ENSEMBLE-BASED ALGORITHMIC OPTIMISATION OF OPENIFS WEATHER MODEL

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Introduction

- Optimisation: final adjustment of closure parameters of a numerical weather prediction model after fixing the model structure
- Need for optimisation: some parameters very difficult to quantify
- Problem of optimisation: labourious trial-and-error process → ensemble forecasting based algorithmic methods

  - Is it possible to optimise large parameter sets simultaneously?

  - How to efficiently search for optimised model versions?

  - How does the model forecast skill change after the optimisation?

  - Is it possible to use lower model resolution during optimisation?

  - Is expert judgment needed when using algorithmic optimisation methods?

Tools

- OpenIFS T399; parameters of SPP scheme, 19 in total
- Optimisation algorithm: EPPES (Bayesian importance sampler)
- OpenEPS + ensemble initial states for 2017, for verification deterministic initial states of 2018
- Operational analyses for 2017 and 2018
- Metric for distance to analysis: moist total energy norm

$$\langle \vec{x}', C_{TE}\vec{x}'\rangle = \frac{1}{2}\iint \left[u'^2 + v'^2 + \frac{c_p}{T_r}T'^2 + c_q\frac{L^2}{c_pT_r}q'^2\right] d\Sigma \frac{\partial p_r}{\partial \eta} d\eta + \frac{1}{2}\int \left[R\frac{T_r}{p_r}\ln {p_s'}^2\right] d\Sigma$$

- The purpose is to minimise the cost function

Methods

- Optimisation setup: ensemble size 20, forecast range 36h, ensembles every 3 days
- Workflow:

  - 1. use EPPES to sample parameter values as 20 vectors of 19 elements

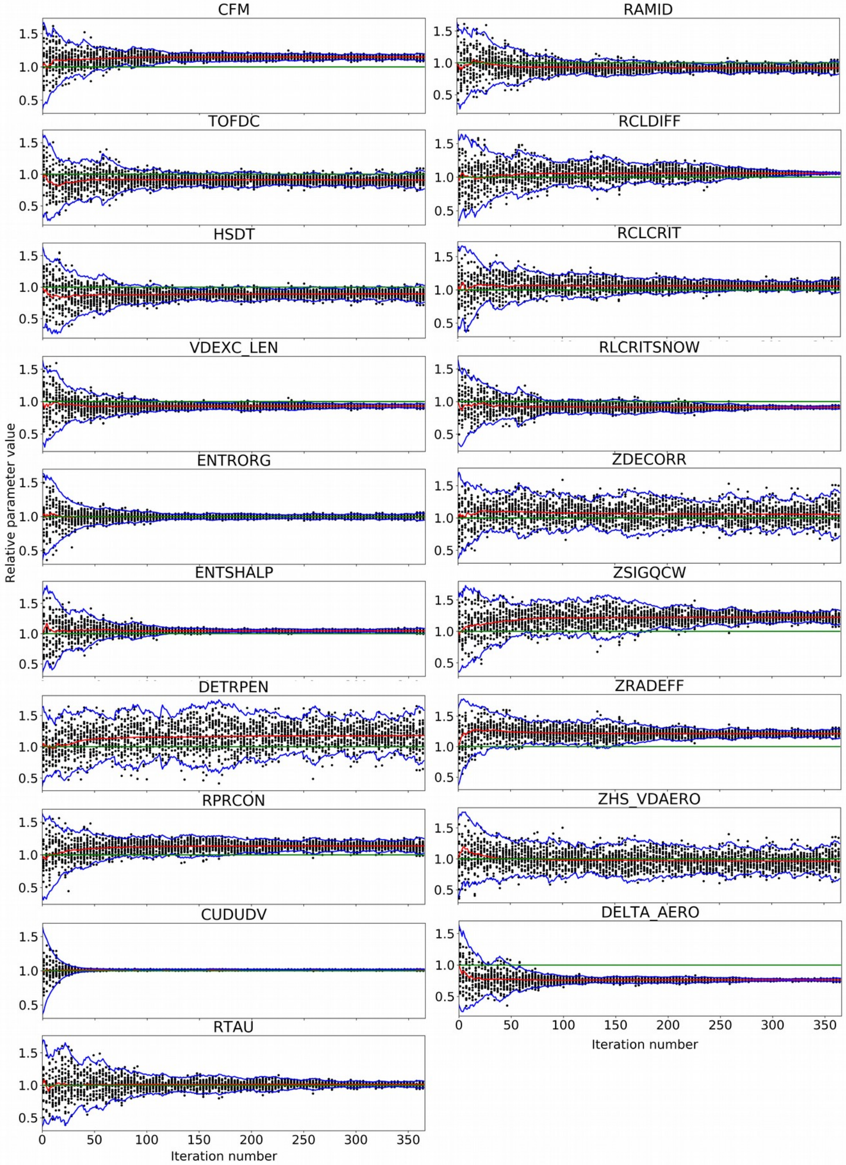
  - 2. assign one vector for each ensemble member

