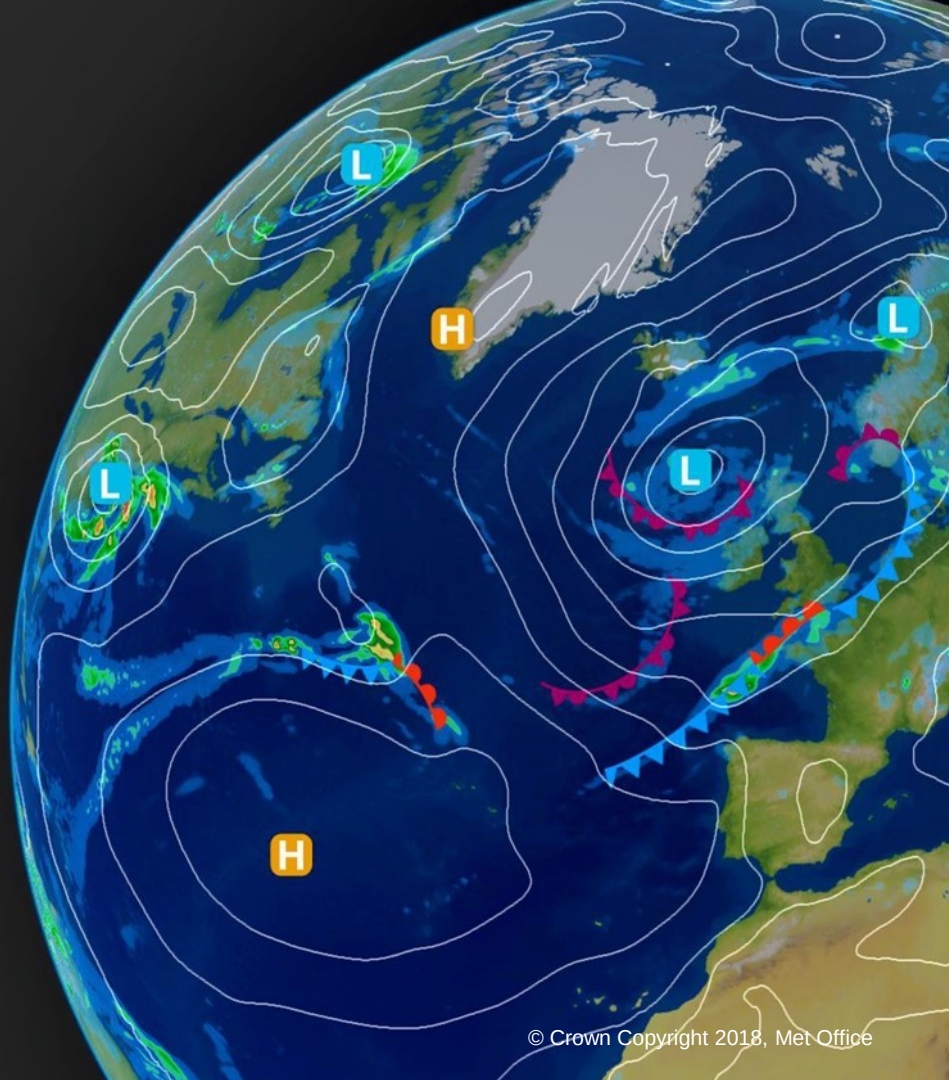
# “Regional Atmosphere”

## Developing a unified science configuration for Convection-Permitting Climate and NWP simulations

Mike Bush + a cast of thousands!

GEWEX Convection-Permitting Climate Modelling Workshop II

Boulder, 4th - 6th September 2018



# Key Motivations for maintaining and developing a CP modelling capability

- NWP
- Climate downscaling
- Process Research and model development
- Developing future capability

# Climate downscaling goals

- Providing sufficient computing resources are available, kilometre-scale regional climate experiments can be used towards several goals:
  - i)  to review the extent to which currently available regional climate projections from coarser resolution models are reliable or robust;
  - ii) for use in policy making decisions;
  - iii) to deliver new guidance and driving data for regional impacts modelling;
  - iv) to inform physical parameterization development in coarser resolution global and regional models (in which convection is parametrized).

