The Abdus Salam
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United Nations
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2165-15

International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

13 - 22 September 2010

Introduction to climate modelling

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Introduction to climate modelling

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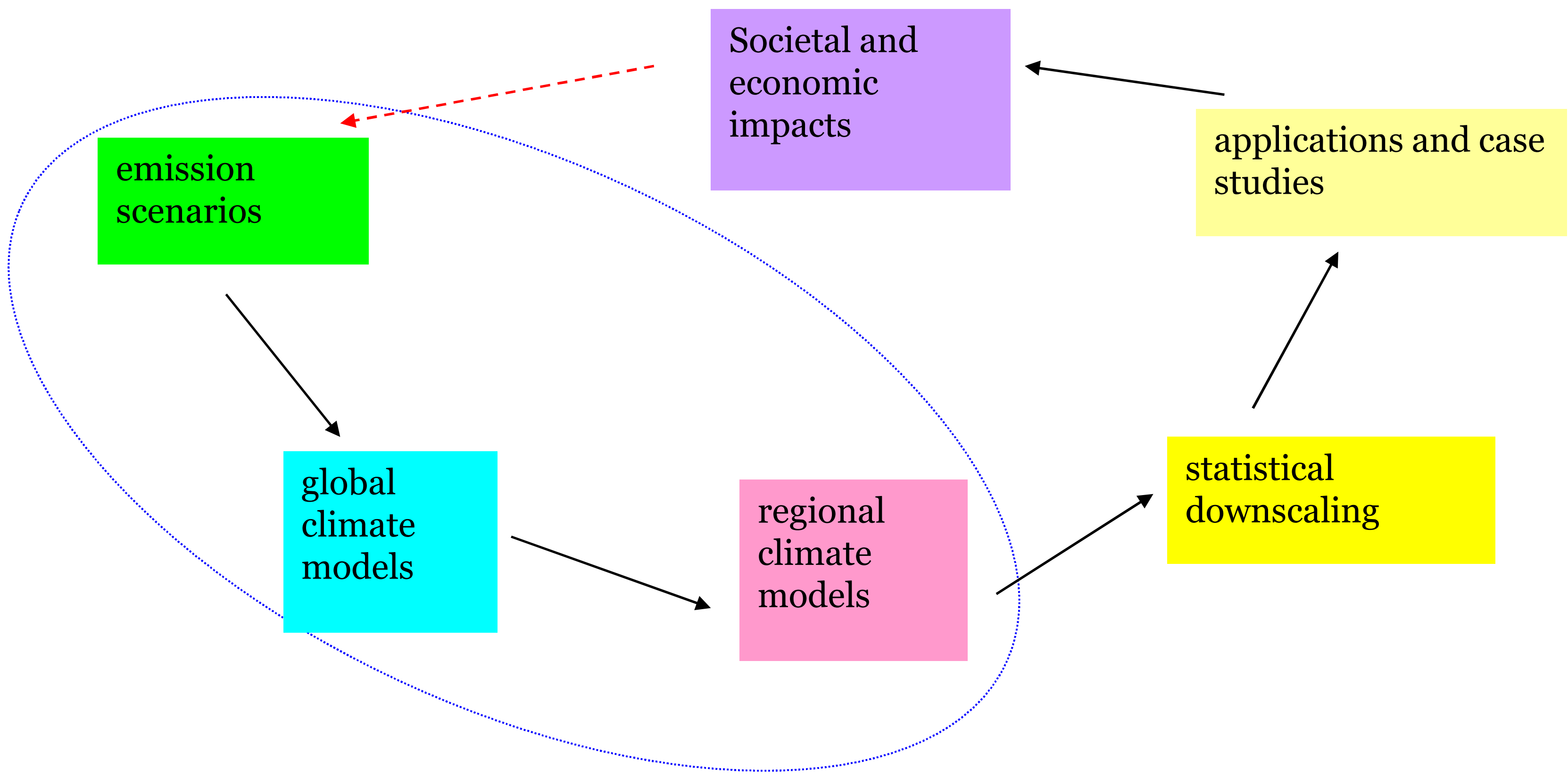
- Physical basis
- **A few examples**
- Anatomy of a GCM

Discussions

- General approach of climate change modeling
- Use multi-model information
- Use regional model to downscale
- A test over France and analyses on extremes
- Two-way nesting test (China and the Med Sea)
- Statistical downscaling: necessary but fragile
- Towards a fully-coupled system for the Med

What is the general approach in modeling climate changes ?

