CLIMATIC DEPENDENCY OF MOUNTAIN SPRINGS: CHALLENGES FOR A SUSTAINABLE GROUNDWATER MANAGEMENT IN THE (SWISS) ALPS

EFG Workshop 22-23 November 2013, Brussels
European Water Policy: challenges for Hydrogeologists

Dr Pierre Christe

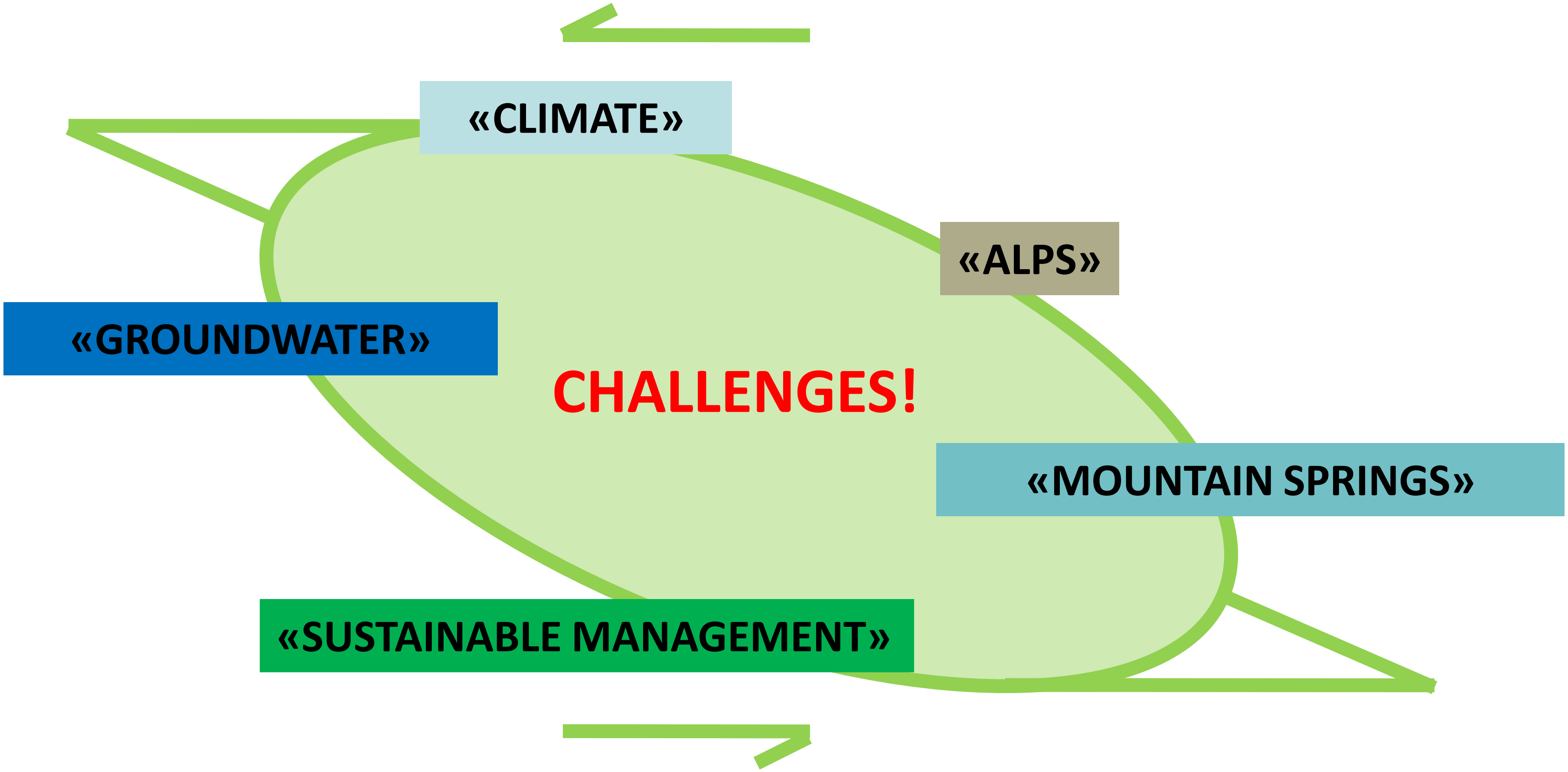
EFG Delegate CHGEOL

Environmental Protection Agency of Canton Valais (Switzerland)

Head Groundwater Group

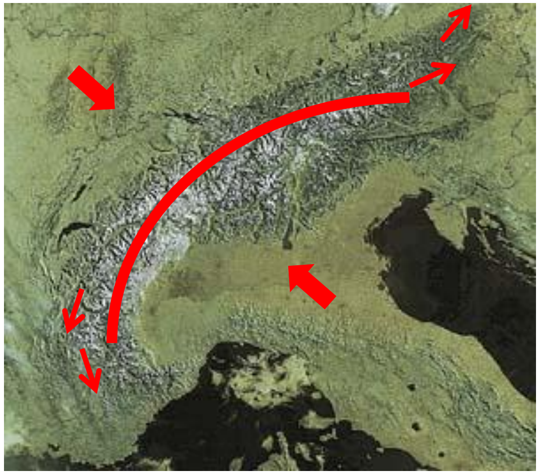
CANTON DU VALAIS
KANTON WALLIS

OUTLINE – WATER IN A DYNAMIC PLANET

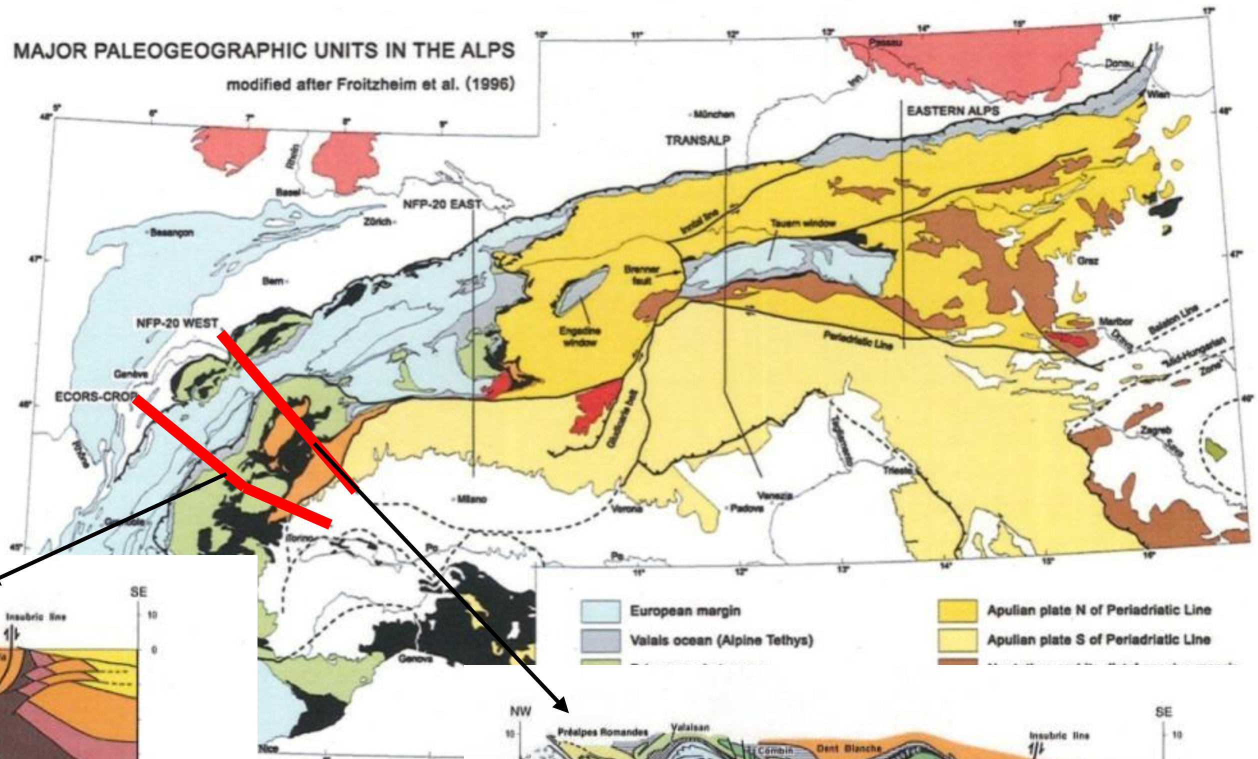


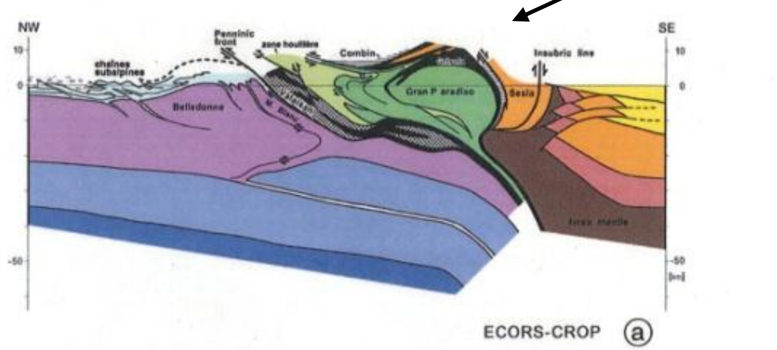
« STRESS – STRAIN RELATIONSHIP »

