

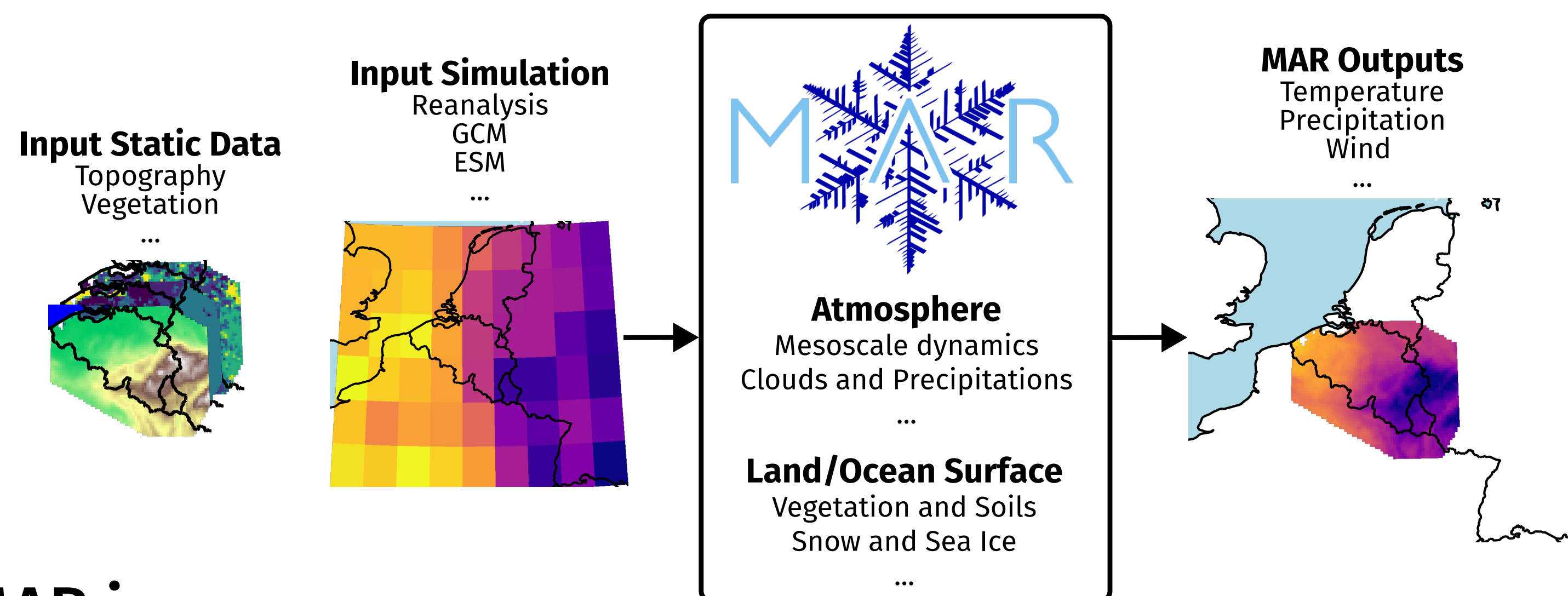
MAR.ia: A Diffusion-Based Emulator for Climate Downscaling Over Belgium

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MAR.ia is an emulator of MAR, an RCM tailored to Belgium [1]. It maps coarse ERA5 reanalysis data (0.25°) to high-resolution surface variables (5 km). The diffusion approach allows for a fast and accurate generation of ensembles to assess uncertainty and explore climate scenarios.

