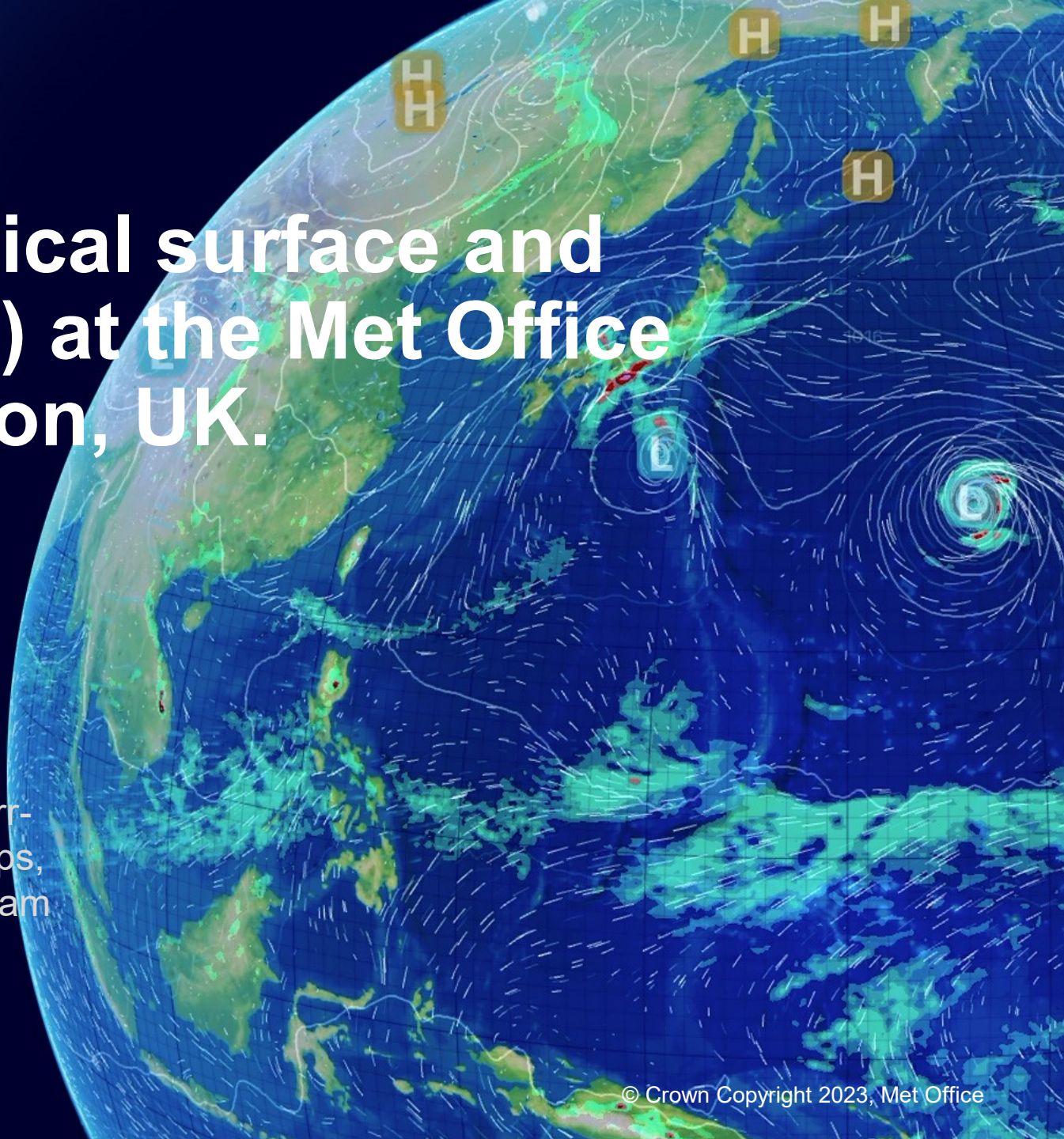


# Continuous meteorological surface and soil records (2004–2024) at the Met Office surface site of Cardington, UK.

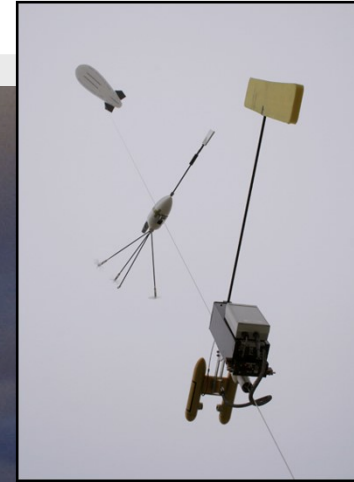
Simon Osborne, 17<sup>th</sup> September 2025

Jenn Brooke, Bernie Claxton, Tony Jones, Amanda Kerr-Munslow, James McGregor, Emily Norton, Nicola Phillips, Martyn Pickering, Jeremy Price, Jenna Thornton, Graham Weedon





