

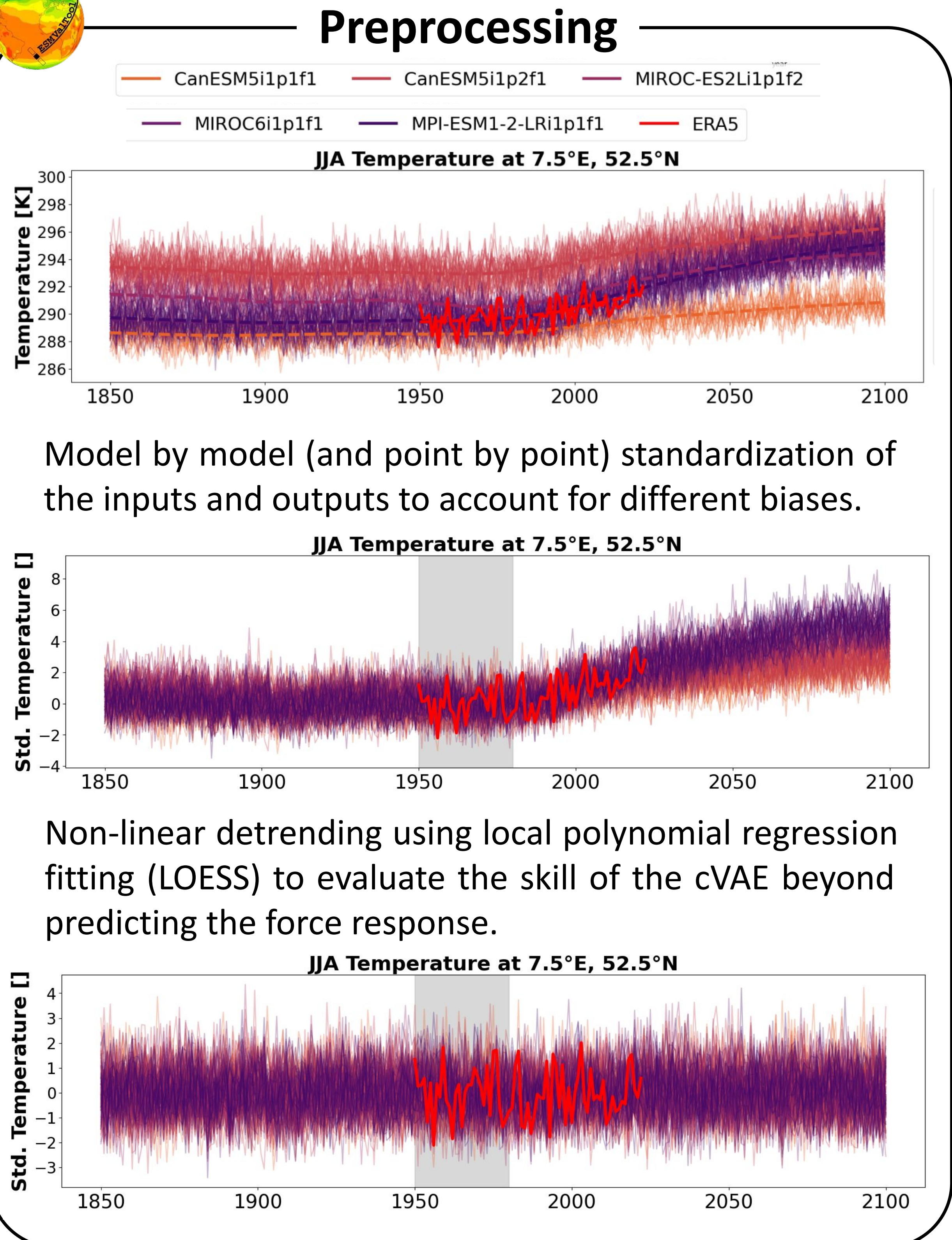
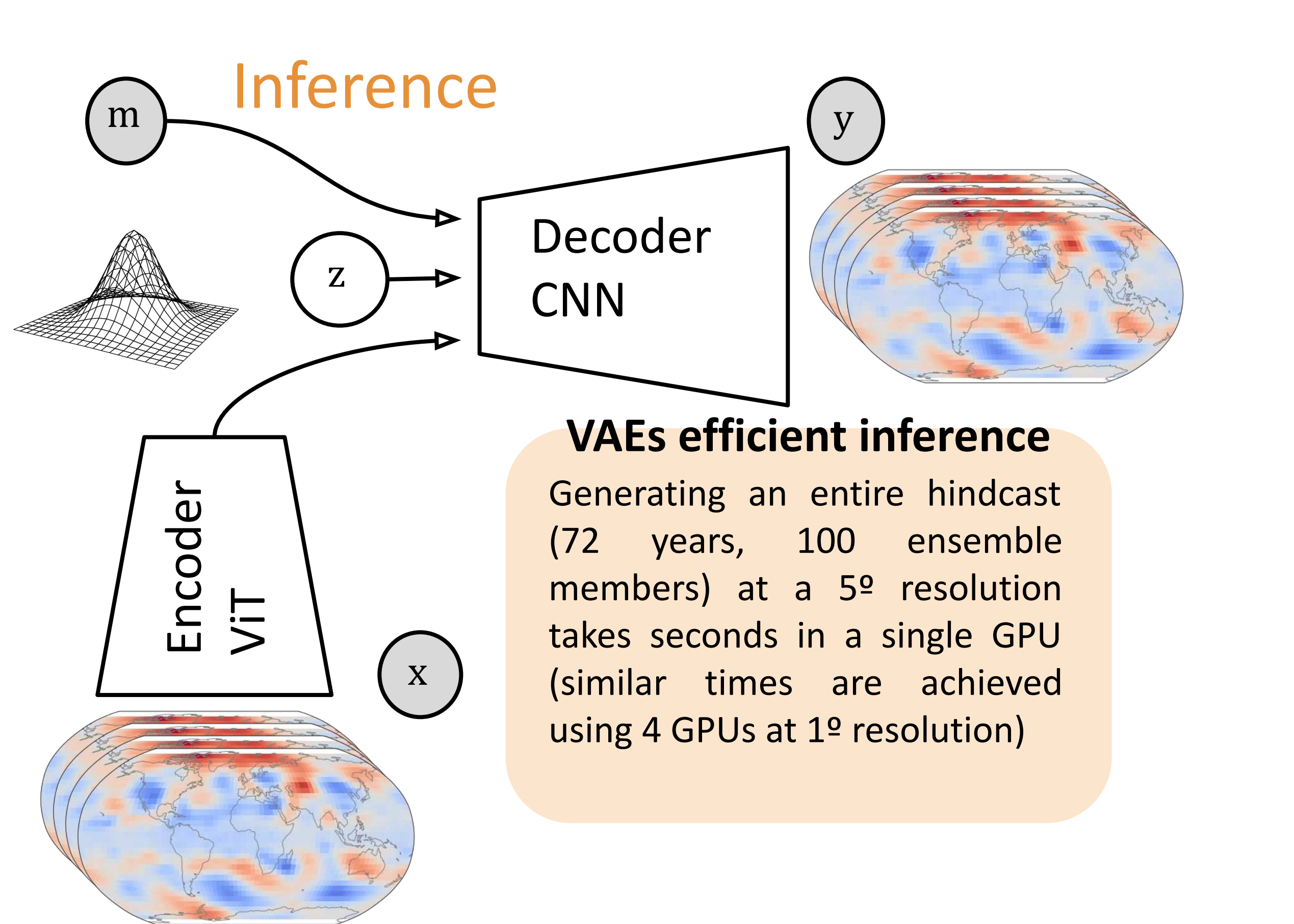