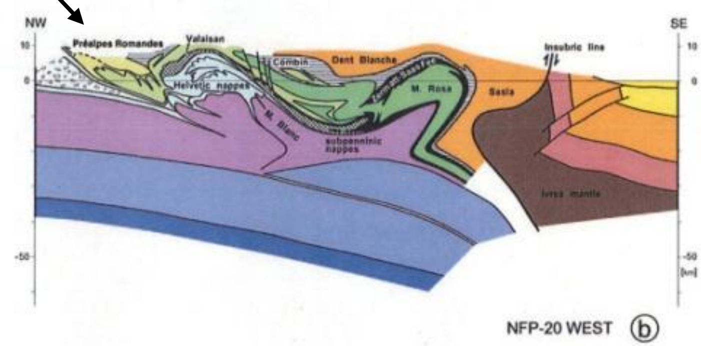
LARGE SCALE PROCESSES (i.e. climate)



Wikipedia





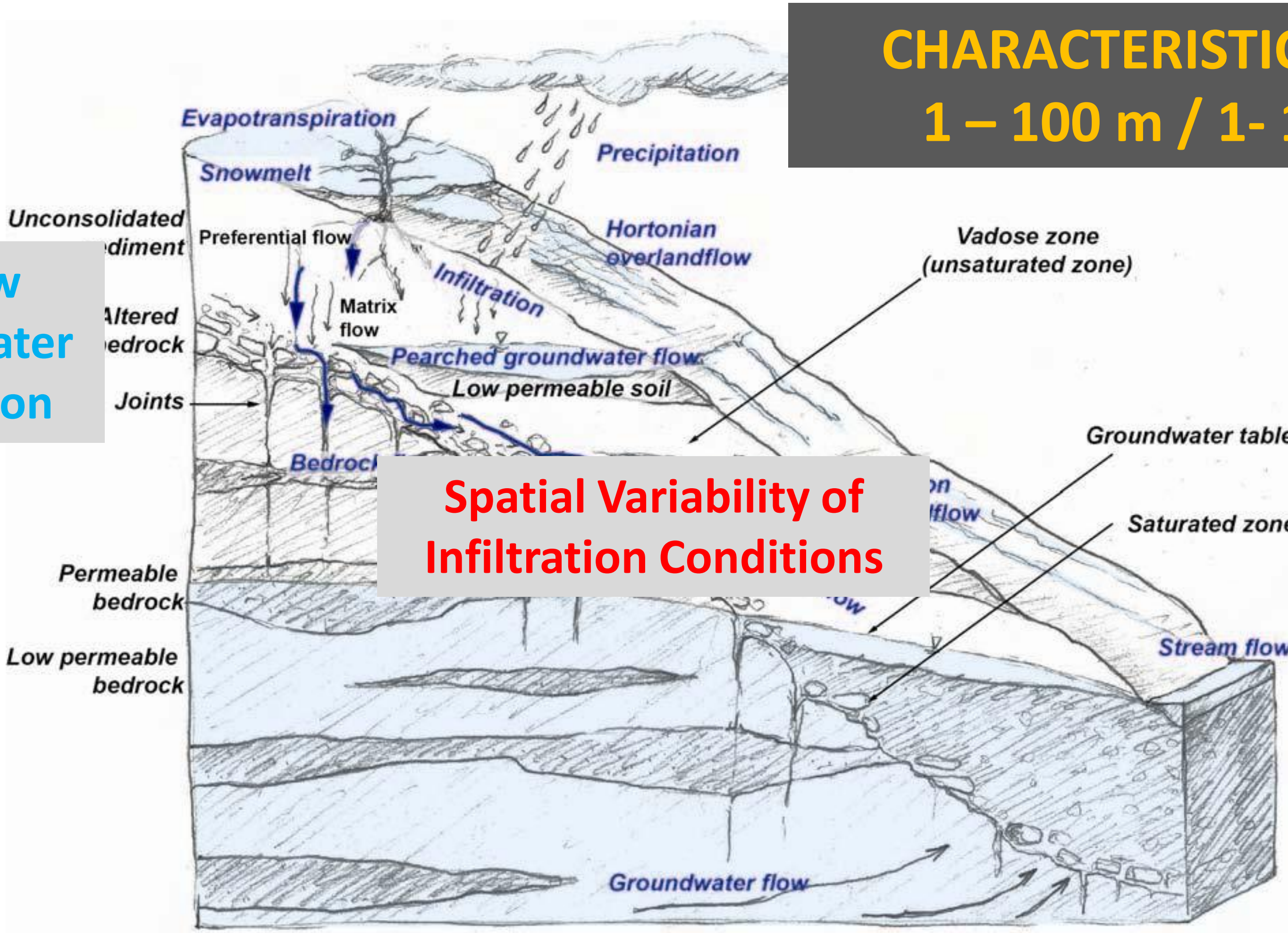


CHARACTERISTIC SCALE:
1 – 100 km / 1- 100 Ma

Schmid et al., 2004

SMALL(er) SCALE PROCESSES (i.e. groundwater)

CHARACTERISTIC SCALE:
1 – 100 m / 1- 100 a !



Shallow groundwater circulation

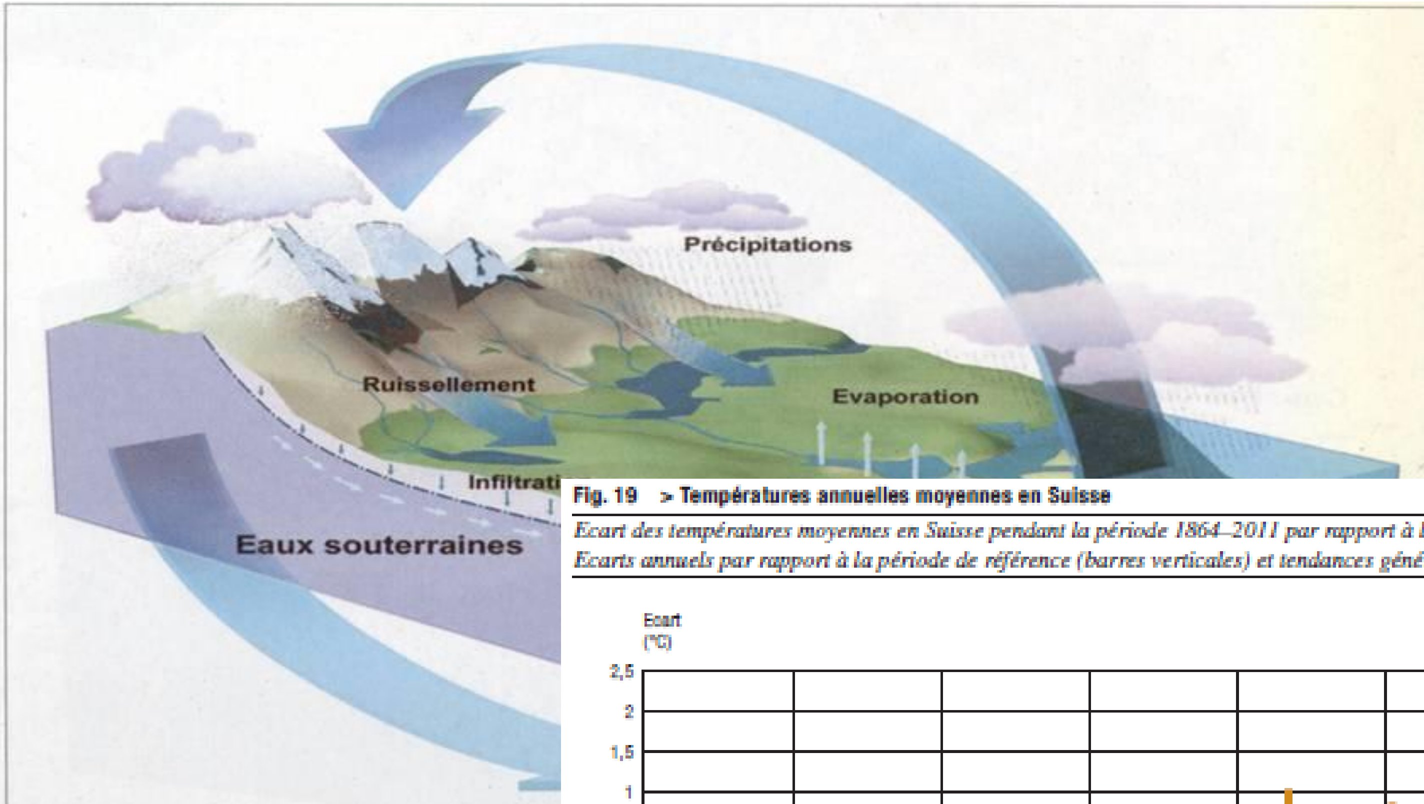
Spatial Variability of Infiltration Conditions

