EN 1991 – climatic actions & Elaboration of maps for climatic actions in Greece

Nikolaos Malakatas

Chairman of CEN/TC250/SC1

Chairman of Eurocodes Hellenic Mirror Committee (ELOT/TE 67)

Director of KEDE, Ministry of Transports, Infrastructures and Networks, Greece

Overview of the presentation

- Introduction
  - Key items of Part 1-3 “Wind actions” of EN 1991
  - Key items of Part 1-4 “Snow loads” of EN 1991
  - Key items of Part 1-5 “Thermal actions” of EN 1991
- Actual situation and near future perspectives concerning Eurocode parts on climatic actions
- Elaboration of maps for climatic actions in Greece
  - Snow maps
  - Wind maps
  - Temperature maps
- Future challenges

Introduction

EN 1991-1-3

- To date the following documents have been issued :
  - EN 1991-1-3:2003
  - EN 1991-1-3:2003/AC:2009
  - EN 1991-1-3:2003/A1:2015

- EN 1991-1-3 gives guidance and actions from **snow** for the structural design of buildings and civil engineering works (for sites at altitudes < 1500m). For higher altitudes advice may be found (if available) in the appropriate NA

EN 1991-1-3 **does not give guidance** on the following specialist aspects of snow loading:

- "impact loads" due to snow sliding off or falling from a higher roof;
- additional wind loads resulting from changes in shape or size of the roof profile due to presence of snow or to the accretion of ice;
- loads in areas where snow is present all the year;
- loads due to ice;
- lateral loading due to snow (e.g. lateral loads due to dirfts);
- snow loads on bridges

Contents of EN 1991-1-3 :

Foreword

Section 1: General

Section 2: Classification of actions

Section 3: Design situations

Section 4: Snow load on the ground

Section 5: Snow load on roofs

Section 6: Local effects

ANNEX A: Design situations and load arrangements to be used for different locations

ANNEX B: Snow load shape coefficients for exceptional snow drifts

ANNEX C: European Ground Snow Load Maps

ANNEX D: Adjustment of the ground snow load according to return period

ANNEX E: Bulk weight density of snow

ANNEX C: European Ground Snow Maps :

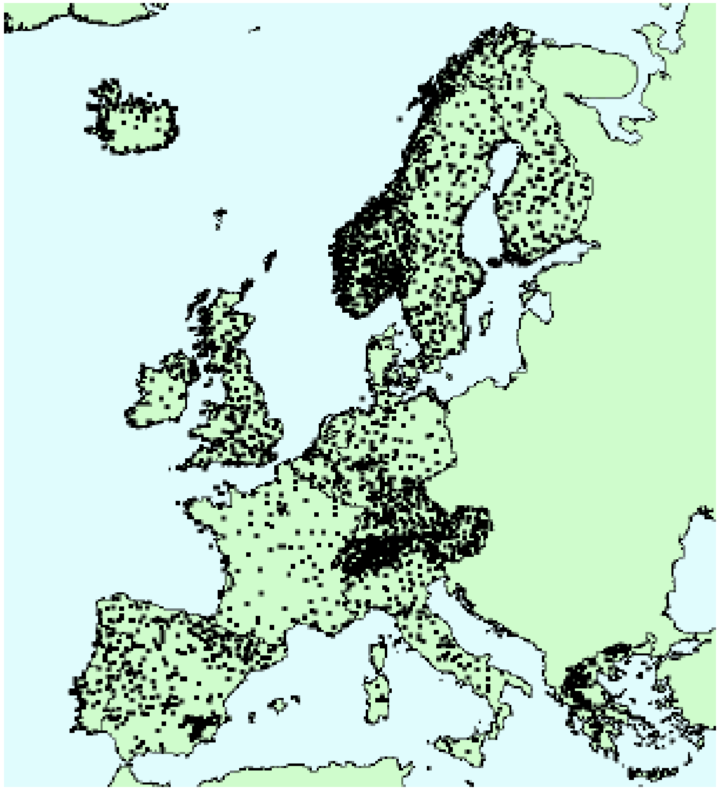
Many clauses of EN 1991-1-3 are based on the results of a research work, carried out between 1996 and 1999, under a contract specific to this Eurocode, to DGIII/D3 of the European Commission.

They were identified four main research items:

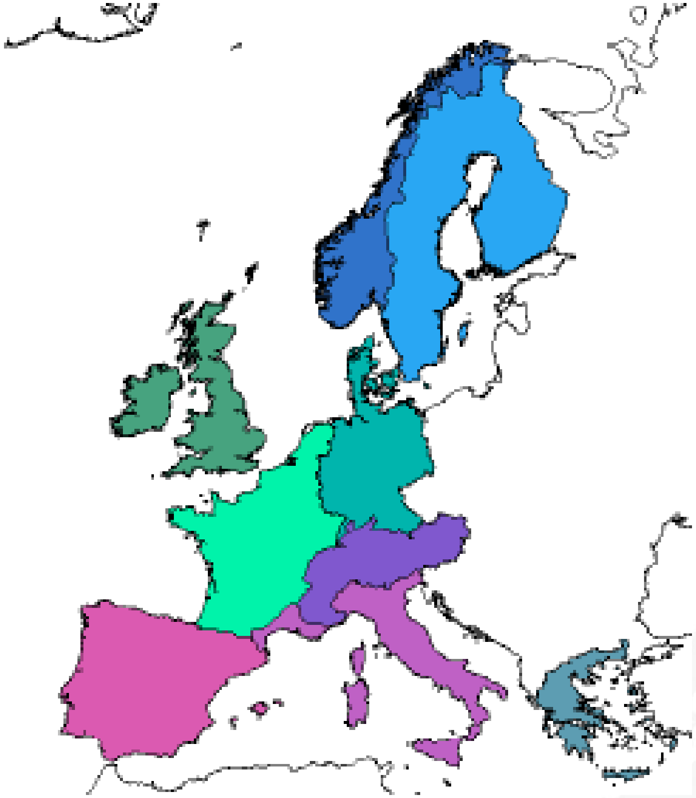
- study of the European ground snow loads map
- investigation and treatment of exceptional snow loads
- study of conversion factors from ground to roof loads
- definition of ULS and SLS combination factors for snow loads.

ANNEX C: European Ground Snow Maps :