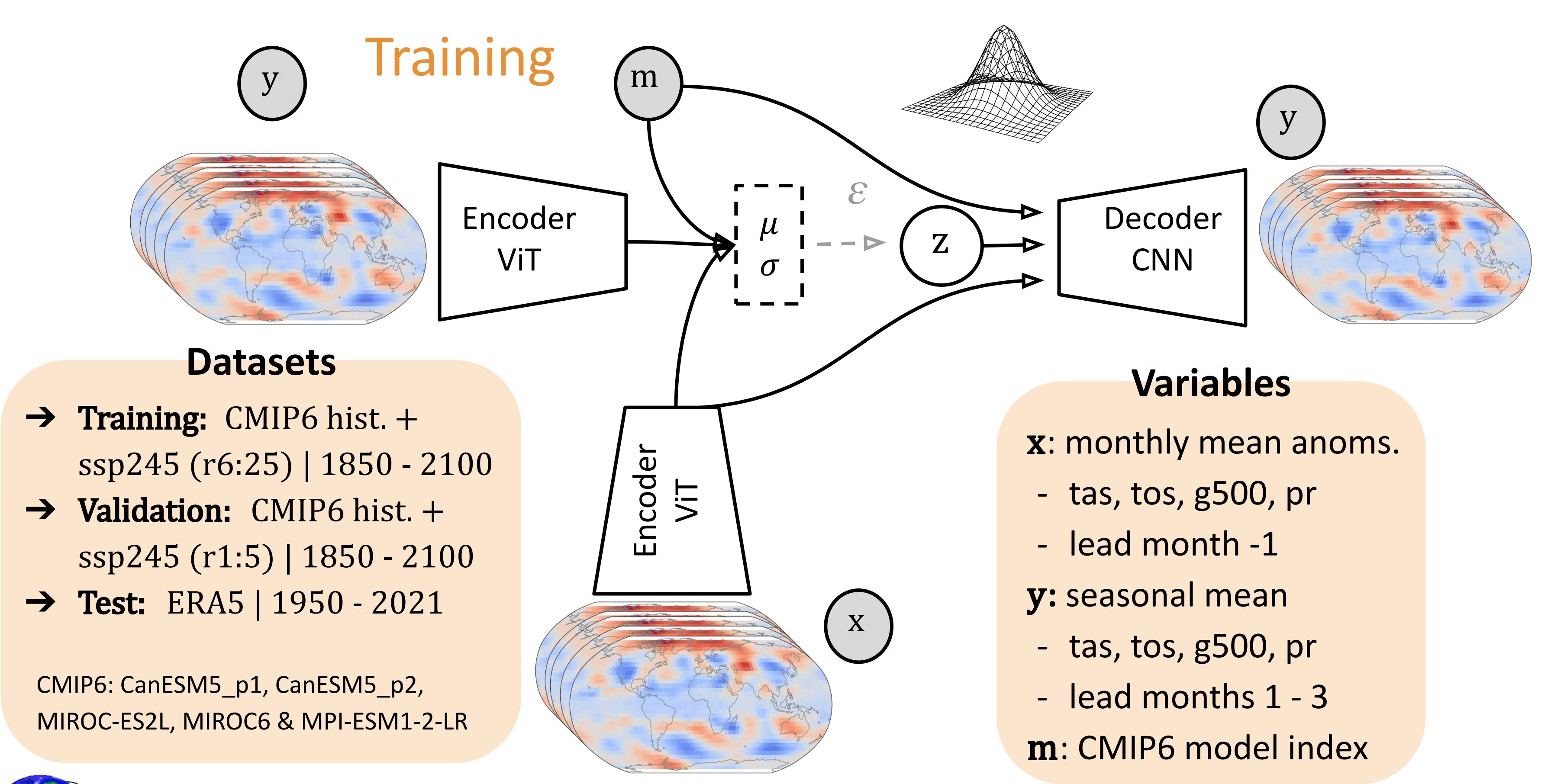
A global empirical system for probabilistic seasonal climate prediction based on generative AI and CMIP6 models



