



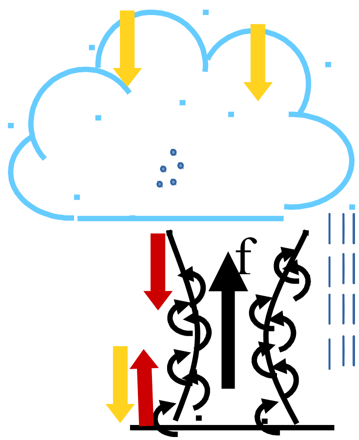
Un outil statistique pour le réglage des paramètres libres inhérents aux paaramétrisations via la comparaison 1D/LES

F Couvreux, F Hourdin, R Roehrig, D Williamson, V Volodina, N Villefranque, R Honnert, C Rio, I Musat, M.P. Lefebvre, O Audouin, B Diallo, F Brient, E Bazile, J.B. Madeleine, F. Favot

The HIGH-TUNE project

<u>Objective :</u> improve the parameterizations involved in the representation of low-level clouds

<u>LL clouds :</u> subgrid clouds + associated to important biases in NWP and climate models



1/<u>Boundary-layer dynamics :</u>
Eddy diffusivity - Mass-Flux scheme

2/ Cloud macrophysics and microphysics
- Pdf (θ,qt)=> cf
- Conversion to rain

3/ <u>Cloud-radiation interactions:</u>

- Plan-parallel Approximation
- Subgrid cloud heterogeneities
- Cloud overlap assumption

The HIGH-TUNE project

Objective : improve the parameterizations involved in the representation of low-level clouds

Deadlock : **many free parameters in any parameterization**

Proposition : Can we use state-of-the-art statistical tools to tune the free-parameters based on a comparison SCM/LES on an ensemble cases ?

Chosen method: the History Matching or Iterative Refocussing (**Williamson et al 2013, 2017**) : an automatic tuning method based on Gaussian Processes that aims at ruling out impossible values of parameters instead of seeking the optimal value ; already used for NEMO & CanAM4

1D cases : Iterative Refocussing applied on SCM/LES

- BOMEX
- RICO

} Oceanic cumulus

- ARM
- SCMS

} Continental cumulus

- FIRE
- DYCOMS

} Stratocumulus

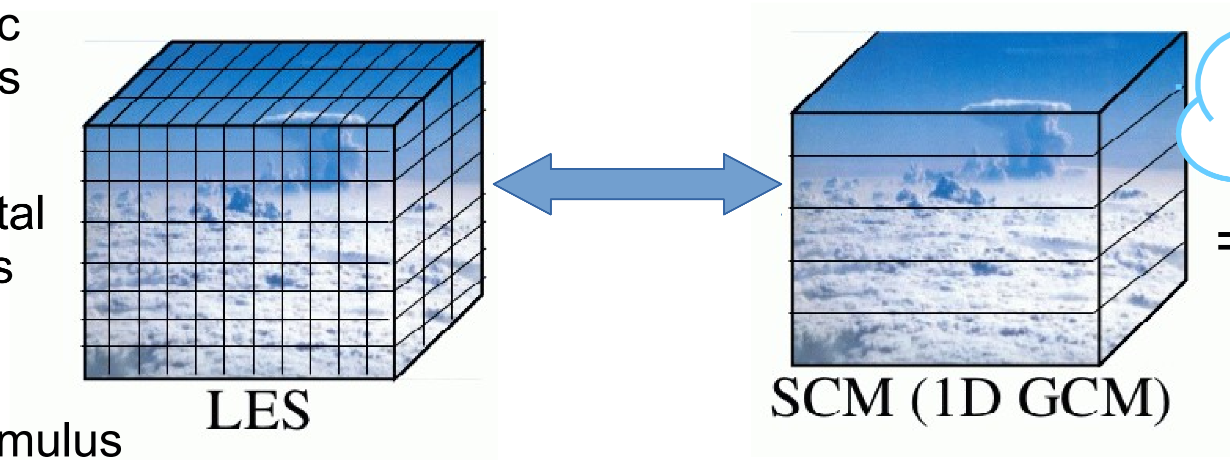
- ASTEX
- CONTRAIL

} Transition Cu→ Stocu

- IHOP
- WANGARA
- AYOTTE (x6)

} Clear convective boundary layer

- GABLS4 Stable boundary layer
- AMMA Deep convection



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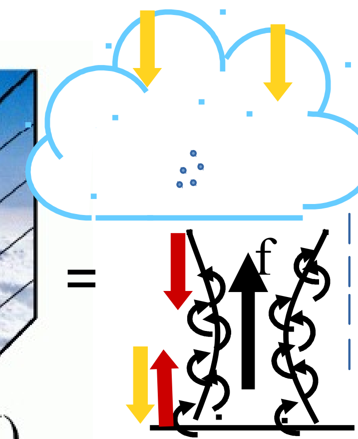

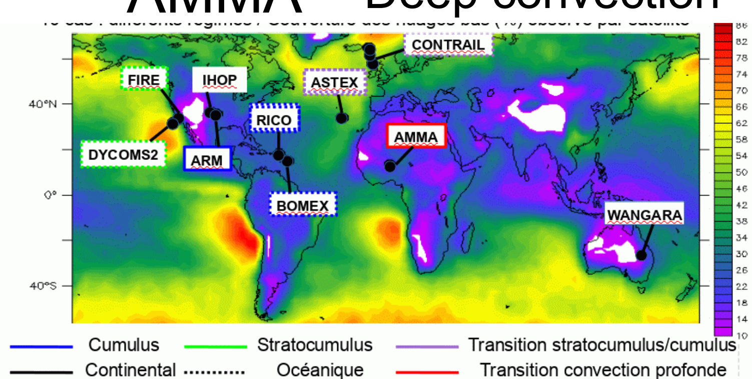

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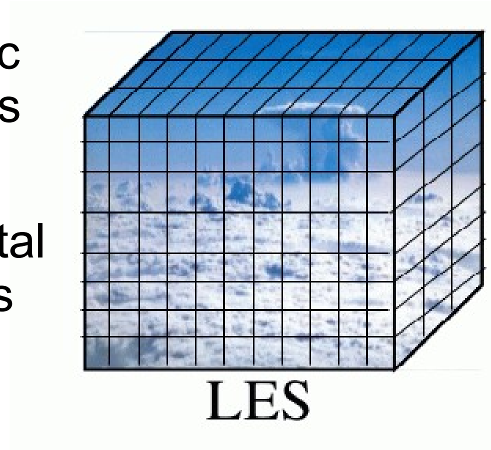
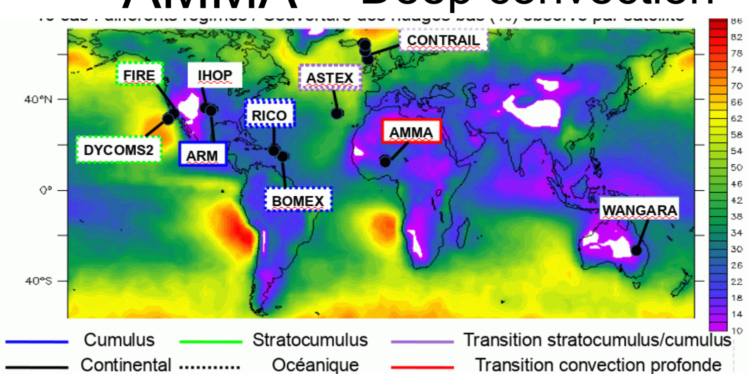
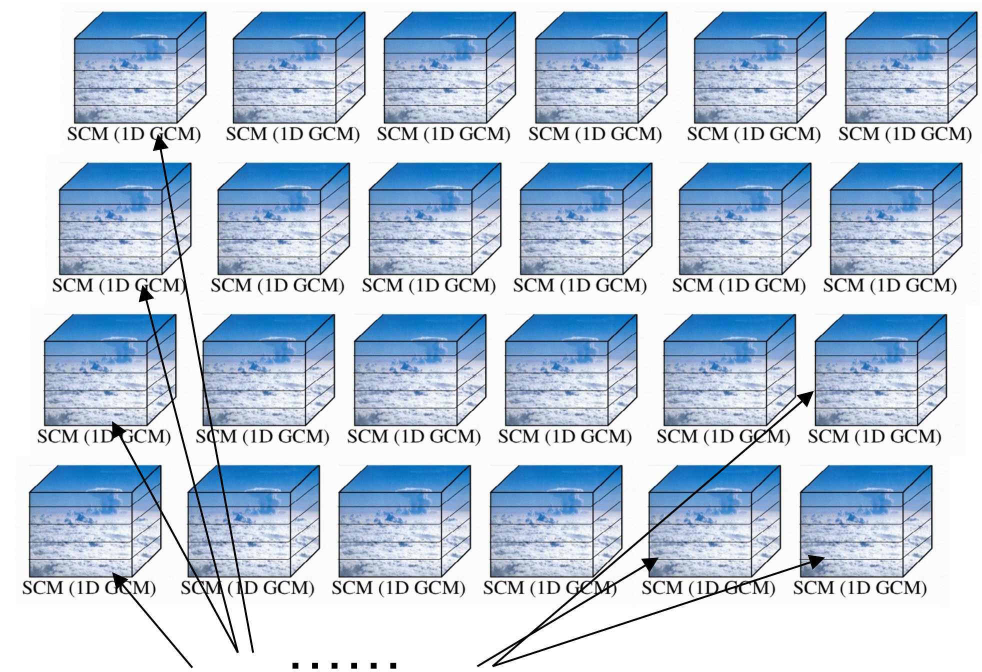




