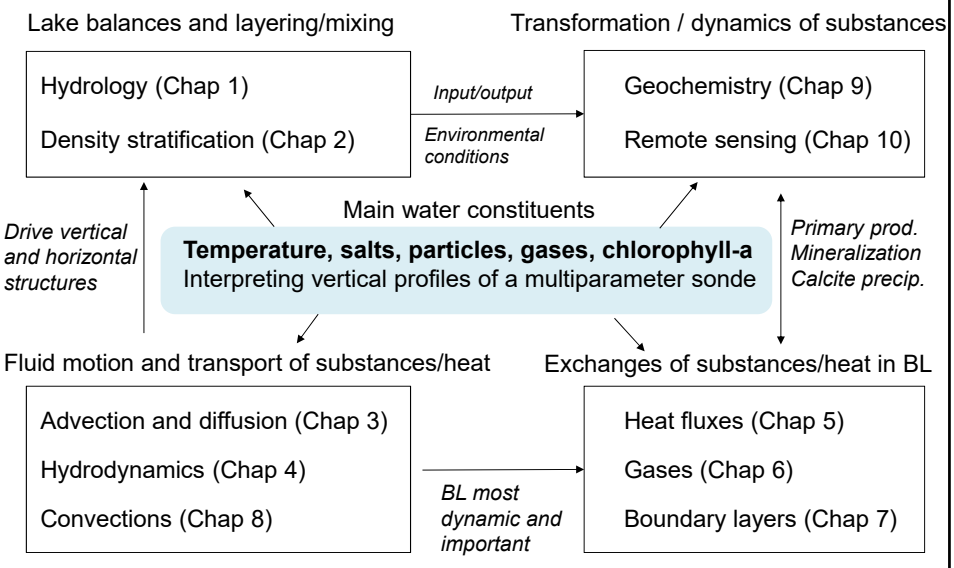
Limnology course
Overall summary

LéXPLORE platform, 2024

1

Interactions between chapters



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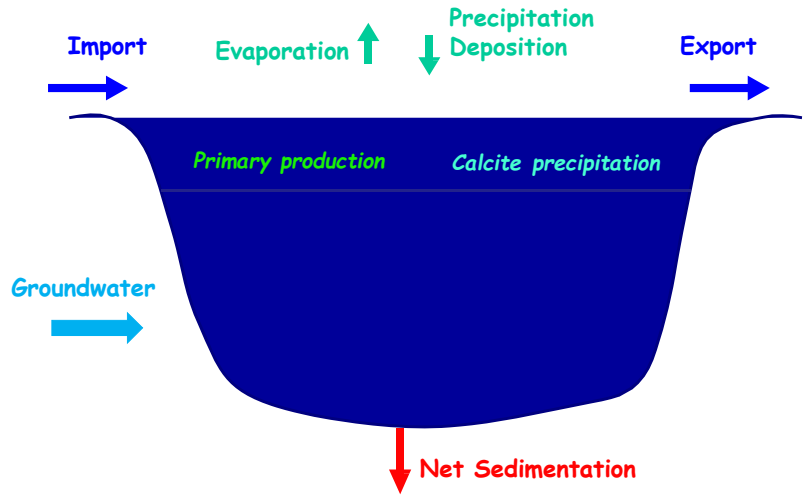
Summary: Chap 1 - Hydrology

Chapter 1: Water balance - Salt balance - Particles balance



→ Key fluxes influencing the lake

3

Summary: Chap 2 – Density stratification

Chapter 2: Lakes are stratified water body → density stratification

Temperature | Salts | Gases | Particles

Thermal expansion α

Temperature of maximum density

Conductivity
Evaporation
Mineralisation

Rivers

Subaquatic sources

Photosynthesis
Mineralisation
Exchange atm

$\beta_{CO2} > 0$

$\beta_{CH4} < 0$

Photosynthesis
Precipitation

River intrusion

Density stratification

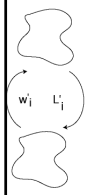
$$\rho = \rho(T) \cdot (1 + \beta_{TDS} \cdot TDS + \beta_P \cdot P + \beta_{CO2} \cdot [CO_2] + h.o.)$$