Lluís Palma¹, Alejandro Peraza¹, Amanda Duarte¹, David Civantos², Stefano Materia¹, Arijit Nandi³, Jesús Peña-Izquierdo², Mihnea Tufis³, Gonzalo Vilella³, Laia Romero², Albert Soret¹, and Markus Donat¹

¹ Barcelona Supercomputing Center, Earth Sciences Department, Spain | ² Lobelia Earth, Barcelona, 08005, Spain | ³ Eurecat Technology Center of Catalunya, Barcelona, 08005, Spain

✉ lluis.palma@bsc.es



Summary

- We train a conditional Variational Autoencoder (cVAE) with CMIP6 simulations to generate probabilistic global seasonal predictions.
- The performance of the predictions obtained are evaluated using ERA5 reanalysis as a input/reference and compared to the ECMWFs dynamical model SEAS5
- We disentangle the performance of the cVAE predicting the force response vs climate variability.

Architecture

Variational Autoencoders (VAEs) can be interpreted as a probabilistic and non-linear extension of classic dimensionality reduction methods like PCA.

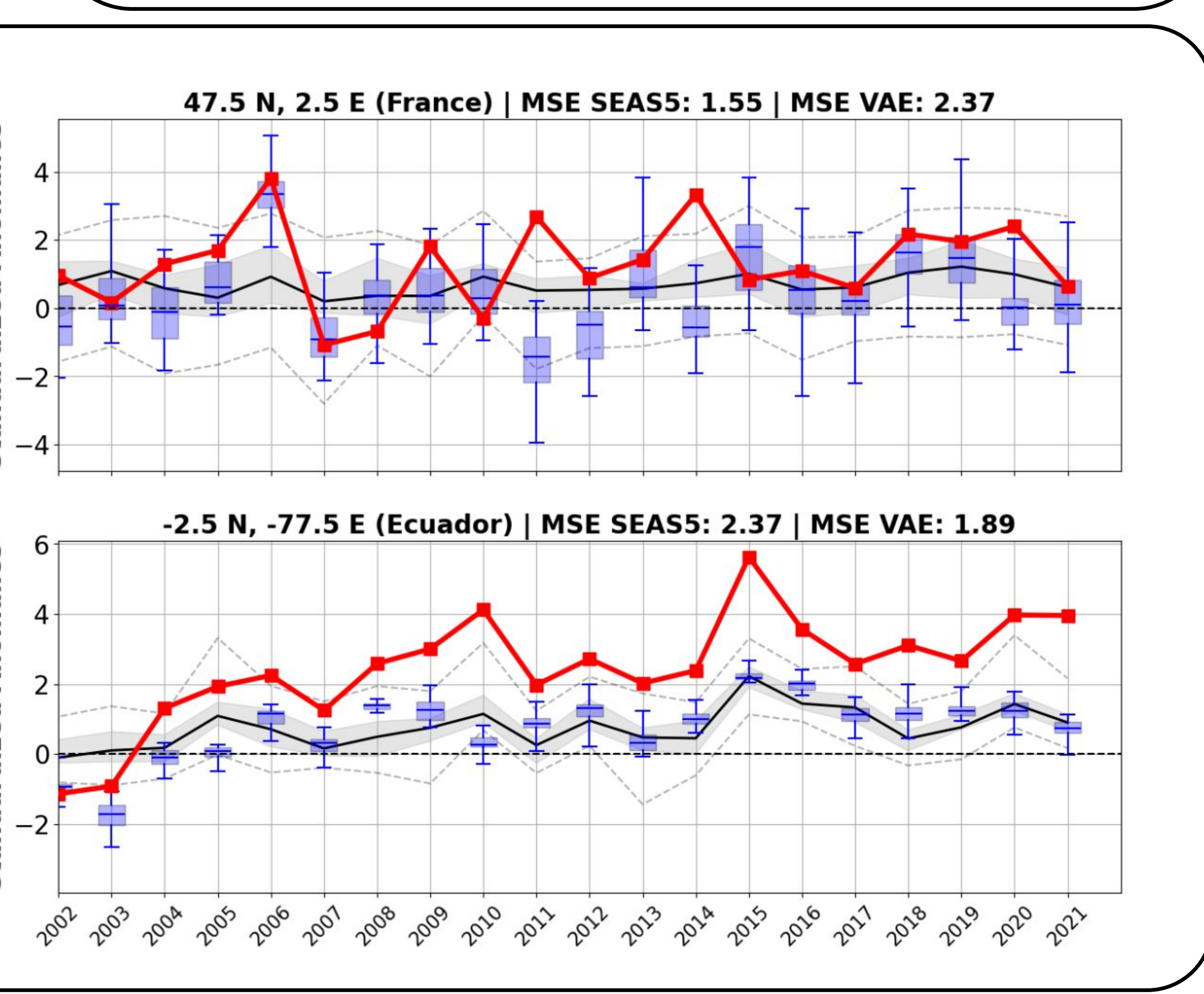
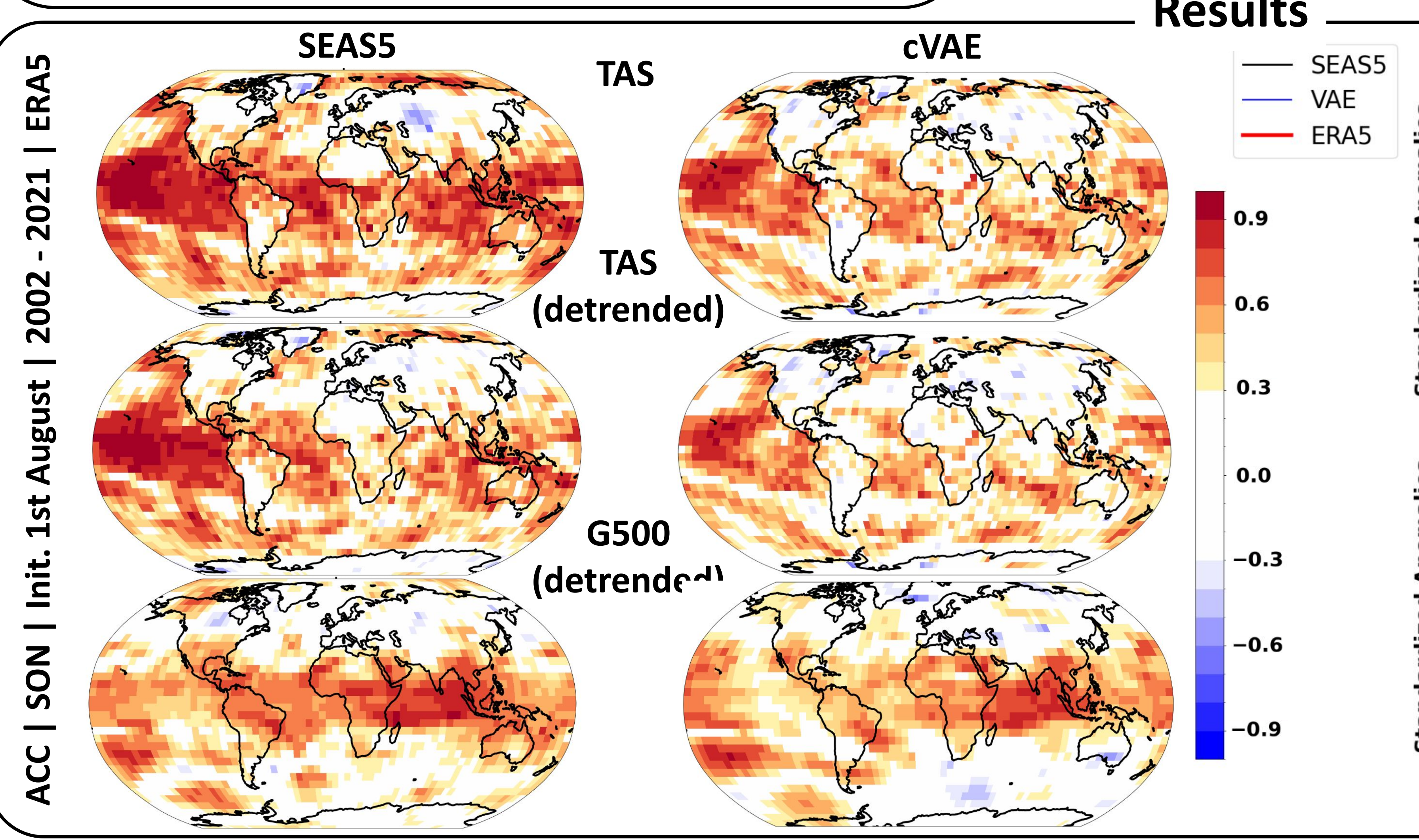