  - 3. run the ensemble forecast

  - 4. evaluate the cost function for each ensemble member

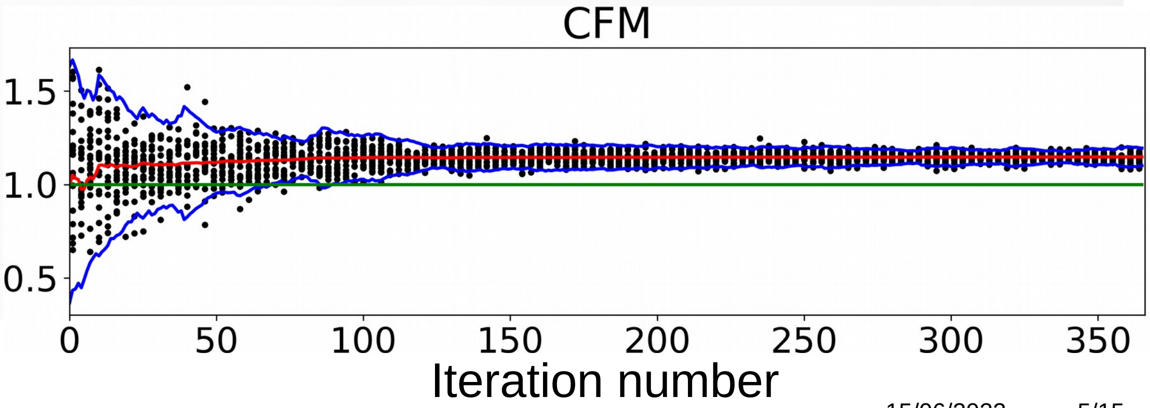
  - 5. use EPPES to sample new 20 parameter vectors based on the cost function values

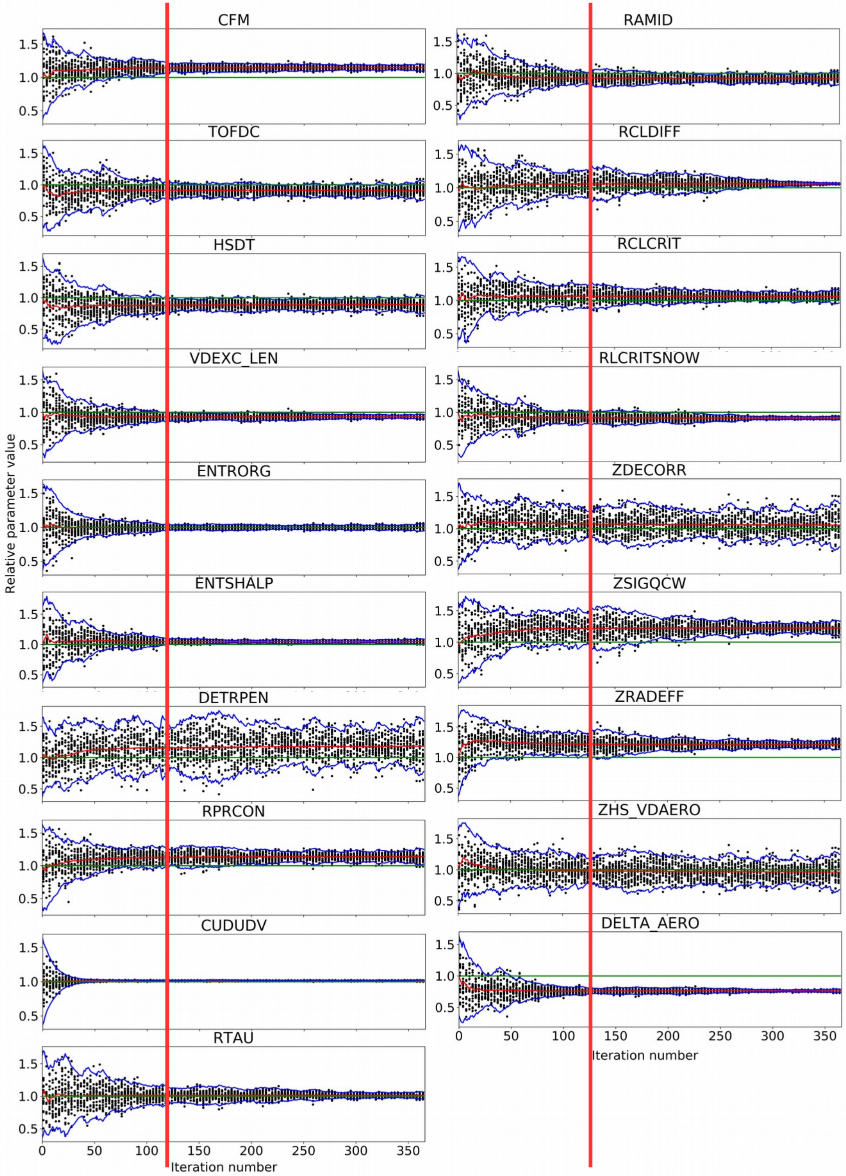
  - 6. go to 2
- Experiments: 1x 3-year, 4x 1-year
- Verification with global root mean squared error using forecasts of year 2018



How does the convergence look like?

