Calibration of model using the LES/SCM comparison in the HIGH-TUNE project : Importance of standardization

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Context

- A NWP or climate model :

State vector *dynamic* *parameterizations*

$$\frac{\partial \boldsymbol{x}}{\partial t} = \mathcal{D}(\boldsymbol{x}) + \sum_p \mathcal{P}_p(\boldsymbol{x}, \boldsymbol{\lambda}_p)$$

- Parameterization :

To represent what is not explicitly resolved (subgrid+other physics)
Summarize our process understanding
Mainly 1D
LES used for their development and evaluation

λp= free parameters to calibrate

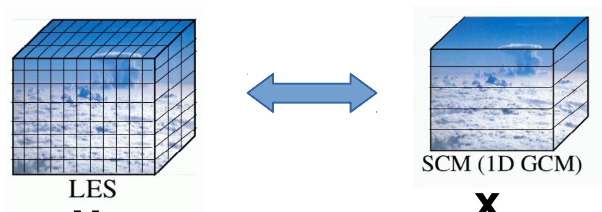
- Calibration :

At the parameterization level
+
Globally : energetic budget of the model / scores

During model devlopment, how to disentangle deficiencies due to parameter values from deficiencies due to model limitation ?
Need Tools

Objectives

- The LES/SCM comparison :



$\mathbf{y}$ $\quad$ $\mathbf{x}_c$

No coupling with large-scale dynamics
SCM=very cheap / representative of global modelling
LES= reference for boundary layers & low clouds
Still a lot to be learnt from this comparison

$$\frac{\partial \boldsymbol{y}}{\partial t} = \mathcal{L}(\boldsymbol{y}) + \mathcal{F}_c(\overline{\boldsymbol{y}}) \quad \Longleftrightarrow \quad \frac{\partial \boldsymbol{x}_c}{\partial t} = \sum_{p_{\text{activated}}} \mathcal{P}_p(\boldsymbol{x}_c, \boldsymbol{\lambda}_p) + \mathcal{F}_c(\boldsymbol{x}_c)$$

$$\boldsymbol{x}_c(t=0) = \overline{\boldsymbol{y}}(t=0)$$

- Multi-cases:

Cover diversity of regimes [dry, cumulus, stratocumulus, transitions]
Validate parameterizations in different conditions
Various contributions of the different parameterizations over the different cases
Avoid some error compensation

- Use of Machine learning to further exploit the LES/SCM comparison:

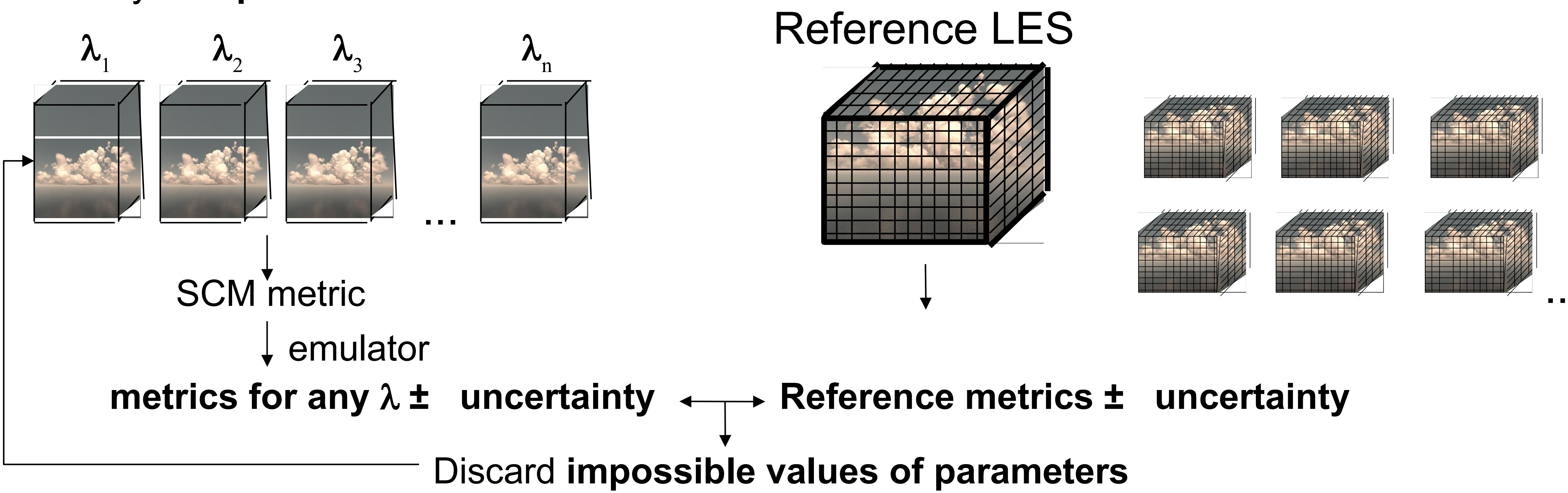
Method imported from the Uncertainty Quantification Community
To tackle parameterization improvement and calibration together