Deep groundwater circulation

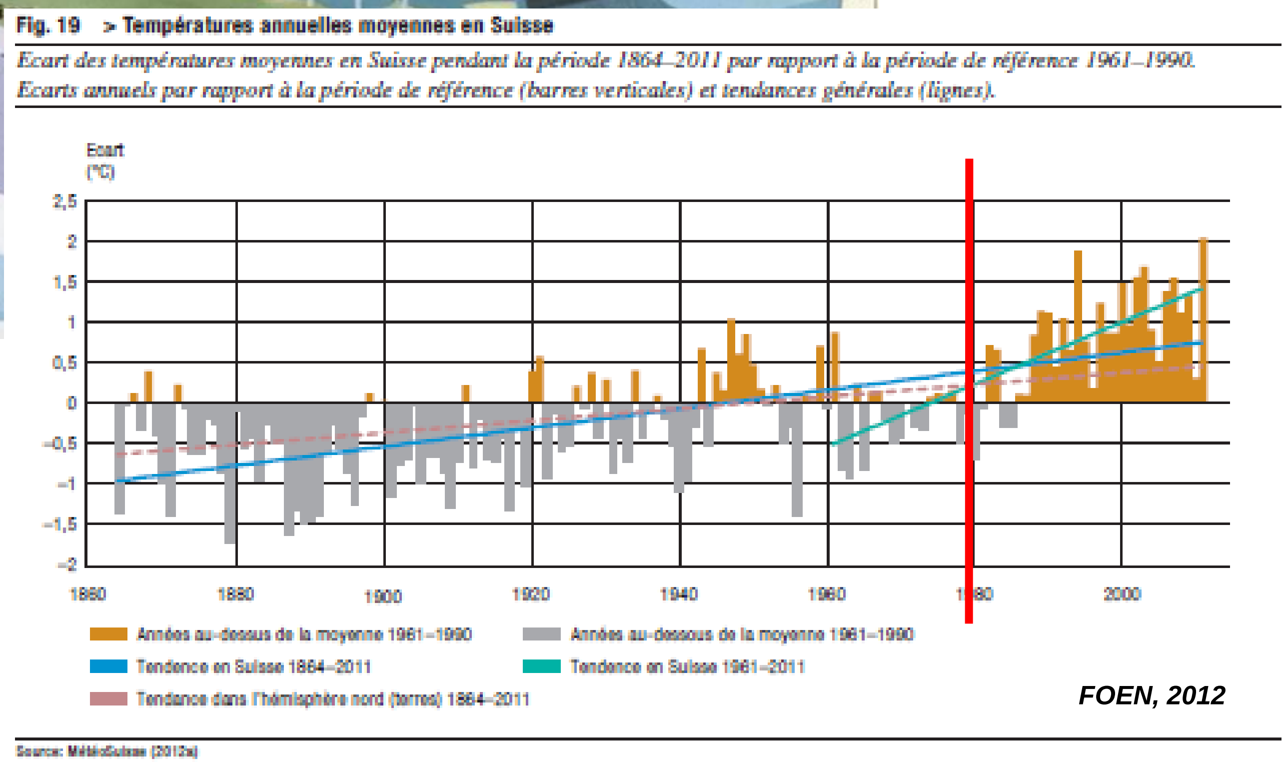
Brönnimann, 2011

SRUCTURAL + GEOLOGICAL CONTROL OF GROUNDWATER FLOW PATHS

THE WATER CYCLE – NOT STEADY OVER TIME



FOEN, 2004



FOEN, 2012

TEMPERATURE:
TREND 1864 - 2011

CLIMATE CHANGE vs. WATER : PROGNOSED IMPACTS

Until 2035

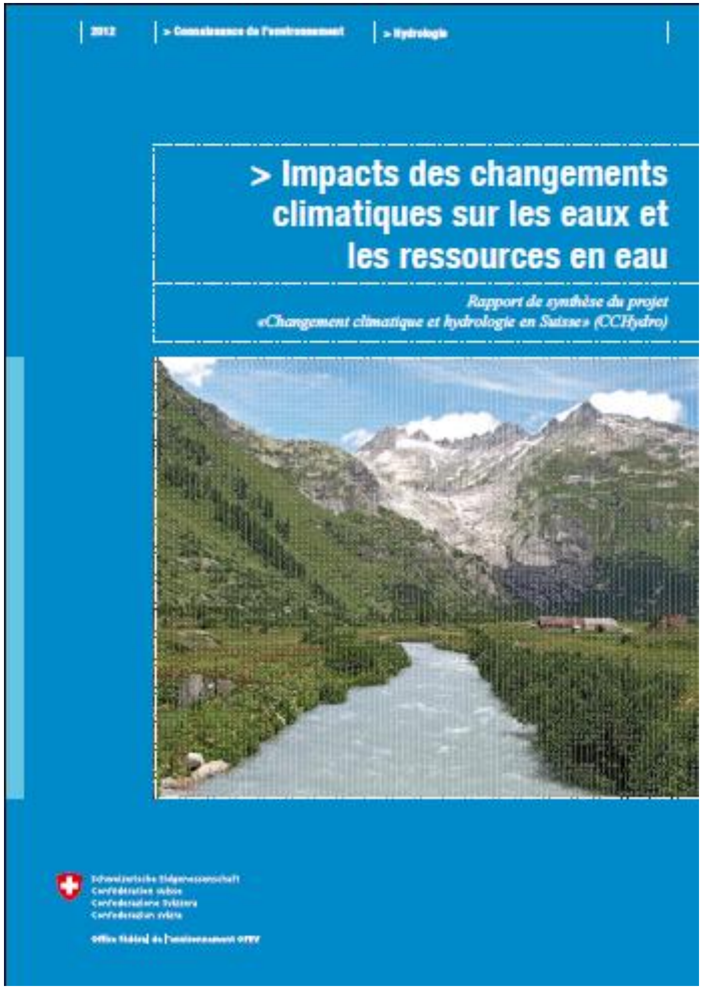
• Slight modification in the annual disponibility of the water ressource

Until 2085

• Slight decrease of both available and renewable water ressources

• Winter increase and summer decrease of inflow rates = drift and/or increased duration of water recharge/drought periods

• Impact on overall outflow rate: flood risk & potential water shortage

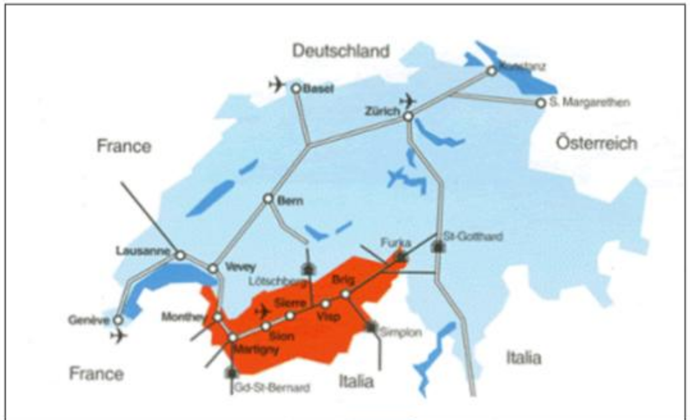


FOEN (2012)

WATER ECONOMY → CONFLICT POTENTIAL

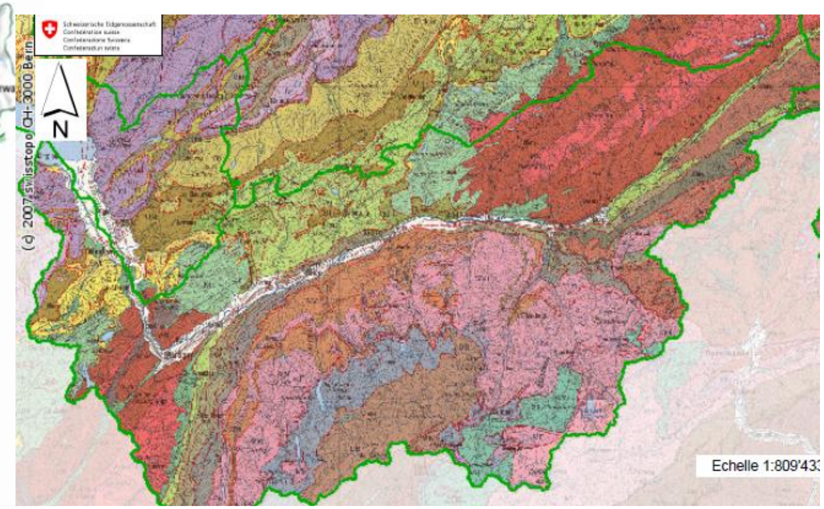
MODIFICATION OF MOUNTAIN SPRING REGIME

CLIMATE CHANGE vs. ALPINE REGIONS



CANTON VALAIS

= « Swiss Field Laboratory » for fundamental research in ***Geology, Tectonics, Paleoclimatology, Glaciology, Sedimentology, Atmospheric Sciences …***



