

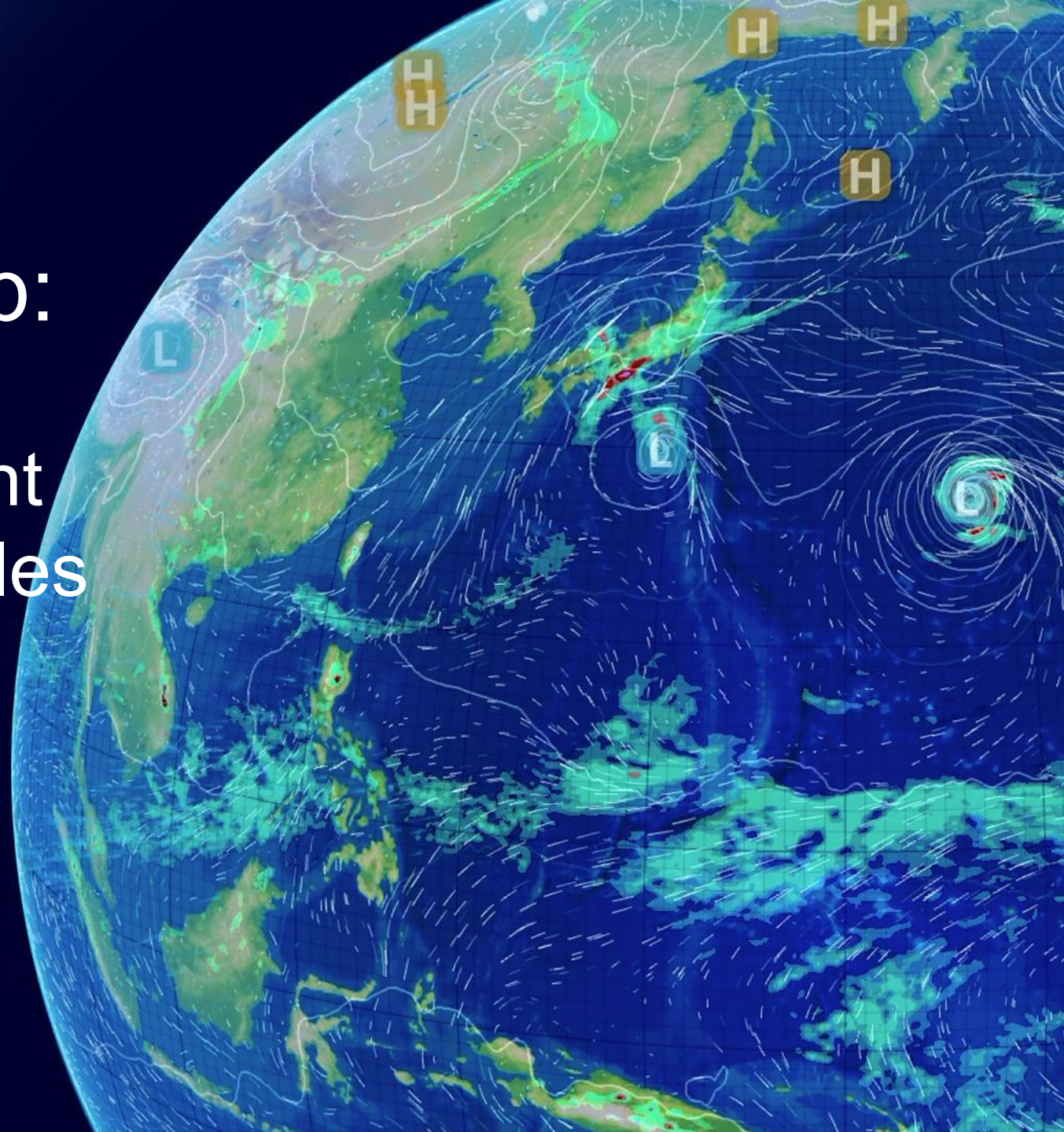
# Momentum partnership: Multi-institute model evaluation and development across time and space scales

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Met Office, UK

UIFCW25



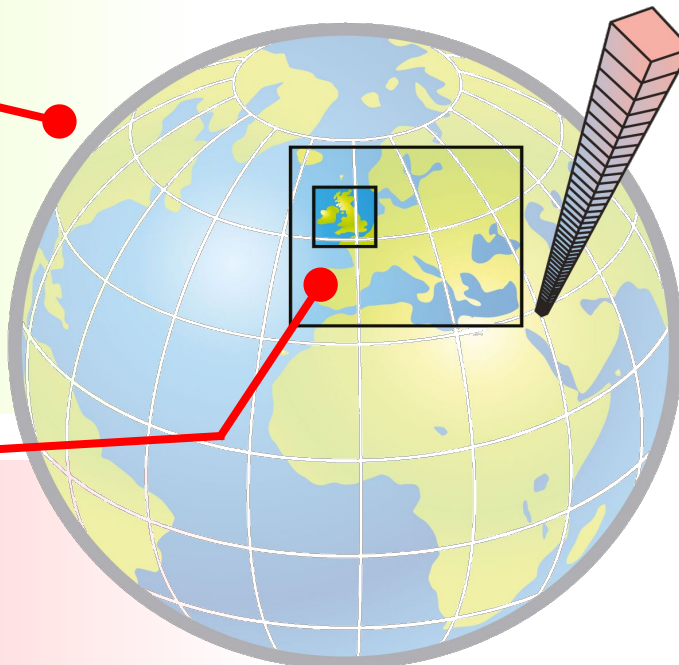
# Overview

- What do we do?
- How do we improve it?
- Seamless (=“unified”?) across time or across space scales?
  - Confronting the convective gray zone.
- Where next, and with who?

