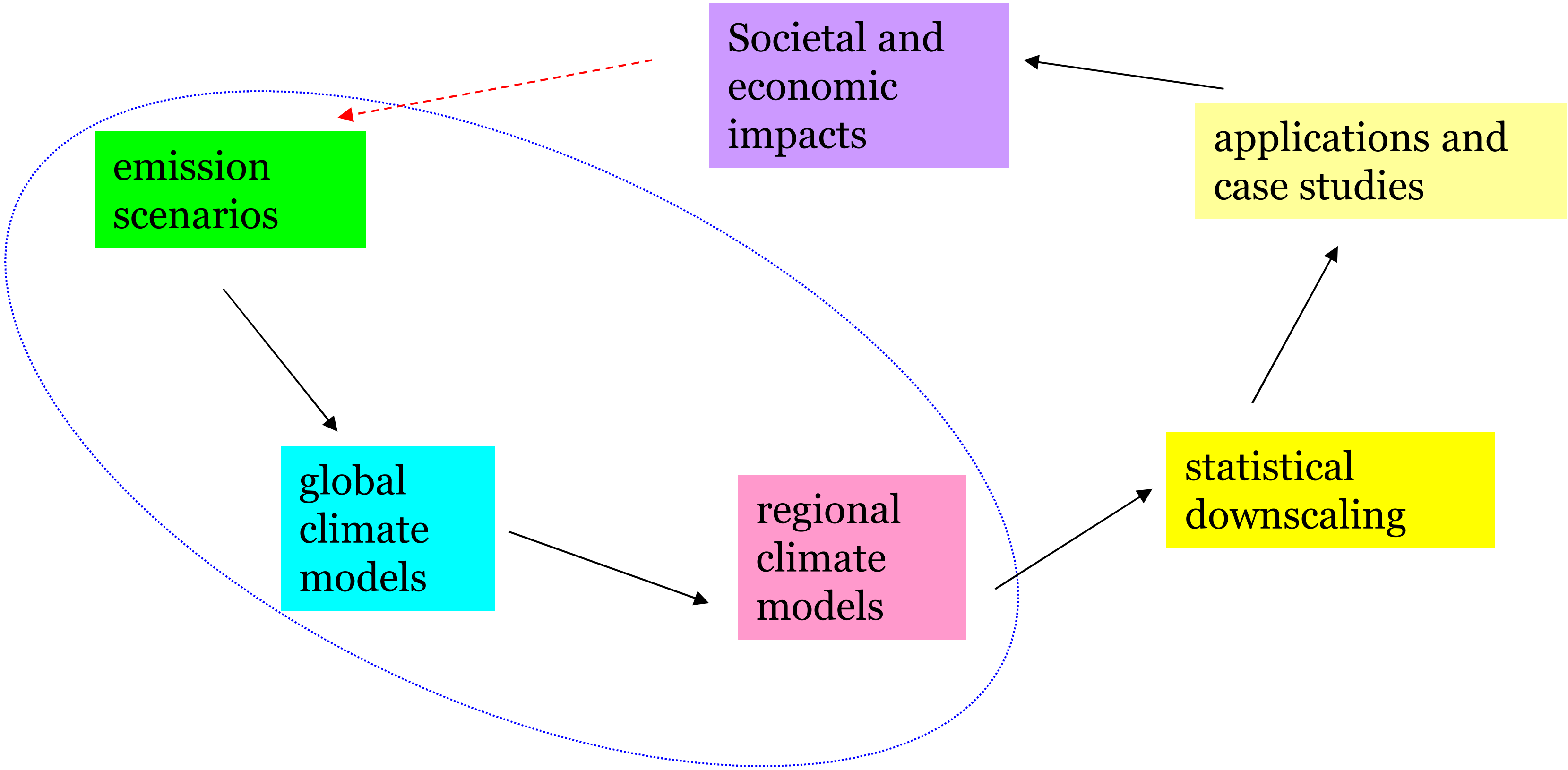
Modelling climate change: from global to regional

Laurent Li (李肇新，li@lmd.jussieu.fr)
Laboratoire de Météorologie Dynamique (LMD)
Institut Pierre-Simon Laplace (IPSL)
CNRS/UPMC-Paris 6, France

- Earth system model, regional coupled model
- How to use multi-model information
- Using regional model: examples (China, France)
- Using two-way-nesting: a case of afforestation in Europe
- Statistical downscaling: necessary but fragile

General approach in modeling climate changes

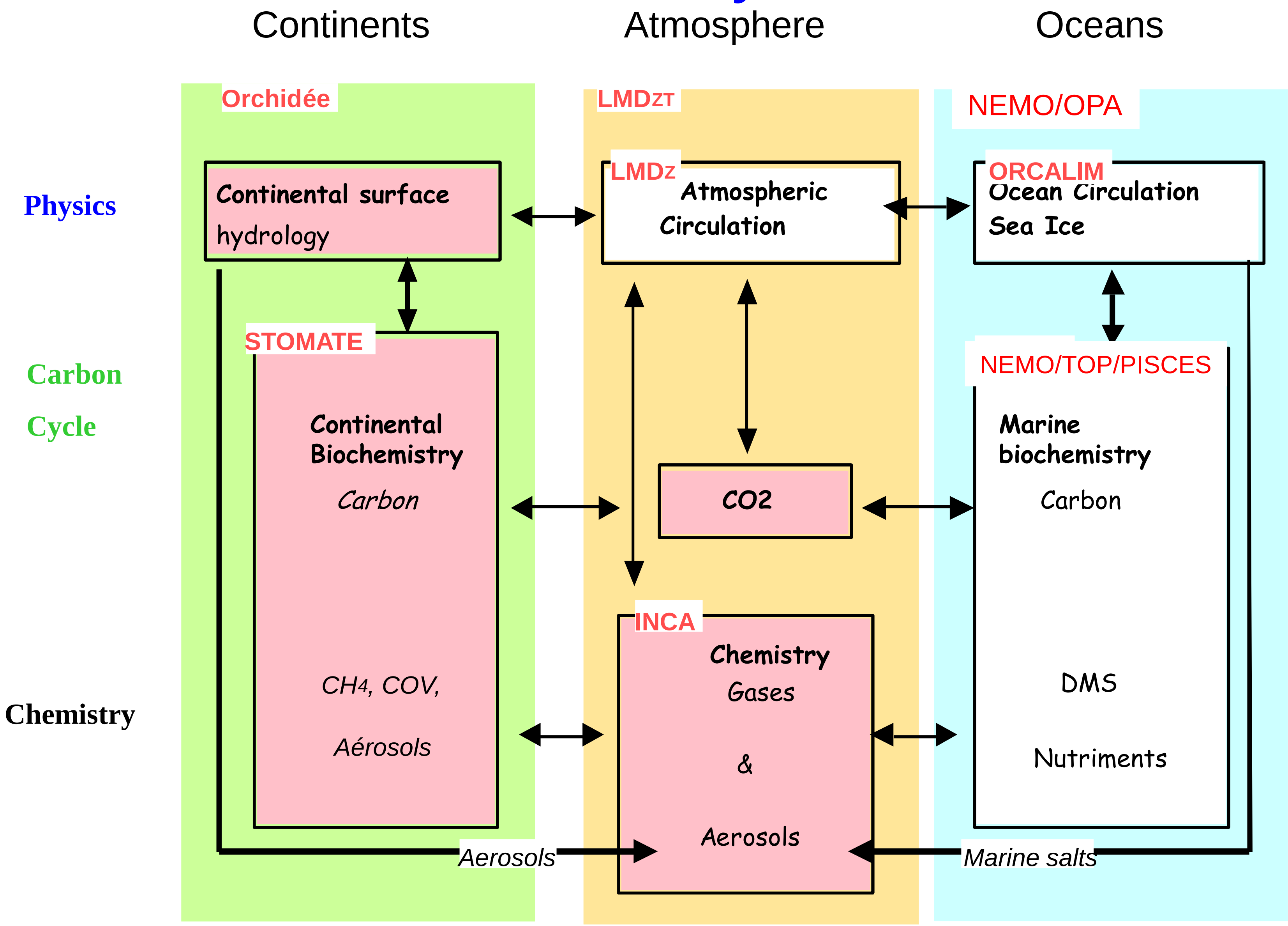


Coupled AOGCMs, with adequate regionalization methods are the most appropriate tools for projecting climate under scenarios of greenhouse gas emission.

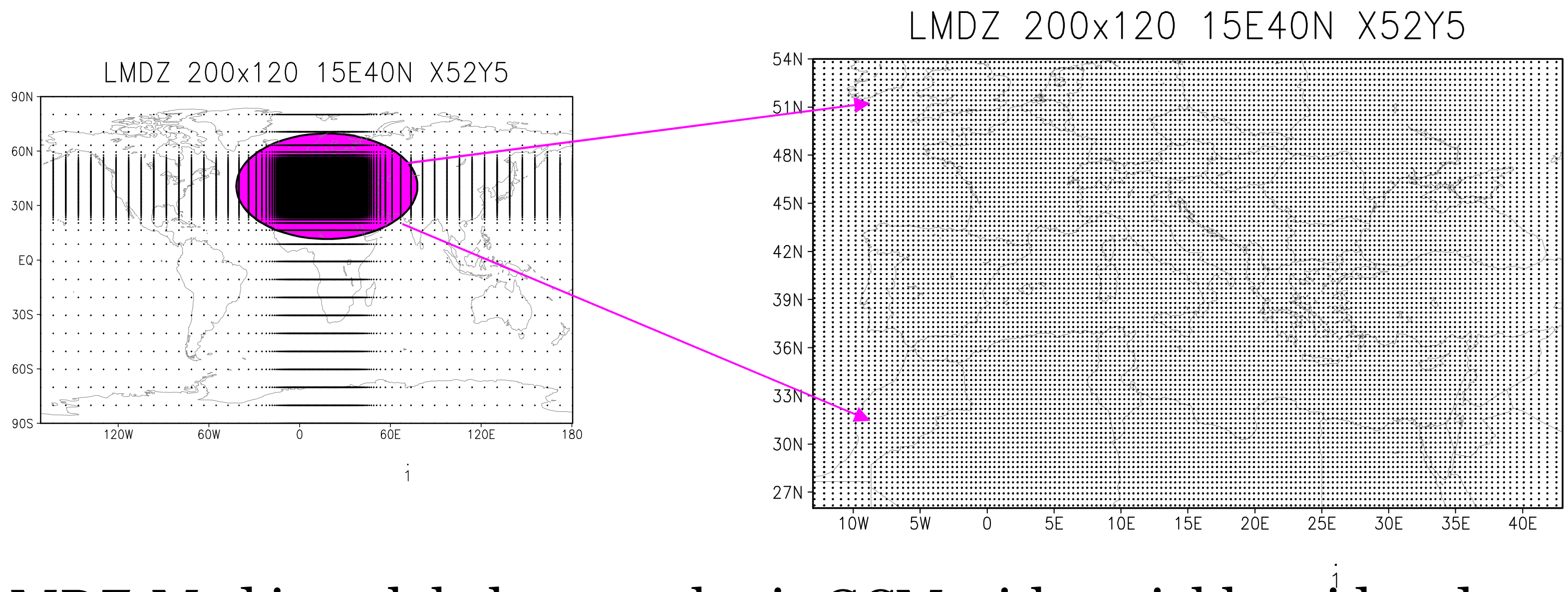
- Considerable uncertainties exist in different steps of future climate projection.
- Multi-model databases (CMIP3,CMIP5) offer both scientific opportunities and challenges in combining these datasets. How to use information

How about RCP (Representative Concentration Pathway: 2.6, 4.5, 6.5 and 8.5) in IPCC-AR5 ?

