Model error representation in AROME-EPS

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AROME-EPS

Horizontal resolution: 2.5km

Vertical levels: 90

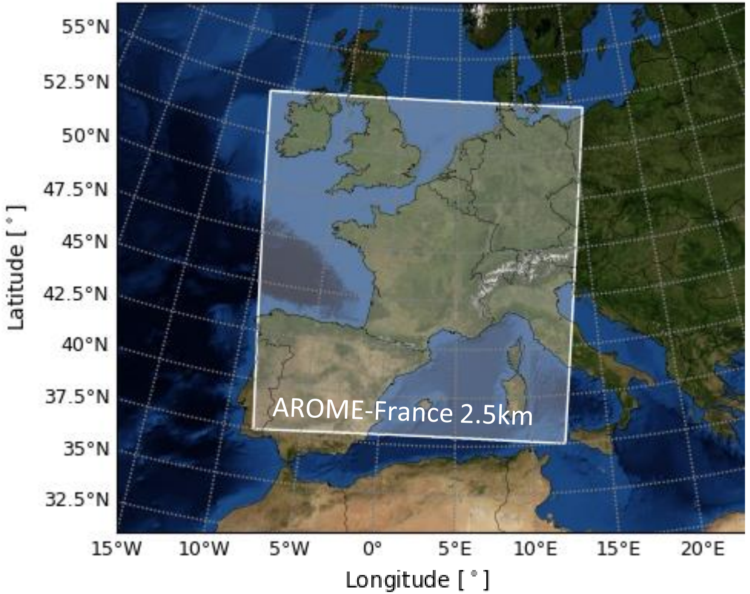
Members: 12 (16 members since July 2019)

Initial state: EDA

Lateral boundary coupling: ARPEGE-EPS (clustering)

Surface error: random surface parameters

Model error: SPPT



Objective:
Implement other model error representations using parameters perturbation

Implementation steps of Parameters Perturbation methods

1 Determine parameters to perturb

- Radiation
- Microphysic
- Turbulence
- Diffusion
- Surface
- Convection

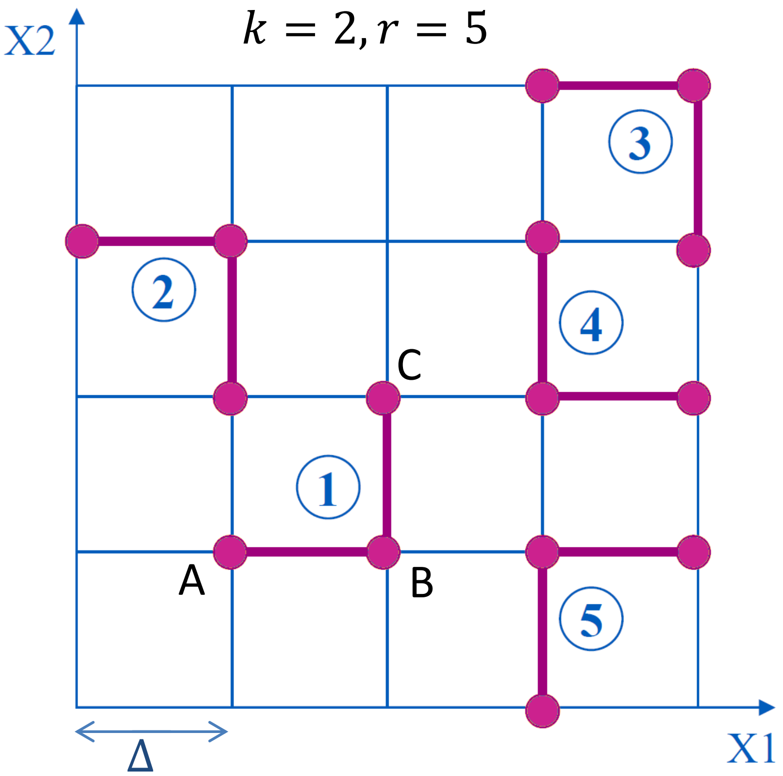
RSWINHF
RLWINHF
RCRIAUTI
RCRIAUTC
VSIGQSAT
XLINI
XCTD
XCTP
XCED
XCEP
XCET
XPHI_LIM
SLHDEPSH
SLHDKMIN
SLHDKMAX
XRIMAX
XFRACZ0
XCMF
XABUO
XBDETR
XENTR_DRY

