Modelling climate change: from global to regional

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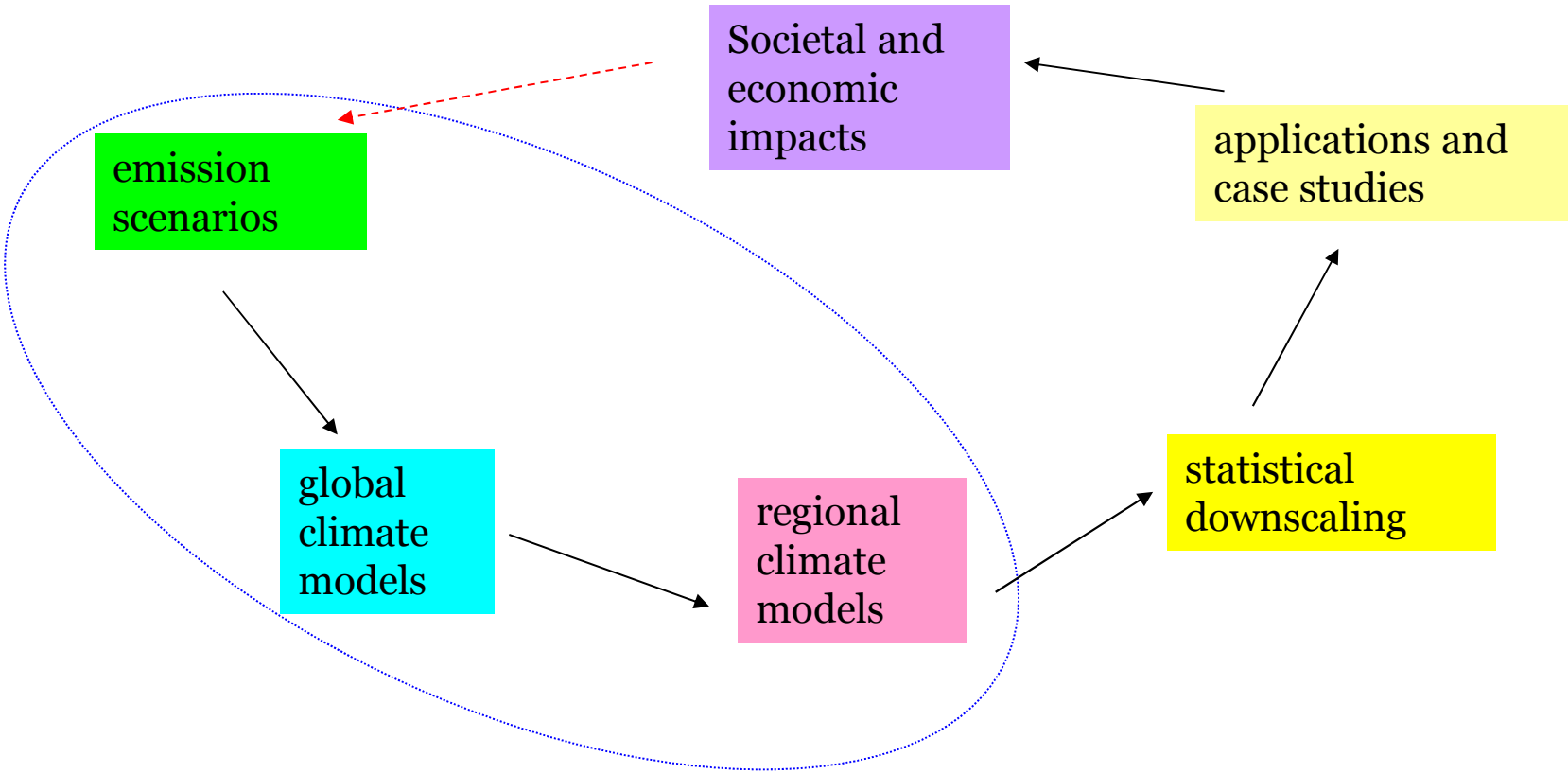
Some points to consider

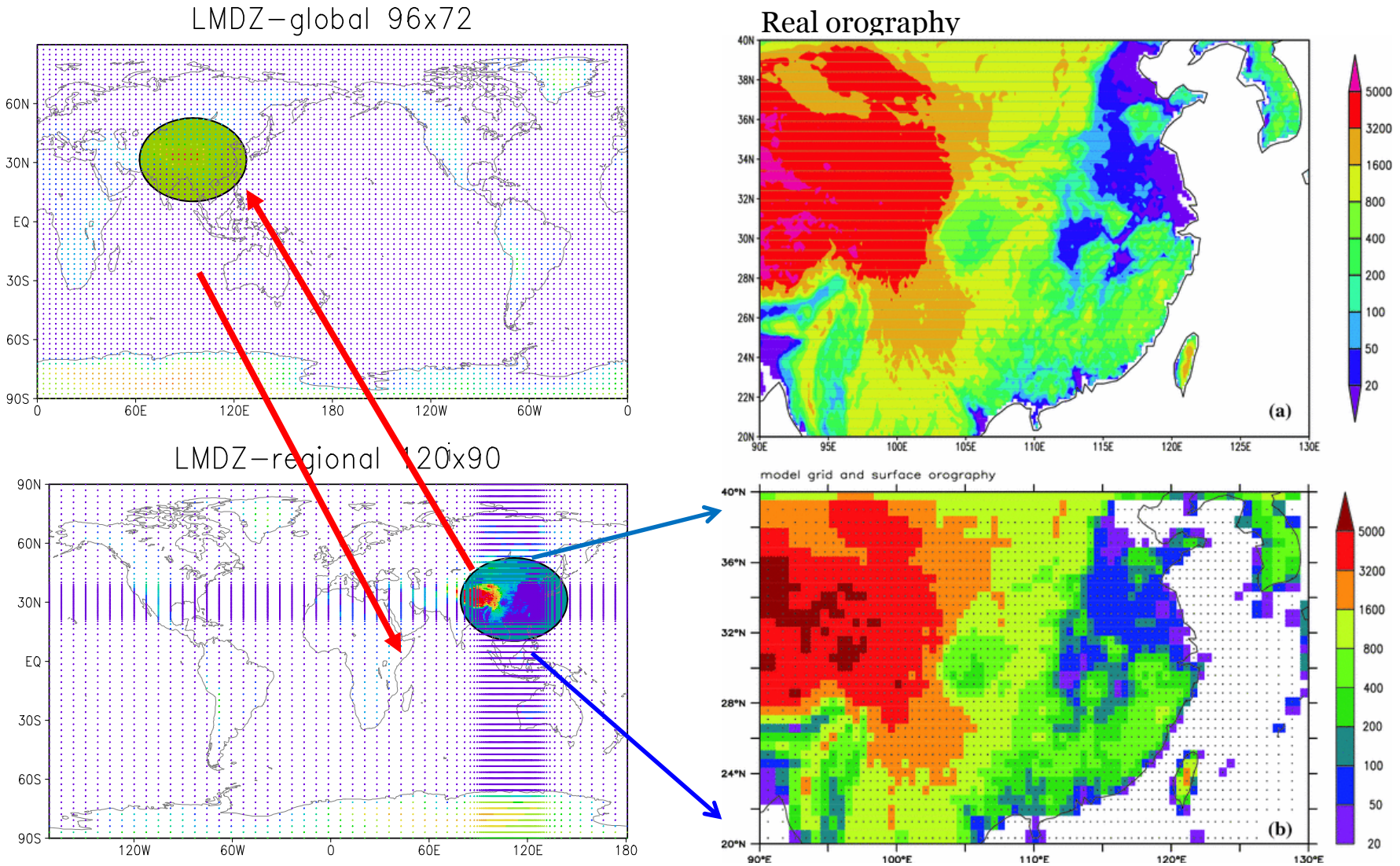
- **Added values of RCM**
- **Scale interactions between global and regional**
- **Uncertainties in model results**

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.

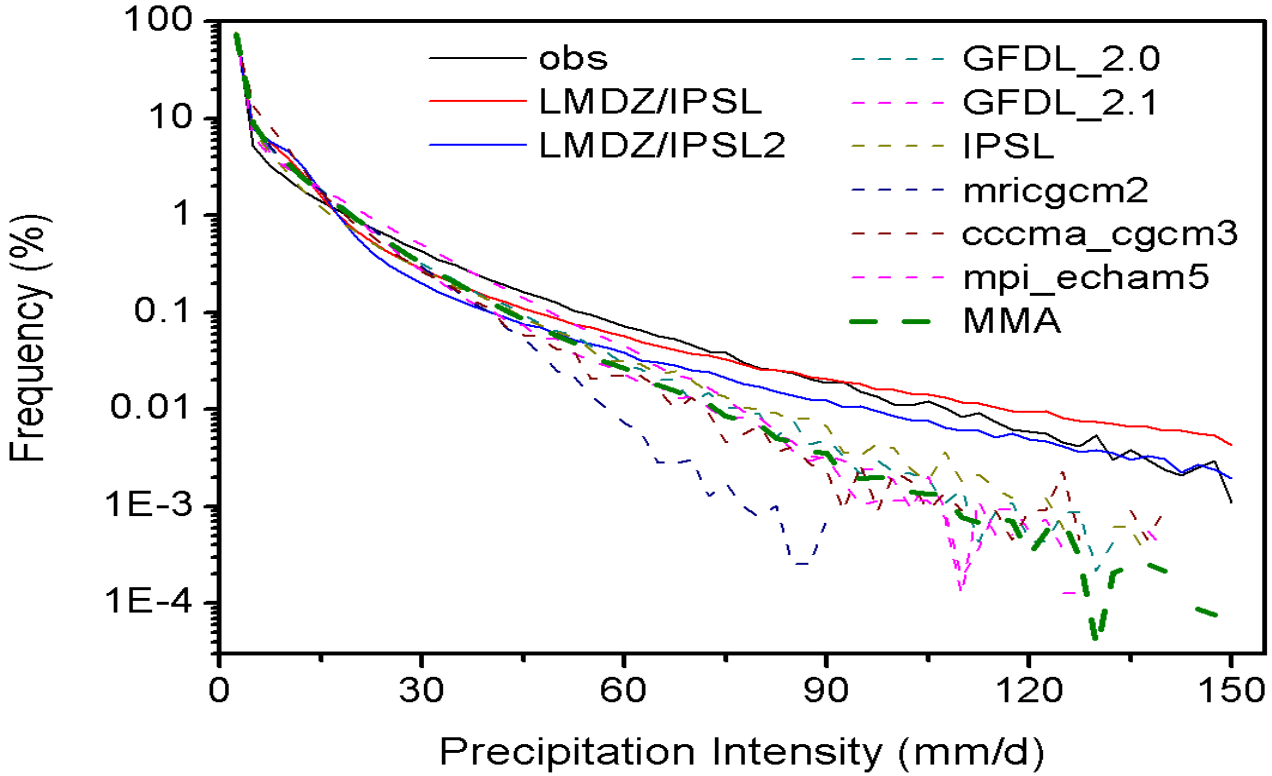
- Considerable uncertainties exist in different steps of future climate projection.
- Multi-model databases (CMIP3,CMIP5) offer both scientific opportunities and challenges in combining these datasets. How to use information



- LMDZregional is a global GCM with a zoom over Southeast China. Local resolution: 50 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.
- It is possible to do two-way nesting with LMDZ-global

