The effect of drying and irrigation on the local climate with WRF-ARW model: a case of the Po Valley (Italy).

Arianna Valmassoi[1], Jimy Dudhia[2], Silvana Di Sabatino[3], Francesco Pilla[1]

[1] Dept. of Planning and Environmental Policy, University College Dublin
[2] National Center for Atmospheric Research, NCAR
[3] Department of Physics and Astronomy, University of Bologna, Italy

Abstract

The climate system is complex and non-linear with many feedbacks that connect different parts, such as land-atmosphere. It is scientifically agreed that changes in the atmospheric state can impact changes in the land, an example is plant species migration due to shifts in climates. However, this feedback effect also happens in the opposite direction: land use changes affect the climate on multiple scales. Recent studies found that conversion from higher natural vegetation to agricultural land cause a cooling effect on climate, though it responds drastically differently to heat waves. In fact, the low agricultural cultivar is more sensitive to drying due to the lower depth of the root zone. Therefore, soil moisture depletion due to dry conditions affects this type of vegetation strongly. To avoid drying, semi-arid summer regions use irrigation to support agriculture. These two semi-dynamic processes are not well represented within limited area numerical weather prediction models, such as the Weather Research Forecast (WRF-ARW 3.8.1) model.

Therefore, this study aims to assess the impact of drying and irrigation processes on the local climate and circulation. Firstly, the current WRF-ARW representation of the local climate is determined for a test case: the Po Valley in northern Italy, which is highly cultivated and irrigated, under heat wave conditions. Then the drying process under heat stress conditions is studied from the soil-atmosphere coupling perspective. Subsequently, the irrigation process is implemented in WRF-ARW with different parametrizations.

Research questions

- Are the drying-out plant conditions well represented in the model?
- How do these two processes affect the local circulation during heat-wave conditions?
- **Is the irrigation process affecting the local climate? How?**

Methods

Study area: Po Valley (Italy)

- Mediterranean climate type: low precipitation during summer season
- Surrounded by mountains (north, south and west) and by the Adriatic sea (east)
- Highly cultivated and **irrigated**

↓

Amount of water used for irrigation (on cropland area, category 12 in Fig. 1) for the whole summer season: **3mm/day** [Eurostat].

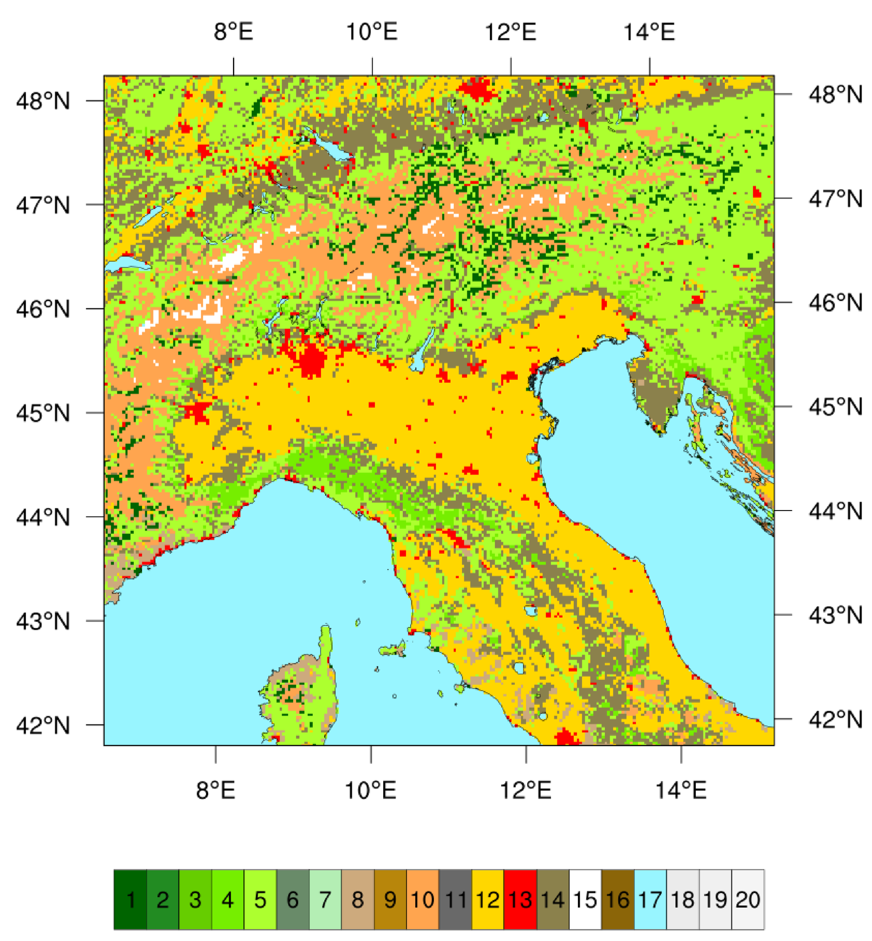


Figure 1: Representation of the land-use MODIS categories in the inner domain for the model simulation at 3 km resolution.

