Sensitivity of ICON Setup and Physics over Türkiye at Convection-Permitting Scale

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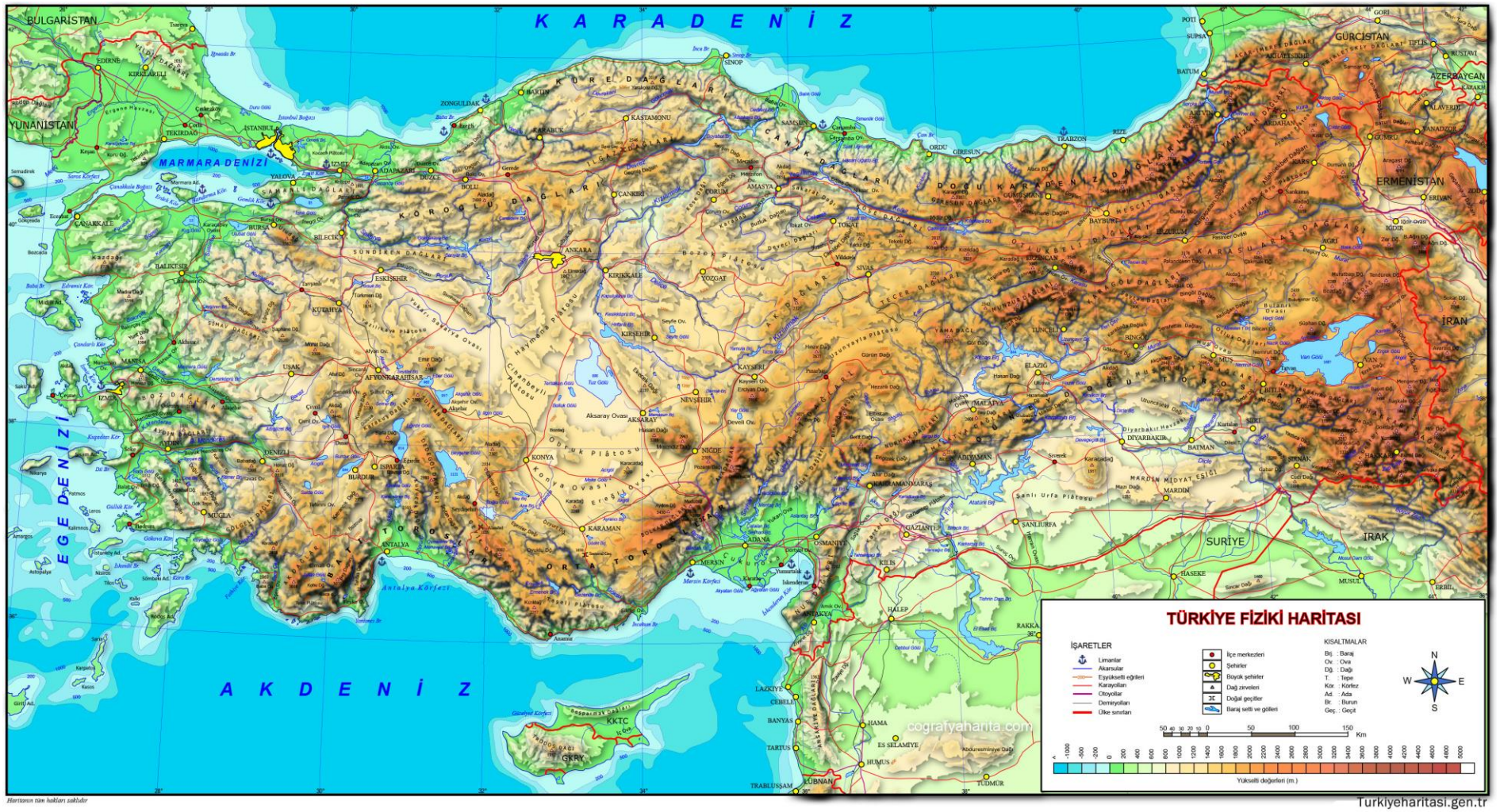


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Motivation and research questions

Türkiye combines complex terrain with strong regional climate contrasts.

These features motivate a systematic assessment of regional model configuration.



How do domain size, physical parameterizations and resolution affect performance?

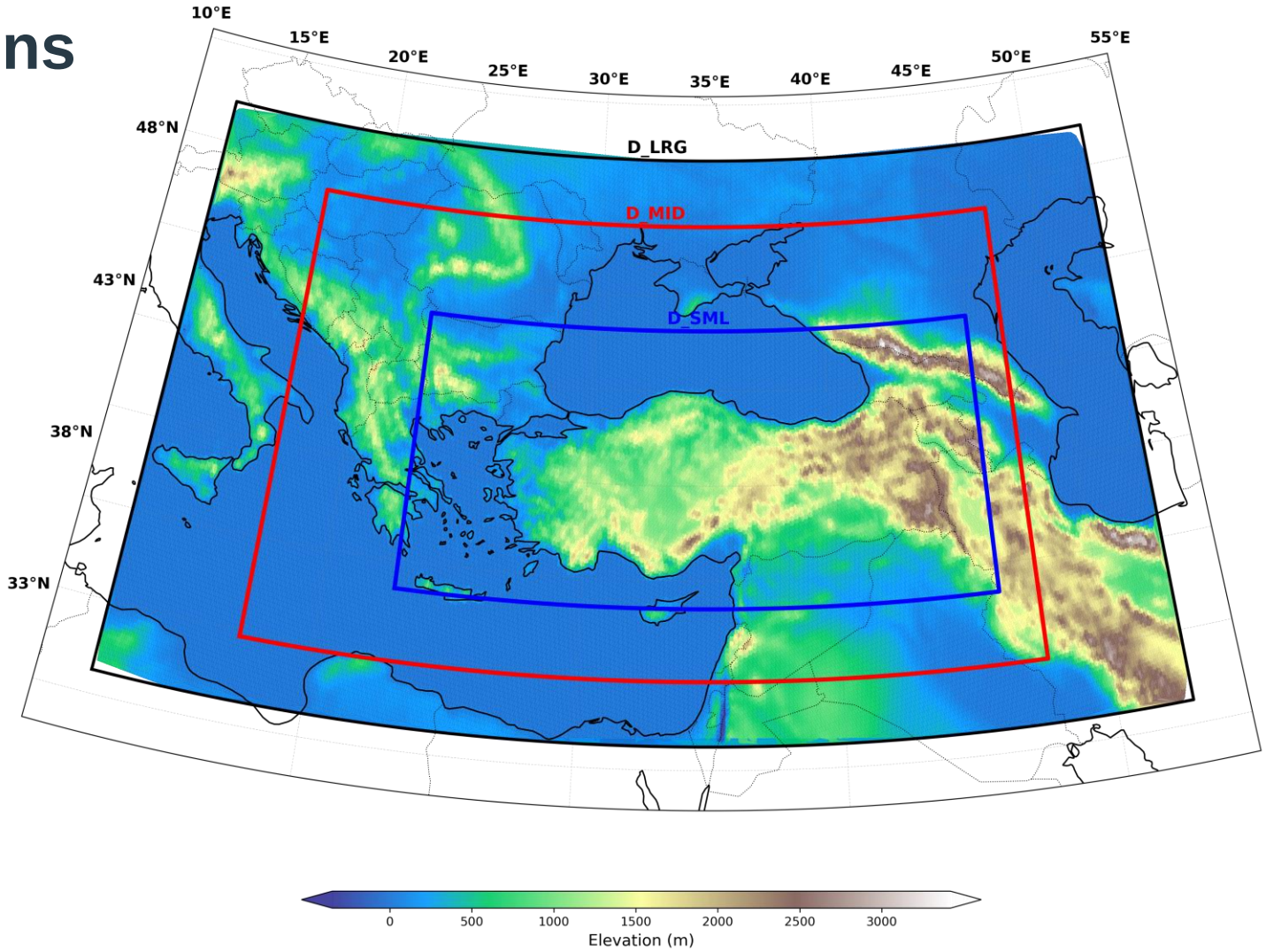
Experimental design

Stage	Experiment	Evaluation question	Status
1	D_LRG, D_MID and D_SML	How sensitive are results to domain extent?	Completed
2	R1–R6, with D_MID as reference	How do alternative physics settings affect skill?	Completed
3	Direct and nested 3 km runs	What does finer resolution add?	Ongoing
4	Selected configuration: 1992 and 2024	Does performance transfer to contrasting years?	Future Work

Study area and model domains

D_LRG, D_MID and D_SML share the R2B8 grid configuration.

Different extents change the distance between Türkiye and the lateral boundaries.



The domain experiments assess sensitivity to lateral boundary placement.

Selection of Representative and Extreme Simulation Years

212 TSMS stations | Türkiye | 1960–2024

Annual station observations were aggregated to characterize long-term temperature and precipitation variability and select simulation years representing contrasting climatic regimes.

2015 – Representative baseline

T = 13.9 °C (climatology: 13.3 °C)

P = 614.58 mm (climatology: 615.46 mm)

