



# Improvement of a neural network convection scheme by including triggering and evaluation in present and future climates

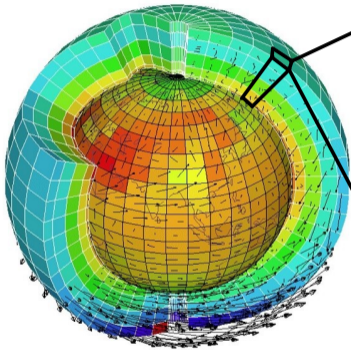
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(CNRM/GMGEC/GLOB-ATM)

Journées de l'IA, Météo-France, Toulouse, 18 Février 2026

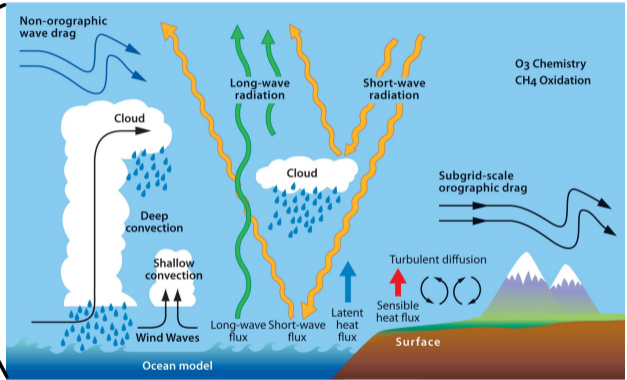
# Overview

- Context
- Previous works
- NN parameterization with triggering
- Evaluation in warmer climate
- Physical consistency

# Context : Climate Modeling



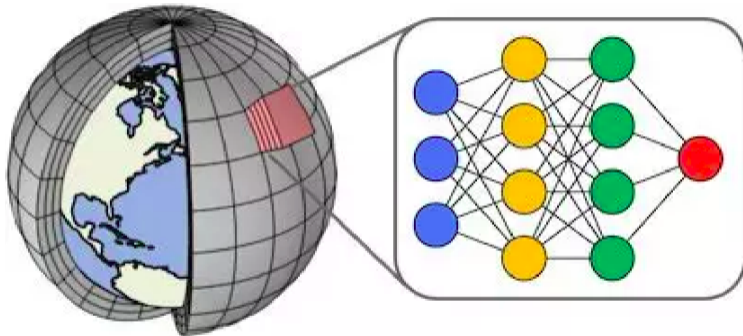
Climate model



Physical parameterizations

## Context : Physics-AI hybrid modeling

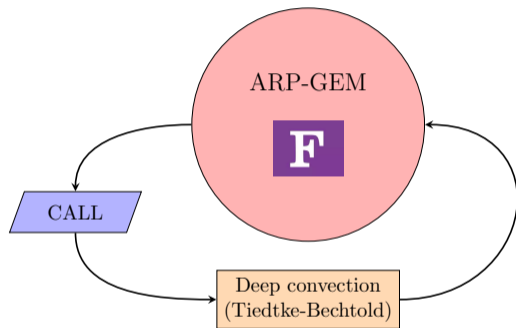
Goals : Speeding, Improving, Correcting,...



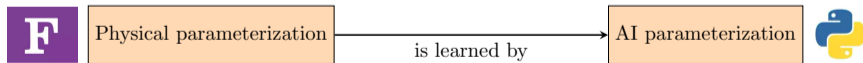
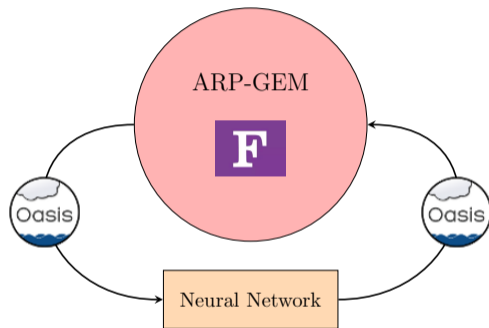
Issues : Extrapolation, Stability, Conservations, Explainability

