

Supplementary materials for ‘Winter chill simulations combined with expert knowledge emphasize the vulnerability of temperate fruit orchards in the Mediterranean region’

Eduardo Fernandez^{1*}, Hajar Mojahid¹, Erica Fadón^{2,3}, Javier Rodrigo^{2,3}, David Ruiz⁴, Jose A. Egea⁴, Mehdi Ben Mimoun⁵, Ossama Kodad⁶, Adnane El Yaacoubi⁷, Mohamed Ghrab⁸, José Egea⁴, Haifa BenMoussa^{5,9}, Nadia Borgini⁵, Olfa Elloumi⁸ and Eike Luedeling¹

¹ Department of Horticultural Sciences, Institute of Crop Science and Resource Conservation (INRES), University of Bonn, 53121 Bonn, Germany

² Área de Ciencia Vegetal, Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Gobierno de Aragón, Avda. Montaña 930, 50059 Zaragoza, Spain

³ Instituto Agroalimentario de Aragón-IA2 (CITA-Universidad de Zaragoza), 50013 Zaragoza, Spain

⁴ Department of Plant Breeding, Fruit Breeding Group, CEBAS-CSIC, PO Box 164, Espinardo, 30100 Murcia, Spain

⁵ University of Carthage, Institut National Agronomique de Tunisie (INAT), Laboratory GREEN-TEAM (LR17AGR01), 43 avenue Charles Nicolle, 1082 Tunis, Tunisia

⁶ National School of Agriculture of Meknes (ENAM), Department of Arboriculture and Viticulture, PB. S/40, 50000 Meknes, Morocco

⁷ University Sultan Moulay Slimane, Higher School of Technology Khenifra, P.B. 170, Khenifra, Morocco

⁸ University of Sfax, Olive Institute, LR16IO01 & LR16IO02, BP 1087 Sfax 3000, Tunisia

⁹ University of Carthage, Higher School of Agriculture of Mograne, Department of Agricultural Production, Zaghouan, Tunisia

Introduction

In this document, we provide supplementary materials for the work ‘Winter chill simulations combined with expert knowledge emphasize the vulnerability of temperate fruit orchards in the Mediterranean region’ by Eduardo Fernandez and co-authors. The work is published in the journal Climatic Change under the doi: DOI. We conducted this study in collaboration with researchers from northern and southern Spain, Tunisia, Morocco and Germany under the umbrella of an international project (AdaMedOr) funded by the Partnership for Research and Innovation in the Mediterranean Area (PRIMA).

Compared to previous similar studies, we provide now an analysis that combines the spatial interpolation of winter chill accumulation in the Mediterranean region under future scenarios with expert’s knowledge regarding the impacts of climate change on temperate orchards as well as future concerns of farmers cultivating temperate species. Our approach allowed us to frame and contextualize the results of our chill estimations, potentially contributing to the development of management strategies to adapt Mediterranean orchards to future climate conditions.

We offer figures that were not included in the main manuscript, as well as pictures of observed impacts of global warming on the development of temperate trees in Mediterranean countries. In addition, we include information about the weather stations used for the analysis.

*Corresponding author: Eduardo Fernández (efernand@uni-bonn.de)

Weather stations used in the analysis

For this study, we used 387 weather stations as primary source of minimum and maximum records between 1974 and 2020. In the following table (Table S1), we provide the name, location (coordinates) and percentage of data complete for each weather station.

Table S1: Weather stations used as primary source of minimum and maximum records between 1974 and 2020 in the Mediterranean basin

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Kharga	Egypt	25.4	30.5	77.8	77.8
Luxor Intl	Egypt	25.7	32.7	93.3	93.4
Wejh	Saudi Arabia	26.2	36.5	94.5	94.5
Asyut Intl	Egypt	27.0	31.0	84.0	83.9
In Amenas	Algeria	28.1	9.6	93.0	93.0
Minya	Egypt	28.1	30.7	76.6	76.6
Baharia	Egypt	28.3	28.9	70.5	70.5
Tabuk	Saudi Arabia	28.4	36.6	96.0	96.0
Hon	Libya	29.1	15.9	70.2	70.2
Siwa	Egypt	29.2	25.5	72.2	72.3
Eilat	Israel	29.6	35.0	99.3	99.4
Al Jouf	Saudi Arabia	29.8	40.1	91.8	91.9
Cairo Intl	Egypt	30.1	31.4	99.7	99.7
Ghadames East	Libya	30.2	9.7	75.7	75.7
El Golea	Algeria	30.6	2.9	98.1	98.1
Arar	Saudi Arabia	30.9	41.1	93.0	93.1
Ouarzazate	Morocco	30.9	-6.9	98.1	98.1
Alexandria Intl	Egypt	31.2	29.9	95.6	95.6
Sirte	Libya	31.2	16.6	77.8	77.8
Port Said	Egypt	31.3	32.3	71.5	71.5
Menara	Morocco	31.6	-8.0	99.7	99.7
Bechar	Algeria	31.6	-2.3	98.9	98.9
Oued Irara	Algeria	31.7	6.1	95.6	95.7
Turaif	Saudi Arabia	31.7	38.7	97.2	97.2
El Borma	Tunisia	31.7	9.3	70.2	70.3
Moulay Ali Cherif	Morocco	31.9	-4.4	90.9	90.9
Marka Intl	Jordan	32.0	36.0	99.4	99.4
Ben Gurion	Israel	32.0	34.9	99.5	99.5
Benina Airport	Libya	32.1	20.3	86.9	86.9
Misurata	Libya	32.2	15.0	81.3	81.3
Safi	Morocco	32.3	-9.2	91.6	91.6
Remada	Tunisia	32.3	10.4	96.0	96.0
Beni-Mellal	Morocco	32.4	-6.4	93.2	93.3
Noumerat	Algeria	32.4	3.8	98.5	98.5
Zuara	Libya	32.6	12.1	78.8	78.8
Mohammed V	Morocco	33.4	-7.6	99.3	99.3
Damascus Intl	Syria	33.4	36.5	99.2	99.3
Guemar	Algeria	33.5	6.8	95.6	95.6
Anfa	Morocco	33.6	-7.7	97.7	97.7
El-Bayadh	Algeria	33.7	1.1	91.3	91.3
Zarzis	Tunisia	33.9	10.8	99.8	99.8
Gabes	Tunisia	33.9	10.1	99.5	99.4

