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Irrigation contrasts in the morning transition

J. K. Brooke, M. Best, A. Lock, S. R. Osborne, J. Price, J. Cuxart, A. Boone, G. Canut-Rocafort, O. Hartogensis, A. Roy

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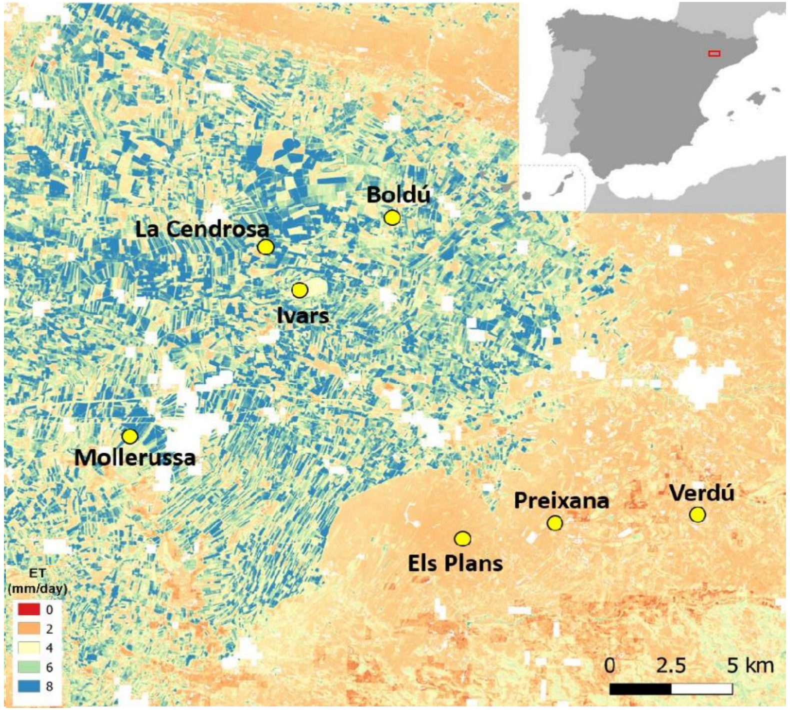
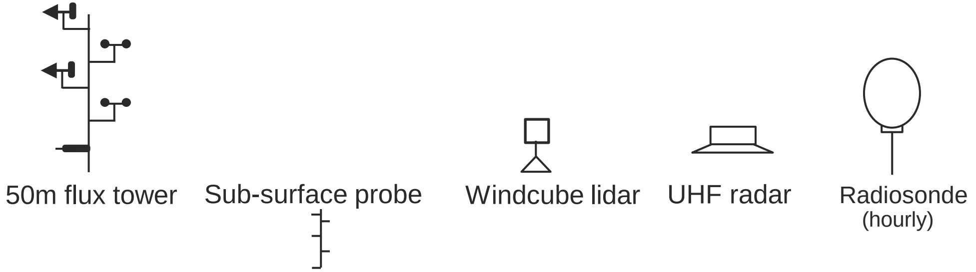
LIAISE Special Observing Periods (SOP)



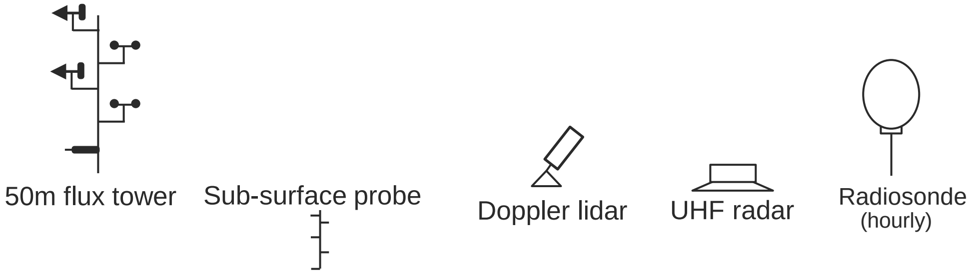
Crop evapotranspiration (17 July 2021) from Two-Source Energy Balance (TSEB) model using Sentinel-2 and Sentinel-3. Prepared by IRTA (J. Bellvert).

Co-ordinated and co-located observations between irrigated and natural areas: surface & sub-surface measurements, remote sensing platforms, and boundary layer.

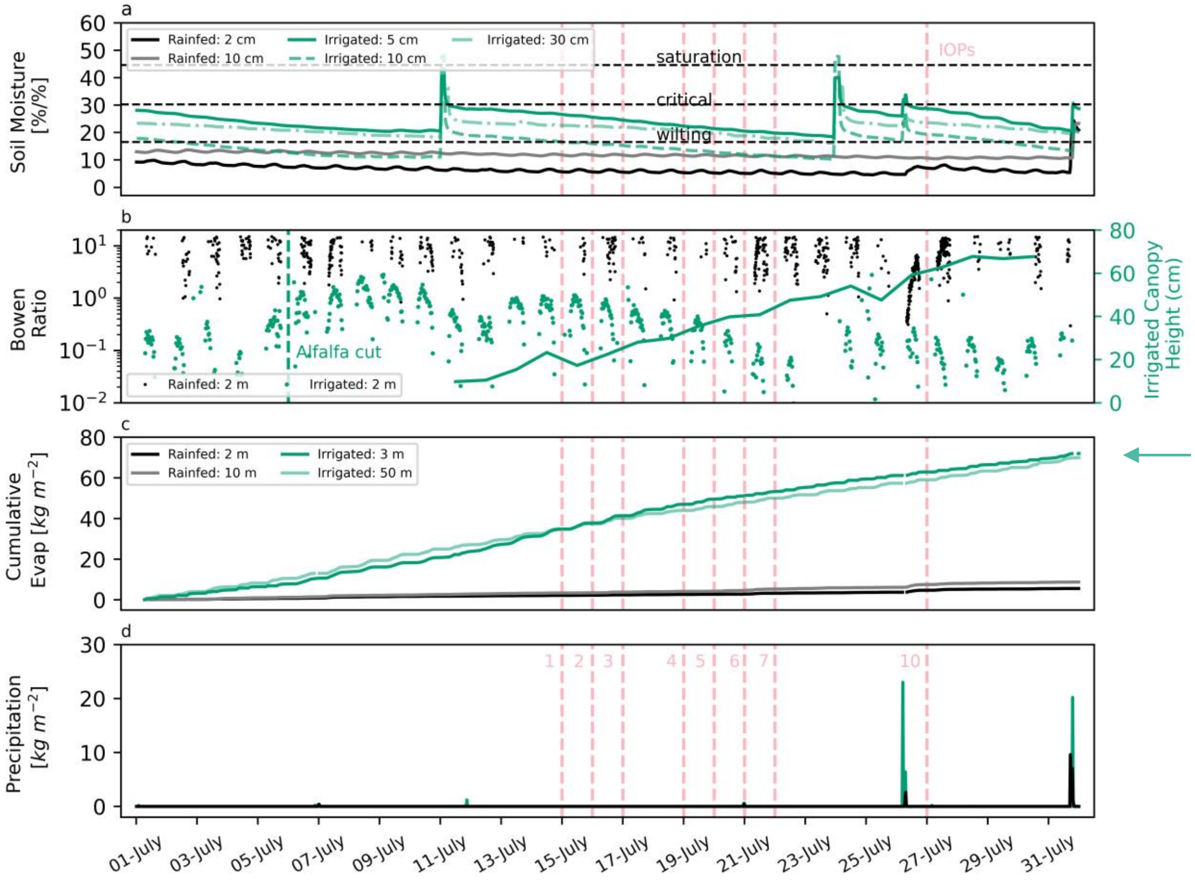
Supersite 1: Irrigated site



Supersite 2: Natural/Arid site



LIAISE SOP Evolution: July 2021



Irrigated site: variable soils

Arid site: dry soils

Arid site: Sensible heating dominates

Irrigated site: Evapotranspiration dominates

The cumulative evapotranspiration during July 2021 was a factor of 10 greater at the irrigated site

