HIGH-TUNE, High-resolution simulations to improve and Tune boundary-layer cloud parameterizations

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(CNRM, LMD, University of Exeter)

Using state-of-the art statistical tools applied to the comparison SCM/LES to tune the boundary-layer cloud parameterizations

ANR

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The HIGH-TUNE project

Context : important biases in NWP and climate models for the reproduction of low-level clouds

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

Deadlock : many free parameters in any parameterization

Proposition : use state-of-the-art statistical tools to propose values for those parameters based on a comparison SCM/LES on an ensemble cases

Advantages : a new way to tune parameterization one by one with 1D simulations

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

1D cases :

- BOMEX
- RICO

} Oceanic cumulus

- ARM
- SCMS

} Continental cumulus

- FIRE
- DYCOMS

} Stratocumulus

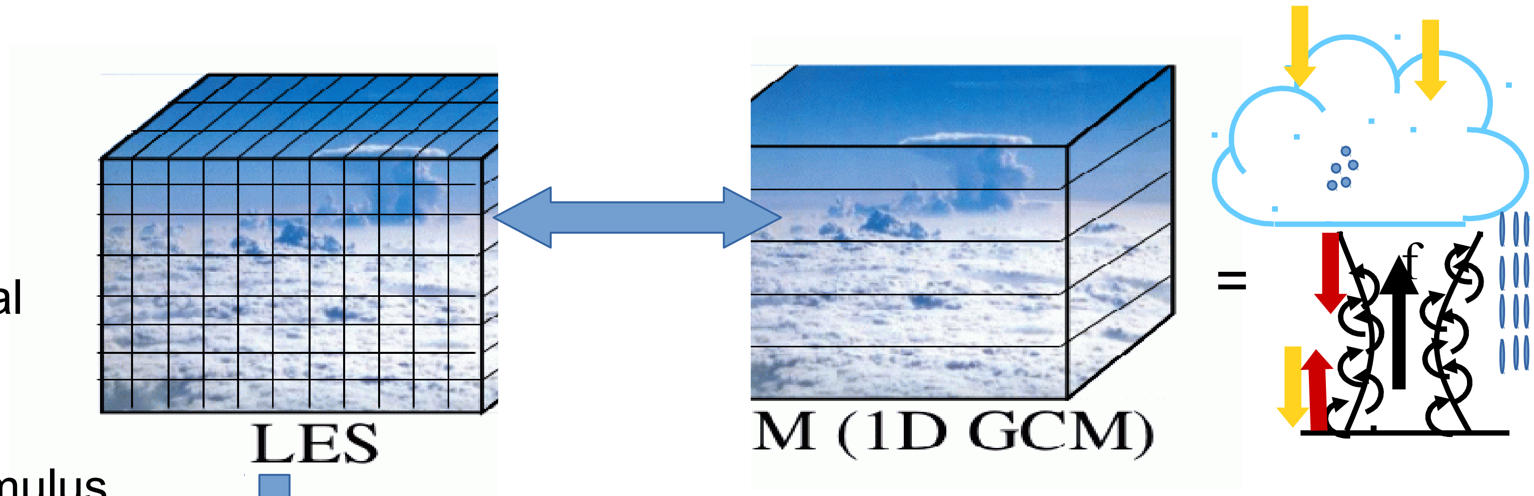
- ASTEX

} Transition Cu→ Stocu

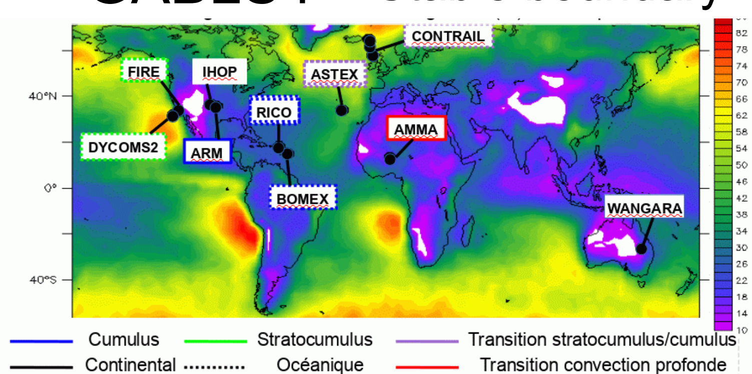
- IHOP
- WANGARA
- AYOTTE (x6)

