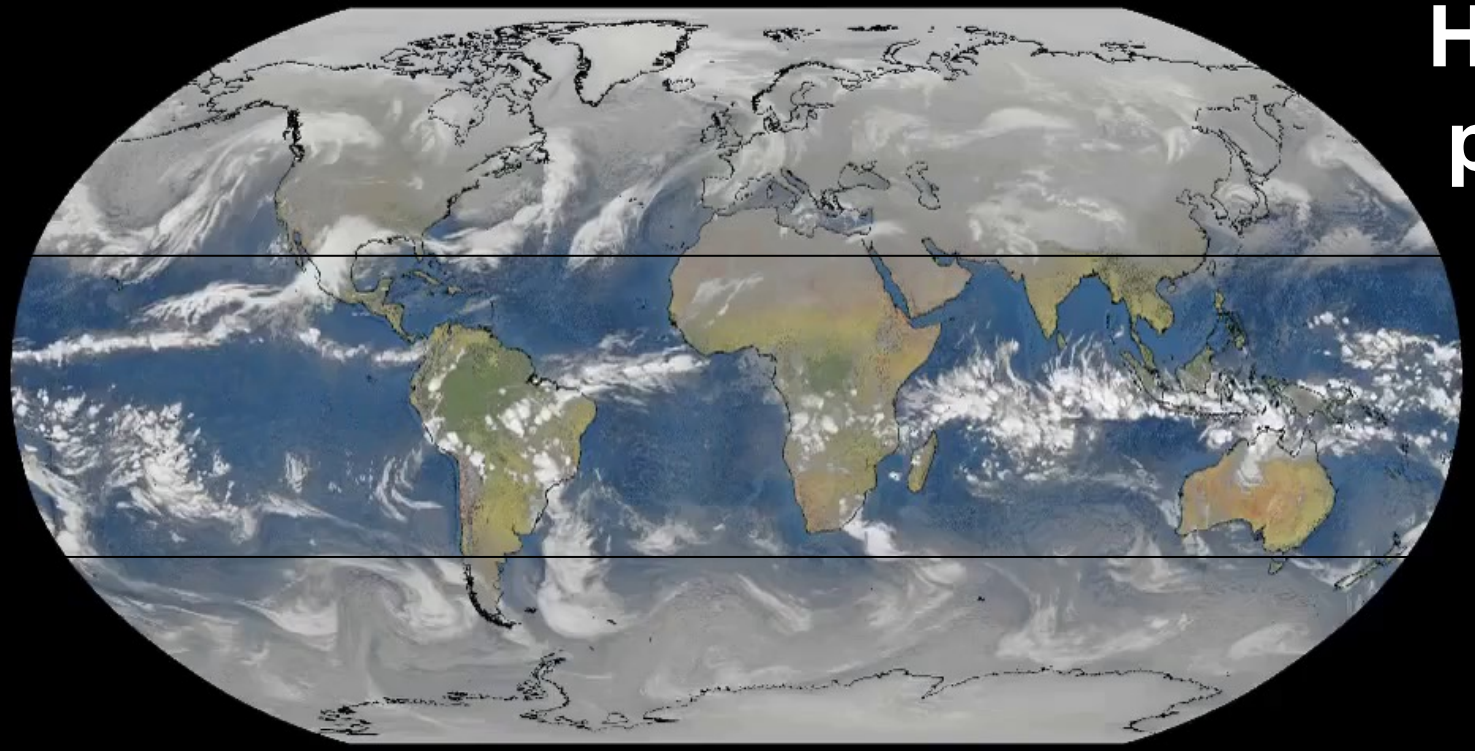


High-resolution modelling progress and plans at the Met Office

Richard W Jones, Huw Lewis, Tim Graham,
Marion Mittermaier, Calum Scullion,
Claudio Sanchez, Dasha Shchepanovska
Lorenzo Tomassini & K-Scale science team
Met Office, UK

WGNE Annual meeting November 2025

Richard.W.Jones@metoffice.gov.uk

Met Office

Presentation outline

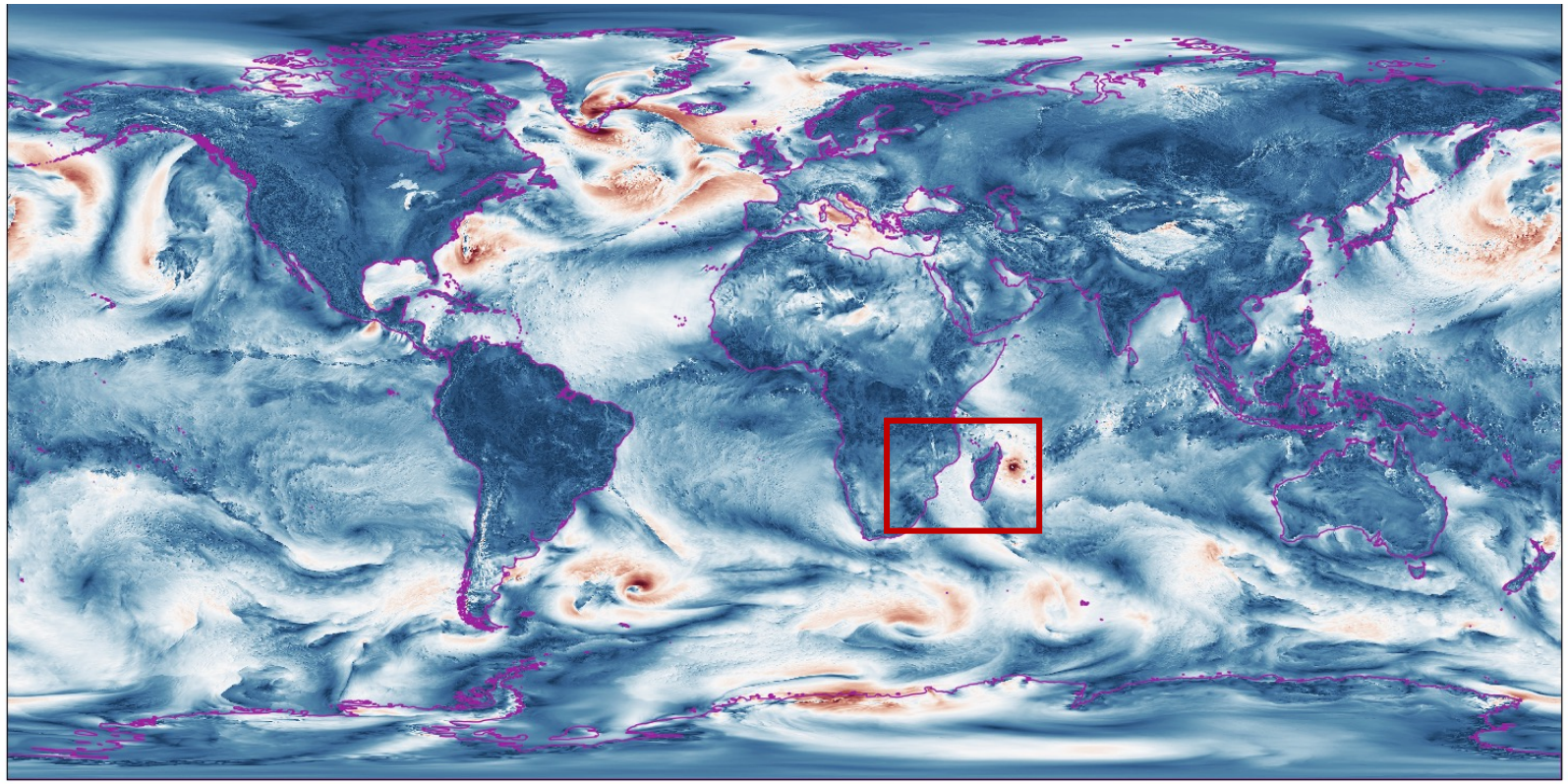
- K-Scale research - Implementing a global-regional model hierarchy as our contribution to the DYAMOND-3 intercomparison project.
- CoMorph convection scheme – a new mass-flux convection scheme and adaptions for convective grey-zone simulations
- Global 5km demonstrator simulations – repeated 15-day NWP simulations through the 2020-21 period.
- From the Unified Model to LFRic – upgrading our modelling system for scalability to higher resolutions.
- (Re-)Training AI/ML models using global high-resolution datasets?