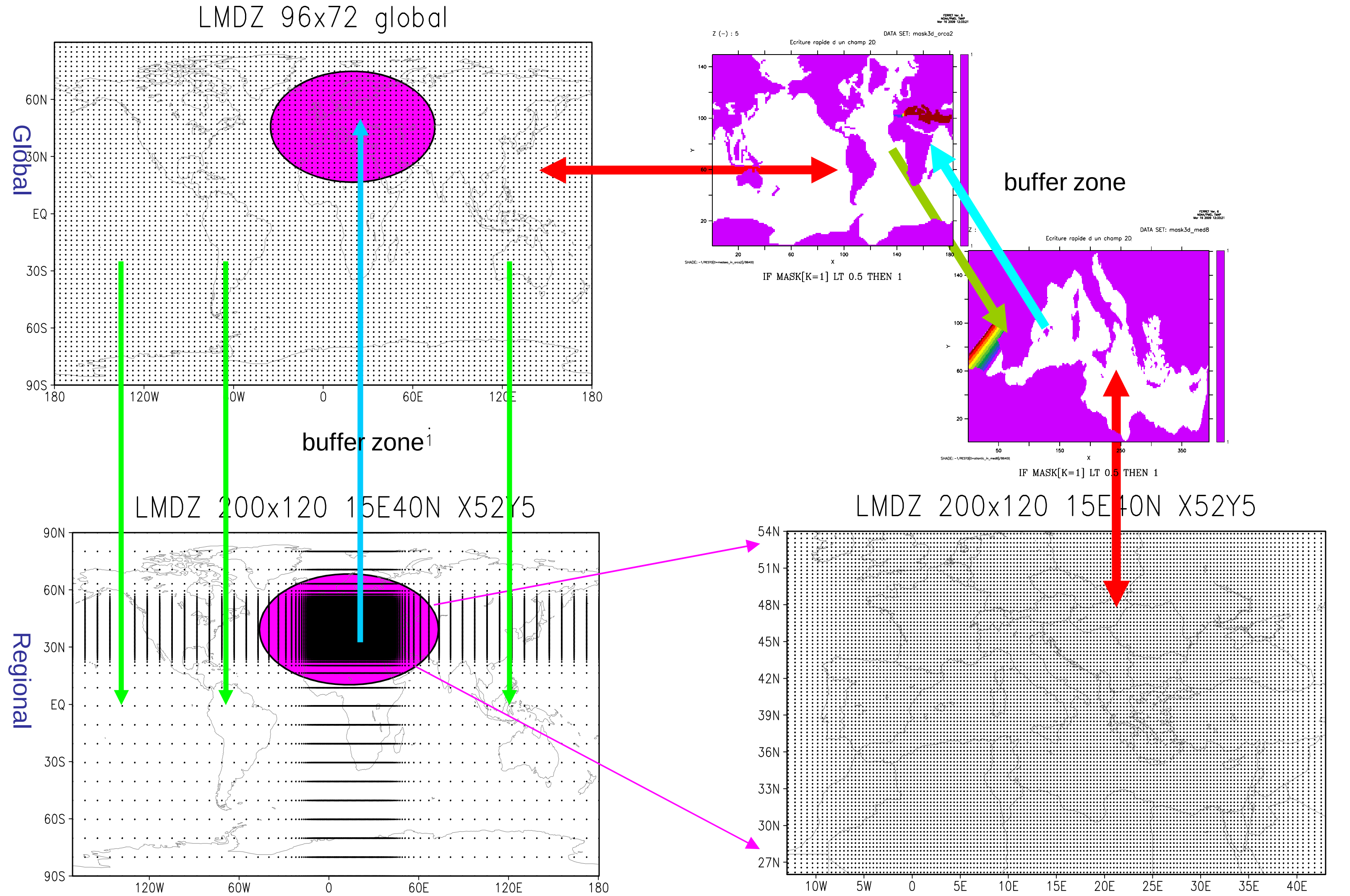
The IPSL Earth System Model



LMDZ-regional: Med version



- LMDZ-Med is a global atmospheric GCM with variable grid and a zoom over the Mediterranean basin. Local resolution: 30 km.
- It is run as a regional climate model, with nudging conditions (every 6 hours) from a global model (LMDZ-g, ERA40, IPCC, etc.) at low resolution outside the zoom. The model is free to have its own behaviours inside the zoom. $\frac{\partial X}{\partial t} = M(X) + \frac{X^a - X}{\tau}$



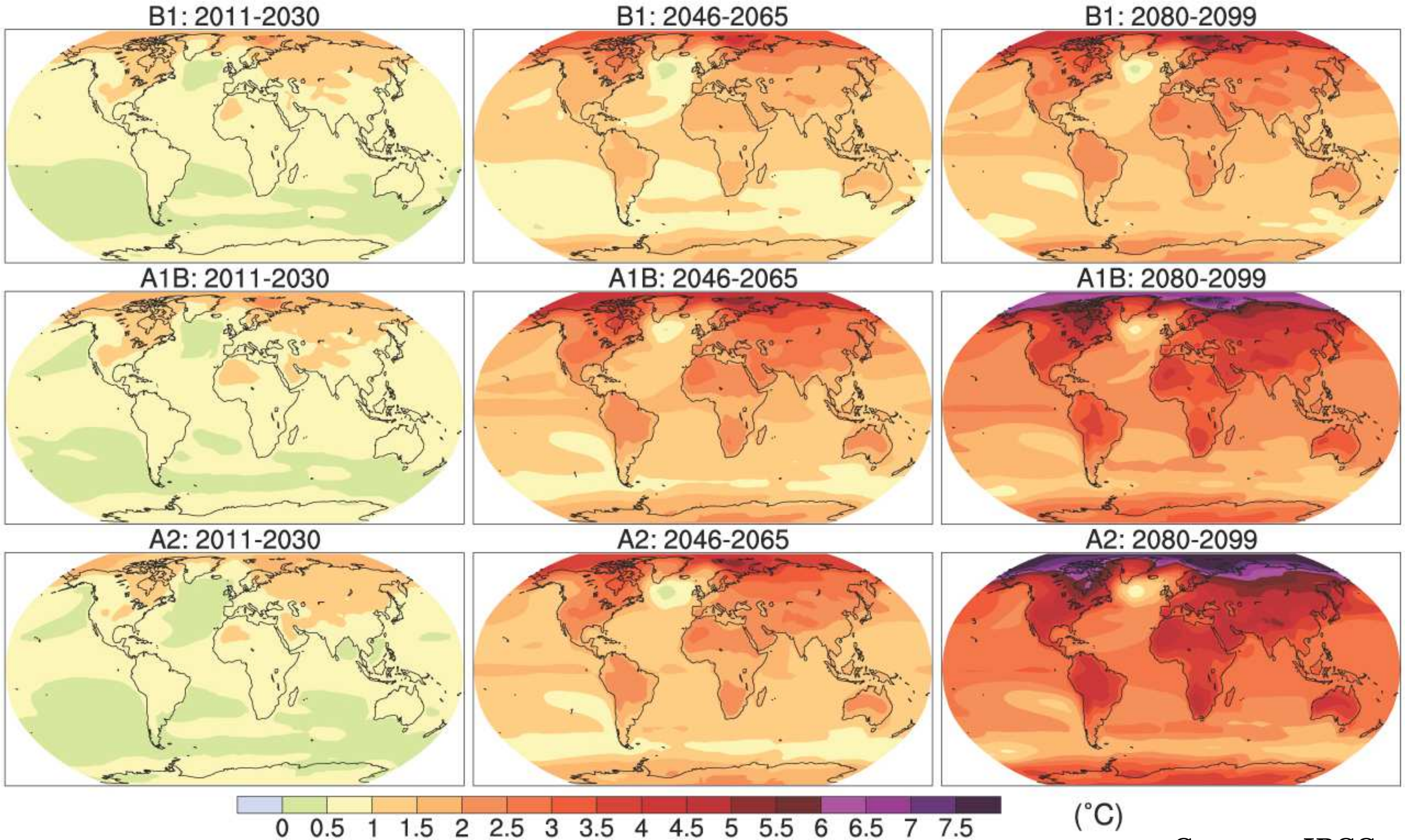
- **Global O-A coupled model: LMDZ-global / ORCA2**
- **Regional O-A coupled model: LMDZ-regional / MED8**
- **Two atmospheric models are coupled through buffer zones**
- **Two oceanic models are also coupled through buffer zones**

Schematic of the quadruple coupling in IPSL: M4

IPCC-AR4 and AR5, Projection of global climate to the future, an unprecedented exercise of the international scientific community

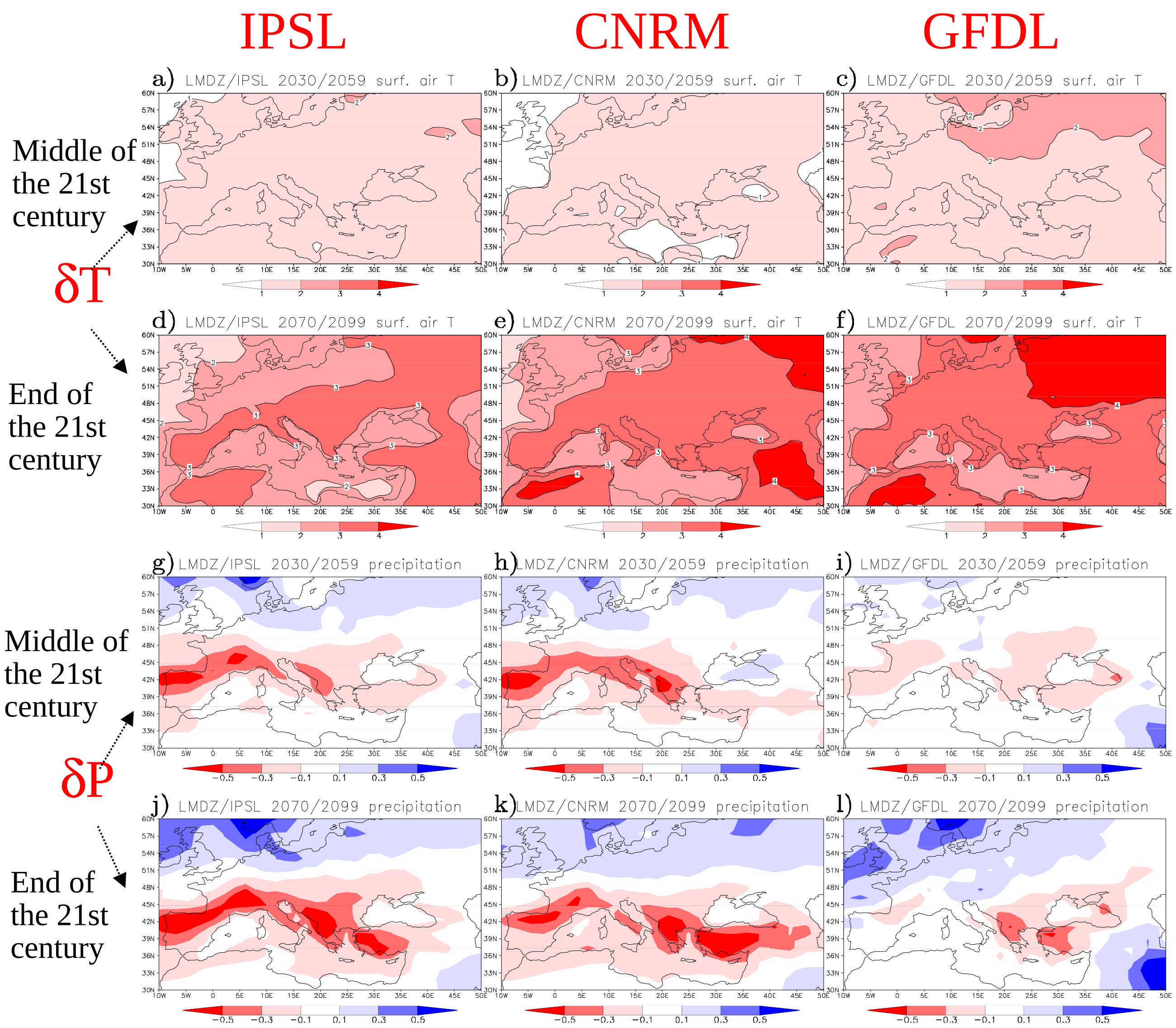
How to use information from the multi-model ensemble to assess uncertainties of climate change?

