RÉPUBLIQUE FRANÇAISE
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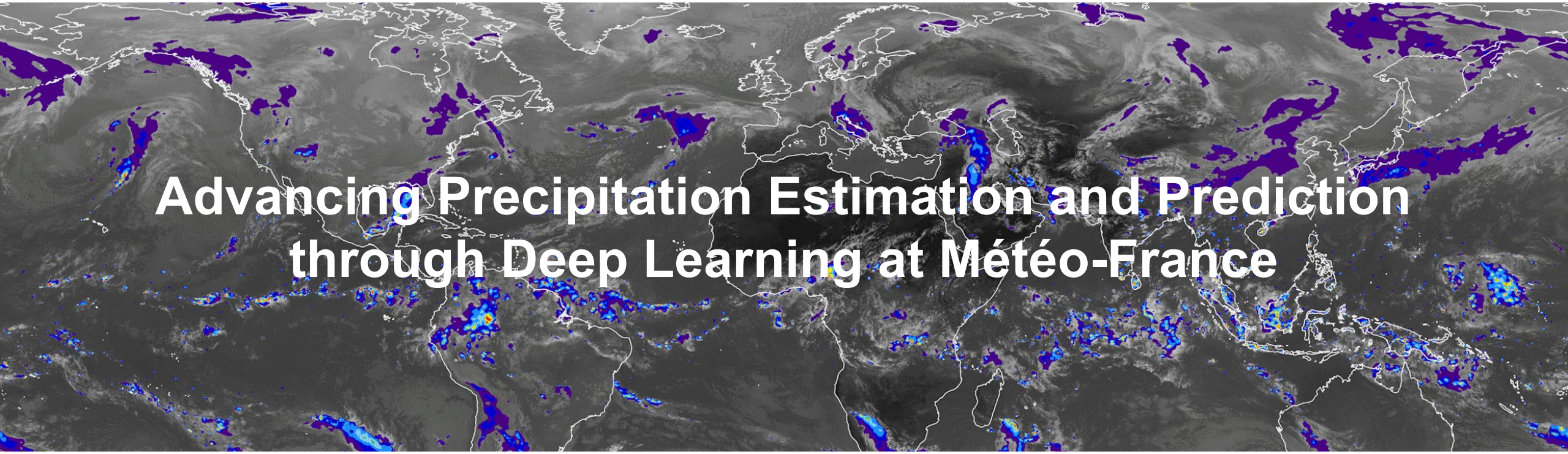

Advancing Precipitation Estimation and Prediction through Deep Learning at Météo-France

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Météo-France

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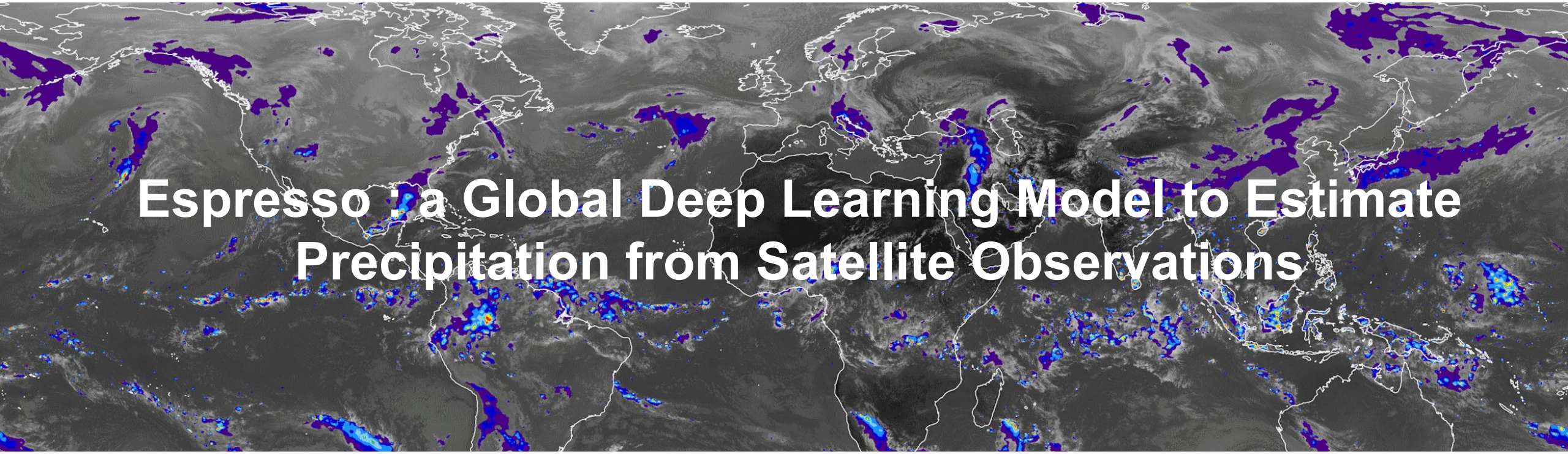
Summary

- **Observations**
  - Precipitation estimation from satellite observations
  - Severe hail detection using convolutional neural networks
  - Commercial Microwave Links to estimate rainfall
- **Nowcasting**
  - Comparison of multiple AI Nowcasting products
- **Medium range forecasting**
  - Emulation of AROME with Deep Neural Networks



Espresso : a Global Deep Learning Model to Estimate Precipitation from Satellite Observations

Météo-France AI Lab
L. Berthomier
M. Feirrera
F. Guibert
B. Pradel
T. Tournier

Meteorological Satellite Center, Météo-France
L. Perier, S. Le Moal, JB. Hernandez, O. Membrive, A. Mauss, G. Gouez, Y. Niort

French National School of Meteorology
L. Bouzid, C. Cadoret, C. Nicolas, L. Soulard-Fisher

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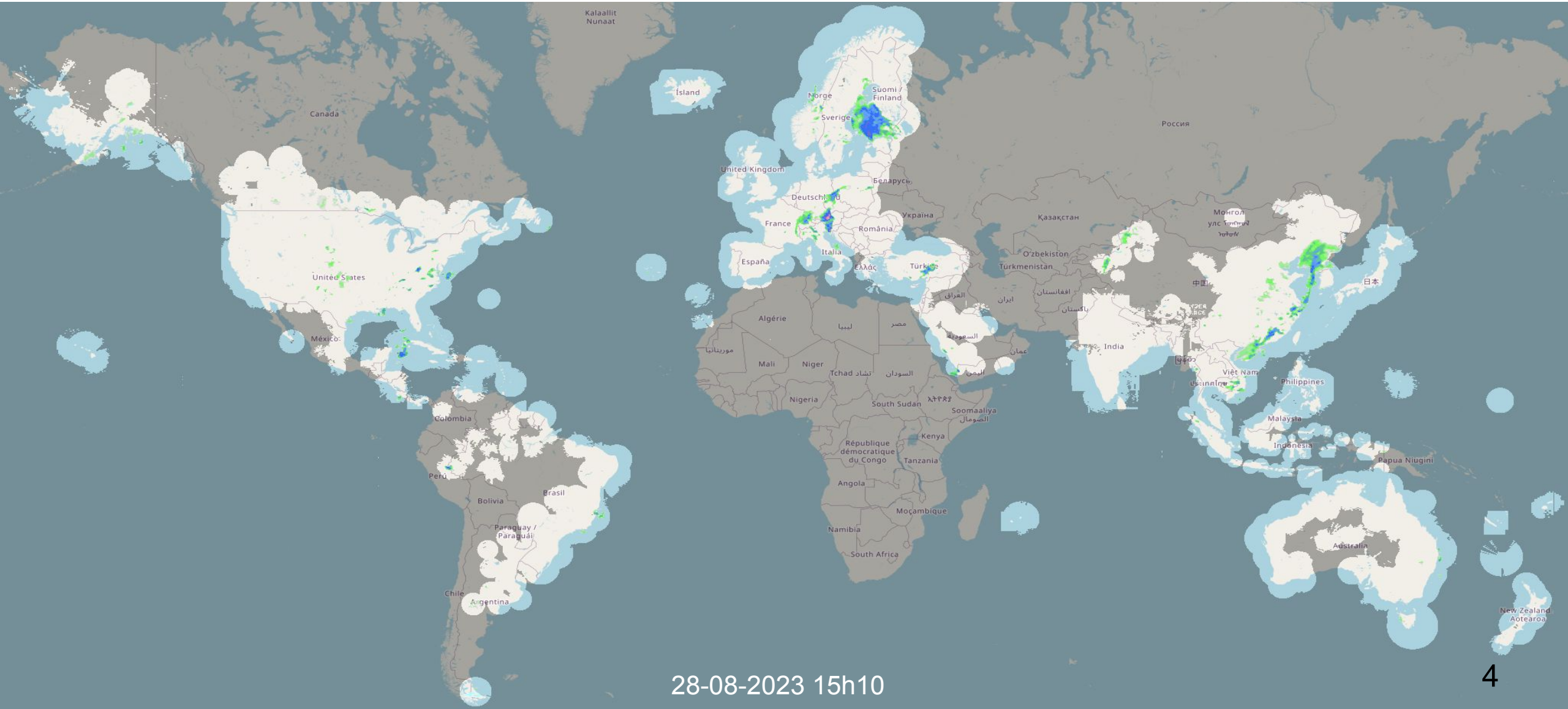
Context