→ *ICON parameterization sensitivity*

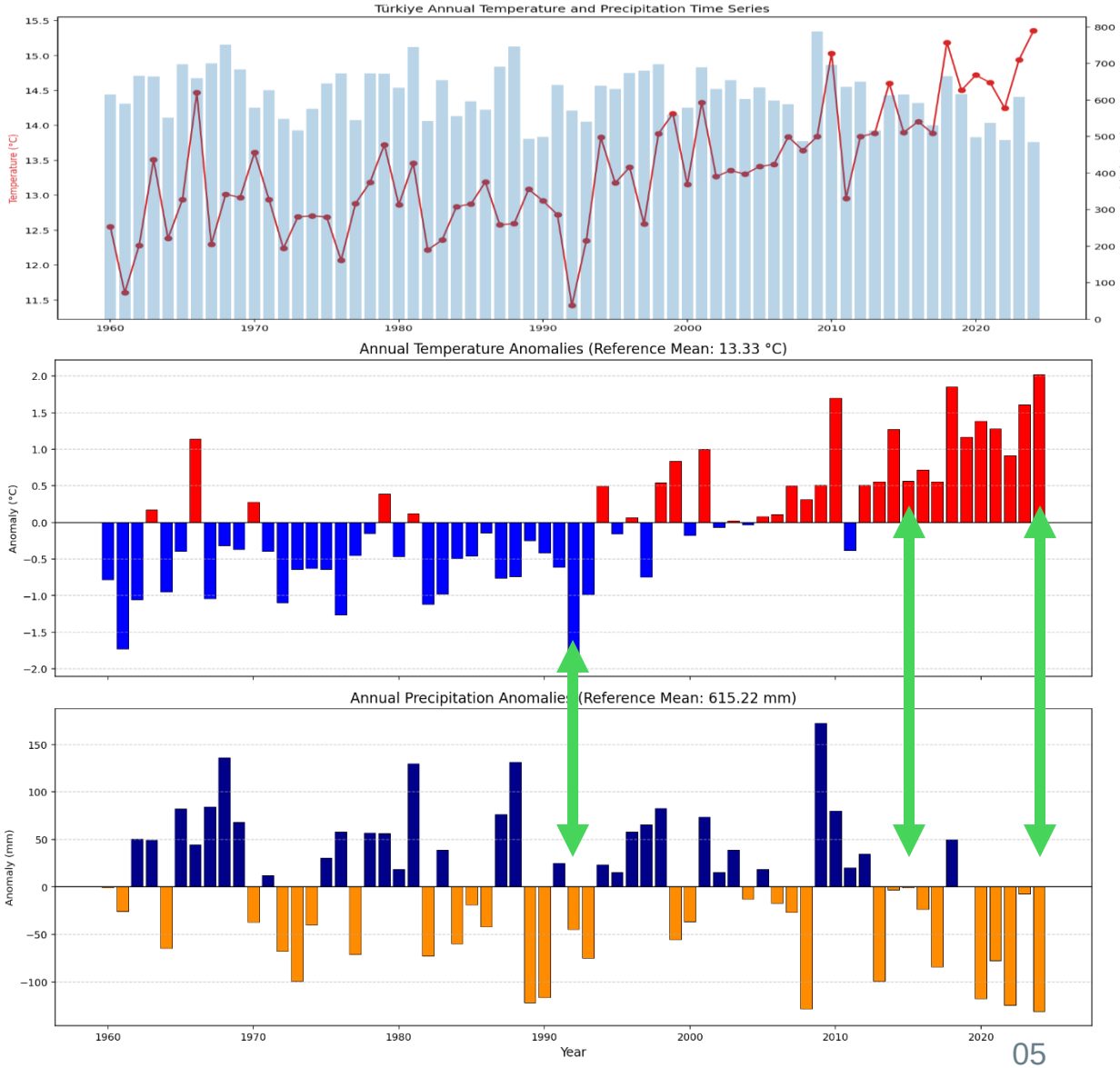
1992 – Extreme cold-wet year

→ *Cold–wet regime stress test*

2024 – Extreme warm-dry year

→ *Warm–dry regime stress test*

2015 supports baseline testing; 1992 and 2024 test contrasting climatic conditions.



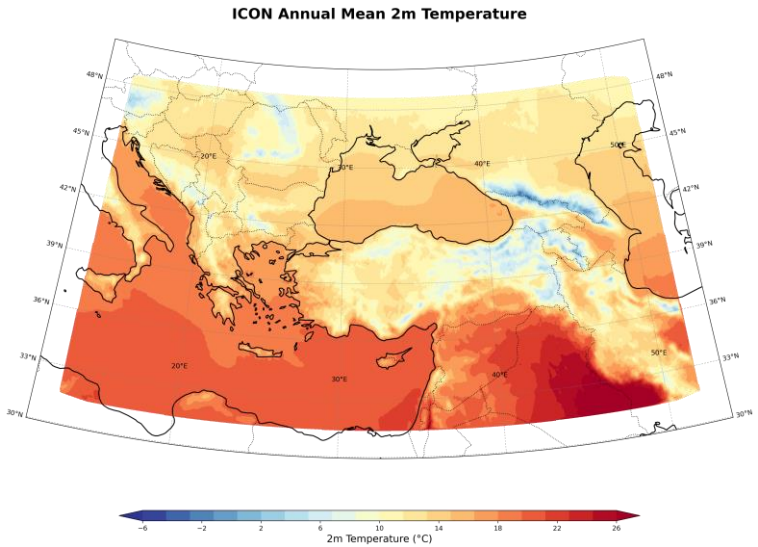
Model setup and evaluation data

Role	Data / configuration
Regional model	ICON 2025.10 and SPICE 2.3
Initial and boundary conditions	ERA5
Primary evaluation	TSMS meteorological stations
Additional comparisons	ERA5-Land, E-OBS ...

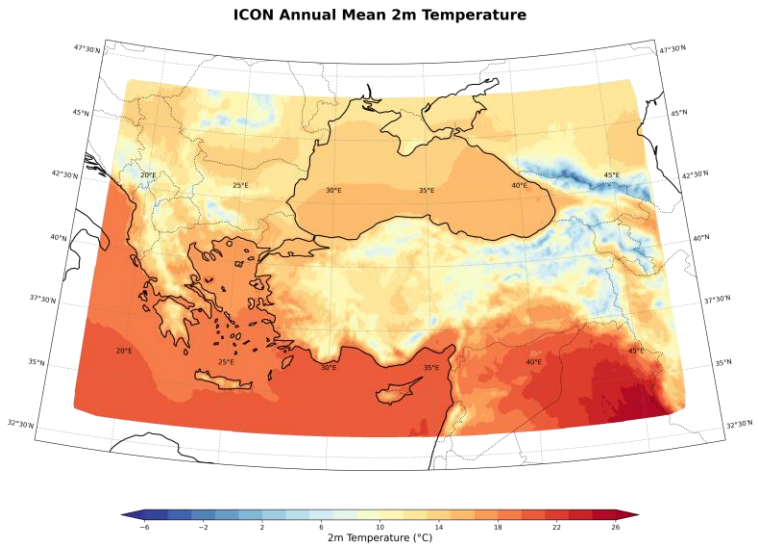
Grid and integration details: [spatial resolution: ~10 km] [spin-up period: 2 months]

Domain sensitivity: temperature patterns

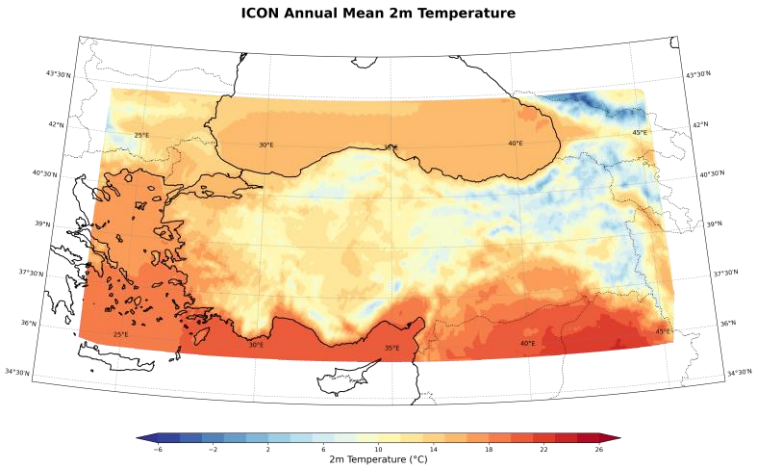
D_LRG



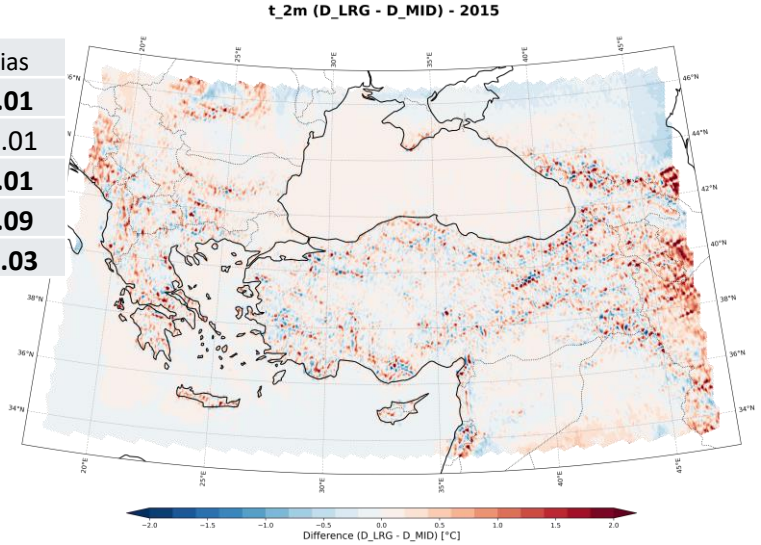
D_MID

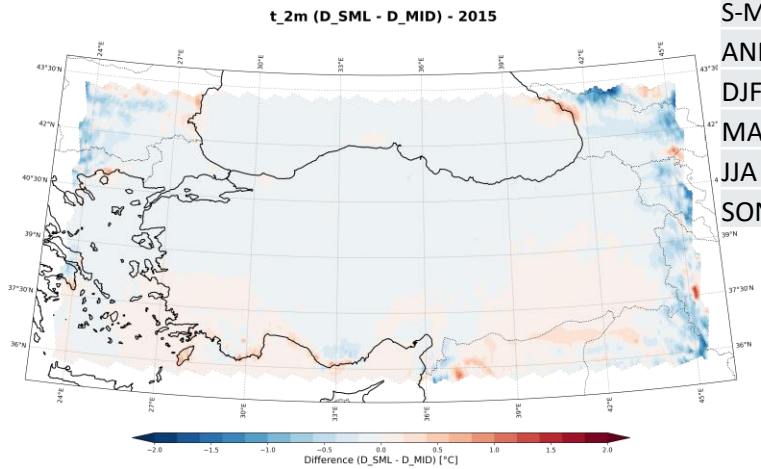


D_SML



L-M	Mean_LRG	Mean_MID	Bias
ANN	11.98	11.98	**0.01**
DJF	2.91	2.92	-0.01
MAM	9.71	9.70	**0.01**
JJA	21.97	21.88	**0.09**
SON	14.25	14.29	**-0.03**

