Mountain Ecosystem Goods and Services

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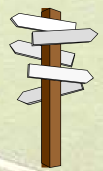
Overview

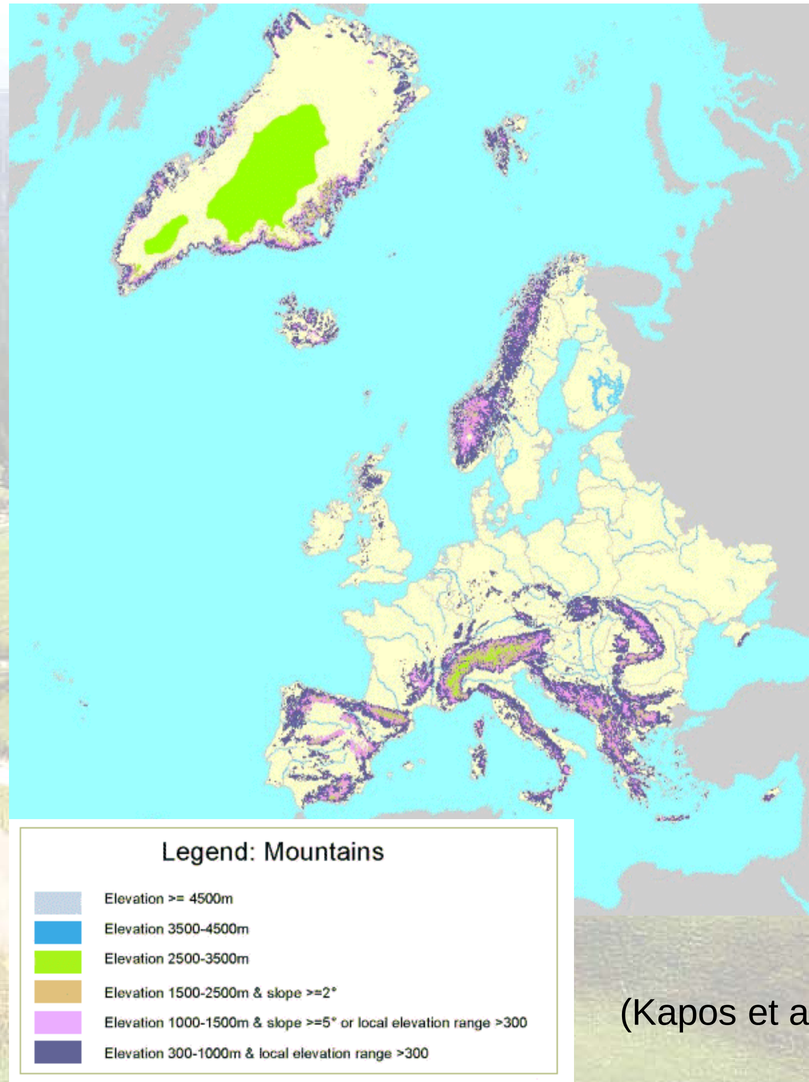
- Why the focus on mountains?
  - Significance of mountains and their goods and services
  - Peculiarities of mountain systems
- A brief review of an earlier case study
- The ATEAM mountain project:
  - Approach
  - Stakeholder dialogue
  - Modeling and simulation studies and stakeholder responses
- Conclusions




Why the focus on mountains?
Significance and peculiarities

Global significance of mountains

- **24.3% of the terrestrial land surface is mountainous**
- **28% of the global forest area is in mountains**
- **>10% of human population live in mountains**

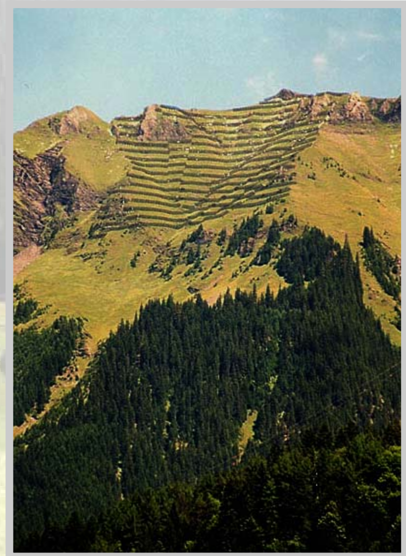


(Kapos et al. 2000)

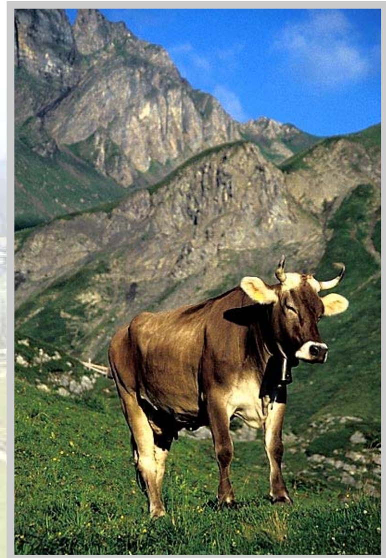
Mountain ecosystem goods & services

Freshwater

Protection



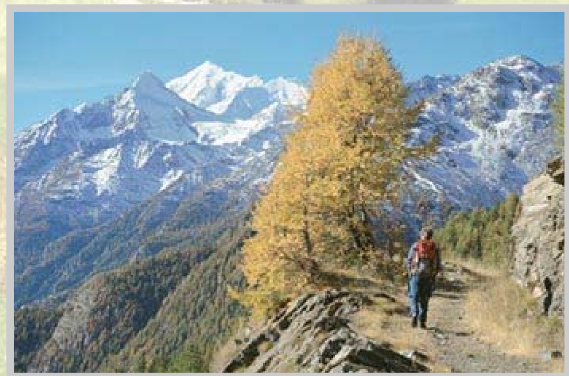
Resource extraction



Mountain ecosystem goods & services

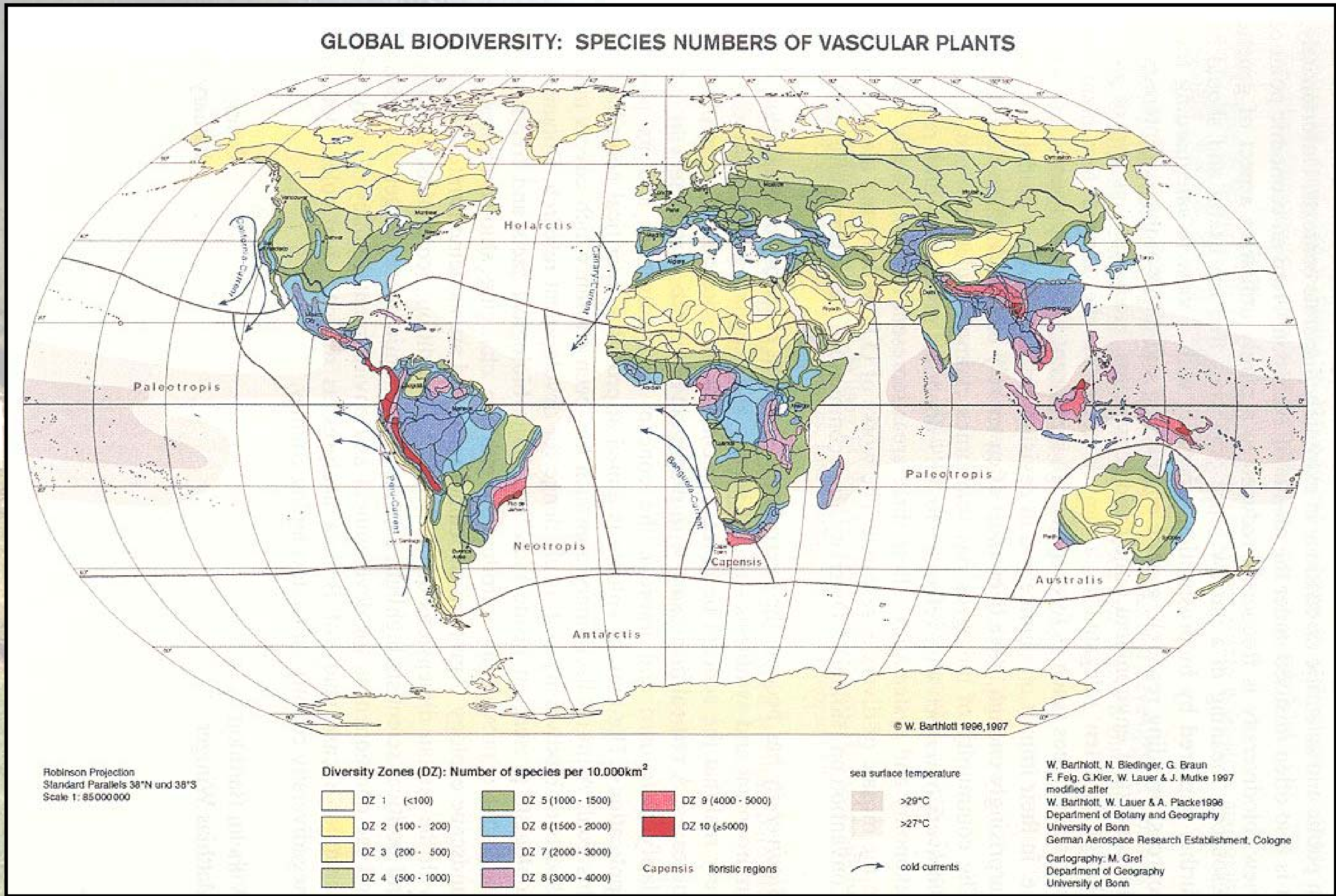
Carbon storage

Tourism



Biodiversity

Global vascular plant diversity



(Barthlott et al. 1997)

The future of mountain regions

socioeconomic environment:

- energy system
- agriculture
- tourism

political environment:

- demand for forest functions (e.g. Kyoto protocol)

chemical environment:

- nitrogen deposition
- CO_2 increase

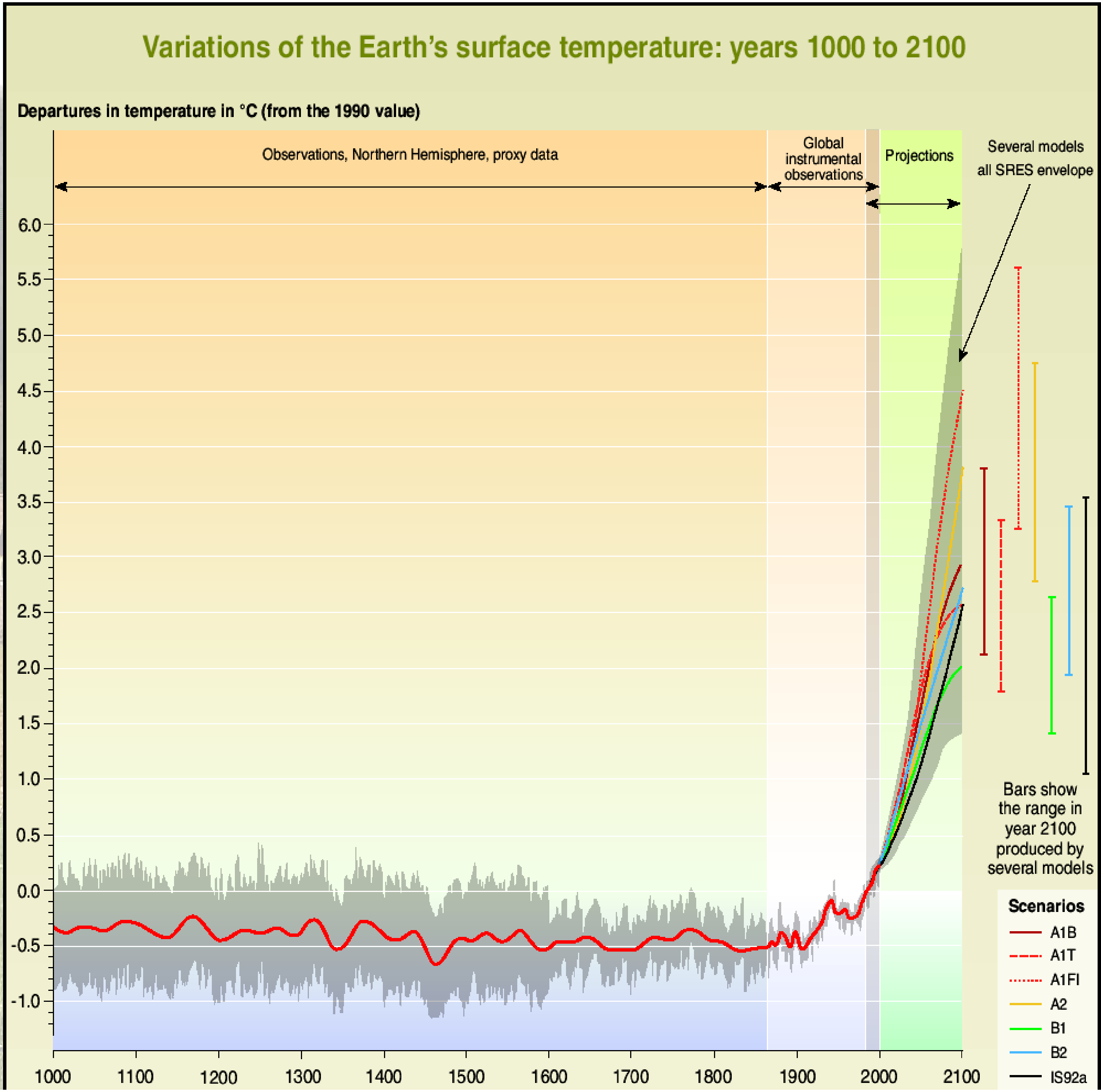
physical environment:

- ‘chronic‘ climate change (averages)
- ‘disturbances’ (extreme events)

(Bugmann 2001)

Land use history and mountain forests

- many mountain ecosystems protect human infrastructure from natural hazards
  - avalanches, rockfall, erosion, flooding, …
- in many developed countries of the temperate zone
  - overexploitation in 19th century
  - today many even-aged, single-species forests
  - problematic for protective function
- extensification of management since 1950s
  - increase of standing volume, dead wood, and forest area
  - increasing importance of natural forest dynamics



Variations of the Earth's surface temperature: years 1000 to 2100
Departures in temperature in °C (from the 1990 value)
Observations, Northern Hemisphere, proxy data
Global instrumental observations
Projections
Several models all SRES envelope
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Bars show the range in year 2100 produced by several models
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a

IPCC (2001)

The complexity of mountain landscapes

- Several factors are crucial in mountains, but are much less important elsewhere, e.g.:
  - slope stabilization by plants (and ice)
  - lateral flows of matter (water, snow, rocks, soil)
  - i.e., dependency on ‘upslope processes’
- **Processes and systems in mountain landscapes are tightly linked**
  ⇒ landscape integrity depends on weakest element!
- □° Projecting the impacts of climate and LU change on mountain ecosystems requires
  - a consideration of a range of ecological and hydrological processes
  - the use of mathematical models to handle this complexity


