Met Office Unified Model Development

Best Practice

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Overview

- The Met Office Unified Model
- Unified Model development process
- Benefits and costs of unified modelling

2023 Met Office NWP Suite

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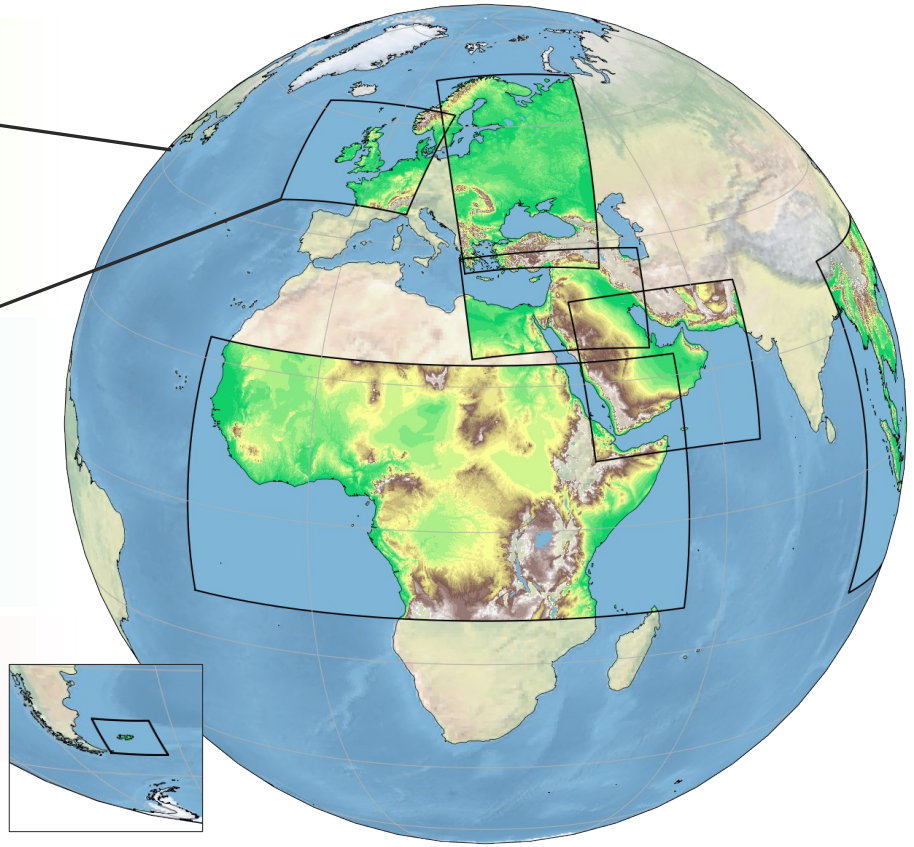
Global NWP:
- 10/20km deterministic/ensemble
- Both coupled to ORCA025 (0.25°) ocean
- 70 vertical levels (80km top)
- Hybrid 4DVar/En-4DEnVar Data Assimilation (DA)
- Forecasts to T+54 or T+192hr every 6 hours

UK NWP:
- 1.5/2.2km deterministic/ensemble
- 70 vertical levels (40km top)
- Hourly 4DVar DA
- Forecasts to T+12 - 120hr every hour
- Hourly updating ensemble (up to T+120hr)

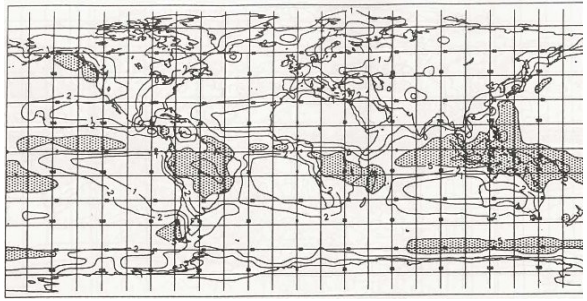
Other Models:
- 1km to 4.4km (without DA)
- 70 vertical levels (40km top)



