# Improving our understanding of land-surface and boundary-layer coupling using the LIAISE observational campaign

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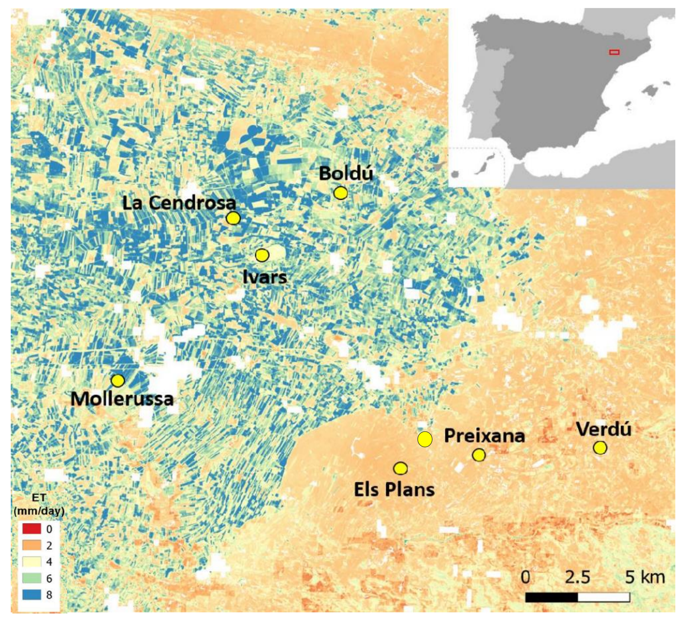
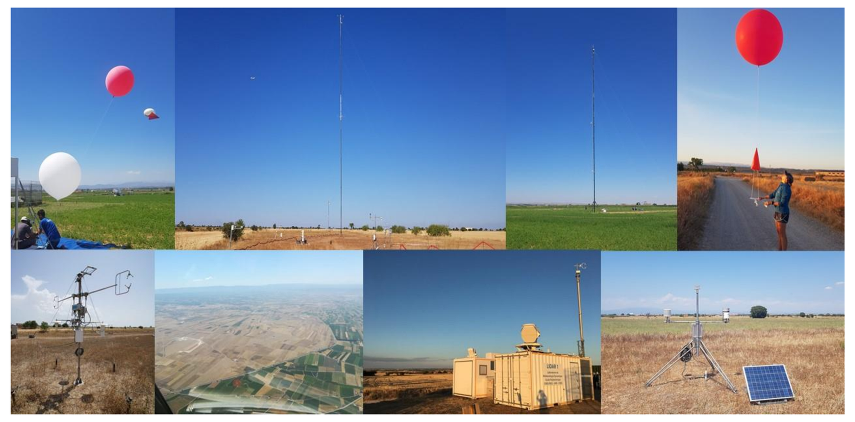
## Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE)

The LIAISE observational campaign has been designed to improve the understanding of land-atmosphere-hydrology interactions in a semi-arid region characterized by strong surface heterogeneity owing to contrasts between the natural, rainfed landscape and intensive agriculture.




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



Co-located surface observations (6-13 months)
- Two super-sites with 50m masts
- Eddy-covariance flux stations (8 locations)
- Heterogeneous land cover (irrigated & rainfed)
- Coordinated radiosonde launches

## Single Column Model (SCM) and Large Eddy (LES) intercomparison framework

The intercomparison protocol extends on the previous DICE project conducted under a joint activity within the Global Land Atmosphere System Study (GLASS) and Global Atmospheric System Studies (GASS) projects.

**Research Questions:**

- What is the impact of surface fluxes (rainfed & irrigated) on the boundary layer evolution?
- How well can SCM&LES simulate the boundary layer evolution for irrigated and rainfed surfaces?
- What can we understand in terms of land-surface/atmosphere interactions?
- Framework will help assess the model error contribution from 1) errors in surface fluxes in land surface models, and 2) errors in the boundary layer parameterization in the vertical distribution of heat and moisture flux.

**Stage 1 Uncoupled** The individual components are assessed in isolation, driven and evaluated against observational data.

**1a Uncoupled SCM (Single Column Model)**
NWP models to be run in SCM mode. The boundary layer process is primarily driven by the observed surface fluxes and initialised with radiosonde observations. The large-scale advective forcing terms will be derived.

