

LMDZ : use and configurations

- 1. Operating modes of the 3D GCM**
 - a) Free climatic mode**
 - b) Zooming or/and nudging for climate**
 - c) Tracer transport**

- 2. Intercomparison exercises and reference versions**
 - a) IPSL climate model and CMIP exercises**
 - b) LMDZ reference versions**
 - c) Robust improvements from version to version**
 - d) Evolution of climatic biases and sensitivity**

- 3. Model development and tuning**
 - a) Choice of a new configuration : content and resolution**
 - b) Importance of tuning**
 - c) Methodology 1D/nudged simulations/tuning**

LMDZ : Un modèle / des configurations

Coeurs 3D

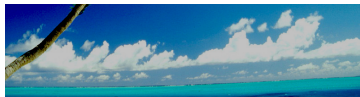
- Longitude-latitude
- Icosaèdre
- (bientôt disponible)
- Aire limité
- (en préparation)

Cas 1D

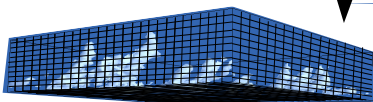
(Dephy/High-Tune)

LES à disposition
20 aine de cas

- Convection
- RCE
- Nuages bas
- Couplage surf.



Campagne

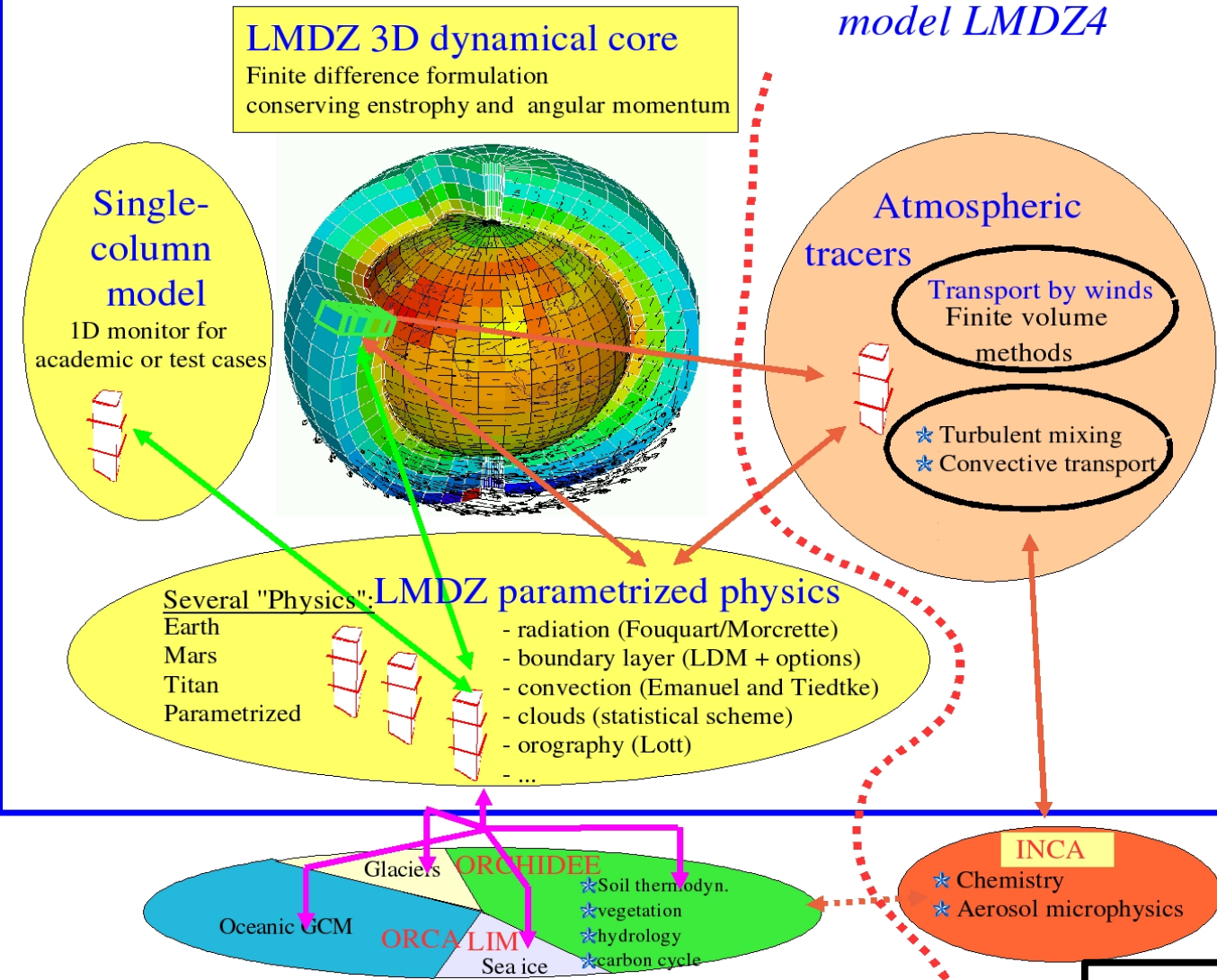


3D explicite (LES)



Modèle uni-colonne

Atmospheric component of the IPSL integrated climate



Mode d'utilisation 3D

- Climatique couplé ou non
- Océan slab
- β -clim/bucket
- Zoomé
- Guidé ou initialisé
- Aqua ou terra planète

IO/Evaluation :

- Multi-atlas sur ciclad
- Pilotage xml de XIOS
- Simulateurs satellite

Couplage en surface (4 sous surface/maille)

- Océan : SST forcées, **Nemo**, Océan slab
- Banquise : imposée (conduction LMDZ), **Lim**, slab
- Continents : **Orchidee**, bucket, betaclim
- Glaciers : bucket ajusté

Composition

- **Inca** (chimie/aérosols)
- **Reprobus** (chim./strato)
- LMDZaer (arérosols)
- Isotopologues de l'eau

Which model version and which setup should I use for my work ?

*Depends on the problem you want to address
The first question should be :*

What do I need a model for ?

Those questions are an essential part of YOUR WORK

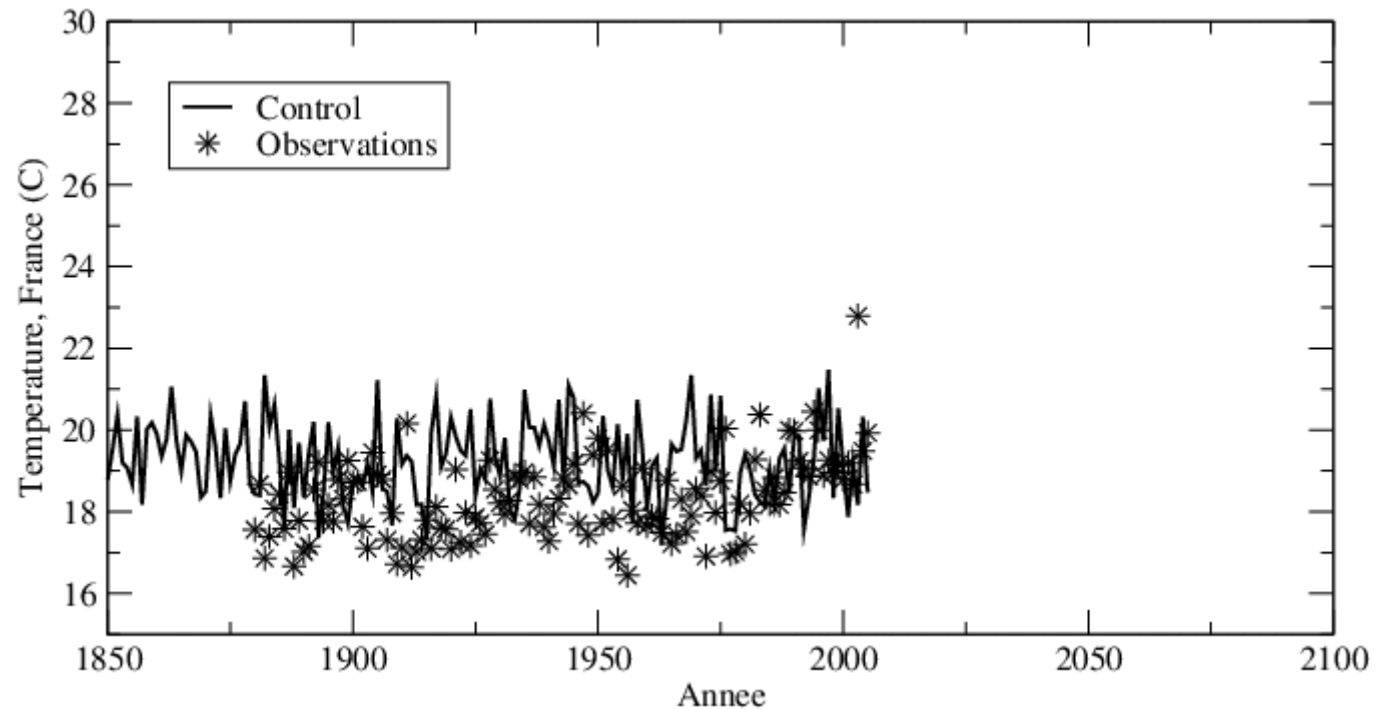
The presentation tries to help you answer to question #1 once you have the answer to question #2

Example 1 :

Coupled simulation for climate change projections

1. Operating modes : a) free climatic mode

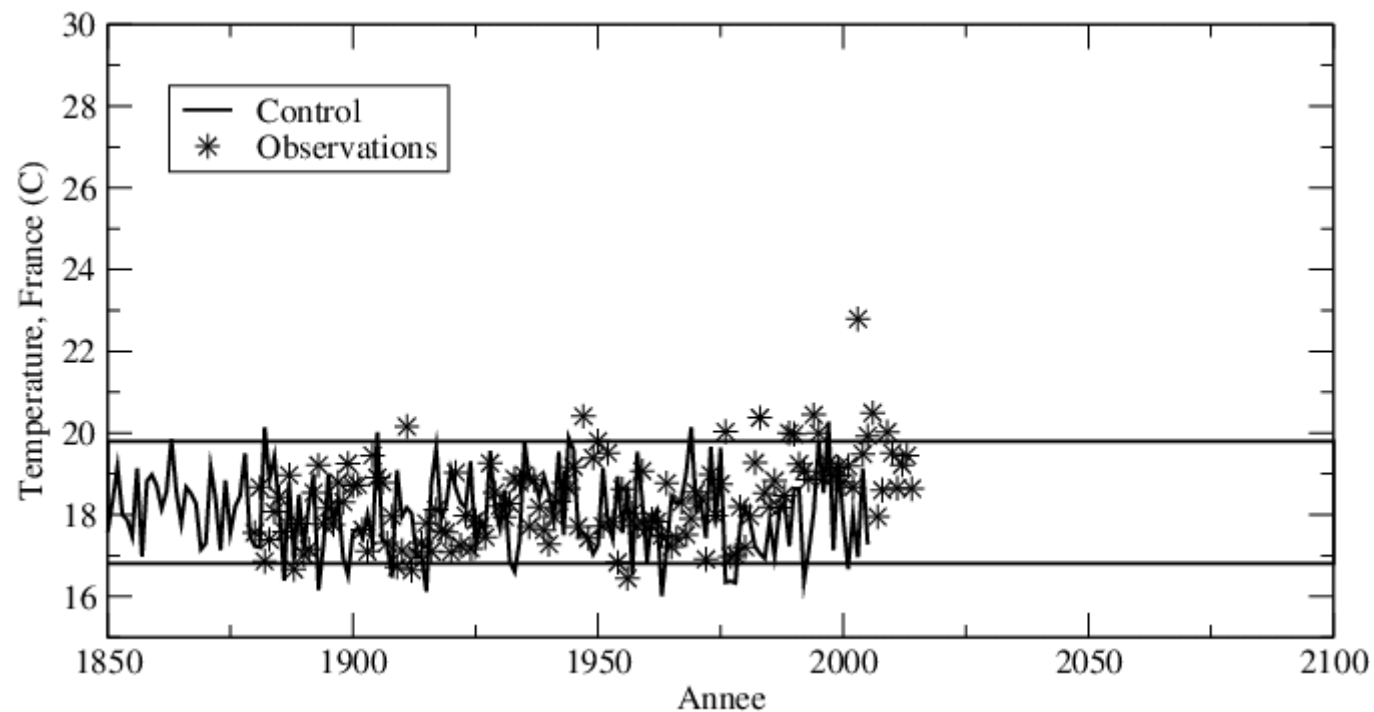
Climate change projections



→ Global coupled ocean-atmosphere model. Model not perfect. Biases.

1. Operating modes : a) free climatic mode

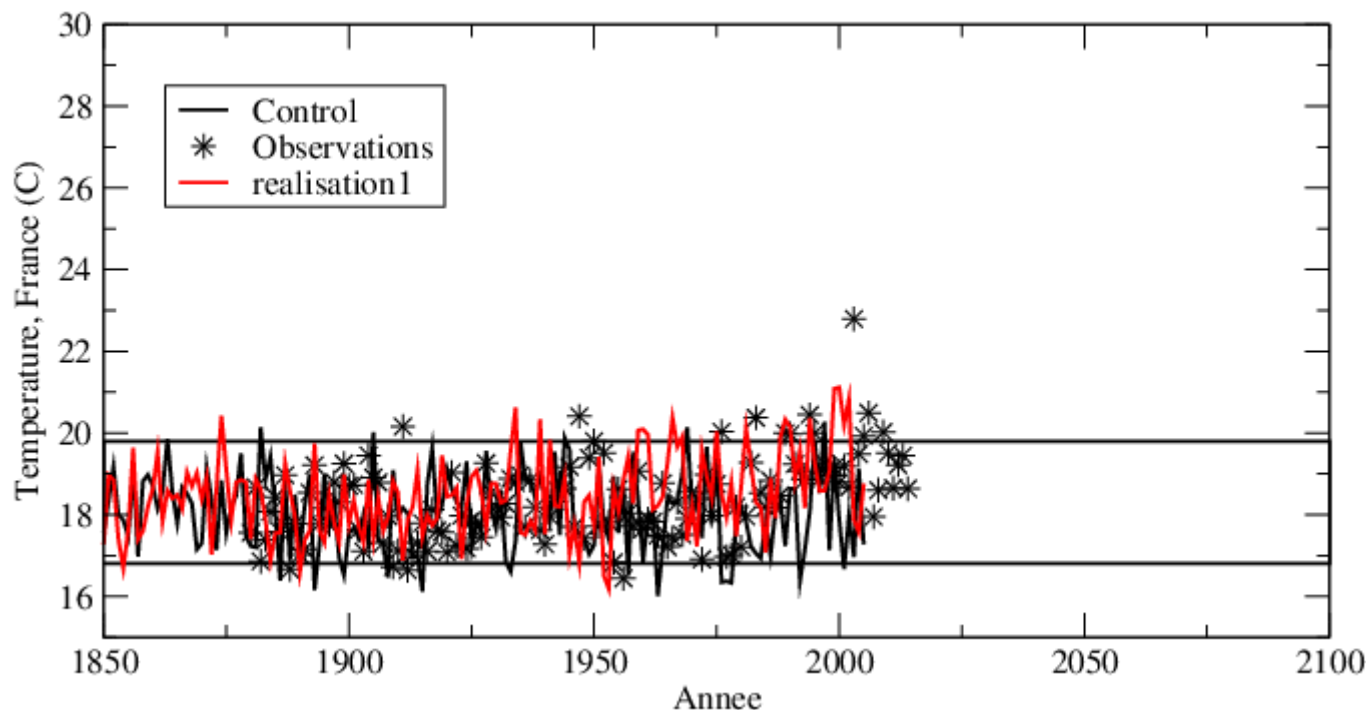
Climate change projections



- Global coupled ocean-atmosphere model. Model not perfect. Biases.
- Analyzed in terms of statistics. Biased on average. Variance ...

1. Operating modes : a) free climatic mode

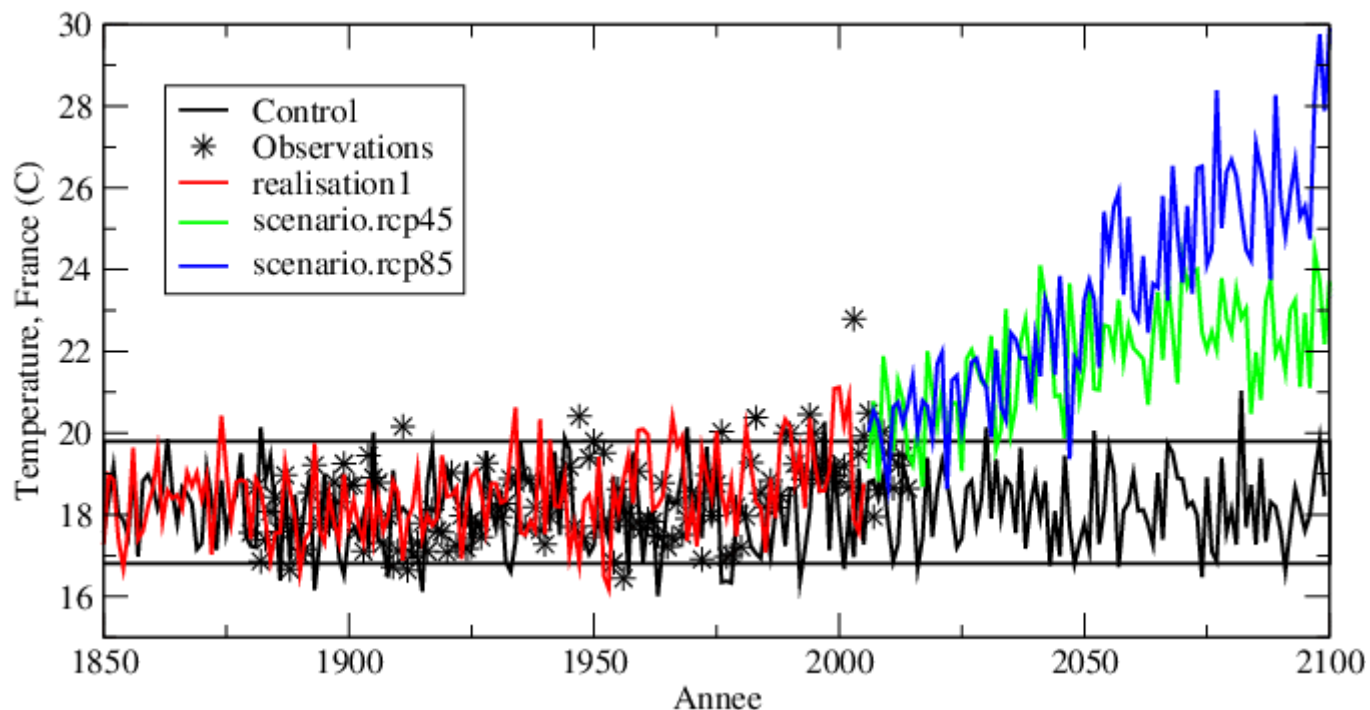
Climate change projections



- Global coupled ocean-atmosphere model. Model not perfect. Biases.
- Analyzed in terms of statistics. Biased on average. Variance ...
- Perturbed versus control run (small perturbation compared to biases)

1. Operating modes : a) free climatic mode

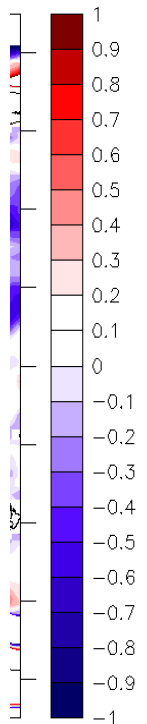
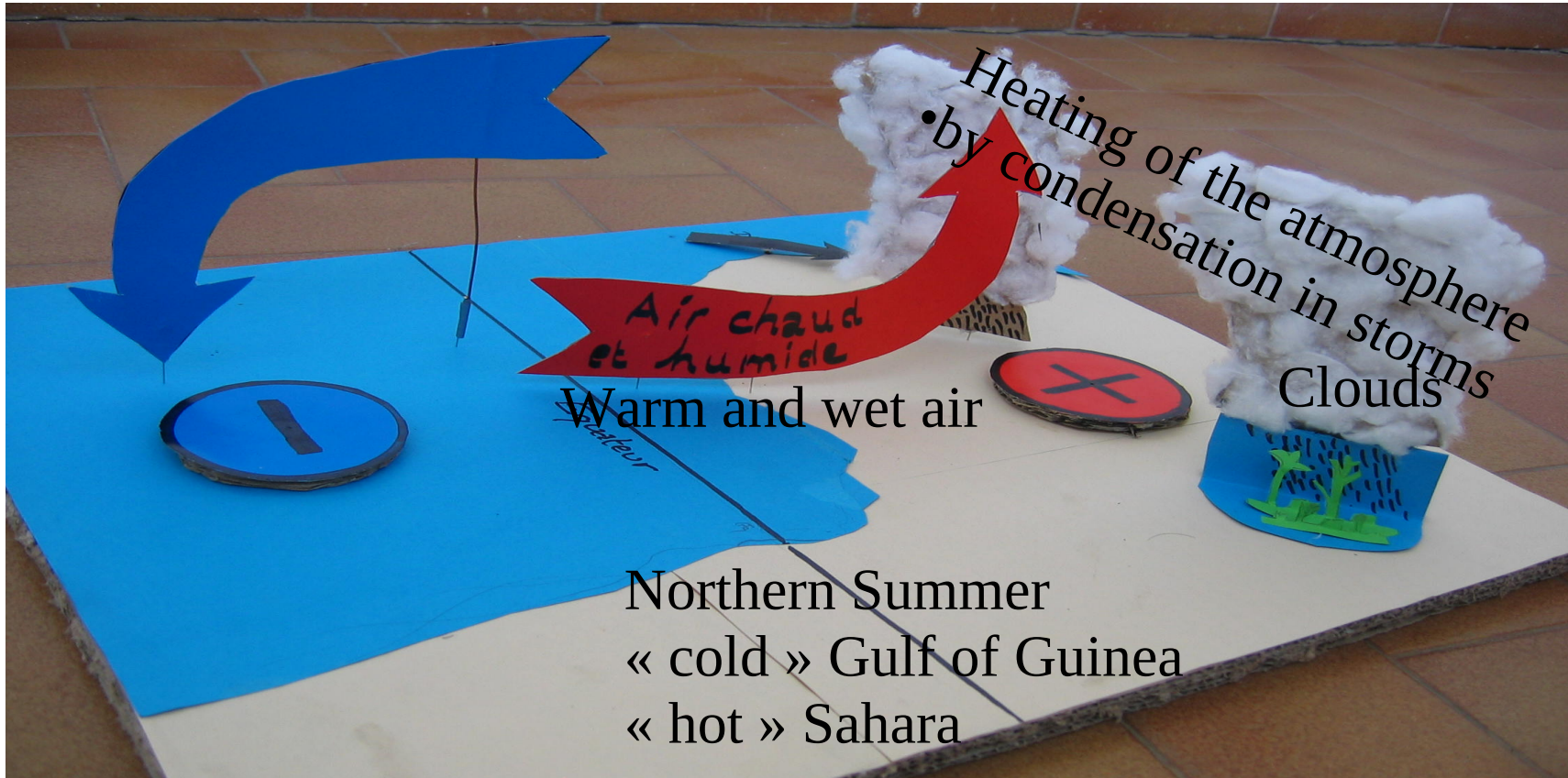
Climate change projections



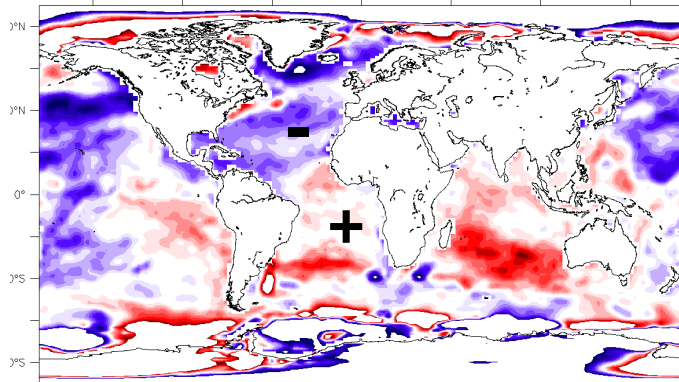
- Global coupled ocean-atmosphere model. Model not perfect. Biases.
- Analyzed in terms of statistics. Biased on average. Variance ...
- Perturbed versus control run (small perturbation compared to biases)
- Scenarios of future concentrations or emissions

Example 3 :
Forced-by-SST simulations to understand the
Sahelian drought of the 70'

1. Operating modes : a) free climatic mode

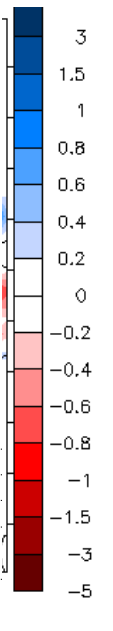


$\Delta \text{SST} : [1955-1965] - [1975-1985]$

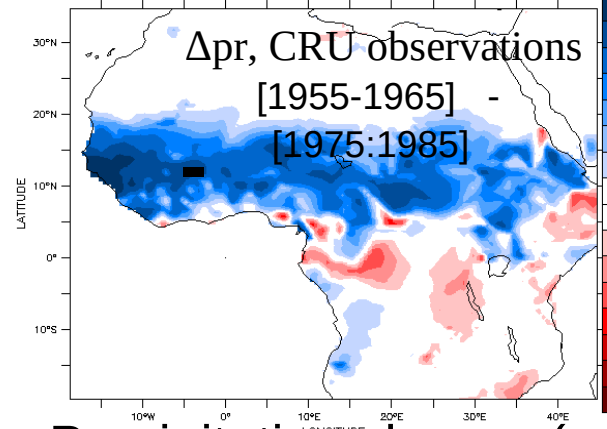


Temperature change ($^{\circ}\text{C}$)

- 1975-1985 :
- Warm SSTs in the south
 - Drought over Sahel
 - A large scale pattern
 - Linked to sea surface
 - Temperature changes.



