



irc 2023 SYDNEY

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GLOBAL CROP - GOLDEN OPPORTUNITIES



Climate change challenges and adaptations for rapeseed

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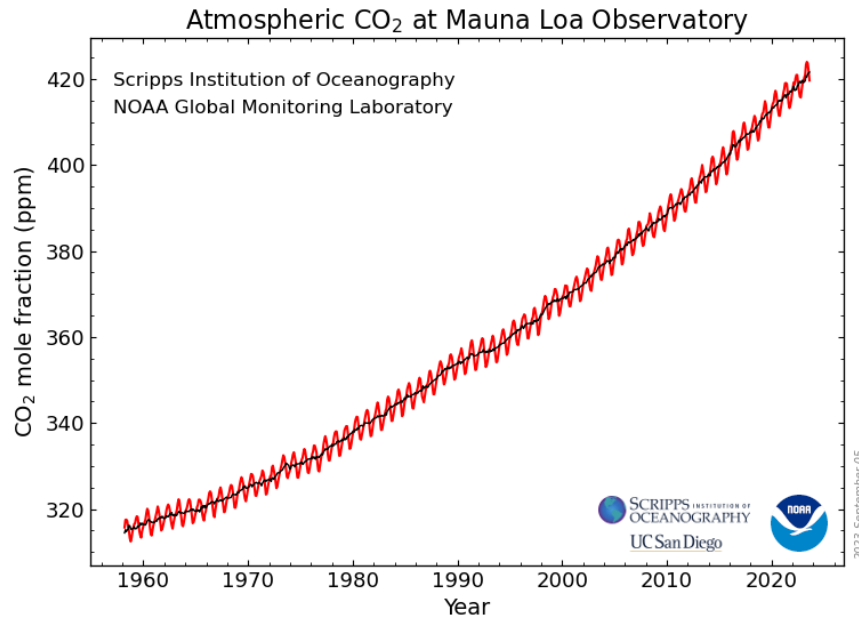
Daniel Miralles, Gabriela Abeledo, Gonzalo Rivelli, Daniel Calderini, Malcolm Morrison, Julianne Lilley & John Kirkegaard



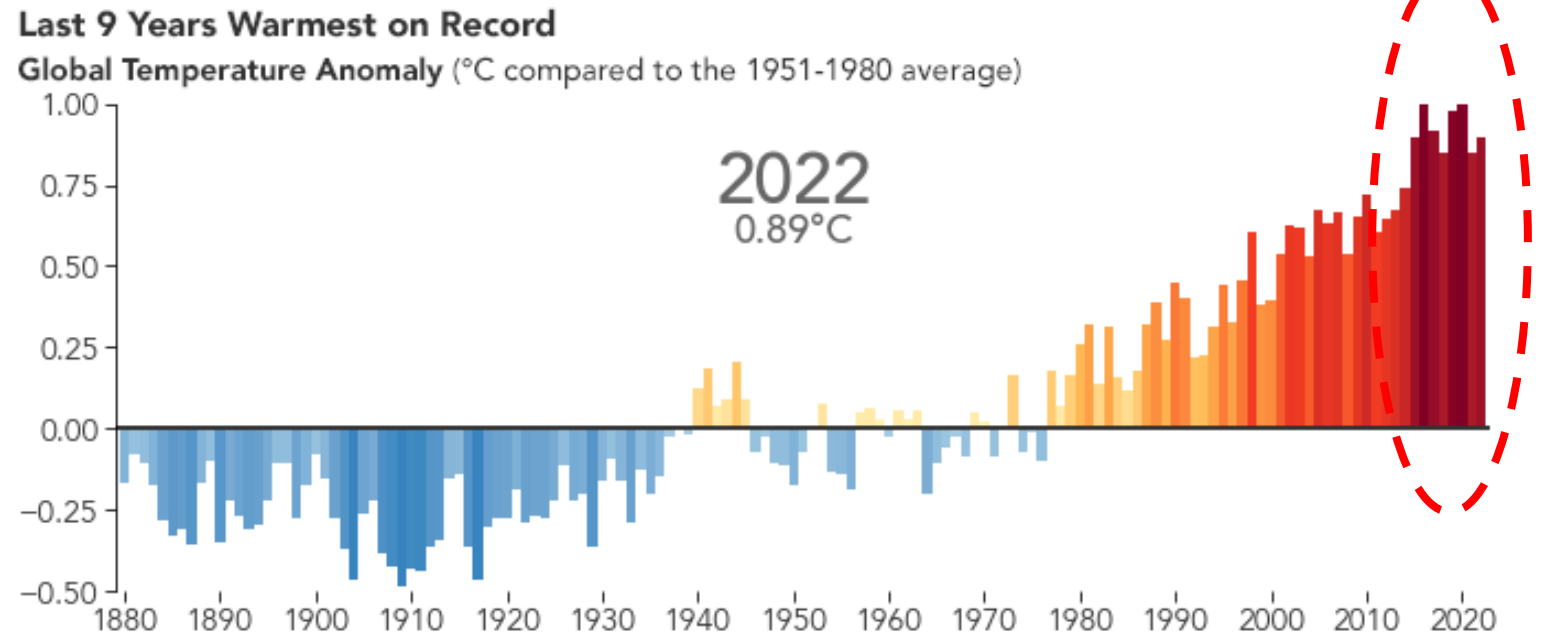
Global warming is palpable

Global greenhouse gas (GHG) emissions are in the highest level of human history

Last 9 years are the warmest on record



NOAA (2023)



424 ppm of CO₂ measured in Hawaii May 2023
[CO₂] varied 180-280 ppm during the Ice Ages
[CO₂] was 180 ppm in the pre-industrial era

<https://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php>

IPCC- Sixth Assessment Report in 2023 (AR6)

We have already reach the 1.1 °C

The estimates of reaching 1.5°C is in the next decade

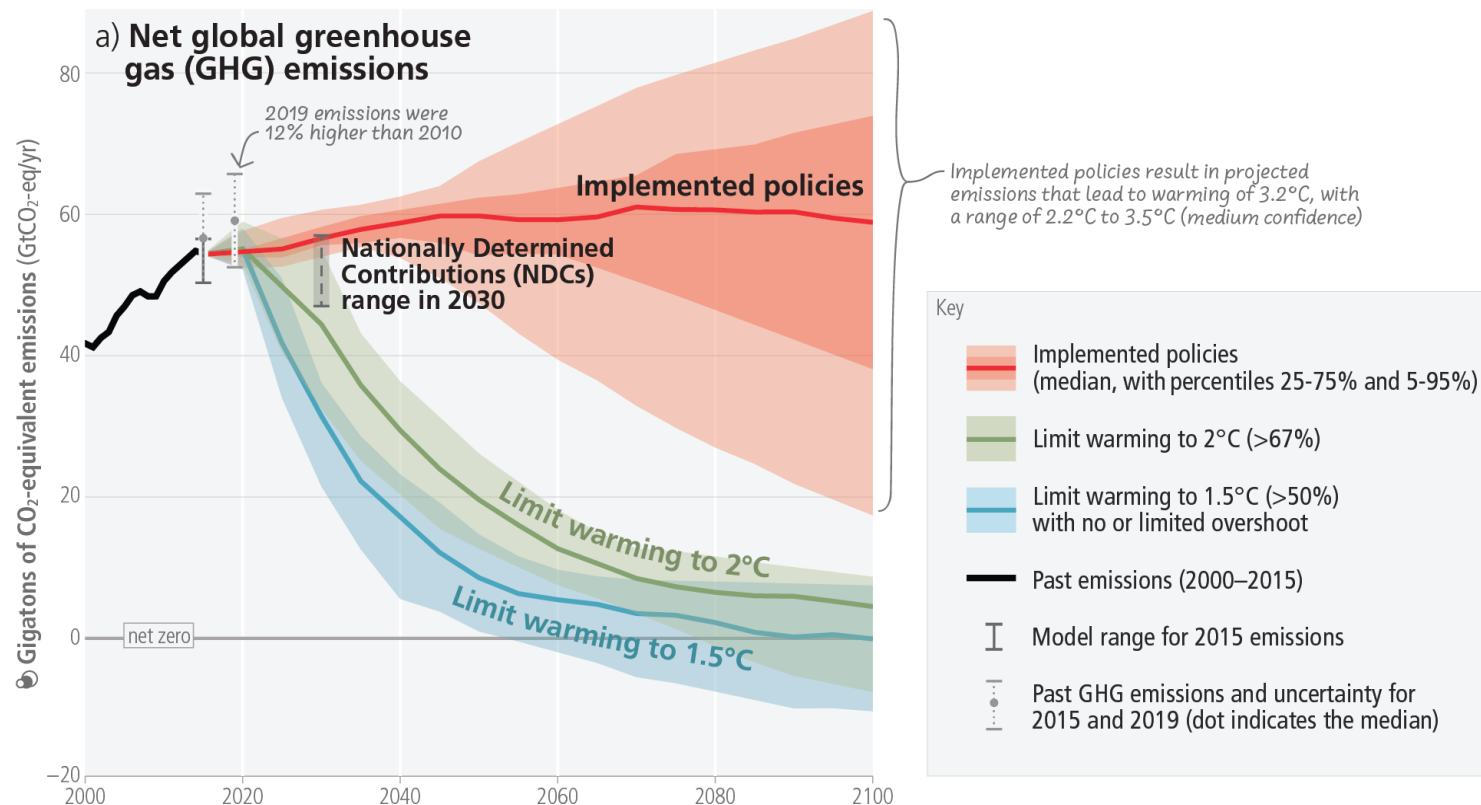


The average anual rate of emissions growth have slowed in the last decade

It is possible to reach net zero with actual technology, but adoption must be faster

