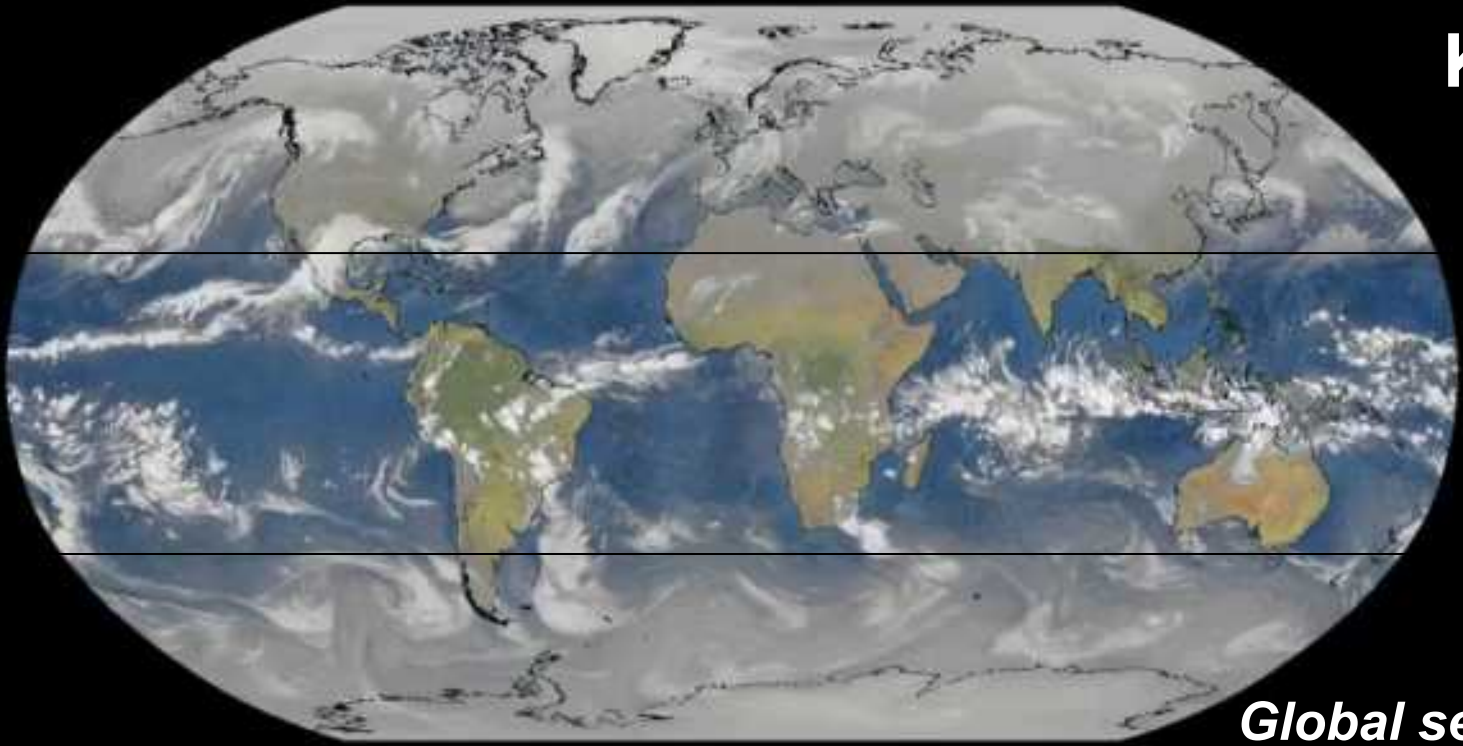
K-Scale: Year-long global UM simulations for DYAMOND-3



Richard W Jones, Huw Lewis
Sally Lavender, Claudio Sanchez,
Dasha Shchepanovska, Calum Scullion &
wider K-Scale project team

Global seamless modelling workshop, June 2025

Richard.W.Jones@metoffice.gov.uk

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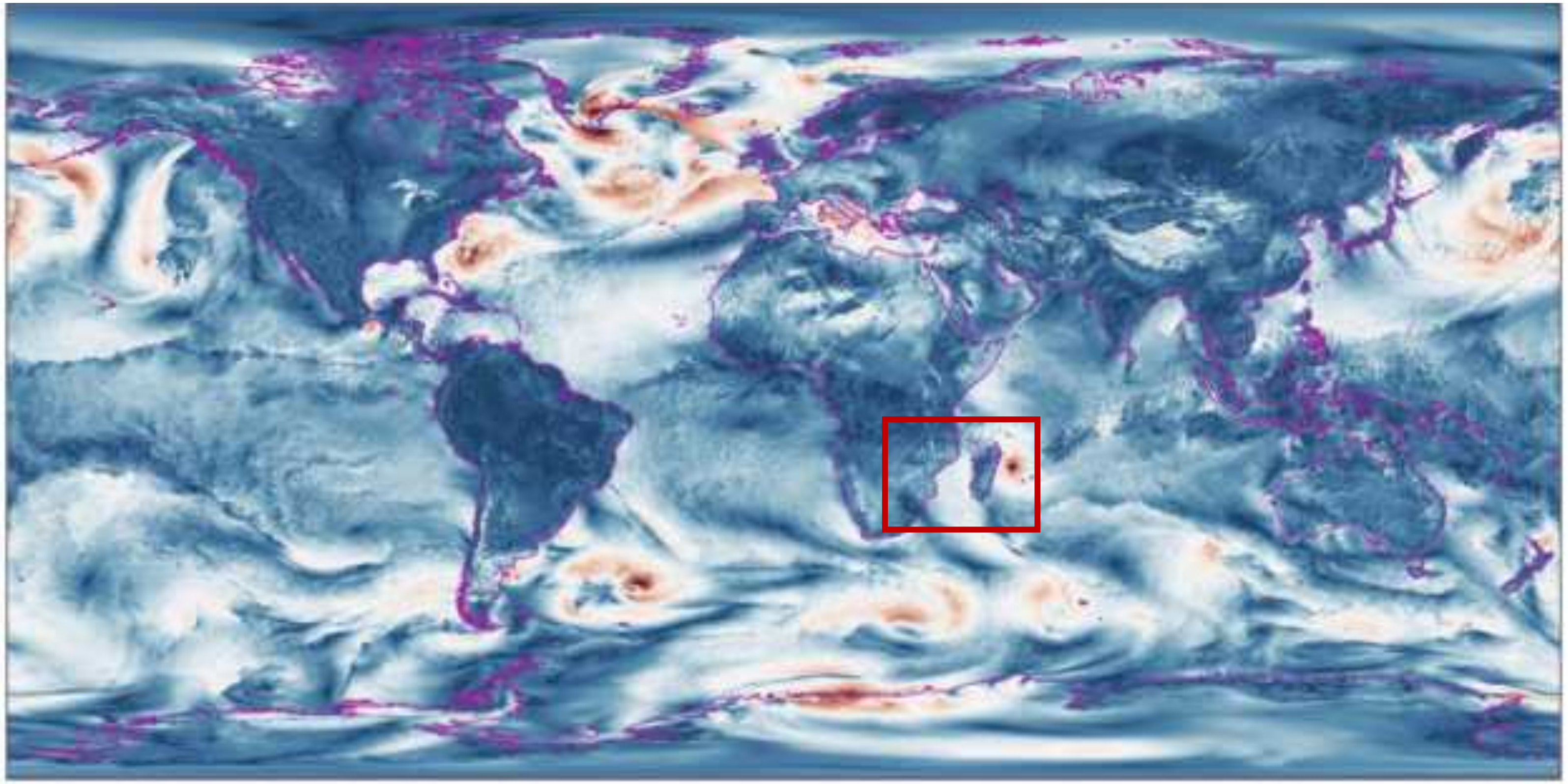

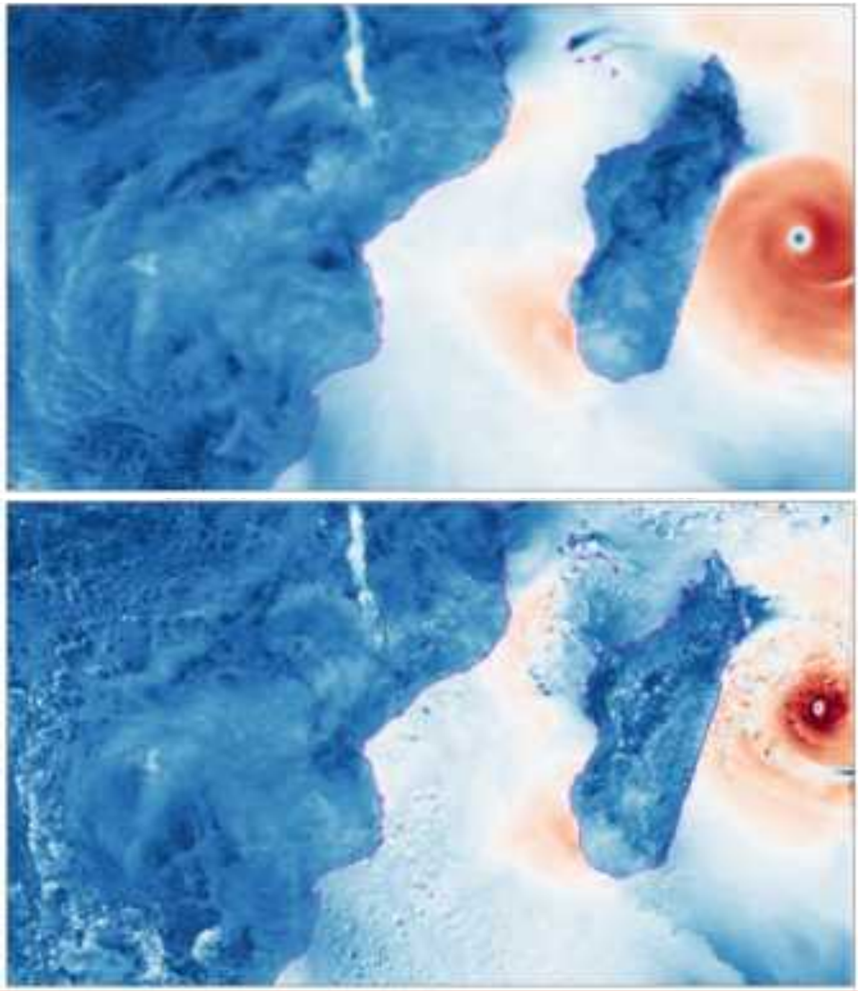

“…it's *not* about having a better downscaled forecast,…

…it’s actually about **<u>how better resolving the kilometre scale will upscale to these synoptic and larger planetary scale</u>.**

