Land-atmosphere feedbacks in a high-resolution RCM: sensitivity to the land-surface forcing

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Land-surface forcing

SOIL TEXTURE
- Other (land-ice)
- Bedrock
- Water
- Organic Material
- Clay
- Silty Clay
- Sandy Clay
- Clay Loam
- Silty Clay Loam
- Sandy Clay Loam
- Loam
- Silt
- Silt Loam
- Sandy Loam
- Loamy Sand
- Sand

LAND USE
- Barren Tundra
- Mixed Tundra
- Wooded Tundra
- Water
- Barren or Sparsely Vegetated
- Snow and Ice
- Cropland/natural vegetation mosaic
- Urban and Built-Up
- Croplands
- Permanent wetlands
- Grasslands
- Savannas
- Woody Savannas
- Open Shrublands
- Closed Shrublands
- Mixed Forests
- Deciduous Broadleaf Forest
- Deciduous Needleleaf Forest
- Evergreen Broadleaf Forest
- Evergreen Needleleaf Forest

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Land-surface forcing

Contact person: Hans-Stefan Bauer, hans-stefan.bauer@uni-hohenheim.de

SOIL TEXTURE

FAO

HWSD

Other (land-ice)
Bedrock
Water
Organic Material
Clay
Silty Clay
Sandy Clay
Clay Loam
Silty Clay Loam
Sandy Clay Loam
Loam
Silt
Silt Loam
Sandy Loam
Loamy Sand
Sand

LAND USE

CORINE

Barren Tundra
Mixed Tundra
Wooded Tundra
Water
Barren or Sparsely Vegetated
Snow and Ice
Cropland/natural vegetation mosaic
Urban and Built-Up
Croplands
Permanent wetlands
Grasslands
Savannas
Woody Savannas
Open Shrublands
Closed Shrublands
Mixed Forests
Deciduous Broadleaf Forest
Deciduous Needleleaf Forest
Evergreen Broadleaf Forest
Evergreen Needleleaf Forest

Milovac et al. 2014a
Milovac et al. 2014b
Motivation

Milovac et al. 2014a
Milovac et al. 2014b

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Hans-Stefan Bauer, hans-stefan.bauer@uni-hohenheim.de
Objectives

**SQ1:** Sensitivity of WRF to LS static data

**SQ2:** Sensitivity of WRF to LS & BL sophistication

**SQ3:** Sensitivity of WRF to season
**SQ1:** Sensitivity of WRF to LS static data

4 simulations with various land surface forcing

1. CORINE-HWSD (CH)  
   WRF-FPS setting  
2. CORINE-FAO (CF)  
3. MODIS-HWSD (MH)  
4. MODIS-FAO (MF)  
   WRF default setting

**SQ2:** Sensitivity of WRF to LS & BL sophistication

2 WRF model configurations

1. More sophisticated: MYNN PBL, NOAHMP LSM (UHOH)  
2. Less sophisticated: YSU PBL, NOAH LSM (FZJ)

**SQ3:** Sensitivity of WRF to season

2 case studies  

1. Summer case  
   (Austria, 1.6.-1.7.2009)  
2. Fall case  
   (Foehn, 1.10.-7.11.2014)

8-member ensemble for 2 case studies
WRF version 3.8.1
- WRF-CORDEX FPS Domain
- 15 km to 3 km one-way nesting
- Forcing: ECMWF ERA-Interim
- Simulations ~1 month long
2 analysis regions

- **ST region**: Sensitivity to ST changes (79% grids change)
- **LU region**: Sensitivity to LU changes (77% grids change)
Diurnal cycles: Summer case

Sensitivity to ST changes

Sensitivity to LU changes

- MODIS FAO (WRF def.)
- MODIS HWSD
- CORINE FAO
- CORINE HWSD (FPS)

UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)
Diurnal cycles: Summer case

Sensitivity to ST changes

Sensitivity to LU changes

UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)
Diurnal cycles: Summer case

Sensitivity to ST changes

Sensitivity to LU changes

UHOH (more sophisticated: NOAH-MP+MYNN)
FZJ (less sophisticated: NOAH+YSU)
Diurnal cycles: Fall case

Sensitivity to ST changes

Sensitivity to LU changes

UHOH (more sophisticated: NOAH-MP+MYNN)
FZJ (less sophisticated: NOAH+YSU)
Mixing Diagram: Well mixed PBL can be represented with near surface humidity and temperature.

Mixing Diagram: Well mixed PBL can be represented with **near surface humidity** and **temperature**

Daily coevolution of moisture and heat

Mixing Diagram: Well mixed PBL can be represented with **near surface humidity** and **temperature**

Daily coevolution of moisture and heat

Quantifies the impact of advective and entrainment fluxes (from the diagram)

Quantifies the impact of surface fluxes (from model output)

Mixing diagrams: Summer case

Sensitivity to ST changes

UHOH(NOAH-MP+MYNN)
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Mixing diagrams: Summer case

Solid lines:
- Sensitivity to changes in ST evident (colors)
- Stronger PBL drying with FAO than with HWSD (line shapes)
Sensitivity to ST changes

Solid lines:
- Sensitivity to changes in \( ST \) evident (colors)
- Stronger PBL drying with FAO than with HWSD (line shapes)

**Atmospheric vector** \( \mathbf{V}_{\text{atm}} \):
- More atmospheric drying than surface moistening with FAO
Mixing diagrams: Summer case

Solid lines:
- Effects of the ST changes on PBL evolution in FZJ not as pronounced as in UHOH
Mixing diagrams: Summer case

- **Sensitivity to ST changes**
- **Sensitivity to LU changes**

Solid lines:
- Effects of the LU change on the PBL evolution clearly evident in FZJ simulations.

