TERENO – A new Network of Terrestrial Observatories for Global Change Research

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Facts of Global Change

World population development from 1950 to 2050:

- Climate change is affecting all compartments of the terrestrial system
- 50% of the global land surface has been changed by human activity; 23% of the land surface is degraded in quality
- Loss of agricultural land (e.g., in China -3.5 Mio ha since 2002)
- In 2003: 2% of the agricultural land was lost: Production of rice, corn and wheat -18%
- Worldwide loss of biodiversity
- Decline of water availability (49,000 km³ per year) and water quality
- 1/3 of the earth’s annual renewable water may be affected by pollution in 2050 (Gleick et al., 1998) due to waste water
Motivation

- The effects of Global Change on terrestrial systems are regionally differentiated
- Global Change affects all compartments of the terrestrial environment (water, soil, vegetation, atmosphere) with complex feedback mechanisms
- Existing measurement networks are typically focused on specific compartments and research questions
- Long-term hydrological and ecological data are urgently needed for validating terrestrial environmental models
- There is a need for capacity building in the field of terrestrial research by bringing together different research communities
Climate Change in Germany

Climate models are projecting significant climate change in Germany in the next 100 years:

- Increase in temperature (2.5 – 3.5°C)
- Decrease in precipitation (up to 30 %)

From Umweltbundesamt
Künftige Klimaänderungen in Deutschland – Regionale Projektionen für das 21. Jahrhundert
Hintergrundpapier
April 2006, aktualisiert im September 2006
Effects of Climate Change in Germany

- Droughts
- Heat waves
- Floods
- Winter storms
- Loss of biodiversity
- Landslides

Regions of high vulnerability

From:
Rüdiger Glaser (2008)
Klimageschichte Mitteleuropas
1200 Jahre Wetter, Klima, Katastrophen
The TERENO Network

- **Northeastern German Lowland Observatory**
  Coordination: GFZ

- **Harz / Central German Lowland Observatory**
  Coordination: UFZ

- **Eifel / Lower Rhine Valley Observatory**
  Coordination: FZJ

- **Bavarian Alps / pre-Alps Observatory**
  Coordination: HMUG und KIT
The TERENO concept

- To bring together scientists from different scientific communities and to integrate disciplines
- To exploit the availability of novel technologies and high performance computer facilities for terrestrial research
- To establish common measurement platforms as the basis for long term data sets
- To combine observation and experimentation
- To foster synergies between Helmholtz-centers and national and international research organizations
Research Goals

Investigate interactions and feedbacks between different compartments:

Bridging the gap between measurement, model and management:

<table>
<thead>
<tr>
<th>Spatial scale</th>
<th>The Basin Scale (e.g. the Rur basin)</th>
<th>The Sub-basin Scale</th>
<th>The Hillslope/Plot Scale</th>
<th>The Point Scale (e.g. Lysimeter)</th>
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<tbody>
<tr>
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- Upscaling via process-based models
- Spaceborne Remote Sensing
- Hydrological Monitoring (e.g. runoff, load)
- Meteorological Monitoring (e.g. C-Band Radar)
- Airborne Remote Sensing
- Hydrological Monitoring (e.g. runoff, load)
- Meteorological Monitoring (e.g. X-Band Radar)
- Groundbased Remote Sensing
- Geophysical Methods
- Micrometeorological Measurements
- Sensor Networks
- Single Sensors
- Laboratory Methods

Atmosphere

Terrestrial Biosphere

Terrestrial Hydrosphere & Pedosphere
Organizational structure

Scientific Steering Committee
Representatives of the involved Helmholtz Centres

TERENO Coordination Board
Heye Bogena (FZJ)
Steffen Zacharias (UFZ)
Harald Kunstmann (KIT)

Scientific Advisory Board
Independent experts and cooperation partners

Coordination Teams

- CT Atmosphere
- CT Biosphere
- CT Pedosphere
- CT Hydrosphere
- CT Environmental Sensing
- CT Paleoclimate
- CT Socio-Economy
- CT Data Management
- CT Integrative Modelling
TERENO SoilCan
A Large-scale Climate-Feedback-Experiment

Central research question:
How do grassland ecosystems adapt to climate change?

