EUROPE
CENTRAL EUROPE

INDEX TEMPERATURE
YEAR 2080-2099 RELATIVE TO 1980-1999 AND 2080-2099 RELATIVE TO 1961-1990
SCENARIO A1B

Reference: WG1 2007, Tebaldi et al. (2006), Chauvin and Denvil (2007), J. Boé (PhD with L. Terray), Planton et al. (2008)

1 The major trends in temperature

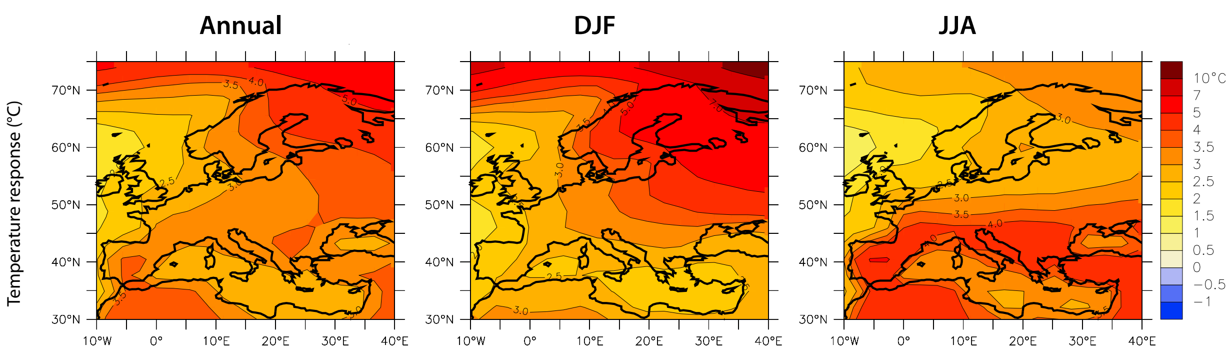
In the course of the 21st century, mean annual temperatures in Europe are likely (66-90% probability) to increase more than the global mean. The change in atmospheric circulation is not the main cause of warming in Europe, but it modulates this warming depending on the region and the time of year. The projection of temperatures in Europe is similar between the different climate models in both winter and summer (see FIGURE 2 of the global temperature fact sheet).

In Central Europe, the temperature increase simulated in 2080-2100 for the A1B scenario rises 3 to 4°C relative to 1980-1999 and 2°C relative to 2030-2049. In the near future, the temperature increase is harder to assess than in the long term (signal to noise ratio[1]). As the 22nd century draws nearer, this increase (66-90% probability) is greater in winter in the north of central Europe (above 50°N) and more pronounced in summer in the south of central Europe (below 50°N), following the trends noted for the whole of Europe (see FIGURES 1 AND 2). Thus, the minimum winter temperatures increase (66-90% probability) more than the mean in northern Europe, and the maximum summer temperatures increase (66-90% probability) more than the mean in central and southern Europe.

Warming is more pronounced in winter in the high latitudes due to the albedo-temperature feedback and the change in weather regimes (increase in the frequency of westerly winds bringing warm, wet air into these regions).