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

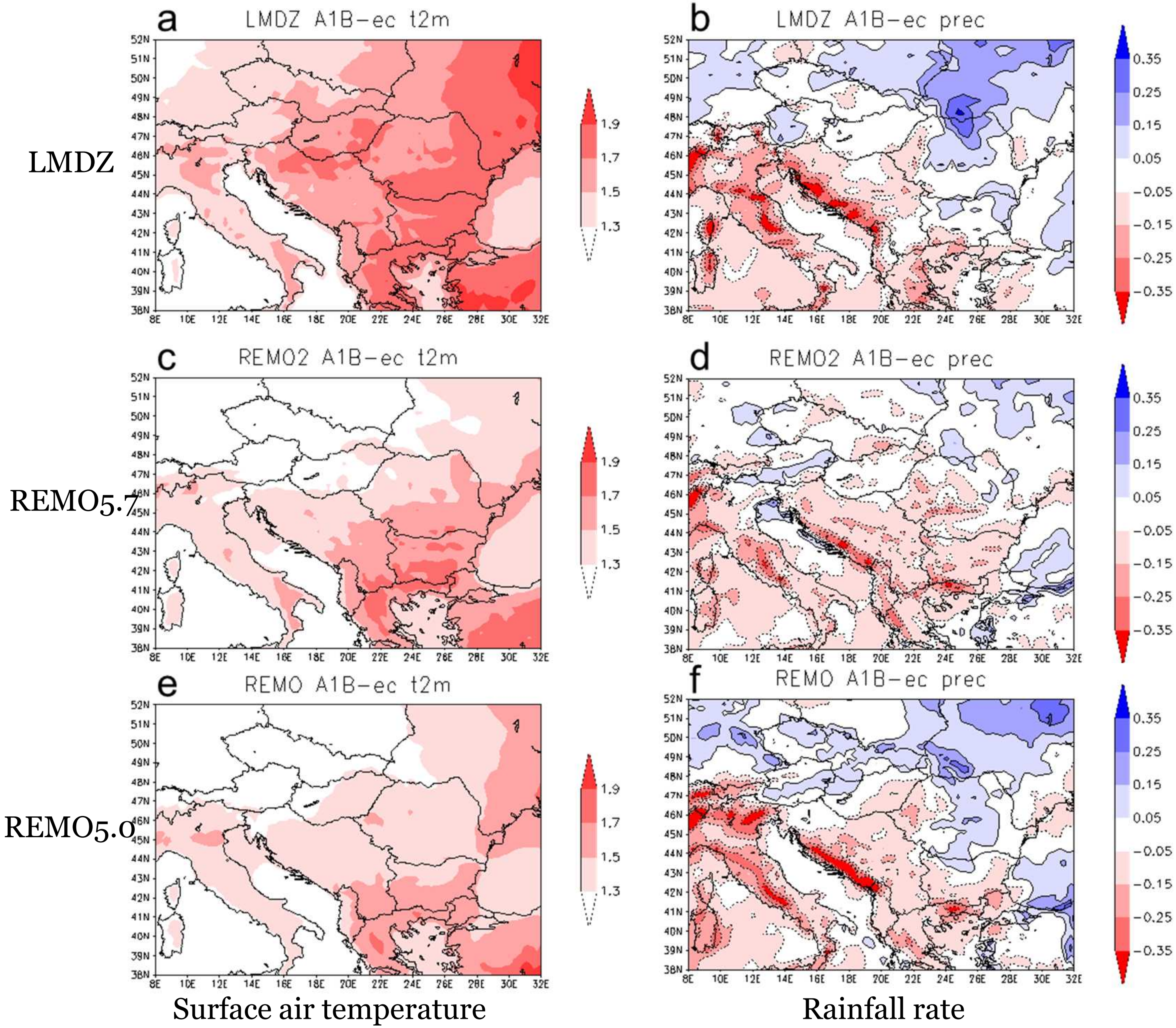


Courtesy IPCC

IPCC-A2 scenarios regionally-enhanced with LMDZ-Med



LMDZ-regional and REMO for climate change downscaling (ECHAM A1B) in Eastern Europe (2021/2050 – 1961/1990)

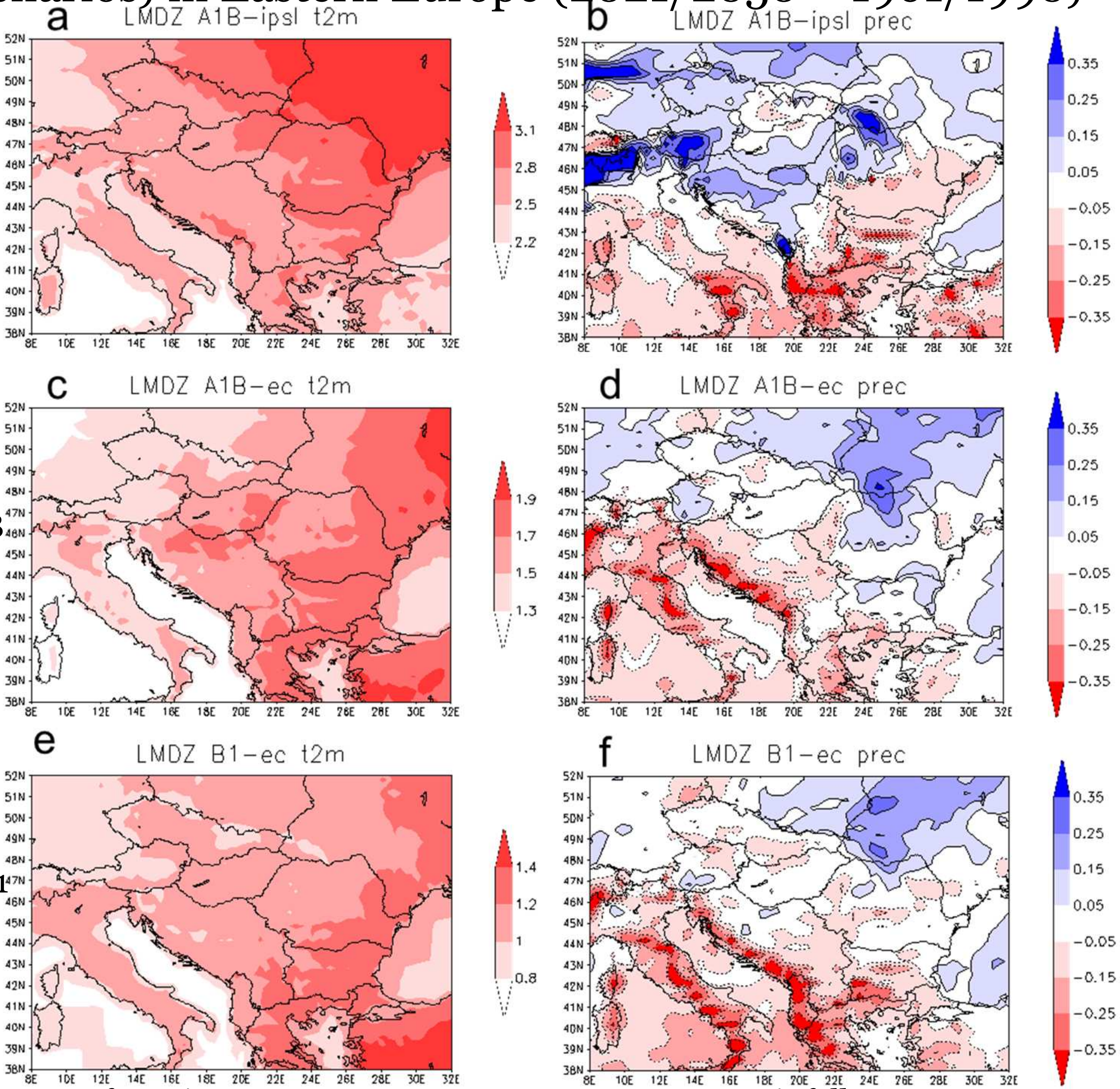


LMDZ-regional climate change downscaling (3 different scenarios) in Eastern Europe (2021/2050 – 1961/1990)

