Sensitivity of the modelled precipitation in South-Norway to changes in vegetation, snow cover and sea surface temperature.

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Outline

Provoking Statement

Motivation

Method

Set Up

Experiments
  A - Treeline
  B - Snow Cover
  C - Diurnal SST
  D - SST +0.4K

Results

Summary & Conclusions
Take home message

- Given the relative ease of implementing LULCC it should be included in climate projections (as it is in CMIP5→IPCC AR5) and regional (downscaling) studies, of Norway.

- Disclaimer: Additional sensitivity studies are needed, and also studies including the densification of existing forests, and the biogeochemical effects of LULCC.
Models
Underlying Goal

Answering: How simple is too simple?

-A study of the modelled local land-atmosphere coupling in South Norway.
Why?

- Chaos limits weather forecasting predictability,
- International studies point to regions where the land surface has a high influence on temperature and precipitation with soil moisture regimes that are neither too dry or too wet.
- In Norway $\frac{E}{R} \approx \frac{1}{3}$: an energy limited regime. Norway has not stood out as a hot spot for soil moisture-atmosphere coupling.
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Future Hotspots in European Climate-Vegetation Feedbacks

The role of vegetation-climate feedbacks over Europe has been investigated in a Ph.D. thesis by Wramneby (2010). One conclusion drawn in the thesis is that contrasting feedback mechanisms between climate and vegetation differ by region and season (Wramneby et al., 2010a).

In the Scandinavian mountains, feedbacks related to surface albedo amplify the warming in winter and spring. Over continental Europe, feedbacks related to summertime evapotranspiration both dampen (central Europe) and amplify (southern Europe) the warming. Climate-vegetation feedbacks also affect the variability of temperature. As for the seasonal mean conditions, whether feedbacks act to dampen or enhance temperature variability depends on the region and the season (Wramneby et al., 2010b).

RCA-GUESS
The study is made with a coupled model system RCA-GUESS (Smith et al., 2010). It consists of the Rossby Centre regional climate model RCA3 (Kjellström et al., 2005; Samuelsson et al., 2006) and the dynamic vegetation model LPJ-GUESS (Smith et al., 2001; Wramneby et al., 2008).

Meanwhile, in the Scandinavian mountains, vegetation expansion feedbacks related to surface albedo amplify warming in winter and spring.
Norway

~2/3 energy from hydropower

- ~50% from snowmelt

STORMS OF MY GRANDCHILDREN
THE TRUTH ABOUT THE COMING CLIMATE CATASTROPHE AND OUR LAST CHANCE TO SAVE HUMANITY
JAMES HANSEN
CC - Rain in Bergen
Flood & reservoir management
Rain/snow + mountains = kr, kr kr

Motivation
METHOD

- $\Delta x,y=i: 3.7\text{km}$
- $\circ: 18.5\text{km}$
- rotated Lambert grid,
- 10yr spin-up using HRLDAS
- dry 2009-10 hyd. year and wetter 2010-11
MODIS Land Use Index

Mixed Tundra
Wooded Tundra
Water
Barren or Sparsely Vegetated
Snow and Ice
Cropland/Natural Vegetation
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

Changed according to Moen’s Vegetation zone atlas,
North boreal ⇒ Wooded tundra, Alpine zones ⇒ Mixed tundra

[?] http://stend.wikispaces.com/Metoder+for+kartlegging+av+natur
- **Green Tundra**: The vegetation types wooded tundra and mixed tundra below 1150m are changed to evergreen needleleaf forest, i.e. the boreal tree line is increased with about 200m.
**S/R+2.5°C:** The snow cover is perturbed by changing the discrimination of rain and snow from input from the microphysics scheme to a threshold temperature of 2.5°C.
Diurnal SST: The daily ERA-I SST is changed according to (Zeng, 2005), letting the SST respond to atmospheric fluxes and stresses at the surface, resulting in a mean monthly winter SST about 0.3°C lower, and certain summer spikes.
D - SST + 0.4K

- Relevance
  - Climate change: SST change
  - NAO/AMO - natural oscillations - impact of hit or miss
  - slab: proxy for CC (greenhouse gases/rad. change)
  - SST bias & uncertainty
CHANGE IN PRECIPITATION, p < 0.05

Results
CHANGE IN $T_{2m}$, $p<0.05$
CHANGE IN SNOW (SWE), p < 0.05

Results

% change in SWE

-15 -12 -9 -6 -3 0 3 6 9 12 15
CHANGE IN EVAPORATION, $p < 0.05$

Results
CHANGE IN RUNOFF, $p < 0.05$

Results
Increasing SST by 0.4°C has the largest effect on precipitation (+4.9%, remote)

Increasing the treeline with about 200m has comparable effect (+4.1%)

The LSM is very sensitive to the rain/snow threshold, which influence temperature (-0.2K), evaporation (-8.8%), and thus runoff (+1.1%).

