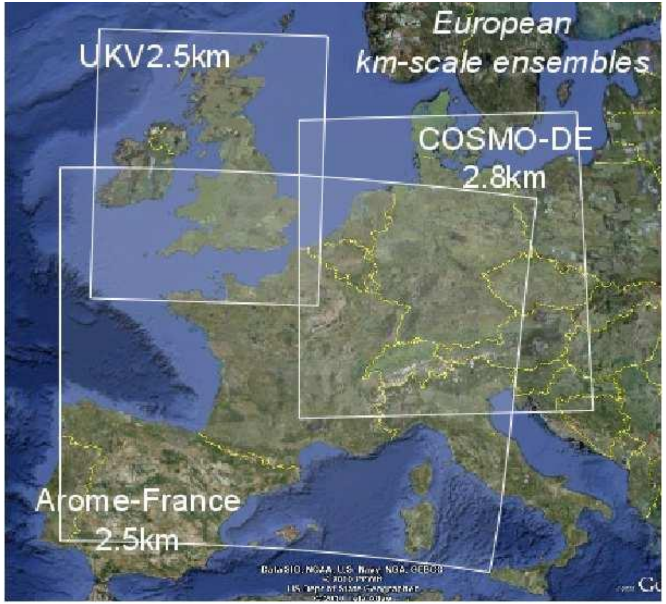
Representation of model errors in AROME-EPS

Meryl WIMMER
GMAP/RECYF CNRM, Météo-France, Toulouse
meryl.wimmer@meteo.fr

with Loïk BERRE, Laurent DESCAMPS, Laure RAYNAUD, Yann SEITY, Philippe ARBOGAST

AROME-EPS

- Horizontal resolution : 2,5km
- 90 vertical levels
- 12 members (16 members since July 2019)
- Initial state : EDA
- Lateral boundary coupling : ARPEGE-EPS (clustering)
- Random surface perturbations
- Model error representation : SPPT



Add another model error representation : SPP

SPP implementation steps

1 Determine parameters to perturb

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

SPP implementation steps

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

SPP implementation steps

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

2 Sensitivity analysis : Morris, Sobol'(surrogates)

SPP implementation steps

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 → Stochastic perturbation of parameters

2 Sensitivity analysis : Morris, Sobol'(surrogates)

3 Set up the SPP approach

SPP implementation steps

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 → Stochastic perturbation of parameters → Probabilistic evaluation with scores

2 Sensitivity analysis : Morris, Sobol'(surrogates)

Set up the SPP 3 approach

SPP implementation steps

1 Determine parameters to perturb

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

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

→ Parameters subspace → Stochastic perturbation of parameters → Probabilistic evaluation with scores

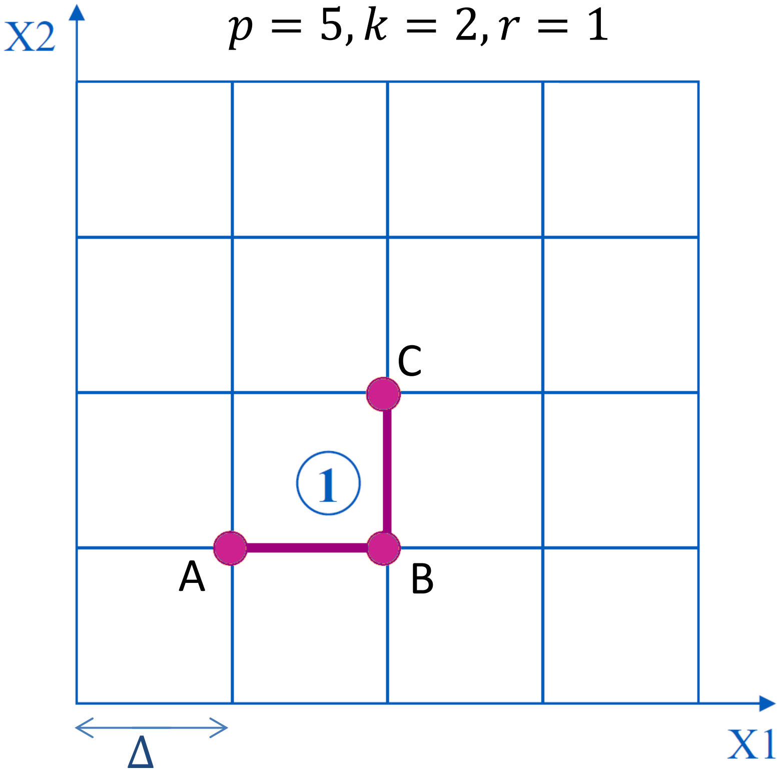
2 Sensitivity analysis : Morris, Sobol’(surrogates)