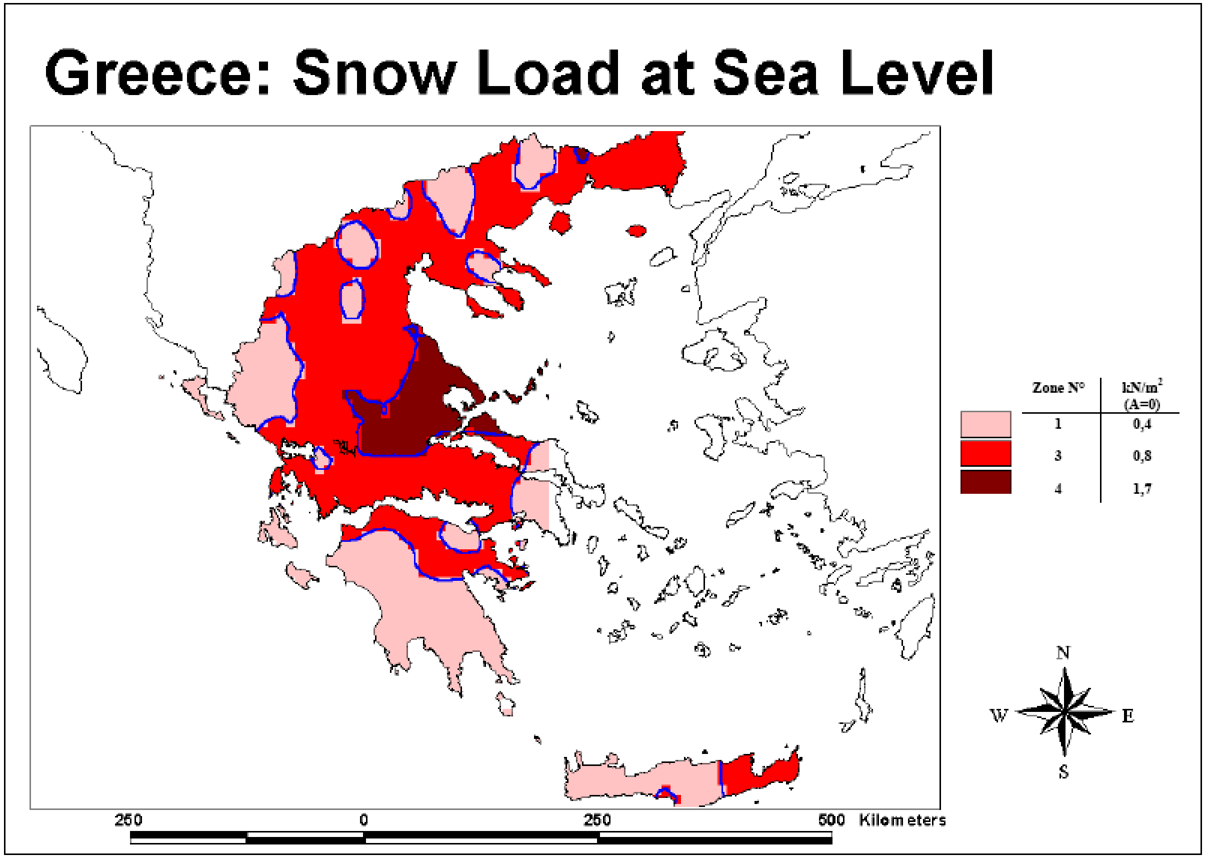
Data Points



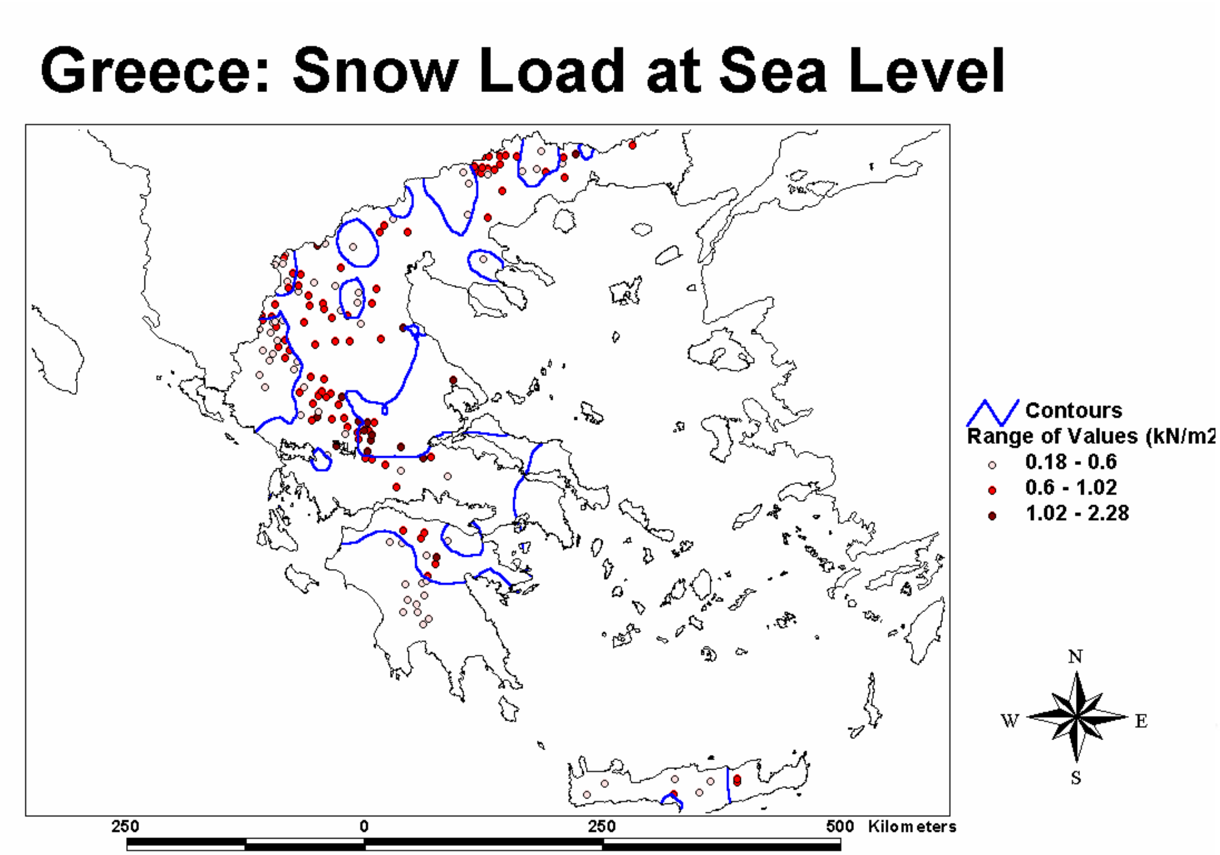
European Regions



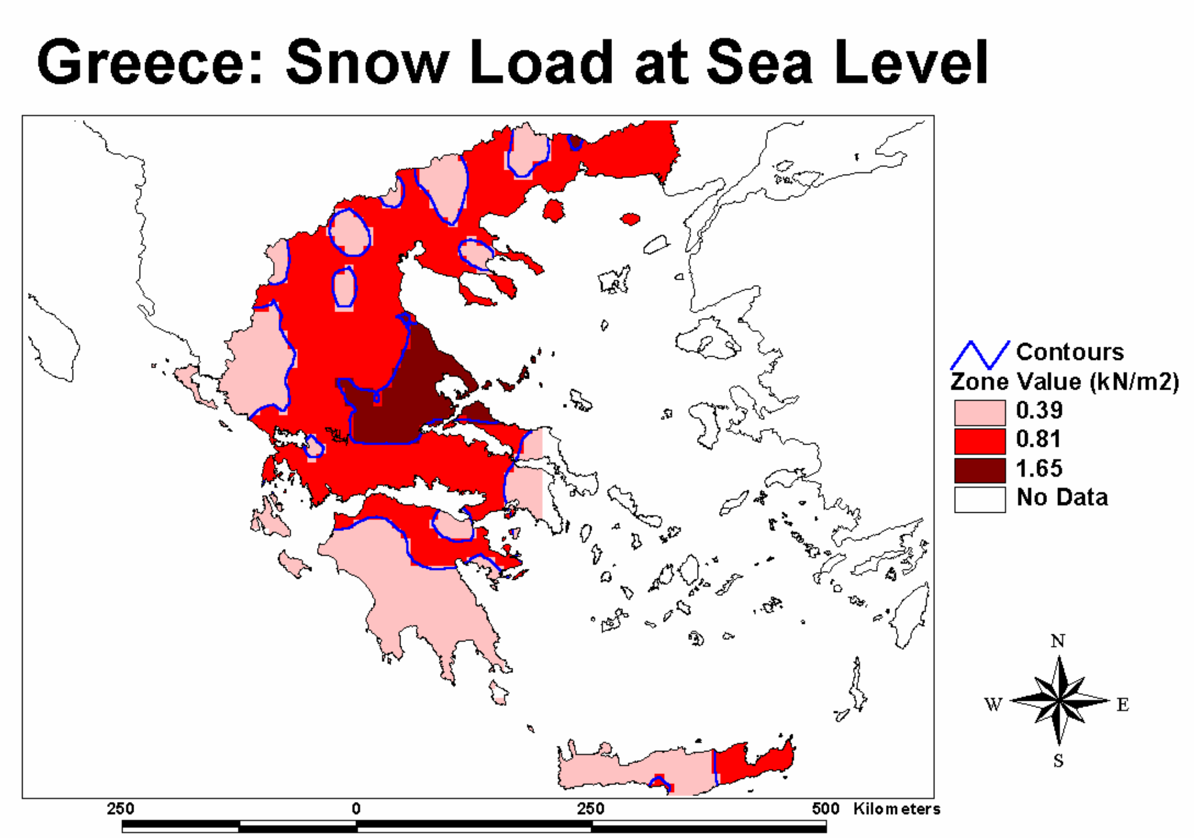
ANNEX C: European Ground Snow Maps : Example for Greece