# Operational Prediction Systems

## Global NWP

- 10km resolution
- MOGREPS 20km ensemble
- 70 vertical levels (80km top)
- Hybrid Ensemble-4DVar DA
- **1/4 degree NEMO Ocean**



## GloSea5

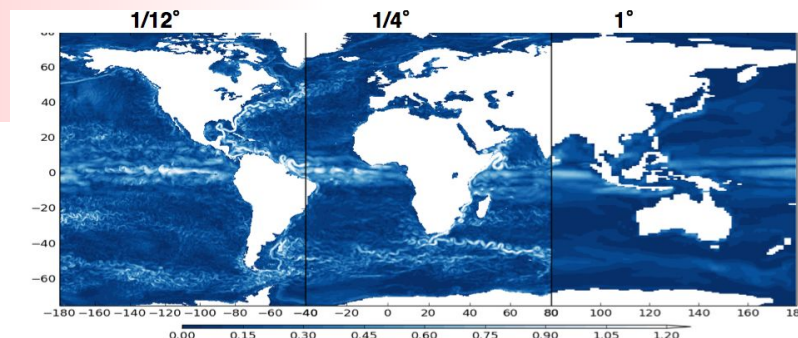
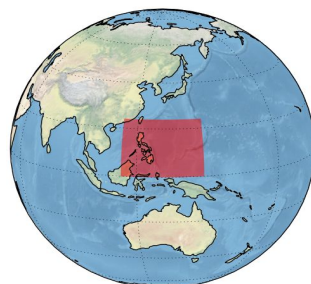
### Coupled Seasonal Prediction

- Coupled Model
- 60km resolution
- 1/4 degree NEMO Ocean
- ensemble
- 85 vertical levels (85km top)

## UKV

- 1.5km UK model (2.2km ensemble)
- 70 vertical levels (40km top)
- 36 hour forecast eight times/day
- 3DVar DA

Regional models can be re-located rapidly to anywhere on the globe for weather or climate...



## Marine Prediction

### FOAM

- 1/4 degree NEMO Ocean
- 75 vert. levels (1m top layer)
- NEMOVAR Data assimilation

Surge Model  
Shelf Seas Model

# Global Seamless Coupled Model

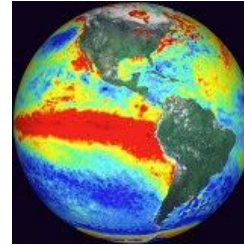


NWP

Coupled Deterministic



Coupled Ensemble



CLIMATE

GloSea (Seasonal)

DePreSys (Decadal)