Δpr , CRU observations [1955-1965] - [1975-1985]



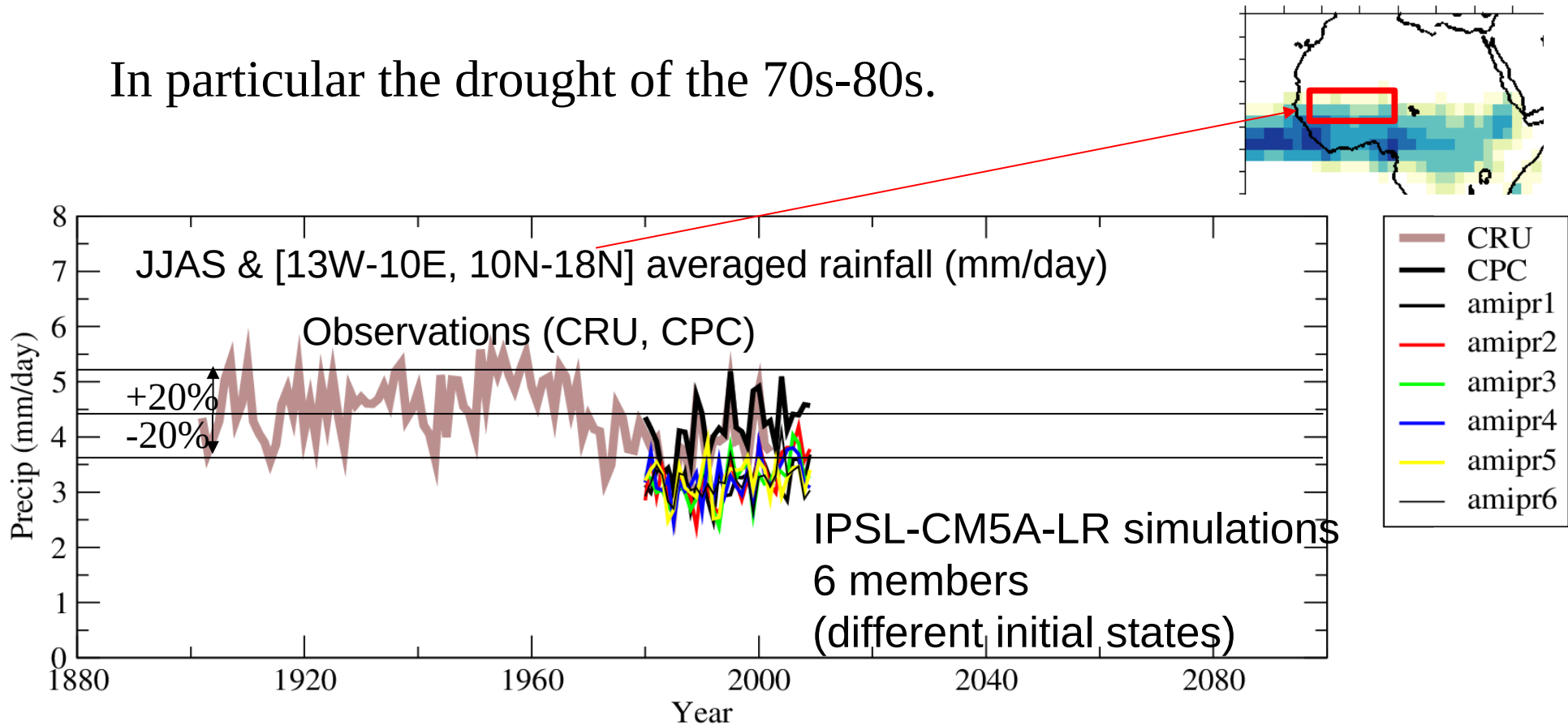
Precipitation change (mm/year)

Example 2 : the Sahelian drought

1. Operating modes : a) free climatic mode

Are the model able to represent the climate variability of the past decades ?

In particular the drought of the 70s-80s.



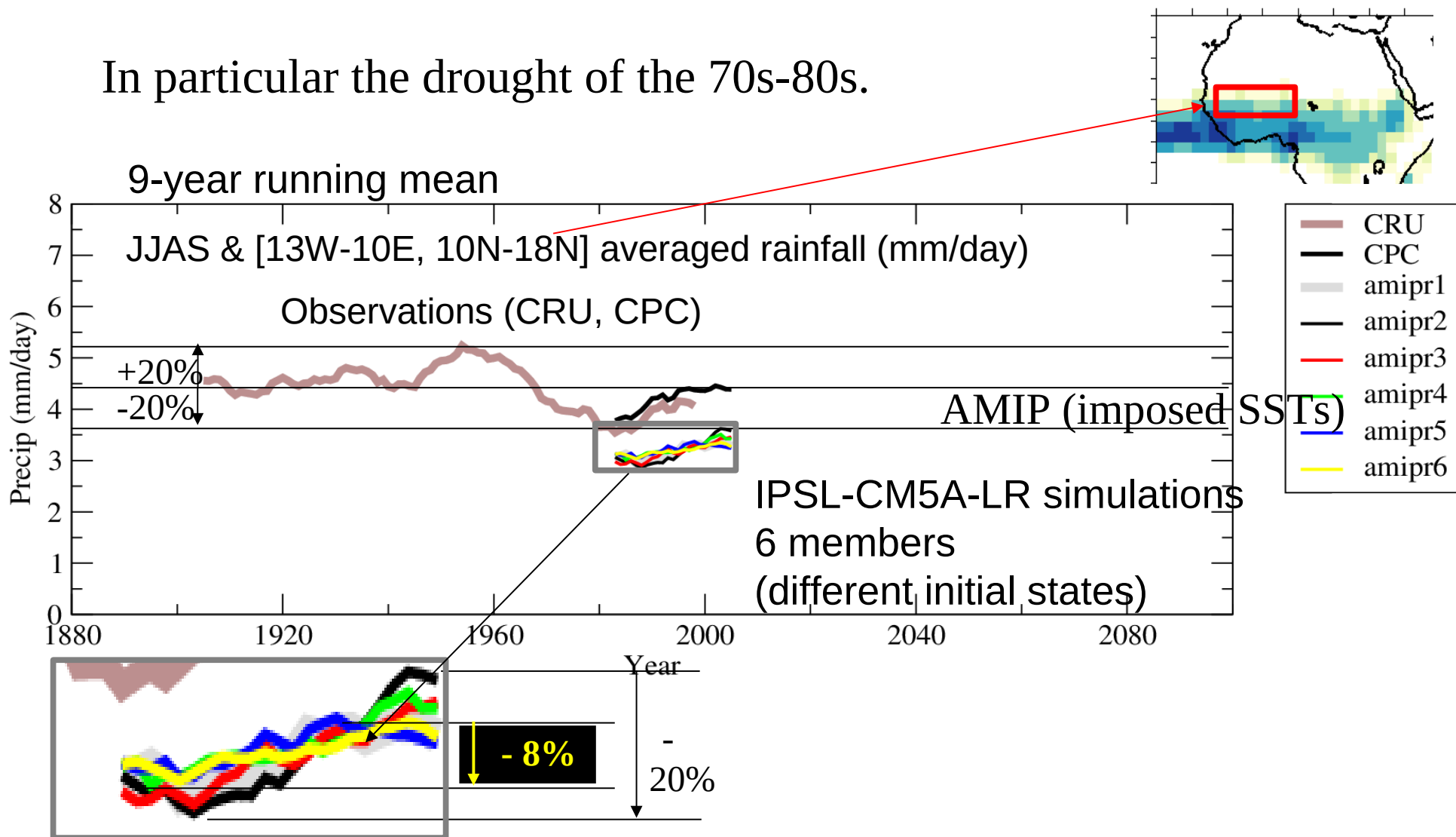
AMIP with imposed Sea Surface Temperature (SST)

Roehrig, R., D. Bouniol, F. Guichard, F. Hourdin and J.-L. Redelsperger, 2012, The present and future of the West African monsoon: a process-oriented assessment of CMIP5 simulations along the AMMA transect., J. Climate, 26, 6471–6505. doi: <http://dx.doi.org/10.1175/JCLI-D-12-00505.1>

1. Operating modes : a) free climatic mode

Are the model able to represent the climate variability of the past decades ?

In particular the drought of the 70s-80s.



Simulations have a skill to reproduce decadal variations of monsoon rainfall in response to sea surface temperature changes
But strong internal variability even with imposed SSTs
The observation is one possible experience

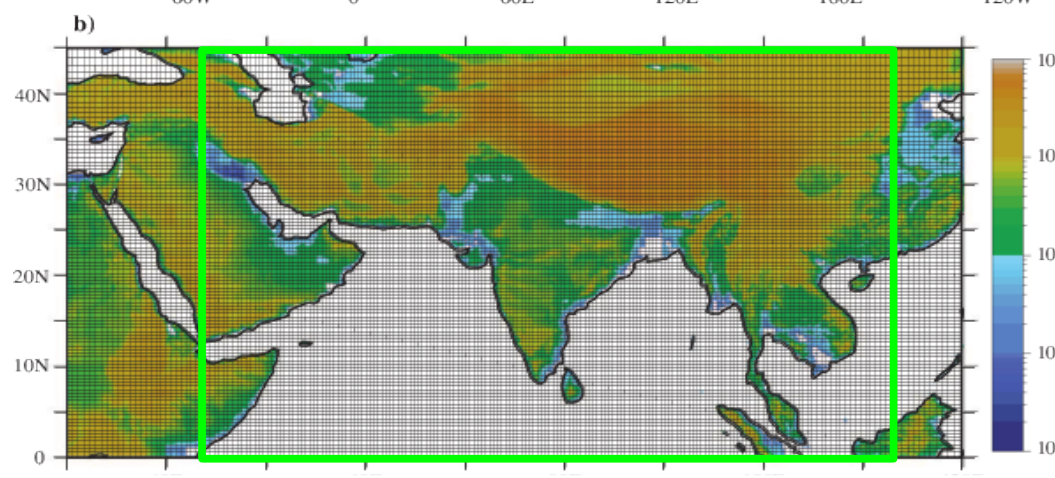
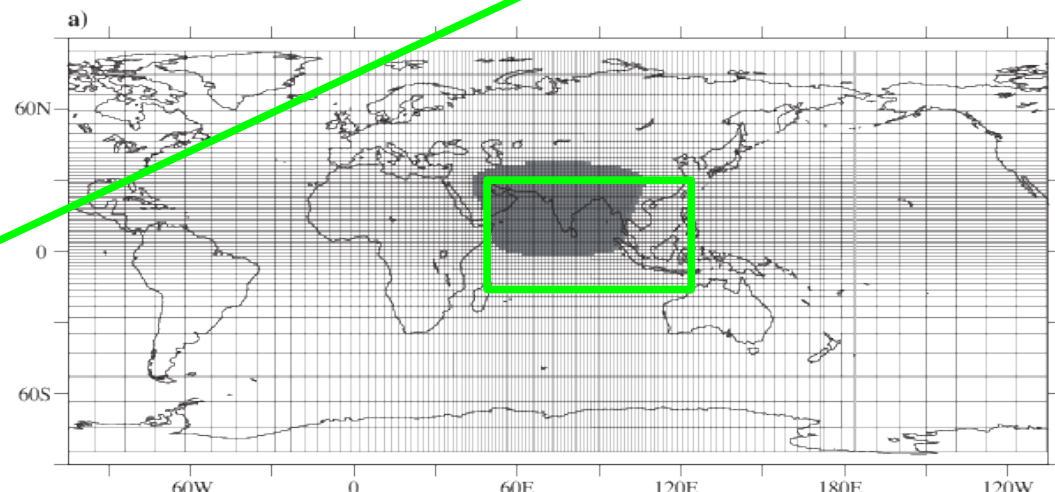
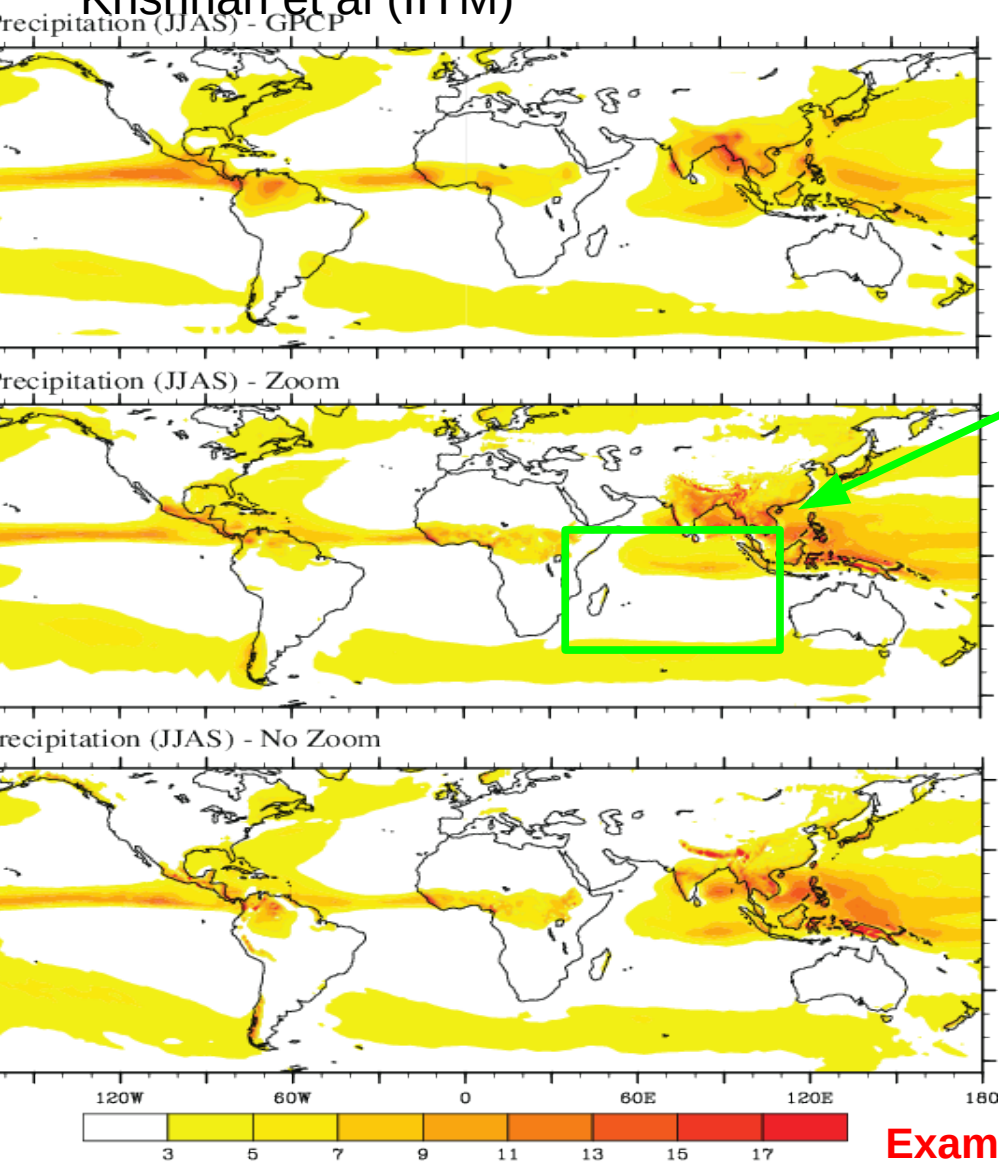
Example 3 :
Forced-by-SST simulations with zoom to improve the
representation of monsoon rainfall over India

1. Operating modes : b) Zooming or/and nudging for climate

Free climate simulation with zoom

Zoomed free climate simulation for Cordex South Asia,

Krishnan et al (IITM)



Example of improvement due to increased resolution

- **Better representation of depressions coming from Bay of Bengal**

Example 4 :
Forced-by-SST simulations with zoom and nudging
to evaluate and improve the parameterized physics
using site observations

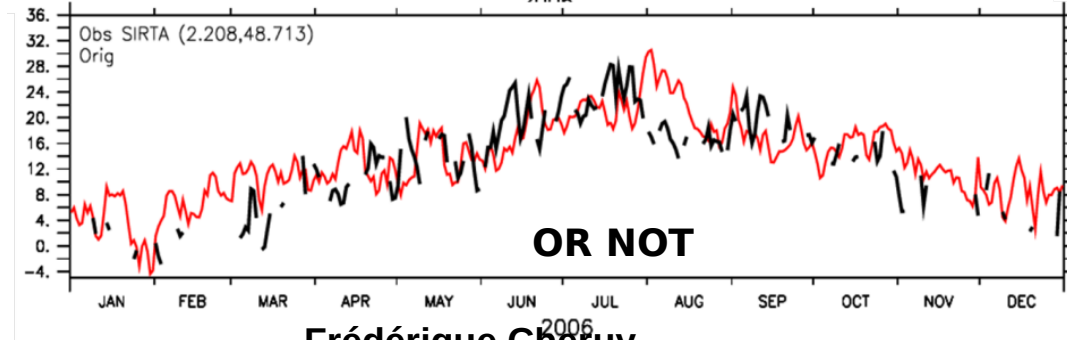
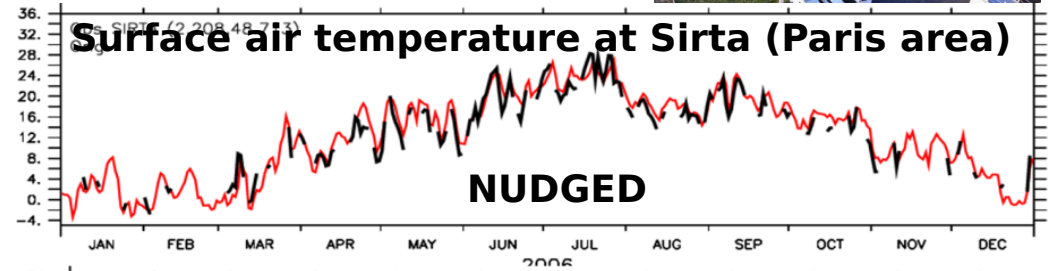
1. Operating modes : b) Zooming or/and nudging for climate

Nudging capability

$$\frac{\partial X}{\partial t} = F(X) + \frac{X^a - X}{\tau}$$

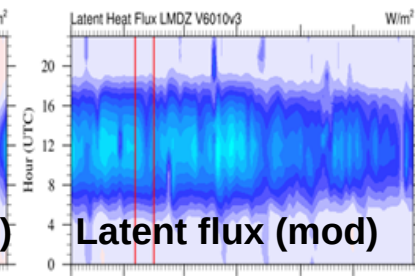
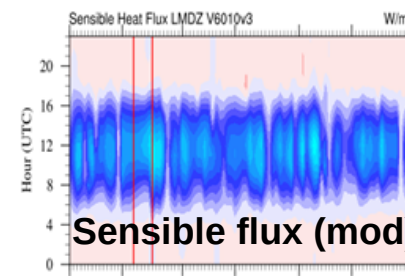
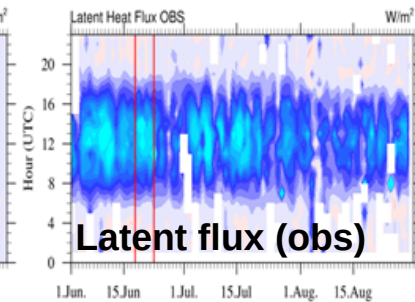
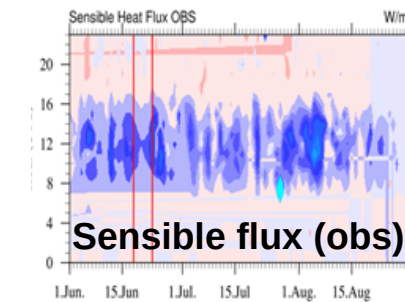
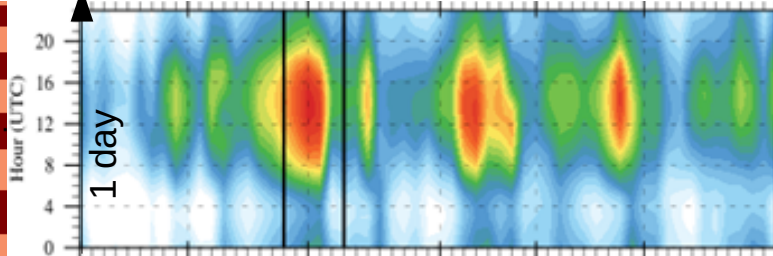
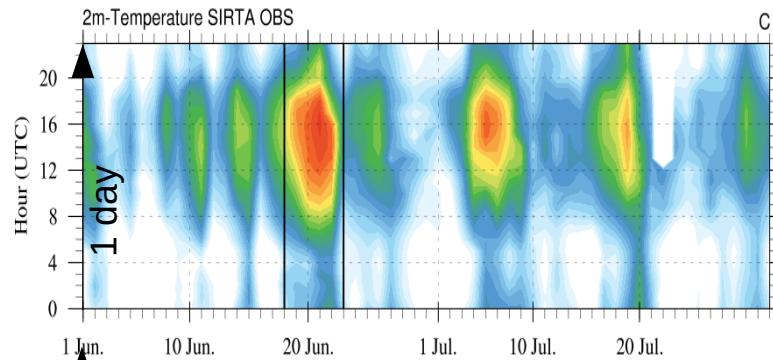
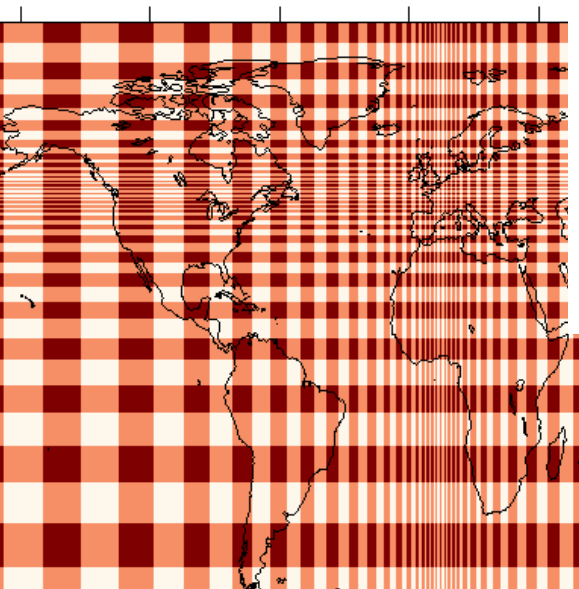
X : model state variables, u, v, T, q
X^a : X from (re)analysis regridded on the model grid
F(X) : state variables model tendencies
τ : time constant

Often using nudging in u and v only
 relying on the model physics for the
 thermodynamics (~ simulations with
 imposed large scale dynamics)



Frédérique Cheruy

HEAT-WAVE SUMMER 2017



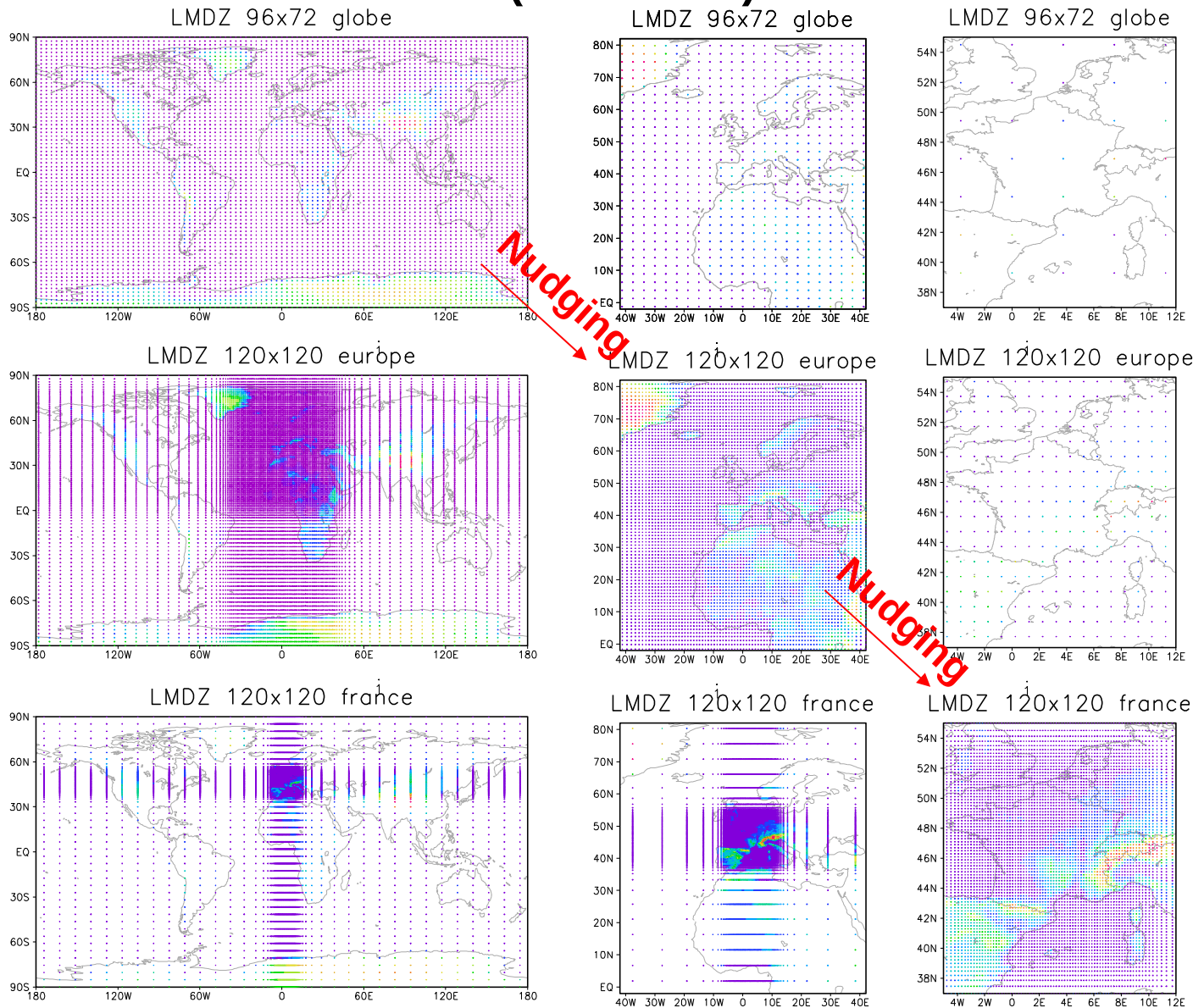
Example 5 :
Forced-by-SST simulations with zoom and nudging
by other coarser grid for down-scaling

