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Population Growth and Climate Change : their impact on Planet Earth and its Human Societies

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February 12, 2008

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LA SCIENCE A PARIS

INSTITUT DE FRANCE
Académie des sciences

Reference :

French Academy of Sciences

"Science and Technology Report" # 25

Prepared for the French Government

Published, October, 16, 2006

"EDP Sciences" Paris, 322 p.

Title : **"Continental Waters"**

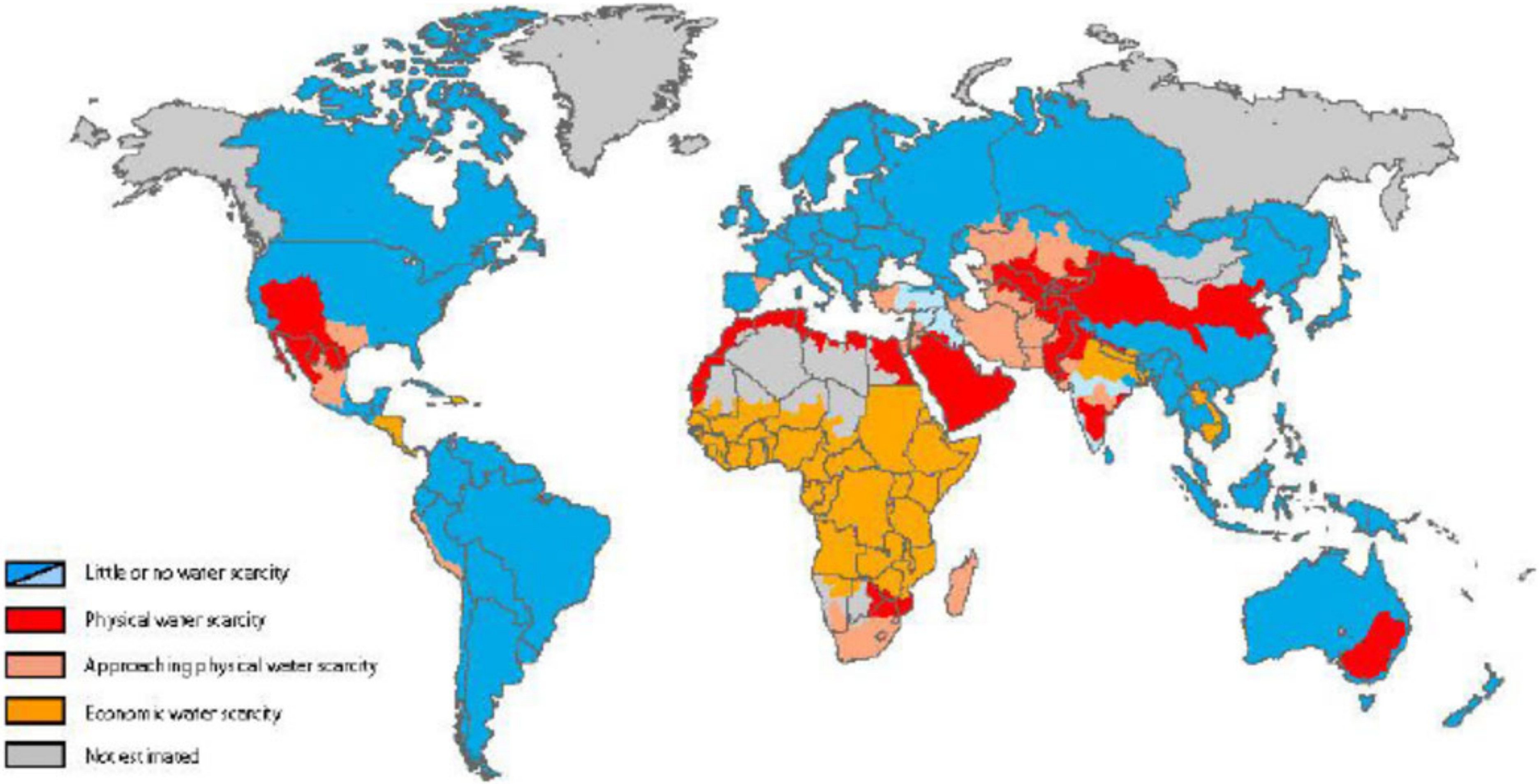
"Les Eaux Continentales"

(in French, abstract in English)

Outline :

- Current water shortages
- Hydrologic consequences of climate change on water resources
- Water for food & demographic growth
- Water for biofuel production
- Ecosystems
- Droughts
- Conclusions

Current water shortages…



<u>Zones with water shortages in 2000, fom IWMI [2007].</u>

<u>Red</u> : Physical water shortage ; more than 75% of the river flow is withdrawn for human needs, taking into account recycling

<u>Pink</u> : More than 60% of the river flow is withdrawn. These basins will soon become red

<u>Orange</u> : Economical water shortage. Resources are large compared to the withdrawals, with less than 25% of the river flow, but the population is undernourished.

The financial resource is lacking for water resource development.

<u>Blue</u> : Abundant water resources. Withdrawal are less than 25% of river flow.

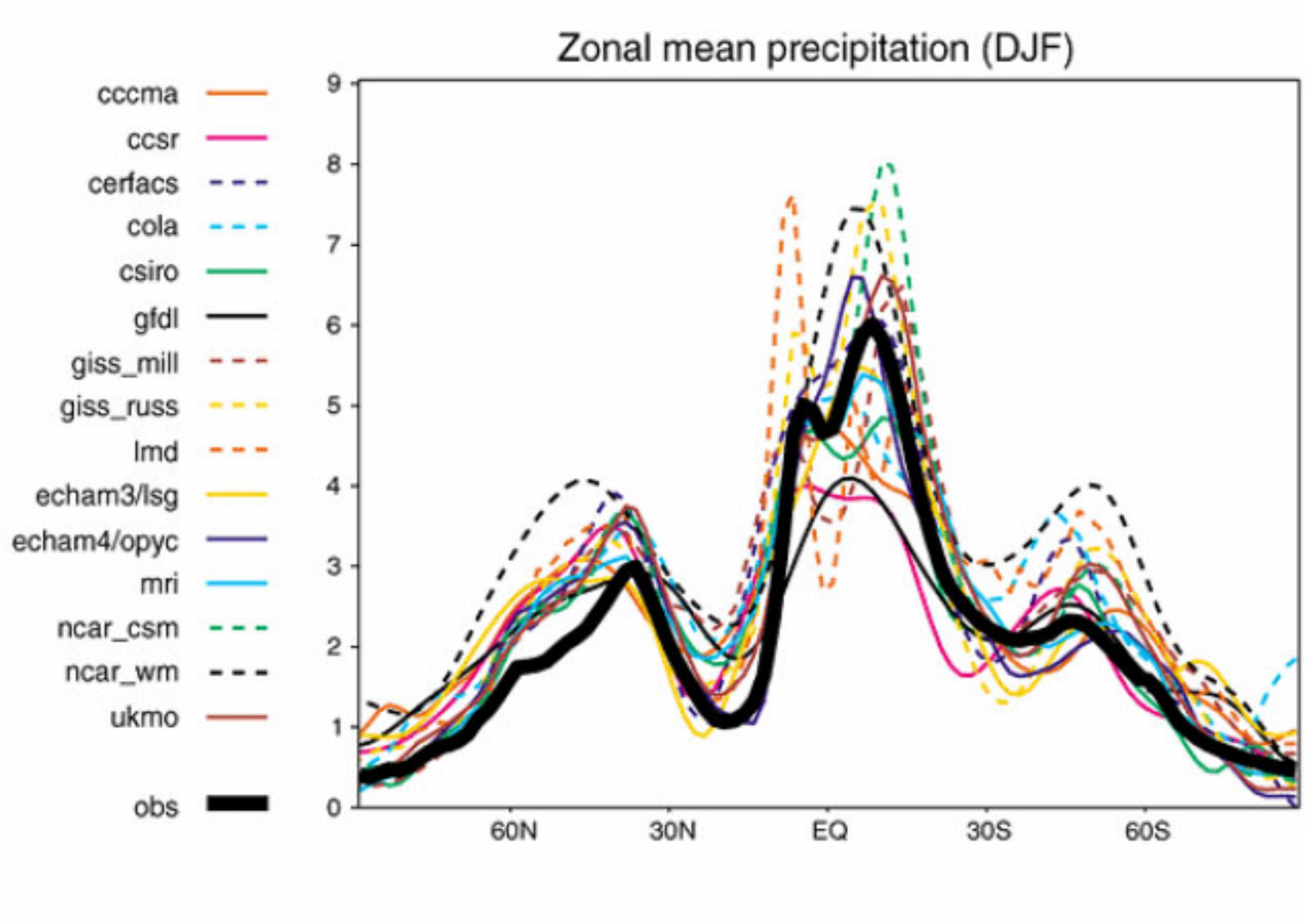
Expected effects of Climate Change…

Consequences of Climate Changes on the hydrologic regime : **More uncertainties than for temperature… but** :

