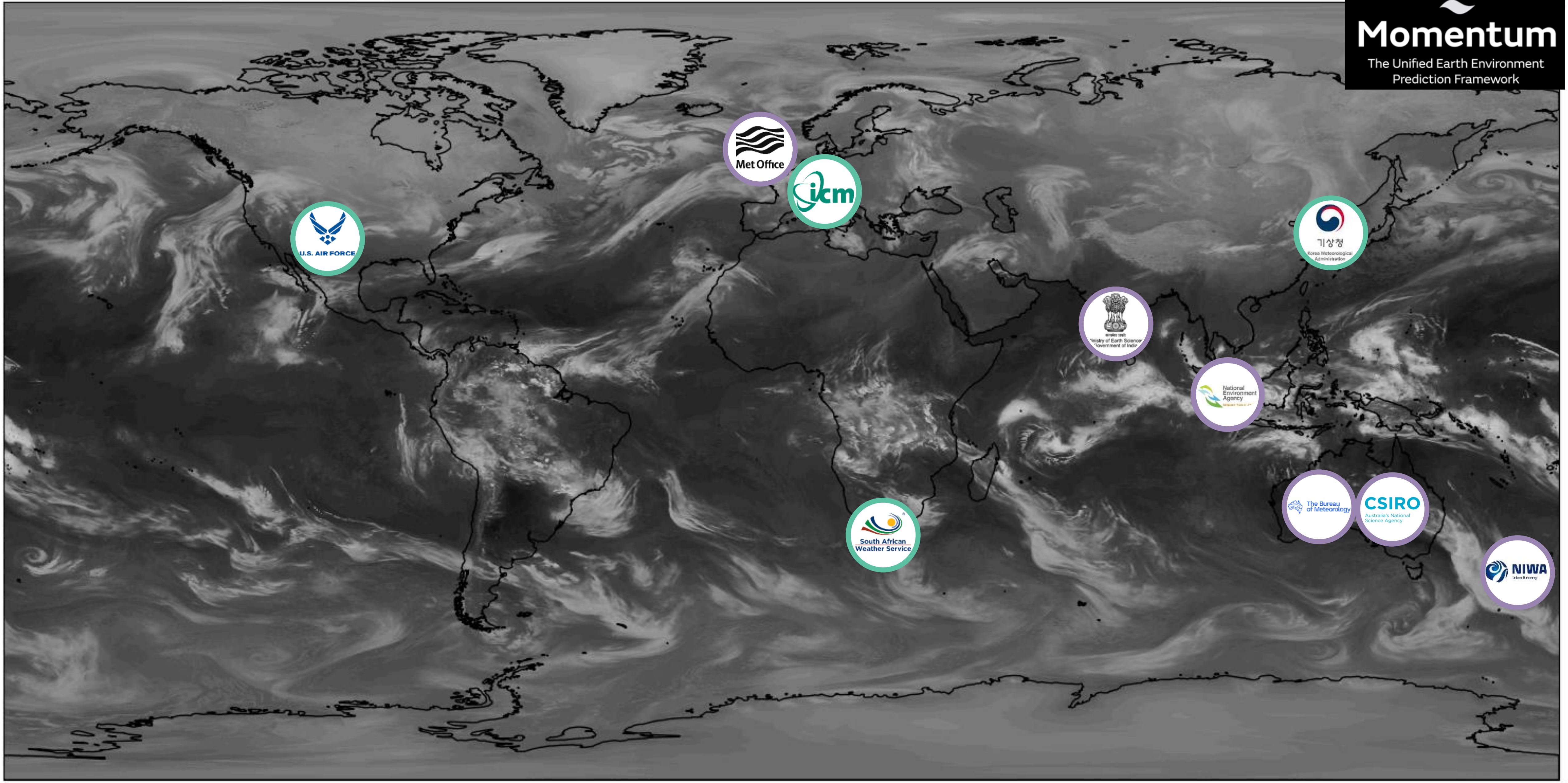
Advancing convective-scale predictions through collaboration

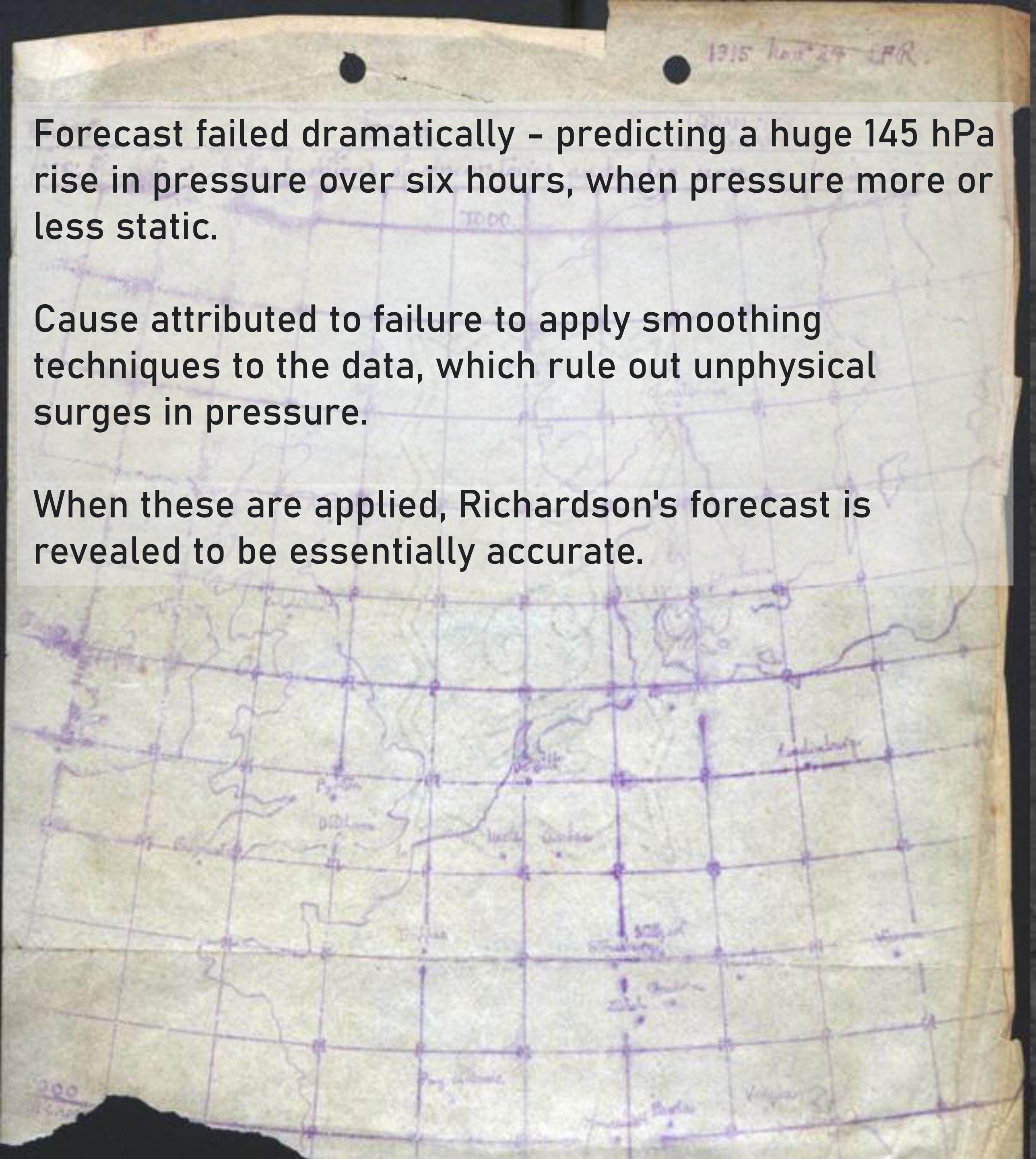
Momentum
The Unified Earth Environment Prediction Framework



Dr Huw Lewis, *Head Regional Modelling Evaluation & Development,* Met Office

September 2024

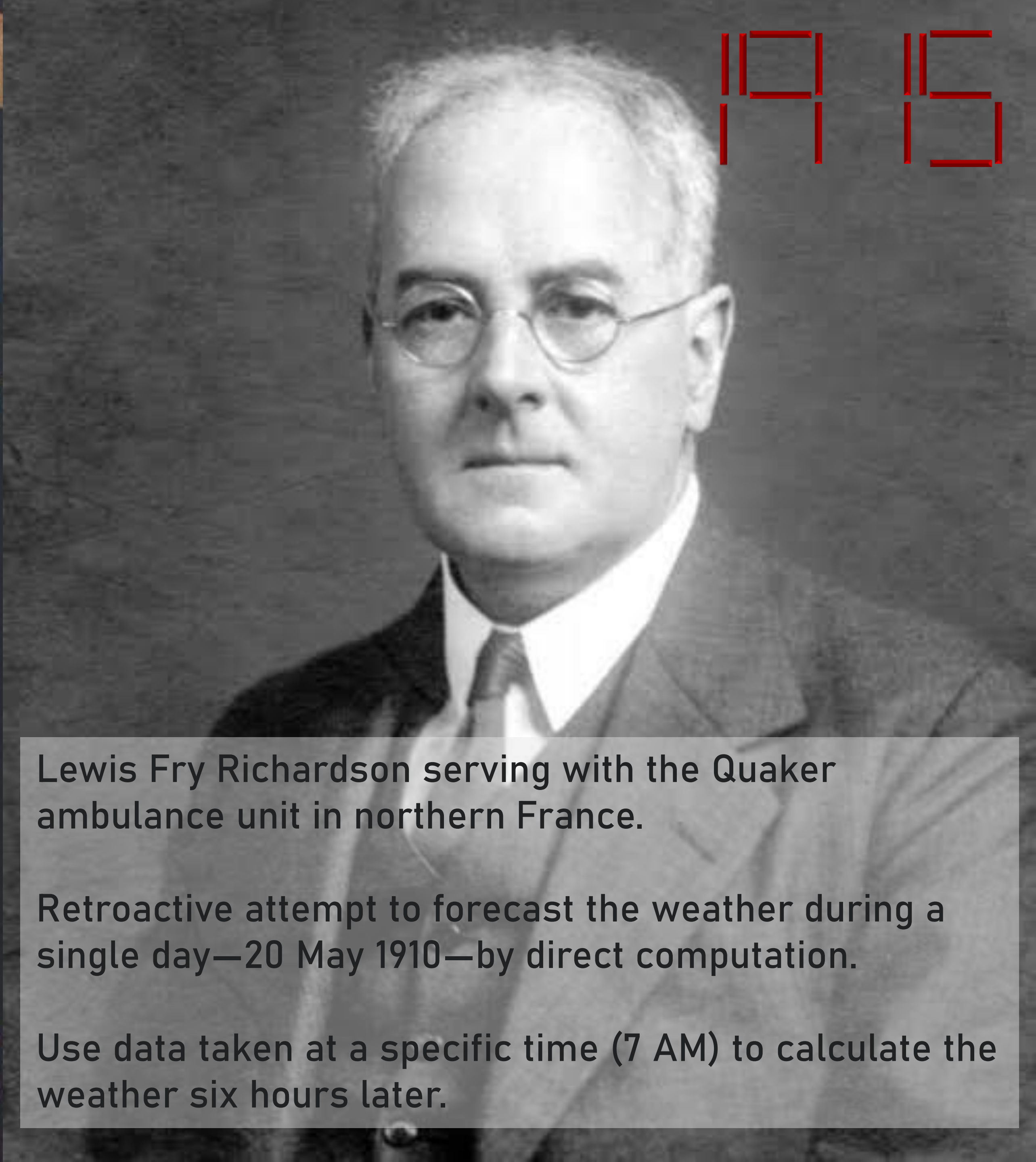
1915



Forecast failed dramatically - predicting a huge 145 hPa rise in pressure over six hours, when pressure more or less static.

Cause attributed to failure to apply smoothing techniques to the data, which rule out unphysical surges in pressure.

When these are applied, Richardson's forecast is revealed to be essentially accurate.



Lewis Fry Richardson serving with the Quaker ambulance unit in northern France.

Retroactive attempt to forecast the weather during a single day—20 May 1910—by direct computation.

Use data taken at a specific time (7 AM) to calculate the weather six hours later.


The picturesque harbour of Boscastle is one of Cornwall's most romantic places.
The long narrow valley runs down to a twisting rocky entrance hiding the raging sea beyond…
2004
E507

2004

75mm rain fell in two hours (typical monthly average)

Residents had little time to react

Rivers Valency and Jordan overflowed

Major rescue operation

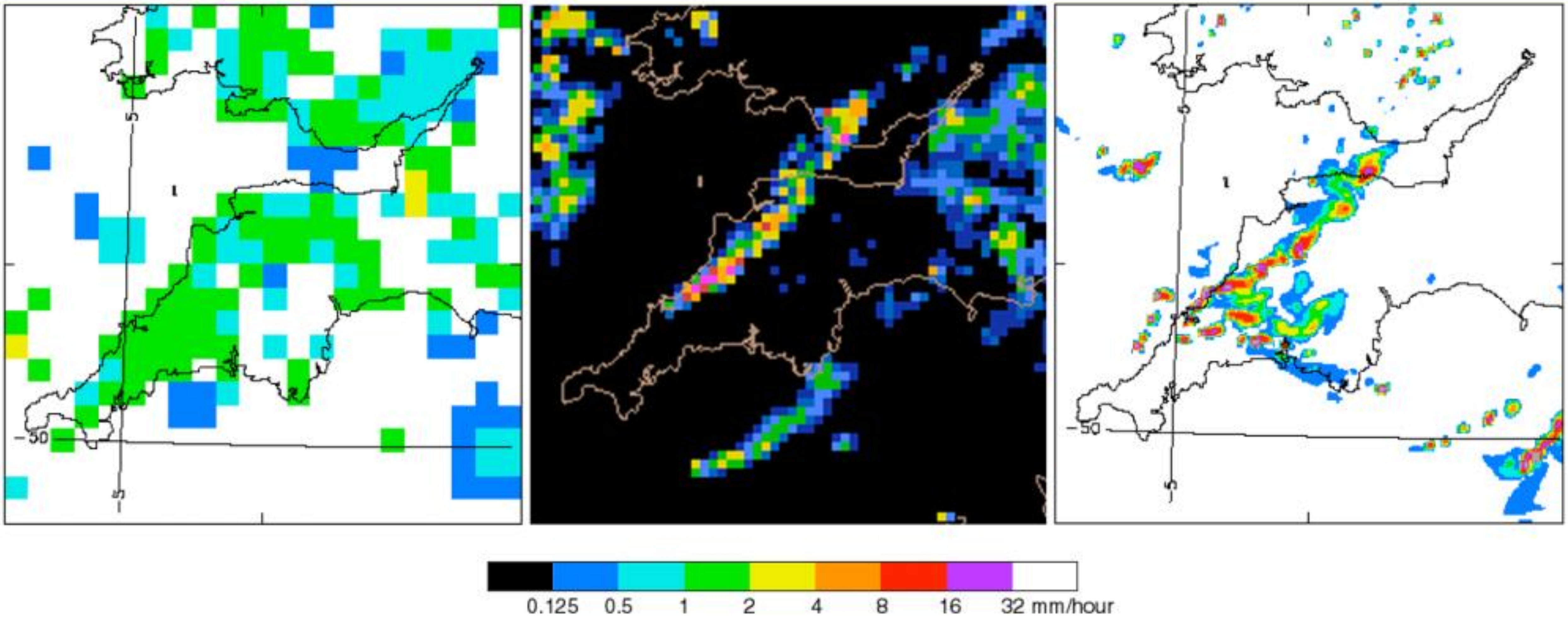
Short and long-term disruption and damage to property and livelihoods

Boscastle model comparison

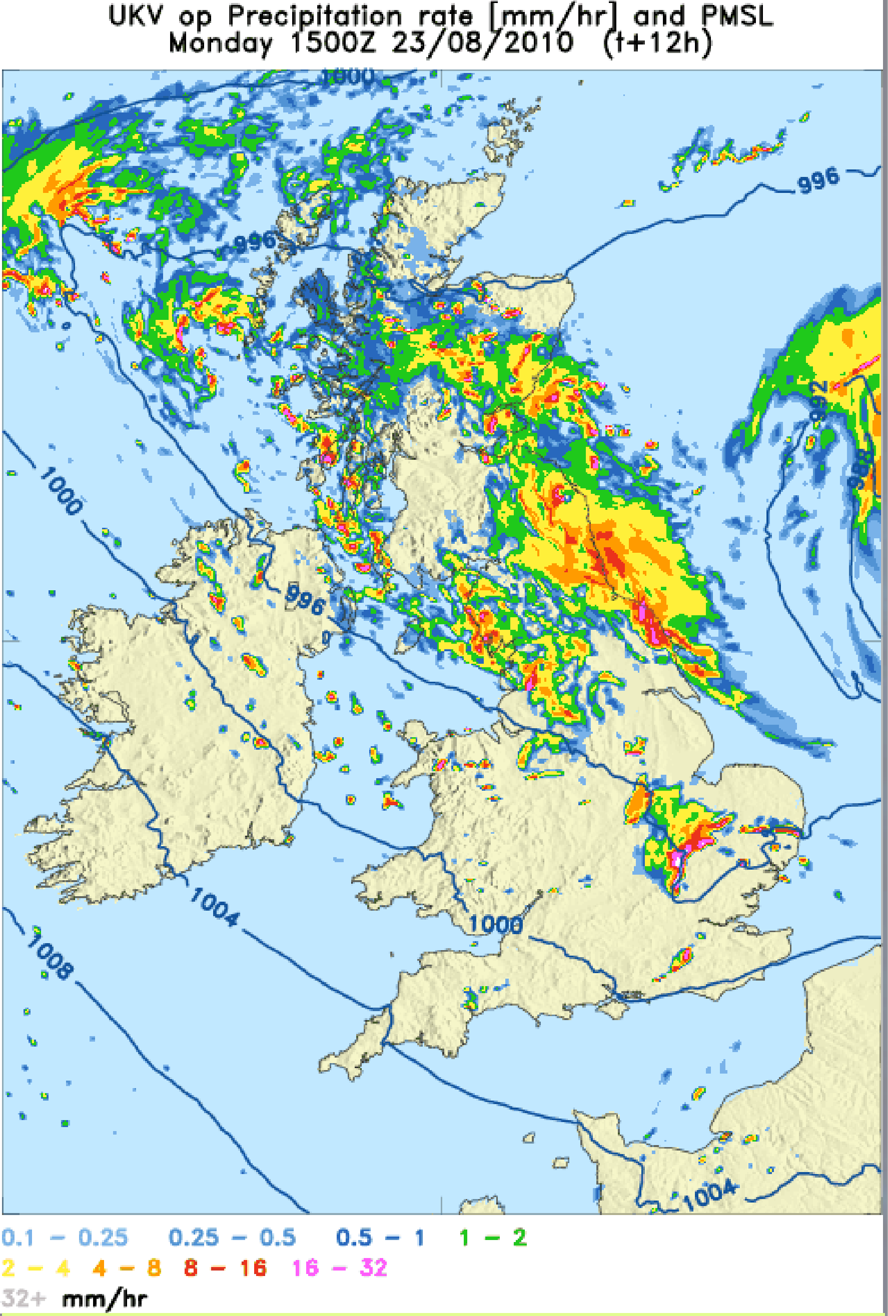
Rainfall rates over South West England at 15:00 16 August 2004

