

# The Consequences of Climate Change in the Alps

# Structure

- **The Alps: What is Changing?**
- **Floods and Sediments: New Sources and More Mobility**
- **Discharge: Why Seasonality is so Important**
- **Droughts: What does History tell us ?**
- **Adaptation and Best Practice: The Past and the Future**

# Glacier Retreat



Photo: Hagenmuller

# Lake formation



*Photo: Hagenmuller*

# Colonization of Moraines by Forest



**Plant species discovered 1500 m above highest limit  
(Mont Blanc, germinated during drought 1976 or 2003)**



# Lakes and wetlands before



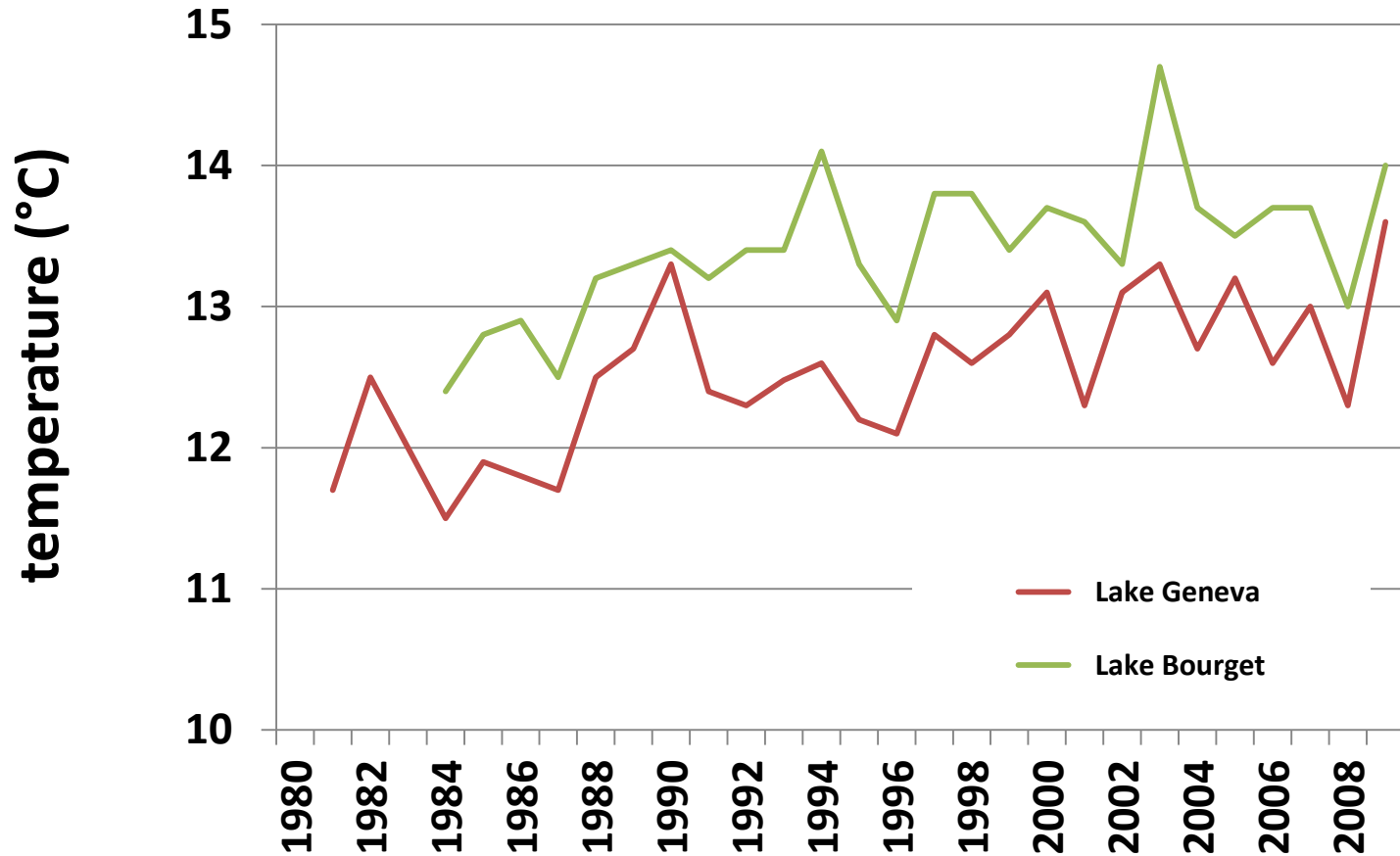
*Photo: MacArthur*

and after.....