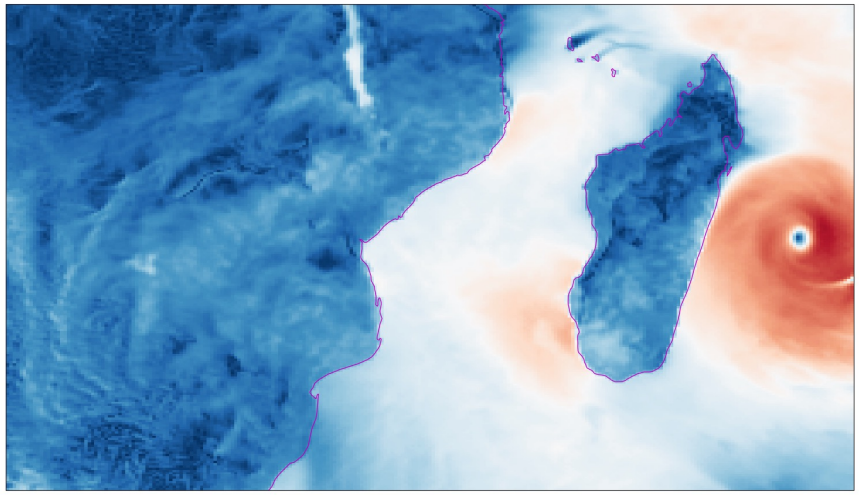
Constructing a K-Scale model hierarchy to explore the upscale impacts of explicitly simulating deep-convection

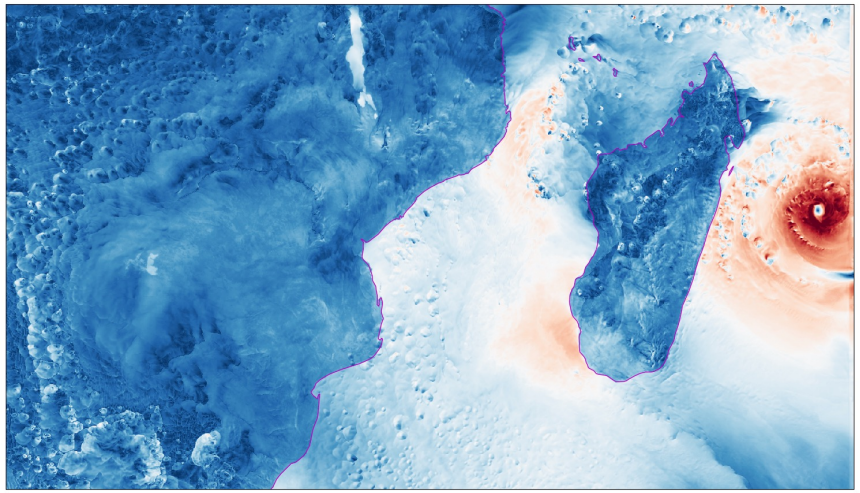
Richard W Jones, Huw Lewis, Calum Scullion, Dasha Shchepanovska, Claudio Sanchez

Jones et al. 2025 (in review)

Met Office







"…it's *not* about having a better downscaled forecast,…

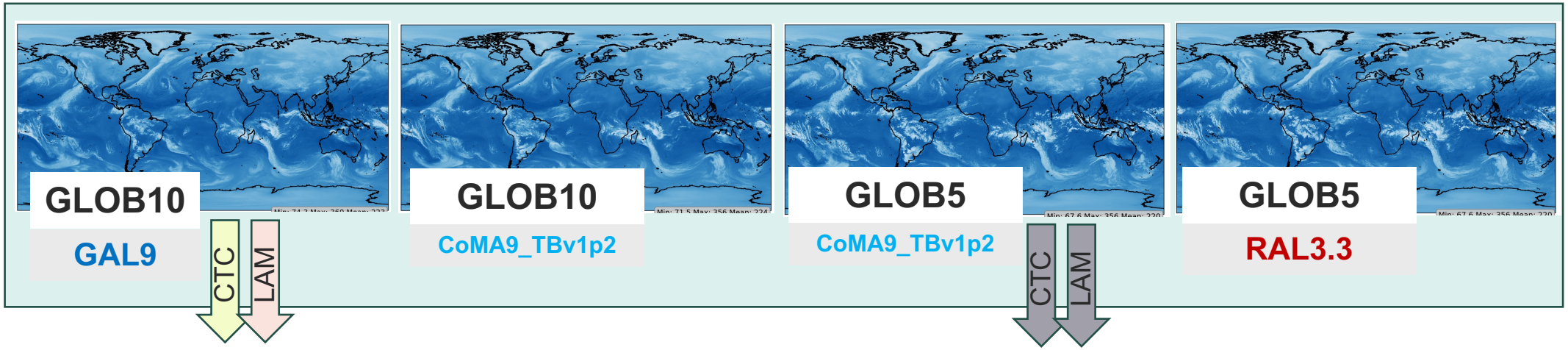
Prof. Tim Palmer [Climate Computing Summit, Sept 2024]

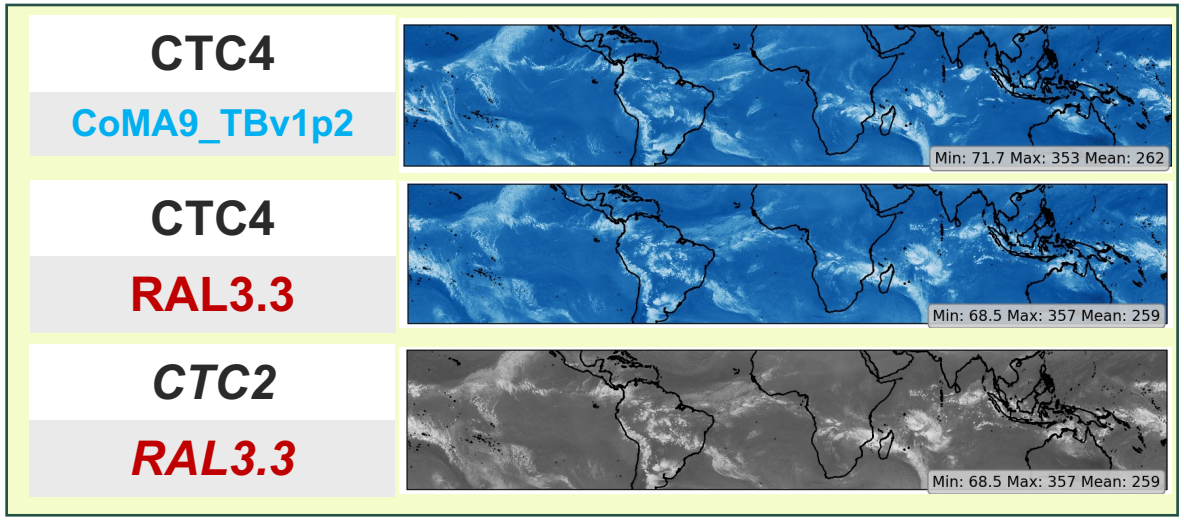
…it's actually about **how better resolving the kilometre scale will upscale to these synoptic and larger planetary scale.**

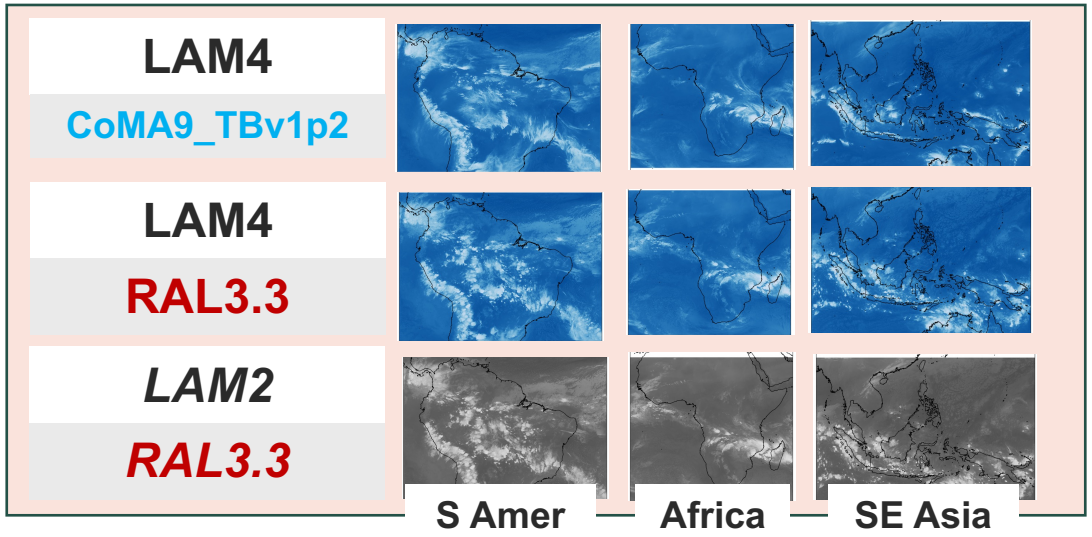
…So we still in a way have to prove that that is the case – that we can reduce these large biases with much higher resolution models"

