



Future trends of the Sea Surface Temperature for the Caribbean and the Western Mediterranean Seas

L. Garcies and J. Cuxart

Departament de Física, Universitat de les Illes Balears, Ctra. Valldemossa, km 7.5. 07122 Palma de Mallorca

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Correspondence to: lorenagarcies@gmail.com

Abstract

Global Climate Models foresee a general warming of the atmosphere, with varying intensity depending on the characteristics of each model and the hypotheses made on the release of gases of antropoc origin. The warming is not expected to be homogeneous over the planet. In this work we focus on the evolution of the sea surface temperature of the Caribbean and the Mediterranean seas, and its linked with the likely prolongation of the hurricane season and the increase of strength of the hurricanes in the Caribbean, as well as with the more apt conditions for severe weather in the Mediterranean sea. In both areas more frequent occurrence and intensity of severe weather events are expected due to the predicted increment of the sea surface temperature, 1.5°C for the Caribbean sea and 2.5°C for the Mediterranean sea.

1 Introduction

Severe weather events have a large impact on people, their possessions and the environment where they live. Intense rainfalls, often combined with strong winds, cause floods and damages in buildings and crop fields. They can be linked to the formation of mesoscale convective systems at mid-latitudes or to tropical cyclones or hurricanes in the tropics. The areas where these phenomena take place often are adapted to them, according to its frequency and intensity, and they take the necessary actions of prevention, in accordance with the available climatological information. The likely damages are indexed, for instance, by the insurance companies or in the technical specifications to build living houses or public infrastructures.

The global warming expected for the 21st century, that seems to be detected in some measurements (Gayà, 2005) implies that there is more available energy in the Climate System. Changes can alter the distribution of temperatures on the planet, especially if there is a significant melting of ice at high latitudes. The temperature gradients between the poles and the tropics may decrease and change the patterns of heat transport –either atmospheric or oceanic.

IPCC¹ points that, with the rise of temperatures, there

will be more water vapour in the atmosphere and a general increase of precipitation, although some areas in low and middle latitudes can receive a lesser amount of rainfall, especially those that become are under the downward branches of the Hadley cells. It is also expected that the interannual variability increases and that there will be more extreme rainfall events at low and mid-latitudes.

This work tries to make an estimation, through a simple study of the foreseen evolution of the Sea Surface Temperature (SST), how the frequency of severe weather events can increase during this century. The working hypothesis is very simple, maybe over-simplistic: if the SST rises on the Caribbean and the Mediterranean seas, there is more energy available to feed severe weather events, let them be hurricanes or mesoscale convective systems. Other factors are not explicitly taken into account, like the dynamic mechanisms necessary to transform this available energy into a complex cyclonic structure. If there is the enough energy at the surface of the sea, but the necessary perturbing factors to generate cyclogenesis are not set, there will be no severe weather events. In summary, in the case of the Climate Change affects the atmospheric dynamics, the conclusions that can be extrapolated of this study could be questioned.

The study is focussed on two areas of special interest:

¹<http://www.ipcc.ch>



those affected by hurricanes², that here will be represented by the Caribbean, and the Western Mediterranean, an area threatened by a significant decrease of the amount of precipitation, following the results of a number of climate models.

Tropical cyclones are systems with a centre of low pressure, with a warm nucleus surrounded by winds blowing in a cyclonic sense. They originate in the amplification of a perturbation in the tropical area of warm waters (the threshold value is 26.7 °C or 80 °F) taking energy of water and generating a cyclone. To build completely the structure, sufficient moisture throughout the troposphere is necessary, the area of warm waters above the threshold must be large, the winds must not have strong vertical shear and there must be wind divergence in the upper layers (Fernández, 2003a).

The phases preceding a hurricane are tropical wave, tropical depression and tropical storm, more intense as the wind speed increases. The phase of hurricane is reached when the sustained maximum winds are above 117 km h⁻¹ and the pressure of the centre falls below 1000 hPa. Hurricanes cause strong winds, large waves, intense rainfalls, tornados and floods. Their right side, relative to the sense of its motion, is the more dangerous because the general winds add to the hurricane wind speed; furthermore, tornados are more usual in this part of the system.

Three areas are distinguishable in a hurricane: the eye or vortex that has a diameter up to 100 km, with relatively slow winds, the ring of very strong winds reaching more that 200 km from the centre and the spiral bands or feeding bands with winds that converge to the centre at the low levels. The strongest updrafts take place near the vortex, where large quantities of latent heat of condensation are released.

