4. EVALUATION OF THE TYPING SCHEME AND THE WEATHER GENERATOR

4.1 INTRODUCTION

In Chapter 2 it was demonstrated that the automated LWT classification scheme (Jenkinson and Collison, 1977; Jones *et al.*, 1993) can be successfully transferred from its region of development to another region, southeast Spain. The 14 basic circulation types were combined into eight groups to facilitate the analysis. These groups provide a legitimate basis for downscaling because each was shown to have a characteristic pressure pattern which produces the expected type and direction of surface flow over the study region (Chapter 2). Furthermore, a set of consistent and distinct relationships has been identified between these circulation types and daily rainfall in the Guadalentin Basin (Chapter 3). These relationships provide the basis for a statistical weather generator which was used with control and perturbed-run output from the UKTR GCM to produce rain-day scenarios for six stations in the Guadalentin Basin.

The rain-day scenarios presented at the end of Chapter 3 are intended as illustrative results and demonstrate the potential of the circulation-based approach to downscaling. However, a number of issues arising from the initial development and testing of the methodology can be identified and are discussed in this Chapter. These issues concern:

- The need for a good understanding of the physical processes underlying the circulation-surface climate relationships;
- The failure of the GCM to reproduce the observed circulation-type frequencies;
- The poor reproduction of the persistence and variability of precipitation in the weather generator;
- The implications of the very small circulation-type frequency changes in the GCM and hence the plausibility of the rainfall scenarios; and,
- The assumption of stationarity in the circulation/surface climate relationships.

4.2 UNDERLYING PHYSICAL PROCESSES

Empirical downscaling methods should be based on strong relationships between the predictor variable(s) and the predictand (here, daily precipitation in the Guadalentin Basin) and, ideally, these relationships should be supported by an understanding of the underlying physical processes (Section 1.2.1). The identification of consistent and distinct relationships between the circulation types and daily precipitation, which can be explained in terms of the underlying circulation, is seen as an important aspect of the thesis work (Section 1.3).

These issues are dealt with, in part, in Sections 2.3, 3.2 and 3.3. A major element of this work is the construction and interpretation of composite SLP maps (see Sections 2.3.2 and 3.3). Most of the circulation/rainfall relationships identified in Section 3.2 were shown to be physically realistic in terms of the underlying synoptic situation. The influence of large-scale (North Atlantic-European) circulation is evident in some of these synoptic patterns. The SLP anomaly pattern associated with the C and HYC-types, for example, resembles that of the Greenland Above mode of the NAO, while the A/HYA-type anomaly pattern resembles that of the Greenland Below mode (Section 2.3.2).

Links between precipitation over the western Mediterranean/Iberian Peninsula and the NAO, together with other large-scale patterns such as the Southern Oscillation Index (SOI) have been explored in a number of recent studies (Laita and Grimalt, 1997; Rodo *et al.*, 1997; Esteban-Parra *et al.*, 1998; Rodriguez-Puebla *et al.*, 1998; Rocha, 1999). Rodo *et al.* (1997) calculated correlations between 17 monthly precipitation records from the Iberian Peninsula, Balearic Islands and Northern Africa, and the NAO (winter NAO index versus winter precipitation) and the SOI (previous winter SOI versus spring precipitation). Distinctive regional patterns are evident in the correlation results. Significant negative correlations with the NAO occur over most of the western and central Iberian Peninsula. Non-significant negative correlations occur in eastern coastal regions (including the station of Murcia in the Guadalentin Basin) and the Balearic Islands. Over most of the Peninsula, correlations with the SOI are not significant. There is, however, an area of significant positive correlation in the southeast, centred over Albacete and Alicante to the north of Murcia. Over the period 1953-1995 the correlation between monthly precipitation at Murcia and the SOI is 0.43 (significant at the 0.01 level). The correlations have increased over time towards the present day. Over the period 1910-1994, for example, the correlation for Murcia is 0.25 (significant at the 0.05 level). Similar relationships to those found by Rodo *et al.* between the NAO and SOI and precipitation over the Iberian Peninsula have been identified by Rodriguez-Puebla *et al.* (1998) and by the author of this thesis as part of the ACCORD project (see the Final Report of Partner 01, January 2000, at http://www.cru.uea.ac.uk/cru/projects/accord/contents.htm).

