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EUROPEAN COMMISSION
Horizon 2020
EUROPEAN UNION FUNDING FOR RESEARCH & INNOVATION

Summer School 2017

Adverse Weather Conditions and Crop Production Risks

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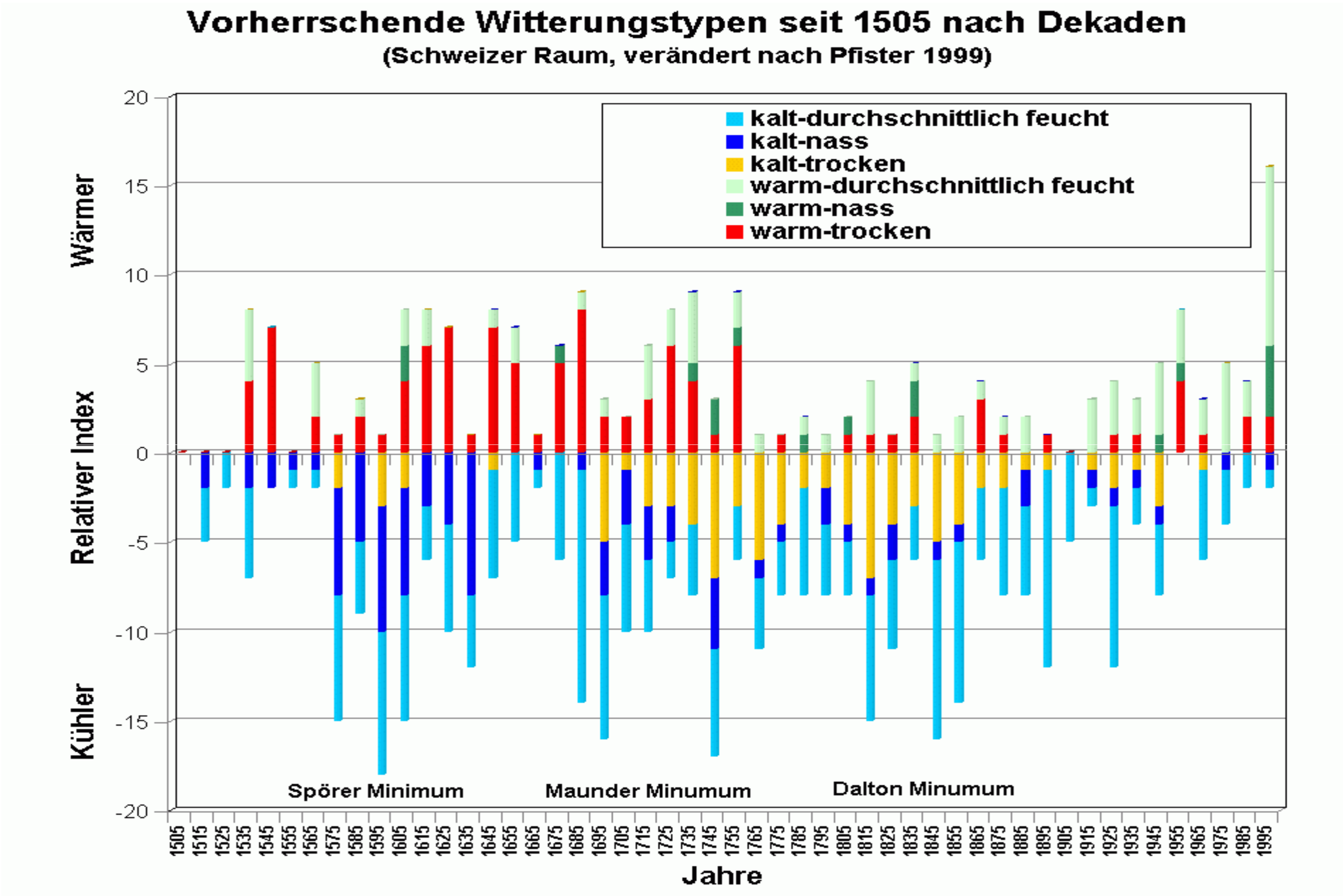
$A_gM_{net}^+$ INTERNATIONAL SUMMER SCHOOL IN AGROMETEOROLOGY AND CROP MODELLING 2017

Adverse Weather Impacts are result of climate variability

Observations

Historic climate variability– Central Europe



Reconstructed weather conditions 1505 till 1995 (after Pfister 1999)

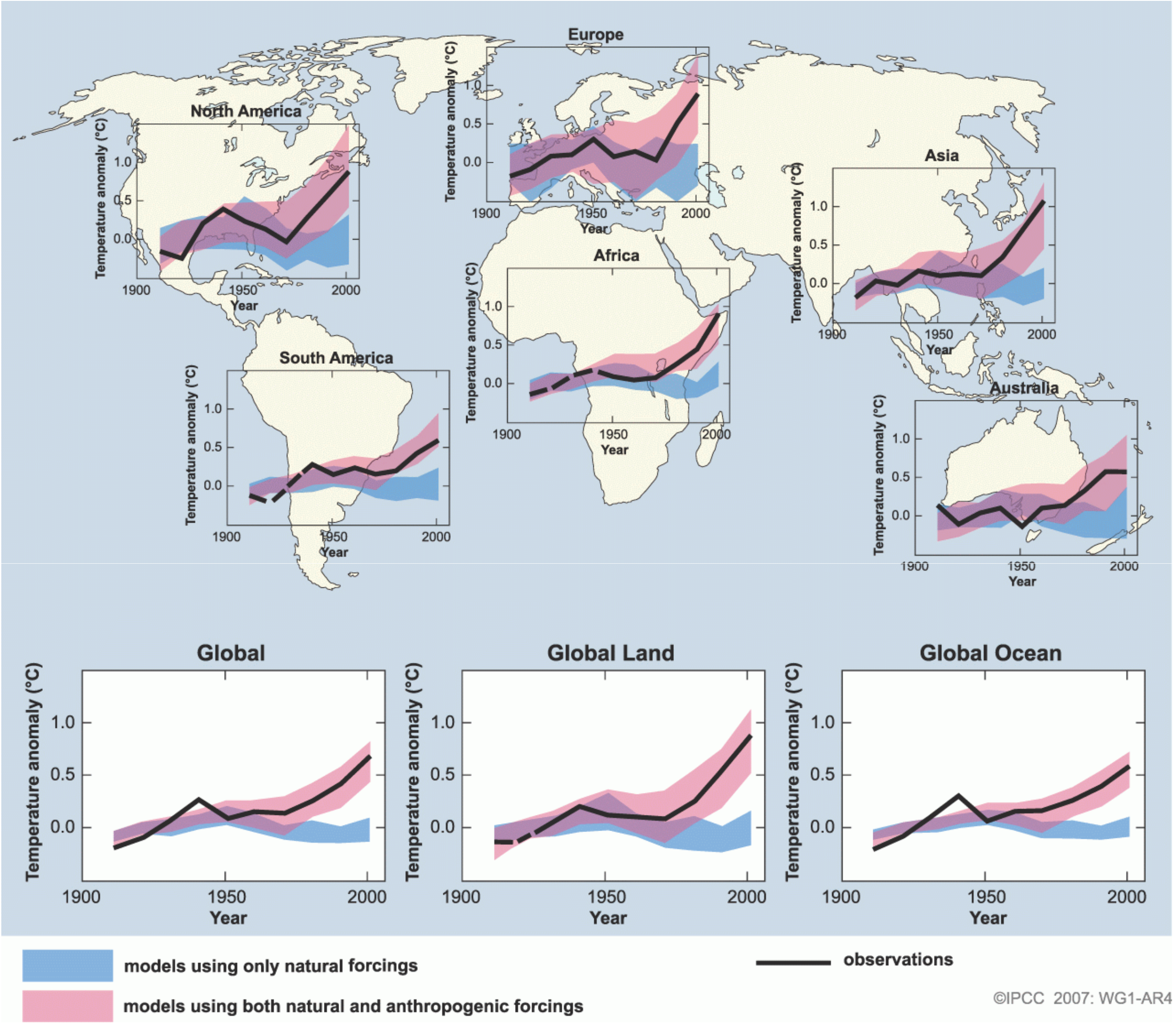
(Source: Eitzinger et al., 2009)

Climate variability in history – impact reports

1292	—	—	—	—	—	—	Sehr harter, schneereicher Winter.
1294	—	—	—	—	—	—	Sehr heißer Sommer, gutes Weinjahr.
1296	—	—	—	—	—	—	Sehr kalter Winter, häufige Ungewitter.
1297	—	—	—	—	—	—	Gutes Weinjahr.
1302	—	—	—	—	—	—	Sehr schlechter Wein, wie anno 1275.
1303	—	—	—	—	—	—	Sehr gutes Weinjahr.
1304	—	—	—	—	—	—	Sehr trockener Sommer, man konnte die Donau an vielen Stellen durchwaten.
1310	—	—	—	—	—	—	Sehr kalter Winter. Das Getreide verdarb gänzlich, die Käfer fraßen die Bäume und Weinstöcke ab.
1311	—	—	—	—	—	—	Sehr wenig, fast gar kein Wein wegen der Käfer.
1312	—	—	—	—	—	—	Regen und Hagel verwüstete Felder und Weingärten, Theuerung in Oesterreich.
1313	—	—	—	—	—	—	Fruchtbares Jahr, sehr guter Wein.
1316	—	—	—	—	—	—	Die seit drei Jahren anhaltende Hungersnoth erreichte den höchsten Grad; fast Alles verschmachtete. Allgemeine Seuchen, großes Sterben. Kein Wein.
1317	—	—	—	—	—	—	Harter Winter, unerhörter Mangel und Hunger. Gänzlicher Getreidemangel.
1321	—	—	—	—	—	—	Schlechtes Weinjahr.
1323	—	—	—	—	—	—	Der Frost am 24. Mai zerstörte Wein und Getreide.
1328	—	—	—	—	—	—	Wein von seltener Güte.
1332	—	—	—	—	—	—	Ein sehr fruchtbares Weinjahr, so daß man die Fässer zum Füllen nicht auftreiben konnte.
1335	—	—	—	—	—	—	Viel Regen, schlechte Ernte und Weinlese.
1338	—	—	—	—	—	—	Viele Heuschrecken.
1342	—	—	—	—	—	—	Heftige Stürme.
1343	—	—	—	—	—	—	Schlechtes Weinjahr.

