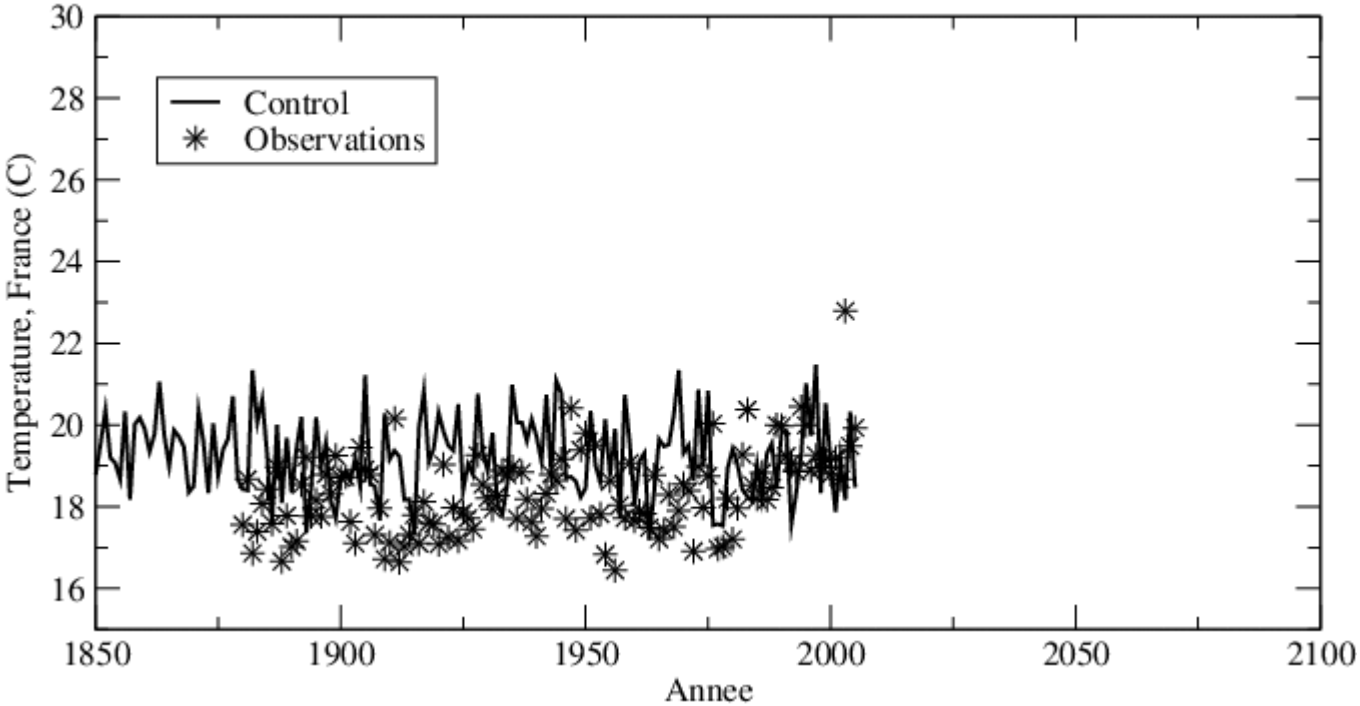
LMDZ : use and configurations

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

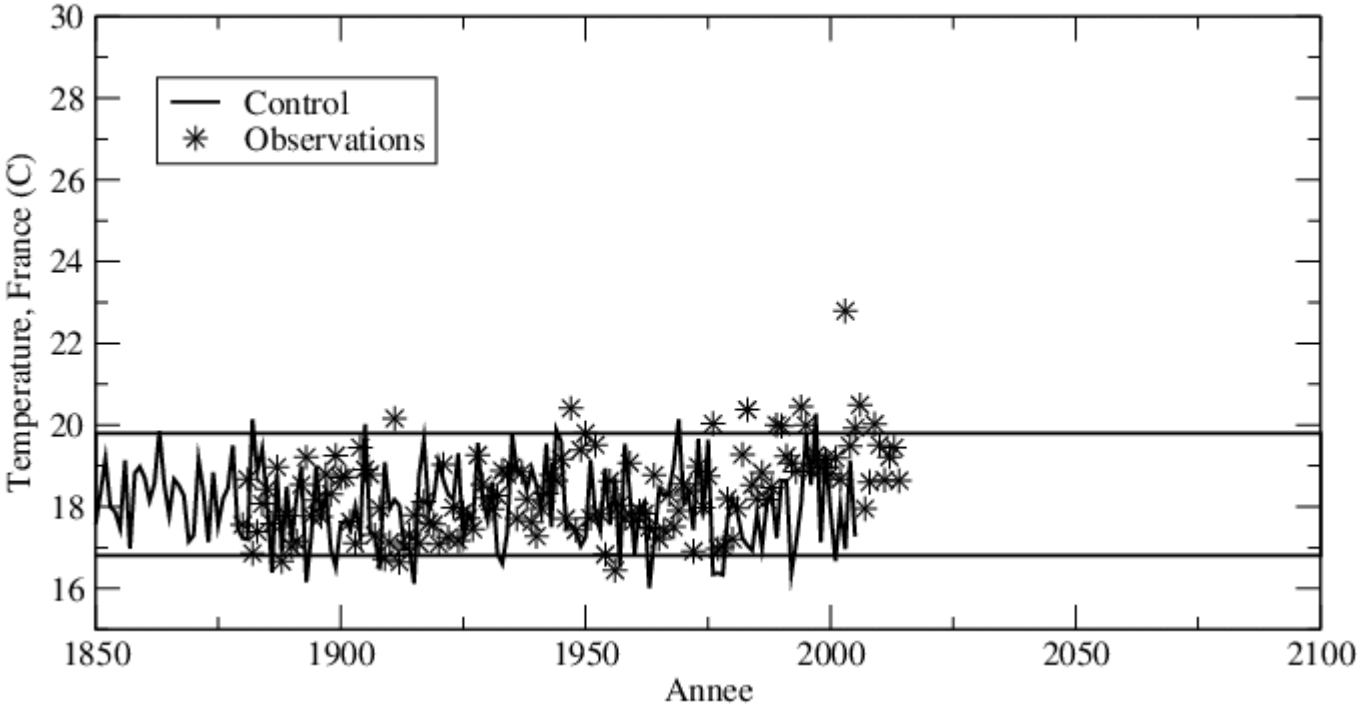
3. Model development and tuning
   a) Choice of a new configuration : content and resolution
   b) Importance of tuning
   c) Methodology 1D/nudged simulations/tuning

Climate change projections



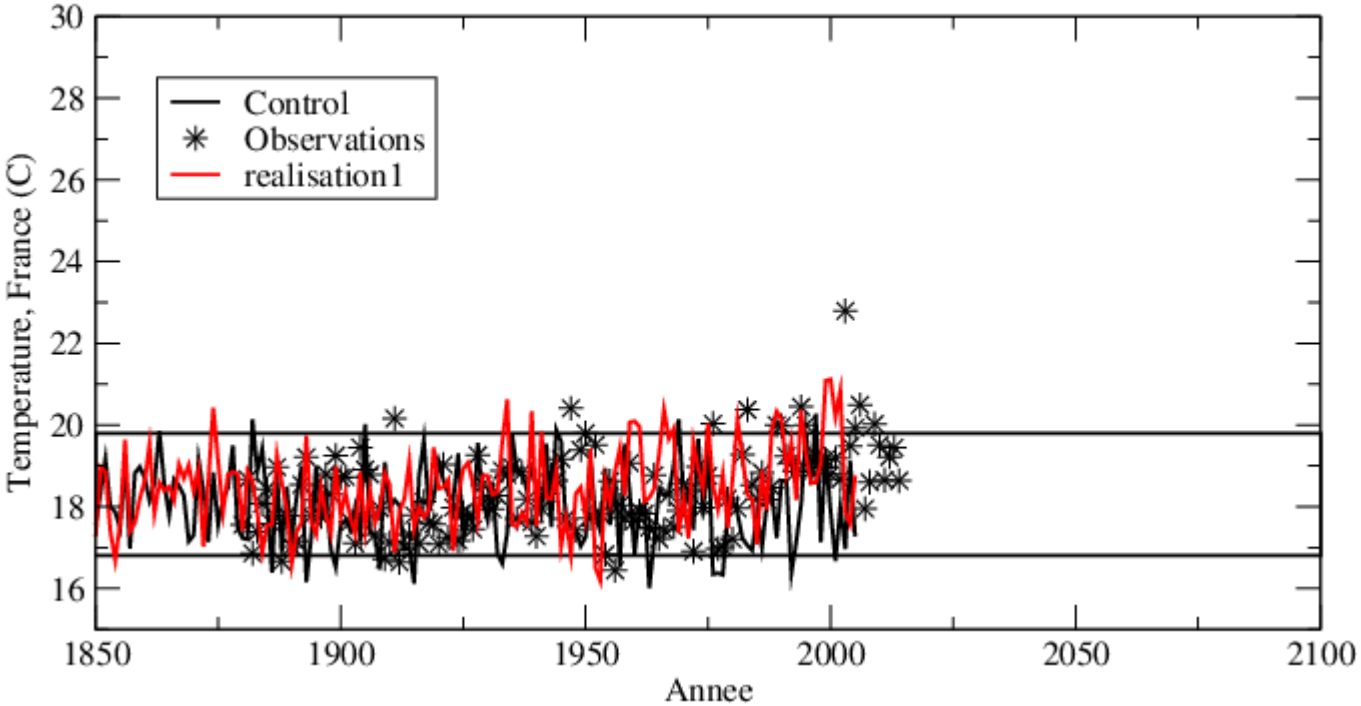
→ Global coupled ocean-atmosphere model. Model not perfect. Biases.

Climate change projections



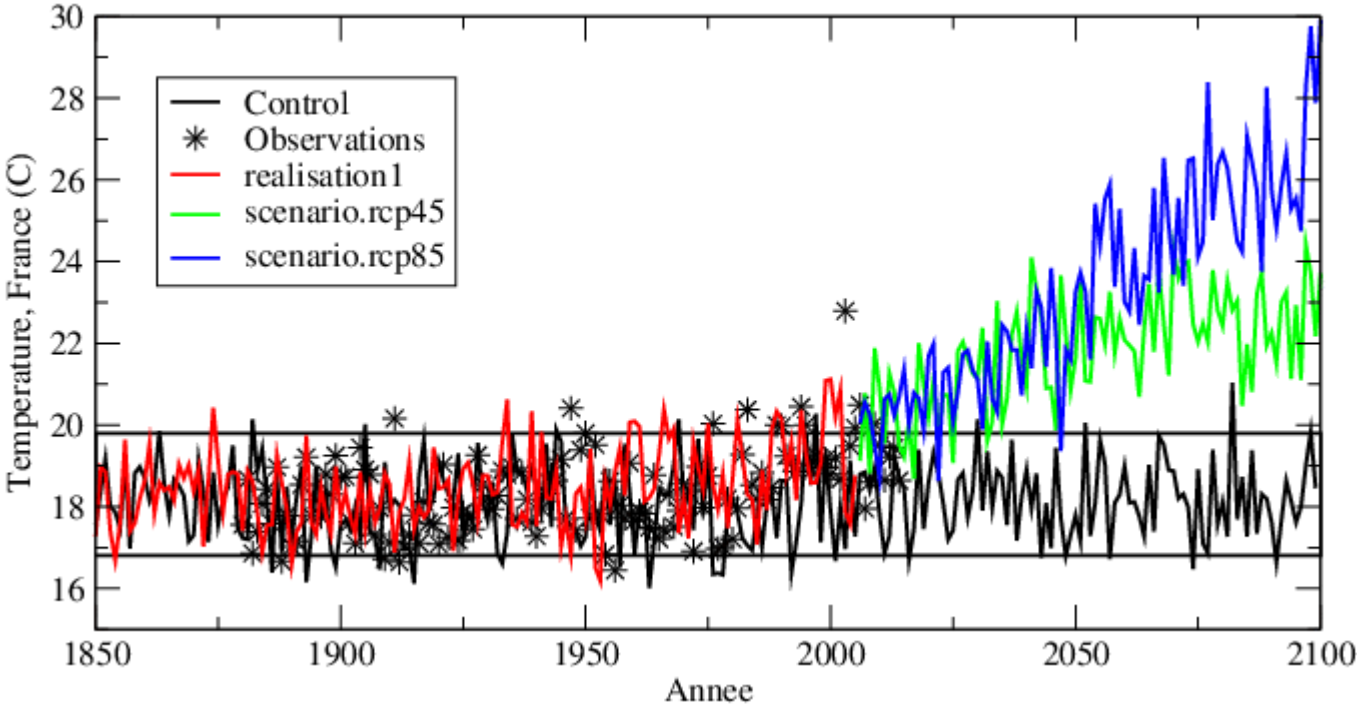
→ Global coupled ocean-atmosphere model. Model not perfect. Biases.
→ Analyzed in terms of statistics. Biased on average. Variance ...

Climate change projections



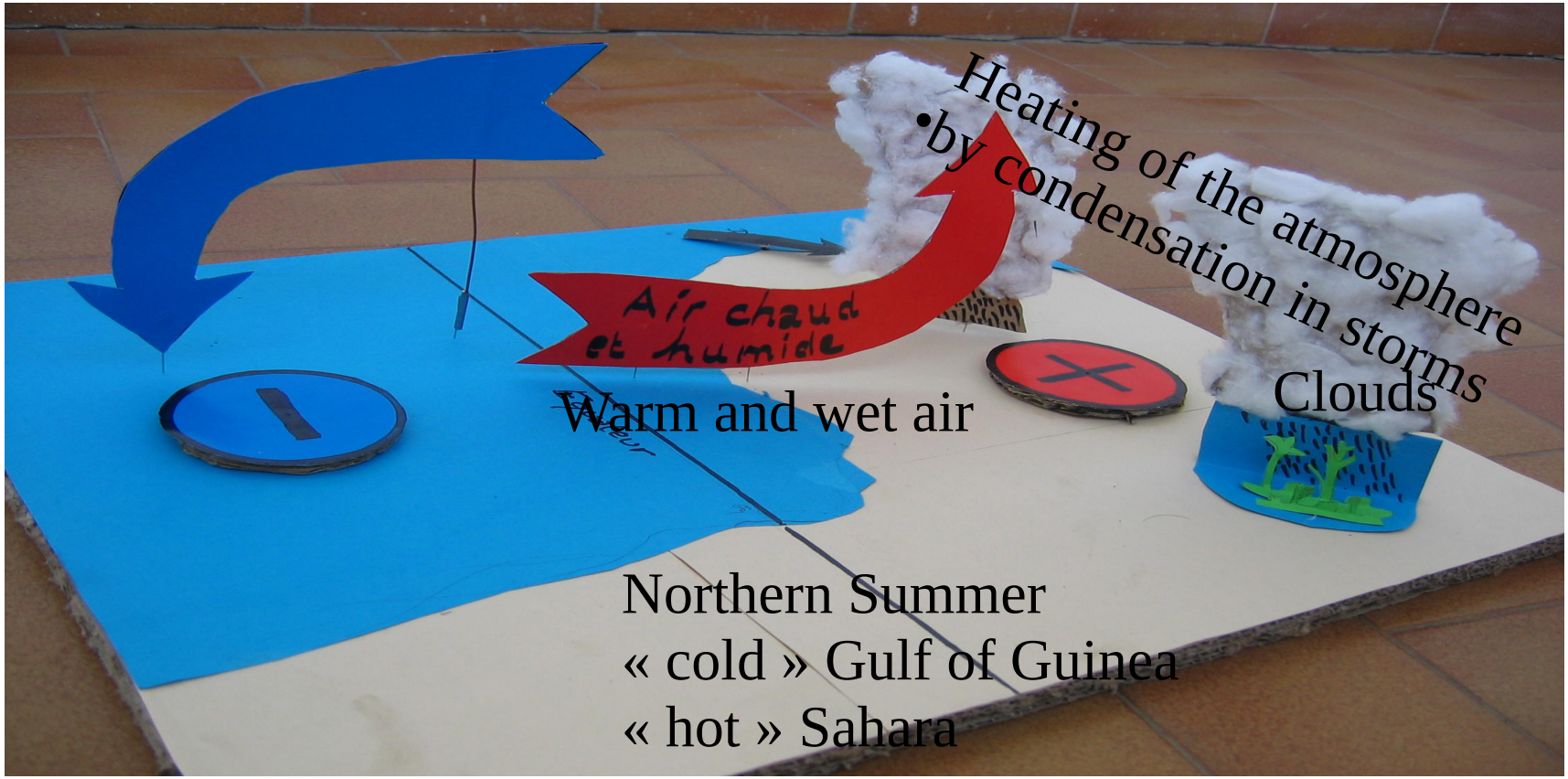
→ Global coupled ocean-atmosphere model. Model not perfect. Biases.
→ Analyzed in terms of statistics. Biased on average. Variance ...
→ Perturbed versus control run (small perturbation compared to biases)

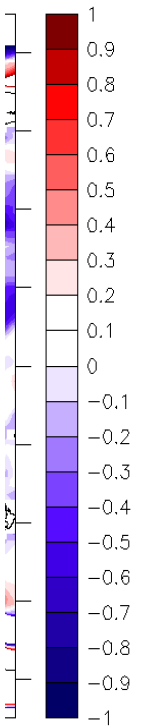
Climate change projections



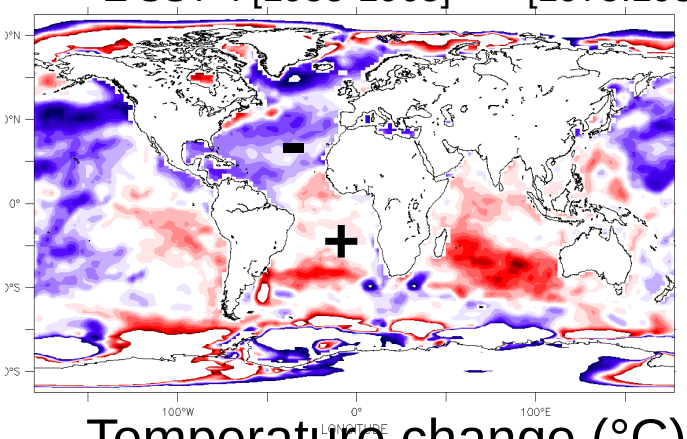
→ Global coupled ocean-atmosphere model. Model not perfect. Biases.
→ Analyzed in terms of statistics. Biased on average. Variance ...
→ Perturbed versus control run (small perturbation compared to biases)
→ Scenarios of future concentrations or emissions

1. Operating modes : a) free climatic mode



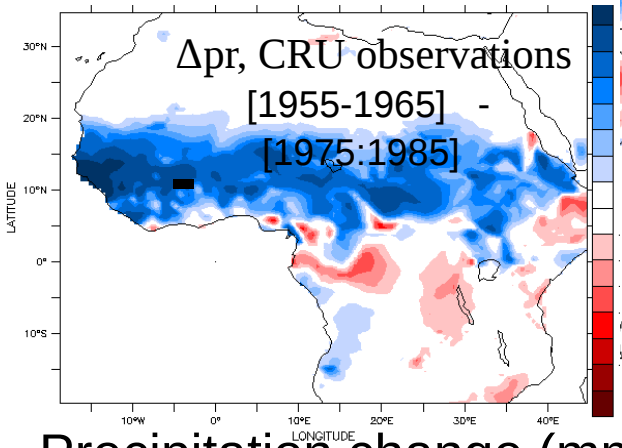


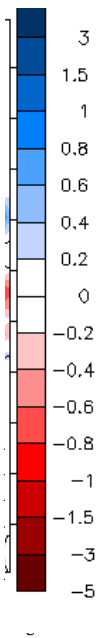
Δ SST : [1955-1965] - [1975:1985]



Temperature change (°C)

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



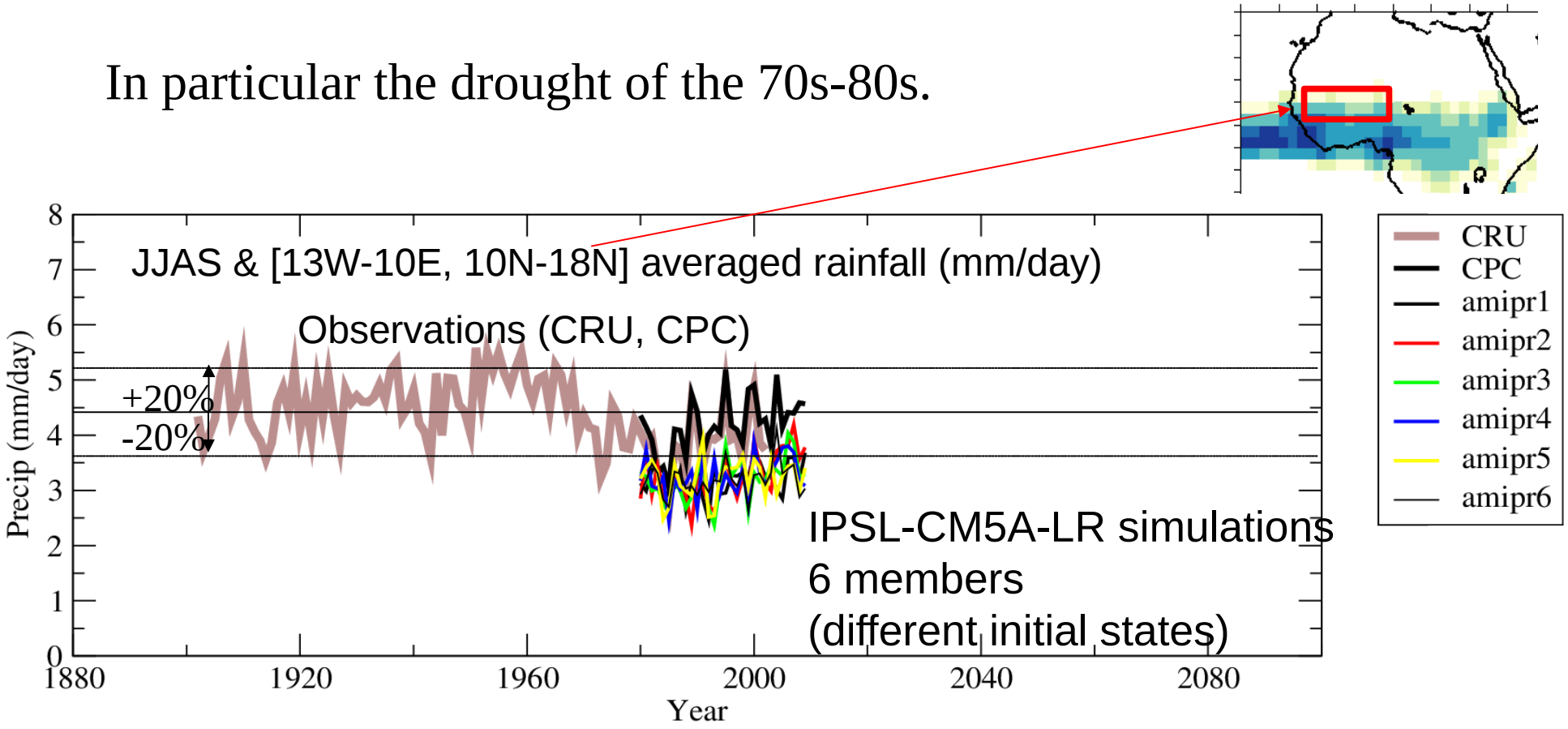


Precipitation change (mm/year)

