Variations in the Simulation of Climate Change Impact Indices due to Different Land Surface Schemes over the Mediterranean, Middle East and Northern Africa

Katiana Constantinidou, George Zittis, Panos Hadjinicolaou

24 - 06 - 2019
Introduction

Recent past:
High temperatures & dryness

Future:
More extreme climatic conditions

Ecosystem & societal impacts

Mediterranean, Middle East and Northern Africa
Introduction

Regional Climate models (RCM) used for climate simulations (downscaling technique)

The output of the simulations are affected by different sources of uncertainty

RCMs have uncertainties that are related to the representation of the dynamical & physical processes

Land-Atmosphere interactions play an important role in climate through the exchange of heat, moisture & radiation between the ground and the air above it.

Land Surface Schemes (LSSs) are used to represent land surface processes in climate models
Introduction

Changes in prevailing climatic conditions simulated by RCMs → Consequences on society and natural ecosystems, projected and evaluated by impact assessments

**Objective:**

to explore the implied uncertainty of the variations of certain climate change impact related indices as it is induced by the modelled climate from different land surface schemes.

- Radiative Index of Dryness (RID)
- Fuel Dryness Index (Fd)
- Water-limited Yield (Yw)
Methodology

Data:

RCM: Weather Research Forecast (WRF) version 3.8.1
Boundary conditions: ERA-Interim reanalyses
Horizontal resolution: 50 km
Time period: December 2000 – November 2010
Domain: MENA-CORDEX (Coordinated Regional Climate Downscaling Experiment)

<table>
<thead>
<tr>
<th>Experiment No.</th>
<th>Land Surface Scheme</th>
<th>Number of soil layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>run1</td>
<td>Noah</td>
<td>4</td>
</tr>
<tr>
<td>run2</td>
<td>NoahMP (dynamic vegetation = OFF)</td>
<td>4</td>
</tr>
<tr>
<td>run3</td>
<td>NoahMP (dynamic vegetation = ON)</td>
<td>4</td>
</tr>
<tr>
<td>run4</td>
<td>CLM</td>
<td>10</td>
</tr>
<tr>
<td>run5</td>
<td>RUC</td>
<td>6</td>
</tr>
<tr>
<td>run6</td>
<td>RUC</td>
<td>9</td>
</tr>
</tbody>
</table>
Methodology

Impact Indices:

**Radiative Index of Dryness (RID)**

A non-dimensional measure of the long-term balance between rainfall and net radiation

\[
RID = \frac{r_n}{\lambda H \times p}
\]

- \(r_n\) → net radiation
- \(\lambda H\) → latent heat flux
- \(p\) → precipitation

*Budyko et. al. 1974*
Methodology

Impact Indices:

**Fuel Dryness Index (Fd)**

A simple way to calculate fuel moisture content and assess the fire risk in an area.

\[ Fd = 1 - \frac{LH}{r_n - G} \]

- \( r_n \rightarrow \) net radiation
- \( LH \rightarrow \) latent heat flux
- \( G \rightarrow \) ground heat flux

*Snyder et. al. 2006*
Methodology

Impact Indices:

**Water-limited yield (Yw)**

Agro-Ecological Zones (AEZ) methodology to assess the suitability of crops and to quantify expected production.

1. thermal suitability test: result to the suitable grid-boxes for cultivation of a certain crop

2. potential crop yields are calculated with regard to the prevailing temperature and radiation regimes

3. water-limited yield are derived using the potential yields and a water-stress limiting factor

Crop: **Durum wheat**
(Triticum turgidum)
Growing cycle: **180 days**
1\(^{st}\) November - 30\(^{th}\) April

Constantinidou et. al. 2016
Results

For each of the sub-domain and for every index
mean values derived from the 6 experiments,
the difference (Δ) of each run from the overall mean value,
two times the standard deviation
and “relative dispersion” (2σ/mean(r1:r6)) are calculated.
Results
### Results