1. Operating modes : b) Zooming or/and nudging for climate

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8

Use for climate downscaling

LMDZ - Grid Cascade - (Laurent Li)



LMDZ Globe
(300 km)

LMDZ Europe
(100 km)

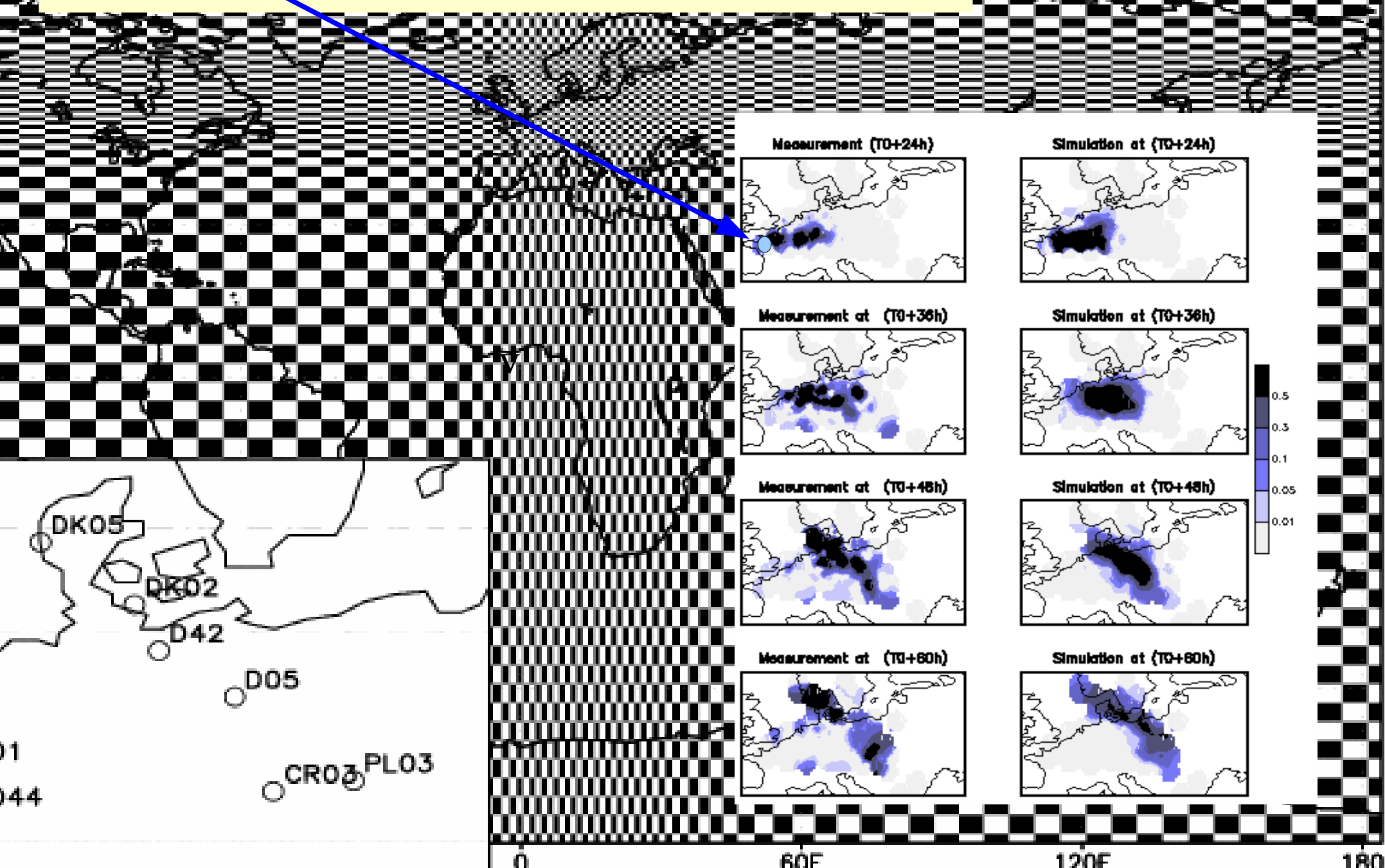
LMDZ France
(20 km)

Similar to what is done with limited area models (like WRF)

Examples with tracer transport

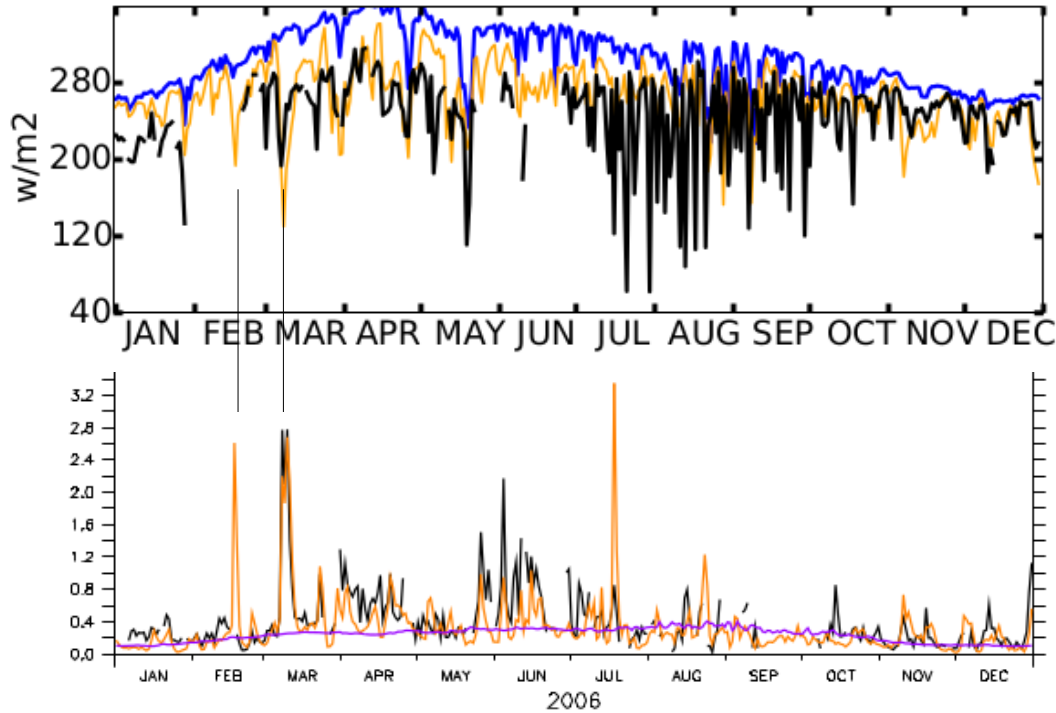
1. Operating modes : c) Tracer transport

Numerical simulation with LMDZ
Chemical tracer (PMCH) emitted in French Brittany (ETEX)

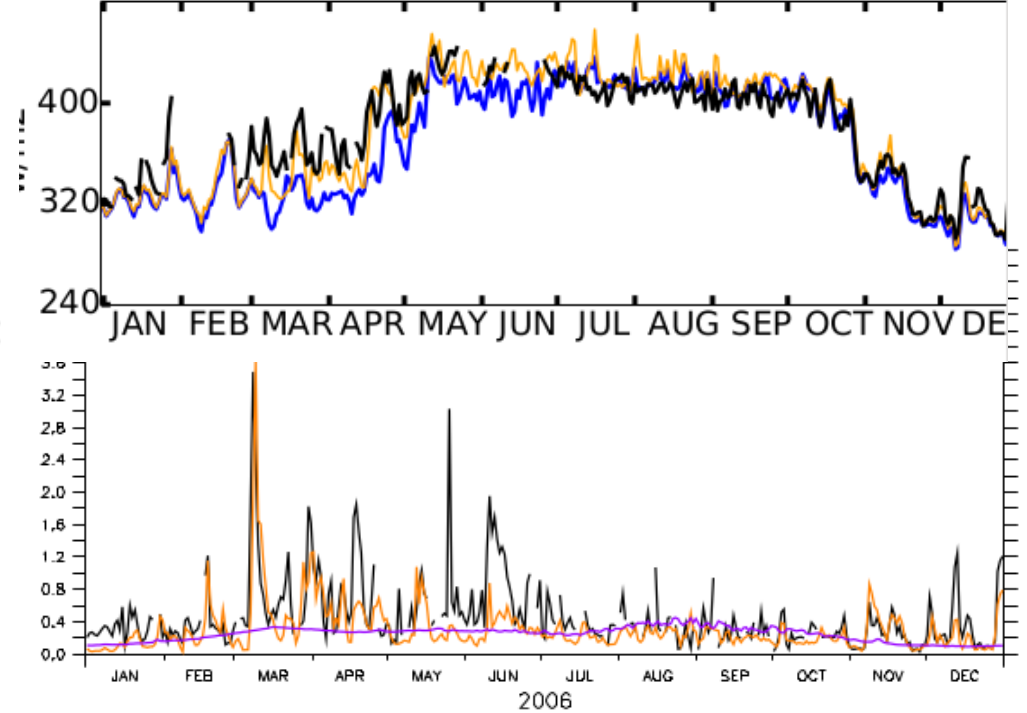


1. Operating modes : c) Tracer transport

SW downward flux surf. (W/m²)

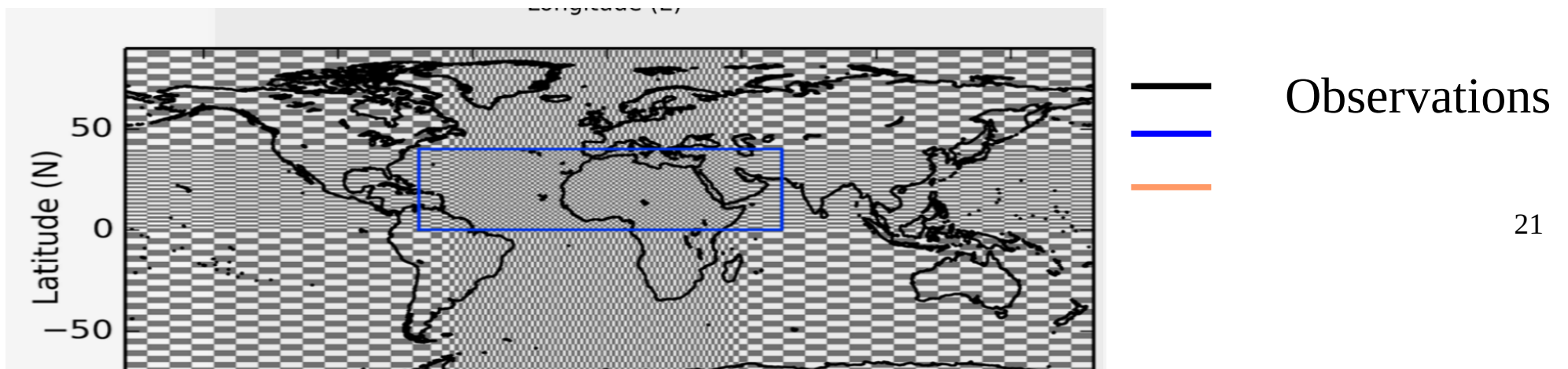


LW downward flux surf. (W/m²)



Coupled simulations with interactive aerosols (Dialo et al., 2017)

Tracer concentrations in $\mu\text{g} / \text{kg}$, 2006



1. Operating modes : c) Tracer transport

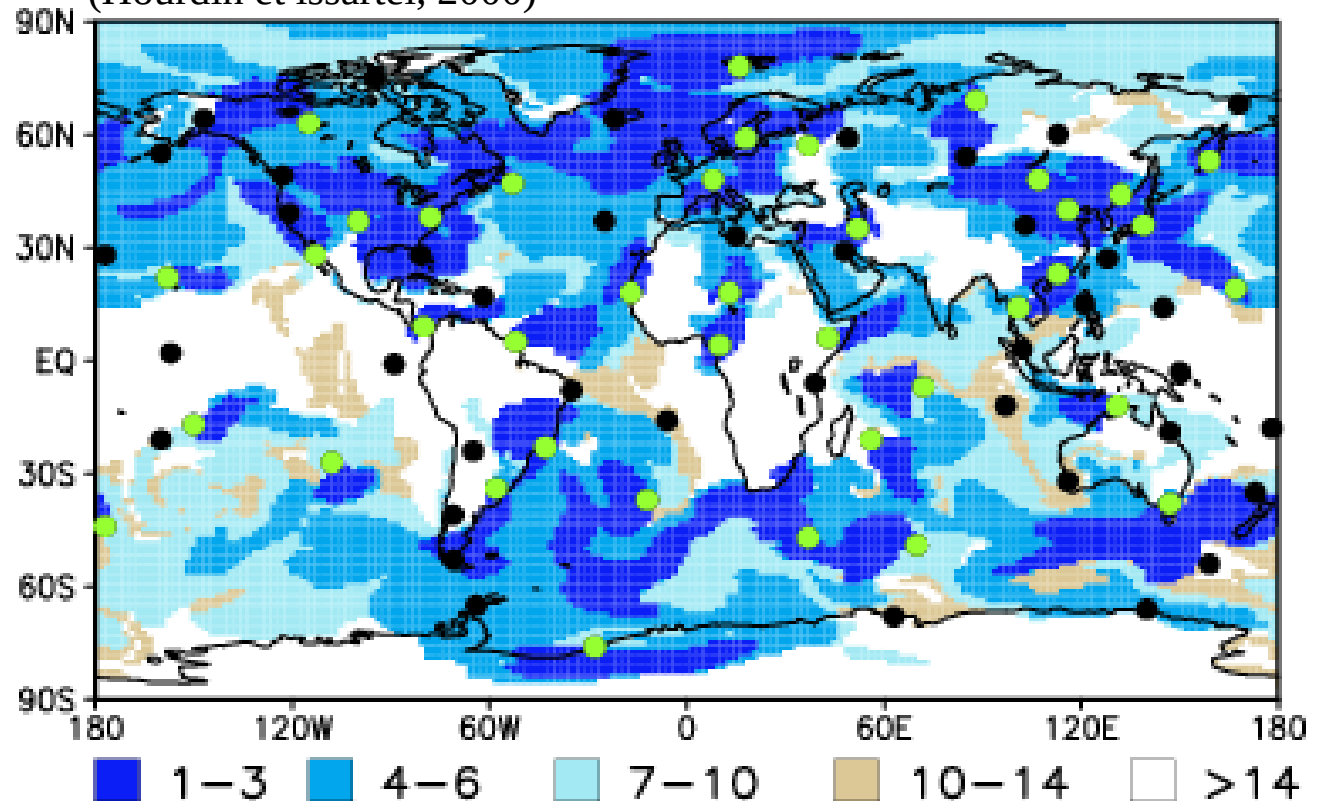
Use in off-line transport model, direct and inverse

- **First simulations with full meteorology computation**
- **Storing the explicit mass fluxes, turbulent coefficient, sub-scale mass fluxes**
- **Run transport of tracers only, in direct or backward mode (↔ adjoint model)**

Example of back-tracking simulation
Off-line model used in reverse mode

Retro-transport : transport is computed injecting a tracer at the detection stations (green) reversing the time to come back to the possible origins. Equivalent to an adjoint computation Used also for estimation of CO₂ and CH₄ inversions.

14-day Visibility of the Xenon detection network
(Hourdin et Issartel, 2000)



F. Hourdin et J.-P. Issartel, 2000, Sub-surface nuclear tests monitoring through the CTBT ¹³³Xe network, Geophysical Research Letters, Vol. 27, p. 2245-2248, 2000

F. Hourdin et O. Talagrand, 2006, Eulerian backtracking of atmospheric tracers: I Adjoint derivation and parametrization of subgrid-scale transport, Q. J. R. M. S., 132 : 567-583 PDF, 2006

F. Hourdin, O. Talagrand et A. Idelkadi, 2006, Eulerian backtracking of atmospheric tracers: II Numerical aspects, Q. J. R. M. S., 132 : 585-603, 2006

4. Operating modes

Summary of 3D operating modes

	Global regular	Zoomed
Free	<p>« Earth system » modeling</p> <p>Forced by SST (clim or interannual)</p> <p>Idealized experiments (aquaplanets, ...)</p> <p>Analyzes/evaluation in terms of statistics Need for ensemble and/or long simulations Strongly depends on model parameters tuning</p>	
Nudged*	<p>Chemistry-Transport model and source invasion (coupled to Inca, Reprobus or LMDZ aerosol component)</p> <p>*everywhere, u & v or u, v, T & q</p> <p>Evaluation of physical parameterizations with imposed dynamics (*everywhere, u & v only)</p>	<p>Analysis of field campaign experiments and site observations</p> <p>Climate downscaling (*everywhere)</p> <p>Regional modeling (*outside zoom)</p> <p>Analyses/evaluation on day-by-day bases Can be used in quasi real-time / forecast mode</p>

LMDZ : use and configurations

1. Operating modes of the 3D GCM
 - a) Free climatic mode
 - b) Zooming or/and nudging for climate
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- 2. Intercomparison exercises and reference versions**
 - a) The IPSL climate model and CMIP exercises**
 - b) LMDZ reference versions**
 - c) Robust improvements from version to version**
 - d) Evolution of climatic biases and sensitivity**

3. Model development and tuning
 - a) Choice of a new configuration : content and resolution
 - b) Importance of tuning
 - c) Methodology 1D/nudged simulations/tuning

2. Reference configurations : a) The IPSL climate model and the CMIP exercises

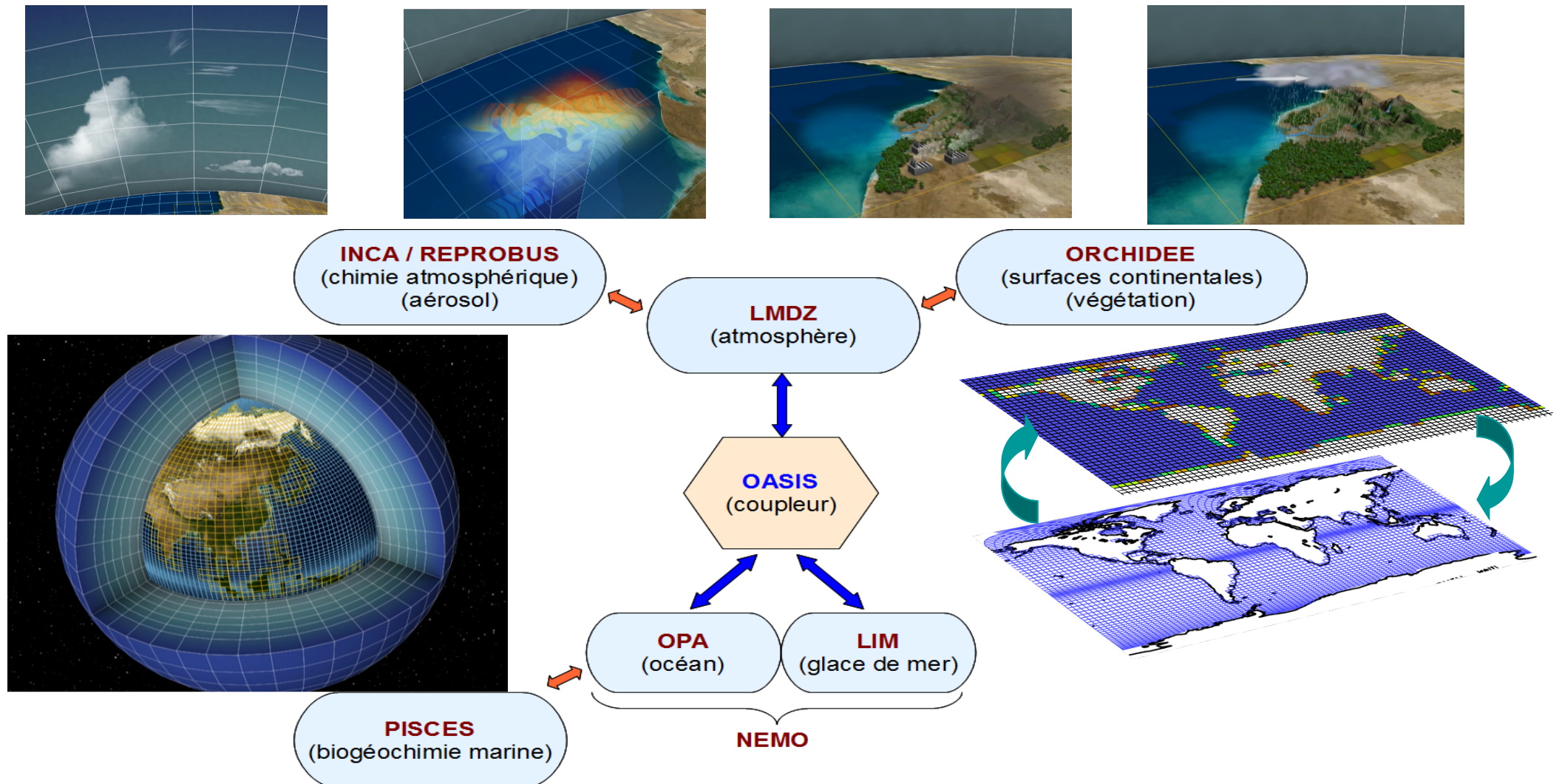
Coupled model Intercomparison Project (CMIP)

Comparison of coupled atmosphere/ocean models or ESM (for Earth System Models)

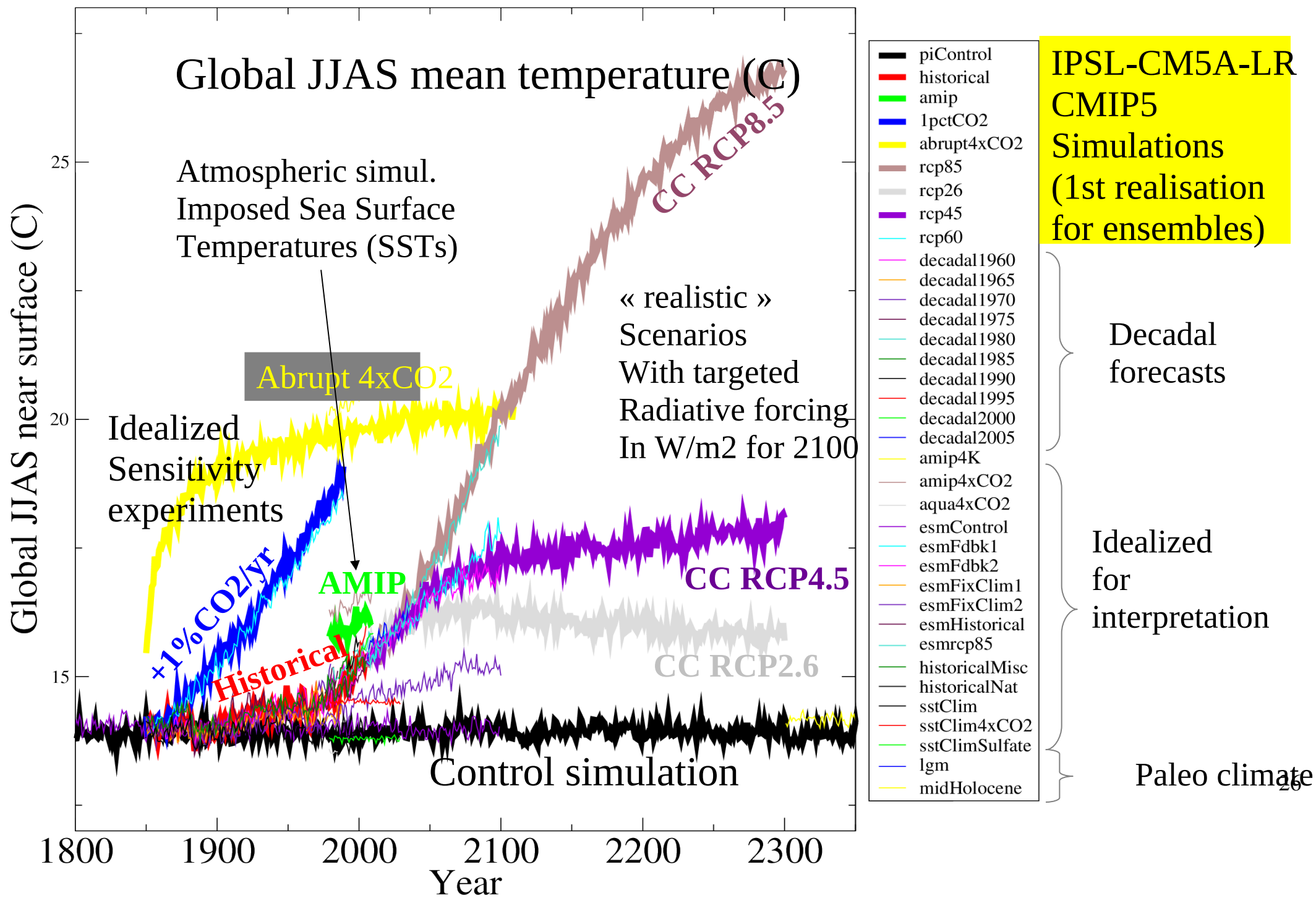
Each 7-year

Production of an ensemble of simulations with imposed boundary conditions / protocol

The IPSL coupled Model



2. Reference configurations : a) The IPSL climate model and the CMIP exercises



2. Reference configurations : a) The IPSL climate model and the CMIP exercises

Development of LMDZ and the CMIP rendez-vous CMIP

Development : new parameterizations, new dynamical core ...

