ELABORATION OF MAPS FOR CLIMATIC AND SEISMIC ACTIONS FOR STRUCTURAL DESIGN IN THE BALKAN REGION

27-28 October 2015, Zagreb

European Commission

General Principles of the Elaboration of Maps for Climatic and Seismic Actions

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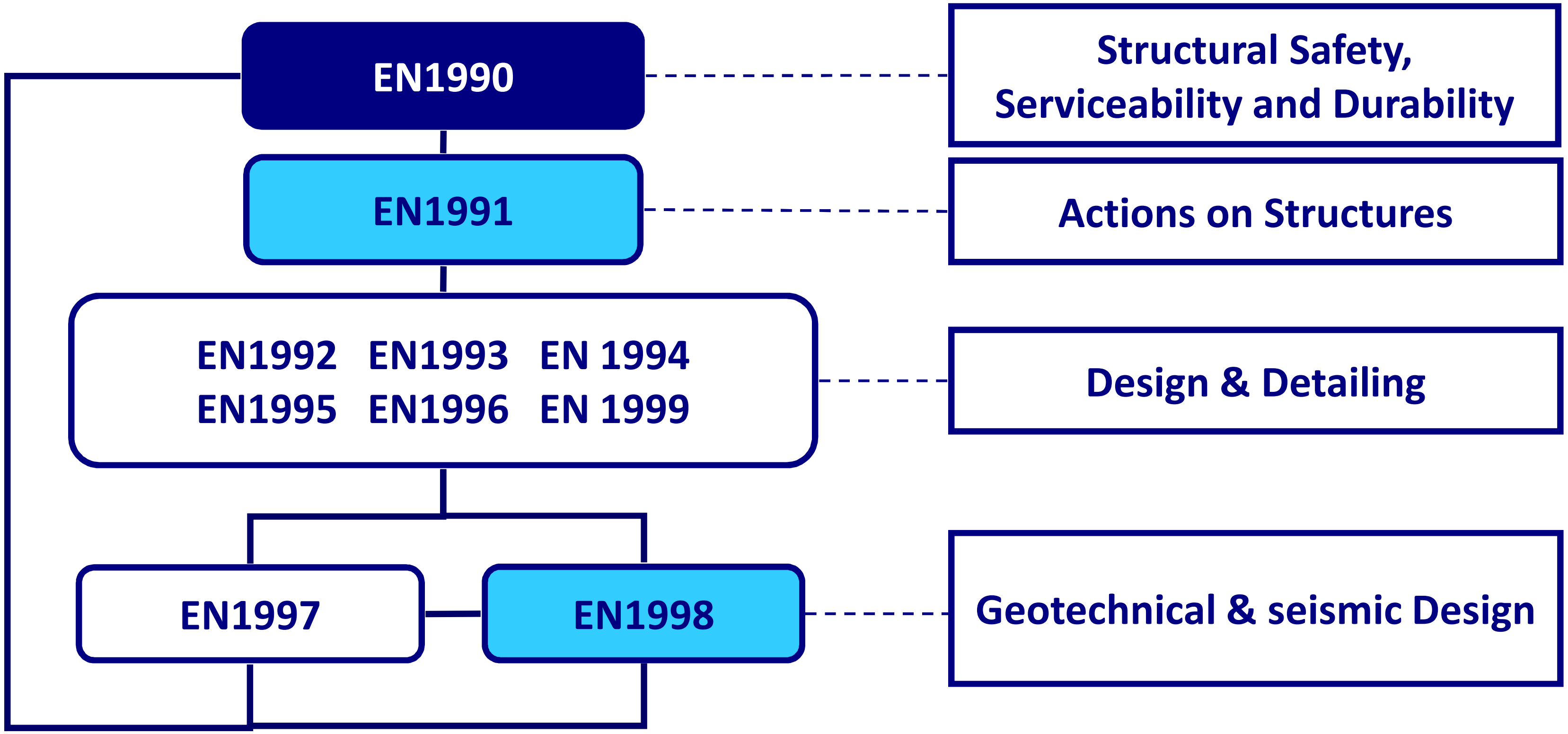
Basis of Structural Design

UNIVERSITÀ DI PISA

Overview of the presentation

- *Climatic and Seismic Actions in the Eurocodes*
- *Reference Basis of Design*
- *General principles for the assessment of climatic actions. Examples for the snow load maps.*
- *Climate change influences.*
- *General principles for the assessment of seismic actions. Open points.*

Links between the Eurocodes



Eurocode standards recognise the ***responsibility of regulatory authorities in each Member State*** *and have safeguarded* ***their right to determine values related to regulatory safety matters at national level*** *where these continue to vary from State to State.*

National Annex - NDPs

ECs Foreword

*The National annex may **only** contain information on those **parameters** which are **left open in the Eurocode for national choice**, known as **Nationally Determined Parameters**, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :*

– values and/or classes where alternatives are given in the Eurocode,

– values to be used where a symbol only is given in the Eurocode,

*– **country specific data** (geographical, climatic, etc.), e.g. snow map,*

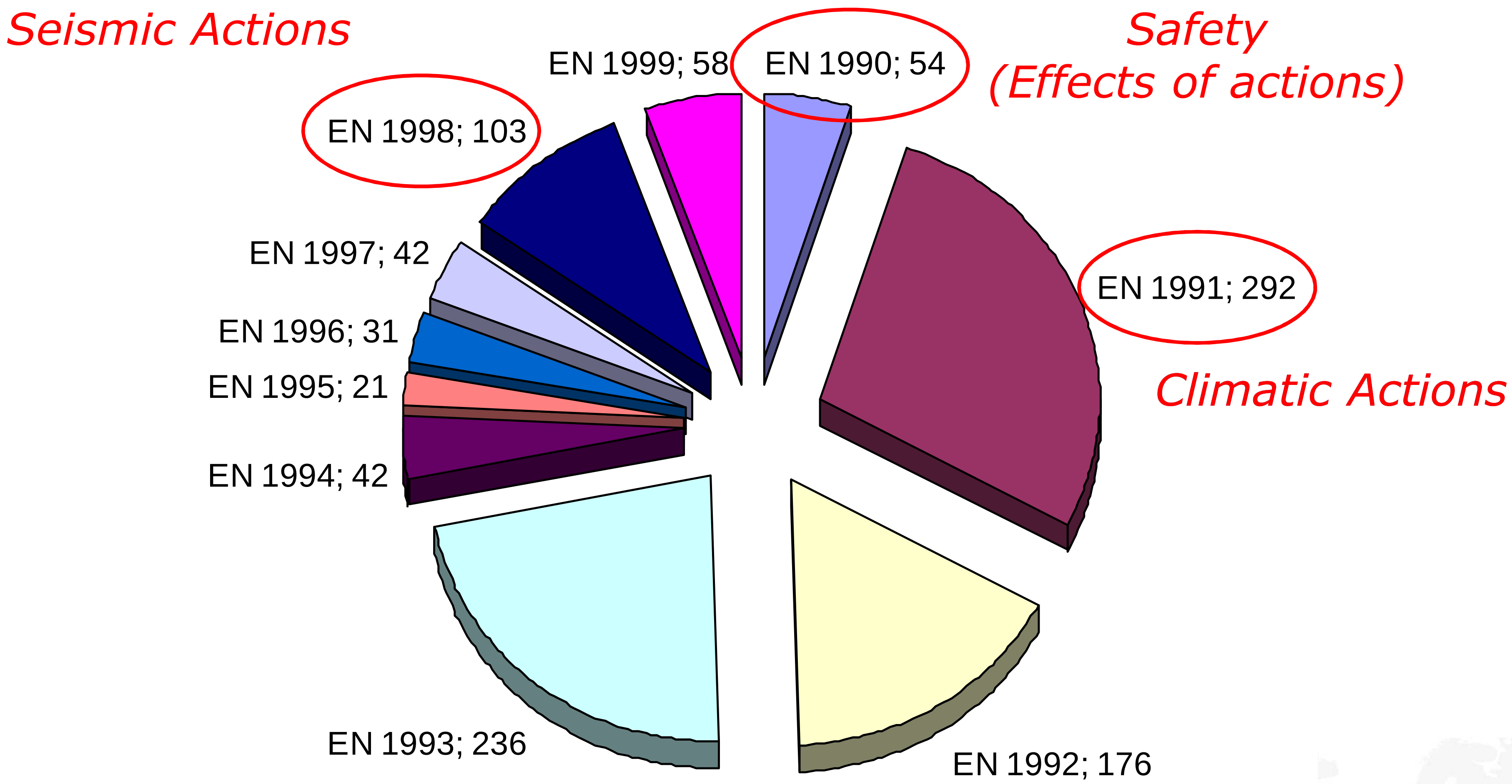
– the procedure to be used where alternative procedures are given in the Eurocode.

It may also contain:

– decisions on the application of informative annexes,

– references to non-contradictory complementary information to assist the user to apply the Eurocode.

Distribution of NDPs in the ECs



Basic requirements EN 1990

2.1(1)P *A structure shall be designed and executed in such a way that it will, **during its intended life**, with appropriate degrees of reliability and in an economical way:*

*– **sustain all actions** and influences **likely to occur during execution and use**, and*

*– **meet the specified serviceability requirements** for a structure or a structural element.*

2.1(2)P *A structure shall be designed to have adequate :*

- *structural resistance,*
- *serviceability, and*
- *durability.*

"ULS" + "SLS"

2.1(3)P *Safety in case of fire*

2.1(4)P *Robustness*

Design Situations

1.5.2.2 design situations

sets of physical conditions representing the real conditions occurring during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded

3.1(3)P *Limit states shall be related to design situations*

3.1(4) *Design situations should be classified as* ***persistent***, ***transient*** *or* ***accidental (seismic)***

Design Situations

1.5.2.3 Transient design situation

design situation that is relevant during a period much shorter than the design working life of the structure and which has a high probability of occurrence.

NOTE A transient design situation refers to temporary conditions of the structure, of use, or exposure, e.g. during construction or repair.

Design Situations

1.5.2.4 persistent design situation

design situation that is relevant during a period of the same order as the design working life of the structure.

NOTE Generally it refers to conditions of normal use.

Design Situations

1.5.2.5 accidental design situation

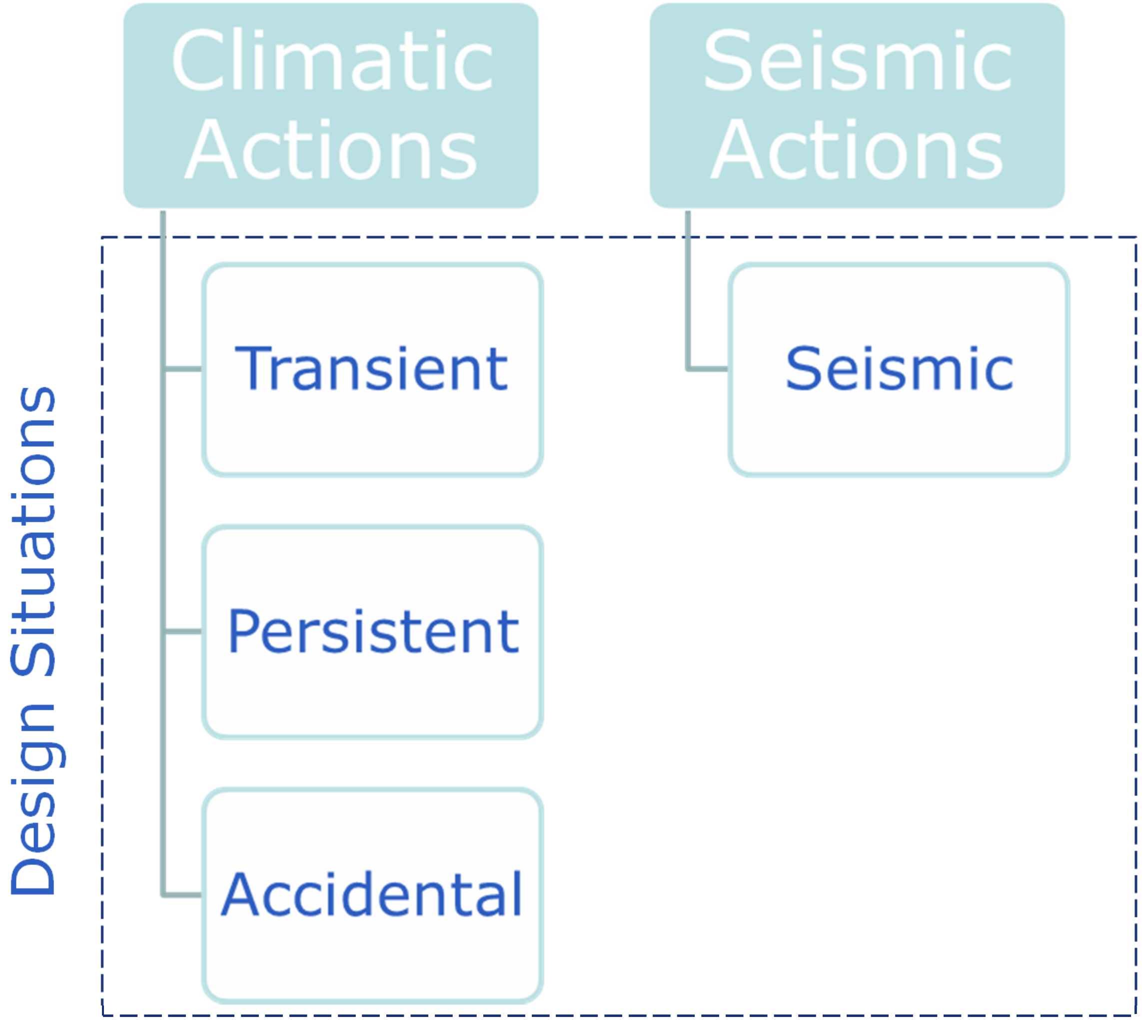
design situation involving exceptional conditions of the structure or its ***exposure****, including fire, explosion, impact or local failure*

Design Situations

1.5.2.7 seismic design situation

design situation involving exceptional conditions of the structure when subjected to a seismic event

Actions, ULS Design situations



ULS Persistent Transient Design Situations

$$\sum_{j\geq1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$ Eq. (6.10)

or, alternatively for STR and GEO limit states, the less favourable of the two following expressions:

$$\left\{ \begin{array}{l} \sum_{j\geq1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} \psi_{0,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \\ \sum_{j\geq1} \xi_j \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \end{array} \right.$$

Eq. (6.10a)

Eq. (6.10b)

ULS Accidental Design Situations

$$\sum_{j\geq 1} G_{k,j} "+" P "+" A_d "+" (\psi_{1,1} \text{ or } \psi_{2,1}) Q_{k,1} "+" \sum_{i>1} \psi_{2,i} Q_{k,i}$$

ULS Seismic Design Situations

$$\sum_{j\geq 1} G_{k,j} "+" P "+" A_{Ed} "+" \sum_{i\geq 1} \psi_{2,i} Q_{k,i}$$

SLS Design Situations

Characteristic Combination

$$\sum_{j\geq 1} G_{k,j} "+" P "+" Q_{k,1} "+" \sum_{i>1} \psi_{0,i} Q_{k,i}$$

Frequent Combination

$$\sum_{j\geq 1} G_{k,j} "+" P "+" \psi_{1,1} Q_{k,1} "+" \sum_{i>1} \psi_{2,i} Q_{k,i}$$

Quasi Permanent Combination

$$\sum_{j\geq 1} G_{k,j} "+" P "+" \sum_{i\geq 1} \psi_{2,i} Q_{k,i}$$

Reliability Differentiation (Persistent)

EN 1990 Annex B

Table B2 - Recommended minimum values for reliability index β (ultimate limit states)

Reliability Class	Minimum values for β	
	1 year reference period	50 years reference period
RC3	5,2	4,3
RC2	4,7	3,8
RC1	4,2	3,3

NOTE A design using EN 1990 with the partial factors given in annex A1 and EN 1991 to EN 1999 is considered generally to lead to a **structure with a β value greater than 3,8 for a 50 year reference period**.