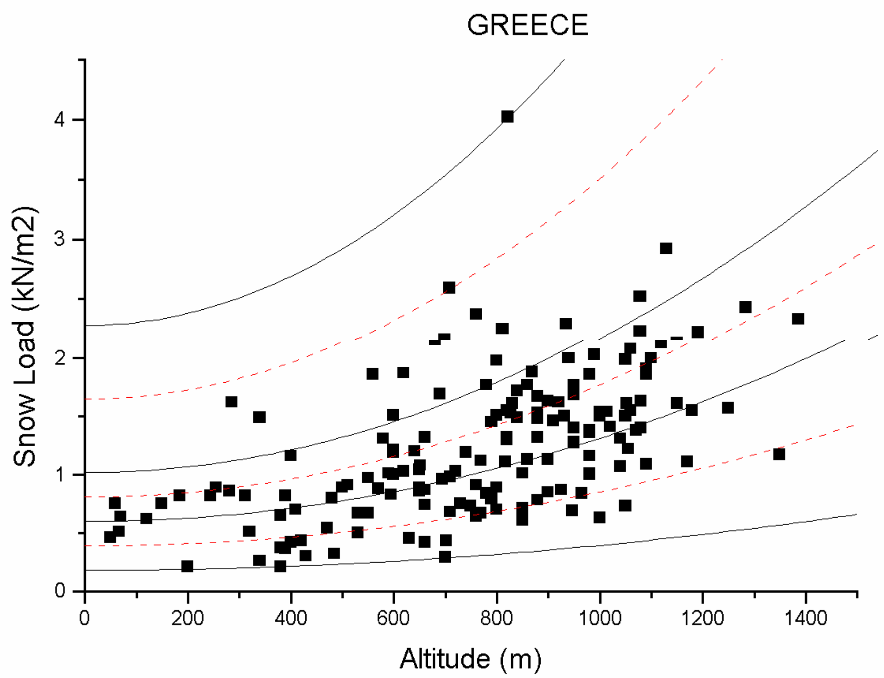
European Ground Snow Maps : Example for Greece (extract form the Final Report)



European Ground Snow Maps : Example for Greece (extract form the Final Report) (cont'd)



European Ground Snow Maps : Example for Greece (extract form the Final Report) (cont'd)



(black line = zone limit)

(red line = representative altitude - snow load relationship for the corres-ponding zone)

PROPOSAL : Investigation into the needs of further research on snow loads following roof collapses 2005/2006

- Form and expert research group
- Examine the cause of the failures and their implication on EN 1991-1-3.
- Apply for financial support if the steps below need to be carried out
- Determine and compare the values of ground snow loads causing the collapses with the values given in Annex C of EN 1991-1-3.
- If there are safety implications the following aspects will need re-consideration :

i. snow load on the ground

ii. shape factors, and the effects of roof dimension on these factors

iii. effects of melting/freezing of snow

iv. other influences.

- Update EN 1991-1-3 to the satisfaction of National Delegations to CEN/TC250/SC1
- Extend Annex C of EN 1991-1-3 to cover all the Member States of the EU and EFTA.
- Examine National Annex maps with the maps of Annex C of EN 1991-1-3 **as a first step to obtain a harmonised snow map of Europe by ensuring consistency at borders**.

EN 1991-1-4

- To date the following documents have been issued :
  - EN 1991-1-4:2005
  - EN 1991-1-4:2005/AC:2010
  - EN 1991-1-4:2005/A1:2010
- EN 1991-1-4 gives guidance on the determination of natural **wind** actions for the structural design of buildings and civil engineering works for each of the loaded areas under consideration. This includes the whole structure or parts of the structure or elements attached to the structure

- EN 1991-1-4 is applicable to buildings with heights up to 200m and to bridges with spans not greater than 200m (provided they satisfy the criteria for dynamic response)
- EN 1991-1-4 does not give guidance on the following aspects:
  - ❑ Torsional vibrations, e.g. tall buildings with central core
  - ❑ Bridge deck vibrations from transverse wind turbulence
  - ❑ Cable supported bridges
  - ❑ Vibrations where more than the fundamental mode needs to be considered

  The NA may provide guidance on this aspects as NCCI
- Guyed masts and lattice towers are treated in EN 1993-3-1
- Lighting columns are treated in EN 40

Contents of EN 1991-1-4 :

Contents of EN 1991-1-4 (cont'd):

- **Annex A (informative)** – Terrain effects
- **Annex B (informative)** – Procedure 1 for determining the structural factor $c_s c_d$
- **Annex C (informative)** – Procedure 2 for determining the structural factor $c_s c_d$
- **Annex D (informative)** – $c_s c_d$ values for different types of structures
- **Annex E (informative)** – Vortex shedding and aeroelastic instabilities
- **Annex F (informative)** – Dynamic characteristics of structures

No maps provided in an Annex

EN 1991-1-5

- To date the following documents have been issued :
  - EN 1991-1-5:2003
  - EN 1991-1-5:2003/AC:2009

- EN 1991-1-5 gives principles and rules for calculating **thermal** actions for buildings, bridges and other structures including their structural elements. Principles needed for cladding and other appendages of buildings are also provided.