New version

CMIP Simulations

New physics
For CMIP5

Analyses
Publications

Assesment
Report

Starting control simulation for
preindustrial conditions

Submission/acceptation of publications
To be taken into account in IPCC/AR

CM5A-LR
07/2010

CM5A-MR
05/2011

CM5B-LR
08/2011

CMIP5 : 2008

2009

2010

2011

07/2012

10/2013

CMIP6 : 2014

2015

2016

2017

07/2018

10/2019

CMIP7 : ...

...

2025

...

...

...

IPSL-CM6ALR

LMDZ :

RRTM

QBO

stochastique

Stratocu

Nuages mixtes

144x142x79 (rebaptisée LR)

Ocean 1°, Orchidee 11

New versions
Under test

Example 5 :
Forced-by-SST simulations with zoom and nudging
by other coarser grid for down-scaling

2. Reference configurations : b) LMDZ reference configurations

Summary of reference climate configurations

	Horizontal grid	Vertical grid	Physics content	Name
CMIP3	96 x 71	L19	Changing convection from Tiedtke to Emanuel Subgrid scale orography	LMDZ4 IPSL-CM3
CMIP5	LR : 96 x 71	L39	Standard Physics (SP) : same as LMDZ4	IPSL-CM5A
	MR : 144 x 142	Extension to stratosph.	New Physics (NP) : SP + thermals and cold pools + ALE/ALP closure for deep convection	IPSL-CM5B
CMIP6	VLR : 96 x 71	L39	Standard Physics (SP) : same as LMDZ4	IPSL-CM5A2
	LR : 144 x 142 MR : 256 x 256 HR : 512 x 360	L79 $\delta z/z = 0.1$, for $z < 3$ km $\delta z/z \leq 1$ km, for $z < 50$ km	New Physics (NP) + New radiation : RRTM + SW 6 bands Stochastic triggering of deep convection Stratocumulus from thermal plumes Ice thermodynamics Improve coupling with surface Non orographic gravity wave	IPSL-CM6A

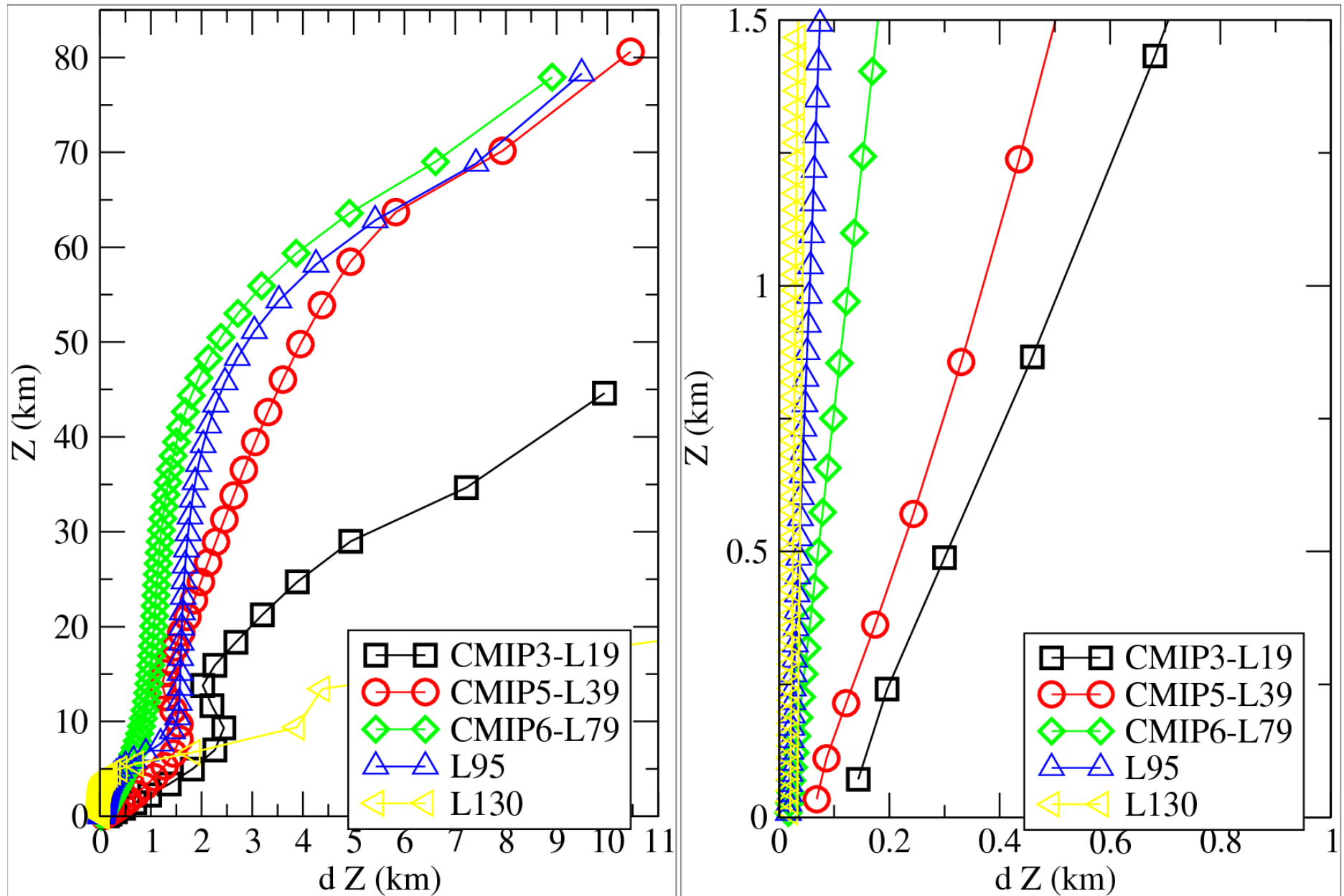
Hourdin, F., C. Rio, J.-Y. Grandpeix, J.-B. Madeleine, F. Cheruy, N. Rochetin, A. Jam, I. Musat, A. Idelkadi, L. Fairhead, M.-A. Foujols, L. Mellul, A. Traore, J.-L. Dufresne, O. Boucher, M.-P. Lefebvre, E. Millour, E. Vignon, J. Jouhaud, B. Diallo, F. Lott, G. Gastineau, A. Caubel, Y. Meurdesoif, and J. Ghattas,

LMDZ6A: the atmospheric component of the IPSL climate model with improved and better tuned physics, James,

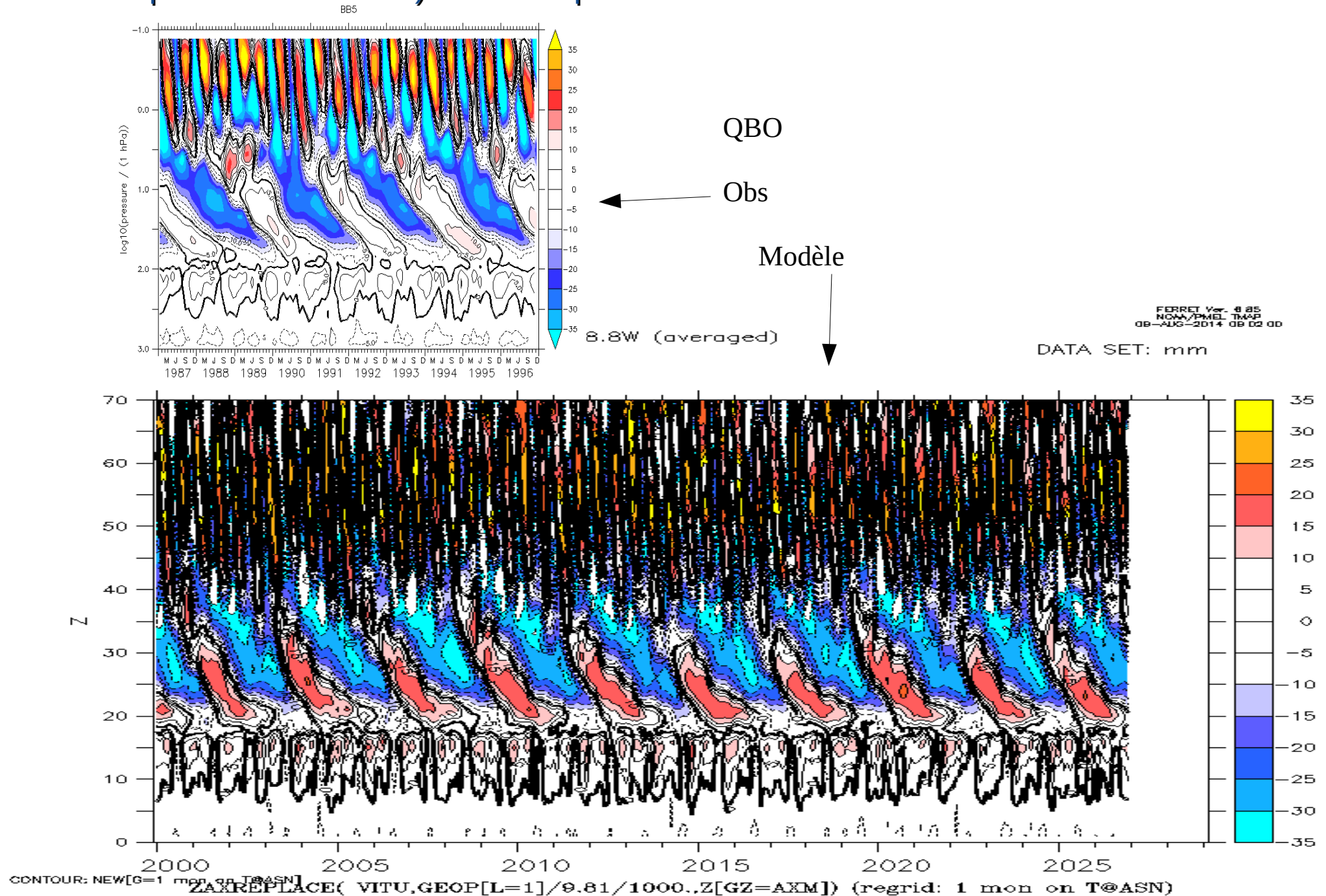
<http://dx.doi.org/10.1029/2019MS001892>

2. Reference configurations : b) LMDZ reference configurations

Evolution of the vertical discretization in LMDZ reference configurations



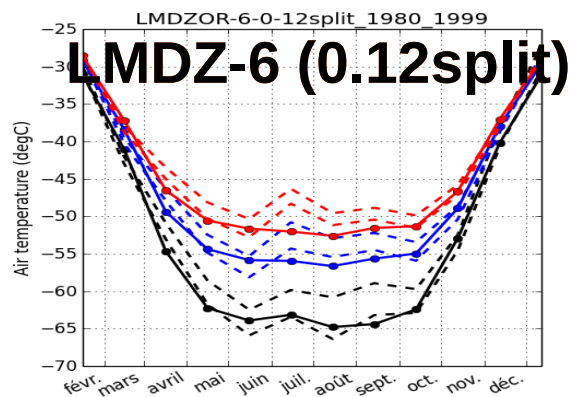
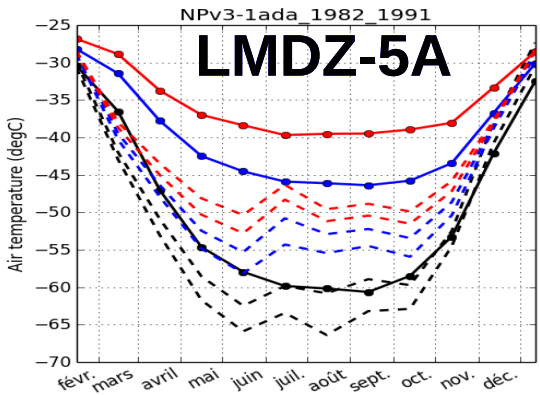
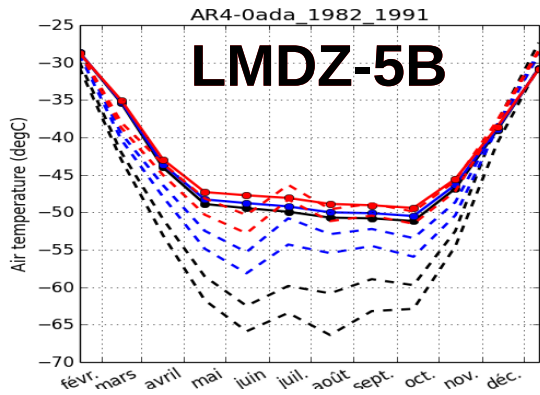
2. Inter-comparison exercises c) Robust improvements from version to version



Among the models with a Quasi Bienal Oscillation

2. Inter-comparison exercises c) Robust improvements from version to version

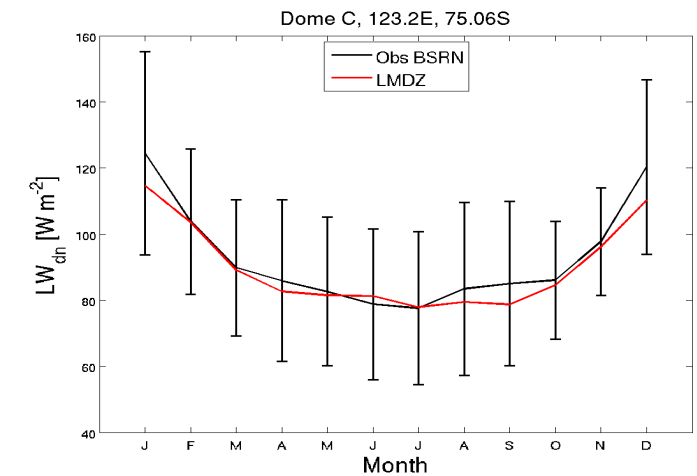
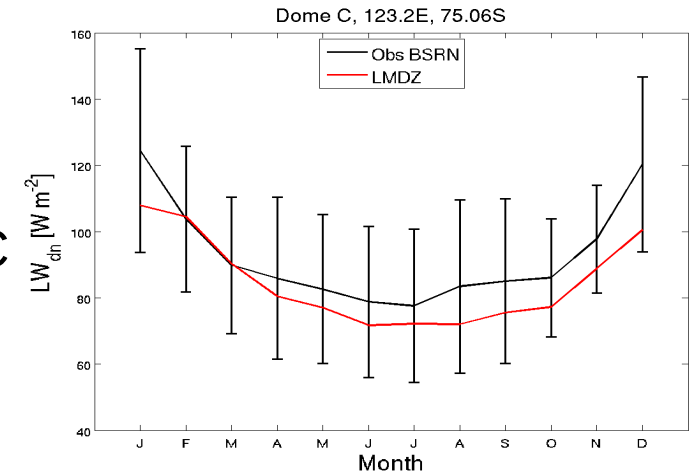
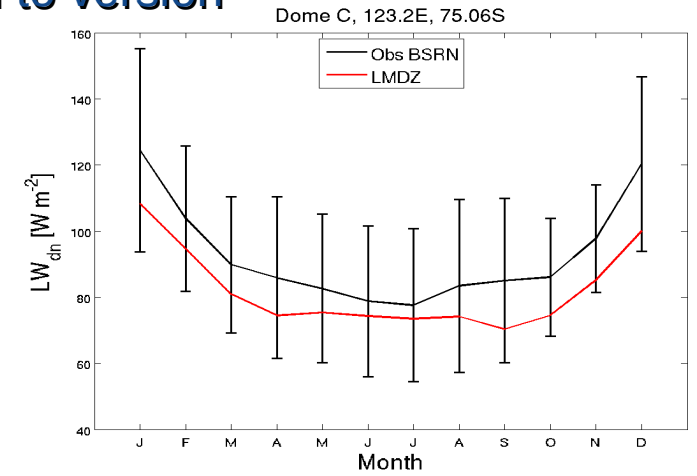
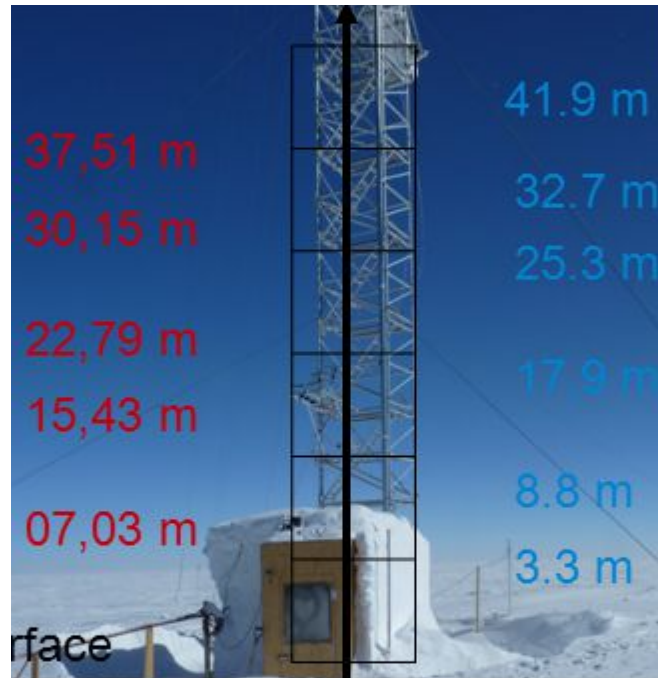
T at Dome C Antarctic Plateau



- LMDz (z=21.8m)
- - OBS 3.5m (2010)
- - OBS 10.9m (2010)
- LMDz (z=71.3m)
- - OBS 18.3m (2010)
- - OBS 25.6m (2010)
- LMDz (z=139.0m)
- - OBS 33.0m (2010)
- - OBS 42.2m (2010)

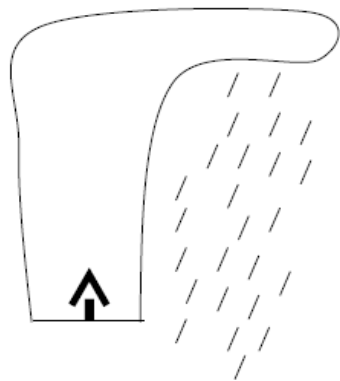
Improvement of the representation of the stable boundary layer.
Vignon et al. 2017

Compared to observations at 5 levels over a 40m measurement tower at Dome C



2. Reference configurations : b) LMDZ reference configurations

The different physical packages of LMDZ reference versions

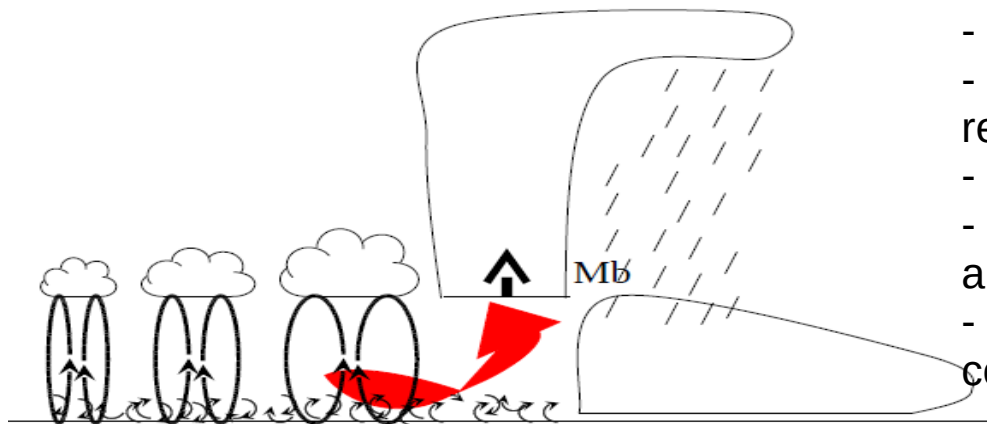


LMDZ5A (old or standard physics)

- Diffusion scheme (Louis, 1979)
- Deep convection (Emanuel, 1991)
- Cloud scheme (Bony et Emanuel, 2001)

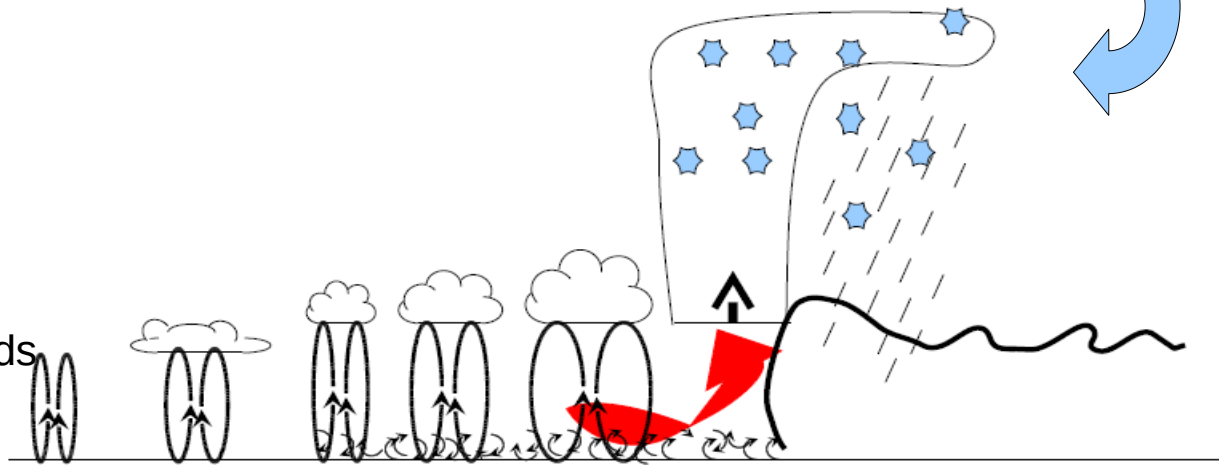
LMDZ5B (« new physics »)

- Diffusion scheme (Yamada, 1983)
- Thermal plume model except in strato cumulus regions (Rio et al., 2010)
- Cold pools (Grandpeix et Lafore, 2010)
- Deep convection controlled by thermals and wakes (Rio et al., 2012)
- Bi-gaussian cloud scheme for shallow convection (Jam et al., 2013)



LMDZ6 = LMDZ5B ++

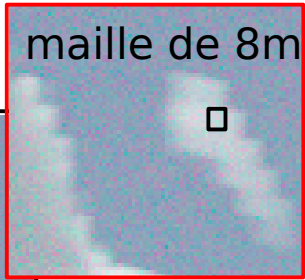
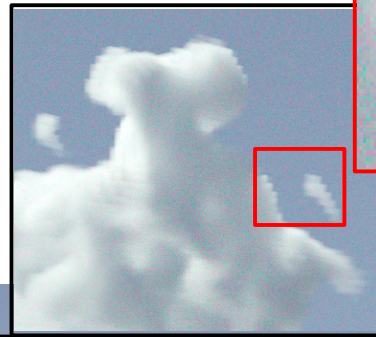
- + Thermal plume model everywhere
- + Stochastic triggering of deep convection
- + Different convective mixing formulation
- + Thermodynamical effect of ice
- + RRTM for infrared radiation and SW 6 bands
- + Better boundary layer for stable conditions
- + Non orographic gravity waves





Field campaign experiment

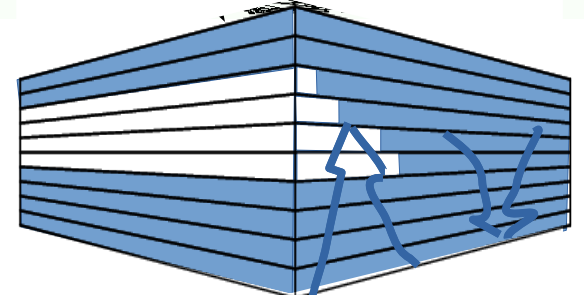
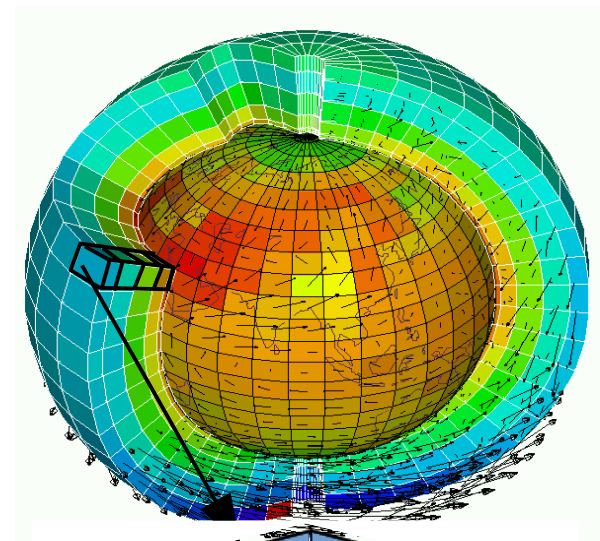
Evaluation