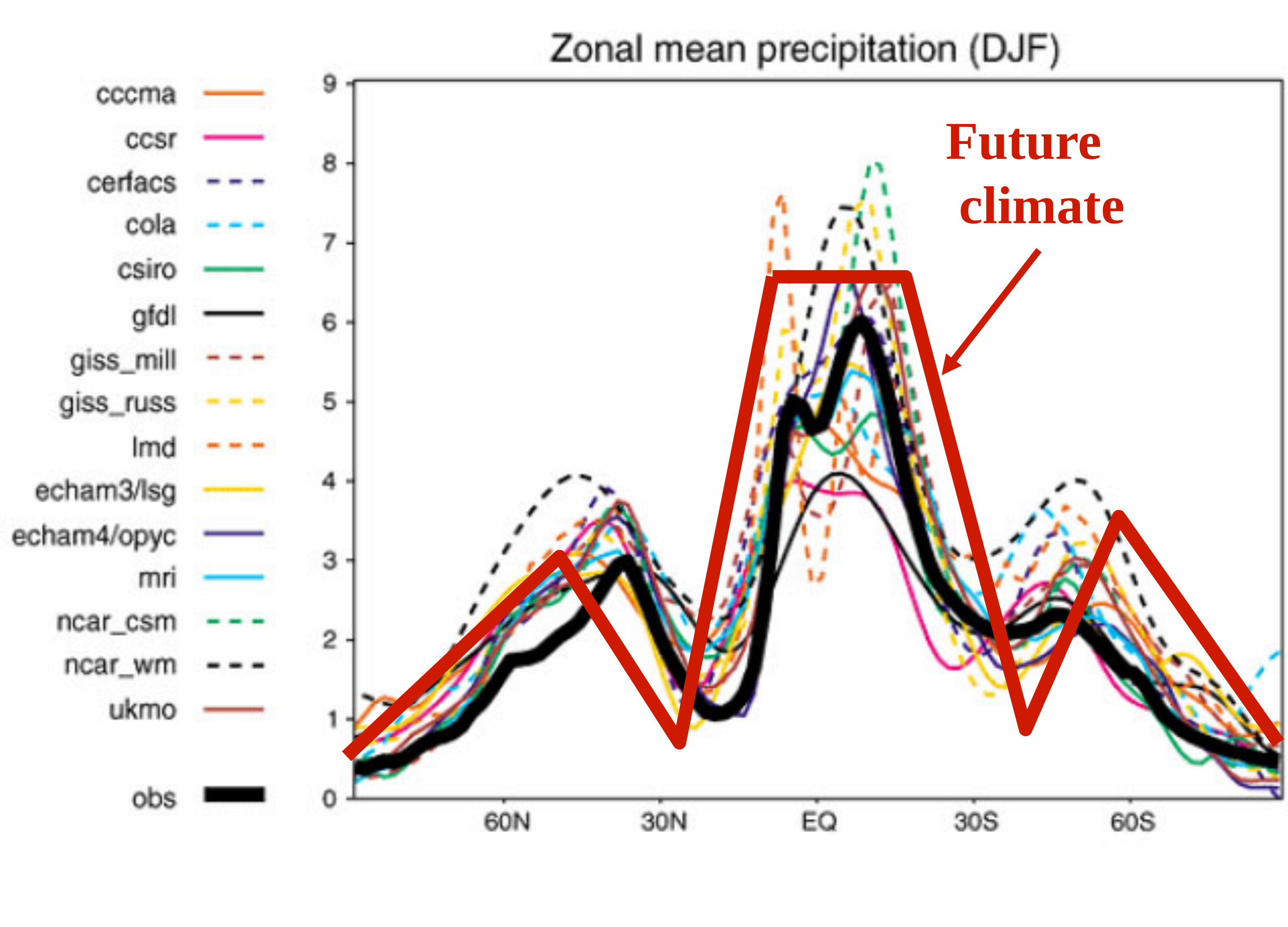
- **General acceleration of the water cycle**

  (more evaporation on oceans and continents, more rainfall…)
- Globally, a general **shift of the climate zones** form the Equator towards the Poles
- With large regional variations
- And large controversies on extreme events…

Variation of rainfall (from pole to pole) for 15 climate models, and current observations

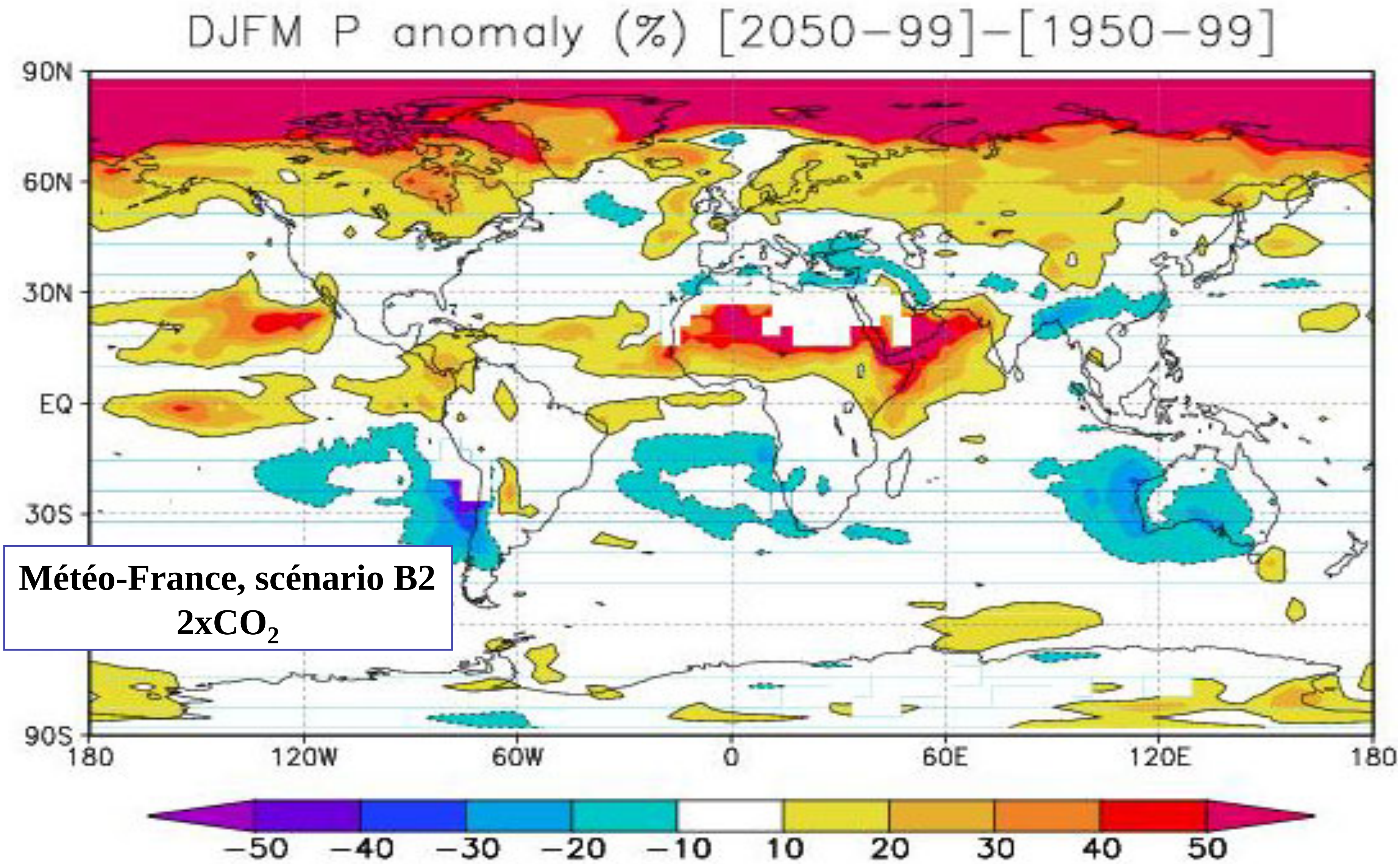


Variation of rainfall (from pole to pole) for 15 climate models, and observations



