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*Supplement of*

## **The third Met Office Unified Model–JULES Regional Atmosphere and Land Configuration, RAL3**

**Mike Bush et al.**

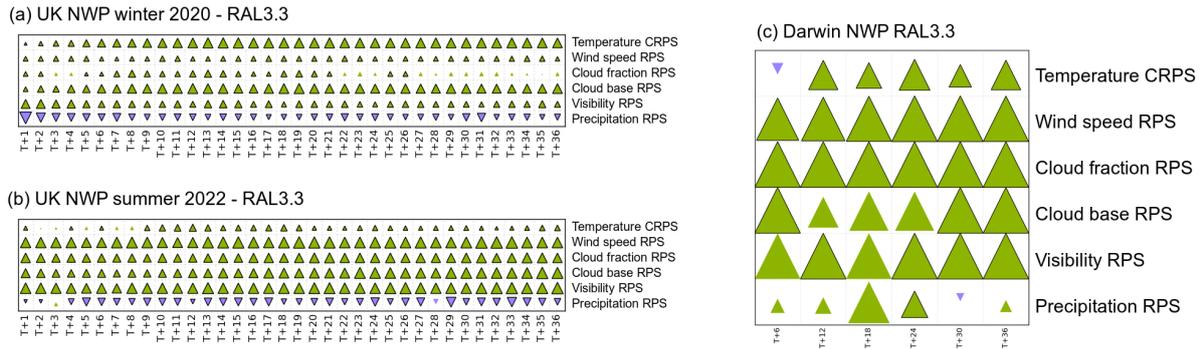
*Correspondence to:* Mike Bush ([mike.bush@metoffice.gov.uk](mailto:mike.bush@metoffice.gov.uk))

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Table S1 summarises information on simulations discussed in this paper. Each experiment is listed with an identifier that corresponds to the workflow that was used with rose/cyclc frameworks to define and manage the execution of case study, NWP trial or climate simulations. Workflows are archived and revision-controlled using the Met Office Science Repository Service, and contain the information required to extract and build the code as well as configure and run the simulations. Workflows used in development of RAL3 are available to any licensed user of both the UM and JULES.

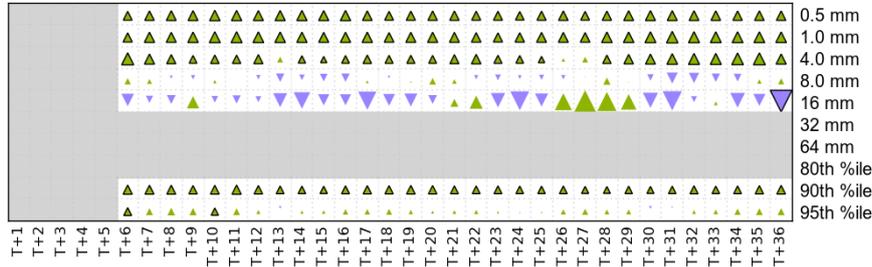
**Table S1.** Simulation details of experiments conducted to support evaluation of RAL3 discussed in this paper across timescales, resolutions and domains of interest. This covers a sub-set of domains and experiments used through the RAL3 development to assess aspects of candidate configuration packages, initial release version and subsequent revisions. Simulation workflows, with 'mi-' or 'u-' identifiers are archived on the Met Office Science Repository Service <https://code.metoffice.gov.uk/trac/home>