Met Office

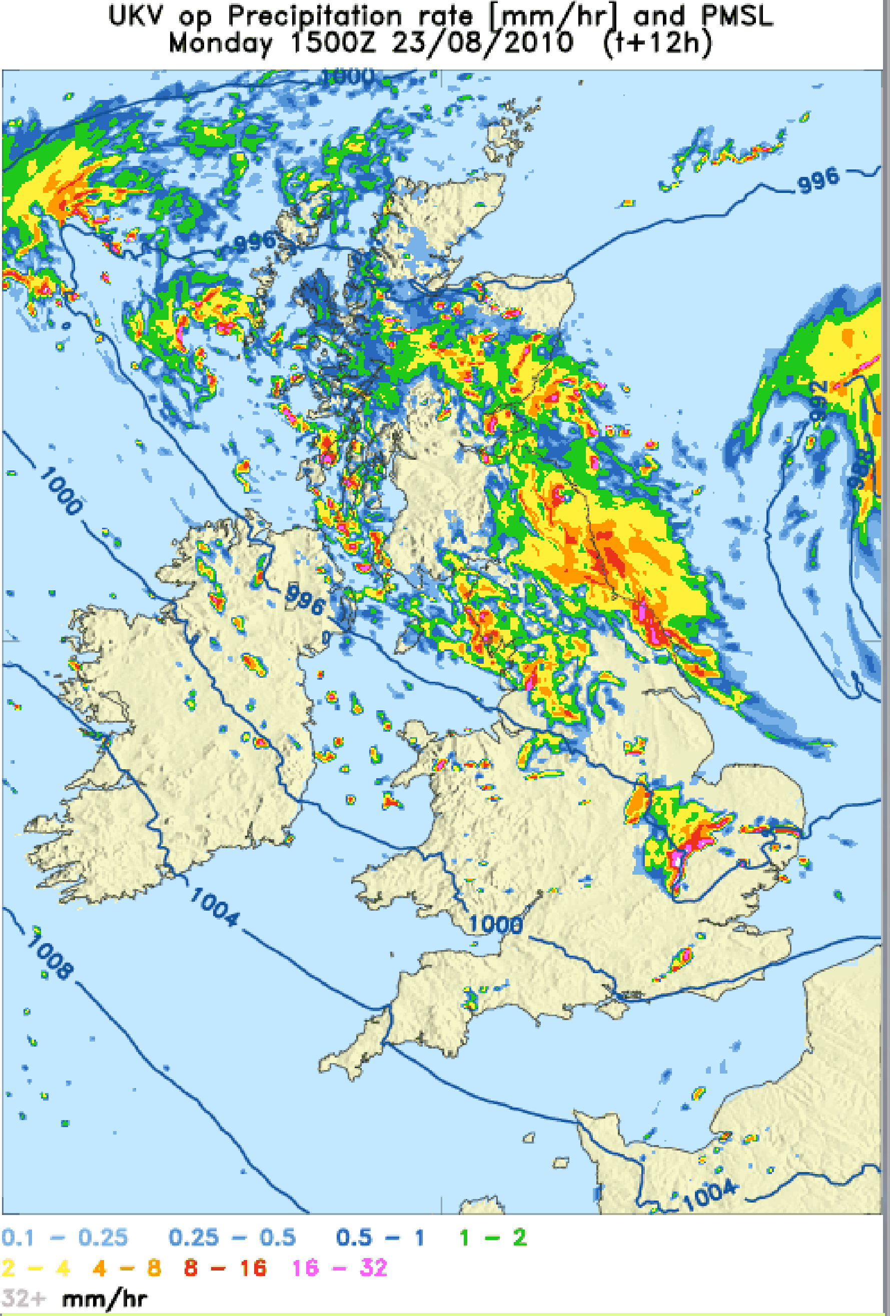
Operational capability: 12km forecast	Actual radar	Potential capability: 1km forecast