Contents of EN 1991-1-5 :

Forward

Section 1 – General

Section 2 – Classification of actions

Section 3 – Design situations

Section 4 – Representation of actions

Section 5 – Temperature changes in buildings

Section 6 – Temperature changes in bridges

Section 7 – Temperature changes in industrial chimneys, pipelines, silos, tanks and cooling towers

Contents of EN 1991-1-5 (cont'd):

- **Annex A (normative)** – Isotherms of national minimum and maximum shade air temperatures. No maps provided
- **Annex B (normative)** – Temperature differences for various surfacing depths
- **Annex C (informative) –** Coefficients of linear expansion
- **Annex D (informative) –** Temperature profiles in buildings and other construction works

Actual situation and near future perspectives concerning Eurocode parts on climatic actions

- During the last years 3 Working Groups have been established by CEN/TC250/SC1 in order to follow up the "maintenance" of existing Eurocode parts associated with climatic actions, on one hand, as well as to deal with the development of new parts in the future, namely :
  - WG 01 "Climatic actions" to deal with snow, wind and thermal actions
  - WG 02 "Atmospheric icing of structures"

    and more recently
  - WG 06 "Actions from waves and currents on coastal structures"

- A systematic review concerning (among others) the EN 1991-1-3, EN 1991-1-4 and EN 1991-1-5 has been launched and concluded with the collection of comments one year ago
- Within the framework of the Mandate 515 signed by CEN and EC, the preparation of Phase II calls for tendering has started, in order that Project Teams (PT) be established, among which those to deal with the future development (revision) of the aforementioned climatic actions parts of the EN Eurocodes
- In addition to that the future evolution of ISO 21650 to EN 1991-1-8 : General Actions – Waves and currents on coastal structures, as well as of ISO 12494 to EN 1991-1-9: General Actions – Atmospheric icing is scheduled
- At a later stage the interdependence of snow, wind and temperature with atmospheric icing will be considered

- Among the sub-tasks of all three future Project Teams to deal with the future development (revision) of snow, wind and thermal parts of the actual EN Eurocodes (EN 1991-1-3, EN 1991-1-4 and EN 1991-1-5, respectively) the following are included :

Collect snow load on ground based on existing national values and present the values in a snow load map emphasizing differences across borders and revealing the introduction of the exceptional ground snow loads to be dealt with accidental design situations.

Collect basic wind velocities based on existing national values and present the values in a wind map emphasizing differences across borders

Collect characteristic temperatures based on existing national values and present the values in a temperature map emphasizing differences across borders

Elaboration of maps for climatic actions in Greece

The relevant maps, together with the additional NDPs are included in the corresponding National Annexes, namely :

- Greek National Annex (NA) for snow loads (ELOT EN 1991-1-3:2003/NA, issued 2010-11-15)
- Greek National Annex (NA) for wind actions (ELOT EN 1991-1-4:2005/NA, issued 2010-11-15)
- Greek National Annex (NA) for thermal actions (ELOT EN 1991-1-5:2004/NA, issued 2010-11-15)

Snow map for Greece :

The usual practice used for the establishment of the European snow maps consists of the choice of a probabilistic model, the estimation of the parameters and the evaluation of the characteristic value for a 98% fractile.

More specifically, the maximum yearly ground level snow load is assumed to follow a type I extreme value (Gumbel) distribution, with a cumulative distribution function :

$$F_S(s) = P(S < s) = e^{-e^{-\frac{s-u}{b}}} ,$$

The distribution parameters u and b are assessed form the yearly maximum values and the characteristic value is evaluated from the relation : $s_k = u + 3.90b$

Snow map for Greece (cont'd):

- Snow data were obtained from the archives of the National Electric Company (ΔΕΗ), for a total number of 96 stations. These were chosen for the duration of the period of measurement (longer than 20 years) and to give a reasonably homogenous coverage throughout all of Greece. Stations are located mainly at high altitudes, but there are stations located at low altitudes which have fewer and less reliable data.
- The data contain daily measurements indicating the water equivalent of snow fallen in the 24 h period; measurements are taken at 09:00.
- For all stations geographical co-ordinates and altitude were available, as were the following supporting qualitative information: wind presence and sunny or cloudy weather.

Snow map for Greece (cont'd):

- The relation established for Greece in the framework of European snow maps project of Pisa Univeristy was the following :

$$s_k = (0,420 * Z - 0,030)\left[1 + \left(\frac{A}{917}\right)^2\right]$$

where:

s_k the characteristic snow load [kN/m²]

A the site altitude above Sea Level [m]

Z the zone number given in the map with the values 1, 2 and 4, respectively for zones A, B and C (Γ)

Snow map for Greece (cont'd):

- The aforementioned relation has been simplified in the Greek National Annex as follows :

$$s_k = s_{k,0}\left[1+\left(\frac{A}{917}\right)^2\right]$$

where:

$s_{k,0}$ the characteristic snow load [kN/m^2]

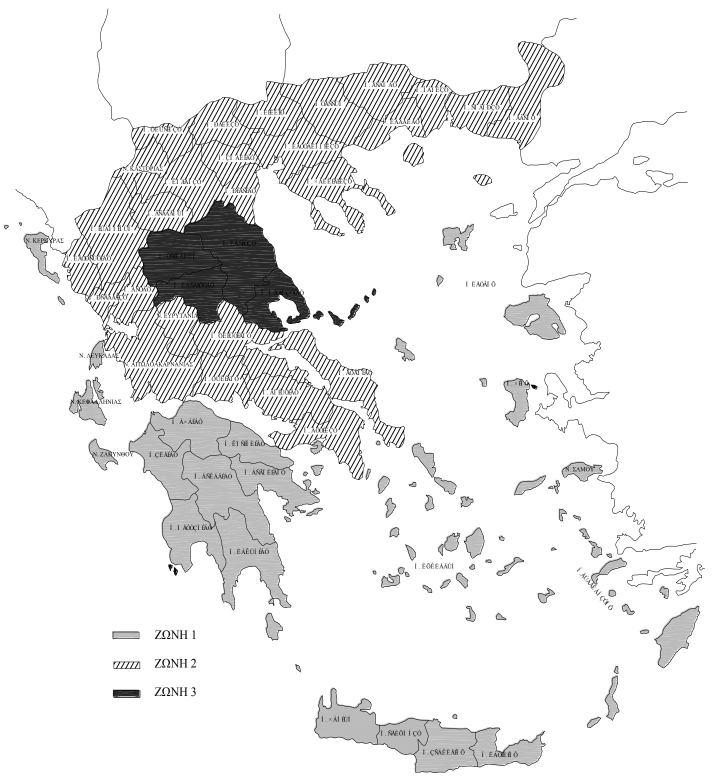
A the site altitude above Sea Level [m]

Z the zone number given in the map, with the values

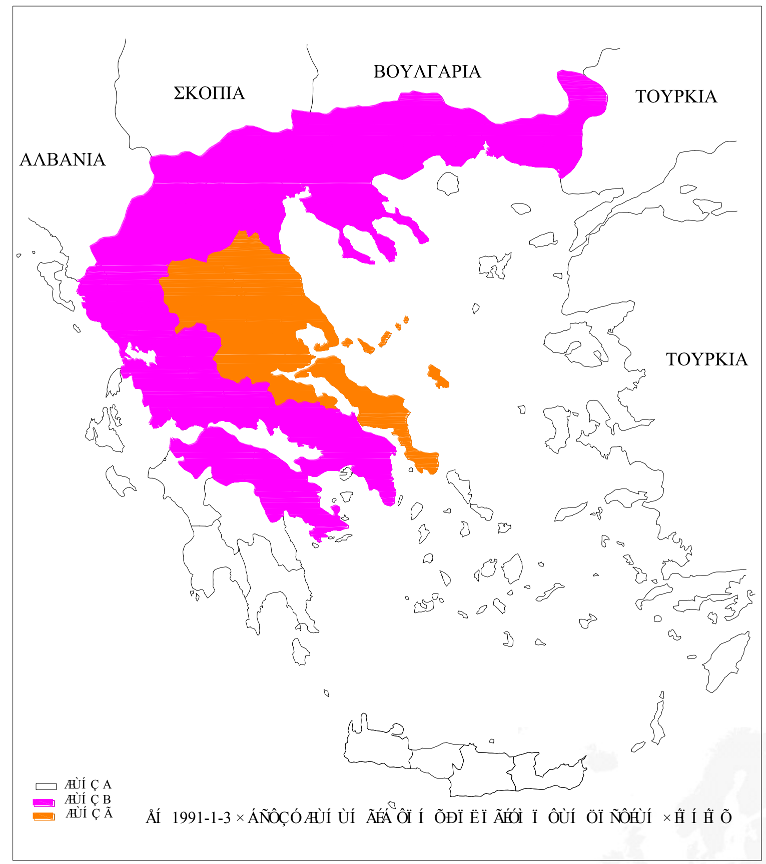
0,4 kPa, 0,8 kPa and 1,7 kPa, respectively for zones A, B and C (Γ).