$\alpha > \beta_{TDS} > \beta_{PART} > \beta_{CO2}$

N^2 = strength of stratification ← Summer stratification, Deep mixing, Winter inverse stratification → **Lake mixing types**

→ **Direct link to salt and particles balances (Chap 1)**

Summary: Chap 3 – Advection diffusion



1st Fick Law gases (Chap 6)

Transport processes for heat, salts and gases:

Molecular and turbulent diffusion

Diffusive fluxes = - (Dc + K_x) dC/dx

From high to low = smoothing effect

Advection

Advective fluxes = - U C

follow the motion of water

2nd Fick Law gases (Chap 6)

Ocean (Chap 4):
Thermohaline circulation
Munk-Model
Banana curves

Rate of change

Flux in – flux out +/- sink / source

$dC/dt = - u\, dC/dz + (Dc + Kz)\, d^2C/d^2z +/- R$

Sedimentation
Mineralization
Photosynthesis

Distribution of temperature, salts and gases within the lake (Chap 2)

Summary: Chap 4 – Hydrodynamics

Hydrodynamics: describe flow and circulation in oceans and lakes

Total derivative

$DC/Dt = dC/dt + u\,(dC/dx) = R$

(Lagrange) (Euler) (Advection, Chap 3)

Conservation of mass:

Upwelling and downwelling
Global ocean circulation (Chap 3)

Navier-Stokes equations with fluctuations:

Acceleration + advection = gravity + pressure + friction + Reynolds stress

Rotating Earth - dynamics of atmosphere

Geophysical flows

Coriolis force

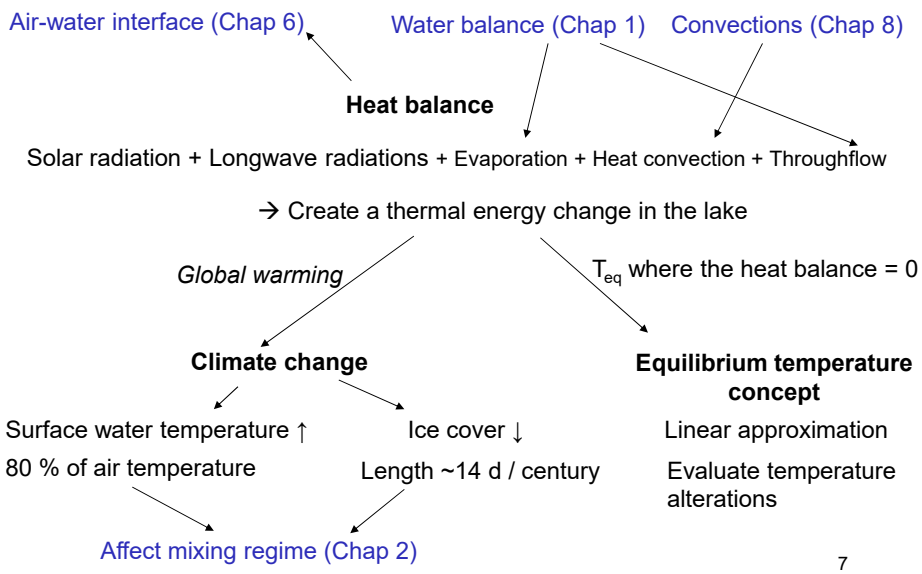
Inertial currents

Flow
Wind
Coriolis

Ekman flow

Motion of water and acting forces (Chap 3)

