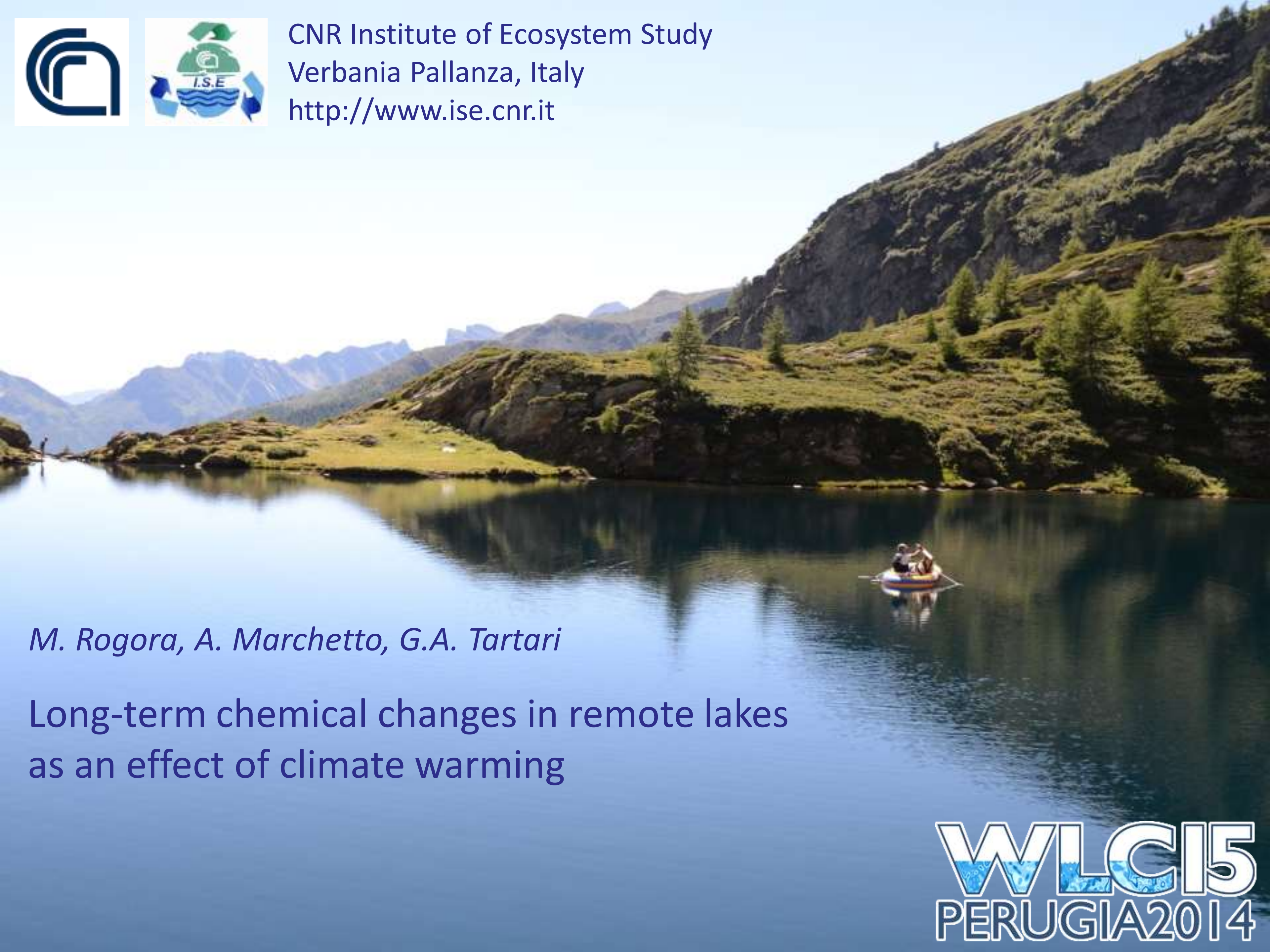


CNR Institute of Ecosystem Study
Verbania Pallanza, Italy
http://www.ise.cnr.it

M. Rogora, A. Marchetto, G.A. Tartari

Long-term chemical changes in remote lakes as an effect of climate warming

WLC15
PERUGIA2014

Remote lakes as early warning systems

They are relevant elements of the mountain landscape, with a primary touristic ad recreational importance and a role as biodiversity pool

Not affected by direct anthropogenic forcings, however subject to the deposition of pollutants transported with air masses from industrialised areas in the lowlands

Strongly dependent on catchment characteristics (morphology, land cover), they rapidly respond to changes in atmospheric inputs, hydrology and climate

Mountain lakes are suitable "early warning" indicators of changes in atmospheric deposition (acidifying compounds, nitrogen…) and in the regional climate

Study area

High altitude lakes (above the local tree line) in the **Western Alps (Ossola and Sesia valleys, Piedmont, Italy):**