Example 2 : the Sahelian drought

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

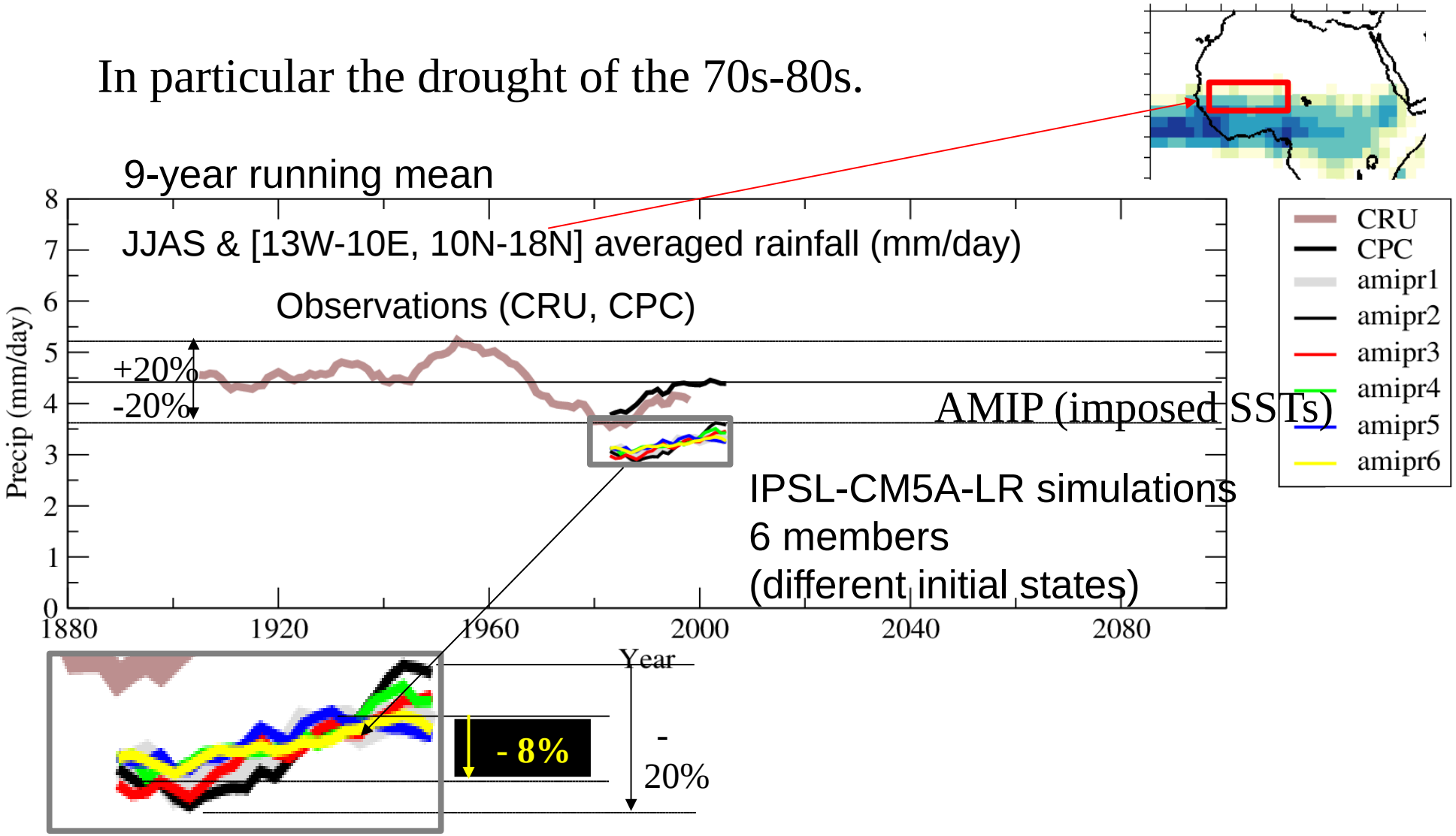
In particular the drought of the 70s-80s.



AMIP with imposed Sea Surface Temperature (SST)

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

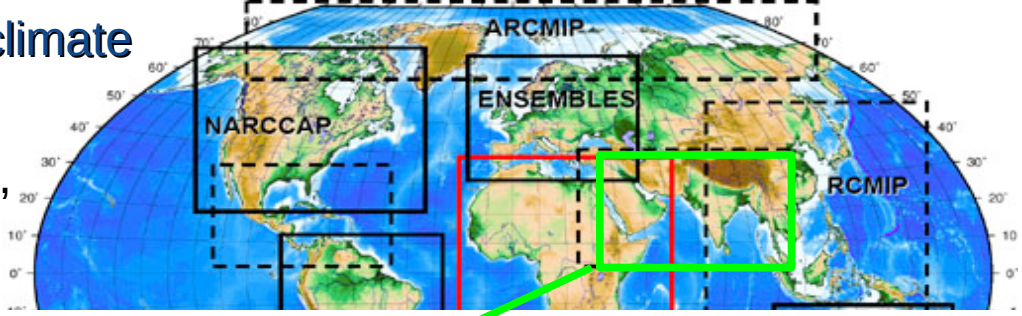
In particular the drought of the 70s-80s.

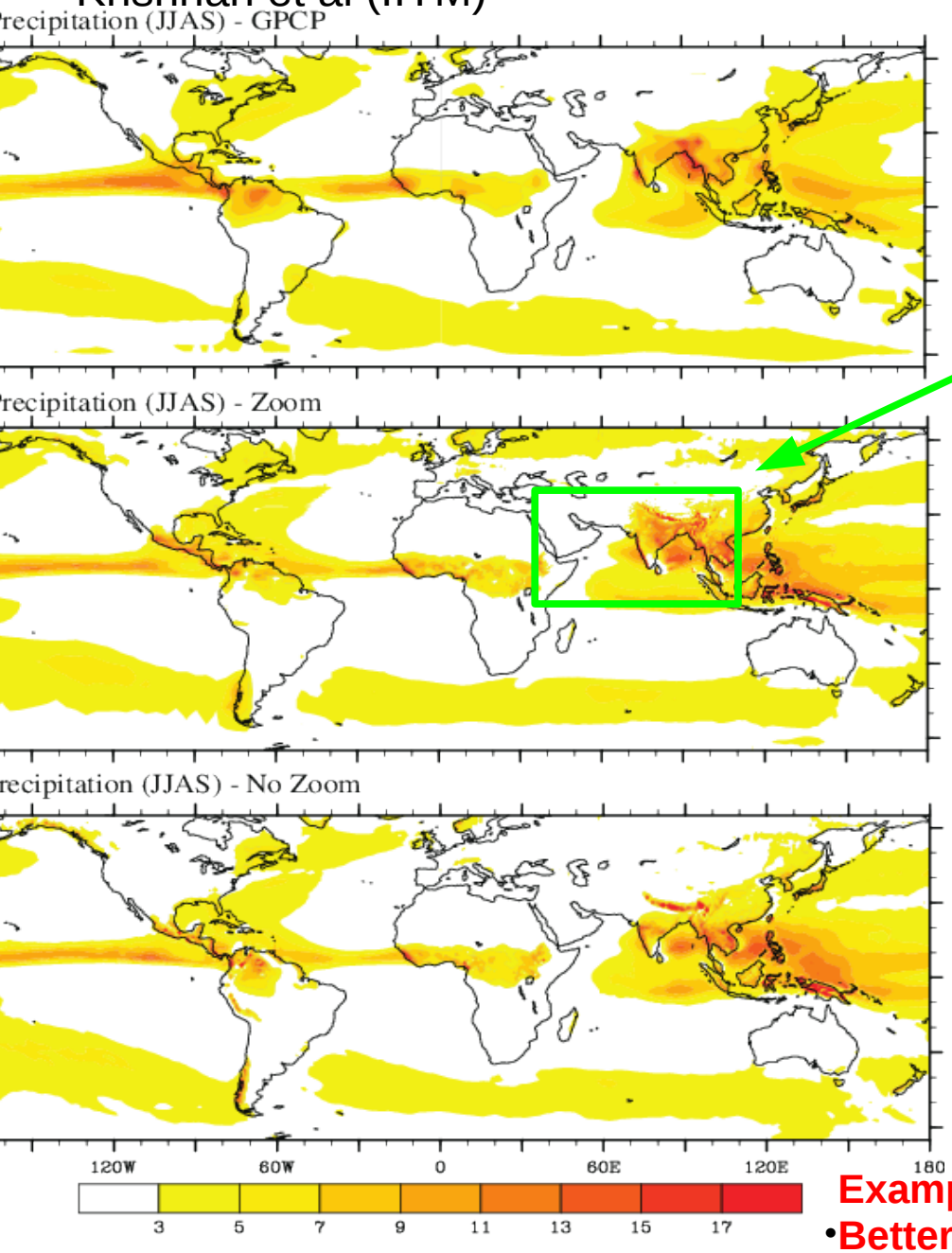


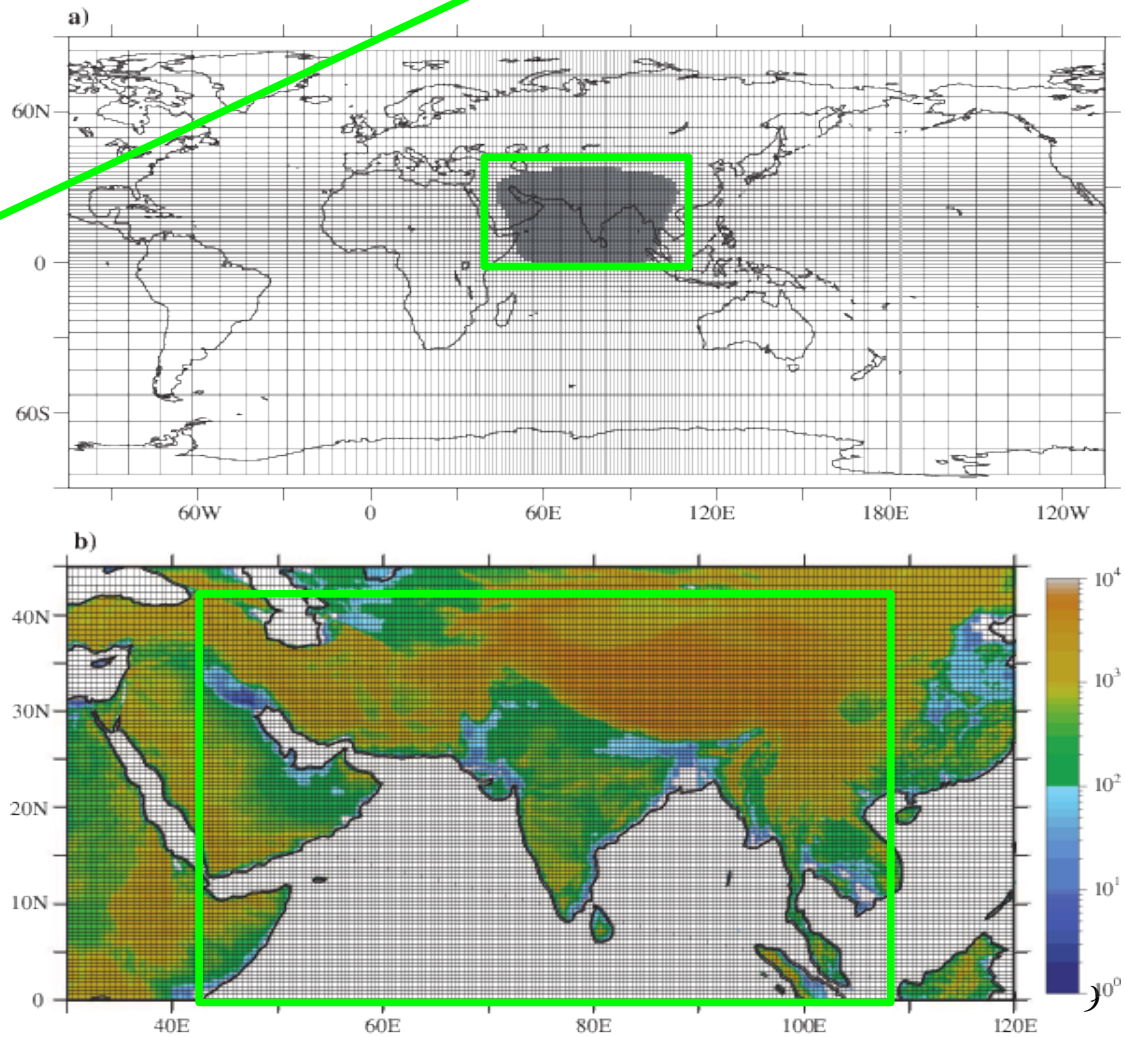
Simulations have a skill to reproduce decadal variations of monsoon rainfall in response to sea surface temperature changes
But strong internal variability even with imposed SSTs
The observation is one possible experience

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 Benghal**

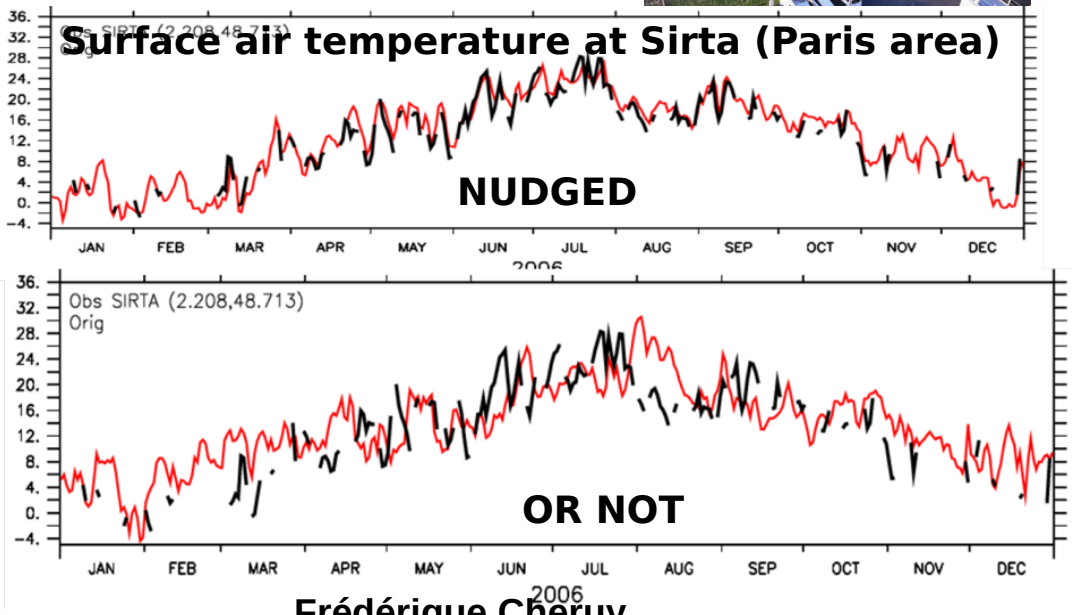
1. Operating modes : b) Zooming or/and nudging for climate

Nudging capability

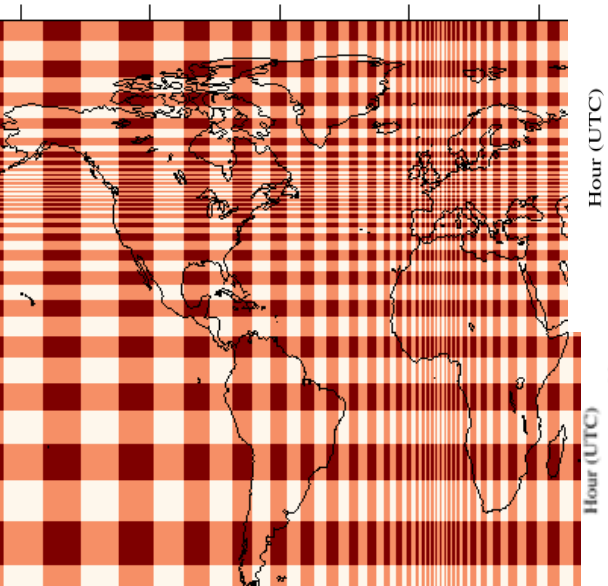
$$\frac{\partial X}{\partial t} = F(X) + \frac{X^a - X}{\tau}$$

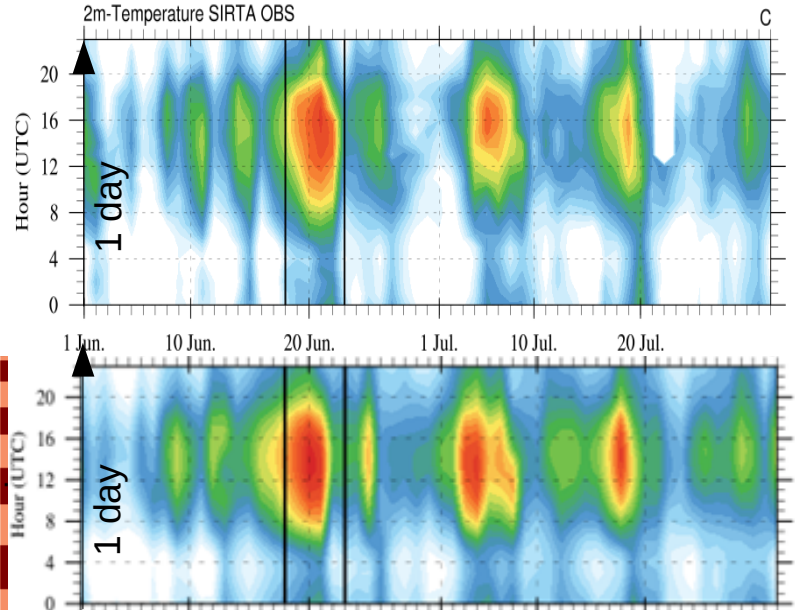
X : model state variables, u, v, T, q
Xa : X from (re)analysis regrided on the model grid
F(X) : state variables model tendencies
τ : time constant

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

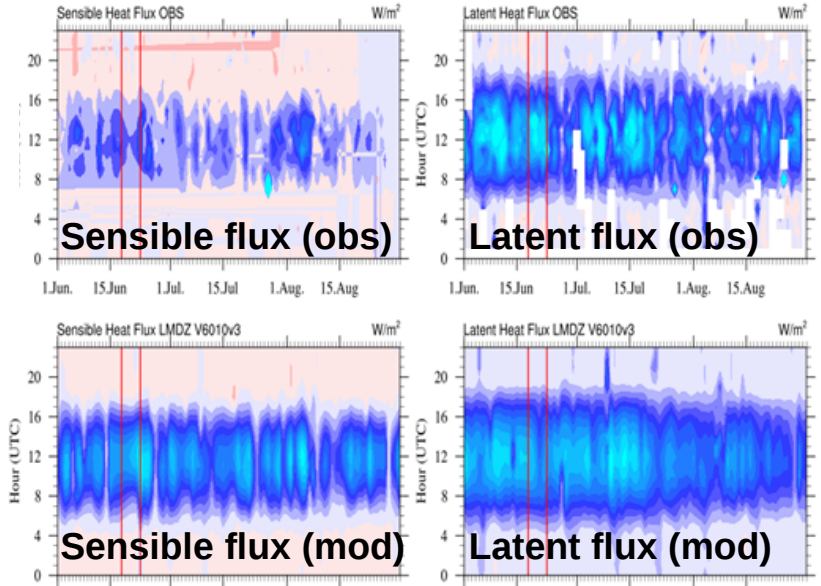


Frédérique Cheruy



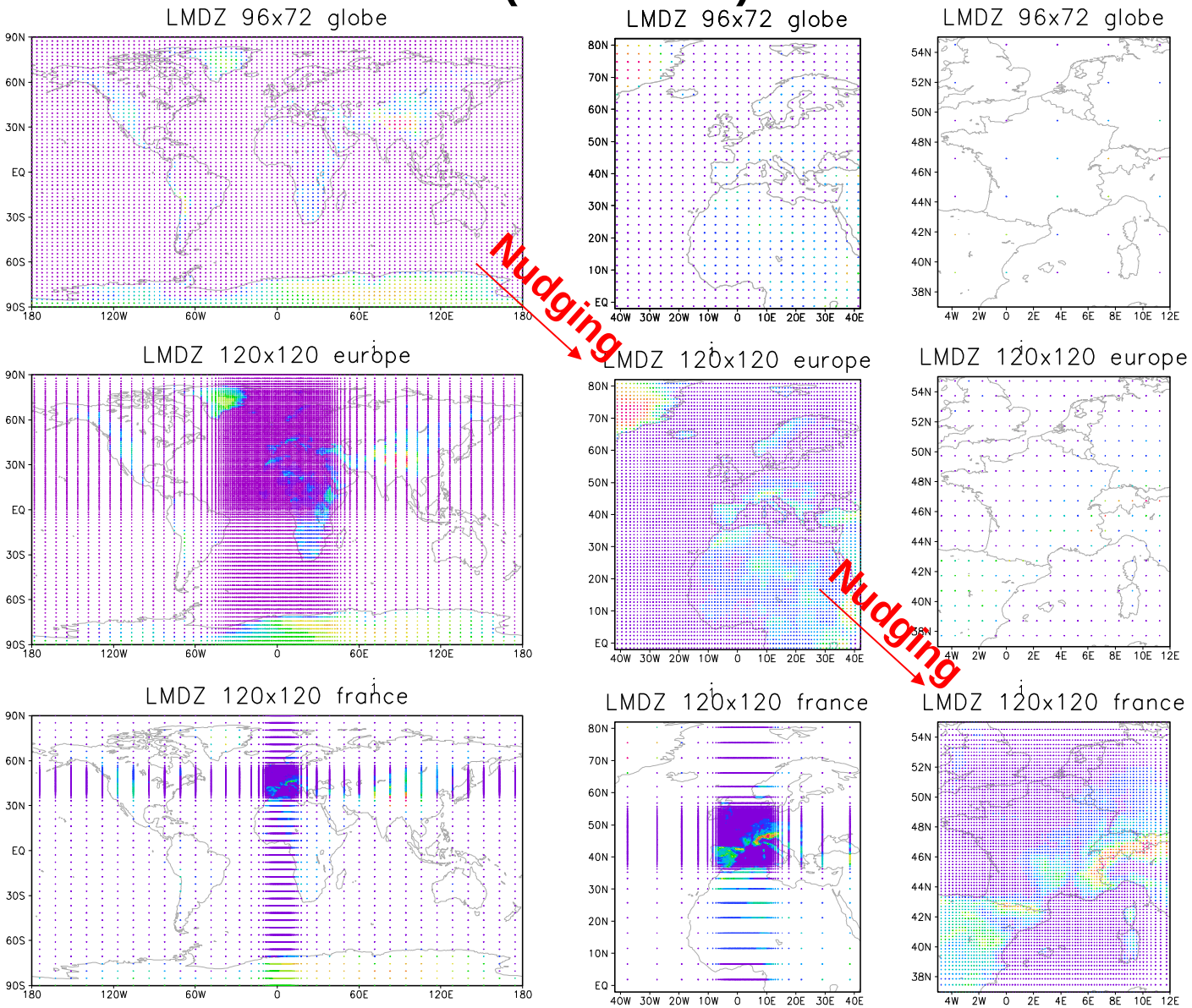


HEAT-WAVE SUMMER 2017



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

- Use for climate downscaling
- **LMDZ - Grid Cascade - (Laurent Li)**



LMDZ Globe (300 km)