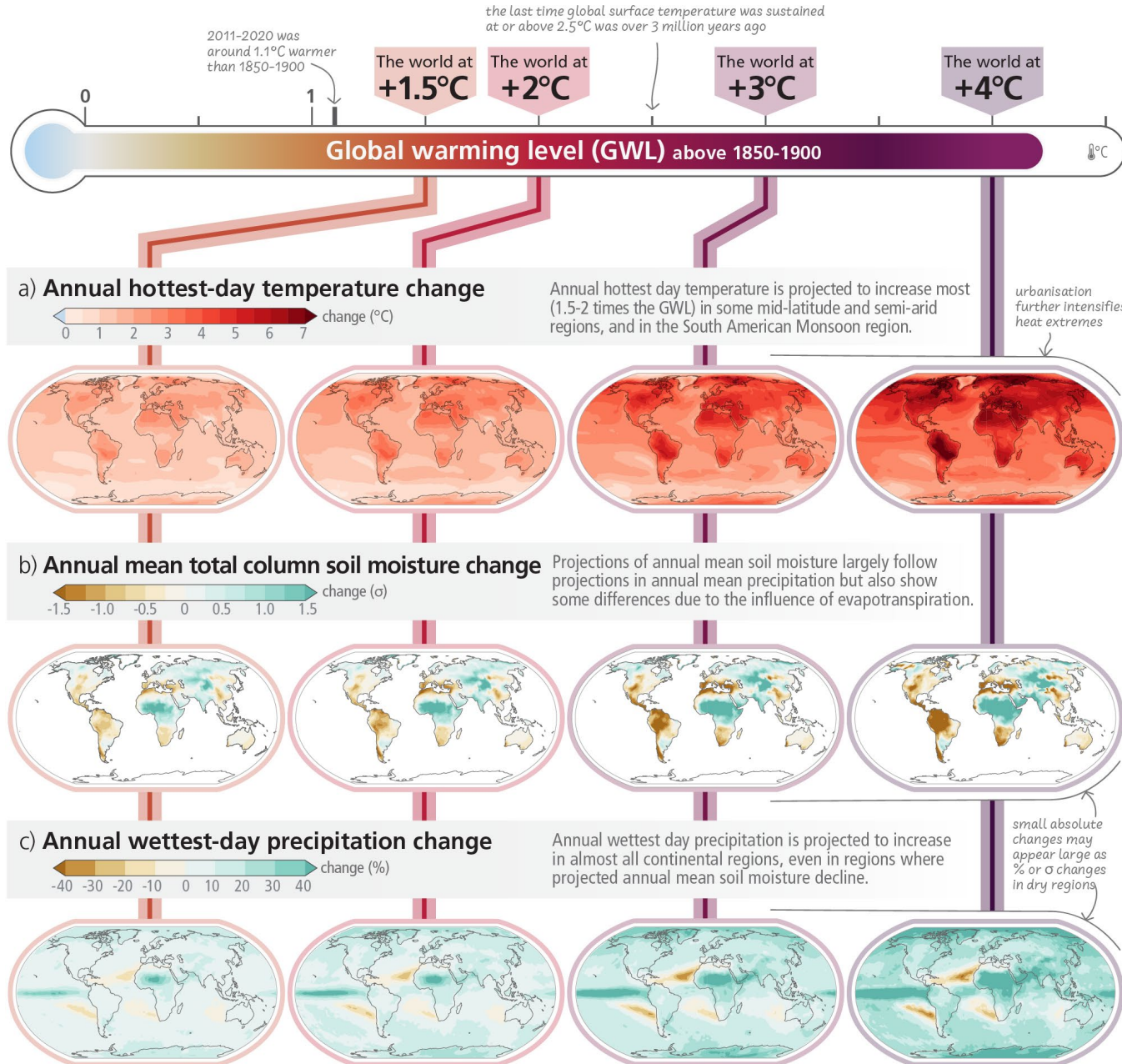
Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions

Net zero CO₂ and net zero GHG emissions can be achieved through strong reductions across all sectors



The challenge is to reduce emissions quickly to keep global warming below 2 °C until the end of the century

With every increment of global warming, regional changes in mean climate and extremes become more widespread and pronounced



We can expect globally:

High thermal variability with extreme temperatures (more predictable)

(more very hot days
more heat waves, and more intense)

asymmetric temperature rise
(higher night temperature)

Uneven rains (less predictable)

Wettest-day precipitation increase

Change in annual soil moisture depends on the region

Low rainfall predictability complicates predictions of the thermal effect on crop productivity

We have already observed some of these changes in recent years

Northward shift of the agriculture

Some effects of global warming may be relatively positive:
reduction of frost period, new arable land at high latitudes

Growing Degree Days ($>1200^{\circ}\text{Cd}$)
with 5°C base temperature
feasible for the small cereals (and
canola) crop cycle

Temperature projections from 7
global climate models

By the end of century, **76%** of the
boreal region might reach crop
feasible conditions, compared to
the **current 32%**

The arable frontier would shift
northwards up to 1200 km by the
end of century
Doubling the actual acreage