general approach

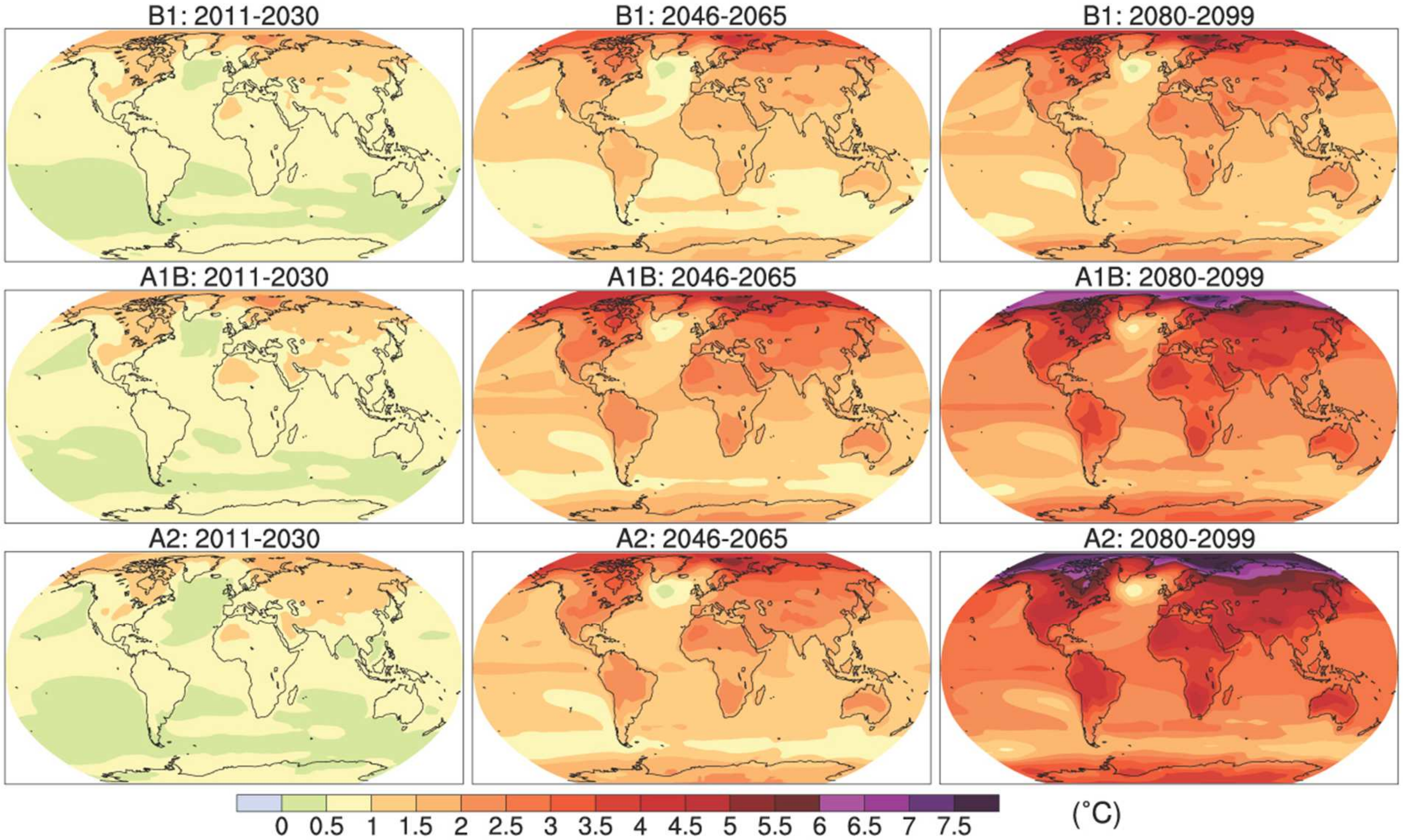


IPCC-AR4, Projection of global climate to the future, an unprecedented exercise of the international scientific community: about 15 groups

How to use information from the multi-model ensemble to assess uncertainties of climate change?

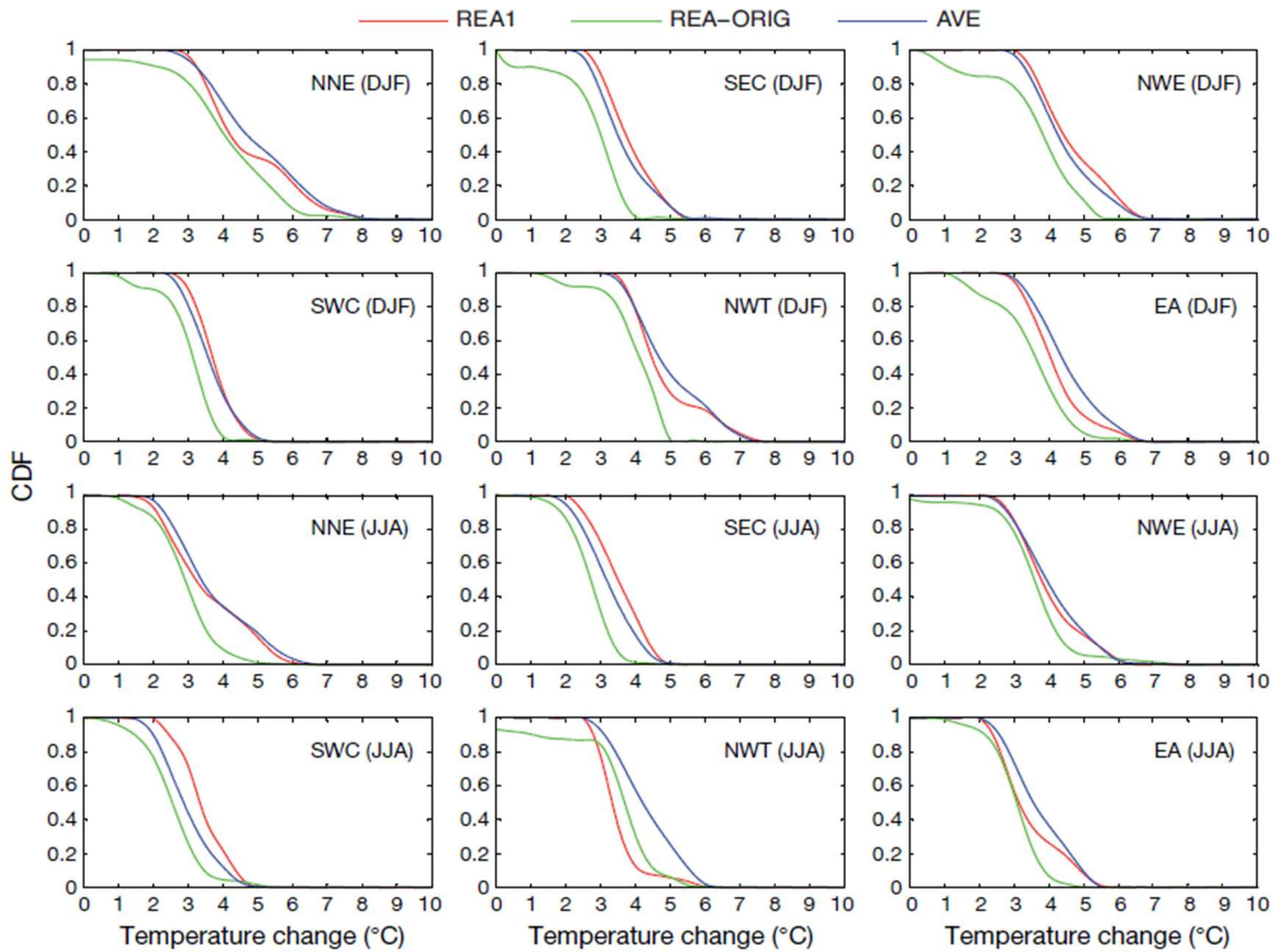
Model I.D.	Originating Group/Country	Atmosphere Resolution
BCCR_BCM2.0	Bjerknes Centre for Climate Research(BCCR) /Norway	2.8°×~2.8°
CGCM3.1 (T47)	Canadian Centre for Climate Modelling and Analysis (CCCMA) /Canada	3.75°×~3.75°□
CGCM3.1 (T63)	Canadian Centre for Climate Modelling and Analysis (CCCMA) /Canada	2.8°×~2.8°□
CNRM_CM3	Centre National de Recherches Me´te´orologiques (CNRM) /France	2.8°×~2.8°
CSIRO_MK3.0	CSIRO Atmospheric Research/Australia	1.875°×~1.875°□
CSIRO_MK3.5	CSIRO Atmospheric Research/Australia	1.875°×~1.875°□
GFDL-CM2.0	Geophysical Fluid Dynamics Laboratory (GFDL)/USA	2.5°×2.0°
GFDL-CM2.1	Geophysical Fluid Dynamics Laboratory (GFDL)/USA	2.5°×2.0°
GISS-EH	NASA/Goddard Institute for Space Studies (GISS)/USA	5°×4°□
FGOALS-G1.0	LASG/Institute of Atmospheric Physics (IAP)/China	2.8°×2.8°□
INGV_ECHAM4	National Institute of Geophisics and Volcanology(INGV)/Italy	1.125°×~1.125°□
INMCM3.0	Institute for Numerical Mathematics(INM)/Russia	5.0°×4.0°
IPSL_CM4	Institut Pierre Simon Laplace(IPSL)/France	3.75°×2.5°
MIROC3. 2 (hires)	Center for Climate System Research , National Institute for Environmental Studies, and Frontier Research Center for Global Change (FRCGC) /Japan	1.125°×1.12°□
MIROC3.2 (medres)	Center for Climate System Research , National Institute for Environmental Studies, and Frontier Research Center for Global Change (FRCGC) /Japan	2.8°×~2.8°
MIUB_ECHO_G	Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, and Model and Data group/Germany and Korea	3.75°×~3.75°□
ECHAM5/MPI-OM	Max Planck Institute for Meteorology/Germany	1.875°×~1.875°□
MRI_CGCM2.3.2	Meteorological Research Institute(MRI)/Japan	2.8°×~2.8°□
NCAR_CCSM3.0	National Center for Atmospheric Research (NCAR)/USA	1.4°×~1.4°□
NCAR_PCM1	National Center for Atmospheric Research (NCAR)/USA	2.8°×~2.8°□
UKMO_HADCM3	Hadley Centre for Climate Prediction and Research, Met Office /UK	3.75°×2.5°
UKMO_HADGEM1	Hadley Centre for Climate Prediction and Research, Met Office /UK	1.875°×1.25°