A brief review of
an earlier case study:
Succession in mountain forests

The model approach

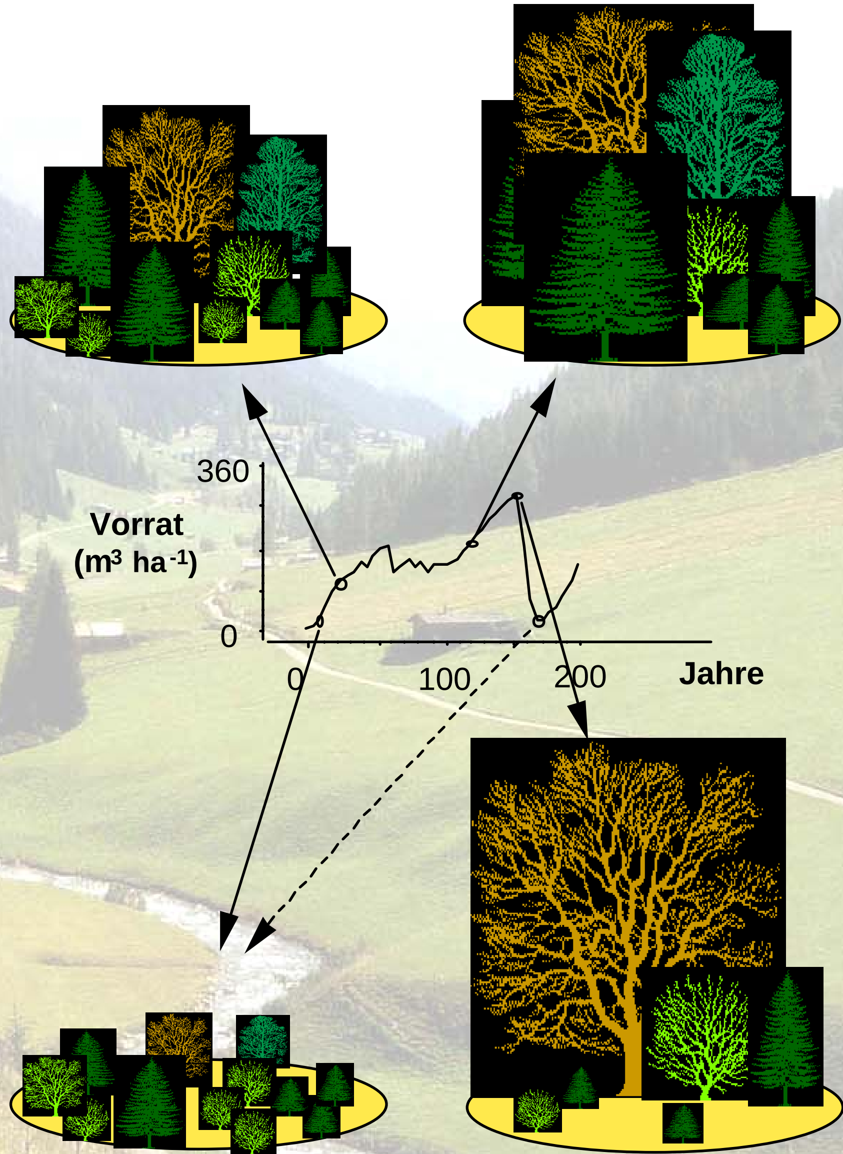
- Concept of individualis-tic, cyclical succession on small patches

  (H. Gleason)

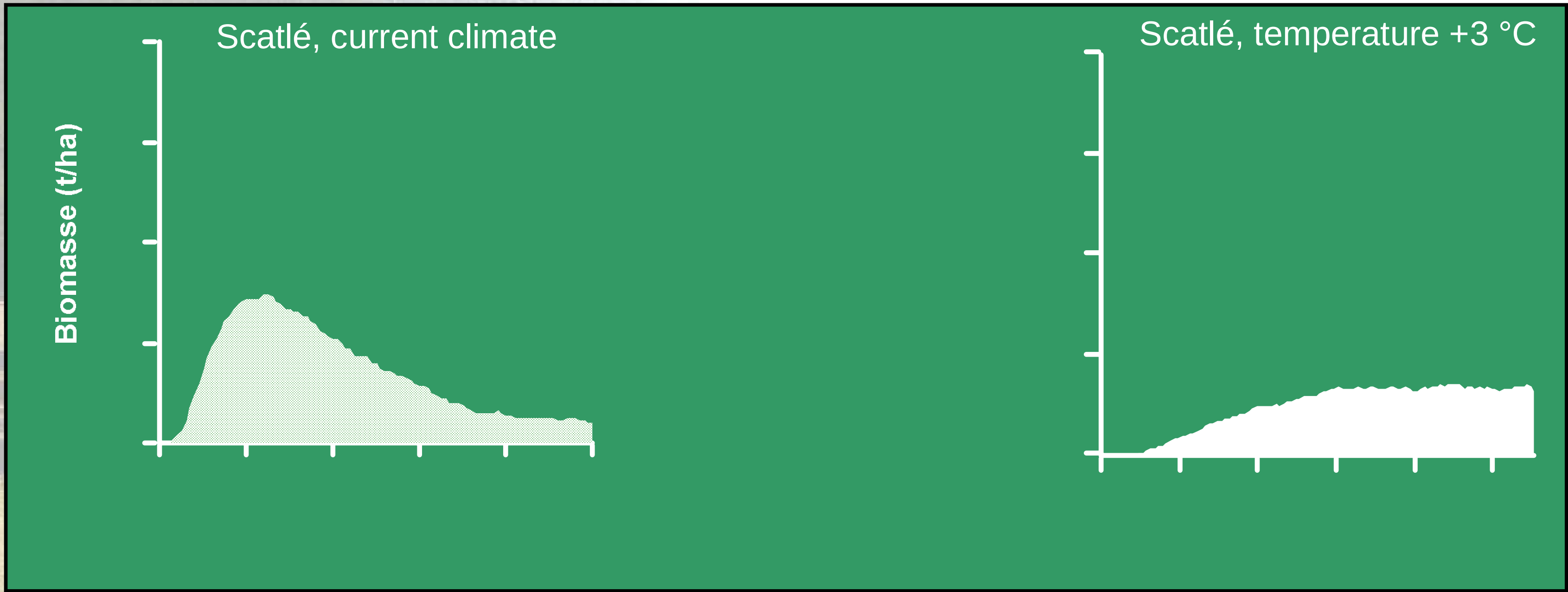
- Quantitative description of tree population dynamics:

  “gap“ models

  (D. Botkin, H. Shugart)



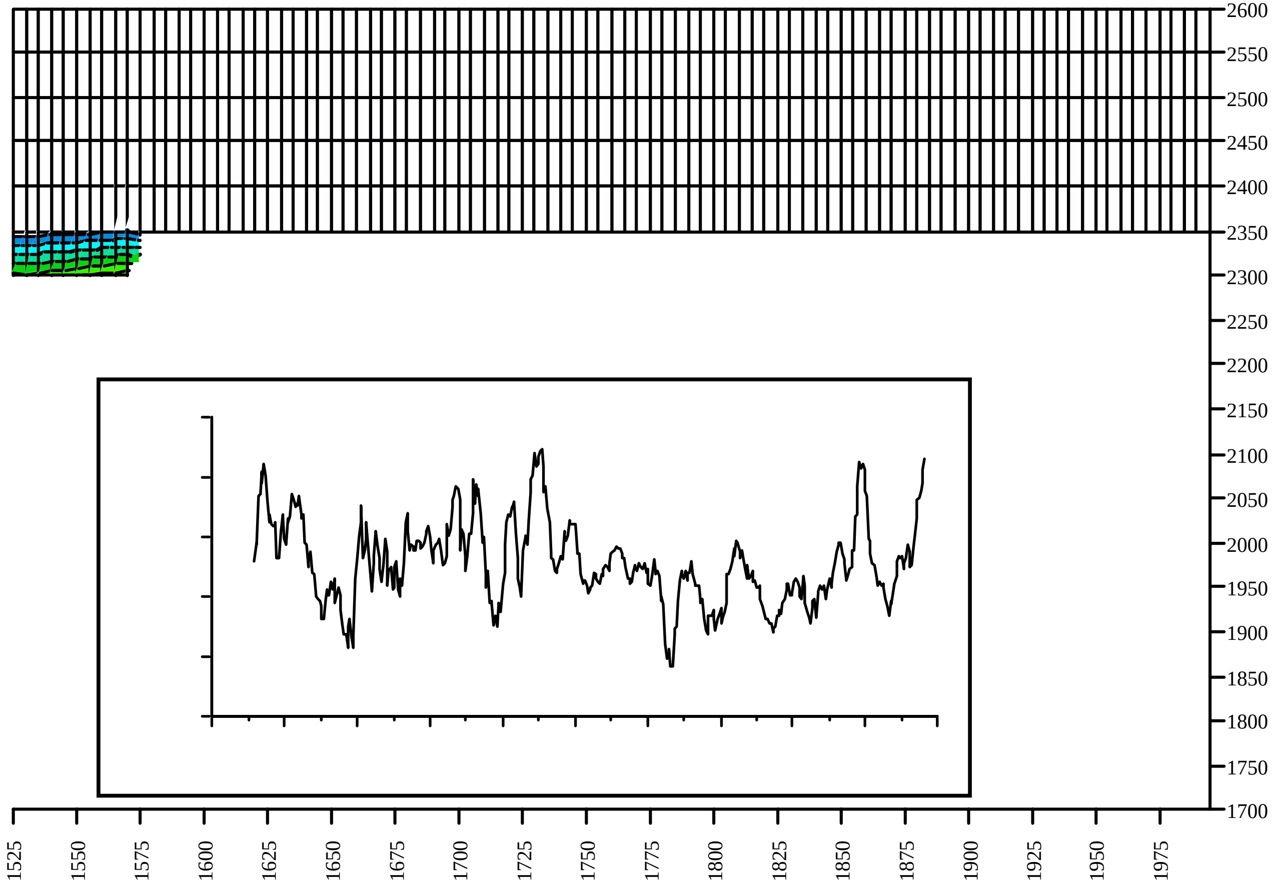
A flavor of the impact studies



(Badeck et al. 2001)

- **strong changes in species composition, 400-500 yrs**
- **rarely: forest dieback as a consequence of clim change**
- **no analyses of structural dynamics yet (protection?)**

The role of 'extreme' events



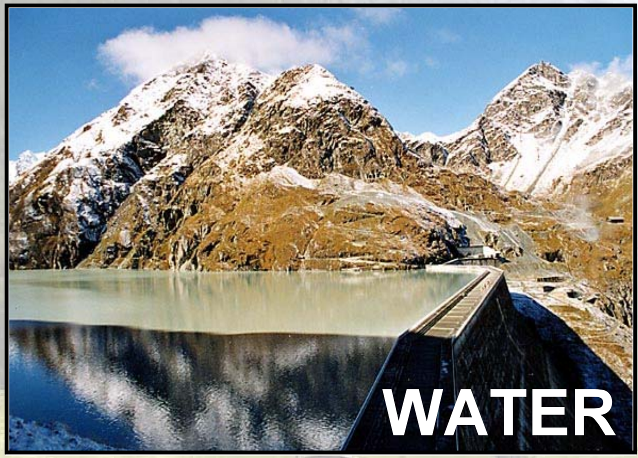
Bugmann & Pfister (2000)

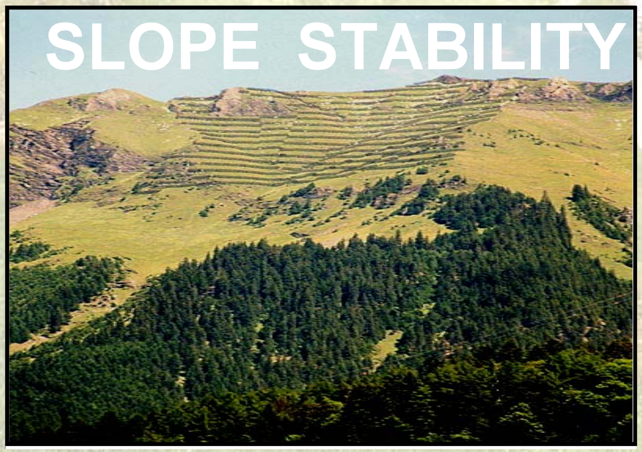

The ATEAM mountain project:
I. Approach

Objectives

- To assess the impacts of climate and LU change on selected mountain ecosystem goods and services:
  - sensitivity of ecosystems
    => use of mathematical models
  - adaptive capacity of human ‘users‘
    => stakeholder dialogue
  - final result: vulnerability assessment
- Purely scientific aim: to evaluate the importance of the coupling between fluxes of
  - carbon (vertical)
  - water (lateral and vertical)

Selected ecosystem services






The ATEAM mountain project:
II. The stakeholder dialogue

How it works (I)

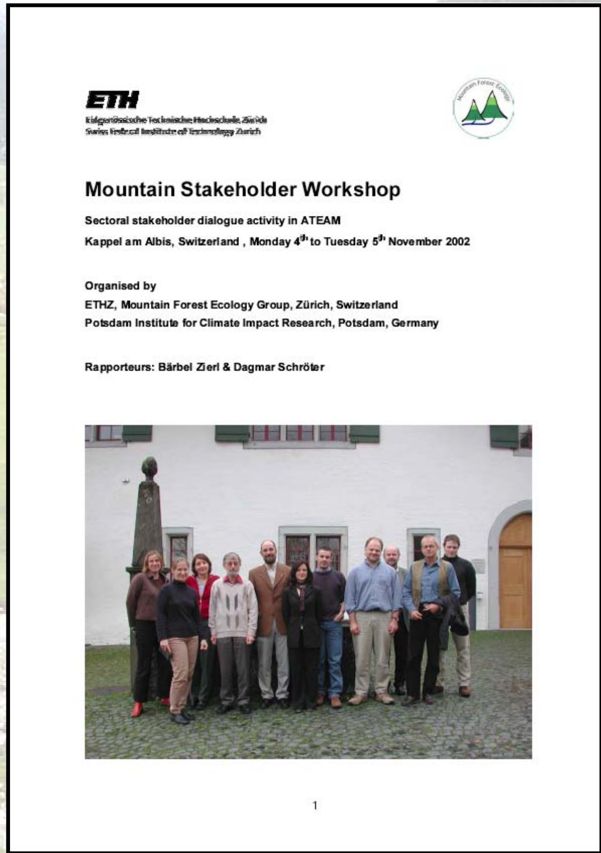
- First round:
  via bilateral discussions in early project phase
  - Aim 1: to learn about the experiences and major concerns of mountain stakeholders
  - Aim 2: to identify the most important mountain ecosystem services and the associated indicator variables ✓

- Second round:
  via dedicated workshop in the middle of the project
  - Aim 1: to critically evaluate first (preliminary) research results
  - Aim 2: to discuss a strategy for vulnerability assessment
  - Aim 3: to obtain guidance from the stakeholders for the research in the second half of the project ✓

How it works (II)

- Final round:
  bilateral discussions & meetings to evaluate project results, to take place in last project year
  - Aim 1: to critically evaluate research results
    - simulations
    - semi-quantitative assessments (e.g., tourism)
  - Aim 2: to provide feedback on
    - adaptive capacity of SHs / sectors
    - sectoral vulnerability