- Overview
- Year 2017 repeated 3 times → 365 iterations
- Mostly good convergence
- Mean values settle during the first year, uncertainty may decrease slower

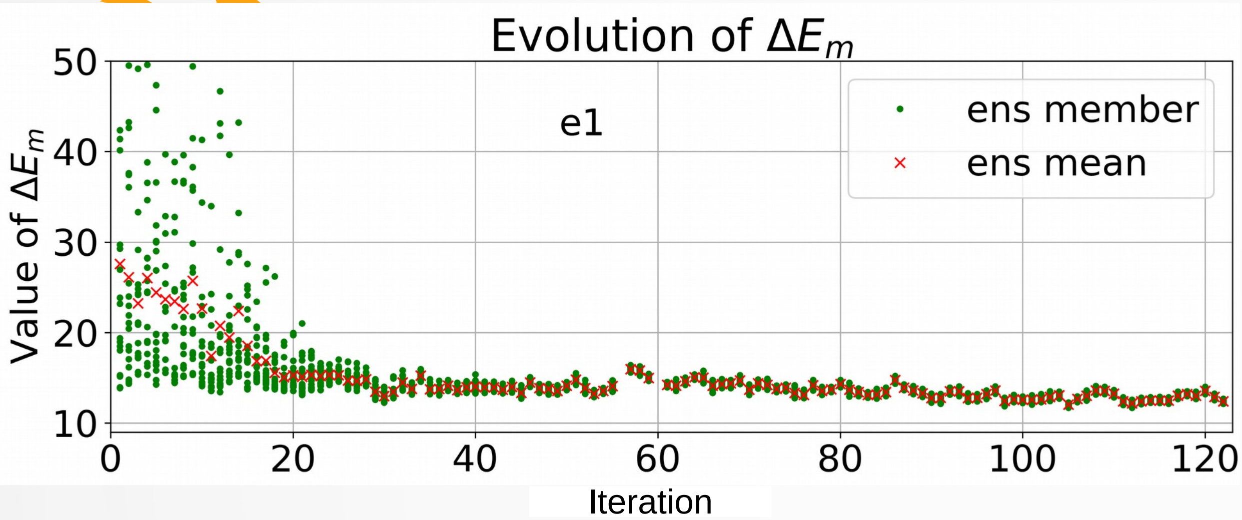


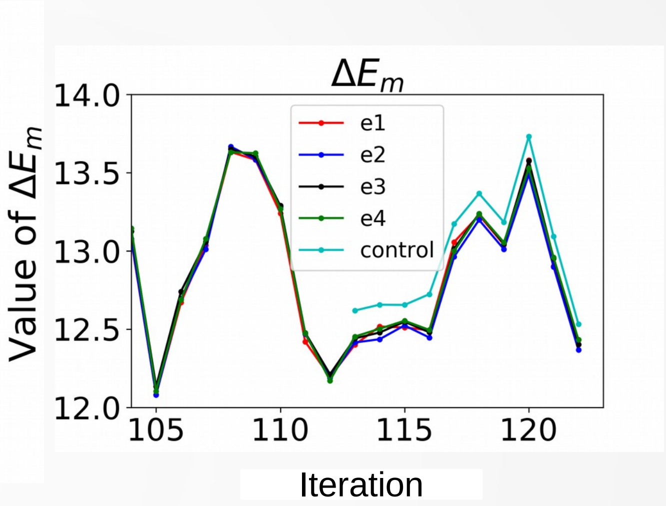


How does the convergence look like?

- Overview
- Year 2017 repeated 3 times → 365 iterations
- Mostly good convergence
- Mean values settle during the first year, uncertainty may decrease slower
- Interested in the mean values → use 1 year (122 iterations) hereafter; lower cost, more efficiency

Distance to reference

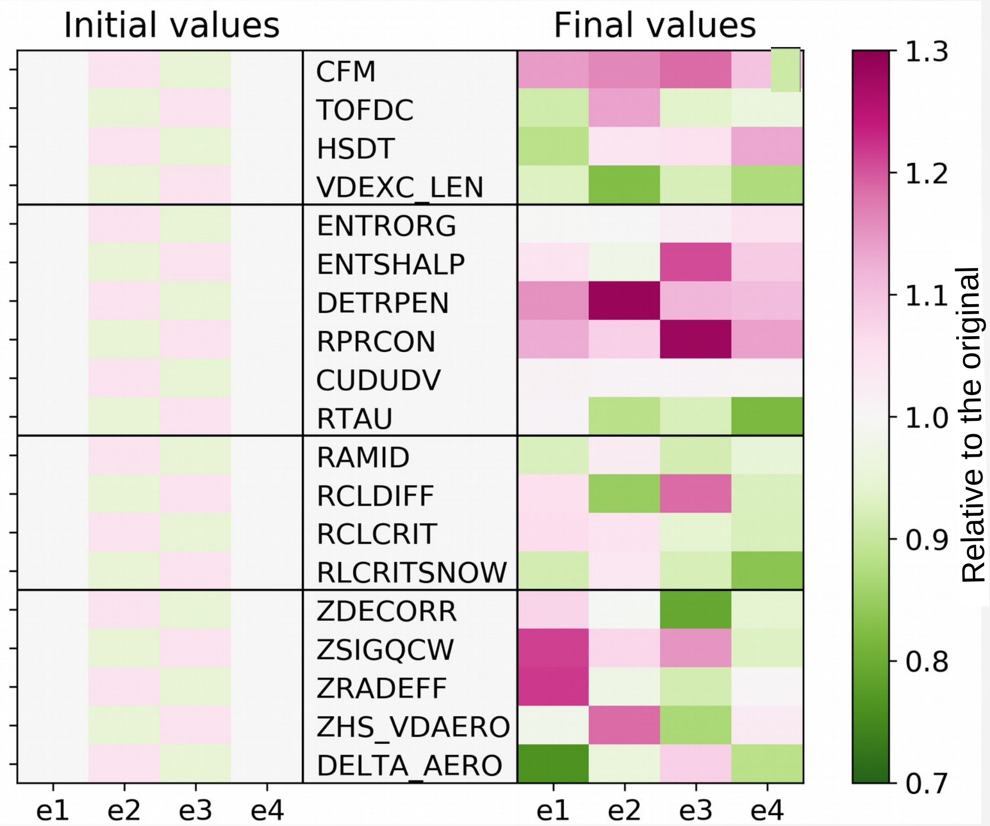




- Cost function: moist total energy norm
- Decreasing value → optimisation progressing towards better model