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Bassatine	Morocco	33.9	-5.5	92.2	92.2
Saiss	Morocco	33.9	-5.0	93.9	93.9
Nefta	Tunisia	33.9	8.1	99.6	99.6
Sale	Morocco	34.1	-6.8	95.4	95.4
Taza	Morocco	34.2	-4.0	95.2	95.2
Gafsa	Tunisia	34.4	8.8	98.5	98.5
Akrotiri	Cyprus	34.6	33.0	99.5	99.5
Djelfa-Tletsi	Algeria	34.7	3.2	91.8	91.8
Thyna	Tunisia	34.7	10.7	99.4	99.4
Pafos Intl	Cyprus	34.7	32.5	99.5	99.5
Angads	Morocco	34.8	-1.9	98.6	98.6
Biskra	Algeria	34.8	5.7	97.4	97.4
Hama	Syria	35.1	36.8	90.9	90.9
Cherif El Idrissi	Morocco	35.2	-3.8	96.7	96.7
Melilla	Spain	35.3	-3.0	99.2	99.2
Nikos Kazantzakis	Greece	35.3	25.2	99.8	99.8
Cheikh Larbi Tebessi	Algeria	35.4	8.1	92.4	92.5
Lampedusa	Italy	35.5	12.6	98.7	98.7
Souda	Greece	35.5	24.1	98.7	98.7
Lattakia	Syria	35.5	35.8	90.8	90.7
Es Senia	Algeria	35.6	-0.6	99.4	99.4
Monastir-Skanes	Tunisia	35.7	10.8	99.5	99.5
Kairouan	Tunisia	35.7	10.1	99.5	99.5
Ibn Batouta	Morocco	35.7	-5.9	99.6	99.6
Luqa	Malta	35.9	14.5	99.8	99.8
Gibraltar	Gibraltar	36.2	-5.3	99.8	99.8
Kithira	Greece	36.3	23.0	96.1	96.1
Mohamed Boudiaf Intl	Algeria	36.3	6.6	99.7	99.7
Silifke	Turkey	36.4	33.9	95.4	95.4
Diagoras	Greece	36.4	28.1	99.8	99.8
Jendouba	Tunisia	36.5	8.8	99.1	99.1
Rota Naval Air Station	Spain	36.6	-6.3	99.8	99.8
Malaga	Spain	36.7	-4.5	99.8	99.8
Cozzo Spadaro	Italy	36.7	15.1	98.6	98.5
Houari Boumediene	Algeria	36.7	3.2	99.6	99.6
Soummam	Algeria	36.7	5.1	96.3	96.3
Milos	Greece	36.7	24.4	92.4	92.4
Jerez	Spain	36.7	-6.1	99.5	99.5
Pantelleria	Italy	36.8	12.0	99.3	99.3
Annaba	Algeria	36.8	7.8	99.4	99.4
Methoni	Greece	36.8	21.7	97.2	97.2
Almeria	Spain	36.8	-2.4	99.8	99.8
Kelibia	Tunisia	36.9	11.1	98.8	98.8
Carthage	Tunisia	36.9	10.2	99.8	99.8
Faro	Portugal	37.0	-8.0	99.7	99.8
Gela	Italy	37.1	14.2	96.4	96.4
Moron Ab	Spain	37.2	-5.6	97.5	97.6
Granada	Spain	37.2	-3.8	99.8	99.8
Mugla	Turkey	37.2	28.4	95.5	95.5
Sidi Ahmed Air Base	Tunisia	37.2	9.8	99.3	99.3
Catania-Sigonella	Italy	37.4	14.9	99.5	99.5

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Sevilla	Spain	37.4	-5.9	99.7	99.7
Catania Fontanarossa	Italy	37.5	15.1	99.8	99.8
Tripolis	Greece	37.5	22.4	97.8	97.8
Murcia San Javier	Spain	37.8	-0.8	99.7	99.7
Isparta	Turkey	37.8	30.6	97.4	97.4
Cordoba	Spain	37.8	-4.8	98.8	98.8
Athinai	Greece	37.9	23.7	94.8	94.8
Diyarbakir	Turkey	37.9	40.2	97.5	97.6
Trapani Birgi	Italy	37.9	12.5	99.8	99.8
Andravida	Greece	37.9	21.3	98.8	98.8
Alcantarilla	Spain	38.0	-1.2	96.2	96.2
Konya	Turkey	38.0	32.6	91.2	91.2
Elefsis	Greece	38.1	23.6	99.1	99.1
Reggio Calabria	Italy	38.1	15.7	95.8	95.8
Beja	Portugal	38.1	-7.9	96.5	96.5
Palermo	Italy	38.2	13.1	99.8	99.8
Messina	Italy	38.2	15.6	99.3	99.3
Alicante_2	Spain	38.3	-0.6	99.8	99.8
Erhac	Turkey	38.4	38.1	99.1	99.2
Van	Turkey	38.5	43.3	98.7	98.7
Cigli	Turkey	38.5	27.0	95.2	95.2
Elazig	Turkey	38.6	39.3	96.4	96.4
Usak	Turkey	38.7	29.4	97.3	97.3
Ustica Island	Italy	38.7	13.2	96.2	96.2
Afyon	Turkey	38.7	30.6	95.0	95.0
Erkilet	Turkey	38.8	35.5	97.6	97.6
Lisboa	Portugal	38.8	-9.1	99.6	99.6
Akhisar	Turkey	38.8	27.8	99.2	99.2
Ibiza	Spain	38.9	1.4	99.8	99.8
Lamia	Greece	38.9	22.4	93.7	93.7
Talavera La Real	Spain	38.9	-6.8	95.9	95.9
Aktio	Greece	38.9	20.8	98.5	98.5
Albacete	Spain	38.9	-1.9	99.3	99.3
Skiros	Greece	39.0	24.5	98.1	98.1
Ciudad Real	Spain	39.0	-3.9	97.8	97.8
Crotone	Italy	39.0	17.1	96.9	96.9
Mitilini	Greece	39.1	26.6	99.5	99.5
Elmas	Italy	39.3	9.1	99.8	99.8
Portalegre	Portugal	39.3	-7.4	96.1	96.1
Decimomannu	Italy	39.4	9.0	97.8	97.9
Caceres	Spain	39.5	-6.3	98.9	98.9
Valencia	Spain	39.5	-0.5	99.8	99.8
Palma De Mallorca	Spain	39.5	2.7	99.9	99.9
Ioannis Kapodistrias Intl	Greece	39.6	19.9	99.8	99.8
Balikesir	Turkey	39.6	27.9	99.6	99.6
Larisa	Greece	39.6	22.5	96.6	96.6
Erzincan	Turkey	39.7	39.5	96.4	96.5
Eskisehir	Turkey	39.8	30.6	99.7	99.7
Sivas	Turkey	39.8	36.9	97.2	97.2
Santa Maria Di Leuc	Italy	39.8	18.4	98.8	98.8
Menorca	Spain	39.9	4.2	99.8	99.8