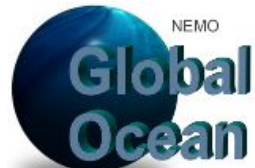


Climate Change UKESMI, UKCPI8

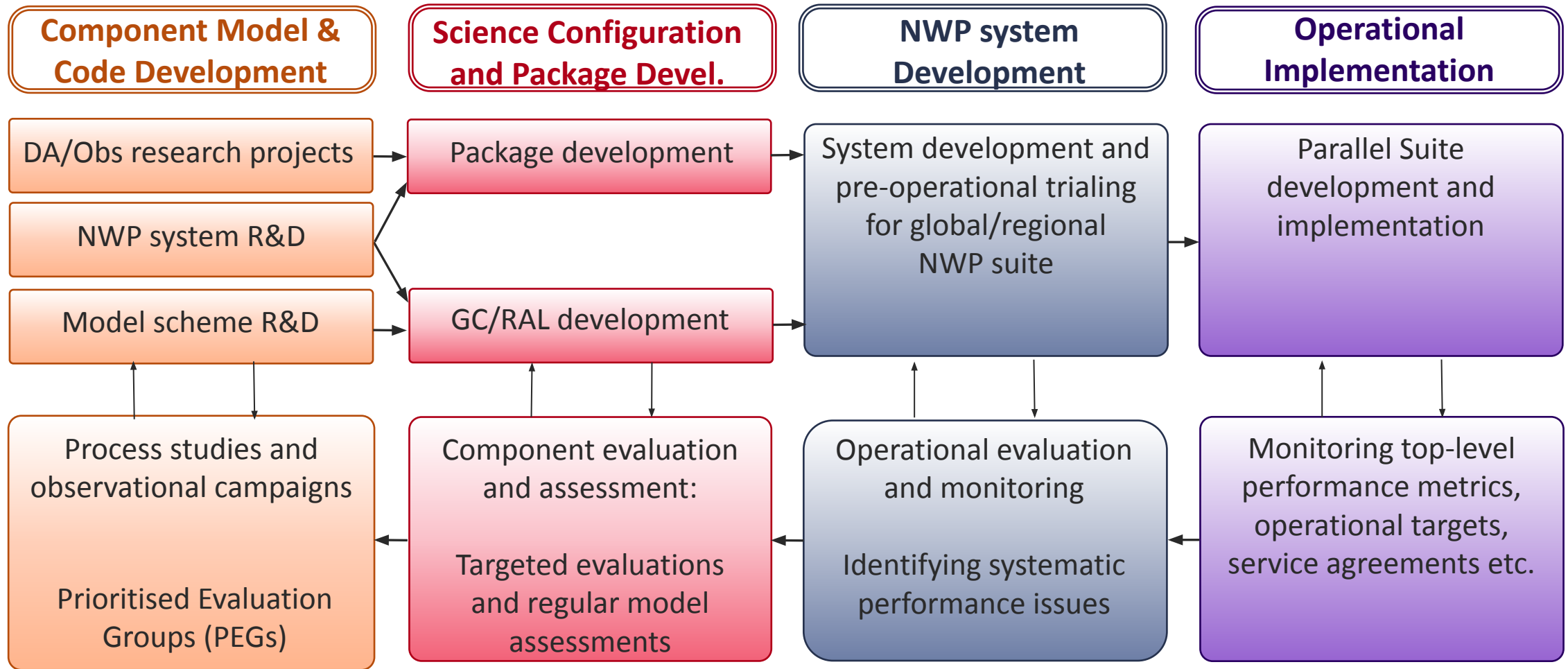
Component Models  
GAL, GOSI, GW

Global Coupled

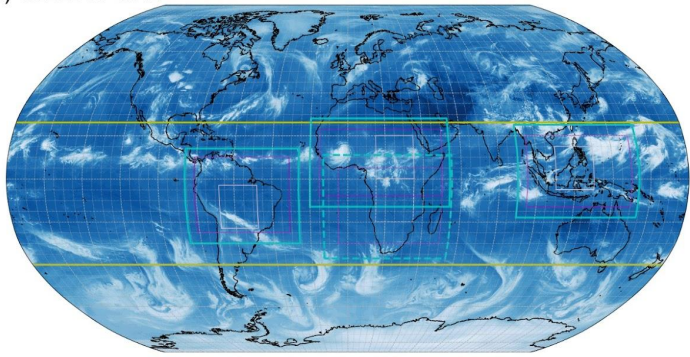
GC Model  
GC.x



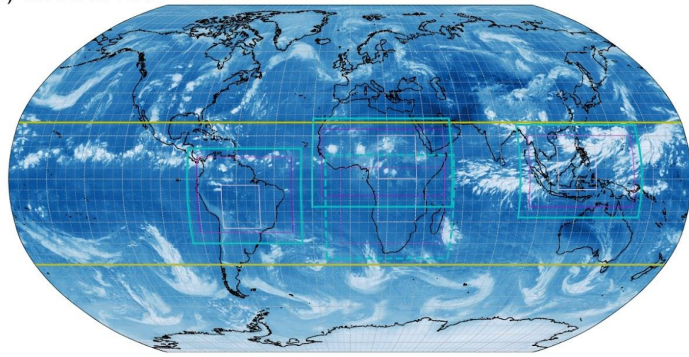
# Met Office R2O/O2R process



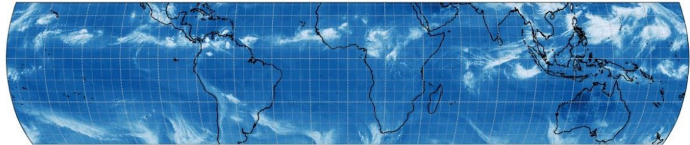
(a) GLOB10 GAL



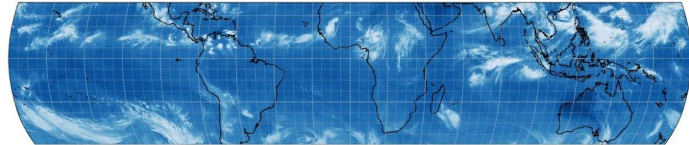
(b) GLOB10 RAL



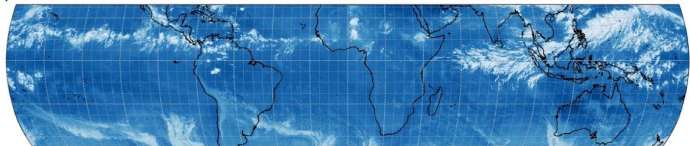
(c) CTC5 GAL North/South LBCs from (a)



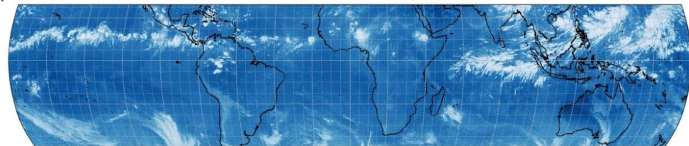
(d) CTC5 GAL North/South LBCs from (b)



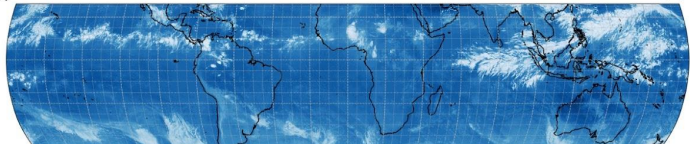
(e) CTC5 RAL North/South LBCs from (a)



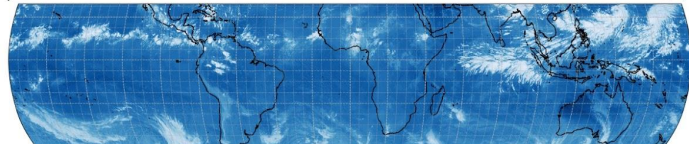
(f) CTC5 RAL North/South LBCs from (b)