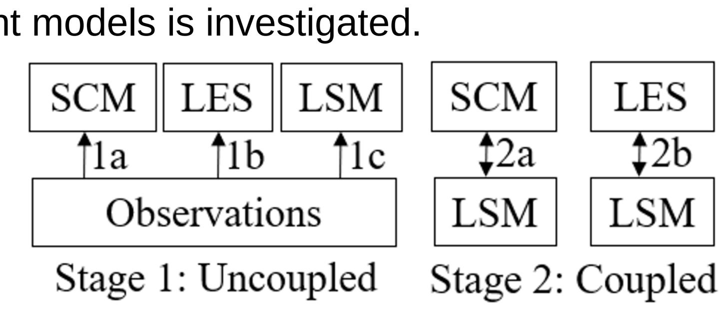
**1b Uncoupled LES (Large Eddy Simulation)**
The boundary layer process is primarily driven by the observed surface fluxes; sensible heat flux and latent heat flux and initialised with radiosonde observations.

**1c Uncoupled LSM (Land Surface Model)**
Land surface processes driven with the observed meteorological states. The surface schemes will be evaluated against the turbulent heat fluxes, moisture fluxes, and momentum fluxes.

**Stage 2 Coupled** The impact of coupling component models is investigated.

**2a Coupled LSM-SCM**
Coupling with interactive land surface capabilities.

**2b Coupled LSM-LES**
Coupling with interactive land surface capabilities.



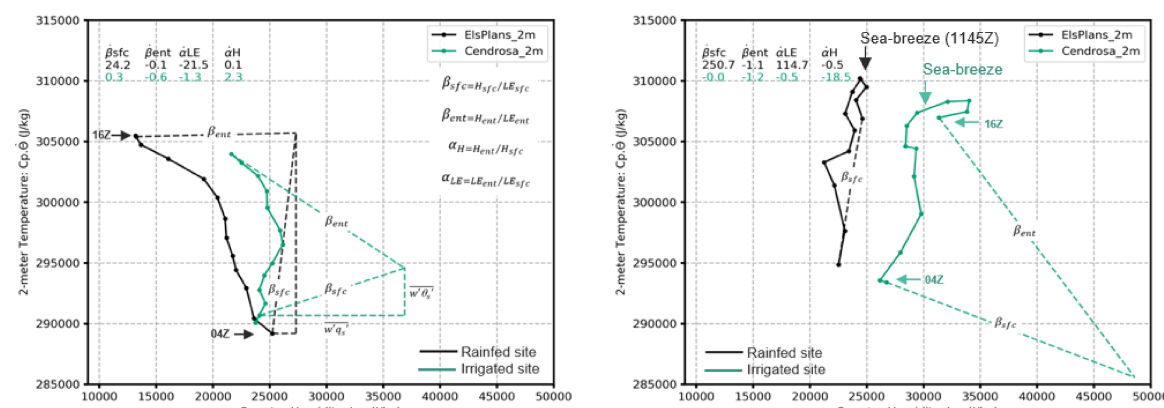

## LIAISE heat and moisture budget: LoCo approach

Application of GEWEX Local Land-Atmosphere Coupling (LoCo) to LIAISE observations. LoCo mixing diagram approach: to understand the relative roles of surface (heat and moisture fluxes) and entrainment (heat and moisture) fluxes on the boundary layer evolution using surface level observations & PBL height (from hourly radiosondes during LIAISE).

Irrigation leads to significant contrasts in 2-m heat and moisture evolution. Both the meteorological flow regime and growing irrigated vegetation canopy height (which strongly influences the flux partitioning & Bowen ratio, $\beta_{sfc}$) play a role in the mixing diagram evolution.