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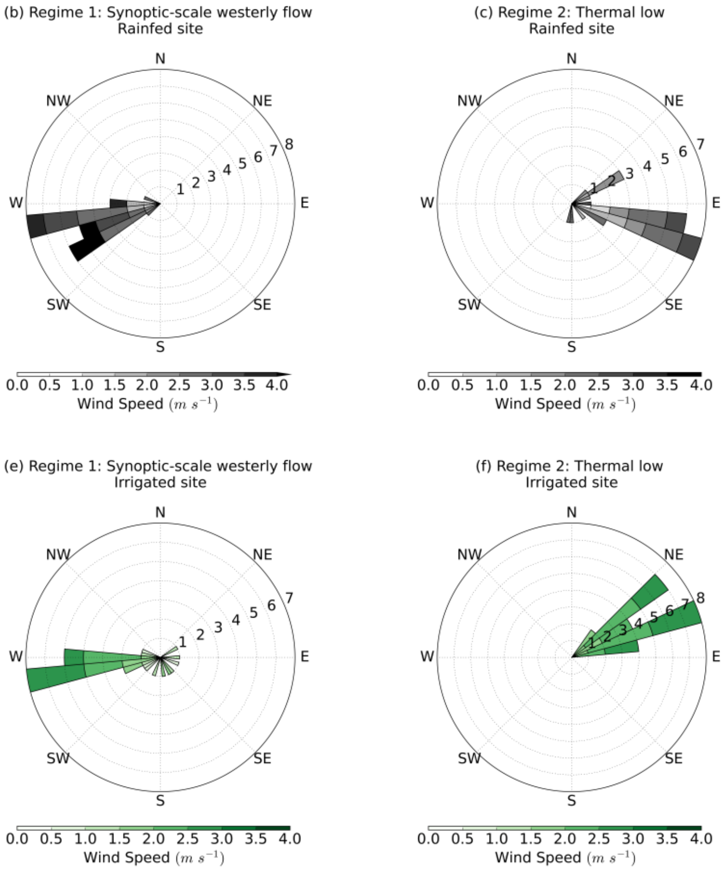
LIAISE flow regimes

during the morning transition



Regime 1: Synoptic-scale westerly flow

- 4 IOPs (IOP1-4)
- 15-19 July

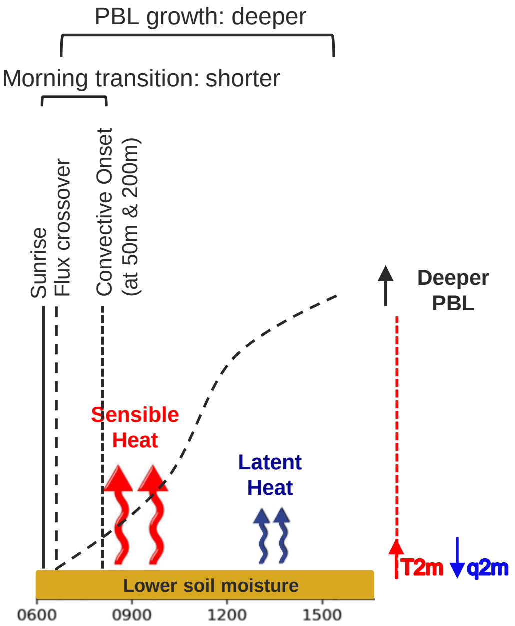
Regime 2: Thermal low

- 3 IOPs (IOP5-7)
- 20-22 July
- Without the presence of synoptic-scale westerly flow, local nocturnal flows are established, and the direction of these winds is influenced strongly by local topography. These local nocturnal flows predominate over the flow during the morning transition period.
- Rainfed site generally aligned with down-slope flows from the Serra del Terrat range.

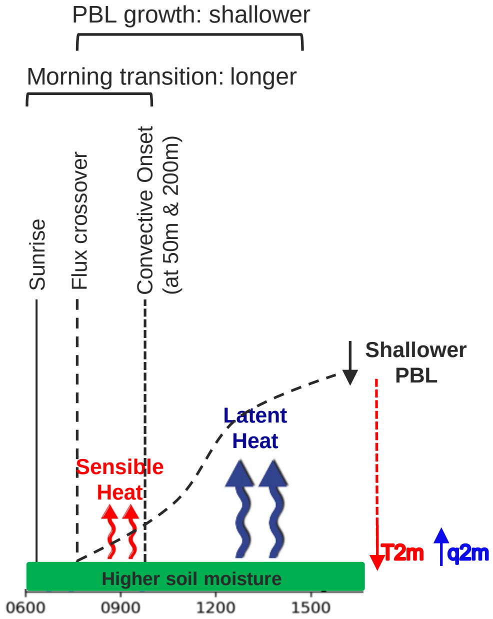
Morning Transition Period

Contrasts in near-surface meteorological parameters and boundary-layer thermodynamic profiles at an irrigated and rainfed (arid) site **were established during the morning transition**.

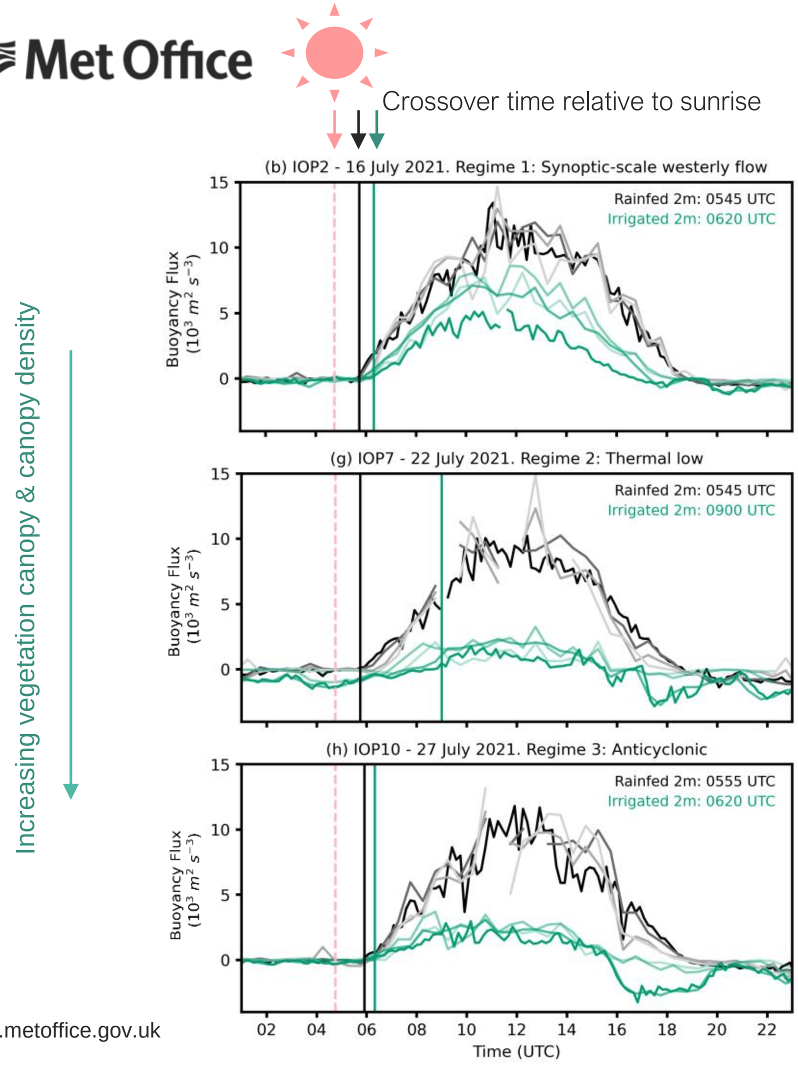
Arid/rain-fed site



Irrigated site



Kinematic Buoyancy flux



The morning transition mean buoyancy flux was x2.8 times smaller at the irrigated site (1.1 m^2s^{-2})* compared with the rainfed(arid) site (3.1 m^2s^{-2}).