Detailed simulation (LES : Large Eddy Simulation)

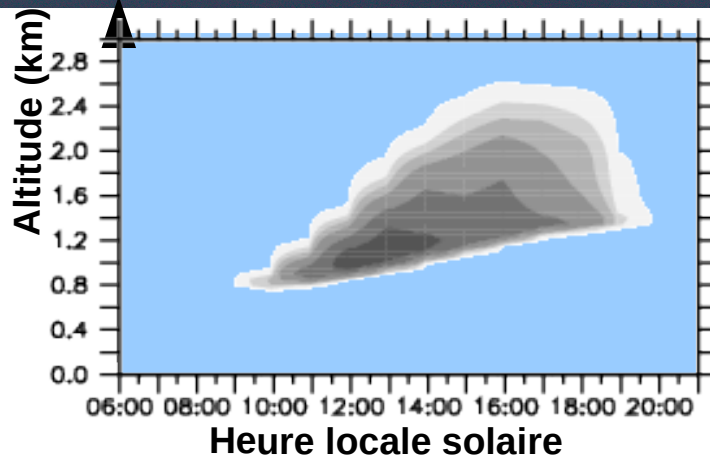


12km

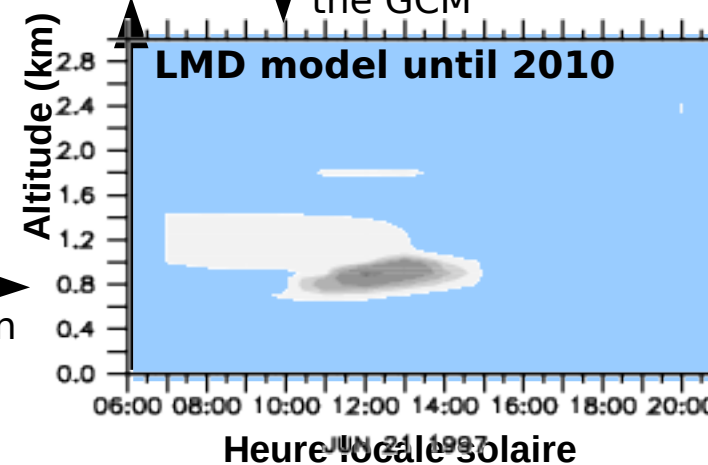


Computing the cloud fraction for each grid cell in one column of the GCM

Computing at each altitude the fraction of the horizontal domain covered by clouds. Also called : **the cloud fraction**



Evaluation

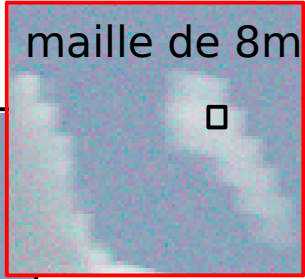
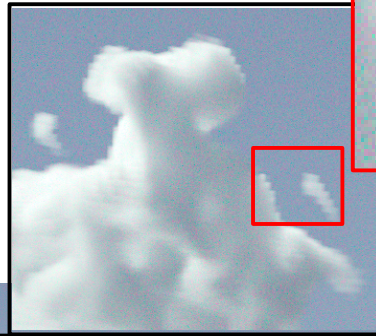


JUN 21 1997



Field campaign experiment

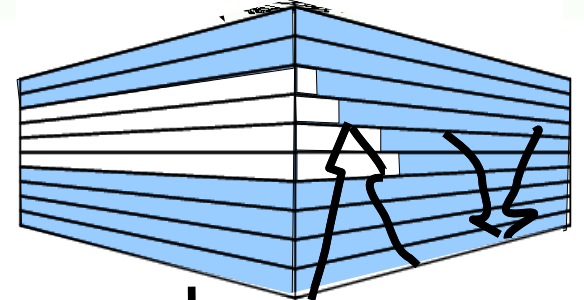
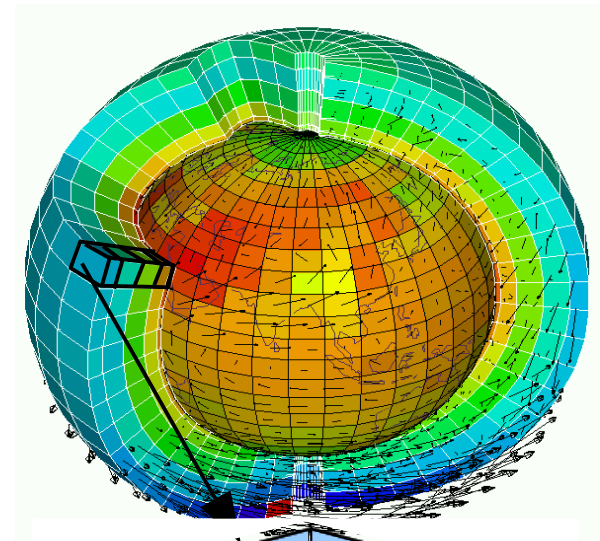
Evaluation



Detailed simulation (LES : Large Eddy Simulation)

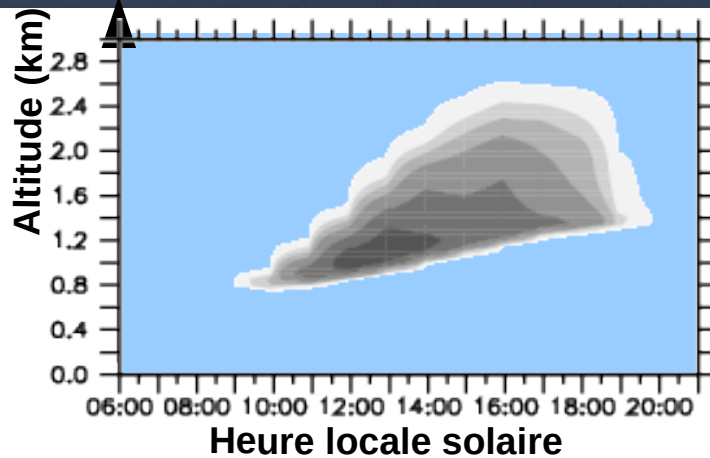


12km

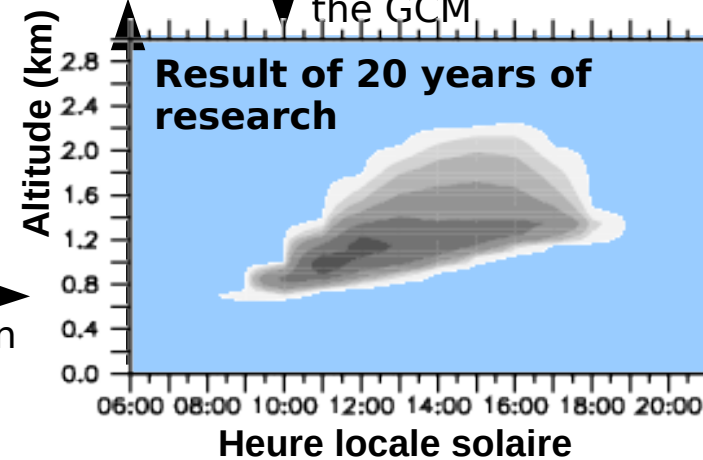


Computing the cloud fraction for each grid cell in one column of the GCM

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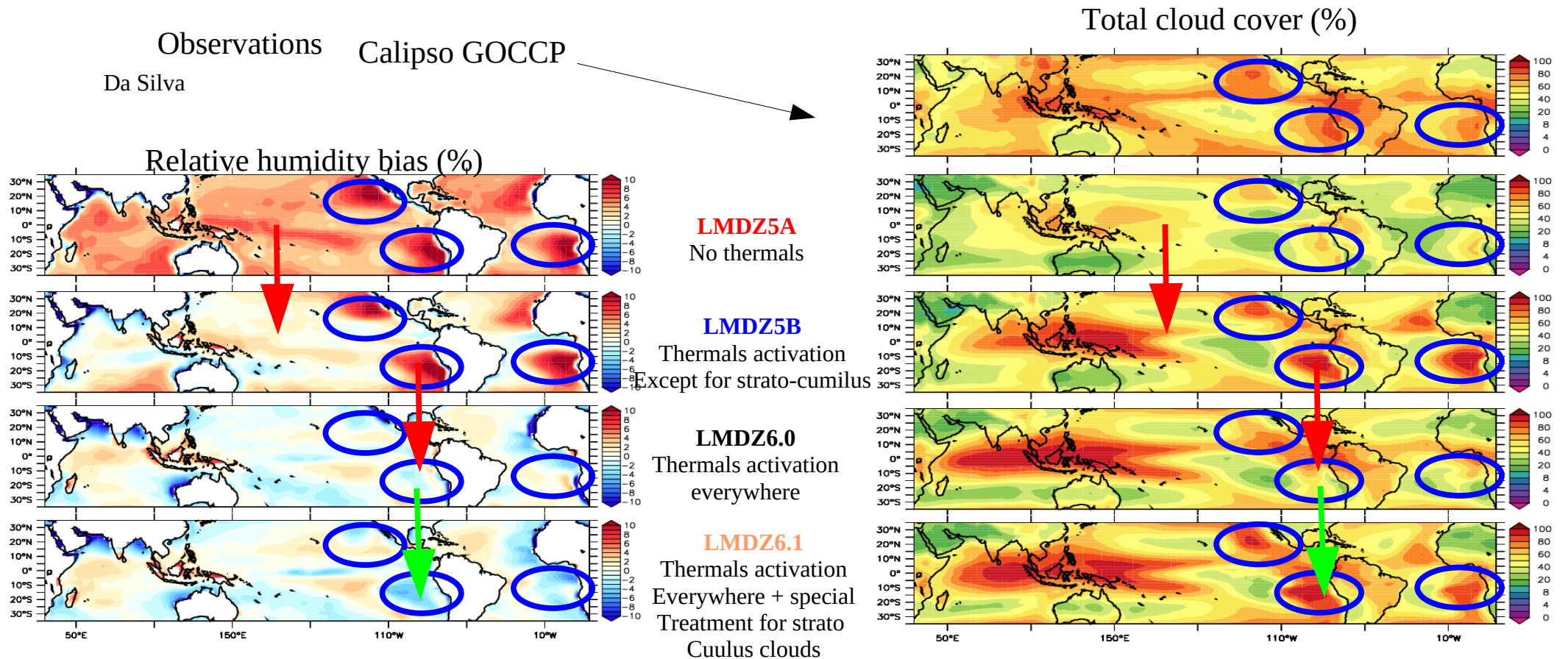
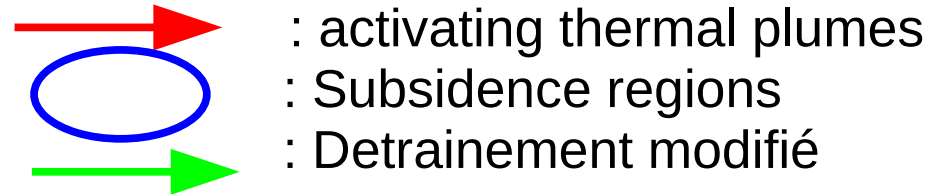
Evaluation



2. Inter-comparison exercises c) Robust improvements from version to version

Successive activation of the thermal plume model

Results from atmospheric simulations forced by climatic sea surface temperature



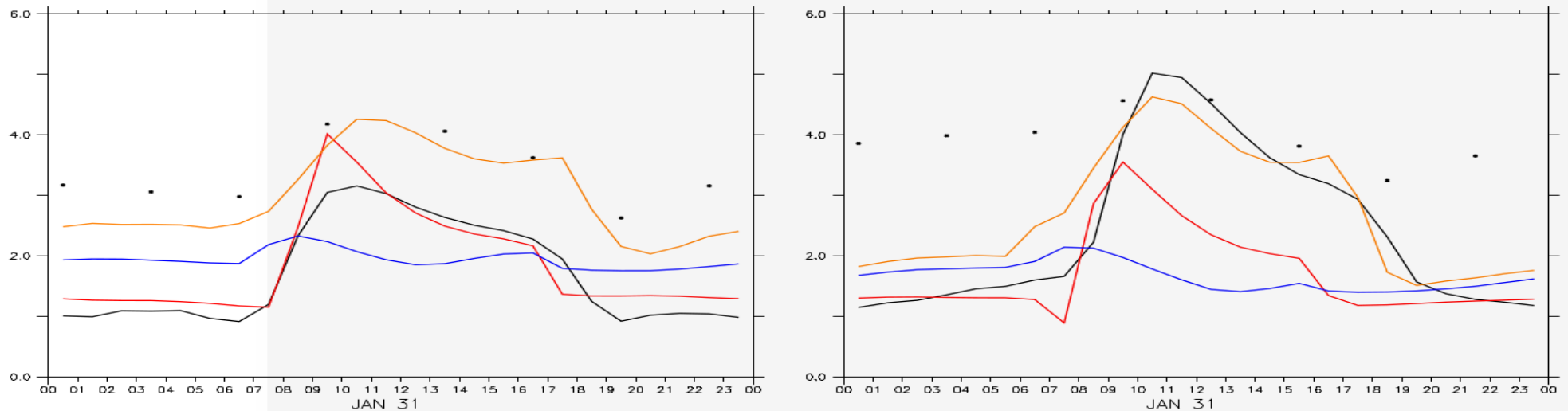
Frédéric Hourdin, Arnaud Jam, Catherine Rio, Fleur Couvreur, Irina Sandu, Marie-Pierre Lefebvre, Florent Brient, and Abderrahmane Idelkadi, Unified Parameterization of Convective Boundary Layer Transport and Clouds With the Thermal Plume Model, James, 2019, <https://doi.org/10.1029/2019MS001666>

Hourdin, Frédéric and Rio, Catherine and Jam, Arnaud and Traore, Abdoul Khadre and Musat, Ionela, Convective boundary layer control of the sea surface temperature in the tropics, Journal of Advances in Modeling Earth Systems, 12, <https://doi.org/10.1029/2019MS001988>

2. Inter-comparison exercises c) Robust improvements from version to version

- • • Observations
- Reanalyses (used to nudge)
- 5A
- 5B
- 6

Wind speed diurnal cycle over Sahel (Jan. to March 2006, Cinzana and Banyzoumbou)



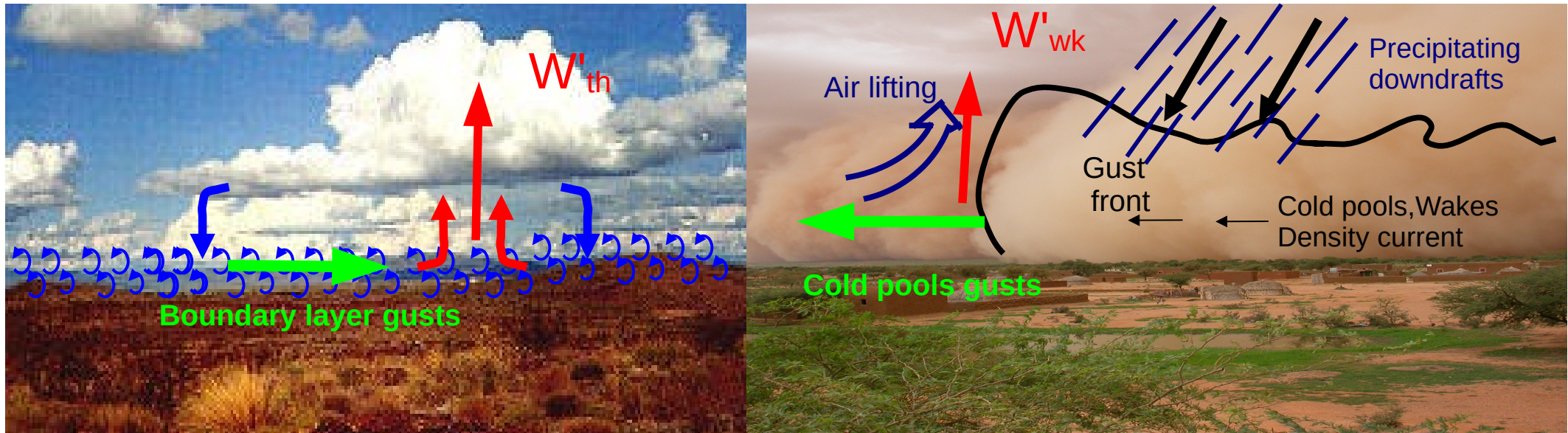
Summary of « thermal plume » model added value :

- Better vertical transport
- Drying of the surface
- Better representation of winds
- Coupled to bi-gaussian cloud scheme: representation of cumulus and strato-cumulus clouds

2. Inter-comparison exercises c) Robust improvements from version to version

New physics (LMDZ5B)

Deep convection closure (triggering and intensity) controled by sub-cloud processes :
Using vertical velocity coming from the thermals and cold pools

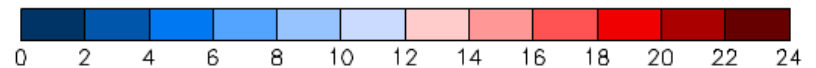
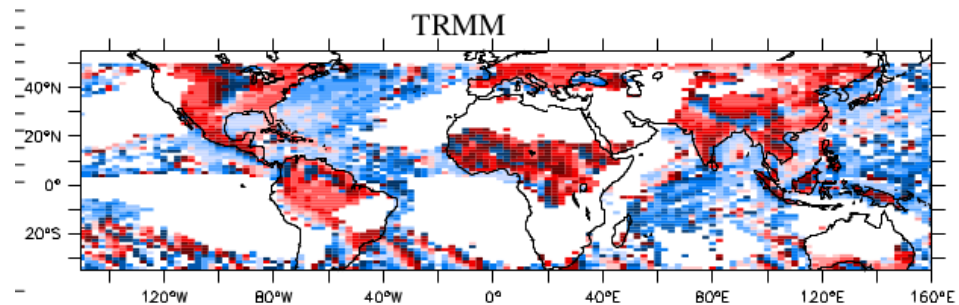
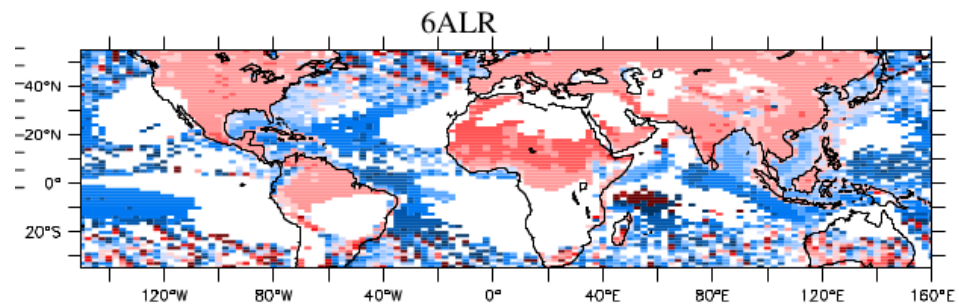
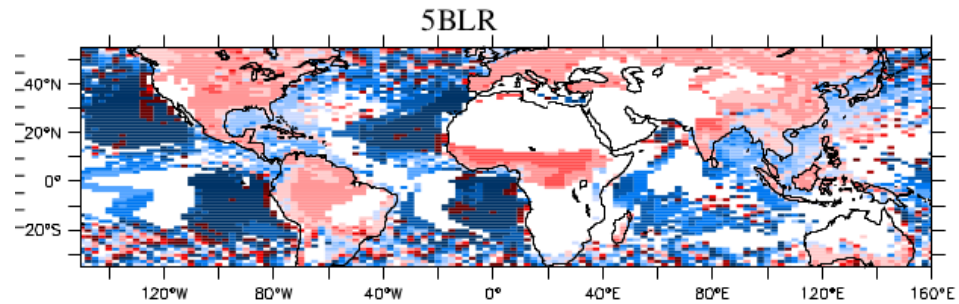
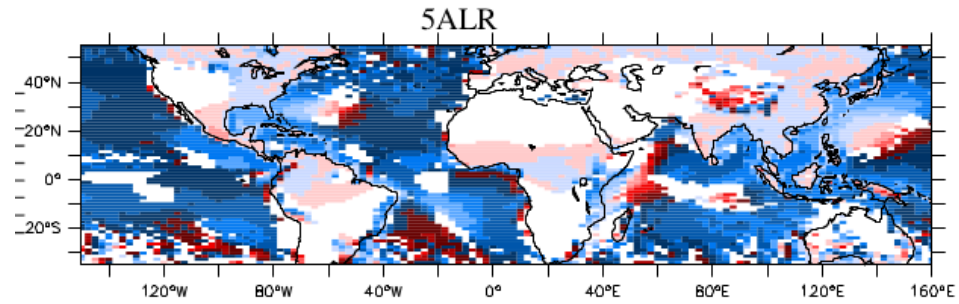
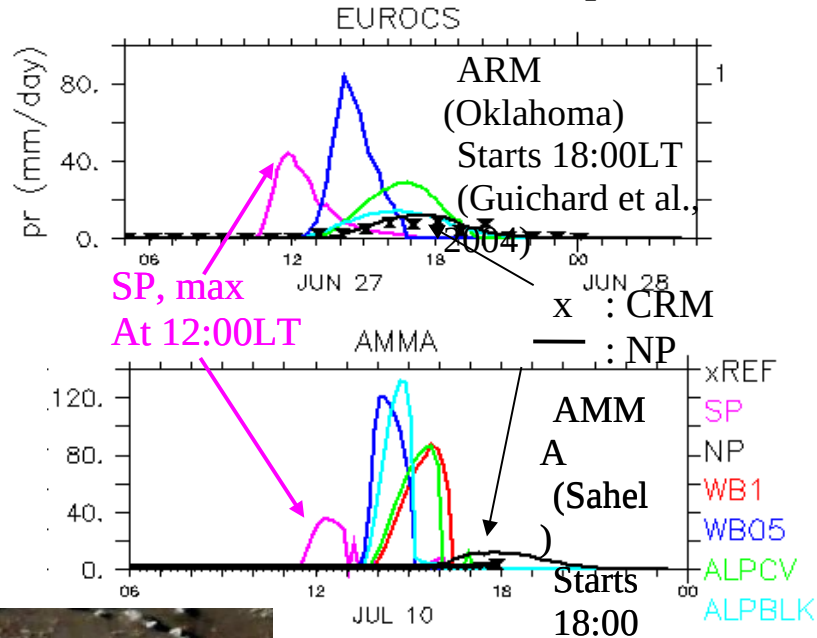


Improvements since LMDZ5 :
Random triggering
Accounting for gusts

2. Inter-comparison exercises c) Robust improvements from version to version

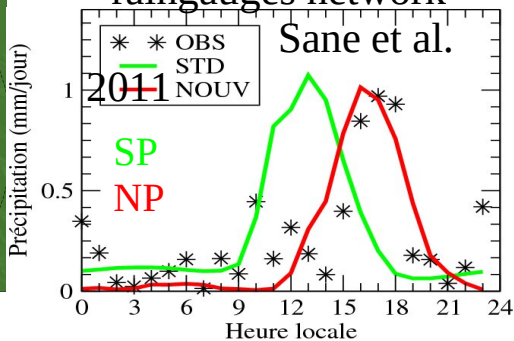
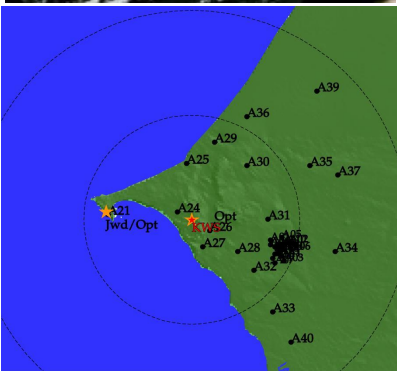
Shifting the diurnal cycle of convective rainfall : possible with parameterized convection

1D test cases/ comparison with explicit simulations (MesoNH)



AMMA 10 July case, convection initiation, Niamey
Couvreur et al., 2012
Rio et al., 2012