Identify free parameters + range



Ensemble design : Latin Hypercube sampling in order to optimally sample the space of parameters for which SCM will be runs

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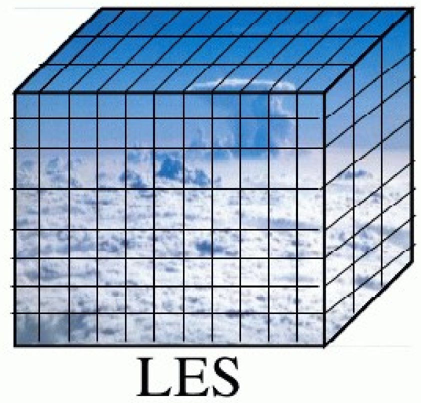
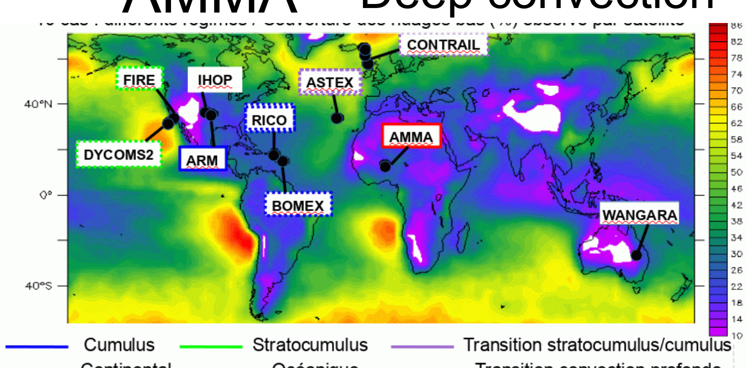
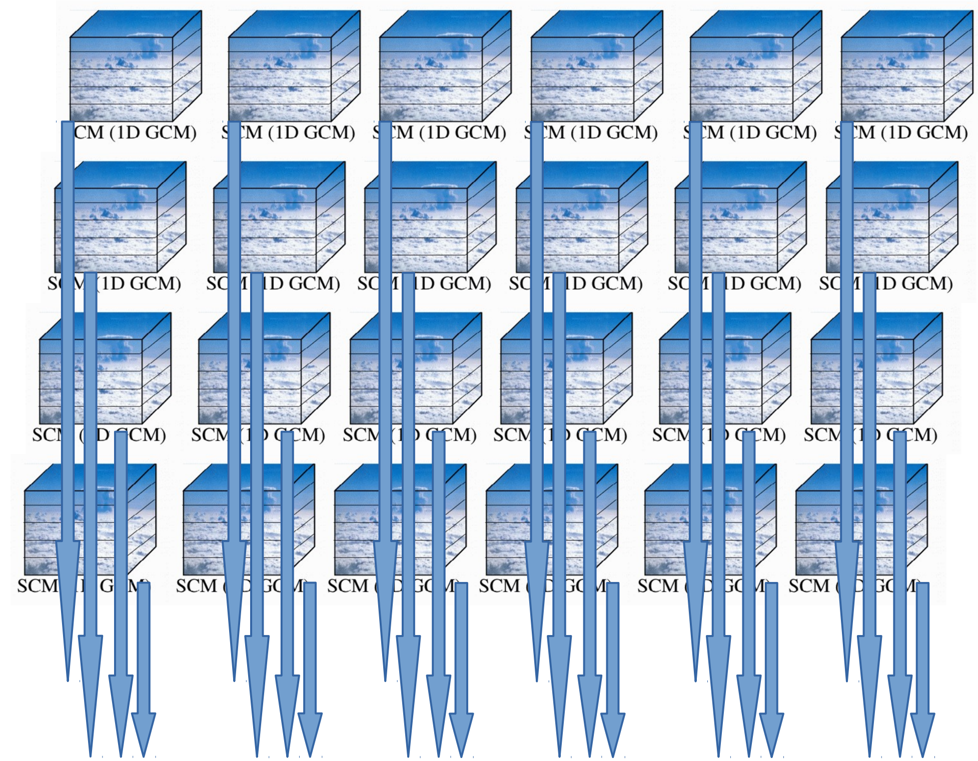




Different free parameters



Choice of Metrics : BL thermodynamics, cloud fraction, cloud height,...

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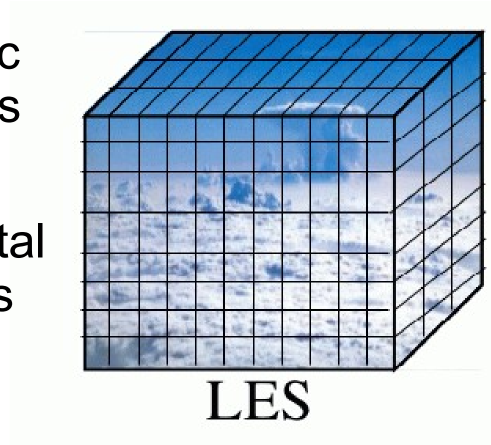

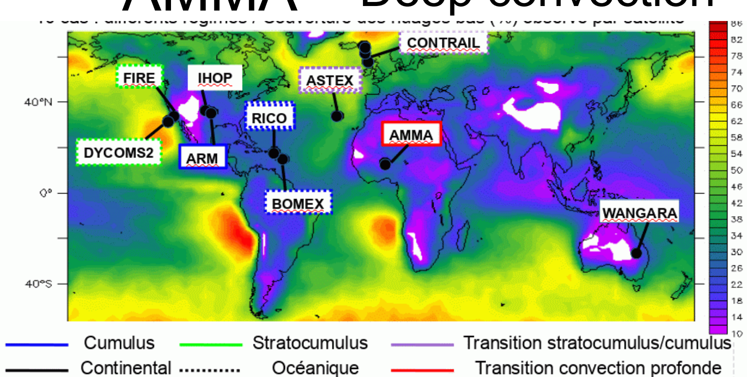

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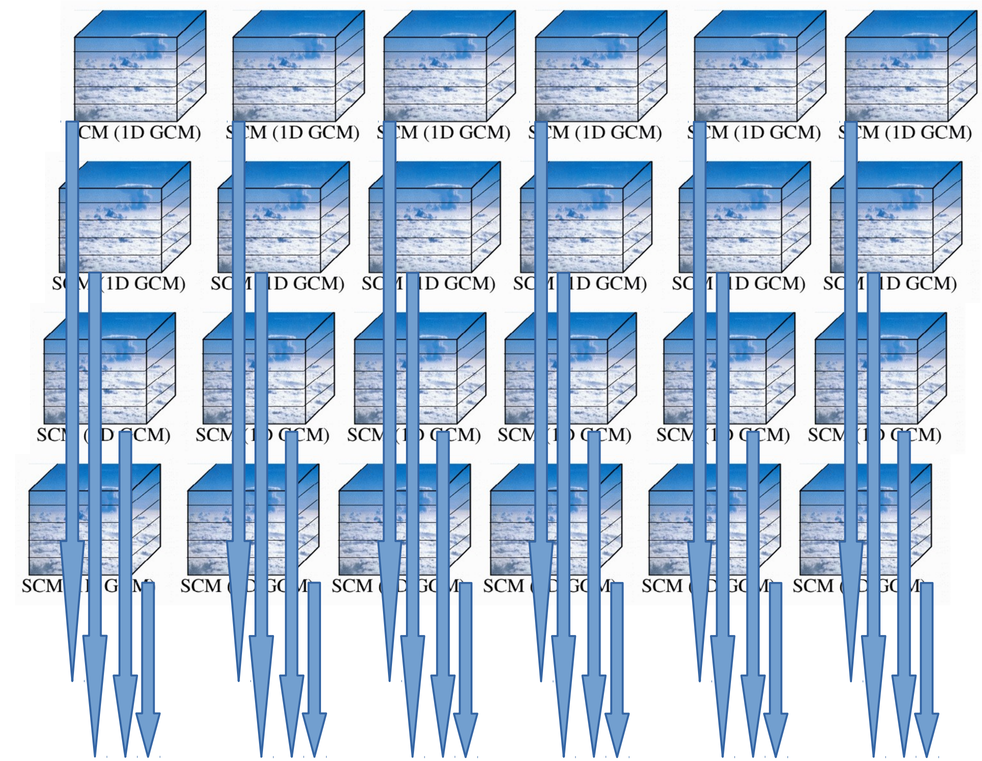