Austrian source from 1292-1343 (after Puntschert 1894)

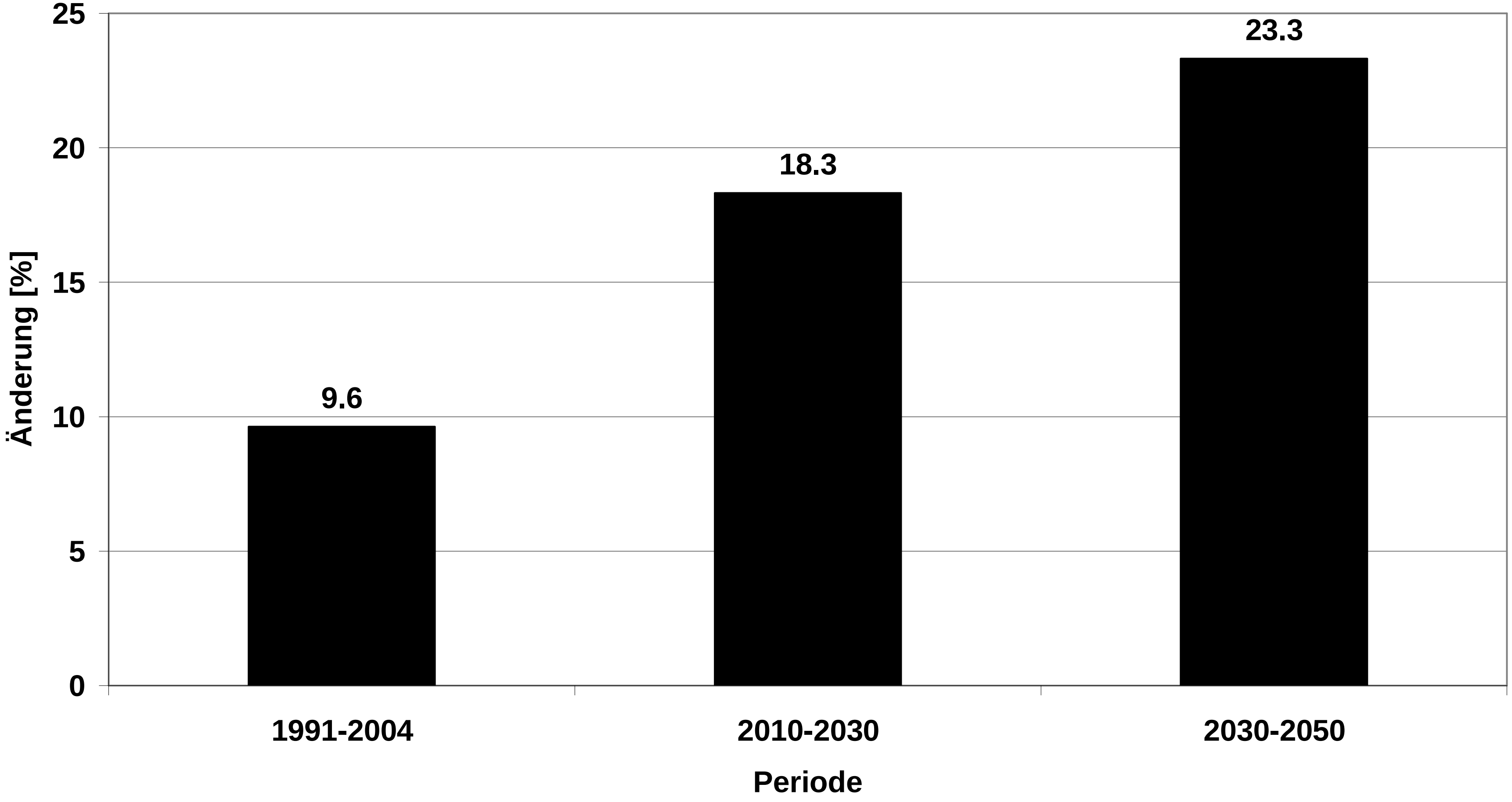
(Source: Eitzinger et al., 2009)



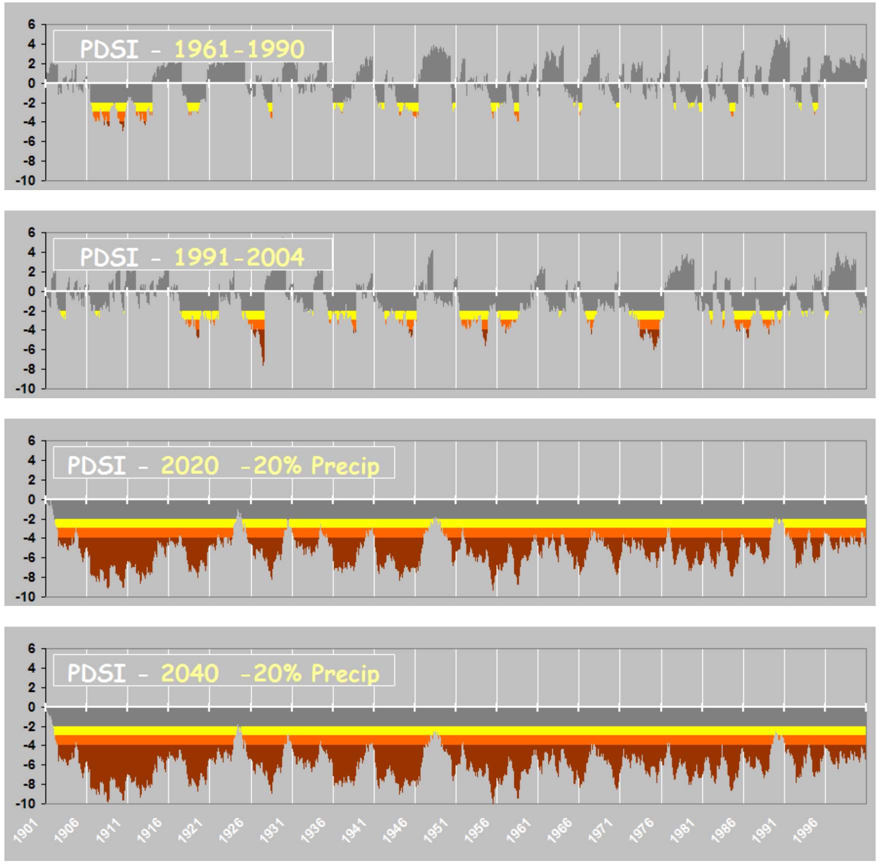
Der „anthropogen“ force of climate change

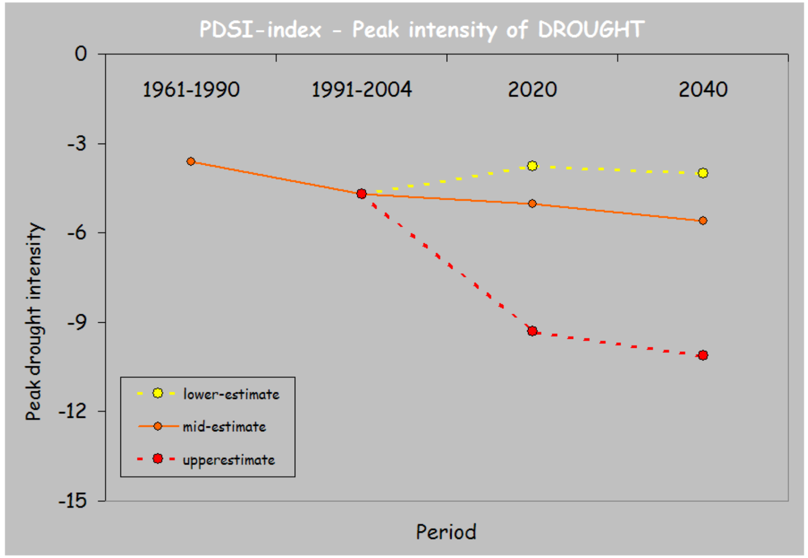
(Source: IPCC, 2001)

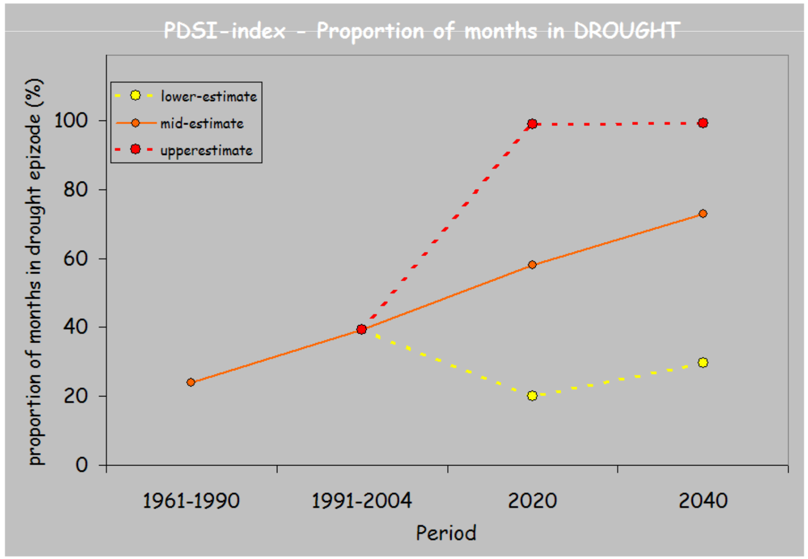
Forced potential evapotranspiration vs. 1961-1990 (eastern Austria)



(Eitzinger et al., 2009)