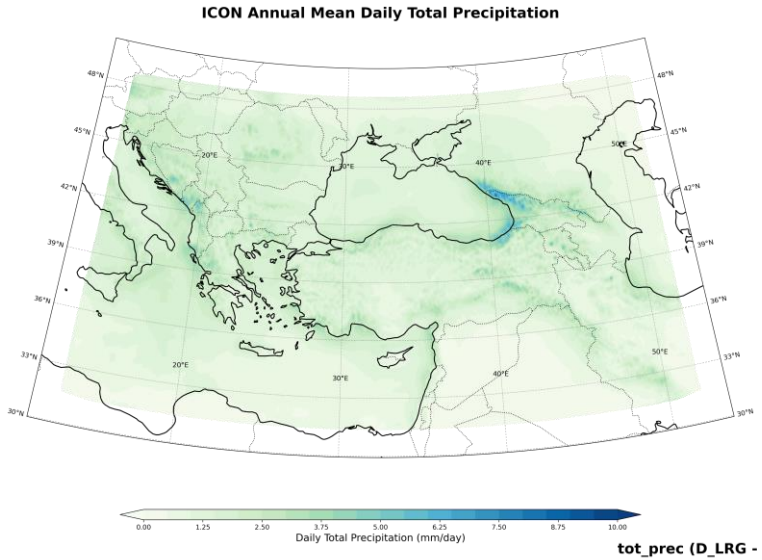




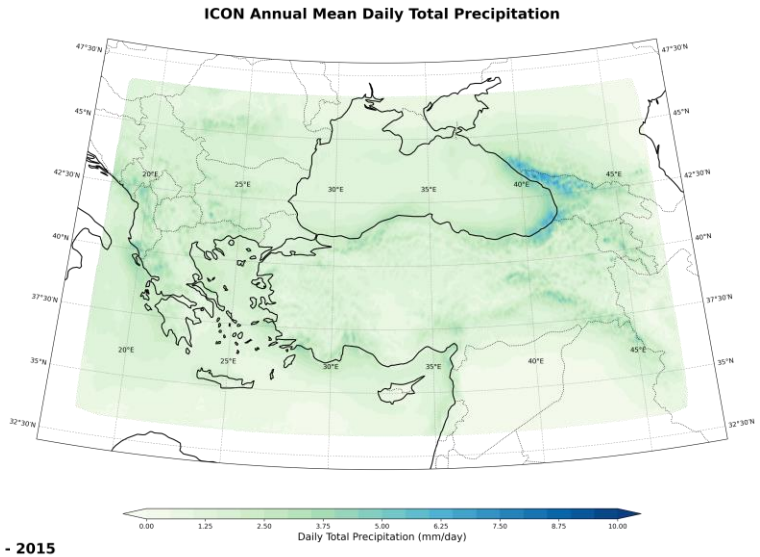
S-M	Mean SML	Mean MID	Bias
ANN	11.92	11.98	-0.06
DJF	2.91	2.92	-0.01
MAM	9.67	9.70	-0.02
JJA	21.75	21.88	-0.13
SON	14.24	14.29	-0.04

Domain sensitivity: precipitation patterns

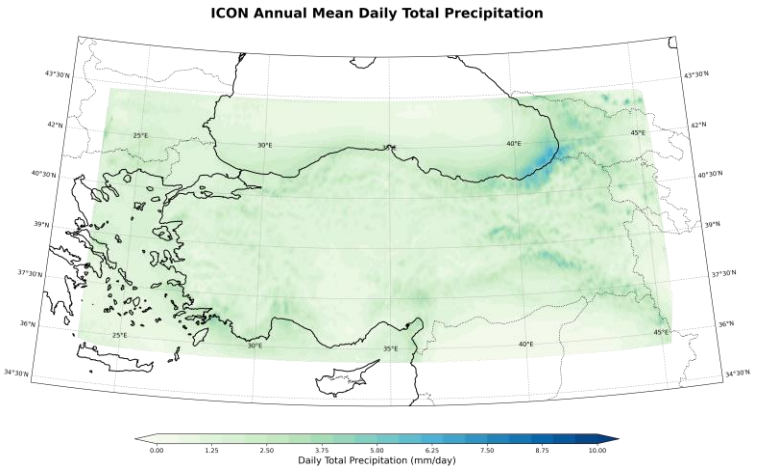
D_LRG



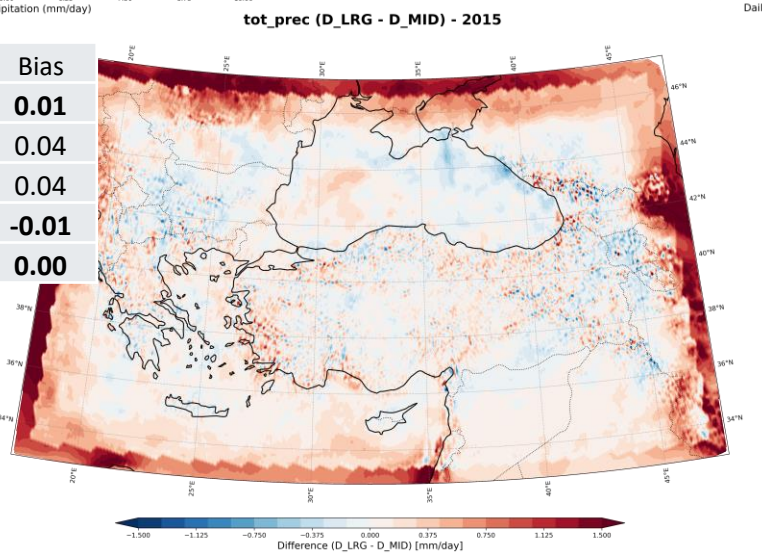
D_MID

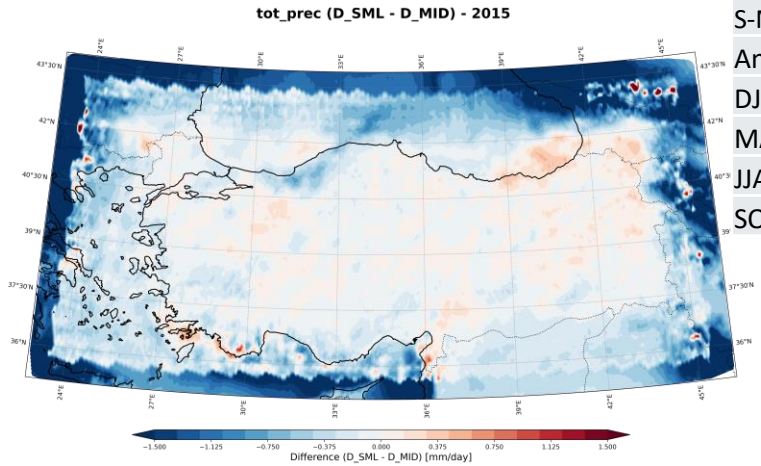


D_SML



L-M	Mean LRG	Mean MID	Bias
Annual	1.73	1.72	**0.01**
DJF	2.86	2.82	0.04
MAM	2.51	2.47	0.04
JJA	0.91	0.92	**-0.01**
SON	1.30	1.30	**0.00**





S-M	Mean SML	Mean MID	Bias
Annual	1.68	1.72	-0.04
DJF	2.80	2.82	**-0.02**
MAM	2.44	2.47	**-0.03**
JJA	0.83	0.92	-0.09
SON	1.26	1.30	-0.04

Domain sensitivity: Evaluations against station observations

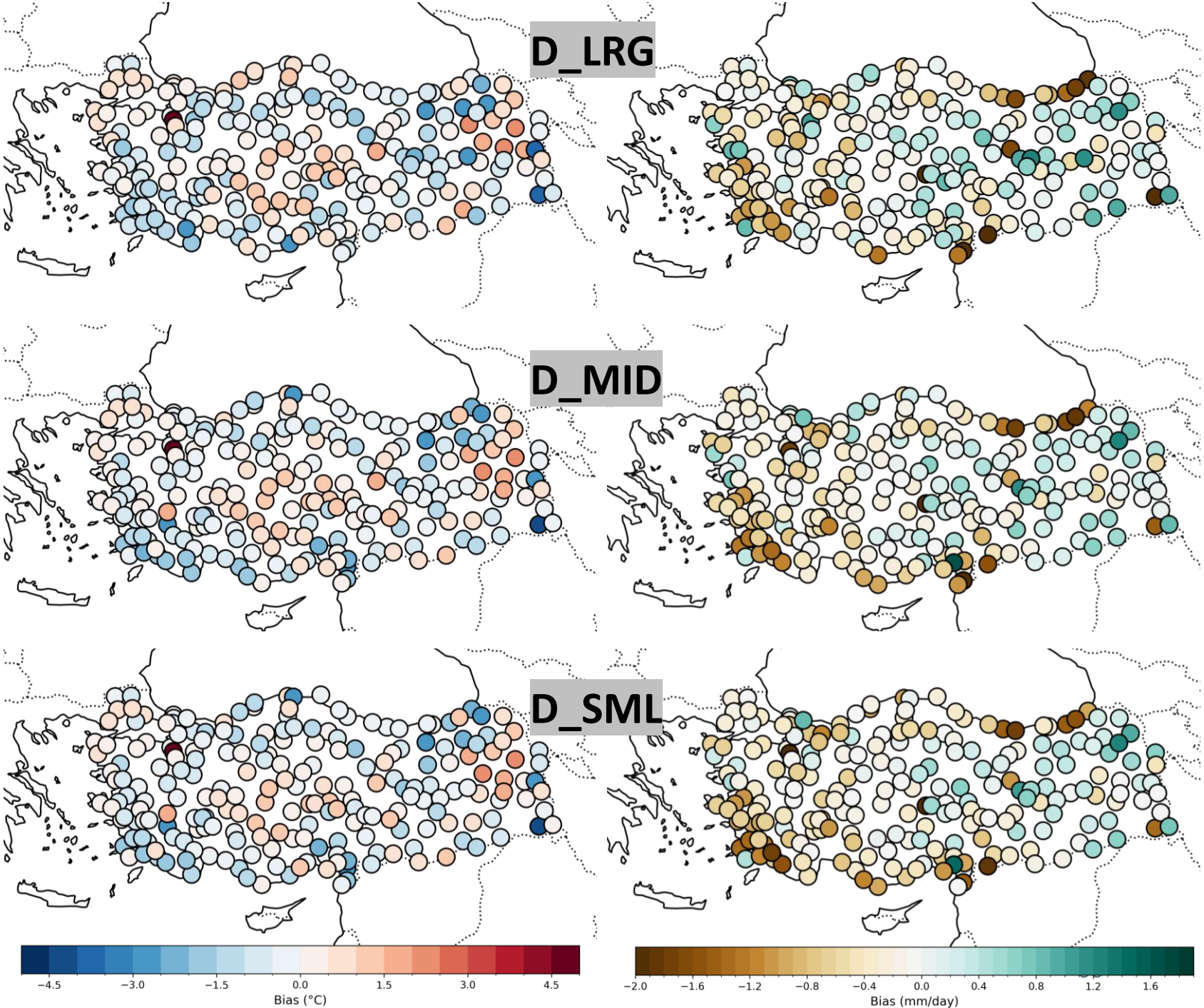
Independent point-based validation - 212 TSMS stations

2m Temp	TSMS Mean	ICON Mean	Bias	RMSE	Pearson_R
D_LRG	13.90	13.67	-0.23	1.10	0.96
D_MID	13.90	13.72	**-0.18**	1.09	0.96
D_SML	13.90	13.70	-0.21	**1.08**	**0.96**

Total Prec	TSMS Mean	ICON Mean	Bias	RMSE	Pearson_R
D_LRG	1.70	1.53	**-0.17**	0.67	0.71
D_MID	1.70	1.49	-0.22	**0.65**	**0.75**
D_SML	1.70	1.44	-0.26	0.67	0.74

Near-surface temperature is robust to domain-size selection, with all three domains producing comparable performance against station observations.