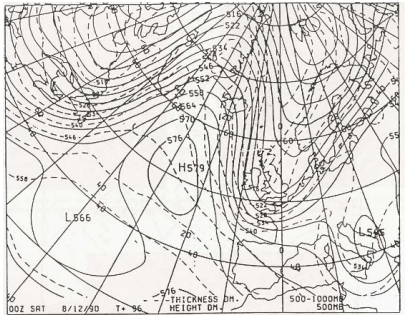
The Met Office Unified Model™

Unified forecast/climate model

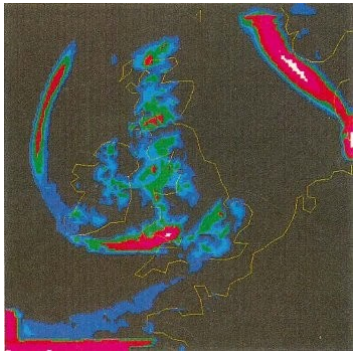
(Cullen, 1993)



Global coupled climate



Global NWP



Mesoscale NWP

- Technical consolidation of code
- 1990: initial operational implementation
- ***Benefit:*** Improvements to regional NWP performance from improved (climate) parametrisations
- ***Compromise:*** Temporary step-back in some capabilities (e.g. regional model went from non-hydrostatic → hydrostatic)

The Met Office Unified Model

(Cullen, 1993) Brown et al. (2010), Walters et al. (2019), Bush et al. (2023)

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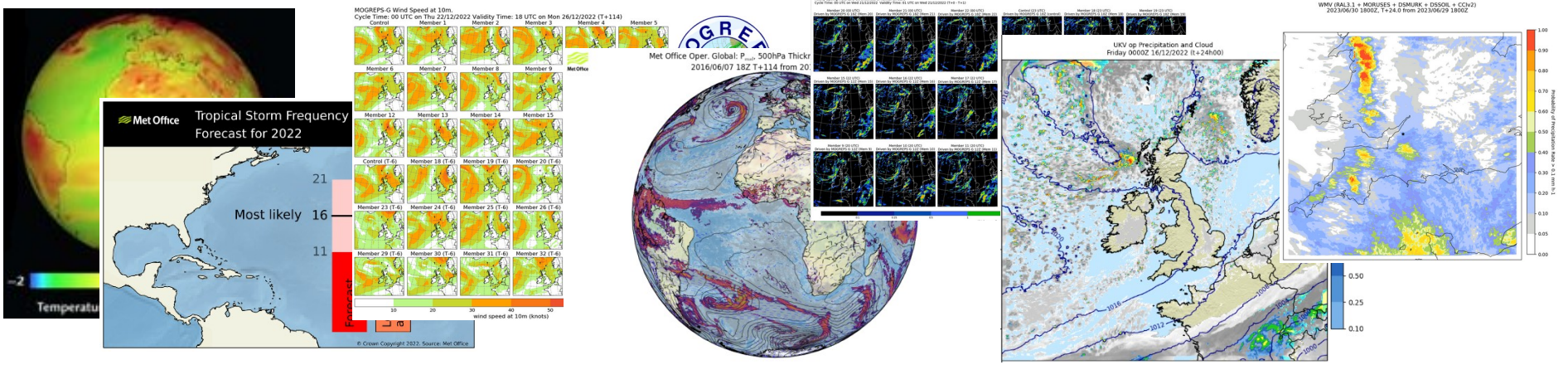
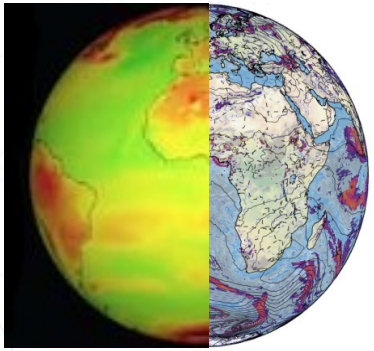