To Do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Mountain Stakeholder Workshop

Sectoral stakeholder dialogue activity in ATEAM

Kappel am Albis, Switzerland , Monday 4th to Tuesday 5th November 2002

Organised by

ETHZ, Mountain Forest Ecology Group, Zürich, Switzerland

Potsdam Institute for Climate Impact Research, Potsdam, Germany

Rapporteurs: Bärbel Zierl & Dagmar Schröter

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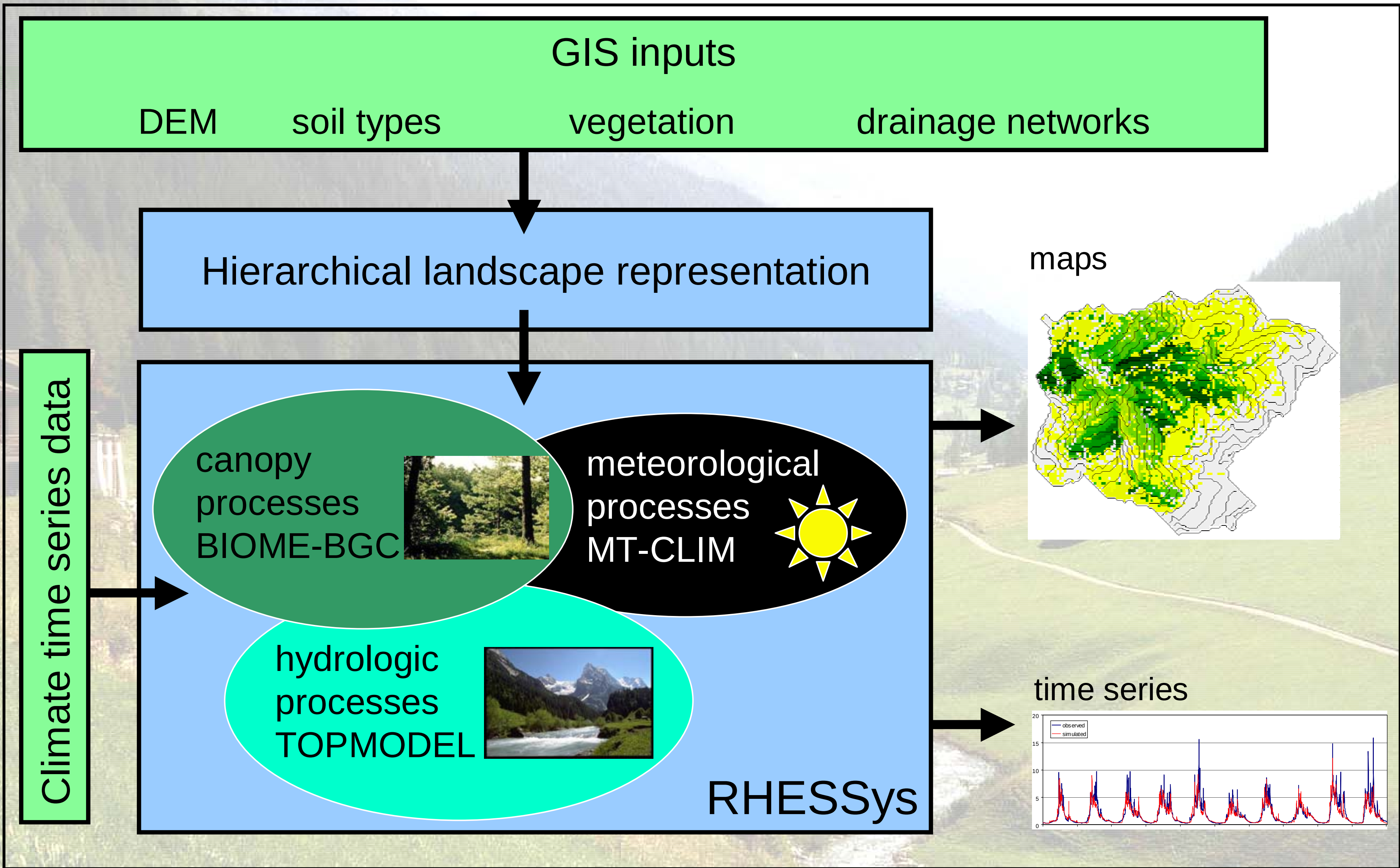
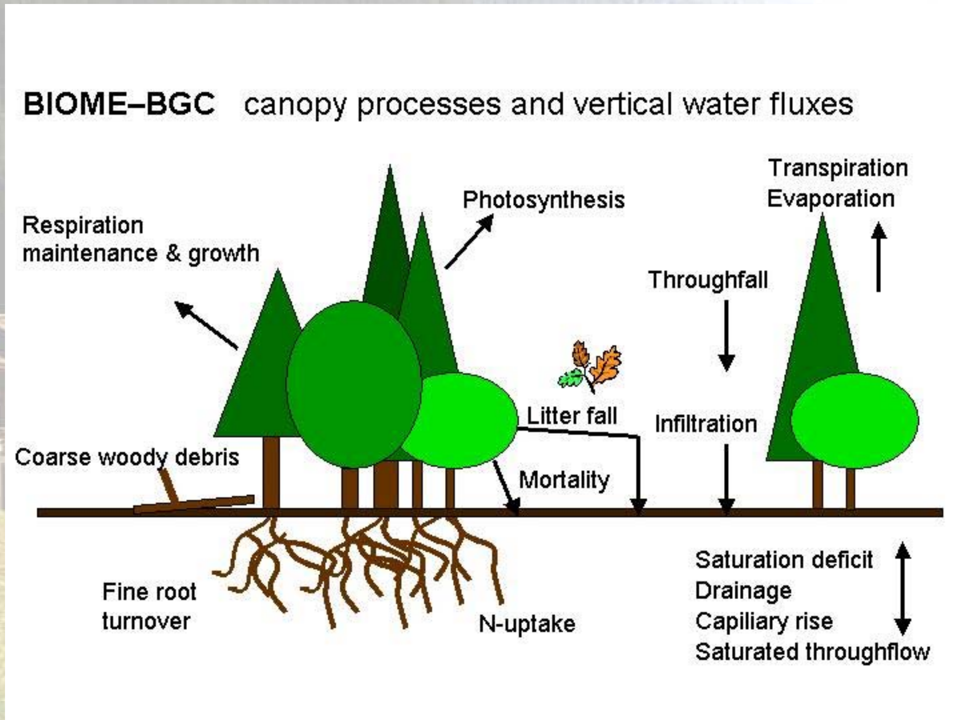
The ATEAM mountain project:
III. Quantitative analyses

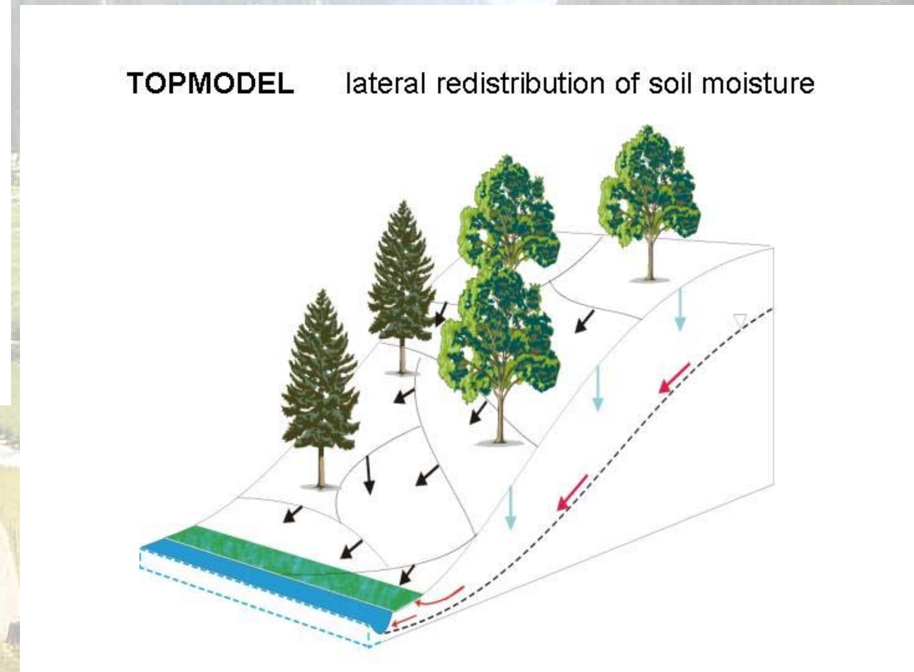
RHESSys: Regional Hydro-Ecological Simulation System



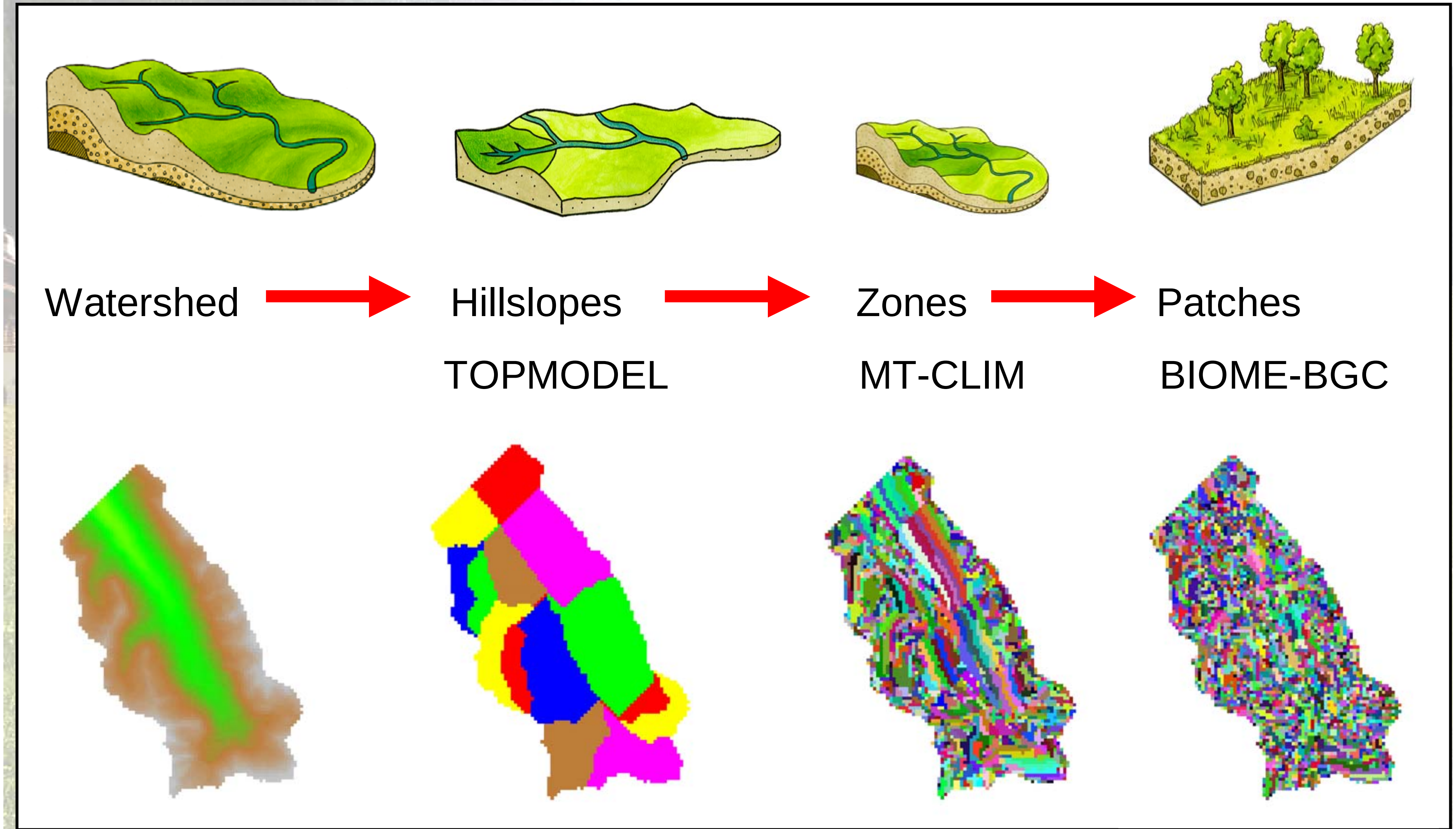
developed by Band, Running, Thornton, Tague et al.

Model approach (II)

