Muse™
Business Analytics Institute

Newsletter #17 – December 2023

– AI to the rescue of the climate and the environment –

On the sidelines of the Conference of the Parties to the **United Nations Framework Convention on Climate Change** (UNFCCC) or more commonly known as "**COP**". **COP28** was held from November 30, 2023 to December 12, 2023 inclusive, hosted earlier this month by the United Arab Emirates.

The editors of Muse™ would like to complement **COP28** with a look at how the development of prediction models based on **artificial intelligence** (AI), more specifically **machine learning** (ML) and **deep learning** (DL), can help to improve weather predictions and to combat the consequences of climate change disruption.

AI may not be the miracle tool capable of combating climate change. It can, however, improve weather forecasting results by revolutionizing current calculation methods.

There are several **Numerical Weather Prediction** (NWP) models, such as :

- The European global forecasting system, the **Integrated Forecasting System** (IFS)
- The American **Global Forecast System** (GFS);
- Canada's **Global Environmental Multiscale Model** (GEM);
- British **Meteorological Office** (Met Office) unified model.

The version of the IFS run at the European Centre for Medium-Range Weather Forecasts (ECMWF) is often referred to as the "ECMWF" or "European model" in North America, which distinguishes it from the American Global Forecast System (GFS) model.

In **addition to its role** in weather forecasting, AI is also used in the **prevention** and management of **meteorological threats**, by calculating the risk of damage caused by meteorological phenomena (snow, storms, rain, etc.) or their consequences (flooding, icing, etc.).
All this is not without reminding us that the use of AI also has its drawbacks. But that's another story. Feel free to comment if you'd like us to tackle the subject of AI's **environmental footprint** in a future issue.We remind you that AI Muse™ Grenoble discussion group and our **website** is available at the following address: Muse™: Listen to your muse.

We also remind you that the GNÔSIS Grenoble group.

If you would like to continue the discussion, feel free to contact Lee Schlenker and Alexandre MARTIN.

Lee Schlenker and Alexandre MARTIN wish you and your families a Happy Holiday Season.

Don't hesitate to leave us a comment, to share our newsletter.

Enjoy reading!

- **[GraphCast: Learning skillful medium-range global weather forecasting](https://arxiv.org/abs/2212.12794) – arXiv**

https://arxiv.org/abs/2212.12794

After developing an artificial intelligence (AI) model capable of playing and competing with the best Go players (AlphaGo), and after developing an AI program (AlphaFold) in the joint fields of bioinformatics and theoretical chemistry (predicting the structure of proteins from their amino acid sequences). Google DeepMind teams are now tackling weather prediction with their GraphCast prediction model.

Instead of presenting you with an article on the possibilities of the GraphCast prediction model. I'd like to show you how Google DeepMind's weather prediction model works.

In this scientific study, Google DeepMind's scientific teams present a new **machine learning-based weather prediction** (MLWP) model. MWLP is an alternative to current NWP models. It improves weather predictions by using historical data, which NWP models do not.