} Clear convective boundary layer

- AMMA — Deep convection
- GABLS4 — Stable boundary layer



Metrics



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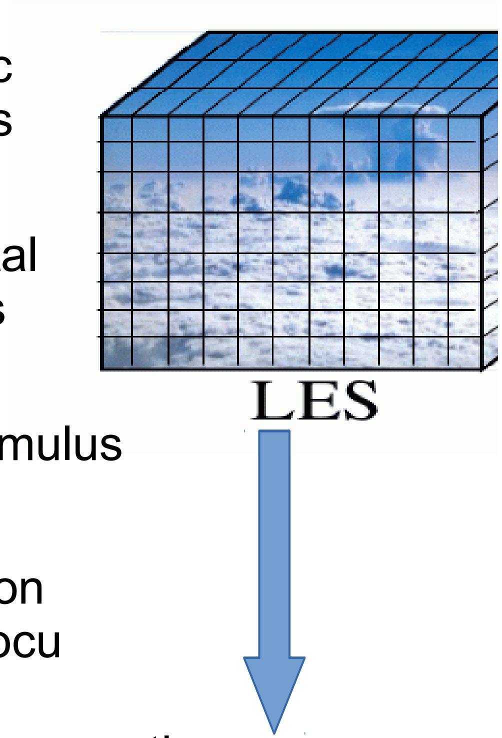
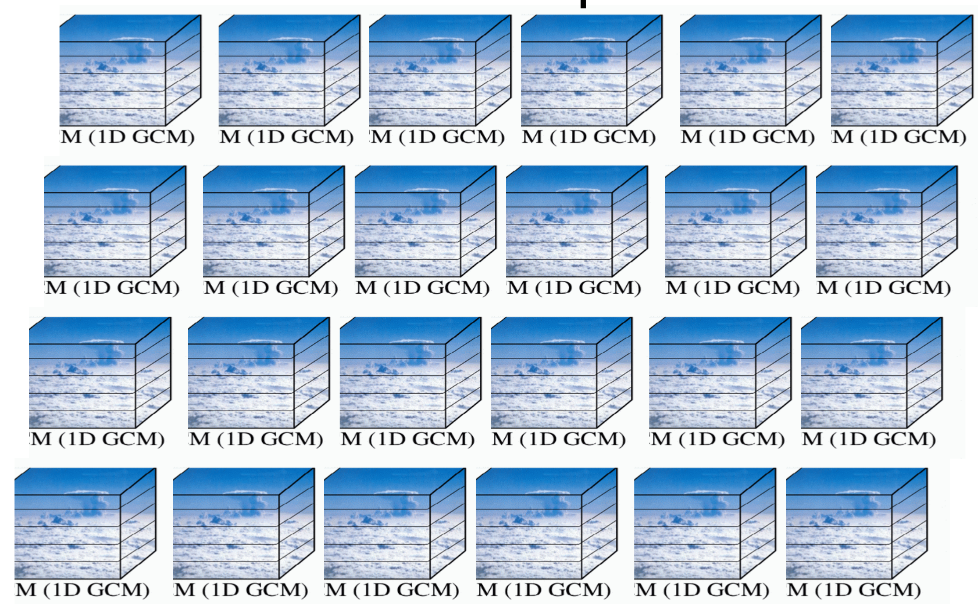
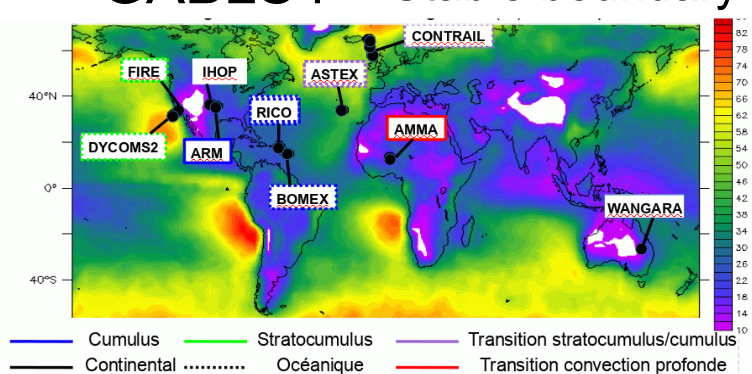


Metrics

Different free parameters





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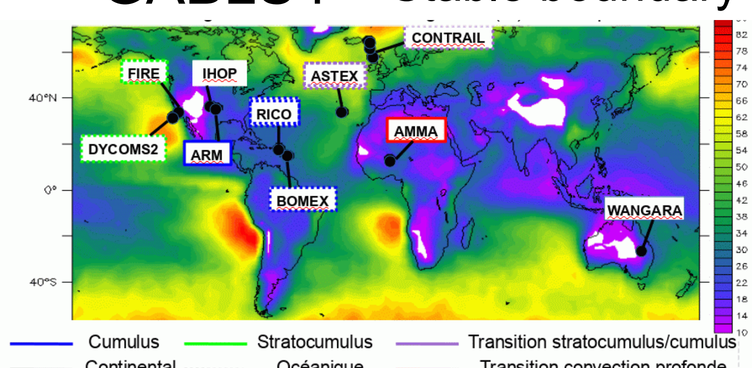