Metrics

[Emulator](#)

Metrics for any values of parameters

Emulator : statistical model based on Gaussian Processes that predicts the metric for any values of parameters

A cheap tool to explore the domain of all values

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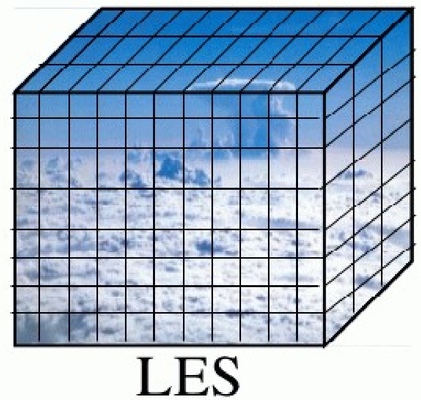
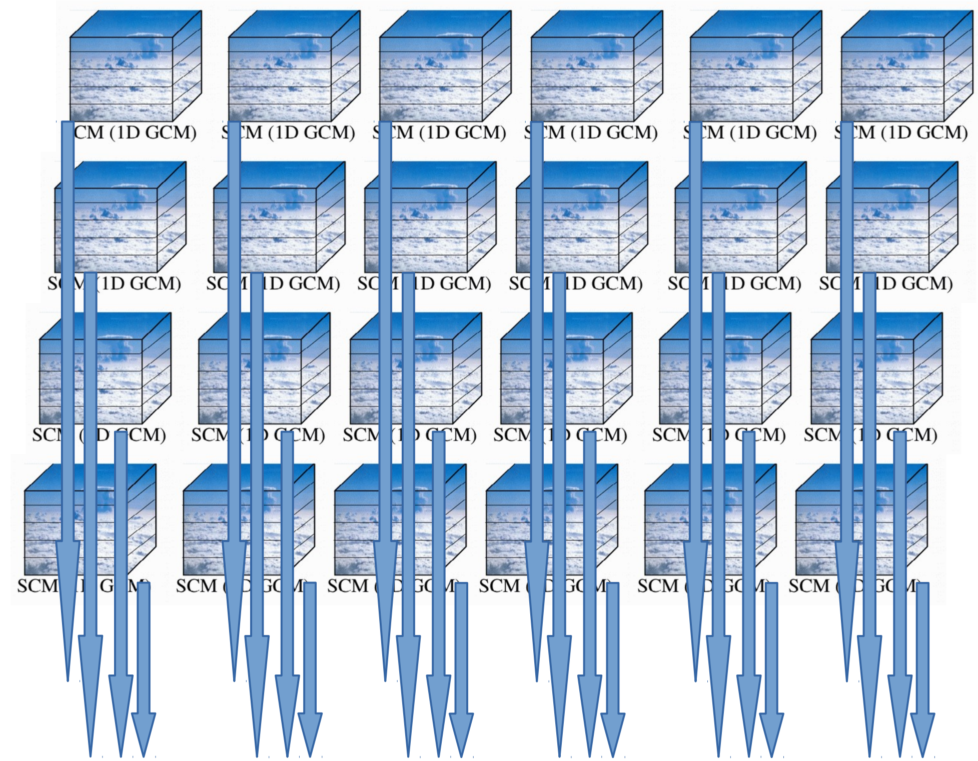


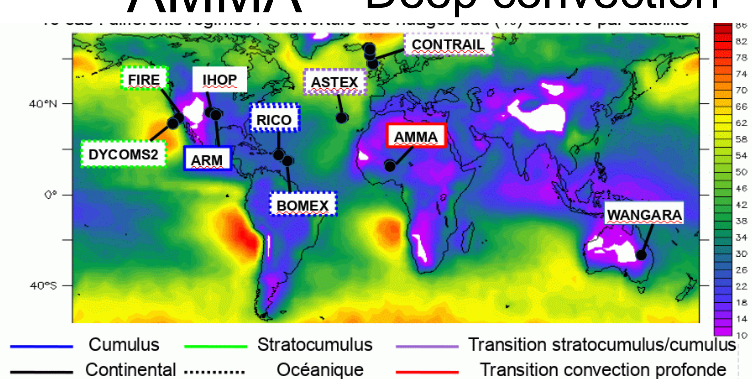
Different free parameters



Metrics

Metrics

Metrics for any values of parameters



- Compute Implausibility :

$$I=\frac{\left(M_{LES}-M_{Emulator=f(p1,\ldots,pn)}\right)^2}{\varepsilon_{LES}^2+\varepsilon_{Structural}^2+\varepsilon_{Emulator}^2}$$

- Use a threshold to rull out impossible space

In the following threshold=3

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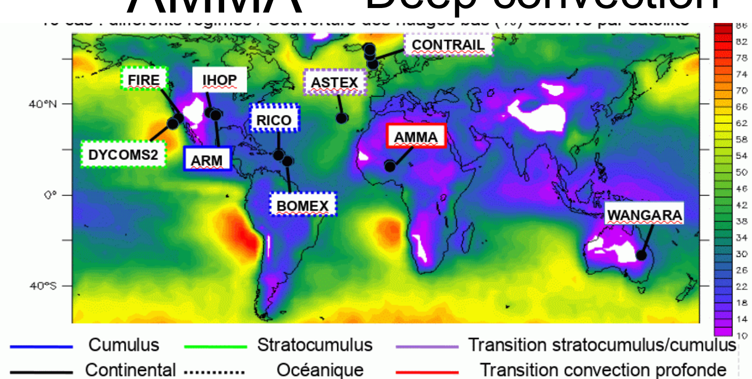
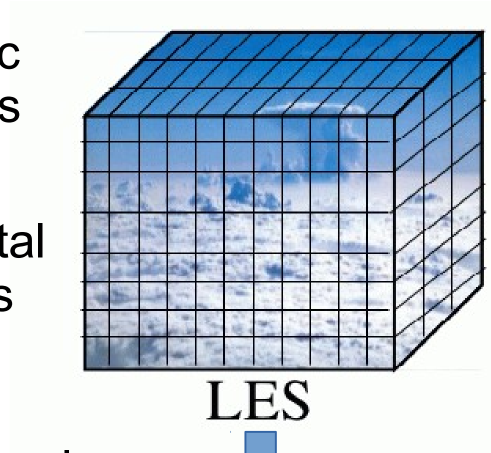
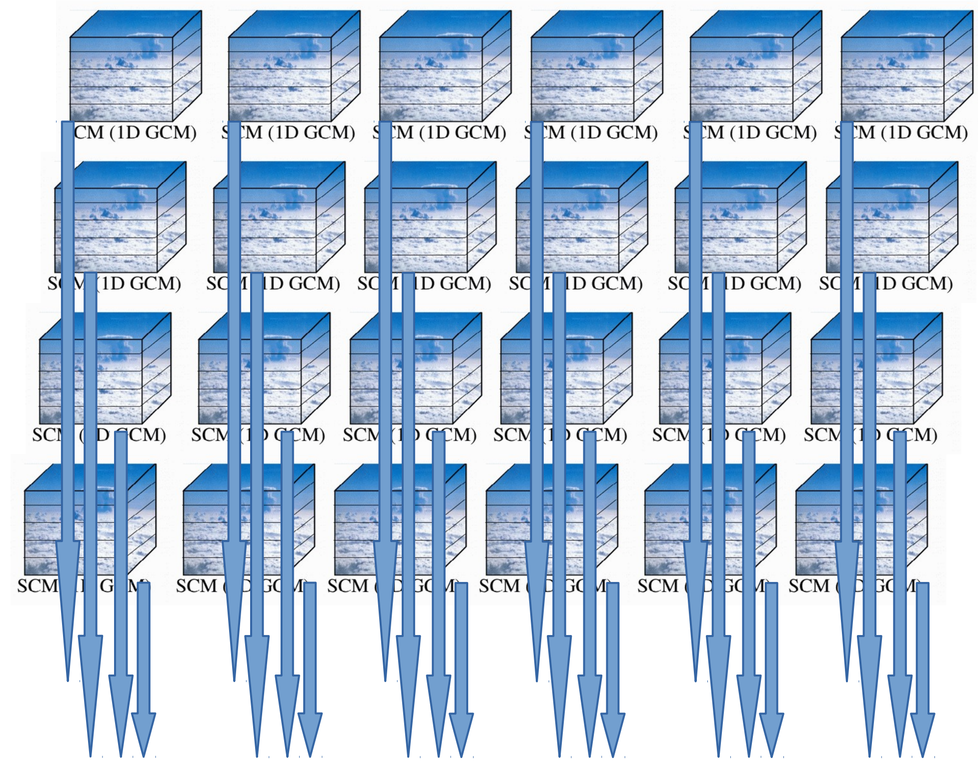




