LSCE

LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES

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Wheat yield anomaly in France – Calibration of an agro-LSM ORCHIDEE-CROP

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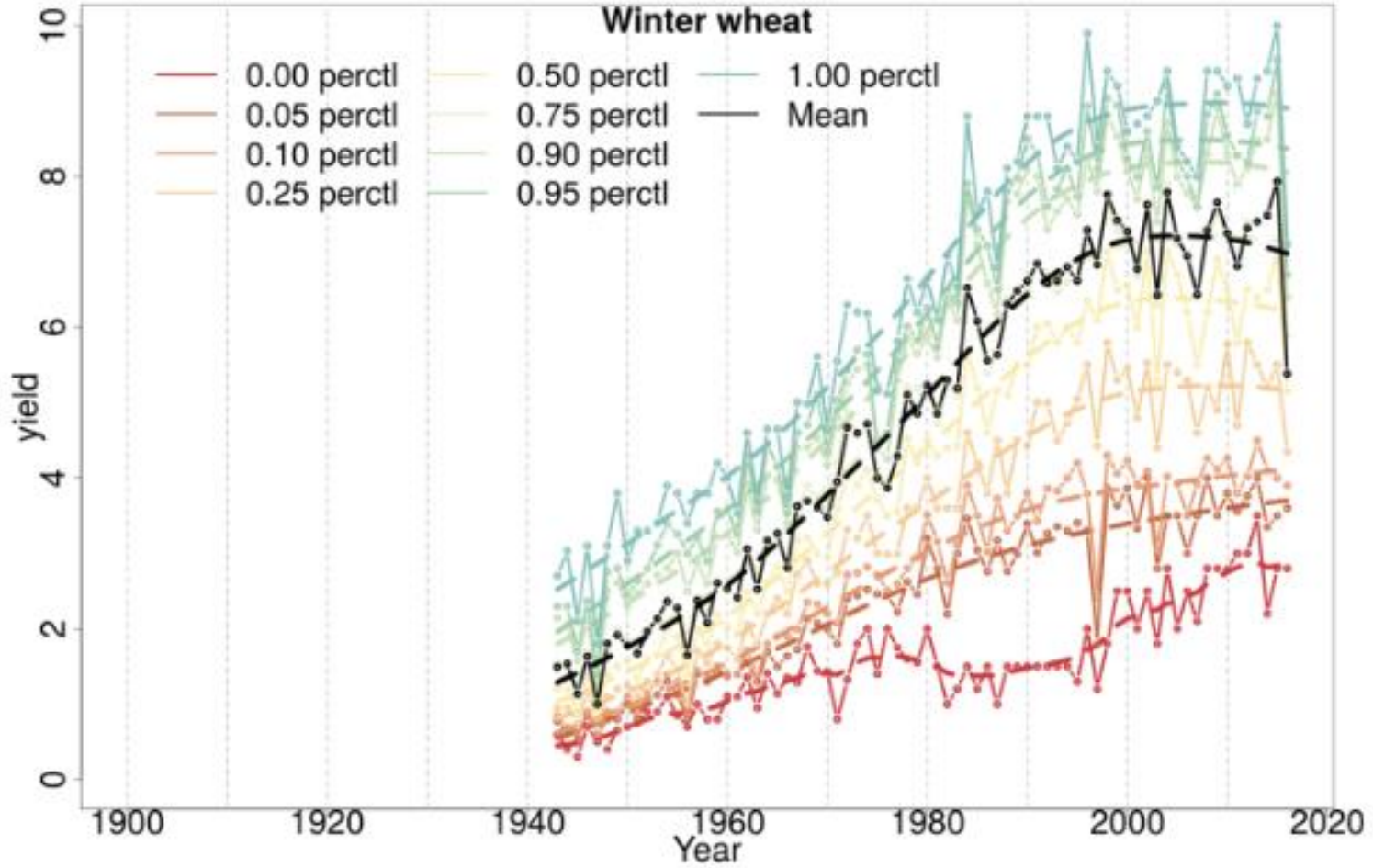
Why Wheat in France ?

Rank	Exporter	2017 Wheat Exports	% World Total
1.	United States	US$6.1 billion	15.7%
2.	Russia	$5.8 billion	14.8%
3.	Canada	$5.1 billion	13%
4.	Australia	$4.7 billion	11.9%
5.	France	$3 billion	7.7%
6.	Ukraine	$2.8 billion	7.1%
7.	Argentina	$2.4 billion	6.1%
8.	Germany	$1.6 billion	4.1%
9.	Romania	$1.1 billion	2.9%
10.	Bulgaria	$772.7 million	2%

