Mountain Ecosystem Goods and Services

Harald Bugmann

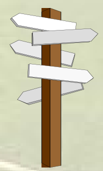
Forest Ecology

Department of Environmental Sciences

ETH Zürich, Switzerland

Overview

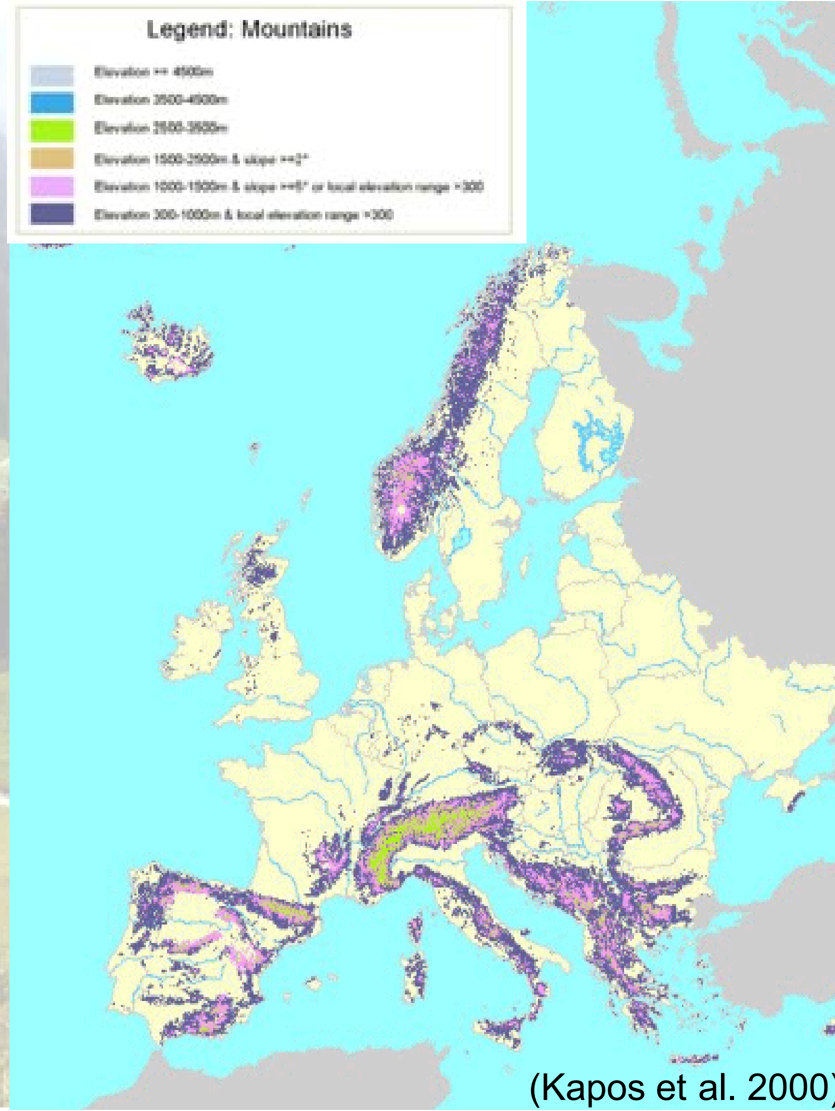
- Why the focus on mountains?
  - Significance of mountains and their goods and services
  - Peculiarities of mountain systems
- The ATEAM mountain project
  - Stakeholder dialogue
  - Scientific objectives and approach
  - Modeling and simulation studies and stakeholder responses
- Conclusions




Why the focus on mountains?
Significance and peculiarities

Global significance of mountains

- **24.3% of the terrestrial land surface is moun-tainous**
- **28% of the global forest area is in mountains**
- **>10% of human popu-lation live in mountains**



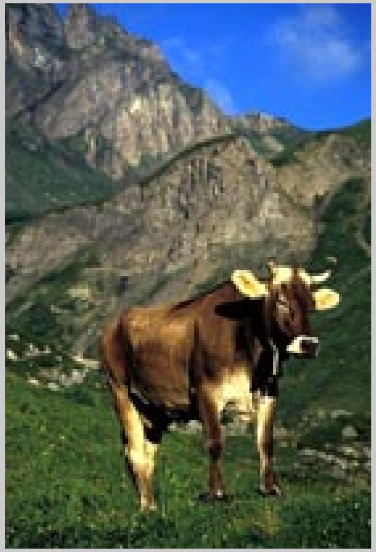
(Kapos et al. 2000)

Mountain (ecosystem) goods & services

Freshwater

Protection

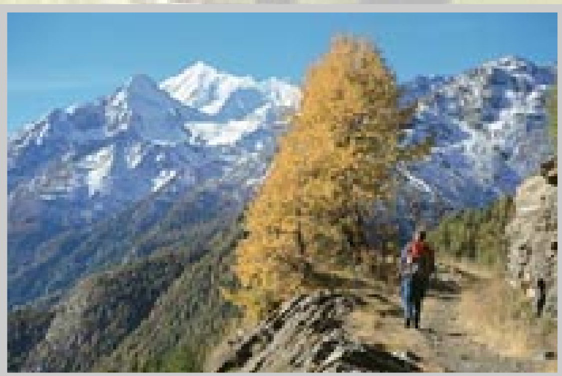
Resource extraction



Mountain (ecosystem) goods & services

Carbon storage

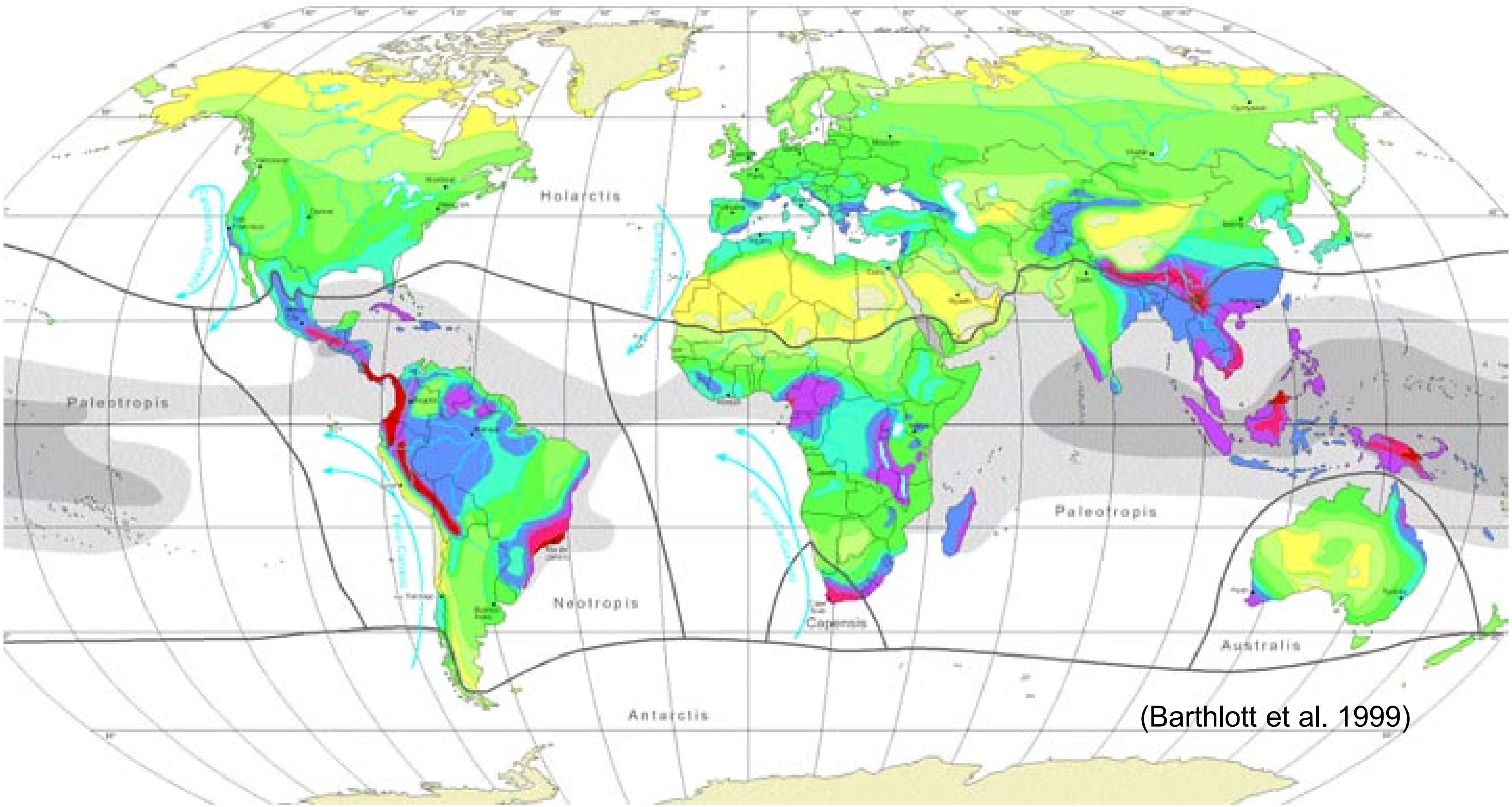
Tourism



Biodiversity

Global vascular plant diversity

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS



(Barthlott et al. 1999)

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

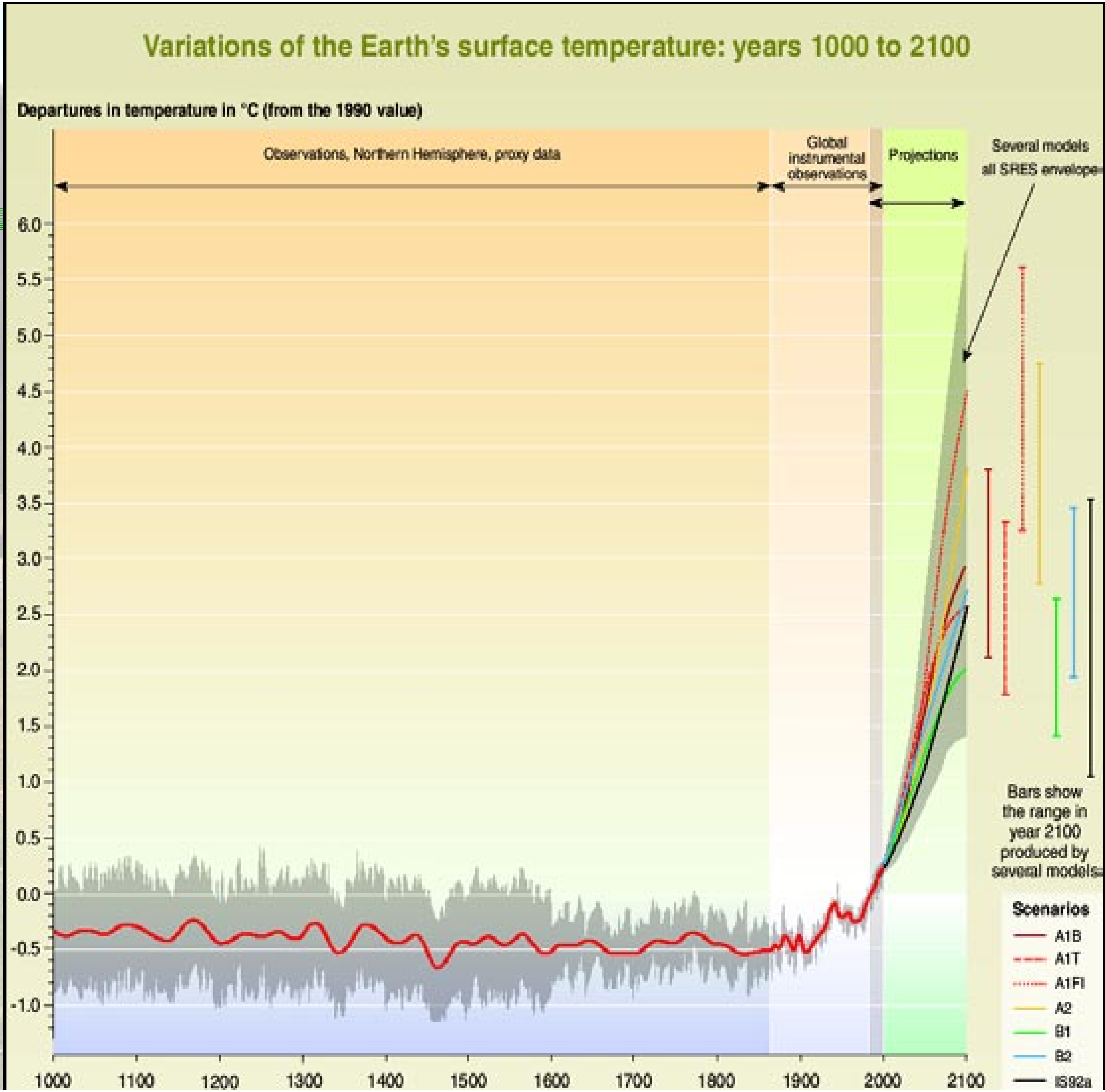
Physical environment:

- ‘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
Bars show the range in year 2100 produced by several models
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
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

IPCC (2001)

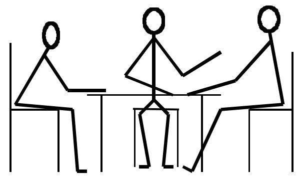
The complexity of mountain landscapes

- **Several factors are crucial in mountains that 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’**
- **The landscape scale (spatial aspect) is of high importance, as landscape integrity depends on weakest element**

⇒ Projecting the impacts of global change on mountain ecosystem goods and services requires
  - **the use of mathematical models to handle the inherent complexity**
  - **a landscape-scale approach**


The ATEAM mountain project:
I. The stakeholder dialogue

How it worked (I)

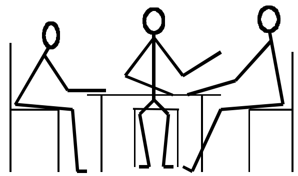


- Who were the sectoral (“mountain”) stakeholders?

Name	Affiliation	W	C	B	T	S
L. Capone	ACTA / WWF			x	x	
M. Harley	English Nature			x		
W. Hauenstein	Swiss Association of Hydropower Companies (SWV)	x				x
M. Kreiliger	Director of Disentis Resort Transporation Systems	x			x	
M. Vogel	Director of the National Park Berchtesgaden			x	x	x
R. Volz	Swiss Environmental Protection Agency (BUWAL)		x			

- Embedded in ATEAM-wide (= much larger!) stakeholder dialogue

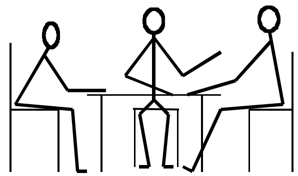
How it worked (II)



- 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 worked (III)



- Final round:
  bilateral discussions & meetings to evaluate project results,
  took place in last project year

  based on flyer and synthesis document

  – 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

ETH

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:

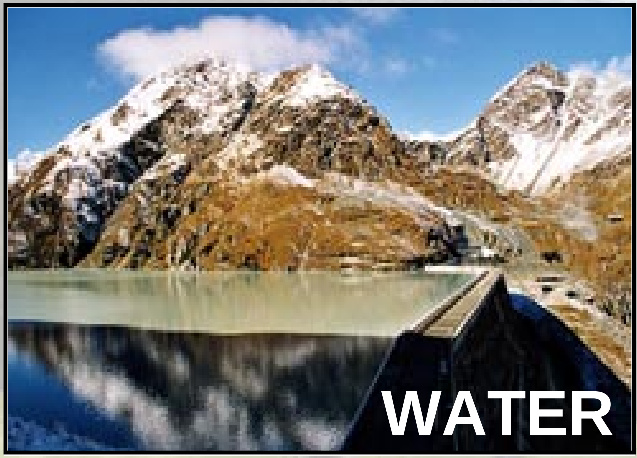
II. Scientific objectives

Scientific 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
  - **End result: vulnerability assessment**

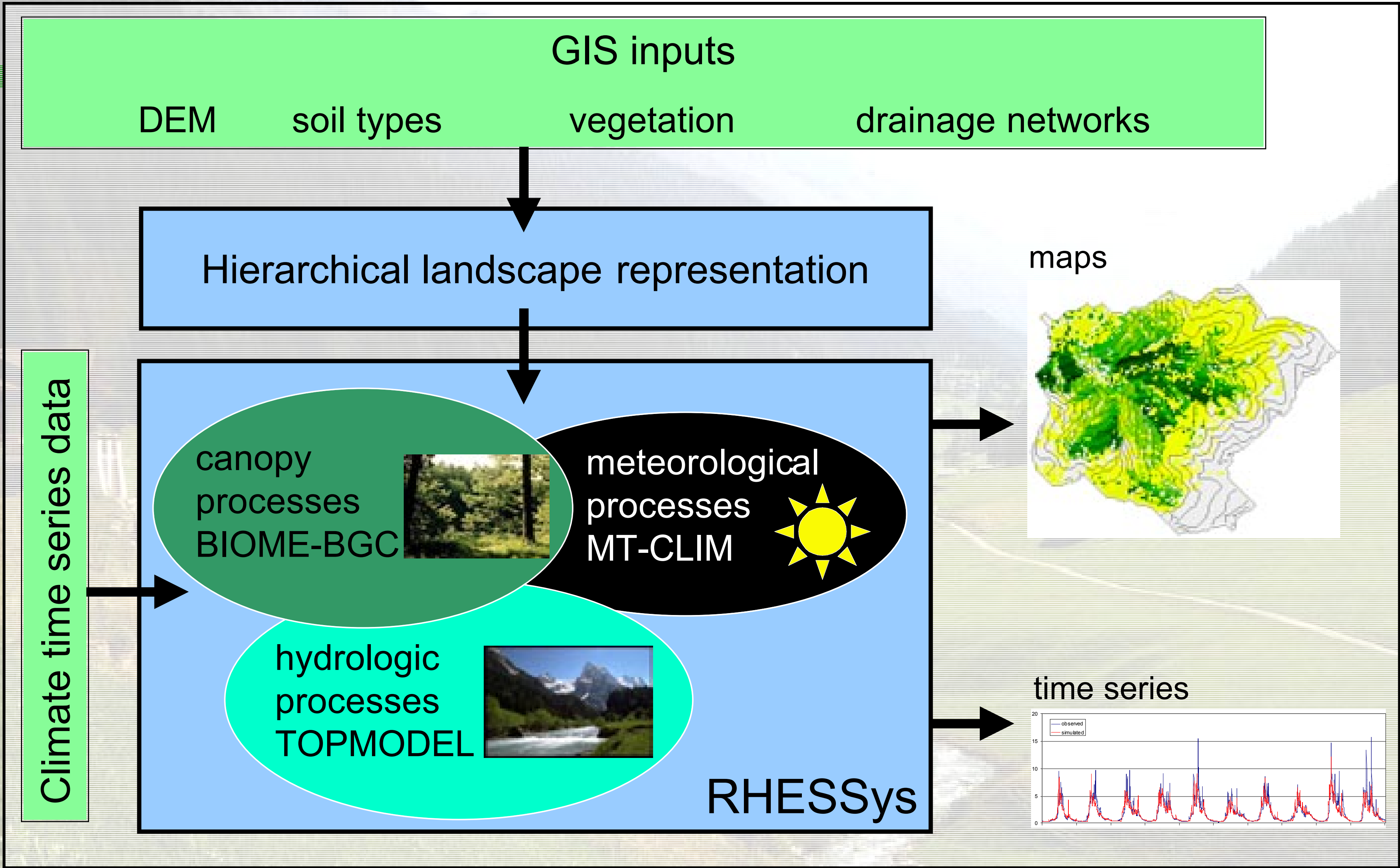
    vulnerability = *f* (sensitivity, adaptive capacity)