# Cardington: Instrumented field site in central England, latitude 52°06'N, longitude 00°25'W



**MRU Cardington**

**Activity:** *Research Observations and analysis*

**Methodology:** *Field campaigns, 24/7 observations at Cardington, Instrument development and evaluation*

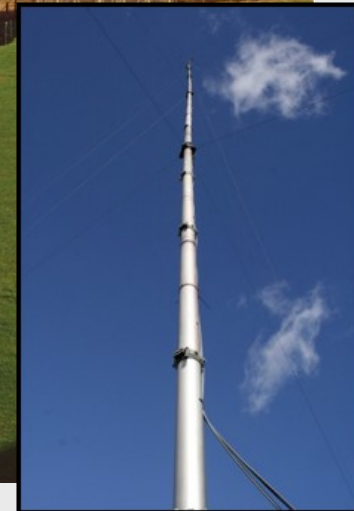
**Focus areas:** *- boundary layer meteorology, fog, visibility, surface processes, stable BL*

**Atmospheric Processes and parametrization**

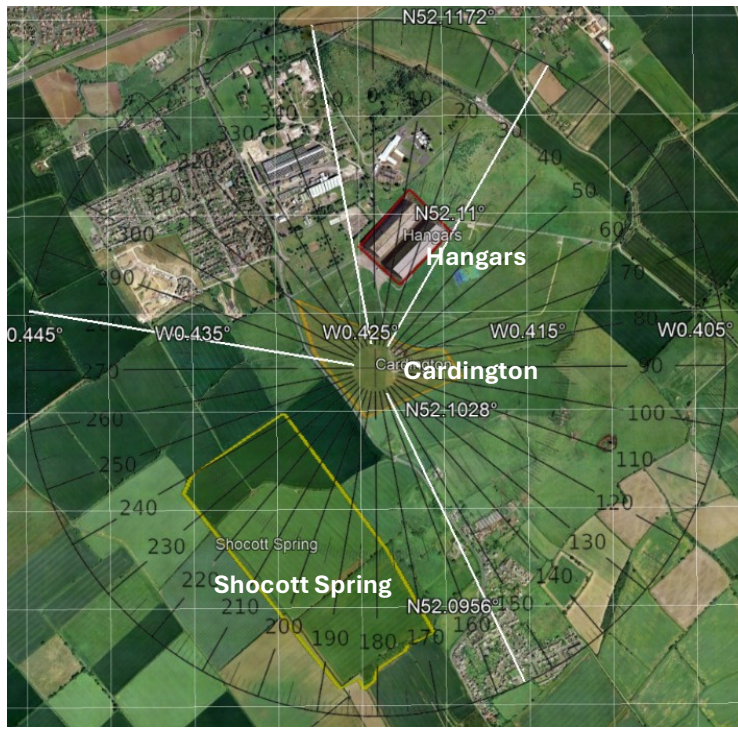
*Improved understanding of physical atmospheric processes*

**Global, regional and high-resolution models**

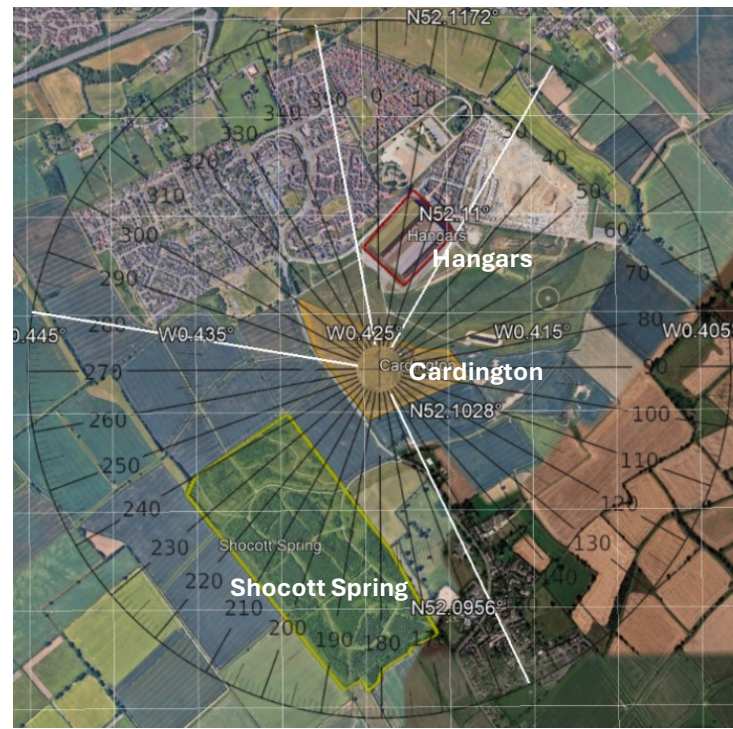
*Model evaluation*      *Improved parametrizations*







2004



2023

- 5 – 10cm grass all year round (44 acre)
- Essentially flat terrain, broad river basin, 29 m amsl
- Annual rainfall 544 mm; annual sunshine 1327 hrs
- Water table depth ranged from 0 → 1.5–2.0 m in all years
- Decommissioned in early 2025
- CEH COSMOS site June 2015 – February 2025
- Some local surface features:
  - airship sheds (350–030°)
  - Urbanisation in general to the north (Bedford 3 km)
  - growing woodland to the SW (170–240°)