# Climate downscaling and rainfall

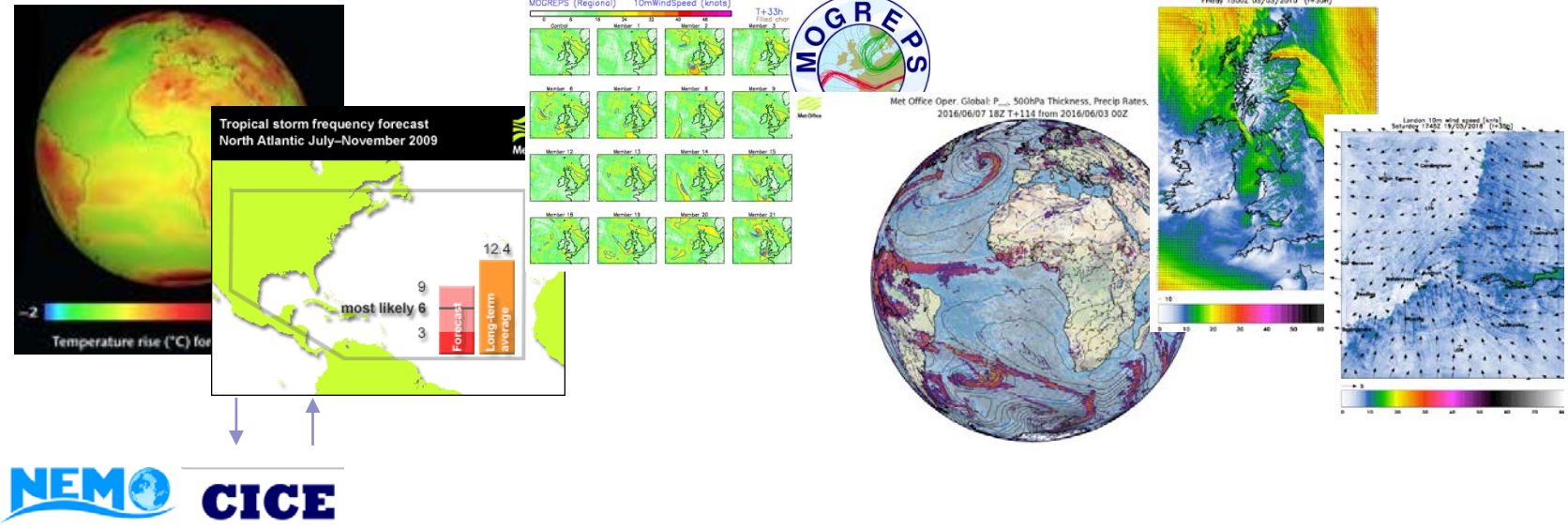
- CP climate models do not necessarily better represent daily mean precipitation, but they have significantly better:
  - i)  sub-daily rainfall characteristics with improved representation of the diurnal cycle of convection;
  - ii) spatial structure of rainfall and its duration-intensity characteristics;
  - iii) intensity of hourly precipitation extremes,
- All of the above are typically poorly represented in climate models.

# The Unified Model (UM)

- The UM has been designed as a flexible code base for use in both global and regional weather and climate prediction and can be implemented with a wide range of grid spacings, from sub-kilometre to hundreds of kilometres.
- There are benefits and disadvantages to this so called seamless approach.  Note that by seamless we do not mean that and identical model configuration is used in all applications, rather that deliberate and traceable differences are made to the model to tackle the task in hand.

# The Met Office Unified Model

## Primary applications of the UM today




Δx ≈ 130 → 60 km | Δx ≈ 20 km | Δx ≈ 10 km | Δx ≈ 1.5 km | Δx ≈ 330m

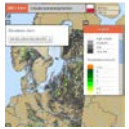
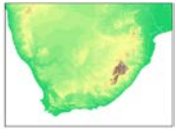
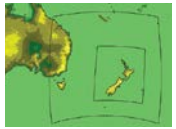
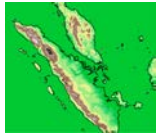
*Cullen (1993), Brown et al. (2010)*

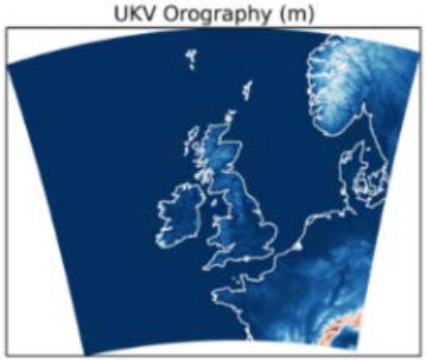
# A Manageable number of scientific configurations

