Koninklijk Meteorologisch Instituut

Institut Royal Météorologique

Königliches Meteorologisches Institut

Royal Meteorological Institute

HarmonEPS VV**UQ** using the URANIE platform

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ACCORD AWS – Ljubljana/Ukkel 2022

Background

Funded by the European Union

Co-ordinated by ECMWF

ESCAPE-2 will develop extreme-scale computing capabilities for European operational numerical weather and climate prediction (NWCP), and provide the key components for NWCP benchmarks to be deployed on extreme-scale demonstrators and beyond.

ESCAPE 2

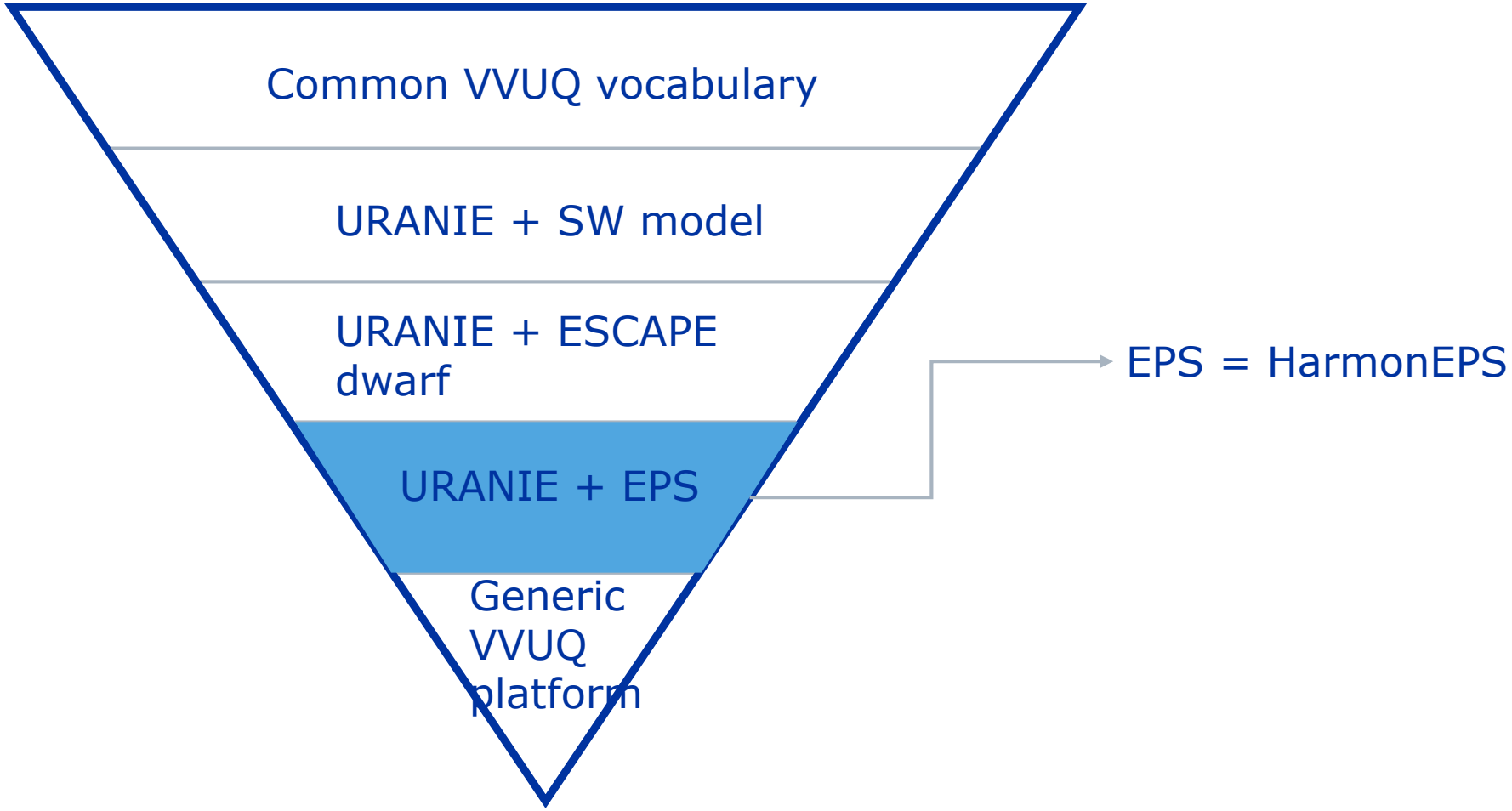
ECMWF · DKRZ Deutsches Klimarechenzentrum · Max-Planck-Institut für Meteorologie · MeteoSwiss · BSC Barcelona Supercomputing Center · cea · Loughborough University · RMI · Politecnico Milano · MOX · DMI · cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici · Bull atos technologies

Background

Verification, Validation and Uncertainty Quantification work package

- Demonstrate the VVUQ package (URANIE) for both dwarf and full forecasting system workloads.
- Develop a generic European VVUQ package for weather and climate simulations that is deployable on supercomputers preparing workloads of pre-exascale computations
- Together with Rudy Chocat [CEA], Kim Serradell, Mario Acosta [BSC], Peter Dueben [ECMWF] and Kristian Pagh Nielsen [DMI]