Projection of future climate, annual-mean surface air temperature (IPCC AR4)



Courtesy IPCC

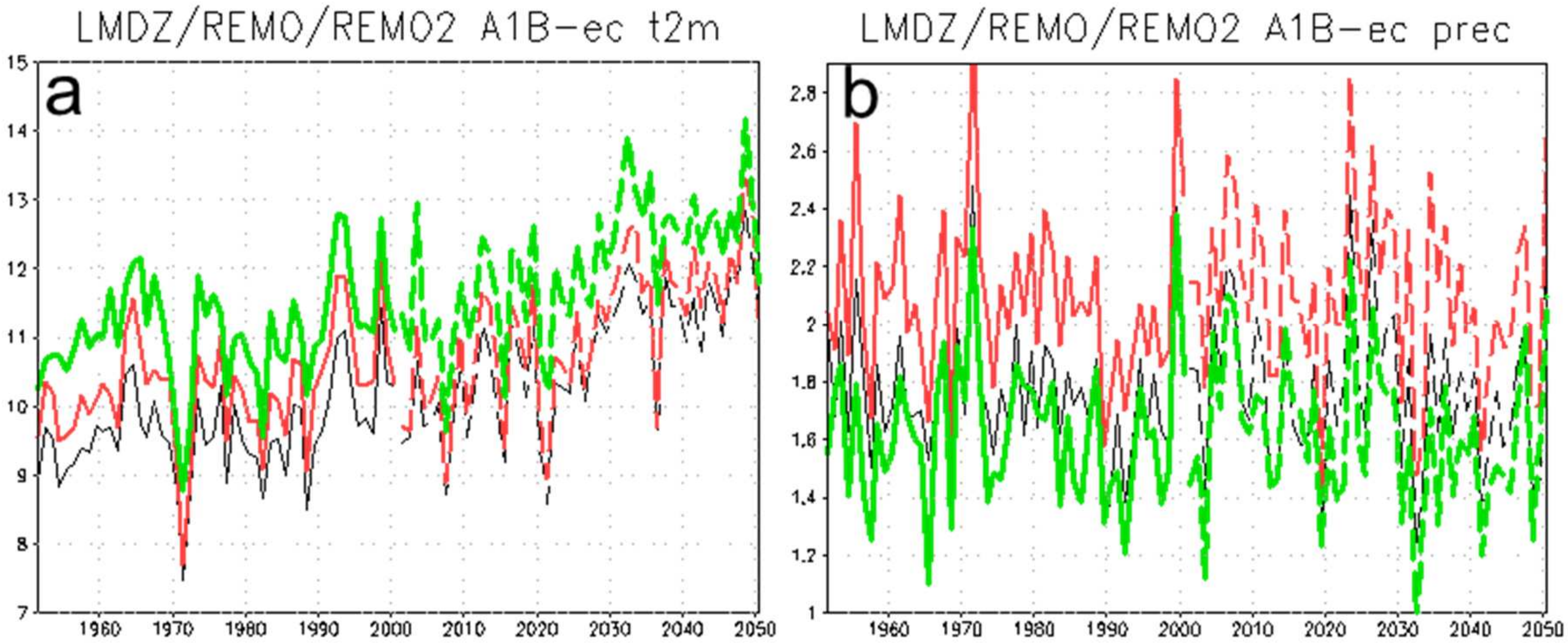
Xu-Gao-Giorgi 2010 Climatic Change



Cumulative distribution function (CDF) of temperature change over the 5 sub-regions and the whole East Asia region (EA) obtained using the REA1, REA-ORIG and AVE models for winter (DJF) and summer (JJA)

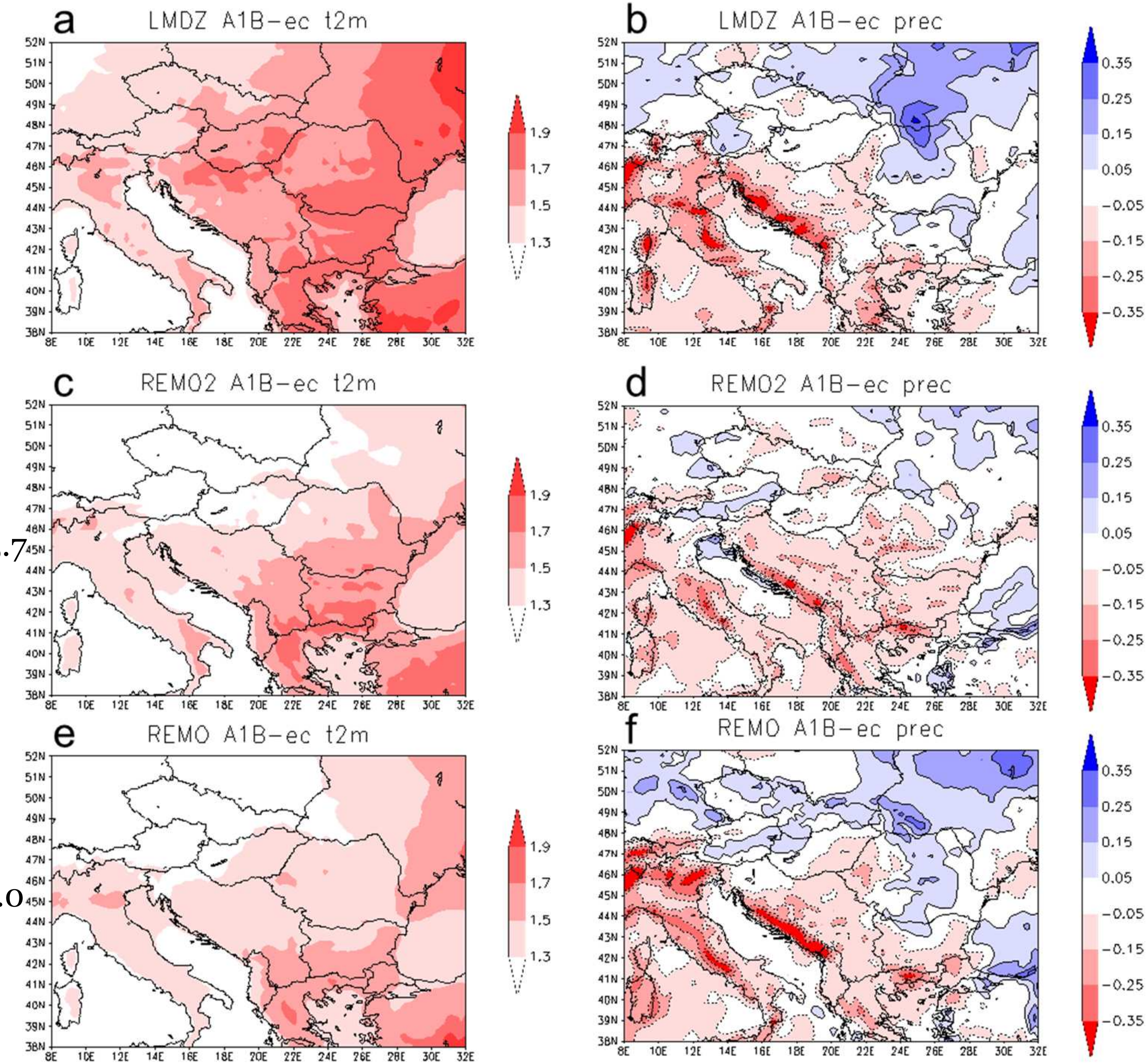
Utilization of RCM:

Different RCMs with a same forcing
v.s.
One RCM with different forcings



Surface air temperature (°C) and precipitation rate (mm/day) averaged over Eastern Europe, from 1951 to 2050. Three regional models are forced by a same boundary forcing

LMDZ-regional and REMO for climate change downscaling (ECHAM A1B) in Eastern Europe



LMDZ

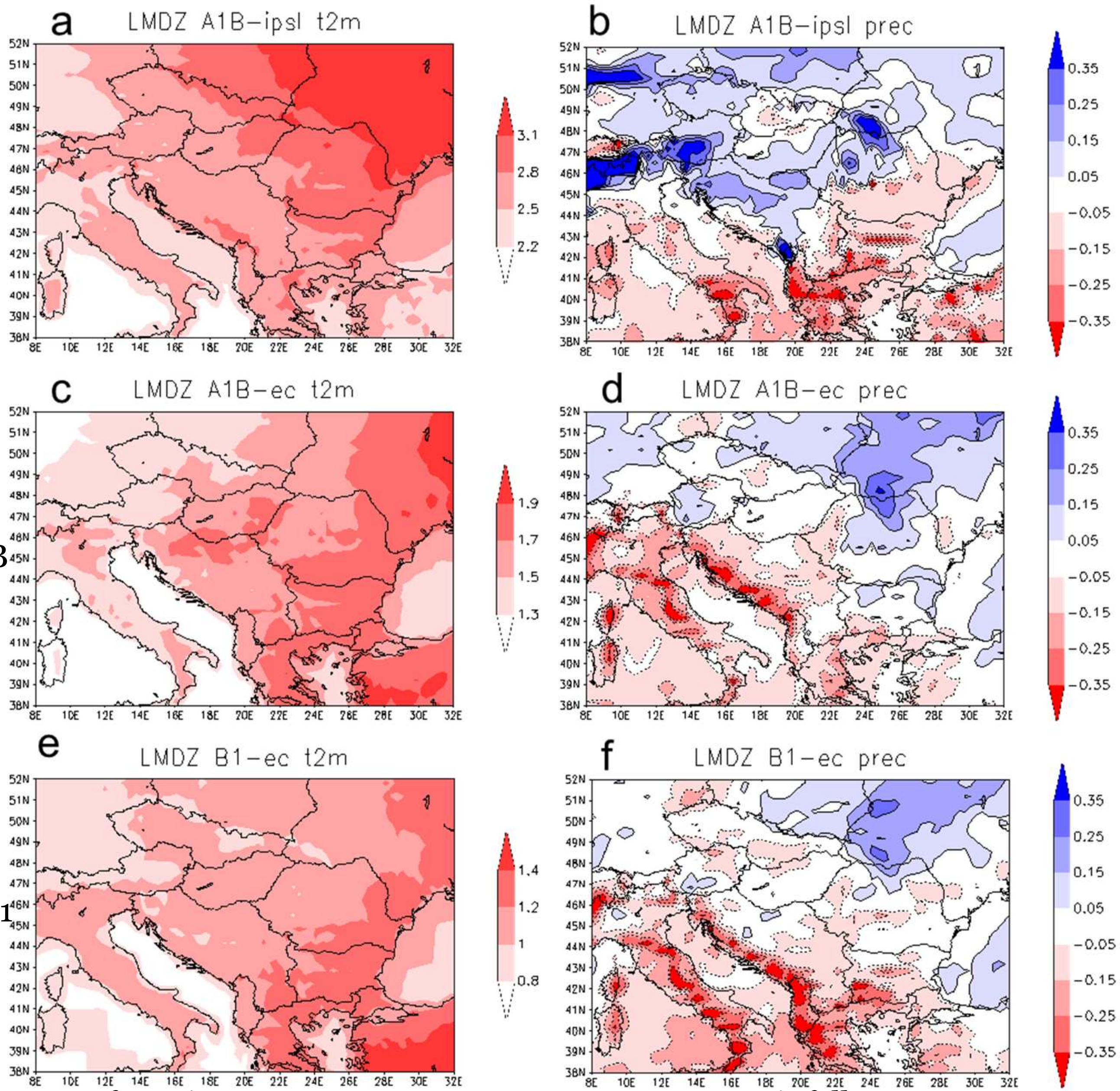
REMO5.7

REMO5.0

Surface air temperature

Rainfall rate

LMDZ-regional climate change downscaling (3 different scenarios) in Eastern Europe



