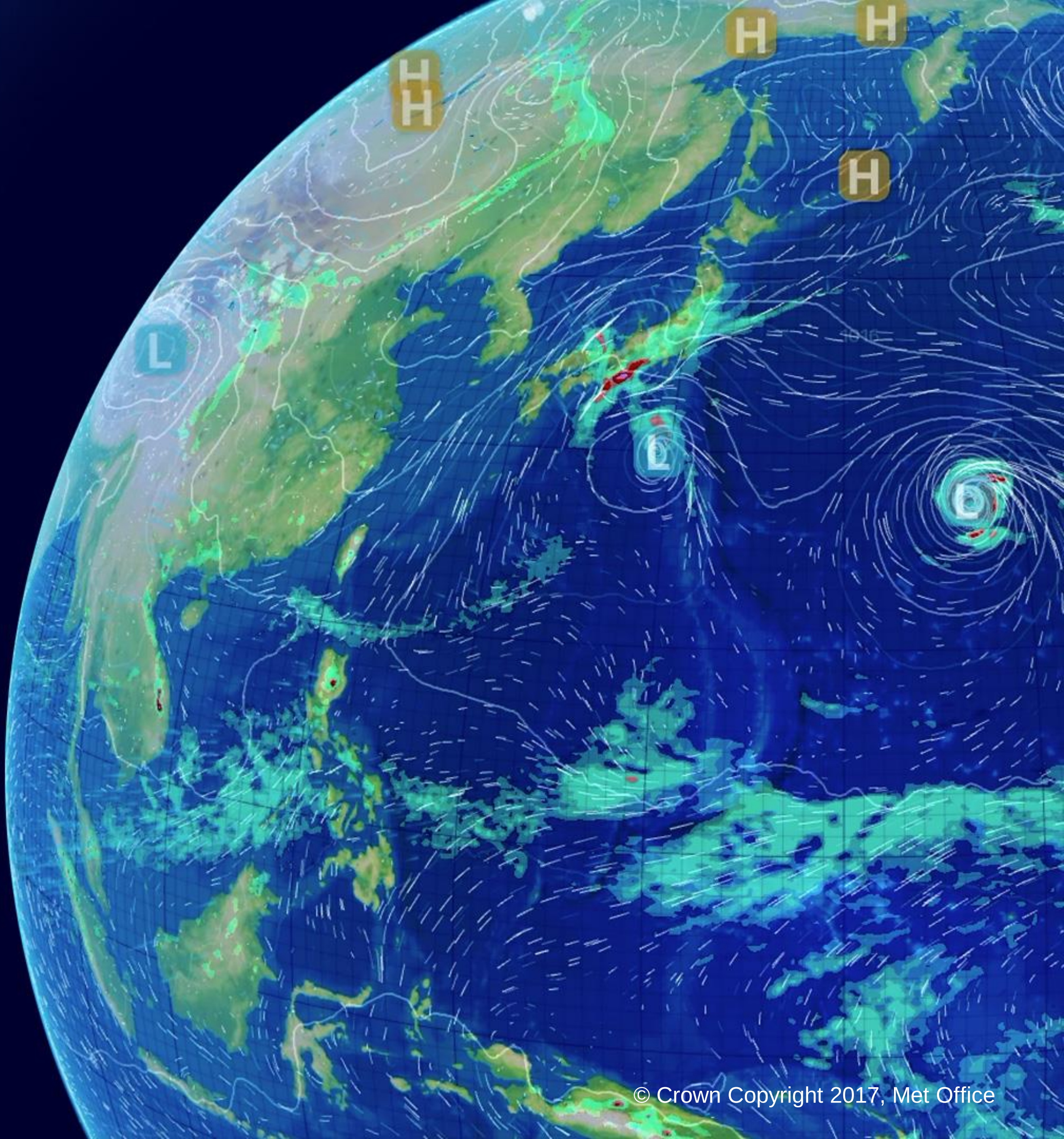
Met Office

Seamless model development at the Met Office

Keith Williams



Unified forecast/climate model

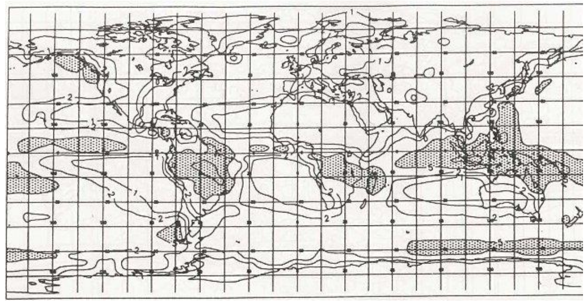
1950s-1980s: Regional/global NWP and climate GCM

Late 1980s: Met Office codes need rewriting to port computers

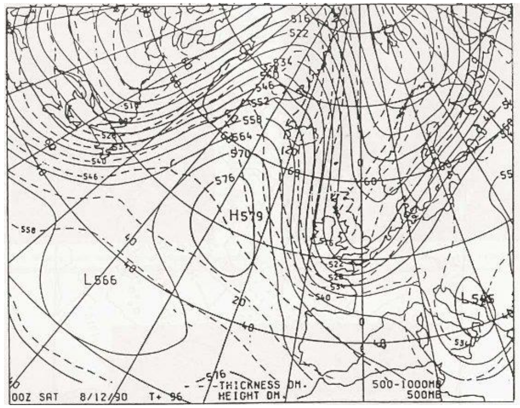
Decision: Put effort behind a single “Unified Model”

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

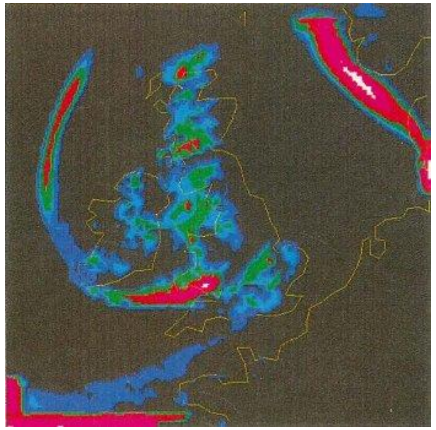
Unified forecast/climate model



Global coupled climate



Global NWP



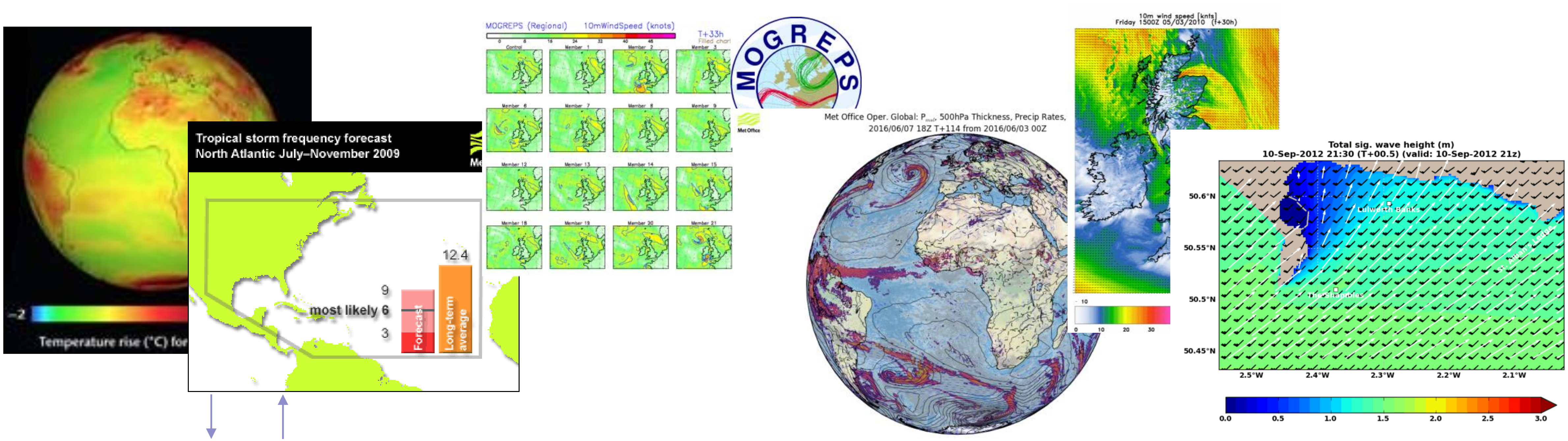
Mesoscale NWP

- Common control/infrastructure
- Common grid structure/dynamical core
- Access to common set of parametrisation schemes selected by user
- Common diagnostic/processing code
- Later drive to make model portable across architectures

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

The Met Office Unified Model

Primary applications of the UM today



NEMO CICE

Δx ≈ 130 → 60 km

Δx ≈ 20 km

Δx ≈ 10 km

Δx ≈ 1.5 km

Δx ≈ 330m

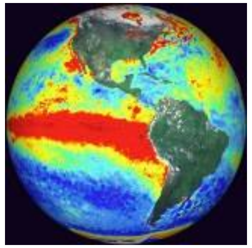
Cullen (1993), Brown et al. (2010)

Global Seamless Physical Model

Hours → *Days.* → *Weeks* → *Months* → *Seasons* → *Decades* → *Centuries*

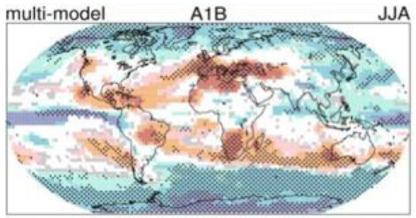
NWP - AL, OI, W
Deterministic Atmos & Marine

Atmos
Ensemble



GloSea

Decadal

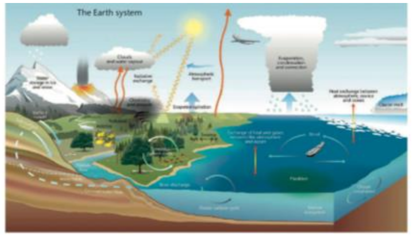


Climate Change &
UKESM1

Component Models
GA6 , GL6, GO5, GSI6

Coupled AOIL Model
GC2.0

Seamless Modelling Framework of the Earth System



Space Weather

Atmosphere - (UM)

Chemistry/Aerosols (UKCA)

Waves - (WaveWatch III)

Sea Ice - (CICE)

Land Ice (BISICLES)

Biogeochemistry (MEDUSA-2)

Ocean (NEMO)

Land Physics & Hydrology - (JULES)

"…these models are our laboratories where we can explore the processes, feedbacks and interactions in and between the holistic atmosphere-ocean-land-ice system..."

Julia Slingo, Met Office Science Strategy 2016-2021

Land biogeochemistry
(Carbon & Nitrogen cycles)
Dynamic Vegetation
(JULES-CN & TRIFFID)

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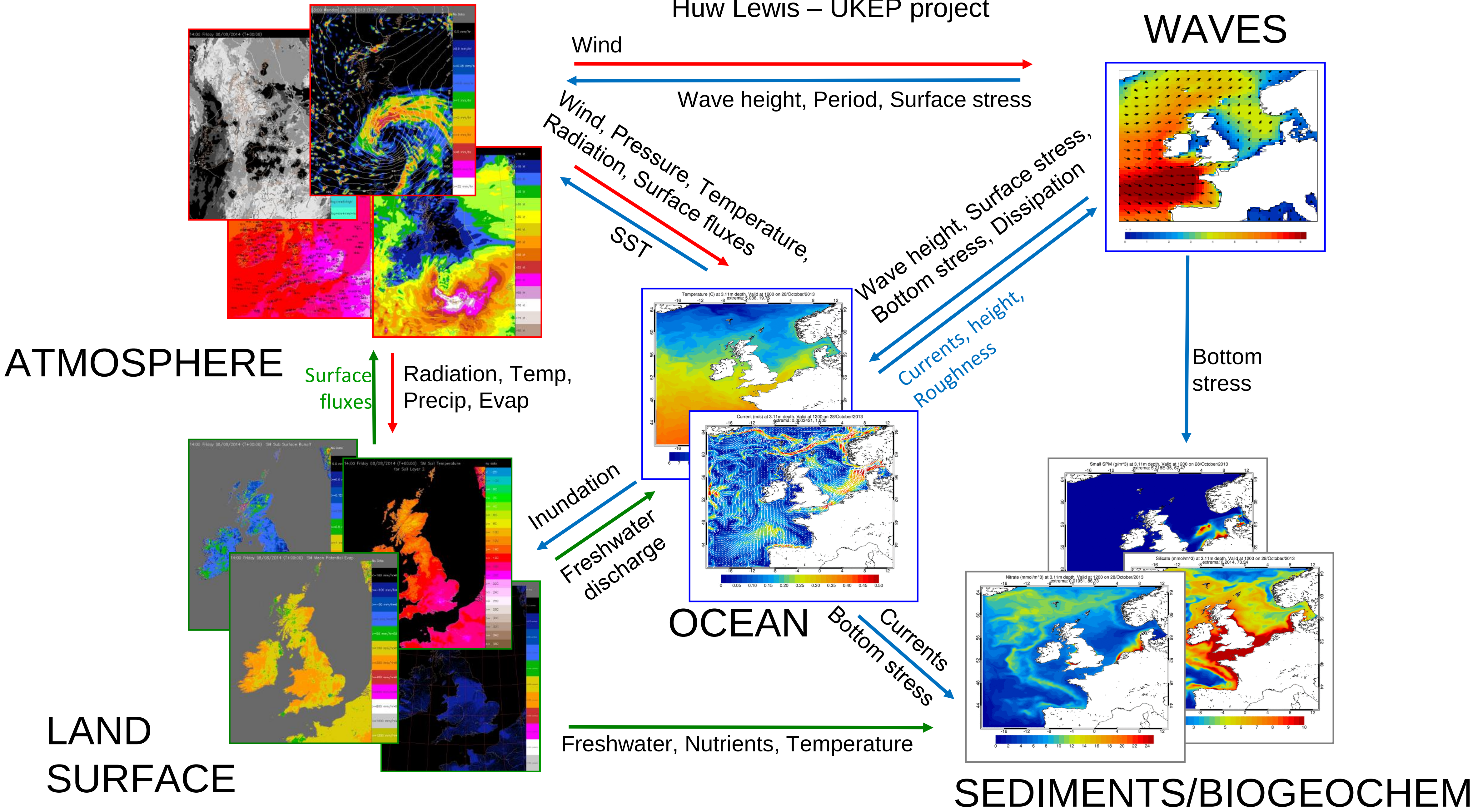
Towards a UK coupled model