A global-regional model hierarchy

UK contribution to DYAMOND3

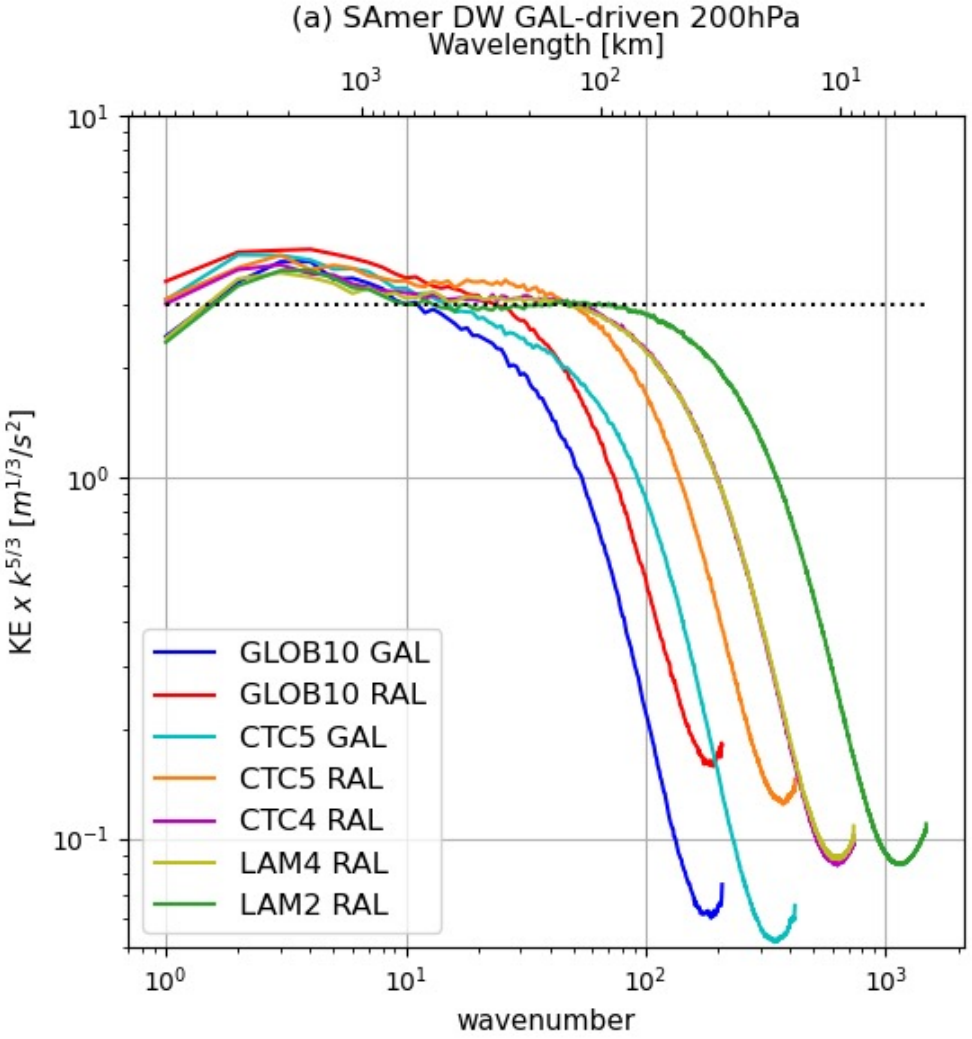


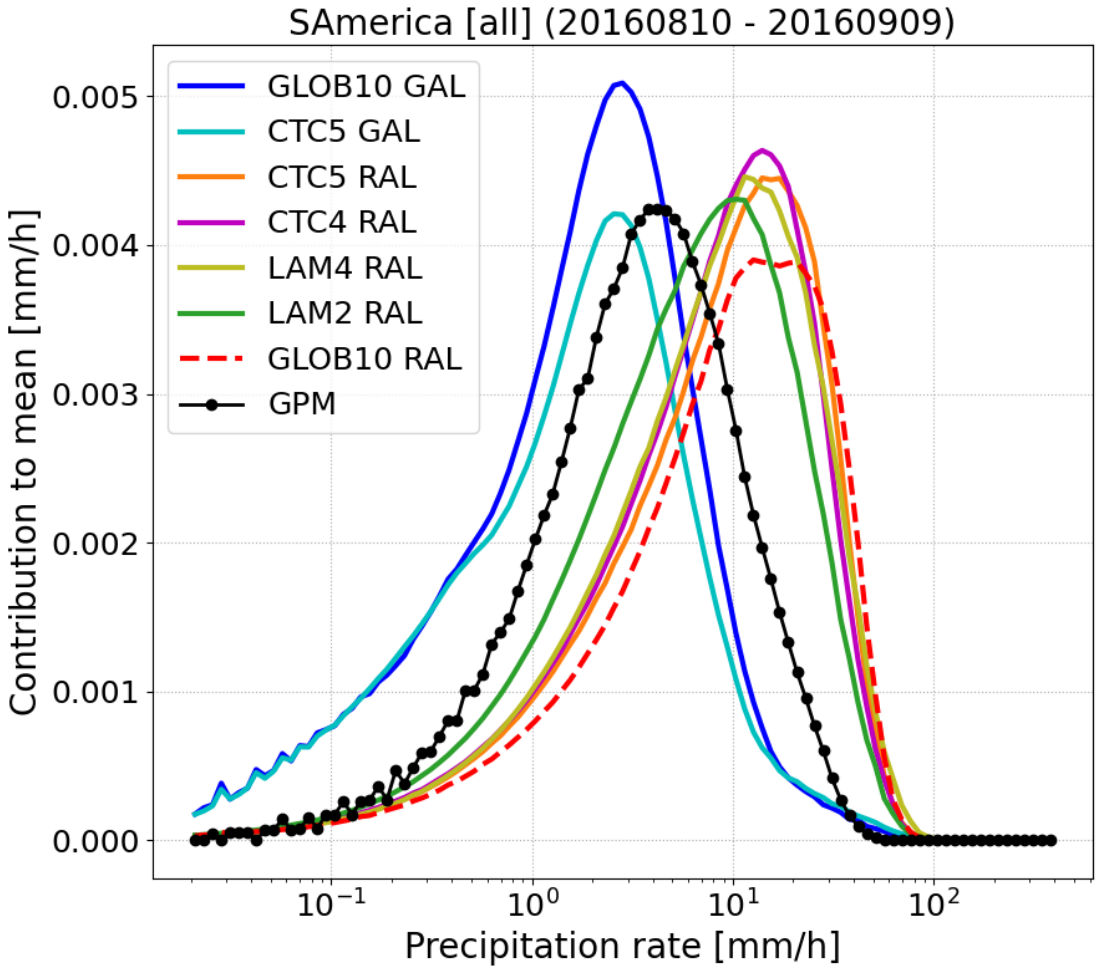




"DYAMOND3" Takasuka et al (2024);

