COMMISSION OF THE EUROPEAN COMMUNITIES
DGIII - D3

SCIENTIFIC SUPPORT ACTIVITY IN THE FIELD OF STRUCTURAL STABILITY OF CIVIL ENGINEERING WORKS
SNOW LOADS

Contract n° 500990 dated December 12th 1997

ANNEX B
TO THE
FINAL REPORT

EUROPEAN GROUND SNOW LOADS MAP

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2. CSTB, CENTRE DE RECHERCHE DE NANTES (FRANCE)
3. ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, (SWITZERLAND)
4. ISMES, STRUCTURE ENGINEERING DEPARTMENT (ITALY)
5. JOINT RESEARCH CENTRE, ISIS (EU)
6. SINTEF, CIVIL AND ENVIRONMENTAL ENGINEERING (NORWAY)
7. UNIVERSITY OF LEIPZIG, INSTITUTE OF CONCRETE DESIGN (GERMANY)
8. UNIVERSITY OF PISA, DEPARTMENT OF STRUCTURAL ENGINEERING (ITALY)

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B.0 Introduction

In the first phase of this project ground snow load data has been collected all over Europe by the partners and a homogeneous elaboration of data has been performed, in order to determine representative values associated with the location of the weather stations. The characteristic values of the snow load on the ground constituted the basic data for the determination of the snow load map.

Although snow load depends on several factors, such as climatic conditions, distance to the sea, dominant wind intensity and direction, the variation with altitude is the most significant one for the European countries. Therefore the best way to present the snow load in a map for the use by engineers is to define areas in which a given snow load-altitude function can be applied.

Experience has shown that the form of the snow load-altitude relationship can vary from region to region across Europe. It was then necessary to identify and define major climatic regions with homogeneous climatic conditions. Within these regions the variations of the snow load with altitude can be described by a family of curves depending on one parameter, called the zoning number. In this way the snow load map becomes a map of zones, which is very useful for engineers.

The zone numbers were obtained by first fitting a formula to the scatterplot showing snow load and altitude for every meteorological station. Varying the zoning parameter of the formula allowed a curve to be fitted through every data point. This zone number refers to the expected snow load at sea level and represents the climatic characteristics of the meteorological station.

In order to extend the point based information available for the meteorological stations to a map covering the whole territory interpolation of the zoning numbers using inverse distance weighting was performed. Smoothing has been applied to the resulting maps, in order to eliminate micro zones (for details see final report phase I). This elaboration was performed separately for every climatic region. Maps were drawn making extensive use of the computer-aided procedure of Geographical Information Systems (GIS).

The interpolated values have been reclassified in order to obtain a small set of zones, characterised by an integer zone number. On the scatterplot this corresponds to a grouping into bands. The representative altitude function for each zone is assumed to be the mean curve within the band. Points remaining on the upper side of the representative curve in a zone's band are assumed to be covered, from the safety point of view, by partial safety factors adopted in ENV 1991-1 Basis of Design. Some of the zones represented by these integer values were very small and therefore have been merged, the new zone number assigned was the mean value of the merged zones (not necessarily an integer number).

Further details can be obtained from the final report for phase I, in which the European ground snow load map is presented.

In the present annex a revised version of the European snow load map is presented as in the mean time, from the publication of the first map, new data became available and previous results suggested some slight improvements, that have been implemented during the second phase of the research.

It is important to underline that the general procedure set up for the elaboration of the map in the first phase is not changed, therefore the new map, here presented is not too much different from the previous one.

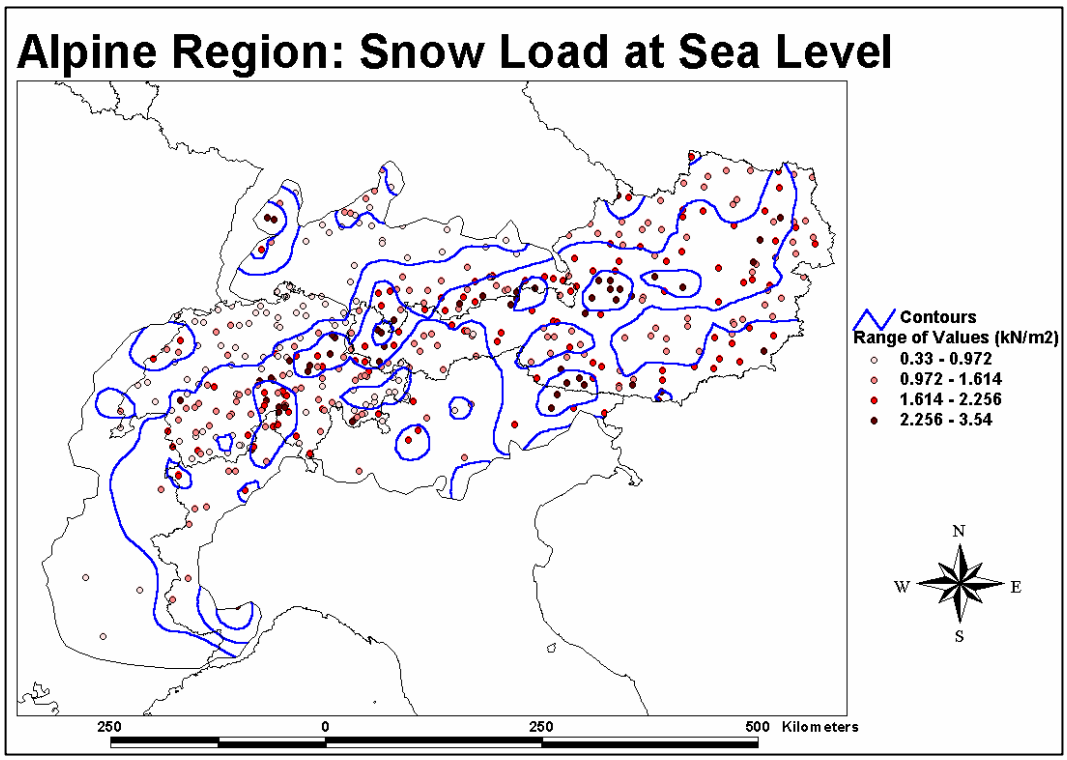
The main improvements made are the following.

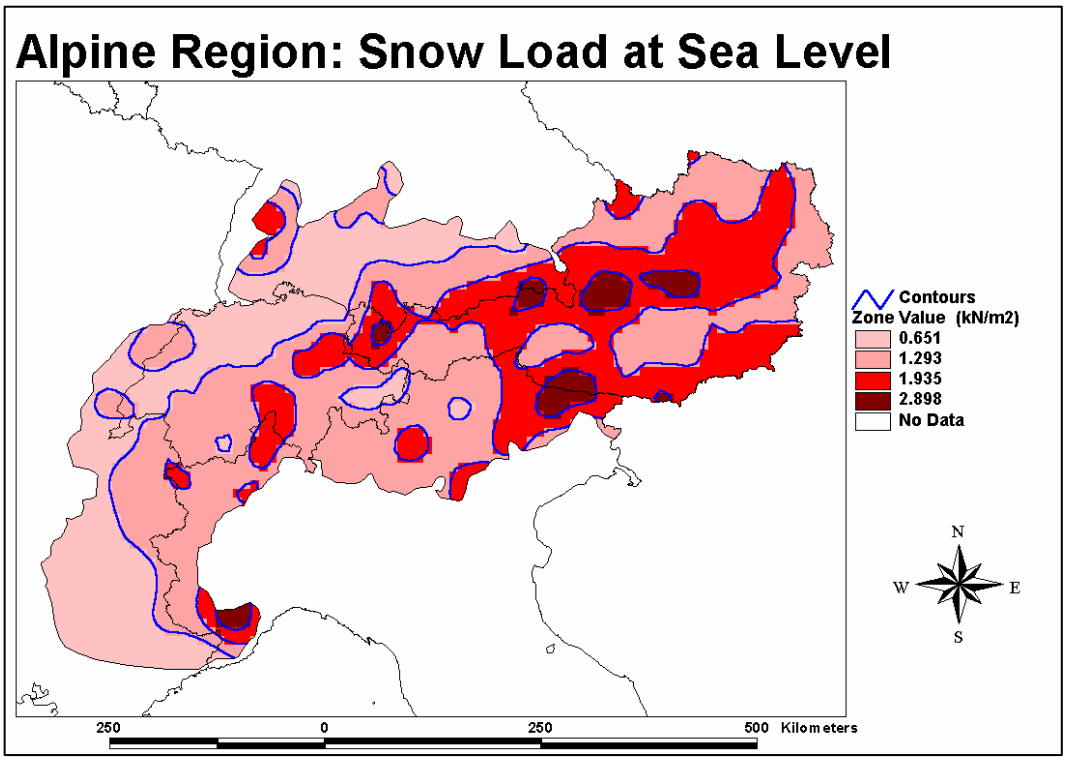
1. A new and wider data set is now available for Sweden and more than 200 Swedish stations (instead of 40) are now the basis for the new map drawn for Sweden and Finland region.
2. A new and wider data set is now available for Italy and the calculation of the map's interpolation surfaces for Alpine and Mediterranean regions is now based upon 125 Italian stations instead of 99.
3. The border between the Iberian peninsula and the Central Western Region has been moved from the country border between Spain and France to the eastern 500 m height contours of the Pyrenean, in order to include this "massif" in one climatic area (treating the Pyrenean mountains as a separate climatic region didn't bring any improvement), especially as the climatic stations on the east side are very scarce and is has been impossible to integrate other climatic stations for that area.
4. Instead of using a standardised approach for inverse distance weighting (exponent =2), for every climatic region the best fitting exponent (standard statistical procedure) has been determined and used for the interpolation process, unless climatological information suggested a different approach. This was the case for Germany, where best results were obtained with an exponent = 4, which is not the best exponent from a statistical point of view. In fact, specific meteorological knowledge should always be taken into account, especially when there are areas where data coverage is low, as for example in north-west Germany. This is the only possibility to alleviate a lack of data.
5. The smoothing is applied as in phase I.
6. The maps drawn for two neighbouring regions is calculated also with reference to a buffer zone 100 km depth. This means that in the calculation of the interpolation surface of region A are taken into account also those stations of the neighbouring region B falling into a buffer of 100 km depth across the border. This helps to reduce the differences in ground snow loads at borderlines between climatic regions.
7. Also the number of snow load zones has been standardised and is now equal to 3 or to 4 zones for every climatic region (before in one or two regions there were 5).

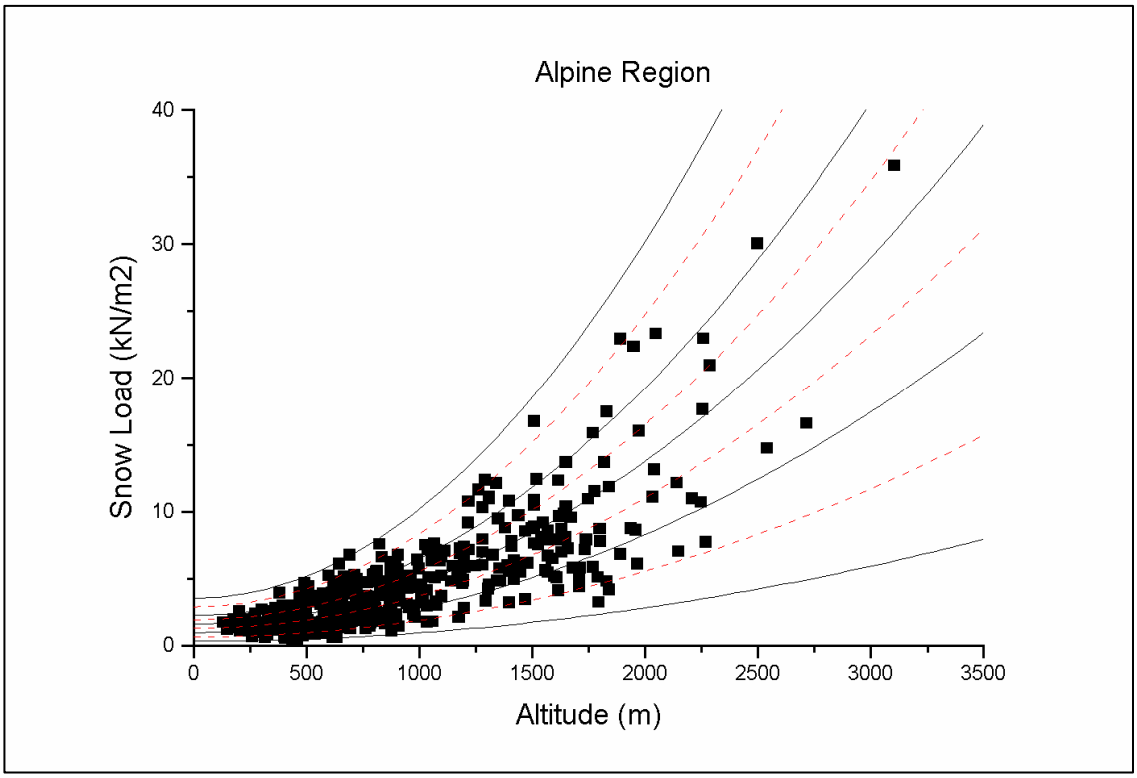
B1 European Ground Snow Load Maps

Climatic regions are grouped by type of curve (quadratic, linear, horizontal). Each group is presented in alphabetical order.

ALPINE REGION







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	a_{min}	a_{max}	**b**
Alpine Region	**Q**	0.33	3.54	728

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=3**	**Z=4.5**
r	0.97	0.97	0.99	0.98

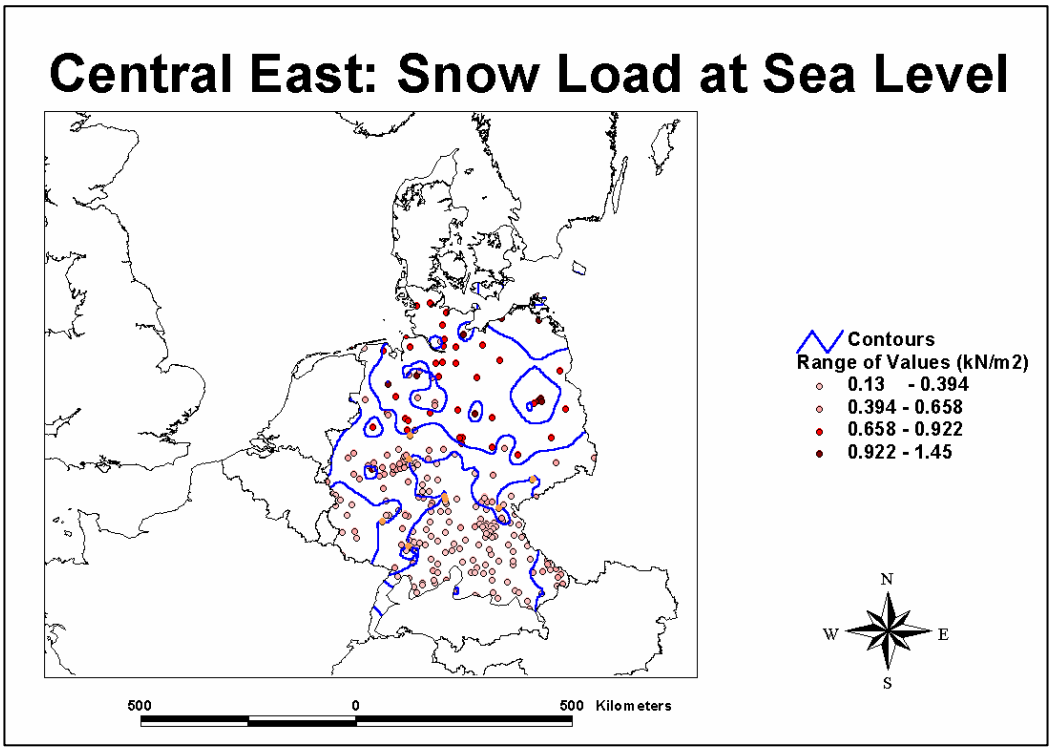
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

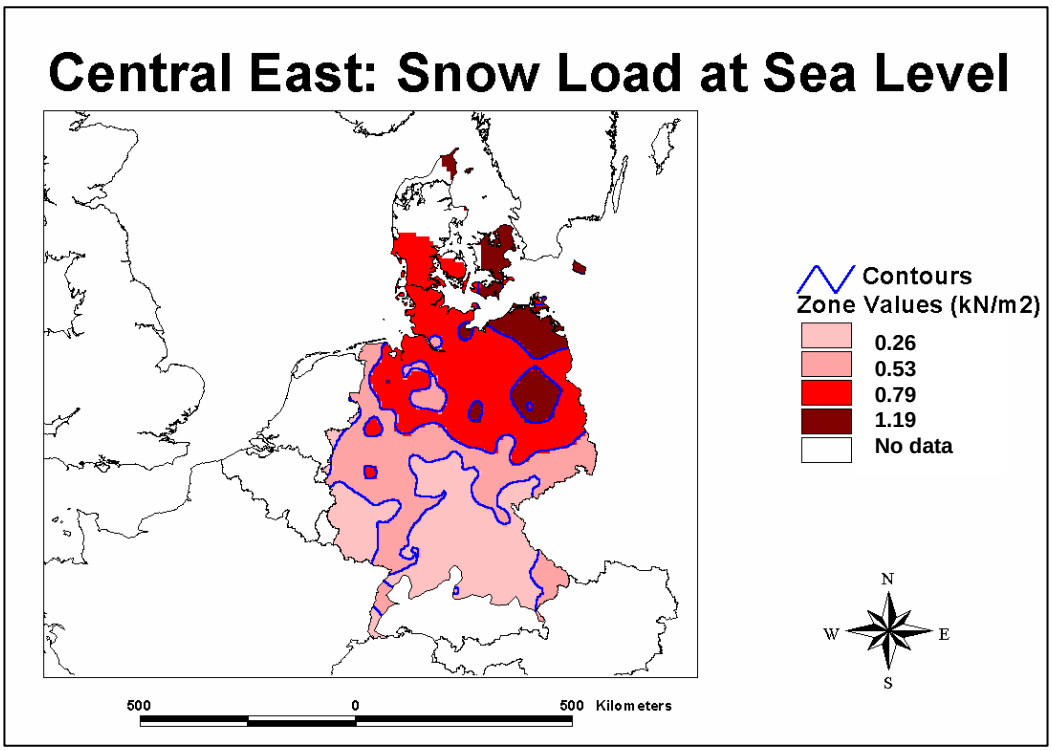
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

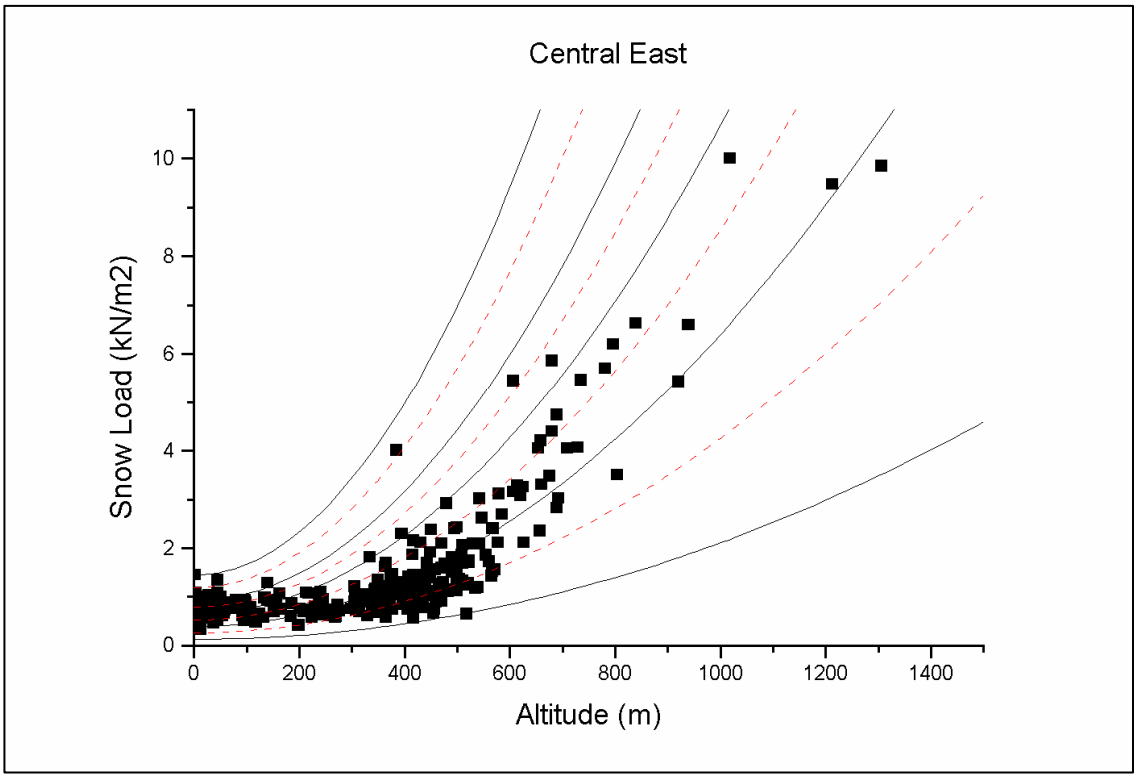
$$s=(0.33+(Z-0.5)*[3.54-0.33]/5)\left[1+\left(\frac{A}{728}\right)^2\right]$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: CENTRAL EAST