Metrics

Different free parameters



Metrics

Metrics for any values of parameters

- Compute Implausibility :

$$I=\frac{\left(M_{LES}-M_{Emulator=f(p1,\ldots,pn)}\right)^2}{\varepsilon_{LES}^2+\varepsilon_{Structural}^2+\varepsilon_{Emulator}^2}$$

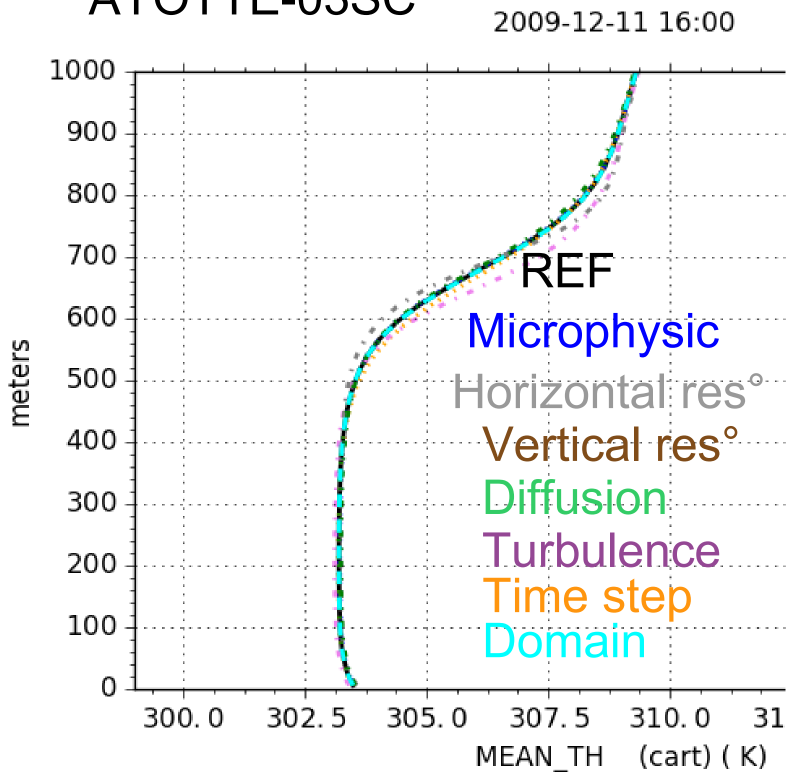
- Use a threshold to rull out impossible space

Uncertainties

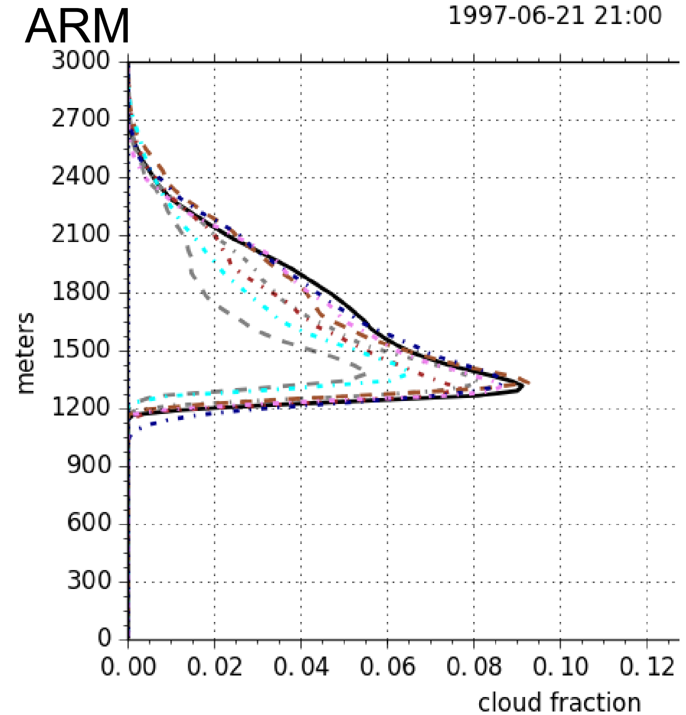
<u>LES uncertainties:</u> run the same model with sensitivities to resolution/numerics/option in parameterization

More on tomorrow's talk

AYOTTE-03SC



ARM



<u>Model discrepancy:</u> difficult to specify ; right now metric dependent and estimated manually ex : 0.1K for potential temperature, 0.1*zhneb, 0.5 g/kg for qv

<u>Emulator uncertainty:</u> estimated by the statistical tool

Applications :

- Applied to different parameterizations :
=> F Hourdin (thermal plume model), R Honnert (EDKF), R Roehrig (PCMT), O Audouin (turbulence), N Villefranque (ecRad)

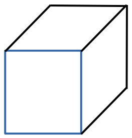
- Analysis of the behaviour of the statistical tool : O Audouin

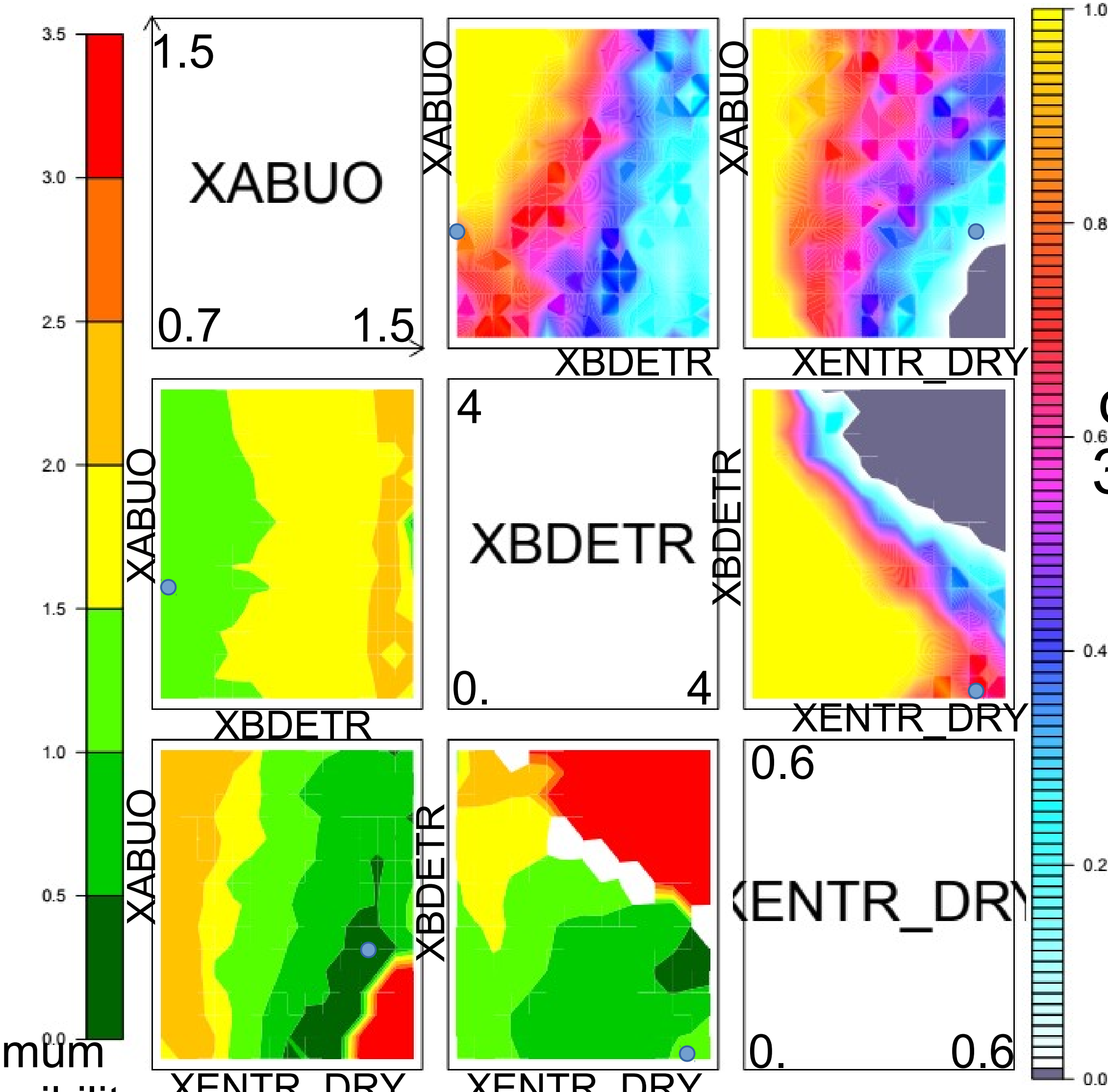
- Use the tool directly with LES to test parameterization formulation : B Diallo

- Apply the same tool for 3D tuning : I Musat & F Hourdin

Visualization of Input Space:

$$I=\frac{\left(M_{LES}-M_{Emulator=f(p1,\dots,pn)}\right)^2}{\varepsilon_{LES}^2+\varepsilon_{Structural}^2+\varepsilon_{Emulator}^2}<3$$