Variations (in %) of Rainfall between 2050-99 and 1950-99

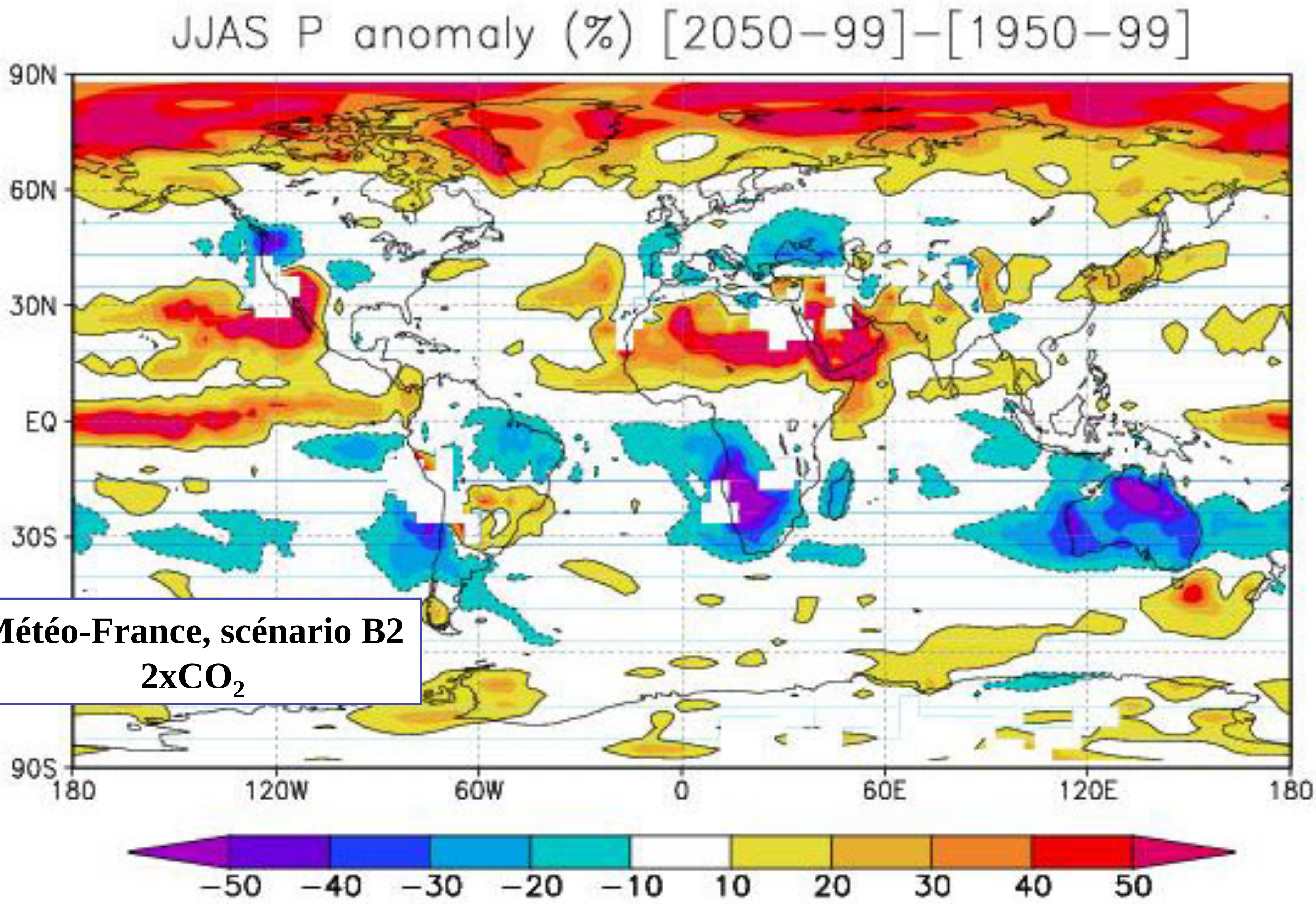
December January February Mars



Météo-France, scénario B2
2xCO_2

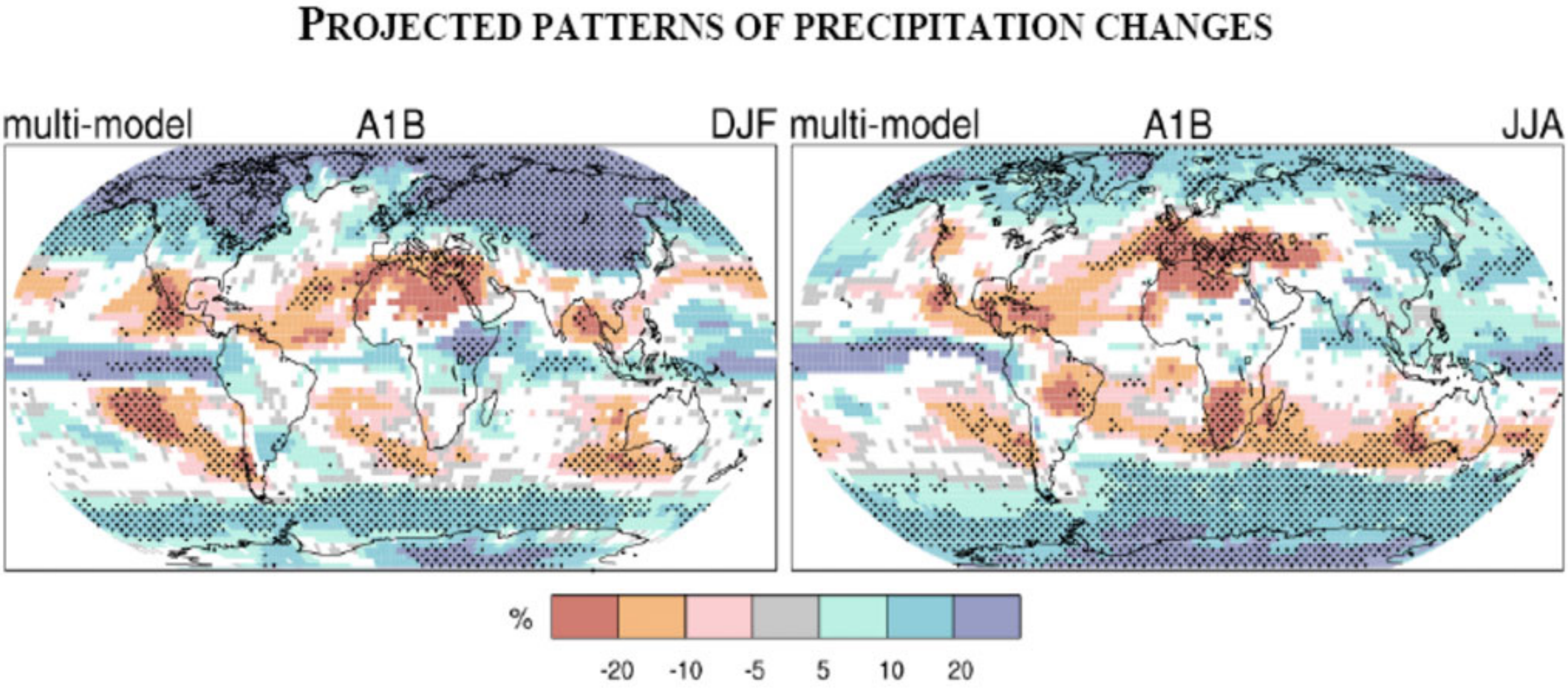
Variations (in %) of Rainfall between 2050-99 and 1950-99