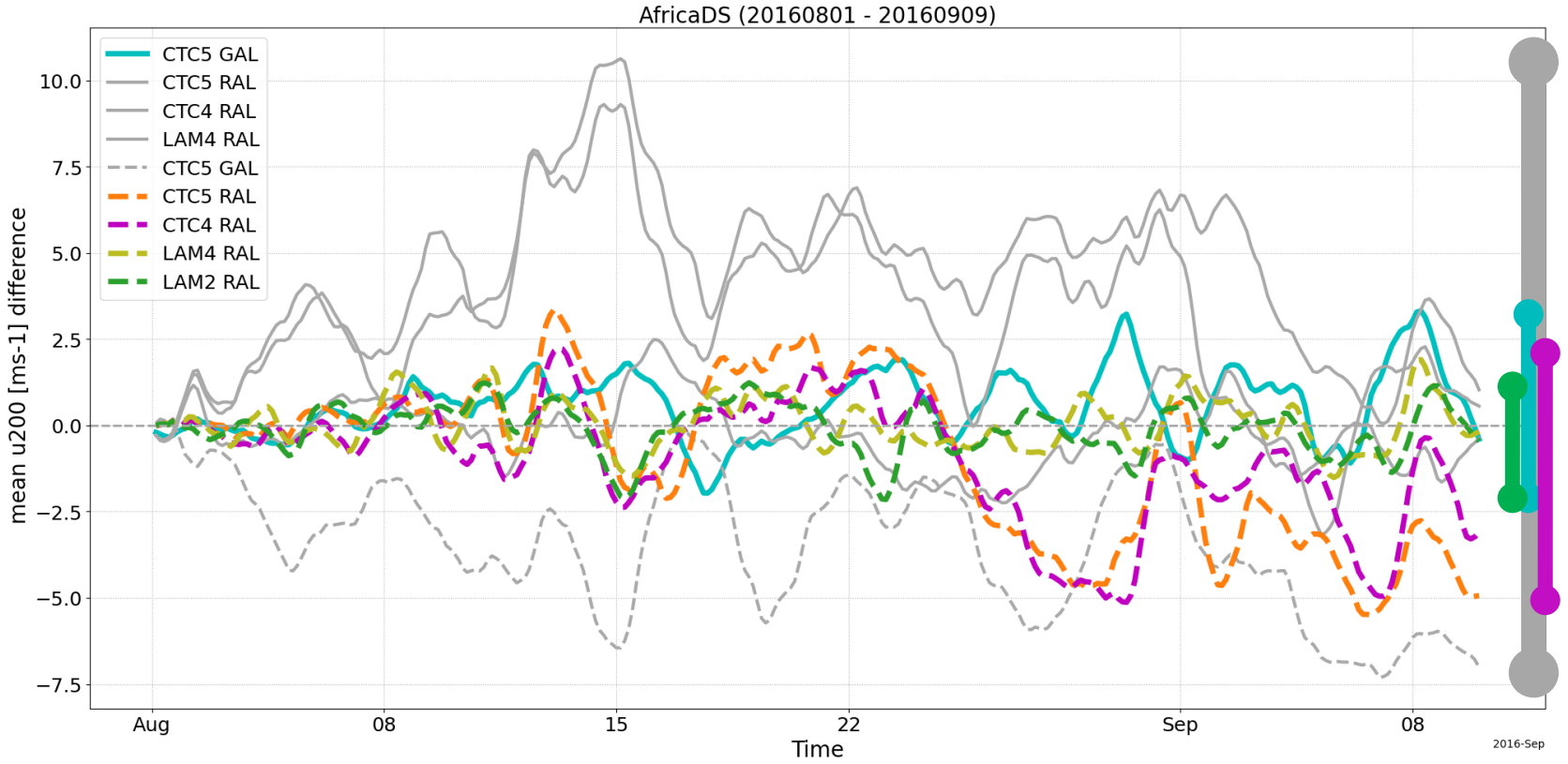
Regional evaluation of resolution and physics dependencies





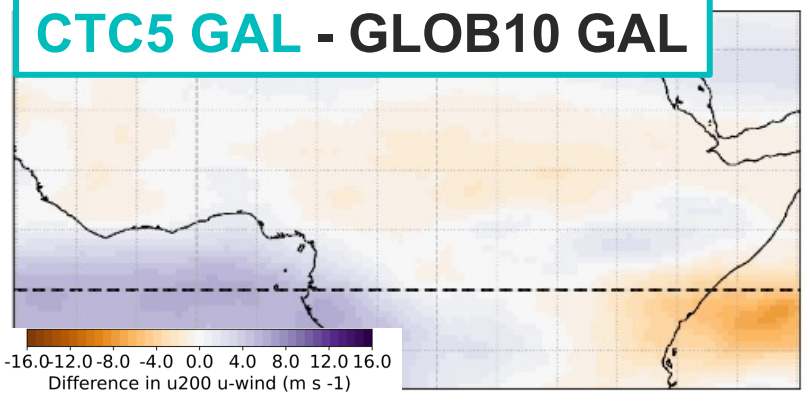
Claudio Sanchez, Met Office

Signatures of upscale to large-scale flow

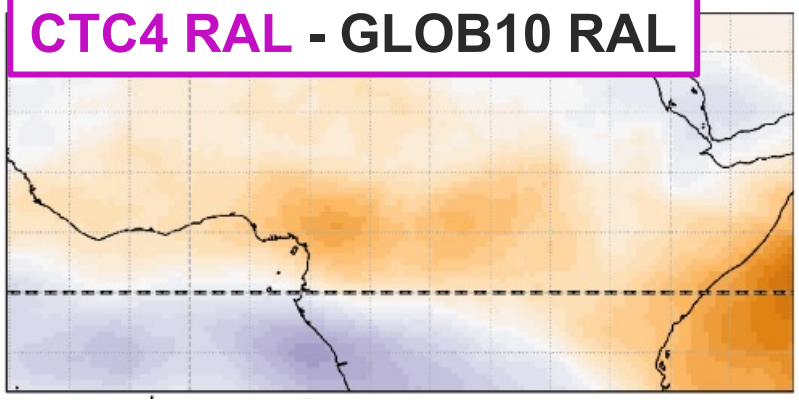


- Consider differences in u200 relative to global driving model
- Strong sensitivity to physics (GAL vs RAL); differences within hours
- Large-scale in continental LAM closely follows driving model
- Large-scale in CTC diverges from driving model more strongly, but only when convection is explicit
- ~10-day spin up period to upscale