Summary: Chap 5 – Heat fluxes



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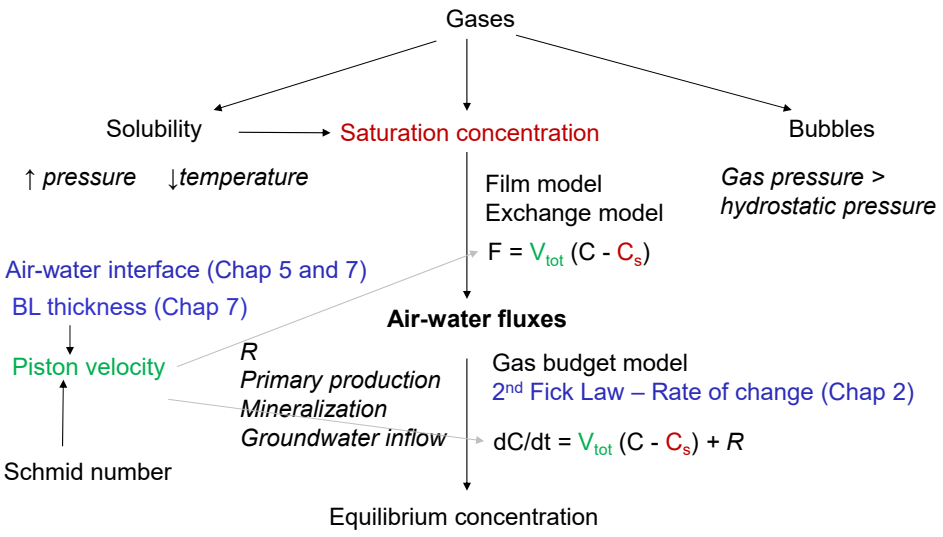
Direct link to water balance, stratification and mixing regimes (Chap 2)

Summary: Chap 6 - Gases



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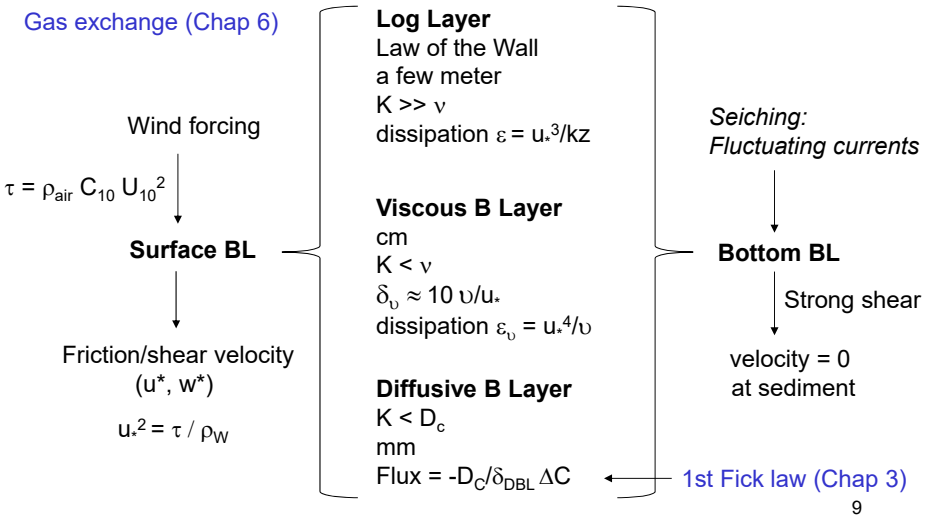
Model for gas balance

