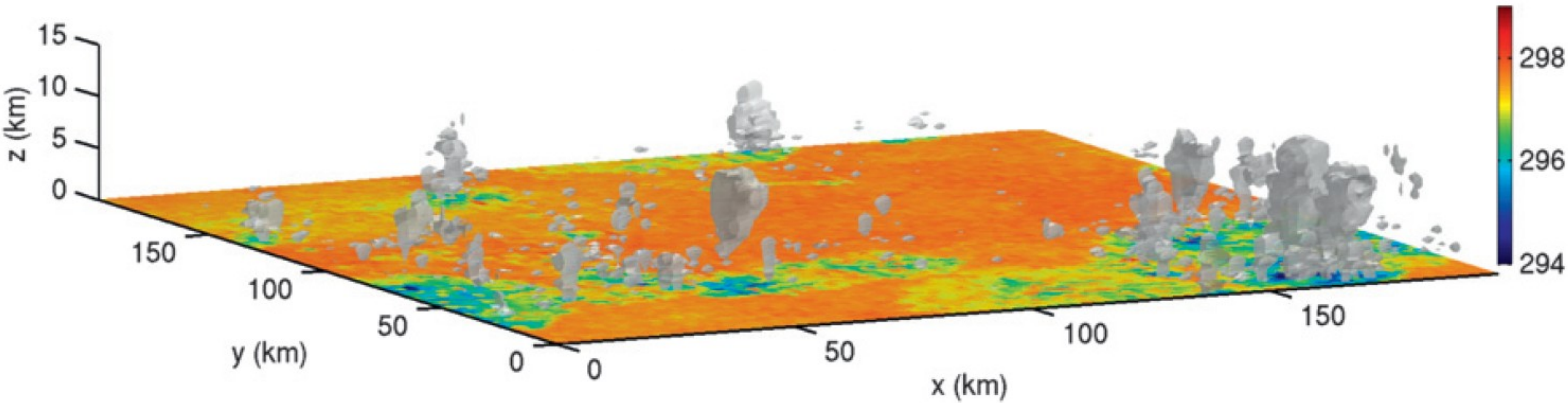
Coexistence of subgrid-scale convective processes within a GCM grid-cell: The picture inferred from a large-eddy simulation



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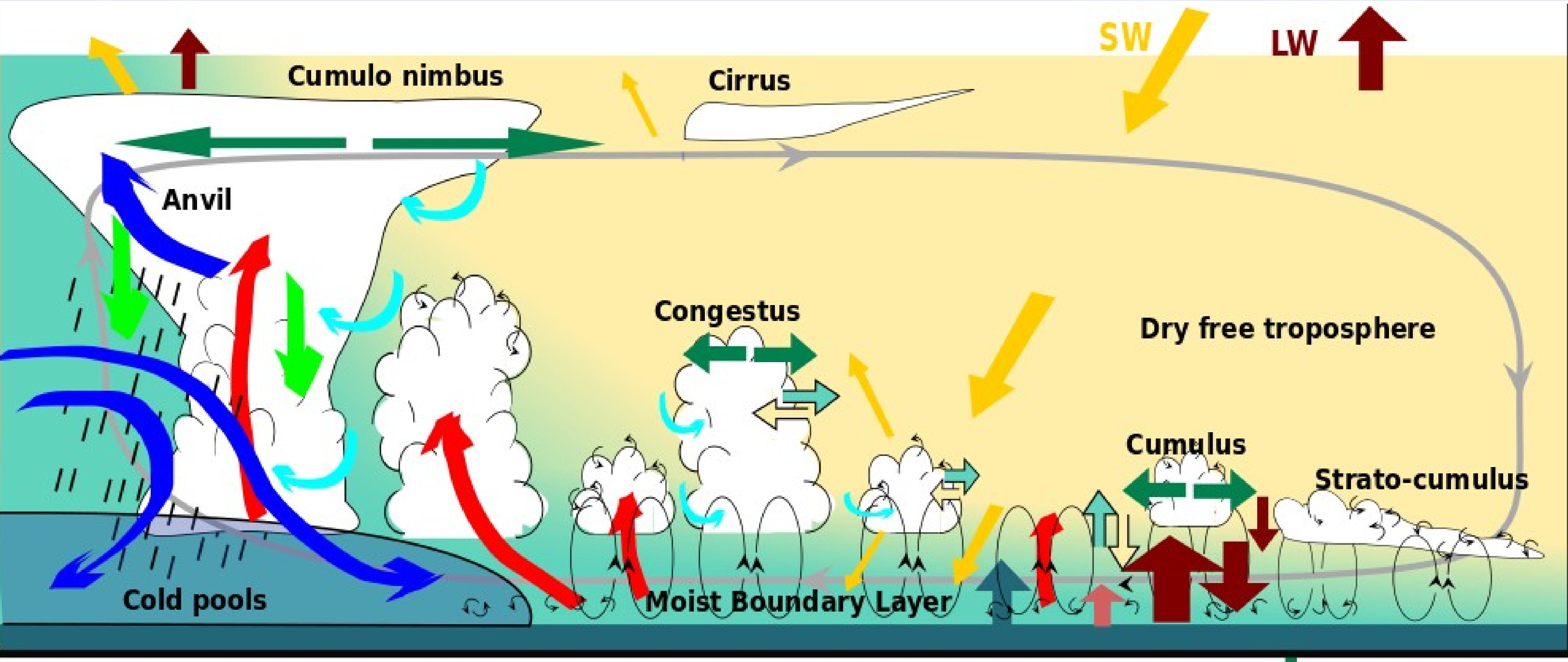
PARACON workshop – 18th of July 2019 - Exeter

Atmospheric convective processes targets for parameterizations

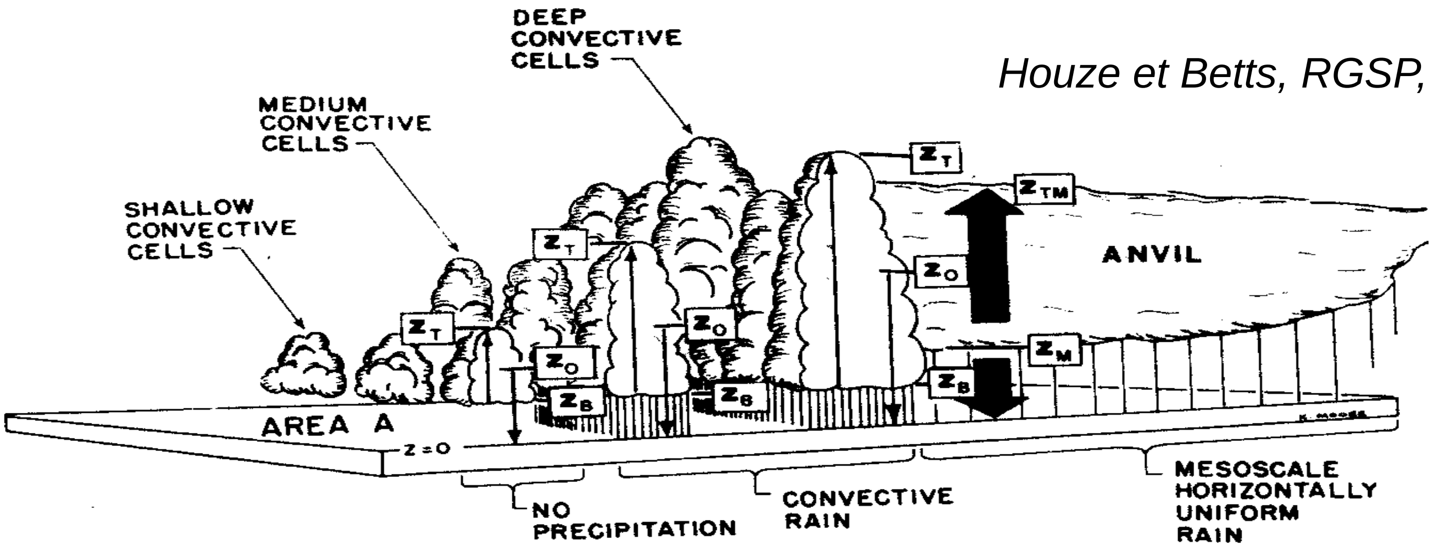


Rio et al., 2019

Parameterizations should be able to represent either dry, shallow or deep convection

But also their **co-existence** within a GCM grid cell

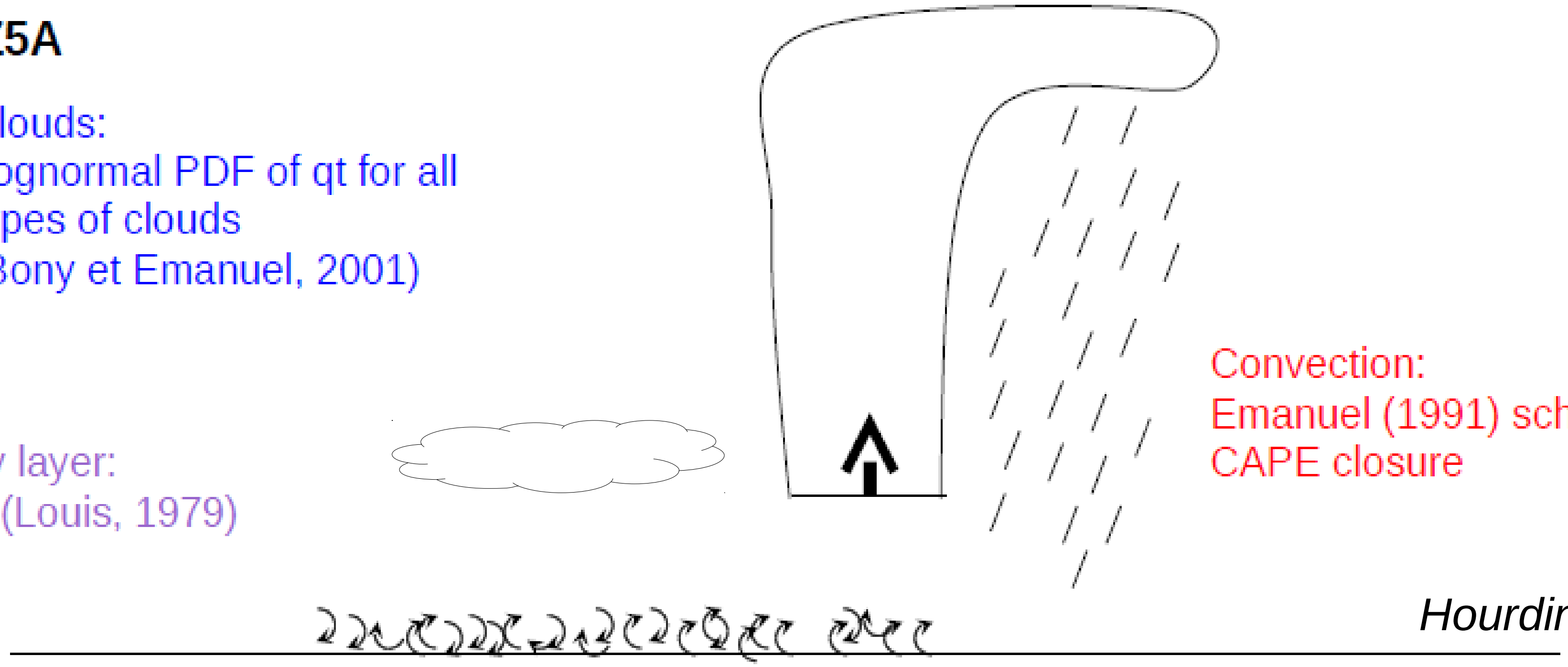
Parameterization of convection and clouds in LMDZ



