Development of a new prognostic convection scheme for NWP and climate Arpege global model

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(presented by F. Bouyssel)
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Outline

- Equations and concepts
- Multi-environments validation
- Conclusions and prospects

PCMT : general description

"PCMT": Prognostic Condensates Microphysics and Transport

- 5 prognostic equations for convective hydrometeors (cloud droplets, ice crystals, rain, snow) and vertical velocity
- Grid-scale equations from the convection scheme separate microphysical processes and transport processes (Piriou et al., 2007)
- Same microphysics (Lopez, 2002) used for resolved and convective precipitations (called twice)
- Triggering condition, mass flux, entrainment based on buoyancy. CAPE relaxation time for closure (Gueremy, 2011)

Piriou J.-M., J.-L. Redelsperger, J.-F. Geleyn, J.-P. Lafore and F. Guichard, 2007: An approach for convective parameterization with memory, in separating microphysics and transport in grid-scale equations , J. Atmos. Sci., Volume 64, Issue 11, pp. 4127–4139

Gueremy, J. F., 2011: A continuous buoyancy based convection scheme: one- and three-dimensional validation. Tellus A, 63: 687–706.

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PCMT : general description

$\partial q/\partial t = \partial/\partial p[M(q_c - q)] - C$, separation of transport and microphysics;

Instead of $\partial q/\partial t = -M\partial q/\partial p + D(q_c - q)$

q specific humidity; M mass flux, C condensation et D detrainment

$$
\begin{aligned}
\frac{\partial}{\partial t}\overline{q_{lc}} \quad = \quad & \mathrm{Advec}(\overline{q_{lc}}) \\
& -\frac{1}{\rho}\frac{\partial}{\partial z}\rho\left[\alpha_u w_u + \alpha_d w_d\right] q_{lc} \\
& +\left(E_u + E_d\right) q_{lr} - \left(D_u + D_d\right) q_{lc} \\
& +\mathrm{CondensEvap}_{q_{lc}} - \mathrm{AutoconvColl}_{q_{lc}} + \mathrm{MeltingIcing}_{q_{lc}}
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial}{\partial t}\overline{q_{lr}} \quad = \quad & \mathrm{Advec}(\overline{q_{lr}}) \\
& -\frac{1}{\rho}\frac{\partial}{\partial z}\rho\left[-\alpha_u w_u - \alpha_d w_d\right] q_{lr} \\
& -\left(E_u + E_d\right) q_{lr} + \left(D_u + D_d\right) q_{lc} \\
& +\mathrm{CondensEvap}_{q_{lr}} - \mathrm{AutoconvColl}_{q_{lr}} + \mathrm{MeltingIcing}_{q_{lr}}
\end{aligned}
$$

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PCMT : general description

From bottom to top, considering an unique bulk ascent, are computed the ascent profile, the vertical velocity, the fractional entrainment-detrainment and the normalised fraction ; then the bottom convective fraction using an integral closure condition.

- Ascent profile: entrainment process followed by an adiabatic ascent (vertical conservation of static energy, dry or moist).
- Prognostic equation for vertical velocity based on buoyancy and including aerodynamic drag
- Entrainment and detrainment : Sum of i) turbulent circulation at the edge of the updraft (function of vertical velocity), ii) organized: mesoscale circulation (Bretherton et al., 2004).
- The normalised fraction is obtained from the mass budget, decreasing from 1 at the bottom. It is calculated with the mass conservation equation.
- The triggering condition is given by the sign of the vertical velocity.
- The closure condition is a CAPE relaxation which provides the bottom convective fraction

Multi-environments validation

A hierarchy of configurations used to characterize (and better understand?) the development of model errors :

Strongly constrained → Weakly constrained

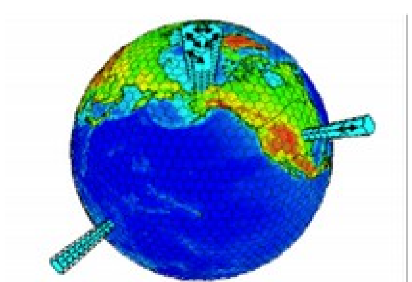
1D model
Pros: obs, LES, Initial conditions and forcings prescribed
Cons: local, few cases, no coupling with dynamics