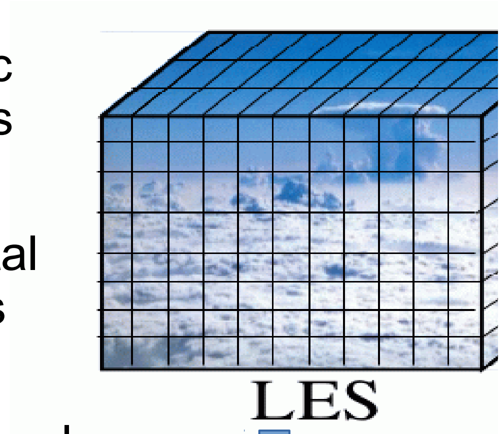

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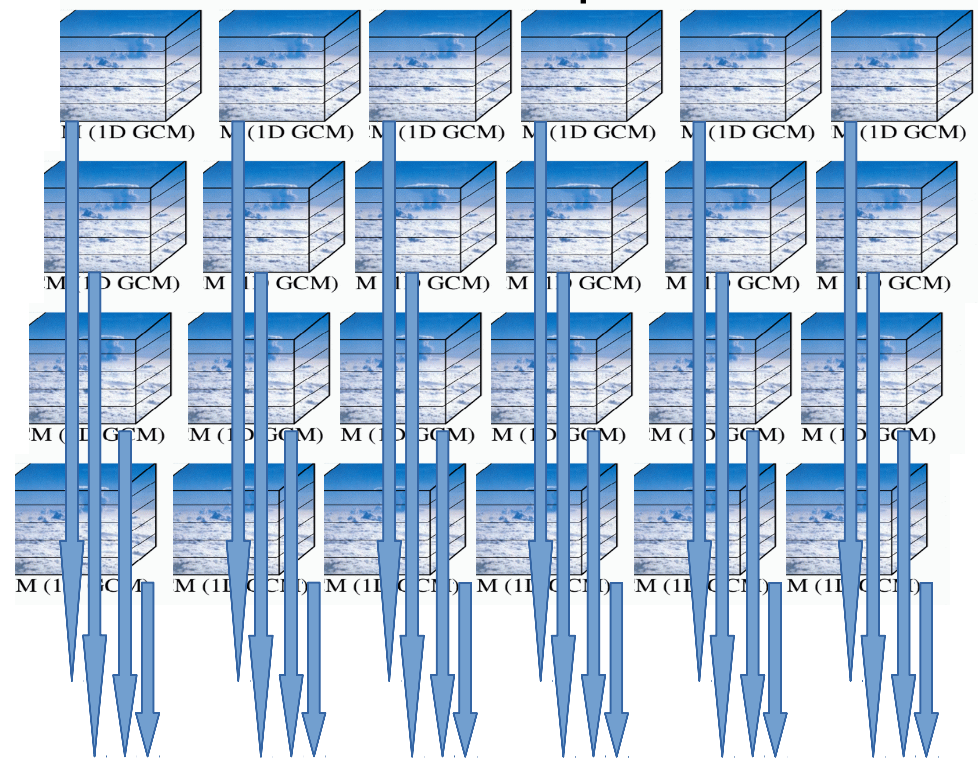


Metrics ⟷ Emulator

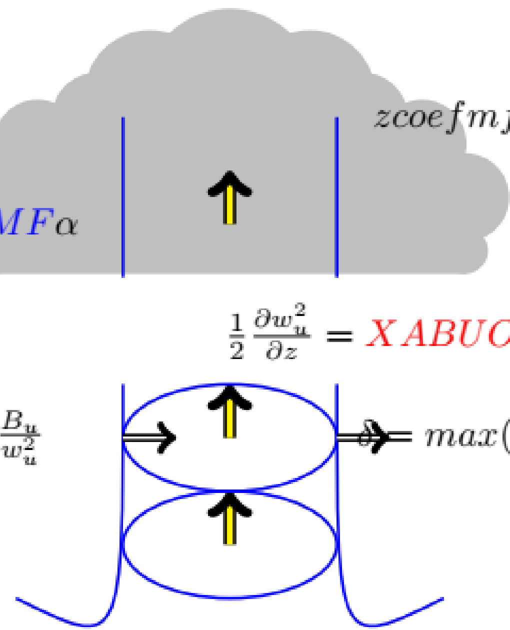
Metrics =f (param1, param2, …,param_n)

History Matching (Williamson et al 2013)

Ensemble of possible values of (param1, param2, …,param_n)

One example with AROME model

<u>Parameters:</u> 3 parameters from the mass-flux scheme of Pergaud et al (2009) involved in entrainment/detrainment formulation



$$zcoefmf\_cloud = g \times \frac{XENTR\_MF}{XCRAD}$$

$$\alpha_{cl} = XKCF\_MF \alpha$$

$$\frac{1}{2}\frac{\partial w_u^2}{\partial z} = XABUO \times B_u - XBENTR \epsilon w_u^2 - XBDETR \delta w_u^2$$

$$\epsilon = XENTR\_DRY \frac{B_u}{w_u^2}$$

$$\delta = max(XDETR\_DRY \frac{B_u}{w_u^2}, \frac{\Delta z_{dry} \times XDETR\_LUP}{l_{up} - z})$$

$$\alpha = min(XFRAC\_UP\_MAX; \frac{M_u}{\rho w_u^2})$$

$$\frac{1}{2}\frac{\partial w_u^2}{\partial z} = (XABUO - XBENTR \times XENTR\_DRY) \times B_u$$