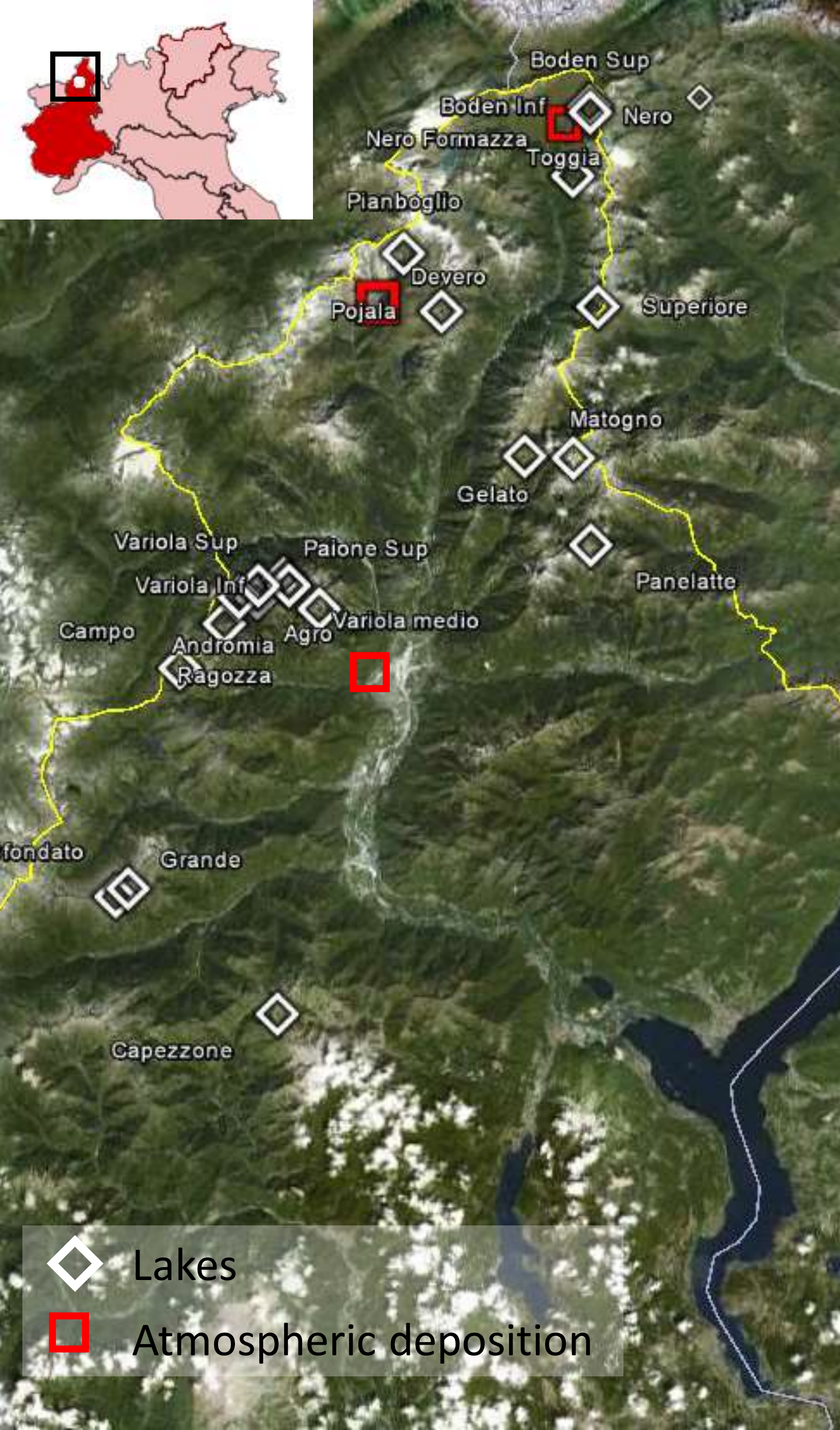
- ✓ 4 sites with continous chemical data (1-4 samples per year) since the late 1970s
- ✓ about 40 survey lakes with long-term discontinuos data

LTER Europe
LTER Italia

- Area subject to high deposition of atmospheric pollutants, transported with the air masses from lowland areas (e.g. Plain of River Po)
- Climate change has proved to be more intense in mountain areas, with several effects on water bodies (water quantity and quality)

MOLAR Mountain Lake Research
RECOVER:2010
Euro-limpacs
wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution
EMERGE
ICP WATERS
LRTAP Long-range Transboundary Air Pollution
NextData

Long-term data

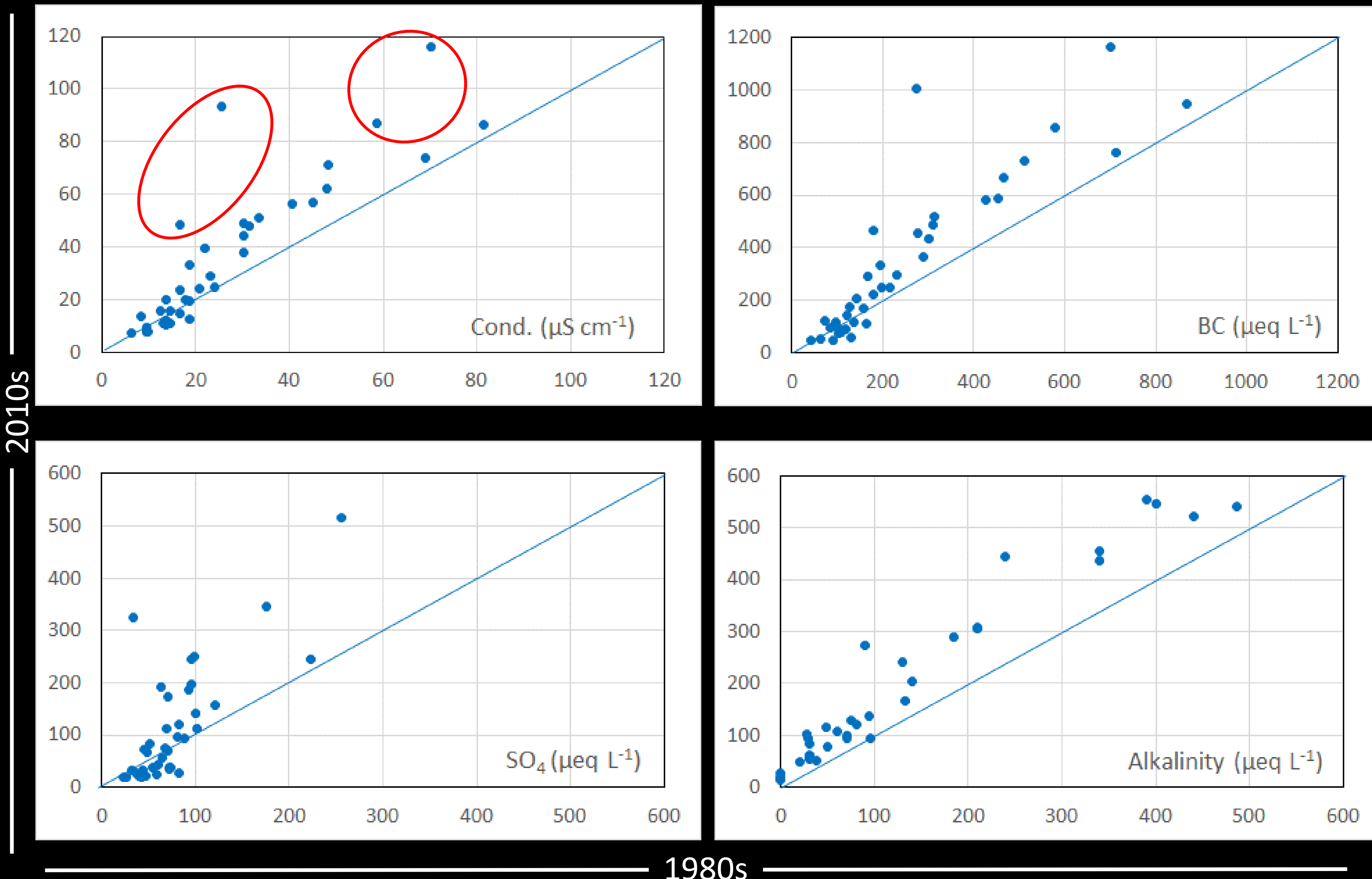


Lake chemistry (pH, cond., alkalinity, major ions, nutrients) since the 1980s

Atmospheric deposition chemistry since the 1980s

Meteorological data from a number of sites in the area, run by ARPA Piemonte or ENEL