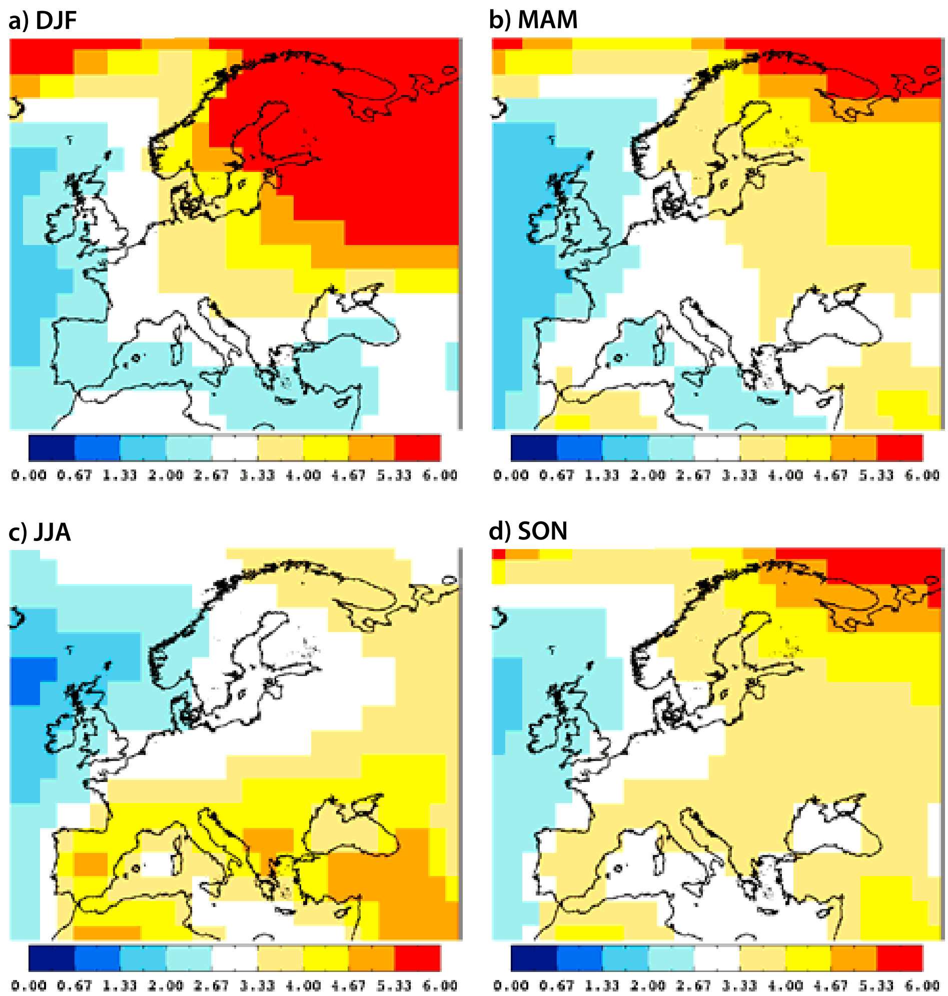
The thesis by Julien Boé (2007, CERFACS) presents an analysis of the different heat and water fluxes making it possible to quantify the ground temperature increase using the 21 IPCC climate models. The results particularly show that the increase in the net surface radiative flux, and therefore that of available energy, is accurate for the south of France, Greece and central Spain. The changes in radiative fluxes result from a major reduction in cloud cover. This reduction in cloud cover leads to an increase

1. The signal to noise ratio denotes the ratio between signal power (useful, meaningful information) and noise power (useless, insignificant information).



MODIFIED AND BASED ON WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. FIGURE 11.5. CAMBRIDGE UNIVERSITY PRESS.

FIGURE 1 Temperature changes over Europe from the multi-model data set-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models.



JULIEN BOÉ PHD DISSERTATION, 2007 (CERFACS)

FIGURE 2 Seasonal temperature changes over Europe according to the SRES A1B scenario, for 2080 to 2099 relative to 1961 to 1990, calculated from the 21-member AR4 multi-model ensemble. Cross denotes areas where there is no sign agreement between the models.

in solar fluxes reaching the surface. The sensible[2] and latent[3] fluxes disperse the net radiative energy available at the surface. In the IPCC climate models, the sensible heat flux increases considerably over southern Europe (robust result). For latent heat, an increase is seen over the north of the continent, and a decrease is seen locally over southern Europe: in Spain, Greece and the Black Sea region. It is in these regions that the maximum temperature increases are projected (see FIGURE 1). Furthermore, Planton et al. (2008) show that the main warming is situated around the Mediterranean Basin, mainly due to the changes in circulation corresponding to an increase in the frequency of cold air damming (fewer westerly winds).