Conditional VAEs (cVAEs) add inputs (X and m [1]) to learn a conditional distribution and make the model generative per se. Thus, the model produces ensembles of predictions at a low computational cost.

Loss: Directly maximizing the likelihood of the target variable is intractable. Hence, we minimize an adaptation of the InfoVAE objective [2] based on the evidence lower bound (ELBO) [3]:

Reconstruction term

$$L = \mathbb{E}_{z \sim Q_\phi} [\log P_\phi(Y|z, X, m)] - (1 - \alpha) D[Q_\phi(z|Y, X, m) || P_\phi(z|X, m)] - (\alpha - \lambda - 1) D[Q_\phi(z) || P_\phi(z)]$$

Dist. Divergences



[1] Pan, B., Anderson, G. J., Gonçalves, A., Lucas, D. D., Bonfils, C. J. W., & Lee, J. (2022). Improving Seasonal Forecast Using Probabilistic Deep Learning. Journal of Advances in Modeling Earth Systems, 14(3). <https://doi.org/10.1029/2021MS002766>

[2] Zhao, S., Song, J., & Ermon, S. (2018). InfoVAE: Information Maximizing Variational Autoencoders (arXiv:1706.02262). arXiv. <https://doi.org/10.48550/arXiv.1706.02262>

[3] Doersch, C. (2021). Tutorial on Variational Autoencoders (arXiv:1606.05908). arXiv. <http://arxiv.org/abs/1606.05908>