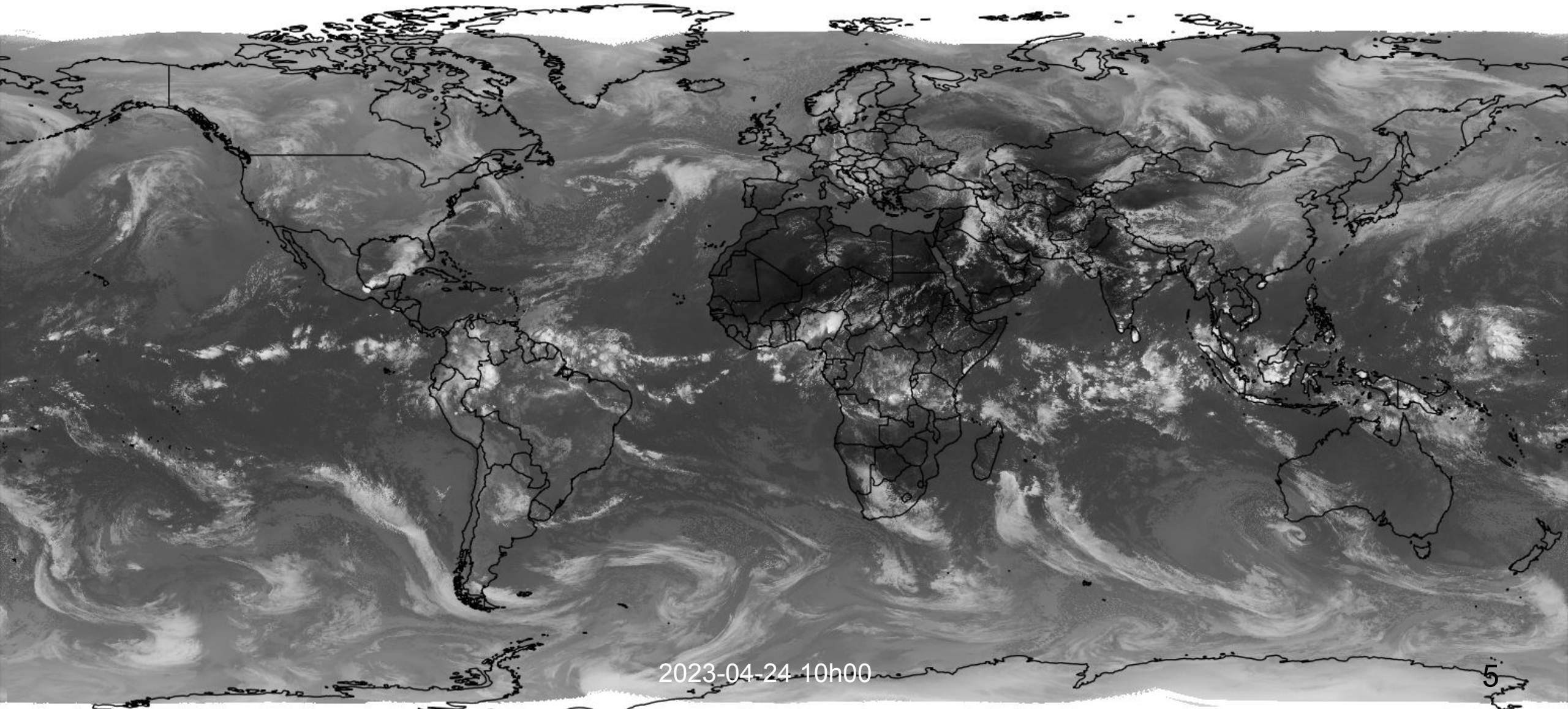
RainViewer



28-08-2023 15h10

Available data

10.8 µm channel
Mosaic from 5 geostationary satellites



2023-04-24 10h00

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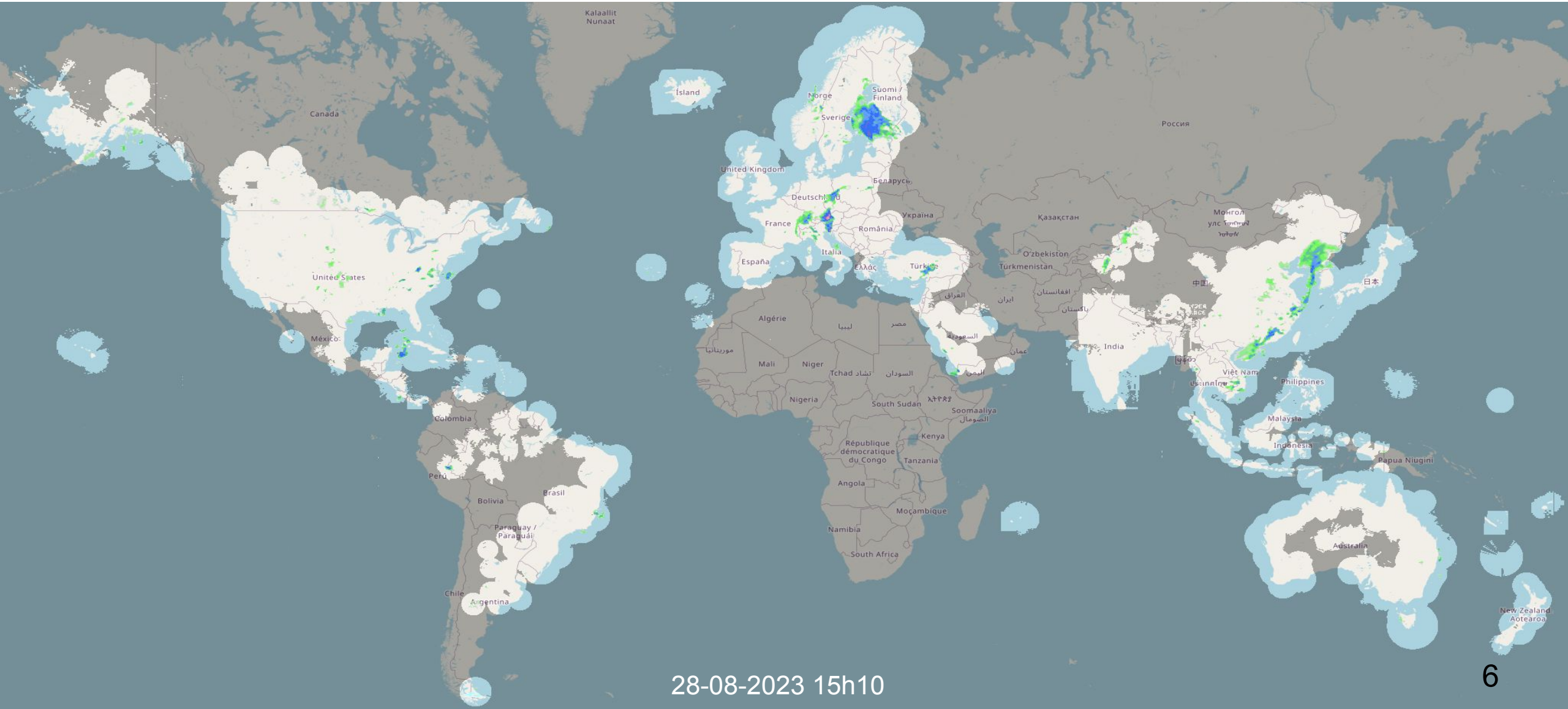
Available data

RainViewer

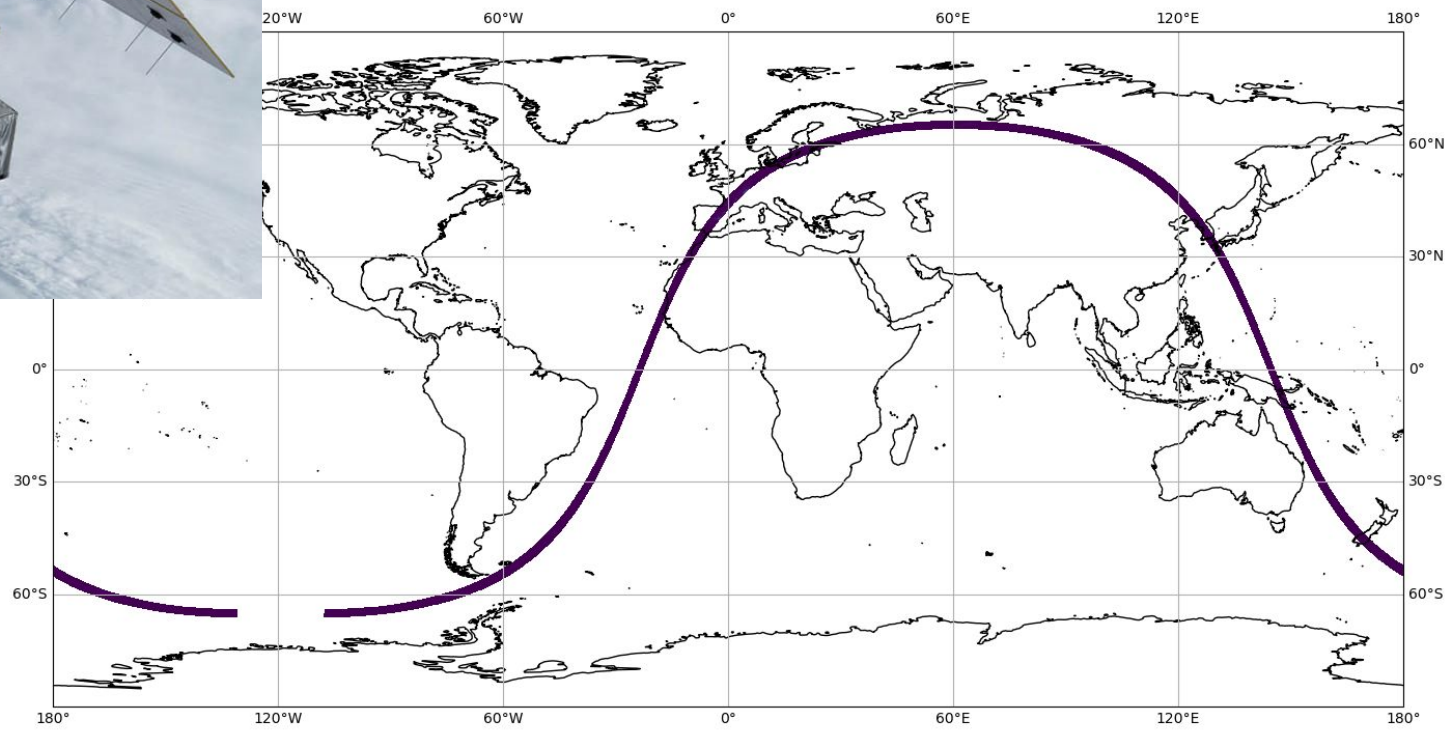


28-08-2023 15h10

Available data

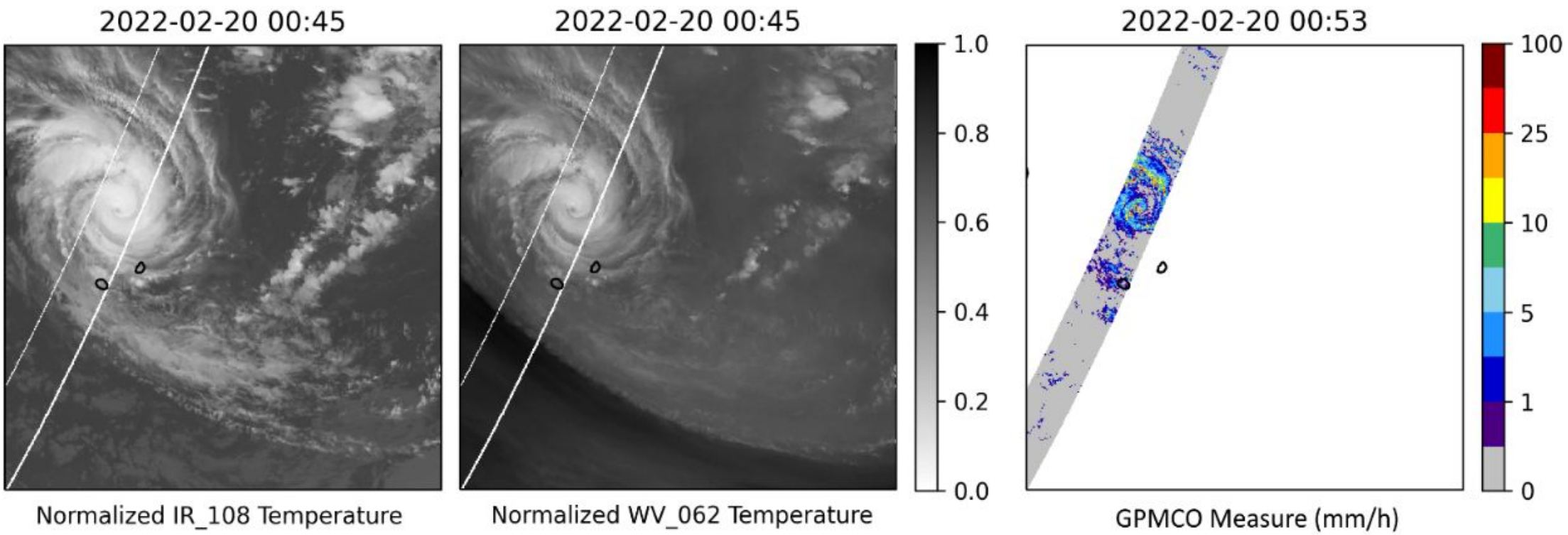
GPM Core Observatory

- GPM Microwave Imager
- Dual-frequency Precipitation Radar :
  - Ka-Band (35.5 GHz)
  - Ku-Band (13.6 GHz)



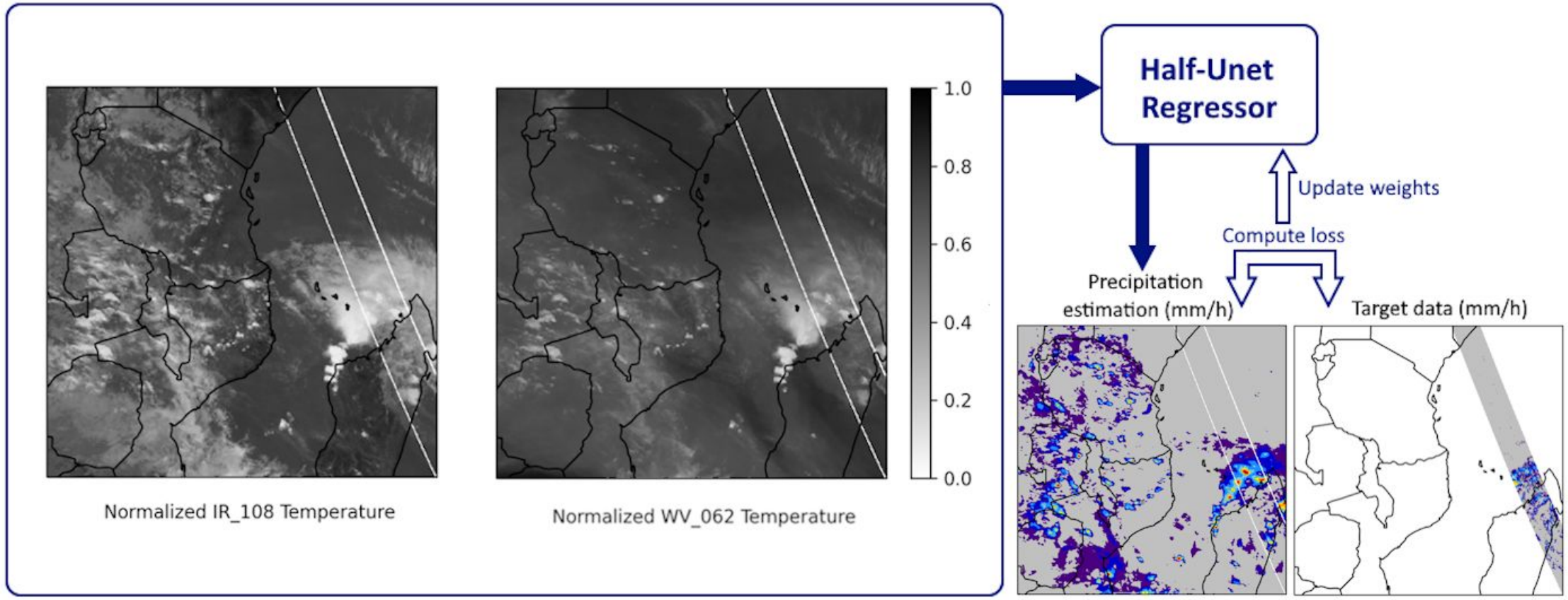
- Orbit duration = 1h30
- 16 daily swaths since 2014
- Rainfall rate measurement in mm/h