www.worldstopexports.com/wheat-exports-country/

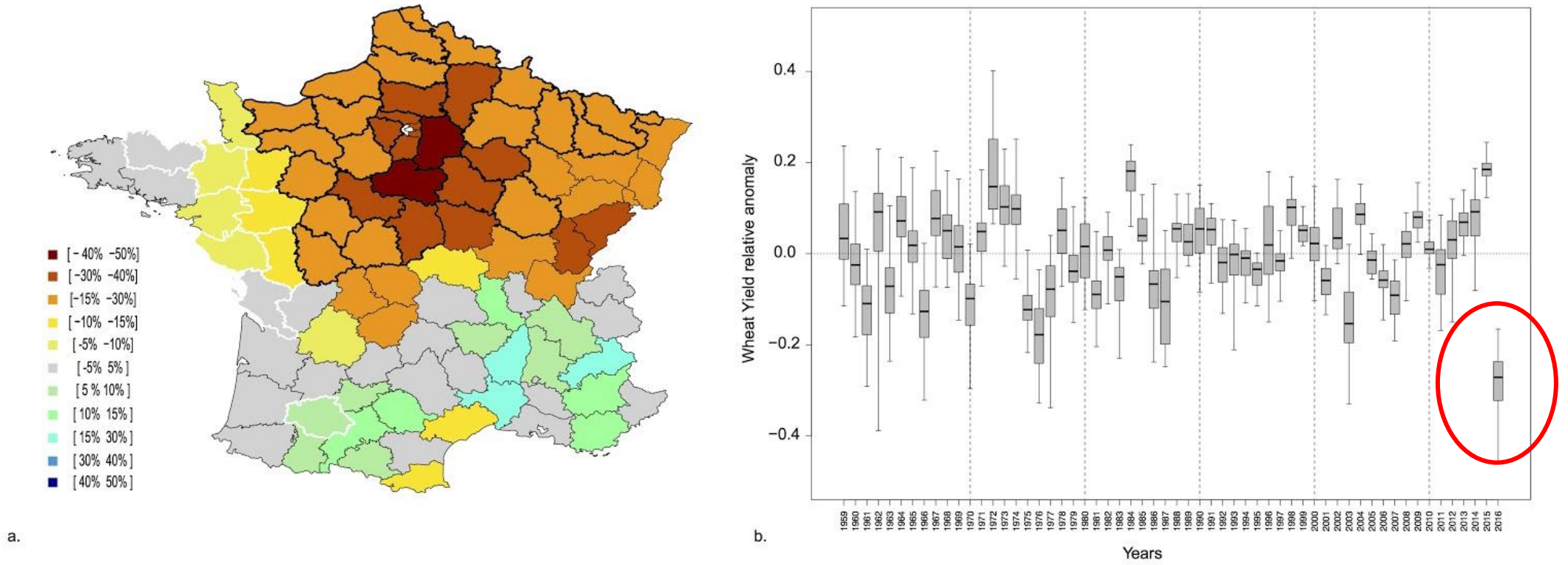
National yield percentiles in France across departments for each year for winter wheat



- Large increase in yields over the last 50 years, but stagnation since ≈ 2000 with high variance

Schauberger et al. 2018 – Yield trends, variability and stagnation analysis of major crops in France over more than a century

Spatio-temporal pattern of the 2016 extreme yield loss

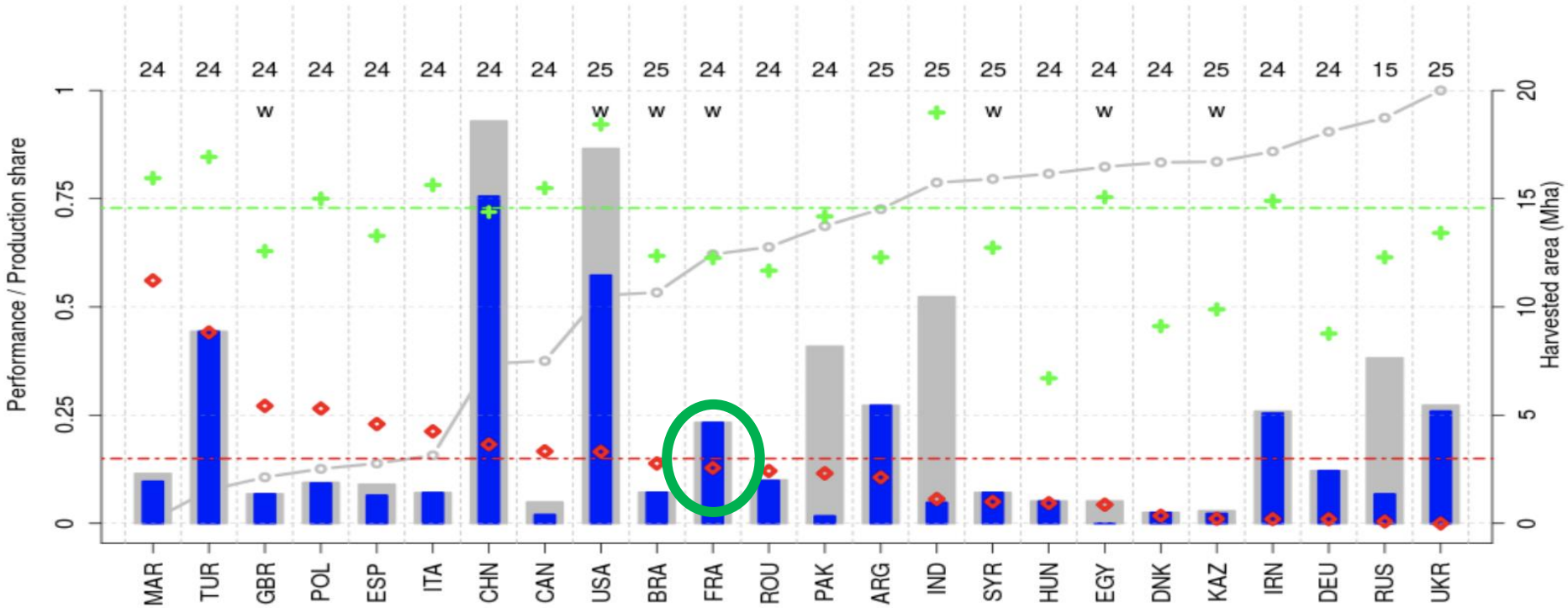


- Figure a – Wheat yield anomaly in 2016 relative to expected values defined by the long term detrended yield trend
- Figure b – Boxplot of the distribution of detrended anomalies in the "breadbasket" region of North-East France (1959-2016)

Ben-Ari et al. 2018 - Causes and implications of the unforeseen 2016 extreme yield loss in the breadbasket of France

Why a process-based model ?