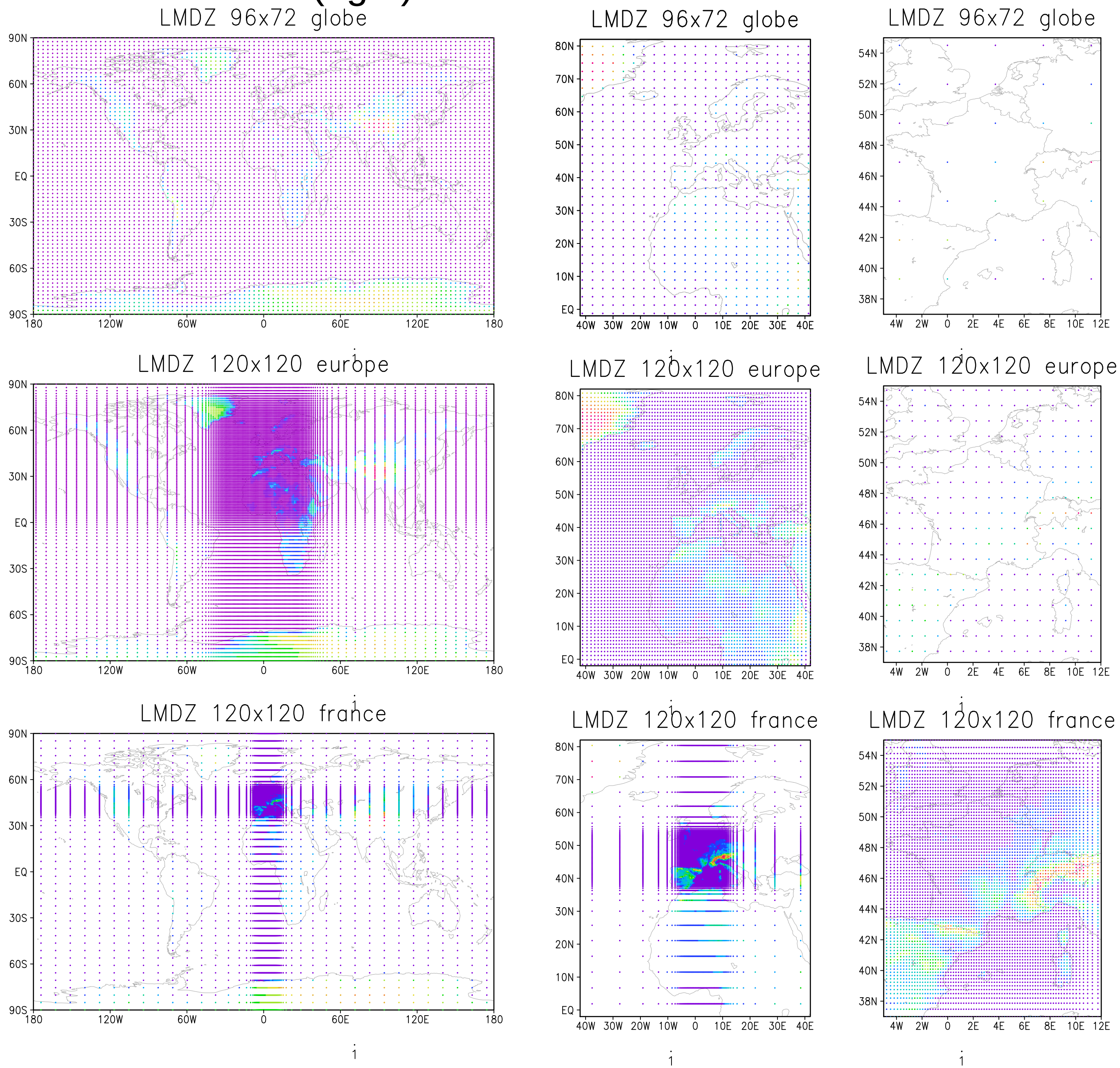
Surface air temperature

Rainfall rate

A downscaling study for France:

- Three versions: Global / Europe / France
- Two-way nesting between Global/Europe
- One-way nesting from Europe to France

LMDZ grid schemes for the whole earth (left), for Europe (middle) and for France (right) in three versions

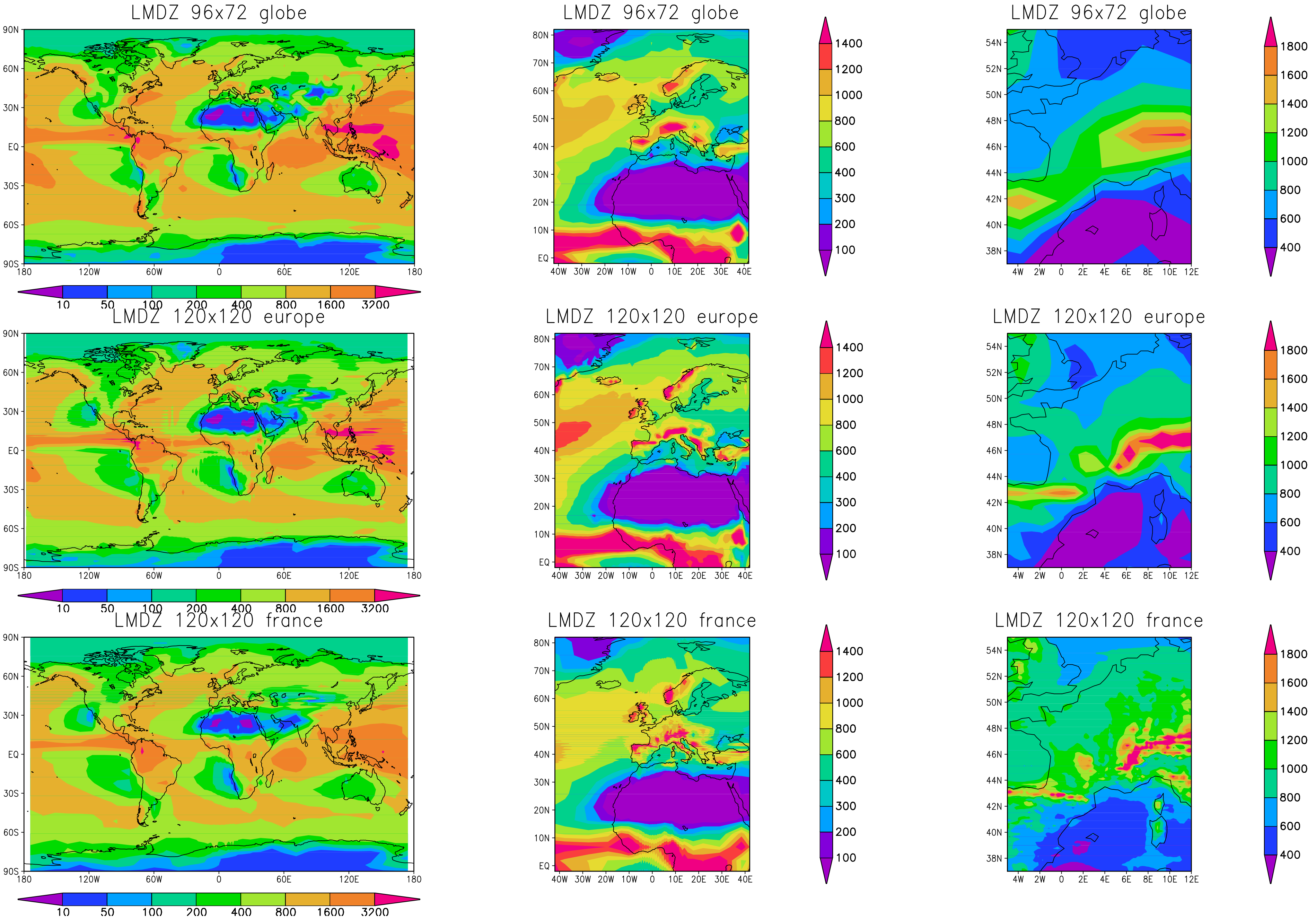


LMDZ Globe (300 km)

LMDZ Europe (100 km)

LMDZ France (20 km)

Annual-mean precipitation (mm) in three LMDZ models: Globe (top), Europe (middle) and France (bottom)



Pr (mm/day), Tx(℃) et Tn (℃) for a return level at 50 years, at Marseille, observation and three resolutions of LMDZ

Pr	Obs	300km	100km	20km
1961/1990	**145**	**43**	**42**	**62**
2021/2050	**?**	**38**	**56**	**93**

Tx	Obs	300km	100km	20km
1961/1990	**38.9**	**32.2**	**34.7**	**35.6**
2021/2050	**?**	**36.0**	**36.9**	**37.5**

Tn	Obs	300km	100km	20km
1961/1990	**26.2**	**21.7**	**24.8**	**25.6**
2021/2050	**?**	**24.0**	**27.0**	**27.8**

Pr: intense precipitations

Tx: hot-day temperature

Tn: hot-night temperature

Intense precipitations (mm/day), return level at 50 years

Marseille	Obs	300km	100km	20km
1961/1990	**145**	**43**	**42**	**62**
2021/2050		**38**	**56**	**93**

Paris	Obs	300km	100km	20km
1961/1990	**84**	**31**	**40**	**37**
2021/2050		**26**	**39**	**48**