Survey lakes (n = 40): 1980s vs 2010s

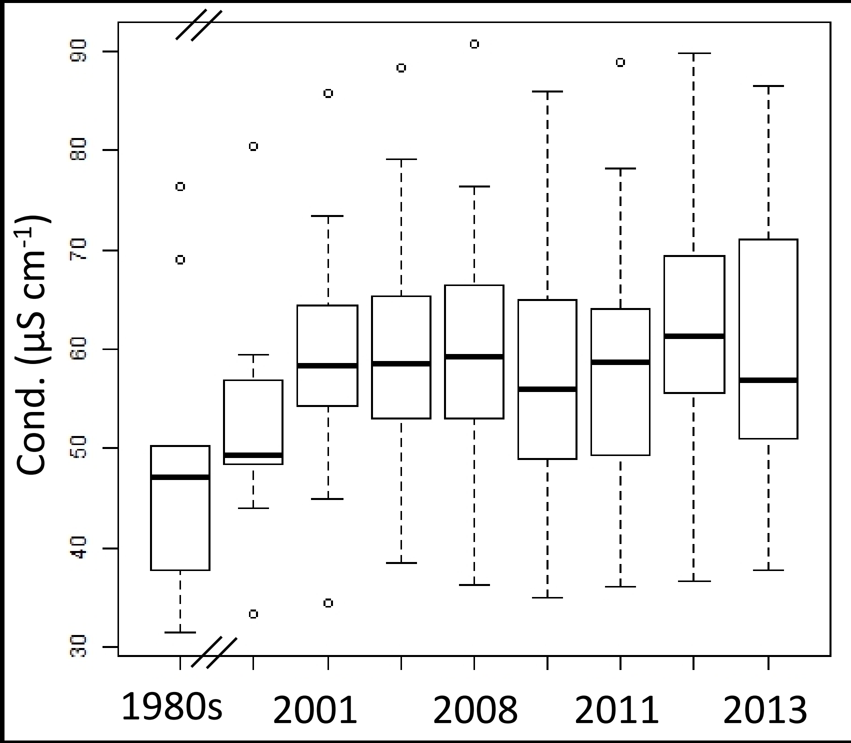


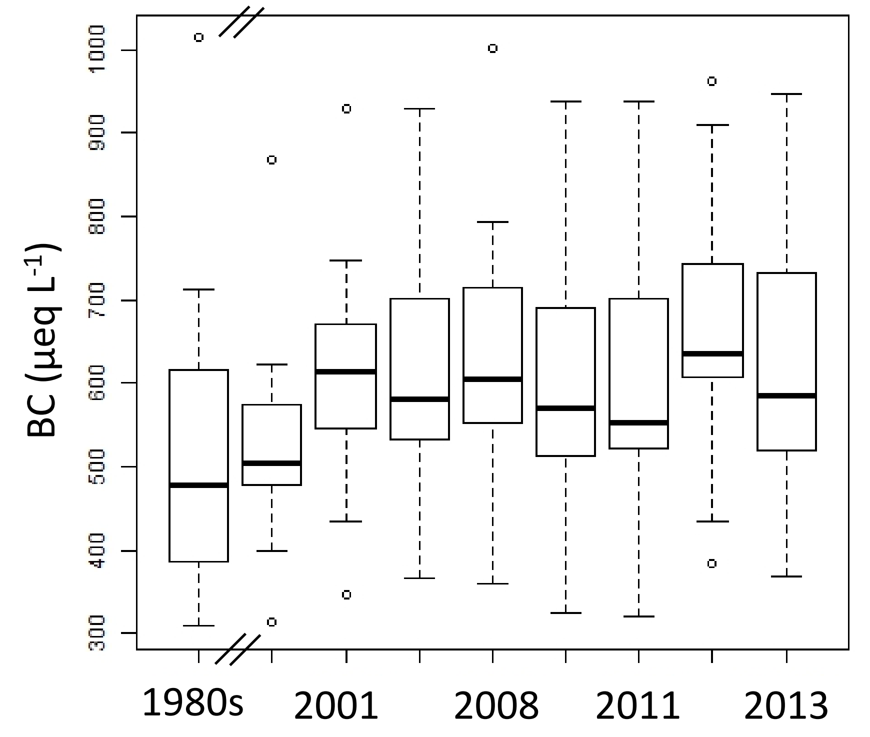
Survey lakes: regional trend analysis

Subgroup of 20 lakes (out of 40): not acid-sensitive, moderate to high solute content (calcium and sulphate dominating)

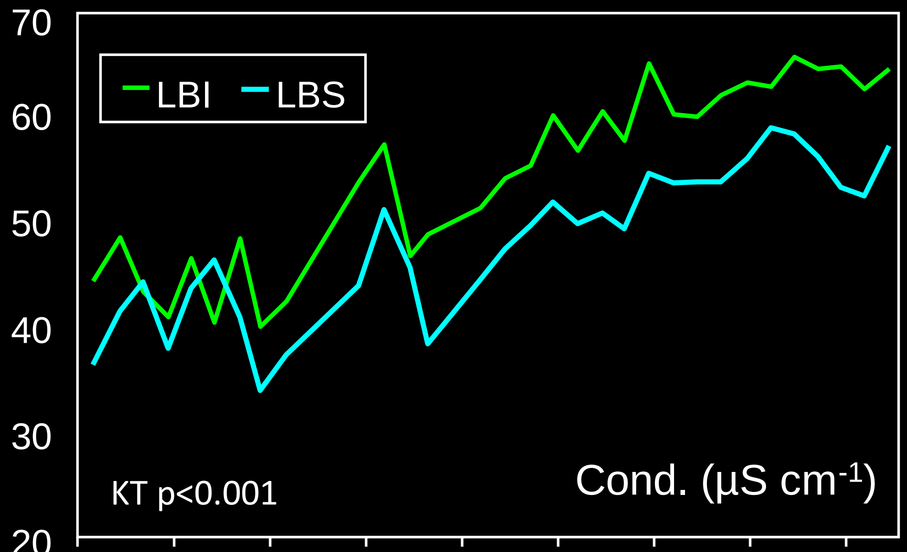
Surveys in the 1980s (between 1981 and 1987), 2000-01, 2007-08, 2010, 2011, 2012, 2013