- Difficulty to simulate good yield variability with statistical models for wheat
- Process models
  - Account for short term stress from weather variability
  - Equations valid for future projections
  - Many parameters, lack of regional calibration, capture only climatic effects



Schauberger et al. 2017 – Global and national performance of a semi-empirical modeling scheme for yield anomalies of maize and wheat

Parameter sensitivity analysis

Goal :

- Identify the **most influential** parameters, before calibrating their value
- Identify which parameters are **separable** among influential ones (co-linearity)

Problem

- Too many parameters (>100)
- Range of time scales
  => some parameters control 'fast' processes, other 'slow' processes
- CPU intensive land surface model (>3 min for simulating one year over one pixel)

Solution proposed

1. Expert judgment

- First 'subjective' selection of a set of 41 influential parameters
- Assign a range of variation to those parameters

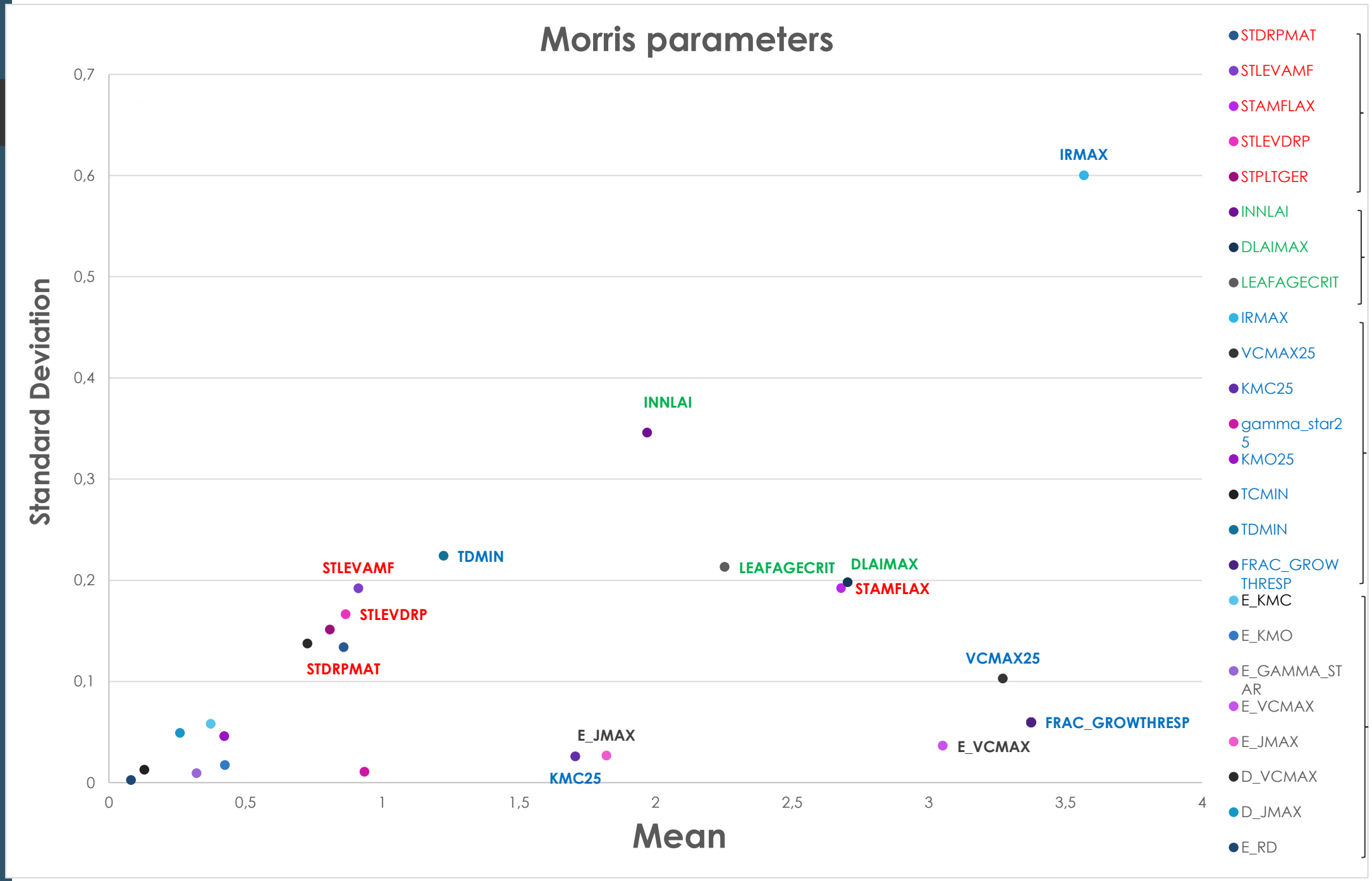
2. Morris sensitivity method (1)

- Run the model one-at-a time with different parameter values, randomly chosen within a hypercube of possibilities
- Select the most influential parameters (10 parameters then 5)
- Final number of parameters for the last calibration = 3

3. Two metrics are used for the final selection

Mean : influence of mean yield
Standard deviation : co-linearity

(1) Morris 1991 – Factorial Sampling Plans for Preliminary Computational Experiments