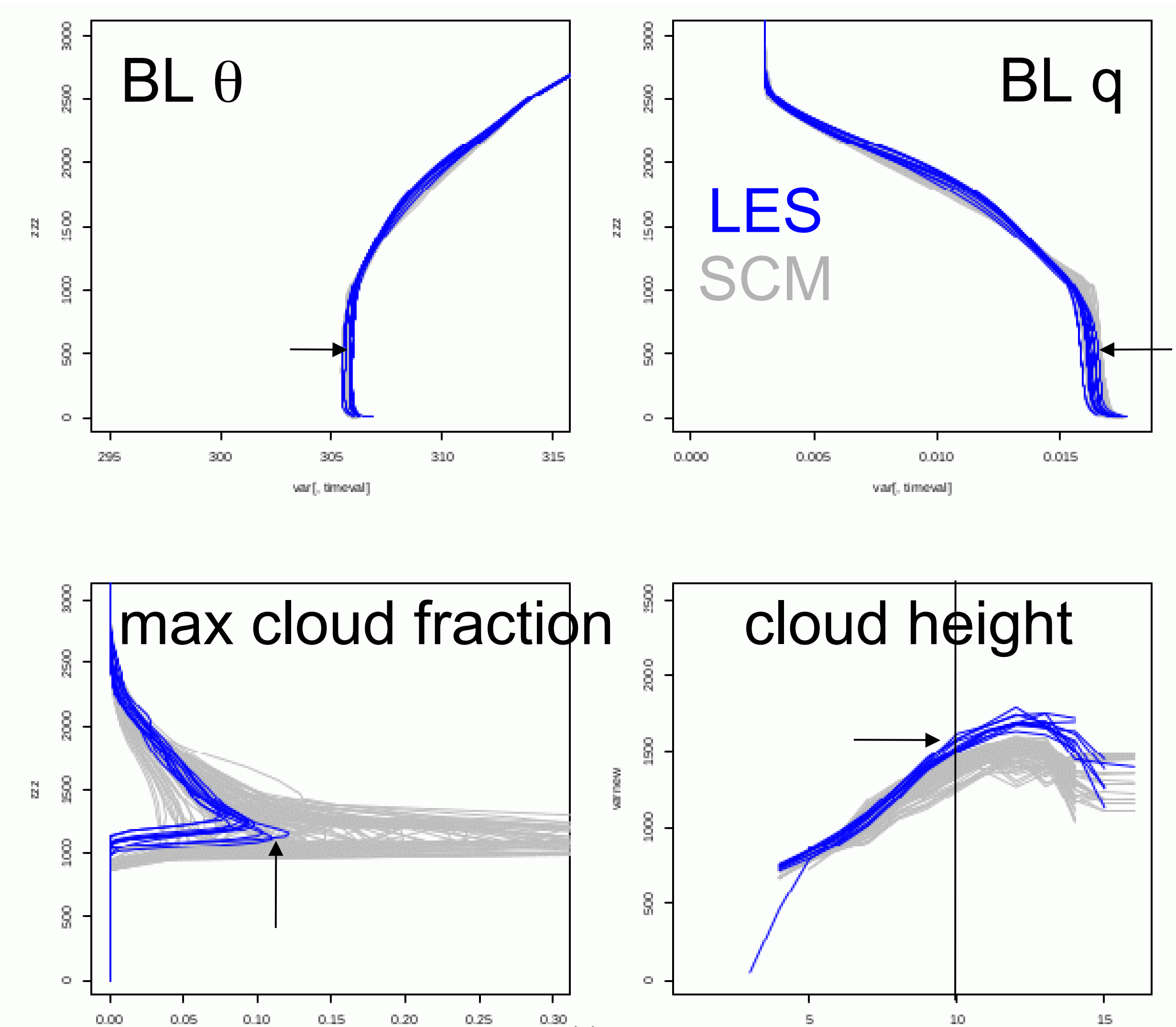
$$\phi_{up}(z_0) = \overline{\phi} + XALP\_PERT \frac{\overline{w'\phi'}_s}{\sqrt{e}}$$

$$M_u(z_0) = XCMF(\beta L_{up} \overline{\theta'_v w'}_s)^{1/3}$$

One example with AROME model

Parameters: 3 parameters from the mass-flux scheme of Pergaud et al (2009) involved in entrainment/detrainment formulation