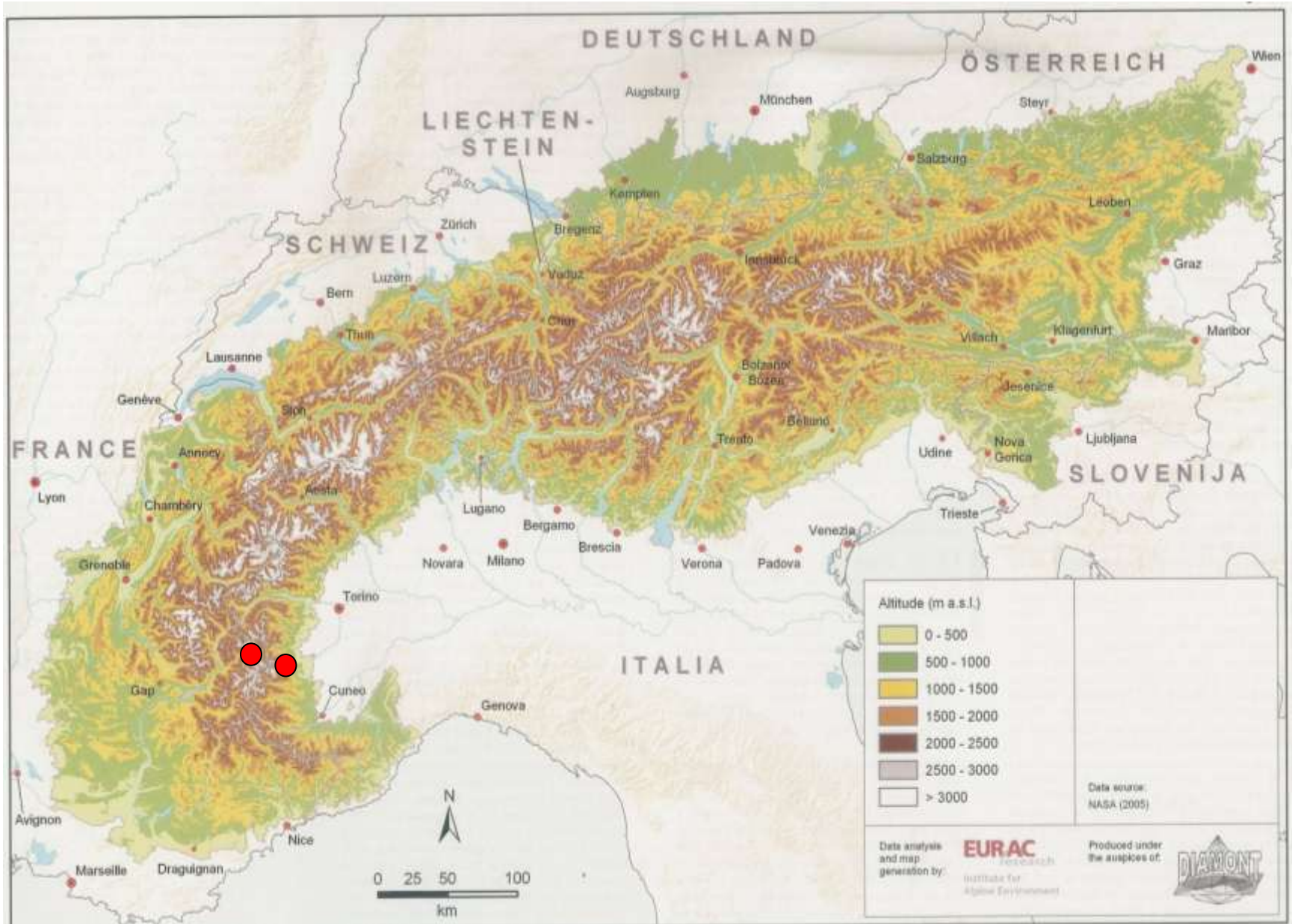
# Alpine Lakes are Warming



*(after INRA)*

# **Floods and Sediments: New Sources and More Mobility**

# Transboundary examples from Italy and France

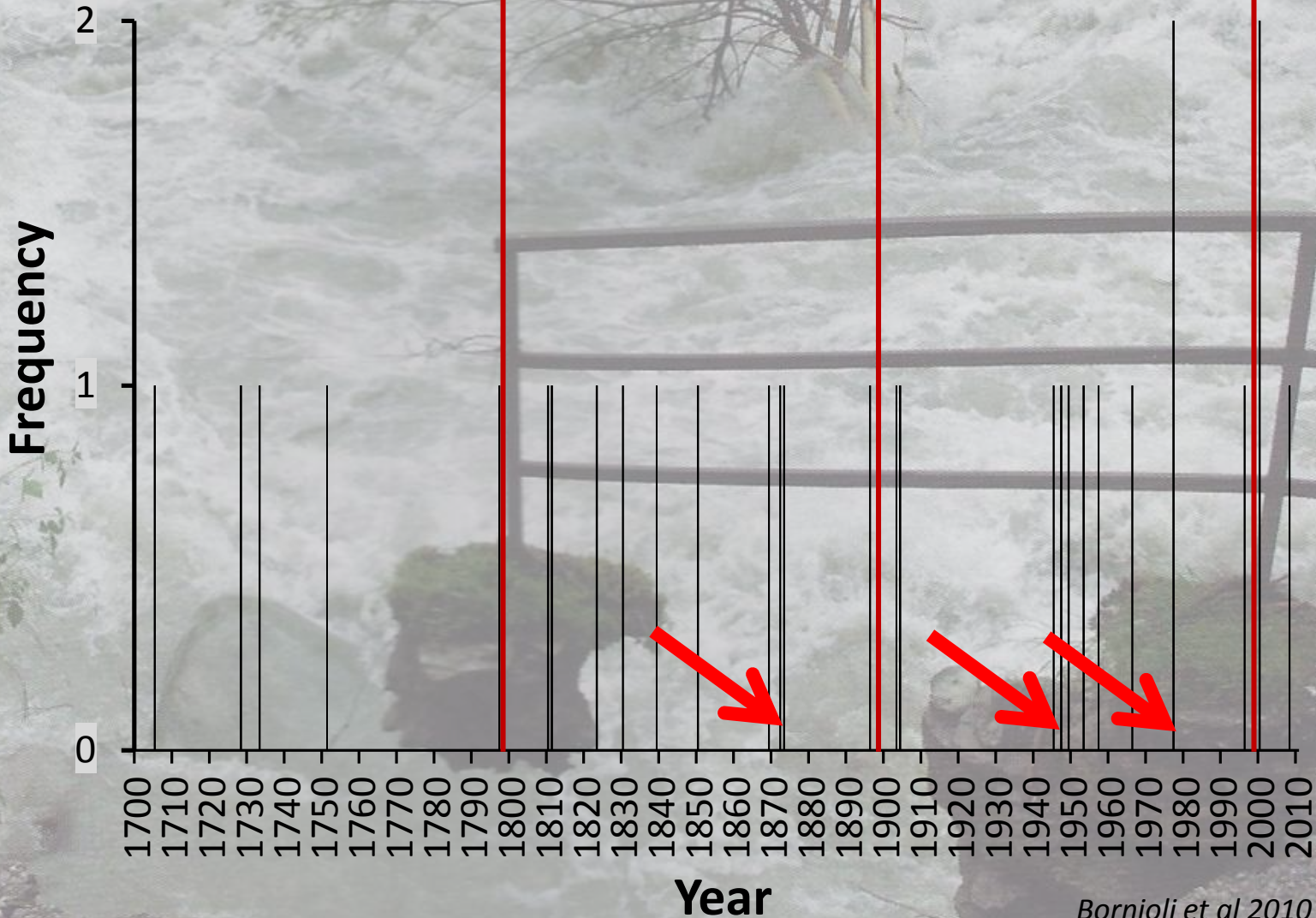


# The Po source

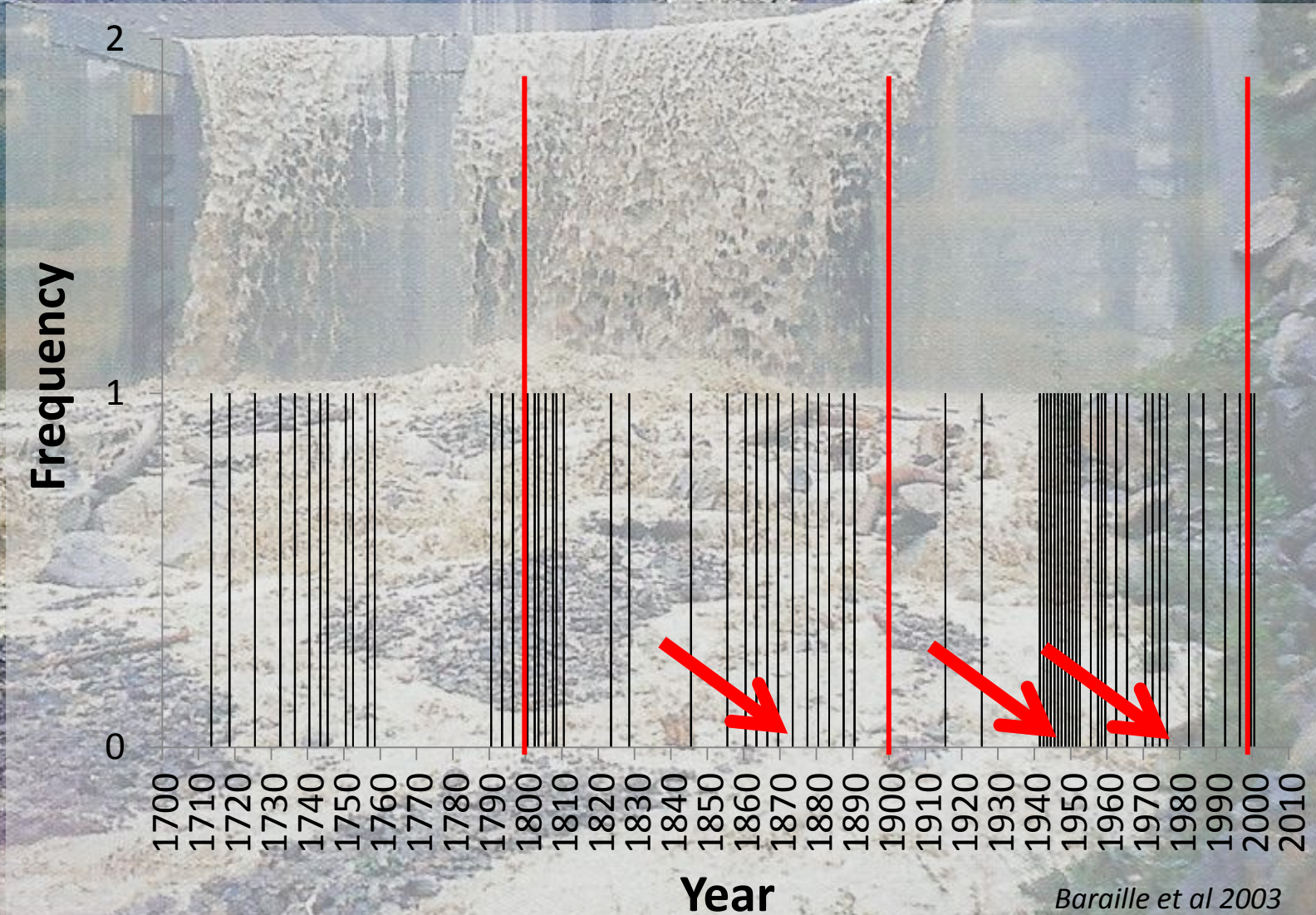


# Frequency of Floods in Upper Po since 1700

(Sanghione)