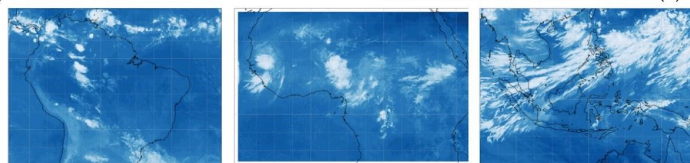
(g) CTC4 RAL North/South LBCs from (a)



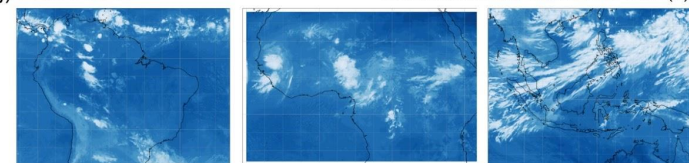
(h) CTC4 RAL North/South LBCs from (b)



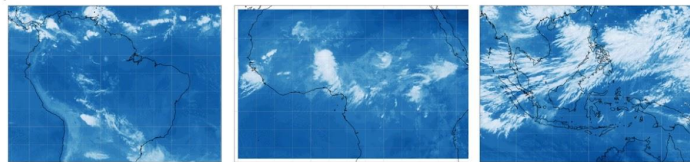
(i) LAM4 RAL North/South/East/West LBCs from (a)



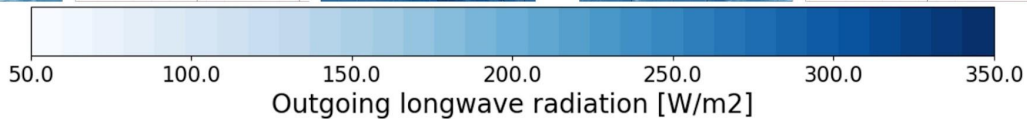
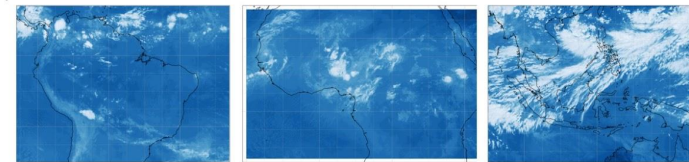
(j) LAM4 RAL North/South/East/West LBCs from (b)



(k) LAM2 RAL North/South/East/West LBCs from (a)