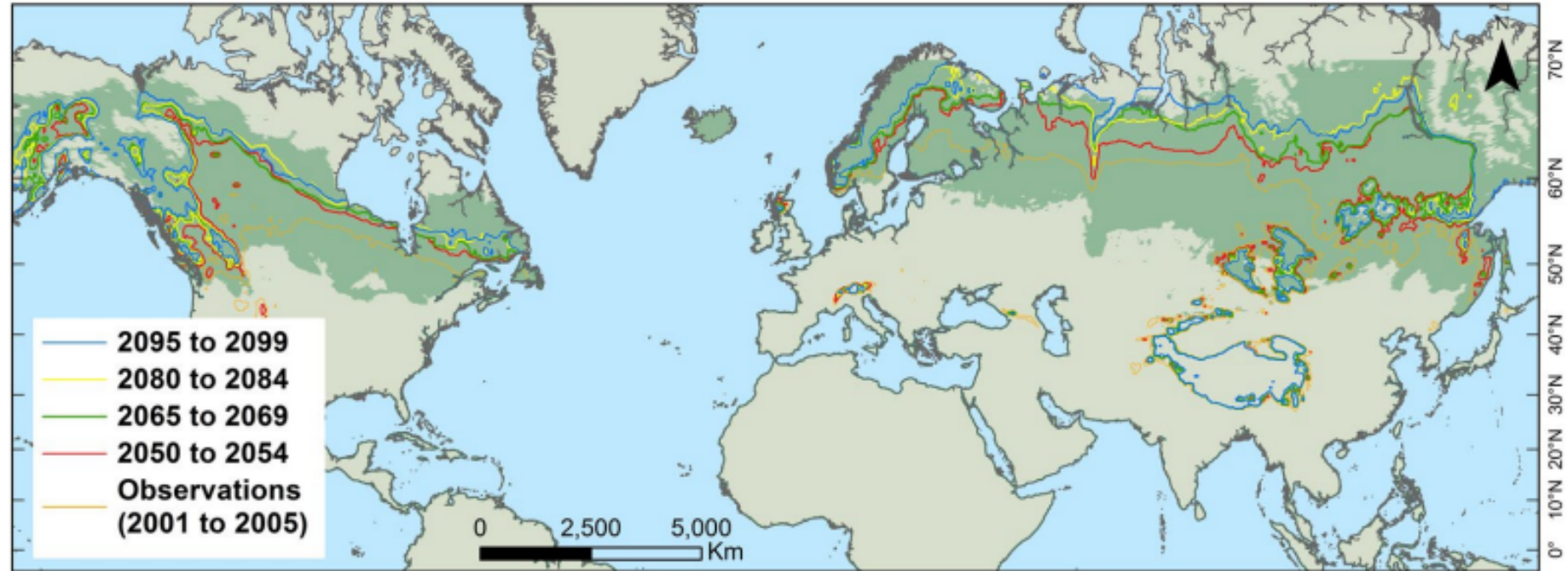


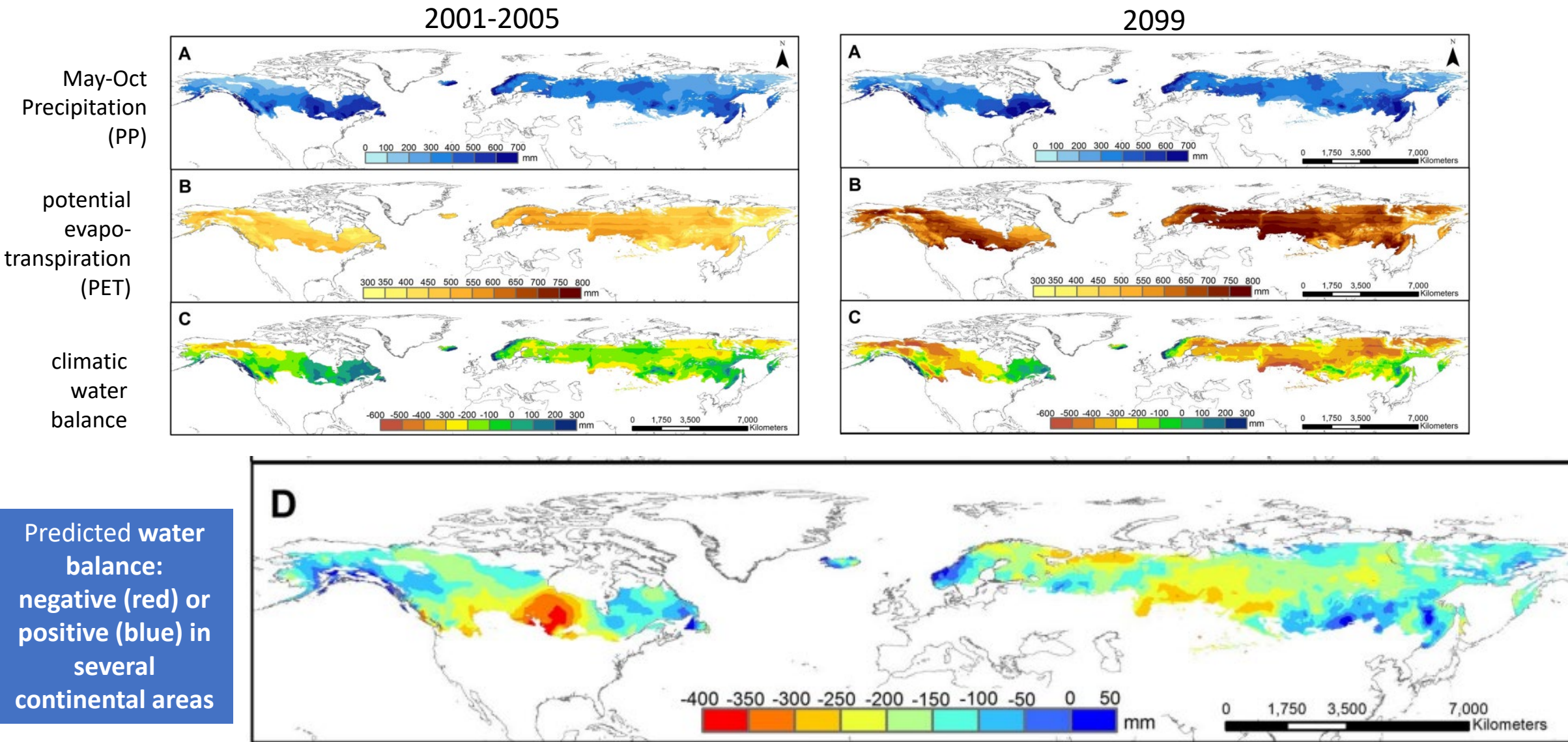
Figure 1. Projected advances of the $\text{GDD}_5 \geq 1200$ boundary. The green area describes the current extent of the boreal region^{66,67}. GDD_5 values were estimated by averaging the projections of seven CO_2 emission based GCMs (Extended Data Table 1). Each time step describes a five-year average of all estimates by the seven GCMs. The variability in projection among models is presented in Fig. 4 and Table 1. Map created using ArcGIS Desktop v. 10.4.1⁶⁵.

King et al (2021) Sci Rep

We could benefit in the short term by adjusting the choice of genotypes and sowing dates

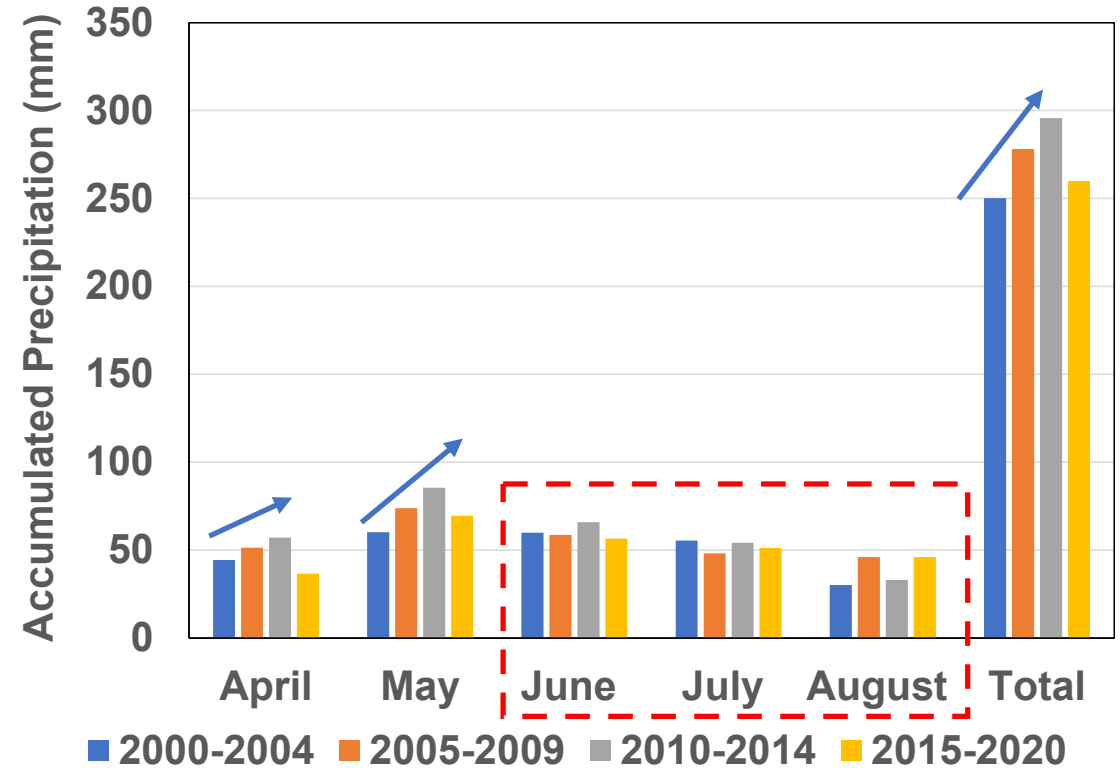
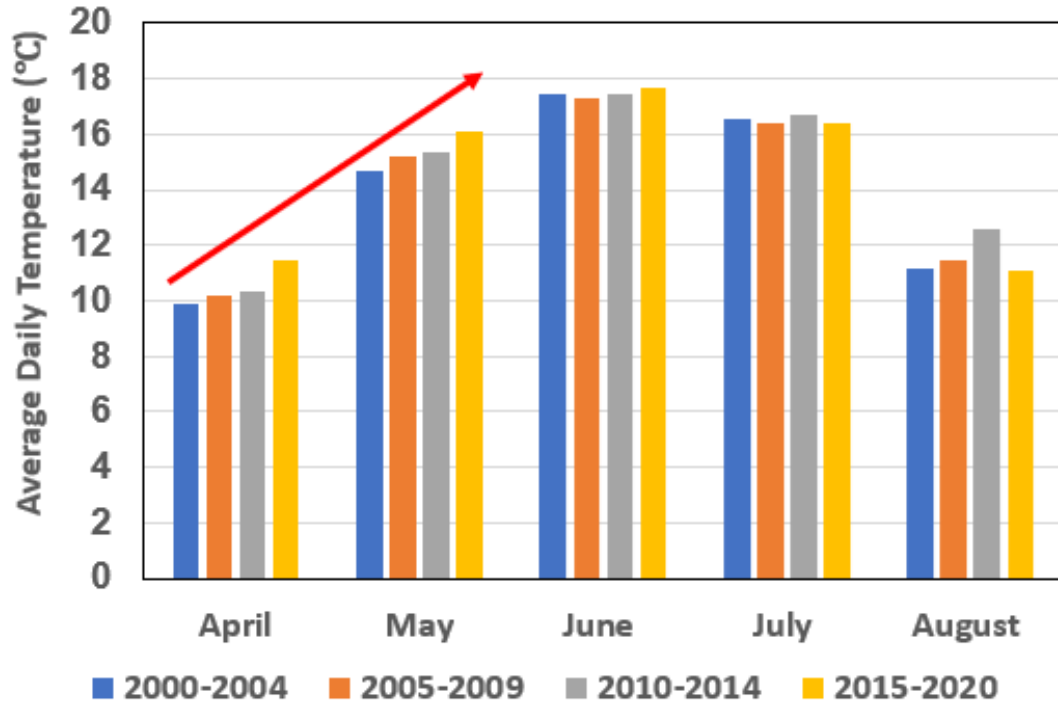
Northward shift of the agriculture

Most of the new areas are associated with highly seasonal and monthly variations in water balances



Uneven rains are one of the main limitation for canola cropping

Changes of rain and temperature in the Canadian Prairies in the past 20 years (2000-2020)



Temperatures have increased in April and May

Total Precipitation has increased - Predominantly in April and May but not in the summer months

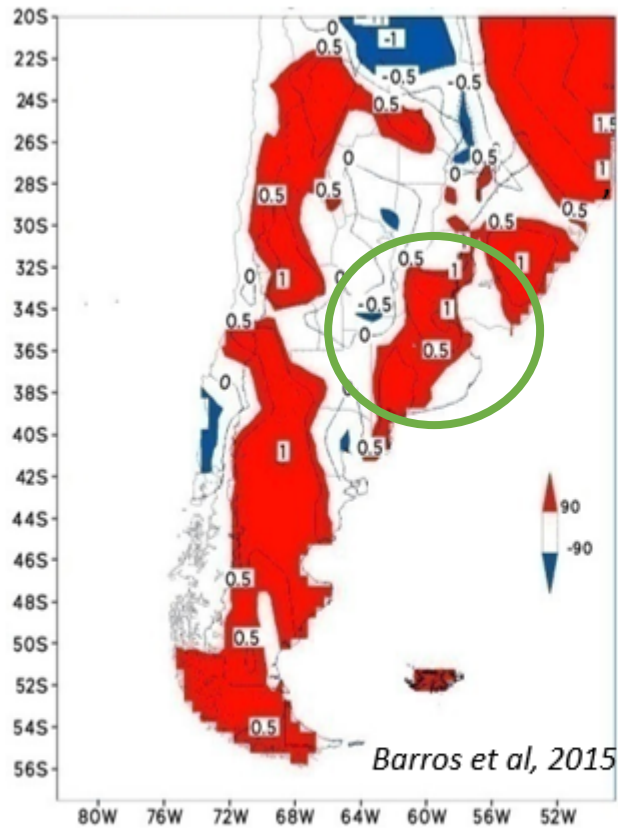
Source: Malcolm Morrison

We can take advantage of wet years and adopt a 'defensive management' in dry years