$\Delta x \approx 130 \rightarrow 60$ km | $\Delta x \approx 20$ km | $\Delta x \approx 10$ km | $\Delta x \approx 2.2$ km | $\Delta x \approx 1.5$ km | $\Delta x \approx 300$ m

Global Coupled

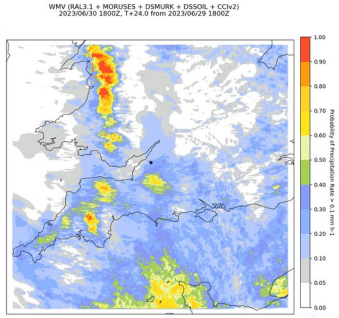
Met Office Unified Model™ / JULES
Regional Atmosphere Land

Flexibility of the Unified Model



Δx ≈ 135 → 10 km

A factor of ~100 – 1000 between these …



Δx ≈ 300 → 100 m

… the same dynamics (and physics) has to continue to work

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The Met Office Unified Model

Developing a seamless science configuration

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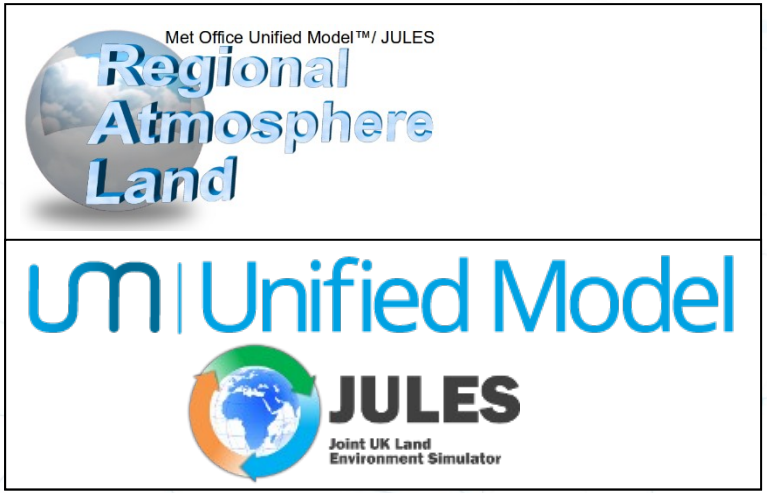

Why attempt seamless model configs?

- Good short-range and forecasts model climatology ensures physical fidelity
- Allows testing in many applications/domains
- Allows feedback (e.g. O2R) to inform all applications and not just those reported
- Allows us to concentrate development on small number of parametrisations/options