29<sup>th</sup> October 2021



Non-drought  
19<sup>th</sup> July 2016



Drought  
7<sup>th</sup> August 2018



# Data Paper & CEDA repository associated with Cardington archival project

- Osborne et al., submitted to ESSD: <https://essd.copernicus.org/preprints/essd-2025-486>
- Open-access CEDA repository of 24/7 data 2004–2024, available for **EVALUATION**
  - Core data at 50m, 25, 10m, screen, surface, subsoil T and  $\theta$ , SW & LW radiation, ground heat flux, visibility, present weather
  - $Q_H$  at 50, 25, 10 and 2 m.  $Q_E$  at 10 m only.
  - 1-, 5-, 10- and 30-min time steps in DAILY files; up to 180 variables
  - Mid-2004 to end of 2024 (but note spin-up during first 6 months)
- **Citable as:** Met Office; Kerr-Munslow, A.; McGregor, J., Price, J.; Osborne, S.; Brooke, J. (2025): Continuous hydrometeorological record (2004–2024) at the Met Office surface site of Cardington, UK Dataset Collection. NERC EDS Centre for Environmental Data Analysis. <https://catalogue.ceda.ac.uk/uuid/5487380511084413a502c4b229273bc6/>
- **JULES forcing files** a subset of this core data (whole years 2005 to 2024)
- Specialist datasets also in archive: ceilometers, Doppler lidars, microwave radiometers, radiosondes (IOP based)
- **Other data not at CEDA:** sun-photometer (AERONET), IR images, dew meters, tethered balloon flying (e.g. fog studies)



