Effets radiatifs des cumulus et organisation

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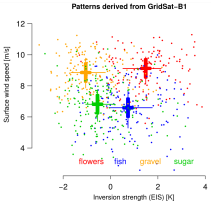
28 avril 2025 — Réunion convection du Lundi au LMD – en visio

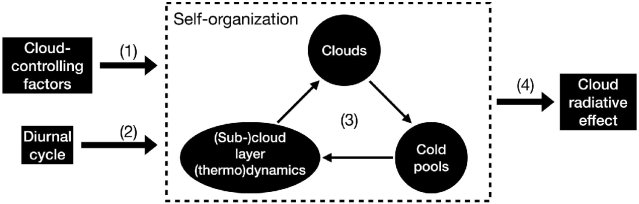
Simulated cloud field (ARM-Cumulus at 8 m resolution) rendered using a Monte Carlo path-tracing model (`htrdr`, Villefranque et al. 2019)

Contexte de l'étude

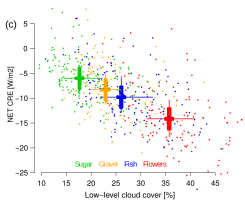
- Organisation des nuages bas
  Conditionnée par la grande échelle ? Par quels mécanismes ? Effet radiatif des nuages résultant ?



from Bony et al. 2020



from Alinaghi et al. 2024



from Bony et al. 2020

- Dans les modèles de climat :
  (1-2) → paramétrisations couche limite (3) → profils thermo et nuageux (*)
  (*) → paramétrisation rayonnement (4) → effet radiatif des nuages

I. Comment réagissent les paramétrisations de couche limite à ces différentes conditions de grande échelle ?
II. Que prédit la paramétrisation de rayonnement pour des profils nuageux parfaits ?

Outils et méthode 1 : Dephy

Un cadre de modélisation
analyse, développement, évaluation, calibration

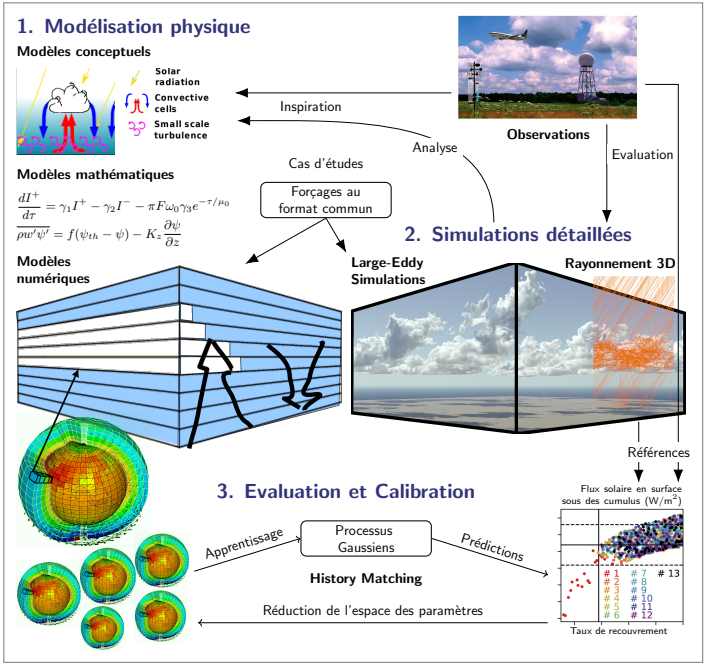
Modèle unicolonne (SCM, 1D) vs.
Simulation explicite (LES, 3D moyenné)

mêmes profils initiaux
mêmes forçages de grande échelle

Une chaine d'outils : description des cas au "format commun" ; scripts pour générer des namelists de modèles, faire tourner les modèles, formatter les sorties ; LES de référence + code de rayonnement 3D ; outils d'exploration des sensibilités paramétriques des modèles (htexplo) pour étudier le modèle ou le calibrer

Un ensemble de cas : continent/océan, peu profond/transition/profond, cumulus/transition/stratocumulus ...