Huw Lewis – UKEP project



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Seamless model assessment

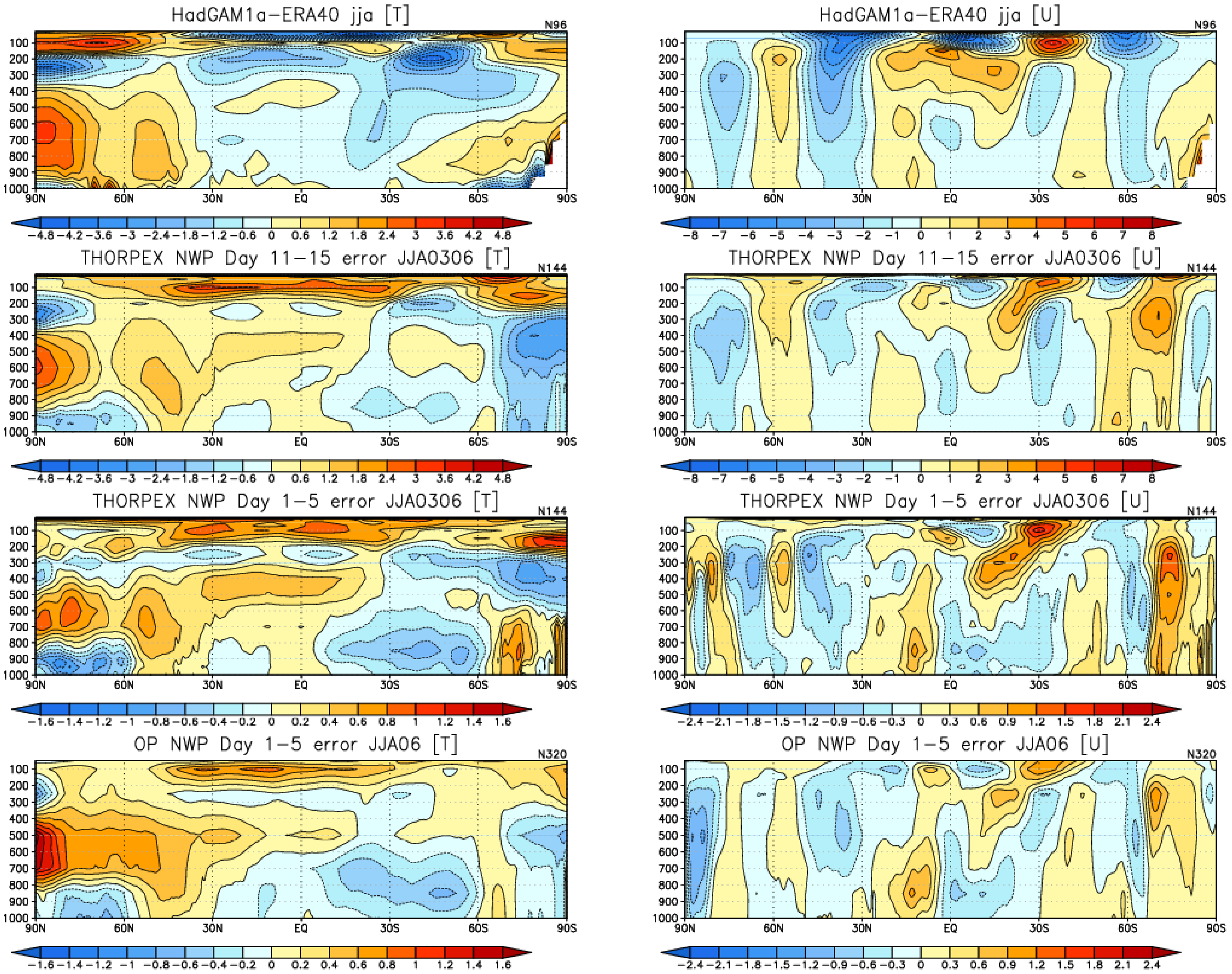
Seamless Model Assessment is the exploitation of the seamless nature of the Unified Model across space and timescales to assess and improve the simulation of processes within the model