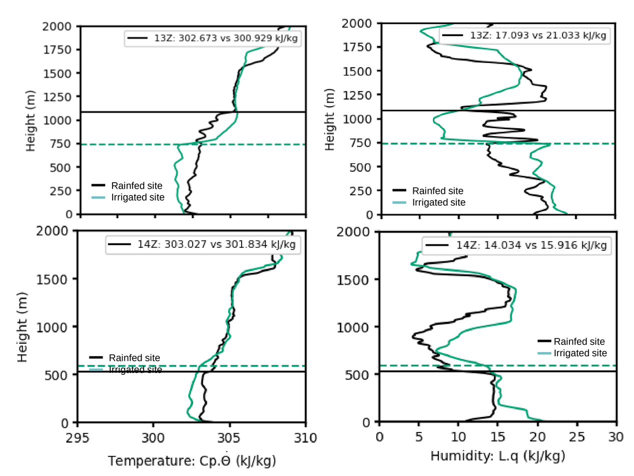
Phase 1: Synoptic westerly flow IOPs & short irrigated canopy height

Phase 2: Thermal (heat) low IOPs & taller irrigated canopy height

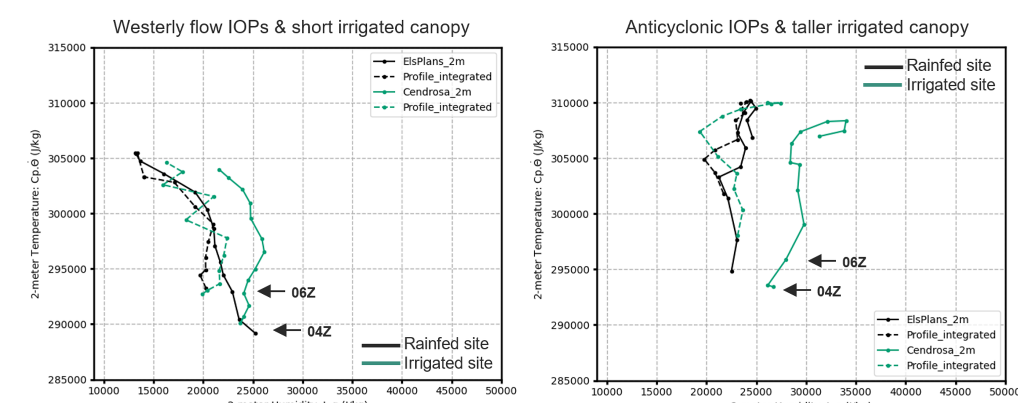



Extend LoCo framework to assess the mixed layer assumption for locally **rainfed** & **irrigated** surfaces. Framework incorporates integrated energy within PBL using hourly radiosonde temperature and humidity profiles, presented as energy variables (J $kg^{-1}$). Apply the integration to all mixed layer profiles (i.e. not stable BL profiles 04Z-06Z).

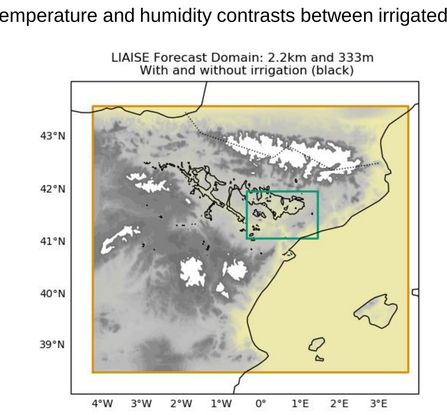
- **Irrigated** profiles have a shallower PBL, colder mixed layer, with larger humidity gradients.
- Temperature evolution similar using both methods, highlighting well-mixed layer assumption is applicable for temperature.
- Integrated PBL humidity is lower than surface humidity, particularly at the **irrigated** site. Integrated methodology incorporates vertical gradients in humidity.




Vertical temperature and humidity contrasts between irrigated and rainfed



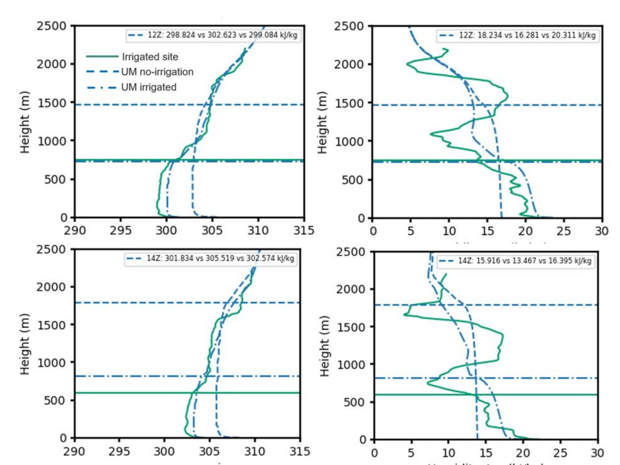

Mixing diagrams compare 2-m surface evolution vs integrated evolution from Phase 1 IOP (16 July 2021)



