SEMI-AUTOMATIC TUNING TOOLS APPLIED ON STATISTICAL CLOUD SCHEME PARAMETERIZATION

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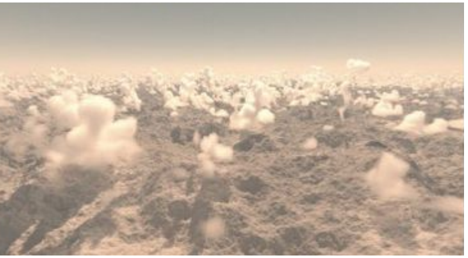
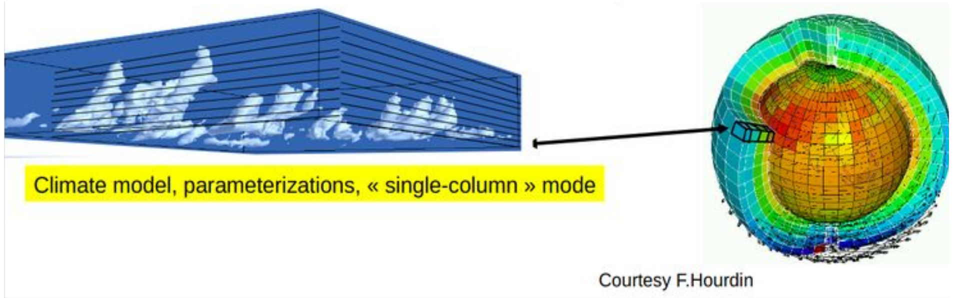
CONTEXT

High-tune project → New tuning tool for climate models

Global tuning of LMDZ model :



Courtesy N. Villefrancque



LES simulation ⟷ Pre-calibration SCM ⟷ 3D tuning ⟷ Observation

PHYSICS AND CALIBRATION

Pre-calibration on 1D cases compared to LES simulation [Couvreux et al.,2020 ; Hourdin et al., 2020] :

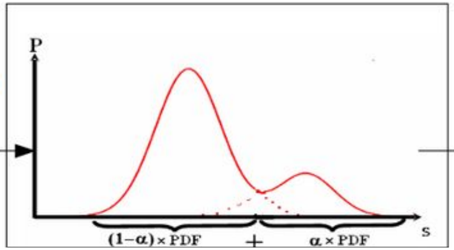
- Validation of new physics (especially thermal plumes and statistical cloud scheme)
- Calibration of parameters

Bigaussian cloud scheme with thermal plumes

Parameterization of the standard deviation of the environment and thermal plumes. The minimum value of both standard deviation is fixed by an imposed parameter b = σ/q.

$$\sigma_{s,\mathrm{th}} = c_{\mathrm{th}}(\alpha + 0.01)^{-\gamma_1}(\bar{s}_{\mathrm{th}} - \bar{s}_{\mathrm{env}}) + b\bar{q}_{t_{\mathrm{th}}}$$

$$\sigma_{s,\mathrm{env}} = c_{\mathrm{env}}\frac{\alpha^{\gamma_2}}{1-\alpha}(\bar{s}_{\mathrm{th}} - \bar{s}_{\mathrm{env}}) + b\bar{q}_{t_{\mathrm{env}}}$$



environment

Thermal plumes

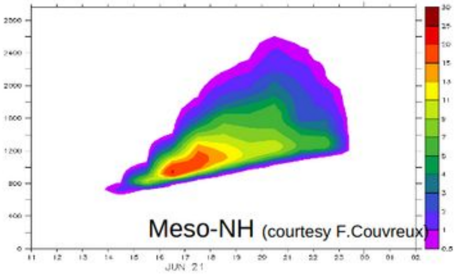
Cloud fraction

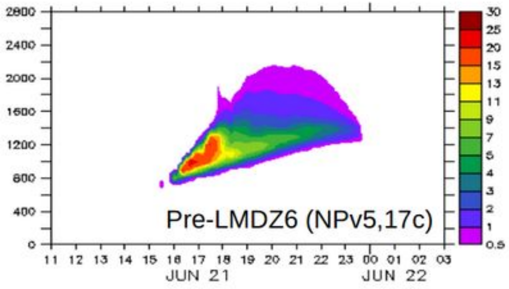
$$\alpha_c = \int_{q_{sat}}^{\infty} P(q)dq$$