Vorticity and SLP composites have been constructed for the Western Mediterranean for springs following years with high positive and negative SOI values (Laita and Grimalt, 1997). These indicate that after a strong negative SOI event (a warm El Niño-Southern Oscillation (ENSO) event), there is a reduction in the number of days with cyclonic circulation and negative pressure anomalies in spring over the Iberian Peninsula. This fits with the association of negative SOI events with lower precipitation in eastern Spain (Rodo *et al.*, 1997) and with the identification of the C and HYC-circulation types as high-rainfall types here (see Table 3.3). The strongest SOI/precipitation correlations occur with a lag of three to six months (Rocha, 1999). Generally, however, it is considered that the ENSO has less of an influence across the Iberian Peninsula than the NAO (Rodo *et al.*, 1997).

The indication of links between the circulation types, rainfall occurrence and large-scale circulation indices is potentially of great interest, particularly in relation to the study of past and future climate variability. Further investigation of this issue is beyond the scope of this thesis where the focus is on downscaling and hence on regional and sub-regional processes, but has been explored by the author as part of the ACCORD project (see the Final Report of Partner 01, January 2000, at http://www.cru.uea.ac.uk/cru/projects/accord/contents.htm).

More regional (Mediterranean) influences were detected in the SLP composites and in the circulation type/rainfall relationships presented in Chapters 2 and 3, particularly in the case of the E/NE and S/SE circulation types (see discussion in Section 3.3, particularly in relation to the occurrence of extreme rainfall events in autumn). This is encouraging because it suggests that the downscaling methodology is capturing some aspects of both the large-scale and the mesoscale features of the circulation which are known to influence the rainfall regime of southeastern Spain (Romero *et al.*, 1998).

The circulation type/rainfall relationships do, however, vary between season and between station (see Figures 3.7 and 3.8). Part of this variability may be due to differences in topography (Figure 3.2), and part due to the effects of convective activity. The extent to which the typing scheme is capturing convective events is not clear and requires further investigation (see Chapter 7). The fact that summer rainfall is well simulated in the *Gen.* runs of the conditional weather generator (Section 3.5.2), and is better simulated than winter rainfall in the *Cont.* runs (Section 3.5.3), suggests that some account is taken of convective activity. In part, however, the latter finding reflects the more reliable GCM simulation of the observed circulation types in summer compared with winter (Section 2.4.2). The reasonable performance of the downscaling method in summer is generally encouraging, particularly in the light of the experience of Frey-Buness *et al.* (1995) who considered their summer results for the Alpine region so spurious that they did not even attempt to discuss them.

Pressure composites provide a useful analytical tool for the work described in Chapters 2 and 3 and are also used in Chapter 5 of the thesis, to investigate whether the typing scheme is still valid in the Guadalentin Basin when a somewhat different SLP grid is used, and to investigate circulation/precipitation relationships in a second study area, the Agri Basin, central Italy. They are used again in Chapter 7 to further investigate underlying physical processes, using a case-study approach, focusing, for example, on the autumn storm events which are a characteristic feature of southeast Spain. In Section 3.3 it was noted that the surface synoptic features underlying the E/NE-type (notably the long sea track of air masses over a warm Mediterranean Sea) are similar to those which are known to be conducive to the onset of major autumn rain events along the Spanish Mediterranean coast (Linés Escardo, 1970; Wheeler, 1988; Tout and Wheeler, 1990; Sumner *et al*., 1993). However, the literature also indicates that the presence of features such as upper-air troughs and cut-off-lows is important for the development of such intense rainfall events. In Chapter 7, therefore, case-study composites are constructed for 500 hPa geopotential height as well as for SLP.

4.3 GCM PERFORMANCE

Another important criterion for assessing empirical downscaling methods is that the predictor variable(s) must be reliably reproduced by the underlying GCM (Section 1.2.1). Thus it is essential to assess the ability of the GCM to reproduce the observed circulation types before the observed circulation type/rainfall relationships can be applied to GCM output. In the case of the UKTR model used for the work described in Chapters 2 and 3, the major problems are associated with the frequency of the circulation types (Table 2.5; Figure 2.4) rather than with the simulation of the synoptic situation underlying each circulation type.

Systematic errors can be identified in the mean annual and seasonal SLP patterns from UKTR (Section 2.4.1) and can be traced through to errors in circulation-type frequency. The mean intensity of the Icelandic Low, for example, is generally overestimated. This deficiency is likely to be related to the underestimation of the frequency of the C and HYC-types in spring and summer, and over the year as a whole (Section 2.4.2).