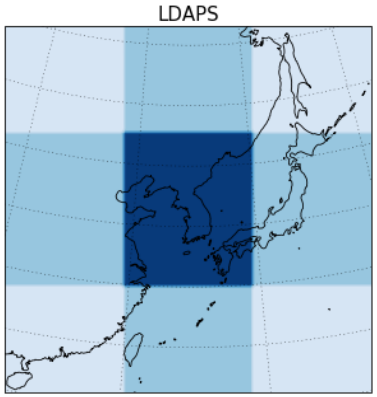
- One challenge is to ensure that there are a manageable number of scientific configurations of the model. One such configuration is the CP version of the model which we name the "Regional Atmosphere" (RA) science configuration.
- This is a derivative of the Global Atmosphere GA configuration but a starting obvious difference is that RA does not include a parametrization scheme for deep convection.

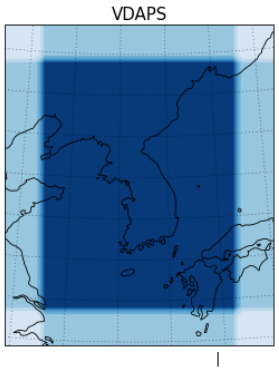
# Met Office and UM Partner domains

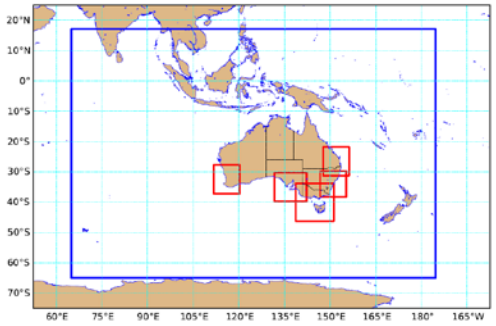
| Organization | Country | Models |
|---|---|---|
| KMA | South Korea | Global (OP05): 10 km; LDAPS and VDAPS: 1.5 km |
| BoM | Australia | LAM: 12 km, 5 km, 1.5 km |
| NCMRWF | India | Global: 12 km; LAM: 4 km |
| NIWA | New Zealand | LAM: 12 km, 1.5 km |
| SAWS | South Africa | LAM: 4.4 km, 1.5 km |
| USAF | USA | Global: 17 km, testing LAMs |
| ICM | Poland | LAM: 4 km, 1.5 km |
| Met Office | UK | UKV: 1.5 km, MOGREPS-UK 2.2km |
| MSS | Singapore | LAM 1.5 km |
| PAGASA | Philippines | LAM to be installed |