D_LRG better reproduces the national mean precipitation amount, whereas D_MID provides the best overall representation of its spatial variability.



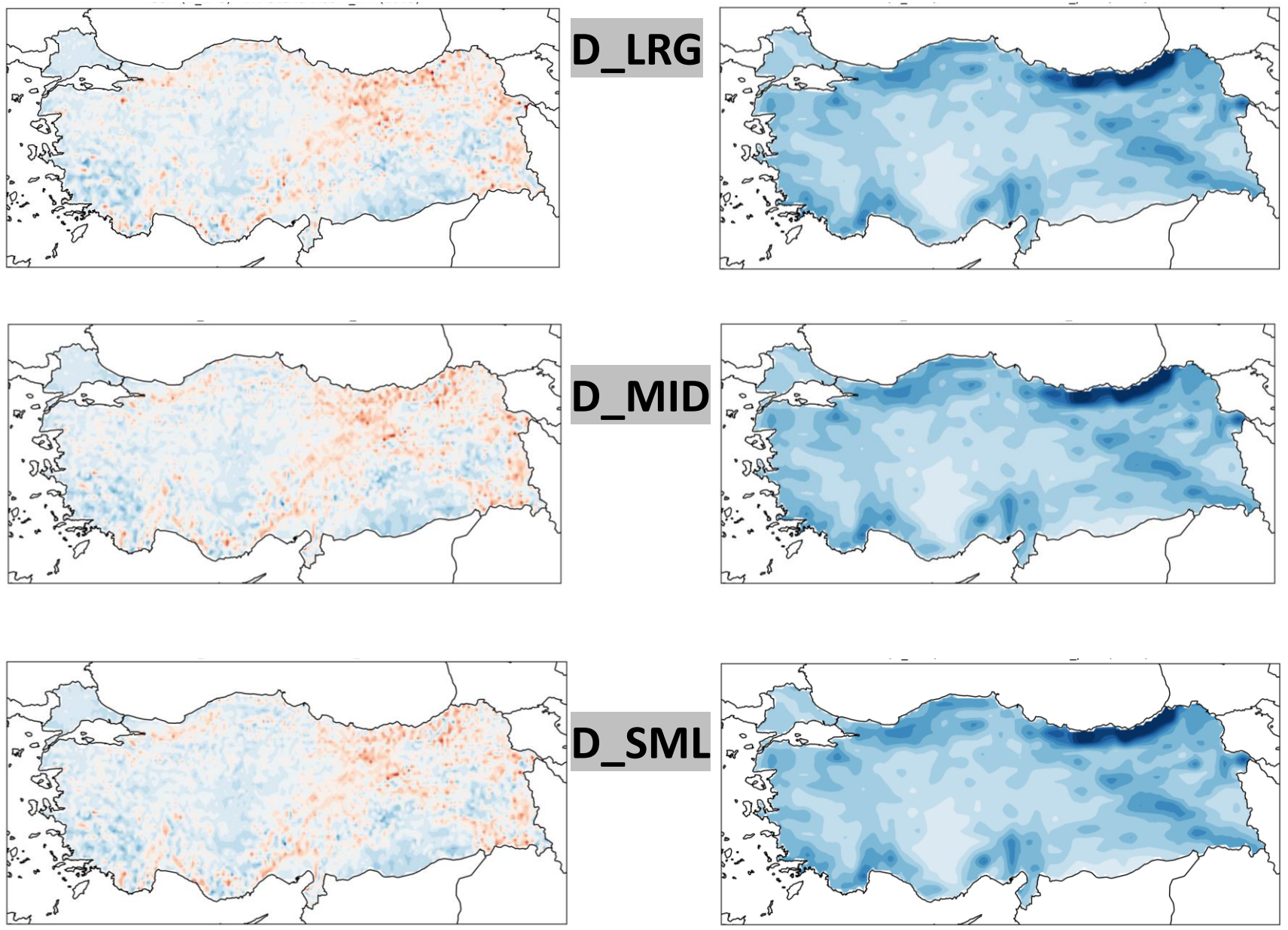
Domain sensitivity: Spatial bias against ERA5Land

Gridded assessment of bias structure

The spatial structures of the temperature and precipitation biases are highly similar across D_LRG, D_MID and D_SML.

2m Temp	ERA5LMean	ICON Mean	Bias	RMSE
D_LRG	11.22	11.01	-0.21	0.91
D_MID	11.22	11.01	-0.21	0.92
D_SML	11.22	10.96	-0.26	0.92

Total Prec	ERA5LMean	ICON Mean	Bias	RMSE
D_LRG	1.98	0.08	-1.9	2.07
D_MID	1.98	0.07	-1.9	2.07
D_SML	1.98	0.07	-1.9	2.07



Domain selection

MID has the smallest absolute bias in 2-m temperature, the lowest precipitation RMSE and highest precipitation Pearson.

LRG has the smallest absolute bias in precipitation.

SML has boundary limitations. while it takes longer to run LRG domain.

Run	Grid Count	prep (avg)	conv2icon (avg)	icon (avg)	arch (avg)	post (avg)	TOTAL (avg/month)
D_LRG	69.809	47m 26s (2846s)	15m 14s (914s)	4h 25m 39s (15939s)	2h 6m 41s (7601s)	23s	7h 35m 23s (27323s)
D_MID	48.788	42m 21s (2541s)	12m 49s (769s)	**3h 16m 33s+ (11793s)**	2h 2m 42s (7362s)	22s	6h 14m 46s (22486s)
D_SML	25.281	46m 31s (2791s)	12m 54s (774s)	51m 16s (3076s)	2h 5m 46s (7546s)	23s	3h 56m 49s (14209s)

- These values are the average of the yearly simulations.

+ The first five months averaged around 6.700–7.400s. but afterward — due to an HPC (High-Performance Computing) center technical maintenance issue — durations rose to roughly 12.000–15.900s. So we simply took the overall monthly average across all months. without excluding this period.

2m Temp	TSMS Mean	ICON Mean	Bias	RMSE	Pearson_R
D_LRG	13.90	13.67	-0.23	1.10	0.96
D_MID	13.90	13.72	**-0.18**	1.09	0.96
D_SML	13.90	13.70	-0.21	**1.08**	**0.96**

Total Prec	TSMS Mean	ICON Mean	Bias	RMSE	Pearson_R
D_LRG	1.70	1.53	**-0.17**	0.67	0.71
D_MID	1.70	1.49	-0.22	**0.65**	**0.75**
D_SML	1.70	1.44	-0.26	0.67	0.74

Increasing domain size modifies the mean climate state, particularly precipitation, but does not substantially reduce the persistent spatial biases.

Given the limited additional skill of D_LRG relative to its higher computational cost, and the stronger boundary limitations of D_SML, D_MID is selected as the reference configuration for subsequent sensitivity experiments.

Parameterization experiments: R1–R6

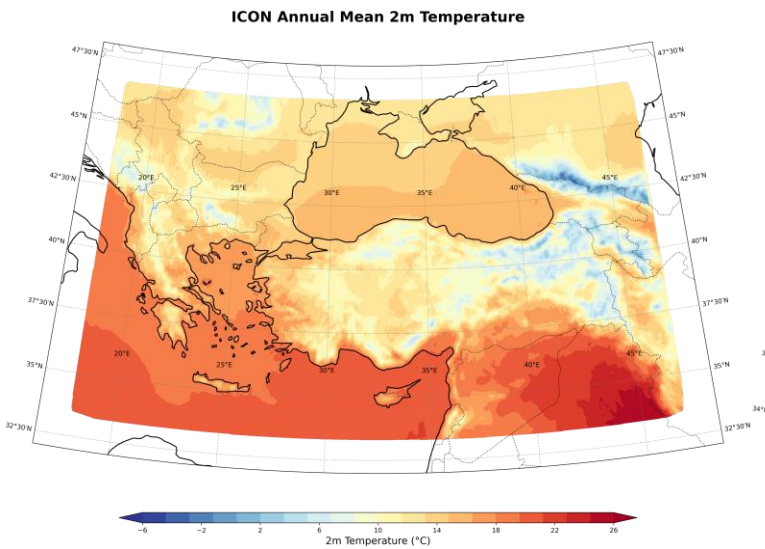
Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	**ON**	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	**RRTM**	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	**2-cat ice**	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	**turbdiff**	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	**Smagorinsky**