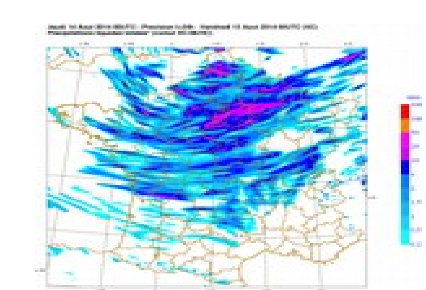
NWP
(short, medium range)
Pros: obs, analysis, forecaster evaluation, Synoptic scales well simulated, Evaluation of fast physical processes
Cons: initial conditions

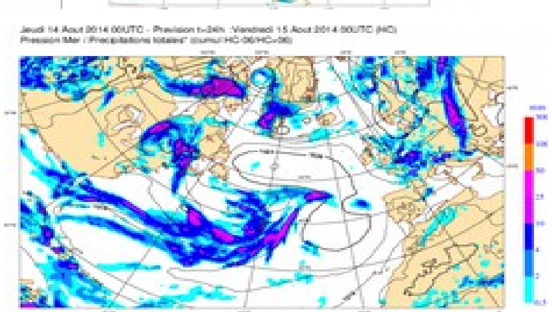
Seasonal
Pros: obs, analysis
Cons: ocean initial conditions, interactions between physics and dynamics

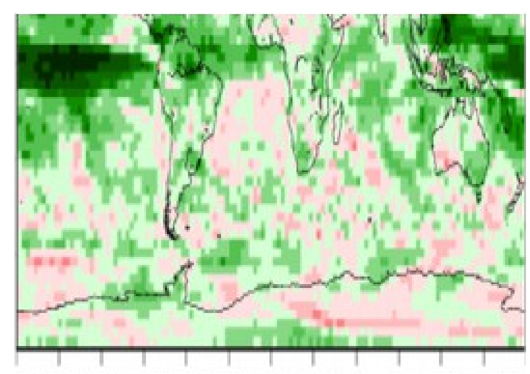
AMIP
Pros: obs, reanalysis
Cons: interactions between physics and dynamics

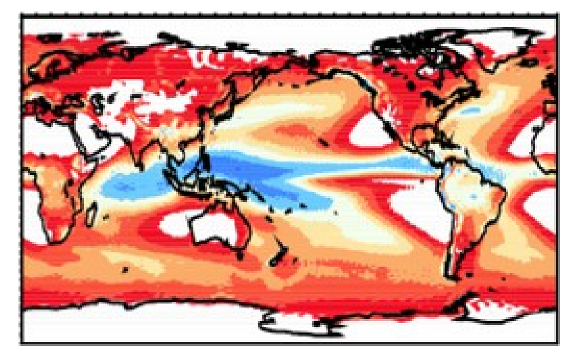
CMIP
Pros: obs, reanalysis
Cons: interactions between physics and dynamics (including ocean)











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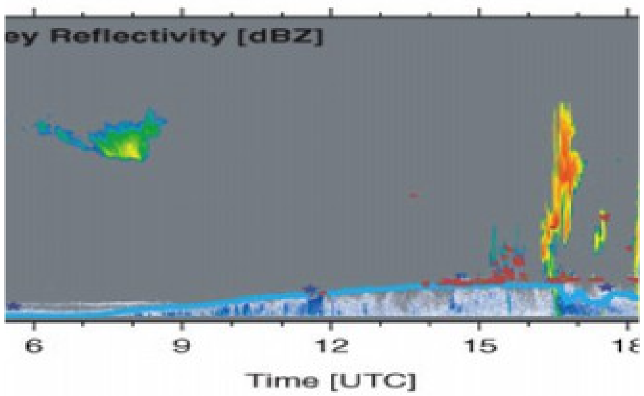
1D model evaluation

Evaluation of several 1D cases: ARM, BOMEX, EUROCS, LBA, AMMA, ...