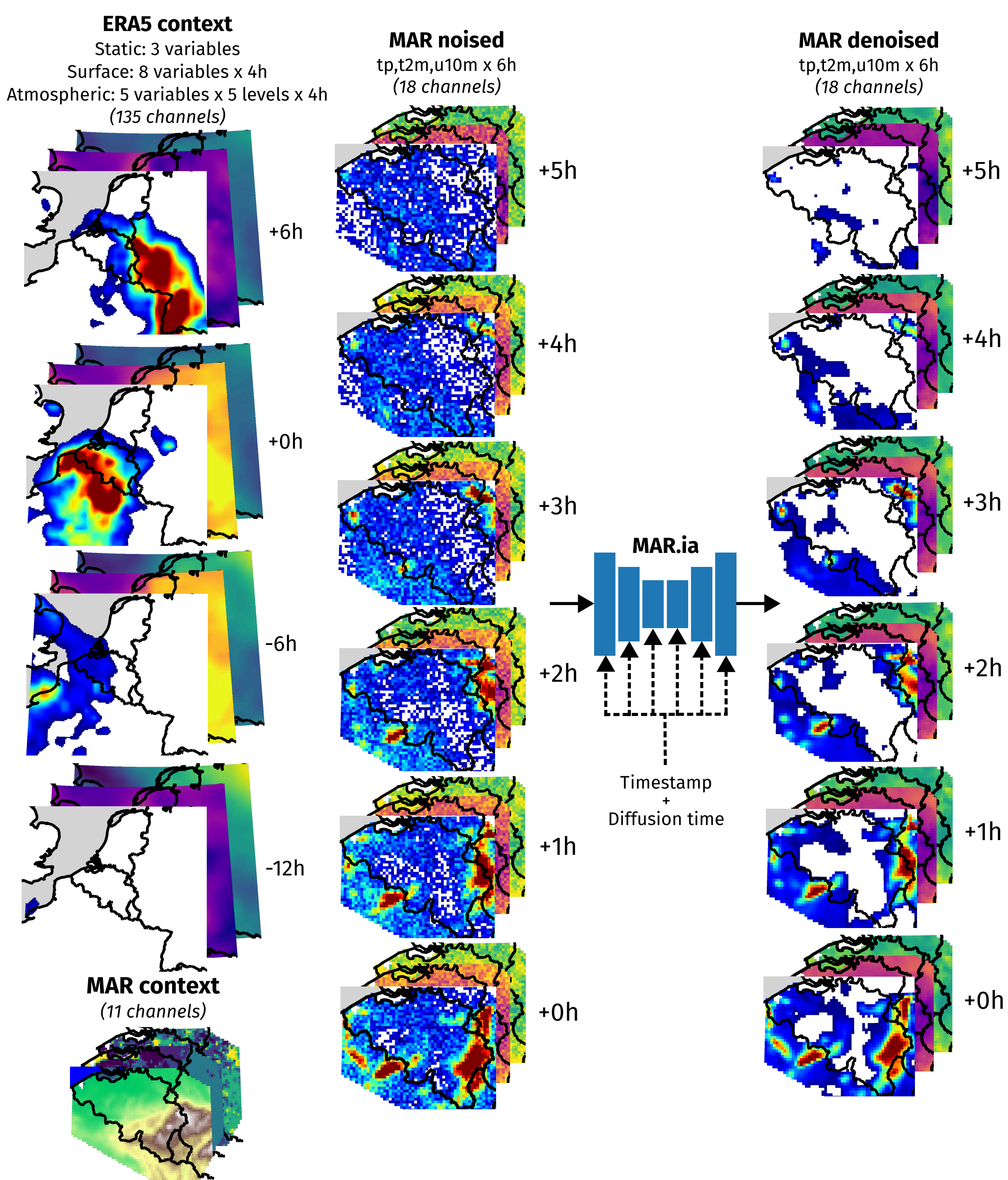
MAR (Modèle Atmosphérique Régional)

MAR is a Regional Climate Model which downscales coarse global simulations to more accurate predictions by taking into account topography, soil type, ... MAR numerically solves the dynamical equations and produces one deterministic output. Generating 100 years of data takes 2 weeks on a 100 CPUs.