Selected ecosystem services



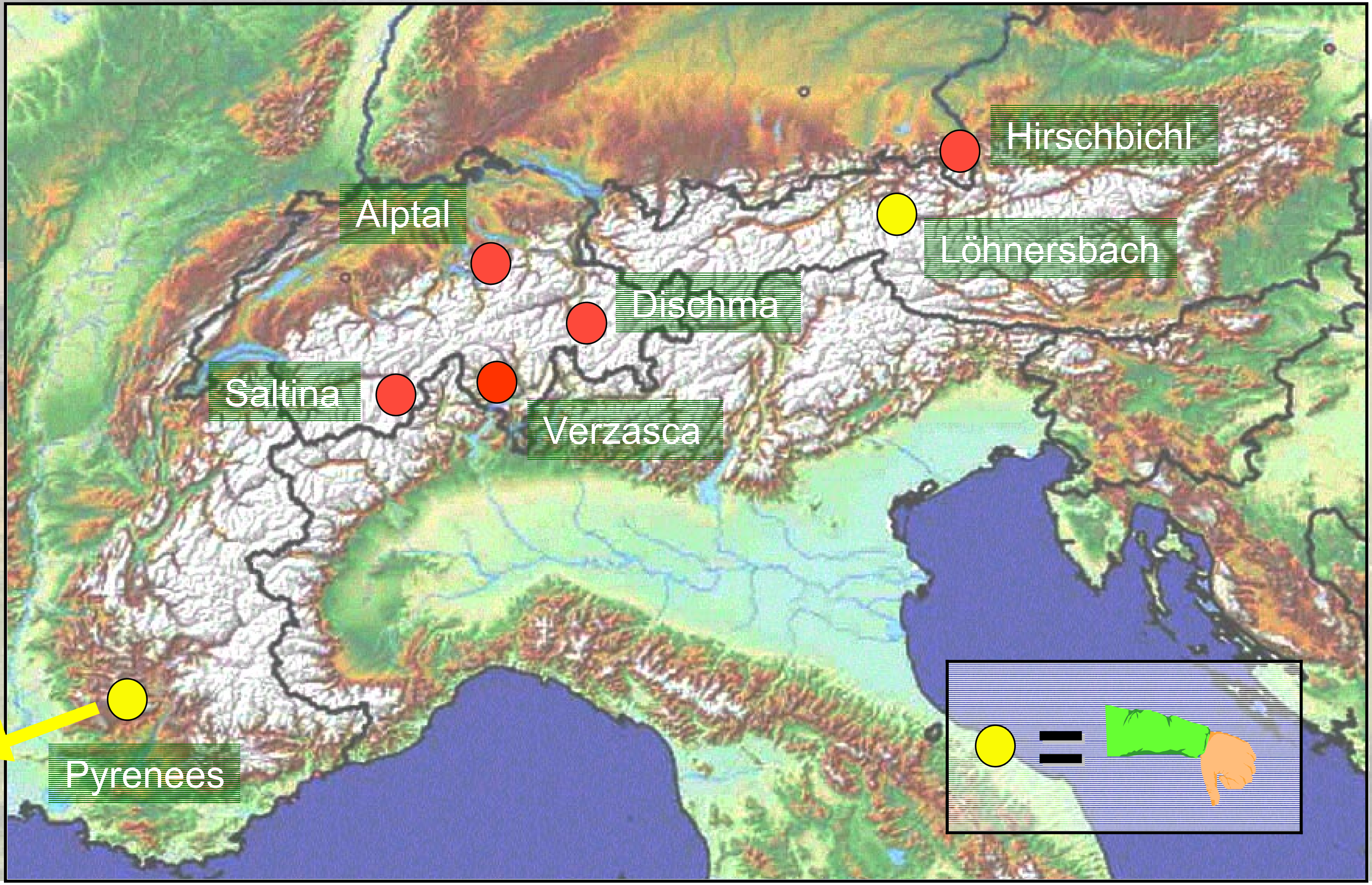

The ATEAM mountain project:
III. Modeling approach

RHESSys: Regional Hydro-Ecological Simulation System

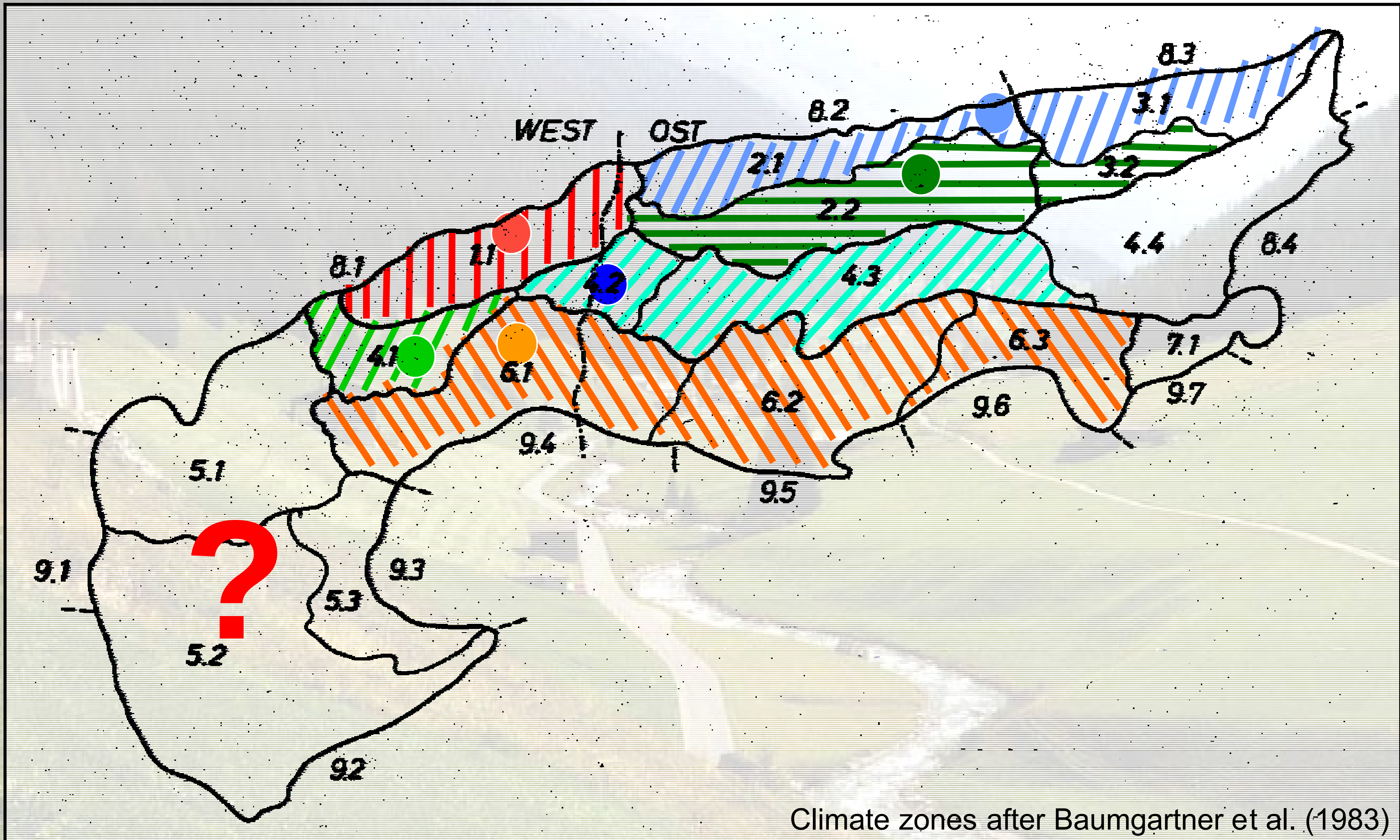


developed by Band, Running, Thornton, Tague et al.

Case studies: Location



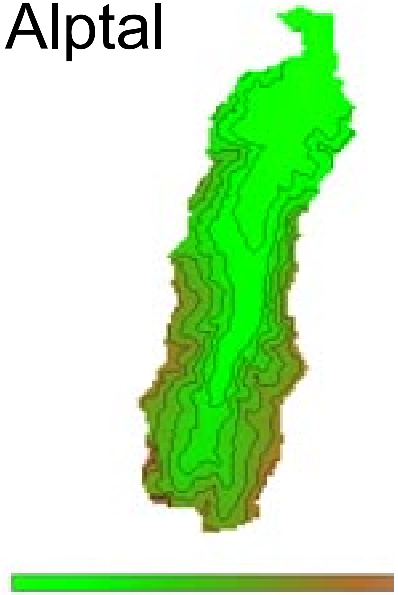
Case studies: Representativeness



Climate zones after Baumgartner et al. (1983)

Case studies: Characteristics

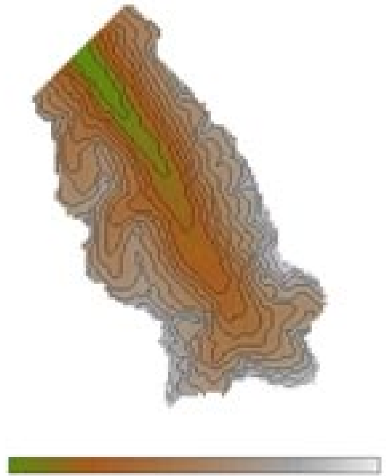
Alptal



prealpine west

area	46.8 km^2
forest	52%
grass	42%
other	6%

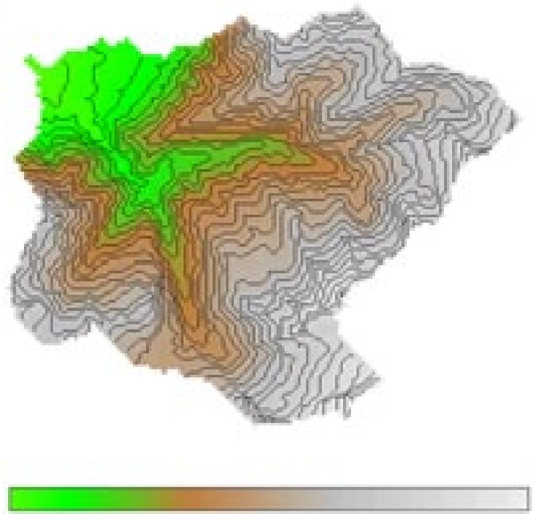
Dischma



high alpine

area	43.3 km^2
forest	10%
grass	38%
other	52%

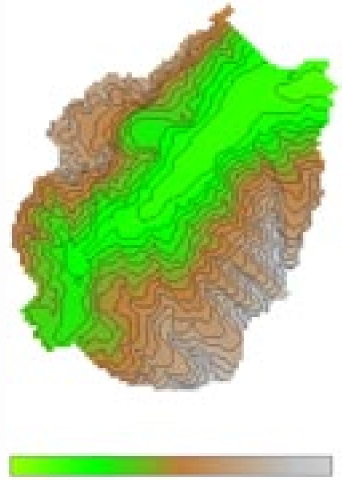
Saltina



inner alpine

area	77.0 km^2
forest	35%
grass	34%
other	31%

Hirschbichl

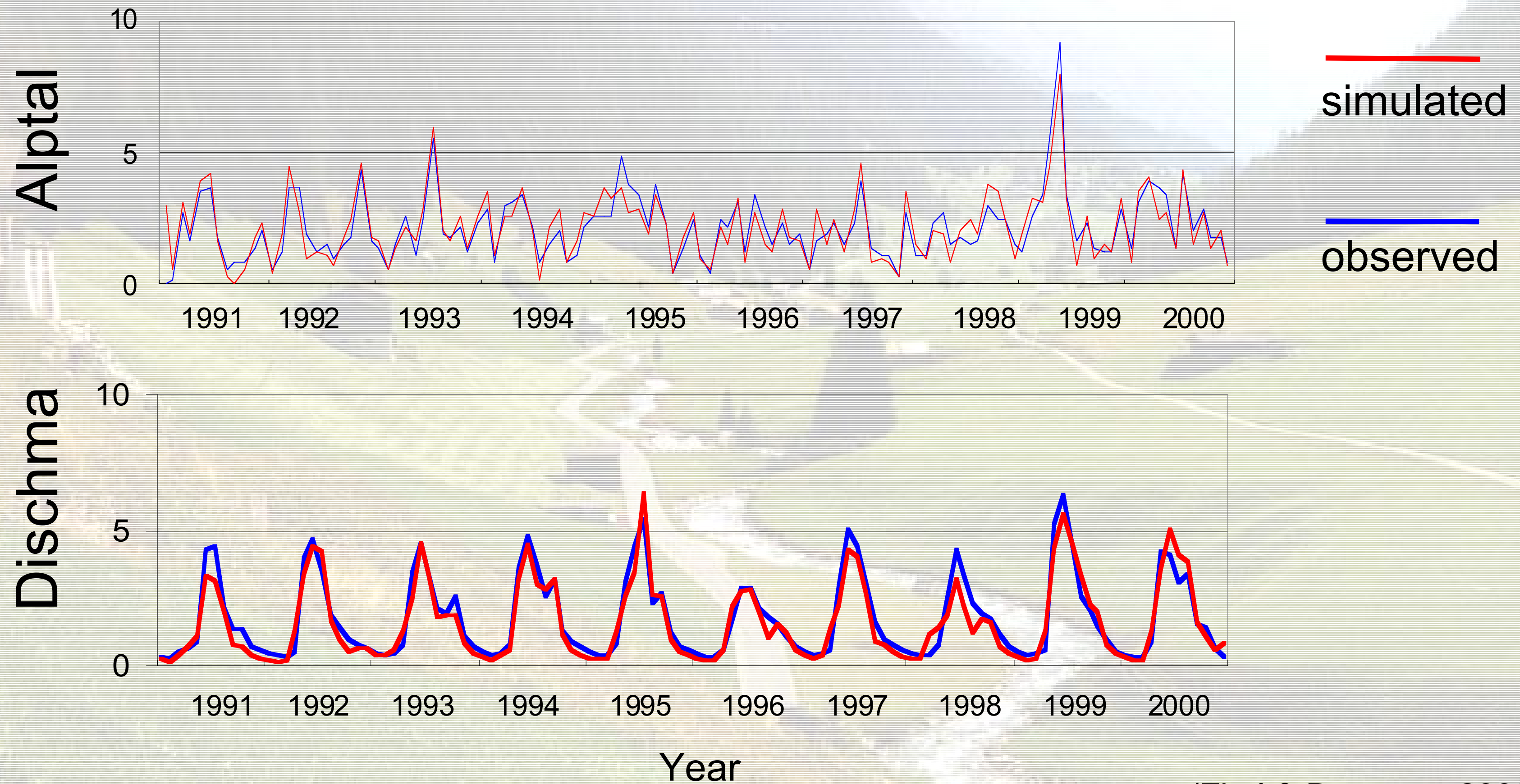


prealpine east

area	44.6 km^2
forest	42%
grass	30 %
other	28%

Model evaluation (I)