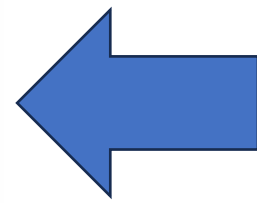
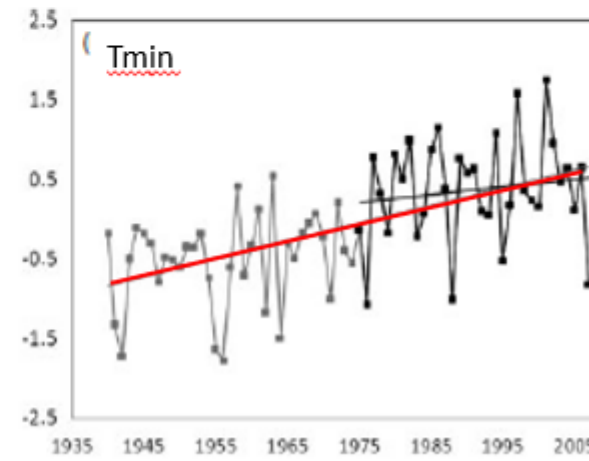
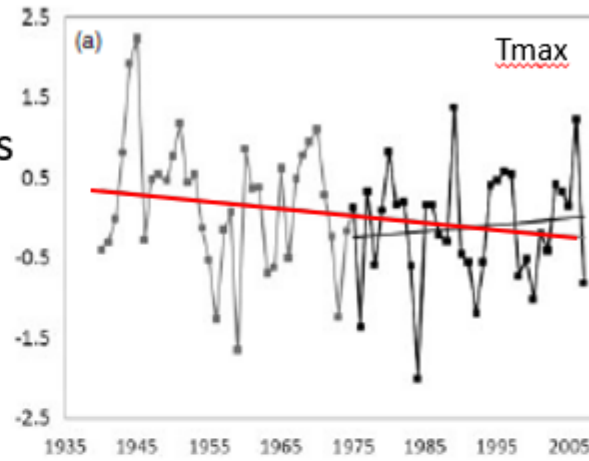
Asymmetric increase in average daily temperature

Greater increase in night temperatures in South America

Climate change in South America: Warmer nights



Asymmetric Warming in the Pampas region. The Pampas is a mostly flat area in central-eastern Argentina and Uruguay, extending 50 M ha



Changes in mean temperature (annual mean temperature) from 1960 to 2010: Mean temperature increased from 0.5 to 1 degree

Fernández Long et al, 2012 (Int. J. Climatol.)

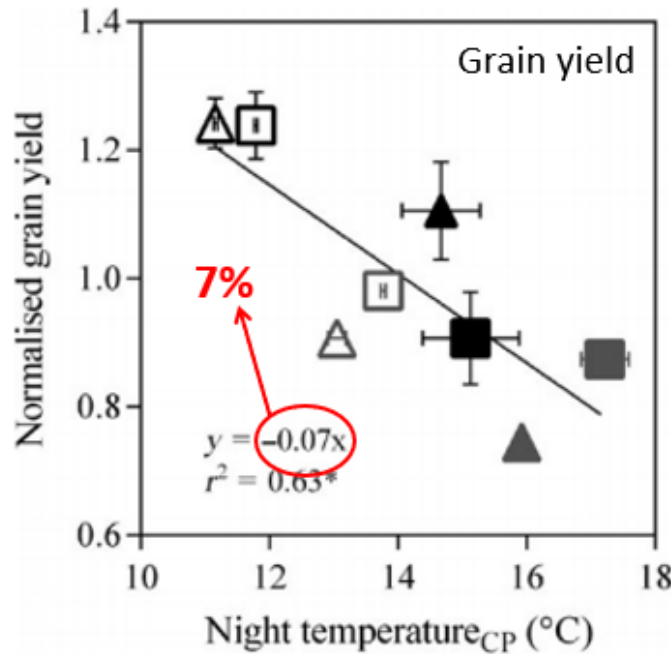
Source: Daniel Miralles

Warm nights during critical period in wheat and barley: A Field approach



Warmer nights during the critical period from stem elongation to flowering

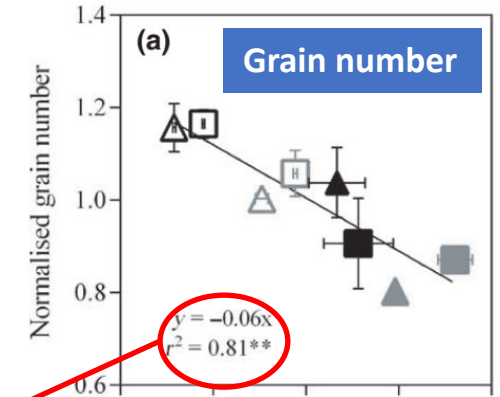
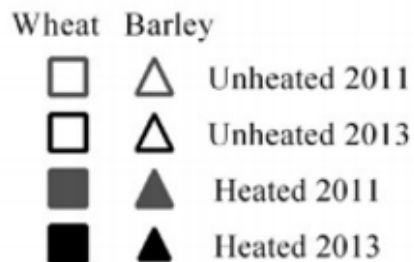
On average, heating -applied from 7 PM to 7 AM -increased night air temperature at spike height by ca. 3.9 °C



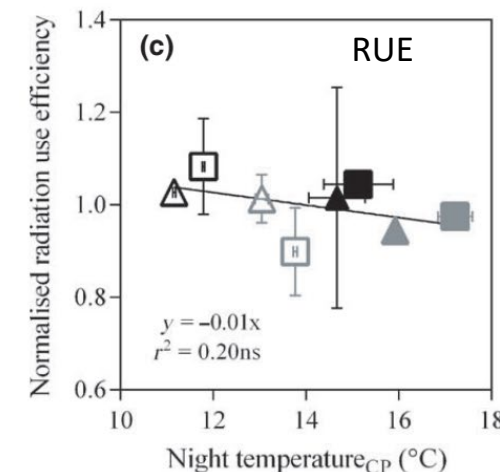
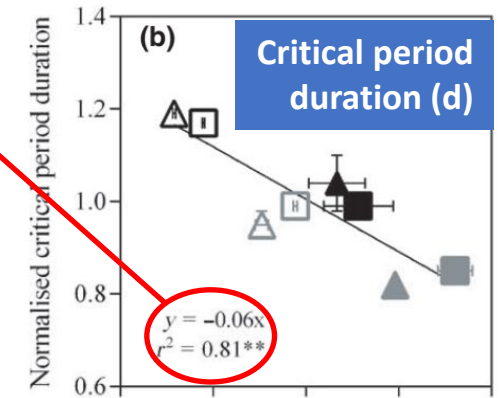
Wheat and barley grain yield loss was 7% per degree of increase in night temperature during the critical period.

High night temperatures during the critical period reduced the time to anthesis and Grain number per unit area by ca. 6%.

Warmer nights reduced the biomass due to lower cumulative radiation interception without changes in Radiation use efficiency.