June July August September



Météo-France, scénario B2
2xCO_2

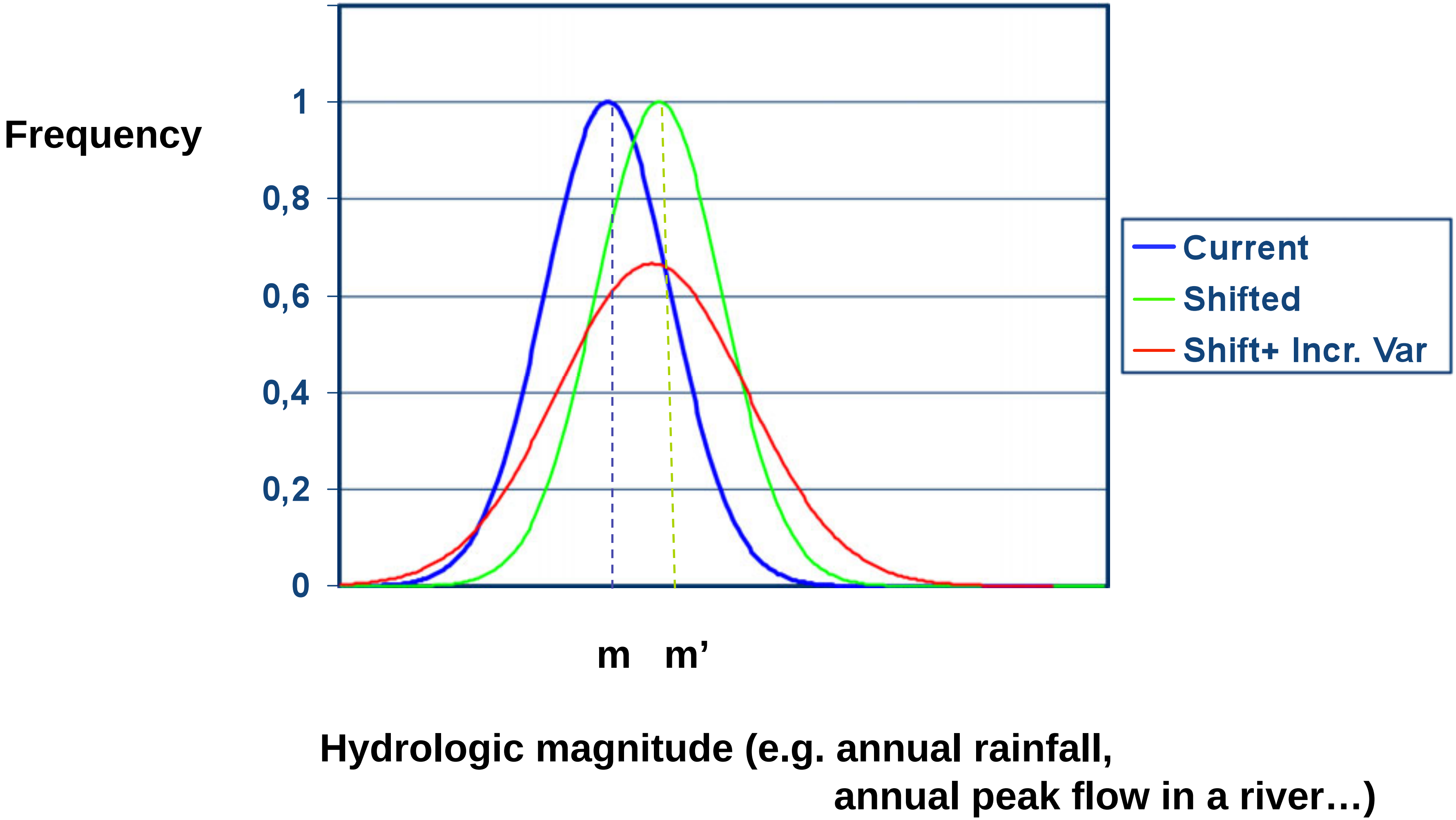
IPCC Report, 2007



Likely changes after 2050

Geographic Zone	December to March	June to September
Equatorial Africa	+25%	+10%
African Sahel	Uncertain +/- 10%	+30%
North Africa	-15%	-10%
Southern Europe	uncertain +/-10%	-20%
France on average	+15%	uncertain +/- 10%
Scandinavia, Siberia	+25%	+15%

Variations of the extremes



Consequences : Water in the soil, Floods and ice melting

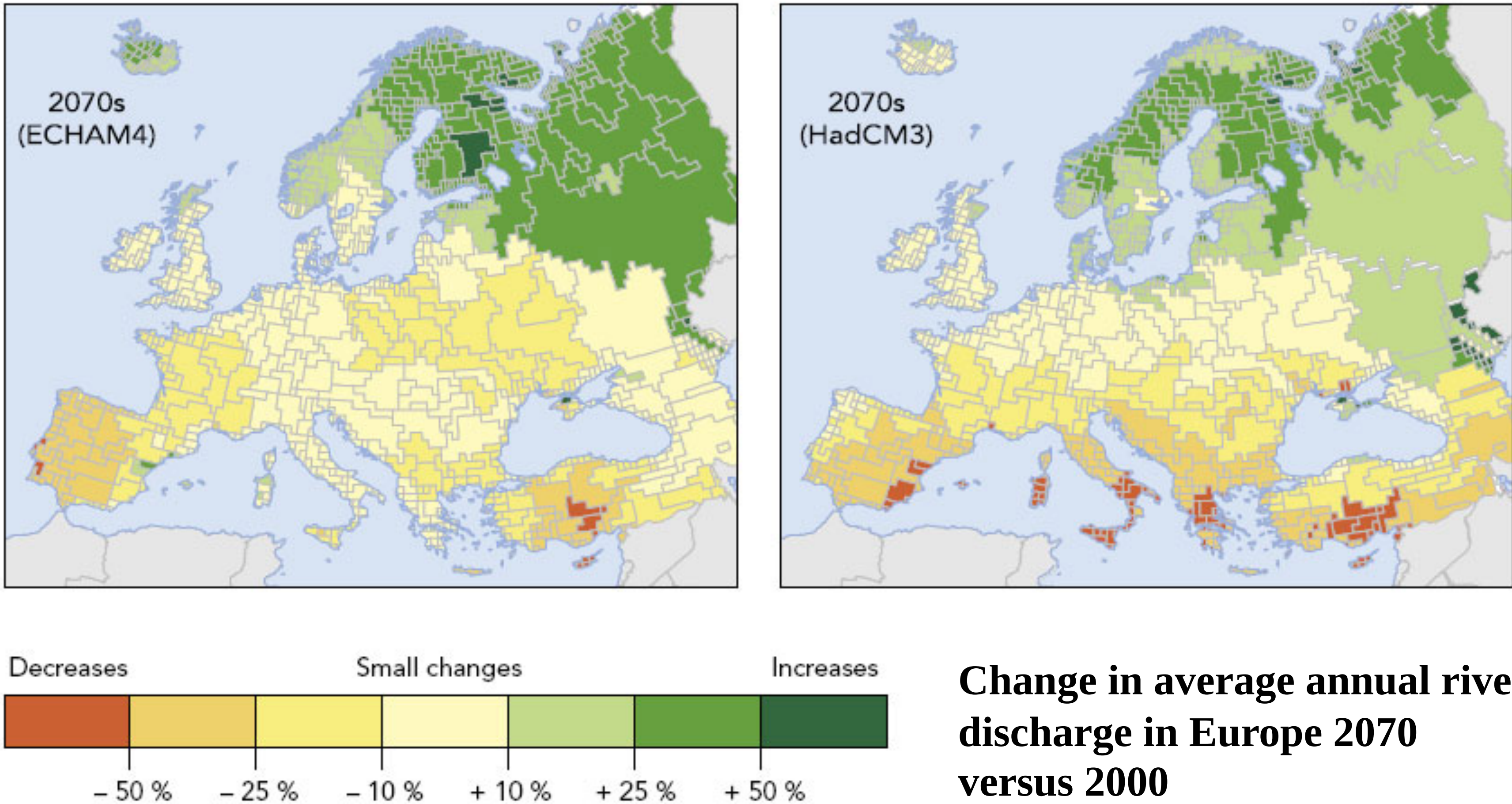
- In **Mediterranean-latitude** zones :

  -Large **decrease of soil water content** (higher evapotranspiration, lower rainfall in summer), more irrigation water needed

  -Increased risk of **edaphic (agricultural) droughts**, more than **hydrologic droughts**

  -Increased risk of **forest fires**
- **In Northern latitudes : floods** are probably more of concern
- **Mountain Ice melting** (Cordillera of the Andes, Alps, Himalayas…)