…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”

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

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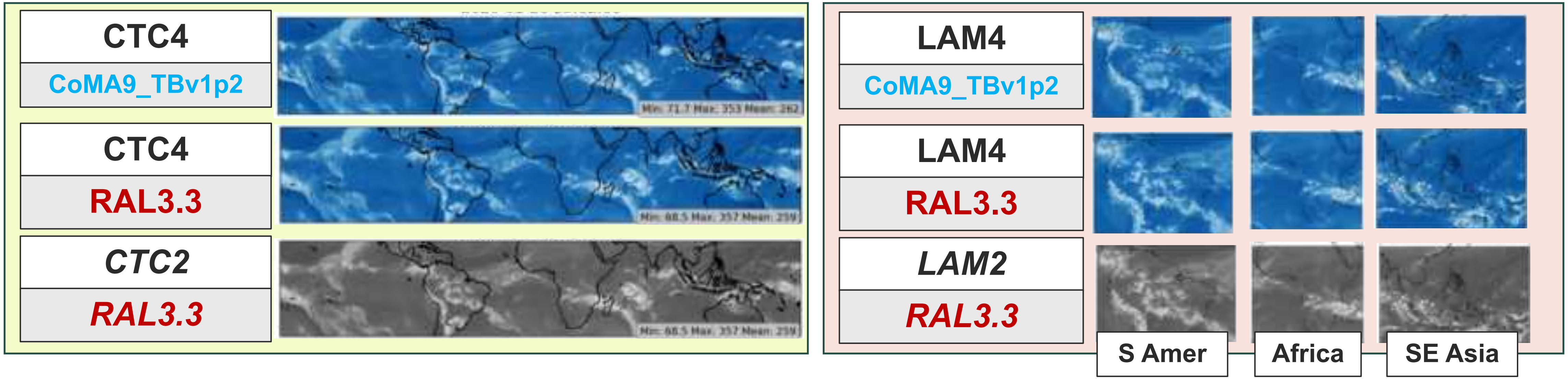
A global-regional model hierarchy

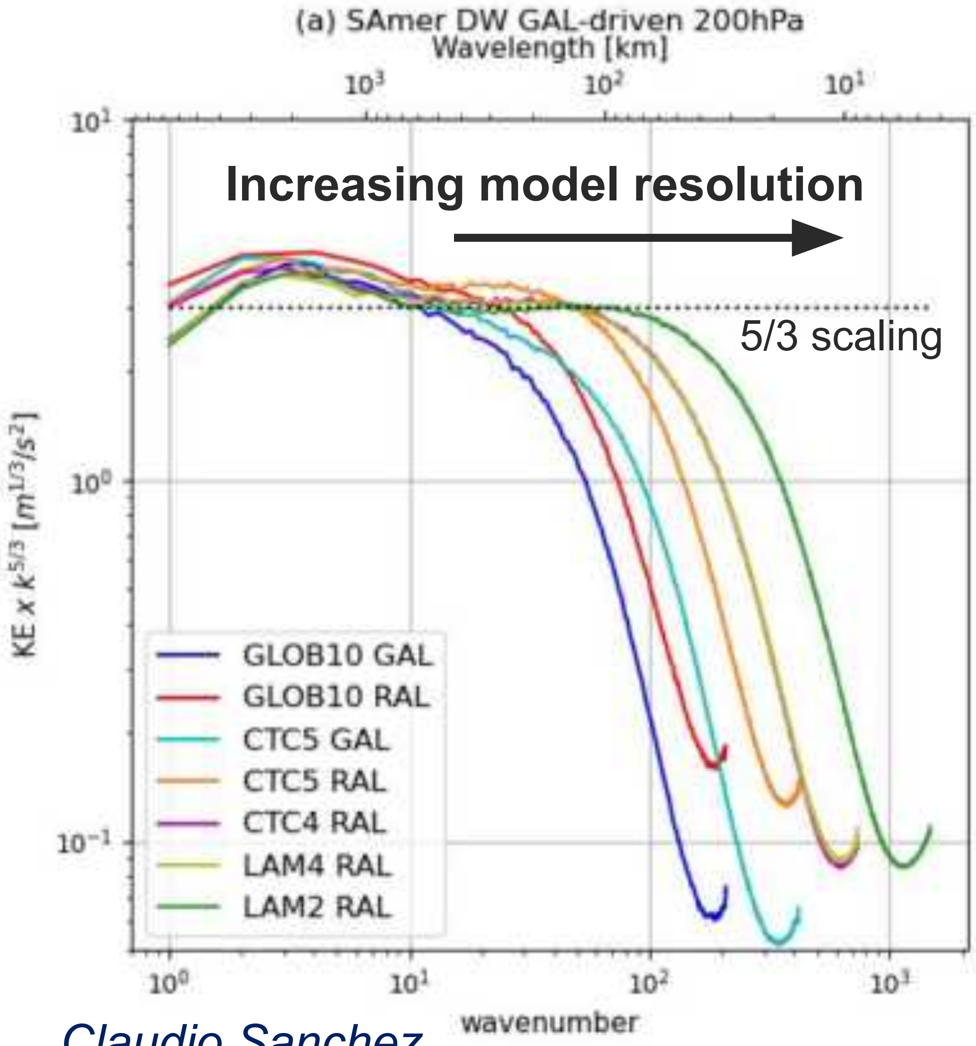
UK contribution to DYAMOND3



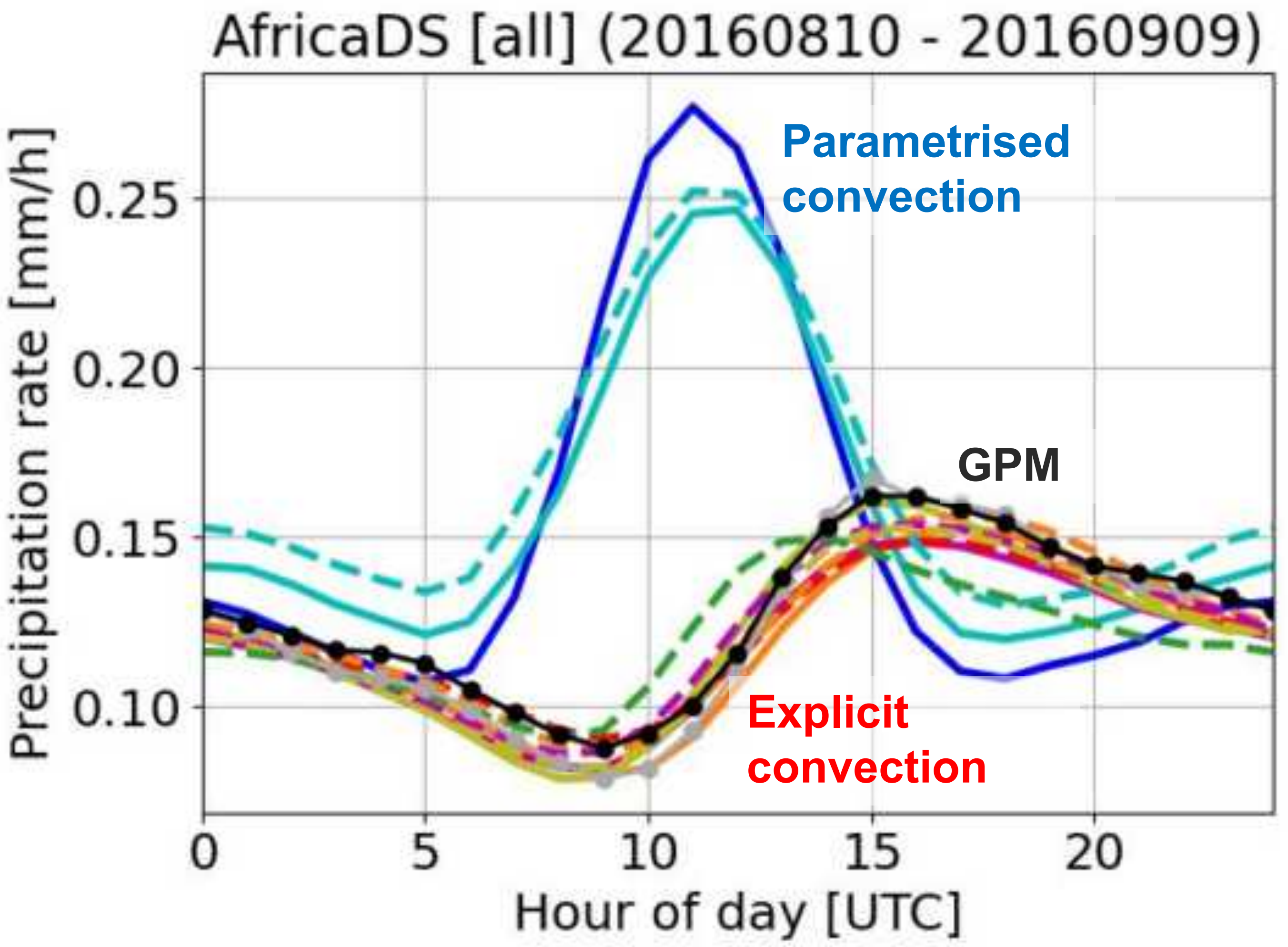
"DYAMOND3" <u>Takasuka et al (2024):</u>

Grey-scale = incomplete and not yet available

Regional evaluation of resolution and physics dependencies



Claudio Sanchez



Results from earlier DYAMOND summer 40-day experiments

Jones et al., BAMS, in prep.