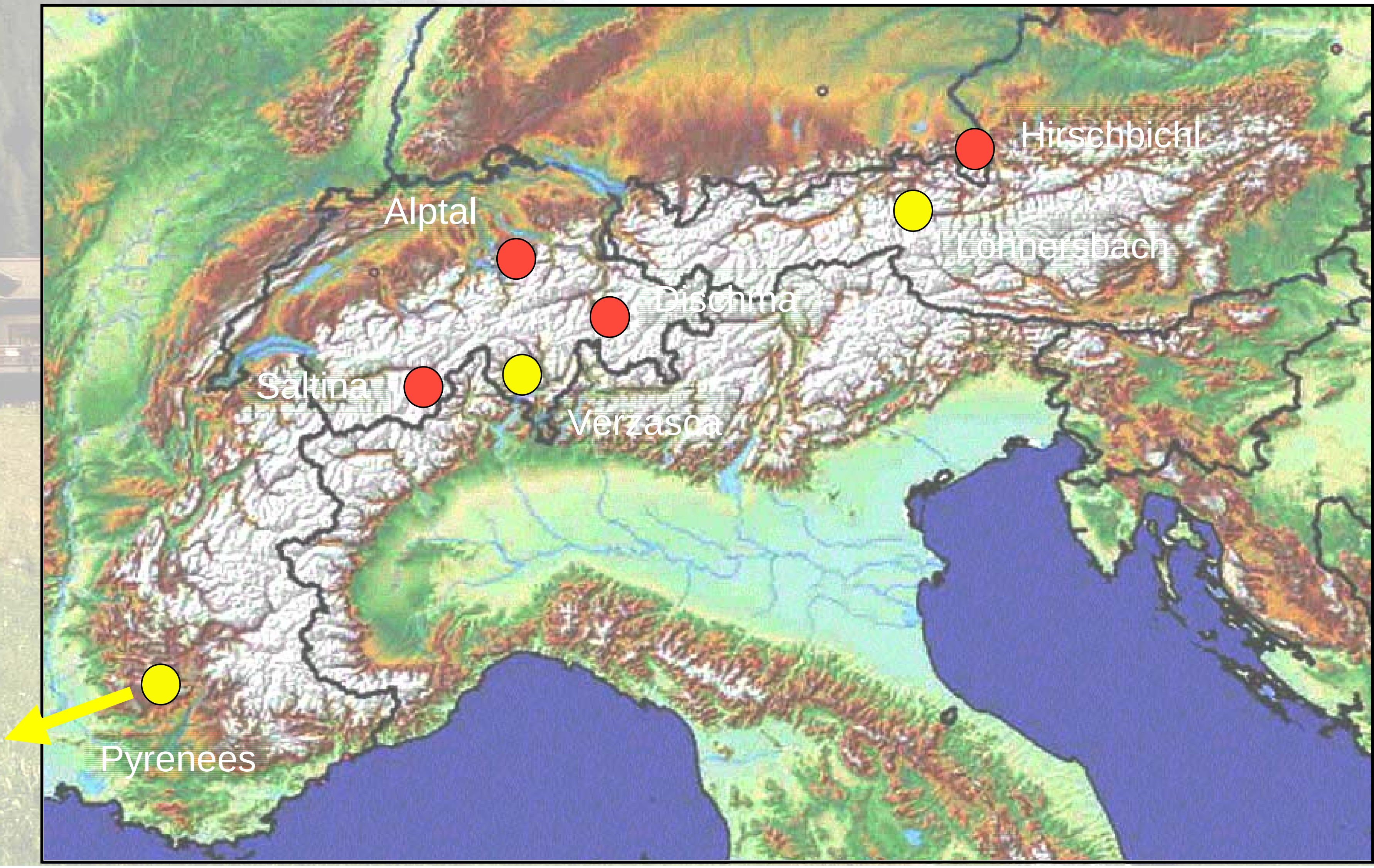




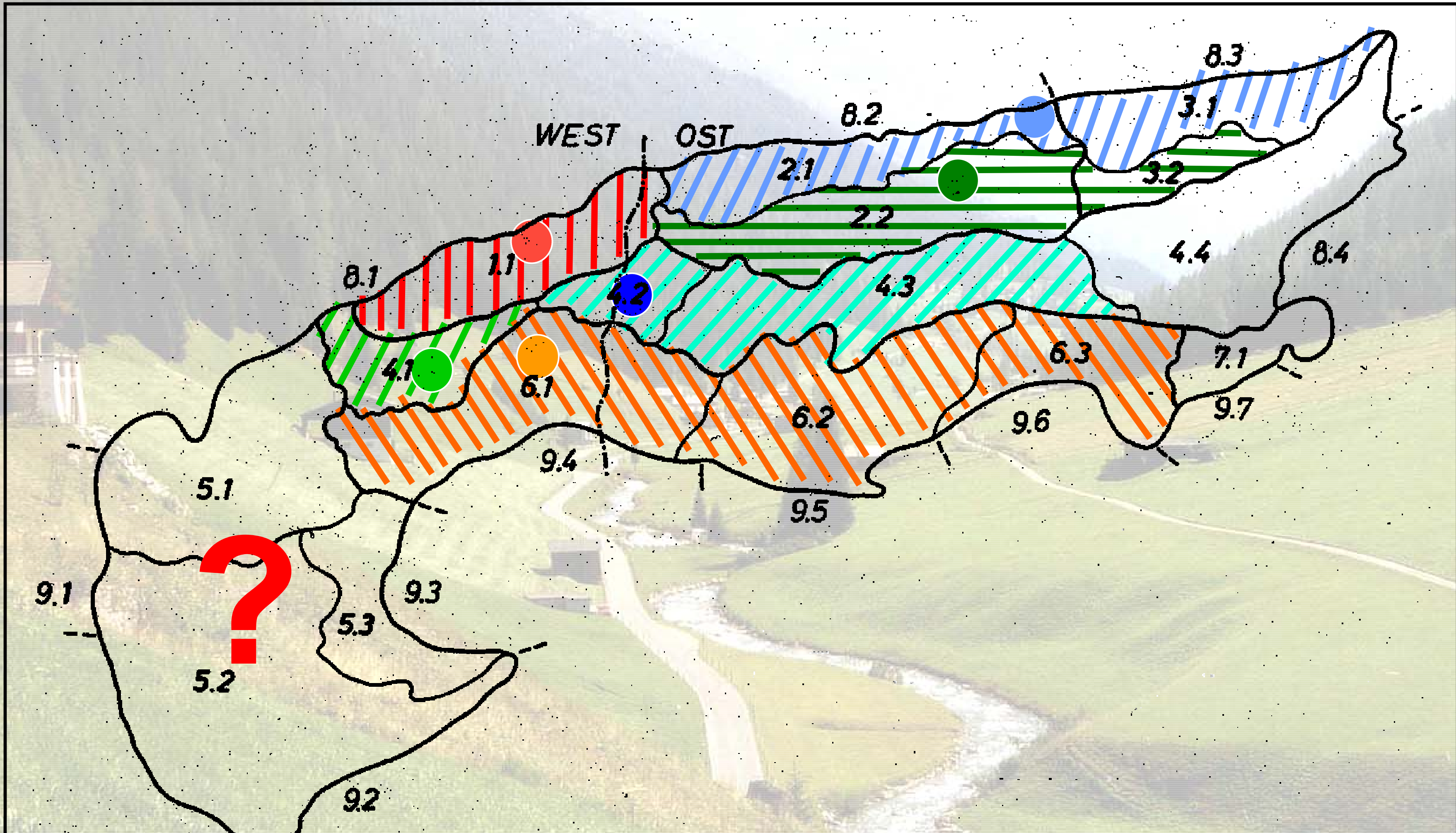
Model approach (III)



Case studies: Location



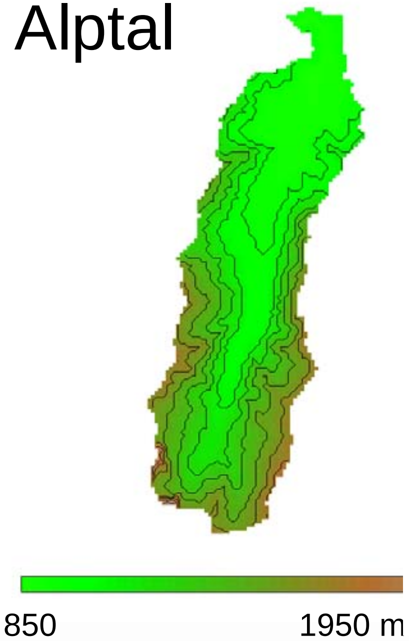
Case studies: Representativeness

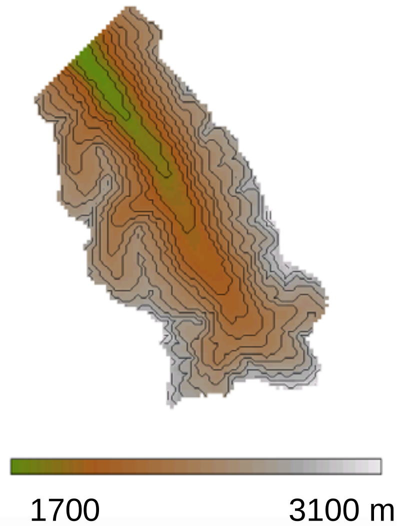


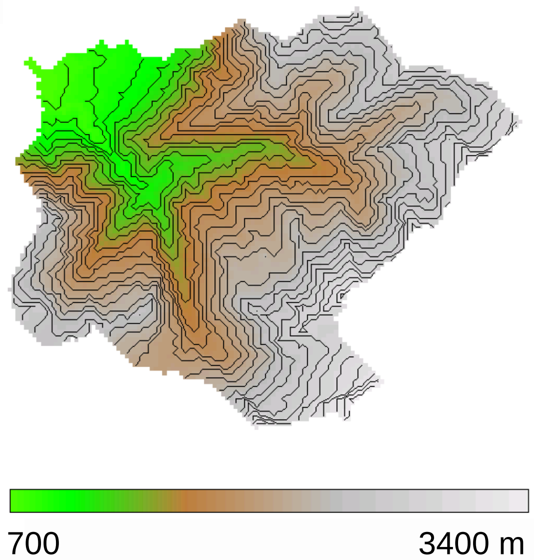
Climate zones after Baumgartner et al. (1983)

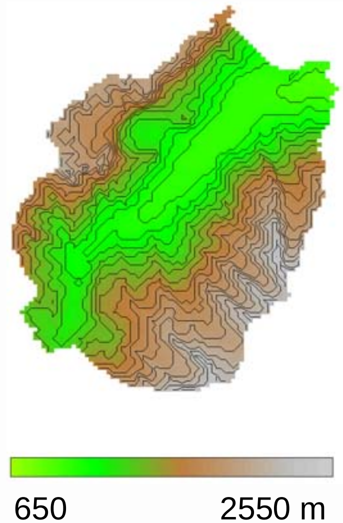
Case studies: Characteristics

	Alptal	Dischma	Saltina	Hirschbichl





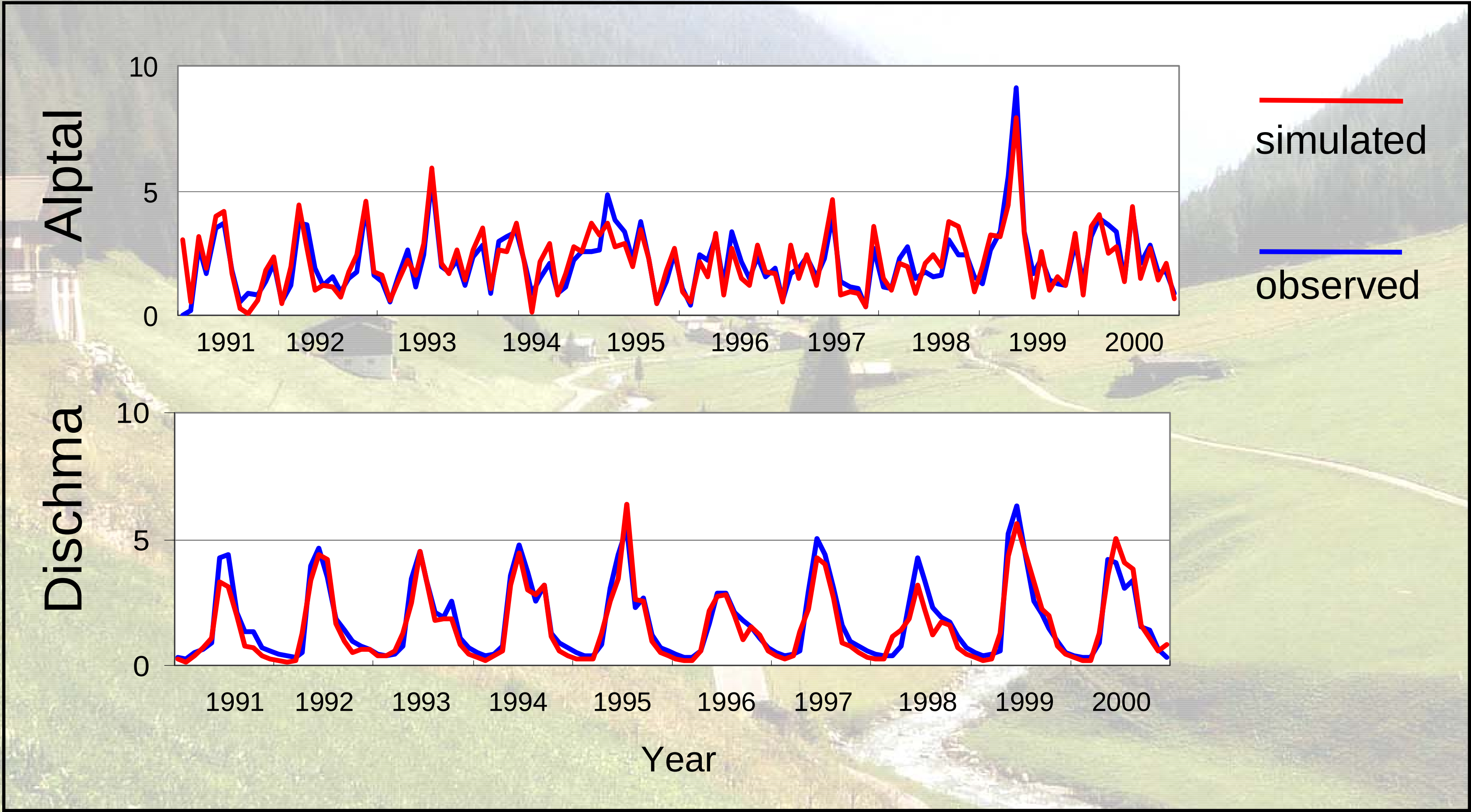




	prealpine west	**high alpine**	**inner alpine**	**prealpine east**
area	46.8 km^2	43.3 km^2	77.0 km^2	44.6 km^2
forest	52%	10%	35%	42%
grass	42%	38%	34%	30 %
other	6%	52%	31%	28%

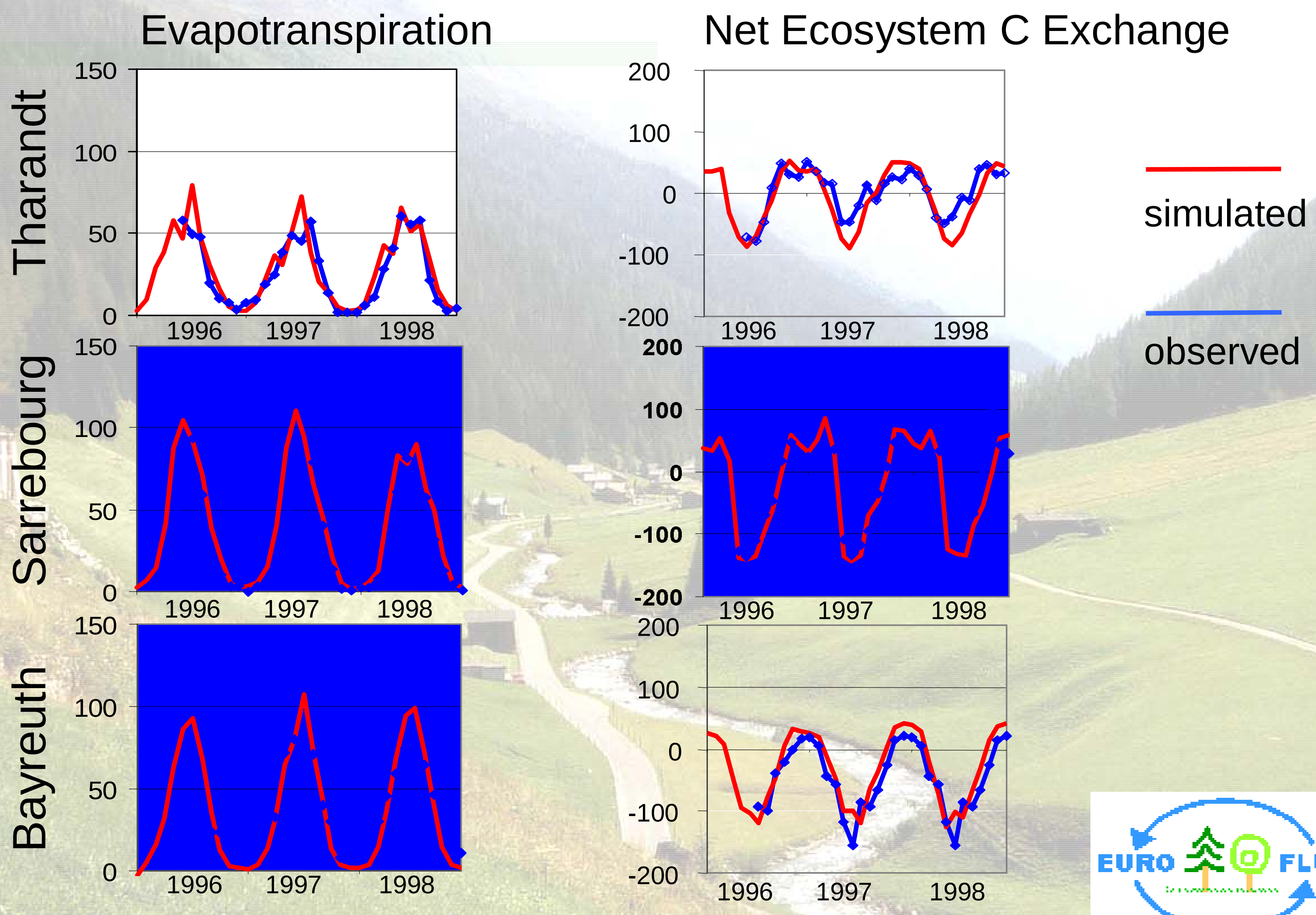
Model evaluation (I)