Snow map for Greece (cont'd):

Initial zoning *Actual zoning*



EN 1991-1-3 ΧΑΡΤΗΣ ΖΩΝΩΝ ΓΙΑ ΤΟΝ ΥΠΟΛΟΓΙΣΜΟ ΤΩΝ ΦΟΡΤΙΩΝ ΧΙΟΝΙΟΥ
ΚΛΙΜΑΚΑ 1:500000



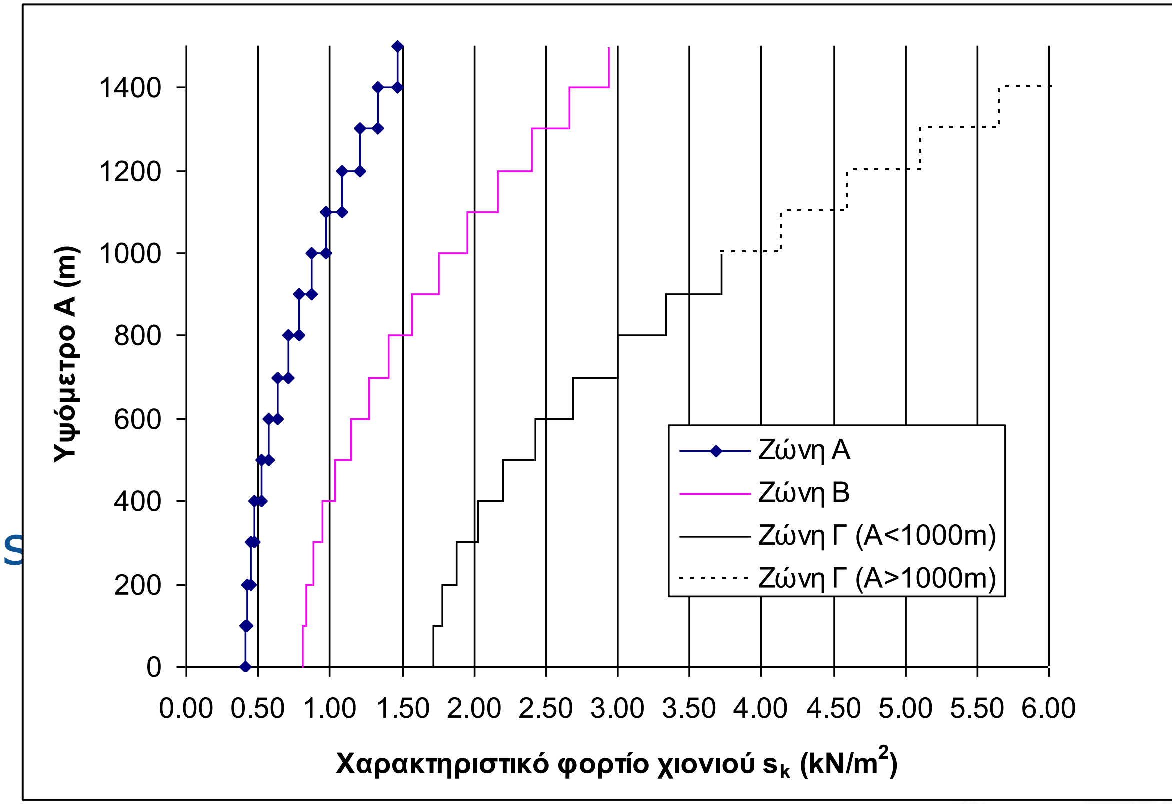
Snow map for Greece (cont'd):

Characteristic ground level snow load, s_k, as a function of the altitude, for the three zones in Greece

Altitude A (m)		Zone A	Zone B	Zone C (Γ)
from	to			
0	100	0.40	0.81	1.72
100	200	0.42	0.84	1.78
200	300	0.44	0.89	1.88
300	400	0.48	0.95	2.02
400	500	0.52	1.04	2.21
500	600	0.57	1.14	2.43
600	700	0.63	1.27	2.69
700	800	0.70	1.41	2.99
800	900	0.79	1.57	3.34
900	1000	0.88	1.75	3.72
1000	1100	0.98	1.95	Ad-hoc evaluation required (based on at least 20 years data)
1100	1200	1.08	2.17	
1200	1300	1.20	2.41	
1300	1400	1.33	2.66	
1400	1500	0.40	0.80	
1500	Higher	Not covered by the Eurocodes		

Snow map for Greece (cont'd):

Characteristic ground level snow load, s_k, as a function of the altitude, for the three zones in Greece



Wind map for Greece:

The data used where gathered from 31 stations of the National Meteorological Service, with an average observation period of 40 years.

Initially the sensitivity of results in relation to the assumed distribution was examined by comparing (for all stations) the Gumbel extreme value distribution, the Weibull distribution, as well as the lognormal distribution.

As it may be seen form the table presented in the next slide Weibull distribution leads systematically to smaller values, while Gumbel distribution leads to greater values. Gumbel and longnormal distributions have more or less the same results

Wind map for Greece (cont'd):

A/A	Station	Characteristic wind value (m/s)		
		Gumbel	Weibull	Lognormal
1	ΑΓΡΙΝΙΟ	23.2	20.9	22.5
2	ΑΓΧΙΑΛΟΣ	26.6	24.1	25.7
3	ΑΛΕΧ/ΠΟΛΗ	30.4	27.5	29.5
4	ΑΝΔΡΑΒΙΔΑ	22.7	20.6	21.9
5	ΑΡΑΞΟΣ	22.9	20.6	22.2
6	ΑΡΓΟΣΤΟΛΙ	28.3	25.4	27.5
7	ΕΛΕΥΣΙΝΑ	25.0	22.8	24.2
8	ΕΛΛΗΝΙΚΟ	25.2	23.0	24.4
9	ΗΡΑΚΛΕΙΟ	27.0	24.8	26.1
10	ΘΗΡΑ	29.0	26.8	28.1
11	ΙΩΑΝΝΙΝΑ	31.4	28.3	30.5
12	ΚΑΛΑΜΑΤΑ	23.6	21.3	22.9
13	ΚΕΡΚΥΡΑ	30.4	27.5	29.4
14	ΚΟΖΑΝΗ	28.7	25.9	27.8
15	ΚΥΘΗΡΑ	35.2	32.7	34.1
16	ΛΑΜΙΑ	20.7	19.0	20.1
17	ΛΑΡΙΣΑ	21.6	19.6	20.9
18	ΛΗΜΝΟΣ	29.5	26.8	28.5
19	ΜΕΘΩΝΗ	28.7	26.1	27.8
20	ΜΙΚΡΑ	34.0	30.5	32.9
21	ΝΑΞΟΣ	33.9	31.8	32.9
22	ΠΥΡΓΕΛΑ	19.8	17.9	19.7
23	ΠΥΡΓΟΣ	29.2	26.3	28.3
24	ΡΟΔΟΣ	32.1	28.8	31.3
25	ΣΑΜΟΣ	31.5	28.5	30.5
26	ΣΟΥΔΑ	29.3	26.3	28.5
27	ΣΚΥΡΟΣ	35.7	32.3	34.5
28	ΤΑΝΑΓΡΑ	21.4	19.4	20.8
29	ΤΑΤΟΙ	28.4	25.6	27.5
30	ΤΡΙΠΟΛΗ	22.1	20.0	21.4
31	ΧΡΥΣ/ΠΟΛΗ	27.3	24.6	26.6
	Mean value	**27.6**	**25.0**	**26.7**

Comparison of three probability distributions

Wind map for Greece (cont’d):

Given also that the estimated parameter values depend on the method used for their evaluation, the three most common estimation methods were applied, namely :

- Method of moments,
- Least square method
- Maximum likelihood method.