Adapting convection parametrization for km-scale resolutions:

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CoMorph-A

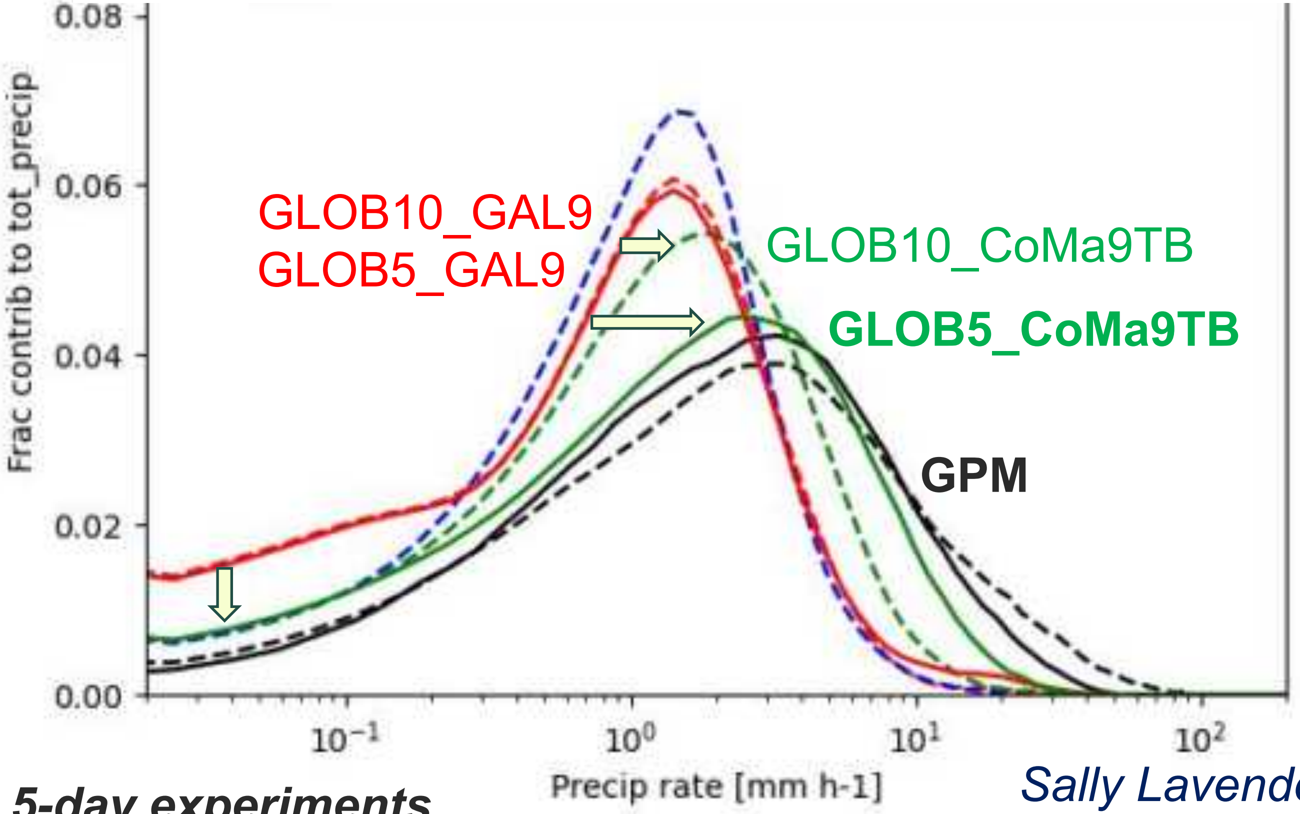
- New mass-flux convection scheme
- Developed for use across traditional global weather (10km) to climate (25-150 km) model resolutions

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*



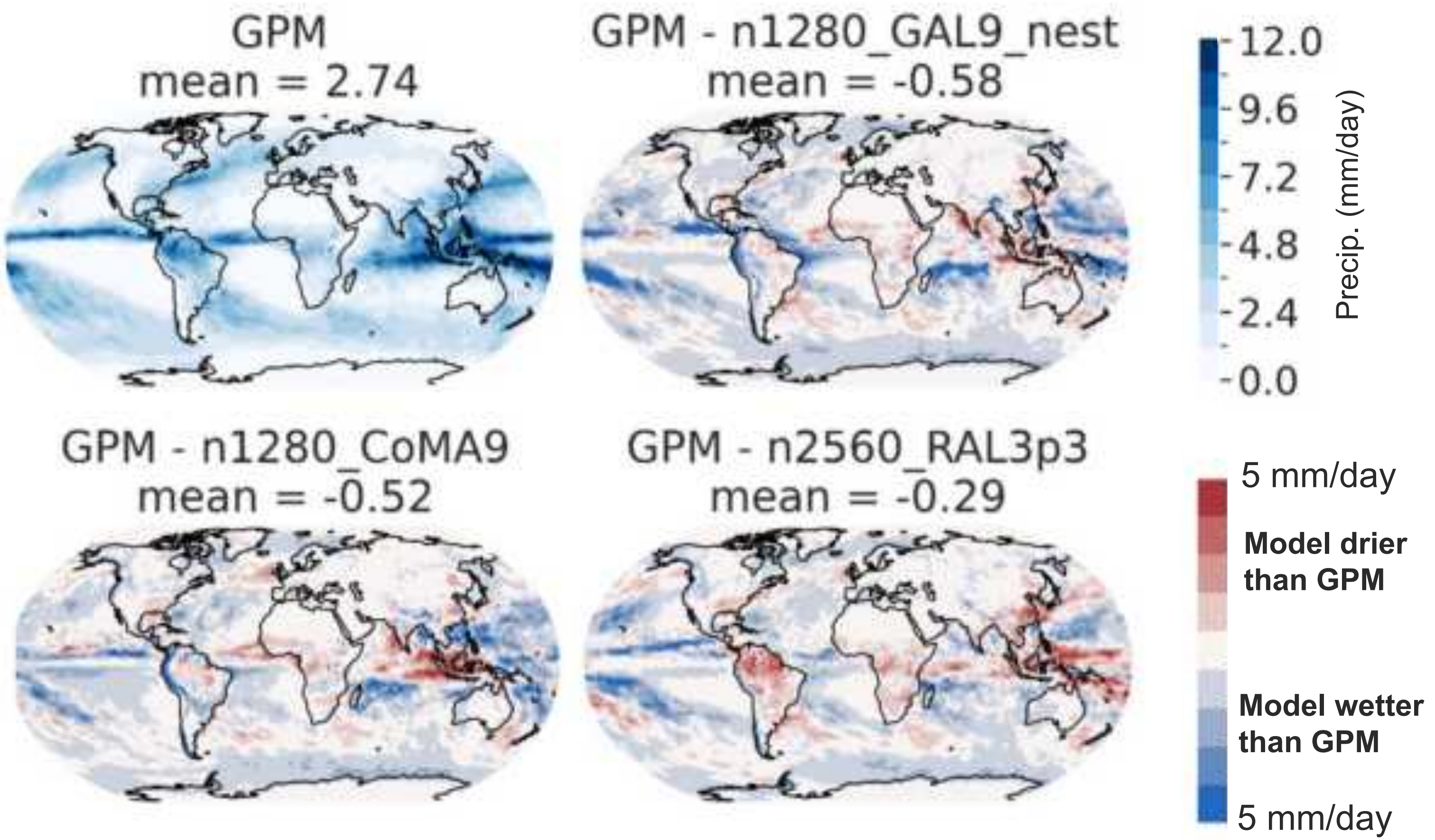
5-day experiments

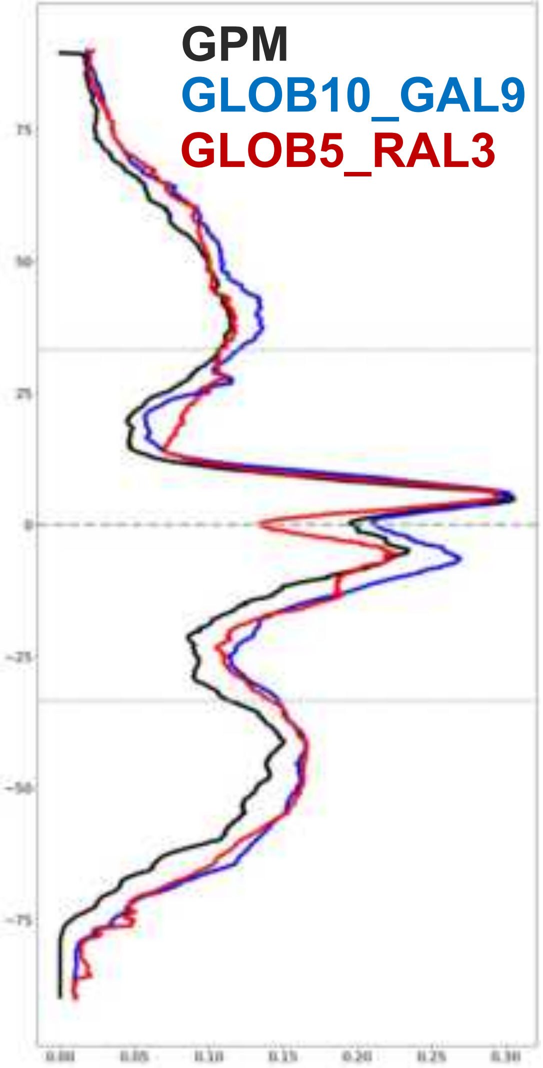
Sally Lavender

Lock et al. (2024)   Lavender et al. (2024)   Zhu et al. (2024)

Running with explicit convection on global domains:
Utilising a unified RAL3 science configuration