Rien de spécifique sur l'organisation des nuages bas so far



Outils et méthode 2 : Botany

Jansson et al. (2023). Cloud Botany: Shallow cumulus clouds in an ensemble of idealized large-domain large-eddy simulations of the trades. JAMES https://doi.org/10.1029/2023MS003796

Search Ctrl + K

Cloud Botany with DALES

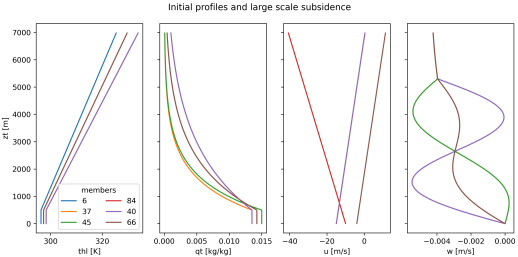
Setup

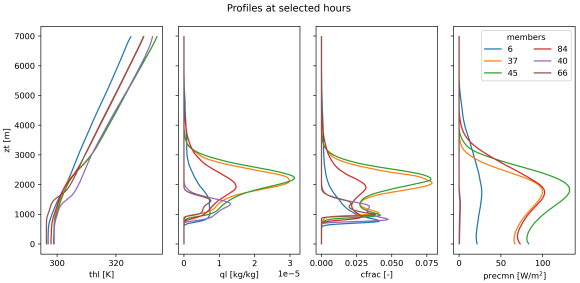
Cloud Botany is a library of idealised large-eddy simulations forced by and initialised with combinations of simplified vertical profiles. Each profile is parameterised by variables which aim to make the ensemble span a range of conditions corresponding to the variability observed over the EUREC^{4}A region during the boreal winter of 2019/2020. The following table lists these varied parameters and their ranges:

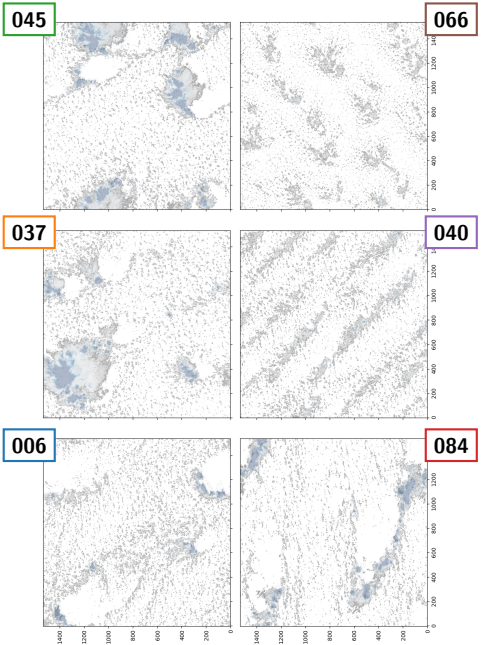
Table 1 Variables governing Cloud Botany simulations

variable	min	max	unit	description
`thls`	297.5	299.5	K	sea surface potential temperature
`u0`	-5	-15	m/s	surface wind
`qt0`	0.0135	0.015	kg/kg	mixed-layer total specific humidity
`qt_lambda`	1200	2500	m	humidity scale height
`thl_Gamma`	4.5	5.5	K/km	lapse rate of `thl`
`wpamp`	-0.35	0.18	cm/s	Amplitude of subsidence first mode
`dudz`	-0.0044	0.0044	1/s	Wind shear[1]

Outils et méthode 3 : Choix des cas







Botany vs Meso-NH LES : max frac, LWP, RWP en fct du temps & profils verticaux de cf, ql, qv

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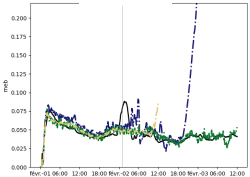

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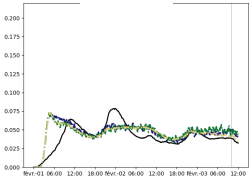