Approach:
• Grassland soil monoliths (lysimeters) transplanted along the natural gradient in temperature and precipitation
• Investigation of Climate Change effects on
  • C/N cycles
  • associated plant and microbial processes/populations/biodiversity
  • terrestrial hydrology
  • water quality
TERENO SoilCan  Natural Climate Gradients:

- **Sehlhausen** (Δ Temp ~ 2.5°C, Δ NS ~ 480 mm)
- **Rollesbroich** (Δ Temp ~ 2.5°C, Δ NS ~ 480 mm)
- **Wüstebach** (Δ Temp ~ 2.5°C, Δ NS ~ 480 mm)
- **Fendt** (Δ Temp ~ 3.7°C)
- **Rotteneck** (Δ Temp ~ 2.5°C, Δ NS ~ 1,120 mm)
- **Graswang** (Δ Temp ~ 2.5°C, Δ NS ~ 480 mm)
- **Demmin** (Δ Temp ~ 0.6°C, Δ NS ~ 70 mm)
- **Dedelow** (Δ Temp ~ 0.6°C, Δ NS ~ 70 mm)
- **Halberstadt** (Δ Temp ~ 3.0°C, Δ NS ~ 160 mm)
- **Schäfertal** (Δ Temp ~ 3.0°C, Δ NS ~ 160 mm)
- **Bad Lauchstädt** (Δ Temp ~ 3.0°C, Δ NS ~ 160 mm)

**TERENO Sites:**
- *Eifel/Lower Rhine Valley Observatory*
- *Ehrenbreitstein*
- *Bavarian Alps/pre-Alps Observatory*
- *Mohne Reservoir*
- *Ammer Catchment*
- *Mecklenburg-Vorpommern (DLR)*
- *National Park Müritz*
- *Schorfheide Biosphere Reserve*
- *Research Station Demmin (DLR)*
- *Research Station Bad Lauchstädt*
- *Research Farm Scheyern (HMGU)*
TERENO SoilCan
A Large-scale Climate-Feedback-Experiment

Lysimeter network at the Ammer catchment:

- **Graswang**: 860m, 6 lysimeter, Δ Temp ~ 3.7°C, Δ NS ~ 880 mm
- **Rottenbuch**: 750m, 12 lysimeter
- **Fendt**: 600m, 18 lysimeter

Single lysimeter

Lysimeter unit consisting of 6 single lysimeters and central service station

Data transfer
System control and maintenance

IMK-IFU Garmisch-Part
TERENO - ICOS

- ICOS is part of ESFRI, the European Strategy Forum on Research Infrastructures.
- ESFRI is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach.
- ICOS mission: “To provide the long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions.”
- 5 EC-sites at TERENO-prealpine, -Harz, and –Eifel received additional funding from BMBF to expand instrumentation to include fluxes of CH\textsubscript{4} and N\textsubscript{2}O and upgrade to ICOS standard
- TERENO is recognized by ICOS-D as primary candidates to receive long-term (staff) funding
TERENO - ICOS

TERENO ICOS instrumentation:

EC-Station at Grasswang:
The Bavarian Prealpine Observatory

Schechenfilz Fen Site
Ammer Catchment Observatory

- Area: ~710 km² (601 km² above Weilheim)
- Alpine and prealpine landscape with high spatial differentiation in geology and pedology
- Elevations: from 533 m.a.s.l. (Ammersee) to 2185m (Kreuzspitze)
- Two dominant landscape units: the prealpine hill country and moorland and the Swabian-Upper Bavarian foothills of the Alps.
- Dominant geology: lime-alpine zone (south), flysch zone (north)
Impact of land use changes on agro-ecosystems

- Adapted and sustainable plant production systems in crop rotations of plants for food, feed and bioenergy
- Optimized energy and trace gas fluxes and balances
- Improved use of soil microbial functions for better plant nutrition and plant protection
TERENO Infrastructure at Ammer catchment

Graswang-, Rottenbuch-, Fendt Sites
- 3 EC towers: momentum, heat, H$_2$O, CO$_2$, N$_2$O, CH$_4$ fluxes
- 36 Lysimeters: soil water balance, GHG (N$_2$O, CO$_2$, CH$_4$)

Geigersau Site
- 1 X-Band precipitation radar

Additional Sites
- 3 Climate stations (Mount Hörnle, Forsthaus Unternogg, Uffing)
**Eifel / Lower Rhine Valley Observatory**