Global precipitation patterns and zonal mean

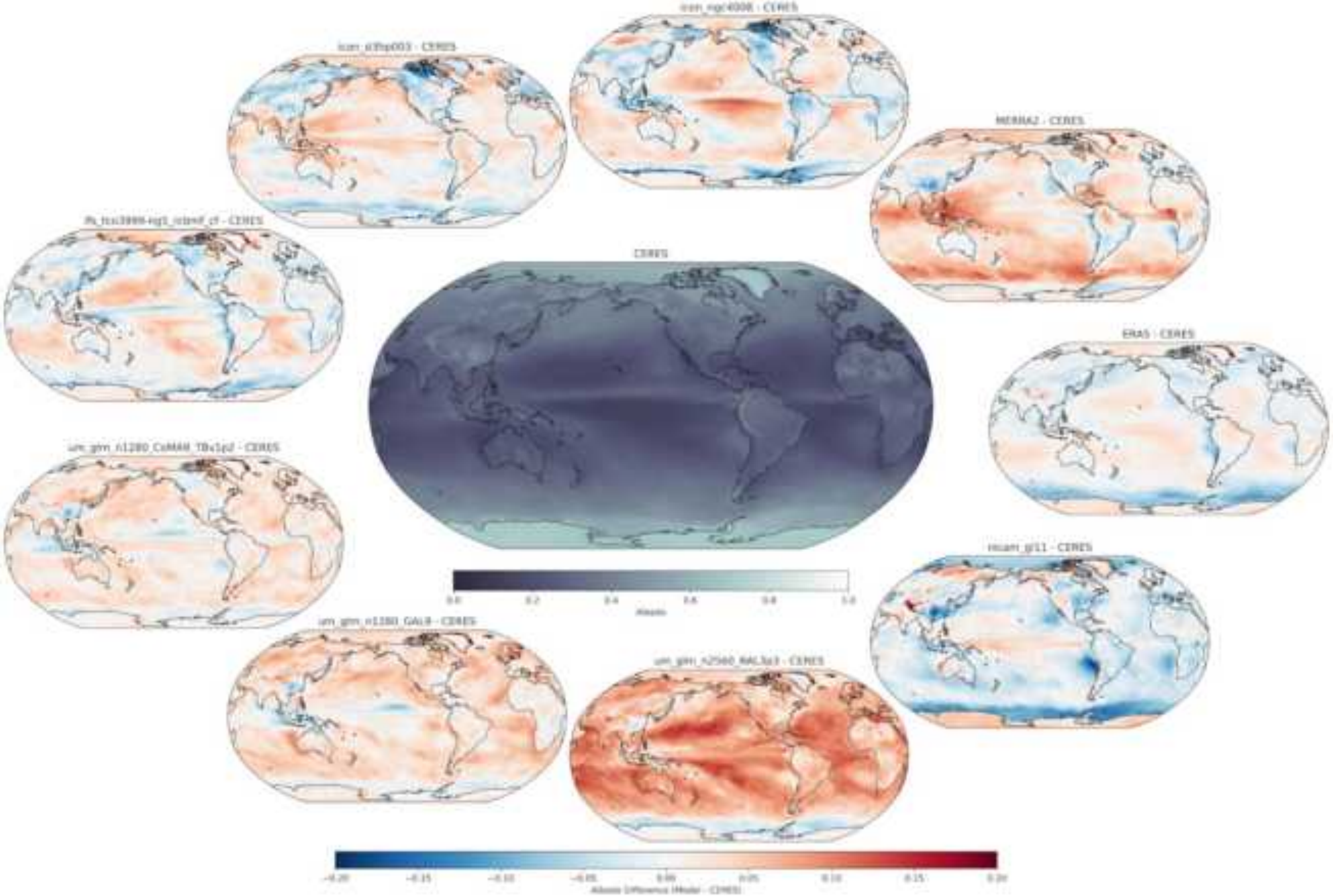


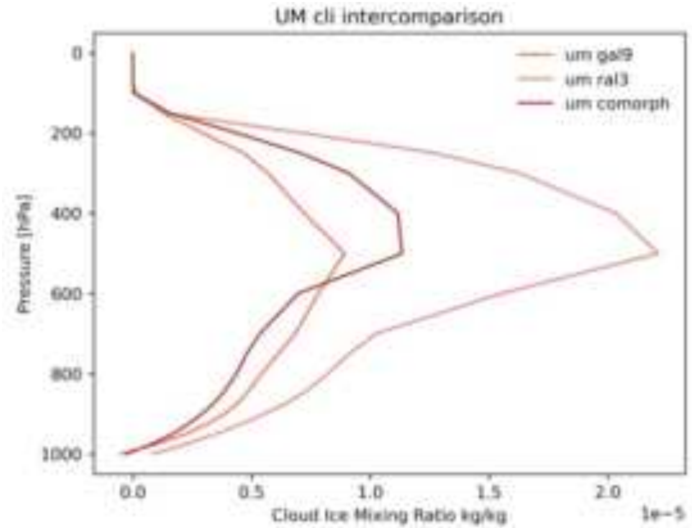


Bush et al. (2024)

Calum Scullion and Huw Lewis

First looks from WCRP global km-scale hackathon



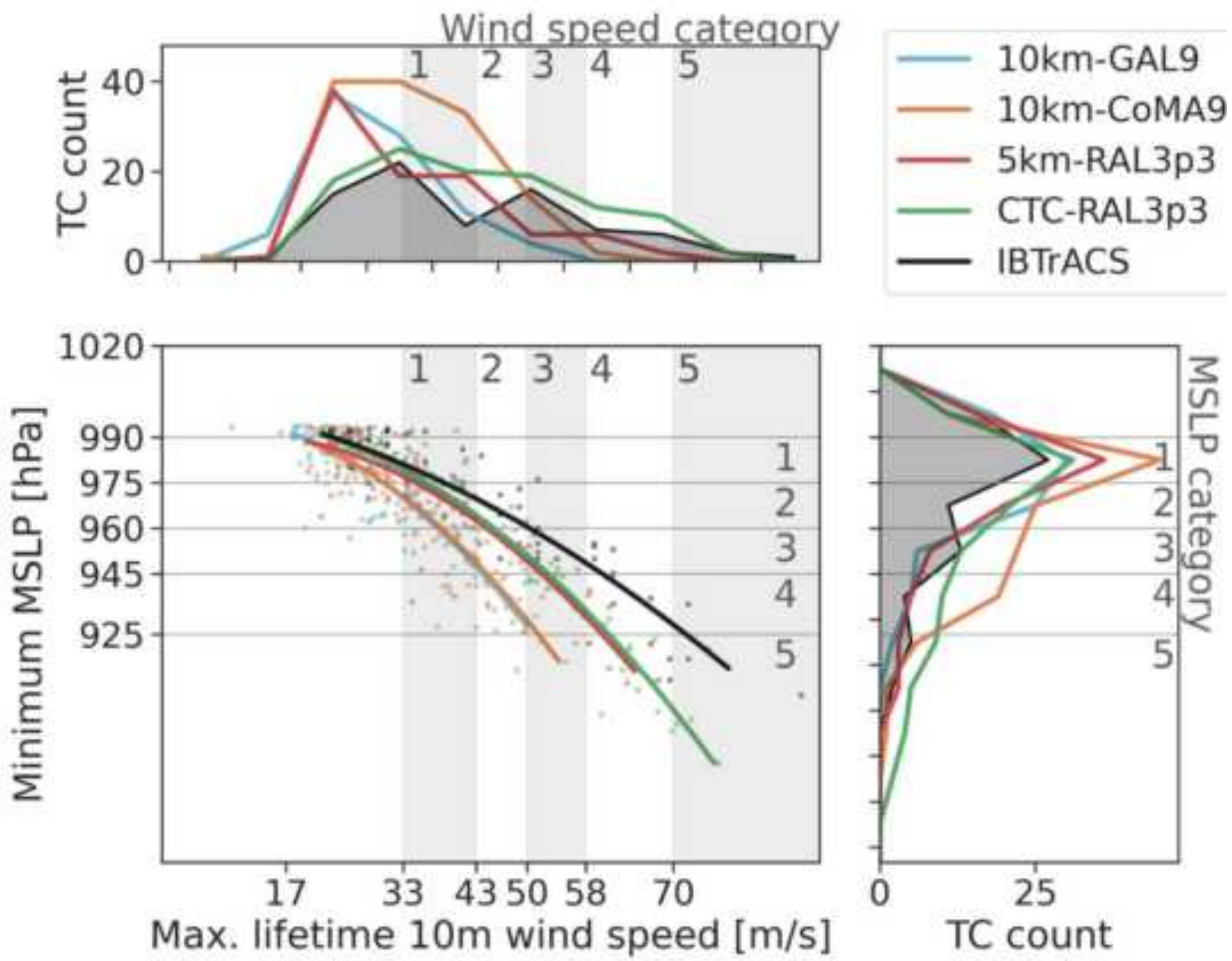


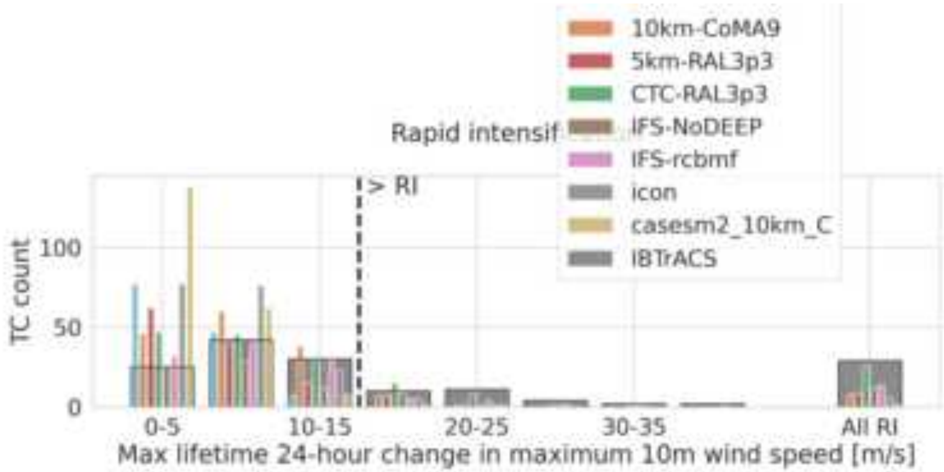
Clouds in N2560 RAL3p3 simulations are more reflective than other GSRMs and CERES. Profile plot above shows additional ice in RAL3p3 – cloud fraction is largely similar to other GSRMs and UM CoMA9 and GAL9