The effect of these GCM problems on downscaled precipitation is clearly traceable in the conditional weather generator results (Section 3.5.3). The implications of poor GCM performance for the plausibility of the climate scenarios, particularly given the relatively small projected changes in circulation-type frequency, are discussed in Section 4.5.

Other studies have identified shortcomings in the performance of the UKTR model, although it is considered to be reasonably successful in reproducing the main features of the general circulation (Murphy, 1995a; Carnell *et al.*, 1996). Systematic errors have also been identified in an earlier version of this model, the UK Meteorological Office High Resolution (UKHI) GCM. Analysis of the 500 hPa geopotential heights over Europe in winter, for example, indicates that the simulated jets are too strong and shifted southwards, whereas the meridional circulation is too weak (Huth, 1997). The UKTR model generally performs better in winter than in summer, but the finding that the frequencies of the C and W/NW/SW/N-types are overestimated in winter and the UA, E/NE and S/SE-types are underestimated in the same season (Section 2.4.2; Figure 2.4) suggests that the UKHI biases identified by Huth persist in UKTR.

After completion of the initial analyses described in Chapters 2-3, daily output from the HADCM2 set of simulations (Johns *et al.*, 1997) became available and was used for all subsequent thesis analyses. The performance of this more recent version of the UK Hadley Centre model is discussed in Chapter 5 and compared with that of UKTR.

While systematic errors can be identified in the performance of the UKHI and UKTR models, it should be noted that GCMs of the same generation developed by other modelling centres also suffer from problems in their ability to reproduce the observed circulation (Crane and Barry, 1988; Hansen and Sutera, 1990; Hewitson and Crane, 1992a; Hulme *et al.*, 1993; Gates *et al.*, 1996). Identification of a single "best" GCM is not straight-forward, particularly when performance is considered across a number of different climate variables and/or regions (Gates *et al.*, 1996; Kattenberg *et al.*, 1996). For this reason a single GCM, rather than a suite of models, is used at each stage of the thesis in order to illustrate the problems that arise in developing a downscaling methodology and constructing plausible climate-change scenarios.

4.4 WEATHER GENERATOR PERFORMANCE

The errors in the UKTR simulation of circulation types are clearly seen in the *Cont.* results from the conditional weather generator (CWG) (see Section 3.5.3). The CWG *Cont.* errors are greatest in winter and spring, and as a consequence the number of rain days is systematically underestimated in these seasons.

In the discussion of the CWG results in Section 3.5, a distinction is made between errors which can be traced back to the GCM and errors which can be attributed to the CWG itself. While the GCM errors affect the mean circulation-type frequencies and the mean number of rain days simulated by the CWG, it is concluded that loss of variance and persistence (runs of wet and dry days) in the simulated number of rain days is an inherent feature of the CWG (Section 3.5.3). The latter feature is a widely recognised problem with conventional Markov Chain weather generators in which rainfall occurrence is only dependent on whether the previous day is wet or dry (Gregory *et al.*, 1993; Mearns *et al.*, 1996; Semenov *et al.*, 1998; Katz and Zheng, 1999; Wilks, 1999a) and has also been identified as a problem in circulation-based weather generators (Wilby and Wigley, 1997; Wilby *et al.*, 1998a). It has been suggested that the underestimation of monthly standard deviations by output from circulation-based weather generators reflects their inability to capture low-frequency variability because forcing on these timescales is not incorporated (Wilby and Wigley, 1997; Wilby *et al.*, 1998a; Wilks and Wilby, 1999). The arguments for incorporating additional forcing mechanisms in downscaling models are discussed further in Section 4.5 and Chapter 7.