6%

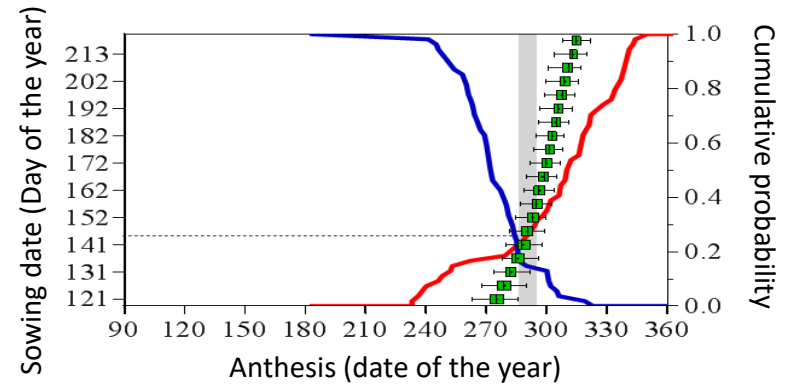


Warm nights during grain filling in wheat and barley: A field Approach

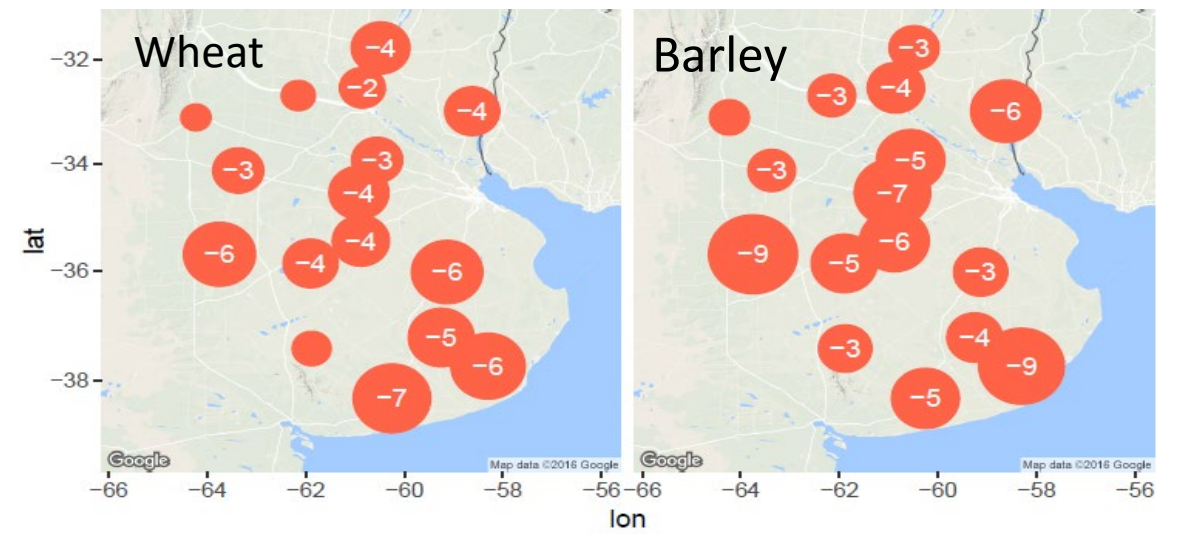


From 10 days after flowering to maturity
Night heating from 7 PM to 7 AM

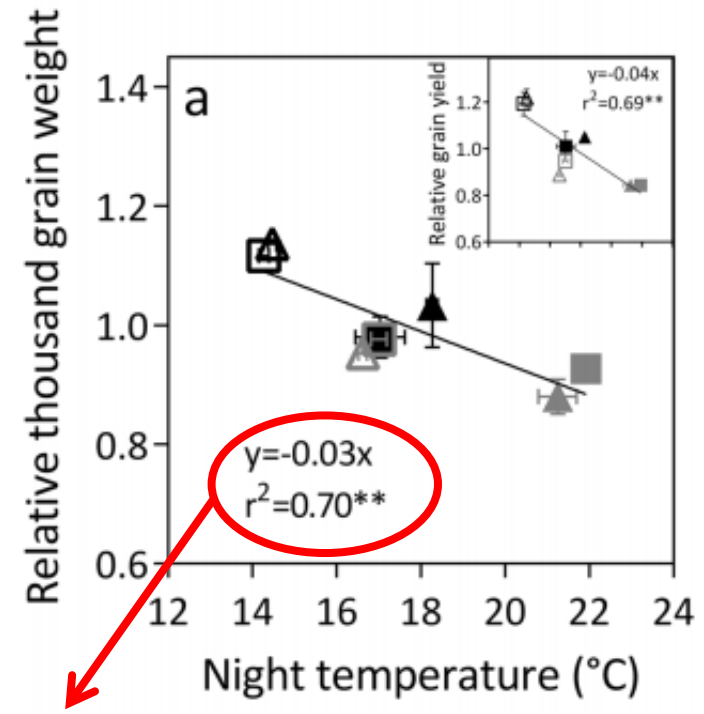
APSIM
AGRICULTURAL PRODUCTION SYSTEMS SIMULATOR
<http://www.apsim.info/>
1960-2015



Simulated relative potential yield response (% per °C) to minimum temperature variations during the critical period

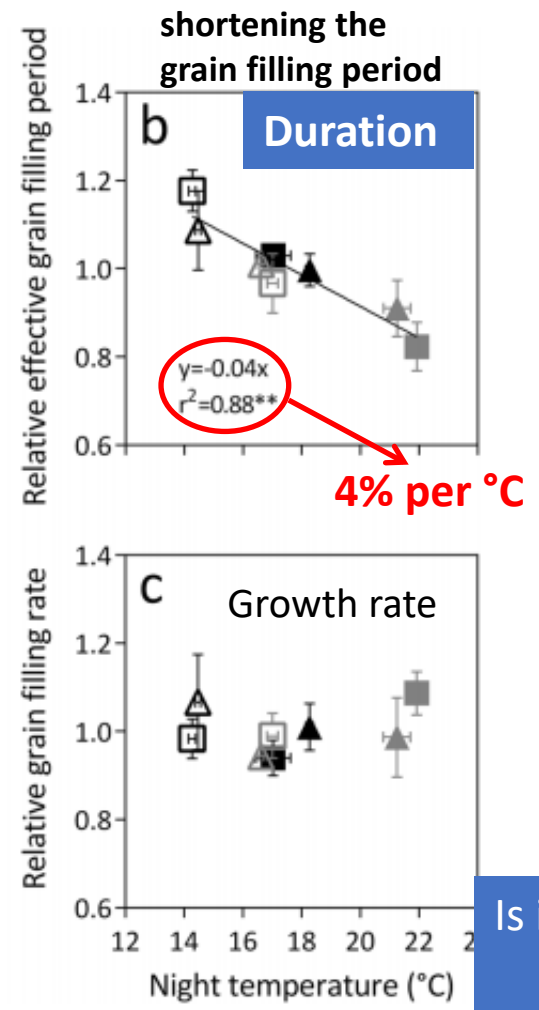


Average yield reduction: **-4% per °C** in wheat, **-5% barley**
Duration of critical period was reduced **1 day per decade** due to **warmer nights** in most locations.



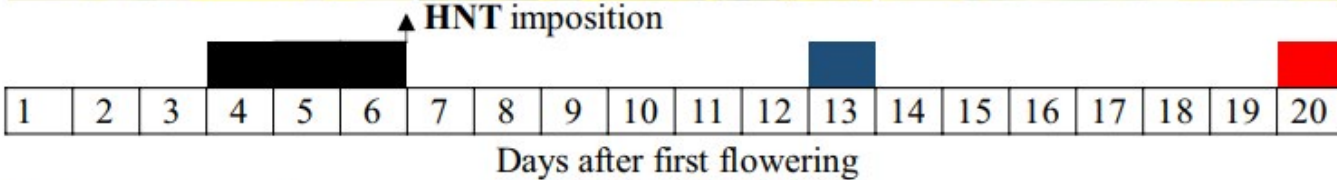
3% per °C

	Wheat	Barley	
2011	□	△	A-NT
	■	▲	H-NT
2013	□	△	A-NT
	■	▲	H-NT



Is it similar in canola? Do we need new genotypes with a longer critical period? (in days, for the same flowering date). How much variability is there for post-flowering duration?

High night temperature in Winter canola



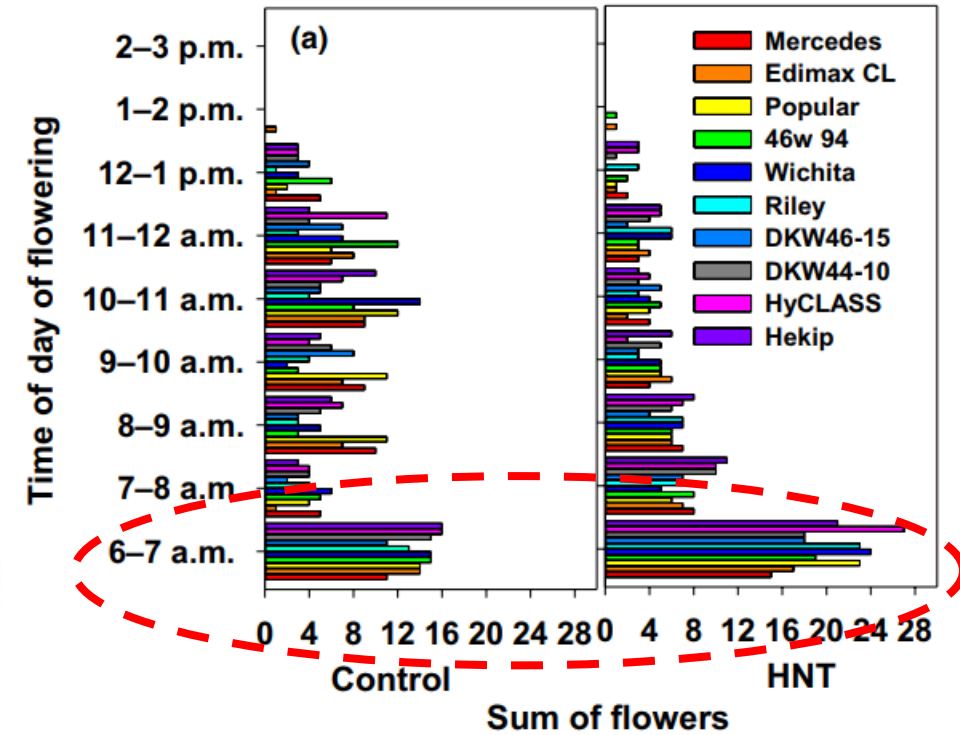
HNT impact on pod setting and pod filling

HNT impact on flowering, pod setting and pod filling

HNT impact on gametogenesis, flowering, pod setting & pod filling

	Control (23/15)	HNT (23/20)
Grain yield (g/pl)	27	22
Oil (%)	40	38

Pockharel et al (2020) JACS

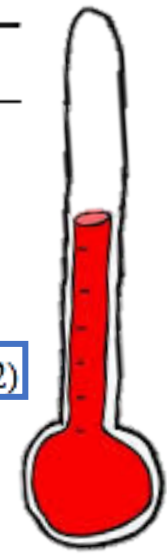


Peak flower opening earlier in the morning when exposed to warm nights

Direct effect of warm nights on canola vernalization, floral induction, and its interaction with photoperiod merit further analysis

