

# Hydro-sedimentary processes of a plunging hyperpycnal river plume revealed by synchronized remote imagery and gridded ADCP measurements

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## Motivation

River inflows are an important input of sediment, oxygen, contaminants, nutrients, heat, and momentum for lakes and reservoirs

- influence on water quality, reservoir storage capacity & hazards
- hydrodynamic processes at the river-lake/reservoir interface control the fate of these components

Evolution of the Upper Rhone River discharge and suspended sediment load during the last 80 years and some implications for Lake Geneva

Jean-Luc Loizeau & Janusz Dominik  
*Aquatic Sciences* 62, 54–67 (2000)

Eutrophication processes regulated by a plunging river inflow

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Volume 540, September 2016, Pages 457–468

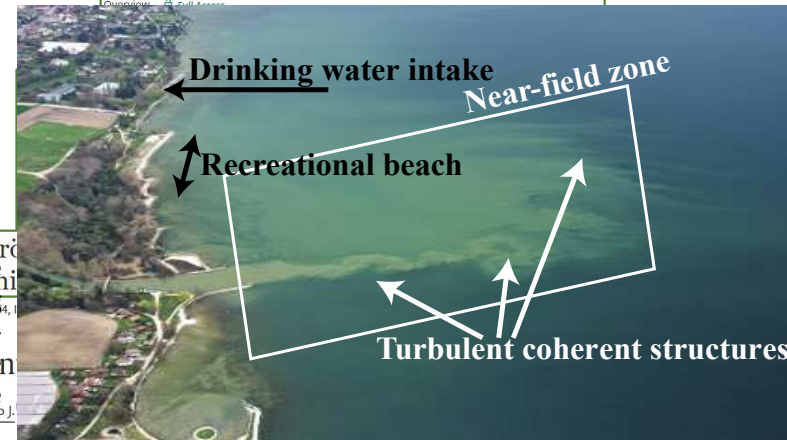
Flood frequency matters: Why climate change degrades deep-water quality of peri-alpine lakes

Gabriel Fink\*, Martin Wessels\*, Alfred Wiest\*\*

Origin and size of hypolimnic mixing in Urnersee, the southern basin of Vierwaldstättersee (Lake Lucerne)

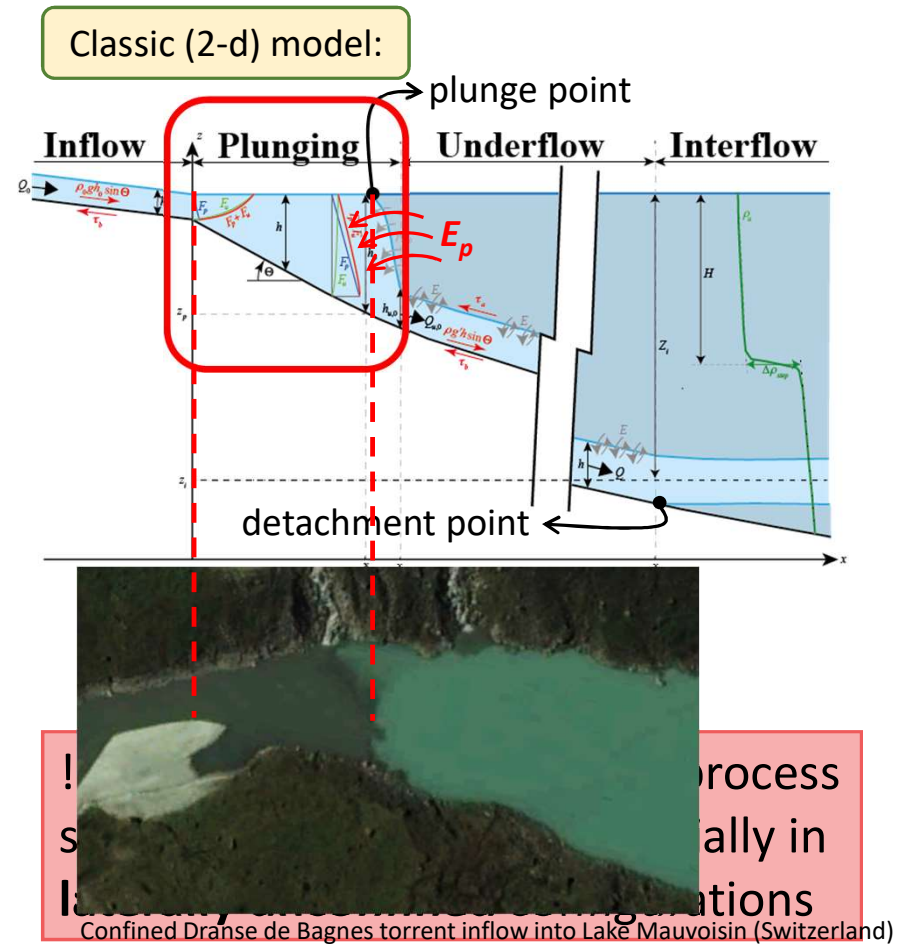
WIREs WATER

Inflow of the Venoge River into Lake Geneva (Switzerland). An intake of drinking water for the highly urbanized Lausanne-Geneva region is situated 1 km from the inflow, and recreational beach areas are situated at both sides of the inflow.