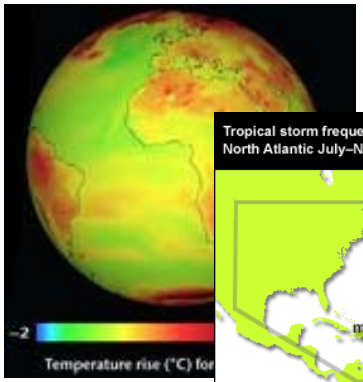



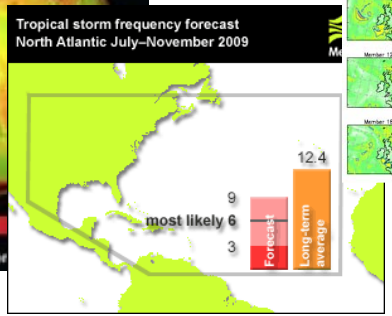



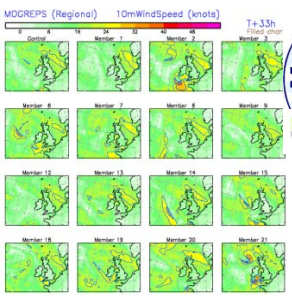



# Tropical domains

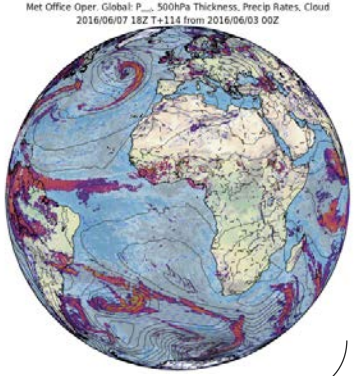
# The Met Office Unified Model

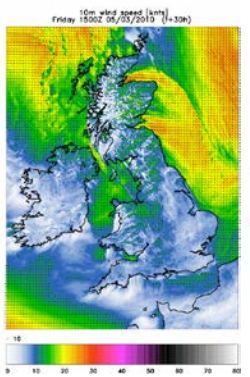


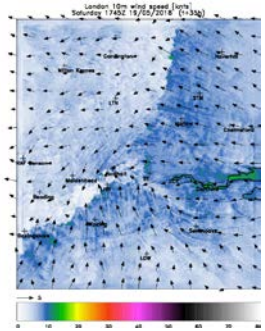








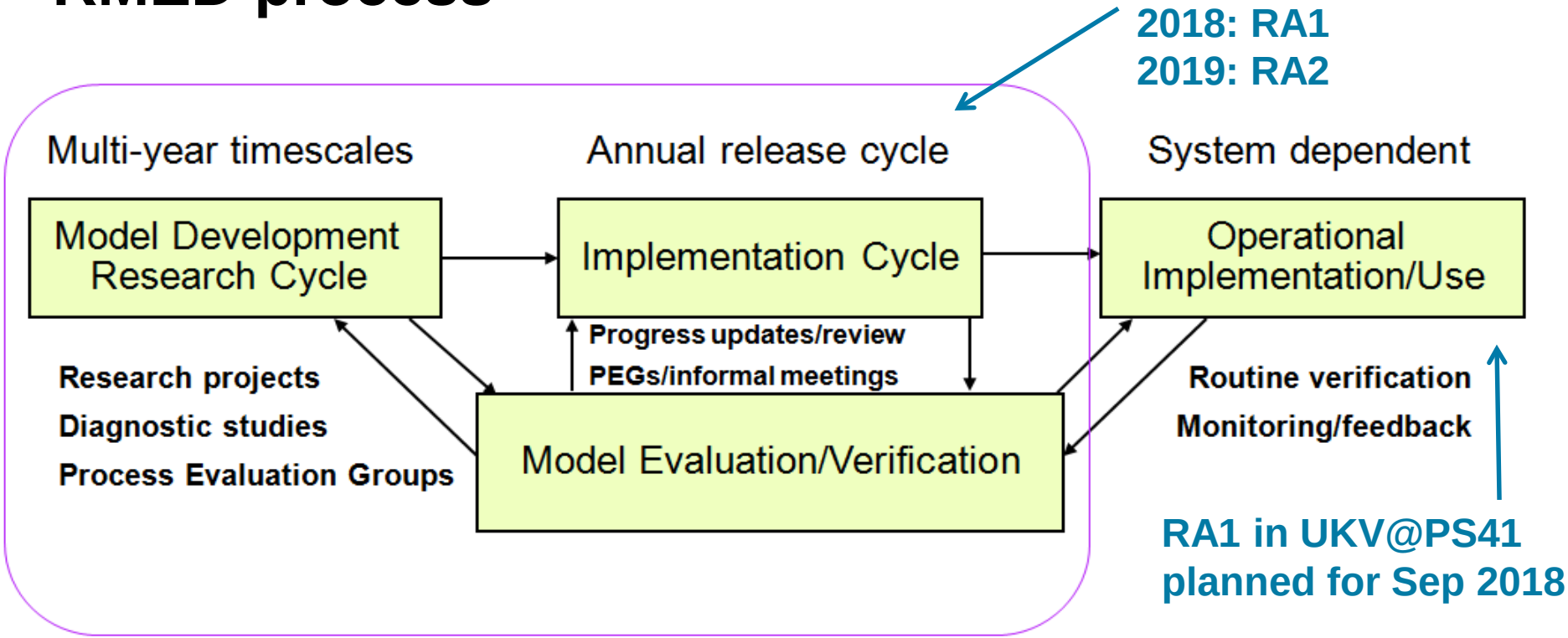
Met Office Unified Model™
Global Atmosphere

Met Office Unified Model™
Regional Atmosphere

# The RA science configuration

- The RA science configuration is a traceable derivative of the equivalent "Global Atmosphere" science configuration of the UM (GA: e.g. Walters et al., 2011) developed for use at grid lengths of ~10 km or larger, where convection parametrization is required.
- The first release of this configuration, RA1, defines a set of dynamics and physics schemes and settings designed to be used in all CP applications of the UM.
- Its coordination and release is led by a central team located in the Met Office, but its development and evaluation relies heavily on a wider effort coordinated across the Met Office science programme with contributions from UK and international partners (including the UM partnership).