# Completeness of core dataset

JULES



50m



25m



10m



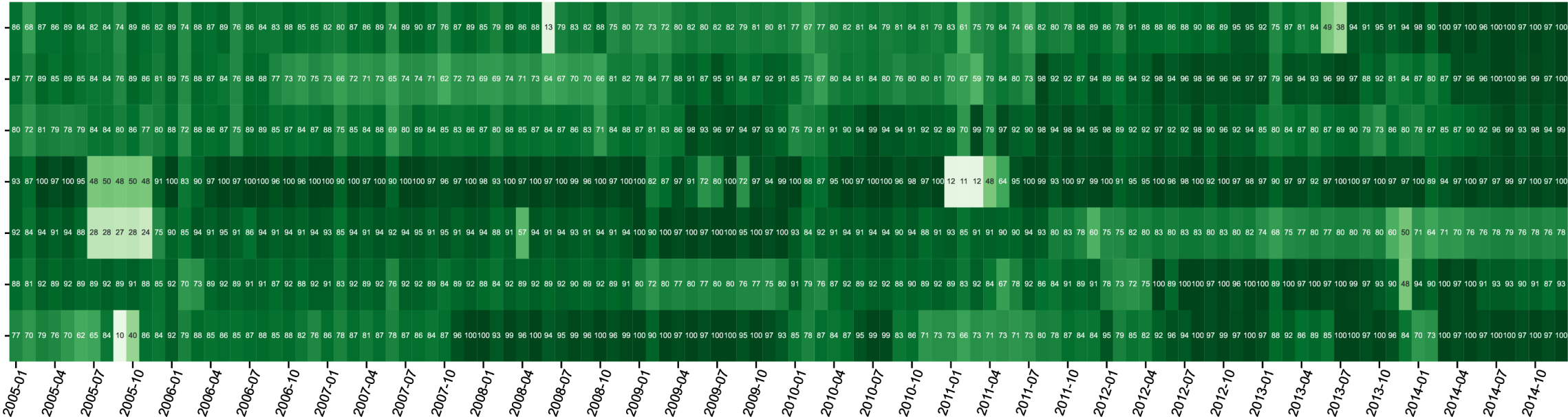
2m

from 2012

scrn

soil

radn



JULES



50m



25m



10m



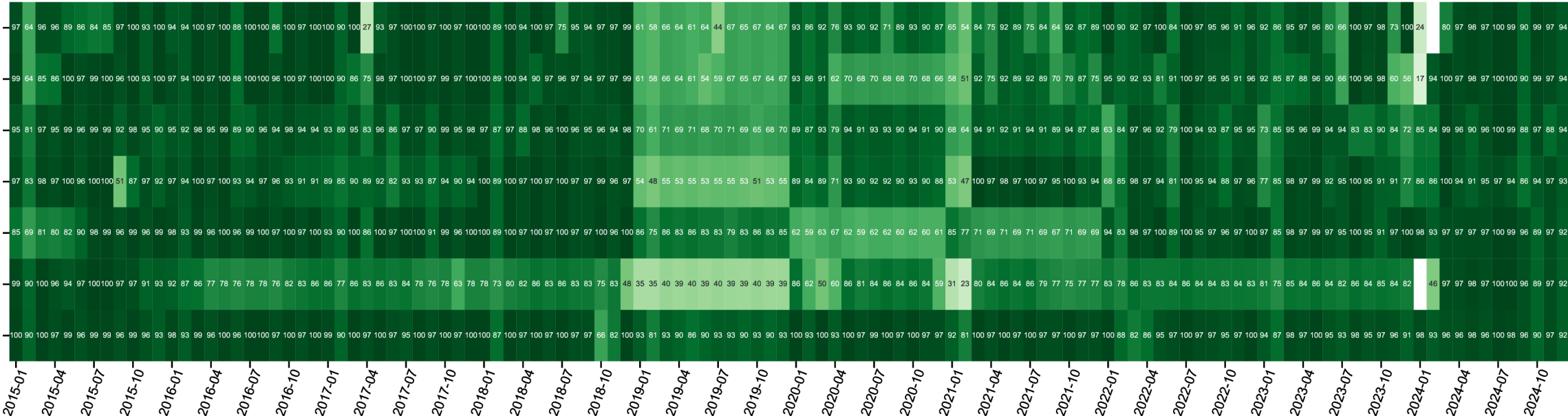
2m

scrn

soil

radn

data completeness



# Met Office JULES forcing files available at CEDA

- T,  $q_v$ ,  $U_{TOT}$ , P, SWDN, LWDN, rainfall: 30-min time steps for single site
- Quality controlled, comprehensive metadata included
- Gap-filled ( $\leq 3$  hr interpolation,  $> 3$  hr using long-term means)
- netCDF files have been tested with vn7.8, but no real analysis done
- Simple flag system: 0 = actual data at time step, 1 = gap-filled

**Citable as:** Met Office; Osborne, S.; Weedon, G. (2025): Met Office Cardington: Land surface model (LSM) meteorological driving data, 2005-2024. NERC EDS Centre for Environmental Data Analysis, 28 April 2025.  
doi:10.5285/19c5dc39bb8c4c40a5643678c31168e7. <https://dx.doi.org/10.5285/19c5dc39bb8c4c40a5643678c31168e7>

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 Dataset

**Met Office Cardington: Land surface model (LSM) meteorological driving data, 2005-2024**  
[View XML](#)

Update Frequency: Not Planned  
Latest Data Update: 2025-04-29  
Status: Final  
Online Status: ONLINE  
Publication State: Citable  
Publication Date: 2025-04-28  
DOI Publication Date: 2025-04-28  
Download Stats: [last 12 months](#)  
Dataset Size: 5 Files | 73MB

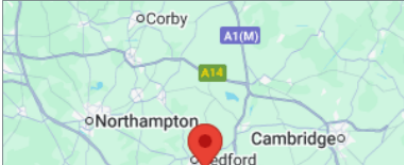
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**Abstract**

The Met Office Observation-based research Boundary Layer Facility, at the semi-rural field site (18 Ha) of Cardington (52° 06' N, 00° 25' W, 29 m  $\pm$  1 m amsl) in central-southern England between 2004 and 2024, compiled a forcing meteorological dataset for the Cardington site to drive the JULES standalone land surface model (LSM) that covers the whole year 2005-2024 data record, albeit only based on 30 min temporal resolution. JULES is the UK community LSM that is used in the Met Office Unified Model (MetUM) from short-range weather forecasts through to climate predictions, from global coverage down to a single point. JULES requires the following seven atmospheric input variables at every time step for it to be able to run using prescribed meteorology from field observations: downwelling shortwave irradiance, downwelling longwave irradiance, rainfall, air temperature, mean horizontal wind, surface barometric pressure, and specific humidity.

The drive dataset is a NetCDF file for each of the four drive heights (2, 10, 25 and 50 m), such that temperature, wind and humidity drive variables are taken from the different mast heights, with the pressure, radiation and rainfall remaining unchanged as they are taken from the same mast.

**Citable as:** Met Office; Osborne, S.; Weedon, G. (2025): Met Office Cardington: Land surface model (LSM) meteorological driving data, 2005-2024. NERC EDS Centre for Environmental Data Analysis, 28 April 2025.  
doi:10.5285/19c5dc39bb8c4c40a5643678c31168e7. <https://dx.doi.org/10.5285/19c5dc39bb8c4c40a5643678c31168e7>

**Coverage**  
**Temporal Range**  
Start time: 2005-01-01T00:00:00  
End time: 2024-12-31T23:30:00  
**Geographic Extent**  


**10 m, 25 m, 50 m files:** 2005 to 2024

**2 m files:** 2012 to 2024 (whole yrs)

**2 m =** winds at 2 m, T and  $q_v$  at 1.2 m

|                                                                                                                                                                            |             |           |                                                                                       |                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| archive / badc / ukmo-cardington / data / complete-collection / land-surface-derived    |             |           |                                                                                       |   73.3 MB   6 files   mostly .nc |
| Met Office Cardington: Land surface model (LSM) meteorological driving data, 2005-2024  |             |           |                                                                                       |                                                                                                                                                                                                        |
| 0 dirs 6 files                                                                                                                                                             | Description | Size      | Actions                                                                               |                                                                                                                                                                                                        |
|  00README_catalogue_and_licence.txt                                                     |             | 847 bytes |    |                                                                                                                     |
|  md5sums.txt                                                                            |             | 420 bytes |    |                                                                                                                     |
|  metoffice-obr-Forcing-10m-W-T-Q-gap-filled-Cardington-2005-2024_v1.nc                  |             | 20.1 MB   |    |                                                                                                                     |
|  metoffice-obr-Forcing-25m-W-T-Q-gap-filled-Cardington-2005-2024_v1.nc                |             | 20.1 MB   |  |                                                                                                                   |
|  metoffice-obr-Forcing-2m-W-1.2m-T-Q-gap-filled-Cardington-2012-2024_v1.nc            |             | 13.0 MB   |  |                                                                                                                   |
|  metoffice-obr-Forcing-50m-W-T-Q-gap-filled-Cardington-2005-2024_v1.nc                |             | 20.1 MB   |  |                                                                                                                   |