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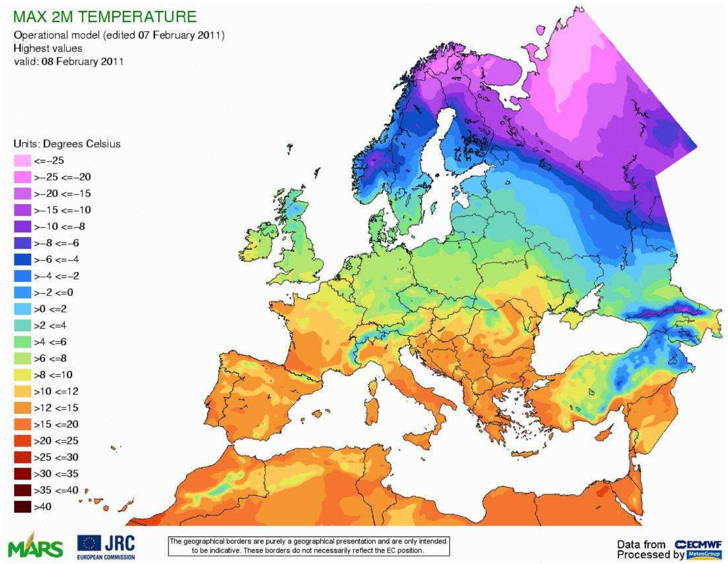
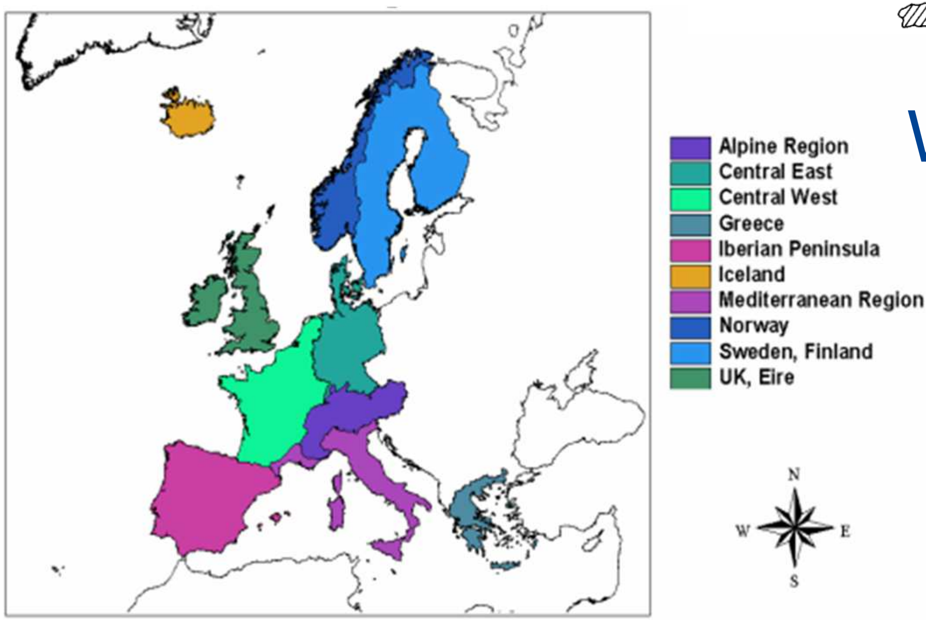
Maps for Climatic Actions



Temperature



Snow

Wind

Characteristic values of climatic actions

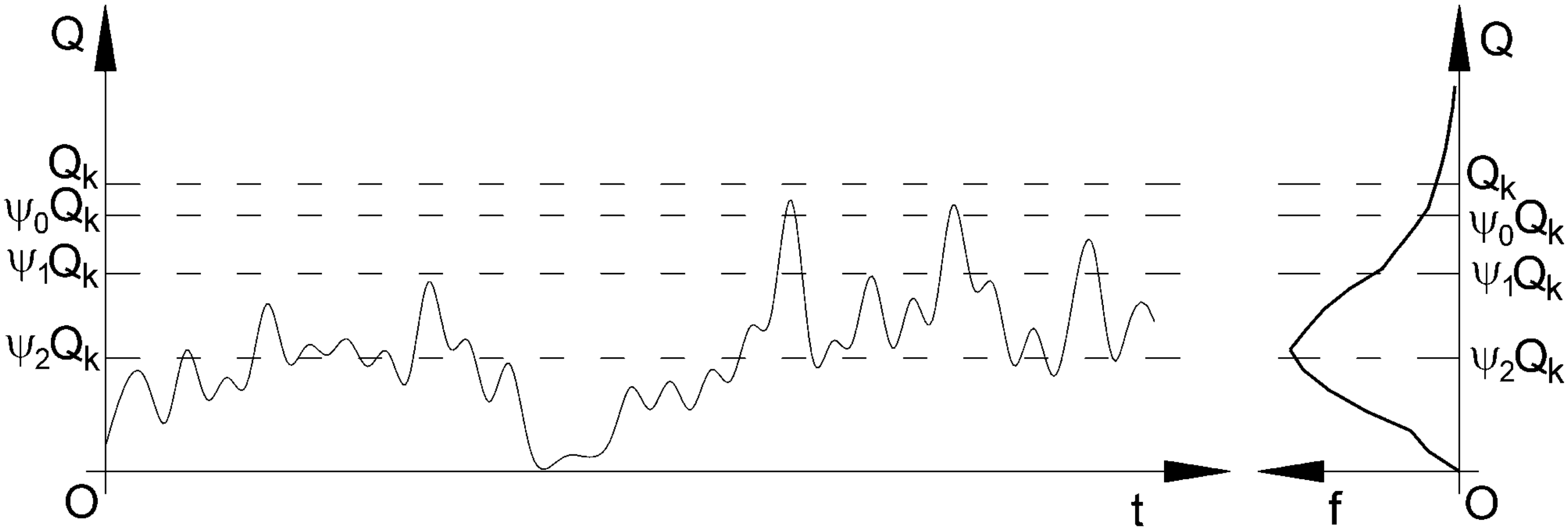
EN 19900 Note 2 to 4.1.2(7)P

*The characteristic value of climatic actions is based upon the **probability of 0,02 of its time-varying part being exceeded for a reference period of one year**. This is **equivalent to a mean return period of 50 years** for the time-varying part. However in some cases the character of the action and/or the selected design situation makes another fractile and/or return period more appropriate.*

$$Q_k = Q_{50yrs}$$

Design Working Life ≠ Return Period

Other Representative Values of variable (climatic) actions



$\psi_0\ Q_k$ Combination value

$\psi_1\ Q_k$ Frequent value

$\psi_2\ Q_k$ Quasi Permanent value

The European Ground Snow Load Map

Many clauses of EN 1991-1-3 are based on the results of a research work, carried out between 1996 and 1999, under a contract specific to this Eurocode, to DGIII/D3 of the European Commission.

They were identified four main research items:

- *study of the **European ground snow loads map***
- *investigation and treatment of **exceptional snow loads***
- *study of conversion factors from ground to roof loads*
- *definition of ULS and SLS combination factors for snow loads.*

The European Ground Snow Load Map

Needs for harmonization – Development of European ground snow load map

- Inconsistencies at borders between existing national maps;
- Different procedures for measuring snow load (mainly ground snow data): snow depths + density conversion, water equivalent measures, direct load measures;
- Different approaches for statistical data analysis (Gumbel, Weibull, Log-normal distributions).

!

The research developed a consistent approach

Produced regional maps (Annex C of EN 1991-1-3)

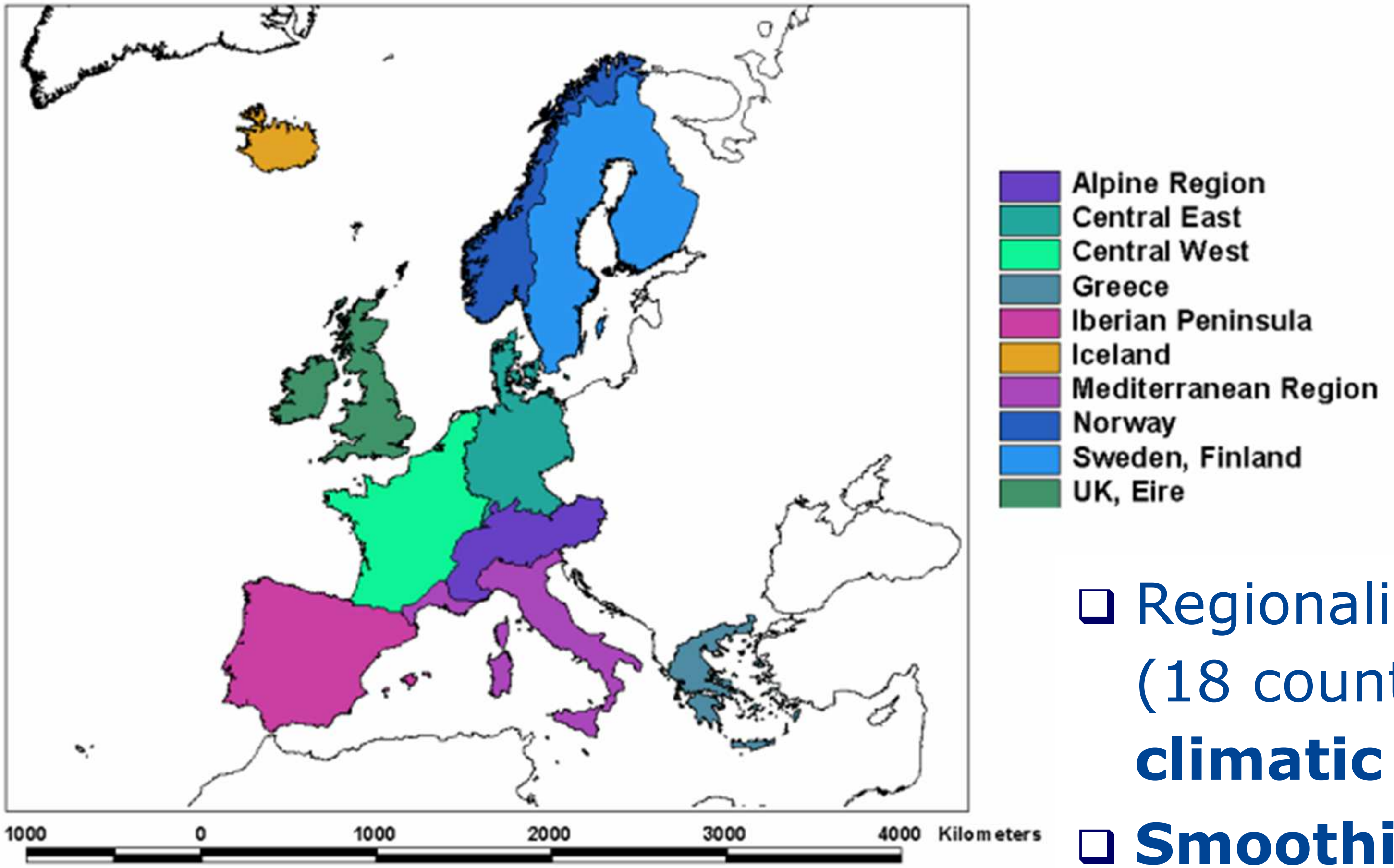
- **Snow load with Altitude relationship**
- **Zone numbers & altitude functions**
- **Geographical boundaries**

The European Ground Snow Load Map

For maps in Annex C of EN 1991-1-3 the following common approach has been followed:

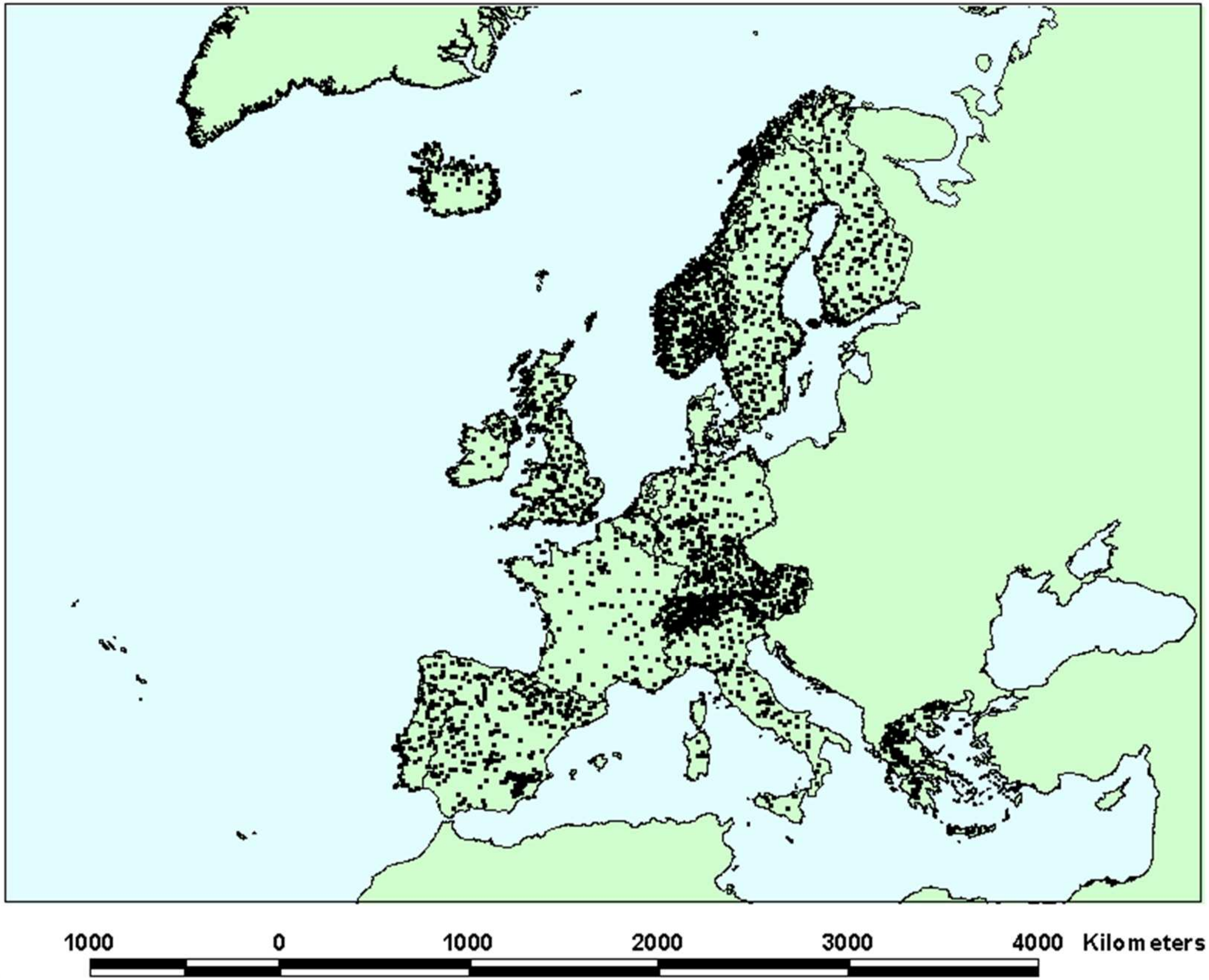
- *Statistical analysis of yearly maxima, using the **Gumbel Type I CDF** (best fitting in the majority of data points);*
- ***LSM** for the calculation of the best fitting regression curve;*
- *Both zero and non zero values have been analysed according to the "**mixed distribution approach**" ;*

The European Ground Snow Load Map

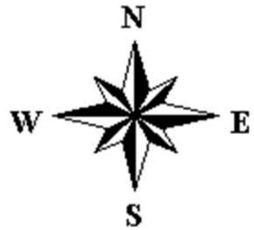


- Regionalization of CEN area (18 countries 1997) into **10 climatic regions**;
- **Smoothing of maps across borderlines** between neighbouring climatic regions (buffer zones 100 km).