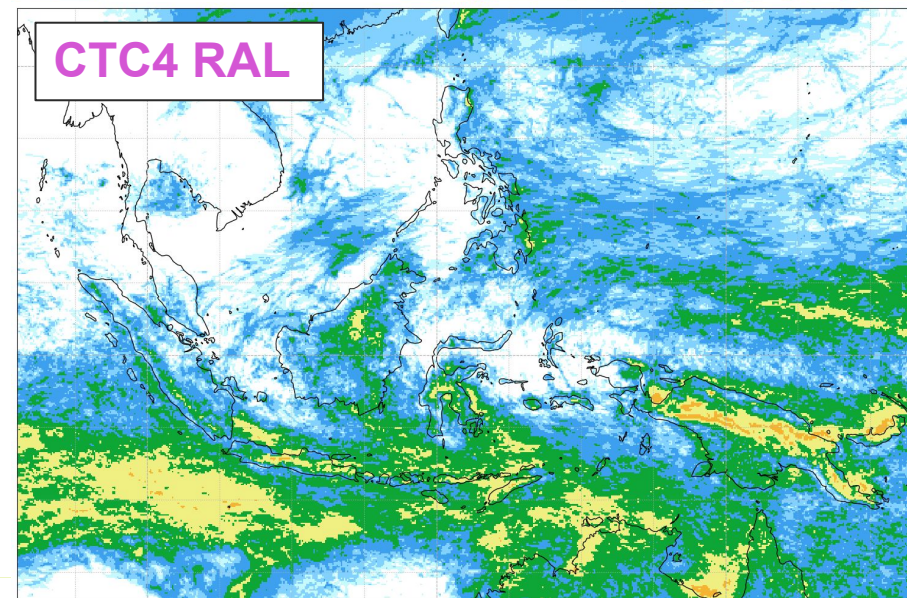
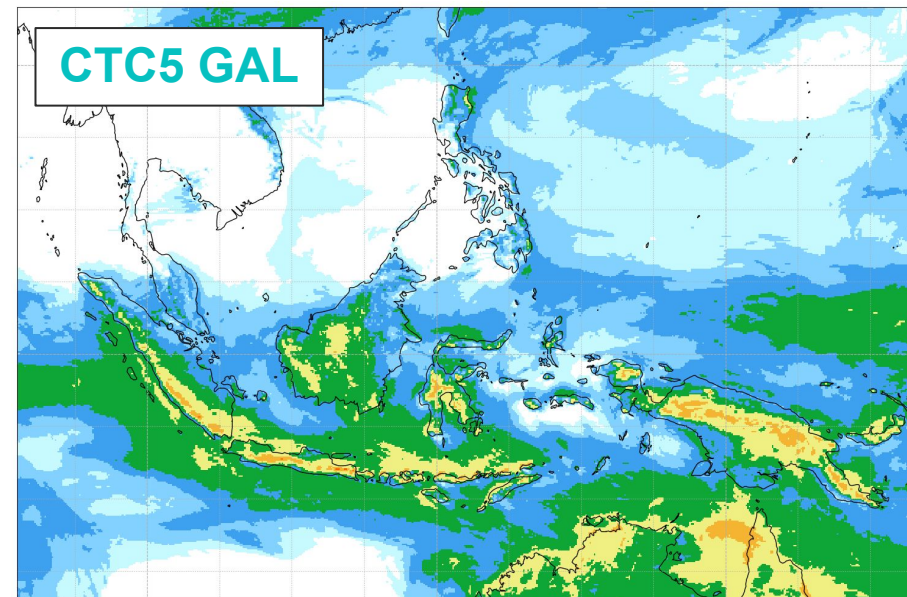
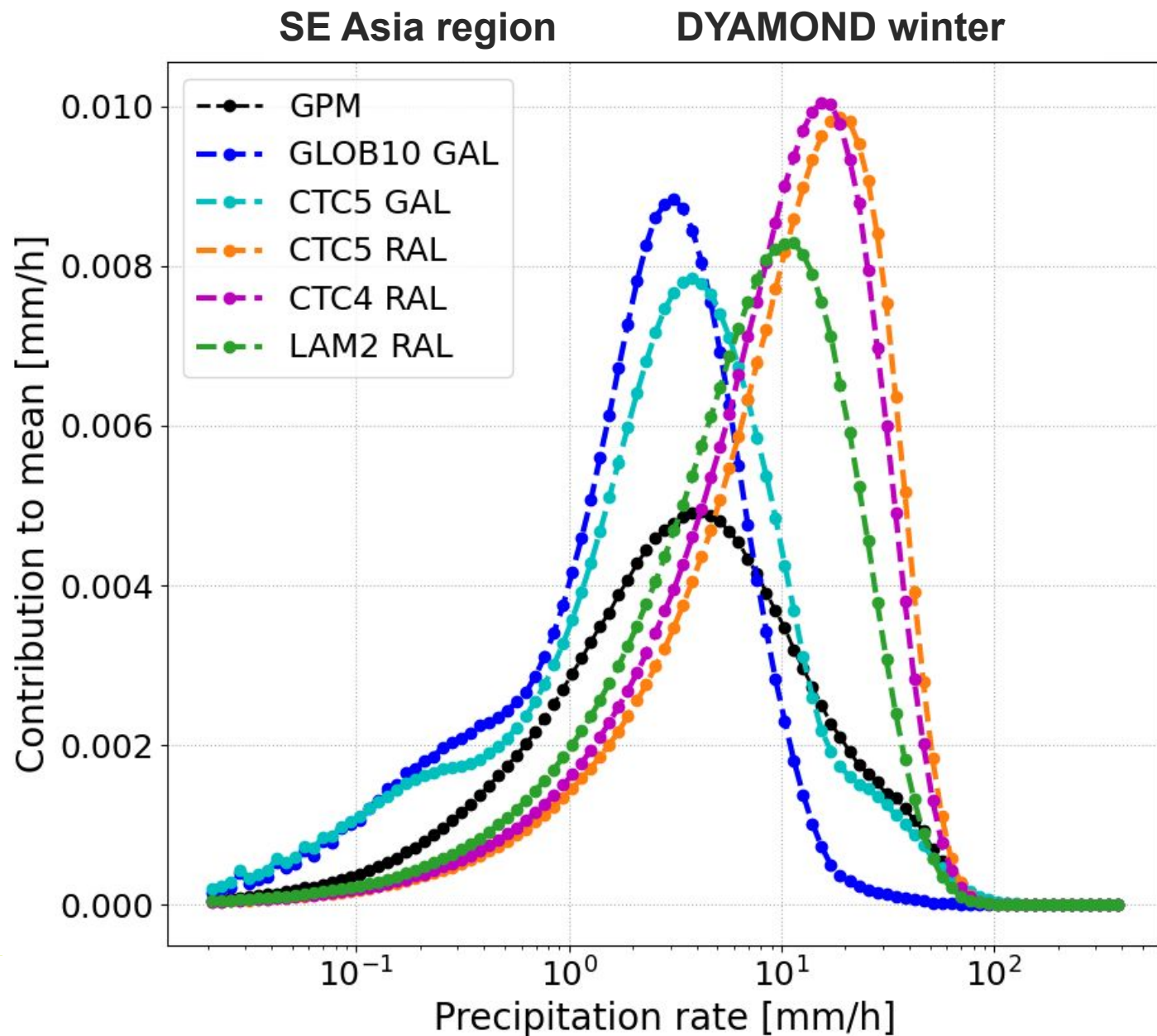
(l) LAM2 RAL North/South/East/West LBCs from (b)



# The K-Scale model hierarchy

- **DYAMOND summer and winter 40-day experiments now completed**
- **Unique global -> cyclic tropical channel -> limited area model hierarchy**
  - Hypothesis-driven questions
  - Allows exploration of how explicit convection global compares with traditional nested LAM approach
- **Writing up**
  - **K-Scale model hierarchy description, motivation and results**
  - Tropical Easterly Jet study (James W)
  - Spectral analyses (Claudio Sanchez)

**Differences between GAL and RAL see next slide!**

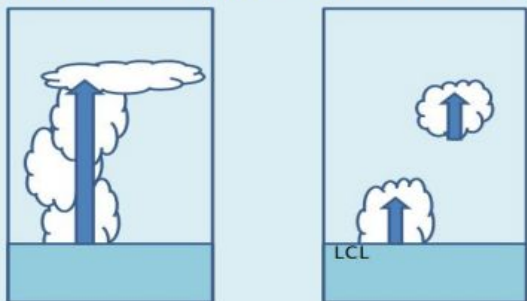


Winter: Daily mean precip [mm/day]