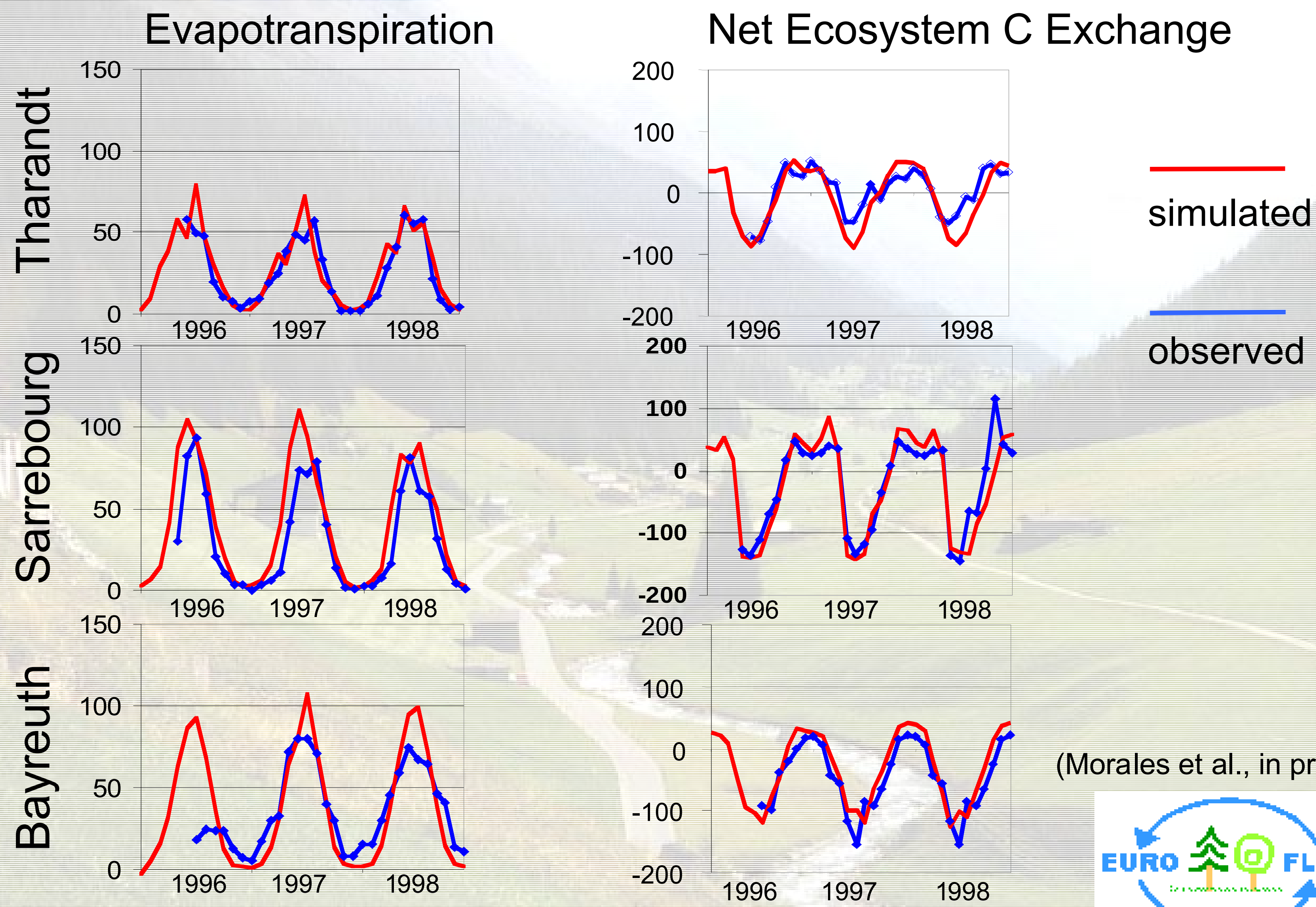
Monthly runoff [m³/s] in two catchments



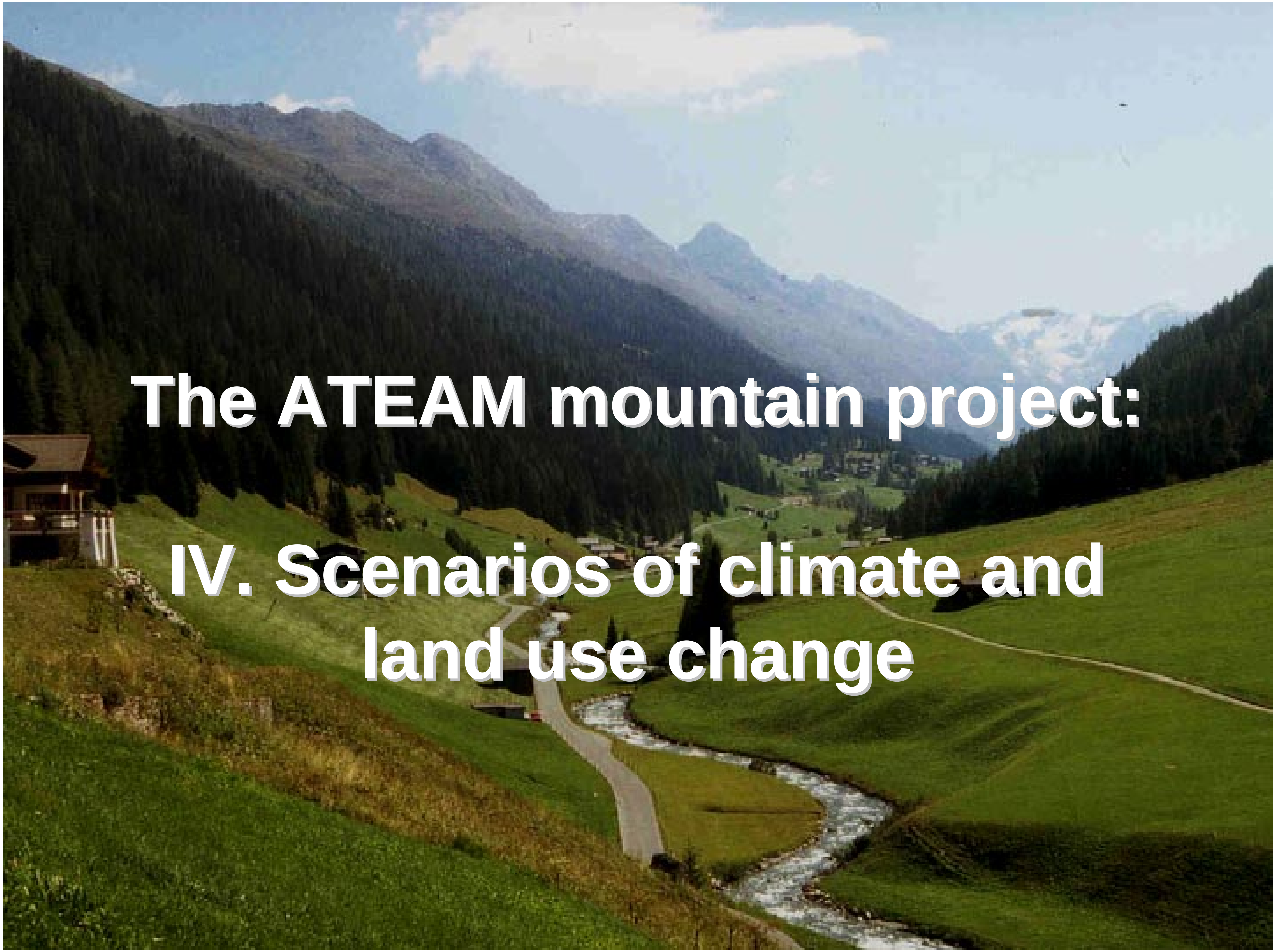
(Zierl & Bugmann 2005)

Model evaluation (II)

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



(Morales et al., in press)


The ATEAM mountain project:
IV. Scenarios of climate and land use change

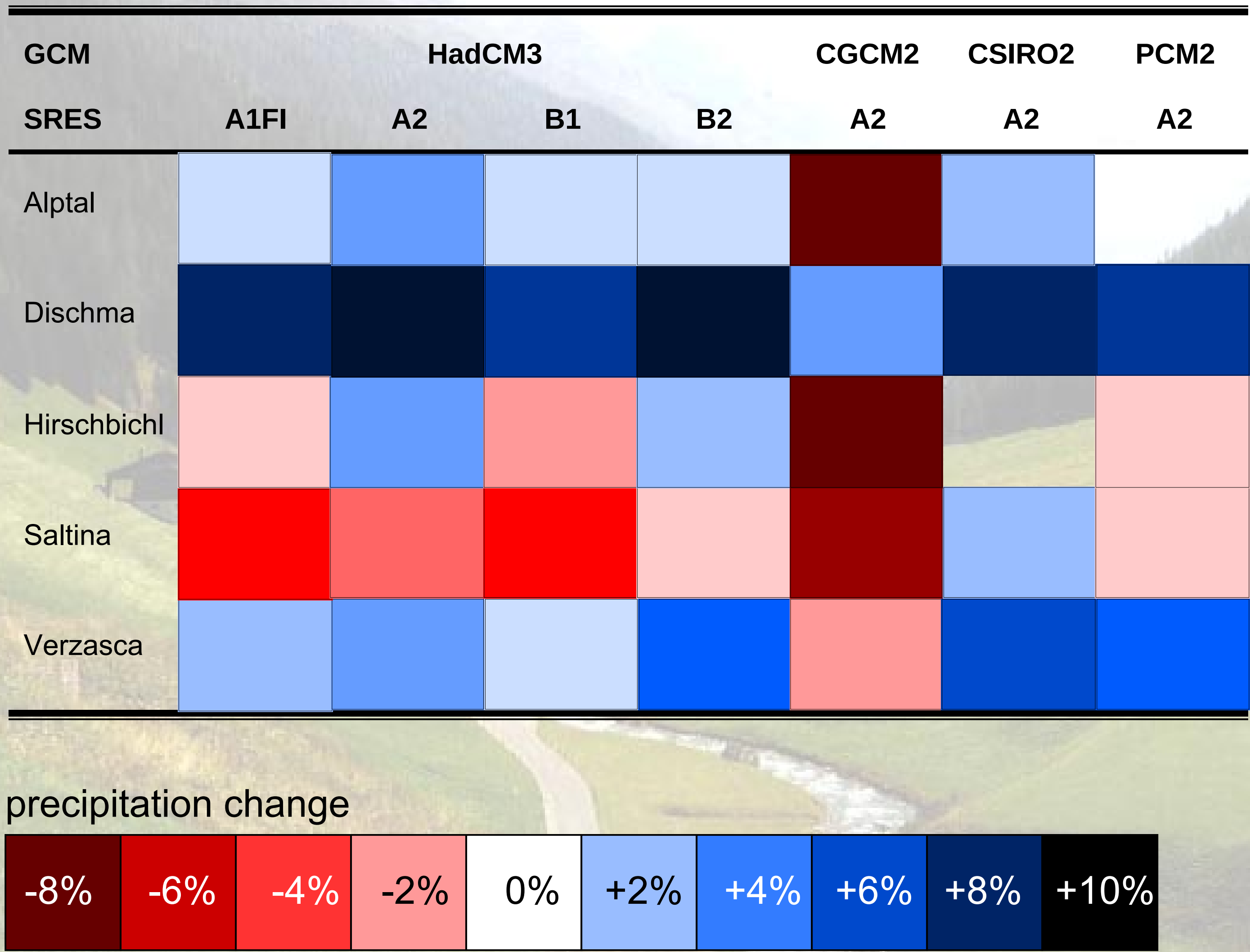
Scenarios: Temperature

GCM	HadCM3				CGCM2	CSIRO2	PCM2
SRES	A1FI	A2	B1	B2	A2	A2	A2
Alptal							
Dischma							
Hirschbichl							
Saltina							
Verzasca							