In the Atlantic ocean the cyclone season starts on June 1st and it lasts until November 30th. The main areas of generation are the Western Caribbean and the Gulf of Mexico at the beginning and the end of the season, whereas the main area of generation is between the Minor Antilles and the Cape Verd Islands in the months in between (Fernández, 2003b)

The intense rainfall events in the Western Mediterranean Sea seem well correlated with the presence of extra-tropical cyclones through all the troposphere or at middle at high levels (Isolated Depression at High Levels), a warm sea providing plenty of moisture, low level winds advecting sea air over land, cold air at high levels or a distribution of potential vorticity that favours the updrafts, and factors to trigger the convection, basically (Romero et al., 1997; Tuduri and Ramis, 1997). Winds are not necessarily strong, contrarily to the hurricanes, neither the energies into play are comparable.

There is not a well defined season for Western Mediterranean intense rainfall events, but they usually take place in Fall (Romero et al., 1998), although they can happen as well in Spring when the SST is a less important factor

(Buzzi et al., 2005). In any case, there seems to be a good correlation between SST and severe weather (Lebeaupin et al., 2006). The SST can be considered as a good indicator of the availability of moisture at low levels and of their thermal stability.

This work will study the SST evolution for a point at the Caribbean and a point at the Western Mediterranean with three different climate models. In section 2 the methodology used will be described, and the next two sections will show the results for both areas, leading finally to some preliminary conclusions.

2 Metodology

The climate models that have participated in the modelling exercises proposed by IPCC put some of their results at the disposal of the scientific community for the control period (end of the 20th century) and for the forecast period (21st century). These are monthly averages for each grid point. The data at disposition have a relatively low resolution (about 300 km). The selected points have been (24° N, 90° W) –representative of the Caribbean and the Gulf of Mexico- and (40° N, 7° E) for the Western Mediterranean, since the models see these points as sea points. For the purposes of this work just 30-year averages have been retained, corresponding to the periods 1961-1990 (the initial conditions of one model are different for the different scenarios because they are integrated with different previous initial conditions), 2010-2039, 2040-2069 and 2070-2099. ECHAM does not provide data for the period 1961-1990. Thus, in each grid point the monthly-averaged temperature is available for every month corresponding to each 30-year block.

The models chosen are CGCM2 (Yukimoto et al., 2001), ECHAM4 of the Max Planck Institute (Roeckner et al., 1996) and R30 of the Geophysical Fluid Dynamics Laboratory (GFDL) (Delworth et al., 2002). The chosen outputs correspond to the A2 and B2 IPCC scenarios, based on different hypotheses on the future global evolutions of some demographic, economic and technologic variables. These hypotheses have a distinct impact on the future evolution of emission of greenhouse-effect gases. The A2 scenario assumes a sustained growth of the population and an extensive consumption of fossil fuel, whereas scenario B2 imposes a demographic regulation on the midterm and the emergence of new forms of energy of low environmental impact. Both scenarios forecast global increases of temperature, but the one based on B2 is about half of the one based in A2.

With the available outputs, the likely evolution of the length of the cyclonic season in the western Atlantic has been analysed. Each season is limited by the months having a SST equal or larger to 26.7°C (80°F). Let us remind again that this is not the only factor intervening in the formation of tropical cyclones, but it is taken here as an indicator of the

²<http://hurricanes.noaa.gov/>

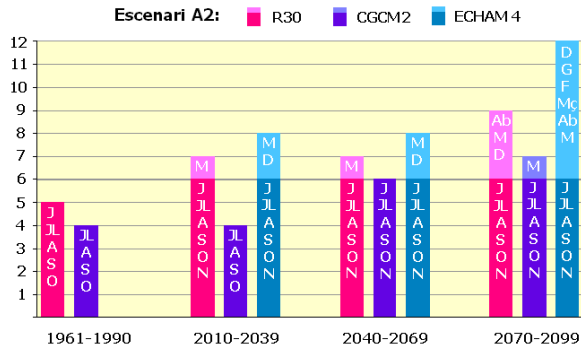


Figure 1. Length (months) of the hurricane seasons as forecasted by the models R30, CGCM2 and ECHAM4 for the A2 scenario, as a function of the Sea Surface Temperature (SST). The hurricane season is taken as the ensemble of months having an average SST above 26.7°C (January, G; February, F; March, Mç; April, A; May, M; June, J; July, JL; August, A; September, S; October, O; November, N; December, D.).

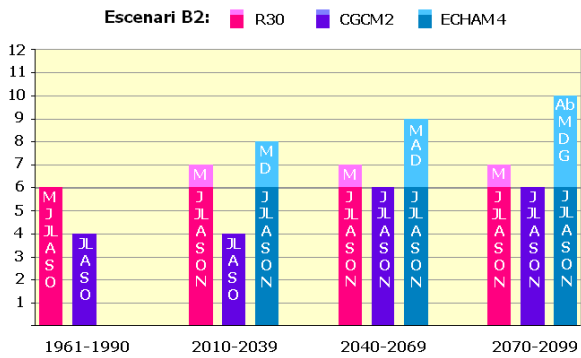


Figure 2. As in Figure 1 for scenario B2.

length of the hurricane season.