Monthly runoff [m³/s] in two catchments

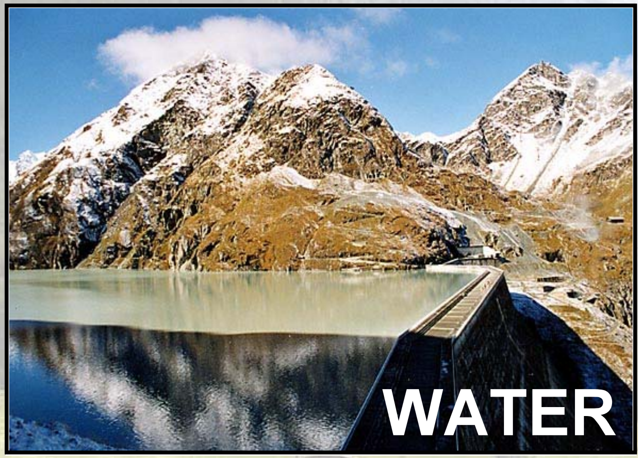


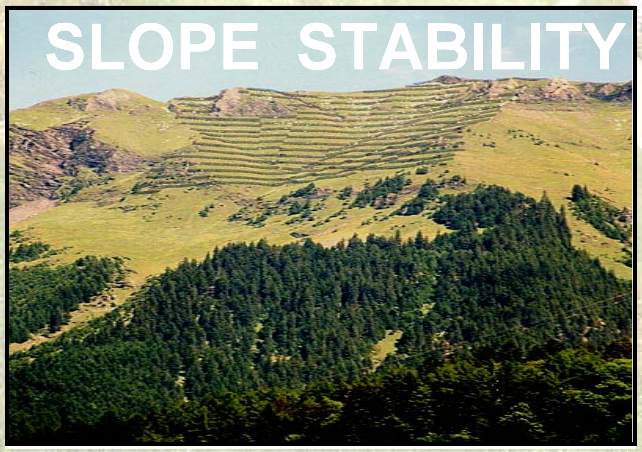
Model evaluation (II)

AET in [mm $month^{-1}$]; NEE in [g m^{-2} $month^{-1}$]

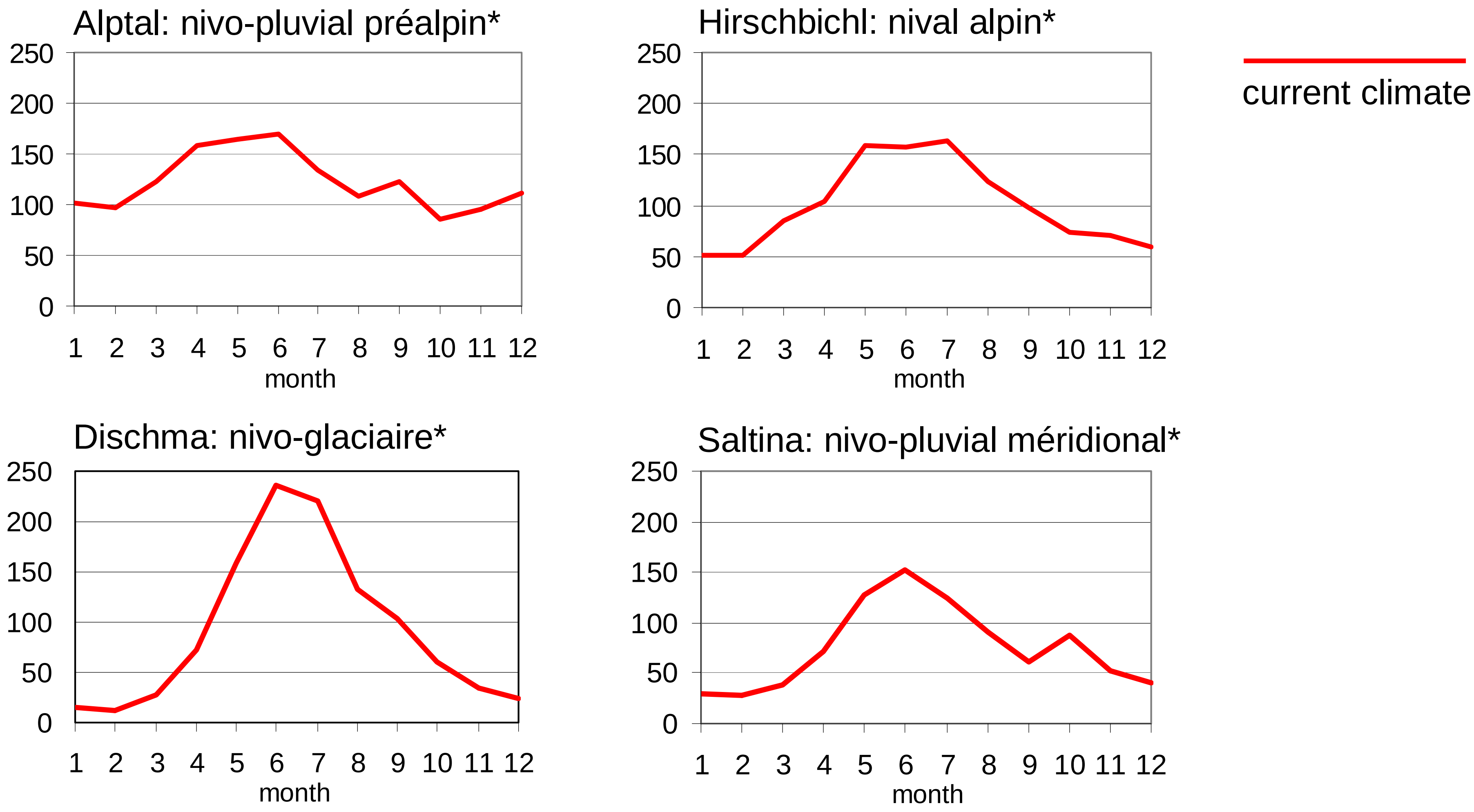


Sensitivity of ecosystem services





Impact of temperature change on runoff regime [mm/month]



* Definition of regions after Weingartner & Aschwanden (1992)

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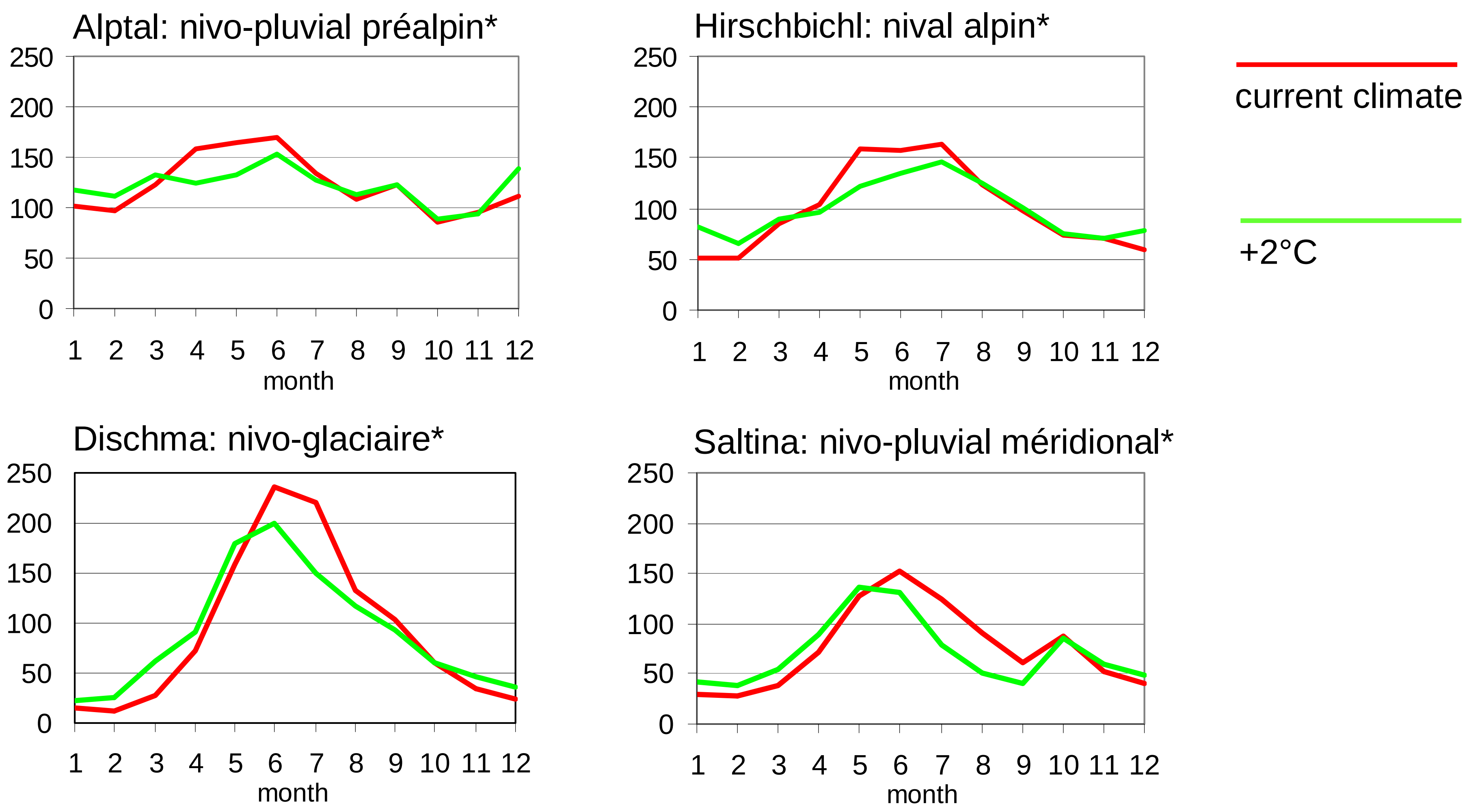

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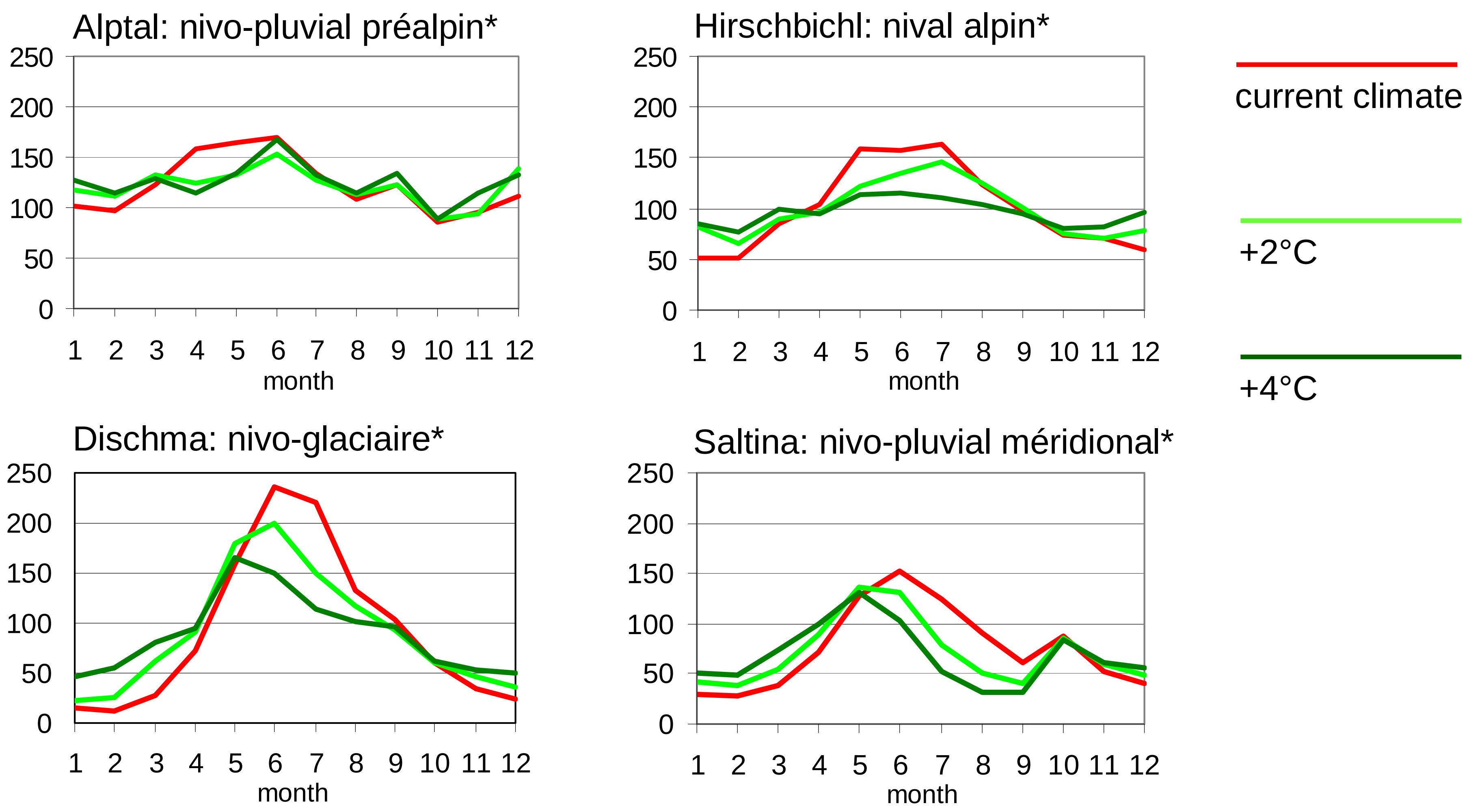