3 Set up the SPP approach

Overview

- Morris Analysis : Theory
- Morris Analysis : Application
- Morris Analysis : Results
- Perturbed Parameters
- Future Works

Morris Analysis : Theory

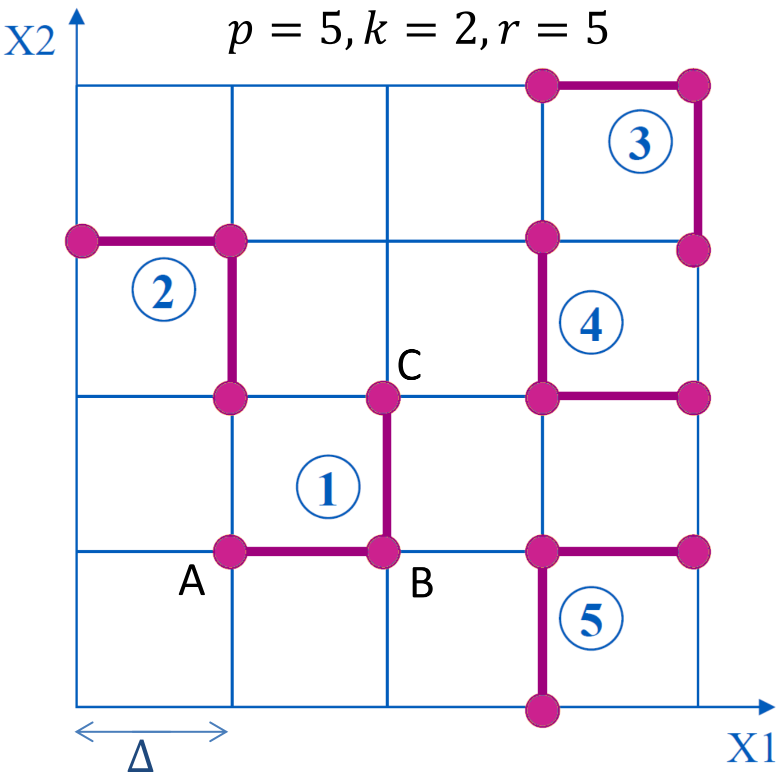


Parameters : X1, X2 ($k = 2$)
Modification of one parameter after another
-> One-At-a-Time design

Elementary effect for each parameter:

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

Morris Analysis : Theory



Parameters : X1, X2 ($k = 2$)
Modification of one parameter after another
-> One-At-a-Time design

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

Mean of |EE| :

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

Standard deviation of EE :

$$\sigma_i = std(EE_i)$$

$$\sqrt{\mu^{*2} + \sigma^2}$$

Morris Analysis : Application

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 : $r = 12, k = 21, p = 8$

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

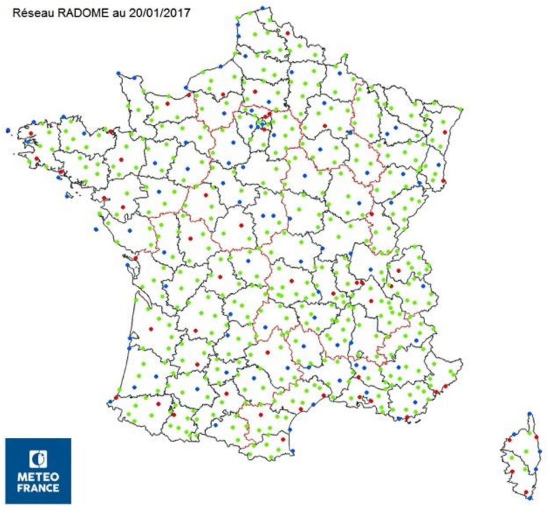
Reduce calculation cost :
Non-hydrostatic -> Hydrostatic
delete Predictor/Corrector Scheme

Morris Analysis : Application

Which scalar outputs ?