As it may be seen form the table presented in the next slide, the least square method gives greater velocities in average, the method of moments gives smaller values, while the maximum likelihood method median values

Wind map for Greece (cont'd):

A/A	Station	Characteristic wind value (m/s)		
		Method of moments	Least Square Method (LMS)	Maximum likelihood method
1	ΑΓΡΙΝΙΟ	23.2	24.4	24.1
2	ΑΓΧΙΑΛΟΣ	26.6	27.8	26.5
3	ΑΛΕΧ/ΠΟΛΗ	30.4	32.2	33.4
4	ΑΝΔΡΑΒΙΔΑ	22.7	23.6	23.6
5	ΑΡΑΞΟΣ	22.9	24.1	22.4
6	ΑΡΓΟΣΤΟΛΙ	28.3	30.0	29.1
7	ΕΛΕΥΣΙΝΑ	25.0	26.3	25.0
8	ΕΛΛΗΝΙΚΟ	25.2	26.3	26.8
9	ΗΡΑΚΛΕΙΟ	27.0	27.9	26.9
10	ΘΗΡΑ	29.0	30.3	29.5
11	ΙΩΑΝΝΙΝΑ	31.4	32.9	30.3
12	ΚΑΛΑΜΑΤΑ	23.6	24.6	24.7
13	ΚΕΡΚΥΡΑ	30.4	31.8	32.6
14	ΚΟΖΑΝΗ	28.7	30.0	28.2
15	ΚΥΘΗΡΑ	35.2	36.6	38.2
16	ΛΑΜΙΑ	20.7	21.7	21.7
17	ΛΑΡΙΣΑ	21.6	22.5	22.2
18	ΛΗΜΝΟΣ	29.5	31.1	29.0
19	ΜΕΘΩΝΗ	28.7	30.1	30.5
20	ΜΙΚΡΑ	34.0	36.0	32.7
21	ΝΑΞΟΣ	33.9	34.8	33.8
22	ΠΥΡΓΕΛΑ	19.8	21.9	18.9
23	ΠΥΡΓΟΣ	29.2	32.6	33.9
24	ΡΟΔΟΣ	32.1	33.8	33.9
25	ΣΑΜΟΣ	31.5	34.0	32.4
26	ΣΟΥΔΑ	29.3	30.9	29.2
27	ΣΚΥΡΟΣ	35.7	37.2	37.9
28	ΤΑΝΑΓΡΑ	21.4	22.4	21.5
29	ΤΑΤΟΙ	28.4	29.6	29.5
30	ΤΡΙΠΟΛΗ	22.1	23.1	21.8
31	ΧΡΥΣ/ΠΟΛΗ	27.3	30.8	25.1
	Mean value	**27.6**	**29.1**	**28.2**

Comparison of three estimation methods

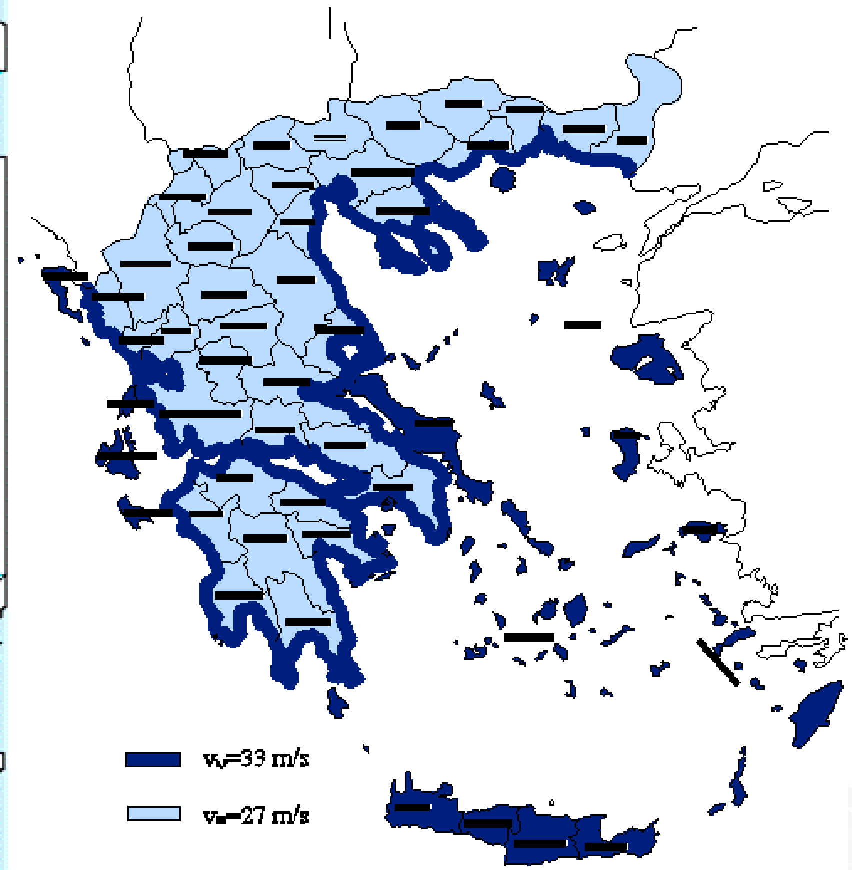
Wind map for Greece (cont'd):

The station network was not dense enough, so as to enable the calculation of the characteristic wind velocity in each region. Therefore the iso-values shown in the map in the left part of the next slide were only drawn.

This resulted in adopting only two zones (continental country and coastal areas & islands) with quite high values for the fundamental value of the basic wind velocity $v_{b,0}$ (see map in the right part of the next slide). As coastal area is considered an inland zone up to 10 km from shore.

It is to note that during the ENV phase these values where even higher by 3 m/s, i.e. 30 m/s and 36 m/s, respectively for the continent and the coast/the islands.

Wind map for Greece (cont’d):



Thermal actions (temperature) maps for Greece:

The data have been collected from 44 temperature measurement stations in Greece with a satisfactory geographical distribution.

As for snow, a Gumbel distribution has been assumed for the yearly extreme (maximum and minimum) temperatures. Initially three methods have been used for the assessment of site and scaling parameters, namely : method of least squares, method of moments and method of highest likelihood. As the differences of the results obtained where not significant, the least squares method (LSM) has been selected for the evaluation of the parameters. Subsequently the characteristic values of maximum and minimum temperatures have been established for a return period of 50 years.

