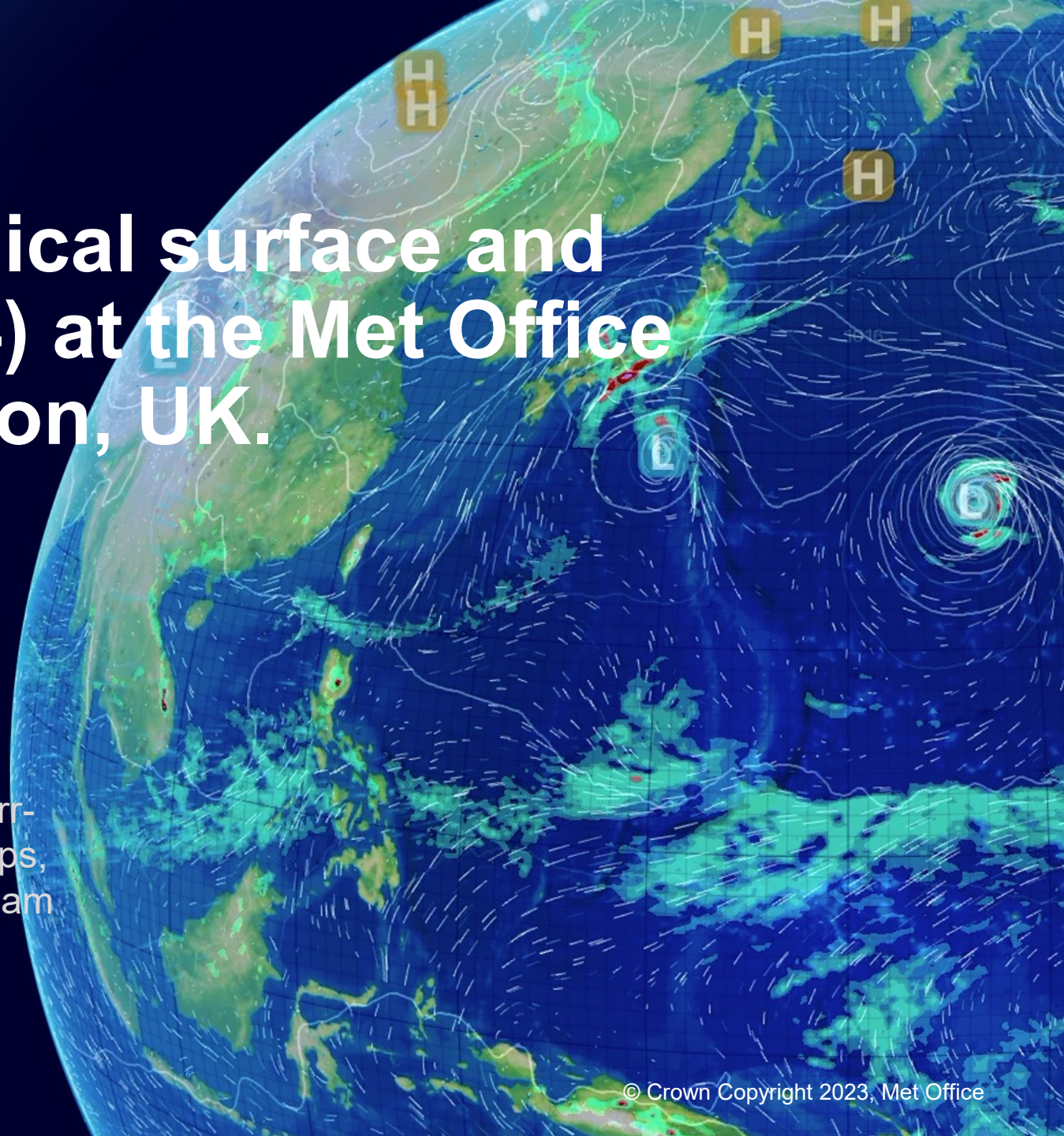
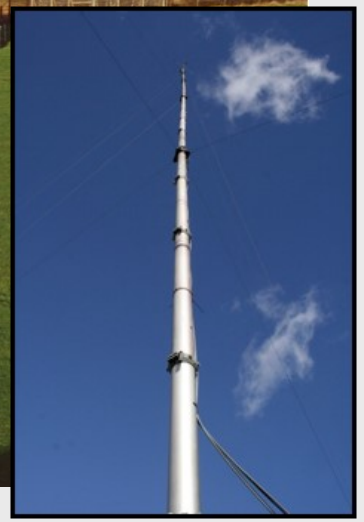
Continuous meteorological surface and soil records (2004–2024) at the Met Office surface site of Cardington, UK.



