

Seasonal prediction of wheat yield and its sensitivity to environmental conditions in the semi-arid Mediterranean

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Agricultural Research Organization



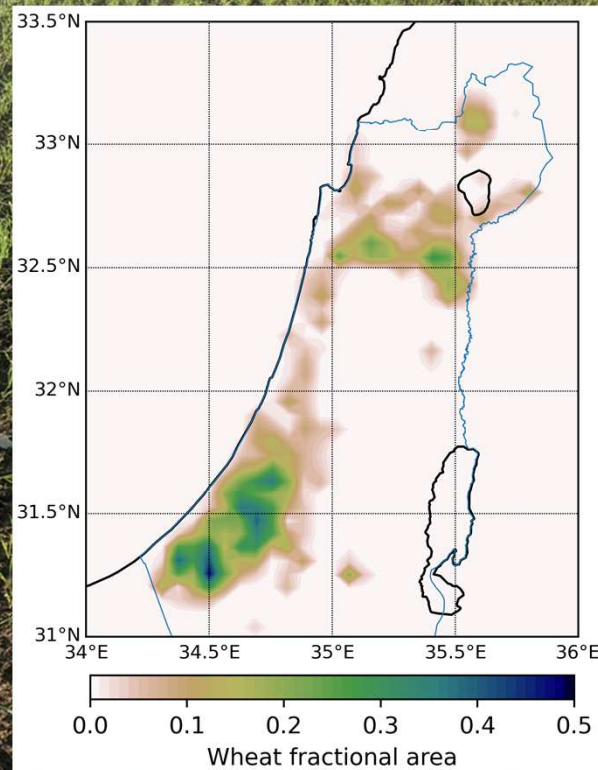
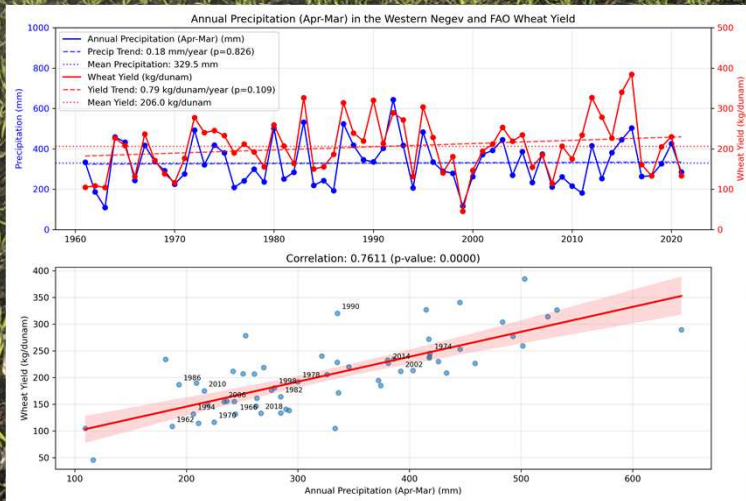
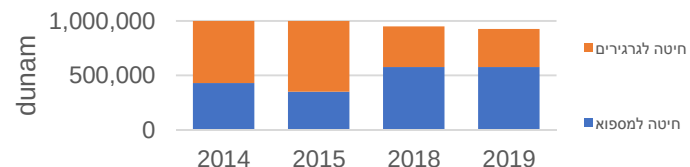
**Ministry of
Agriculture and
Food Security**



AGROCLIMATOLOGY

Wheat in Israel

Designation of the grain/fodder wheat areas



The Israeli wheat sector is based on spring-type wheat, but its growing season occurs during the winter months

About 50% of the wheat is harvested for forage in March–April

High concentration of fields in the northern Negev region

Sensitive to climate change and to inter-annual variability – mostly rainfed farming

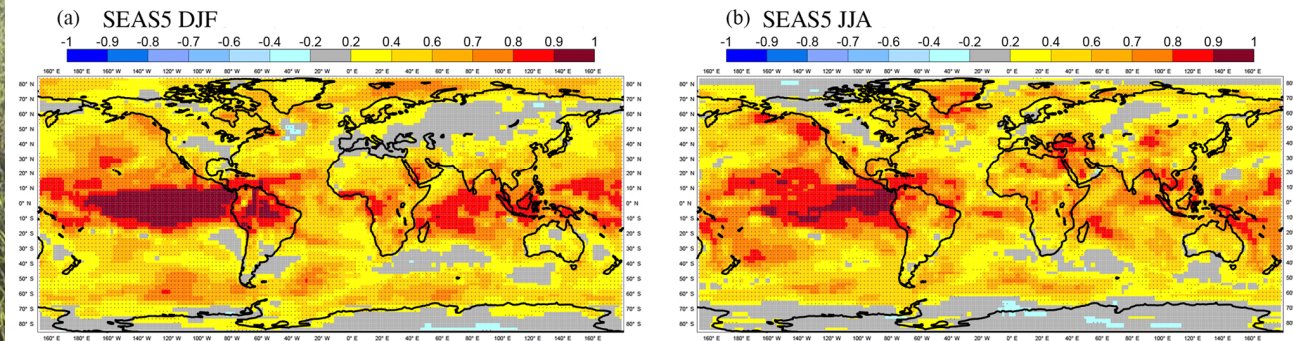
Why seasonal wheat forecasts?

- Alert farmers, policymakers, and stakeholders to seasonal risks
- Enable climate-informed management decisions:
 - Cultivar choice
 - Sowing and harvest timing
 - Fodder (silage/hay) vs. grain
 - Irrigation scheduling
 - Crop rotation

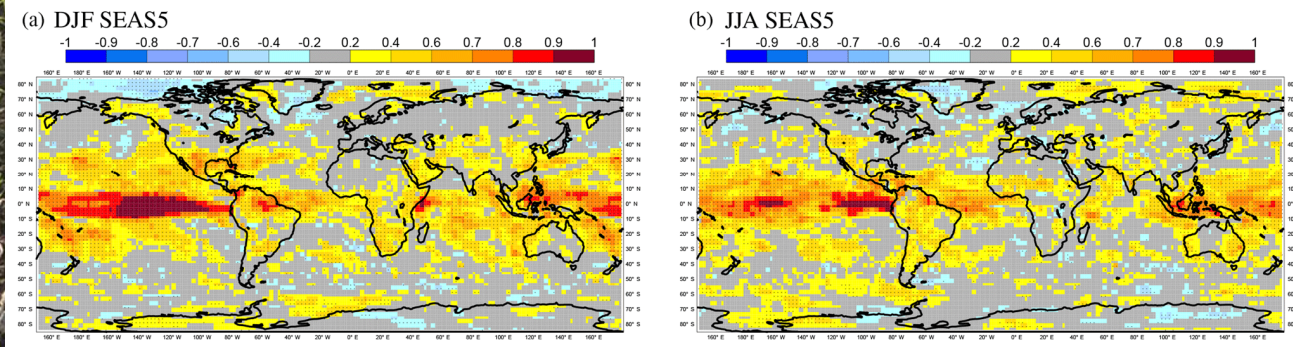


Seasonal prediction systems

Surface temperature anomaly correlation – one month lead



Precipitation anomaly correlation – one month lead

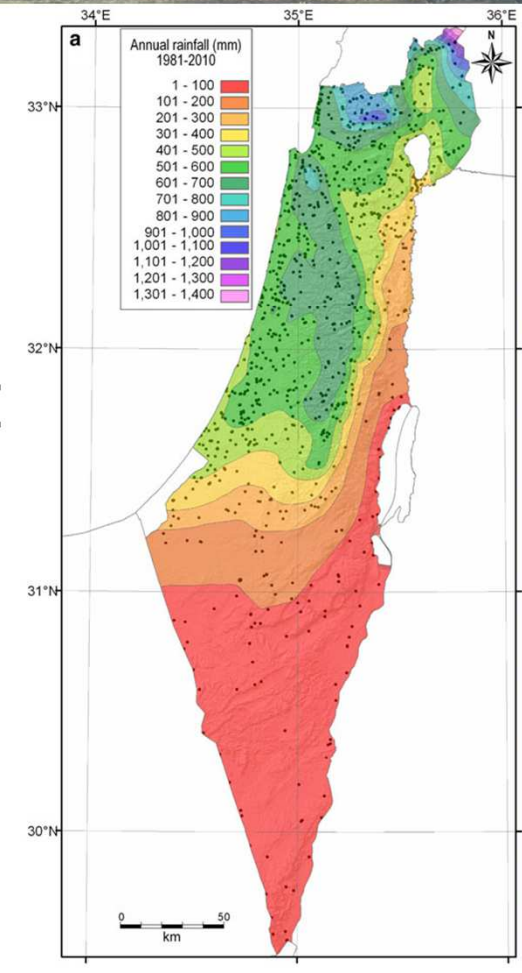
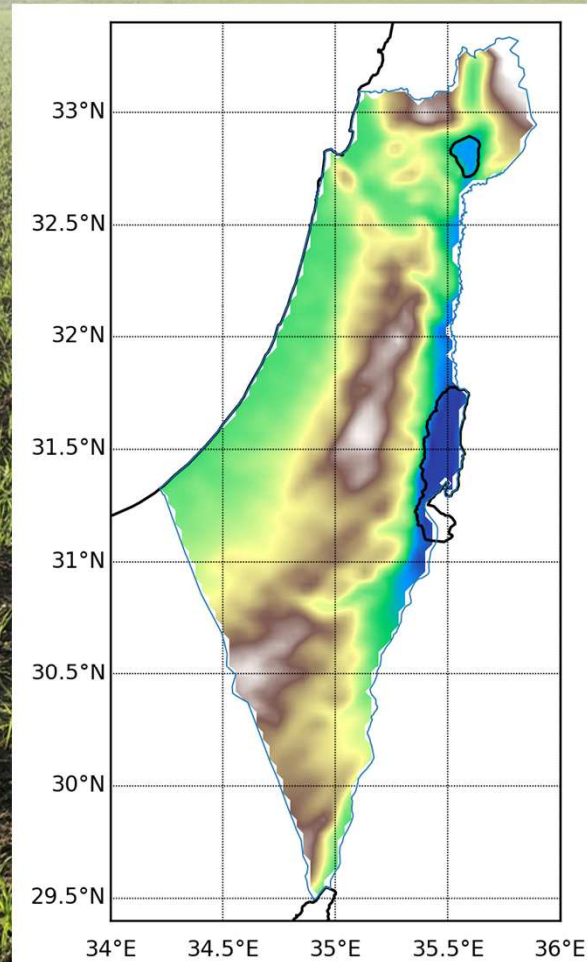