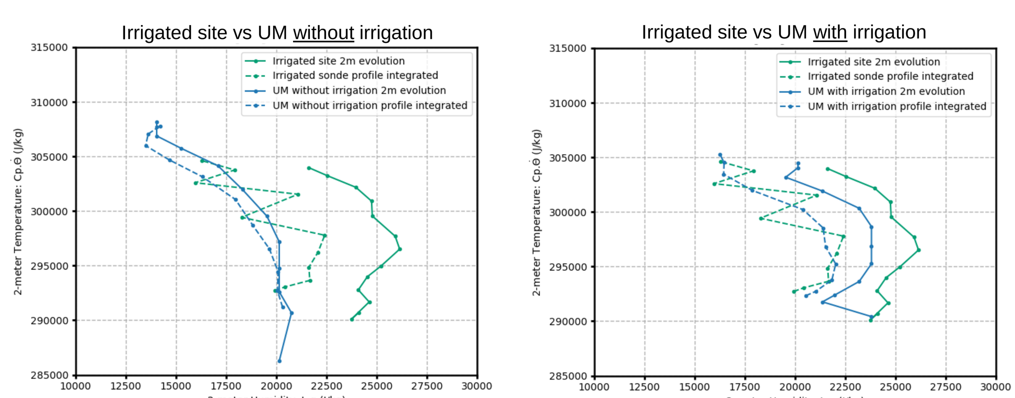

Unified Model (UM) 2.2km regional domain for convection-permitting simulations. ESA CCI irrigated fraction presented.

Met Office Unified Model (UM) 2.2km simulations with and without irrigation (domain left) are incorporated into the LoCo mixing diagram framework, and compared against observations from the LIAISE irrigated site.

UM profiles of temperature and specific humidity show significant improvement with irrigation implemented. The integrated profile approach minimises biases, although the 2-m evolution indicates a dry bias in near-surface humidity.




Vertical temperature and humidity contrasts between irrigated observations, and Unified Model (UM) profiles with and without irrigation processes




Mixing diagrams compare 2-m surface and integrated evolution at the irrigated site: observations (green) vs UM (blue) without irrigation (left) and with irrigation (right).

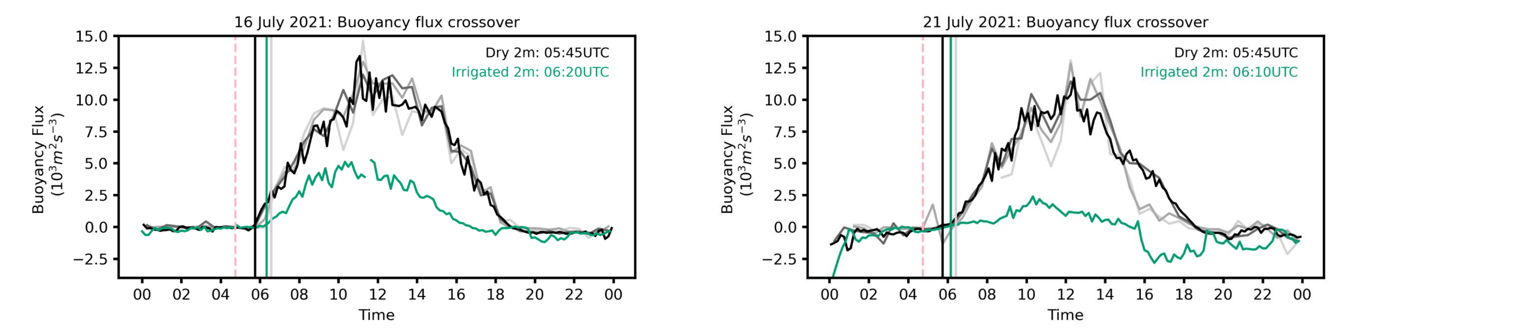
## Irrigation impacts: the morning transition period

The morning transition covers a period of time starting with sunrise and ending when the surface temperature inversion has been eroded and the nocturnal, statically stable boundary layer (SBL) has evolved into a fully convective boundary layer (CBL). We investigate the impact of irrigation processes on the morning transition period for two phases of LIAISE.