## Previous works

Geoffroy et Saint-Martin, 2025



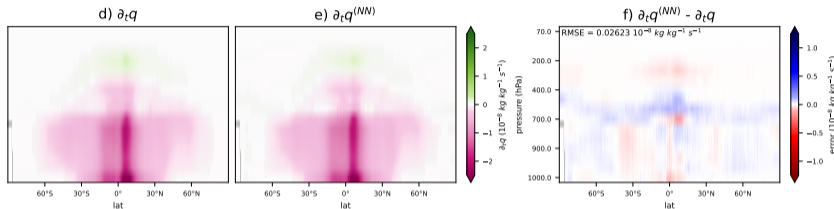
Balogh et al., 2025



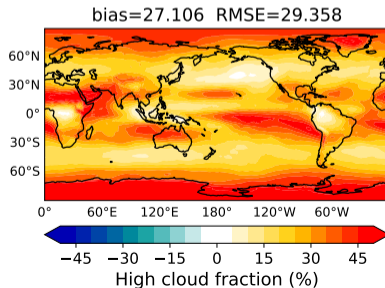
Idealised framework "perfect model"

## Previous works : Balogh et al., 2025

- Represents well the heating  $\partial_t s$  and humidity  $\partial_t q$  tendencies (offline)

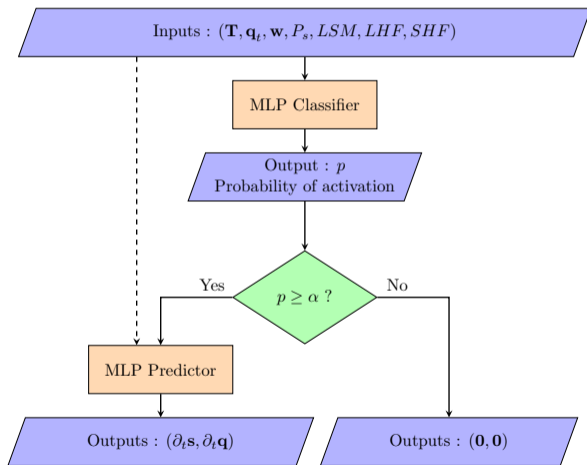


- Stable over a 30 year simulation.
- The mean state is reproduced well.
- Too much detrainment and too many cirrus :

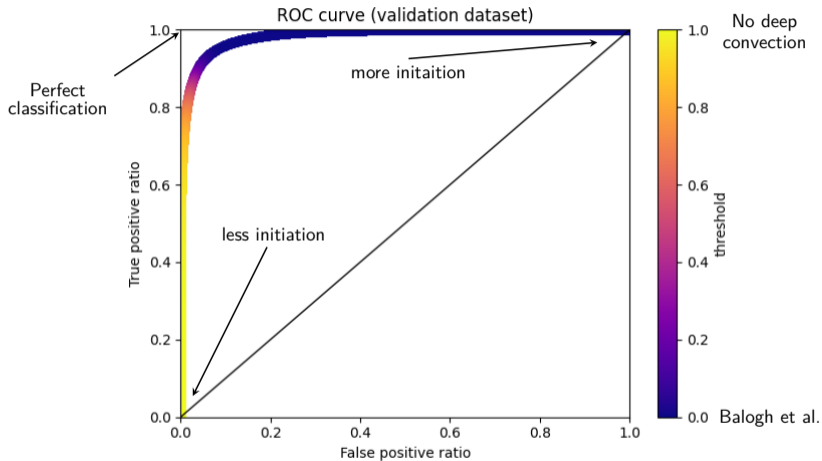


## NN parameterization with triggering : parameterization with two NNs

- Tiedtke-Bechtold does not produce convection in 90% of the columns (Tendencies = zeros). Not the case for the NN.
- How can an AI parameterization produce zeros in the case of no convective initiation ?