Most of the increase in precip. was partly balanced out by more evap. (or vica versa) in the treeline experiment. The signal is also not consistent, regionally or seasonally, resulting in a much lower mean change in runoff (0.6%) than the SST experiment (3.5%)

This diurnal SST parametrization should probably not be used for Norway; needs regionalization
Given the relative ease of implementing LULCC it should be included in climate projections (as it is in AR5) and regional (downscaling) studies, even for Norway.

Disclaimer: additional sensitivity studies are needed, and also studies including the densification of existing forests, and the biogeochemical effects of LULCC
KEEP
CALM
AND
ENJOY
THE RAIN
<table>
<thead>
<tr>
<th>LSM</th>
<th>SF</th>
<th>PBL</th>
<th>CU</th>
<th>MP</th>
<th>SW</th>
<th>LW</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAH-UA</td>
<td>MM5 M-O</td>
<td>YSU</td>
<td>K-F</td>
<td>Goddard</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta x, y \]

- d02: 3.7 km
- d01: 18.5 km
- 1:5

<table>
<thead>
<tr>
<th>LSM Spin-up</th>
<th>Land Use</th>
<th>GVF</th>
<th>Max. ( \alpha_s )</th>
<th>SST</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRLDAS, 10yr loop</td>
<td>MODIS BU IGBP &amp; Moen, 1998</td>
<td>MODIS explicit WRF-incl.</td>
<td>Barlage, 2005 table values</td>
<td>Daily forcing, ERA-I</td>
</tr>
</tbody>
</table>

| d02: 3.7 km | d01: 18.5 km | 1:5 |

**Notes:**

- NOAH-UA
- MM5 M-O
- YSU
- K-F
- Goddard

- HRLDAS, MODIS BU IGBP & Moen, 1998
- MODIS explicit WRF-incl.
- Barlage, 2005 table values

**References:**

- Barlage, 2005
- Moen, 1998
- ERA-I
Table: % of land area with significant change ($p \leq 0.05$)

<table>
<thead>
<tr>
<th></th>
<th>Treeline</th>
<th>Snow Cover</th>
<th>Diurnal SST</th>
<th>SST+0.4K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>23.4</td>
<td>11.0</td>
<td>10.7</td>
<td>27.4</td>
</tr>
<tr>
<td>$T_{2m}$</td>
<td>38.6</td>
<td>95.9</td>
<td>73.4</td>
<td>99.8</td>
</tr>
<tr>
<td>Runoff</td>
<td>63.5</td>
<td>36.3</td>
<td>59.7</td>
<td>66.1</td>
</tr>
<tr>
<td>Latent Heat</td>
<td>37.7</td>
<td>32.2</td>
<td>8.5</td>
<td>20.4</td>
</tr>
<tr>
<td>Snow Cover</td>
<td>93.2</td>
<td>98.2</td>
<td>93.8</td>
<td>94.0</td>
</tr>
</tbody>
</table>
Grid scale & ”convective” change
Accumulated snow melt, @ end of hydrological year

Daily mean runoff

Control
Green Tundra
S/R+2.5C
diurnal SST
The control run is marked in **black**, the green tundra in **green**, the S/R+2.5°C in **blue**, and the diurnal SST is marked in **red**.
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Preliminary Results

- Nov 2010
- Dec 2010
- Jan 2011
- Feb 2011
- Mar 2011
- Apr 2011
- May 2011
- Jun 2011
- Jul 2011
- Aug 2011
- Sep 2011

- PHYSICAL SNOW DEPTH
  - Control
  - Green Tundra
  - S/R+2.5C
  - Diurnal SST

Graph showing physical snow depth over time from November 2010 to September 2011, with data points for Control, Green Tundra, S/R+2.5C, and Diurnal SST.
Preliminary Results

Nov 2010 - Sep 2011

ALBEDO

- Control
- Green Tundra
- S/R+2.5C
- Diurnal SST
Preliminary Results

Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011

0
120
100
80
60
40
20
0
W m\(^{-2}\)
Surface SW upwelling flux
Control
Green Tundra
S/R+2.5C
diurnal SST

Surface SW upwelling flux
Green Tundra, S/R+2.5C, Diurnal SST
Preliminary Results

LATENT HEAT FLUX AT THE SURFACE

- Control
- Green Tundra
- S/R+2.5C
- Diurnal SST

Nov 2010 - Sep 2011

W m⁻²

-20 0 20 40 60 80 100 120
UPWARD HEAT FLUX AT THE SURFACE

- Control
- Green Tundra
- S/R+2.5C
- diurnal SST

W m⁻²

Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Preliminary Results

SOIL TEMPERATURE

- Control
- Green Tundra
- S/R+2.5C
- Diurnal SST

Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011

-10
-5
0
5
10
15
20

C

Results
Preliminary Results

Accumulated precipitation

- Contol
- Green Tundra
- S/R+2.5C
- Diurnal SST

Seasonally mean precipitation change

Green Tundra, S/R+2.5C, Diurnal SST
Preliminary Results

- UNDERGROUND RUNOFF
  - Control
  - Green Tundra
  - S/R+2.5C
  - Diurnal SST

Nov 2010 - Sep 2011

0 - 160,000 mm