Delay in buoyancy flux crossover time at the irrigated site:

- Regime 1: 30-minute delay at the irrigated site
- Regime 2: 90-minute delay at the irrigated site

The daily mean (1000–1400UTC) buoyancy flux was:

- Regime 1: x2.6 times smaller at the irrigated site
- Regime 2: x5.0 times smaller at the irrigated site (attributed to both canopy density & regime)

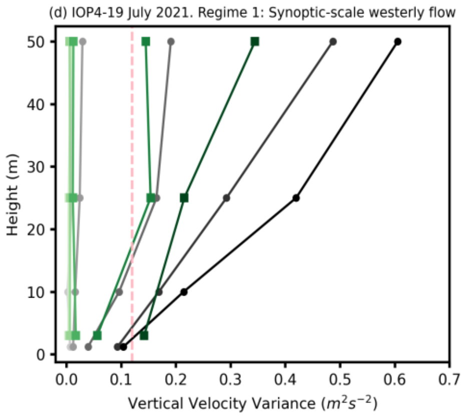
Buoyancy flux units x10^3 m^2s^{-2}

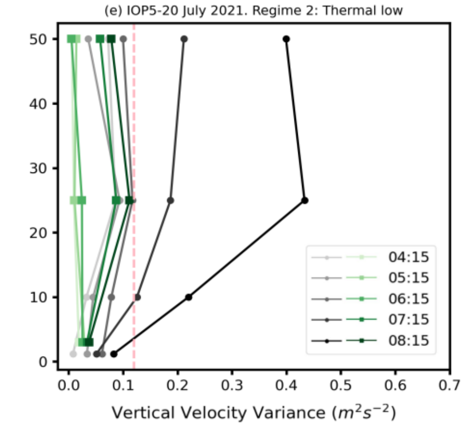
Vertical velocity variance

Measure of the vertical intensity of turbulence

Time of convective onset to be where the variance in vertical velocity exceeds 0.12 $m^2 \cdot s^{-2}$ when combined with a positive skewness.

Threshold 0.12 $m^2 \cdot s^{-2}$





Regime 1: Convective onset is established 100 min (0625 UTC) and 130 min (after sunrise) (0655 UTC) for the rainfed and irrigated sites, respectively.

- This gives rise to a 30-min delay at 50 m (irrigated site compared with the rainfed site).

Regime 2: Convective onset is established 110 min (0635 UTC) and 260 min (after sunrise) (0900 UTC), for the rainfed and irrigated sites, respectively.

- This gives rise to a 150-min delay (0715 UTC) (irrigated minus rainfed) during the thermal low regime.

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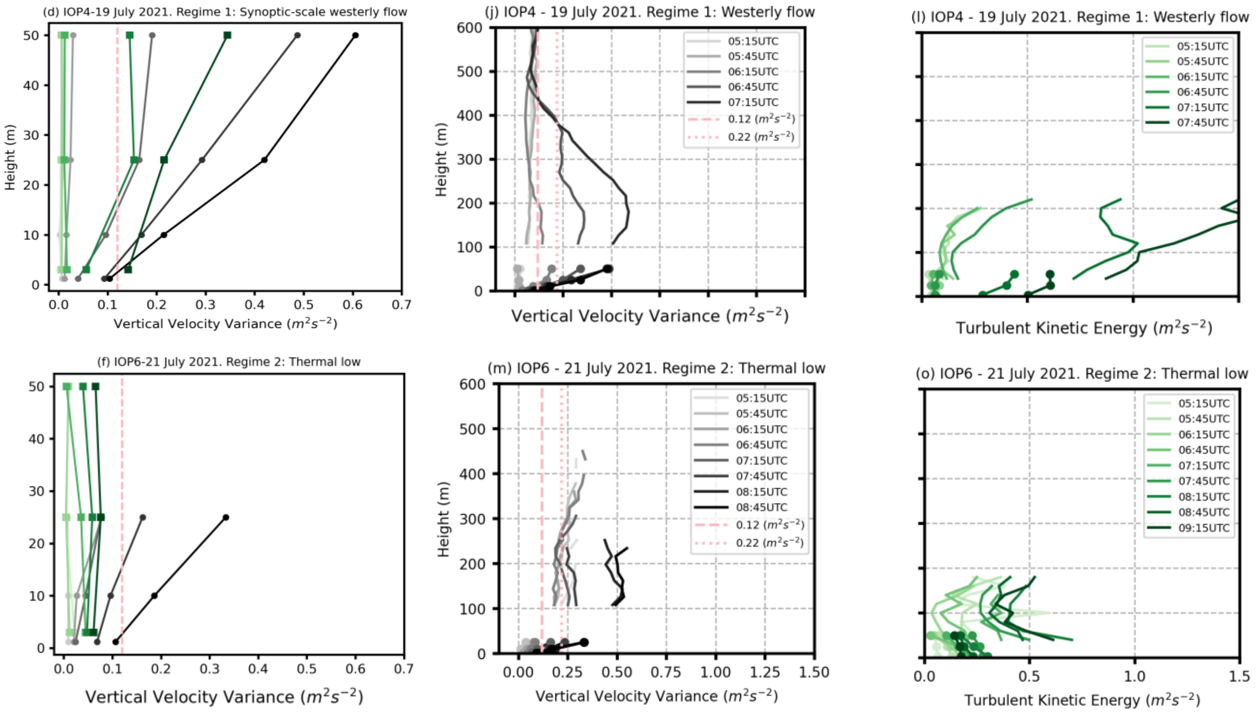
Vertical velocity variance

Measure of the vertical intensity of turbulence

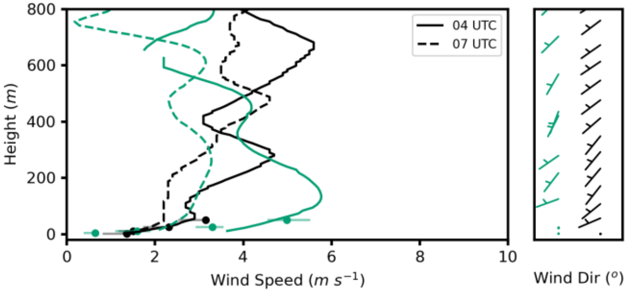
Propagation and vertical growth of turbulence between 50 and 200 m generally occurred within the 30-min averaging window of the Doppler lidar data.

Time of convective onset to be where the variance in vertical velocity is greater than 0.12 $m^2 \cdot s^{-2}$ when combined with a positive skewness.