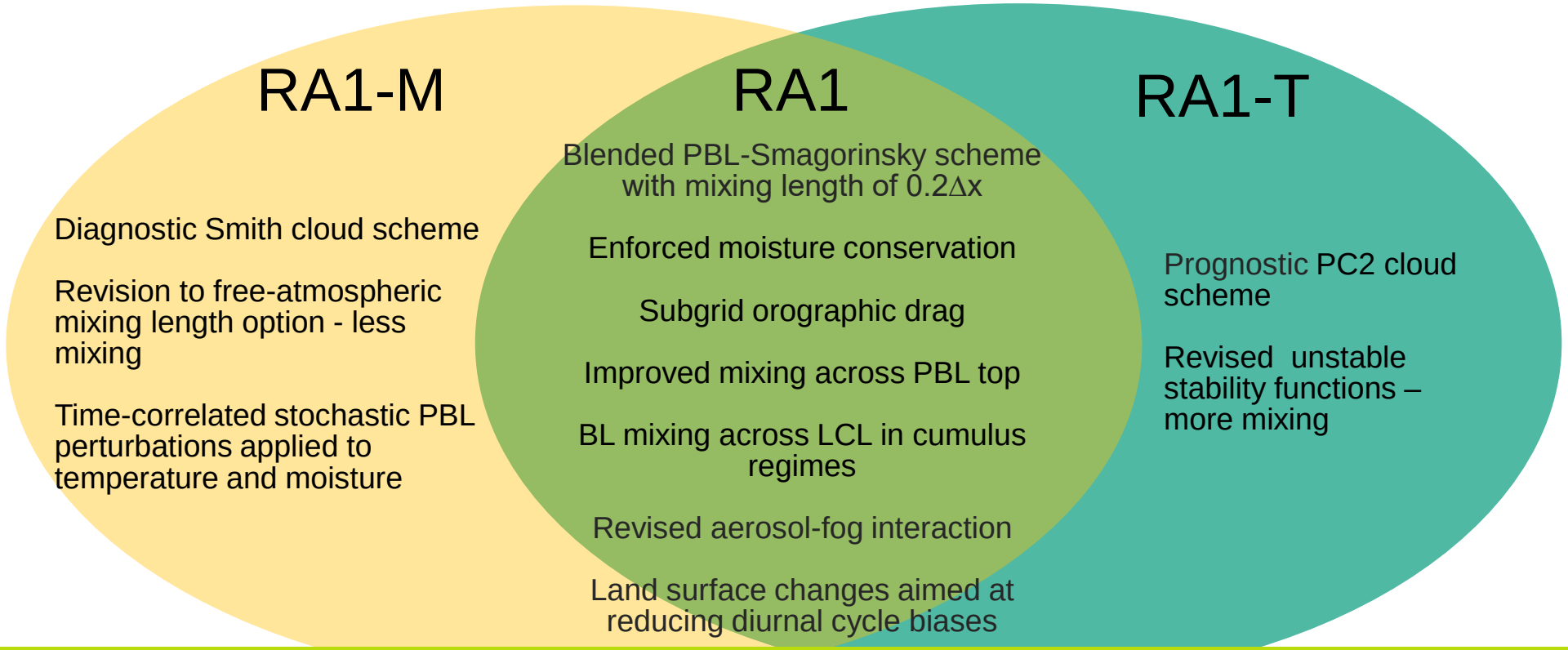
# RMED process



# RA1

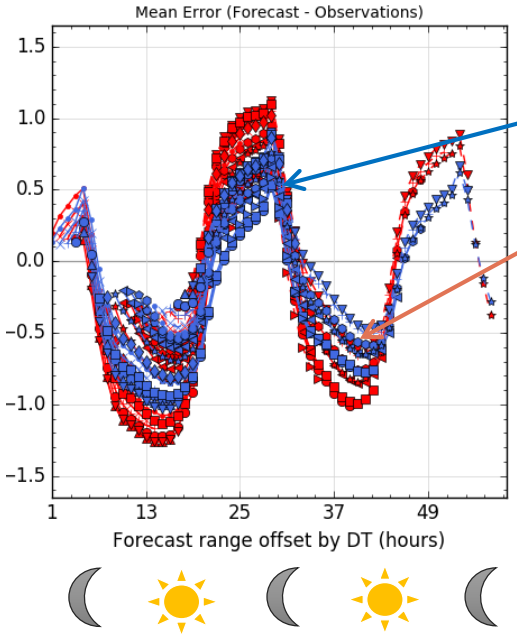
- While a long-term aspiration is to develop a single regional RA configuration which performs well across the globe, at this stage RA1 currently has two sub-versions, one for mid-latitude locations (RA1-M) and one for the tropical regions RA-1T).
- The definition of RA1 is an important step in the development of high resolution configurations of the Unified Model. By concentrating the model development effort on a single convection permitting configuration, the UM community are better placed to learn from each other and to identify and resource the main priorities for future model development.
- The science developments included in RA1 significantly improve two long-standing issues with high resolution UM simulations: the inclusion of moisture conservation reduces overly intense local precipitation rates and the changes to land use and vegetation properties improve a  damped diurnal cycle in near-surface temperatures.