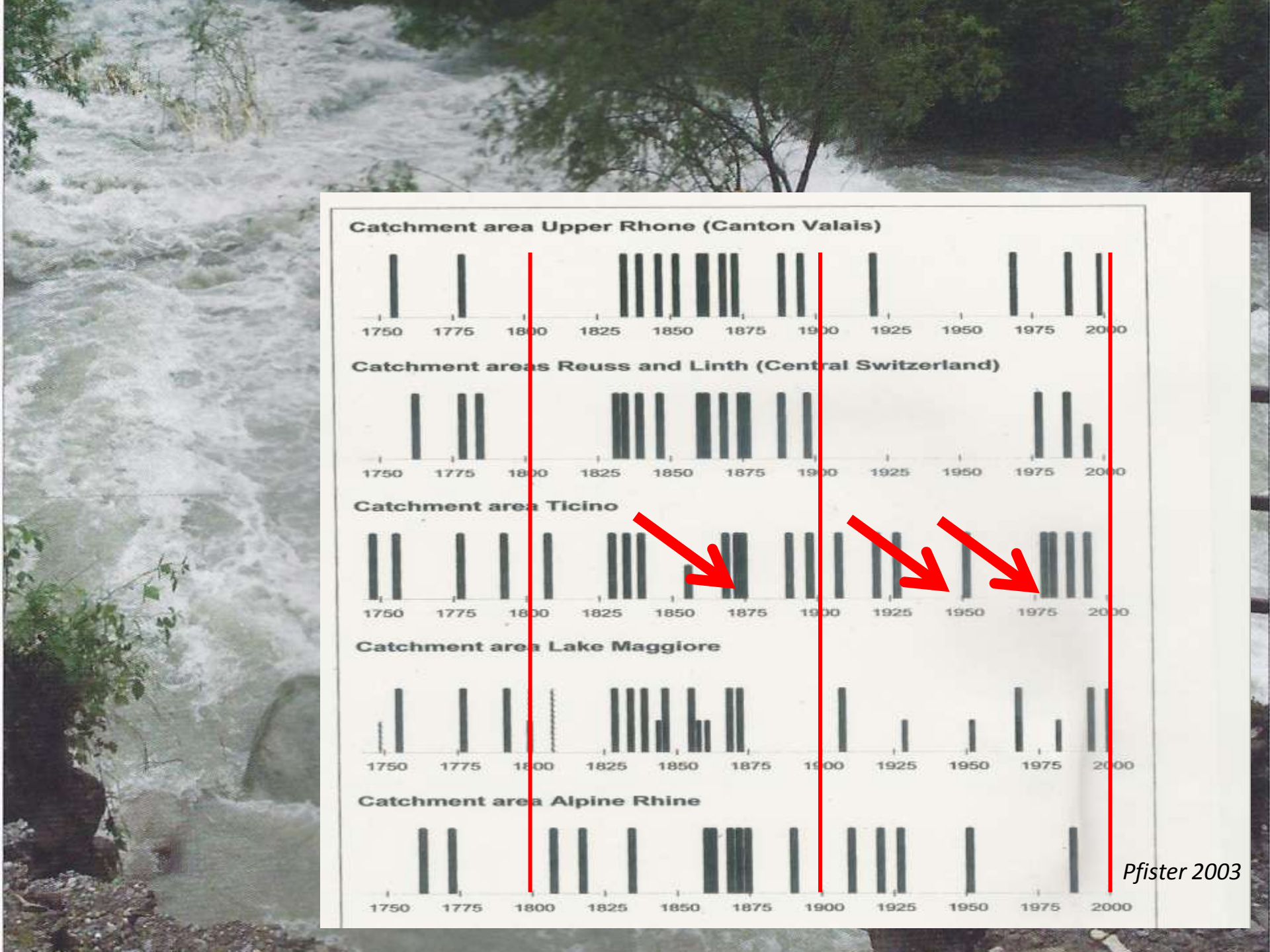


# Frequency of Floods in Upper Durance since 1700



Baraille et al 2003

Photo: Lestournelle



# More rockfalls and instability



*Photo: de Jong 2011*

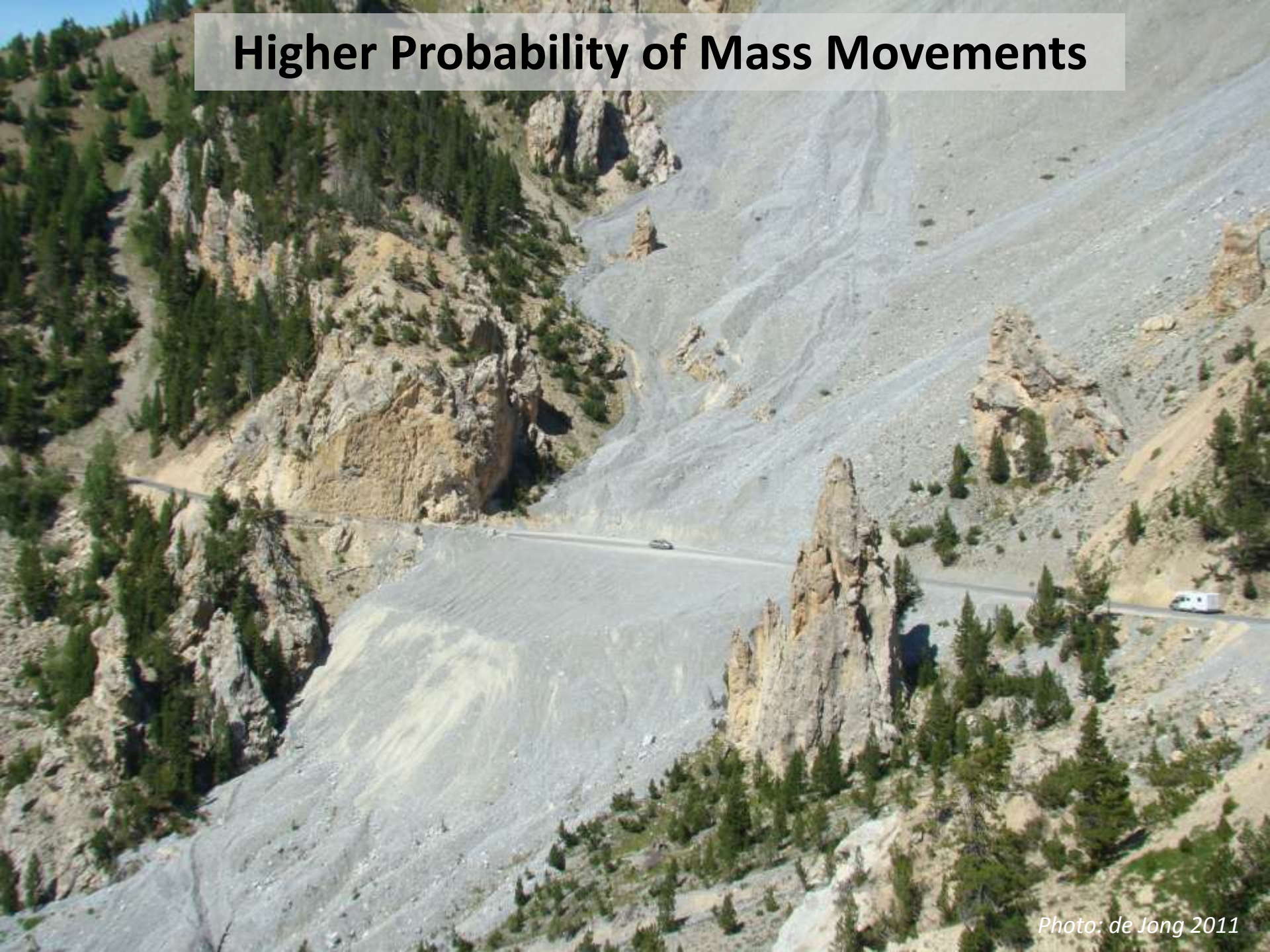


# More active debris flows



*Photo: de Jong 2011*

# Higher Probability of Mass Movements



*Photo: de Jong 2011*

# More landslides



# Impact of slope movement on buildings



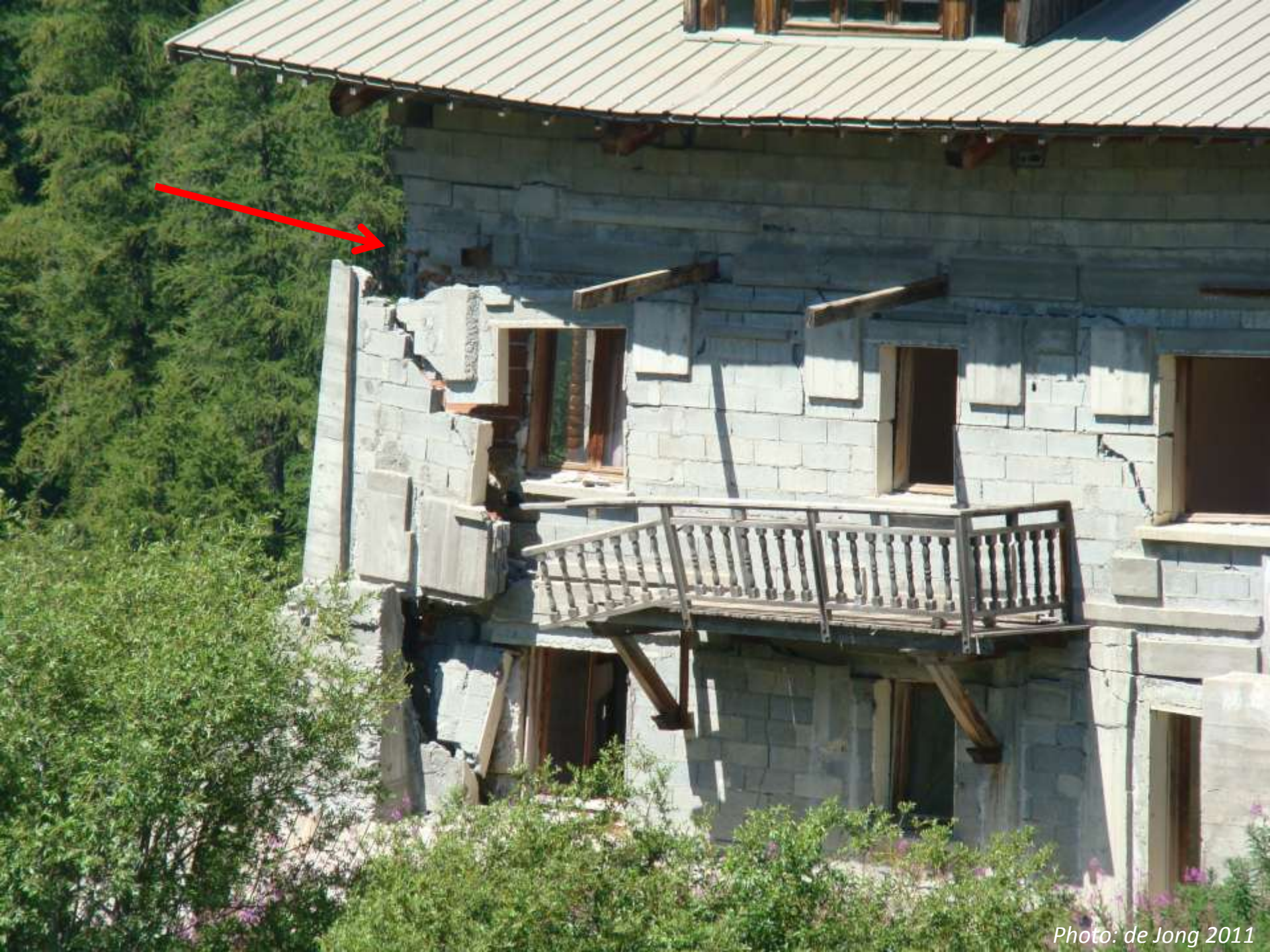


Photo: de Jong 2011

**More sediment transport**

**and more pollutants from glacier and snowmelt !**



# More active sediment retention structures



# More intense avalanches





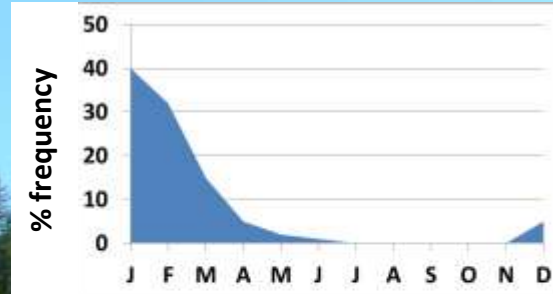
**avalanche track**

**Church untouched by  
avalanche for 600 years !**

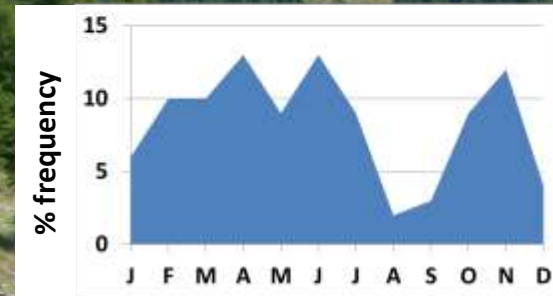
# **Discharge: Why Seasonality is so Important**

# Relative Frequency of Extreme Events in the Future

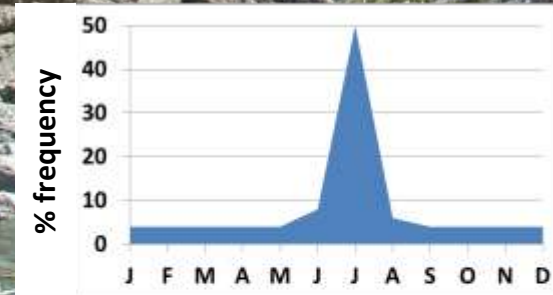
avalanche



landslide



debris flow



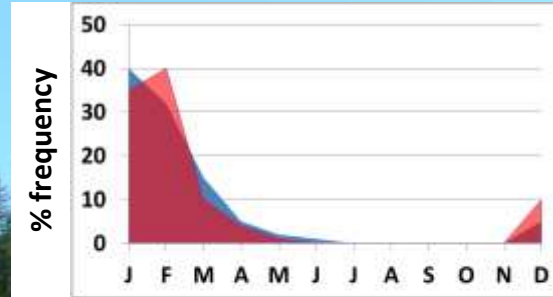
flood



*Based on historical documents,  
1331 – 1988,  
Queyras, French Alps  
(Baraille et al 2006)*