IPSL-A1B

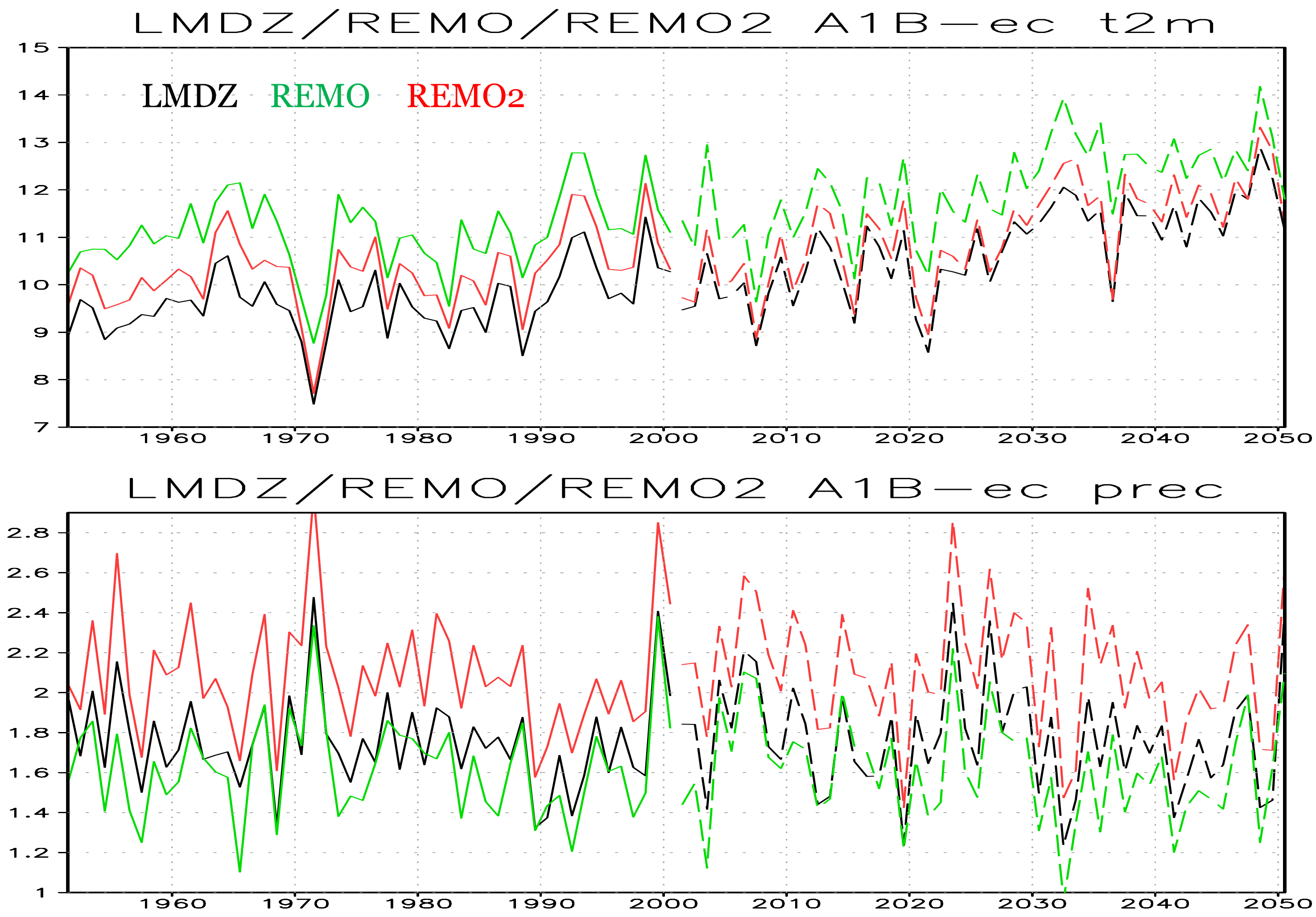
ECHAM-A1B

ECHAM-B1



Surface air temperature

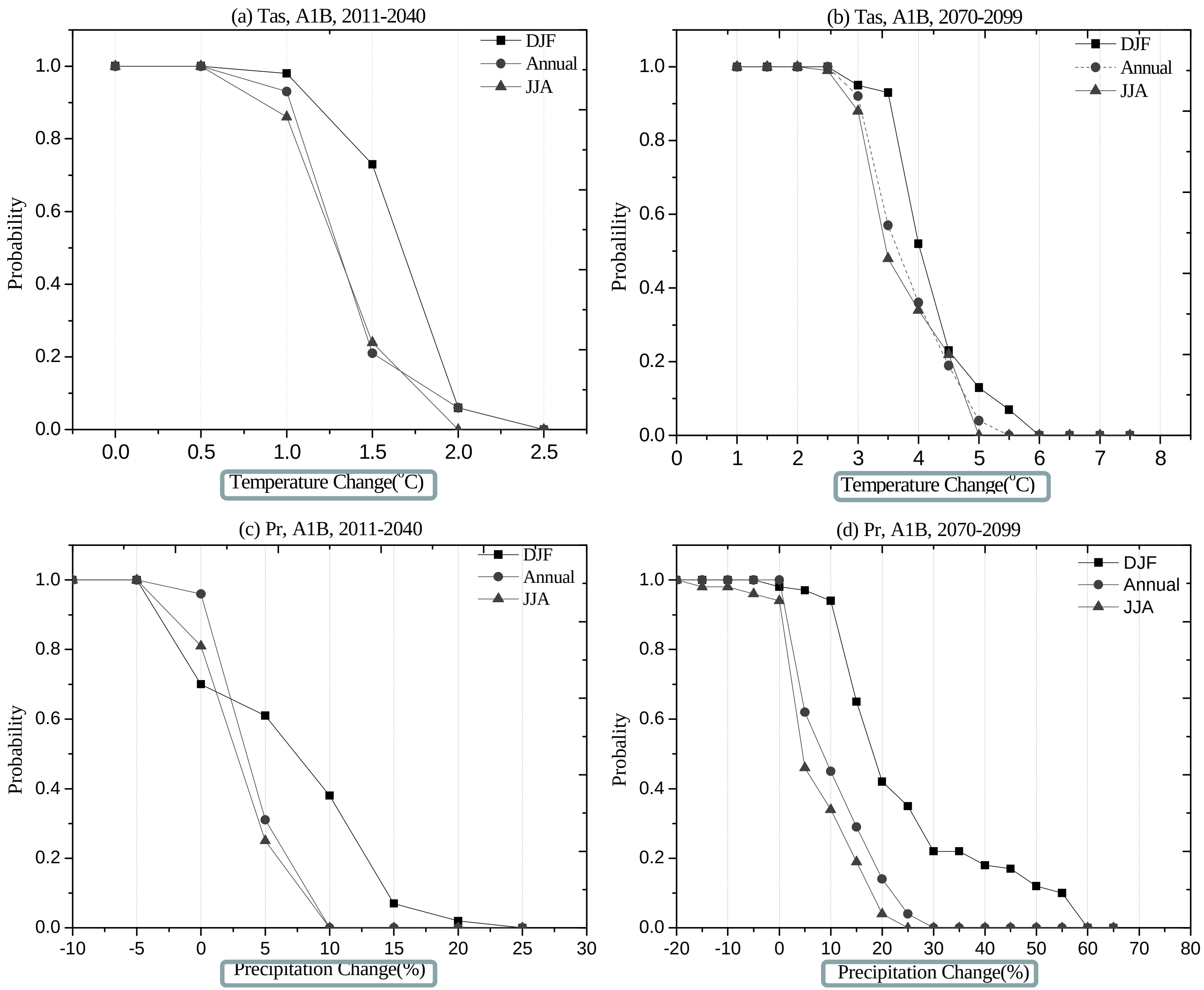
Rainfall rate



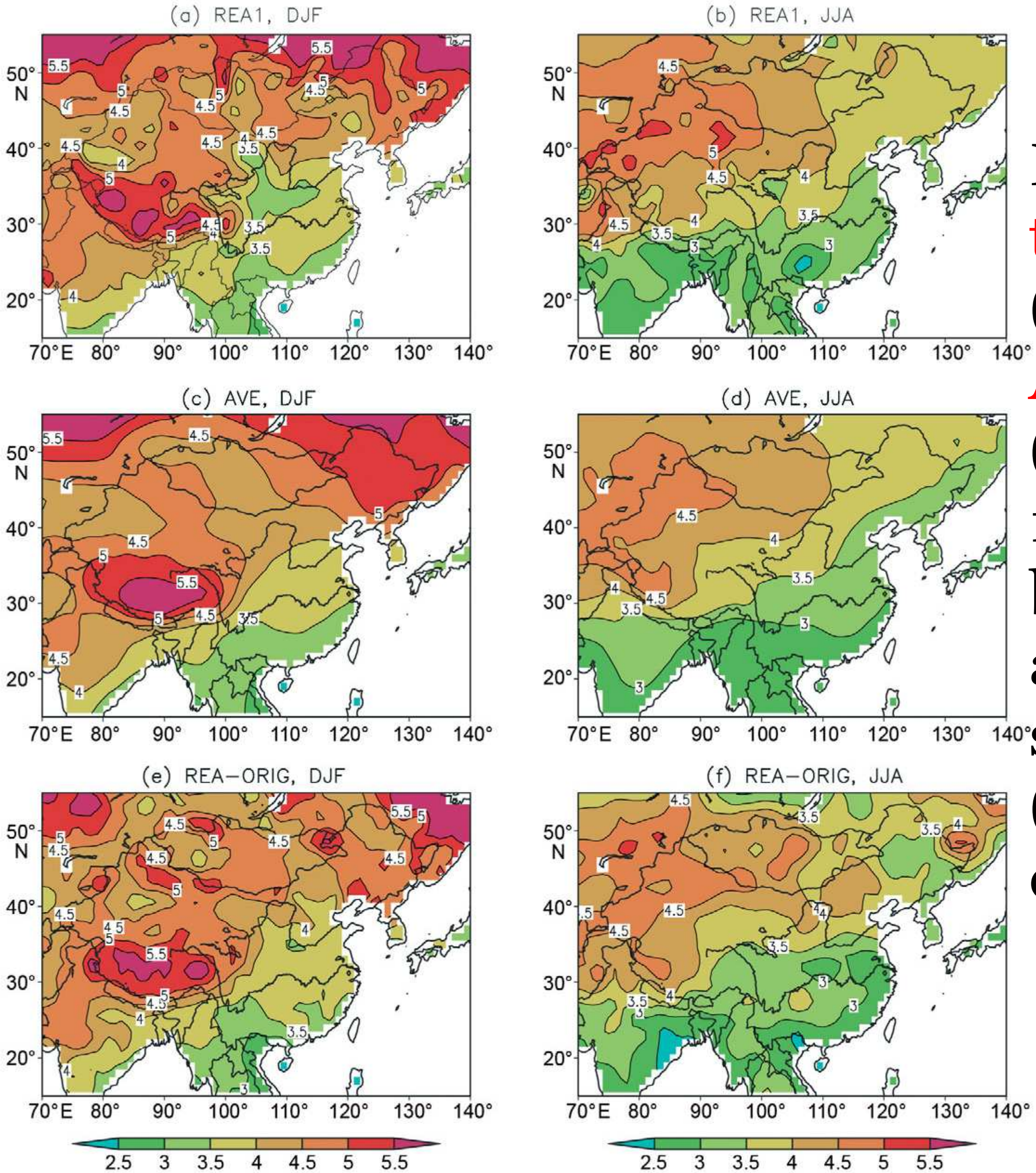
Evolution of T2m and Prec in Eastern Europe

Two main approaches have been developed to combine multi-model ensemble output

- One simply considers each model as equal and produces simple ensemble averages ("one model, one vote")
- Weight the model: down-weight or eliminate some "bad"climate models based on metrics of skill.



Cumulative probability of climate change (temperature and precipitation) over whole China



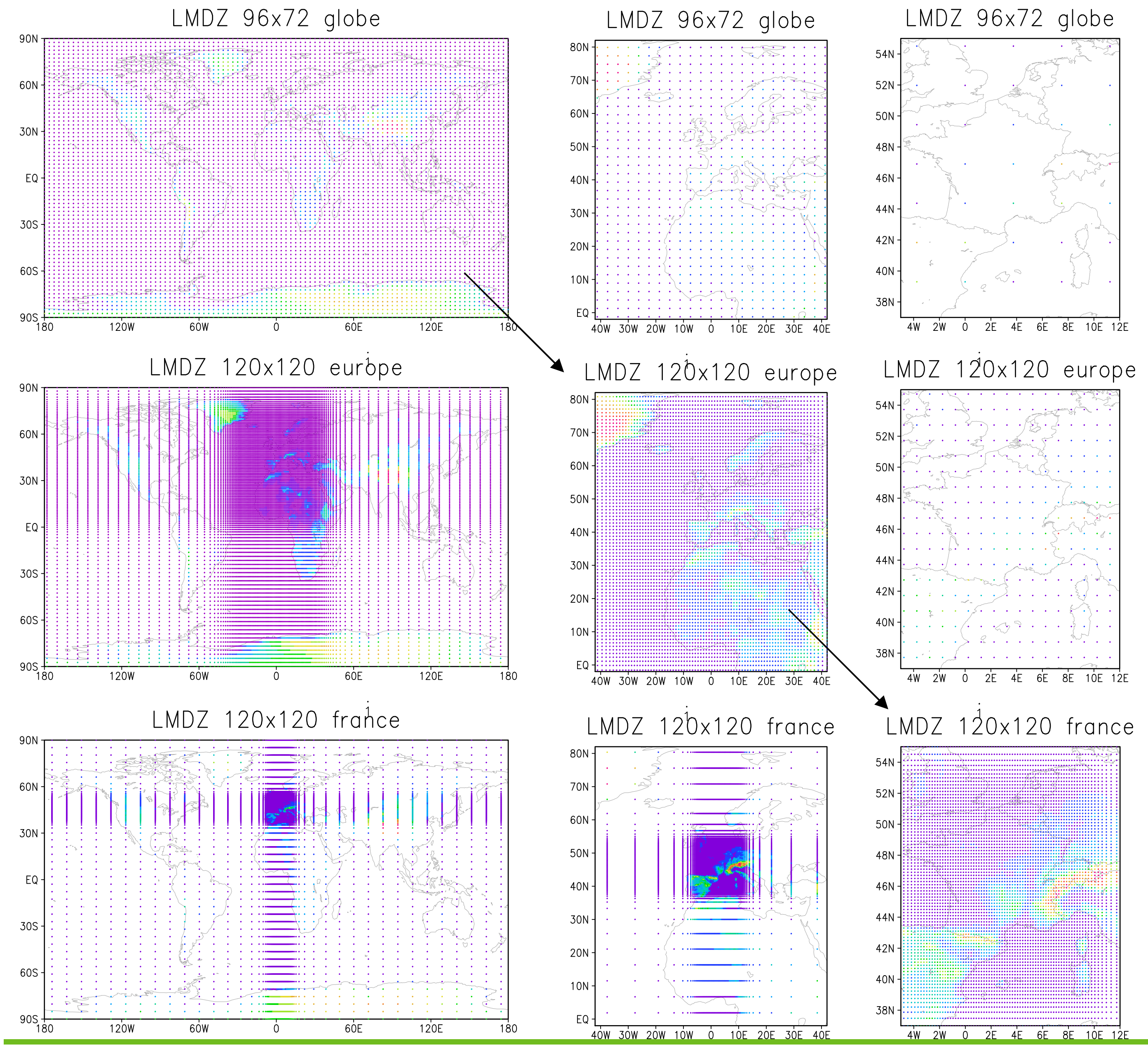
DJF and JJA temperature change (°C) according to the A1B–C20C scenario (2081 to 2100 minus 1961 to 1980) calculated by reliability ensemble averaging (REA1) or simple averaging (AVE). REA-ORIG: original REA method.