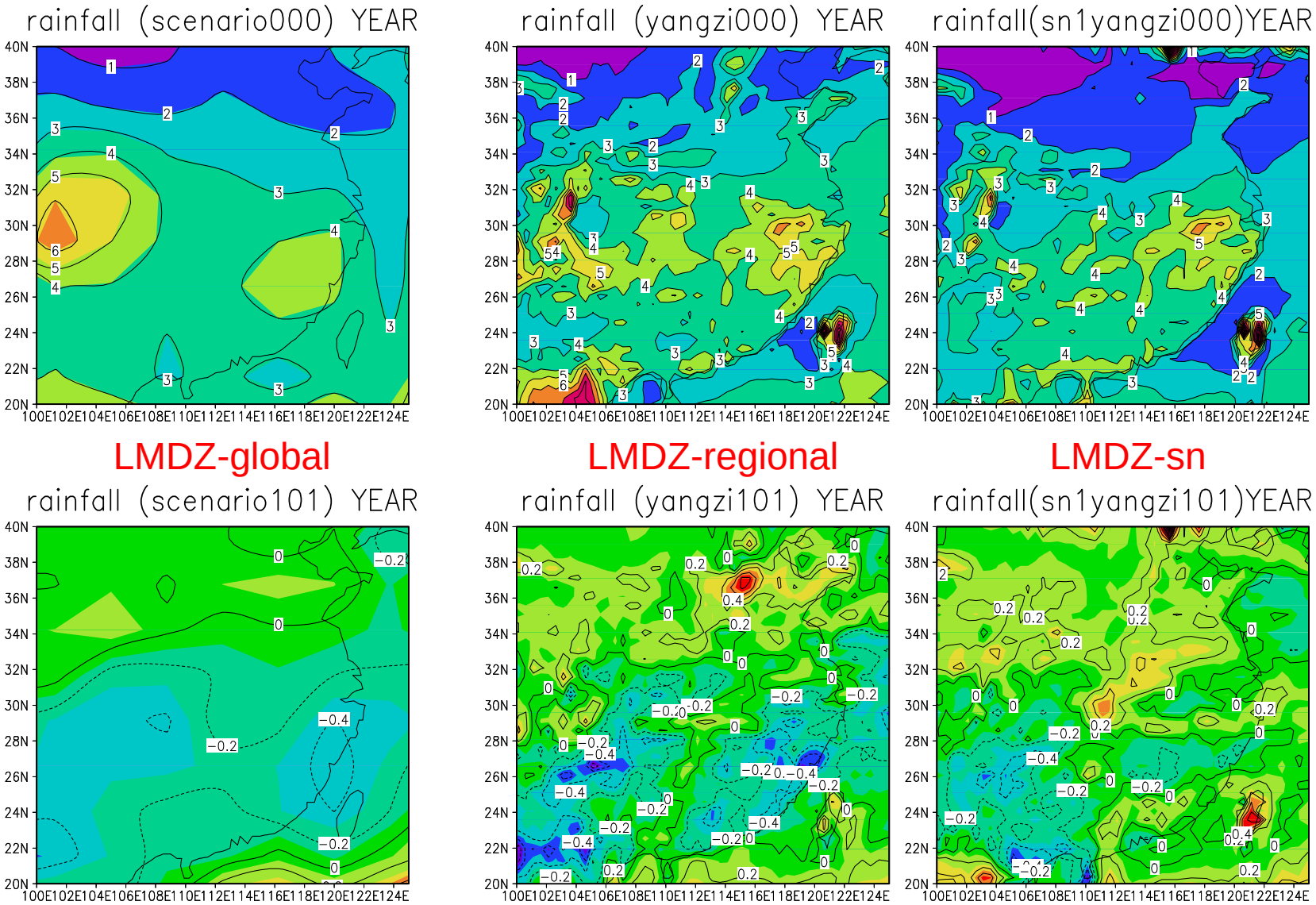
Added values of LMDZ-regional: extremes

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.



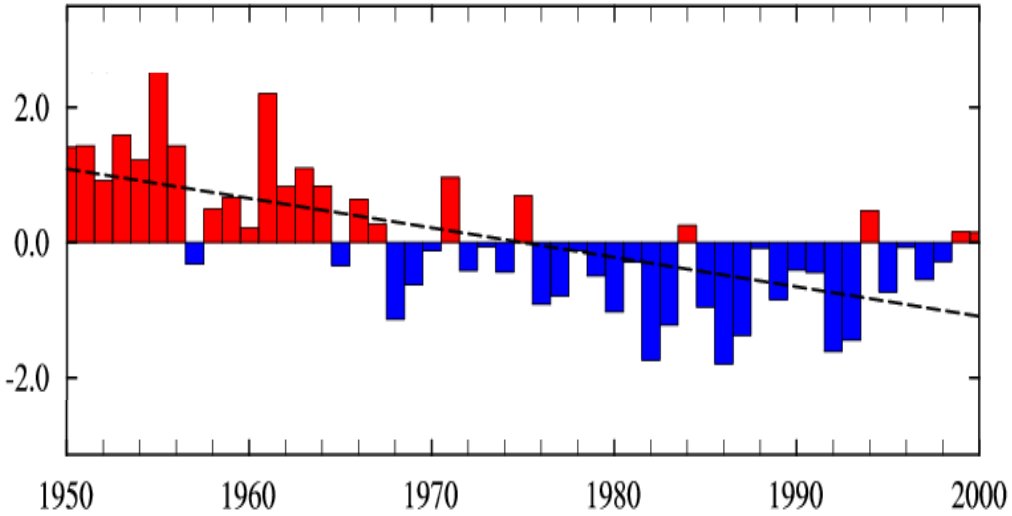
Chen et al. 2011, JCL

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

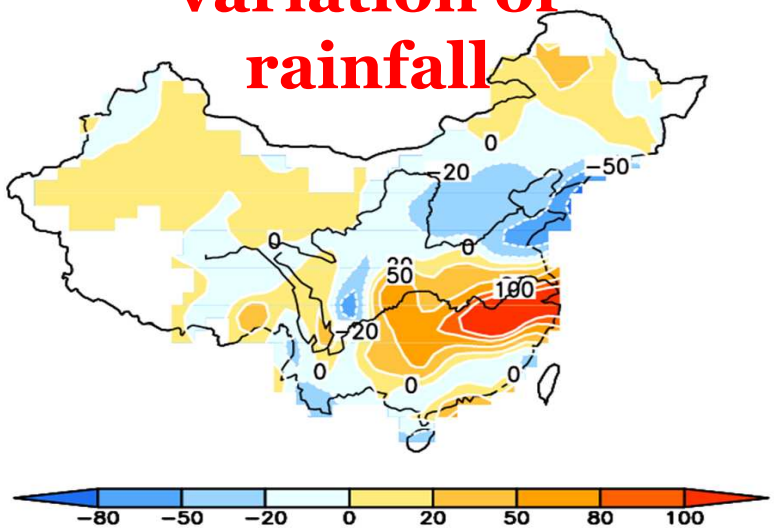


Variation of the East Asian Summer Monsoon during the second half of the 20th century

East Asian Summer Monsoon Index



Decadal variation of rainfall



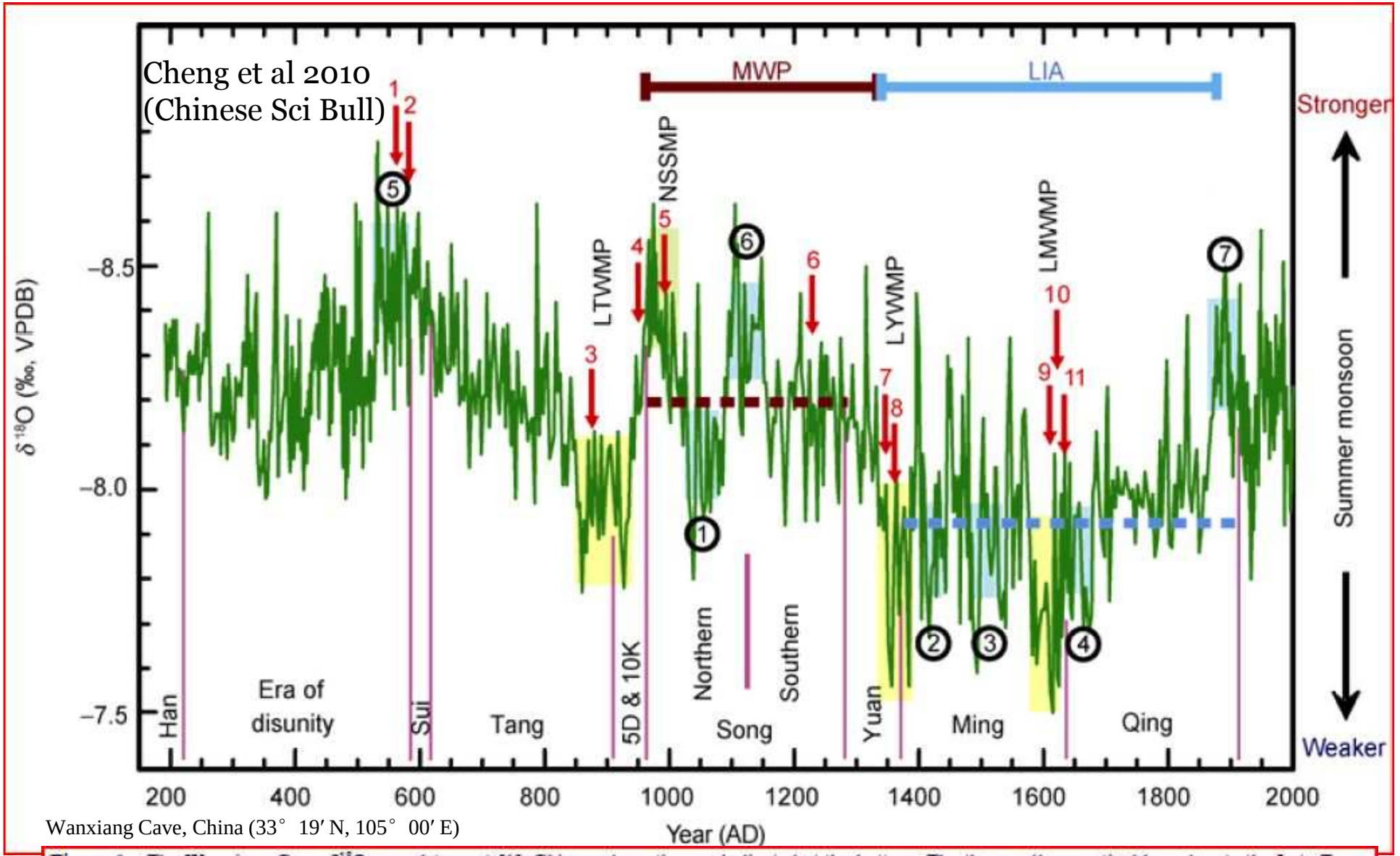
East Asian Summer Monsoon has strong variabilities at interannual and decadal scales. Since the 1980s, the monsoon diminished in intensity, creating precipitation anomalies (above-normal in the south and below-normal in the north).