Minimum Implausibility in the 3D domain

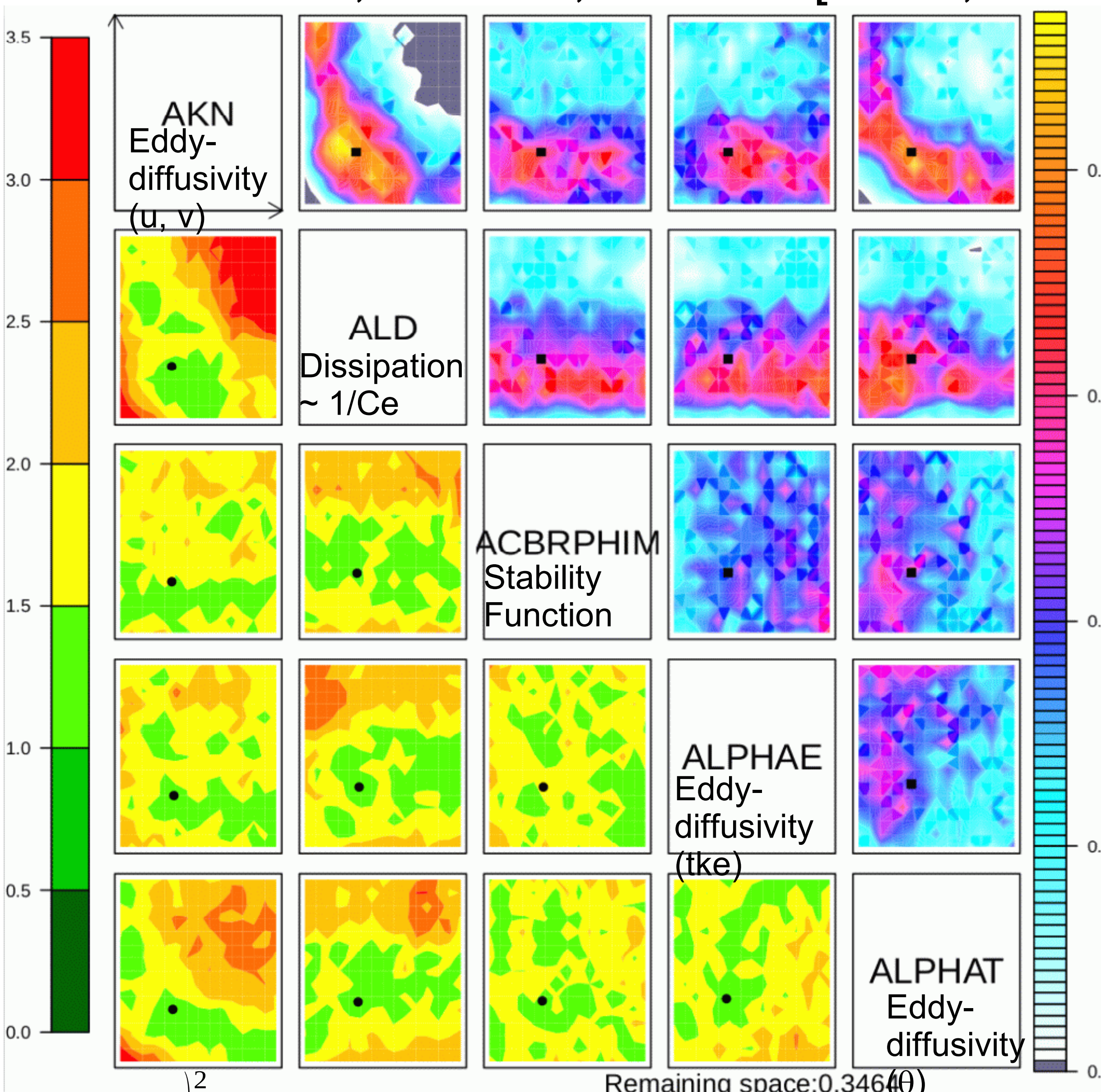
% of the domain of the 3rd parameter kept

A first example : ARPEGE-Climat

Parameters: 5 parameters from the turbulence scheme of Cuxart et al (2000)

Metrics : θBL for ARMCU, BOMEX, AYOTTE[03SC,05SC,05WC,24SC]

Min (I) in the other directions =>looking for green=small distance



% of domain in the other directions that are kept

Corrélation AKN/ALD retrouvée sur les cas stables (cf O Audouin)

$$I=\frac{\left(M_{LES}-M_{Emulator=f(p1,\ldots,pn)}\right)^2}{\varepsilon_{LES}^2+\varepsilon_{Structural}^2+\varepsilon_{Emulator}^2}$$

4 models with the same turbulence scheme

Turbulence scheme : Cuxart et al (2000)- prognostic equation of the tke with a Bougeault-Lacarrere Mixing length

4 models :

- AROME : mesoscale operational model with EDKF scheme (Pergaud et al, 2009) for clear and shallow convection
- ARPEGE : global ~10km operational model with Bechtold scheme for shallow convection (inhibited if no moisture)
- ARPEGE-Climat : global ~ 100km operational model with PCMT scheme (Gueremy, 2011 ; Piriou et al 2007) for clear/shallow/deep convection
- MESO-NH : research model with EDKF scheme (Pergaud et al, 2009) for clear and shallow convection

Cases with no radiation:

- AYOTTE cases
- ARM-Cu

Different steps:

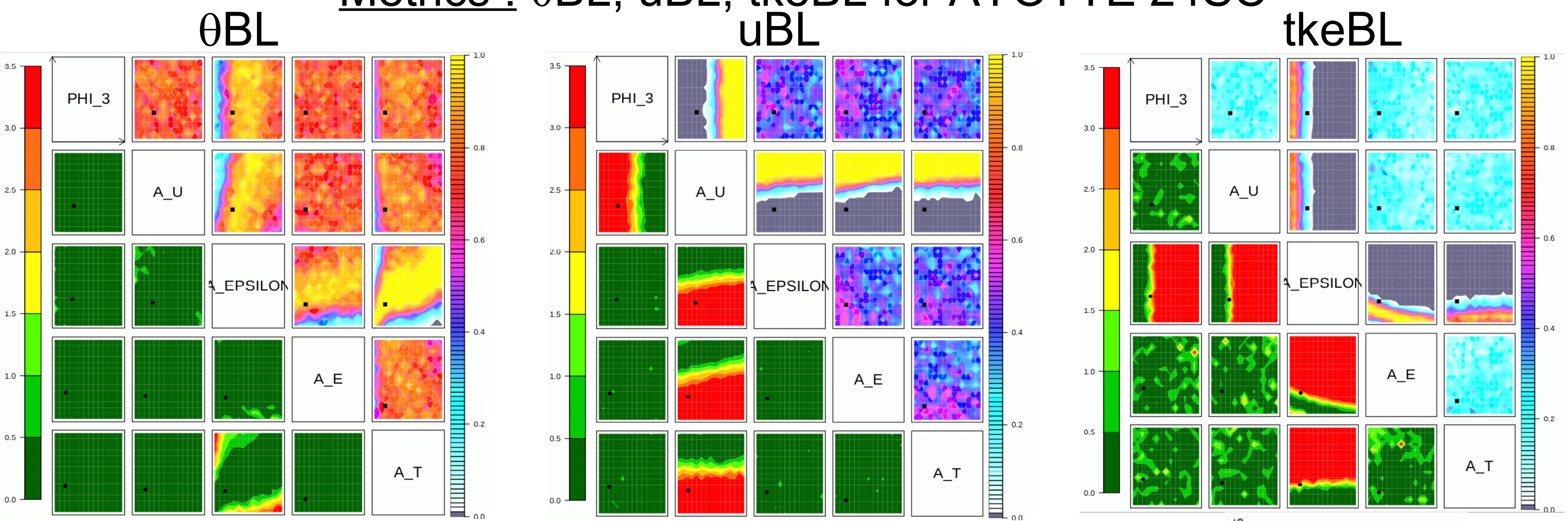
- Operational configuration
- With mass-flux scheme deactivated