EXPECTED CONFLICTS WITH FOLLOWING WATER USES:

- **Domestic**
- **Industry**
- **Public safety**
  (flood, landslides, rockfalls, erosion)
- **Agriculture**
- **Hydro-electrical production**
- **Geothermal systems**
- **Winter tourism**

GROUNDWATER MANAGEMENT – ACTORS (hydrogeologists)

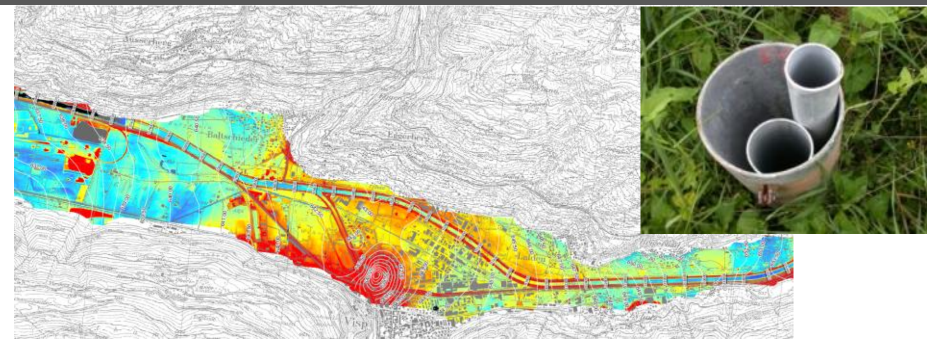
1) GROUNDWATER MONITORING: Quantitative aspects (1980 – present)

CANTON DU VALAIS
KANTON WALLIS

Département des transports, de l'équipement et de l'environnement
Service de la protection de l'environnement
Section protection des eaux

Departement für Verkehr, Bau und Umwelt
Dienststelle für Umweltschutz
Sektion Gewässerschutz

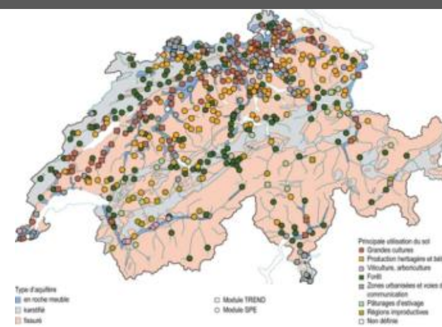
crealp
Centre de recherche sur l'environnement alpin
Zentrum für alpine Umweltforschung
Research center on alpine environment



2) GROUNDWATER MONITORING: Qualitative aspects (2000 – present)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU
Office fédéral de l'environnement OFEV
Ufficio federale dell'ambiente UFAM
Uffizi federal d'ambient UFAM



3) MONITORING OF MOUNTAIN SPRINGS: Quantitative + Qualitative (2010 – present)

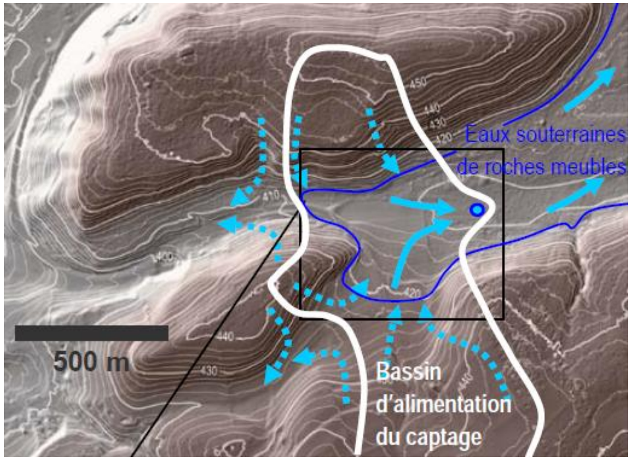
Région Autonome
Vallée d'Aoste
Regione Autonoma
Valle d'Aosta

Département des transports, de l'équipement et de l'environnement
Service de la protection de l'environnement
Section protection des eaux

Departement für Verkehr, Bau und Umwelt
Dienststelle für Umweltschutz
Sektion Gewässerschutz

CANTON DU VALAIS
KANTON WALLIS

GROUNDWATER (SPRING) PROTECTION SWITZERLAND



1

GROUNDWATER
RESSOURCE AVAILABILITY
–
DEFINITION OF
HYDROLOGICAL
ALIMENTATION BASIN

2

GROUNDWATER
RESURGENCE (qualitative +
quantitative constraints)
–
NATURAL SPRINGS,
CATCHMENT

3

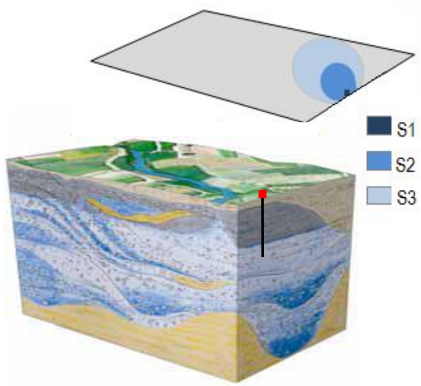
GROUNDWATER
PROTECTION ZONES
S1 – S2 – S3
–
LAND PLANNING
MEASURES & LAND USE
RESTRICTIONS

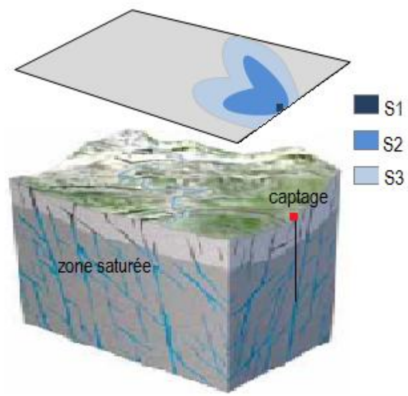
LONG-TERM PROTECTION OF NATURAL DRINKING WATER QUALITY

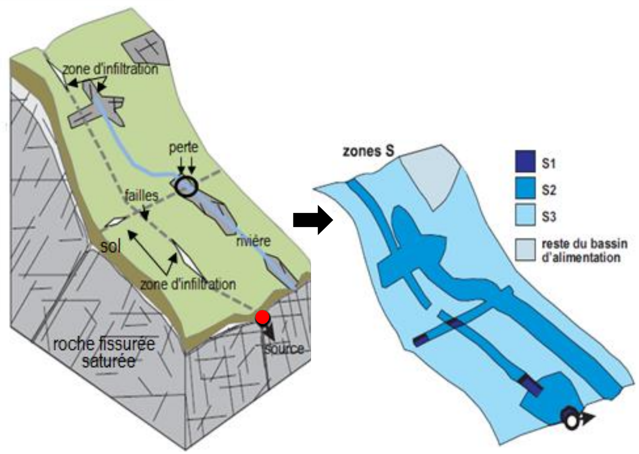
GROUNDWATER (SPRING) PROTECTION SWITZERLAND

VULNERABILITY

DEGREE OF UNCERTAINTY







MEDIA	ISOTROPIC	ANISOTROPIC	HIGHLY HETEROGENEOUS
FLOW PATH	FREE	PREFERENTIAL	MULTIPLE
FLOW VELOCITY	1 - 5 m/day	5 - 10 m/day	30 - 1000 m/h
FLOW CONDITIONS	LAMINAR	LAMINAR	TURBULENT
SIZE OF PROTECTION ZONES	EMPIRICAL OR MATHEMATICAL MODEL (10-day isochrone)	EMPIRICAL OR MATHEMATICAL MODEL (10-day isochrone)	CASE TO CASE APPROACH (hydrodynamical 3D model + risk analysis)
CONFLICT POTENTIAL	LOW	LOW- MEDIUM	HIGH

MOUNTAIN SPRING VULNERABILITY : PRESENT & FUTURE

UNCERTAINTY

IS TODAY'S VULNERABILITY THE ONE OF TOMORROW?

HOW DOES VULNERABILITY OF MOUNTAIN SPRINGS RELATE TO CLIMATE CHA GE?

HOW TO USE « VULNERABILITY » FOR QUALITATIVE OR QUANTITATIV

ARE ALL MOUNTAIN SPRINGS EQUALLY VULNERABLE?

IF NOT, WHY? ARE SOME SPRINGS MORE «RESISTANT» THAN OTHER

WHICH ARE THE CONTROL PARAMETERS?