# Mid-latitude vs tropical configuration



# Improvement to diurnal cycle of temperature

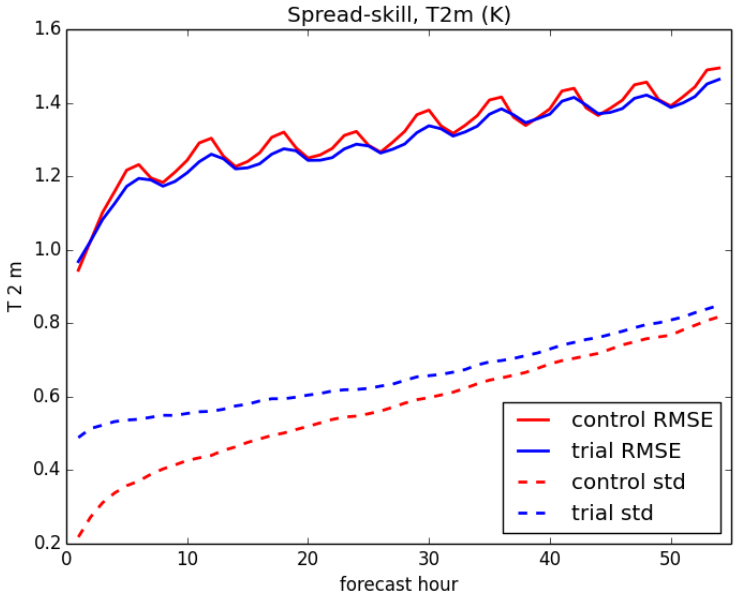
OS40 RA1-M




RA1-M colder at night-time, warmer during daytime

29th May - 06th August 2018

# Impact of RA1 on variability:
## Spread-skill of MOGREPS-UK PS41 (blue) vs control (red)



# Examples of climate vs NWP differences

- Climate settings different to NWP to be consistent with GCM (which uses GA7):
  - i) Time varying vegetation fraction ancillary
  - ii) Use of Easy Aerosol (Bellouin et al);
  - iii) jules_hydrology: TOPMODEL scheme instead of PDM;
  - iv) l_rad_use_clim_volc = true
  - v) l_use_methox = true
  - vi) L_VG_SOIL =FALSE

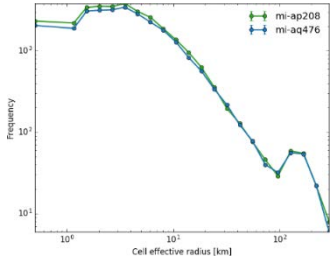
# Coordinated assessment

- In addition to these scientific improvements, the coordinated assessment of RA1 has benefited from technical developments that have enhanced our ability to share results and experience across the UM partnership.
- We have continued to develop relocatable modelling suites that are portable between different high performance computing sites and architectures.
- Similarly, we are developing generalised and portable diagnostics and verification tools that will allow developers to compare results in different domains and systems using a common assessment framework.

# RMED Toolbox
## Model diagnostics

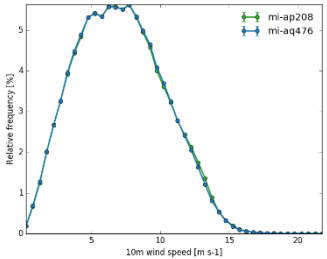
Statistics for convective cells

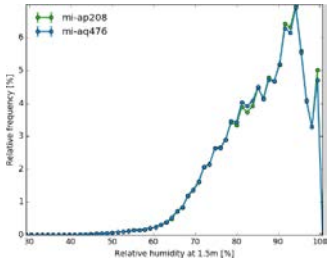
- Frequency distribution of effective cell radius
- Cell mean value




Descriptive statistics for 2D model fields

- Area average
- Histogram
- Analysed fields
  - FF 10 m w, RH 1.5 m, T 1.5 m,
  - LW out at TOA, Cloud amount