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**
Central East	**Q**	0.13	1.45	256

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=3**	**Z=4.5**
r	0.97	0.98	0.99	0.98

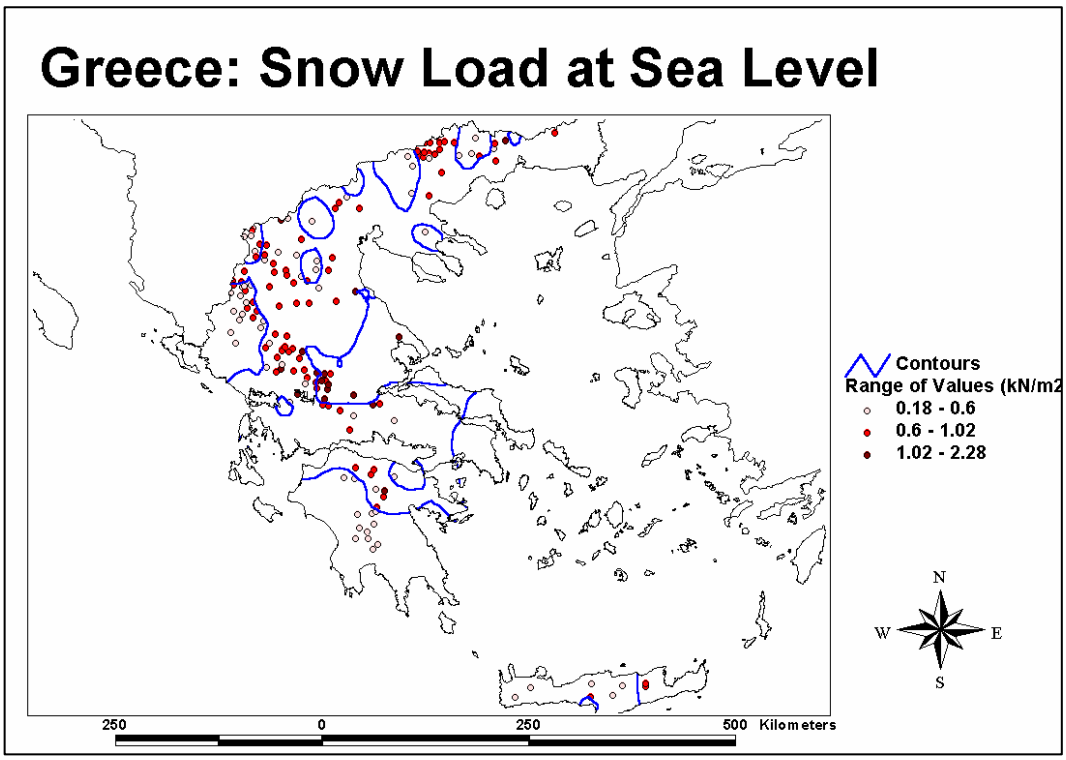
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

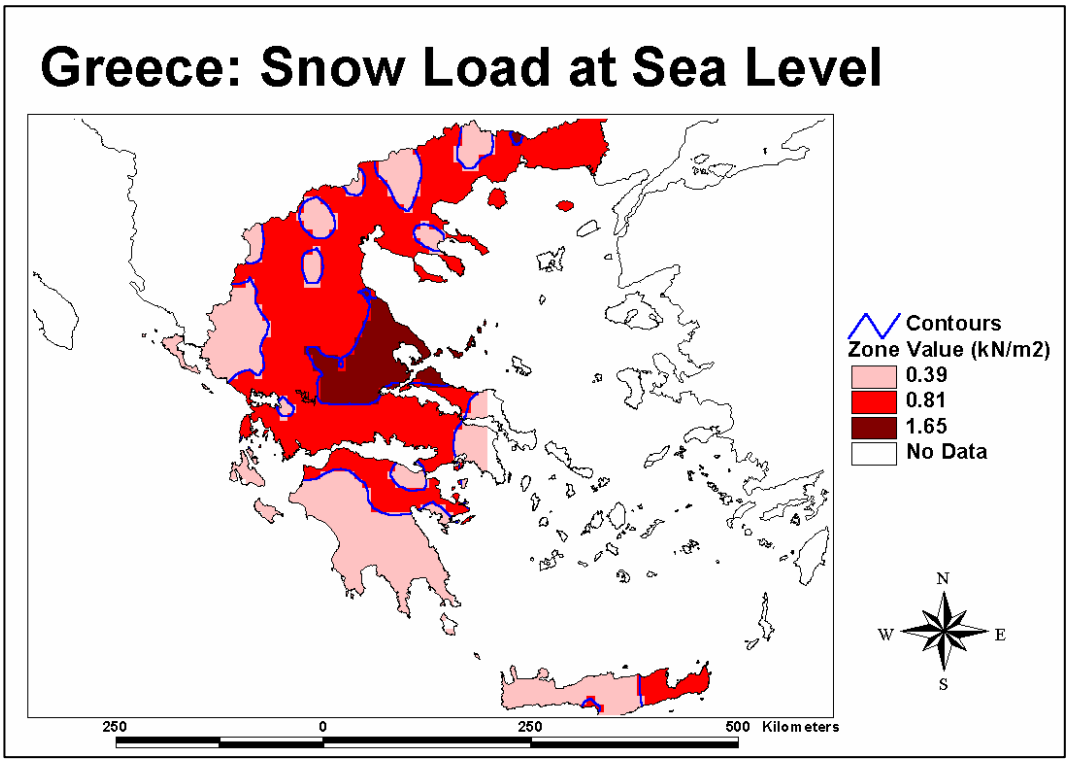
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

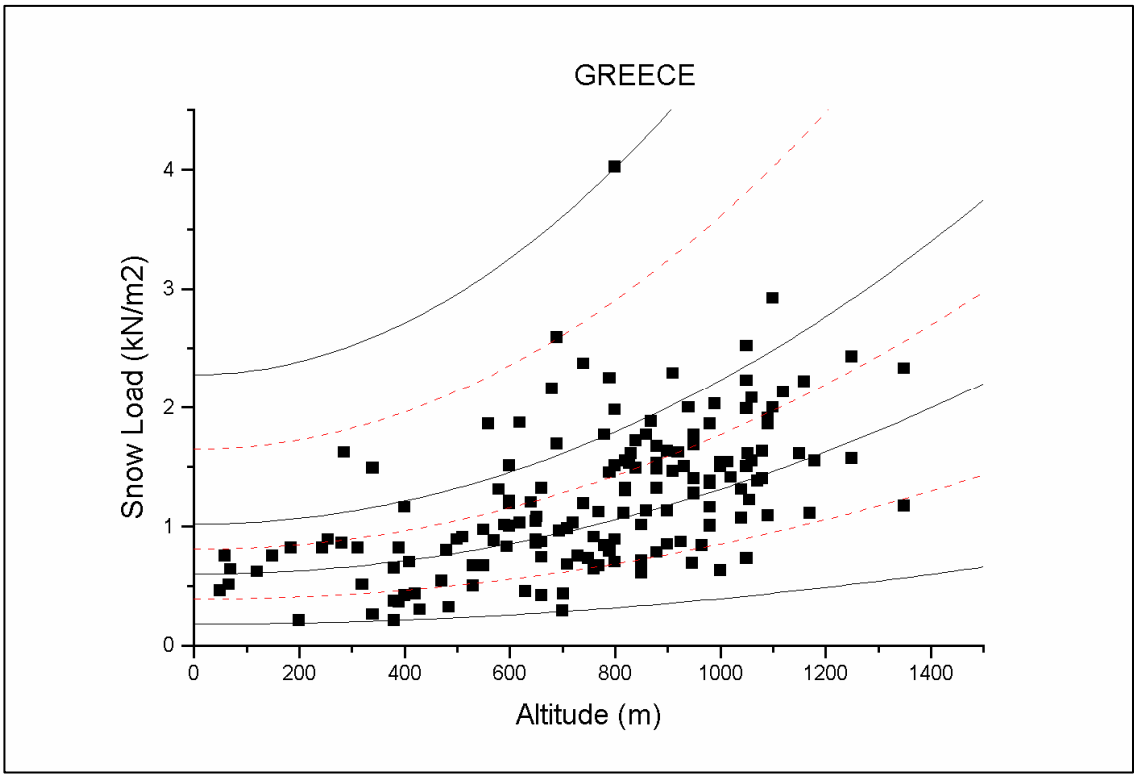
$$s = (0.13 + (Z - 0.5) * [1.45 - 0.13] / 5) \left[1 + \left(\frac{A}{256} \right)^2 \right]$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: GREECE







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	$\mathbf{a_{min}}$	$\mathbf{a_{max}}$	**b**
Greece	**Q**	0.18	2.28	917

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=4**
r	0.82	0.89	0.57

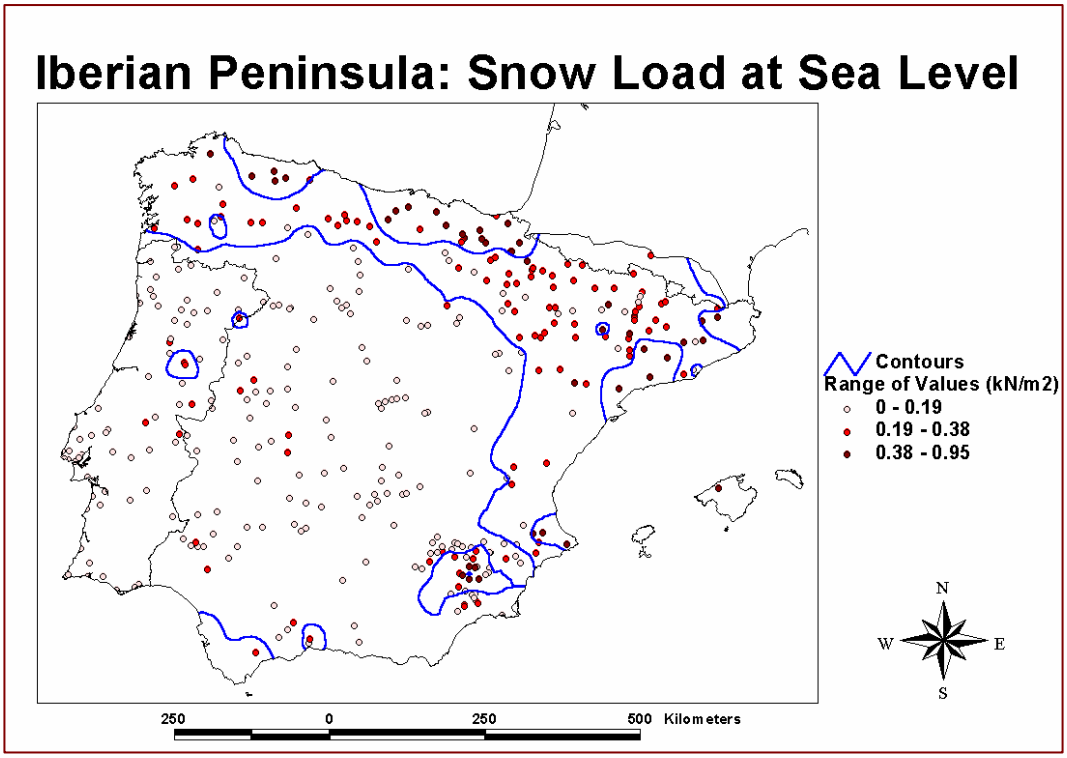
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

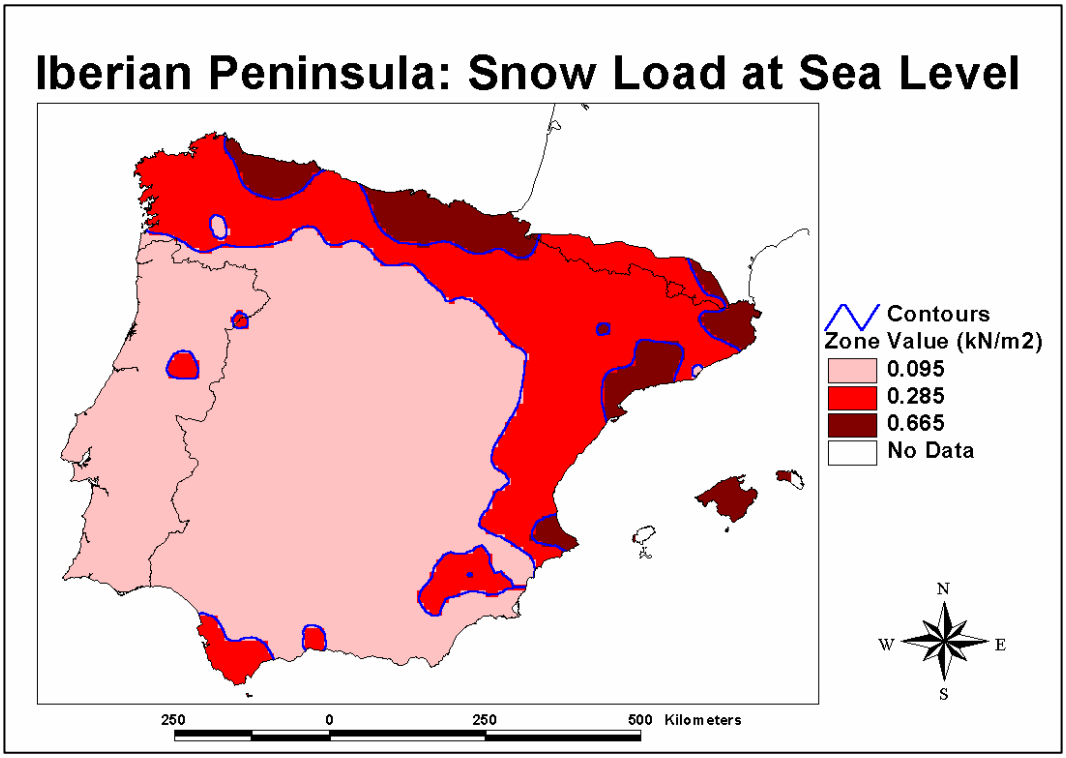
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

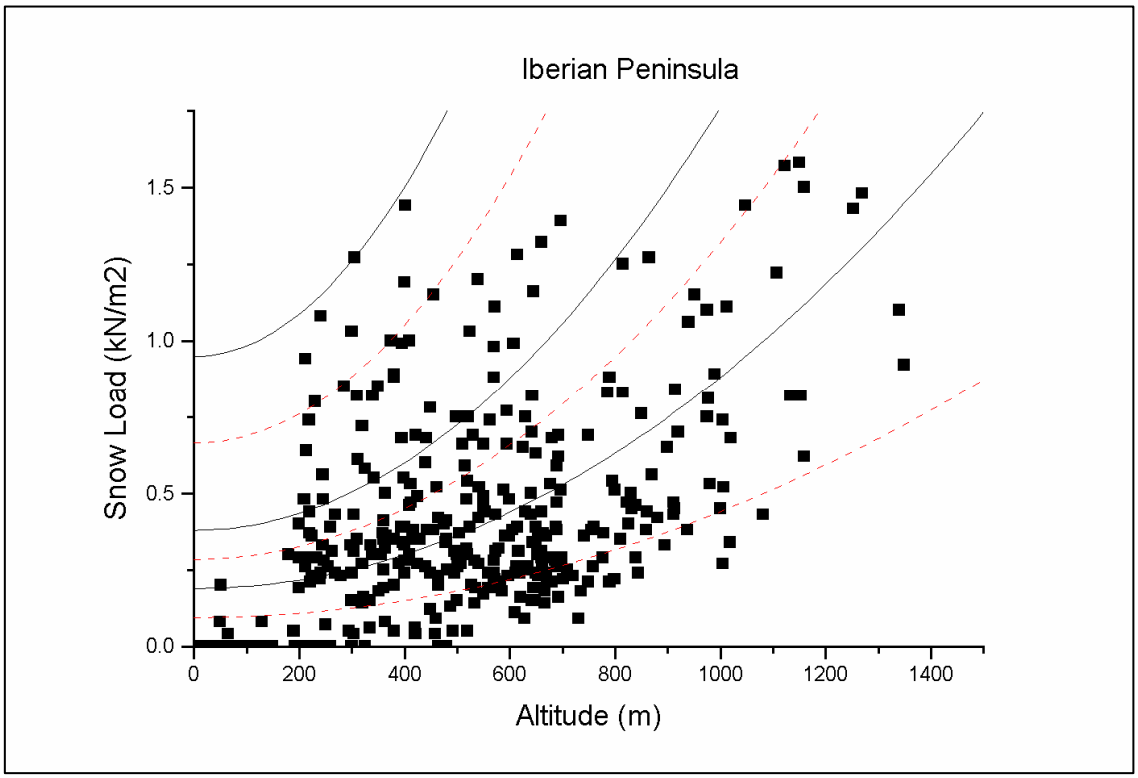
$$s=(0.18+(Z-0.5)*[2.28-0.18]/5)\left[1+\left(\frac{A}{917}\right)^2\right]$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: IBERIAN PENINSULA







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**
Iberian Peninsula	**Q**	0	0.95	524

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=4**
r	0.87	0.96	0.75

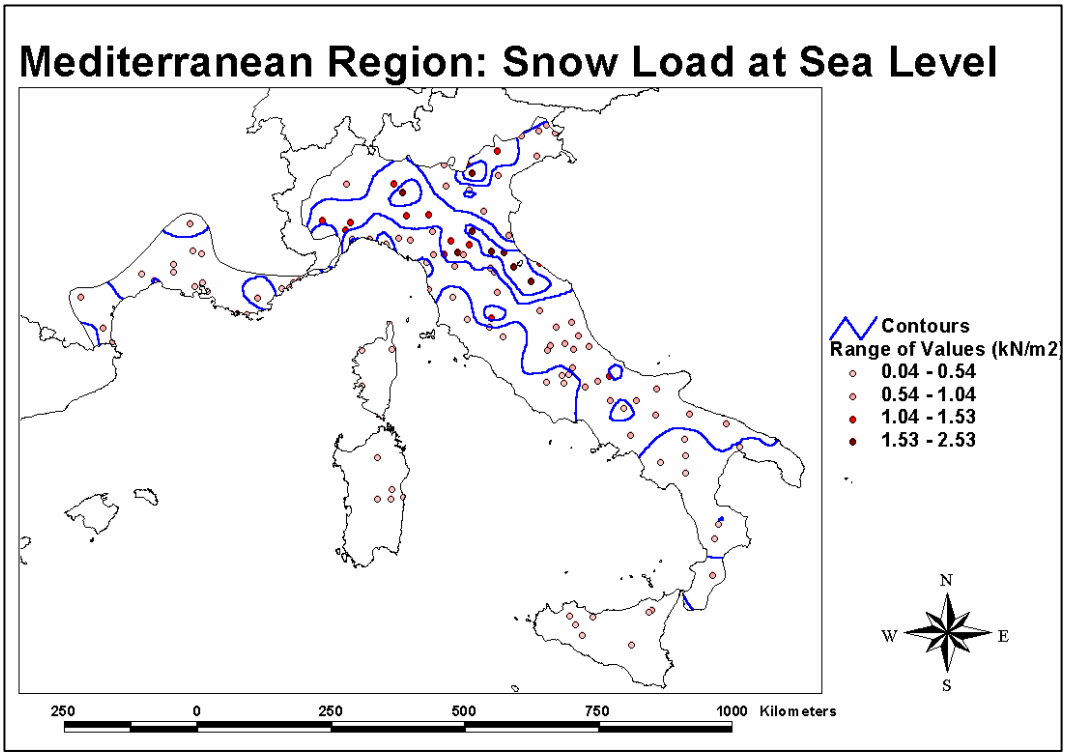
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