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Cape Bellavista	Italy	39.9	9.7	96.8	96.8
Etimesgut	Turkey	40.0	32.7	96.3	96.3
Erzurum	Turkey	40.0	41.2	97.1	97.1
Cape Palinuro	Italy	40.0	15.3	98.5	98.5
Esenboga	Turkey	40.1	33.0	97.6	97.6
Canakkale	Turkey	40.1	26.4	99.2	99.2
Bursa	Turkey	40.2	29.1	99.4	99.4
Lecce	Italy	40.2	18.1	97.6	97.6
Getafe	Spain	40.3	-3.7	97.6	97.6
Bandirma	Turkey	40.3	28.0	97.4	97.4
Cuatro Vientos	Spain	40.4	-3.8	92.7	92.8
Marina Di Ginoza	Italy	40.4	16.9	98.2	98.2
Barajas	Spain	40.5	-3.6	99.9	99.8
Torrejon	Spain	40.5	-3.4	91.3	91.3
Grottaglie	Italy	40.5	17.4	95.6	95.6
Makedonia	Greece	40.5	23.0	97.6	97.6
Alghero	Italy	40.6	8.3	99.4	99.4
Casale	Italy	40.7	17.9	99.8	99.8
Gioia Del Colle	Italy	40.8	16.9	97.2	97.2
Tortosa	Spain	40.8	0.5	93.9	94.0
Merzifon	Turkey	40.8	35.5	98.7	98.7
Dimokritos	Greece	40.9	26.0	99.6	99.6
Olbia Costa Smeralda	Italy	40.9	9.5	95.5	95.5
Ponza Island	Italy	40.9	12.9	99.2	99.2
Salamanca	Spain	41.0	-5.5	99.4	99.4
Ataturk	Turkey	41.0	28.8	99.8	99.8
Tekirdag	Turkey	41.0	27.6	99.0	99.0
Trabzon	Turkey	41.0	39.8	97.3	97.3
Bitola	North Macedonia	41.0	21.4	90.3	90.3
Grazzanise	Italy	41.1	14.1	94.2	94.2
Bari	Italy	41.1	16.8	99.8	99.8
Reus	Spain	41.1	1.2	99.0	99.0
Porto	Portugal	41.2	-8.7	99.8	99.8
Barcelona	Spain	41.3	2.1	99.9	99.9
Zonguldak	Turkey	41.5	31.8	97.1	97.2
Amendola	Italy	41.5	15.7	94.1	94.1
Latina	Italy	41.5	12.9	93.2	93.2
Sandanski	Bulgaria	41.5	23.3	97.4	97.4
Campobasso	Italy	41.6	14.7	96.8	96.8
Frosinone (It-Afb)	Italy	41.6	13.3	91.1	91.2
Valladolid	Spain	41.6	-4.8	99.0	99.0
Kurdjali	Bulgaria	41.6	25.4	97.7	97.7
Pratica Di Mare	Italy	41.7	12.4	98.2	98.2
Zaragoza Ab	Spain	41.7	-1.0	99.8	99.8
Edirne	Turkey	41.7	26.6	97.0	97.0
Valladolid_2	Spain	41.7	-4.9	98.3	98.3
Tbilisi - Lochini Airport	Georgia	41.8	44.8	92.4	92.4
Ciampino	Italy	41.8	12.6	99.7	99.7
Fiumicino	Italy	41.8	12.3	99.6	99.8
Braganca	Portugal	41.9	-6.7	99.6	99.6

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Girona	Spain	41.9	2.8	99.8	99.8
Campo Dell Oro	France	41.9	8.8	99.3	99.4
Urbe	Italy	42.0	12.5	93.8	93.8
Skopje	North Macedonia	42.0	21.6	99.7	99.7
Inebolu	Turkey	42.0	33.8	91.8	91.8
Sinop	Turkey	42.0	35.2	96.9	96.9
Plovdiv	Bulgaria	42.1	24.9	97.5	97.5
Mussala (Top-Sommet)	Bulgaria	42.2	23.6	95.7	95.7
Kriva Palanka	North Macedonia	42.2	22.3	90.3	90.3
Vigo	Spain	42.2	-8.6	99.8	99.8
Burgos	Spain	42.4	-3.6	93.4	93.5
Podgorica - Golubovci	Montenegro	42.4	19.2	98.5	98.5
Rieti	Italy	42.4	12.8	92.4	92.4
Viterbo	Italy	42.4	12.1	95.2	95.2
Pescara	Italy	42.4	14.2	99.5	99.5
Logrono-Agoncillo	Spain	42.5	-2.3	98.7	98.7
Poretta	France	42.6	9.5	97.4	97.5
Burgas	Bulgaria	42.6	27.5	97.7	97.7
Leon	Spain	42.6	-5.7	98.7	98.7
Sliven	Bulgaria	42.7	26.3	97.5	97.5
Rivesaltes	France	42.7	2.9	99.3	99.6
Pamplona	Spain	42.8	-1.6	98.4	98.4
Vitoria	Spain	42.9	-2.7	98.6	98.7
Santiago	Spain	42.9	-8.4	99.8	99.8
Antichan	France	43.0	1.1	99.0	99.0
Vladikavkaz	Russia	43.0	44.7	93.9	93.9
Perugia	Italy	43.1	12.5	99.2	99.2
Le Palyvestre	France	43.1	6.1	96.1	96.3
Lourdes	France	43.2	0.0	99.4	99.5
Salvaza	France	43.2	2.3	97.7	97.8
Varna	Bulgaria	43.2	27.8	97.7	97.7
San Sebastian-Igueldo	Spain	43.3	-2.0	97.8	97.8
Bilbao	Spain	43.3	-2.9	99.8	99.8
Oviedo	Spain	43.4	-5.9	99.3	99.3
San Sebastian	Spain	43.4	-1.8	99.7	99.7
La Coruna	Spain	43.4	-8.4	99.5	99.5
Pau Pyrenees	France	43.4	-0.4	99.6	99.7
Santander	Spain	43.4	-3.8	93.1	93.1
Provence	France	43.4	5.2	99.5	99.6
Sochi	Russia	43.5	40.0	97.3	97.3
Anglet	France	43.5	-1.5	99.5	99.6
Santander_2	Spain	43.5	-3.8	99.5	99.5
Asturias	Spain	43.6	-6.0	99.3	99.3
Mediterranee	France	43.6	4.0	99.6	99.7
Falconara	Italy	43.6	13.4	99.7	99.7
Blagnac	France	43.6	1.4	99.4	99.6
Cote D Azur	France	43.7	7.2	99.6	99.6
Pisa	Italy	43.7	10.4	99.8	99.8
Kraljevo	Serbia	43.7	20.7	95.8	95.8
Garons	France	43.8	4.4	97.4	97.6