Calibration

The parameter b is fixed to a small value b = 0.002

Example on Armcu case after calibration with the tuning tool :



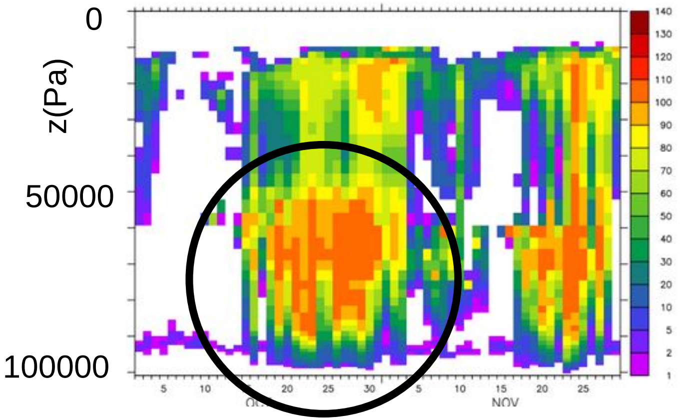


Cloud Fraction
LES

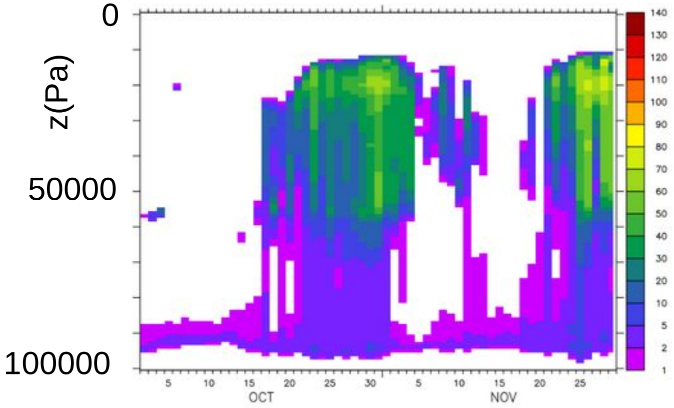
Cloud Fraction
LMDZ6

DIAGNOSTICS OF THE PROBLEM

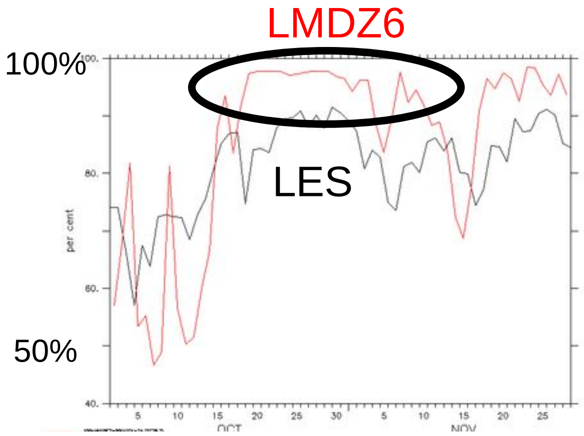
Major default on oceanic deep convection case (DYNAMO)



Cloud Fraction
LMDZ6 REF (DYNAMO)



Cloud Fraction
LES (DYNAMO)



Averaged relative humidity
(2000m-4000m)

