The impact of soil moisture variability on seasonal climate simulations of precipitating convection over complex terrain

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Why study land-climate interactions?

§ Relevant for climate variability and extreme events, numerical weather prediction and seasonal forecasting
§ High complexity due to the range of involved feedbacks and interactions, as well as the spatial heterogeneity. Important source of uncertainty for our understanding of the climate system due to complexity and the lack of observations

Motivation

• Long-standing topic in the research literature, studies presenting some evidence for positive, negative, and no feedbacks, inconclusive results.
• To gain confidence in statements about the present and future changes in weather and climate, it is necessary to assess how well and with what uncertainties the components of the regional water cycle such as soil moisture, evapotranspiration and precipitation can be modelled

Aim

• To identify model deficiencies which could affect the representation of the land-climate interactions
• To investigate the possible feedback processes and to assess, if possible, the sign and strength of the soil moisture-precipitation coupling
Soil moisture–precipitation coupling / feedback

Seasonal climatic simulations of precipitation over a complex terrain

ICAM 05.2011
COSMO-CLM model

**Model domain**

Period of investigation: JJA 2007
SVATs: TERRA-ML & VEG3D

**Model Setup**

<table>
<thead>
<tr>
<th>Model version</th>
<th>COSMO-CLM 4.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution</td>
<td>7 km</td>
</tr>
<tr>
<td>Forcing data</td>
<td>GME 40 km</td>
</tr>
<tr>
<td>Size of the simulation area</td>
<td>124 x 140 gridpoints</td>
</tr>
<tr>
<td>Number of vertical layers</td>
<td>40</td>
</tr>
<tr>
<td>Time integration scheme</td>
<td>Leapfrog</td>
</tr>
<tr>
<td>Time step</td>
<td>40 s</td>
</tr>
<tr>
<td>Convection scheme</td>
<td>Tiedtke</td>
</tr>
<tr>
<td>Scheme for grid-scale precipitation</td>
<td>Two-Category Ice Scheme</td>
</tr>
</tbody>
</table>
The impact of soil moisture initialization
Moisture recycling / indirect interactions?

There is a significant impact but the relationship is uncertain

Seasonal climatic simulations of precipitation over a complex terrain

ICAM 05.2011
Local feedbacks?

Transient runs 2005-2009 JJA period

Seasonal climatic simulations of precipitation over a complex terrain ICAM 05.2011
The impact of upstream soil moisture conditions
Non-local feedbacks?

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<tr>
<th>INFLOW</th>
<th>AIR MASSES</th>
<th>Number of days</th>
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</thead>
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<tr>
<td>SW</td>
<td>Humid</td>
<td>51</td>
</tr>
<tr>
<td>NW</td>
<td>Dry</td>
<td>19</td>
</tr>
<tr>
<td>SE</td>
<td>Humid</td>
<td>6</td>
</tr>
<tr>
<td>NE</td>
<td>Humid</td>
<td>2</td>
</tr>
<tr>
<td>n. defined</td>
<td>Humid</td>
<td>9</td>
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Classification of weather situations for the summer period (JJA) of 2007 (R. Sasse)
The impact of upstream soil moisture conditions
Non-local feedbacks?

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Classification of weather situations for the summer period (JJA) of 2007 (R. Sasse)
Soil-vegetation-atmosphere transfer models

TERRA - VEG3D

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Convective and Orographically-induced Precipitation Study (COPS)

Soil moisture/Prec stations
Energy balance stations
Radiosoundings
GPS stations

60 stations: 43 IMK + 8 COPS + 9 extern
June 2007 – June 2009
Soil-vegetation-atmosphere transfer models

OBS-TERRA

OBS-VEG3D

Seasonal climatic simulations of precipitation over a complex terrain

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The soil moisture

Seasonal climatic simulations of precipitation over a complex terrain ICAM 05.2011
The surface fluxes
The atmospheric water vapour

Advection of moisture is overestimated. Secondary circulation systems are not well represented.
The atmospheric conditions: CAPE and CIN

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Soil moisture–precipitation coupling

Non-local feedback and indirect interaction

Advection of evaporated moisture

PBL/atmospheric conditions

Local feedback

precipitation

Seasonal climatic simulations of precipitation over a complex terrain

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Seasonal climatic simulations of precipitation over a complex terrain

ICAM 05.2011
Soil type-precipitation

4 experiments:

CCLM_TERRA-ML
CCLM_VEG3D
CCLM_VEG3D_FAO
CCLM_VEG3D_FAO_horizons
Conclusion

• Coupling between SM and convective precipitation exists, but the relationship is complex for the time scale investigated.

• Indirect interactions and non-local feedbacks, i.e., advection of evaporated moisture from neighbouring areas rather than moisture recycling.

• OBS are extremely important, but scarce, for validation of the models. Remote sensing retrieval of SM in a „systematic way“ (e.g. SMOS mission) very important for the scientific community.

• Model deficiencies should be corrected to improve our simulations.

• A correct representation of the soil textures and land use turned out to be more important than the land-surface scheme used.

• Initialization could be helpful for forecast purposes but not for seasonal or climatic simulations, assimilation and remote sensing should be further explored.

• Crucial role of land-atmosphere interactions in future climate change.
Thank you for your attention