Morris parameters
Standard Deviation
Mean
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
0,5
1
1,5
2
2,5
3
3,5
4
IRMAX
INNLAI
TDMIN
STLEVAMF
LEAFAGECRIT
DLAIMAX
STAMFLAX
STLEVDRP
STDRPMAT
VCMAX25
FRAC_GROWTHRESP
E_JMAX
E_VCMAX
KMC25
STDRPMAT
STLEVAMF
STAMFLAX
STLEVDRP
STPLTGER
INNLAI
DLAIMAX
LEAFAGECRIT
IRMAX
VCMAX25
KMC25
gamma_star25
KMO25
TCMIN
TDMIN
FRAC_GROWTHRESP
E_KMC
E_KMO
E_GAMMA_STAR
E_VCMAX
E_JMAX
D_VCMAX
D_JMAX
E_RD
Phenology-specific parameters
LAI-specific parameters
Mean yield-specific parameters
Energy (activation/ deactivation) parameters

Phenology-specific parameters

- **STAMFLAX** : number of days necessary between AMF and LAX
- **STLEVDRP** : number of days necessary between LEV and DRP
- **STDRPMAT** : number of days necessary between DRP and MAT

LAI-specific parameters

- **DLAIMAX** : maximum rate of production of net leaf area surface
- **INNLAI** : nitrogen limitation for leaf growth
- **LEAFAGECRI** : mean leaf life time

Mean yield-specific parameters

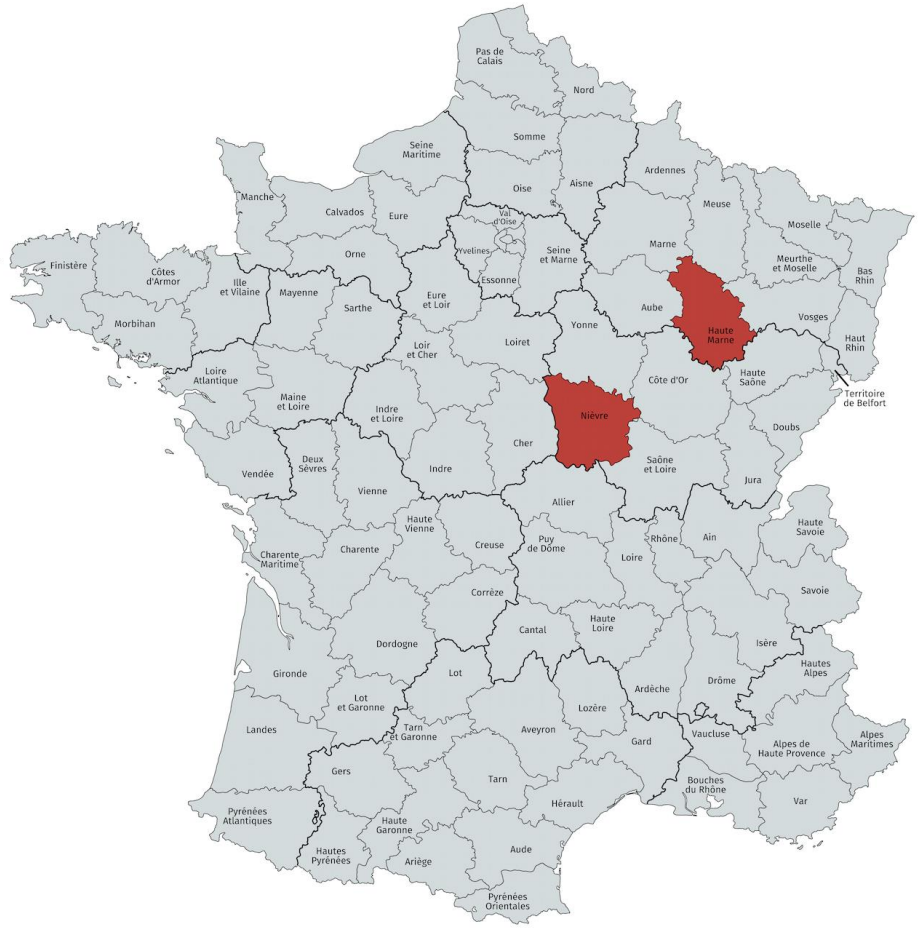
- **IRMAX** : maximum harvest index
- **VCMAX25** : maximum rate of Rubisco-activity limited carboxylation at 25°C
- **FRAC_GROWTHRESP** : fraction of biomass allocated to growth respiration
- **TDMIN** : minimum threshold for development

Energy (activation/ deactivation) parameters

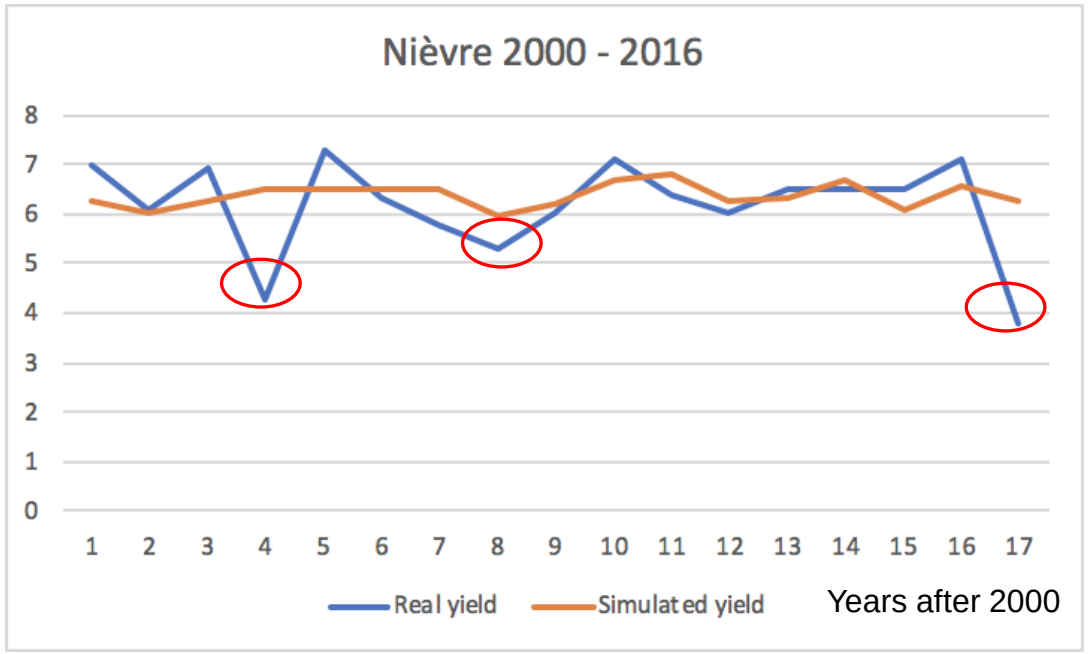
- **E_VCMAX** : energy of activaton of VCMAX