Simon Osborne, 17th 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

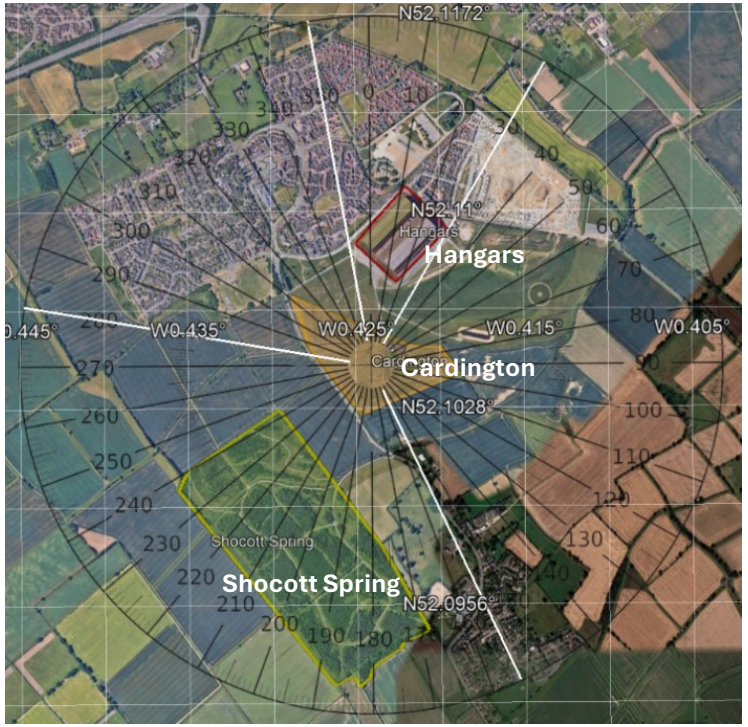
Improved understanding of physical atmospheric processes

Global, regional and high-resolution models

Model evaluation *Improved parametrizations*

1 km

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°)