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Firenze	Italy	43.8	11.2	99.8	99.8
Sarajevo	Bosnia & Herzegovina	43.8	18.3	97.7	97.7
Mont De Marsan	France	43.9	-0.5	97.2	97.4
Cape Mele	Italy	44.0	8.2	99.7	99.7
Rimini	Italy	44.0	12.6	97.7	97.7
Albenga	Italy	44.1	8.1	97.4	97.5
St-Auban-Sur-Duranc	France	44.1	6.0	96.7	96.7
Rosiorii De Vede	Romania	44.1	25.0	94.2	94.2
Millau	France	44.1	3.0	97.8	97.8
Caritat	France	44.1	4.9	95.8	96.0
La Garenne	France	44.2	0.6	99.4	99.5
Forli	Italy	44.2	12.1	95.2	95.2
Calarasi	Romania	44.2	27.4	97.6	97.6
Constanta	Romania	44.2	28.6	97.6	97.6
Cervia	Italy	44.2	12.3	98.5	98.6
Mineralnyye Vody	Russia	44.2	43.1	99.4	99.4
Negotin	Serbia	44.2	22.6	92.8	92.8
Craiova	Romania	44.3	23.9	97.6	97.6
Mihail Kogalniceanu	Romania	44.4	28.5	94.8	94.7
Genova Sestri	Italy	44.4	8.8	99.8	99.8
Cazaux	France	44.5	-1.1	96.4	96.6
Bologna	Italy	44.5	11.3	99.7	99.6
Loznicica	Serbia	44.5	19.2	97.1	97.1
Embrun	France	44.6	6.5	99.1	99.1
Montelimar-Ancone	France	44.6	4.7	97.2	97.2
Drobeta Turnu Severin	Romania	44.6	22.6	99.7	99.7
Simferopol'	Ukraine	44.7	34.1	99.7	99.7
Gourdon	France	44.8	1.4	99.2	99.2
Beograd	Serbia	44.8	20.3	99.8	99.8
Merignac	France	44.8	-0.7	99.5	99.7
Piacenza	Italy	44.9	9.7	96.5	96.5
Torino-Bric Croce	Italy	45.0	7.7	94.8	94.8
Krasnodar	Russia	45.0	39.1	99.7	99.7
Vrsac	Serbia	45.1	21.3	93.7	93.7
Buzau	Romania	45.1	26.8	99.7	99.7
Sulina	Romania	45.2	29.7	98.9	98.9
Torino Caselle	Italy	45.2	7.7	99.8	99.8
Rijeka	Croatia	45.2	14.6	91.5	91.5
Saint Geoirs	France	45.4	5.3	99.3	99.5
Villafranca	Italy	45.4	10.9	97.7	97.7
Kerch	Ukraine	45.4	36.4	99.7	99.7
Caransebes	Romania	45.4	22.3	99.7	99.7
Ghedi	Italy	45.4	10.3	94.3	94.3
Varfu Omu	Romania	45.5	25.4	99.3	99.3
Galati	Romania	45.5	28.0	99.7	99.7
Venezia Tessera	Italy	45.5	12.4	99.8	99.8
Chornomors'ke	Ukraine	45.5	32.7	99.6	99.6
Bouthéon	France	45.5	4.3	93.3	93.5
Bourg St-Maurice	France	45.6	6.8	99.2	99.2
Malpensa	Italy	45.6	8.7	99.8	99.8

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Aix Les Bains	France	45.6	5.9	96.0	96.2
Treviso	Italy	45.6	12.2	98.0	97.9
Trieste	Italy	45.6	13.8	95.1	95.1
Chateaubernard	France	45.7	-0.3	98.9	99.0
Bergamo Orio Al Serio	Italy	45.7	9.7	99.8	99.8
Istrana	Italy	45.7	12.1	99.8	99.8
Saint Exupery	France	45.7	5.1	96.6	96.6
Bron	France	45.7	4.9	97.7	97.9
Sibiu	Romania	45.8	24.1	97.3	97.3
Auvergne	France	45.8	3.2	97.3	97.5
Traian Vuia	Romania	45.8	21.3	96.7	96.8
Ronchi Dei Legionari	Italy	45.8	13.5	99.6	99.6
Tihoreck	Russia	45.9	40.1	90.1	90.1
Bellegarde	France	45.9	1.2	99.6	99.7
Deva	Romania	45.9	22.9	95.9	95.9
Divnoe	Russia	45.9	43.4	99.8	99.8
Pecs South	Hungary	46.0	18.2	99.8	99.8
Lugano	Switzerland	46.0	8.9	91.3	91.4
Aviano Ab	Italy	46.0	12.6	92.4	92.4
Primorsko-Ahtarsk	Russia	46.0	38.1	91.6	91.6
Chassiron	France	46.0	-1.4	96.7	96.7
Palic	Serbia	46.1	19.8	96.6	96.6
Locarno-Monti	Switzerland	46.2	8.8	98.6	98.6
Charmeil	France	46.2	3.4	95.5	95.5
Arad	Romania	46.2	21.3	99.8	99.8
Baja	Hungary	46.2	19.0	96.4	96.4
Sion	Switzerland	46.2	7.3	99.8	99.8
Geneva Cointrin	Switzerland	46.2	6.1	99.8	99.9
Szeged (Aut)	Hungary	46.2	20.1	99.8	99.8
Charnay	France	46.3	4.8	97.3	97.3
Miercurea Ciuc	Romania	46.4	25.7	92.4	92.3
Odesa Intl	Ukraine	46.4	30.7	98.4	98.4
Nagykanizsa	Hungary	46.5	17.0	99.7	99.7
Bolzano	Italy	46.5	11.3	96.3	96.3
Vidrasau	Romania	46.5	24.4	96.6	96.6
Tarvisio	Italy	46.5	13.6	94.2	94.2
Bacau	Romania	46.5	26.9	99.7	99.7
Jungfraujoch	Switzerland	46.5	8.0	97.8	97.7
Biard	France	46.6	0.3	99.5	99.6
Kherson	Ukraine	46.6	32.6	99.6	99.6
Klagenfurt(Civ-Mil)	Austria	46.6	14.3	97.7	97.7
Guetsch Ob Andermatt	Switzerland	46.6	8.6	99.4	99.4
Saint-Sauveur	France	46.7	-2.3	96.1	96.1
Dobbiaco	Italy	46.7	12.2	96.9	96.9
S. Valentino Alla Muta	Italy	46.8	10.5	96.4	96.4
Payerne	Switzerland	46.8	7.0	99.8	99.8
Lienz	Austria	46.8	12.8	94.0	94.0
Siofok	Hungary	46.9	18.0	99.4	99.4
Ceahlau Toaca	Romania	47.0	26.0	99.7	99.8
Chisinau	Moldova	47.0	29.0	99.3	99.3