Parameters subspace → Parameters perturbations → Evaluation with probabilistic scores

2 Sensitivity analysis: Morris, Sobol'(surrogates)

3 Set up different model error representations

Morris Sensitivity Analysis: Theory



Modification of one parameter after another
-> One-At-a-Time design

Parameters: X1, X2 ($k = 2$)
Elementary effect for each parameter:

$$EE_1 = \frac{f(B)-f(A)}{\Delta} \qquad EE_2 = \frac{f(C)-f(B)}{\Delta}$$

Repeat: r times ⇒ $r(k+1)$ simulations

For each parameter :
Mean of |EE|:

$$\mu_i{}^* = E(|EE_i|)$$

Standard deviation of EE:

$$\sigma_i = std(EE_i)$$

$$\left.\right\} \sqrt{\mu^{*2} + \sigma^2}$$

Morris Sensitivity Analysis: Applications to AROME-EPS

Parameter influence may change with seasons

→ 3 Sensitivity Analysis for 3 seasons (31 days):

- Summer 2018:
  01/05/2018 -> 30/07/2018: every 3 days
- Fall 2018:
  01/10/2018 -> 30/11/2018: every 2 days
- Winter 2018-2019:
  01/12/2018 -> 30/01/2019: every 2 days

Morris parameters: $r = 12, k = 21$
Parameter discretization : $p = 8$

$$r(k+1) = 12 \times (21+1)$$
$$= 264 \text{ simulations}$$
$$(\times 3 seasons \times 31 days)$$
$$= 24\,552\ forecasts$$

Reduce calculation cost:
Non-hydrostatic -> Hydrostatic
delete Predictor/Corrector Scheme

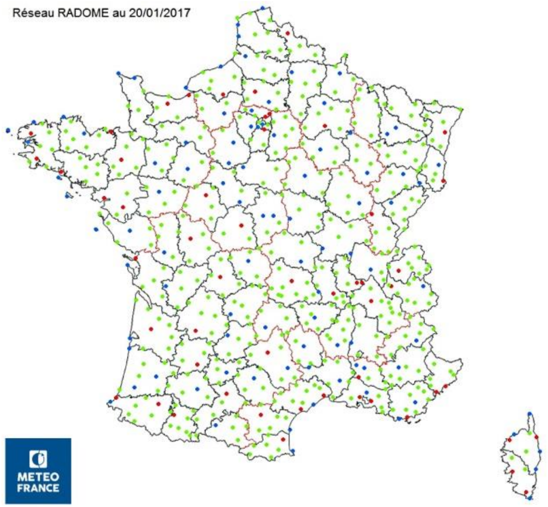
Morris Sensitivity Analysis: Applications to AROME-EPS

Influence on which scalar outputs ?