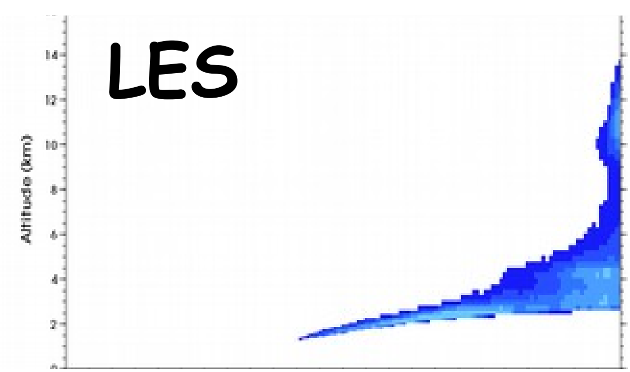
EMBRACE FP7 project : Diurnal cycle of convection over the Sahel derived from the AMMA campaign (10th of July 2006 over Niamey)



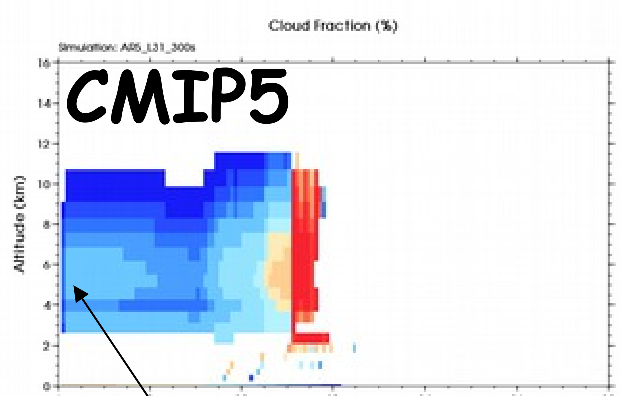
- Well documented case: Lothon et al. 2012
- Convection in a semi-arid environment
- Transition between shallow and deep convection
- Deep convection starts around 16h30

Deep convection underestimated

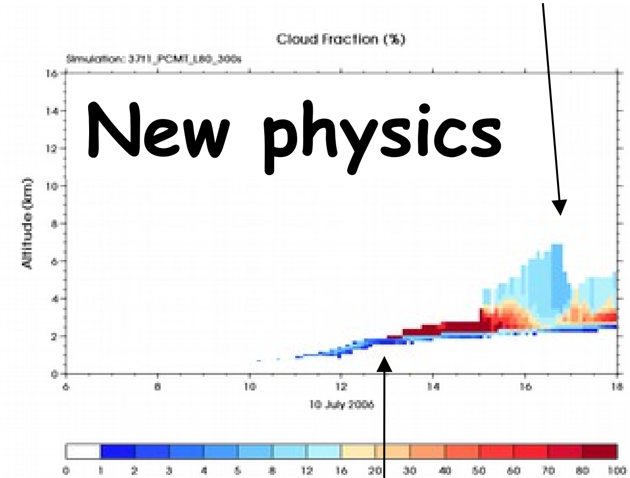
Cloud fraction



LES simulations
Couvreux et al. 2012



Triggering from the start of the simulation



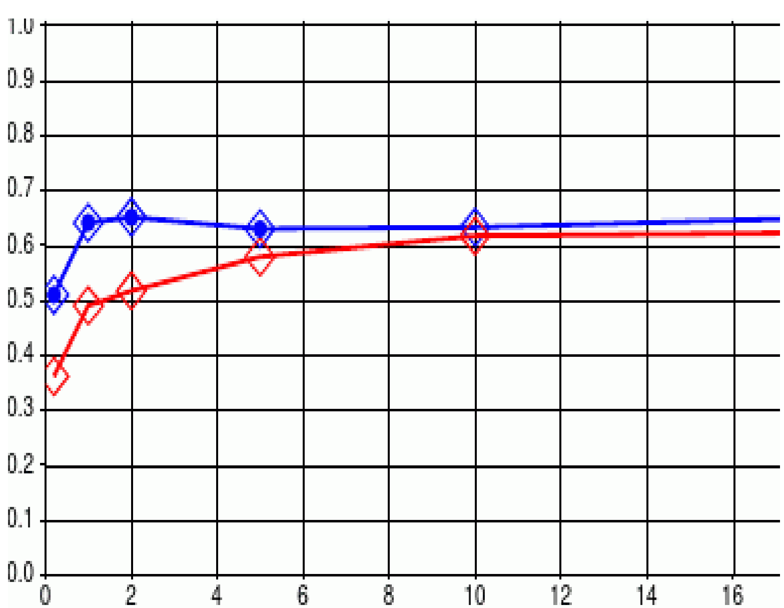
Better representation of BL and shallow convection development