WRF-ARW 3.8.1:

- Simulation period: 1^{st} - 17^{st} July 2015 at 00 UTC
- Initial and Boundary conditions: ERA-Interim (atmosphere and surface parameters) and GFS 0.25° (soil moisture and temperature)
- Two runs: (i) control run (**CTR**) and (ii) include irrigation (**IRR**).
- Main parameterizations used:

Test	Micro physics	Radiation (SW+LW)	Land surface model	Boundary layer
T1	WSM6	RTTG	Noah	YSU
T2[a]	WSM6	RTTG	Noah-MP	YSU

Table 1: Parameterizations used; [a] Next test

Plan

- Test Noah-MP, as Table 1
- Test different irrigation values, to assess the sensitivity to the water amount.
- Test WRF-ARW sensitivity to agricultural vegetation greenness.

Acknowledgments

This work is carried out as a part of the NCAR Advanced Study Graduate Visitor Program and the iSCAPE (Improving Smart Control of Air Pollution in Europe) project (funded by the European Community's H2020 Programme H2020-SC5-04-2015 under the Grant Agreement No. 689954).

Results

The difference between the runs is defined as :

$\Delta\chi = \chi_{IRR} - \chi_{CTR}$.

Fig.2 shows that irrigation increases the water vapor mixing ratio at 2 meters above the ground.

The black rectangle represent the limits for the spatial averaging of the cropland area used in the next figures, cropland area is gray-shaded.

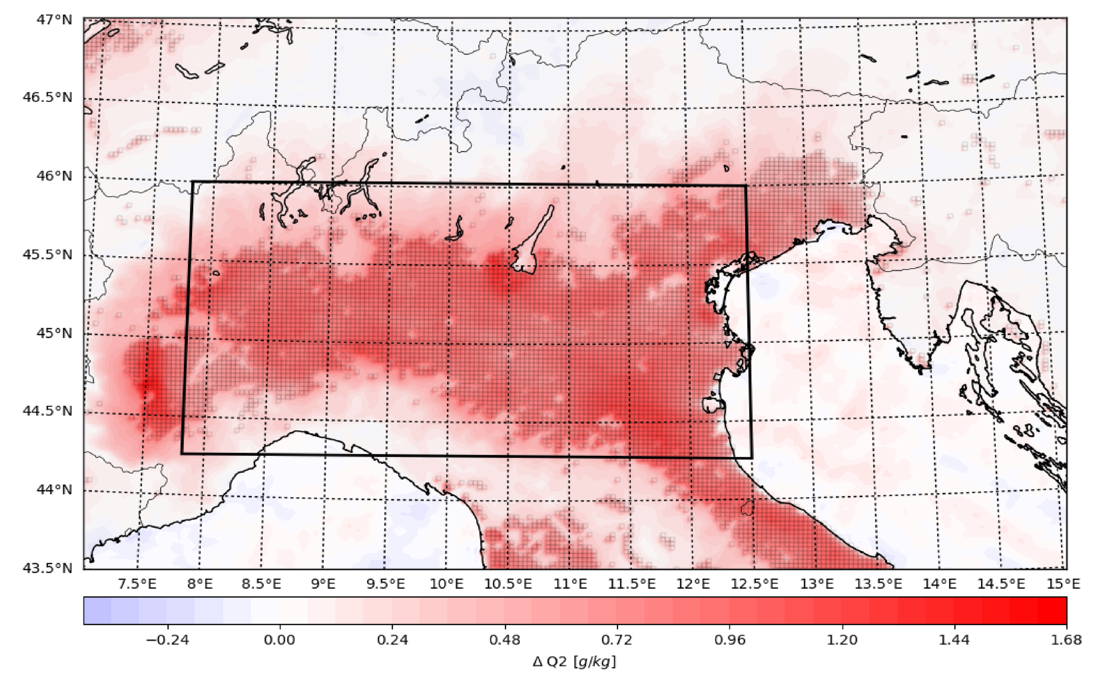


Figure 2: Q2 averaged over the whole period for 08-13 UTC.