Thermal actions (temperature) maps for Greece (cont'd):

Maximum and minimum shade air temperatures for Greece (at sea level and for a 50 years return period)

Χαρακτηριστικές θερμοκρασίες για χρήση στον Ευρωκώδικα 1 (πρωτογενή στοιχεία από ΕΜΥ)						μέθοδος ελαχίστων τετραγώνων										
						ΜΕΓΙΣΤΕΣ ΘΕΡΜΟΚΡΑΣΙΕΣ					ΕΛΑΧΙΣΤΕΣ ΘΕΡΜΟΚΡΑΣΙΕΣ					
α/α	**ΚΩΔΙΚΟΣ ΣΤΑΘΜΟΥ**	**ΣΤΑΘΜΟΣ**	**ΥΨΟΜΕΤΡΟ (m)**	**ΕΤΗ ΠΑΡΑΤΗΡΗΣΕΩΝ**	**ΠΛΗΘΟΣ ΕΤΩΝ**	$m_{t,max}$	$\sigma_{t,max}$	$maxt_{max}$	$mint_{max}$	$t_{0max,50}$	$m_{t,min}$	$\sigma_{t,min}$	$maxt_{min}$	$mint_{min}$	$t_{0min,50}$
1	672	ΑΓΡΙΝΙΟ	25	1956-1997	42	39,3	2,1	44,8	34,5	**45,8**	-4,5	1,7	0,8	-7,8	**-9,4**
2	665	ΑΓΧΙΑΛΟΣ	15	1956-1997	42	39,1	2,8	46,2	34,6	**47,5**	-5,0	1,9	-2,0	-9,8	**-10,6**
3	627	ΑΛΕΞ/ΠΟΛΗ	3	1951-1997	47	39,3	1,5	39,0	32,4	**39,9**	-8,8	2,6	-4,6	-14,0	**-16,4**
4	682	ΑΝΔΡΑΒΙΔΑ	15	1959-1997	39	36,3	1,6	39,8	32,2	**41,3**	-2,7	1,2	0,2	-5,0	**-6,2**
5	687	ΑΡΑΞΟΣ	12	1955-1997	43	37,2	1,9	41,2	33,8	**42,9**	-1,6	1,3	1,0	-3,8	**-5,5**
6	685	ΑΡΓΟΣΤΟΛΙ	22	1970-1997	28	35,2	2,3	40,6	30,8	**42,3**	2,2	1,2	4,8	-0,4	**-1,4**
7	607	ΔΡΑΜΑ	104	1975-1997	22	37,5	1,8	41,6	34,0	**44,1**	-7,4	2,5	-3,4	-13,8	**-14,7**
8	718	ΕΛΕΥΣΙΝΑ	31	1958-1997	40	39,9	2,7	48,0	35,0	**48,0**	-1,8	1,5	1,5	-5,0	**-6,1**
9	716	ΕΛΛΗΝΙΚΟ	15	1955-1998	44	37,3	2,1	42,0	32,6	**43,6**	-0,4	1,3	2,2	-3,2	**-4,3**
10	719	ΖΑΚΥΝΘΟΣ	8	1982-1997	16	37,4	2,3	42,2	34,4	**45,0**	-0,7	1,5	1,8	-4,0	**-5,9**
11	754	ΗΡΑΚΛΕΙΟ	39	1955-1998	44	37,6	2,2	43,6	33,0	**44,3**	3,0	1,2	5,8	0,2	**-0,5**
12	744	ΘΗΡΑ	37	1974-1997	24	34,9	2,1	39,4	30,2	**41,9**	2,5	2,1	6,0	-2,0	**-4,0**
13	756	ΙΕΡΑΠΕΤΡΑ	10	1956-1997	42	38,9	2,1	44,0	34,0	**45,2**	2,8	1,3	5,0	0,0	**-1,1**
14	642	ΙΩΑΝΝΙΝΑ	484	1956-1997	42	37,0	2,4	42,4	29,6	**47,5**	-8,4	1,8	-4,8	-13,0	**-10,8**
15	625	ΚΑΒΑΛΑ	65	1956-1984	29	34,7	1,4	38,1	31,5	**39,6**	-9,8	4,7	-4,2	-23,6	**-24,4**
16	726	ΚΑΛΑΜΑΤΑ	11	1956-1997	42	38,2	2,2	42,6	32,4	**45,0**	-1,6	1,6	1,6	-5,0	**-6,3**
17	614	ΚΑΣΤΟΡΙΑ	661	1980-1997	18	36,6	2,3	41,6	33,4	**48,6**	-13,6	4,0	-9,4	-22,4	**-22,6**
18	641	ΚΕΡΚΥΡΑ	4	1955-1997	43	36,5	2,1	42,4	32,4	**42,6**	-2,5	1,2	0,0	-4,6	**-6,1**
19	743	ΚΥΘΗΡΑ	167	1955-1997	43	36,0	2,4	41,0	31,2	**44,3**	-2,5	1,9	6,0	-4,3	**-2,5**
20	742	ΚΩΣ	129	1981-1997	17	36,5	1,3	39,0	34,4	**41,8**	1,7	1,6	4,2	-1,2	**-2,9**
21	650	ΛΗΜΝΟΣ	5	1974-1997	24	33,8	1,7	39,4	30,8	**39,4**	-3,2	1,4	-0,2	-6,0	**-7,7**
22	675	ΛΑΜΙΑ	17	1970-1997	28	40,2	2,1	46,5	37,6	**46,9**	-3,8	2,0	-0,2	-7,0	**-10,0**
23	648	ΛΑΡΙΣΑ	74	1955-1997	43	40,7	2,2	45,2	35,4	**47,9**	-8,9	3,3	-4,6	-21,6	**-18,6**
24	734	ΜΕΘΩΝΗ	52	1956-1997	42	35,0	2,4	41,0	30,8	**42,6**	0,4	0,4	3,2	-3,6	**-3,9**
25	738	ΜΗΛΟΣ	165	1955-1997	27	37,1	2,2	41,6	31,0	**44,8**	1,7	1,9	5,8	-2,0	**-2,9**
26	622	ΜΙΚΡΑ	5	1959-1997	39	37,4	2,0	42,0	34,0	**43,5**	-7,6	2,4	-3,8	-14,0	**-14,6**
27	667	ΜΥΤΙΛΗΝΗ	5	1955-1997	43	37,1	1,6	40,4	34,2	**42,0**	-0,8	1,8	3,2	-4,4	**-6,1**
28	701	Ν.ΦΙΛΑΔΕΛΦΕΙΑ	138	1955-1998	44	40,0	2,5	45,0	34,5	**48,3**	-2,2	1,6	0,6	-5,8	**-6,1**
29	732	ΝΑΞΟΣ	10	1955-1997	43	33,6	1,7	37,4	28,8	**38,9**	2,6	1,6	5,6	-1,0	**-1,9**
30	689	ΠΑΤΡΑ	1	1955-1997	43	36,9	1,8	41,3	33,0	**42,3**	-1,1	1,6	2,2	-4,5	**-6,0**
31	643	ΠΡΕΒΕΖΑ	4	1971-1997	27	35,1	1,4	37,4	31,8	**39,8**	0,1	1,5	3,0	-3,6	**-4,6**
32	724	ΠΥΡΓΕΛΑ	11	1980-1997	18	40,1	1,7	43,2	37,6	**45,9**	-4,4	0,9	-3,0	-6,0	**-7,4**
33	749	ΡΟΔΟΣ	12	1955-1997	43	36,0	2,1	42,0	32,8	**42,3**	2,0	2,5	7,6	-4,0	**-5,6**
34	723	ΣΑΜΟΣ	7	1978-1997	20	37,1	1,6	40,4	34,2	**42,0**	-0,5	1,3	1,6	-3,4	**-4,8**
35	606	ΣΕΡΡΕΣ	35	1971-1997	27	38,4	2,0	42,8	35,0	**44,8**	-8,7	3,0	-5,2	-17,6	**-18,0**
36	757	ΣΗΤΕΙΑ	116	1960-1997	38	36,1	1,8	40,6	32,2	**42,4**	3,1	1,5	6,0	0,5	**-0,6**
37	684	ΣΚΥΡΟΣ	18	1955-1997	43	35,2	2,4	42,5	31,6	**42,4**	0,5	1,6	4,0	-3,6	**-4,1**
38	746	ΣΟΥΔΑ	152	1958-1997	40	38,8	1,8	44,5	35,5	**45,2**	1,8	1,4	4,8	0,0	**-1,5**
39	699	ΤΑΝΑΓΡΑ	140	1957-1997	41	39,9	2,3	46,0	35,2	**47,6**	-5,3	2,9	-1,4	-16,6	**-13,1**
40	715	ΤΑΤΟΙ	235	1956-1997	42	39,2	2,5	48,0	35,0	**48,0**	-4,4	2,0	-0,6	-8,8	**-8,6**
41	710	ΤΡΙΠΟΛΗ	652	1957-1997	41	37,9	2,2	43,0	32,8	**48,9**	-8,6	3,1	-4,6	-17,0	**-13,5**
42	613	ΦΛΩΡΙΝΑ	695	1961-1997	37	36,1	2,1	40,8	31,4	**46,9**	-14,9	-14,9	-7,4	-21,4	**-21,2**
43	706	ΧΙΟΣ	4	1973-1997	25	35,9	1,9	40,6	32,0	**42,0**	-1,8	1,3	1,0	-4,0	**-6,0**
44	624	ΧΡΥΣΟΥΠΟΛΗ	5	1984-1997	14	35,0	1,6	39,0	33,0	**40,7**	-6,6	1,9	-3,4	-11,0	**-13,2**
							min:	37,4	28,8	**38,9**		min:	-9,4	-23,6	**-24,4**
							max:	48,0	37,6	**48,9**		max:	7,6	0,5	**-0,5**