NWP evaluation

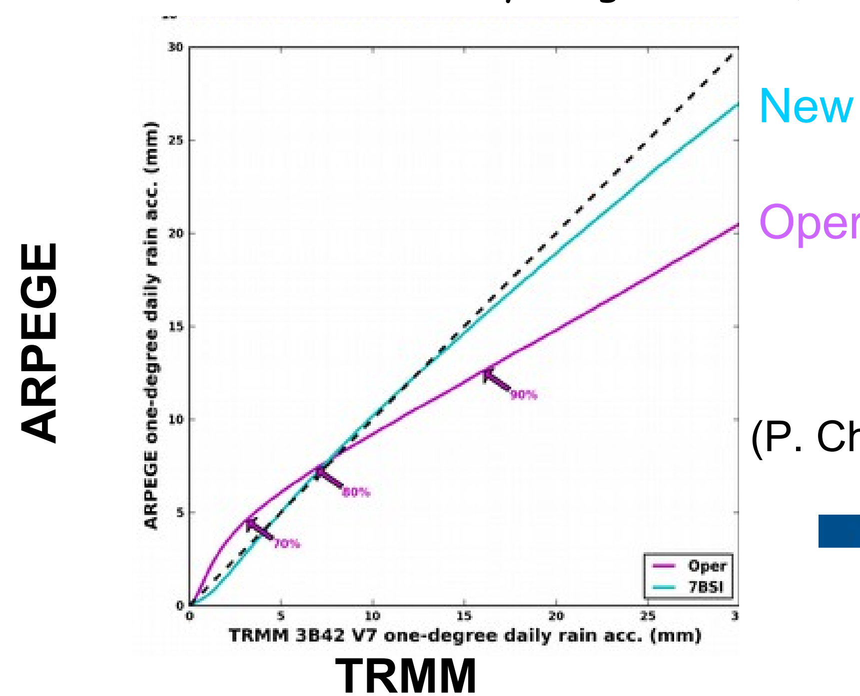
Evaluation based on global forecasts starting from operational analysis and with full assimilation (4DVar and EDA):

- Objectives scores on upper-air and surface parameters against observations and analyses
- Diagnostic based on analysis increments, initial tendencies, etc.
- Comparison to ground-based observatories, to satellite observations, etc.
- Subjective evaluation by forecasters: focused on synoptic and high impact weather

<u>24h Precipitation score against rain-gauges over France:</u>
BSS score (50km tolerance)
July-August 2013