Courtesy Dr. T. Zhou

Inter-basins water transfer projects: West / Middle /East

Severe droughts in China (> 3 yrs and > 4 provinces) during the last millennium:
14 events in total, the most severe ones are:

- **989-991** (**North Song**): Drought in Central China with less than 300 mm of annual precipitation.
- **1209-1211** (**South Song**)
- **1370-1372** (**Yuan**): Decline of the Yuan Dynasty
- **1483-1485** (**Ming**)
- **1585-1590** (**Ming**): Large geographic covering. Propagation of droughts from North to South (warm conditions before the cold years of LIA)
- **1637-1643** (**Ming**): Long lasting and large geographic covering. Transition from “dry north – wet south” to “wet north – dry south” (cold years of the LIA). Decline of the Ming Dynasty
- **1784-1787** (**Qing**): Droughts in the mid and low ranges of the Yangtze river (warm years of the LIA)
- **1875-1877** (**Qing**): Droughts in North China (beginning of the anthropogenic warming)



Wanxiang Cave, China (33° 19′ N, 105° 00′ E)

Figure 1 The Wanxiang Cave $\delta^{18}O$ record (green) [1]. Chinese dynasties are indicated at the bottom. The three yellow vertical bars denote the Late Tang, Late Yuan and Late Ming Weak Monsoon Periods (LTWMP, LYWMP, and LMWMP), and the shaded green bar the Northern Song Strong Monsoon Period (NSSMP). Two bars at the top show the Medieval Warm Period (MWP) and the Little Ice Age (LIA). Additional weak (①–④) and strong (⑤–⑦) monsoon times are the same as in Figure 1 of [3]. The red arrows depict events in Chinese history: (1) the era of "A Shepherd's Song". (2) China was reunited in AD 589. (3) The Huang Chao Uprising. (4) The Guge Kingdom was established. (5) Huang Mao proved that Hebei was suitable for rice cultivation. (6) The Mongols defeated the Former Jin in AD 1234. (7) Four family members of Zhu Yuanzhang died due to drought. (8) The Hongjinjun Uprising leading to the end of the Yuan Dynasty. (9) Collapse of the Guge Kingdom. (10) The Mongols surrendered to the Later Jin in AD 1636. (11) The ChongZhen Drought. Two dashed horizontal lines show the EASM difference between the Song (brown, in the MWP) and Ming-Qing Dynasties (light blue, mainly in the LIA).

A numerical study on climate effect of the urbanization in the Yangtze River Delta

Motivation: The recent Chinese economic boom is accompanied by a massive urbanization in Eastern China, to the detriment of arable lands. What impacts are expected for climate at local and large scales ?

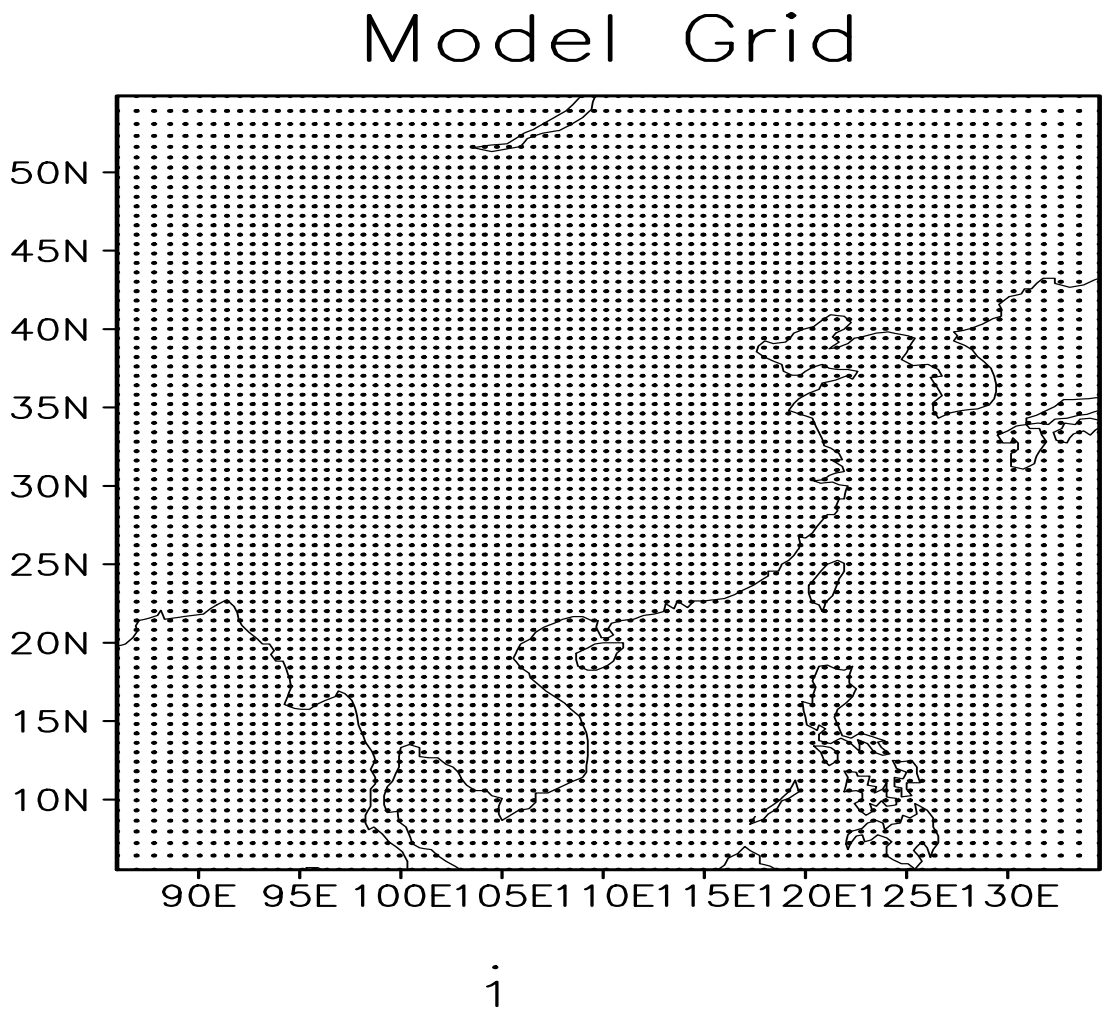
A sensitivity study:
Change agriculture land into bare soil

Vegetation types in ORCHIDEE:

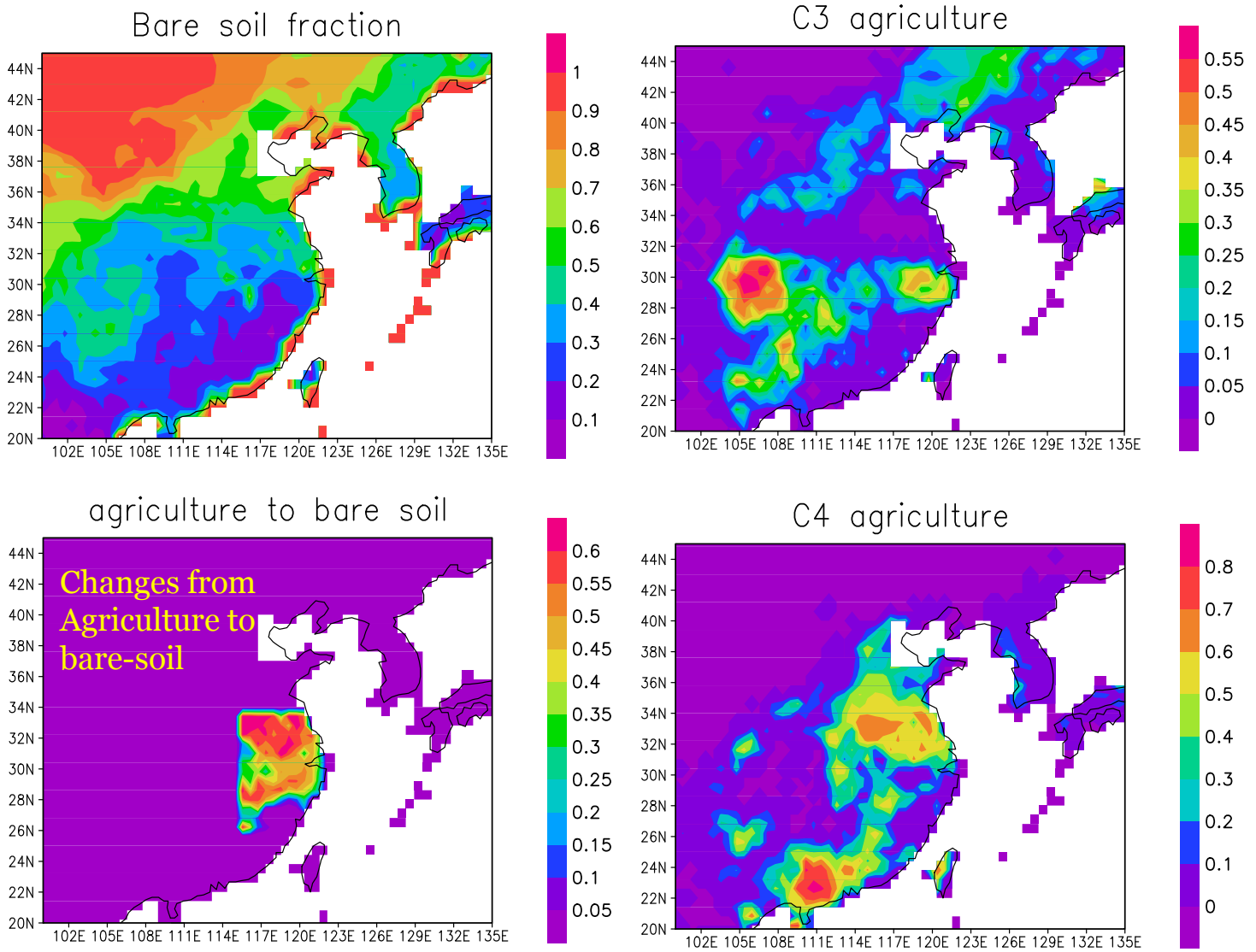
1. Bare soil
2. Tropical broad-leaved evergreen
3. Tropical broad-leaved rain-green
4. Temperate needle-leaf evergreen
5. Temperate broad-leaved evergreen
6. Temperate broad-leaved summer green
7. Boreal needle leaf evergreen
8. Boreal broad-leaved summer green
9. Boreal needle leaf summer green
10. C3 grass
11. C4 grass
12. C3 agriculture
13. C4 agriculture

LMDZ-regional is driven, for lateral boundary, by ERA-Interim 4xdaily T, u, v, q from 1989 to 2009

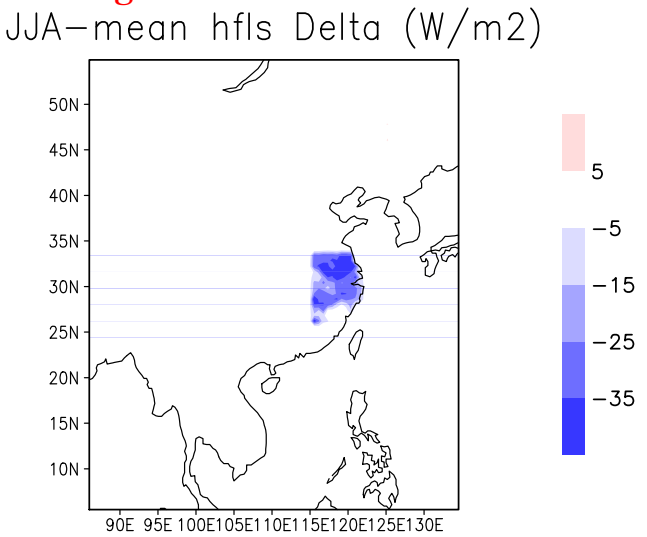
LMDZ-regional : lon (77) x lat (80), about 50 km



