River Ammer, Germany

Location

The catchment of the River Ammer is located in the southern Bavarian Alps and alpine forelands, in Germany, about 45km south-west of Munich. The total size is 709 km^2 up to the inflow into Lake Ammersee and 601 km² until Weilheim. The highest elevation is 2185 m.a.s.l. (Kreuzspitze) in the Ammergau Alps. The outflow into Lake Ammersee is the lowest part within the catchment (533 m.a.s.l.). Our investigation area also includes the small river Rott catchment in the northwestern part until gauge Raisting.

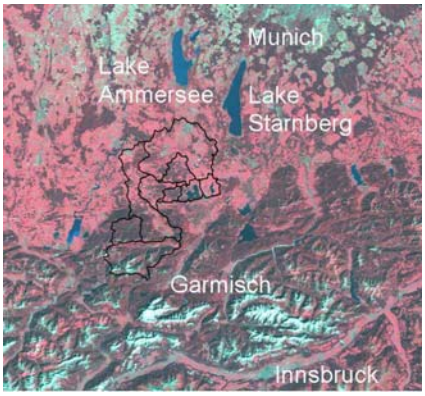

Figure. Location of the Ammer

Catchment Description

The river starts in the Linder Valley in the south west of the Ammergau Alps. Due to karstic underground, the Linder drains away near Linderhof castle, just to appear some hundred meters downstream. Further downstream it is named Ammer.

Due to the complex orography and heterogeneity in topography, the catchment is characterised by big north-south differences in soils, land-use, and climate.

The landscape of the alpine and prealpine drainage basin is characterised by high spatial geological and pedological differentiation, a complex orography and corresponding climatological conditions. The catchment can be divided into two landscape units: the prealpine hill country and moorland and the Swabian-Upper Bavarian foothills of the Alps. The main geological units are the lime-alpine zone in the southern part, the flysch zone bordering in the north, the folded molasses and the unfolded molasses in the northern part of the catchment.

The landuse types and hydrogeology are shown below.

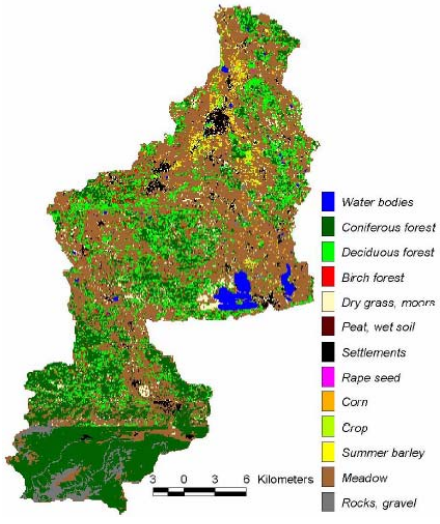

Figure. Landuse types

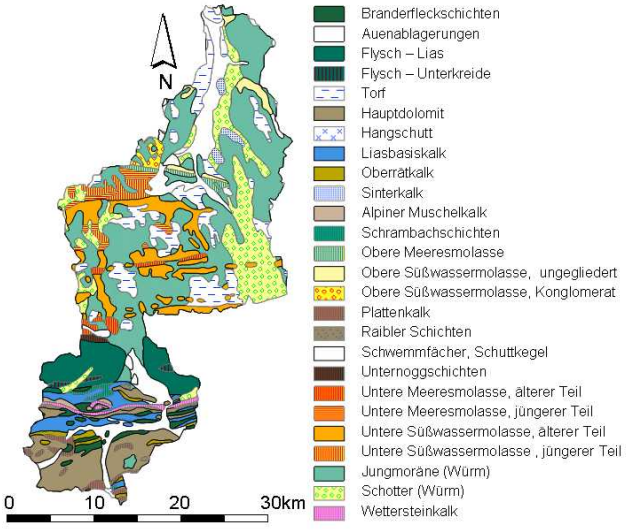

Figure. Geological map

Hydrological Summary

The River Ammer flows into the Lake Ammersee, which in turn drains (via the river Amper) to the River Danube. The location of the gauges are shown in the figure below, the characteristic water discharges of the 6 major gauges are shown in the table below. The length of Linder and Ammer until drainage into Lake Ammersee is 84km.