Houze et Betts, RGSP, 1981

LMDZ5A

Clouds:
Lognormal PDF of qt for all types of clouds
(Bony et Emanuel, 2001)

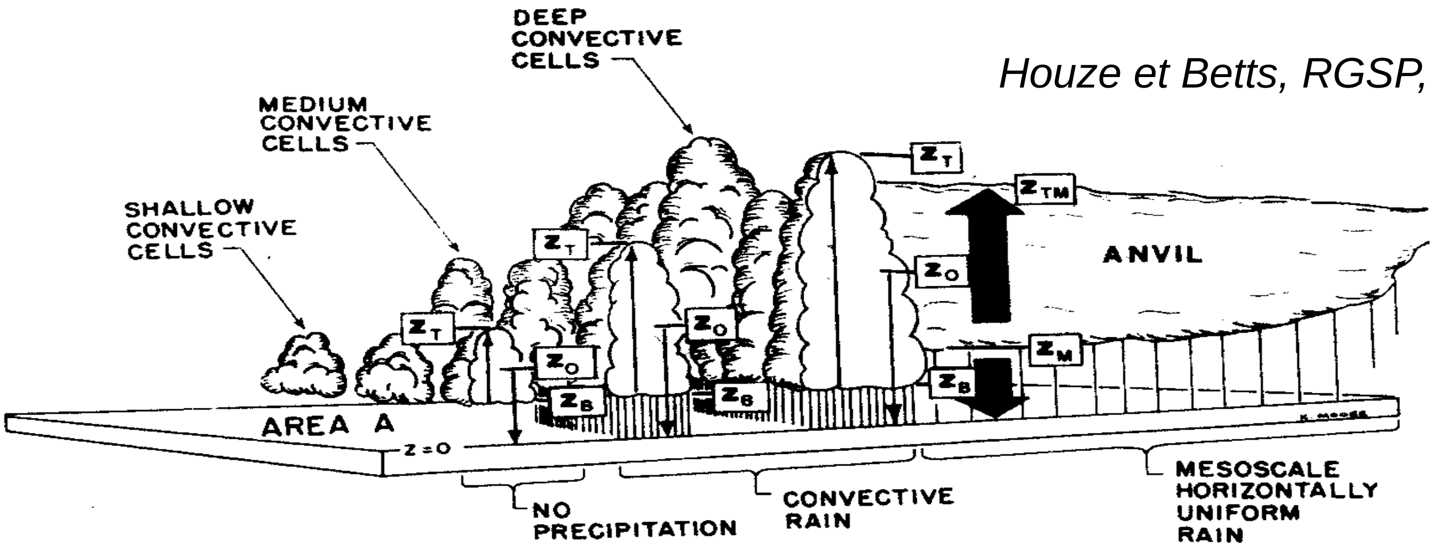


Boundary layer:
Diffusion (Louis, 1979)

Convection:
Emanuel (1991) scheme with CAPE closure

Hourdin et al., 2006

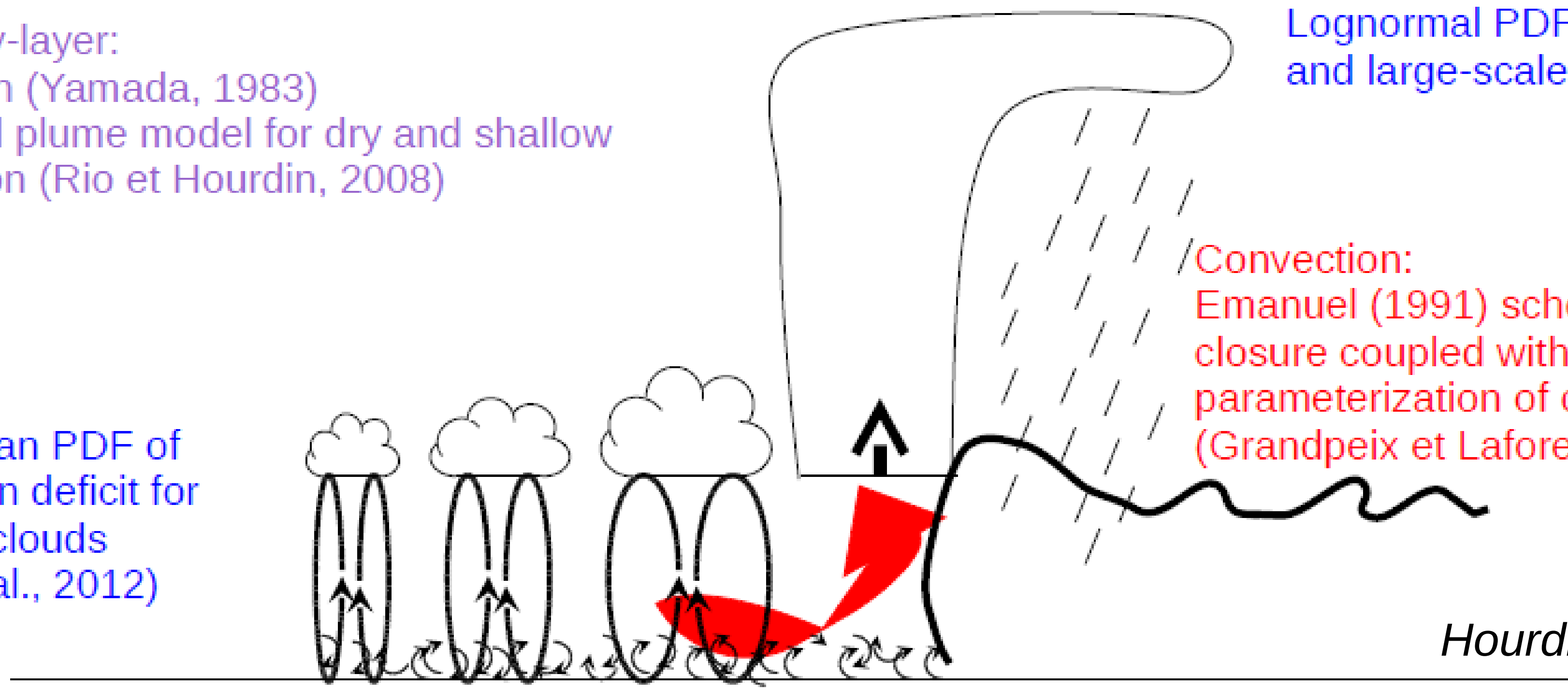
Houze et Betts, RGSP, 1981



LMDZ5B

Boundary-layer:
- Diffusion (Yamada, 1983)
- Thermal plume model for dry and shallow convection (Rio et Hourdin, 2008)

Clouds:
Lognormal PDF of qt for deep and large-scale clouds

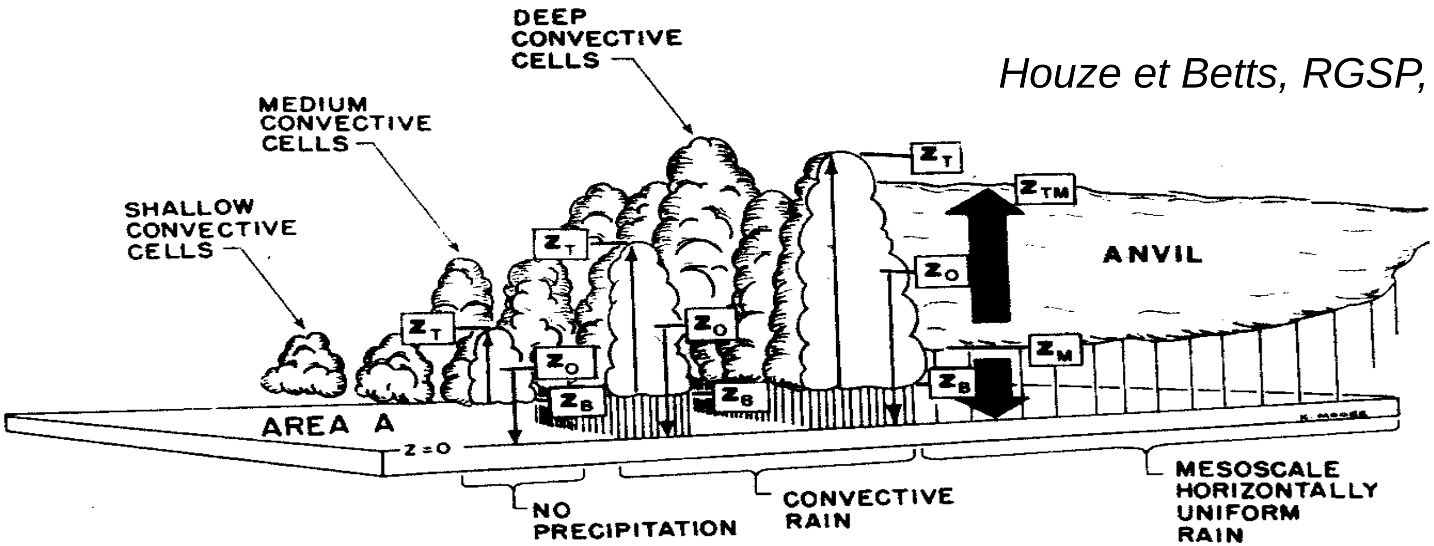


Convection:
Emanuel (1991) scheme with ALP closure coupled with a parameterization of cold pools (Grandpeix et Lafore, 2010)

Clouds:
Bigaussian PDF of saturation deficit for shallow clouds
(Jam et al., 2012)