Changes in flow rates of rivers

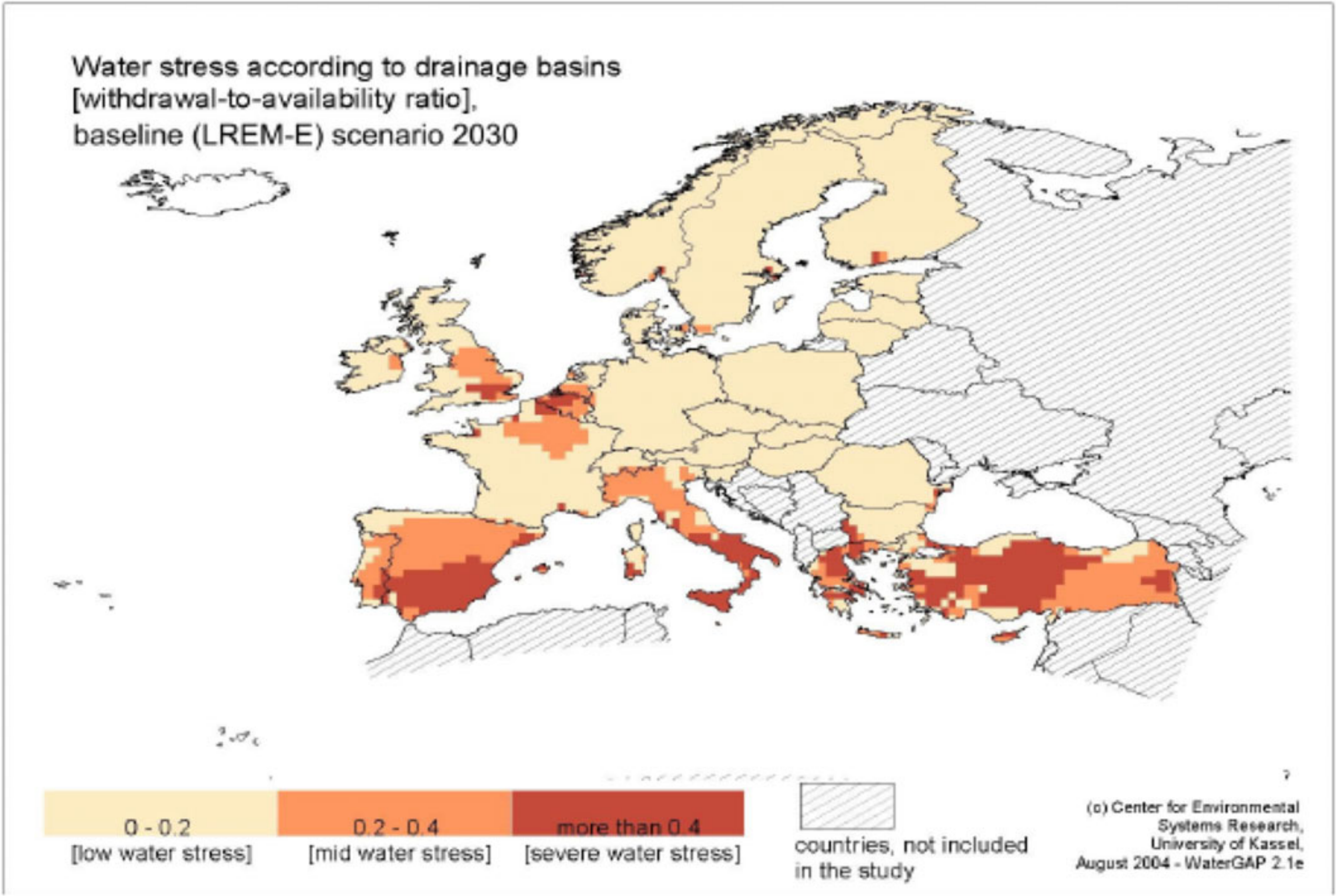


Note: Two different climate models (ECHAM4 and HadCM3).
Source: Lehner *et al.*, 2001.

Change in average annual river discharge in Europe 2070 versus 2000

Source: Henrichs et al 2002;
EEA (2004) – (Eurowasser)

Water Stress in Europe, 2030 *(From EU Water saving potential, Fig 12, July 2007)*



Water for food
and demographic growth…

Water Demand	**1900**	**1950**	**1980**	**1990**	**2000**
Population (millions)	2,000	2,542	4,410	5,285	**6,200**
Total annual withdrawal, km^3/y	579	1,382	3,175	3,632	4,000
Total Consumption, km^3/y	330	758	1,554	1,821	**1,950**
Irrigated area, M ha	47.3	101	198	243	**265**
Agricultural withdrawal, km^3/y	513	1,080	2,112	2,425	2,600
Agricultural consumption, km^3/y	321	722	1,445	1,697	**1,800**
Consumption/withdrawal ratio	63 %	67 %	68 %	70 %	70 %
Cultivated area, M ha					**1,300**
Rain-fed Agriculture, km^3/y					**5,000**
Domestic withdrawal, km^3/y	21.5	86.7	219	305	380
Domestic Consumption, km^3/y	4.6	16.7	38.3	45	**50**
Consumption/withdrawal ratio	21 %	19 %	17 %	15 %	14 %
Industrial withdrawal, km^3/y	44	204	713	735	780
Industrial Consumption, km^3/y	5	19	71	79	**100**
Consumption/withdrawal ratio	11 %	9 %	10 %	11 %	11 %
Evaporation from dams, km^3/y	0.3	11.1	131	167	**210**

Adapted from Shiklomanov, 1999, and Académie des Sc., 2006
(Estimated available water resource : 13,500 km^3/y for withdrawal)

Today's situation :

- Today, 6.2 billion inhabitants
- Among which **856 millions undernourished**, this number was decreasing for the last 50 years, but has started to increase for the last 5 years.
- Food comes from :
  - **265 millions irrigated ha**, (water : 1,800 km^3/an)
  - **1,300 millions ha rain-fed agriculture** (water : 5,000 km^3/an)
  - 17% of irrigated land produces 40% of the food
- Rice, maize and wheat currently provide, in equal shares, 60% of the world food production (around 700 million tons/ year each).
- Rice and maize depend greatly on irrigation water supply.

In 2050

- About 9 billion inhabitants, i.e. ~ 70 millions more/y
- More food required to feed them and eradicate current hunger (856 million people); diet changes must also be considered :

Plant products	Water consumed	Animal products	Water consumed
Vegetable oil	**5000**	Beef	**13,000**
Rice	**1500-2000**	Poultry	**4,000**
Wheat, C3 cereals	**1000**	Eggs	**2,700**
Corn, C4 cereals	**700**	Milk	**800**
Citrus fruit	**400**		
Vegetables	**200-400**		
Potatoes	**100**		

Water needed (m^3/t) to produce raw food (consumed fraction, not in dry matter)

The food multiplier factor 2050/2000

(Cereals)

Regions	Asia	Latin America	West Asia North Africa	Sub-Saharan Africa	OECD and Russia
Food needs multiplier 2050/2000	2.34	1.92	≈2.5	5.14	≈1
Production 2000, Mt	**1800**	**272**	**154**	**262**	**-**
Production needed in 2050, Mt	**4150**	**520**	**390**	**1350**	**Idem 2000**

From P. Collomb and M. Griffon (2006).

Solutions :

4,500 km^3/y additional water is needed

- Improve crop efficiency
- more irrigated crops
- more rain-fed agriculture
- Favour the cultivation of hardier, less “thirsty” varieties, and develop new ones that are more suited to semiarid conditions (30 to 40 % of the earth’s surface is arid or semiarid) or even to slightly saline soils (several tens of millions of hectares).
- But genetic means cannot drastically modify the “water for CO_2” exchange….

