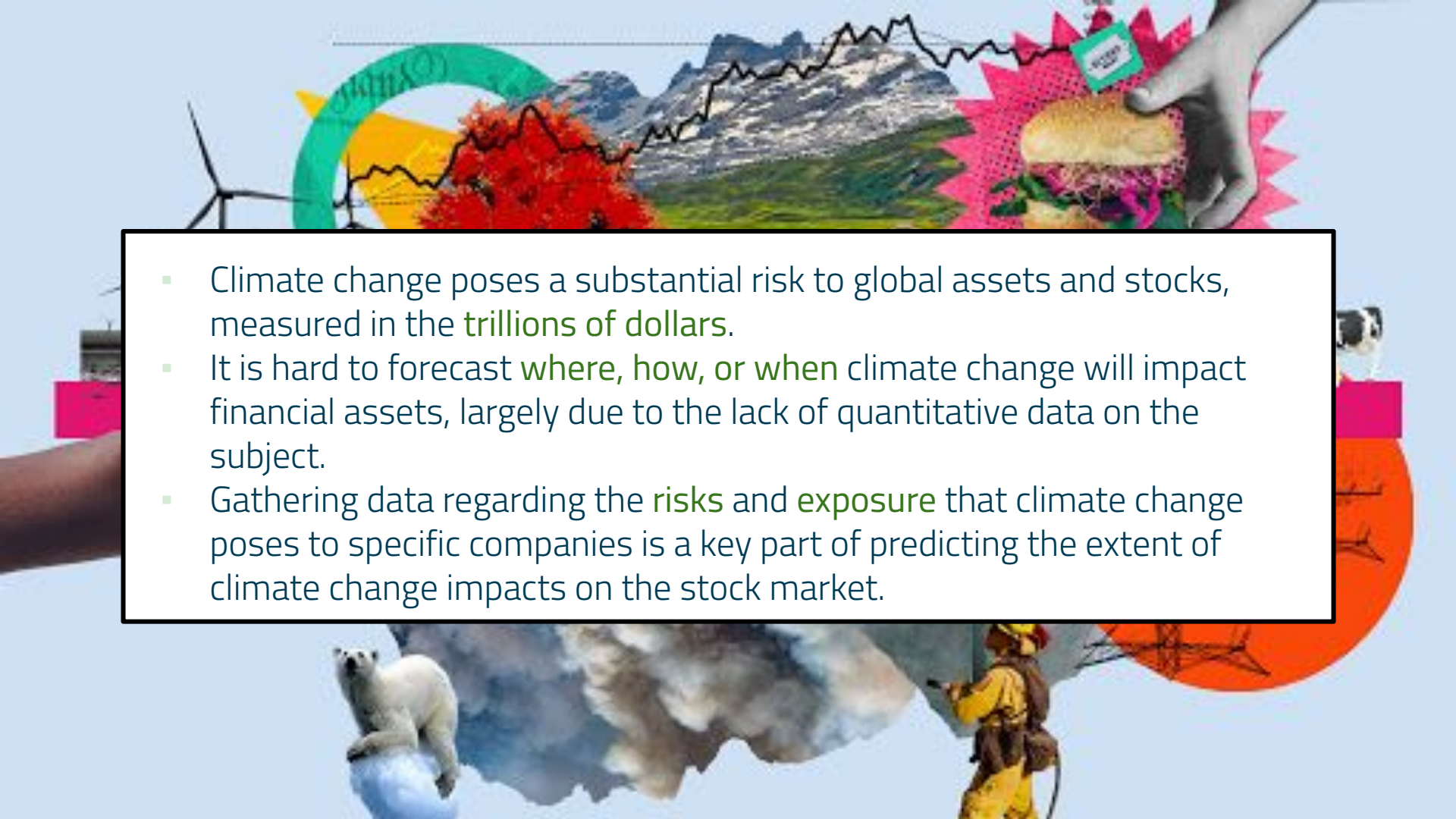
Smog

While it is impossible at this time to predict when or whether this phenomenon could affect this location, we should all be concerned about the high probability of it happening to thousands or millions of people around the world.