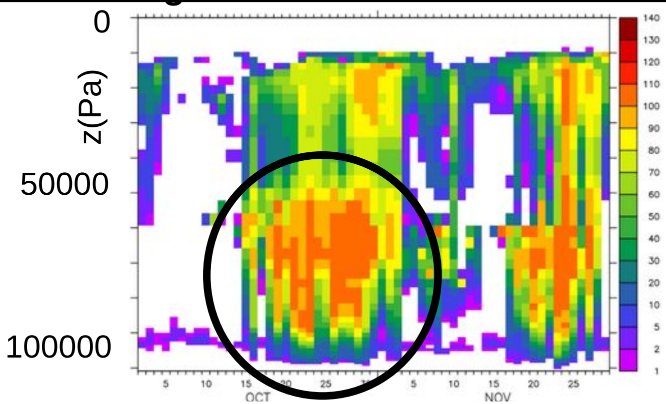
Hypothesis

Rising humidity by thermal plumes → Too small sub-grid water distribution variability in mid-atmosphere → "All or nothing" behavior of the cloud scheme with a near dirac distribution → Lack of precipitation (positive feedback)

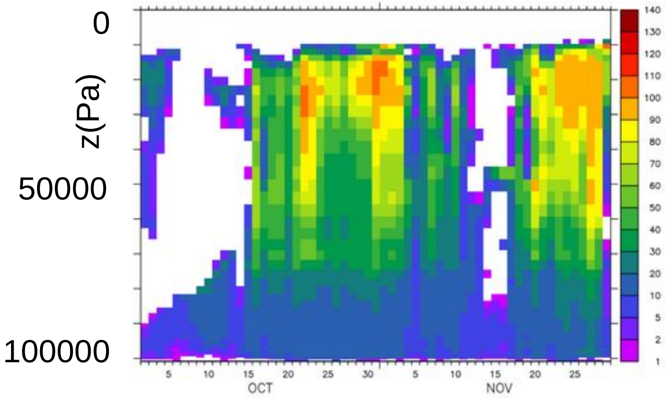
Missing source of variability in mid-atmosphere when deep convection occurs

PRELIMINARY WORK : MANUAL TUNING

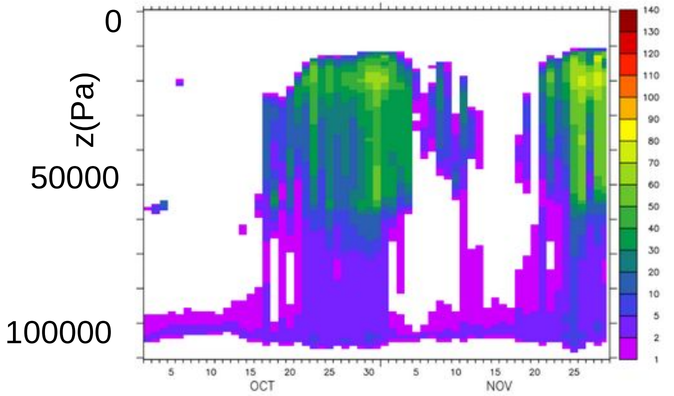
Increasing of the standard deviation of the cloud scheme :



Cloud Fraction
LMDZ6 REF (b = 0.002)

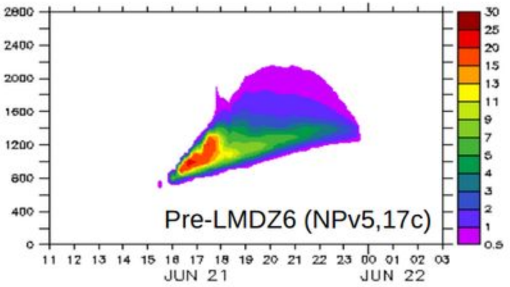


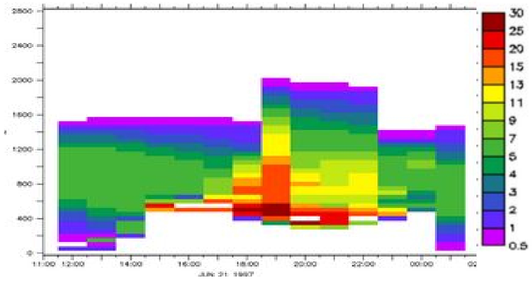
Cloud Fraction
LMDZ6 (b = 0.128)