Experiment	Description	RAL3	RAL2
UK Climate	Free-running 6-year simulations, initialised 01/01/2007. 2.2 km model over UK with 60 s timestep, nested within UKCP18 12 km RCM spanning Europe, driven by ERA-Interim reanalyses and SST derived from observational analysis (?). First year of simulation is not included in analyses as spin-up.	mi-bd046	mi-bc053
UK NWP winter 2022	Deterministic 6-hourly cycling data assimilation NWP trial, using UKV model domain with variable resolution and 2.2 km grid spacing in inner domain (?), nested within operational global NWP. Testing RAL3 revisions. Trial period 1 December 2021 - 28 January 2022 (59 days).	mi-bf303	mi-be497
UK NWP summer 2022	As UK NWP winter trial. Testing RAL3 revisions. Trial period 8 July - 17 August 2022 (41 days).	mi-bf312	mi-bf338
UK NWP winter 2020	As UK NWP winter trial. Testing initial RAL3 release. Trial period 2 December 2019 - 22 January 2020 (52 days).	mi-bc895	mi-bb676
UK NWP summer 2019	As UK NWP winter trial. Testing initial RAL3 release. Trial period 16 June - 4 August 2019 (50 days).	mi-bc924	mi-bb692
Darwin NWP	Deterministic 12-hourly cycling trial with 1.5 km grid spacing, initialised from ECMWF operational analysis and driven by ECMWF global forecast lateral boundary conditions out to. Trial period 21 January - 19 March 2017 (58 days)	u-co345; u-da769	u-cj172
Tropical Africa NWP	Deterministic 12-hourly cycling trial with 4.4 km grid spacing run at 06Z and 18Z daily out to 72h. Nested within 17 km (GA7.2) operational MetUM global NWP. Trial period 1 August - 14 September 2020 (45 days)	u-ci247	u-ce073
SE Asia NWP	Deterministic 12-hourly cycling trial with 4.4 km grid spacing run at 00Z and 12Z daily out to T+120h. Nested within 17 km (GA7.2) operational MetUM global NWP. Trial period 1 January - 30 January 2020 (30 days). Only 00Z results analysed here.	u-ci088	u-ci088
India NWP	Deterministic 4.4 km NCUM-R daily run simulations with 90 vertical levels. Experiment period March - June 2019	u-ck361	u-cl425
UK ensemble winter	Month-long 18-member trials using MOGREPS-UK model domain with variable resolution and 2.2 km grid spacing in inner domain (?), nested within operational global MOGREPS-G ensemble. RAL2-M driven by GC4, RAL3.3 with/without new random parameters driven by GC5. Trial period 1 December 2021 - 1 January 2022	mi-bf883 mi-bf597	mi-be989
UK ensemble summer	As UK NWP ensemble trial. Trial period 15 July - 15 August 2022	mi-bg042 mi-bf700	mi-bf739
Darwin ensemble	10-day 12-member trials comparing RAL3.0 with RAL2-T, initialised every 6 hr using 2.2 km grid spacing. Trial period 29 November - 8 December 2020		
UK summer case study	Deterministic case study simulations over UK for summer 2021, using 1.5 km and 300 m grid spacing models.	u-cj967	u-ce890

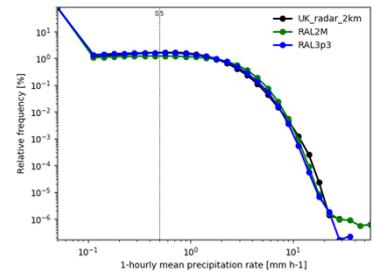


**Figure S1.** Summary scorecards for the percentage differences between the RAL3.3 revision and RAL2-M for the Ranked Probability Score or Continuous Ranked Probability Score (dependent upon variable) calculated within the High Resolution Assessment (HiRA) framework for a neighbourhood of seven grid lengths from NWP simulation experiments for a) UK NWP winter [to T+36h, hourly statistics, RAL3.3 vs RAL2-M], b) UK NWP summer [to T+36h, hourly, RAL3.3 vs RAL2-M] and c) Darwin NWP [to T+36h, RAL3.3 vs RAL2-T]. Green triangles represent an improved score, and purple triangles represent a degradation in the score. Black borders mark changes that are statistically significant at a 95% significance level. See Figure 2 for results based on RAL3.0.