- Seasonal prediction systems have potential prediction skill arising from the slow varying process in the ocean and the land surface
- Operational forecasts are currently performed at low horizontal resolution (~0.5°)

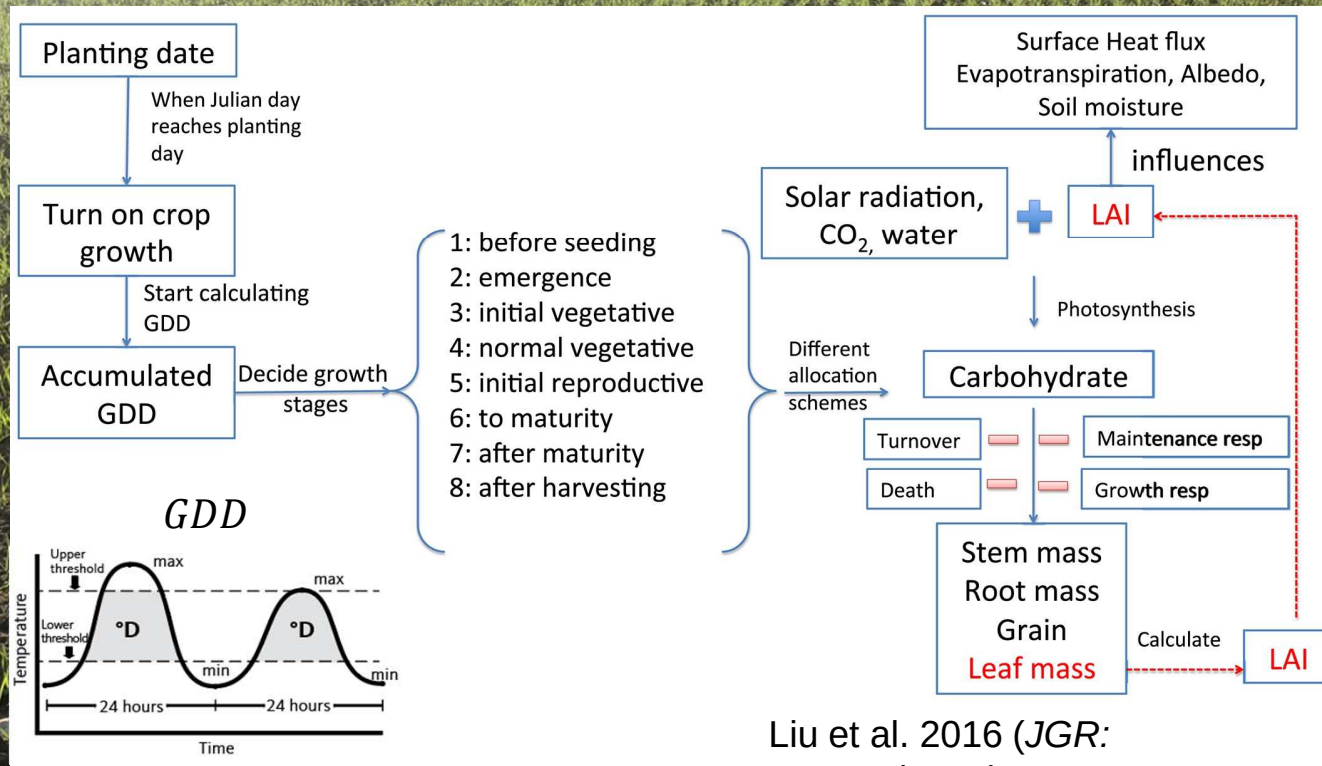
Johnson et al. 2019
(Geoscientific Model Development)

Israel's topography and rain

- Complex topography
- Sharp precipitation gradients, north-south and west-east



NoahMP-Crop model

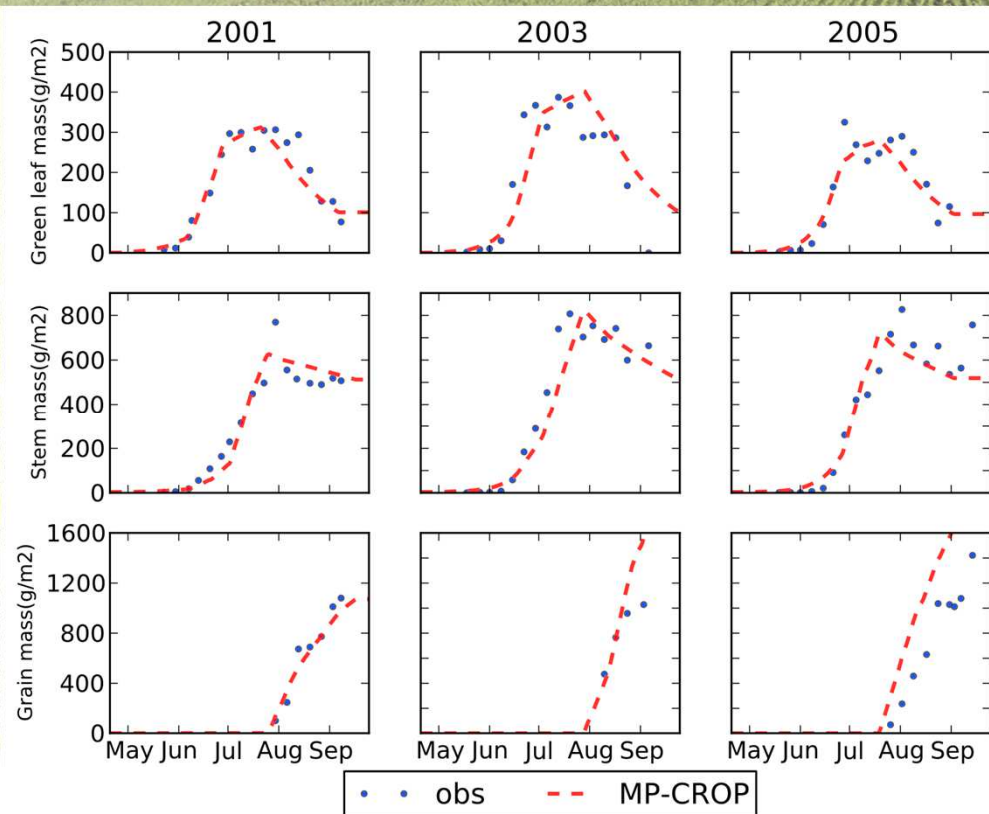


Liu et al. 2016 (JGR:

Atmospheres)

Includes a component for water and heat transfer in the soil

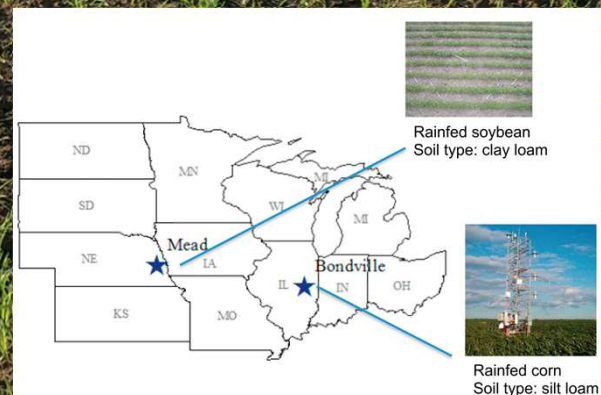
A coupled version to the WRF weather and climate model exists, enabling modeling of the plant-environment interaction.