Systematic Errors – NWP to Climate

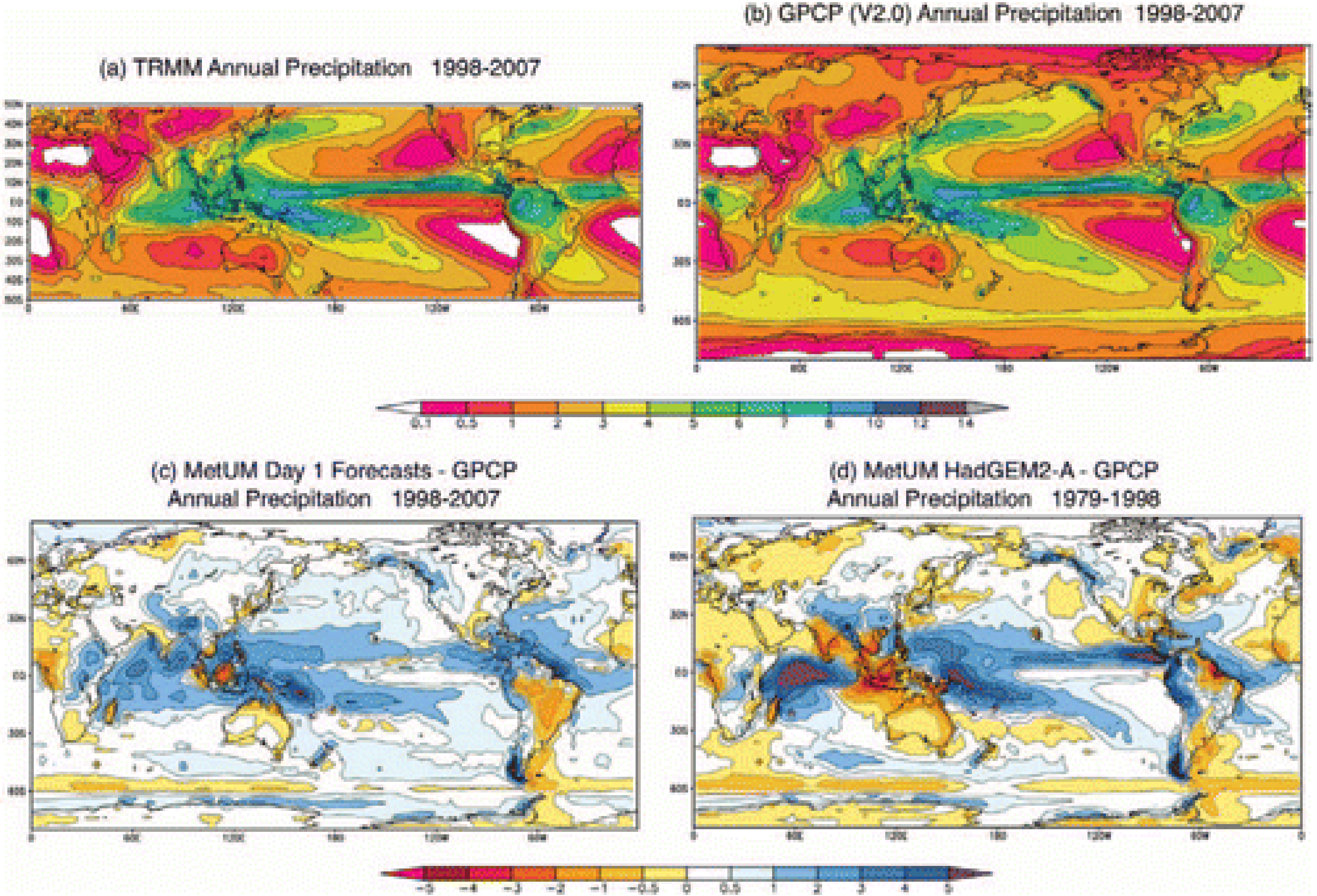
N96 Decadal

Resolution Timescale

N320 5 Days



Systematic Errors in Precipitation

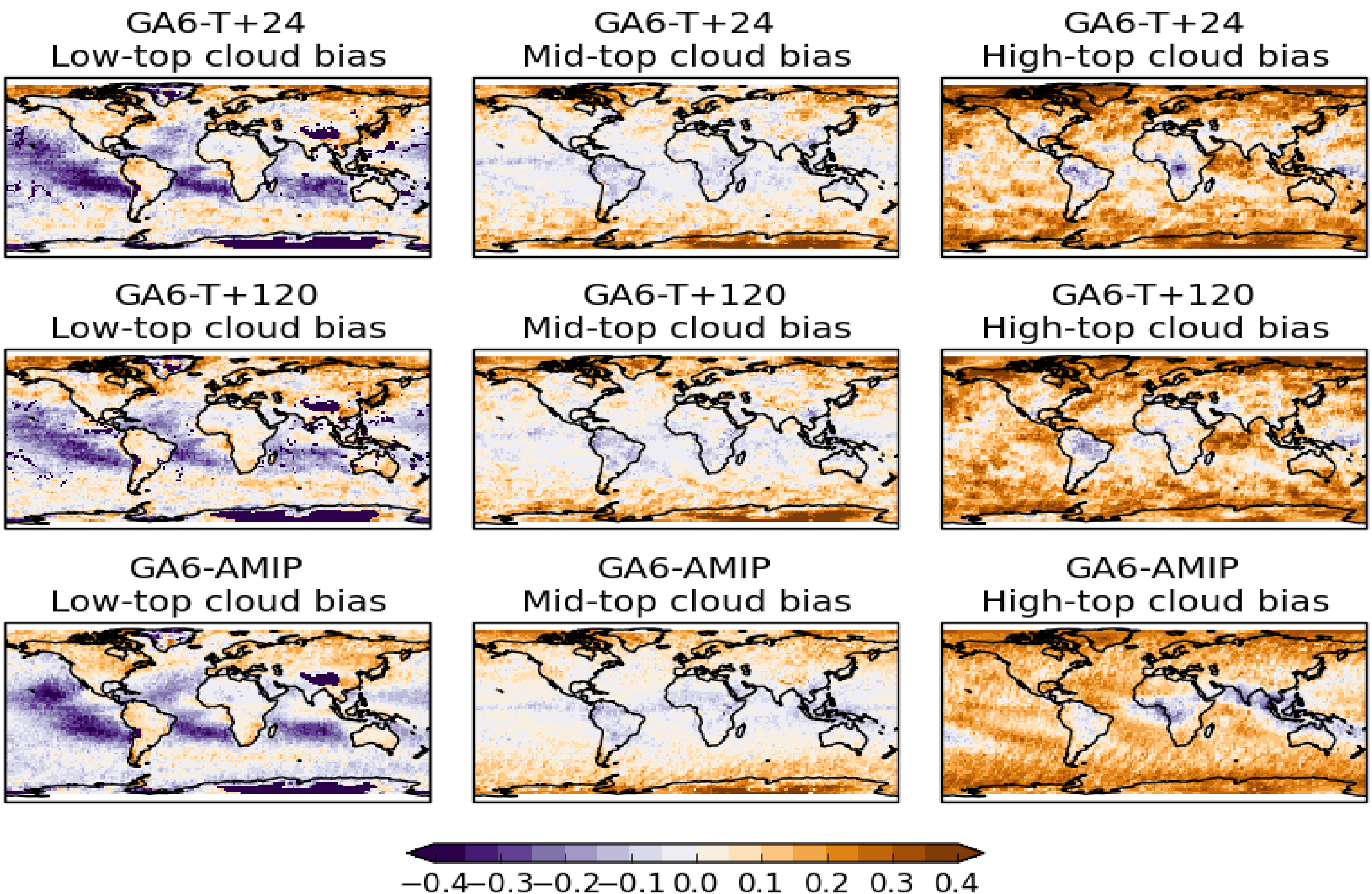


NWP error

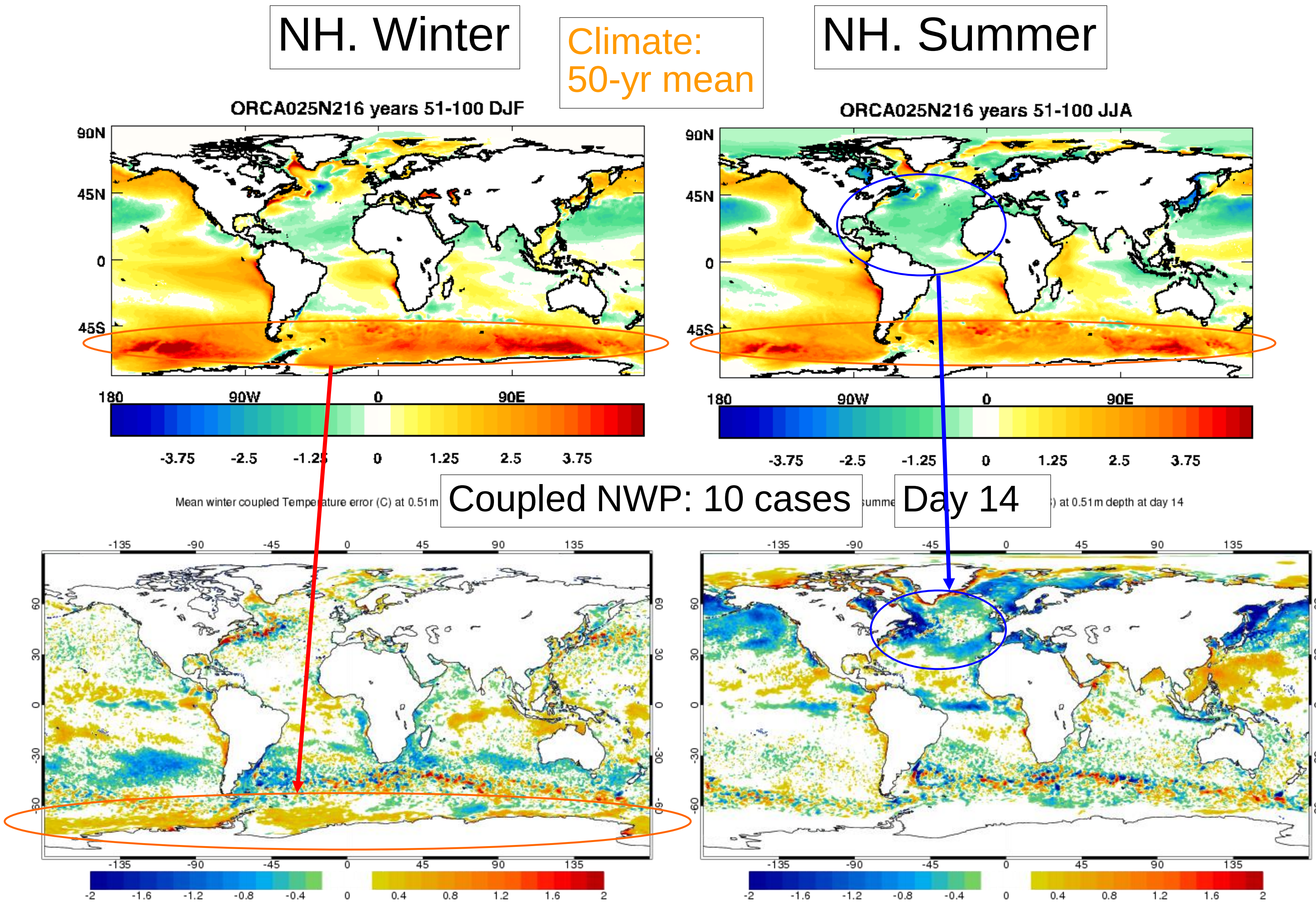
Climate error

Bias in cloud cover

(against CALIPSO)



SST Bias Evolution Coupled NWP vs. Climate



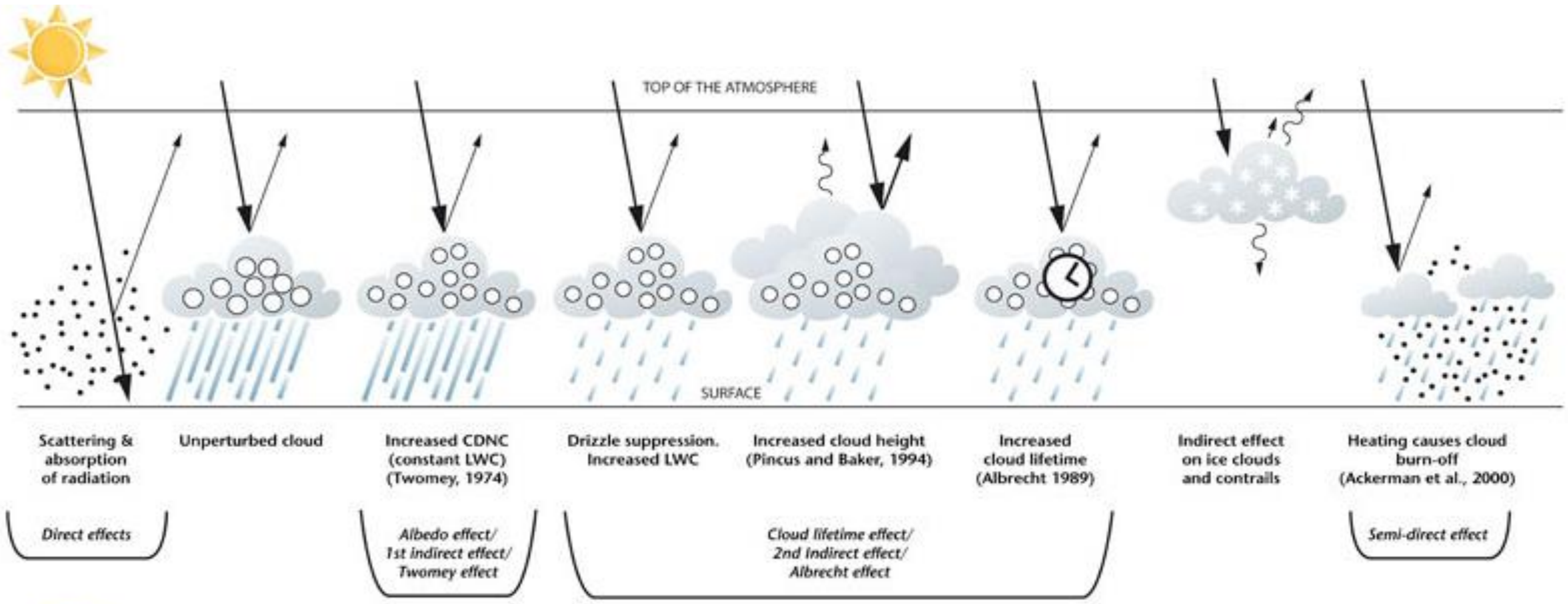
Johns et al.
2012

Aerosol indirect effects

An example of seamless model development

Jane Mulcahy

- Direct & indirect aerosol effects:



Adapted from Haywood & Boucher (2000)

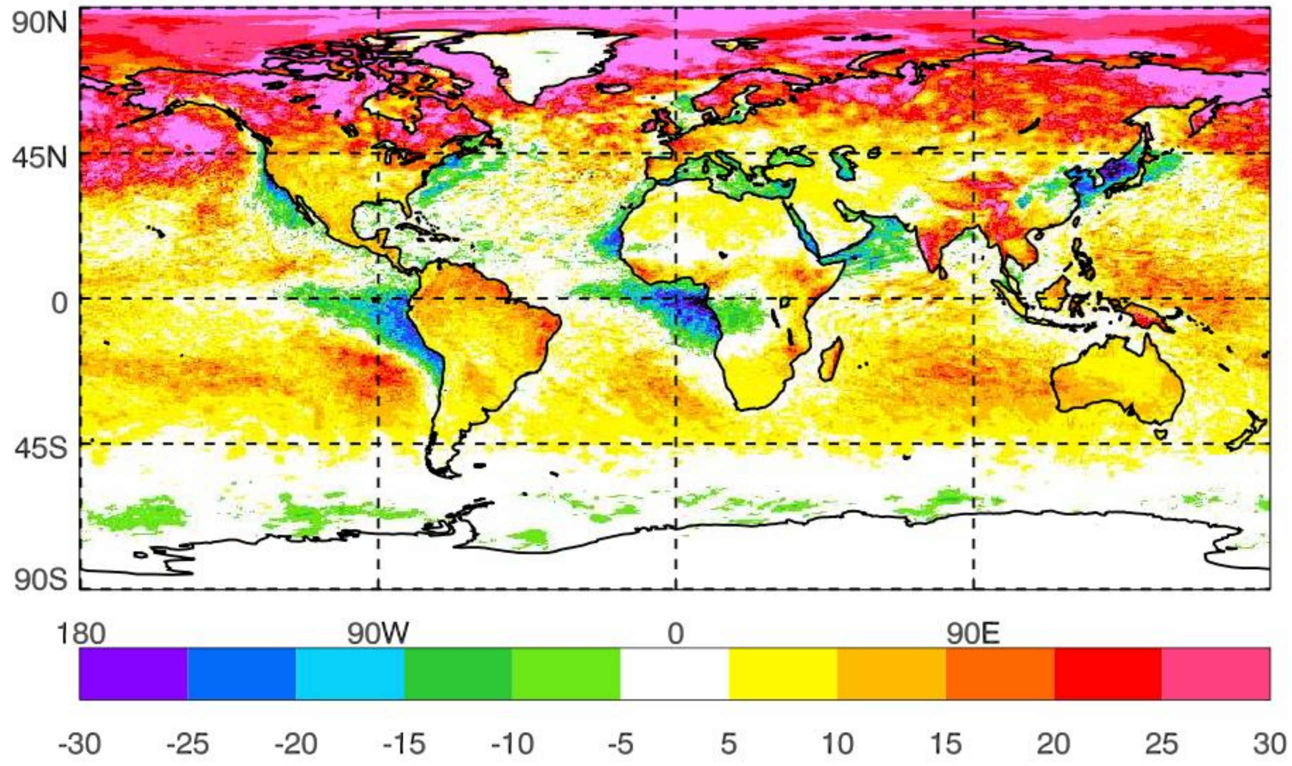
Pre-2007: NWP models assume fixed values for land/sea
2007-2014: Direct effect only uses 3D climatologies

Aerosol indirect effects

An example of seamless model development

Mulcahy et al (2014)

Impact of full “climate” aerosol scheme on surface SW (W/m^2)
at day 5 in 1 month of rerun global NWP forecasts (June 2012):

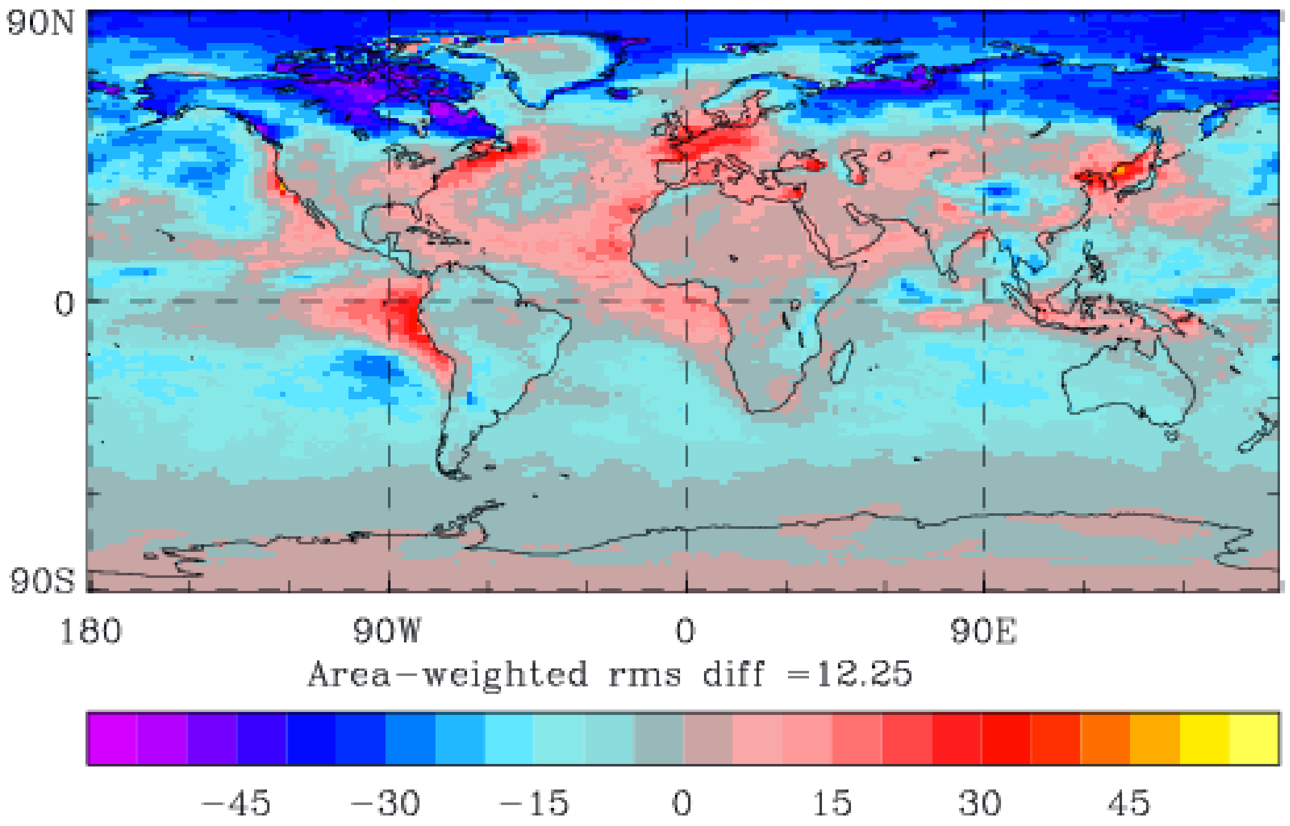


Aerosol indirect effects

An example of seamless model development

Tom Riddick

Reverse experiment: impact on JJA surface SW from running 20 year climate model with NWP treatment of aerosol scheme