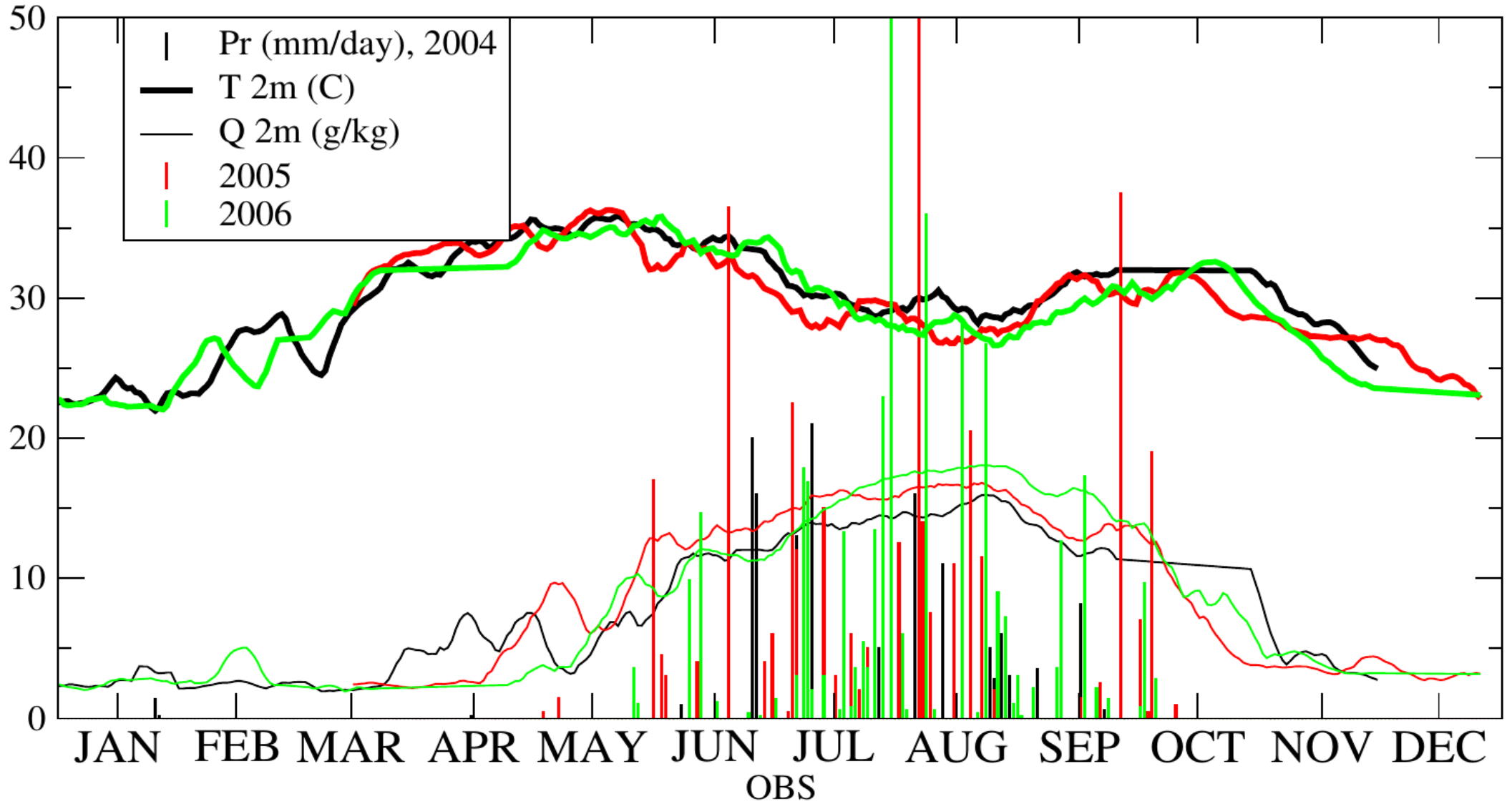
Dakar LPAOSF/NASA raingauges network



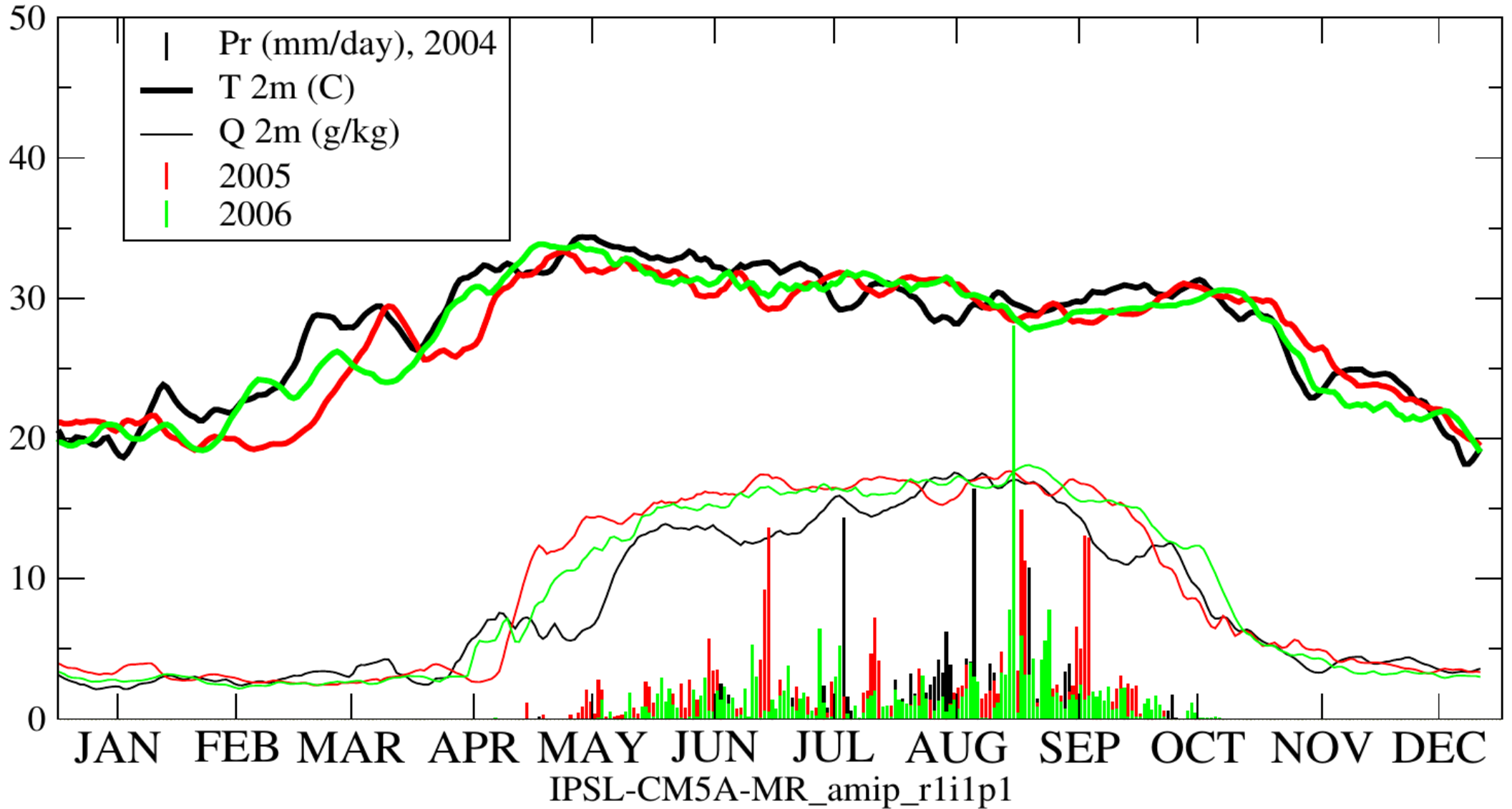
- Evolution moyenne de la pluie dans la journée
- au Sénégal dans une Simulation 3D

A good representation of the diurnal cycle of rainfall over continents

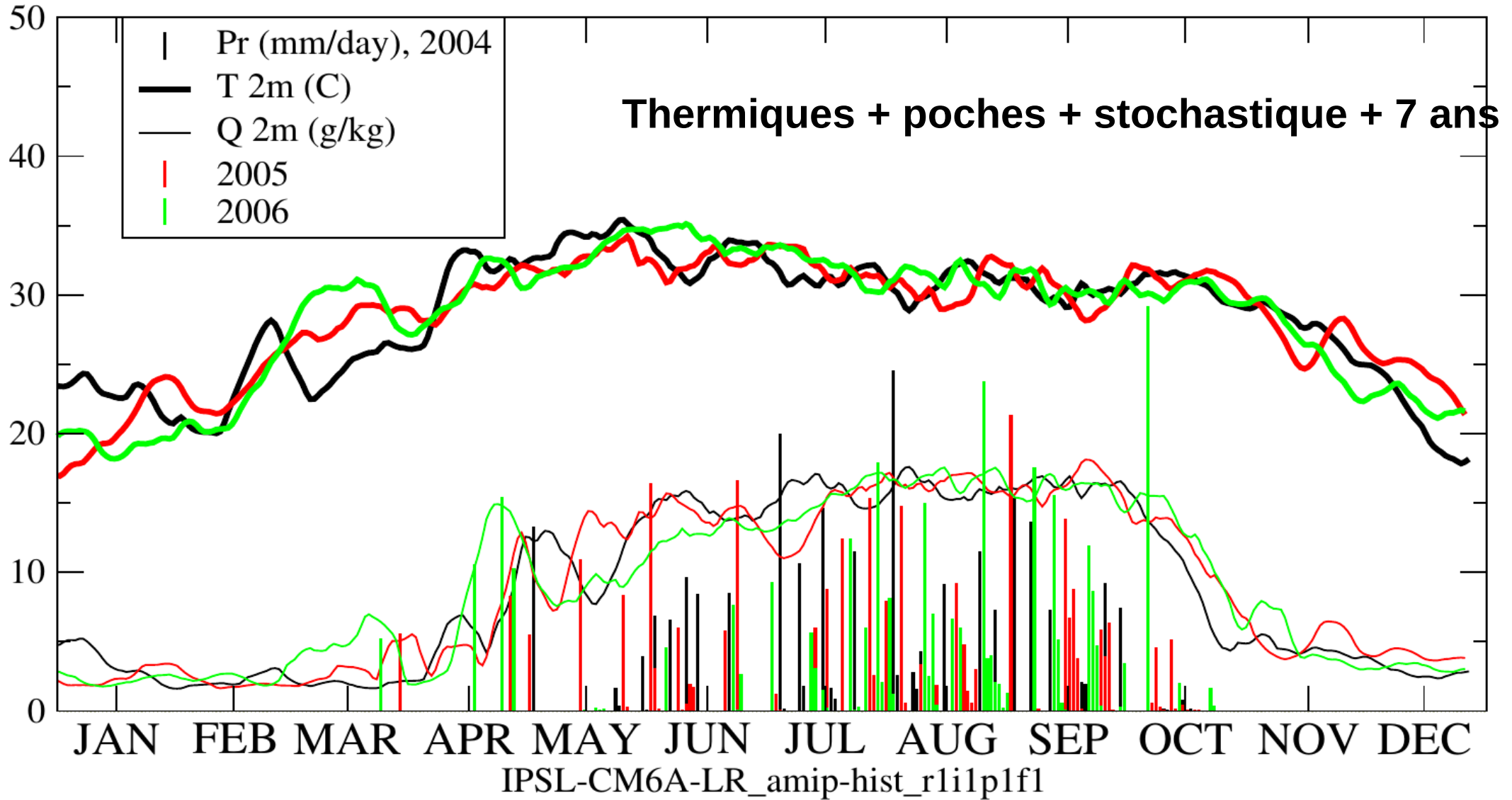
Observations Agoufou, Mali, 2004, 2005, 2006



Simulations amip, IPSL-CM5A Agoufou, Mali, 2004, 2005, 2006

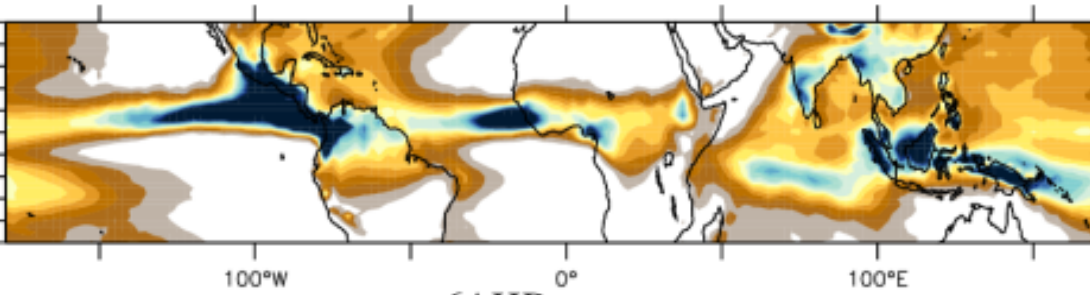
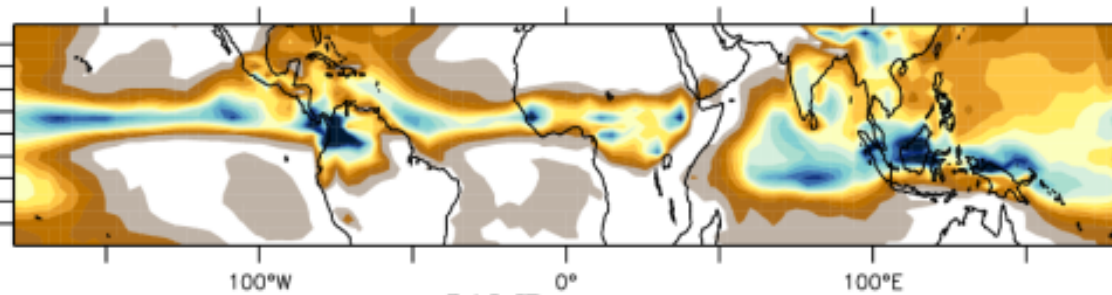


Simulations amip, IPSL-CM6A Agoufou, Mali, 2004, 2005, 2006



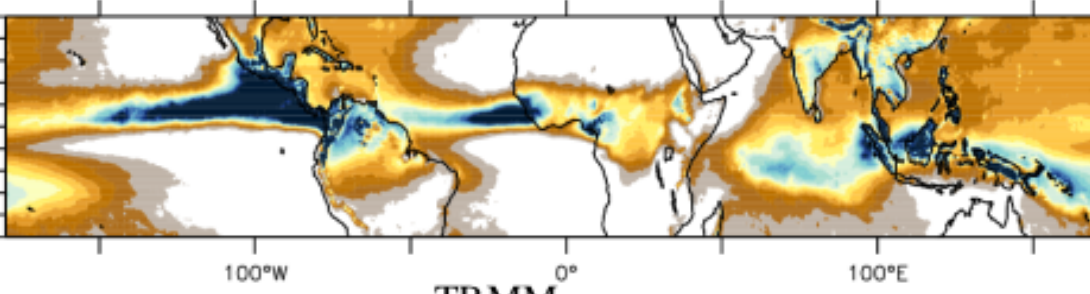
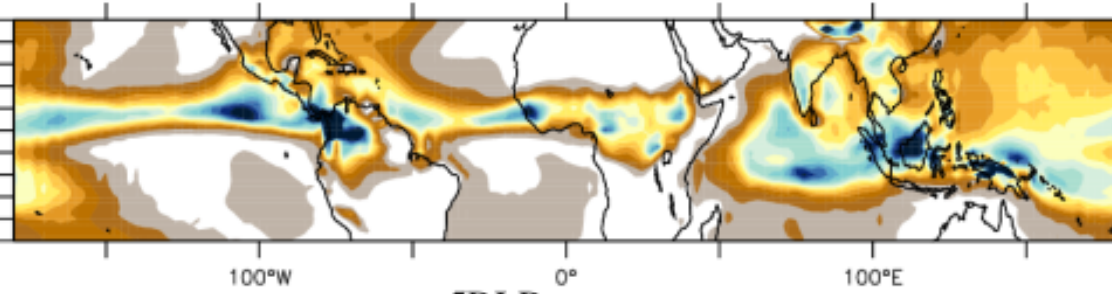
5ALR

6ALR



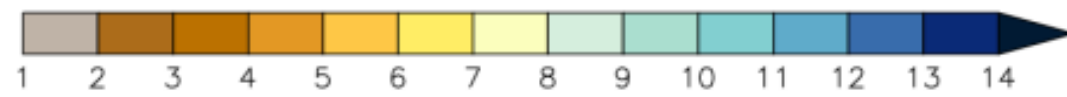
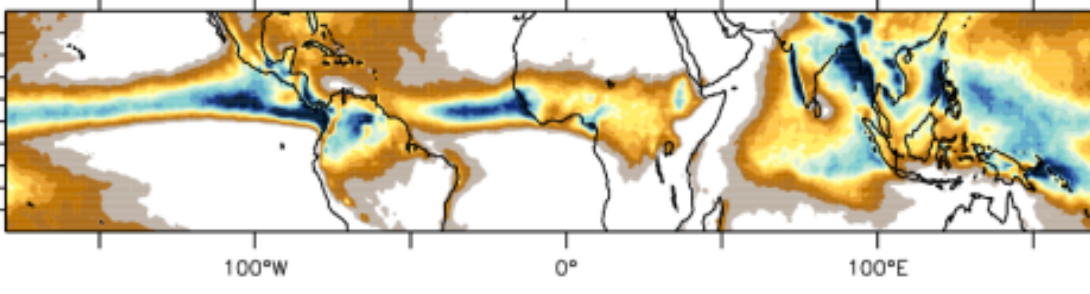
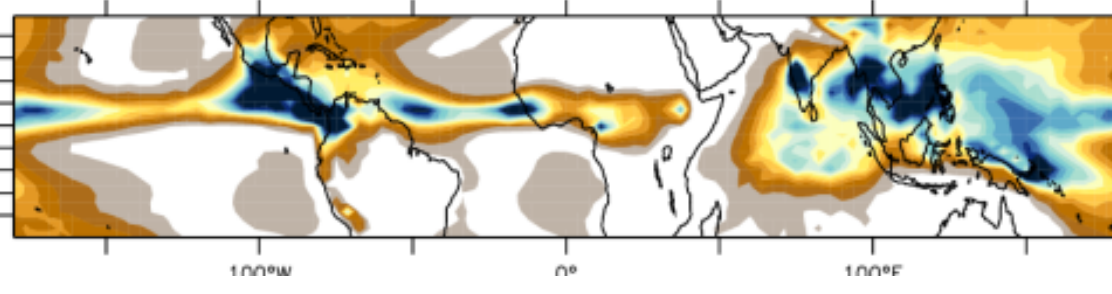
5AMR

6AHR

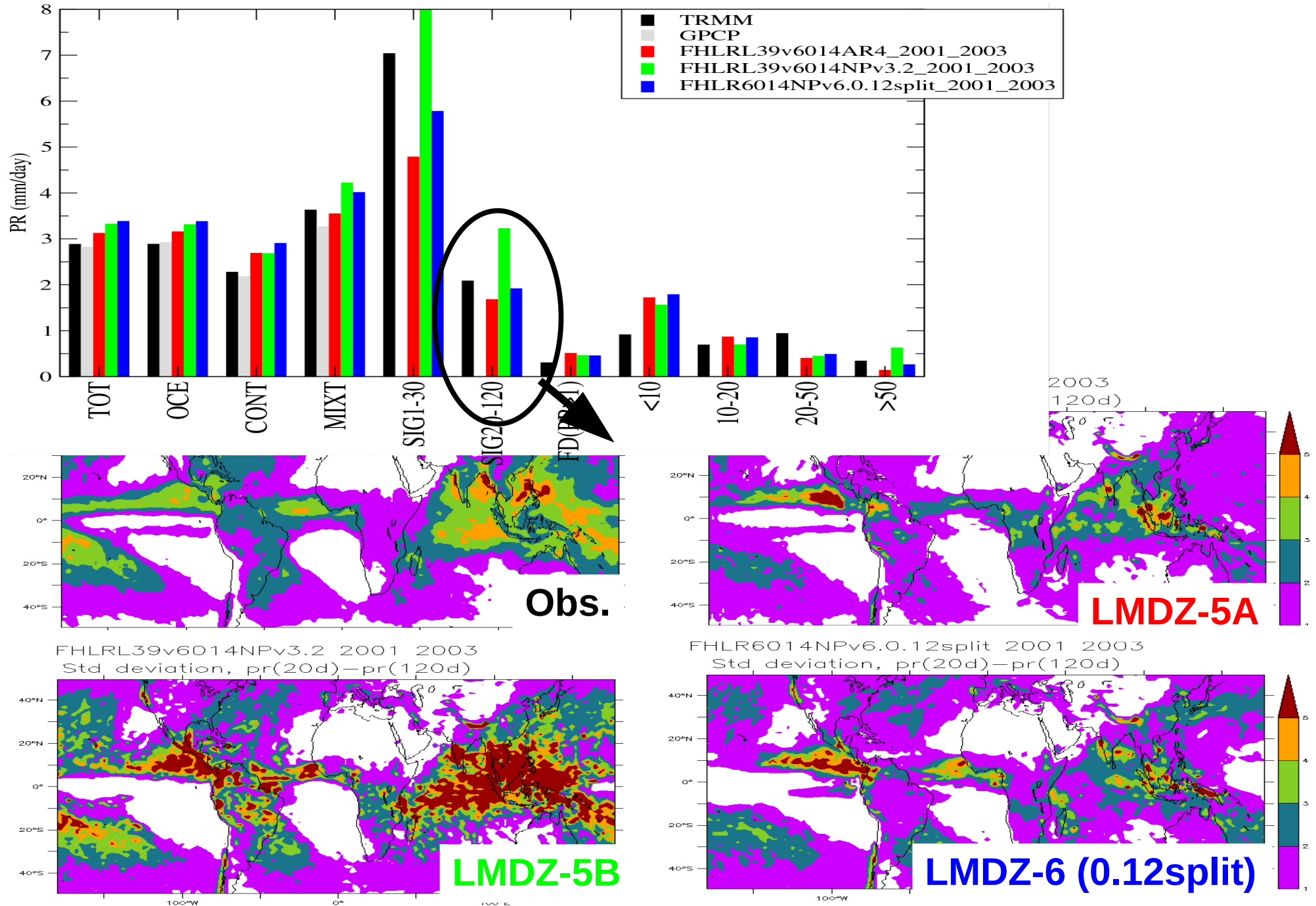


5BLR

TRMM



2. Reference versions d) Evolution of climatic biases and sensitivity



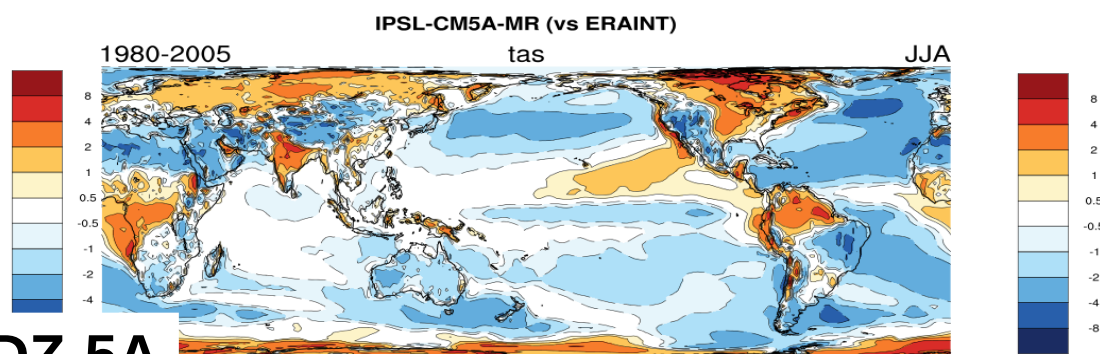
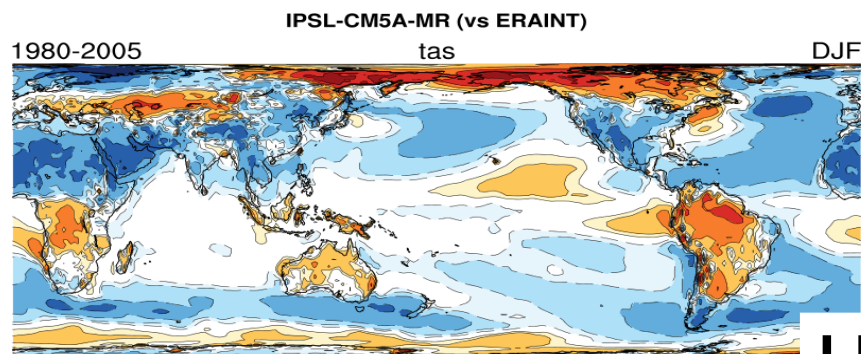
Rainfall variability in the 20 – 120 day period range

2. Reference versions d) Evolution of climatic biases and sensitivity

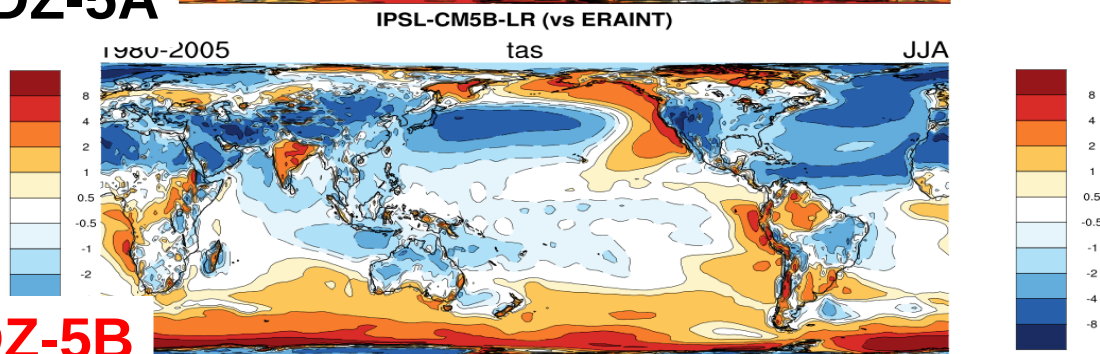
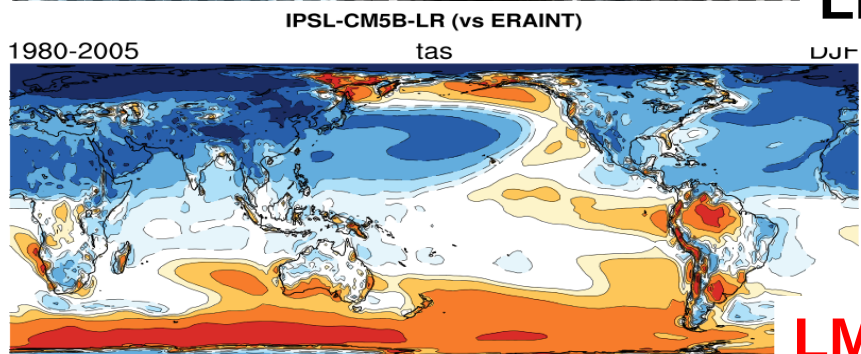
Air surface temperature bias ($^{\circ}\text{C}$), coupled simulations

Dec.-Jan.-Feb.