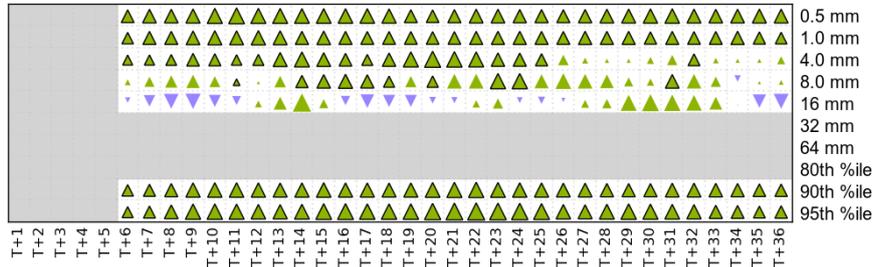
(a) UK NWP winter 2020 - RAL3.3



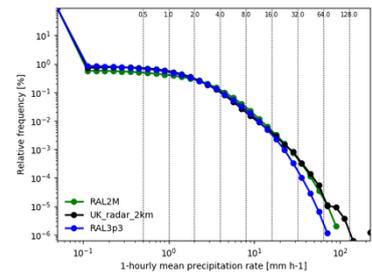
(b) UK winter - RAL3.3



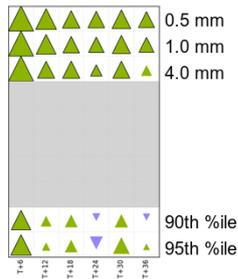
(c) UK NWP summer 2022 - RAL3.3



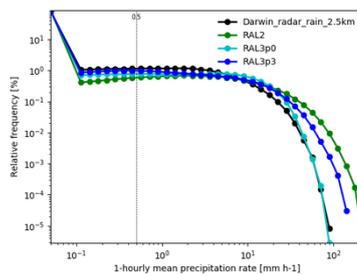
(d) UK summer - RAL3.3



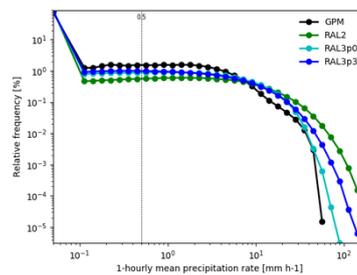
(e) Darwin - RAL3.3



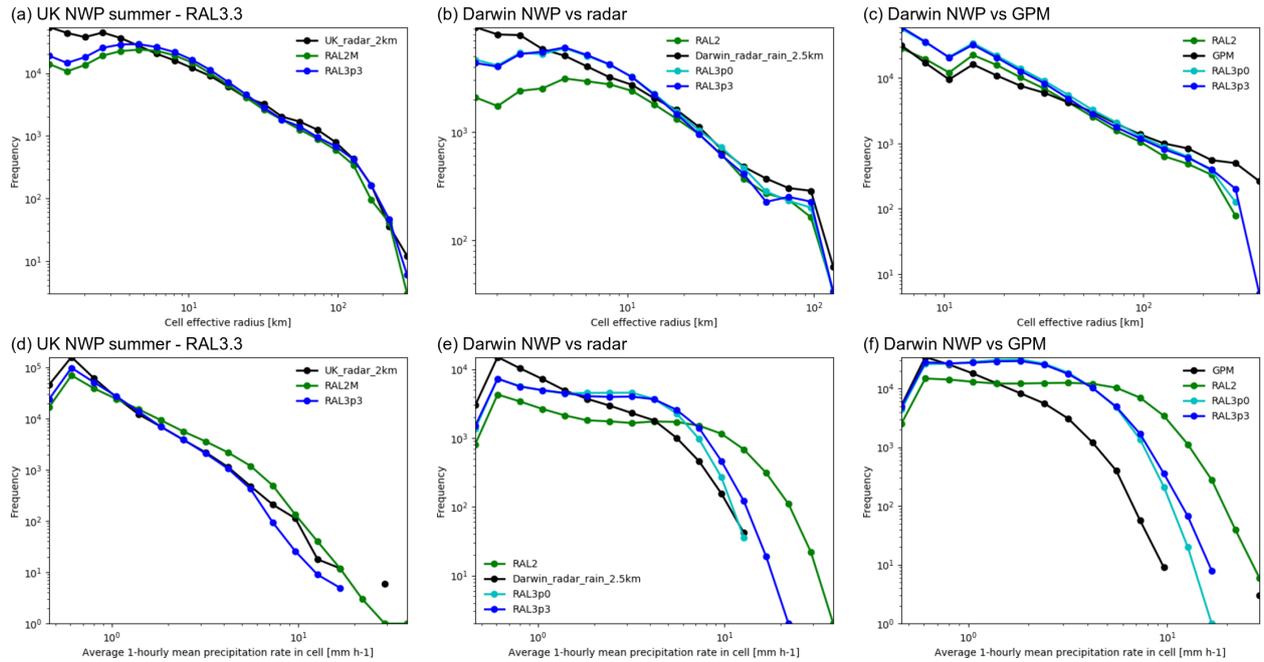
(f) Darwin NWP vs radar



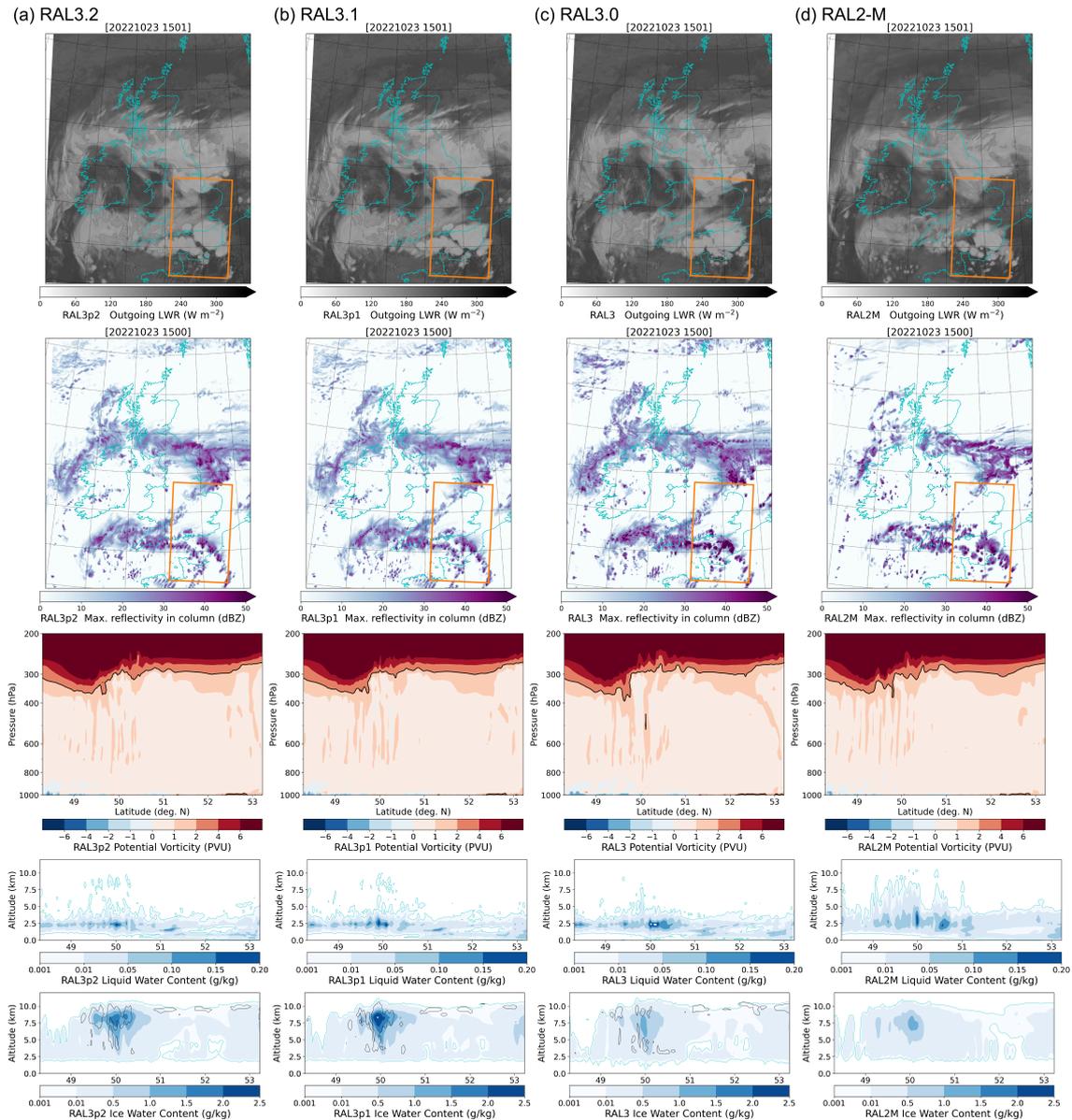
(g) Darwin NWP vs GPM



. **Figure S2.** Summary scorecards for the percentage differences between RAL3.3 and relevant RAL2 baseline for the Fractions Skill Score (FSS) at differing thresholds (both absolute and percentile). The FSS presented are for neighbourhood widths of five grid lengths from NWP simulation experiments for a) UK winter 2021 [to T+36h, hourly statistics, RAL3.3 vs RAL2-M], c) UK summer 2022 [to T+36h, hourly, RAL3.3 vs RAL2-M], e) Darwin NWP [to T+36h, 6-hourly statistics, RAL3.3 vs RAL2-T]. Green triangles represent an improved score, purple triangles represent a degradation in the score. Black borders mark changes that are statistically significant at a 95% significance level. Panels (b) and (d) show hourly mean precipitation rate histograms relative to UK radar observations for simulations using RAL3.3 and RAL2-M configurations. Panels (f) and (g) show hourly mean precipitation rate histograms for simulations over Darwin relative to radar and GPM IMERG V07B respectively. See Figure 3 and Figure 4 for equivalent results based on RAL3.0.