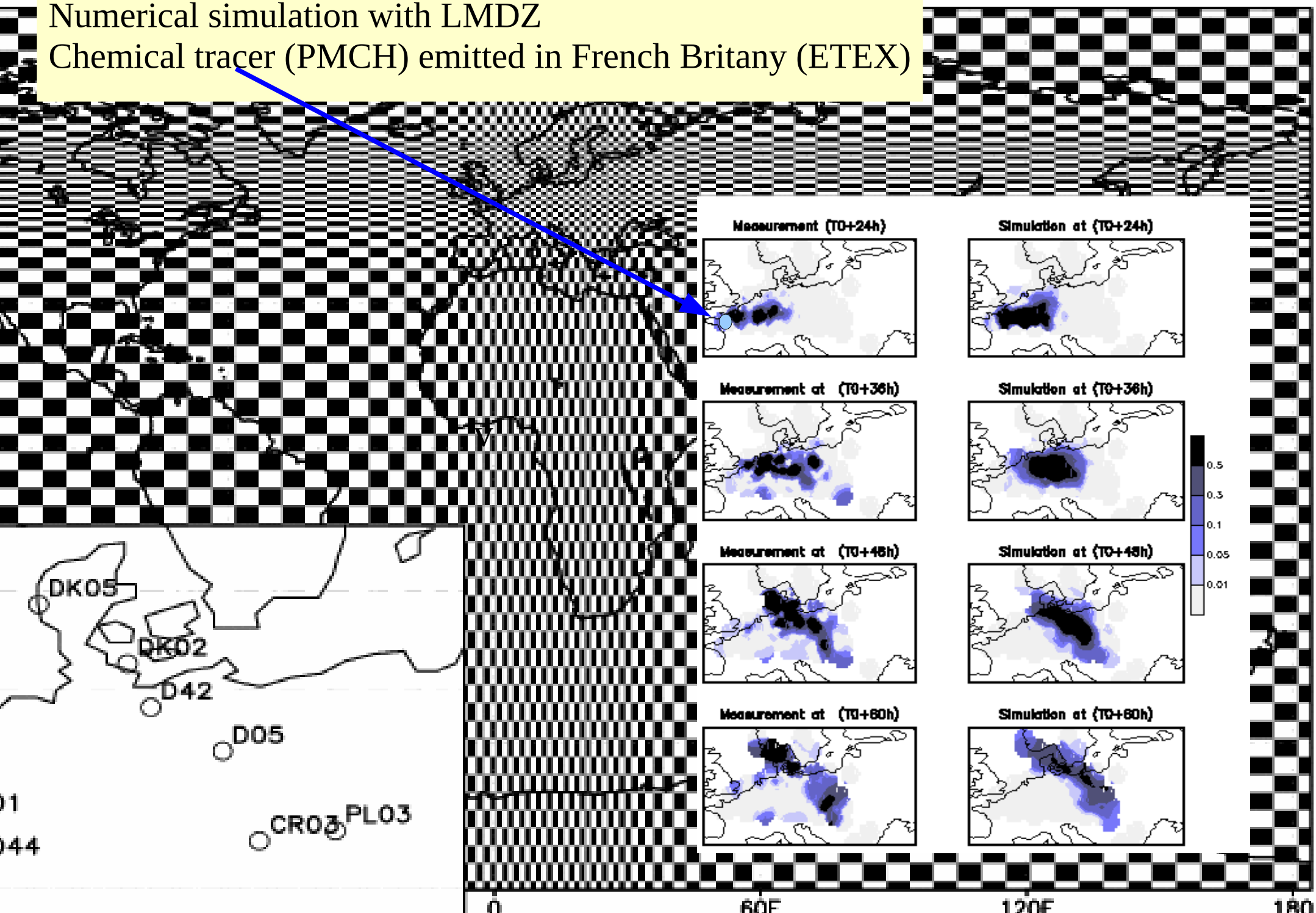
LMDZ Europe (100 km)

LMDZ France (20 km)

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

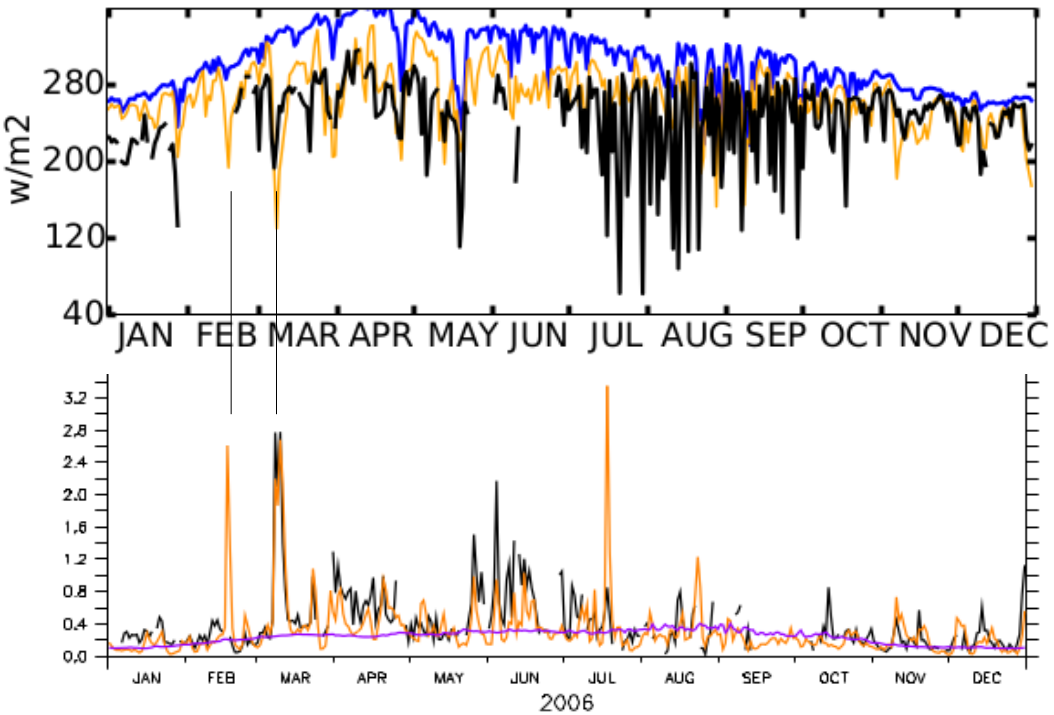
1. Operating modes : c) Tracer transport

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

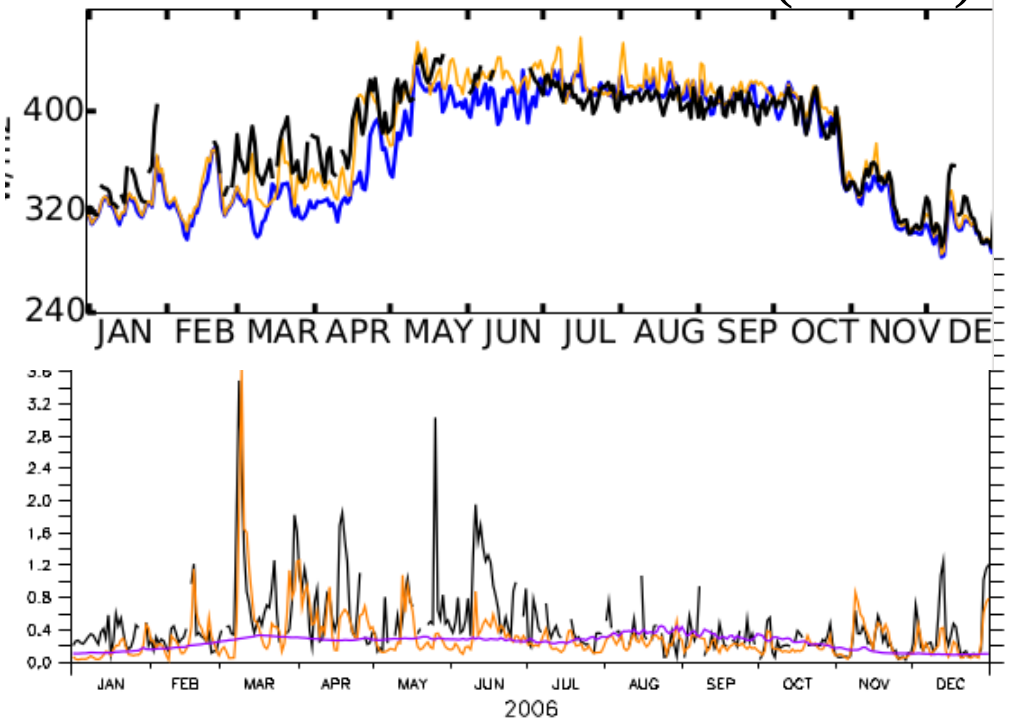


1. Operating modes : c) Tracer transport

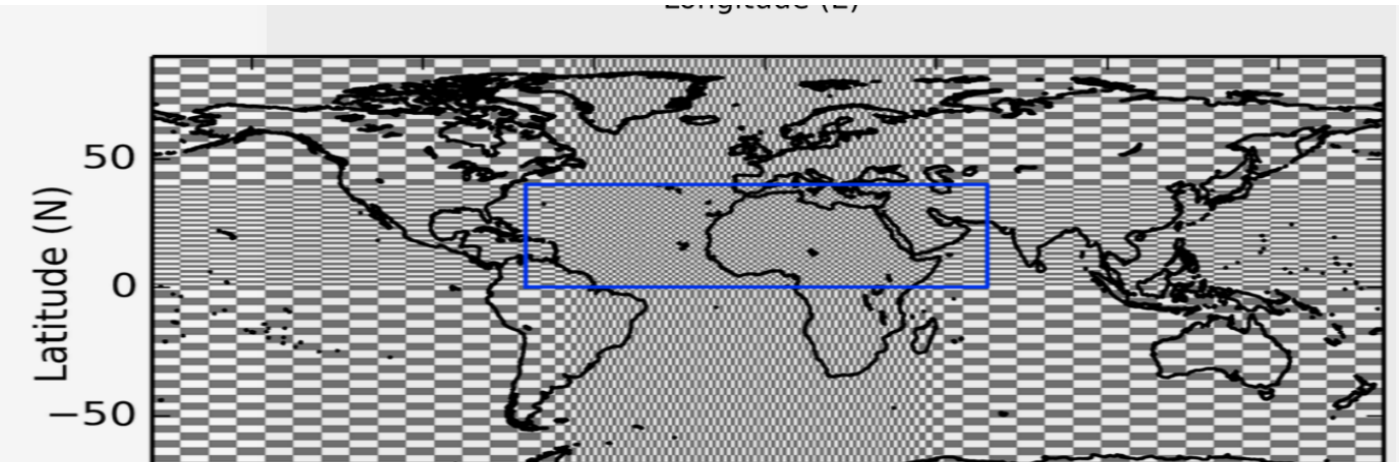
SW downward flux surf. (W/m2)



LW downward flux surf. (W/m2)



Coupled simulations with interactive aerosols (Dialo et al., 2017)
Tracer concetrations in µg / kg, 2006



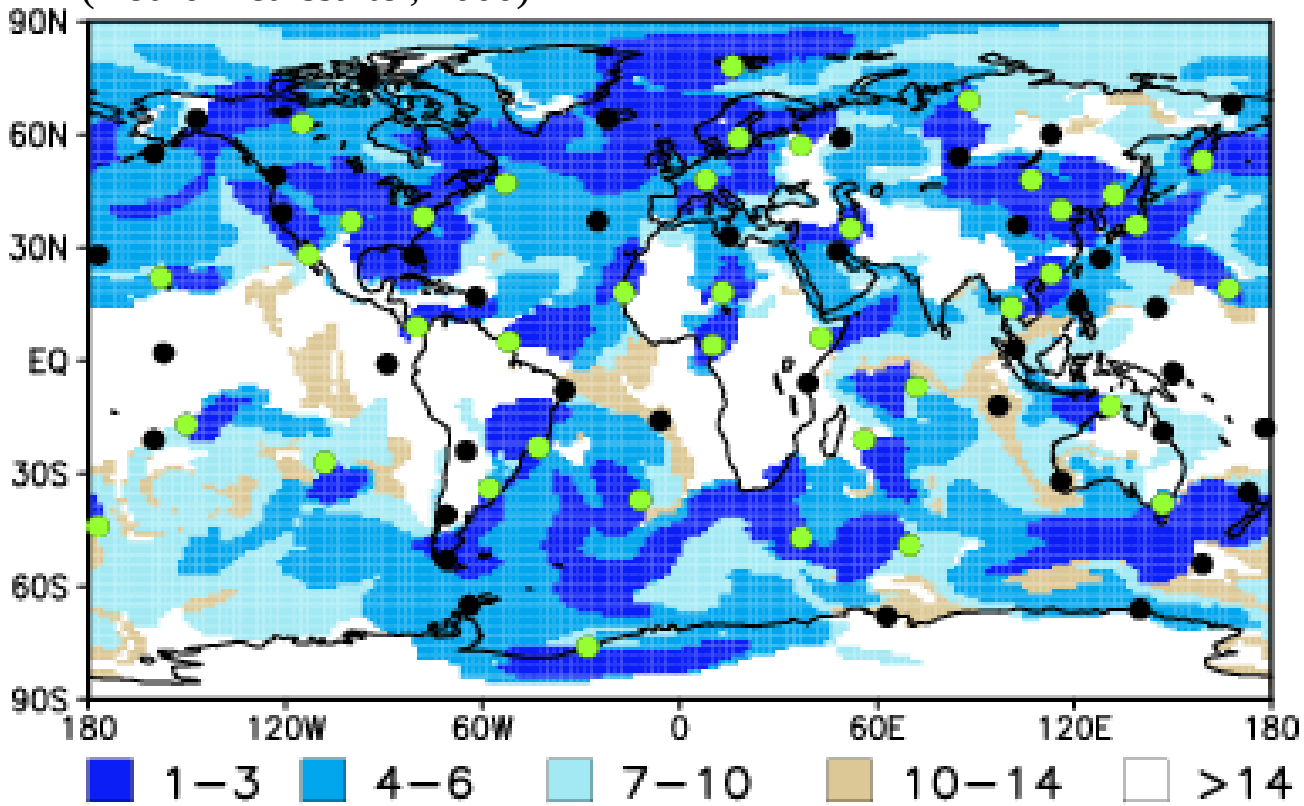
Observations

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

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



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.

Summary of 3D operating modes

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

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

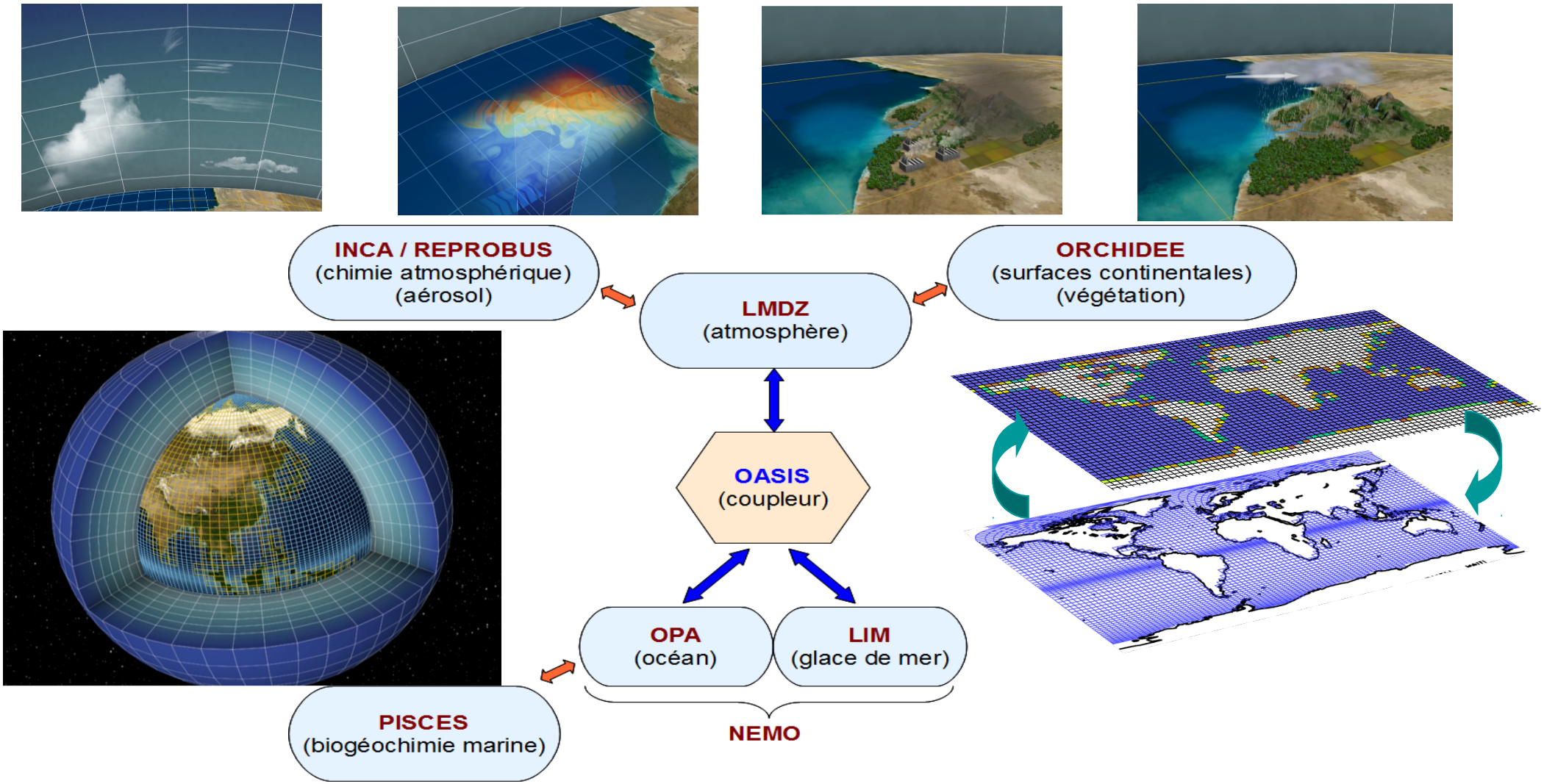
2. Intercomparison exercises and reference versions
   a) The IPSL climate model and CMIP exercises
   b) LMDZ reference versions
   c) Robust improvements from version to version
   d) Evolution of climatic biases and sensitivity

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

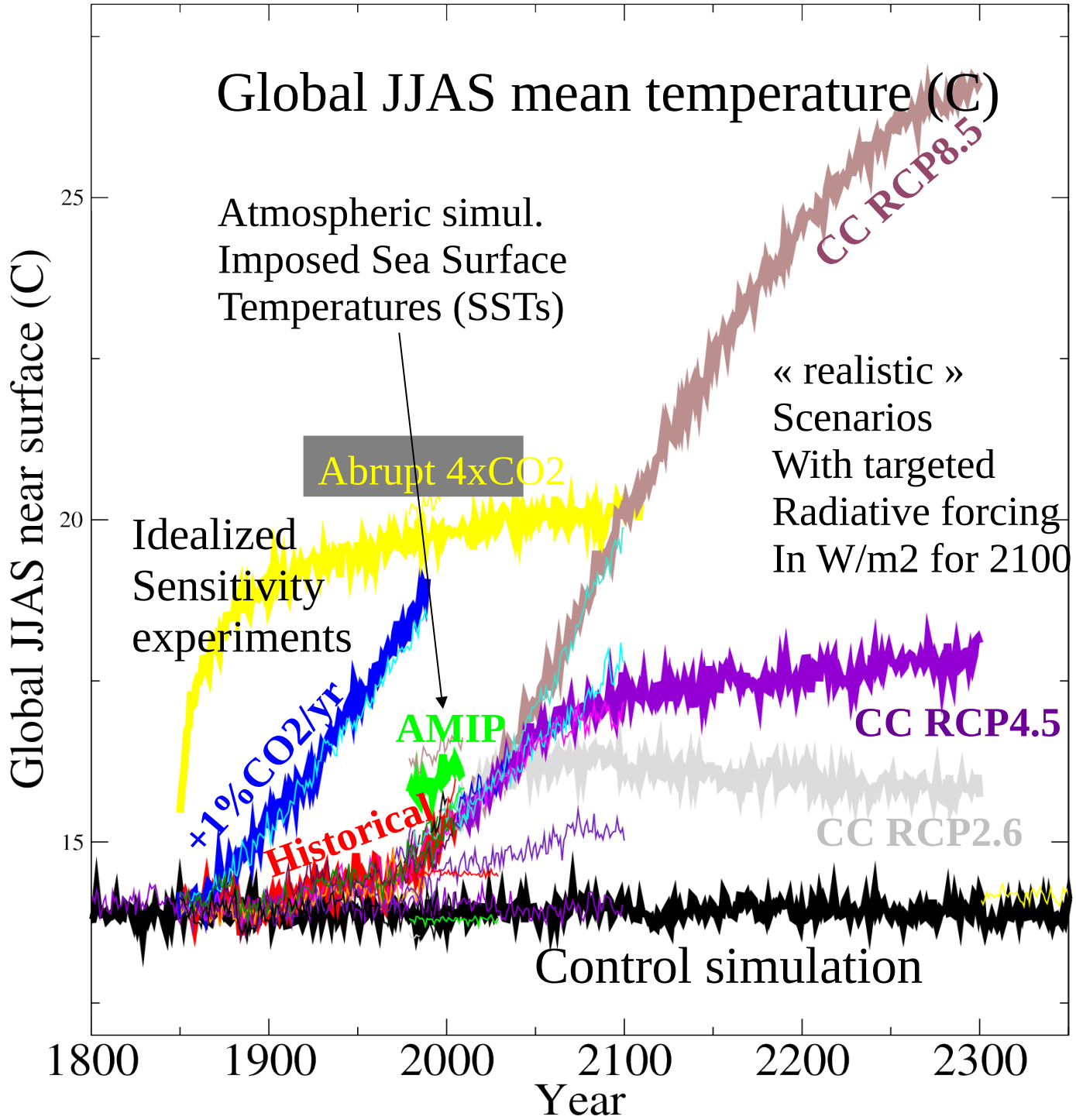
2. Reference configurations : a) The IPSL climate model and the CMIP exercises

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



piControl
historical
amip
1pctCO2
abrupt4xCO2
rcp85
rcp26
rcp45
rcp60
decadal1960
decadal1965
decadal1970
decadal1975
decadal1980
decadal1985
decadal1990
decadal1995
decadal2000
decadal2005
amip4K
amip4xCO2
aqua4xCO2
esmControl
esmFdbk1
esmFdbk2
esmFixClim1
esmFixClim2
esmHistorical
esmrcp85
historicalMisc
historicalNat
sstClim
sstClim4xCO2
sstClimSulfate
lgm
midHolocene