Liu et al. (2016), *Journal of Geophysical Research: Atmospheres*

NoahMP-Crop Maize and soybean in the United States

Model values versus
observations of leaf, stem and
grain biomass for maize in
Bondville, USA



FIELD LOCATIONS

Season 3: 2024-25

YZ
EY
CW
SQ
MD
AV
ML
KS
ON
SF
BK
RS

Season 2: 2023-24

IC
SH
YS
RV
KM
NH
KN
KW
MH

Season 1: 2022-23

115
165
236
BH
8-NORTH
ZEITEM
URIM
D-WEST
YASHAM-5

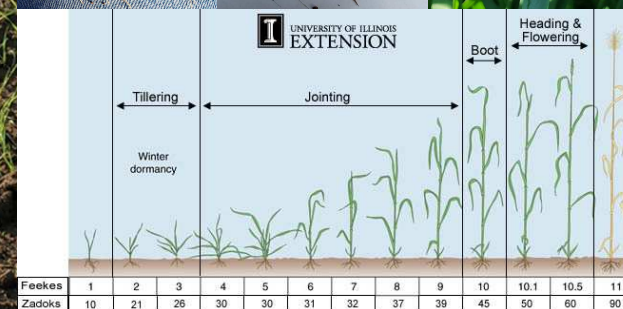
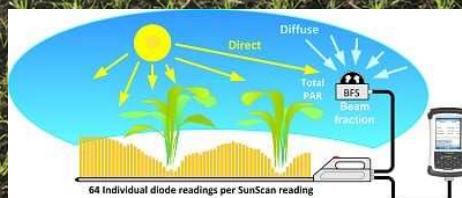


FOR SPRING WHEAT

Calibration for Israeli wheat cultivars

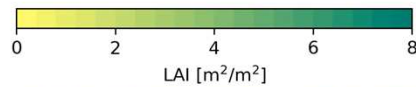
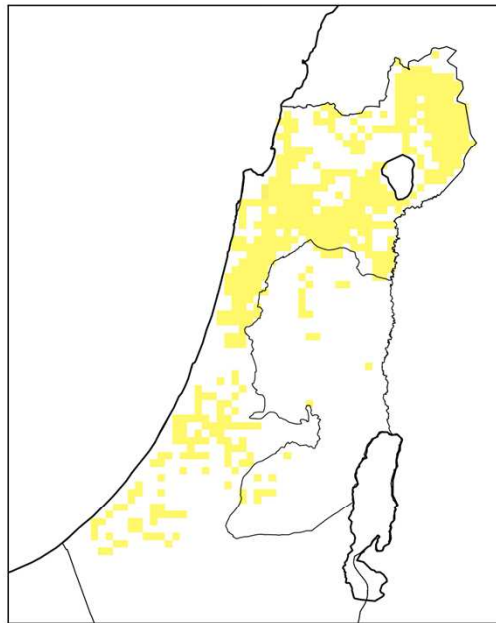
- Commercial wheat fields
- 3 seasons
- ~10 fields per season
- 30 fields in total
- Field visits every 1–2 weeks

Calibration for Israeli wheat cultivars

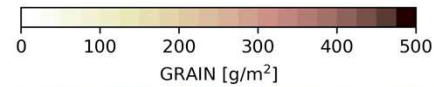


2016-2017

2016-11-01T00:00

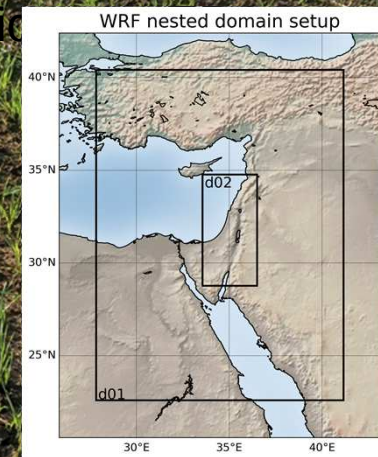


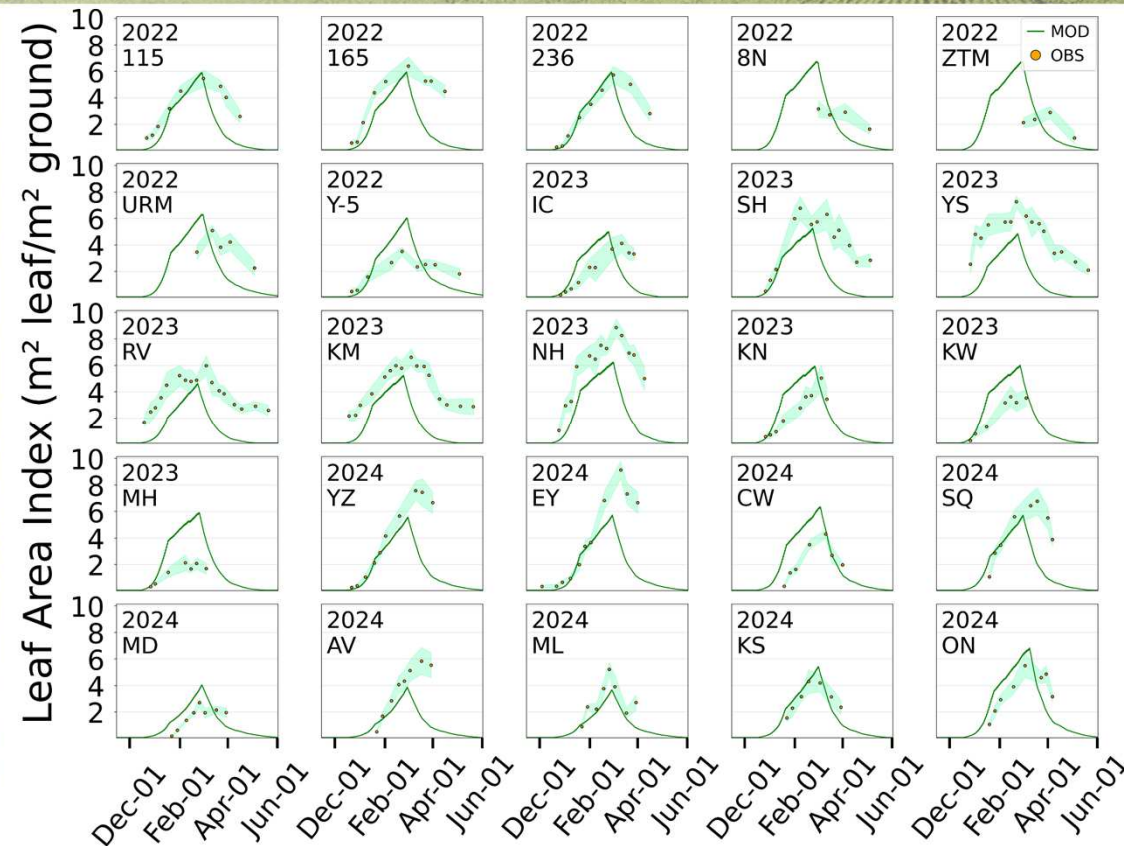
2017-01-25T00:00



Calibration for Israeli wheat cultivars

- WRF climate model
- 2016-2017
- Sowing date: November 1st
- Boundary and initial conditions