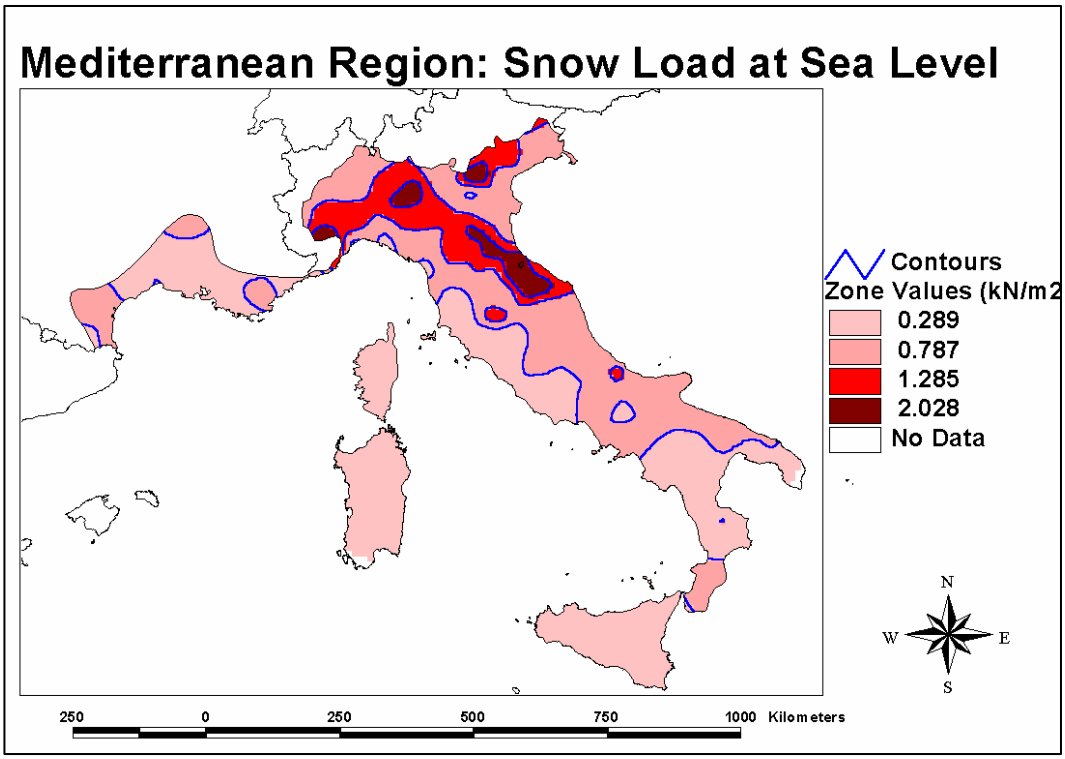
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

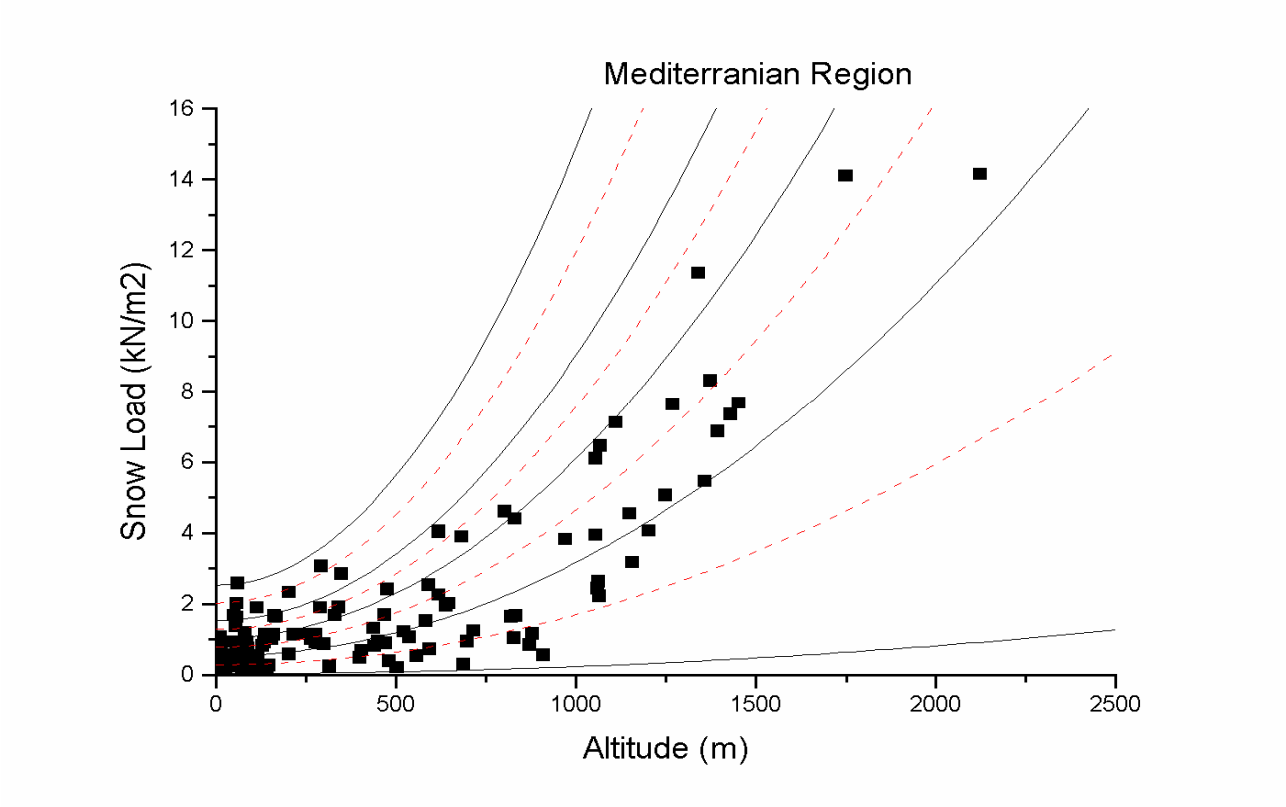
$$s=(0+(Z-0.5)*[0.95-0]/5)\left[1+\left(\frac{A}{524}\right)^2\right]$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: MEDITERRANEAN REGION







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	$\mathbf{a_{min}}$	$\mathbf{a_{max}}$	**b**
Mediterranean Region	**Q**	0.04	2.53	452

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=3**	**Z=4.5**
r	0.90	0.97	0.99	0.79

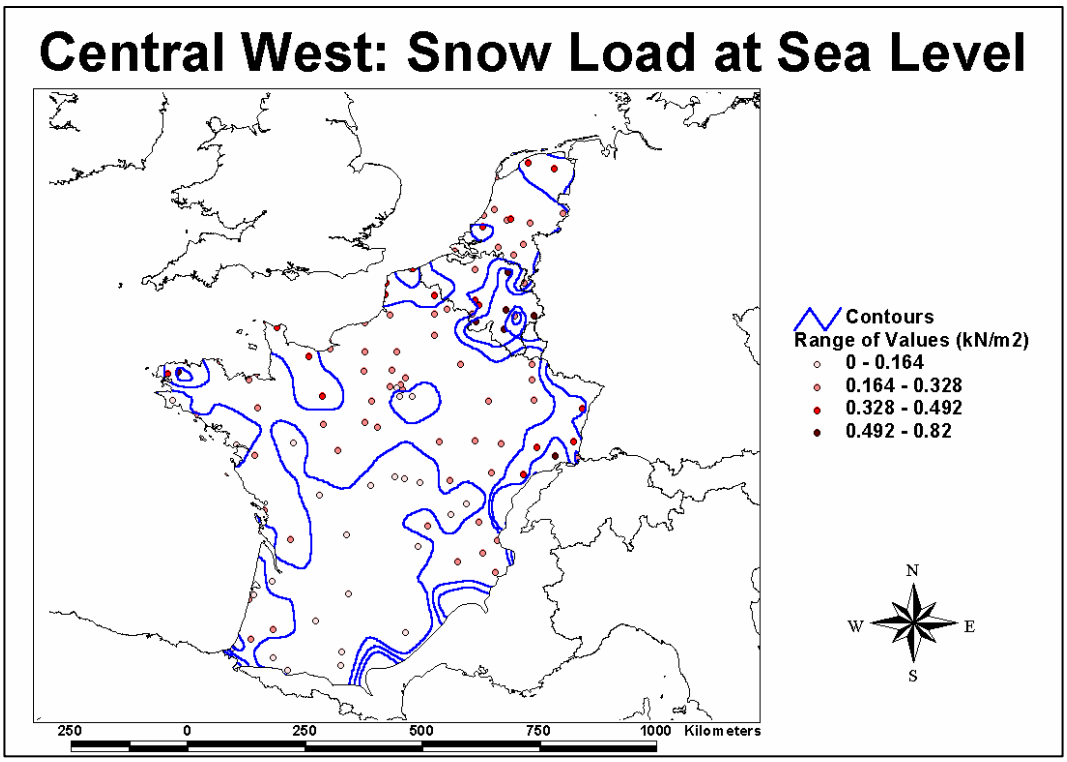
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

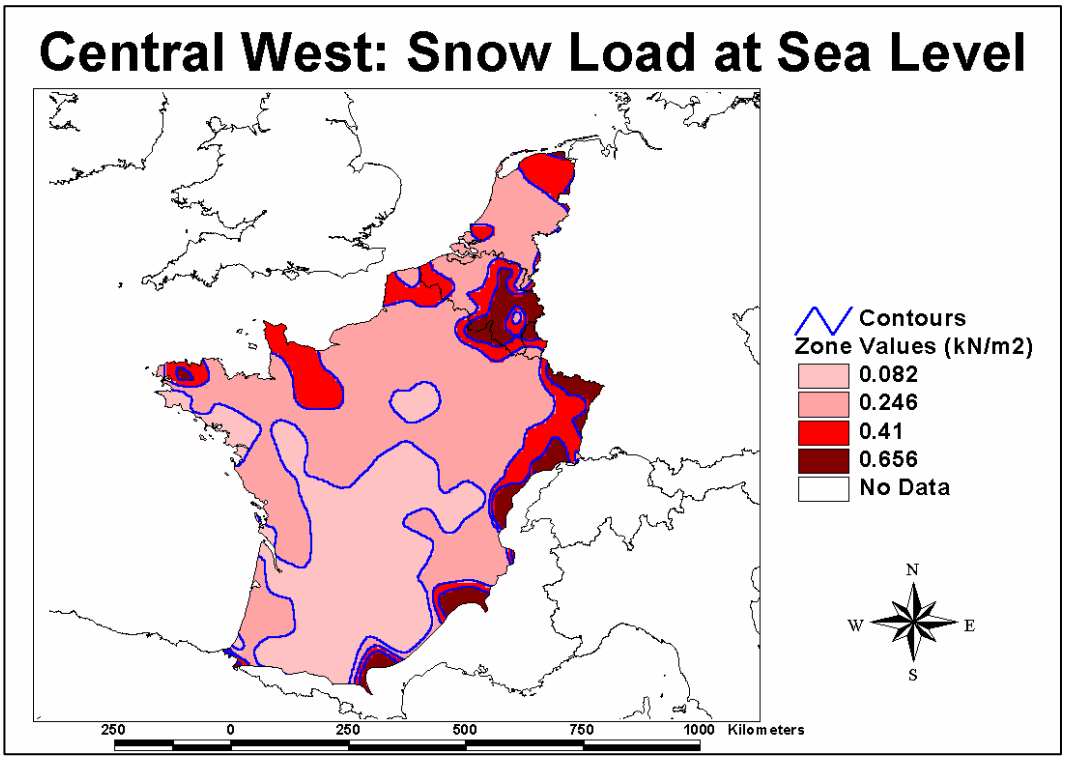
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

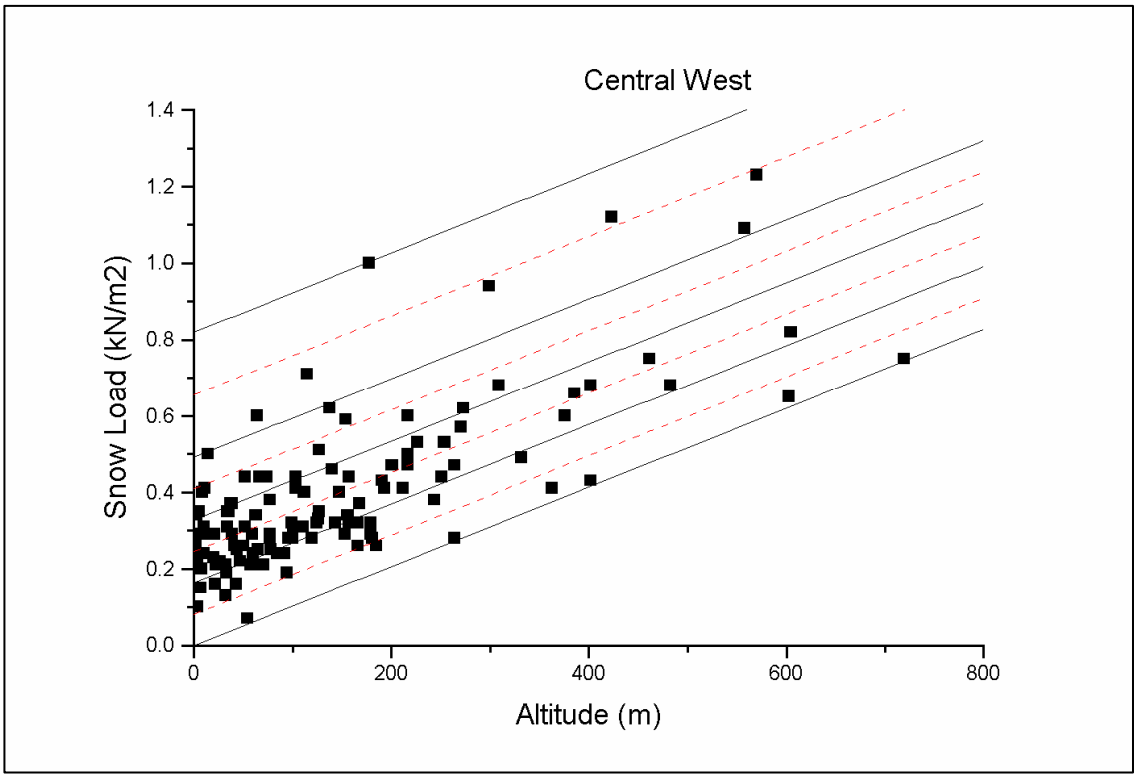
$$s=(0.04+(Z-0.5)*[2.53-0.04]/5)\left[1+\left(\frac{A}{452}\right)^2\right]$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

Linear Function:
CLIMATIC REGION: CENTRAL WEST







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**
Central West	**L**	0.00	0.82	966

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=3**	**Z=4.5**
r	0.96	0.95	0.91	0.90

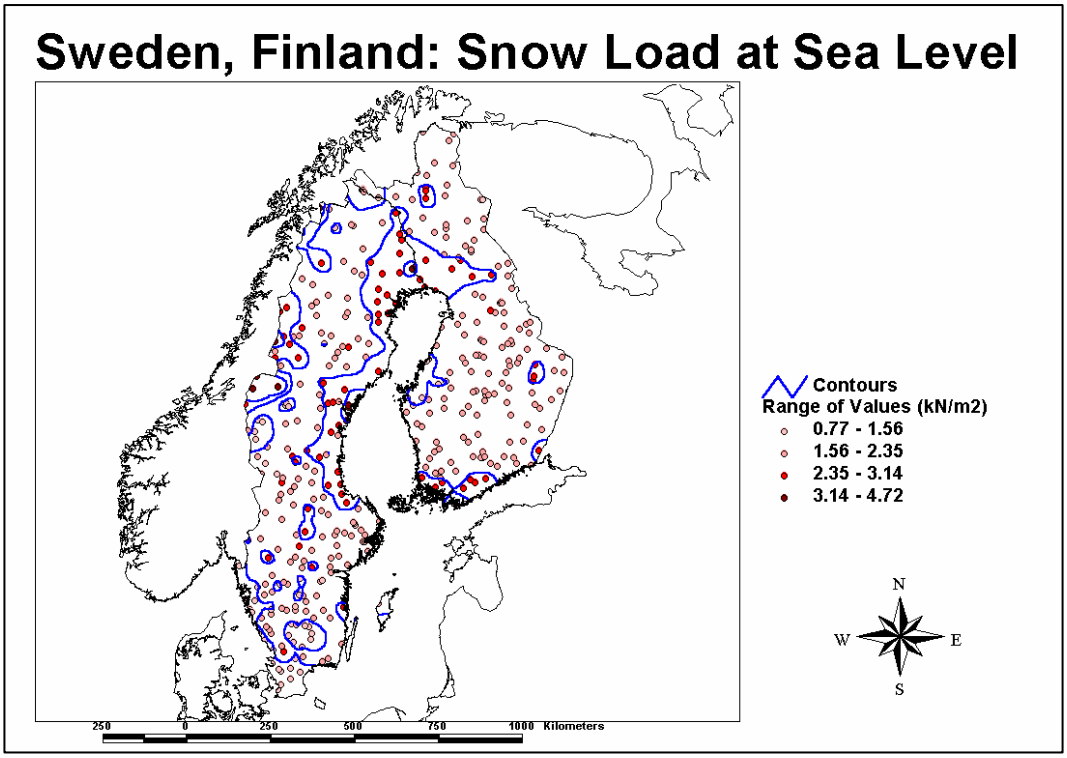
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

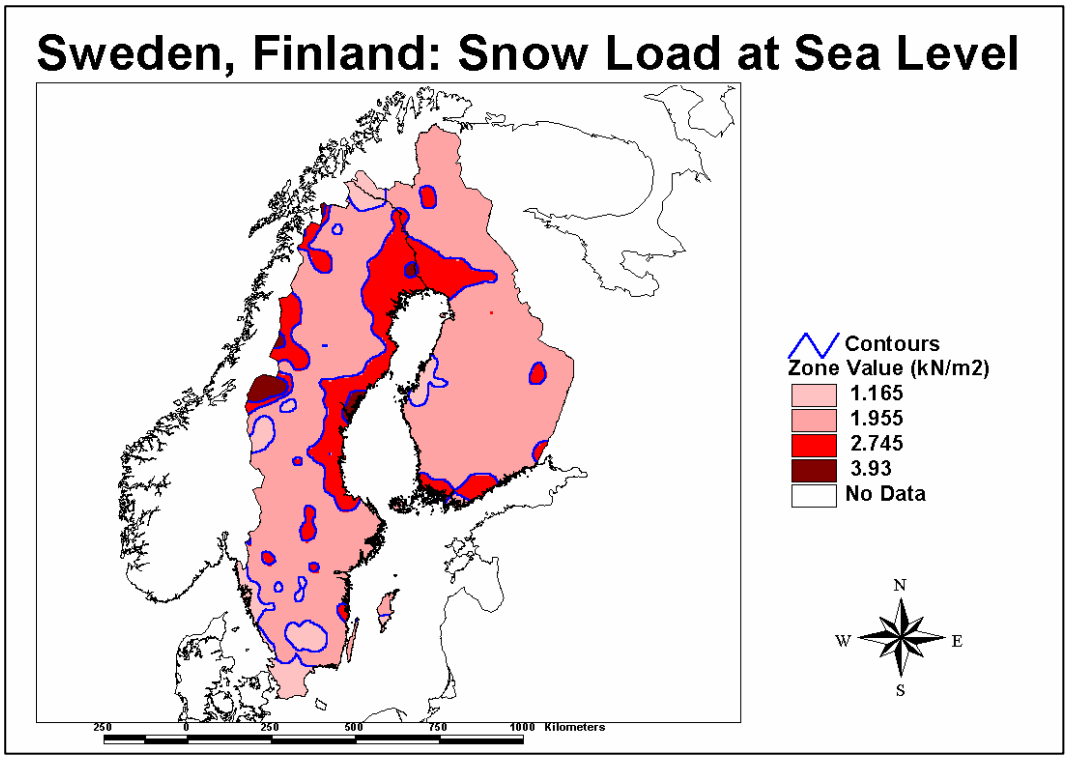
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