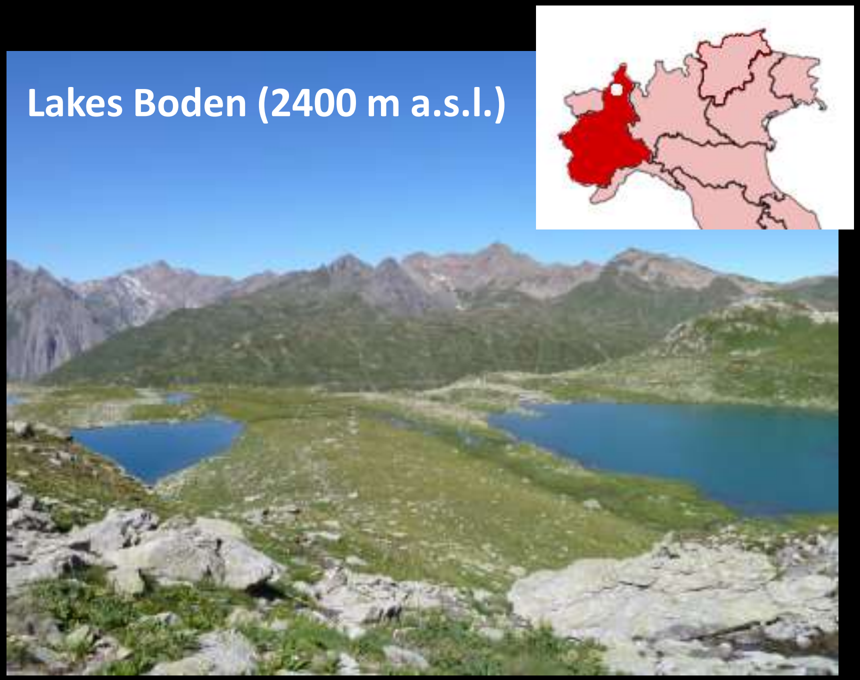
Regional kendall Test for trend at a regional level (20 lakes as a group) ⇒ significant increase of conductivity, alkalinity, sulphate and base cations (BC)