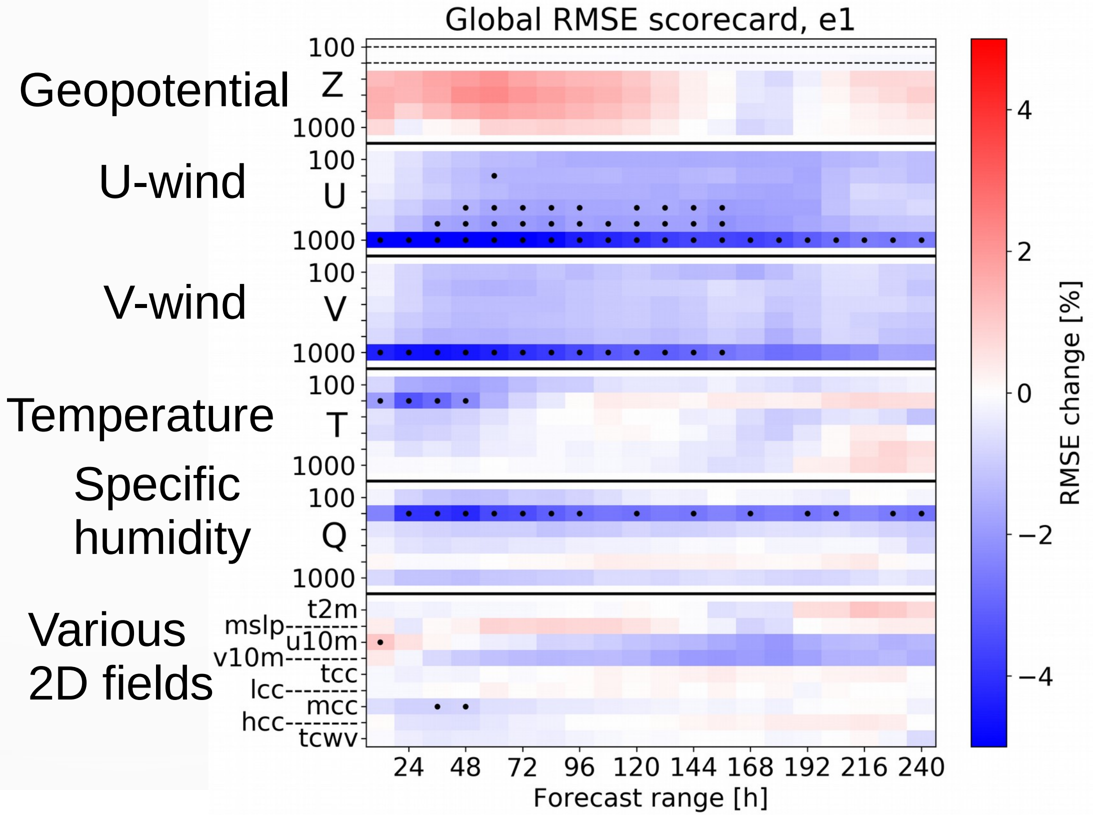
The optimisation results

- 4 experiments with different initial parameter values
- Different looking results but all are good models (cost function + verification)
- 10 additional short experiments: different outcomes as well
- Focus on e1



Verification with global root mean squared error

- Verification using independent set of forecasts: 53 deterministic forecasts in 2018
- With optimised and original model