Rebecca Murray-Watson and Emilie Fons

Met Office

First looks from WCRP global km-scale hackathon

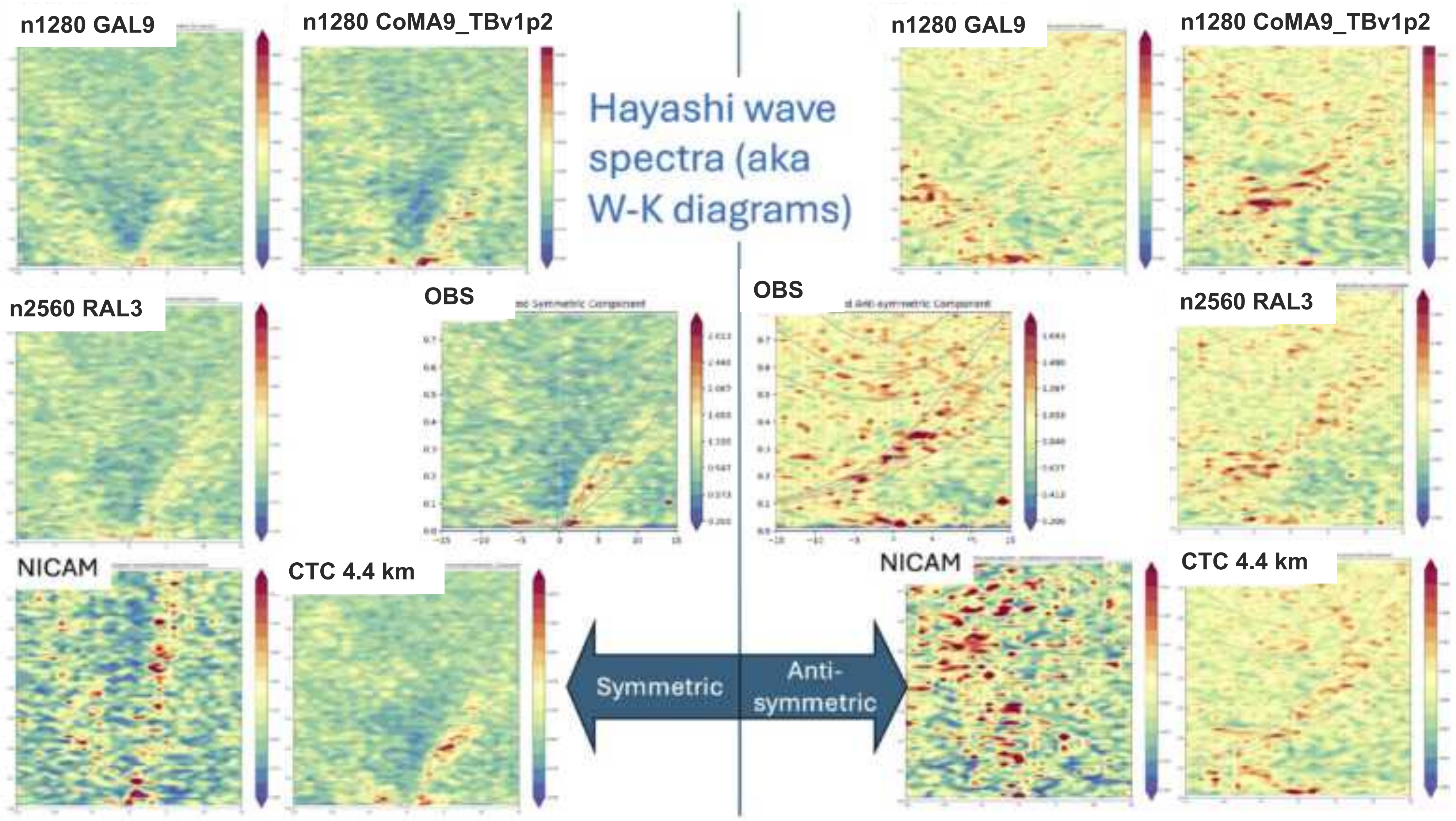




UM CTC 4.4 km has too many intense (>=cat 3 storms) TCs. N2560 RAL3p3 slightly too few. Absence of cat 5 storms in N1280 CoMA9_TBv1p2 and N1280 GAL9 is expected at this resolution.

Calum Scullion (Met Office) *– see poster session 4 & 5 (today) for more details*

First looks from WCRP global km-scale hackathon



Pier Luigi Vidale (NCAS, Uni of Reading)

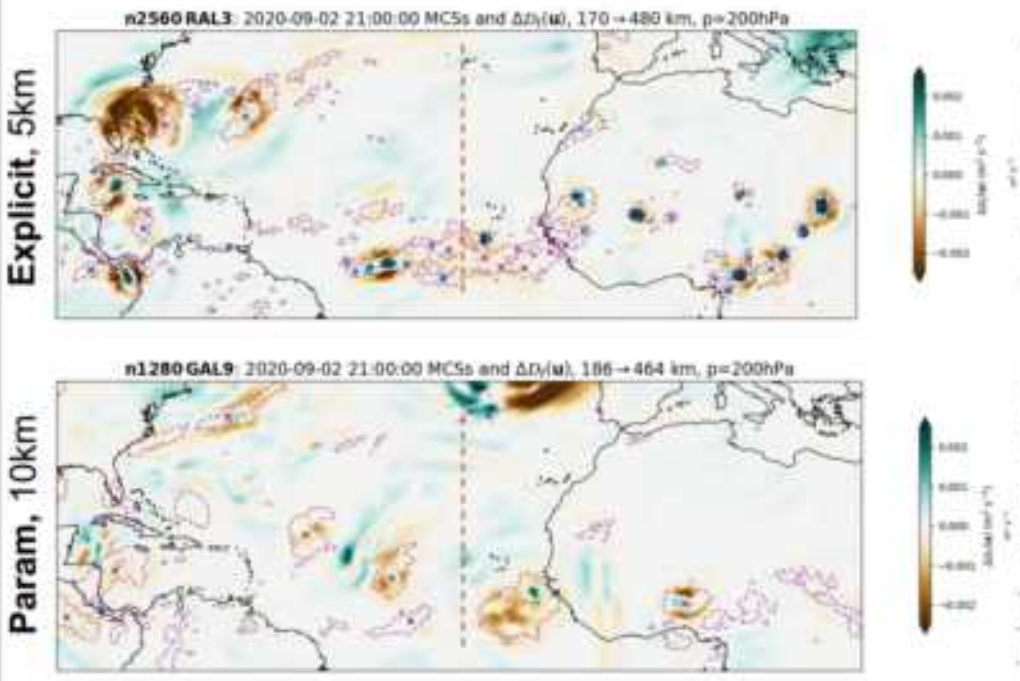
First looks from WCRP global km-scale hackathon

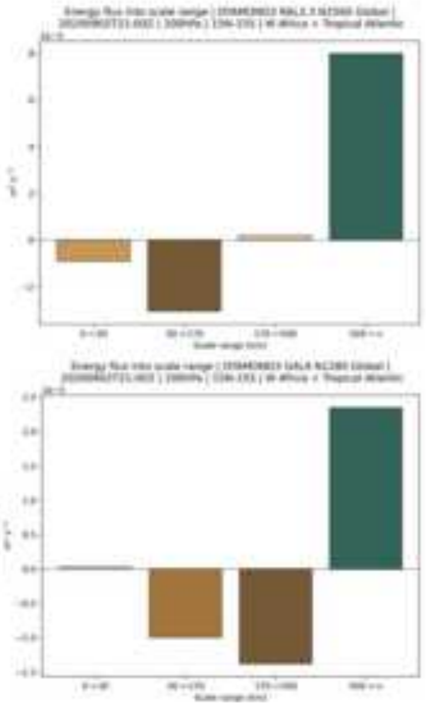
Met Office

RAL3.3
n2560

GAL9
n1280

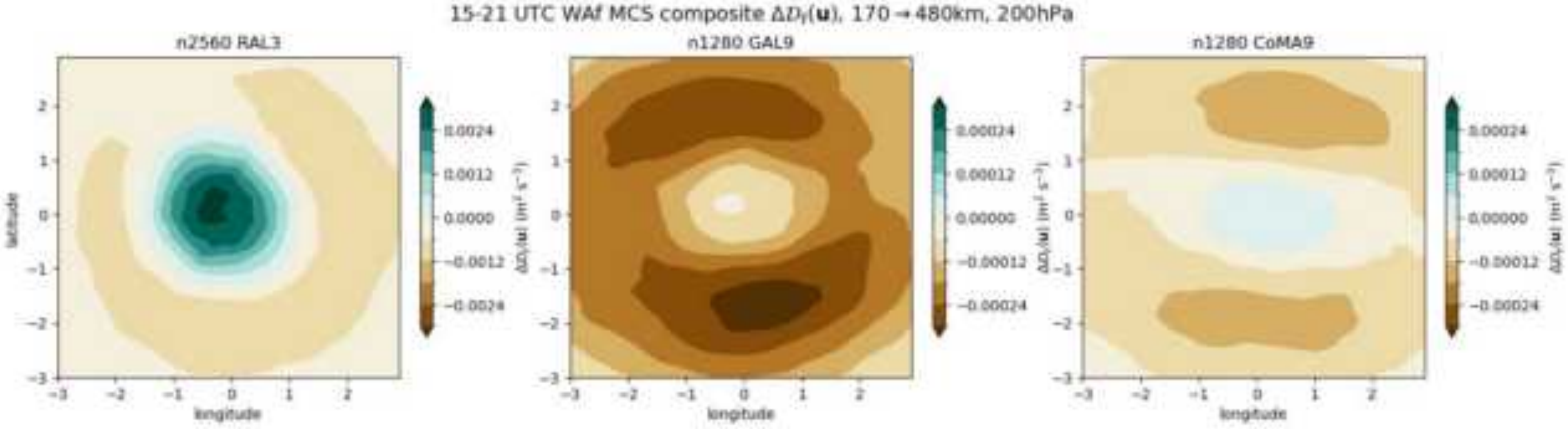
241K brightness T tracked MCS
centroid





Shading is the difference between ~450km and ~85km scale kinetic energy transfer at 200hPa, so positive here is upscale transport from scales >140km to those beyond ~450km. Bars show cumulative mean flux into distinct scale ranges across W Africa

Note different y-axis limits – 3-4x more flux into scales >480km in RAL3.3!



Composites of all September evening MSCs over W Africa show similar story. CoMA9 is beginning to show progress towards RAL3p3.

Elliot McKinnon-Grey, Dan Shipley, Ben Maybee

LoSSETT = Local Scale-to-Scale Energy Transfer Tool

Progress towards seamless convection-permitting global simulations

Previous delays or barriers

- Different param. schemes in GAL and RAL
- Convection parameterised or explicit
- "Seams" in regional config(s)
- More limited HPC resource
- Large data volumes difficult to work with
- Model scalability

Key enablers to future progress

- Global and UK partners
- Scale-aware convection scheme +
- Unified Physics
- Exploit AI and new file formats
- Additional resource on new HPCs
- Transition to LFRic

