The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

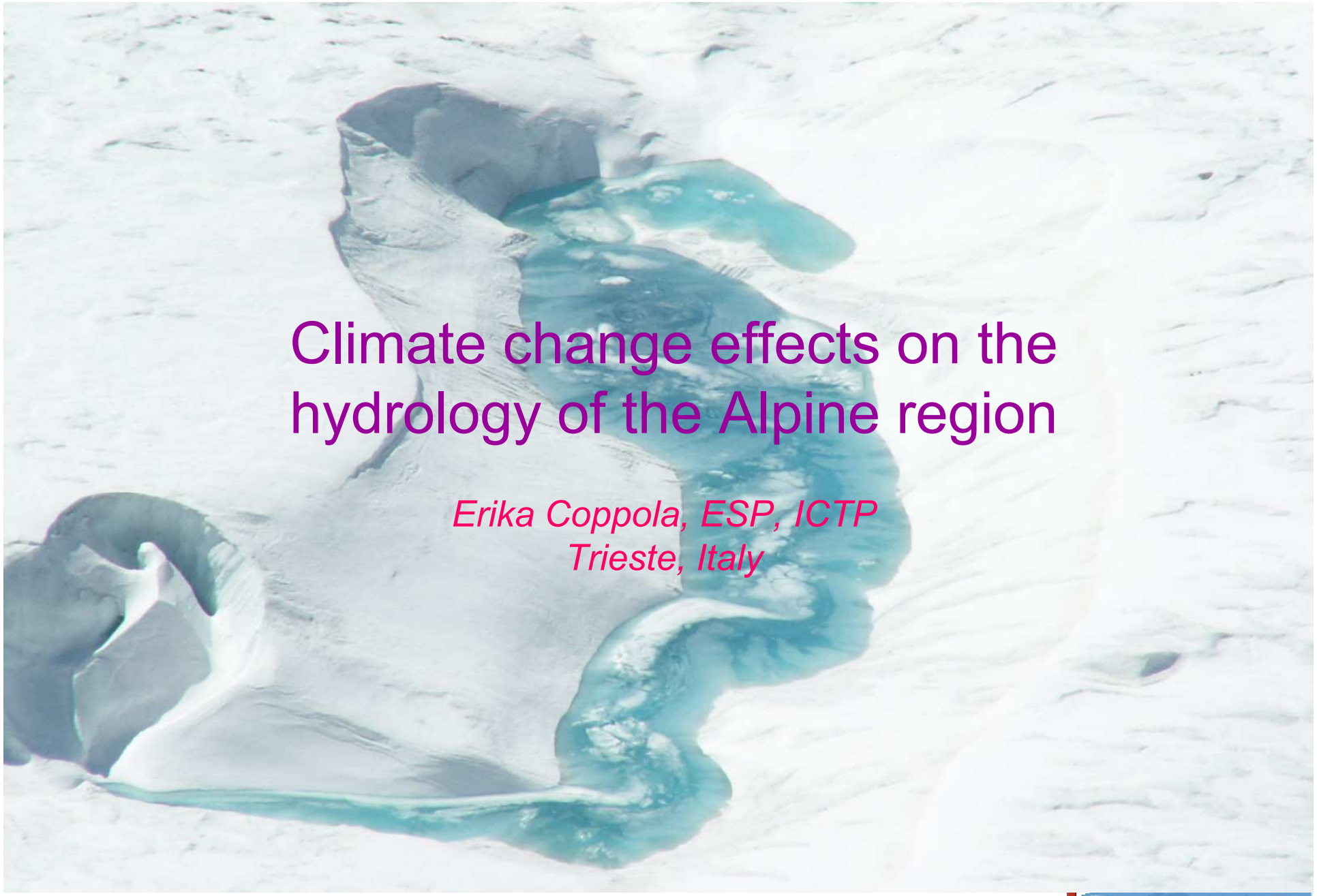
2138-13

Joint ICTP-IAEA Workshop on Vulnerability of Energy Systems to Climate Change and Extreme Events

19 - 23 April 2010

Climate change effects on the hydrology of the Alpine region

Erika Coppola
ICTP
Trieste
Italy



Climate change effects on the hydrology of the Alpine region

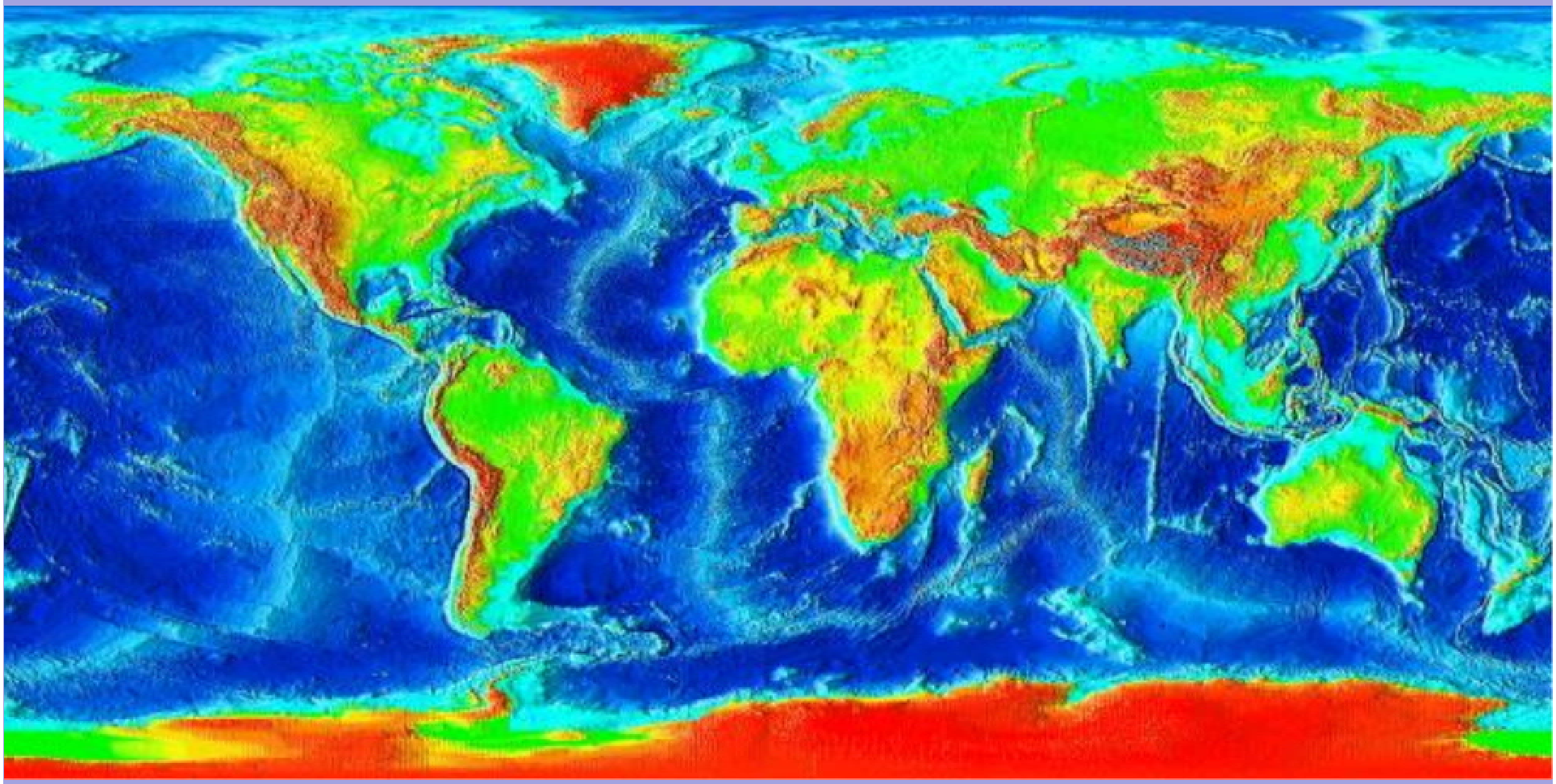
Erika Coppola, ESP, ICTP
Trieste, Italy

Overview

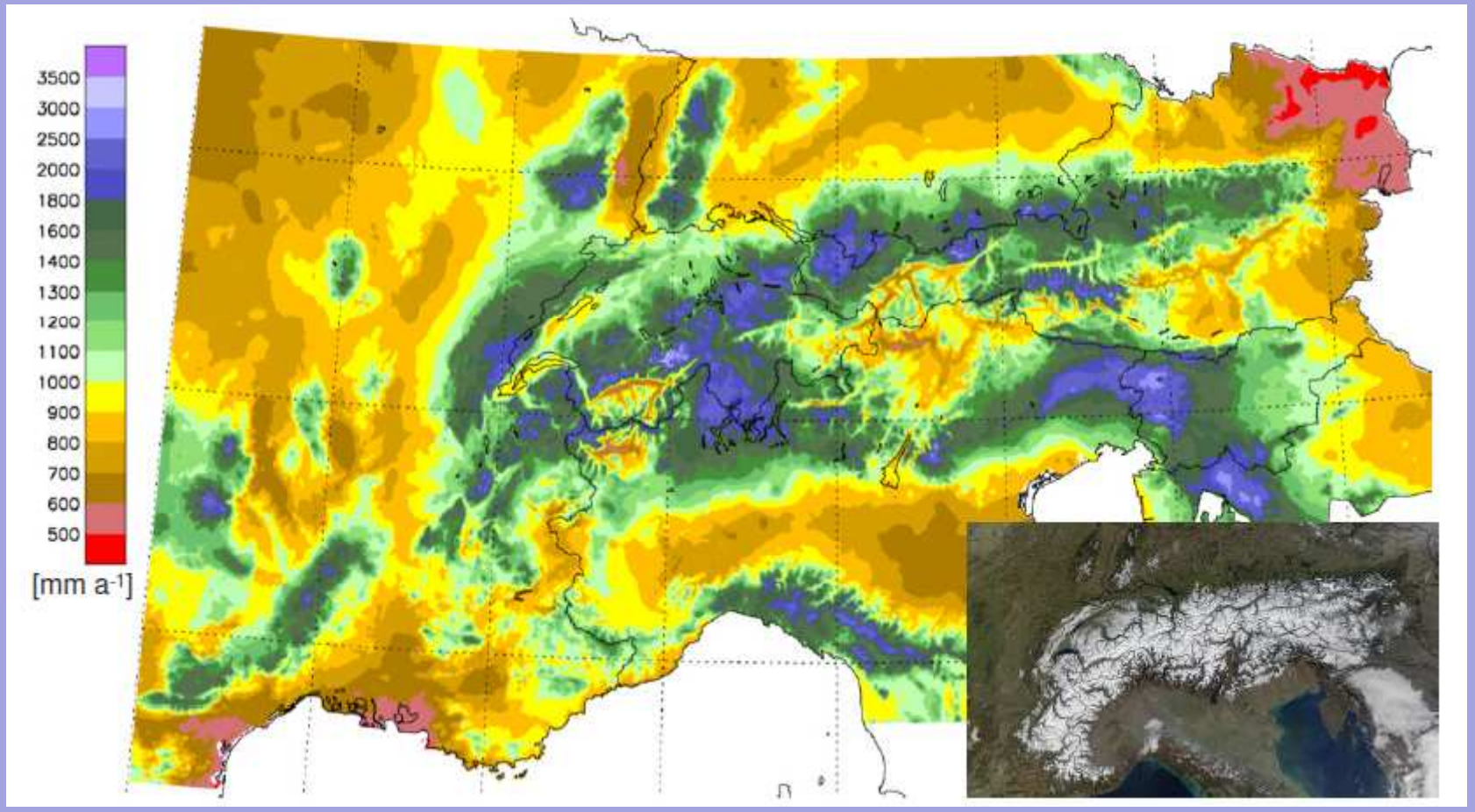
- Mountains and water
- Current and future climate (Alps)
- Potential impacts
- The EU « ACQWA » Project
- Concluding remarks

- Mountains and water
- Current and future climate (Alps)
- Potential impacts
- What ACQWA aims to achieve
- ACQWA partners

Mountains as a source of more than half the world's rivers



The Alps water tower of Europe



What is a *water tower* ?

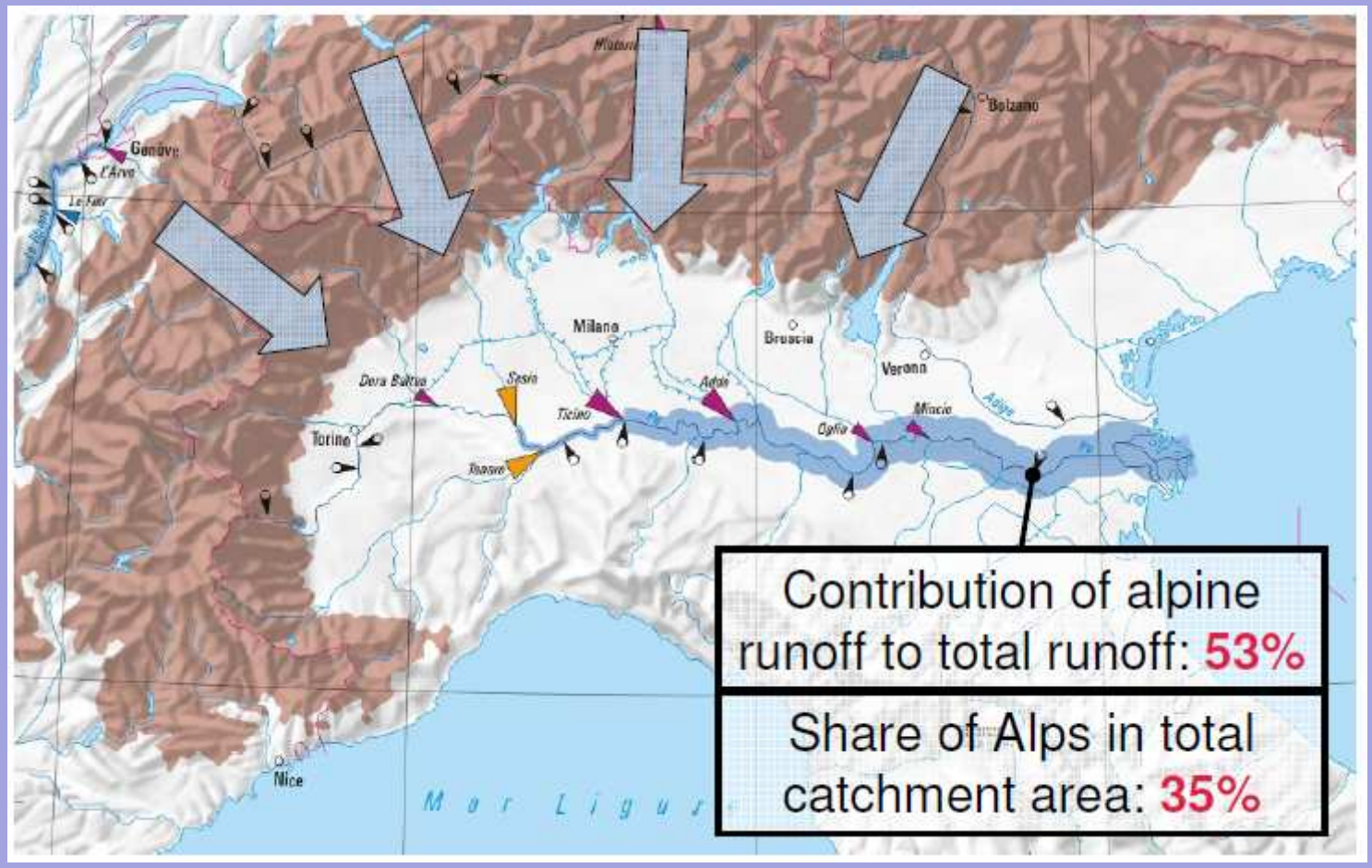
What is a *water tower* ?