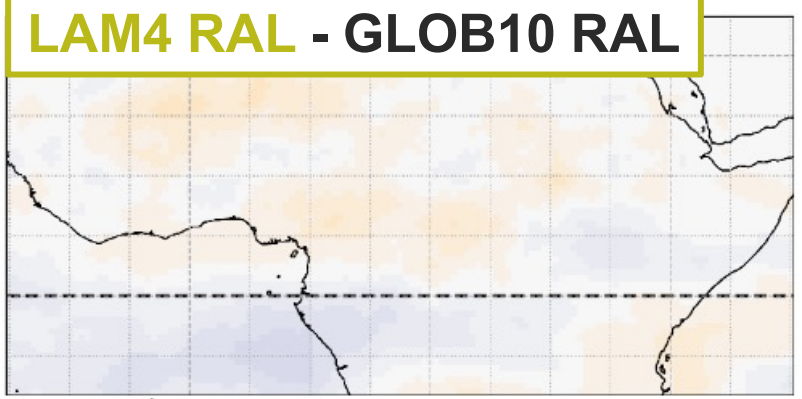
CTC5 GAL - GLOB10 GAL



CTC4 RAL - GLOB10 RAL

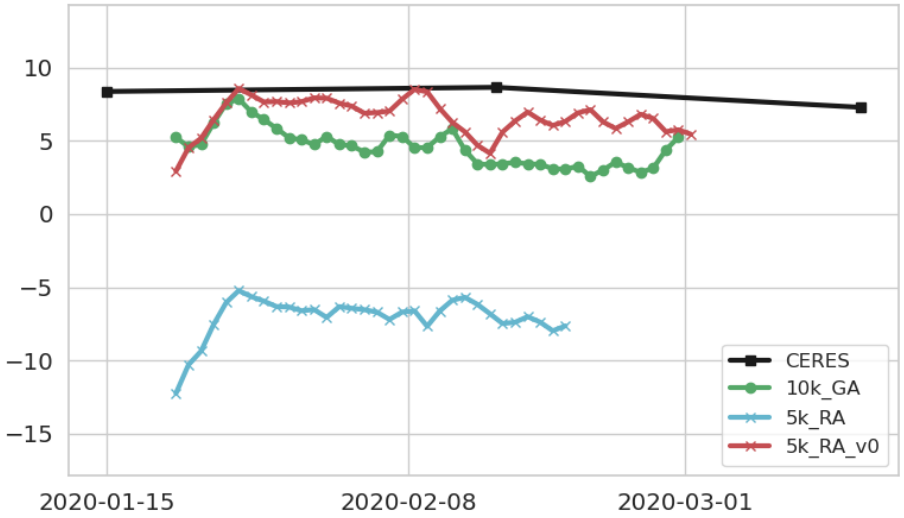


LAM4 RAL - GLOB10 RAL

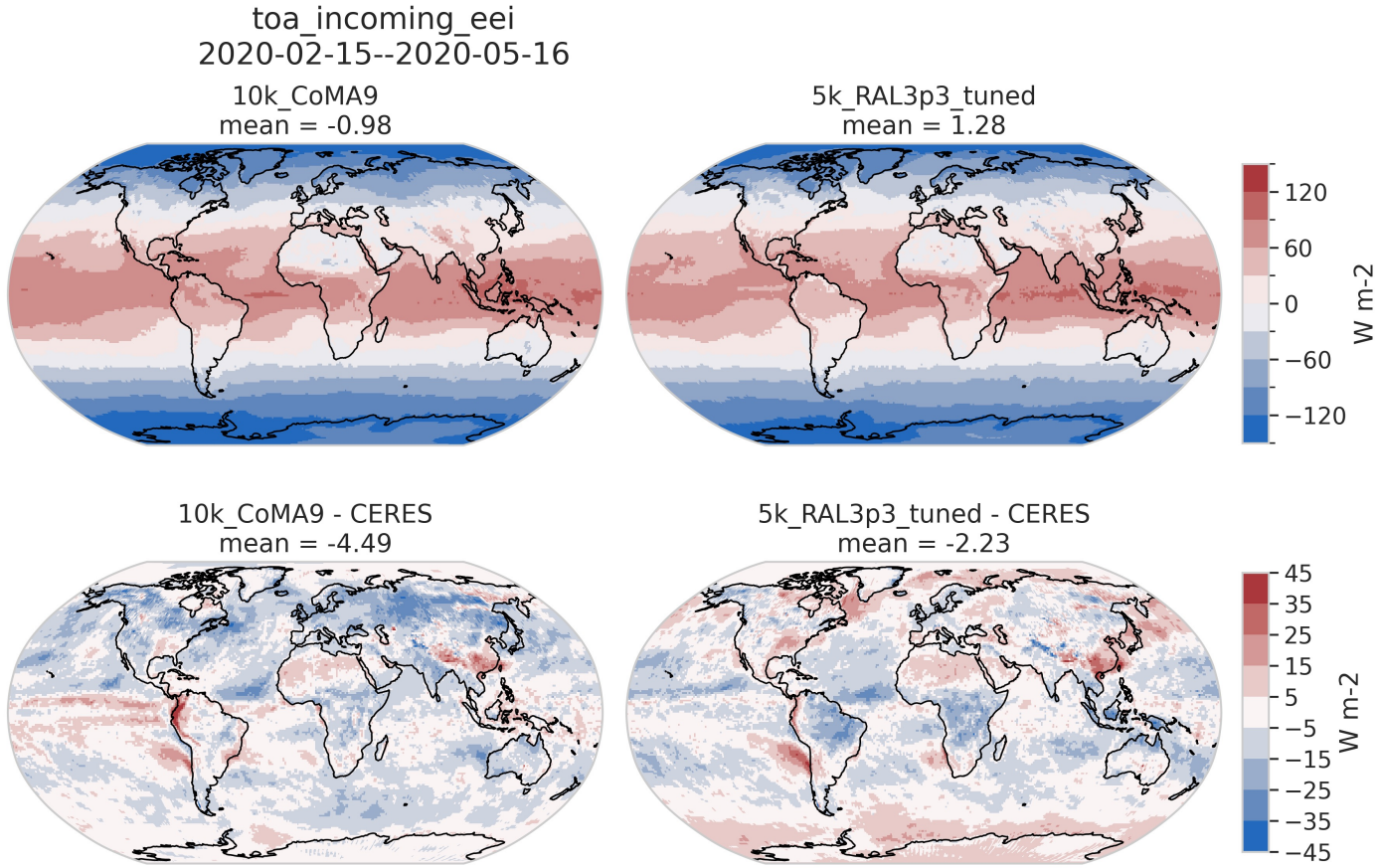


The challenges of explicit convection global simulations

Global 5km RAL3 – Top of Atmosphere Earth Energy Imbalance (EEI)



Original Global 5km explicit convection simulations in blue (re-run in red).



Re-runs now underway in preparation for our submission to the DYAMOND-3 global high-res modelling inter-comparison project.

Calum Scullion, Met Office

CoMorph-A – adapting our new mass-flux convection-scheme for global simulations in the convective grey-zone

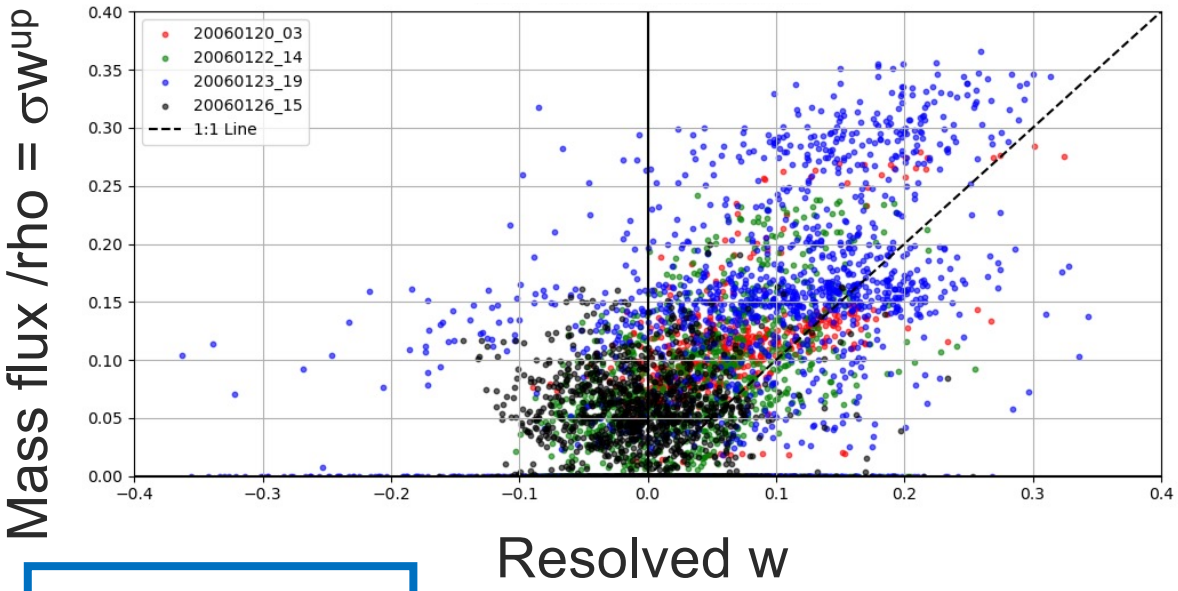
Sally L. Lavender, Alison J. Stirling, Samantha Smith, Michael Whitall, Adrian Lock

Lavender et al. 2026 (in prep.)

Link between resolved and sub-grid W behaviour.

5km 3D idealised UM simulations of TWP-ICE using a convection scheme

GAL9 (Ctrl)

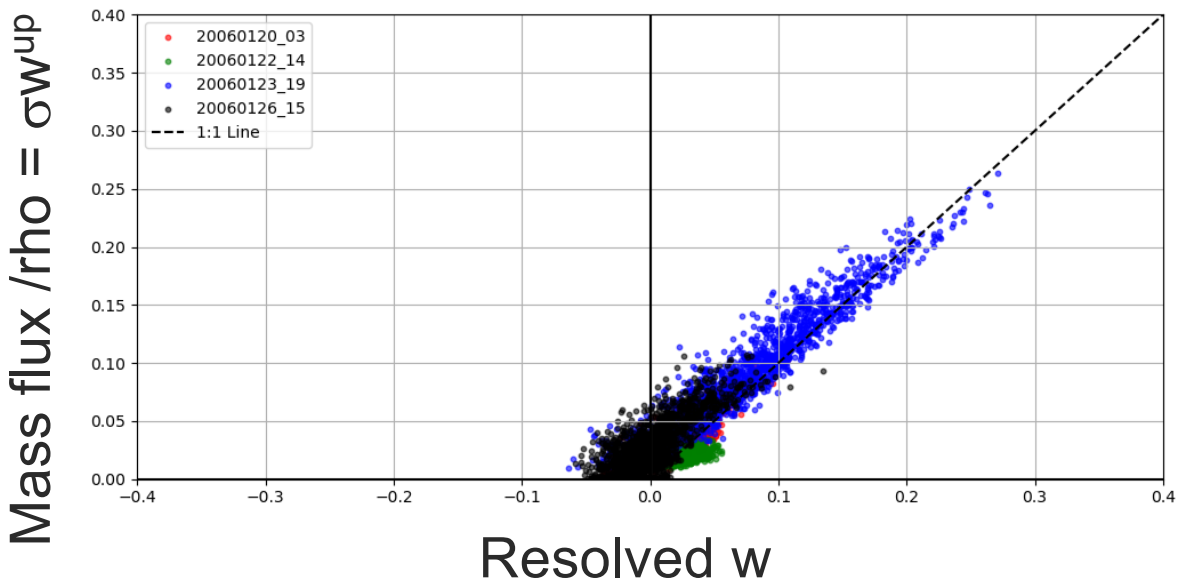


GAL9's intermittency prevents this balance from establishing.

Heating from convection scheme creates a resolved adjustment (WTG) that (at equilibrium) (should) balance the mass flux /rho.

CoMorph

Implicit application of detrainment



CoMorph's smooth behaviour allows the convective heating to translate more directly to resolved dynamical behaviour giving better convection-dynamics coupling.