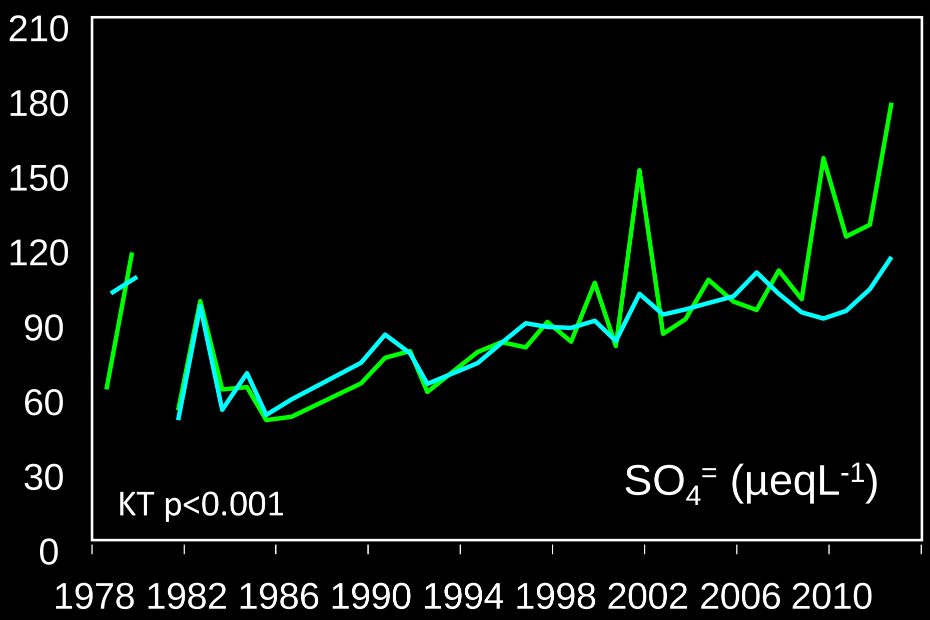


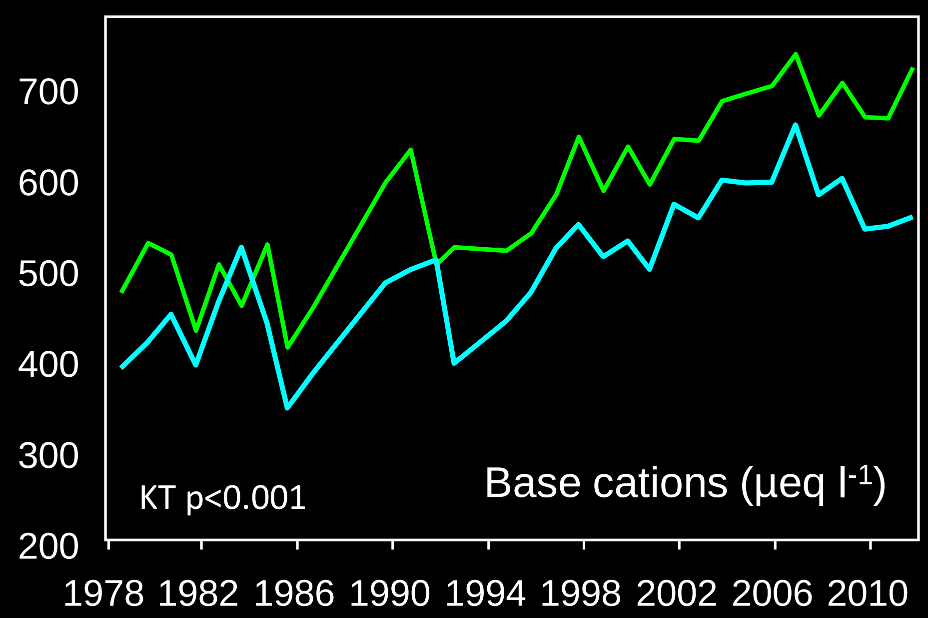


Key sites: chemical trends



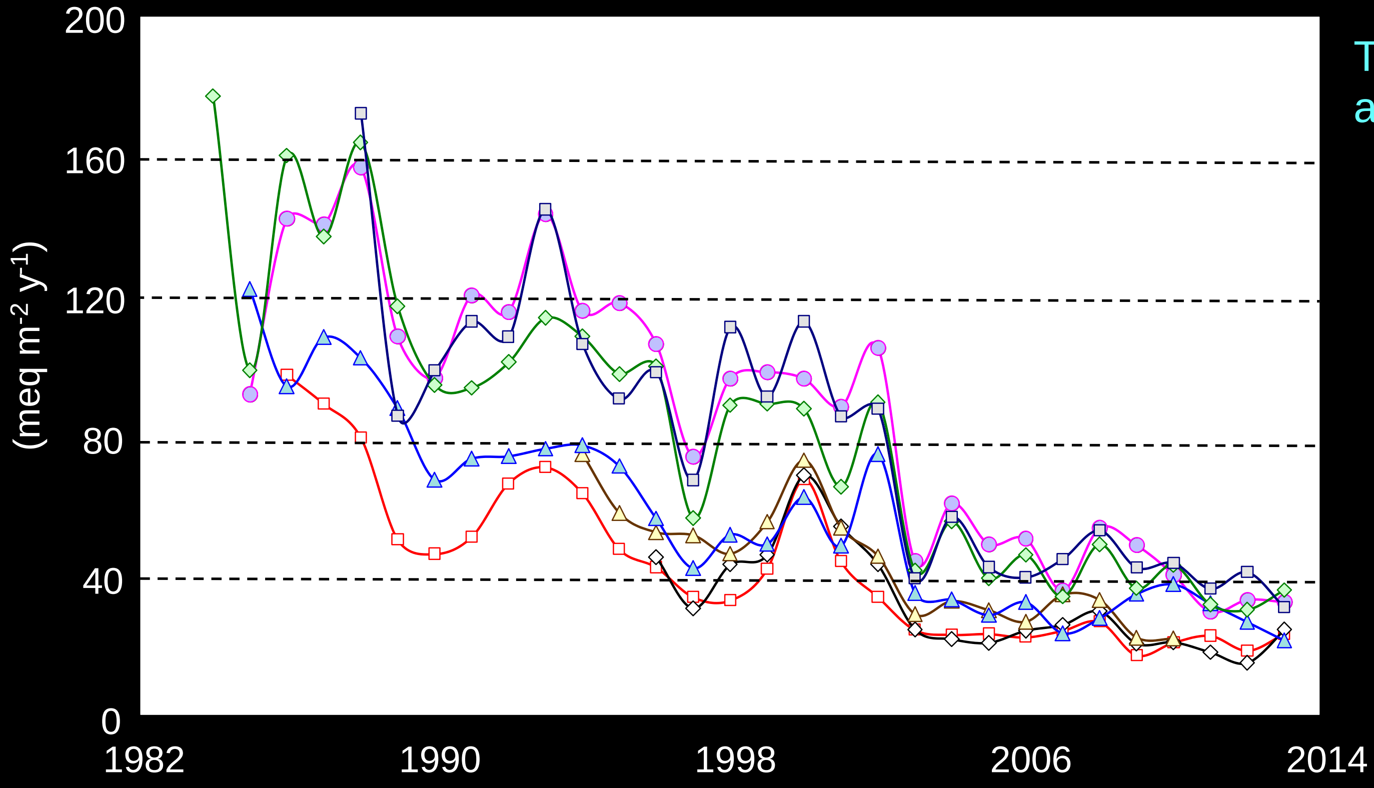






Sulphate trend: deposition vs climate

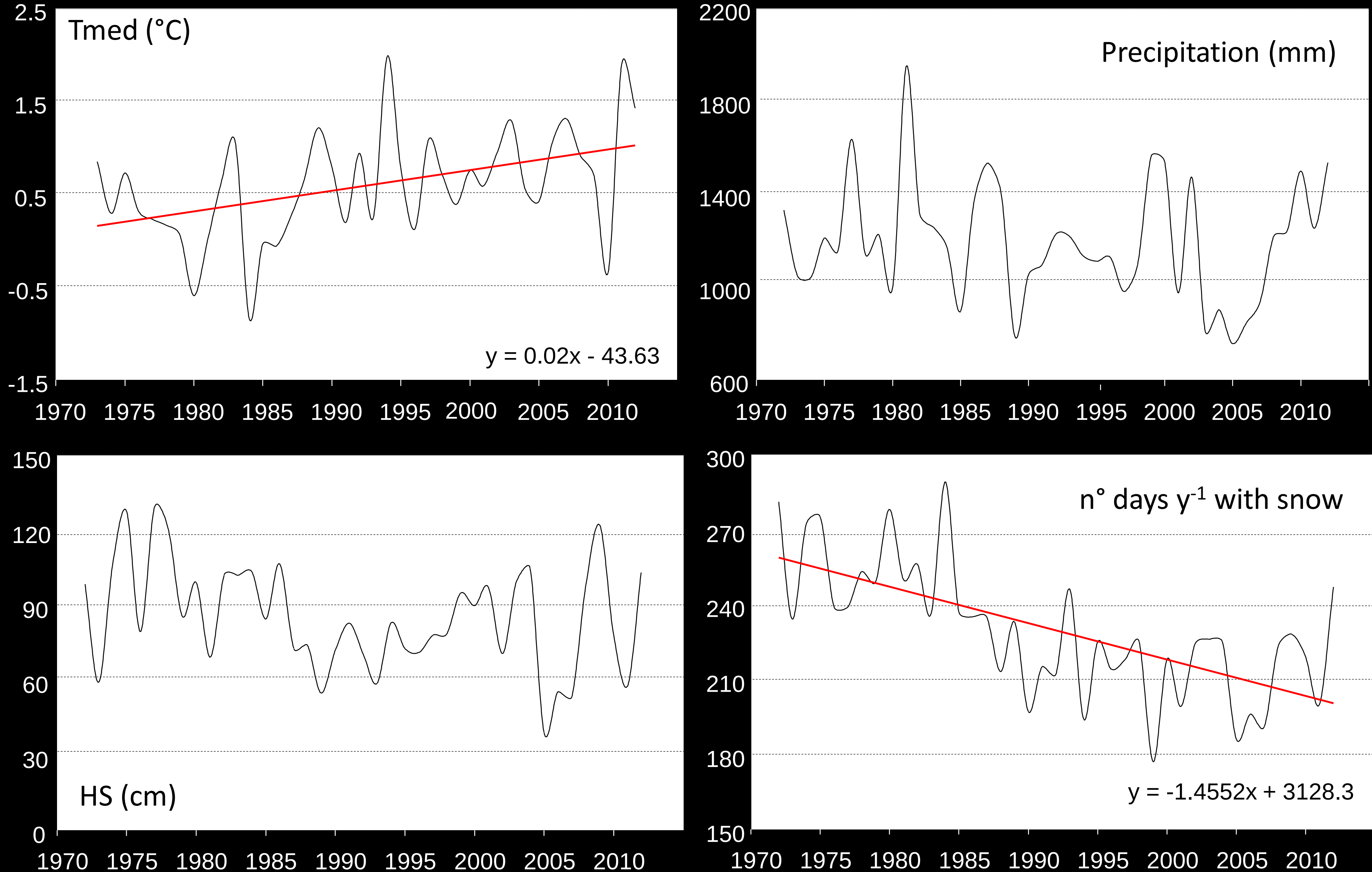
- ✓ Sulphate sharply decreased in atmospheric deposition in the last 30 years



