Analyzing simulated irrigation effects on convection-permitting scale

Does irrigation in Northern Italy affect convective processes?

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MOTIVATION

- By applying irrigation humans alter the biogeophysical properties of the land surface
- Altered surface properties lead to altered land-atmosphere interaction causing effects and feedback mechanisms in the atmosphere (Fig.1), e.g., soil moisture-precipitation-feedback
- Implementing land management practices such as irrigation, and land use and land cover changes into climate models quantifies their impact on the climate
- Using regional climate models, irrigation effects and feedback mechanisms can be simulated but in particular convective processes are highly dependent on the resolution

→ **Aim: Understanding the role of resolution in modeling irrigation effects on convection**

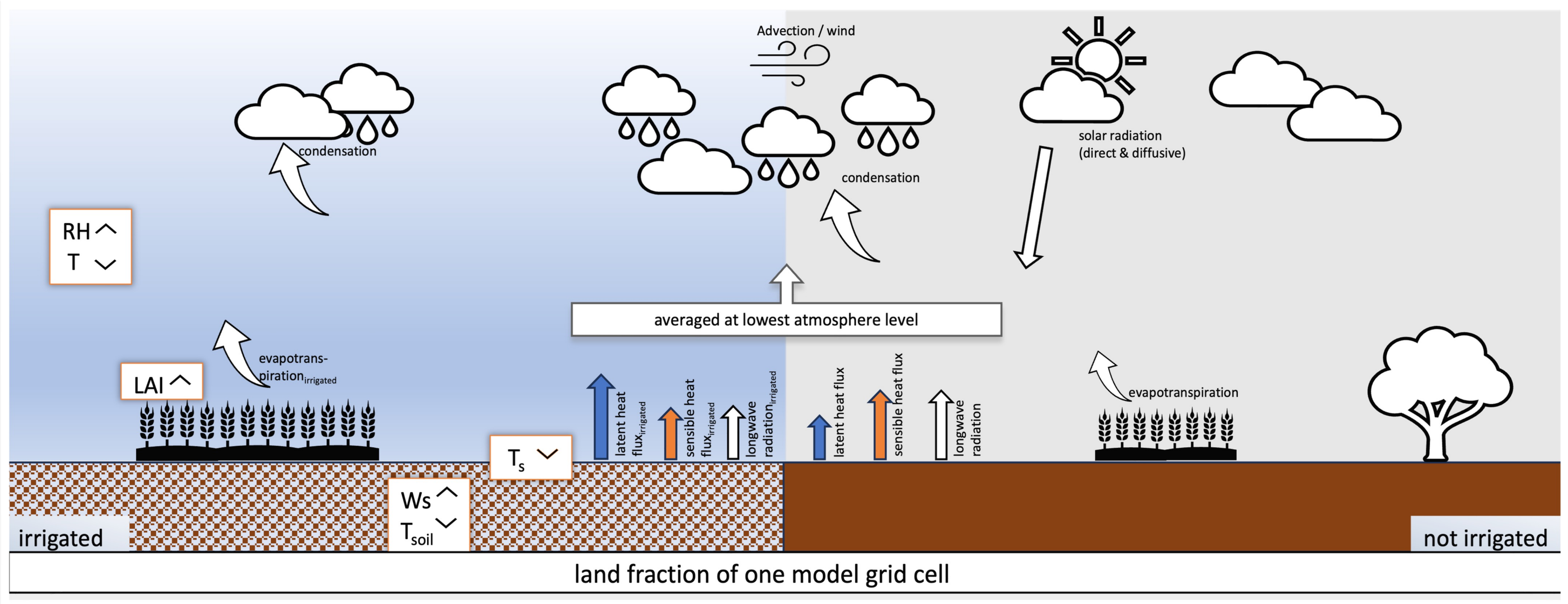


Fig. 1: Visualization of irrigation effects on physical processes and parameters on separated irrigated and not irrigated land fraction in one model grid cell.