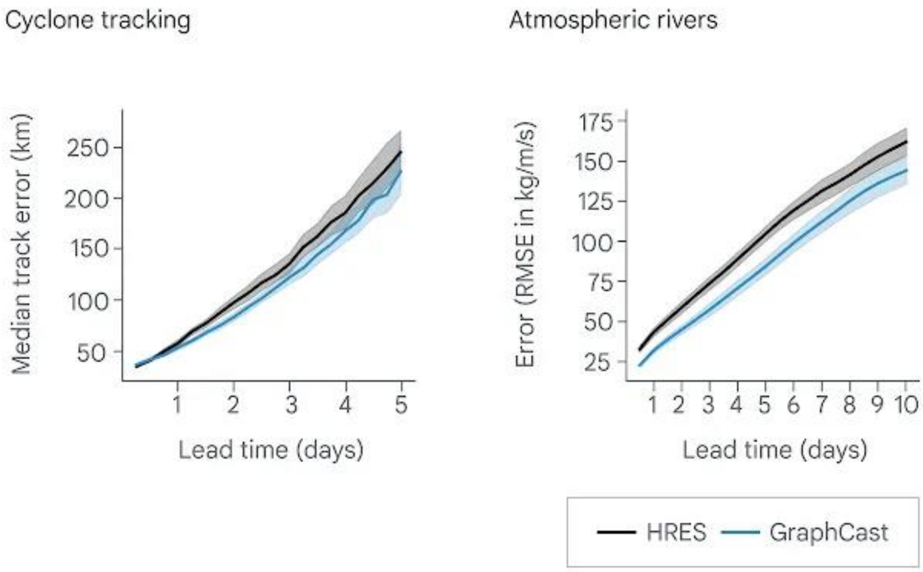

Figure 1 - Severe-event prediction - how GraphCast and HRES compare.

*Source: https://deepmind.google/discover/blog/graphcast-ai-model-for-faster-and-more-accurate-global-weather-forecasting/?_gl=1*5f68cq*_up*MQ..*_ga*NzQwMDE4MzQ1LjE3MDE3ODQzODc.*_ga_LS8HVHCNQ0*M*

It's worth noting that the researchers are making GraphCast's source code freely available (GitHub repository).

- **Artificial Intelligence and the Climate Emergency: Opportunities, Challenges, and Recommendations – SSRN**

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3873881

Is the use of AI a step forward in the fight against global warming, or does the way it works actually increase global warming?

This is the question that researchers Mariarosaria Taddeo, Andreas Tsamados, Josh Cowls and Luciano Floridi attempt to answer in this scientific article.

For researchers Mariarosaria Taddeo, Andreas Tsamados, Josh Cowls and Luciano Floridi, the use of AI is an opportunity to combat global warming. However, it is necessary to take into account the carbon footprint that is generated by the use of AI.

To improve the use of AI in the fight against global warming, researchers Mariarosaria Taddeo, Andreas Tsamados, Josh Cowls and Luciano Floridi **propose 14 recommendations**.

Below, an extract from the **first 4 recommendations** written by Mariarosaria Taddeo, Andreas Tsamados, Josh Cowls and Luciano Floridi.

Table 2. Recommendations to ensure the development of equitable and sustainable AI
Recommendation 1: Incentivize a world-leading initiative (an Observatory) to document evidence of AI being used to combat climate change worldwide, derive best practices and lessons learned, and disseminate the findings among researchers, policymakers, and the public.
Recommendation 2: Develop standards of quality, accuracy, relevance, and interoperability for data to be included in the forthcoming Common European Green Deal data space; identify aspects of climate action for which more data would be most beneficial; and explore, in consultation with domain experts and civil society organizations, how these data could be pooled in a shared global climate data space.
Recommendation 3: Incentivize collaborations between data providers and technical experts in the private sector with domain experts from civil society, in the form of "challenges," to ensure that the data in the Common European Green Deal data space are utilized effectively against climate change.
Recommendation 4: Incentivize the development of sustainable, scalable responses to climate change that incorporate AI technology, drawing on earmarked Recovery Fund resources.

Figure 2 - Recommendations to ensure the development of equitable and sustainable AI

- **AI for climate impacts: applications in flood risk | npj Climate and Atmospheric Science – Nature Portfolio**

https://www.nature.com/articles/s41612-023-00388-1

Published on the website of the journal Nature, this contribution by researchers Anne Jones and al. have created an AI-based application, specifically Machine Learning, to quantify and model flood risks.

To develop their program, researchers Anne Jones and al. used Bayesian optimization with Gaussian process regression to computational fluid dynamics problems.