Summary: Chap 7 - Boundary layers

the most dynamic and important zones for a number of processes



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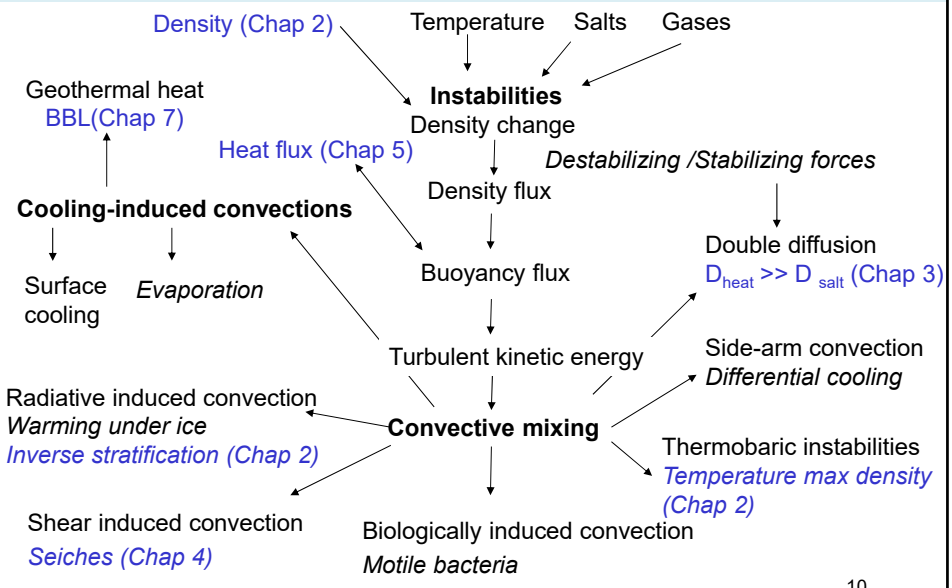
Summary: Chap 8 – Convections



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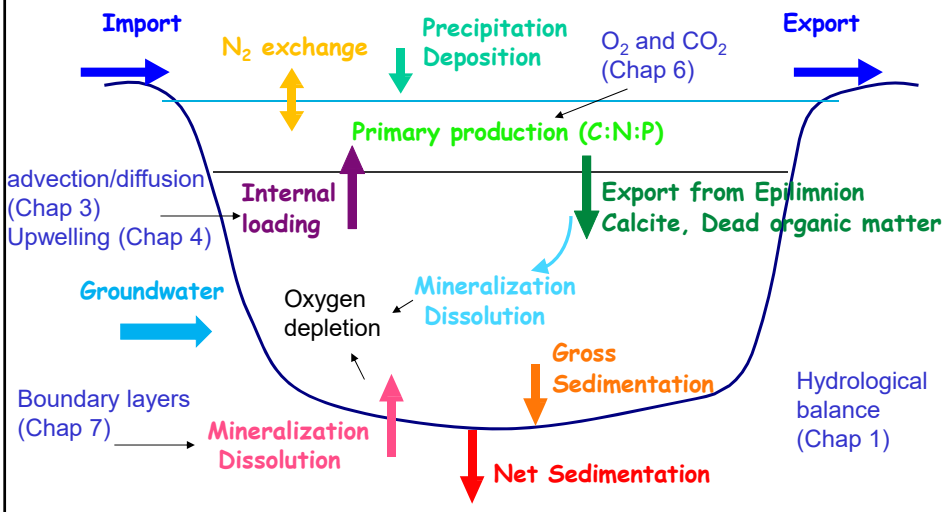
Efficient mixing explains homogeneous section in a profile

Summary: Chap 9 - Geochemistry

Cycles of nutrients and carbon (gases) within a lake



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Link to water and particles balances (Chap 1), mixing (Chap 2), gases (Chap 6)

Summary: Chap 10 – Remote sensing

Monitoring water quality with satellite images

Sun light

Air water interface

Reflection — Refraction

Underwater light

scattering — absorption

Inherent optical properties
independant of light field

Challenge:
surface water only

Apparent optical properties
Dependant of light field

Remote-sensing reflectance
irradiance reflectance

Water constituent retrieval algorithms

Chlorophyll-a — Particles — Coloured dissolved organic matter

Applications: spatio-temporal information, phytoplankton phenology, floating vegetation,cyanobacteria, upwelling

Thermal repartition (Chap 5)
Particles distribution (Chap 1 and 2)
Hydrodynamics (Chap 4)
Geochemistry (Chap 9)