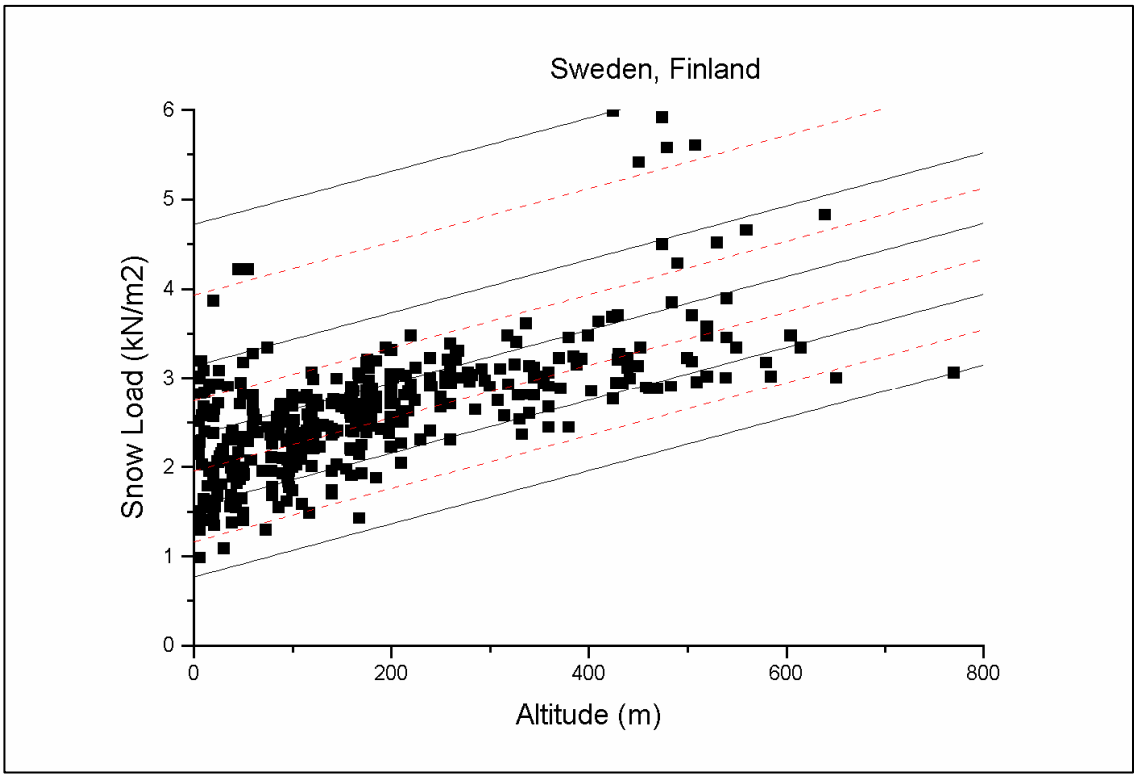
$$s=(0.00+(Z-0.5)*[0.82-0.00]/5)+\frac{A}{966}$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: SWEDEN, FINLAND







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	Function Type	a_{min}	a_{max}	b
Sweden, Finland	**L**	0.77	4.72	336

Zone Number (Scatter Plot)	Z=1	Z=2	Z=3	Z=4.5
r	0.96	0.86	0.88	0.91

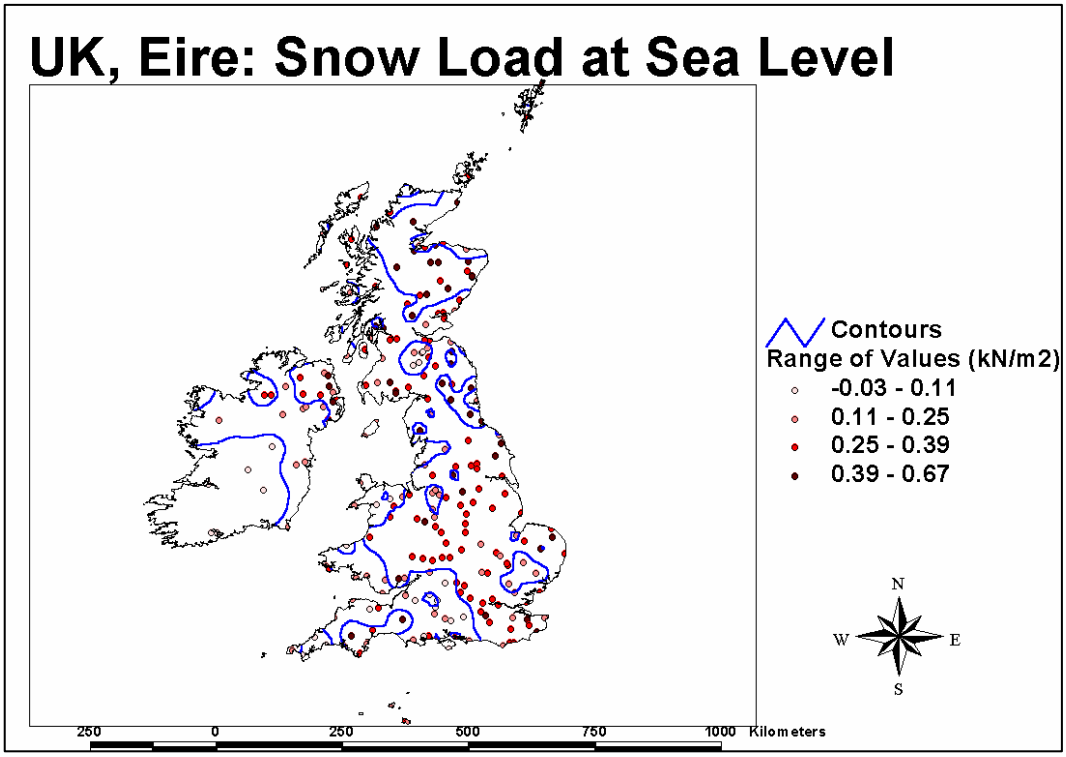
r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

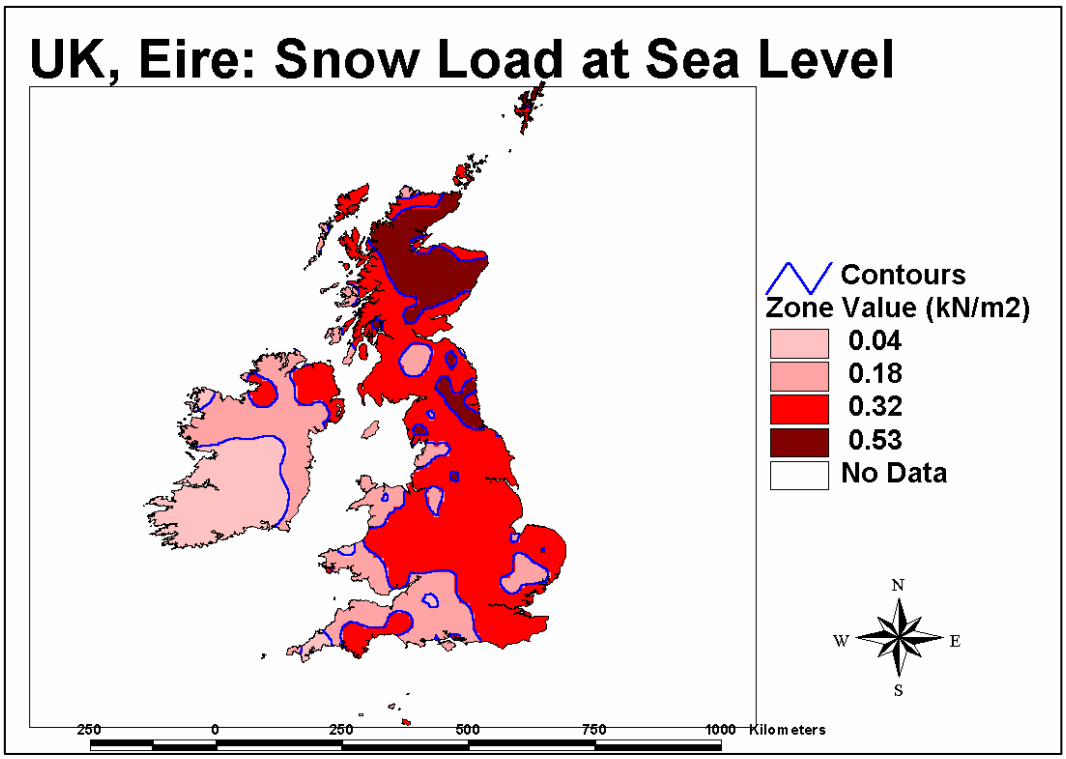
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

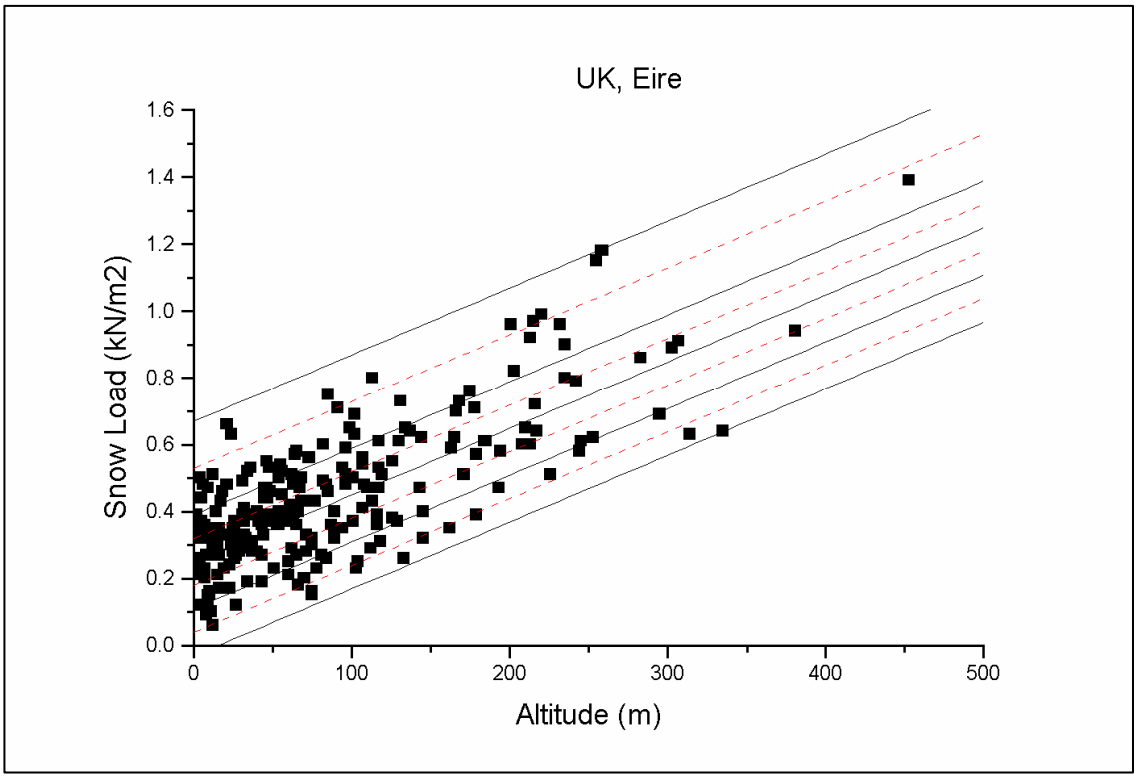
$$s=(0.77+(Z-0.5)*[4.72-0.77]/5)+\frac{A}{336}$$

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

CLIMATIC REGION: UK, EIRE







(black line = zone limit)
(red line = representative altitude - snow load relationship for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**
UK, Eire	**L**	-0.03	0.67	501

Zone Number (Scatter Plot)	**Z=1**	**Z=2**	**Z=3**	**Z=4.5**
r	0.98	0.96	0.96	0.96

r = correlation coefficient (snow load values / representing function)
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

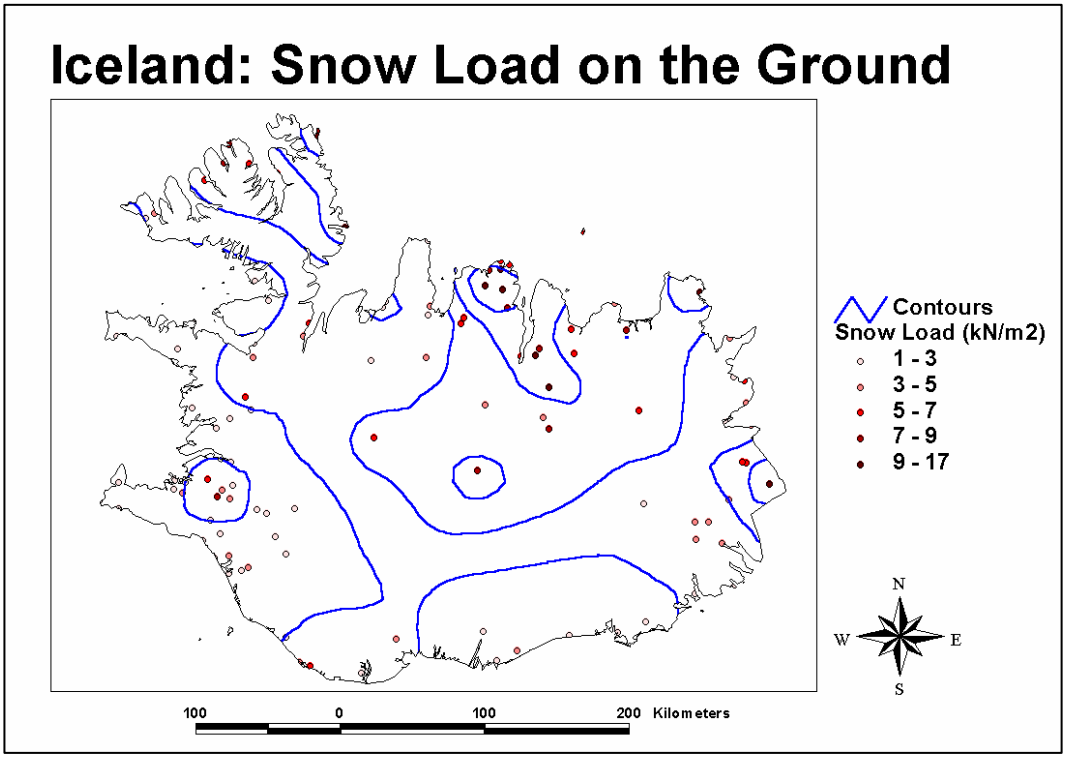
REPRESENTATIVE SNOW LOAD FOR ZONE Z AT ALTITUDE A:

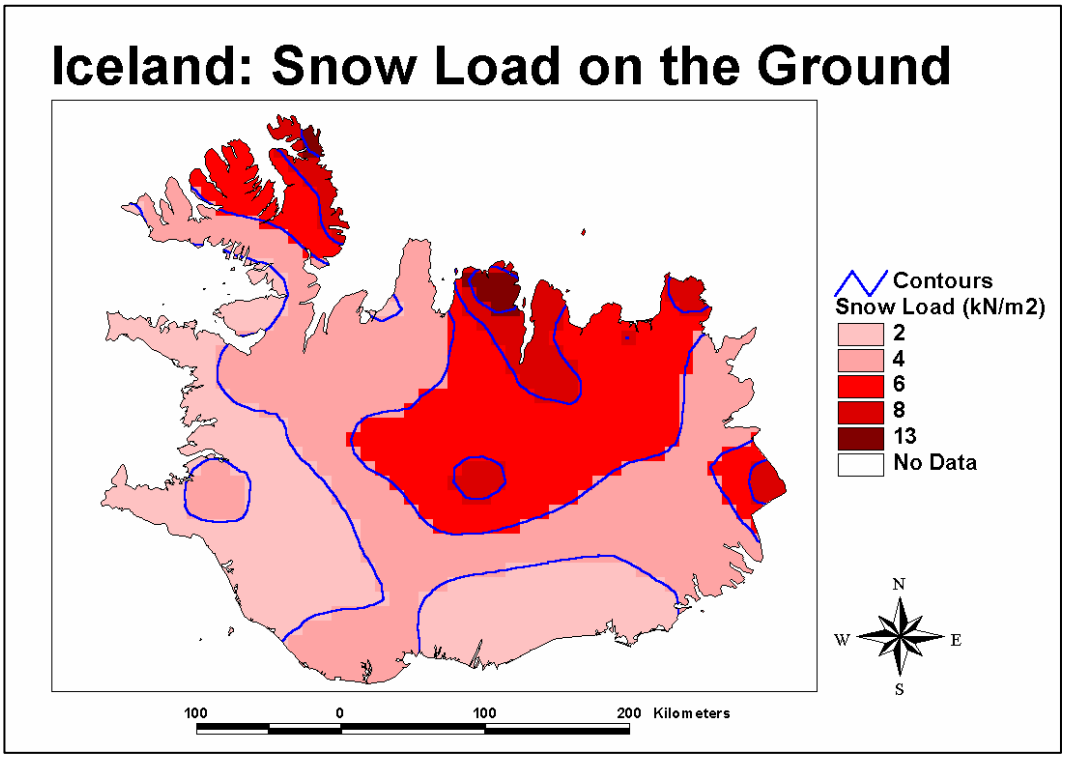
$$s=(-0.03+(Z-0.5)*[0.67+0.03]/5)+\frac{A}{501}$$

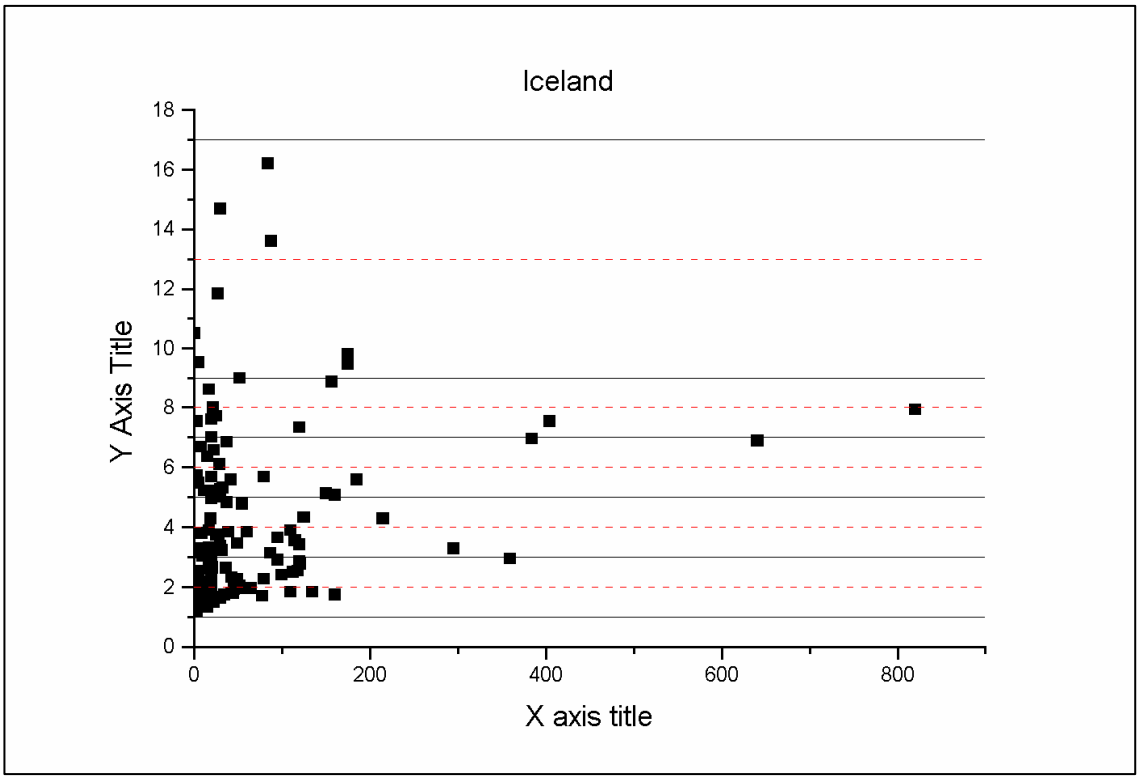
s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number

No Altitude-Snow Load Relationship:

CLIMATIC REGION: ICELAND







(black line = zone limit)
(red line = characteristic snow load for the corresponding zone)

PARAMETERS:

Climatic Region	Function Type	a_{min}	a_{max}	b
Iceland	**H**	-	-	-

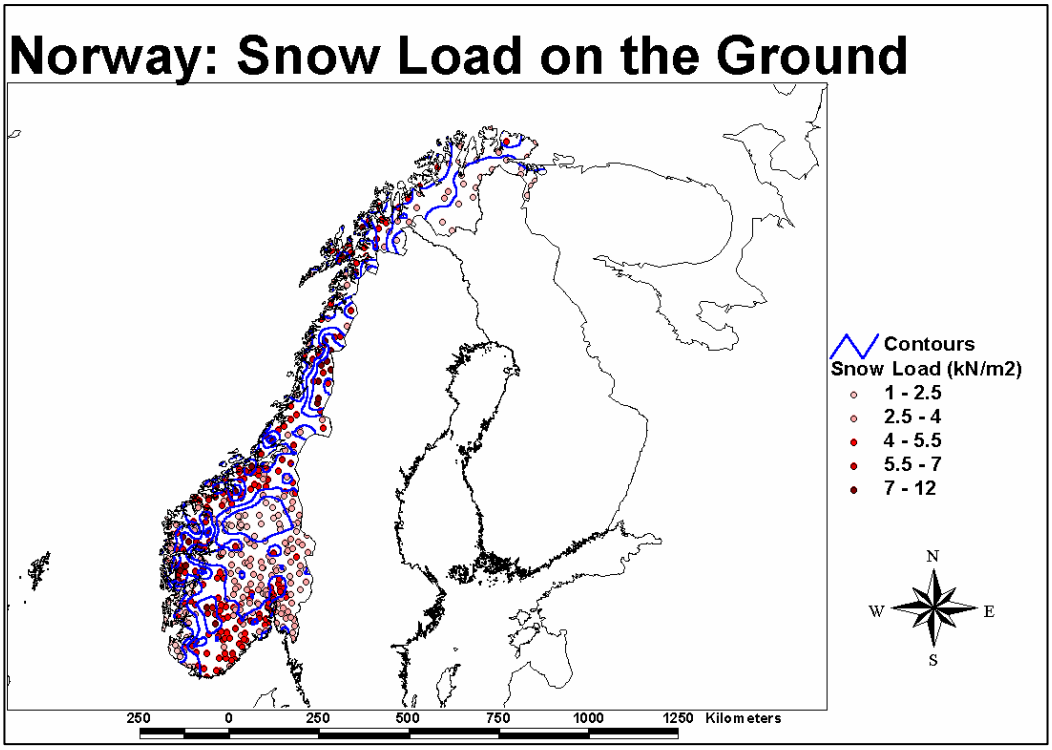
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

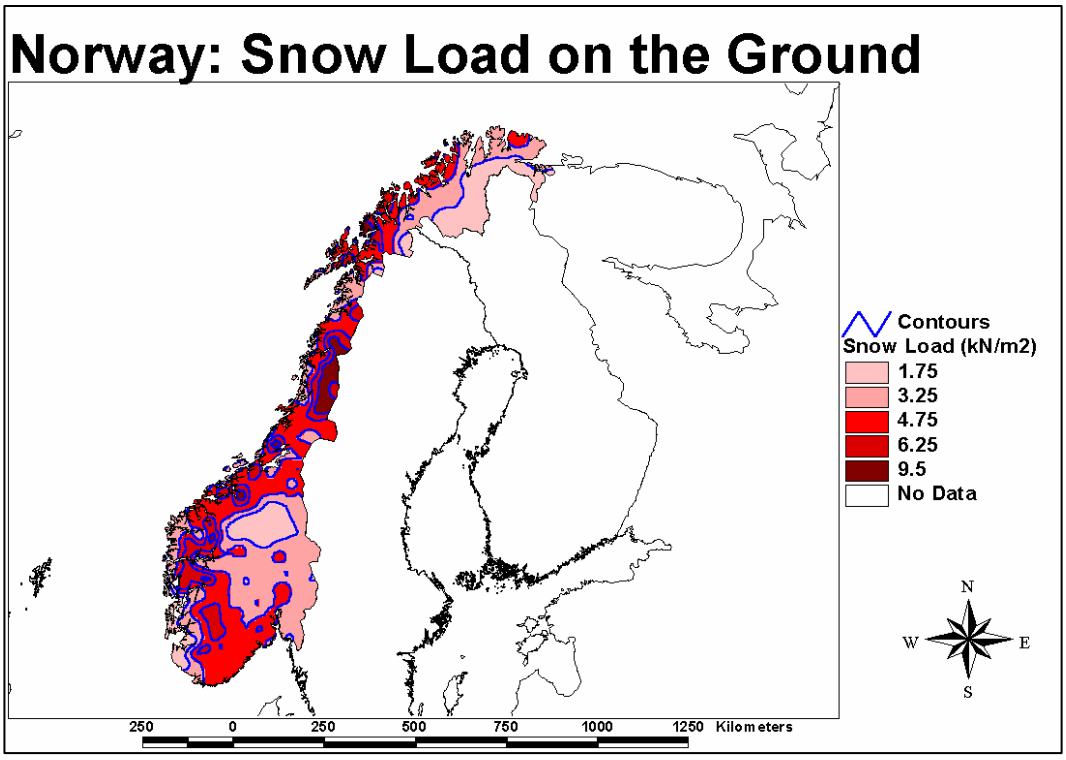
CHARACTERISTIC SNOW LOAD FOR ZONE Z:
No altitude - snow load relationship.
The characteristic snow load value for a zone is the middle value:

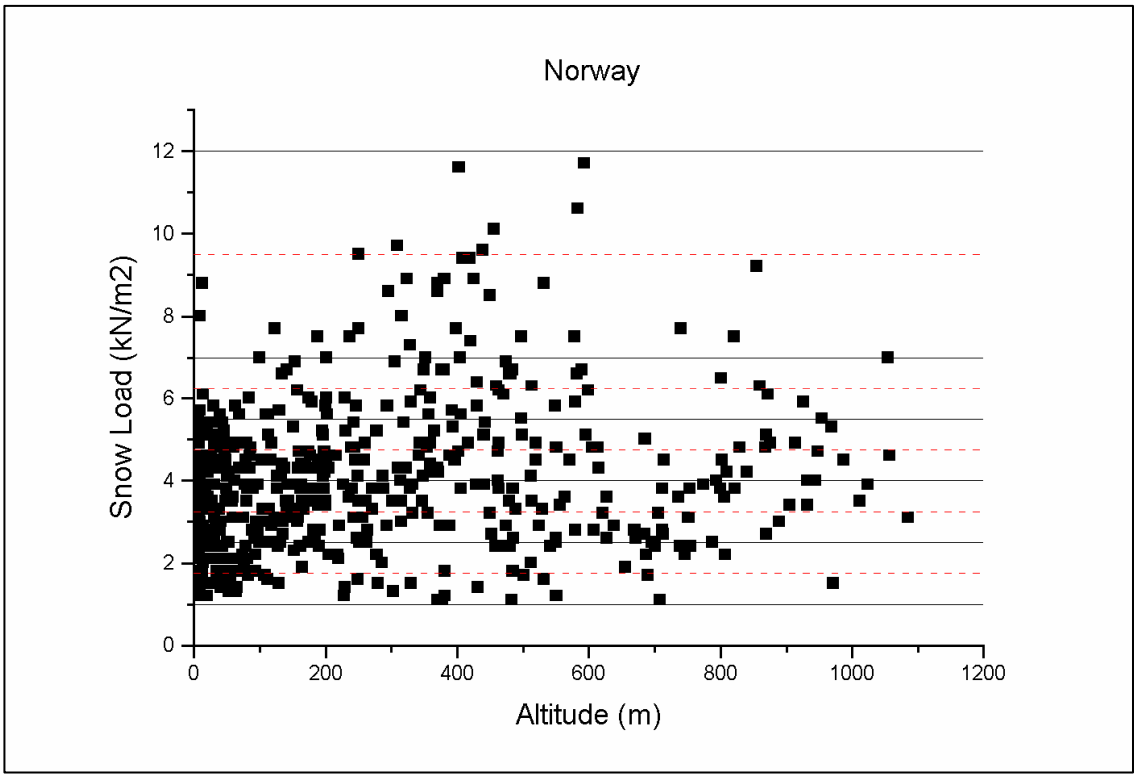
Z=1	Z=2	Z=3	Z=4	Z=5
2 KN/m^2	4 KN/m^2	6 KN/m^2	8 KN/m^2	13 KN/m^2

Z = Zone Number

CLIMATIC REGION: NORWAY







(black line = zone limit)
(red line = characteristic snow load for the corresponding zone)

PARAMETERS:

Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**
Norway	**H**	-	-	-

H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function

CHARACTERISTIC SNOW LOAD FOR ZONE Z:
No altitude - snow load relationship.
The characteristic snow load value for a zone is the middle value:

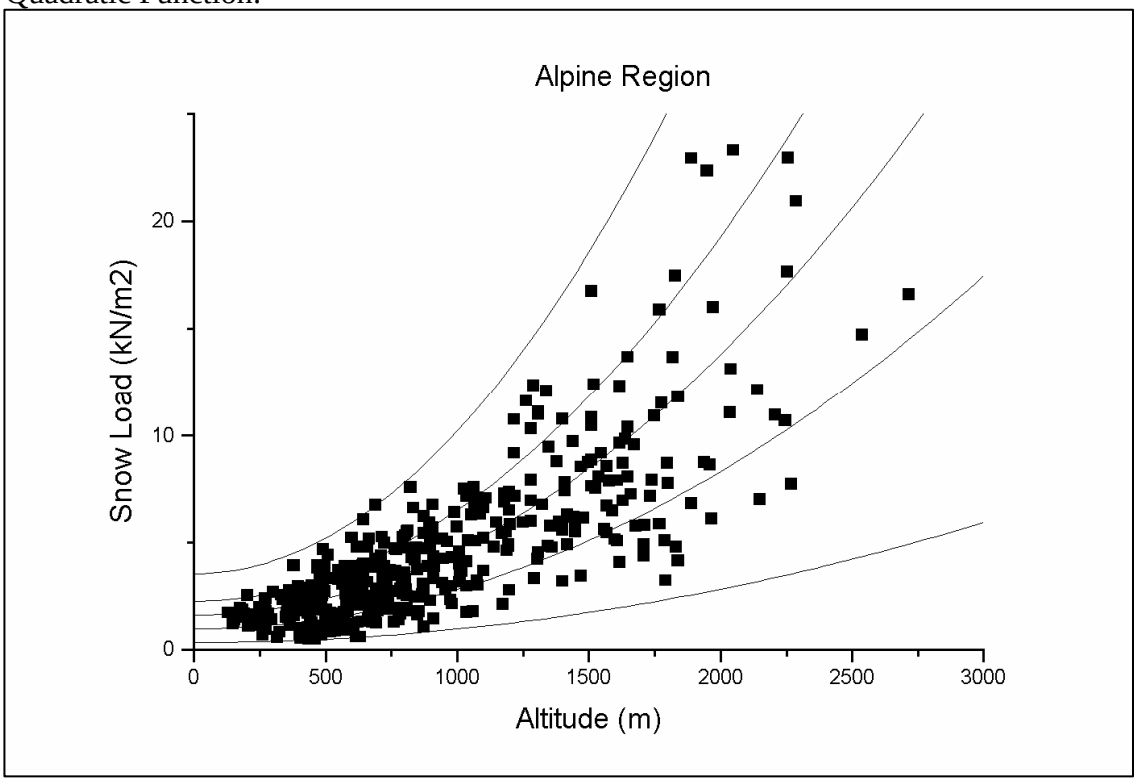
Z=1	Z=2	Z=3	Z=4	Z=5
1.75 KN/m^2	3.25 KN/m^2	4.75 KN/m^2	6.25 KN/m^2	9 KN/m^2

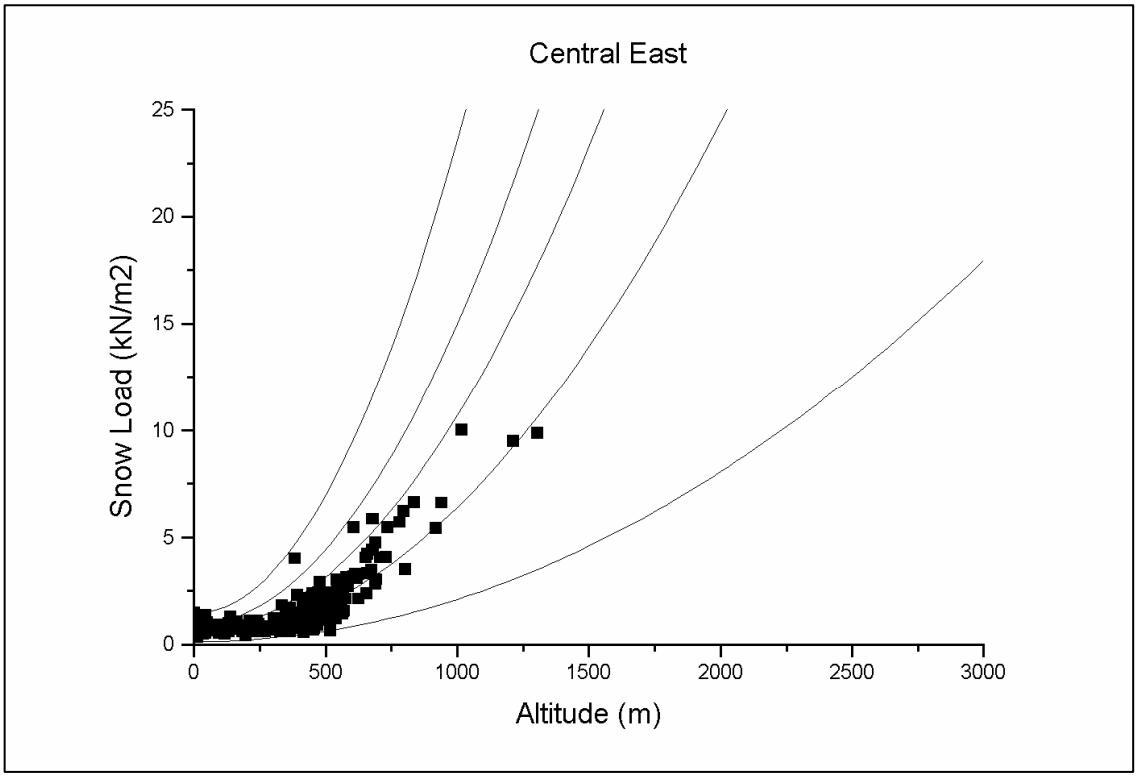
Z = Zone Number

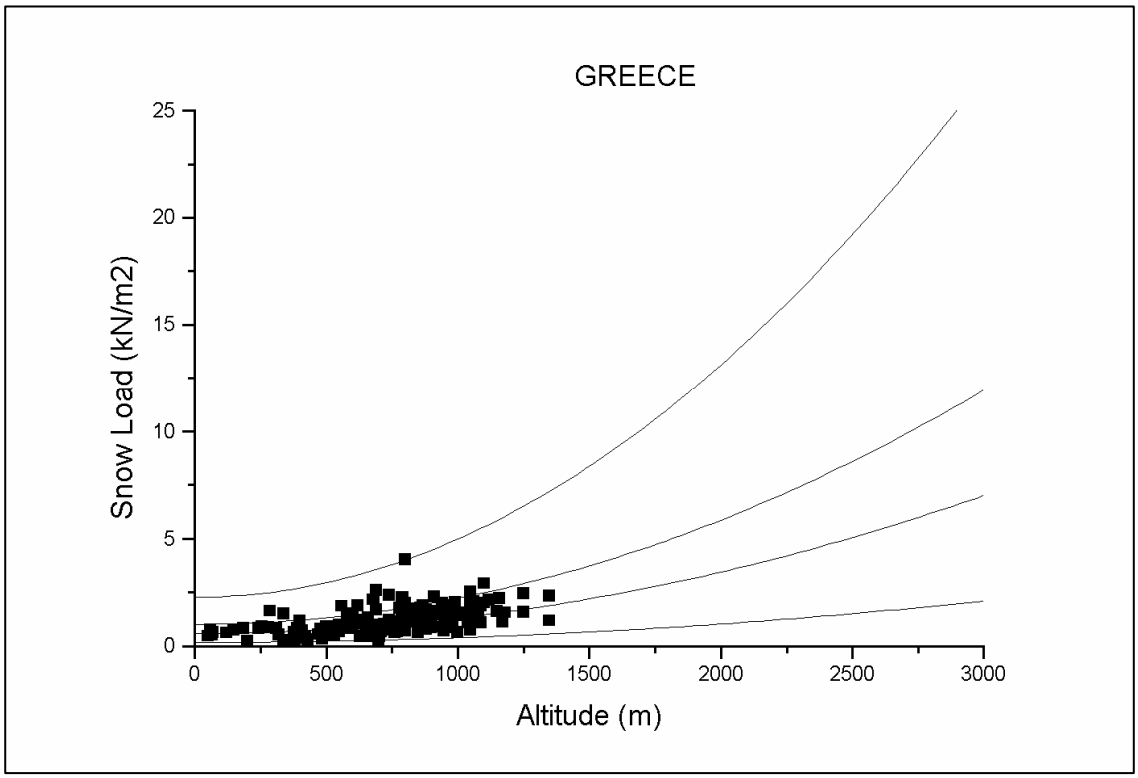
B.2 Standardised Scatterplots for each climatic region

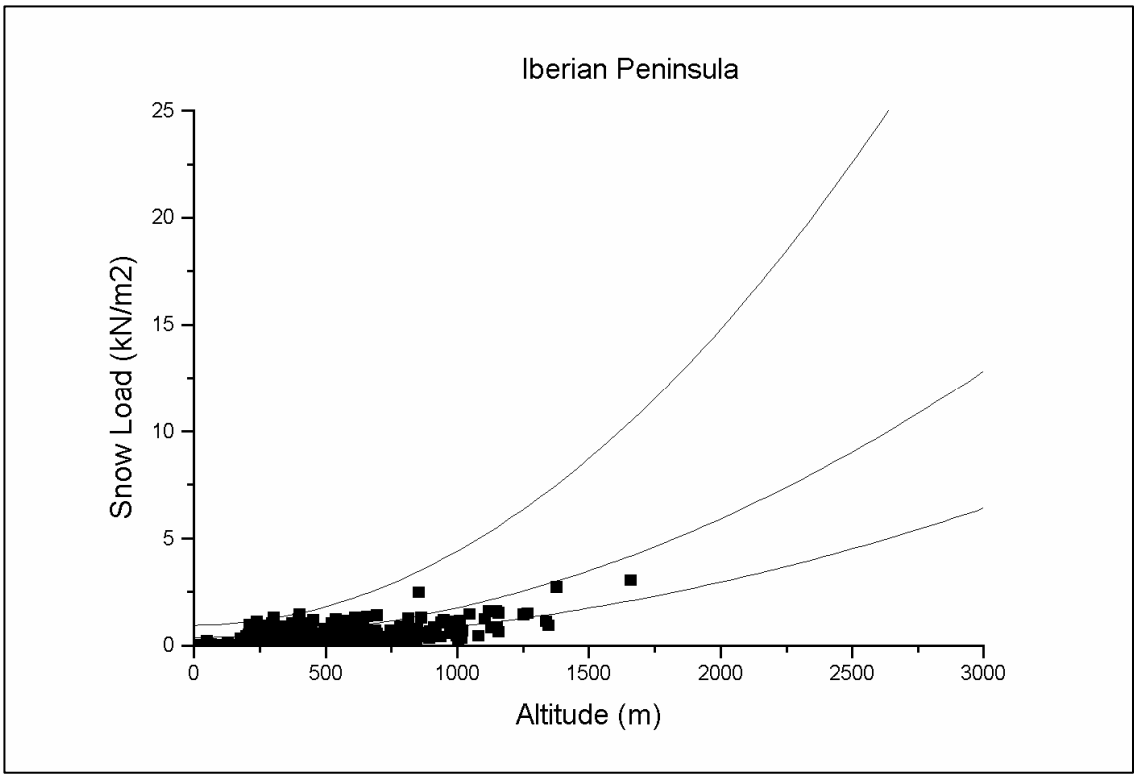
Climatic regions are grouped by type of curve (quadratic, linear, horizontal). Each group is presented in alphabetical order.

