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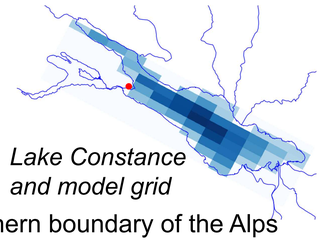
Advances in the scenario study
Estimating climate sensibility of a large lake



Lake Constance and model grid

Lake Constance:

- Situated at the northern boundary of the Alps between Austria, Germany and Switzerland.
- maximum depth 253 m, average depth 100 m
- total volume 50 km³,
- monomictic lake (today it mixes once in 2-3 years)

The mixing behaviour of the lake is mainly driven by meteorology and thus will be affected by climate change.

Scenario study:

Measured meteorological data: Konstanz DWD 1980 – 2000 (**reference period**)

user-defined properties:
·ΔT
·Variability
·GCM data
·...

→ vector-autoregressive statistical weather generator **VG**

→ Artificial meteorological time series as boundary conditions

→ 3D hydrodynamics and water quality model ELCOM-CAEDYM [1], [2], [3]

→ scenarios

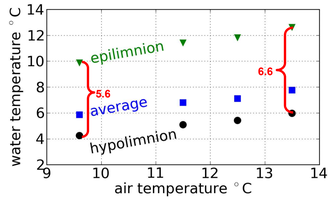
1D lake model DYCD

Reference simulation

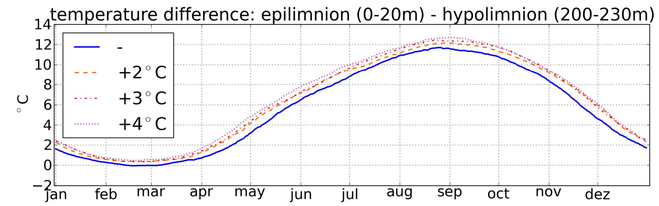
What's the effect of
· Warmer climate
· More variable climate
on
· Water temperature
· Stratification / mixing
· Hypolimnetic oxygen concentration
?

Increased mean air temperature:

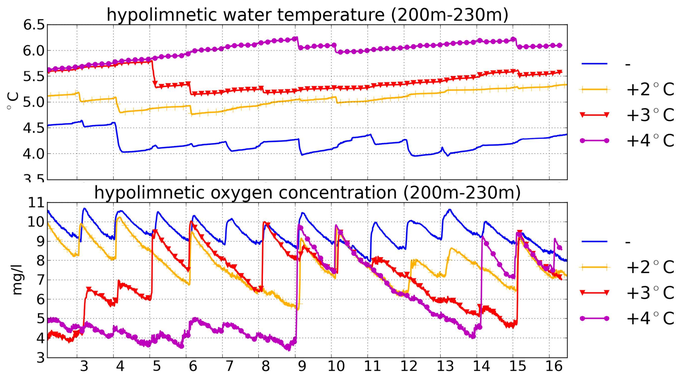
Scenario simulation input data: VG data with 0°C (**unchanged**), **2 °C, 3 °C** and **4 °C** temperature increase.
Water temperatures increase in all depths with increasing air temperature, but the absolute values differ:



With 1 °C air temperature increase, the epilimnion temperature increases by 0.685 °C, in the hypoliomnion only 0.43 °C.
→ Enhanced stratification



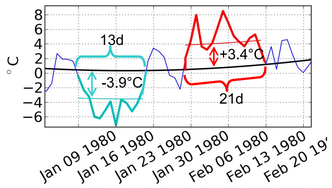
→ deep water renewal is decreased
→ decrease of **O_2 concentration in the hypolimnion**:



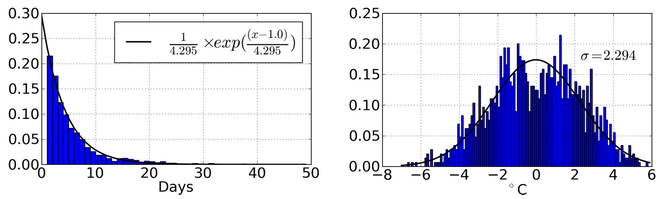
The hypolimnion in changing climate:

- Fewer complete mixing events
- Higher air temperature: Complete mixing at higher temperatures
- → higher variability: long periods without mixing after cold winters
- Longer periods of oxygen depletion
- Biogeochemical processes are temperature dependent
- → Oxygen depletion is faster in warmer water
- Minimum concentration ~3.5 mg/l

"Climate variability":



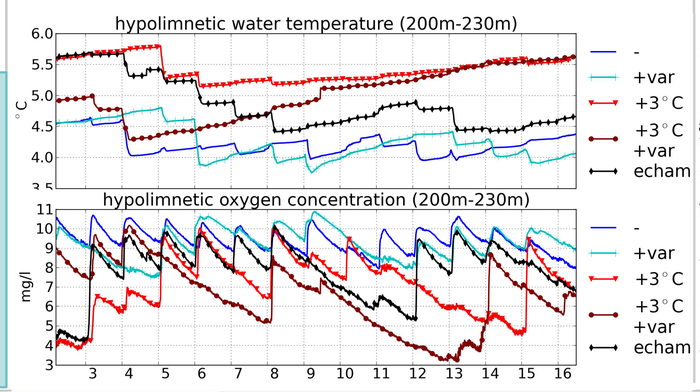
= Length [days] and amplitude [°C] of episodes colder or warmer than average for this time of year.
In the measured temperature data, episode length is exponentially distributed with an average value of 5.3 days. Amplitude is normally distributed with σ=2.3 °C.



VG reproduces the climate variability of the reference period. Furthermore, stronger episodes can be added to get more variable climate. In the scenarios with enhanced variability (**+var** and **+3 °C+var**), mean episode length is 7.8 /7.4 days and σ of the amplitude is 3.5/3.3 °C.

Downscaling GCM-Data:

Besides producing artificial random climate time series, VG can also be fed with the output of **Global Circulation Models**. We used the years **2040-2060** of the **MPI/OM ECHAM5 A1B** scenario.
The downscaled data has an average air temperature of **11.35 °C** and **episodes of 6.35 days and 2.8 °C**.
➔ Increased mean (+1.8°C) and increased variability



Conclusions:

- Temperature increase in the lake is weaker than in air temperature.
- Temperature increase in the epilimnion is weaker than in the hypolimnion.

→Enhanced stratification
→Less deep water renewal events
→Oxygen depletion in the hypolimnion

Open questions:

- Sediment processes under anoxic conditions
- Halocline development due to biogeochemical processes
  → chemically induced meromixis

References:

[1] Hodges and Dallimore: Estuary, Lake and Coastal Ocean Model: ELCOM. v2.2 Science Manual. Centre for Water Research, University of Western Australia, 2006.
[2] Hipsey, M. et al., *Science Manual: Computational Aquatic Ecosystem Dynamics Model: CAEDYM v2*, Centre for Water Research, University of Western Australia, 2005
[3] Appt, J.; Imberger, J.; Kobus, H.: Basin-scale motion in stratified Upper Lake Constance. In: Limnol. Oceanogr. 49 (2004), Nr. 4, S. 919-933.

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ENWAT International Doctoral Program Environment Water

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