To define the sub-space of the parameter values for which SCM matches LES on selected metrics for a series of cases within a given uncertainty

The HIGH-TUNE tool

Selection of **metrics** [can combine different cases and metrics]

Identify **free parameters**



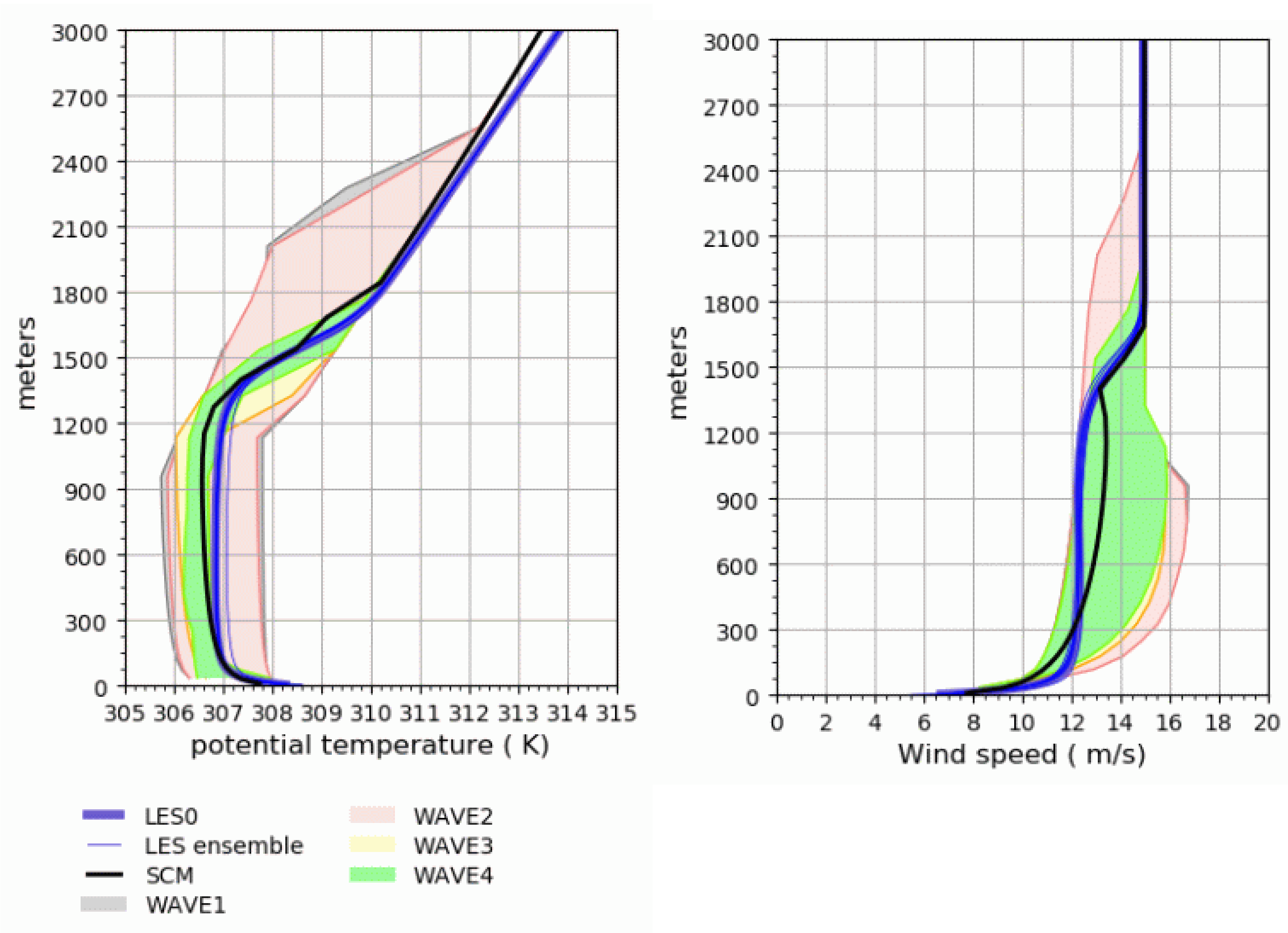
History matching with iterative refocusing (Williamson et al 2013) provides :