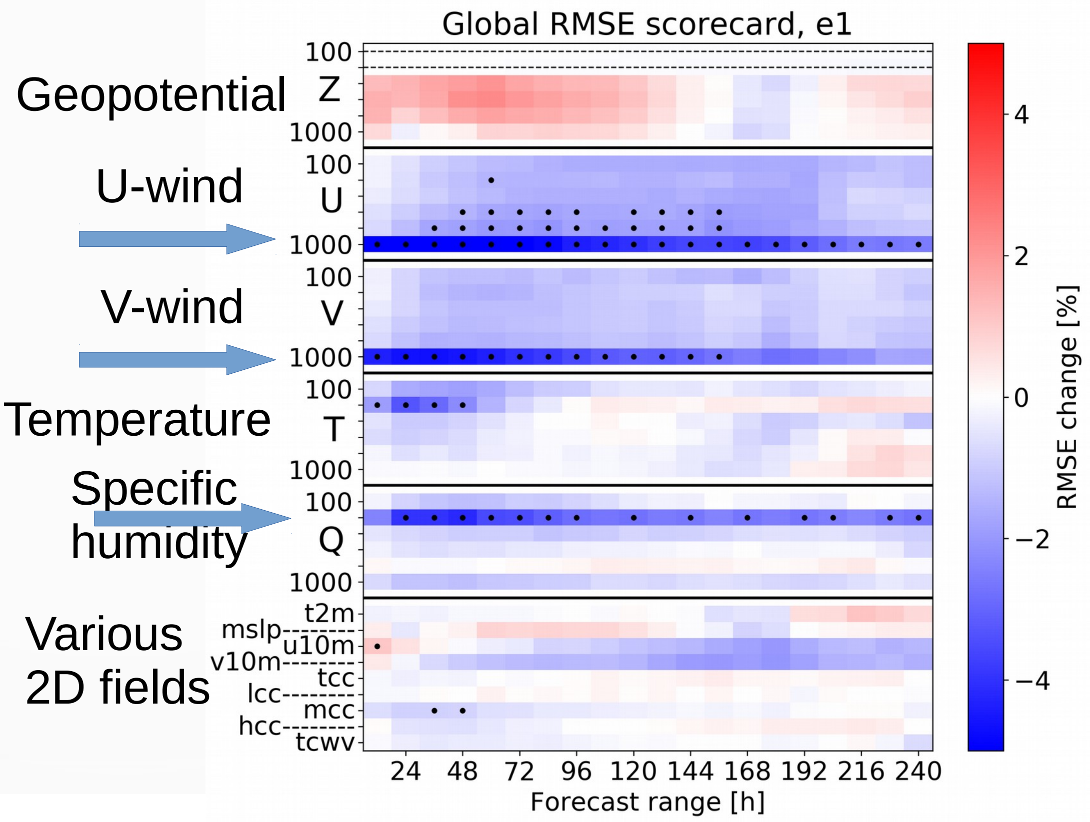
= better

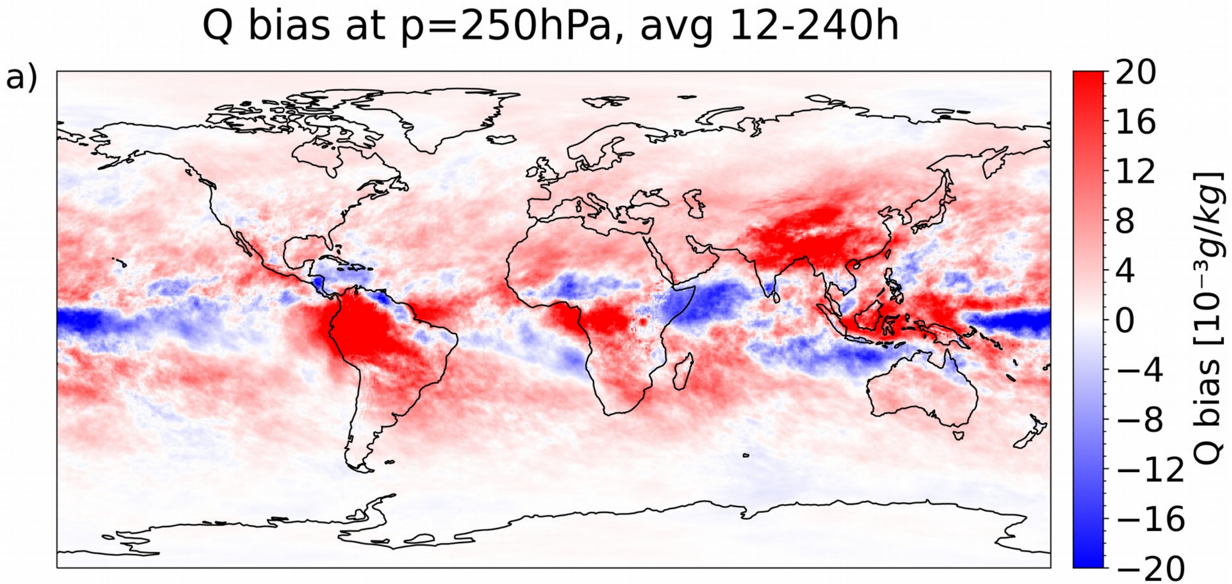
= worse than the original model

= Statistical significance (95%)

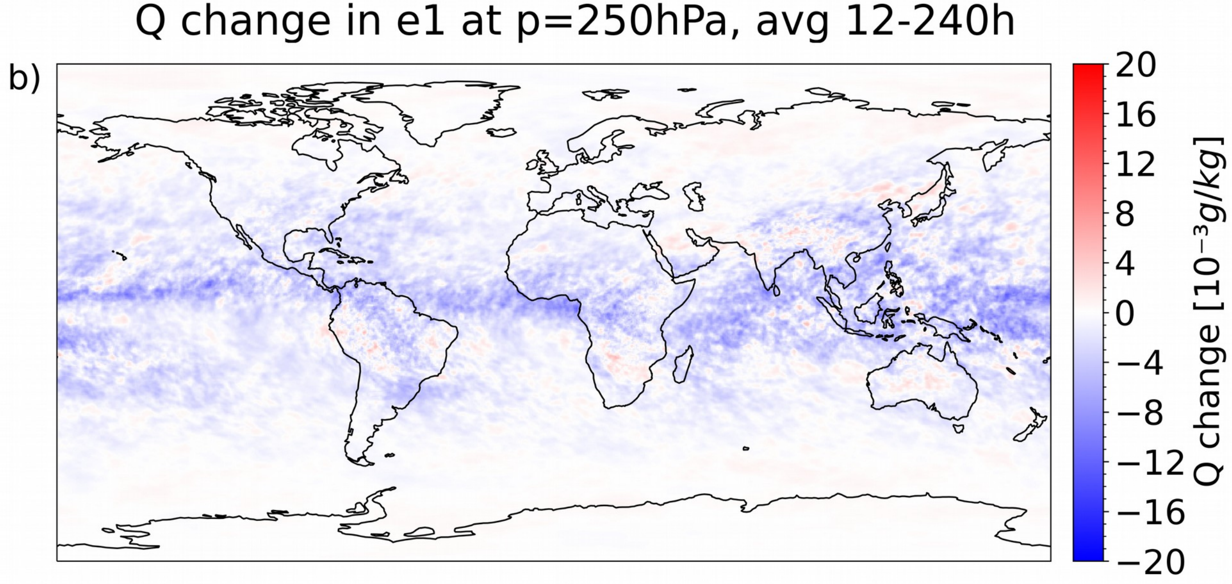
Verification with global root mean squared error