# Relative Frequency of Extreme Events in the Future

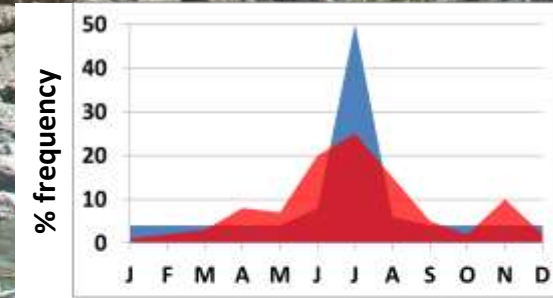
avalanche



landslide



debris flow

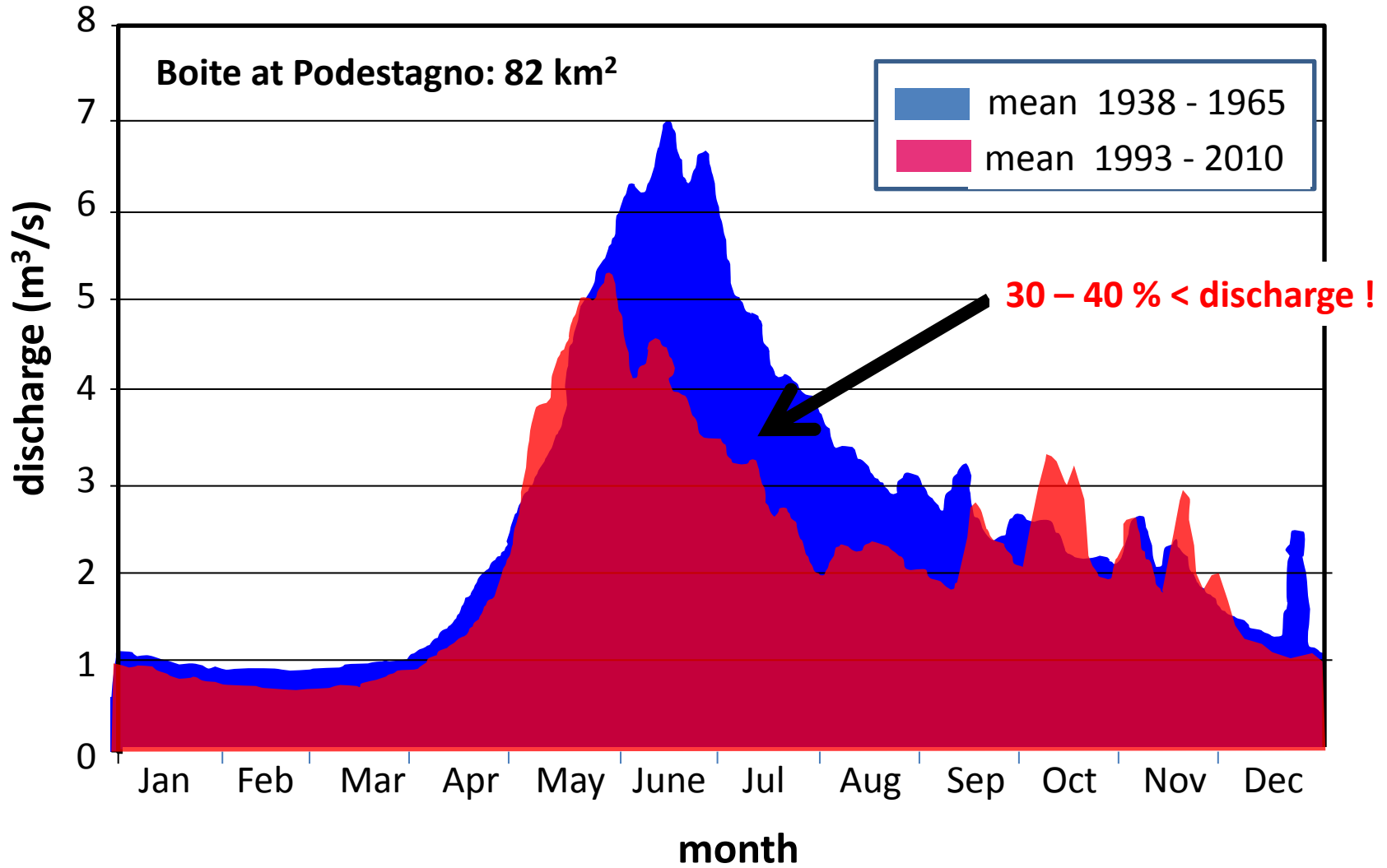


flood



*Conceptual Model for 2020  
( de Jong 2011)*

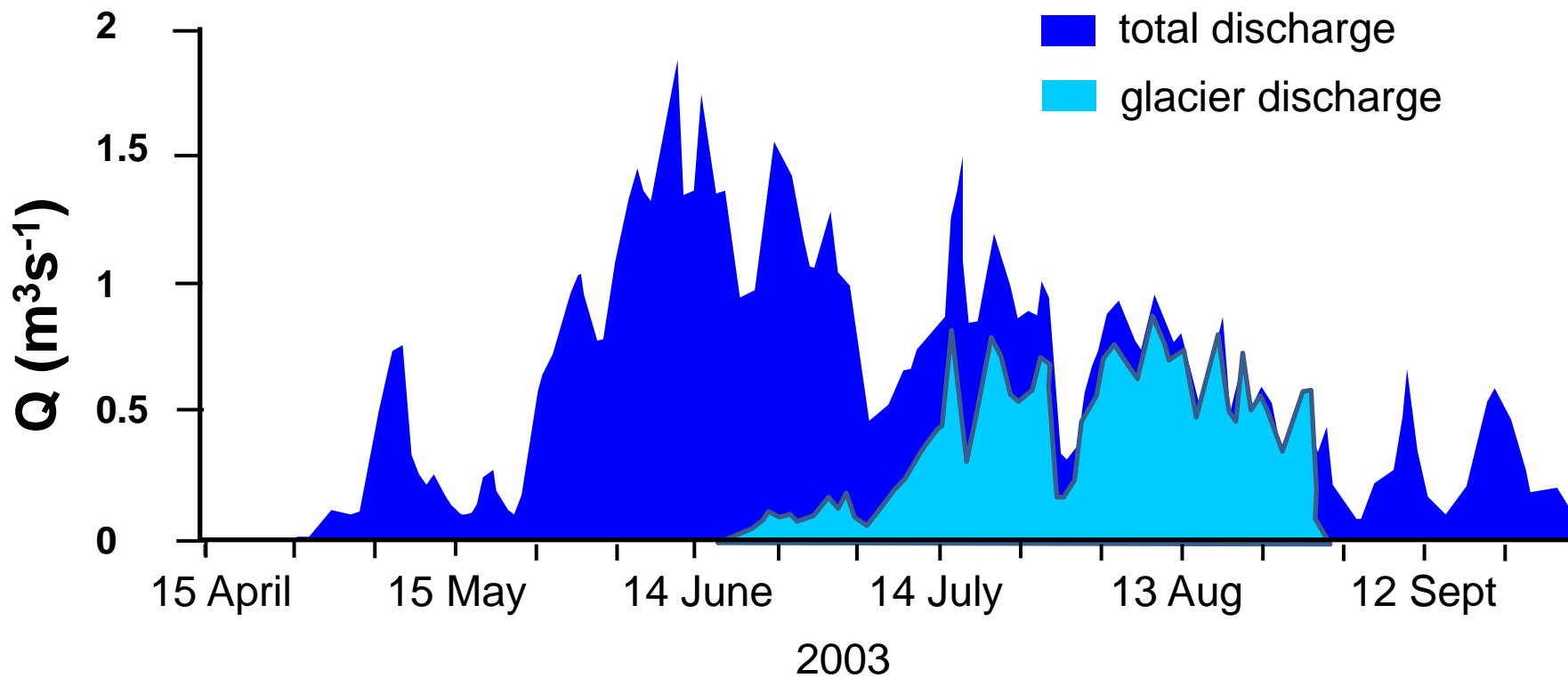
# Discharge Change of River Piave



*modified by de Jong after Rampazzo & Vecelio (2011)*

# Daily Discharge

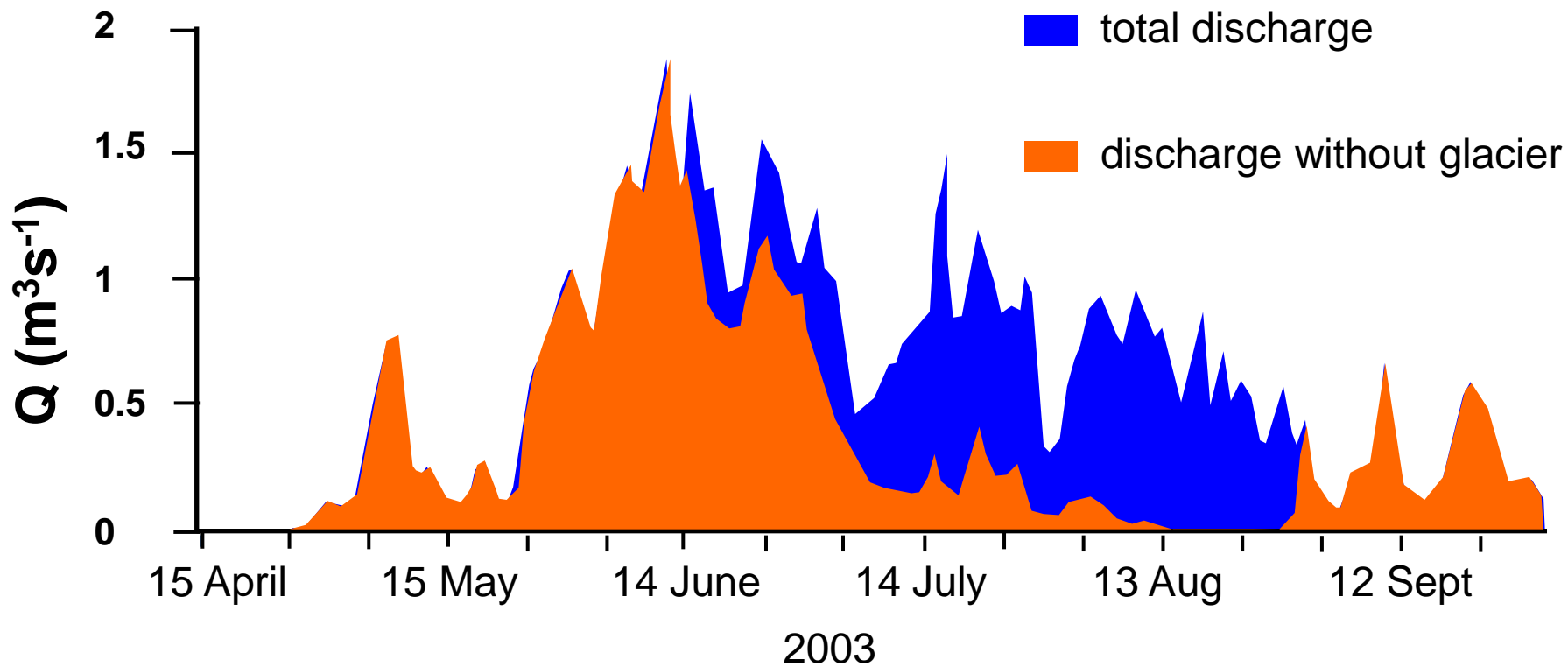
## (Glacier Goldbergkees, Austria)



*modified after Kobltschnig 2009*

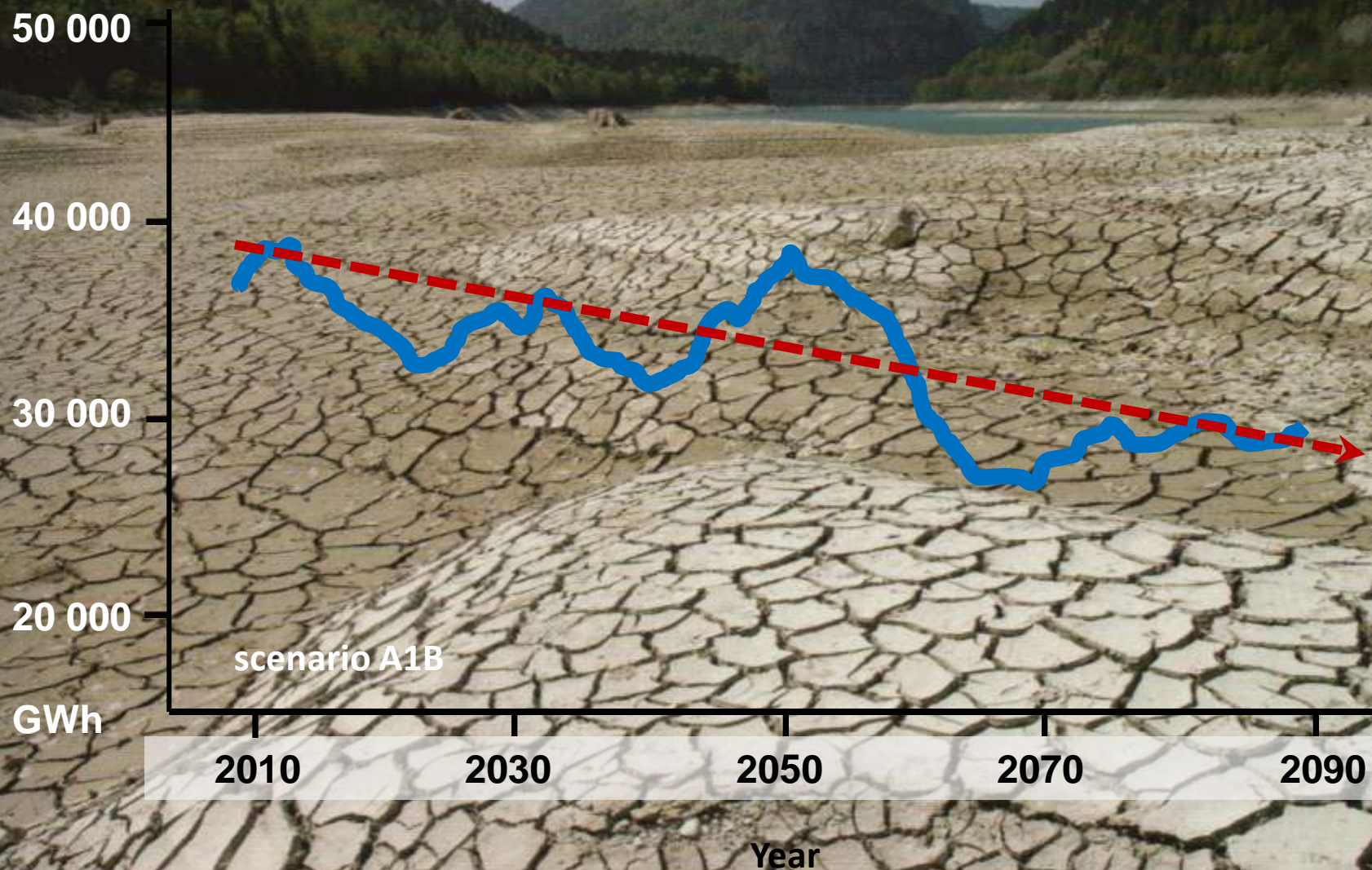
# Daily Discharge

(Glacier Goldbergkees, Austria)