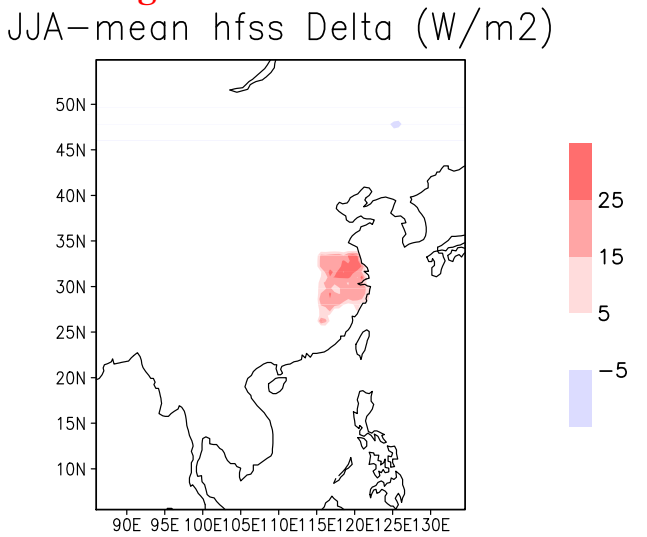
Fractions of bare soil, C3 and C4 agriculture

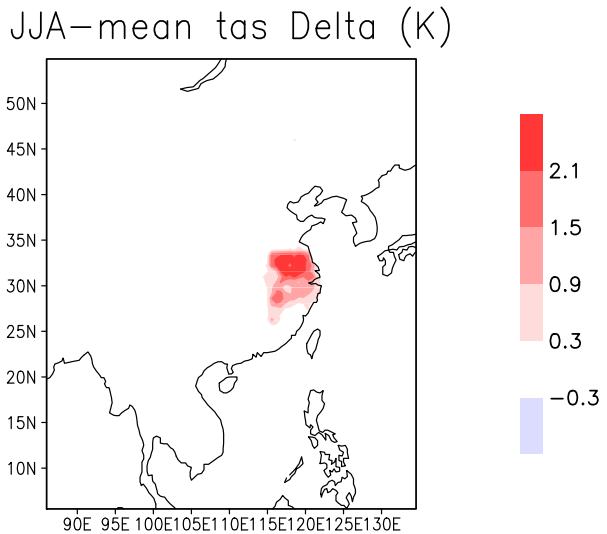


Changes in Latent heat flux

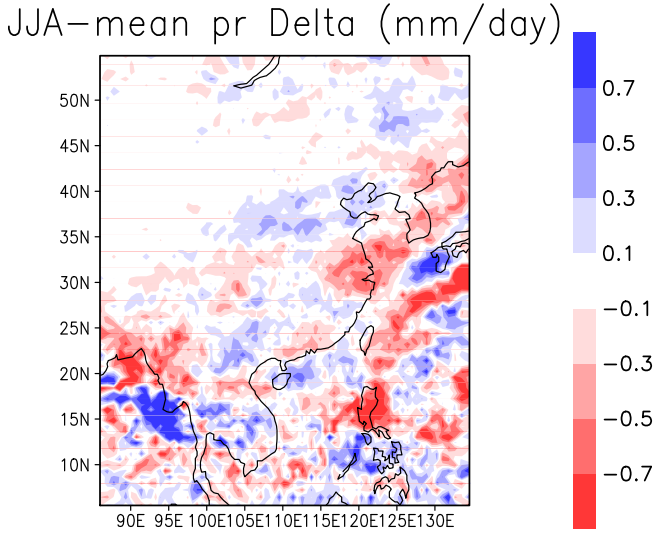


Changes in Sensible heat flux



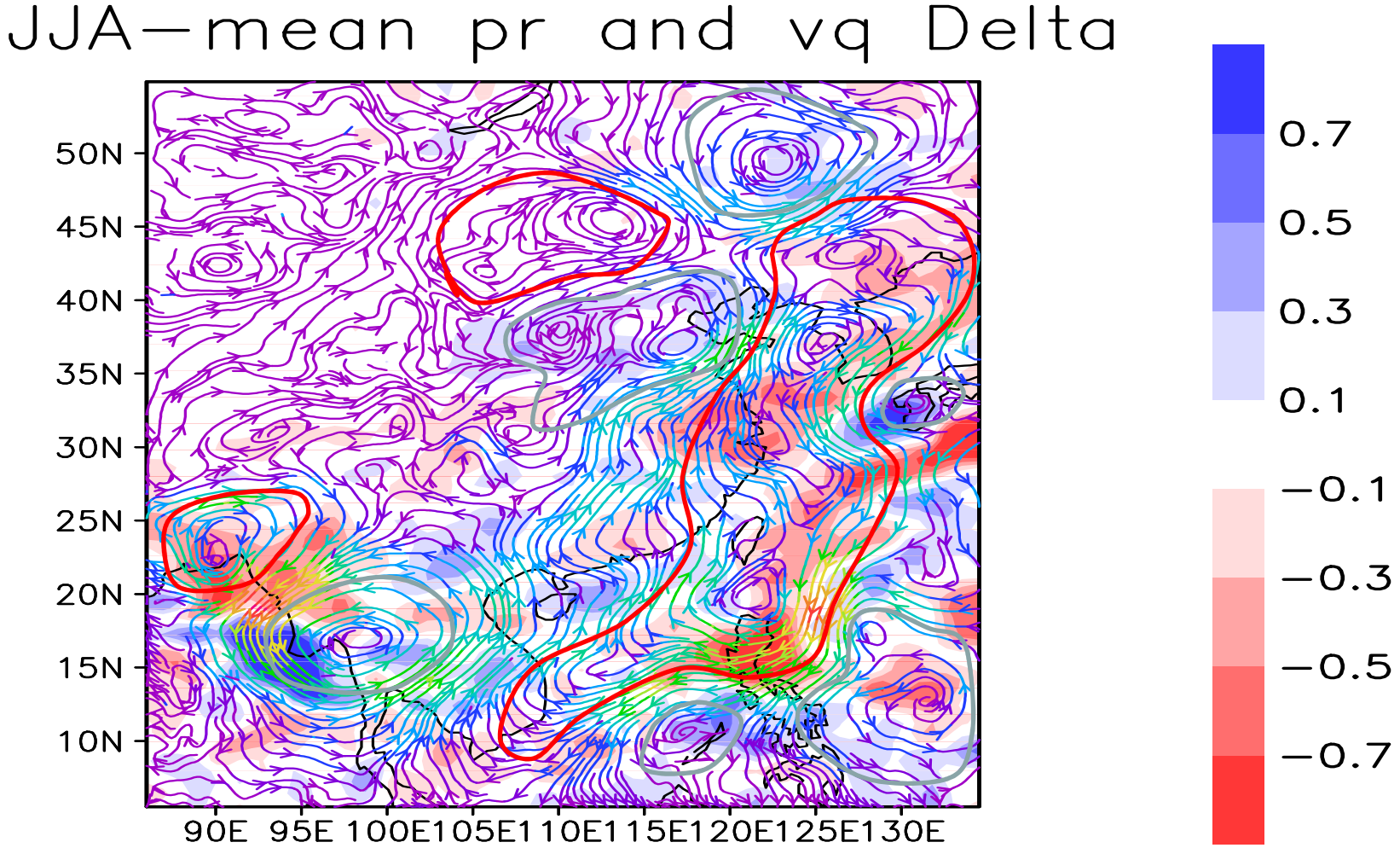


Changes in surf air temp



Changes in precipitation

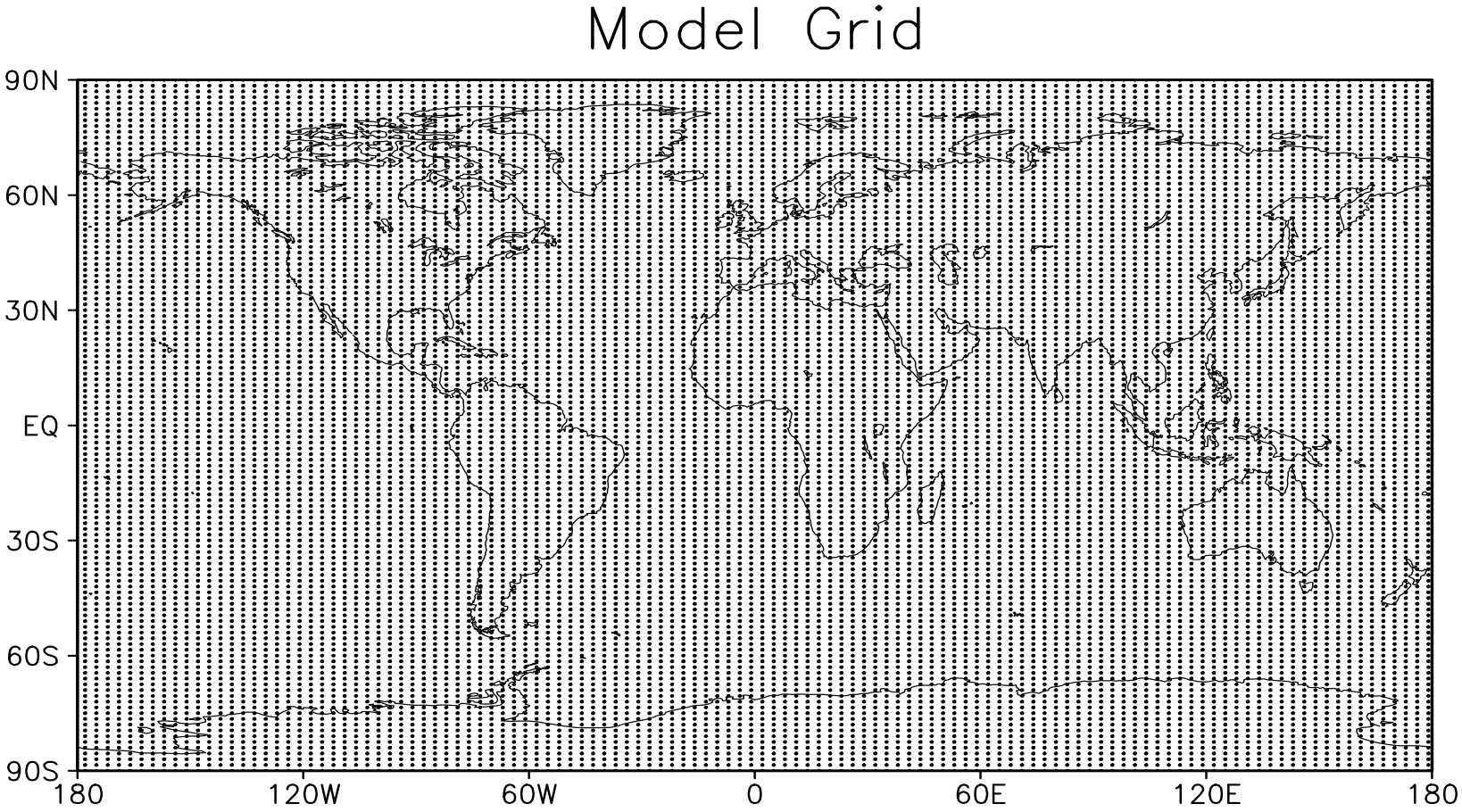
Changes in precipitation (smoothed) and moisture transport