- Acceptable range of parameters => to be used for the 3D tuning
- Identify model parameters that limit model performance
- Quantify parametric uncertainty

The HIGH-TUNE tool : examples (1)

AYOTTE-24SC

ARPEGE-Climat (MUSC)



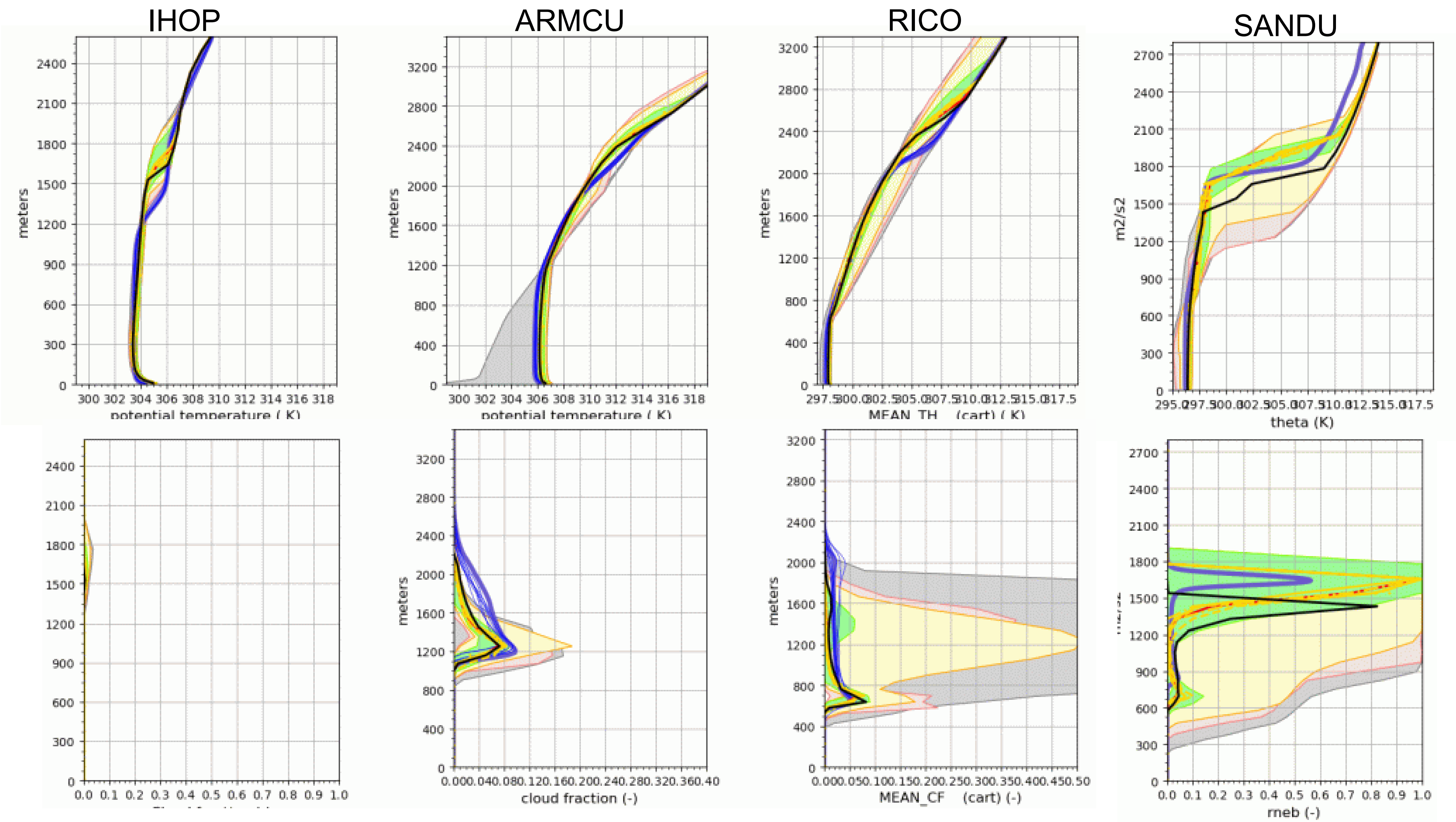
AYOTTE-24SC

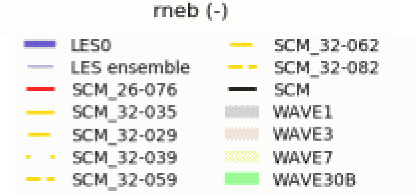
Metrics : $=\int \theta(z)\, dz\theta$

$$W\bar{N}D=\int \sqrt{u(z)^2+v(z)^2}(z)\,dz$$

3 Parameters : turbulence scheme

The HIGH-TUNE tool : examples (2)





