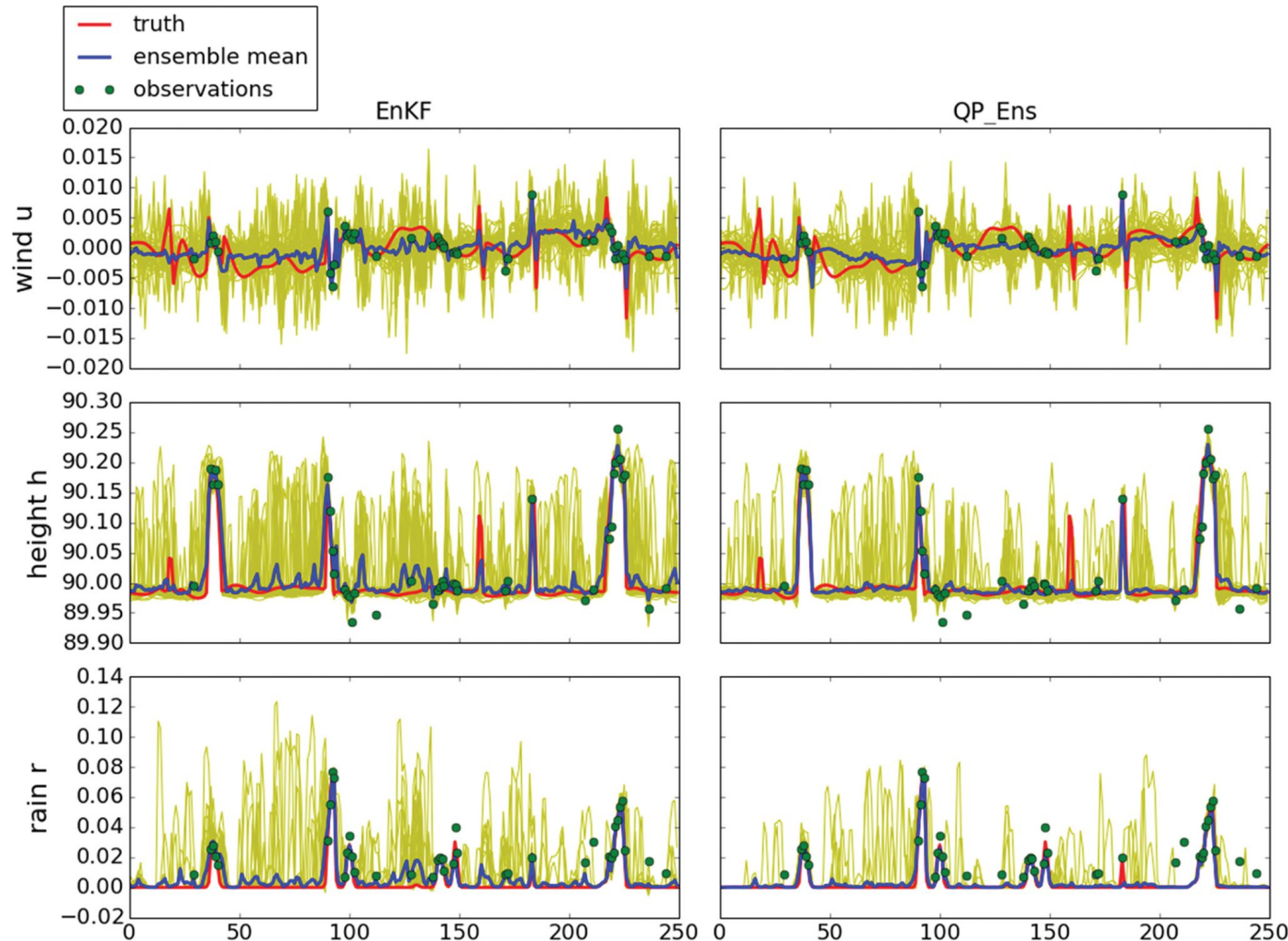


Conserving mass in DA



Snapshot of an analysis of a twin experiment with the modified shallow water model (Würsch and Craig, 2014) for the ensemble Kalman filter (EnKF) and the quadratic programming ensemble (QPEns) which conserves mass and positivity of rain.