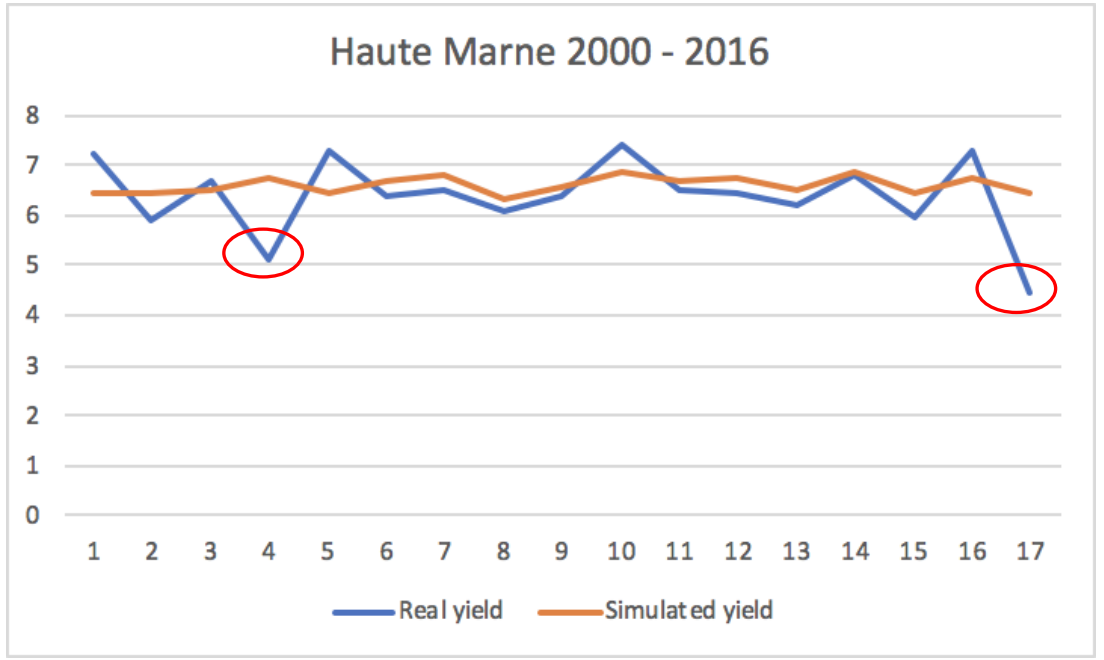
First Calibration

- Departements
- Years : 2010 ->
- Parameters se
  - **VCMAX25 :** ation at 25°C
  - **FRAC_GROV** respiration
  - **DLAIMAX :** r ce
  - **INNLAI :** nitr
  - **LEAFAGECRI**
- **Results : calibr**
  - **VCMAX25** :
  - **DLAIMAX** : 0
  - **INNLAI** : 0.5(
  - **FRAC_GROWTHRESP** : 0.29 (0.28)
  - **LEAFAGECRIT :** 85 (90)



Simulated yields VS Observed yields (in-sample data)





Extreme yields for the two departments : 2003, 2007, 2016

Second Calibration

- Departements (NUTS-3) : **20 units**
- Years : 1990 -> 2015 (26 years)
- **Parameters that are re-calibrated**:
  - **VCMAX25 :** maximum rate of Rubisco-activity limited carboxylation at 25°C
  - **FRAC_GROWTHRESP :** fraction of biomass allocated to growth respiration
  - **DLAIMAX :** maximum rate of production of net leaf area surface
- **Values for other parameters fixed from the 1st calibration**

- **Question adressed : How does Orchidee react to different sets of calibration ?**
  - **Spatial variability :** calibration over different groups of departments
  - **Temporal variability :** calibration over extreme vs average years