Name	Country	Latitude (dec. degrees)	Longitude (dec. degrees)	Data complete Tmin (%)	Data complete Tmax (%)
Oradea	Romania	47.0	21.9	99.7	99.7
Mariupol'	Ukraine	47.0	37.5	99.1	99.0
Bourges	France	47.1	2.4	98.9	98.9
Szolnok	Hungary	47.1	20.2	99.8	99.8
Vaduz	Liechtenstein	47.1	9.5	99.5	99.5
Nantes Atlantique	France	47.2	-1.6	99.7	99.7
Iasi	Romania	47.2	27.6	97.1	97.1
Zeltweg	Austria	47.2	14.7	91.1	91.1
Patscherkofel	Austria	47.2	11.5	91.9	92.0
Saentis	Switzerland	47.2	9.3	98.9	98.9
Besancon-Thisse(Aut)	France	47.2	6.0	97.1	97.1
Innsbruck	Austria	47.3	11.3	97.7	97.7
Feldkirch	Austria	47.3	9.6	93.2	93.2
Longvic	France	47.3	5.1	97.5	97.7
Szombathely Arpt - Vas	Hungary	47.3	16.6	99.5	99.5
Belle Ile-Le Talut	France	47.3	-3.2	99.1	99.2
Montoir	France	47.3	-2.1	92.1	92.1
Zuerich-Fluntern	Switzerland	47.4	8.6	91.2	91.2
Val De Loire	France	47.4	0.7	97.5	97.5
Ferihegy	Hungary	47.4	19.3	99.7	99.7
Zurich	Switzerland	47.5	8.5	99.8	99.8
Beaucouze	France	47.5	-0.6	95.1	95.1
Debrecen	Hungary	47.5	21.6	99.7	99.8
Bregenz	Austria	47.5	9.8	94.5	94.6
Aigen-Ennstal (Mil)	Austria	47.5	14.1	97.6	97.6
Kufstein	Austria	47.6	12.2	98.7	98.7
Bale Mulhouse	France	47.6	7.5	99.7	99.7
Sopron	Hungary	47.7	16.6	96.8	96.8
Satu Mare	Romania	47.7	22.9	99.7	99.7
Gyor	Hungary	47.7	17.7	99.7	99.8
Botosani	Romania	47.7	26.6	99.8	99.8
Lann Bihoue	France	47.8	-3.4	99.6	99.6
Saint Sauveur	France	47.8	6.4	94.9	95.0
Salzburg	Austria	47.8	13.0	97.7	97.7
Feuerkogel	Austria	47.8	13.7	91.1	91.3
Liubashivka	Ukraine	47.9	30.3	96.1	96.1
Hurbanovo	Slovakia	47.9	18.2	99.7	99.7
Kekesteto	Hungary	47.9	20.0	96.5	96.5
Zaporizhzhia Intl	Ukraine	47.9	35.3	99.7	99.7
Arnage	France	47.9	0.2	95.0	95.1
Pluguffan	France	48.0	-4.2	91.2	91.2
Nyiregyhaza	Hungary	48.0	21.7	96.5	96.5
Bricy	France	48.0	1.8	99.0	99.1

Correction model

As mentioned in the main manuscript, we implemented a spatial interpolation and used a 3D model to correct for large errors originated after the initial Kriging. This 3D correction model (Fig. S1) consisted of the relation between the monthly minimum and maximum temperature in January (x- and y-axis, respectively) and the observed chill in each weather station. This allowed us identify the combination of temperature that was associated to a given amount of chill, which was later extracted from the temperature-interpolated map.

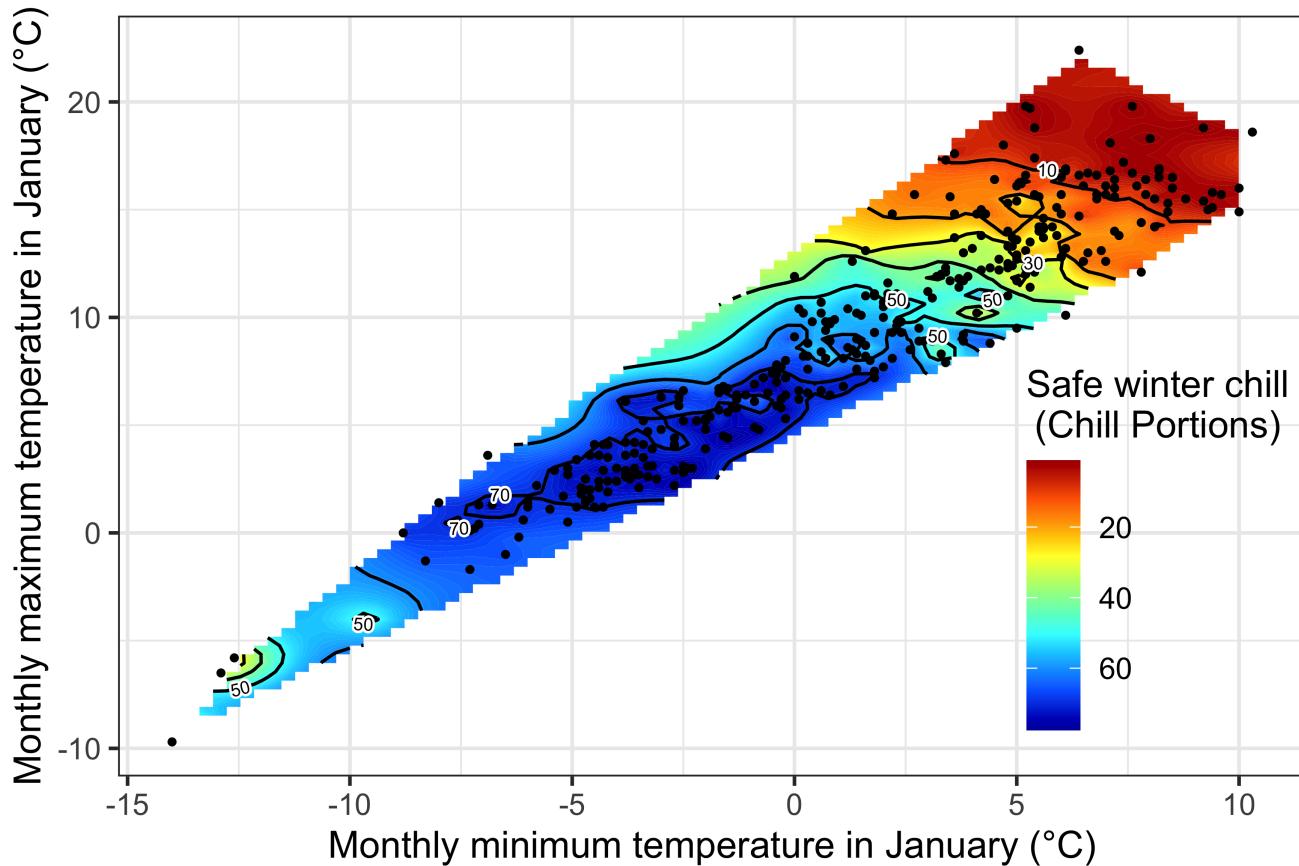


Figure S1: Three-dimensional model used to correct for the initial error generated by interpolating Safe Winter Chill only based on data from the weather stations. In the figure, we show the 3D correction model for the scenario 1975. Different relations were established for each of the many scenarios evaluated in this study

Additional figures

In the following figures, we show the expected change in Safe Winter Chill compared to the baseline period (median SWC between the historic simulated scenarios) for the pessimistic and optimistic climate model classes for the RCP4.5 and RCP8.5 scenario by 2050 and 2085. As expected, major chill losses will occur under the pessimistic version of the RCP8.5 scenario by 2085, whereas minor changes may be expected by the near future under the RCP4.5 scenario.