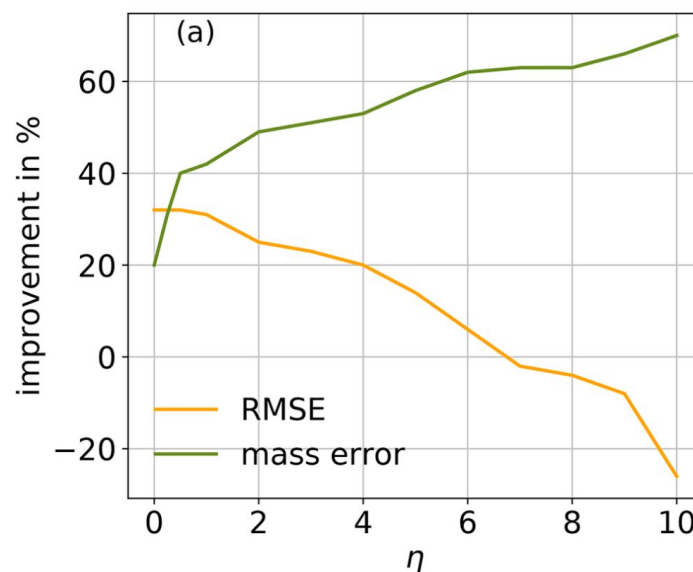
The QPEns significantly reduces spurious convection (Ruckstuhl and Janjic, 2018).

Convolutional NN to Conserve mass in DA

QPEns requires solving a constrained minimisation problem for each ensemble member → **expensive**

We replace the QPEns with a CNN that is trained on QPEns analyses

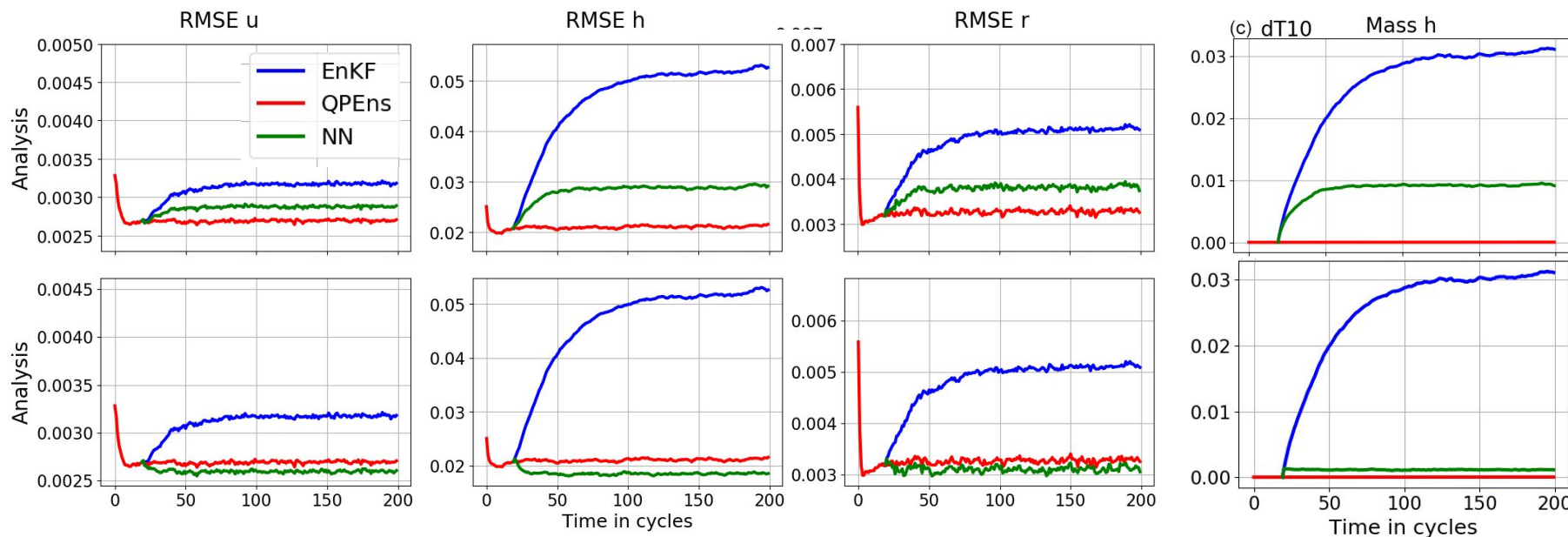
The loss function of the CNN training process is the RMSE plus a penalty term to penalise mass conservation violation.
 $loss = RMSE + \eta * mass\ error$



Relative improvement of RMSE and mass error of the CNN toward QPEns analyses (CNN output) with respect to EnKF analyses (CNN input) as function of the penalty parameter.

A higher penalty parameter yields a decrease in mass error, but an increase in RMSE (Ruckstuhl et al, 2021).

Results when applied within DA



RMSE of model variables and mass error as function of assimilation cycles for $\eta = 0$ (top) and $\eta = 2$ (bottom).

Although the CNN yields an improvement over EnKF already for $\eta = 0$ (no penalty term), **the CNN clearly benefits from the penalty term**. We found that $\eta = 2$ yields the CNN that results in the lowest RMSE when applied within the DA cycling (Ruckstuhl et al, 2021).

References

Würsch, M. and Craig, G. C.: A simple dynamical model of cumulus convection for data assimilation research, Meteorol. Z., 23, 483–490, 2014. [a](#), [b](#)

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