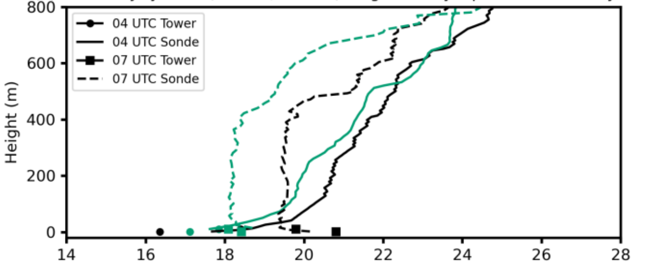


Wind & temperature vertical profiles

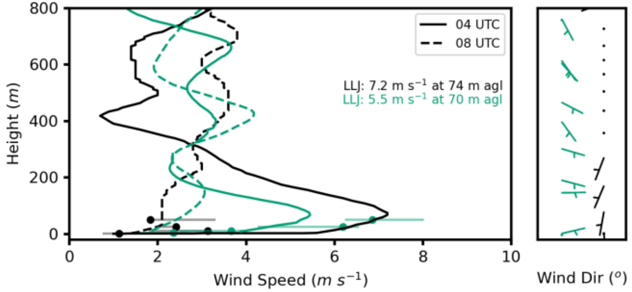
(b) IOP2: 16 July 2021 (04 UTC, 07 UTC). Regime 1: Synoptic-scale westerly flow



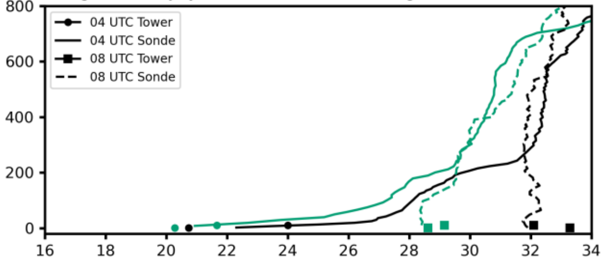
(b) IOP2: 16 July 2021 (04 UTC, 07 UTC). Regime 1: Synoptic-scale westerly flow



(g) IOP7: 22 July 2021 (04 UTC, 08 UTC). Regime 2: Thermal low



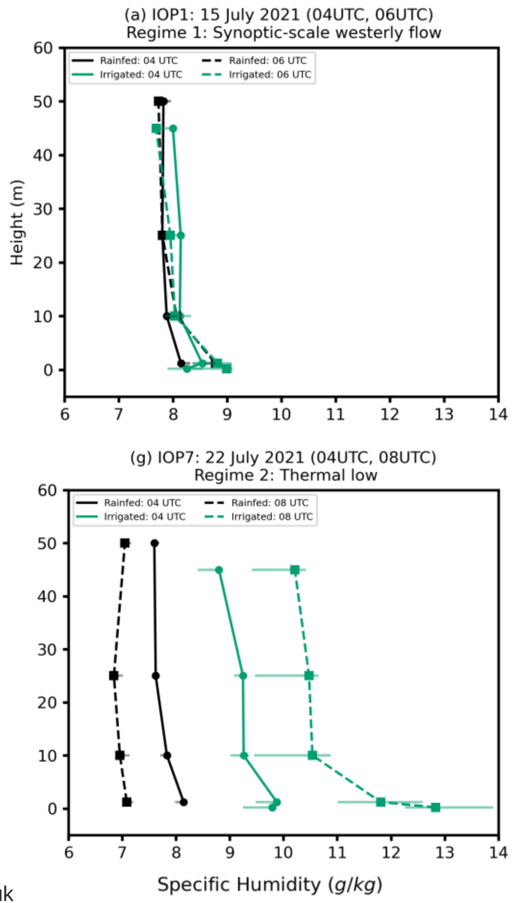
(g) IOP7: 22 July 2021 (04 UTC, 08 UTC). Regime 2: Thermal low



- Regime 1: Well mixed wind profiles with dominance of westerly synoptic-scale flow.
- Regime 2: Nocturnal low-level jet (LLJ), is more prominent during the thermal low regime (IOP5–7). The mean height of the LLJ is 97±38 m.

- At the start of the morning transition (sunrise), the average screen-level (50-m) temperature was −1.2 K (−1.9 K) colder (irrigated minus arid).
- At the end of the morning transition (convective onset), temperature differences between the two sites increased in magnitude. Average screen-level (50-m) temperature difference was −3.6 K (−2.4 K) colder (irrigated minus arid).

Near-surface specific humidity



- Distinctions between irrigated and rainfed surfaces and between the meteorological regimes are less clearly defined as was seen for other parameters *during the morning transition.*
- At the irrigated site there is virtually no gradient in specific humidity between 10 m and 50 m at sunrise or convective onset for any of the IOPs *during the morning transition.*
- The mean daytime (1400–1600 UTC) specific humidity (at 2 m) was greater at the irrigated site compared with the rainfed (arid) site, of the order of 3.0 g·kg^{-1} for the synoptic-scale westerly flow regime (IOP1–4) and 4.6 g·kg^{-1} for the thermal low and anticyclonic regimes (IOP5–7 and 10).

Conclusions

Irrigation contrasts through the morning transition

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Abstract
The Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) campaign was conducted in July 2021, primarily to investigate the role of irrigation in modulating the boundary-layer evolution in the Catalan region of northeastern Spain. Contrasts in near-surface meteorological parameters and boundary-layer thermodynamic profiles at an irrigated and rainfed (arid) site were established during the morning transition. Evapotranspriation dominated the flux partitioning at the irrigated site (Bowen ratio of 0.07–1.1), whilst sensible heat flux dominated at the rainfed (arid) site (Bowen ratio greater than 10.0). The cumulative evapotranspiration during July 2021 was a factor of 10 greater at the irrigated site than at the rainfed (arid) site. The presence of irrigation was shown to modulate the vertical gradients of turbulence, temperature, and moisture. Irrigation is shown to have a significant effect on the development of the boundary layer, including during the morning transition. The morning transition mean buoyancy flux was 2.8 times smaller at the irrigated site (1.1 $m^2 \cdot s^{-2}$) compared with the rainfed (arid) site (3.1 $m^2 \cdot s^{-2}$), with a resultant delay in the near-surface buoyancy-flux crossover time (30–90 min) at the irrigated site. At the start of the morning transition (sunrise), the average screen-level (50-m) temperature was −1.2 K (−1.9 K) colder at the irrigated site relative to the rainfed (arid) site. The colder temperatures at sunrise at the irrigated site are predominantly the result of a colder boundary-layer thermodynamic profile from the previous day. At the end of the morning transition (convective onset), temperature differences between the two sites extend through much of the boundary layer and increase in magnitude. The average screen-level (50-m) temperature difference was −3.6 K (−2.4 K) colder at the irrigated site relative to the rainfed (arid) site. There was considerable day-to-day variability in temperature contrasts at a regional level (−2.4 to −6.0 K).

KEYWORDS
buoyancy flux, convective onset, LIAISE, semi-arid, thermodynamic profiles, turbulence

- Contrasts in near-surface meteorological parameters and boundary-layer thermodynamic profiles at an irrigated and rainfed (arid) site were established during the morning transition.
- The cumulative evapotranspiration during July 2021 was a factor of 10 greater at the irrigated site than at the rainfed (arid) site.
- The morning transition mean buoyancy flux was 2.8 times smaller at the irrigated site compared with the rainfed (arid) site,
- Irrigated site has a delay in the near-surface buoyancy-flux crossover time (30–90 min) at the irrigated site.
- At the start of the morning transition (sunrise), the average screen-level (50-m) temperature was −1.2 K (−1.9 K) colder (irrigated minus arid).
- At the end of the morning transition (convective onset), temperature differences between the two sites increased in magnitude. Average screen-level (50-m) temperature difference was −3.6 K (−2.4 K) colder (irrigated minus arid).