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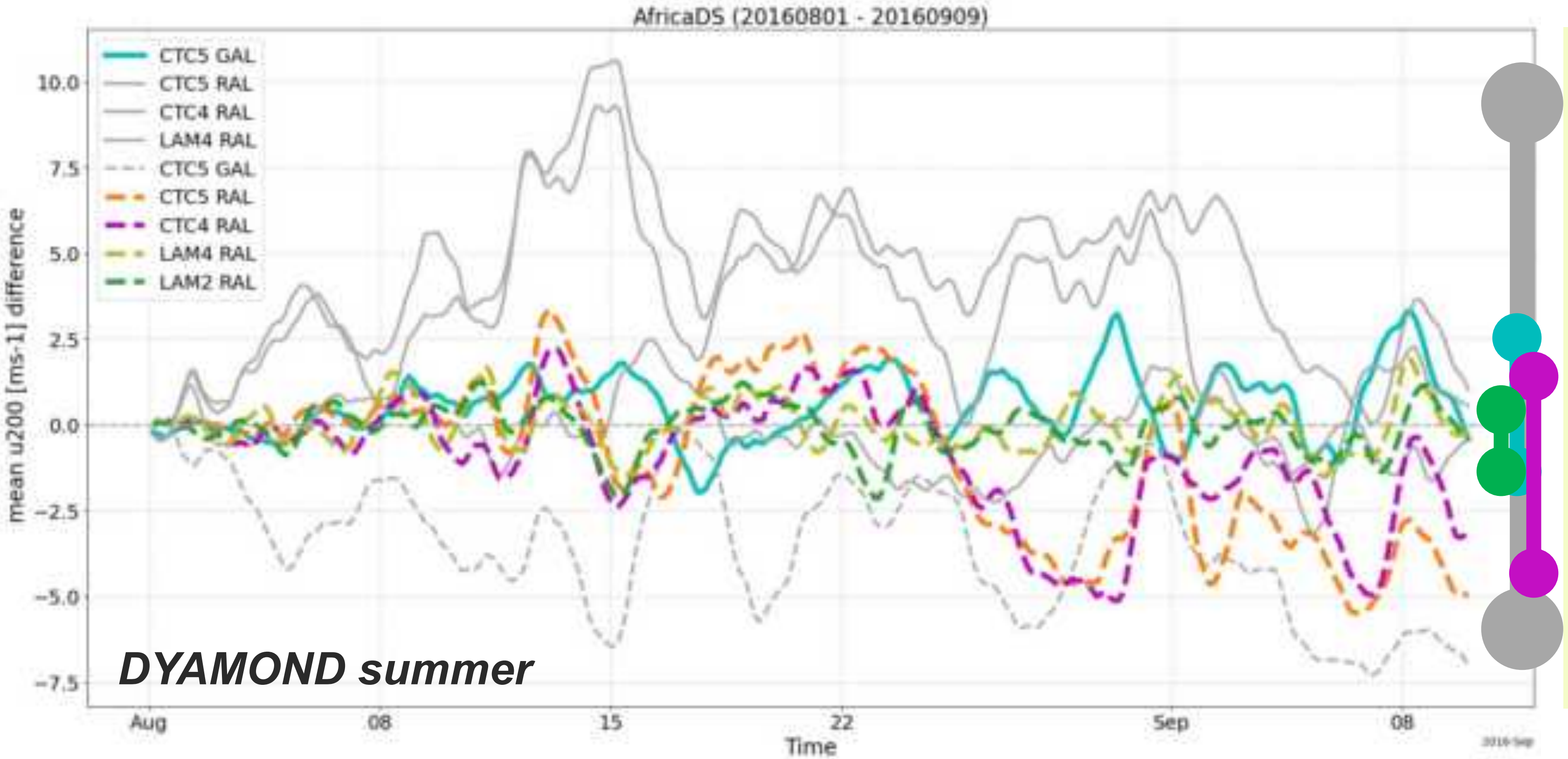
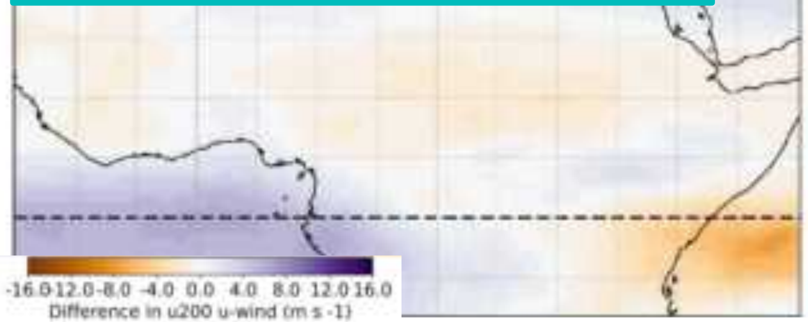
Signatures of upscale to large-scale flow

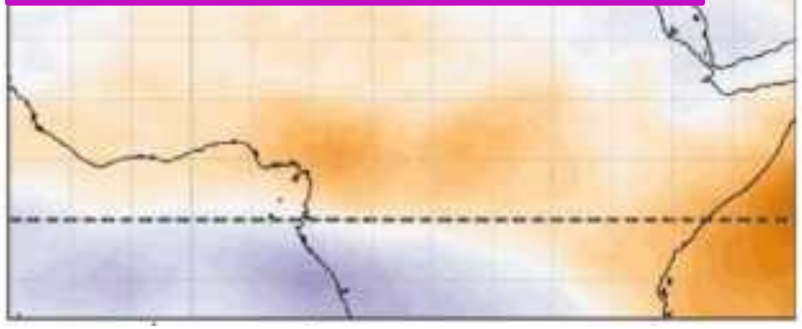


- Consider differences in u200 relative to global driving model
- Strong sensitivity to physics (GAL vs RAL); differences within hours
- Large-scale in continental LAM closely follows driving model
- Large-scale in CTC diverges from driving model more strongly, but only when convection is explicit
-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

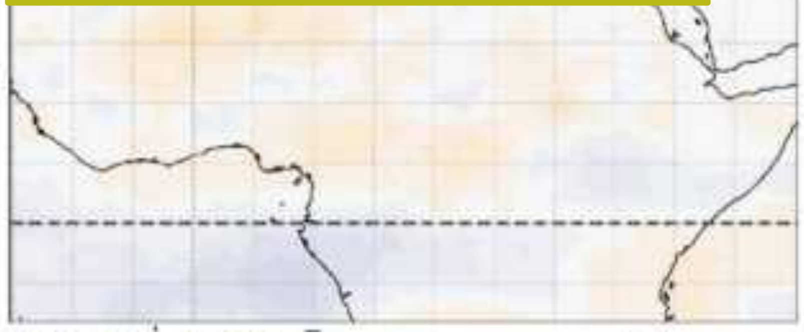
CTC5 GAL - GLOB10 GAL



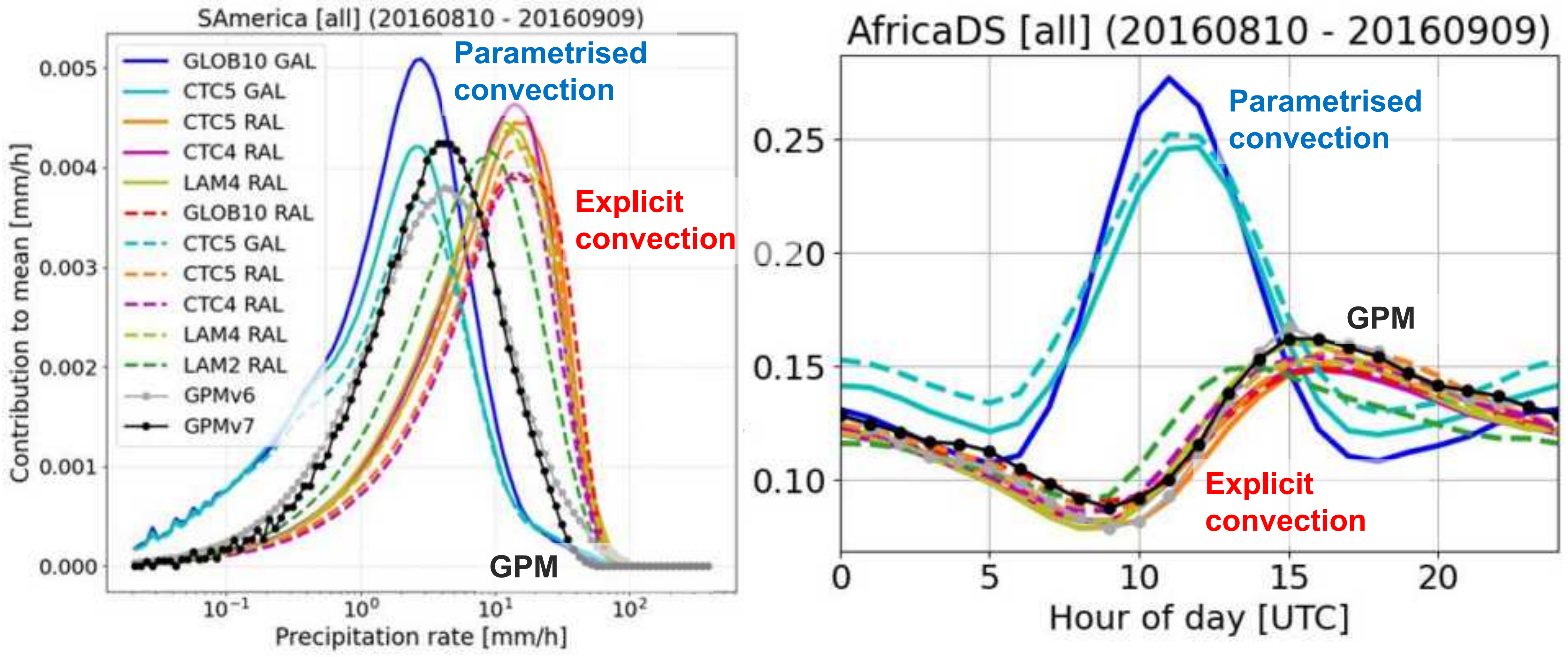
CTC4 RAL - GLOB10 RAL



LAM4 RAL - GLOB10 RAL



Regional evaluation of resolution and physics dependencies



Results from earlier DYAMOND summer 40-day experiments

Jones et al., BAMS, in prep.

First looks from WCRP global km-scale hackathon

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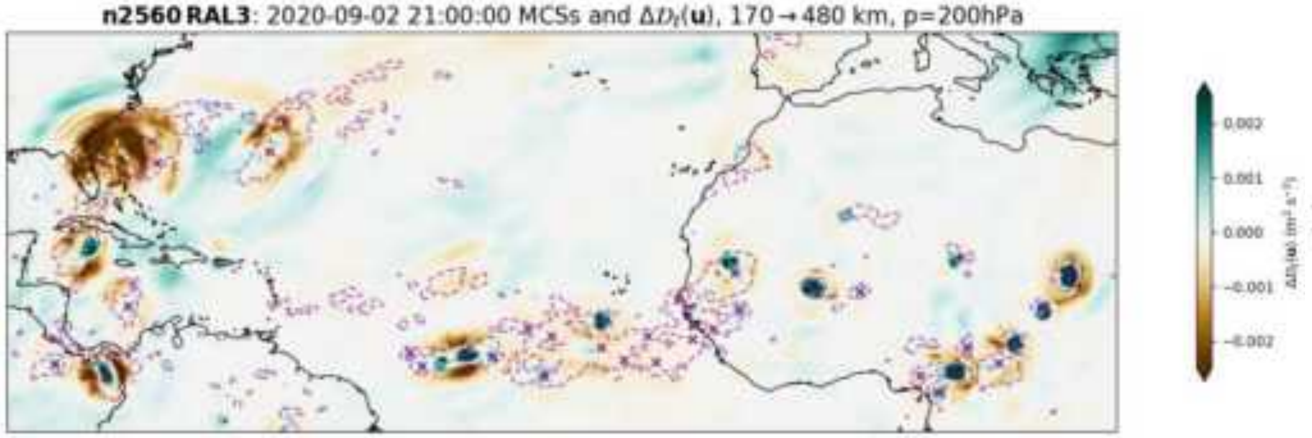
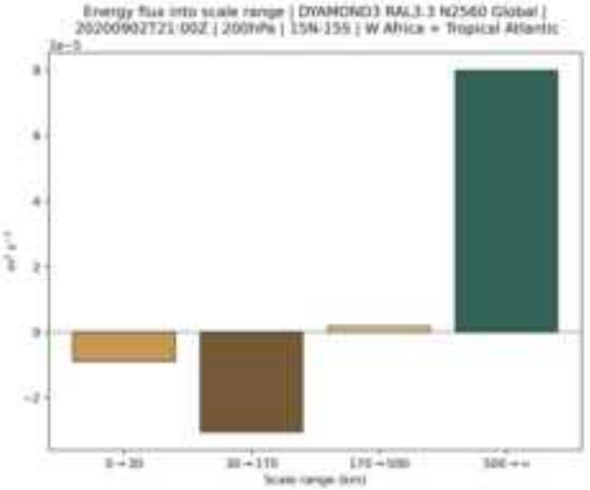
RAL3.3
n2560