## Convection

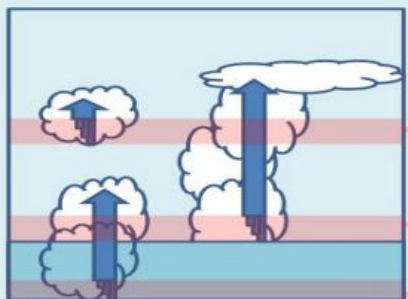
6A

Separate schemes for deep, shallow and mid-level convection



CoMorph

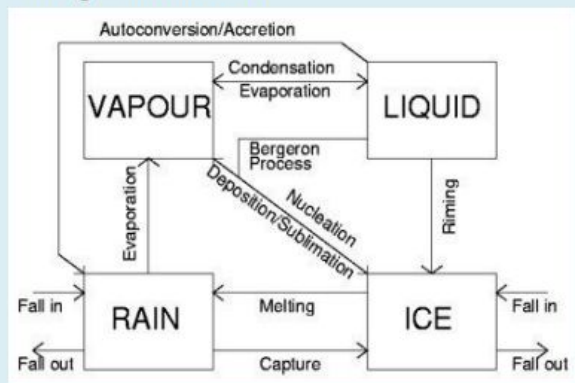
Single parcel ascent / descent code for all plumes



## Microphysics

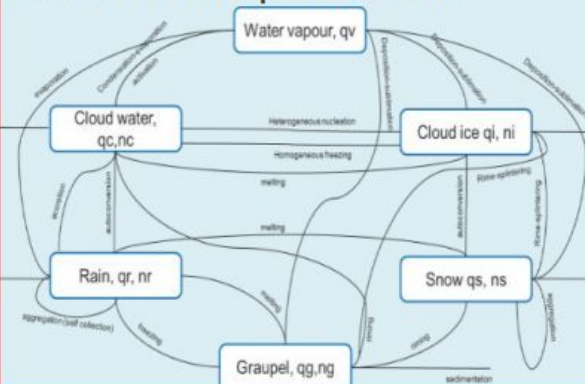
Wilson & Ballard

Single moment



CASIM\*

Can have multiple moments



## Large-Scale Cloud

Smith

*Diagnostic*

Assumes triangular subgrid saturation-departure probability density function with a fixed width, linked to profile of critical relative humidity

Bi-Modal

*Diagnostic*

Like Smith scheme but accounts for coexistence of two modes of variability within a grid box near entrainment zones

PC2

*Prognostic*

Calculates increments to liquid and ice cloud fraction and condensate amounts that get advected by the resolved wind