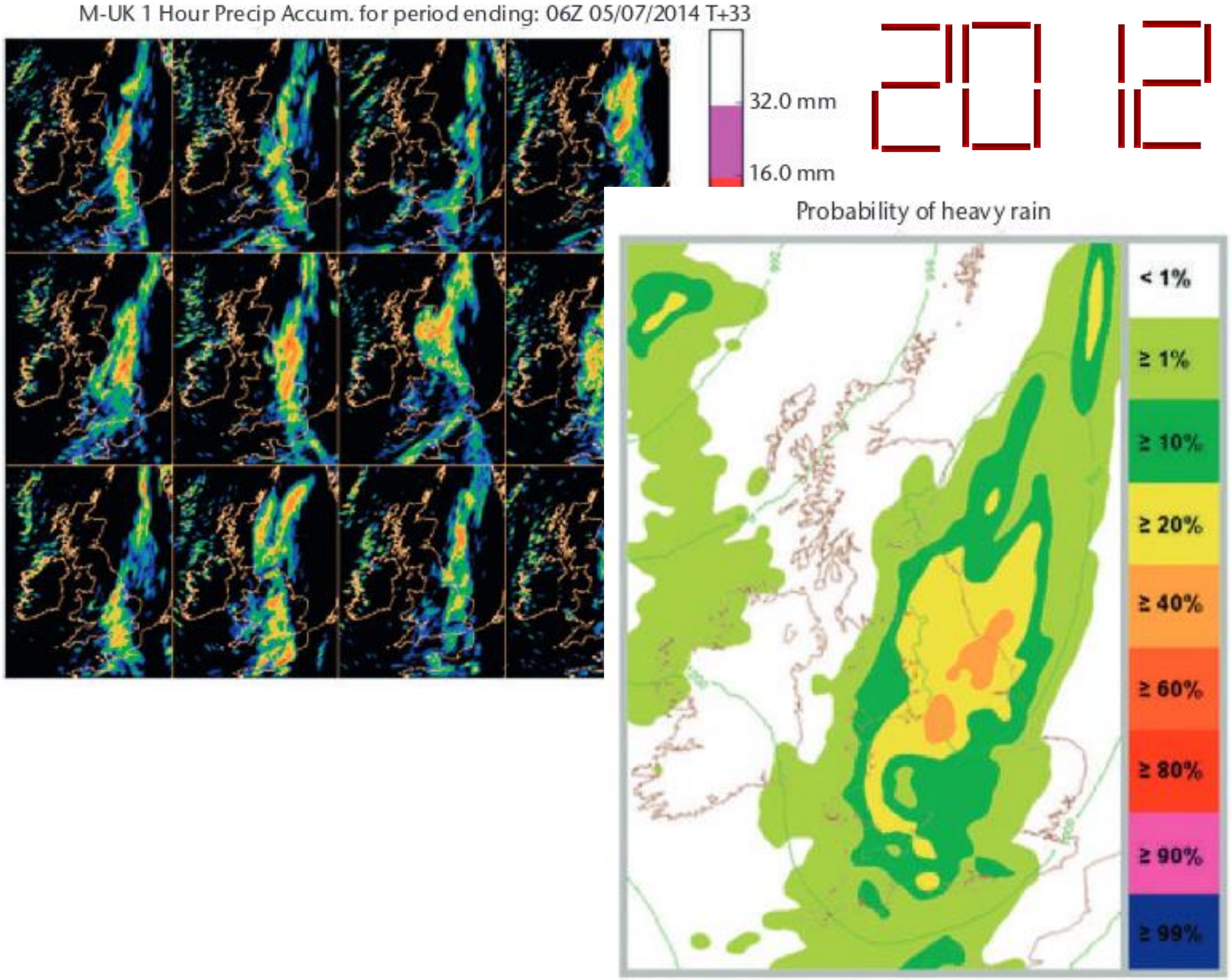
2010



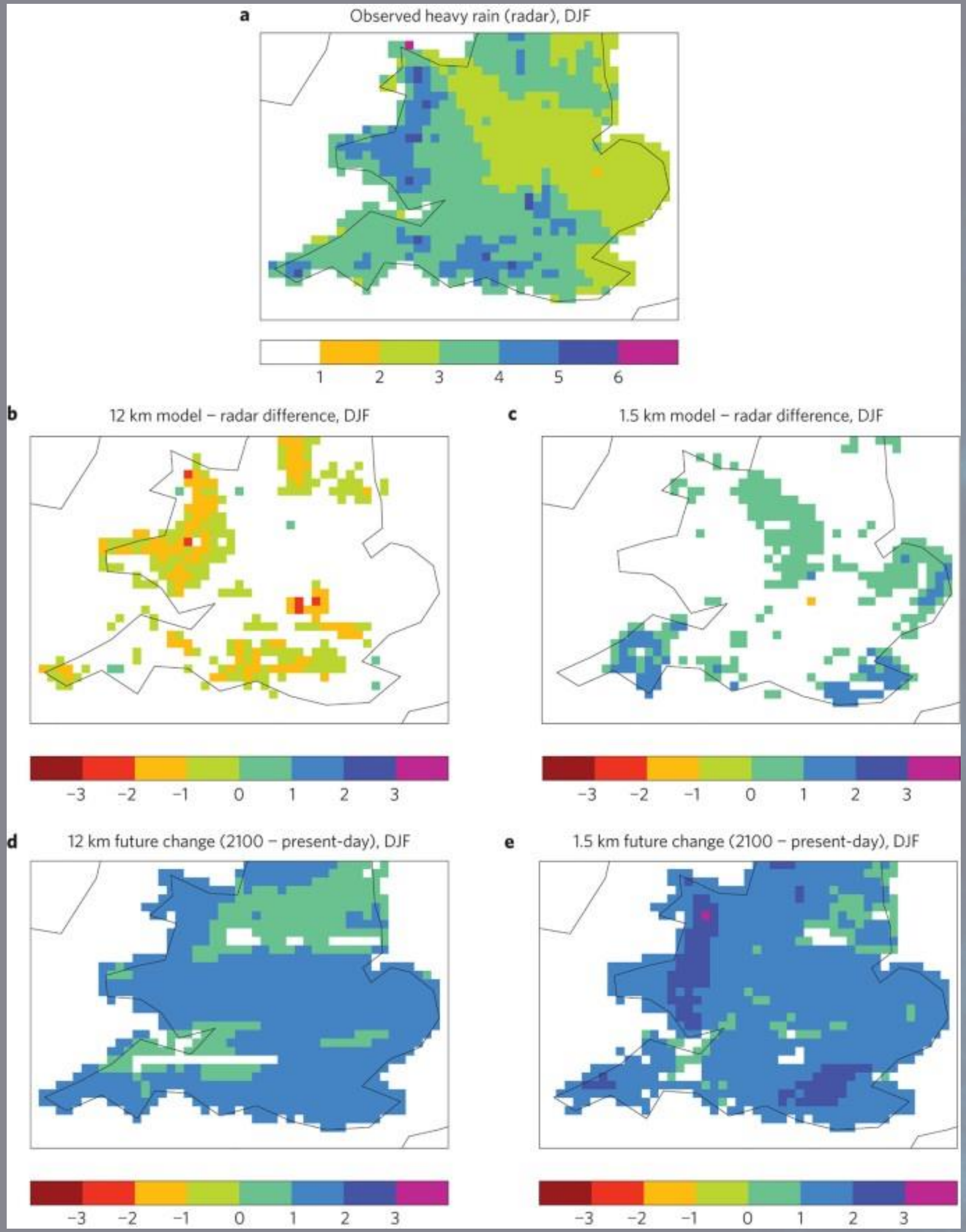
2010: Introduction of 1.5 km UKV

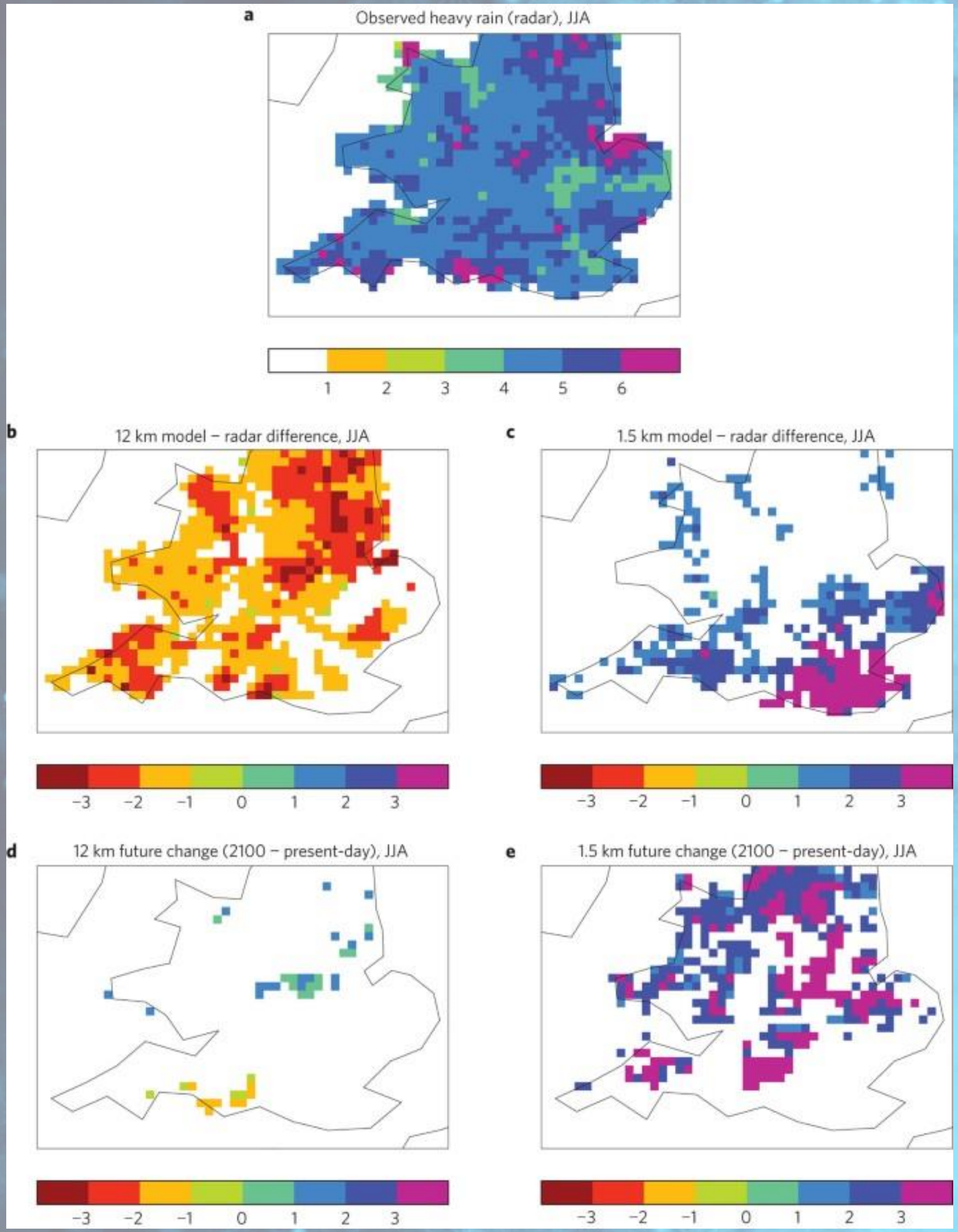


2010: Introduction of 1.5 km UKV



2012: Introduction of 2.2 km convective-scale ensemble

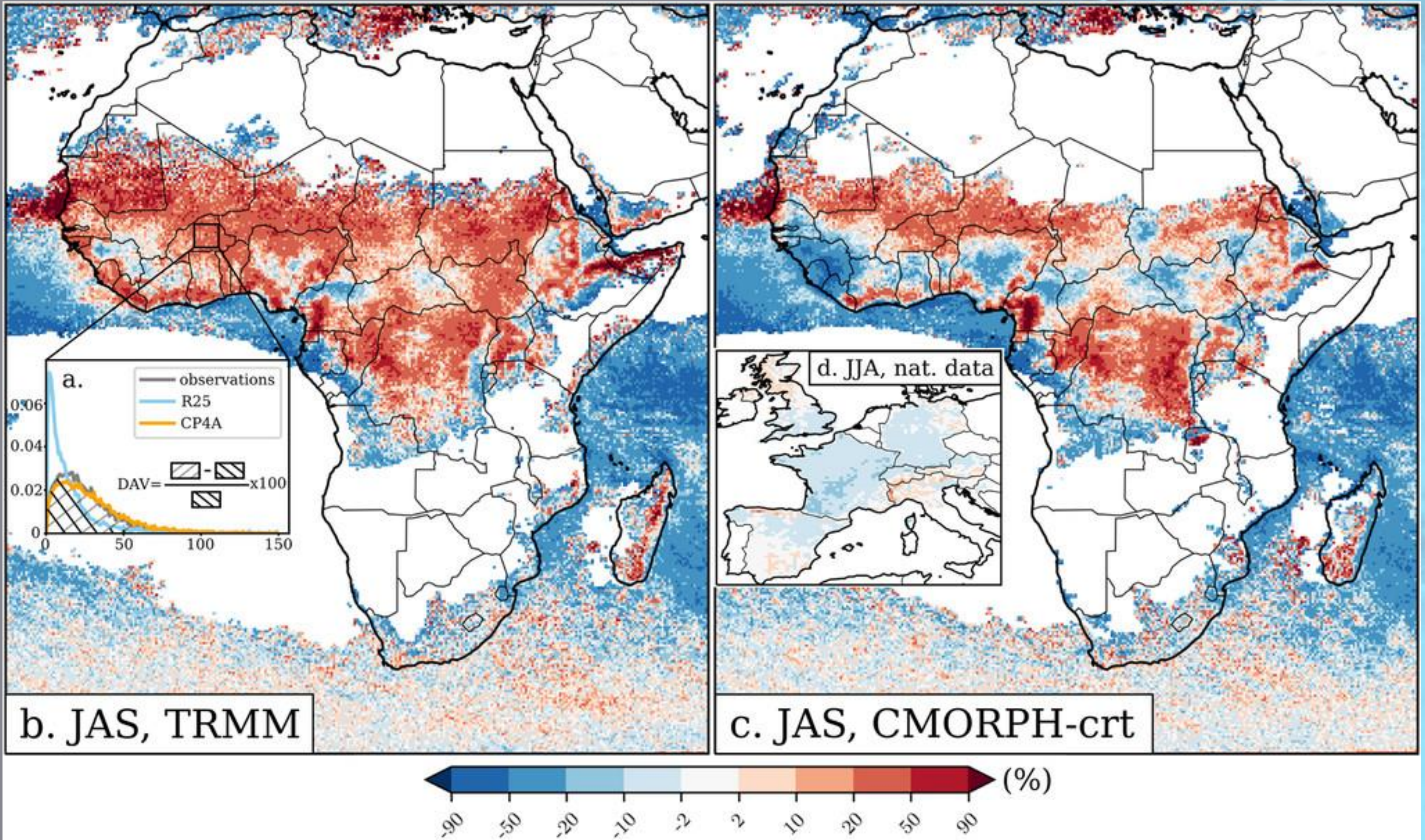




2014

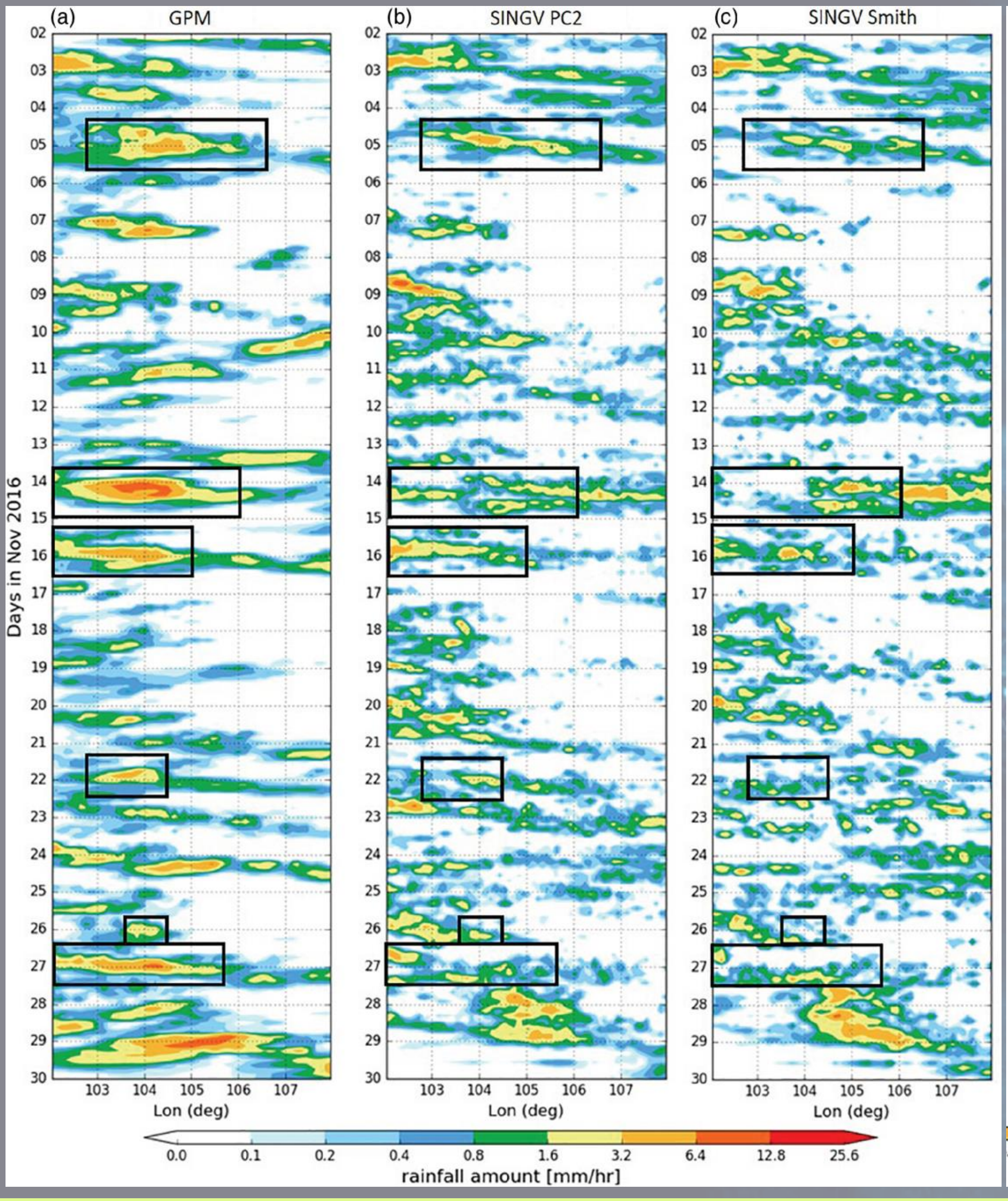
2014: Climate change revealed by weather forecast resolution model

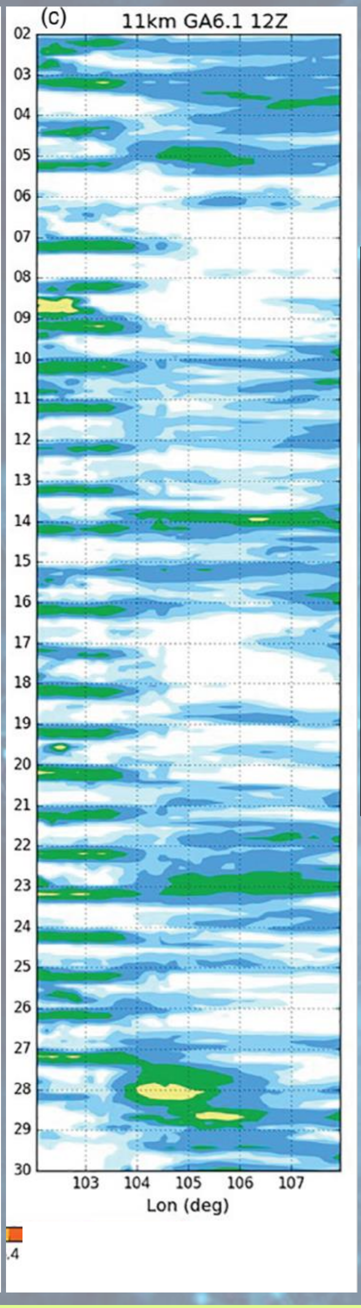
2018

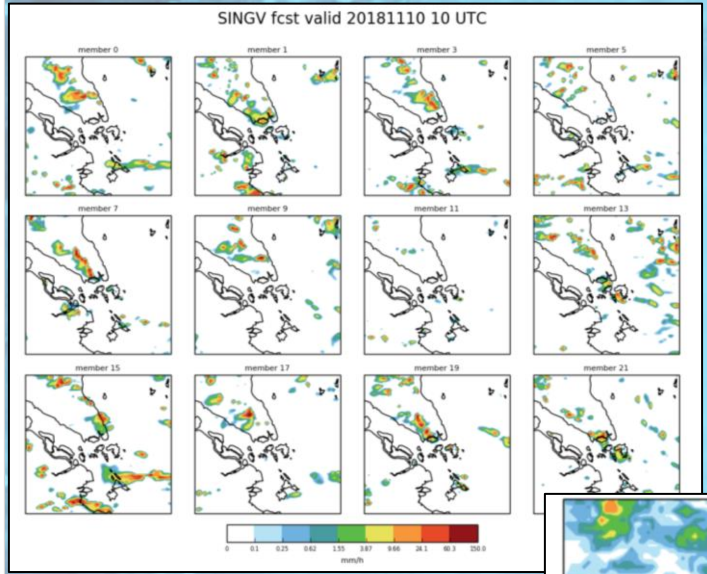


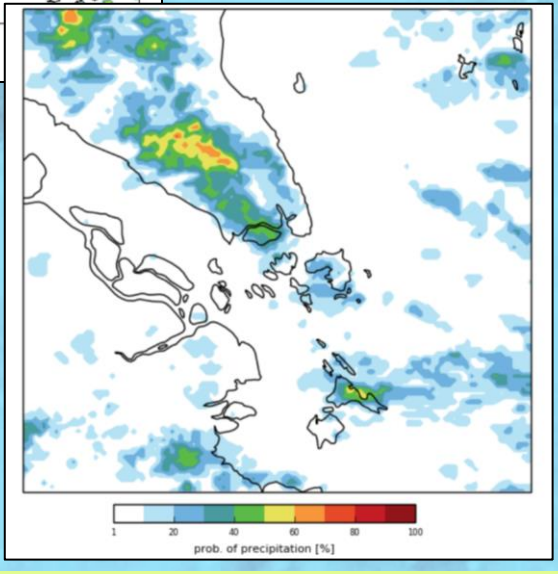
2014: Pan-African Convection-Permitting Regional Climate Simulations

2019



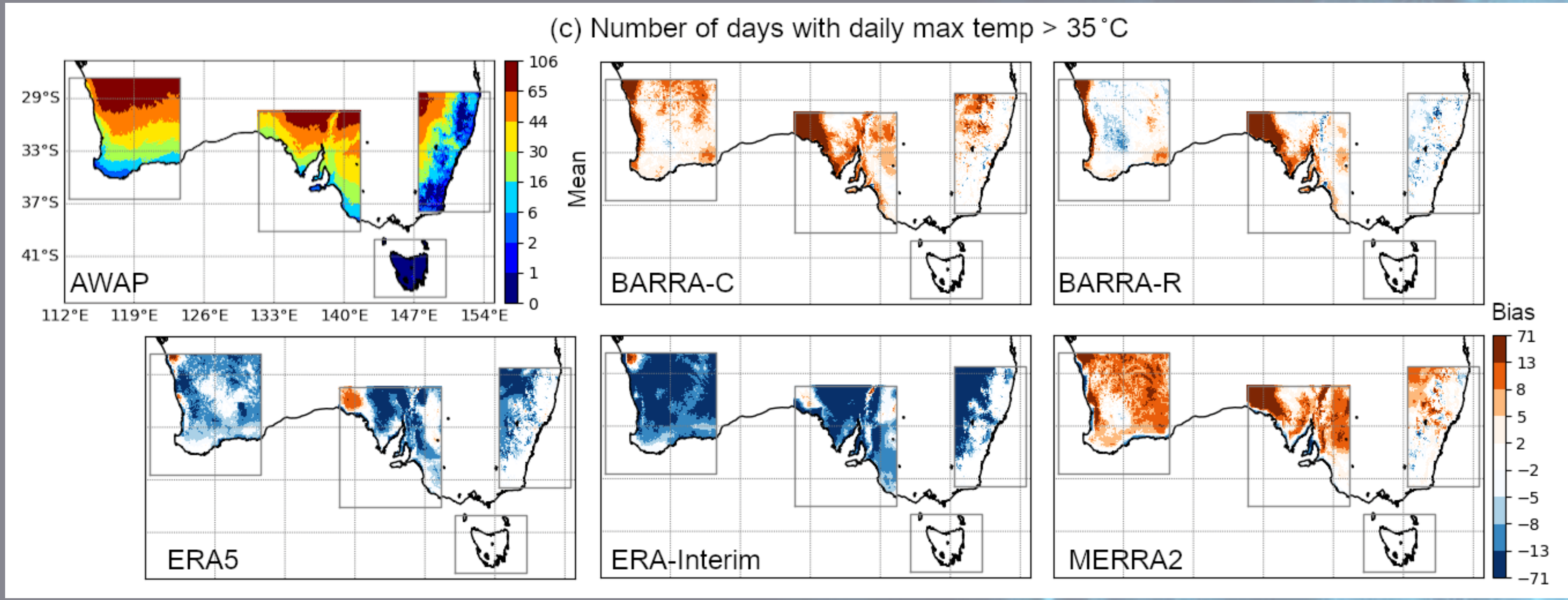


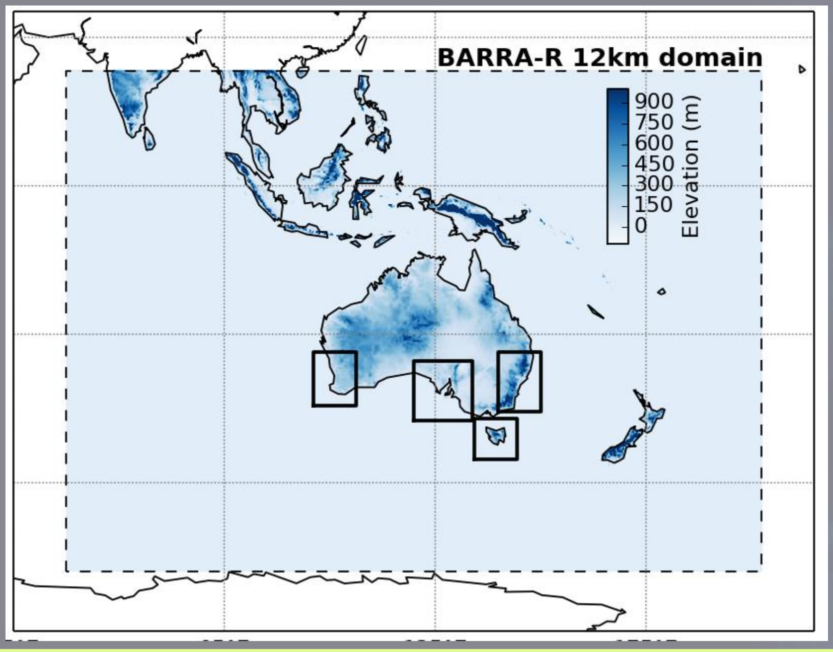


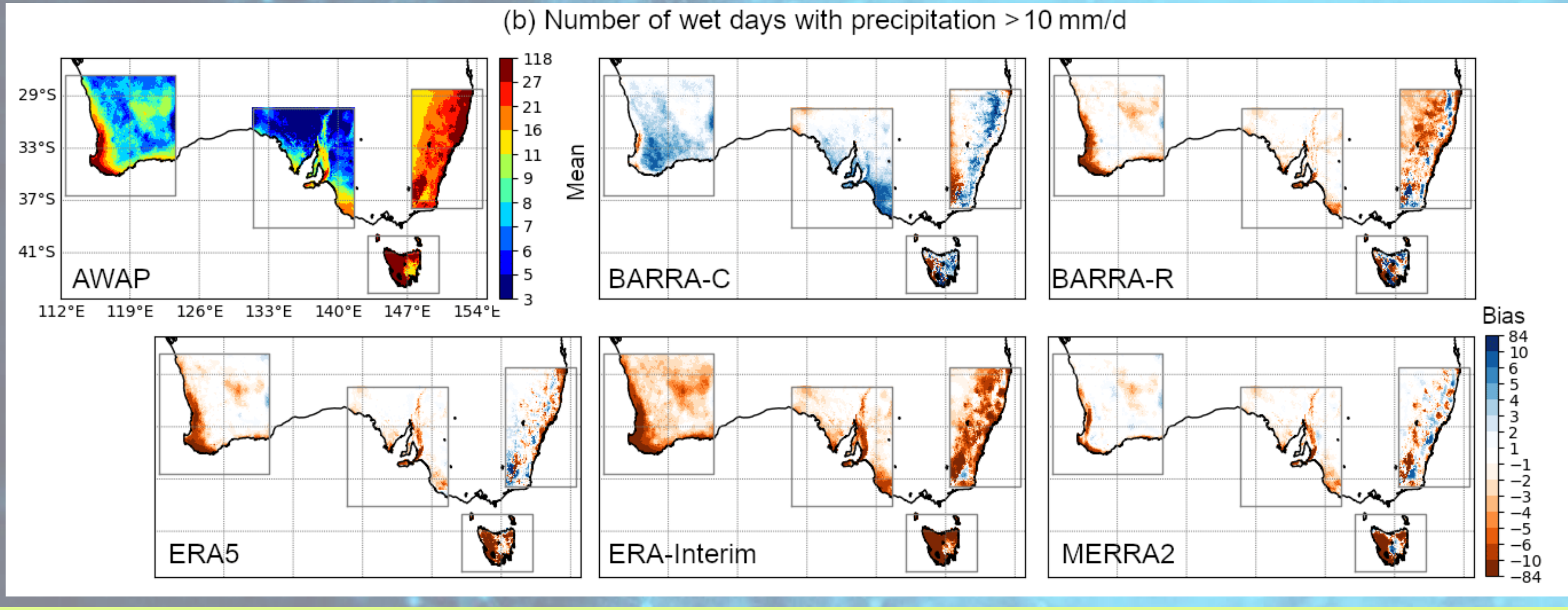


2019: SINGV-DA configuration operational providing convective-scale NWP for Singapore