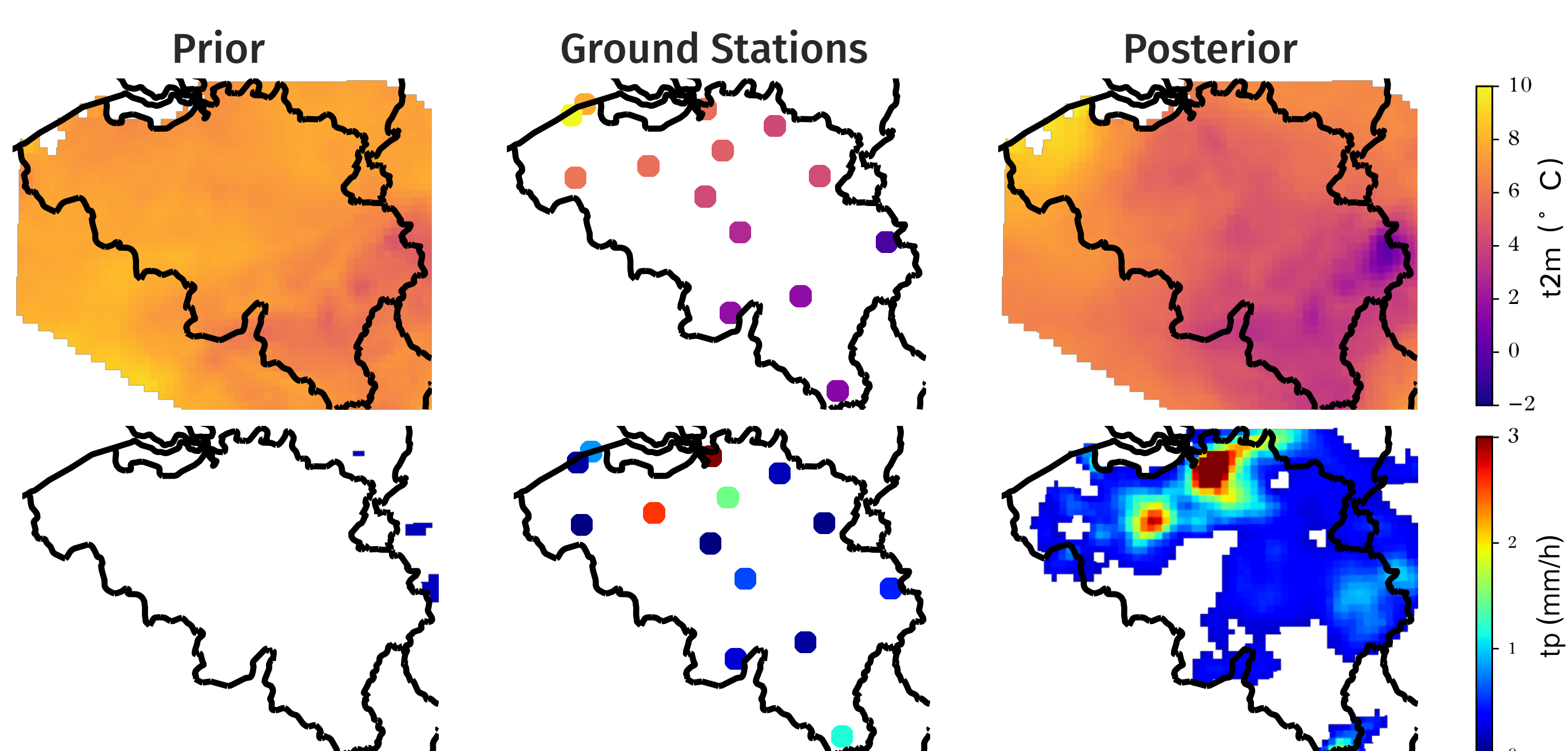


MAR.ia

MAR.ia is a generative model. Starting from Gaussian noise, it can generate data via iterative denoising. Generating 100 years of data takes 3 hours on 20 A100 GPUs.