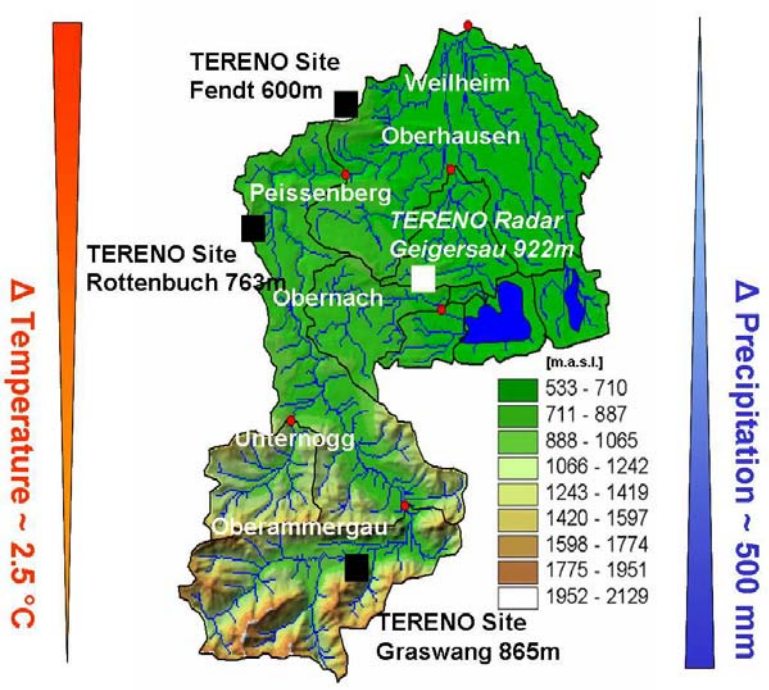

Figure. Location of river gauges and hydrometeorological TERENO Sites.

Gauge	Elev (m)	Size (km^2)	Qmin (m^3/s)	MQlow (m^3/s)	MQ (m^3/s)	MQhigh (m^3/s)	Qmax (m^3/s)
Oberammergau	831	114	0.4	1.2	3.6	52.5	135
Unternogg	849	44	0.2	0.3	1.7	46.4	126
Obernach	652	42	0.01	0.1	1	29.2	49.2
Oberhausen	585	585	0.1	0.7	2.6	21.5	51.7
Reißrnberg	592	294	1.3	2.9	8.9	114	286
Weilheim	550	601	2.6	5.7	14.7	156	338

Table. Characteristic water discharges (Qmin: lowest observed discharge, MQlow: mean low water discharge, MQ: mean discharge, MQhigh: mean high water discharge, Qmax: highest observed discharge)

Rivers in the Ammer catchment are generally natural. During the past ten years, the Ammer catchment was affected two times by century flooding events: The Christophorus Flood in 1999 and the flood in August 2005.

Climate in the catchment can be characterized as cool-temperate and sempiternal humid. Maximum precipitation is in summer. Due to the relief, all climate variables have latitude and height dependent gradients. Long-term mean temperature is 7-8°C. In the southern mountainous regions, mean temperature reduces to 4.5°C. Temperature distribution shows a height-dependent gradient of around 0.6°C/100m in summer and 0.45°C/100m in winter. Maximum precipitation is in June and July. Days with snow cover (snow depth > 10 cm) in the catchment is around 130 days per year. The figure below shows the strong decrease of mean monthly precipitation

between the alpine part (Ettal) and the northern part (Weilheim) of the Ammer catchment.

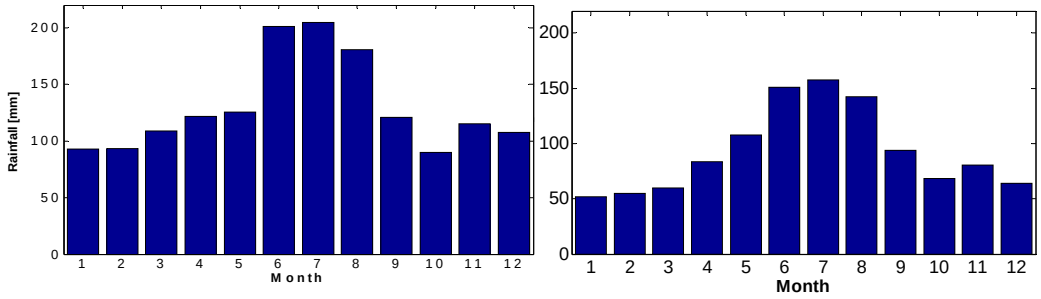

Figure. Mean monthly precipitation in *Ettal* (left) and *Weilheim* (right) (1970-1999)

The figure below shows the results of a linear trend analysis of mean annual temperature and precipitation and thereby footprints of climate change in the Ammer catchment.