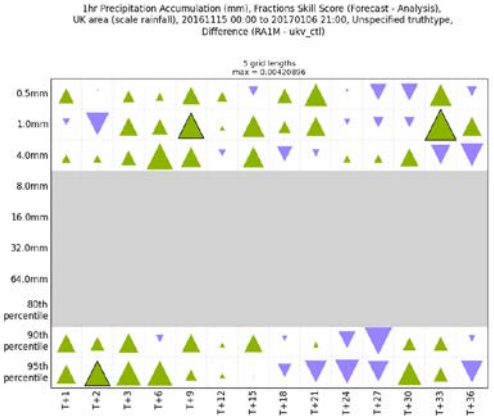


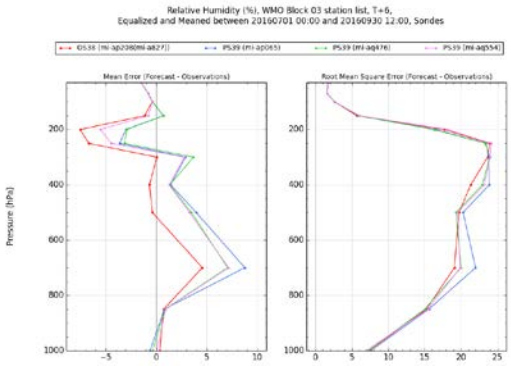

https://code.metoffice.gov.uk/trac/rmed/wiki/suites/eval

# RMED Toolbox
## Objective verification

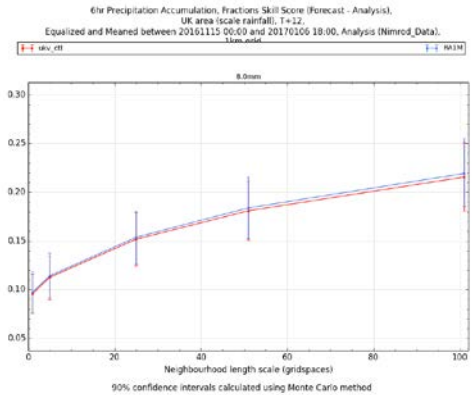
### Hinton Diagrams (FSS & HiRA)




### Mean Error (Profiles)




### Scale Series (FSS)



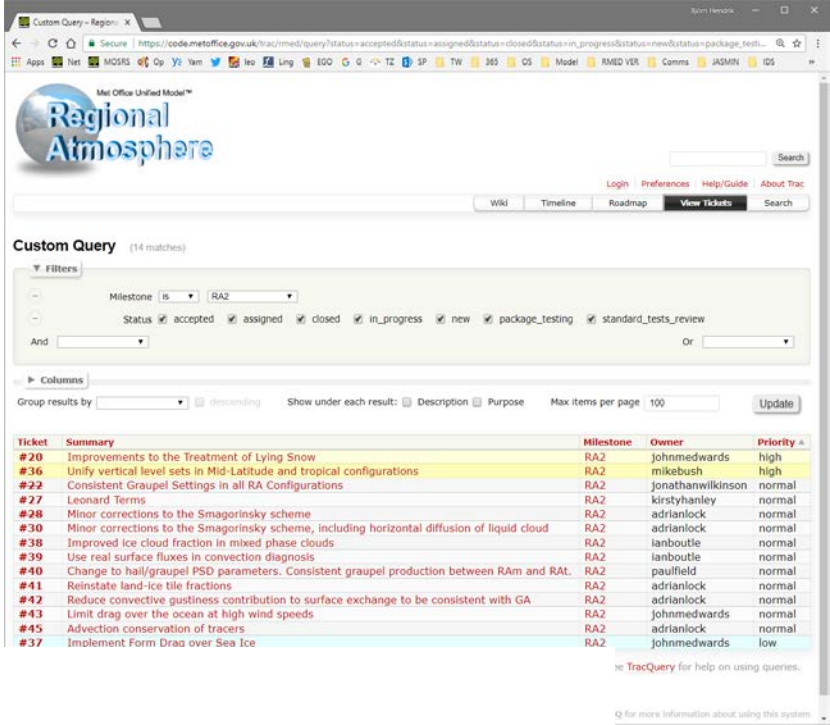

https://code.metoffice.gov.uk/trac/rmed/wiki/suites/eval

# Unification plans: cloud scheme

- The definition of the two ``flavours'' of RA1 --- RA1-M and RA1-T --- is a compromise that has allowed us to make progress in this work without enforcing degraded performance in one or more operational systems.
- Research into the reasons for these differences, particularly when running with different cloud schemes, has highlighted sensitivities to the point during the model's time step in which particular adiabatic heating terms are added to its prognostic fields, as opposed to large sensitivities to the structure of the internal workings of the schemes themselves.
- The aim of this work is to propose changes to allow a future unified configuration, which may be achievable as early as the definition of RA3.