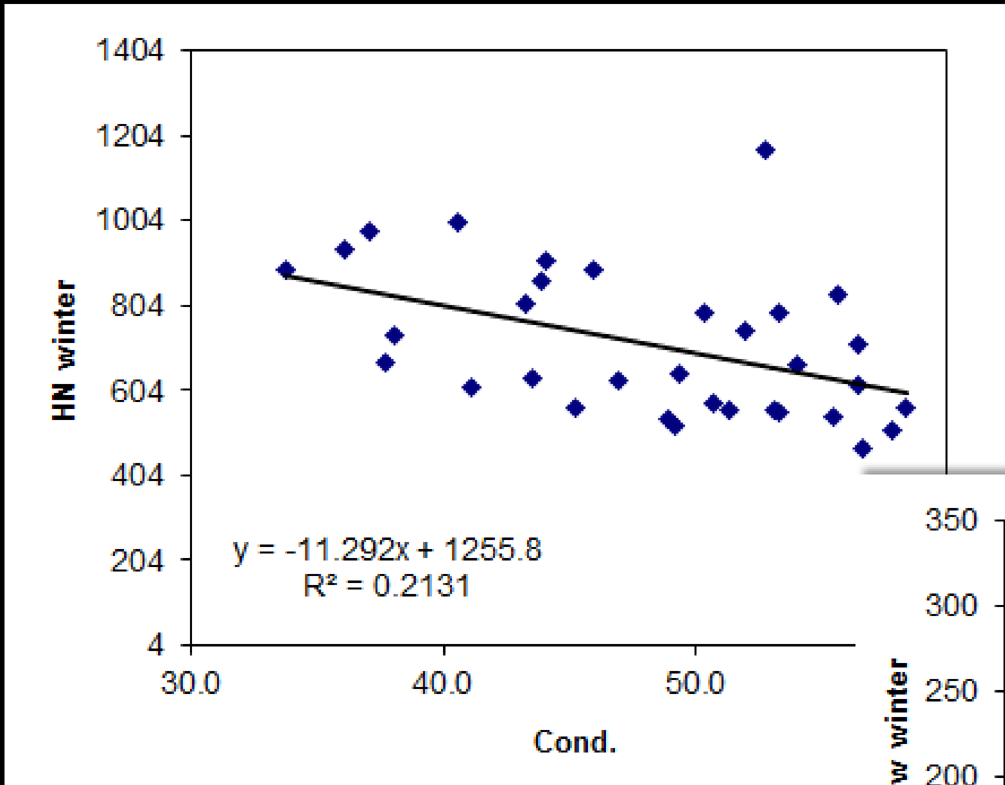
Trend of SO_4 deposition at 7 sites in the lake area

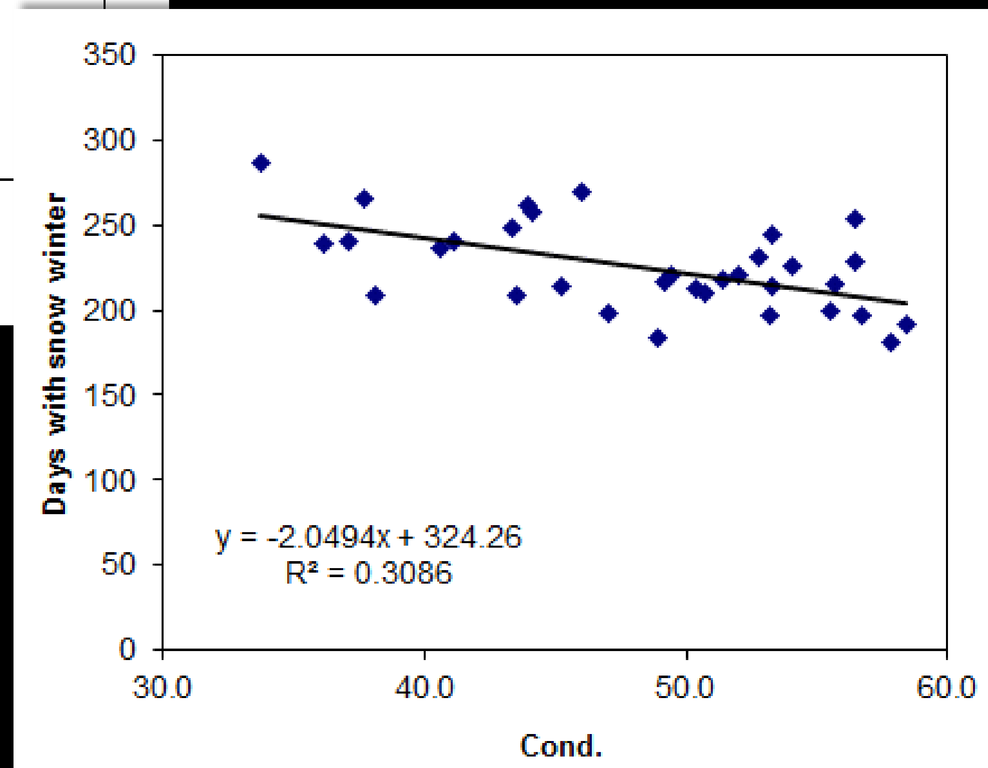
➡ The increasing trend of sulphate in lakes has to be ascribed to weathering or other inputs from the catchments

Trends of meteorological variables (Toggia station)



Climate-chemistry relationship





Climate-chemistry relationship

Response variables: conductivity, ion concentrations (annual values 1984-2012)

Explanatory variables: Tn, Tx, Tm, P (annual, winter, summer), HS, HSx, LS

Multiple regression model (backward selection):

Cond/ΣIons ~ Tm_{winter} (°) + HS (*) + Hsmax (*)+ LS (**)

Adj R^2: 0.6258 $\quad$ $P<0.001$

Catchment-based indirect effect

Less snow on the ground

↓

More exposed surface (soils and rocks)