Sam Smith, Met Office

Adapting convection parametrization for km-scale resolutions:

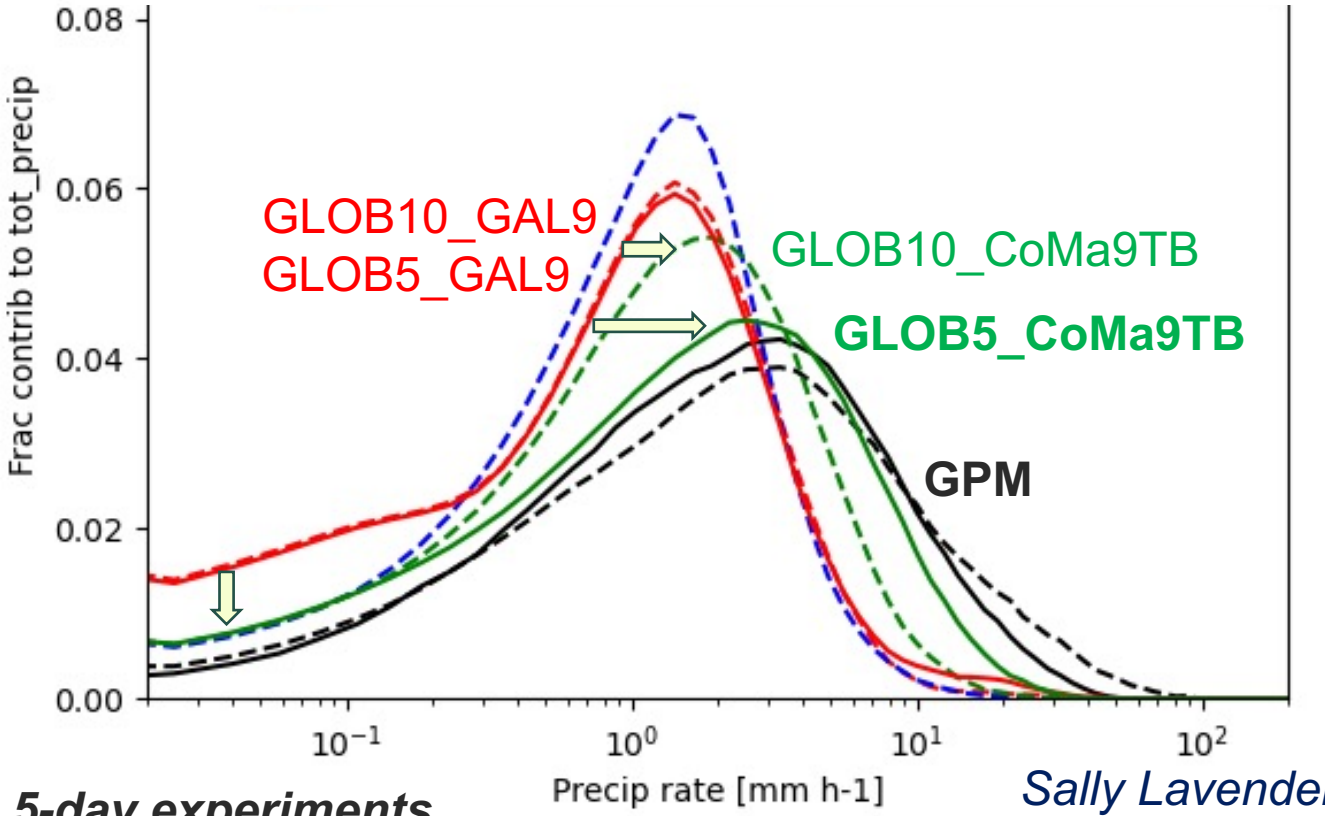
CoMorph-A

- New mass-flux convection scheme
- Developed for use across traditional global weather (10km) to climate (25-150 km) model resolutions

Modifications for higher grid resolutions
"Trailblazer" CoMA9_TBv1p2:

- Reduced initial moisture perturbations
- Reduced scaling of initiating mass-flux at each height
- Increased precipitation rate leading to the maximum updraught size (and introduced grid-size dependency)
- Higher rain evaporation at high rain rates
- *[Moisture conservation settings when run for regional domains]*

Tropics [20S-20N]: *Contribution precipitation to total*



5-day experiments

Sally Lavender

[Lock et al. (2024)]

[Lavender et al. (2024)]

[Zhu et al. (2024)]

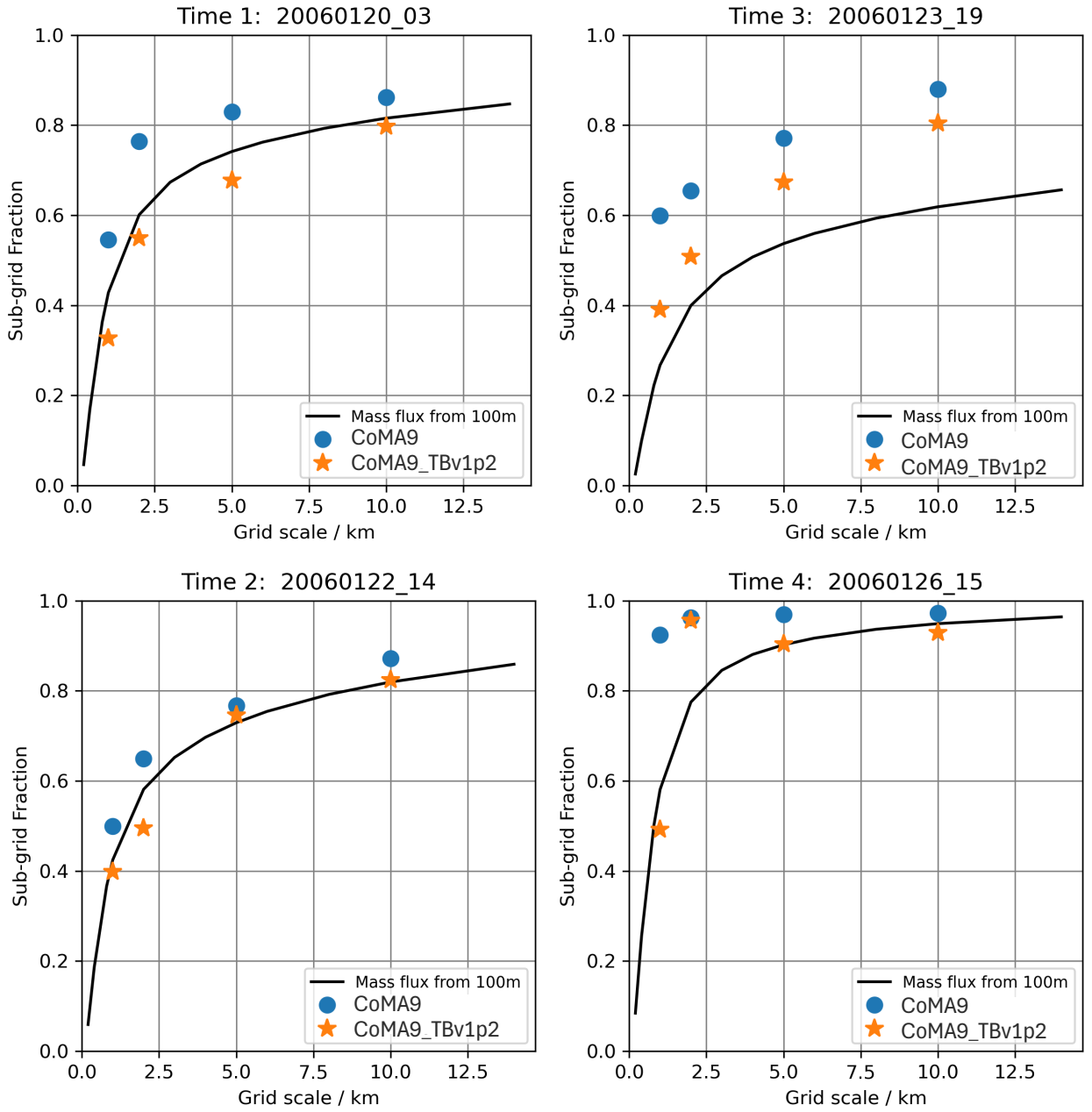
CoMA9 generally doing too much.

CoMA9_TB improves scale-aware performance compared to 100m data analysis.

A few things to consider:

- Drizzle from anvils will always be large-scale, even though it is produced by convection - will skew results.
- Things other than cloud base mass flux likely modify convective rain amount. Might be better to look at proportion of mass flux produced by CoMorph instead.
- Need to consider how to account for effects of clustering (many small updrafts within a “grid-box” will increase mean w, even though updrafts are actually sub-grid).