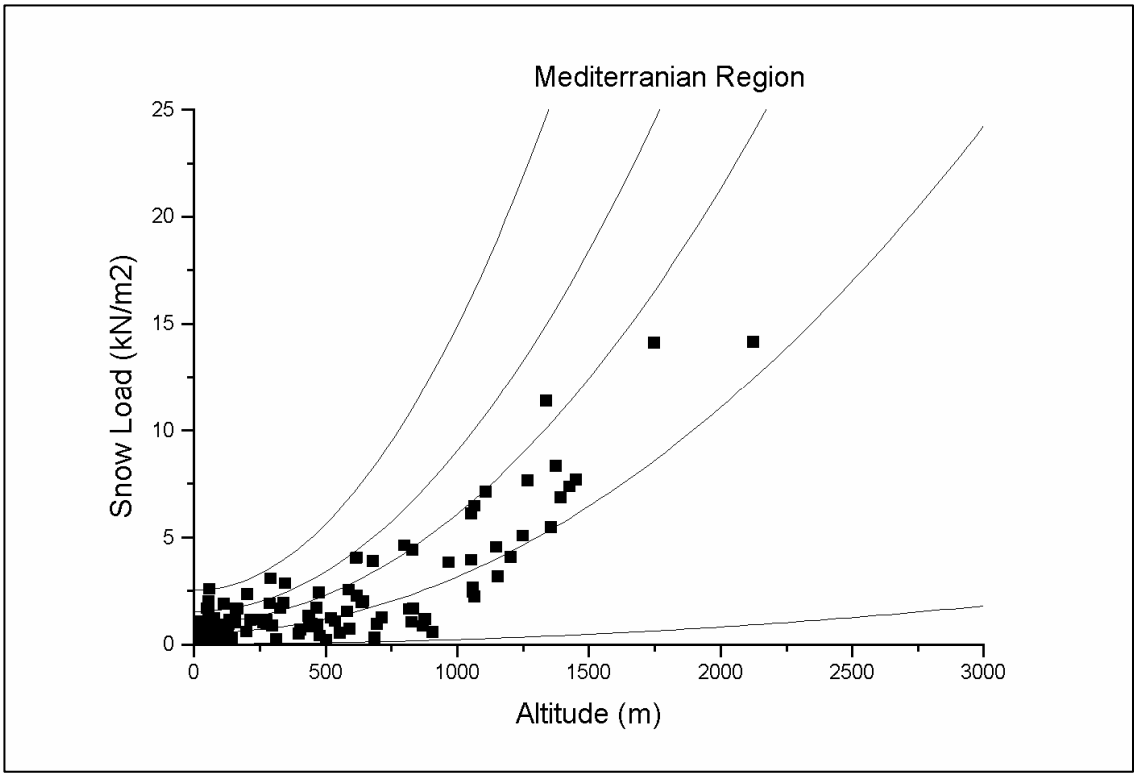
Quadratic Function:



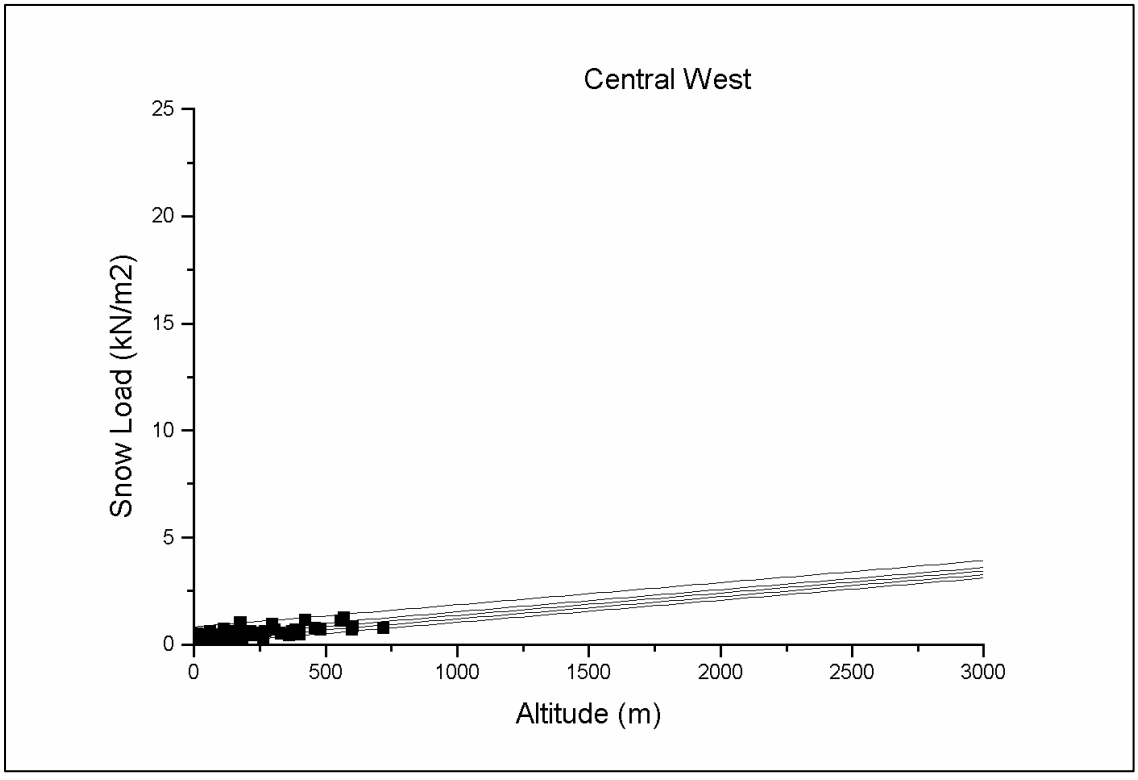


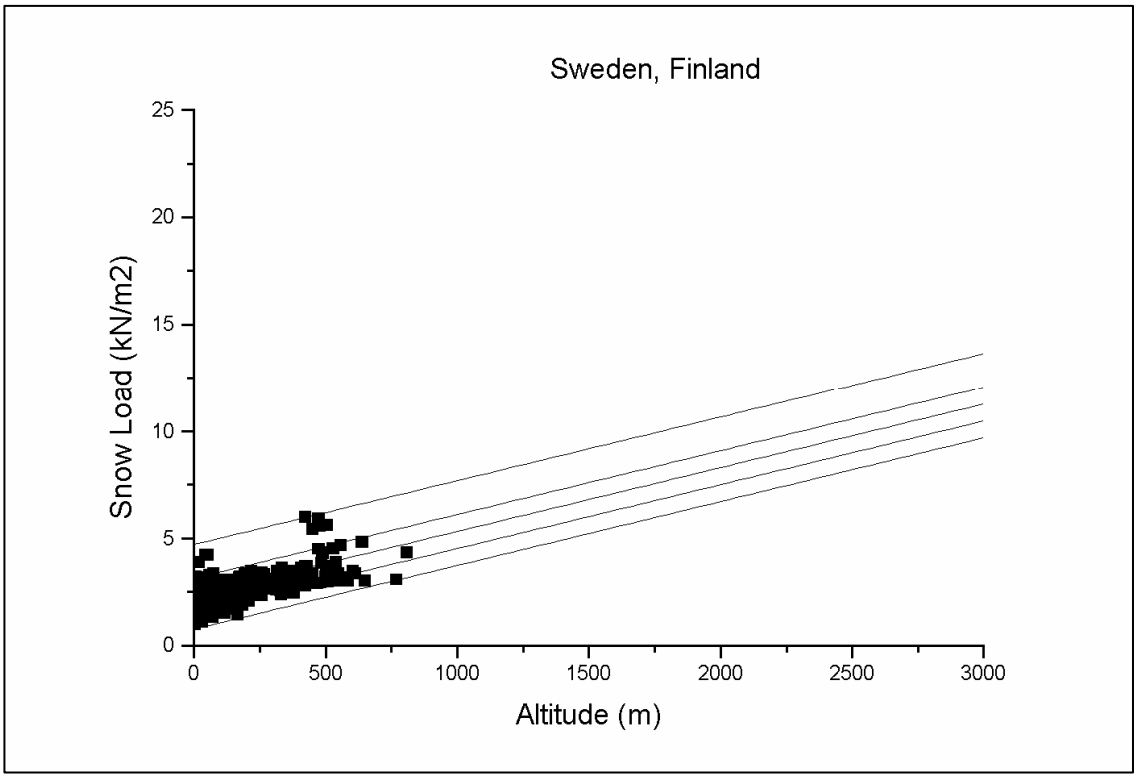

GREECE
Snow Load (kN/m2)
Altitude (m)
0
5
10
15
20
25
0
500
1000
1500
2000
2500
3000

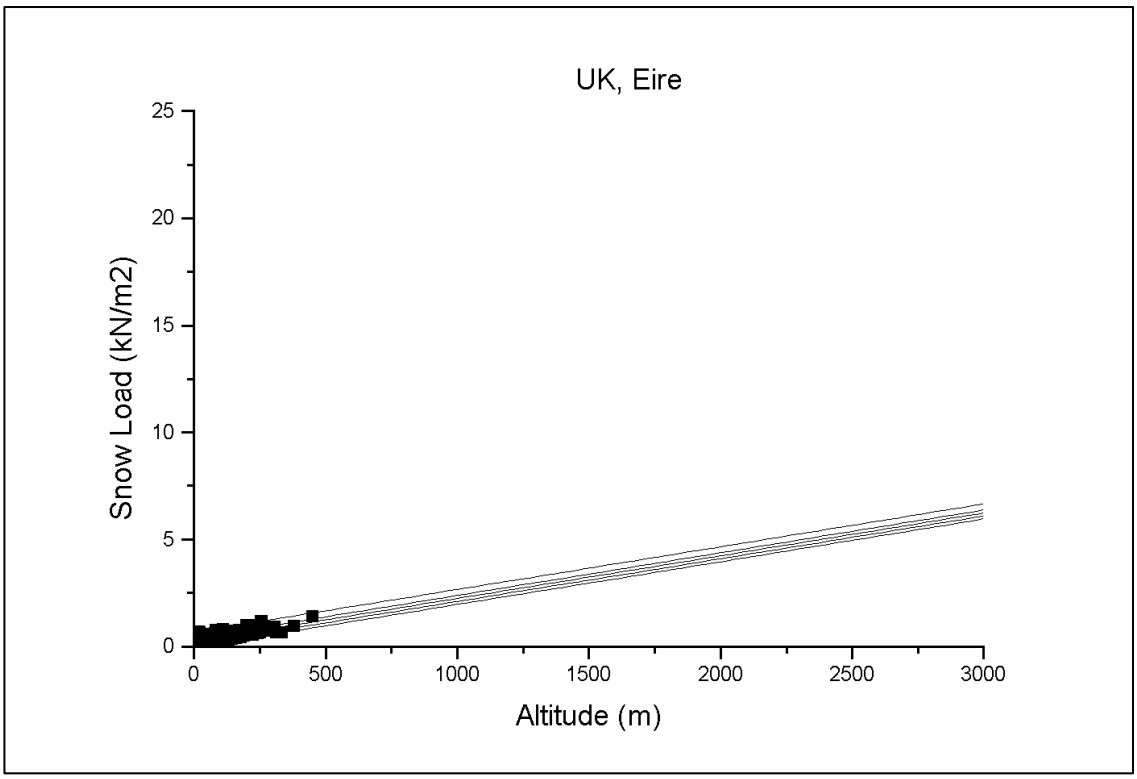

Iberian Peninsula
Snow Load (kN/m2)
Altitude (m)
0
5
10
15
20
25
0
500
1000
1500
2000
2500
3000



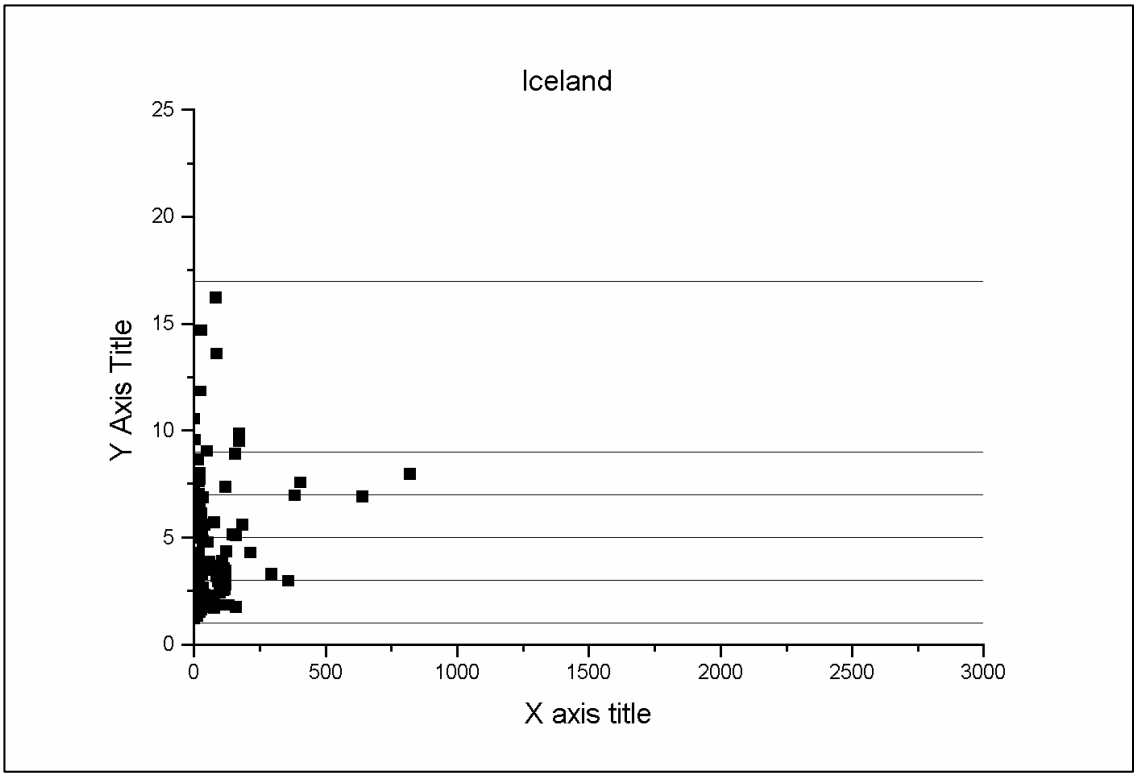
Linear Function:

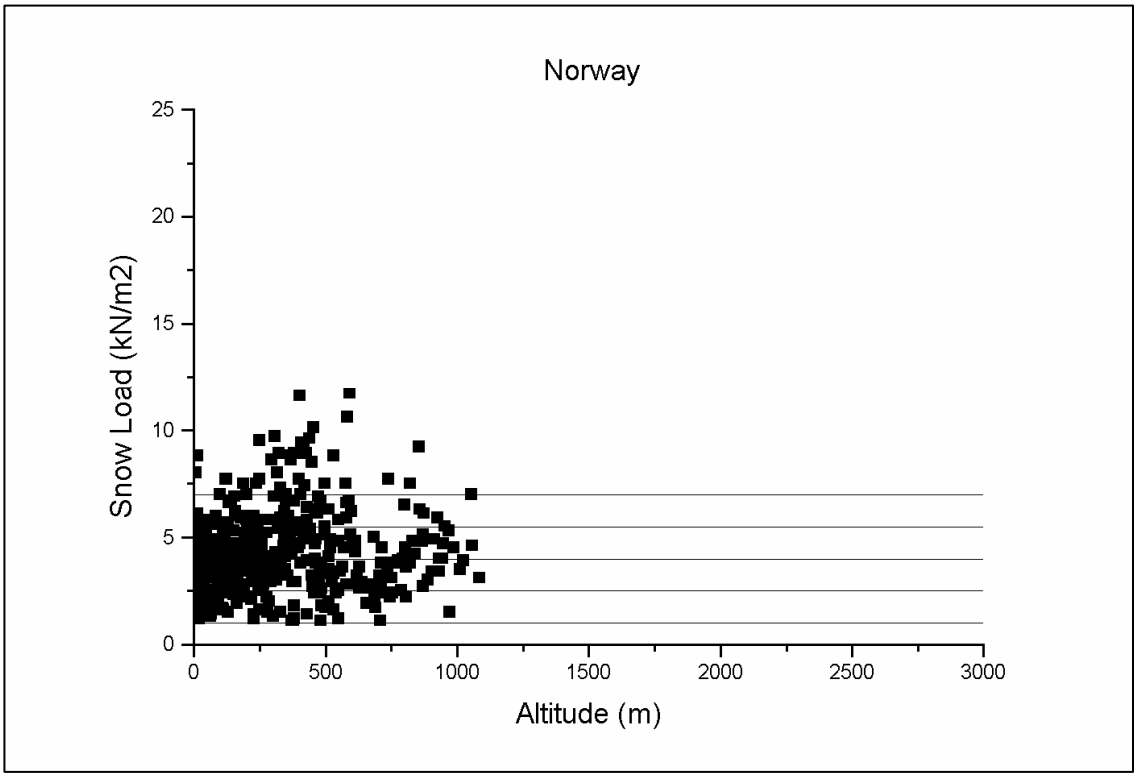



Sweden, Finland
Snow Load (kN/m2)
Altitude (m)
0
5
10
15
20
25
0
500
1000
1500
2000
2500
3000


UK, Eire
Snow Load (kN/m2)
Altitude (m)
0
5
10
15
20
25
0
500
1000
1500
2000
2500
3000

No Altitude - Snow Load Relationship:





B.3 Summary Table: Basic Parameters

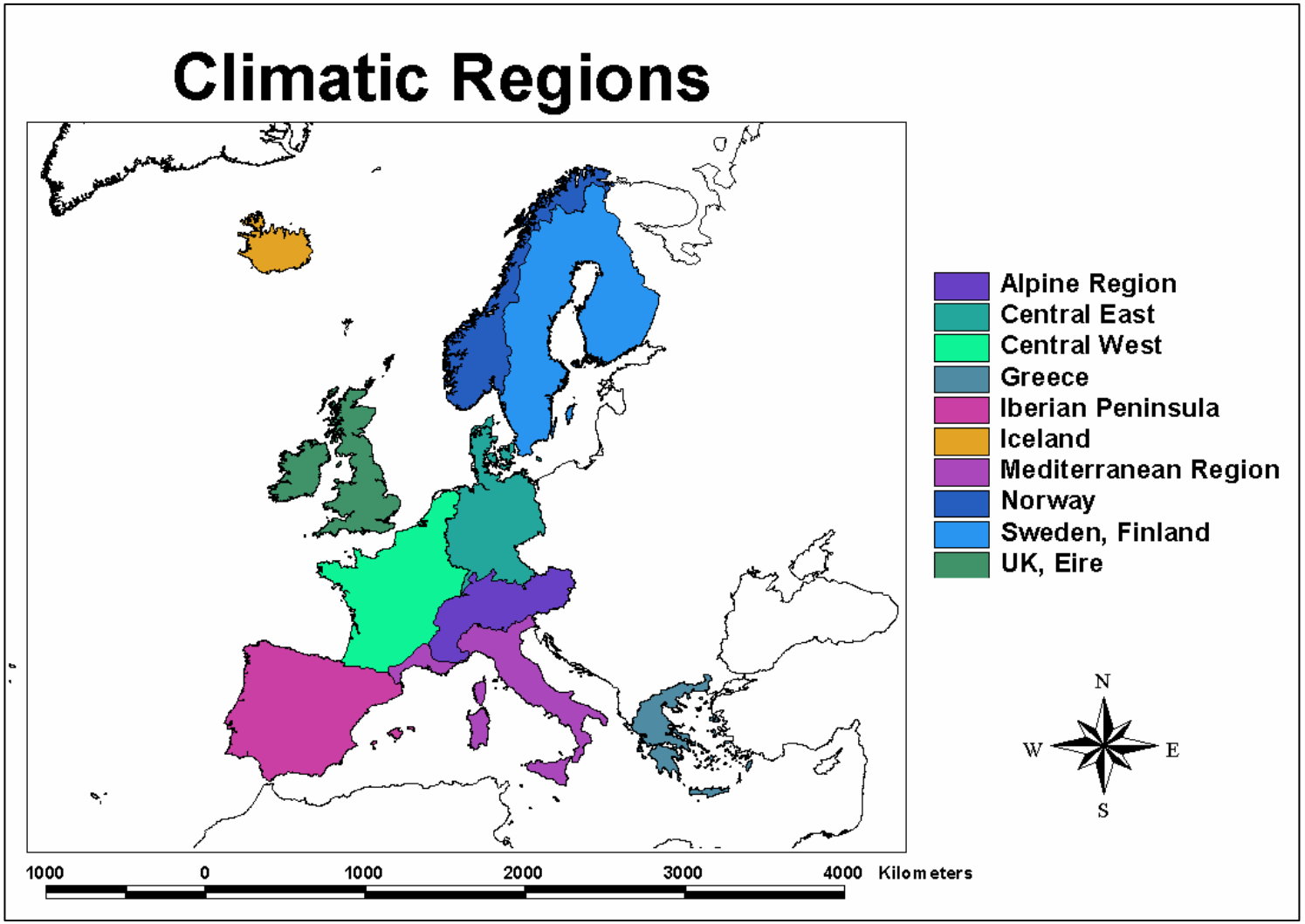
Climatic Region	**Function Type**	**a_{min}**	**a_{max}**	**b**	**r1**	**r2**	**r3**	**r4.5**	**r4**
Alpine Region	**Q**	0.33	3.54	728	0.97	0.97	0.99	0.98	-
Central East	**Q**	0.13	1.45	256	0.97	0.98	0.99	0.98	-
Greece	**Q**	0.18	2.28	917	0.82	0.89	-	-	0.57
Iberian Peninsula	**Q**	0.00	0.95	524	0.87	0.96	-	-	0.75
Mediterranean Region	**Q**	0.04	2.53	452	0.90	0.97	0.99	0.79	-
Central West	**L**	0.00	0.82	966	0.96	0.95	0.91	0.90	-
Sweden, Finland	**L**	0.77	4.72	336	0.96	0.86	0.88	0.91	-
UK, Eire	**L**	-0.03	0.67	501	0.98	0.96	0.96	0.96	-
Iceland	**H**	-	-	-	-	-	-	-	-
Norway	**H**	-	-	-	-	-	-	-	-