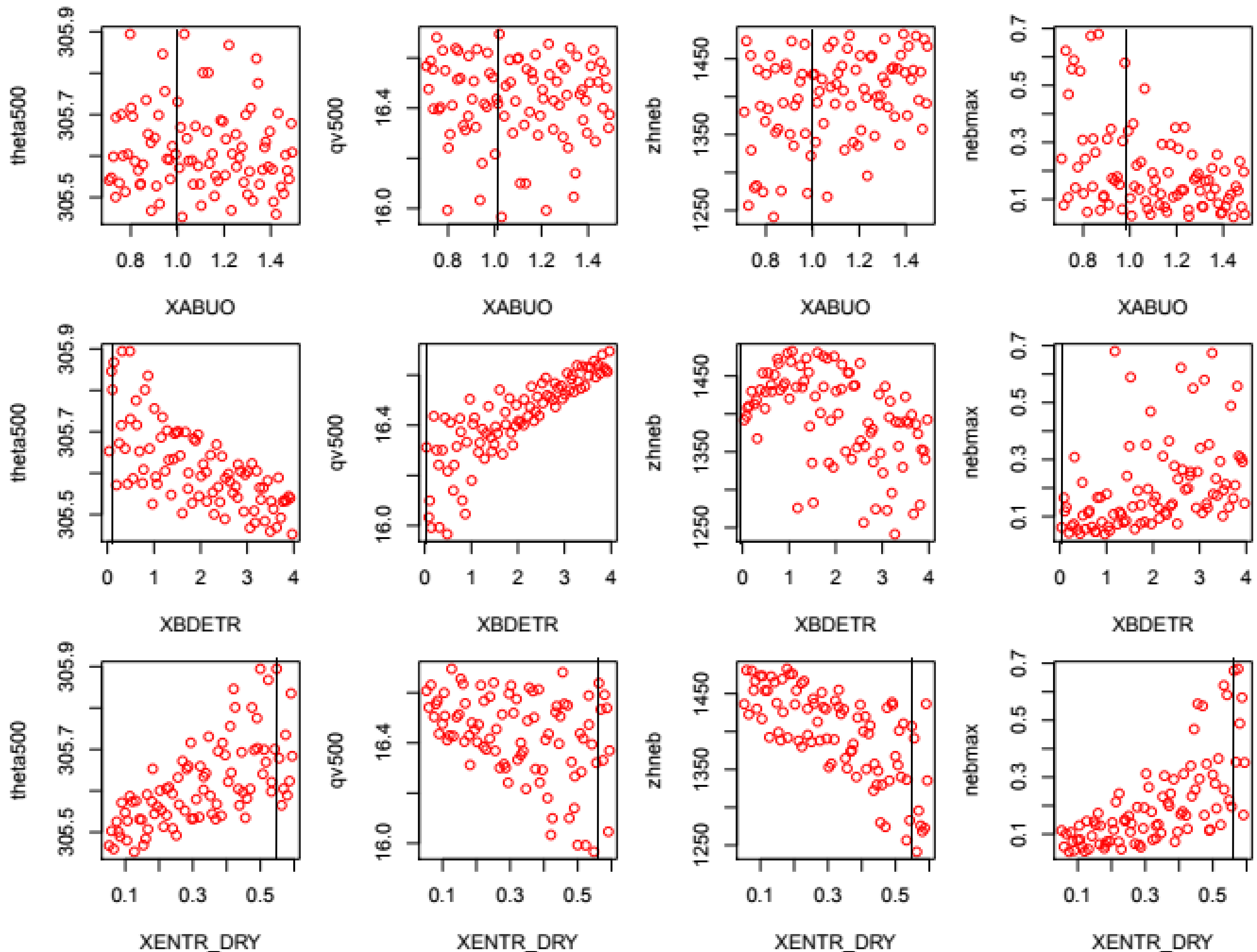
Case and metrics: ARM (Brown et al 2002) ; BL θ, BL q, max of cloud fraction, cloud equivalent height



One example with AROME model

Parameters: 3 parameters from the mass-flux scheme of Pergaud et al (2009) involved in entrainment/detrainment formulation