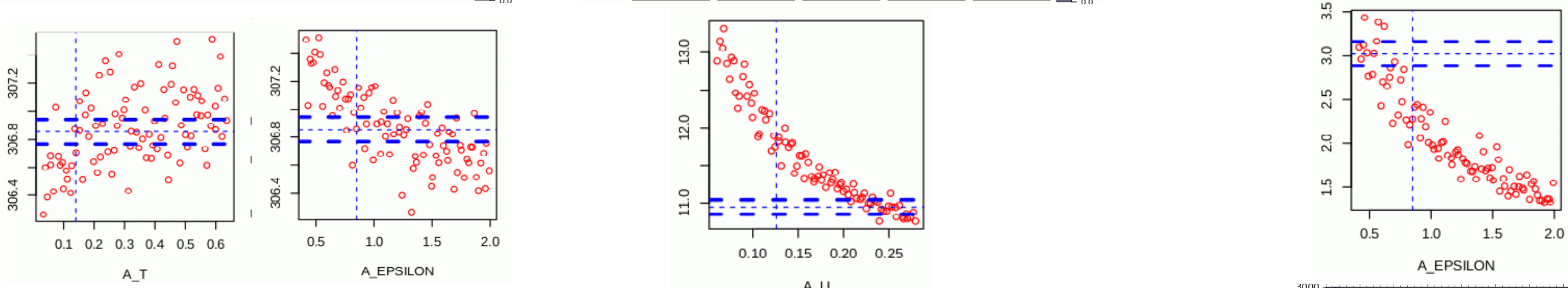
Stage EMI de S Nicolau, S Barbier, S Richet, T Costabloz

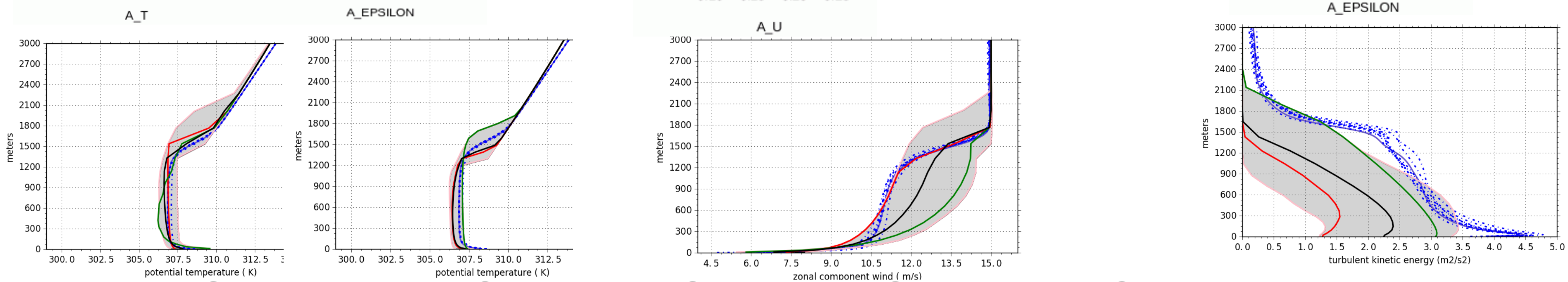
A first example : ARPEGE-Climat

Parameters: 5 parameters from the turbulence scheme of Cuxart et al (2000)

Metrics : θBL, uBL, tkeBL for AYOTTE 24SC





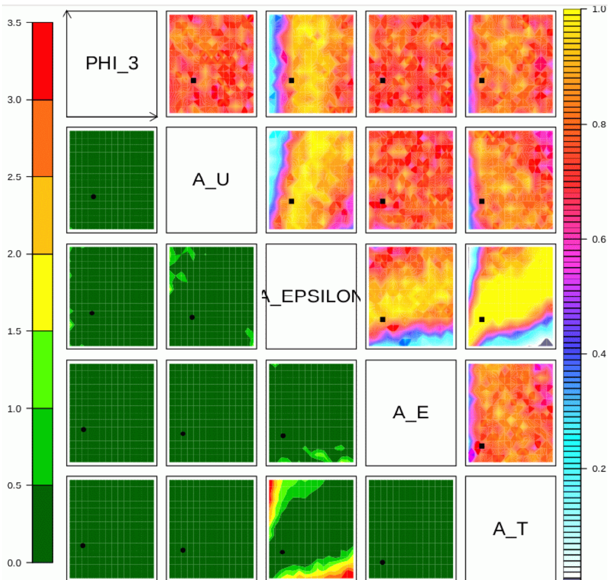


Stage EMI de S Nicolau, S Barbier, S Richet, T Costabloz

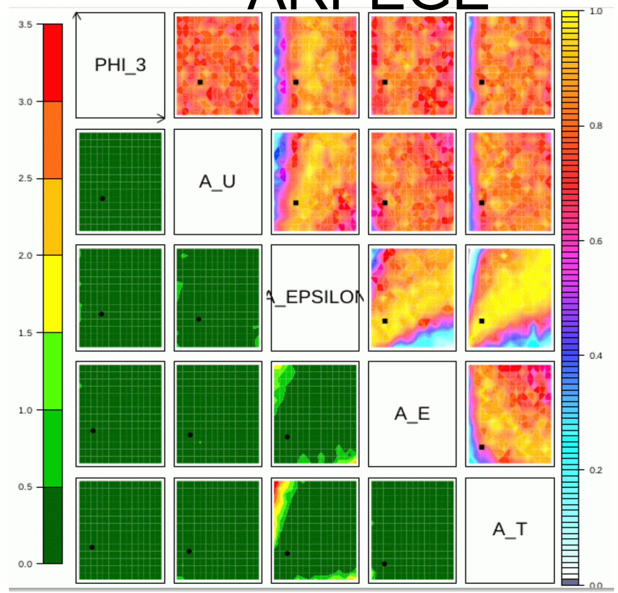
4 models with the same turbulence scheme