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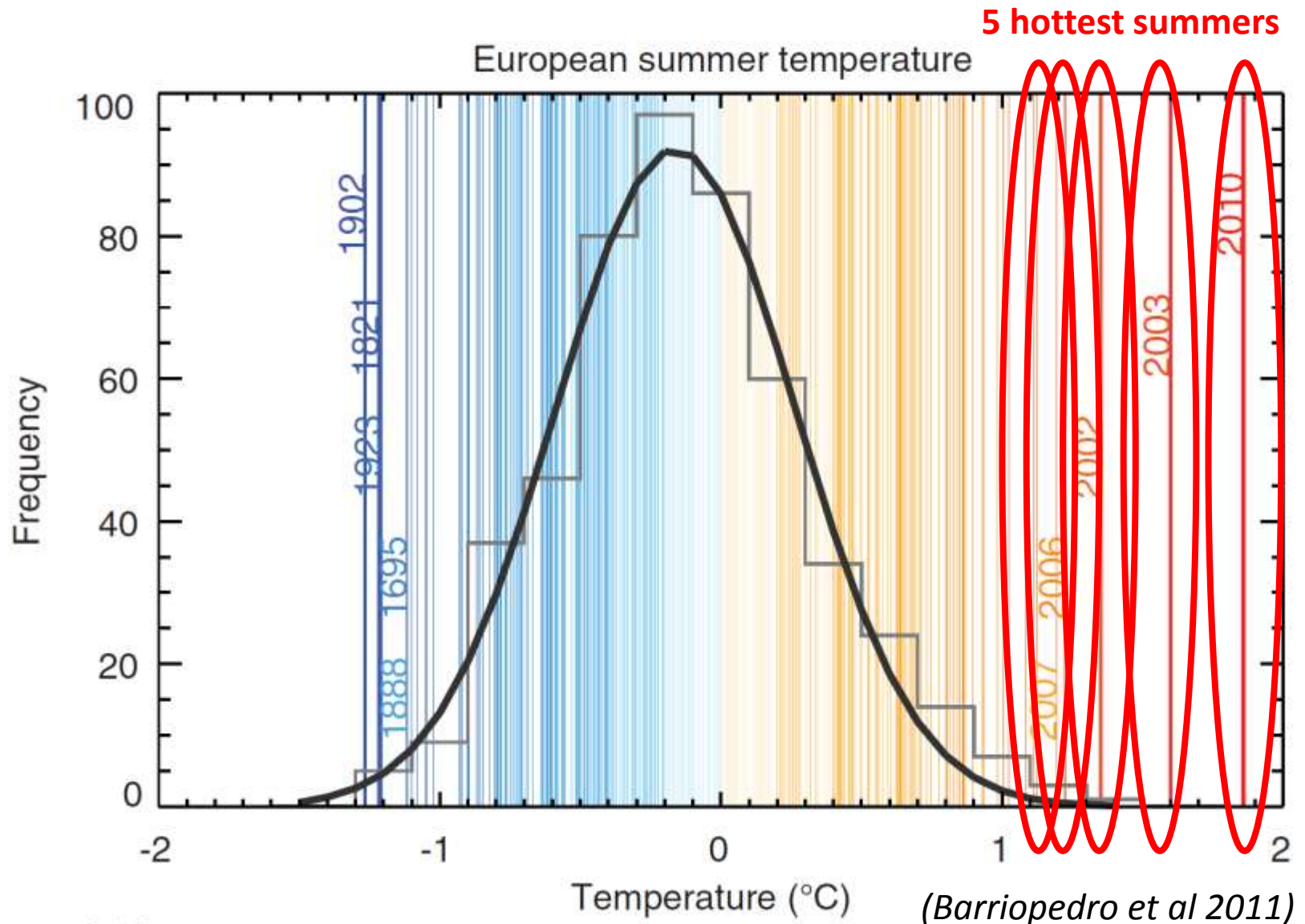
# Projected Hydropower Production in Austria



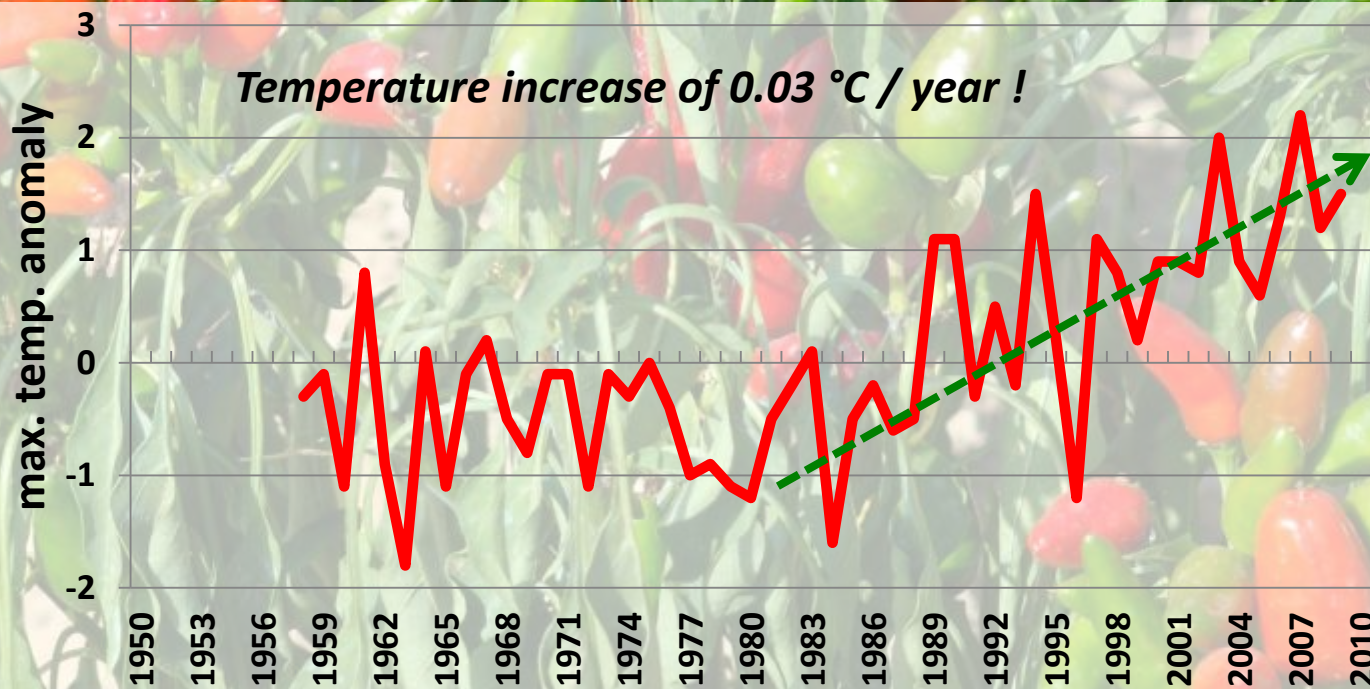


**Droughts: What does History tell us ?**

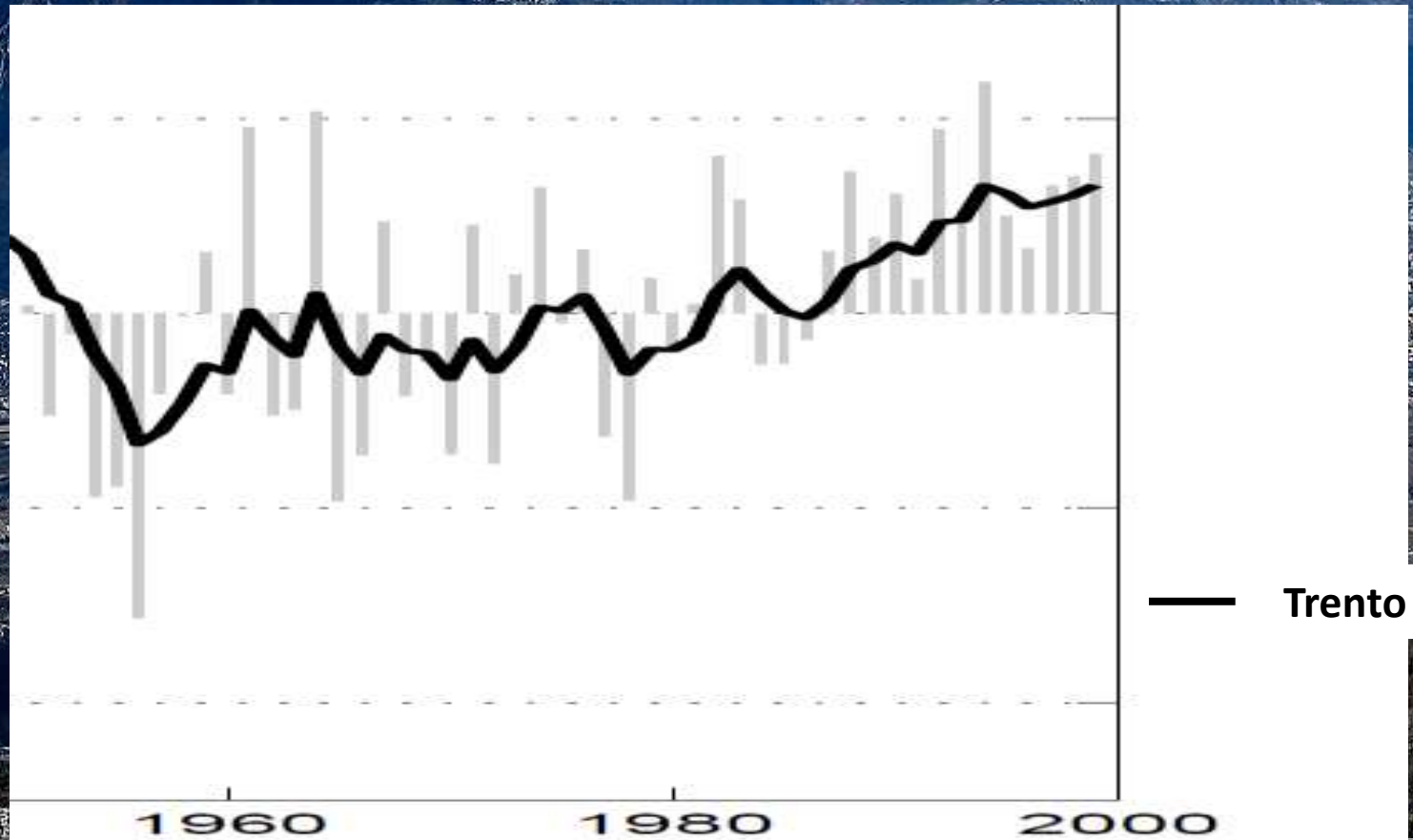
# Anomalies of European Summer Temperatures (1500 - 2010)