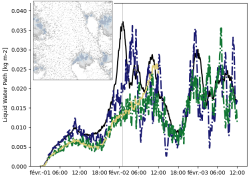

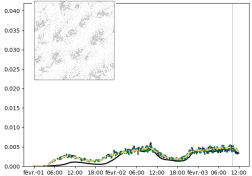

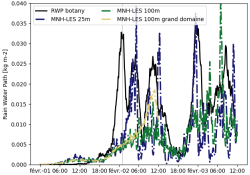

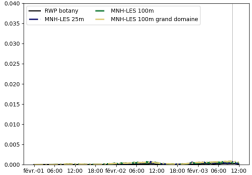

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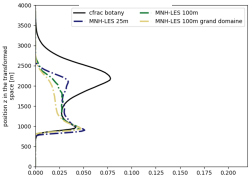

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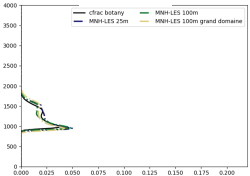

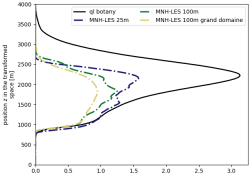

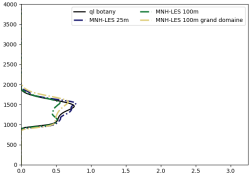

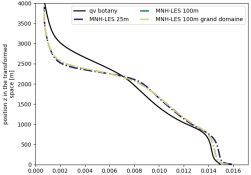

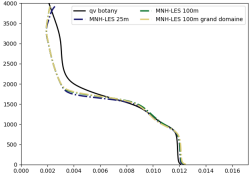

Botany vs Meso-NH LES vs SCM : max frac, LWP, RWP en fct du temps & profils verticaux de cf, ql, qv

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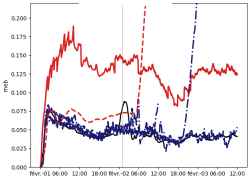

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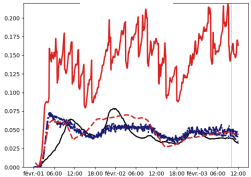

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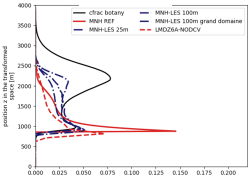

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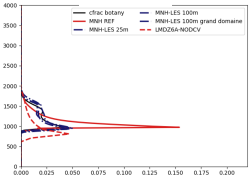

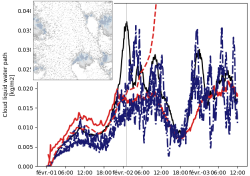

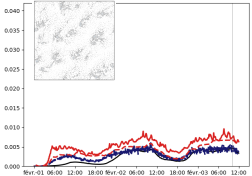

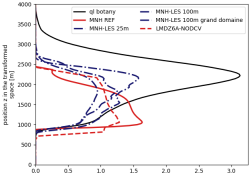

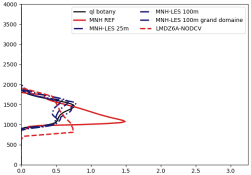

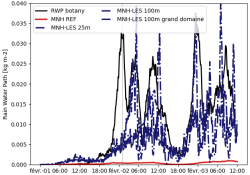

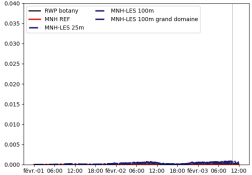

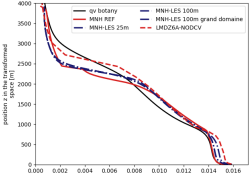

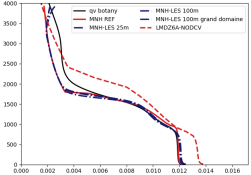

Botany vs Meso-NH LES vs SCM : max frac, LWP, RWP en fct du temps & profils verticaux de cf, ql, qv