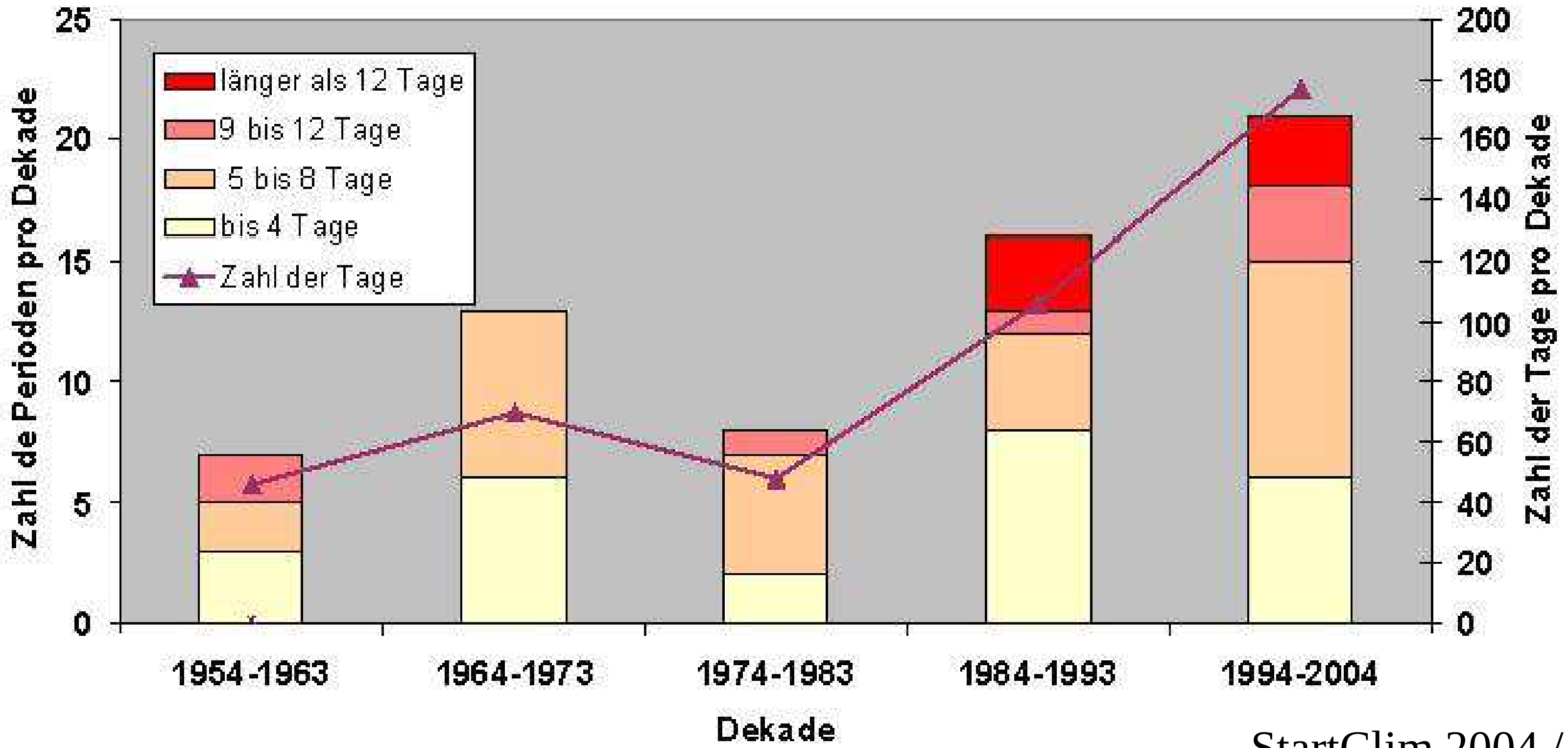






PDSI drought index
under precipitation scenarios eastern Austria (Trnka et al, 2008)

Heat waves in Austria
1954 - 2004



StartClim 2004 / ZAMG

Central European **drought impacts** on Maize and Wheat (exp. yield statistics > 15years)

Table 8. Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of dry days and observed MZ yield. No effect: *11 of 22*; with effect: **7** of **22**.

Location	Dstart		Dintensive			Dextreme			Dvextreme		
	AMJ	JJA	MAM	AMJ	JJA	MAM	AMJ	JJA	MAM	AMJ	JJA
Ziharec	**0.59**	*0.10*	**0.65**	**0.59**	*0.13*	**0.52**	**0.50**	*0.08*	*0.08*	**0.63**	*−0.12*
	(0.05)	*(0.76)*	**(0.03)**	**(0.05)**	*(0.70)*	**(0.10)**	**(0.11)**	*(0.81)*	*(0.81)*	**(0.03)**	*(0.72)*
Podhajska	*0.19*	−0.42	*0.26*	*0.23*	**−0.51**	0.49	*0.10*	−0.32	0.40	*0.12*	*−0.15*
	(0.57)	(0.19)	*(0.44)*	*(0.49)*	**(0.10)**	(0.12)	*(0.76)*	(0.33)	(0.22)	*(0.72)*	*(0.65)*

Maize: April-June

Table 9. Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of dry days and observed WW yield. No effect: *27 of 49*; with effect: **3** of **49**.

Location	Dstart	Dintensive		Dextreme		Dvextreme	
	AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ
Gross-Enz.	−0.49	−0.41	**−0.52**	*−0.16*	−0.39	*0.10*	*−0.16*
	(0.04)	(0.10)	**(0.03)**	*(0.53)*	(0.12)	*(0.70)*	*(0.53)*
RimskiSancevi	*−0.22*	*−0.13*	−0.32	−0.41	*−0.30*	−0.48	−0.34
	(0.30)	*(0.54)*	(0.12)	(0.04)	*(0.15)*	(0.01)	(0.10)
Ziharec	−0.37	*−0.26*	−0.31	*−0.28*	−0.43	**−0.61**	−0.39
	(0.213)	*(0.39)*	(0.30)	*(0.35)*	(0.14)	**(0.02)**	(0.18)
Podhajska	−0.34	−0.38	−0.31	*−0.17*	**−0.51**	−0.42	−0.41
	(0.21)	(0.16)	(0.26)	*(0.54)*	**(0.05)**	(0.11)	(0.12)
Belusa	*−0.24*	*0.00*	−0.38	*−0.27*	*−0.27*	*−0.18*	*−0.15*
	(0.37)	*(1.00)*	(0.14)	*(0.31)*	*(0.31)*	*(0.50)*	*(0.57)*

WW: May-June

Lalic et al., 2014

Central European **heat impacts** on Maize and Wheat
(exp. yield statistics > 15years)

Table 6. Correlation coefficients and *p* values (in brackets, underlined values are significant) between AMI describing number of days with extreme temperatures and observed MZ yield. No effect: *17 of 30*; with effect: **6** of **30**.

Location	April		May		June		July		August	
	SumD	FrostD	TropD	SumD	TropD	SumD	TropD	SumD	TropD	SumD
DubrovčakLijevi	*0.03*	−0.43	−0.31	−0.34	*−0.07*	−0.37	*0.15*	*−0.05*	**−0.64**	−0.42
	(*0.93*)	(0.18)	(0.35)	(0.30)	(*0.83*)	(0.26)	(*0.65*)	(*0.88*)	**(0.03)**	(0.19)
Ziharec	*0.09*	*0.24*	**0.51**	0.38	*−0.01*	*−0.01*	**−0.58**	**−0.72**	*−0.25*	*−0.25*
	(*0.79*)	(*0.47*)	**(0.10)**	(0.24)	(*0.97*)	(*0.97*)	**(0.06)**	**(0.01)**	(*0.45*)	(*0.45*)
Podhajska	−0.47	*0.08*	*0.00*	*−0.20*	*−0.19*	*−0.11*	*0.08*	*0.06*	**−0.56**	**−0.56**
	(0.14)	(*0.81*)	(*1.00*)	(*0.55*)	(*0.57*)	(*0.74*)	(*0.81*)	(*0.86*)	**(0.07)**	**(0.07)**

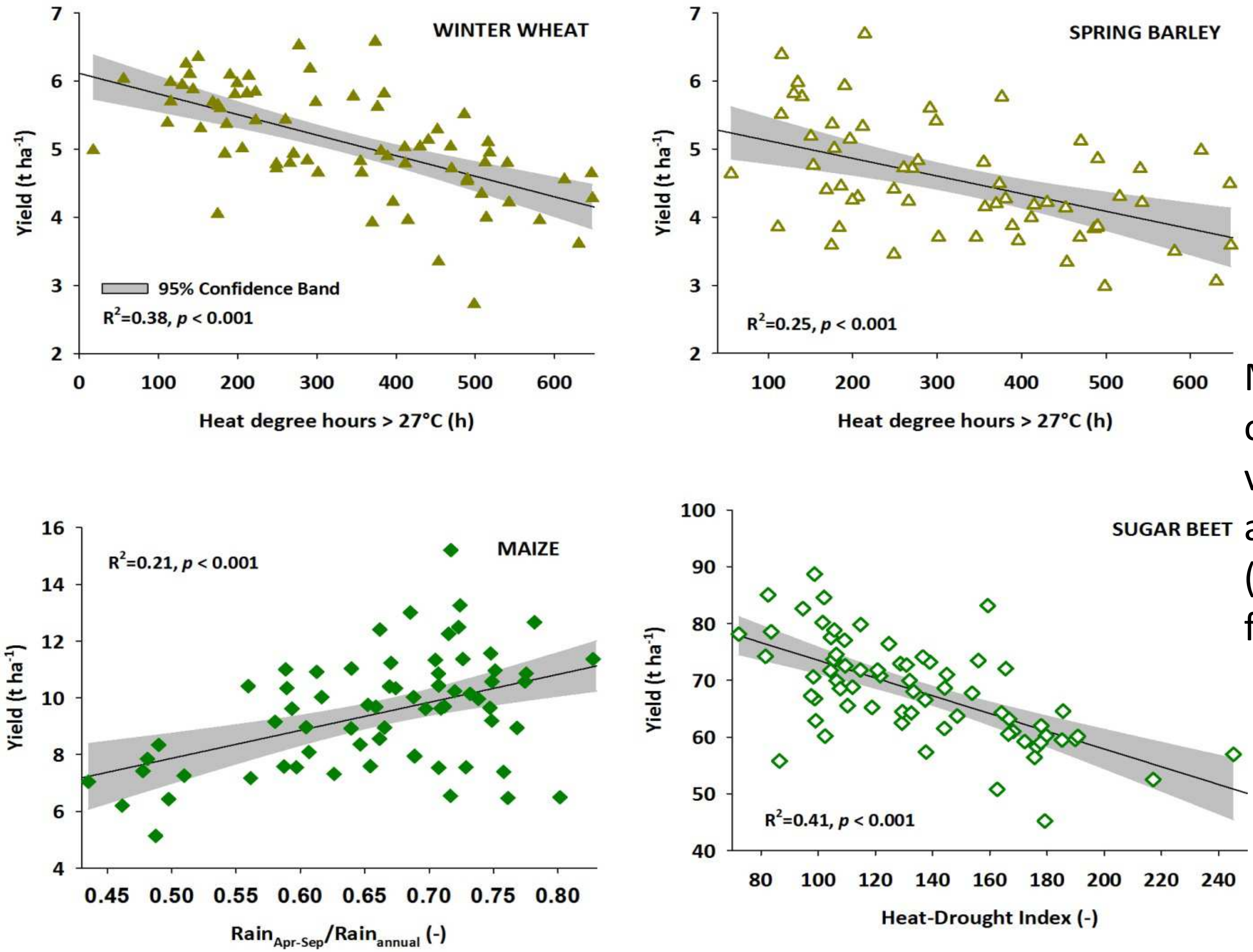
Maize:
May-August

Table 7. Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of days with extreme temperatures and observed WW yield. No effect: *41 of 63*; with effect: **2** of **63**.