Dataset


2022-02-20 00:45
2022-02-20 00:45
2022-02-20 00:53
1.0
0.8
0.6
0.4
0.2
0.0
100
25
10
5
1
0
Normalized IR_108 Temperature
Normalized WV_062 Temperature
GPMCO Measure (mm/h)

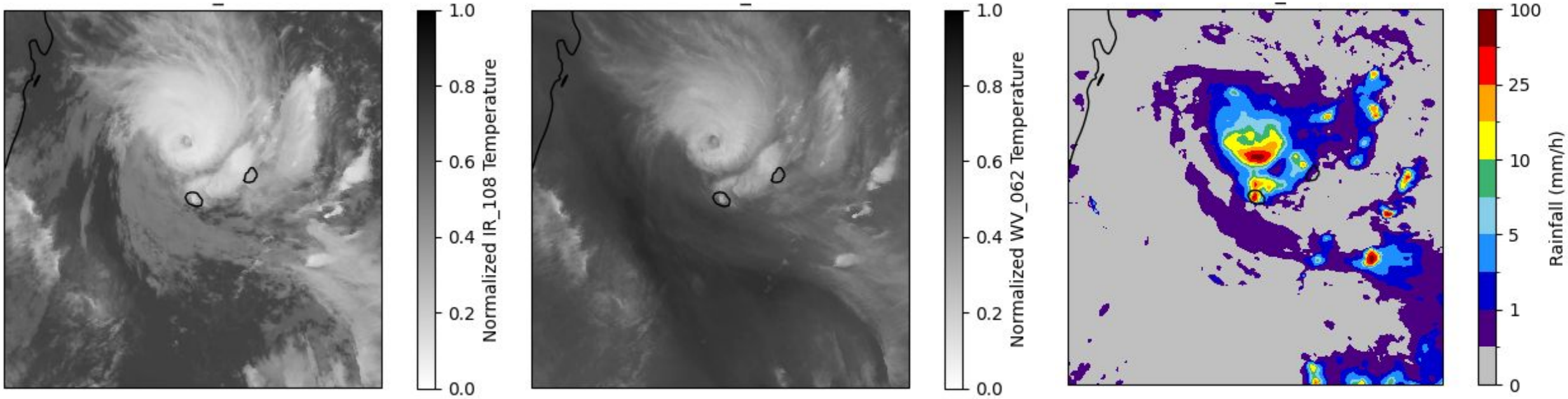
Methodology

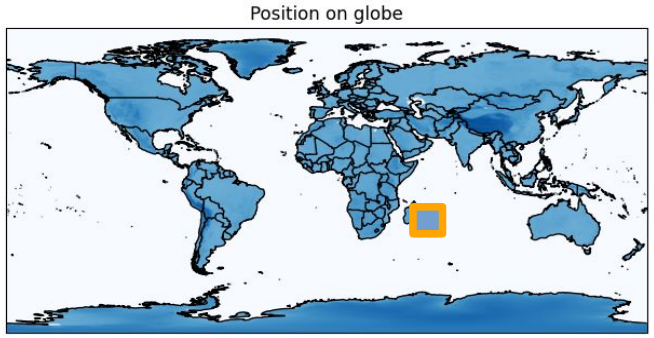
Input features



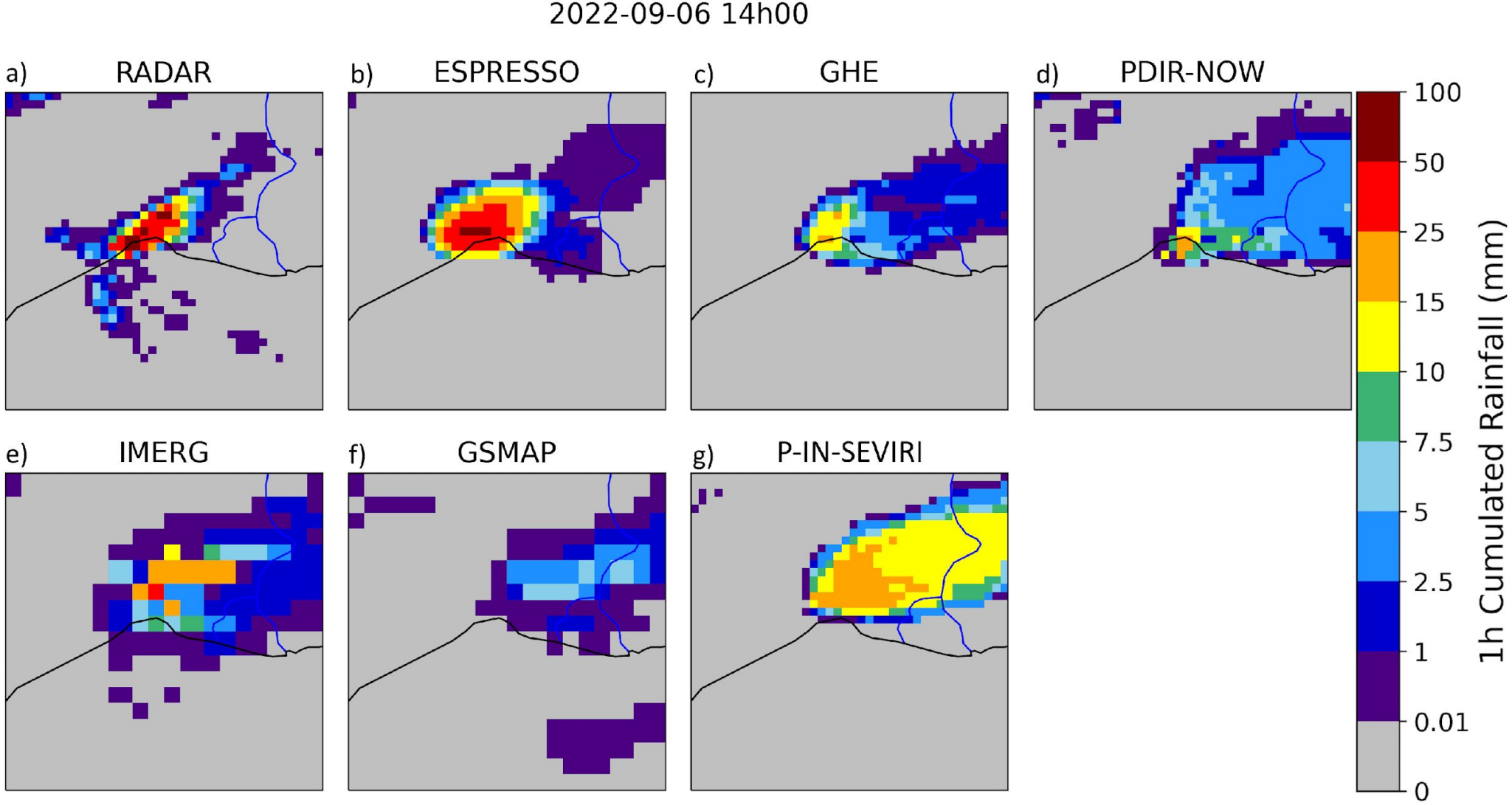
Results : Cyclone Garance

2025-02-27 19h45 UTC

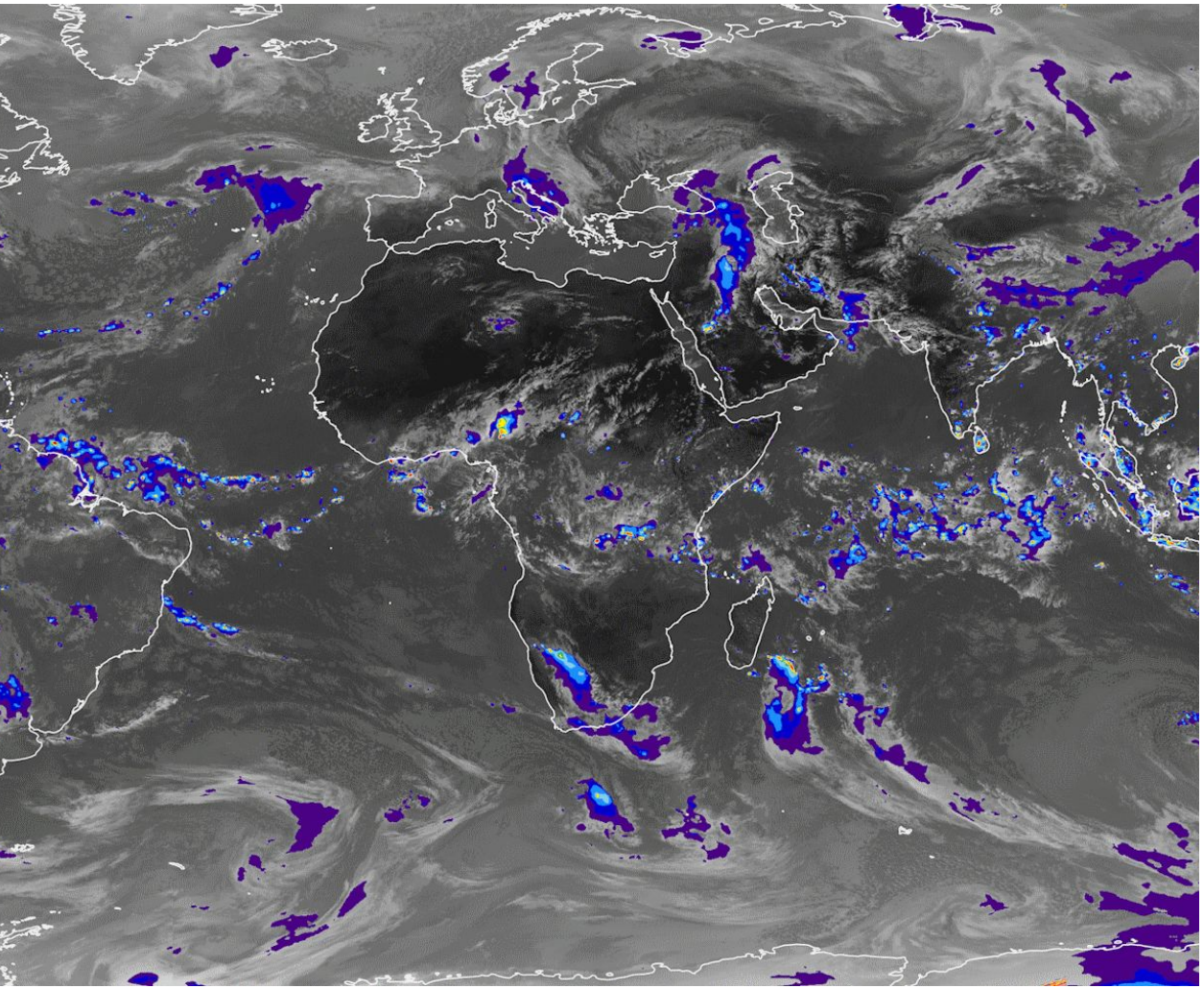




Results: “Cevenol” storm in Montpellier



Conclusion on Espresso



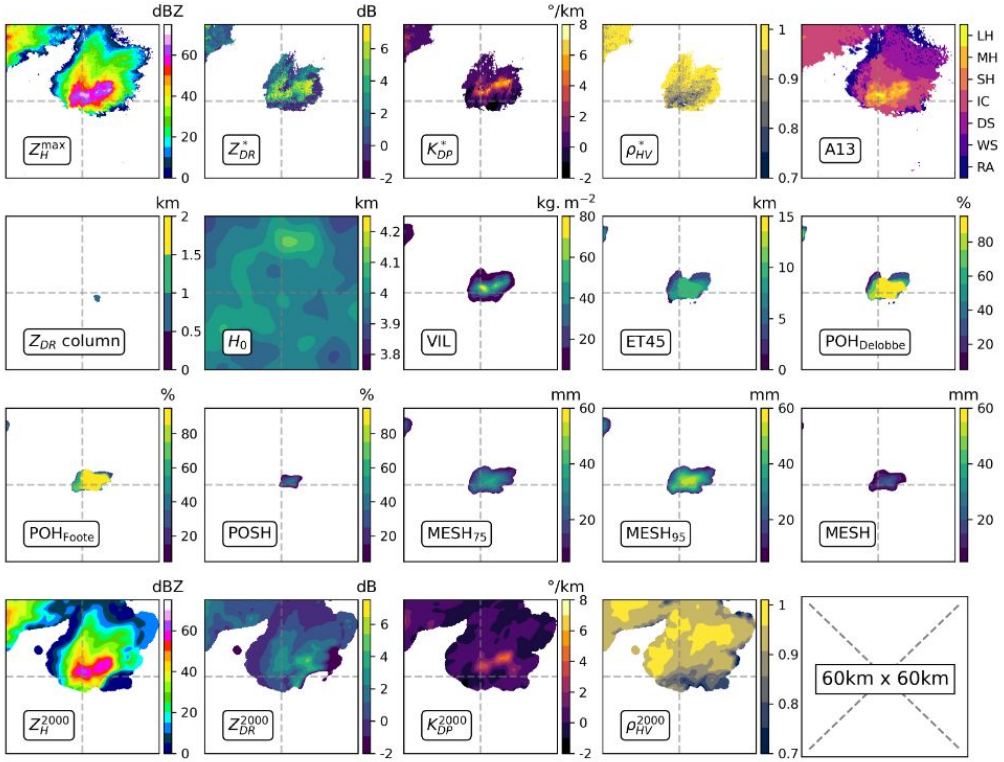
- Model is now **operational** and produces **real time estimations** every **15 minutes.**
- Accessible to French forecasters for French oversea territories without ground radar.

Espresso: A Global Deep Learning Model to Estimate Precipitation from Satellite Observations
L. Berthomier and L. Perier, 2023, *Meteorology*

Other AI Products for Precipitation Observation