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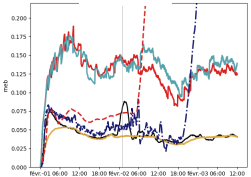

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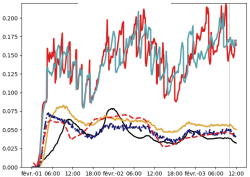

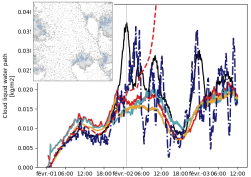

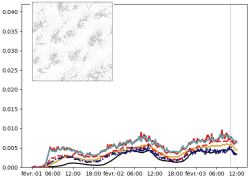

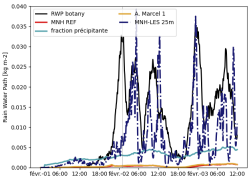

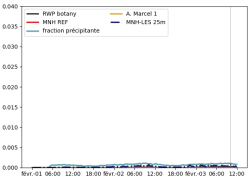

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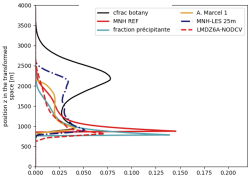

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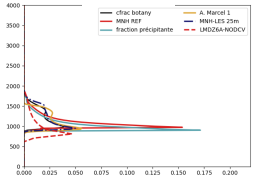

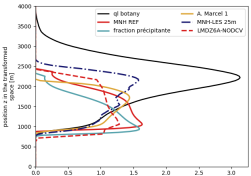

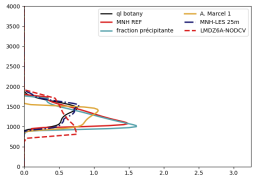

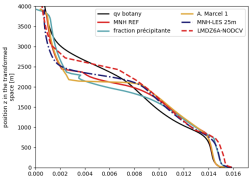

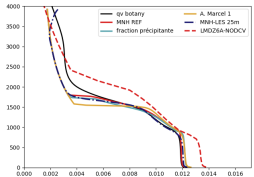

Botany vs Meso-NH LES vs SCM : fractions nuageuses

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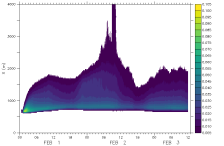
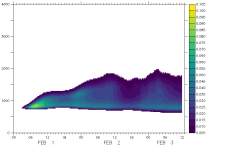
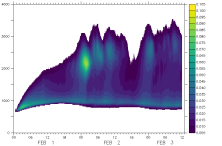
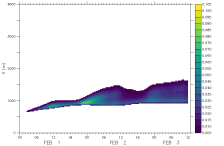
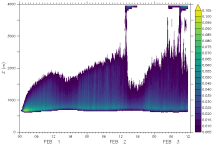
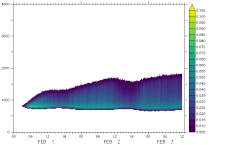
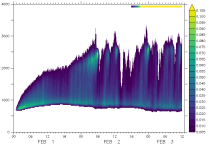
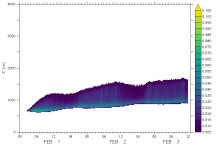
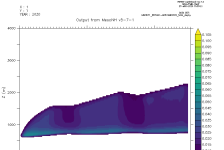
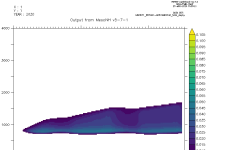
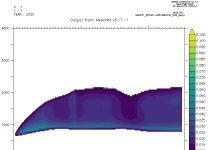
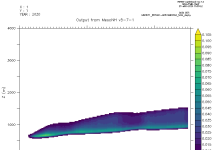
BOTANY				
MNH-LES				
MNH-AM-SCM				

Effets radiatifs des nuages

Pour les 6 cas, toutes les heures de 24 à 60, un calcul de rayonnement 3D sur le champ LES botany 3D

+ un calcul Monte Carlo en mode colonnes indépendantes (sans effets 3D)