**processing\_level = 2 ;**

**Conventions = "CF-1.8 ACDD-1.3" ;**

# Deriving soil properties from site composition (top ~1 m) plus canopy mods

**LAI** derived during 2018 only from NDVI radiation data (site & MODIS)

**rootd** from Osborne & Weedon (2021) from trial and error...

| Property                                                    | site                        | UKV                   | units                              |
|-------------------------------------------------------------|-----------------------------|-----------------------|------------------------------------|
| Soil dry heat capacity ( <b>hcap</b> )                      | <b>1.235x10<sup>6</sup></b> | 1.228x10 <sup>6</sup> | J m <sup>-3</sup> K <sup>-1</sup>  |
| Soil dry thermal conductivity ( <b>hcon</b> )               | <b>0.234</b>                | 0.230                 | W m <sup>-1</sup> K <sup>-1</sup>  |
| Soil hydraulic conductivity at saturation ( <b>satcon</b> ) | <b>0.00312 ± 0.0255</b>     | 0.00286               | Kg m <sup>-2</sup> s <sup>-1</sup> |
| Soil matric suction at saturation ( <b>sathh</b> )          | <b>0.26714 ± 0.0255</b>     | 0.31282               | m                                  |
| Soil moisture at saturation ( <b>sm_sat</b> )               | <b>0.4454 ± 0.0556</b>      | 0.4489                | m <sup>3</sup> m <sup>-3</sup>     |
| Soil moisture at critical point ( <b>sm_crit</b> )          | <b>0.3801</b>               | 0.3408                | m <sup>3</sup> m <sup>-3</sup>     |
| Soil moisture at wilting point ( <b>sm_wilt</b> )           | <b>0.1942</b>               | 0.2262                | m <sup>3</sup> m <sup>-3</sup>     |
| Canopy height ( <b>canht</b> )                              | <b>0.05–0.10</b>            | 1.46                  | m                                  |
| Leaf area index ( <b>lai</b> ) during 2018 dry-down         | <b>2.36–1.62</b>            | 2.8–1.1               | -                                  |
| Rooting depth ( <b>rootd</b> ) during 2018 drought          | <b>0.2</b>                  | 0.5                   | m                                  |

# Examples of Cardington data analysis

- Evolution of roughness length (unpublished)
- Comparison of obs and JULES in a drought year (Osborne & Weedon, 2021)
- Lifted temperature minimum (Weedon et al., 2024)



# An example of turbulence data analysis: $Z_{0,m}$

Roughness length (momentum) in neutral stability  $|z/L| \leq 0.1$

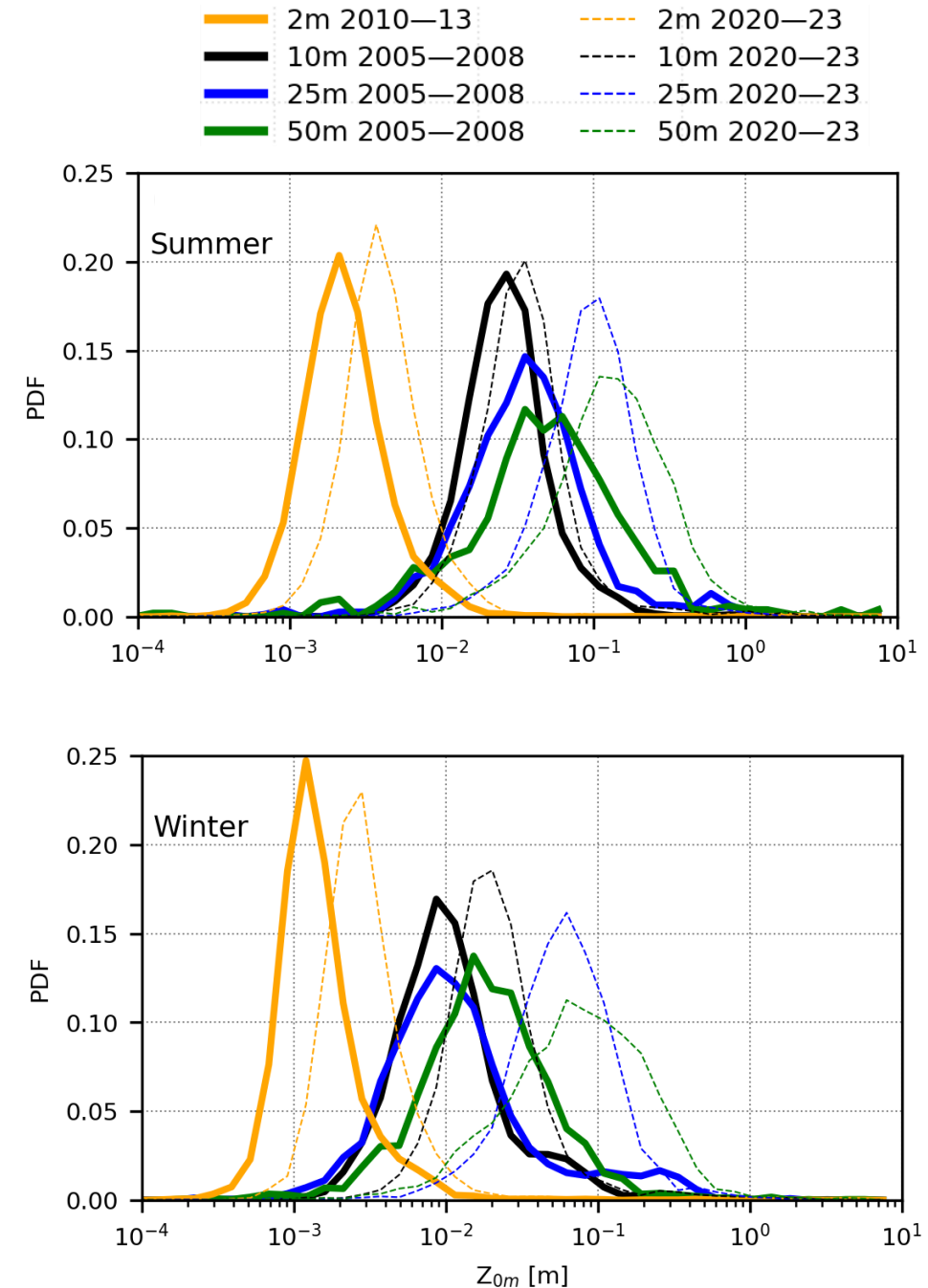
155—280° wind direction (66% of data)