Strasbourg	Obs	300km	100km	20km
1961/1990	**65**	**40**	**49**	**41**
2021/2050		**32**	**61**	**44**

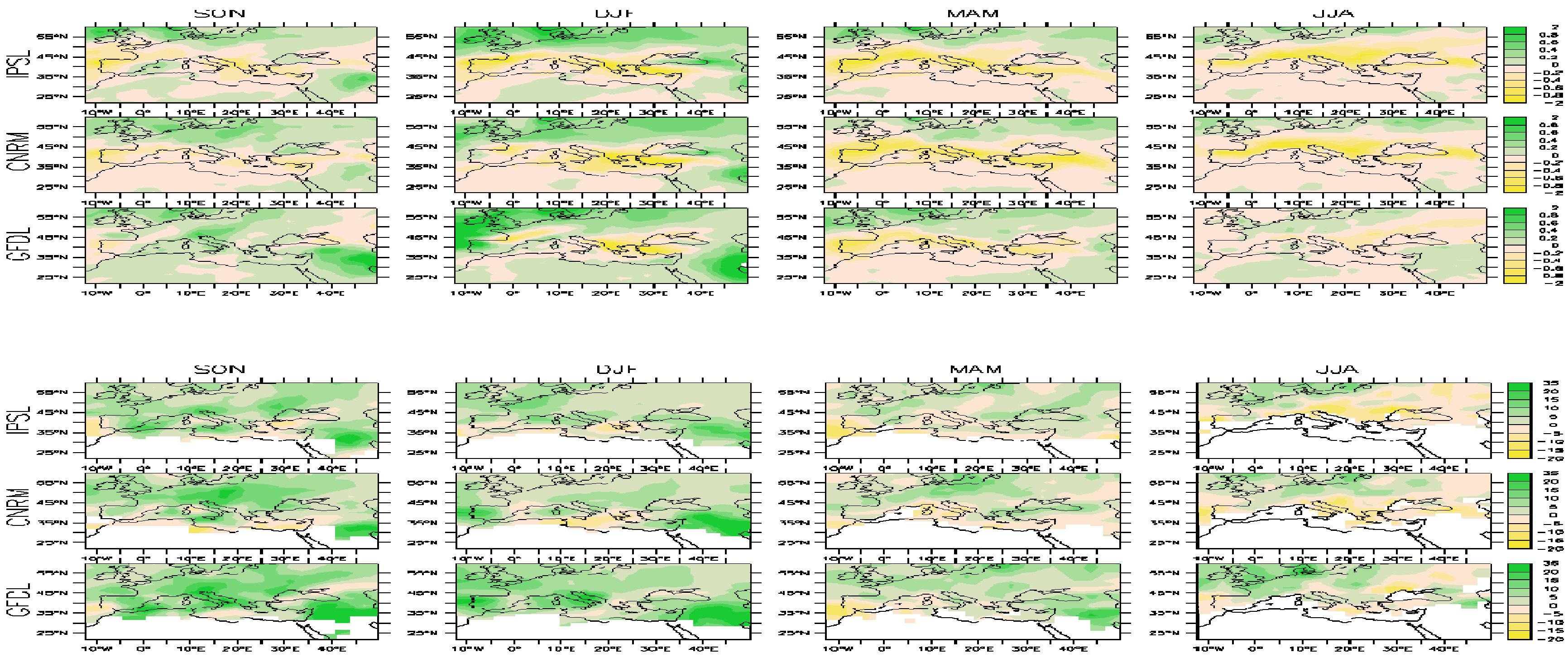
Observations and three versions LMDZ

Future evolution of extremes

Precipitation (mm/day)