→ NEEDED OBSERVATION PERIOD TO ANSWER THESE QUESTIONS

STANDARDIZED CHARACTERIZATION OF GROUNDWATER RESSOURCES, COHERENT CONCEPTUAL MODEL

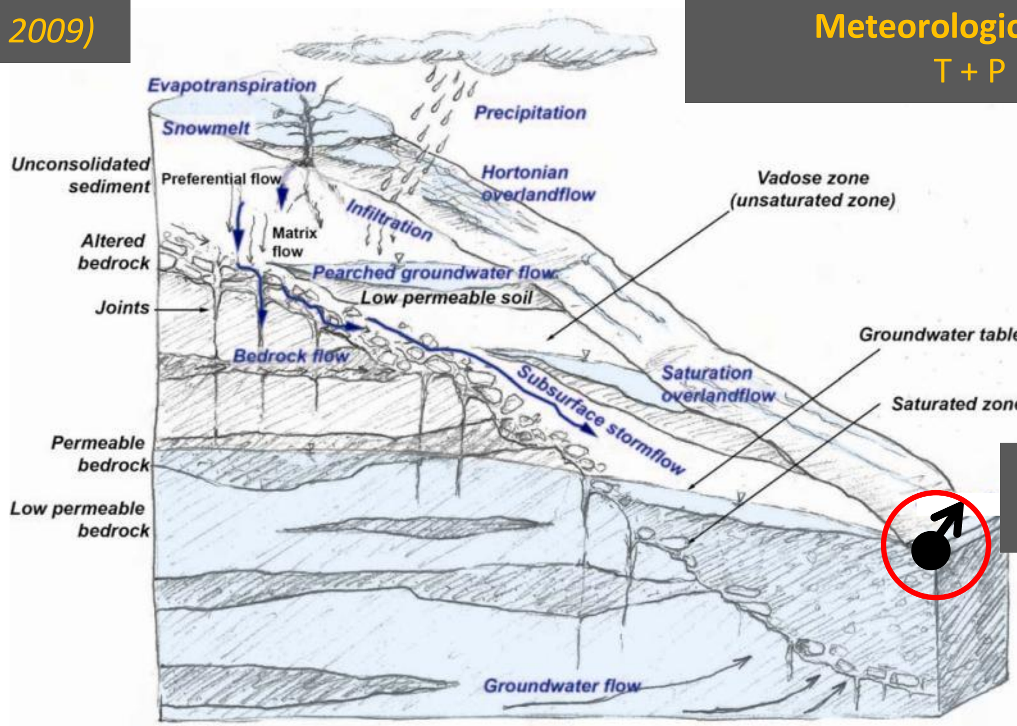
PREDICTION
+
MANAGEMENT

PROJECT STRADA – MOUNTAIN SPRINGS

Combine data together to understand the present and maybe better anticipate the future.
Valorize existing database and stimulate interdisciplinary exchange.

Snow melt - SWE
(Jonas et al. 2009)

Meteorological data
T + P



Physico-chemical parameters
Q + EC + T

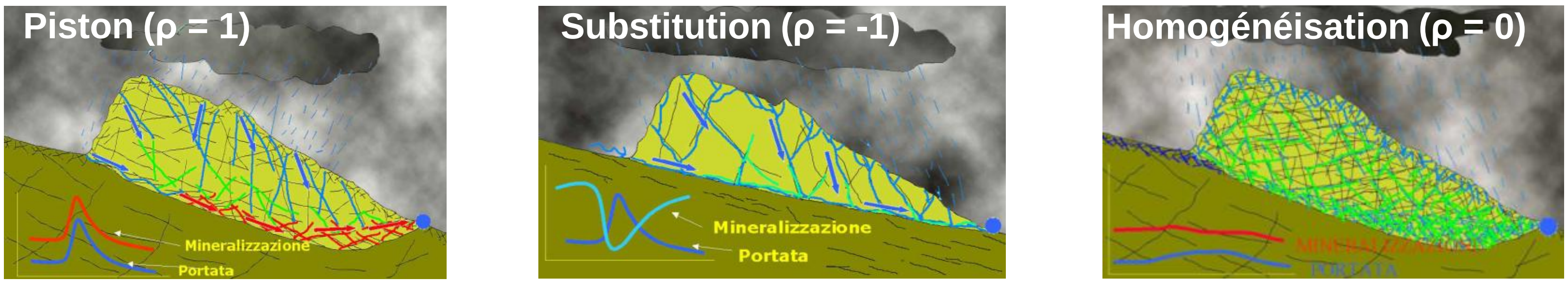
Geological , structural and hydrogeological conditions

Adapted from Brönnimann, 2011

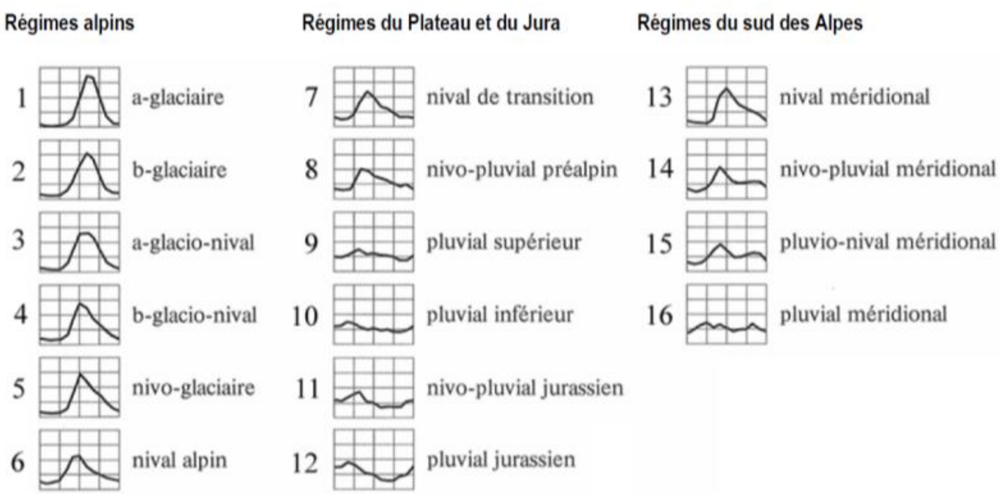
PROJECT STRADA – MOUNTAIN SPRINGS

CHARACTERIZATION OF MOUNTAIN SPRINGS IN VARIOUS HYDROGEOLOGICAL SETTINGS

- → Simple monitoring strategy (physico-chemical parameters)
- → 2 bacteriological analysis per year (auto-control)
- → Cross-correlation hydrogrammes + meteorological events (precipitation + snow-melt)
- → Comparison with generic groundwater regime characteristic of alpine regions



Galleani et al., 2011



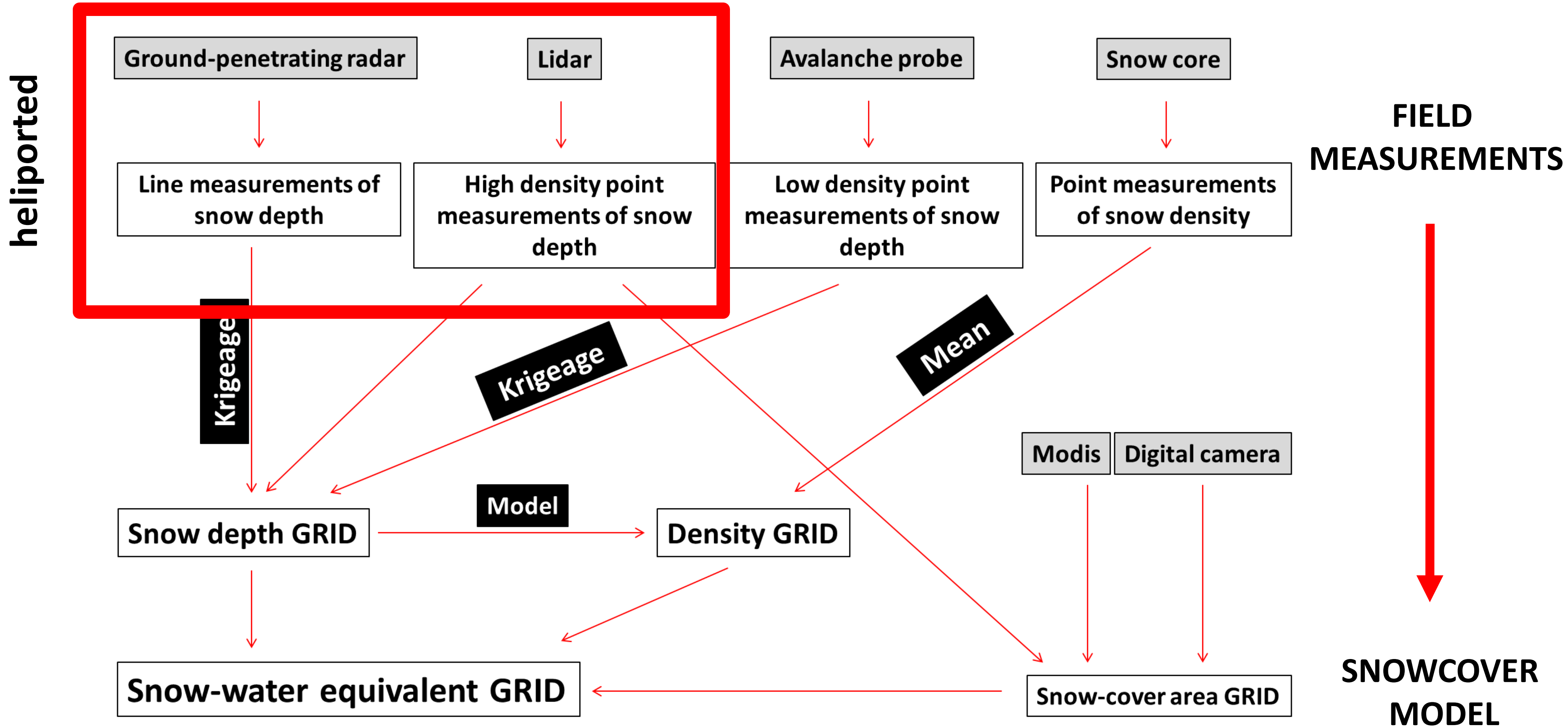
Indicative coefficients (monthly discharge) for 16 characteristic groundwater regime in Switzerland *(FOEN, 2010)*