> **Superior water supply**
- higher precipitation
- lower evapotranspiration

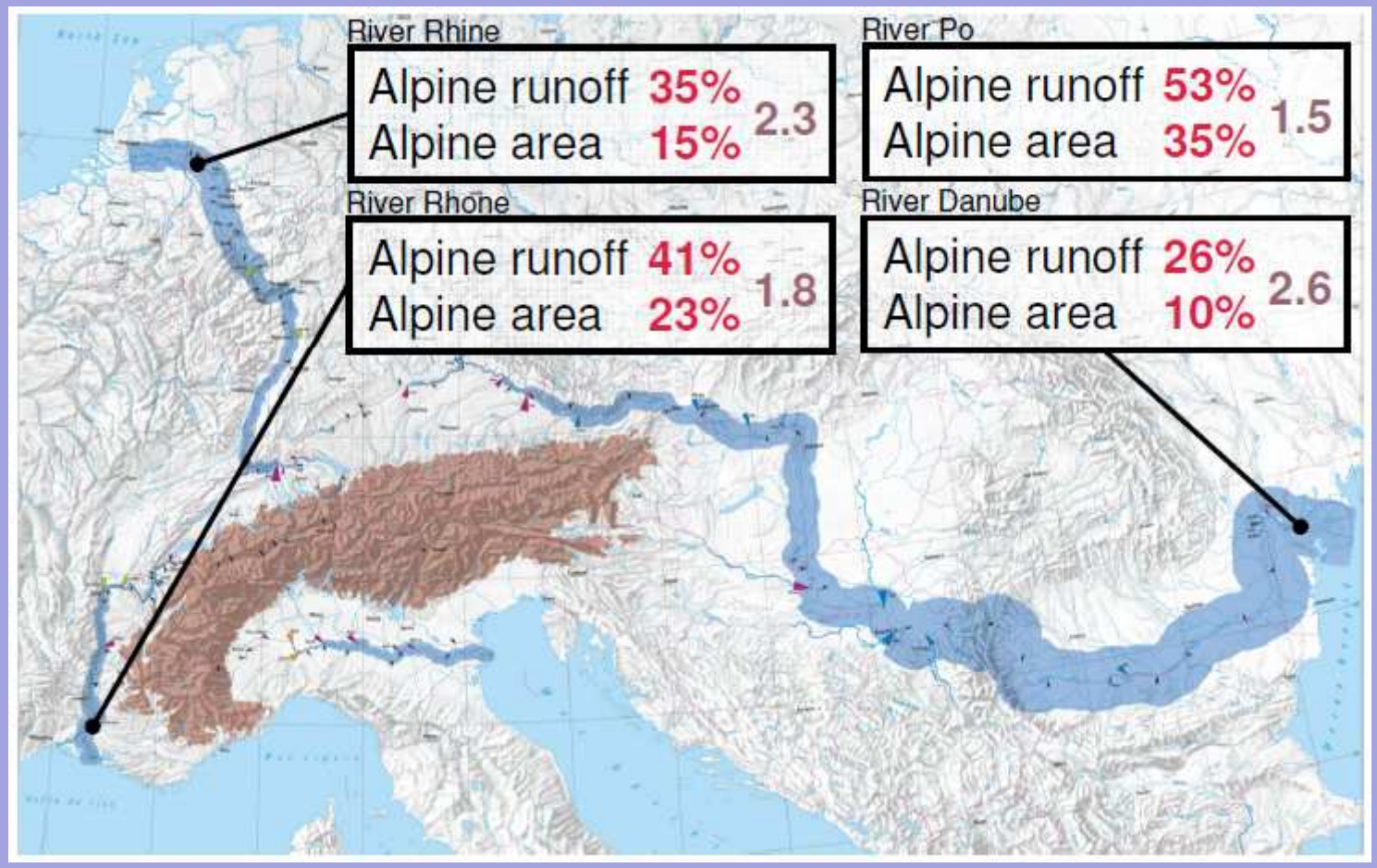
> **Seasonal redistribution of precipitation**
- snow accumulation in winter
- snow- and icemelt in spring and summer

> **Highly reliable flows arrive just in time**
- highly dependable flows from snow- and icemelt
- attenuation of downstream water deficits in summer

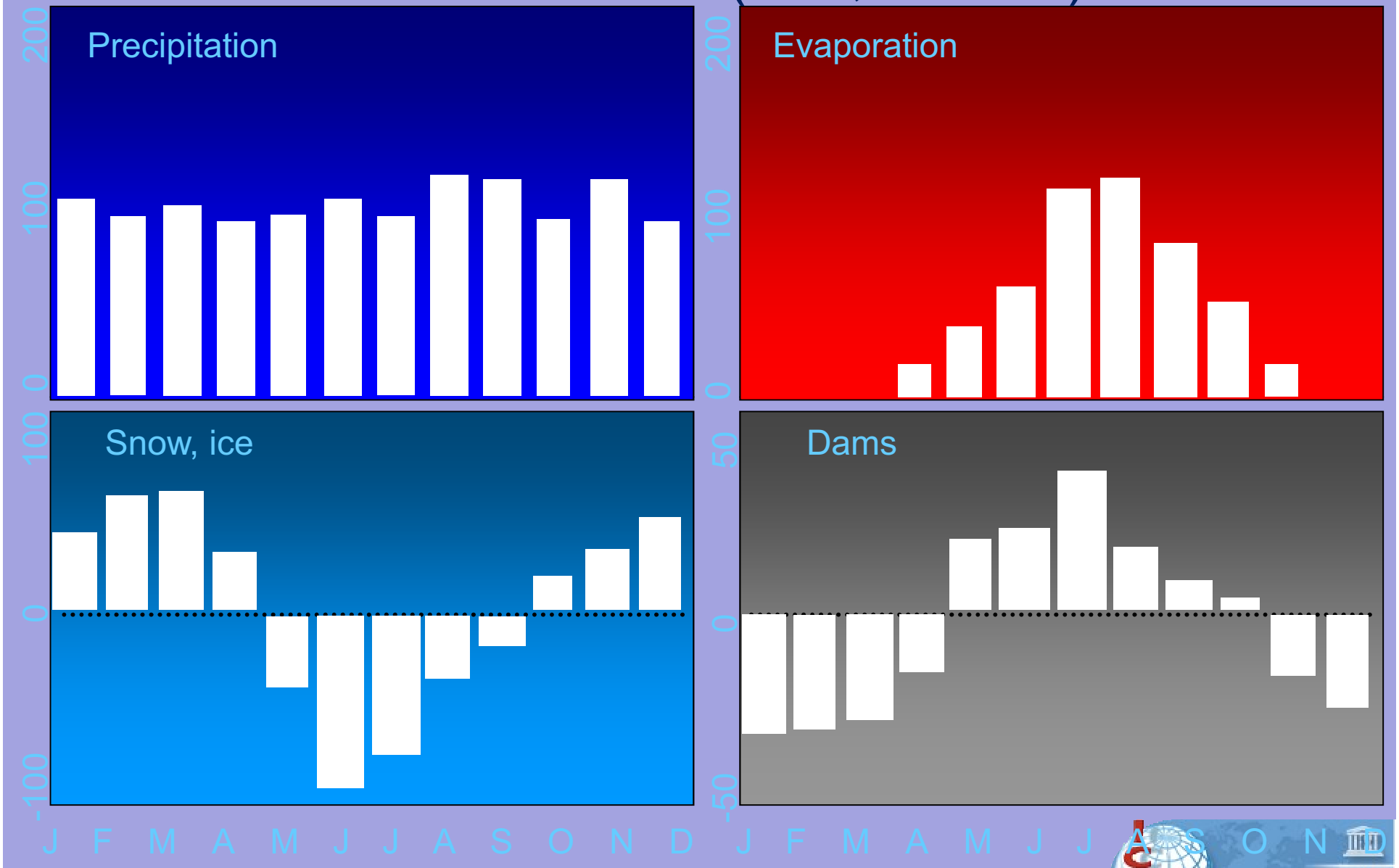
The Alps water tower of Europe the river Po



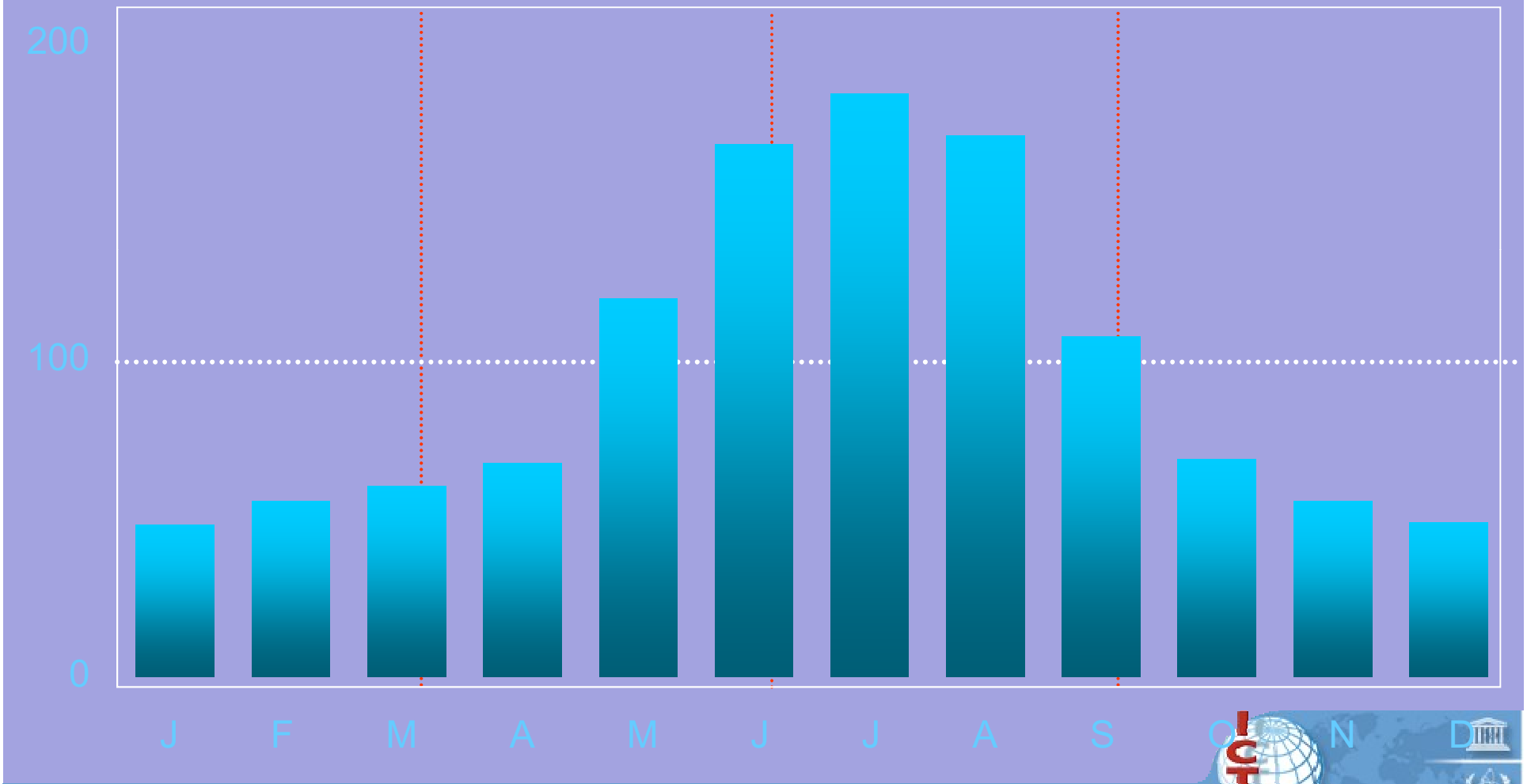
The Alps water tower of Europe: the 4 major rivers