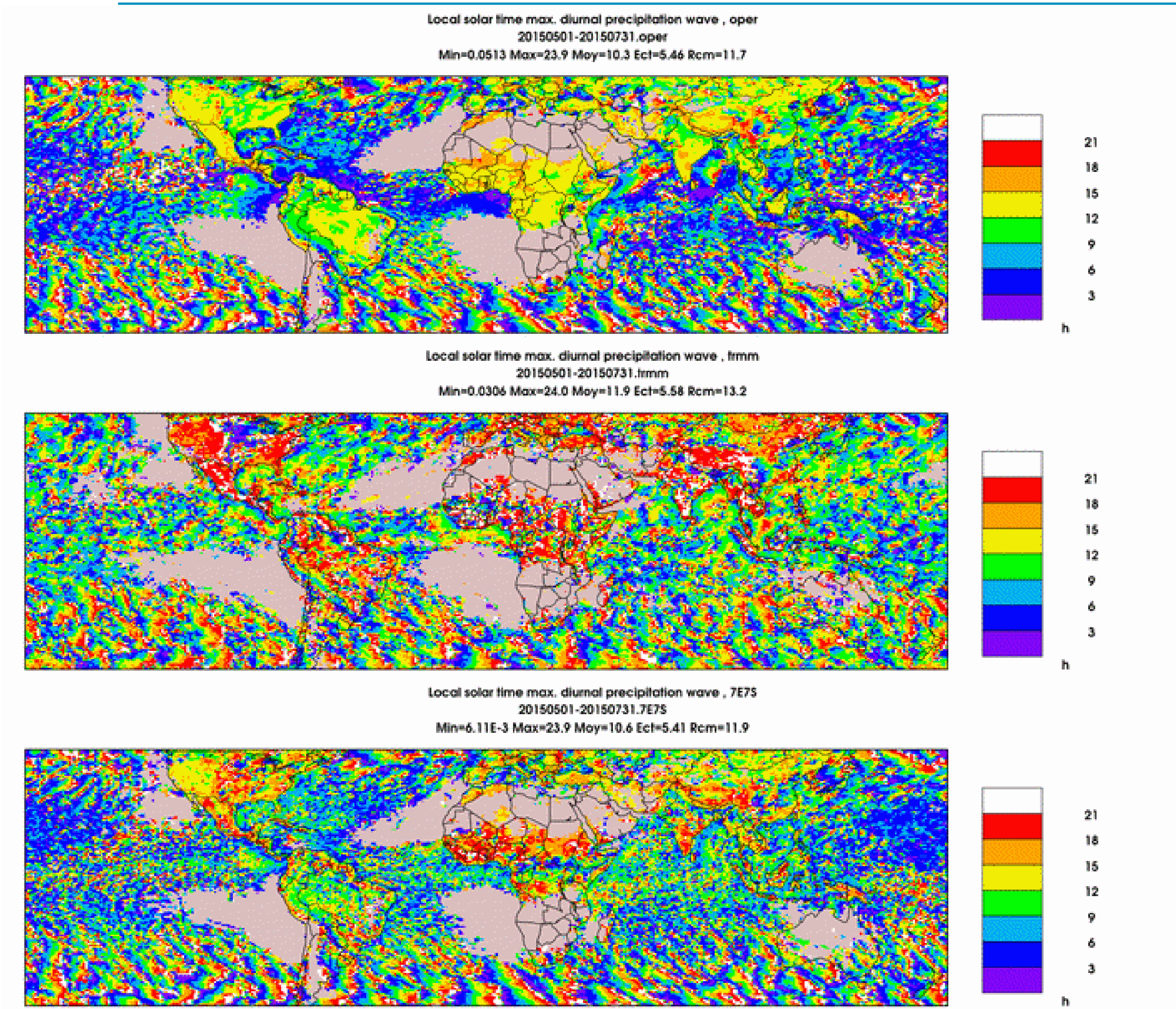


<u>Forecast versus observed 24h precipitation distributions comparison</u>
(intertropical zone ; 1° by 1° ;
TRMM 3B42 V7 ; July/August 2013)



(P. Chambon)

NWP evaluation



ARPEGE operational

Observations TRMM

ARPEGE with PCMT scheme

Diurnal cycle shifted later during the afternoon with PCMT.