ARPA Valle d'Aosta GEOSAT SA EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

CANTON DU VALAIS
KANTON WALLIS

PROJECT STRADA – MOUNTAIN SPRINGS

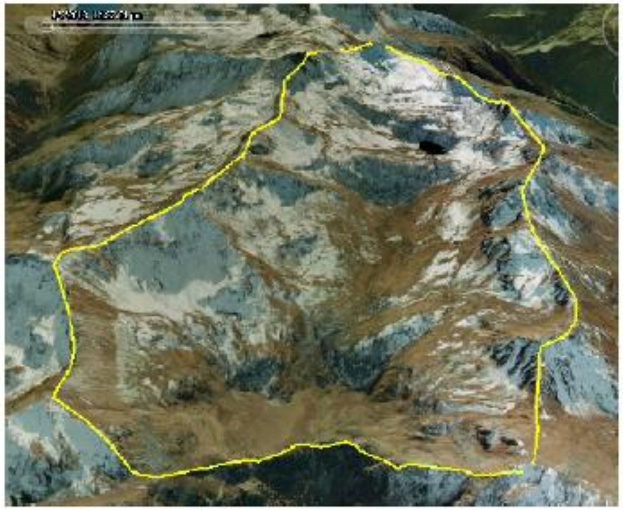
SWE: CONTRIBUTION OF SNOW MELT IN AQUIFER RECHARGE



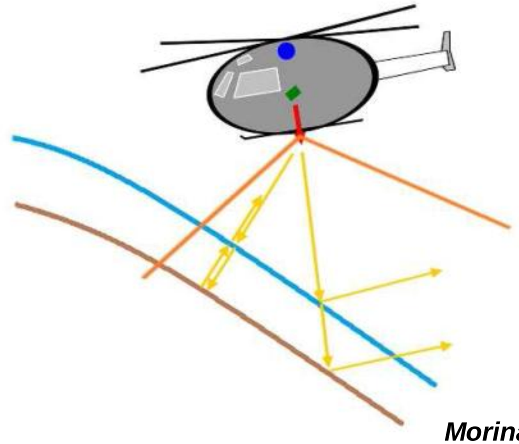
Tavernier, 2013 (CREALP)

PROJECT STRADA – MOUNTAIN SPRINGS

HELIPORTED SNOW-MEASUREMENT CAMPAIGNS 2012 - 2013

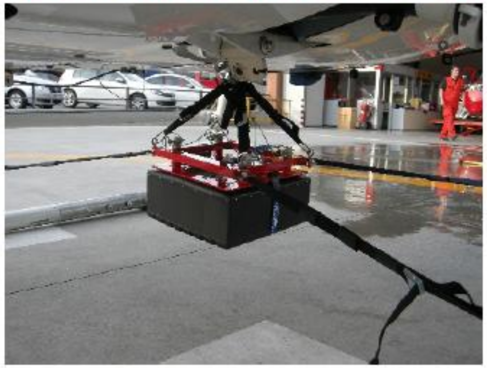


Vallon de Réchy

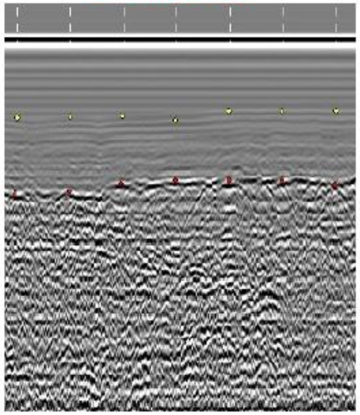


Morina & Milani, 2013 (EPFL)

Système GPR-Hél (antenne 400 MHz)



GPR-Hél data



Test GPR-Hél vs. MAN (Réchy 2013)

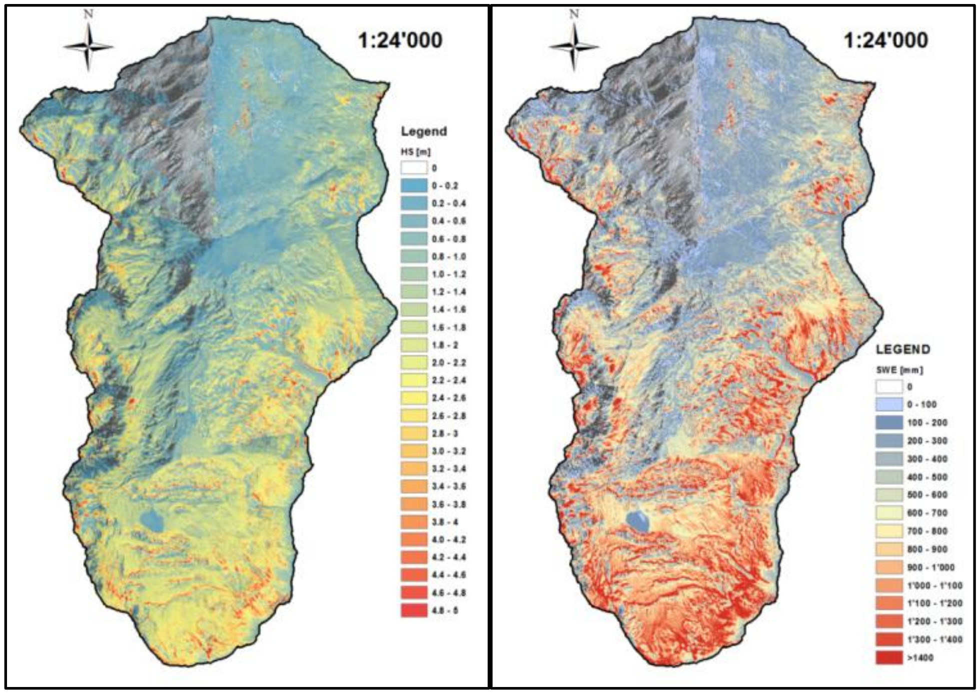
Morradicella, 2013 (ARPA)

STRADA – STRATEGIE DI ADATTAMENTO AI CAMBIAMENTI CLIMATICI PER LA GESTIONE DEI RISCHI NATURALI NEL TERRITORIO TRANSFRONTALIERO | Alpgeo – Hydrogéologie, Eaux minérales, Dangers naturels, Environnement, GEOTHERMIE – Passionnés de géothermie profonde depuis 1987 | chyn – Centre d'hydrogéologie | Politecnico di Torino 1859 1906 | ARPA Valle d'Aosta | GEOSAT SA | EPFL – ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE | CANTON DU VALAIS KANTON WALLIS

PROJECT STRADA – MOUNTAIN SPRINGS

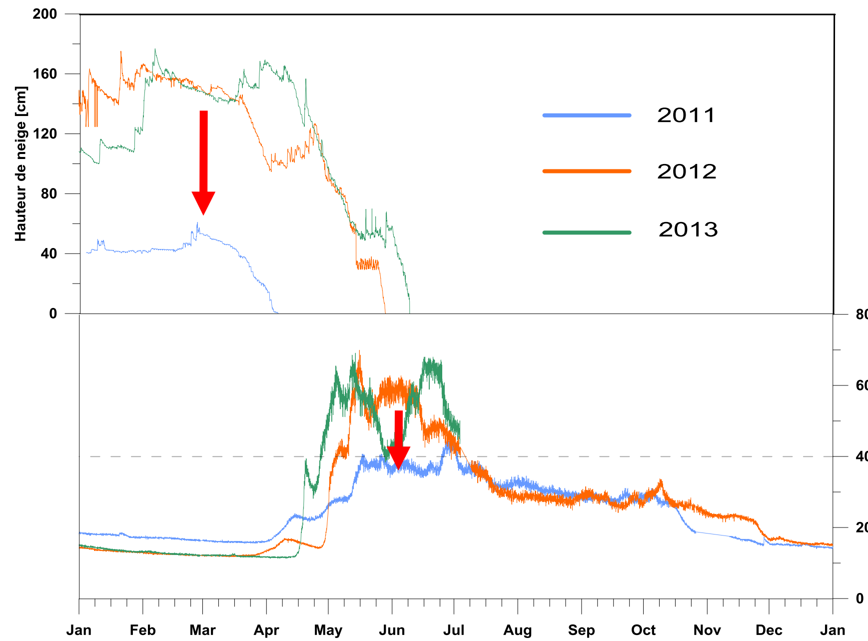
SNOW HEIGHT & SWE: CONFRONTATION WITH SPRING DISCHARGE

LIDAR snow campaign Vallon de Réchy (June 2013)



a) Snow height **b) SWE**

Temporal evolution of snow height (winters 2011 – 2013) and subsequent summer response of spring discharge (La Lé).