- **Mean Meteorological variables**
  -> **ff10m**, ffgust, prec01, prec03, prec06, prec24, tcc, RH2m, T2m, Solar01

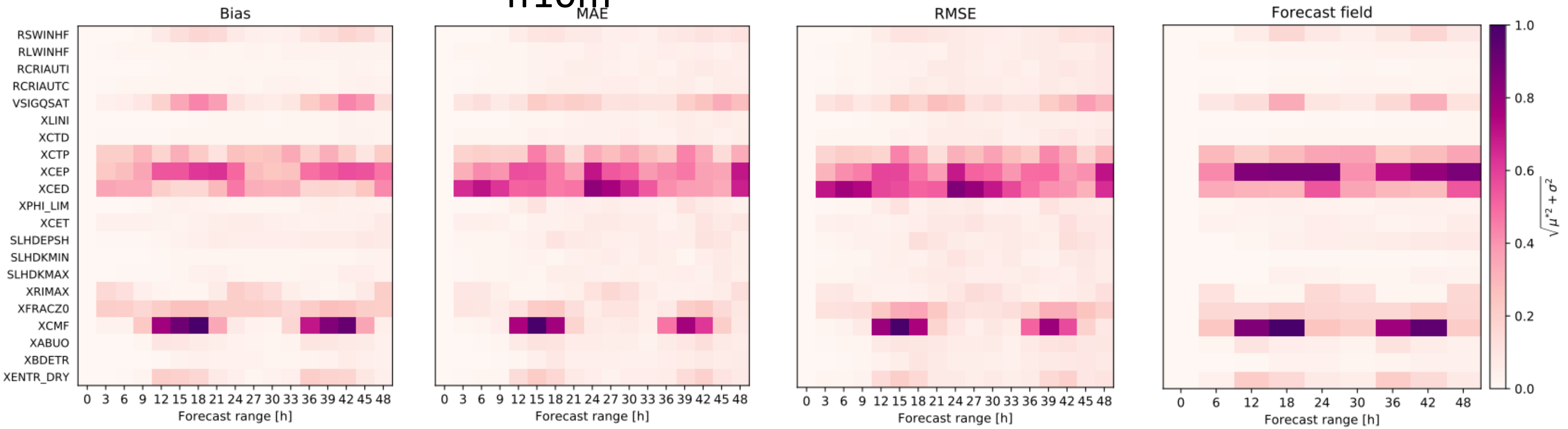
- **Deterministic Scores** : Mean Bias, RMSE, MAE
  -> RADOME & SYNOP observations



SUMMER

$$Morris\left(\frac{1}{N_d}\sum_{d}\left(\frac{1}{N_x}\sum_{x} f(x,d,h)\right)\right)$$