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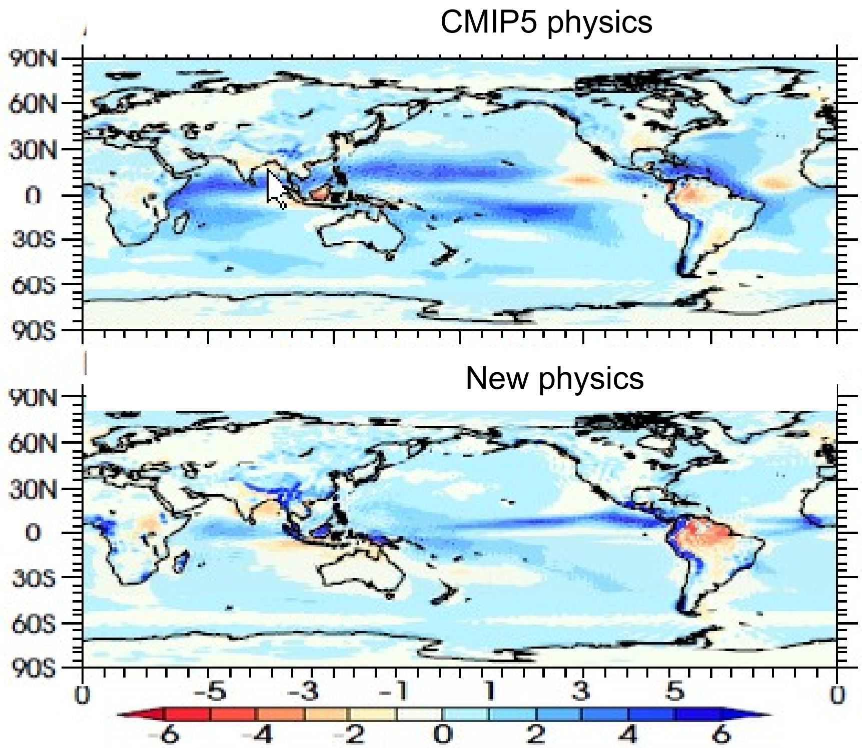
Climate evaluation

Wide range of configurations (regional/global, nudging/forced/coupled) and diagnostics :

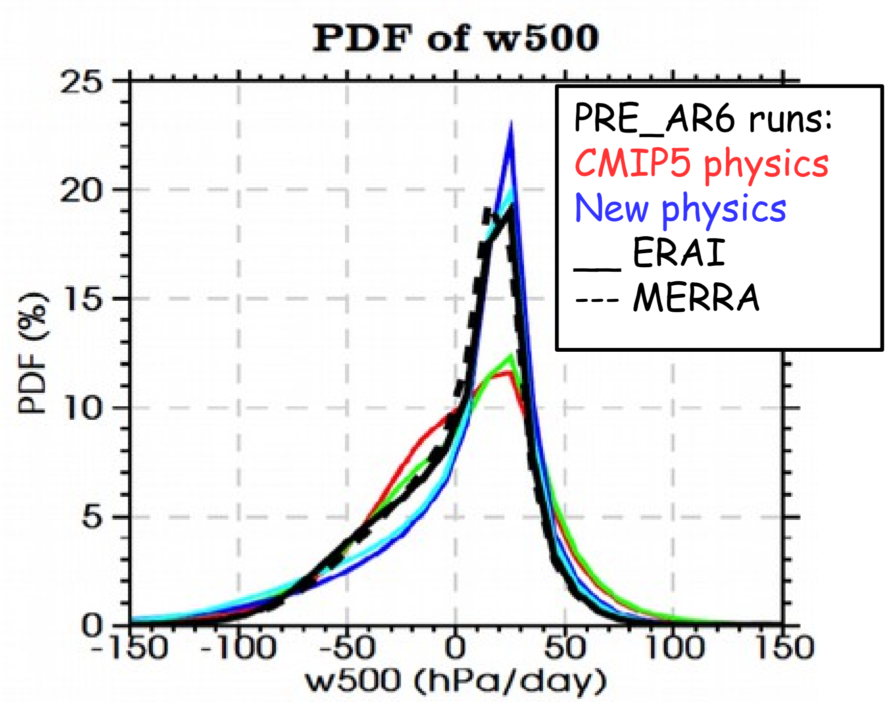
T127 AMIP simulations [1979-2012]

Annual precipitation biases vs GPCP



- Partially reduced double ITCZ
- Overestimation of convective RR (East Pacific,Himalaya, ...)
- Underestimation over Amazonia

Circulation over tropical oceans [30°S-30°N]