- **Mean meteorological field**
- **Deterministic Scores**: Mean Bias, RMSE, MAE

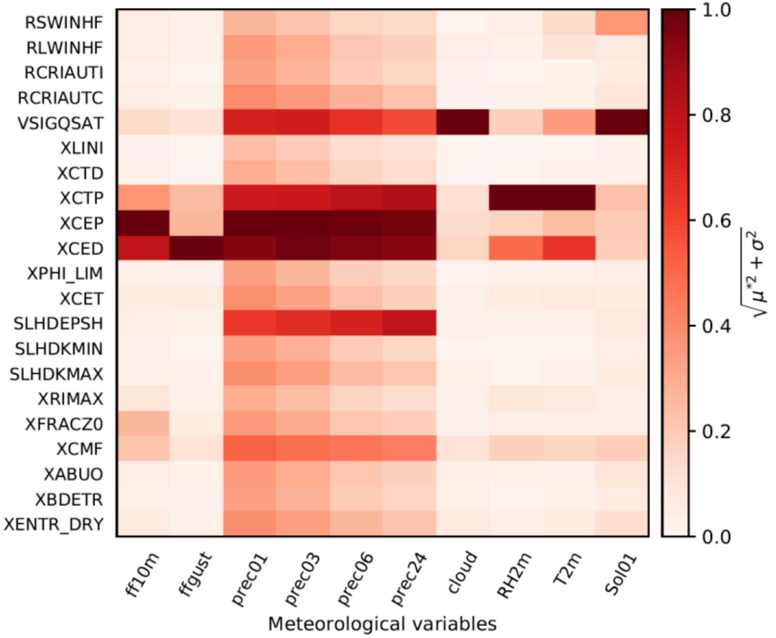
  -> RADOME & SYNOP observations

ff10m, ffgust, prec01, prec03, prec06, prec24, tcc, RH2m, T2m, Solar01

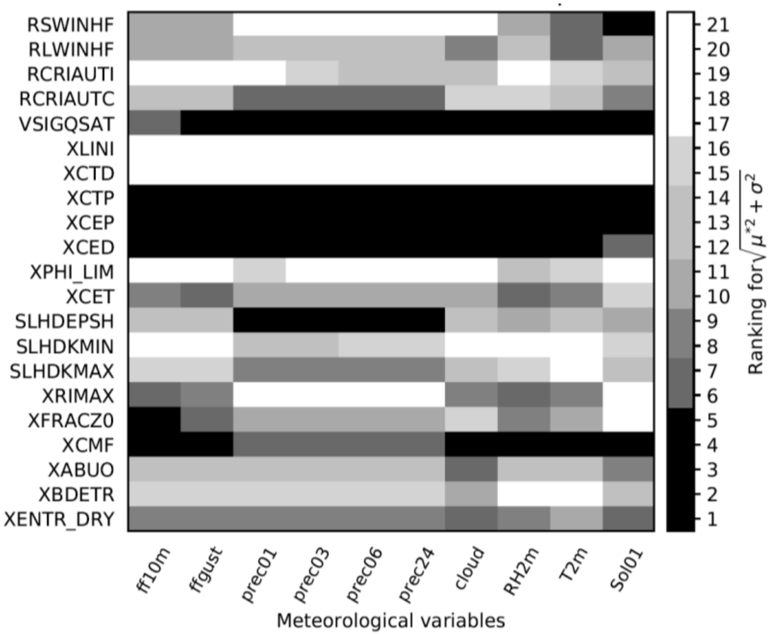


RADOME network

Mean parameters influence over 3 seasons and all model outputs



Parameters ranking



8 influential parameters : RSWINHF, VSIGQSAT, XCTP, XCEP, XCED, SLHDEPSH, XFRACZ0, XCMF

Model error representation

Perturbation parameter according to …	…members	…dates	… forecast range	… space
Perturbed Parameter (PP)	✓			
Random Perturbed Parameter (RPP)	✓	✓		
Random Parameter (RP)	✓	✓	✓	
Stochastically Perturbed Parametrization (SPP)	✓	✓	✓	✓

1000 Perturbed Parameter EPS generated from Morris forecasts

264 Morris forecasts differ only in their parameter values

→ **264-members EPS**

without initial, surface, lateral condition error representation

with model error representation

→ Perturbed Parameters method (PP)

Comparison with the current SPPT approach

Problem: SPPT has 12 members ≠ 264

264 Morris forecasts → Random draw of 12 forecasts → PP with 12 members → 1000 PP → PP with the smallest CRPS in wind and rain **(B-CRPS-PP)**

x 1000

Random Perturbed Parameters (RPP)

for each member and date

RSWINHF
RLWINHF
RCRIAUTI
RCRIAUTC
VSIGQSAT
XLINI
XCTD
XCTP
XCED
XCEP
XCET
XPHI_LIM
SLHDEPSH
SLHDKMIN
SLHDKMAX
XRIMAX
XFRACZ0
XCMF
XABUO
XBDETR
XENTR_DRY

Random draw of parameter values from a uniform distribution

Comparison between 5 different model error representations

Comparison of model error representations only: no initial, surface, lateral perturbations