29th October 2021

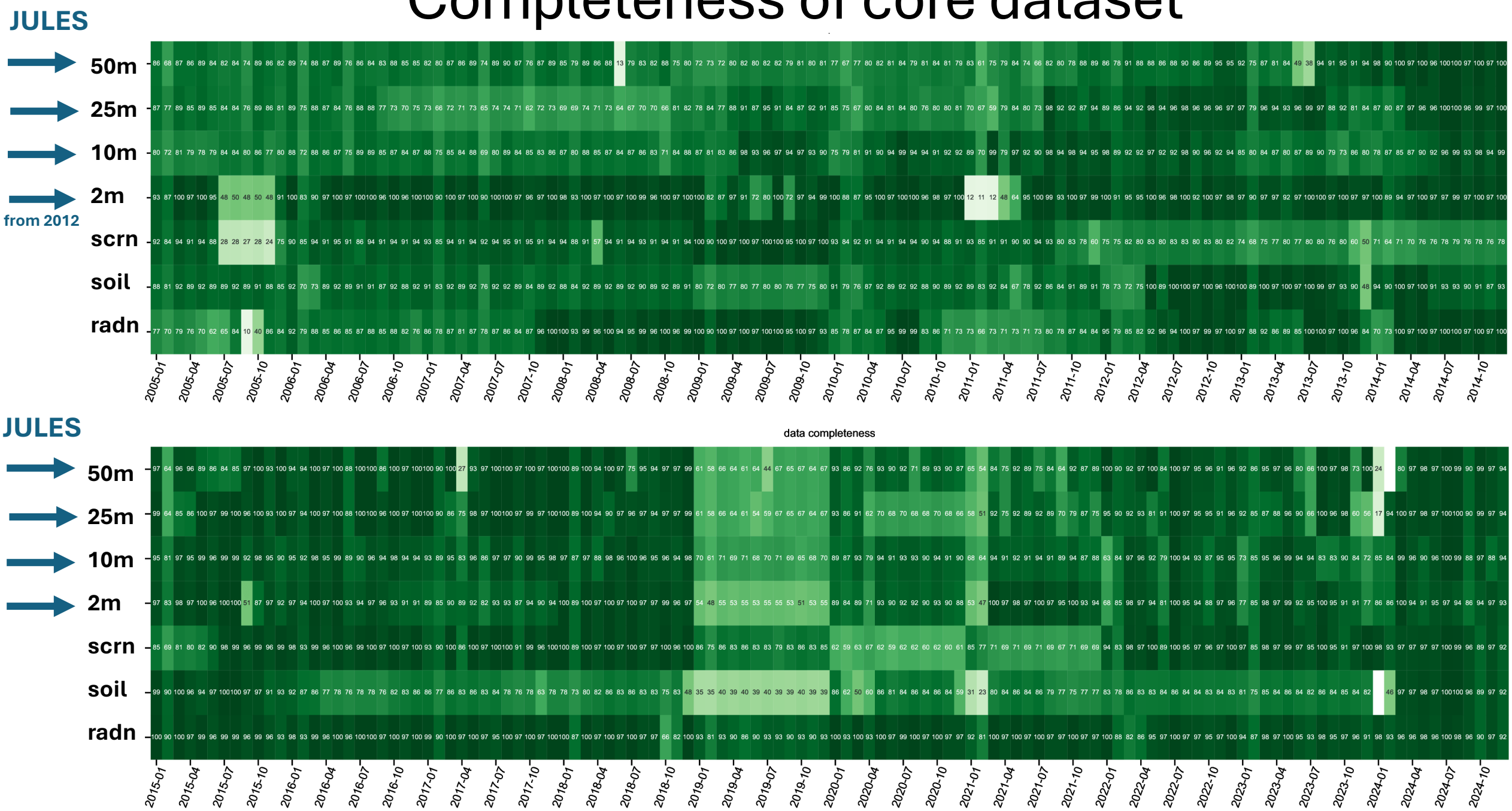
Non-drought
19th July 2016

Drought
7th 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 θ, 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/54873805110844413a502c4b229273bc6/
- 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 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 (<=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

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

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 **(hcap)**	**1.235×10^6**	1.228×10^6	J m^{-3} K^{-1}
Soil dry thermal conductivity **(hcon)**	**0.234**	0.230	W m^{-1} K^{-1}
Soil hydraulic conductivity at saturation **(satcon)**	**0.00312 ± 0.0255**	0.00286	Kg m^{-2} s^{-1}
Soil matric suction at saturation **(sathh)**	**0.26714 ± 0.0255**	0.31282	m
Soil moisture at saturation **(sm_sat)**	**0.4454 ± 0.0556**	0.4489	m^3 m^{-3}
Soil moisture at critical point **(sm_crit)**	**0.3801**	0.3408	m^3 m^{-3}
Soil moisture at wilting point **(sm_wilt)**	**0.1942**	0.2262	m^3 m^{-3}
Canopy height **(canht)**	**0.05–0.10**	1.46	m
Leaf area index **(lai)** during 2018 dry-down	**2.36–1.62**	2.8–1.1	-
Rooting depth **(rootd)** during 2018 drought	**0.2**	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 $|z/L| <= 0.1$

