The RCA3 model

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Why bother with regional climate modelling?

What is good with downscaling, aren’t GCMs good enough?

Higher resolution is just better!
Limitations of a GCM

- Inside each box many processes take place that must be described in an approximate way (e.g. turbulence, cloud and rain formation, how aerosols interact with radiation and clouds, …)
- Very small boxes would give us less approximations BUT a very time consuming and slow model.
- Thus, a GCM is a compromise between details in physics and numerical speed of the model (how long simulations you need)!
Regional modelling gives more detail

GCM 300 km

Simulated precipitation
GCM interp. to 50 km

RCM 50 km
RCA3 with higher resolution

Precipitation (DJF, 1987-2007) as a function of resolution

E-OBS 50 km
E-OBS 25 km
RCA3 50 km

RCA3 25 km
RCA3 12 km
RCA3 6 km

mm/month

10 20 30 40 50 100 150 200 250 300 350 1000
Tropical Cyclone Eline hit Moçambique in February 2000

Sea-level air pressure every 6th hour February 17-28

Global ERA40 100 km  Regional RCA 50 km
At Rossby Centre we do dynamic downscaling of GCM output using the RCM called RCA.
Special Issue with RCA3 as common denominator

11 papers + introduction

More than 30 authors

SMHI authors from FoUrc, FoUI, FoUp, FoUh, Mh

Authors outside SMHI from Univ. of Lund
Univ. of Gothenburg
Univ. of Buenos Aires
RCA3 – documentation and applications

- RCA3 and later development versions have been used for more than five years.

- Earlier model documentation in RMK109 and Me122 (land-surface scheme).

- RCA3 has generated a large number of regional climate scenarios (e.g. ENSEMBLES).

- Data from RCA3 has been used - by many project/research groups - for effect studies and adaptation studies (e.g. water resources and Klimat- & sårbarhetsutredningen).

- RCA3 is used at LU and UU and in Canada, Ireland, Spain, Argentina and Chile.
The Rossby Centre regional Climate Model

RCA3

Radiation
... clouds ...
... convection ...
... and precipitation

Cloud microphysics...
Turbulence ...
... and precipitation

Lakes
Land surface and soil
Sea ice
Water mixing

Atmosfär
RCA is applied world-wide

RCA is used by other regional climate research groups:

Lund University, Sweden
Uppsala University, Sweden
INM AEMET, Spain
Met Eireann, Ireland
University of Buenos Aires, Argentina
University of Santiago, Chile
The role of the land surface in weather prediction and climate models

- Act as a lower boundary for the atmosphere
- Provide diagnostic values of 2m temperature and humidity and 10m wind speed
- Represent a memory of changes in energy and water fluxes (snow storage, soil moisture, soil temperature)
- Provide runoff for ground water and river discharge
The role of the land surface in weather prediction and climate models

The water balance components

ERA40: 2.2 mm d⁻¹
Precipitation
ERA40: -1.4 mm d⁻¹
Evapotranspiration
ERA40: -0.9 mm d⁻¹
Runoff

~2m
Storage of water

change in storage = \int \text{Prec.} - \text{Evap.} - \text{Runoff}

ERA40 from P. Viterbo
The role of the land surface in weather prediction and climate models

The energy balance components

\[
\text{change in storage} = \int R_n - H - LE + \text{phase ch.}
\]

ERA40 NetSW: 134 Wm\(^{-2}\)
ERA40 NetLW: -65 Wm\(^{-2}\)
ERA40: -40 Wm\(^{-2}\)
ERA40: -27 Wm\(^{-2}\)

ERA40 from P. Viterbo
Temporal and spatial scales of climate models

- A few kilometers in mesoscale models
- 10-50 km in most RCMs
- 50-300 km in GCMs

The intensity of processes involved limits the length of the time step.

Typical time step:
A few minutes to 30-40 minutes.
RCA-GUESS

RCA and LPJ-GUESS together

Dynamic vegetation
**Why couple a RCM to a DVM?**

| RCM → DVM | Yes, we know this is important! |
| DVM → RCM | Yes, this is especially important in some areas (Koster et al. 2004: South USA, NW Africa, North India) |
| RCM → DMV → RCM | Okay, gives some feedback (e.g. Strandberg et al. 2011) |
| RCM ↔ DVM | Where do we need this? |

Take Scandinavian mountains as an example:
Trees are established due to increased temperature → decreases the albedo, especially due to shading of snow → makes the local climate even warmer (understory climate) → makes it even more favourable for trees → and so on...

The RCM gives a better representation of the altitude differences than a GCM which is important for this region.
Forcing from ECHAM5-A1B

Initial veg state based on a 300 year spinup using detrended 61-90 RCA-GUESS results

A transient scenario over Europe

Time

1800 1900 2000 2100

RCA-GUESS

1961-2100

CO₂
Future vegetation in RCA-GUESS

A model of the coupled dynamics of climate, vegetation and terrestrial ecosystem biogeochemistry for regional applications

Benjamin Smith, Patrick Samuelsson, Anna Wramneby and Markku Rummukainen

(a) Mediterranean

(b) Mediterranean

(c) Mediterranean

(d) Alpine

Precipitation (mm yr⁻¹)

Leaf area index

Temperature °C

- coldest-warmest month temperature range
- mean annual temperature
- 10-year running mean temperature
- annual precipitation
- 10-year running mean precipitation

- needleleaved trees
- broadleaved trees
- herbaceous
More information on

**RCA3 model:**


**RCA-GUESS:**


**RCA and LPJ-GUESS for paleo climate:**


In ongoing and upcoming research RCA-GUESS will be applied over the Arctic region, over Africa and over South America.