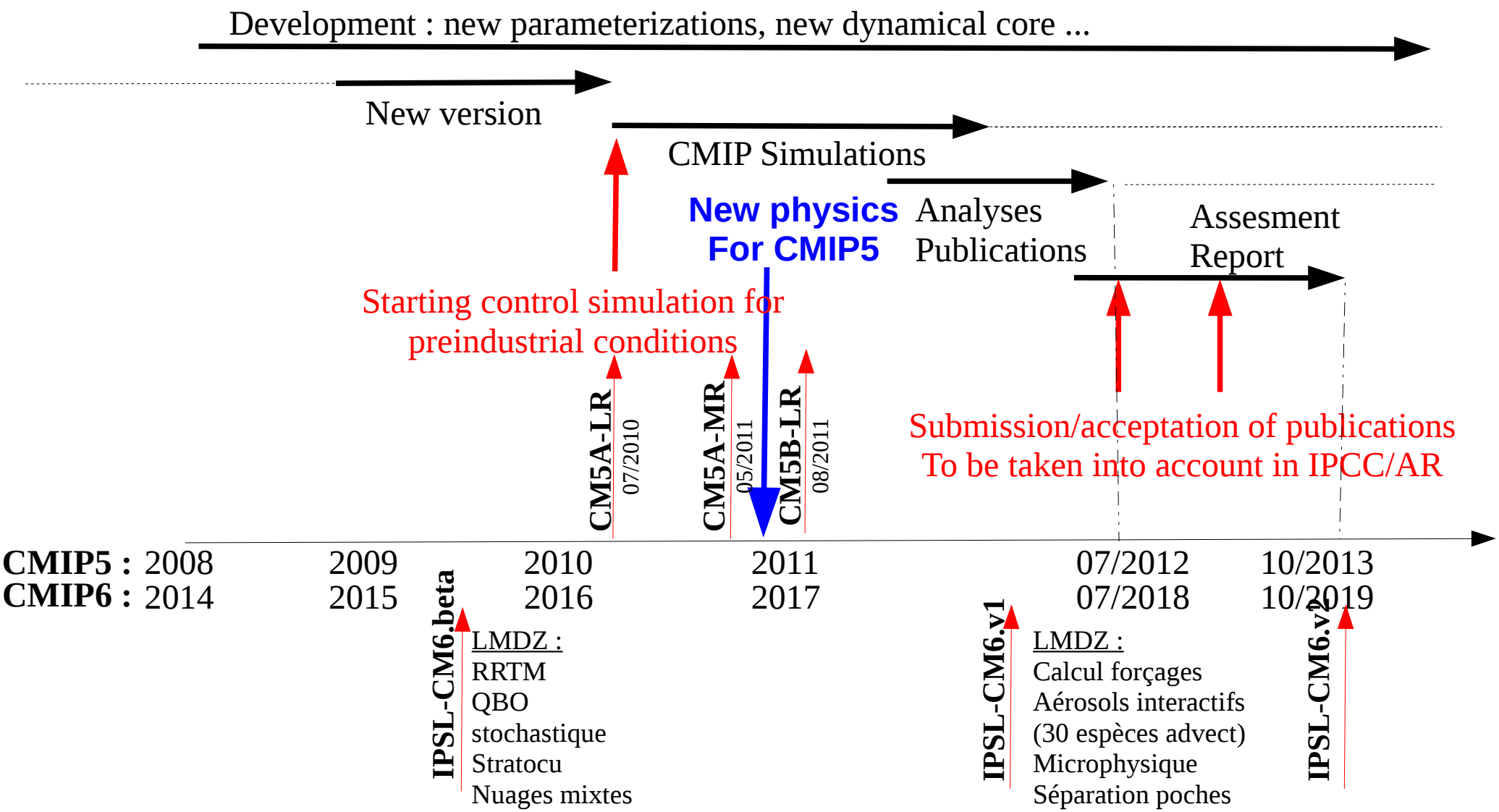
IPSL-CM5A-LR
CMIP5
Simulations
(1st realisation
for ensembles)

Decadal
forecasts

Idealized
for
interpretation

Paleo climate

Development of LMDZ and the CMIP rendez-vous CMIP

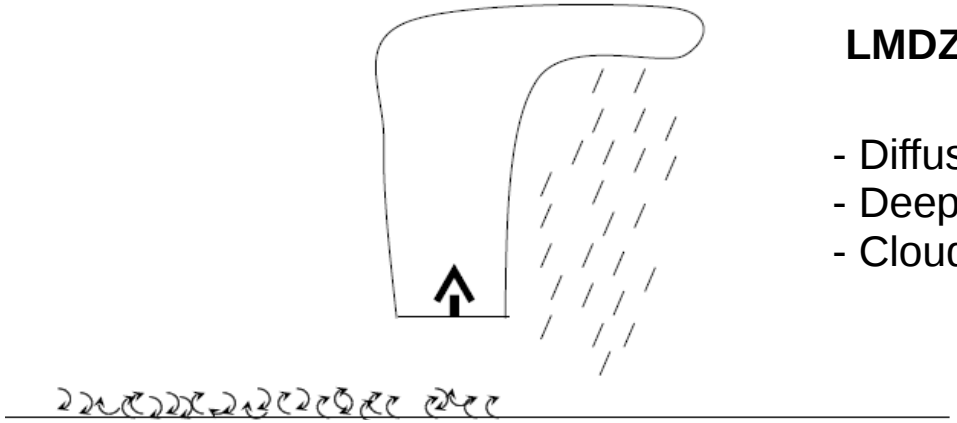


144x142x79 (rebaptisée LR)
Ocean 1°, Orchidee 11

280x280x79 (rebaptisée MR)
Ocean 0.25°, Orchidee 11

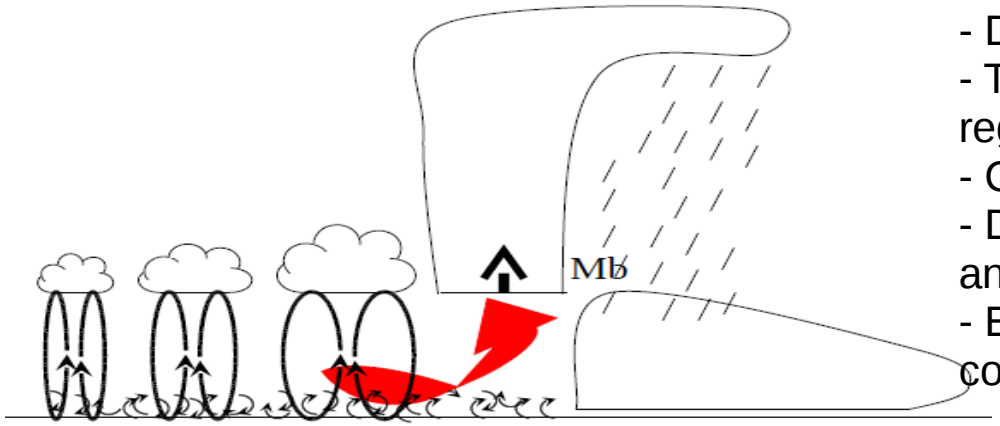
2. Reference configurations : b) LMDZ reference configurations

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)

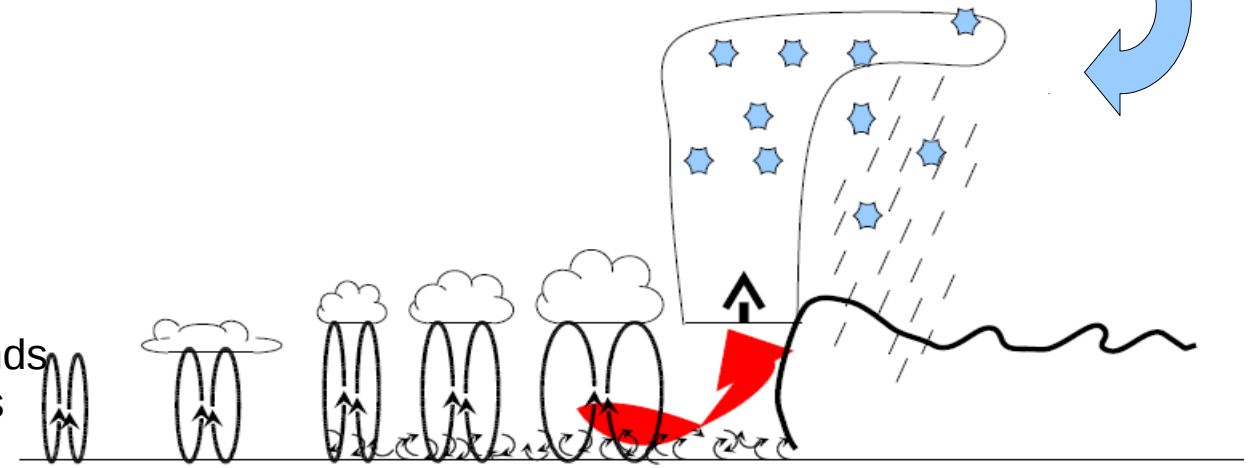


LMDZ5B (« new physics »)

- 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 ++

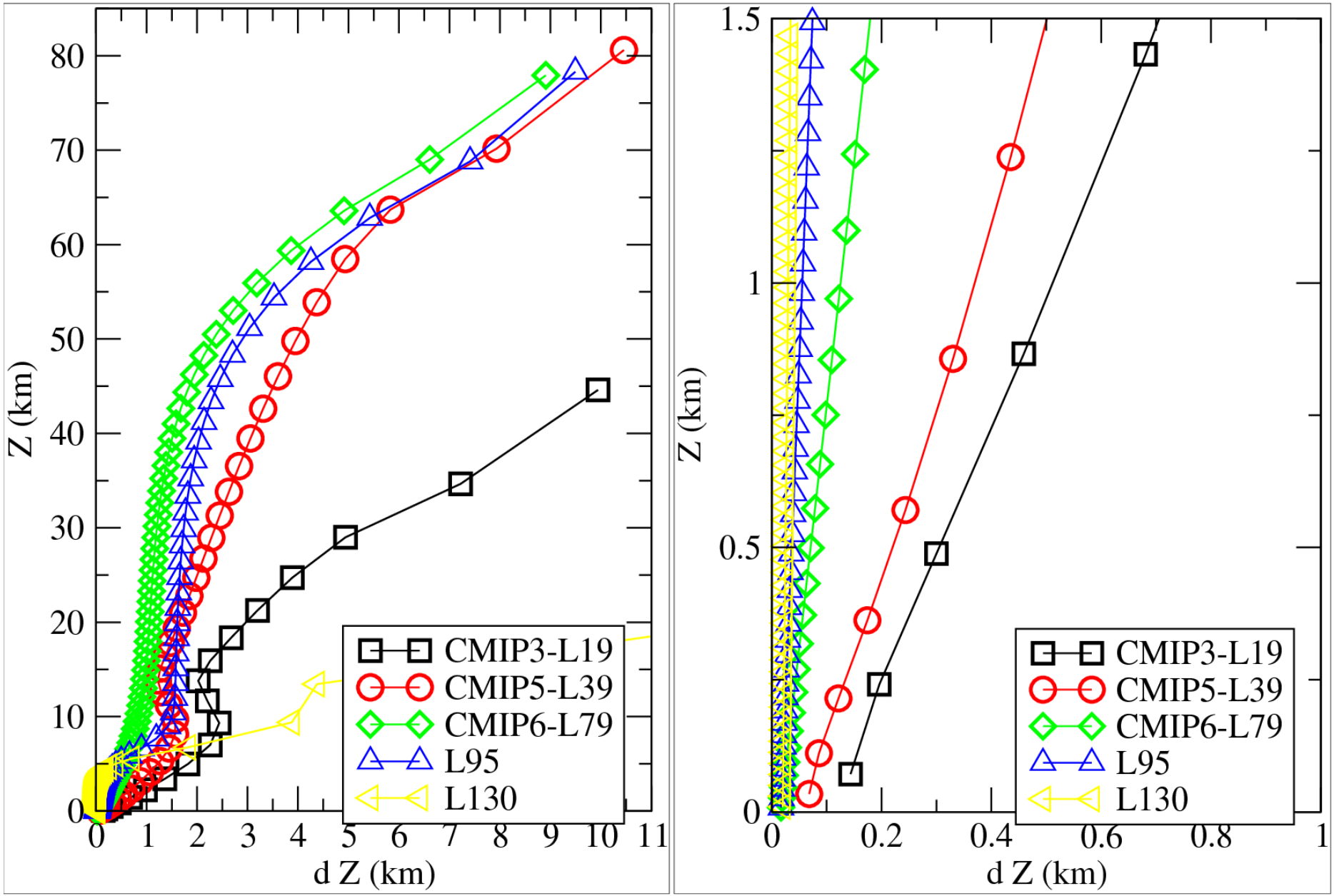
+ Thermal plume model everywhere
+ Stochastic triggering of deep convection
+ Different convective mixing formulation
+ Thermodynamical effect of ice
+ RRTM for infrared radiation and SW 6 bands
+ Better boundary layer for stable conditions
+ Non orographic gravity waves



Summary of reference climate configurations

	Vertical resolution	Horizontal grid	Physical parameterizations	Name
CMIP3	L19	96x71	New convection scheme (Emanuel) Subgrid scale ororgaphy	IPSL-CM3 **LMDZ4**
CMIP5	L39 Extension to the stratosphere	LR = 96x95 MR = 144x143	2 versions A : Standard Physics (SP) same as CMIP3 B : New physics (NPv3) with thermal plumes and cold pools	IPSL-CMX **LMDZX** **X=** **5A-LR** **5A-MR** **5B-LR**
CMIP6	L79	VLR = 96x95 LR = 144x143 MR = 280x280 ?	NP v4,5,6 New radiation Stochastic closure Improved clouds Non orog. gravity waves	**LMDZ6**

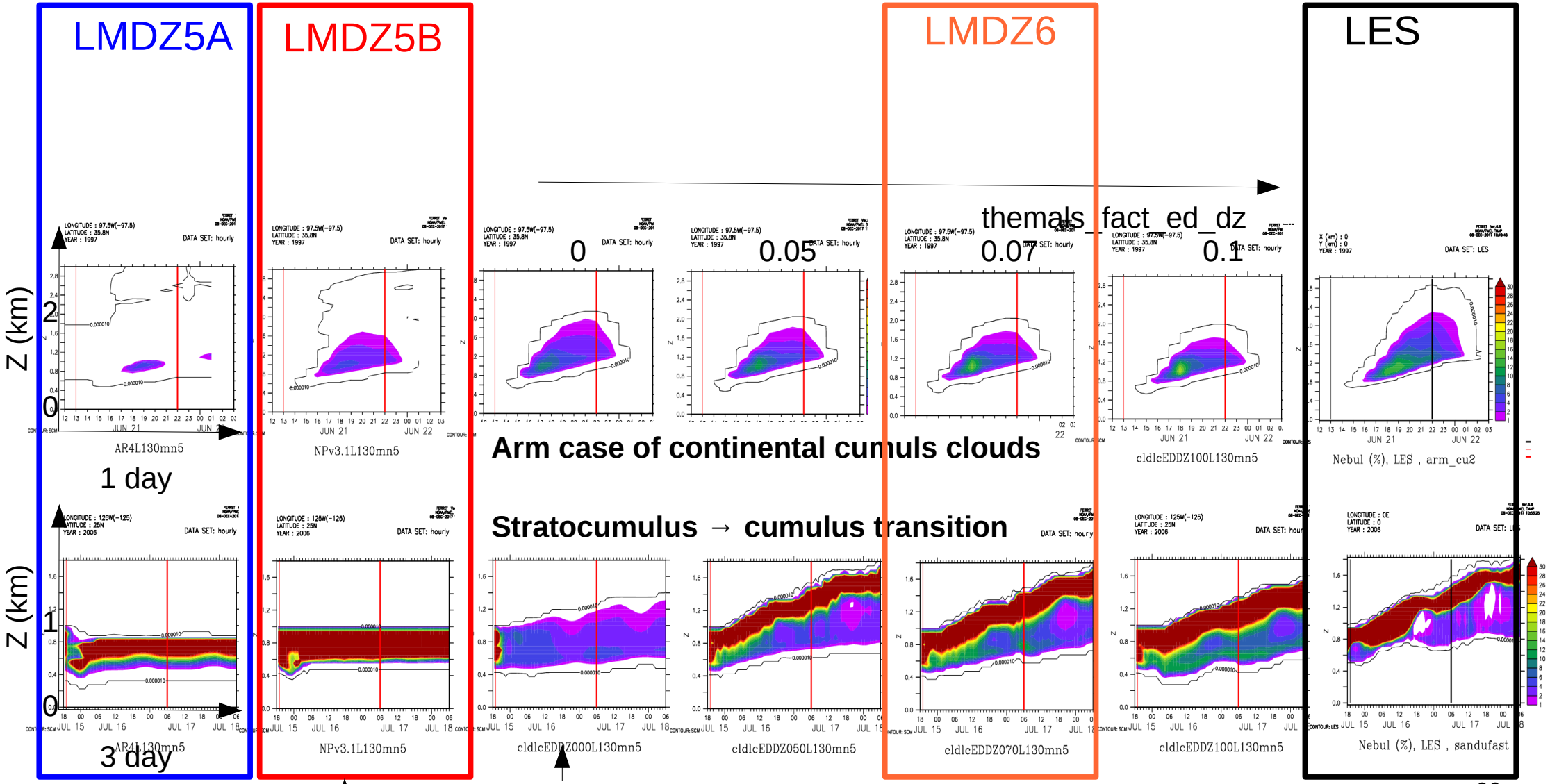
Evolution of the vertical discretization in LMDZ reference configurations