Methodology



The URANIE platform

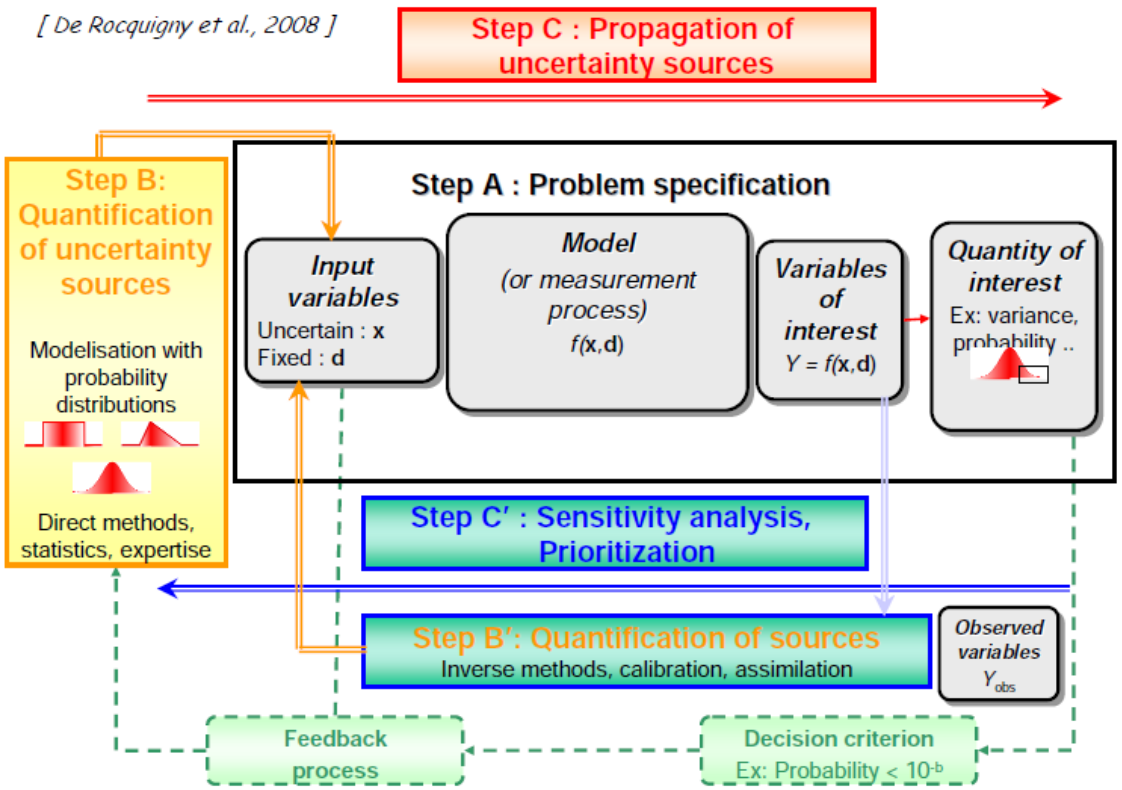
- Developed at CEA to help with sensitivity (meta)-modelling and optimization problems (mostly for radiative transfer codes)
- Based on the ROOT platform (developed at CERN)
- C++ with Python/Ruby interfaces
- Allows for analysis with parallel computing
- Open-Source [code, description paper]

The URANIE platform

Main purpose:

- Uncertainty propagation
- Surrogate model generation
- Sensitivity analysis
- Optimization problems
- Reliability analysis