- Verification using independent set of forecasts: 53 deterministic forecasts in 2018
- With optimised and original model
- e2, e3 and e4 also better than the original model
- Next: focus on the most notable improvements in e1

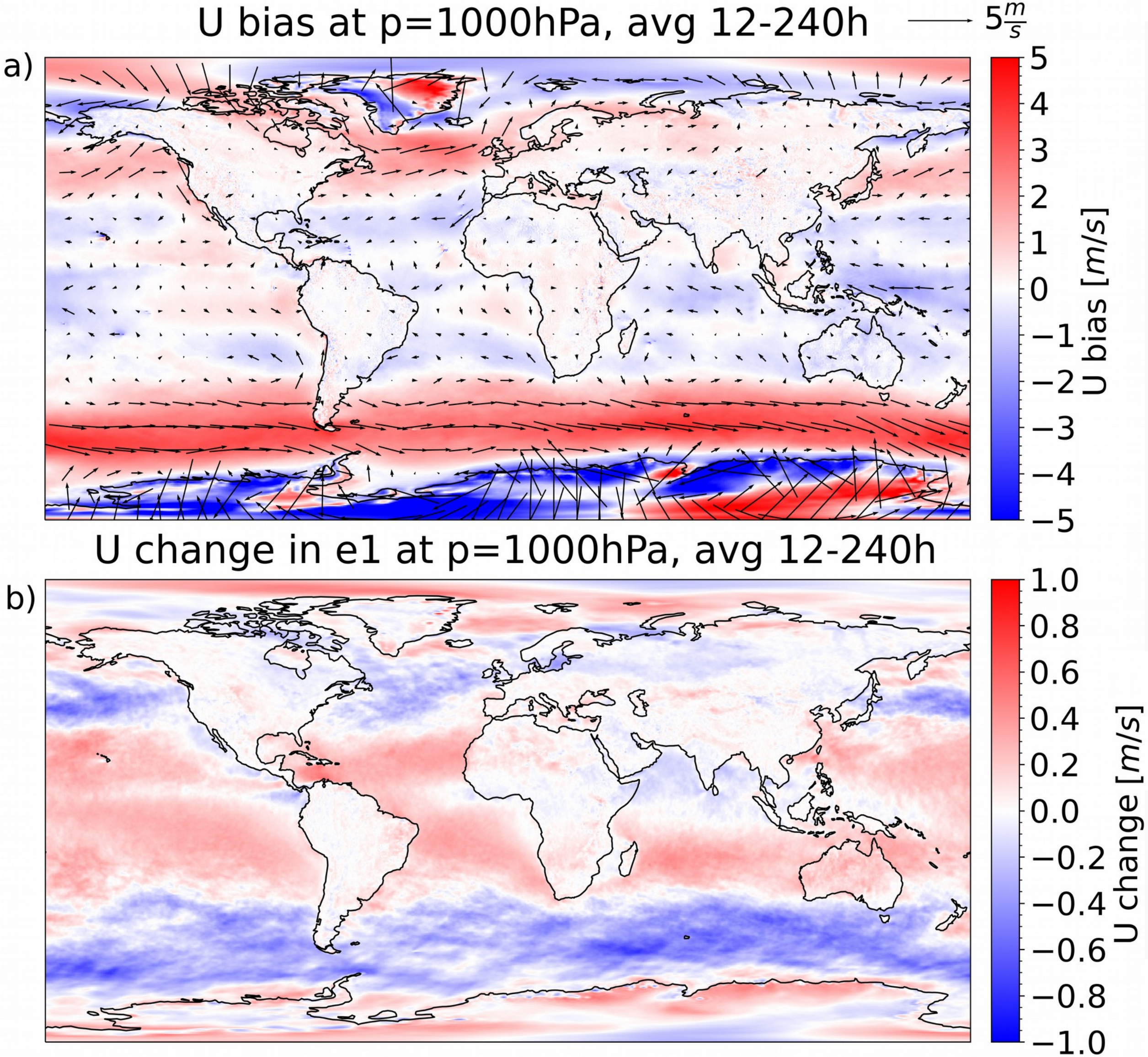




- Mostly too much moisture in the original model
- (reference: operational analyses)
- Some displacement errors as well