Xu-Gao-Giorgi 2010 Climatic Change

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

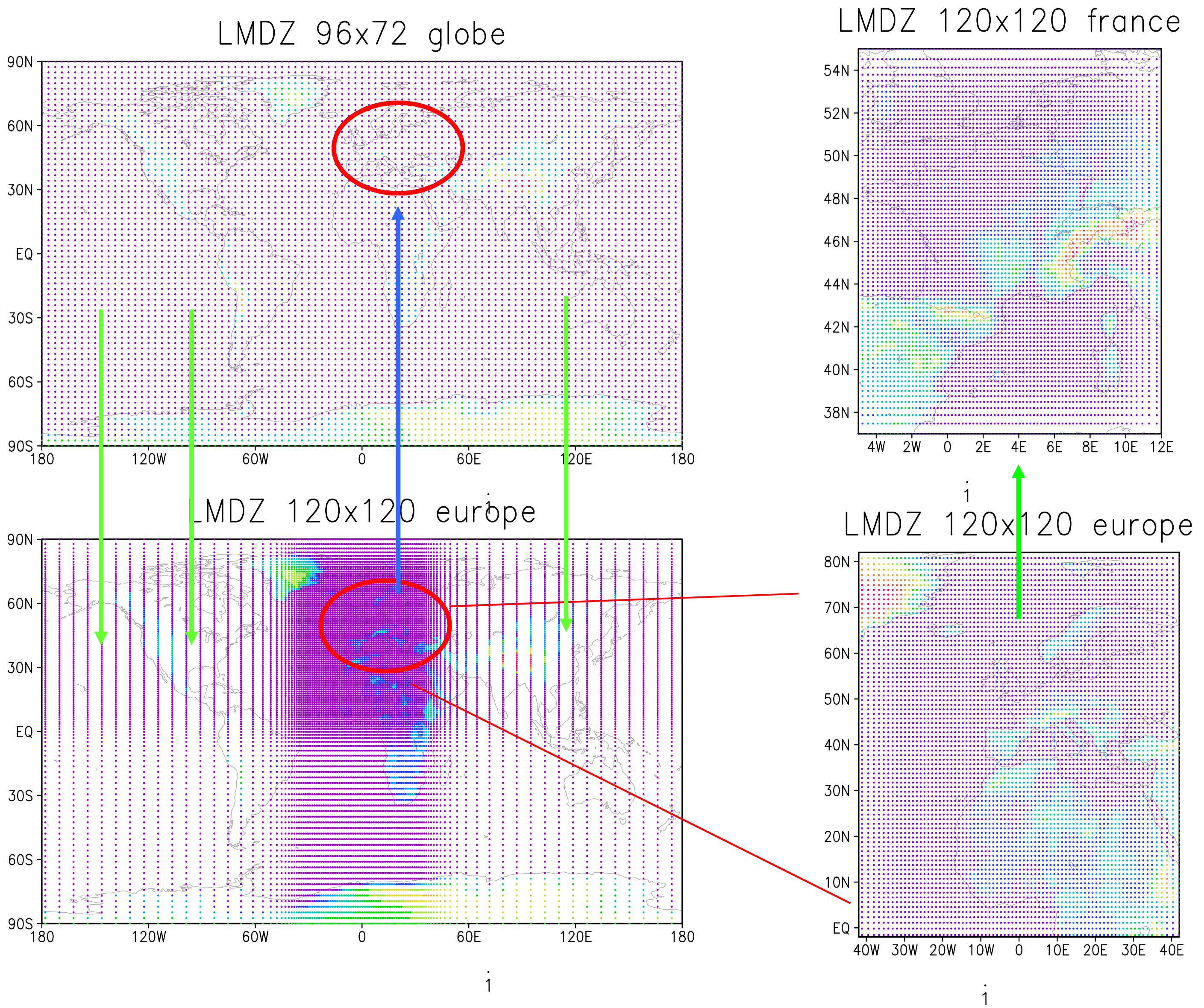


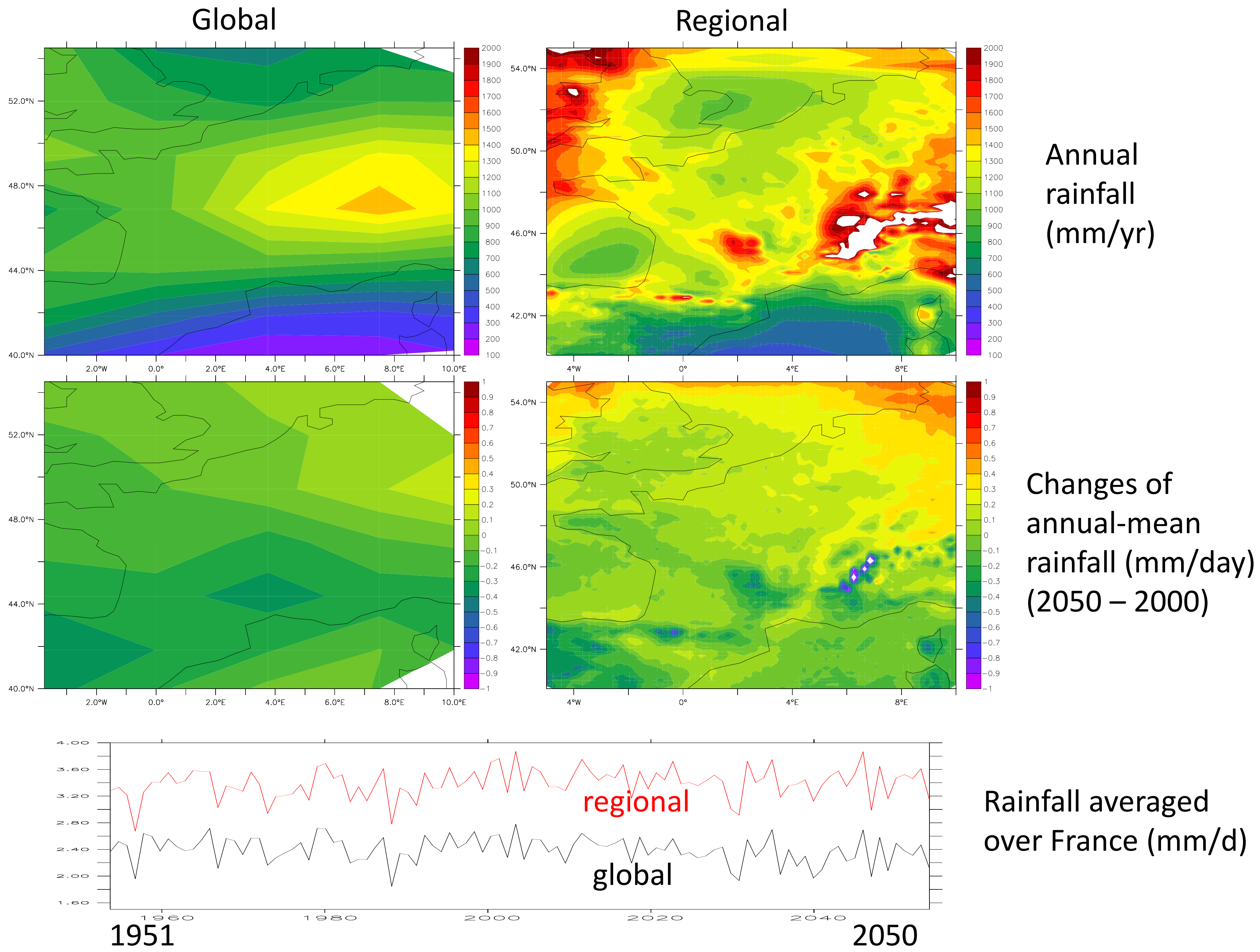
LMDZ Globe (300 km)

LMDZ Europe (100 km)

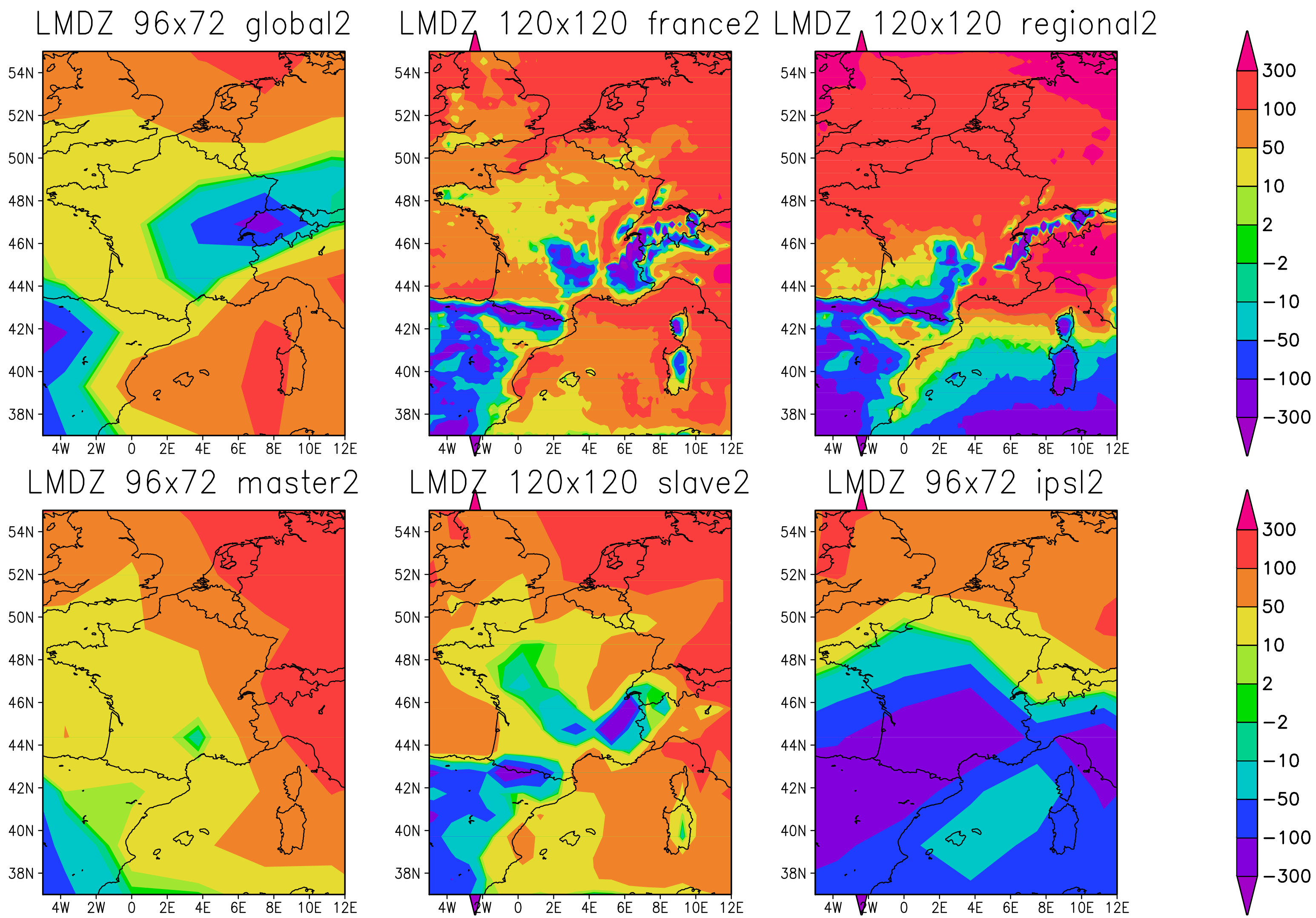
LMDZ France (20 km)

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




Global
Regional
Annual rainfall (mm/yr)
Changes of annual-mean rainfall (mm/day) (2050 – 2000)
regional
global
Rainfall averaged over France (mm/d)
1951
2050

Annual Delta precipitations



- Two downscaling chains, Master/Slave/France and Global/Regional, show consistent relationship between Global scale and Regional scale.
- Two-way nesting does show up-scaling effects.
- The two chains reveal significant differences in terms of climate change. This seems caused by excitation of different intrinsic modes in relation with the basic state of the model (SST).

Pr (mm/day), Tx(℃) et Tn (℃) for a return level at 50 years in Marseille, observation and 3 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: precipitation

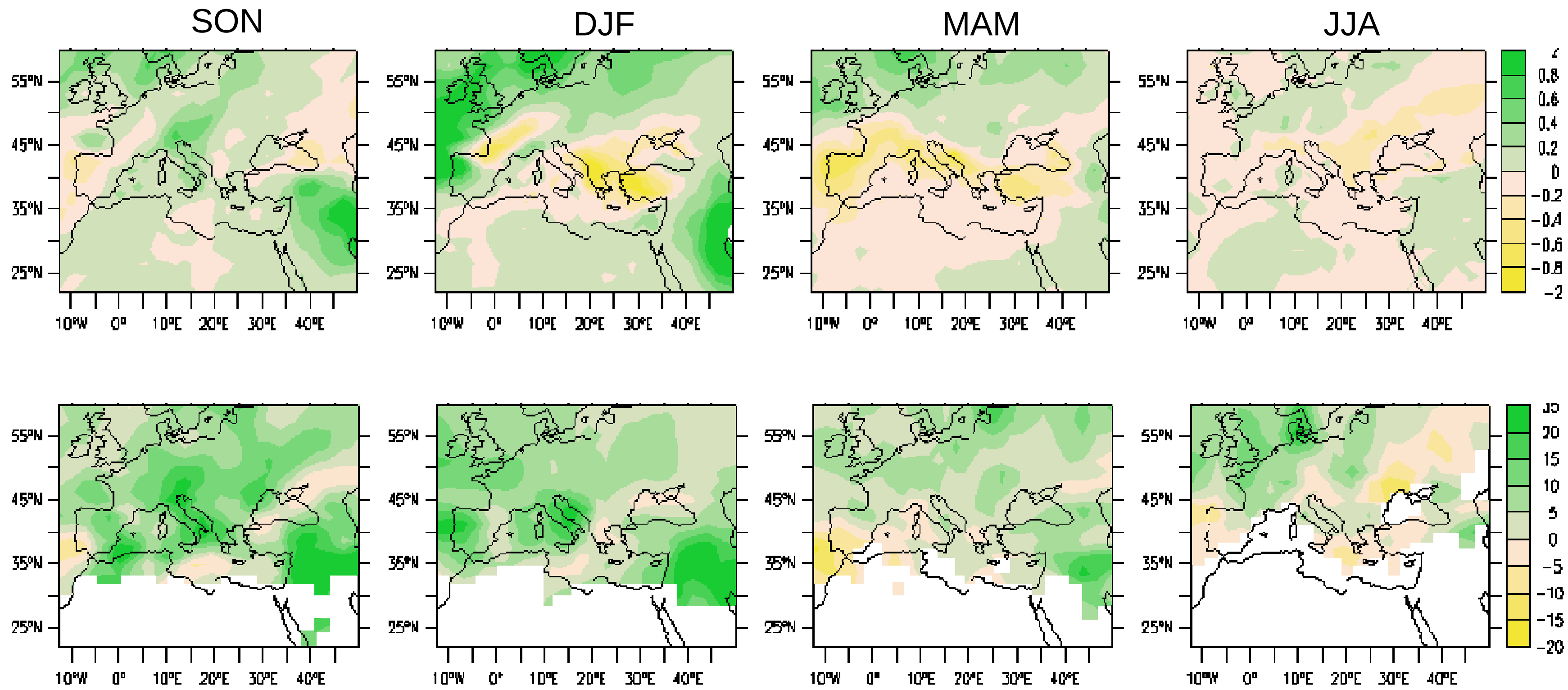
Tx: daily-maxi temperature

Tn: daily-mini temperature

Future evolution of extremes

Precipitation (mm/day)