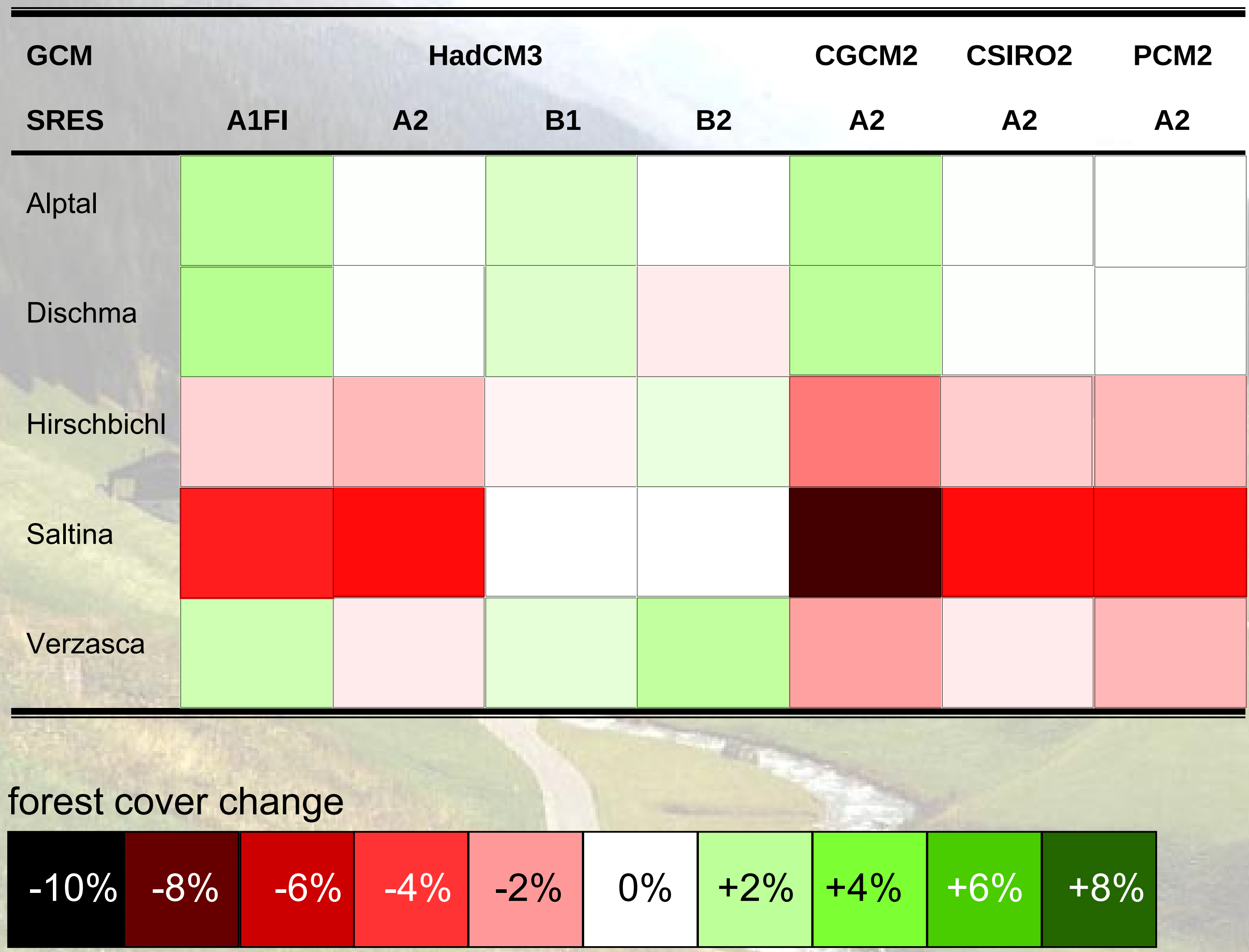
temperature change

+1°C | +2°C | +3°C | +4°C | +5°C | +6°C | +7°C

Scenarios: Precipitation

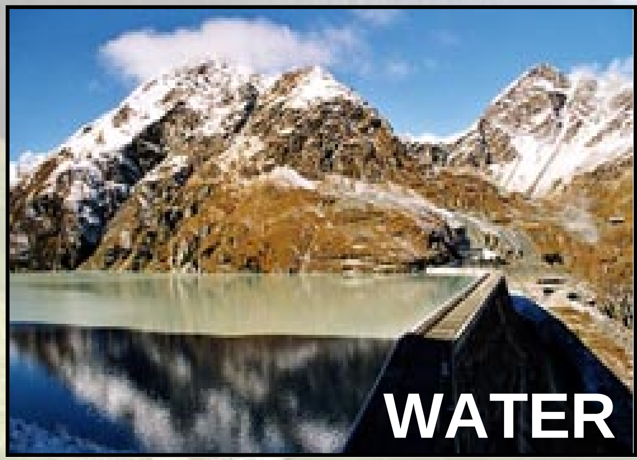


Scenarios: Forest cover change



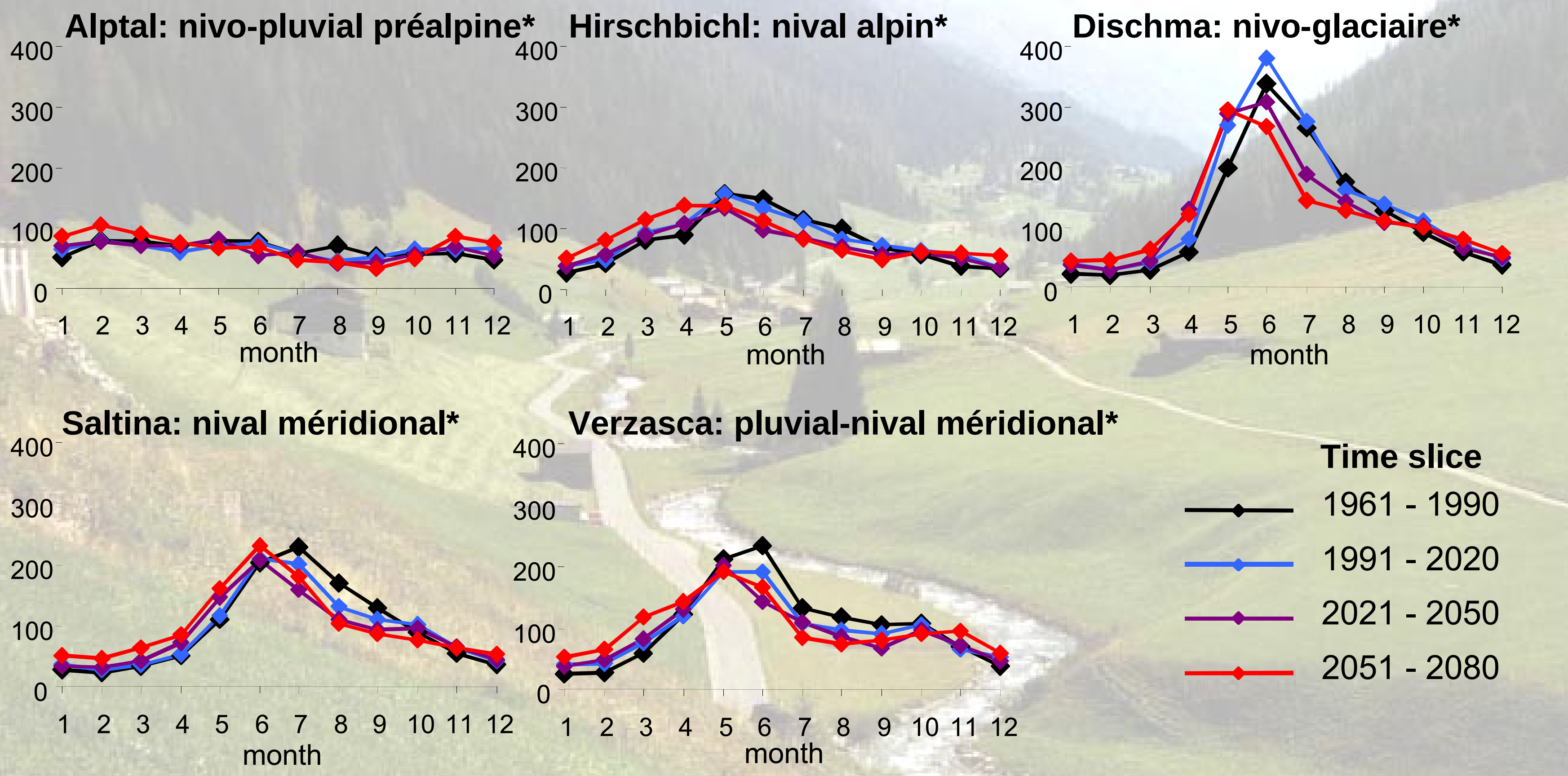

The ATEAM mountain project:
V. Impacts on ecosystem goods and services

Sensitivity of ecosystem services



Water supply: runoff regime [mm/month]