Divergence and anticyclonic circulation

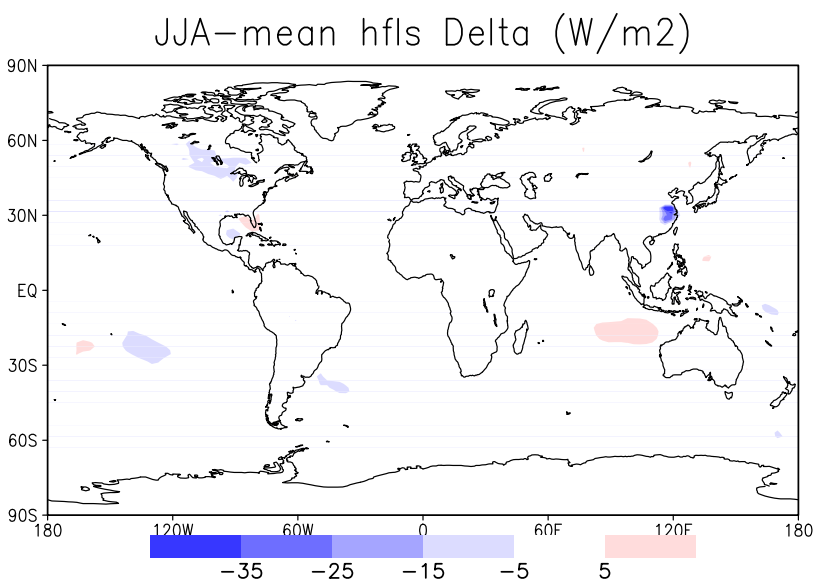
Convergence and cyclonic circulation

Same model physics and same experimental design, but there are no more boundary conditions from ERA-Interim. SST at the lower boundary is the observed one with interannual variability (21 years: 1989 to 2009, 3 ensemble members)

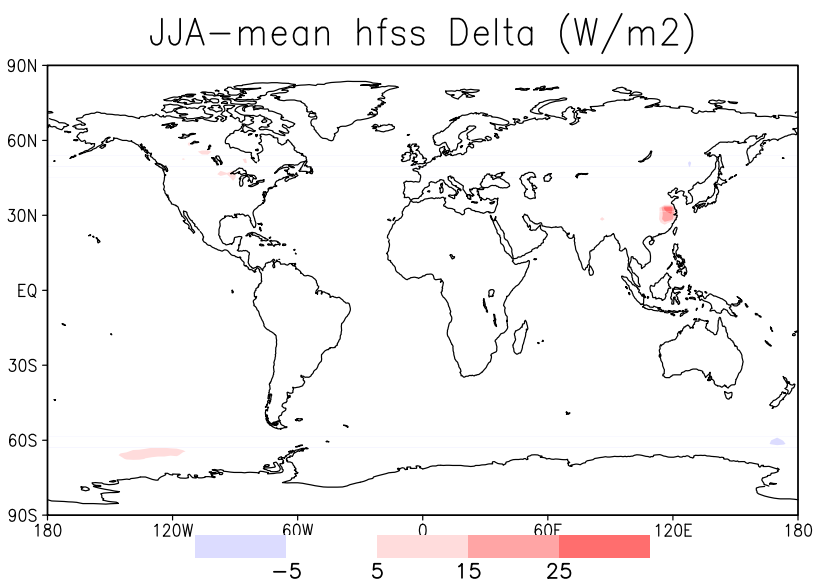


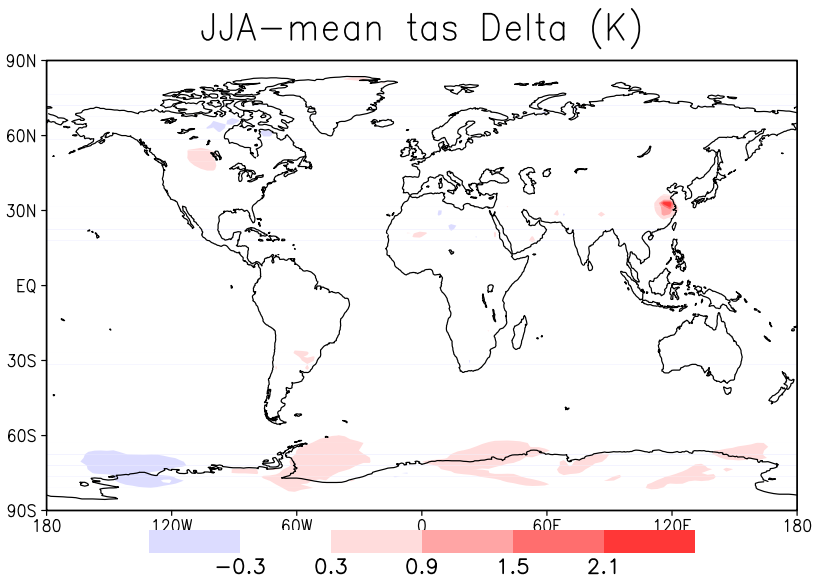
LMDZ-global: 120(lon) x 120(lat); about 200 km

Changes in Latent heat flux

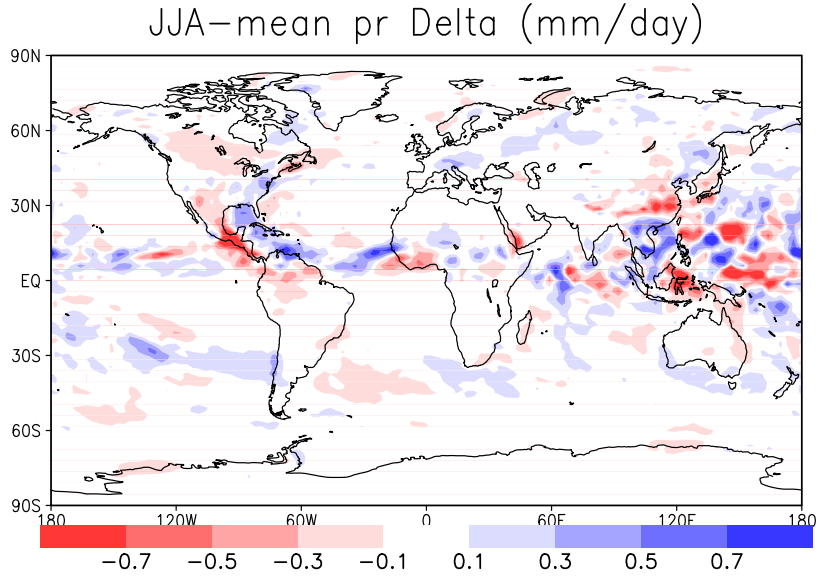


Changes in Sensible heat flux

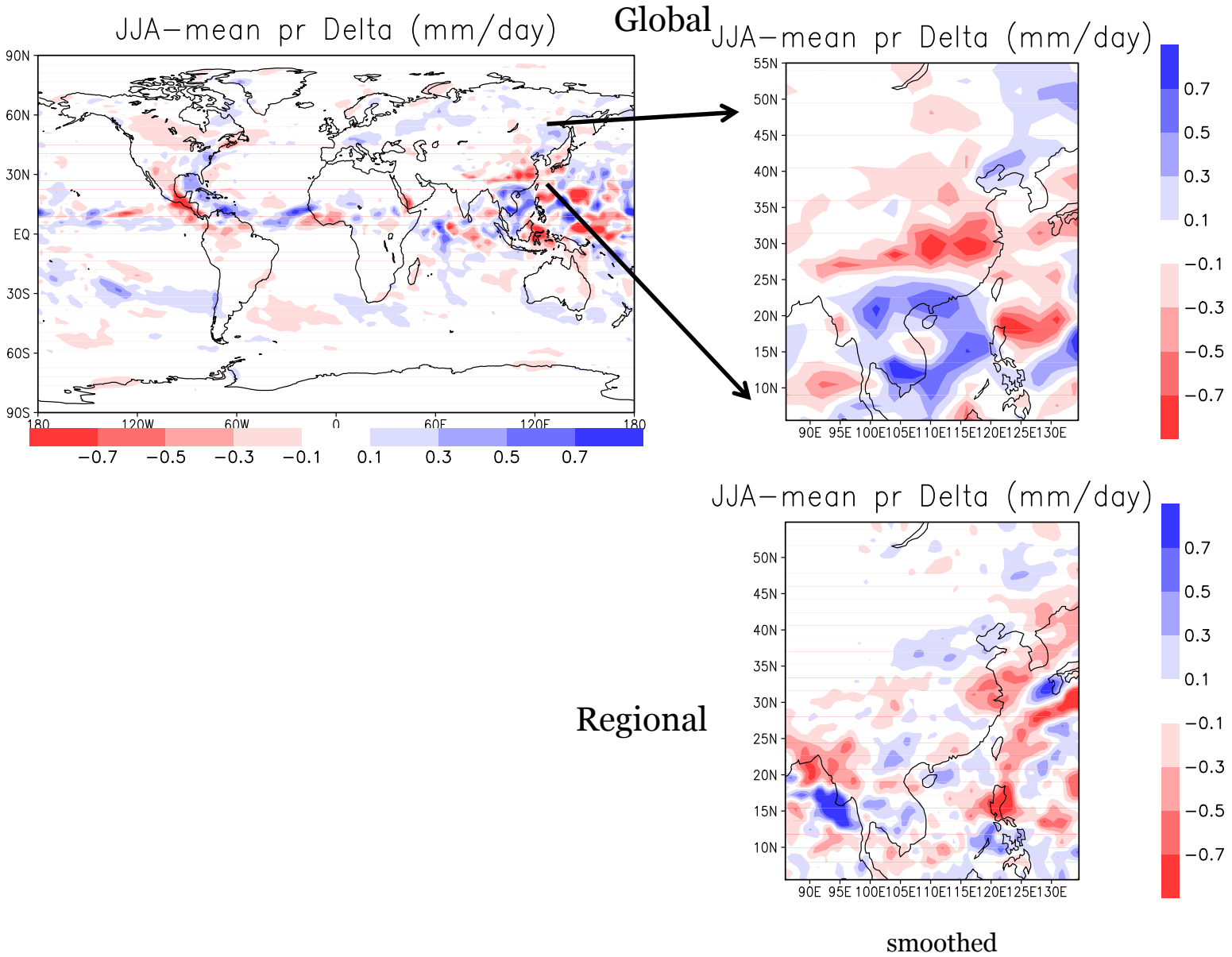




Changes in surf air temp



Changes in precipitation


Global
JJA−mean pr Delta (mm/day)
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
−0.7 −0.5 −0.3 −0.1 0.1 0.3 0.5 0.7
JJA−mean pr Delta (mm/day)
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
90E 95E 100E105E110E115E120E125E130E
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
−0.7
Regional
JJA−mean pr Delta (mm/day)
50N
45N
40N
35N
30N
25N
20N
15N
10N
90E 95E 100E105E110E115E120E125E130E
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
−0.7
smoothed

Urbanization in the Yangtze river Delta :

- **Local warming and drying effects.**
- **Enhance the summer monsoon.**
- **Global effects are difficult to assess.**

A downscaling study for France with three resolutions of LMDZ:

Global / Europe / France

Pr (mm/day), Tx(° C) et Tn (° C) 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**

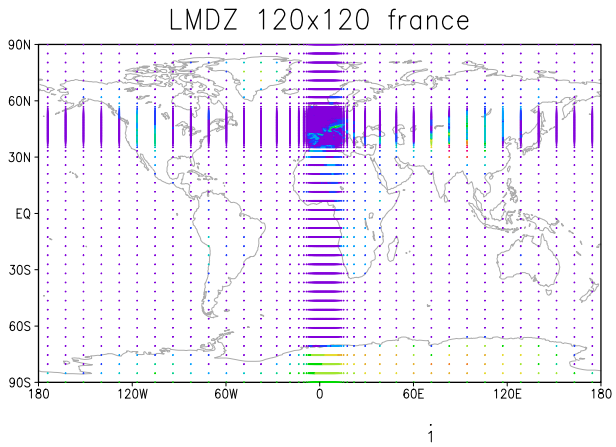
Tx	Obs	300km	100km	20km
1961/1990	**38.9**	**32.2**	**34.7**	**35.6**
2021/2050	**?**	**36.0**	**36.9**	**37.5**