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

The thermal plume model and the associated cumulus and strato-cumulus clouds

1D tests versus LES : 130 layers (L130), time-step 5 min

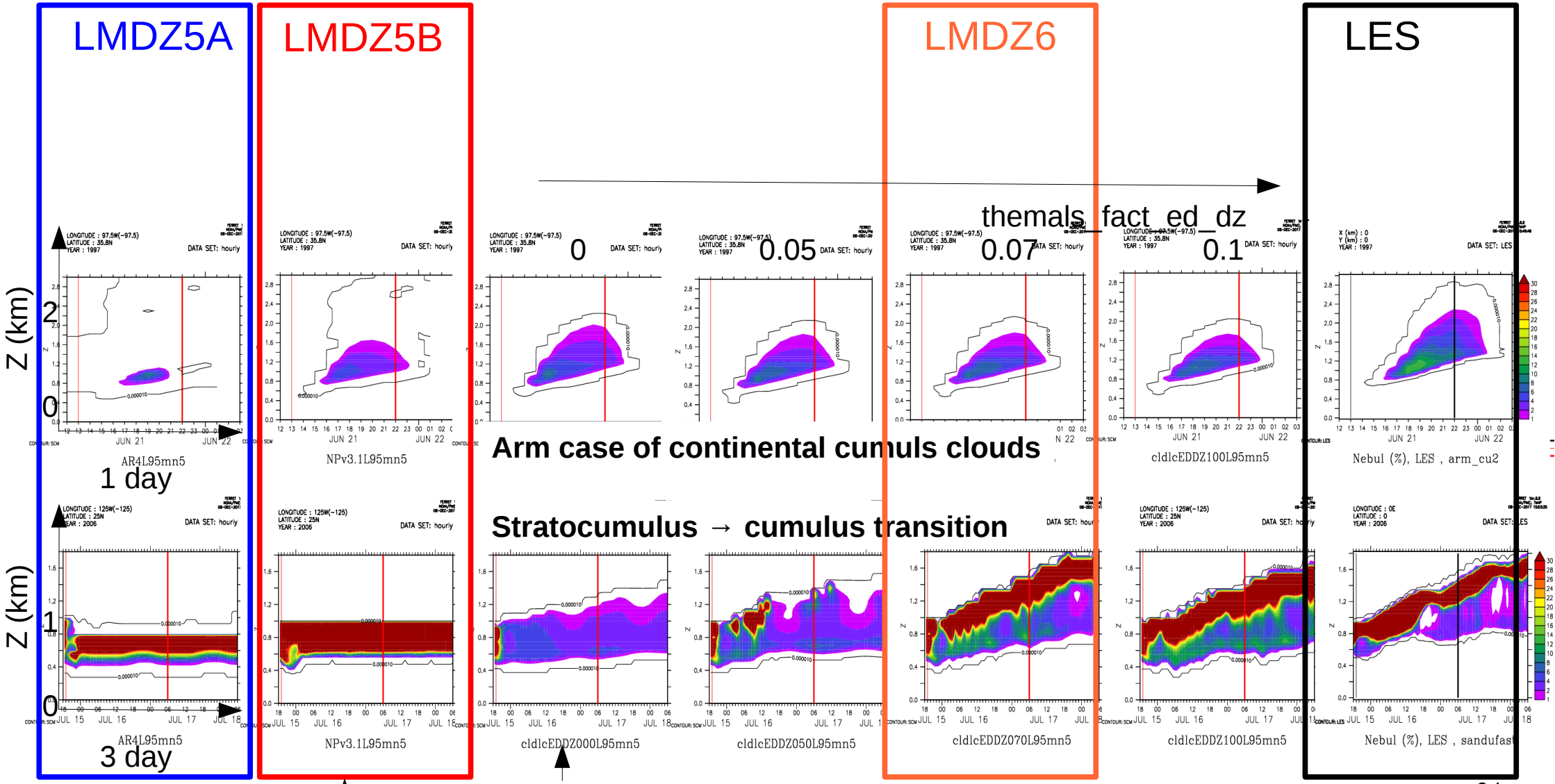


Not desactivating thermal plumes

Thermal plumes artificially turned off in presence of a strong inversion

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

1D tests versus LES : 95 layers (L95), time-step 5 min



Arm case of continental cumuls clouds

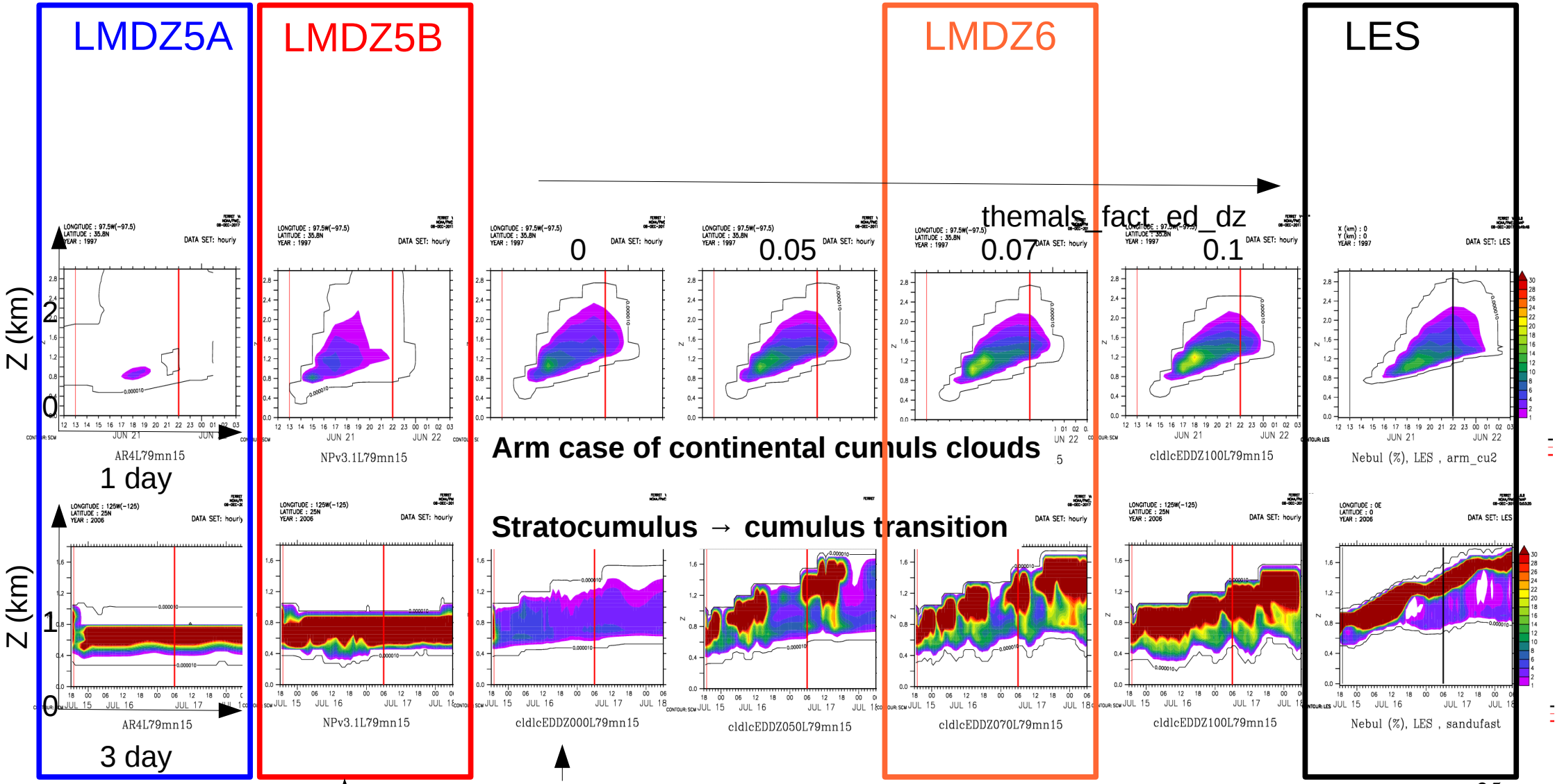
Stratocumulus → cumulus transition

Not desactivating thermal plumes

Thermal plumes artificially turned off in presence of a strong inversion

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

1D tests versus LES : 79 layers (L79), time-step 15 min



Arm case of continental cumuls clouds

Stratocumulus → cumulus transition

Not desactivating thermal plumes

Thermal plumes artificially turned off in presence of a strong inversion

Successive activation of the thermal plume model

Results from atmospheric simulations forced by climatic sea surface temperature

: activating thermal plumes
: Subsidence regions
: Detrainement modifié

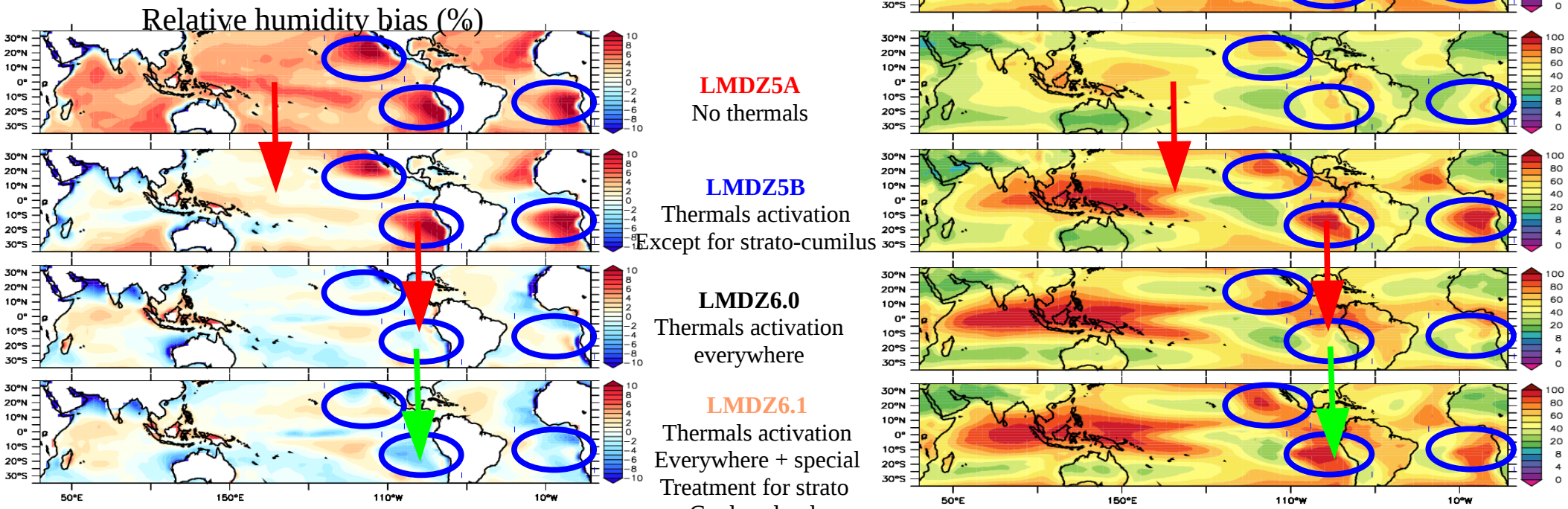
Observations

Calipso GOCCP

Da Silva

Total cloud cover (%)

Relative humidity bias (%)



LMDZ5A
No thermals

LMDZ5B
Thermals activation
Except for strato-cumilus

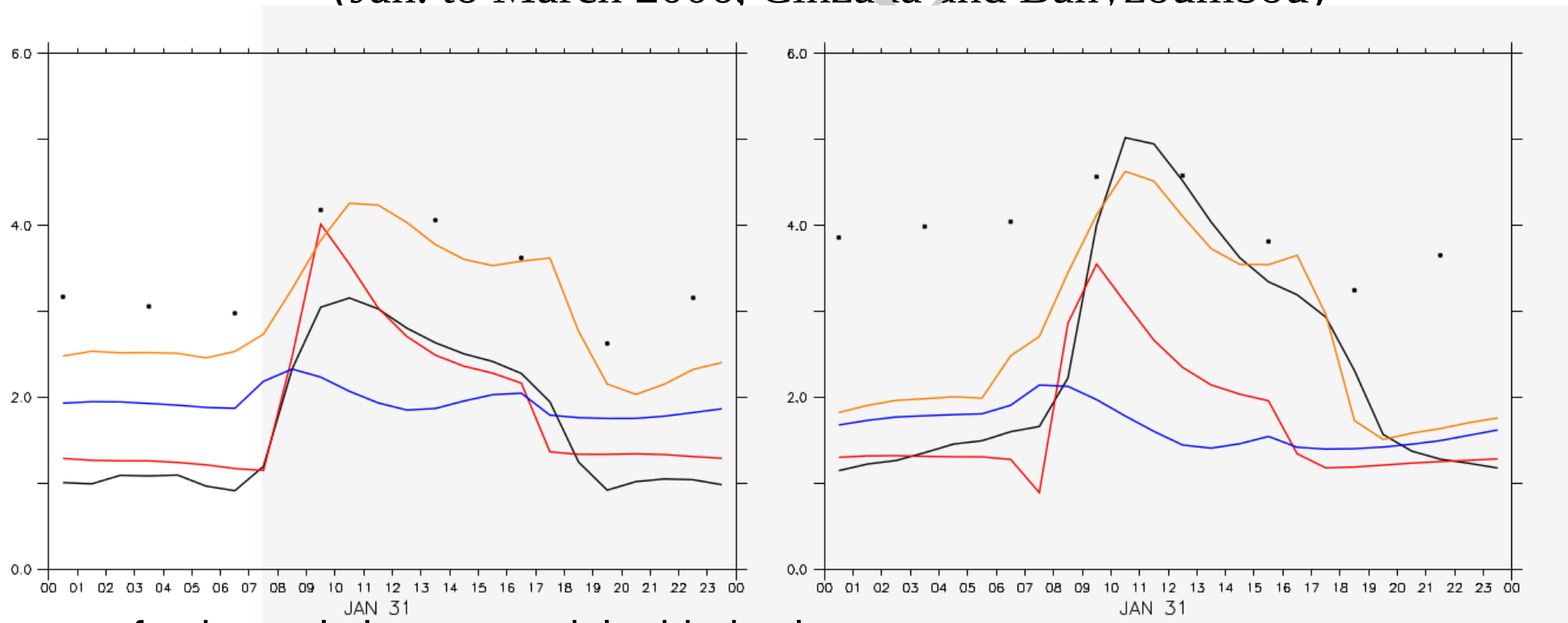
LMDZ6.0
Thermals activation
everywhere

LMDZ6.1
Thermals activation
Everywhere + special
Treatment for strato
Cuulus clouds

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

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

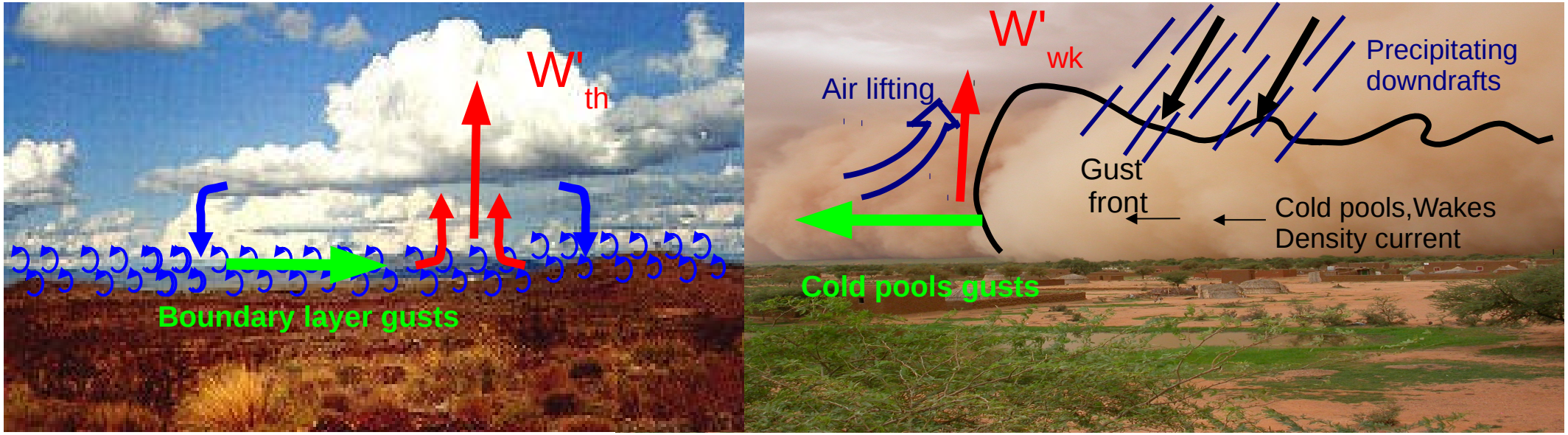
Wind speed diurnal cycle over Sahel
(Jan. to March 2006, Cinzana and Banyzoumbou)



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

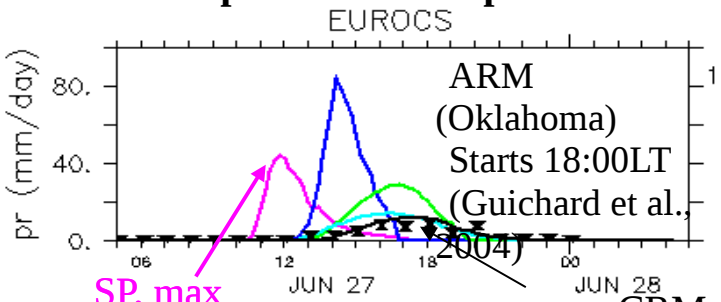
New physics (LMDZ5B)
Deep convection closure (trigerring and intensity) controled by sub-cloud processes :
Using vertical velocity coming from the thermals and cold pools



Improvements since LMDZ5 :
Random triggering
Accounting for gusts

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

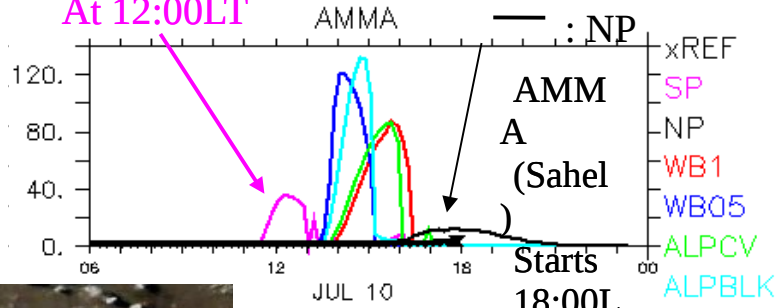
1D test cases/ comparison with explicit simulations (MesoNH)



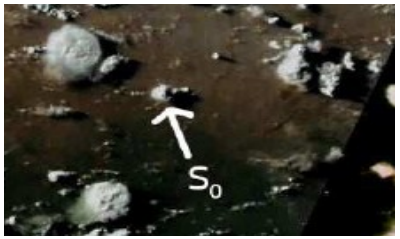
ARM (Oklahoma) Starts 18:00LT (Guichard et al., 2004)

SP, max At 12:00LT

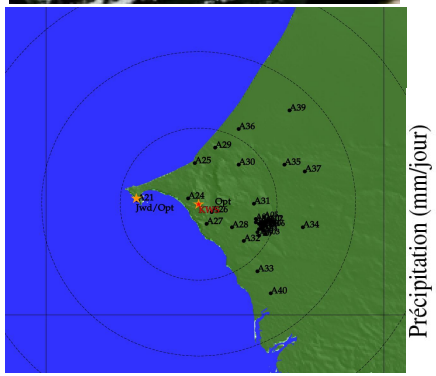
x : CRM
— : NP



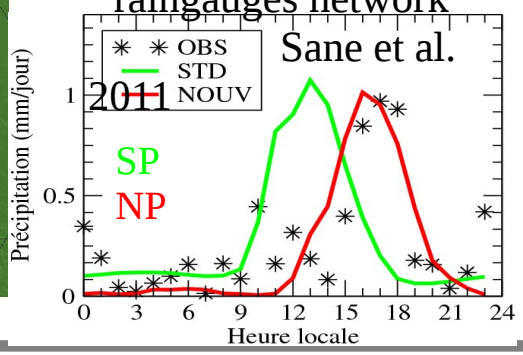
AMMA (Sahel) Starts 18:00LT



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



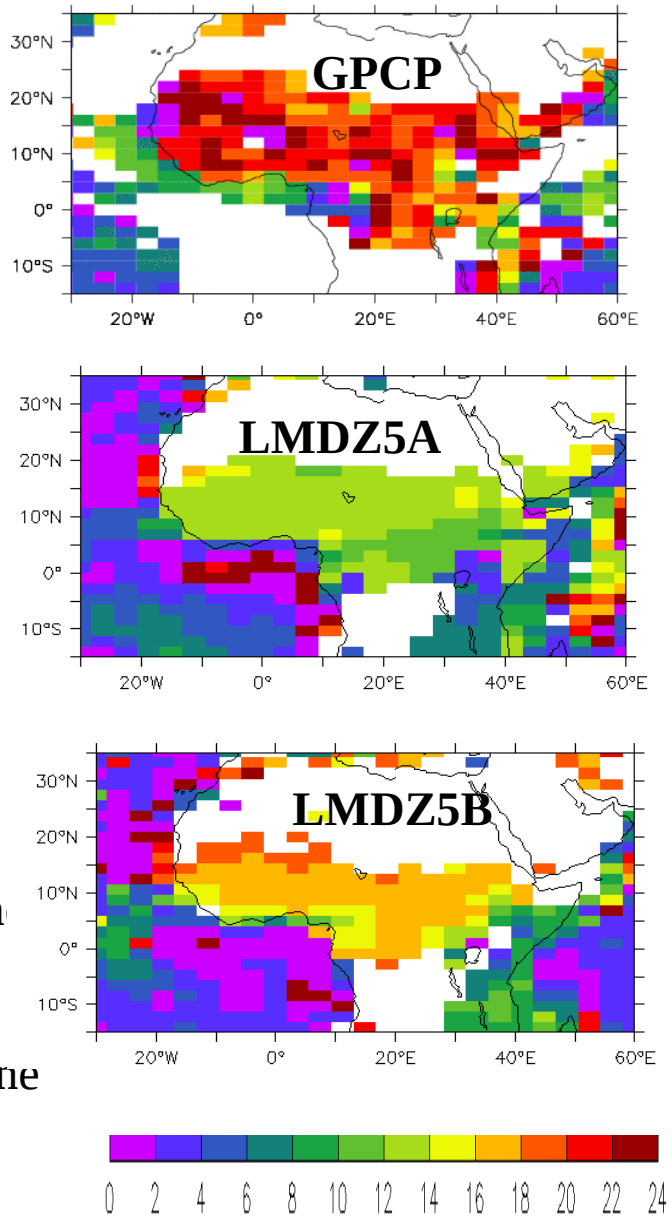
Dakar LPAOSF/NASA raingauges network



Sane et al. 2011

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

Local hour of maximum rainfall in July



A good representation of the diurnal cycle of rainfall over continents

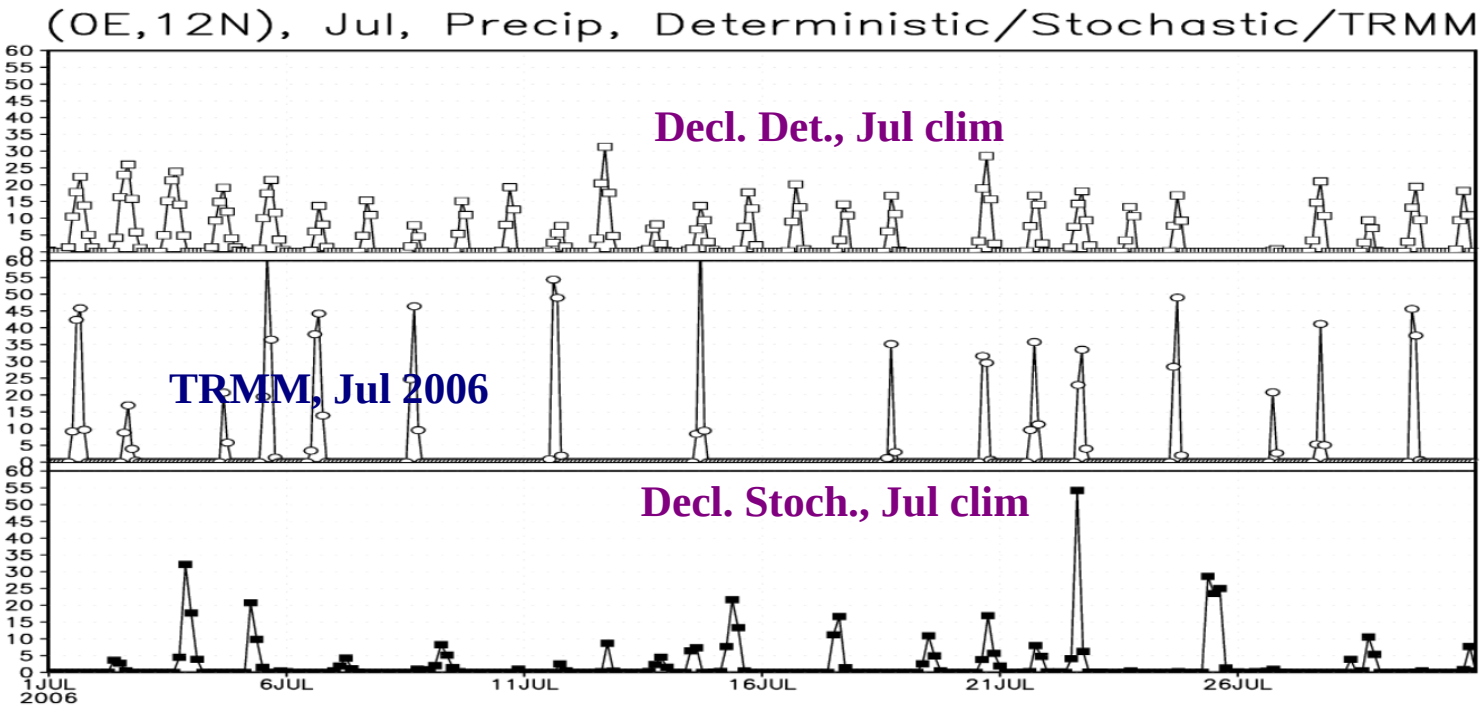
2. Inter-comparison exercises c) Robust improvements from version to version

New trigerring :
It is asked that the surface of one of the thermal plume within the grid cell is larger than a threshold value.
Thermal plume model → Size distribution → triggering based on a random number

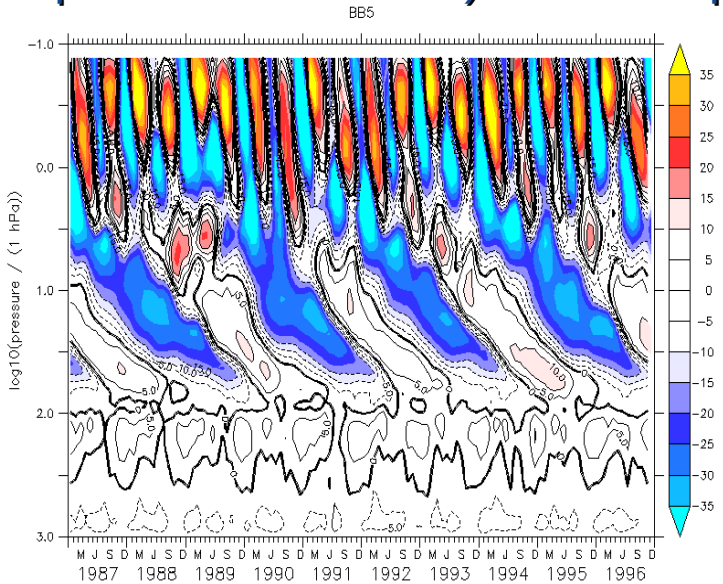
LMDZ5
Too regular rainfall

Observation

LMDZ6



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



QBO

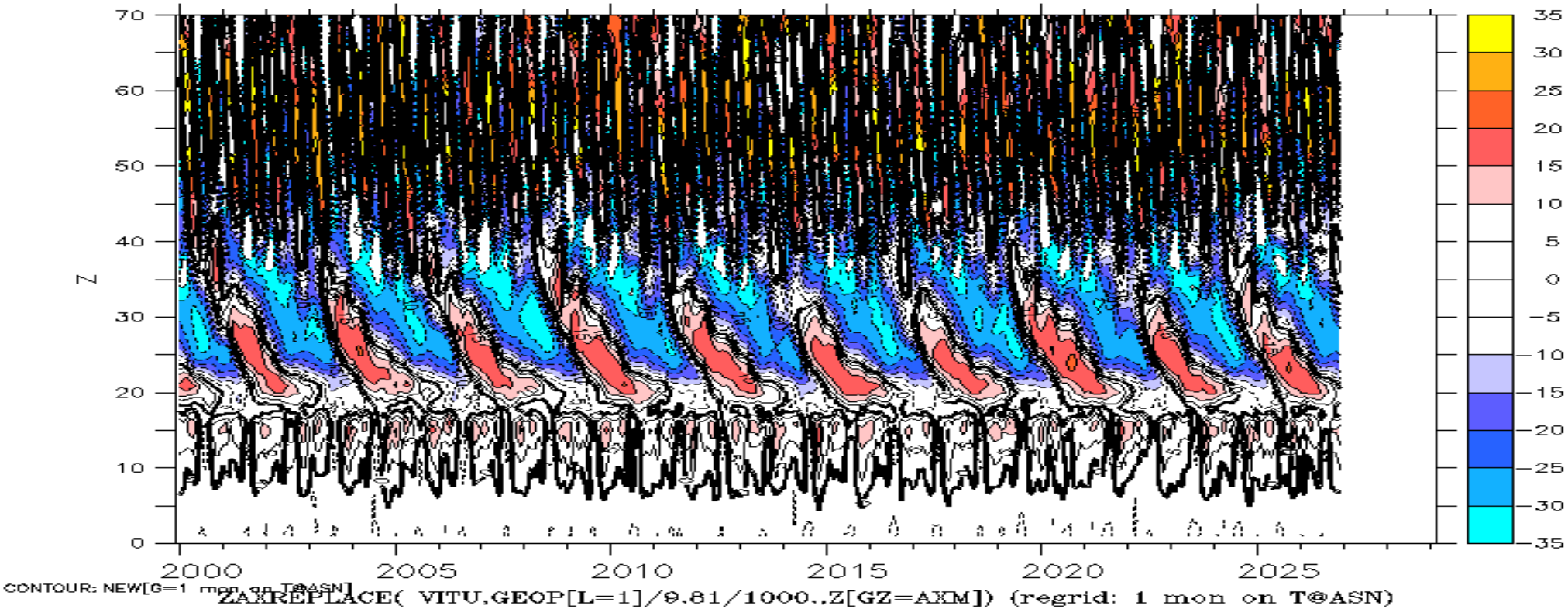
Obs

Modèle

8.8W (averaged)