HadCM3 A2

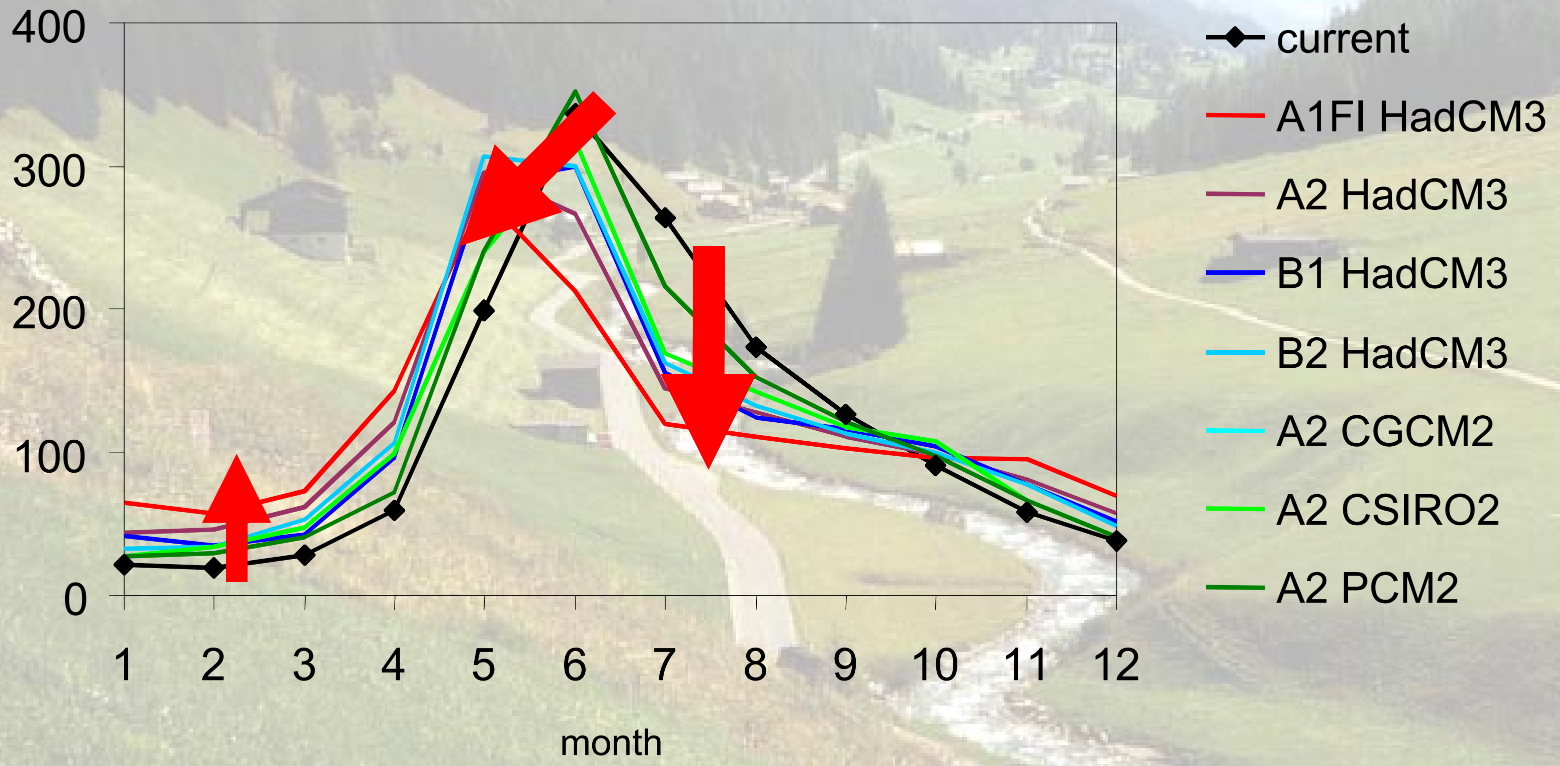


* after Weingartner & Aschwanden (1992)

Water supply: runoff regime [mm/month]

Dischma valley, 2051 - 2080

Comparison of scenarios



Water supply: conclusions

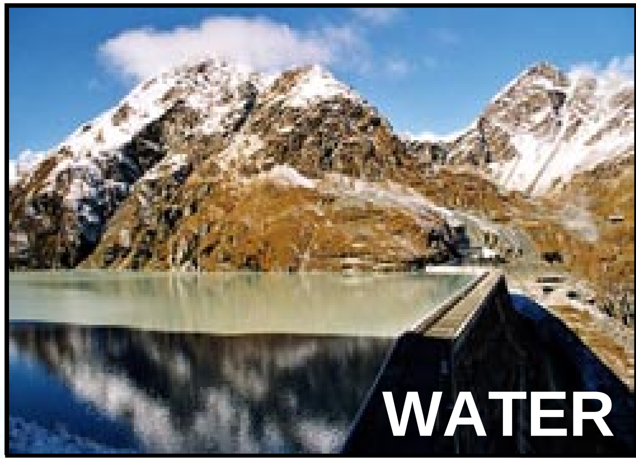
Redistribution of discharge in the course of the year

- slightly reduced annual discharge
- strongly reduced summer discharge (irrigation, drinking water)
- somewhat higher winter discharge (hydropower)

- earlier peak streamflow in spring
- decrease of maximum *monthly* discharge

- little effect of land use scenarios compared to climatic effects

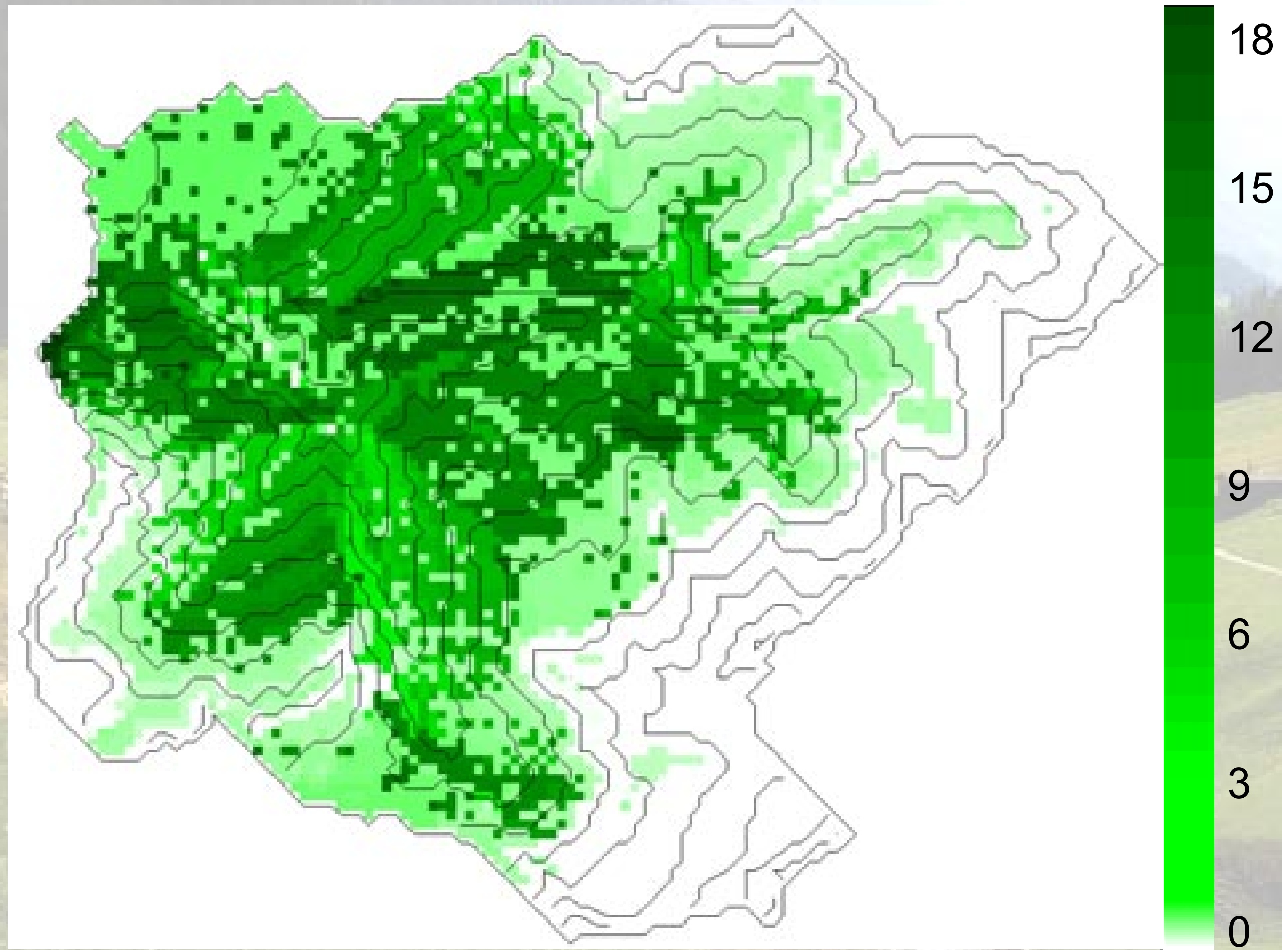
Stakeholder responses



- 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)

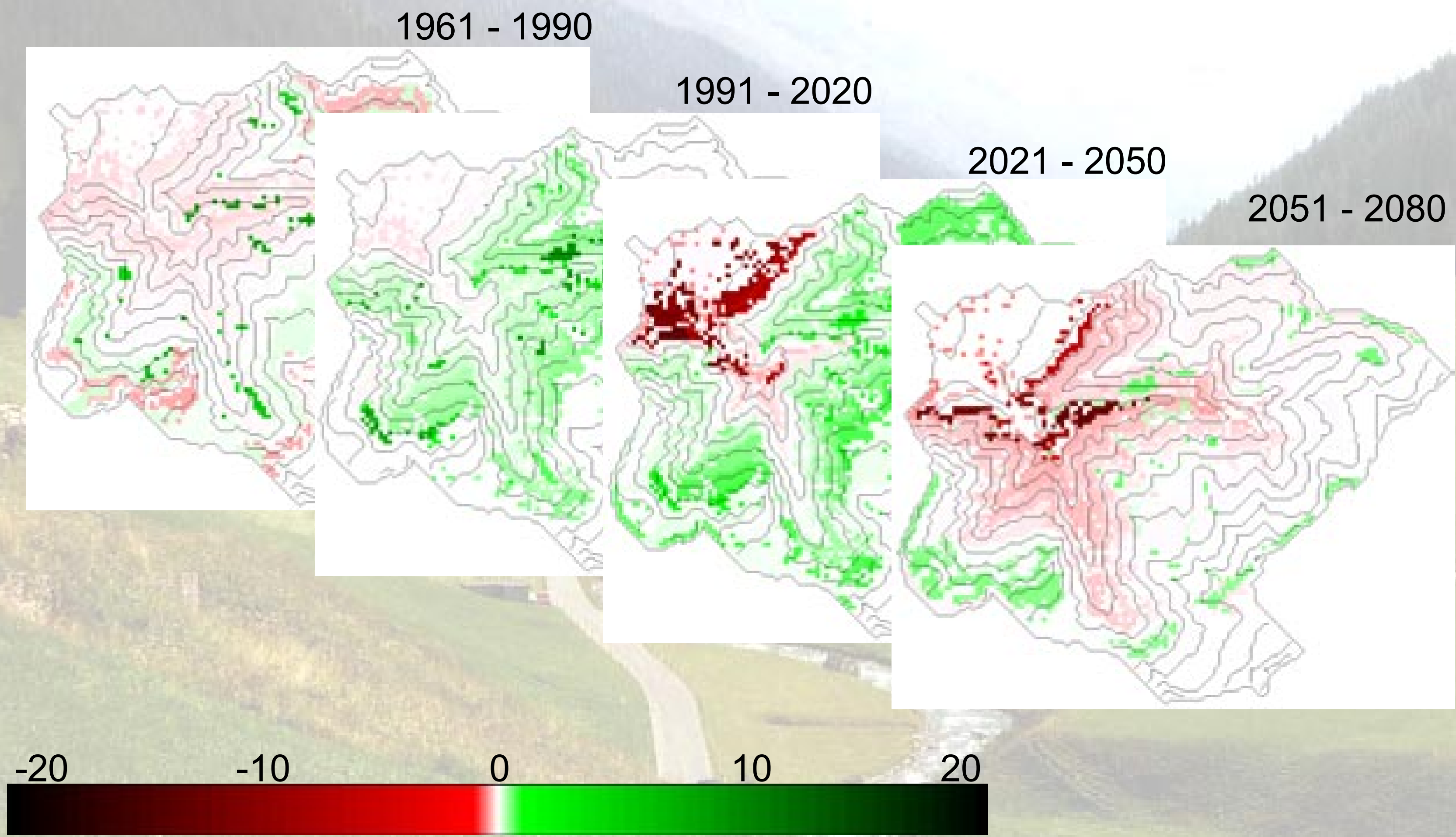
Sensitivity of ecosystem services

C storage: Saltina, vegetation C [kg m^{-2}]