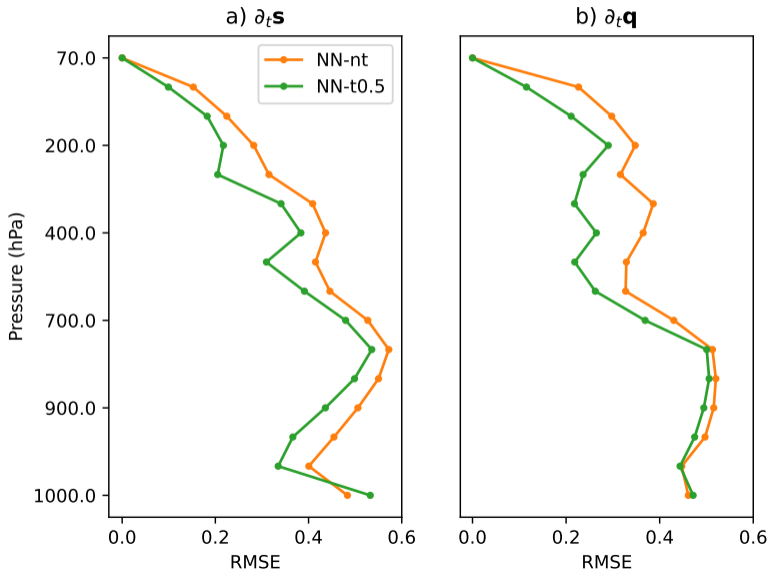


# NN parameterization with triggering : ROC curve



Accurate classification performed by the NN.

# NN parameterization with triggering : Offline results



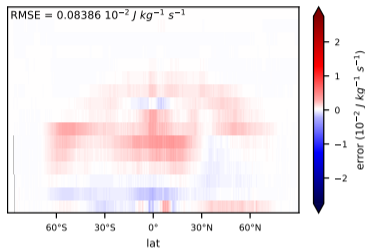
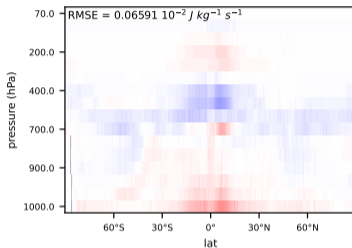
# NN parameterization with triggering : Offline results

No triggering

Triggering

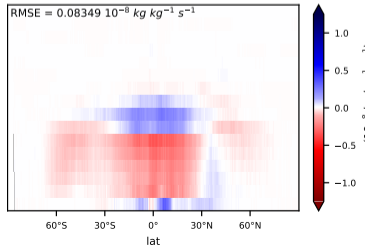
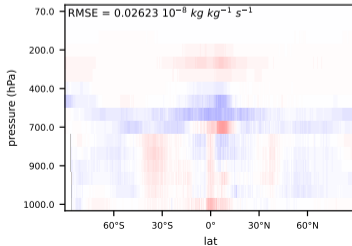
a) (NN-nt)  $\partial_t s^{(NN)} - \partial_t s$

c) (NN-t0,5)  $\partial_t s^{(NN)} - \partial_t s$



b) (NN-nt)  $\partial_t q^{(NN)} - \partial_t q$

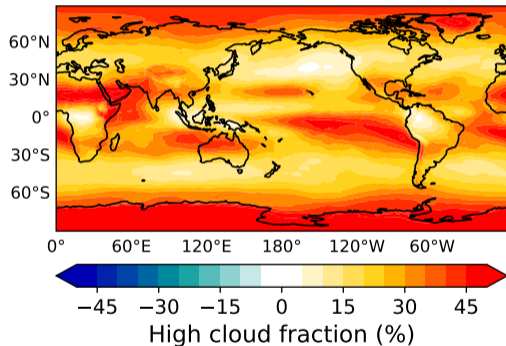
d) (NN-t0,5)  $\partial_t q^{(NN)} - \partial_t q$