A hybrid scheme e.g. PC2+

*Prognostic/diagnostic*

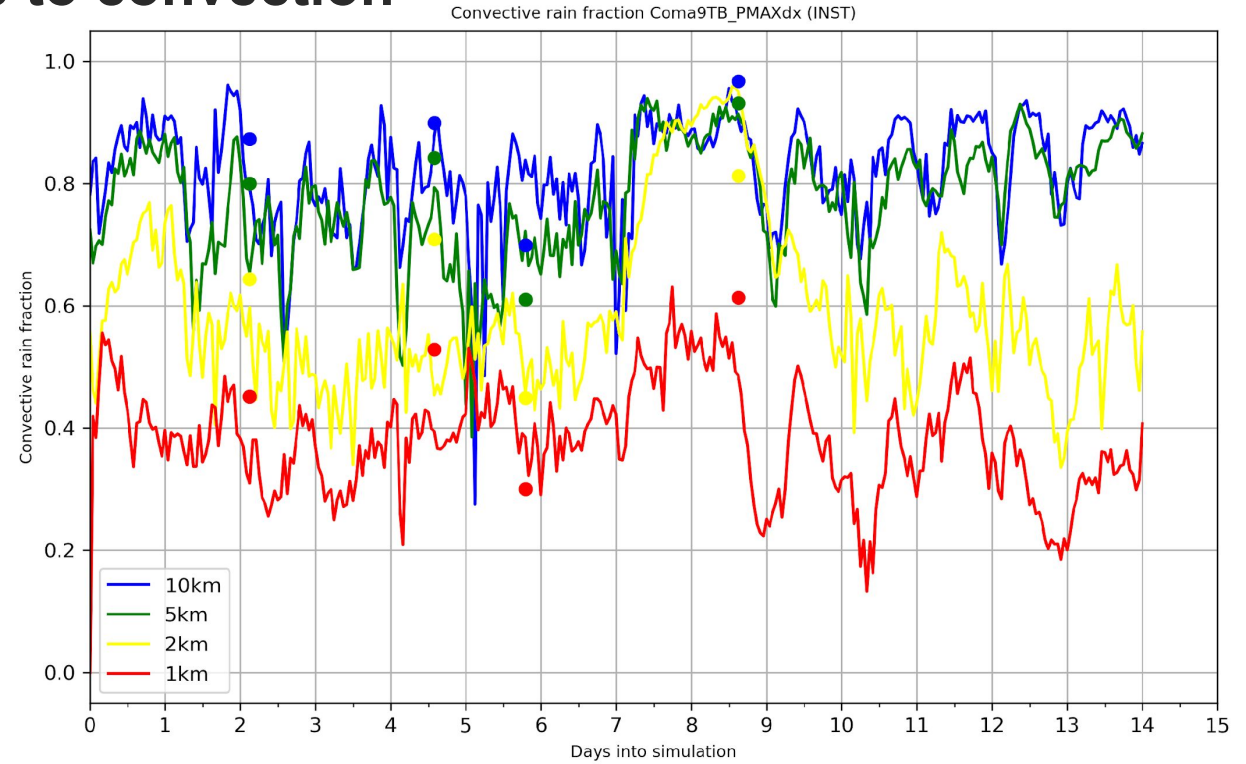
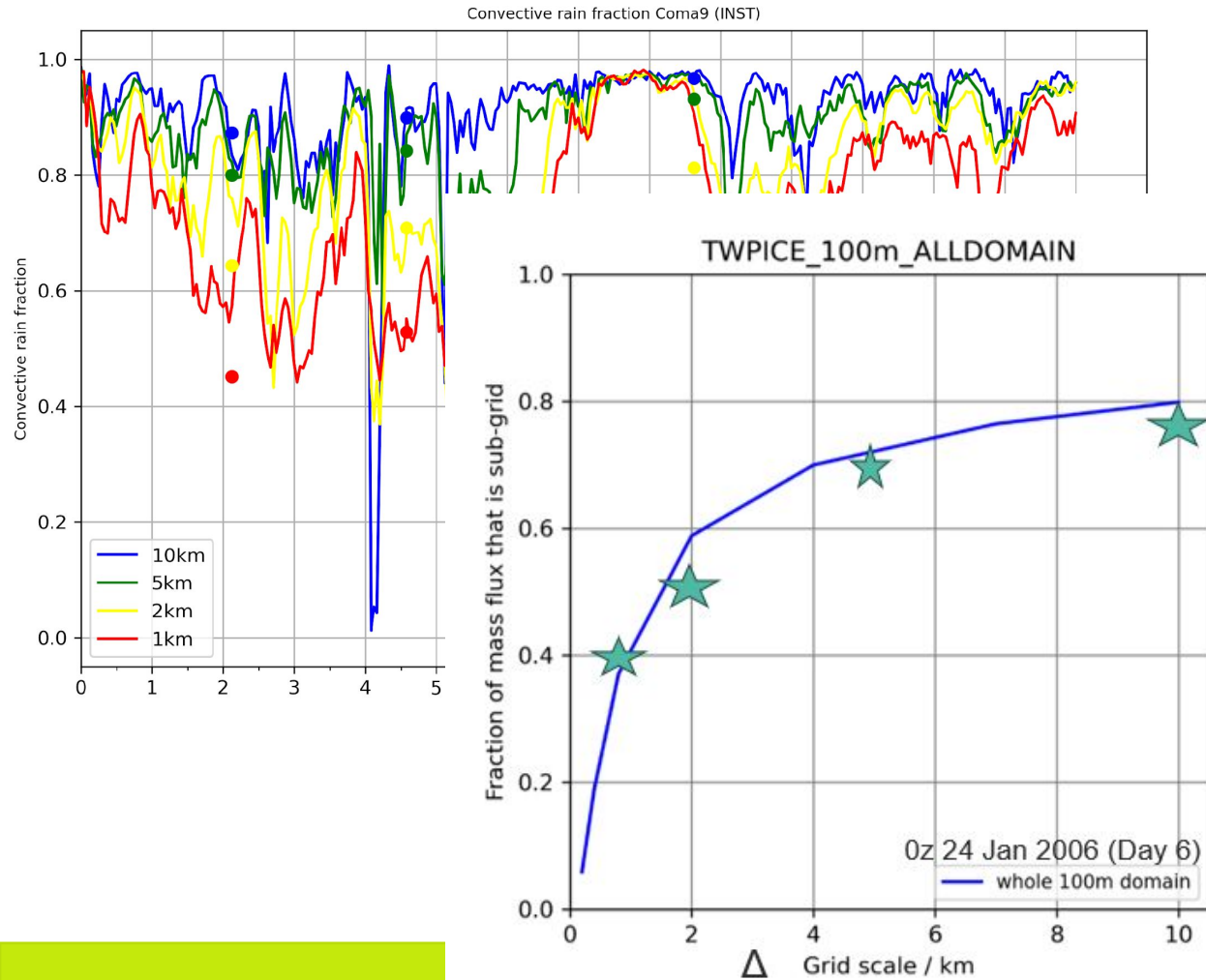
PC2 for ice, Bi-modal for liquid