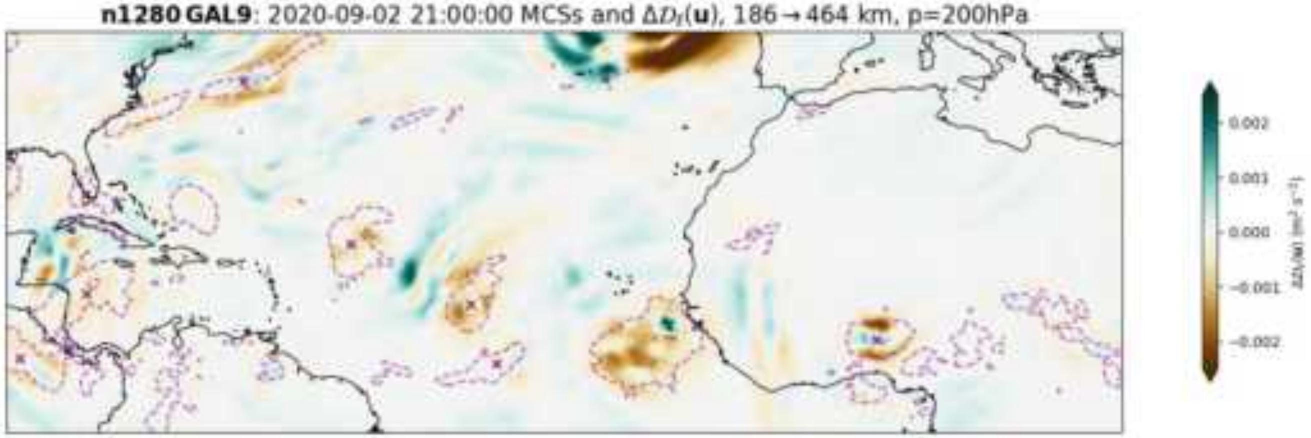
241K brightness T
tracked MCS centroid

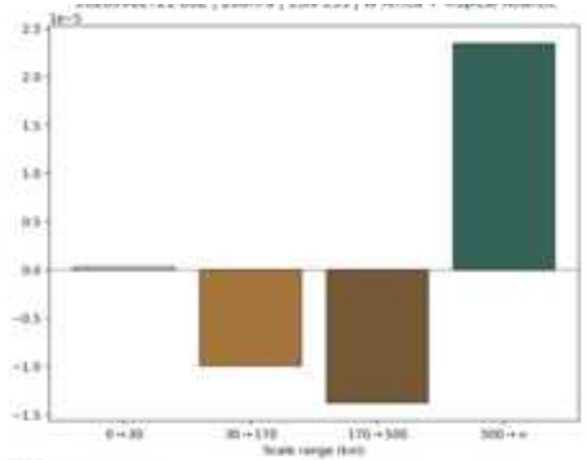


energy flux into scale ranges
- <30km
- 30-170km
- 170-480km
- >480km

averaged over domain of left column plots

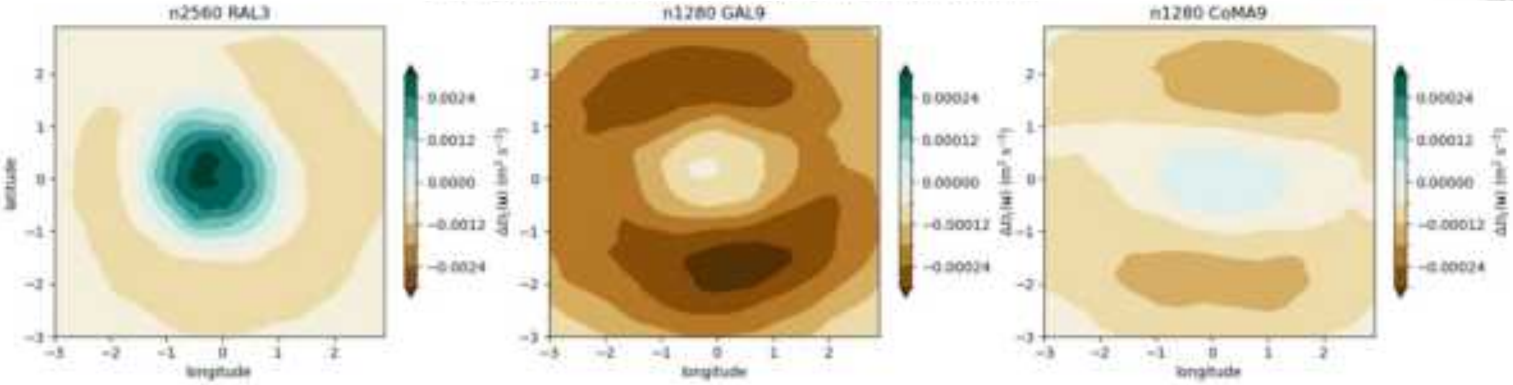
GAL9
n1280





Note different y-axis limits – 3-4x more flux into scales >480km in RAL3.3!

__Ben Maybee__, Elliot McKinnon-Gray, Dan Shipley, Callum Scullion



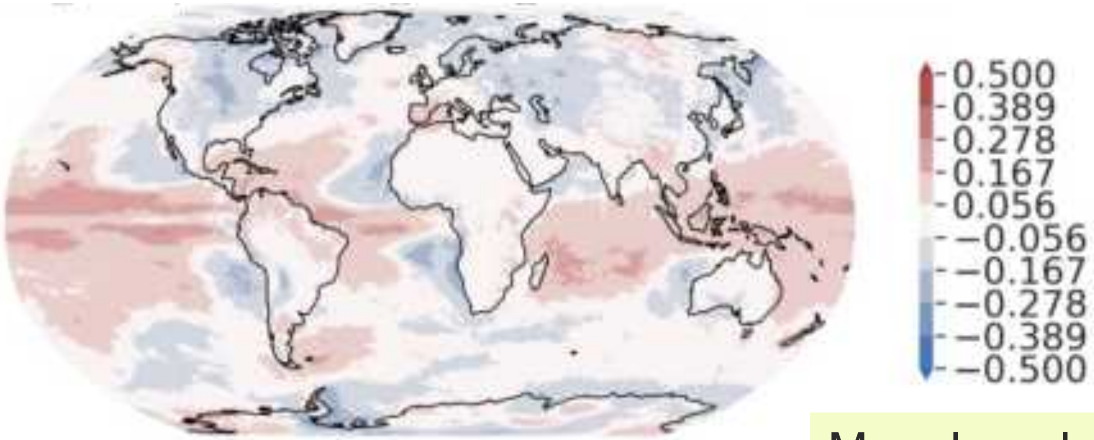
← Composites for Sept. 15-21UTC MCSs in W. Africa + Trop Atlantic

Messages to get across

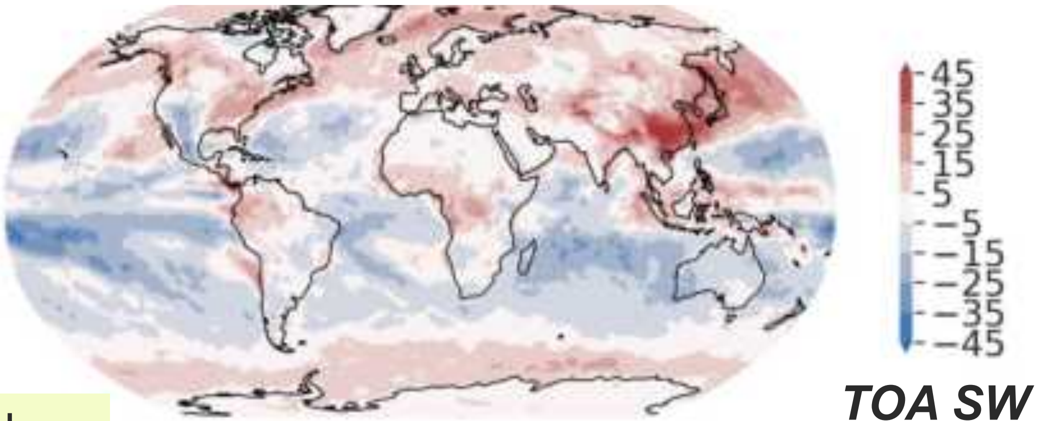
- Why the hierarchy – its not about having a better downscaled forecast(!) – as well as comparing with coarser resolution benchmarks also compare with high-res regional simulations
- DYAMOND-3 simulations – year long (Jan 2020-Feb 2021) – simulations using a variety of physics configurations including explicit convection global (N2560 RAL3p3) and the utilising the new CoMA9_TBv1p2 convection parameterisation (tuned for running at ~5 km resolution).
- Initial results – often physics dominates over resolution in terms of model behaviour, however when looking at KE spectra its of course resolution that dominates what wavelengths are resolved…
- First looks from WCRP hackathon outputs – exciting new results – further configuration development needed for exp. convection global
- A nod to the past and a look to the future

Running with explicit convection on global domains:
Cloud and radiation feedbacks