<table>
<thead>
<tr>
<th>RID</th>
<th>anat</th>
<th>balk</th>
<th>wmed</th>
<th>cmd</th>
<th>emed</th>
<th>meso</th>
<th>Whole Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (r1:r6)</td>
<td>0.301</td>
<td>0.176</td>
<td>5.846</td>
<td>11.473</td>
<td>27.379</td>
<td>8.212</td>
<td>3.511</td>
</tr>
<tr>
<td>$\Delta$Noah</td>
<td>0.110</td>
<td>0.064</td>
<td>-3.618</td>
<td>7.594</td>
<td>34.397</td>
<td>6.660</td>
<td>7.038</td>
</tr>
<tr>
<td>$\Delta$NoahMP</td>
<td>0.001</td>
<td>0.008</td>
<td>9.114</td>
<td>4.097</td>
<td>0.670</td>
<td>-0.149</td>
<td>-1.464</td>
</tr>
<tr>
<td>(dyn. veg. = off)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta$NoahMP</td>
<td>-0.023</td>
<td>-0.012</td>
<td>9.595</td>
<td>4.608</td>
<td>0.028</td>
<td>-0.071</td>
<td>-1.450</td>
</tr>
<tr>
<td>(dyn. veg. = on)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta$CLM</td>
<td>-0.052</td>
<td>0.004</td>
<td>-5.120</td>
<td>-6.715</td>
<td>-19.813</td>
<td>-4.905</td>
<td>-2.529</td>
</tr>
<tr>
<td>$\Delta$RUC (6soil)</td>
<td>-0.015</td>
<td>-0.031</td>
<td>-4.945</td>
<td>-4.626</td>
<td>-7.700</td>
<td>-1.216</td>
<td>-0.978</td>
</tr>
<tr>
<td>$\Delta$RUC (9soil)</td>
<td>-0.022</td>
<td>-0.034</td>
<td>-5.027</td>
<td>-4.959</td>
<td>-7.581</td>
<td>-0.318</td>
<td>-0.616</td>
</tr>
<tr>
<td>2*$\sigma$</td>
<td>0.114</td>
<td>0.072</td>
<td>14.536</td>
<td>12.224</td>
<td>36.801</td>
<td>7.484</td>
<td>3.507</td>
</tr>
<tr>
<td>Rel. Disp.</td>
<td>0.379</td>
<td>0.409</td>
<td>2.487</td>
<td>1.065</td>
<td>1.344</td>
<td>0.911</td>
<td>0.999</td>
</tr>
</tbody>
</table>

2*$\sigma$ – 2 * standard deviation
Rel. Disp. - “Relative dispersion”
Results
### Results

<table>
<thead>
<tr>
<th>Fd</th>
<th>anat</th>
<th>balk</th>
<th>wmed</th>
<th>cmd</th>
<th>emed</th>
<th>meso</th>
<th>Whole Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (r1:r6)</td>
<td>0.332</td>
<td>0.417</td>
<td>0.453</td>
<td>0.107</td>
<td>0.120</td>
<td>0.039</td>
<td>0.154</td>
</tr>
<tr>
<td>ΔNoah</td>
<td>0.023</td>
<td>0.101</td>
<td>0.053</td>
<td>0.023</td>
<td>0.017</td>
<td>0.006</td>
<td>0.018</td>
</tr>
<tr>
<td>ΔNoahMP (dyn. veg. = off)</td>
<td>0.015</td>
<td>−0.028</td>
<td>0.015</td>
<td>0.004</td>
<td>0.011</td>
<td>0.004</td>
<td>0.005</td>
</tr>
<tr>
<td>ΔNoahMP (dyn. veg. = on)</td>
<td>0.019</td>
<td>0.006</td>
<td>0.048</td>
<td>0.015</td>
<td>0.015</td>
<td>0.007</td>
<td>0.014</td>
</tr>
<tr>
<td>ΔCLM</td>
<td>0.030</td>
<td>0.087</td>
<td>0.030</td>
<td>0.011</td>
<td>0.011</td>
<td>0.004</td>
<td>0.014</td>
</tr>
<tr>
<td>ΔRUC (6soil)</td>
<td>−0.040</td>
<td>−0.079</td>
<td>−0.071</td>
<td>−0.026</td>
<td>−0.027</td>
<td>−0.011</td>
<td>−0.025</td>
</tr>
<tr>
<td>ΔRUC (9soil)</td>
<td>−0.046</td>
<td>−0.086</td>
<td>−0.076</td>
<td>−0.027</td>
<td>−0.026</td>
<td>−0.010</td>
<td>−0.026</td>
</tr>
<tr>
<td>2*σ</td>
<td>0.068</td>
<td>0.160</td>
<td>0.117</td>
<td>0.043</td>
<td>0.042</td>
<td>0.016</td>
<td>0.041</td>
</tr>
<tr>
<td>Rel. Disp.</td>
<td>0.205</td>
<td>0.384</td>
<td>0.258</td>
<td>0.402</td>
<td>0.350</td>
<td>0.406</td>
<td>0.265</td>
</tr>
</tbody>
</table>

2*σ – 2 * standard deviation  
Rel. Disp. - “Relative dispersion”
Results
# Results

\[ 2*\sigma - 2 \times \text{standard deviation} \]