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LoCo (local land atmosphere coupling) framework: exploring sensitivity of PBL evolution

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A. Philibert, M. Lothon

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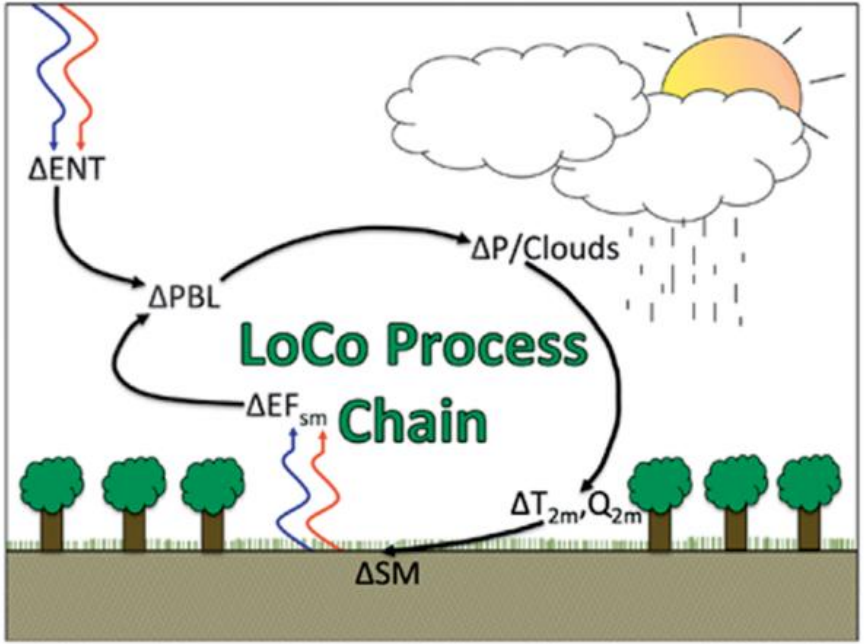
LoCo (local land atmosphere coupling) framework



$$\Delta SM \underset{a}{\rightarrow} \Delta EF \underset{b}{\rightarrow} \Delta PBL \underset{c}{\rightarrow} \Delta Ent \underset{d}{\rightarrow} \Delta T_{2m}, Q_{2m} \Rightarrow \Delta P, Cloud.$$

Santanello et al., 2018 Land-atmosphere interactions The LoCo Perspective

(a) Exploring sensitivity of surface fluxes to soil moisture

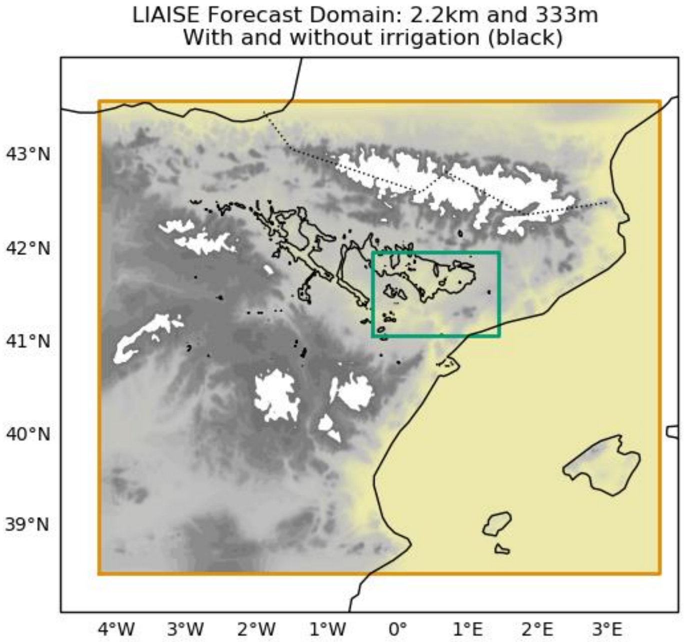
$$\Delta SM \underset{a}{\rightarrow} \Delta EF$$

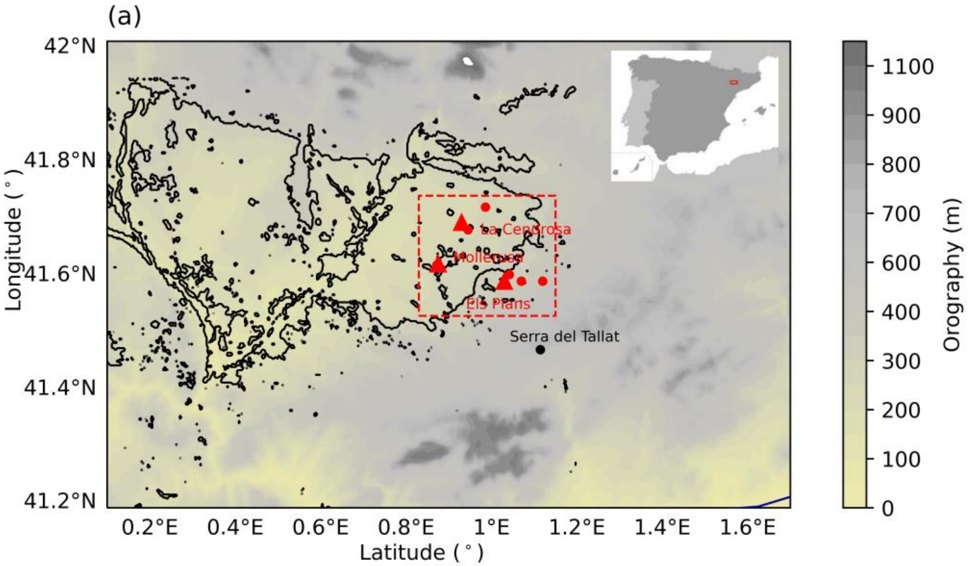
(b) Exploring sensitivity of PBL evolution to surface fluxes

$$\Delta EF \underset{b}{\rightarrow} \Delta PBL$$

Unified Model Simulations

- Daily 2.2km forecasts initialised at 00 UTC
- Simulations for 1-31 July 2021
- Frozen version of RAL3.1
- Without irrigation scheme (control)
- With irrigation scheme