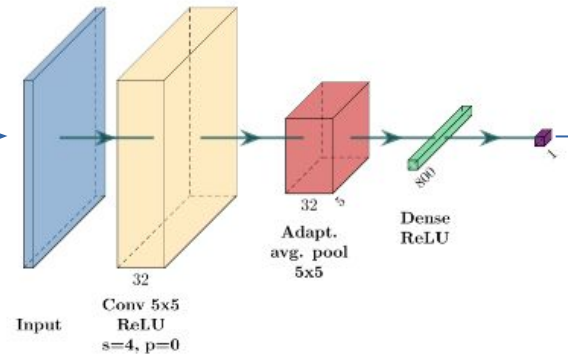
Severe hail detection with C-band dual-polarisation radars using convolutional neural networks

Vincent Forcadell et al., 2024



19 inputs : Polarimetric, Storm proxy and Hail proxy data

SmallConvNet



Probability of severe hail on the ground

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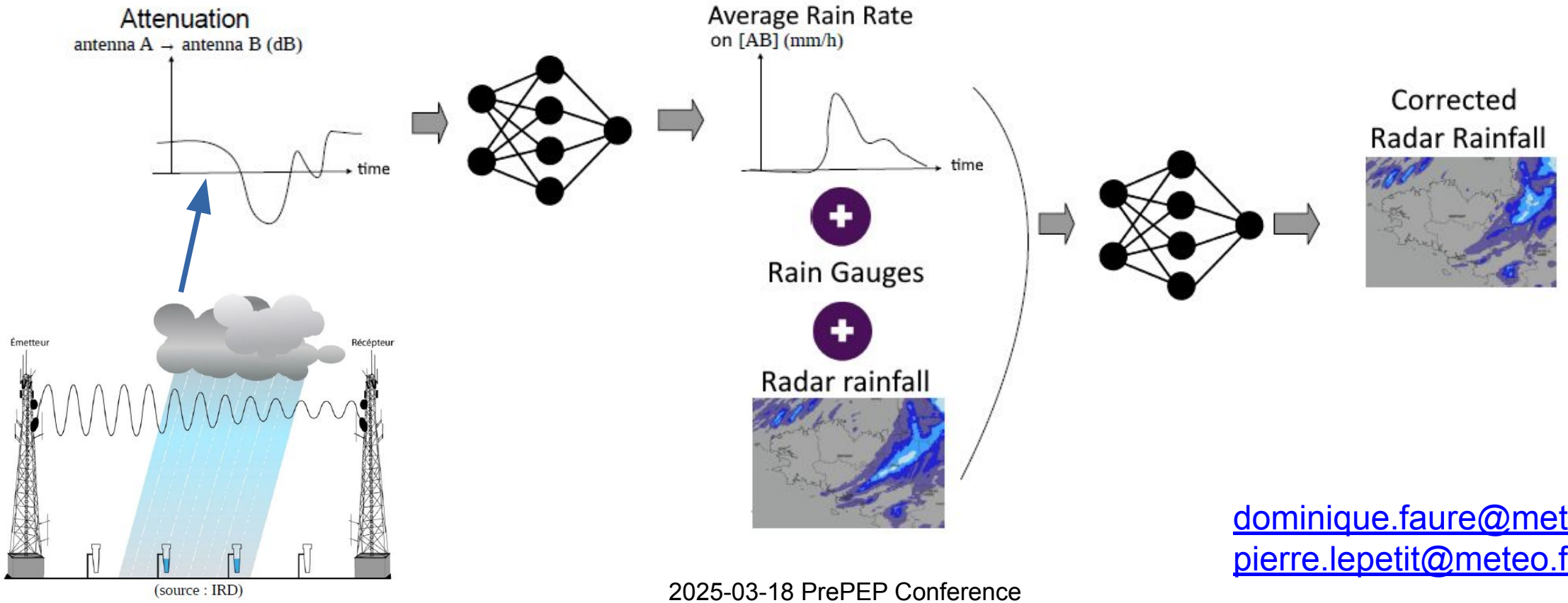
vincent.forcadell@gmail.com

Other AI Products for Precipitation Observation

Raincell project: Commercial Microwave Links to estimate rainfall at Météo-France

Dominique Faure et al., ERAD, 2024



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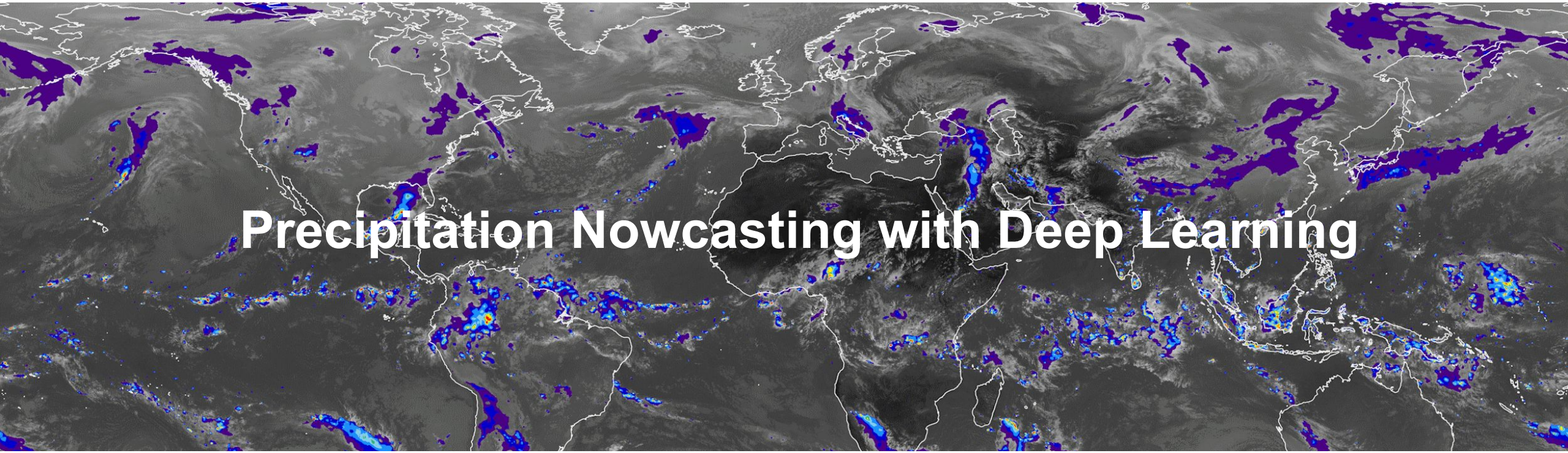

Precipitation Nowcasting with Deep Learning

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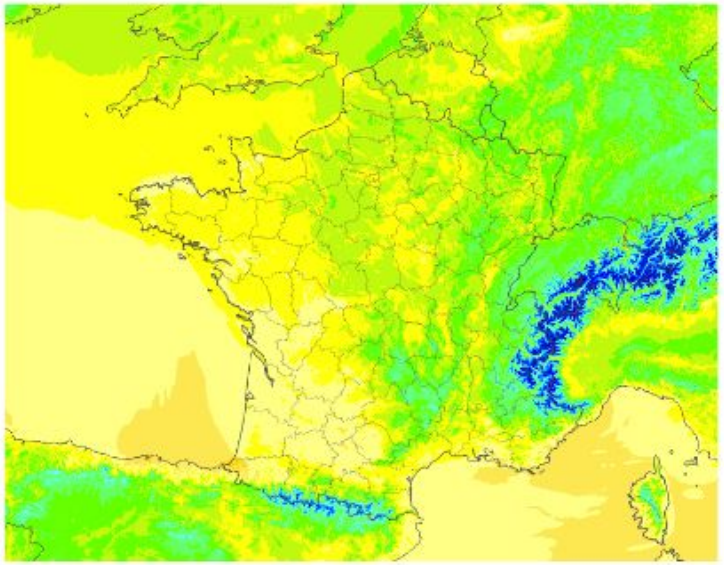
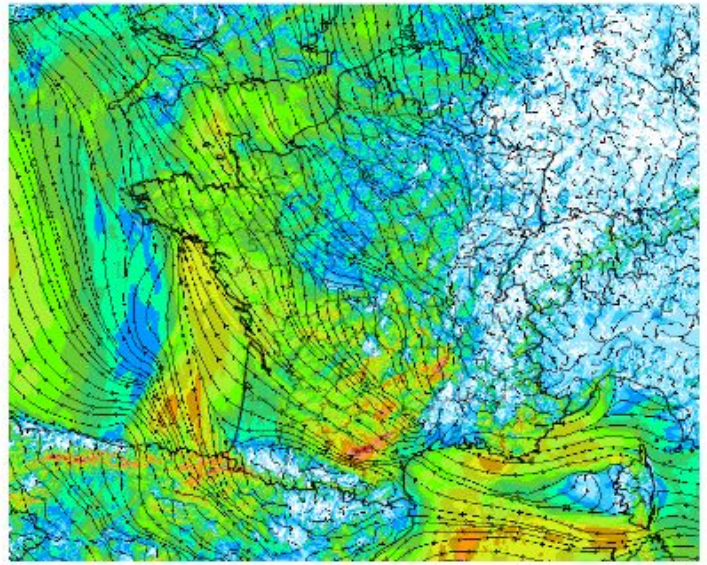
N. Merlet
T. Montmerle