# Temporal Variation of Temperature in Piedmont (over last 50 years)

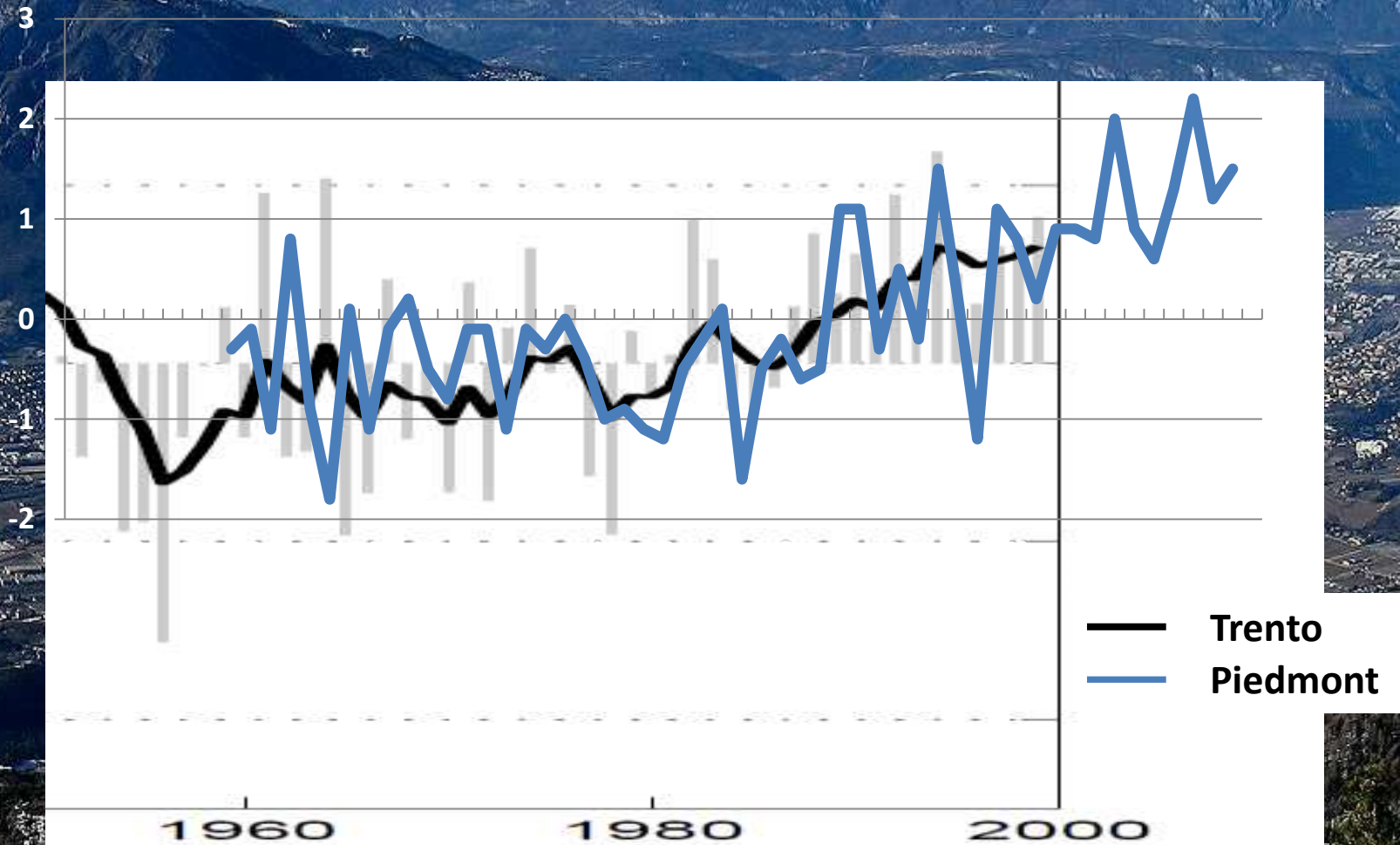


# Temperature Anomalies for Central and Western Alps



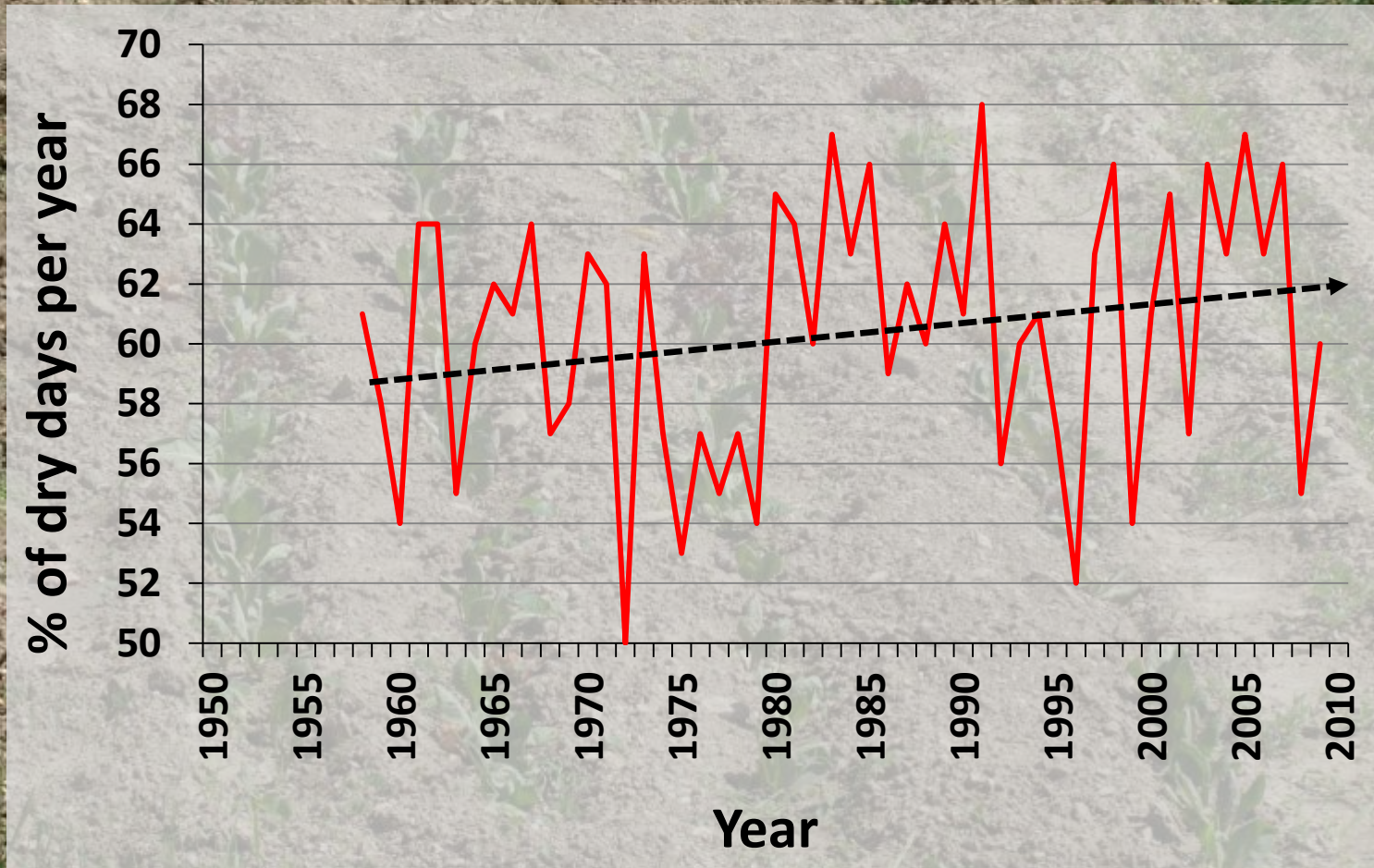
(ARPA Piemonte 2010 and Rea et al)

# Temperature Anomalies for Central and Western Alps

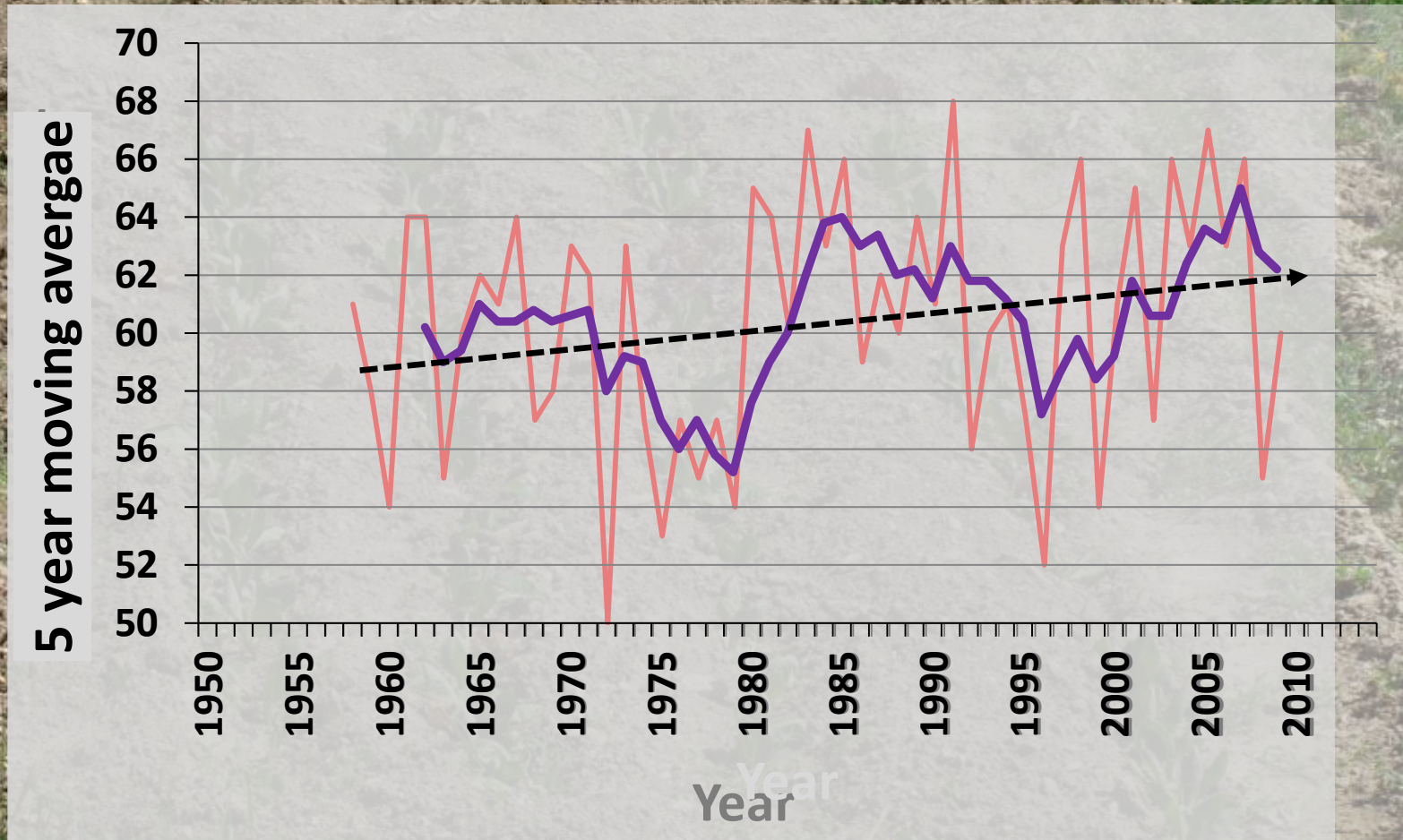


(ARPA Piemonte 2010 and Rea et al)

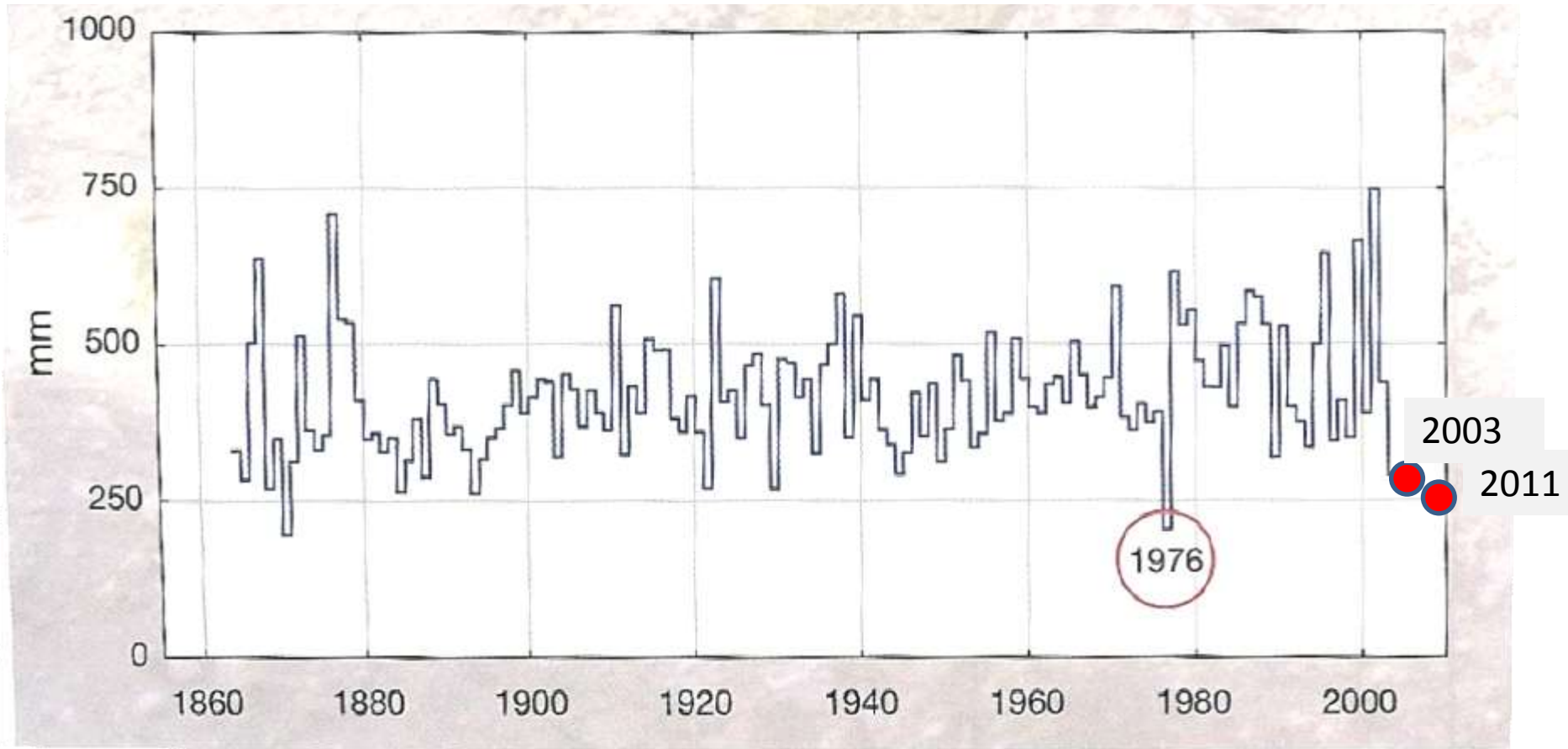
# Percentage Dry Days in Piedmont over last 50 years