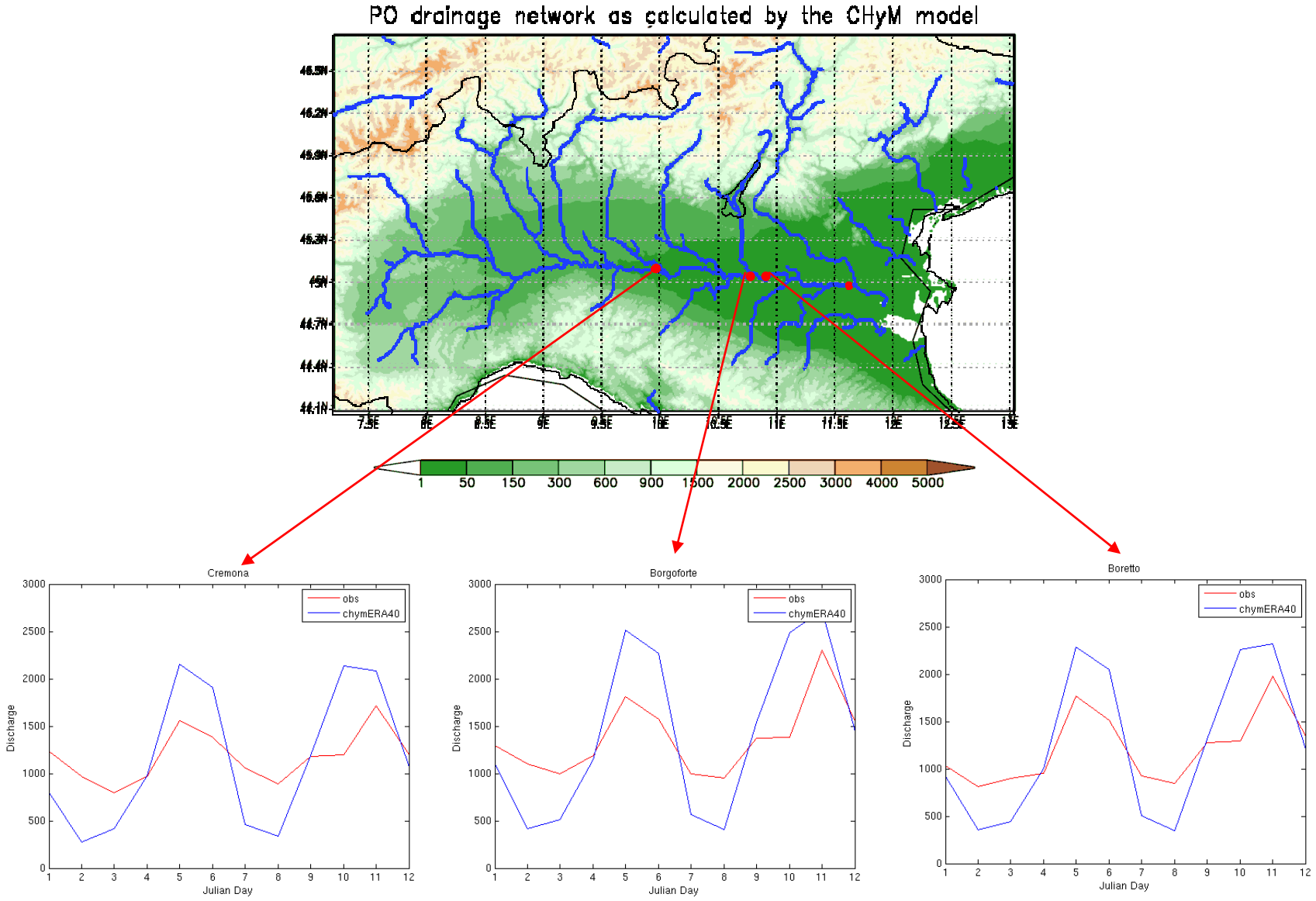
Components of the hydrological cycle under current climate (mm, Rhone)



Average monthly discharge (mm, Rhone)



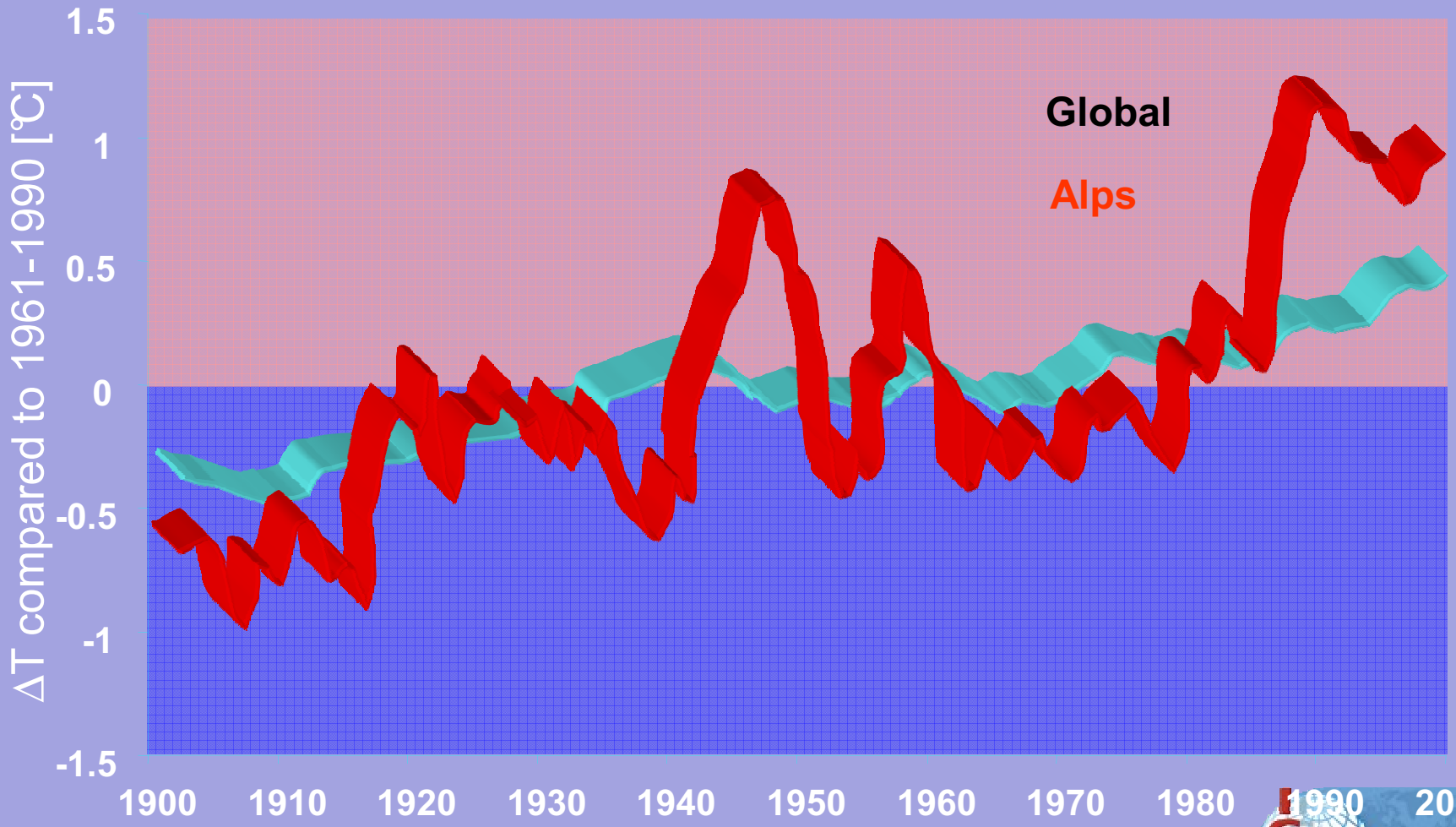
Average monthly discharge (mm, Po)



Avg. discharge 1540 m³/s

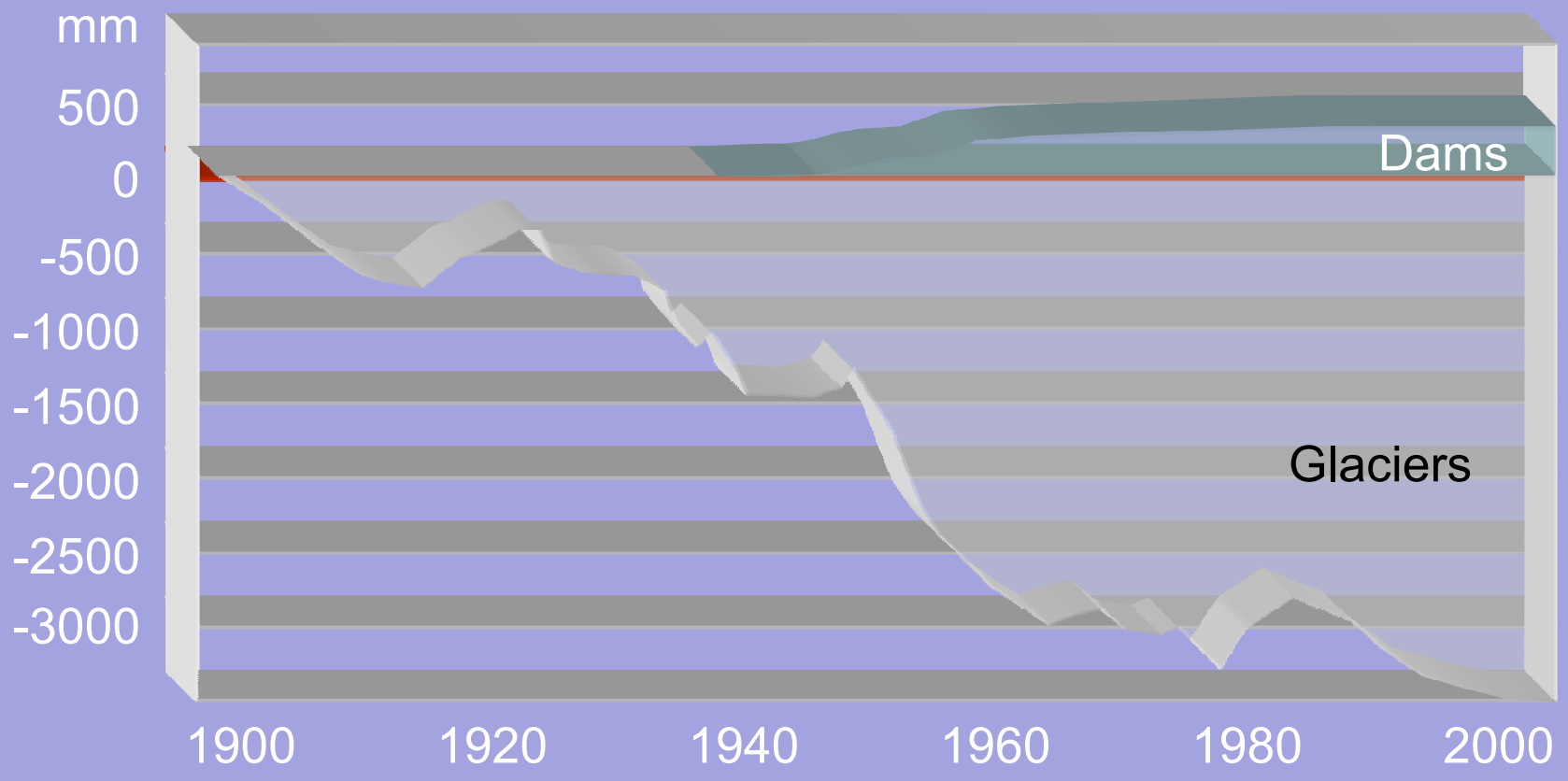
- Mountains and water
- Current and future climate (Alps)
- Impacts
- The EU « ACQWA » project
- Concluding remarks