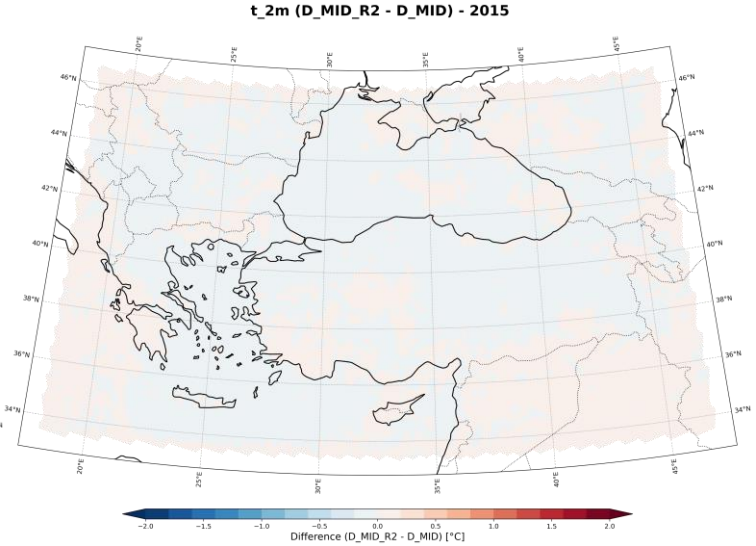
Reference: R4 = D_MID

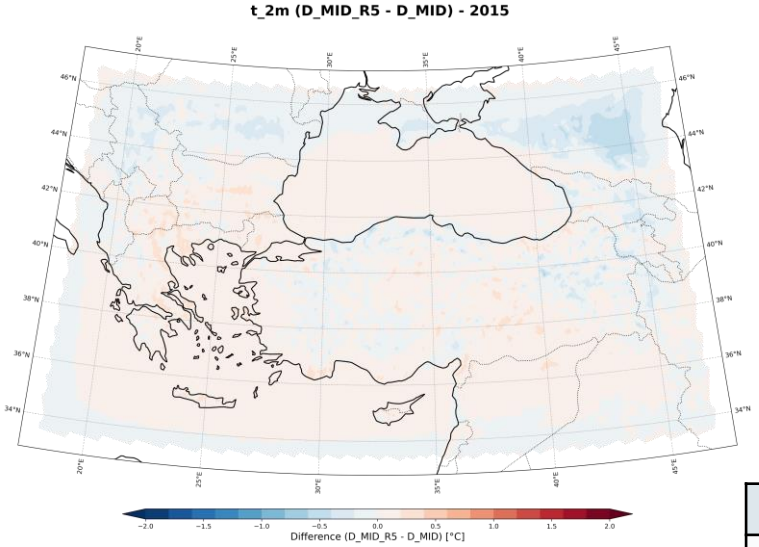
Difference = experiment − D_MID

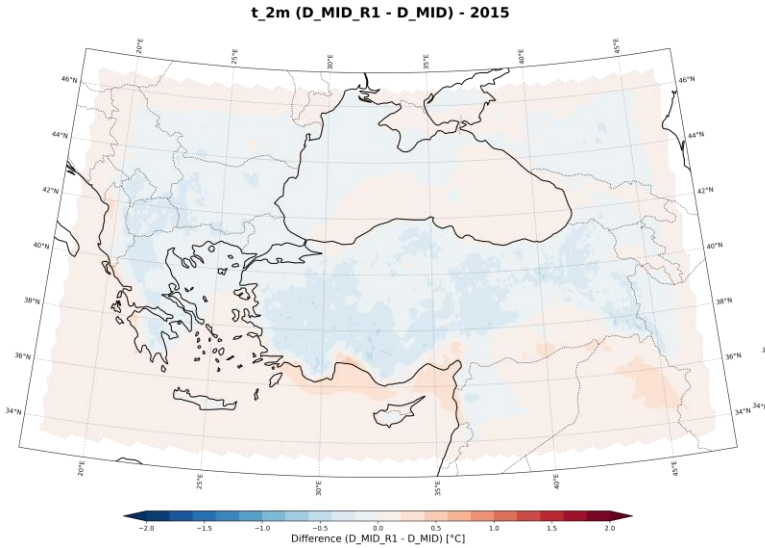
Temperature response to parameterization changes

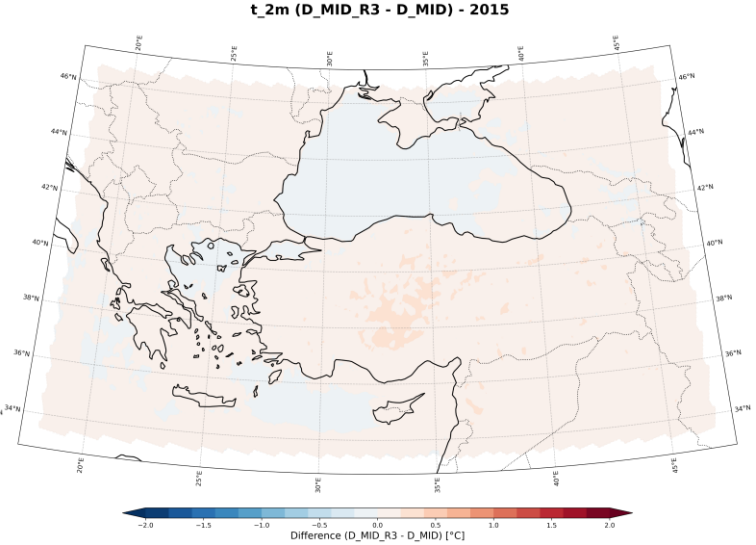
Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	ON	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	RRTM	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	2-cat ice	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	turbdiff	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	Smagorinsky

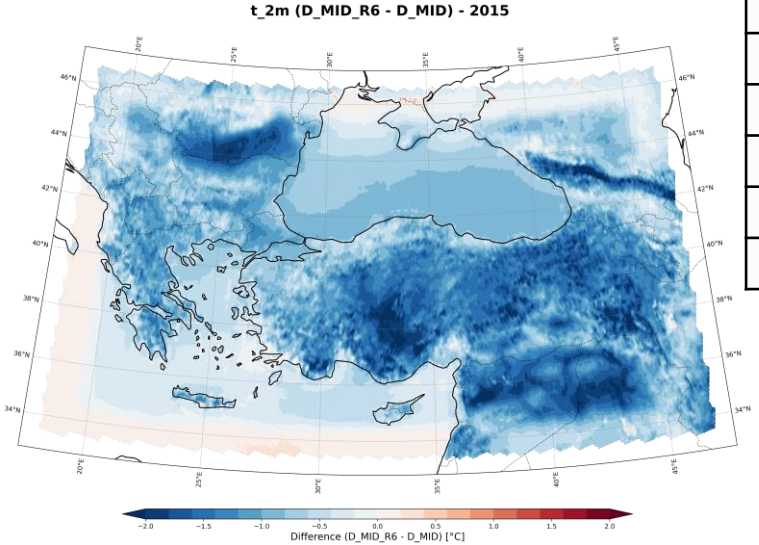












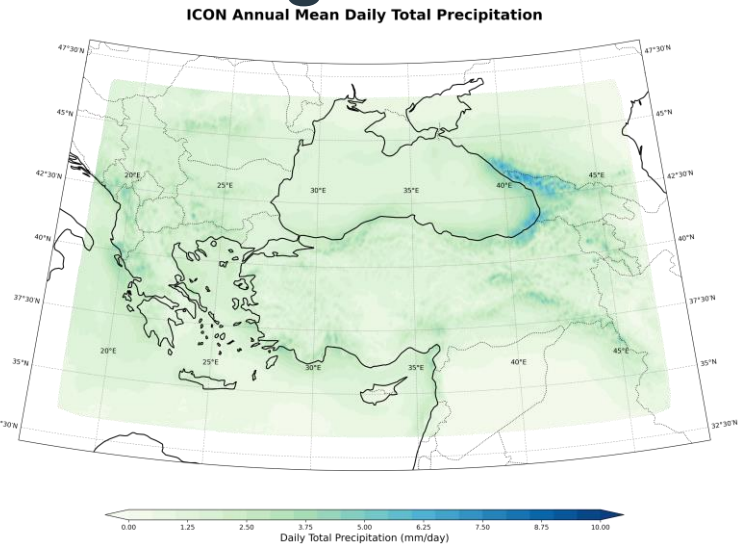
Main response: R1 is colder bur R6 is the coldest, R2 and R5 close to D_MID, R3 is hotter in general

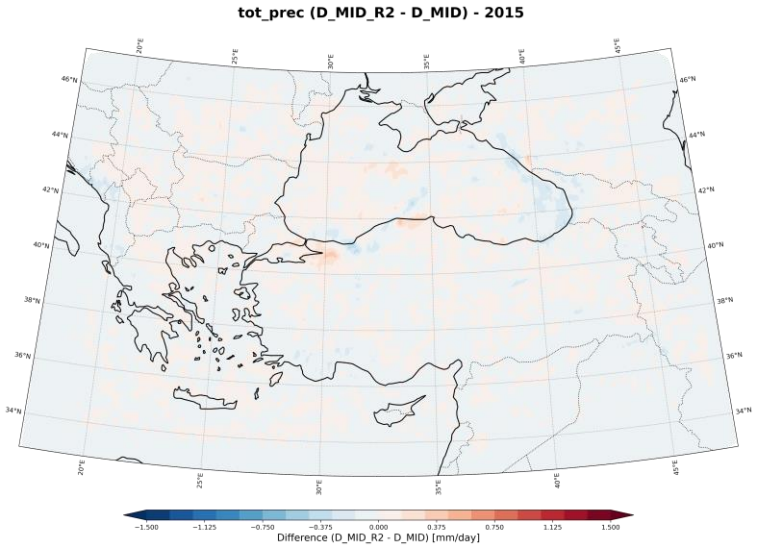
Run	T2m
R1	-0.16
R2	**-0.01**
R3	0.11
R4 / MID	—
R5	0.08
R6	-1.27

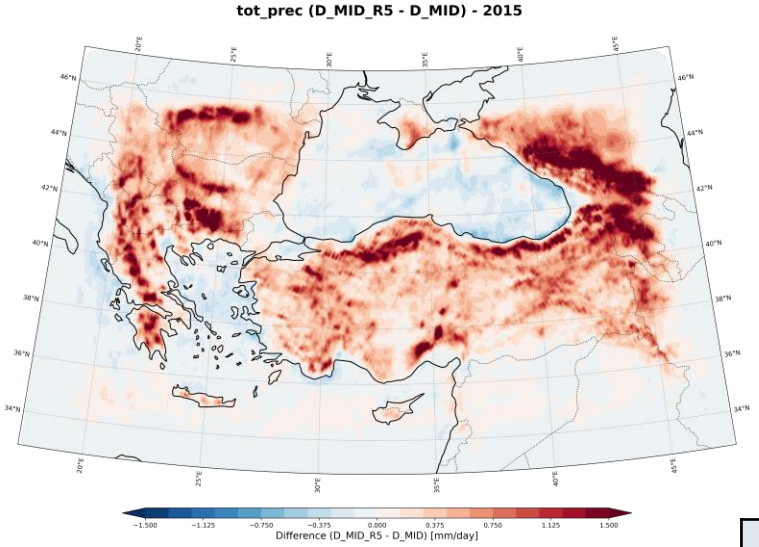
Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	ON	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	RRTM	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	2-cat ice	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	turbdiff	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	Smagorinsky