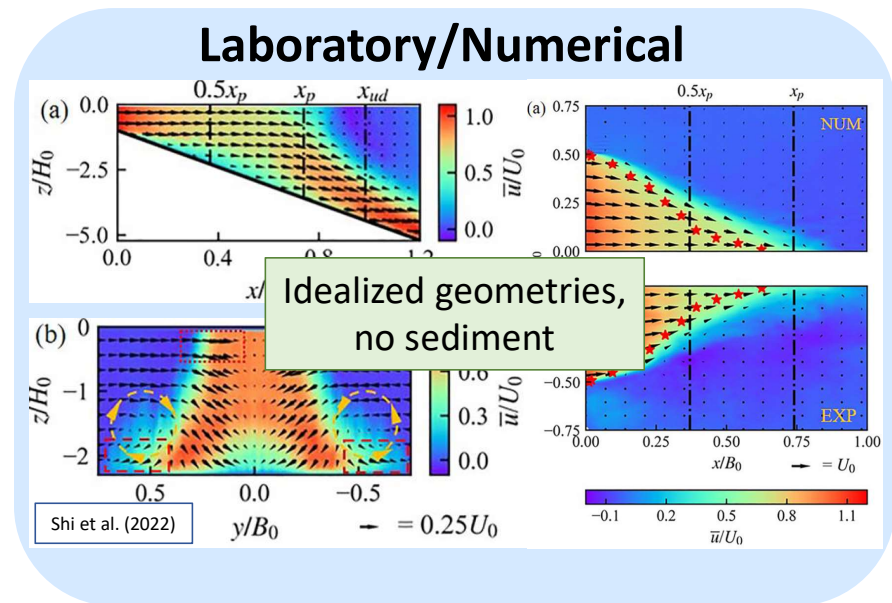
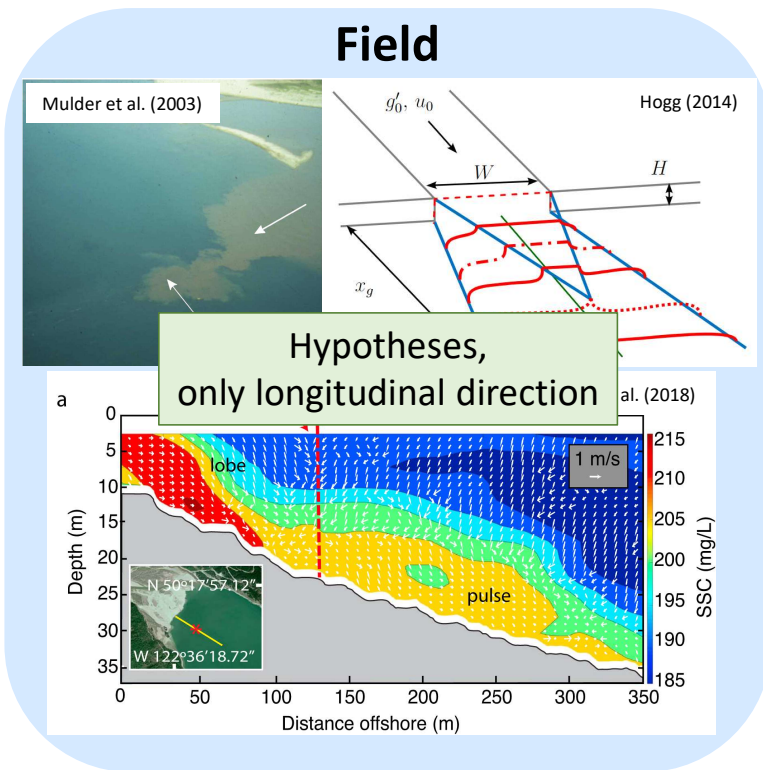


# Current knowledge

- Hyperpycnal river inflows will plunge and form an underflow and/or interflow
  - current knowledge mostly based on **laterally confined** lab experiments
  - plunging process provides upstream boundary conditions for underflows (entrainment of ambient water)
  - plunging process has crucial influence on pathway and final destination of sediment, nutrients and contaminants



# Current knowledge (3-d)



**! no direct field measurements**

## Science questions

- Can the dominant **three-dimensional** hydro-sedimentary processes related to unconfined plunging be resolved for the first time using transect **field** measurements and remote imagery?
- What is the three-dimensional **flow structure** of an unconfined plunging plume and, in particular, **where is the plunge** located?
- What are the **sedimentary processes** of a plunging plume and are they **depositional or erosive** in nature?
- How can existing **conceptual models** of plunging plumes be extended for **unconfined configurations**?