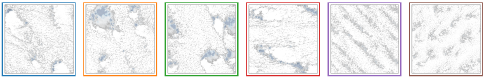
+ des calculs ecRad sur les profils moyens des LES

CRE = flux up all sky - flux up clear sky au sommet du domaine

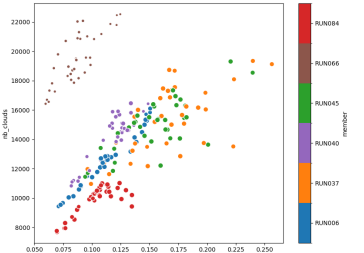
effets 3D = flux up 3D - flux up 1D

Effets radiatifs des nuages par Monte Carlo

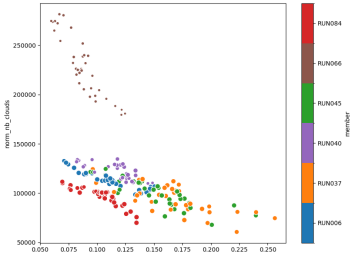
taille des points = épaisseur des nuages



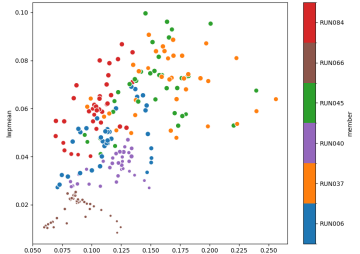
cover vs nb clouds



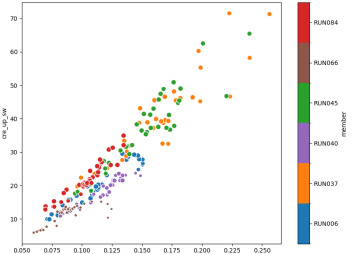
cover vs nb clouds / cover



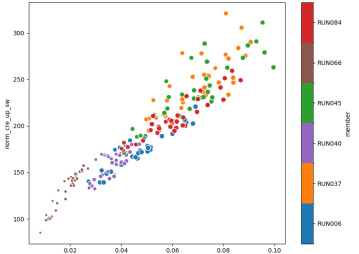
cover vs mean LWP



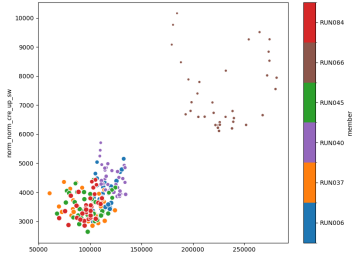
cover vs CRE SW (sza=0)



LWP vs CRE / cover

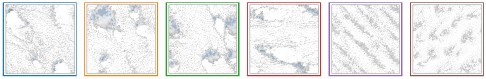


nb clouds / cover vs CRE / cover / LWP

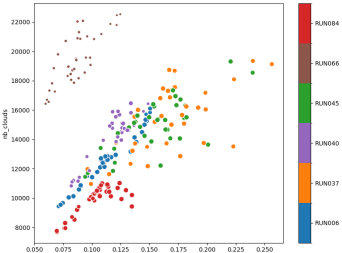


Effets radiatifs des nuages par Monte Carlo

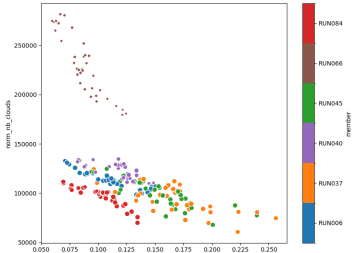
taille des points = épaisseur des nuages