Hourdin et al., 2013

Parameterization of convection and clouds in LMDZ

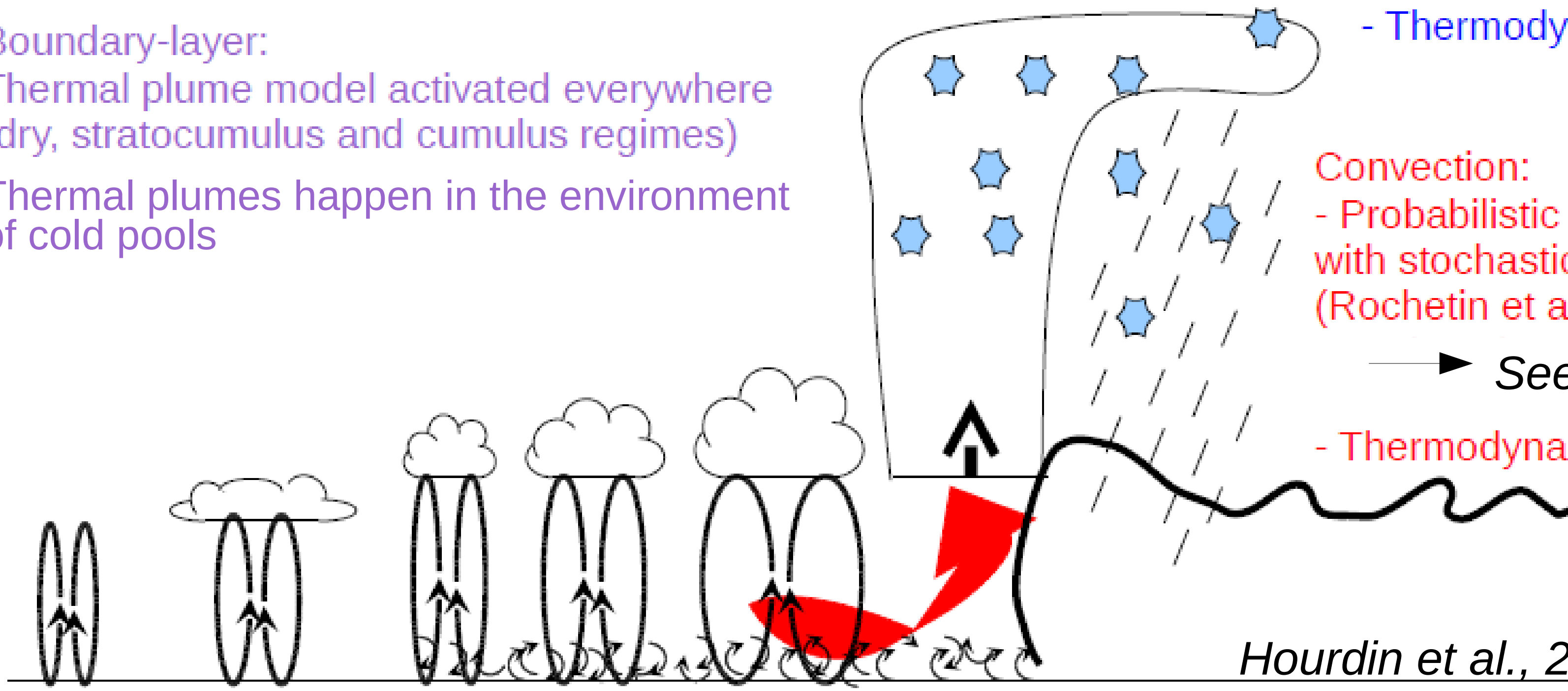


Houze et Betts, RGSP, 1981

LMDZ6A : LMDZ5B +

Boundary-layer:
Thermal plume model activated everywhere (dry, stratocumulus and cumulus regimes)

Thermal plumes happen in the environment of cold pools



Convective and large-scale clouds:
- Thermodynamical effect of ice

Convection:
- Probabilistic triggering formulation with stochastic component (Rochetin et al., JAS, 2014)

→ *See Nicolas' talk*

- Thermodynamical effect of ice

Hourdin et al., 2019, in preparation

Parameterization of convection and clouds in LMDZ

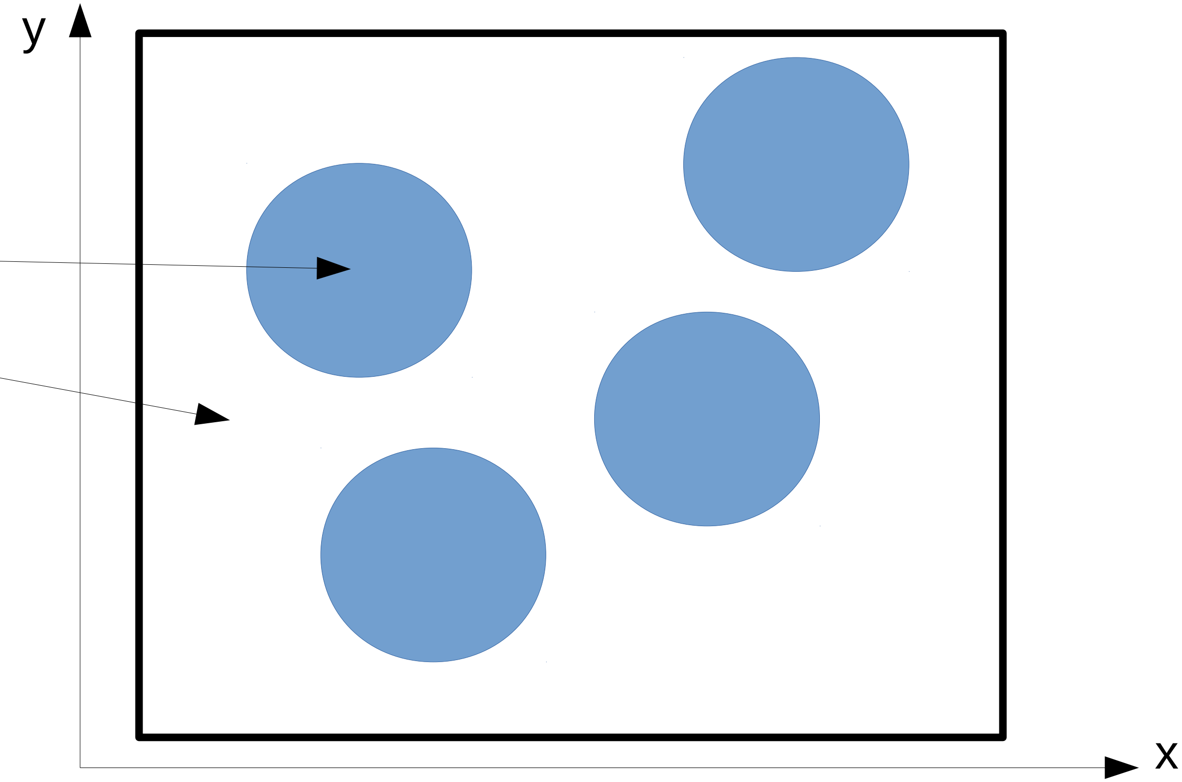
Parameterization of the coupling between boundary-layer thermals, deep convection and cold pools

The grid cell is split into two parts below 600hPa :

- the wake area and

- the environment of wakes

Imposed density of cold pools :
5B : 8.e-12
6A : 1.e-9



Thermodynamical coupling :
Deep convective updrafts happen in the environment of wakes while
Unsaturated precipitating downdrafts fall into the wake area
Boundary-layer thermals either see the mean environment (5B) or the environment of wakes (6A)

Dynamical coupling :
Boundary-layer thermals and cold pools provide :
An available lifting energy (ALE) compared to CIN to trigger convection
An available lifting power (ALP) used for the closure

An additional coupling between the thermal plume model and the cold pools is underway
→ See Ludovic Touze Peiffer's talk