Model Evaluation Department, Météo-France
V. Lion

Nowcasting currently in production at Météo France

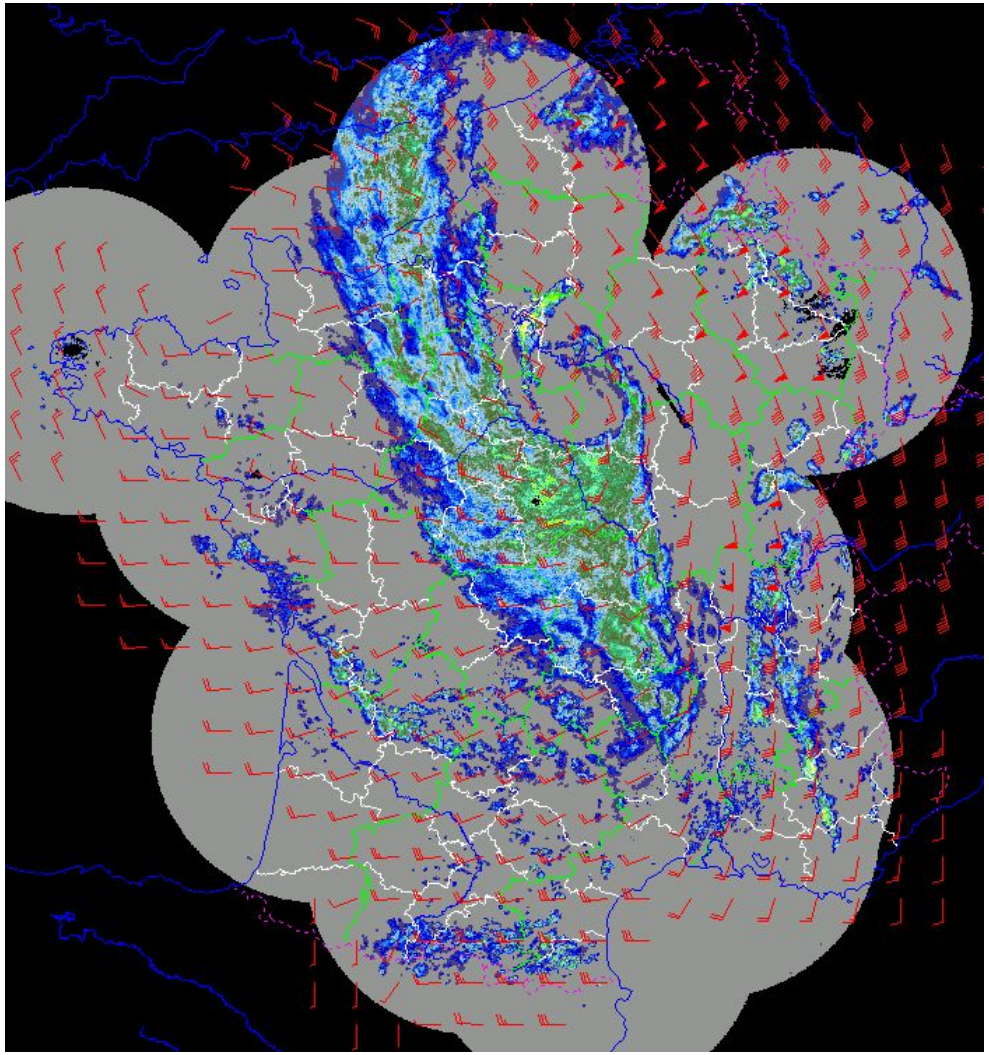
AROME-Ncst : nowcasting version of the French NWP model AROME





Nowcasting currently in production at Météo France

Radar image extrapolation



T. Montmerle - Météo-France

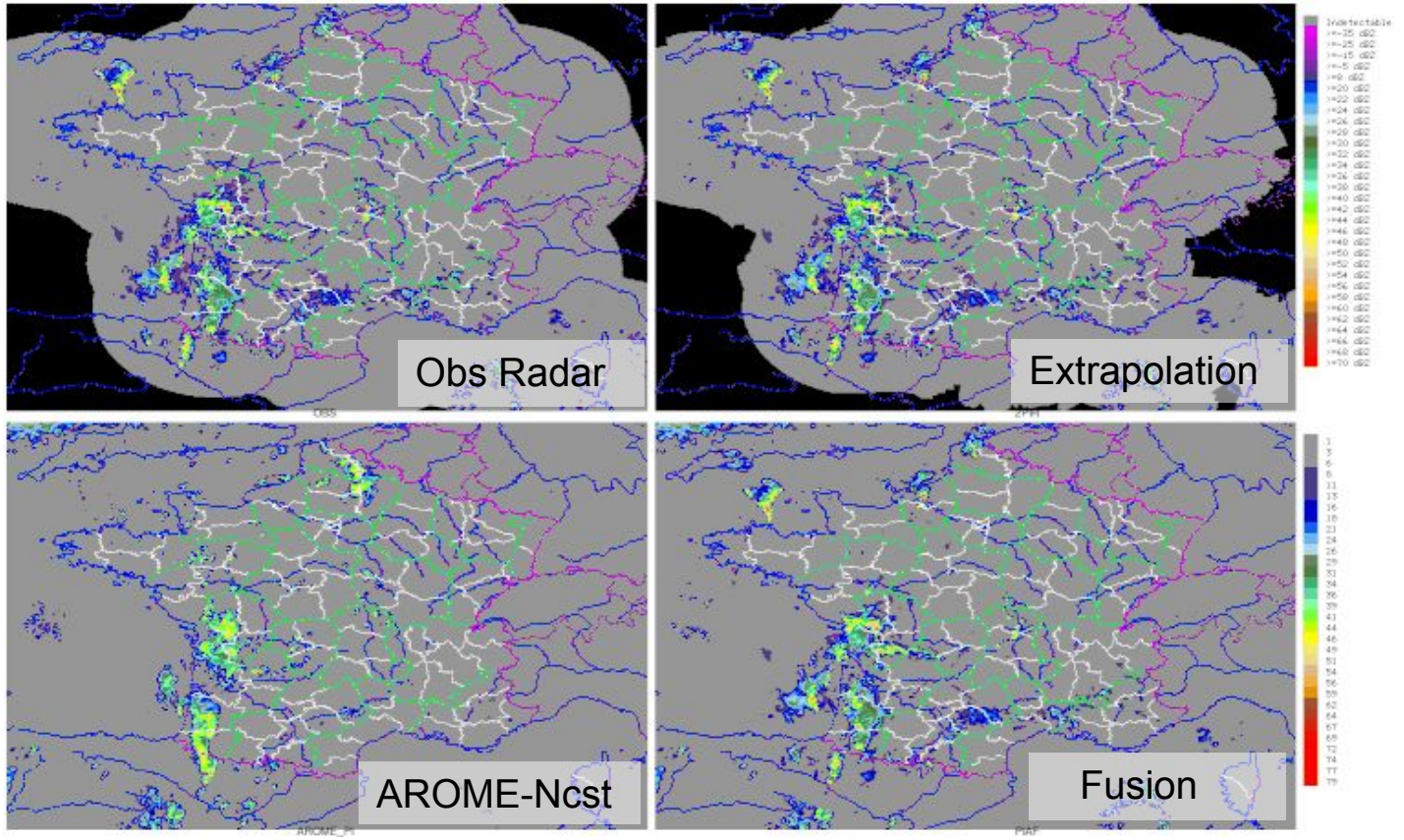
Nowcasting currently in production at Météo France

Fusion between AROME Nowcasting and Radar Extrapolation

Fusion = α Extrapolation + (1 - α) AROME-Ncst

α is computed from a statistical training on recent data from the previous 6h

Goal : **replace Extrapolation by Deep Learning** in fusion product

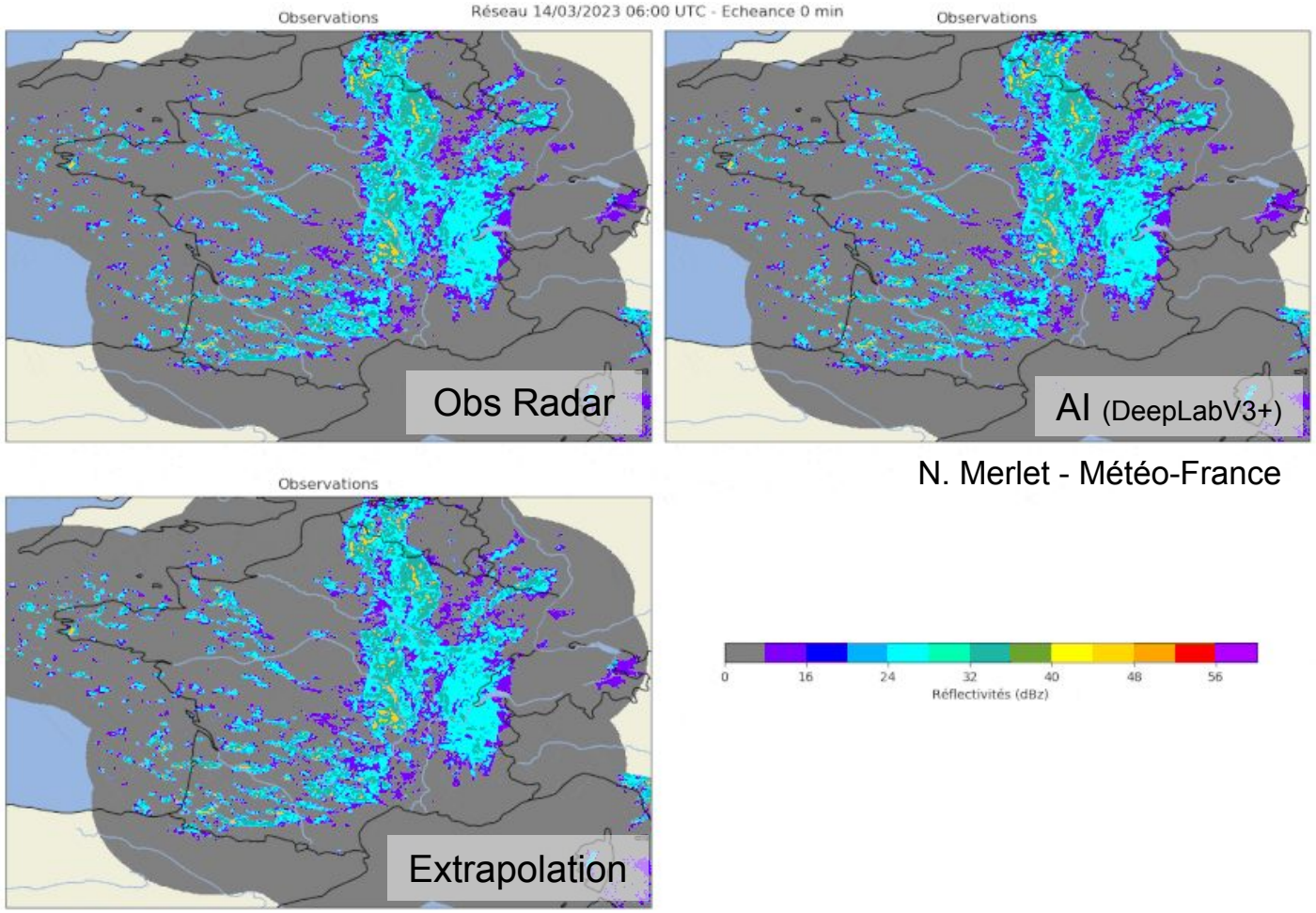


T. Montmerle - Météo-France

AI Nowcasting with supervised learning

Supervised training on several neural networks (U-Net, DeepLabV3+, …)

- **Inputs** = 4 last radar images
- **Target** = 24 next radar images
- **Loss function = MSE** or derivates



N. Merlet - Météo-France

AI Nowcasting with GANs and diffusion models

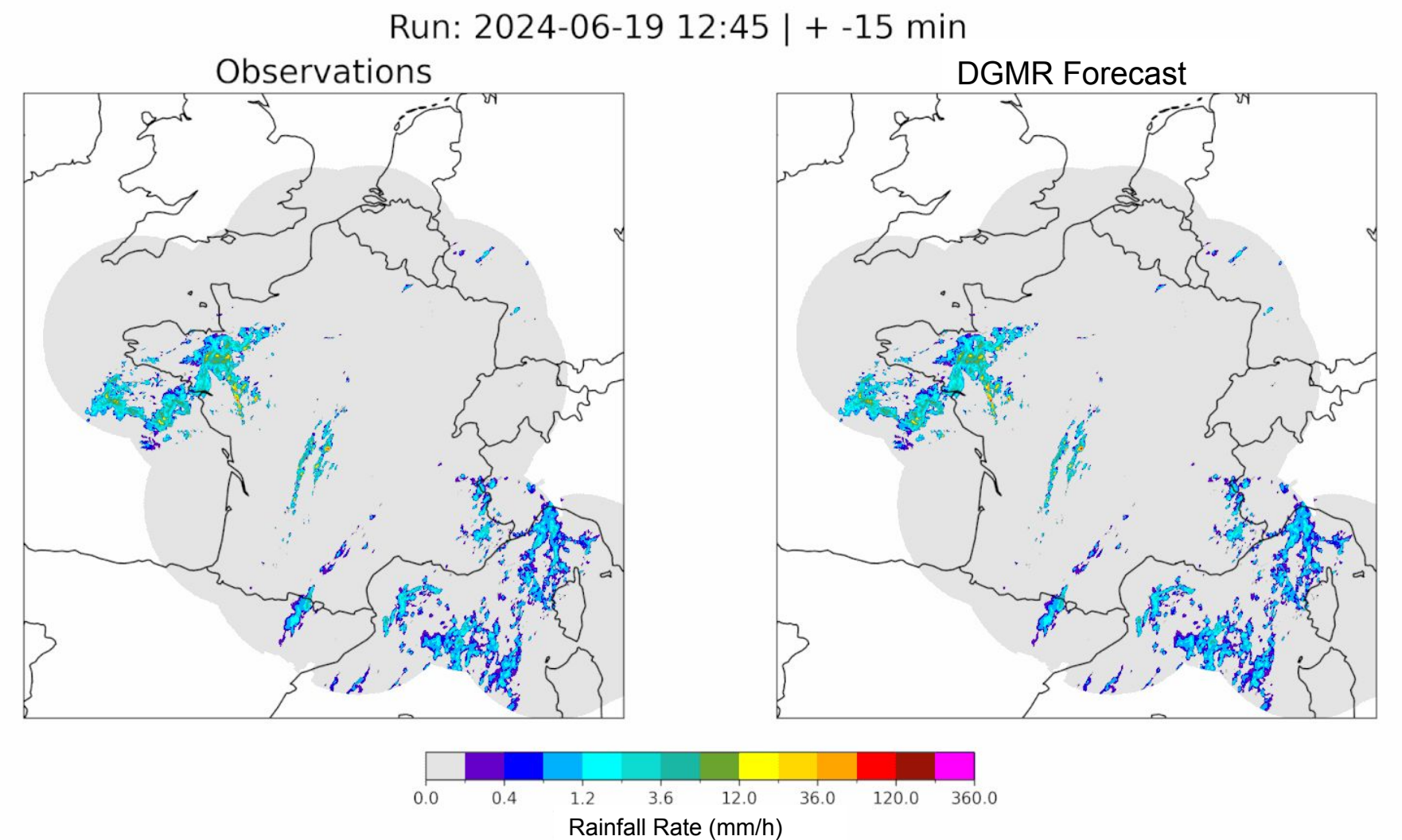
Work In Progress :