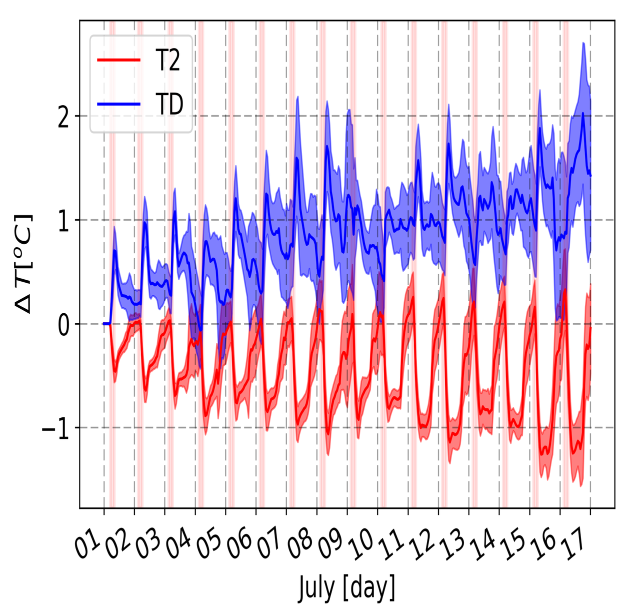


Figure 3: $\Delta T2$ (red) and ΔTD (blue) time series.

Irrigation reduces the 2-meter temperature, with a diurnal period, and increases the dew point temperature (Fig.3). It prevents the drying out of the soil by increasing soil moisture at the first level, and reducing the drying of the second one (Fig.4).

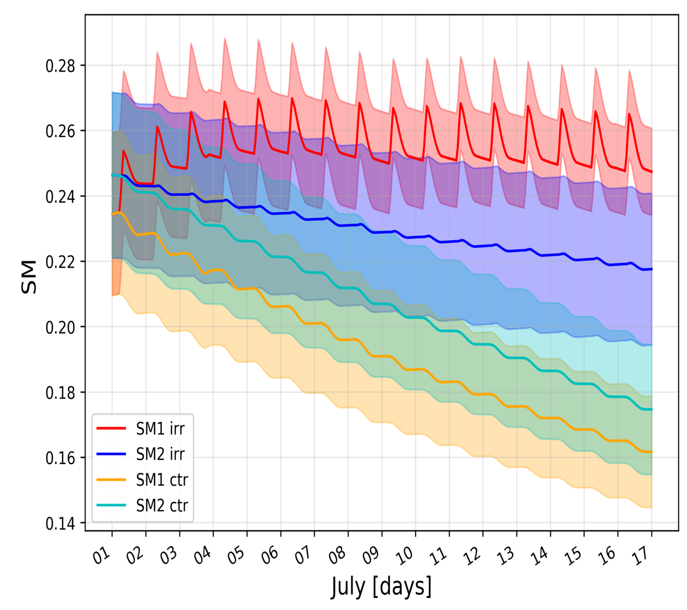
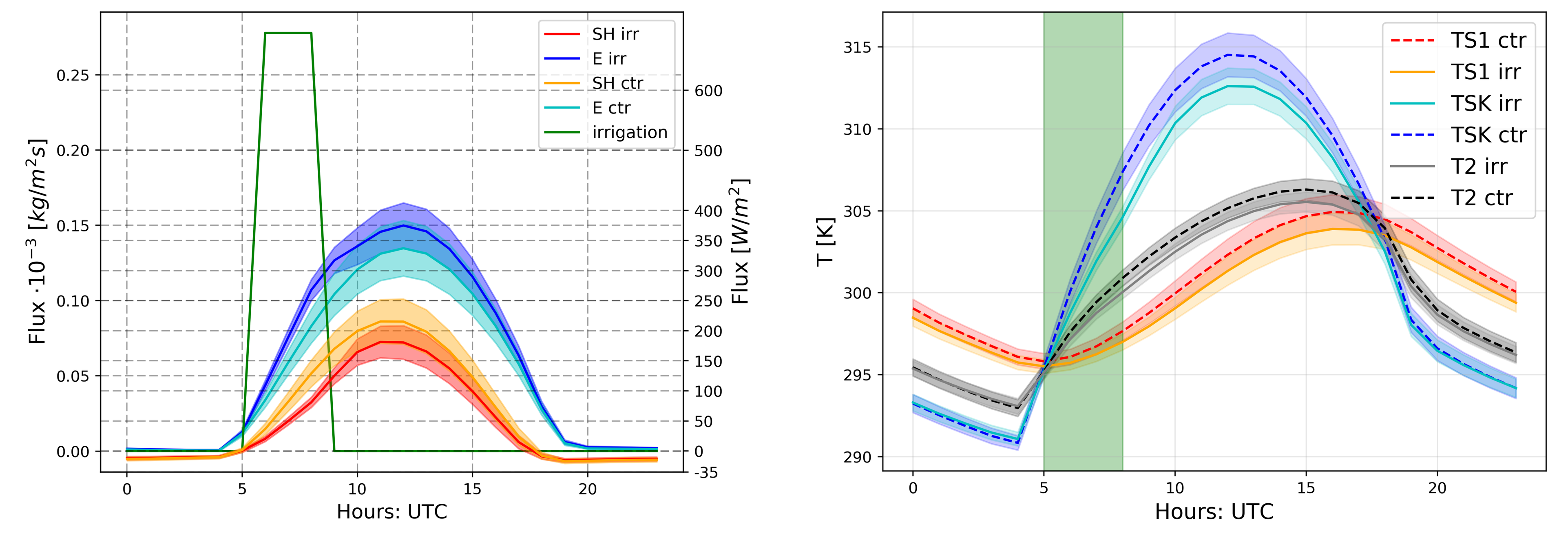