Location	January		February		March	April	May	June	
	FrostD	FreezD	FrostD	FreezD	FrostD	FrostD	SumD	TropD	SumD
Gross-Enz.	*−0.14*	*−0.14*	−0.43	−0.43	*−0.27*	*0.14*	−0.32	*0.04*	*−0.24*
	(*0.59*)	(*0.59*)	(0.08)	(0.08)	(*0.29*)	(*0.59*)	(0.21)	(*0.87*)	(*0.35*)
RimskiSancevi	*−0.27*	*−0.10*	−0.42	−0.44	*−0.03*	*−0.22*	*−0.02*	*−0.24*	*−0.30*
	(*0.20*)	(*0.64*)	(0.04)	(0.03)	(*0.88*)	(*0.30*)	(*0.92*)	(*0.25*)	(*0.15*)
Ziharec	−0.37	−0.44	*−0.12*	−0.34	−0.33	*−0.06*	*−0.22*	−0.33	*0.07*
	(0.21)	(0.13)	(*0.69*)	(0.25)	(0.27)	(*0.84*)	(*0.47*)	(0.27)	(*0.82*)
Podhajska	*−0.23*	−0.32	*−0.15*	*0.08*	*−0.02*	*−0.23*	**−0.64**	**−0.58**	*−0.29*
	(*0.40*)	(0.24)	(*0.59*)	(*0.77*)	(*0.94*)	(*0.40*)	**(0.01)**	**(0.02)**	(*0.28*)
Belusa	*0.11*	*−0.23*	*−0.30*	*−0.28*	*−0.21*	*−0.03*	*−0.20*	−0.32	*−0.17*
	(*0.68*)	(*0.39*)	(*0.25*)	(*0.29*)	(*0.43*)	(*0.91*)	(*0.45*)	(0.22)	(*0.52*)

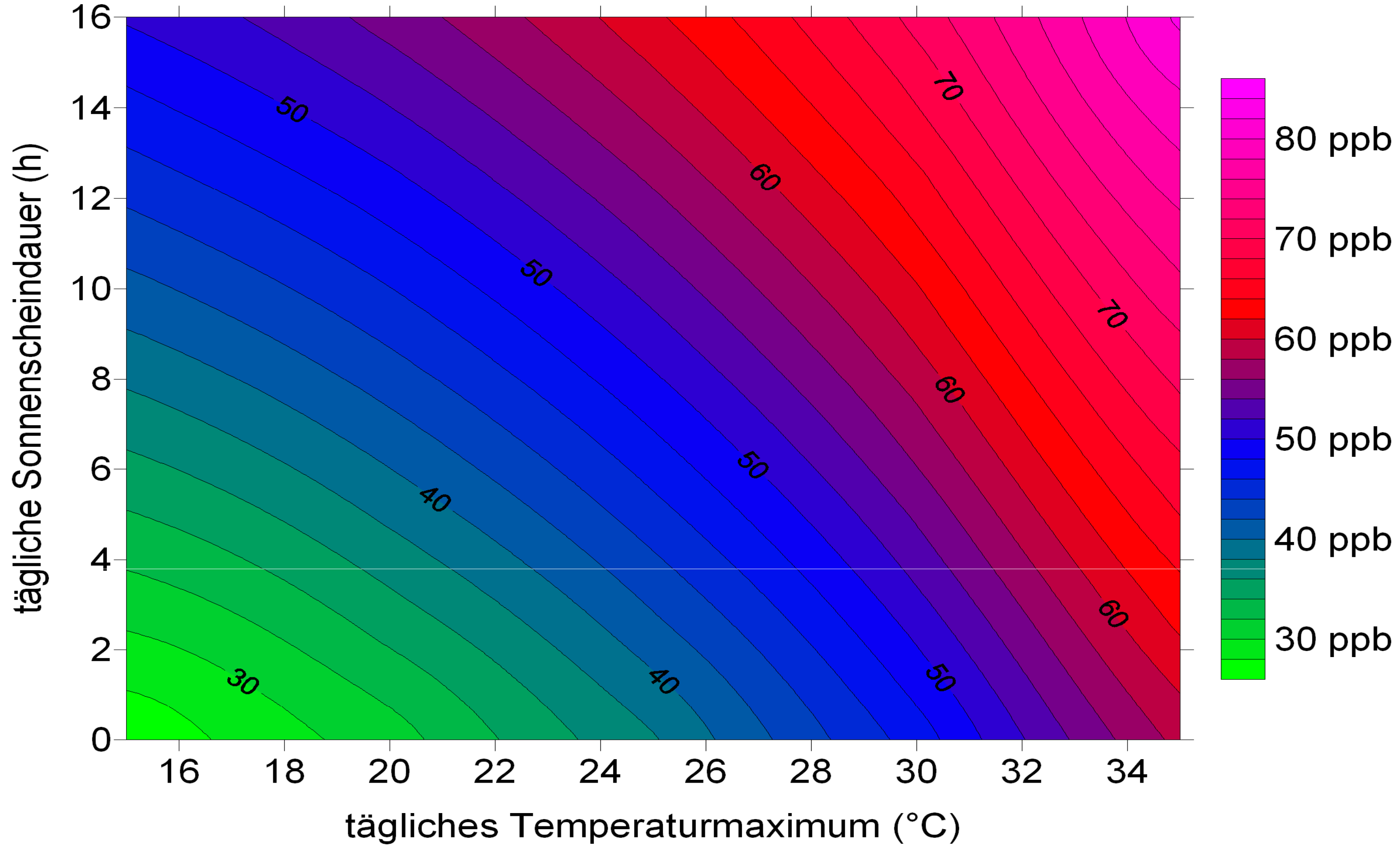
WW: May-June

Lalic et al., 2014



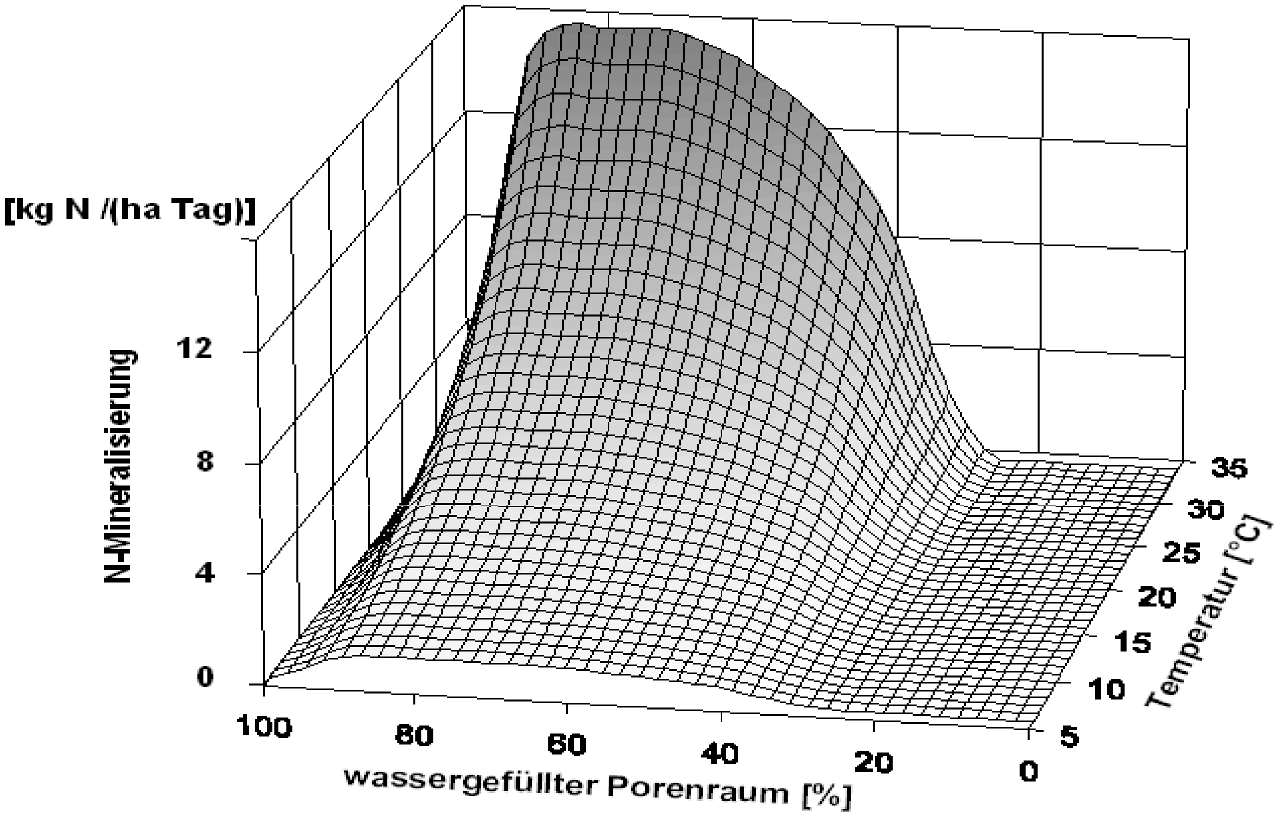
Multi-site evaluation
of crop yield
vs. drought
and heat impacts
(based on Austrian
farm yield statistics)