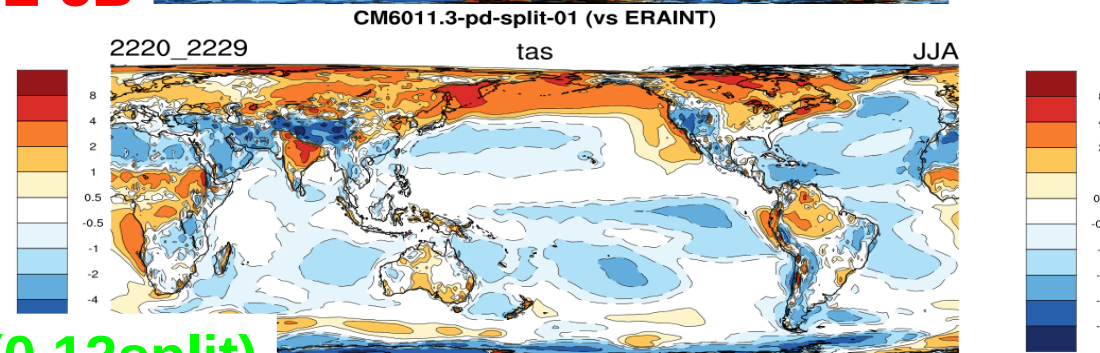
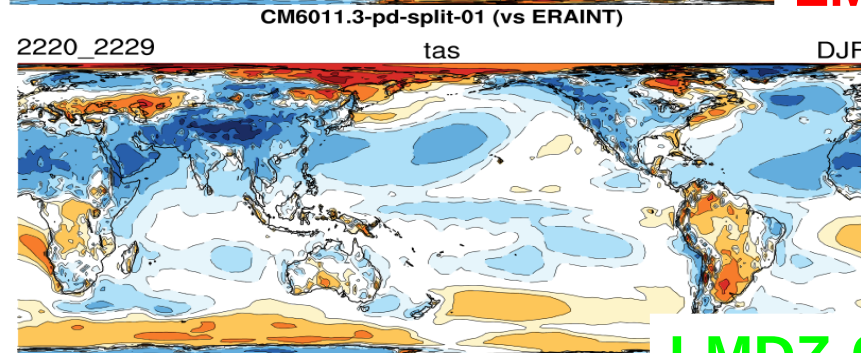
Jun.-Jul.-Aug.



LMDZ-5A



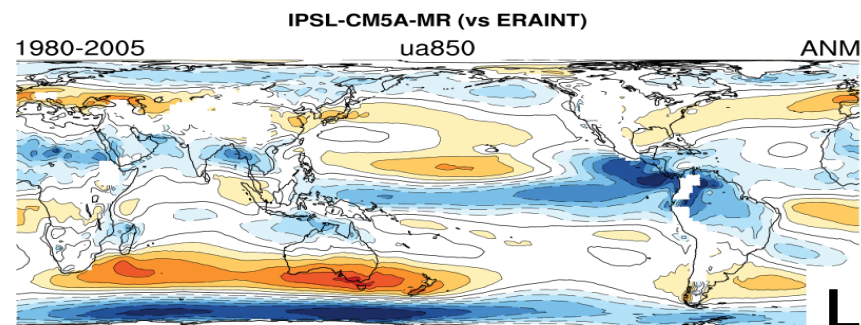
LMDZ-5B



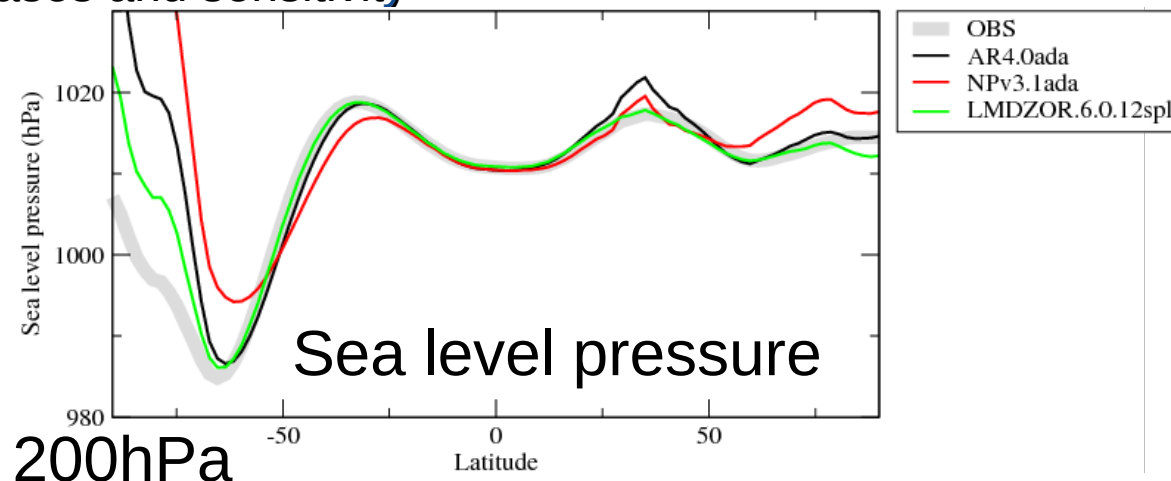
LMDZ-6 (0.12split)

2. Reference versions d) Evolution of climatic biases and sensitivity

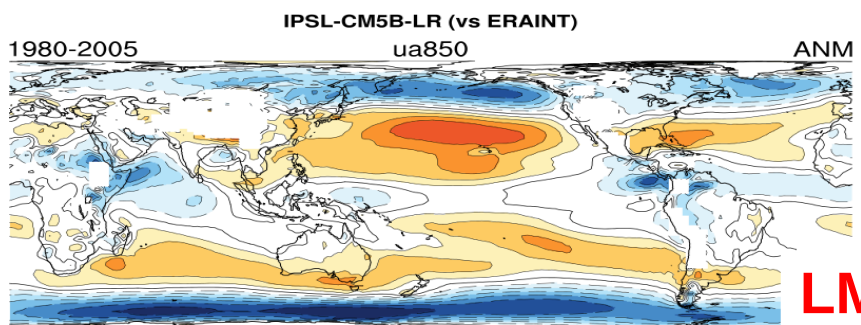
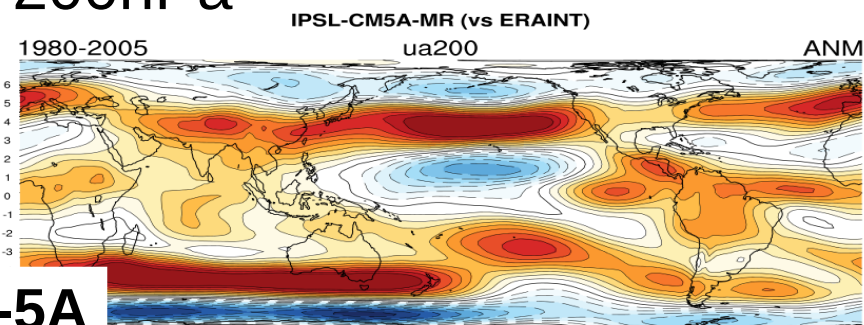
Zonal wind (m/s), coupled model
850hPa



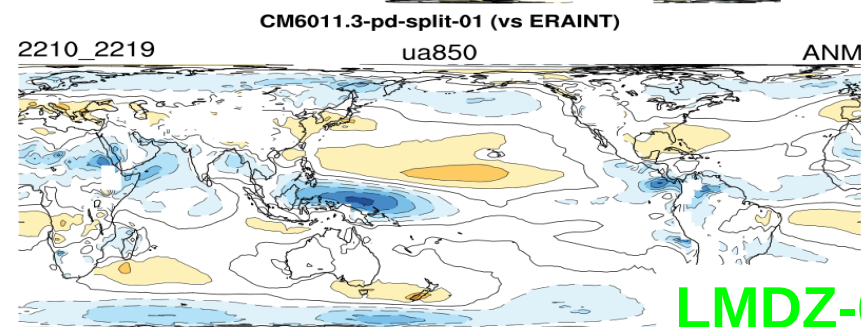
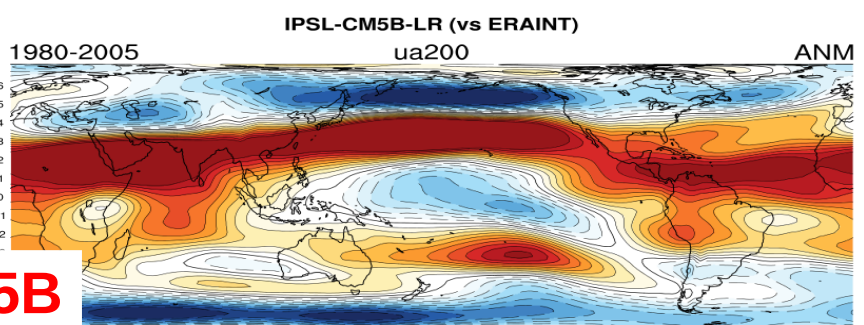
LMDZ-5A



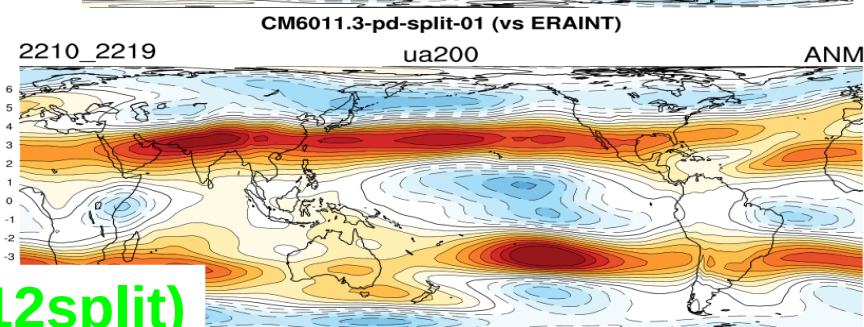
200hPa



LMDZ-5B



LMDZ-6 (0.12split)



2. Reference versions

Summary

Robust improvements

Convective boundary layer : diurnal cycle of clouds and wind

Better cumulus and stratocumulus clouds

Better phasing of the diurnal cycle of deep convection

Intermittency of convection over continents

Better representation of stable boundary layer

QBO representation

Biases

Reduced summer continental warm biases in LMDZ6

Better position of the mid-latitude jets

Reduced bias of monsoon rainfall

Reduced warm biases over oceans

Reduced continental surface temperature biases (?)

Enso acceptable but room for improvement

Variability of rainfall too small in LMDZ6 (>LMDZ5A (low) and <B (high))

LMDZ : use and configurations

1. Operating modes of the 3D GCM
 - a) Free climatic mode
 - b) Zooming or/and nudging for climate
 - c) Tracer transport

2. Intercomparison exercises and reference versions
 - a) IPSL climate model and CMIP exercises
 - b) LMDZ reference versions
 - c) Robust improvements from version to version
 - d) Evolution of climatic biases and sensitivity

- 3. Model development and tuning**
 - a) Choice of a new configuration : content and resolution**
 - b) Importance of tuning**
 - c) Methodology 1D/nudged simulations/tuning**

6. Model development and tuning : a) choice of a new configuration

Definition of model configurations

1. Horizontal resolution and vertical discretization
2. Physical content – Choice of a particular set of parameterizations
3. **Tuning of free parameters !**

Preparation of a configuration is a long process

Sensitivity tests to the grid, physical parameterizations, free parameters

Compromises. Can depend on team priorities.

For global climate coupled atmosphere/ocean modeling the tuning of the radiative forcing is a key issue. Several months of tuning for one version.

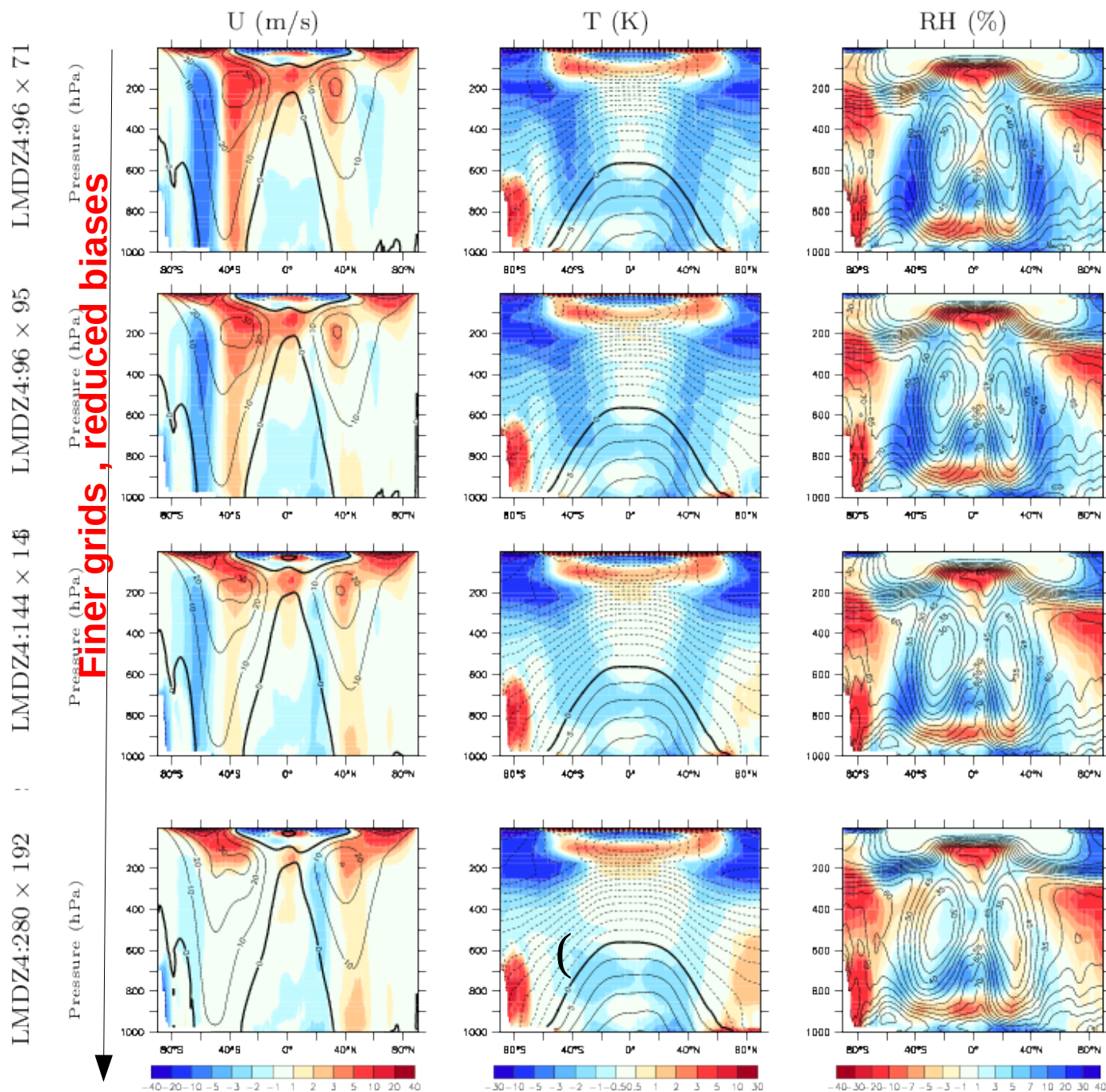
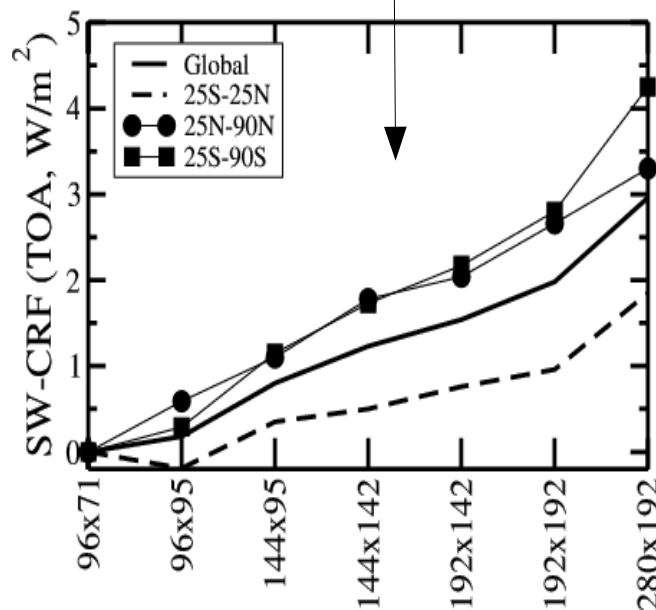
6. Model development and tuning : a) choice of a new configuration

From LMDZ4 to LMDZ5 and LMDZ6 : change of horizontal resolution

Dependance of model biases to the horizontal resolution.

Because of the number of simulations to be performed in CMIP exercises, the reference configurations are a compromise.

The global energy balance is sensitive to the horizontal resolution



6. Model development and tuning : a) choice of a new configuration

Definition of model configurations

1. Horizontal resolution and vertical discretization
2. Physical content – Choice of a particular set of parameterizations
3. Tuning of free parameters !

Preparation of a configuration is a long process

Sensitivity tests to the grid, physical parameterizations, free parameters

Compromises. Can depend on team priorities.

For global climate coupled atmosphere/ocean modeling the tuning of the radiative forcing is a key issue. Several months of tuning for one version.

6. Model development and tuning : b) tuning of free parameters

Definition of model configurations

1. Horizontal resolution and vertical discretization
2. Physical content – Choice of a particular set of parameterizations
3. **Tuning of free parameters !**

Preparation of a configuration is a long process

Sensitivity tests to the grid, physical parameterizations, free parameters

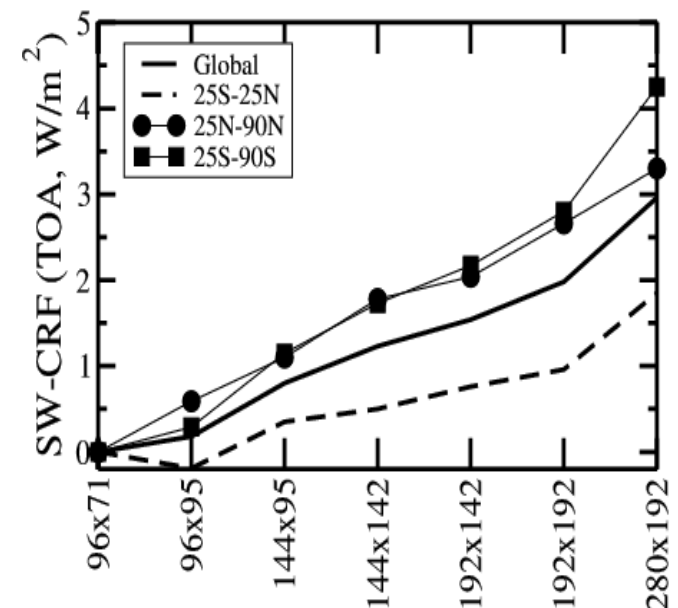
Compromises. Can depend on team priorities.

For global climate coupled atmosphere/ocean modeling the tuning of the radiative forcing is a key issue. Several months of tuning for one version.

1W/m² in radiative balance translates into 1K temperature bias in the coupled model

Much below uncertainties in modeling and observation of radiative fluxes

So the global temperature of climate models is a result of tuning !!!



Tuning of free parameter : a fundamental aspect of climate modeling

Feeling that this question was not discussed enough, we organized a one-week workshop on model tuning with Torsten Mauritsen in October 2014 in Garmisch-Partenkirchen.

The Art and Science of Climate Model Tuning, Hourdin et al., **BAMS**, march 2017

**One particularly important aspect shared by most groups:
tuning of cloud parameters to obtain a reasonable representation of radiative forcing**

Example of tuning of a scale factor on the fall velocity of ice particles shared by several models

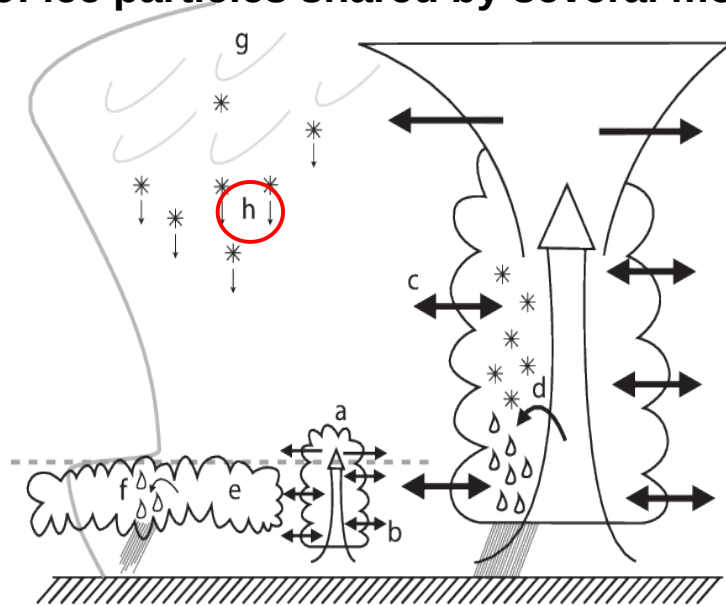
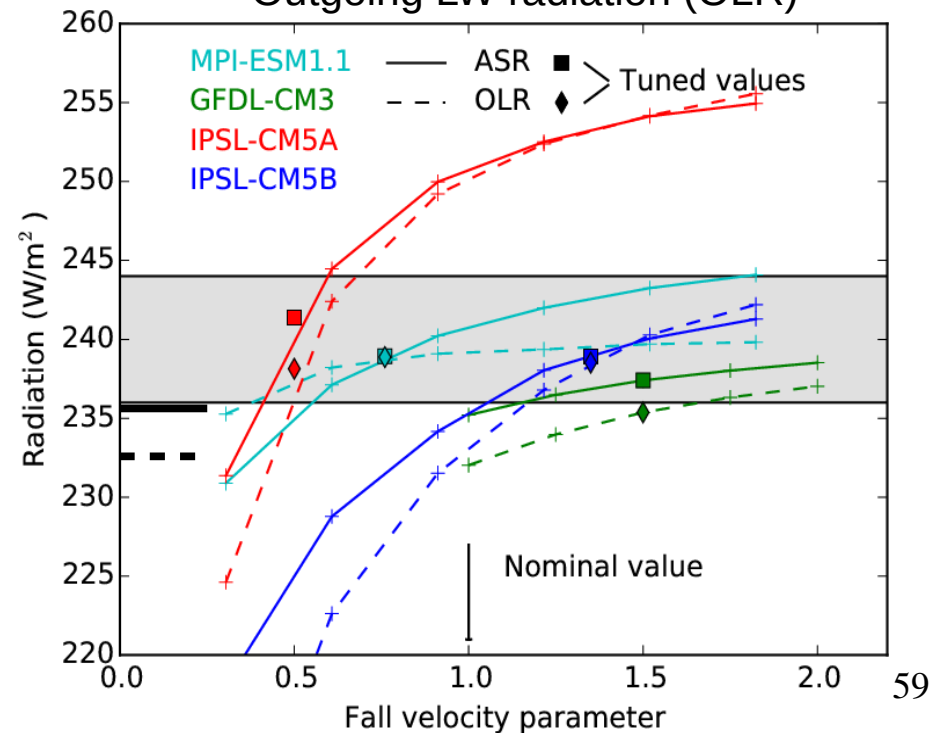