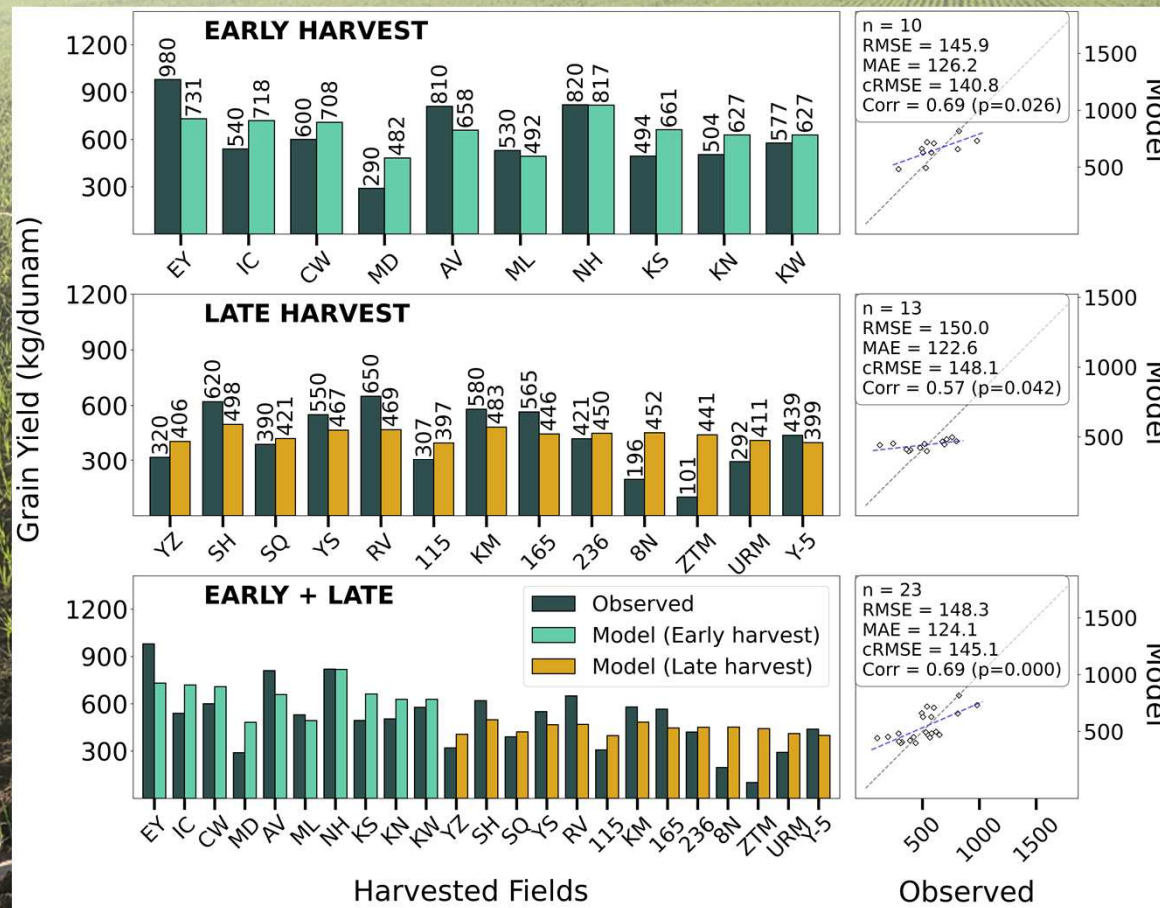


Model vs. observation

Leaf area index (LAI)

Three seasons

- 2022–2023
- 2023–2024
- 2024–2025



Model vs. observations

Total aboveground biomass and grain yield

Three seasons:

- 2022-2023
- 2023-2024
- 2024-2025

The seasonal prediction system

Config	Microphysics	Radiation (LW/SW)	PBL scheme	Surface layer
A	WSM6	CAM	YSU	Revised MM5
B	WSM6	RRTMG	YSU	Revised MM5
C	Goddard 4-ice	CAM	YSU	Revised MM5
D	Goddard 4-ice	RRTMG	YSU	Revised MM5
E	WSM6	CAM	MYJ	Janjic (Eta)
F	WSM6	RRTMG	MYJ	Janjic (Eta)
G	Goddard 4-ice	CAM	MYJ	Janjic (Eta)
H	Goddard 4-ice	RRTMG	MYJ	Janjic (Eta)

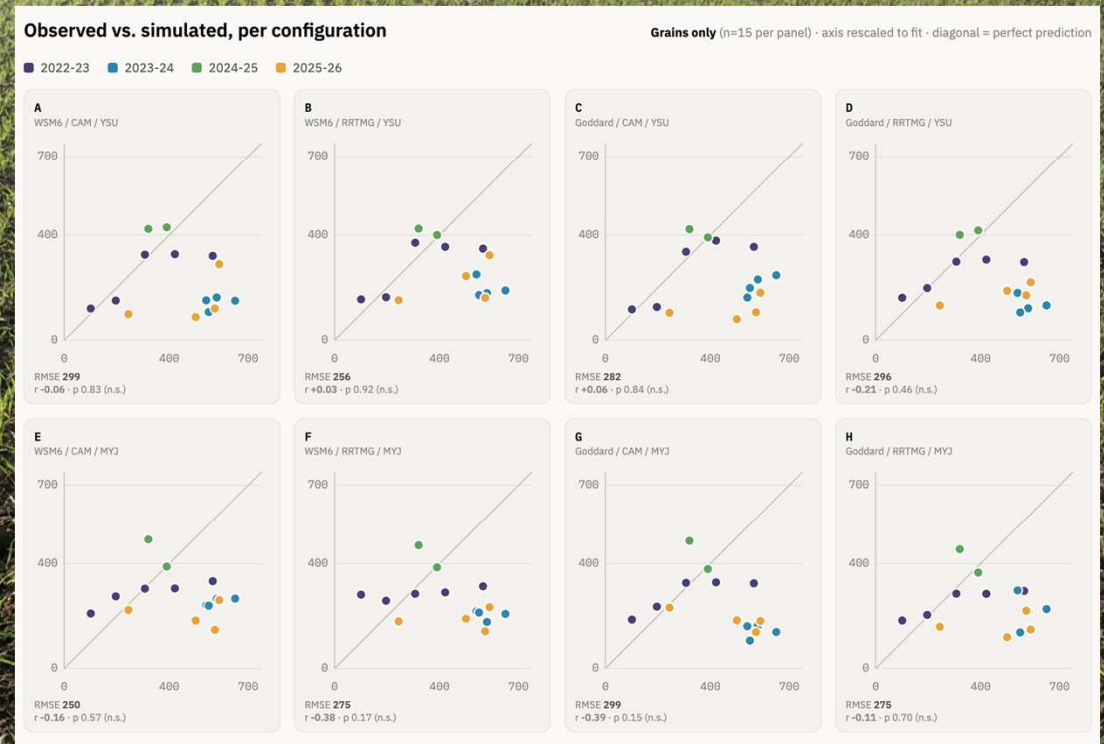
Held fixed across all 8 configs: Noah-MP land surface, Rain-Fritsch cumulus on the 9 km outer domain only (explicit convection on the 3 km validation domain), SEAS5 boundary conditions, initialized 1 Nov each season, sowing date 1 Dec each season.

Predicted vs. observed grain yield

No significant correlation — slightly negative

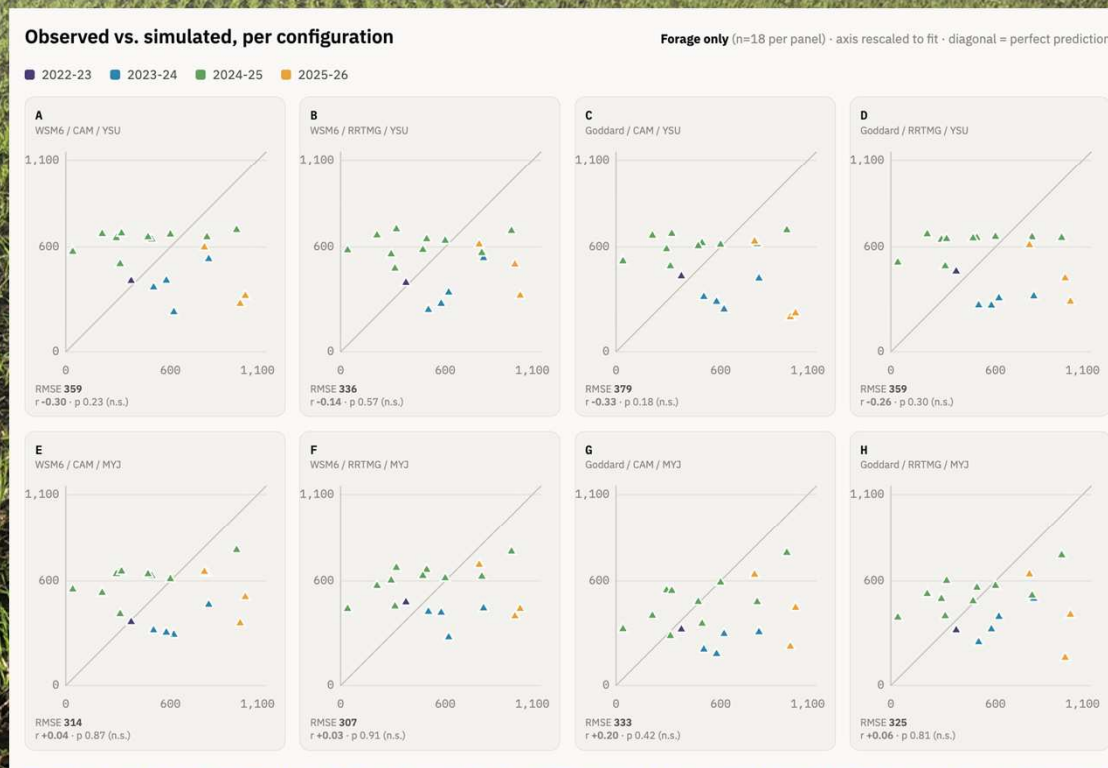
Results cluster by year: two years track the 1:1 line, two are strongly underpredicted

Only configuration B gives a positive correlation



Predicted vs observed above-ground biomass

- **No significant correlation** in any of the 8 configurations (all $p \geq 0.18$, $n = 18$)
- **YSU runs trend negative** ($r -0.14$ to -0.33); **MYJ runs near zero**
- **RMSE of ~300–400** in every configuration
- **Points cluster by season:** 2024-25 above the 1:1 line, 2023-24 and 2025-26 below