Impact on precipitation variability

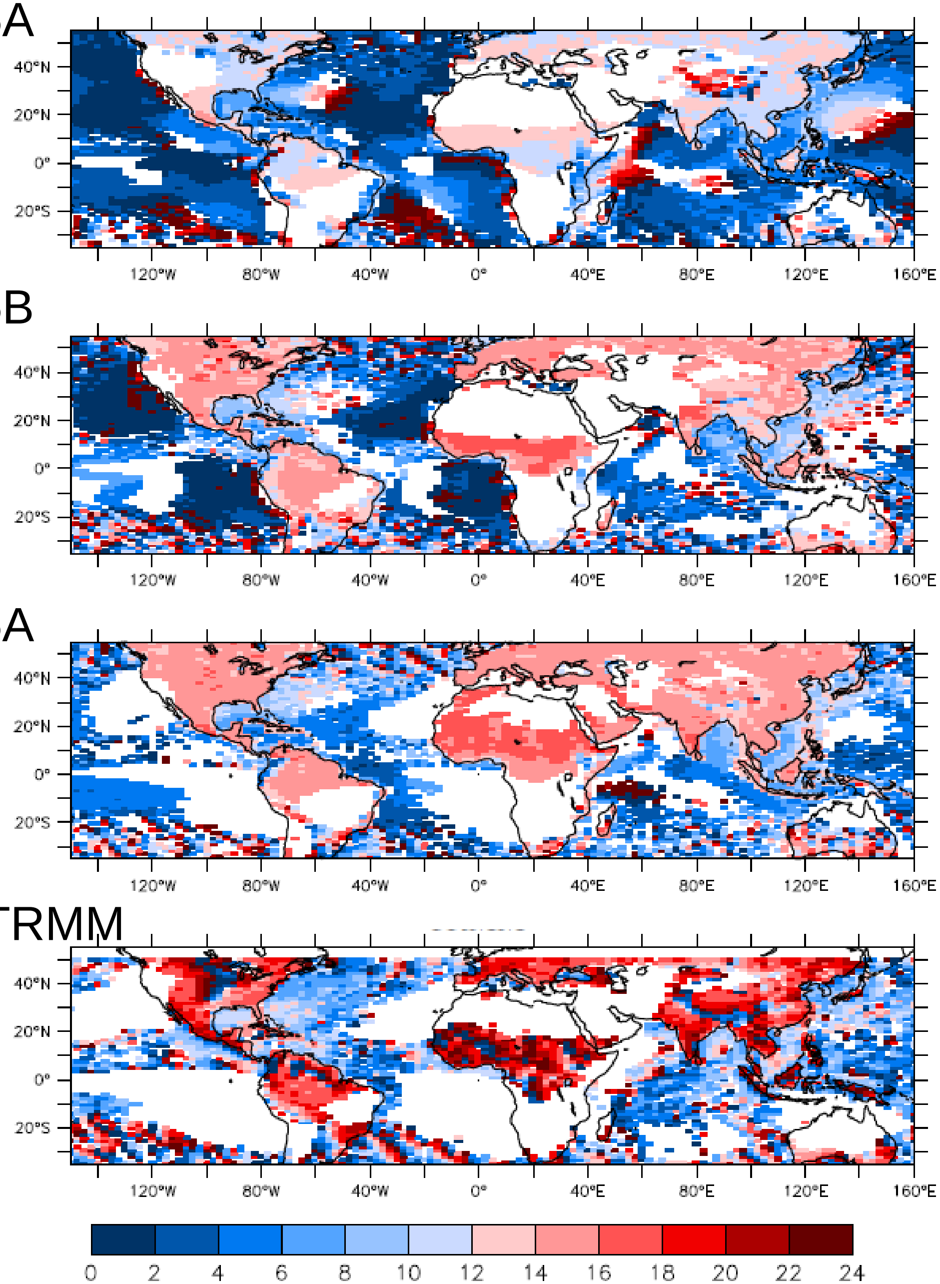
Local hour of precipitation maximum

5A

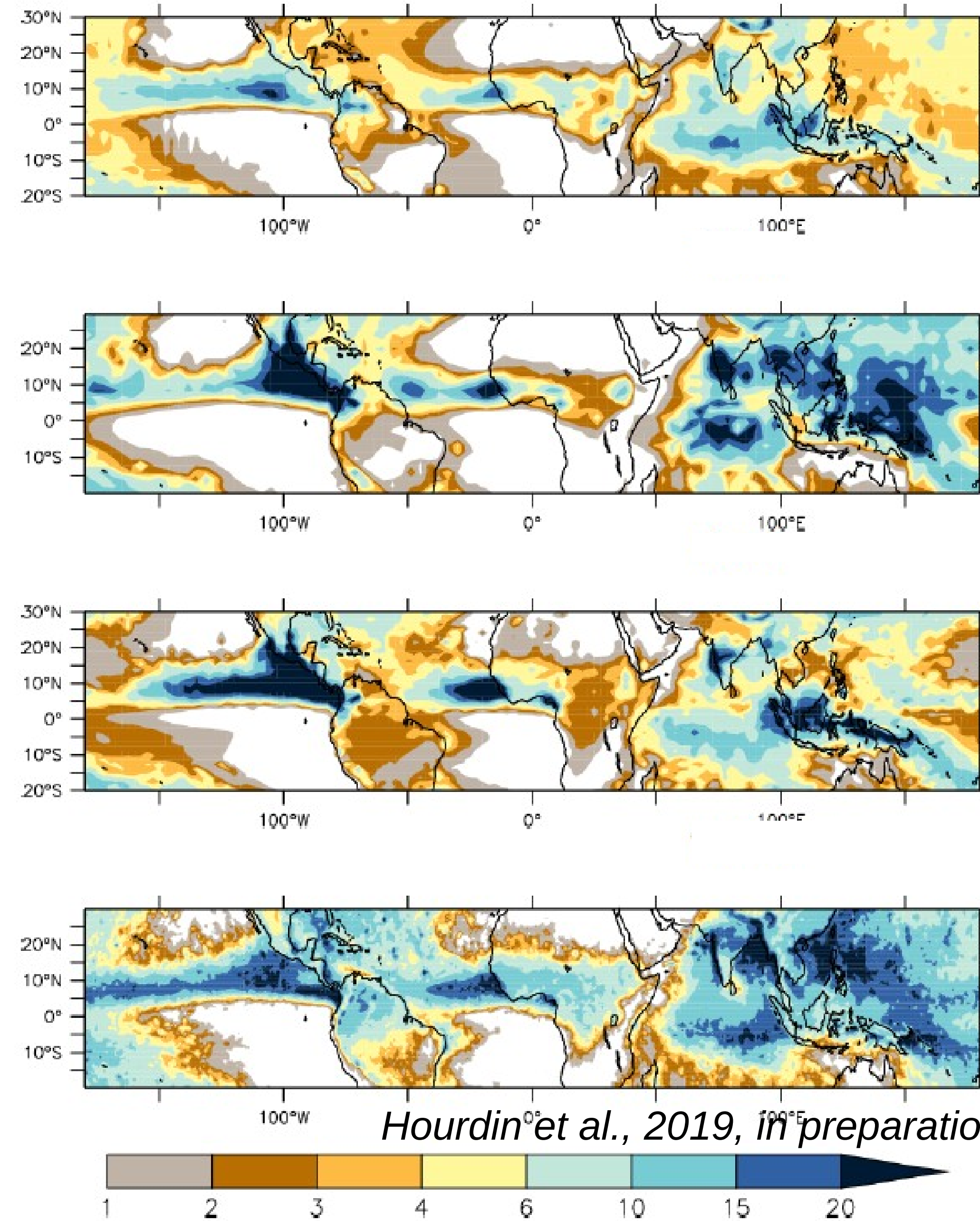
5B

6A

TRMM



Variability of precipitation (mm/day)



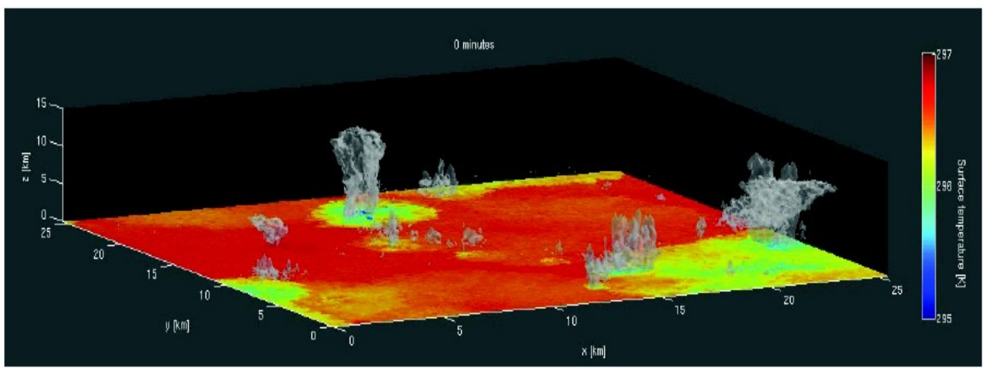
Hourdin et al., 2019, in preparation

Importance of the respective role of shallow versus deep convection :
How to better constrain the shallow/deep partitioning when both are active simultaneously?

An idealized framework

A simulation of radiative/convective equilibrium over ocean:
imposed radiation (-1.5 K/day)
SST=300K
Initialization of temperature and relative humidity
Horizontal wind nudging
No rotation

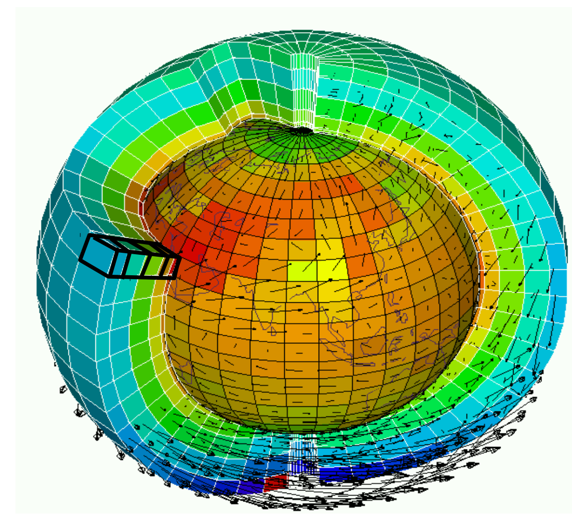
LES simulation using the SAM non-hydrostatic model



Clouds (grey) and surface potential temperature (colors)