Evolution of global and alpine temperatures, 1901-2000

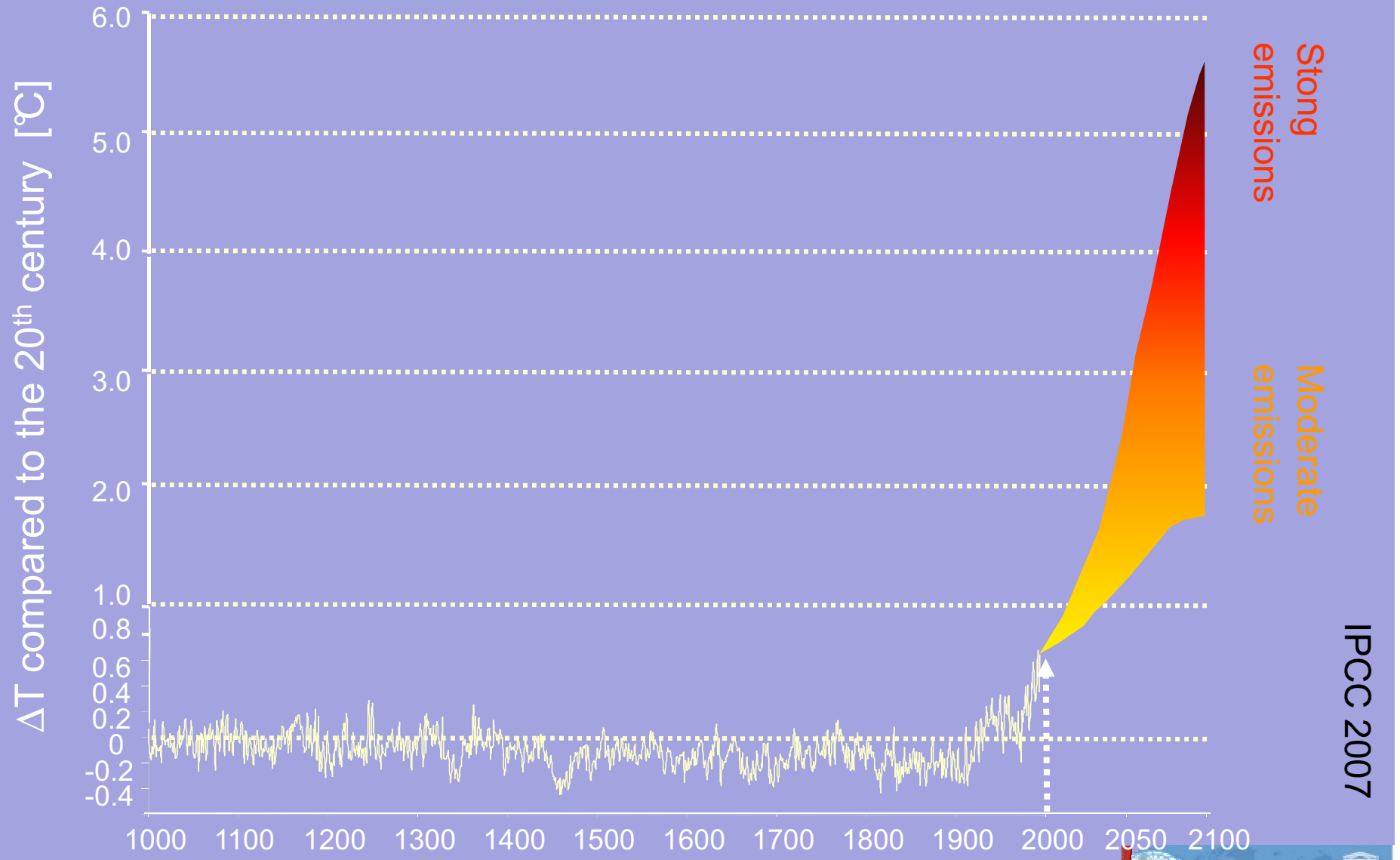


Beniston, 2000: Environmental Change in Mountains, Arnold, London

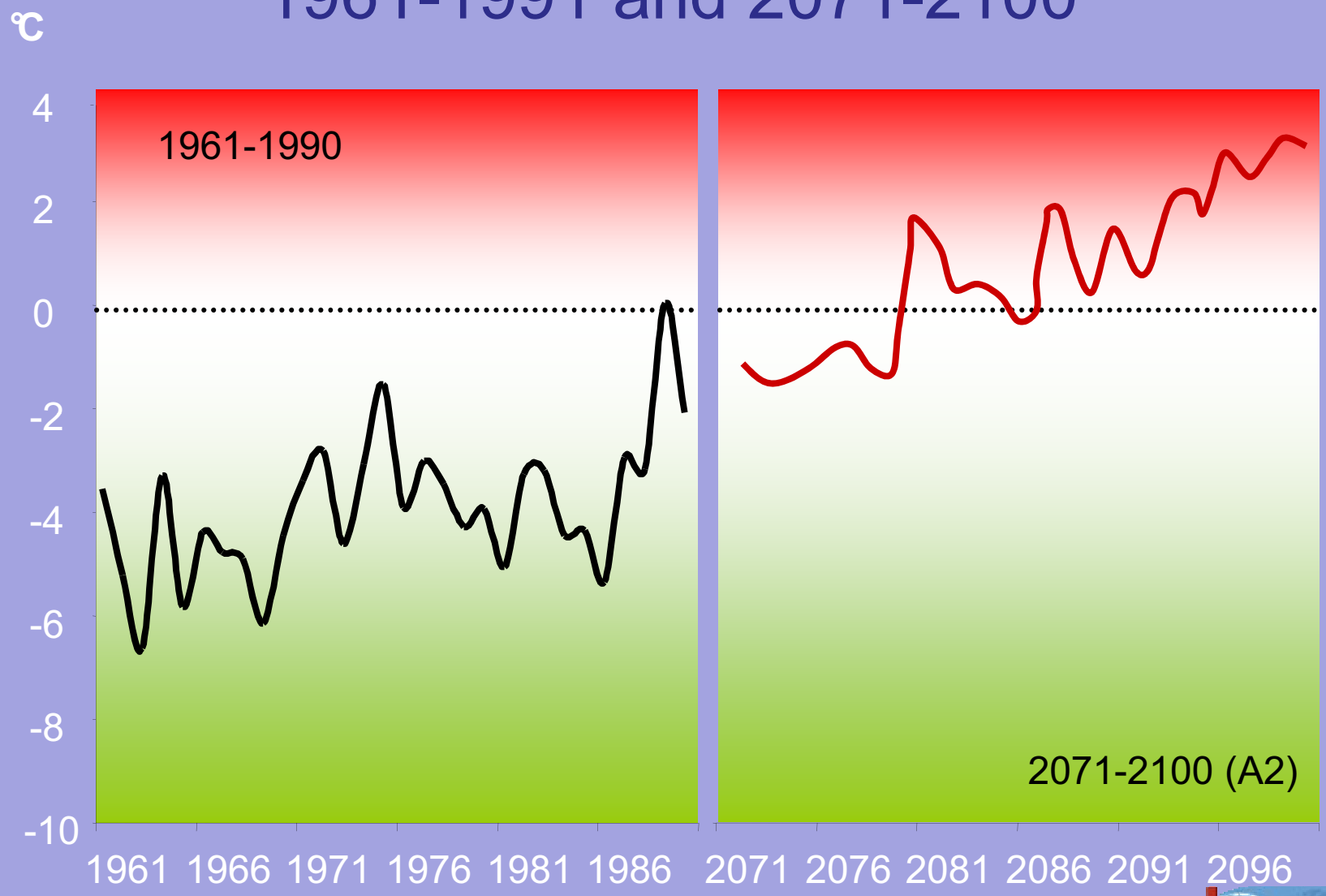
Changes in water availability for the Rhône River



Climate futures



Winter temperatures at Säntis (2,500 m): 1961-1991 and 2071-2100



Beniston, 2004: Climatic Change and Impacts, Springer Publishers

Global

Regional

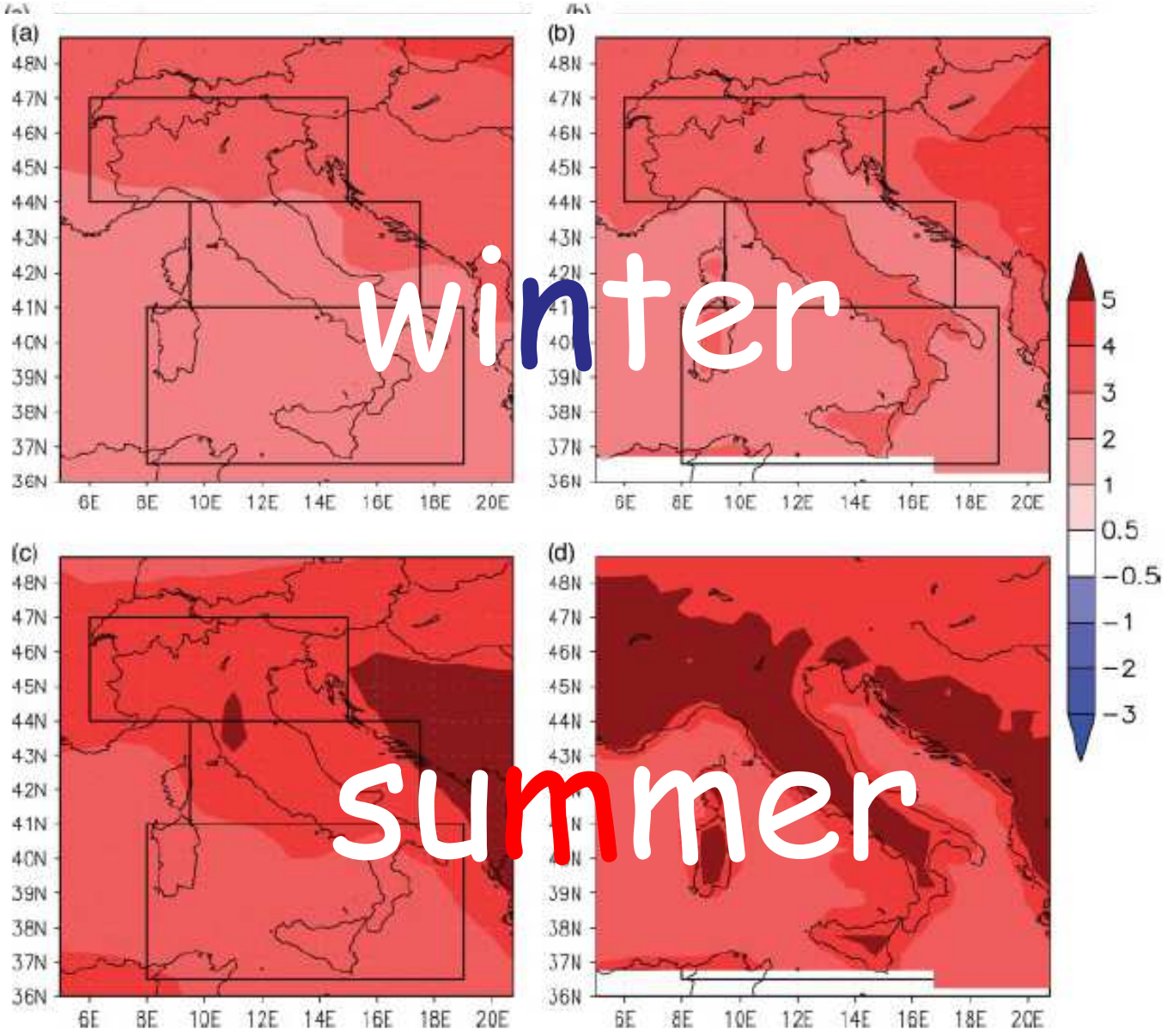
CMIP3 model – country-resolution	20C	B1	A1B	A2
BCCR–Norway(1.9°)	1			1
CGCM-Canada(2.8°–1.9°)	6	4	4	2
CNRM-CM3-France(1.9°)	1	1	1	1
CSIRO-MK-Australia(1.9°)	2	1	1	1
GFDL–CM2.0-USA(2° × 2.5°)	3		1	1
GFDL-CM2.1-USA(2° × 2.5°)	3	1	1	1
GISS-AOM-USA(3° × 4°)	1		2	1
GISS-EH-USA(4° × 5°)	5	1	1	
INMCM-Russia(4° × 5°)	1	1	1	1
IPSL-CM4-France(2.5° × 3.75°)	1	1	1	1
MIROCH-Japan(1.1°)	1		1	
MIROCM-Japan(2.8°)	3	3	3	3
ECHO-G-Germany/Korea(3.9°)	5	3	3	3
ECHAM5/MPI-Germany(1.9°)	3	3	2	3
MRI-CGCM-Japan(2.8°)	5	5	5	5
NCAR-CCSM3 – USA(1.4°)	8	8	6	4
NCAR-PCM-USA(2.8°)	4	2	3	4
UKMO-HadCM3-UK(2.5° × 3.75°)	1	1	1	1
UKMO-HadGEM-UK(1.3° × 1.9°)	1		1	

PRUDENCE model-institute	20C	B2	A2
DMI-HIRHAM(HadAM3H/ECHAM4)	8	2	7
ETH -CHRM (HadAM3H)	1		1
GKSS -CLM (HadAM3H)	2		2
HC -HadCM3 (HadAM3H)	3	1	3
ICTP -RegCM (HadAM3H)	1	1	1
KNMI -RACMO (HadAM3H)	1		1
CNRM -Arpège (Arpege/HadCM3H)	3	4	4
MPI -REMO (HadAM3H)	1		1
SMHI-RCAO (HadAM3H/ECHAM4)	3	2	4
UCM -PROMES (HadAM3H)	1	1	1

19 models

10 models

Global Regional



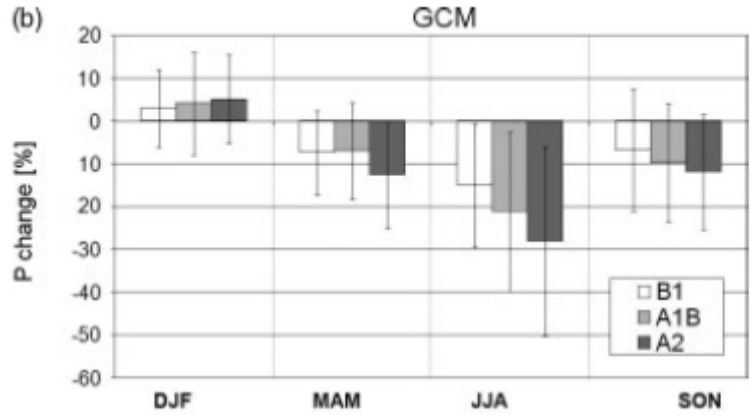
winter

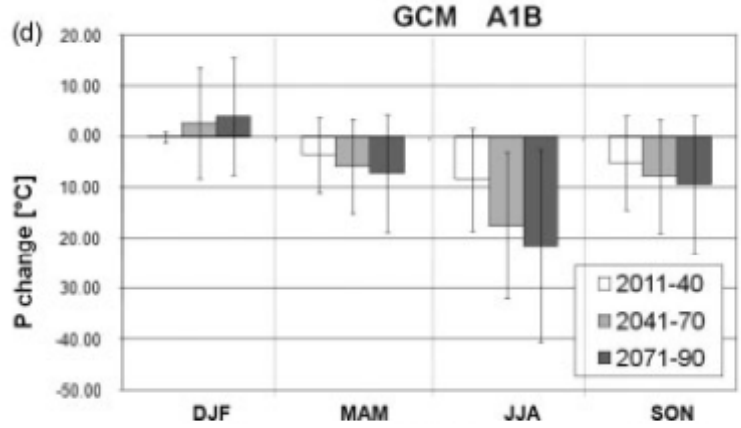
summer

Ensemble average surface air temperature and precipitation change (A2 scenario, 2071 2100 minus 1961 1990)