EXPERIMENT SETUP

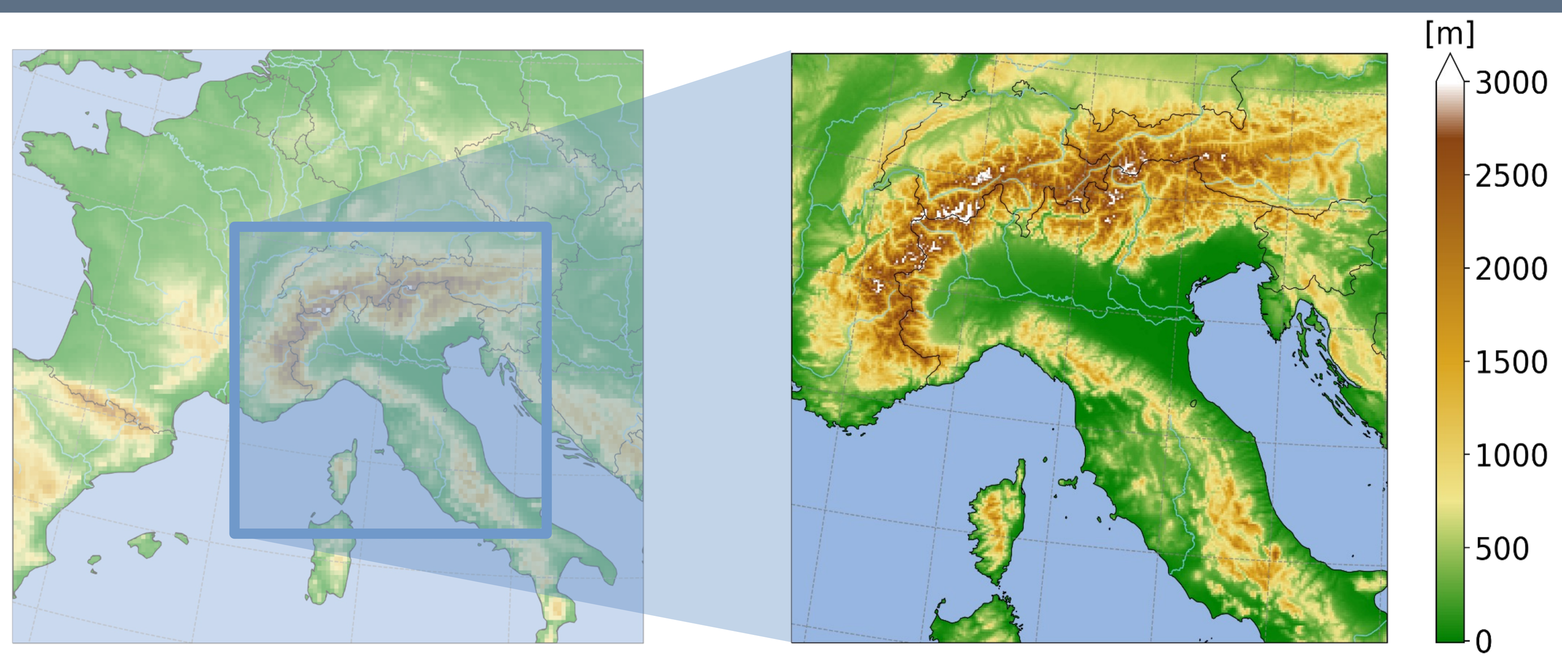
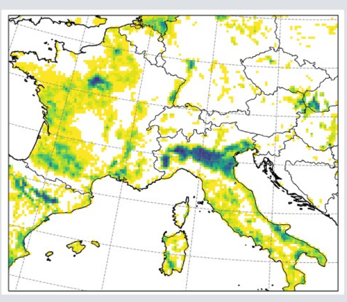
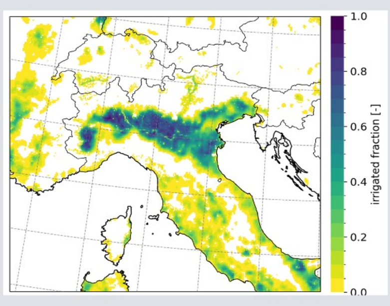


Fig. 2: Model domains for double nesting. Left: Pilot region GAR at 0.11° (~12.5 km) . Right: Pilot region SGAR at 0.0275° (~3 km).

Simulation set	Convection-parameterized 0.11°	Convection-permitted 0.0275°
Model	hydrostatic REMO2020 + FLAKE (lake model) + iMOVE (interactive vegetation module) + Irrigation (newly developed parameterization)	non-hydrostatic REMO2020 + FLAKE (lake model) + iMOVE (interactive vegetation module) + Irrigation (newly developed parameterization)
Forcing	ERA5 (single nesting)	ERA5 → 0.11° GAR → 0.0275° SGAR (Double nesting)
Convection	Massflux (Tiedke, 1989)	Resolved after Goettel (2009)
Simulation period	01/2017 – 12/2017, inc. heat waves in June and August	01/2017 – 09/2017 inc. heat waves in June and August
Irrigation	 Irrigated fraction on 0.11° based on Siebert et al. (2013) Control: off Irrigated: on, with a direct increase of soil moisture for separate irrigated land fraction using relaxation approach (Asmus et al., 2023)	 Irrigated fraction on 0.0275° based on Siebert et al.(2013)