Bodner et al., 2016)



High temperatures influencing troposhperic ozone

(Eitzinger et al., 2009)



Soil temperature and wetness vs. soil N-mineralization

(Eitzinger et al., 2009)

Wind erosion – a combination of drought and wind and soil management

(Eitzinger et al., 2009)

Water erosion (up to 300t/ha during one precipiataion event of 80mm/h)

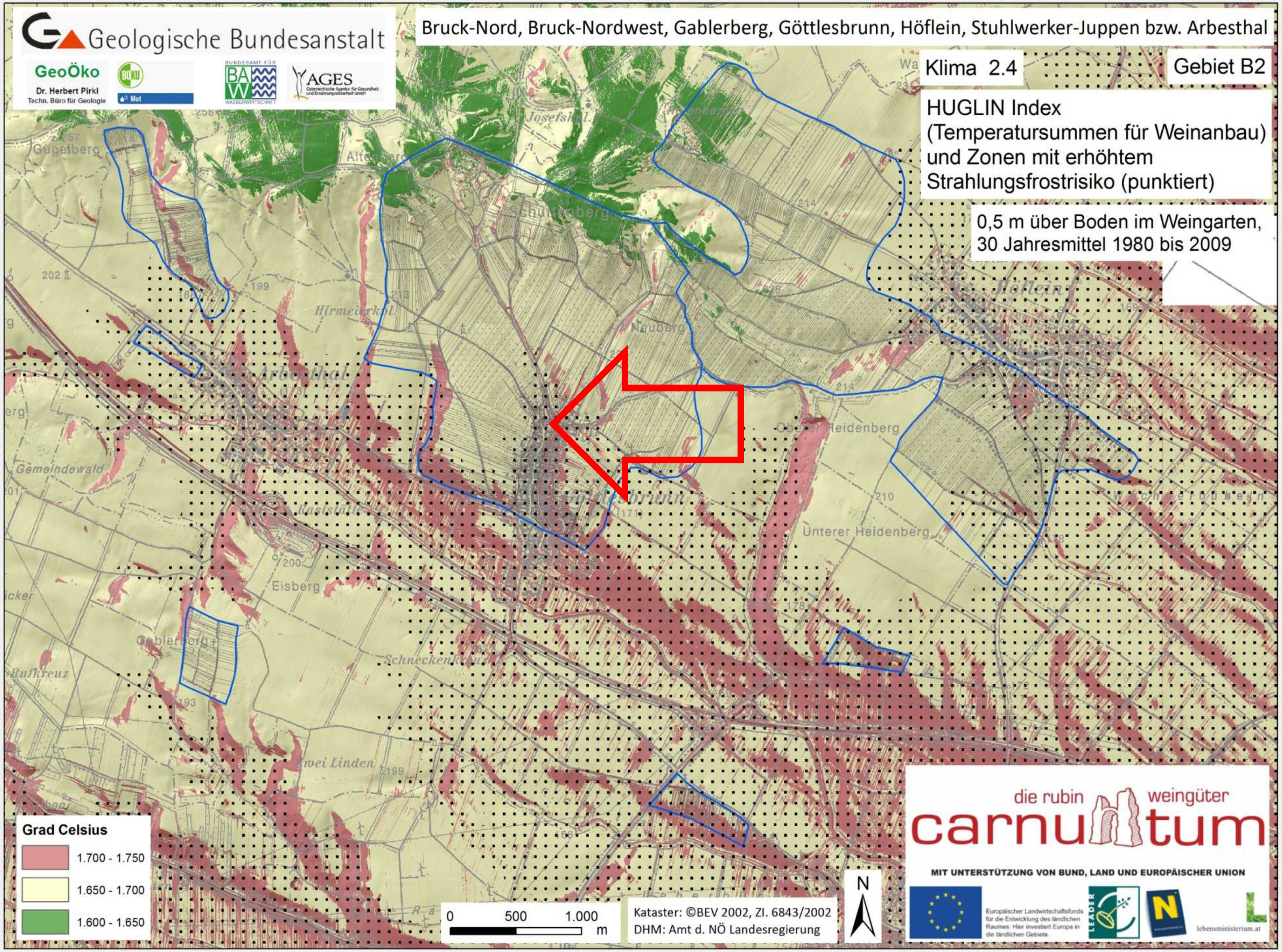
(Eitzinger et al., 2009)

Mulching and reduced soil cultivation: Grass soil cover (Mulch) agains soil erosion

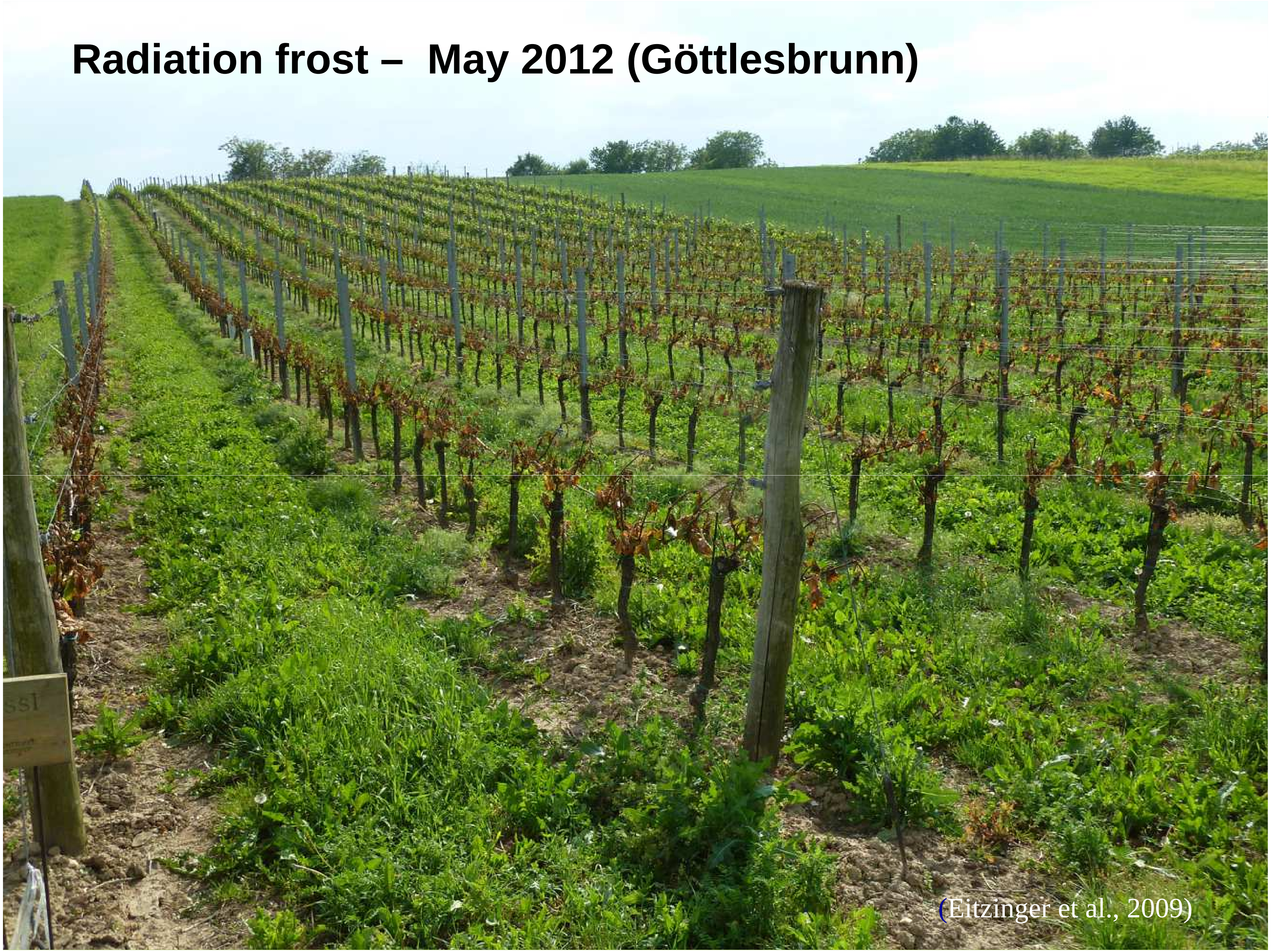
(Eitzinger et al., 2009)

Developement of pests depend on temperature (corn borer)

(Eitzinger et al., 2009)