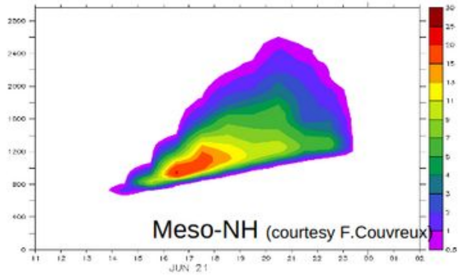


Cloud Fraction
LES

Damage on low level clouds (example on armcu case) :







- Significant improvement on DYNAMO by changing parameter b but major damage on ARMCU
- Validation of our hypothesis but variability should be interactive

NEW PARAMETERIZATION

Variability can't be manually increased without losing consistency → Looking for a new source of variability in case of deep convection → There is a significant difference of humidity between Cold wakes and the environment → Introducing a new parameterization depending on cold wakes

Proxy with exponential time relaxation

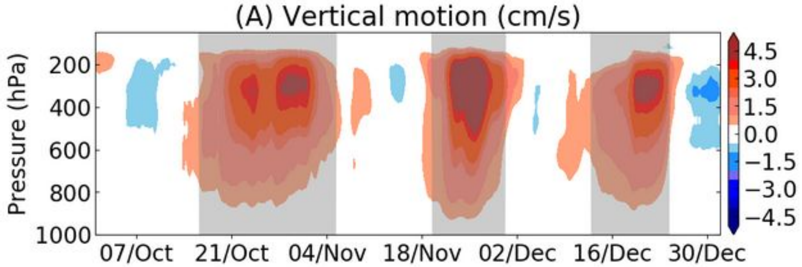
$$b(t+pdt) = b(t).exp(-\frac{pdt}{\tau}) + a\frac{S_{wake}^{0,5}}{1-S_{wake}}\frac{\delta q_{max}}{q_{max}}(1-exp(-\frac{pdt}{\tau}))$$

- b : variable of the model driving the standard deviation of the statistical cloud scheme
- pdt : time step
- S : the fraction of surface occupied by the cold wakes
- δqmax : the maximum difference of total humidity between cold wakes and environment
- qmax : the maximum total humidity of the environment
- a and τ : new tunable parameters

A new source of variability depending on cold wakes with exponential time relaxation

TUNING WITHOUT PARAMETERIZATION

Identification of active and suppressed MJO phases with a criterion based on vertical motion



Principle of the tuning tool :

Inputs
- Parameters
- Metrics
- Number of waves
- Target (LES or observations)

→

- SIMULATIONS
- EMULATOR
- STATISTICS (EMULATOR vs TARGET)

→

Outputs
- Plots metrics/parameters
- Synthesis remaining space

First choice of parameters

Four main parameters used for the low level cloud tuning

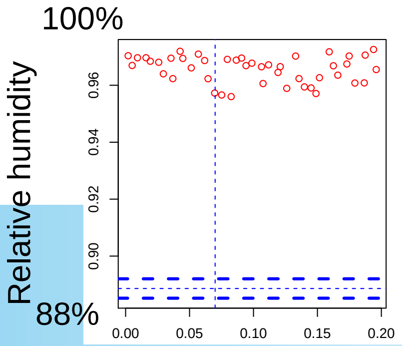
First choice of metrics

Metrics of Armcu, Rico and sandu cases
Averaged relative humidity in active phase (DYNAMO)
Averaged relative humidity in suppressed phase (DYNAMO)