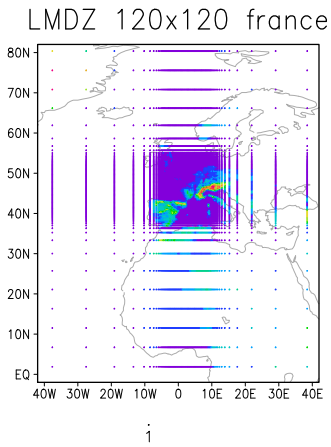
Tn	Obs	300km	100km	20km
1961/1990	**26.2**	**21.7**	**24.8**	**25.6**
2021/2050	**?**	**24.0**	**27.0**	**27.8**

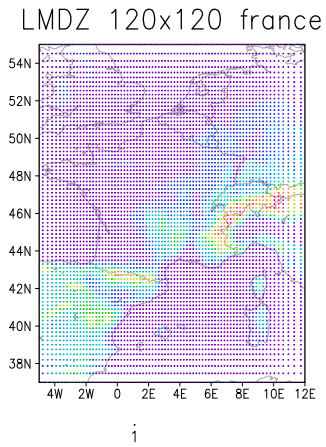
Pr: precipitation

Tx: daily-maxi temperature

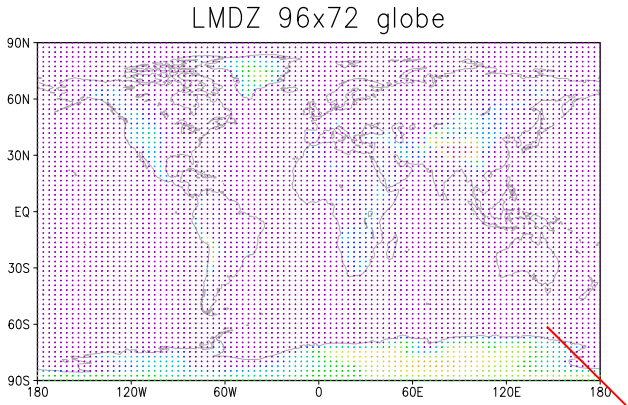
Tn: daily-mini temperature

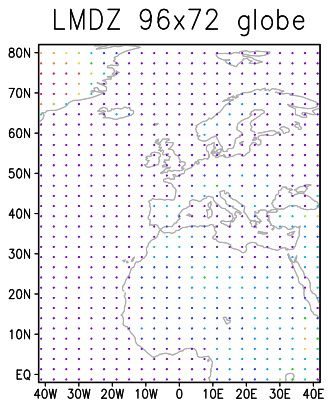


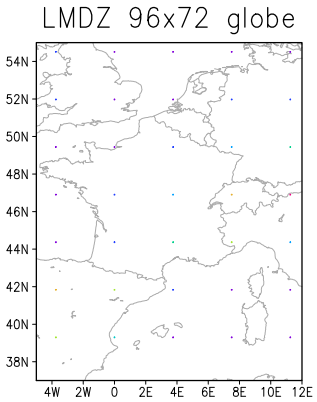




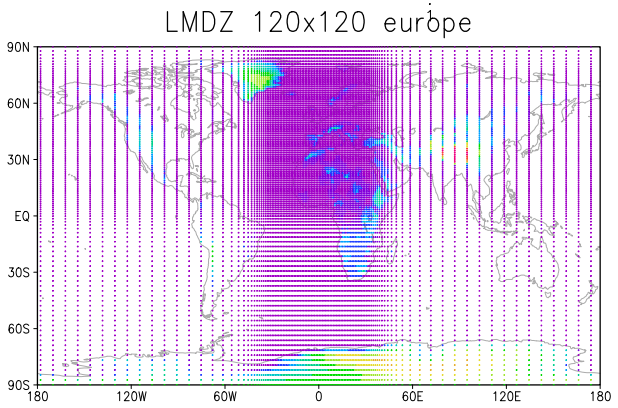
LMDZ grid schemes for the whole earth (left), for Europe (middle) and for France (right) in three versions

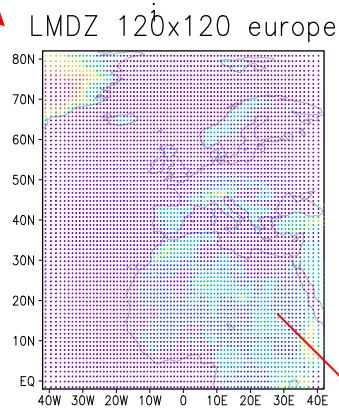


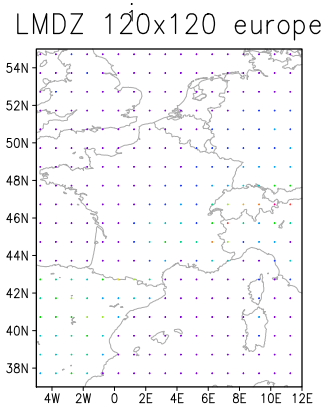




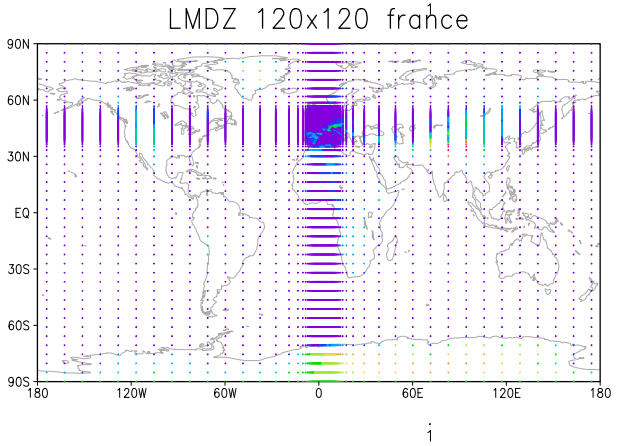
LMDZ Globe
(300 km)

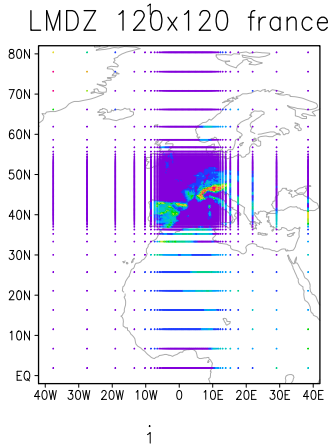


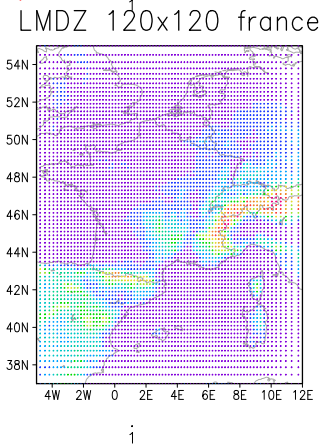




LMDZ Europe
(100 km)