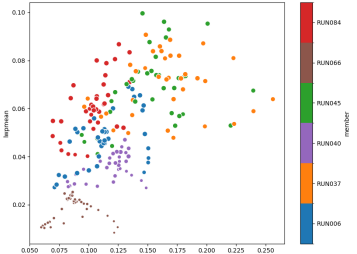
cover vs nb clouds



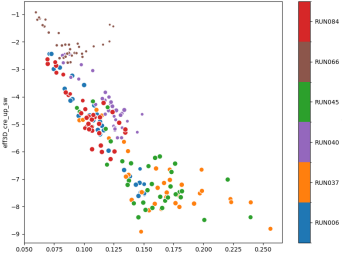
cover vs nb clouds / cover



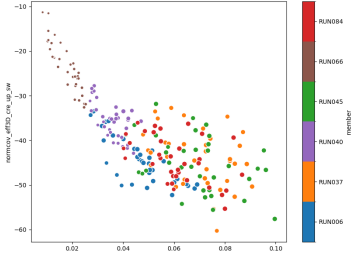
cover vs mean LWP



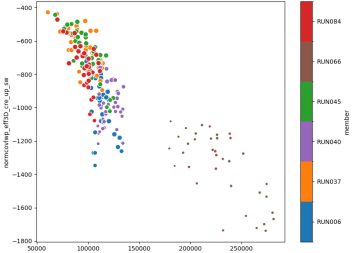
cover vs 3D effects (sza=0)



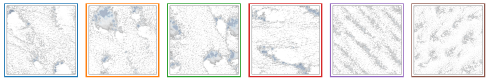
LWP vs 3D effects / cover



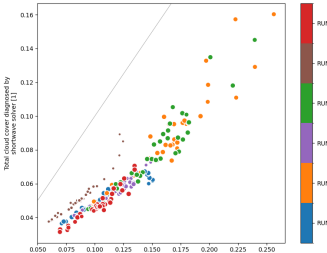
nb clouds / cover vs effets 3D / cover / LWP



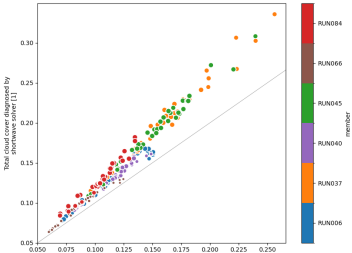
Effets radiatif des nuages paramétrisés – overlap



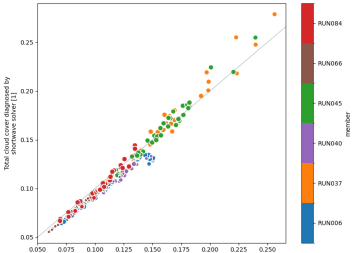
true cover vs overlap default



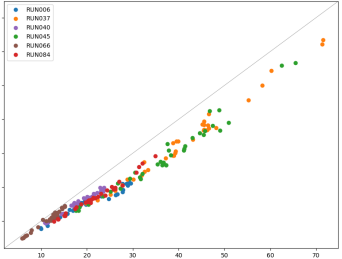
true cover vs true overlap



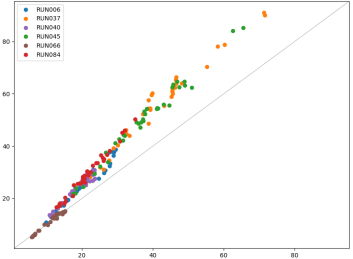
true cover vs scaled overlap



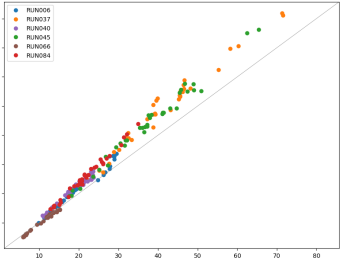
CRE (sza=0) MC vs ecRad default



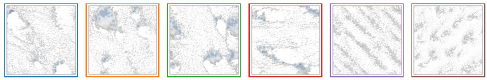
CRE MC vs ecRad cloud geom



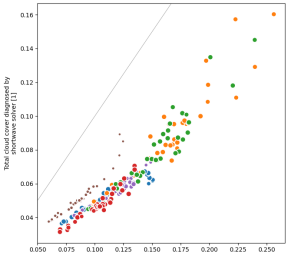
CRE MC vs ecRad scaled overlap



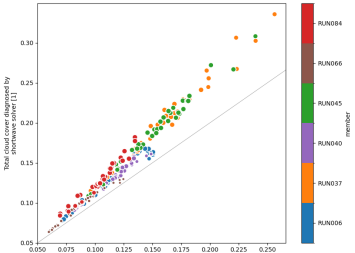
Effets radiatif des nuages paramétrisés – overlap