2019

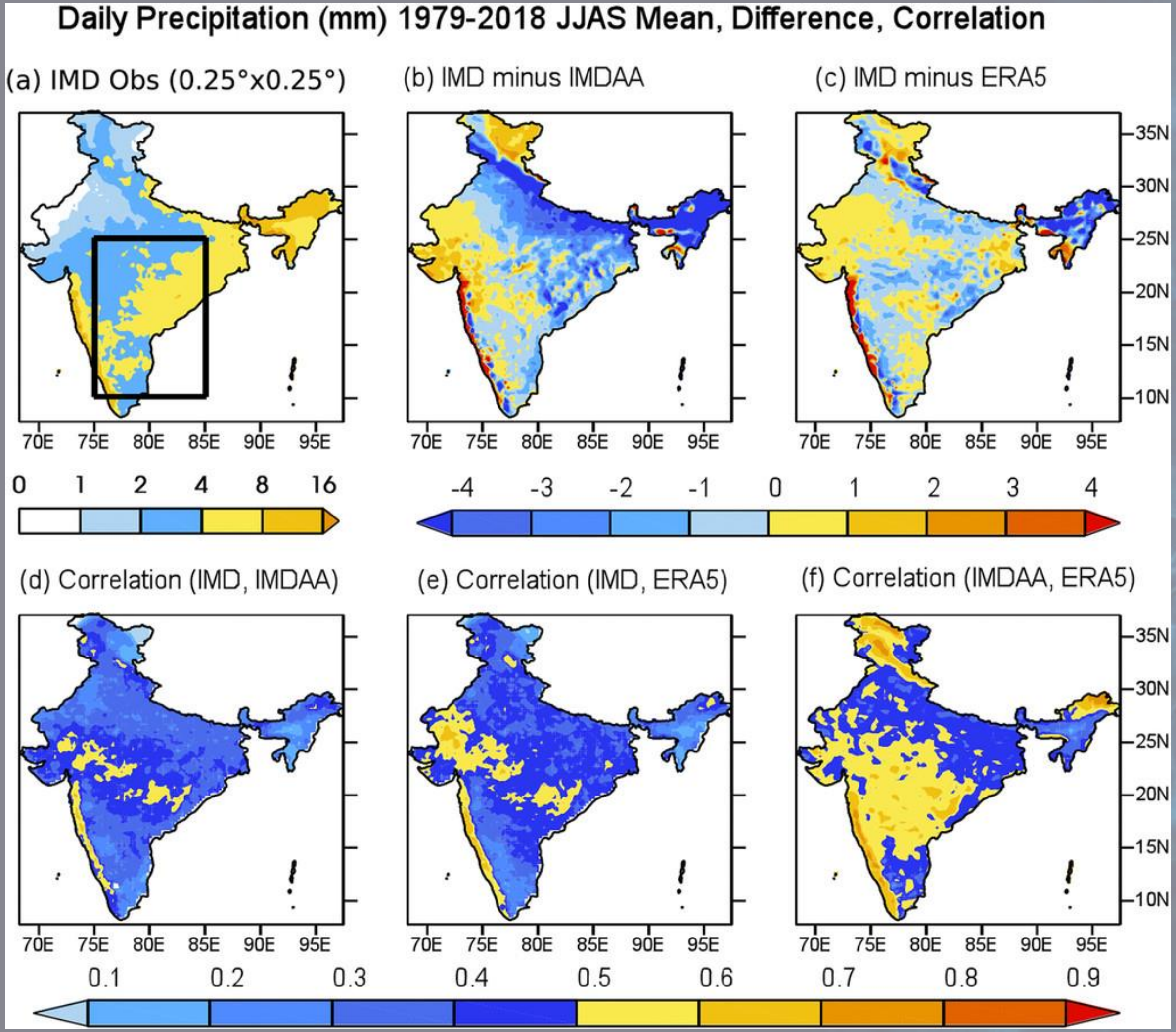


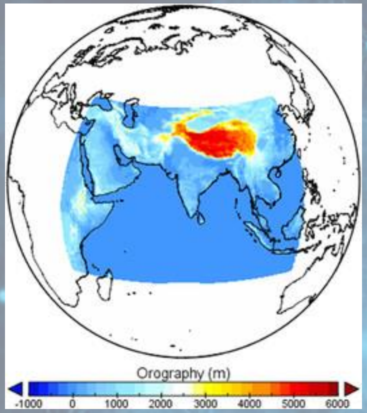


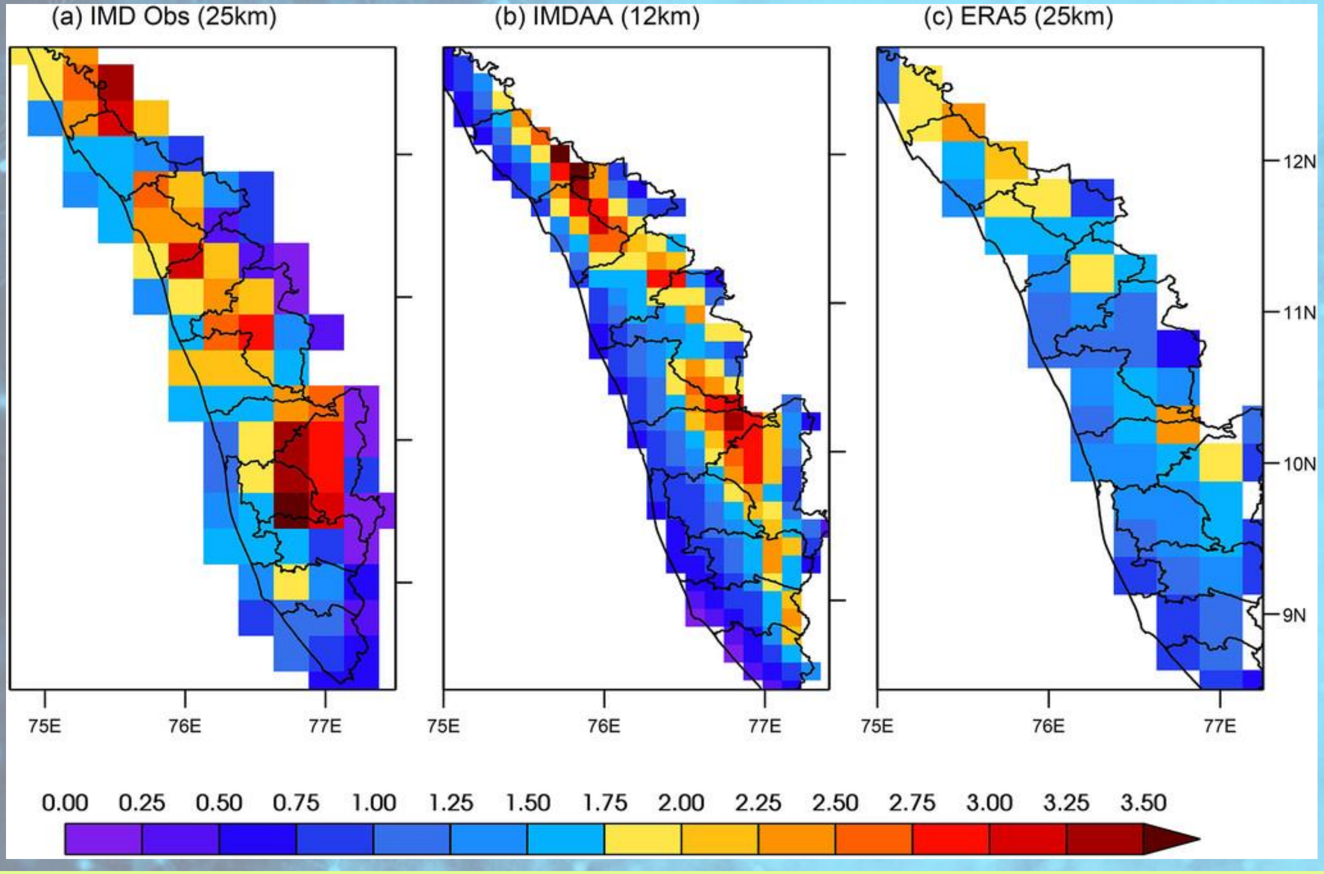


2019: First release of Bureau Atmospheric Regional Reanalysis for Australia (BARRA)
BARRA-R (12 km) and BARRA-C (1.5 km)

2020

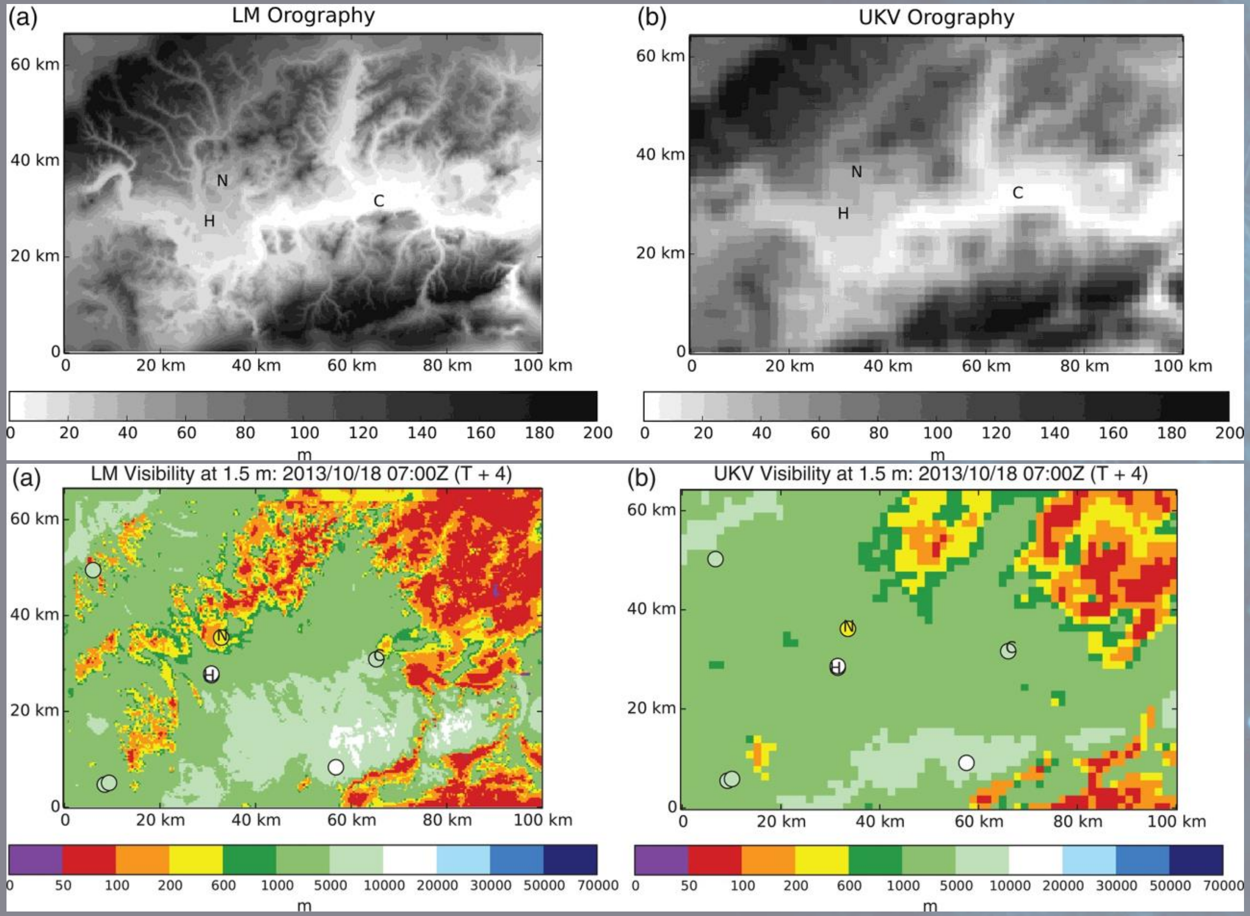




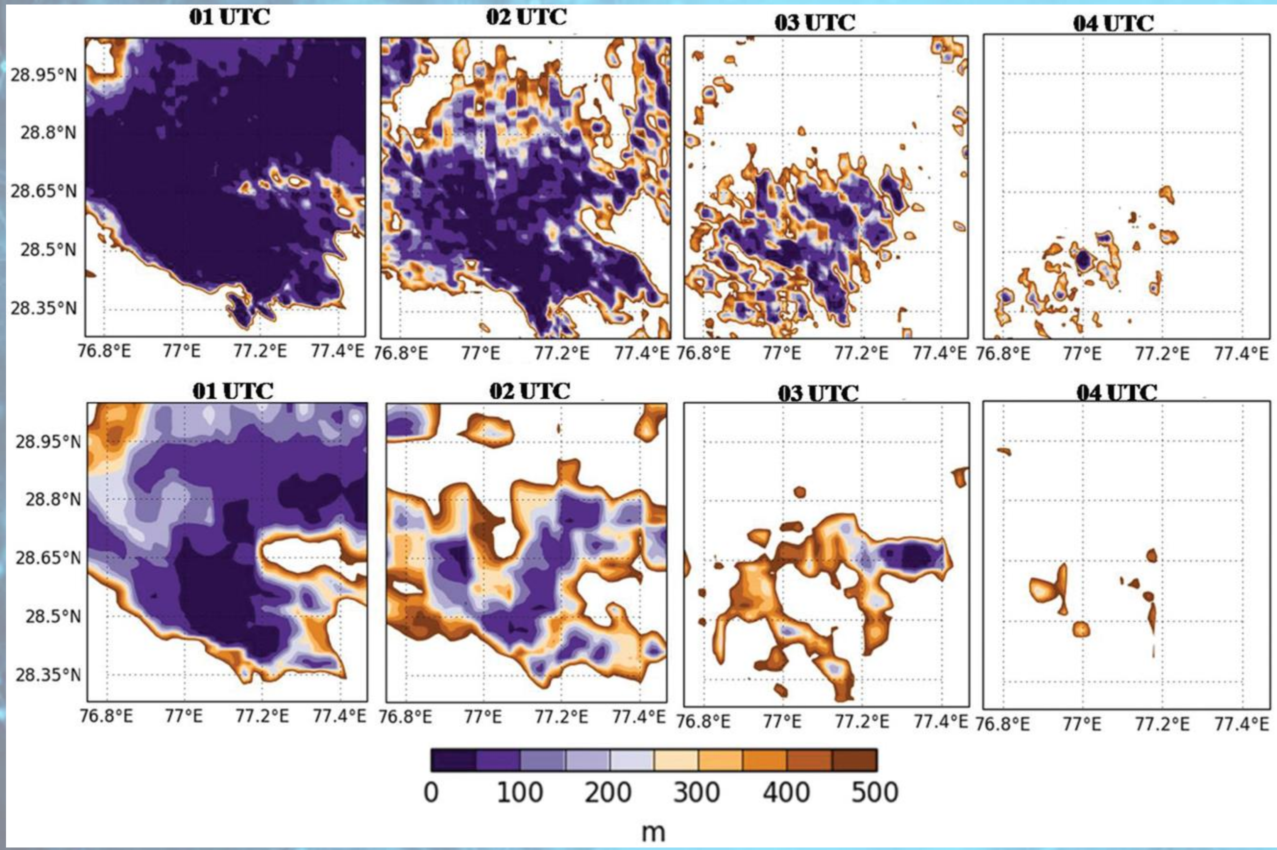


2020: First release of 12km Indian Monsoon Data Assimilation and Analysis (IMDAA)

2010s

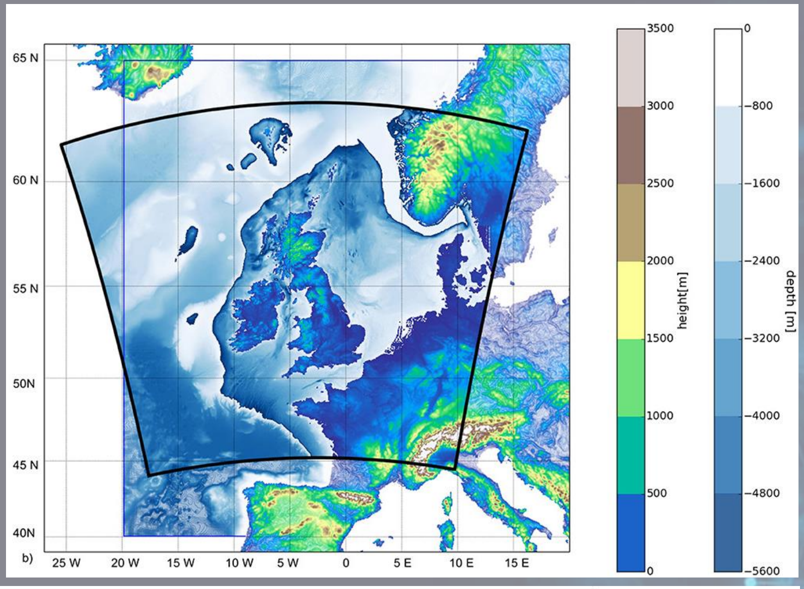


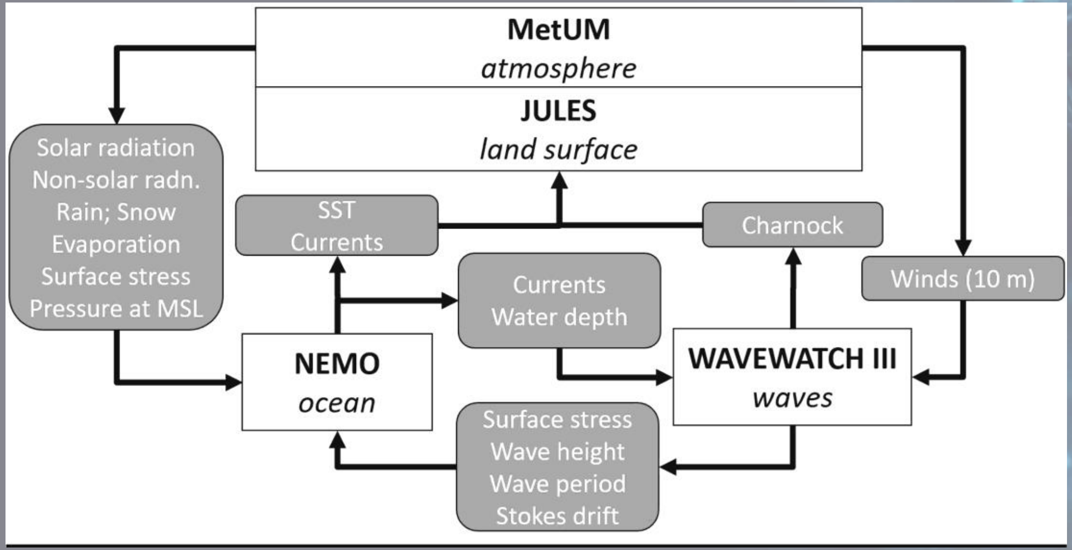
2015: London Model research for local fog prediction