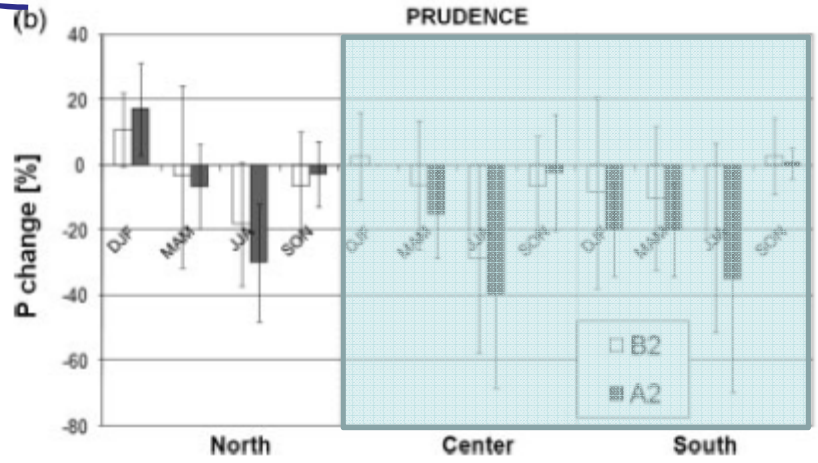
Coppola E. and Giorgi F., 2010

Global





Regional



Ensemble average precipitation [%] changes over the Alps region. For each mean change value the corresponding inter-model standard deviation of the changes is reported

Coppola E. and Giorgi F., 2010

- Mountains and water
- Current and future climate (Alps)
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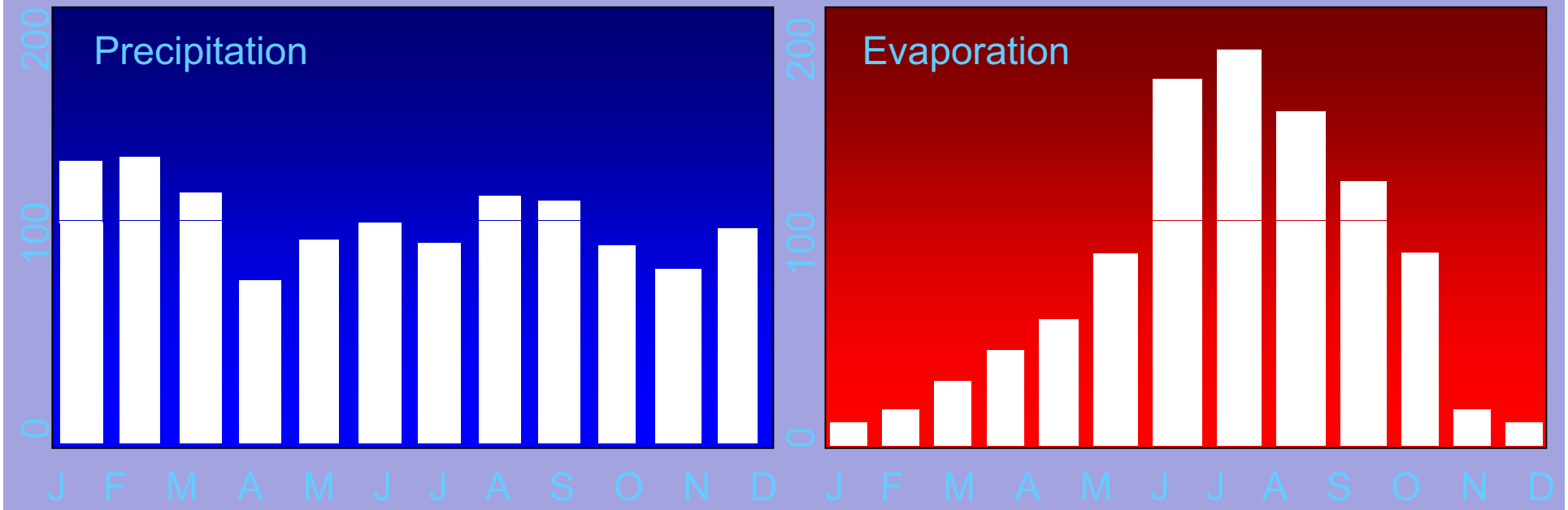
- The EU « ACQWA » project
- Concluding remarks

Components of the hydrological cycle by 2100 (mm, Rhone)

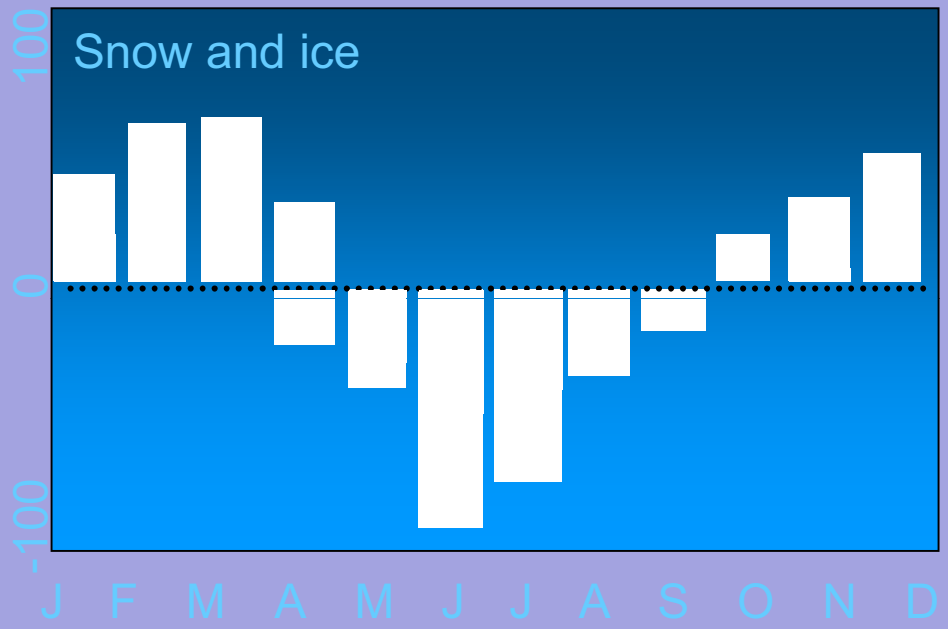


Glacier retreat: Italian Alps

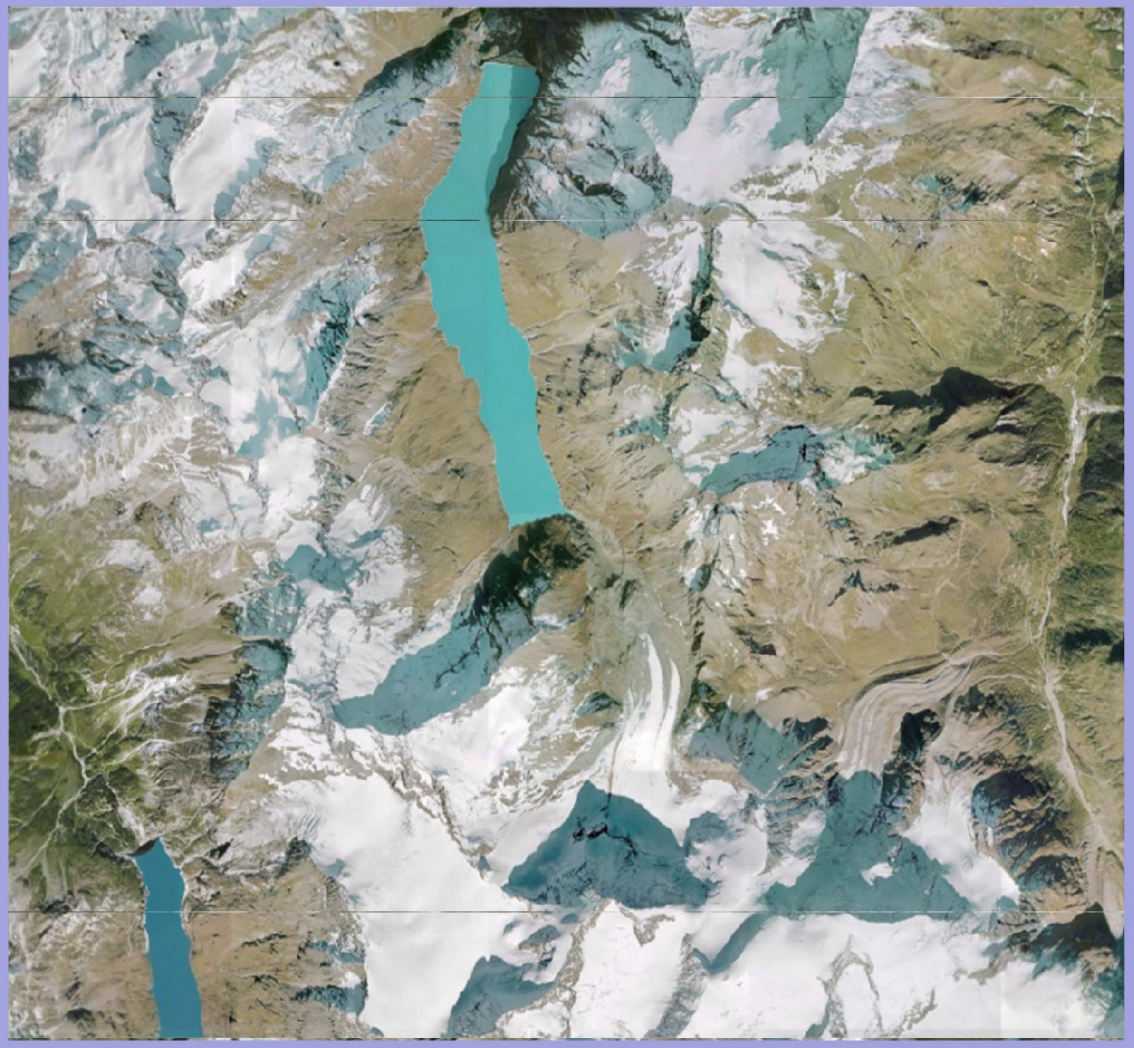
Glacier retreat: Tschierva Glacier, Engadine

Courtesy: Max Maisch
University of Zurich, Switzerland

Components of the hydrological cycle by 2100 (mm, Rhone)

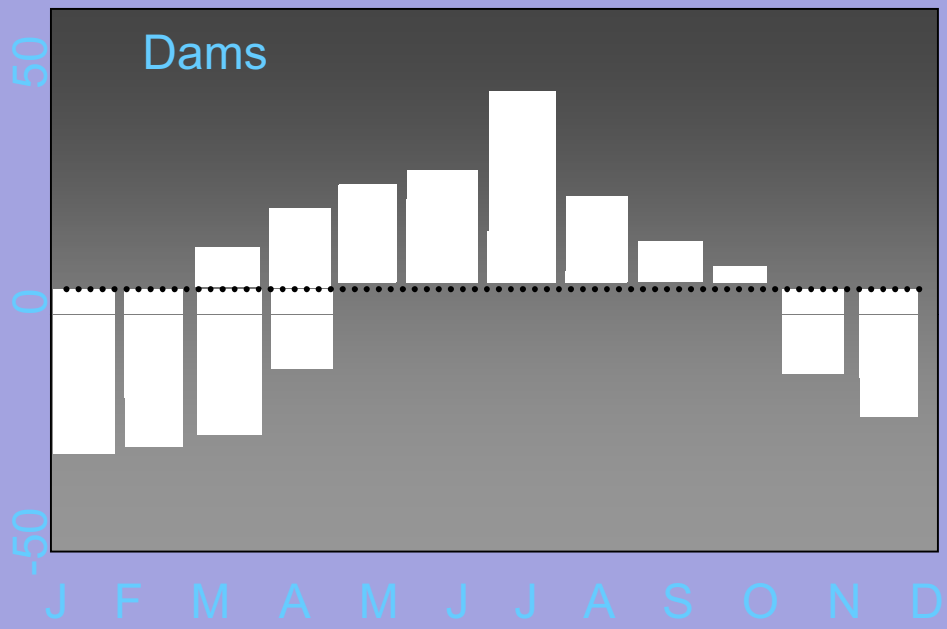


Grande Dixence, Switzerland



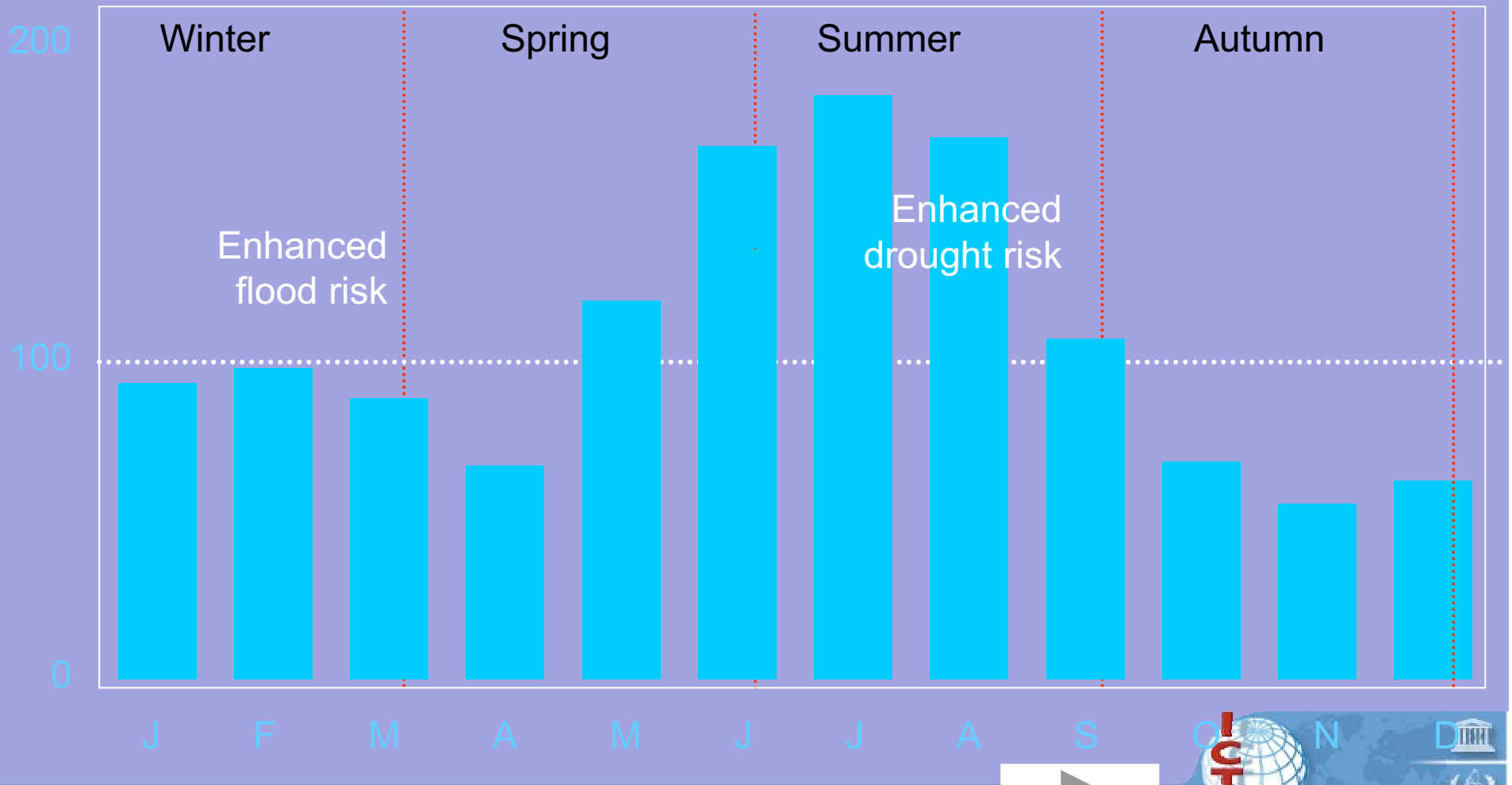
Grande Dixence, Switzerland

Components of the hydrological cycle by 2100 (mm, Rhone)