# NN parameterization with triggering : Online results

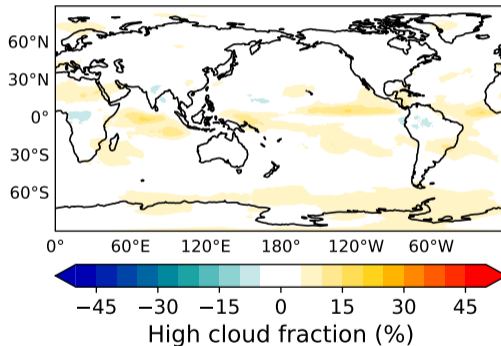
No triggering

ARP-GEM (NN-nt) minus ARP-GEM  
bias=27.106 RMSE=29.358



Triggering

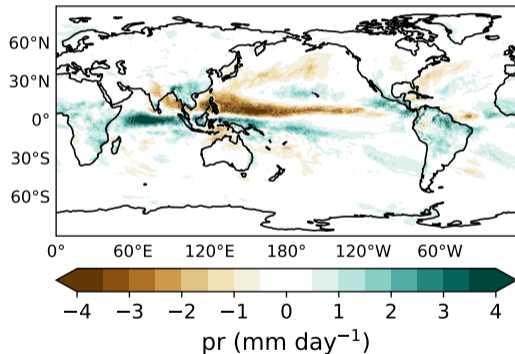
ARP-GEM (NN-t0.5) minus ARP-GEM  
bias=2.915 RMSE=4.369