→ Non-intrusive



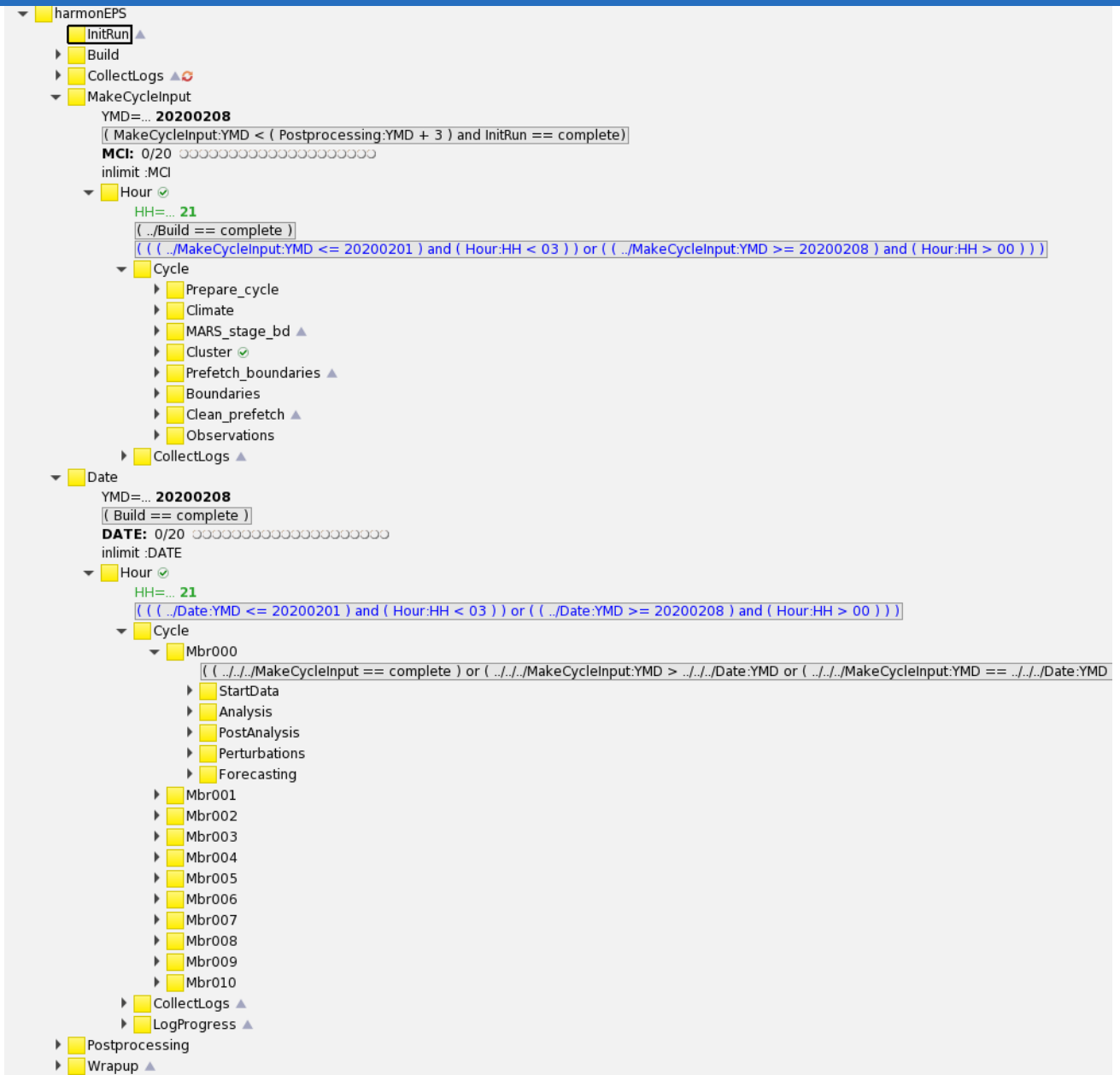
Combining URANIE and HarmonEPS

- EPS workflow too complex
  - cycling
  - perturbations

  to use as a black box

→ Integrate the different URANIE steps in the HARMONIE scripting system*

* Many thanks to Inger-Lise for all the help



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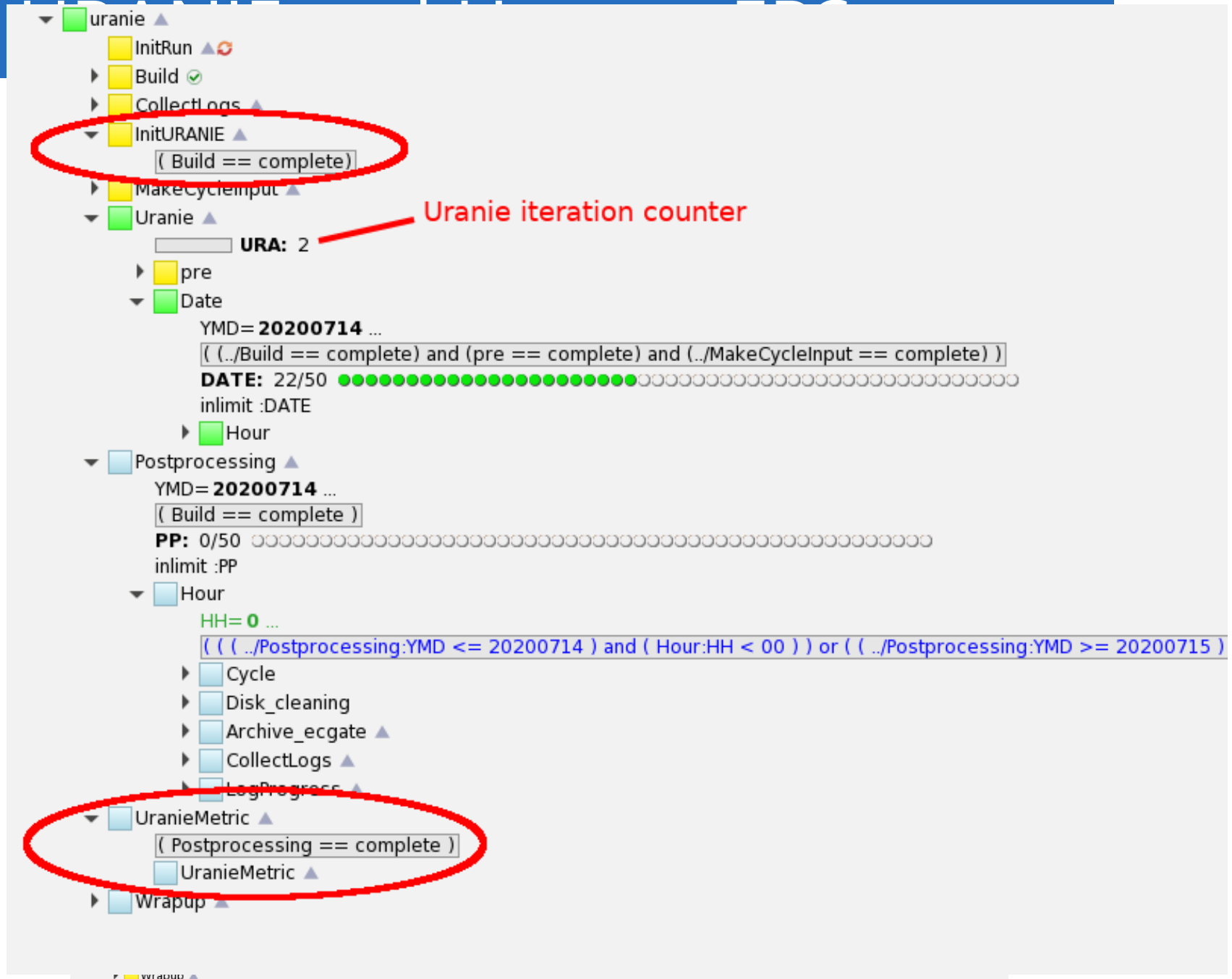
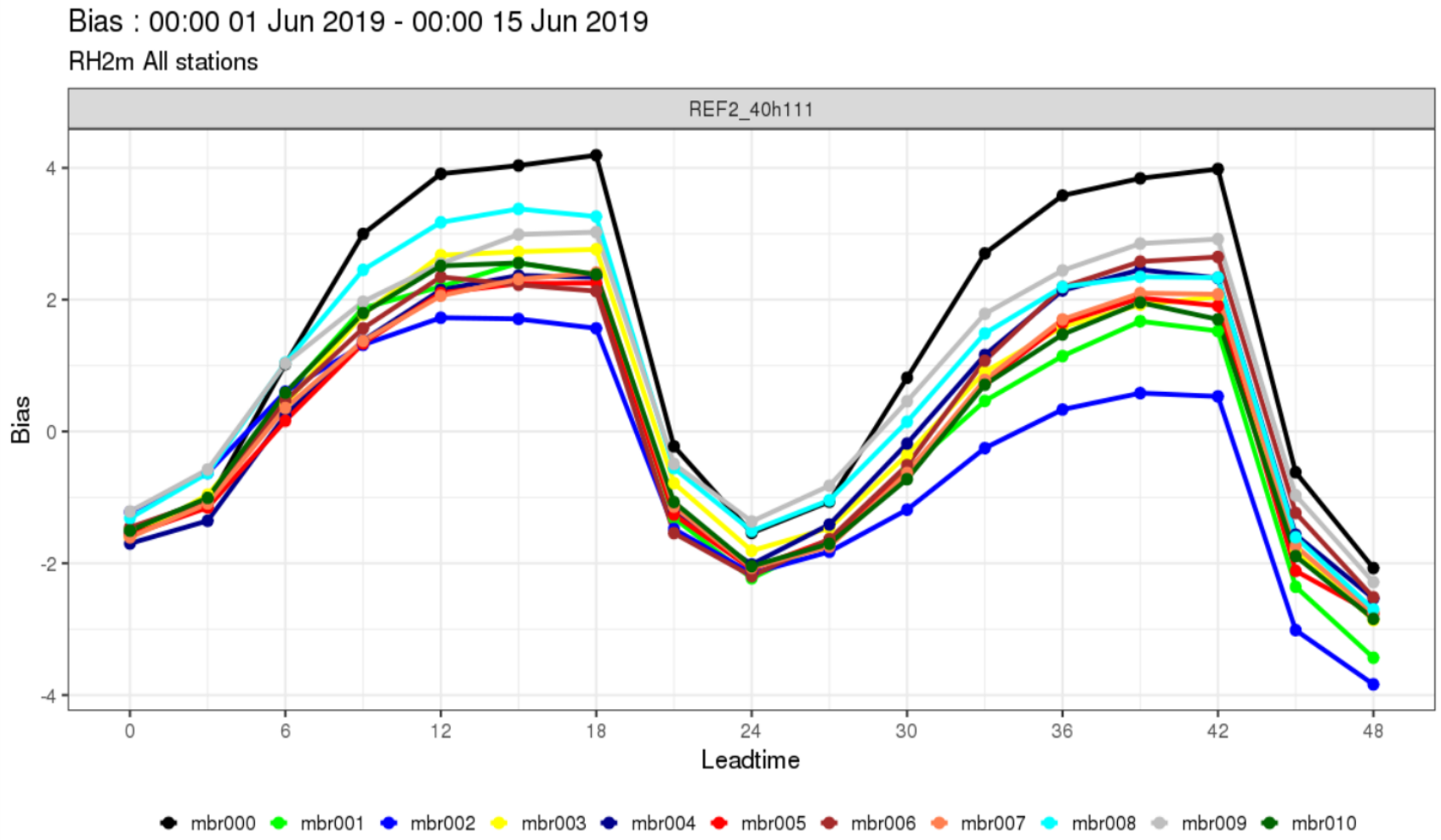