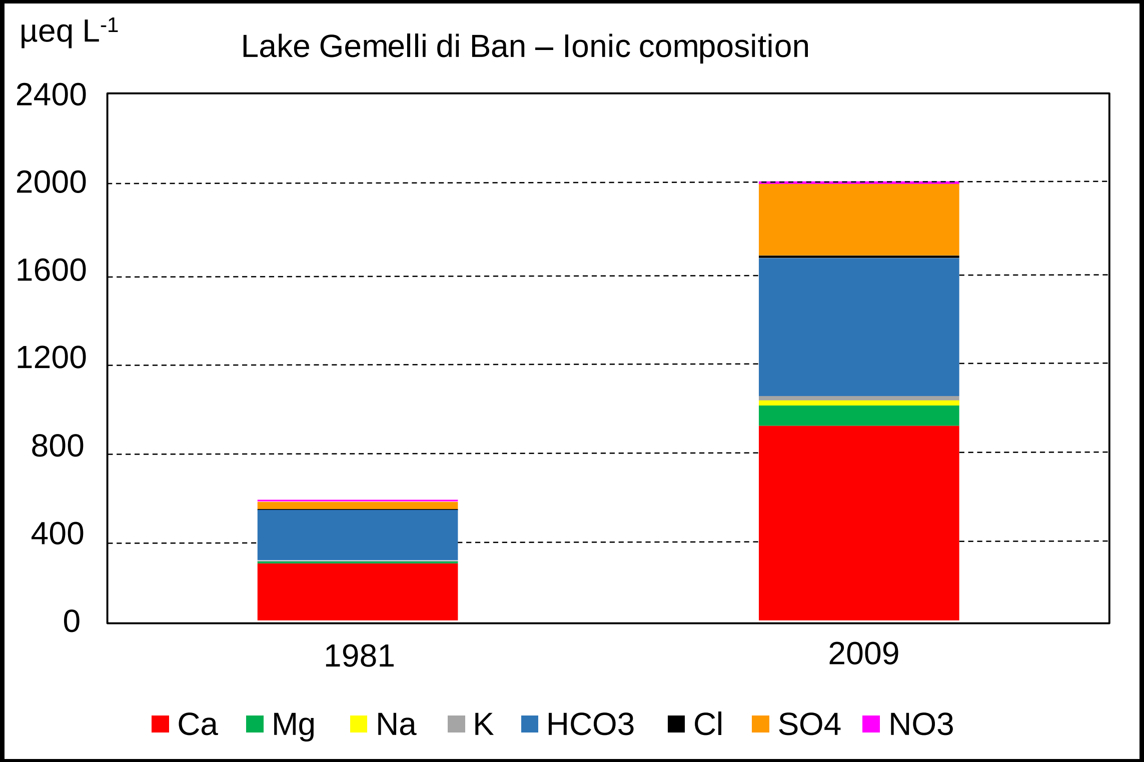
↓

Enhanced weathering and solute export from catchments to lakes

Glaciers and permafrost

✓ Lakes with glaciers in their catchment experienced the greatest chemical changes

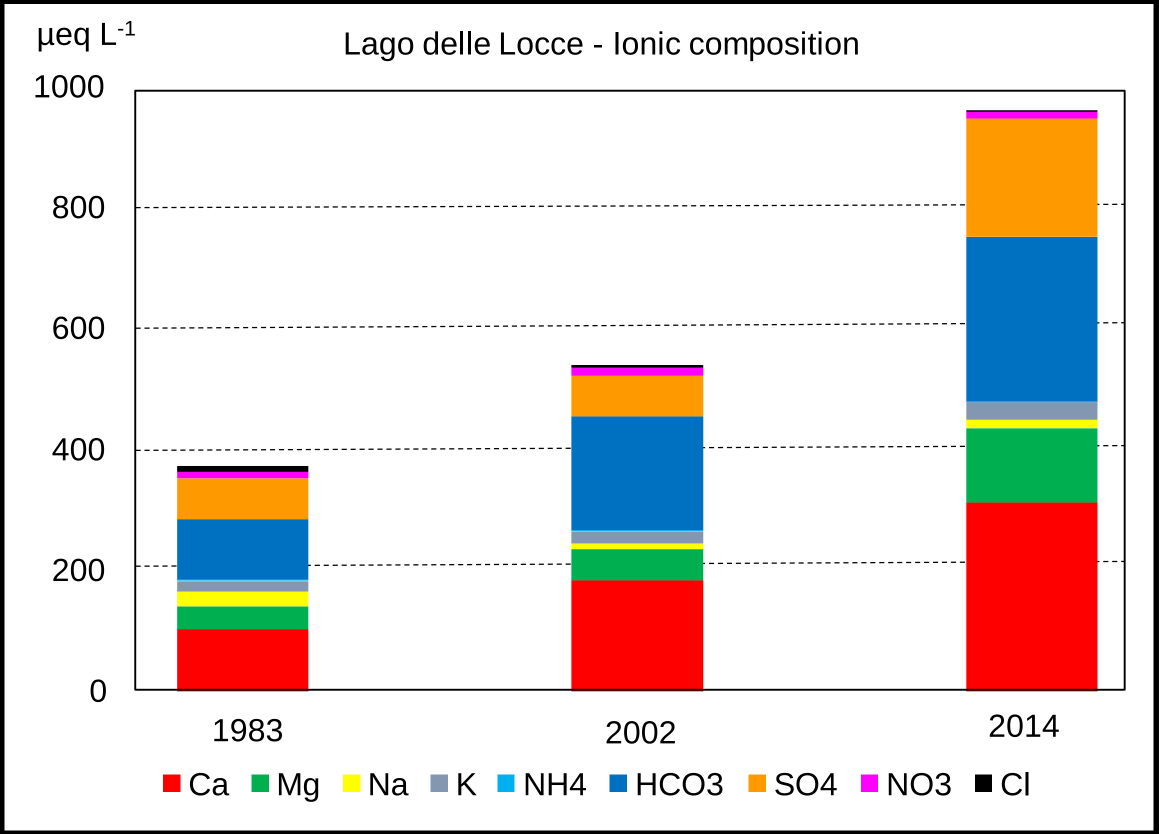
e.g. Glacier and Lake Gemelli di Ban



Glaciers and permafrost

✓ Lakes with glaciers in their catchment experienced the greatest chemical changes

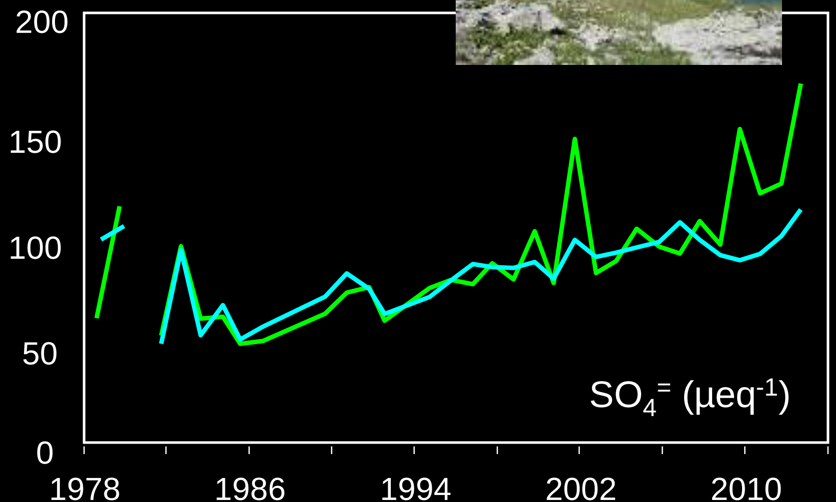
e.g. Belvedere glacier (Mt. Rosa) and Lago delle Locce