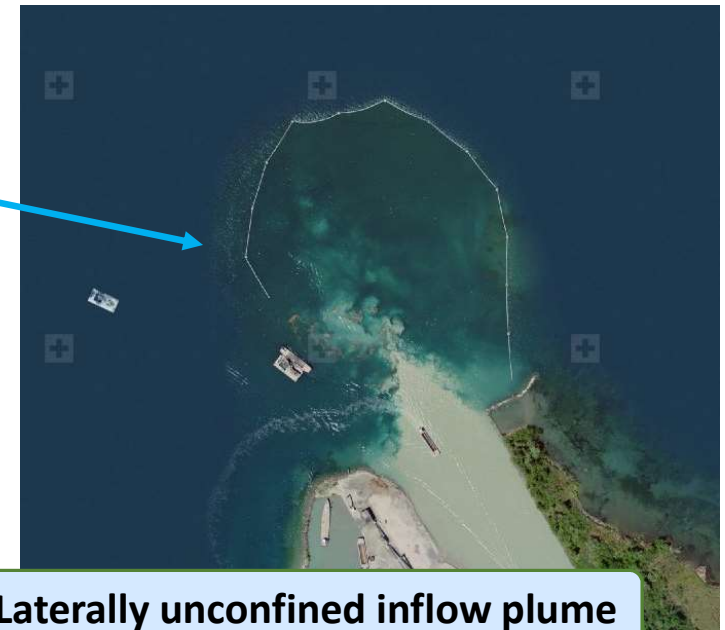
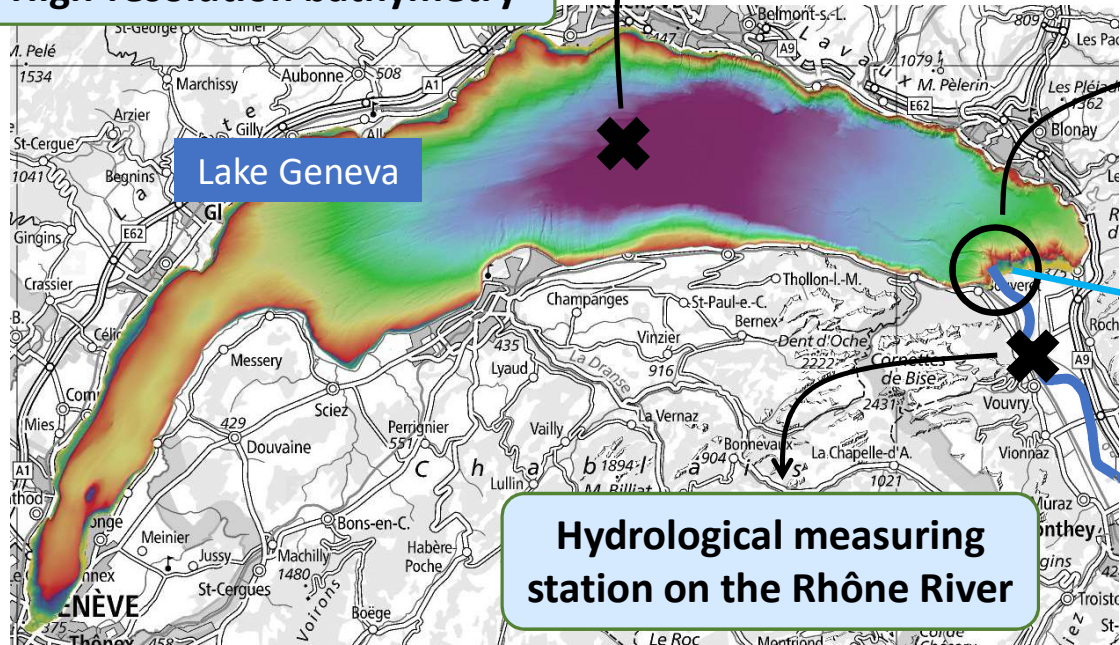
## Study site