ff10m

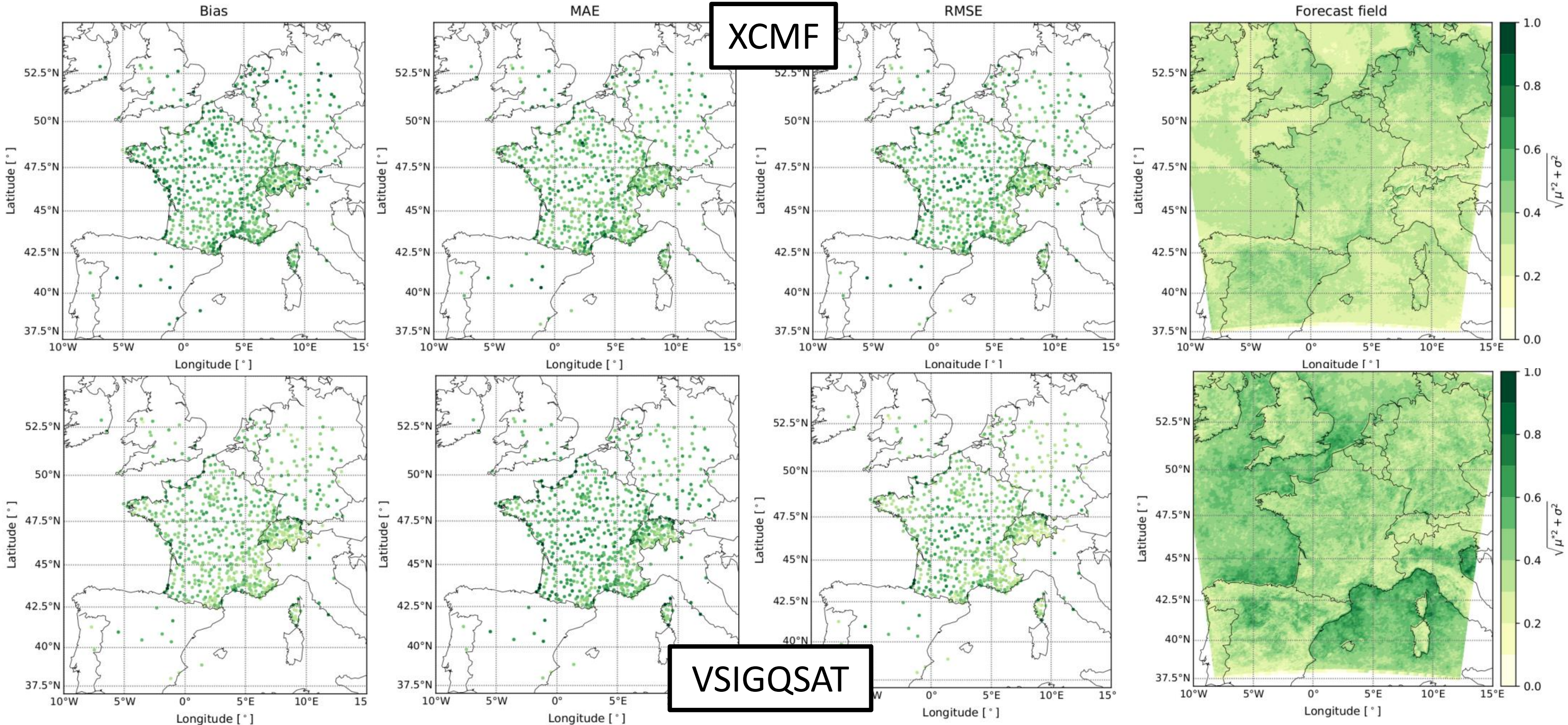


Influent parameters : RSWINHF, VSIGQSAT, XCTP, XCEP, XCED, XRIMAX, XFRACZ0, XCMF, XENTR_DRY