FERRET Ver. 6.85
NOAA/PMEL TMAP
08-AUG-2014 08:02:00

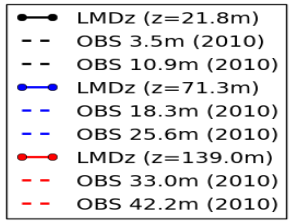
DATA SET: mm

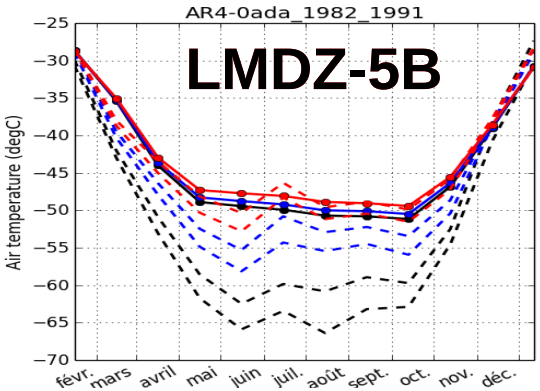


Among the models with a Quasi Bienal Oscillation

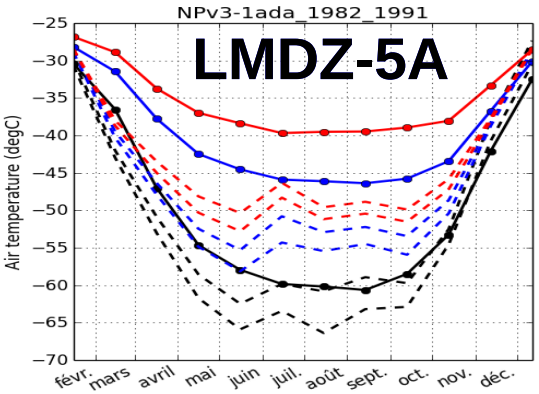
2. Inter-comparison exercises c) Robust improvements from version to version

T at Dome C
Antartic Plateau

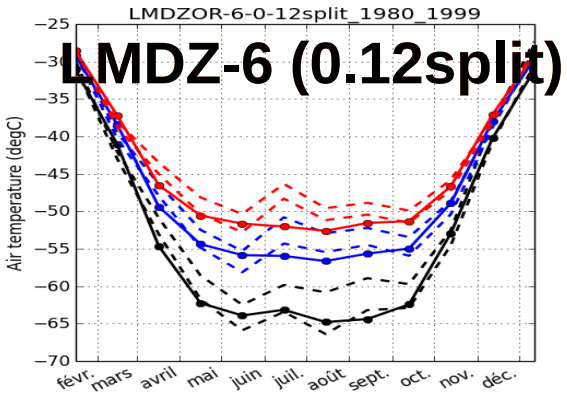


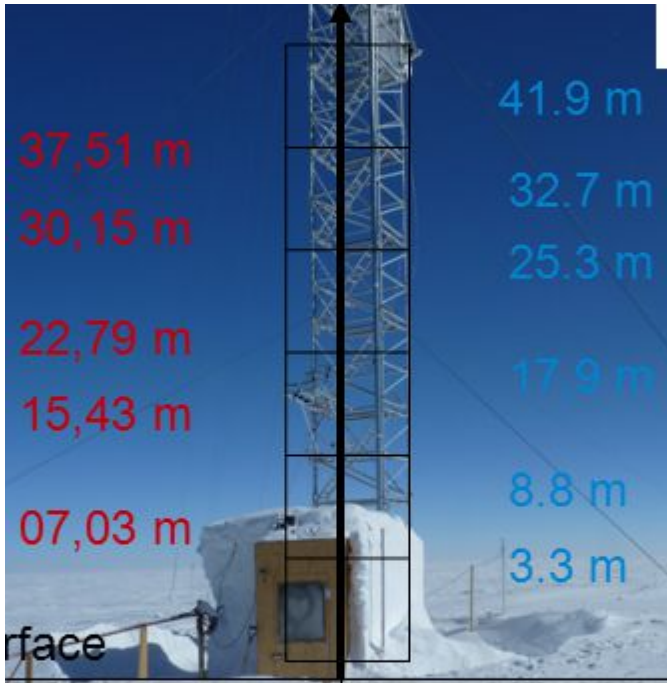


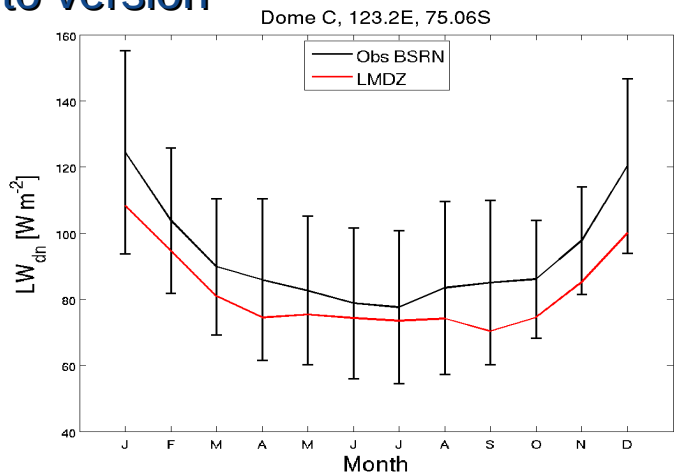
Improvement of the respresentation of the stable boundary layer.
Vignon et al. 2017

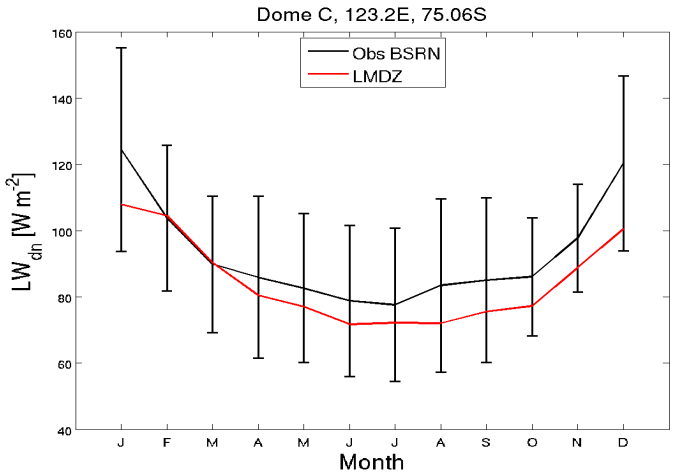


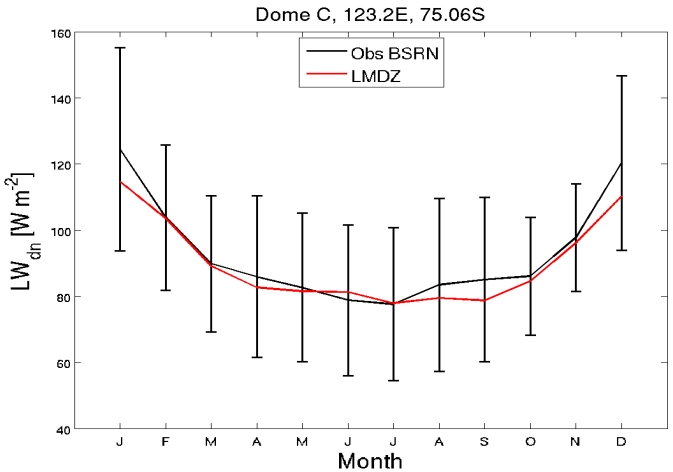
Compared to observations at 5 levels over a 40m measurement tower at Dome C





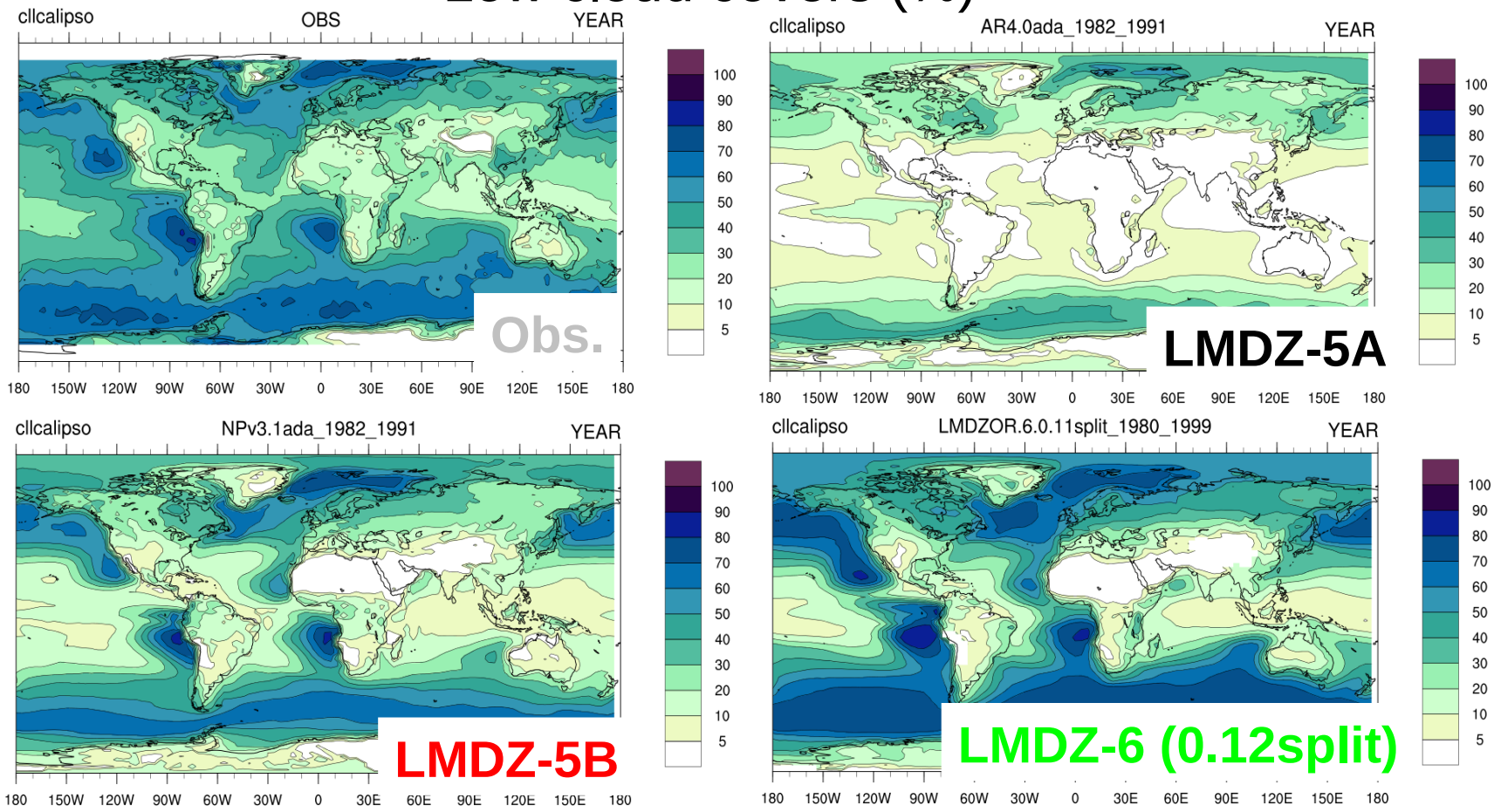


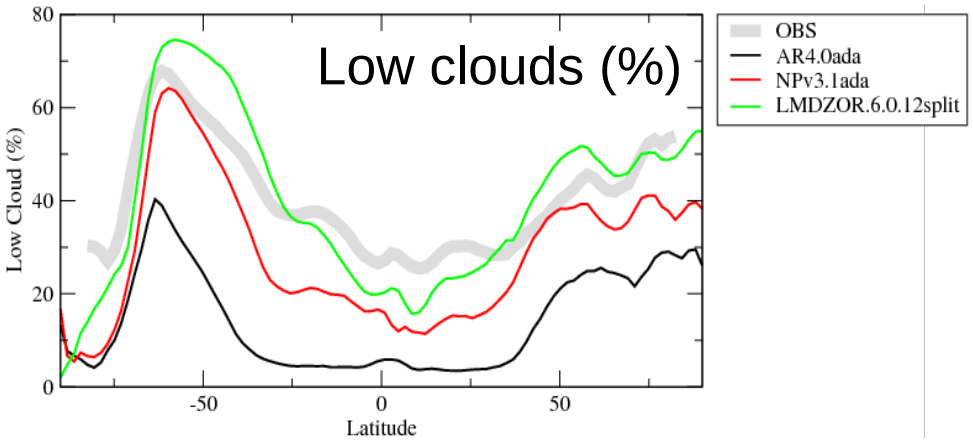


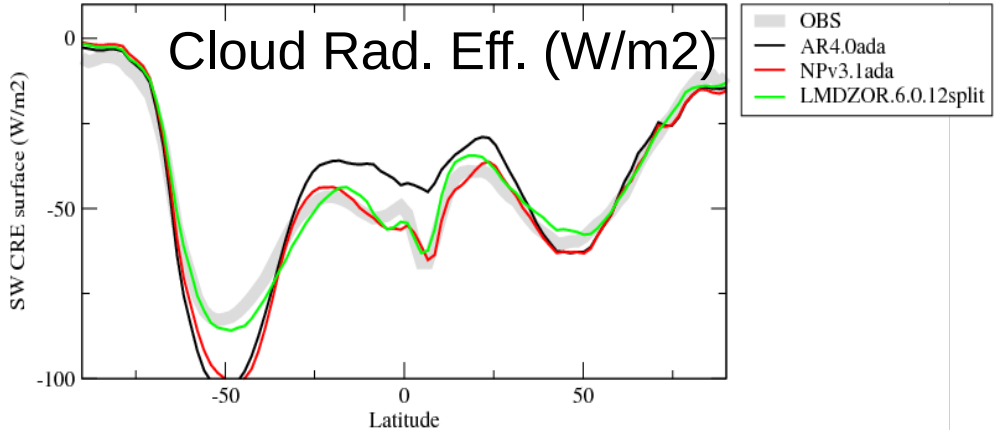


2. Reference versions d) Evolution of climatic biases and sensitivity

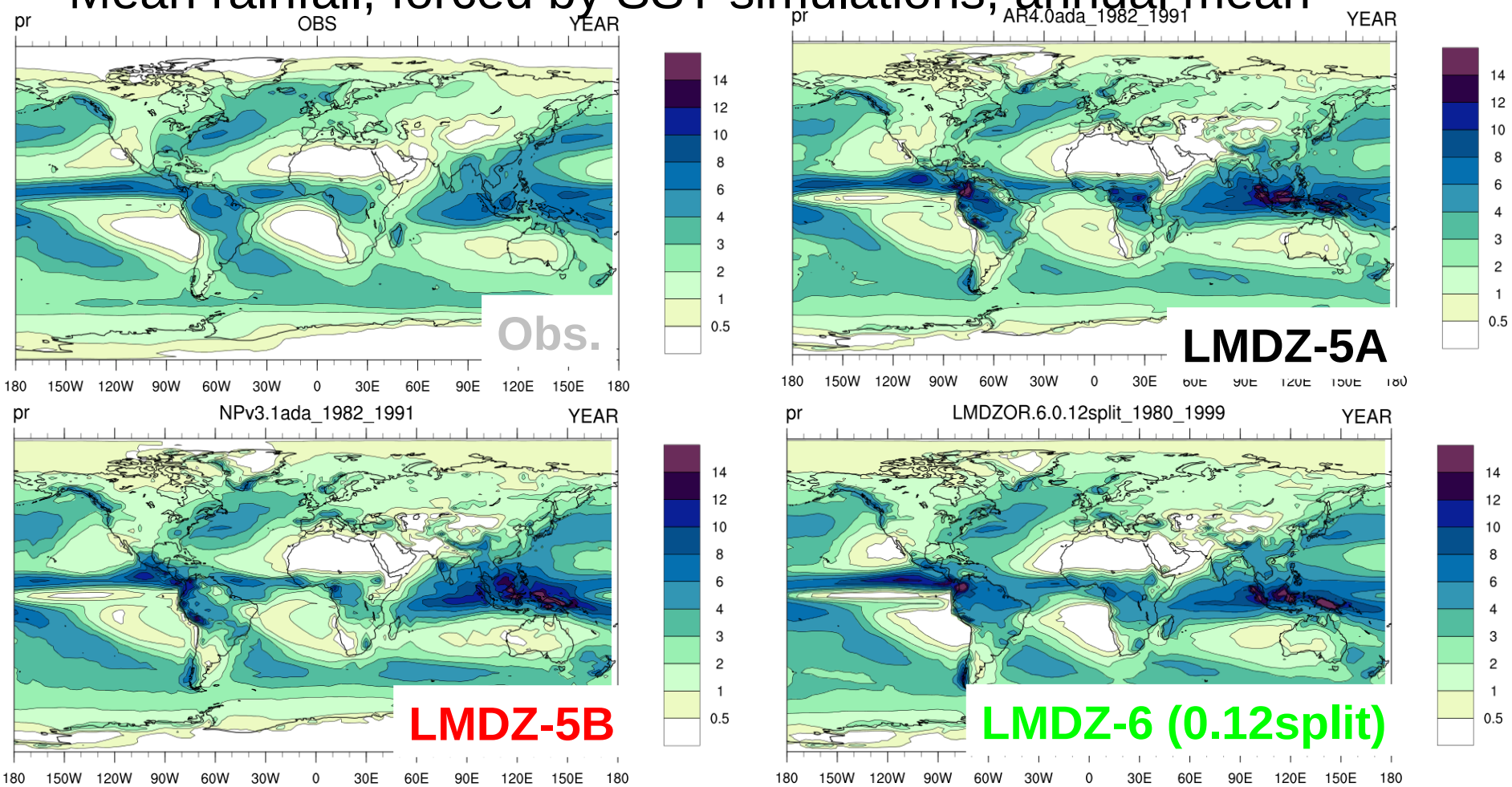
Low cloud covers (%)