Human activity has the greatest impact on current rates of global heating. Click on "What now?" to find out what you can do about it.

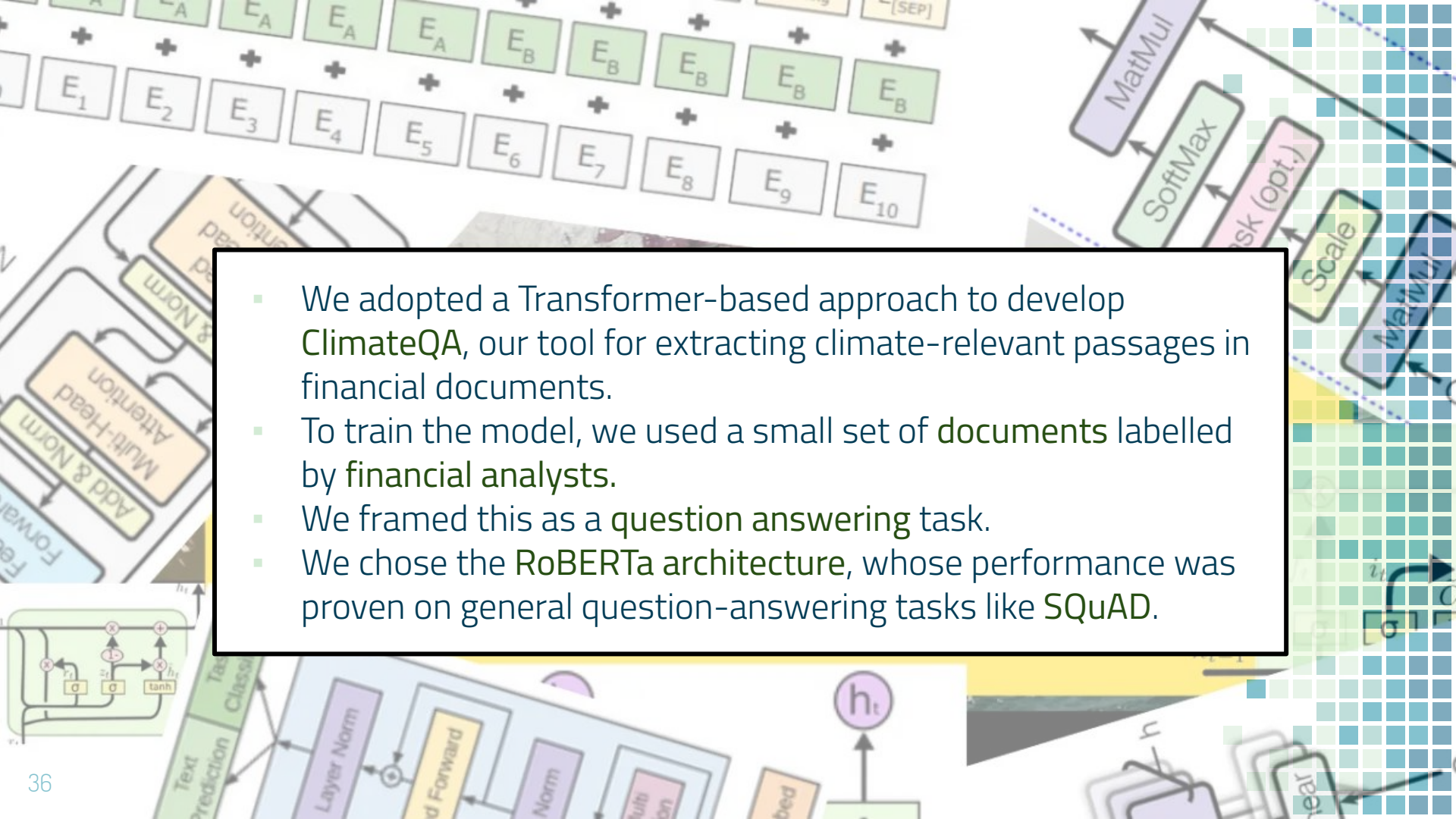
ClimateQA

SASHA LUCCIONI, EMILY BAYLOR, NICOLAS DUCHENE



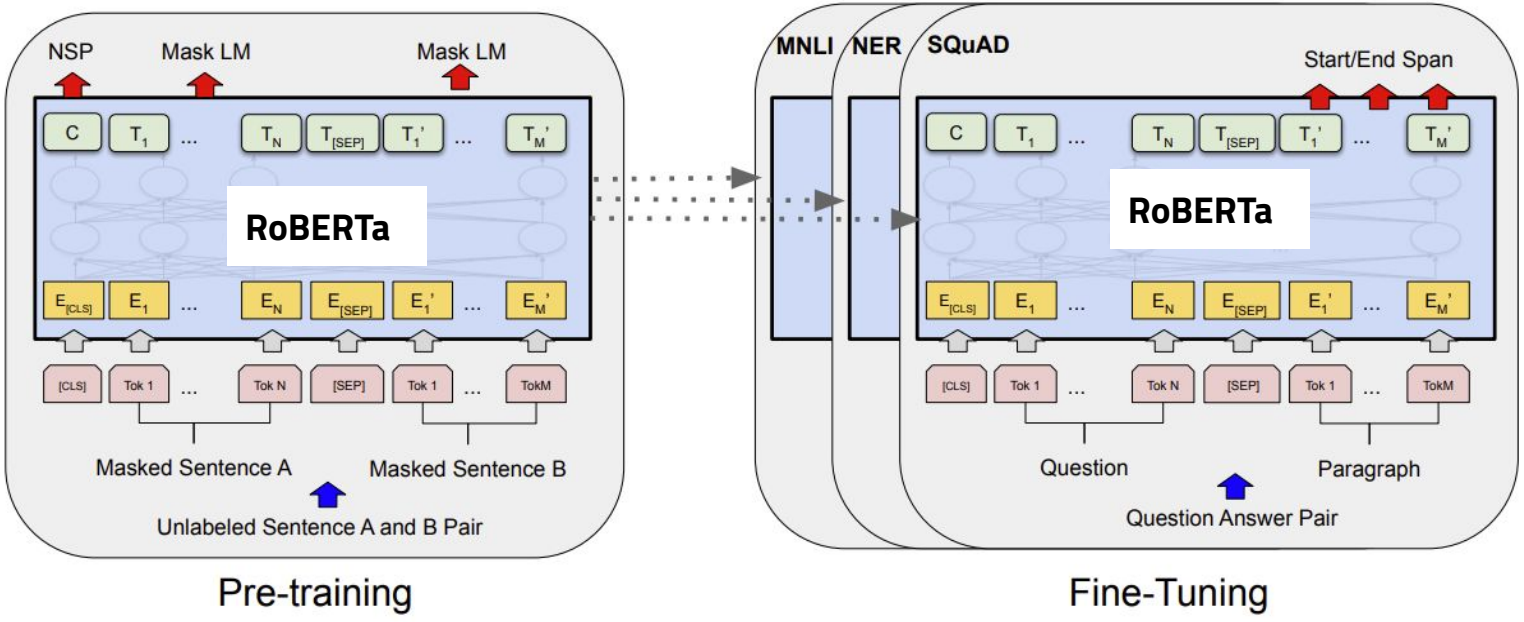
- Climate change poses a substantial risk to global assets and stocks, measured in the trillions of dollars.
- It is hard to forecast where, how, or when climate change will impact financial assets, largely due to the lack of quantitative data on the subject.
- Gathering data regarding the risks and exposure that climate change poses to specific companies is a key part of predicting the extent of climate change impacts on the stock market.

- Disclosing climate change risks and liabilities currently consists of a mix of mandatory and voluntary initiatives.
- In 2015, the Task Force on Climate-related Financial Disclosures (TCFD) was founded to improve the state of voluntary climate disclosing and to encourage companies to increase their climate transparency.
- They released a set of 14 questions to guide sustainability reporting.
    - These questions are extensively used to guide the analysis of climate risk disclosures, with analysts using them to assess the extent and type of climate exposure of companies.