For the CWG simulations described in Section 3.5 the transition from one circulation type to another is modelled as a Markov Chain process. Thus the daily sequence of circulation types is different for each of the 100 sequences making up each simulation set. This approach was used, rather than taking the circulation sequences directly from the UKTR model, in order to give a longer time series than available from the GCM. It also introduces a greater Monte Carlo and probabilistic element to scenario construction. However, because both the circulation types and the number of rain days are modelled as Markov Chain processes, it is not possible to determine to what extent variations in circulation-type frequency and/or precipitation generation account for the wide spread of simulation results. For summer rain-day perturbed minus control run changes at Alcantarilla, for example, the range across 100 simulations (provided by the maximum $M_{p(NRD)}$ value minus the minimum $M_{c(NRD)}$ value (upper limit) and the minimum $M_{p(NRD)}$ value minus the maximum $M_{c(NRD)}$ value (lower limit)) is +2.9 to -1.4 days (Section 3.5.4). Since the circulation-type output from the CWG strongly reflects the errors in the underlying GCM, it is considered that modelling the circulation types as a Markov Chain process has little benefit (unless very long time series are required for the estimation of extreme events with long return periods, for example) and complicates interpretation of the results. In subsequent analyses, therefore, it was decided to take the circulation types directly from the GCM (see Chapter 6). This has the additional advantage of making it easier to construct self-consistent scenarios for incorporating multiple stations and/or parameters.

Attempts to include a persistence or inflation parameter (Hay *et al.*, 1991; Wilby *et al.*, 1994) in the CWG were unsuccessful (see Section 3.5.2). It was, therefore, decided to try a different way of increasing the persistence of wet/dry day spells in subsequent CWG simulations, by making the occurrence of precipitation conditional both on the circulation type of each day, and on whether the previous day was wet or dry (Chapter 6). In order to further increase the stochastic element of the simulations, it was also decided to increase the number of runs in each simulation set from 100 to 1000. Maximising the stochastic element is seen as a way of overcoming, in part, problems of loss of information and over-generalisation which may arise when using discrete classes rather than continuous distributions to describe circulation/surface climate links (Hewitson and Crane, 1996). It also allows the CWG results to be presented in the form of frequency histograms which are considered to have a number of advantages for scenario construction and assessment (Chapter 6).

It would be very time consuming to analyse simulation sets consisting of 1000 runs for a number of different stations within the study region. In subsequent analyses, therefore, CWG simulations are performed for a single baseline station in each study region (see Chapter 6). Methods by which the baseline scenarios can be used to construct scenarios which are consistent throughout a group of stations in the region are discussed in Chapter 7.

4.5 PLAUSIBILITY OF THE SCENARIOS

The simulated rainfall series based on UKTR control and perturbed-run output (*Cont*. and *Pert*.) contain errors because of the GCM's failure to reproduce the observed circulation types (discussed in Sections 4.3 and 4.4 above). The illustrative climate-change scenarios presented in Section 3.5.4 (see Table 3.7) are, therefore, calculated as the difference between the *Cont*. and *Pert*. means, on the (un-testable) assumption that the errors are consistent in the two GCM runs. The UKTR changes in SLP and circulation-type frequency between the control and perturbed runs are generally small and, except in summer, not significant (see Section 2.5). The CWG results, however, indicate changes in the number of rain days which are significant (in terms of model variance but not observed variance) in spring and summer. (Only rain-day changes are considered in Chapter 3. No information is provided about changes in precipitation intensity or amount, which may not necessarily be of the same magnitude as the rain-day changes. In Chapter 6, the CWG is modified to simulate rainfall amount as well as the number of rain days.)

The downscaled rain-day changes derived from UKTR are consistent with the changes in circulation type. In summer, for example, the frequencies of the C, HYC, E/NE and S/SE high-rainfall types all increase, while those of the A/HYA, UA and W/NW/SW/N low-rainfall types decrease. The combined effect of these changes is an increase in the number of rain days in summer.

The downscaled rain-day scenarios are not, however, consistent with the changes indicated by the 'raw' UKTR precipitation output. Grid-point rain-day data from the UKTR model for the land square closest to the Guadalentin Basin indicate little change or a small decrease in the number of rain days in autumn and winter, a greater decrease (about 26%) in spring (in agreement with the sign of the downscaled scenarios), and the largest percentage decrease (about 60%) in summer (Figure 4.1a), whereas the downscaled scenarios indicate an increase in summer (Table 3.7).