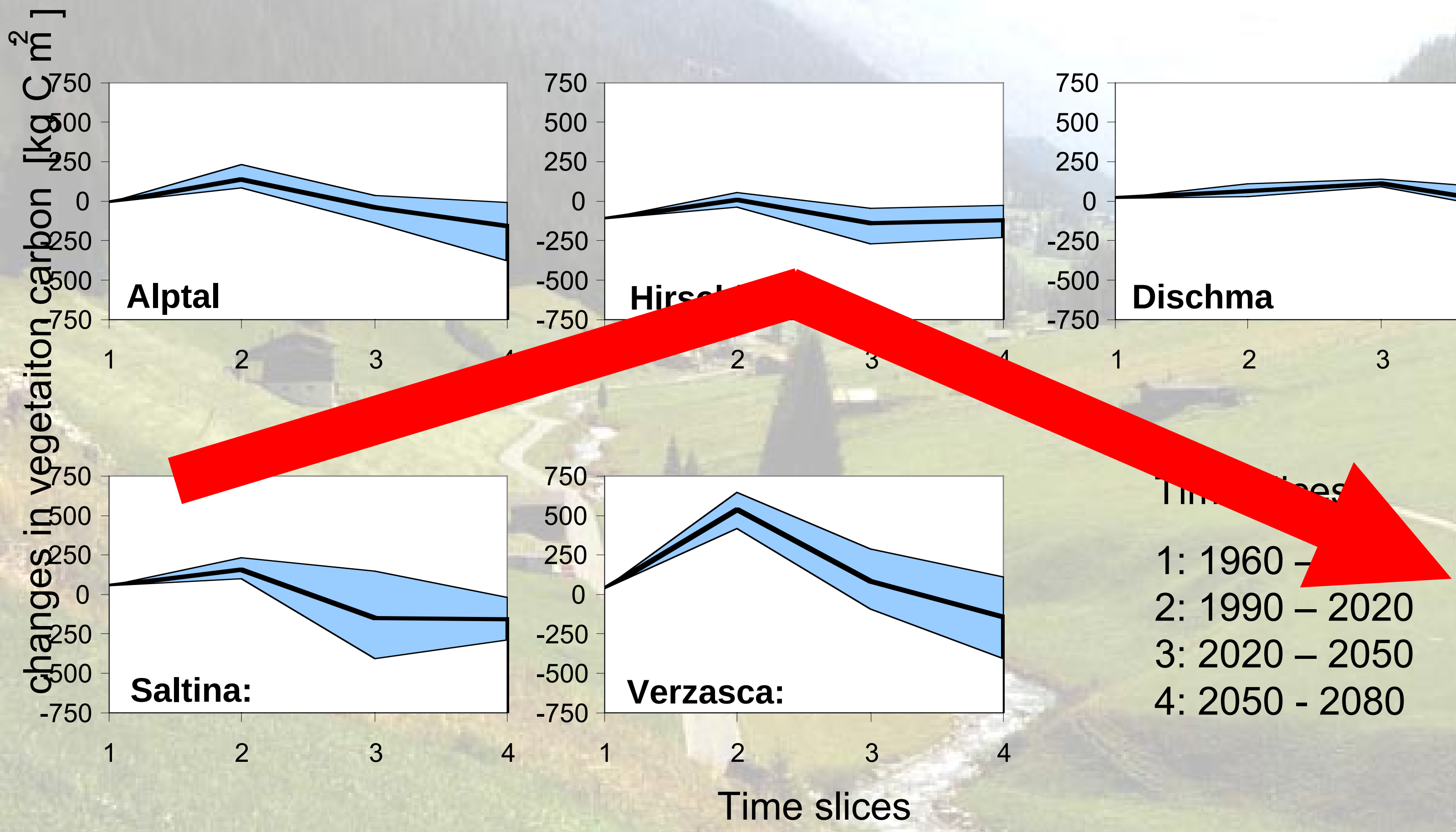
(Zierl & Bugmann, submitted)

Saltina, change in vegetation C [kg m^{-2}]



(Zierl & Bugmann, submitted)

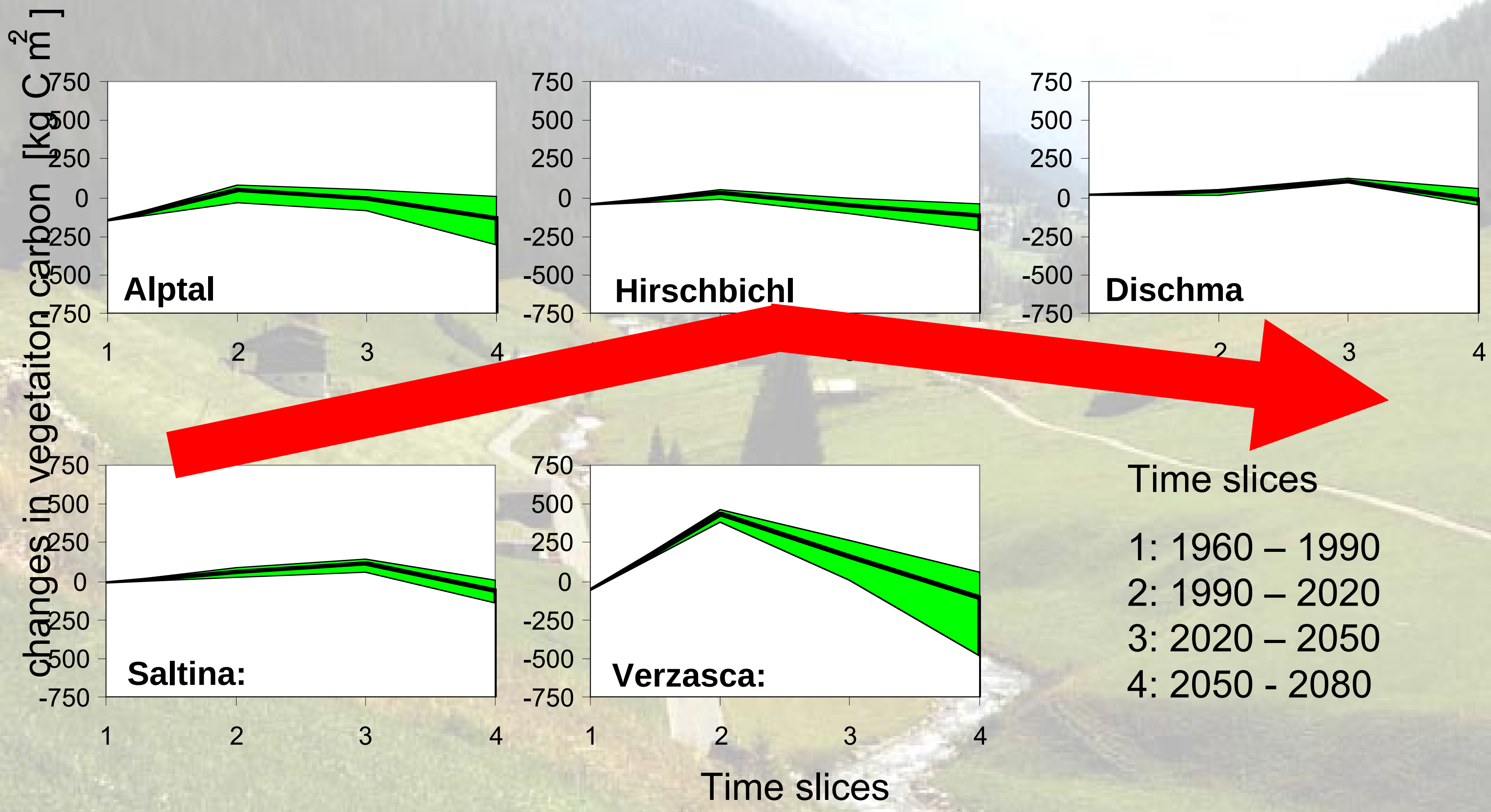
All catchments, change in veg C [kg m^{-2}]



(Zierl & Bugmann, submitted)

All catchments, change in veg C [kg m^{-2}]

without land use change



Time slices

1: 1960 – 1990
2: 1990 – 2020
3: 2020 – 2050
4: 2050 - 2080

(Zierl & Bugmann, submitted)