The situation in other regions appears less certain, as the variation is greater from one model to another. For example, although the total net surface radiative fluxes increase over most of Europe, there is no consistency between models for northern France, the Iberian coasts and central Europe. In central Europe and France, the sign of the change in the latent heat flux is uncertain mainly due to modelling of land surface processes. For example, the fact that despite the increase in radiative energy available at the surface, the response is not increased evaporation but an increased sensible heat flux, is a clear direction of evaporation stress resulting from overly dry ground. The lack of accuracy in the direction of the response for evapo-

2. Heat absorbed or transmitted by a substance during a temperature change that does not involve a change in state.

3. Amount of heat of a substance that is gained or lost during a change of state (liquid, gas, solid) with given temperature and pressure.

ration over France and central Europe indicates that this moisture stress is not present in all of the models and that processes linked to ground moisture are thus involved. Weather regimes describe certain preferred and recurrent atmospheric states that represent the maxima in the probability distribution function.[4] According to Julien Boé thesis, the European climate is sensitive to four major weather regimes:

- Cold air damming, which limits the penetration of westerly flows from the Atlantic over northern Europe, resulting in a very cold, dry climate;
- NAO+, which favours this penetration of westerlies, resulting in a very warm, rainy climate;
- NAO-, which results in heavy rainfall over the Iberian Peninsula, not particularly warm;
- Anomalies associated with the Atlantic Ridge, which are wet and relatively warm in the north, and dry and relatively cold in the south, particularly over the Iberian Peninsula.

Regarding warming between the periods 2080-2099 and 1961-1990, there are two weather regimes: the regime that is wet in northern Europe and dry in the south are reinforced (NAO+ and the Atlantic Ridge), while the regime that is very wet in the south and relatively dry in the north diminishes in importance.

4. See paragraphs 1.1 and 1.2 of the technical fact sheet for further explanations.

2 Percentiles of temperature distribution

TABLE 1 represents the different percentiles of the probability distribution for the temperatures (°C) projected by the A1B scenario for 2080-2099 relative to 1980-1999. Winter and summer are represented over both northern and southern Europe.

For these two regions. we notice a temperature increase over the whole distribution in summer and winter.

In the north of Europe, the different percentiles show that the temperatures increase more in winter than in summer (see **FIGURE 1**). The median value for warming is 4.2°C in winter compared to 2.7°C in summer. The difference between the 5th and 95th percentiles is greater in winter (2.8°C) than in summer (2.0°C). The 5th and 95th percentiles show that in winter the lowest temperature values will increase less than 2.9°C as the highest values will increase more than 5.7°C. In summer, the increase of the low values will be below 1.7°C (5th percentile), whereas the increase of the high values (95th percentile) will be 3.7°C.

TABLE 1

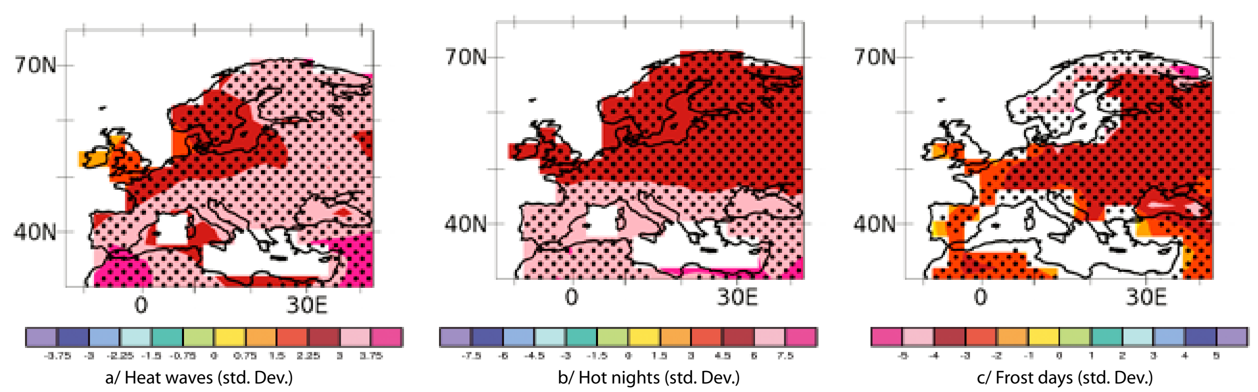
		Centiles				
Region	seasons	5	25	50	75	95
Northern Europe	DJF	2.9	3.7	4.2	4.8	5.7
	JJA	1.7	2.3	2.7	3.1	3.7
Southern Europe	DJF	1.7	2.3	2.7	3.0	3.6
		3.1	3.6	3.9	4.3	4.8