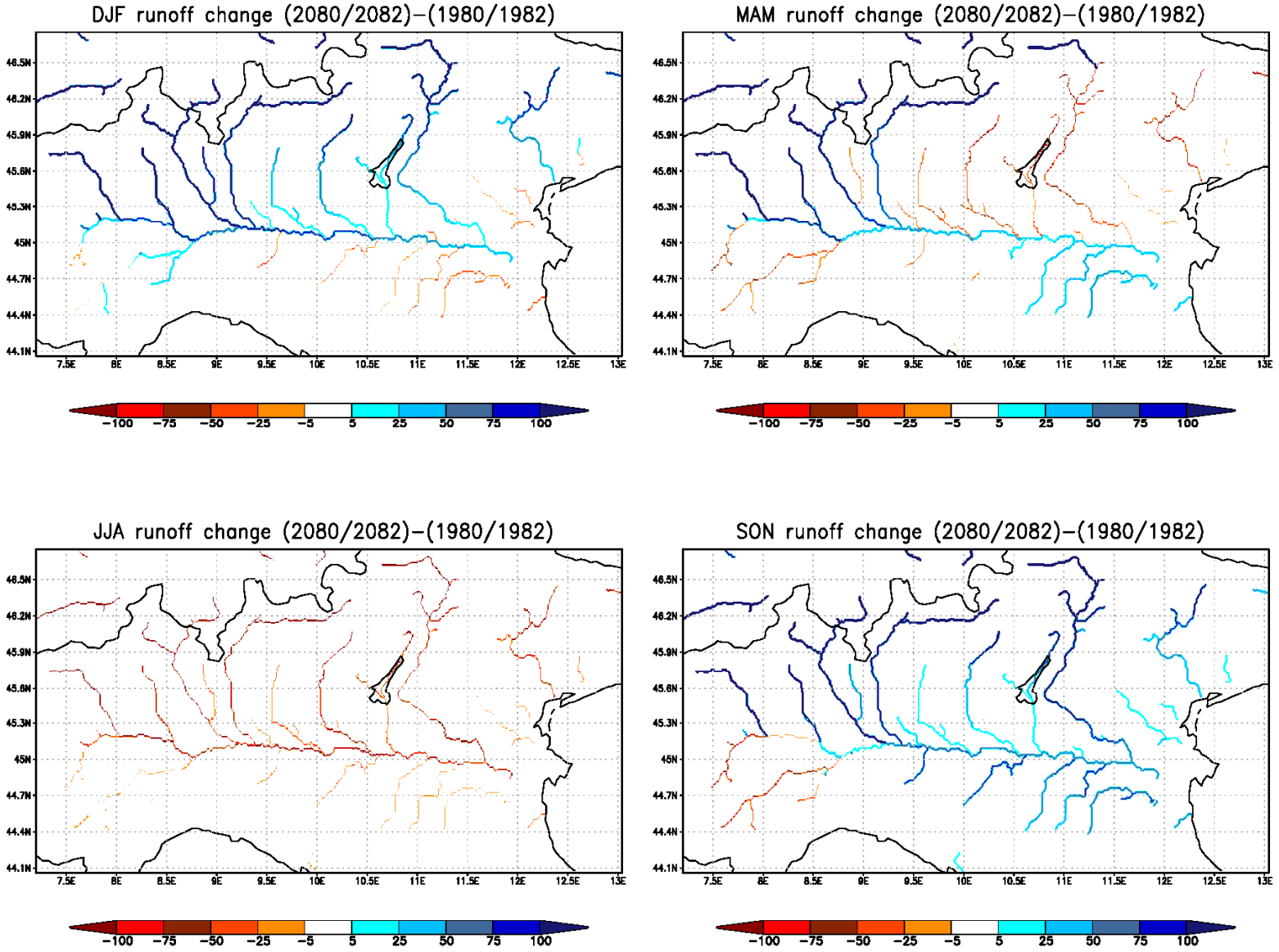


Average discharge by 2100 (mm, Rhone)

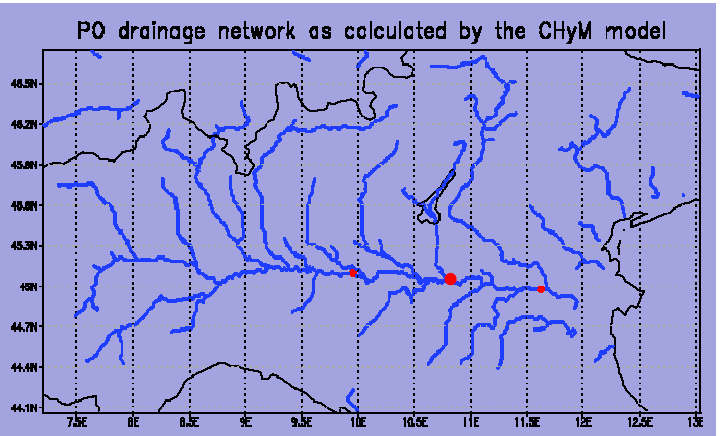
Beniston, 2004:
Climatic Change and Impacts,
Springer Publishers

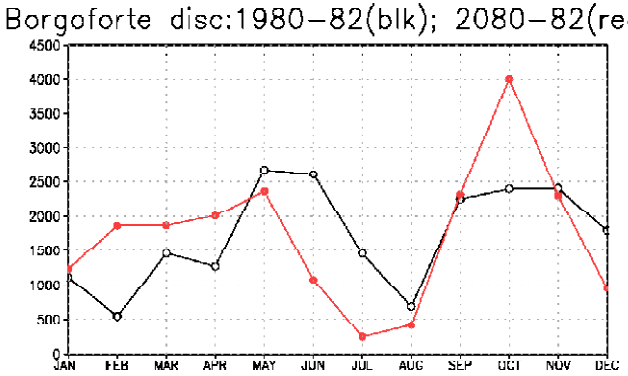


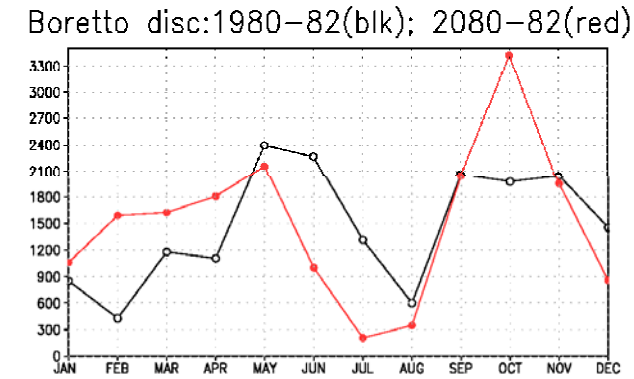
Average discharge change by 2100 (%, Po)

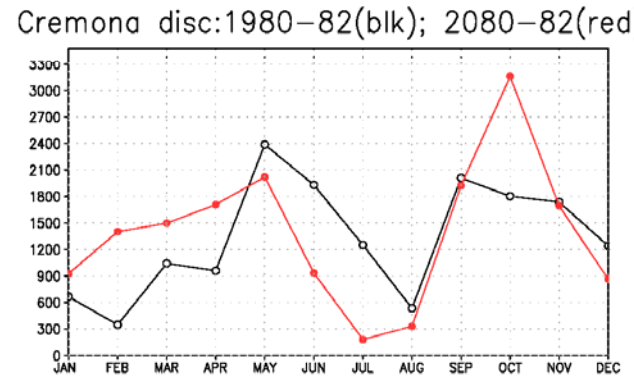


Coppola 2010, personal comun.









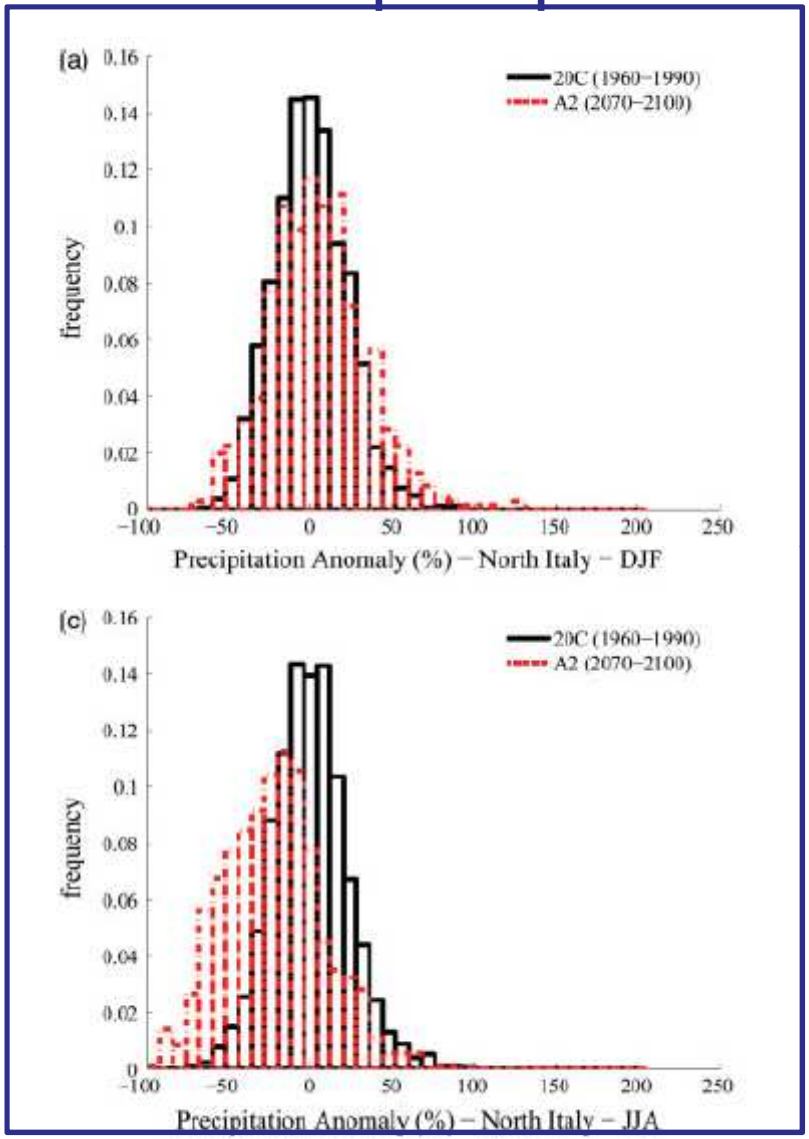
- Shift of the spring peak toward the early part of the season
- Decrease of runoff during the summer months (Jul. and Aug.)
- Increase of the autumn runoff

Coppola 2010, personal comun.