Growth curve validation



Config H

Leaf area index
tracks well, peaks
too low in many
cases

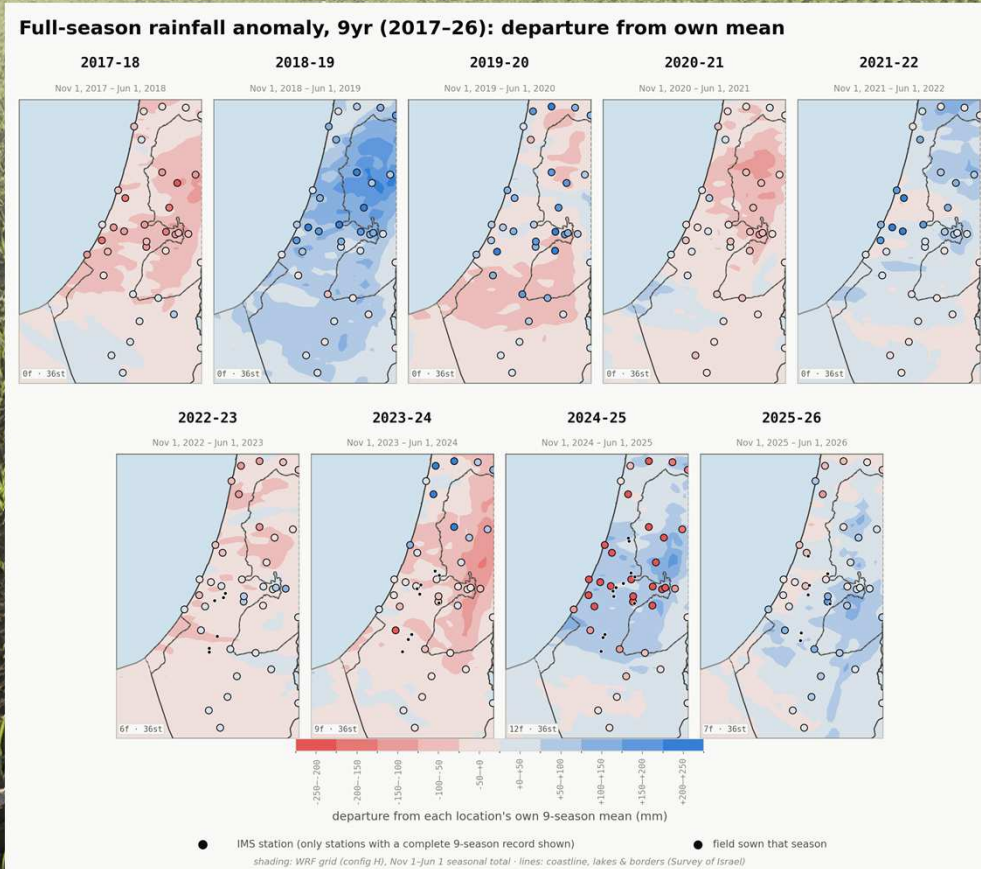
Growth curve validation



Config H

Total biomass:
good track but
low bias

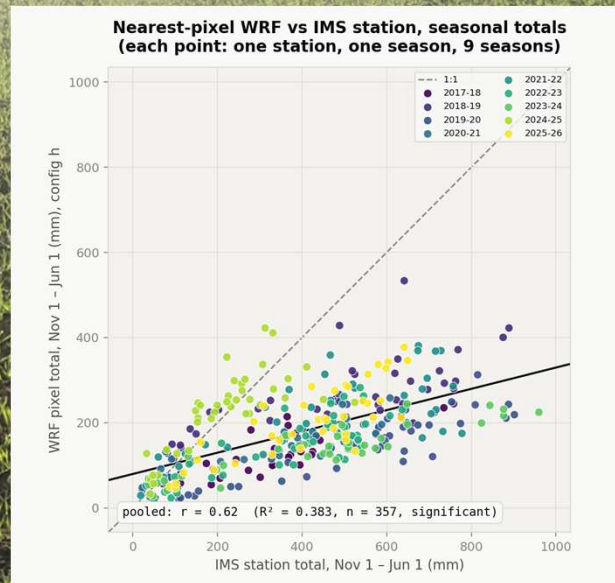
Rainfall anomaly: no coherent season-to-season pattern



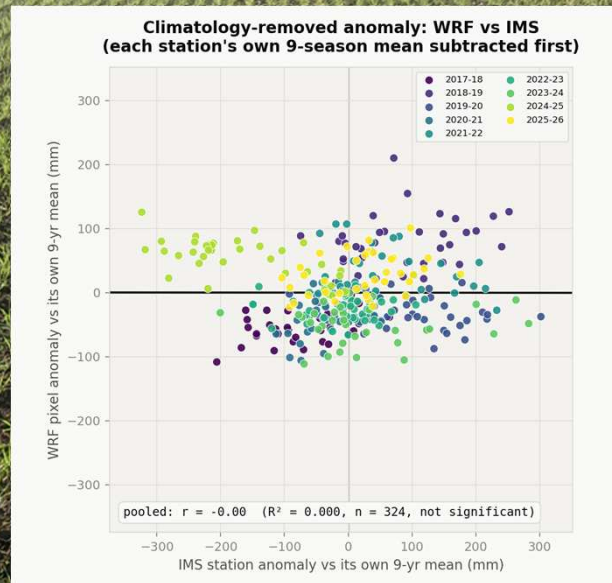
Config H

- **Shading:** WRF pixel departure from its own 9-season mean, config H
- **Dots:** matched IMS stations on the same scale, complete record stations only
- **Period:** Nov 1-Jun 1, 2017-18 through 2025-26

Rainfall: the anomaly signal vanishes over the full season



Raw seasonal totals

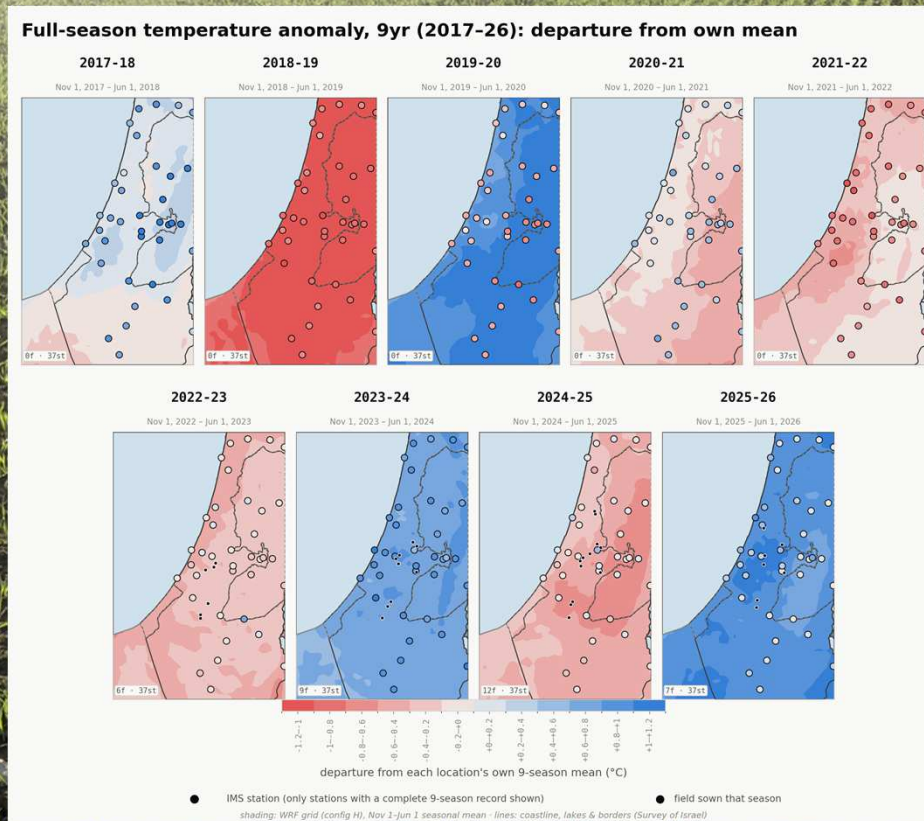


Climatology-removed anomaly

Config H

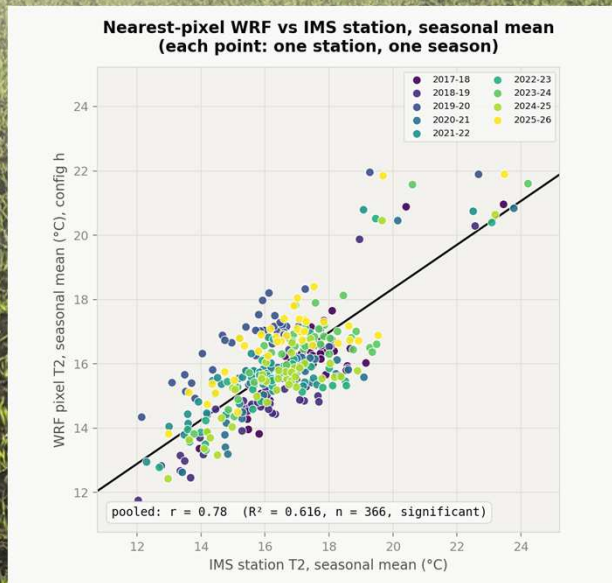
- **Raw totals:** $r = 0.62$
($p < 0.0001$, $n = 357$), but mostly
Spatial climatology
- **Anomaly:** $r \approx 0.00$
($p = 0.98$, $n = 324$)
- **The short window's**
 $r \approx 0.25$