Difference = experiment − D_MID

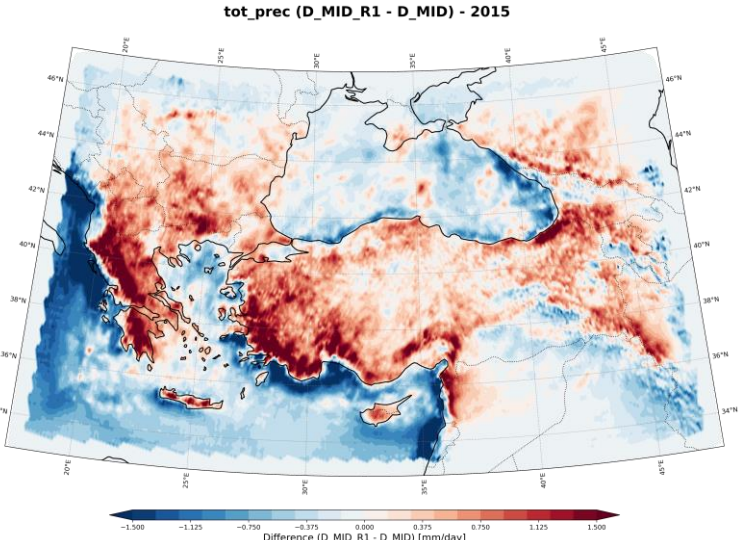
Precipitation response to parameterization changes

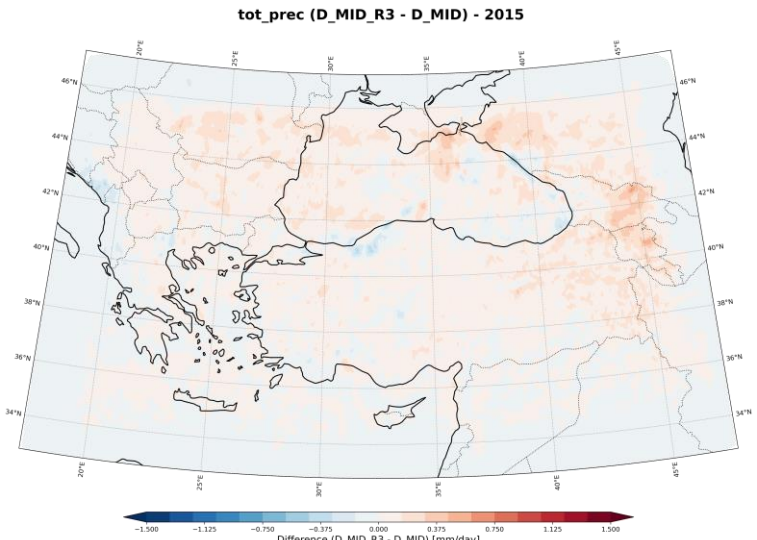


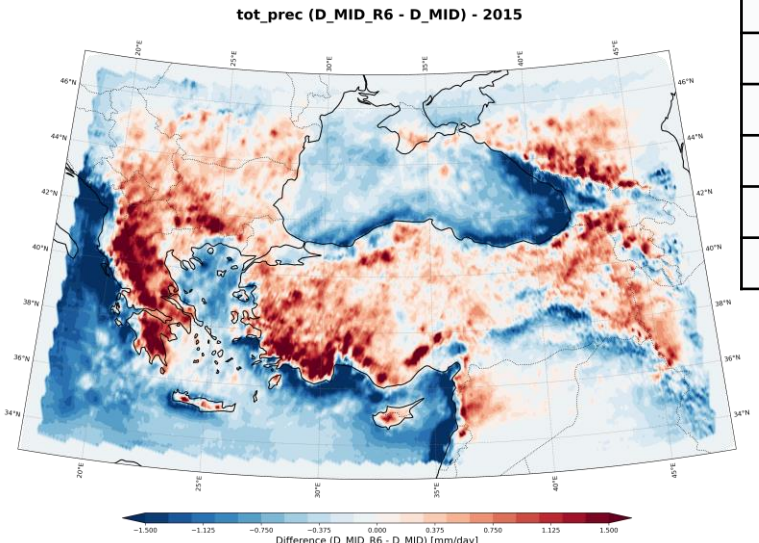




Main response: R1, R5 and R6 is generally wetter, R2 is close to D_MID, R3 is wetter but not as much as R1 or R5





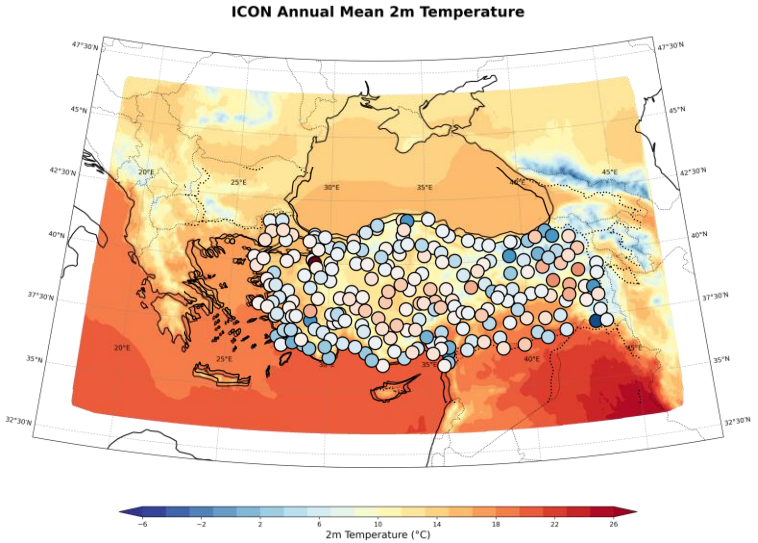


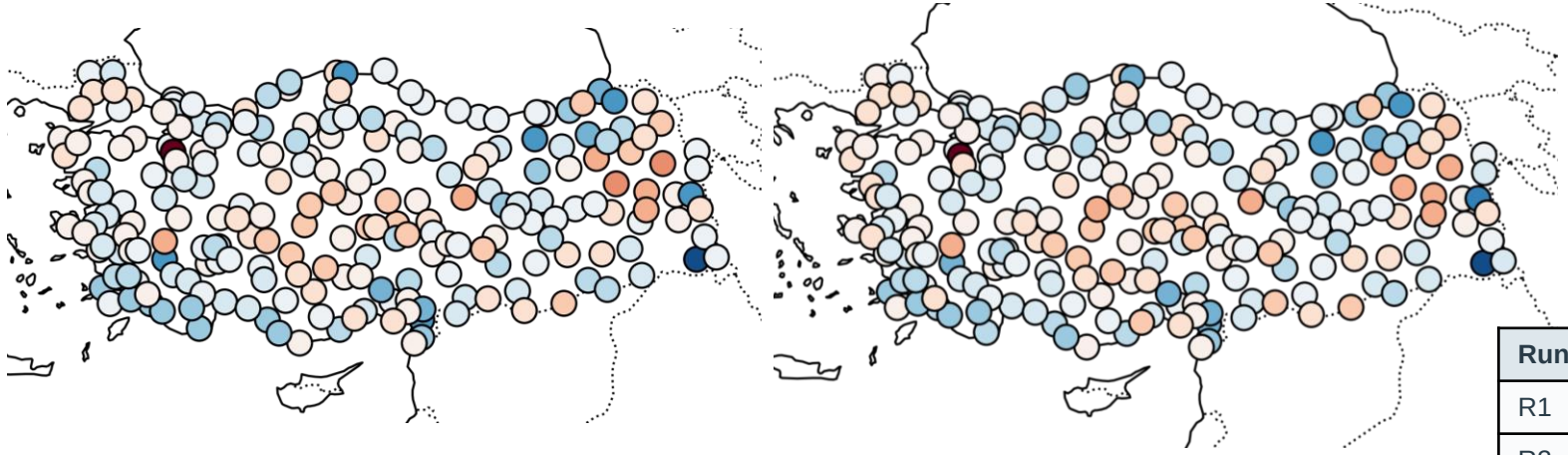
Run	Precip.
R1	0.42
R2	**-0.02**
R3	0.04
R4 / MID	—
R5	0.49
R6	0.27

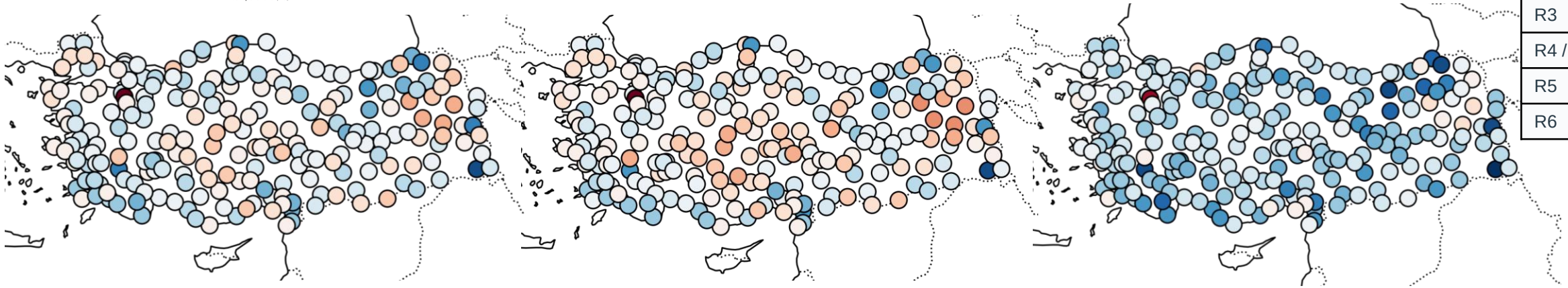
Difference = experiment − TSMS

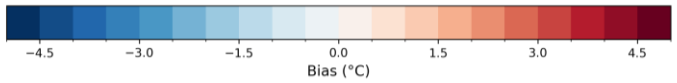
Temperature response to parameterization changes

Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	ON	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	RRTM	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	2-cat ice	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	turbdiff	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	Smagorinsky