Investigating other methods for comparison



Global5km demonstrator simulations – Exploring Global 5km global NWP simulations and developing a suitable science configuration

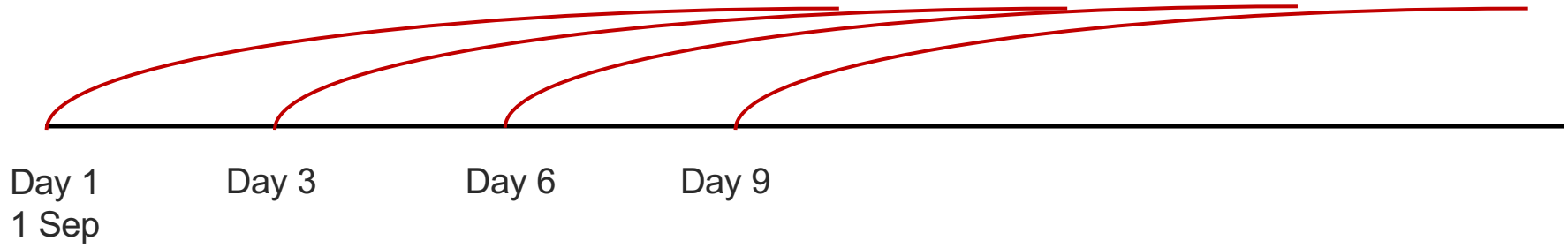
Marion Mittermaier, Tim Graham, Lorenzo Tomassini and Global Model Evaluation and Development team

Global 5km coupled Trailblazer/Demonstrator simulations

The Global 5km coupled Trailblazer simulations consist of initialised forecasts at global 5km atmospheric resolution, coupled to a 10km-resolution ocean model. 122 forecasts were run covering the period September 2020 to August 2021. Initial times are 3 days apart. **The length of the forecasts is 15 days**.

Science configuration is CoMA9_TBv1p2 (as used in K-Scale DYAMOND-3 simulations).

Global 10 km (N1280) control also now complete.

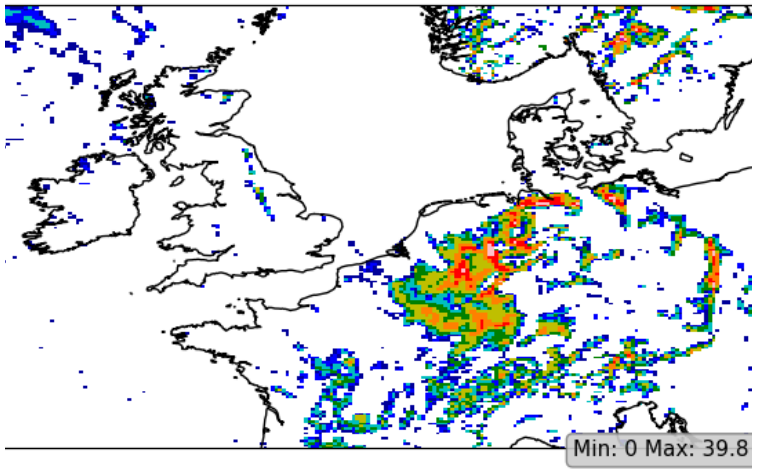


Lorenzo Tomassini, Marion Mittermaier, Tim Graham

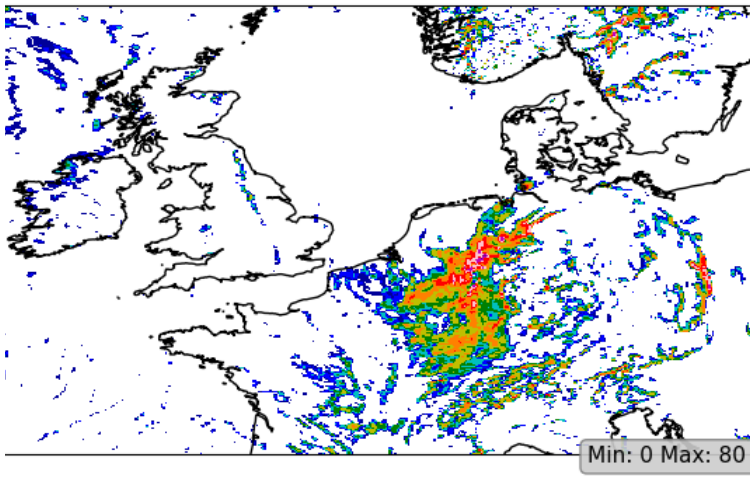
Western Europe flooding July 2021

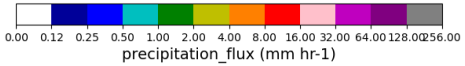
Met Office Hadley Centre

Global 10km control

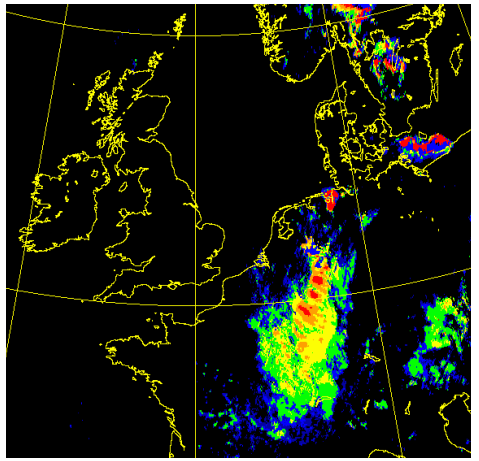


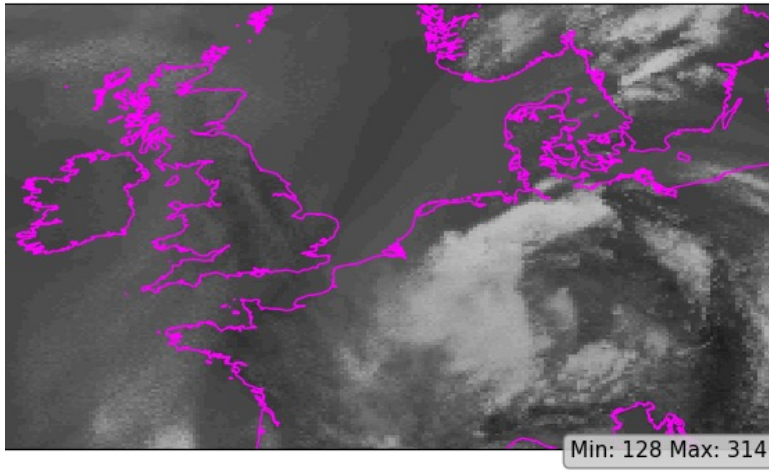
Global 5km demonstrator

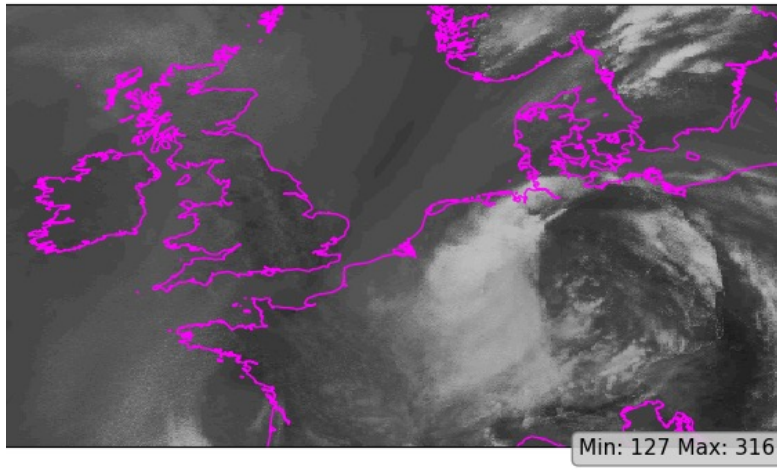


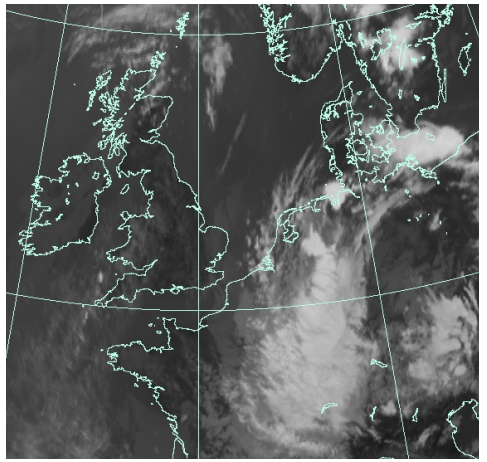


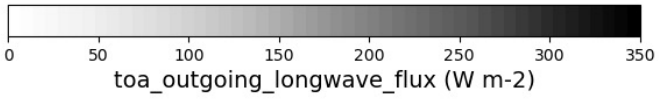
Satellite obs.