Temperature anomaly: whole-region agreement each season

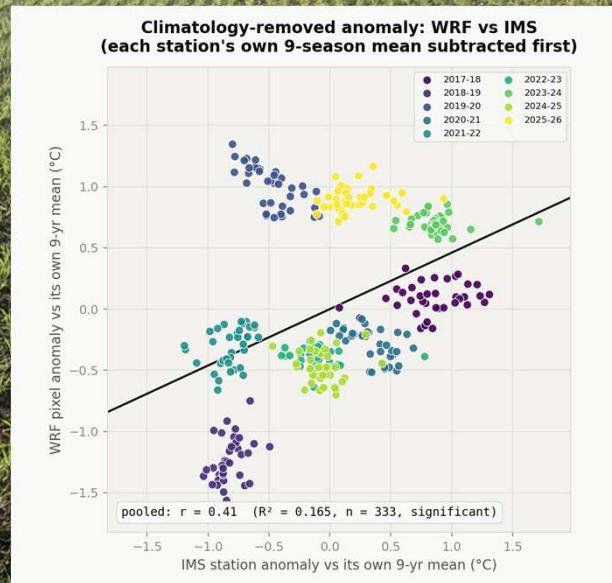


- **Shading:** WRF pixel departure from its own 9-season mean, config H
- **Dots:** matched IMS TD stations on the same scale, complete-record stations only
- **Period:** Nov 1–Jun 1, 2017–18 through 2025–26

Temperature: the anomaly signal holds over the full season



Raw seasonal means

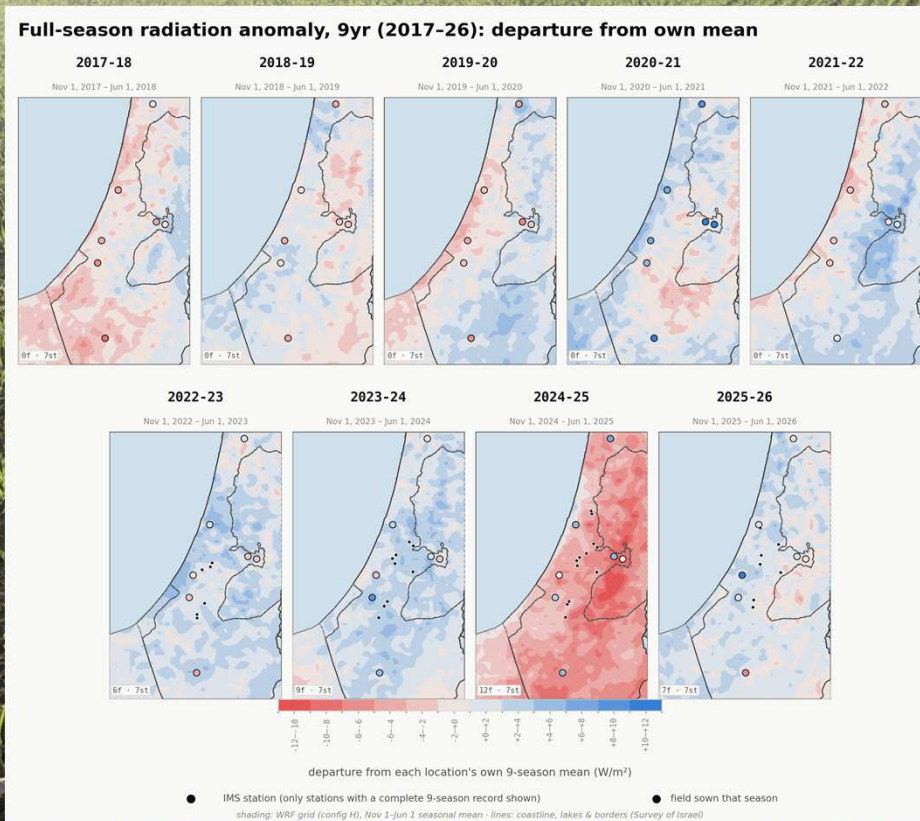


Climatology-removed anomaly

- **Raw means:** $r = 0.79$ ($p < 0.0001$, $n = 366$), driven by the coastal-to-desert gradient
- **Anomaly:** $r = 0.41$ ($p < 0.0001$, $n = 333$), still significant
- **Below the short window's 0.69**, the longer period dilutes the signal

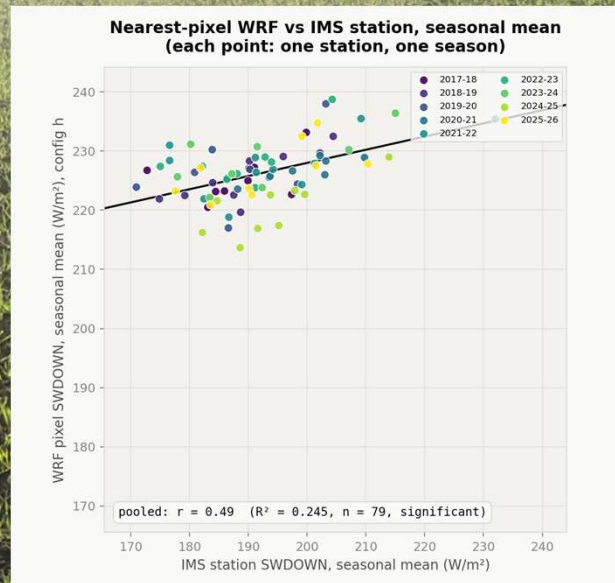
Seasons: 2017-18 through 2025-26 pooled

Radiation anomaly: noisy, no coherent seasonal pattern

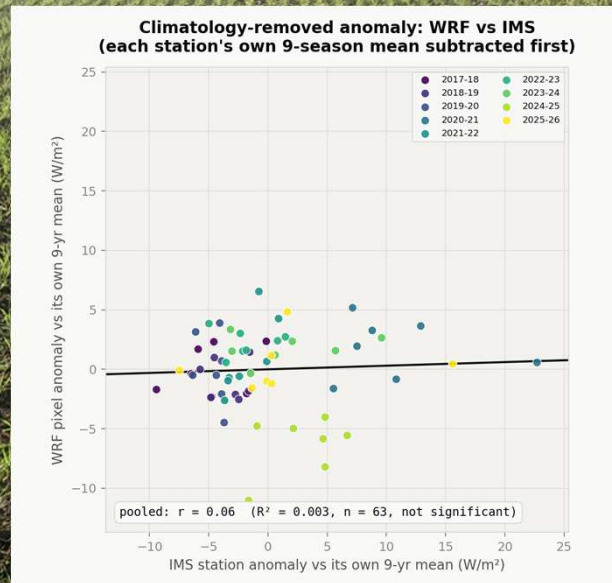


- **Only 7 stations** have a complete 9-season record
- **Too few stations** have a complete record to test the anomaly well

Radiation: raw relationship holds, anomaly stays null



Raw seasonal means



Climatology-removed anomaly

- **Raw means:** $r = 0.50$ ($p < 0.0001$, $n = 79$), but WRF runs high and varies less than the stations
- **Anomaly:** $r = 0.06$ ($p = 0.67$, $n = 63$), not significant

Summary

WRF climate input validation, config H, full season (Nov 1–Jun

1)