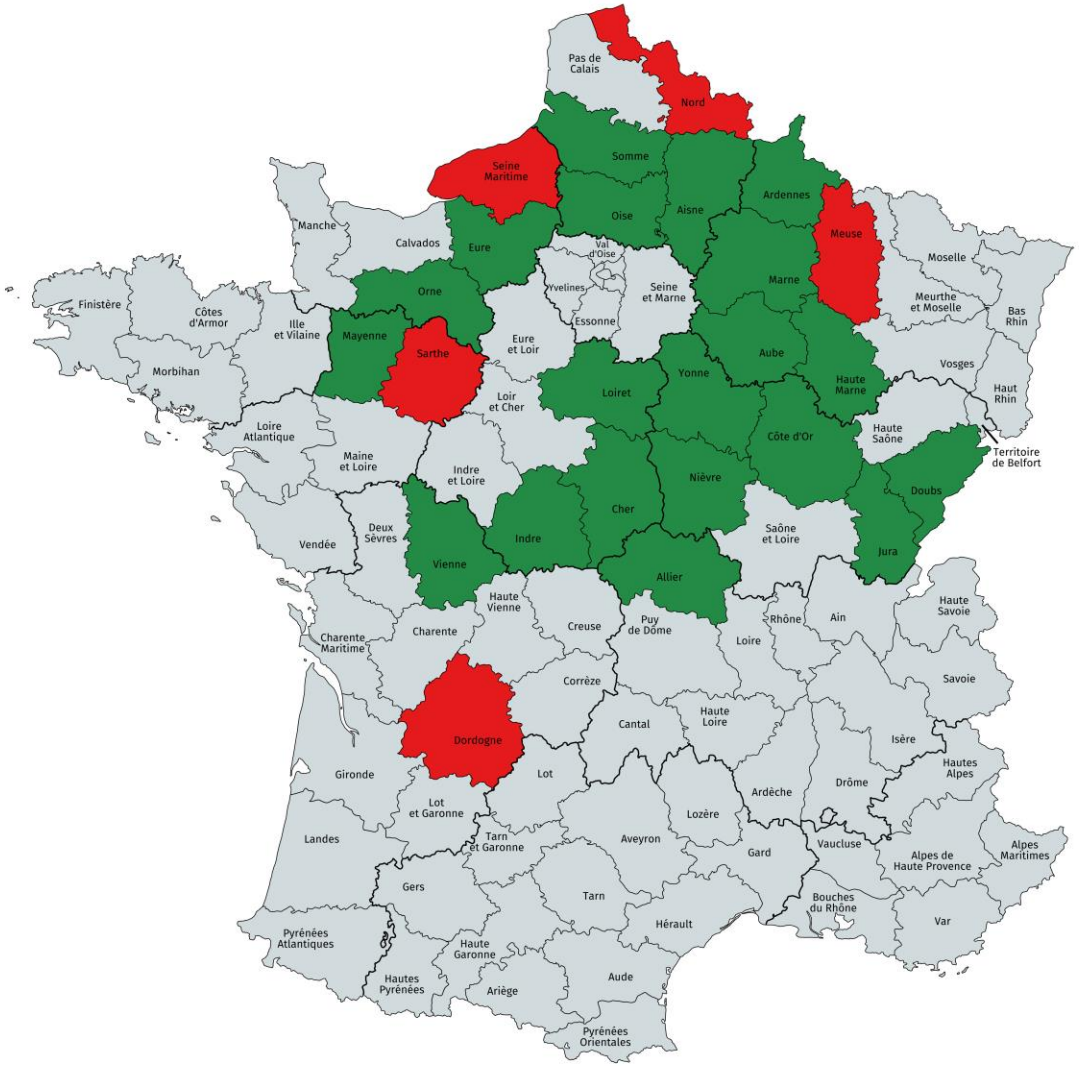
Departments

In-sample

- Aisne
- Allier
- Ardennes
- Aube
- Cher
- CoteD'or
- Doubs
- Eure
- Haute-Marne
- Indre
- Jura
- Loiret
- Marne
- Mayenne
- Nievre
- Oise
- Orne
- Somme
- Vienne
- Yonne

Out-of-sample

- Meuse
- Nord
- Sarthe
- Seine-et-Marne
- Dordogne



Parameters values after 2nd calibration

Calibration	VCMAX25 (100)	DLAIMAX (0.00044)	FRAC_GROWT (0.29)
All (20 departments)	105	55	26
10 departments	105	55	27
Other 10 departments	105	58	26
5 departments	110	58	26
Other 5 departments	110	54	29
Other 5 departments	110	58	28
Other 5 departments	110	55	32
2 departments	110	57	26
Other 2 departments	110	54	27

- Calibrating on a few (2, 5, 10) departments is enough
- Departments are taken randomly among the dataset used for the calibration (20 departments)