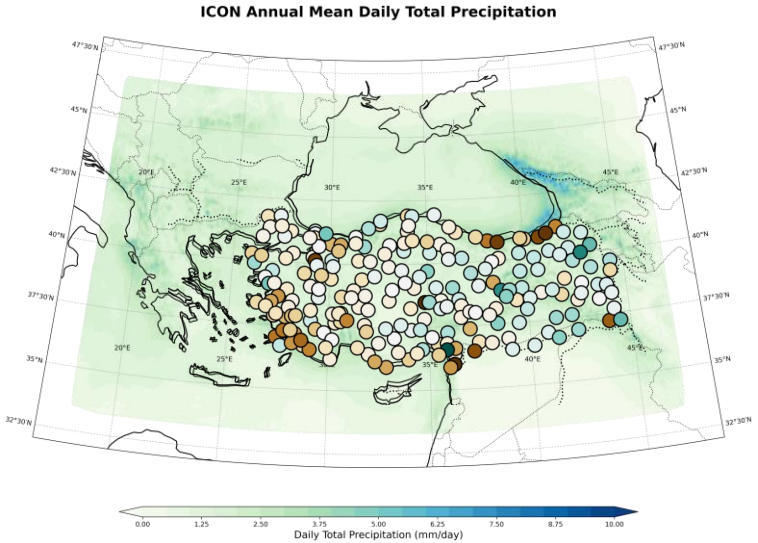
Run	T2m
R1	-0.30
R2	-0.19
R3	**-0.06**
R4 / MID	-0.18
R5	-0.15
R6	-1.30

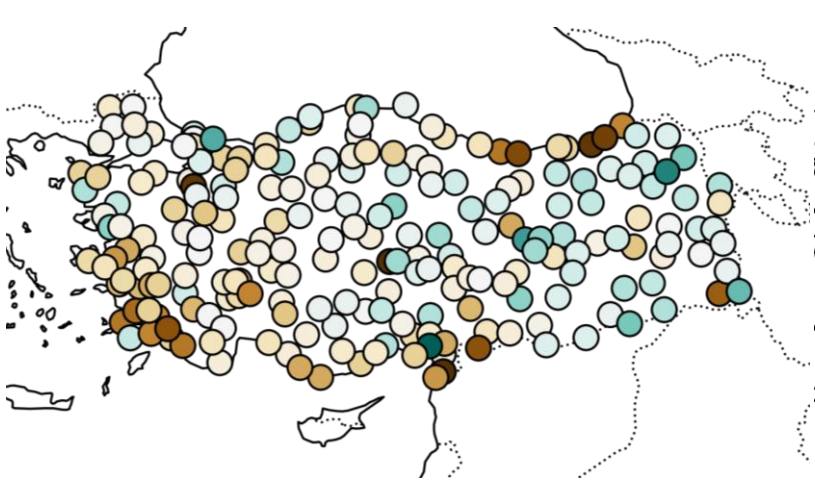
Main response: R6 is colder in all of the domain, R3 is smallest bias, while R2 and R5 close to D_MID

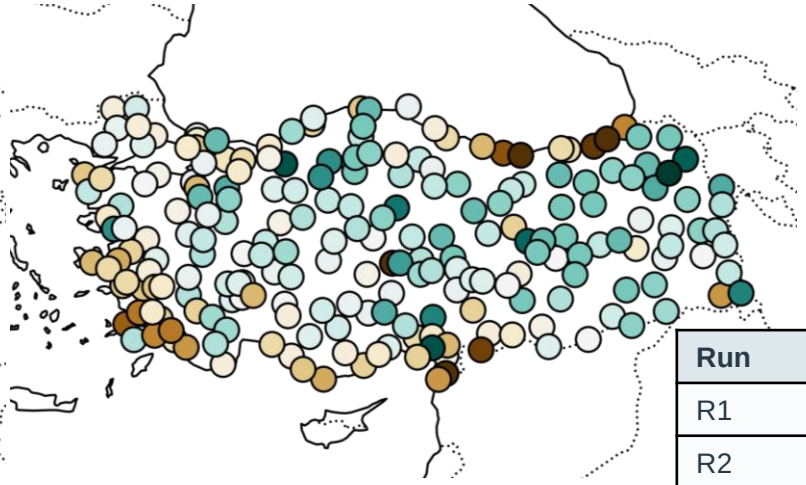
Difference = experiment − TSMS

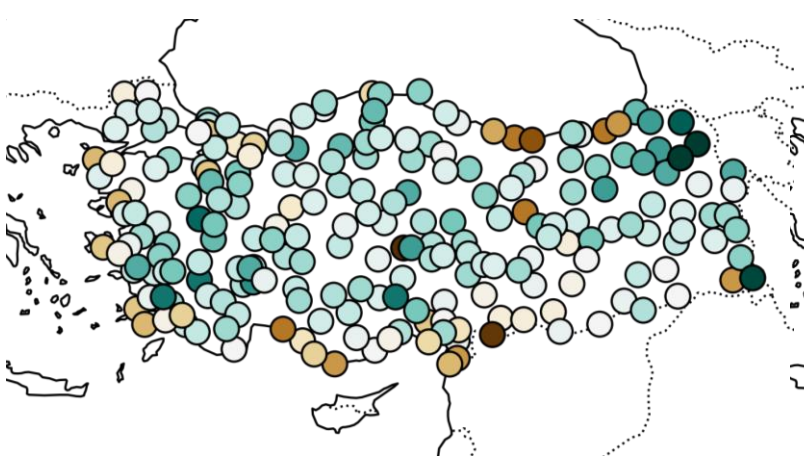
Precipitation response to parameterization changes

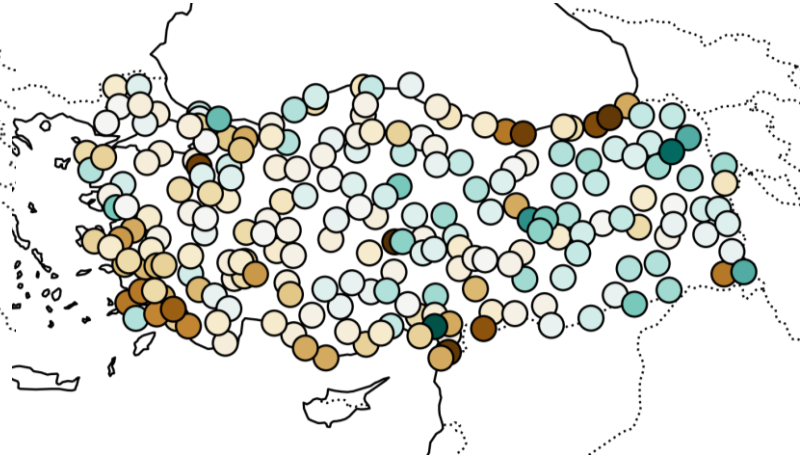
Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	ON	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	RRTM	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	2-cat ice	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	turbdiff	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	Smagorinsky

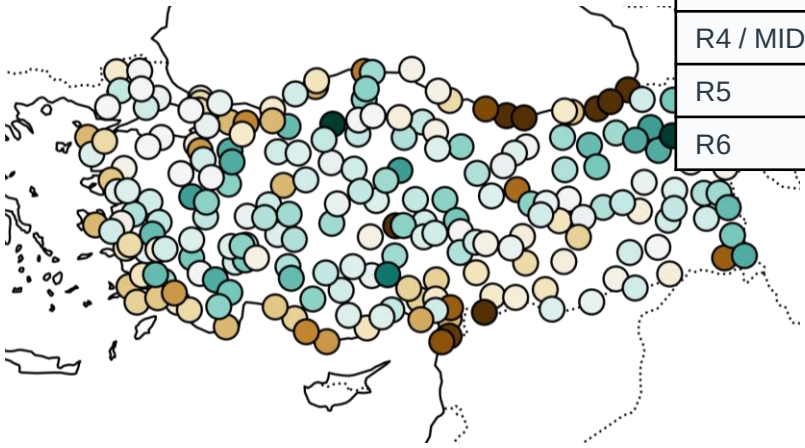




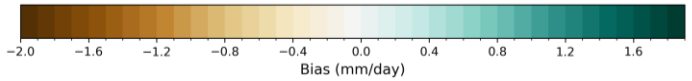








Run	Precip.
R1	0.22
R2	-0.23
R3	-0.18
R4 / MID	-0.22
R5	0.05
R6	**-0.02**



Main response: R5 and R6 are lowest bias, R1, R2 and R3 are close to D_MID

R1–R6 performance against D_MID & TSMS

Annual averages can hide seasonal and regional errors.

Future Work:
Check whether leading configurations remain consistent across seasons?

Bias: closest to zero

D_MID

Run	T2m	Precip.
R1	-0.16	0.42
R2	**-0.01**	**-0.02**
R3	0.11	0.04
R4 / MID	—	—
R5	0.08	0.49
R6	-1.27	0.27

TSMS

Run	T2m	Precip.
R1	-0.30	0.22
R2	-0.19	-0.23
R3	**-0.06**	-0.18
R4 / MID	-0.18	-0.22
R5	-0.15	0.05
R6	-1.30	**-0.02**

RMSE: lowest error

Run	T2m	Precip.
R1	0.22	0.64
R2	**0.02**	**0.06**
R3	0.12	0.09
R4 / MID	—	—
R5	0.13	0.63
R6	1.34	0.62

Run	T2m	Precip.
R1	1.09	0.69
R2	1.09	**0.65**
R3	1.10	**0.65**
R4 / MID	1.09	**0.65**
R5	**1.08**	0.74
R6	1.70	0.77

Temperature: °C
Total precipitation: mm/day

Main findings and next steps

Run	Convection	Radiation	Microphysics	Cloud cover	Turbulence
R1	ON	ecRad	3-cat ice	Koehler	COSMO
R2	OFF	ecRad	3-cat ice	Koehler	COSMO
R3	OFF	RRTM	3-cat ice	Koehler	COSMO
R4 / D_MID	OFF	ecRad	2-cat ice	Koehler	COSMO
R5	OFF	ecRad	3-cat ice	turbdiff	COSMO
R6	OFF	ecRad	3-cat ice	Koehler	Smagorinsky

Domain size

Domain sensitivity is modest for temperature but stronger for precipitation, **D_MID** provides the best overall compromise between skill, boundary effects, and computational cost and was therefore retained as the reference domain.

No single configuration is optimal for all variables. Selection should therefore consider temperature and precipitation jointly, together with seasonal and regional consistency.

ICON performance over Türkiye is more sensitive to physics choices than to domain extent; **R2 and R3** emerge as the most promising configurations, but their performance must be tested seasonally and under contrasting climatic conditions.