In southern Europe, the opposite applies as the percentiles indicate that the temperatures increase more in summer than in winter (see **FIGURE 1**). The median value of temperature increases is 2.7°C in winter (which is also equal to the median for summer in northern Europe), compared to 3.9°C in summer. The difference between the 5th and 95th percentiles is slightly greater in winter (1.9°C) than in summer (1.7°C). The increase in the lowest temperatures will be below 1.7°C in winter, compared to 3.1°C in summer. The highest temperatures will increase by over 3.6°C in winter, compared to 4.8°C in summer.

3 Climate indices for temperature

In Europe, the models are reliable for the increase in heat waves and hot nights, especially for the Mediterranean Basin. The number of frost days decreases, especially in the high latitudes (see FIGURE 3). More specifically, Weisheimer and Palmer (2005) show that in central Europe, the probability of experiencing hot summers by 2081-2100 increases by 40 to 80% and the probability of experiencing very warm winters increases by around 40 to 60%.

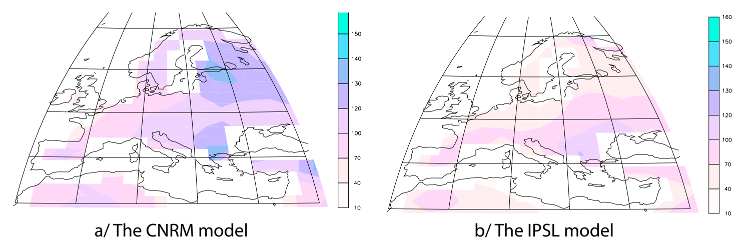
FIGURE 4 gives an illustration of the change in the number of heat waves between two French models. Both models project an increase in the number of heat wave in Europe, which is consistent with the previous figure. In central Europe, for example, the number of heat waves increases in 2080-2099 by between 90 and 160 days and between 50 and 120 days, depending on the climate model.



SPRINGER AND THE CLIMATIC CHANGE, VOL. 79, 2006, P. 185-211, GOING TO THE EXTREMES AN INTERCOMPARISON OF MODEL-SIMULATED HISTORICAL AND FUTURE CHANGES IN EXTREME EVENTS, TEBALDI, C., HAYHOE, K., ARBLASTER, J. M., MEEHL, G. A., FIGURE 3, © SPRINGER SCIENCE + BUSINESS MEDIA BV; WITH KIND PERMISSION FROM SPRINGER SCIENCE AND BUSINESS MEDIA. FIGURES A AND C, MODIFIED AND TAKEN FROM WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. FIGURE 10.19. CAMBRIDGE UNIVERSITY PRESS.

FIGURE 3 Changes in extremes based on multi-model simulations from nine global coupled climate models, adapted from Tebaldi et al. (2006). Changes in spatial patterns of simulated (a) heat waves, (b) warm nights, and (c) frost days, between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. Stippling denotes areas where at least five of the nine models concur in determining that the change is statistically significant. Extreme indices are calculated only over land. Frost days are only calculated in the extratropics. Extremes indices are calculated following Frich *et al.* (2002). Each model's time series is centred around its 1980 to 1999 average and normalised (rescaled) by its standard deviation computed (after de-trending) over the period 1960 to 2099. The models were then aggregated into an ensemble average, both at the global and at the grid-box level. The changes are thus given in units of standard deviations. (See paragraph 1.3 of the technical fact sheet for further information).

FIGURE 4 Changes in the number of heat wave events between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. Only two French models are shown here: IPSL (in left) and CNRM (right).



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