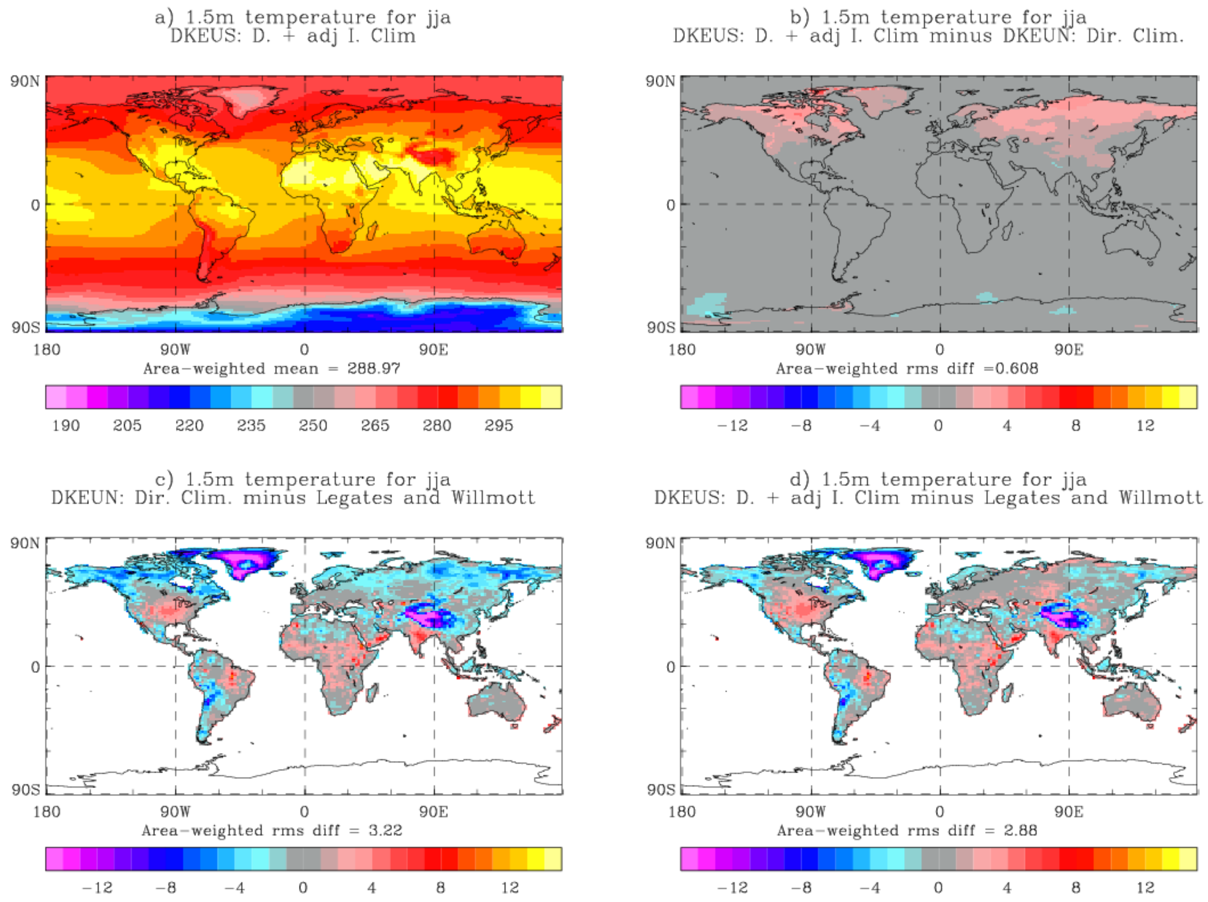


Aerosol indirect effects

An example of seamless model development

James Manners, Tom Riddick, Jonathan Wilkinson

Impact of adding climatological indirect aerosol effects on 20 year mean JJA $T_{1.5m}$ error:



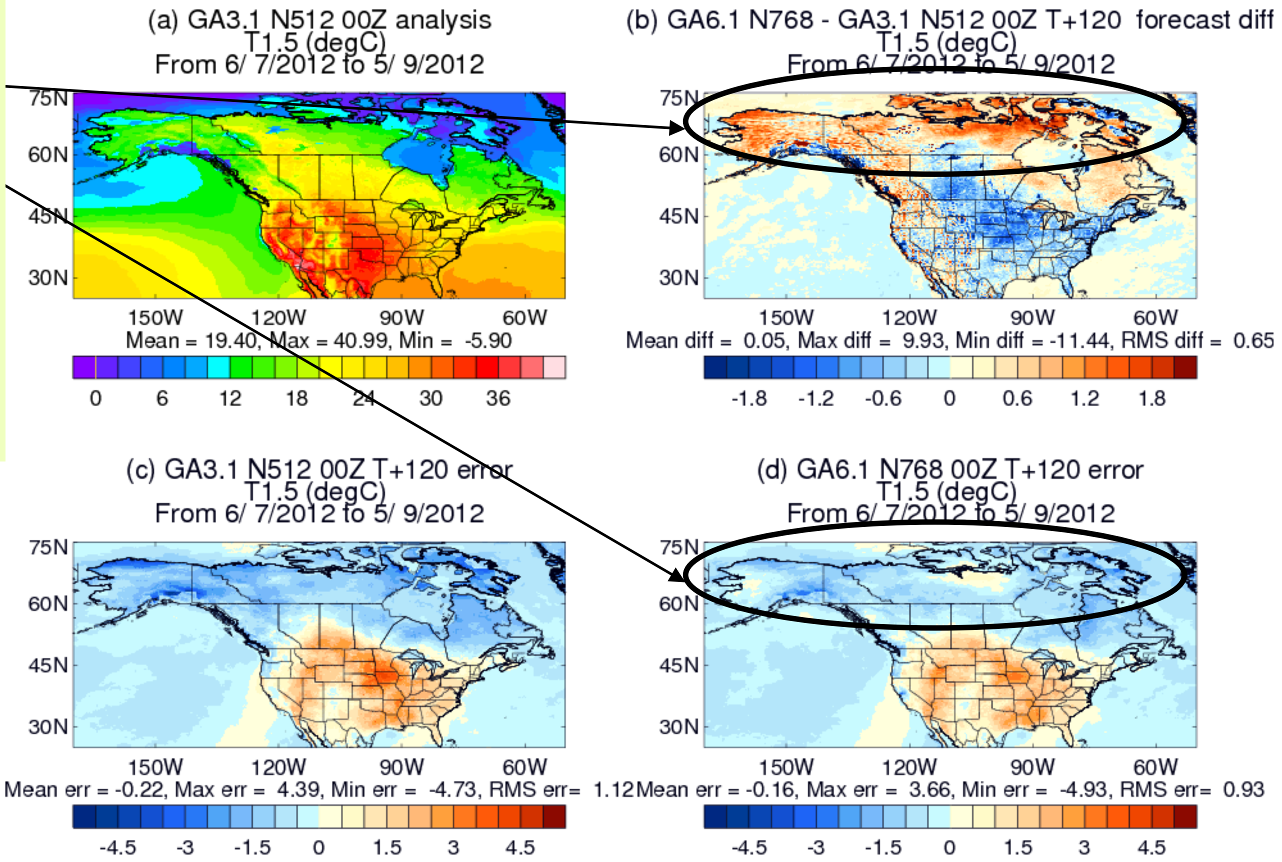
Aerosol indirect effects

An example of seamless model development

Tom Riddick

- Impact on operational implementation (alongside other model changes)

- High lat improvements from aerosol climatologies
- Lower lat improvements from other changes



Aerosol indirect effects

An example of seamless model development

Seamless framework helped progress by:

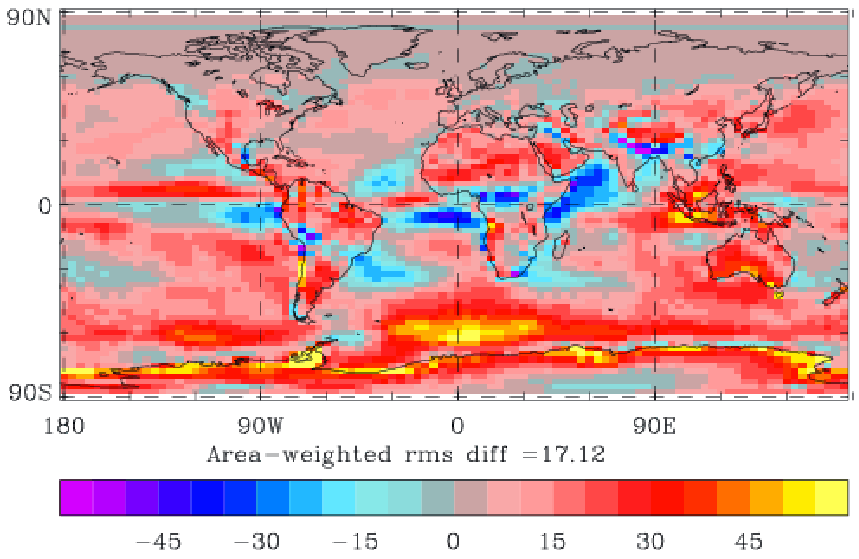
- Exposing sources of errors in one system by studying in the context of another
- Providing appropriate tools/systems with which to develop the improved schemes

  Other good examples include ENDGame, stochastic physics, multi-layer snow scheme …

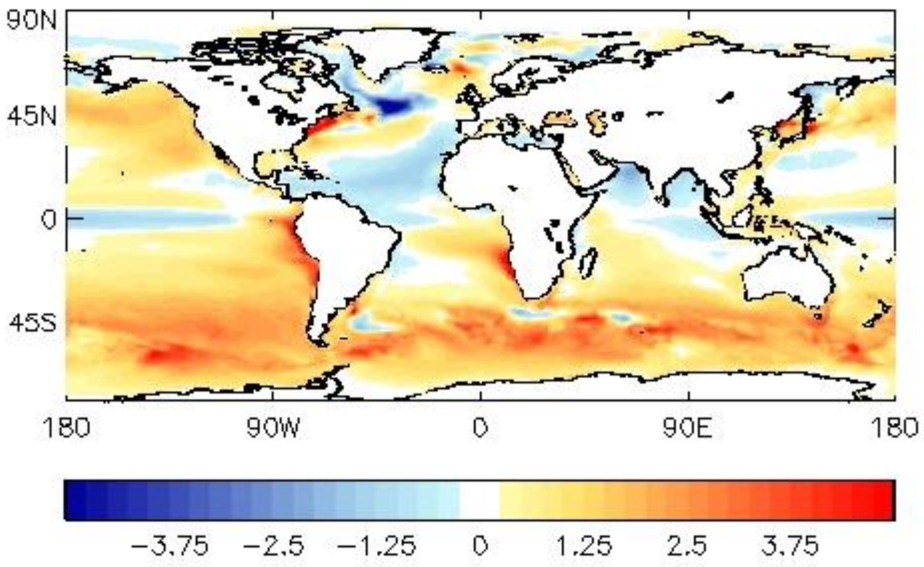
  … but most GA developments benefit from this sort of seamlessness, albeit often more subtly