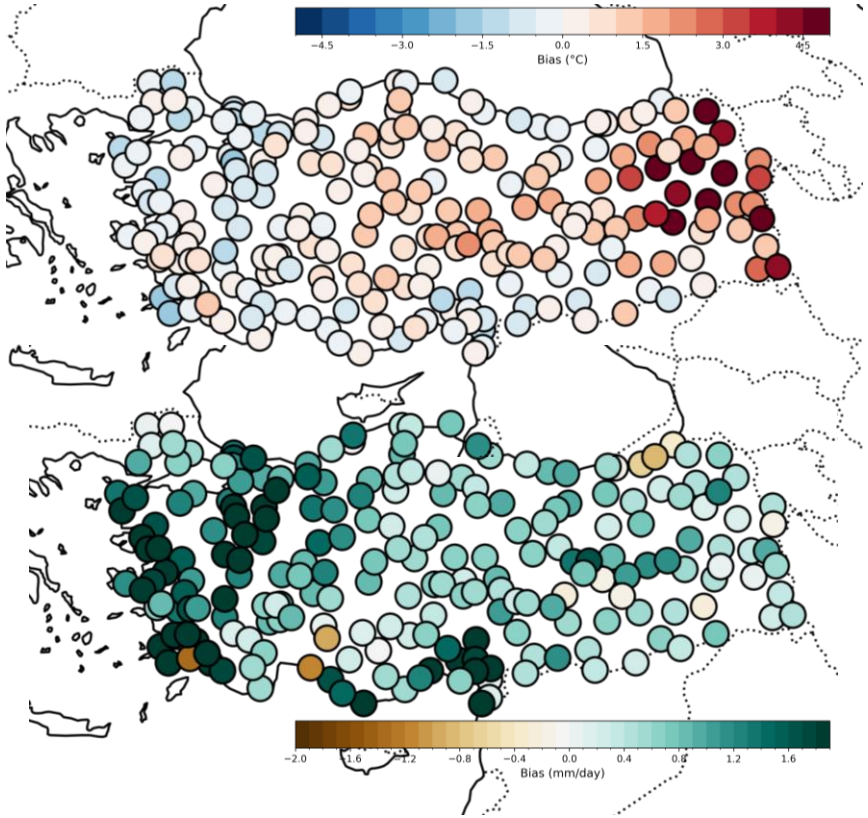
Physical parameterizations

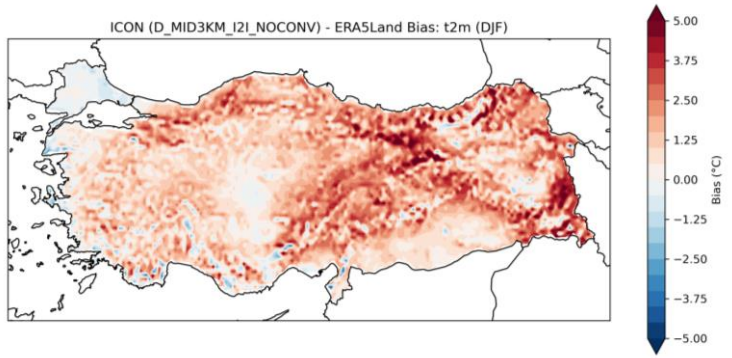
Physical parameterizations **produce larger responses** than domain-size changes, particularly for precipitation and near-surface temperature.

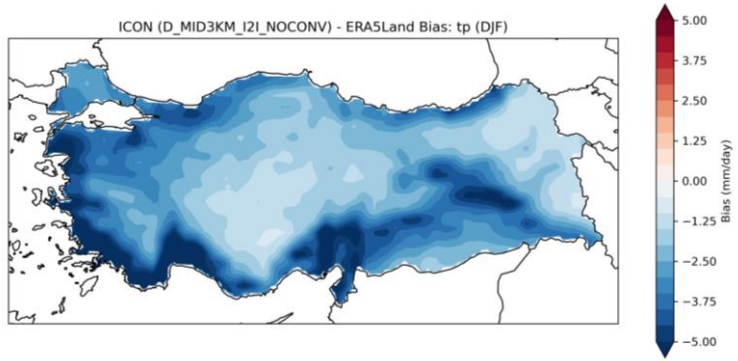
- Convection ON (R1) produces a cooler and substantially wetter simulation, while R2 and RRTM radiation (R3) gives the smallest temperature bias (−0.06 °C) with precipitation skill comparable to D_MID.
- turbdiff cloud cover (R5) substantially reduces the mean precipitation bias (+0.05 mm day^{-1}) while maintaining a small temperature bias, although precipitation RMSE increases.
- Smagorinsky turbulence, together with 3-category ice microphysics (R6) produces an almost unbiased mean precipitation but a pronounced cold bias (~−1.3°C), demonstrating that improving one variable can substantially degrade another.

Convection-permitting experiments at 3 km

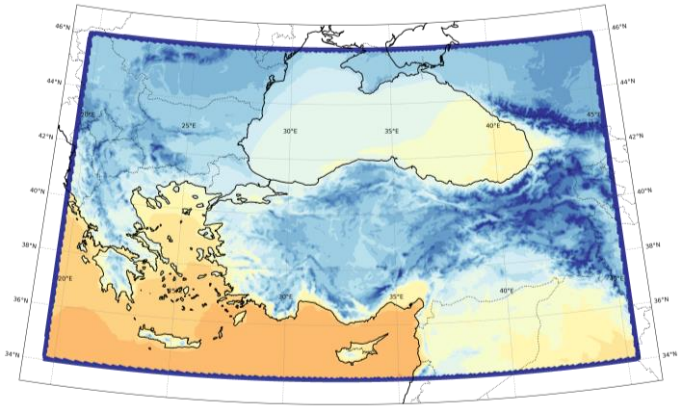
ICON-to-ICON nesting - ongoing
Domain is D_MID but 10 km -> 3 km results

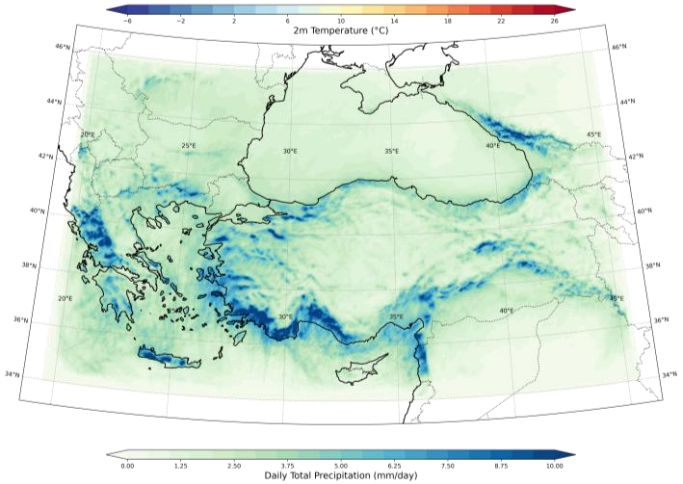






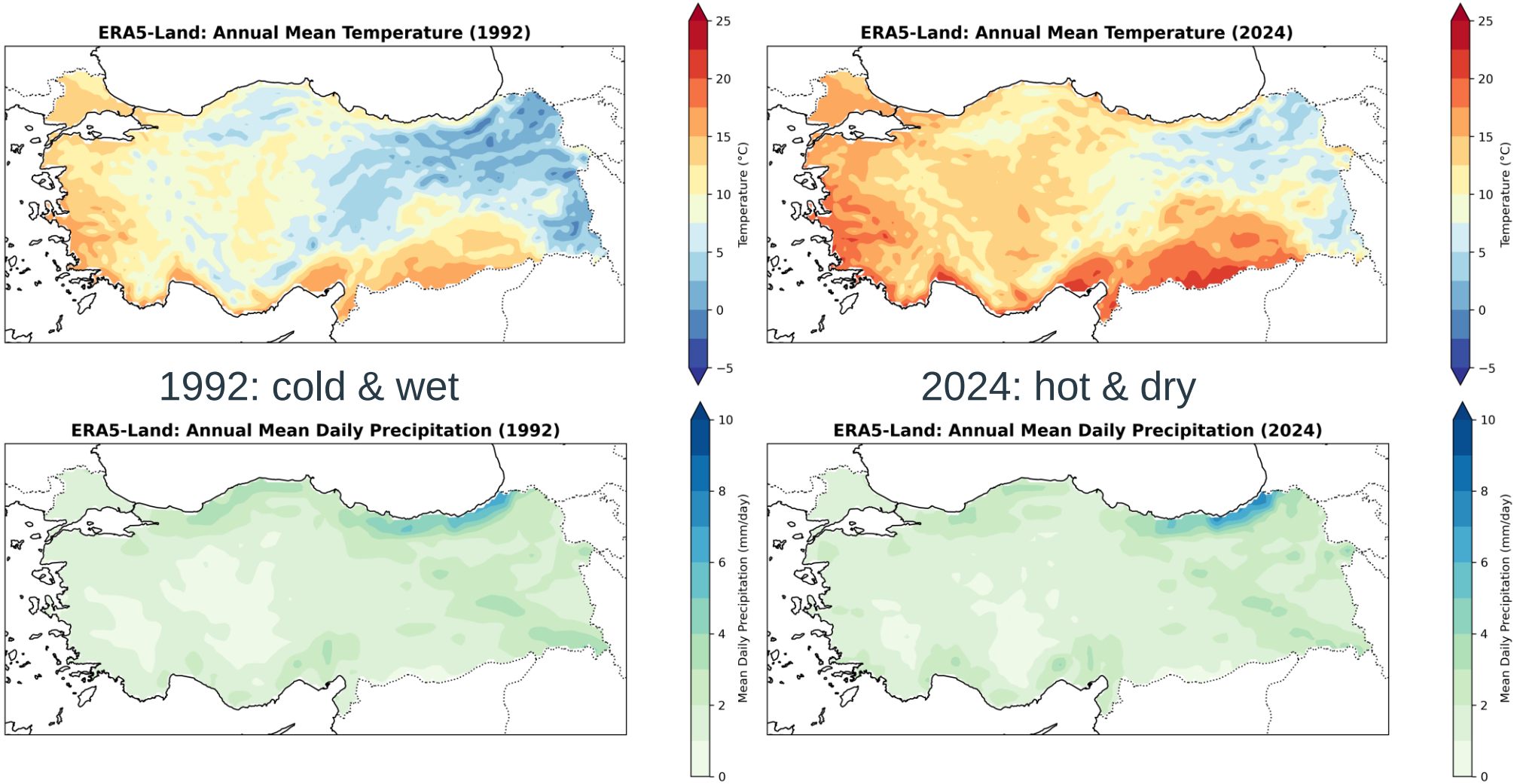
DJF





Evaluation under contrasting years

Apply one/or more selected configuration(s) to both years.



DISCUSSION

Thank you

Questions, comments… or any feedbacks?

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