The European Ground Snow Load Map

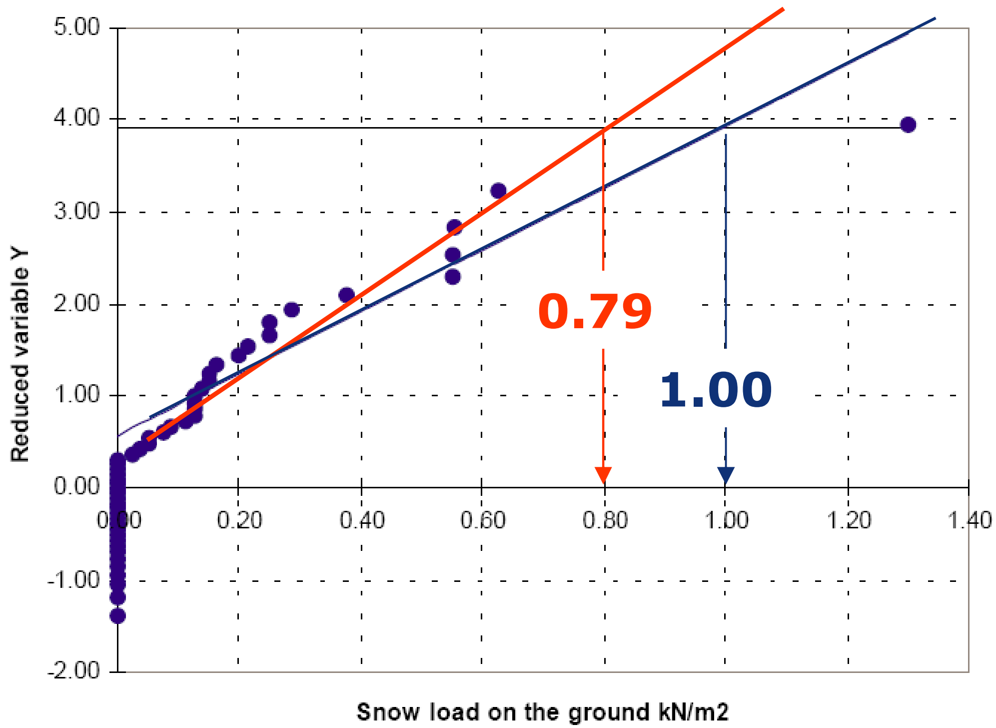


- 2’600 weather stations



The European Ground Snow Load Map

In some regions, particularly southern Europe, isolated very heavy snow falls have been observed resulting in snow loads which are significantly larger than those that normally occur. Including these snowfalls with the more regular snow events for the lengths of records available may significantly disturb the statistical processing of more regular snowfalls.



Gumbel probability paper: *Pistoia (IT)*

N° of recorded years = 51

N° of no snowy winters = 26

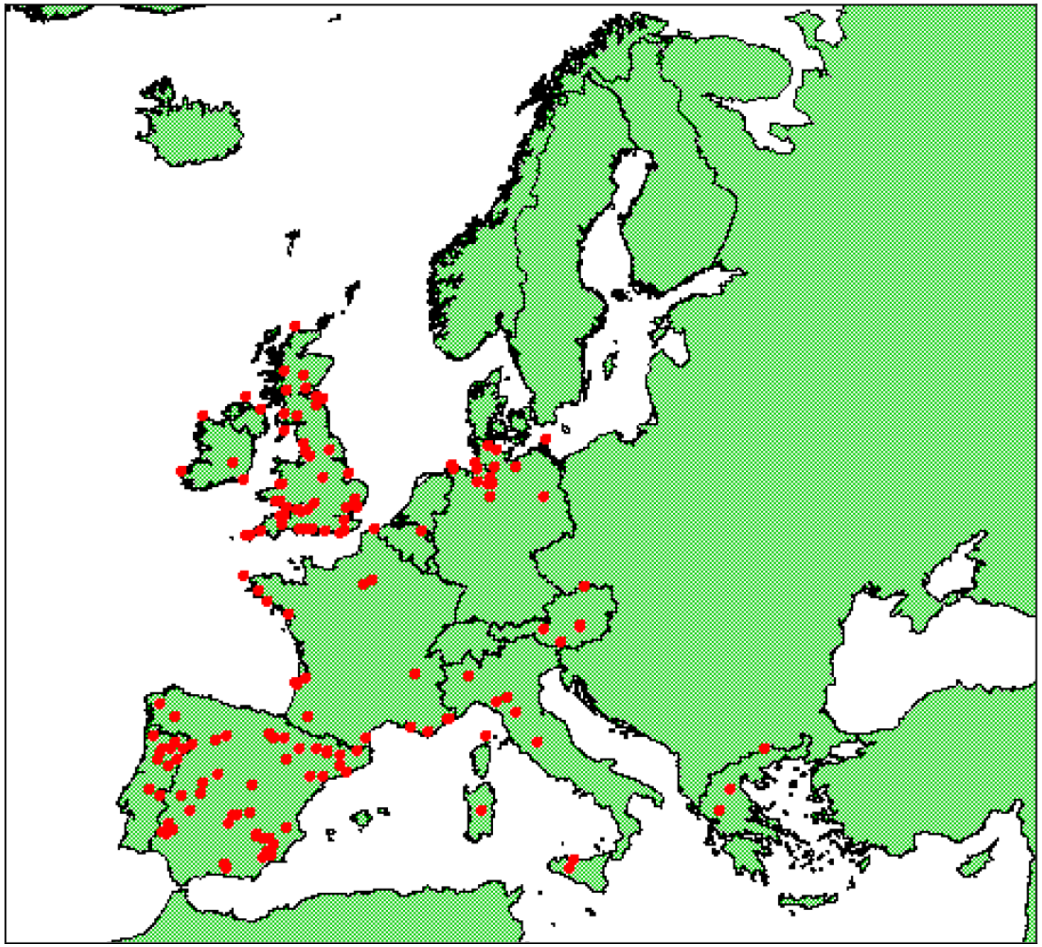
s_m = Max. snow Load = 1.30 kN/m²

50yrs load incl. Max Load = 1.00 kN/m²

s_k = 50yrs load excluded Max Load = 0.79 kN/m²

$k = s_m/s_k$ = 1,65

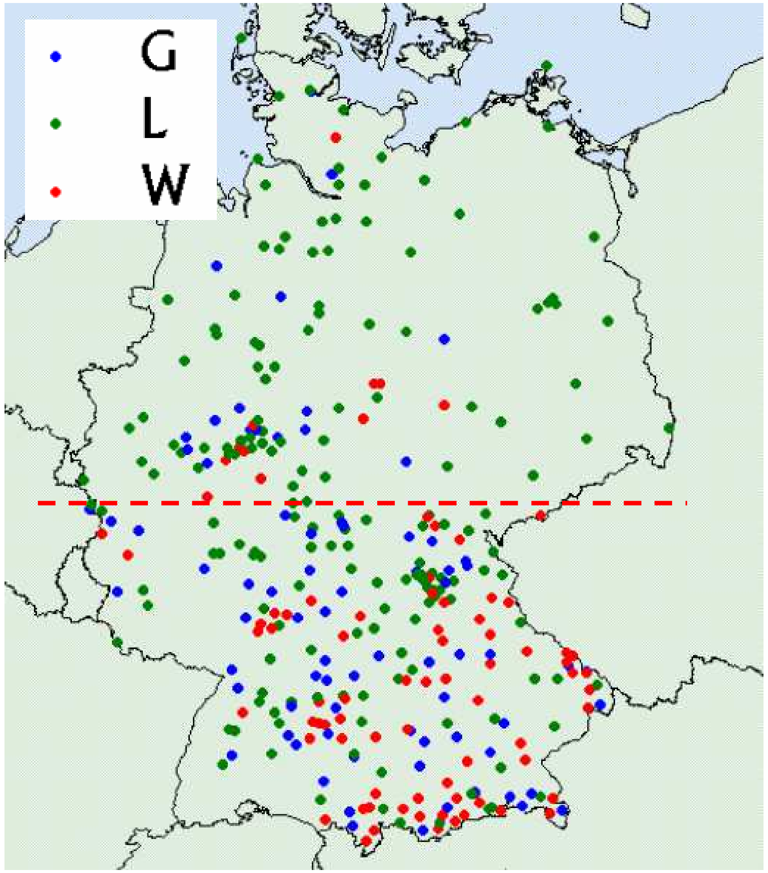
The European Ground Snow Load Map



Location of weather stations (159) where exceptional ground snow loads were detected (1996-1999)

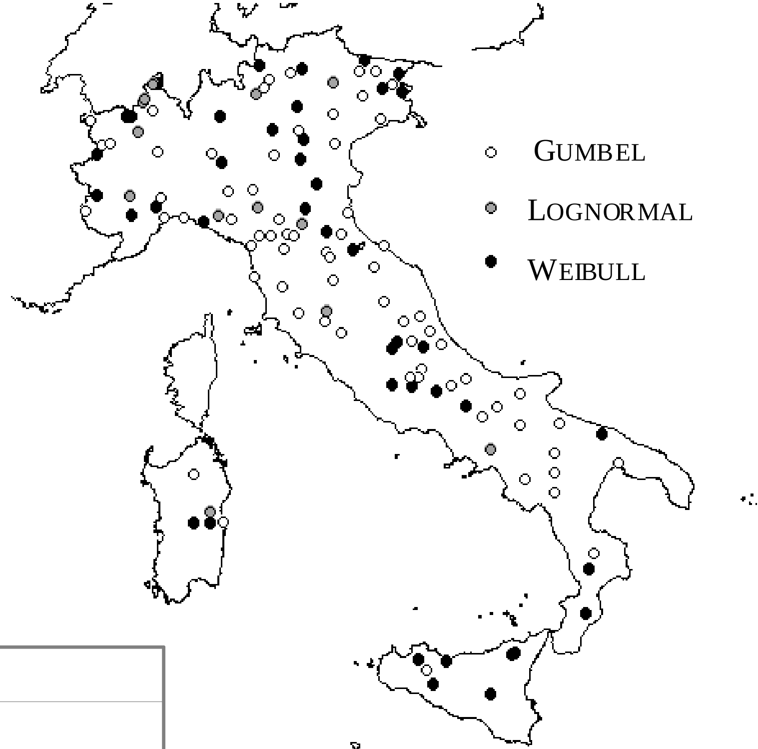
The European Ground Snow Load Map

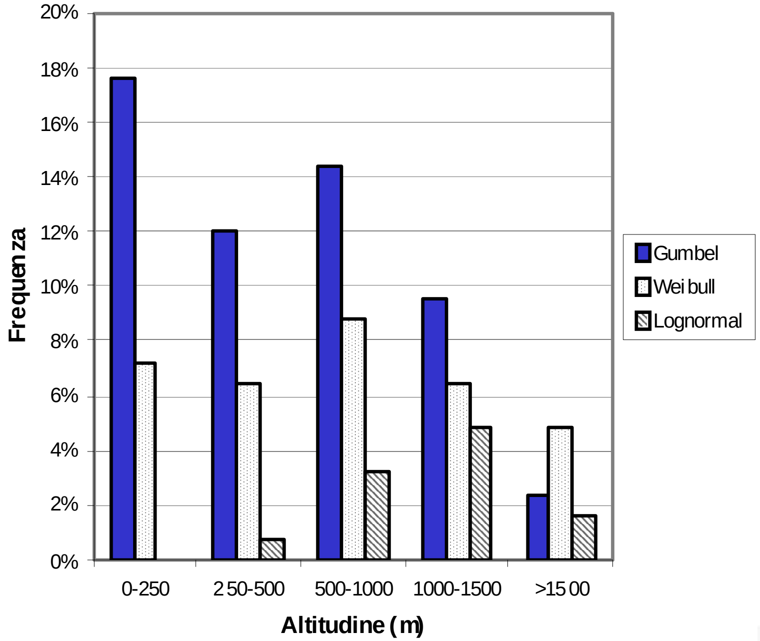
Which PDF?