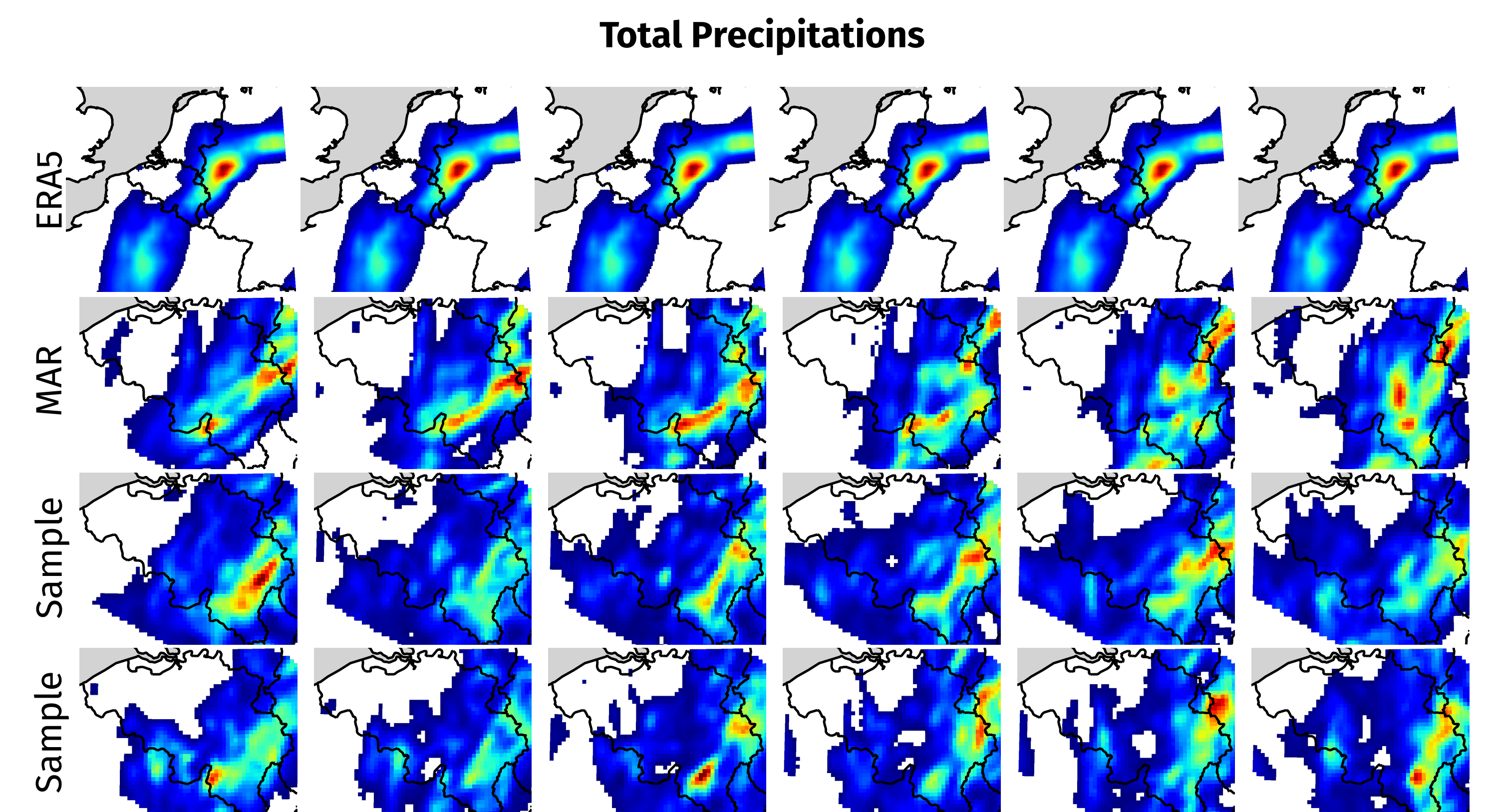
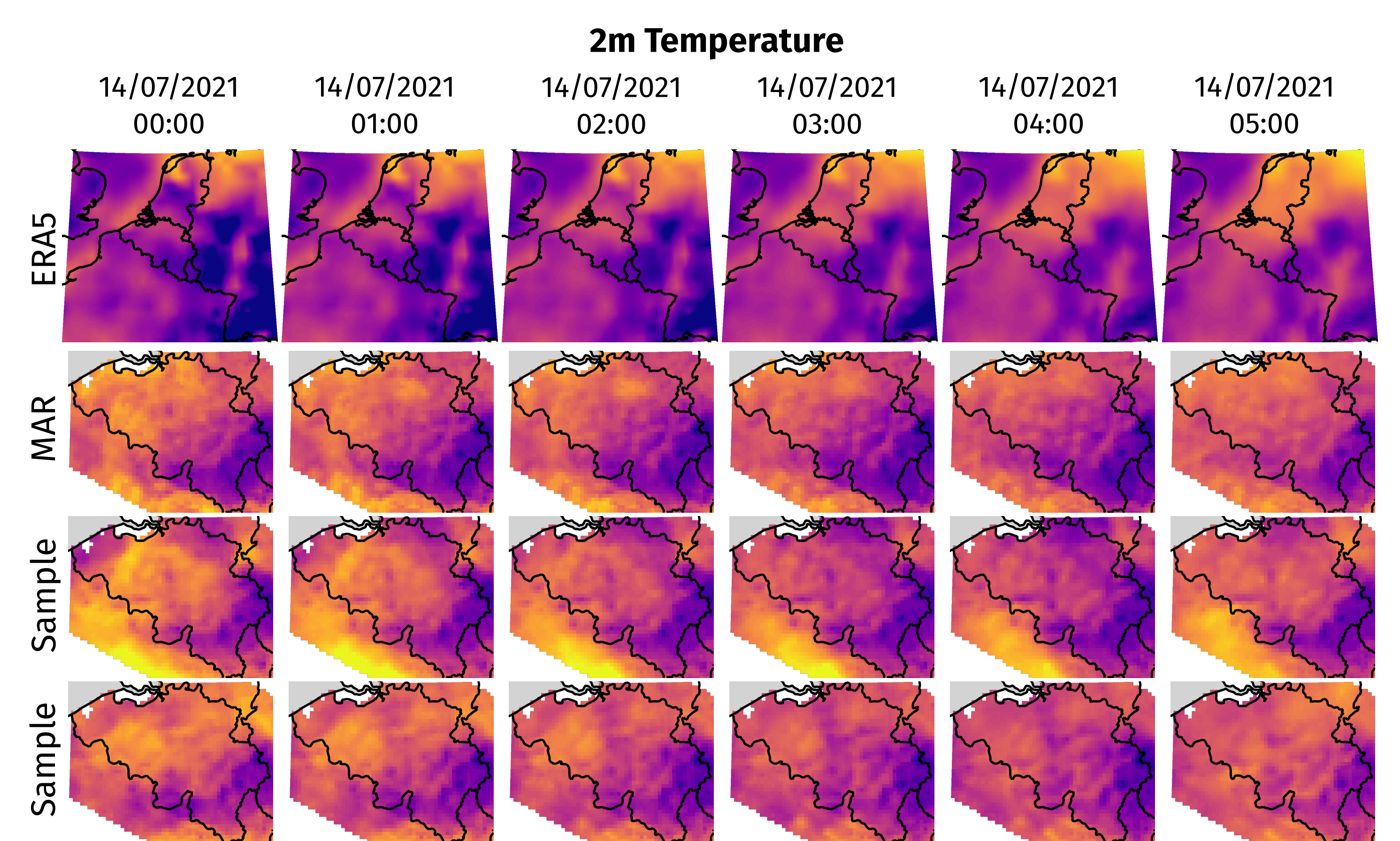