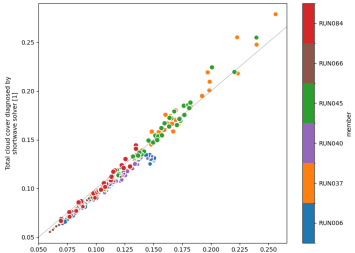
true cover vs overlap default



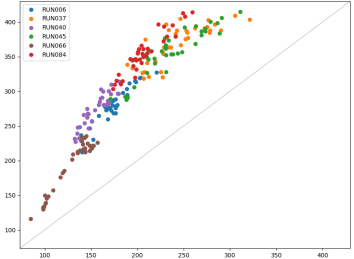
true cover vs true overlap



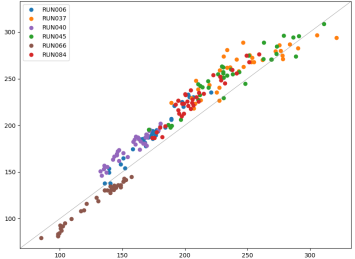
true cover vs scaled overlap



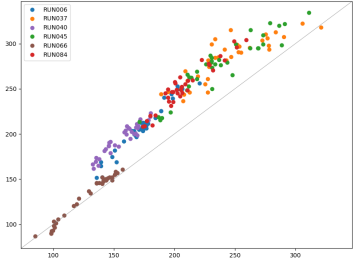
CRE/cover MC vs ecRad default



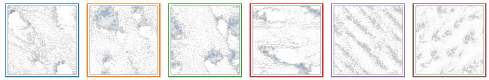
CRE/cover MC vs ecRad cloud geom



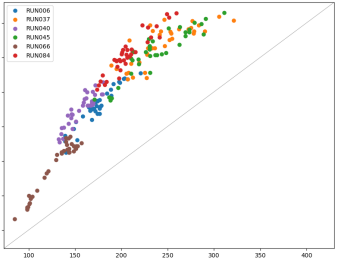
CRE/cover MC vs ecRad scaled overlap



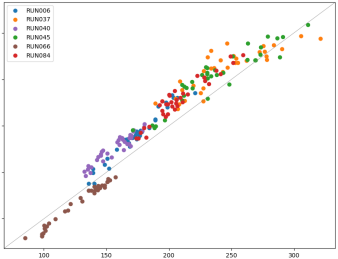
Effets radiatif des nuages paramétrisés – effets 3D