High temperature: Thermal thresholds for crops

Crop plants	Threshold temperature (°C)	Growth stage	References
Wheat	26	Post-anthesis	Stone and Nicolás (1994)
Corn	38	Grain filling	Thompson (1986)
Cotton	45	Reproductive	Rehman et al. (2004)
Pearl millet	35	Seedling	Ashraf and Hafeez (2004)
Tomato	30	Emergence	Camejo et al. (2005)
Brassica	29	Flowering	Morrison and Stewart (2002)
Cool season pulses	25	Flowering	Siddique et al. (1999)
Groundnut	34	Pollen production	Vara Prasad et al. (2000)
Cowpea	41	Flowering	Patel and Hall (1990)
Rice	34	Grain yield	Morita et al. (2004)



Lethal temperature
> 50°C

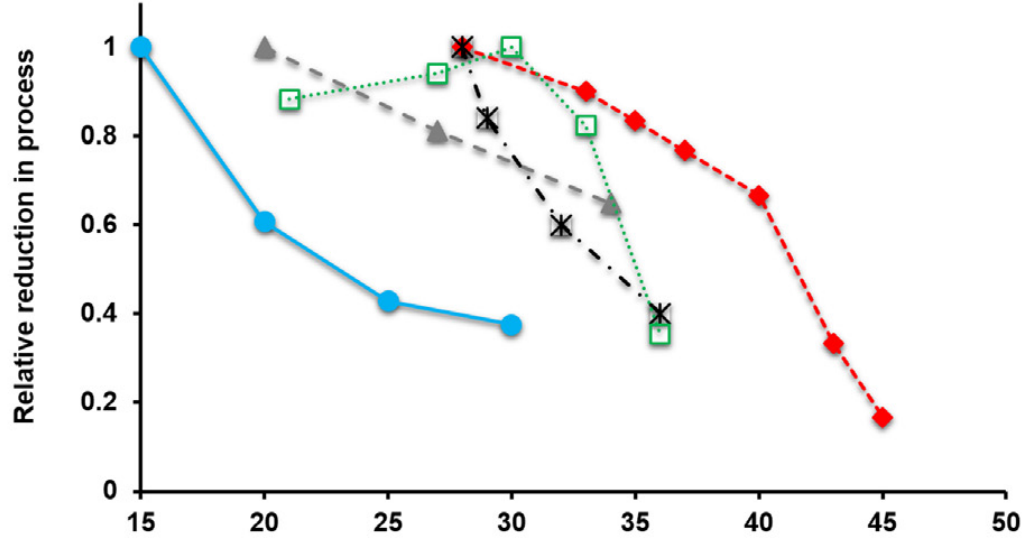
Very high temperature
from 29-32 to 50°C

Moderately high temperatures
from 15 to 32°C

Stone, 2001



-♦- Photosynthesis (Salvucci and Crafts-Brandner, 2004)
 -▲- Stomatal conductance (Shah and Paulsen, 2003)
 -✕- Grain number per ear (Ferris et al., 1998)
 Wahid et al, 2007
-●- Grain filling period (Tashiro and Wardlaw, 1990)
-□- Grain filling rate (Tashiro and Wardlaw, 1990)



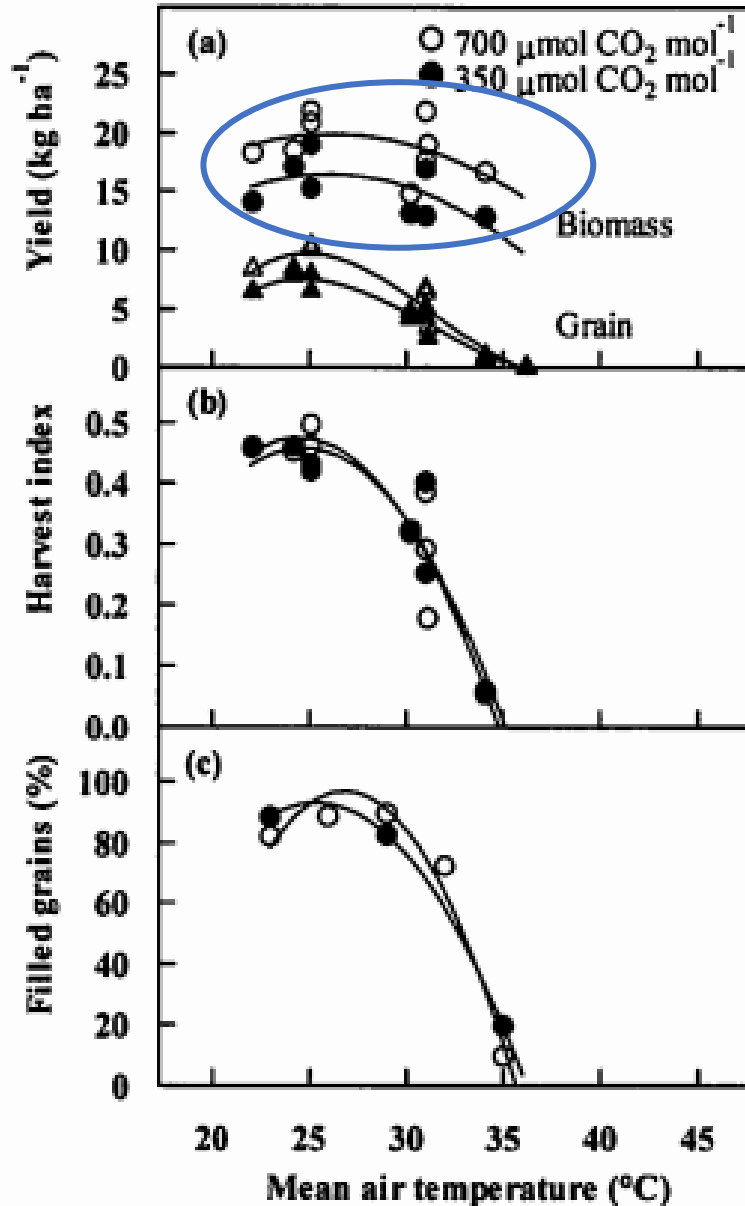
Eyshi Rezaei et al, 2015 EJA

Most negatively affected by high temperature:

Crop development rate

Floral development

High mean temperature and CO₂



High mean temperature and CO₂ for the whole crop cycle

Well-watered



Positive effects of temperature and CO₂ on biomass

High temperatures >25-30°C affect the reproductive stages more than the vegetative stages

Detrimental effects of high temperatures on grain number, with no benefit from high CO₂

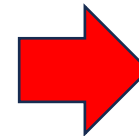
Well-watered plants reduce the effect of heat due to the transpiration cooling

Stomatal closure due to drought or high CO₂ reduces the transpiration cooling and rises canopy temperature



Positive effects of high CO₂ and temperature on biomass of C3 species will depend on water availability ('carbon fertilization' will depend on water balance)

Failures in pollen germination, pollen tube growth and grain set caused directly by high temperature, and not improved by more carbon, water or nutrients



The same is true for canola, with high temperatures affecting flower development and grain setting

Extreme events: heat shock

Some facts:

There are **no positive consequences** of this effect of climate change for grain yield

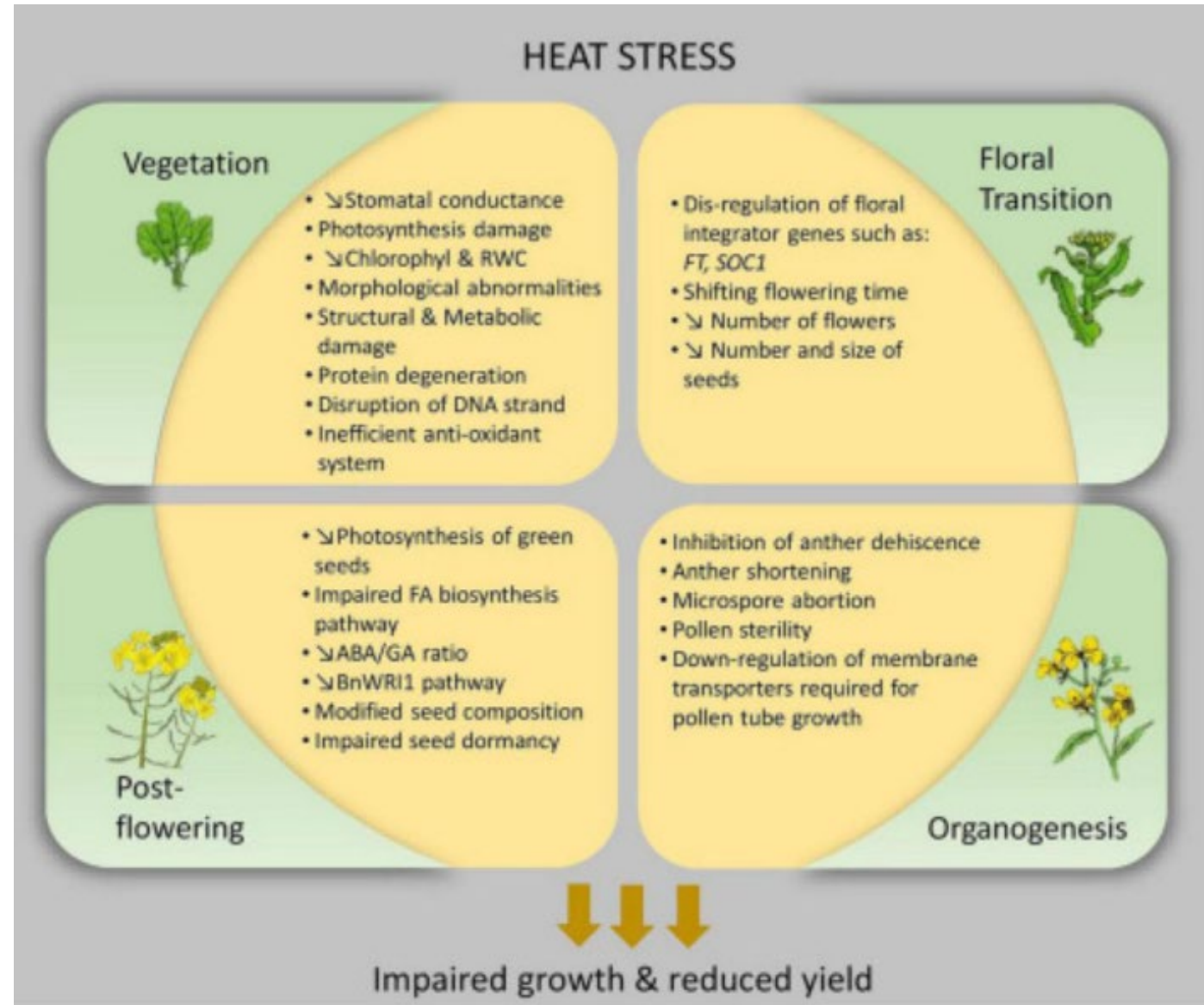
Predicting and adapting to it is more complex