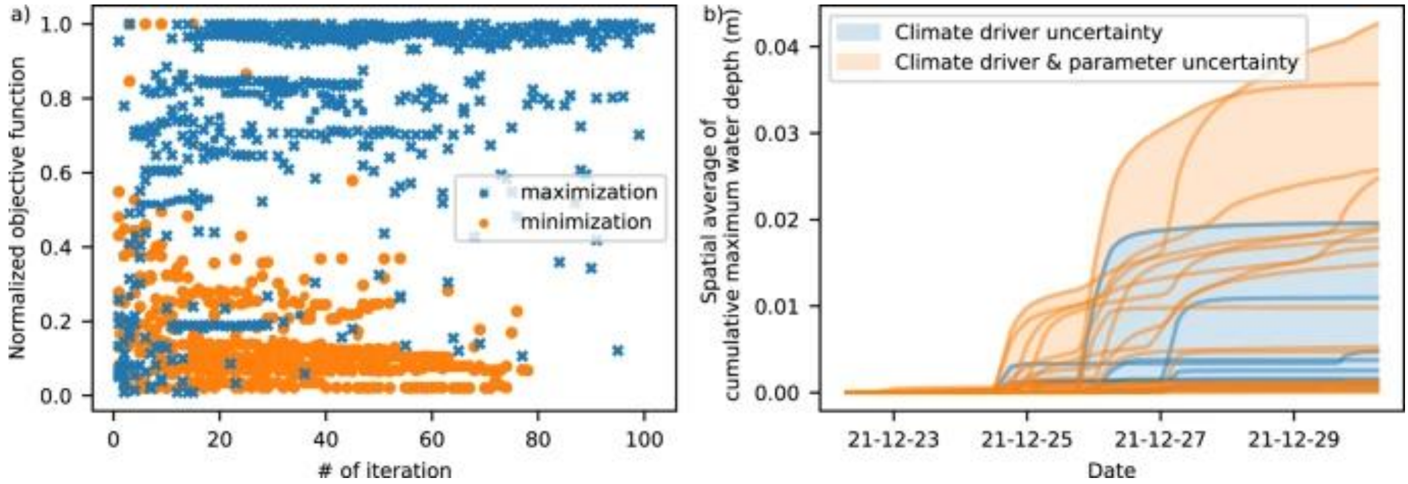

Figure 3 - Time series illustrating flood prediction uncertainty quantification.

- **Detection of Bow Echoes in Kilometer-Scale Forecasts Using a Convolutional Neural Network - [American Meteorological Society](https://journals.ametsoc.org/view/journals/aies/1/2/AIES-D-21-0010.1.xml)**

https://journals.ametsoc.org/view/journals/aies/1/2/AIES-D-21-0010.1.xml

In this study, researchers Arnaud Mounier and this team describe how their **convolutional neural network** (CNN) model was used to predict thunderstorm intensity.

To train their model (CNN), the researchers proceeded as follows:

- **Step 1:**

Patches from the pseudoreflectivity fields are randomly selected, and *N*patches are extracted from each field (values in Table 1). The associated ground truth patches are also extracted.

- **Step 2:**

The pairs of patches (pseudoreflectivity/ground truth) are split into two groups: the patches with BEs in which at least one grid point is labeled as a BE and the patches without any BE.

- **Step 3:**

The number of patches with BEs is very limited compared to patches without any BE (1 patch with a BE for every **1600 patches without a BE**). Initially, BEs with moderate pseudoreflectivities were not correctly predicted because they were underrepresented in the dataset. A data augmentation technique is proposed to solve this problem: in a given patch, the pseudoreflectivities are multiplied by a coefficient of **0.75 if a BE** is within this patch and the maximum pseudoreflectivity is above a given threshold (mentioned in the next section). This new patch is added in the ones with BEs (**step 2**). The pseudoreflectivity field must remain physically consistent as much as possible. That is why lower coefficients are not investigated and only patches with large magnitude in pseudoreflectivities are taken into account.

- **Step 4:**

To reduce the number of patches without a BE, the patches without precipitation (pseudoreflectivity **maximum < 0.1 mm h−1)** are deleted.