Figure 4: Soil moisture at level 1 (SM1) and 2 (SM2) for the two runs.

Diurnal cycle:

Irrigation decreases the sensible heat flux (SH), while it increases the moisture flux (E). The daily integrated moisture flux is increased by $0.2 \cdot 10^{-3}\ kg/m^2$ (from $1.2 \cdot 10^{-3}$ to $1.4 \cdot 10^{-3}$) due to the irrigation (which is $0.8 \cdot 10^{-3}\ kg/m^2$).



(a) Upward moisture (E) and irrigation fluxes, and sensible heat flux (SH), for each run.

(b) T2, skin temperature (TSK) and first level soil temperature (TS1), for each run.

A higher mean skin temperature in the irrigation run at sunrise (Fig.5(b)) causes a positive difference in the first layer's potential temperature (Fig.6). The decrease of all temperatures (IRR run) during the daytime reflects on the vertical potential temperature (Θ) profile. Notice that the PBL height is lower for the IRR run and the stable boundary layer formation is delayed in the afternoon.

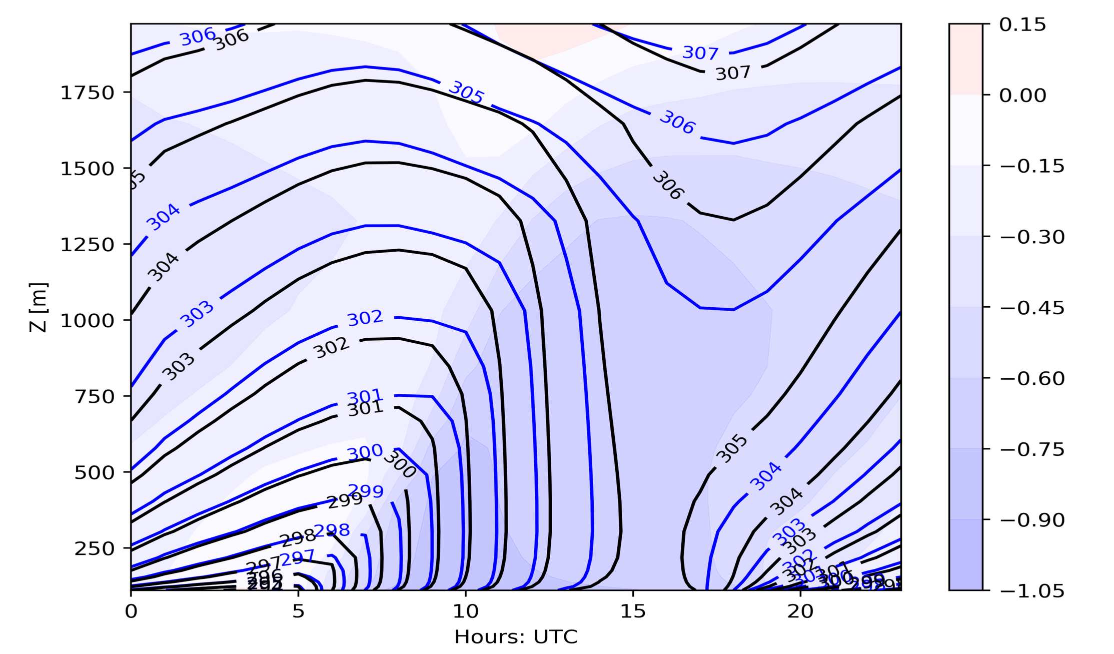


Figure 6: Diurnal cycle of the vertical distribution of Θ, for IRR (blue) and CTR (black) run.