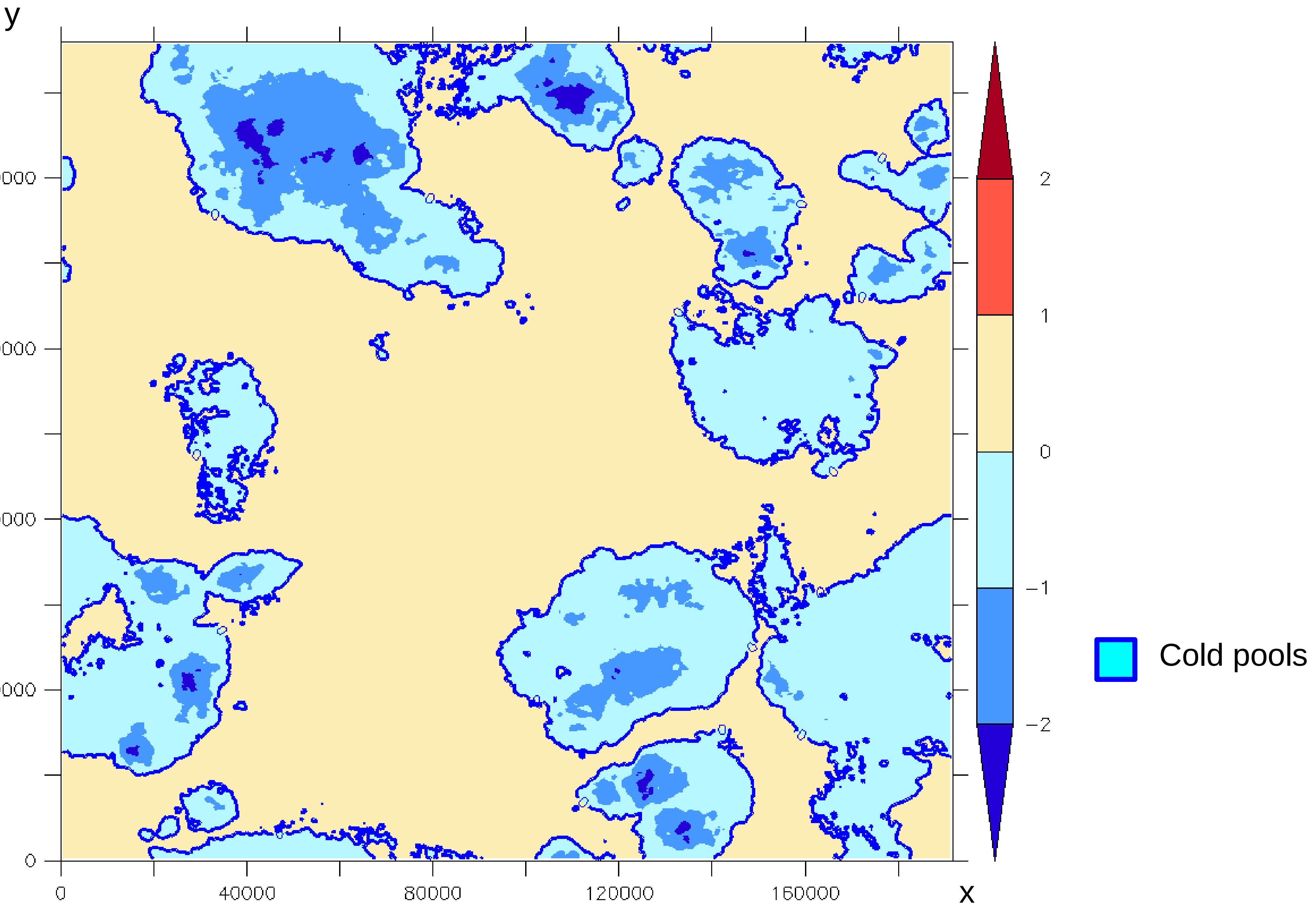
same forcing

LMDZ in single-column mode

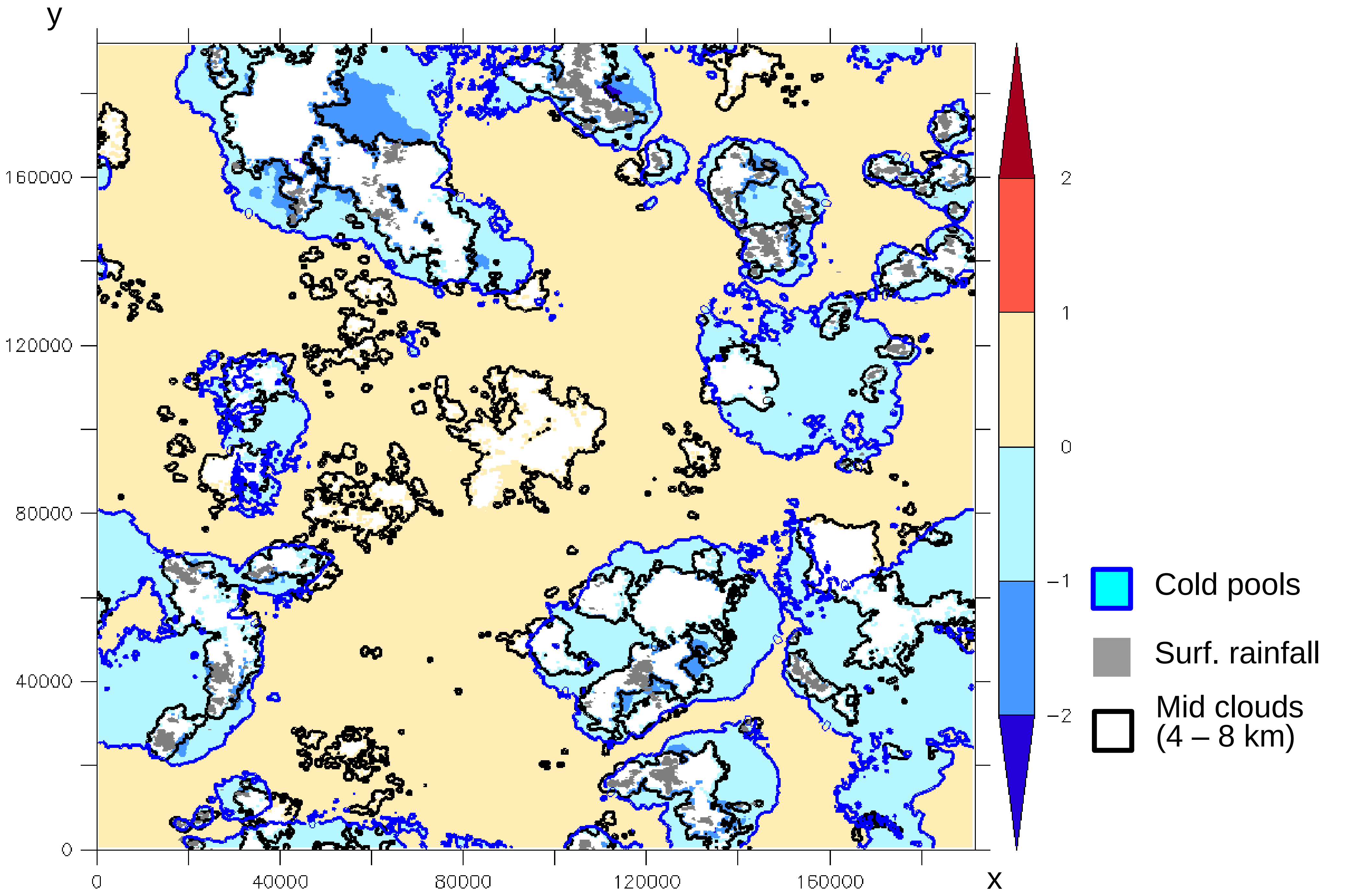


Domain: 190kmx190km
dx=dy=250m
Equilibrium reached after 40 days

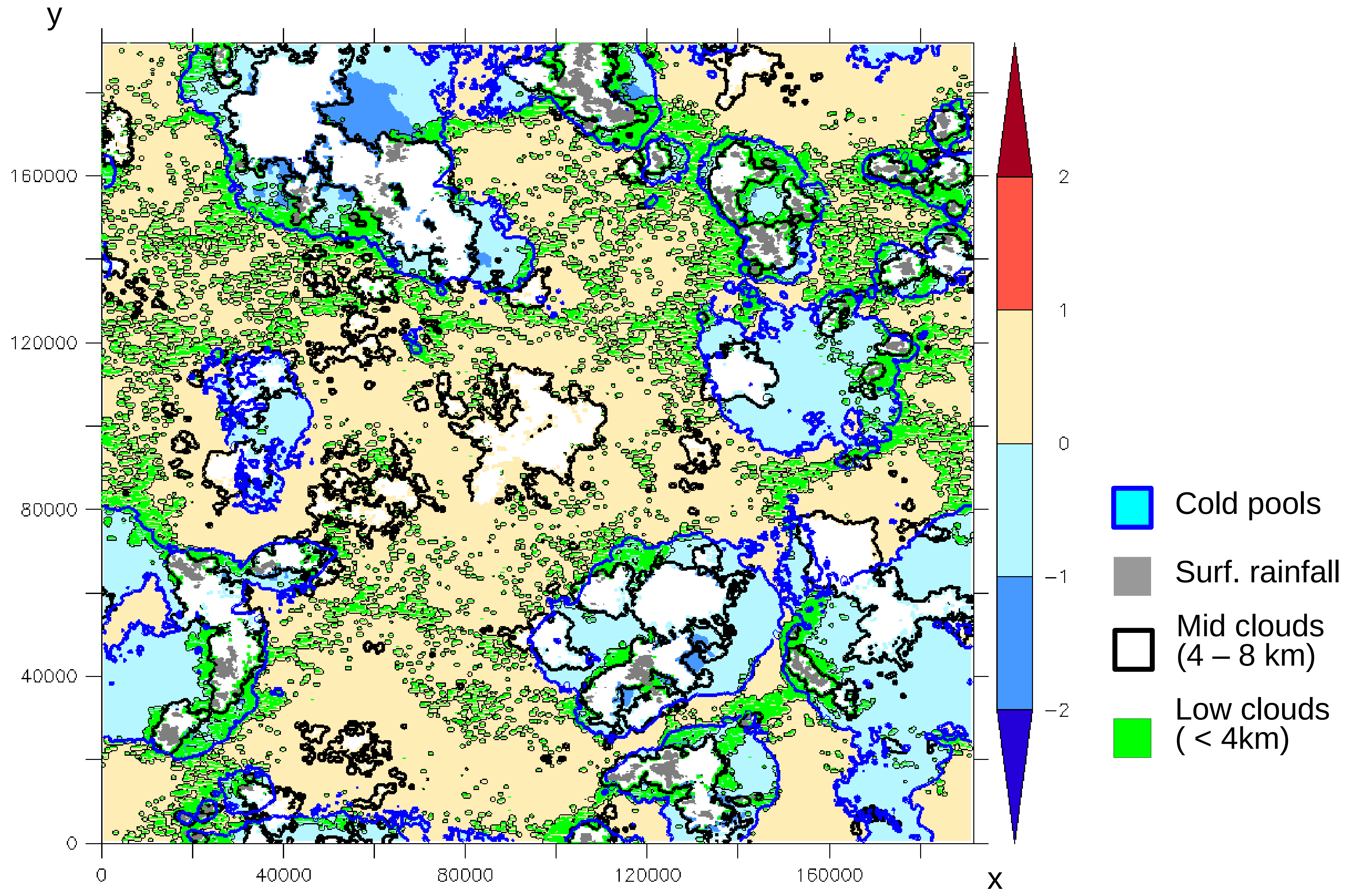
Convection and clouds within the LES



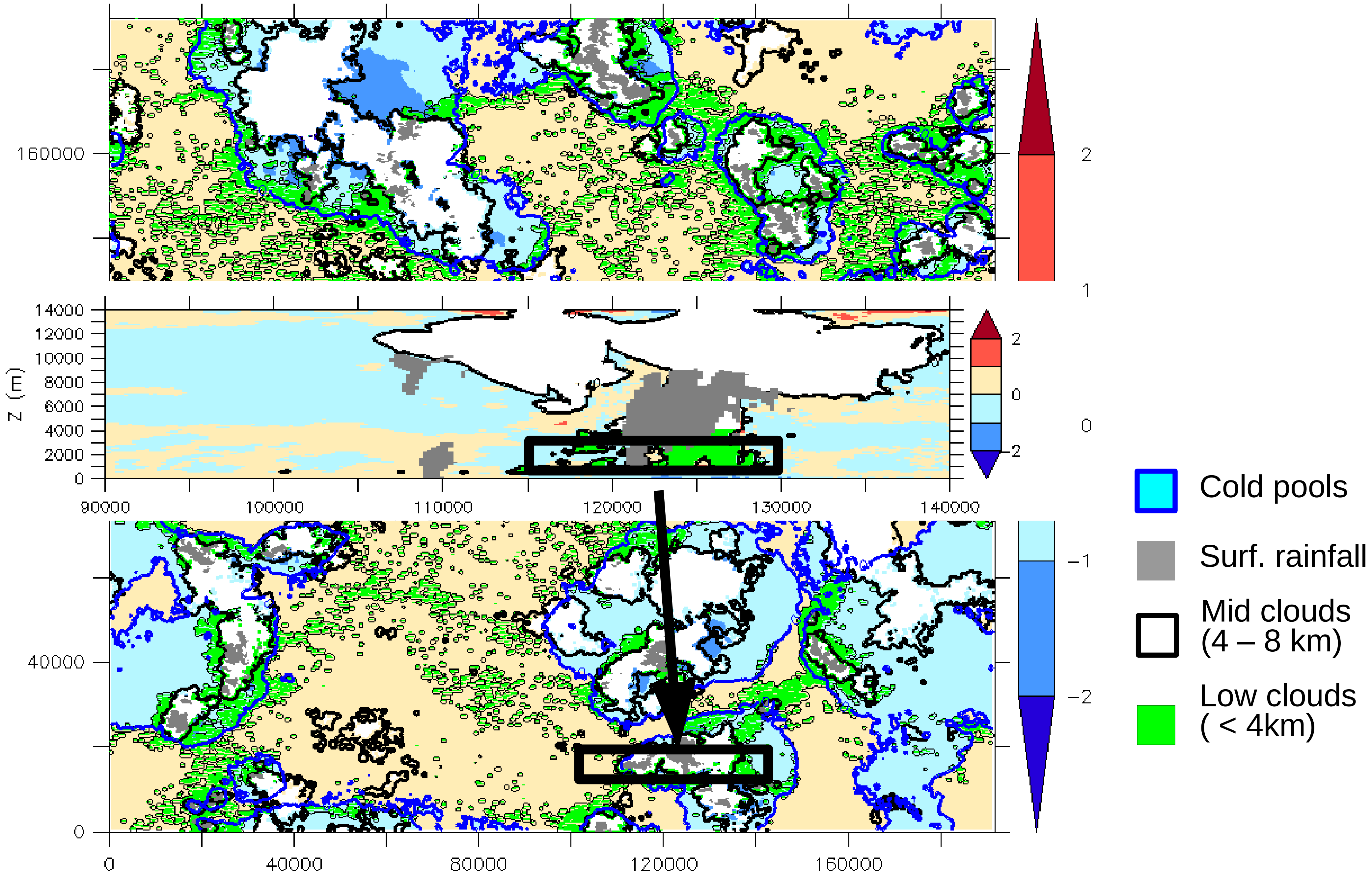
Convection and clouds within the LES



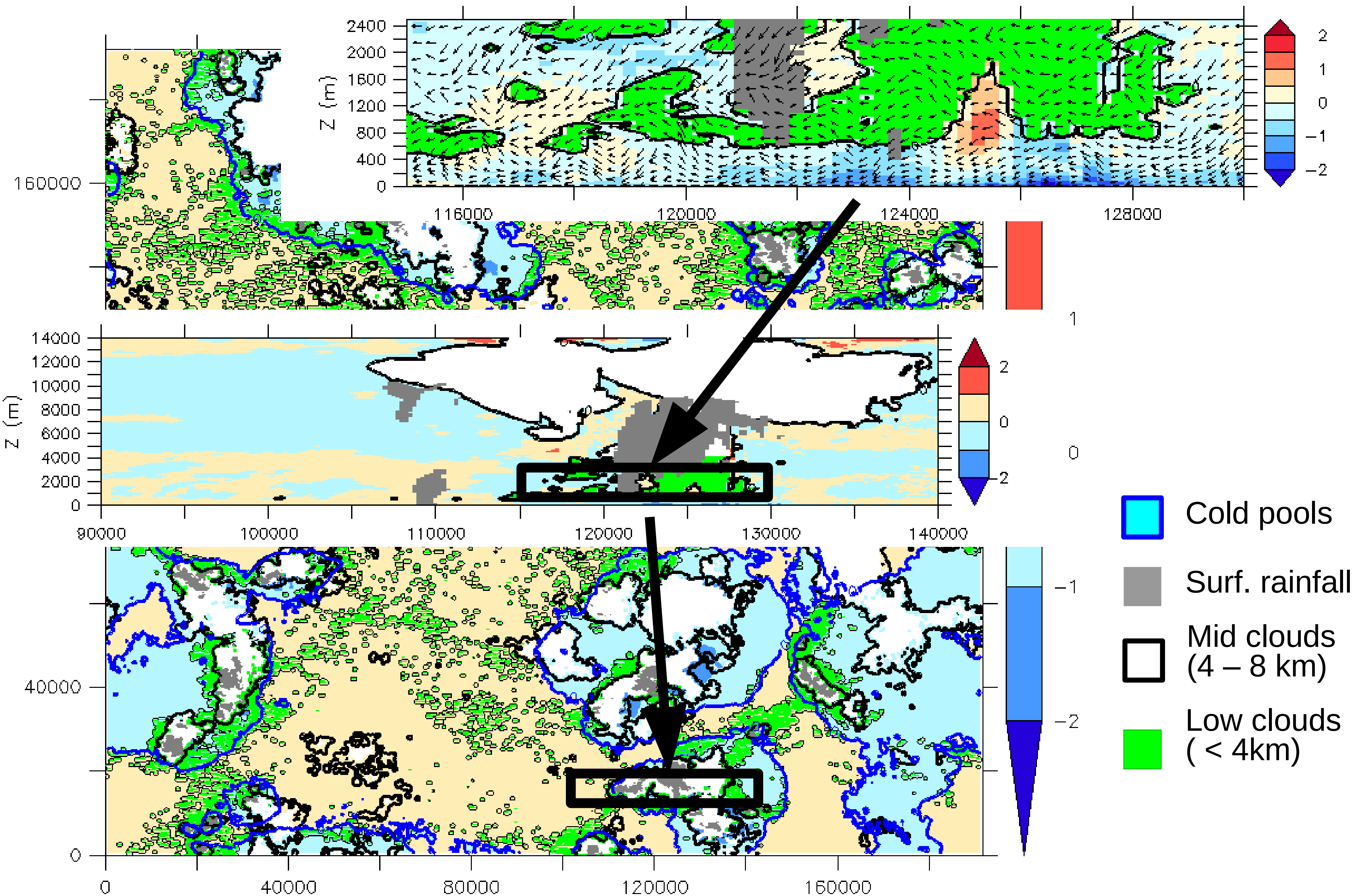
Convection and clouds within the LES