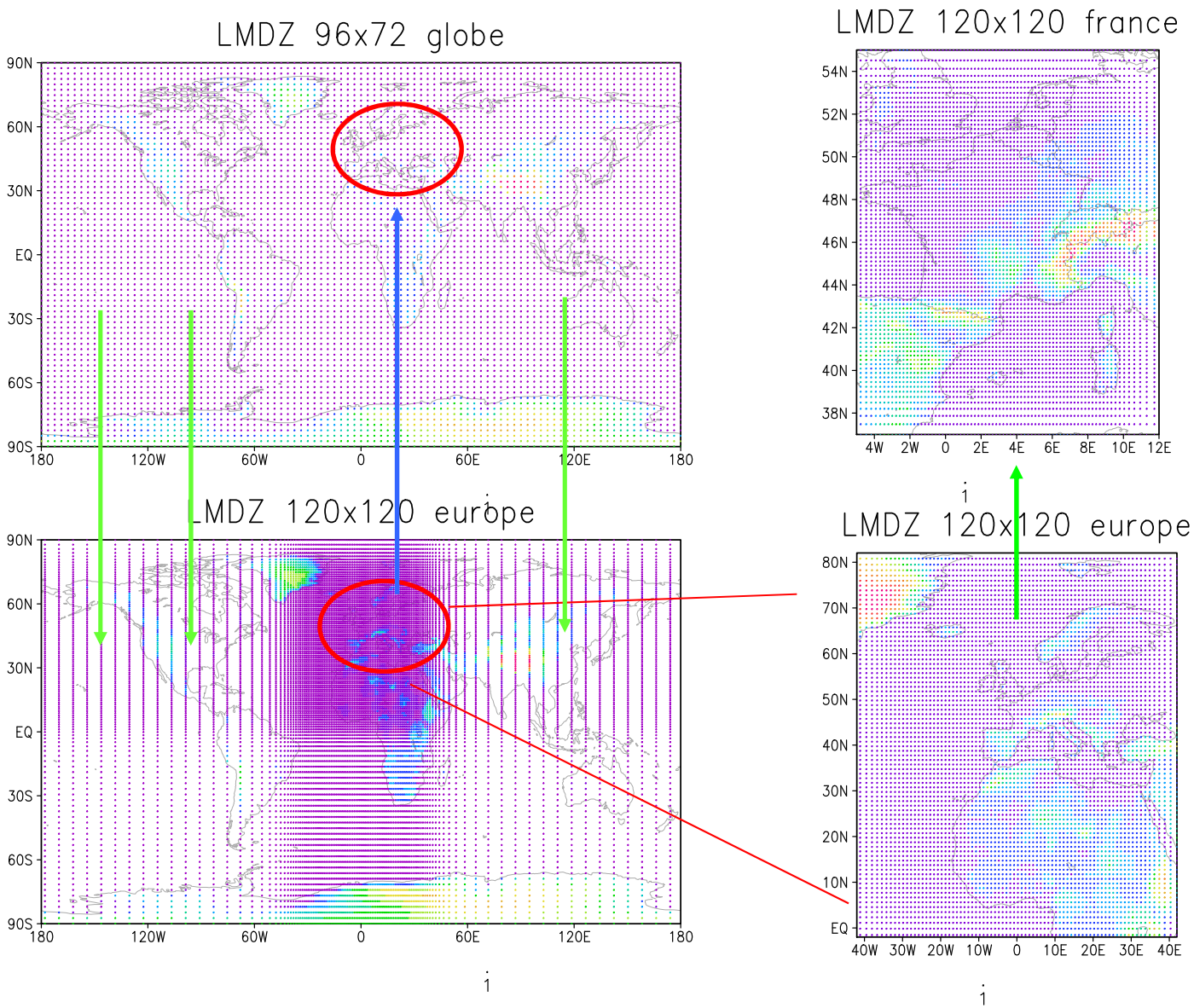




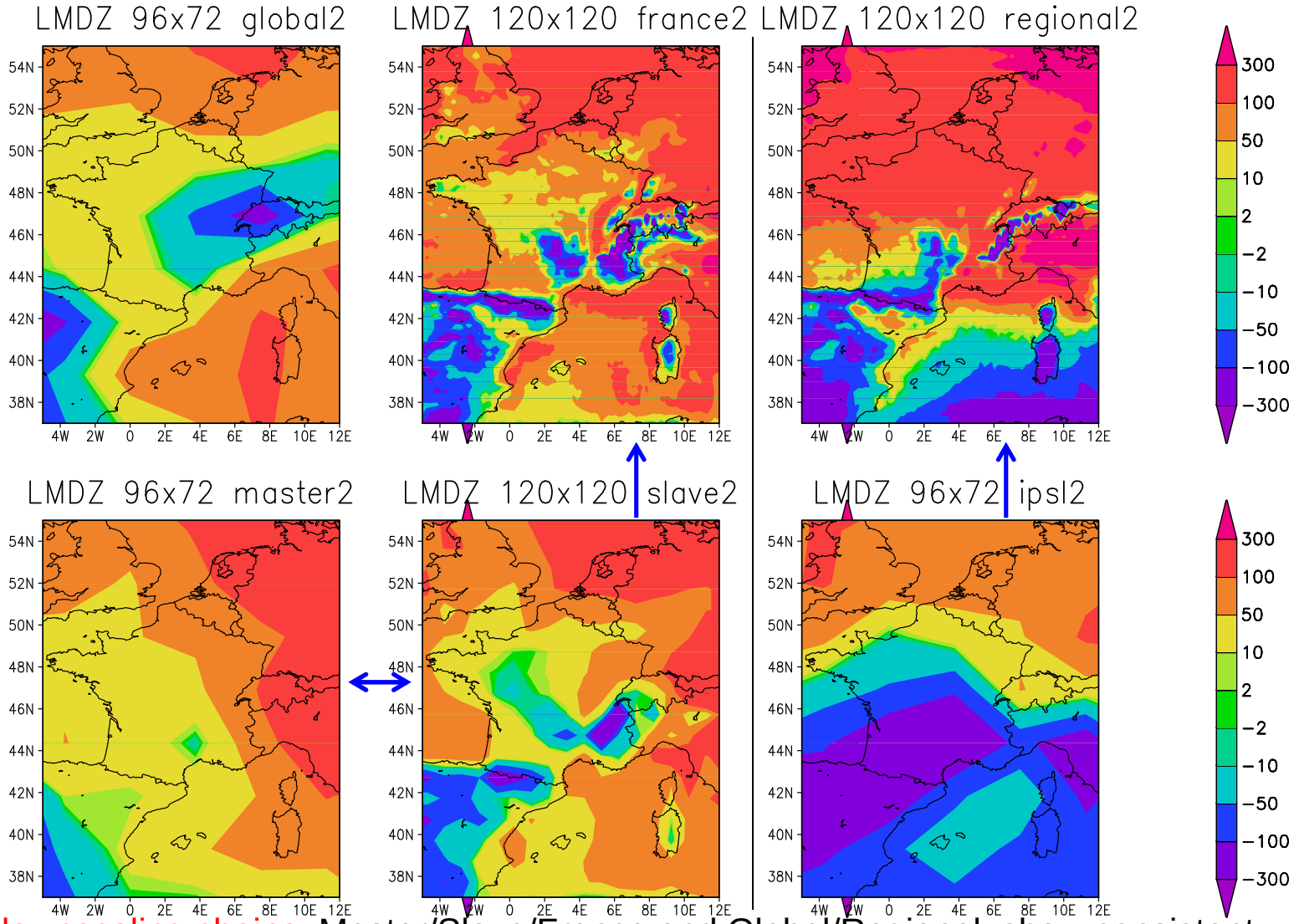


LMDZ France
(20 km)

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

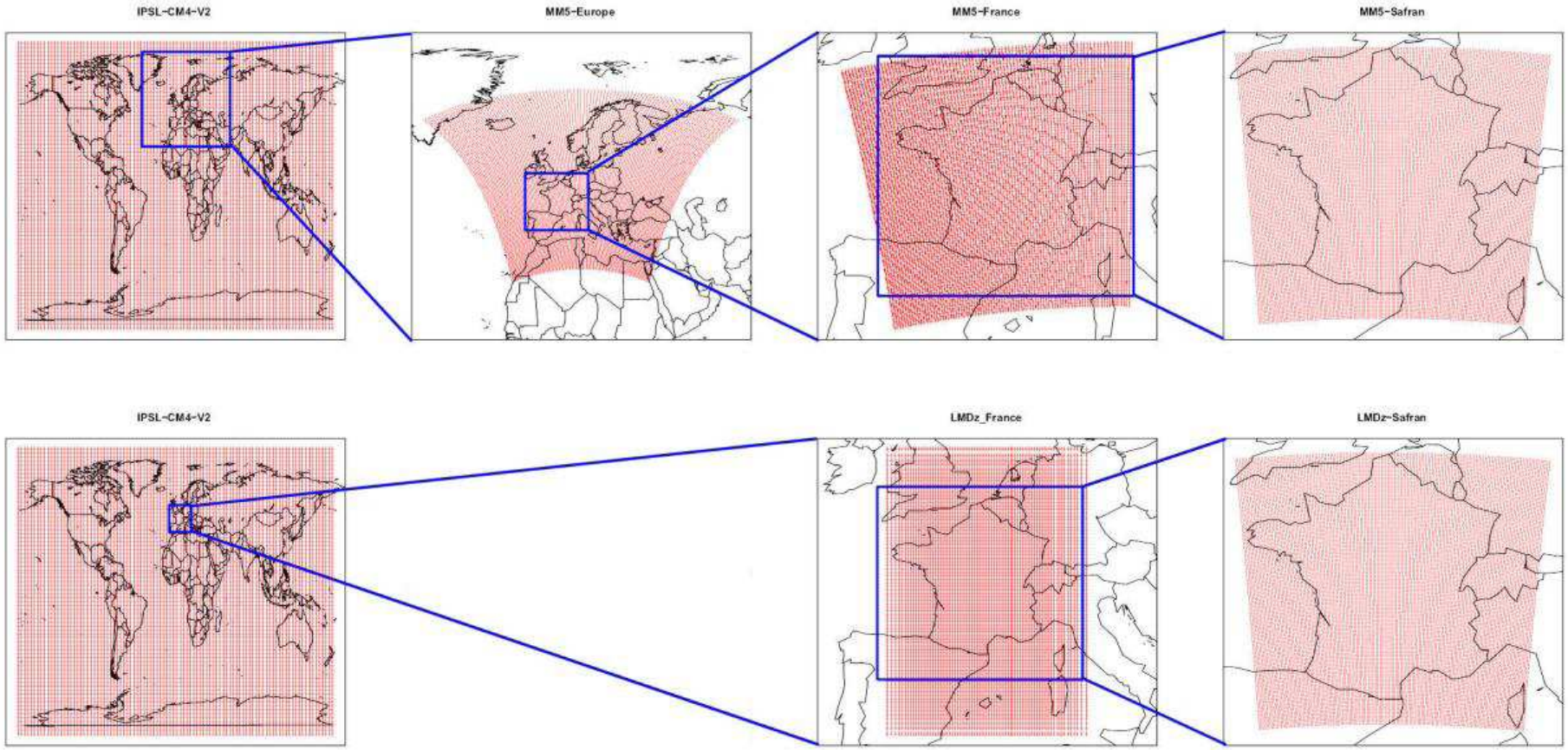


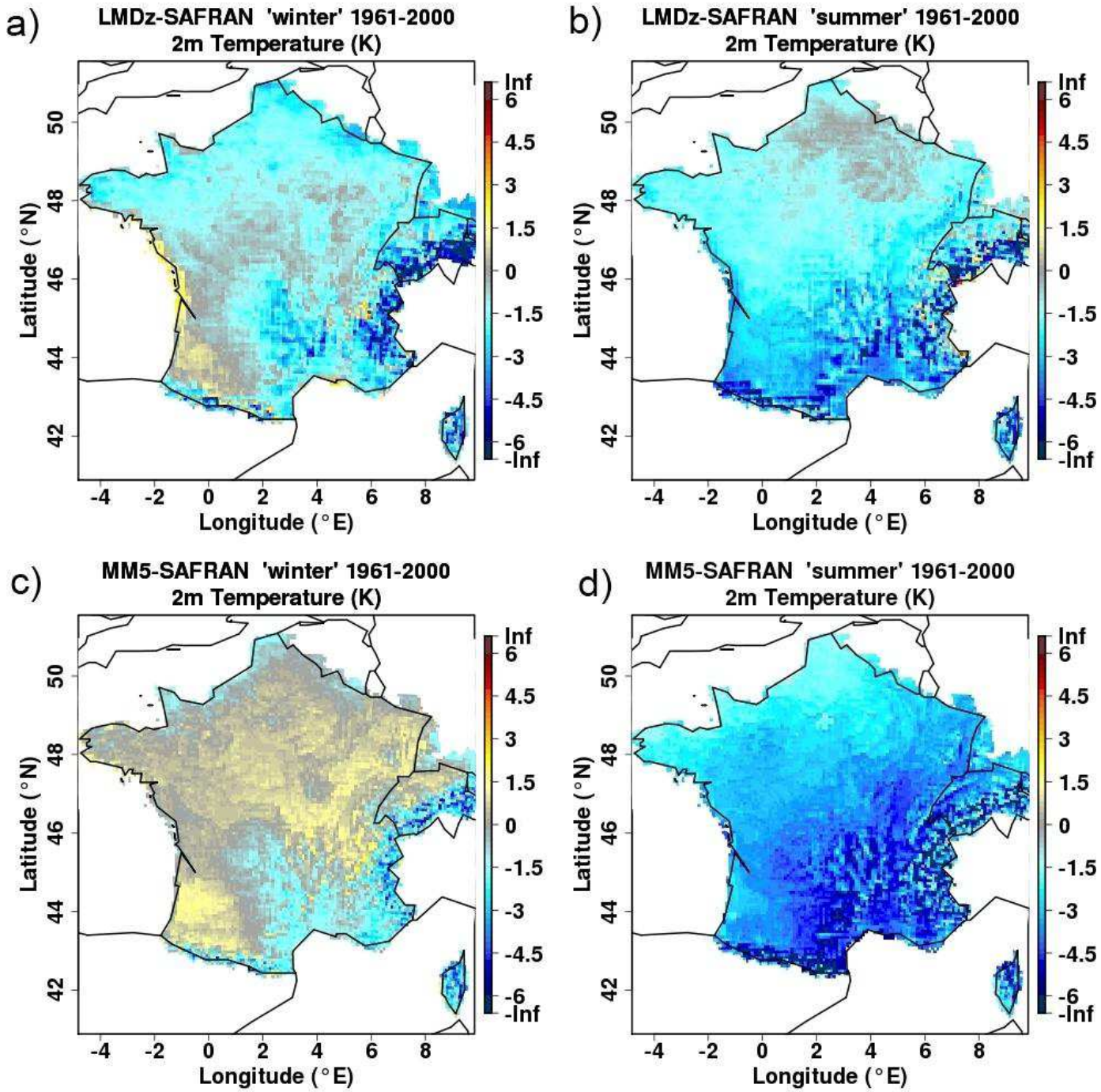
Annual Delta precipitations (2071/2100 – 1971/2000)