Tavernier, 2013 (CREALP)

STRADA STRATEGIE DI ADATTAMENTO AI CAMBIAMENTI CLIMATICI PER LA GESTIONE DEI RISCHI NATURALI NEL TERRITORIO TRANSFRONTALIERO

Alpgeo — Hydrogéologie, Eaux minérales, Dangers naturels, Environnement, GEOTHERMIE — Passionnés de géothermie profonde depuis 1987

chyn Centre d'hydrogéologie

Politecnico di Torino 1859 1906

ARPA Valle d'Aosta

GEOSAT SA

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

CANTON DU VALAIS KANTON WALLIS

PROJECT STRADA – MOUNTAIN SPRINGS

DIFFERENT VULNERABILITY DETERMINATIONS AND « RESISTANCE » INDICATORS

Source	Type d'aquifère	Mode d'écoulement	Risque de pollution		Résistance aux changements climatiques		Résistance sécheresse	Risque de tarissement
			VESPA	Risque	Indice	Résistance	Coef. de tarissement	
La Lé	Poreux hétérogène	Substitution - piston	5.7	Elevé	9.1	Moyenne	0.0069	Moyen terme
La Brocard	Fissuré	Homogénéisation	0.026	Faible	5	Élevée	0.0004	Long terme
La Vouette	Fissuré	Homogénéisation	0.006	Faible	6	Élevée	0.0022	Moyen à long terme
Pierrier de Visse	Karstique	Substitution	1.78	Élevé	11	Faible	0.0138	Court terme
BaltschiederBrun1	Fissuré hétérogène	Substitution	5.14	Élevé	10.7	Faible	0.0146	Court terme

1 Vulnerability to pollution

2 Vulnerability to climate change and droughts

STRADA — Strategie di adattamento ai cambiamenti climatici per la gestione dei rischi naturali nel territorio transfrontaliero
Alpgeo — Hydrogéologie, Eaux minérales, Dangers naturels, Environnement, GEOTHERMIE — Passionnés de géothermie profonde depuis 1987
chyn Centre d'hydrogéologie
Politecnico di Torino 1859 1906
ARPA Valle d'Aosta
GEOSAT SA
EPFL École Polytechnique Fédérale de Lausanne
Canton du Valais Kanton Wallis

CHARACTERIZATION OF MOUNTAIN SPRINGS

INDEX TO QUANTIFY THE « SPRING RESISTANCE TO CLIMATE CHANGE»

Function of ***hydrological alimentation basin***, ***available water*** (ice, snow, rain), ***aquifer type*** and its ***storage capacity*** (e.g. effective porosity, volume, etc).

Indice de résistance aux changements climatiques (v)	Résistance
v ≥ 13	Très faible
13 > v ≥ 10	Faible
10 > v ≥ 7	Moyenne
7 > v ≥ 4	Élevée
v < 4	Très élevée

PARAMÈTRES	SCORE DE VULNERABILITE						Pondération
		score		score		score	
TYPE D'AQUIFERE	POREUX	1	FISSURAL	3	KARSTIQUE	5	-
TAILLE BASSIN D'ALIMENTATION (km^2)	LIMITEE (<4)	5	MOYENNE (4-7)	3	IMPORTANTE (>7)	1	-
STOCK D'EAU ($Ø_e$ ou S [m^{-1}] K [m/s] Dimensions aquifère	FAIBLE (Ø < 10) (K > 10^{-2}) Restreinte	5	MOYENNE (10 <Ø < 15) (10^{-2}> K > 10^{-5}) Moyenne	3	IMPORTANTE (Ø > 15) (K < 10^{-5}) Importante	1	0 à 1
PLUVIOMETRIE ANNUELLE (mm)	FAIBLE (<600)	5	MOYENNE (600-800)	3	FORTE (>800)	1	0 à 1
SURFACE ENGLACEE (km^2)	LIMITE (<4)	5	MOYEN (4-8)	3	ETENDU (>8)	1	0 à 1
HAUTEUR DE NEIGE MOYENNE ANNUELLE (cm)	RESTREINT (<50)	5	MOYEN (50-150)	3	IMPORTANT (>150)	1	0 à 1

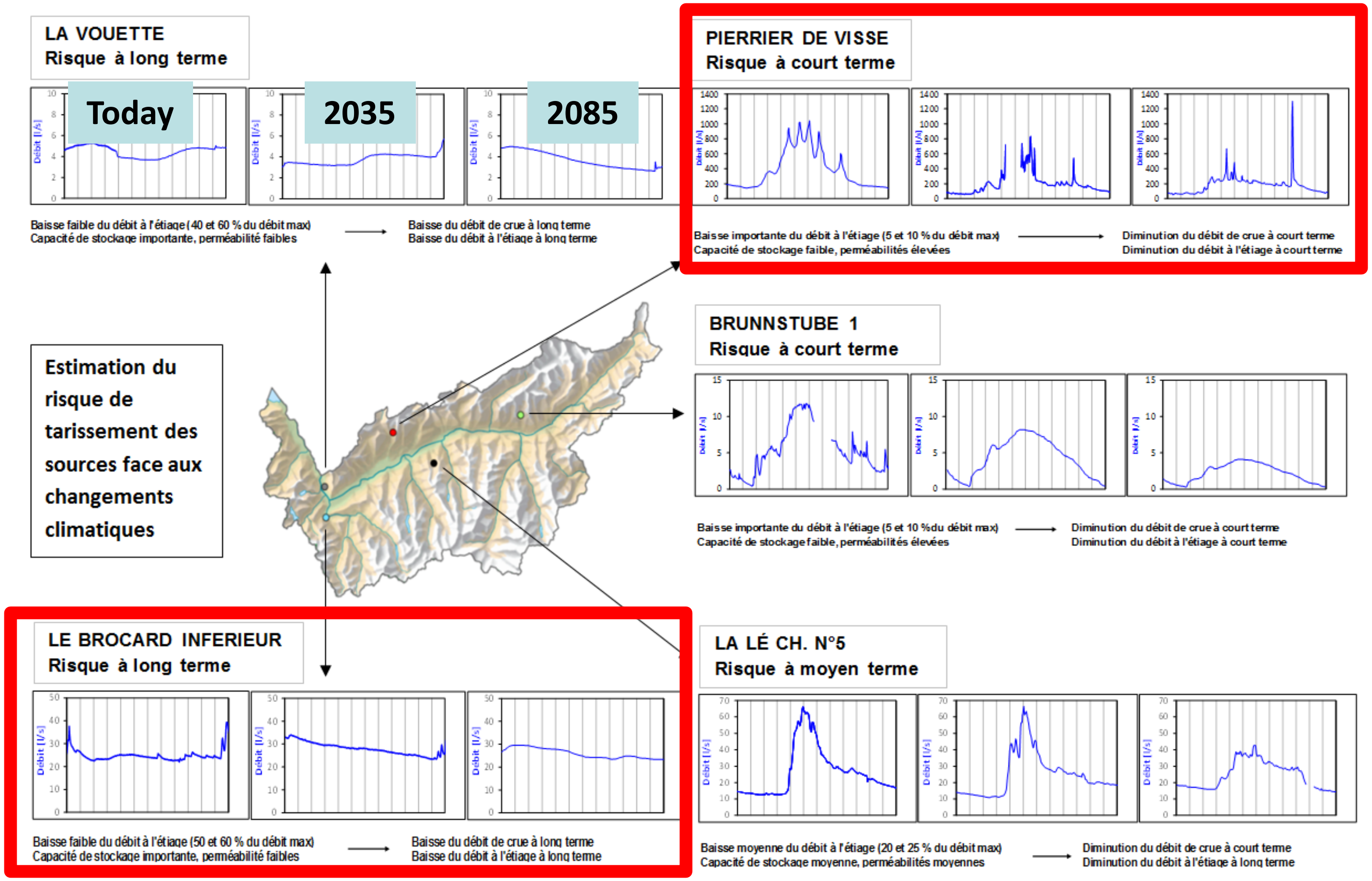
1

STRADA — Strategie di adattamento ai cambiamenti climatici per la gestione dei rischi naturali nel territorio transfrontaliero
Alpgeo — Hydrogéologie, Eaux minérales, Dangers naturels, Environnement, GEOTHERMIE — Passionnés de géothermie profonde depuis 1987
chyn — Centre d'hydrogéologie
Politecnico di Torino 1859 1906
ARPA Valle d'Aosta
GEOSAT SA
EPFL — École Polytechnique Fédérale de Lausanne
Canton du Valais Kanton Wallis