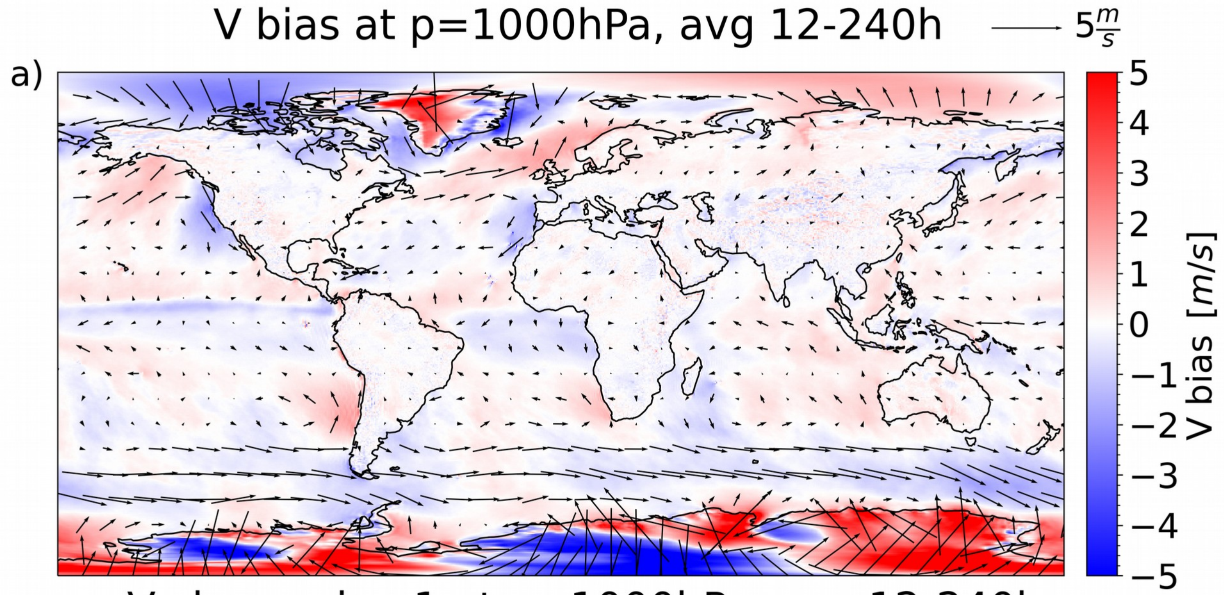


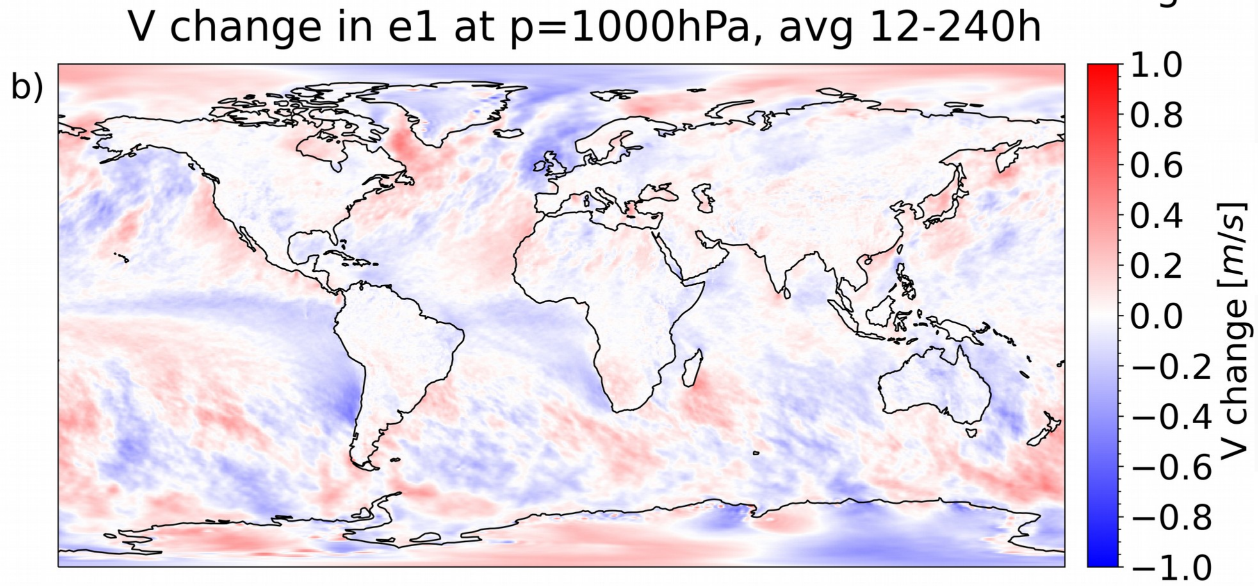
- e1 decreases the amount of moisture almost everywhere
- Cannot fix the displacement error → perhaps a structural model error



- Control model: U bias with colour and mean wind with arrows
- Too strong U wind in general

- e1 tends to slow down the wind
- Midlatitudes improve
- Some tropical areas degrade