In the Western Mediterranean sea, the SST is a factor to consider in the development of severe weather in Fall, and its evolution will be also studied. Here the SST maxima will be taken, and from it an estimation of the possible displacements and intensification of the maximal temperatures on the cyclogenesis events with large amounts of precipitation on the area.

From the monthly averaged data, the month having a large value for the SST will be selected for each 30-year period in order to inspect the evolution of the maximum SST. In this Mediterranean area the study has been made not focussing on the possible similarities between Mediterranean cyclones to tropical cyclones, but on the conditions that favour severe weather. Looking at the ensemble of the three models and two scenarios the existence of a trend in the evolution of the SST can be assessed for both areas of study.

3 Trends for the area of the Caribbean and the Gulf of Mexico

In the 20th century the hurricane season months in the Western Atlantic basin have been June (J), July (JL), August (A), September (S), October (O) and November (N). In this study, for the different periods and models, the months have been counted in the hurricane season when the SST was above 26.7°C. The six-month period just mentioned has been considered as the reference, and the changes in respect to it are highlighted in figures 1 and 2.

As mentioned, only two of the three models are available for the control period (1961-1990). It worth noting that the results are different between the models in this control period, and that the hurricane season is either too short in respect to observations or displaced in time (May to October for R30 in B2). This allows to see how large is the indetermination in the model data analysed, due to a number of factors (resolution, too simple parameterizations, incomplete forcings ...) and, in consequence, the study of the future trends will contain, and maybe amplify, these errors.

For both scenarios and all the models the hurricane season tends to last longer as the 21st century advances. Nevertheless, each model follows a distinct evolution. For the A2 scenario, ECHAM4 extends the season one month before (May) and one after (December) the reference for the periods and 2010-2039 and 2040-2069, but at the end of the century all the year has SST above the 26.7°C threshold, meaning that the whole year would be a hurricane season. The other models do not have such an extreme forecast, but they also produce longer seasons than the present ones. ECHAM4 increases the seasons 6 months for A2 and 4 for B2, CGM2 3 months in respect its own control season for A2 and 2 for B2; R30 4 for A2 and 1 for B2. In any case, according to the models, the hurricane season will last longer during the next century if only this parameter is considered, and the prolongation will be very important if the scenario A2 finally takes place (continuous increase of the population and use of fossil fuels). On the other hand, the correction of both factors (scenario B2), will mitigate the extension in time of the season, but will not stop it.

Figure 3 indicates the month when the maximum SST is reached and its value. It is worth noting the large differences between the models in the control period. R30 has the warmer water in August (near 30°C) whereas CGM2 peaks in September at about 28°C, two degrees of difference for both scenarios. R30 keeps August as the warmest month with an increase of 1.5°C between 2020 and 2080, ECHAM4 has September as the warmest with an increase of 2 °C and GCM2 oscillates between August and September, with larger increases than the other models, but smaller values of temperature.

Therefore, no significant temporal displacement of the temperature maximum is foreseen by any of the models, that estimate increases of temperature between 1.8°C and 2.4°C, implying that, besides the prolongation of the hurricane

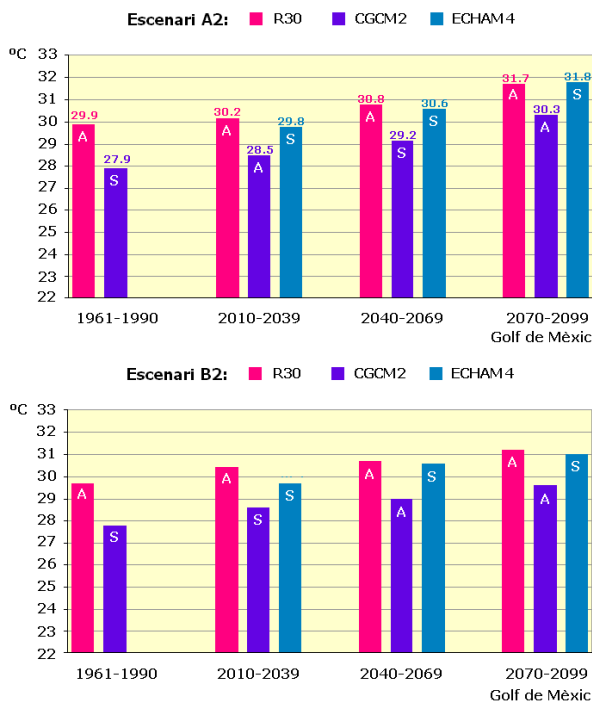


Figure 3. Maxima SST for the Caribbean and the Gulf of Mexico for models R30, CGCM2 and ECHAM4 and scenarios A2 and B2. Months as in Figure 1.

season, the would be significantly warmer and more energy available for the generation of hurricanes.