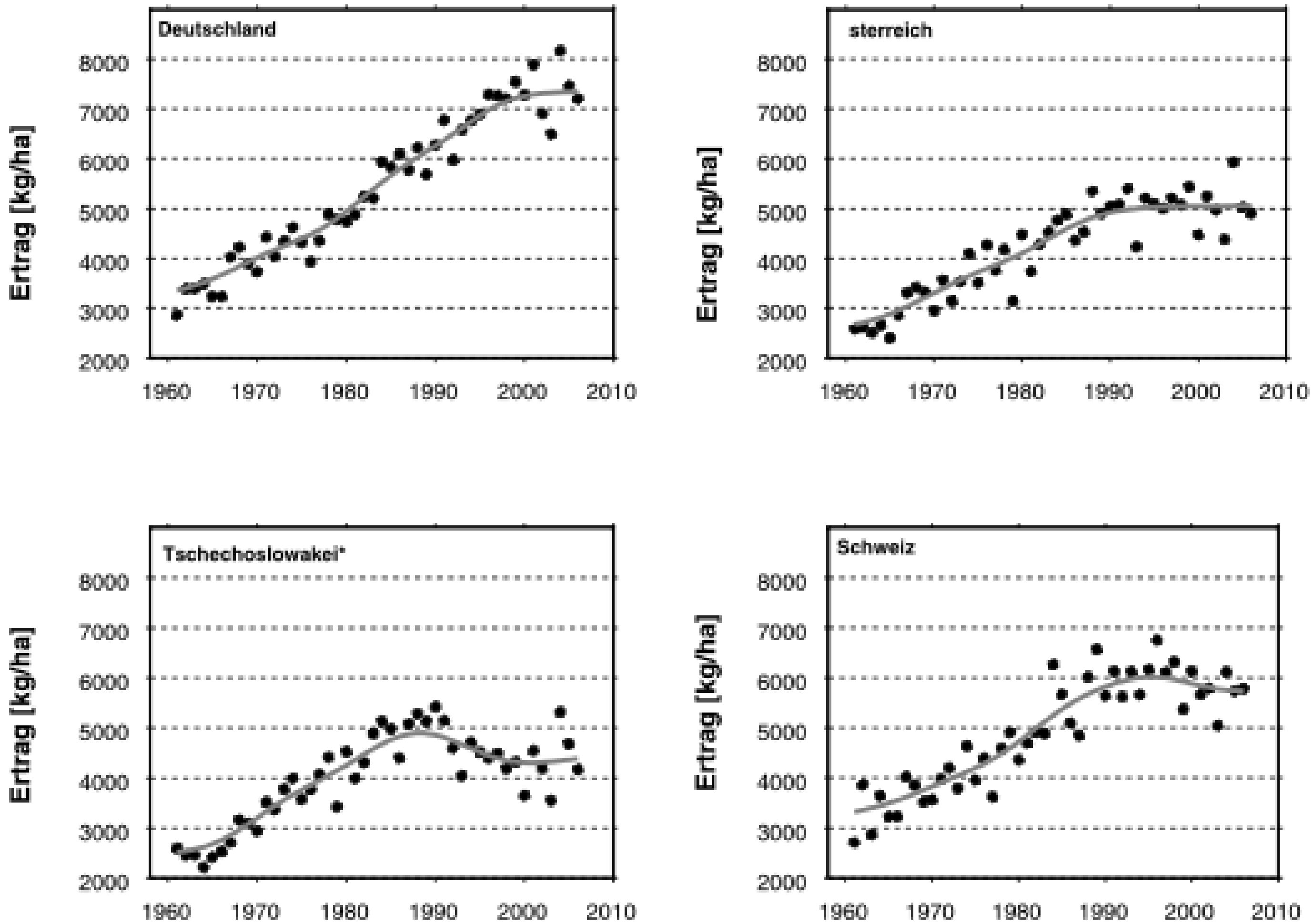

Geologische Bundesanstalt
GeoÖko
Dr. Herbert Pirkl
Techn. Büro für Geologie
AGES
Bruck-Nord, Bruck-Nordwest, Gablerberg, Göttlesbrunn, Höflein, Stuhlwerker-Juppen bzw. Arbesthal
Klima 2.4
Gebiet B2
HUGLIN Index
(Temperatursummen für Weinanbau)
und Zonen mit erhöhtem
Strahlungsfrostrisiko (punktiert)
0,5 m über Boden im Weingarten,
30 Jahresmittel 1980 bis 2009
Grad Celsius
1.700 - 1.750
1.650 - 1.700
1.600 - 1.650
0 500 1.000 m
Kataster: ©BEV 2002, Zl. 6843/2002
DHM: Amt d. NÖ Landesregierung
N
die rubin weingüter
carnuntum
MIT UNTERSTÜTZUNG VON BUND, LAND UND EUROPÄISCHER UNION

Radiation frost – May 2012 (Göttlesbrunn)



(Eitzinger et al., 2009)

National yield trends in Europe



(Eitzinger et al., 2009)

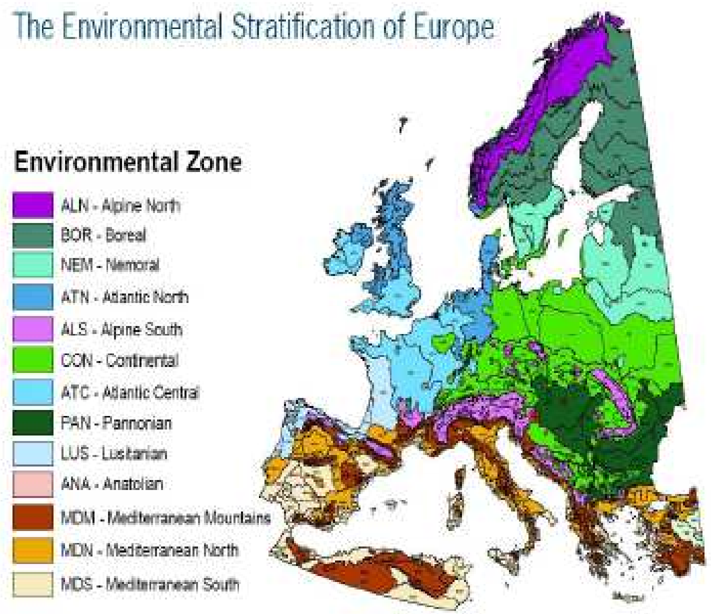
Adverse weather indicators (examples)	Hot spots
Drought	Drought prone regions, relevant for crop stress and pest development
Heat	Mainly lowland regions; heat stress and fertility impact on several crops; related increased ozone levels leading to yield losses
Soil conditions for crop (root) growth	All regions with loamy-clay soils (critical temperatures and wetness) and sandy soils (drought)
Heavy precipitation	Especially humid regions (alpine and pre-alpine regions); relevant for lodging and diseases as well as soil surface hardening
Snow cover conditions	In all regions with extreme snow cover variation (too much, too long or too less)
Overwintering conditions	Frequency and duration of mild/cold fluctuations during winter; weakening frost hardiness, chilling conditions
Humidity and leaf wetness	Humid crop growing regions; important conditions for many diseases
Harvest conditions	Crop specific, include all weather parameters
Soil workability	For soil cultivation and crop management; danger of soil compaction
Suitable conditions for crop management measures	i.e. number of frequency of dry / calm days within certain periods, crop specific
Drying conditions	Field drying conditions, relevant for yield quality and diseases (i.e. fusarium)
Frequency of rains	Relevant for diseases and pests; biomass accumulation (low radiation and cloudiness)
Frost damage	Especially spring crops and orchards; huge damage potential for sensitive crops; strong impact of orography
Soil erosion	Direct damage and long term effects on soil fertility (and nutrient and water storage capacity); strong effect of soil cover and orography
N-leaching	Cereals and high yielding crops such as maize; strong impact of soil conditions and crop management, high spatial variability
Disease risks	Many
Pest risks	Many (Eitzinger et al., 2016)

Climate change impacts

ATN (2)	w.wheat	s.barley	w.rape	Maize	Potato	sugar b.	Grassland	Apple	Grape
Duration of growing season	-0.5	0.0	-0.5	2.0	1.5	0.5	1.0	2.0	1.0
Overwintering damage	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0
Frost damage	-0.5	0.0	-0.5	-1.0	-1.0	0.0	-0.5	-0.5	-0.5
Suitable harvest conditions	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Interannual variability	0.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0
Drought	-0.5	-0.5	-0.5	0.0	-0.5	-1.0	-0.5	-1.0	-0.5
Heat stress	-1.0	-0.5	-0.5	0.0	-0.5	-1.0	0.0	-0.5	0.0
Hail	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0	-1.0
Pest and diseases	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.0	-0.5	-1.5
Weeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Soil erosion	-0.5	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	0.0	-1.0
Nitrogen losses	-1	-1	-1	1	1	0.0	-0.5	0.0	-1.0

ATC (2)	w.wheat	s.barley	w.rape	Maize	Potato	sugar b.	Grassland	Apple	Grape
Duration of growing season	-1.5	-1.0	-1.5	0.0	1.0	0.0	1.5	0.0	-0.5
Overwintering damage	1.0		1.0				0.0	0.0	0.0
Frost damage	-1.0		-1.0				-1.0	-1.0	-1.0
Suitable harvest conditions	0.5	0.5	0.5	1.5	1.0	1.0	1.5	1.0	1.5
Interannual variability	0.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0
Drought	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.5	-1.0	-1.0
Heat stress	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-0.5	-1.0	-0.5
Hail	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0	-1.0
Pest and diseases	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-0.5	-1.5	-1.0
Weeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Soil erosion	-0.5	-1.0	-0.5	-1.0	-1.0	-1.0	0.0		
Nitrogen losses	-1	-1	-1	1	1	1.0	0.0		

CON (7)	w.wheat	s.barley	w.rape	Maize	Potato	sugar b.	Grassland	Apple	Grape
Duration of growing season	-0.3	-0.2	-0.3	-0.9	0.2	-0.5	0.5	0.8	0.4
Overwintering damage	-0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.6
Frost damage	0.3	0.6	0.1	-0.8	-0.8	-0.6	-0.5	0.5	0.2
Suitable harvest conditions	1.2	1.3	1.2	0.7	1.5	1.3	1.0	1.0	-0.3
Interannual variability	-0.7	-1.0	-1.0	-0.7	-1.2	-1.4	-1.2	-1.4	-1.6
Drought	-1.0	-1.5	-1.0	-1.5	-1.5	-1.7	-1.5	-1.3	-1.0
Heat stress	-1.0	-1.3	-0.7	-0.5	-1.3	-1.5	-1.3	-1.2	-0.7
Hail	-1.0	-1.0	-1.0	-1.0	-0.5	-0.5	0.0	-1.5	-1.5
Pest and diseases	-1.4	-1.4	-1.8	-1.8	-1.8	-1.8	-1.4	-1.3	-1.3
Weeds	-0.3	-0.5	-1.0	-0.5	-0.5	-1.0	-0.5	0.0	0.0
Soil erosion	-0.7	-1.0	-0.7	-1.4	-1.4	-1.3	-0.6	-1.2	-1.6
Nitrogen losses	-1	-0.6	-1	-0.5	0	-0.3	-0.7	-0.5	-1.0