High-resolution bathymetry

Hydrological measuring station on Lake Geneva

Presented data gathered under **high discharge, high sediment load conditions**

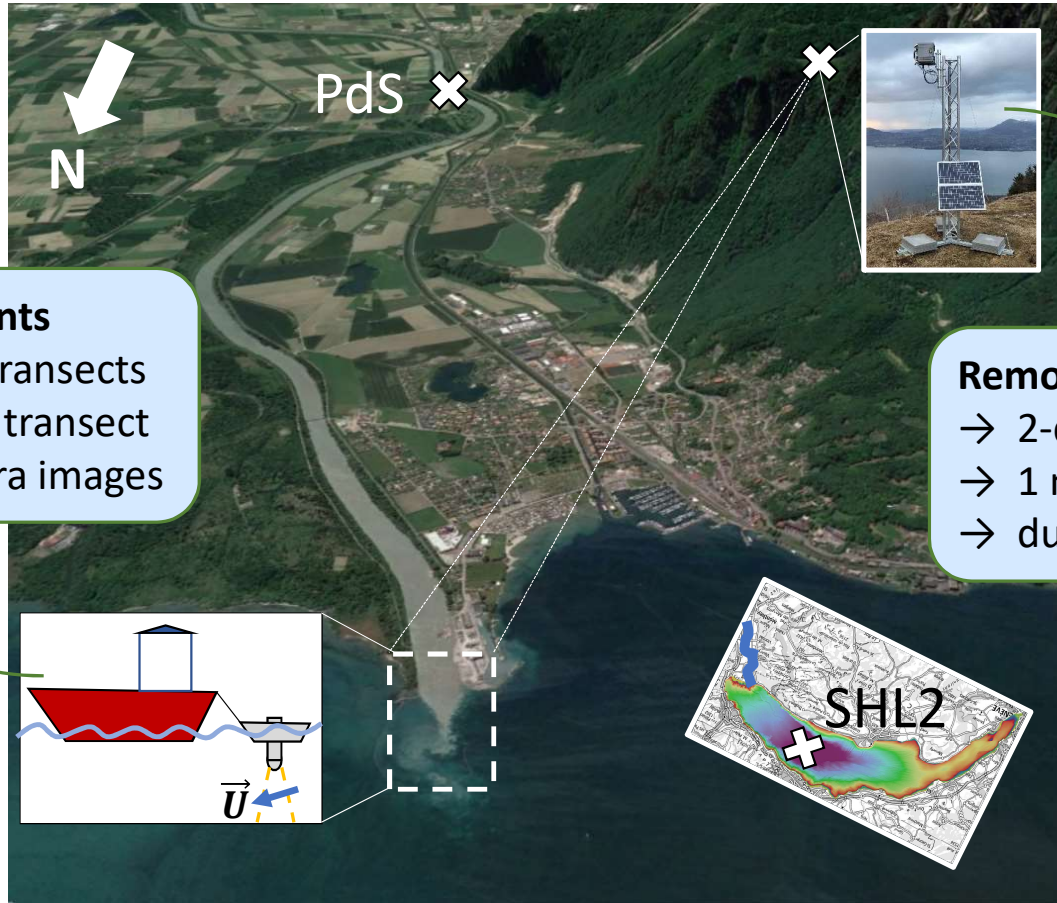
Wide range of inflow conditions



Virtually all boundary conditions are known!