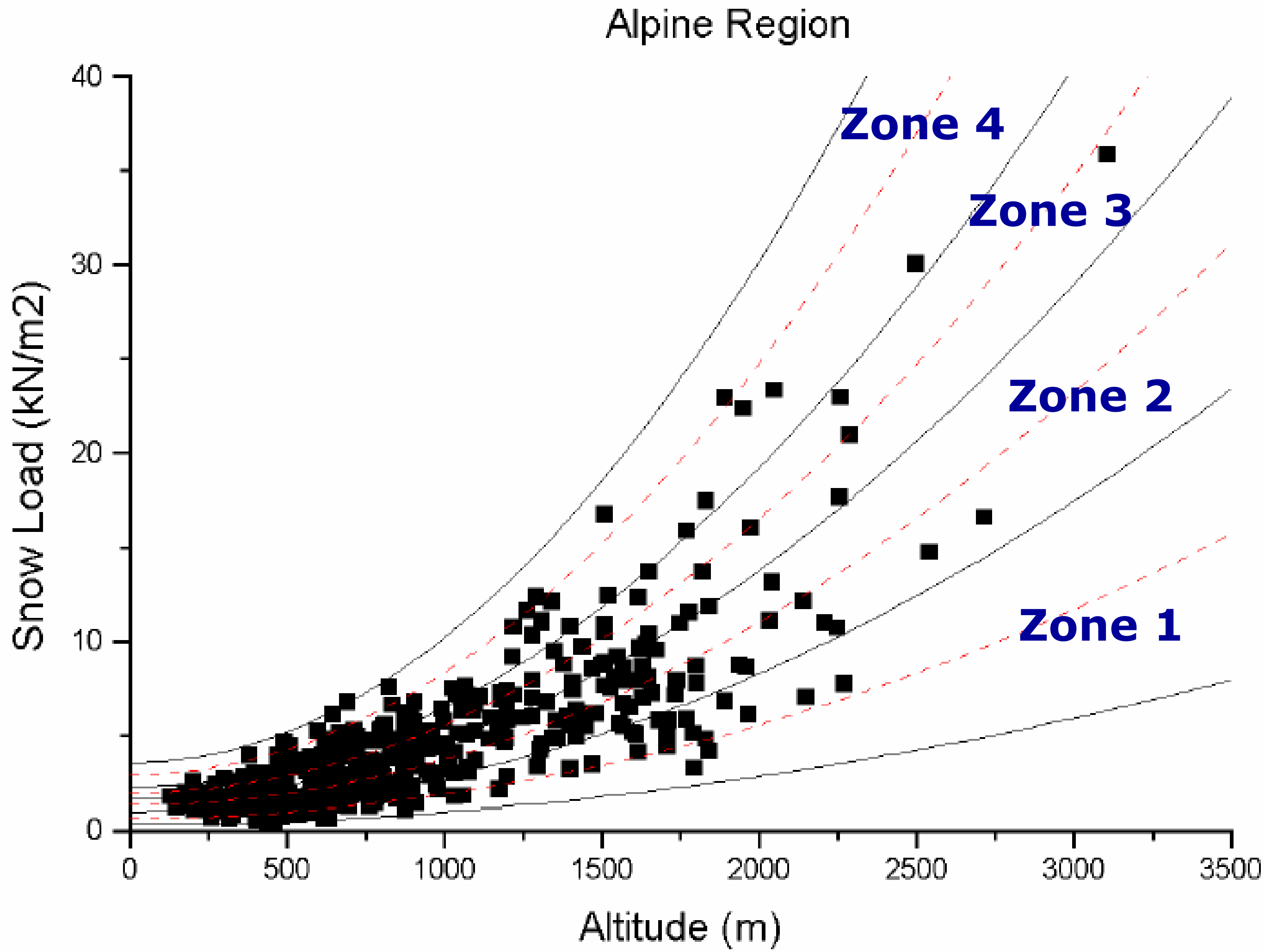
Latitude

Altitude





The European Ground Snow Load Map



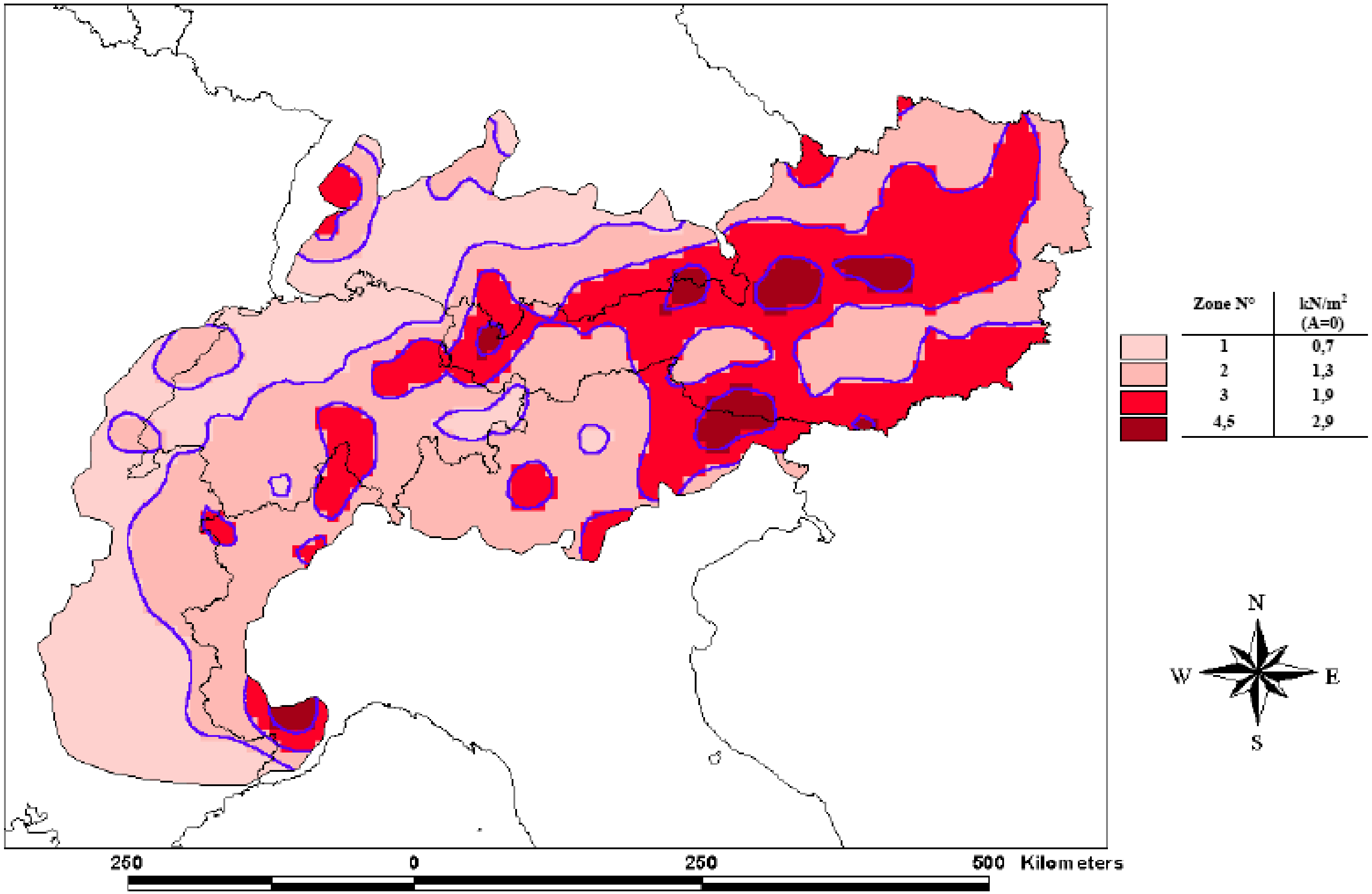
$$s_k = (0{,}642Z + 0{,}009)\left[1 + \left(\frac{A}{728}\right)^2\right]$$

z = Zone number given on the map
A = site altitude above Sea Level [m]

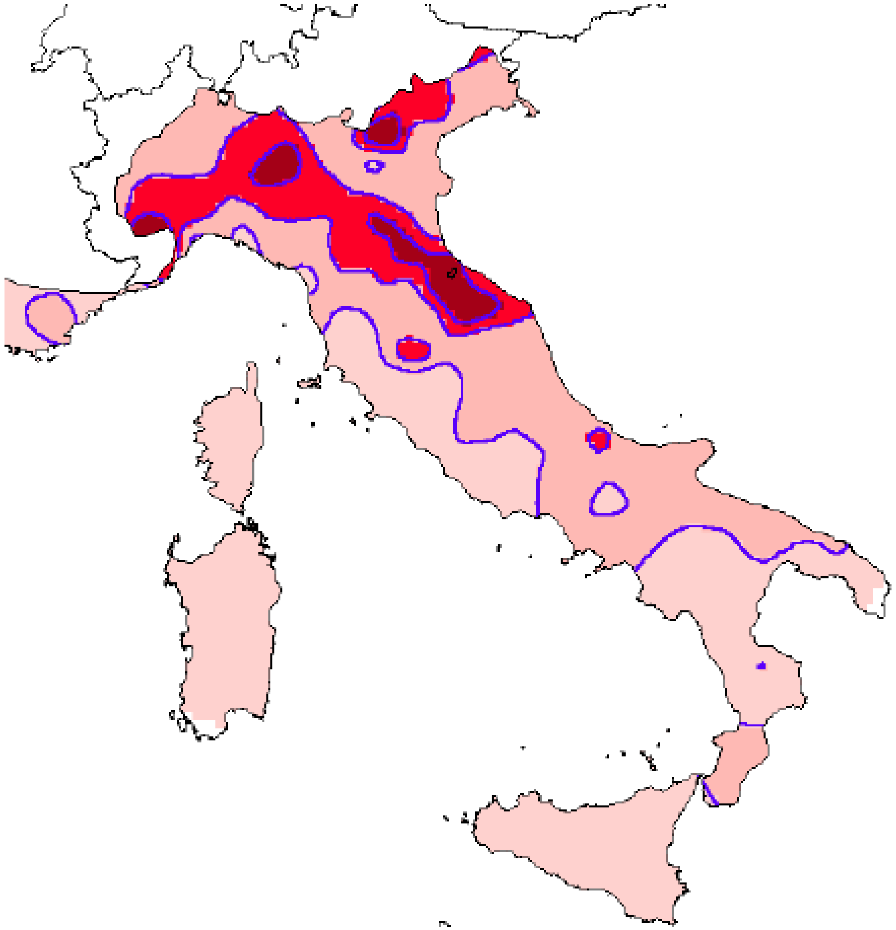
European Commission

The European Ground Snow Load Map

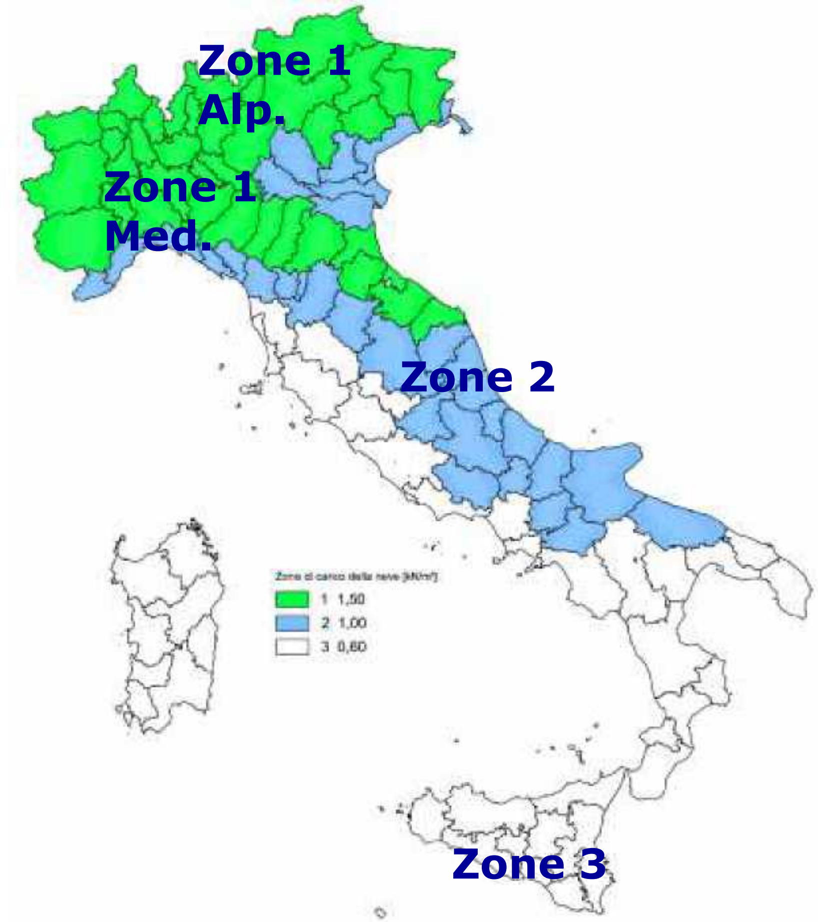
Alpine Region – Snow load at sea level



The European Ground Snow Load Map



Map for Mediterranean region
Annex C EN 1991-1-3
(geographical boundaries)



Italian National Annex
(administrative boundaries)

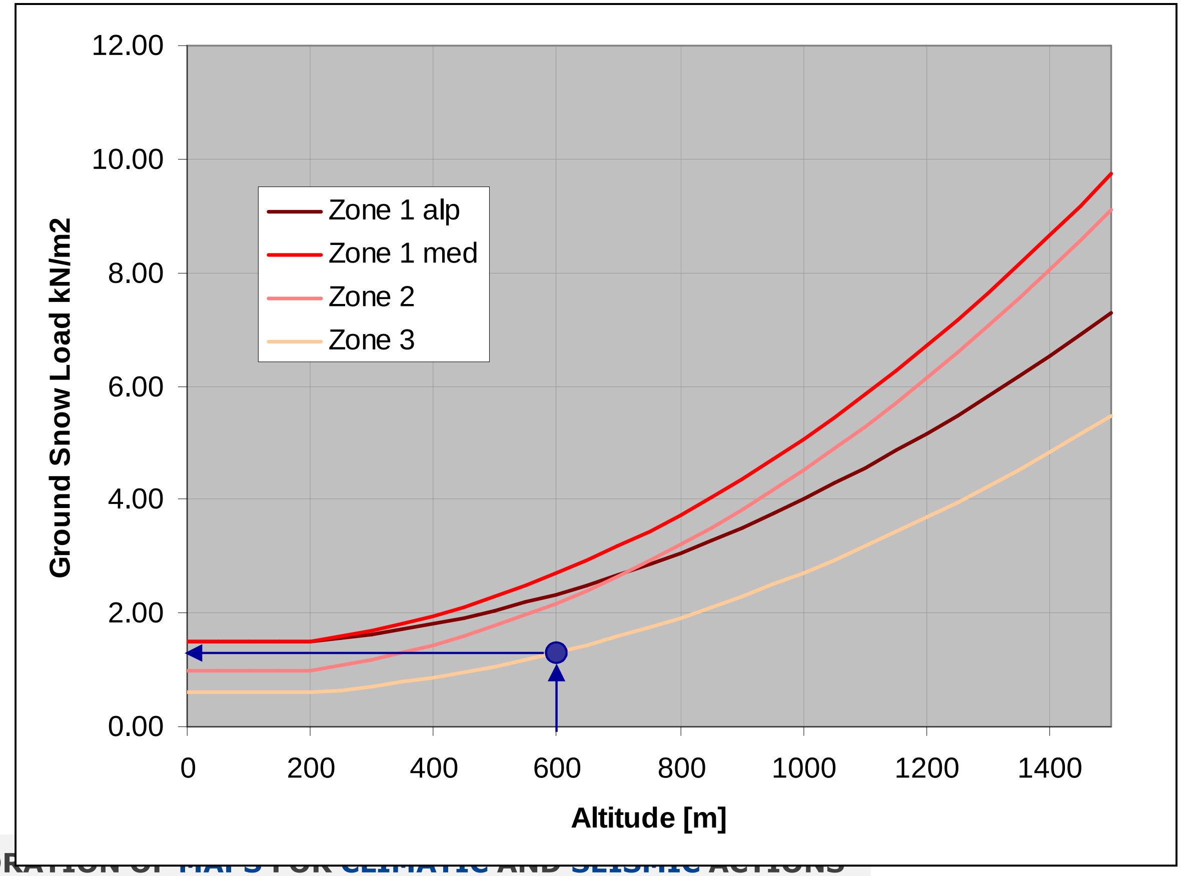
The European Ground Snow Load Map

Italian ground Snow load Map:

-4 different zones (3 Med. + 1 Alpine)

-Administrative boundaries (110 provinces)

-4 Altitude correlation functions



Example of calculation of ground snow load at a given location:

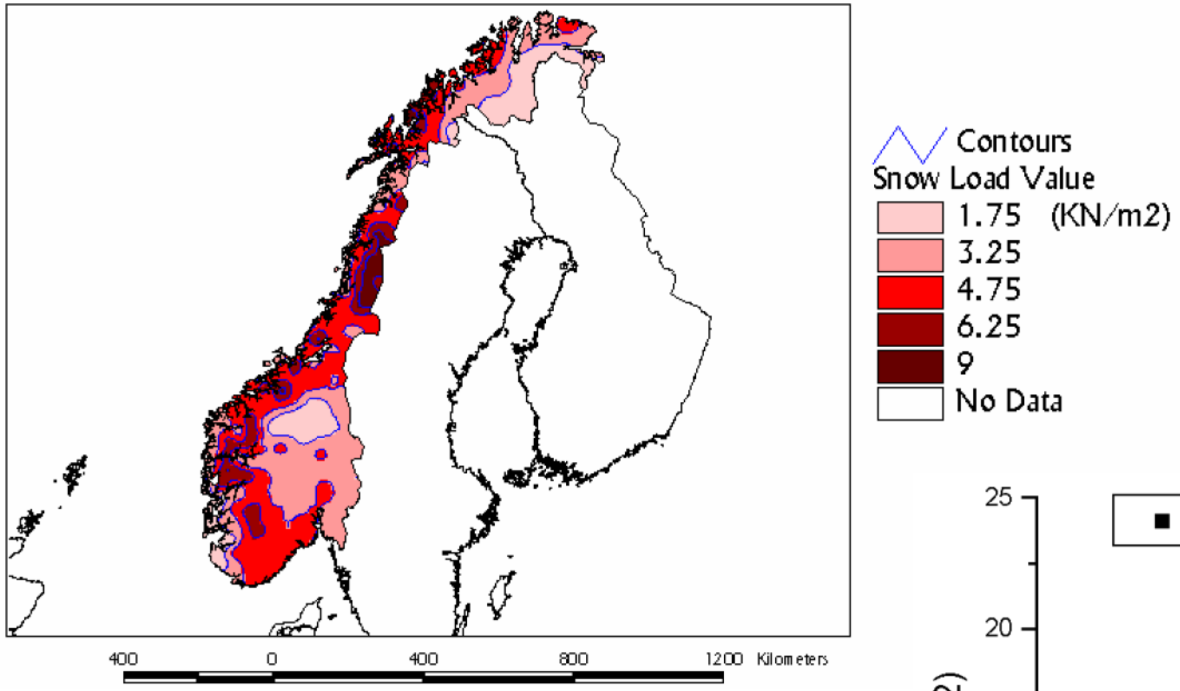
Inputs:

*- **zone** n. 3*

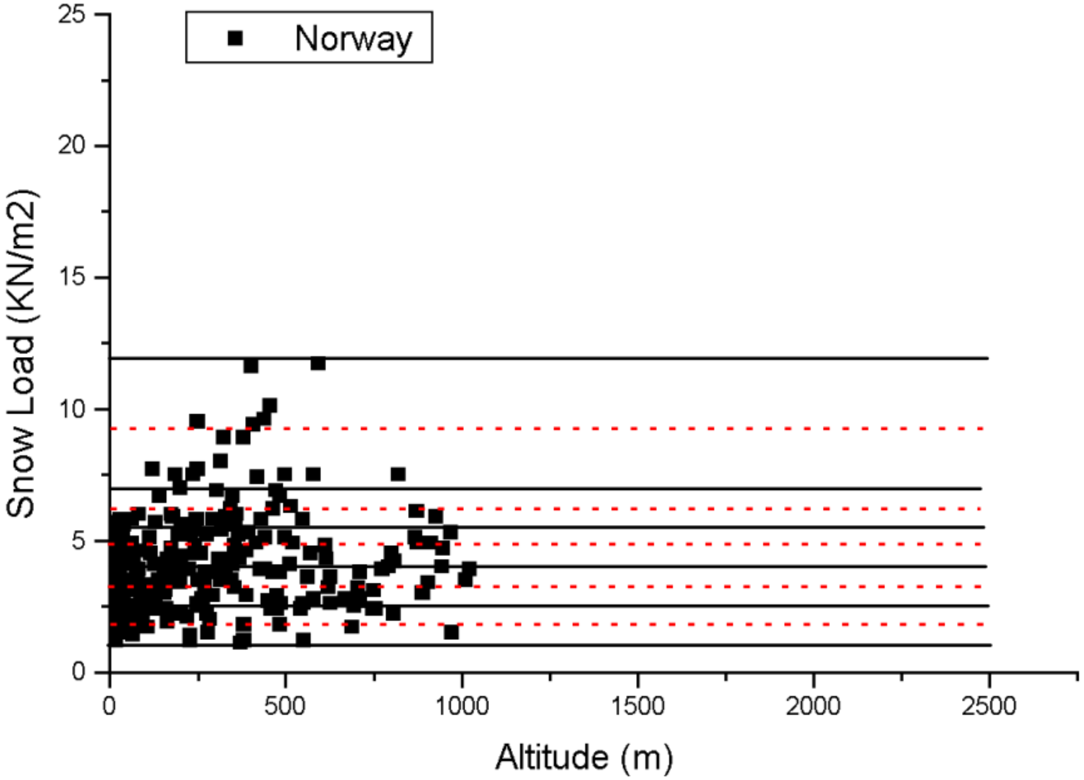
*- **altitude** = 600m a.s.l.*

s_k = 1,30 kN/m²

The European Ground Snow Load Map

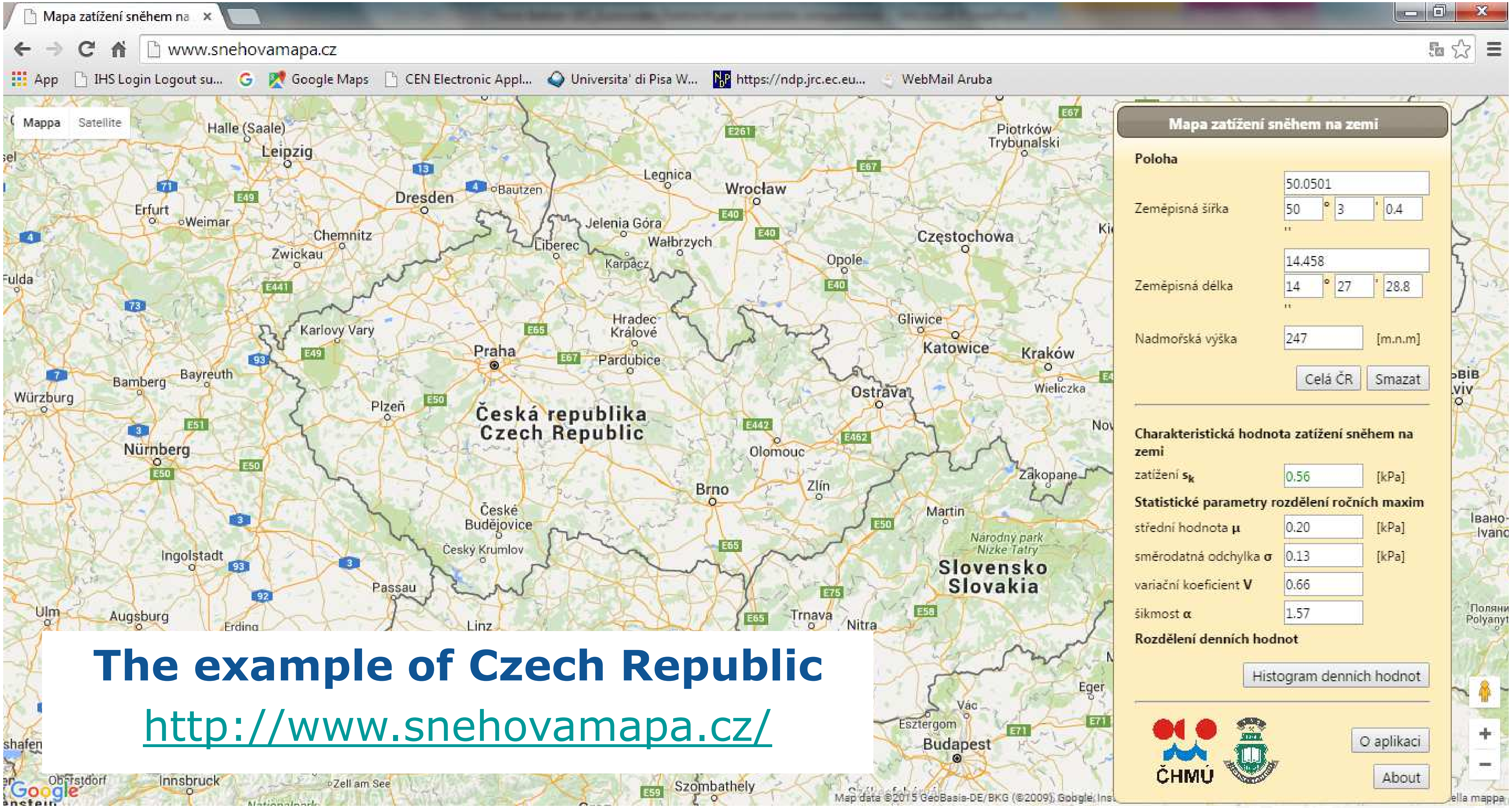


Norway
Lack of correlation between ground snow load and altitude a.s.l.



European Commission

The European Ground Snow Load Map

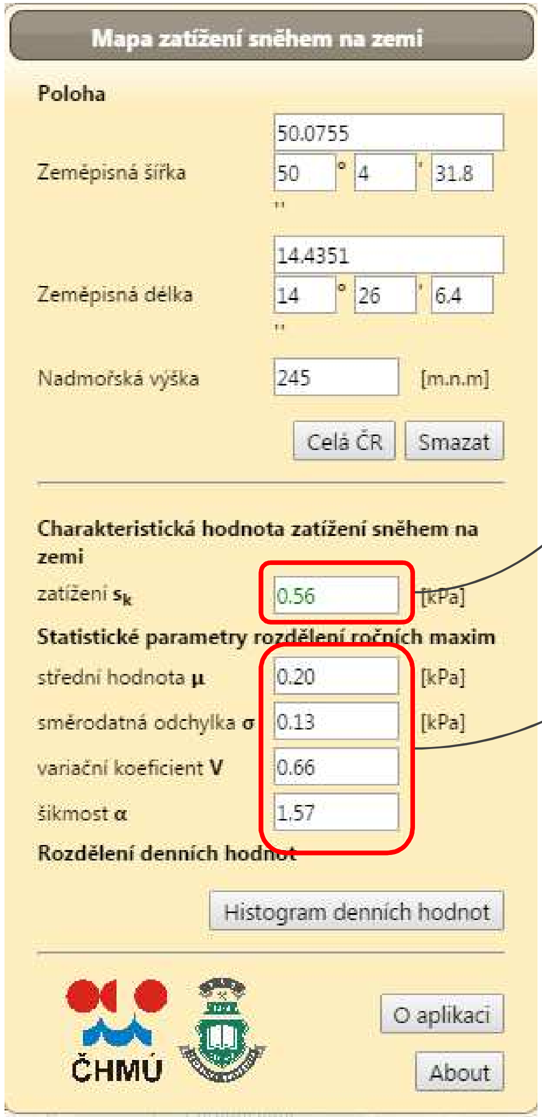


The example of Czech Republic

http://www.snehovamapa.cz/

European Commission

The European Ground Snow Load Map



- The digital map is applicable also for **direct probability assessments of structures**:

a) characteristic value of the snow load on the ground (s_k) (based on 1961-2009 obs.)

b) statistical characteristics for the distribution of annual maximum of snow load on the ground:
- mean value μ,
- standard deviation σ,
- coefficient of variation V,
- skewness α

The European Ground Snow Load Map

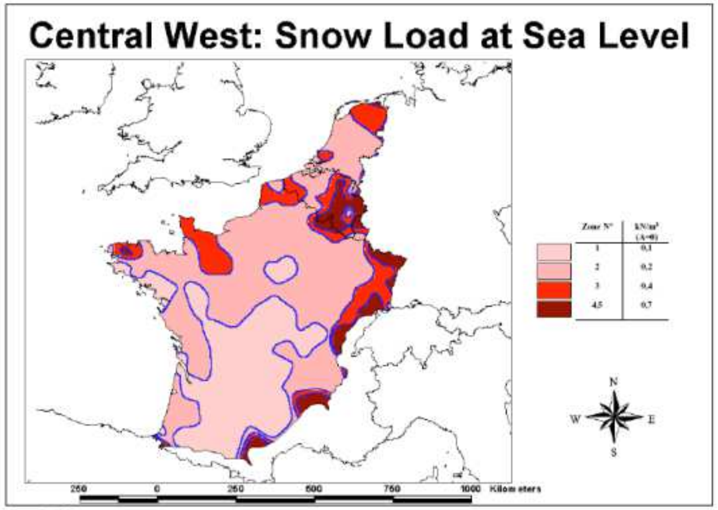
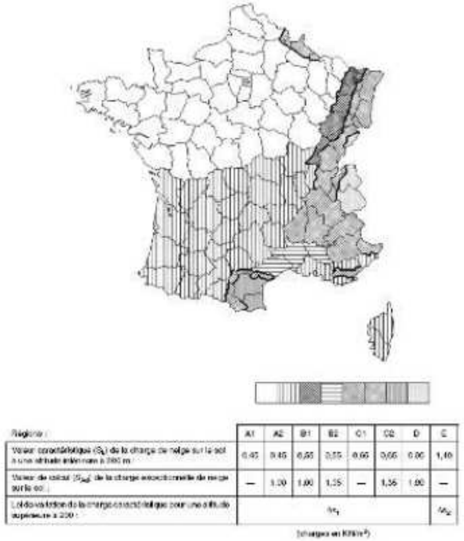


Figure C.7



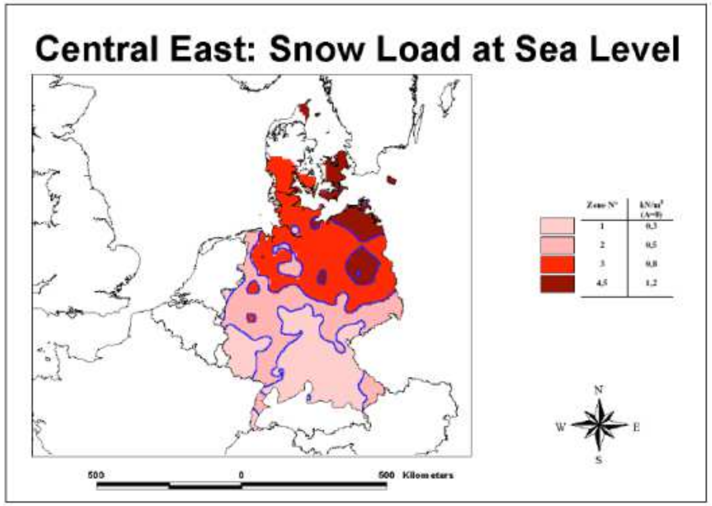
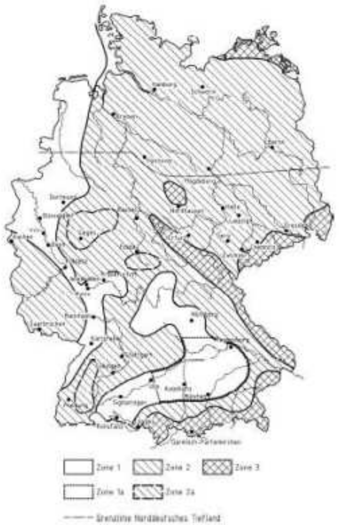
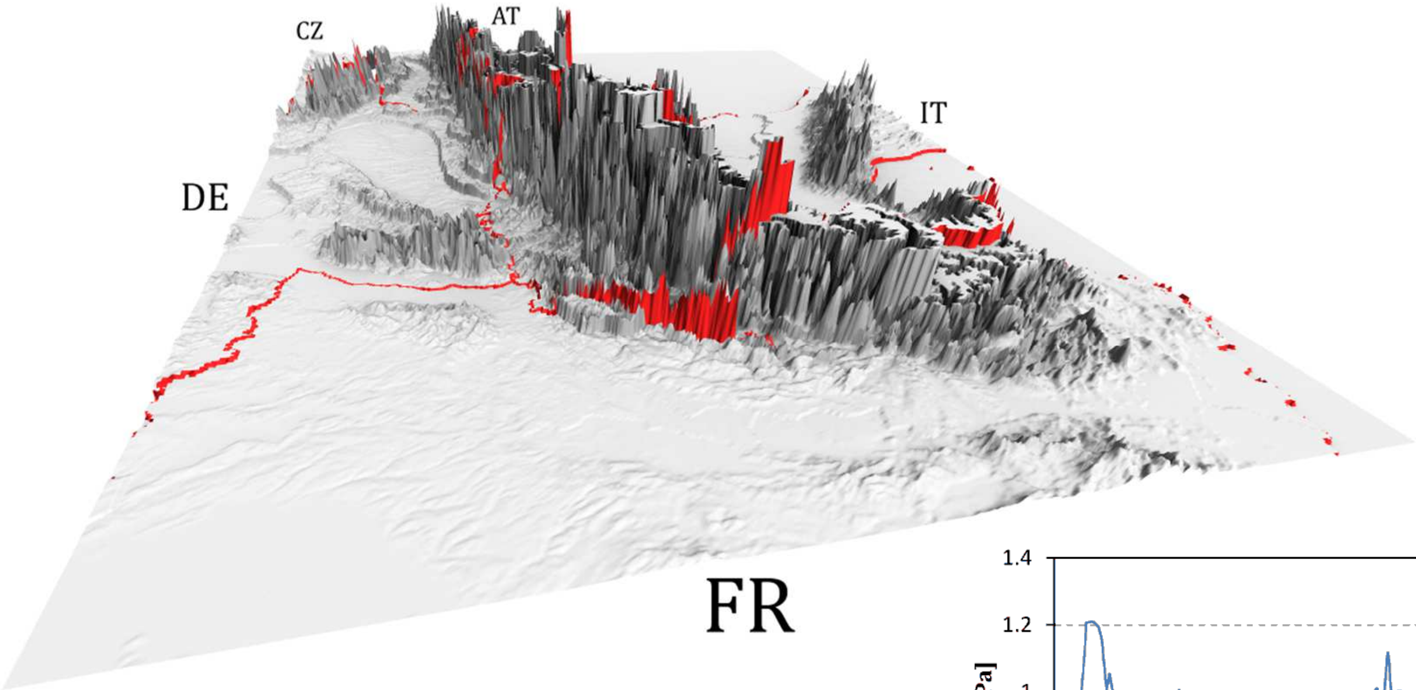


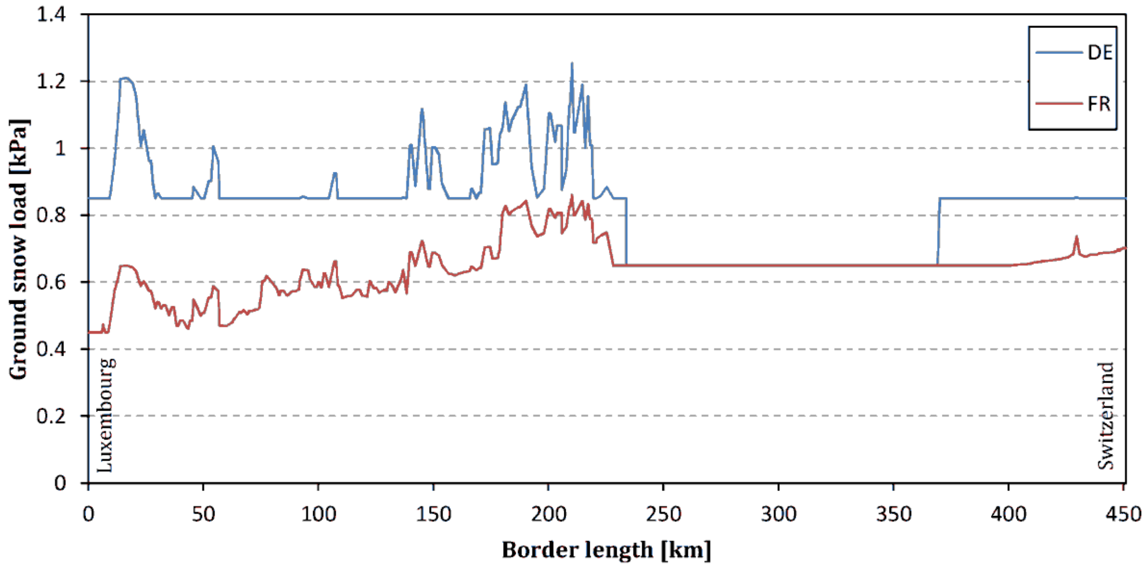
Figure C.3



Consistency at borders?