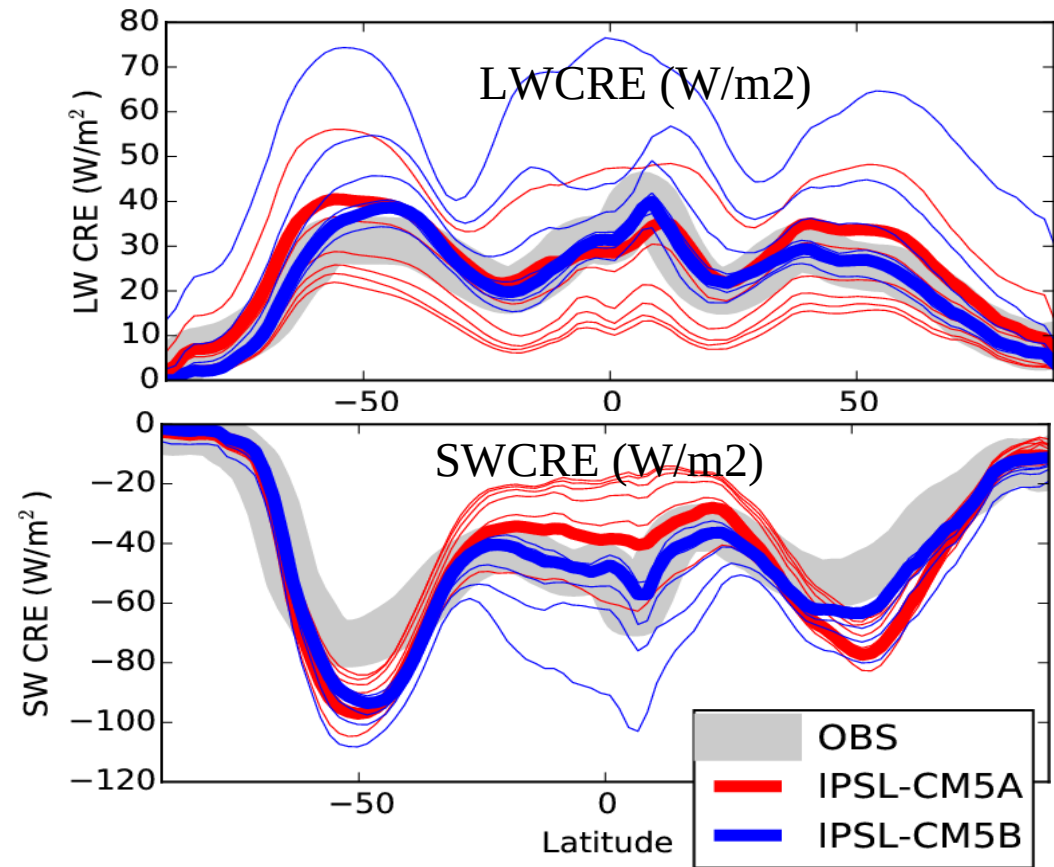
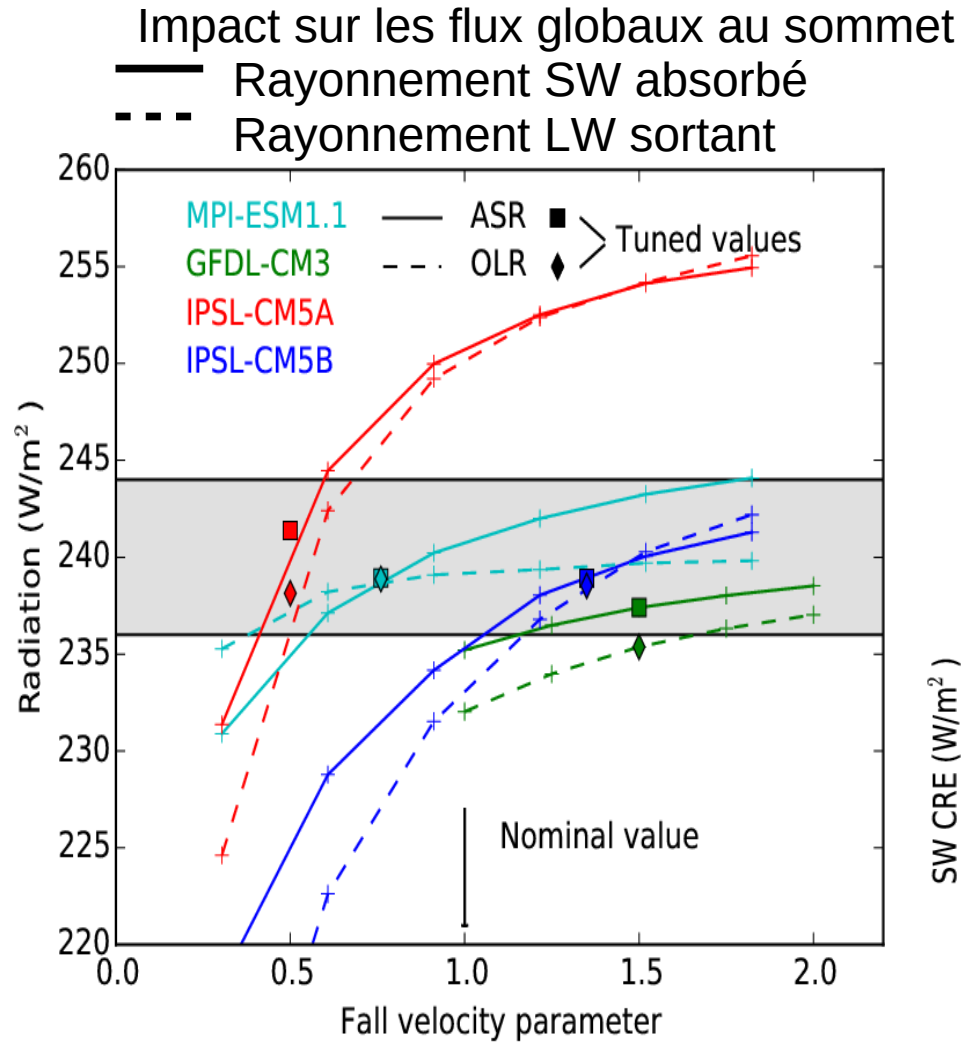
Figure from Mauritsen et al, 2013 (MPI model)

Impact on the global Top-Of-Atmosph. fluxes
Absorbed SW radiation (ASR)
Outgoing LW radiation (OLR)



6. Model development and tuning : b) tuning of free parameters

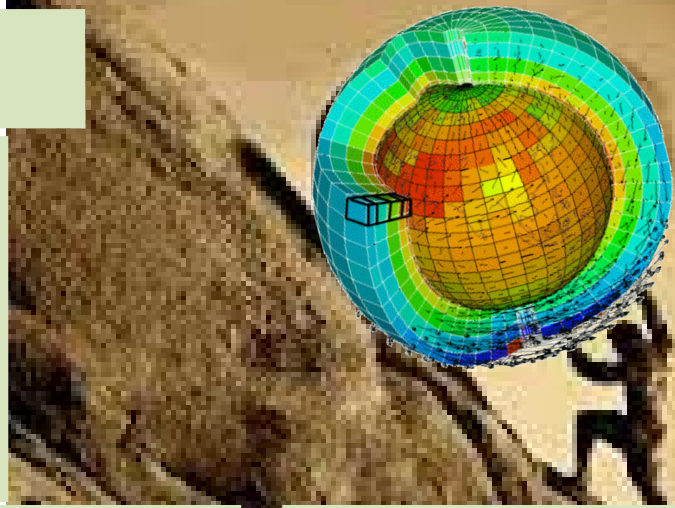
Use of a scaling factor on the fall velocity of cloud ice particles Impact on global radiative balance and latitudinal radiative forcing of the circulation



2012 : CMIP5B « nouvelle physique »
Thermiques + poches + fermeture

Été 2015, 1eres simulations longues :

- Stabilisation num couche lim.
- Déclench. Stochast. Convect.
- Strato-cus avec thermiques.
- Microphysique glace
- Ondes non orog. → QBO
- L39 → L79



Convection
-Conditionnée par point de congélation
- densité de poches diff. 0/A
- réglage w base convection
- rafales → z0 océaniques
Conserv. E.2

Thermiques à l'extérieur des poches. Effet des arbres et des colines

Reréglage des nuages bas :
Nb noyaux réévaporation

Nuages-convection
iflag_mix=1
iflag_coud_vert=1

RRTM
+fisrt+
lmix

Nouveaux z0
Sur océans
Conserv E.1

Orographie
Tuning param
+ Accélération x2

IPSLCM6.0.1

IPSLCM6.0.2

IPSLCM6.0.3

IPSLCM6.0.4

IPSLCM6.0.5

IPSLCM6.0.6

IPSLCM6.0.7

IPSLCM6.0.8

IPSLCM6.0.9

IPSLCM6.0.10

IPSLCM6.0.11split

IPSLCM6.0.12split

IPSLCM6.0.14splith

IPSLCM6.1

Ete 2015

Ete 2016

Printemps 2017

Eté 2017

Début 2018

New Tmix

Calving

Température de la neige (SST->Tice)
Température de la pluie pondérée

Améliorations de code

Tests de paramètres

Corrections de bugs

paramètres liés à la glace de mer
Conductivité de la neige
Lmixmin, amaxn,
amaxs, hstar

paramètres liés à la glace de mer
Albedo, amaxn, amaxs, pstar

Continuous improvement accompanied by a systematic tuning

2014	2015	2016	2017	<u>Evolution du contenu physique par rapport à NPv3.1</u>
V	V	V	V	Déjà dans les sources (2014) :
V	V	V	V	- schémas numériques stabilisés pour la couche limite
C	V	V	V	- déclenchement stochastique
C	C	V	V	- Thermodynamique de la glace
C	C	V	V	- RRTM (Marie-Pierre/Olivier/Jean-Louis) : bascule septembre/octobre
C	C	V	V	- startocu (Arnaud/Frédéric)
C	C	C	C	- splitting de la couche limite poche/extérieur (Jean-Yves)
X	V	V	V	- pdf bigaussiennes pour la convection profonde (Arnaud/Catherine, Jean-Yves)
X	C	C	V	- « pdf verticales » (Jean-Louis & Arnaud → Jean + Jean-Louis + Jean-Baptiste)
X	V	V	V	- Paramétrisations pour la QBO (F. Lott)
X	V	V	V	- Extension de la phase mixte liquide / glace des nuages.
C	C	C	V	- Evolution de la fermeture stoch. (orages points de grille, convection trop faible)
C	V	V	V	- Albedo océan f(vents) (Sunghye)
C	V	V	V	- Orchidee 11 couches (utilisé en standard)
X	C	V	V	- nouvelle thermo du sol (Frédérique, Fuxing, Sonia, Jean-Louis)
X	C	C	V	- Revisite des flux O/A, prise en compte des rafales
			C	- Conservation de l'énergie. Sèche (2016), puis nuages (2017)
			V	- Modification du schéma de Mellor et Yamada
			V	- Terme source de TKE provenant de l'orographie sous maille
			V	- freinage par les bosquets
				En réserve
				- Convection sur le relief
				- microphysique nuages de glace
				- Calcul de TKE basé sur la conservation.
				- SRTM ?

V : Validé
C : en cours
X : non engagé

6. Model development and tuning : b) tuning of free parameters

2006 : IPSL-CM4 (CMIP3)
2012 : IPSL-CM5A (CMIP5)
2016 : IPSL-CM5A2
(used for paleo climates)

	LMDZ5A
Boundary-layer	
Mellor et Yamada	iflag_pbl=1
Thermals	iflag_thermals=0
Mixing rates in thermals	iflag_thermals_ed=0
Thermals top mixing	fact_thermals_ed_dz UNDEF
Coupling with deep convection	iflag_coupl=0
Convection	
Emanuel old/new	iflag_con=30
Closure CAPE/ALP	iflag_clos=1
Cold pools	iflag_wake=0
Stochastic closure	iflag_trig_bl UNDEF
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=1
Efficiency of precipitation	epmax=0.999
Clouds	
Ice thermodynamics	iflag_ice_thermo UNDEF
Cloud scheme	iflag_cldcon=3
Profile of σ/qt	iflag_ratqs=0
σ/qt min	ratqsbas=0.005
σ/qt max	ratqshaut=0.33
Mixed phase of clouds	iflag_t_glance UNDEF
Threshold cloudy water LS	cld_lc_lsc=0.000416
Threshold cloudy water CV	cld_lc_con=0.000416
Ice crystals fall speed LS	ffallv_lsc=0.5
Ice crystals fall speed CV	ffallv_con=0.5
Coefficient of evaporation	coef_eva=2e-05
Radiation	iflag_rrtm=0

6. Model development and tuning : b) tuning of free parameters

2012 : IPSL-CM5B (CMIP5)
First version with the
New Physics
(thermal plumes and
Cold pools)

	NPv3.1 (LMDZ5B)
Boundary-layer	
Mellor et Yamada	iflag_pbl=8
Thermals	iflag_thermals=15
Mixing rates in thermals	iflag_thermals_ed=10
Thermals top mixing	fact_thermals_ed_dz=0.1
Coupling with deep convection	iflag_coupl=5
Convection	
Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=0
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.997
Clouds	
Ice thermodynamics	iflag_ice_thermo=0
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=2
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.25
Mixed phase of clouds	iflag_t_glance=0
Threshold cloudy water LS	cld_lc_lsc=0.0006
Threshold cloudy water CV	cld_lc_con=0.0006
Ice crystals fall speed LS	ffallv_lsc=1.35
Ice crystals fall speed CV	ffallv_con=1.35
Coefficient of evaporation	coef_eva=0.0001
radiation	iflag_rrtm=0

6. Model development and tuning : b) tuning of free parameters

2014 : toward IPSL-CM6
First version with
Stratocumulus and
Stochastic closure

	NPv4.12
Boundary-layer	
Mellor et Yamada	iflag_pbl=11
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.1
Coupling with deep convection	iflag_coupl=5
Convection	
Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=2
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.97
Clouds	
Ice thermodynamics	iflag_ice_thermo=0
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=4
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.24
Mixed phase of clouds	iflag_t_glance=1
Threshold cloudy water LS	cld_lc_lsc=0.000192
Threshold cloudy water CV	cld_lc_con=0.000192
Ice crystals fall speed LS	ffallv_lsc=0.9504
Ice crystals fall speed CV	ffallv_con=0.9504
Coefficient of evaporation	coef_eva=1e-05
radiation	iflag_rrtm=0

6. Model development and tuning : b) tuning of free parameters

NPv5.17h (IPSL-CM 6.0.1)

Boundary-layer

Mellor et Yamada
Thermals
Mixing rates in thermals
Thermals top mixing
Coupling with deep convection

iflag_pbl=11
iflag_thermals=18
iflag_thermals_ed=8
fact_thermals_ed_dz=0.1
iflag_coupl=5

Convection

Emanuel old/new
Closure CAPE/ALP
Cold pools
Stochastic closure
PDF for mixing
Computation of condensate
Efficiency of precipitation

iflag_con=3
iflag_clos=2
iflag_wake=1
iflag_trig_bl=1
iflag_mix=0
iflag_clw=0
epmax=0.998

Clouds

Ice thermodynamics
Cloud scheme
Profile of σ/qt
 σ/qt min
 σ/qt max
Mixed phase of clouds
Threshold cloudy water LS
Threshold cloudy water CV
Ice crystals fall speed LS
Ice crystals fall speed CV
Coefficient of evaporation
radiation

iflag_ice_thermo=**1**
iflag_cldcon=6
iflag_ratqs=4
ratqsbas=0.002
ratqshaut=0.312
iflag_t_glance=1
cld_lc_lsc=0.0003
cld_lc_con=0.0003
ffallv_lsc=0.66528
ffallv_con=0.66528
coef_eva=2e-05
iflag_rrtm=0

Summer 2015

Ice thermo dynamics

First multi decadal simulations

6. Model development and tuning : b) tuning of free parameters

LMDZ 5.4 (IPSL-CM 6.0.2)

Boundary-layer

Mellor et Yamada
Thermals
Mixing rates in thermals
Thermals top mixing
Coupling with deep convection

iflag_pbl=11
iflag_thermals=18
iflag_thermals_ed=8
fact_thermals_ed_dz=0.1
iflag_coupl=5

Convection

Emanuel old/new
Closure CAPE/ALP
Cold pools
Stochastic closure
PDF for mixing
Computation of condensate
Efficiency of precipitation

iflag_con=3
iflag_clos=2
iflag_wake=1
iflag_trig_bl=1
iflag_mix=1
iflag_clw=0
epmax=0.9995

Clouds

Ice thermodynamics
Cloud scheme
Profile of σ/qt
 σ/qt min
 σ/qt max
Mixed phase of clouds
Threshold cloudy water LS
Threshold cloudy water CV
Ice crystals fall speed LS
Ice crystals fall speed CV
Coefficient of evaporation
radiation

iflag_ice_thermo=1
iflag_cldcon=6
iflag_ratqs=4
ratqsbas=0.002
ratqshaut=0.312
iflag_t_glance=1
cld_lc_lsc=0.0001
cld_lc_con=0.0001
ffallv_lsc=1
ffallv_con=1
coef_eva=2e-05
iflag_rrtm=0

Feb 2016

New mixing
+ crash fixed

6. Model development and tuning : b) tuning of free parameters

LMDZ 5.5 (IPSL-CM 6.0.3)

Boundary-layer

Mellor et Yamada
Thermals
Mixing rates in thermals
Thermals top mixing
Coupling with deep convection

iflag_pbl=11
iflag_thermals=18
iflag_thermals_ed=8
fact_thermals_ed_dz=0.1
iflag_coupl=5

April 2016

Convection

Emanuel old/new
Closure CAPE/ALP
Cold pools
Stochastic closure
PDF for mixing
Computation of condensate
Efficiency of precipitation

iflag_con=3
iflag_clos=2
iflag_wake=1
iflag_trig_bl=1
iflag_mix=1
iflag_clw=0
epmax=0.999

Clouds

+ RRTM !
Minimum mixing length

Ice thermodynamics
Cloud scheme
Profile of σ/qt
 σ/qt min
 σ/qt max
Mixed phase of clouds
Threshold cloudy water LS
Threshold cloudy water CV
Ice crystals fall speed LS
Ice crystals fall speed CV
Coefficient of evaporation
radiation

iflag_ice_thermo=1
iflag_cldcon=6
iflag_ratqs=4
ratqsbas=0.002
ratqshaut=0.312
iflag_t_glance=1
cld_lc_lsc=0.00022
cld_lc_con=0.00022
ffallv_lsc=0.67
ffallv_con=0.67
coef_eva=2e-05
iflag_rrtm=1

6. Model development and tuning : b) tuning of free parameters

NPv5.70 (IPSL-CM 6.0.5)

Boundary-layer

Mellor et Yamada	iflag_pbl=11
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.1
Coupling with deep convection	iflag_coupl=5

Convection

Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=1
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.999

Clouds

Ice thermodynamics	iflag_ice_thermo=1
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=4
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.4
Mixed phase of clouds	iflag_t_glance=2
Threshold cloudy water LS	cld_lc_lsc=0.0002
Threshold cloudy water CV	cld_lc_con=0.0002
Ice crystals fall speed LS	ffallv_lsc=0.5
Ice crystals fall speed CV	ffallv_con=0.5
Coefficient of evaporation	coef_eva=0.0002
radiation	iflag_rrtm=1

July 2016

Tuning of sub grid

Scale orography

Dt phys : 10 → 15 min

6. Model development and tuning : b) tuning of free parameters

LMDZ6.0.9

Boundary-layer	
Mellor et Yamada	iflag_pbl=11
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.1
Coupling with deep convection	iflag_coupl=5

January 2017

Convection	
Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=1
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.997

Clouds	
Ice thermodynamics	iflag_ice_thermo=1
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=4
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.4
Mixed phase of clouds	iflag_t_glance=2
Threshold cloudy water LS	cld_lc_lsc=0.00015
Threshold cloudy water CV	cld_lc_con=0.00015
Ice crystals fall speed LS	ffallv_lsc=1
Ice crystals fall speed CV	ffallv_con=1
Coefficient of evaporation	coef_eva=0.0002
radiation	iflag_rrtm=1

6. Model development and tuning : b) tuning of free parameters

LMDZ6.0.12

Boundary-layer

Mellor et Yamada	iflag_pbl=12
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.07
Coupling with deep convection	iflag_coupl=5

Convection

Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=1
Mixing with env	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.9985

Clouds

Convection triggering if $T_{top} < T_{topmax}$	Ice thermodynamics	iflag_ice_thermo=1
Energy conservation (partial)	Cloud scheme	iflag_cldcon=6
MY improved for stable conditions	Profile of σ/qt	iflag_ratqs=4
	σ/qt min	ratqsbas=0.002
	σ/qt max	ratqshaut=0.4
	Mixed phase of clouds	iflag_t_glance=2
	Threshold cloudy water LS	cld_lc_lsc=0.00012
	Threshold cloudy water CV	cld_lc_con=0.00012
	Ice crystals fall speed LS	ffallv_lsc=0.6
	Ice crystals fall speed CV	ffallv_con=0.6
	Coefficient of evaporation radiation	coef_eva=0.0001 iflag_rrtm=1

6. Model development and tuning : b) tuning of free parameters

LMDZ6.0.12ttop

Boundary-layer

Mellor et Yamada
Thermals
Mixing rates in thermals
Thermals top mixing
Coupling with deep convection

iflag_pbl=12
iflag_thermals=18
iflag_thermals_ed=8
fact_thermals_ed_dz=0.07
iflag_coupl=5

June 2017

Convection

Emanuel old/new
Closure CAPE/ALP
Cold pools
Stochastic closure
PDF for mixing
Computation of condensate
Efficiency of precipitation

iflag_con=3
iflag_clos=2
iflag_wake=1
iflag_trig_bl=1
iflag_mix=1
iflag_clw=0
epmax=0.998

Clouds

Ice thermodynamics
Cloud scheme
Profile of σ/qt
 σ/qt min
 σ/qt max
Mixed phase of clouds
Threshold cloudy water LS
Threshold cloudy water CV
Ice crystals fall speed LS
Ice crystals fall speed CV
Coefficient of evaporation
radiation

iflag_ice_thermo=1
iflag_cldcon=6
iflag_ratqs=4
ratqsbas=0.002
ratqshaut=0.4
iflag_t_glance=2
cld_lc_lsc=0.000106
cld_lc_con=0.000106
ffallv_lsc=0.6
ffallv_con=0.6
coef_eva=0.0001
iflag_rrtm=1

Accounting for
gustiness in surface
oceanic fluxes

6. Model development and tuning : b) tuning of free parameters

June 2017

Thermals plume
accounted for outside
cold pools only

	LMD6 split
Boundary-layer	
Mellor et Yamada	iflag_pbl=12
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.1
Coupling with deep convection	iflag_coupl=5
Convection	
Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=1
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.9997 wbmax=3, flag_wb=30
Clouds	
Ice thermodynamics	iflag_ice_thermo=1
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=4
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.4
Mixed phase of clouds	iflag_t_glance=3
Threshold cloudy water LS	cld_lc_lsc=0.000205
Threshold cloudy water CV	cld_lc_con=0.000205
Ice crystals fall speed LS	ffallv_lsc=0.6
Ice crystals fall speed CV	ffallv_con=0.6
Coefficient of evaporation radiation	coef_eva=0.0001 iflag_rrtm=1 iflag_prce=2

6. Model development and tuning : b) tuning of free parameters

LMD6.1

Boundary-layer	
Mellor et Yamada	iflag_pbl=12
Thermals	iflag_thermals=18
Mixing rates in thermals	iflag_thermals_ed=8
Thermals top mixing	fact_thermals_ed_dz=0.07
Coupling with deep convection	iflag_coupl=5

April 2018

Convection	
Emanuel old/new	iflag_con=3
Closure CAPE/ALP	iflag_clos=2
Cold pools	iflag_wake=1
Stochastic closure	iflag_trig_bl=1
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.9997
	wbmax=3, flag_wb=30

Clouds	
Ice thermodynamics	iflag_ice_thermo=1
Cloud scheme	iflag_cldcon=6
Profile of σ/qt	iflag_ratqs=4
σ/qt min	ratqsbas=0.002
σ/qt max	ratqshaut=0.4
Mixed phase of clouds	iflag_t_glance=3
Threshold cloudy water LS	cld_lc_lsc=0.00065
Threshold cloudy water CV	cld_lc_con=0.00065
Ice crystals fall speed LS	ffallv_lsc=0.8
Ice crystals fall speed CV	ffallv_con=0.8
Coefficient of evaporation	coef_eva=0.0001
radiation	iflag_rrtm=1
	iflag_prec=3

Thermals plume
accounted for outside
cold pools only

Concluding remarks / recommendations

Recommendation when using LMDZ (or analyzing model results)

LMDZ is a flexible tool (3D, with or without nudging, 1D, coupled or not, aquaplanets, run on HPC computers or laptops, ...)

→ The model setup should depend on the question you want to address.

Try to use referenced configurations when possible. In particular **LMDZ6A**

Don't forget that a model is defined by its grid configuration, physical content, tuning parameters, forcing files (aerosols, ozone, ...)

Don't forget the internal variability. Often underestimated.

Model evaluation (classical approach) :

→ Running long simulations or ensembles of them → until you reach robust statistics :
depends on the variable and question addressed

→ Compare observations and models in terms of statistics (taking into account that you have only one trajectory among other possible for observations)

Alternatives :

→ Run nudged simulations to get rid of chaos and have the meteorological trajectory in phase with the observed one. Then you can compare model and observation day-by-day. Of course you can not evaluate the large scale circulation itself which is imposed

→ Using 1D simulations for parameterization development and evaluation or studies dedicated to tracer transport and chemistry

Concluding remarks / recommendations

Importance of tuning

A parameterization or a model : Grid configuration + set of equations + tuning

- Tuning parameters are often uncertain and even not observables
- Tuning is often seen as a dirty part of modeling. It is a misunderstanding !!!!
- Tuning is an intrinsic and very important aspect of climate modeling.
- Especially the tuning of the energetics of atmospheric models
- Tuning should be considered when intercomparing models (if parts of the models use a particular metrics for tuning for instance)

Tuned versions are available for LMDZ : LMDZ5A, 5B, and LMDZ6

Tuning could/should be revisited if the model is significantly modified for an application

Classical approach for tuning :

- Run a series of sensitivity experiments
- Summarize the skill and deficiencies as a series of metrics or numbers.
- Choose a satisfactory set of parameters values « by hands »
- Limited by the number of parameters that you can explore and by the brain of the scientists who try to make the choice from sensitivity experiments.

NEW : semi-automatic tuning with « history matching »

- Run a series of simulations with a subset of parameter values and use meta-models or emulators to produce the metrics in parameter values which were not explored.
- apply so called objective methods