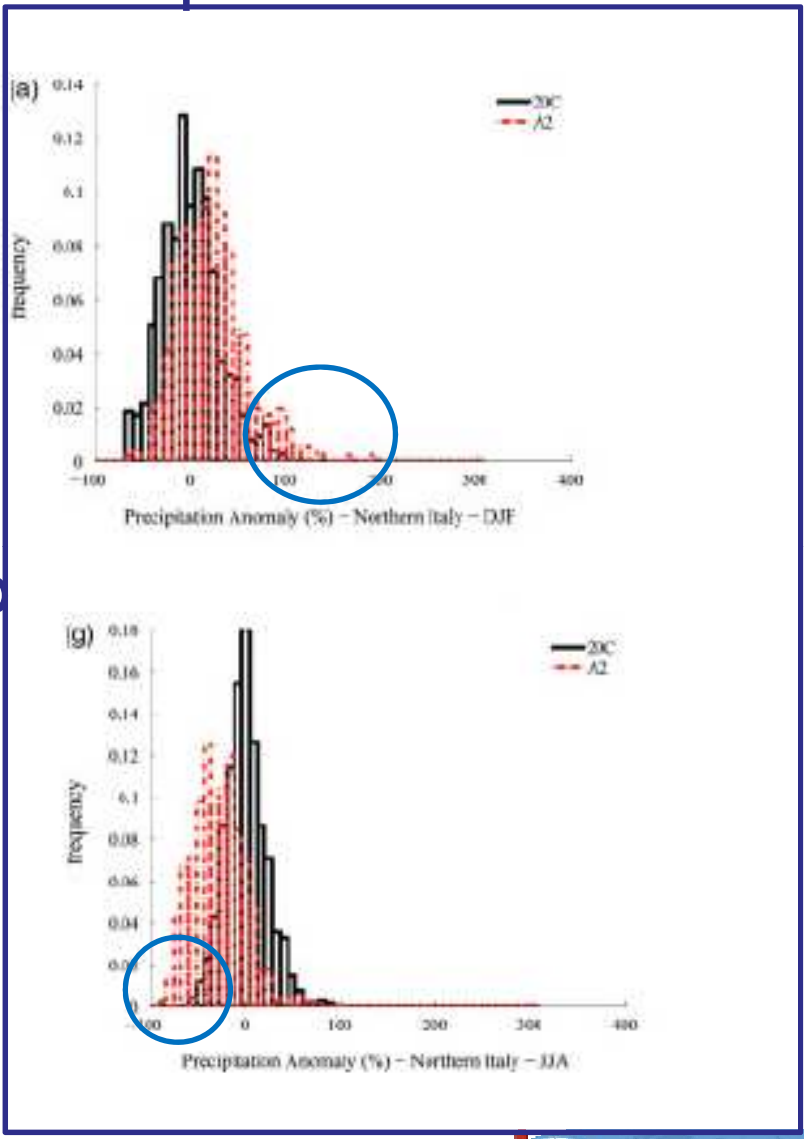
Coppola E. and Giorgi F., 2010,

Changes in extreme precipitation in the Alps

Global



Regional



Increase in both extreme dry (drought prone) and wet (flood prone) seasons

- Mountains and water
- Current and future climate (Alps)
- Potential impacts
- The EU « ACQWA » project
- Concluding remarks

Assessing **C**limate change impacts on the **Q**uantity and quality of **WA**ter

www.acqwa.ch

EU FP7 1st call (2007)

Pressures on Environment and Climate
1st Call (WP 2007) : 39 M€

The Earth System and Climate: Functioning & abrupt changes

Natural and anthropogenic emissions and pressures

The Global Carbon cycle and GHG budgets

Climate Change Natural and Socio-economic Impacts

Response strategies; Adaptation, Mitigation and Policies

Air quality and climate in megacities:
CITYZEN
MEGAPOLI

Climate change impacts in the Parana-Plata river basin
CLARIS LPB

Full costs of climate change
CLIMATECOST

Stability of the Thermohaline Circulation
THOR

Ocean acidification
EPOCA

Climate Change impacts & adaptation in water policies
CLIMATEWATER

Impacts of climate policies on land use and ecosystems
CCTAME

37 partners
Budget 6.5 million Euros
2008-2013

Climate change impacts on mountain regions
ACQWA

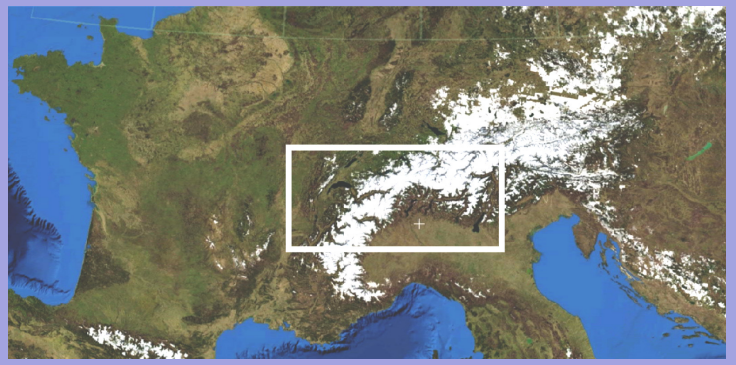
ACQWA Project objectives

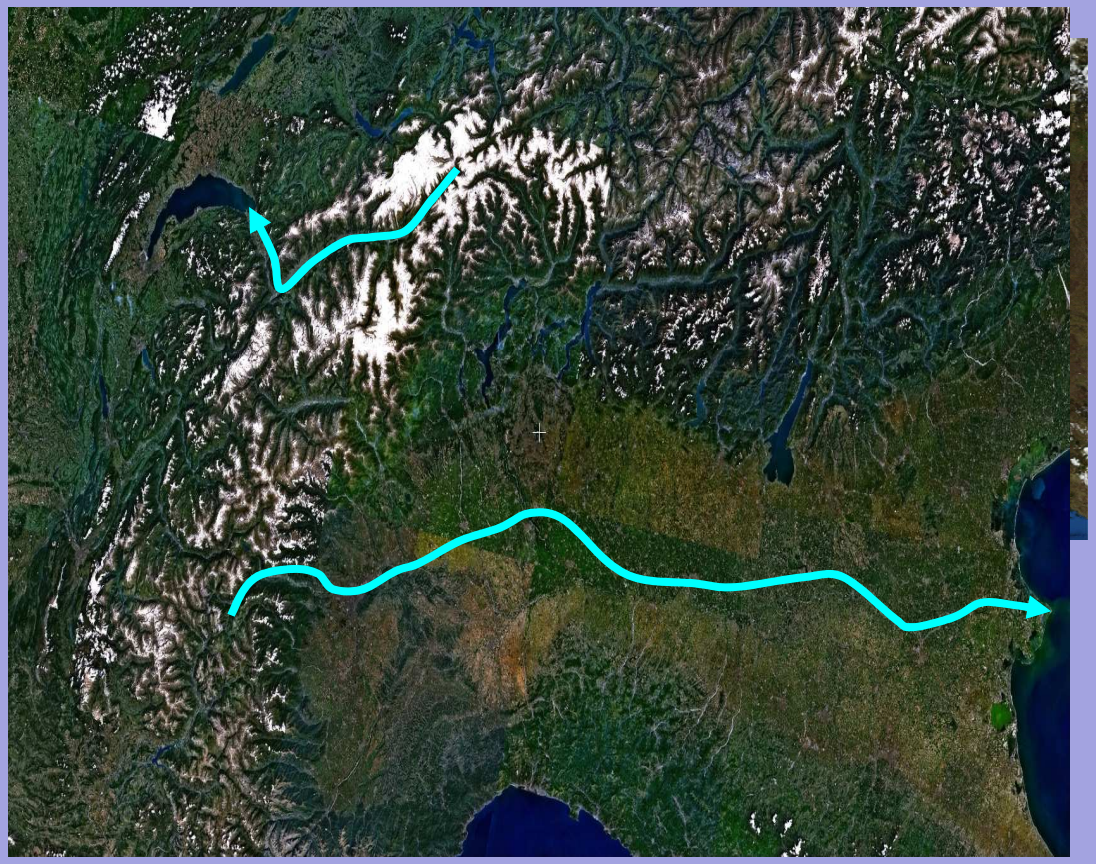
- To assess the vulnerability of water resources in mountain regions where snow and ice is a major component of the hydrological cycle
  - Water in these regions will be vulnerable in a warmer climate because of reduced volumes of snow and ice
- The primary objective will be to use, refine, and develop numerical models to help understand interlinks between climate system components:
  - climate, hydrology, cryosphere
- To predict the evolution of these systems over the next 50 years
  - more useful target date than 2100 for water policies

ACQWA Project objectives

- To assess the potential impacts on:
  - Extreme events
  - Energy
  - Agriculture
  - Tourism
- To identify possible conflicts of interest among economic actors, in the context of a resource that may become rarer in a warmer climate
- To assess how such conflicts could be resolved through improved governance

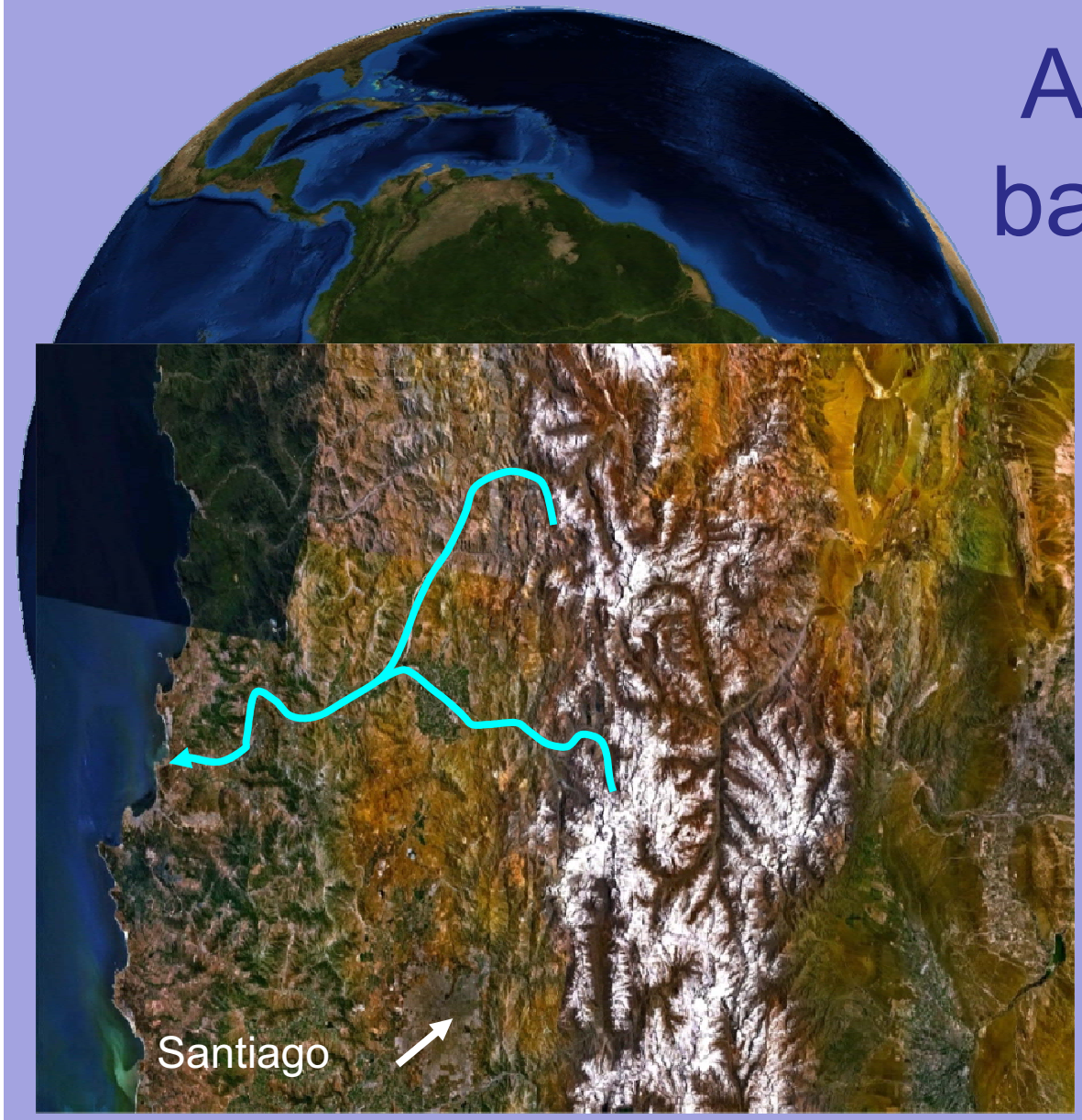
Case-study regions





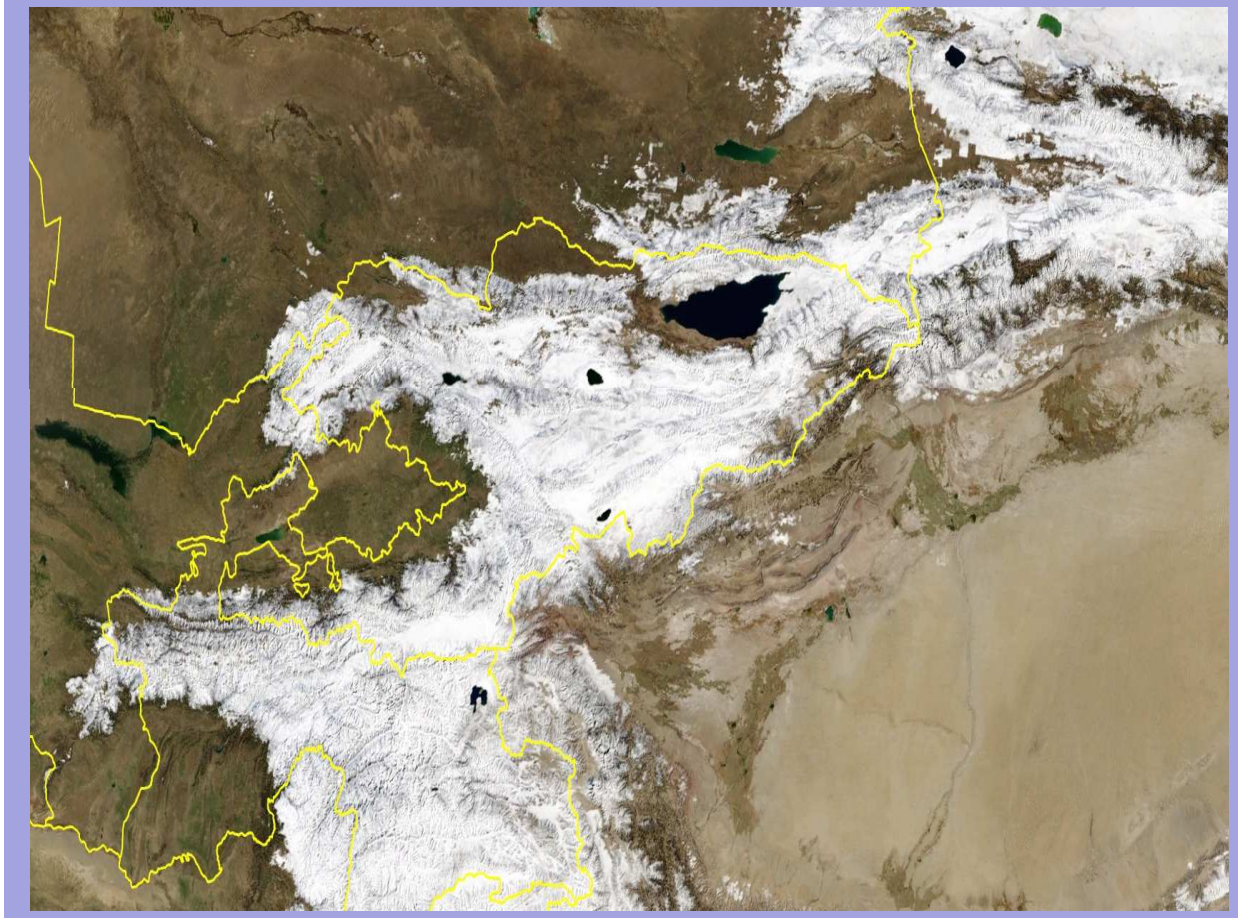
- Data rich regions
- Opportunities to test modeling strategies and integration of results
- Possibilities of investigating socio-economic issues
  - Energy, tourism, agriculture
- Access to information for assessing governance and forward planning