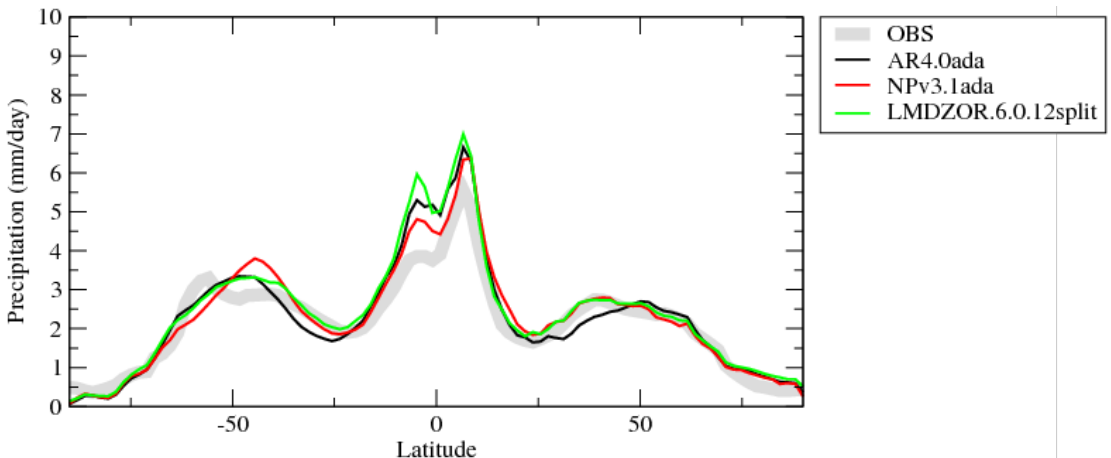




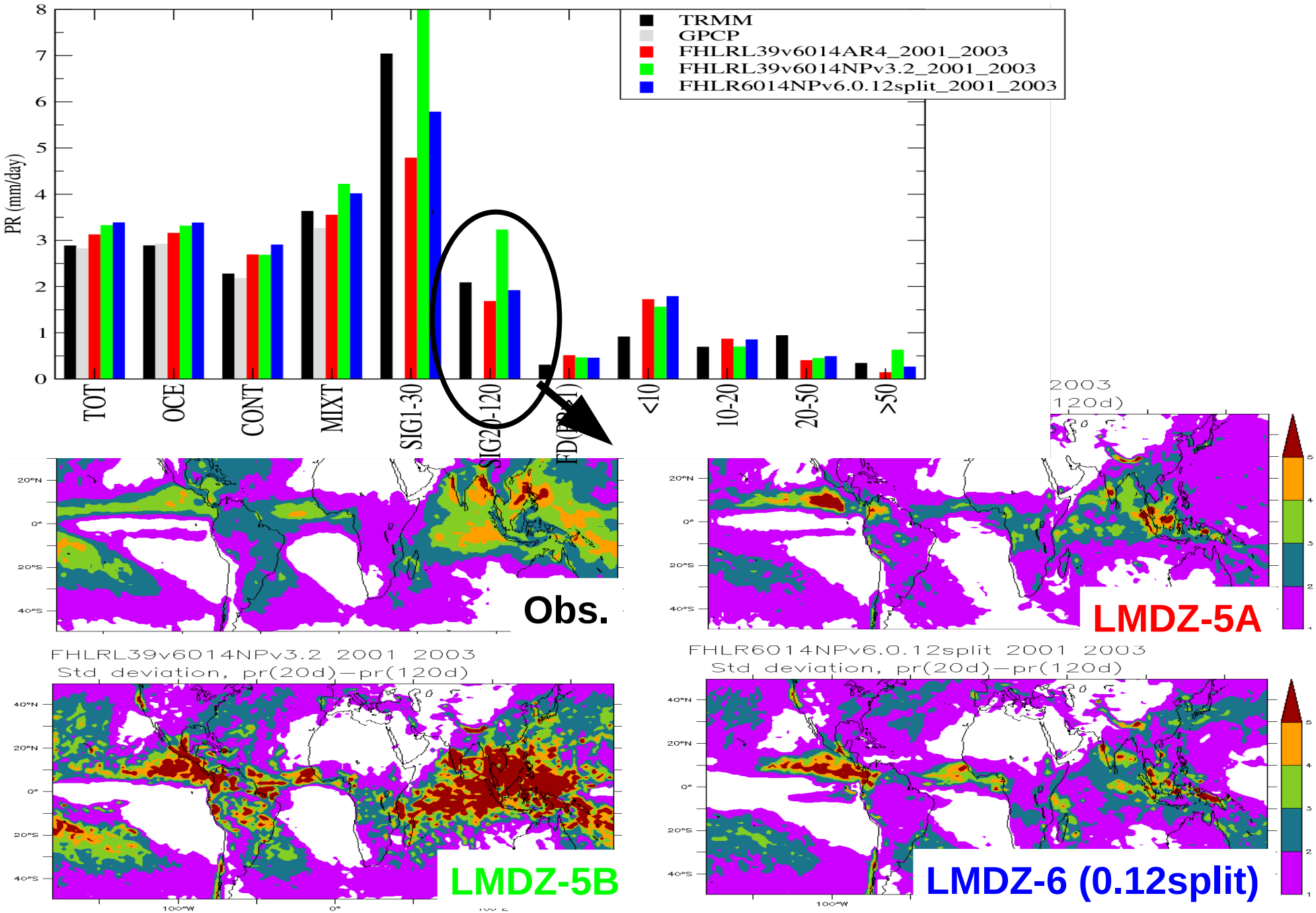


Mean rainfall, forced by SST simulations, annual mean





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

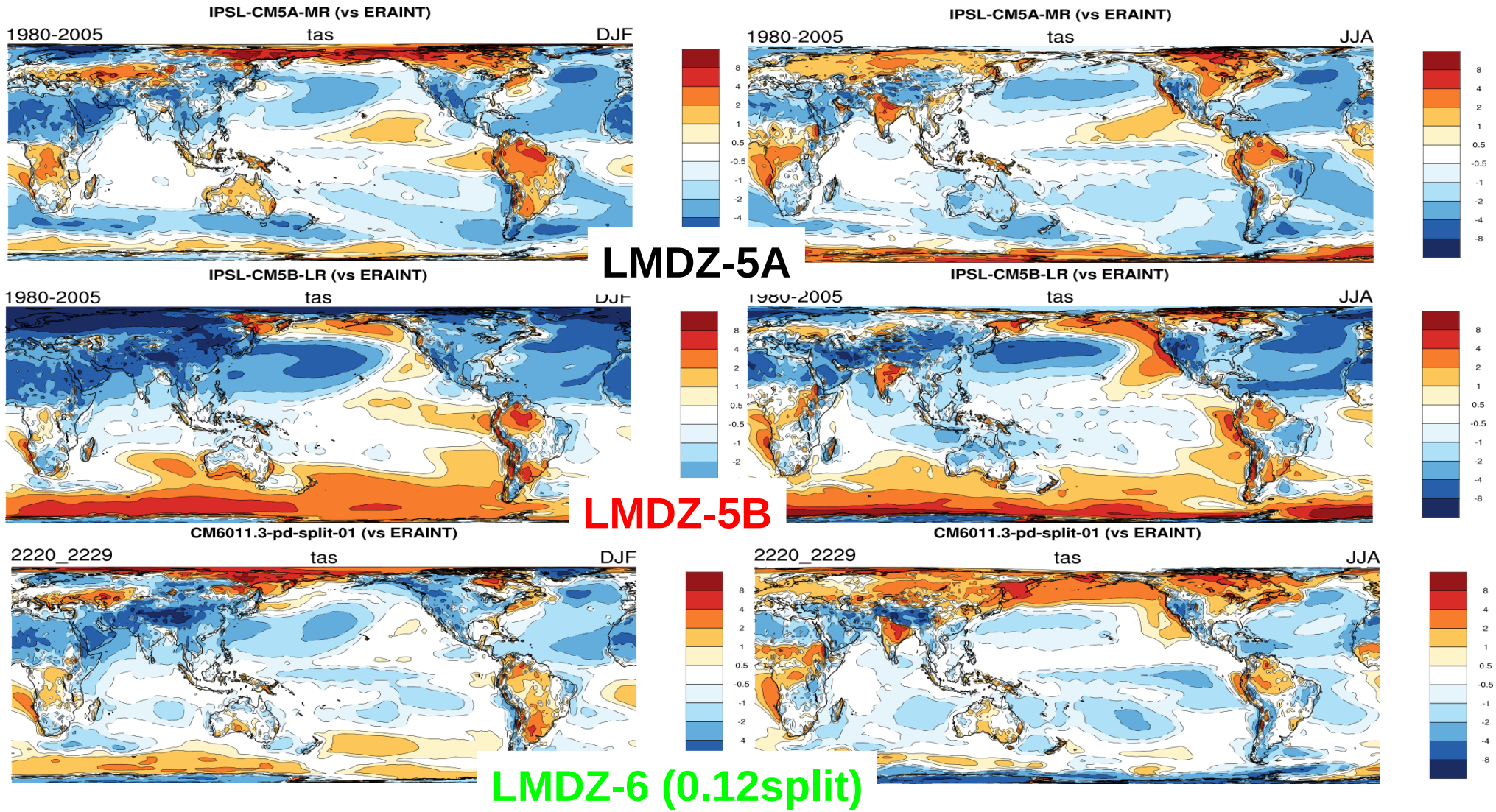


Rainfall variability in the 20 – 120 day period range

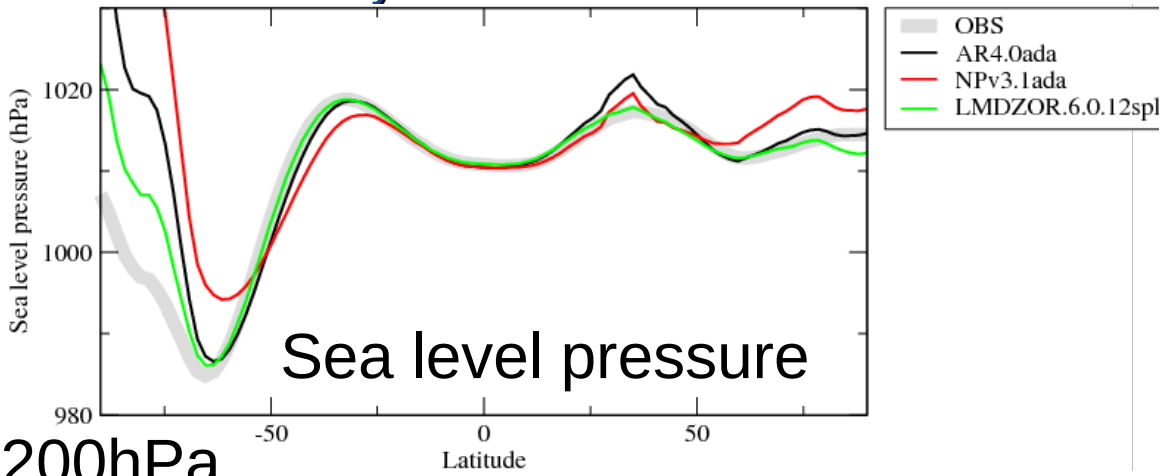
2. Reference versions d) Evolution of climatic biases and sensitivity

Air surface temperature bias (°C), coupled simulations

Dec.-Jan.-Feb. Jun.-Jul.-Aug.



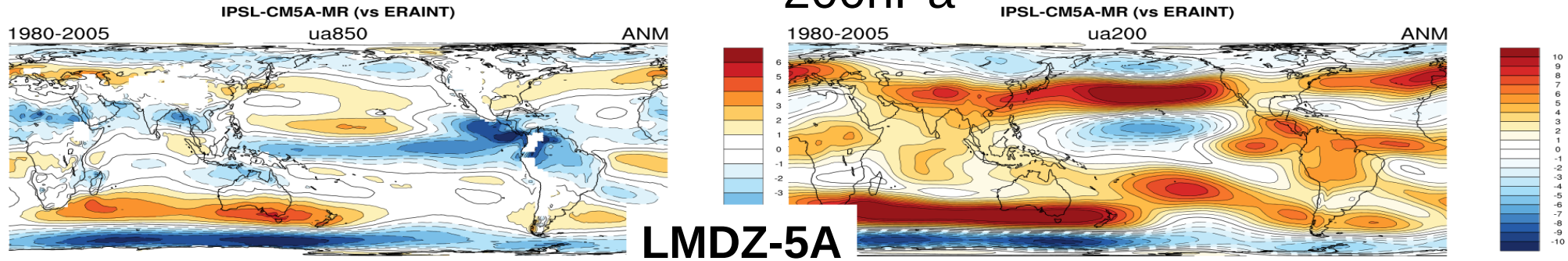
2. Reference versions d) Evolution of climatic biases and sensitivity



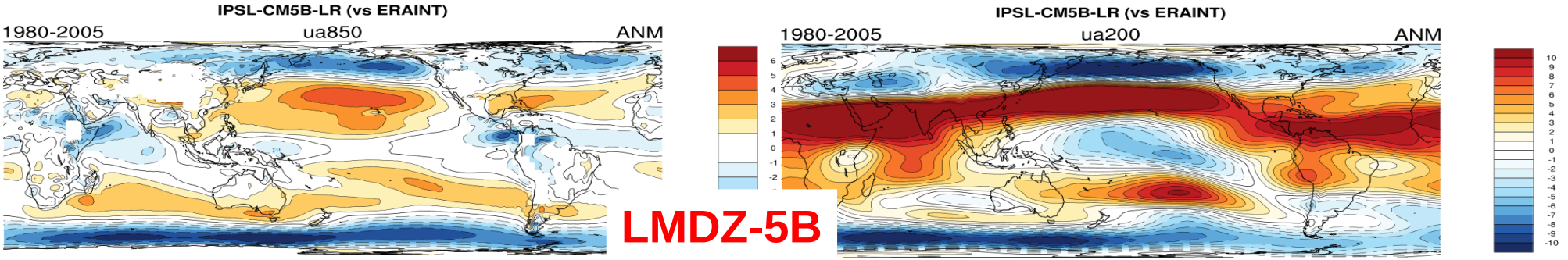
Zonal wind (m/s), coupled model

850hPa

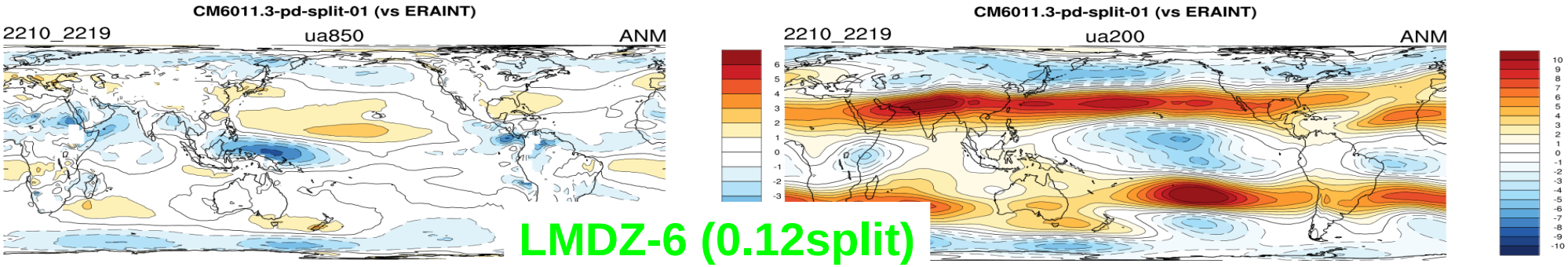
200hPa



LMDZ-5A

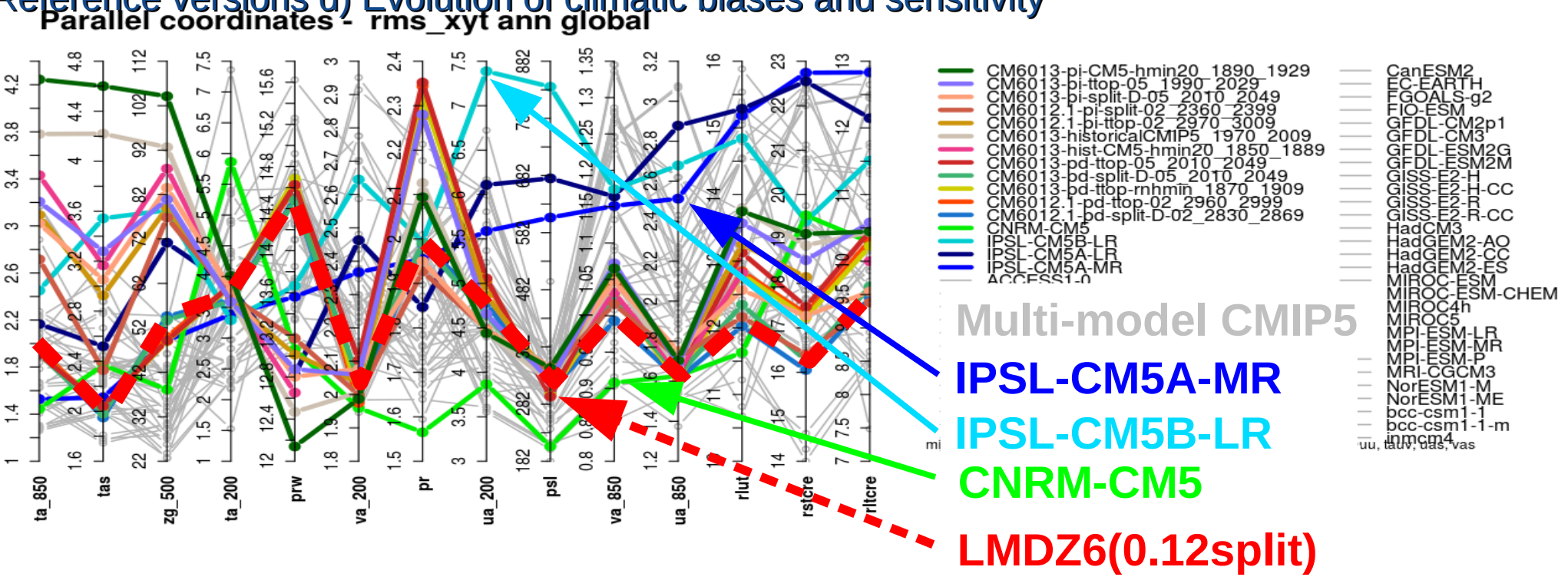


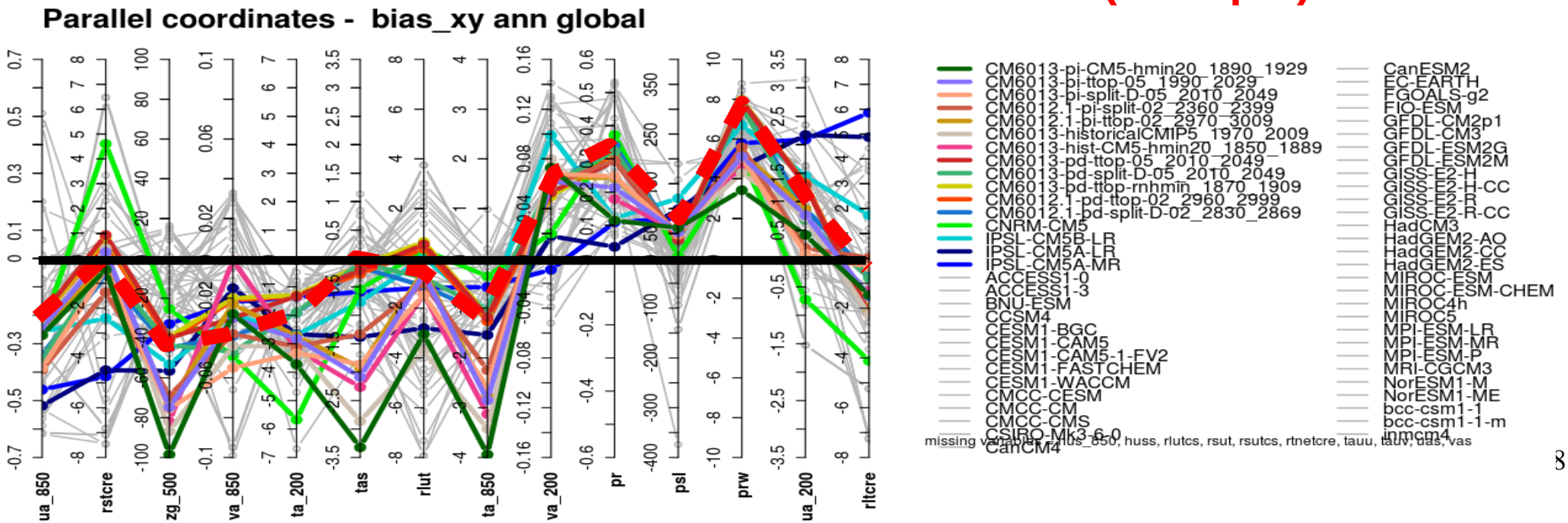
LMDZ-5B



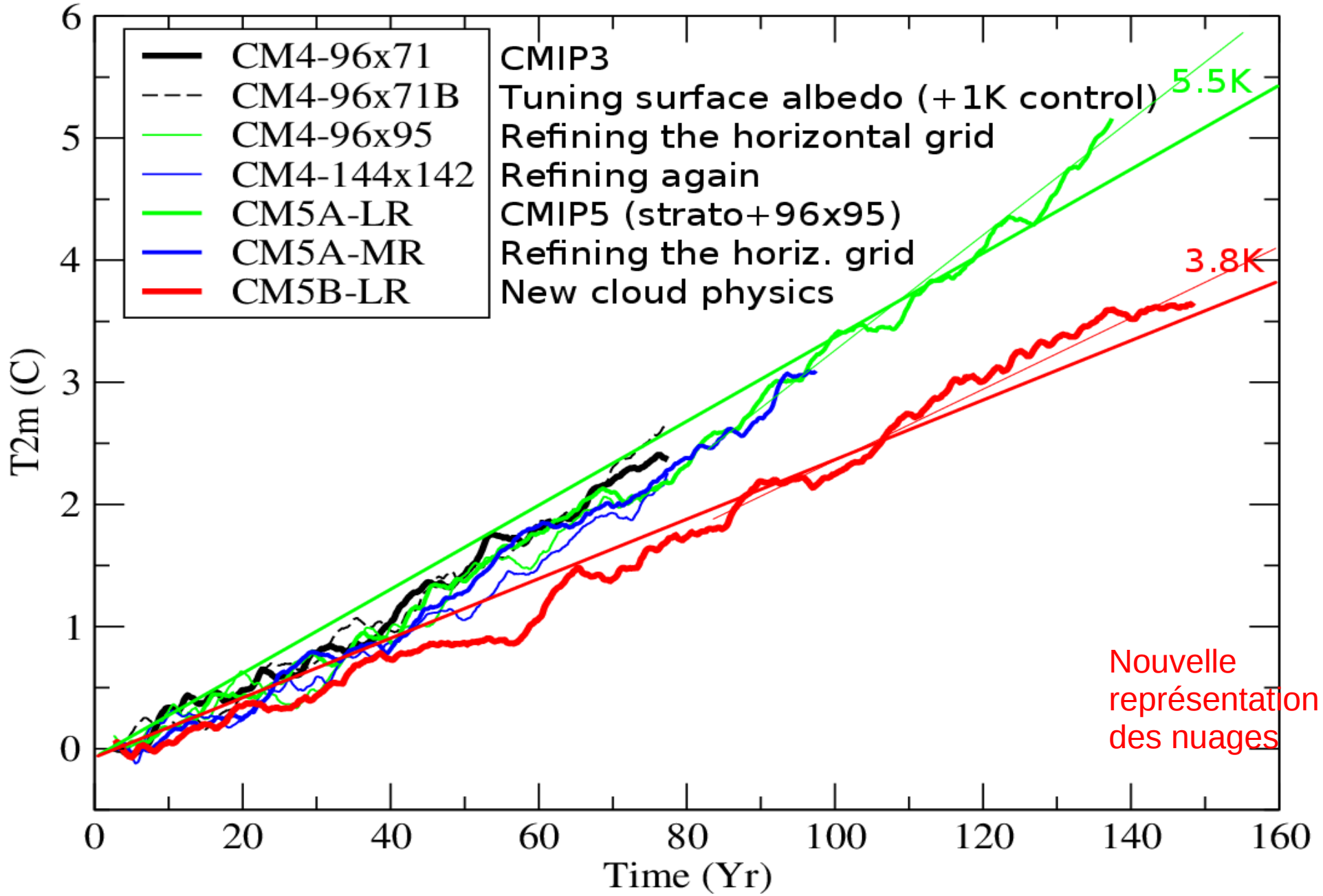
LMDZ-6 (0.12split)

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





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



Climate sensitivity highly dependent on model physics.
IPSLCM among models with high climate sensitivity

Summary

Robust improvements

Convective boundary layer : diurnal cycle of clouds and wind
Better cumulus and straocumulus clouds
Better phasing of the diurnal cycle of deep convection
Intermitency 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

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.

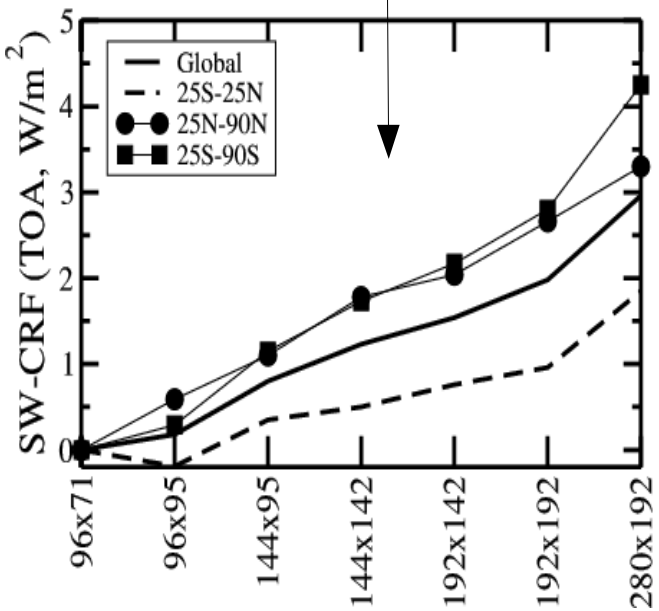
For global climate coupled atmosphere/ocean modeling the tuning of the radiative forcing is a key issue. Several months of tuning for one version.