RESOLUTION EFFECTS

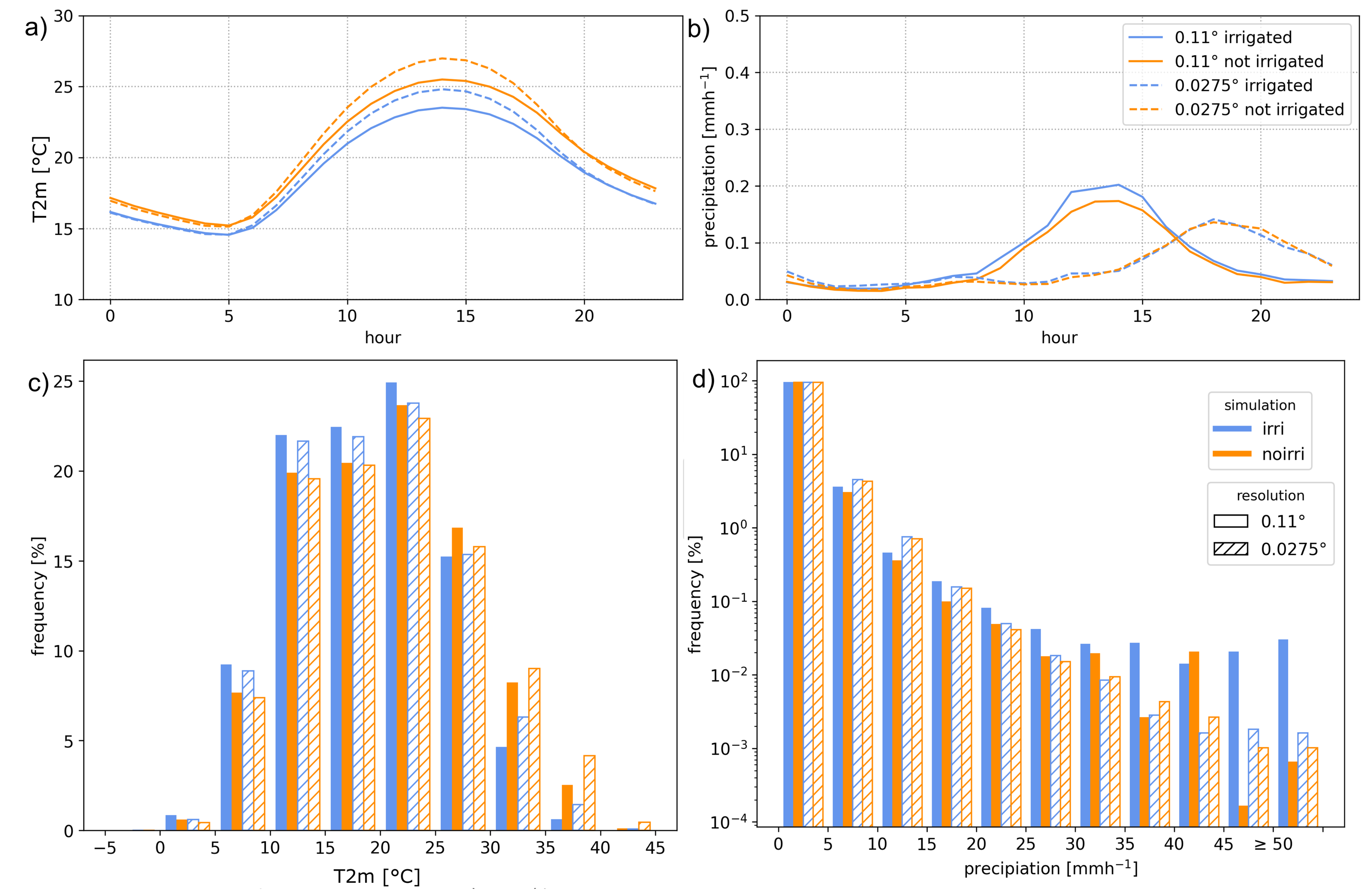


Fig. 3: Diurnal cycle (a, b) and frequency distribution of hourly values (c, d) of 2 m air temperature (T2m) (a,c) and precipitation (b, d)) for grid cells with irrigated fraction > 0.3 during MAMJJ in simulations with and without irrigation.