- But … additional constraints do add to the burden of model development process

The Unified Model Development Process

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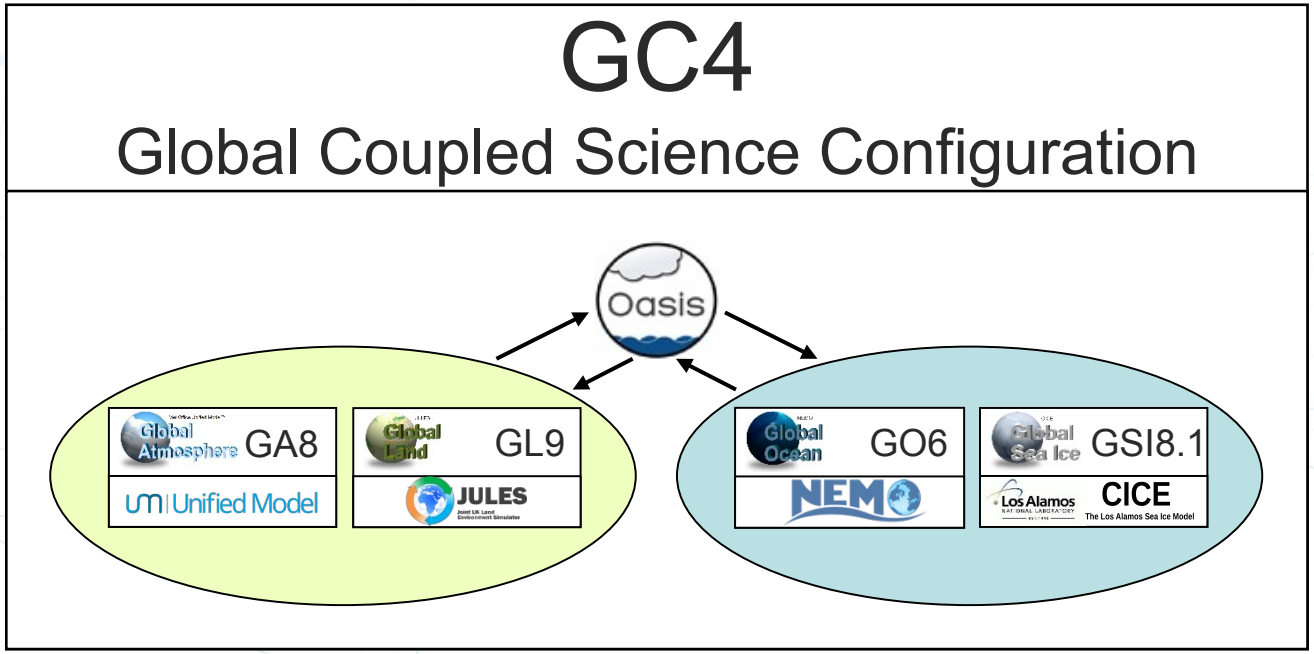
The Global Coupled (GC) development process

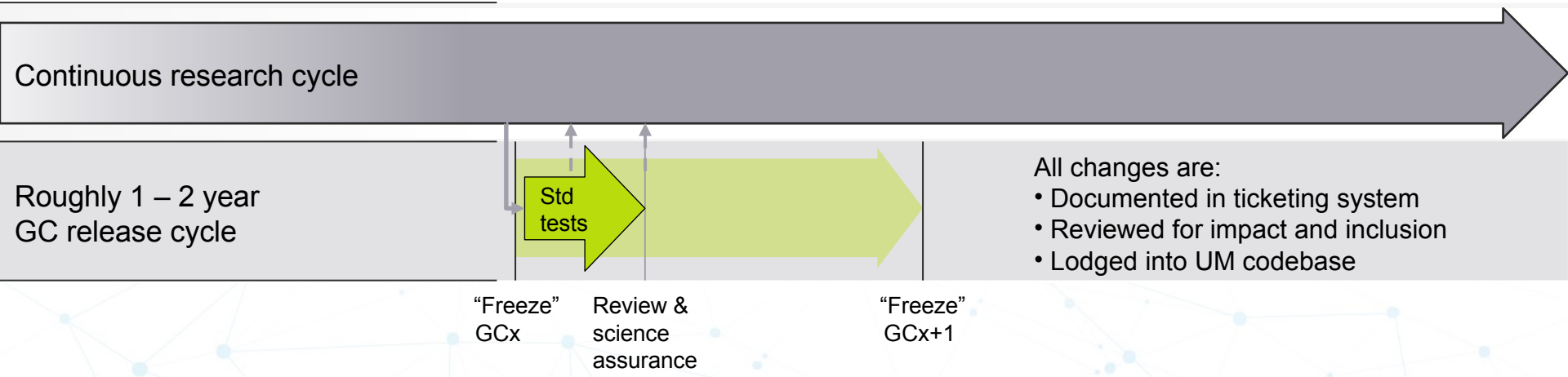


The GC development process

- All developments start here.
- Testing based on a previous well-known GC configuration.
- Includes multi-year projects and programmes.
- Also includes Prioritised Evaluation Groups (PEGs).
- Engagement with a wide range of partners …

… but majority of physics development done within the Met Office.