Shift to the right with height, time, and comparing winter (non-leafy) to summer (leafy)

Change with time associated with woodland growth 0.5—1.3 km away to the SW

$Z_{0,m}$  at 10-m level has increased from 3 to 8 cm over the 20-year period (median for all data)

What else can be done..?  $\Psi_m, Z_{0,h}, Z_{0,q}$



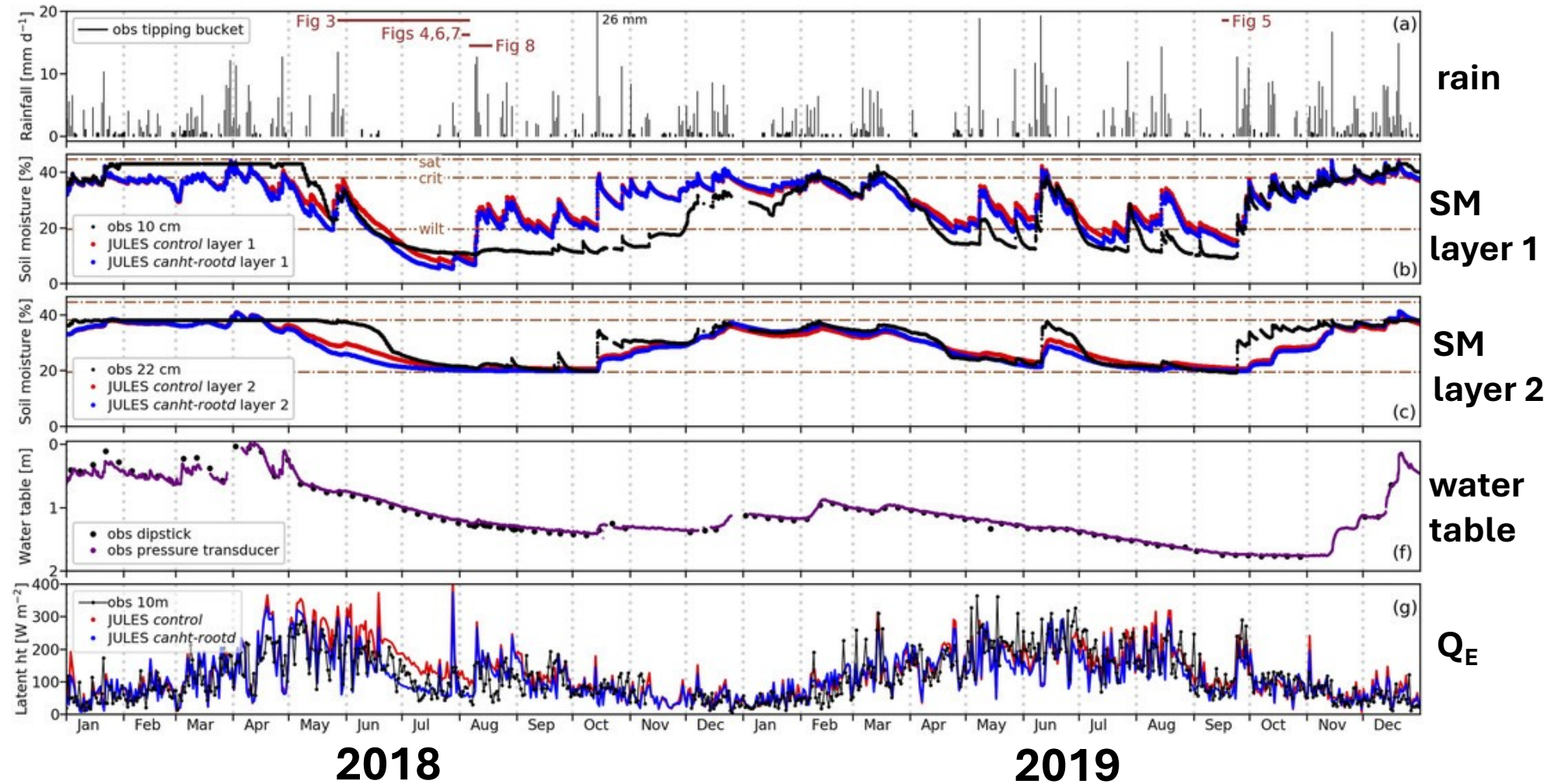
# Osborne & Weedon (2021) drought paper: focus on summer of 2018