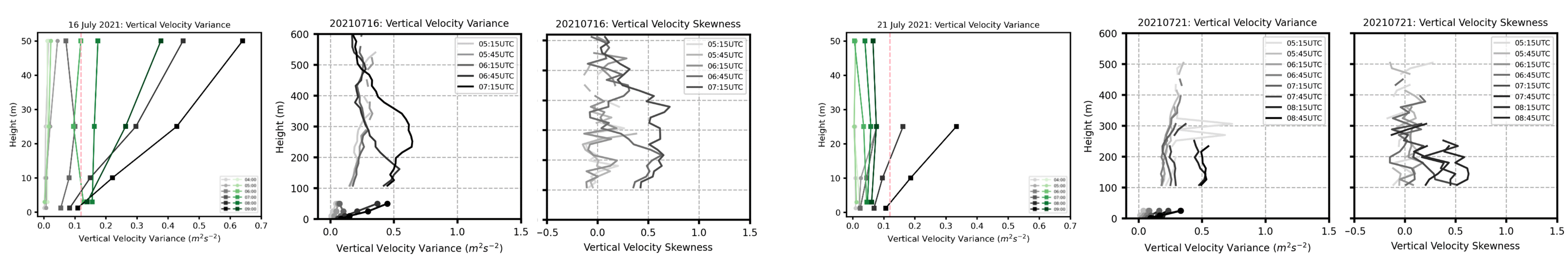
Phase 1: Synoptic westerly flow IOPs & short irrigated canopy height

Phase 2: Thermal (heat) low IOPs & taller irrigated canopy height

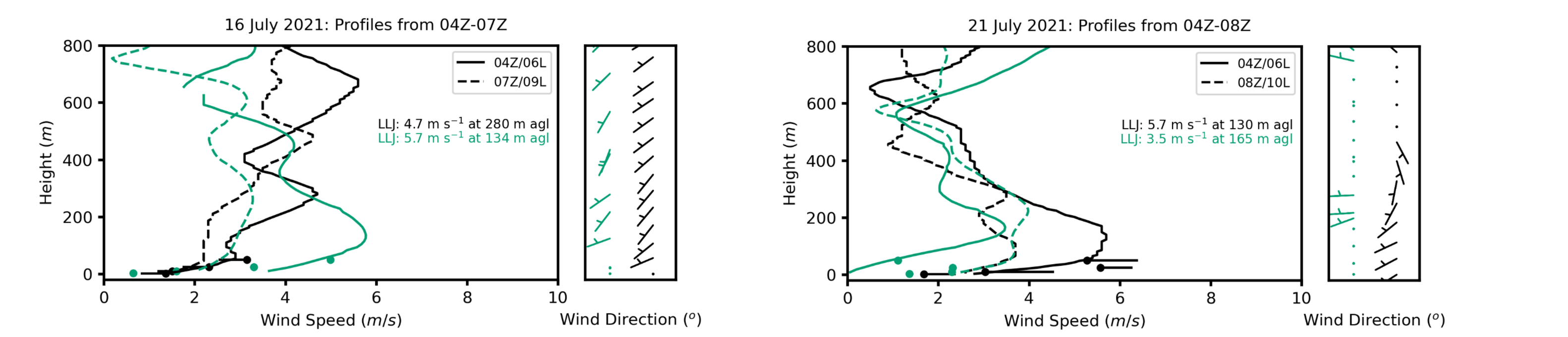
**Buoyancy fluxes.** The presence of **irrigation** suppresses the buoyancy flux compared with **rainfed** surfaces, which delays the cross-over time (when the flux becomes positive). The moisture flux increases as the height of the irrigated canopy grows.