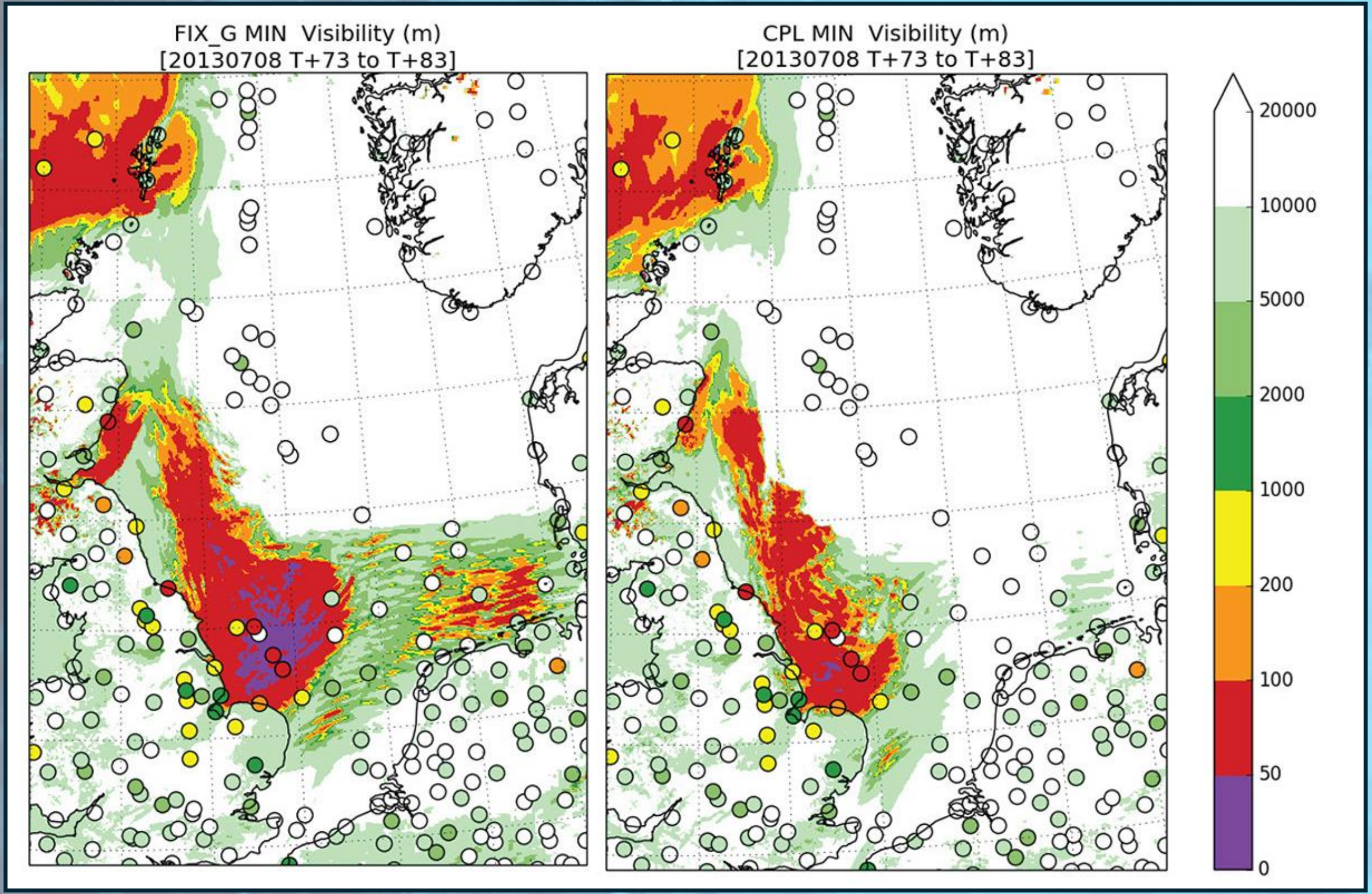


2017: Delhi Model research for local fog and air quality

2010s







2017: Developing Regional Coupled Environmental Prediction research models

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Momentum
The Unified Earth Environment Prediction Framework

2017


Geosci. Model Dev., 13, 1999–2029, 2020
https://doi.org/10.5194/gmd-13-1999-2020

Geoscientific Model Development
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The first Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL1

Mike Bush[1], **Tom Allen**[1], **Caroline Bain**[1], **Ian Boutle**[1], **John Edwards**[1], **Anke Finnenkoetter**[1], **Charmaine Franklin**[2], **Kirsty Hanley**[1], **Humphrey Lean**[1], **Adrian Lock**[1], **James Manners**[1], **Marion Mittermaier**[1], **Cyril Morcrette**[1], **Rachel North**[1], **Jon Petch**[1], **Chris Short**[1], **Simon Vosper**[1], **David Walters**[1], **Stuart Webster**[1], **Mark Weeks**[1], **Jonathan Wilkinson**[1], **Nigel Wood**[1], and **Mohamed Zerroukat**[1]

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[2]Bureau of Meteorology (BoM), Melbourne, Victoria, Australia

Correspondence: Mike Bush (mike.bush@metoffice.gov.uk)

Received: 9 May 2019 – Discussion started: 14 June 2019
Revised: 25 October 2019 – Accepted: 29 October 2019 – Published: 21 April 2020

Abstract. In this paper we define the first Regional Atmosphere and Land (RAL) science configuration for kilometre-scale modelling using the Unified Model (UM) as the basis for the atmosphere and the Joint UK Land Environment Simulator (JULES) for the land. RAL1 defines the science configuration of the dynamics and physics schemes of the atmosphere and land. This configuration will provide a model baseline for any future weather or climate model developments to be described against, and it is the intention that from this point forward significant changes to the system will be documented in the literature. This reproduces the process used for global configurations of the UM, which was first documented as a science configuration in 2011. While it is our goal to have a single defined configuration of the model that performs effectively in all regions, this has not yet been possible. Currently we define two sub-releases, one for mid-latitudes (RAL1-M) and one for tropical regions (RAL1-T). The differences between RAL1-M and RAL1-T are documented, and where appropriate we define how ... figuration relates to the corresponding confi... global forecasting model.

1 Introduction

It is becoming standard practice for national meteorological services (NMSs) and those involved in the prediction of high-impact weather to use regional atmospheric and land models with grid lengths of the order of a kilometre as their prediction systems (e.g. Baldauf et al., 2011; Brousseau et al., 2016; Bengtsson et al., 2017; Klasa et al., 2018). While not truly resolving deep convection, kilometre-scale atmospheric models are able to explicitly represent deep convective processes within the resolved dynamics. These models provide valuable information on local weather and high-impact weather that is critical to the core function of NMSs. The representation of convective systems, topographically driven weather ...

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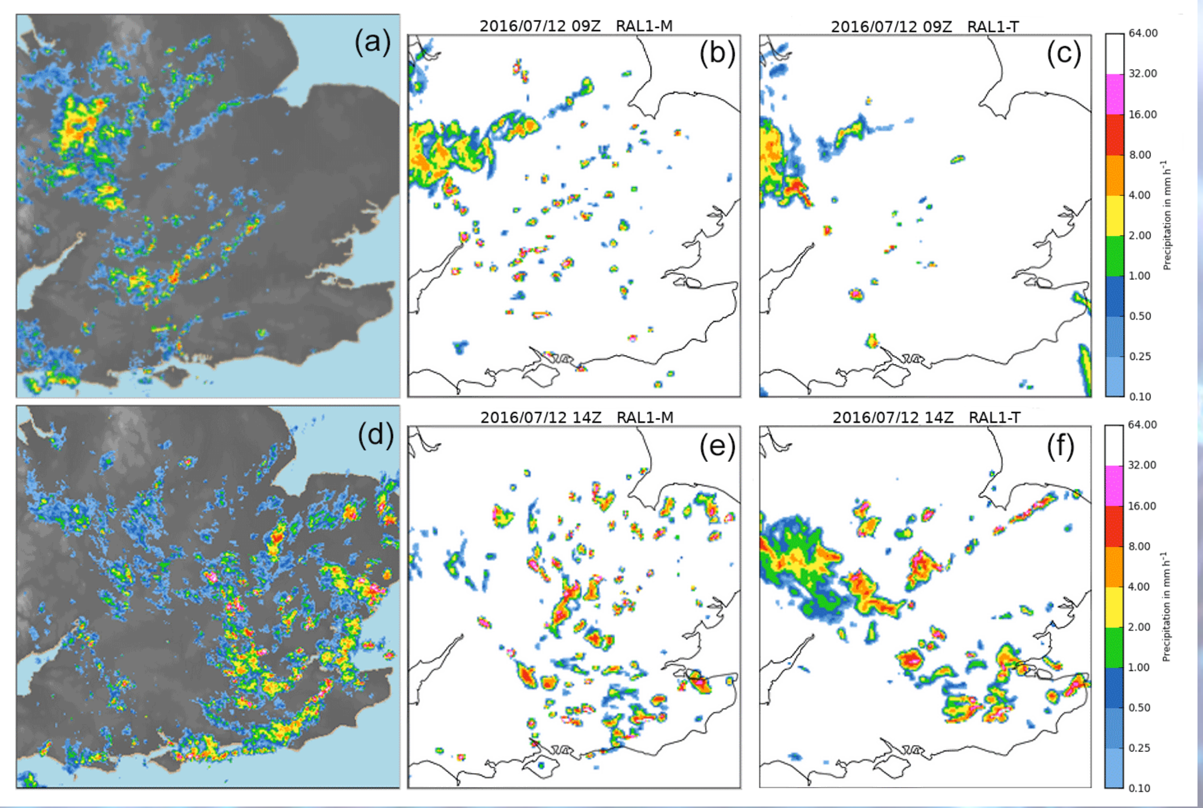

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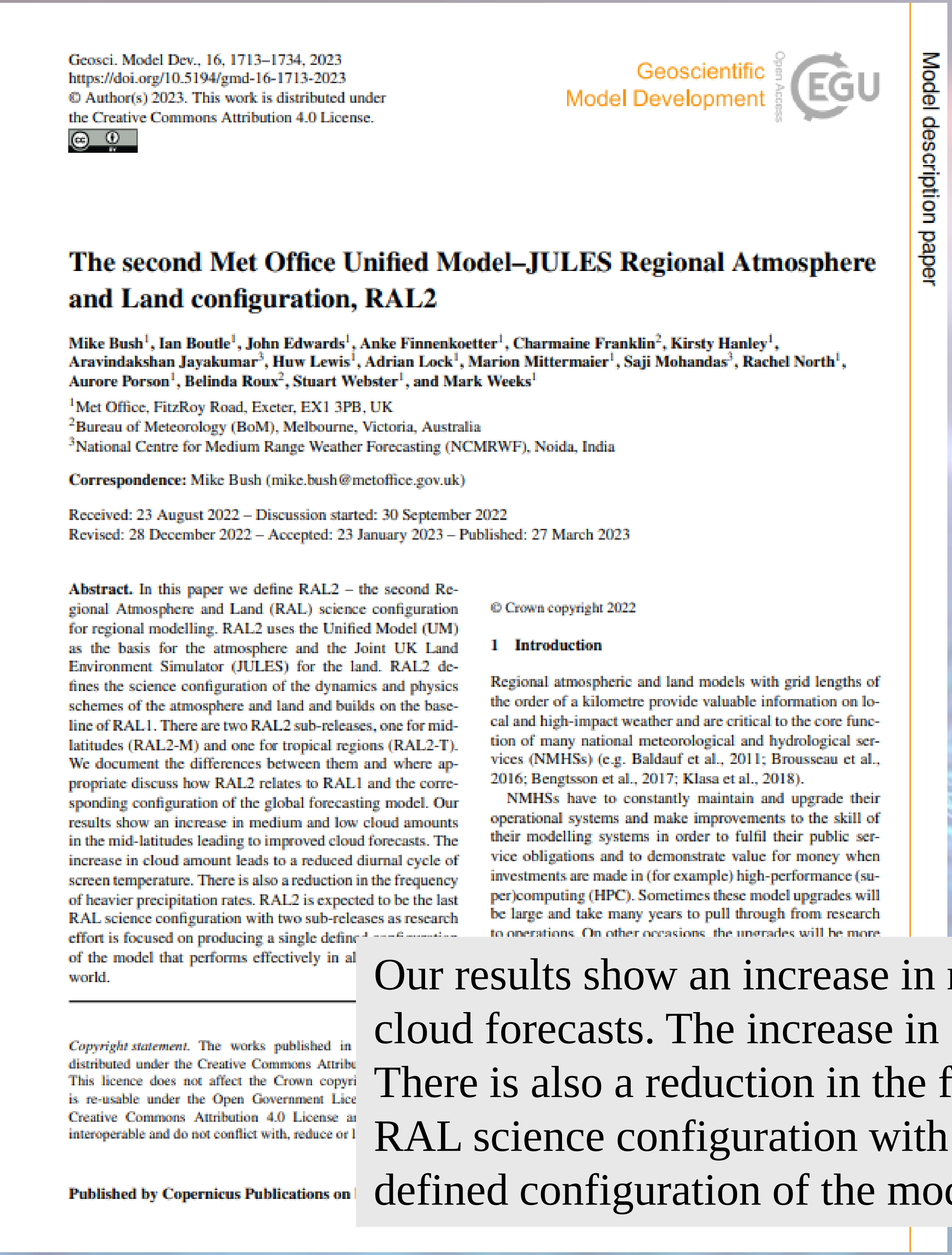
Geosci. Model Dev., 16, 1713–1734, 2023
https://doi.org/10.5194/gmd-16-1713-2023

Geoscientific Model Development
Open Access
EGU

Model description paper

The second Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL2

Mike Bush[1], Ian Boutle[1], John Edwards[1], Anke Finnenkoetter[1], Charmaine Franklin[2], Kirsty Hanley[1], Aravindakshan Jayakumar[3], Huw Lewis[1], Adrian Lock[1], Marion Mittermaier[1], Saji Mohandas[3], Rachel North[1], Aurore Porson[1], Belinda Roux[2], Stuart Webster[1], and Mark Weeks[1]

[1]Met Office, FitzRoy Road, Exeter, EX1 3PB, UK
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Revised: 28 December 2022 – Accepted: 23 January 2023 – Published: 27 March 2023

Abstract. In this paper we define RAL2 – the second Regional Atmosphere and Land (RAL) science configuration for regional modelling. RAL2 uses the Unified Model (UM) as the basis for the atmosphere and the Joint UK Land Environment Simulator (JULES) for the land. RAL2 defines the science configuration of the dynamics and physics schemes of the atmosphere and land and builds on the baseline of RAL1. There are two RAL2 sub-releases, one for mid-latitudes (RAL2-M) and one for tropical regions (RAL2-T). We document the differences between them and where appropriate discuss how RAL2 relates to RAL1 and the corresponding configuration of the global forecasting model. Our results show an increase in medium and low cloud amounts in the mid-latitudes leading to improved cloud forecasts. The increase in cloud amount leads to a reduced diurnal cycle of screen temperature. There is also a reduction in the frequency of heavier precipitation rates. RAL2 is expected to be the last RAL science configuration with two sub-releases as research effort is focused on producing a single defin... of the model that performs effectively in al... world.

1 Introduction

Regional atmospheric and land models with grid lengths of the order of a kilometre provide valuable information on local and high-impact weather and are critical to the core function of many national meteorological and hydrological services (NMHSs) (e.g. Baldauf et al., 2011; Brousseau et al., 2016; Bengtsson et al., 2017; Klasa et al., 2018).

NMHSs have to constantly maintain and upgrade their operational systems and make improvements to the skill of their modelling systems in order to fulfil their public service obligations and to demonstrate value for money when investments are made in (for example) high-performance (super)computing (HPC). Sometimes these model upgrades will be large and take many years to pull through from research to operations. On other occasions, the upgrades will be more

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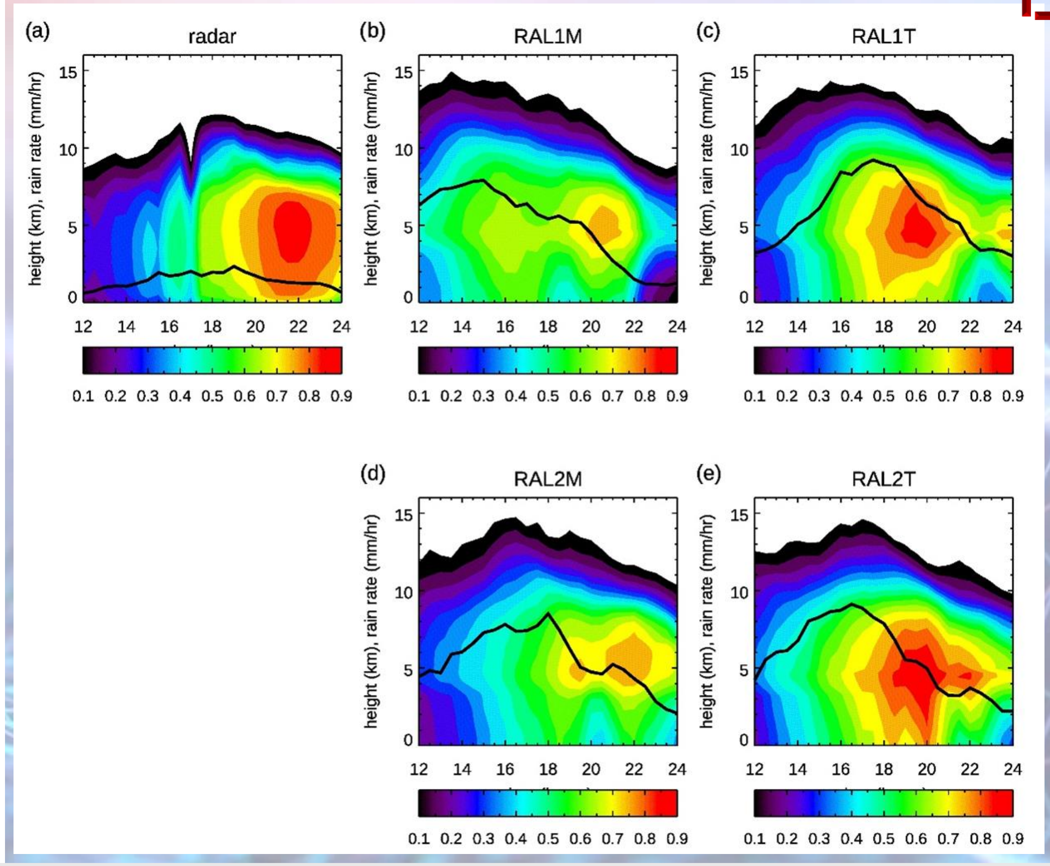

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2024

Unifying Mid-latitude and Tropical Regional Model Configurations: The third Met Office Unified Model/JULES Regional Atmosphere and Land Configuration, RAL3

Mike Bush[1], David L.A. Flack[1], Huw W. Lewis[1], Sylvia I. Bohnenstengel[2], Charmaine Franklin[3], Adrian Lock[1], Martin Best[1], Paul Field[1], Anne McCabe[1], Kwinten Van Weverberg[1], Alex Arnold[1], Segolene Berthou[1], Ian Boutle[1], Jenn Brooke[1], Seb Cole[1], Shaun Cooper[3], Gareth Dow[1], John Edwards[1], Anke Finnenkoetter[1], Kalli Furtado[4], Kate Halladay[1], Kirsty Hanley[2], Maggie Hendry[1], Adrian Hill[1], A. Jayakumar[5], Richard W. Jones[1], Joshua Lee[4], Andy Malcolm[1], Marion Mittermaier[1], Saji Mohandas[5], Stuart Moore[6], Cyril Morcrette[1], Rachel North[1], Aurore Porson[2], Susan Rennie[3], Nigel Roberts[2], Belinda Roux[3], Claudio Sanchez[1], Chris J. Short[1], Chun-Hsu Su[3], Simon Tucker[1], Simon Vosper[1], David Walters[1], James Warner[1], Stuart Webster[1], Mark Weeks[1], Jonathan Wilkinson[1], Michael Whitall[1], Keith Williams[1], and Hugh Zhang[4]