averages

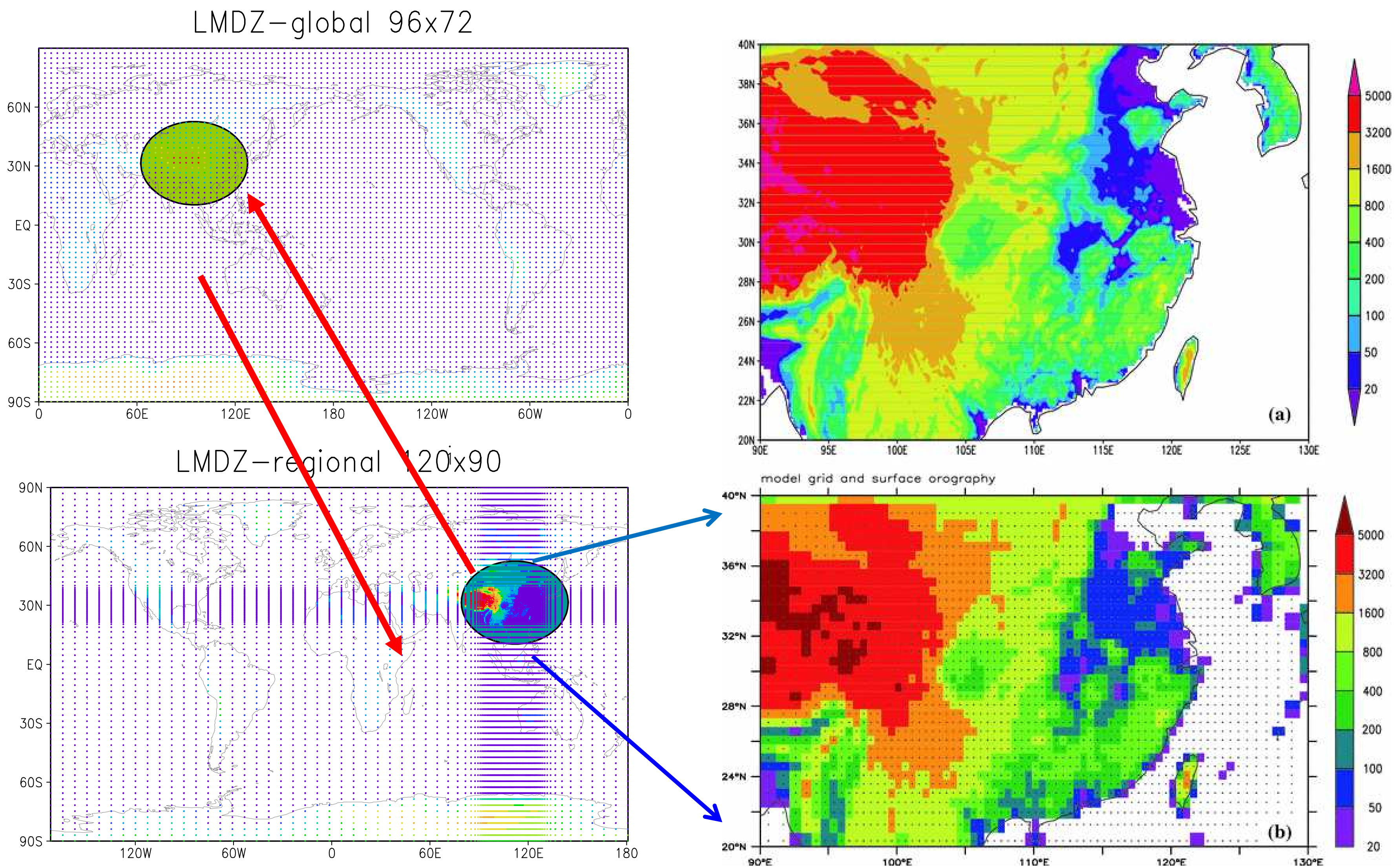


30-year return levels

2070/2099 minus 1970/1999

Two-way nesting between global scales and regional scales:

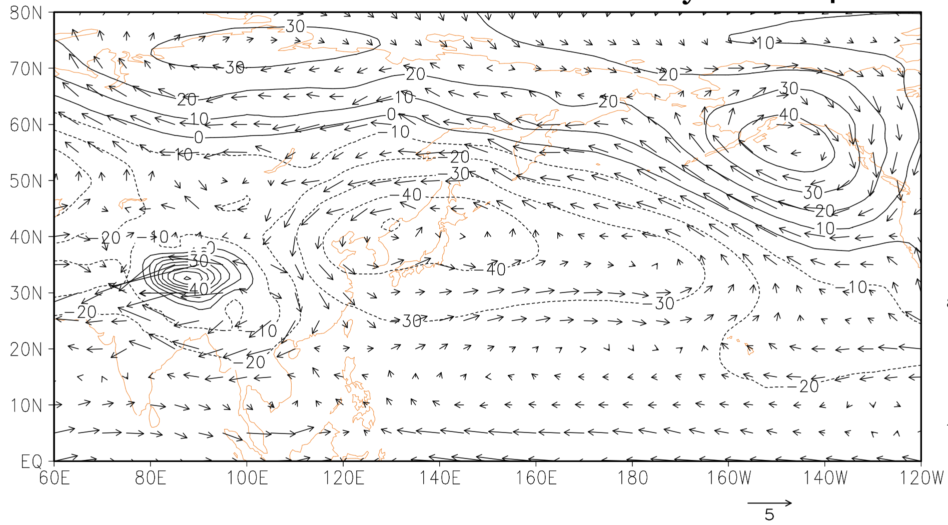
- test in South-east Asia ;
- test in the Mediterranean basin



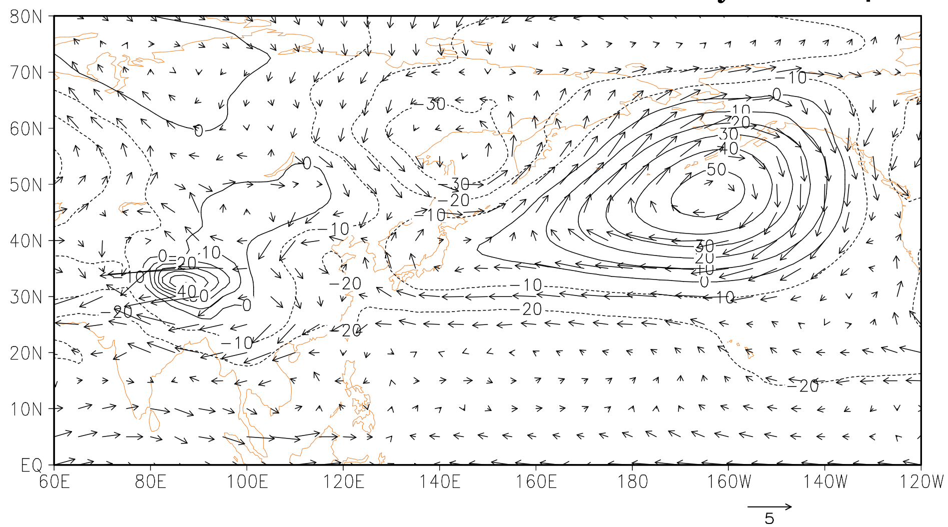
[Two-way nesting between LMDZ-regional and LMDZ-global]

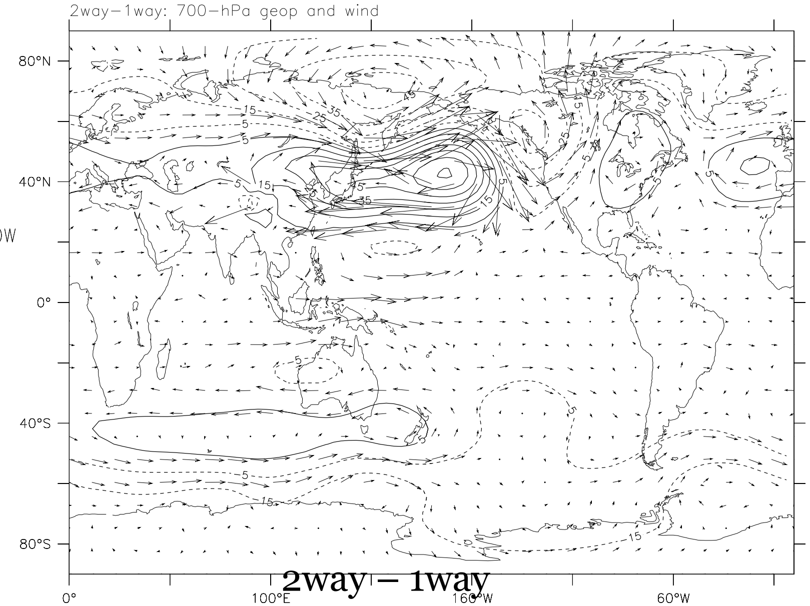
700-hPa geopotential height and wind in LMDZ-global