David Flack, Met Office

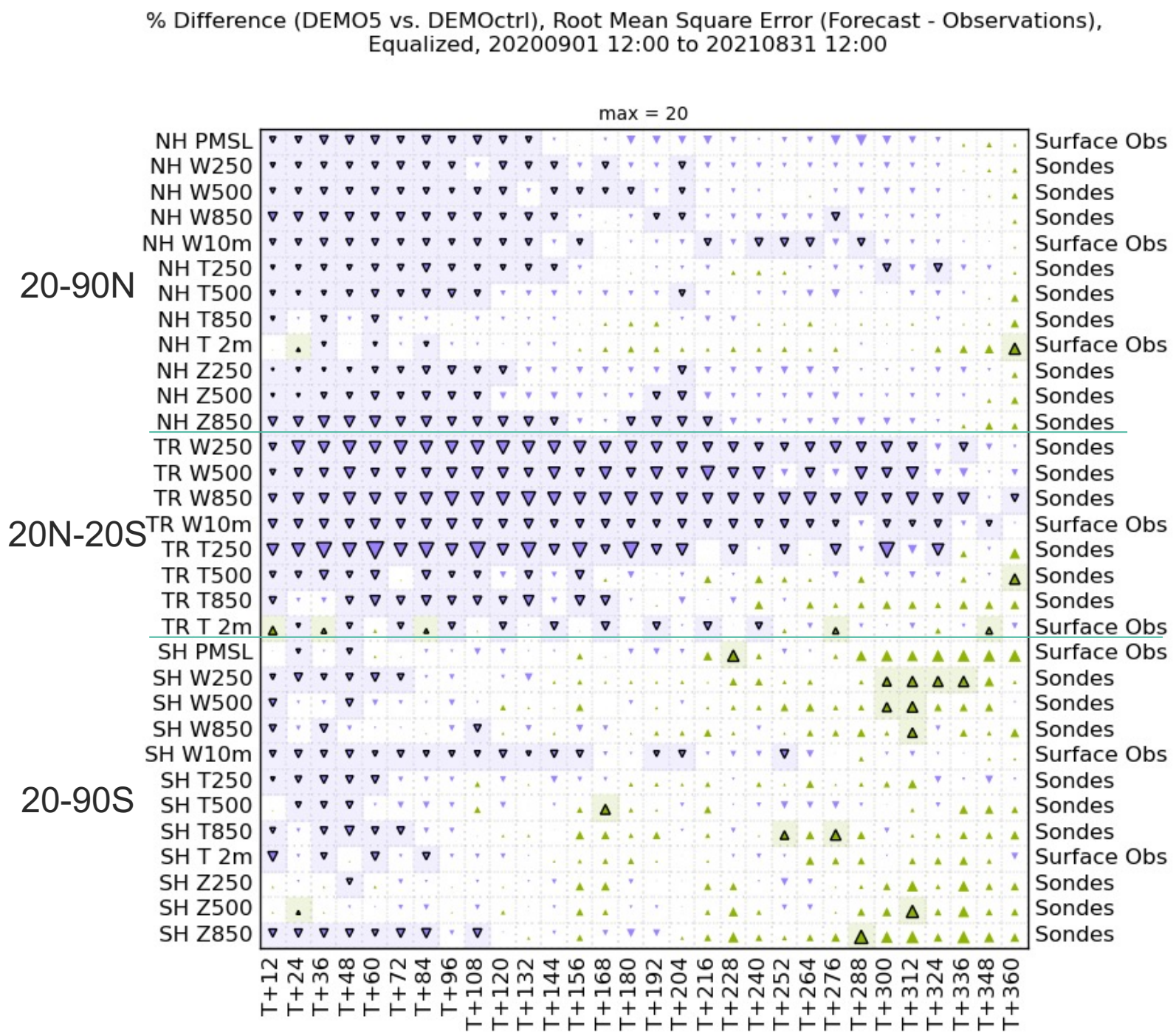
Met Office

Global 5km demonstrator scorecard

5 km demonstrator vs 10 km control
Same science configuration
GC5 + CoMorphA variant (modified for convective grey-zone simulations)

123 cases between
1 Sep 2020 – 30 Aug 2021

Initialised every 3 days at 00 UTC to 15 days



Marion Mittermaier, Met Office

Met Office

LFRic – The new dynamical core (GungHo) and a cubed-sphere mesh to enable efficient and timely high-resolution global simulations

Ben Shipway, Thomas Bendall, Zoe Plain, and the wider next-generation-modelling system programme

LFRic – improved scalability at high-resolution

- Move to quasi-uniform mesh to remove polar singularity
- Maintain ‘good’ aspects of current model
  - No computational modes
  - Accurate wave dispersion
  - Mimetic properties, e.g. $\nabla x \nabla \equiv 0$
  - Semi-implicit timestepping
  - Same subgrid parametrizations
- Improve inherent conservation
- Improve scalability

UM

LFRic

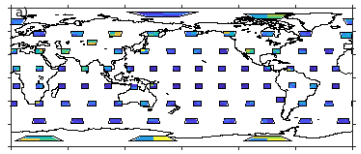
Ben Shipway, Tom Bendall, Met Office

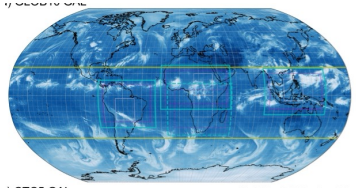
Exploiting K-Scale for ML

Evaluation of K-Scale for ML training

- Can km-scale simulations be used as “nature runs” for improved training?
  - *Self-consistent 3D coverage, typically at higher resolutions than available global reanalyses*
  - *What new information is captured in global/large-domain km-scale simulations that are missed in e.g. regional reanalyses?*
  - *Developing improved metrics and methods for physical-science-based evaluation of ML-based models (e.g. CSET)*

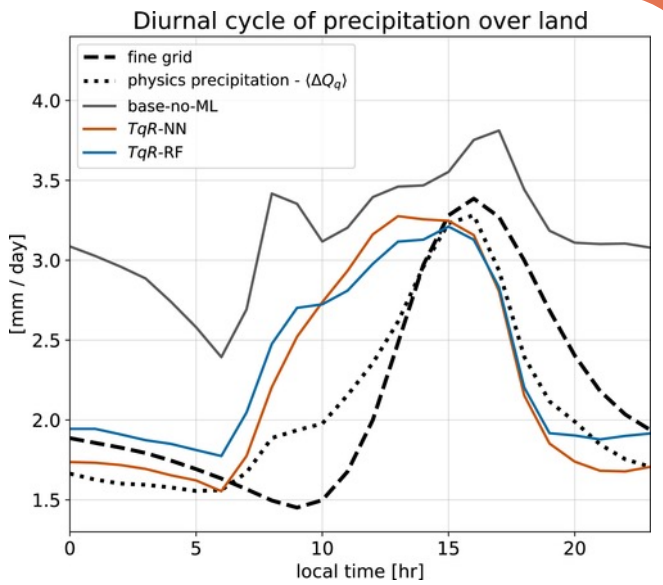
Use ML and global km-scale data to improve coarse-scale models





- Can we use globally available km-scale training data to predict coarse-grained variables?
- How do the outcomes compare to the **C**loud **R**esolving **M**odel **M**achine **L**earning methodology using 80 nested km-scale model sampling?

e.g. [Bretherton et al. (2022)]



Huw Lewis, Cyril Morcrette, Met Office

Current progress and plans

1. Submission of year-long global-regional hierarchy simulations to DYAMOND-3 intercomparison project - *enabling application and research across timescales*.

1. Jointly with UK academic partners – use the hierarchy to focus on understanding the *upscale* effects of resolving small(er) scale processes on the large-scale circulation

1. LFRic dynamical core and new cubed-sphere mesh will be key to running global high-resolution simulations more efficiently and towards climate-timescales (even at ~10 km resolution)

1. Global5km NWP demonstrator simulations using the new CoMorph-A convection scheme (adapted for running at 5-10 km horizontal resolution).

1. Exploiting K-Scale simulations for AI/ML modelling efforts.
   - *Is there new information captured in global/large-domain km-scale simulations? Does this provide benefit for AI/ML models trained with additional K-Scale data?*

Met Office

Thank you for listening!

Questions?

Richard.W.Jones@metoffice.gov.uk