The GC development process

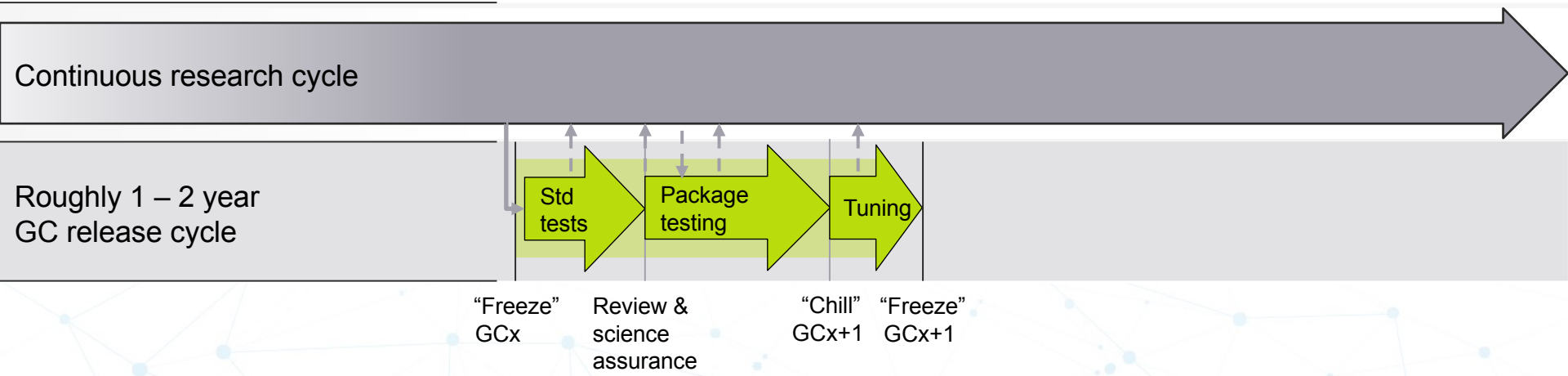


Plan next release:
- Aims/scope
- Resources
- Constraints
- Timescales

Identify changes:
- Maturity
- Priority

Current std tests:
- 20 yr AMIP simulation
- Coupled/atmos-only NWP tests
- Atmos-only NWP DA trials

The GC development process



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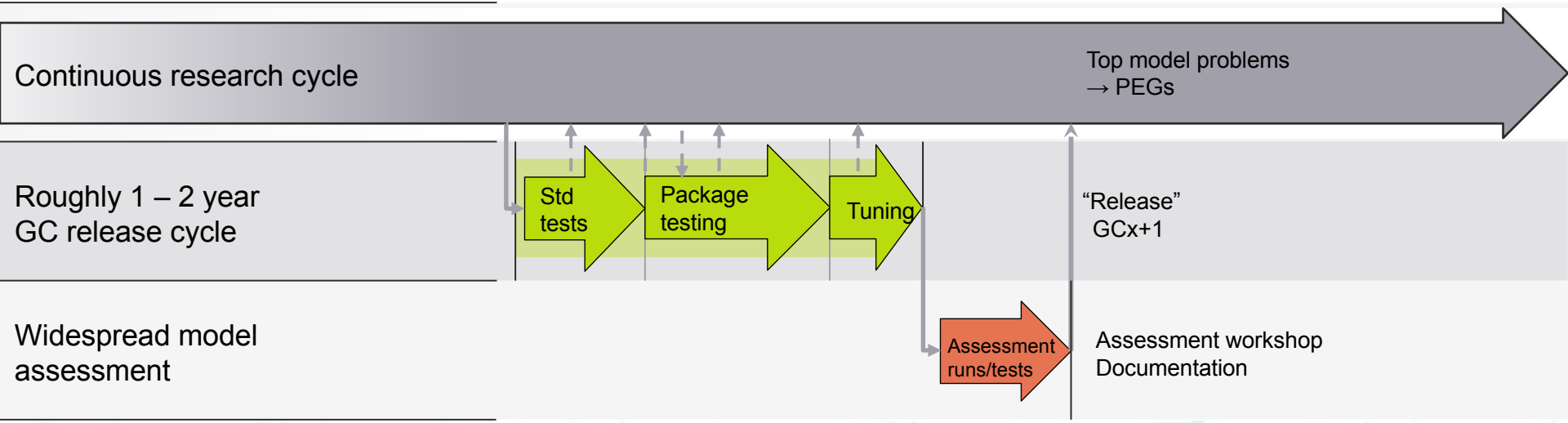
Increase complexity of tests:
- Higher resolution/coupled climate
- Higher-res/more complex NWP