1way – ERA40



2way – ERA40

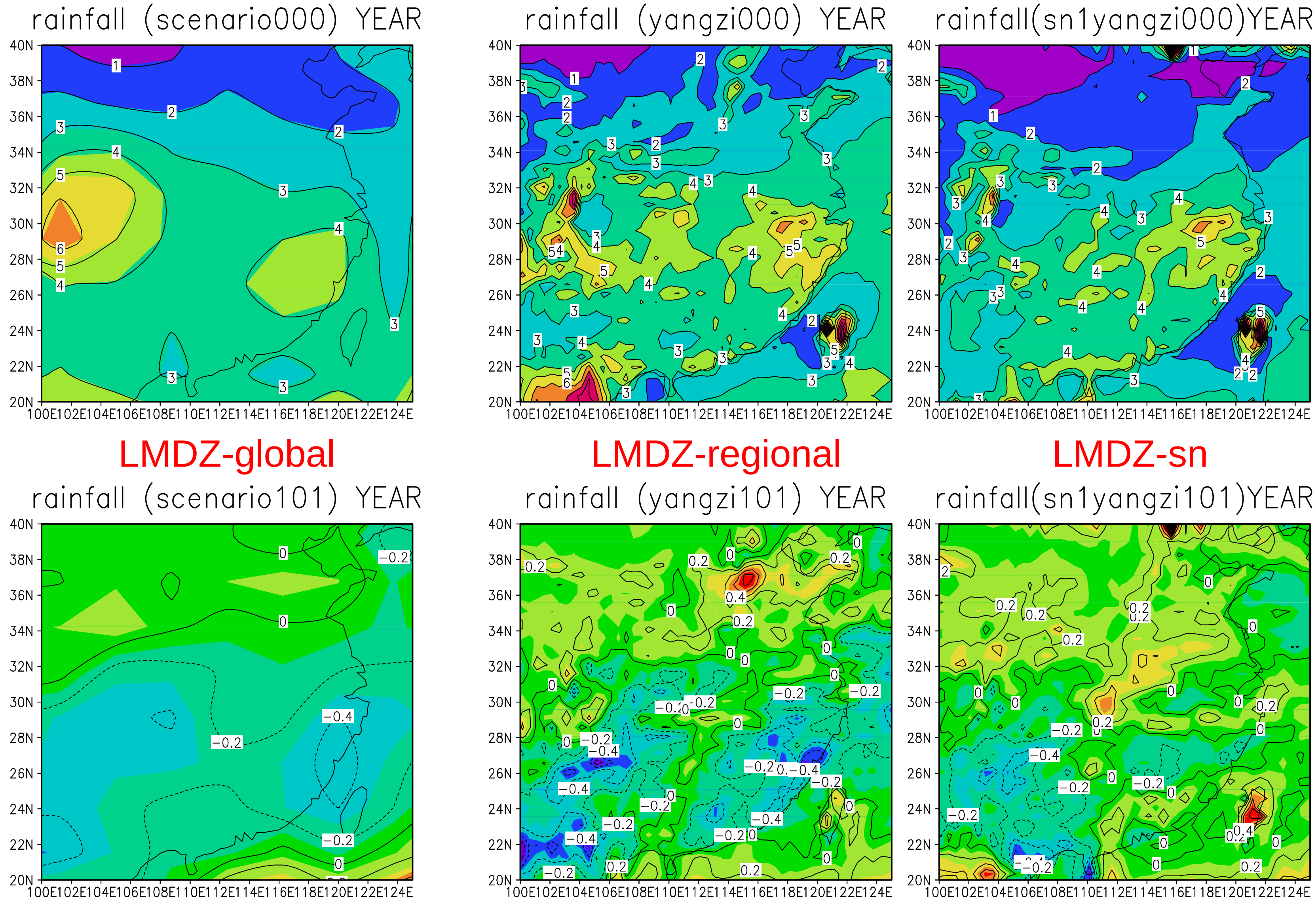




2way – 1way

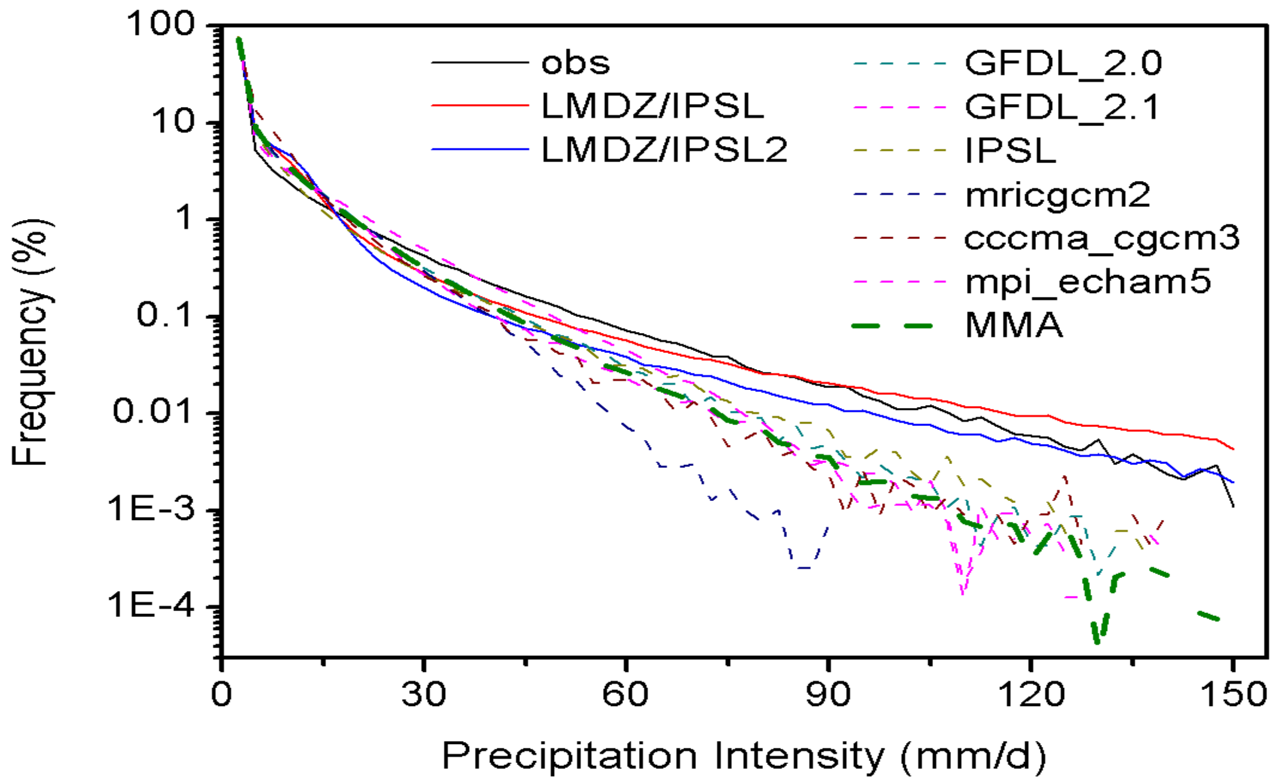
Chen et al. 2010, Cli Dyn

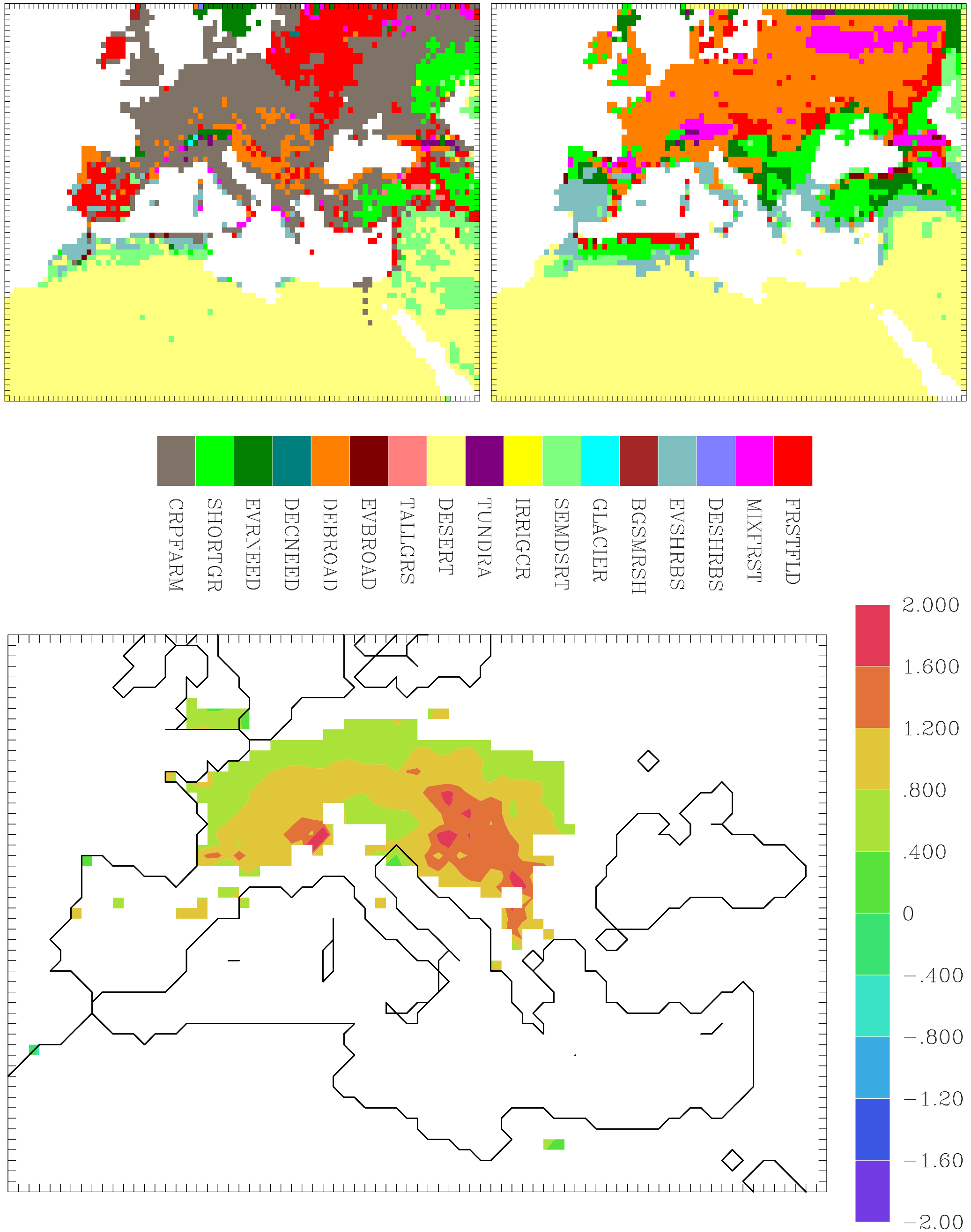
Annual-mean rainfall (mm/d) (top), and its future variation (bottom: 2050-2000)



Added values of LMDZ-regional: extremes

Spectral distribution of rainfall in southeast China, comparison between the observation, LMDZ/CTRL, LMDZ/CTRL2, and a few other coarse-resolution global models. Added values of high-resolution models can be clearly identified.





Upper panels: observed land-use distribution (left) and natural potential vegetation distribution (right). The labels are acronyms for crops and mixed farming, short grass, evergreen and deciduous needle leaf and broadleaf trees, tall grass, desert, tundra, irrigated crops, semi-desert, ice caps and glaciers, bogs and marches, evergreen and deciduous shrubs, mixed woodland and forest/field mosaic, respectively.

Lowerpanel: differences (potential vegetation minus current vegetation) of mean June-July-August 2-m temperature averaged over 10 summers. Colored areas are statistically significant at the 90% confidence level.

An example of the two-way nesting atmospheric system

Two configurations:

•LMDZ-regional forced by prescribed lateral boundary conditions;

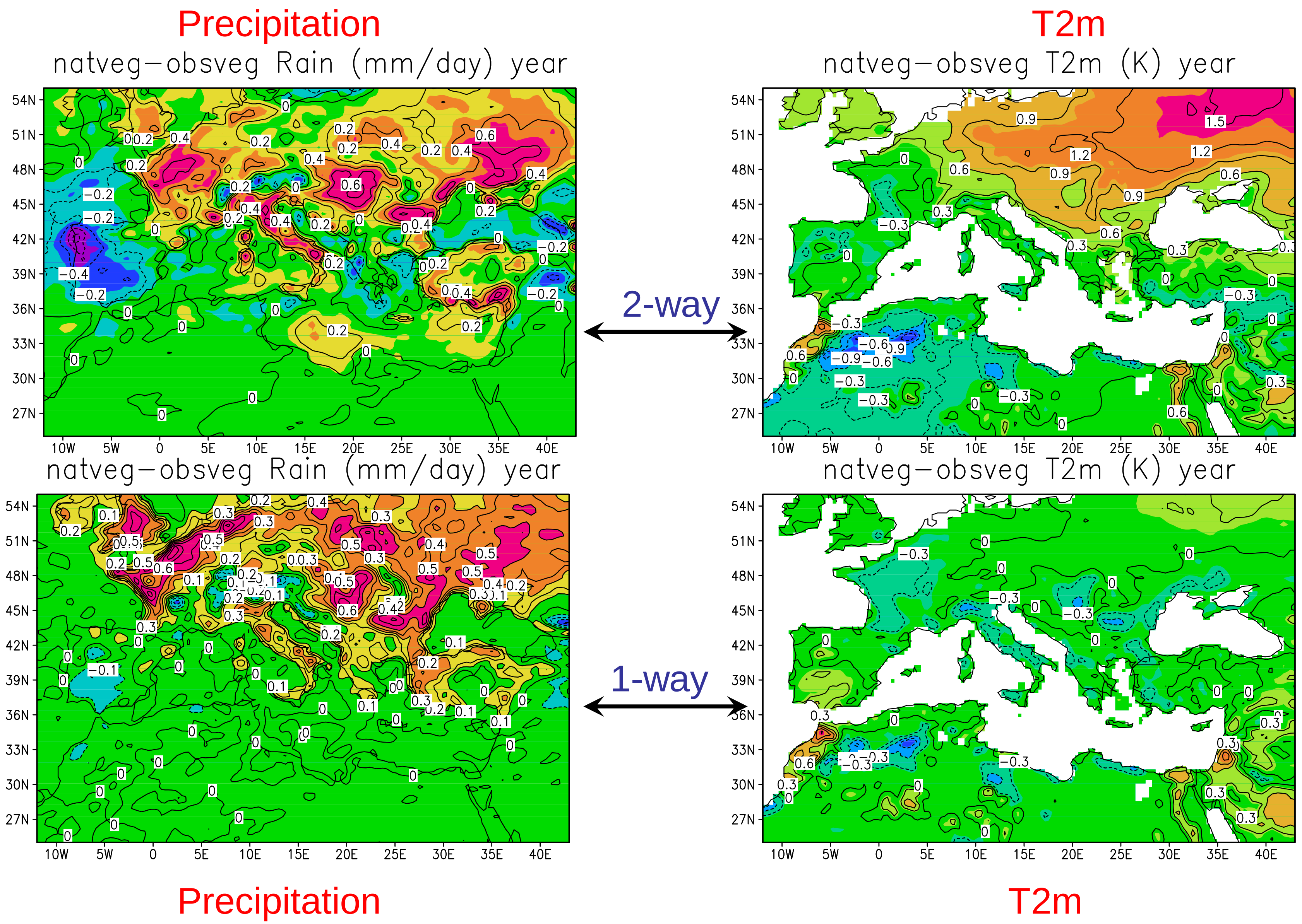
•Two-way nesting system between LMDZ-regional and LMDZ-global.

Two experiments (10 years for each simulation):

•<u>ObsVeg</u>: Observed Vegetation of present day,

•<u>NatVeg</u>: Natural vegetation in the Mediterranean basin – idealized situation without any anthropogenic land use (statistical model).