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LéXPLORE platform

Remote sensing

Data in real time on Datalakes

Heat fluxes

Gas exchange

Automatic profilers

Carbon cycling

Primary production

Temperature, salts, particles, gases, chlorophyll-a

↓ At high frequency

Interpreting vertical profiles of a multiparameter sonde

Many possibilities for a master thesis

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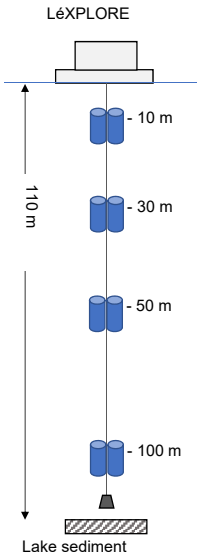
Master project 1: Detect and predict the Rhône intrusion under LéXPLORE platform



Measured fluxes from sediment traps

2020

Depth (m)	Total mass flux [g m^{-2}d^{-1}]	Biomasse flux [g m^{-2}d^{-1}]	CaCO3 flux [g m^{-2}d^{-1}]	Minerals flux [g m^{-2}d^{-1}]
10	3.4	0.5	1.3	1.5
30, 50, 100	5.9	0.5	1.4	3.2

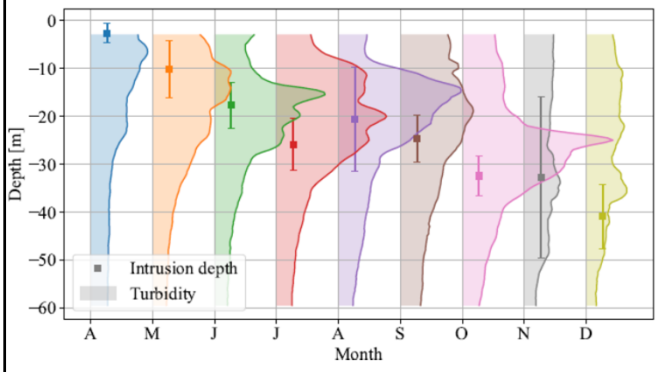
2021

Depth (m)	Total mass flux [g m^{-2}d^{-1}]	Biomasse flux [g m^{-2}d^{-1}]	$CaCO_3$ flux [g m^{-2}d^{-1}]	Minerals flux [g m^{-2}d^{-1}]
10	3.5	0.4	1.2	1.5
30, 50, 100	5.3	0.4	1.4	2.0

Higher flux below 30 m → Due to the mineral flux

Master project 1: Detect and predict the Rhône intrusion under LéXPLORE platform

Mean turbidity profiles at LéXPLORE and theoretical intrusion depth in 2020



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Master project 1: Detect and predict the Rhône intrusion under LéXPLORE platform

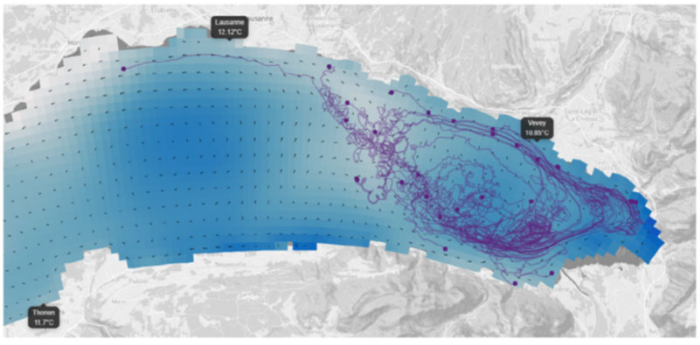

Figure 14: Alplakes particle tracker delft3d-flow: layer 22.5m Sep 20. – Oct 11.