- **Step 5:**

Even after the filtering procedure of **step 4**, the number of patches without a BE remains high (1 patch with a BE for every 400 patches without a BE). To limit the number of patches without a BE, the ratio between the patches with and without a BE (Ratio_noBE/BE) is fixed to a lower value. The patches retained are randomly selected and the unnecessary patches without a BE are deleted. This ratio is discussed in the next section.

- **Step 6:**

During the first tests, all patterns with strong pseudoreflectivities were detected as BEs and consequently the number of false alarms was very high in the validation database. Strong pseudoreflectivities are rare in space and time and the majority of patches without a BE contains no or weak precipitation, whereas BEs are frequently associated with heavy precipitation. Only **0.7% of patches** without a BE are associated with heavy precipitation (i.e., above **60 mm h−1**), whereas, after the data augmentation in amplitude (**step 3**), around **55% of patches with BEs** are associated with heavy precipitation. In this case, the pseudoreflectivity magnitude is relied on too heavily to detect the BEs in the pseudoreflectivity fields. Patches with large magnitude pseudoreflectivities but without a BE are forced in the training database to solve this problem and the rate of large magnitude pseudoreflectivity patches without a BE in the total number of patches without a BE is defined (heavy_rate). A patch is considered with large magnitude pseudoreflectivities if the maximum is above **60 mm h−1**. Another way to address this problem could be to add more input predictors.
Source: Mounier, A., L. Raynaud, L. Rottner, M. Plu, P. Arbogast, M. Kreitz, L. Mignan, and B. Touzé, 2022: Detection of Bow Echoes in Kilometer-Scale Forecasts Using a Convolutional Neural Network. *Artif. Intell. Earth Syst.*, **1**, e210010, https://doi.org/10.1175/AIES-D-21-0010.1.