Example of lack of cloud over Southern Ocean

Surface net downward SW bias



Coupled SST bias



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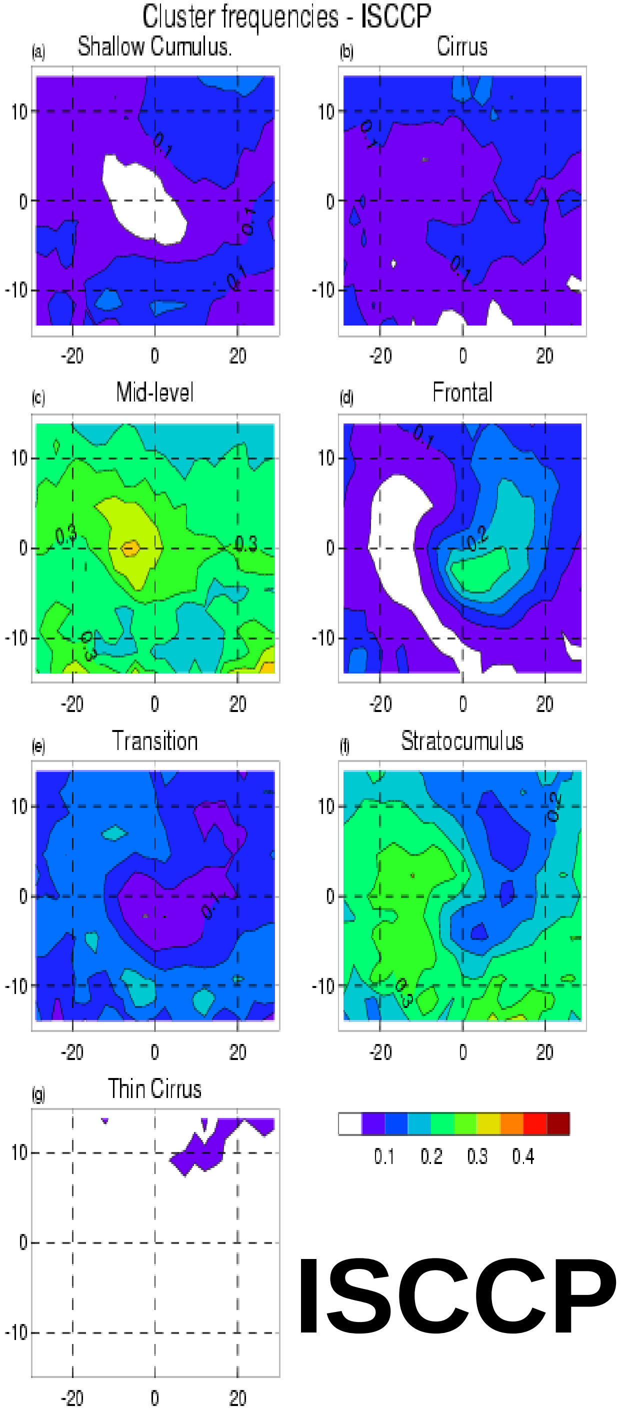
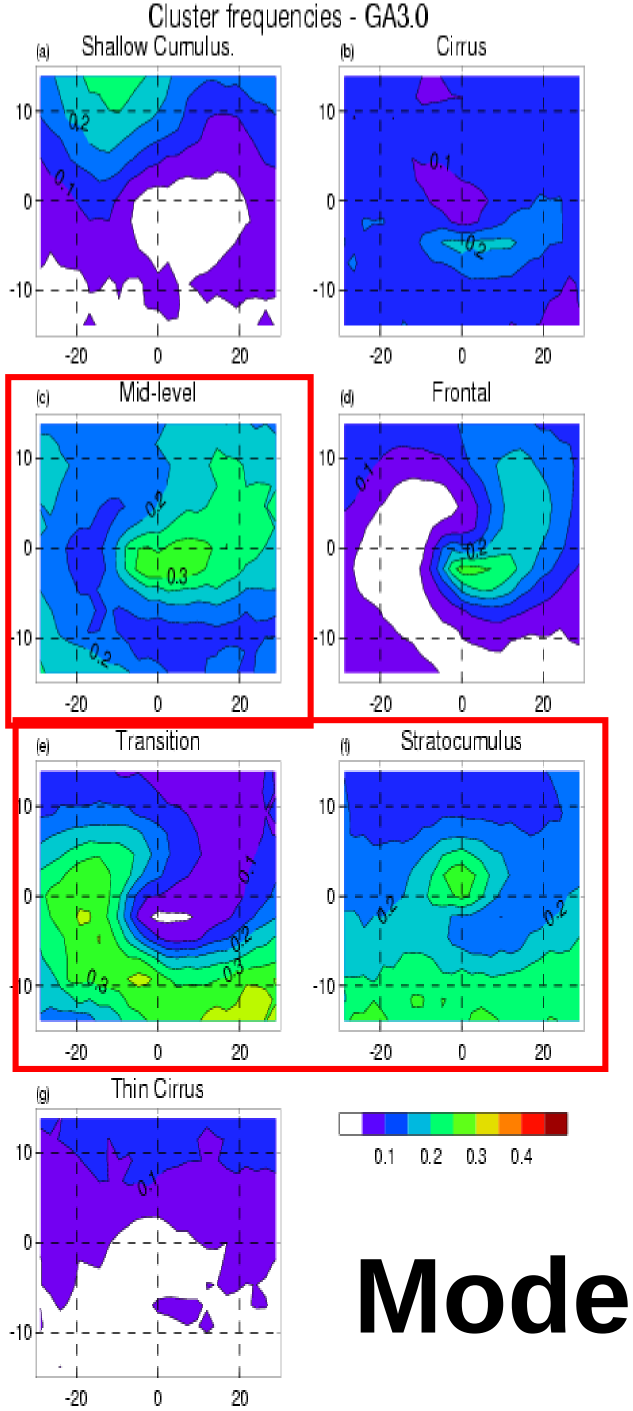
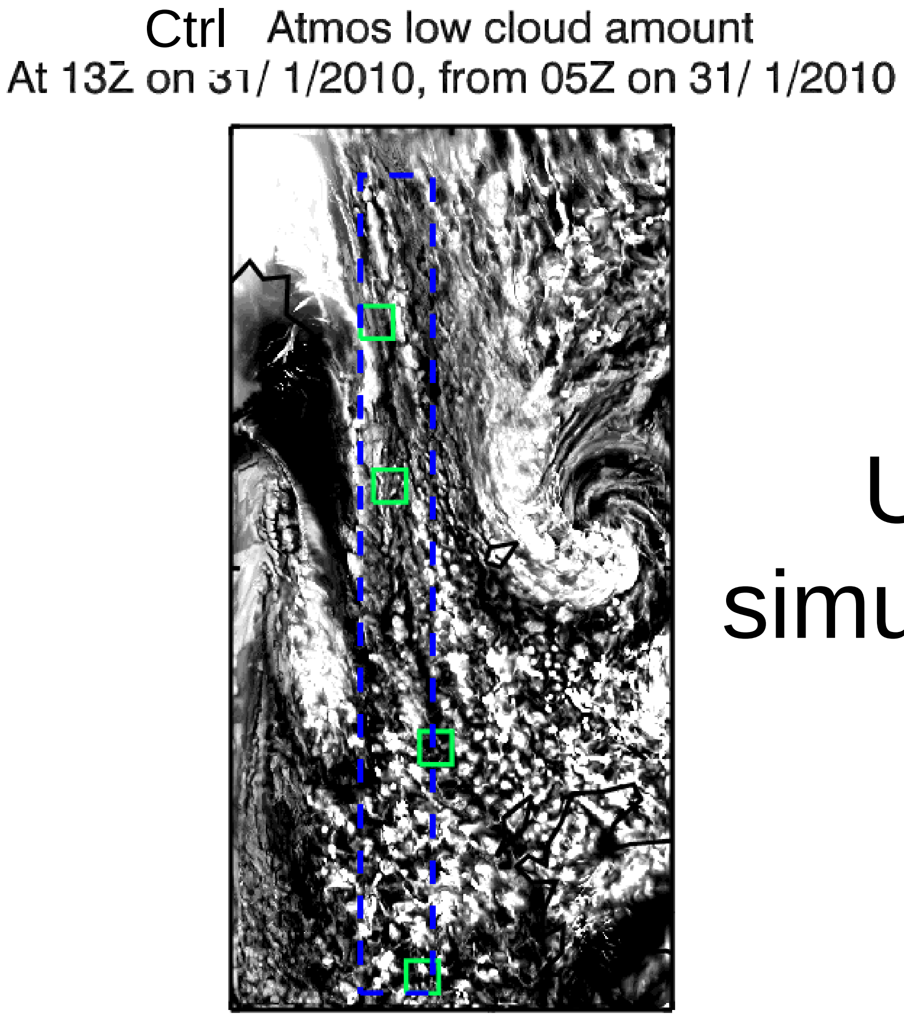


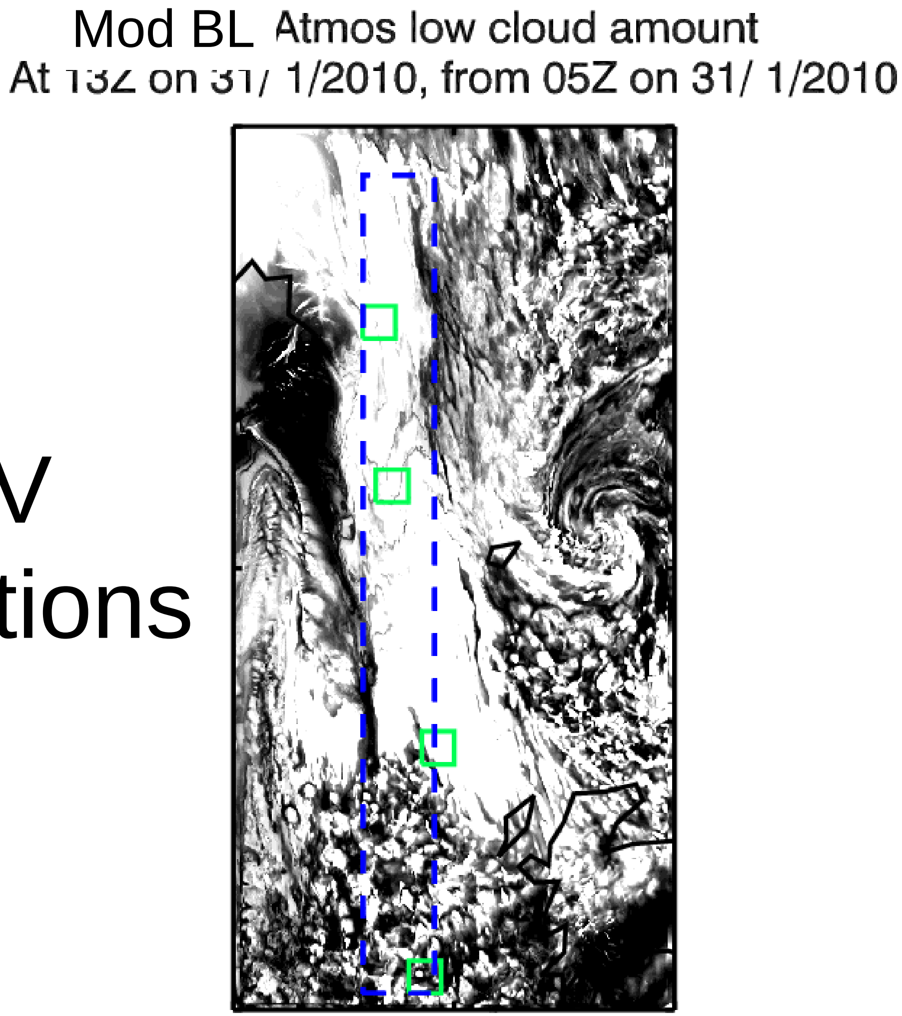
ISCCP



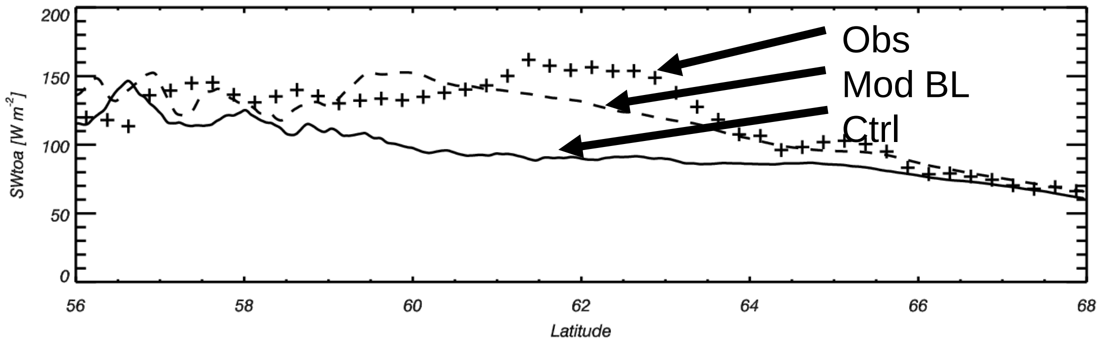
Model



UKV simulations



CONSTRAIN field campaign
(off NW Scotland)



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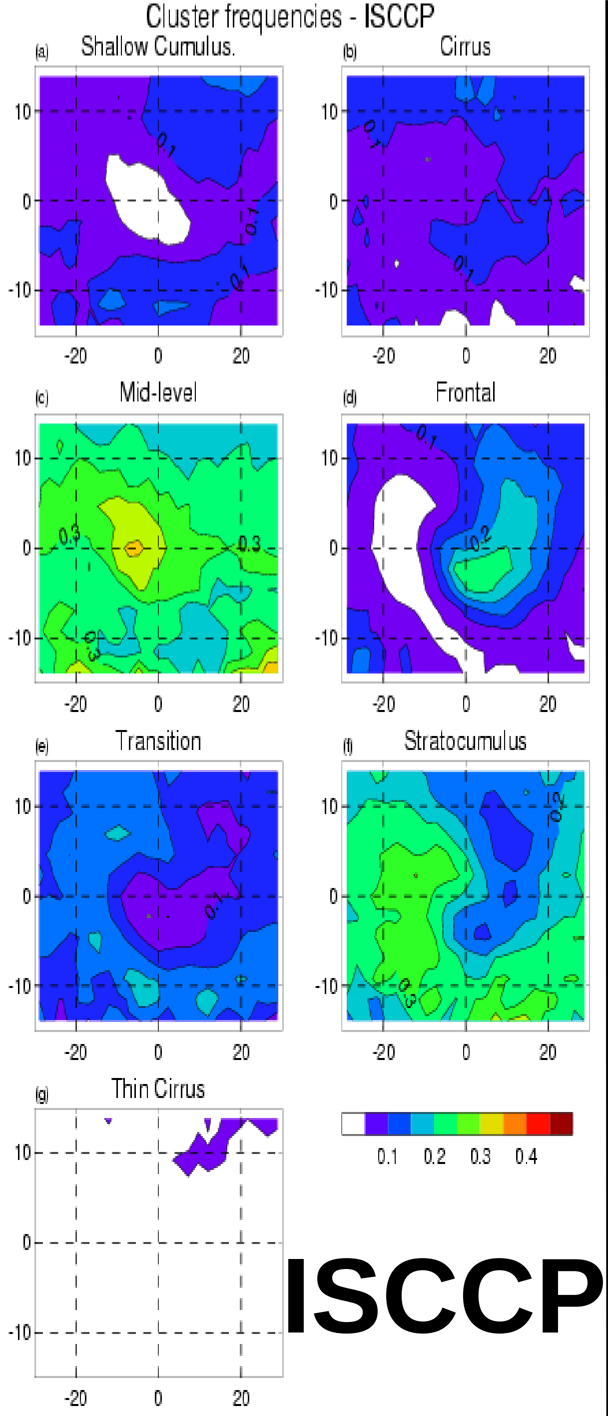
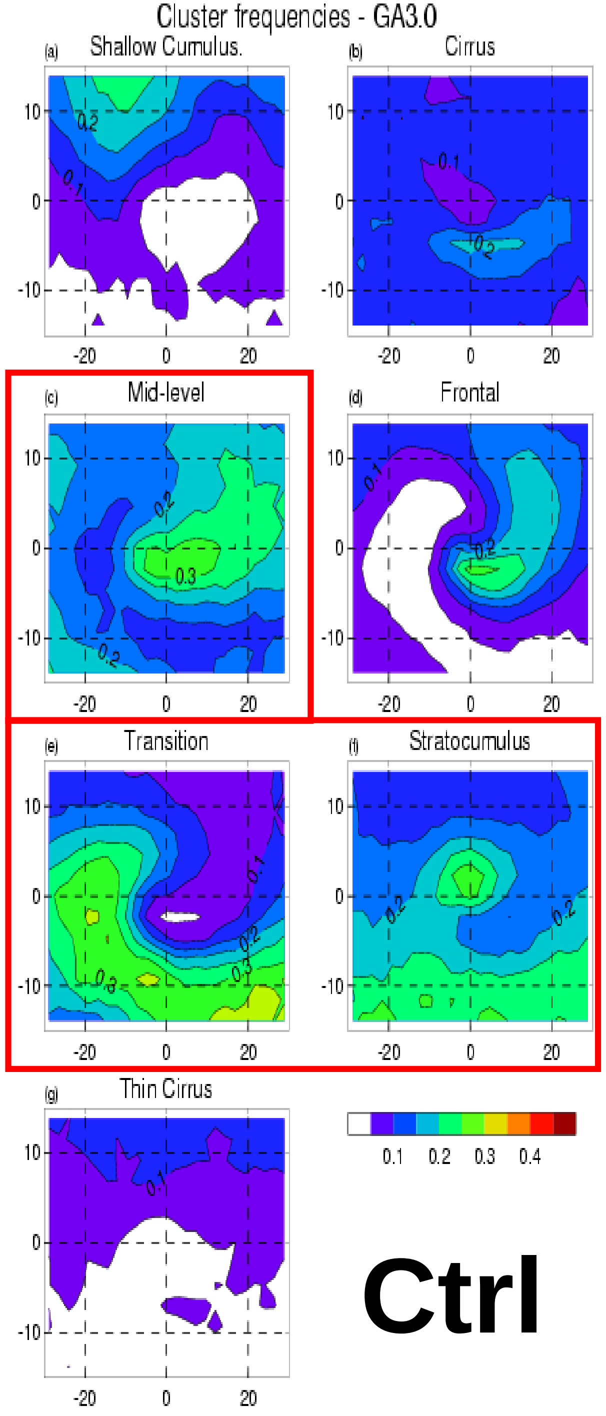