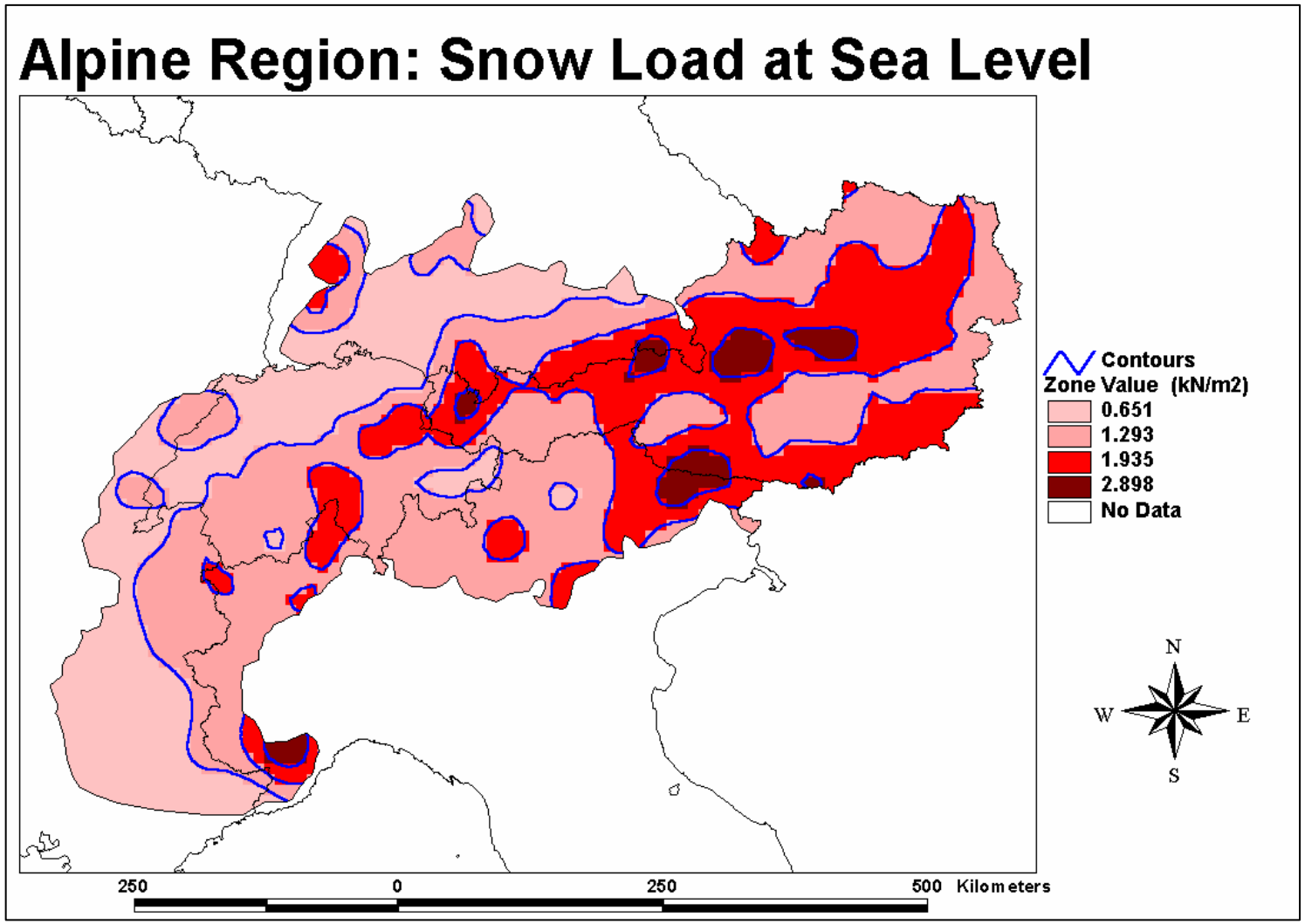
H = horizontal line, no altitude - snow load relationship
L = linear function
Q = quadratic function
a_{max}, a_{min} = max and min of parameter a
b = parameter b
r =correlation coefficients (snow load/representative function) for every zone from the lowest zone number (r1) to the highest

B.4 Summary Table: Altitude - Snow Load Relationship

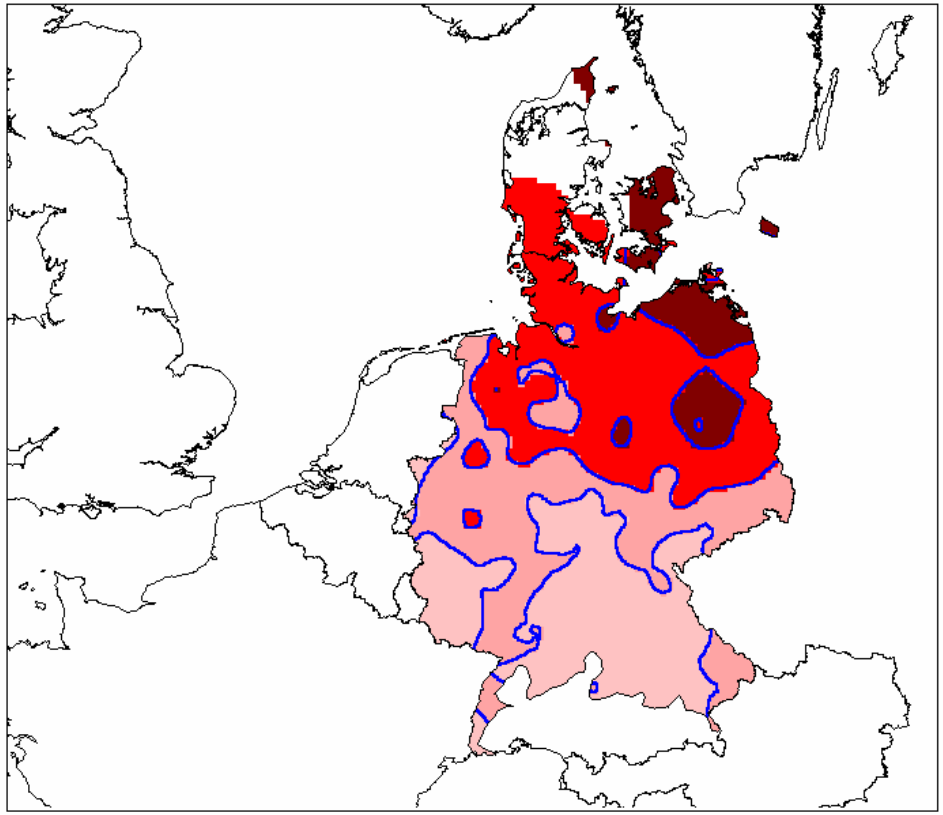
Climatic Region	***FORMULA***
Alpine Region	$s=(0.33+(Z-0.5)*[3.54-0.33]/5)\left[1+\left(\frac{A}{728}\right)^2\right]$
Central East	$s=(0.13+(Z-0.5)*[1.45-0.13]/5)\left[1+\left(\frac{A}{256}\right)^2\right]$
Greece	$s=(0.18+(Z-0.5)*[2.28-0.18]/5)\left[1+\left(\frac{A}{917}\right)^2\right]$
Iberian Peninsula	$s=(0+(Z-0.5)*[0.95-0]/5)\left[1+\left(\frac{A}{524}\right)^2\right]$
Mediterranean Region	$s=(0.04+(Z-0.5)*[2.53-0.04]/5)\left[1+\left(\frac{A}{452}\right)^2\right]$
Central West	$s=(0.00+(Z-0.5)*[0.82-0.00]/5)+\frac{A}{966}$
Sweden, Finland	$s=(0.77+(Z-0.5)*[4.72-0.77]/5)+\frac{A}{336}$
UK, Eire	$s=(-0.03+(Z-0.5)*[0.67+0.03]/5)+\frac{A}{501}$
Iceland	-
Norway	-

s = Snow Load (KN/m^2)
A = Altitude above Sea Level (m)
Z = Zone Number


Climatic Regions
Alpine Region
Central East
Central West
Greece
Iberian Peninsula
Iceland
Mediterranean Region
Norway
Sweden, Finland
UK, Eire
N
W
E
S
1000
0
1000
2000
3000
4000
Kilometers


Alpine Region: Snow Load at Sea Level
Contours
Zone Value (kN/m2)
0.651
1.293
1.935
2.898
No Data
N
W
E
S
250
0
250
500 Kilometers

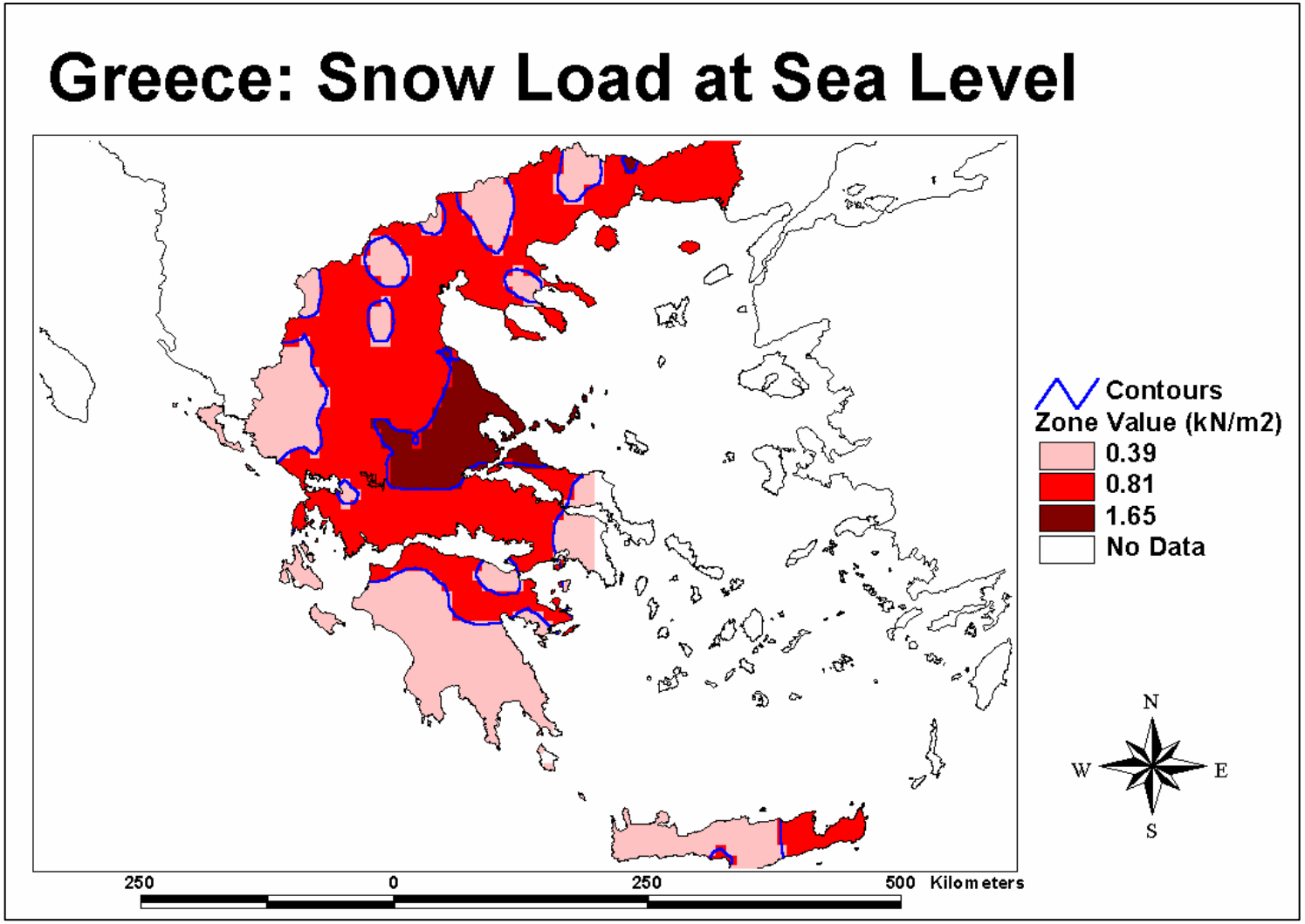
Central East: Snow Load at Sea Level

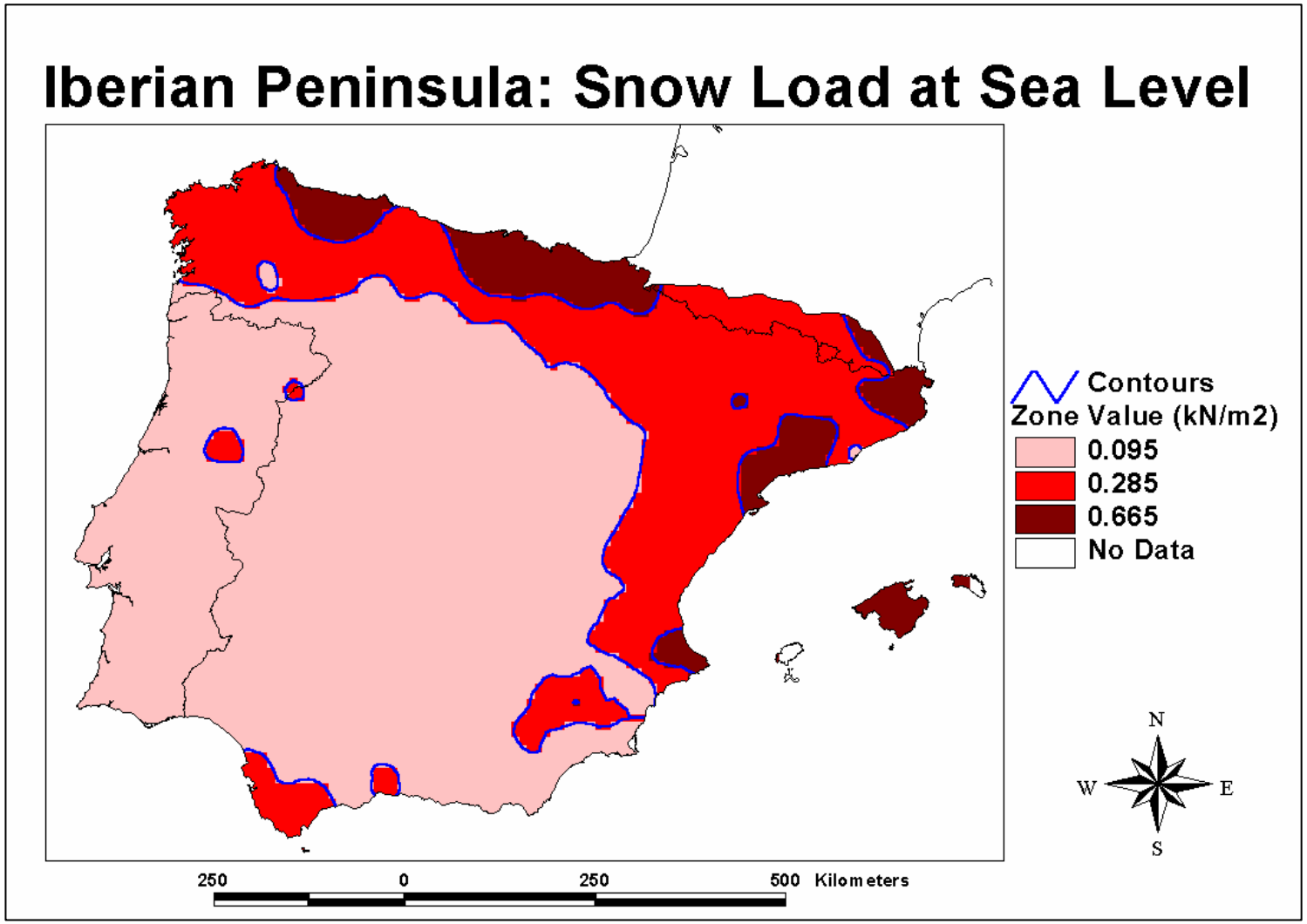


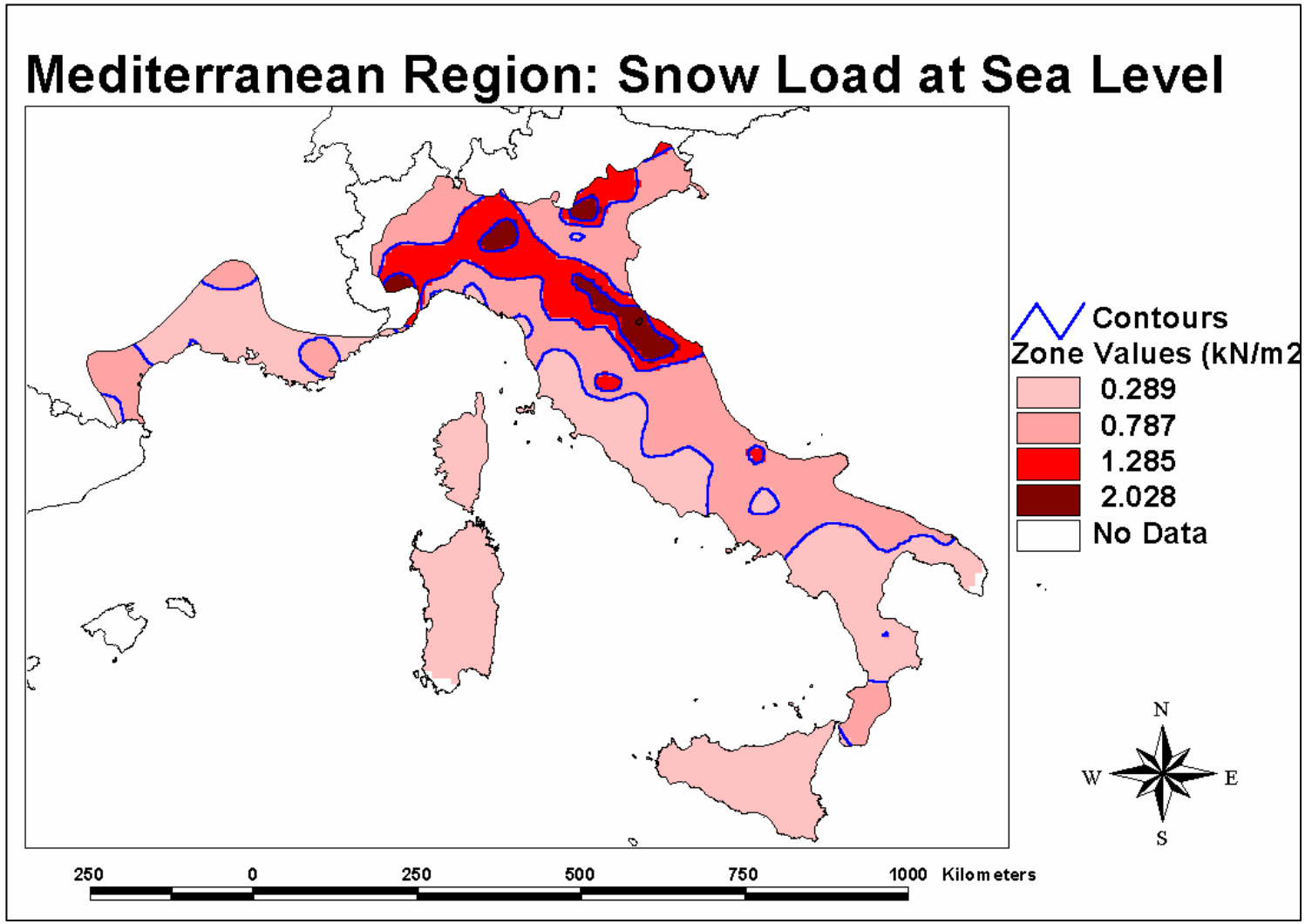
Contours
Zone Values (kN/m2)
0.26
0.53
0.79
1.19
No data