LMDZ

IHOP/ARMCU/RICO/SANDU

Metrics : $=\int \theta(z)dz\theta$ $\bar{q}v=\int qv(z)dz$ $\bar{q}v=\int qv(z)dz$ $z_{cld,ave}=\frac{\int cf(z)zdz}{\int cf(z)dz}$ $cld_{max}=max(cf(z))$

9 Parameters : Mass-flux scheme+ Cloud scheme +autoconversion+ reevaporation of rain

Need for a standardization of inputs and outputs

A standard input format :

1/ Reliability : to be sure to use the exact same forcings for LES and SCM

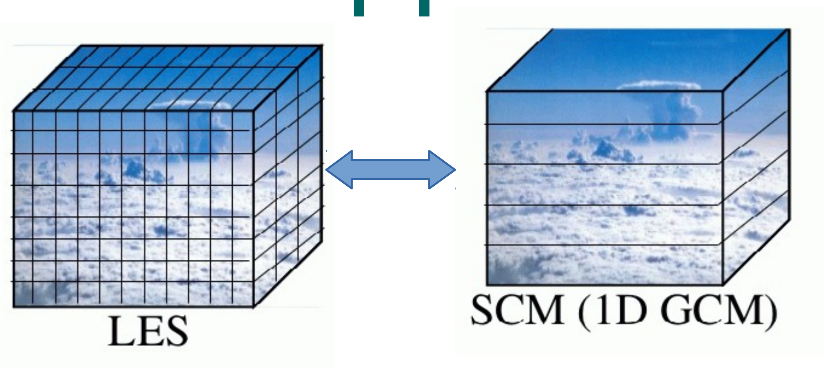
2/ Ease the use of multicases :
- to revisit the cases developed by the community (for ex : GCSS)
- to easily add new cases (ex ARMcomposite-CASS ; LASSO ; EUREC4A)

A standard output format :

1/ Ease the computation of metrics :
for most metrics, same computation of metrics for SCM and LES

2/ towards the construction of a library of LES data available for the community

Supplementary : SCM/LES cases



Case name	grid resolution dx=dy, dz (m, m)	Domain Lx=Ly, H (km, km)	Specificity	Radiation	Reference	Observations
Academic cases of dry convective boundary layer						
AYOTTE-1	50, 40	10, 2	Varying inversion (strong/weak capping) and varying cst-in-time surface fluxes	No	Ayotte et al. 1996	No
AYOTTE-2	50, 40	10, 2		No		No
… 6	50, 40	10, 2		No		No
Cases of clear sky continental convective boundary layer						
IHOP	50, 40	10, 5	USA great plains	No	Couvreux et al., 2005	Yes
AMMA	50, 40	10, 5	Semi-arid, West-Africa	No	Canut et al., 2011	Yes
WANGARA	50, 40	10, 5	Semi-arid, Australia	No		Yes
Boundary layer cumulus						
ARM	50, 40	13, 4	Continental shallow, SGP	No	Brown et al., 2002	Yes
BOMEX	50, 40	13, 4	Oceanic shallow, Caraibes	No	Siebesma et al., 2003	Yes
RICO	50, 40	13, 4	Precipitating oceanic, Caraibes	No	Van Zanten et al., 2011	Yes
SCMS	50, 40	13, 4	Continental shallow, Florida	No	Neggers et al, 2002	Yes
CASS	50, 40	13,4	Composite cont. shallow, SGP	No	Zhang et al., 2017	Yes
Marine strato-cumulus clouds						
FIRE	25, 5-15	5, 1.2	Day and Nighttime stratocumulus	Yes	Duynkerke et al. 2004	Yes
DYCOMS2	25, 5-15	5, 1.5	Stratocumulus	Yes	Stevens et al., 2005	Yes
SANDU	35,5-15	9, 3.2	Transition to cumulus, Pacific	Yes	Sandu and Stevens, 2011	Yes
ASTEX	25, 5-15	5, 2	Transition to cumulus, Atlantic	Yes	Van Der Dussen et al., 2013	Yes
GreyZone	250,25-90	100, 5	Transition to cumulus,North Sea	Yes	De Roode et al, in prep	Yes
Stable boundary layer						
GABLS1	?	1000, 500	Academic case	No	Beare et al, 2006	No
GABLS4	1,1	500,200	Antarctica	No	Bazile etal, 2019; Couv et al 2019	Yes
Transition to deep convection						
AMMA	100, 50	100, 20	Niamey, initiation of local storm	No	Couvreux et al., 2012	Yes

- Ensemble of cases covering the diversity of boundary-layer regimes

- Reference simulation +sensitivities to configuration and parameterization => provide uncertainty around this reference