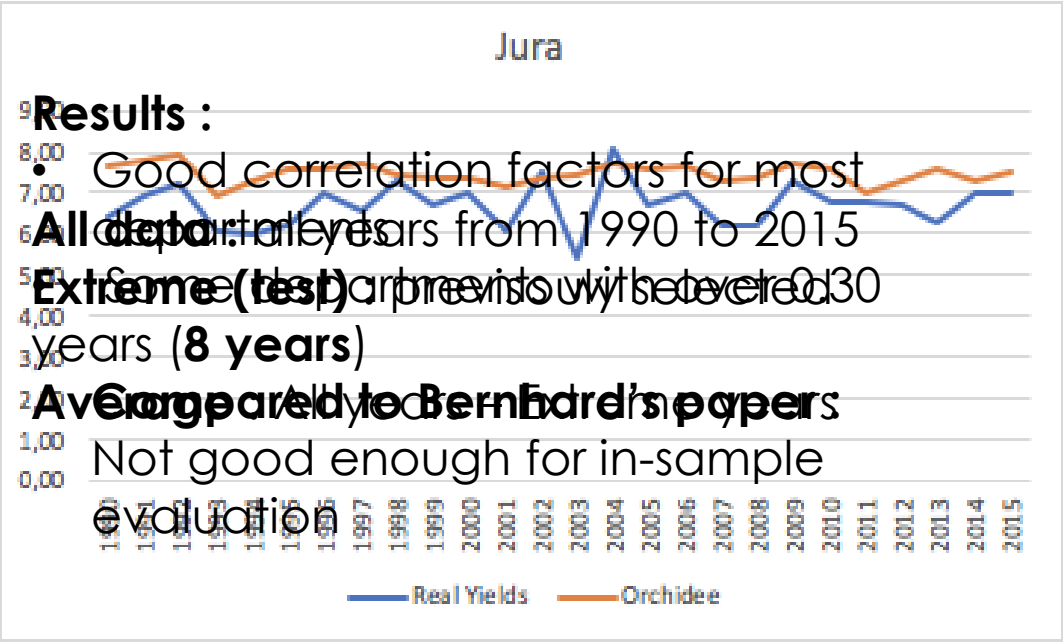
Results

- Calibration : 1990 - 2015 on 20 departments :
  - **VCMAX25 : 105** (70 -> 100)
  - **DLAIMAX : 0.00055** (0.00044 -> 0.00054)
  - **FRAC_GROWTHRESP : 0.26** (0.28 -> 0.29)

Evaluation

- **Person-correlation factor**
- **In-sample :** 20 departments over 26 years (1990 -> 2015)
- **Out-of-sample :**
  - **Temporal :** the same 20 departments over 10 more years (1980 -> 1989)
  - **Spatial :** 5 more departments over 36 years (1980 -> 2015)

In-sample (dataset used for the calibration):
20 departments over 26 years (1990 -> 2015)



Results :

- Good correlation factors for most departments
- Some departments with correlation factors lower than 0.30

All data: all years from 1990 to 2015

Extreme (test): previously selected years (**8 years**)

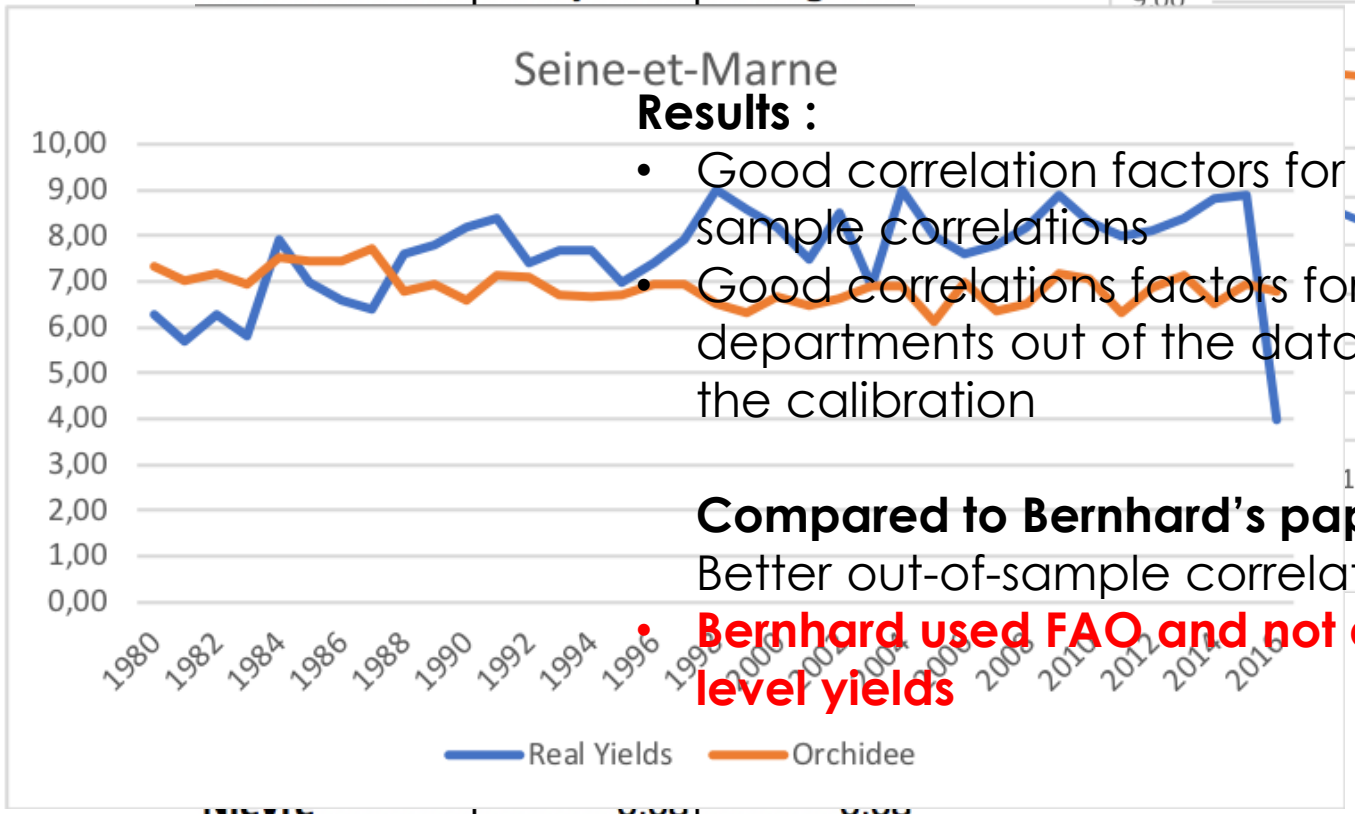
Average: All years – Extreme years

Not good enough for in-sample evaluation

Green > 0.45
0.45 > Blue > 0.30
0.30 > Red > 0.15

	All data	Average	Extrem
Aisne	0,01	0,24	0,5
Allier	0,14	0,04	0,32
Ardennes	0	0,29	0,43
Aube	0,06	0,13	0,05
Cher	0,19	0,23	0,19
Coted'Or	0,17	0,09	0,31
Doubs	0,17	0,14	0,26
Eure	0,05	0,11	0,45
HauteMarne	0,02	0,03	0,12
Indre	0,06	0,17	0,3
Jura	0,37	0,45	0,1
Loiret	0,04	0,17	0,08
Marne	0	0,21	0,41
Mayenne	0,26	0,25	0,31
Nievre	0,08	0,03	0,2
Oise	0,03	0,11	0,46
Orne	0,24	0,02	0,68
Somme	0,05	0,26	0,67
Vienne	0,13	0,27	0,14
Yonne	0,04	0,03	0,02