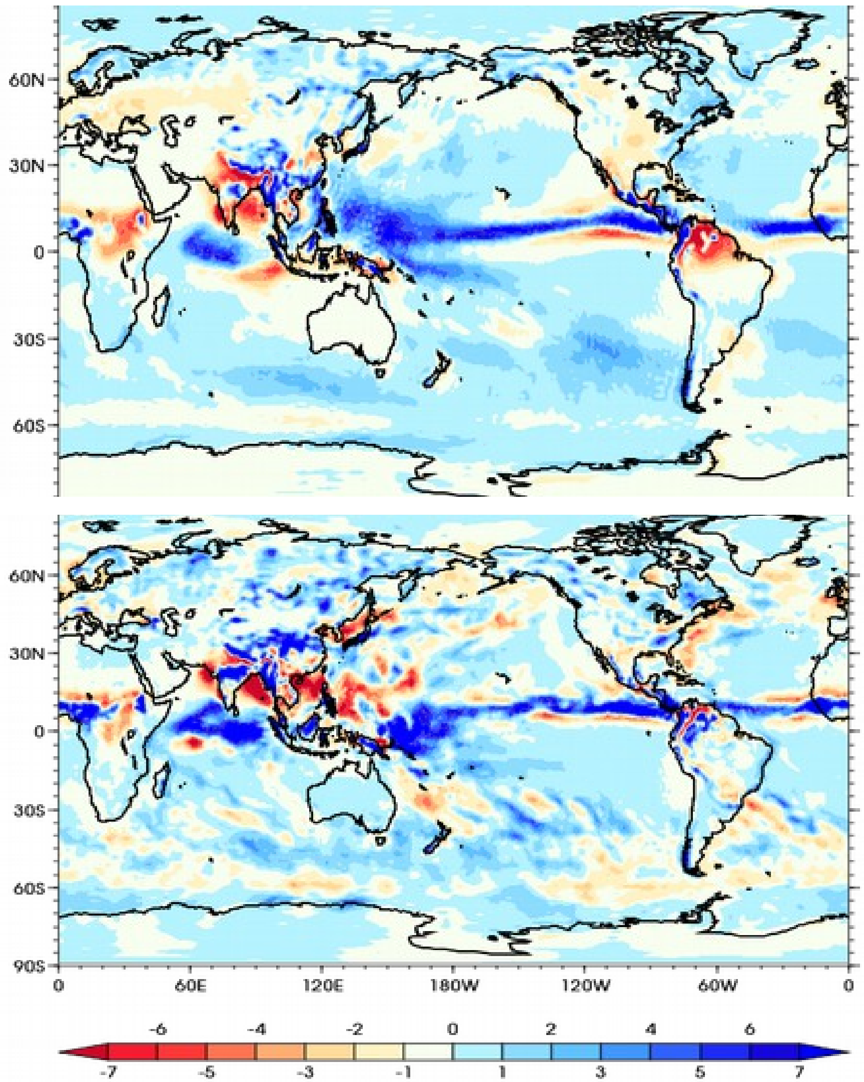


- Improvement of dynamical regimes
- Overestimation of strong ascendant regimes
- Underestimation of weak ascendant regimes

Transpose-AMIP method

A methodology where climat models are used as NWP ones, designed for tackling with climate models biases related to fast processes (Xie et al. 2012, Williams et al. 2013, Ma et al. 2014).

New physics precipitation bias (July) – Reference GPCP



- Importance of surface state initialization with informations consistent with the surface scheme for continental biases (not shown)

- TA method seems relevant for many biases of the CNRM climate model

- Decomposition of rainfall biases between thermodynamic and dynamics contributions --> insight in their origins, identification of different processes in AMIP and TA configurations.

- Analysis of terms contributing to the budget equations in both frameworks (Amip and TA). What are the predominant terms in a short-term forecast and in a long-term/climate simulations ?

(A. Ahmat Younous, R. Roehrig, I. Beau)

Conclusions and prospects

- New convection developed for global NWP and climate model
- Evaluation in multi-environments framework
- Will be used in monthly to seasonal forecasts and in CMIP6 simulations
- Should be part of the next NWP e-suite (hopefully !)
- Work in progress concerning downdrafts and density current