**Research Site Sehlhausen**
- SoilCan Site
- TERENO-ICOS Site
- SMOS Reference Site
- SoilNet Soil Moisture Monitoring
- Soil Respiration Monitoring
- Geophysical Monitoring
- Remote Sensing (IR, Far-field GPR, Microwaveradiometer)

**Research Site Rollesbroich**
- SoilCan Site
- TERENO-ICOS Site
- SMOS Reference Site
- SoilNet Soil Moisture Monitoring
- Groundwater Monitoring
- Runoff and Solute Monitoring

**Research Site Wüstebach**
- SoilCan Site
- TERENO-ICOS Site
- LTER-D and SMOS Reference Site
- SoilNet Soil Moisture Monitoring
- Groundwater Monitoring
- Runoff and Solute Monitoring
- Biodiversity Assessment
Research station Wüstebach

after deforestation

Ecosystem C-Pool

Cutting

Time

Einmündung Schwarzbach in Wüstebach nach Entfichtung © Röös / NLP Eifel
Hypotheses

- Long-term changes of the water balance with reduced water retention capacity, faster efflux with fast increasing and decreasing runoff peaks
- Larger energy-input by direct solar radiation resulting soil warming, enhanced biological activity of the soil and higher conversion rates
- Higher conversion rates of the litter layer, higher losses of the soil C-pools and change in biodiversity

Nutrient cycling

Atmospheric forcing

Runoff, Erosion

Respiration
Instrumentation of the Wüstebach research station

- Eddy-Flux Towers
- Soil Respiration Chambers
- Groundwater Wells
- SoilCan Lysimeter
- Soil Moisture Sensor Network
- Runoff Gauging Stations
- Sapflow and Dendrometer
- Deforestation Area
EC-tower at Wüstebach research station

- Rainscanner® Weather radar
- Ultra-sonic anemometer
- Inlet funnel for gas analyzer
- Quantum Cascade laser (CH₄, N₂O)
- EC (open and closed path analyzer) (H₂O, CO₂)
- H₂O, CO₂ Gradient Measurement System (Closed path analyzer)
Runoff gauging station at Rollesbroich research station

Meteorological sensor
(rainfall, temperature, air humidity, wind direction, wind velocity)

Data logger with remote transmission

Multi parameter probe
(water temperature, electrical conductivity, pH, nitrate, chloride)

Automatic sampling system

Venturi-Gauging Weir
(water level, drainage volume)
Wireless soil moisture sensor network SoilNet

- Ecosystem
- Router unit
- Coordinator unit
- Sensor unit (below ground)

Long-distance data transmission (GMS)

Communication between Router and Coordinator

Communication between Sensor unit und Router

MODEM
RS232, GPRS

virtual RS232 "ControlPanel" Application

Data bank
Web

Büro
SoilNet instrumentation at Wüstebach research

150 Sensor units
18 Router units
900 Soil water content sensors
300 Temperature sensors
Time series of soil moisture pattern

Mean soil water contents from August to November 2009:

5 cm

20 cm

Mean SWC [vol. %]

- 5 cm
- 20 cm

Measurement variable:
- Soil water content

Measurement date:
- 14.08.2009

Measurement depth:
- 5 cm

Sensor type:
- EC5

Interpolation method:
- Ordinary Kriging

Experimental semivariogram and fitted model

Legend

\[
\begin{align*}
\text{SWC (vol. %)} & \\
& \begin{array}{cccc}
0 - 28 & 28 - 30 & 30 - 32 & 32 - 34 \\
34 - 36 & 36 - 38 & 38 - 40 & 40 - 42 \\
42 - 44 & 44 - 100 & & \\
\end{array}
\end{align*}
\]
From the local to the regional Scale…

Test sites

Radiometer and Sensor Networks (SoilNet) ⇒ long-term continuous monitoring

Model based regionalisation

Airborne campaigns

EMIRAD, PLMR, SAR ⇒ momentary imaging

Satellites (e.g. SMOS) ⇒ continuous monitoring

PLMR Rur Campaign 2008
Environmental Sensing with Multi-Sensors

Example of an airborne campaign:

**Campaign Preparation:**
- Flight planning
- Testsite location

**Campaign Execution:**
- Calibration instrument
- Measurement campaign

**Data Processing:**
- Flight position processing (DGPS)
- Raw data processing

**Parameter Estimation:**
- Algorithms for environ. parameter estimation
- Validation with ground measurements

SAR Data from the SARTEO campaign 2008 over the Rur catchment
Northeastern Lowland Observatory

landuse: from intensive agriculture to natural park (quasi-natural)
Combination of process observations with geoarchives

- Region impacts of Global Change on near-natural terrestrial ecosystems and landscape in space and time
- Integrated system analysis of climate- and landscape development/process understanding
- Combination of real-time process observations (e.g. soil moisture, hydrology, vegetation) and evaluation of geoarchives (seaborne, colluvials, peats, soils)

Remote Sensing  
Field observation  
Geoarchive
Harz/Central German Lowland Observatory
Conceptual approach

Example: Solute Flux management at catchment scale

- Process studies in high intensity measurement areas
  - small subcatchments
  - groundwater transsects
  - Stream mapping locations

- Identification of dominant processes and development of effective descriptions guided by the structure of the system

- Stochastic representation of biochemical transformations (streamline approach)

- Estimation of residence time distributions for mesoscale catchments via pedotransfer functions and geophysical proxies

- Process-oriented transport simulations based on distributed hydrological model
Integrating different disciplines in TERENO

E.g. Floodplain habitats - Assessment targets

- Soil, hydrology, matter fluxes
- Organisms groups
  - Vegetation primary producers
  - Carabides as predators important indicators for land use intensity and hydrology quality
  - Molluscs important indicators for hydrology and connectivity
  - Mosquitoes possible disease vectors
  - Amphibians highly mobile, sensitive to landscape context
- Habitat mapping by remote sensing and fieldwork

Example: Floodplain Testsite Roßlauer Oberluch
Stratified random study design (monitoring plots covering flood channels, semi-natural wet grassland and mesophilic grassland)
TERENO Data management

- Data storage and archiving
- Intellectual property rights and TERENO data policy
- Control of data utilization within TERENO and data dissemination to third parties
- Implementation of a web based data bank and data visualization tool for the presentation of research results
- Simple data allocation to a broad scientific community
TERENO management concept

Catalog Services

Central metadata database

Portal web server

Data access

Data/Metadata Search engine

Data data access tools

Data visualization tools

TERENO portal

Local databases

Catalog Services

Local databases

Local databases

Local databases

Local databases
Locale TERENO Data bank structure

- Internal/external user
- File server
- Logger data
- Auto-scripts
- Metadata
- Web-Server
- PostGIS-database
- GIS-Server
- GIS data, WFS, WCS, WMS
- GIS-Datenportal
- Web-Interface
- GIS-Web clients
- ArcGIS Desktop Clients
- File based data
- GIS data, WFS, WCS, WMS
Pilot projects

Three pilot projects already established to develop and test:

• Local data infrastructure for meteorological, hydrological and pedological data
  (FZJ – Eifel / Lower Rhine Valley Observatory)

• Local data infrastructure for biodiversity data
  (UFZ – Harz / Central German Lowland Observatory)

• Data communication and data exchange
  (all observatories, coordination FZJ)
TERENO Data portal

TERENO - Data portal

http://tereno.icg.kfn-juelich.de - select attribute for raster interpolation - Mozilla Firefox

Please select your field of investigation:
- Wüstebach

Please select an attribute for raster interpolation:
- moisture_percent_ec_5_1

Please select interpolation method:
- IDW

Please select aggregation method:
- Averaged value

Please select grid resolution [m]:
- 2

Please select the time period to visualize:
- Start: 16-10-2009 14:00

... create raster

TERENO - Data portal

http://tereno.icg.kfn-juelich.de - select attribute for raster interpolation - Mozilla Firefox

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... create raster
TERENO Vision and Challenge

Prediction of terrestrial processes

Multi-scale Observation using non-invasive technologies

Terrestrial Processes

Evapotranspiration

Data Fusion

Upscaling

Data management

Super Computing

Visualization

Data assimilation

Coupled Modeling

SMOS

SAR

Weather-Radar

Radio-meter

EM

Soil moisture

Runoff
Thanks a lot for your attention!

For further information please visit our homepage:
www.tereno.net