Low cloud fraction difference



Cloud radiative effect *[TOA clear-sky – actual]*

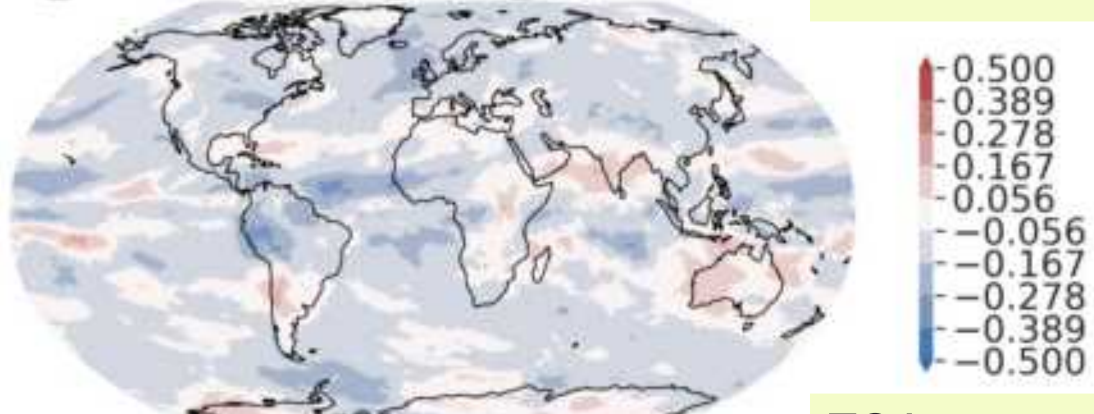


TOA SW

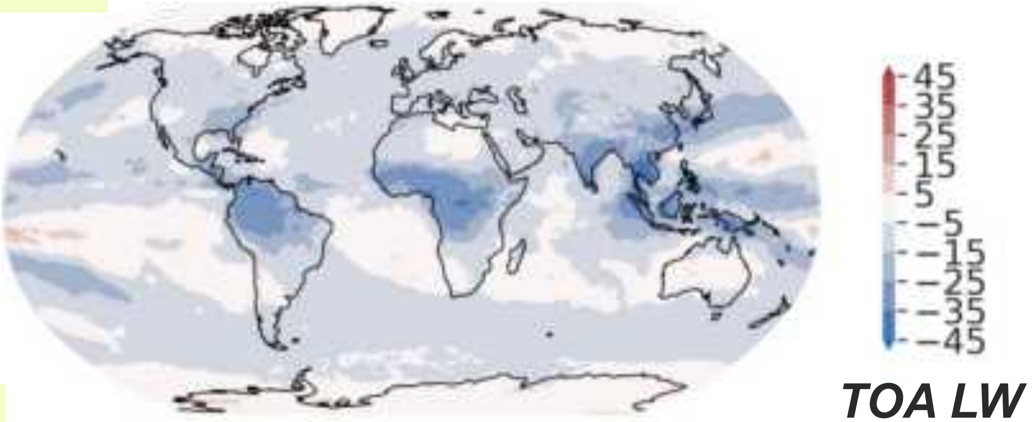
GLOB5_RAL3 - GLOB10_GAL9

More low cloud, less high cloud with RAL3 than GAL9

GLOB5_RAL3 - CERES



High cloud fraction difference



TOA LW

TOA energy imbalance with RAL3

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Seamless journey

The past

- Convection-permitting (RAL) configurations with differences between mid-latitude and tropical regions
- Significant “seams” between regional and global configurations e.g. different large-scale cloud and cloud microphysics schemes
- Push towards high-resolution global simulation slowed by competing challenges of LFRic global and regional development (also the present!)
- Technical challenges with ancillary generation, HPC resources, STASH output limited due to data volumes…

(My) Vision for the future

- Unified physics across regional and global model configurations to enable agile model development
- Scale-aware parameterisations to simplify comparison of high-resolution with coarser resolution benchmarks
- **Collaborative effort to push towards a global physics configuration that can be exploited in LFRic (and UM) at resolutions of ~ 5 km and finer (use of GAL vs RAL physics options?).**
- **Convection-permitting global simulations running on our new HPC**
- Exploiting new technologies and file formats that allow new global collaborations to grow

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Met Office

Summary remarks

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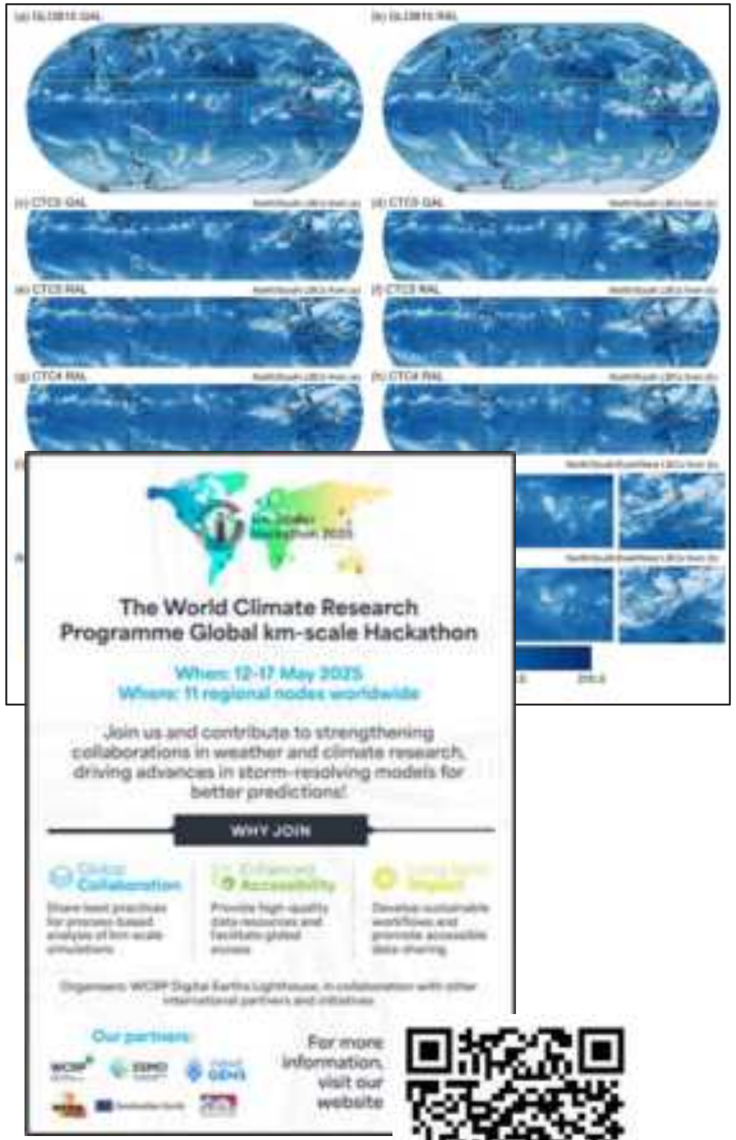
- Encouragement to develop and exploit global and regional (coupled) model *hierarchies*…
- …to unpick impacts of resolution, physics and domain size on unlocking representation of *upscale processes* in weather and climate models
- Many more outputs to come out of the WCRP global hackathon and new collaborations created. International intercomparison and learning from each other
- Sharing of evaluation and diagnostic tools, *e.g. CSET*, will enhance our community efforts

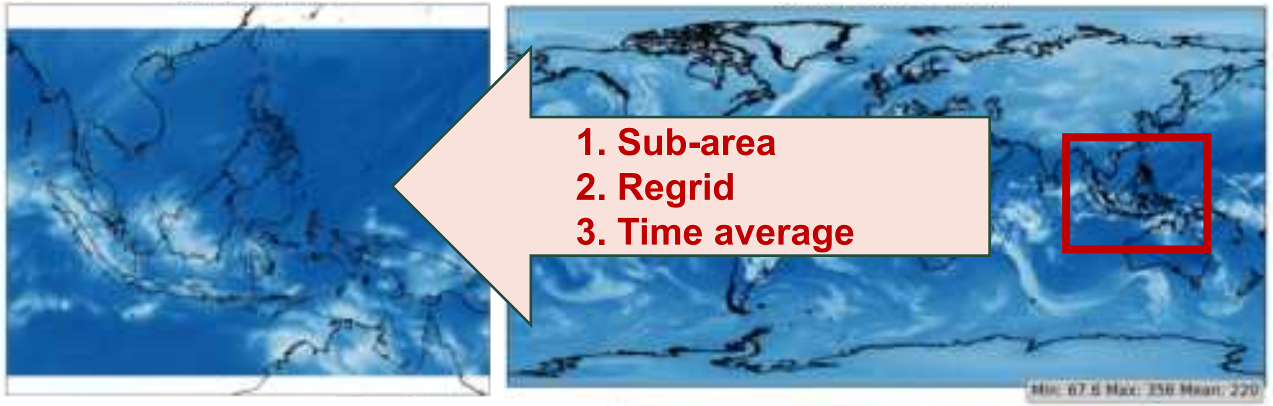


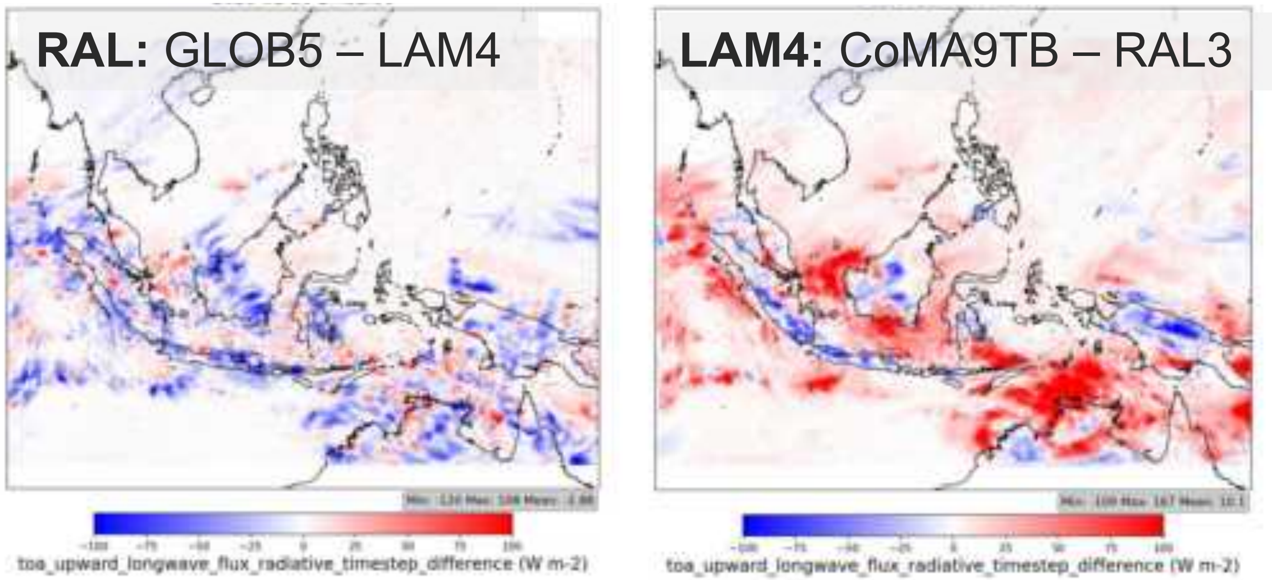
WCRP hackathon

Introducing CSET:

Convective-Scale Evaluation Toolkit

- Open-source, portable
- python-based libraries
- Recipe-driven flexibility
- ***Collaboration welcome!***





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