Proof of concept experiment

Perturbed members display dry BIAS in RH2m (cy40h1.1.1)



Culprit was found to be:

- surface **pertrubations** of **soil moisture**

Proof of concept experiment

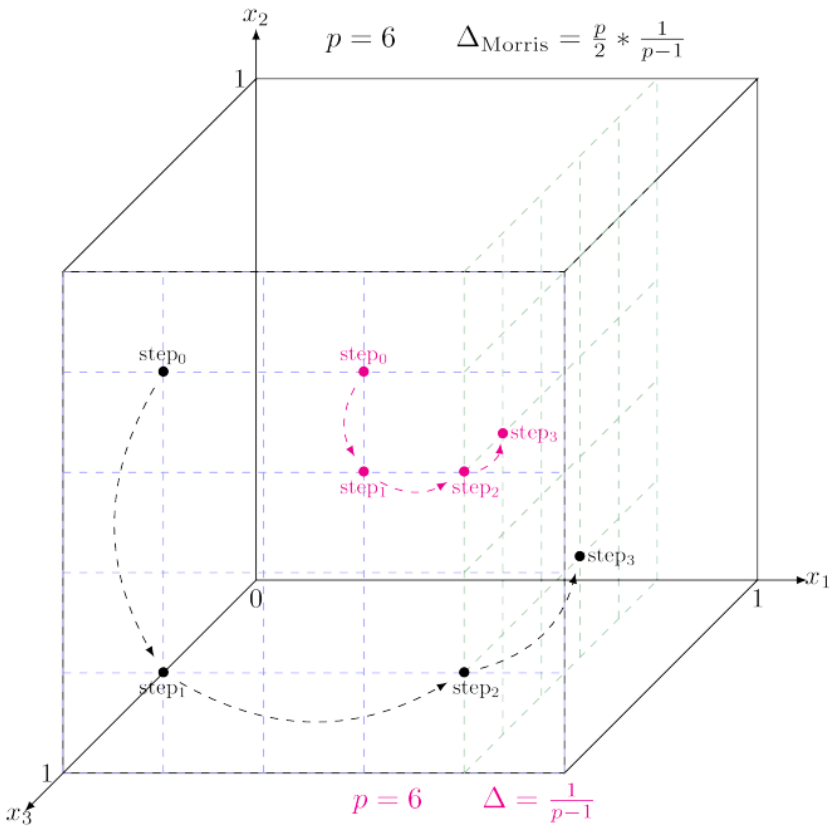
Can we retrieve this result using URANIE?

→ Use of Morris screening method:

- Extension of the One-Factor-at-a-Time variation method
- $EE_i^t = \frac{y(X_1^t,\ldots,X_i^t\ldots,X_n^t)-y(X_1^t,\ldots,X_i^t+\Delta^t,X_n^t)}{\Delta^t}$
- $\mu_i^* = \frac{1}{r}\sum_{t=1}^{r}|EE_i^t|$
- $\sigma_i = \frac{1}{(r-1)}\sum_{t=1}^{r}\left(EE_i^t - \mu_i^*\right)^2$
- Parameters under investigation:

  standard deviation of perturbations for 9 fields:

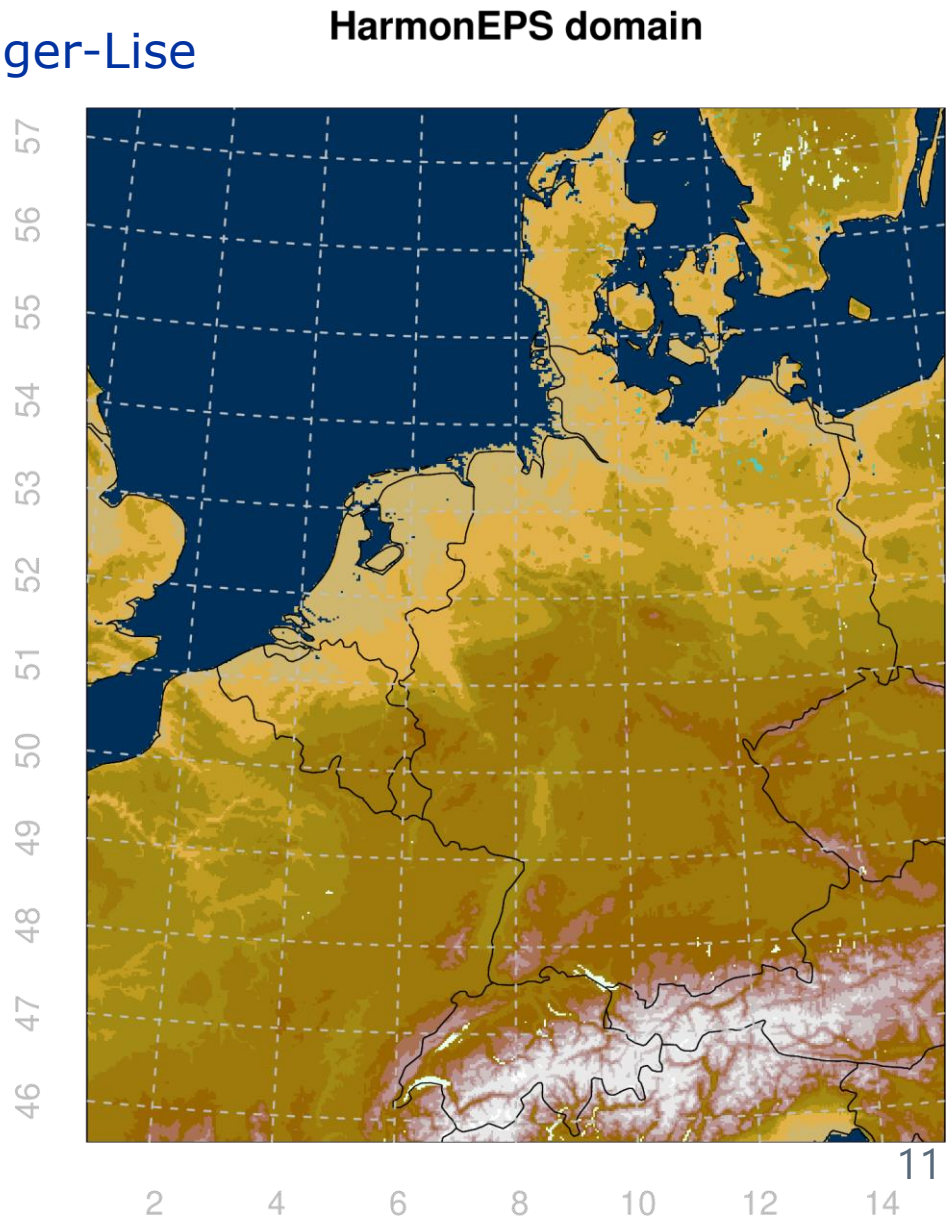
  VEG, LAI, CV, Z0, ALB, SST, ST, WG, SNOW



HarmonEPS setup*

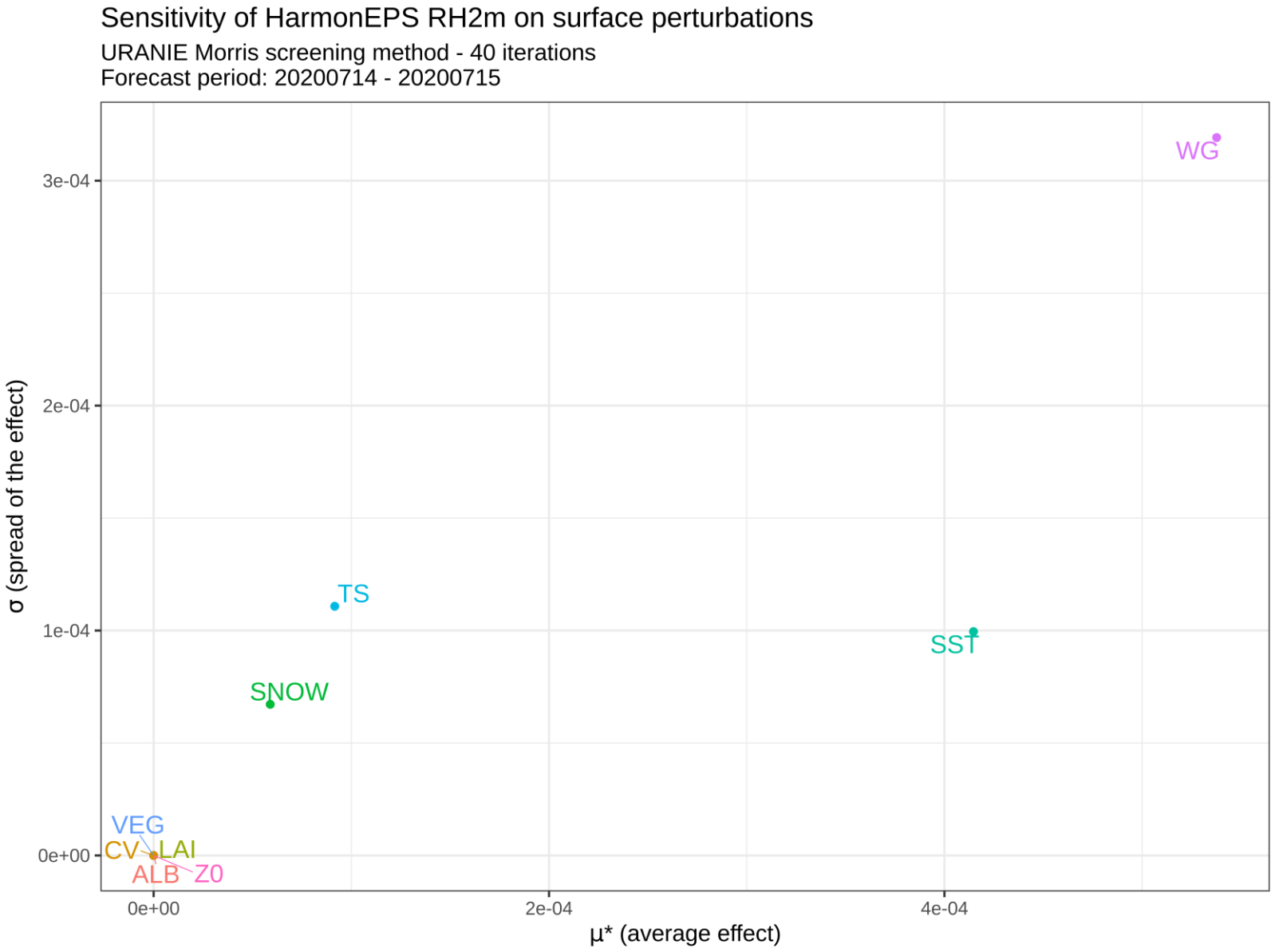
* Many thanks to Inger-Lise

- cy40h1.1.1
- 2.5 km resolution
- 65 vertical levels
- 3-hourly Surface & UA DA (14 days spinup)
- Only surface perturbations
- 10+1 members (Harmonie-AROME)
- Only 2 days under inverstigation:
  - 1 & 2 juli 2020 (36h forecast started at 00 UTC)
- Number of trajectories (r) = 4



Proof of concept - results

- RH2m bias most sensitive to soil moisture (standard deviation)
- No sensitivity to VEG,CV,ALB,Z0,LAI?
  - → ALB and Z0 fields only updated every 10 days (no perturbations?)
  - → Bug in code: no perturbations in VEG,CV and LAI!