averages

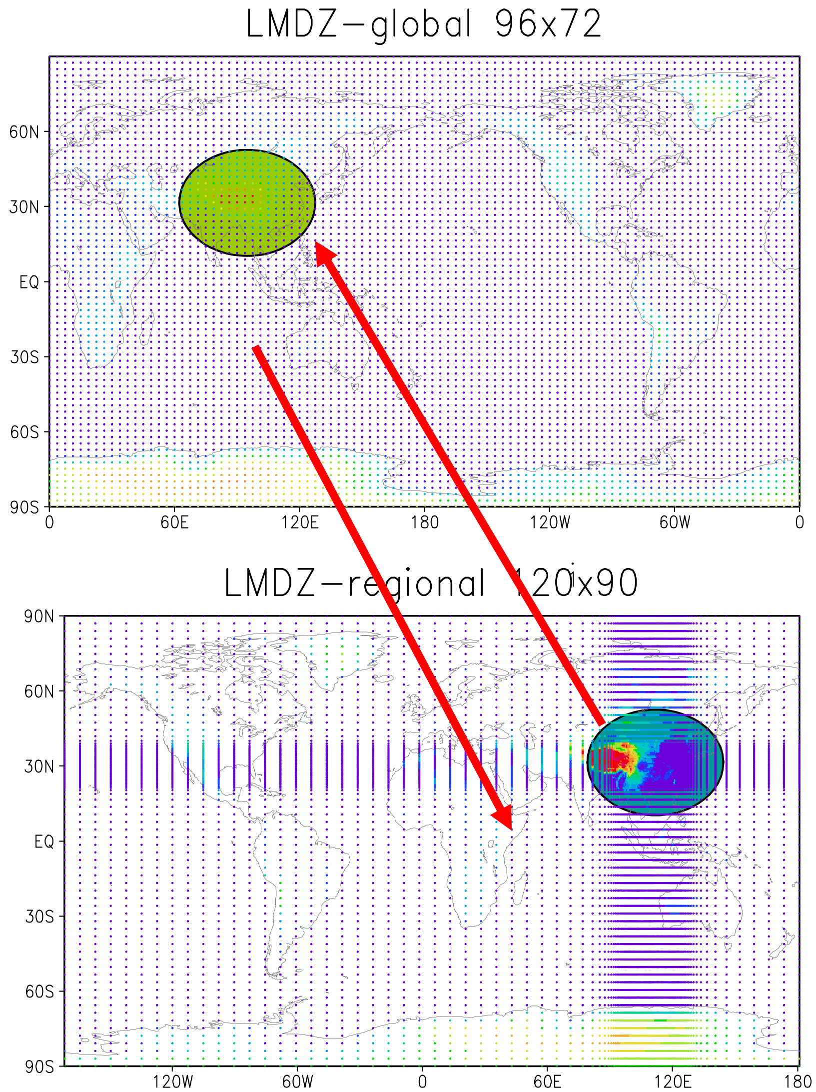
SON DJF MAM JJA



30-year return levels

2070/2099 minus 1970/1999

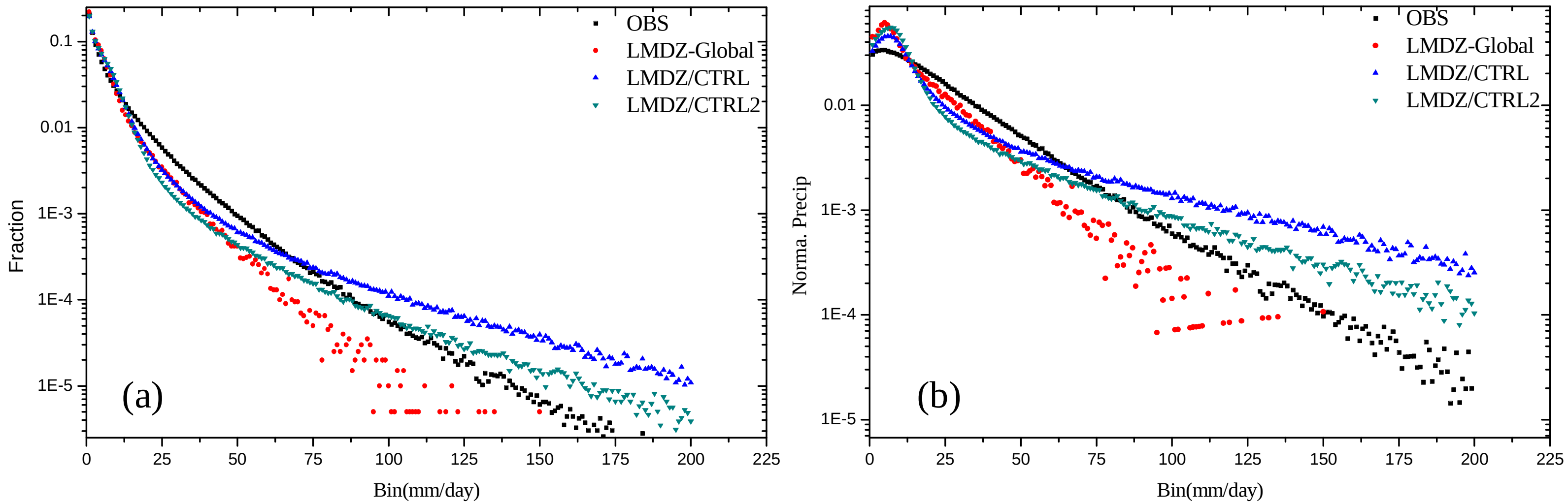
Two-way nesting between global scales and regional scales: A test in South-east Asia



Feedbacks from LMDZ-regional to LMDZ-global: toward a super-parametrisation?

Two-way nesting between LMDZ-regional and LMDZ-global

Added values of LMDZ-regional: extremes

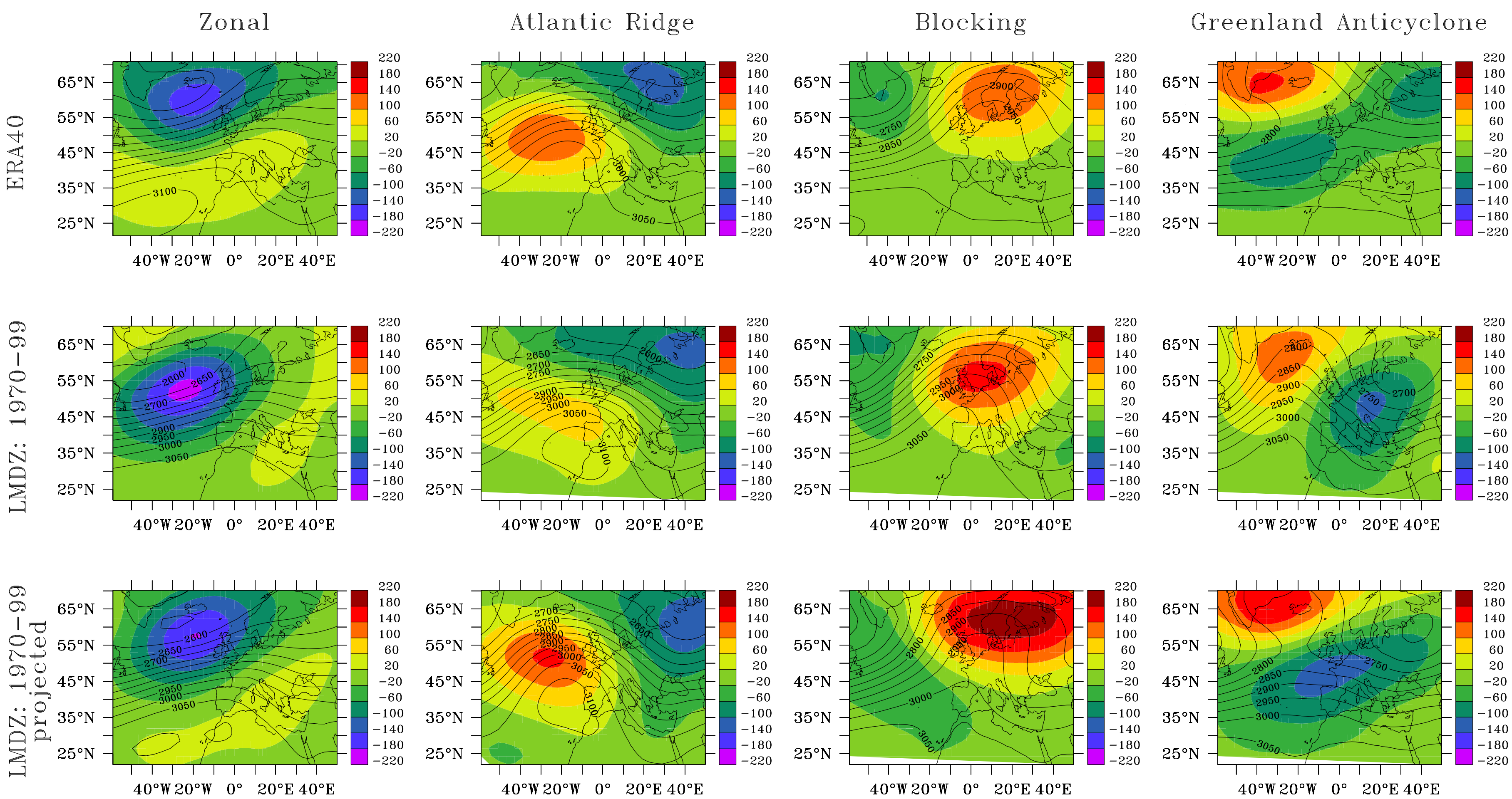


(a) Normalized frequency and (b) amount of precipitation as a function of daily intensity for observation and the reference simulations of LMDZ-Global、LMDZ/CTRL and LMDZ/CTRL2.

Chen et al. 2010, Cli Dyn

Statistical downscaling: a necessary step
for climate impact studies,
but with fragile hypothesis.