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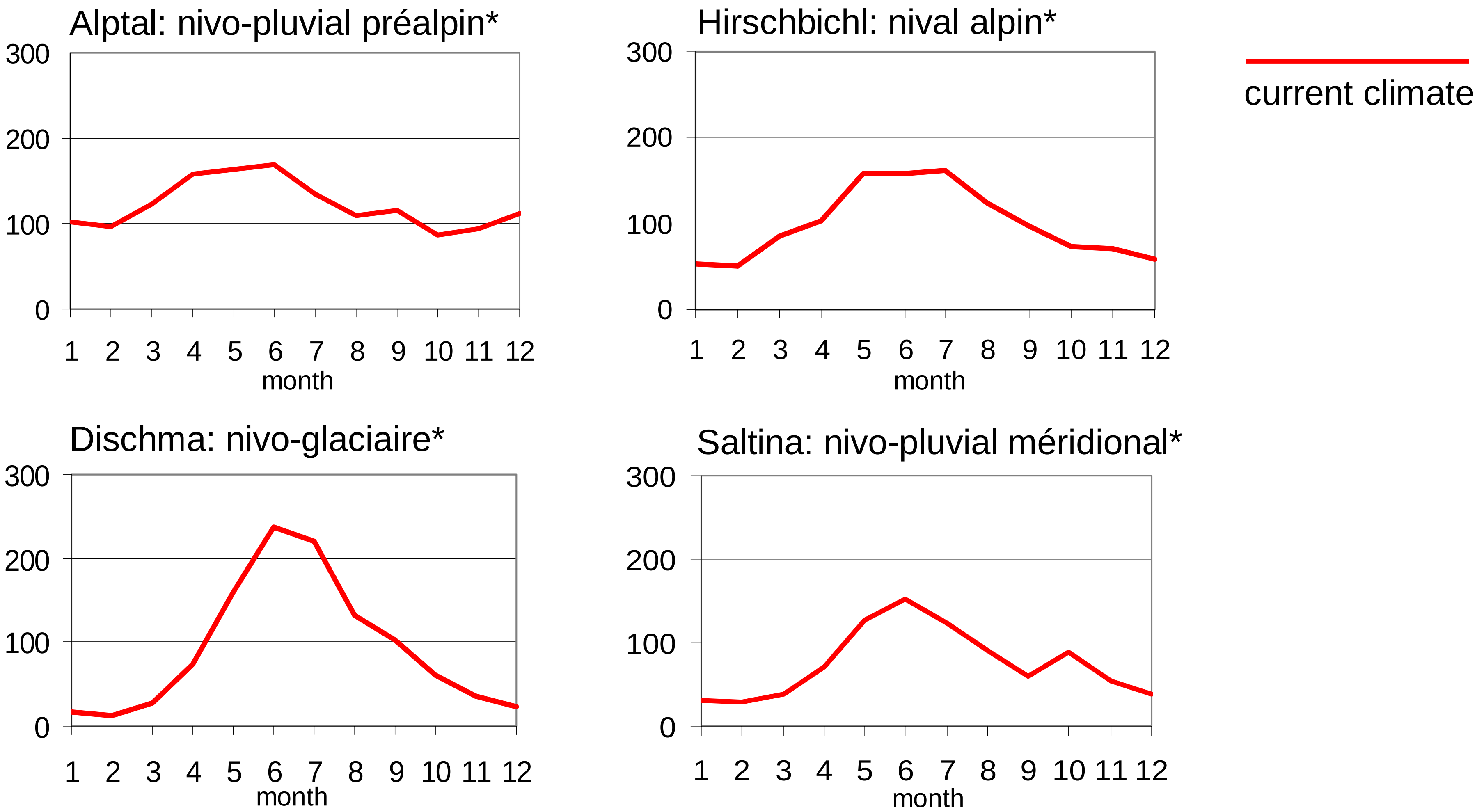
Impact of precipitation change on runoff regime [mm/month]



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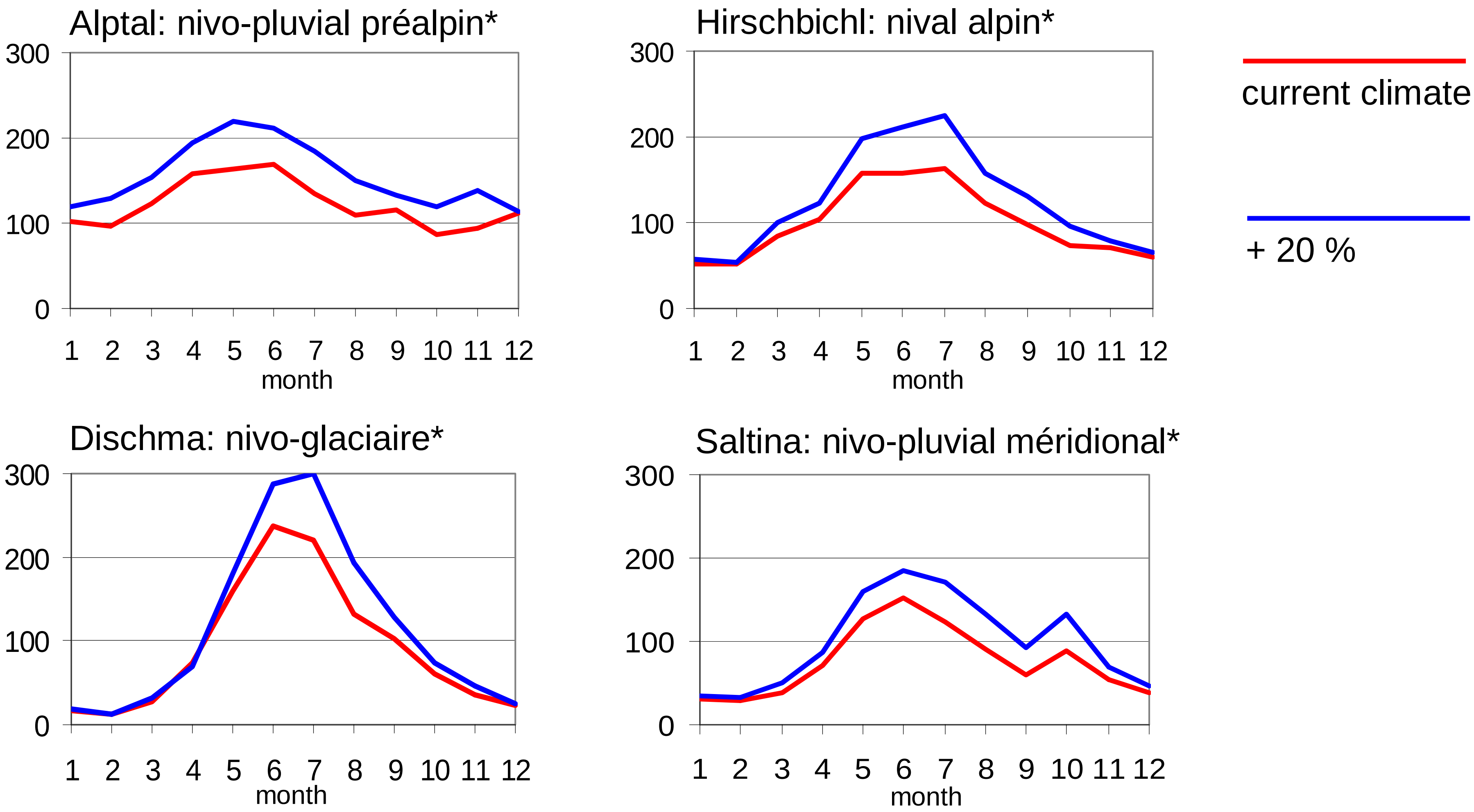
Impact of precipitation change on runoff regime [mm/month]



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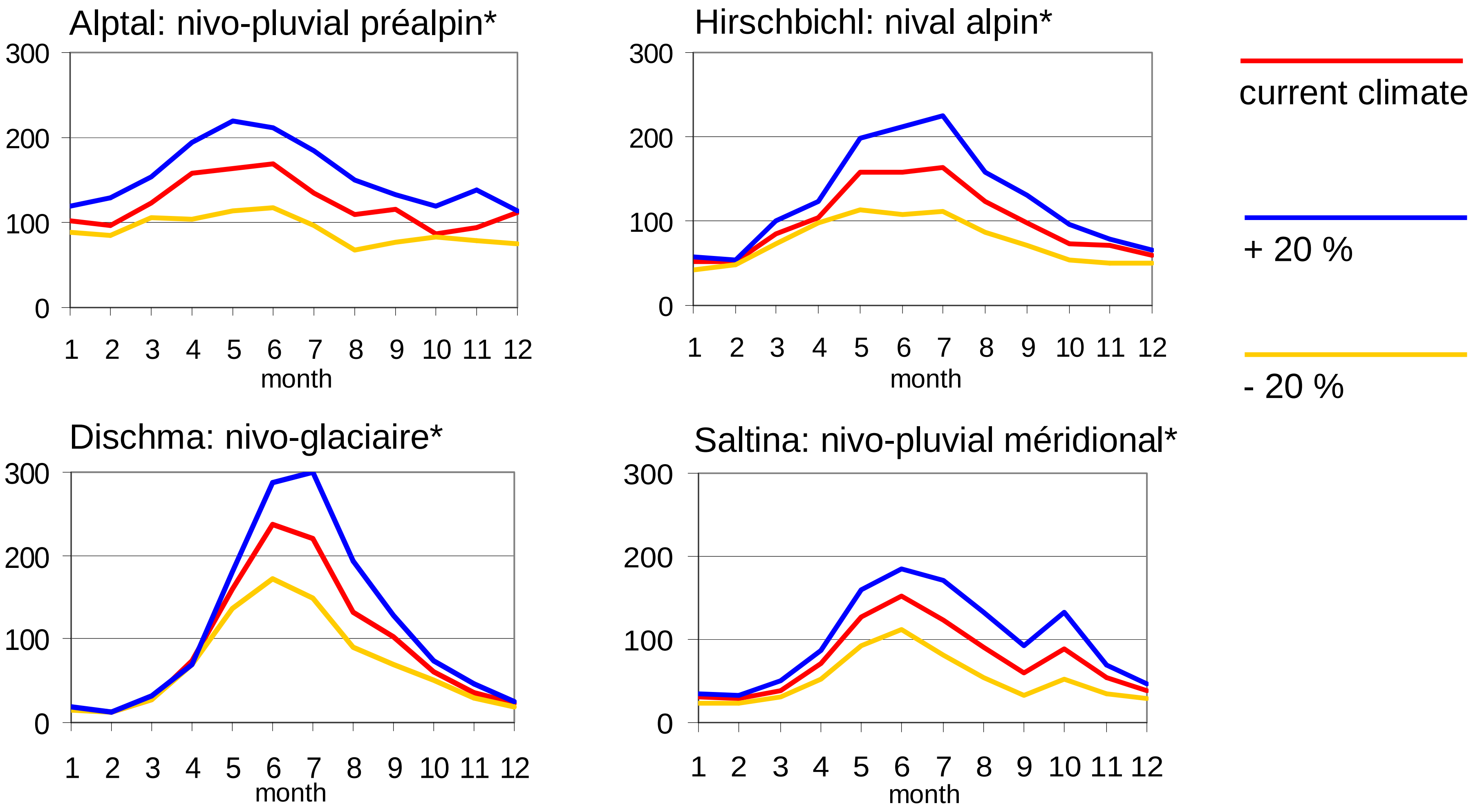
Impact of precipitation change on runoff regime [mm/month]



* Definition of regions after Weingartner & Aschwanden (1992)

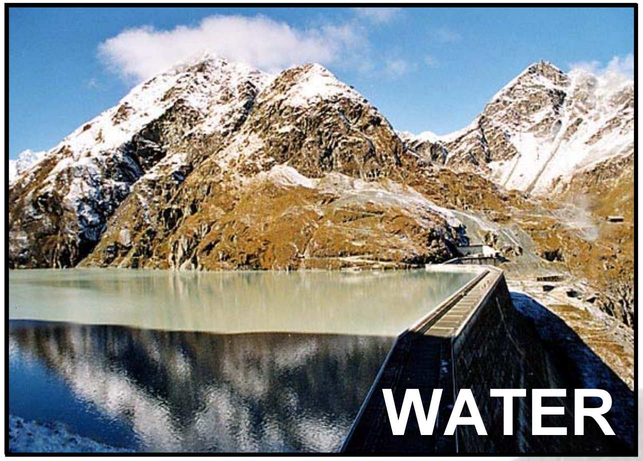
Results: Water (II)

Climate sensitivity of runoff regime:
Dischma valley, absolute values [$m^3\ sec^{-1}$]

Scenario	Year	Apr - Jun	Jul - Sep	Oct - Dec	Jan - Mar
current climate	1.77	2.70	3.25	0.88	0.38
+ 2°C	1.72	1.62	2.23	1.44	1.70
- 10% precip	1.57	2.44	2.75	0.82	0.37

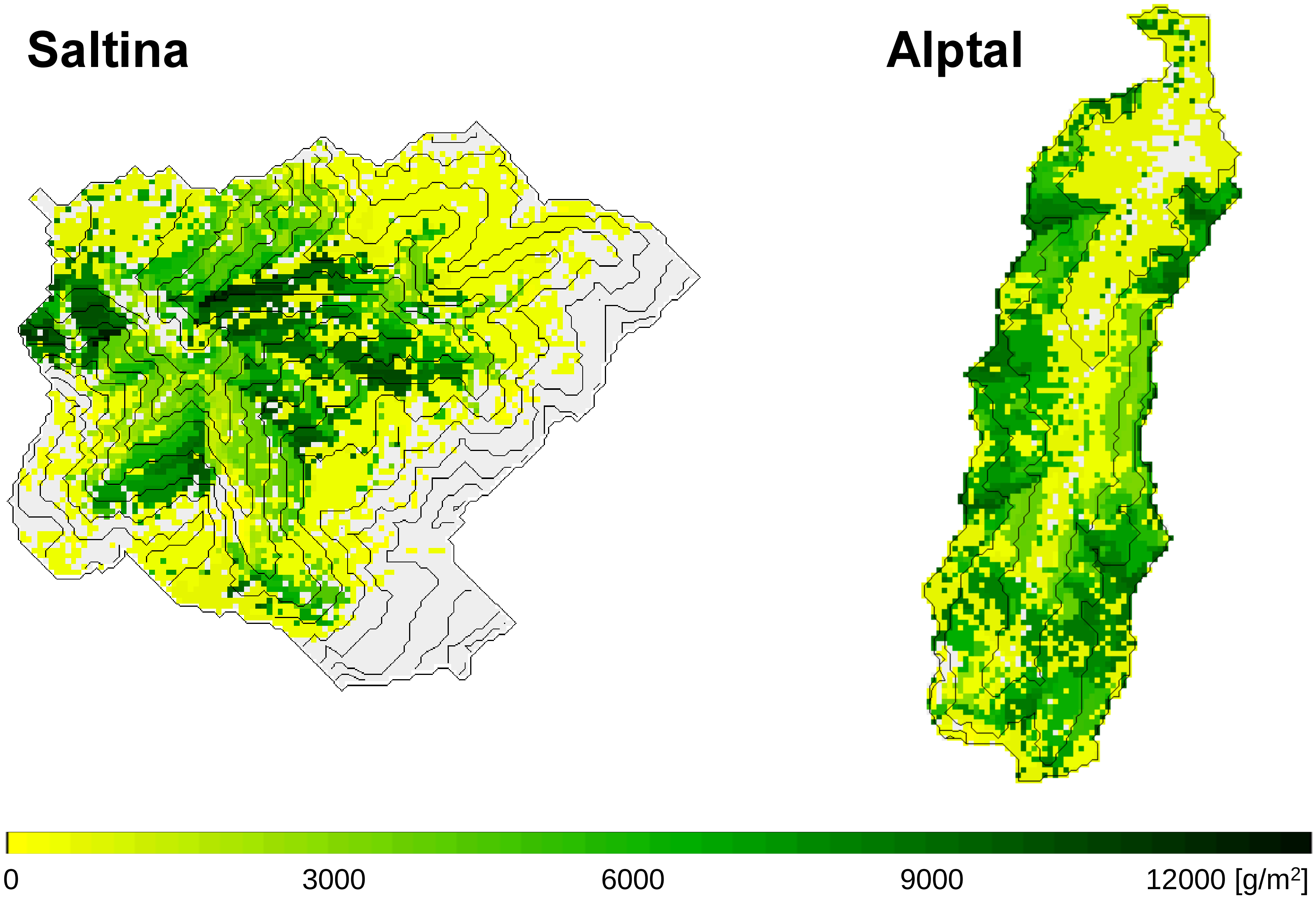
Zierl (in prep.)