ΥΠΟΜΝΗΜΑ:
t_{max} μέγιστες θερμοκρασίες
t_{min} ελάχιστες θερμοκρασίες
m μέση τιμή
σ τυπική απόκλιση
t_{50} χαρακτηριστική τιμή με μέση περίοδο επαναφοράς 50 έτη (=πιθανότητα υπέρβασης 2% κάθε έτος)
$t_{0,50}$ η χαρακτηριστική τιμή ανηγμένη στην στάθμη της θάλασσας(αναγωγή με χρήση της κατακόρυφης θερμοβαθμίδας=0,65° C μείωση θερμοκρασίας ανά 100m αύξησης του υψομέτρου)

Thermal actions (temperature) maps for Greece (cont'd):

Initially isotherm curves have been drawn, naturally following the correction required in order to obtain values at sea level (with a vertical temperature grade of $0,65^{o}$/100m). The number of years of measurements in each station have also been considered as appropriate. The results are summarised in the table presented in the next slide.

The maximum temperatures vary between appr. 39^{o} and 48^{o} and the isotherm curve of 45^{o} covers practically most of the area of the continental part of the country. This is a reason for selecting only one or two zones.

Thermal actions (temperature) maps for Greece (cont’d):

As far as the minimum temperatures are concerned there is a clear variation form north to south. In most cases minimum temperatures vary between appr. -5^{o} and -20^{o}

A four zone approach associated to the division of administrative regions has been considered as the most sensible choice.

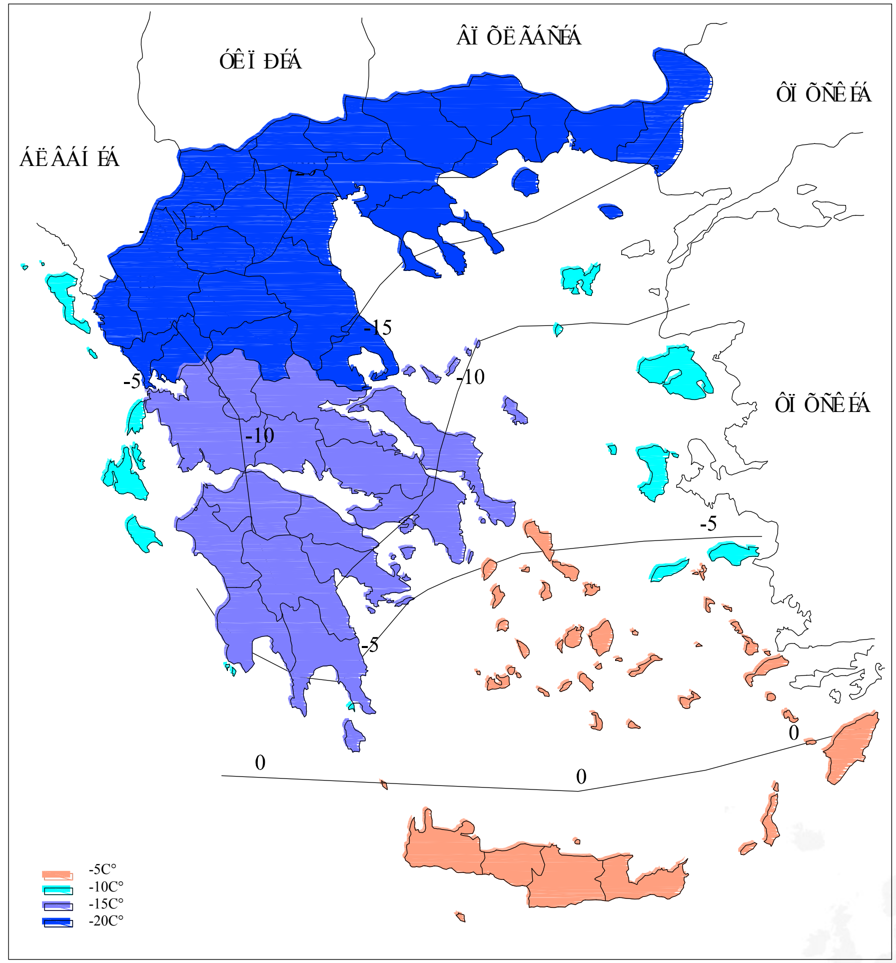
Taken into account some inaccuracy and other inconvenaiants of isotherm curve drawing, the use of maps with zoning has been considered more appropriate and has been adopted.

Thermal actions (temperature) maps for Greece (cont'd):

Maximum shade air temperatures for Greece

Thermal actions (temperature) maps for Greece (cont'd):

Minimum shade air temperatures for Greece



Future challenges

Climate change impact ? *Some fundamental questions :*

- Is there (adequate) evidence of climate change (more specifically : increased variability of climatic actions) ?
- If yes, how this may be expressed ?
- ➢ Differentiation of return period ?
- ➢ Differentiation of extreme values ?
- ➢ Differentiation of statistical distribution ?
- ➢ Other direct or indirect impact on actions ?
- ➢ Or, eventually, considered only "on the material side", i.e. dimensioning /detailing the structure (without any modifications "on the action side")?
- ➢ Other practical (e.g. mitigation) measures?
- ➢ ???

Thank you for your attention!

See you in the next Balkan Workshop