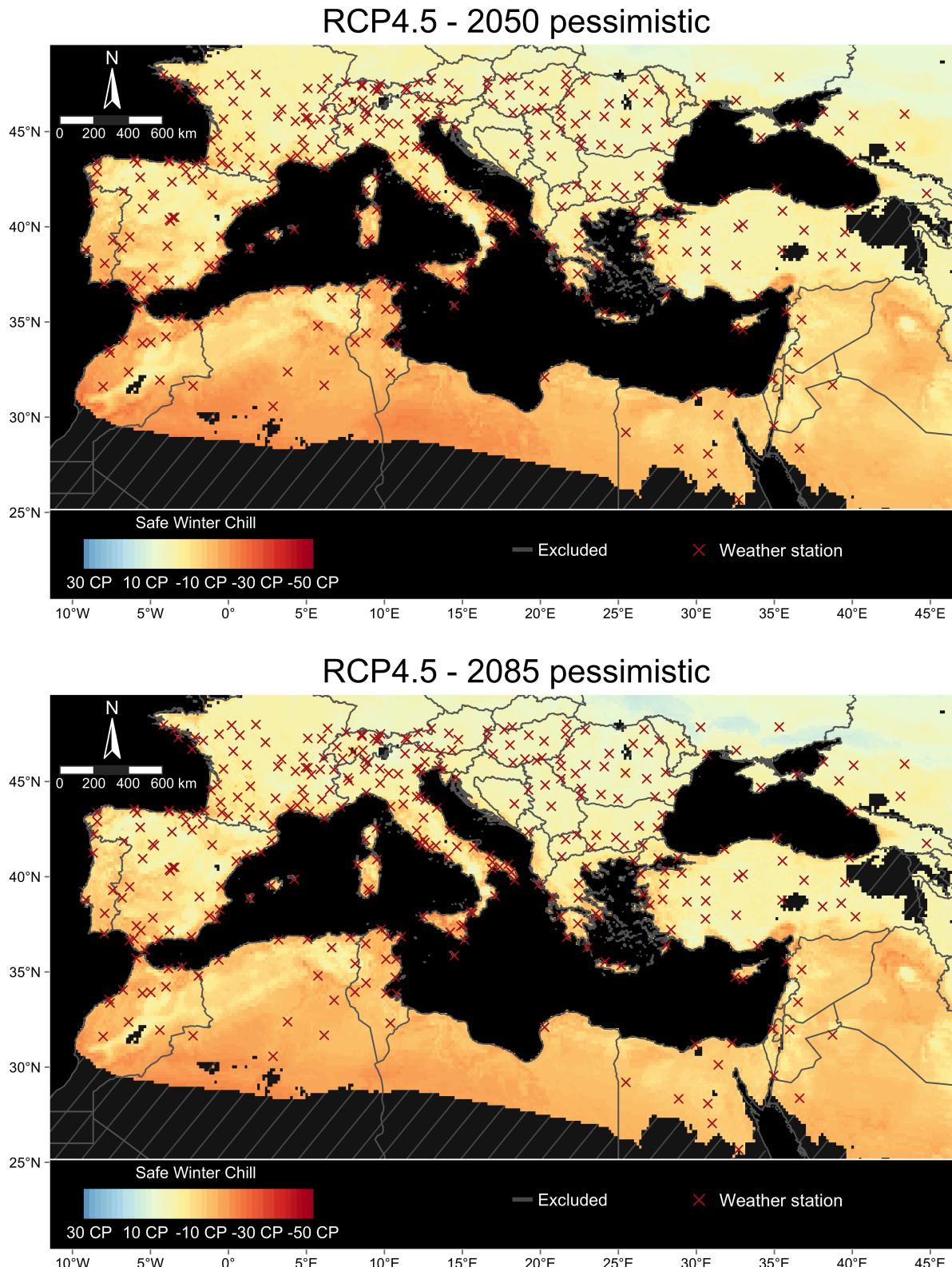


Figure S2: Estimation of Safe Winter Chill change for the Mediterranean region under the RCP4.5 scenario by two time horizons relative to historic simulated scenarios. In both panels, we show the difference in SWC between the respective combination of future scenario and year and the median across historic simulated scenarios between 1975 and 2019. For future scenarios, we used the results of the “pessimistic” climate model class (percentile 15th among 15 General Circulation Models). The grey hatched areas in the maps represent regions excluded from the 3D correction model. The red crosses represent the locations of the weather stations used in the analysis