4 Trends for the Western Mediterranean Sea

For the Western Mediterranean no particular period has been selected since it is no clear, to our knowledge, that there is a specific severe weather season for the area, neither a special value of the SST to determine when severe weather is more likely to occur. Let us remind that a warm sea is an important factor for having severe weather events, but a dynamical factor is usually needed, usually of synoptic scale. Nevertheless, the warmer the sea, the more moisture and latent heat release available when the convective processes are set, more intense storms and stronger rainfalls.

Figure 4 shows, for each model, period and scenario, the month that has a warmer SST and its value. In this case the models having values for the control period show very similar results for both scenarios, although one has the maximum in August at 25°C and the other in September at 23.5°C. Each model keeps the maximum value in the same month, independently of the scenario and period (August for R30 and ECHAM4, and September for CGM2).

The most relevant fact for this area is that the SST increases are largely superiors to the ones found for the Caribbean. ECHAM4 is still the model producing the largest

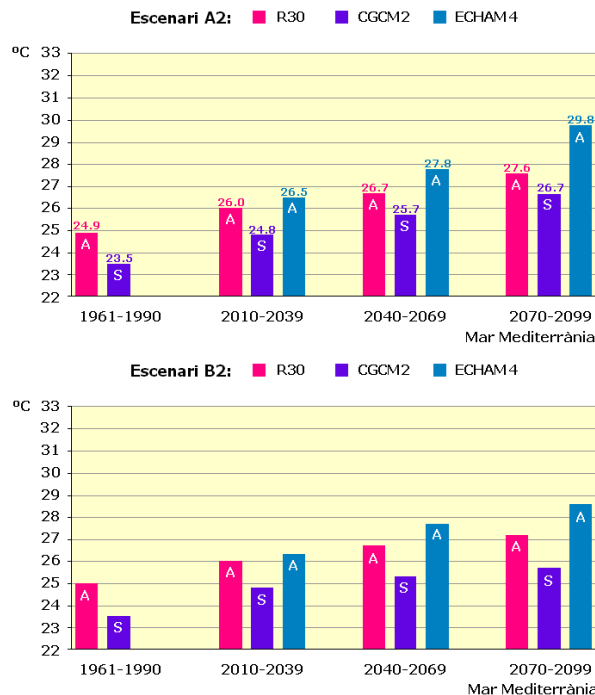


Figure 4. As Figure 3 for the Western Mediterranean Sea.

increases giving 3.3°C for A2 and 2.5°C for B2 between 2020 and 2080, with final values of 29.8°C and 28.6°C respectively, very similar to the present maximum values at the Caribbean. The other models estimate increases larger than 3°C for A2 and than 2°C for B2, with values between 25.7°C and 27.6°C depending on the model and the scenario.

Therefore, the Western Mediterranean would experience an increase of the SST larger than the one in the Caribbean and would reach values similar to the present ones in that area. No supplementary sources have been consulted, but this situation would be compatible with a decrease of the mid-latitude circulation on the area, with less cloud cover and precipitation and larger insolation throughout the year, leading to higher temperatures at the end of the summer that could favour the occurrence of severe weather when the appropriate conditions are met, most likely with more intense precipitations than today.

5 Conclusions

The analysed global models, with their known limitations (low vertical and horizontal resolution, too simplistic parameterizations, incomplete forcings), provide consistent trends of the SST for two selected points of the Caribbean and the Western Mediterranean Seas.

SST will rise about 1.5°C at the Caribbean; the 26.7°C threshold for the formation of hurricanes will be overcome

during longer seasons that at the end of the 20th century, varying between one to six more months depending on the model and the scenario. A six month increase would mean that the whole year is a hurricane season. Furthermore, warmer SST means more water vapour and energy available to feed the cyclones, that would probably be more violent.

The expected rise in the Western Mediterranean is about 2.5°C, giving temperatures of the order of present day Caribbean. In fact, for scenario A2, all the models forecast SST above the hurricane threshold (26.7°C), and for B2 two of the three models also overcome it. This shows the large availability of moisture and energy in the case of favourable conditions to the development of convective systems in the area. It would be necessary to explore with more detail if the general circulation would suffer changes that could explain such large variations.

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