ISCCP



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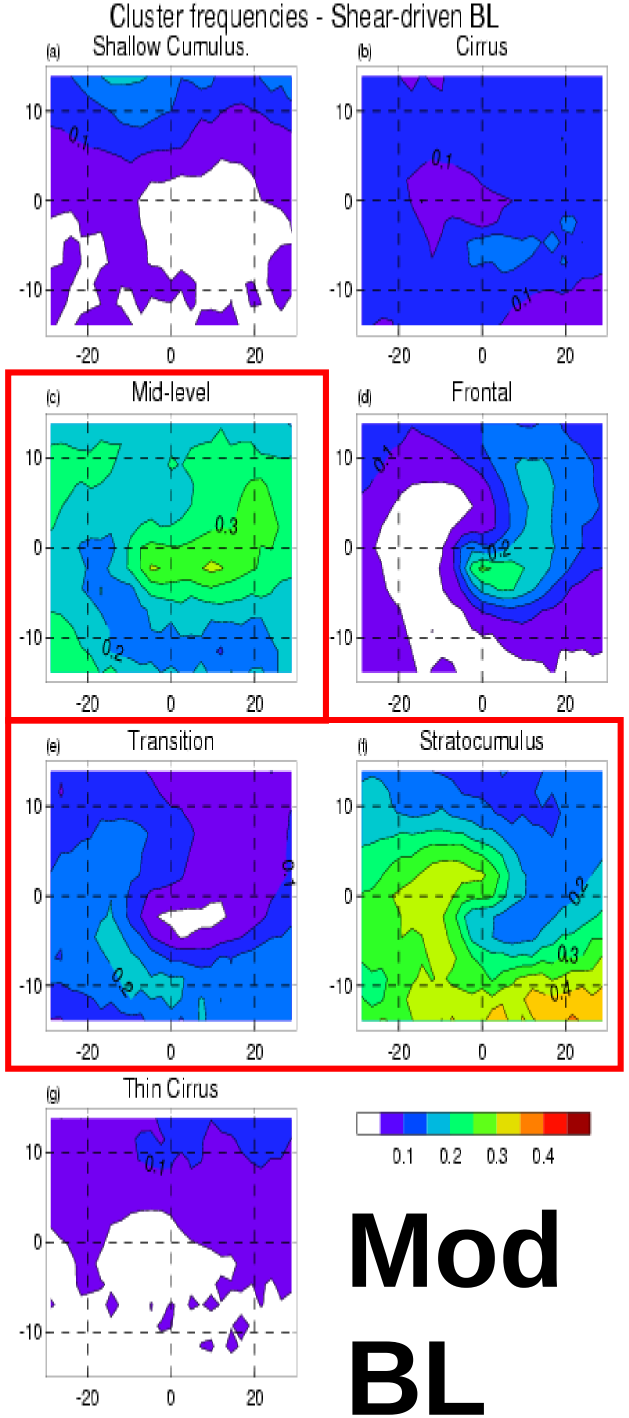
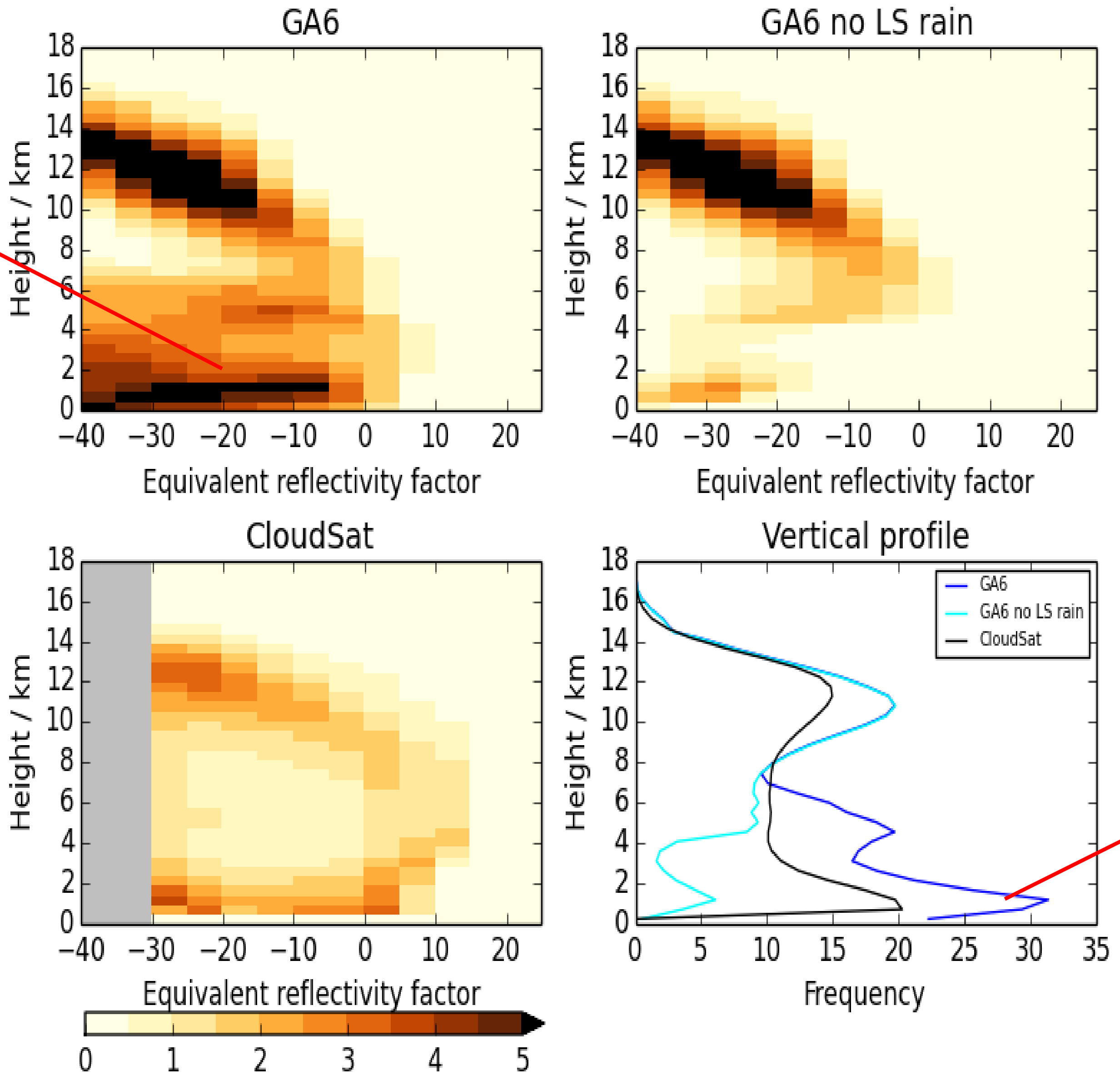


Mod BL

Example of warm rain microphysics

Excess hydro-meteor at low levels

Comparison of mean radar reflectivity over the tropics against CloudSat



Excess "drizzle" (<0.005mm/hr)

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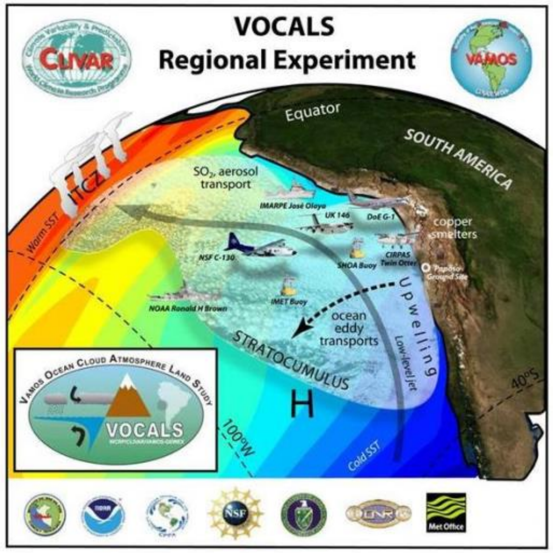
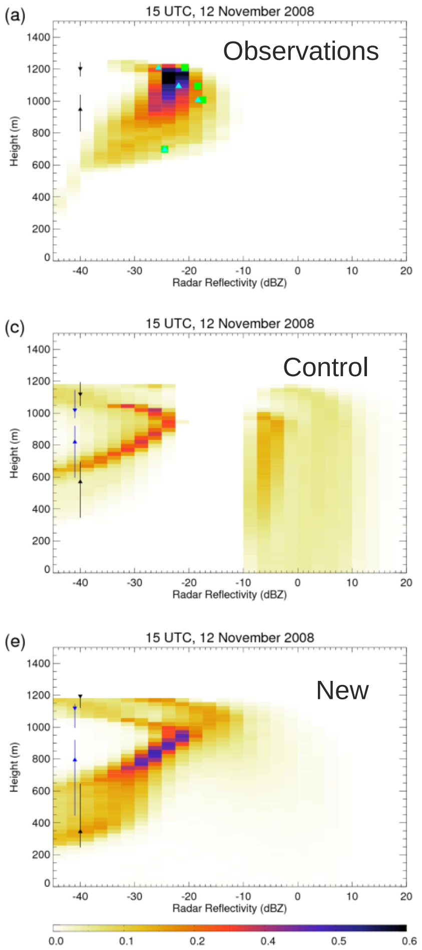
Addressing excess drizzle in the model using field experiments

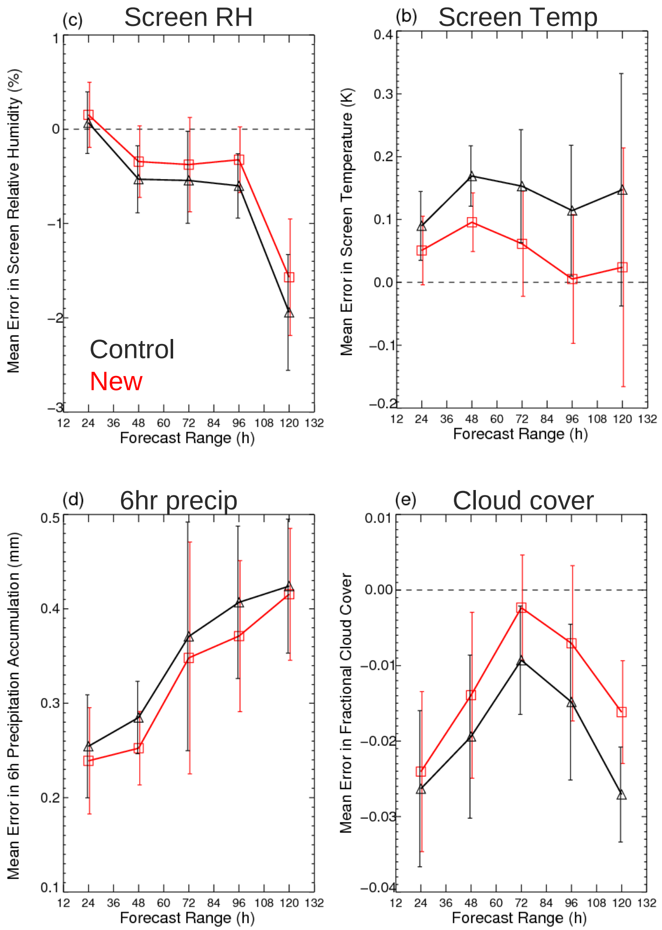
Develop new cloud microphysics parametrizations from observations