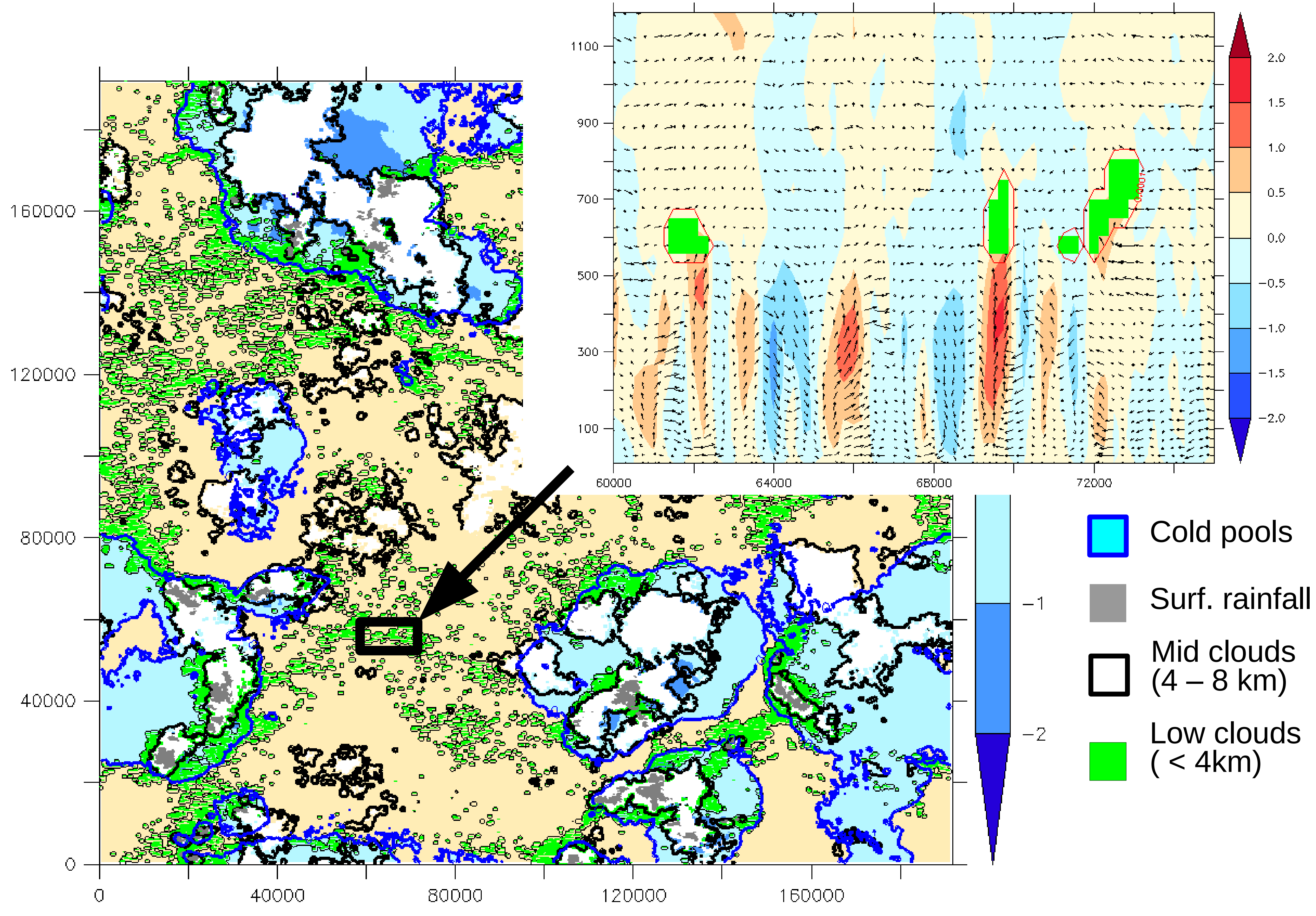
Convection and clouds within the LES



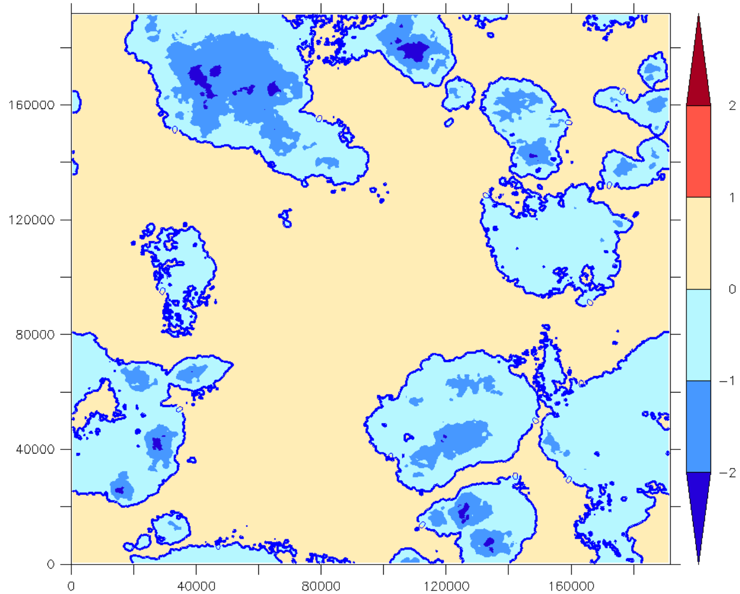
Convection and clouds within the LES



Convection and clouds within the LES



Splitting the grid cell into two environments



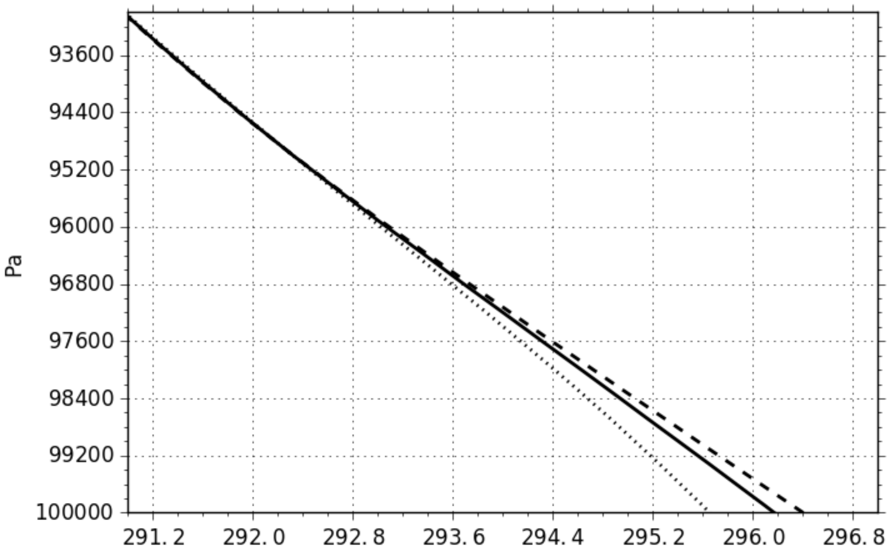
Cold pool mask at the surface

Mean environment

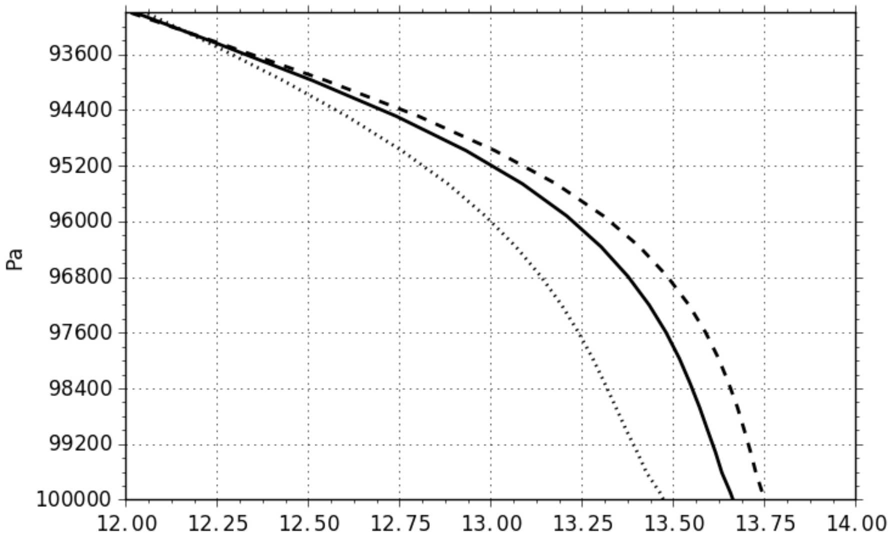
Cold pool region

Environment of the cold pool

Temperature (K)