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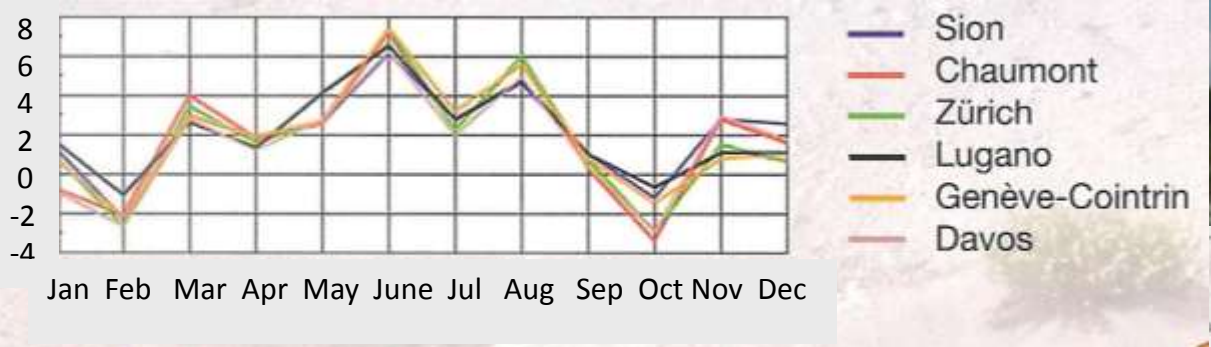
# Cumulative Precipitation on the Swiss Plateau (from January to June)



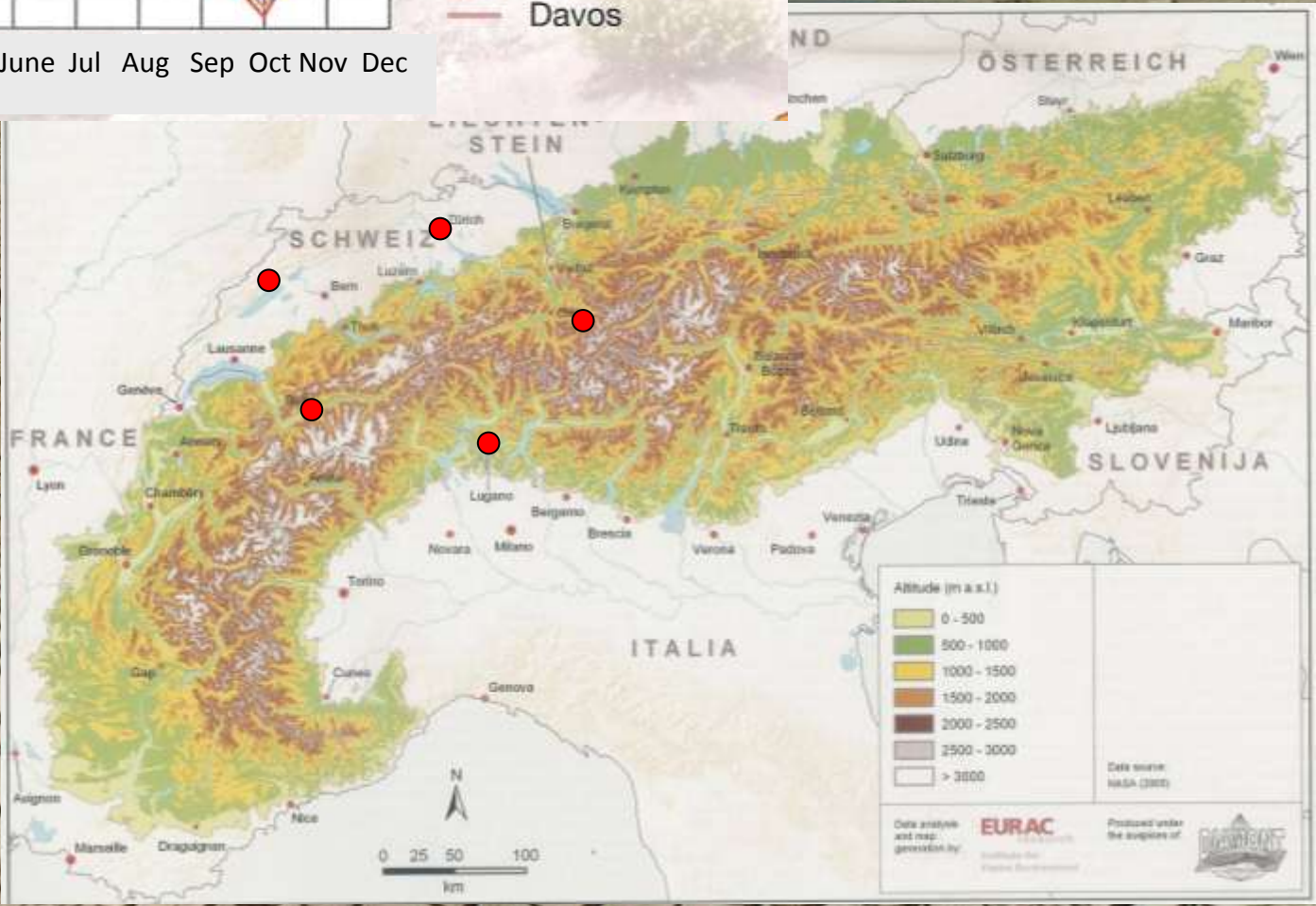


# Deviation in Temperature from Mean for Drought 2003

temp. (°C)