Rainfall

RAW MEANS

$r = 0.62$

Significant, but WRF runs low and varies less

ANOMALY

$r = 0.00$

Not significant; earlier signal came from a few seasons

Temperature

RAW MEANS

$r = 0.79$

Significant

ANOMALY

$r = 0.41$

Significant, but points cluster by season

Radiation

RAW MEANS

$r = 0.50$

Significant, but WRF runs high and varies less

ANOMALY

$r = 0.06$

Not significant, too few stations

Grain yield

4 SEASONS

**$r = -0.11$
to -0.27**

Not significant; more seasons of observations needed

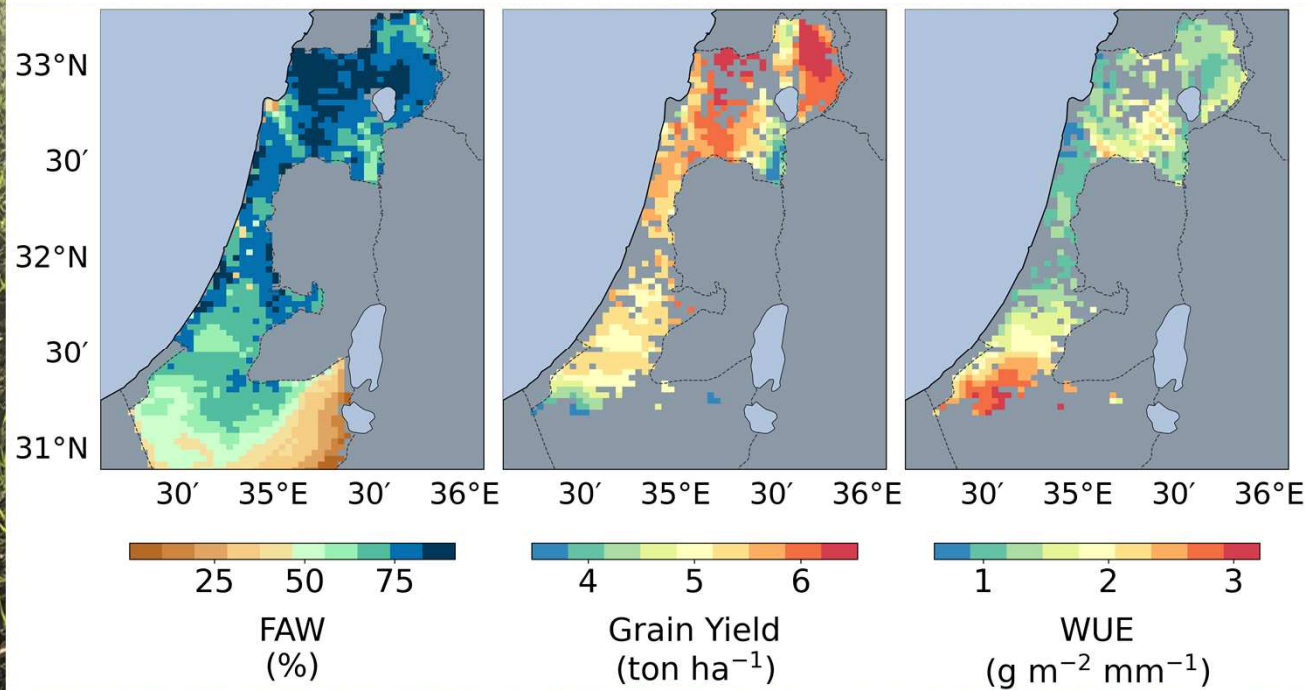


Summary

- **Noah-MP-Crop reproduces wheat development and biomass** in Israel when forced with ERA5, but runs low when forced with SEAS5
- **Full wheat season:** partial prediction skill for temperature only
- **Two-month lead:** partial prediction skill for temperature and rainfall

Water availability, grain yield, and production efficiency

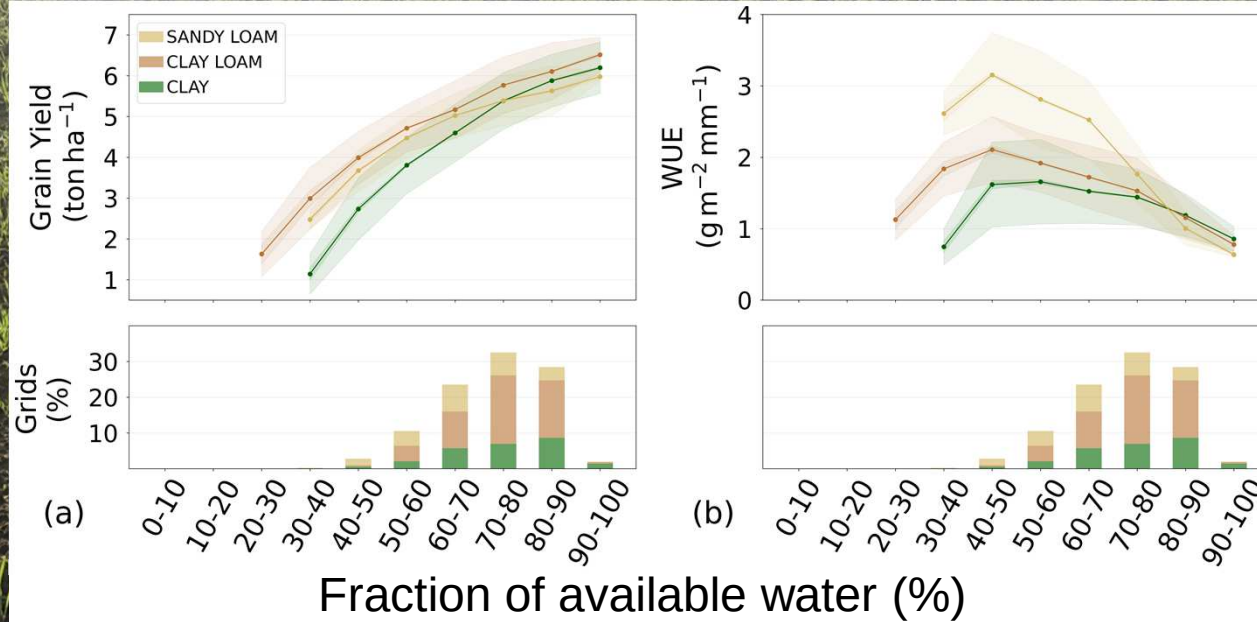
30-seasons (1994-2024)



In most cases, high-yield regions do not overlap with regions of high production efficiency.

Grain yield as a function of water availability

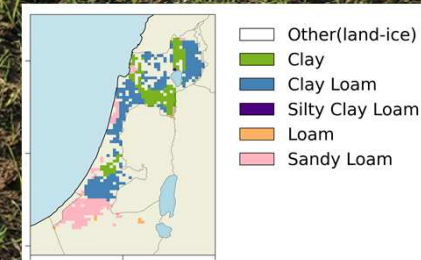
30-seasons (1994-2024)



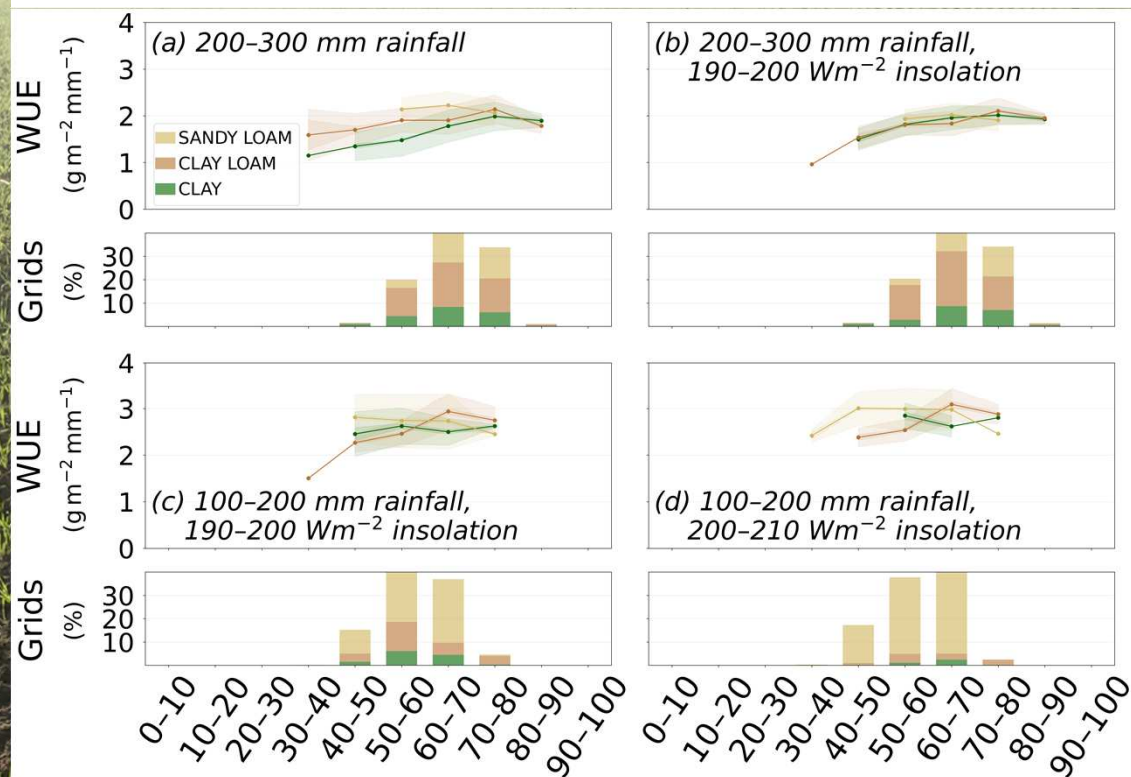
Different soil textures separate out at the same moisture level