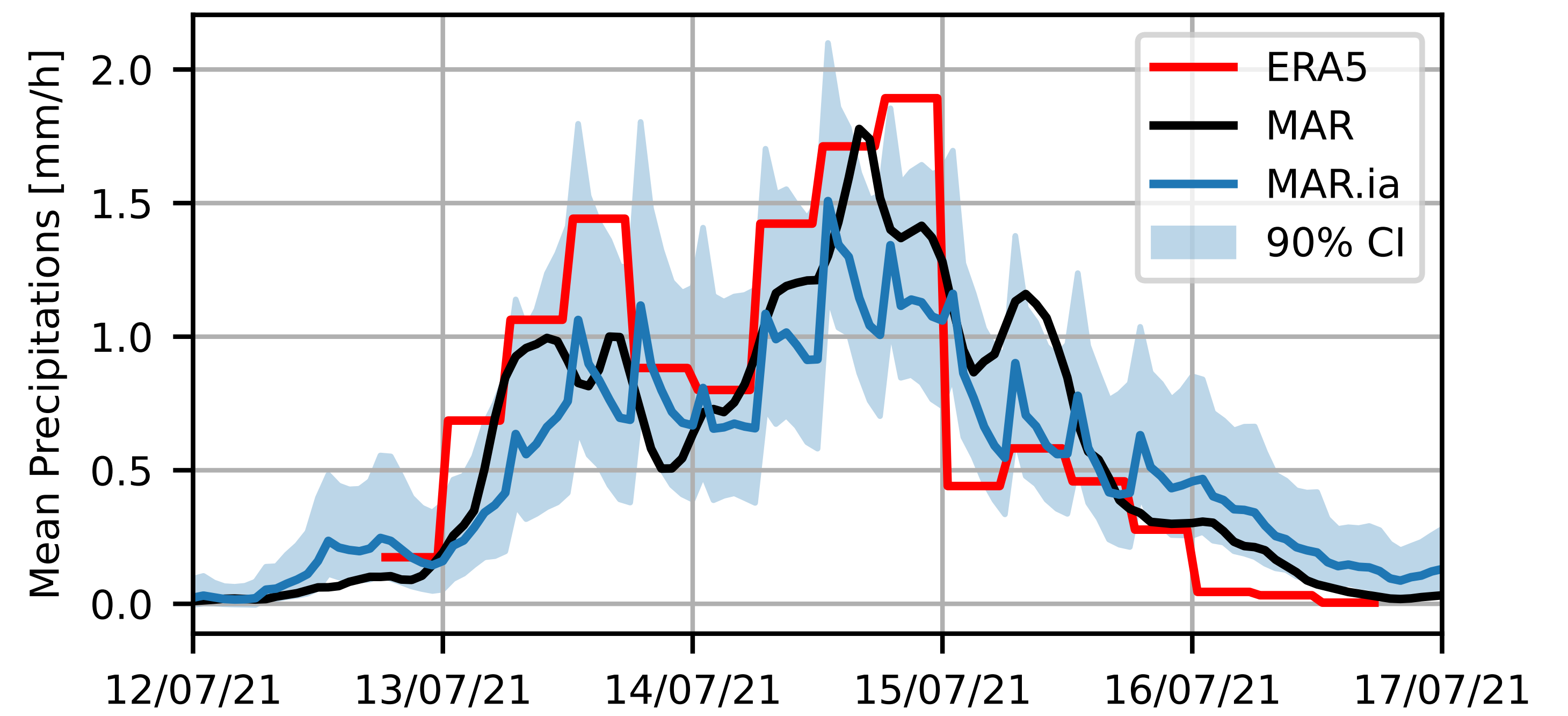