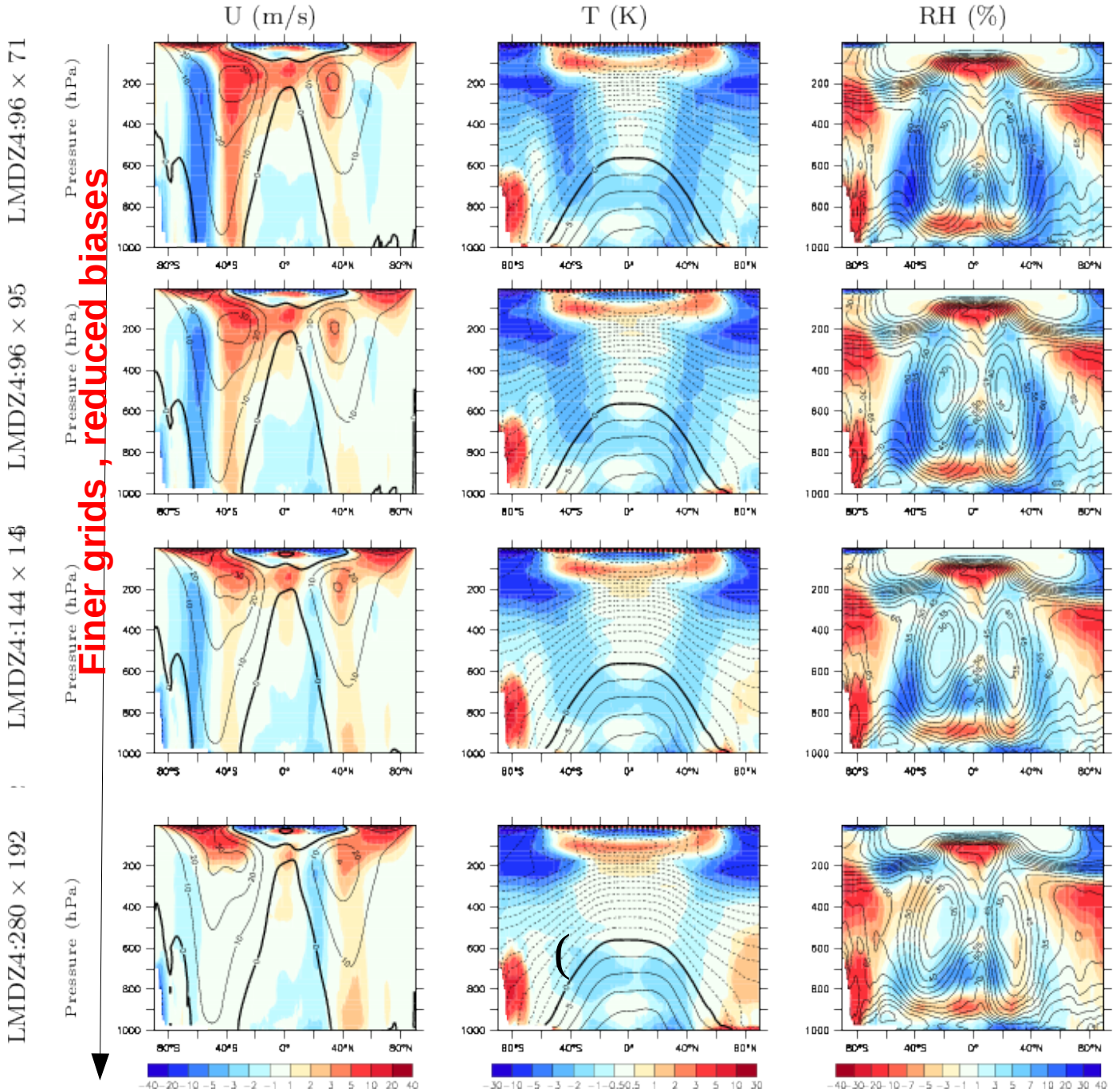
From LMDZ4 to LMDZ5 and LMDZ6 : change of horizontal resolution

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





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.

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 !**

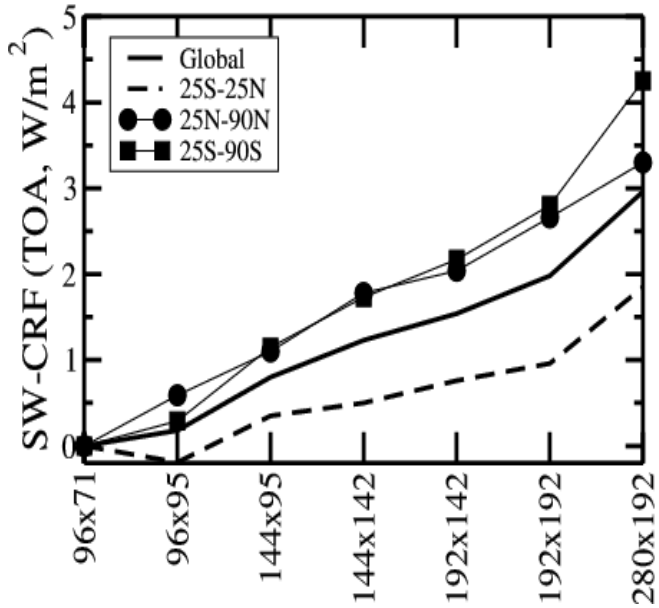
Preparation of a configuration is a long process
Sensitivity tests to the grid, physical parameterizations, free parameters
Compromises. Can depend on team priorities.

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

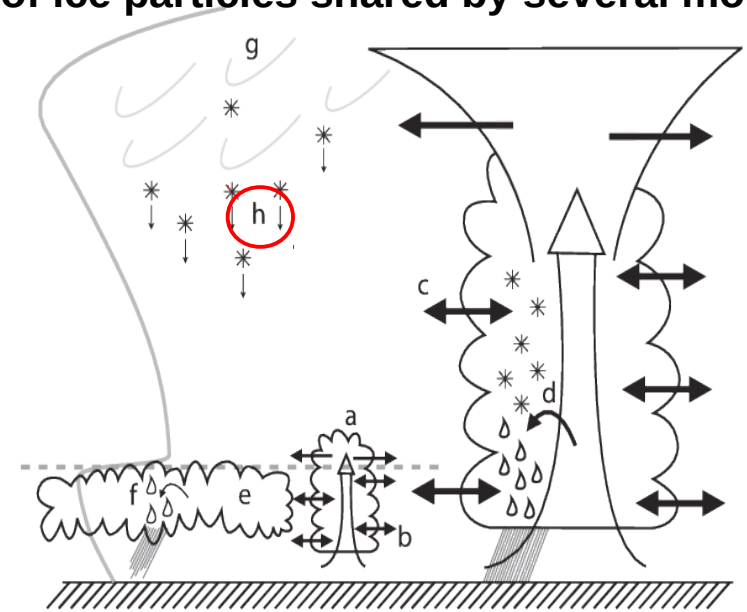
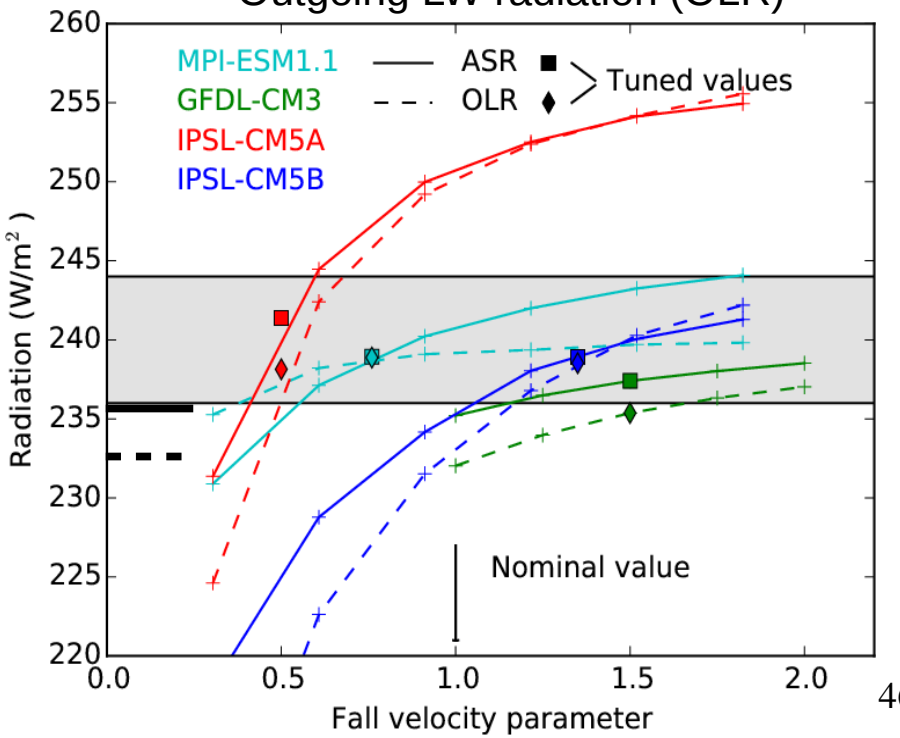


Figure from Mauritsen et al, 2013 (MPI model)

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

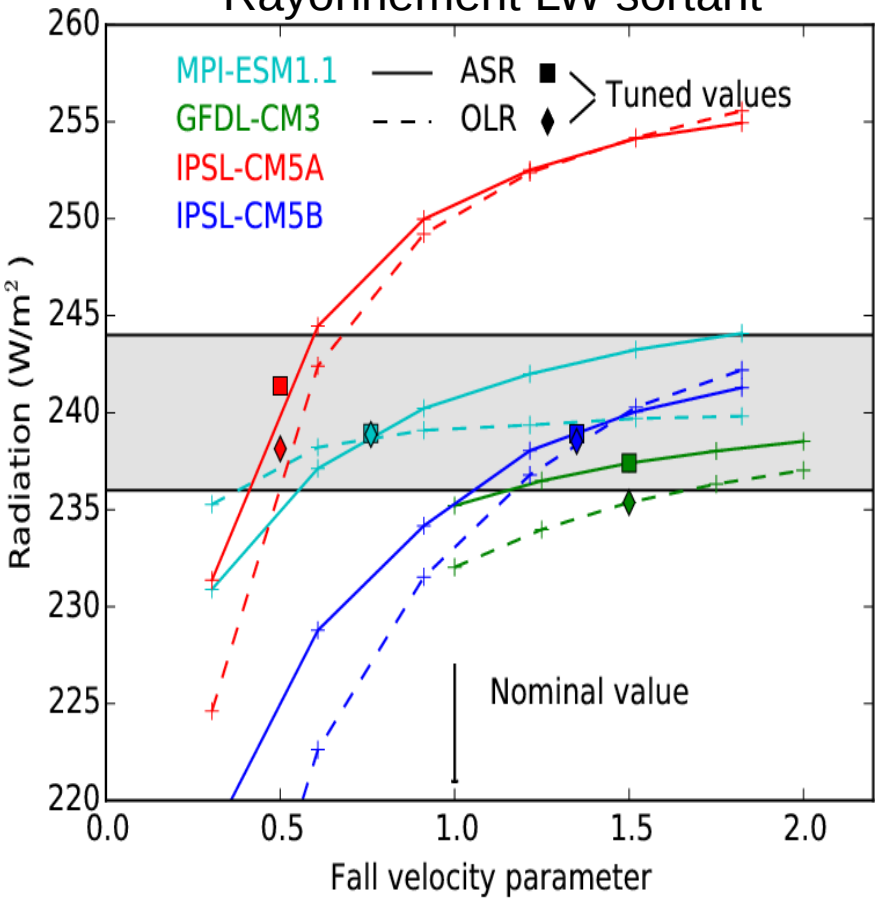


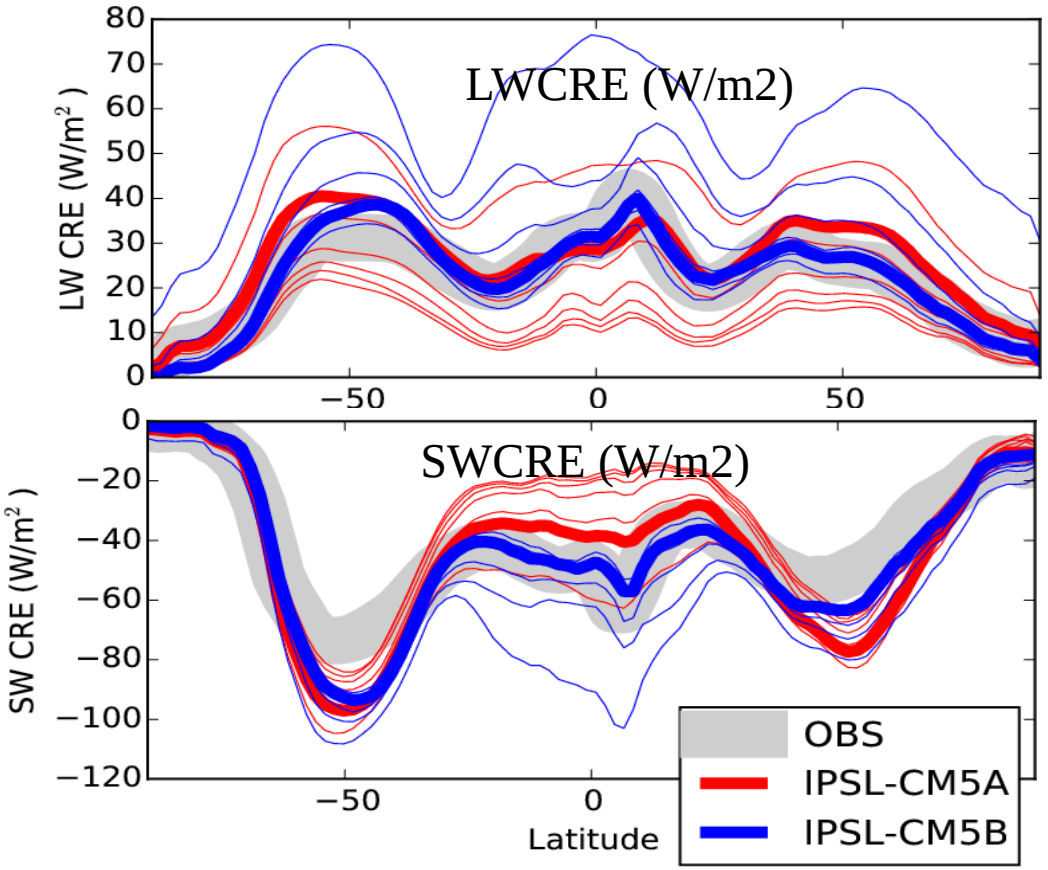
Use of a scalling factor on the fall velocity of cloud ice particles
Impact on global radiative balance and latitudinal radiative forcing of the circulation

Impact sur les flux globaux au sommet

Rayonnement SW absorbé

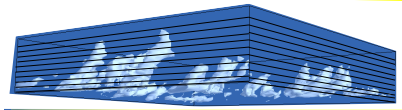
Rayonnement LW sortant



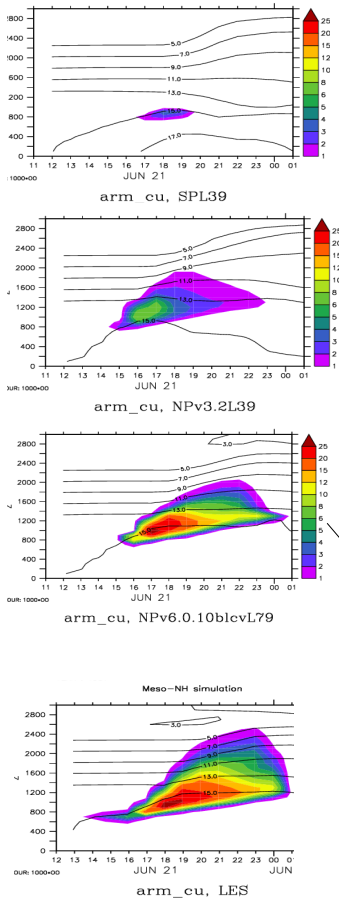


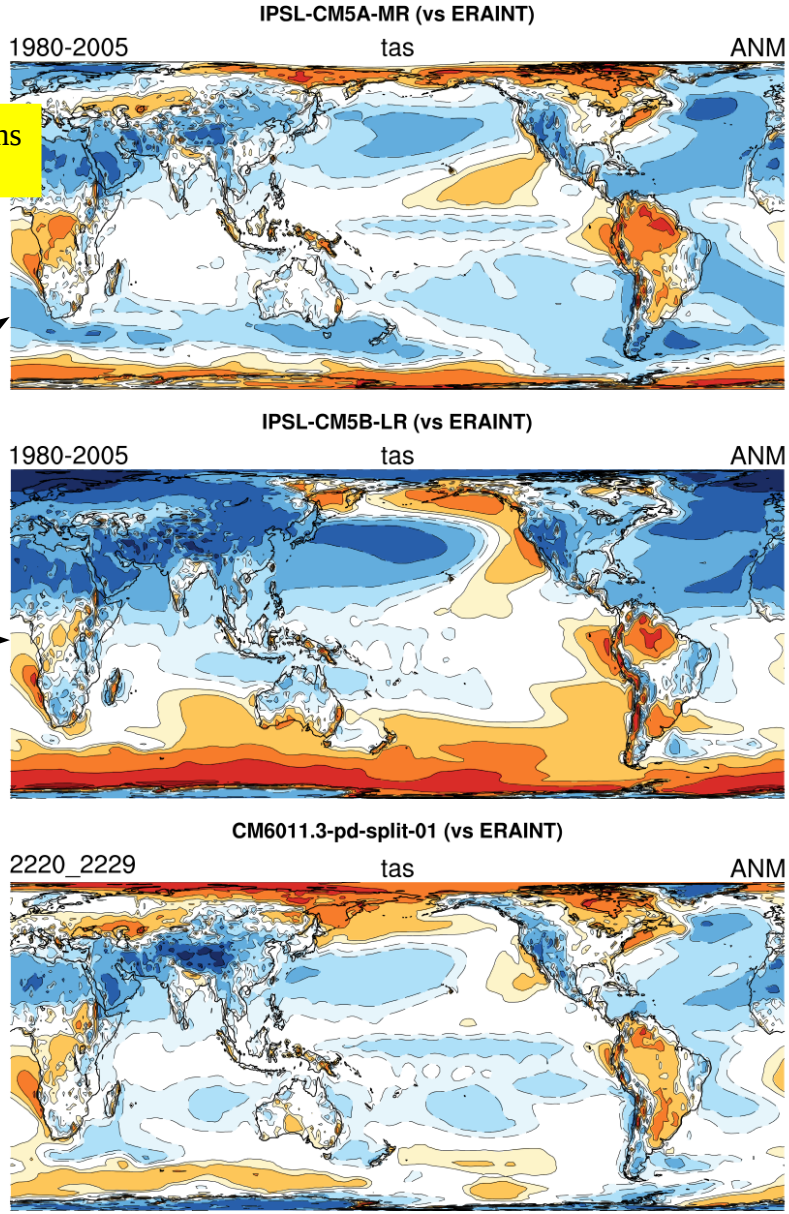
IPSL-CM4 to 6 : (slow) physics improvement
+ slow resolution increase
+ tuning free parameters

Explicit simulations, dx ~20-100 m



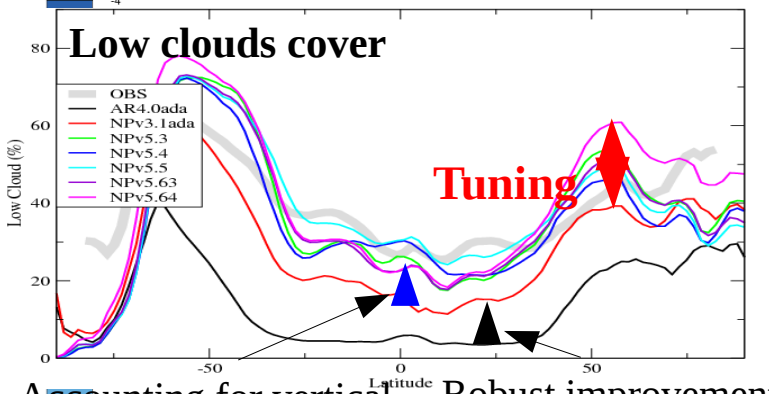
Climate model, parameterizations
« single-column » mode





Tuning targets:

Global energy balance
Decomposition clear sky/CRE
Latitudinal distribution
Dyn. regime sorting in tropics
+ « systematic » warm biases
→ Eastern tropical oceans
→ Roaring forties



Accounting for vertical inhomogeneities

Robust improvement
Thermal plume model

Continuous improvement accompanied by a systematic tuning

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

Eté 2015, 1eres simulations longues :
- Stabilisation num couche lim.
- Déclench. Stochast. Convect.
- Strato-cus avec thermiques.
- Microphysique glace
- Ondes non orog. → QBO
- L39 → L79

Nuages-convection
iflag_mix=1
iflag_coud_vert=1

RRTM
+fisrt+
lmix

Nouveaux z0
Sur océans
Conserv E.1

Orographie
Tuning param
+ Accélération x2

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

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

Ete 2015 → Ete 2016 → Printemps 2017

New Tmix

Améliorations de code
Tests de paramètres
Corrections de bugs

Calving

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

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

paramètres liés à la glace de mer
albedo
amaxn
amaxs
pstar

Continuous improvement accompanied by a systematic tuning

V : Validé
C : en cours
X : non engagé

Evolution du contenu physique par rapport à NPv3.1

2014	2015	**2016**	2017	
				Déjà dans les sources (2014) :
V	V	V	V	- schémas numériques stabilisés pour la couche limite
V	V	V	V	- déclenchement stochastique
C	V	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/Cahterine, 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 proveneant 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 ?

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_glace 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_glace=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_glace=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

Summer 2015
Ice thermo dynamics
First multi decadal simulations

	NPv5.17h (IPSL-CM 6.0.1)
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=0
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.998
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=0.312
Mixed phase of clouds	iflag_t_glace=1
Threshold cloudy water LS	cld_lc_lsc=0.0003
Threshold cloudy water CV	cld_lc_con=0.0003
Ice crystals fall speed LS	ffallv_lsc=0.66528
Ice crystals fall speed CV	ffallv_con=0.66528
Coefficient of evaporation	coef_eva=2e-05
radiation	iflag_rrtm=0

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

Feb 2016

New mixing
+ crash fixed

	LMDZ 5.4 (IPSL-CM 6.0.2)
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=0.9995
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=0.312
Mixed phase of clouds	iflag_t_glace=1
Threshold cloudy water LS	cld_lc_lsc=0.0001
Threshold cloudy water CV	cld_lc_con=0.0001
Ice crystals fall speed LS	ffallv_lsc=1
Ice crystals fall speed CV	ffallv_con=1
Coefficient of evaporation	coef_eva=2e-05
radiation	iflag_rrtm=0

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

April 2016

+ RRTM !
Minimum mixing length

	LMDZ 5.5 (IPSL-CM 6.0.3)
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=0.312
Mixed phase of clouds	iflag_t_glace=1
Threshold cloudy water LS	cld_lc_lsc=0.00022
Threshold cloudy water CV	cld_lc_con=0.00022
Ice crystals fall speed LS	ffallv_lsc=0.67
Ice crystals fall speed CV	ffallv_con=0.67
Coefficient of evaporation	coef_eva=2e-05
radiation	iflag_rrtm=1

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

July 2016

Tuning of sub grid
Scale orography
Dt phys : 10 → 15 min

	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_glace=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

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

January 2017

	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
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_glace=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

May 2016

Convection triggering if
Ttop < Ttopmax
Energy conservation (partial)
MY improved for stable conditions

	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	
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_glace=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	coef_eva=0.0001
radiation	iflag_rrtm=1

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

April 2016

Accounting for gustiness in surface oeceanic fluxes

	LMDZ6.0.12ttop
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
PDF for mixing	iflag_mix=1
Computation of condensate	iflag_clw=0
Efficiency of precipitation	epmax=0.998
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_glace=2
Threshold cloudy water LS	cld_lc_lsc=0.000106
Threshold cloudy water CV	cld_lc_con=0.000106
Ice crystals fall speed LS	ffallv_lsc=0.6
Ice crystals fall speed CV	ffallv_con=0.6
Coefficient of evaporation	coef_eva=0.0001
radiation	iflag_rrtm=1

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

April 2016

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
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_glace=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	coef_eva=0.0001
radiation	iflag_rrtm=1

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
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.

Coming soon :

→ 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

Concluding remarks / recommendations

Reference tuned versions are available for LMDZ : LMDZ5A, 5B, and almost for LMDZ6

Which means :

→ Long term investment on physical parameterizations. In particular with 1D vs LES

→ Long phases of evaluation and tuning (nudged, forced by SST, coupled ...)

~ 2400 simulations, 650 multi-atlas for CMIP6

→ Constant evolution and improvement of coding (parallelism, modularity, post-processing , efficiency, flexibility)

TEAM EFFORT

Made possible thanks to all the LMDZ Team !!