Statistical tools: Able to predict the metrics for any values of parameters



One example with AROME model

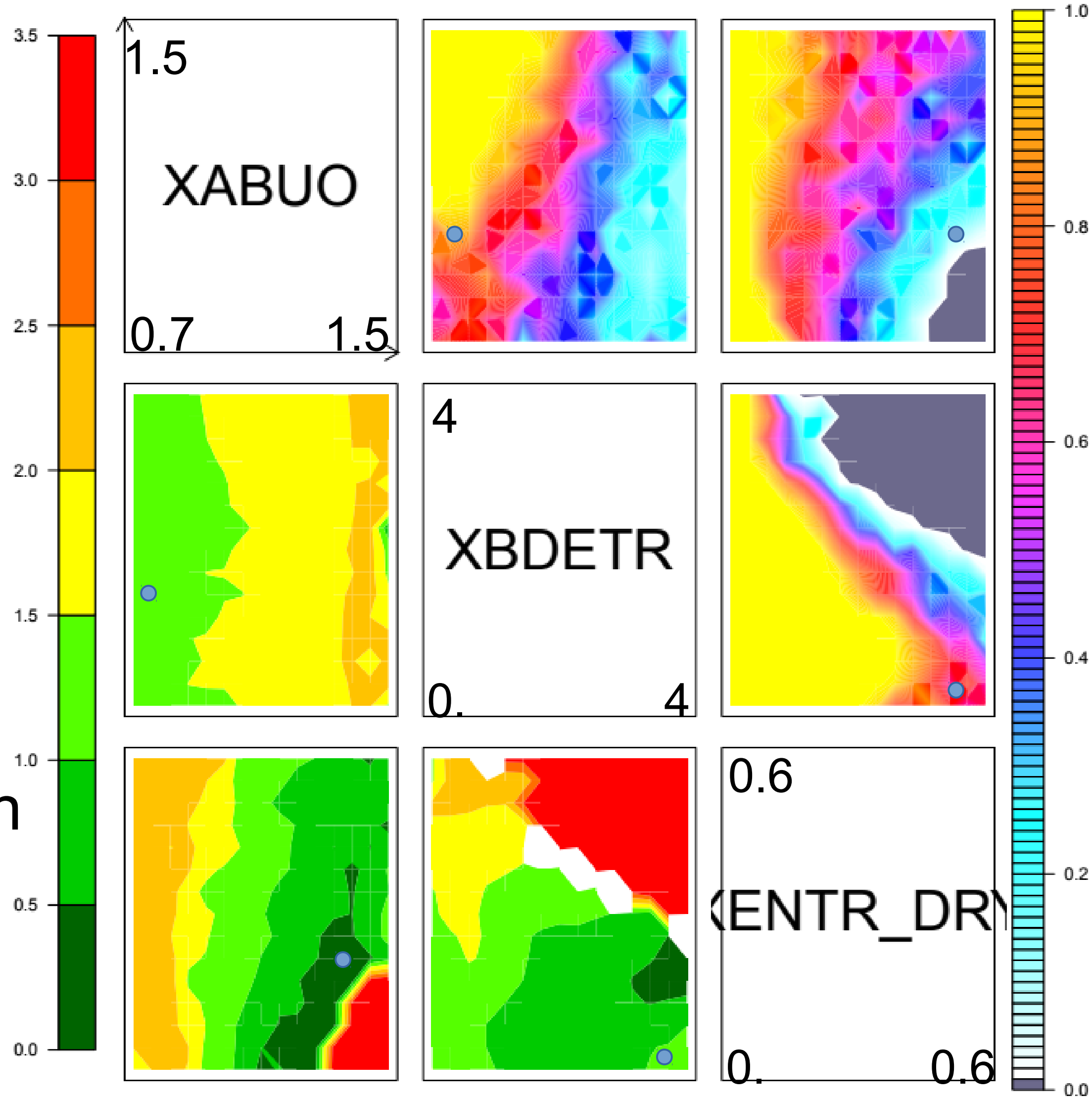
Parameters: 3 parameters from the mass-flux scheme of Pergaud et al (2009) involved in entrainment/detrainment formulation