T2m

- At 0.0275° resolution, T2m reaches higher temperatures during the day than at 0.11°
- Irrigation reduces extreme high temperatures in particular at 0.0275°

Precipitation

- At 0.11° resolution, maximum precipitation during noon, whereas the convection develops in the late afternoon at 0.0275° resolution
- Higher precipitation rates at 0.11° resolution through irrigation than on 0.0275°.

→ Convection parameterization reacts more sensitive to irrigation than resolved convection

IRRIGATION EFFECTS

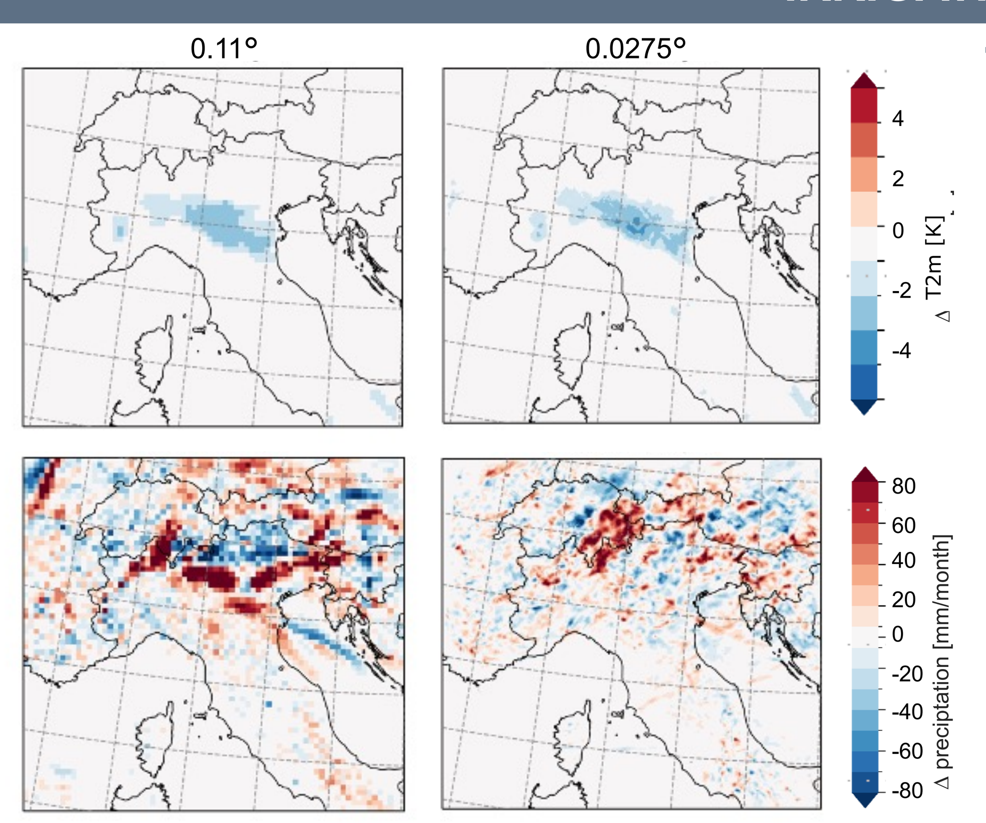


Fig. 4: Simulated irrigation effects as monthly mean on 2 m air temperature (T2m) (a,b), and as monthly sum of precipitation (c, d) in June 2017 in different resolutions.

T2m

- T2m is particularly reduced above areas with high irrigated fraction (cooling effect)

→ Cooling effect is more pronounced at 0.0275° resolution caused by better resolved extreme temperatures, orography and more grid cells with a higher irrigated fraction

→ The cooling effect in both resolutions lead to further feedback mechanism such as a shifted harvest time

Precipitation

- At 0.11° resolution precipitation increases in the Po Valley and at the border to the Alps
- At 0.0275° resolution precipitation increases in the Alps whereas above the irrigated areas no clear signal develops

→ Convection parameterization reacts more sensitive to the additional moisture from irrigation

CONCLUSIONS

- Irrigation reduces T2m in both simulations, with greater cooling (-3 K) at 0.0275° resolution due to improved representation of extreme temperatures, orography, and irrigated areas.
- Precipitation increases in the 0.11° resolution simulation with parameterized convection over irrigated regions, but no clear signal is seen in the 0.0275° resolution simulation with resolved convection.
- The convection parameterization at 0.11° resolution responds more sensitively to increased soil moisture, potentially leading to an overestimation of irrigation's impact on precipitation.

References

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