Aconcagua basin (Chile)



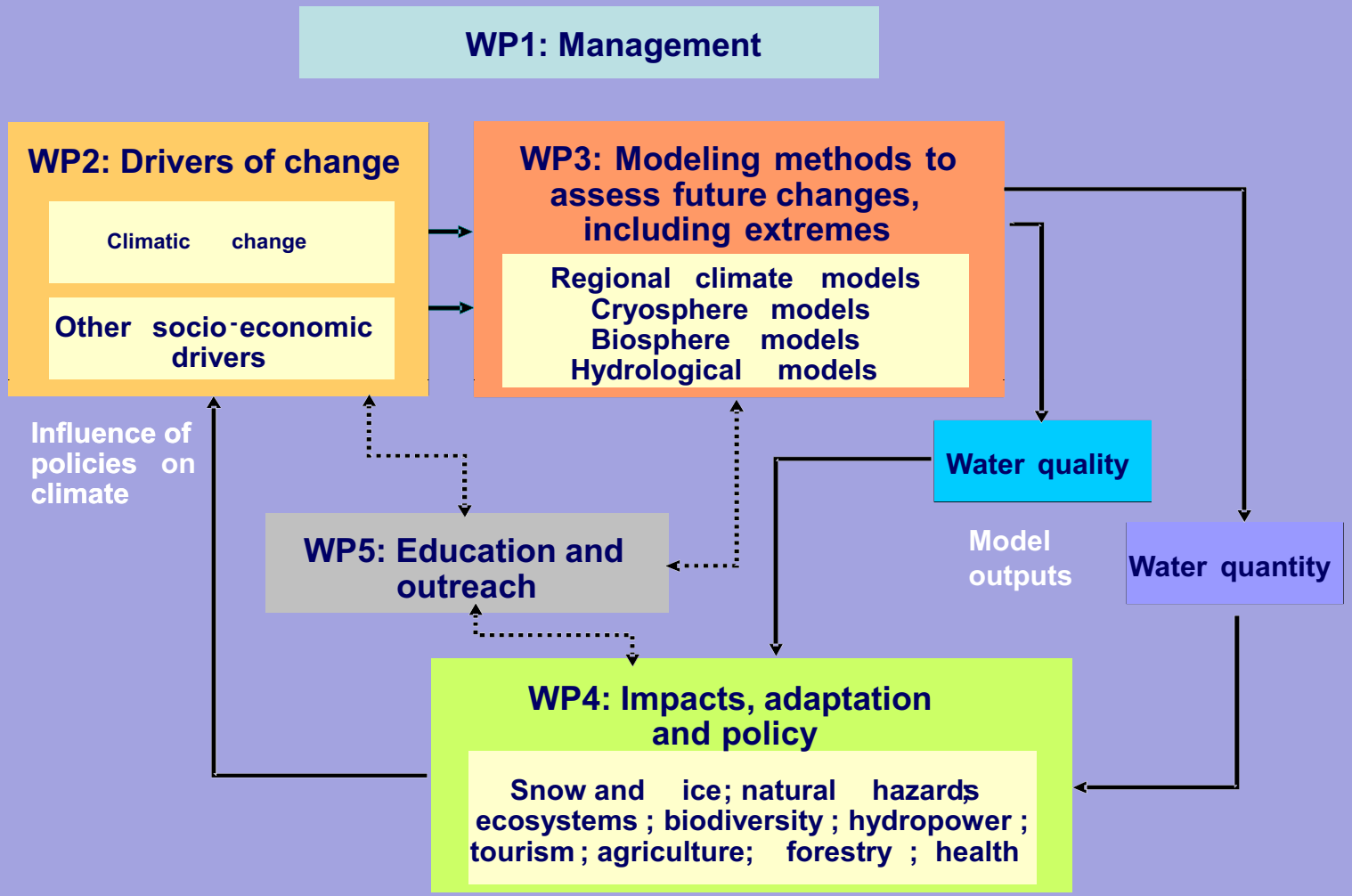
- Major supply problems in a matter of decades:
  - The essential source of water comes from rapidly dwindling ice-caps on the Andes
- Exacerbation of an already competitive situation for water between sectors:
  - Agriculture
  - Energy
  - Mining

Kyrgyzstan



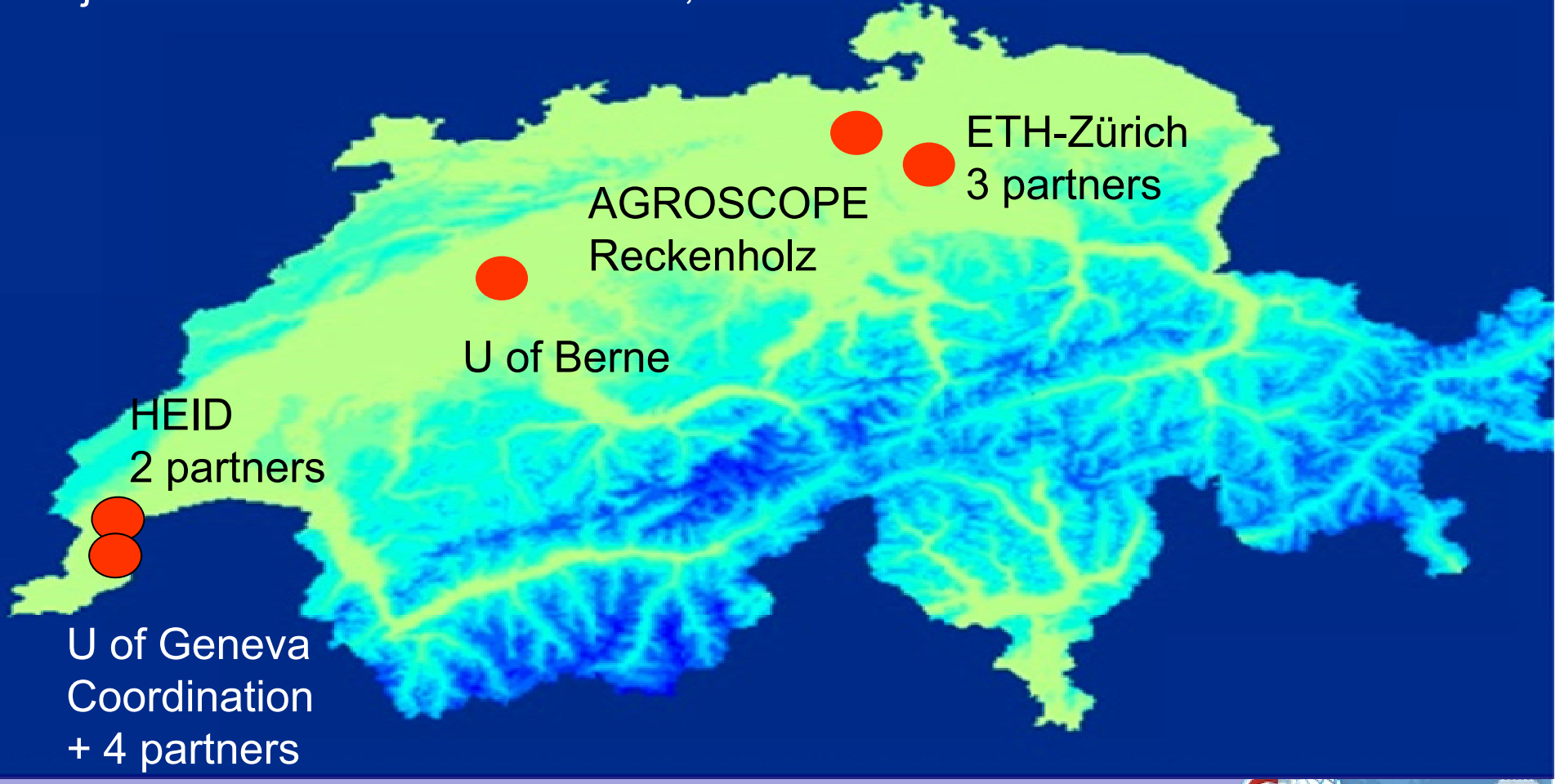
- New opportunities over the next century and beyond because of the large volume of ice remaining
  - Development of hydro-power
  - Foreign income from sales of energy to neighbors (e.g., to Russia)
  - Possible development of agriculture for export

ACQWA Project Flowchart



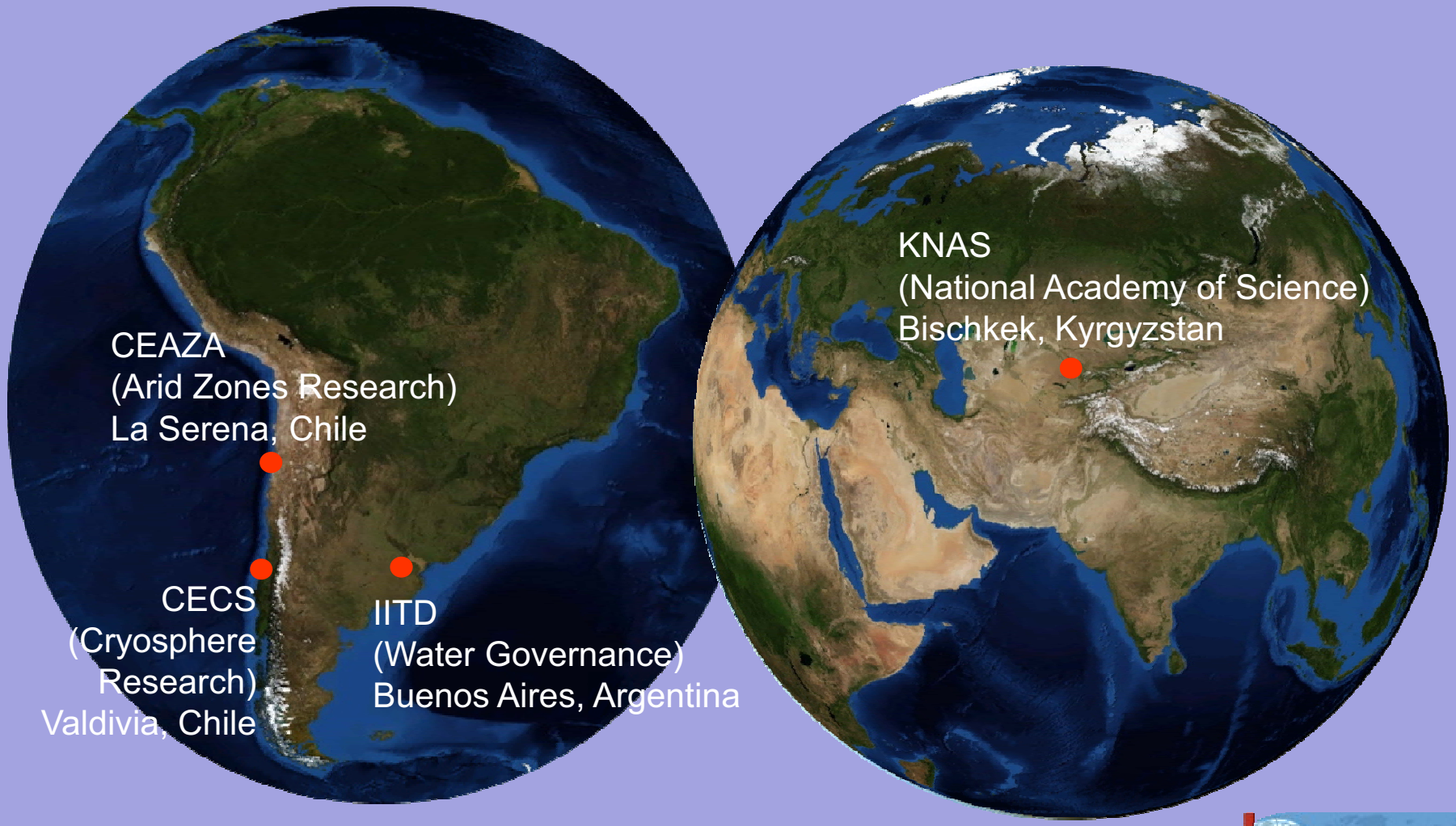
Swiss partners
11 groups, 5 institutions

Coordinator: Prof. Martin Beniston, U of Geneva
Project Director: Dr. Markus Stoffel, U of Geneva



European partners
22 institutions, 6 countries

Partners outside of Europe
Chile-2, Argentina-1, Central Asia-1



- Mountains and water
- Current and future climate (Alps)
- Potential impacts
- The EU « ACQWA » project
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Snow and ice in mountains:

expect major hydrology impacts in a warmer climate!

- Snow and ice in many mountain regions are dominant factors that control runoff characteristics for numerous river catchments
- Shifts in temperature and precipitation regimes could significantly modify the behavior of the mountain snow pack, thus changing:
  - the seasonal character of runoff
  - the timing of the peak flow
- Changing water amount will have numerous impacts:
  - Tourism
  - Energy (hydropower)
  - Agriculture
  - Mining
  - Natural hazards
    - Insurance sector

Originalities of the ACQWA Project

- Water as a measure of vulnerability of regions to climatic change
- Truly integrated model simulations rather than a juxtaposition of sector-by-sector simulations
  - Building better bridges across the disciplines
- Enhanced knowledge on extreme events
- Understanding the mechanisms underlying conflicting uses of water
- How to improve policy approaches through more efficient governance

Exploring threats to water in mountain regions with the European «ACQWA» project

http://www.euronews.net/2010/03/11/mapping-out-the-future-of-alpine-glaciers/

www.acqwa.ch

coppolae@ictp.it