Irrigated agriculture

- Today 264 million ha
- Current rate of increase : 1.34 millions ha/y
- In 2050, with current rate, 331 millions ha
- Additional water consumption 500 km^3/y

- **Insufficient…compared to the nedeed 4,500 km^3/y … multiply by 10 the rate of increase ???? More dams and canals ?**

Rain-fed agriculture

- Current rain-fed agriculture :1.3 billion ha, using 5,000 km^3/y
- Total continental surface area :13,4 billion ha
- 4,2 billion ha could be cultivated (FAO)
- **Find 1 billion more ha…(forest, marshland, steppe..) ?**

Land available for agriculture in 2000 (10^6ha)

	World	Asia	Latin Amer.	WANA	SS Africa	OECD	Russia
Area cultivated 2000 (a)	1600	439	203	86	228	387	265
Area fitted for agriculture (b)	4400 (IIASA) 4153 (FAO)	586	1066	99	1031	874	497
a/b	39%	75%	19%	87%	22%	44%	53%

FAO data

Scenario 1: Tendancy; increase based on rain-fed agriculture, Yields and Surface Area (Griffon, 2006)

	Asia	Latin Am.	WANA	SSAfrica
A: increase (M ha) of agr. to supply food for needs in 2050	+50 (100 kept for protected areas)	+185	0 All space used	+600 (200 kept for protected areas)
B: assumtions on rain-fed yields	+50% (possible but difficult) **4t/ha=>6t/ha**	No change **1.35t/ha**	Difficult to increase significantly yields; lack water	+40% Starting from low yields (1.15t/ha) could reach easily **1.60t/ha**
C: expected increase of production (Mt)	≈+1200	+250	0	+1090
D: Total expected production 2050 (prod 2000+C)	3000	≈520	154	1350
E: Needs 2050	4150	520	154	1350
F:Deficit 2050 (D-E)	**-1150**	**0**	**-236**	**0**

Scenario 3: Compensation of deficits by Latin America only (Africa balance =0) (Griffon, 2006)

	Asia	Latin America	WANA	SSAfrica
Production needed	4150	520	390	1350
Production obtained	3190±100	1704±100	166±10	1350
Shortage / surplus	-960 ±100	**+1184 ±100**	-224 ±10	0

What if land was also used for energy production from biomass?

Scenario 5: Combining food and energy : reasonably ambicious for 2050 (Griffon, 2006)
Million ha

	Asia	Latin America	WANA	SSAfrica	OECD	Russia and CIS	World
Area fitted for cropping	**585**	**1,066**	**99**	**1,031**	**874**	**497**	**4,152**
Protected areas	**100**	**300**	**0**	**200**	**300**	**100**	**1,000**
Area for food	**460**	**646**	**99**	**711**	**424**	**247**	**2,587**
Area for irrigation	*250*	*26*	*49*	*17*	*24*	*47*	*413*
Area rain-fed	*210*	*620*	*50*	*694*	*400*	*200*	*2,174*
Area for energy	**25**	**120**	**0**	**120**	**150**	**150**	**565**

Conclusions on Water and Food

- The World can be fed by 2050 with 9 billion inhabitants
- Large international food exchange required (virtual water)
- Water and land resources management will be very demanding

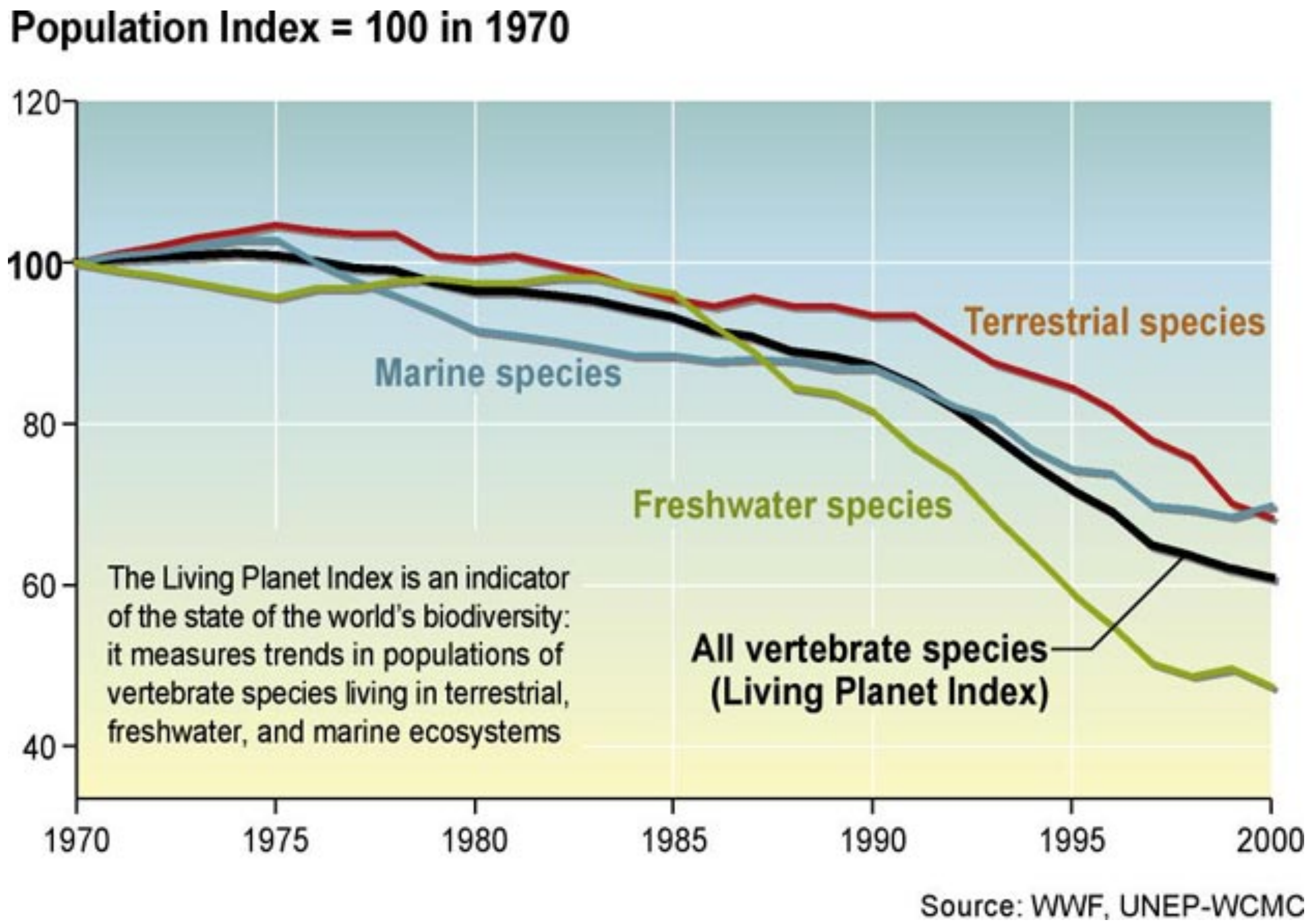
  - -allocation of resources, i.e. land and water
  - -optimal allocation of crops between rain fed and irrigated agriculture
  - -optimal crop efficiency,
  - -little room available for biofuels…

    see also Paul Crutzen, N_2O
  - **-Biodiversity conservation, if any left... ????**
  - **-droughts management…**

Water and land for ecosystems…

Blue Nile falls near lake Tana (Ethiopia)