First results

Remaining space of parameters is empty

No viable solution with existing parameters



Parameter of thermal plumes

TUNING WITH NEW PARAMETERIZATION

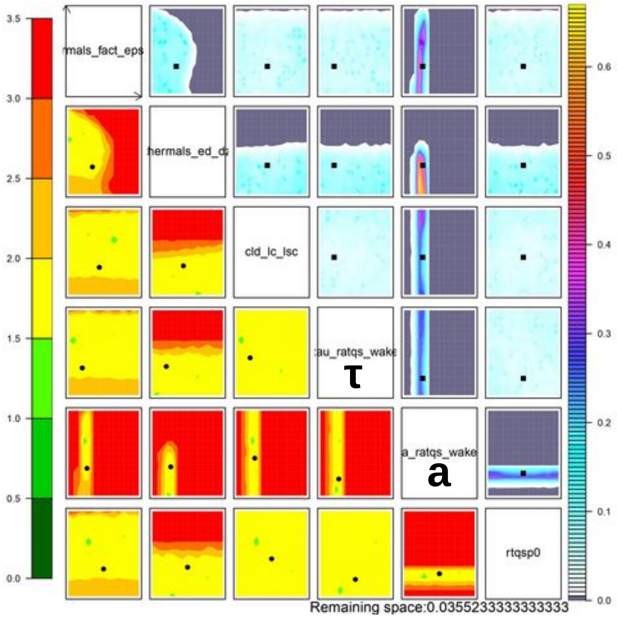
New choice of parameters

Four main parameters used for the low level cloud tuning	a
	τ

New choice of metrics

Metrics of Armcu, Rico and sandu cases
Averaged relative humidity in active phase (DYNAMO)
Averaged relative humidity in suppressed phase (DYNAMO)