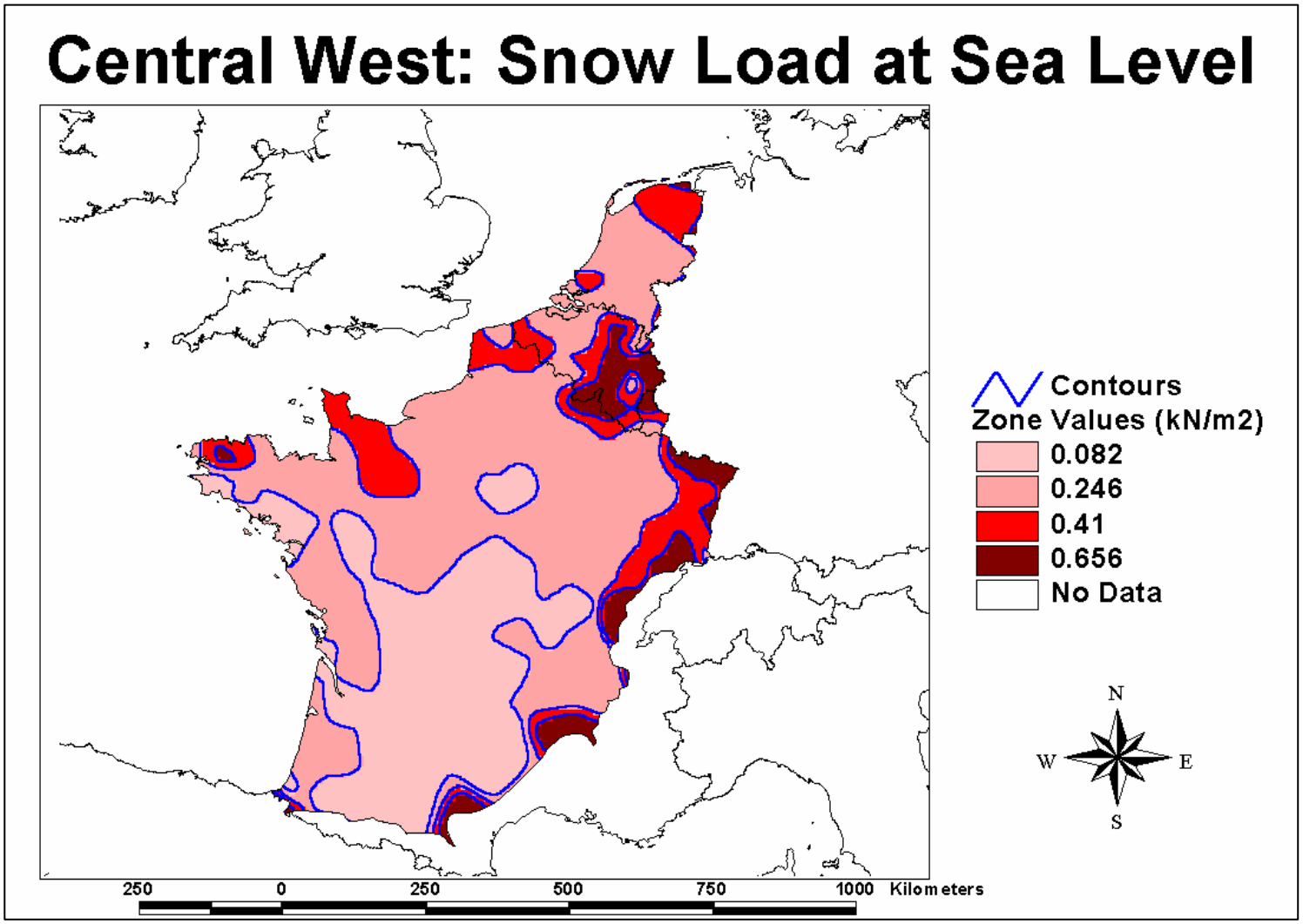
N
W
E
S

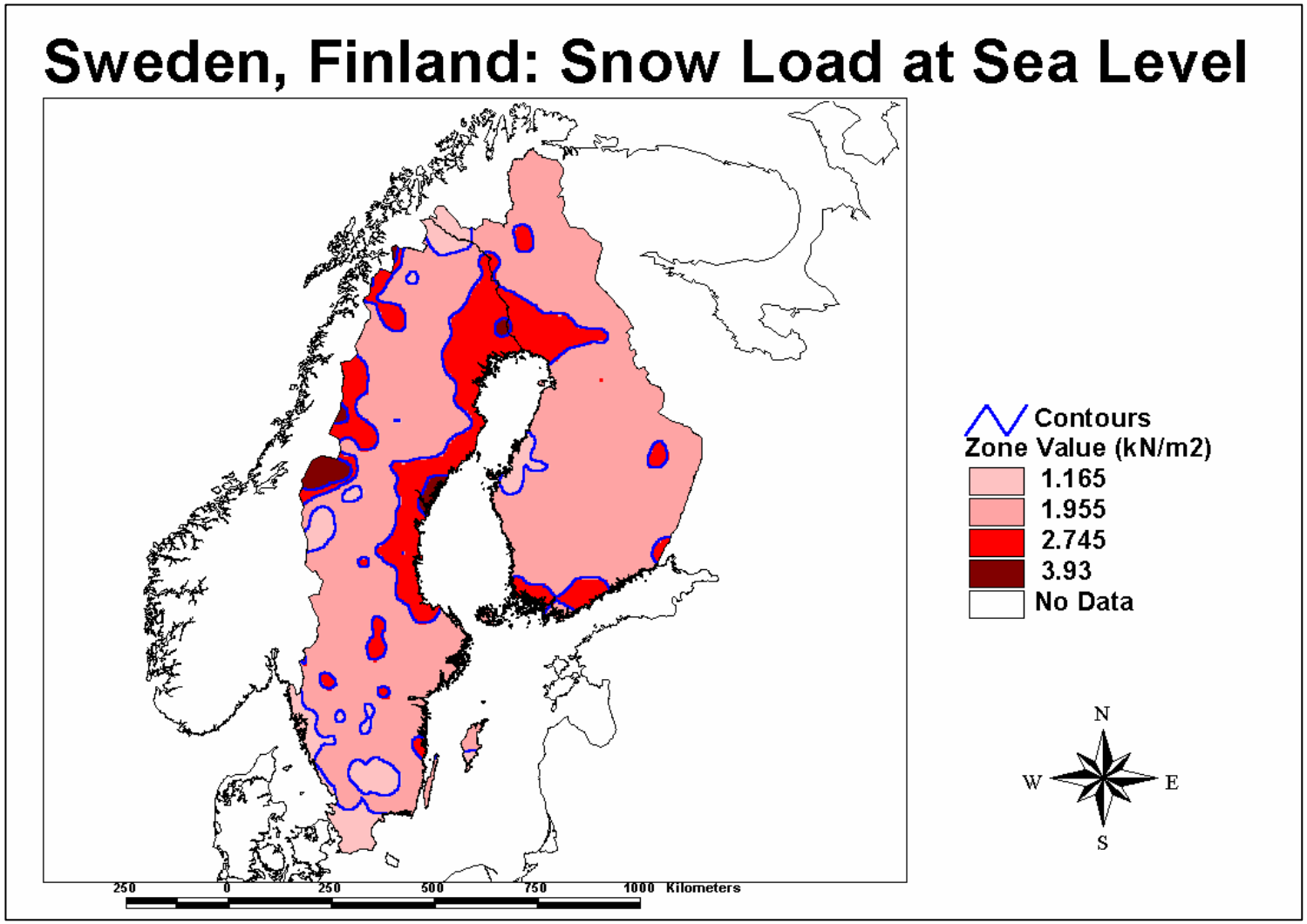
500 0 500 Kilometers

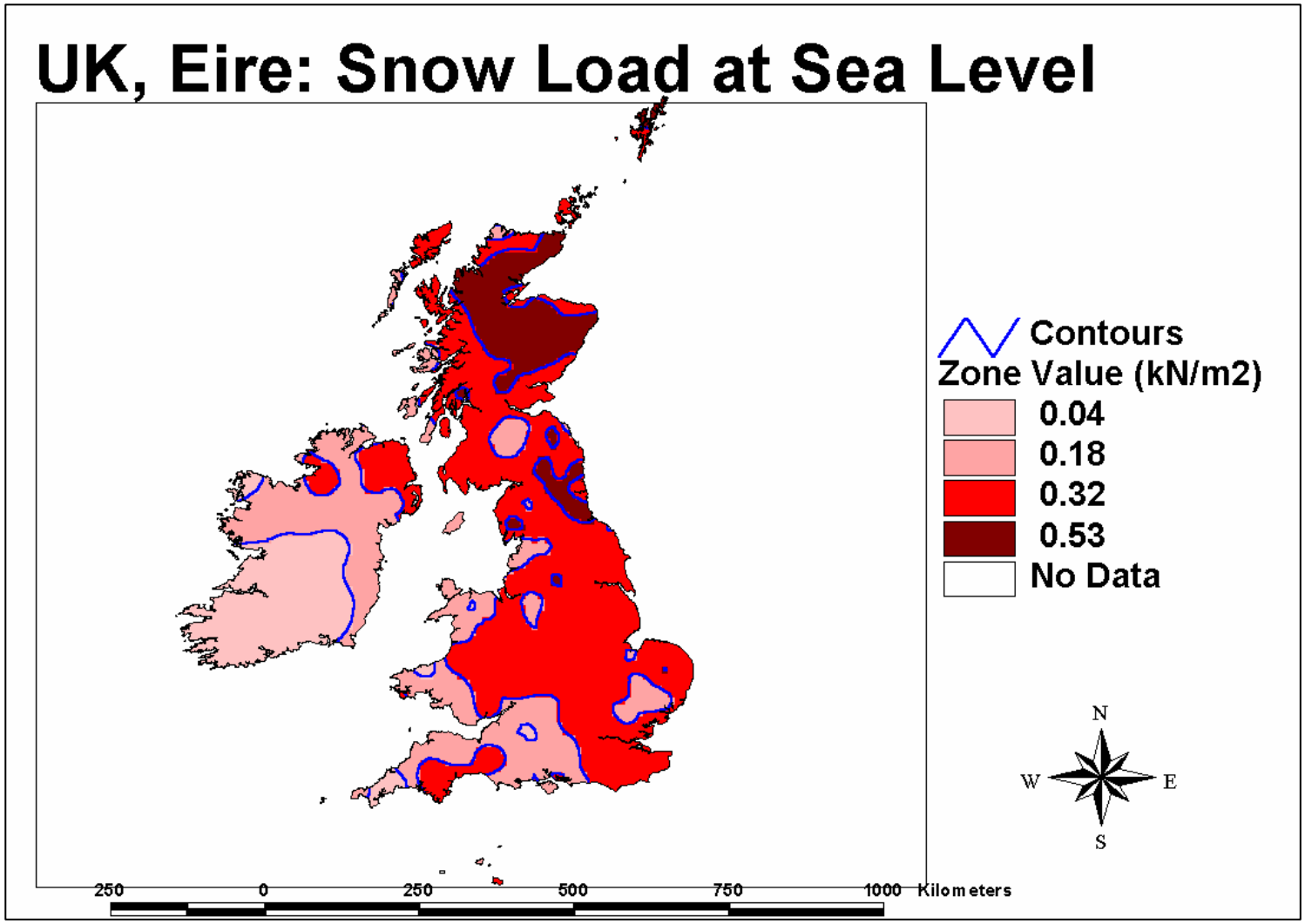

Greece: Snow Load at Sea Level
Contours
Zone Value (kN/m2)
0.39
0.81
1.65
No Data
N
W
E
S
250
0
250
500
Kilometers

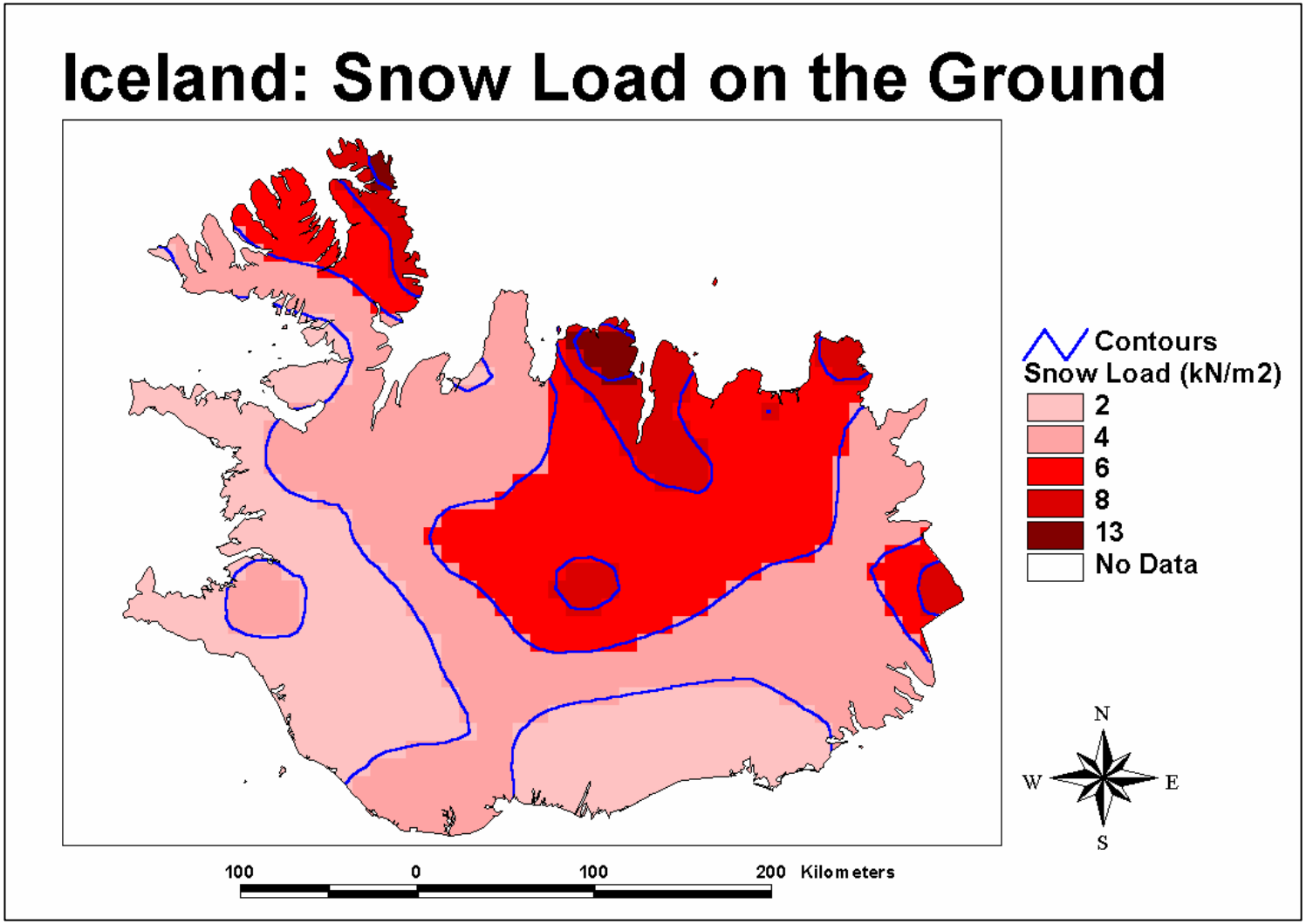

Iberian Peninsula: Snow Load at Sea Level
Contours
Zone Value (kN/m2)
0.095
0.285
0.665
No Data
N
W
E
S
250
0
250
500
Kilometers

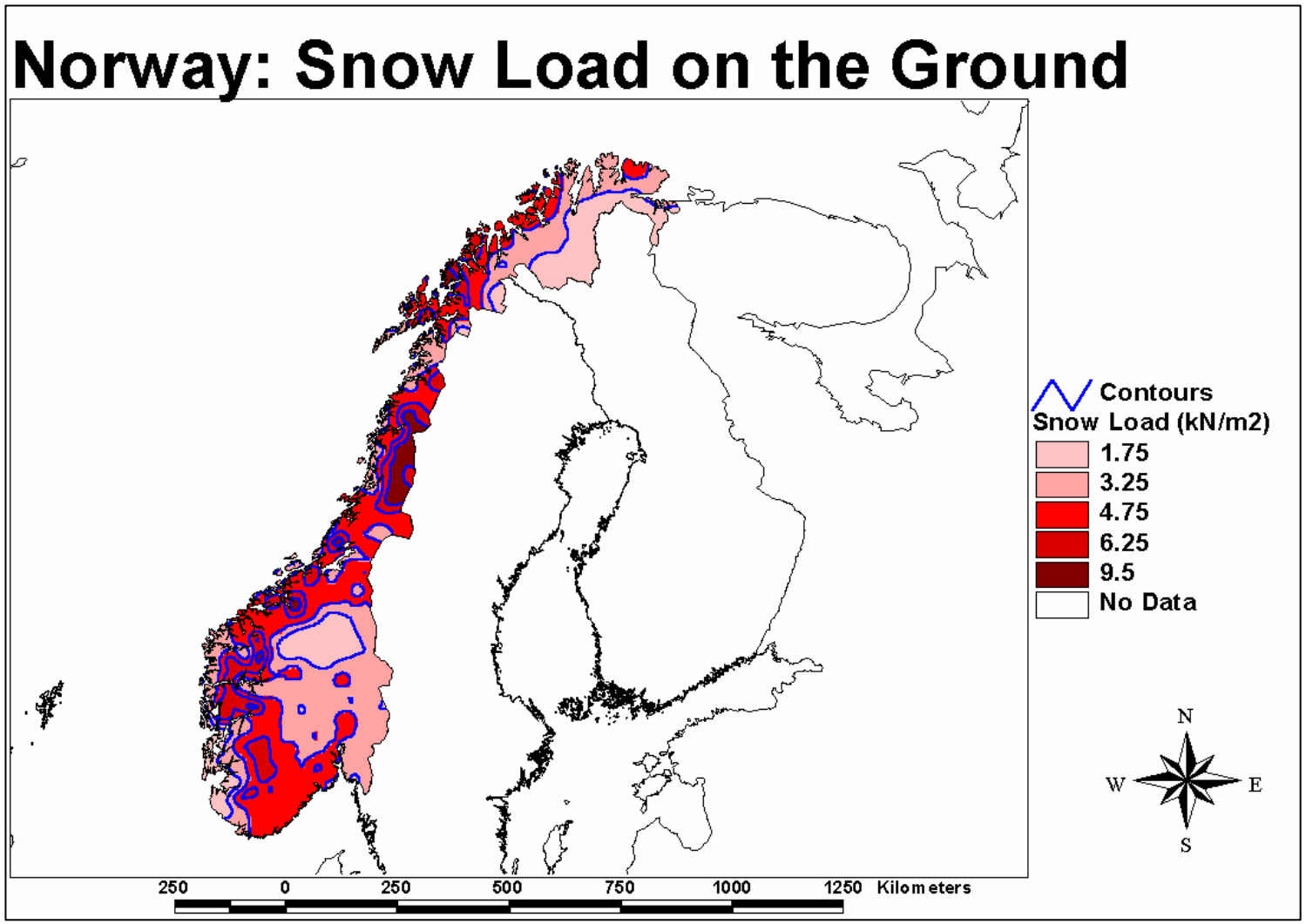

Mediterranean Region: Snow Load at Sea Level
Contours
Zone Values (kN/m2
0.289
0.787
1.285
2.028
No Data
N
W
E
S
250
0
250
500
750
1000
Kilometers


Central West: Snow Load at Sea Level
Contours
Zone Values (kN/m2)
0.082
0.246
0.41
0.656
No Data
N
W
E
S
250
0
250
500
750
1000
Kilometers


Sweden, Finland: Snow Load at Sea Level
Contours
Zone Value (kN/m2)
1.165
1.955
2.745
3.93
No Data
N
W
E
S
250
0
250
500
750
1000 Kilometers


UK, Eire: Snow Load at Sea Level
Contours
Zone Value (kN/m2)
0.04
0.18
0.32
0.53
No Data
N
W
E
S
250
0
250
500
750
1000
Kilometers


Iceland: Snow Load on the Ground
Contours
Snow Load (kN/m2)
2
4
6
8
13
No Data
N
W
E
S
100
0
100
200
Kilometers


Norway: Snow Load on the Ground
Contours
Snow Load (kN/m2)
1.75
3.25
4.75
6.25
9.5
No Data
N
W
E
S
250 0 250 500 750 1000 1250 Kilometers