Okavango Delta (Namibia)
Kinzelbach, 2006



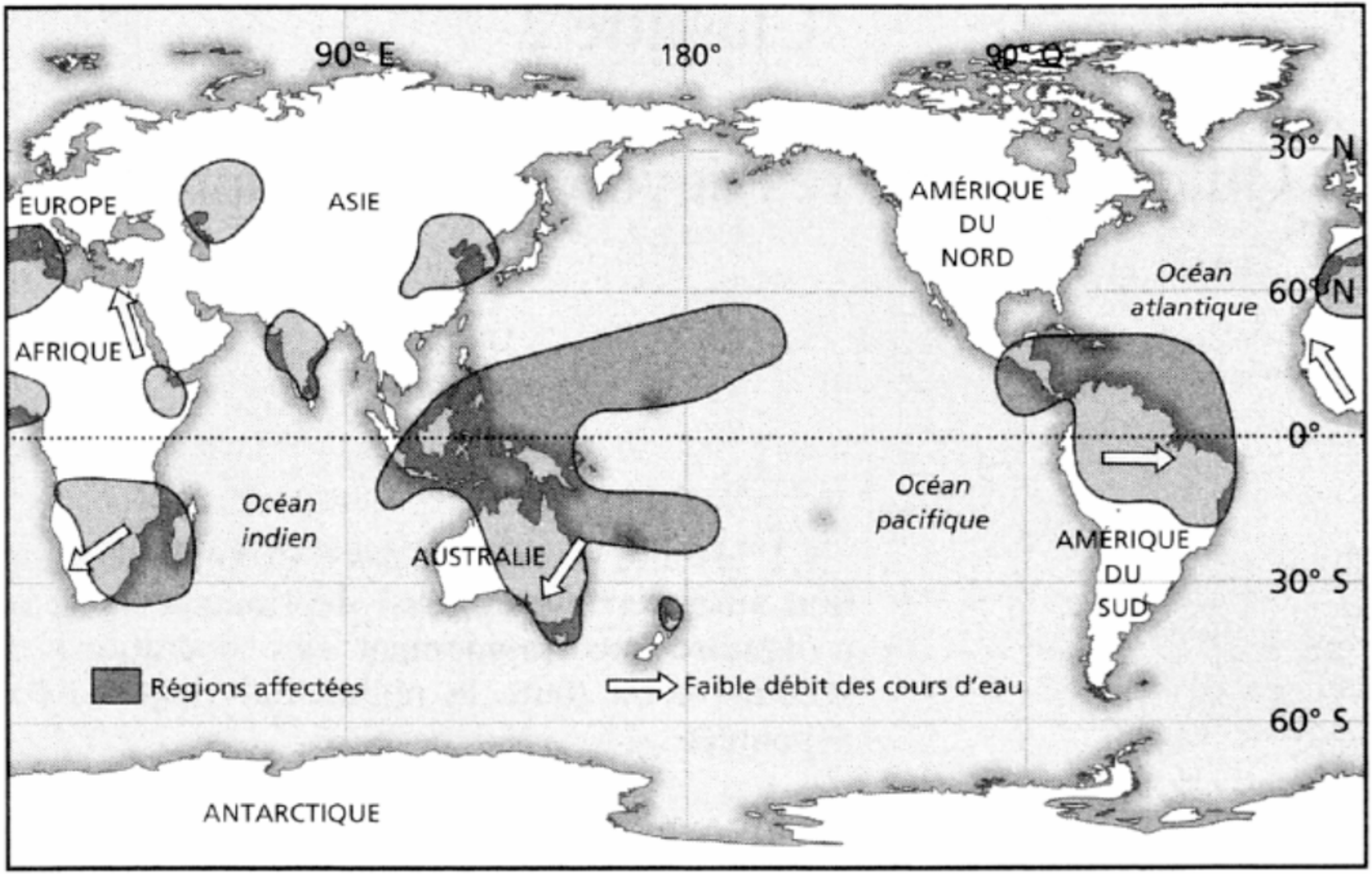
Population Index = 100 in 1970
120
100
80
60
40
1970
1975
1980
1985
1990
1995
2000
Terrestrial species
Marine species
Freshwater species
All vertebrate species
(Living Planet Index)
The Living Planet Index is an indicator of the state of the world's biodiversity: it measures trends in populations of vertebrate species living in terrestrial, freshwater, and marine ecosystems
Source: WWF, UNEP-WCMC