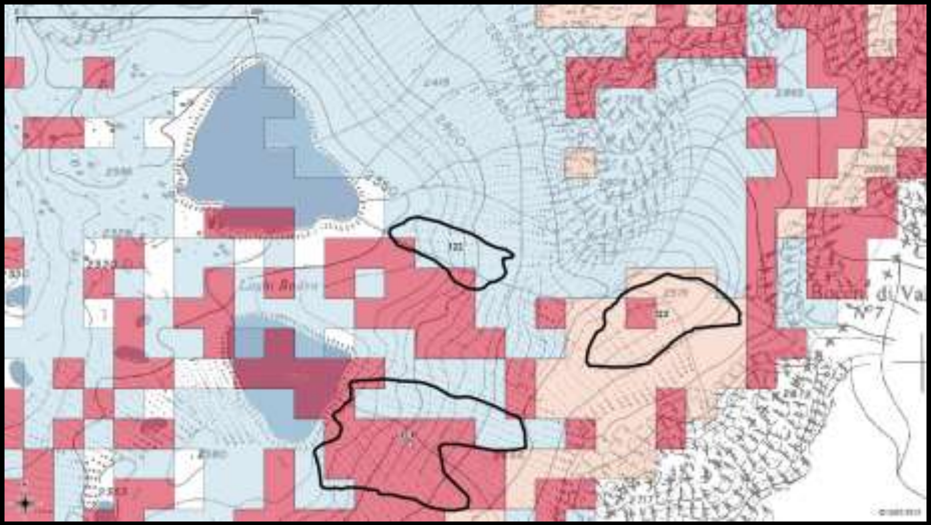


Glaciers and permafrost

- ✓ Among the lakes with the greatest SO_4 increase, there are lakes with (active) rock glaciers in the catchment

e.g. Boden lakes



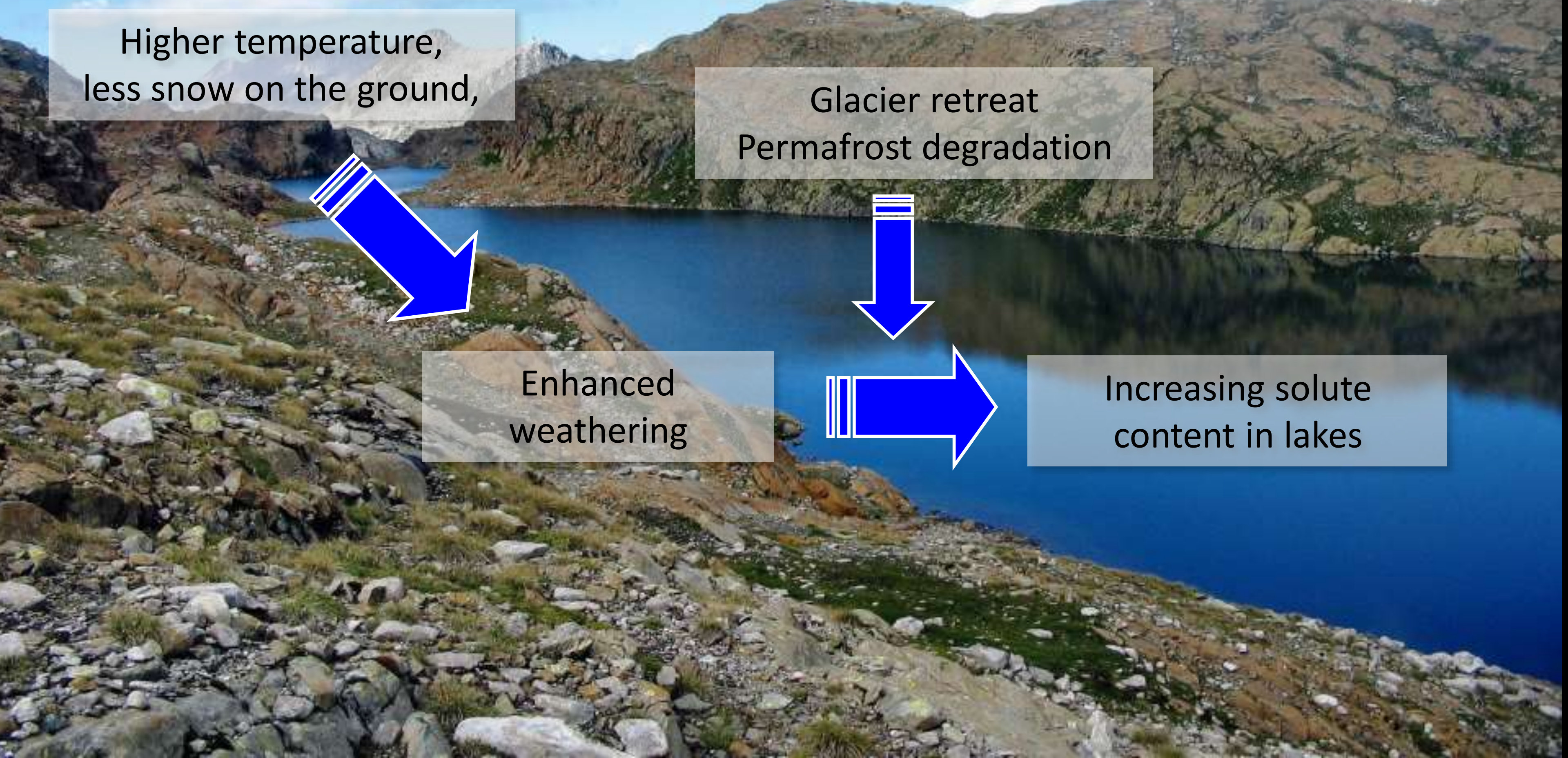


Maps by L. Paro, ARPA Piemonte

Drivers of chemical changes

Upward trend of major ions in the lakes in the last 30 years, change in the ionic composition

Main driving factors: temperature, snow cover (extent and duration)



Main findings and future work

Mountain lakes proved to be sensitive indicators of climate change. Lake chemistry (major solutes) changed in time in relation to meteorological drivers

Chemical changes are important because they modify the acid/base status (and the eventual release of toxic metals), nutrient availability (e.g. change in the N:P ratio) and the lake habitat as a whole, with possible consequences on the biota

Snow cover, especially the length of the snow cover season, seems to be the main driving factor for Alpine lakes; the cryosphere (glaciers, permafrost) also plays a role

Importance of
LONG-TERM ECOLOGICAL RESEARCH
to detect environmental changes

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Thank you for your attention