Tuning:
- Individual phenomena e.g.dust, non-orog GWs
- Emergent properties e.g. TOA radiation
- Approach is to improve known problems and remain in obs. constraint

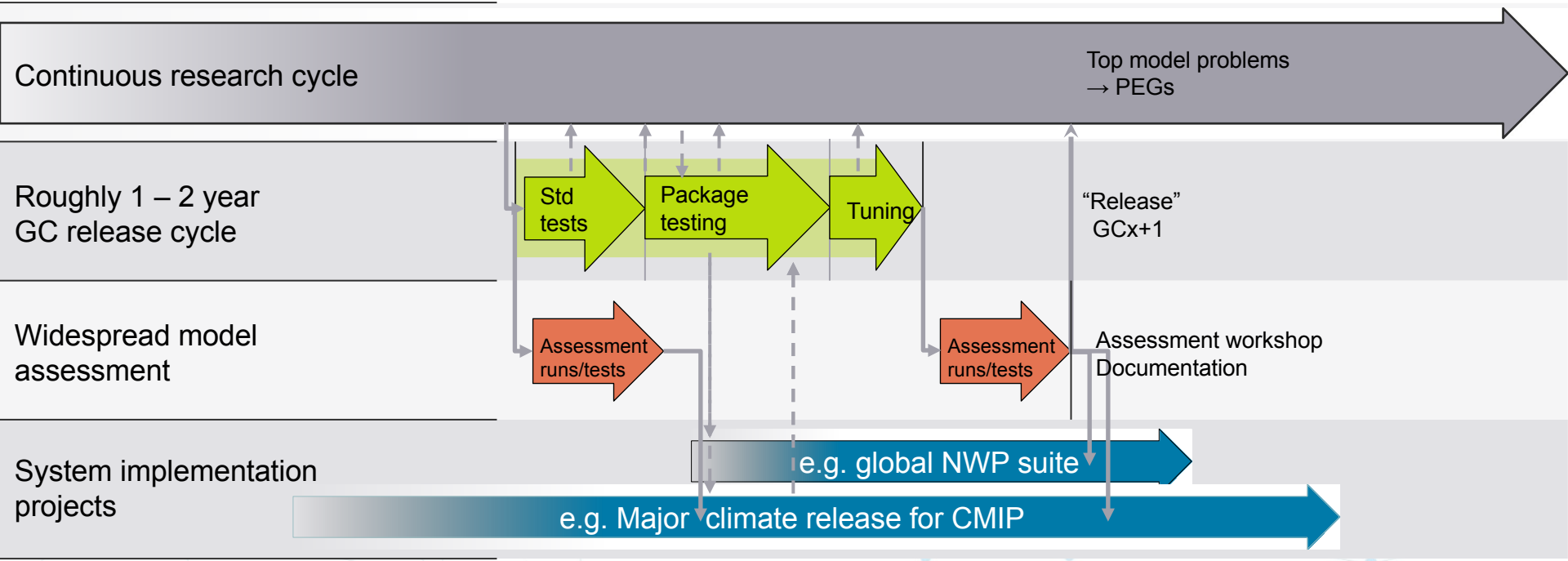
The GC development process



Assessment runs include:

- ~100yr Higher resolution/coupled climate simulations
- High resolution Coupled Ensemble NWP
- Seasonal hindcast runs

The GC development process



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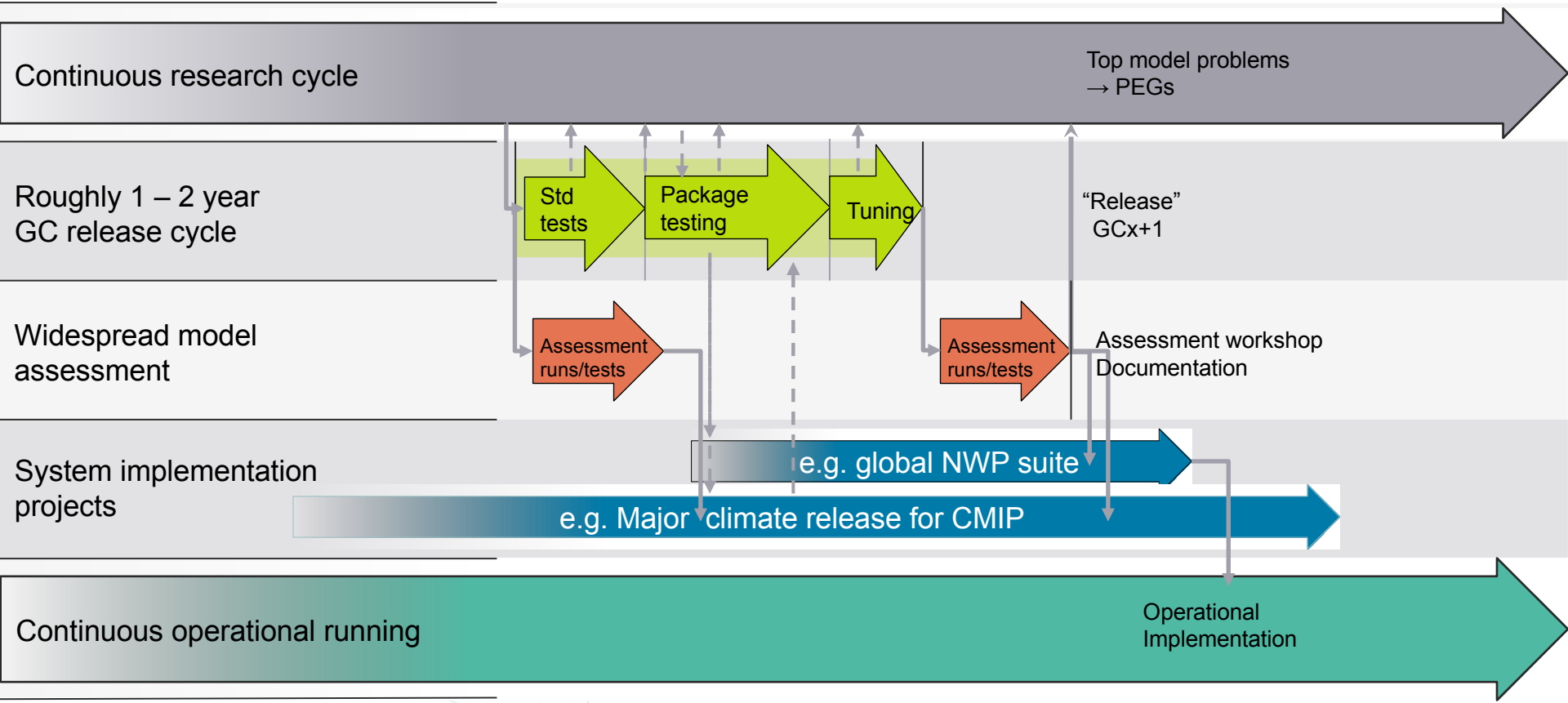