Carbon storage: conclusions

Dominance of land use over climatic signal in results

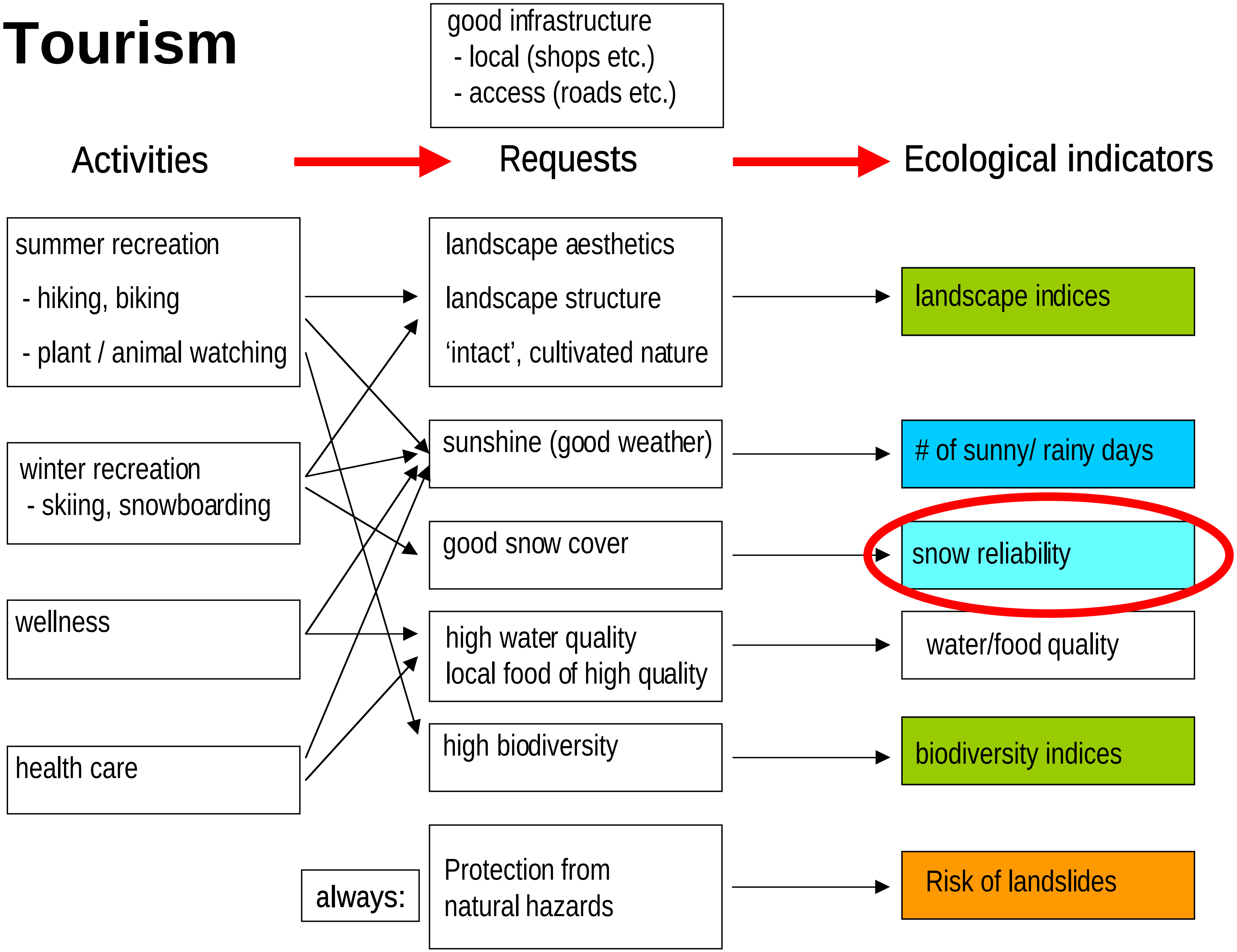
- vegetation carbon at high elevations profits from warming climate throughout most of the 21st century
- vegetation carbon at low elevations decreases
- for several decades no strong difference between scenarios

Stakeholder responses

- increasingly recognized by SHs,
  also in mts
- politically important
- SHs expected that LU changes are more important than climate,
  => our results lead to a differentiated view: scenario & region matter
- large LU changes are going on / may 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.)
  => not considered in our study

Sensitivity of ecosystem services

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 reliability
water/food quality
biodiversity indices
Risk of landslides

Tourism: What is ‘reliable snow cover‘?

Elsasser & Messerli (2001):

- presence of snow cover of >30 cm

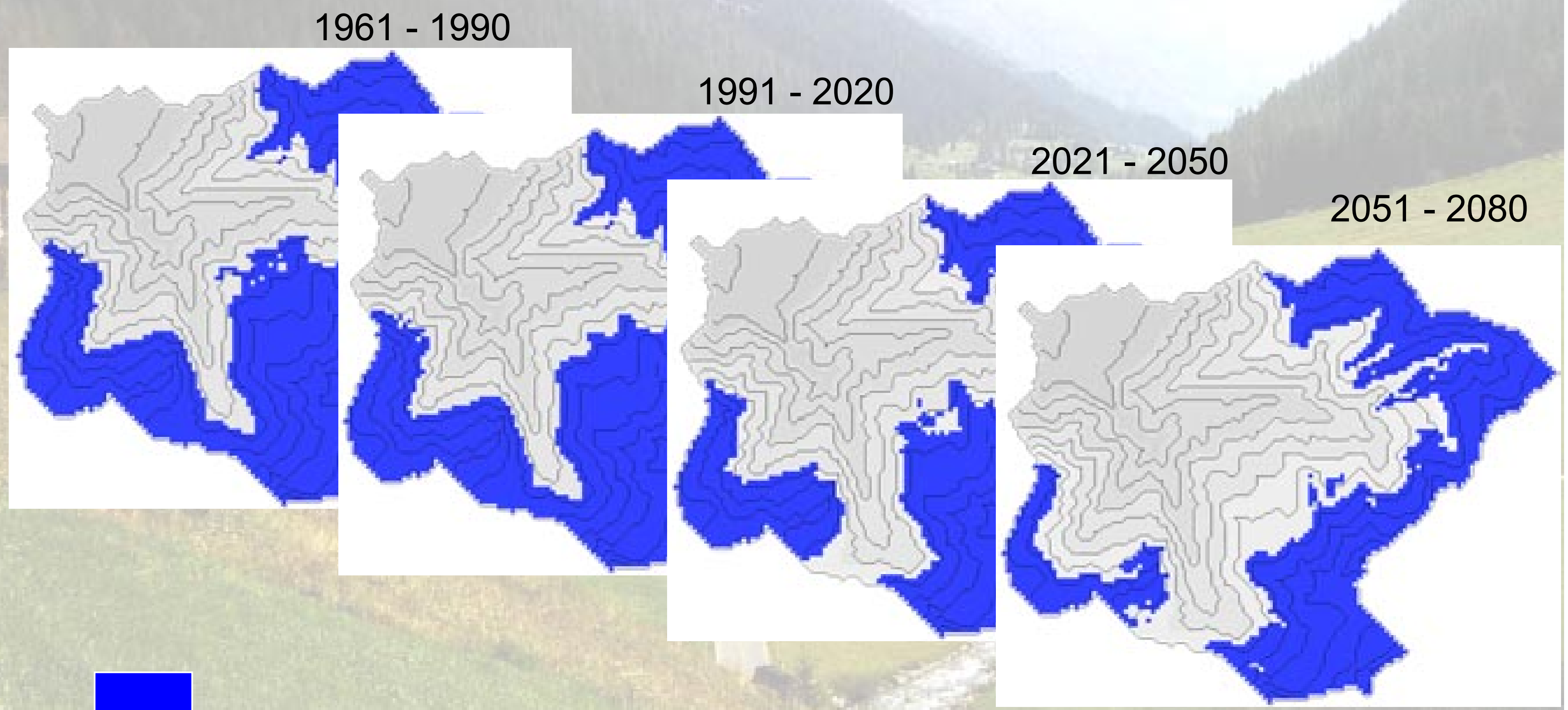
- during at least 100 days in the period 1 December – 15 April

- in 7 out of 10 winters

(Photo by S. Fiore, Keystone)

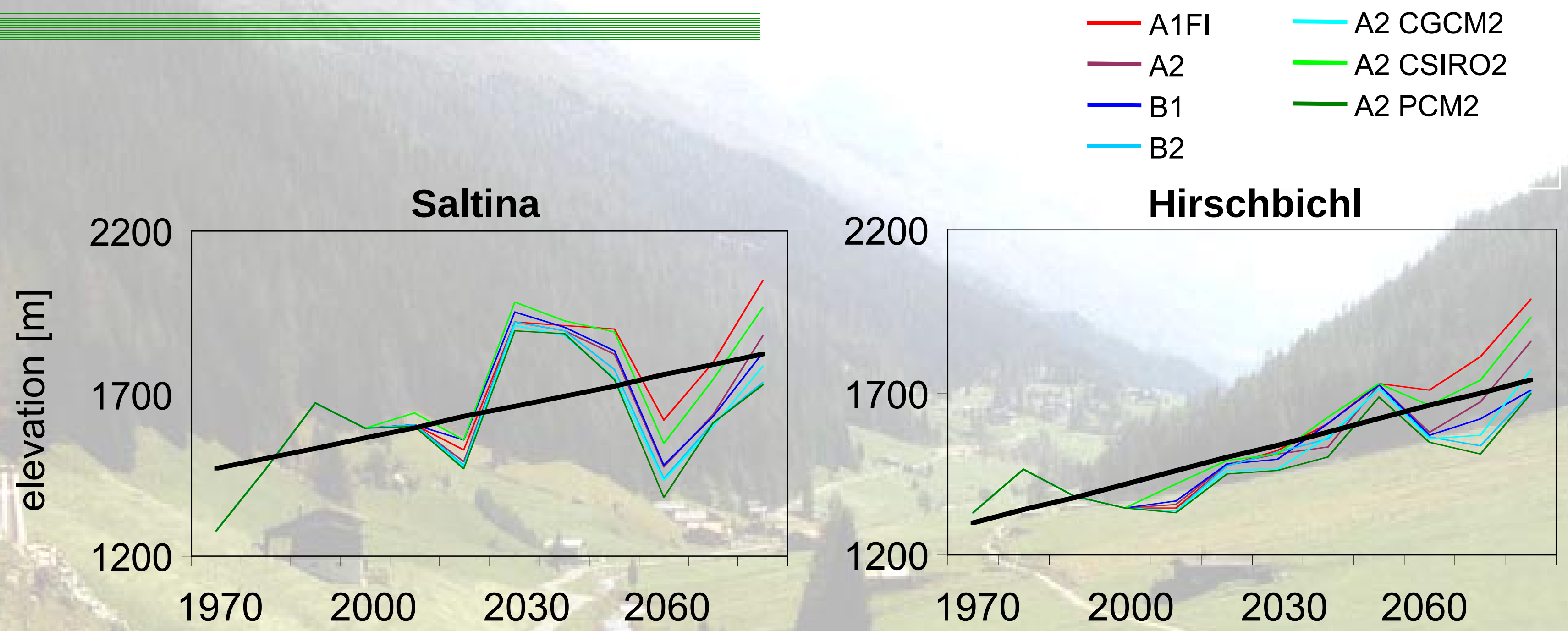
Tourism: reliable snow cover

Saltina, Scenario A1FI HadCM3



reliable snow cover

Tourism: elevation of reliable snow cover



rise of snow line by

320 (220 – 490) m per century   380 (270 – 540) m per century

Tourism: rise of snow line within 100 yrs

Alptal	210 m	160 – 280 m
Hirschbichl	380 m	270 – 540 m
Dischma	210 m	90 – 410 m
Saltina	320 m	217 – 490 m
Verzasca	300 m	200 – 460 m

Tourism: conclusions

Winter

- today 85% of Swiss resorts have reliable snow cover; in future much fewer (≈63%)

- Winners: resorts at high altitudes
- Losers: resorts at altitudes < 1500 m

- Lower winter maintenance costs for communation routes; reduced energy consumption for heating purposes

Summer

- fewer glaciers, loss of attractiveness of high mountain landscapes

- permafrost: loosening of constructions or installations located at high altitudes => increase of maintenance & construction cost

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!
- serious concerns regarding the impacts of global change on tourism, particularly in winter

Conclusions

Conclusions (I)

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

- **Spatial interdependency of processes and systems requires landscape-scale view**

- **Considerable sensitivity of mt ecosys services to global changes:**
  - **short term (10-50 yrs): LU change, N deposition**
  - **long term: (>80 yrs): Climate change**

Conclusions (II)

- **Stakeholder dialogue has been**
  - **important for shaping the design of our project**
  - **useful for providing “real-world” perspective for science**

- **Adaptive capacity and vulnerability:**
  - **varies by service**
    (and by region – only central/eastern Alps considered here!)
  - **water: fairly high vulnerability (undesired changes, adaptive capacity low), depends on specific use of water**
  - **carbon: low vulnerability (desired changes!)**
  - **tourism: in winter high, in summer low vulnerability**


Mountain Ecosystem
Goods and Services
Oops, that was a long one –
Thanks for your attention!
visit http://www.fe.ethz.ch
http://www.pik-potsdam.de/ateam