**Multi-GCM Climate Projection for the Mediterranean and Related Impact on the Forest Fire Risk (with a stress on Sardinia)**

Martin Dubrovsky (Institute of Atmospheric Physics, Prague, Czech Republic; madu1110@gmail.com)

Pierpaolo Duce, Bachisio Arca, Grazia Pellizzaro (CNR - IBIMET, Sassari, Italy)

The PRASCE project (2008-2011) aimed at a development of the probabilistic future climate scenarios accounting for uncertainties originating from various sources. The methodology was based on linking the stochastic weather generator (which may represent uncertainty due to natural climate variability) with the GCM-based climate change scenarios, which are determined by the pattern scaling method accounting for uncertainties in emission scenario, climate sensitivity and between-GCM variability. The methodology is being used to create synthetic weather series representing present & future climates for various climate change impact experiments. One of the regions under focus was the Mediterranean (MT).

### Box 1: Multi-GCM climate change scenarios for the Mediterranean based on monthly outputs from 17 GCMs. The maps show the standardised changes (related to 1K rise in global mean temperature) in temperature and precipitation, and the shifts in Palmer Drought Indices (PDSI and Z) calibrated with 1991-2020 GCM series and then applied to 2070-99.

### Box 2: Shows the climate change scenarios in terms of changes in Weather Generator (M&Rfi) parameters, focusing on parameters, which affect high-frequency variability, e.g. changes in probability of wet day occurrence and variability of daily values.

### Box 3: Choosing a representative subset of GCMs for Sardinia. This part is motivated by the fact, that some climate change impact studies do not allow to employ all available GCMs, so the task arises to choose the subset of GCMs based on the (a) quality of GCMs and (b) ability of the subset to represent the between GCM uncertainty. To demonstrate the methodology, the procedure is applied to Sardinia.

### Box 4: Assessment of possible impacts of climate change on wildland fire risk. The M&Rfi weather generator linked to GCM-based climate change scenarios is used to create synthetic weather series (air temperature, relative humidity, wind speed, and precipitations) to assess impact of the projected climate change in terms of changes in Fire Weather Index (FWI) in Sardinia.

#### Finding a representative subset of GCMs

The maps of CC scenarios show large inter-GCM variability (which is partly related to natural climate variability, but it is mostly due to differences between structure of the models). To account for this variability, all available GCMs might be used in a given climate change impact study. In some cases, it is not possible to use scenarios from all GCMs, so the task arises to choose a representative subset of GCMs. Here, we suggest to use the subset of 5 GCMs:

- **1 Best** = the GCM which best represents annual cycle of temperature and precipitation
- **1 Central** = the GCM, which is closest to the centroid of scenarios from all GCMs
- **3 Most diverse** = the GCM triplet, which maximises the sum of inter-GCM distances

**example: subset of GCMs for Italy & Sardinia:**

<table>
<thead>
<tr>
<th>GCM</th>
<th>Sardinia</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best</td>
<td>GCM20</td>
<td>GCM20</td>
</tr>
<tr>
<td>Central</td>
<td>GCM17</td>
<td>GCM11</td>
</tr>
<tr>
<td>1Diverse</td>
<td>GCM21</td>
<td>IP4M1</td>
</tr>
<tr>
<td>2Diverse</td>
<td>GCM40</td>
<td>NCMI</td>
</tr>
</tbody>
</table>

Sardinia is quite homogeneous in terms of the inter-GCM variability, so that the choice of the unique representative GCM subset for its whole territory is relatively straightforward. In contrast, this task would be more difficult for a larger region, such as whole Italy!

### Main Results:

- **The standardised temperature change** derived from the monthly series simulated by multiple GCMs indicate temperature increase in all parts of MT in all seasons with the highest increase in summer in the interiors of the Iberian and Balkan peninsulas, and the lowest over the Mediterranean Sea. The projected increase shows a high inter-GCM concordance.

- **The precipitation change** is affected by much higher inter-GCM uncertainty. PREC will decrease in whole MT in all seasons except for winter, when the zonal band of statistical insignificant change (precipitation tends to increase/decrease north/south of this band) lies along the northern MT. The highest decrease will occur in summer nearly everywhere in MT, especially in the southern Balkan and Aegean Sea areas.

- **Drought:** The increased temperature together with decreased precipitation will result in increased drought risk, especially in summer.

- **WG-friendly scenarios:** The scenarios given in terms of the Weather Generator (M&Rfi) parameters suggest trend towards more intensive temperature and precipitation extremes. Note that these scenarios are affected by higher uncertainty (compared to standardised scenarios shown in Box 1), mainly due to shorter available time series. It is therefore advised to handle these scenarios with a greater care (by averaging over GCMs, using smoothed annual cycles, and/or applying spatially smoothed scenarios).

- **FWI simulations** for 2050 made with use of M&Rfi weather generator forced by multiple GCM scenarios indicate increased wildfire risk.
GCMs used to derive the standardized climate change scenarios and changes in drought conditions (Box.1), and WG-friendly scenarios (Box.2). All GCM simulations were made using the SRES-A2 emissions for IPCC-AR4.

These maps show the multi-GCM median (represented by colour) and inter-GCM variability (in terms of STD/Median ratio represented by the shape of the symbol) from a set of 17 (Figs.1.1 and 1.2) and 16 (Fig.1.3) GCMs. The standardised changes in TAVG and PREC relate to 1K rise in global mean temperature.

WG-friendly climate change scenarios

Changes in some important climatic characteristics (e.g. probability of wet day occurrence) cannot be derived from the monthly GCM series (which are used in Box.1). These characteristics are derived here from GCM daily outputs. As the weather series for the future climate are often produced by stochastic weather generators, it appears advantageous to give scenarios in terms of changes in WG parameters.

Here, we focus on WG (M&Rfi) parameters, which may affect occurrence of extremes (incl. wet/dry / hot/cold periods) and interdiurnal variability:

- $P_{wet}$, $P_{dry}$ ... parameters of Markov chain for wet day occurrence
- $s(TAVG)$ ... variability of daily avg temperature
- $a(DTR)$, $s(DTR)$ ... avg and std of DTR ($DTR = TMAX – TMIN$)

The changes are derived for 30 Mediterranean sites, based on 9 GCM runs:

$$\Delta WG = P[2081-2100]_{GCM} \div P[1961-1990]_{GCM}$$

where:

- $\Delta$ = difference (temperature); ratio (PREC, DTR and STDs)
- WG parameters are derived from detrended time series.

The figures below show changes related to year, summer and winter.

Acknowledgements: The underlying research was funded by (i) The Ministry of Education, Youth and Sports of the Czech Republic (project LD12029 - "Downscaling the Global Climate Models with use of the Stochastic Weather Generator"), (ii) CNR(Italy)-ASCR(Czech Rep.) bilateral project ("Climate change impacts on crop production and fire danger in selected Mediterranean areas", and (iii) FUME project ("Forest fire under climate, social and economic changes... "); 7FP, Theme ENV.1.3.1.1, Grant Agreement 243888).