Drought situations

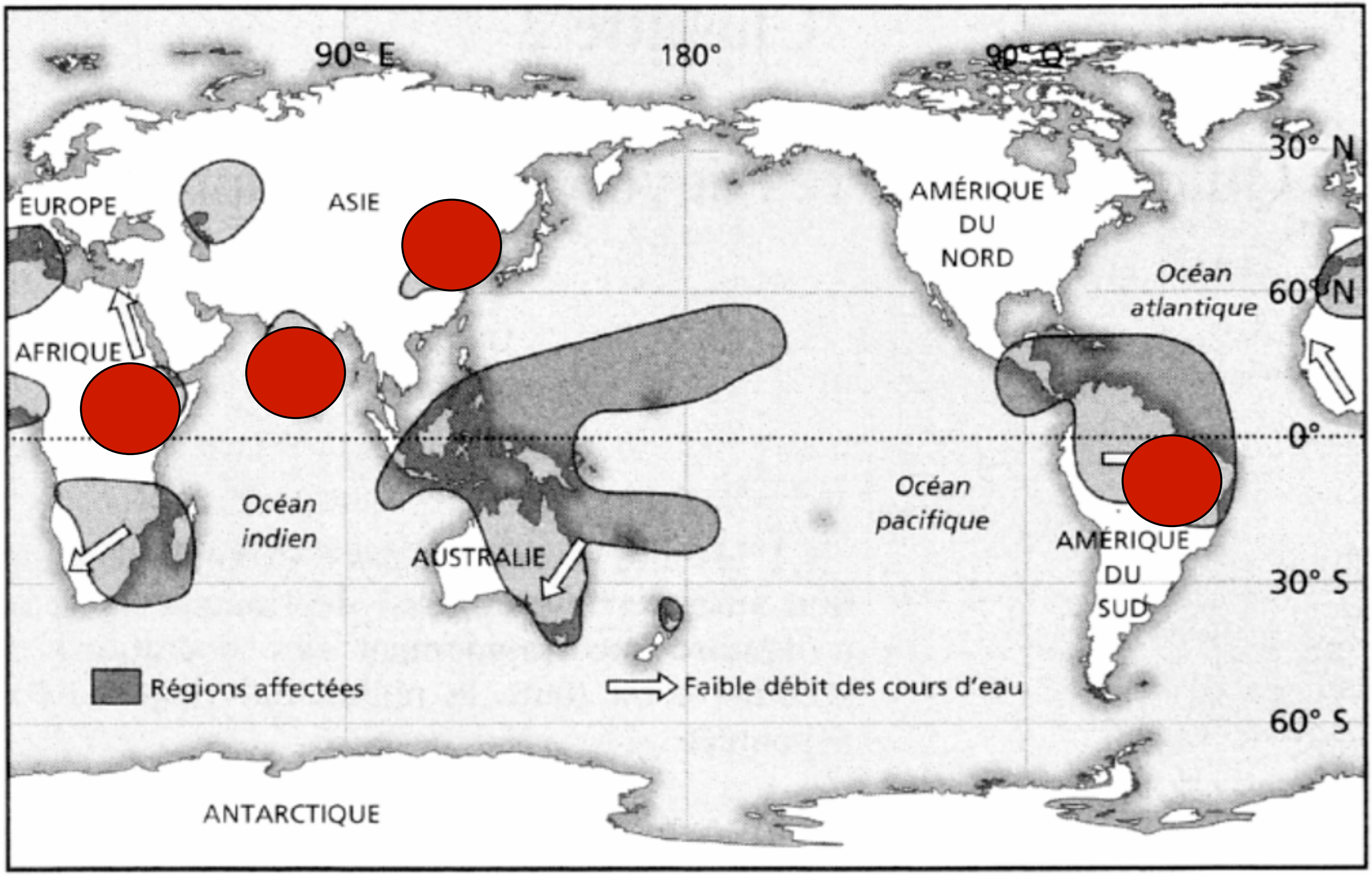
Mike Davis

Génocides tropicaux

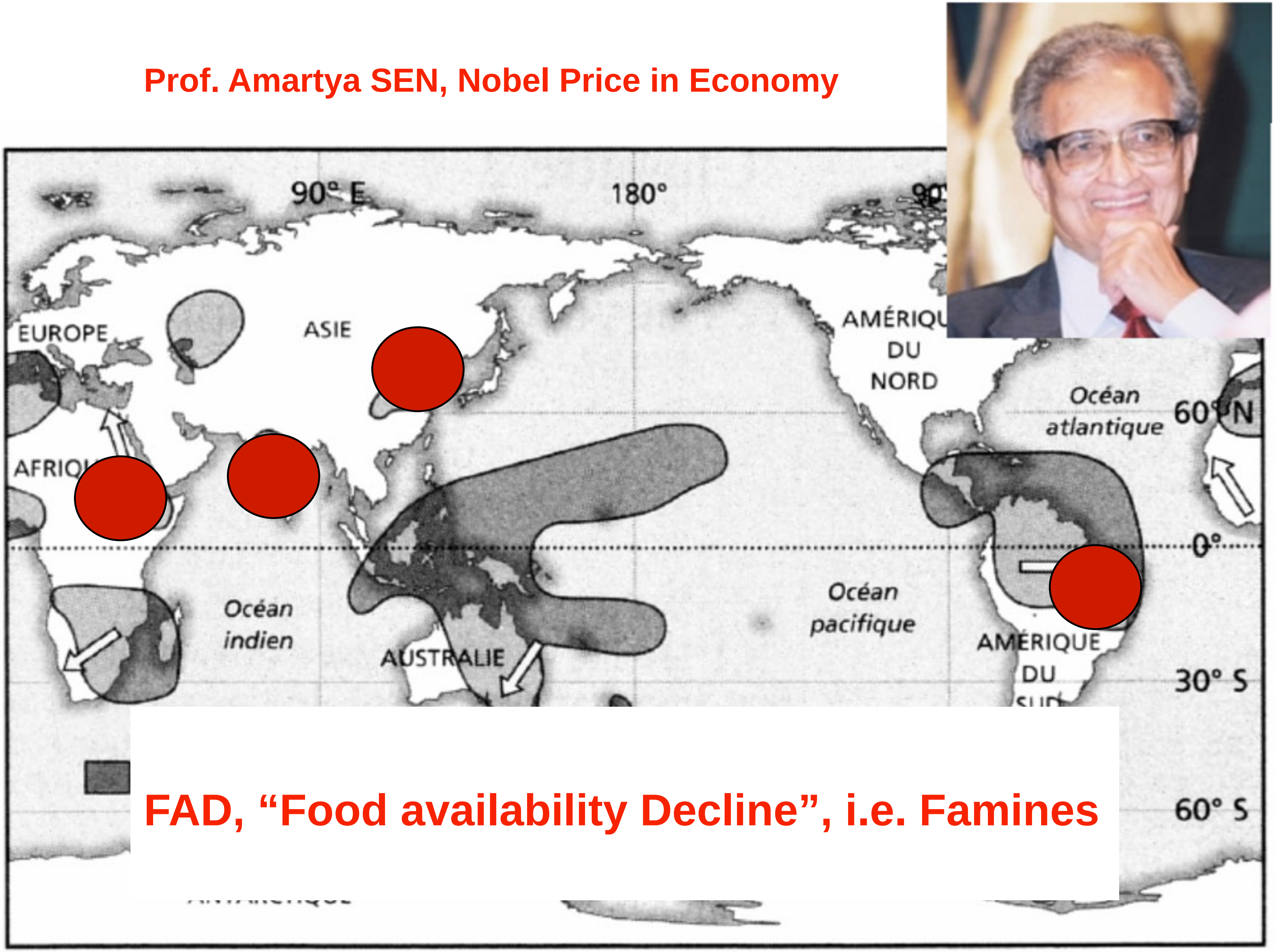
Catastrophes naturelles et famines coloniales
Aux origines du sous-développement



Drought, 1876-1878, and 1896-1900


90° E
180°
90° O
30° N
60° N
0°
30° S
60° S
EUROPE
ASIE
AFRIQUE
AMÉRIQUE
DU
NORD
Océan
atlantique
Océan
indien
Océan
pacifique
AUSTRALIE
AMÉRIQUE
DU
SUD
ANTARCTIQUE
Régions affectées
Faible débit des cours d'eau

Prof. Amartya SEN, Nobel Price in Economy



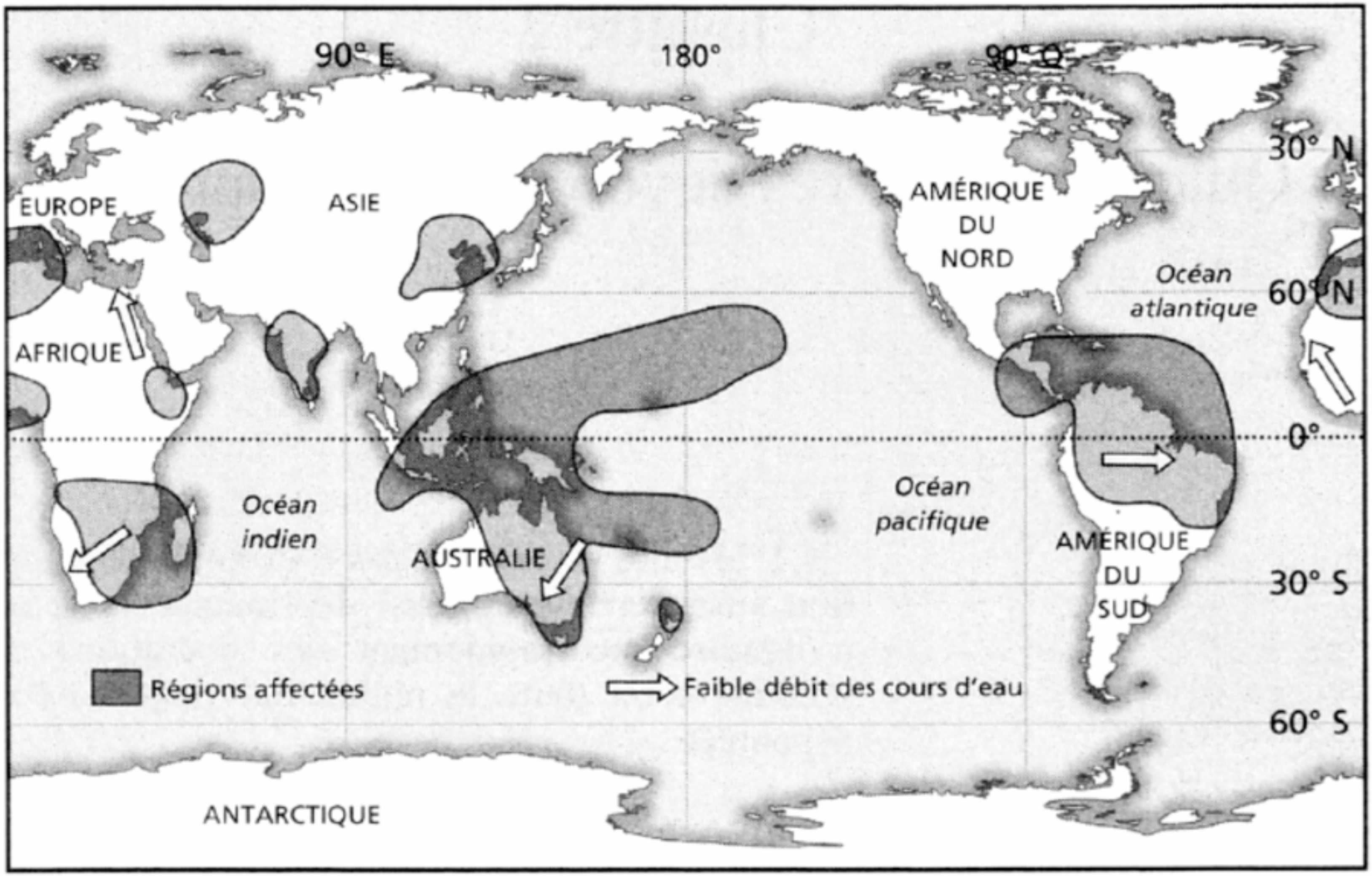
FAD, “Food availability Decline”, i.e. Famines

Deaths due to Famine

India	1876-1879 1896-1902	10 million 20 million
China	1876-1879 1896-1900	20 million 10 million
Brazil	1876-1879 1896-1900	1 million ?
Total		30 to 60 million

i.e. 4% of the World's population (1.5 billion in 1875)

Monsoon area, El Niño influence



Davis, 2006

Strong and **Very Strong** El Niño years, 1525 – 2000 (Ortlieb, 2000) :

1539, 1546, 1552, 1559, 1567,1574, 1578,
1589, 1600, 1604, 1607, 1614, 1618, 1621,
1630, 1640, 1650, 1652, **1661**, 1671, 1681,
1687, **1694**, 1703, 1715, 1723, **1728**, 1737,
1747, 1761, 1776, **1782**, **1790**, 1802, 1814,
1824, 1827, 1832, 1837, **1844**, 1850, 1854,
1864, 1867, **1876**, **1877**, 1887, **1891**, **1899**,
1904, 1913, 1918, 1925, **1940**, **1983, 1998**,

on average, **2/century**

World Stocks

- At present ~400 million tons of cereals, less than **2 month needs** (it used to be more than 1 year)
- **El-Niño 1998, strong deficit** in China and Indonesia, massive international buy, very low stocks
- Consumption 2270 million tons/y of cereals (2004), representing 60% of the World's food, 1/3 wheat, rice, corn
- **Meat stock alive** however **larger than 2 month needs**

Conclusion

- Climate change may significantly affect Mediterranean-latitude zones, with water resources decrease and increased risk of droughts, food deficit, fires
- Continued demographic growth is likely to force many countries in Asia, the Middle East and North Africa to import food from other continents
- The World is likely to be able to feed 9 billion inhabitants, but at the expense of natural ecosystems and biodiversity (little room for biofuels)
- Severe droughts could occur simultaneously, as they did in the past, on several continents, and trigger famines of unknown magnitude

Thank you !