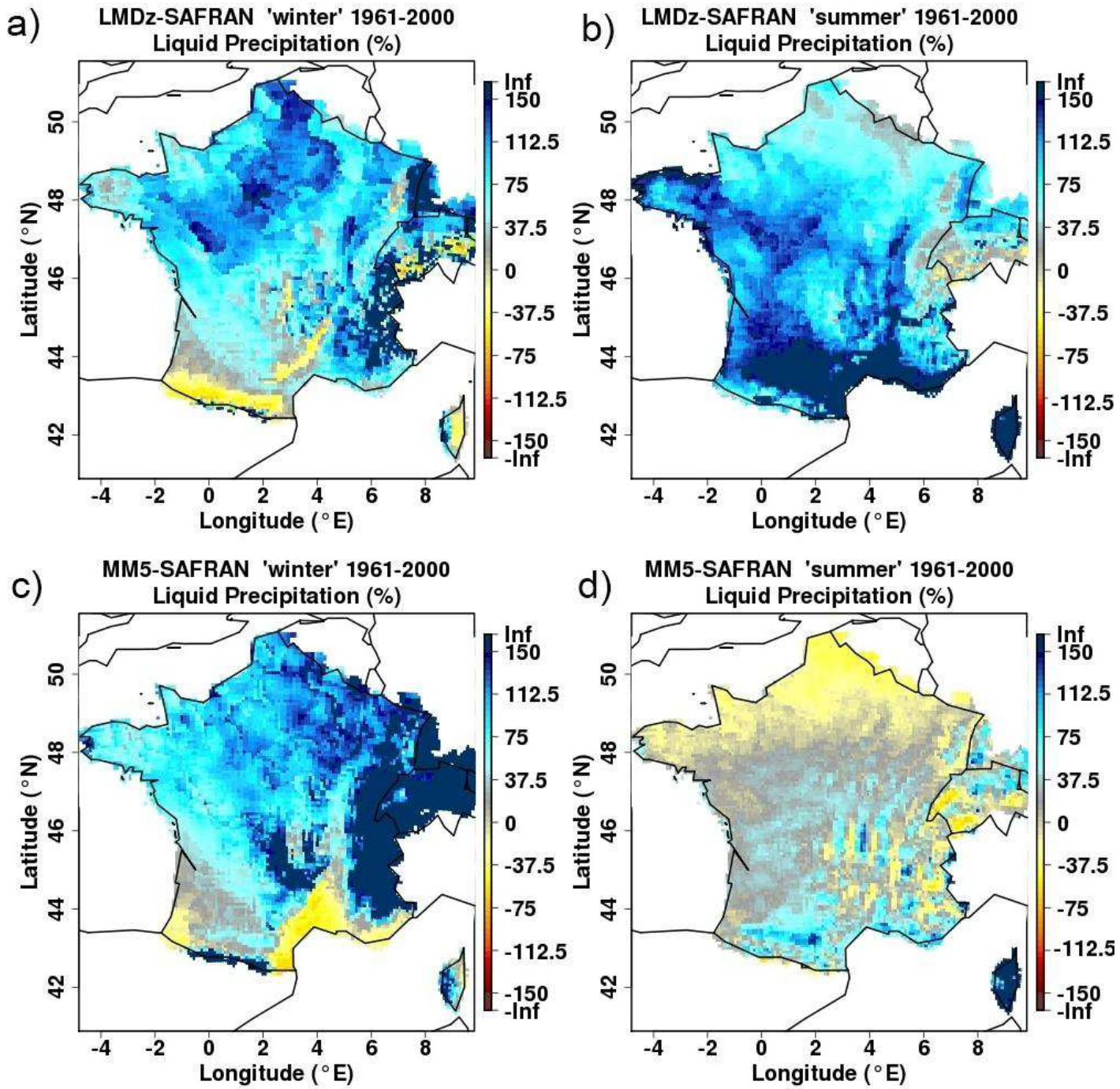
- Two downscaling chains, Master/Slave/France and Global/Regional, show consistent relationship between Global scale and Regional scale.
- Two-way nesting does show up-scaling effects.
- The two chains reveal significant differences in terms of climate change. This seems caused by excitation of different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

Comparing LMDZ and MM5 Metropolitan France

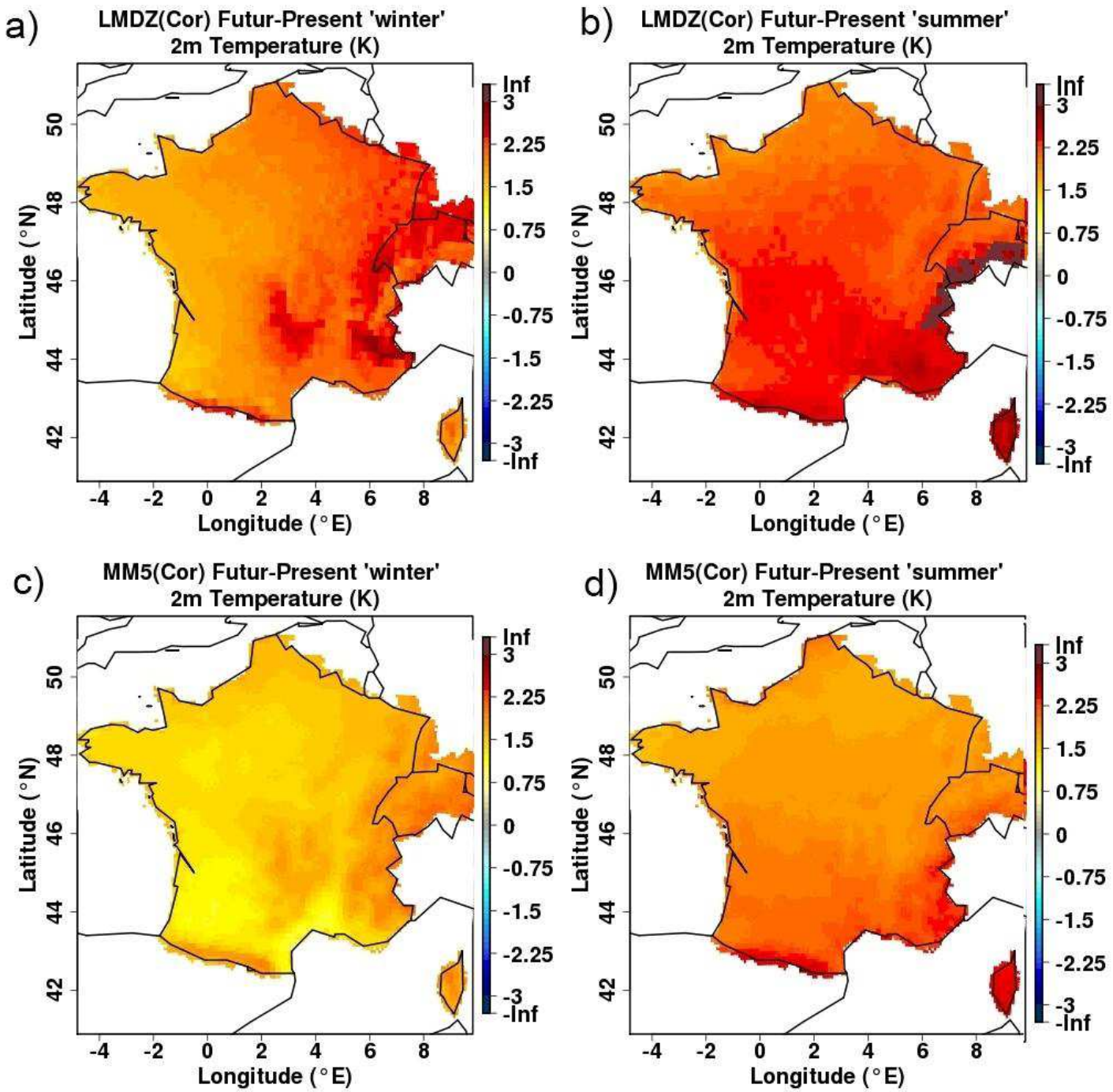




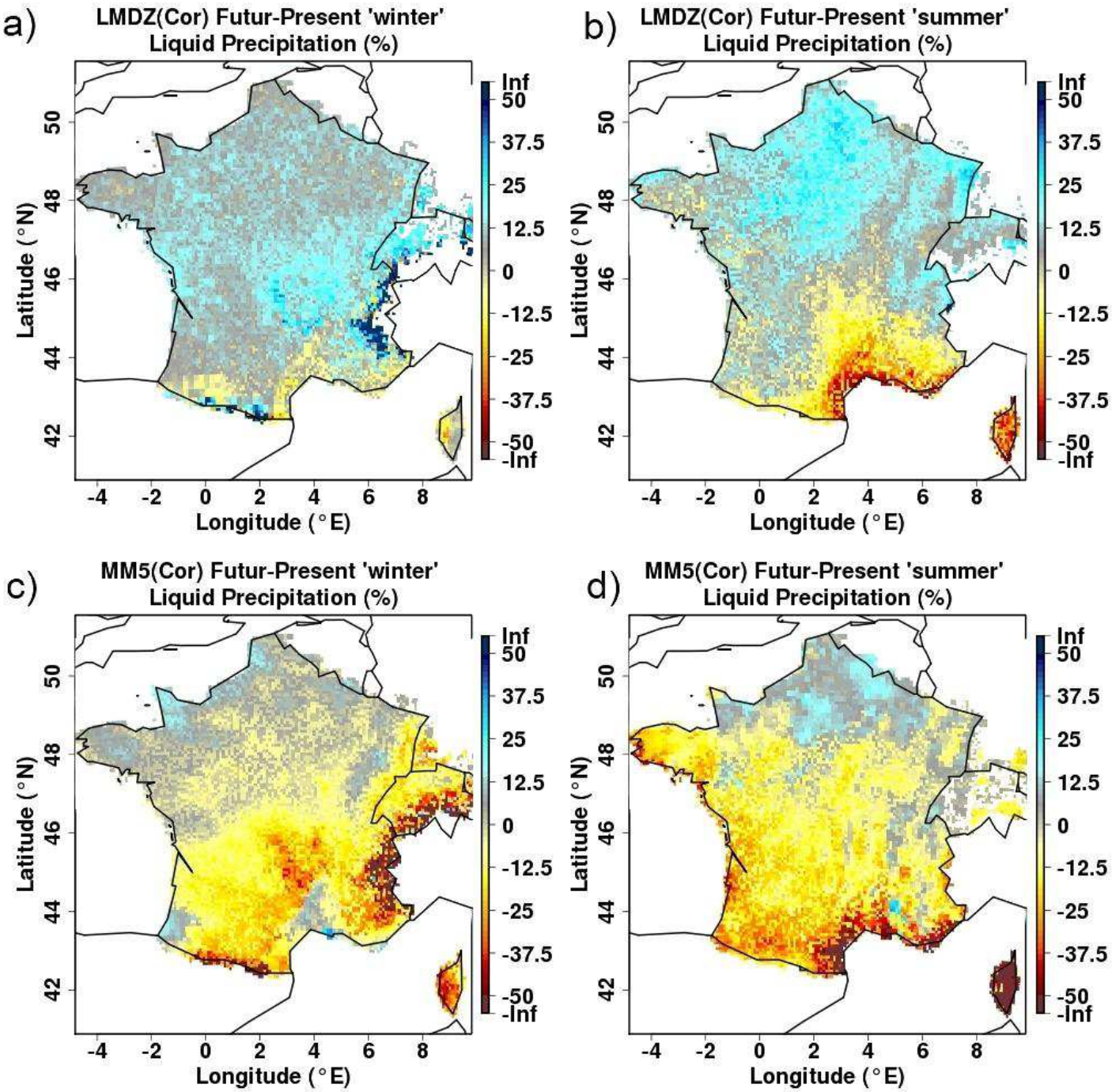
Models biases
2m temperature



Models biases
Rainfall



Future projection (2050)
2m temperature



Future projection (2050)
Rainfall

Conclusions

- **Added values of RCM: spatial details and extreme events**
- **Scale interactions between global and regional: choice of global or regional models is dependent on the phenomenon to study; downscaling / up-scaling**
- **Uncertainties in model results: multi-model approach**