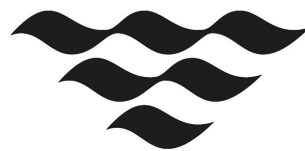


## CoMorph-A

## CoMorph-A with dx-dependent PMAX

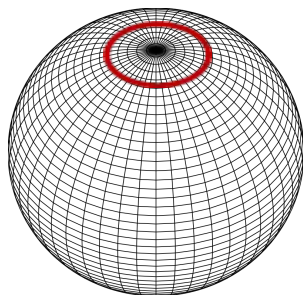
### Fraction of rain due to convection





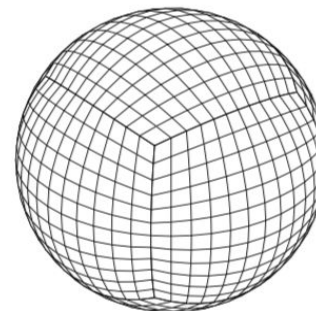
# Momentum™

The Unified Earth Environment  
Prediction Framework



## Unified Model (UM)

- Finite Differences
- Fortran 90 code + Python scripts
- Operational System



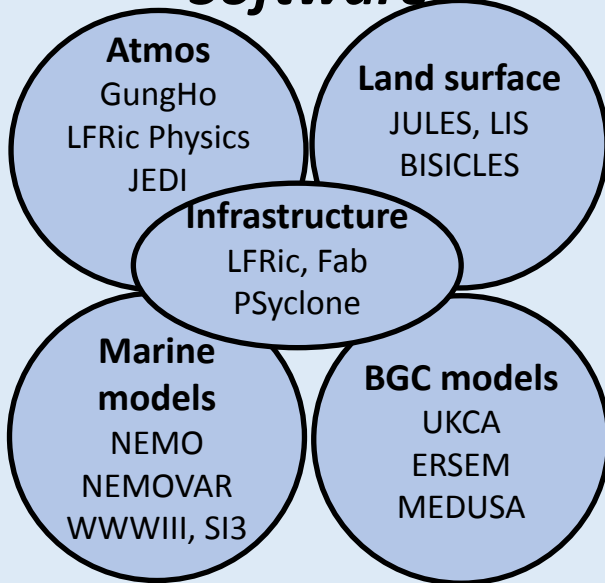
## LFRic system & GungHo dynamical core

- Finite Elements
- Modern Fortran, Automatic Code Generation in Python (DSL)
- GPU adaptation

# The Momentum™ Partnership

## Momentum™: The Unified Earth Environment Prediction Framework

### Software



### Science Configurations

GC: GAL, GOSI and RC: RAL, CO  
JOPA & JADA

MOGREPS

GLOSEA

UKESM

ACCESS

NCUM

GALWEM

NZESM

### Prediction Systems



**Momentum™**

The Unified Earth Environment  
Prediction Framework

**Software** comprising the model codes and supporting infrastructure *provides the ability to run regional and global applications*

**Science Configurations** *define the way model codes are run for regional or global applications*

**Prediction Systems** *enable delivery of forecasts and predictions*

# The Momentum® Partnership

Bringing together international partners to use and effectively contribute to the development of a world leading seamless **Unified Earth Environmental Prediction Framework, Momentum®**, which provides foundations for weather and climate science and services



## Benefits:

By leveraging the diverse strengths and specialisations of all partners we enable a faster rate of improvement of Earth System prediction services than any single organisation can make

## Priority areas:



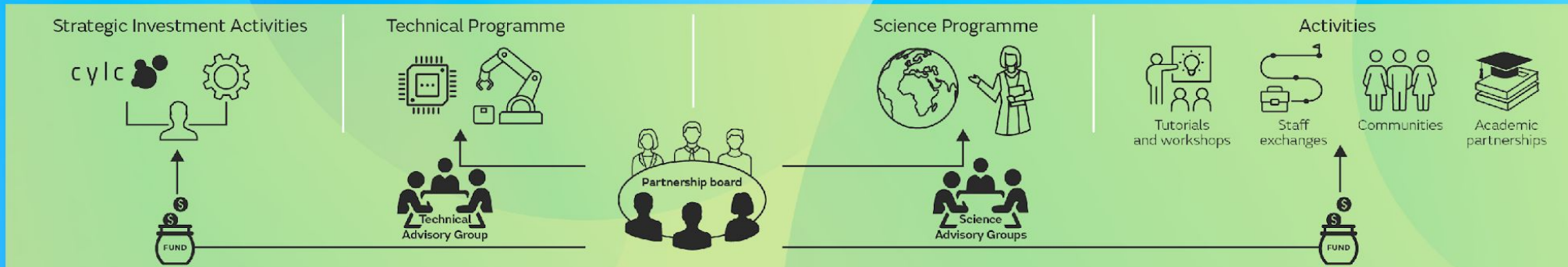
Global, regional and local prediction and projections



Applications of Artificial Intelligence and Machine Learning



Technical Infrastructure development that supports Momentum



**Key**

- Core partner
- Associate partner

Through funding of Strategic Investment and Leadership Activities, we build a robust Partnership with both scientific and technical infrastructure programmes

# Met Office Seamless Global Modelling workshop

Bristol, 3-6 June 2025





# Aims of the workshop

- Review the seamless model development and evaluation approach to ensure a sustainable and relevant process for the future of Seamless modelling across a range of modelling centres
- Share perspectives and solutions about upcoming challenges: evolving user requirements, ML, km-scale, capturing uncertainty...
- Attendees from
  - Momentum partners: Met Office, NERC, ABoM, CSIRO, NCMRWF, KMA, CCRS
  - And other modelling groups using seamless approaches: ECMWF, ECCO, MPI, NOAA , NCAR

# Themes emerging from workshop discussions

- Diversity of seamlessness approaches, adapted to specific needs of users, model/systems context and development community
  - This diversity provides opportunities to share experiences across modelling frameworks
- Seamless approaches bring costs and benefits. It was clear that for those systems represented that seamless development had brought more value than cost.
  - Approaches are continually evolving to meet new requirements and leverage new technology
  - Value of seamless approach to academic collaborators came through strongly
- Seamless approaches will need to adapt to:
  - support machine learning model improvement, and
  - support the increasing need to understand uncertainty in predictions and projections

# In conclusion

- We (and you) are part of a wider community that are exploring unified or seamless approaches to model development.
  - Different approaches being tried – how we can learn from each other?
- Unified Model development is being succeeded by the Momentum partnership
- These approaches can be hard work but it's worth the effort
  - There are challenges and we have approaches for solving some, but not all, of these