Rel. Disp. - “Relative dispersion”

<table>
<thead>
<tr>
<th>Yw</th>
<th>anat</th>
<th>balk</th>
<th>wmed</th>
<th>cmed</th>
<th>emed</th>
<th>meso</th>
<th>Whole Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (r1:r6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>241.175</td>
</tr>
<tr>
<td>( \Delta \text{Noah} )</td>
<td>0.314</td>
<td>26.180</td>
<td>25.759</td>
<td>12.039</td>
<td>2.900</td>
<td>-2.519</td>
<td>2.287</td>
</tr>
<tr>
<td>( \Delta \text{NoahMP} )</td>
<td>100.220</td>
<td>22.357</td>
<td>3.994</td>
<td>-5.814</td>
<td>14.032</td>
<td>9.782</td>
<td>3.942</td>
</tr>
<tr>
<td>(dyn.veg. = off)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta \text{NoahMP} )</td>
<td>17.929</td>
<td>-35.816</td>
<td>6.455</td>
<td>-11.823</td>
<td>0.770</td>
<td>5.657</td>
<td>-21.633</td>
</tr>
<tr>
<td>(dyn.veg. = on)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta \text{CLM} )</td>
<td>33.076</td>
<td>88.141</td>
<td>91.379</td>
<td>36.844</td>
<td>17.946</td>
<td>5.119</td>
<td>26.918</td>
</tr>
<tr>
<td>( \Delta \text{RUC (6soil)} )</td>
<td>-171.354</td>
<td>-127.924</td>
<td>-72.245</td>
<td>-8.818</td>
<td>-23.278</td>
<td>1.734</td>
<td>-4.329</td>
</tr>
<tr>
<td>( \Delta \text{RUC (9soil)} )</td>
<td>19.814</td>
<td>27.062</td>
<td>-55.341</td>
<td>-22.429</td>
<td>-12.370</td>
<td>-19.773</td>
<td>-7.186</td>
</tr>
<tr>
<td>( 2*\sigma )</td>
<td>181.581</td>
<td>147.875</td>
<td>117.824</td>
<td>42.491</td>
<td>31.277</td>
<td>21.056</td>
<td>22.056</td>
</tr>
<tr>
<td>Rel. unc.</td>
<td>0.259</td>
<td>0.201</td>
<td>0.147</td>
<td>0.120</td>
<td>0.064</td>
<td>0.349</td>
<td>0.091</td>
</tr>
</tbody>
</table>
Summary & Conclusions

Aim: to investigate the variations in the estimation of three climate change-related indices from RCM output due to different LSS.

The indices are: Radiative Index of Dryness (RID), the Fuel Dryness Index (Fd) & Water-limited Yield (Yw) of durum wheat.

6 performed simulations using the WRF RCM over the MENA-CORDEX domain driven by ERA-Interim reanalysis data for the period of 2000–2010 using 4 different LSSs (Noah, NoahMP, CLM and RUC).

The indices directly related to certain impact sectors are found to be sensitive to the choice of LSSs employed.
Summary & Conclusions

RID:
CLM simulations deviate the most from Noah (reference) and gives less dry simulated conditions (Δ CLM)
MENA’s relative dispersion = 1 (0 < RID < 4)

Fd (JJA):
Most vulnerable areas: western Mediterranean and Balkans
Fire potential: CLM and both options of NoahMP - high
   RUC → reduced
Fd (JJA) ==> Noah: highest & RUC: lowest
“Relative dispersion”: sub-domains = 0.2 - 0.4, MENA region ~ 25%

Yw (Durum wheat):
Southern & most of the northern parts of MENA: not suitable
All LSSs (except CLM): lower values compared to Noah
Yw ==> Mesopotamia:lowest & western Mediterranean highest
“Relative dispersion”: MENA ~ 10%, sub-regions up to 40%

A certain degree of uncertainty in these indices should be expected because of the land surface treatment.
Article
Variations in the Simulation of Climate Change Impact Indices due to Different Land Surface Schemes over the Mediterranean, Middle East and Northern Africa

Katiana Constantinidou *, George Zittis and Panos Hadjinicolaou

Energy, Environment and Water Research Center, The Cyprus Institute, 2121 Nicosia, Cyprus; g.zittis@cyi.ac.cy (G.Z.); p.hadjinicolaou@cyi.ac.cy (P.H.)
* Correspondence: k.constantinidou@cyi.ac.cy; Tel.: +357-22-208662
Thank you !!!

Katiana Constantinidou
k.constantinidou@cyi.ac.cy