Laterally unconfined inflow plume

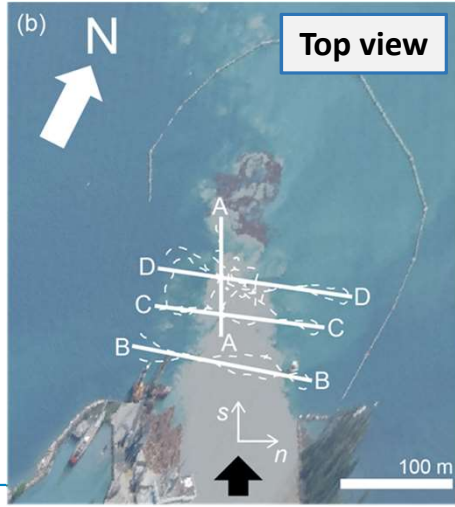
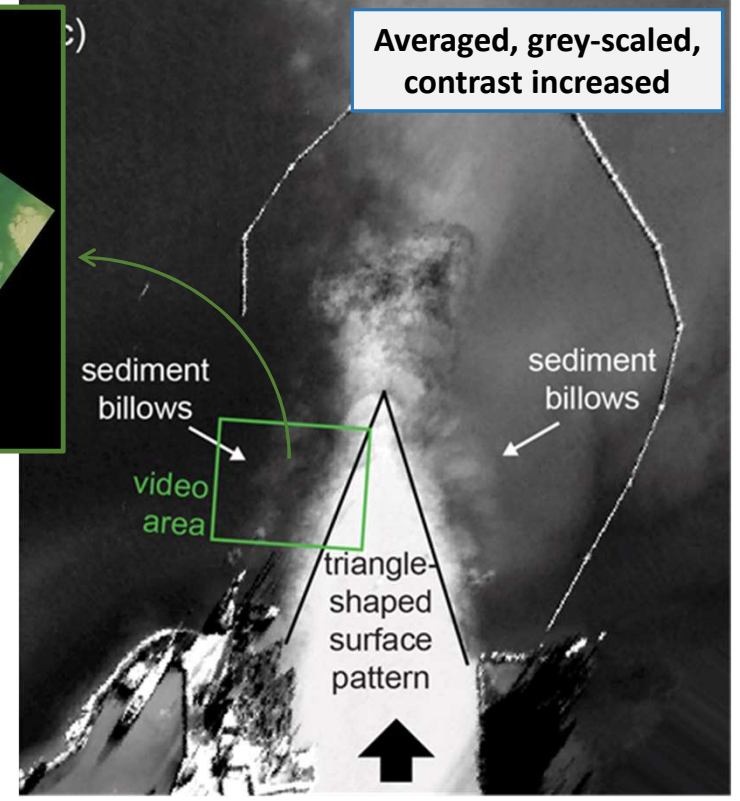
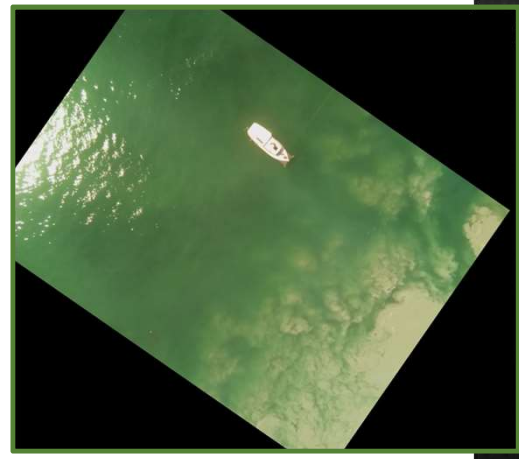
# Methods



**Gridded ADCP measurements**  
 → 3-d velocity field along transects  
 → multiple repetitions per transect  
 → guided by remote camera images