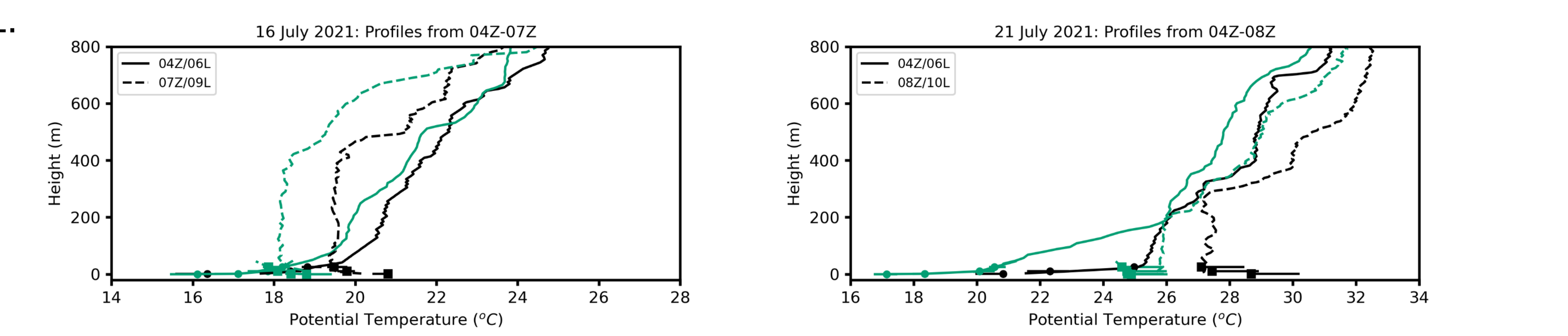

**Vertical velocity variance and skewness profiles** provide a measure of vertical intensity of turbulence. A delay in turbulent intensity is seen at the **irrigated** site compared with the **rainfed** site. The length of the delay is dependent on phase; 30-min (phase 1) & 150-min delay (phase 2).



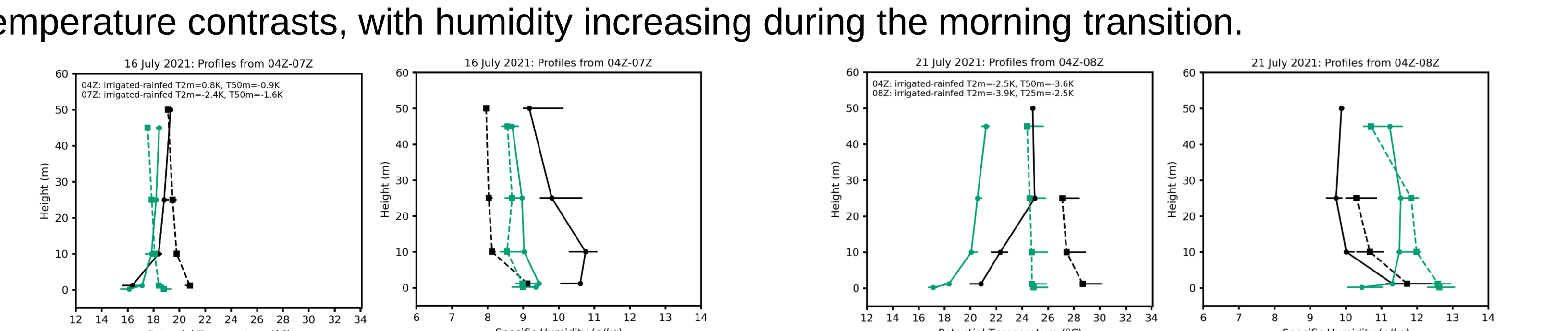
**Vertical profiles of wind** are shown for the start and end of the morning transition. During phase 1, the dominance of the westerly synoptic scale flow is evident and wind profiles are more well mixed with height. During phase 2, a low-level jet is more prominent in both profiles, although different wind directions in the jet suggest locally established nocturnal flows influencing the sites.




**Vertical potential temperature profiles** for the morning transition period demonstrate that temperature contrasts between **rainfed** and **irrigated** regions persist through the statically stable BL, and these contrasts grow through the morning transition & are significant in an established CBL.




**Near-surface to 50-m profiles of temperature and specific humidity** demonstrate significant near-surface contrasts between the **rainfed** and **irrigated** sites. Phase 1 profiles are colder with smaller temperature contrasts, and humidity decreases. Phase 2 profiles show significant temperature contrasts, with humidity increasing during the morning transition.

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