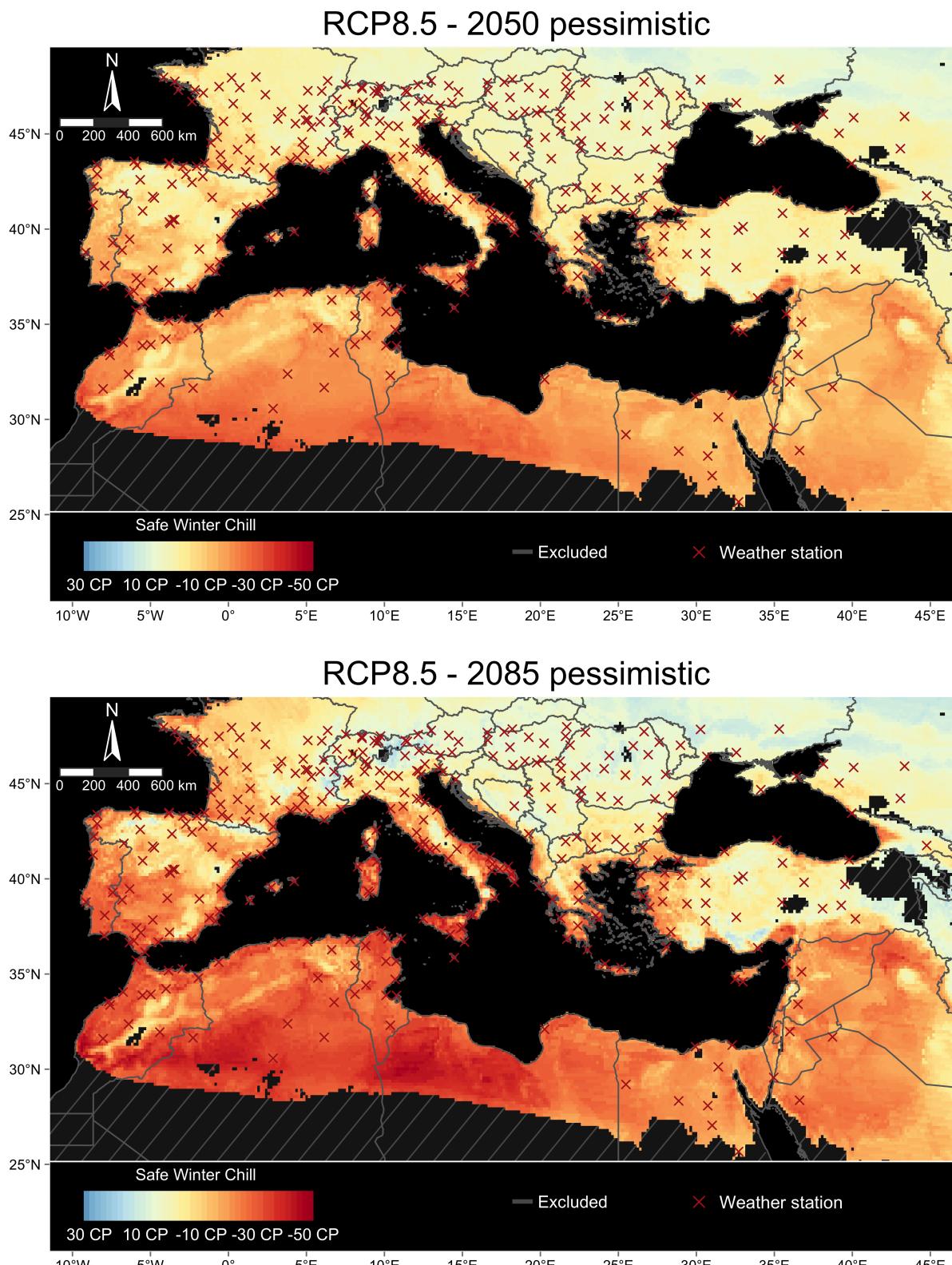


Figure S3: Estimation of Safe Winter Chill change for the Mediterranean region under the RCP8.5 scenario by two time horizons relative to historic simulated scenarios. In both panels, we show the difference in SWC between the respective combination of future scenario and year and the median across historic simulated scenarios between 1975 and 2019. For future scenarios, we used the results of the “pessimistic” climate model class (percentile 15th among 15 General Circulation Models). The grey hatched areas in the maps represent regions excluded from the 3D correction model. The red crosses represent the locations of the weather stations used in the analysis

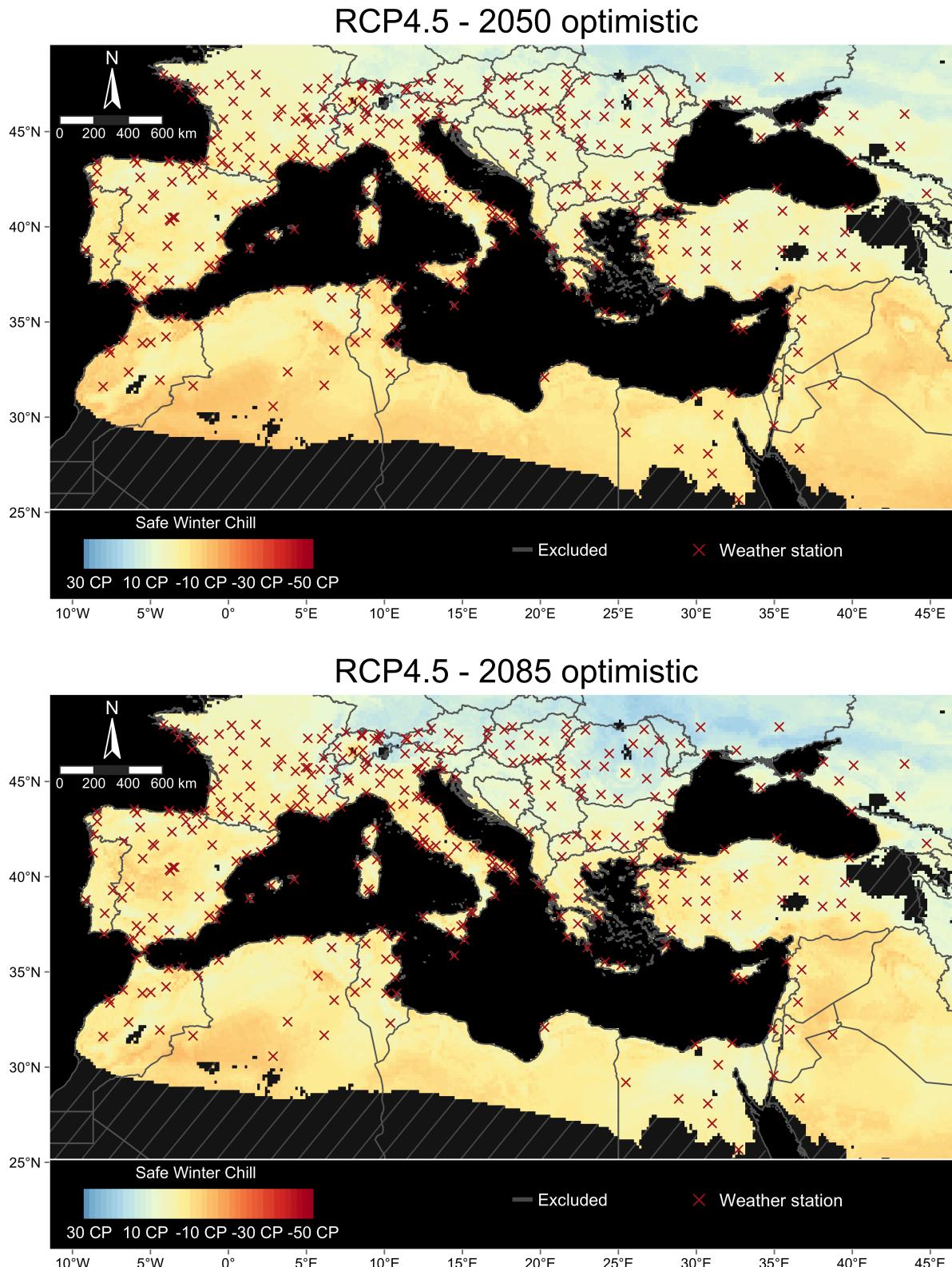
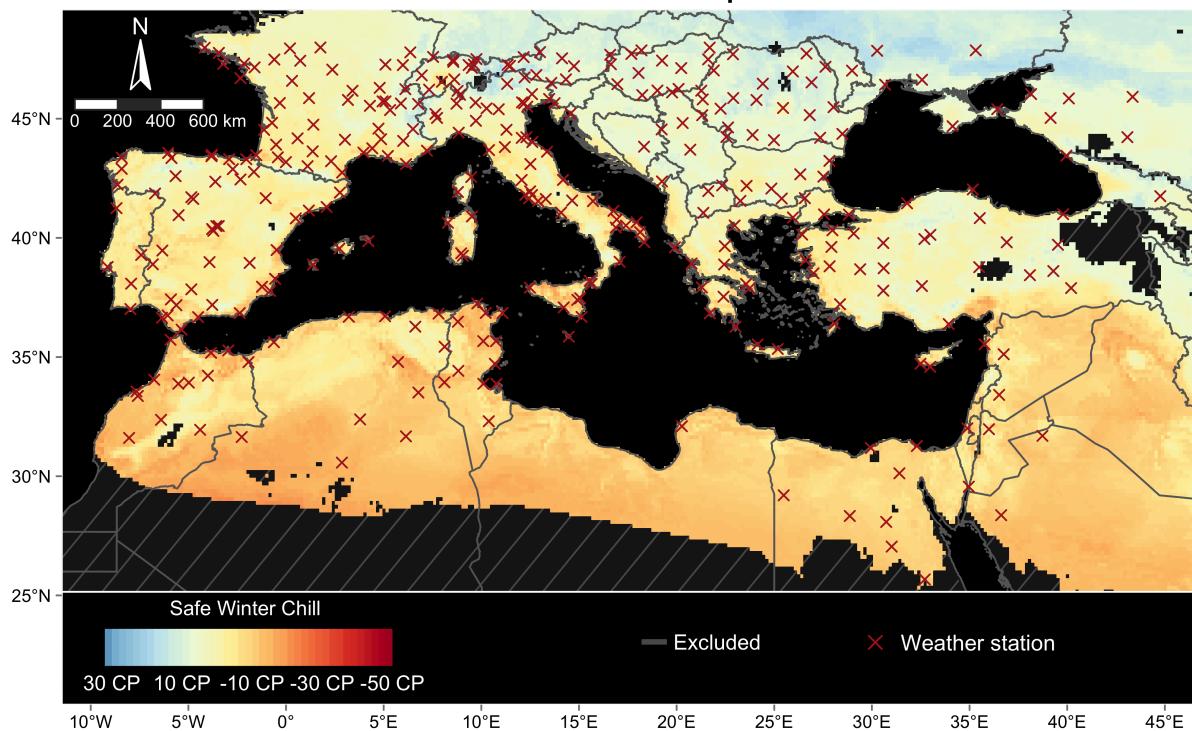