Slow recovery of  
soil water (but not  
JULES in layer 1)

JULES immediately  
responds to rainfall  
on dry ground

Water table depth  
also measured  
(2019 deeper than  
2018)

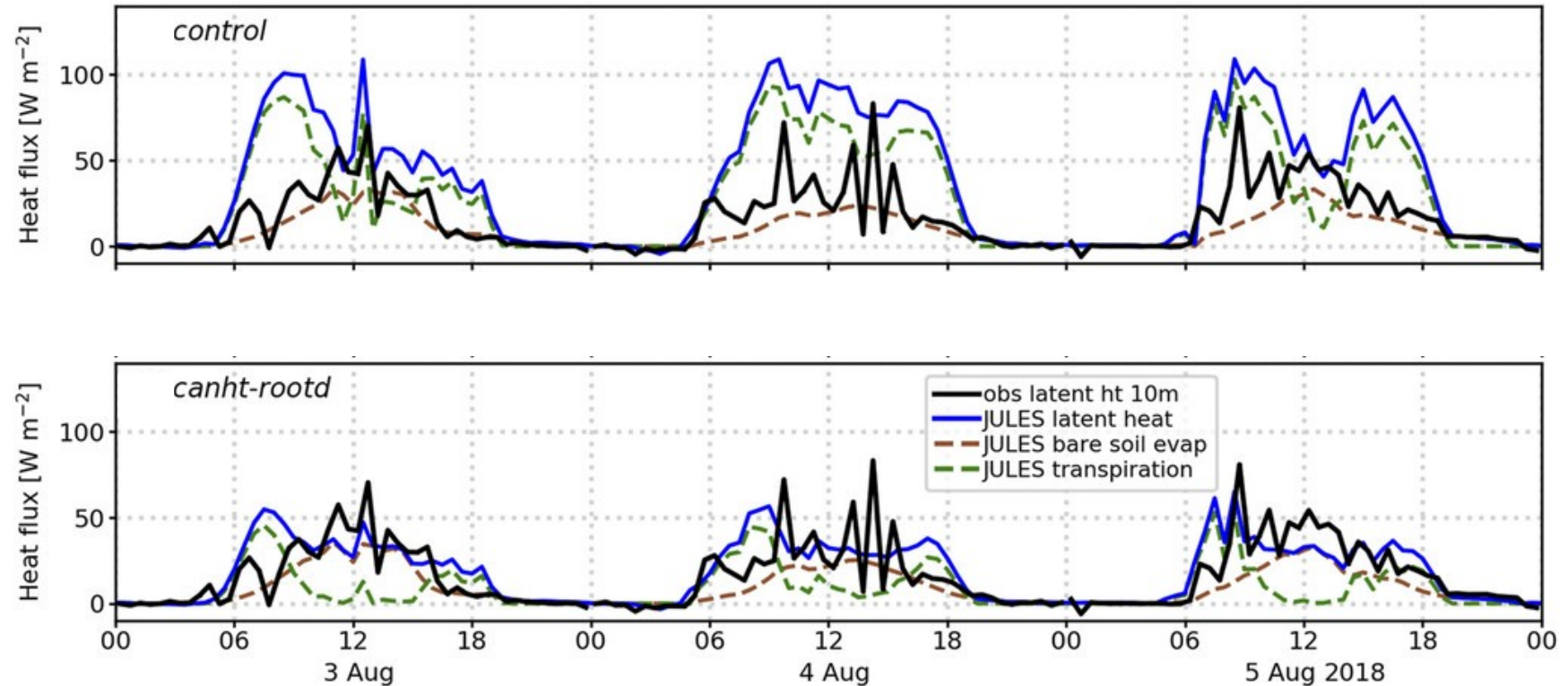
Attempt to improve  
JULES latent heat  
flux in summer  
2018