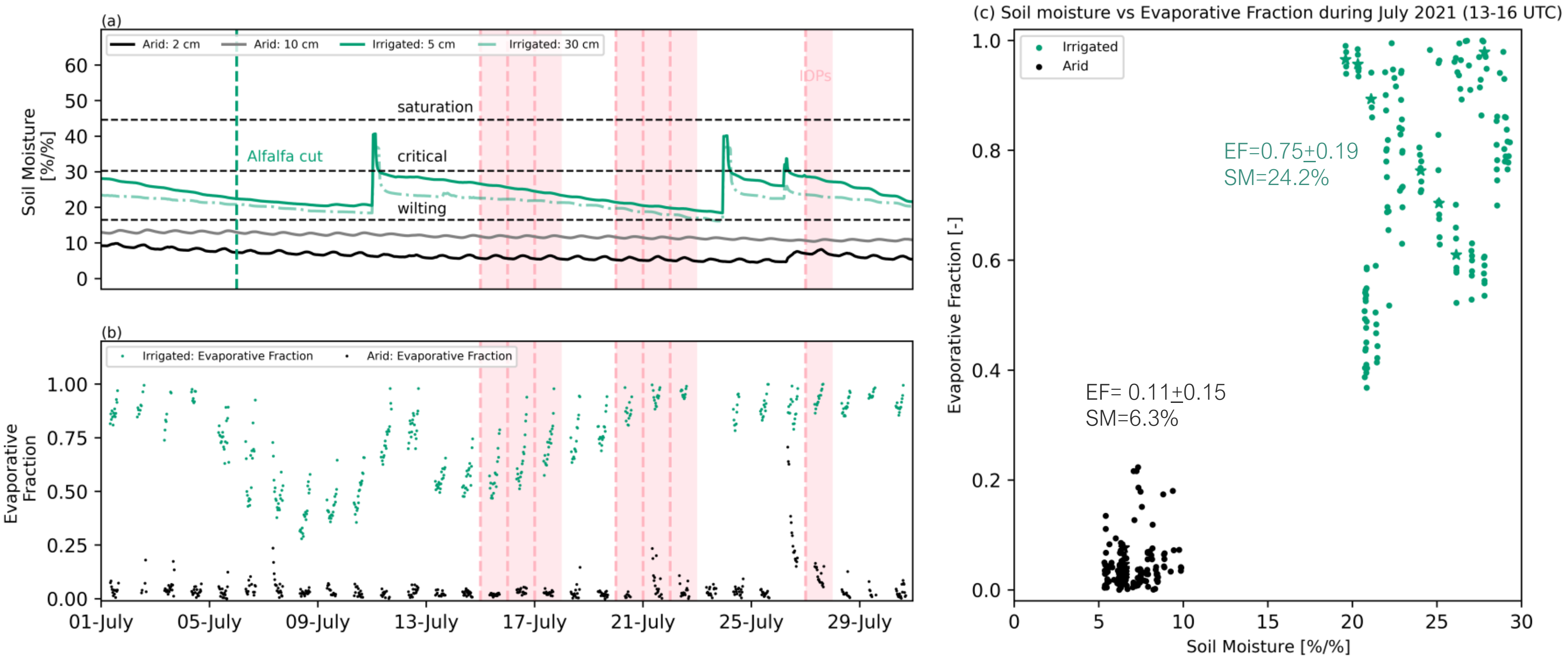




Irrigated region from the ESA Climate Change Initiative Land Cover (ESA CCI LC) dataset

Soil moisture & evaporative fraction

LoCo (local land atmosphere coupling) framework: (a) exploring sensitivity of surface fluxes to soil moisture



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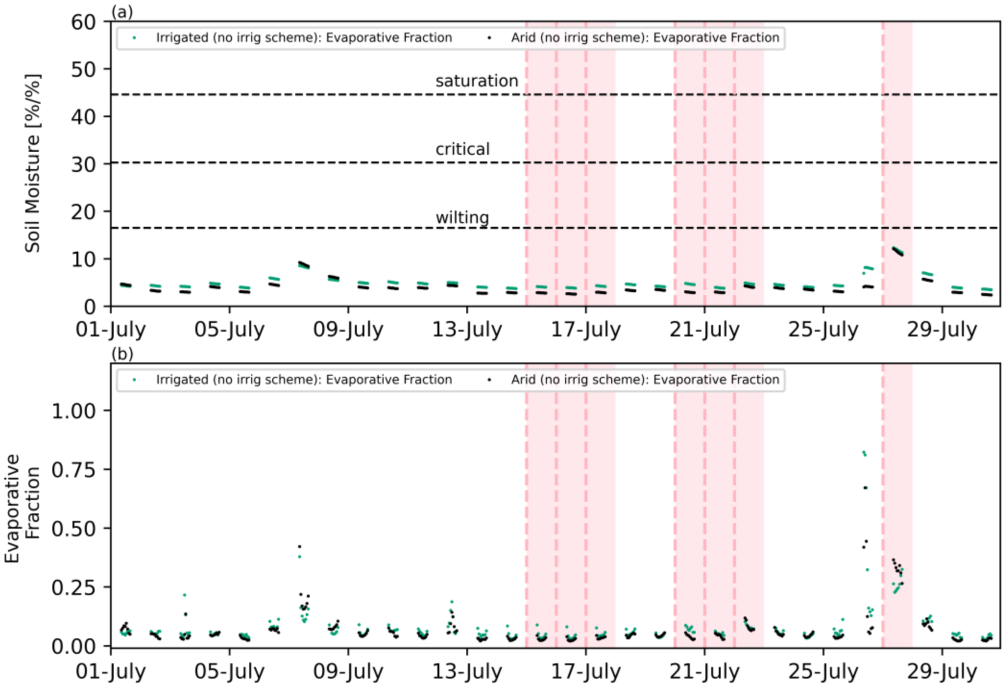
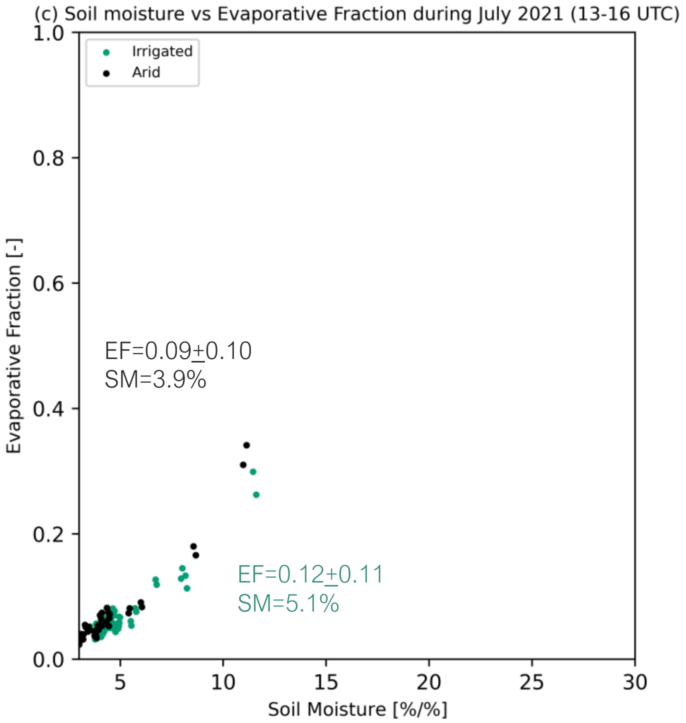
Soil moisture & evaporative fraction

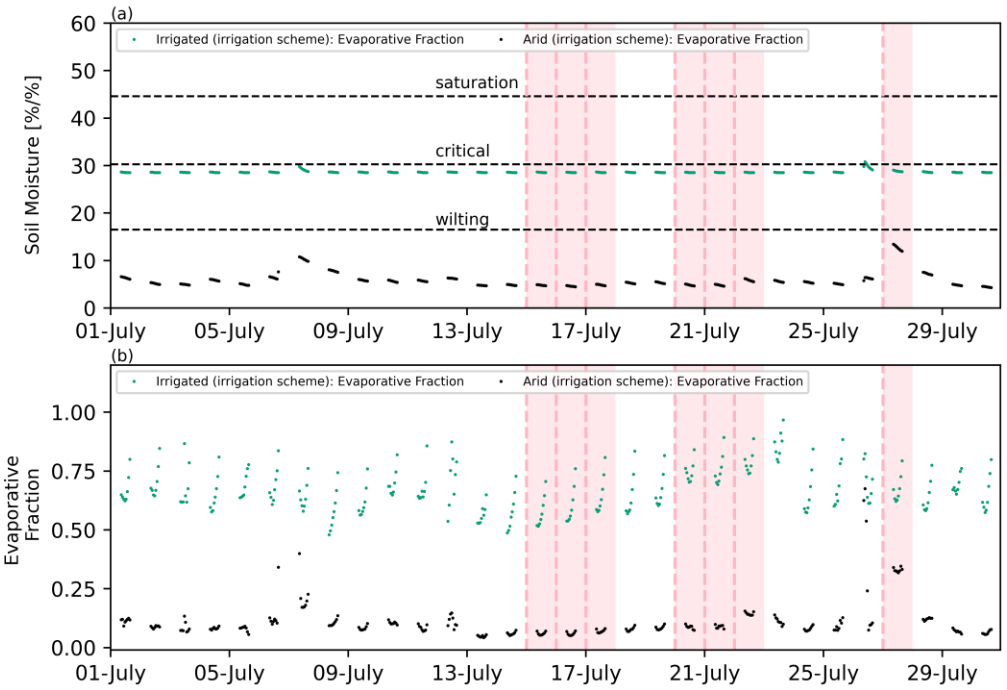
Unified Model (RAL3.1) without irrigation scheme