SUMMER

$$\frac{1}{N_h}\sum_{h} Morris\left(\frac{1}{N_d}\sum_{d}(f(x,d,h)\right)$$

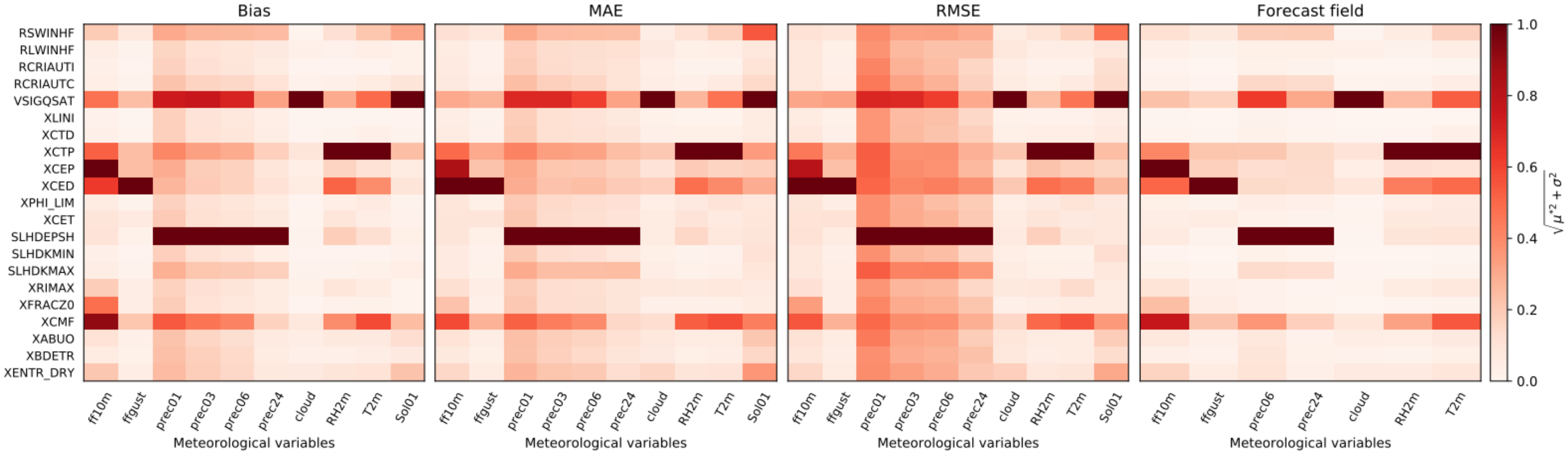
XCMF



VSIGQSAT

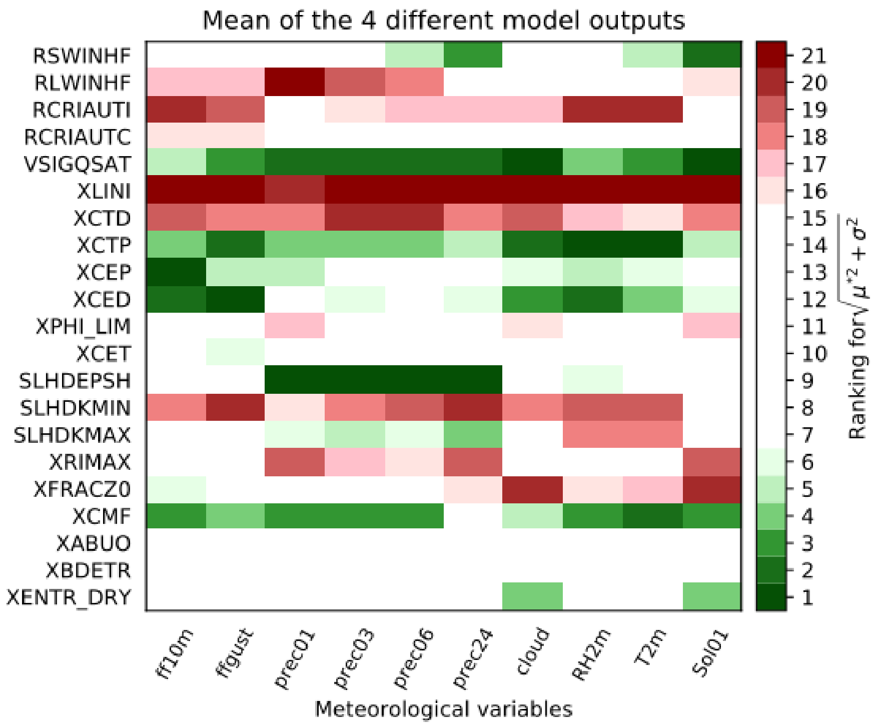
SUMMER

$$\frac{1}{N_h}\sum_h Morris\left(\frac{1}{N_d}\sum_d\left(\frac{1}{N_x}\sum_x f(x,d,h)\right)\right)$$



SUMMER

Ranking



Influent parameter

Non-influent parameter

Delete RLWINHF, RCRIAUTI, XLINI, XCTD, SLHDKMIN ?