Results: Determine the Non-Rulled Out Yet space of parameter values

• Values in the default operational version

Minimum Implausibility in the 3D domain

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

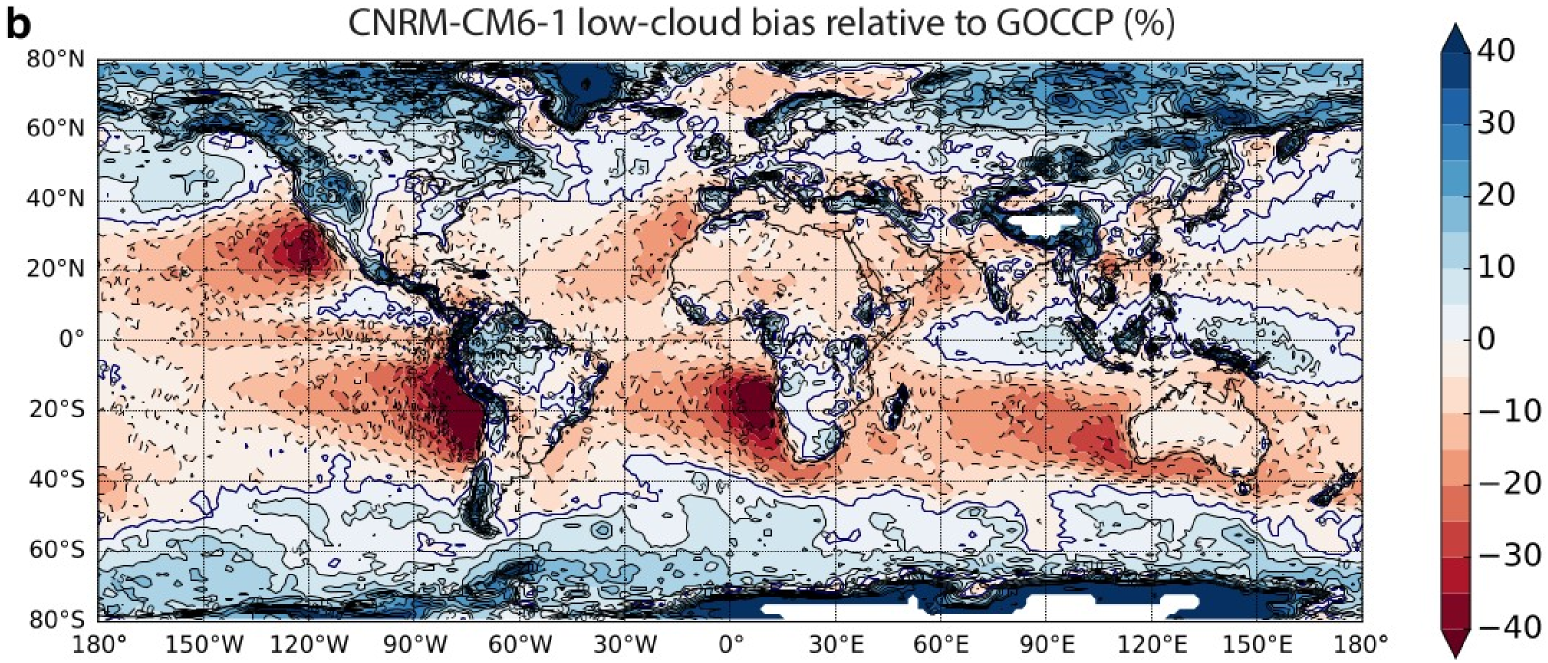


% of the 3D domain of value of parameters kept

Evaluating marine stratocumulus clouds in the CNRM-CM6-1 model using short-term hindcasts

Florent Brient, Romain Roehrig, Aurore Voldoire
In revision to JAMES

Low-cloud biases in the CNRM-CM6 model



- Strong low-cloud underestimation in the eastern parts of tropical oceans (up to -40 %)

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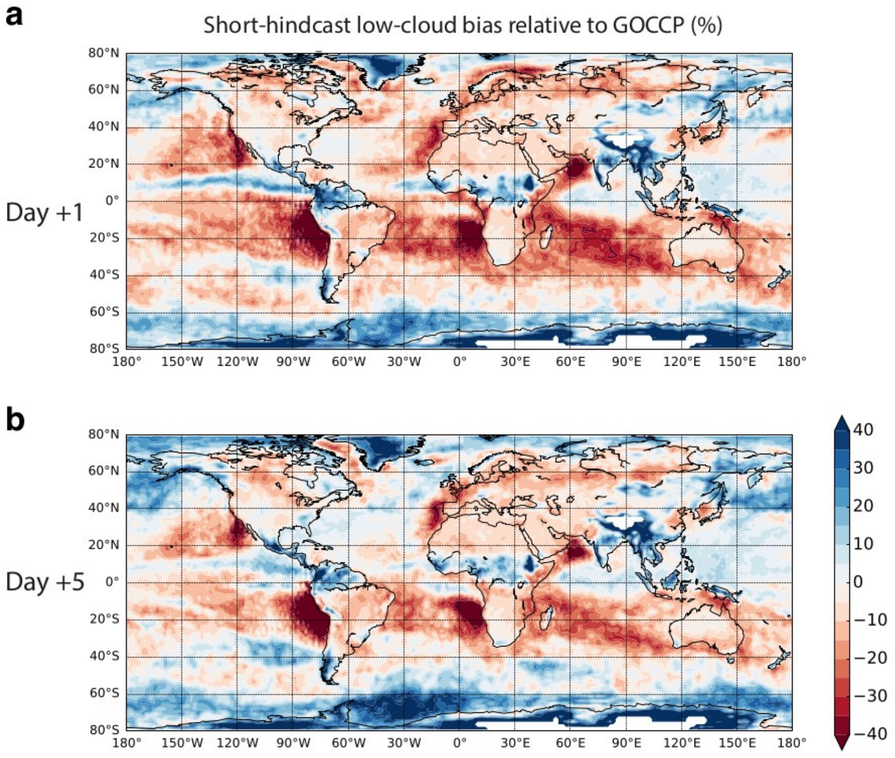
Usefulness of short-term hindcasts