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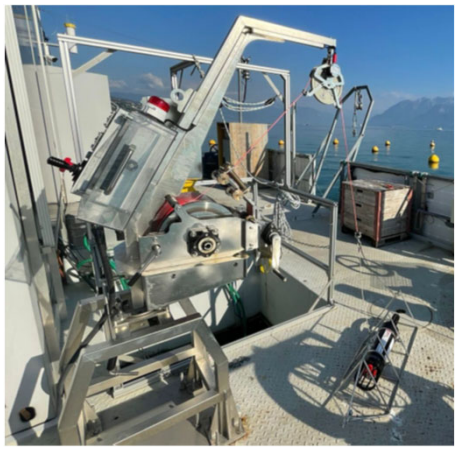
Master project 2: analyse the spatio-temporal dynamics of lake snow in Lake Geneva



Holographic camera images:

- to capture floc formation below the Rhone interflow plume
- to characterize floc composition, size and shape above and below the interflow

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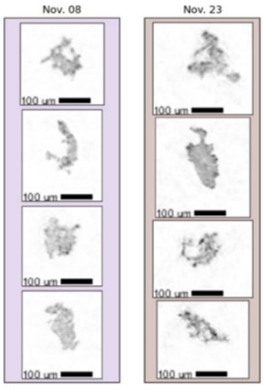
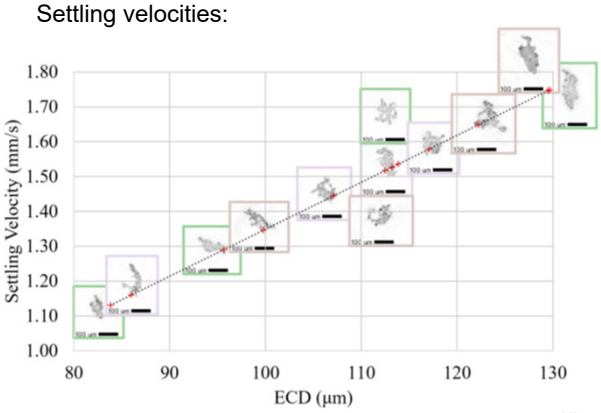
Master project 2: analyse the spatio-temporal dynamics of lake snow in Lake Geneva

Important to determine how nutrients and contaminants attached to sediment particles brought into the lake by rivers, will spread or be deposited.



Settling velocities:



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Master project 2: analyse the spatio-temporal dynamics of lake snow in Lake Geneva

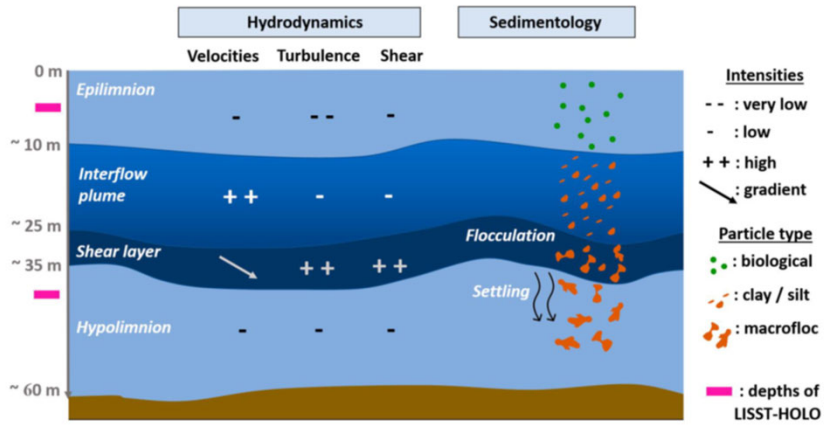


Figure 11. Schematic representation of processes leading to macrofloc formation in the shear layer between the bottom of the Rhône River interflow plume and the hypolimnion below. Note that flocculation and macrofloc formation only occur in the shear layer. See Figure 3 for the formation of the interflow plume layer.