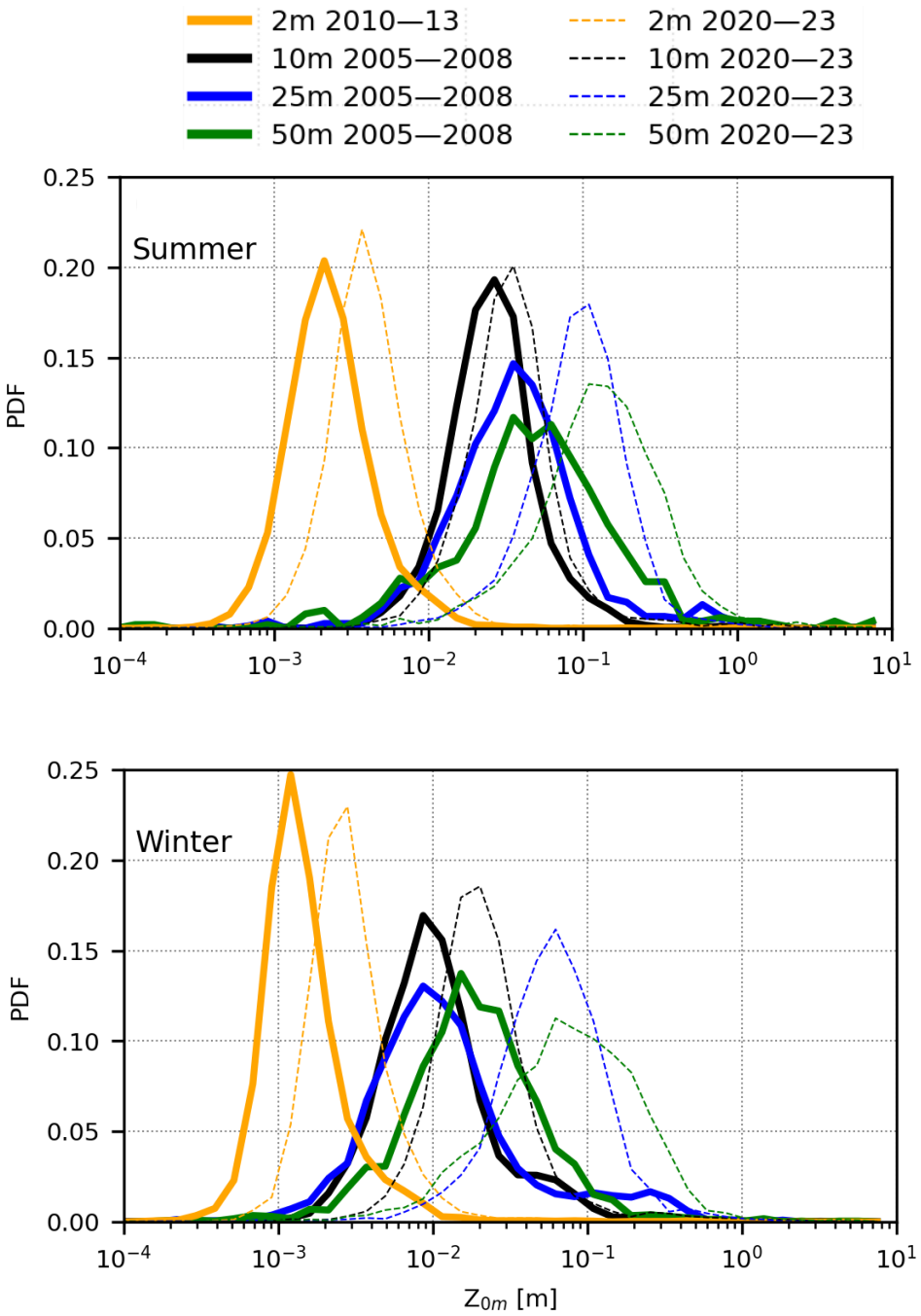
155—280° wind direction (66% of data)

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..? Ψ_m, $Z_{0,h}$, $Z_{0,q}$