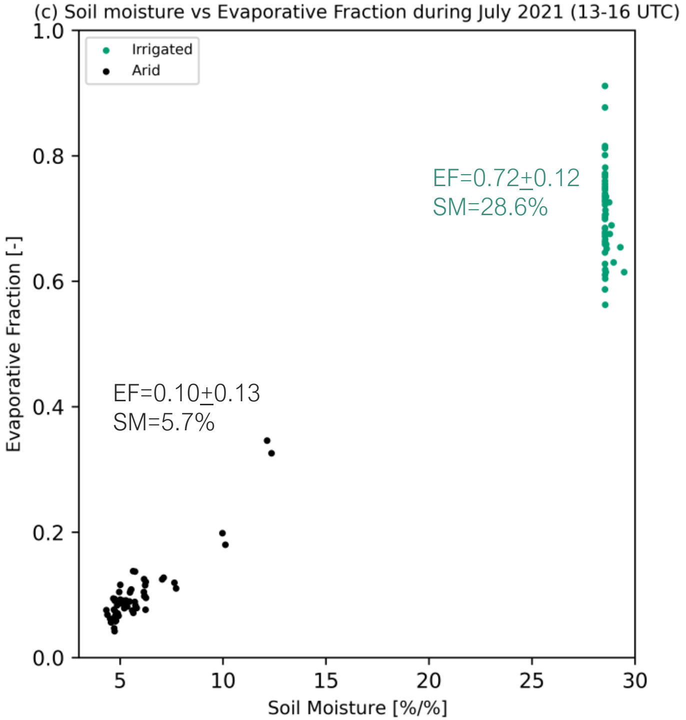




Soil moisture & evaporative fraction

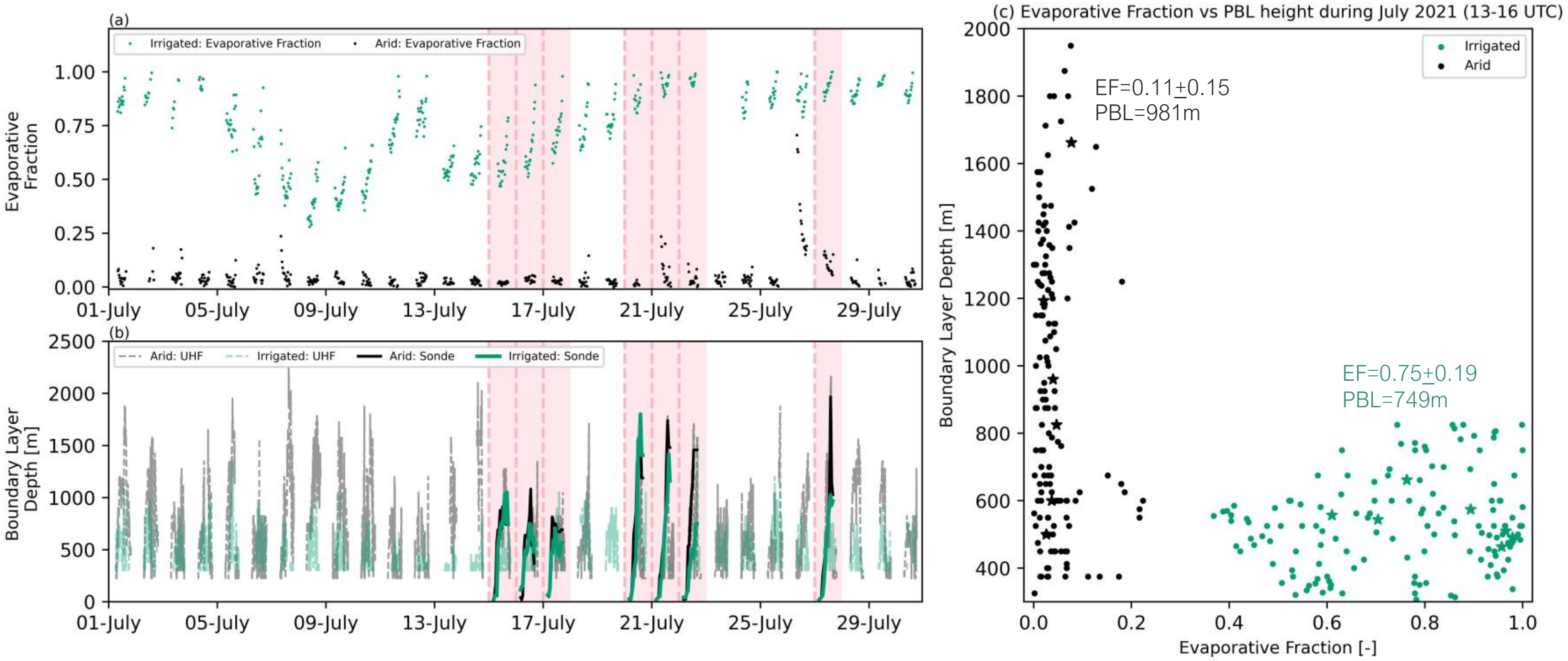
Unified Model (RAL3.1) with irrigation scheme





Evaporative fraction & boundary layer depth

LoCo (local land atmosphere coupling) framework: (b) exploring sensitivity of PBL evolution to surface fluxes



Philibert (2023) CALOTRITON: A convective boundary layer height estimation algorithm from UHF wind profiler data, submitted AMT