Goubanova et al. 2010 J Cli

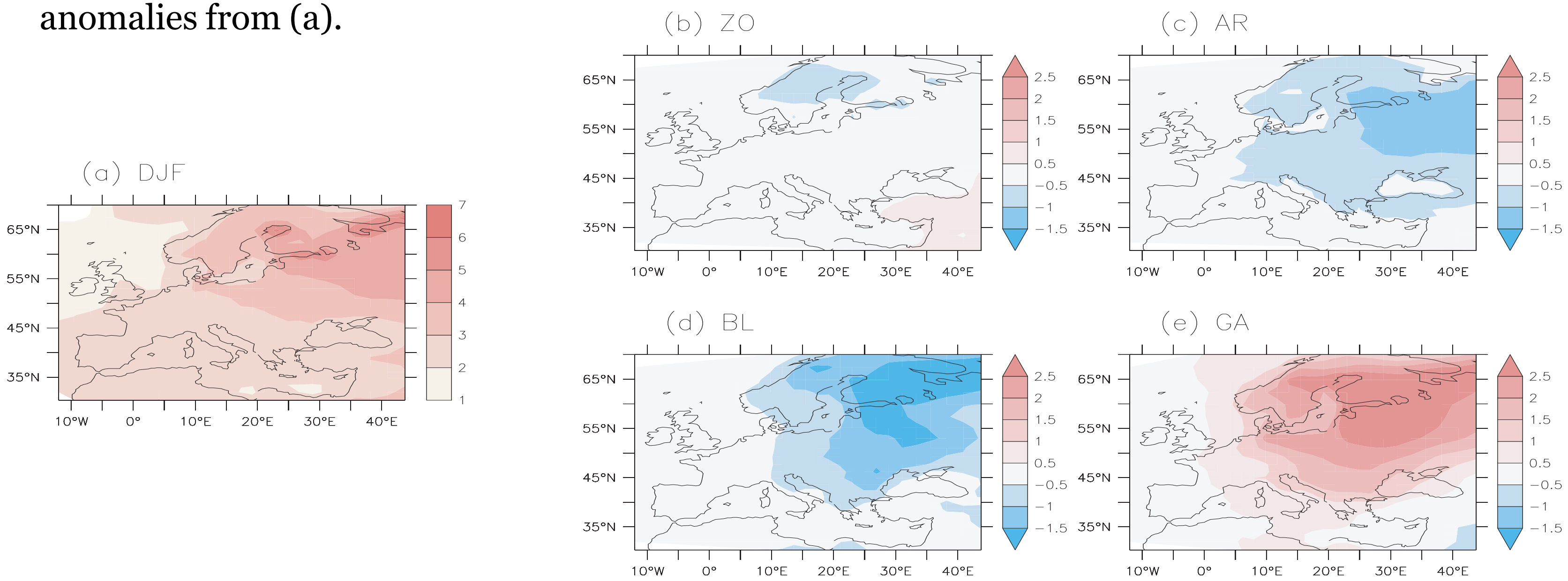


The four weather regimes over the Europe–North Atlantic region obtained from 700-hPa daily geopotential height for (top) ERA-40 data obtained from the k-means algorithm, (middle) the LMDZ present-day climate simulation obtained from the k-means algorithm, and (bottom) the LMDZ present-day climate simulation obtained by projection on the ERA-40 regimes. The full fields (isolines) and regime anomalies (colors) are shown. Units are in geopotential meters.

Goubanova et al. 2010 J Cli

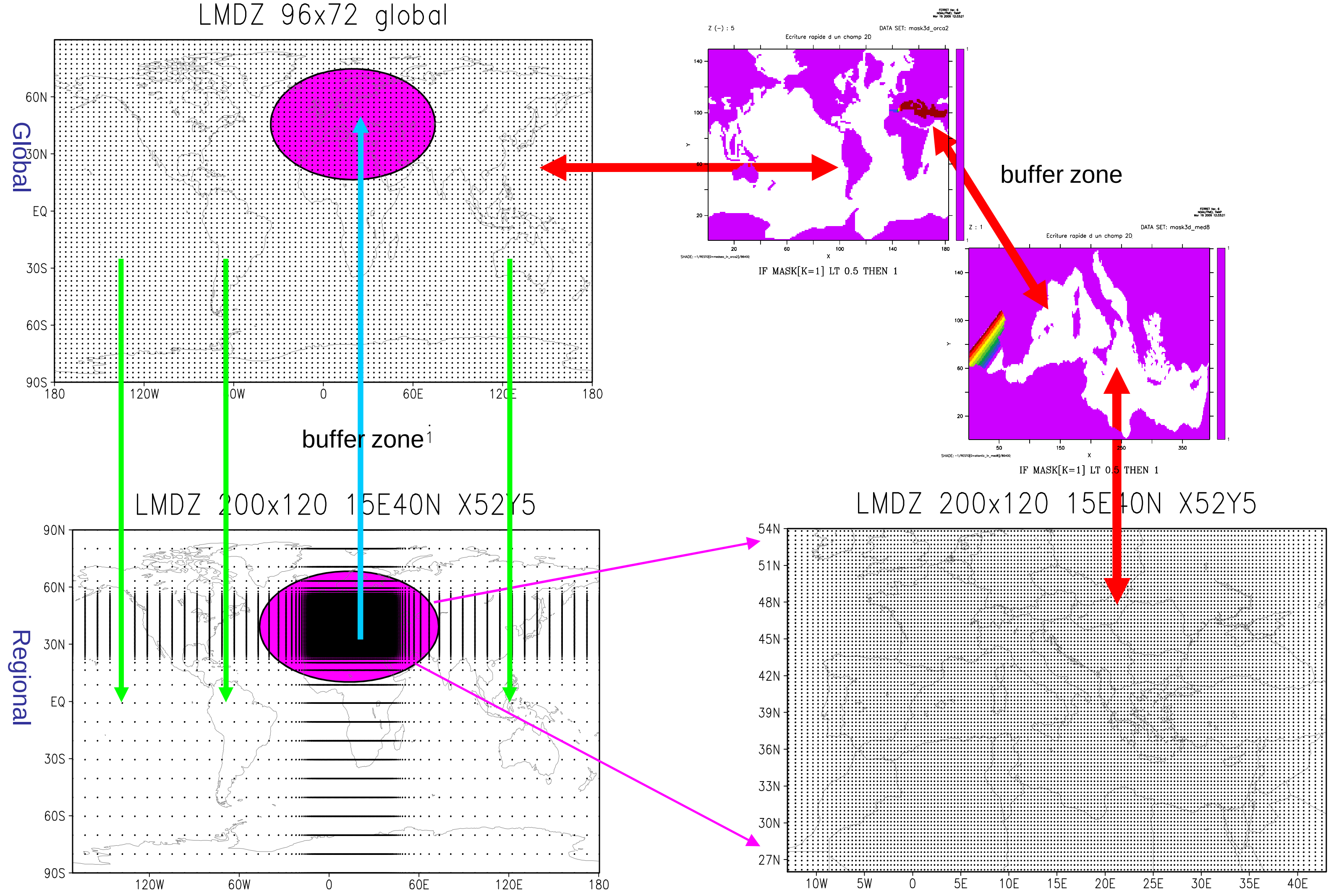
Weather regimes favoring the occurrence of (a),(c),(e) warm and (b),(d),(f) cold temperatures over Europe: (a),(b) the observed relationship for the 1970–99 period, and the relationship simulated by LMDZ for (c),(d) the 1970–99 period and (e),(f) the 2070–99 period. Color legend: zonal regime (red), Atlantic Ridge (green), blocking (blue), and Greenland anticyclone (yellow).

(a) Mean winter temperature change (8C) in 2070–99 relative to 1970–99 for the entire winter season. (b)–(d) The corresponding changes inside the four weather regimes are shown as the anomalies from (a).



Goubanova et al. 2010 J Cli

Toward a fully-coupled Mediterranean system



- Global O-A coupled model: LMDZ-global / ORCA2
- Regional O-A coupled model: LMDZ-regional / MED8
- Two atmospheric models are coupled through buffer zones
- Two oceanic models are also coupled through buffer zones

Schematic of the quardruple coupling in IPSL

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