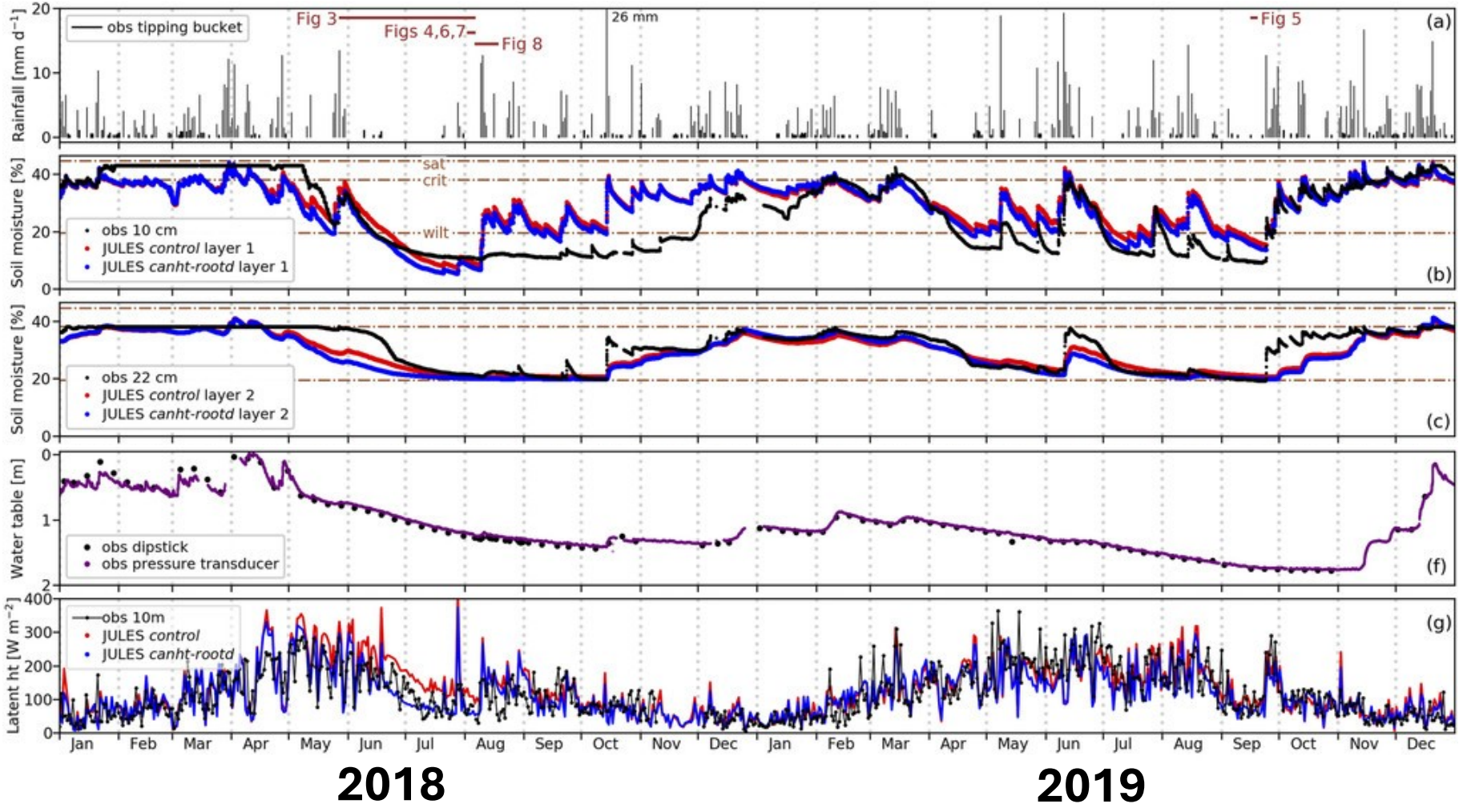
Osborne & Weedon (2021) drought paper: focus on summer of 2018

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)