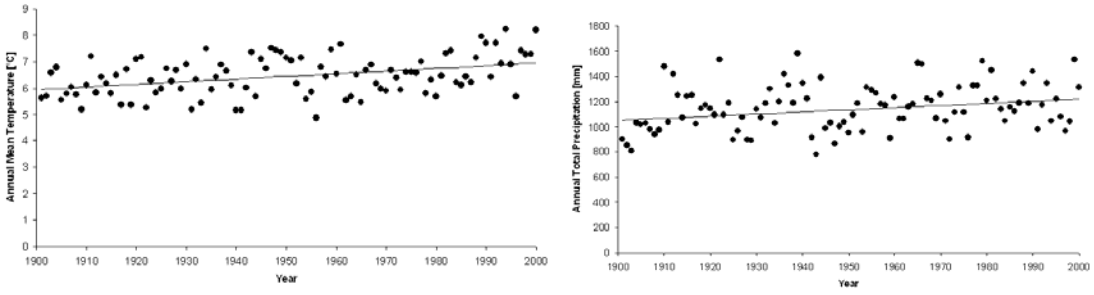

Figure. Trend annual mean temperature: +1°C/100 years (99.9% significant, Mann-Kendall), trend annual total precipitation: +166 mm/100 years (99% significant, Mann-Kendall)

Data availability and facilities

The local water authority (WWA) Weilheim undertakes flow monitoring at nine sites within the catchment on an operational basis, with the longest records starting in the early 1920s in Oberammergau in the alpine part of the catchment. The WWA also maintains a network of groundwater gauge and quality monitoring stations within the catchment. Meteorological data are observed operationally by the German Weather Service (DWD) and the Bavarian state authority (LfU) in an hourly timestep. The DWD installed a radar facility at the Meteorological Observatory Hohenpeissenberg, located at the boundary of the Ammer catchment.

Recently, TERENO (Terrestrial Environmental Observatories, http://www.tereno.net), a collaborative project of FZ Jülich, Karlsruhe Institute of Technology, UFZ Leipzig-Halle, DLR and Helmholtz Centre Munich and Geoforschungszentrum Potsdam (GFZ) has started, with the Ammer Catchment being one of four hydrological observatories. Within this framework, three long term observatories are currently installed in the Ammer catchment. Equipment consists of three Eddy-Covariance stations and three standard climate stations. Additionally, lysimeter fields consisting

of totally 36 devices and a permanently scanning rain radar (50 km radius) are installed.

Facilities not in the WWA and DWD official network

Geigersau Site:

- 1 X-Band precipitation radar

Graswang-, Rottenbuch-, Fendt Sites:

- 3 EC towers: momentum, heat, H_2O, CO_2, plus TERENO-ICOS: N_2O, CH_4 fluxes
- 36 lysimeters: soil water balance, *in situ-climate change experiment* through relocation of samples towards lower elevations
- GHG (N_2O, CO_2, CH_4) measurements at lysimeters
- To be installed till 2010: 3 additional climate stations, meteorological variables and energy balance

Research Activity and Outputs

The Joint Virtual Institute “Regional Precipitation Observation by Cellular Network Microwave Attenuation and Application to Water Resources Management” (PROCEMA) started in 2008. It aims at the development, optimization and exploitation of a methodology to quantify ground-level precipitation using attenuation of microwave signals of cellular networks. This is achieved by mathematical simulations using existing cellular network data, polarimetric transmission measurements at various wavelengths, and application of microwave based precipitation estimations to water resources assessments in the Ammer catchment.

Further, the catchment has been used in several research projects on climate impact studies on the water cycle, for studies on flood forecasting, and estimation of rainfall intensities from radar data using observed river discharge data.

Institutional support

Observations and monitoring is performed by base funds of KIT/IMK-IFU.

Value to network

The Ammer catchment contributes a well equipped alpine catchment to the network, characterised by a strong climate gradient and complex hydrogeology. Both water and energy fluxes are measured. It is part of the TERENO network.

The Ammer Observatory provides data for hydrological conditions that are common in its region but which are quite different from those monitored by many other observatories in the network. Some important distinguishing features of the Ammer catchment in the European context are its high average elevation, its high number snow days, and its pronounced precipitation maximum in summer.

Contact for further information

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