**Remote camera imagery**  
 → 2-d surface patterns  
 → 1 min, 1 m resolution  
 → during ADCP measurements

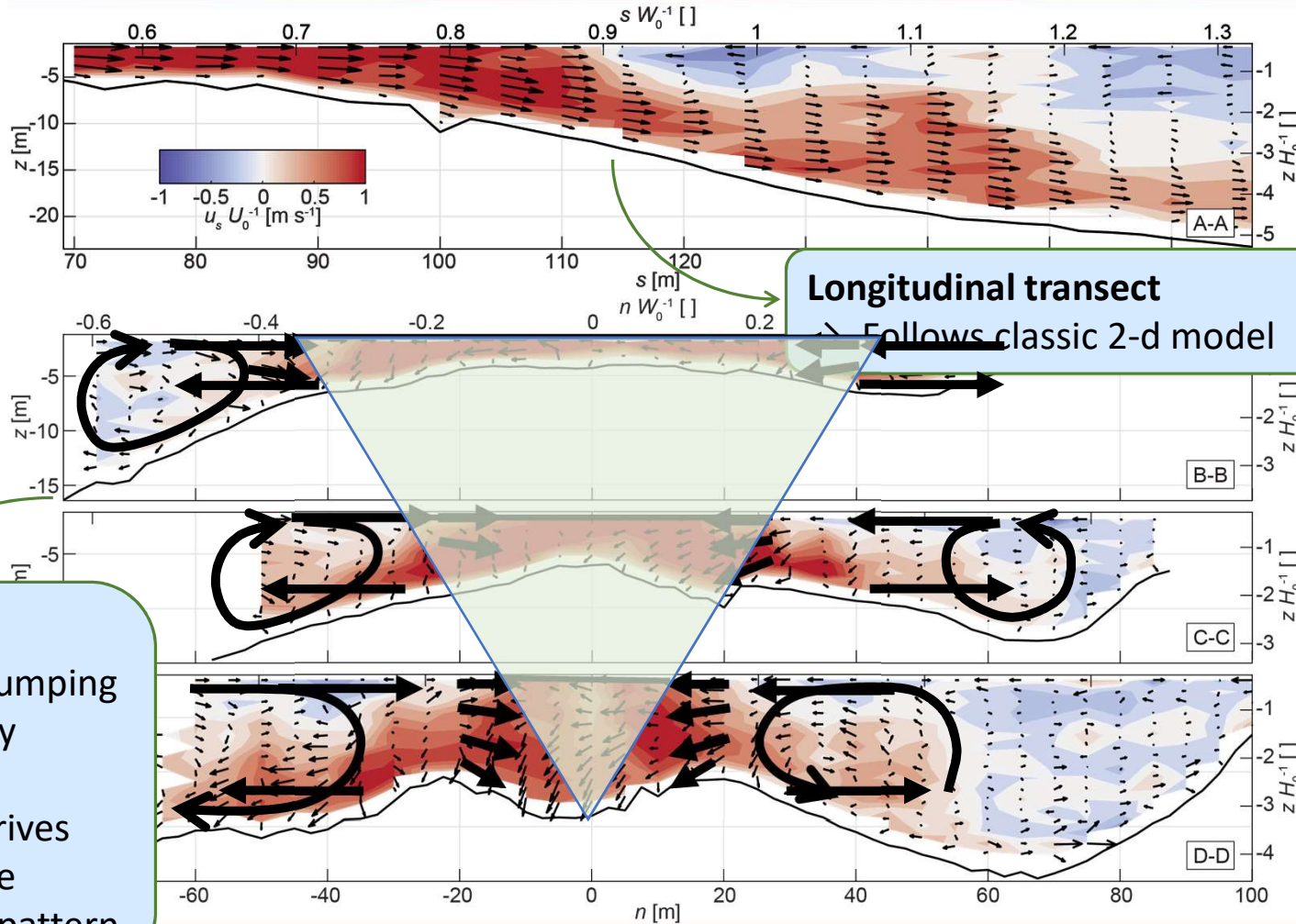
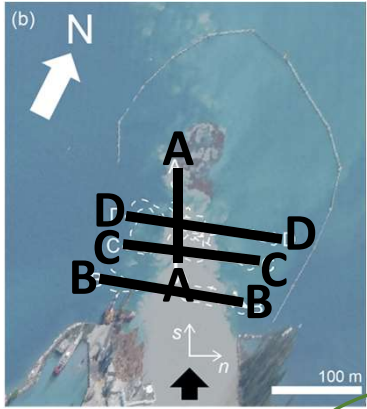