Figure S4: Estimation of Safe Winter Chill change for the Mediterranean region under the RCP4.5 scenario by two time horizons relative to historic simulated scenarios. In both panels, we show the difference in SWC between the respective combination of future scenario and year and the median across historic simulated scenarios between 1975 and 2019. For future scenarios, we used the results of the “optimistic” climate model class (percentile 85th among 15 General Circulation Models). The grey hatched areas in the maps represent regions excluded from the 3D correction model. The red crosses represent the locations of the weather stations used in the analysis

RCP8.5 - 2050 optimistic



RCP8.5 - 2085 optimistic

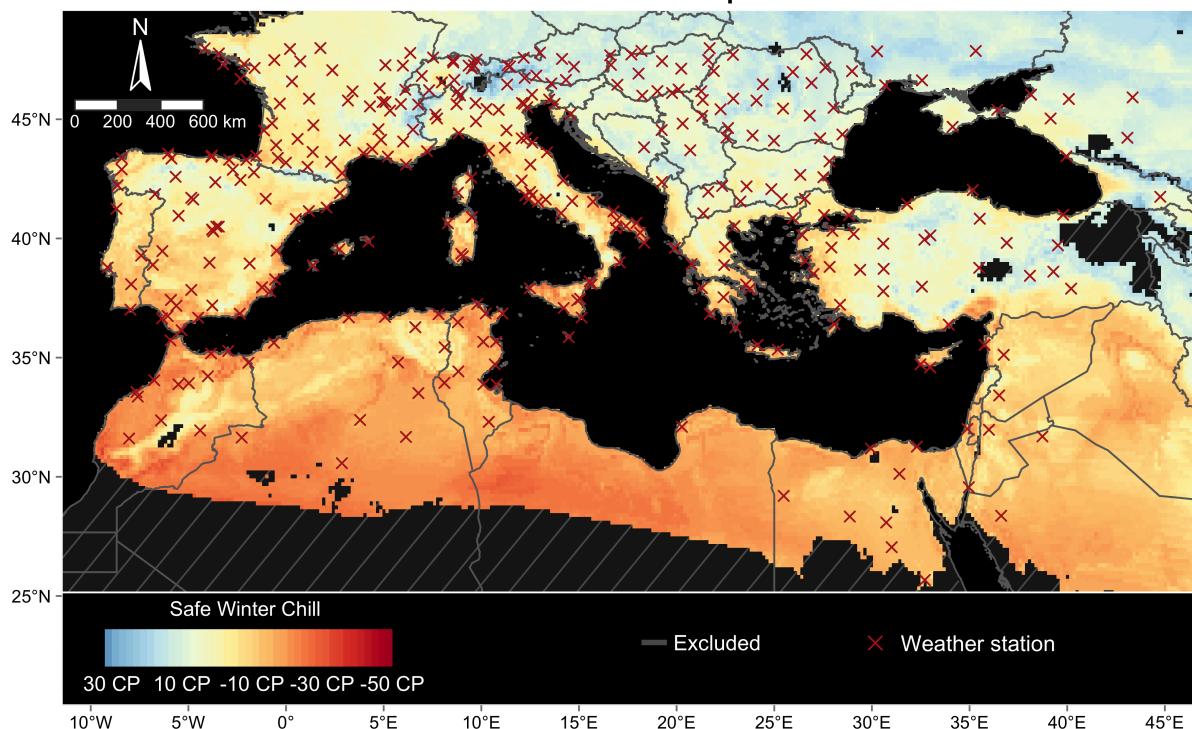


Figure S5: Estimation of Safe Winter Chill change for the Mediterranean region under the RCP8.5 scenario by two time horizons relative to historic simulated scenarios. In both panels, we show the difference in SWC between the respective combination of future scenario and year and the median across historic simulated scenarios between 1975 and 2019. For future scenarios, we used the results of the “optimistic” climate model class (percentile 85th among 15 General Circulation Models). The grey hatched areas in the maps represent regions excluded from the 3D correction model. The red crosses represent the locations of the weather stations used in the analysis