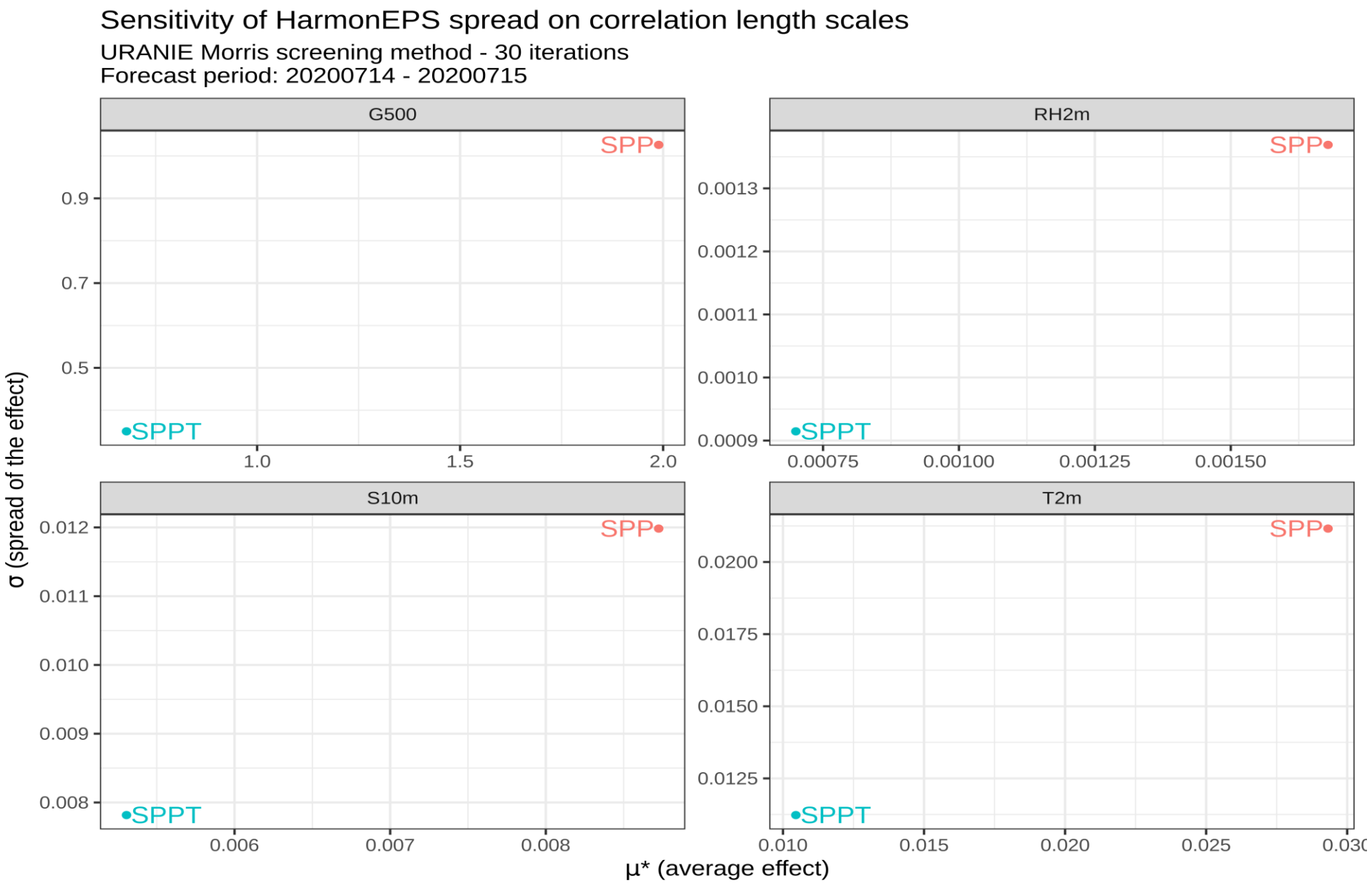
Optimization/tuning experiment

- Optimize/tune perturbation horizontal correlation length scale
- Start simple: 1 length scale and 1 output variable
- Which length scale (SPPT or SPP)?
- Which variable (G500, T2m, RH2m, S10m)?

→ Sensitivity study with Morris screening method

- Same setup but only SPP and SPPT perturbations active
- Inputs: SPPT and SPP length scales range between 100 – 300km (default 200km)
- Outputs: Ensemble spread of G500, T2m, RH2m, S10m