The European Ground Snow Load Map





Proposal for a study on
Eurocode 1 snow load maps
Grzegorz Kimbar, Jerzy Żurański

The European Ground Snow Load Map

*Maps given in National Annexes are determined without taking into account "**exceptional falls**"*

How to determine design values for accidental ground snow loads?

*For locations where exceptional loads may occur (**National Annex**), the ground snow load may be treated as accidental action with the value:*

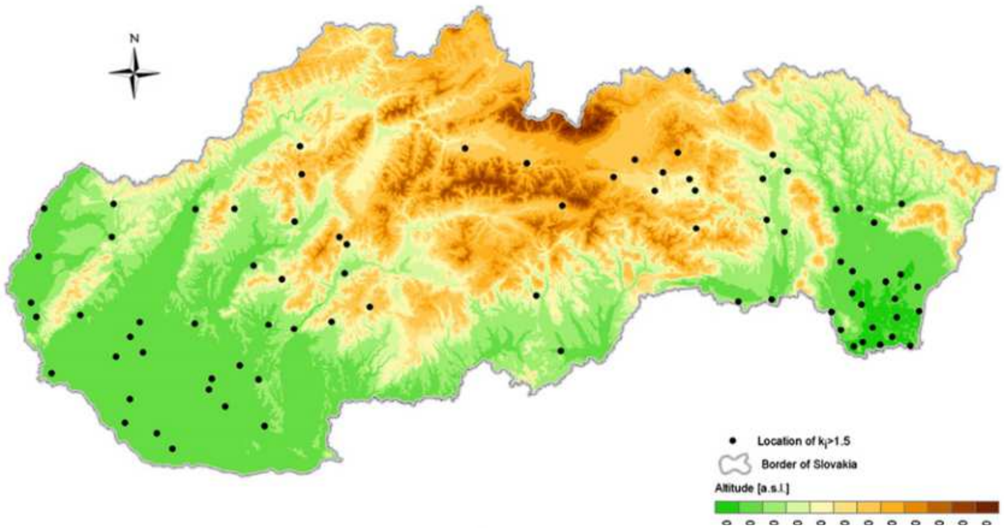
$$s_{Ad} = C_{esl}\, s_k$$

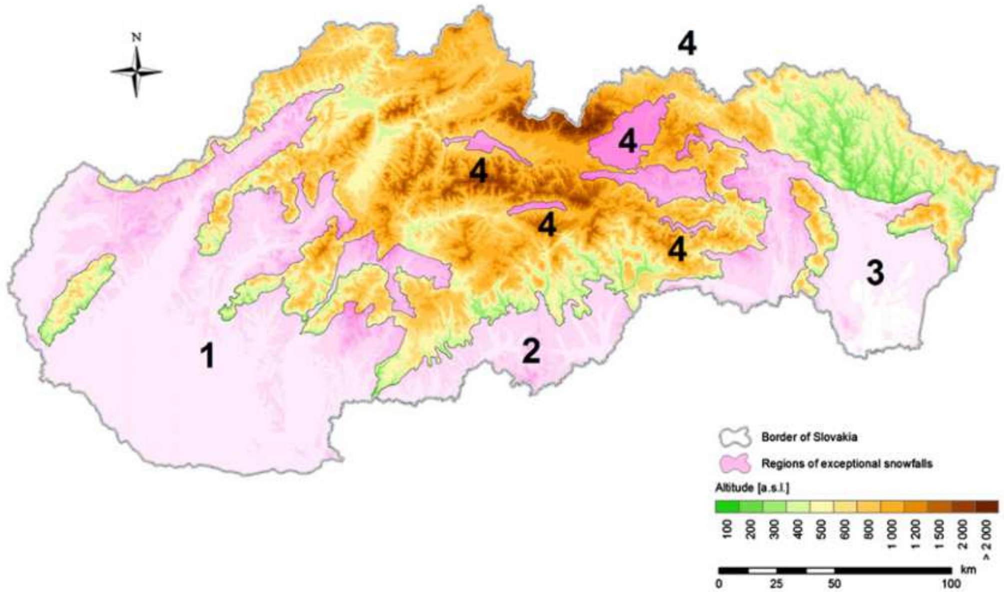
Where:

C_{esl} *(set by the National Annex) - recommended value = 2,0*

s_k *= characteristic ground snow load at the site considered*

The European Ground Snow Load Map



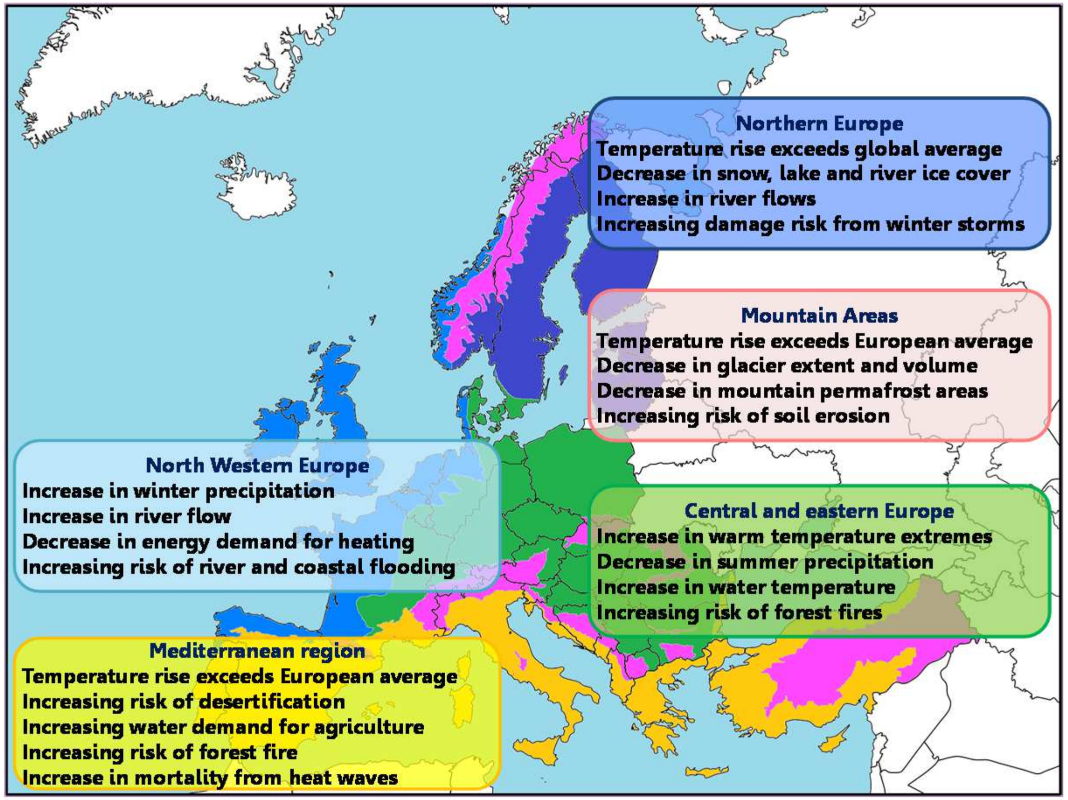


Slovakia

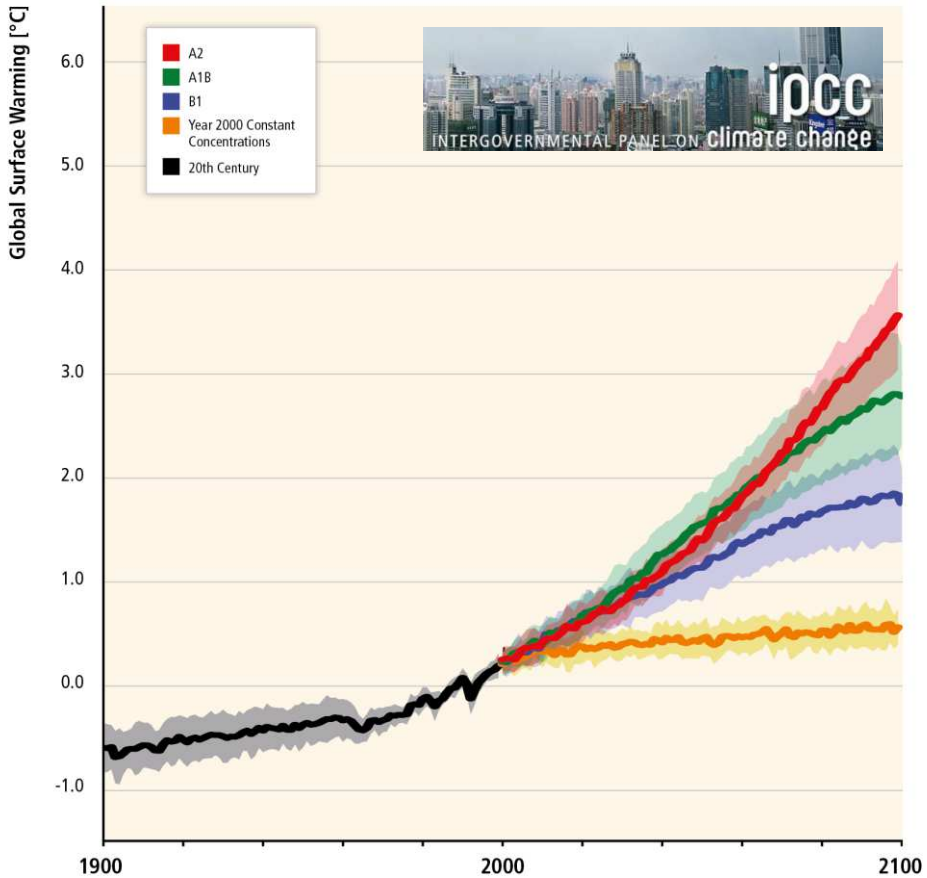
Locations of weather stations with recorded exceptional snow loads (85 over 660)

Region	1	2	3	4
Coefficient C_{esl}	**2.1**	**2.2**	**2.5**	**3.7**

Climatic Actions Maps & Climate Change



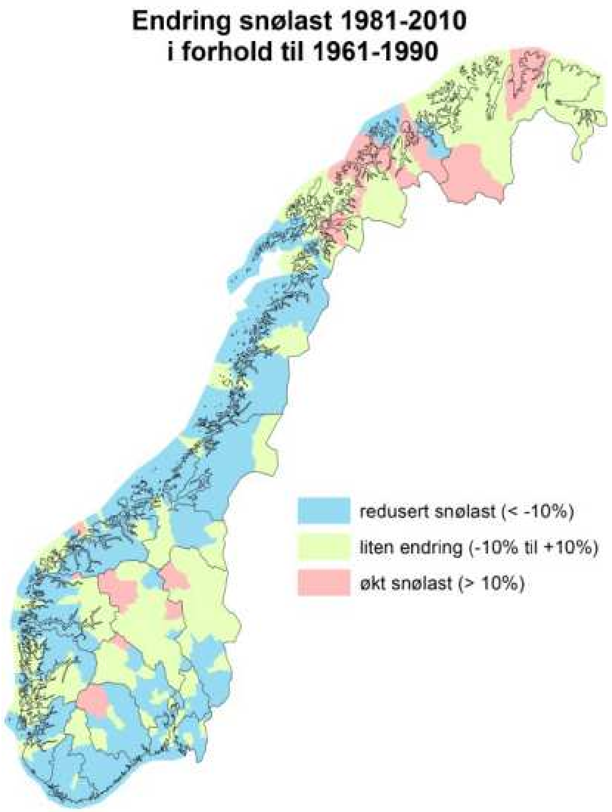
Changes in climate lead to changes in weather, including extreme weather leading to concrete local effects.



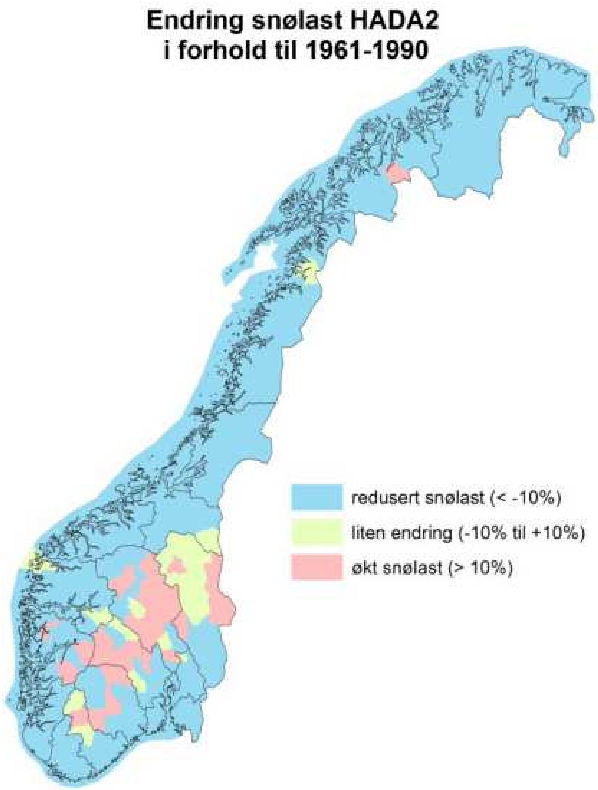
Which effects on climatic actions for structural design?