Mean PP: mean PP score, average over the 1000 PP generated from Morris design

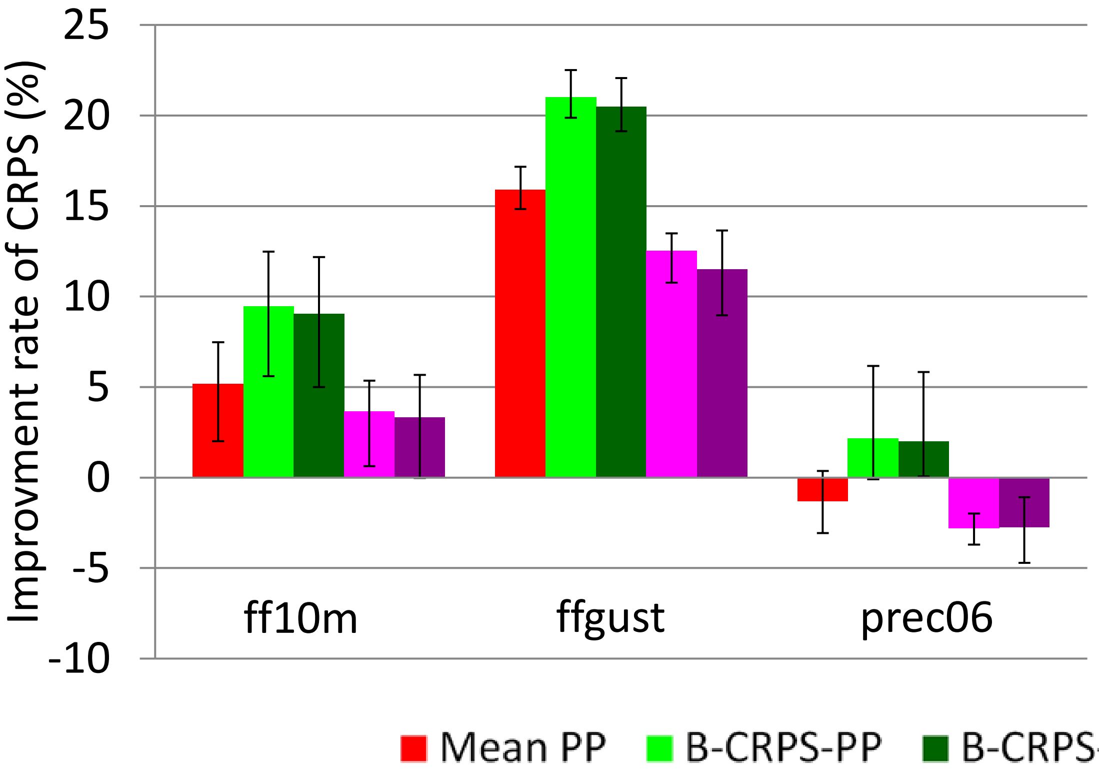
B-CRPS-PP: Best PP on 3 seasons, with the smallest CRPS on ff10m and prec03

B-CRPS-P8P: Best PP on 3 seasons, with the smallest CRPS on ff10m and prec03 with non-influential parameters put at their default values

RPP: Perturbation of all parameters for each member and date

RP8P: Perturbation of the 8 most influential parameters for each member and date

Mean CRPS improvment rate compared to SPPT (average over 3 seasons and 45h lead time)