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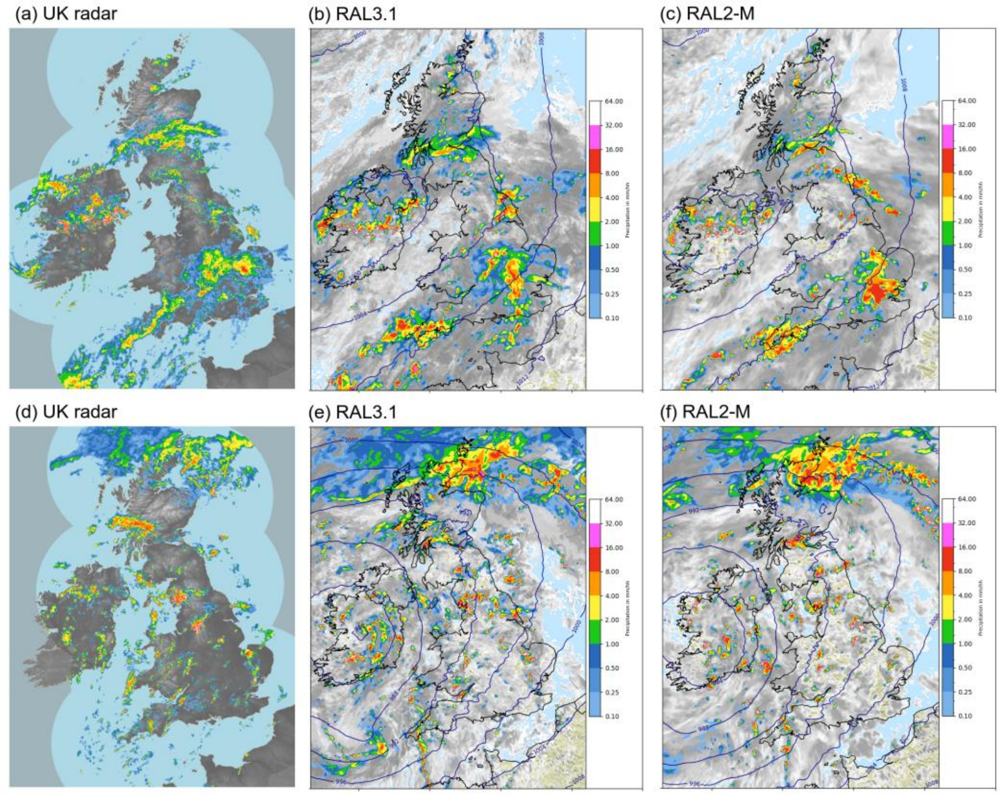
[3]Bureau of Meteorology, Melbourne, Victoria, Australia
[4]Meteorological Service Singapore (MSS), PO Box 8, Changi Airport, Singapore 918141
[5]National Centre for Medium Range Weather Forecasting (NCMRWF), Noida, India
[6]National Institute of Water & Atmospheric Research Ltd (NIWA), 301 Evans Bay Parade, Greta Point, Wellington, 6021, New Zealand

Correspondence: Mike Bush (mike.bush@metoffice.gov.uk)

Abstract.

The third version of the Regional Atmosphere and Land (RAL3) science configuration is introduced. Developed through international partnership, RAL defines settings for the Unified Model atmosphere and Joint UK Land Environment Simulator (JULES) when applied across timescales with kilometre and sub-km scale model grids. The RAL3 configuration represents a major advance. Previous RAL configurations used different parametrization schemes and parameters when applied to domains in the tropics or mid-latitudes in order to achieve satisfactory performance. Scientific changes in RAL3 have enabled delivery of a unified, single configuration suitable for simulations across mid-latitude and tropical regions. Developments within RAL3 include the introduction of a new double-moment microphysics scheme, a new bi-modal cloud scheme, updates to the boundary layer and review of land model settings to be more consistent with Global Atmosphere and Land (GAL) science configurations. Collaborative development and evaluation of a new science configuration across organisations has enabled a more



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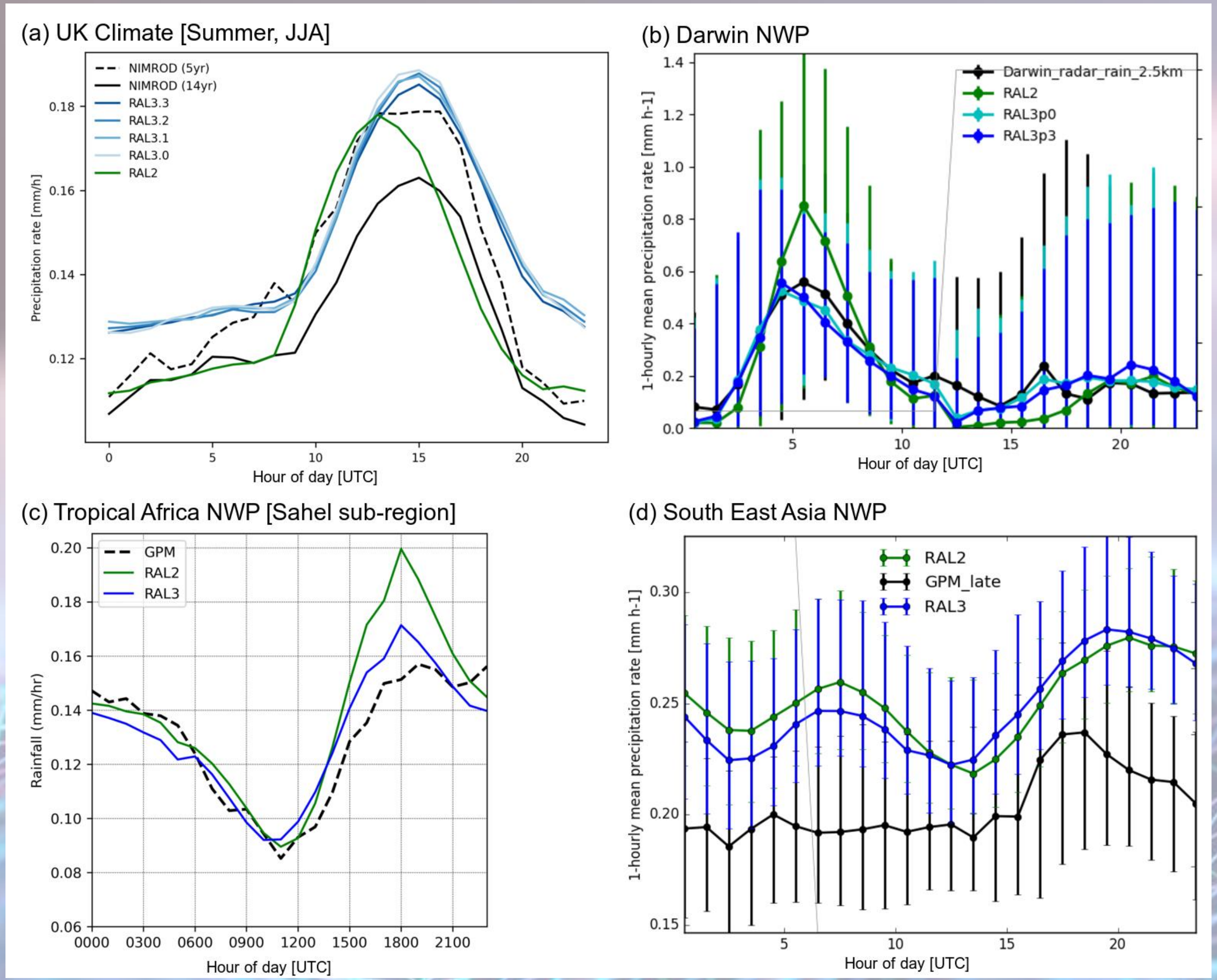
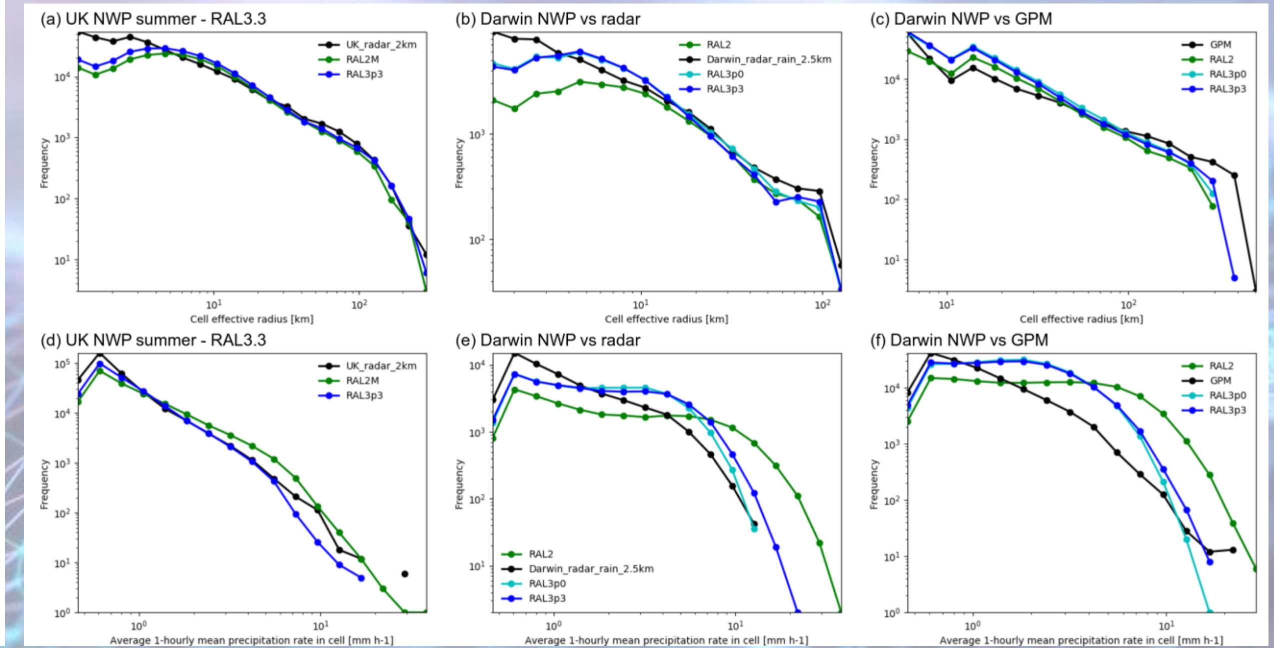
2024





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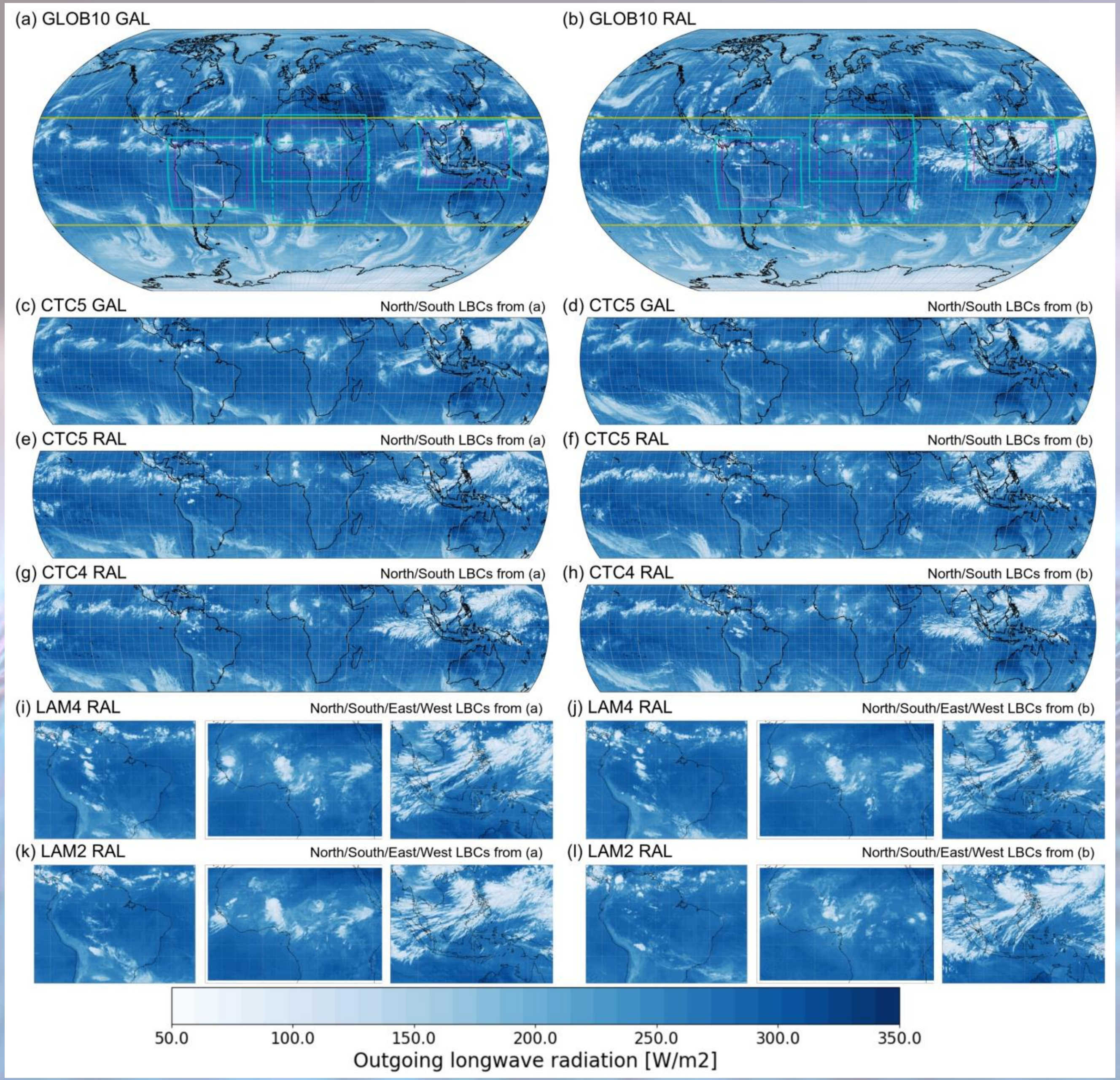
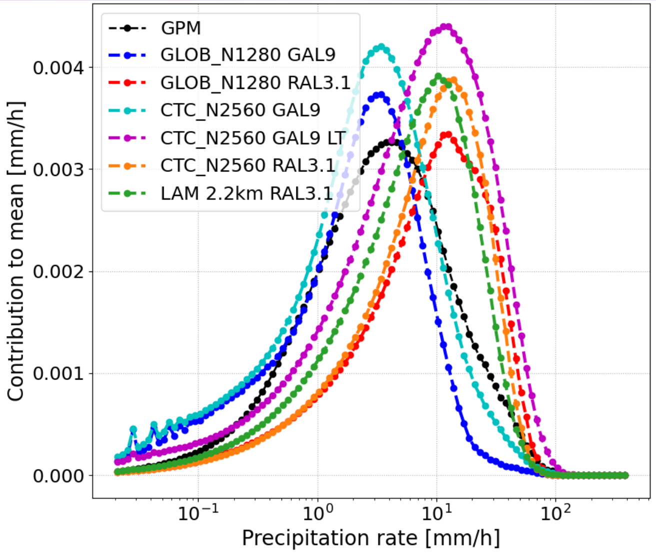
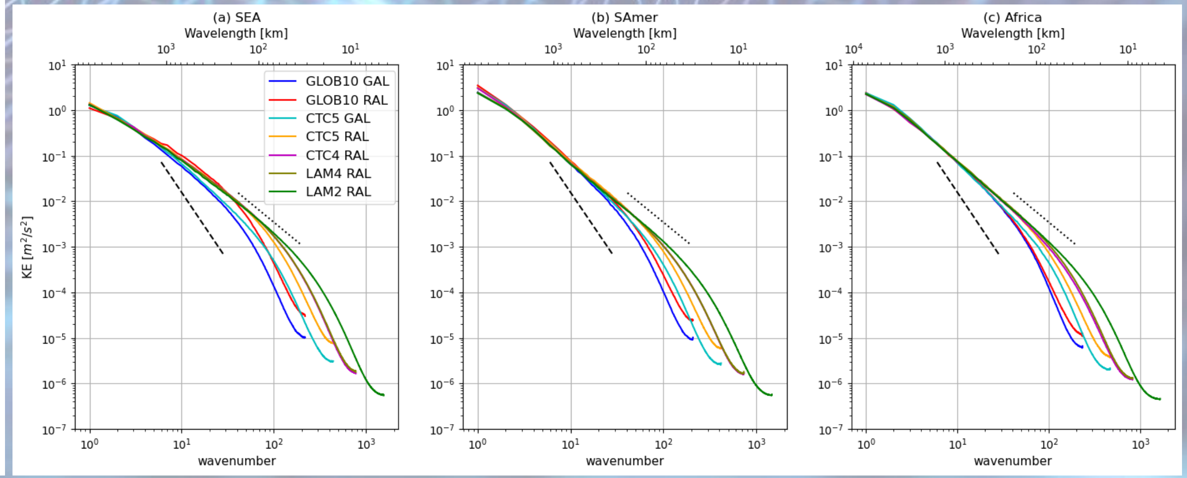
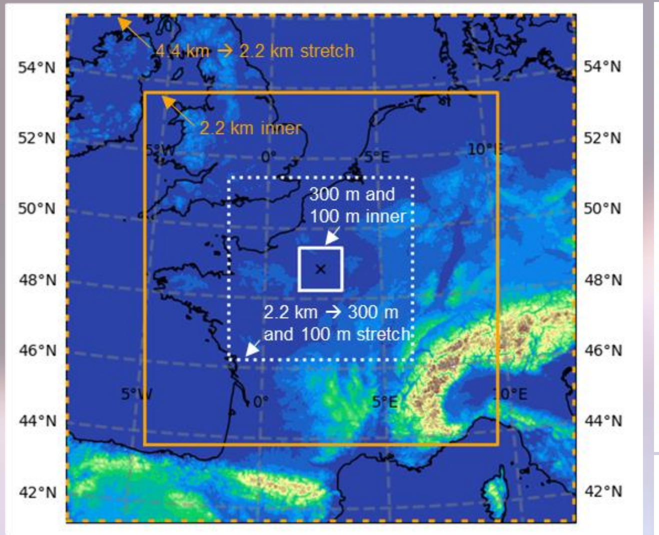