5 parameters turbulence scheme of Cuxart et al (2000)- θBL metric

ARPEGE-Climat



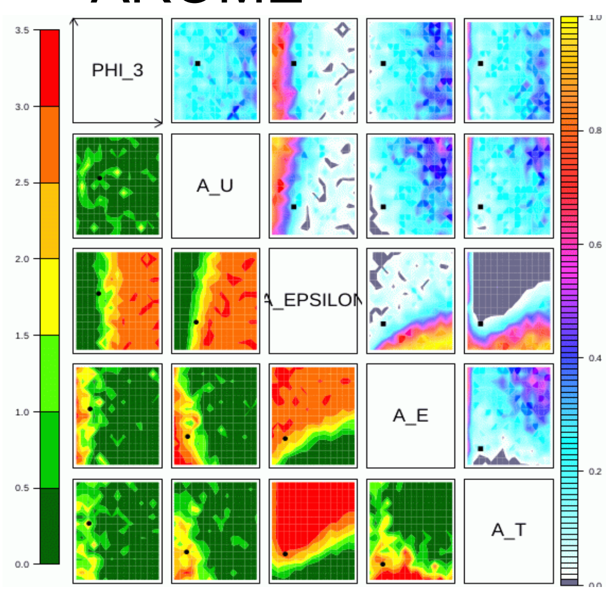
ARPEGE



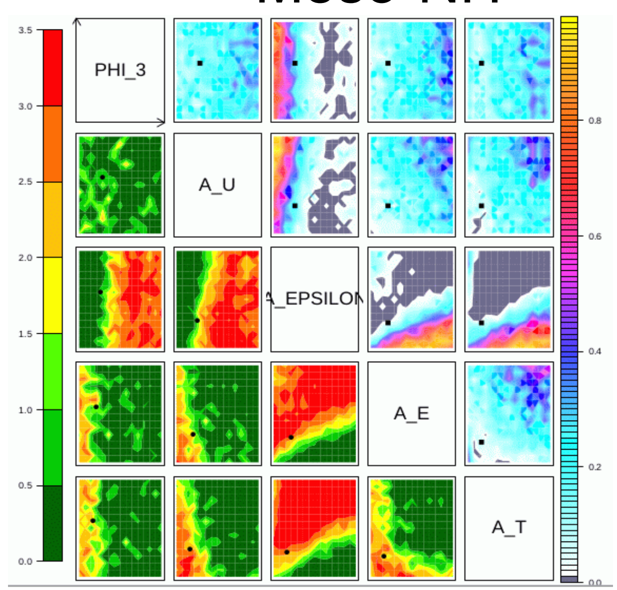
AYOTTE-24SC

ARPEGE-Climat ~ ARPEGE
Only turbulence active

AROME



Méso-NH



AROME ~ Méso-NH
Turbulence + mass-flux scheme active

Stage EMI de S Nicolau, S Barbier, S Richet, T Costabloz

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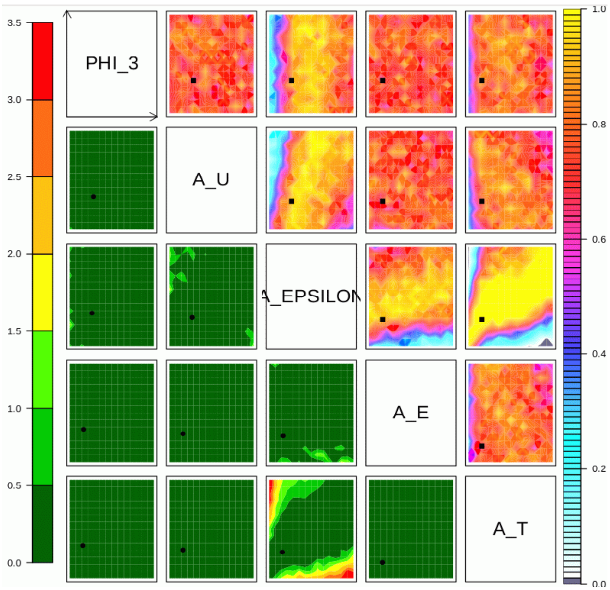
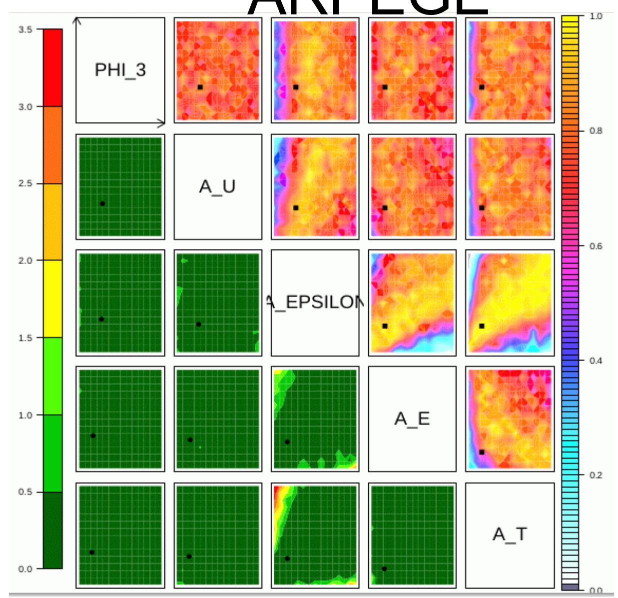
ARPEGE-Climat



ARPEGE



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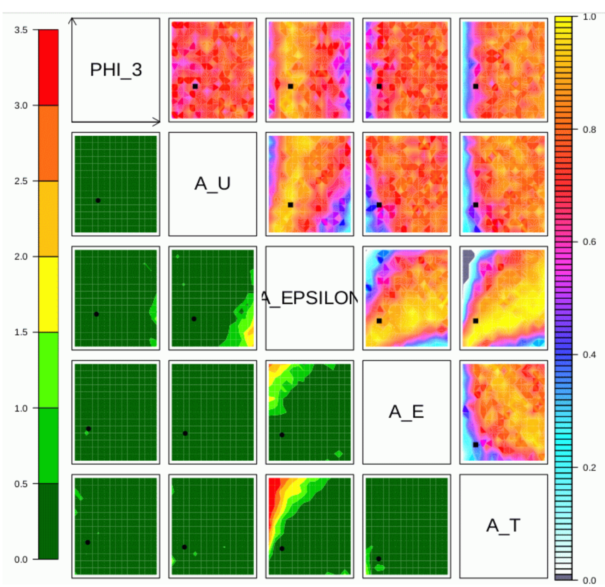
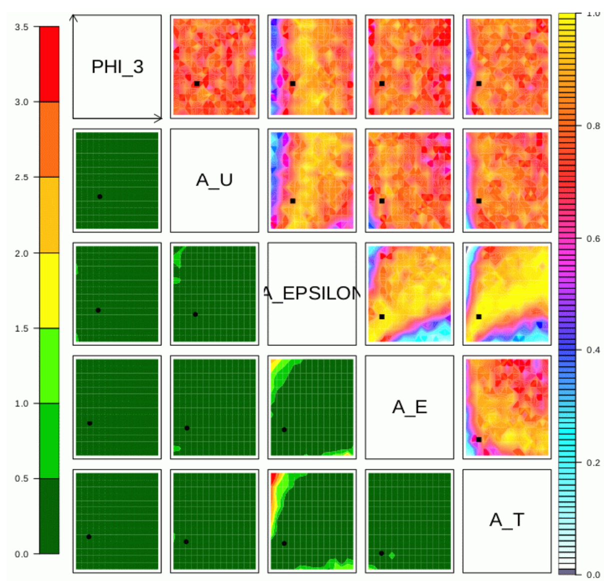




Shallow convection scheme (PCMT/KFB/EDKF) and top-entrainment deactivated

ARPEGE ~ no change
ARPEGE-Climat~ ARPEGE

Stage EMI de S Nicolau, S Barbier, S Richet, T Costabloz

Conclusions :

- A tuning tool to rule out impossible values of free parameters based on a comparison SCM/LES on an ensemble of cases taken into account uncertainties around the reference and inherent limitations of the model => relative independance on the choice of metrics

- A tool conjointly developped by University of Exeter, LMD and CNRM through coding sprints

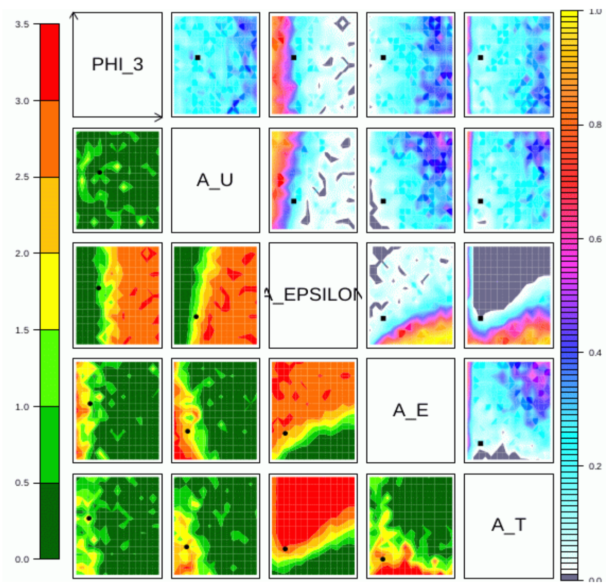
- A better understanding of the behaviour of the parameterizations ; a tool to disentangle structural errors from tuning issues

<u>Future :</u> use more complex metrics (vertical profile/time series), process-oriented metrics, cloud radiative effect... ; Can the SCM/LES tuning be used as a first phase of 3D tuning ?

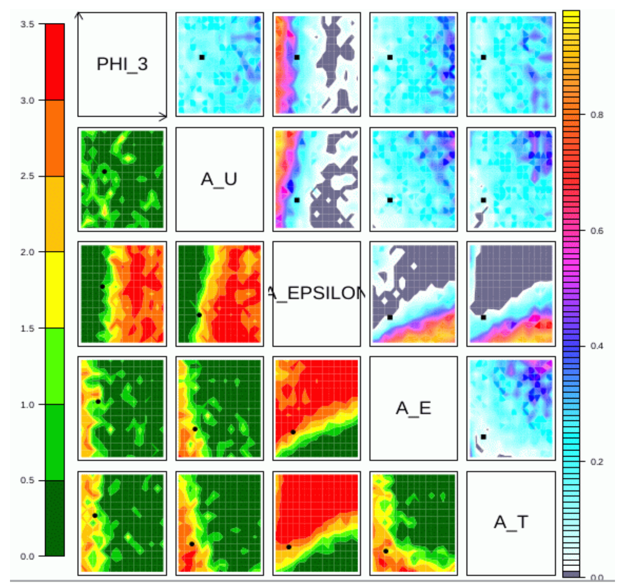
4 models with the same turbulence scheme