Evaluate in high resolution NWP case-studies



Implement in UK/global NWP and climate models

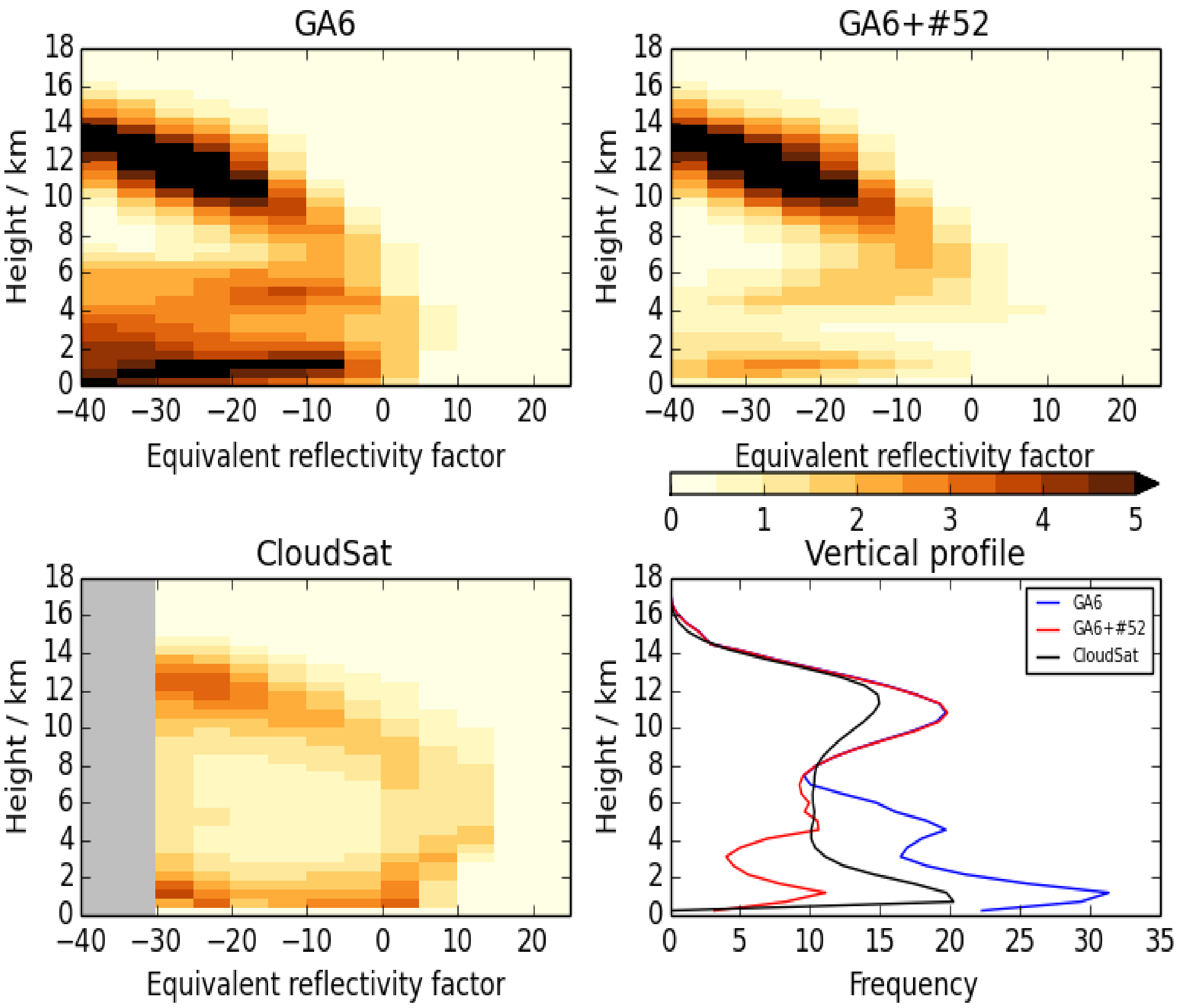


10 JJA NWP case-studies (model - land based observations in extratropical Northern hemisphere)

Steve Abel (OBR) & Ian Boutle (APP)

Example of warm rain microphysics

Comparison of mean radar reflectivity over the tropics against CloudSat



The GA (and RA) development process

Met Office

The GA development process

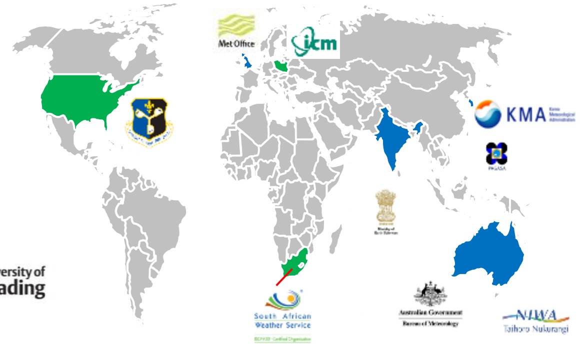
Continuous research cycle

- All developments start here
- Includes multi-year projects and programmes
- Also includes Process Evaluation Groups (PEGs)
- Engagement with a wide range of partners

Met Office Academic Partnership

Met Office | University of Exeter | University of Leeds | University of Oxford | University of Reading

UM partnership



UK Joint Weather and Climate Research Programme

Natural Environment Research Council | Centre for Ecology & Hydrology | National Oceanography Centre, Southampton | British Geological Survey

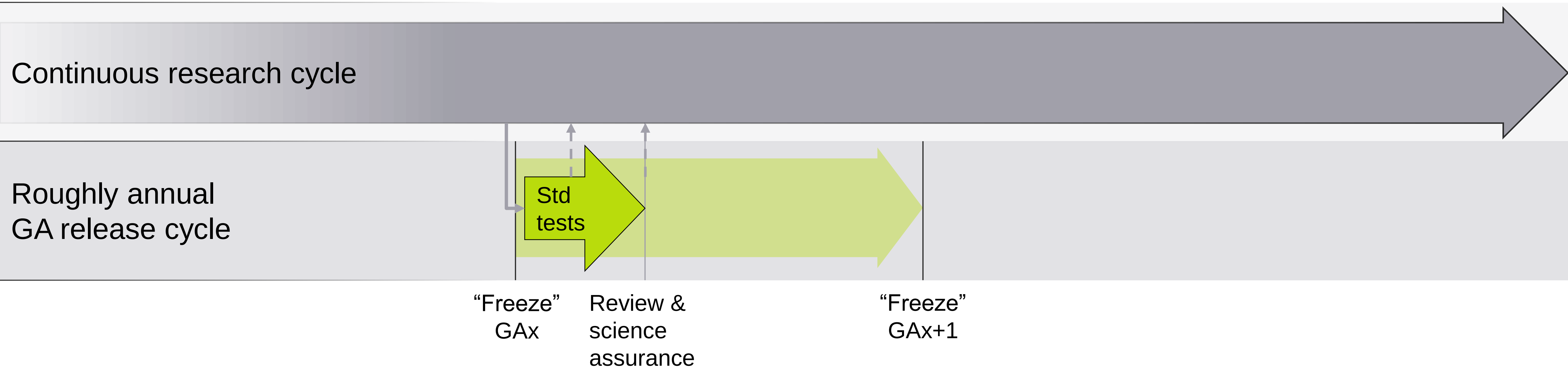
International Organizations and collaborations

ECMWF | EUMETSAT | NCAR | WMO

FAAM

Met Office | Natural Environment Research Council

The GA development process



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

Identify changes:
- Maturity
- Priority

Current std tests:
- 20 yr AMIP simulation
- 24 x 6 day NWP forecasts

Ticket details page

Met Office Unified Model™
Global Atmosphere

Search

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Wiki | Timeline | Roadmap | View Tickets | New Ticket | Search | Admin

wiki: ticket / 64 / TicketDetails

Up | Start Page | Index | History

Ticket Details #64

Main developer: Martin Willett

Scientific description

The 6a convection scheme is primarily a major rewrite of the convection scheme's parcel calculations that provides a more accurate estimate of parcel properties during the ascent. It does this by iteratively solving the implicit equations for the moist ascent and the forced detrainment. Additionally it also addresses numerous issues that were identified during the review of the convection schemes numerics and the development of the 6a scheme. These improvements include: the full integration of PC2 into the convection scheme including corrections to the cloud fraction increment calculations; a simpler and more robust termination condition for convection; improved triggering of mid-level convection including changes to prevent overlapping events; allowing parcels that become sub-saturated parcels to re-evaporate any condensate; more robust handling of failed convection including the rejection of dry convection; correction to the initiation of downdraughts; the option to include heating due to convective momentum transport and an energy correction; and a general tidying up of the code.

Physical basis for the change

The original convection scheme was originally developed at a time when model resolution (especially vertical resolution) and the demand for accuracy in the parcel ascent were lower than they currently are. Although the current scheme performs very well there is considerable anecdotal evidence that deep convection terminates too low down. This change provides a more accurate estimate of the parcel properties and hence allows convection to go deeper (if it should do).

Resolution and timescale dependence

Is the change dependent on model resolution, timescale or applications (yes/no)?: **no**
(*This should be exceptional as wherever possible, resolution dependencies should be built into the code*)

<If yes, provide details here>

Technical implementation

Please describe in detail how the change should be applied to UM jobs. These changes should be UMUI based for UM version 8.Y, and Rose app based for version 9.Y. This should include any UM branches, hand-edits, STASHmaster files, changes to inputs/ancillaries etc. Also, please continue to duplicate this table for each UM version until the code is fully lodged.

UM vn8.6 (UMUI based)

	Reconfiguration	Model run
Branches	-	-
Handedits	-	~frwm/handedits/UM85_mdet_opt_dp_1.ed (mdet_opt_dp=unset->**1**)
User STASHmaster files	-	-
UMUI switches/changes	-	i_convection_vn = 5->**6**; l_cmt_heating=unset->**.TRUE.**; l_cv_conserve_check= .FALSE.->**.TRUE.**
Any other changes		

Please note any complications that arise from use in any particular system:

<Add details here>

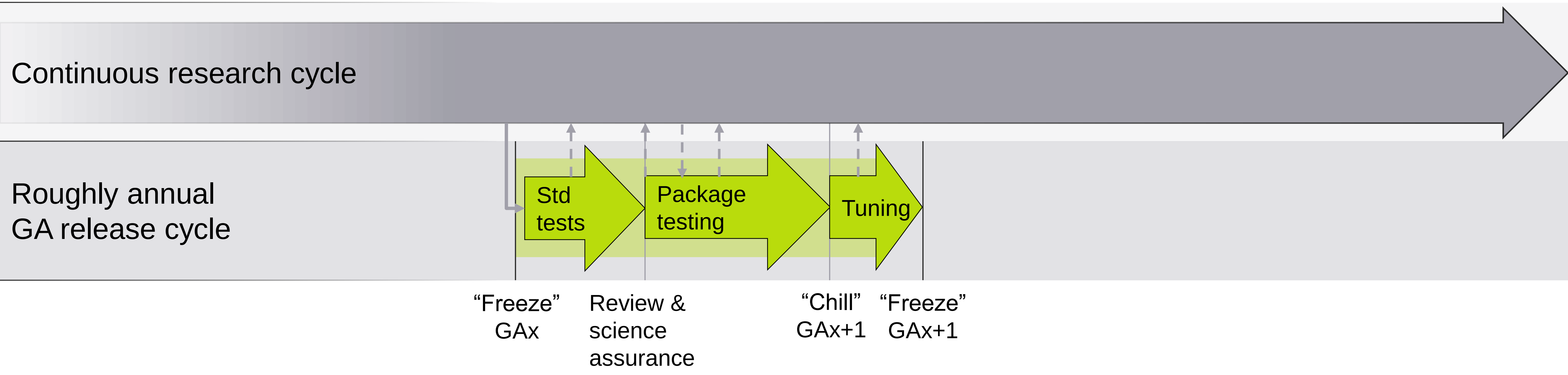
UM vn9.0+ (Rose app based)

	Reconfiguration	Model run
Branches	-	-
Namelist changes	-	i_convection_vn = 5->**6**; (mdet_opt_dp=unset->**1**; l_cmt_heating=unset->**.TRUE.**; l_cv_conserve_check= .FALSE.->**.TRUE.**; eff_dcfl=unset->**1.0**; eff_dcff=unset->**1.0**; fdet_opt=unset->**0**
User Prognostics	-	-
Any other changes	-	-

Please note any complications that arise from use in any particular system:

<Add details here>

The GA development process



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

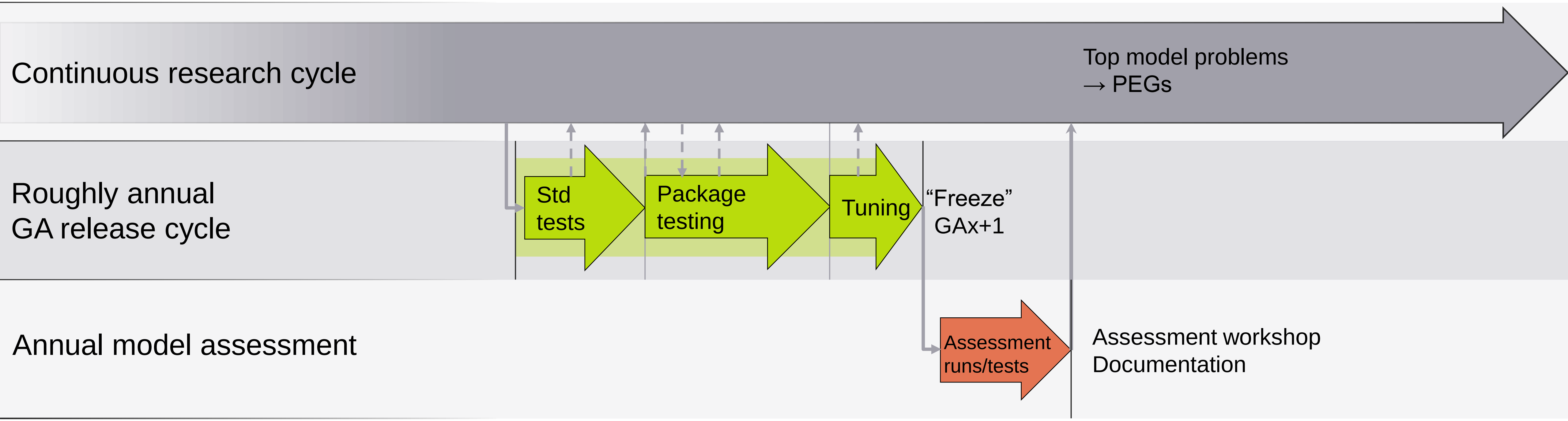
Identify changes:
- Maturity
- Priority

Current std tests:
- 20 yr AMIP simulation
- 24 x 6 day NWP forecasts

Increase complexity of tests:
- Higher resolution/coupled climate
- NWP with cycling data assimilation
- Ensemble prediction system