Olesen J.E., M. Trnka, K.C. Kersebaum, A.O. Skjelvag, B. Seguine, P. Peltonen-Sainio, F. Rossi, J. Kozyrah, F. Micale, 2011- Review- Impacts and adaptation of European crop production systems to climate change. Europ. J. Agronomy 34 96–112

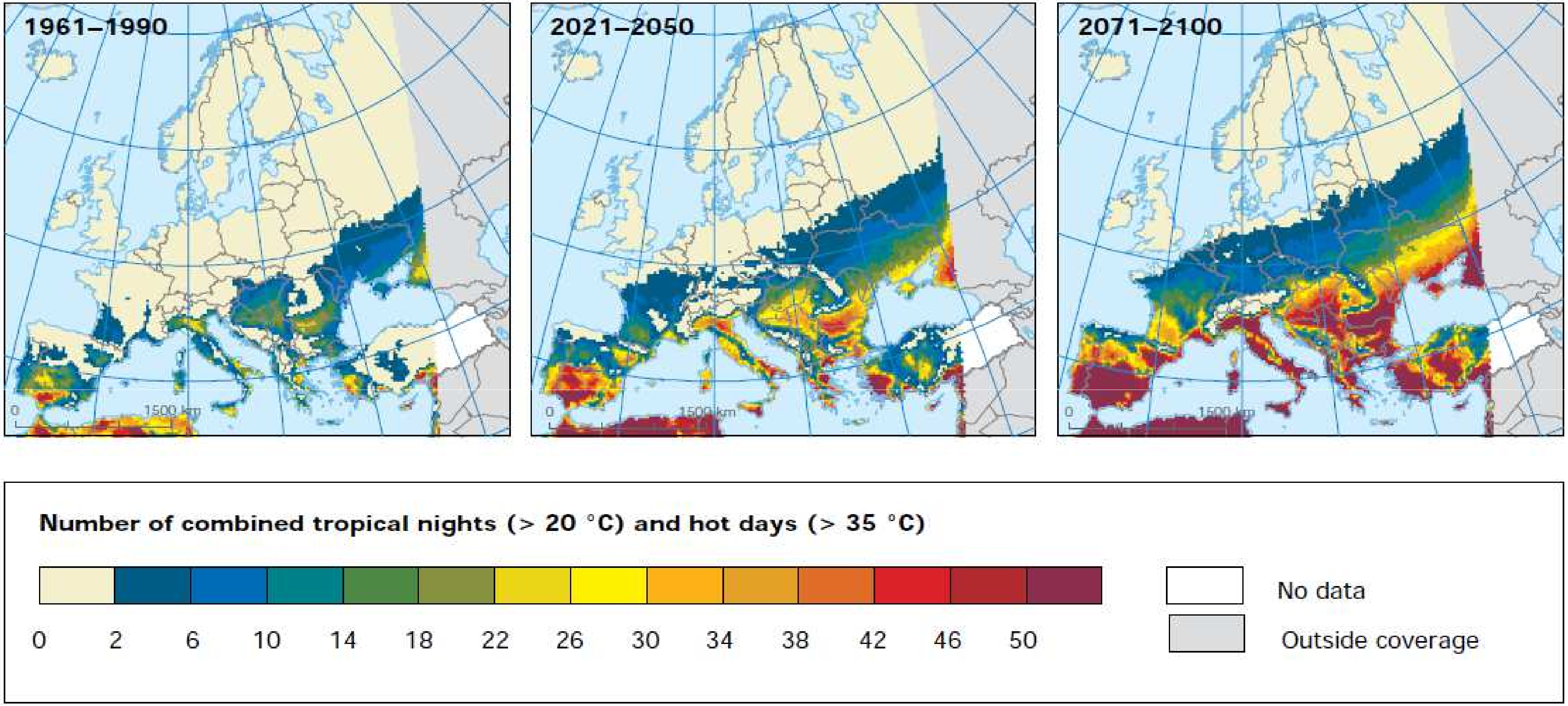
Adverse Weather conditions

under Climate Change scenarios

General climate change impacts in European crop production regions (observed)

- Trend to increasing summer droughts and heat days : more drought stress days for crops
- Increasing length of growing season; shortening of growing cycles
- Regional increasing trends in weather extremes (heat, hail, floods) lead to higher production risks
- Forced changes in occurence of pests, diseases and weeds due to the warming trend (spatial shifts depending on elevation)
- Less snow cover and warmer winter periods can increase disease pressure and change crop timing
- Shift of crop phenology changes timeing of farm management (shift of crop management, harvest date etc.)

Map 2.4 Projections of extreme high temperatures

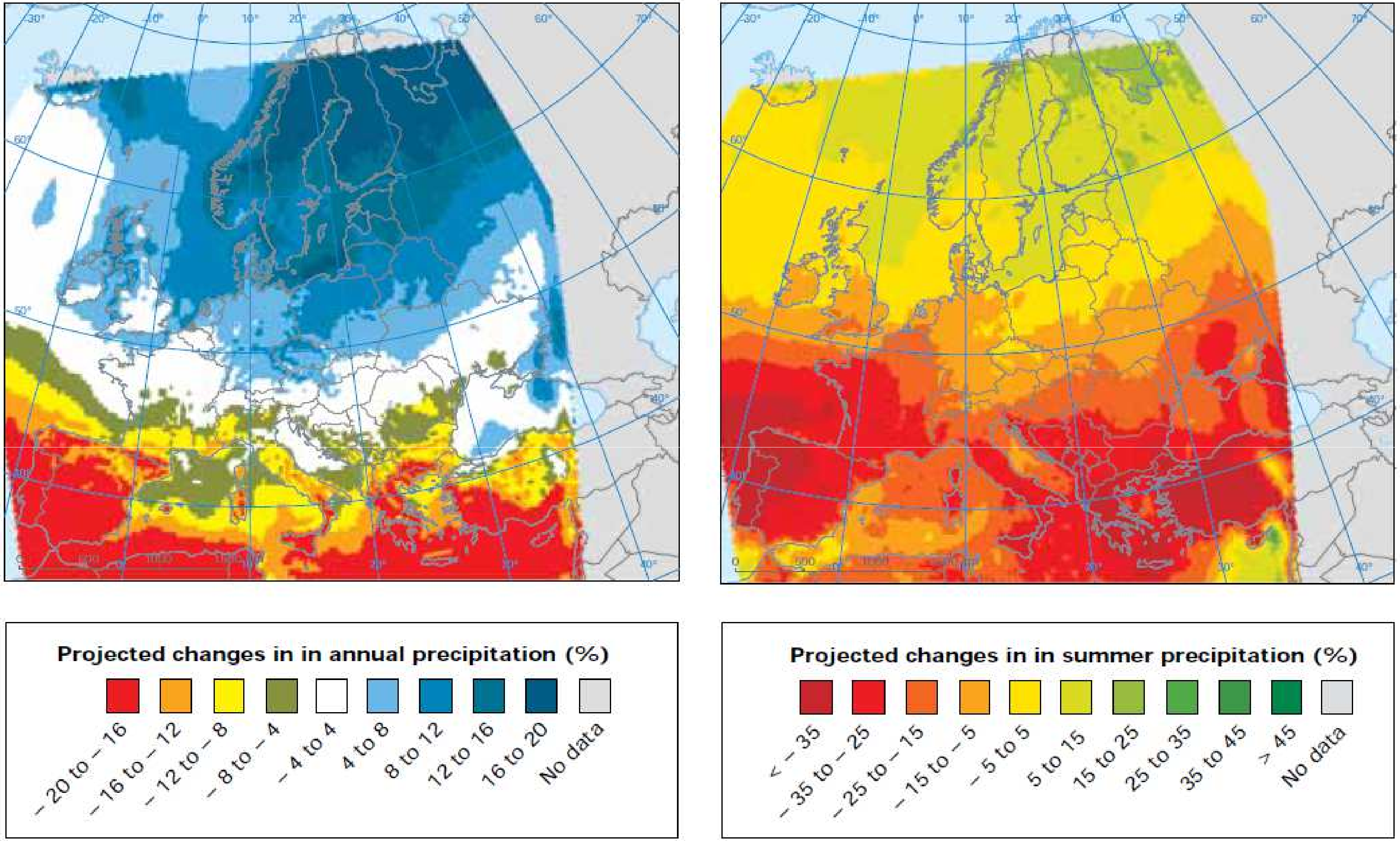


Note: Extreme high temperatures are represented by the combined number of hot summer (June–August) days (TMAX > 35 °C) and tropical nights (TMIN > 20 °C). All projections are the average of six regional climate model (RCM) simulations of the EU ENSEMBLES project using the IPCC SRES A1B emission scenario for the periods 1961–1990, 2021–2050 and 2071–2100.

Source: Fischer and Schär, 2010. © Nature Publishing Group. Reprinted with permission.