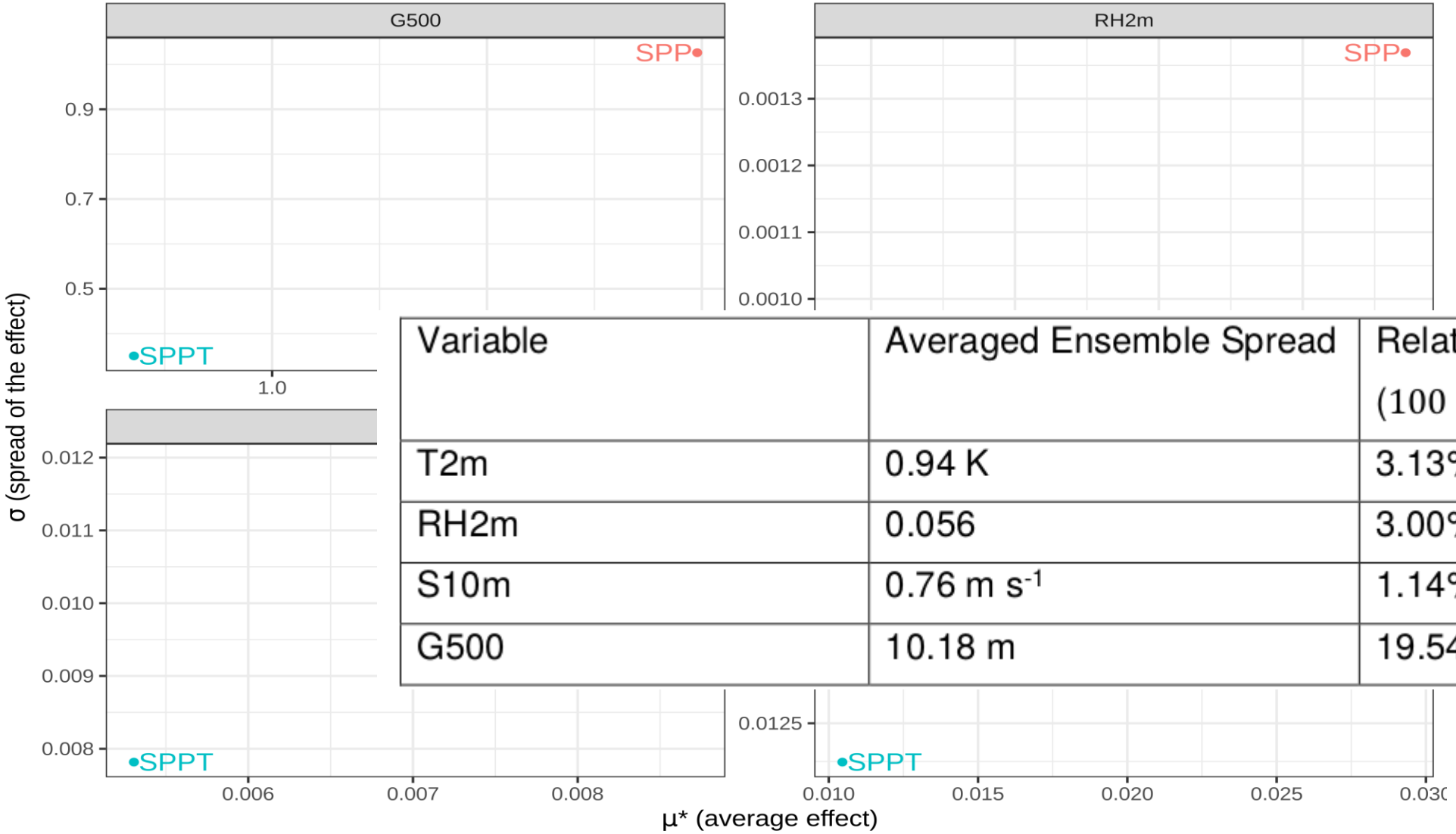
Optimization/tuning experiment



Optimization/tuning experiment

Sensitivity of HarmonEPS spread on correlation length scales

URANIE Morris screening method - 30 iterations
Forecast period: 20200714 - 20200715



Variable	Averaged Ensemble Spread	Relative effect of L_{SPP} $(100 \times \mu^*_{SPP}/spread)$
T2m	0.94 K	3.13%
RH2m	0.056	3.00%
S10m	0.76 m s^{-1}	1.14%
G500	10.18 m	19.54%

Tuning experiment

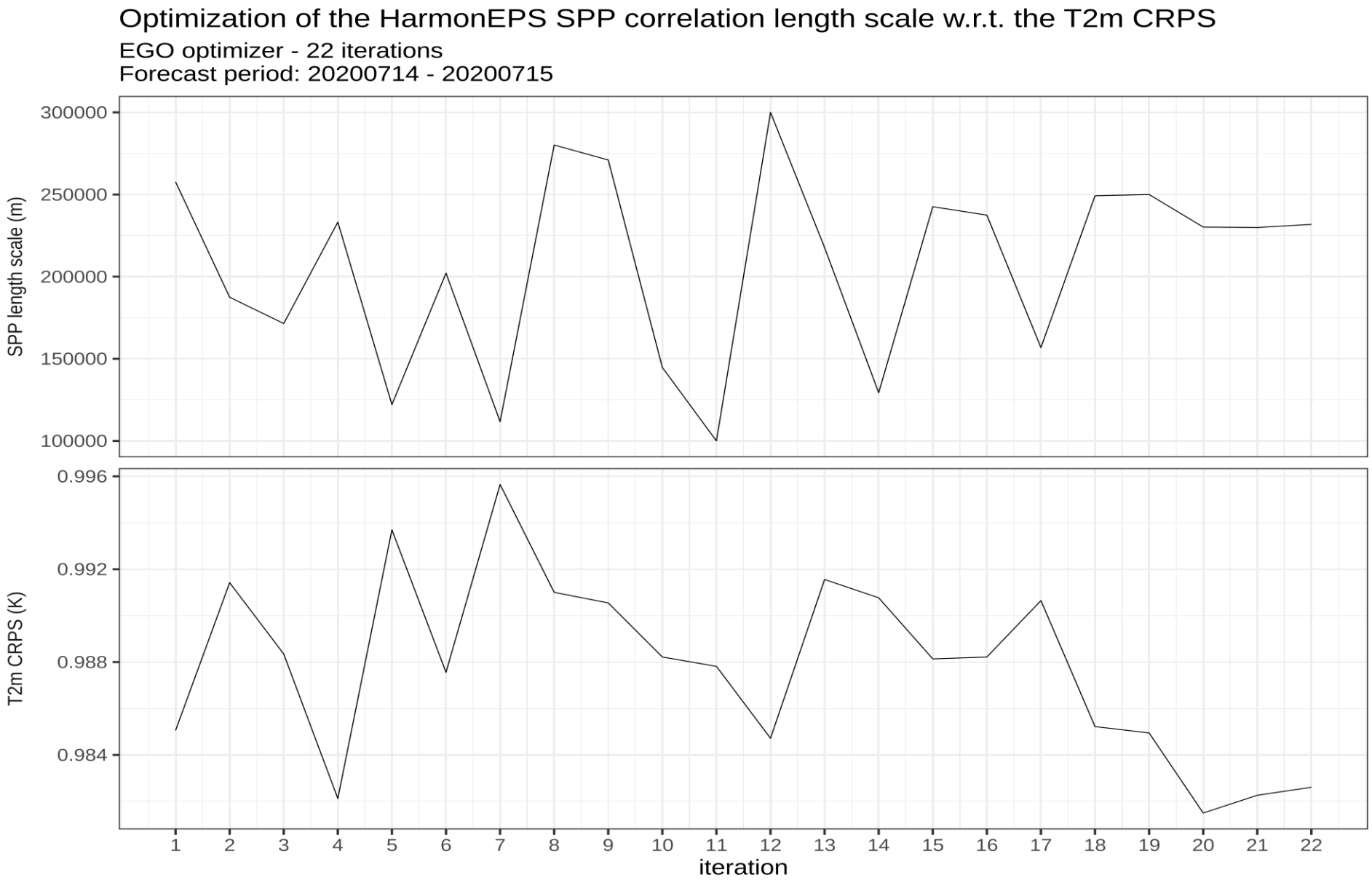
Tune the SPP perturbation length scale on T2m CRPS