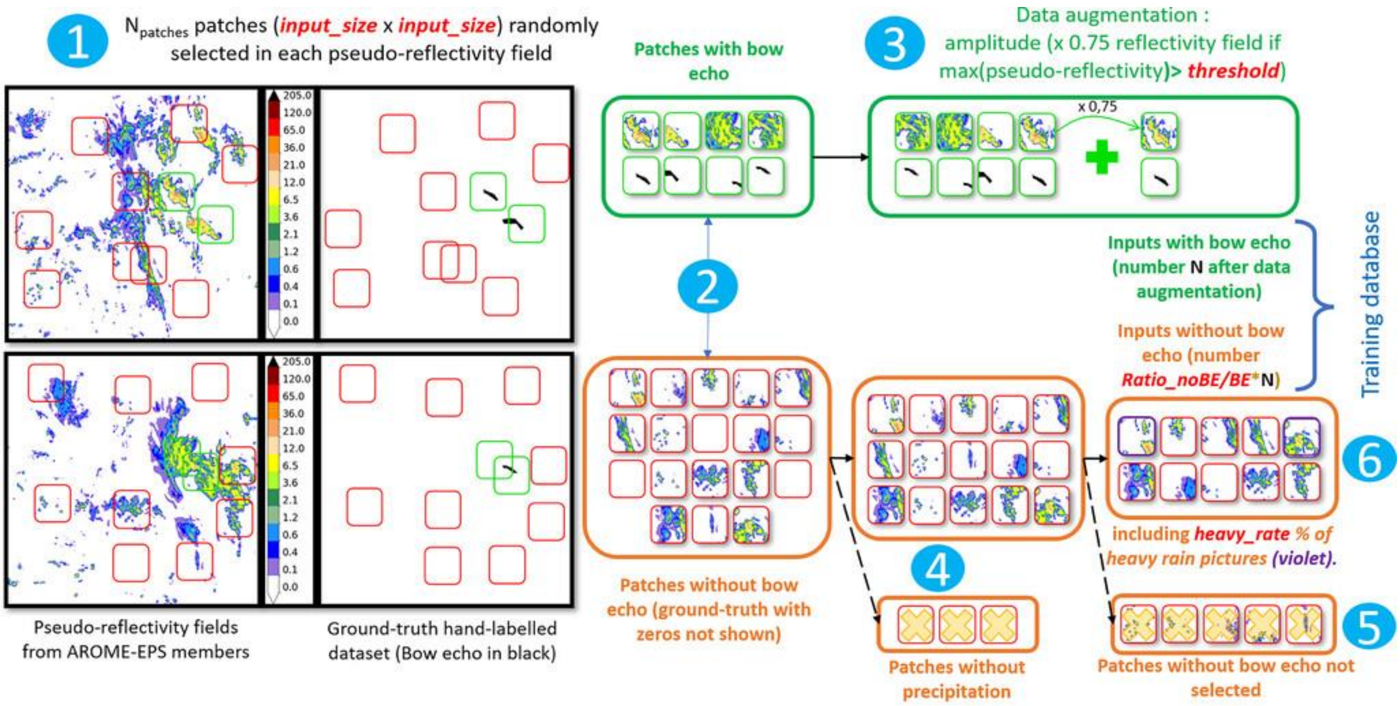

Figure 4 - U-Net architecture for BE detection.
Citation: Artificial Intelligence for the Earth Systems 1, 2; 10.1175/AIES-D-21-0010.1

The researchers have made the source code of their application available.

- **ClimaX: A foundation model for weather and climate – arXiv**

https://arxiv.org/abs/2301.10343

In this scientific publication, researchers Tung Nguyen, Johannes Brandstetter, Ashish Kapoor, Jayesh K. Gupta, Aditya Grover have developed a weather modeling program called ClimaX. ClimaX is based on a deep neural network architecture.

Using Deep Learning, ClimaX algorithms are trained to predict atmospheric variables with **heterogeneous datasets** (**CMPIP6** and **ERA5**) covering different variables, spatio-temporal coverage and physical underpinnings.

ClimaX aims to replace existing models (**general circulation models** - GCM), which are based on **physical laws**. GCMs use a system of differential equations relating to the flow of energy and matter in the atmosphere, land and oceans, which can be integrated over time to obtain forecasts for the relevant atmospheric variables.

The ClimaX model is a versatile model, capable of adapting to the needs of researchers.

The complete work carried out by researchers Tung Nguyen, Johannes Brandstetter, Ashish Kapoor, Jayesh K. Gupta, Aditya Grover to create the model is available in a .PDF file ([ClimaX: A foundation model for weather and climate.pdf]()).

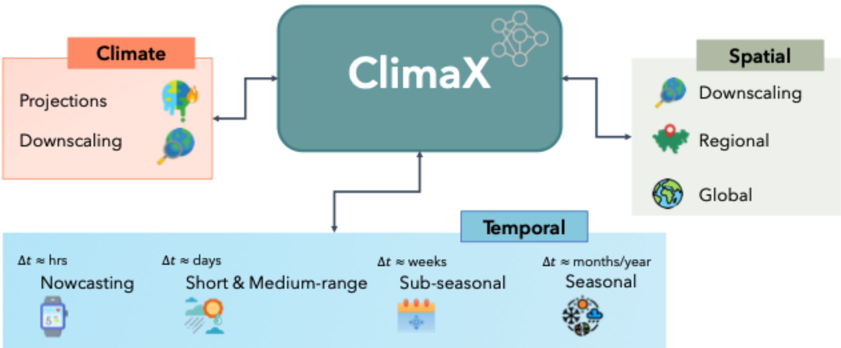

Figure 5 - ClimaX is built as a foundation model for any weather and climate modeling task.