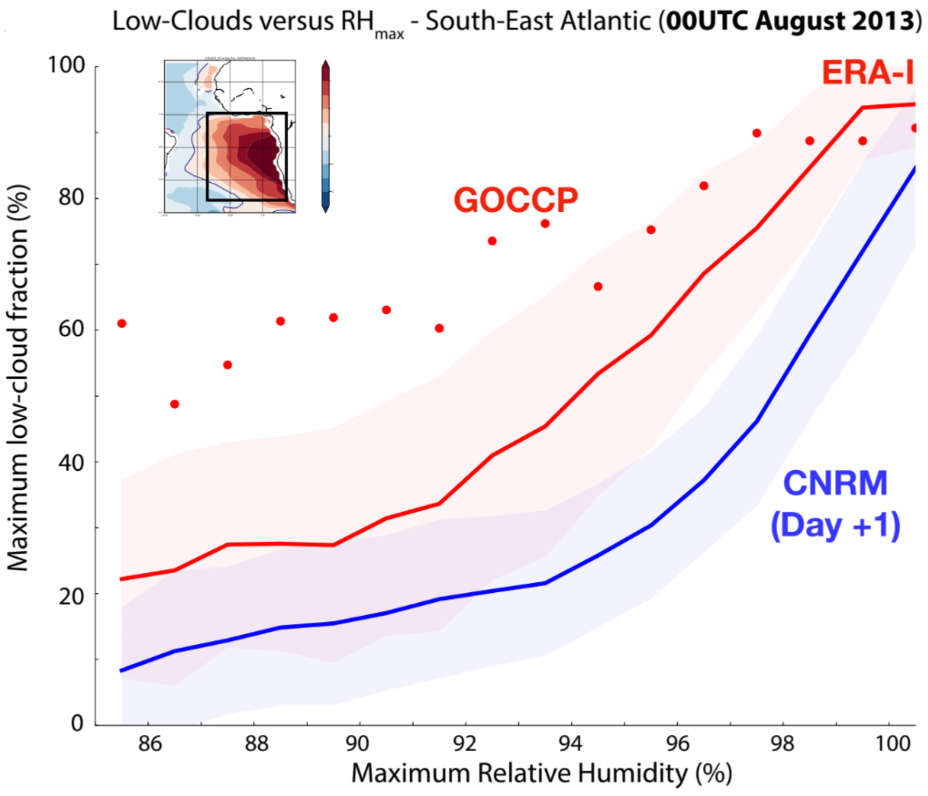
- Ensemble of short-term hindcasts starting each day of August 2013 from ERA-Interim (u, v, T, qv and ps)



- Low-cloud biases appear within only a few hours, thus independently of errors in the large-scale circulation
- Key processes underlying the low-cloud errors are thus mainly local
- Transpose-AMIP is a useful framework to evaluate and improve parameterizations

Process-oriented analysis of low-cloud errors

- RHmax vs CFmax (< 3km) in the South Atlantic
- CNRM model highly biased in all RH regimes

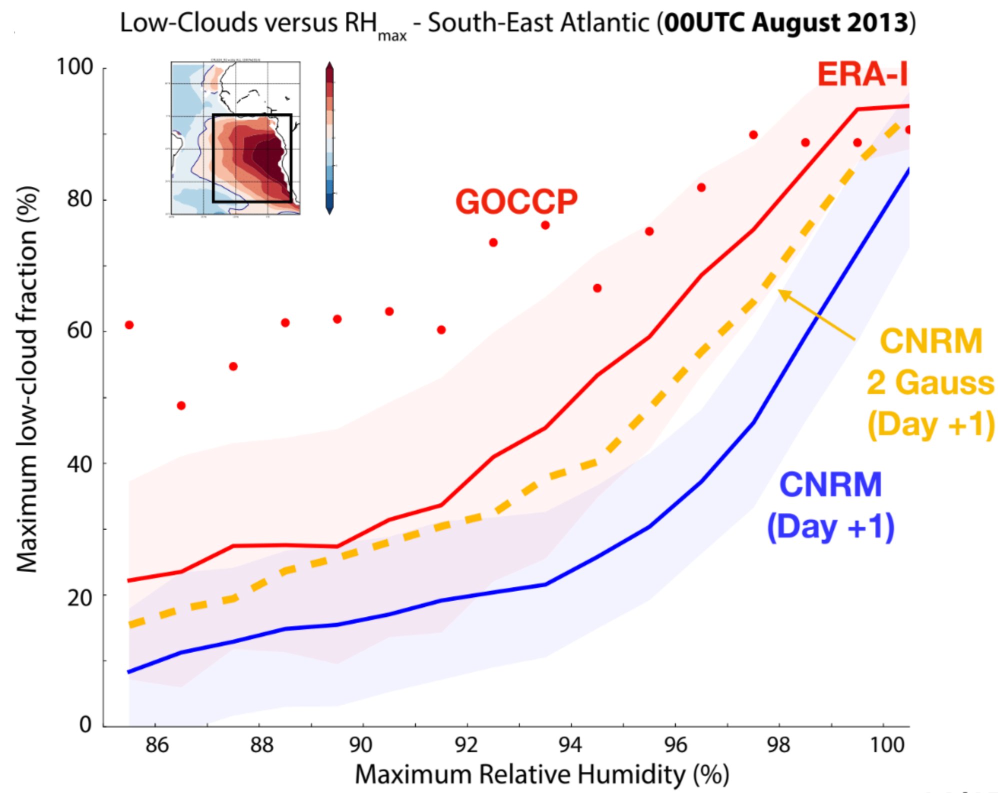


Subgrid-scale distributions of T/qv mostly explain cloud errors

- RHmax vs CFmax (< 3km) in the South Atlantic
- CNRM model highly biased in all RH regimes

$$\overline{CF} = \int_{-Q_1}^{+\infty} G(t)dt$$

$$\overline{Q_1} = a\left[\frac{\overline{q_t} - q_{sat}(\overline{T_l})}{2\sigma_s}\right]$$



- Sensitivity test to the subgrid distribution of T/qv (**G**) improve the relationship between RH and CF
- This calls a revisit of the cloud parameterization subgrid-scale distribution, e.g. by accounting for other sources of moisture subgrid-scale variability.