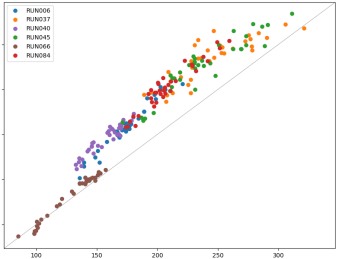
MC CRE/cover vs ecRad default



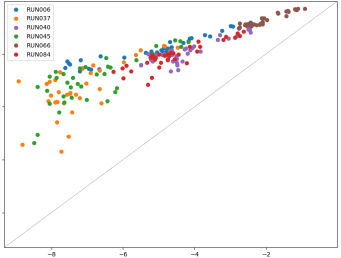
MC CRE/cover vs ecRad cloud geom



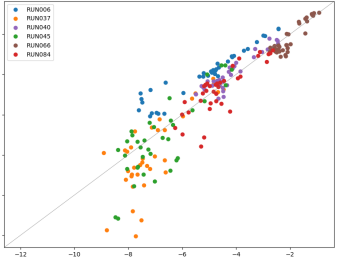
MC CRE/cover vs ecRad scaled overlap



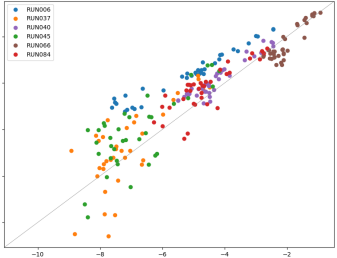
effets 3D MC vs ecRad default



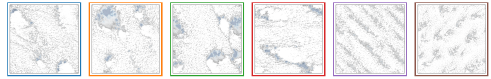
effets 3D MC vs ecRad cloud geom



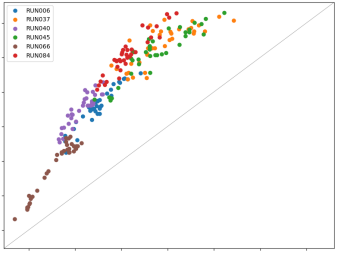
effets 3D MC vs ecRad scaled overlap



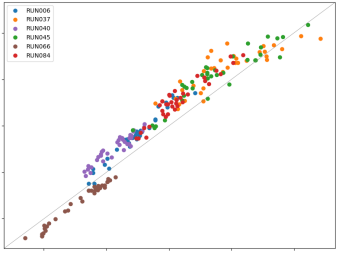
Effets radiatif des nuages paramétrisés – effets 3D



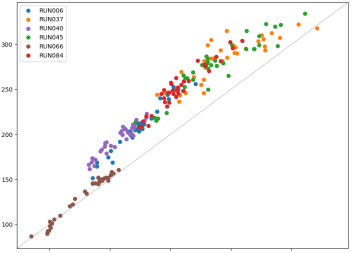
MC CRE/cover vs ecRad default



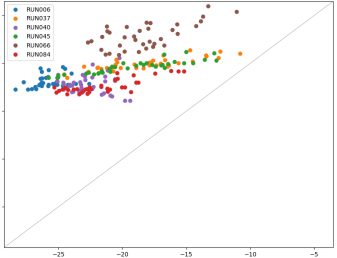
MC CRE/cover vs ecRad cloud geom



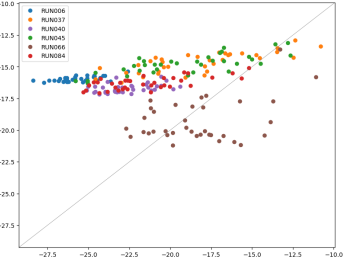
MC CRE/cover vs ecRad scaled overlap



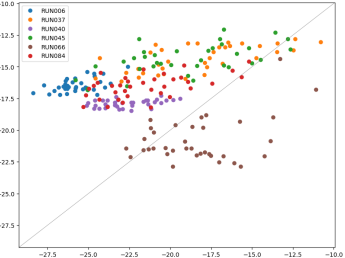
eff3D/CRE [%] MC vs ecRad default



eff3D/CRE [%] MC vs ecRad cloud geom



eff3D/CRE [%] MC vs ecRad scaled overlap



En guise de conclusion

- Que veut dire “représenter l'organisation des nuages bas” dans un GCM ?

- Réponse des SCMs aux différents forçages de grande échelle

  Au premier ordre les propriétés nuageuses moyennes correspondent à celles des LES
  Reste des progrès à faire notamment sur la pluie
  Thèse Adrien Marcel, modifs physique et calibration, bons profils nuageux mais pas pour la bonne pluie ?
  Représenter les poches froides dans les paramétrisations de convection peu profonde ?

- Effet radiatif des nuages organisés

  Côté rayonnement, on retrouve la dépendance au premier ordre à la couverture nuageuse, puis LWP
  L'organisation peut jouer sur les effets radiatifs 3D via la taille / le nombre de nuages ?
  Les processus radiatifs sont représentés dans les params de rayonnement
  Reste à faire le lien organisation vs. pptés géométriques des nuages vues par le rayonnement
  (overlap, hétérogénéité, taille ?)

$\Rightarrow$ Dephy + Botany = un super cadre pour travailler !