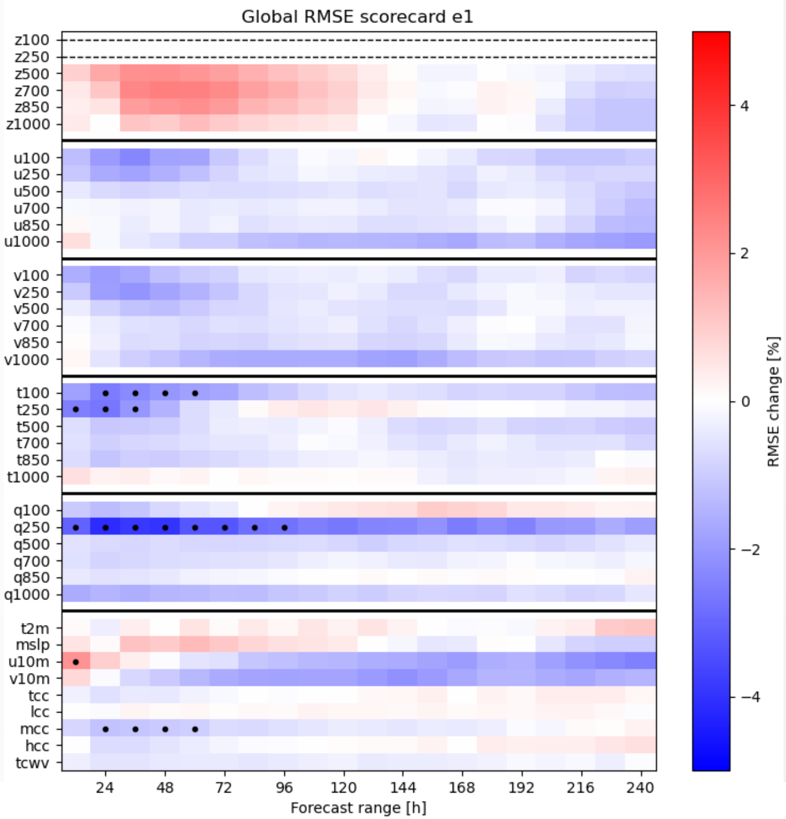


- Mid and high latitudes: too strong V wind
- Tropics: too little convergence towards ITCZ

- Mid and high latitudes: improvement in many places
- Atlantic storm track shifts south, not correct
- Tropics: the lack of convergence towards ITCZ becomes more prominent → structural model error

Applicability to higher resolutions

- Optimisation with T399 (~50 km), verification with T639 (~32 km)
- Milder improvement but generally outperforming the original model



Conclusions

- Efficient algorithmic optimisation of OpenIFS is possible, 1 year experiment → ~10 simulation years
- Candidate model versions can be produced efficiently
- Expert judgment needed for making a choice from a number of optimal models
- Significant improvement of some systematic biases (with the cost of slight increase of some other biases)
- Optimisation using decreased model resolution possible

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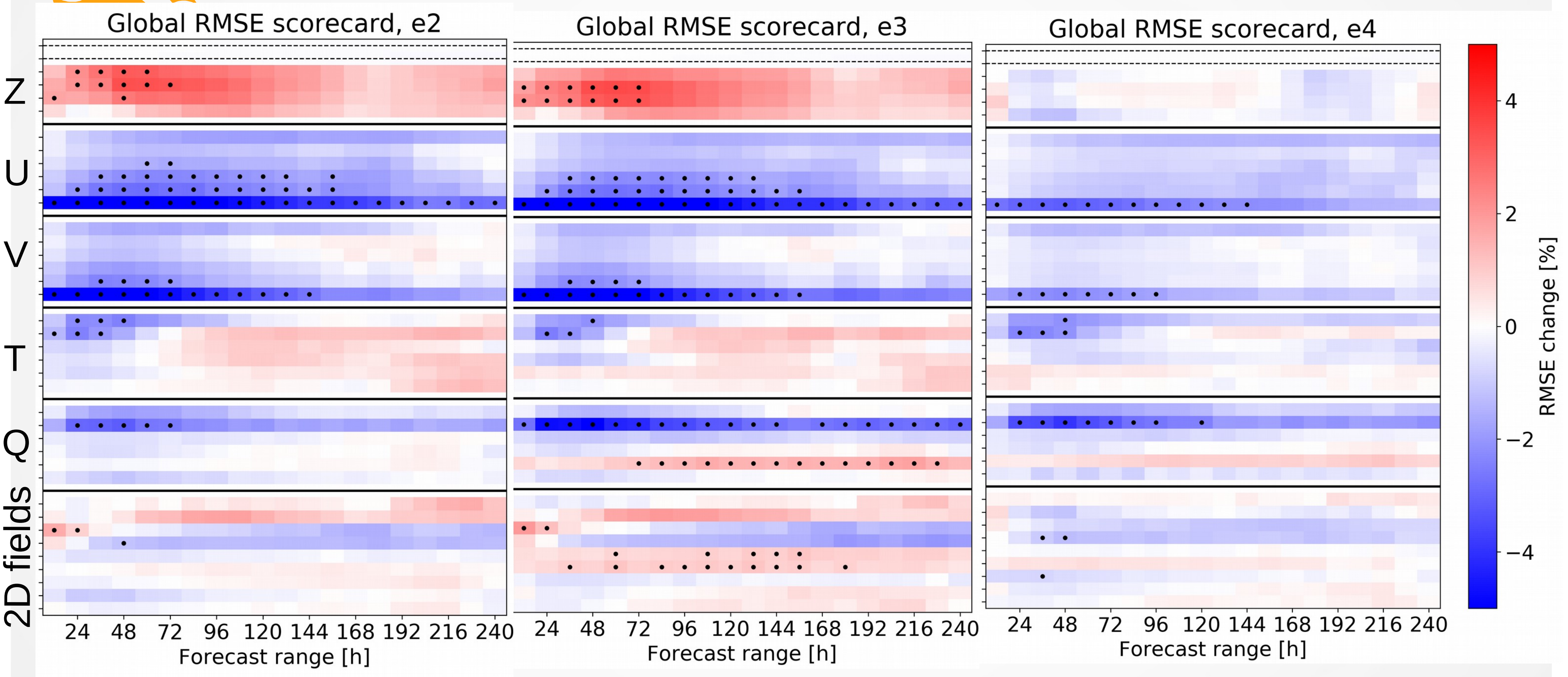
Extra slides



Global RMSE scorecard, e2
Global RMSE scorecard, e3
Global RMSE scorecard, e4
Z
U
V
T
Q
2D fields
24 48 72 96 120 144 168 192 216 240
Forecast range [h]
24 48 72 96 120 144 168 192 216 240
Forecast range [h]
24 48 72 96 120 144 168 192 216 240
Forecast range [h]
RMSE change [%]
4
2
0
−2
−4