It is not unusual for empirical downscaling methods to produce changes which are of the opposite sign to the 'raw' GCM changes (von Storch *et al.*, 1993; Barrow *et al*., 1996; Semenov and Barrow, 1997; Wilby *et al.*, 1998a; Giorgi and Mearns, 1999; Mearns *et al*., 1999). Other studies have also found that precipitation changes indicated by circulation-based downscaled scenarios are smaller in magnitude than the raw GCM changes, and are also small in comparison to the observed variability and errors in the underlying GCM predictor variable(s) (Saunders and Byrne, 1996; Wilby and Wigley, 1997; Schnur and Lettenmaier, 1998; Schubert, 1998; Wilby *et al*., 1998a; Buishand and Brandsma, 1999). It has been suggested that this is because factors other than circulation changes, such as changes in atmospheric stability, humidity and temperature, contribute towards precipitation changes in the GCM, and in the real world (Wilby and Wigley, 1997; Crane and Hewitson, 1998; Kidson and Thompson, 1998; Kilsby *et al*., 1998; Schubert, 1998; Wilby *et al*., 1998a; Buishand and Brandsma, 1999). In contrast, one of the two major assumptions underlying the circulation-type approach to downscaling is that precipitation changes are driven only by changes in the circulation (Section 1.2.2).

The UKTR raw precipitation changes do not appear to be primarily driven by changes in circulation. Circulation type/daily rainfall relationships in UKTR have been explored using output for the land grid square closest to the Guadalentin Basin. $PROP_{ct}/PROP_{tot}$ and $PREC_{ct}/PREC_{tot}$ ratios (see Section 3.2.3 for an explanation) were calculated from the GCM output. Annual ratios are shown in Figure 4.2. These are not precisely comparable with the ratios based on the observations discussed in Section 3.2.3 because the GCM data represent area averages rather than point values (Osborn, 1997; Osborn and Hulme, 1997; 1998; see Section 1.1). Nonetheless, Figure 4.2 indicates that the GCM does capture many features of the circulation/surface climate relationships summarised in Table 3.3. The C, HYC and S/SE-types appear as high-rainfall types in UKTR, while the A/HYA and UA types appear as low-rainfall types, in agreement with the observations. There are some discrepancies. The W/NW/SW/N-type has a higher than average proportion of wet days in the GCM, for example, in contrast to the observations. Similarly, the E/NE-type has a lower than average proportion of wet days in the GCM, in disagreement with the observations.

Overall, however, the broad similarity of the circulation/rainfall relationships in UKTR and the observations suggests that precipitation changes in the same direction as the downscaled changes might be expected if the UKTR precipitation changes were driven by circulation changes alone. The fact that the GCM and CWG-derived changes are not in the same direction in every season implies that additional mechanisms are involved in the GCM. The discrepancies may, however, reflect the fact that the changes in circulation-type frequency (and hence in the number of rain days) are small in relation to the GCM and CWG errors and in relation to the variability of rainfall within each circulation type. Nonetheless, whether the 'correct' mechanisms are included in the GCM and, if so, whether they are reliably parameterised, is open to debate. The possibilities for incorporating additional mechanisms and predictor variables in empirical downscaling methodologies are discussed further in Chapter 7, together with the alternative possibility, that the discrepancies between raw GCM changes and downscaled changes may arise because circulation/precipitation relationships are too strong in the GCM (Wilby and Wigley, 1997; Wilby *et al*., 1998a; Buishand and Brandsma, 1999).

Given the differences between the raw GCM changes and the empirically-downscaled scenarios, the question then arises as to which provide the most plausible scenarios? The extent to which the present-day climate is reproduced in the GCM and CWG control runs is considered to provide a reasonable basis for this evaluation. While it may be possible to demonstrate that a GCM can reliably reproduce areally-averaged precipitation (Hulme and Osborn, 1998), GCM output is unlikely to provide an adequate or a legitimate representation of observed point or station data. This is clearly the case for the UKTR land square closest to the Guadalentin Basin. Over the 10-year control run, an average of 239 annual rain days is simulated (Figure 4.1b). This number is far in excess of the 28-48 annual rain days experienced at the six Guadalentin Basin stations (Table 3.1). The number of rain days tends to be underestimated in the *Cont.* simulations performed with the CWG (Table 3.6), but the CWG output clearly provides a more adequate representation of present-day rainfall than the raw GCM output. On this basis, it is considered that the downscaled rainfall series summarised in Table 3.7 provide more plausible scenarios for individual stations in the Guadalentin Basin than the raw GCM changes. The downscaled changes are small in comparison to the observed variability, but evidence that major changes may not occur in a particular region may be as relevant for impact analysis and other planning issues as evidence supporting the occurrence of major changes.