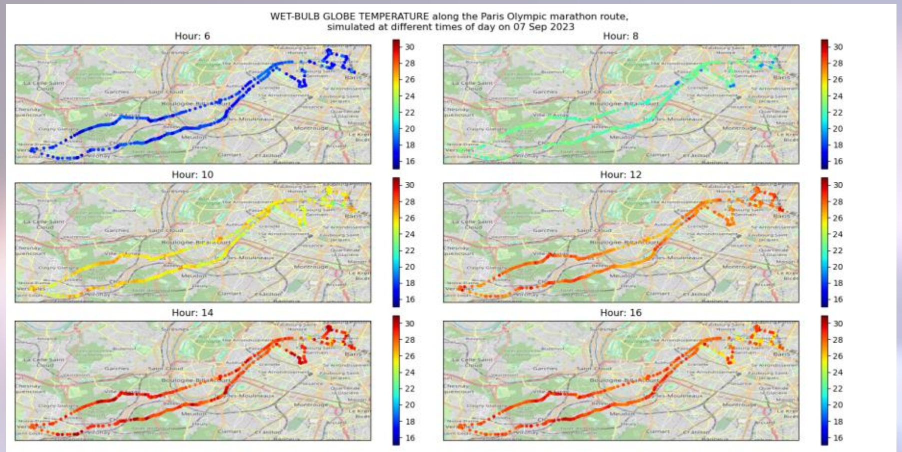


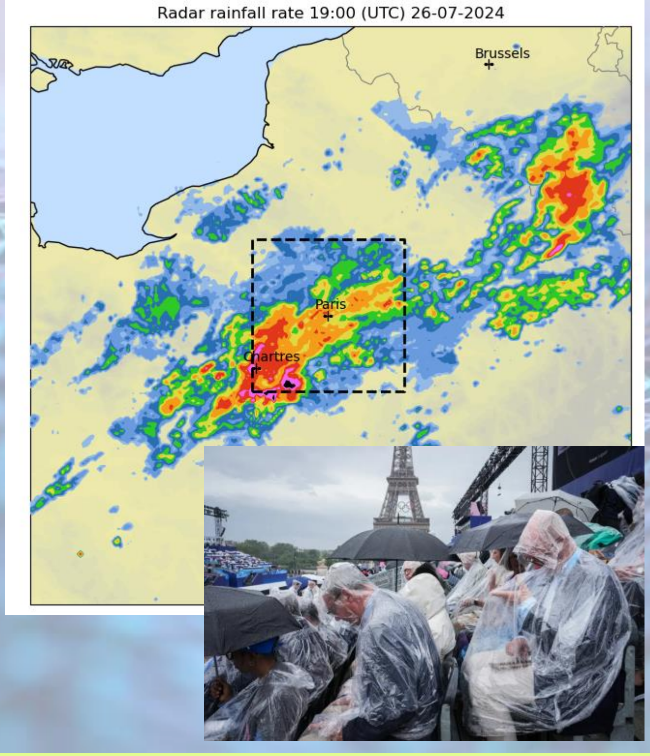


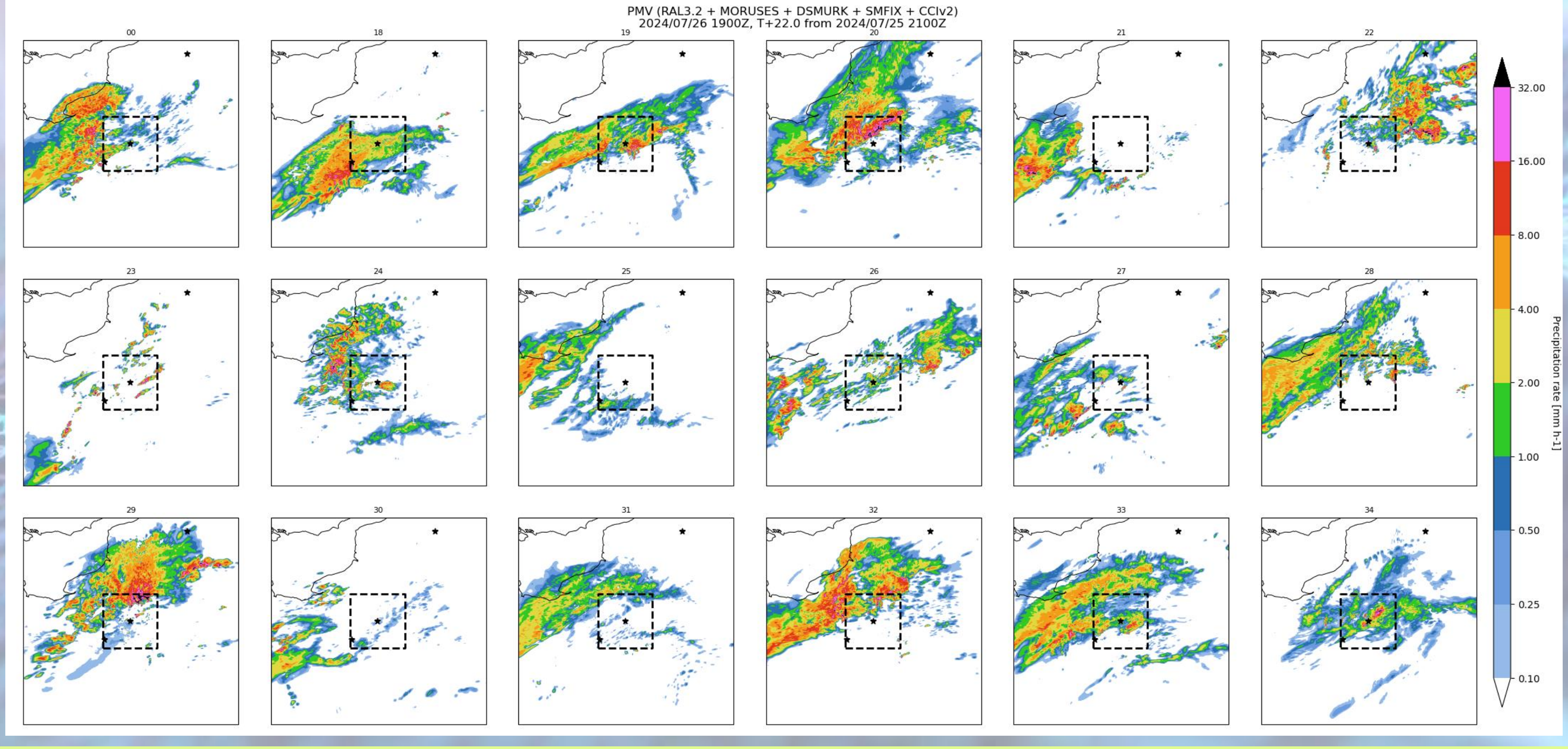
2024: Unlocking K-Scale research

2024



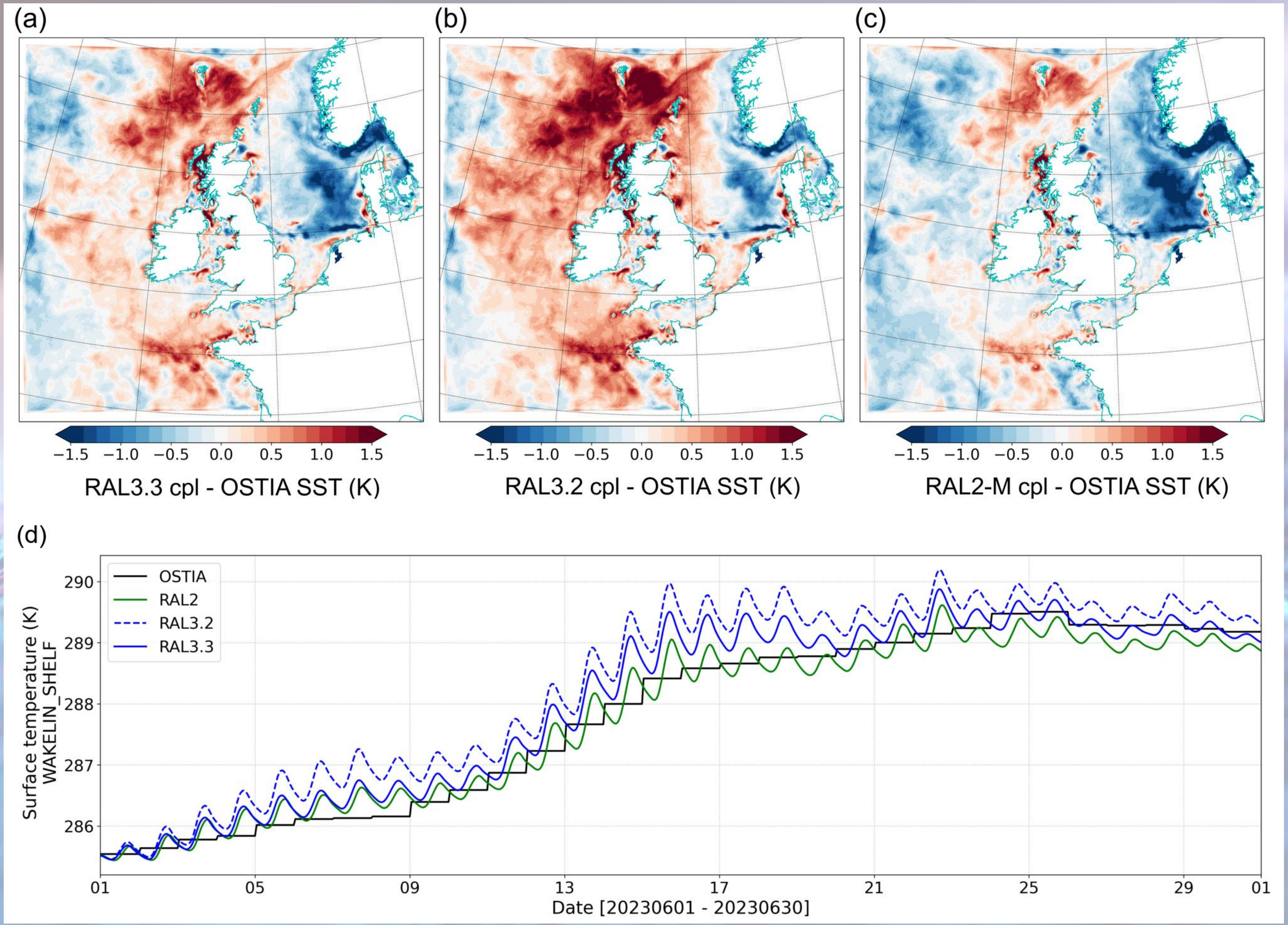


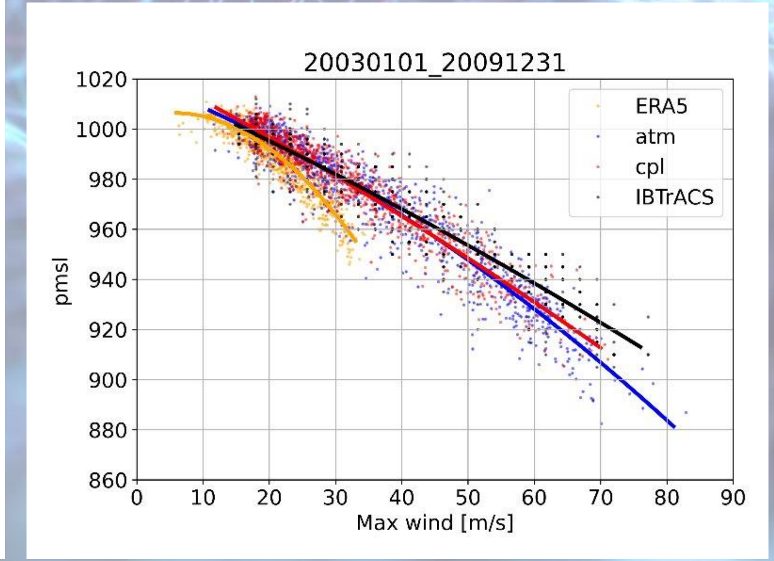




2024: Progressing urban-scale research and application

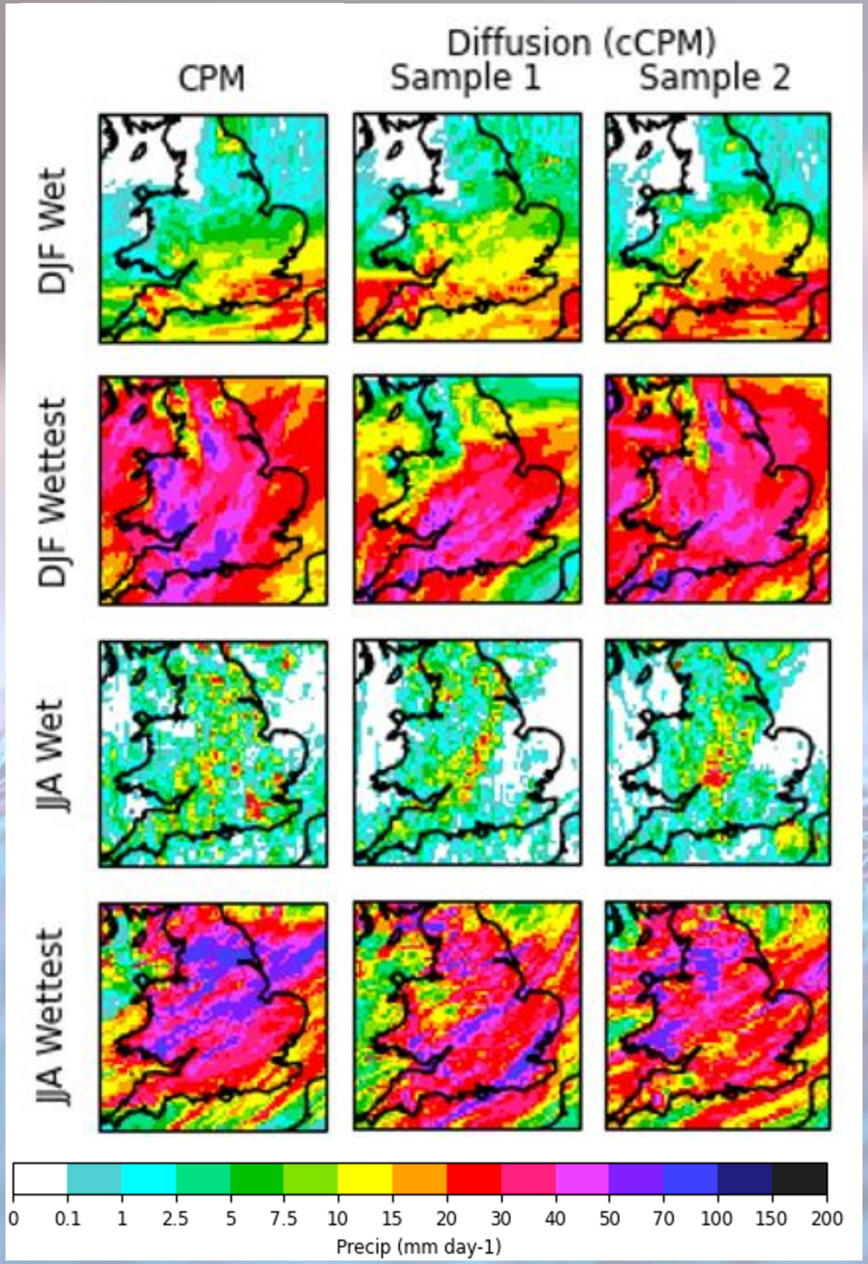
2024

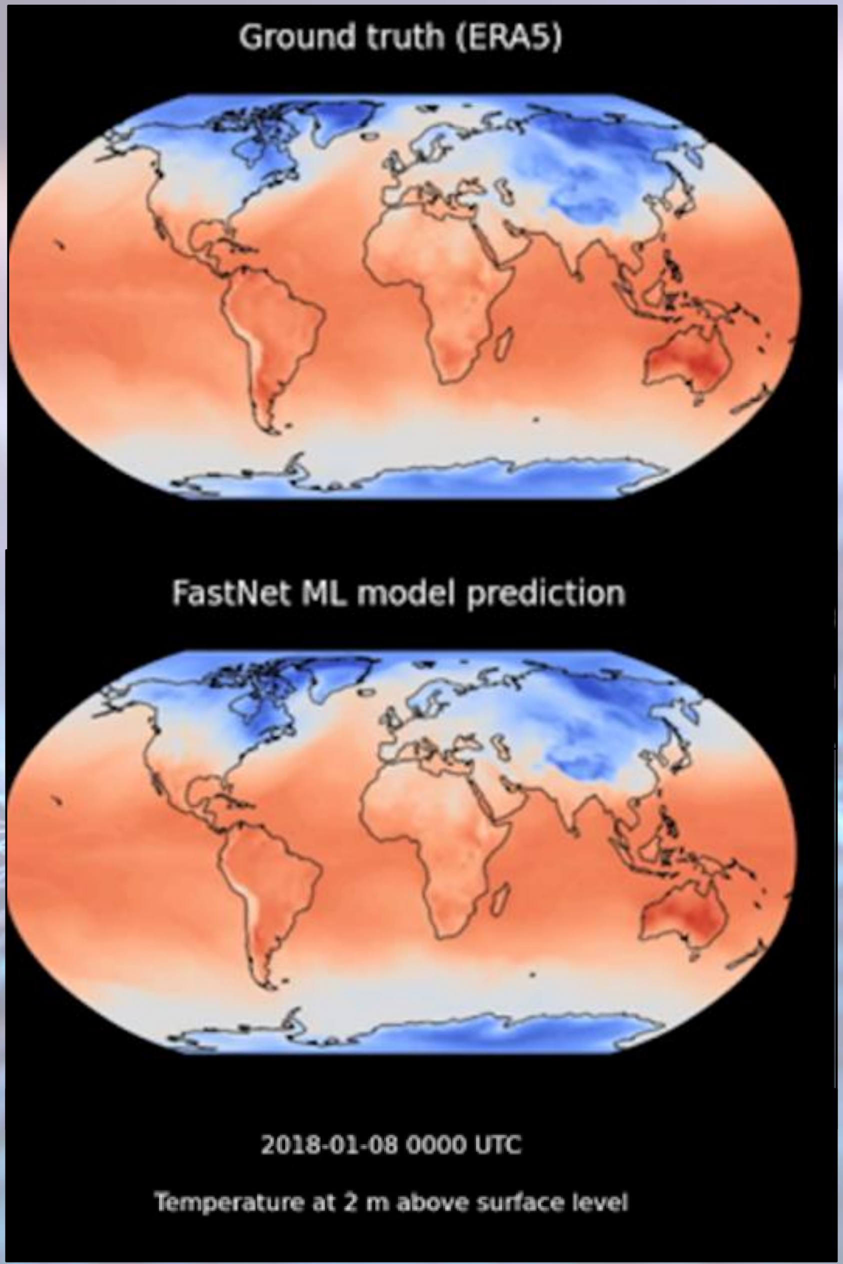


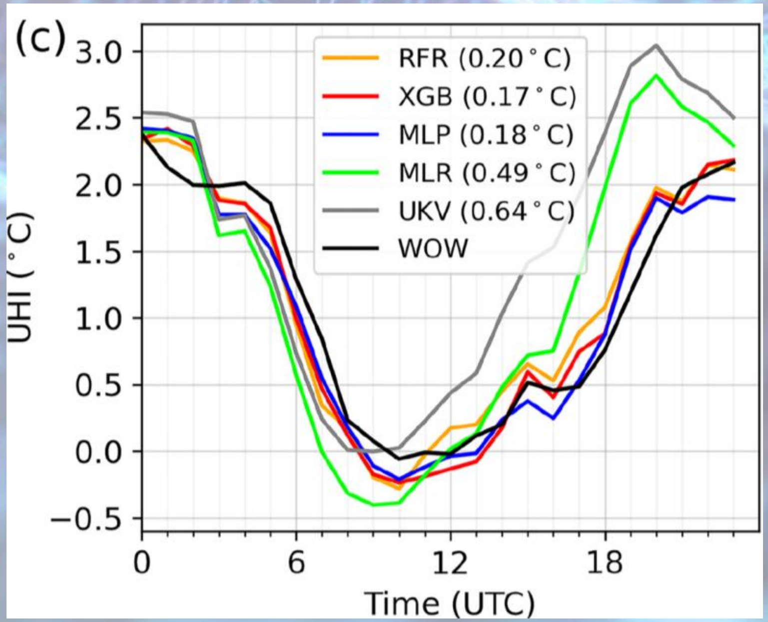


2024: Progressing Regional Environmental Prediction research and application across timescales and regions