Surface vector $V_{sfc}$:
- Strong moistening with CORINE in FZJ due to higher hfls than with MODIS
Mixing diagrams: Fall case

**Solid lines:**
- Effects of the LU and ST changes not as evident as for the summer case
- **FZJ** more sensitive to LU changes than **UHOH**

**Atmospheric vector** $V_{atm}$:
- Atmospheric impact on the PBL evolution significantly larger than the impact from the surface
Convection indices: CTP

Convective triggering potential (CTP): Measure of stability in lower atmosphere

- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only
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Convection indices: CTP

Convective triggering potential (CTP): Measure of stability in lower atmosphere

- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only

Evidently stronger impact of the land surface changes in the summer case

Temperature profile

Not in PBL

~3km

Critical

~1km

P_sfc

900hPa

700hPa

CH (FPS setting)

CH-CF Sensitivity to ST

CH-MH Sensitivity to LU

CH-MF(WRF def.)

Summer case

Fall case

•

Calculated from the morning profiles for the days without morning precipitation

• UHOH model configuration only

(Jkg\(^{-1}\))
Convection indices: $HI_{low}$

Humidity Index at low levels: $HI_{low} = (T_{950} - T_{d950}) + (T_{850} - T_{d850})$

- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only

<table>
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<tr>
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<th>Summer case</th>
<th>Fall case</th>
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<td>CH (FPS setting)</td>
<td><img src="map1.png" alt="Map" /></td>
<td><img src="map2.png" alt="Map" /></td>
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<tr>
<td>CH-CF Sensitivity to ST</td>
<td><img src="map3.png" alt="Map" /></td>
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<td>CH-MH Sensitivity to LU</td>
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<td>CH-MF (WRF def.)</td>
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**Convection indices: $HI_{low}$**

**Humidity Index at low levels:** $HI_{low} = (T_{950} - T_{d950}) + (T_{850} - T_{d850})$

- Croplands and Mixed forest (MODIS) changed to Deciduous broadleaf forest and Grassland (CORINE)
- Higher heterogeneity of the ST data with HWSD than with FAO
- Sensitivity to ST: CH-CF
- Sensitivity to LU: CH-MH
- Sensitivity to LU: MF-CH(WRF def.)
Preliminary conclusions

8 CP simulations for 2 cases ~1 month periods

- Dry days (Mixing Diagram)
- Convective indices ($CTP, HI_{low}$)

SQ1: Sensitivity of WRF to land surface static data
- Evident impact of ST and LU changes on the model output: surface variables, PBL evolution, atmospheric stability and humidity in the lower atmosphere
- Strength of the sensitivity to a specific change depend on the model configuration

SQ2: Sensitivity of WRF to the configuration
- Less sophisticated FZJ (NOAH+YSU) configuration more sensitive to LU changes, and more sophisticated UHOH (NOAH-MP+MYNN) more sensitive to ST changes in representing PBL evolution

SQ3: Sensitivity of WRF to season
- Sensitivity of WRF higher to the land surface changes in the summer case
Convection: CTP-HI\textsubscript{low}

Calculated from early morning heat and moisture profiles

Convection: CTP-\(H_{\text{low}}\) regimes:

1. Atmospherically controlled (Atm) 
   (Too stable to rain; too dry to rain; rain everywhere)
2. Dry soil advantage (DSA) – negative feedback 
   (rain favoured over dry soils)
3. Wet soil advantage (WTA) – positive feedback 
   (rain favoured over wet soils)
4. Transition regions (Trans) 
   (positive and negative feedbacks possible)

Findell, K.L. & E.A. Eltahir (2003), J. Hydrometeor., 4, 552–569, 
https://doi.org/10.1175/1525-7541(2003)004<0552:ACOSML>2.0.CO;2
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d02:CTP-HI\textsubscript{low}

<table>
<thead>
<tr>
<th>Area fraction</th>
<th>Atm.</th>
<th>WSA</th>
<th>Trans</th>
<th>DSA</th>
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<td>4.0</td>
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<td>MF</td>
<td>86.3</td>
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Higher sensitivity to LU changes

Higher sensitivity to LU changes
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d02: 01.6.-01.07.2009

CORINE-HWSD

MODIS-HWSD

MODIS-FAO

CORINE-FAO

27.06.2009

CORINE-HWSD

CORINE-FAO

MODIS-HWSD

MODIS-FAO

Atm  WTA  Trans  DSA

d02: CTP-HI

low
Afternoon Precipitation

CORINE-HWSD  CORINE-FAO  MODIS-HWSD  MODIS-FAO

UHOH: MYNN + NOAH-MP
FZJ: YSU + NOAH
Dry days

**Surface forcing maps for the limited region:**

- **CORINE-HWSD**
- **CORINE-FAO**
- **MODIS-HWSD**
- **MODIS-FAO**

**RM1**

- Major changes: **Croplands** and **Mixed Forest** in MODIS into **Permanent Wetlands** and **DB Forest** in CORINE.
- 75% of **clay-loam** in FAO into 50% **loam** and 25% **Sandy Loam** in HWSD
Sensitivity to LS forcing

Averages for RM1 over 30-day period, 1.6.2009 - 1.7.2009

<table>
<thead>
<tr>
<th>Sensitivity to:</th>
<th>soil texture(ST)</th>
<th>land use(LU)</th>
<th>ST and LU</th>
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<tbody>
<tr>
<td>CH(FPS)</td>
<td>CH-CF</td>
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<td>hfs_{sfc} (hfss)</td>
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<td>hfl_{sfc} (hfls)</td>
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