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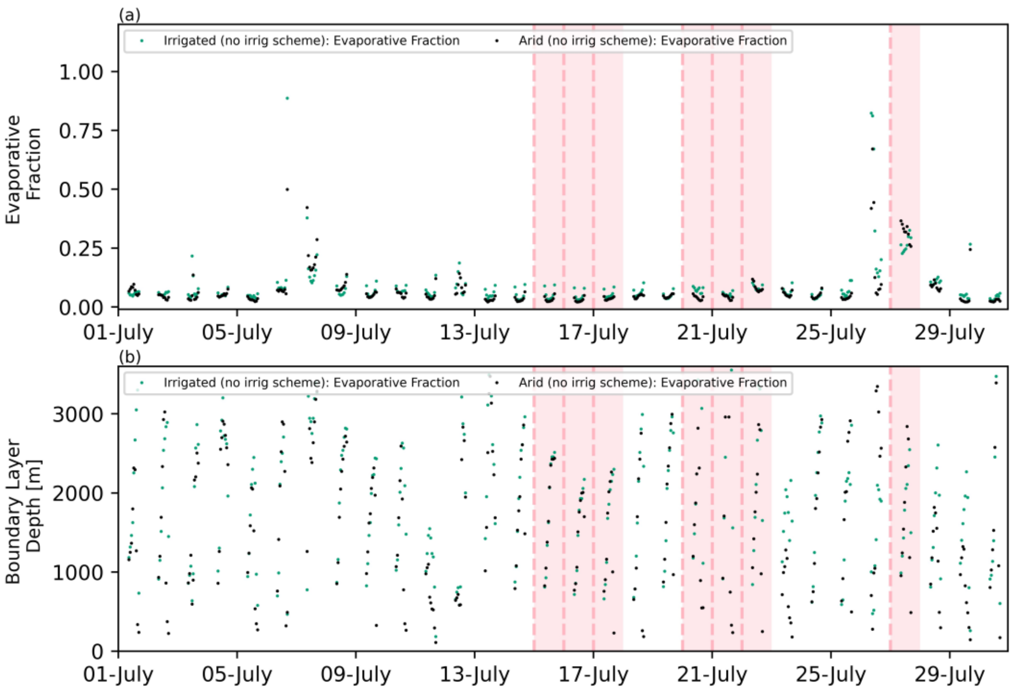
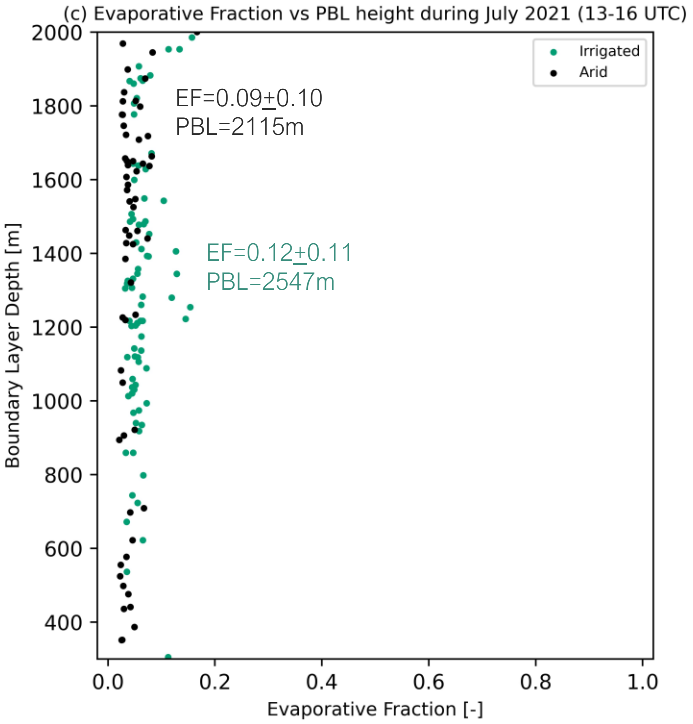
Evaporative fraction & boundary layer depth

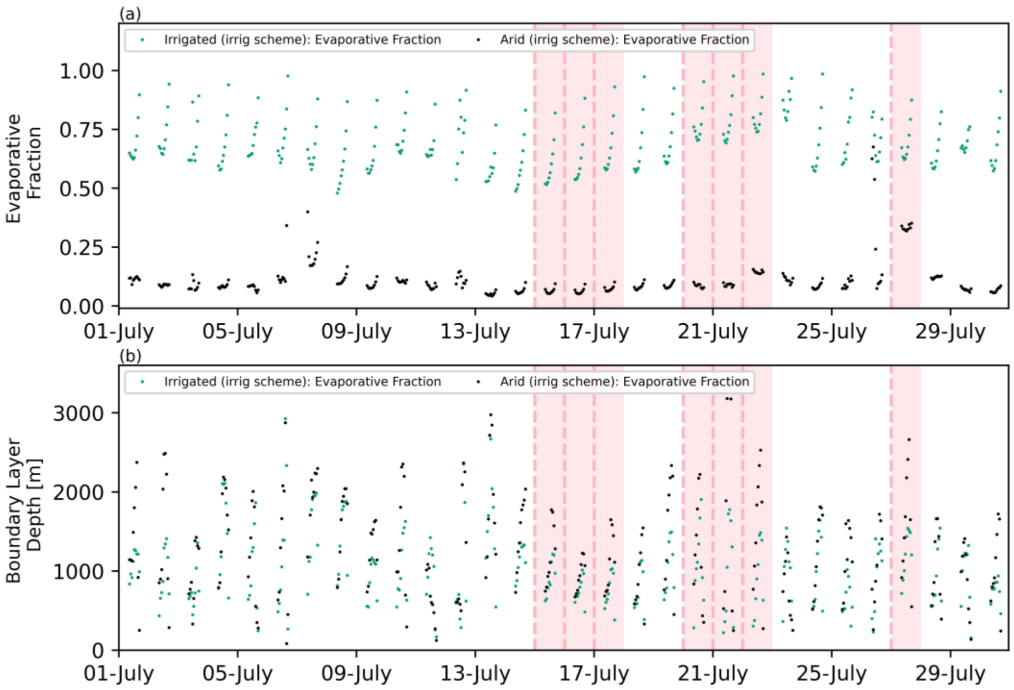
Unified Model (RAL3.1) without irrigation scheme

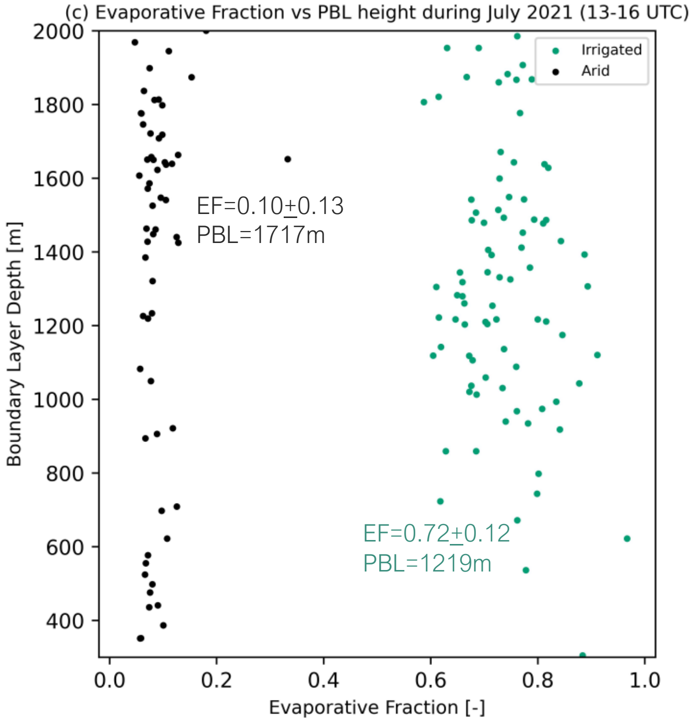




Evaporative fraction & boundary layer depth

Unified Model (RAL3.1) with irrigation scheme





Conclusions

- Observations demonstrate sensitivity of the PBL evolution to surface fluxes – the irrigated site has higher evaporative fraction leading to shallower boundary layer depths.
- Unified Model (RAL3.1) with irrigation scheme reproduces the observed evaporative fraction at the irrigated site
- The July mean boundary layer depth is reduced by over 1km at the irrigated site with the irrigation scheme activated.
- With the irrigation scheme, still overestimate boundary layer depths at both sites – work needed to understand cause of this, including examining vertical structure, heat and moisture budgets, role of entrainment & advective processes etc.
- Next steps: currently using LoCo mixing diagram framework: exploring sensitivity to 1) surface fluxes to soil moisture, 2) PBL evolution to fluxes, 3) entrainment fluxes to PBL evolution.