- We adopted a Transformer-based approach to develop ClimateQA, our tool for extracting climate-relevant passages in financial documents.
- To train the model, we used a small set of documents labelled by financial analysts.
- We framed this as a question answering task.
- We chose the RoBERTa architecture, whose performance was proven on general question-answering tasks like SQuAD.

- RoBERTa (Liu et al., 2019) relies on a two-step approach: **pre-training** and **fine-tuning**



Data and Training

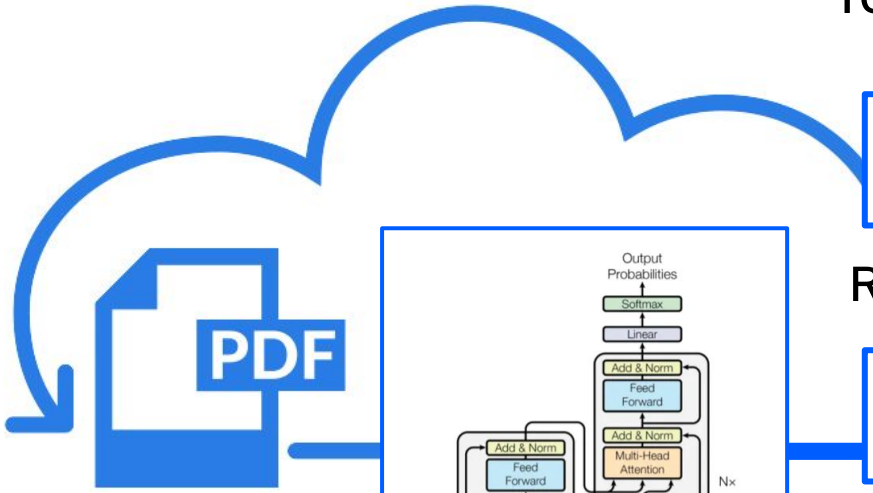
- We **pretrained** our model on unlabeled financial reports, which represent the type of language used in the financial domain
- We **fine-tuned** our model on question-answers paired based on the TCFD questions

Examples of Questions + Answers

Question	Answer
Does the organization describe the targets it uses to manage climate-related risks and/or opportunities?	*15% by 2020 = Targeted reductions in energy and emissions*
Does the organization describe the climate-related risks or opportunities the organization has identified?	*Substantially all of the Company's raw materials are agricultural commodities. In any single year, the availability and price of these commodities are subject to factors such as changes in weather conditions, plantings, government programs and policies, competition, changes in global demand, changes in standards of living, and global production of similar and competitive crops.*

We collected around **300 sustainability reports** that were labeled by experts with the **relevant passages** as **answers** to the 14 TCFD questions

	Validation F1 Score	Test F1 Score	Val - Test Difference
Agriculture, Food & Forests	89.4%	72.1%	-17.2%
Energy	94.2%	89.8%	-4.4%
Banks	91.9%	86.6%	-5.3%
Transportation	86.9%	72.5%	-14.4%
Insurance	92.9%	78.7%	-14.2%
Materials & Buildings	91.8%	67.6%	-24.2%
Average across sectors	**91.7%**	**82.0%**	**-9.7%**



TCFD Question

Does the organization describe the climate-related risks or opportunities the organization has identified?

Relevant Passages

We also understand there can be a financial impact on our operations from climate-related risks.

We continue to develop processes to quantify the potential financial impacts of climate-related risks and the costs of actions taken to manage these risks.

ClimateQA

Overall Conclusion

- No matter your area of skills and expertise, it is possible to put them to use in the **fight against climate change**
- There is a lot to be done, and no single solution to the climate crisis
- Working with **domain experts** is a key part of any project
- **AI is no silver bullet,** but can be one piece of the puzzle, and complement existing endeavors in both **mitigation** and **adaptation**

Thank you for your attention!

Questions?