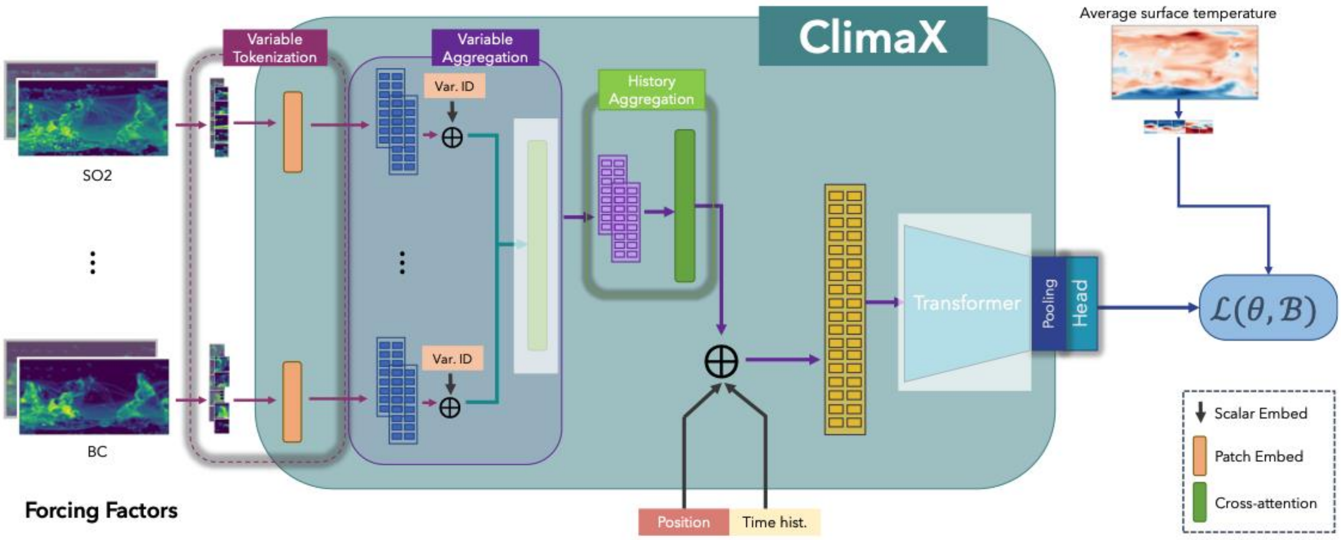

Figure 6 - Finetuning pipeline for ClimateBench. A different set of input and output variables requires different embedding layers and prediction heads. Attention layers can be frozen or finetuned.

The complete work carried out by researchers Tung Nguyen, Johannes Brandstetter, Ashish Kapoor, Jayesh K. Gupta, Aditya Grover to create the model is available in a .PDF file ([ClimaX: A foundation model for weather and climate.pdf]()).

The researchers have made the source code of their application available.

- **A better way to study ocean currents – MIT News**

https://news.mit.edu/2023/new-machine-learning-model-ocean-currents-0517

Published on the MIT News website, this article looks at the creation of a machine learning-based model capable of improving the prediction of ocean currents, with the advantage of being able to trace more easly various types of pollution (oil, plastic...) more easily.

Another advantage is that it helps rescuers to better locate shipwreck victims. This model is also capable of enabling oceanographers to improve biomass monitoring and better understand climate change.