Stakeholder responses

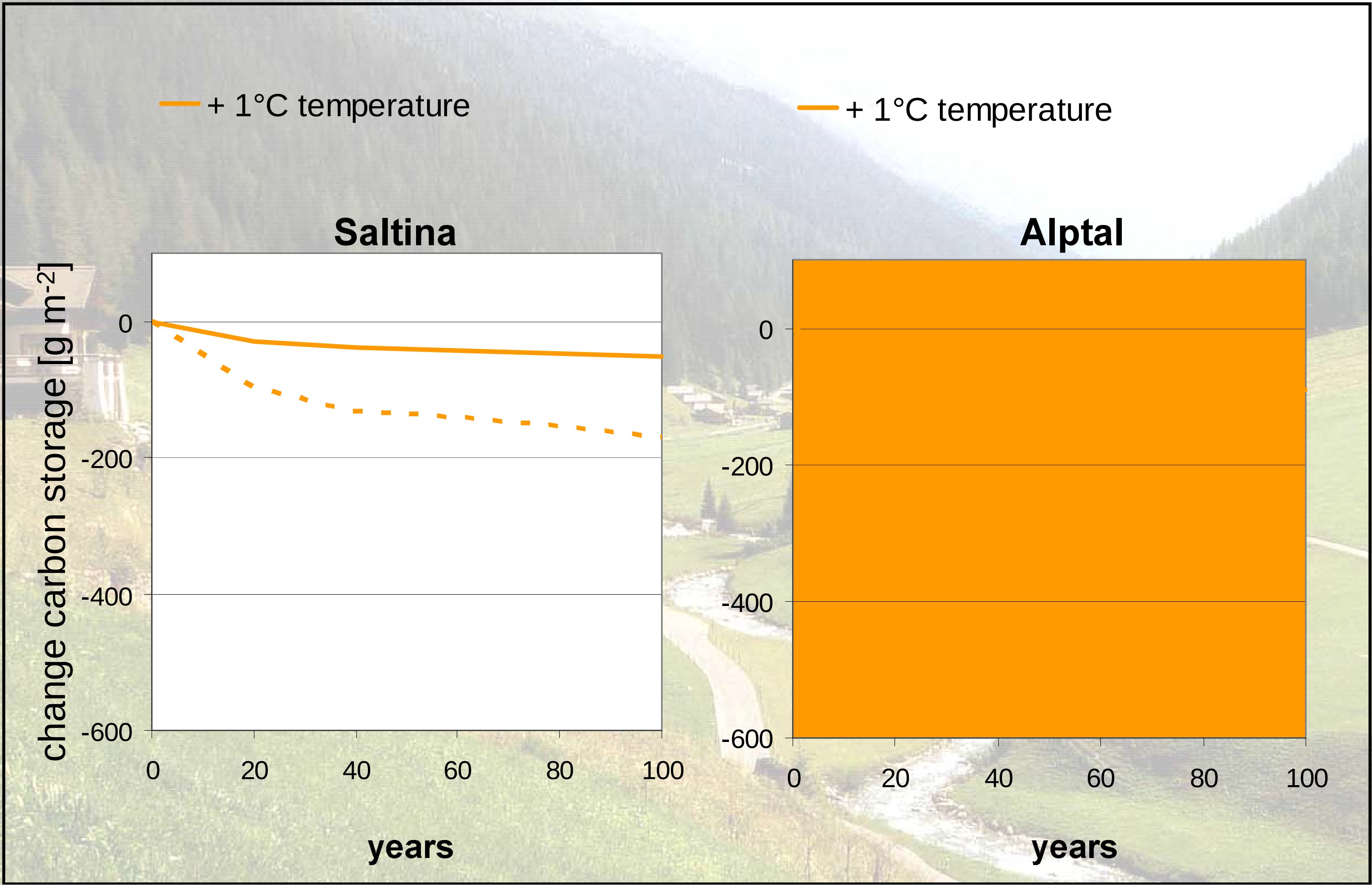


- very important service
- seasonal changes matter most, even though storage is possible
- different ‘water stakeholders’ have very different interests:
  - hydropower generation (mainly winter; but also summer – see 2003!)
  - drinking water (year-round)
  - irrigation (summer; particularly in Mediterranean/other dry areas)

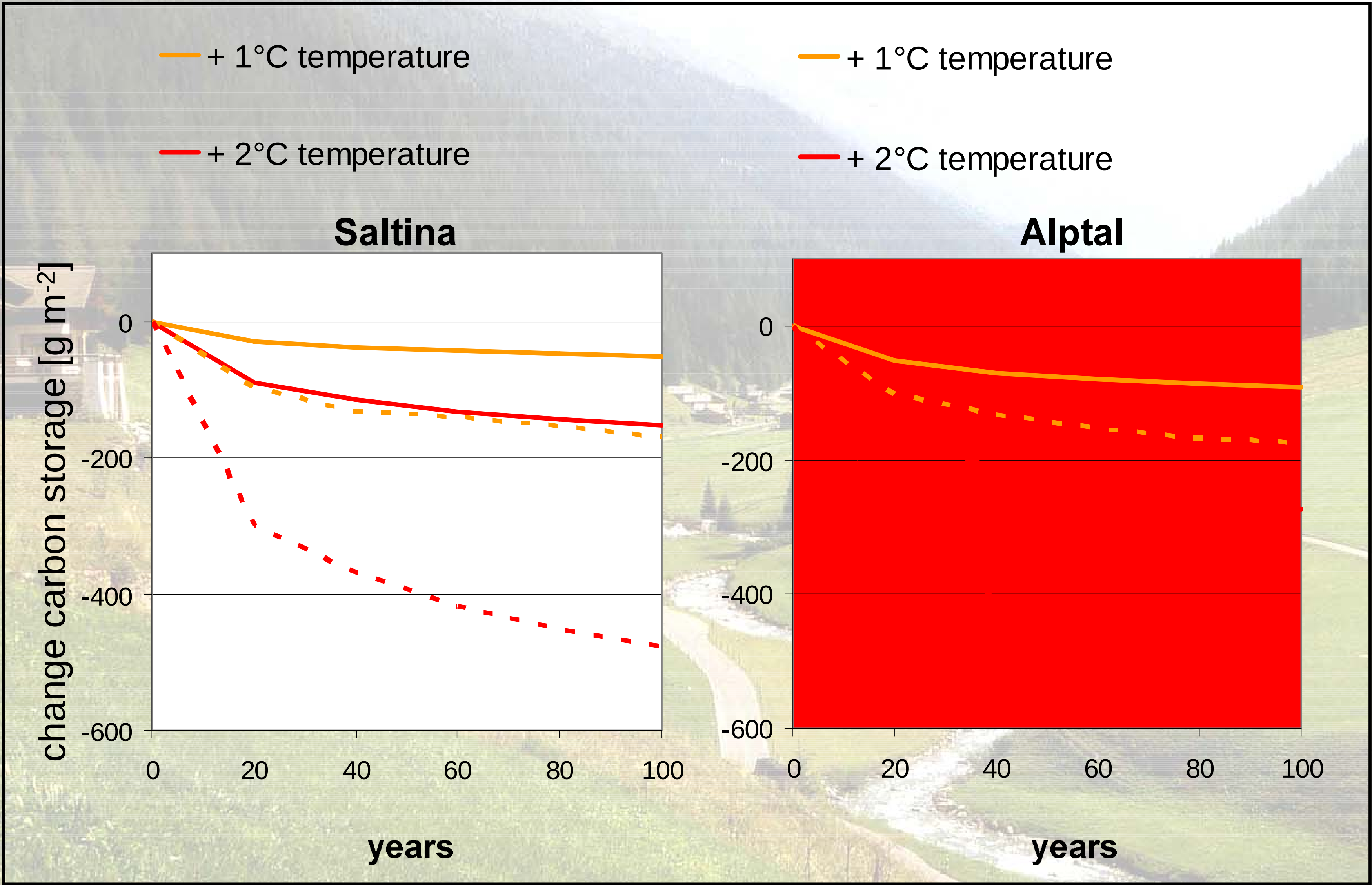
Simulated C storage in vegetation, current climate



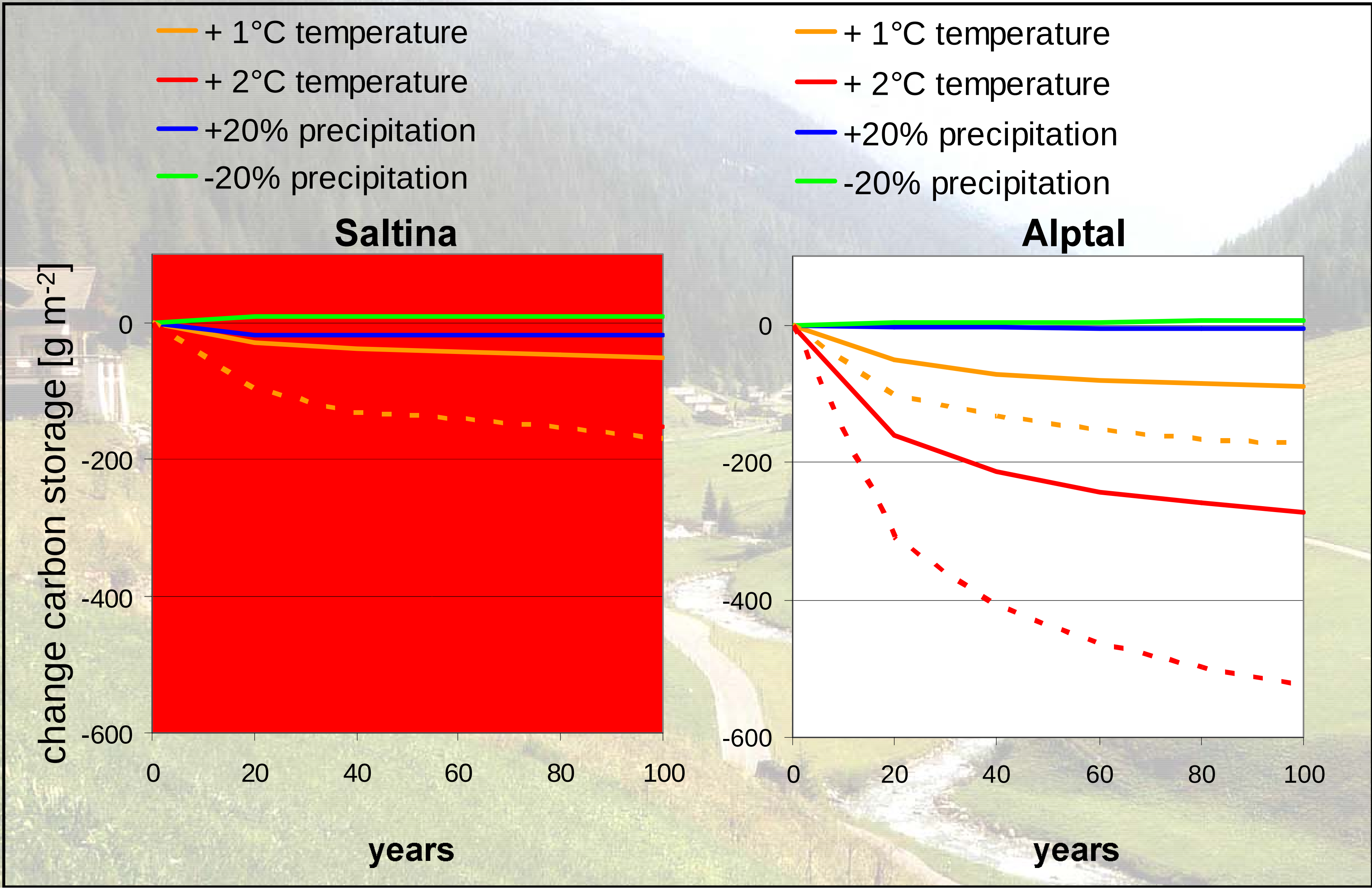
Results: Carbon (II)



Results: Carbon (II)