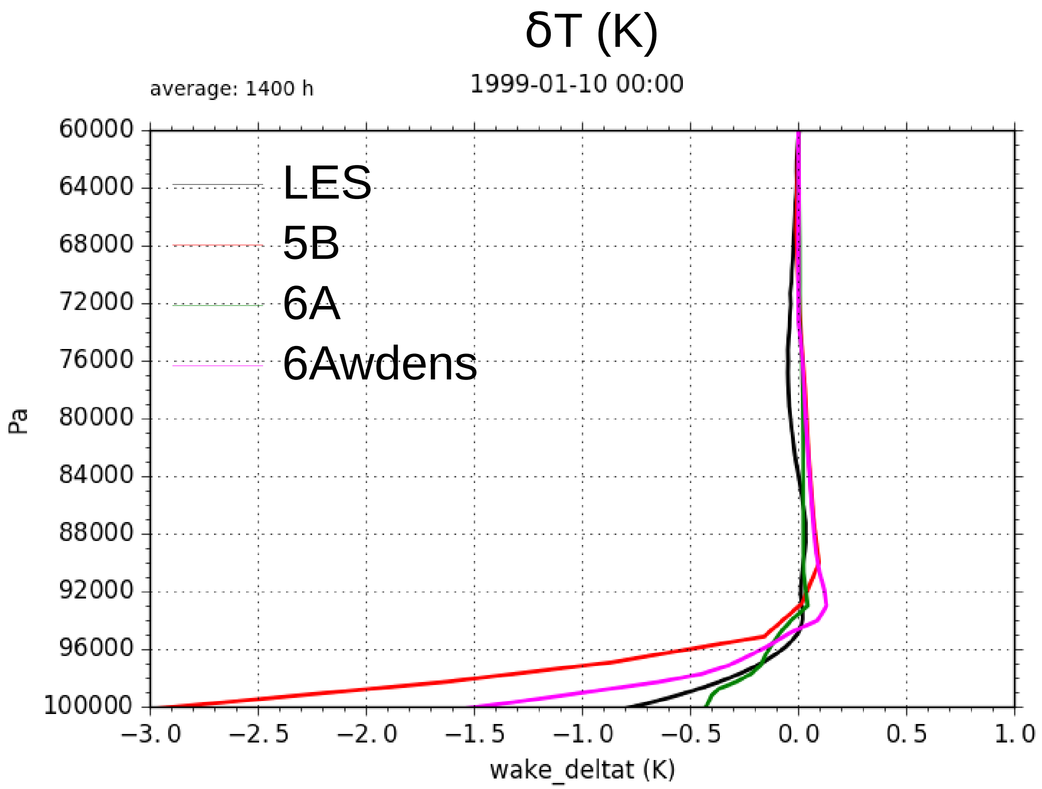


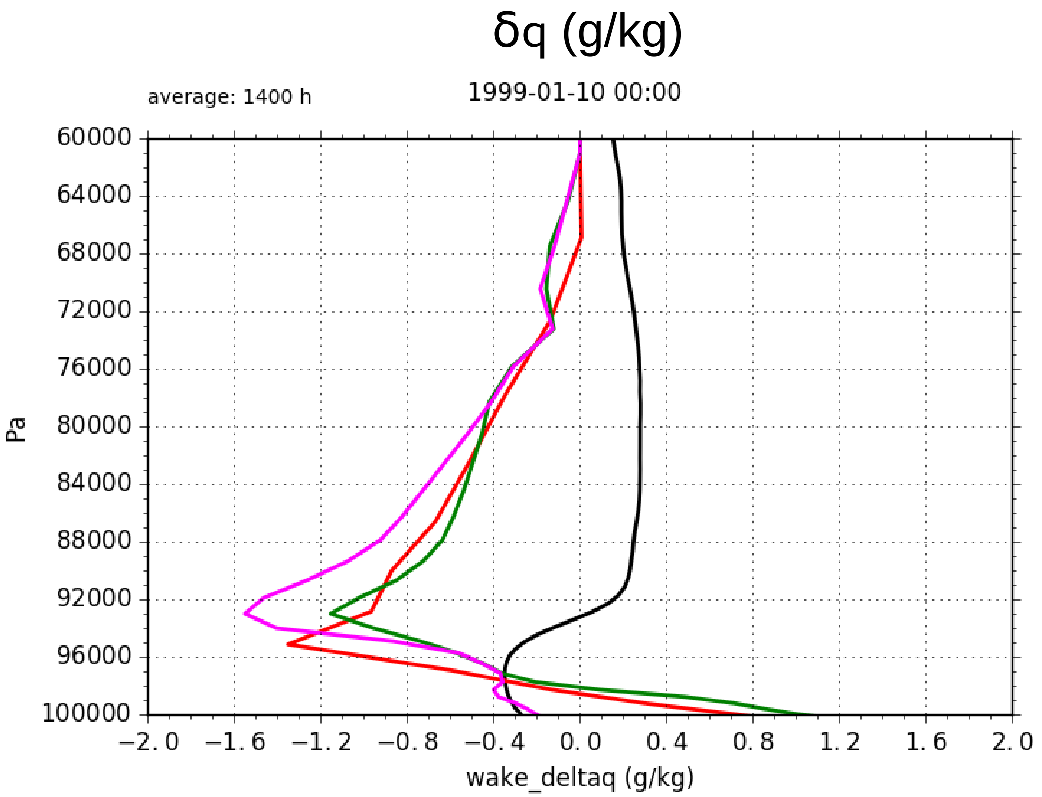
Specific humidity (g/kg)



- Convection initiates in a warmer and moister environment
- Sub-grid variability of CAPE and CIN

Difference of temperature and moisture between inside and outside cold pools





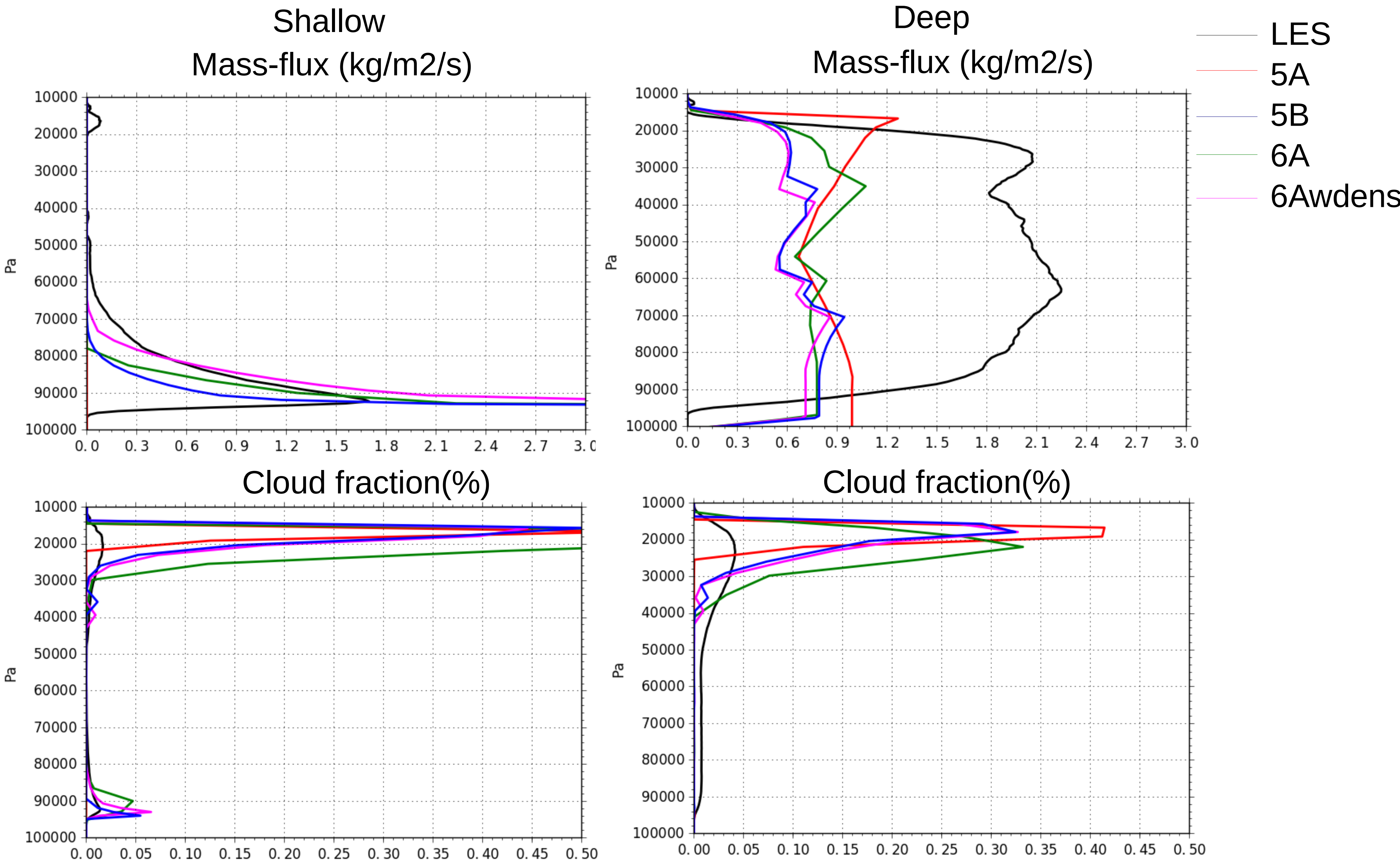
- Cold pools too cold and moist near the surface (5B)

- Making boundary-layer thermals active outside cold pool area and largest cold pool density weakens cold pool T anomalies (6A)

- The density of cold pools is an important variable of the scheme :

Development of a pronostic equation for the wake density (6Awdens simulation)