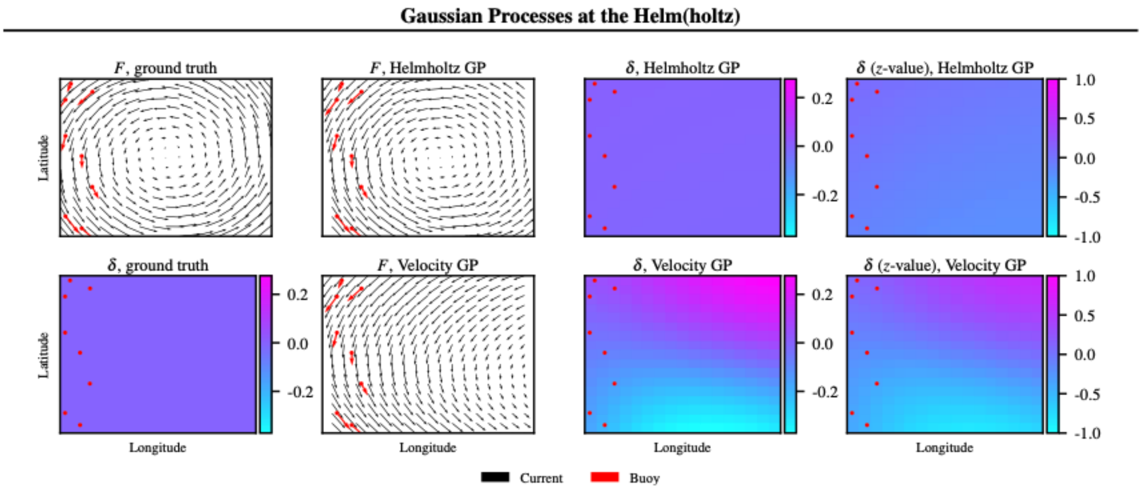

Figure 7 - First column: ground truth predictions (upper) and divergence (lower). Second column: current predictions. Third column: divergence estimates. Fourth column: posterior divergence z-values.

To achieve this, MIT computer scientists and oceanographers have collaborated to develop this predictive model. The research team includes Renato Berlinghieri, Brian L. Trippe, David R. Burt, Ryan Giordano, Kaushik Srinivasan, Tamay Özgökmen, Junfei Xia, Tamara Broderick.

MIT computer scientists have proposed to model buoy velocity (longitude and latitude) using Gaussian processes.

More technical details on the design of this learning model are available at: Gaussian processes at the Helm(holtz): A more fluid model for ocean currents, on ArXiv.org.

- **On the African coast, a unique video surveillance system for better risk management – The Conversation France**

https://theconversation.com/sur-les-cotes-africaines-un-systeme-unique-de-videosurveillance-pour-mieux-gerer-les-risques-202079

The African continent has a unique topography, with the largest number of low-lying coastal areas (e.g. sandy beaches). This low altitude exposes populations to oceanic and climatic hazards. With global warming, these hazards are tending to increase in both frequency and intensity.

In this article, published by The Conversation France, researchers Grégoire Abessolo Ondoa, Bapentire Donatus Angnuureng and Rafael Almar explain that by combining different observation technologies: a network of **video surveillance cameras in coastal areas** (to measure variations in sea level towards the coast), **satellite imagery** (altimetry, spectrometry...), and information gathering in the field, **only** when weather conditions permit. To date, local authorities have set up a network of **8 monitoring and warning systems** along the coastlines of **5 countries** (Senegal, Côte d'Ivoire, Ghana, Benin, Cameroon).

This alert and surveillance system is a combination of an image capture network (video surveillance and satellite images) and **decision-making algorithms**.