# NN parameterization with triggering : Online results

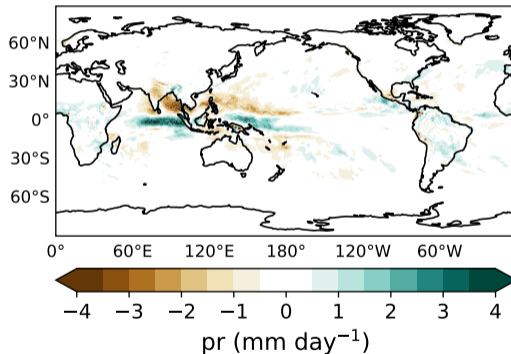
No triggering

a) ARP-GEM (NN-nt) minus ARP-GEM  
bias=0.129 RMSE=0.971

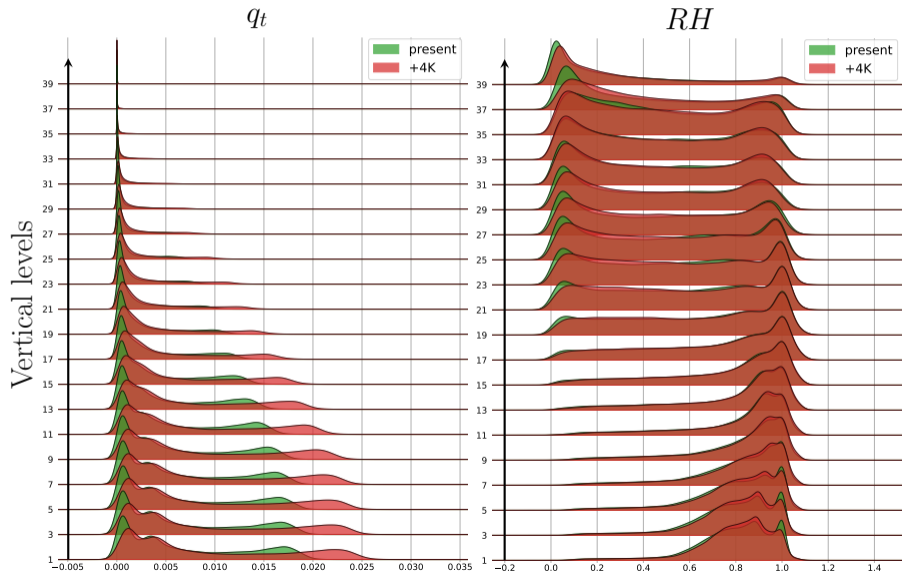


Triggering

b) ARP-GEM (NN-t0.5) minus ARP-GEM  
bias=-0.009 RMSE=0.651

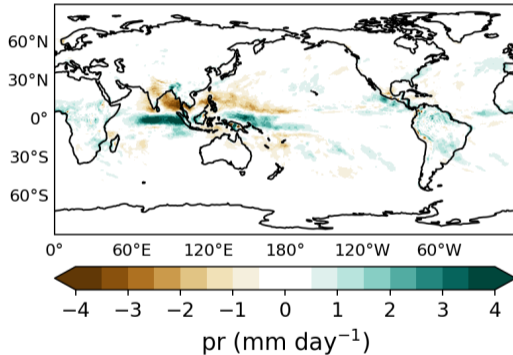


# Evaluation in warmer climate : Clausius-Clapeyron



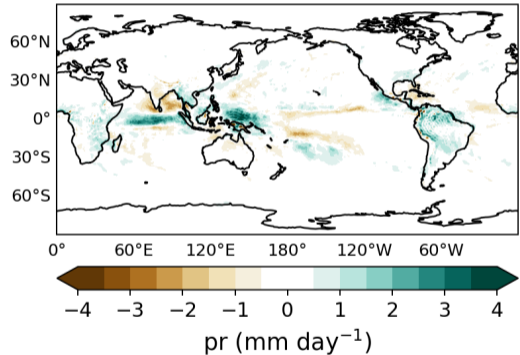
# Evaluation in warmer present climate : Impact of humidity variable

a) ARP-GEM-NN ( $q_t$ ) minus ARP-GEM  
bias=-0.009 RMSE=0.651



NN with **specific humidity**

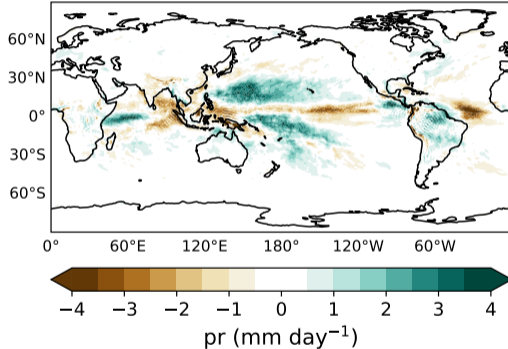
b) ARP-GEM-NN (**RH**) minus ARP-GEM  
bias=-0.004 RMSE=0.643



NN with **relative humidity**

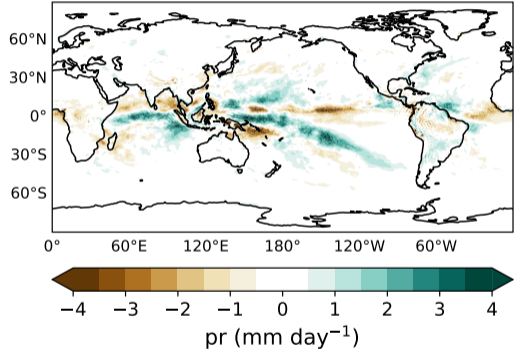
# Evaluation in warmer climate : Impact of humidity variable