Diffusion models allow the assimilation of observations during sampling.



Reanalysis of extreme events (July 2021)

In July 2021, Belgium suffered from catastrophic floods. MAR.ia can reproduce such extreme events which are not encountered in its training distribution (1993-2019). The MAR trajectory is well contained within the MAR.ia ensemble members.



Results (2019-2021)

MAR.ia accurately emulates MAR, especially for the temperature and wind speed.

Metric	Model	Temperature (t2m) (°C)	Wind (u10m) (m/s)	Precipitation (tp) (mm/day)
Skill	ERA5 (1°)	1.529	1.153	2.738
	ERA5 (0.25°)	1.438	1.159	2.844
	MAR.ia (1°)	0.961	0.749	1.911
	MAR.ia (0.25°)	0.853	0.703	1.688
Bias	ERA5 (1°)	-0.322	-0.307	0.262
	ERA5 (0.25°)	-0.355	-0.276	0.238
	MAR.ia (1°)	0.014	0.032	-0.024
	MAR.ia (0.25°)	0.137	-0.120	-0.060
Correlation	ERA5 (1°)	0.983	0.912	0.694
	ERA5 (0.25°)	0.982	0.915	0.687
	MAR.ia (1°)	0.991	0.937	0.795
	MAR.ia (0.25°)	0.993	0.947	0.846
CRPS	MAR.ia (1°)	0.478	0.405	0.666
	MAR.ia (0.25°)	0.397	0.387	0.522

[1] Doutreloup S, Wyard C, Amory C, Kittel C, Ericum M, Fettweis X. Sensitivity to Convective Schemes on Precipitation Simulated by the Regional Climate Model MAR over Belgium (1987–2017). *Atmosphere*. 2019