*Salamin 2010*



# Irrigating Forest in Switzerland to avoid Forest Fires



*Valais, May 2011*

# Quality of Pasture and Droughts



# Quality of Pasture and Droughts



*Cheese labels vulnerable to droughts since they depend 90% on local hay*

# Quality of milk and cheese depends on meteorological conditions for quality of grass

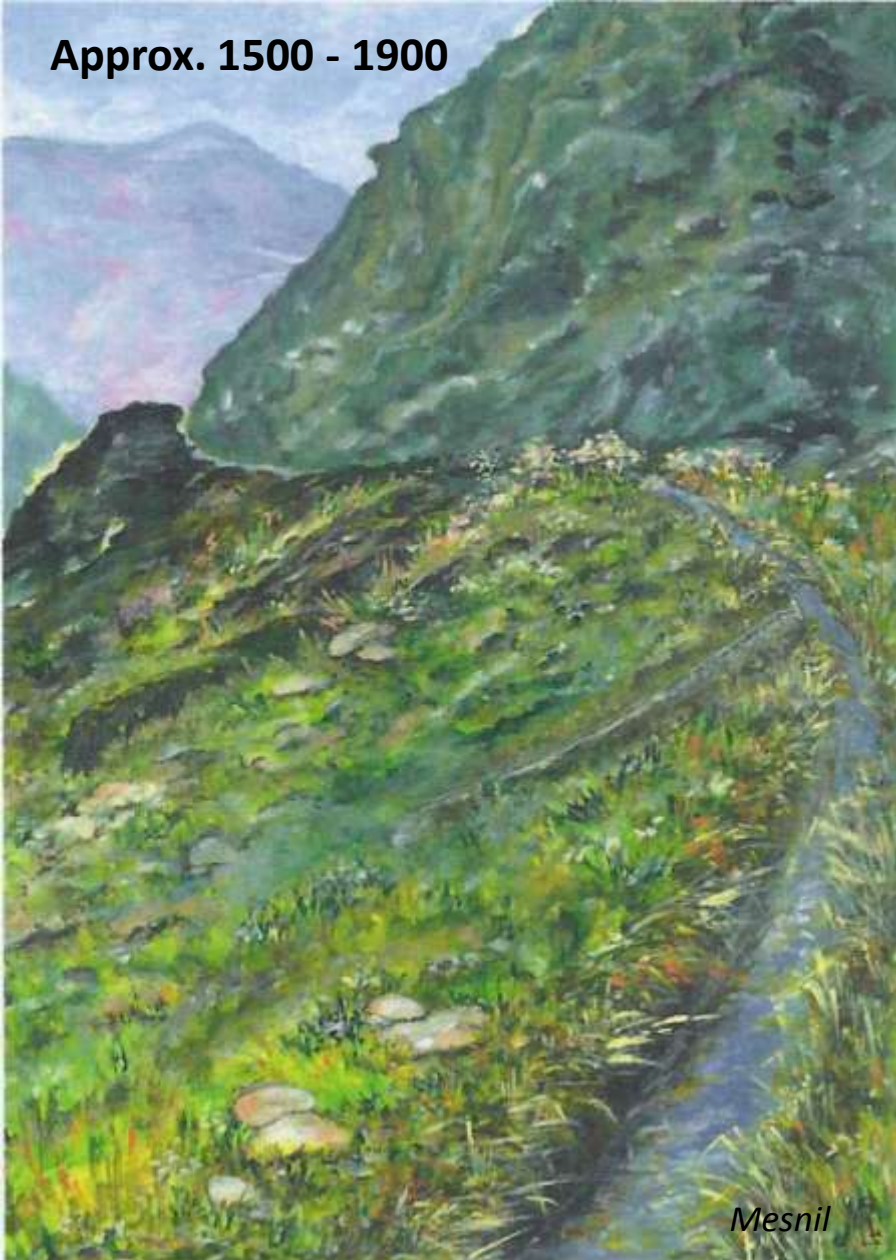


*(Mazure 2008)*

# **Adaptation and Best Practice: The Past and the Future**

# Irrigation Canal in Queyras, French Alps

Approx. 1500 - 1900



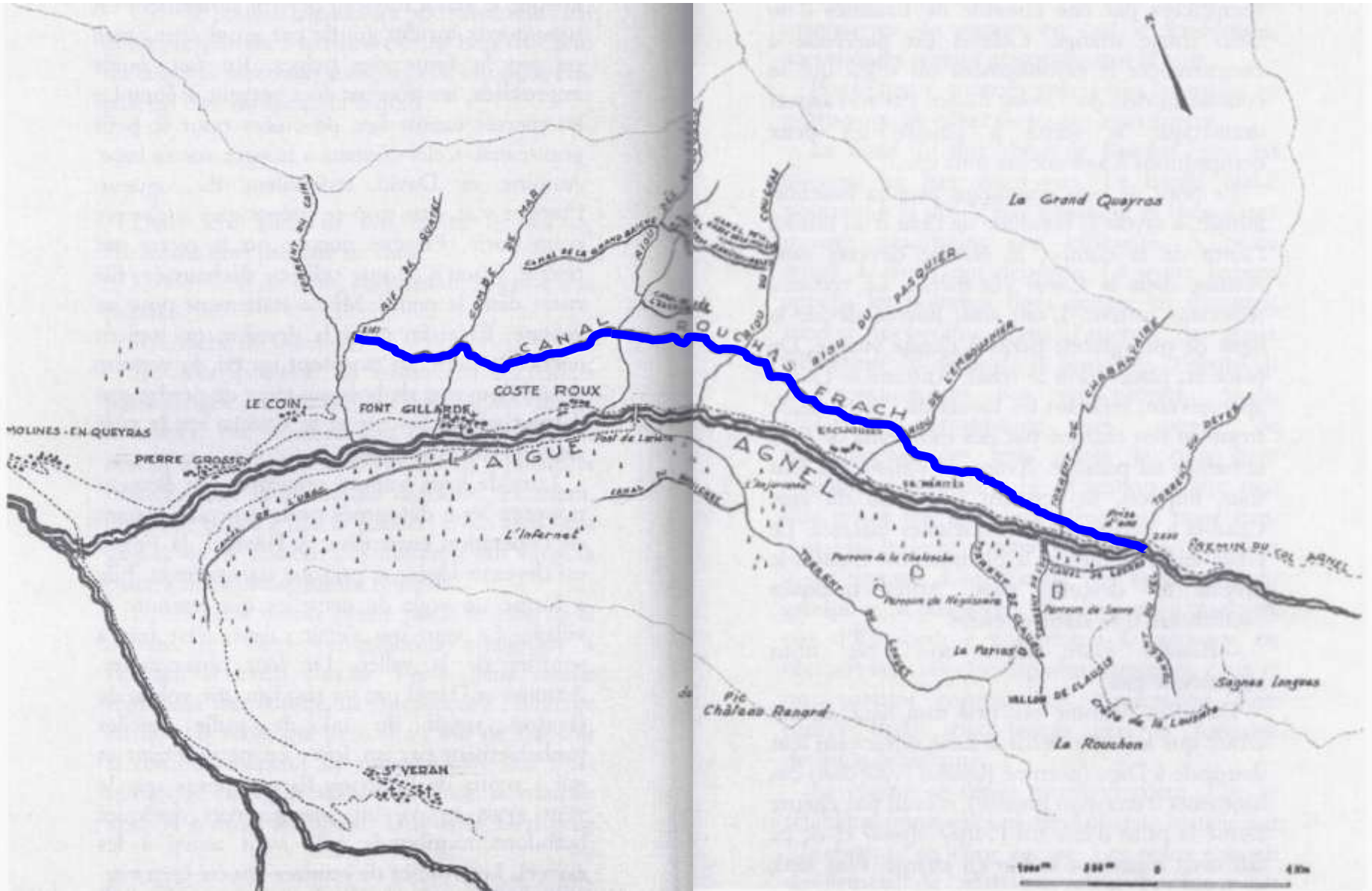
Aug. 2011



(2500 m a.s.l.)



# Historical Map of Rouchas Frach



after Bonnuit 2009



# Location of Irrigation Canal



# Impact of Irrigation Canal on Pasture Today



Image © 2011 DigitalGlobe  
© 2011 Tele Atlas  
© 2011 Google

©2010 Google

Date des images satellite : 16/8/2005 2003

44°43'08.05"N 6°54'18.03"E élév. 2033 m

Altitude 2.33 km

# Modern Irrigation Canal



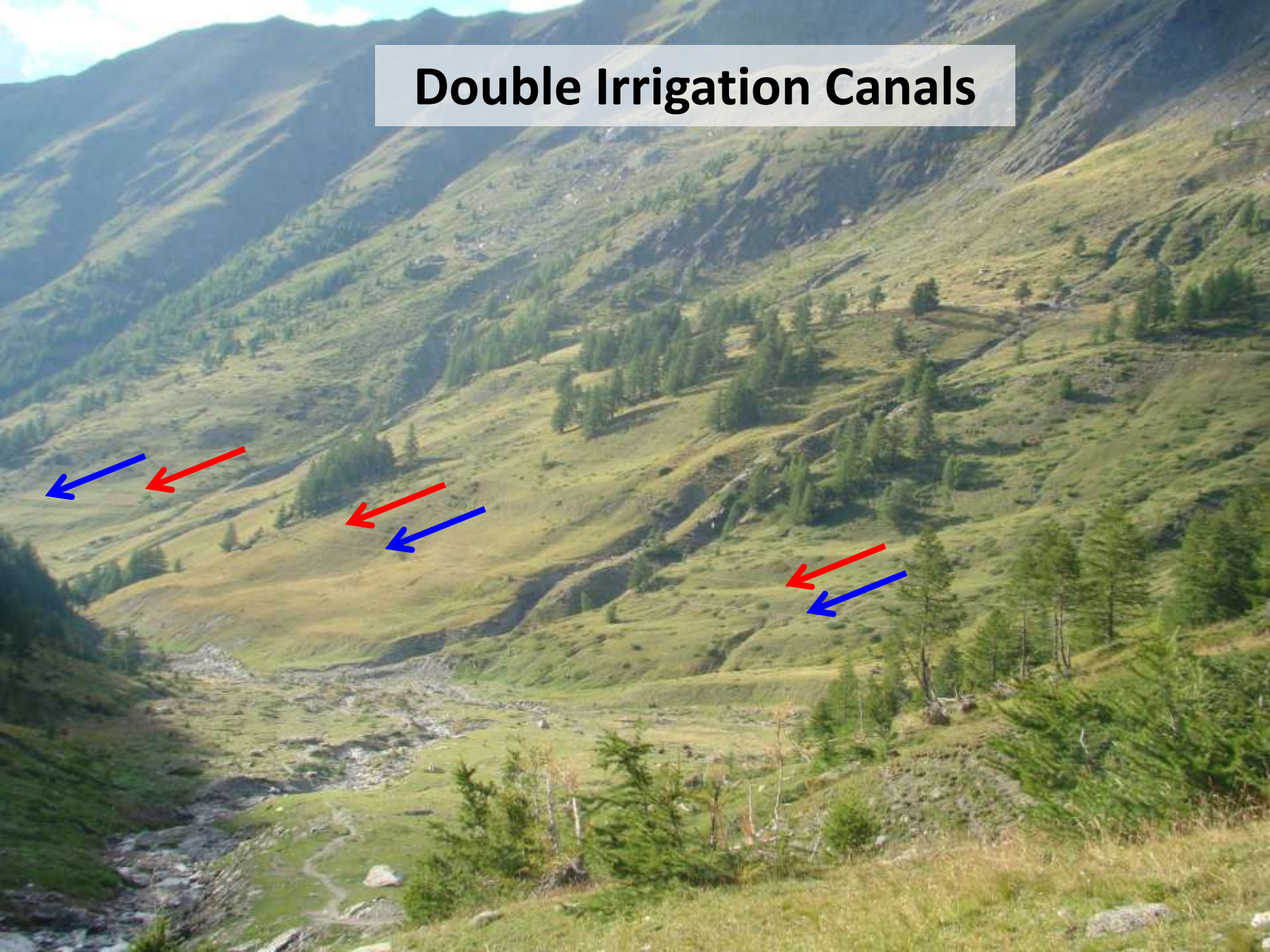
# Ancient Irrigation Canal



# Ancient Irrigation Canal



# Double Irrigation Canals



# Irrigated Patches



# Automated Irrigation on Slopes

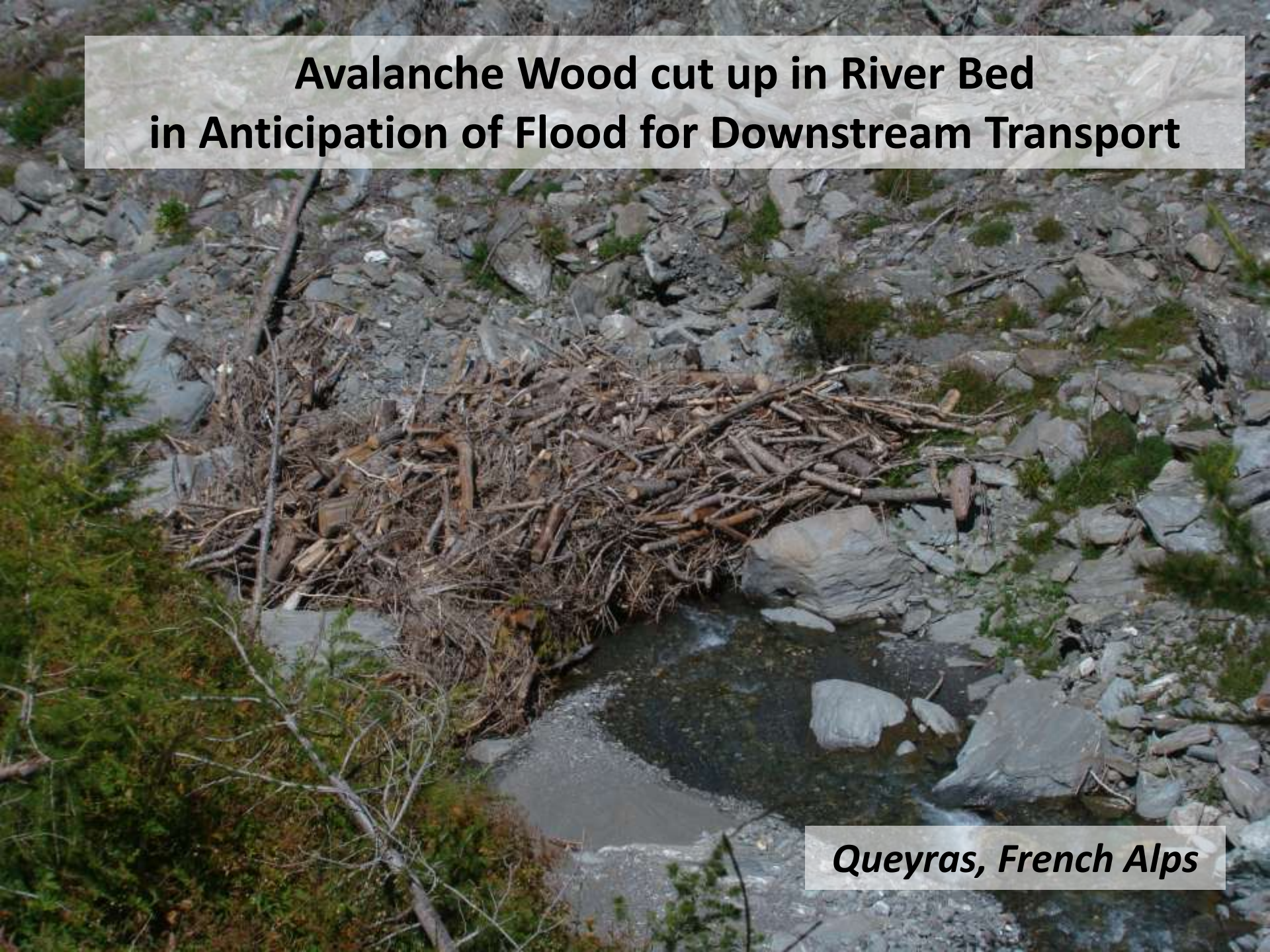




# Automated Irrigation of Potatoes



**Avalanche Wood cut up in River Bed  
in Anticipation of Flood for Downstream Transport**



*Queyras, French Alps*

# Avalanche Wood stored on Veranda



*Chiniale, Italian Alps*

# Human Intuitiveness and Adaptation



**CONSERVE  
WATER  
SHOWER  
WITH ME**

*Photo: de Jong 2010*

# CONCLUSIONS

- In the Alps, **extreme events** related to climate change require special attention, in particular **droughts**
- There are major **seasonal shifts** in discharge and natural risks with important impacts on energy, economy and ecology
- Climate change **impacts** may be so **small scale, complicated** or **rapid** that **interdisciplinary** approaches are required
- **Key stakeholders** should participate and give presentations at applied **scientific conferences**
- **Good practice examples** of adaptation to extreme events already exist but more can be learned from the past
- **Climate Change Witnesses** could be a new component of the Trento Climate Observatory