4.6 THE ASSUMPTION OF STATIONARITY

The assumption that the observed relationships between the circulation types and the daily rainfall regime (or any other aspect of the climate) will be unchanged in a future warmer world is fundamental to this circulation-based approach to downscaling. Clearly this assumption cannot be fully tested although it might be possible to test it in part using GCM output. Figure 4.2 indicates that there are differences in the $PROP_{ct}/PROP_{tot}$ and $PREC_{ct}/PREC_{tot}$ ratios calculated from perturbed and control-run output. However, only 10 years of model output were available for the calculation of these ratios. The differences between the perturbed and control-run ratios are generally small compared with the observed decade-to-decade variability indicated in Figure 3.10. Very much longer GCM time series are needed to investigate the future behaviour of circulation/surface climate relationships.

A similar assumption concerning the stability of predictor/predictand relationships must also, however, be made when using any of the empirical approaches to downscaling (Section 1.2.1), and in many other areas of climate research (Heyen *et al.*, 1996). This assumption is one aspect of the so-called stationarity problem which arises in circulation-based approaches to downscaling (Conway *et al*., 1996; Widmann and Schär, 1997; Wilby, 1997; Wilby and Wigley, 1997; Wilby *et al*., 1998a; Busuioc *et al*., 1999; Zorita and von Storch, 1999). In relation to this assumption, however, the fact that the UKTR changes in circulation-type frequency are small in relation to the observed variability might be considered as something of an advantage, i.e. by reducing the danger of extrapolating beyond the limits of variability experienced over the period of model construction (Schnur and Lettenmaier, 1998; Wilby and Wigley, 1997; Wilby *et al*., 1998a; Zorita and von Storch, 1999).

Another element of the stationarity problem concerns variability in surface climate and the underlying forcing mechanisms. The underestimation of monthly standard deviations in circulation-based weather generator output has, for example, been attributed to the failure to parameterize low-frequency processes in the weather generator (Wilby and Wigley, 1997; Wilby *et al.*, 1998a; see Section 4.4). This aspect of the problem is considered further in Chapter 7.

The third aspect of the stationarity problem concerns temporal variability in circulation/rainfall relationships and the effect this may have on weather generator parameters and the simulated time series. Wilby (1997), for example, demonstrates that the conditional probabilities of precipitation for stations in the British Isles are sensitive to the time period over which they are calculated. Figure 3.10 (discussed in Section 3.4.2) indicates that there is some decade-to-decade variability in the probability of a wet day (one of the CWG parameters) at Alcantarilla associated with each circulation type, although the circulation/rainfall relationships are broadly coherent and stable.

Particularly large divergence in weather generator parameter values might be expected in cases where they are calculated for sub-periods at the beginning and end of a time series containing a marked trend. Significant linear trends cannot be identified in the seasonal SAIs constructed from the Guadalentin Basin station series (see Section 3.1.3). Distinctive sub-periods are, however, evident (Figure 3.4). CWG precipitation parameters calculated over the relatively wet late1960s/early 1970s, for example, are likely to be different to those calculated over the relatively dry late1970s/early 1980s. Since it is not possible to make an objective, *a priori* judgement as to which of these sub-periods is likely to be more representative of future conditions, it is considered appropriate to calculate the CWG rainfall parameters using the longest-possible time series. It is considered particularly important to maximise the sample size when estimating rainfall distribution parameters for simulating precipitation amount (see Chapter 6). Maximising the data period over which an empirical model is constructed also has the potential advantage of increasing the range of variability and thus reducing the dangers of over-extrapolation (von Storch *et al*., 1993; Zorita and von Storch, 1999).

4.7 CONCLUSIONS

Despite the problems and issues raised in this chapter, the performance of the initial downscaling methodology described in Chapters 2 and 3 was considered to be encouraging. After completion of the initial analyses, daily output from a more recent set of GCM simulations performed at the UK Hadley Centre, referred to as HADCM2, (Johns *et al*., 1997) became available and was used for all the analyses described in Chapters 5-7. These build on the initial analyses and address many of the issues discussed here. In particular, the major aims of the analyses presented in Chapters 5 and 6 are to:

- further test the transferability of the downscaling methodology by applying it to a new study region in the central Mediterranean;
- to test the methodology using a more recent version of the GCM, and to compare the performance of the two GCM versions; and,
- to test a new version of the CWG, modified according to the principles outlined in Section 4.4.