# Results



Secondary currents transporting sediment-rich water to the surface?



## Results



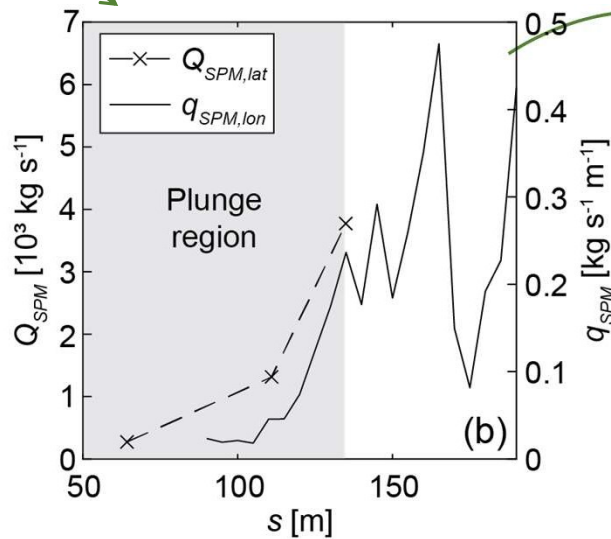
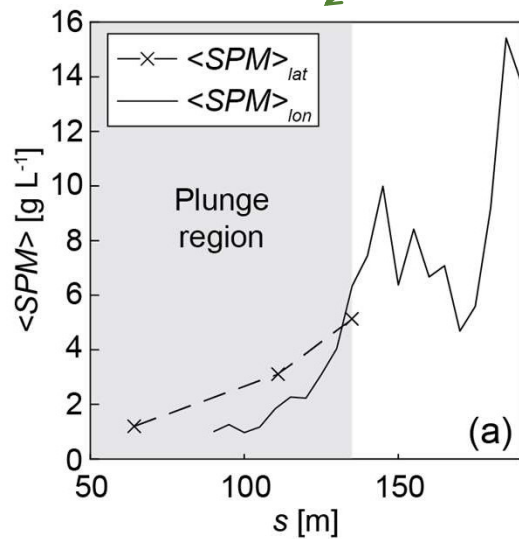
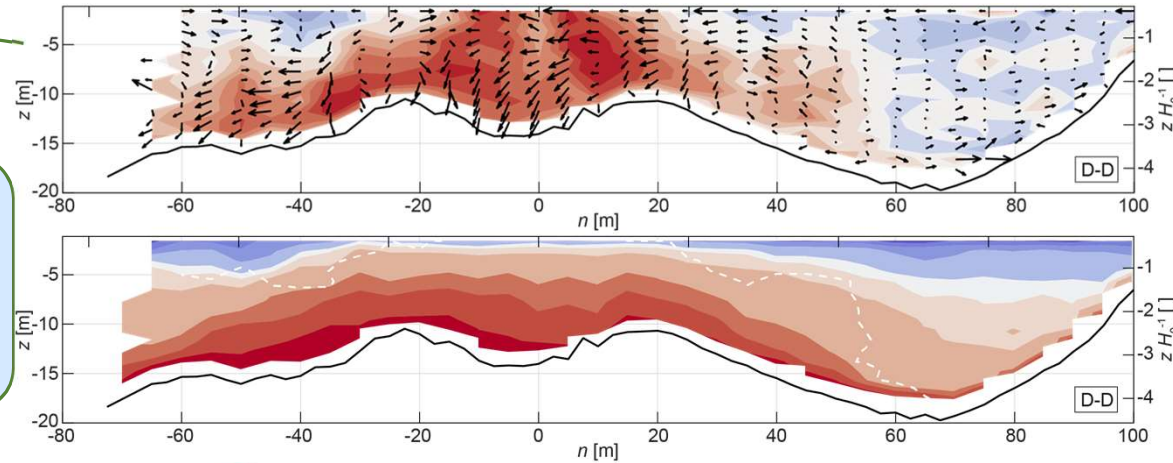
### Transverse transects