Climatic Actions Maps & Climate Change

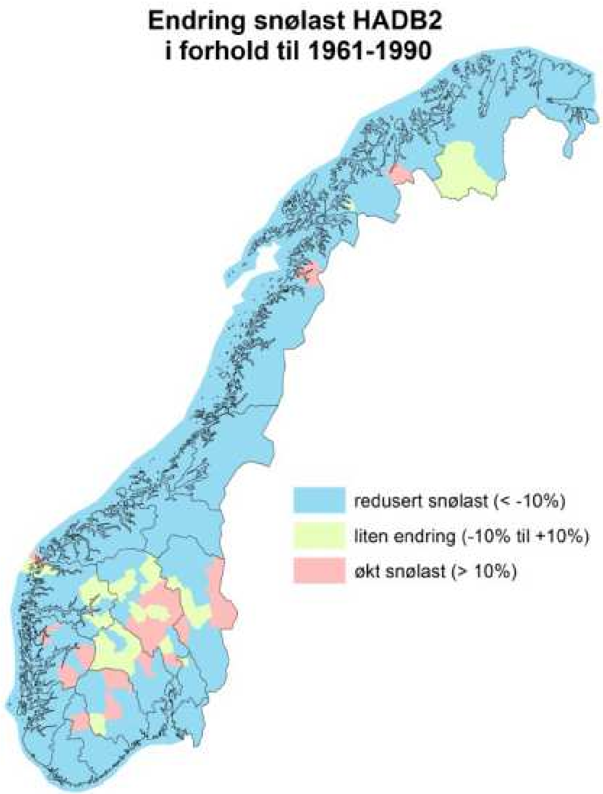
Climate change - Vulnerability of buildings in Norway (SINTEF 2013)



Registered Data



Prediction: scenario HADA2



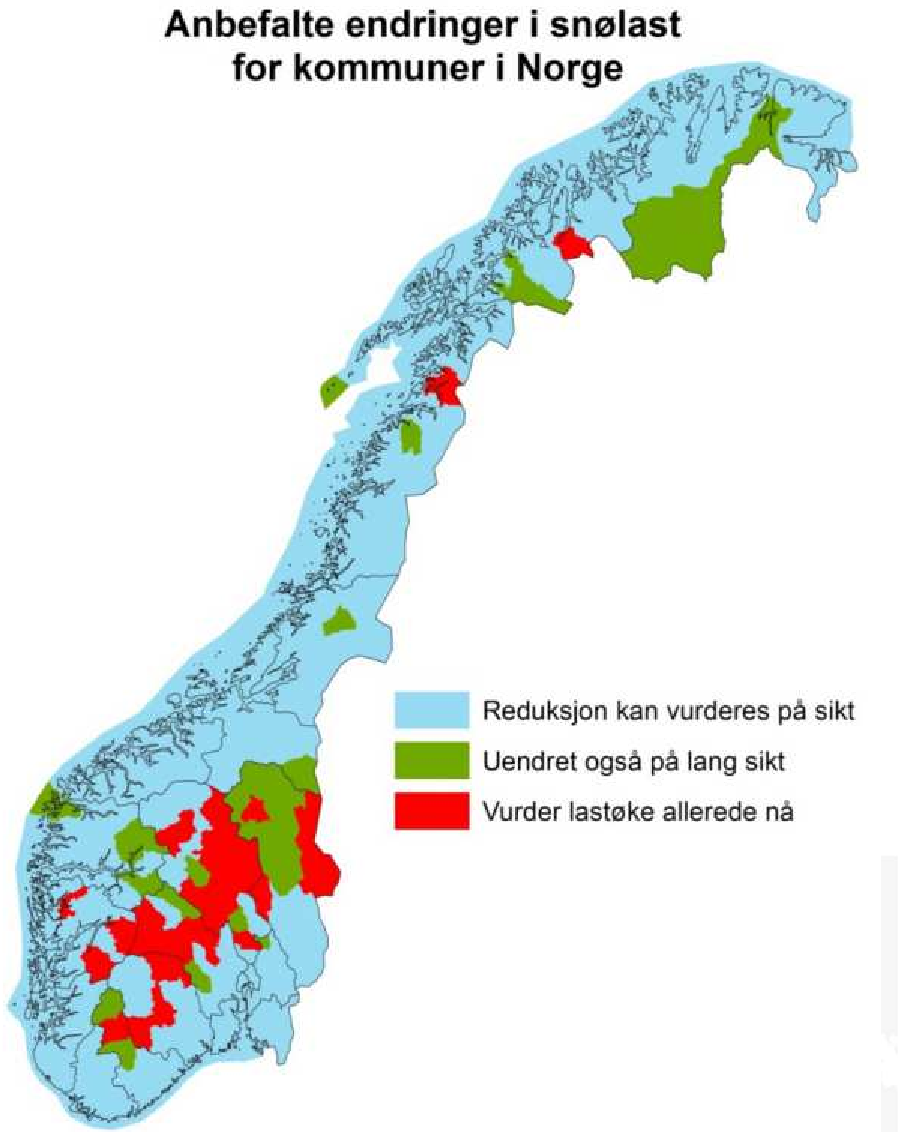
Prediction: scenario HADB2

% variation of 50-yrs ground snow load in the periods:
1961-1990 / 1981-2010 + predictions according IPCC scenarios

Climatic Actions Maps & Climate Change

Climate change - Vulnerability of buildings in Norway (SINTEF 2013)

Estimate of ground snow load variation (resulting from 3 IPCC scenarios) in the ***period 2071-2100*** *compared to the current Norwegian Annex to EN 1991-1-3*



Climatic Actions Maps & Climate Change

*Interaction of Extreme Weather Events (**EWE**)*

M515 Next Generation of ECs: Climate Change Objectives

Climate change consideration embraced within Eurocodes	This will provide increased resilience of long-life infrastructure assets to potential climatic changes. It is very cost effective to address such risks at the design stage rather than through later retrofitting. Such an approach also reduces user disruption and environmental impacts.

- Report on the impact of climate change on climatic actions in relation to structural design issues.
- Modified or additional clauses for **EN 1991-1-3**, **-1-4**, **-1-5** and **EN 1991-1-9** (Atmospheric Icing) (and possibly other Eurocode Parts).
- Background document(s)

Design values of seismic actions

EN 1990 4.1.2(9) *For seismic actions the design value* A_{Ed} *should be assessed from the characteristic value* A_{Ek} *or specified for individual projects.*

NOTE See also EN 1998.

$$A_{Ed} = \gamma_I A_{Ek}$$

Design values of seismic actions

EN 1998-1

2.1(1)P Structures in seismic regions shall be designed and constructed in such a way that the following requirements are met, each with an adequate degree of reliability.

– **No-collapse requirement.**

…..

The design seismic action is expressed in terms of:

a) the reference seismic action associated with a reference probability of exceedance, **P_{NCR}**, in **50 years or a reference return period**, **T_{NCR}**, and

b) the **importance factor γ_I** (…..) to take into account reliability differentiation.

……….

– **No-damage requirement…**

P_{DLR}, in **10 years or a reference return period**, **T_{DLR}**

Design values of seismic actions

EN 1998-1

NOTE 1 The values to be ascribed to P_{NCR} or to T_{NCR} for use in a country may be found in its **National Annex** of this document. The recommended values are $\mathbf{P_{NCR}}$ **= 10%** *(50 yrs ref. period)* and $\mathbf{T_{NCR}}$ **= 475 years**.

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NOTE 3 The values to be ascribed to $\mathbf{P_{DLR}}$ or to $\mathbf{T_{DLR}}$ for use in a country may be found in its **National Annex** of this document. The recommended values are $\mathbf{P_{DLR}}$ **=10%** *(10 yrs ref. period)* and $\mathbf{T_{DLR}}$ **= 95 years**.

European Commission

Design values of seismic actions

EN 1998-1

2.1(2)P **Target reliabilities** for the no-collapse requirement and for the **damage limitation requirement** are **established by the National Authorities** for different types of buildings or civil engineering works on the basis of the **consequence of failure**.

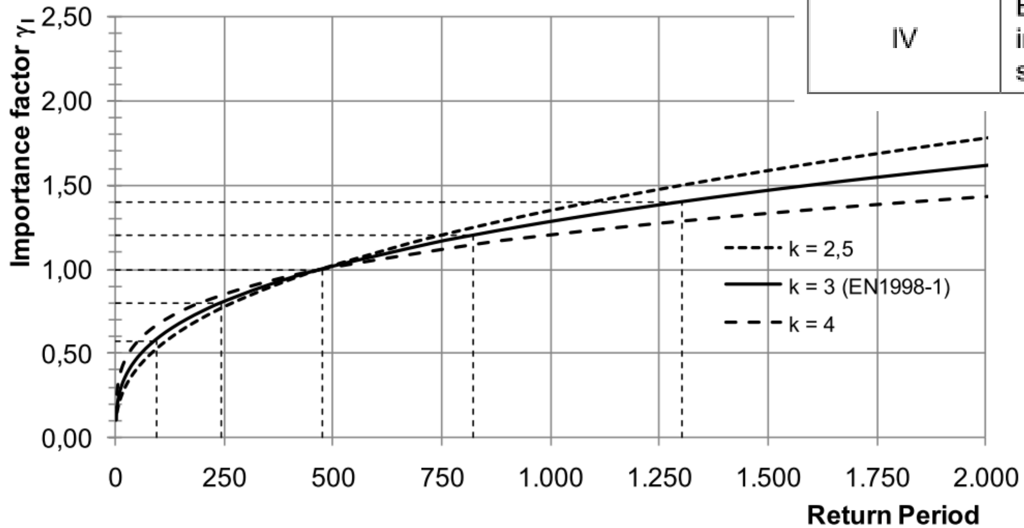
2.1(3)P **Reliability differentiation** is implemented by classifying structures into different **importance classes**. An importance factor γ_I is assigned to each importance class. ……

Reliability Differentiation

EN 1998-1

The value of the importance factor γ_I multiplying the reference seismic action (PGA) to achieve the same probability of exceedance in T_L years as in the T_{LR} years for which the reference seismic action is defined, may be computed as $\gamma_I \sim (T_{LR} / T_L)^{-1/k}$.

Importance class	Buildings	Importance factor γ_I (recommended value)
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.	0,8
II	Ordinary buildings, not belonging in the other categories.	1,0
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.	1,2
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.	1,4



European Commission

Design values of seismic actions

EN 1998-1

3.2.1 Seismic zones

(1)P For the purpose of EN 1998, national territories shall be subdivided by the National Authorities into **seismic zones, depending on the local hazard**. **By definition, the hazard within each zone is assumed to be constant**.

(2) For most of the applications of EN 1998, **the hazard is described in terms of a single parameter**, i.e. the value of the reference **peak ground acceleration on type A ground, a_{gR}** . Additional parameters required for specific types of structures are given in the relevant Parts of EN 1998.

NOTE The reference peak ground acceleration on type A ground, a_{gR} , for use in a country or parts of the country, may be derived from zonation maps found in its **National Annex**.

Maps for Seismic Actions

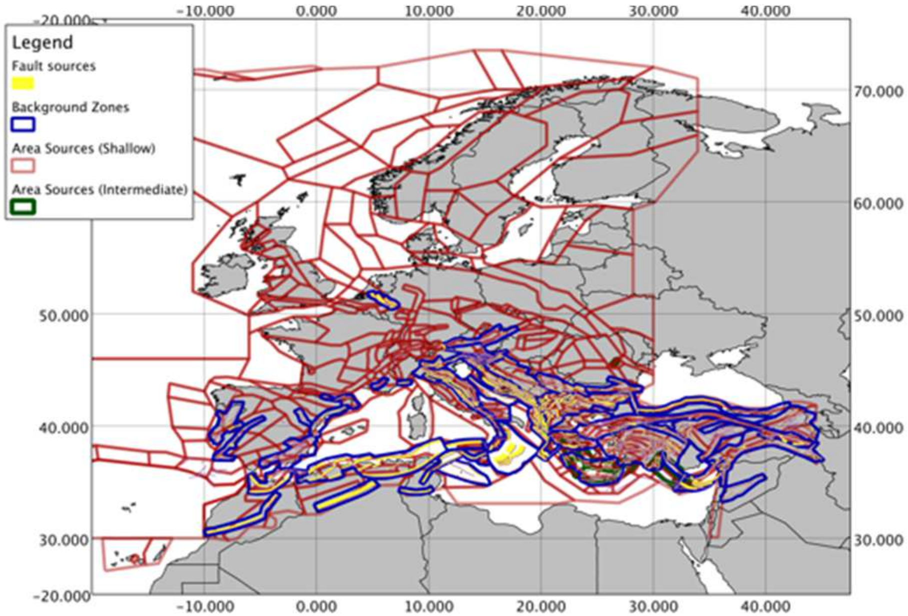
1. **Specification of the models for the seismic sources responsible for the seismic hazard**

2. **Specification of the ground motion models (attenuation relationships)**

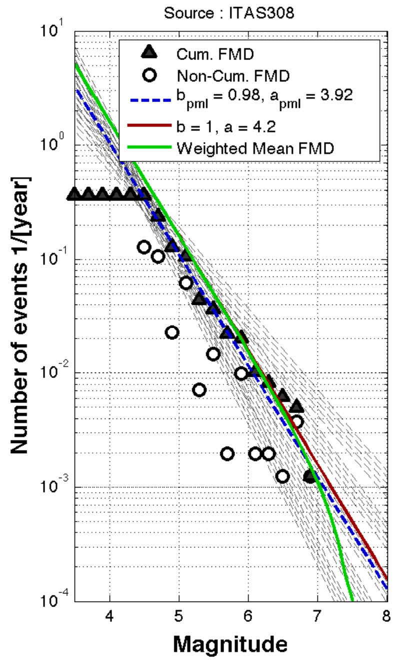
3. **Calculation of the reference parameter (PGA) for the given probability of exceedance**

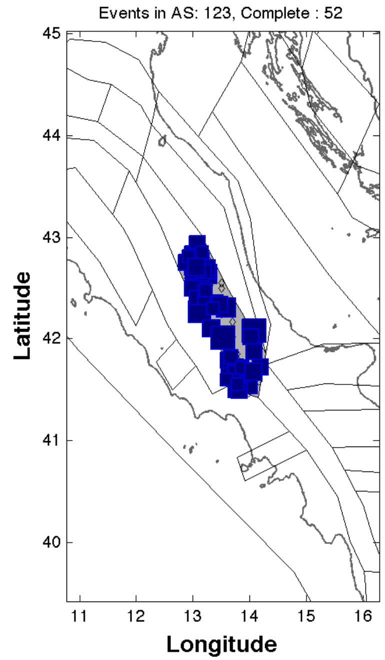
Maps for Seismic Actions

1. Specification of the models for the seismic sources responsible for the seismic hazard



Seismogenic sources





- Statistical description of the seismic hazard for a given location based on earthquake catalogues
- Gutenberg-Richter relationship
- pdf f(m) of events up to a given magnitude (m)

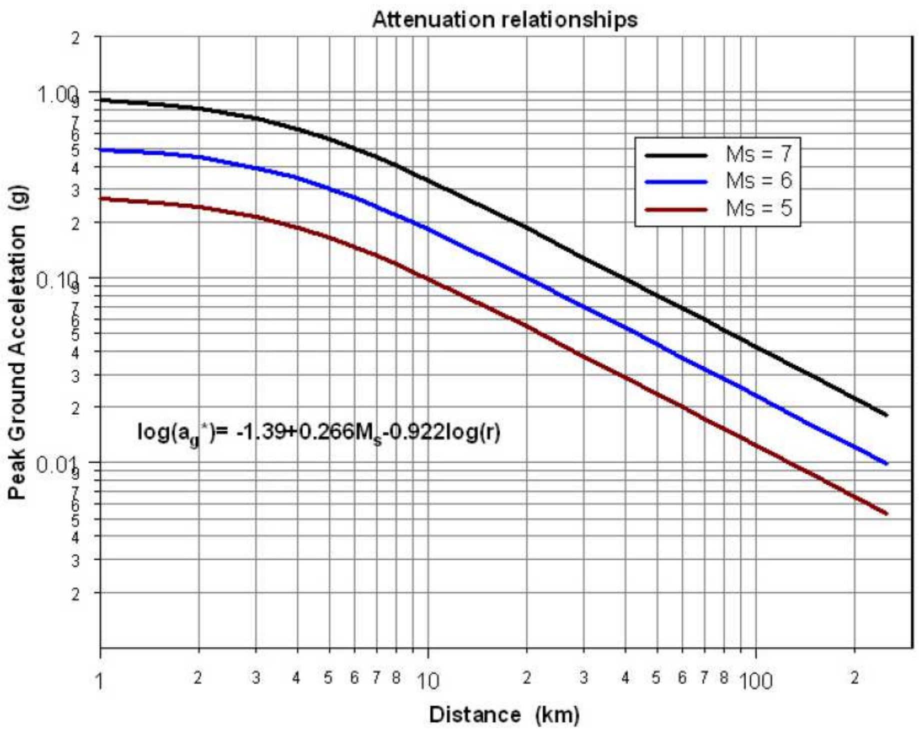
Maps for Seismic Actions

2. **Specification of the ground motion models (attenuation relationships)**

The attenuation relationships provide the value of a ground motion parameter (peak ground acceleration, spectral ordinates…) at a certain Distance (R) from an earthquake of a given magnitude (M)

Empirically determined equations e.g. Ambraseys (1996) for intraplate seismicity in Europe

Statistical estimate of PGA, given the occurrence of a seismic event with a specific magnitude (M) and at a given distance (R) from the site being considered



Maps for Seismic Actions

3. Calculation of the reference parameter (PGA) for the given probability of exceedance

Assumptions:

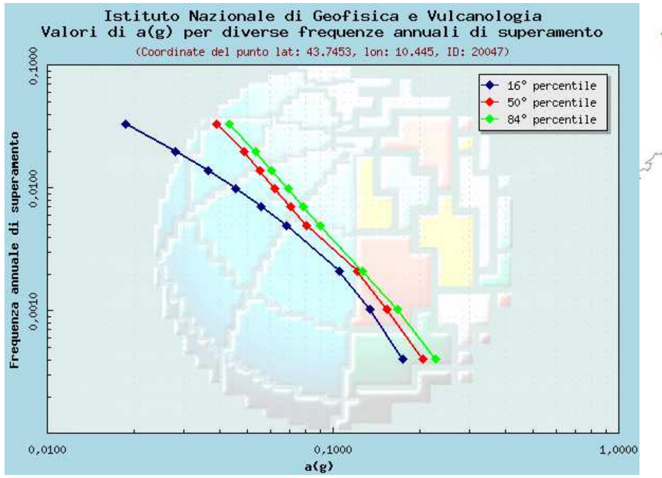
- Each seismic event can take place at any time
- Any seismic event is independent of the occurrence of all others
- Recurrence frequency of seismic events in a given time interval Td is given by λTd, being $\lambda=1/Tr$ the mean recurrence frequency of the seismic event assumed to be constant
- Events follow a Poisson process

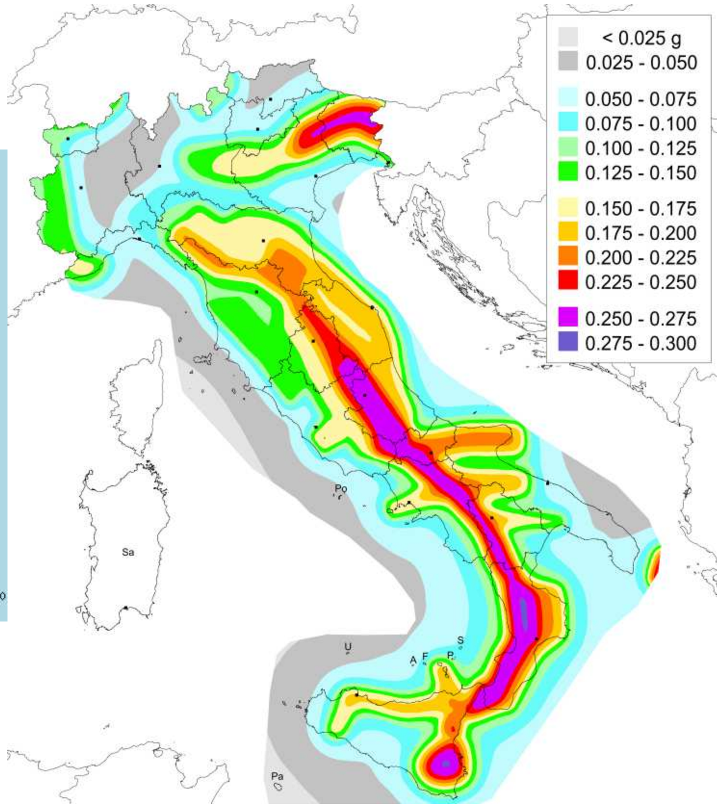
By numerical integration it is possible to evaluate the seismic hazard, in terms of probability of exceedance of a PGA, for each site and for a given time interval.

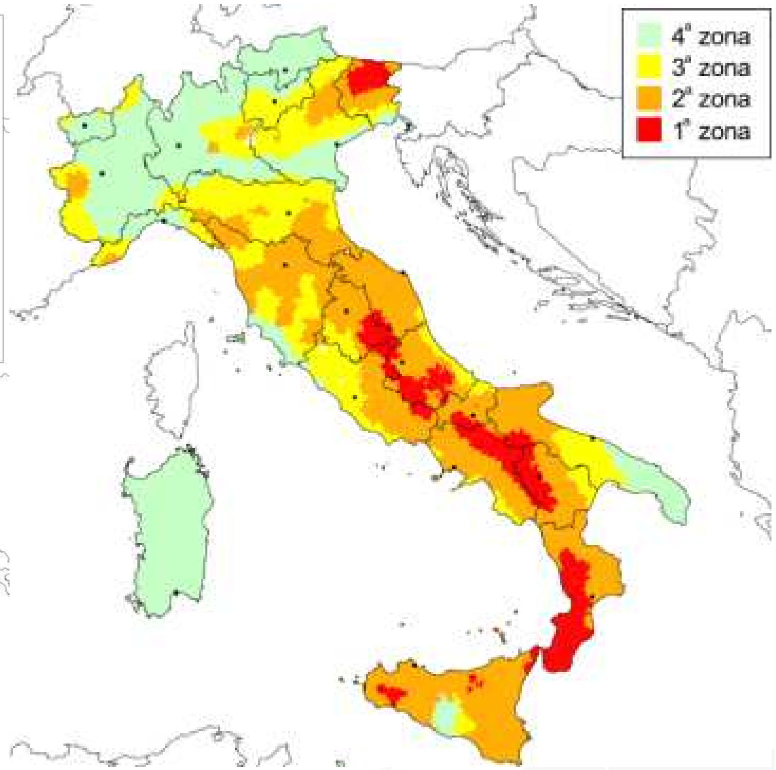
Hazard curves

Maps for Seismic Actions

3. Calculation of the reference parameter (PGA) for the given probability of exceedance



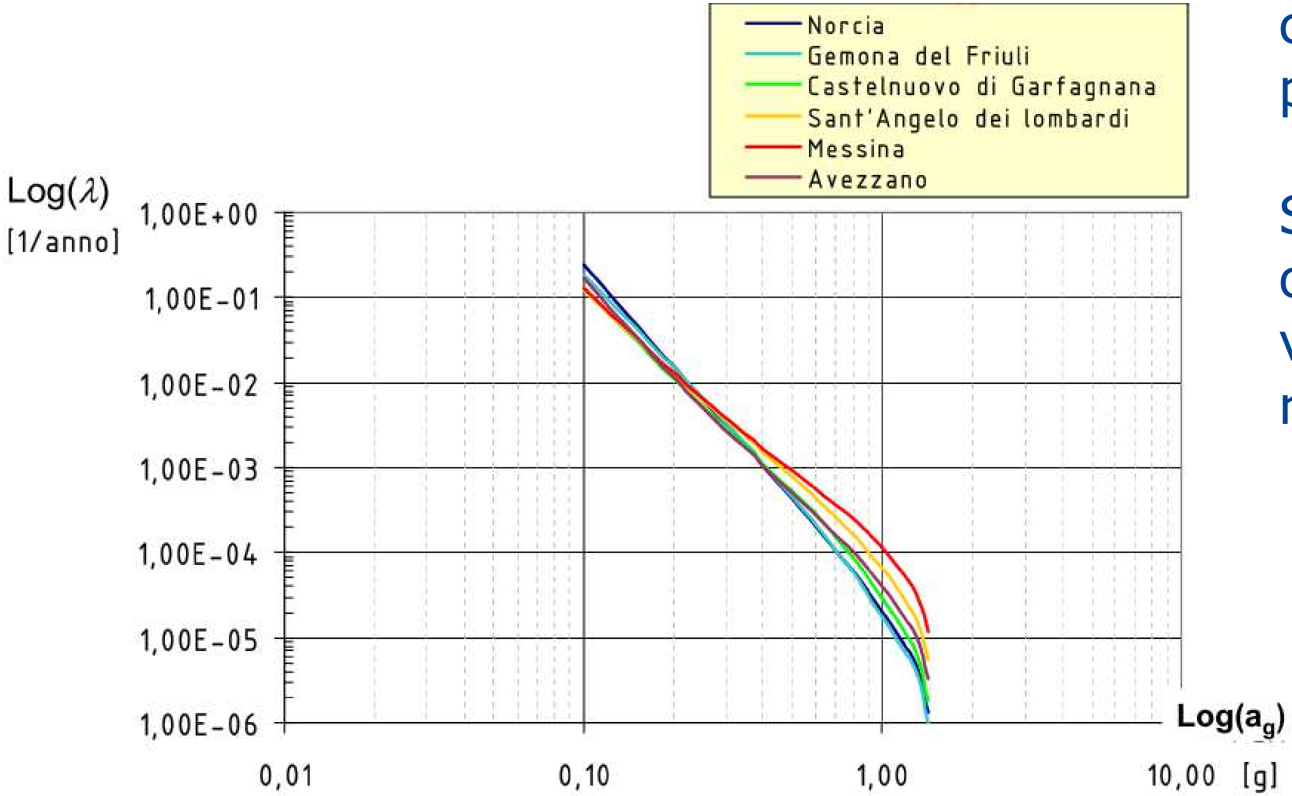




Hazard curves → Hazard map → Seismic zonation

Maps for Seismic Actions

The Italian example

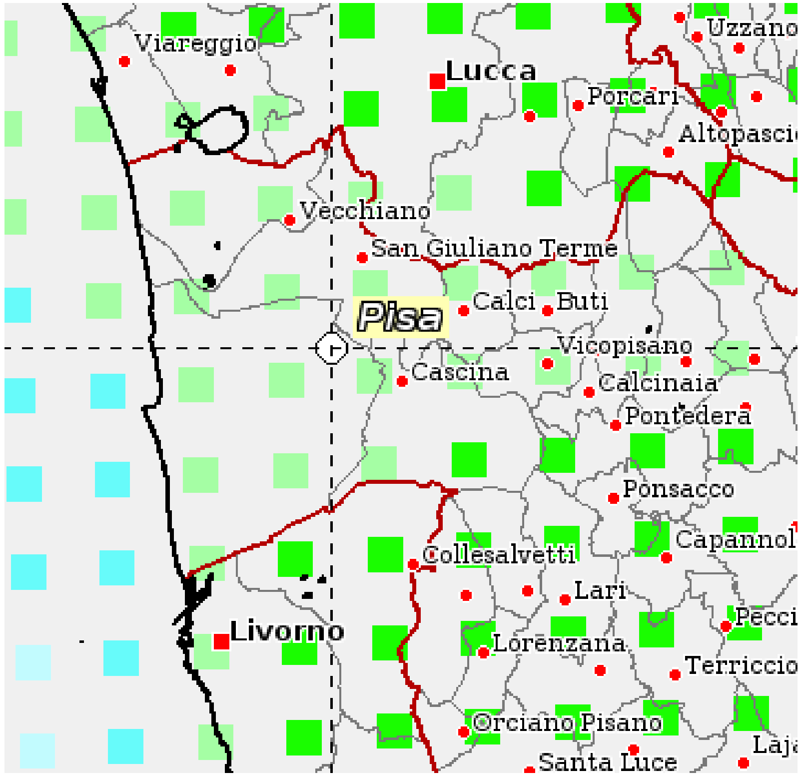


Hazard curves are not homothetic, they change with the return period

Seismic zonation based only upon TR475 PGA values is not fully representative

Maps for Seismic Actions

The Italian approach

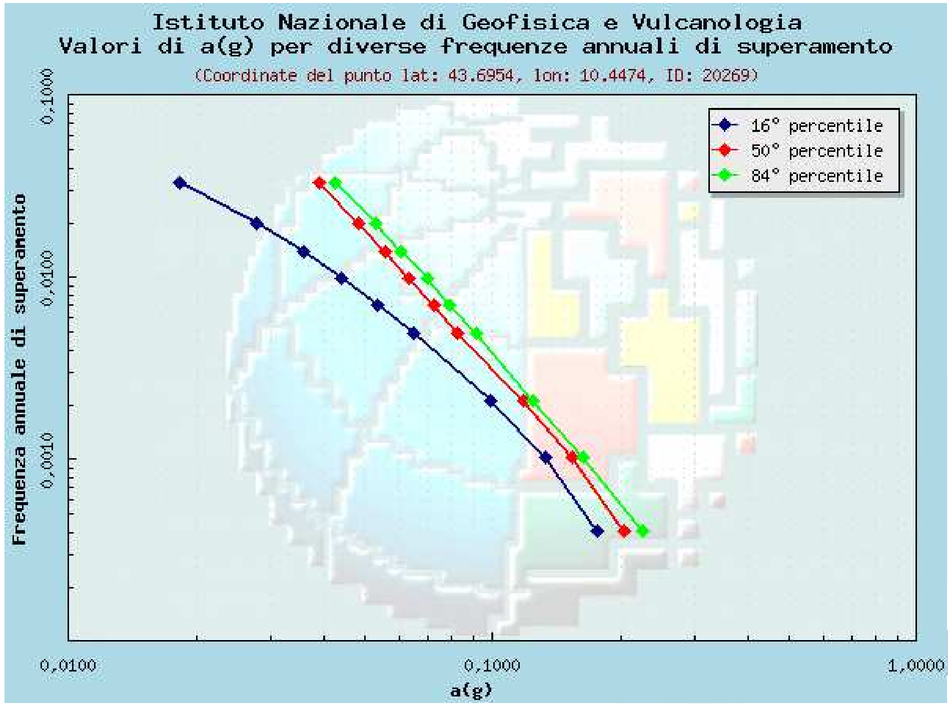


Probability of exceedance
10% in 50 yrs

From seismic zones to the definition of local seismic hazard

Italian territory divided in 10’571 grid points (grid span 5 km)

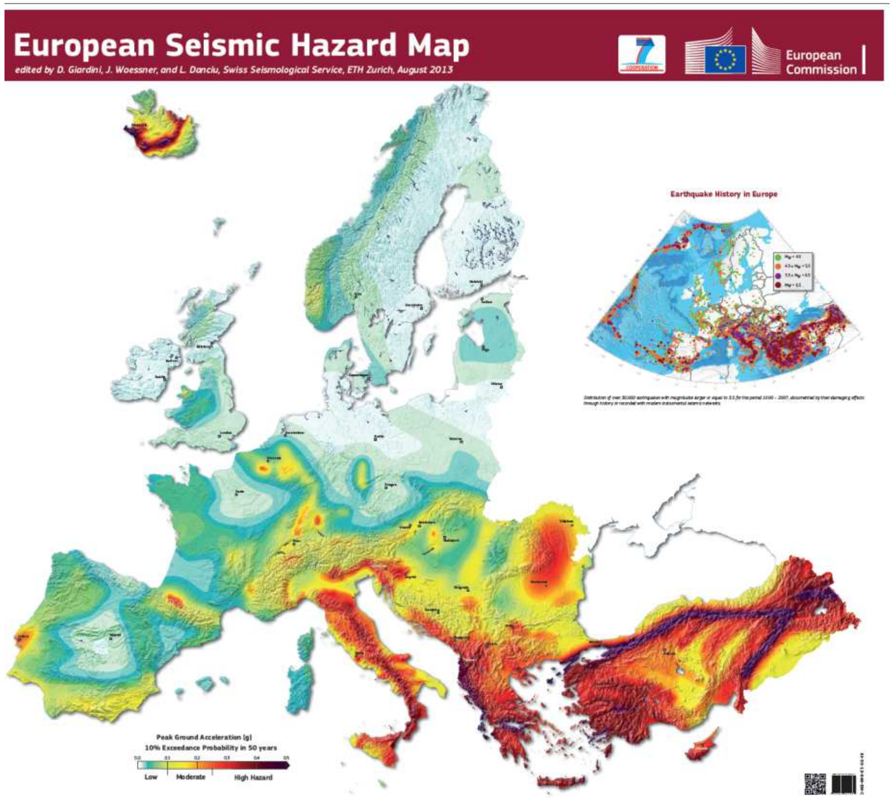
For each grid point derived hazard curves for different probability of exceedance



Maps for Seismic Actions NAs

Open points:

- **Inconsistencies at borders between neighbouring countries**
- **Different presentation of seismic maps**
- **Harmonization of procedures and/or parameter values is highly desirable**



Future evolution of EN 1998-1 (M515)

The main benefit of this action is to update the way in which the seismic zonation is presented, taking profit of the more recent research in this field and aligning EN1998 with the way in which seismic zonation is presented in other national and international seismic codes.

To this effect profit shall be taken from recent European research projects, namely the **project SHARE**, which provided **consistent methodologies and tools to support the establishment of a European seismic zonation**.

Redrafting of Section 3 (Ground conditions and Seismic action) of EN 1998-1.
The redrafting shall provide the advancement towards a harmonized seismic zonation but still enabling the Member States, if required, to establish its own safety levels at different performance levels and for different types of structures (importance classes).

Thank you for your attention