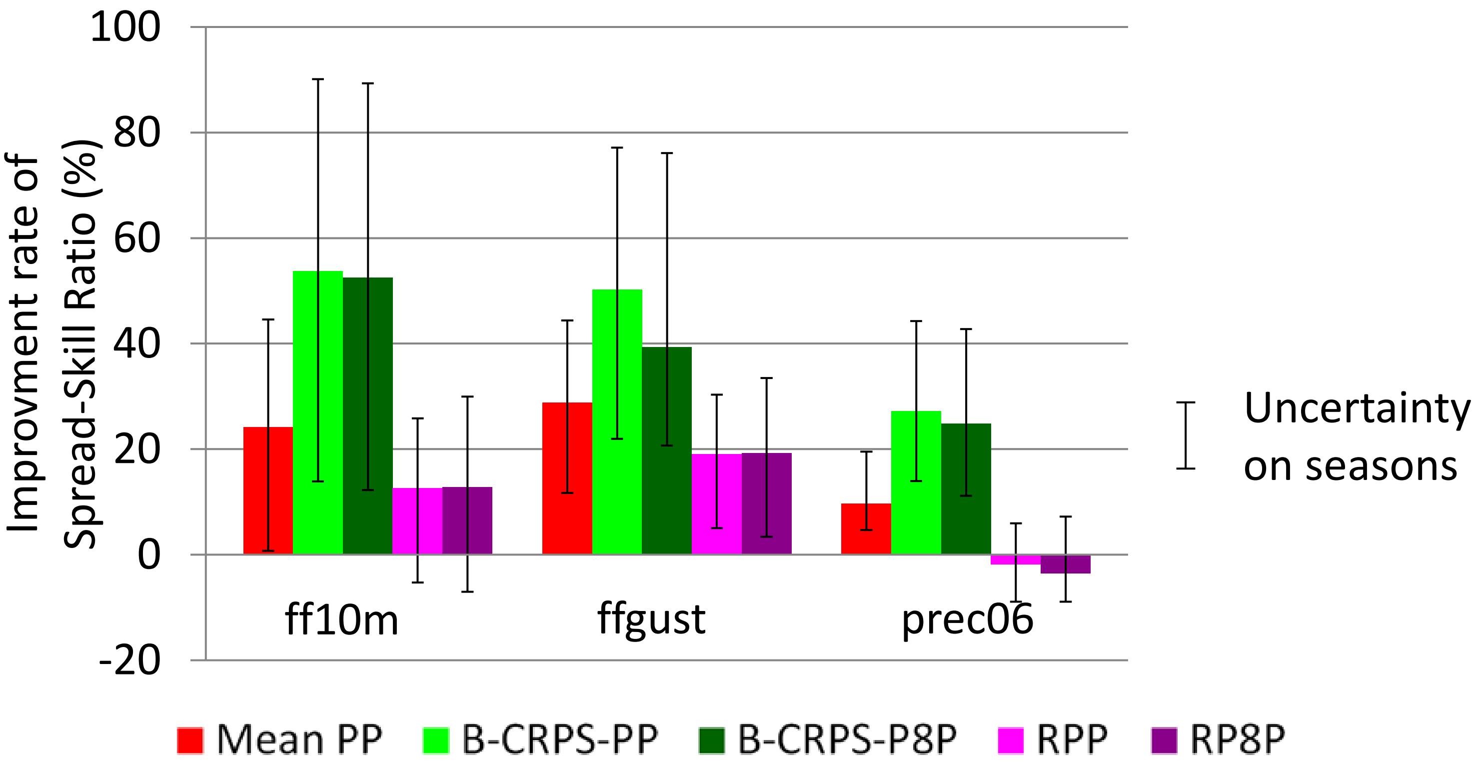


-> High improvment for ff10m and ffgust
-> Smaller improvment or degradation for prec06

Uncertainty on seasons

Remark: Higher improvment on winter than in summer and fall

Mean Spread-Skill ratio improvment rate compared to SPPT (average over 3 seasons and 45h lead time)



Conclusion

Generally: PP and RPP improve scores compared to SPPT in particular for ffgust and on winter

B-CRPS-PP: optimized for CRPS but still good for other scores

B-CRPS-P8P: similar results than B-CRPS-PP

RPP:

- smaller improvment
- degrades prec06 scores

RP8P: similar results than RPP

PP and RPP approaches must be optimized to be performant
-> Reduction to 8 parameters

Improve B-CRPS-PP

Problem: PP generated from Morris forecasts sample only 8 values for each parameter

- Need to sample the whole parameters space
- High computational cost

Emulator

Model: Parameters values for each member → AROME-EPS → $CRPS_{ff10m}$ and $CRPS_{prec03}$

Model approximation (emulator): Parameters values for each member → *function* → $CRPS_{ff10m}$ and $CRPS_{prec03}$