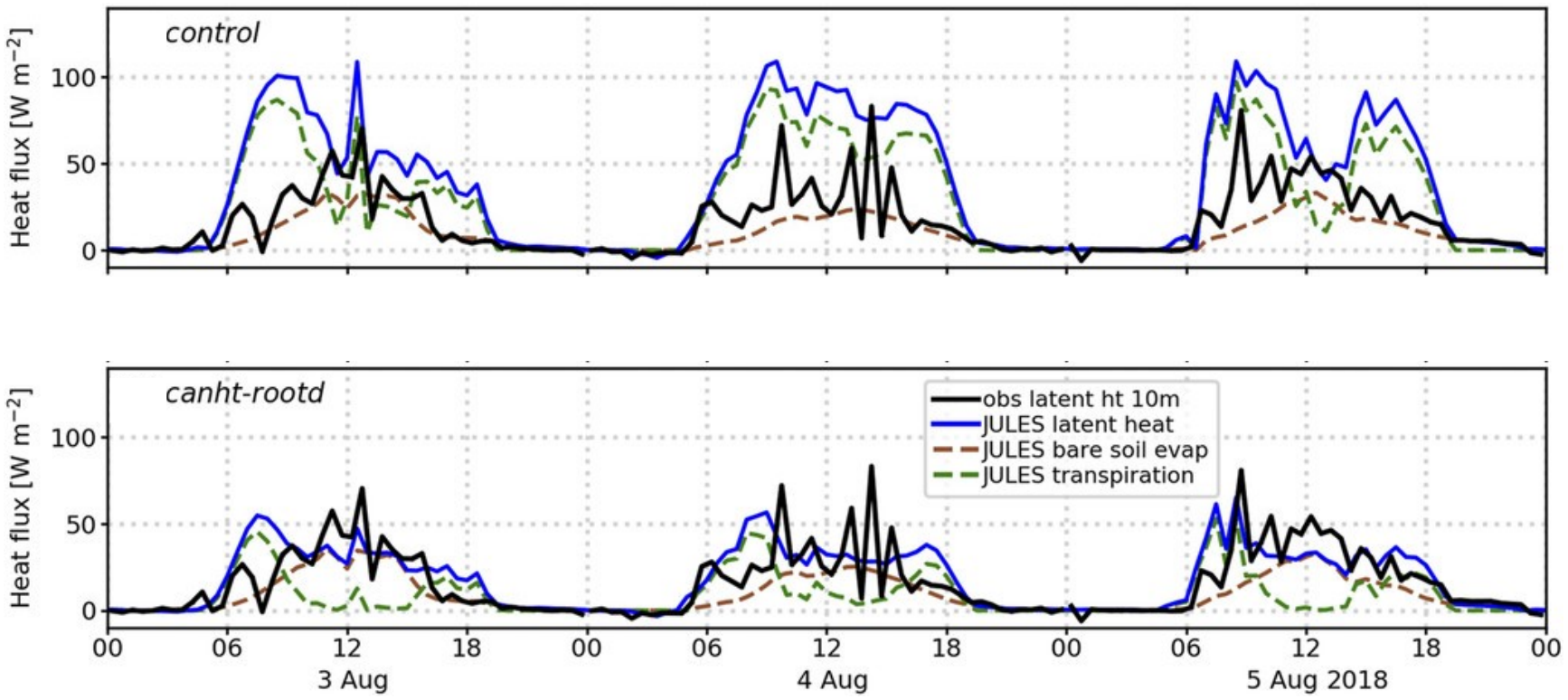
Attempt to improve JULES latent heat flux in summer 2018