- $\Delta\rho$  drives lateral slumping
- LS drives secondary currents
- Vert. divergence drives lateral convergence
- Triangular surface pattern

## Results

### SPM conc. and flux estimation

- Estimate SPM conc. from ADCP backscatter
- Lon. vel. used to identify plume core
- Lon. vel. and SPM used to calculate  $Q_{SPM}$

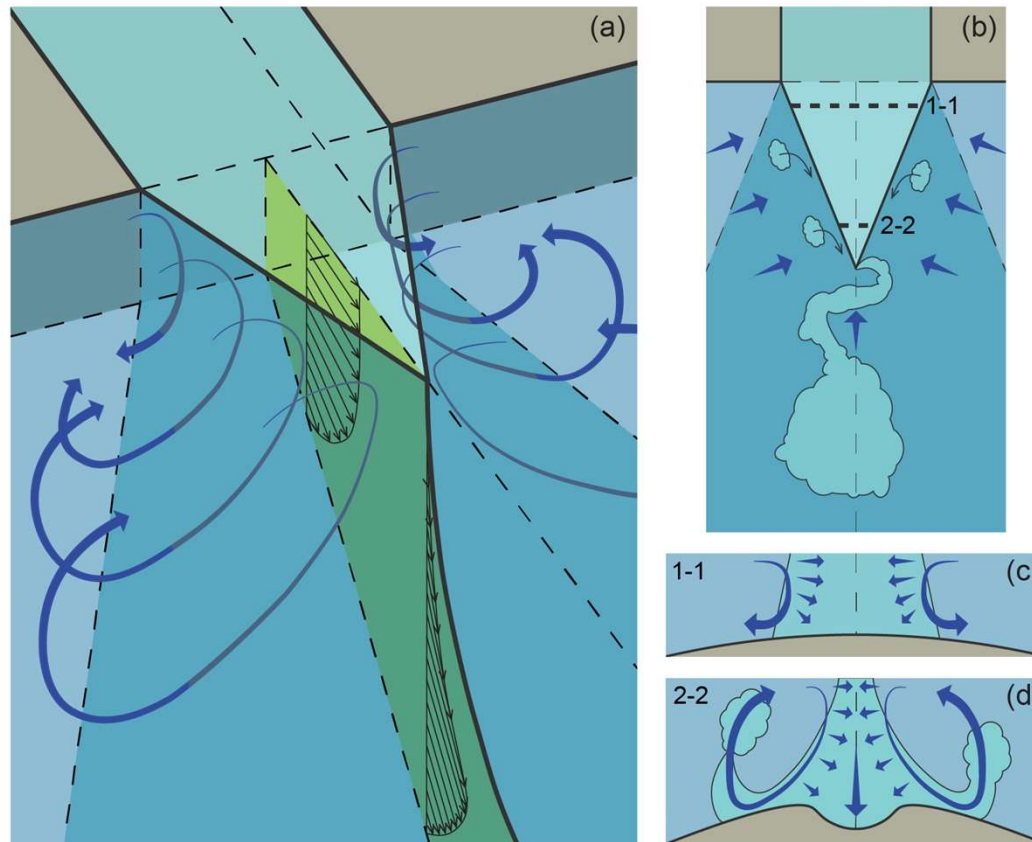


### Erosion or deposition?

- SPM conc. and flux increase in plunge region
- Erosion dominates

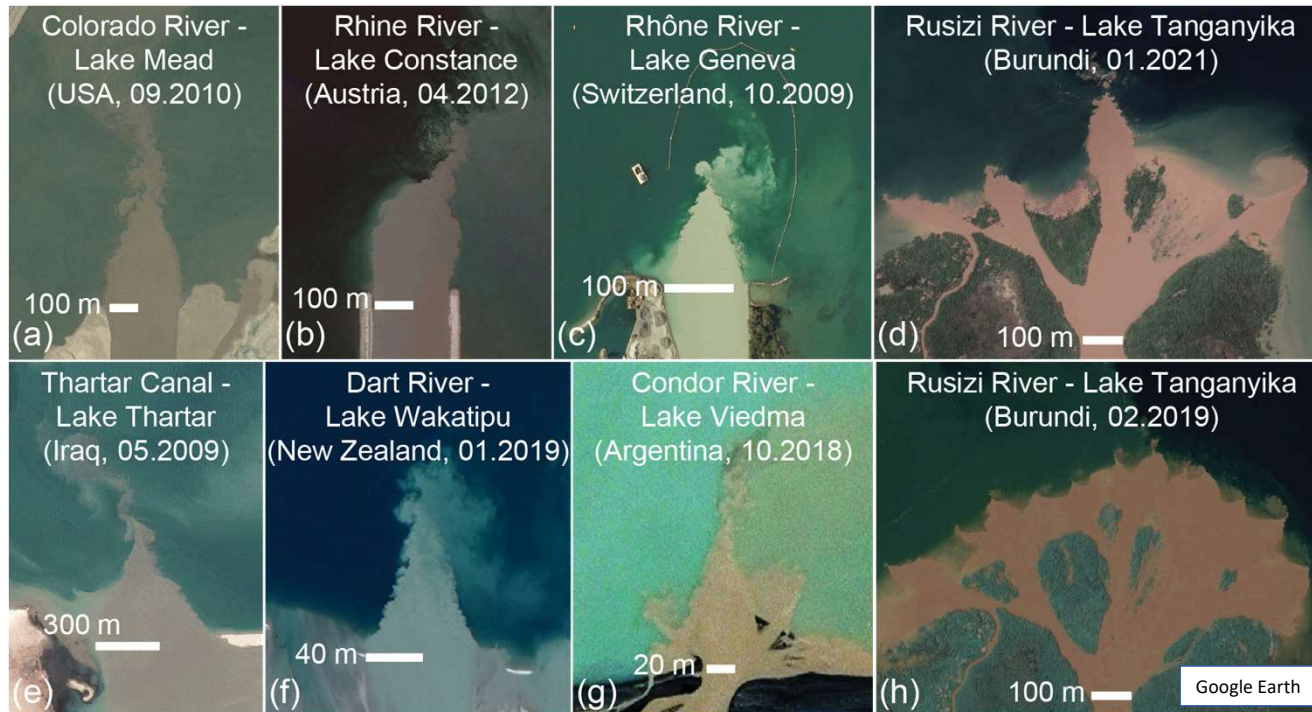
→ Long-term dynamic equilibrium:  
transient storage of sediment?

# Conceptualization



- ✓ Longitudinal velocity field
- ✓ Return current
- ✓ Lateral slumping
- ✓ Secondary currents with sediment transport
- ✓ Lateral flow convergence
- ✓ Triangular surface pattern

# Applicability



Triangular surface pattern is not an exception → conceptual model widely applicable



## Conclusions

- Transect **field** measurements and remote imagery allowed for resolving the dominant **three-dimensional** hydro-sedimentary processes related to unconfined plunging for the first time
- The three-dimensional **flow structure** of an unconfined plunging plume was elucidated
- The **sedimentary processes** of a plunging plume were revealed to be **erosive** in nature under high discharge, high sediment load conditions
- The existing **conceptual models** of plunging plumes were extended for **unconfined configurations**

**! Post-doc candidates wanted !**

4 years

40 h/week

Focus: sediment transport processes

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