- Using Efficient Global Optimization (EGO) scheme
- Start with random sample of 10 perturbations length scales (between 100 and 300 km)

EGO scheme:

1. Take initial sample of parameters space and evaluate code for each configuration
2. Train a kriging surrogate on the results of the sample
3. Based on the kriging variance, the Expected Improvement Criterion is optimized to identify the next parameter value
4. The code is evaluated for this parameter value and results added to the sample
5. The stopping criteria are checked, if not satisfied, the algorithm is repeated from step 2

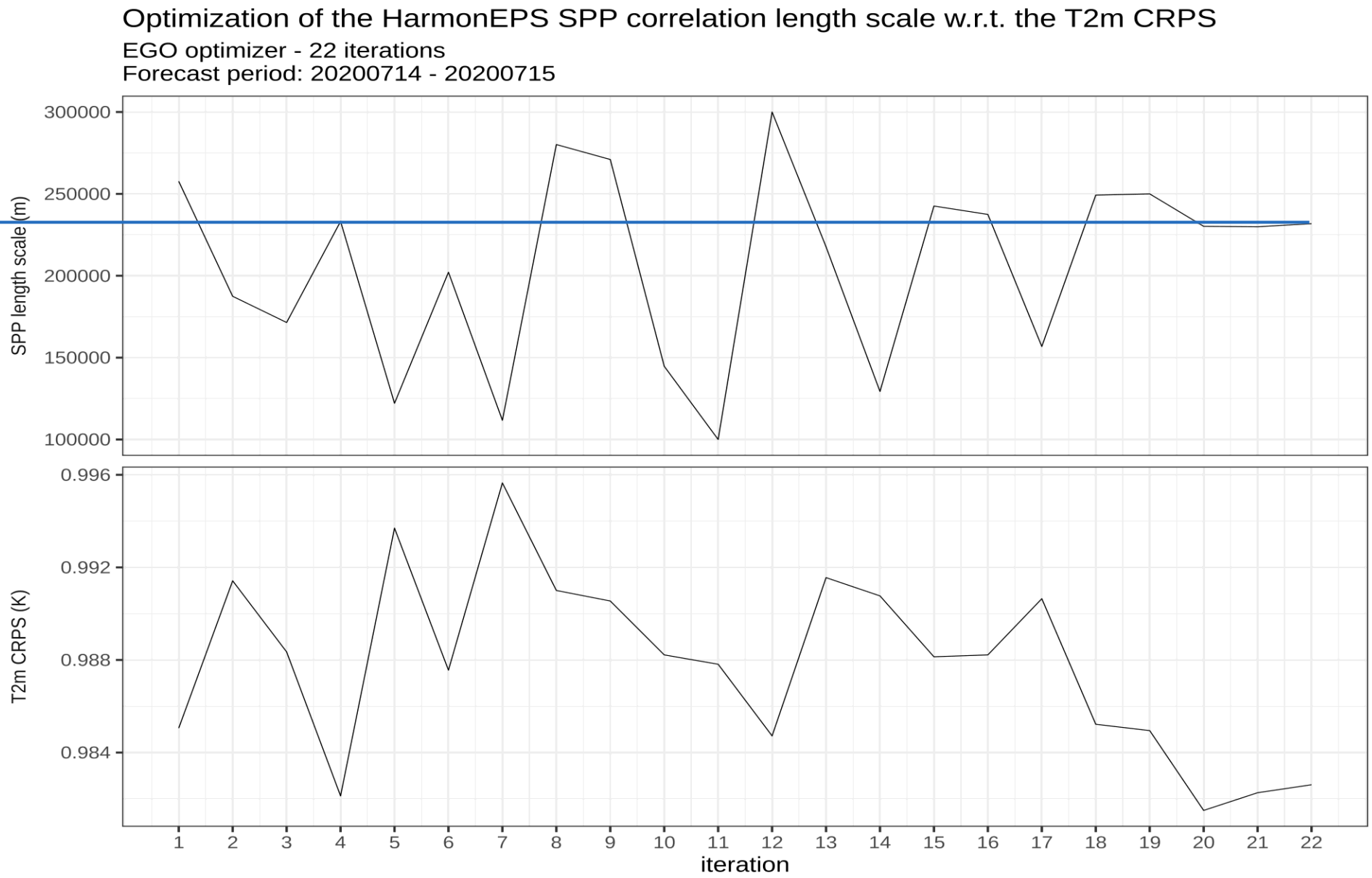
Tuning exercise - results



Tuning exercise - results

~230 km
Close to default 200km

Effect is rather small



Tuning exercise - remarks

- Results is not generally valid
- EGO allows for multiple inputs (*parameters to tune*) and outputs (*cost functions*)
- Outlook:

$$\left.\begin{array}{c} L_{SPPT} \\ \sigma_{SPPT} \\ \tau_{SSPT} \\ L_{SPP} \\ \sigma_{SPP} \\ \tau_{SPP} \end{array}\right\} \xleftarrow{\text{EGO optimization}} \left\{\begin{array}{l} \text{RH2m CRPS} \\ \text{G500 CRPS} \\ \text{S10m CRPS} \\ \text{T2m CRPS} \\ \ldots \end{array}\right.$$

Conclusions

- Application of URANIE platform with EPS is reasonably straightforward
- Is useful for sensitivity and optimization experiments
  - More complex modules exist in URANIE (e.g. a posteriori uncertainty estimators)
- Allows for:
  - systematic screening of EPS characteristics
  - Simultaneous tuning of many parameters
- Some URANIE methods (e.g. meta-modelling) are more challenging for use with EPS due to the many iterations they require
- More details can be found in the ESCAPE2 deliverable: https://www.hpc-escape2.eu/resources/d46-full-system-sized-ensemble-forecasts-within-uranie-framework

THANK YOU

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