It reduces crop productivity, especially when they occur in the **reproductive stages** of the crop cycle, which are more sensitive to the environment

We know some of the effects of **individual stress**

But we know less about **stresses in combination under field crop conditions**

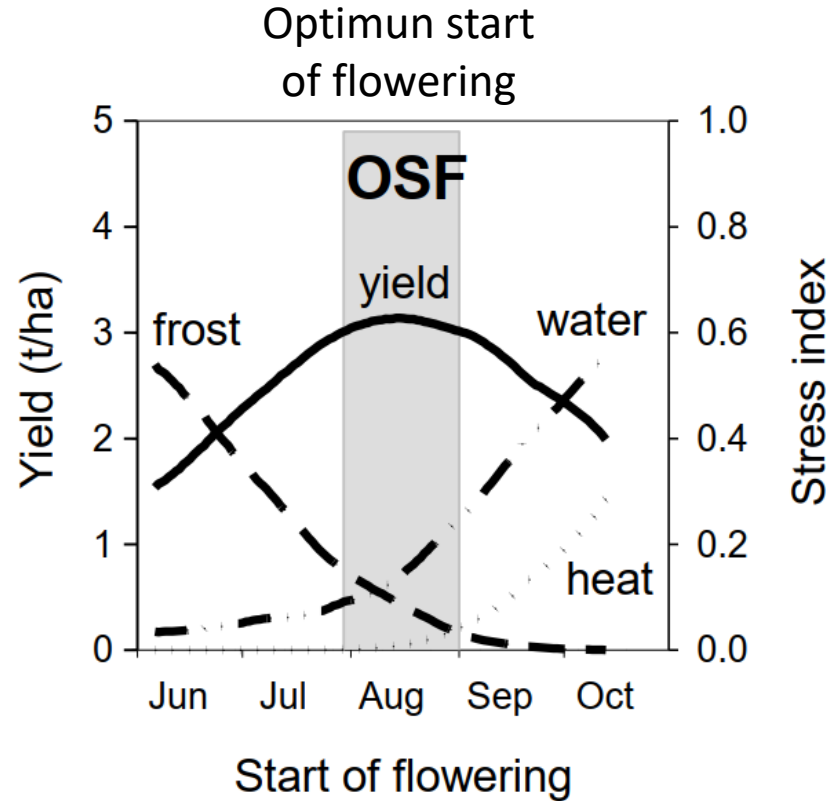
Often, different stresses share the same signaling and response pathways, facilitating the identification of genotypes with **tolerance to multiple stresses**



Escape or tolerate

The adjustment of the crop phenology, through the choice of the genotype and the sowing date, allows to locate the sensitive reproductive window in periods of low risk

Of course, this requires **reliable climate forecast systems** that predict risk several months in advance



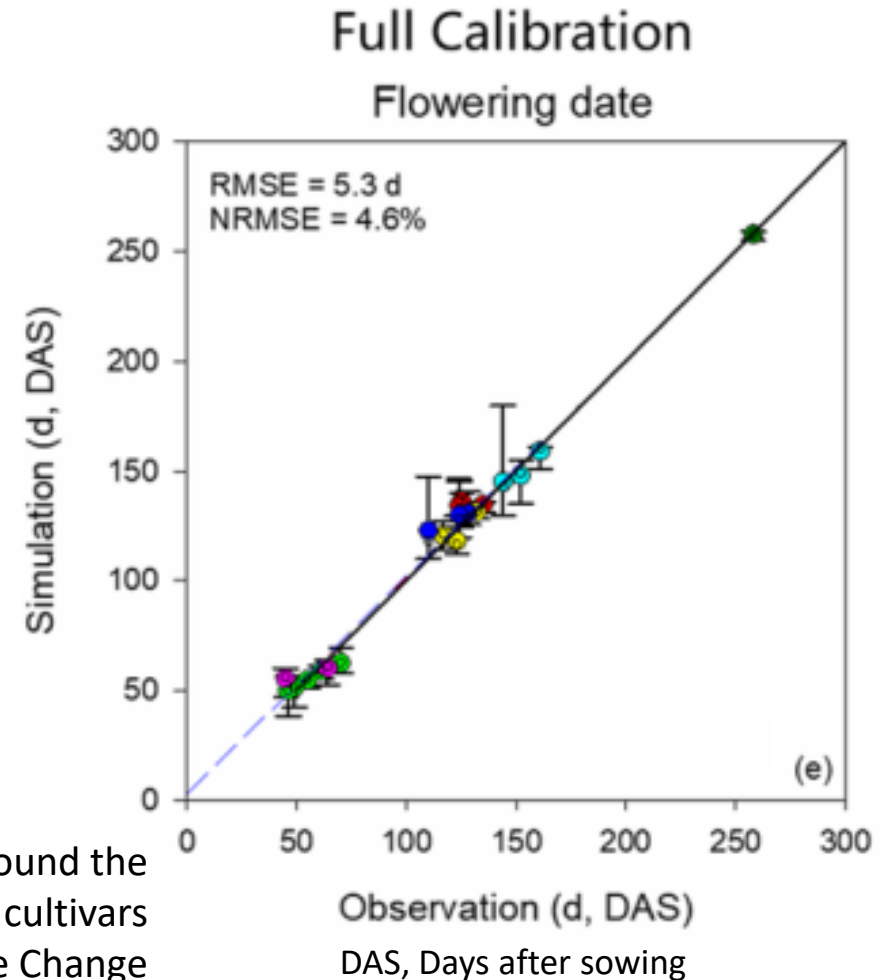
Lilley et al (2019) Field Crops Res

Simulation of biomass and grain yield under climate change requires further adjustments

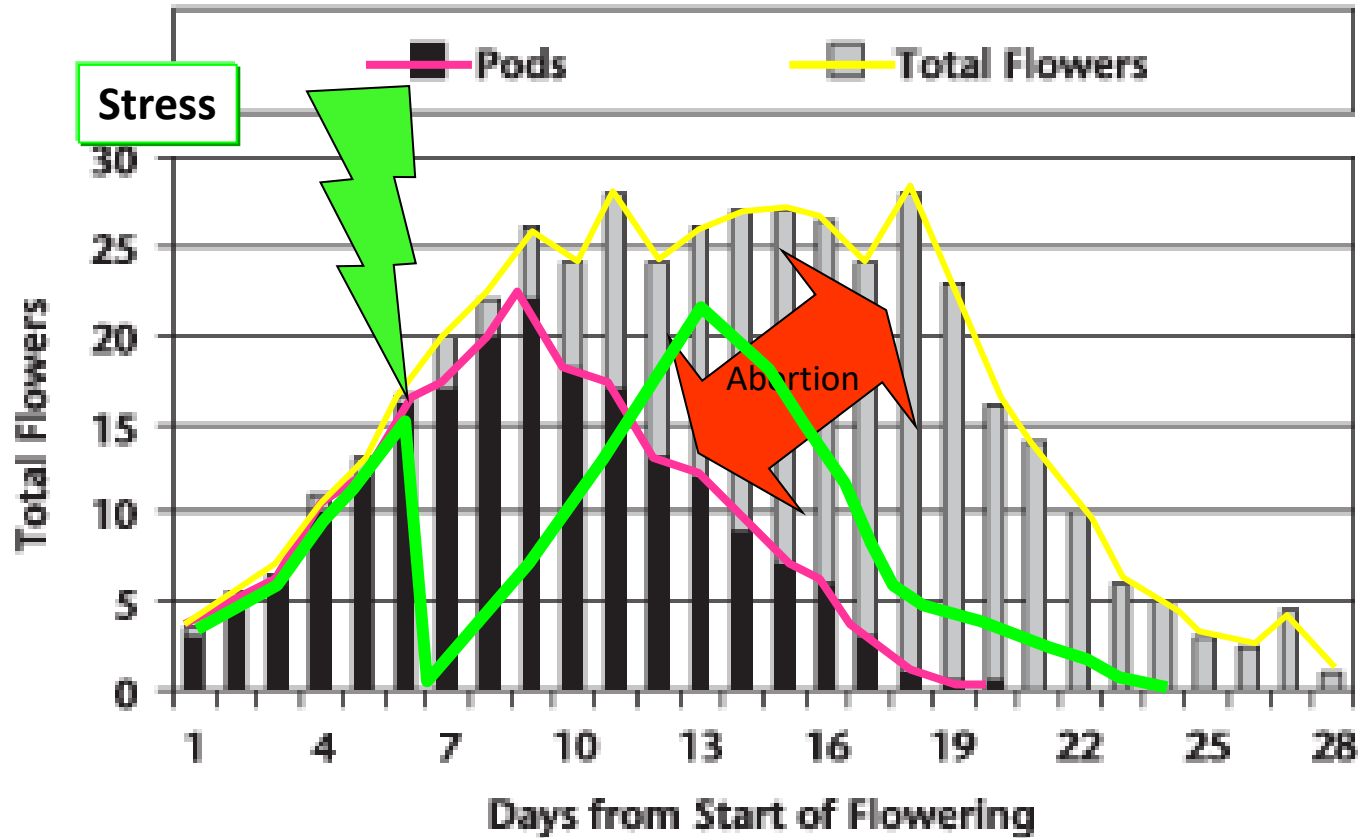
Rapeseed has a wide range of winter and spring cultivars with enough flexibility to adjust the time to flowering