CHARACTERIZATION OF MOUNTAIN SPRINGS

PROBABILISTIC EVOLUTION OF MOUNTAIN SPRING REGIMES

Evaluation of short and long term risks



Low resistance

High resistance

STRADA — STRATEGIE DI ADATTAMENTO AI CAMBIAMENTI CLIMATICI PER LA GESTIONE DEI RISCHI NATURALI NEL TERRITORIO TRANSFRONTALIERO

Alpgeo — Hydrogéologie, Eaux minérales, Dangers naturels, Environnement, GEOTHERMIE — Passionnés de géothermie profonde depuis 1987

chyn — Centre d'hydrogéologie

Politecnico di Torino 1859 1906

ARPA Valle d'Aosta

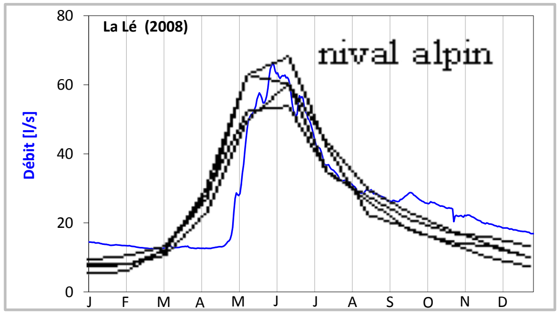
GEOSAT SA

EPFL — ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

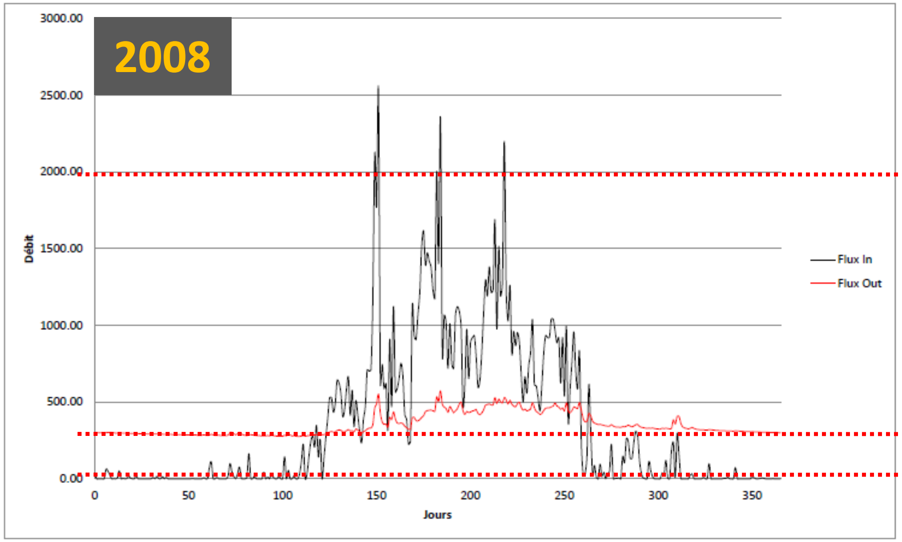
CANTON DU VALAIS
KANTON WALLIS

CHARACTERIZATION OF MOUNTAIN SPRINGS

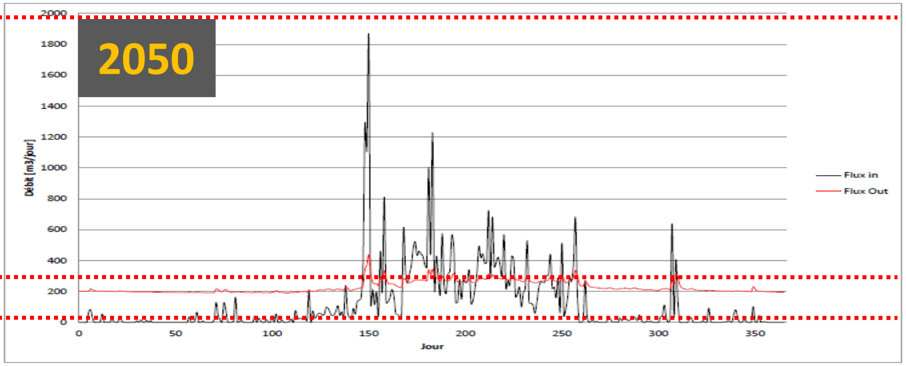
REGIONAL MODELLING OF THE SENSITIVITY OF ALPINE AND PERIALPINE HYDROGEOLOGICAL SYSTEMS TO CLIMATE CHANGE



Annexe 20 : Bilan hydraulique annuel du modèle alpin, 2008



Annexe 30 : Bilan hydraulique annuel du modèle alpin, 2050



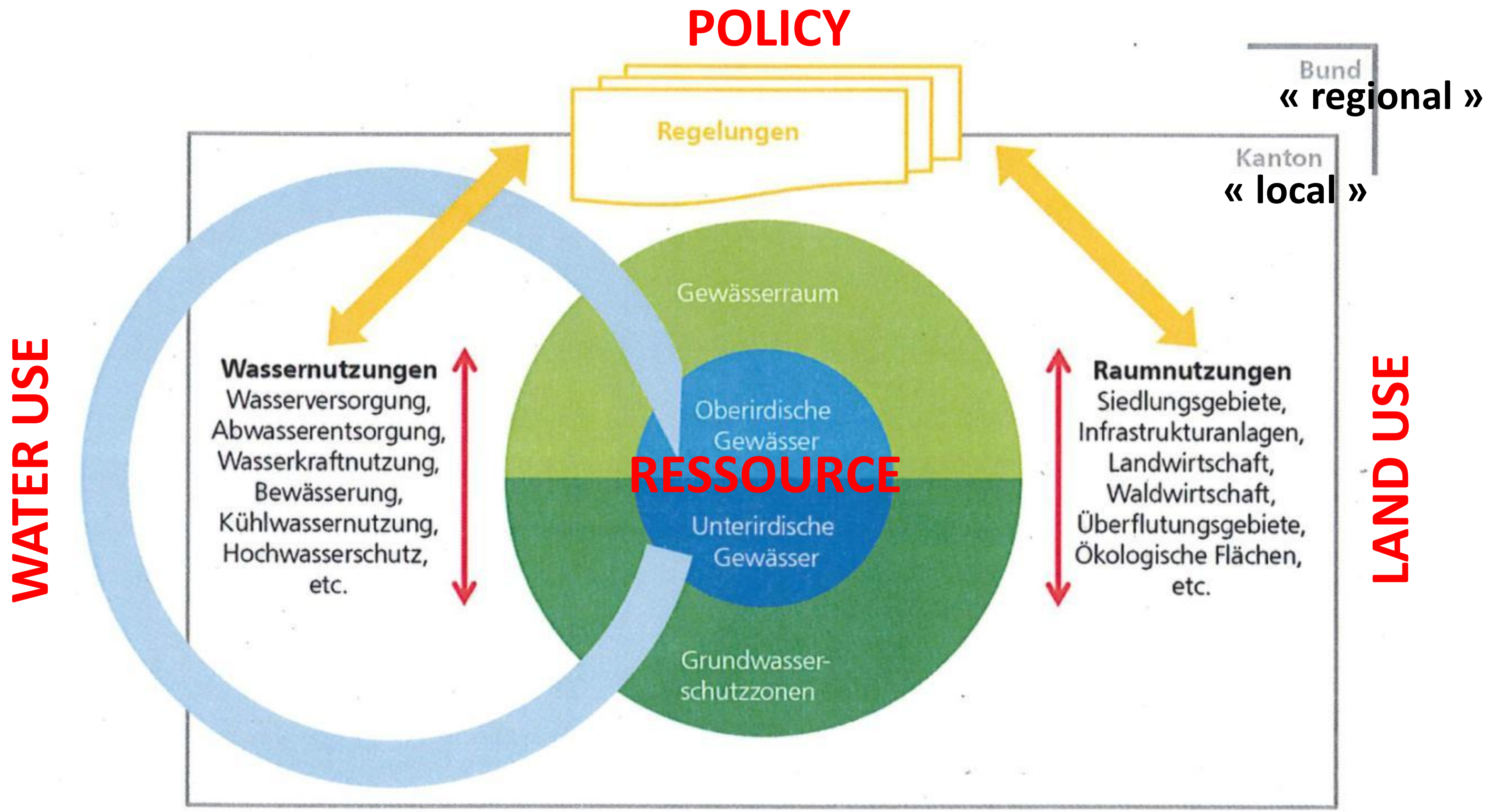
GEOLEP, 2011 (EPFL)

LOSS OF GLACIAL CONTRIBUTION

PROGRESSIVE LOSS OF NIVAL REGIME

CLIMATE CHANGE vs. GROUNDWATER

SUSTAINABLE POLITICAL MANAGEMENT – WATER ECONOMY MODEL



IWAGO, 2012

VULNERABILITY: GROUNDWATER RESSOURCES OR SOCIETY?

CLIMATE CHANGE vs. GROUNDWATER

GROUNDWATER MANAGEMENT: CYCLIC AND NOT LINEAR TASK!