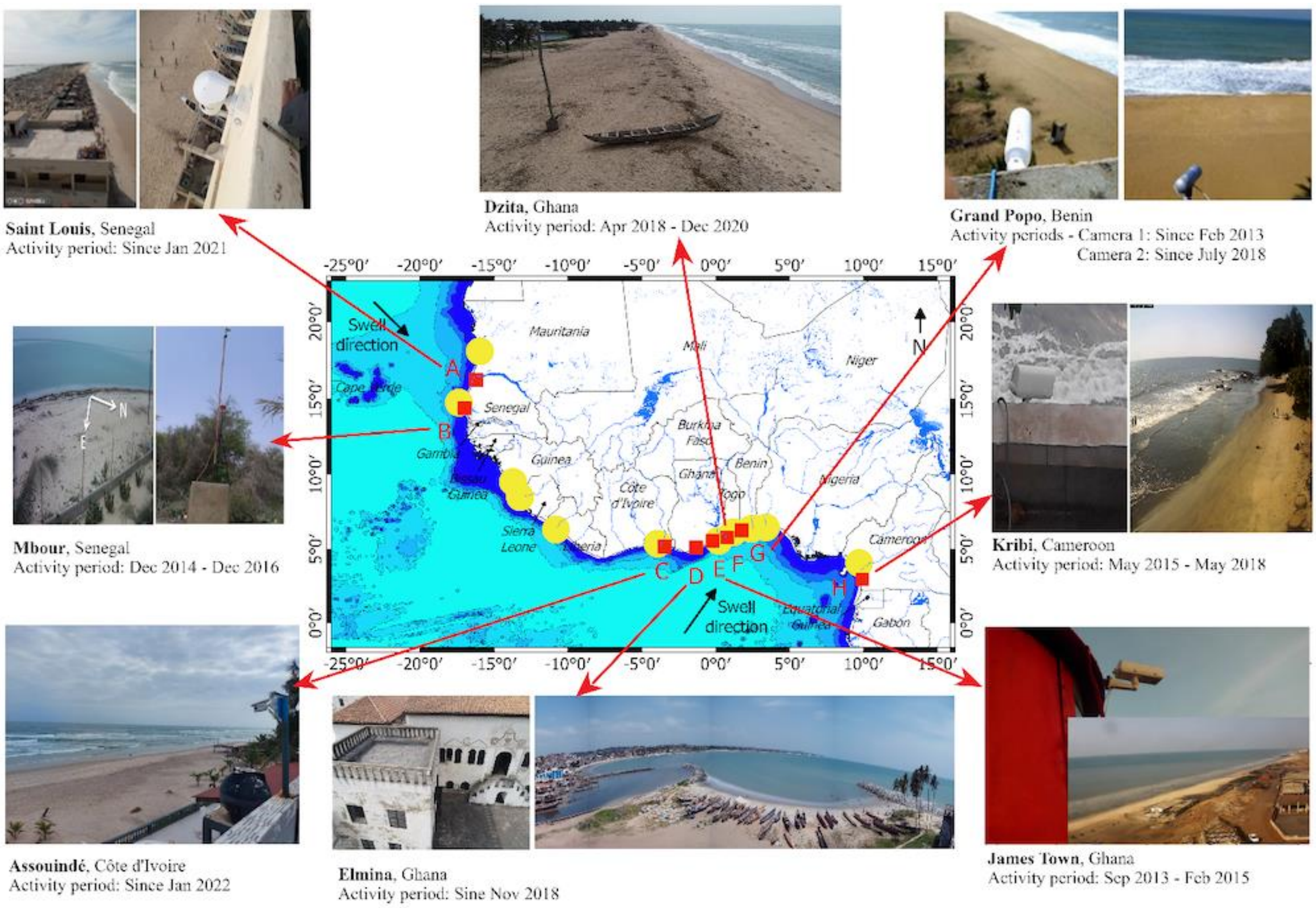

Figure 8 - The African coastal camera network. The photos show the surroundings of the installation sites and the cameras installed. Yellow dots show cities with more than one million inhabitants. Authors, Provided by the author

- **Meteorology: how AI and satellites make rain and shine – Polytechniques Insights**

https://www.polytechnique-insights.com/dossiers/science/meteorologie-comment-lia-et-les-satellites-font-la-pluie-et-le-beau-temps/

These are 3 short articles published by Polytechniques Insights, showing how the **deployment of artificial intelligence** (AI) in **weather forecasting systems** is bringing new perspectives to weather forecasting.

The first two articles, "**New observation systems for weather forecasting**" written by Pierre Tabary (deputy director of operations at Météo France's Direction des opérations pour la prévision [DirOP]) and "**Better weather forecasting with new European satellites**" written by Sébastien Léas, (forecaster at Météo-France). The authors recount the history and technological evolution of weather forecasting methods.

In the third and final article, "**Artificial intelligence, a new ally for meteorologists**" by Samuel Morin, Director of the Centre National de Recherches Météorologiques (@CNRM), we learn how advances in AI (**machine learning**) have improved weather forecasting results. But AI also increases the execution of weather models, and consequently reduces the computational costs of conventional forecasting models.

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