Morris -> Perturbed Parameters

- 264 forecasts differ only in their parameters values

  → **264-members EPS**

  without initial, surface, lateral condition error representation

  with model error representation

  → Fixed Perturbed Parameters method (PP)

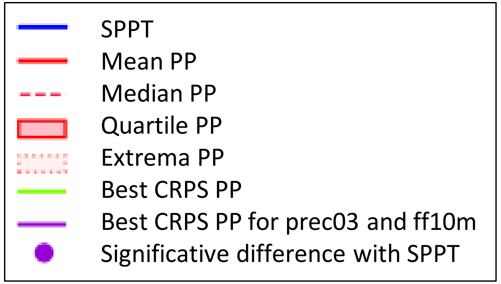
- Comparison with the current SPPT approach

  Problem : SPPT has 12 members ≠ 264

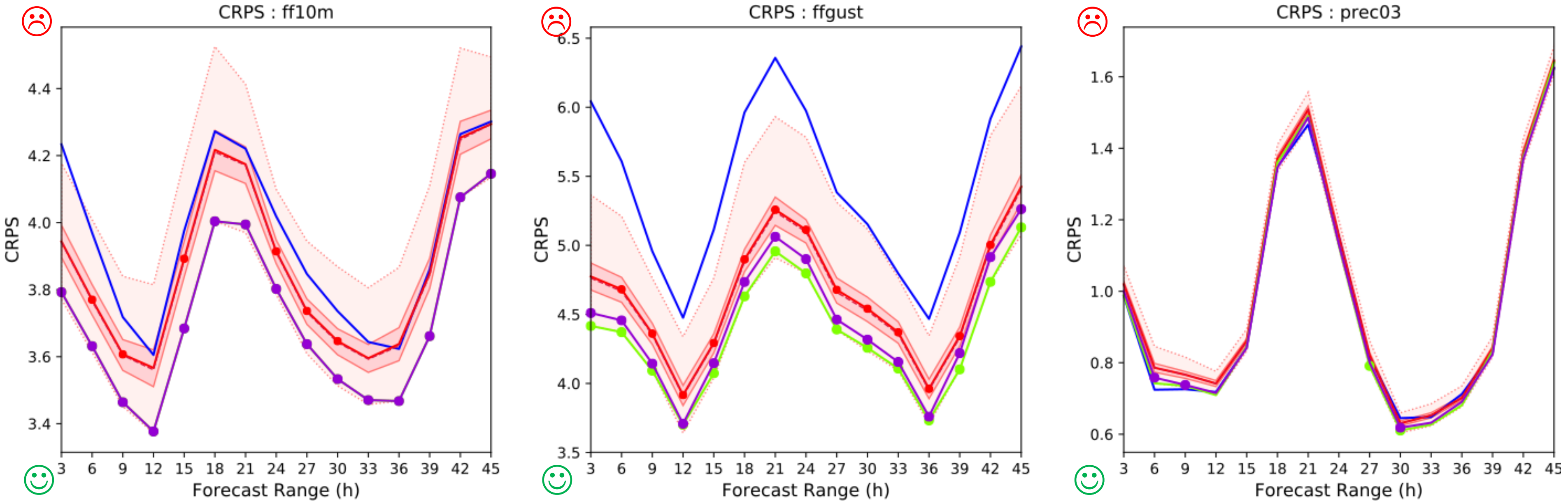
  1000 random draws of 12 forecasts amongst the 264 forecasts