Partitioning between shallow and deep convection

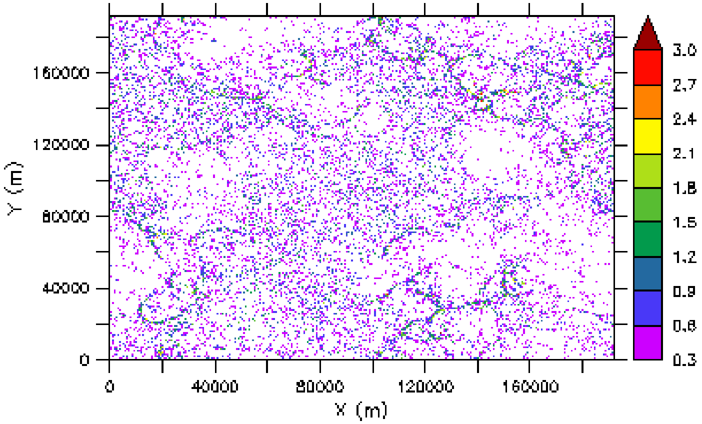


- Representation of shallow convection close to LES for largest cold pool density
- Underestimation of deep convective mass-flux and mid-level convective clouds
- Overestimation of clouds computed by the large-scale condensation scheme

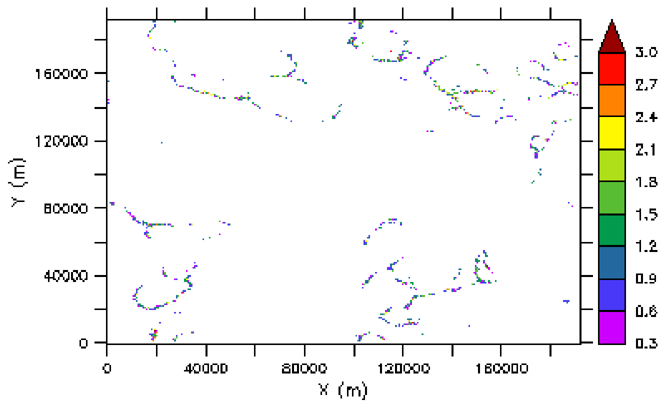
Available Lifting Energy and Power

Estimation of w² et w’3 at cloud base in the LES

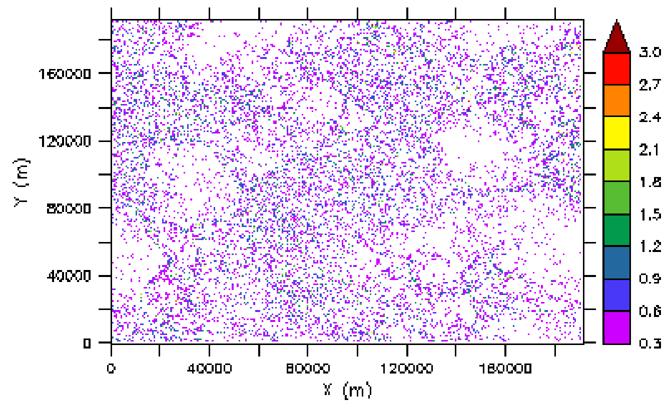
w at cloud-base



w along gust front



w within thermals



J/kg	**LES**	**5B**	**6A**	**6Awdens**
ALE_th	7.5	0.6	4.7	3.8
ALE_wk	8.9	27.2	2.6	12.4

W/m2	**LES**	**5B**	**6A**	**6Awdens**
ALP_th	0.08	0.005	0.013	0.006
ALP_wk	0.04	0.006	0.0015	0.005

→ Competition between thermals and cold pools

→ Underestimation of the available lifting power : due to errors in the representation of thermal fractional cover and gust front length

Conclusions

A RCE LES simulation for parameterization evaluation/development

Exploration of the LES simulation validates the conceptual model behind the physical parameterizations of the LMDZ model

The LES simulation can be used to evaluate and improve the representation of the internal variables of the schemes

To come:

Run the RCE simulation with the MESONH model

Characterization of updrafts and downdrafts by the use of tracers and object identification algorithm

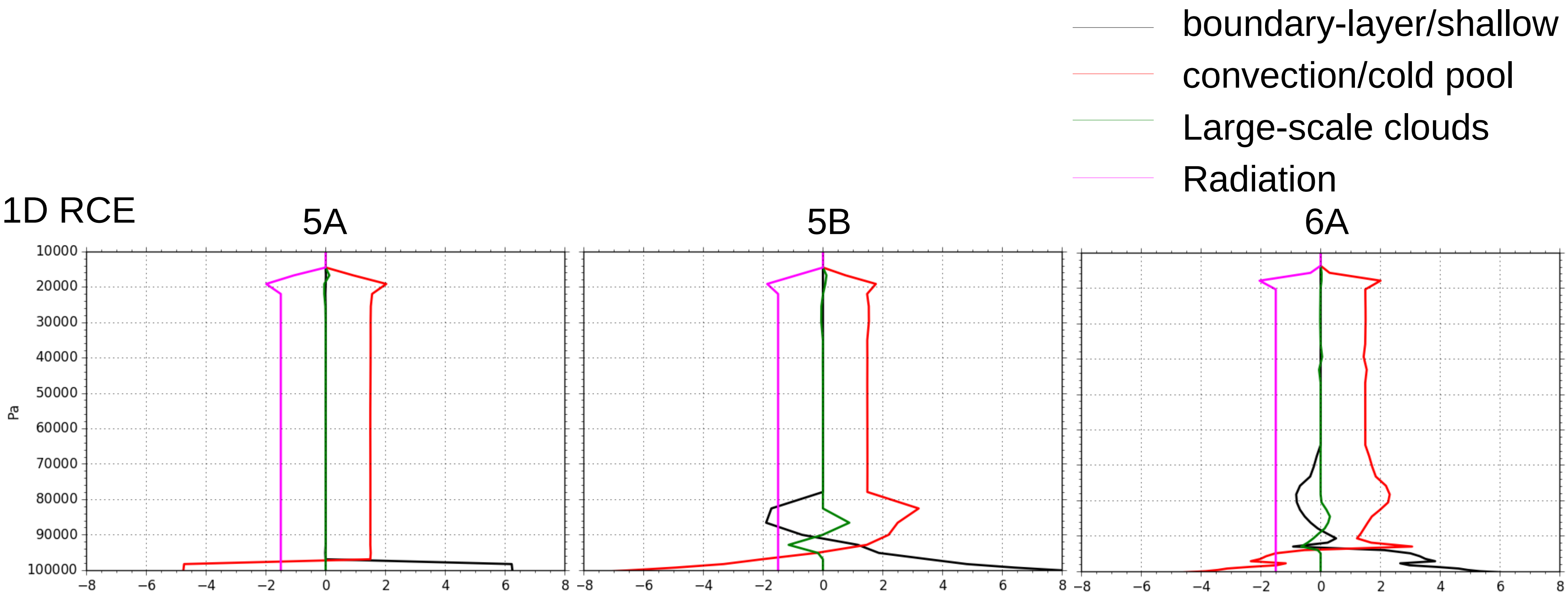
Apply various perturbations/forcing to the RCE to study the response of shallow/deep partitioning

Needed :

Relevant observations to evaluate/constrain the shallow/deep/cold pool partitioning at the global scale

1D RCE versus 3D global simulations

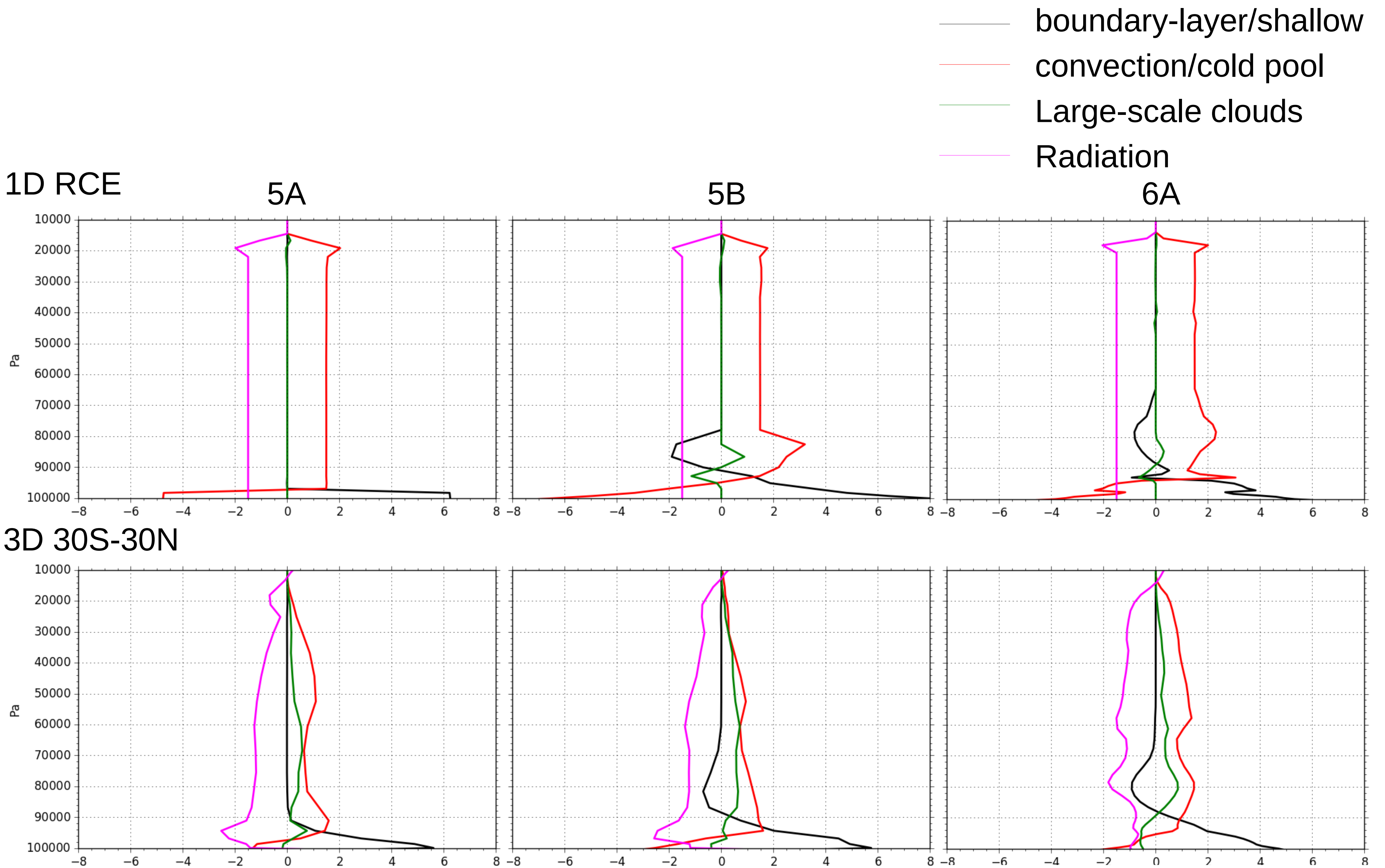
Contribution of the parameterizations to the temperature tendency (K/day)



To what extent is the 1D RCE framework representative of the full 3D model behavior ?

1D RCE versus 3D global simulations

Contribution of the parameterizations to the temperature tendency (K/day)



→ Use the LES to constrain shallow/deep partitioning and their interactions