Out-of-sample temporal :
same 20 departments over 10 more years (1980 -> 1990)



	All years	Average
Oise	0,03	0,21
Orne	0,24	0
Somme	0,05	0,21
Vienne	0,13	0,17
Yonne	0,04	0,11

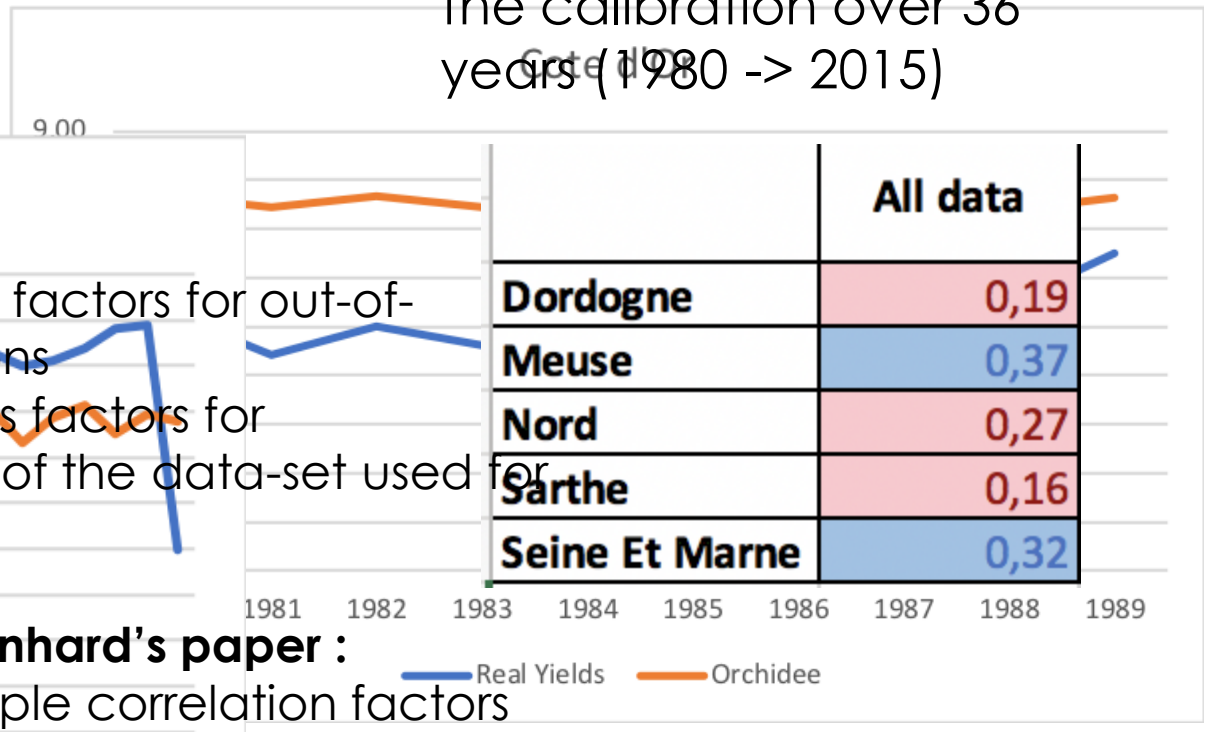
Results :

- Good correlation factors for out-of-sample correlations
- Good correlations factors for departments out of the data-set used for the calibration

Compared to Bernhard's paper :
Better out-of-sample correlation factors

- **Bernhard used FAO and not department-level yields**

Out-of-sample spatial :
5 departments not used in the calibration over 36 years (1980 -> 2015)



	All data
Dordogne	0,19
Meuse	0,37
Nord	0,27
Sarthe	0,16
Seine Et Marne	0,32

Green > 0.45
0.45 > Blue > 0.30
0.30 > Red > 0.15

Conclusions

- **Morris sensitivity analysis :**
  - Selection of performative parameters
  - Expert biases …
- **Calibration :**
  - With the parameters used, no need for more than 5 departments in the Breadbasket
  - Average/extreme years calibration requires hydrology parameters to be incorporated and extreme years to be defined
- **Results :**
  - Good correlation factors for a process-based model, especially for out-of-sample data
  - Good performances over extreme years (with the actual definition)

References

- FAO 2018 –The state of food security and nutrition in the world
- Schauberger et al. 2018 – Yield trends, variability and stagnation analysis of major crops in France over more than a century
- Ben-Ari et al. 2018 - Causes and implications of the unforeseen 2016 extreme yield loss in the breadbasket of France
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- Viridiana Silva Pérez, PhD Thesis 2016 – Screening genetic variation for photoynthetic capacity and efficiency in wheat
- Schauberger et al. 2017 – Global and national performance of a semi-empirical modeling scheme for yield anomalies of maize and wheat
- www.worldstopexports.com/wheat-exports-country/
- …

Thanks ☺