**Figure S3.** Top row shows average size of precipitation cells for a) UK summer relative to radar, b) Darwin NWP relative to radar and c) Darwin NWP relative to GPM IMERG V07B. Bottom row shows average precipitation rate within storm cells for d) UK summer relative to radar observations, e) Darwin NWP relative to radar and f) Darwin NWP relative to GPM IMERG V07B. Observations are shown in black, green lines show relevant RAL2 baseline results and blue lines results for RAL3.3 revision. See Figure 5 for equivalent results based on RAL3.0.



**Figure S4.** Illustration of results from RAL3 revisions and RAL2-M for a severe quasi-linear convective system over south-East England on 23 October 2023. All results are shown for 1500 UTC, and all simulations use the same lateral boundary conditions, and run at UM version 13.0. Map plots shows instantaneous outgoing longwave radiation and maximum reflectivity in the vertical column for a sub-region of the model domain. The lower 3 rows show average latitude-height cross-sections through the orange box marked in upper panels. These show simulated potential vorticity (as function of pressure up to 200 hPa), liquid water content and ice water content (both as function of altitude in the lowest 12 km only). Black contours in the lower panel indicate the presence of cloud ice crystals as a diagnostic from CASIM. See Figure 15 for equivalent results based on RAL3.3, RAL3.2 and RAL2-M at UM version 13.5.