Comparing our methods with state-of-the-art GANs and Diffusion models

Model	Team	Paper	Radar Training Data	Notes
DGMR	Google Deepmind	*Skilful precipitation nowcasting using deep generative models of radar* Ravuri et al., Nature, 2021	United Kingdom	
LDCast	MeteoSwiss	*Latent diffusion models for generative precipitation nowcasting with accurate uncertainty quantification* Leinonen et al., 2023	Swiss	20 min inference time on GPU
NowCastNet	Tsinghua University	*Skilful nowcasting of extreme precipitation with NowcastNet* Zhang et al., Nature, 2023	USA & China	Forecast time step = 10 minutes

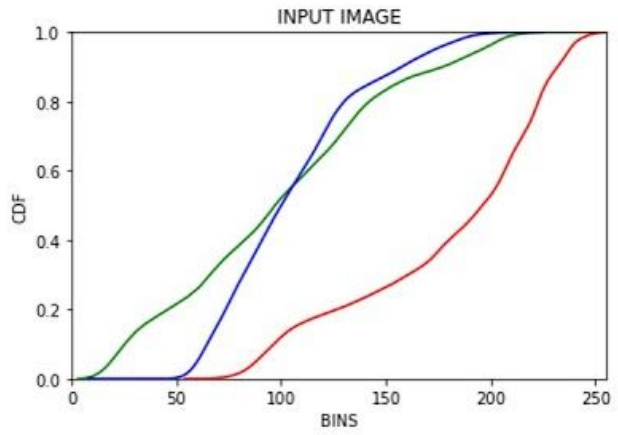
AI Nowcasting with GANs and diffusion models

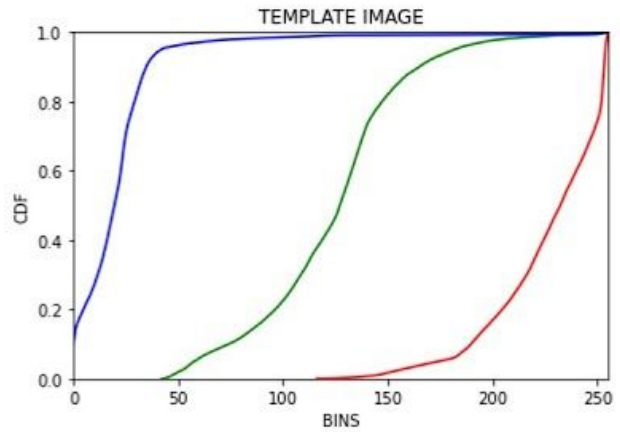
Forecast example from DGMR

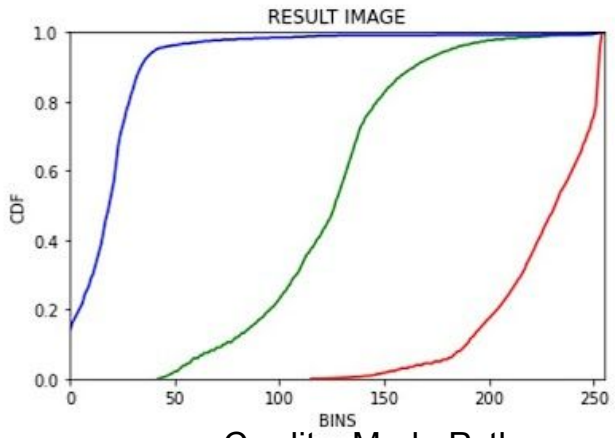


AI Nowcasting with GANs and diffusion models

Maintaining high intensity precipitation :
DGMR post-processing with Histogram Matching