2024



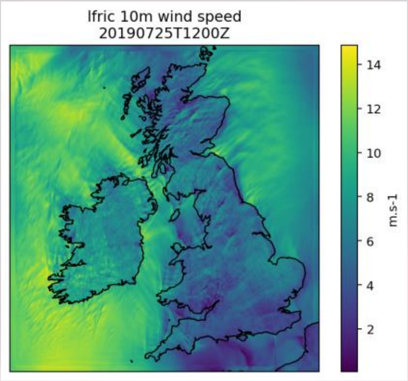


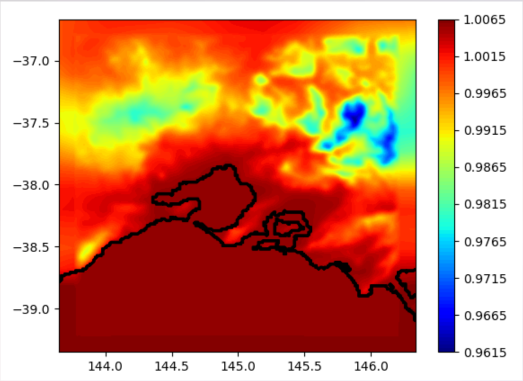


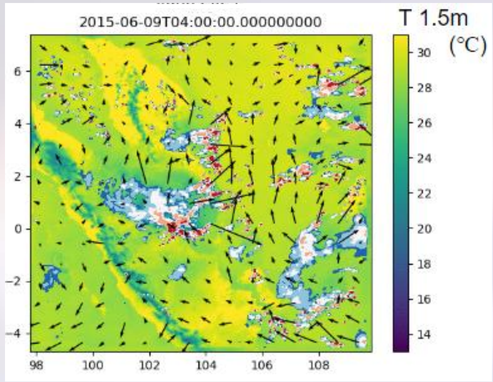
2024: Enabling and exploiting machine learning across time and space scales

2024

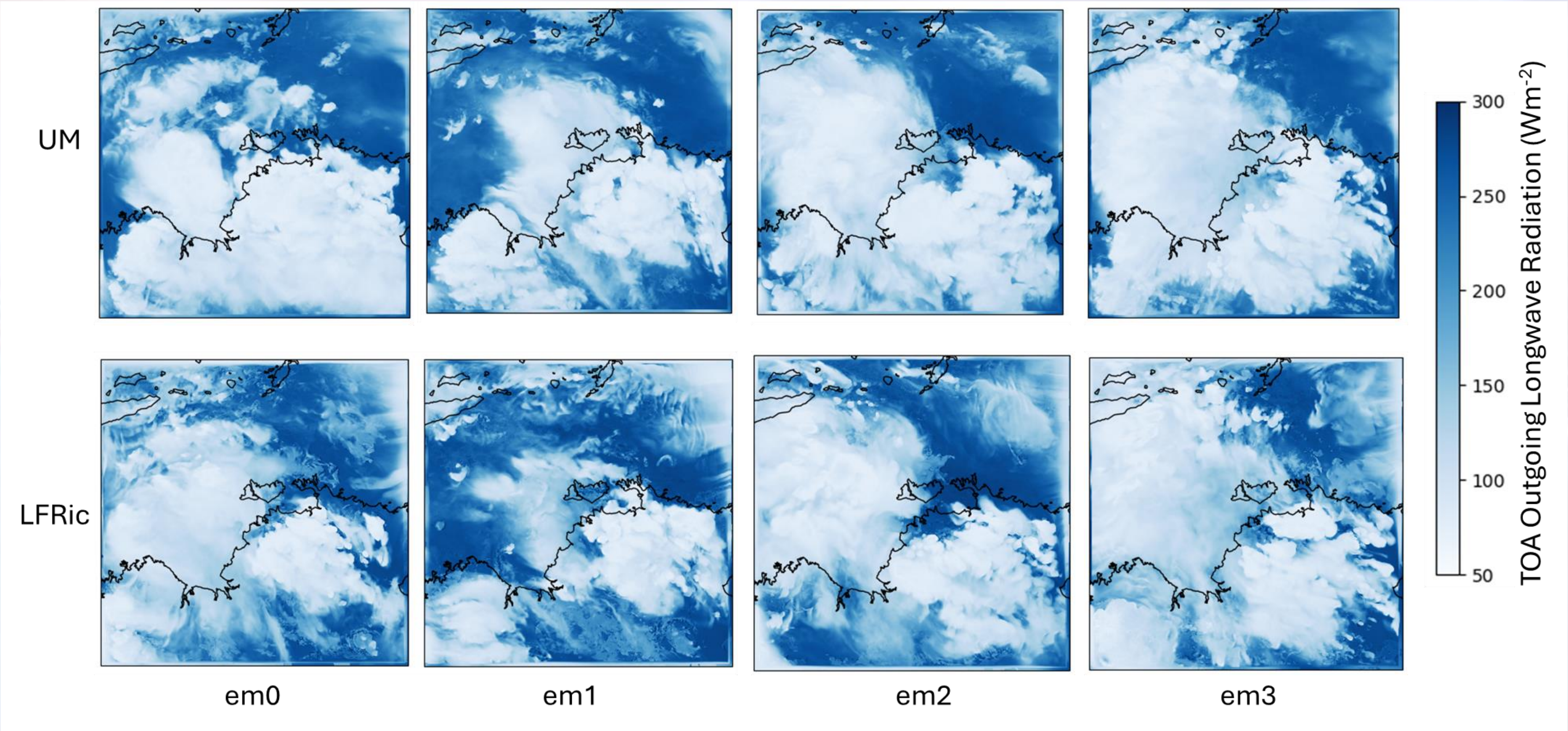
2024: Delivering RAL3-LFRic



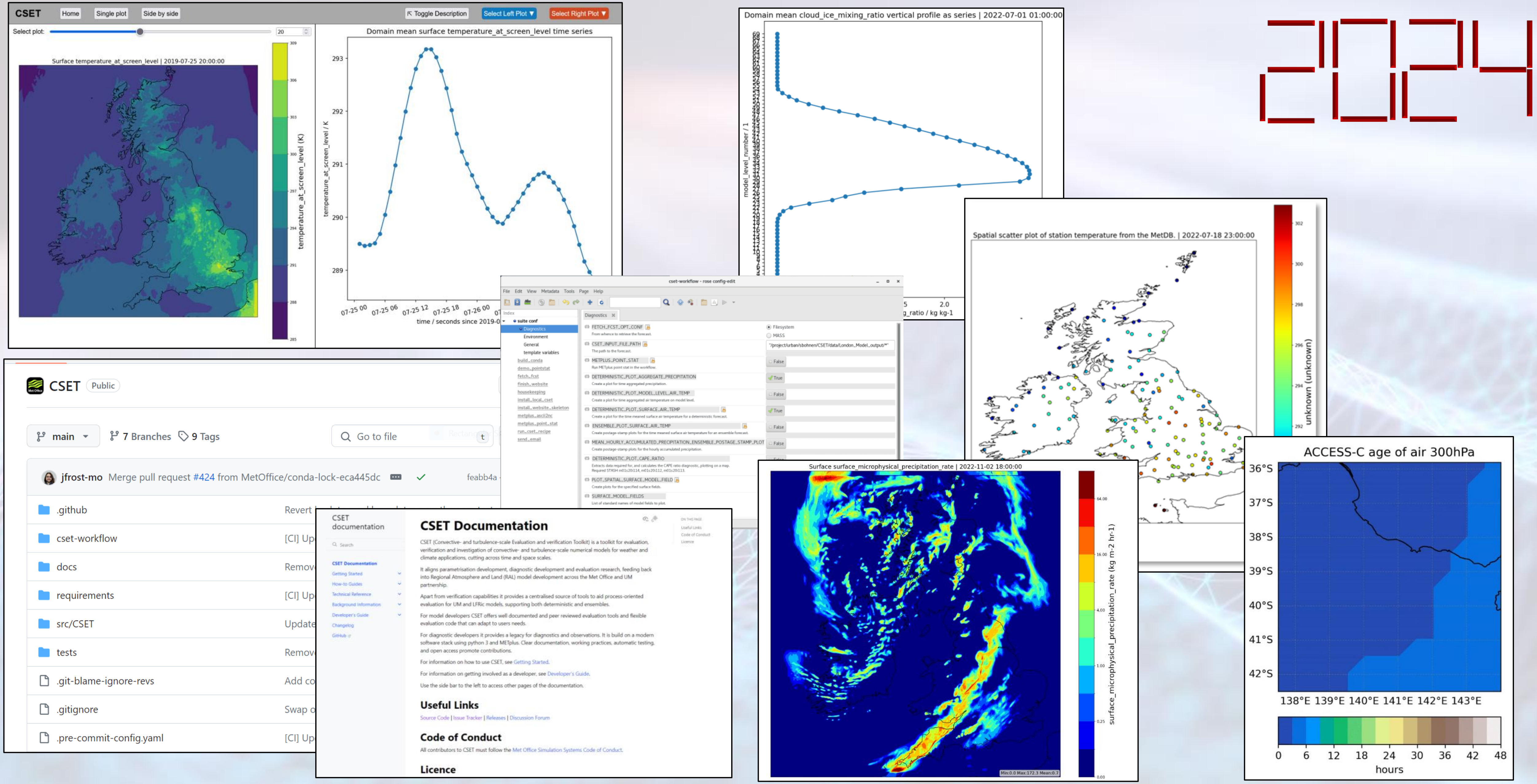




2024



2024: Delivering RAL3-LFRic



2024: Enhancing model evaluation as a community


2044
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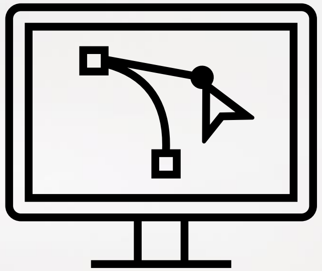
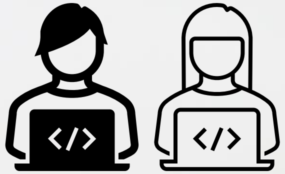
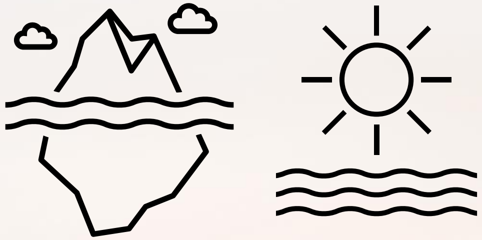
2034

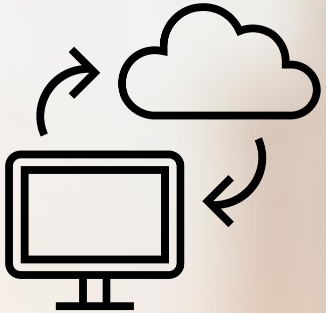
Into the LFRic era: Embrace the fuzziness, embrace the opportunities…

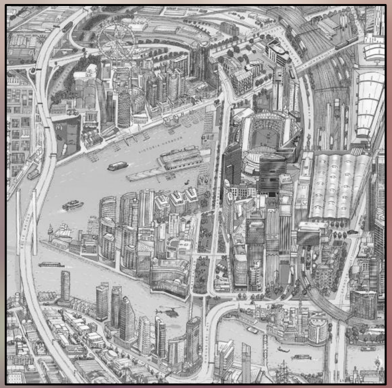
2034











Into the LFRic era: Embrace the fuzziness, embrace the opportunities…

2034

We live and breathe it.

We're experts by nature.

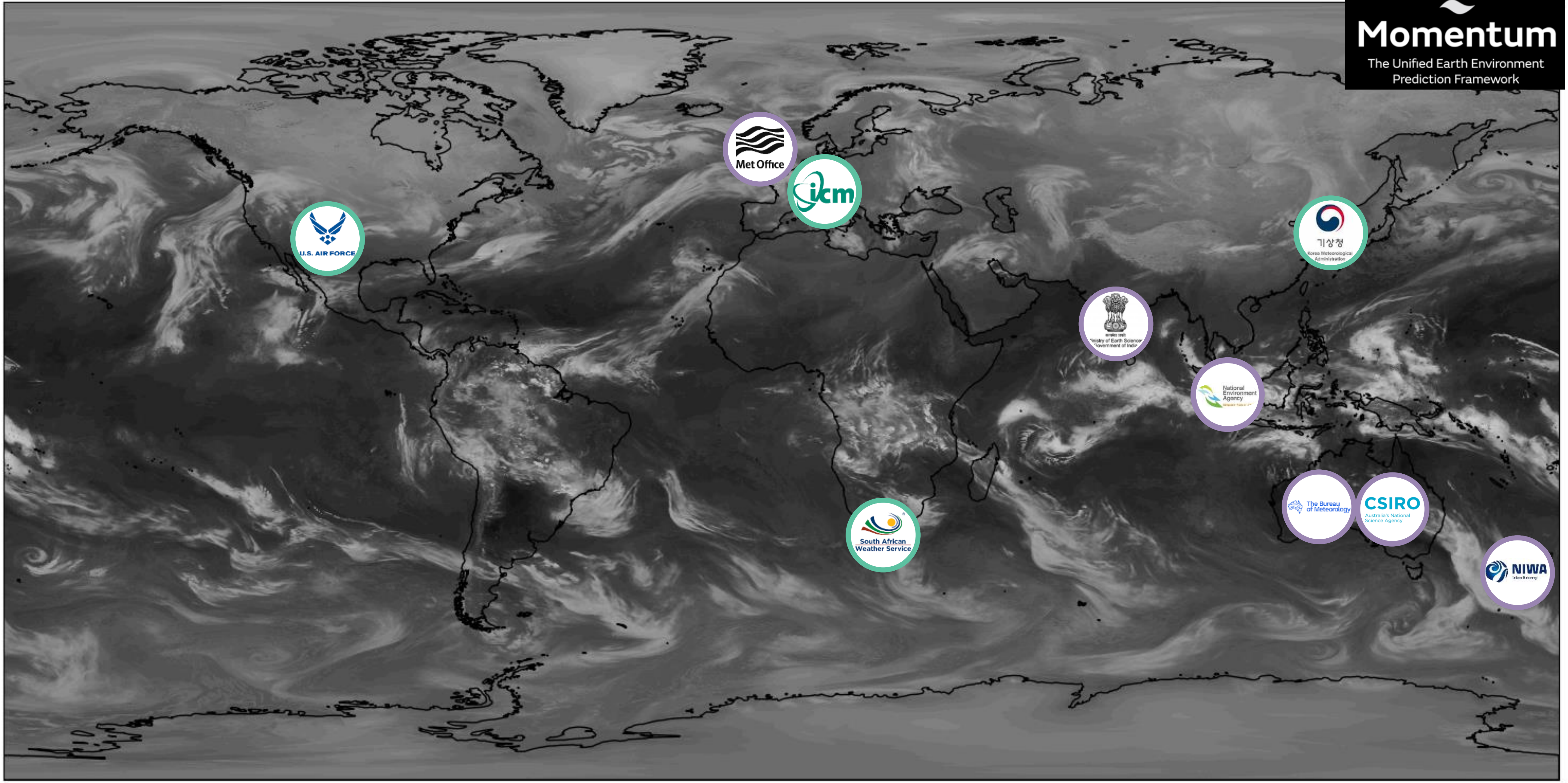
We keep evolving.

We're better together.

We're a force for good.

Advancing convective-scale predictions through collaboration

Momentum
The Unified Earth Environment Prediction Framework



With gratitude to the pioneers, and thanks to all who continue to make it possible day by day…

The London Model: forecasting fog at 333 m resolution, Boutle et al. 2015

An operational fog prediction system for Delhi using the 330 m Unified Model, Jayakumar et al. 2017

A Pan-African Convection-Permitting Regional Climate Simulation with the Met Office Unified Model: CP4-Africa, Stratton et al. 2018

The UKC2 regional coupled environmental prediction system, Lewis et al., 2018

Impact of high-resolution ocean–atmosphere coupling on fog formation over the North Sea, Fallmann et al., 2019

Convection-Permitting Regional Climate Change Simulations for Understanding Future Climate and Informing Decision-Making in Africa, Senior et al. 2021

SINGV – the Convective-Scale Numerical Weather Prediction System for Singapore, Huang et al. 2019

SINGV: A convective-scale weather forecast model for Singapore, Dipankar et al., 2020

IMDAA: High-Resolution Satellite-Era Reanalysis for the Indian Monsoon Region, Rani et al., 2021

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The first Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL1, Bush et al., 2020

The second Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL2, Bush et al., 2023

Exceptional atmospheric conditions in June 2023 generated a northwest European marine heatwave which contributed to breaking land temperature record, Berthou et al., 2024

Machine learning emulation of precipitation from km-scale regional climate simulations using a diffusion model, Addison et al., 2024

Machine learning bias correction and downscaling of urban heatwave temperature predictions from kilometre to hectometre scale, Blunn et al., 2024

With special thanks to.....

Momentum Partner RAL Leads

Regional Working Group Co-chairs

To find out more, see....

https://metoffice.sharepoint.com/sites/MomentumPartnership/SitePages/Regional-Modelling.aspx

https://code.metoffice.gov.uk/trac/rmed/

https://metoffice.github.io/CSET/index.html

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