Gaussian Process Regression

A CRPS-emulator in order to find the best PP

1) Test different Gaussian Process Regression parameters (covariance kernel, number of input data, …)

   ➡ Use a Matern 3/2 covariance function

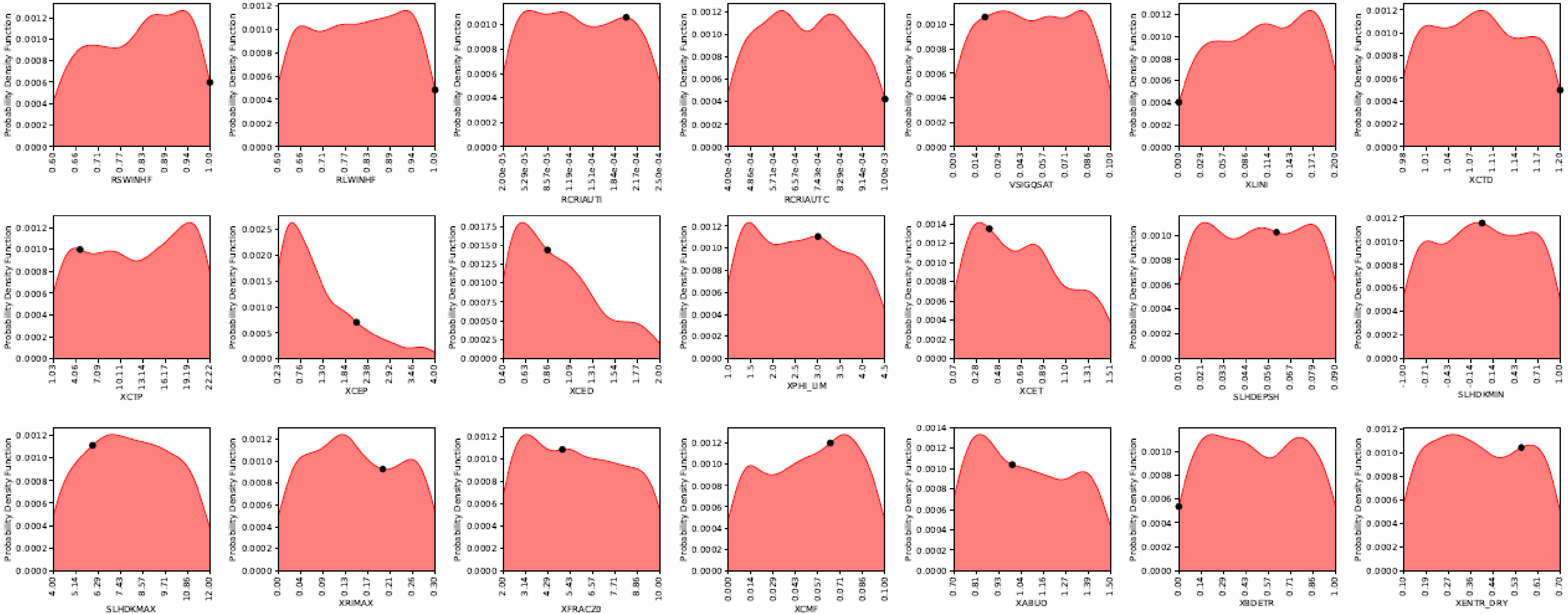
   \+ increase data number by switching members : 1 000 -> 40 000 CRPS

2) Emulator trained on 70% of 40 000 CRPS values
3) Validation error (on 30% remainded data): 0,74% -> validated
4) CRPS prediction of 500 000 inputs, generated from a Monte-Carlo sampling
   - The smallest CRPS -> new Best CRPS PP -> B-eCRPS-PP
   - 50 smallest CRPS -> 50 x 12 physical parameters values

   ➡ Parameter distributions

PDF of each parameter

• Default value



Future Works

Sensitivity Analysis:

– Scientific article redaction

PP:

– Compute scores for B-eCRPS-PP

RPP:

– Optimization with PDF obtained from emulator

SPP:

– Use PDF from emulator

Evaluate perturbed parameters approaches in the full EPS
Combination with SPPT

Thanks for your attention