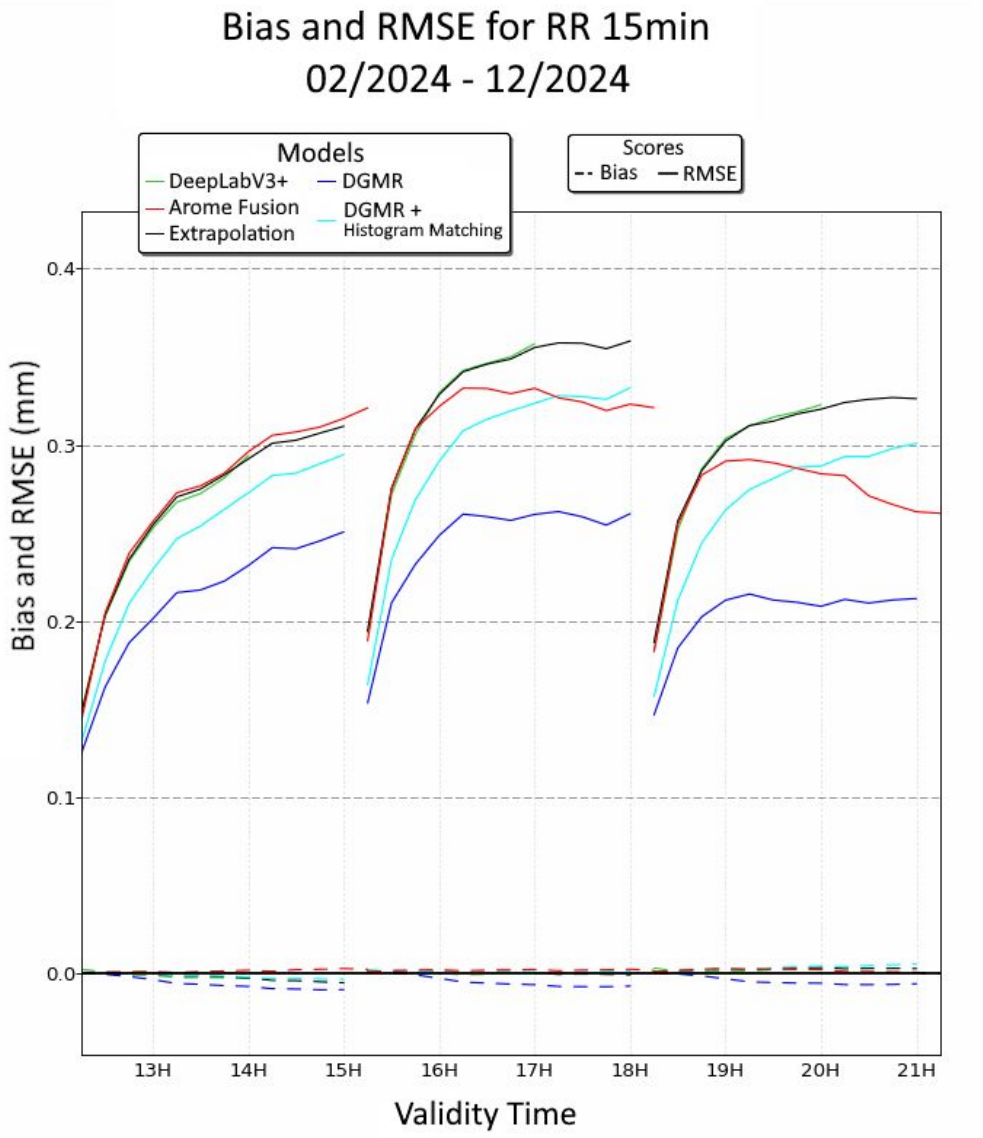




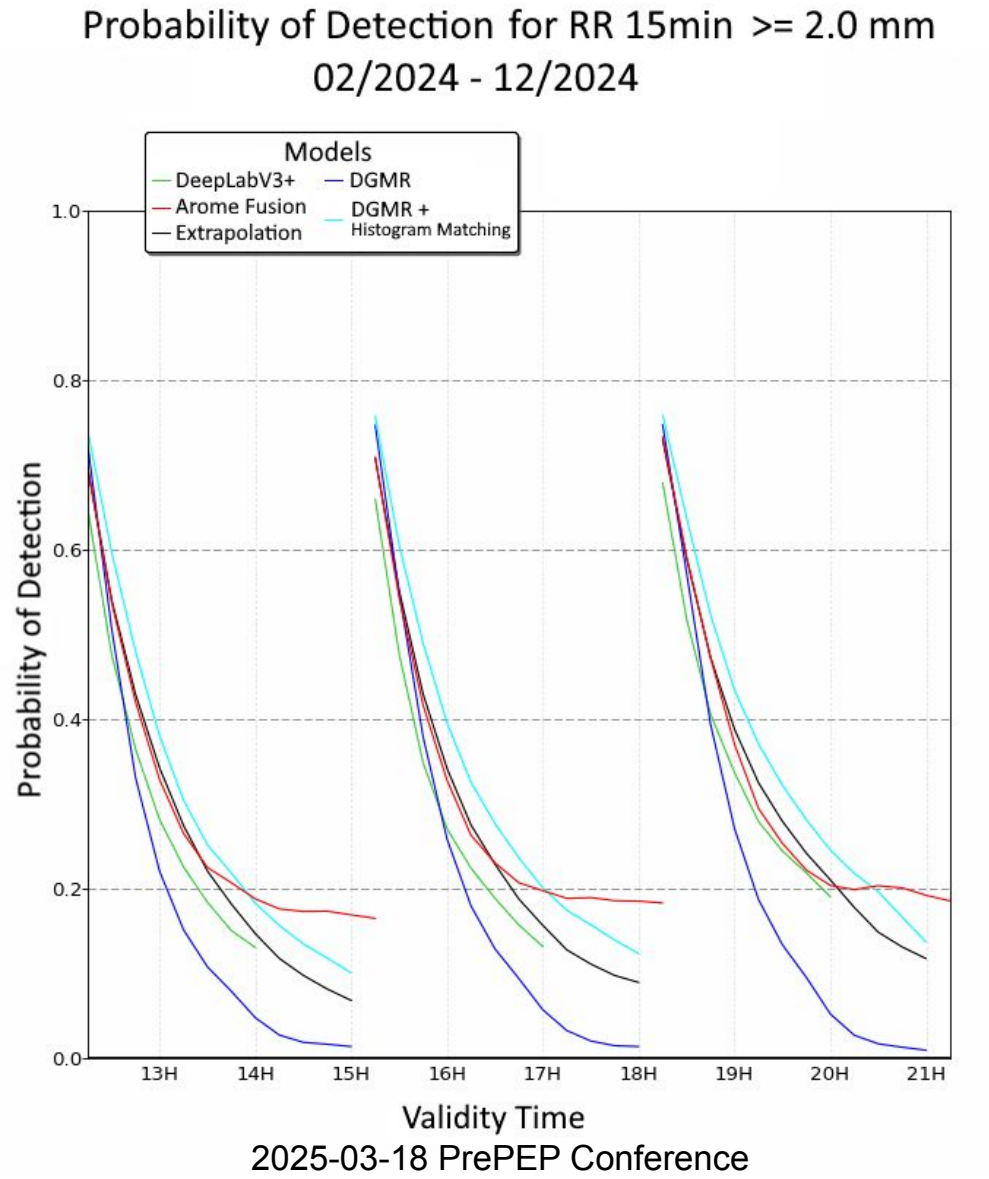


Credits: Made Python

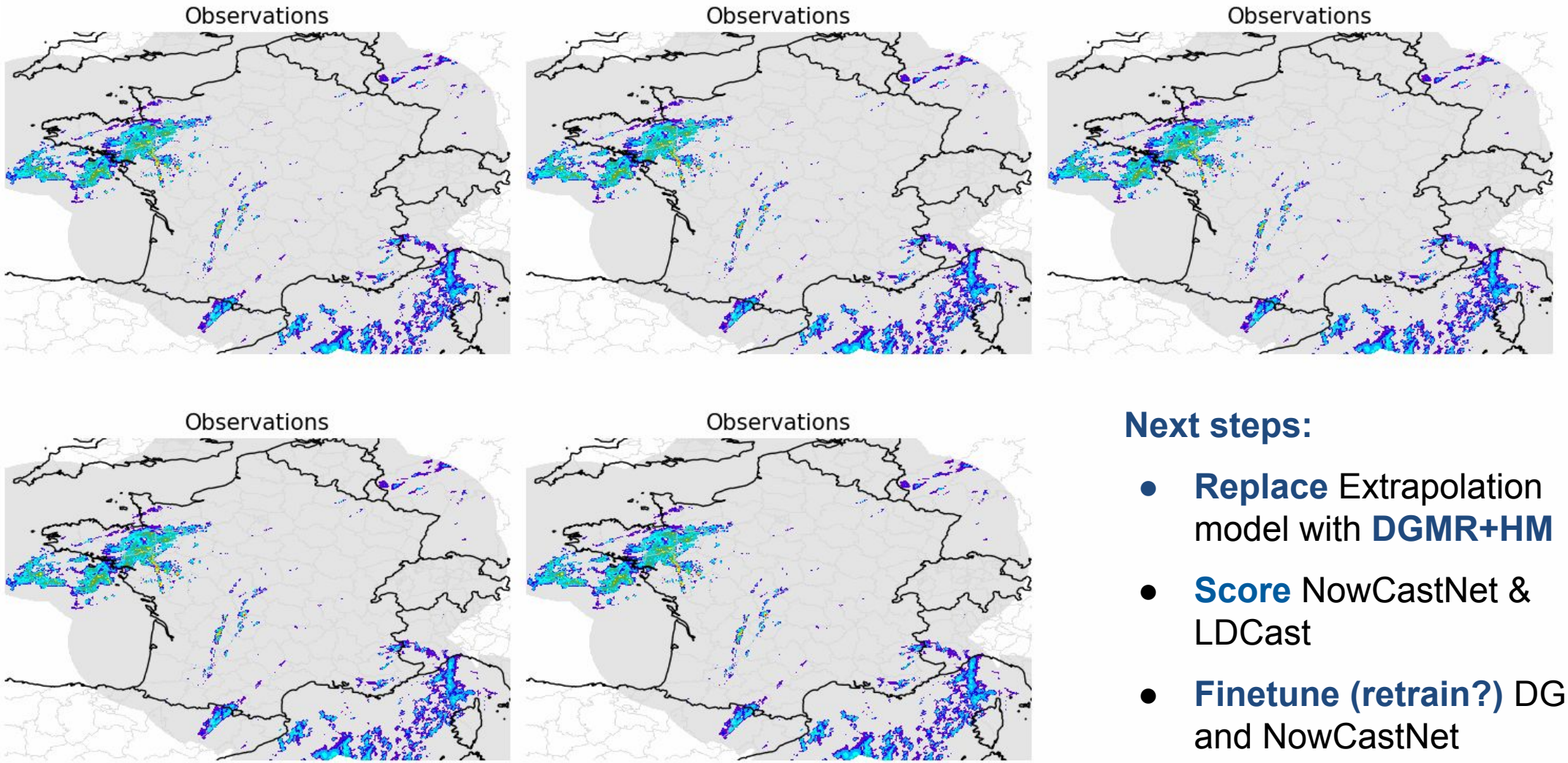
Benchmarking RMSE & bias



Benchmarking rain detection

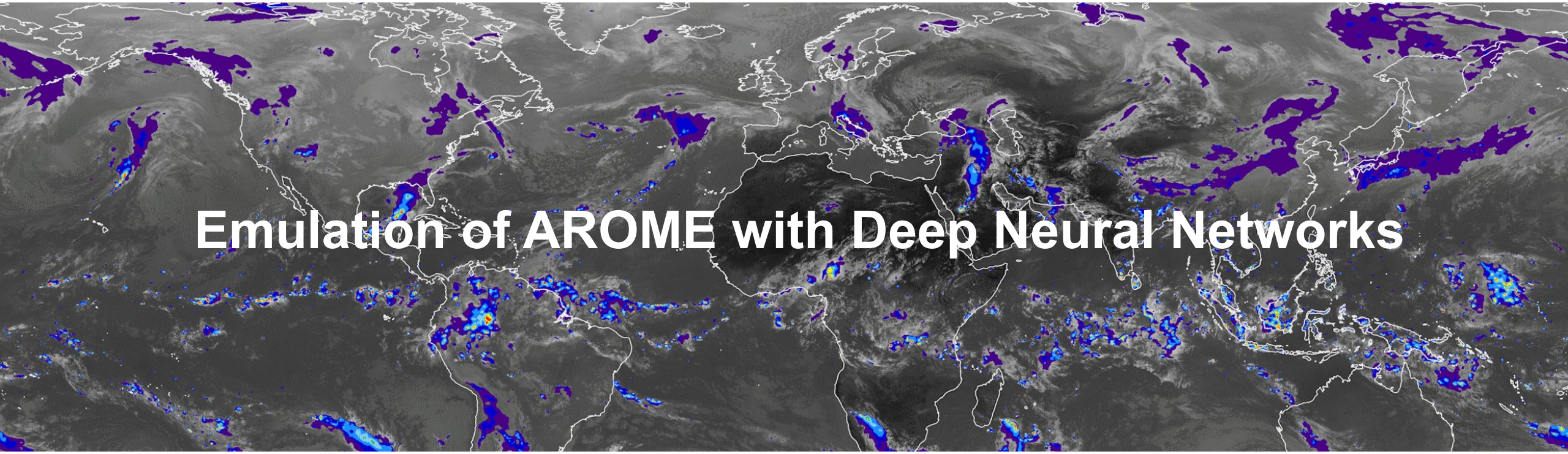


Run: 2024-06-19 12:00 UTC | -15 min



Next steps:

- **Replace** Extrapolation model with **DGMR+HM**
- **Score** NowCastNet & LDCast
- **Finetune (retrain?)** DGMR and NowCastNet



Emulation of AROME with Deep Neural Networks

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L. Berthomier
F. Guibert
B. Pradel
T. Tournier

CNRM
S. Akodad, C. Brochet
V. Chabot, L. Raynaud
C. Seznec

EVIDEN
C. Bovalo
L. Vincent

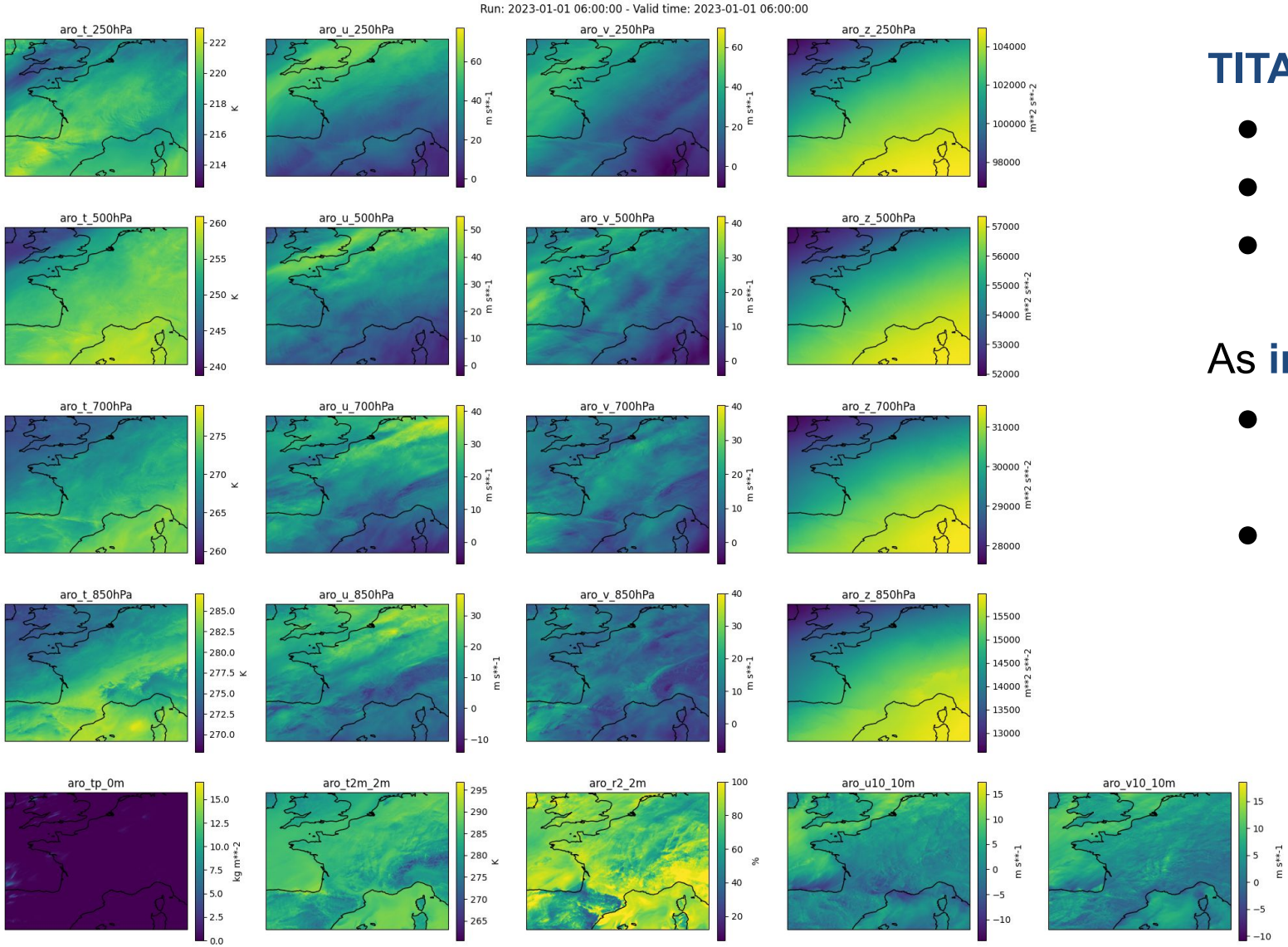
Deep learning Emulator of AROME

- Work started in January 2024
- Started with **building datasets** on **France Limited Area**
- **Py4cast project:** train a variety of **Neural Networks** on various **weather forecasting datasets**
- **open-source MFAI library: neural networks, losses, metrics for meteorology**

meteofrance
py4cast & mfai

Contributions are welcome! 