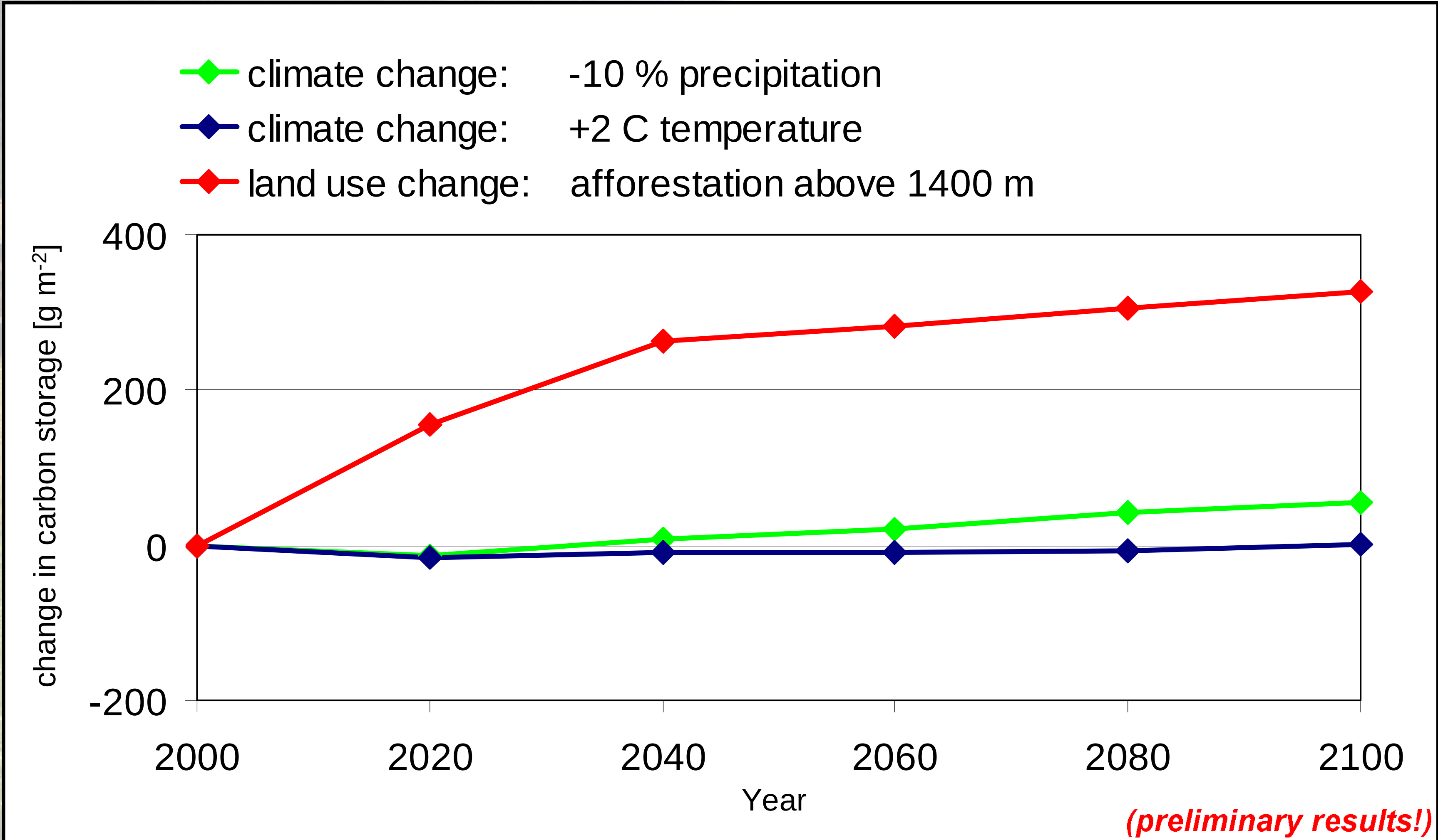


Results: Carbon (II)



Results: Carbon (III)

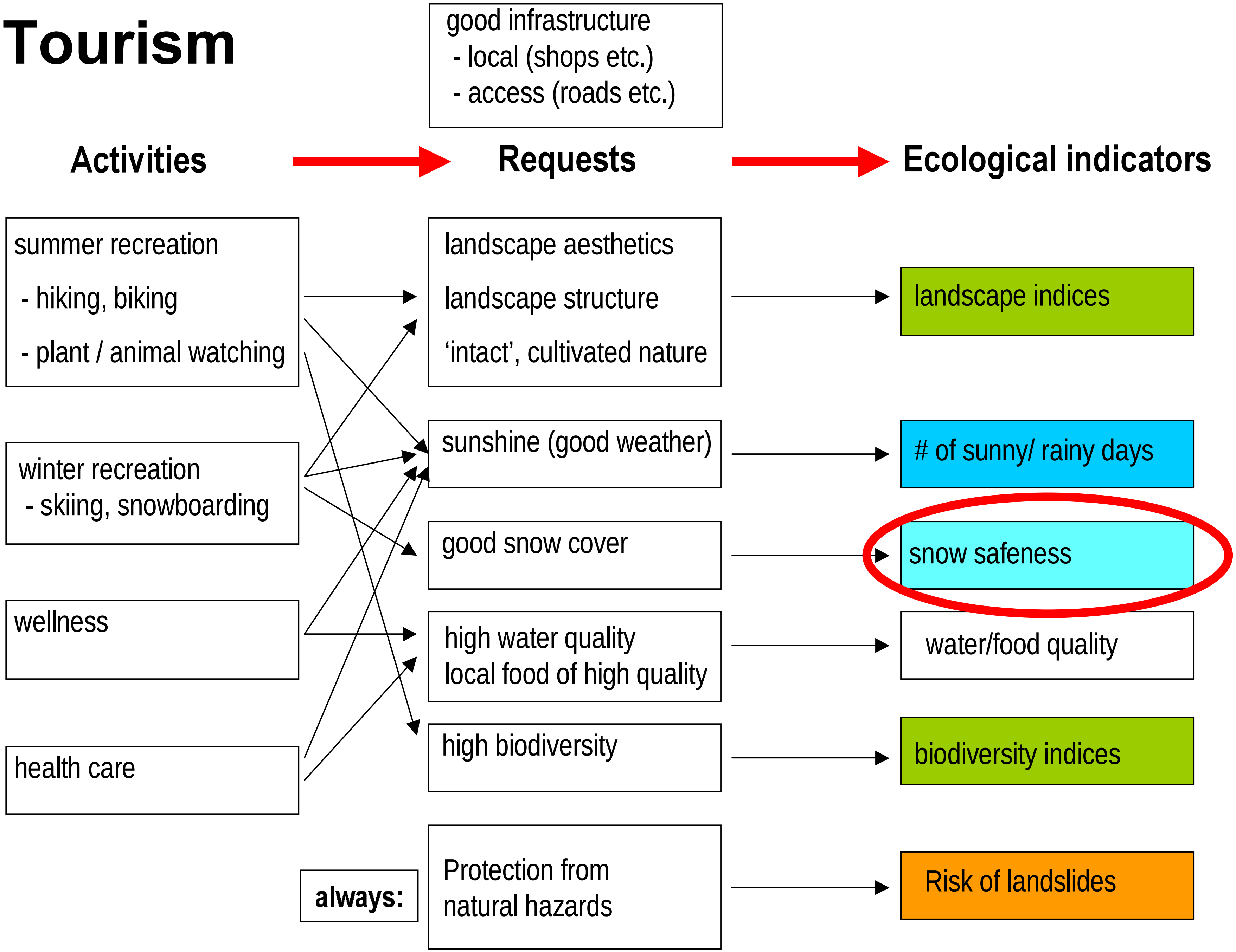
Climate vs. land use change: the case of the Alptal catchment



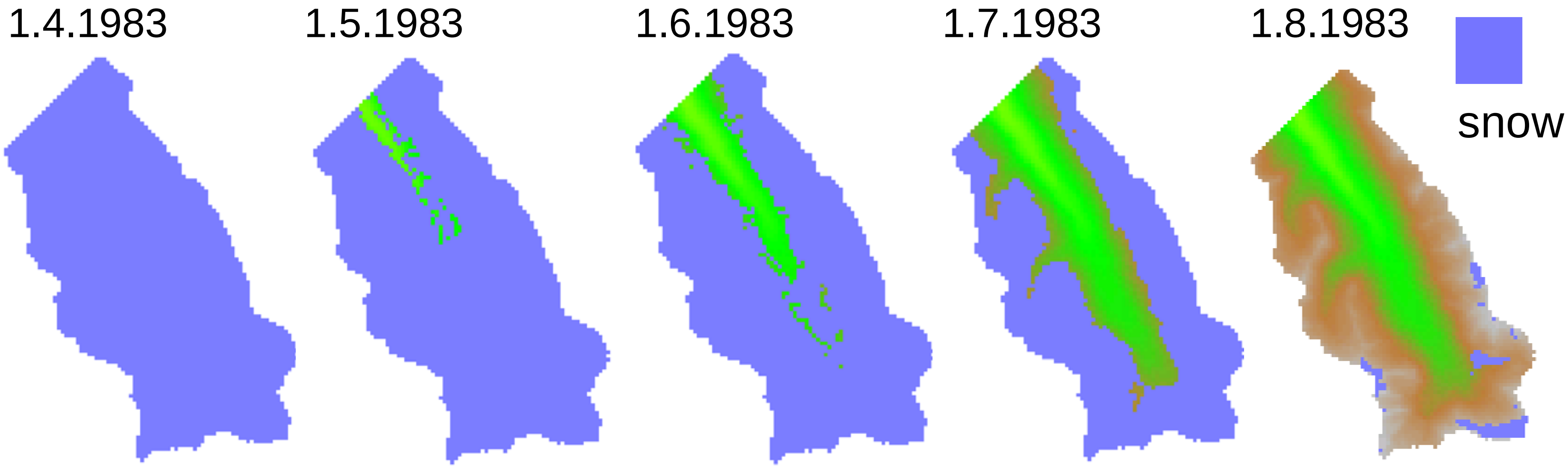
Stakeholder responses

- increasingly recognized by SHs,
  also in mts
- politically important
- SHs expect that LU changes
  are more important than
  climate & deposition (and our results support this)
- large LU changes are going on / may be continue in the future (see scenarios, and yesterday's field trip!)
  => role of mountains for future carbon balance of the continent
- relevance of natural disturbances (fires, insects, etc.)

Tourism


good infrastructure
- local (shops etc.)
- access (roads etc.)
Activities
Requests
Ecological indicators
summer recreation
- hiking, biking
- plant / animal watching
winter recreation
- skiing, snowboarding
wellness
health care
always:
landscape aesthetics
landscape structure
'intact', cultivated nature
sunshine (good weather)
good snow cover
high water quality
local food of high quality
high biodiversity
Protection from
natural hazards
landscape indices
# of sunny/ rainy days
snow safeness
water/food quality
biodiversity indices
Risk of landslides

Tourism Snow cover



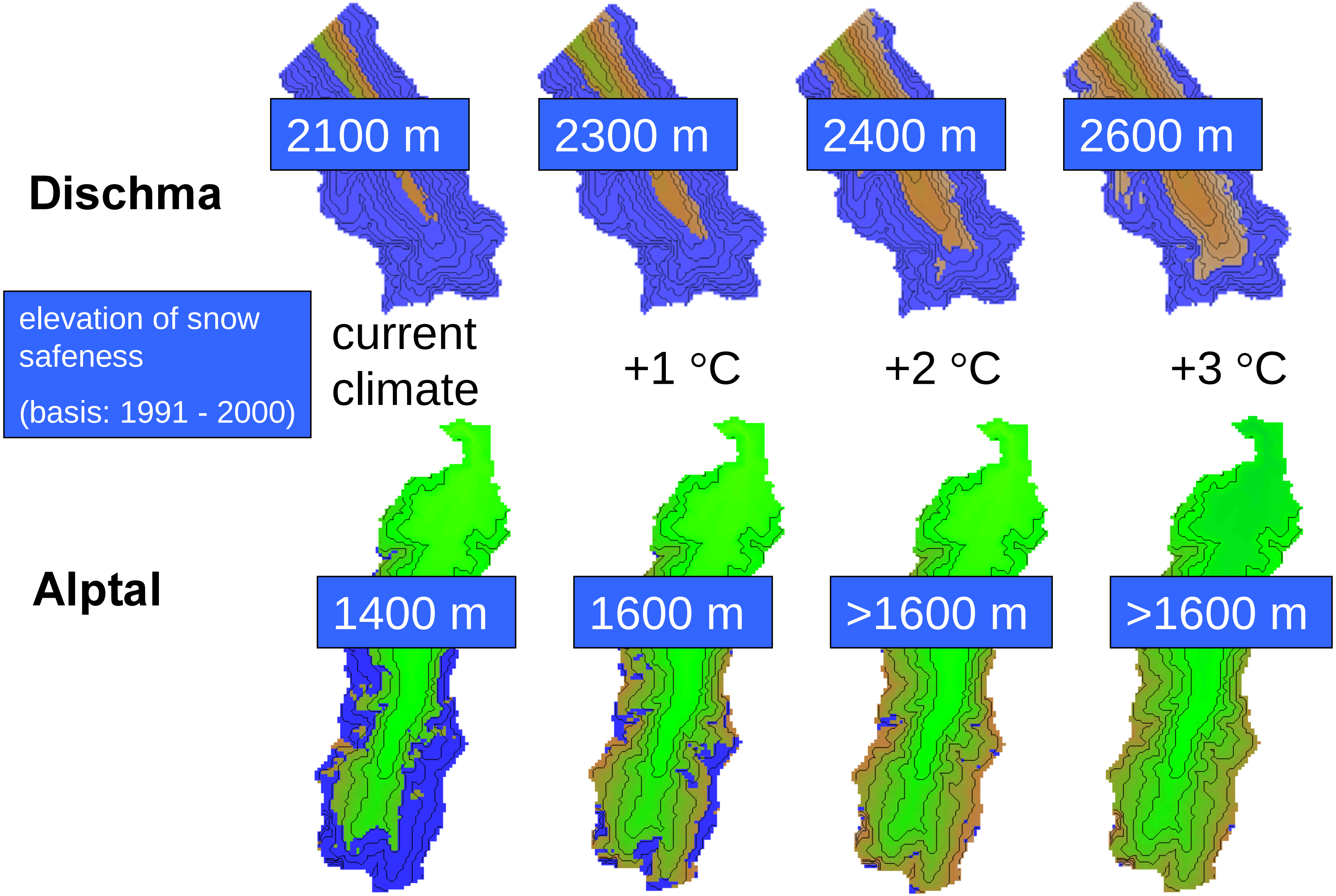
validated by comparison with aerial photography (Petrow, 2002)

Snow safeness (Elsasser & Messerli, 2001) :

- presence of snow cover of >30 cm deep
- during at least 100 days in the period 1 December – 15 April
- in 7 out of 10 winters

Tourism

Snow cover



Stakeholder responses

- the SH discussions changed our views!
- infrastructure is most important => safety from natural hazards is the *primary* concern
- tourism/recreation relies on a wide range of ecosystem services (freshwater, snow, landscape aesthetics, natural hazards), is *secondary* to these services!
- new strategy:
  - determine (quantitatively) the *primary* change: slope stability
  - then work out changes in *secondary* ecosystem services, using RHESSys etc.
  - interpret (qualitatively) these changes in terms of their consequences for tourism & recreation

Slope stability

- Prerequisite for the accessibility and inhabitability of mountain regions (cf. summer 2003: Matterhorn, Grindelwald glacier)
- Assessment of slope stability based on
  - topography
  - soil moisture
  - amount of root carbon (grass/forest)
  - land use patterns
- …it’s in the works!

Stakeholder responses

- cf. Tourism (above):
  protection is crucial
- SHs identified large variety of natural hazards that are relevant for their interests:
  floods, landslides, permafrost melting, debris flows during glacier melting, avalanches, insect infestations, windthrow events, etc.
- we must restrict ourselves to a small subset of these hazards
  e.g. slope stability (is key for mitigating many natural hazards)

Conclusions

Conclusions (I)

- **Mountains are globally significant…**
  … and humanity depends on many mountain ecosystem services

- **Spatial interdependency of processes and systems requires simultaneous consideration at high resolution**

- **Considerable sensitivity of mt ecosys services to global changes:**
  - **short term (10-50 yrs): LU change, N deposition**
  - **long term: (>50 yrs): Climate change**

Conclusions (II)

- **Stakeholder dialogue has been**
  - important for shaping the design of our project
  - successful (at least so far)

- **Adaptive capacity and vulnerability (in the works!!):**
  - varies by service
    (and by region – to date, only central/eastern Alps considered)
  - water: probably high vulnerability (undesired changes!)
  - carbon: probably low vulnerability (desired changes!)
  - tourism: probably winter high, summer low vulnerability


Mountain Ecosystem
Goods and Services
Oops, that was a long one –
Thanks for your attention!