Piton et al. 2024

Master project 3: Seasonal dynamic and vertical structure of the lake food web using high-frequency data

Thermal structure & Photic layer

- Profilers (Idronaut + CTD + Thetis) + mooring (T-chain) + RS
- Processing: https://pypi.org/project/pylake/
- Easy to measure with HF data

Phytoplankton structure

- Biomass: Profilers (Idronaut + CTD + Thetis) + RS
- Individual counts: Cytobuoy
- Primary production: DO & metabolism

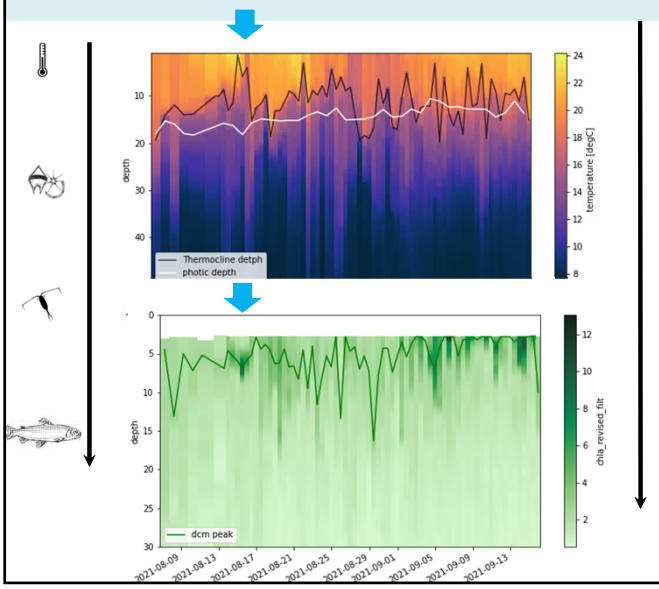
Zooplankton structure

- ADCP (backscattering)
- Automated / manual sampler

Fish structure

- Echosounder

Master project 3: Seasonal dynamic and vertical structure of the lake food web using high-frequency data

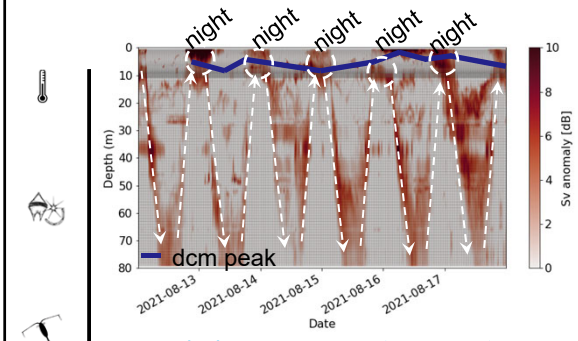


Summer 2021

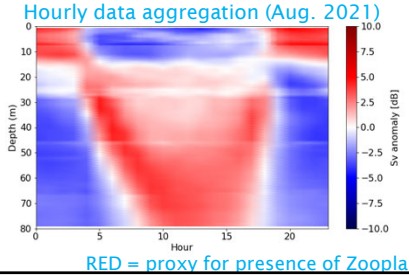
- Well stratified condition
- Strong warming until Aug 16
- Strong cooling + wind Aug 17

- Algae growth around 7 m depth

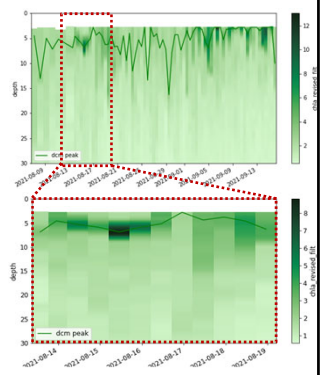
Master project 3: Seasonal dynamic and vertical structure of the lake food web using high-frequency data



Hourly data aggregation (Aug. 2021)



RED = proxy for presence of Zooplankton



Diel migration of Zooplankton (08/2022)

Upper limit
Depending on the location of the primary procucer?