Simulation models that successfully predict canola phenology under contrasting weather conditions

Data from 8 crop models, 6 sites around the world, including winter and spring cultivars
Wang et al (2022) Climate Change



Escape or tolerate



Tayo & Morgan (1975) J Agric Sci

Reproductive plasticity traits: floral branching, extended flowering, adjustment of grains per pod

generate flowers in different positions of the canopy

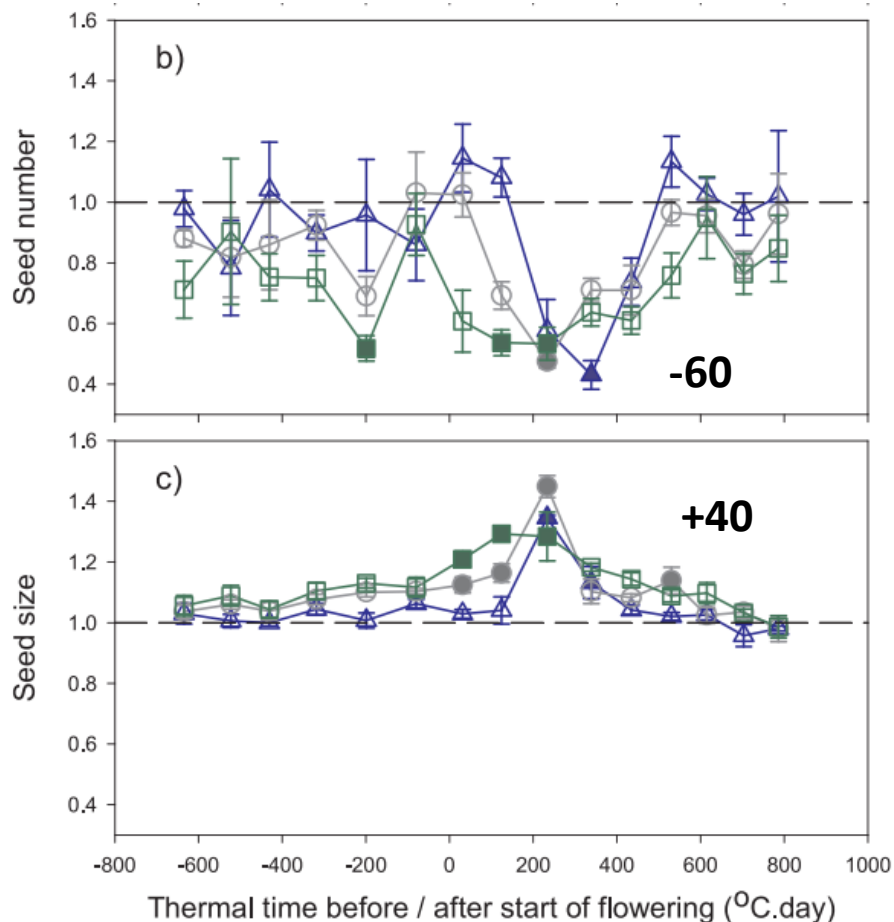
allow reaching a high number of grains in a range of environmental conditions even after stress

Genetic improvement seeks stress-tolerant genotype, particularly for pollen formation, flower fertilization, and grain set

Improvements in oxidative damage repair, rapid recovery of water status, and recovery of enzymatic activity post-stress are promising attributes to tolerance multiple stresses

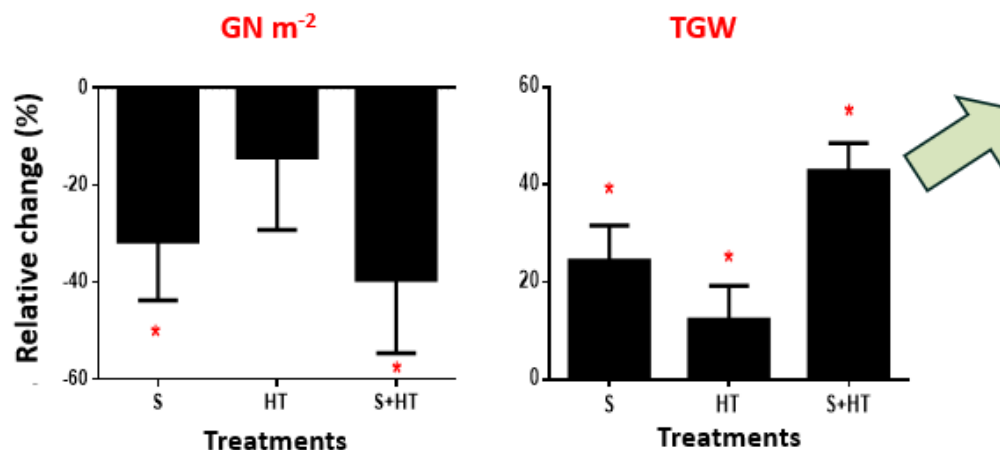
Grain weight compensation when grain number falls

Partial compensation



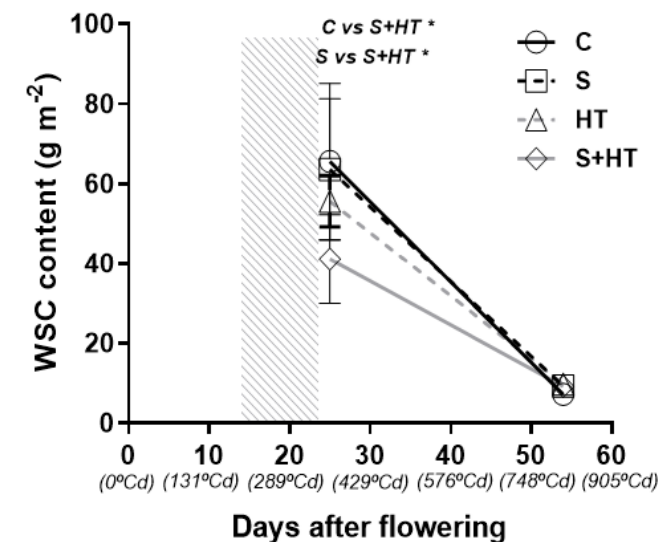
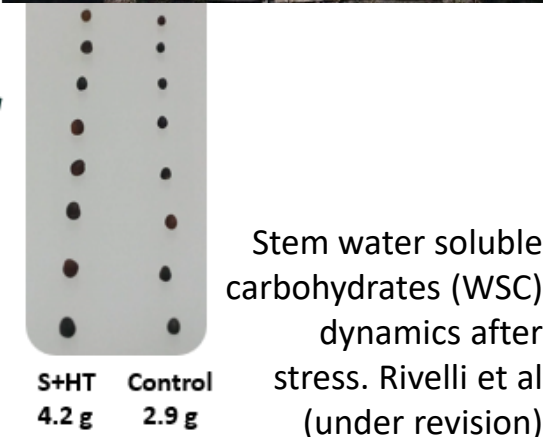
Effects of timing of shading on seed number and seed weight across floral positions, relative to unstressed control. Kirkegaard et al (2018) Field Crops Res.

Total compensation



Effects of shading (S), high daytime temperature (HT) and combined stresses (S+HT) on grain number and seed weight, relative to unstressed control in a high-yielding environment. Rivelli et al (poster # 283)

The ability to increase grain weight when grain number falls, and remobilize stem reserves to sustain grain growth are beneficial plasticity attributes under stressful conditions



There are opportunities to exploit these traits in the short term

Concluding remarks

- Reach net zero quickly
- Genetic improvement for high grain yield (positively drives the entire production)
- Genetic improvement for multiple stresses
- Improve rain forecasts
- Prepare for boreal agriculture (new cultivars, long photoperiod, deforestation)
- Improve simulation models for biomass and grain yield under climate change (considering warm nights and heat stress)

Take advantage of canola plasticity

- Flexible phenology
- Branching capacity
- Low trade-off seed number and seed weight
- Recovery capacity after stress

We face great challenges. There is no time to lose!



Daniel Miralles



Javier Botto



Gabriela Abeledo



Gonzalo Rivelli



Malcolm Morrison



Julianne Lilley



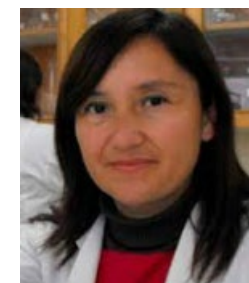
John Kirkegaard

**Thanks for your
attention**

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