# RA2

- Meanwhile, the development of RA2 has already started, which currently includes smaller changes to aid future convergence including the definition of a common tropical/extra-tropical set of vertical levels.

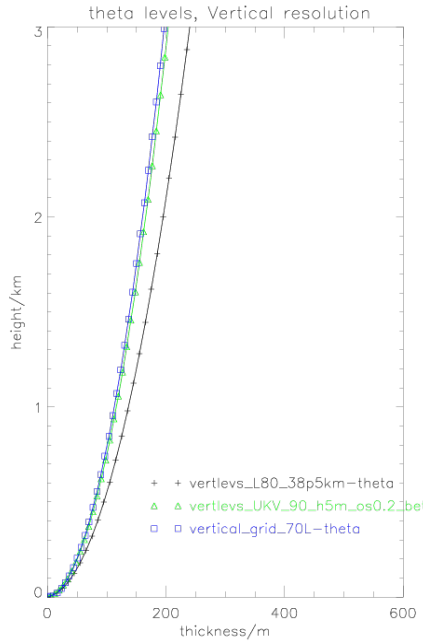


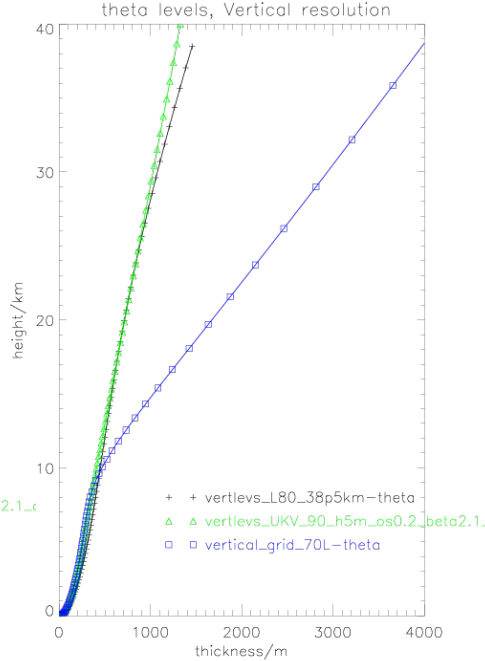

| Date | Milestone |
|---|---|
| Sep-Dec 2018 | Packaging up of RA2 changes into proto-RA2 configuration<br>Evaluation with case studies, DA trials and climate runs for mid-latitude and tropical domains |
| Feb 2019 | Assessment report, freeze and **release** |

# Harmonise tropics and mid latitudes

## #36 Unify vertical level sets

- Merge level sets L70 and L80 to L90
- Keep finer resolution near surface used in L70 / RA-M
- Keep finer resolution of L80 above 10 km, for the tropical configuration RA-T




Current RA-2 tickets

| Ticket | Summary | Milestone | Priority |
|---|---|---|---|
| #36 | Unify vertical level sets in Mid-Latitude and tropical configurations | RA2 | high |

# Future work

- Beyond the definition of these immediate releases, the community of RA developers are currently setting priorities for future research, which includes focussing on the nature of atmospheric convection and the improved configuration and use of convective scale ensembles.
- An important question is how long we can continue to make progress using the convection permitting approach and to what extent some representation of sub-grid convection is required to model the true atmosphere with improved fidelity.
- Projects are underway to develop convection schemes for use in atmospheric models at all resolutions with grid spacings  O(1-100 km), which could be incorporated into a future RA release.

# Top five priorities in the next five years

- Increased use of CP climate simulations in the assessment of RA science and the continued convergence of science settings where appropriate.
- Diagnostics and a deeper understanding of model behaviour
- Scale aware convection
- Increased use of CP Ensembles
- Exascale computing

# Governance

- We are also looking to improve the coordination and traceability between the Regional Atmosphere and Global Atmosphere configurations, and in addressing the governance of their development, it is likely that the direction of their development will be led by a single global/regional modelling programme board
- Ensure that the interests of CP climate stakeholders/teams are represented in the RA decision making process.

# Questions?

For more information please check

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