Benefits and costs of Unified Model development

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Horizontal resolution:

UM (and parametrisations) developed to work across wide range of resolutions

GC developed and tested from Δx=135 – 10km, RAL from Δx=4.5 - 1km (and now < 1km)

Very few settings change with resolution (e.g. from a previous GA atmosphere setup):

Variable	N96	N144	N216	N320	N400	N512	N768
Atmos -> Model resolution and domain							
Number of columns	192	288	432	640	800	1024	1536
Number of rows	144	216	324	480	600	768	1152
Extended EW halo size	4 points	4 points	4 points	4 points	5 points	5 points	5 points
Extended NS halo size	5 points	5 points	5 points	6 points	7 points	8 points	8 points
Atmos -> Sci params -> Timestepping							
Number of timesteps per period (timestep)	72 (20 mins)	72 (20 mins)	96 (15 mins)	120 (12 mins)	120 (12 mins)	144 (10 minutes)	192 (7.5 minutes)
Atmos -> Sci params -> Sec-by-sec -> Sec4: LSP -> Number of substeps over full column*	10	10	7	6	6	5	4
Atmos -> Sci params -> Sec-by-sec -> Sec5: Convection -> Threshold vertical velocity	0.3	0.4	0.4	0.4	0.4	0.4	0.4

Benefits and costs of Unified Model development

Horizontal resolution:
UM (and parametrisations) developed to work across wide range of resolutions
GC developed and tested from Δx=135 – 10km, RAL from Δx=4.5 - 1km (and now < 1km)
Very few settings change with resolution (e.g. from a previous GA atmosphere setup):

Benefit: *increasing res. in lower-res systems is almost trivial*
Benefit: *can trust lower-res tests to teach you about higher-res systems → cheaper testing*
Cost: *more thought and care must be taken when initially developing and testing science*
Cost: *Unified Model is relatively expensive in computational terms*

Benefits and costs of Unified Model development

Complexity/system/timescale/domain dependence:
UM (and parametrisations) developed and tested across systems/timescales/domains
A number of system dependent options *(e.g. from a previous GA atmosphere setup):*

Variable	NWP forecasts	Seasonal forecast	Climate projections
Input/Output Control -> General Configuration -> Use 360 day calendar	Off	Off	On*
Ind sec opts -> Misc sec 94-98 -> Summation type	Fast, non-reproducible	Double-double precision reproducible	Double-double precision reproducible
Atmos -> Sci params -> Sec-by-sec -> Sec3: BL -> Land -> Use coastal tiling	Off	On	On
Atmos -> Sci params -> Sec-by-sec -> Sec12: Advection -> Moisture conservation	Off	More accurate	More accurate
Atmos -> Sci params -> Sec-by-sec -> Sec14: Energy corr.	Energy adjustment not included	<1B> Standard energy adjustment included	<1B> Standard energy adjustment included
Including dry mass corection		Off	Off
Atmos -> Sci params -> Sec-by-sec -> Sec17: Aerosol	%		

% can use prognostic aerosol or traceable climatological aerosol
also can obviously run atmospheric model coupled/uncoupled

Benefits and costs of Unified Model development

Complexity/system/timescale/domain dependence:
UM (and parametrisations) developed and tested across systems/timescales/domains
A number of system dependent options *(e.g. from a previous GA atmosphere setup):*

Benefit: *increased testing/stress improves the robustness of the model*
Benefit: *traceable hierarchies makes extending complexity simpler (e.g. aerosols for NWP)*
Cost: *code can become complex because of the number of different "use cases"*

Requires higher level of governance and top-level control

Summary

Unified Model allows unified approach to model development

Unified science configurations used for Global and Regional modelling

Technical and scientific benefit

Up front cost in dev. and testing

Can make pragmatic implementation choices and maintain integrity

Once adopted, the benefits outweigh the costs