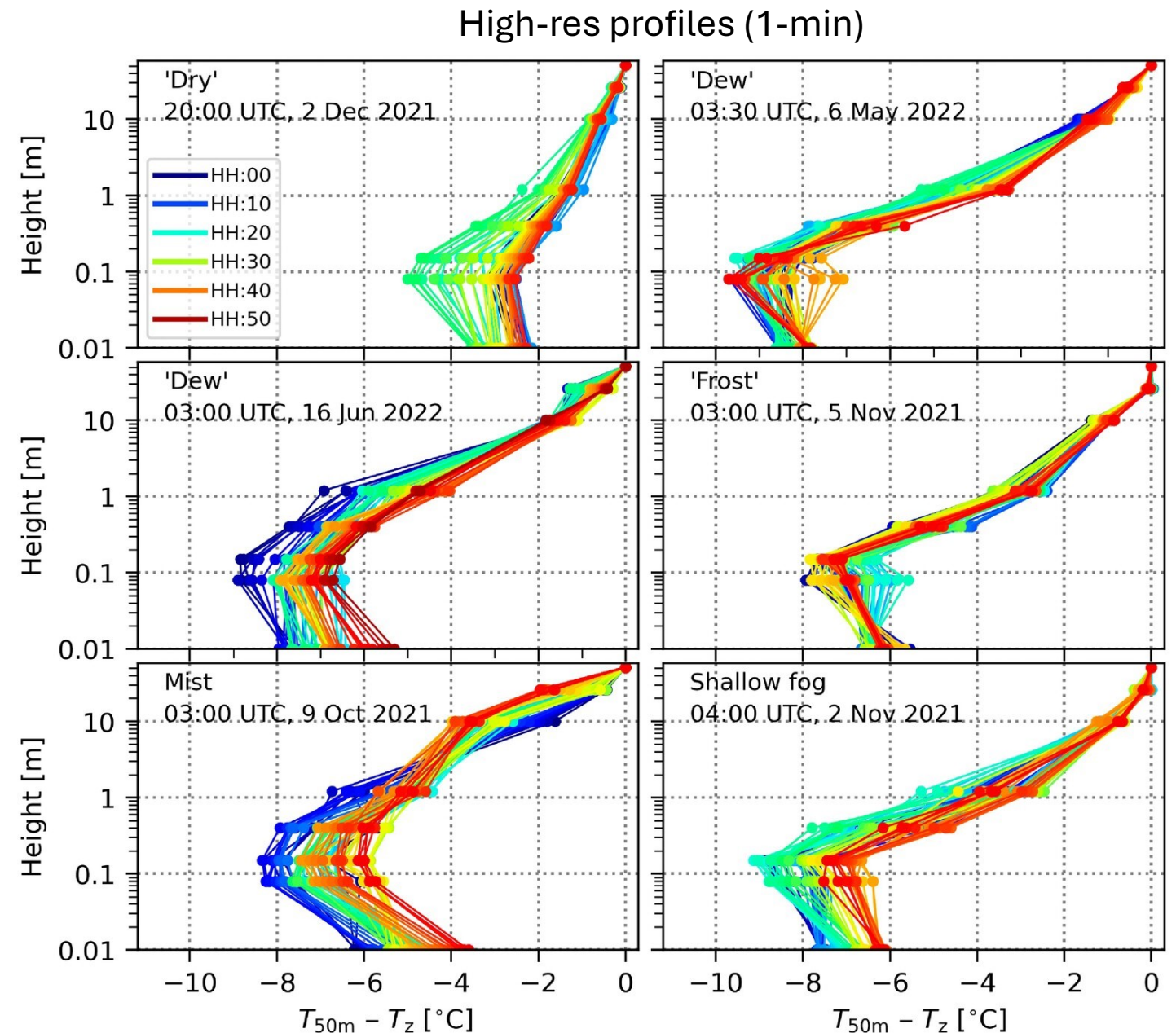
# Zoom in on a few drought days, August 2018

- Example where *Tupp* cuts off transpiration
- *et\_stom* far too high unless *canht* and *rootd* are modified
- Transpiration does not turn off in JULES, but does in reality (senescence)
- ...which implies soil evaporation (*esoil*–*et\_stom*) explains observed LHF
- Observed dew meter values 20–30 W m<sup>-2</sup>, yet *ecan* ≈ 0 (reluctance to form dew in JULES)



# Lifted temperature minimum using extra sensors below screen height

- allowed us to observe the paradoxical LTM on stable nights (invisible at most met sites)
- Explained by radiative effect of aerosol/haze/droplets
- If LTM is deemed important (e.g. fog formation) should it be parametrised?



# Summary

- Large dataset formed of 24/7 and IOP-based data at CEDA from the Cardington site (all netCDF)
- Subset of data used to generate JULES netCDF forcing files at FOUR heights
- Comprehensive site data for evaluating JULES: energy balance, soil conditions, turbulent covariances, skin temp
- *prescribed\_data* using e.g. site SW albedo, soil moisture, CO<sub>2</sub> mmr
- Use of long-range forcing data untapped
- From 2015: canopy 8 cm T+RH sensor... an alternative surface temp
- From 2020: additional 15cm, 40cm T+RH sensors, plus a sonic anemometer at 40cm e.g. collapse of turbulence on stable nights?



# Thanks for listening !