https://doi.org/10.1175/JHM-D-20-0148.1

Zoom in on a few drought days, August 2018

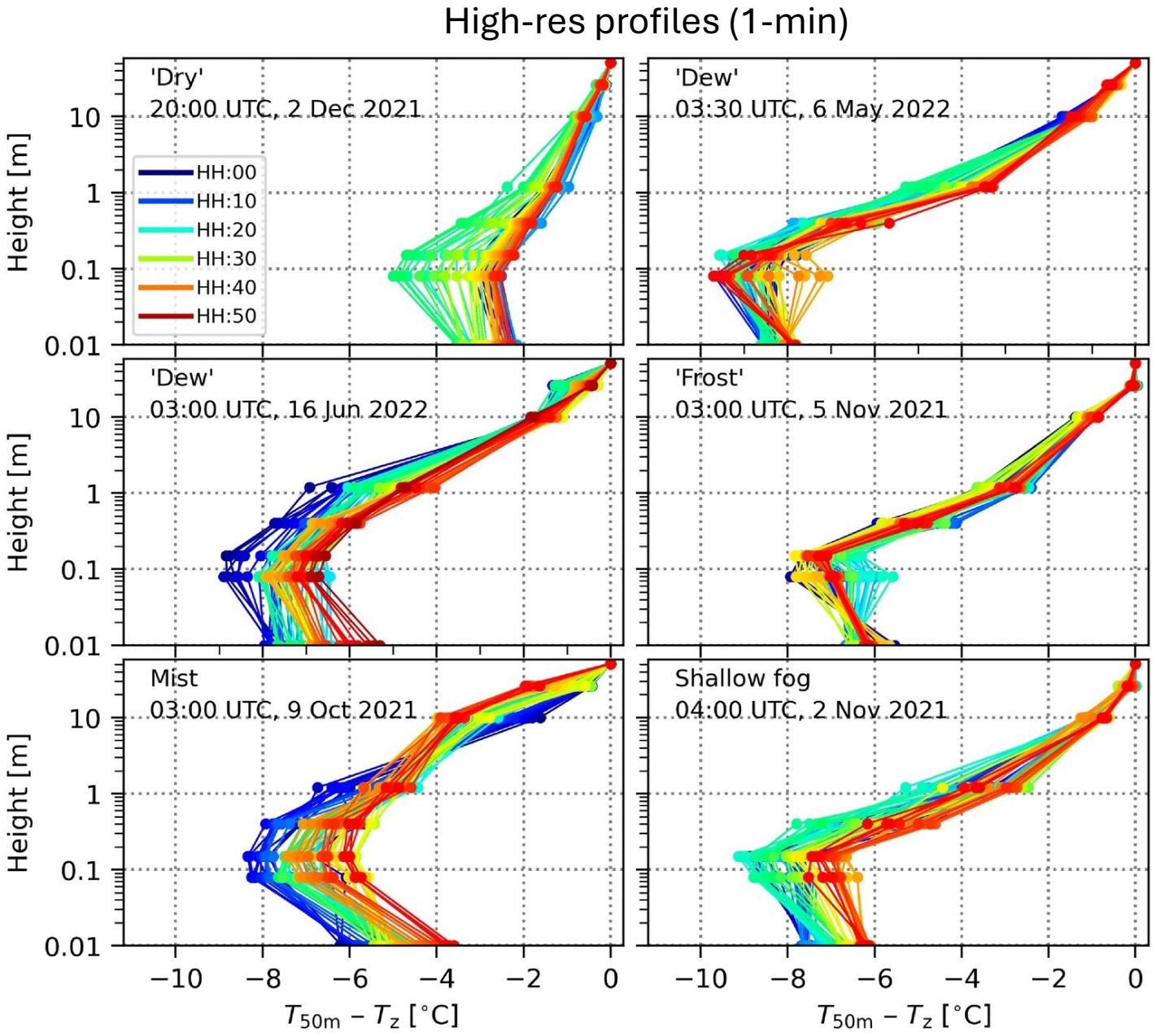
- Example where *Tupp* cuts off transpiration
- *et_stom* far too high unless *canht* and *rootd* are modified
- Transpiration does not turn off in JULES, but does in reality (senescence)
- …which implies soil evaporation (*esoil*–*et_stom*) explains observed LHF
- Observed dew meter values 20–30 W m^{-2},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



https://doi.org/10.1175/JHM-D-20-0148.1

Lifted temperature minimum using extra sensors below screen height

- allowed us to observed 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 ?



https://doi.org/10.1002/qj.4702

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_2 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 !