  → create 1000 PP with 12 members

CRPS

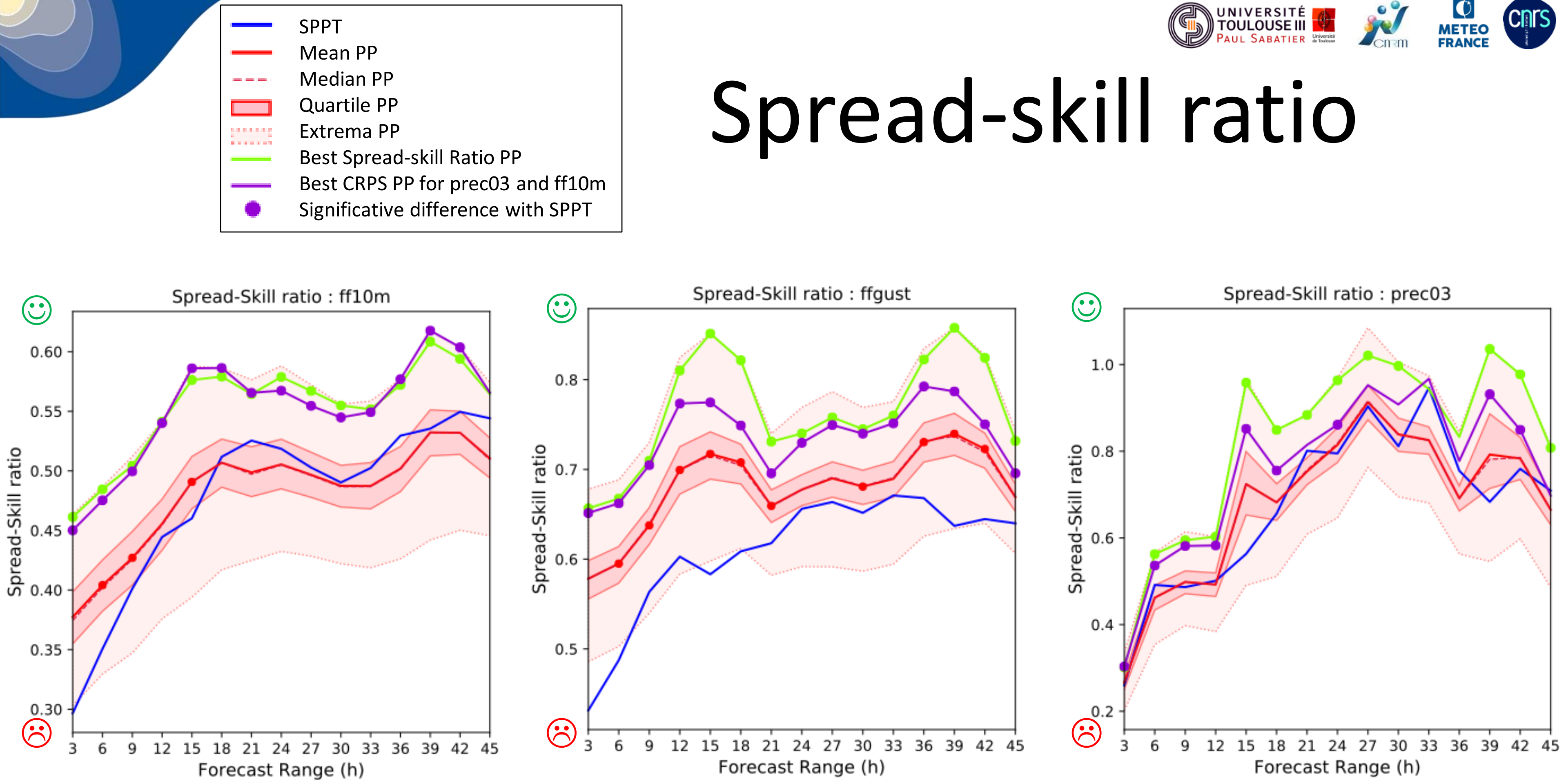


SPPT
Mean PP
Median PP
Quartile PP
Extrema PP
Best CRPS PP
Best CRPS PP for prec03 and ff10m
Significative difference with SPPT



CRPS : ff10m
CRPS
4.4
4.2
4.0
3.8
3.6
3.4
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
Forecast Range (h)
CRPS : ffgust
CRPS
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
Forecast Range (h)
CRPS : prec03
CRPS
1.6
1.4
1.2
1.0
0.8
0.6
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
Forecast Range (h)

Spread-skill ratio



Future Works

- Morris Analysis :
  - Continue to analyse results
  - Comparison with other season
- PP :
  - Understand difference between best/worst PP (preferred parameter value, interactions between parameter,…)
  - Evaluate the best PP in the full EPS
  - Reduce the set of parameter according to the Morris study
  - Combination PP/SPPT
  - Make the same study for other season
- SPP :
  - Use information from the Morris Analysis and the PP study to implement SPP in AROME-EPS
  - Test different parameter distribution, time and space correlation, …
  - Comparison with the best PP

Thanks for your attention