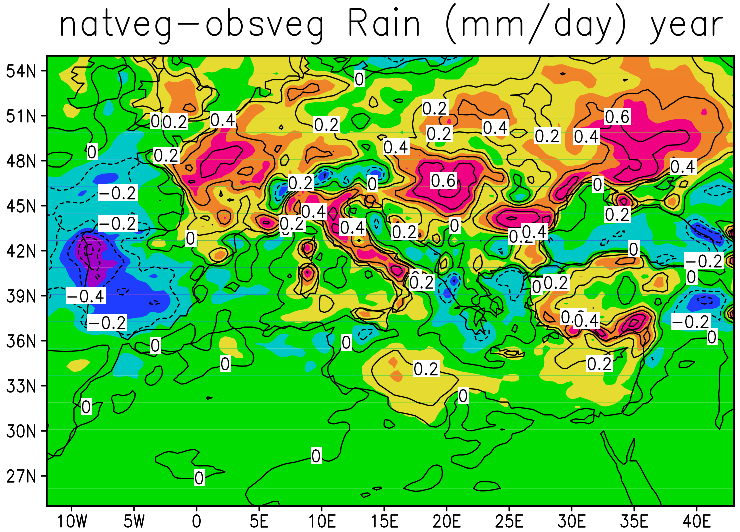
Difference (NatVeg – ObsVeg)

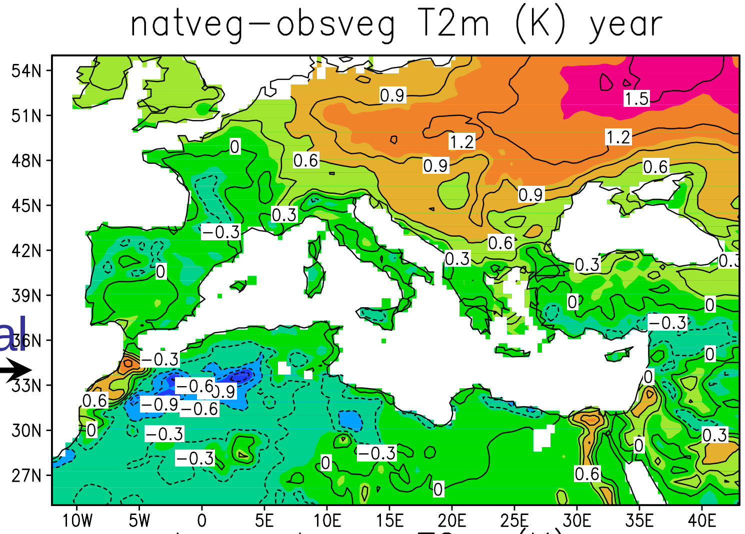


Difference (NatVeg – ObsVeg)

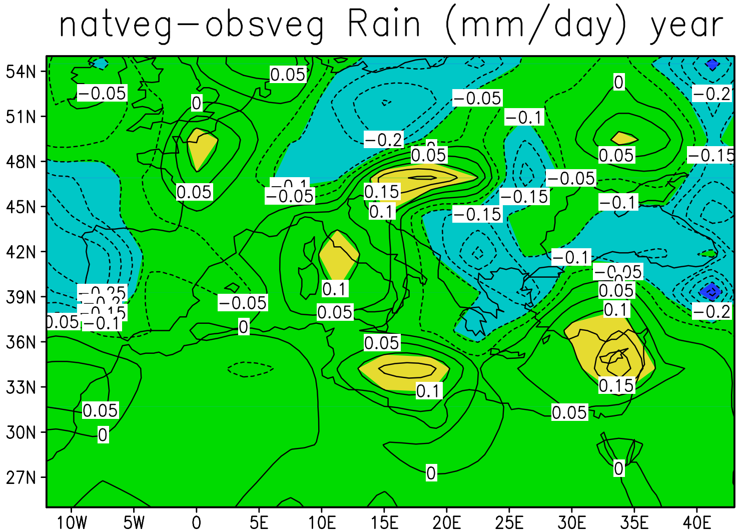
Precipitation

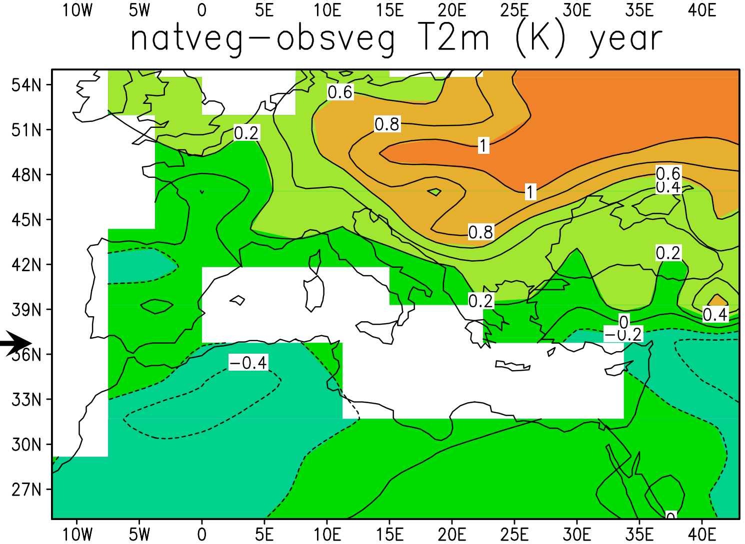
T2m





Regional





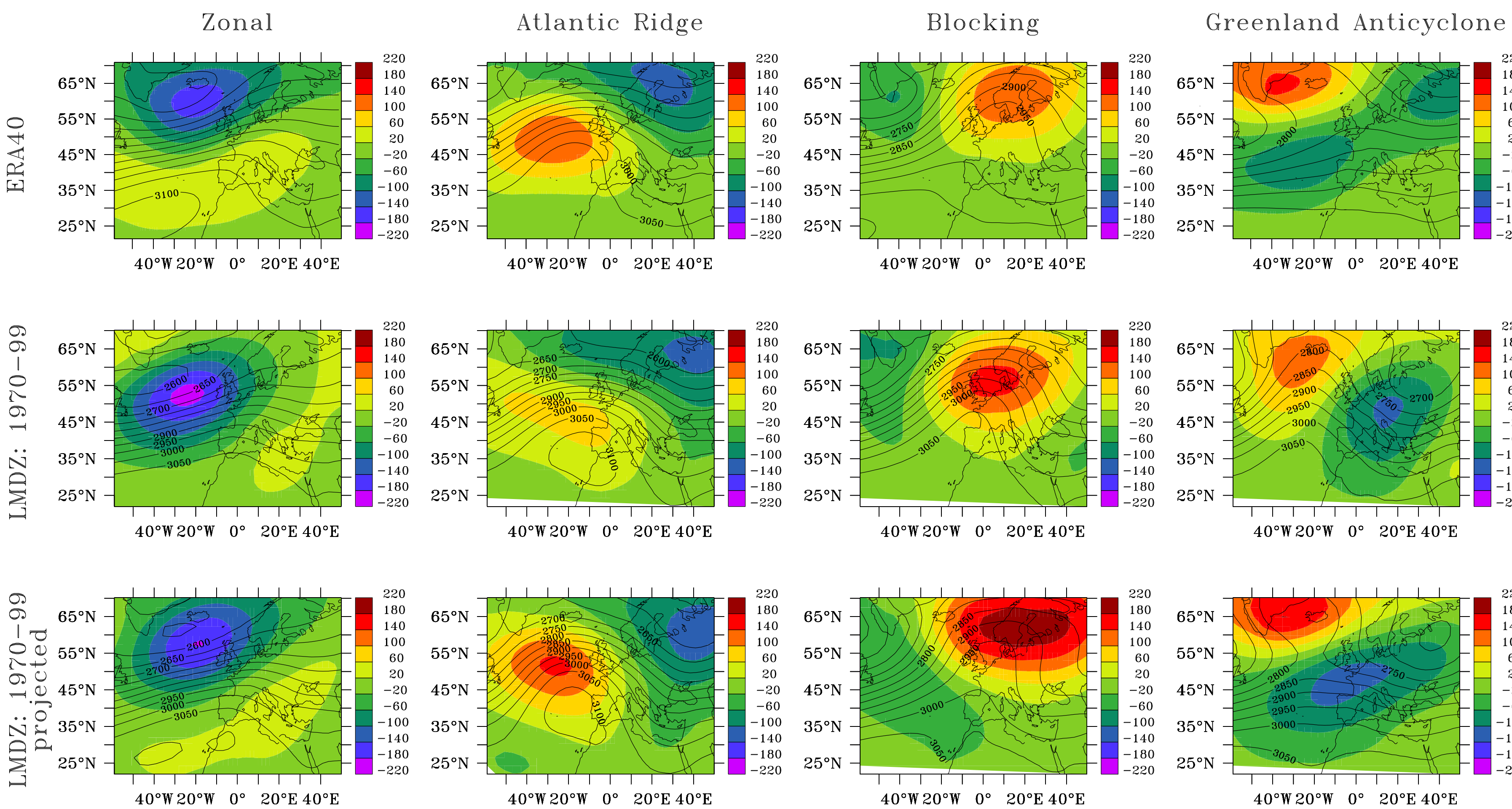
Global

Precipitation

T2m

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.

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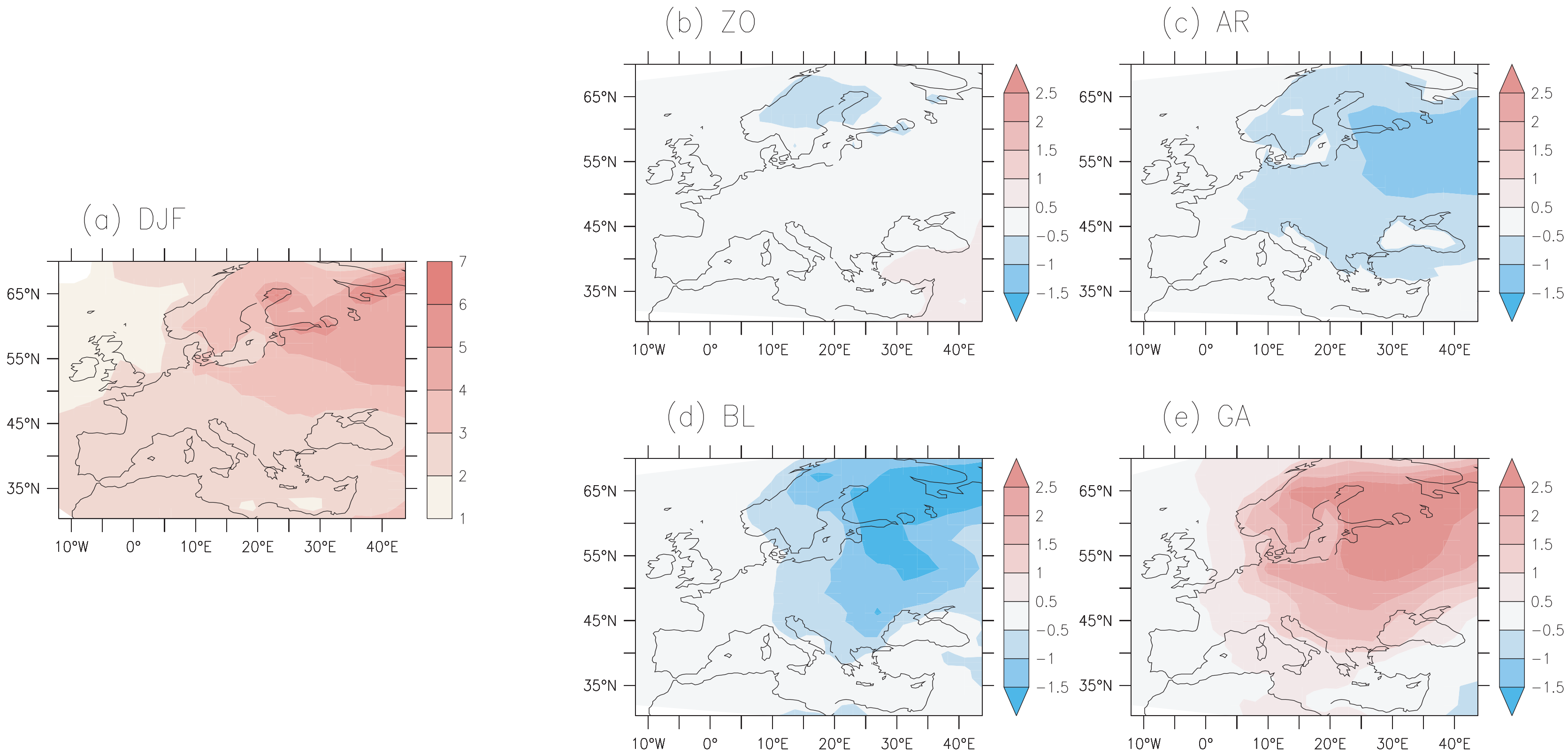
Weather regimes favoring the occurrence of (a),(c),(e) warm and (b),(d),(f) cold temperatures over Europe: (a),(b) the observed relationship for the 1970–99 period, and the relationship simulated by LMDZ for (c),(d) the 1970–99 period and (e),(f) the 2070–99 period. Color legend: zonal regime (red),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



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Discussions

- Earth system model, regional coupled model
- How to use multi-model information
- Example: a downscaling study over China
- Example: a downscaling study over France
- A case of afforestation in Europe
- Statistical downscaling: necessary but fragile