TITAN Dataset



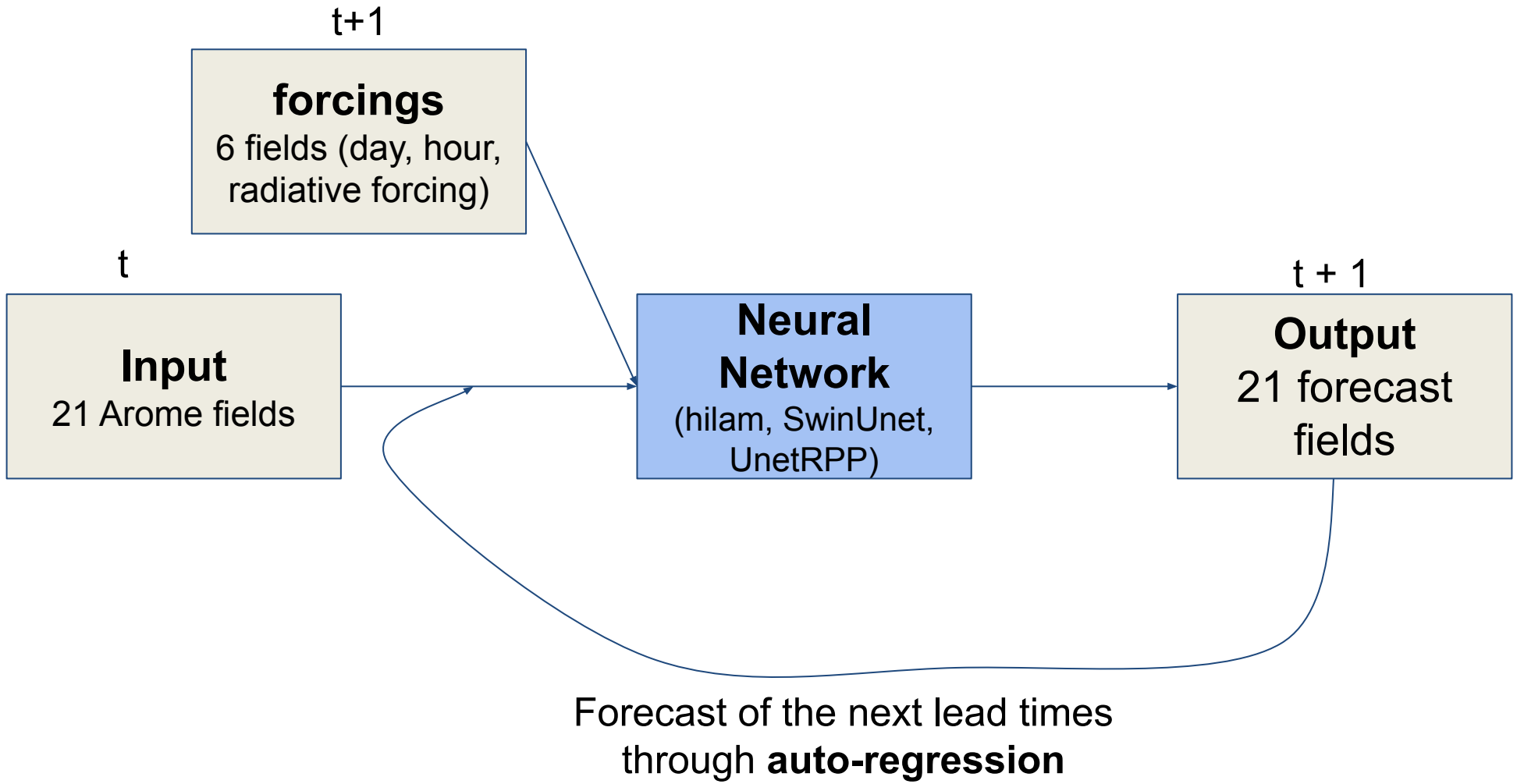
TITAN Dataset:

- AROME analysis
- 2.5km resolution
- Period 2021-2023

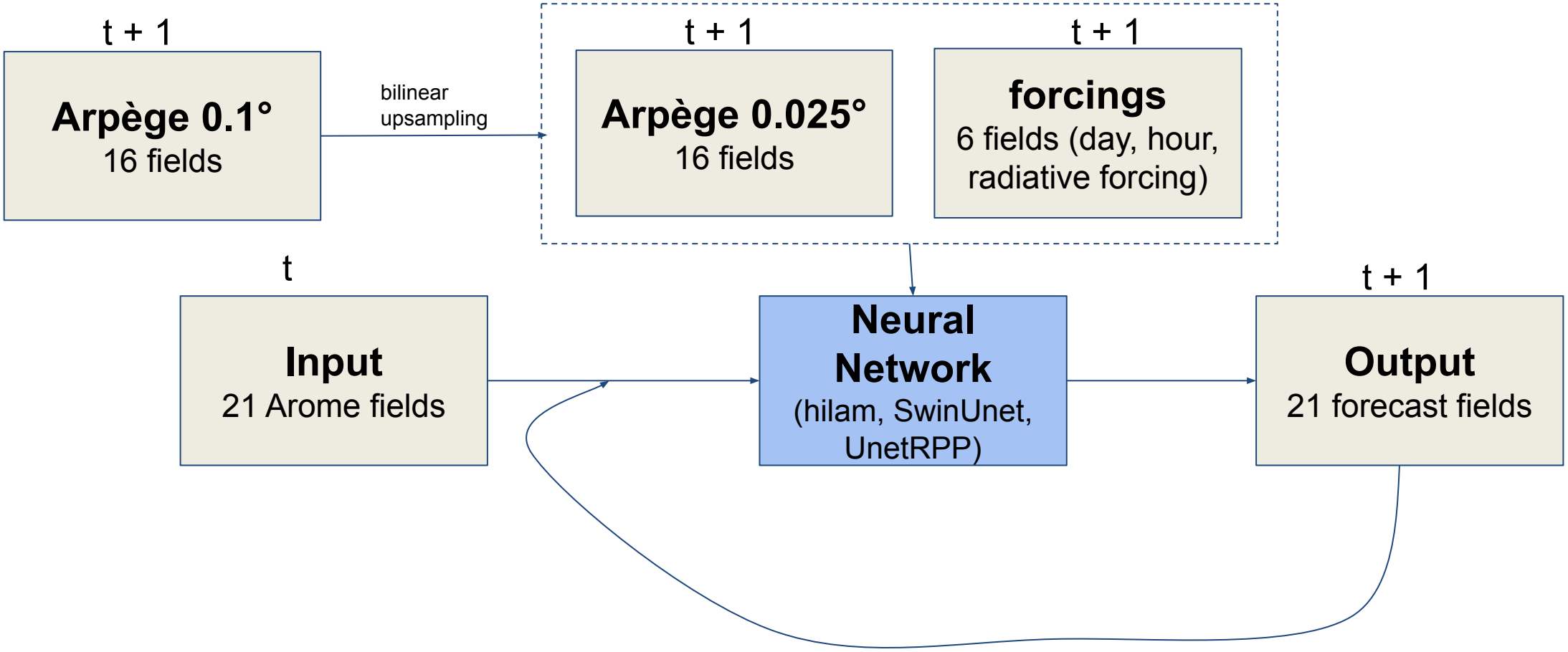
As **input** and **output** of the model :

- 5 surface parameters including precipitation
- 4 parameters on 4 vertical levels

First Experiment



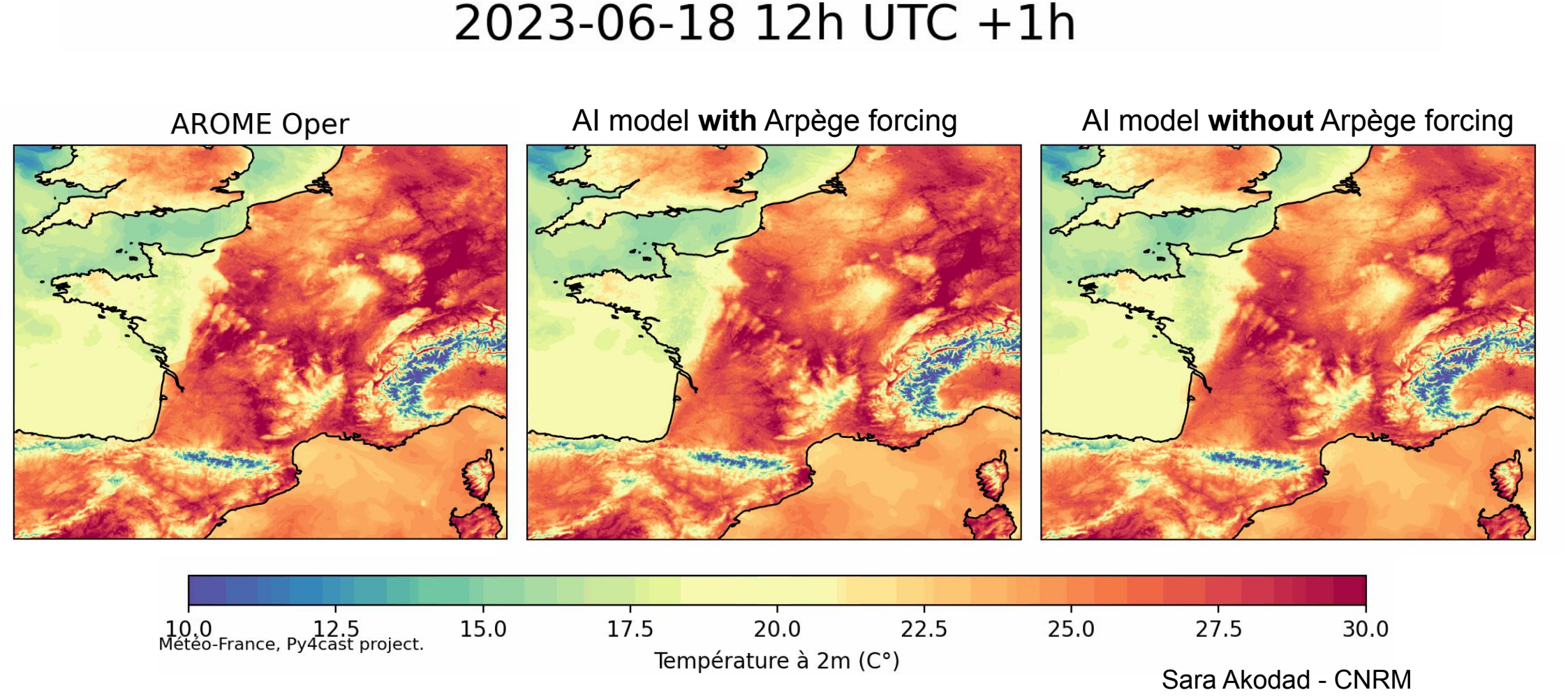
Second Experiment



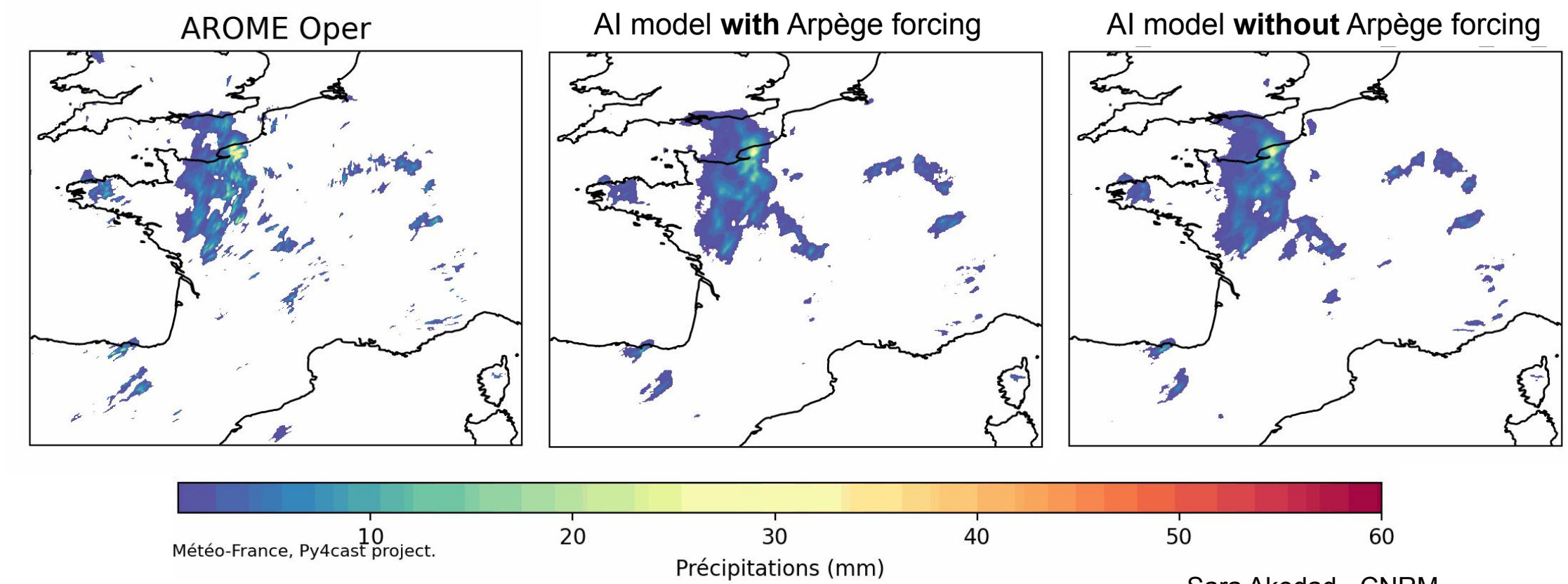
Forecast of the next lead times through **auto-regression**

Computation time between 48h and 6 days on 4 Nvidia V100

Example of forecast +48h



Example of forecast +48h



Sara Akodad - CNRM

Next step: Use **ANEMOI** framework from ECMWF to test the "**stretched grid approach**" (Nipen et al. 2024)

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Thank you for your attention !