a) ARP-GEM+4K (NN-t0.5- $q_t$ )  
minus ARP-GEM+4K  
bias=0.038 RMSE=0.976



NN with **specific humidity**

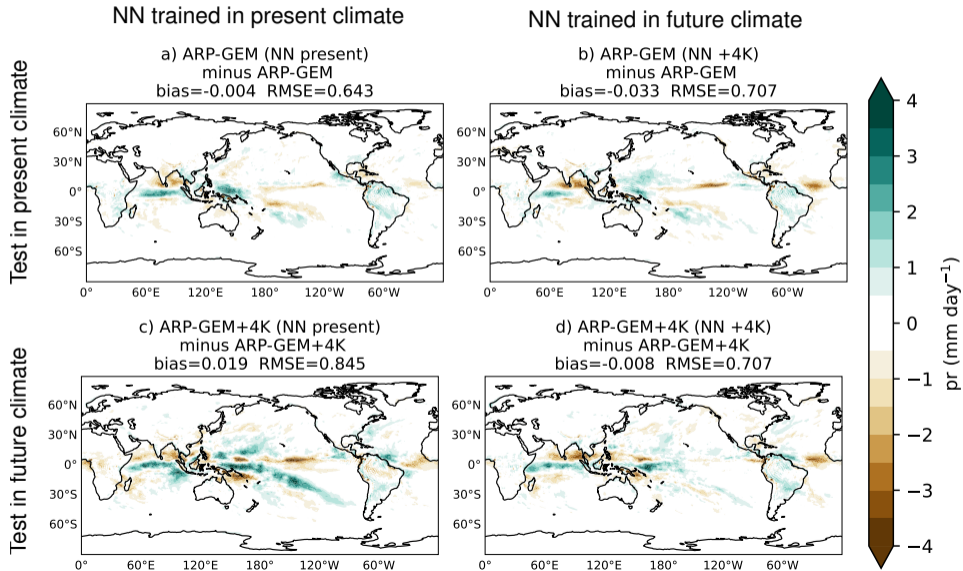
b) ARP-GEM+4K (NN-t0.5-RH)  
minus ARP-GEM+4K  
bias=0.019 RMSE=0.845



NN with **relative humidity**

- Better results with **relative humidity**.
- The simulations run stable with NNs only trained with control climate data.

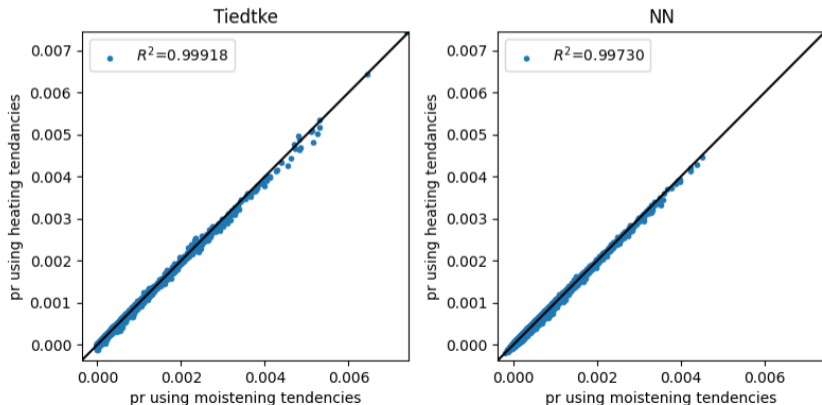
# Evaluation in warmer climate : training with +4K data



## Physical consistency

Precipitations can be computed using moistening or heating tendencies :

$$P_{tot} = - \int_{p_{srf}}^{p_{top}} \frac{\partial \bar{q}}{\partial t} \frac{dp}{g} \approx \int_{p_{srf}}^{p_{top}} \frac{1}{L_{vap/subl}(\bar{T}) - \bar{T}(c_{pv} - c_{pd})} \frac{\partial \bar{s}}{\partial t} \frac{dp}{g}$$



# Conclusion

- The NN parameterization of deep convection is improved when we add triggering.
- Remains stable when tested in warmer climate.
- NN trained with +4K data performs well in present climate.
- It has (some) physical consistency.
- Article submitted to AIES, preprint arXiv : [arXiv:2511.05074](https://arxiv.org/abs/2511.05074).

Thank you for your attention.

Questions ?