5 parameters turbulence scheme of Cuxart et al (2000)- θBL metric

AROME

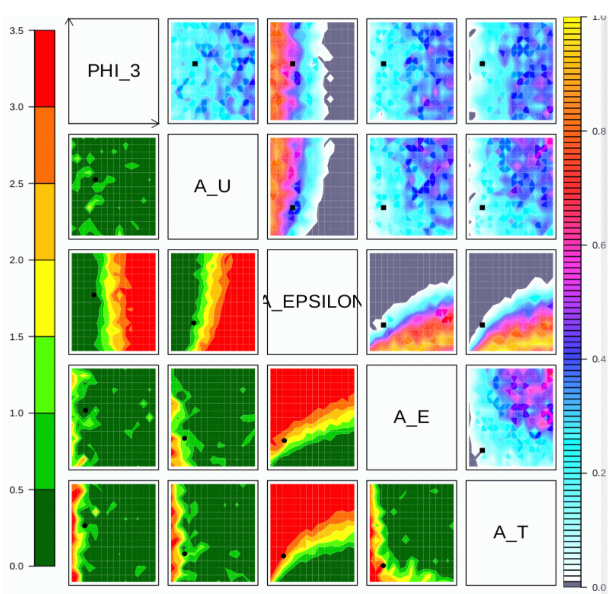


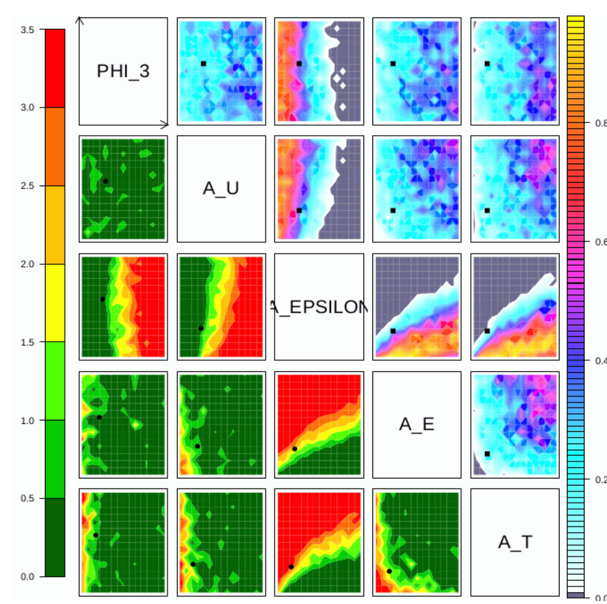
Méso-NH



AYOTTE-24SC

AROME ~ Méso-NH
Turbulence + mass-flux scheme active





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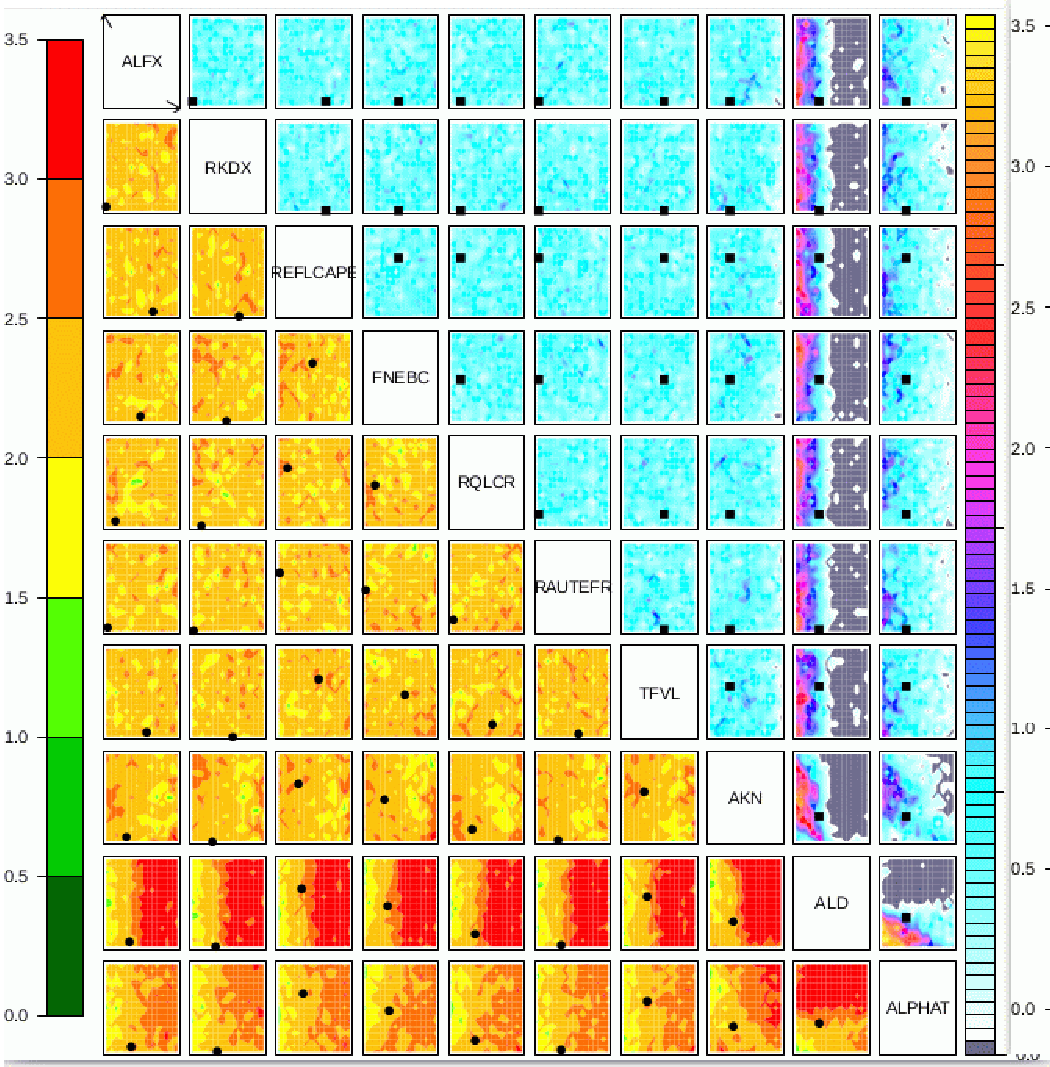
AROME ~ Méso-NH
Turbulence + mass-flux scheme active

Stage EMI de S Nicolau, S Barbier, S Richet, T Costabloz

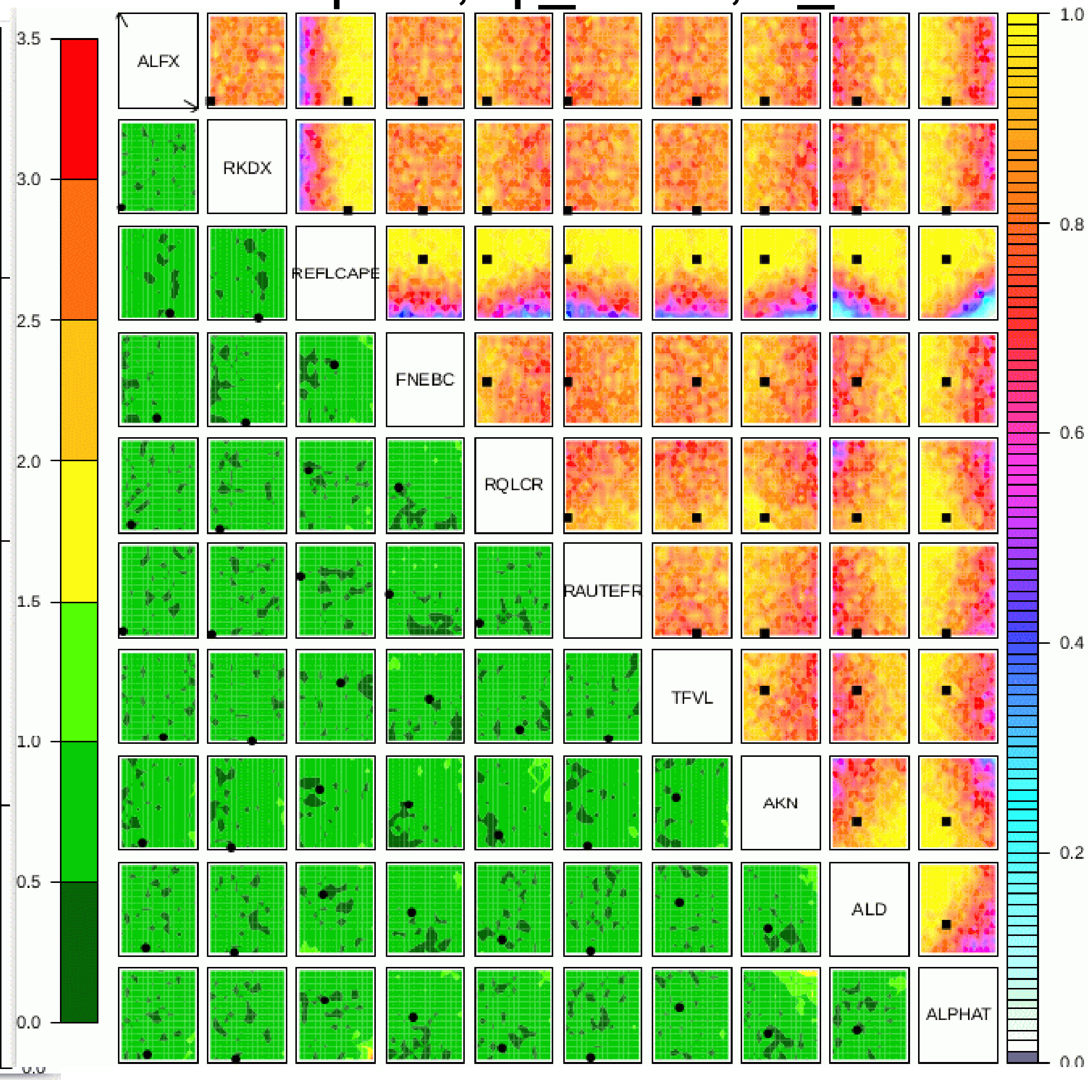
A second example with ARPEGE-Climat

- 10 parameters from convection, microphysics, turbulence
- oceanic + continental cumulus & idealized clear BL

metric=θ BL



metric=qvBL, ql_cloud, h_cloud



Radiative Metrics : 2 complementary methodologies

- use ec-Rad offline on 1D/LES + radiative metrics for the tuning
- use ec-Rad offline on 1D / reference radiative metrics (LES+MC)