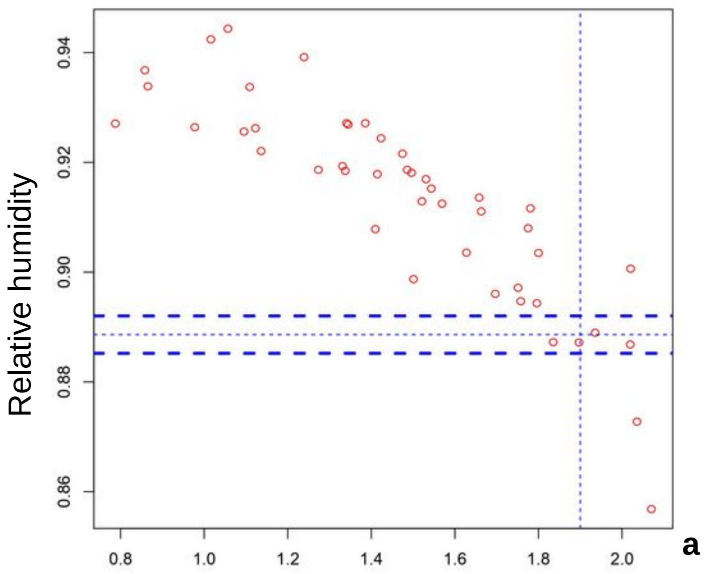
Synthesis and remaining space



Upper right : grey is out of range

Lower left : red is out of range

Relative humidity vs parameter a



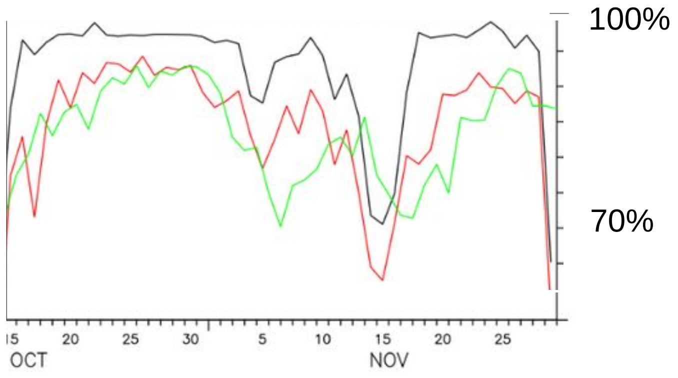
a = 1,85

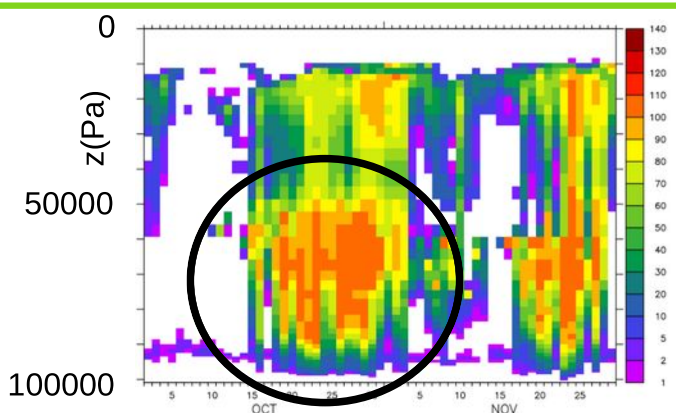
Calibration of the key parameter a with the tuning tool

RESULTS AND ANALYSIS

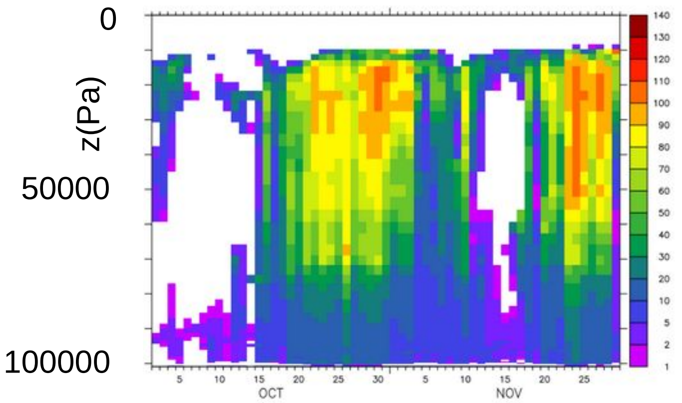
Averaged relative humidity
(2000m-4000m) comparison :

Without parameterization
a = 1,85
LES

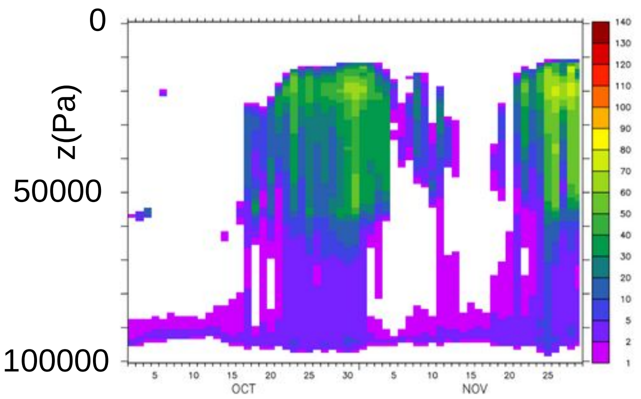




Cloud fraction
LMDZ REF



Cloud fraction
LMDZ : with new parameterization



Cloud fraction
LES

Relative humidity is adjusted to LES, the cloud fraction default is largely resolved but is still too high
A part of the cloud fraction is calculated by the deep convection scheme

CONCLUSION

Summary
- Resolution of the “all or nothing” behavior of the cloud fraction
- Adjustment of the relative humidity
- First validation of the new parameterization and parameters calibration
- No degradation of the shallow cumulus cases
- No major impact on other metrics
- Promising results on TOGA case
- Integration in LMDZ model

Perspective
- Continuation of the global tuning project including deep convection cases
- Working on the deep convection part of the cloud fraction
- Building a prognostic model of sub-grid water distribution variability in the atmospheric column

General perspective
Using semi-automatic tuning tools in climate models to effectively test and calibrate parameterization in comparison with LES simulation

THANK YOU VERY MUCH