CLAY LOAM has the highest yield

SANDY LOAM is usually more efficient



30-seasons (1994-2024)

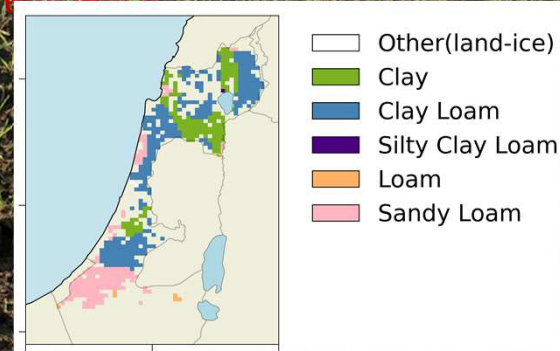


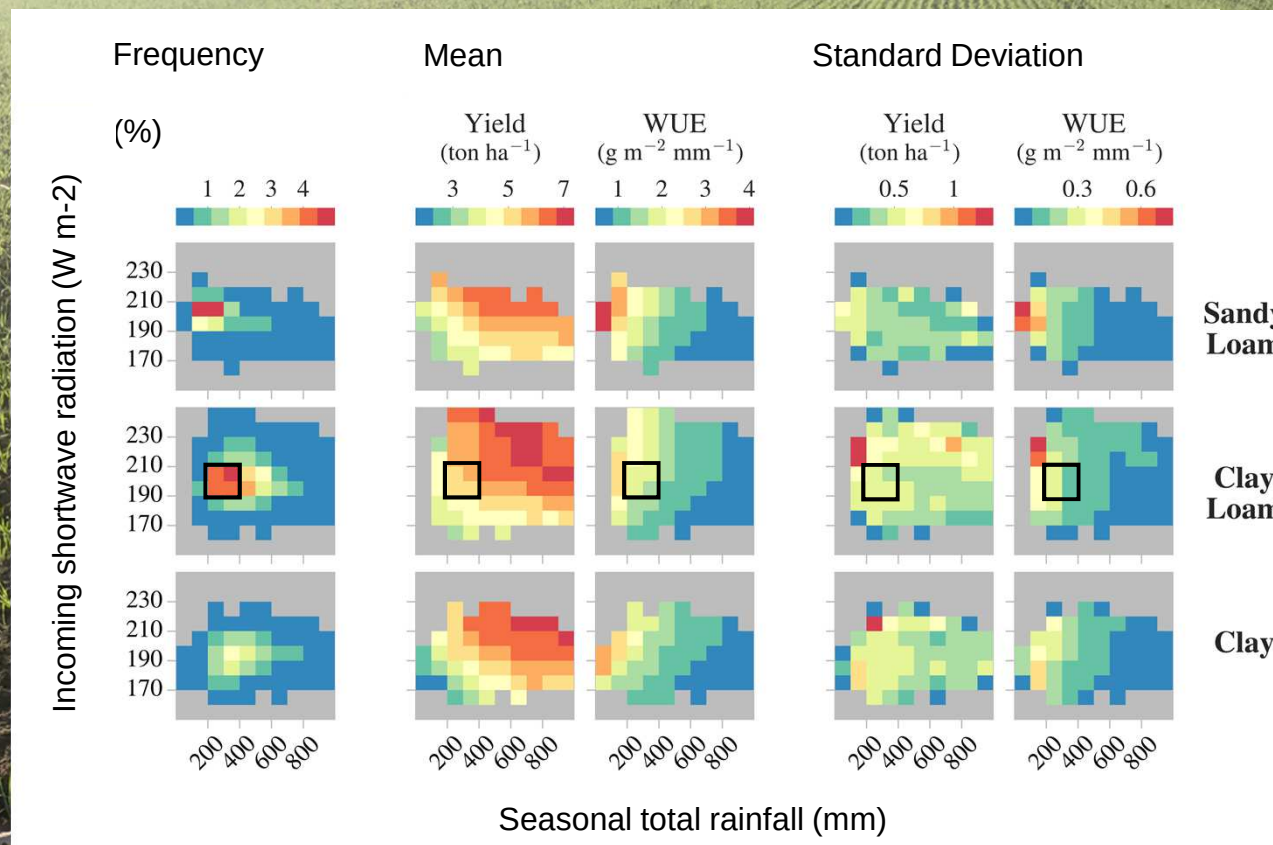
Fraction of available water (%)

Yield under similar climate conditions

Sandy-soil regions in Israel are characterized by strong radiation.

Combining these regions with sandy soil at low moisture leads to high potential.



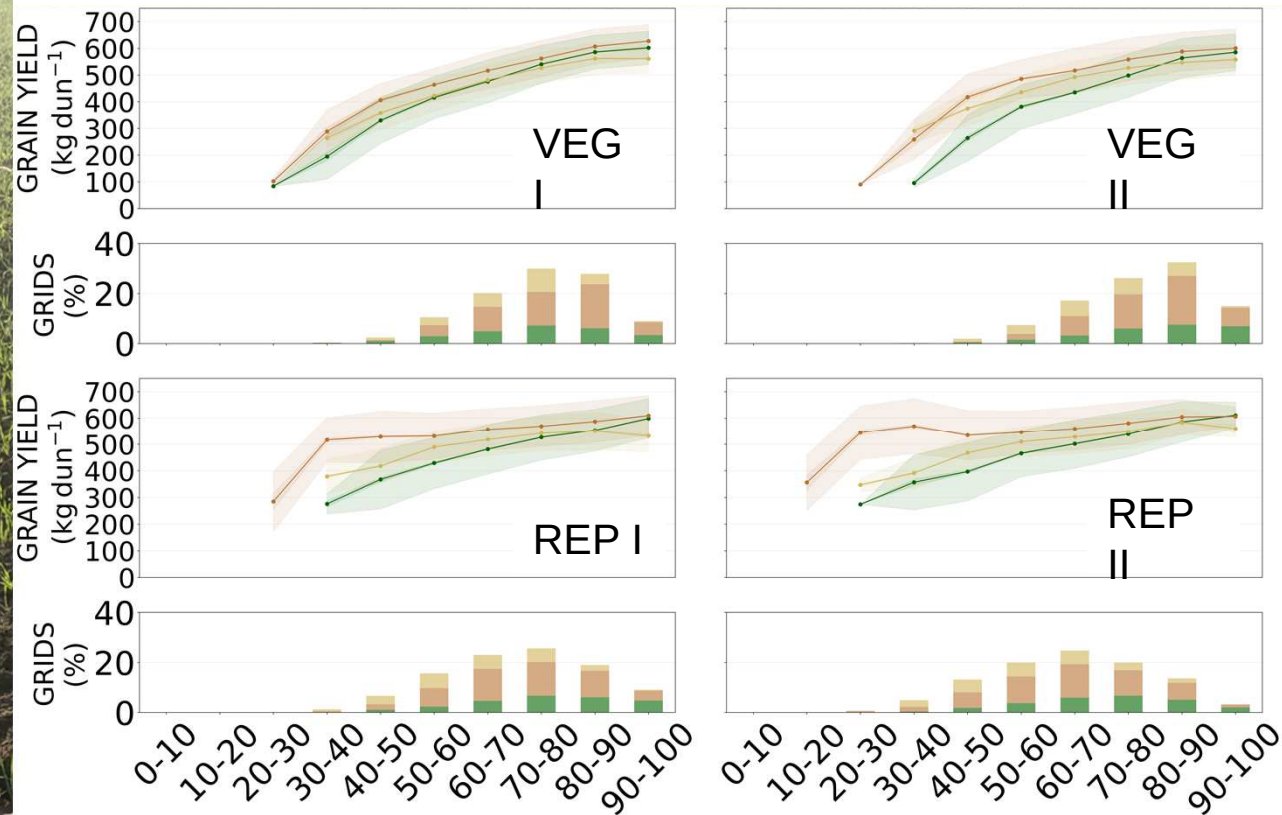


Yield as a function of radiation and rainfall

The main growing regions in Israel are characterized by

- a) moderate yield and water use efficiency
- b) high uncertainty

30-seasons (1994-2024)



Fraction of available water (%)

Grain yield:
sub-
seasonal

Higher sensitivity
to soil moisture
during the
vegetative stages



Summary

- The yield model Noah-MP-Crop adequately represents the development and biomass accumulation of wheat in Israel.
- Regions with sandy soil show higher rainfall-use efficiency in dry seasons than clay soils, related to the specific climate conditions of these regions, but not only.
- The main growing regions today are characterized by very high inter-seasonal variability relative to other locations.

Irrigation in wheat?

- Regions can be identified where there is high yield potential per mm of irrigation.
- Irrigation during the vegetative stages appears preferable to the reproductive stages.

Acknowledgements

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- Sha'alvim field crops (Issi)
- Netiv HaLamed-He field crops (Efi)
- Einat field crops (Amitai)
- Hulda field crops (Uri)