EEA, 2012

Map 2.6 **Projected changes in annual (left) and summer (right) precipitation (%) between 1961–1990 and 2071–2100**

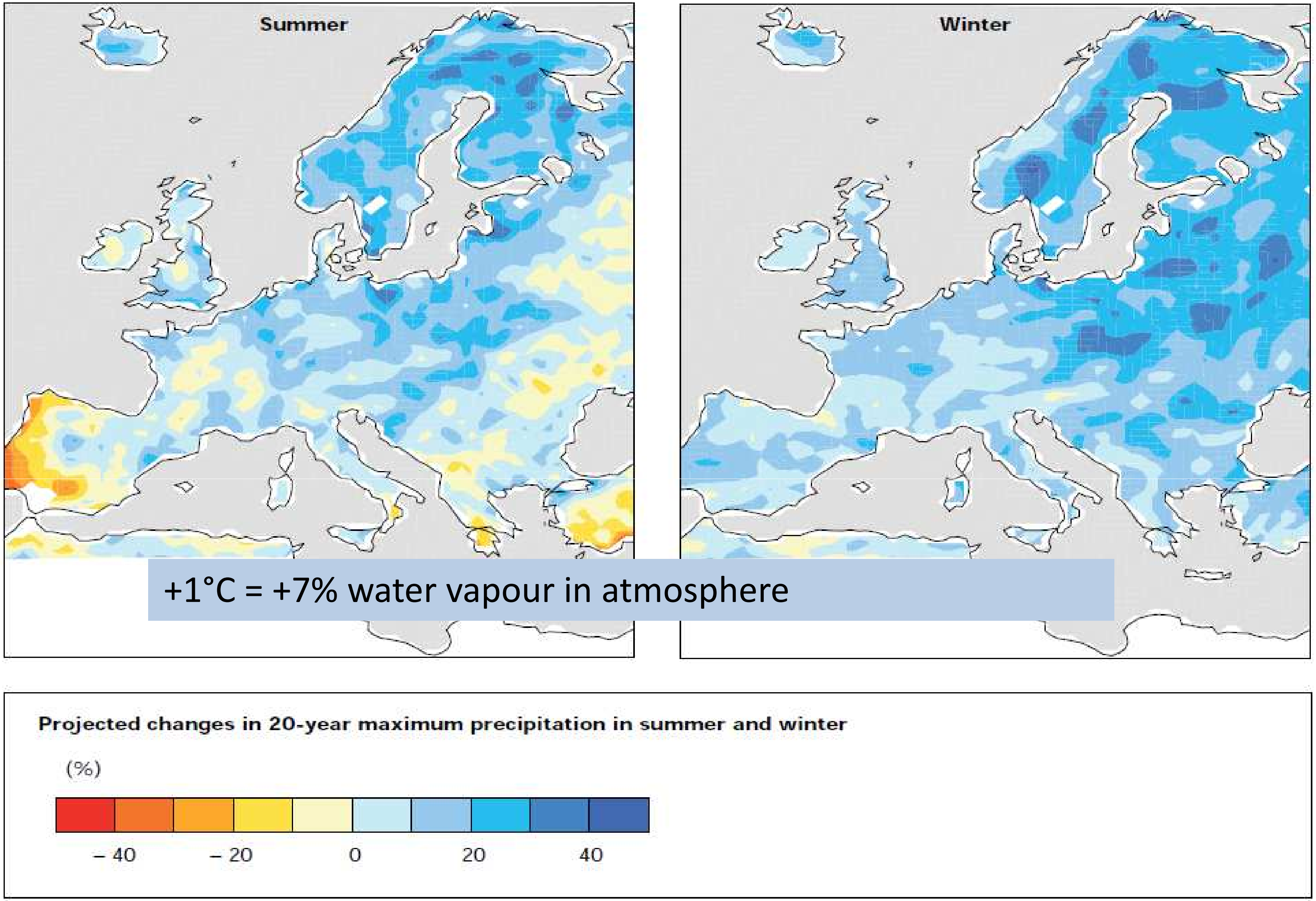


Note: Projections are based on the ENSEMBLES project. They have been obtained from different regional climate models (RCMs) performing at 25 km spatial resolution with boundary conditions from five global climate models (GCMs), all using the IPCC SRES A1B emission scenario.

Source: van der Linden and Mitchell, 2009.

EEA, 2012

Map 2.8 Projected changes in 20-year maximum precipitation in summer and winter

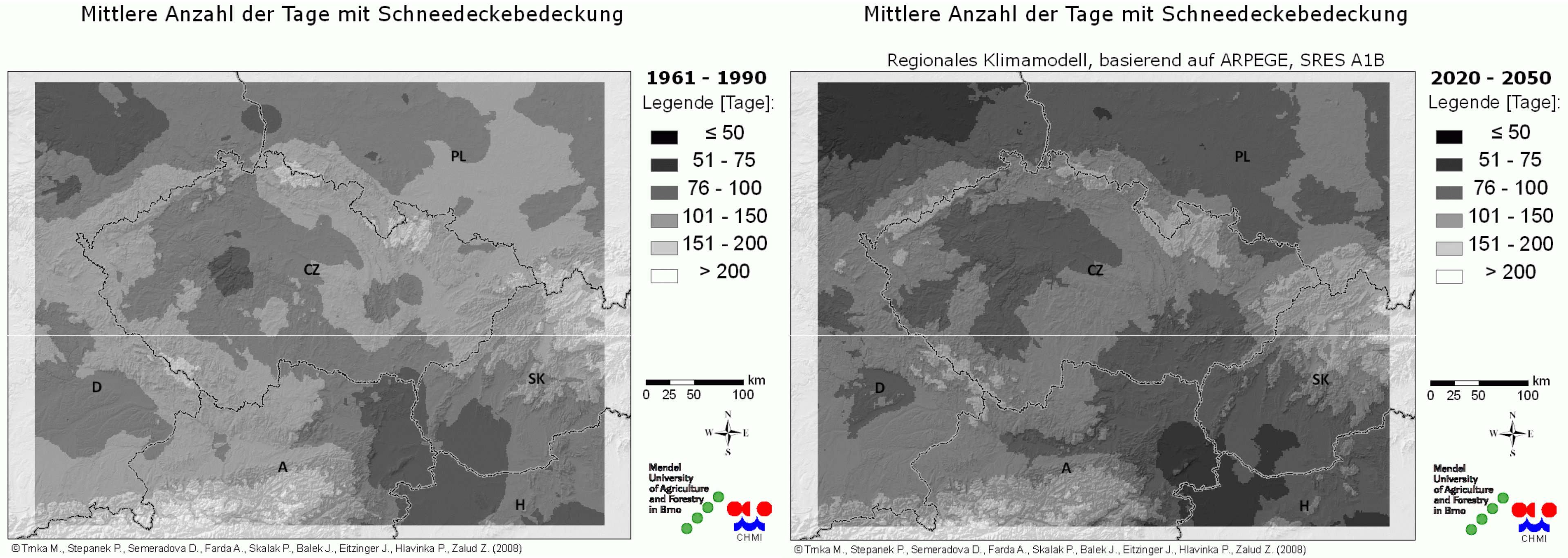


Note: Projected changes in 20-year maximum daily precipitation in summer (left) and winter (right) from 1961–1990 to 2071–2100 based on the ensemble mean using a regional climate model (RCM) nested in 6 general circulation model (GCMs). Changes that approximately lie outside of ± 10 % for the ensemble average are significant at the 10 % significance level.

Source: Nikulin et al., 2011.

EEA, 2012

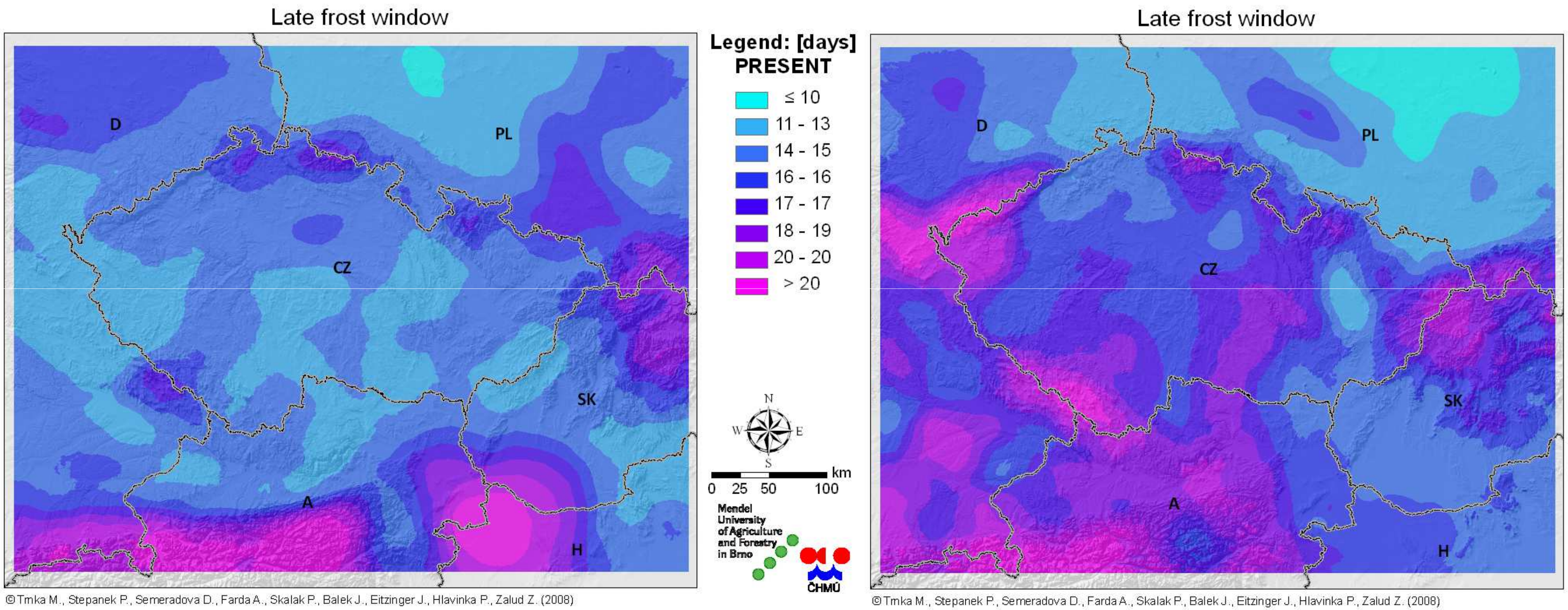
Snow cover duration
Ca. -20 days till 2020/50



(Eitzinger et al., 2009)

Difference between date of the last frost with the return probability 2 and 20 years

RCM - Frost risk (Agriclim)



Median = 14 days
Min = 6 days
Max = 38 days

Median = 16 days
Min = 7 days
Max = 33 days

(Eitzinger et al., 2009)

Main CC impacts on agriculture in Europe

- **Summer drought and heat** are the most negative impacts on crop production potentials, especially for summer crops.
- **Soil conditions** (water storage capacity) plays an increasing important role for differentation of production potential.
- Many **regions with increasing mean production potential** (cool-humid regions (e.g. alps), which could be used due to existing well developed agricultural infrastructure (e.g. introduction of high yielding crops such as maize production)
- **Soil erosion** will be an specific problem to be adressed in many Central European regions due to increasing heavy precipitation and winter precipitation, especially in hilly terrain.
- **Permanent grasslands** will decrease in production potential in many semi-humid regions. Large land use changes could follow in the long term.
- **Increasing potential growing areas** of permanent crops (wine)

Thank you !