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

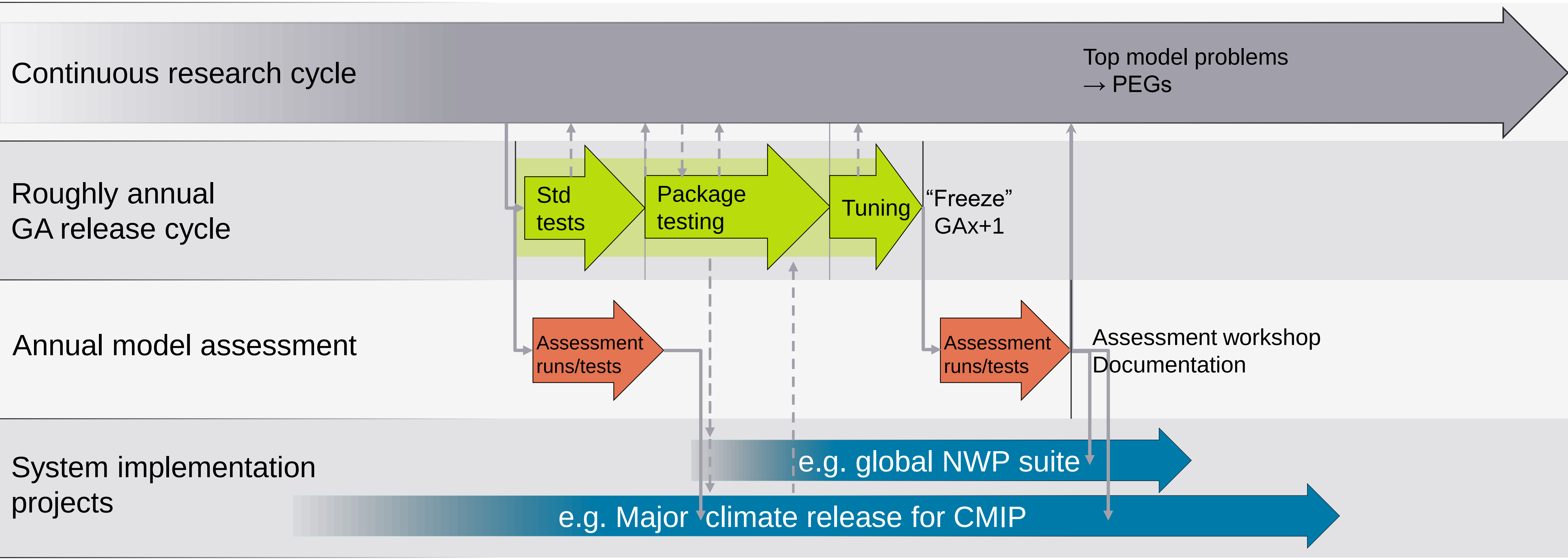
The GA development process



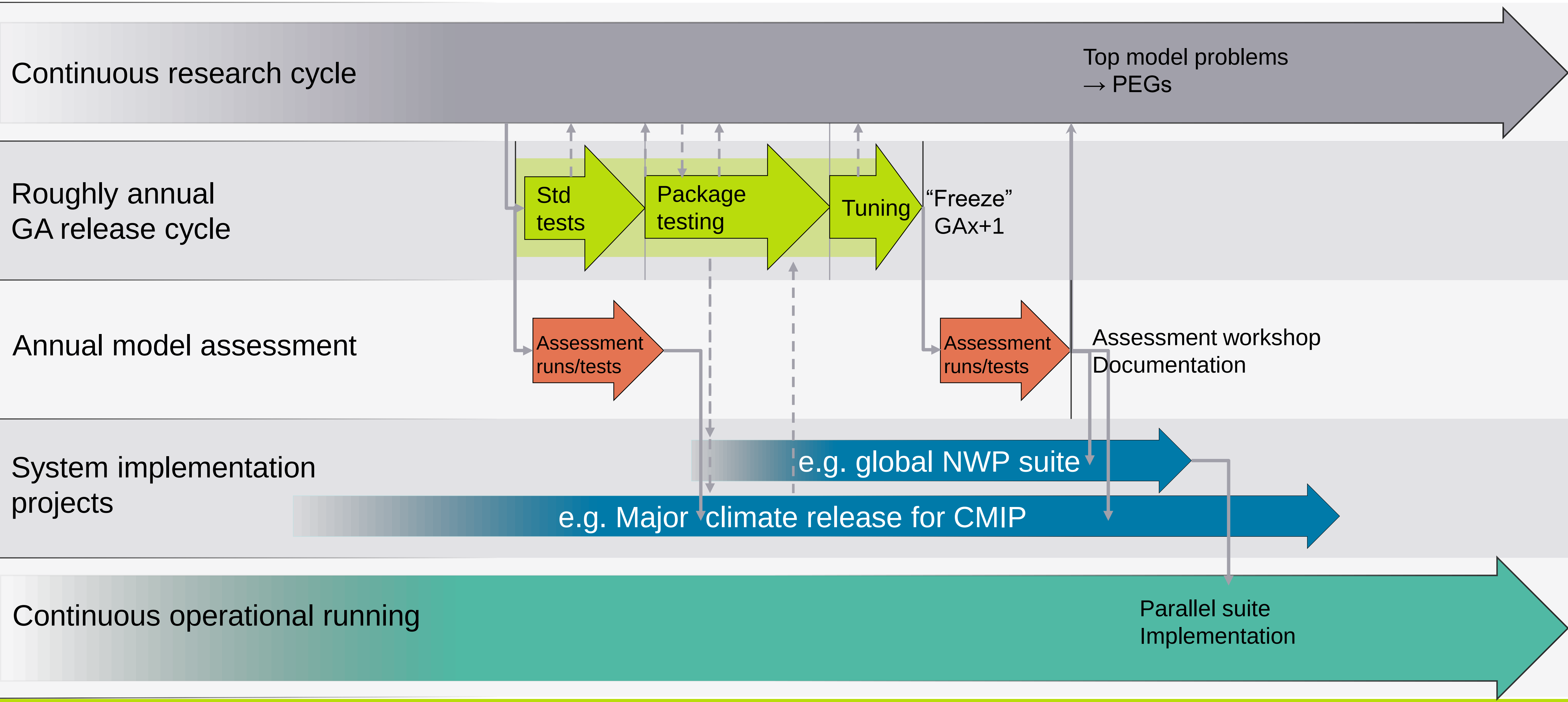
Assessment runs include:

- ~100yr Higher resolution/coupled climate simulations
- High resolution NWP with cycling data assimilation
- High resolution Ensemble prediction system
- Seasonal forecast/hindcast runs

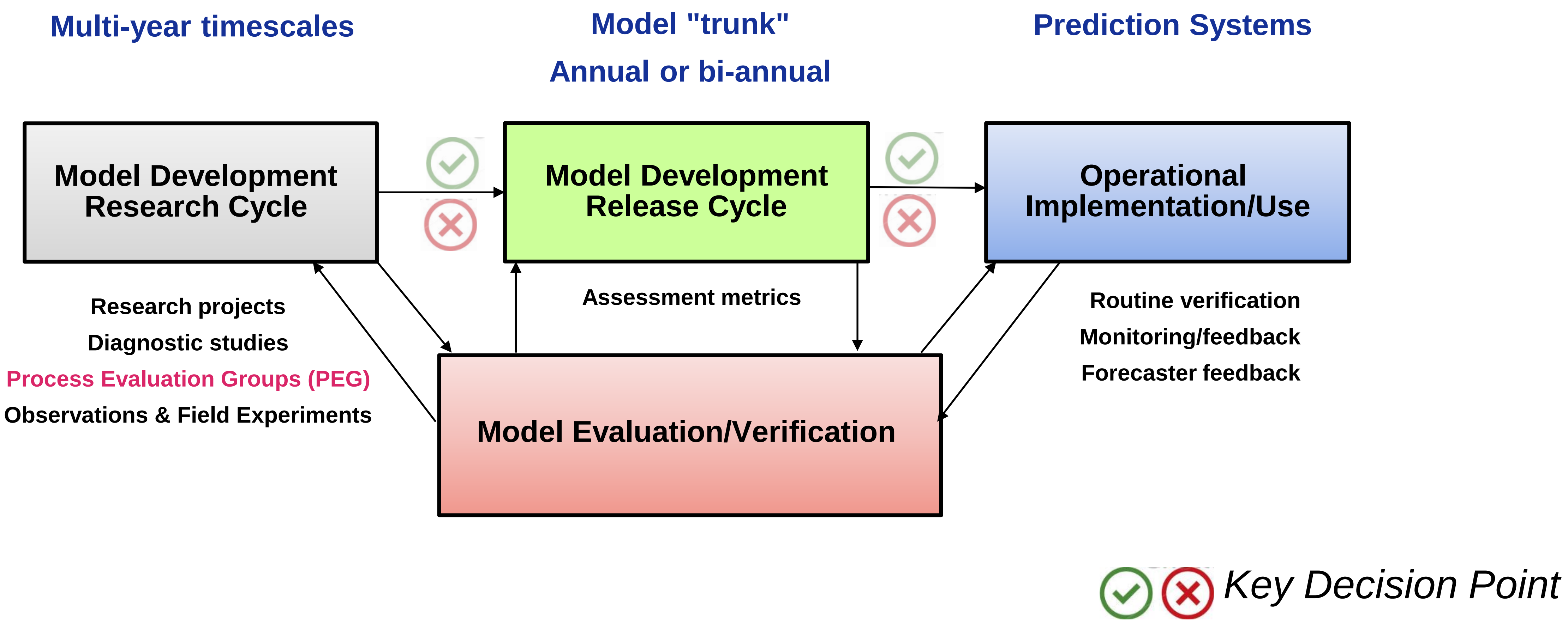
The GA development process



The GA development process



Global Model Development Process



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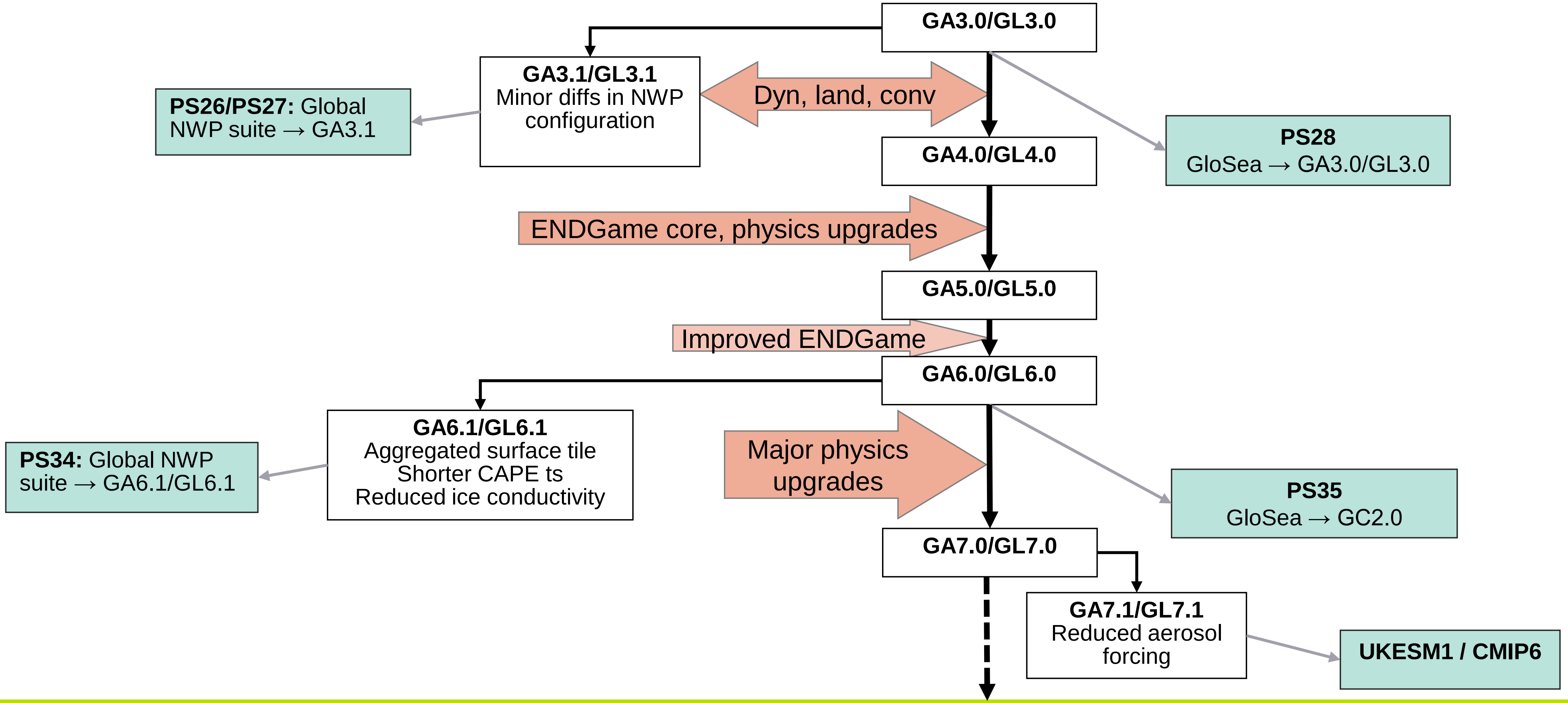
Practicalities/pragmatism

Evolution of the GA “trunk” and “branches”



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Seamless aerosol modelling

Seamless aerosol modelling

- Interactive aerosols are expensive!
- On shorter timescales, does the improved forecast capability justify the expense?
- How do we initialise them?

Seamless aerosol modelling

- Interactive aerosols are expensive!
- On shorter timescales, does the improved forecast capability justify the expense?
- How do we initialise them?
- Our intended way of working is to:
  - Use dust interactively on all timescales.

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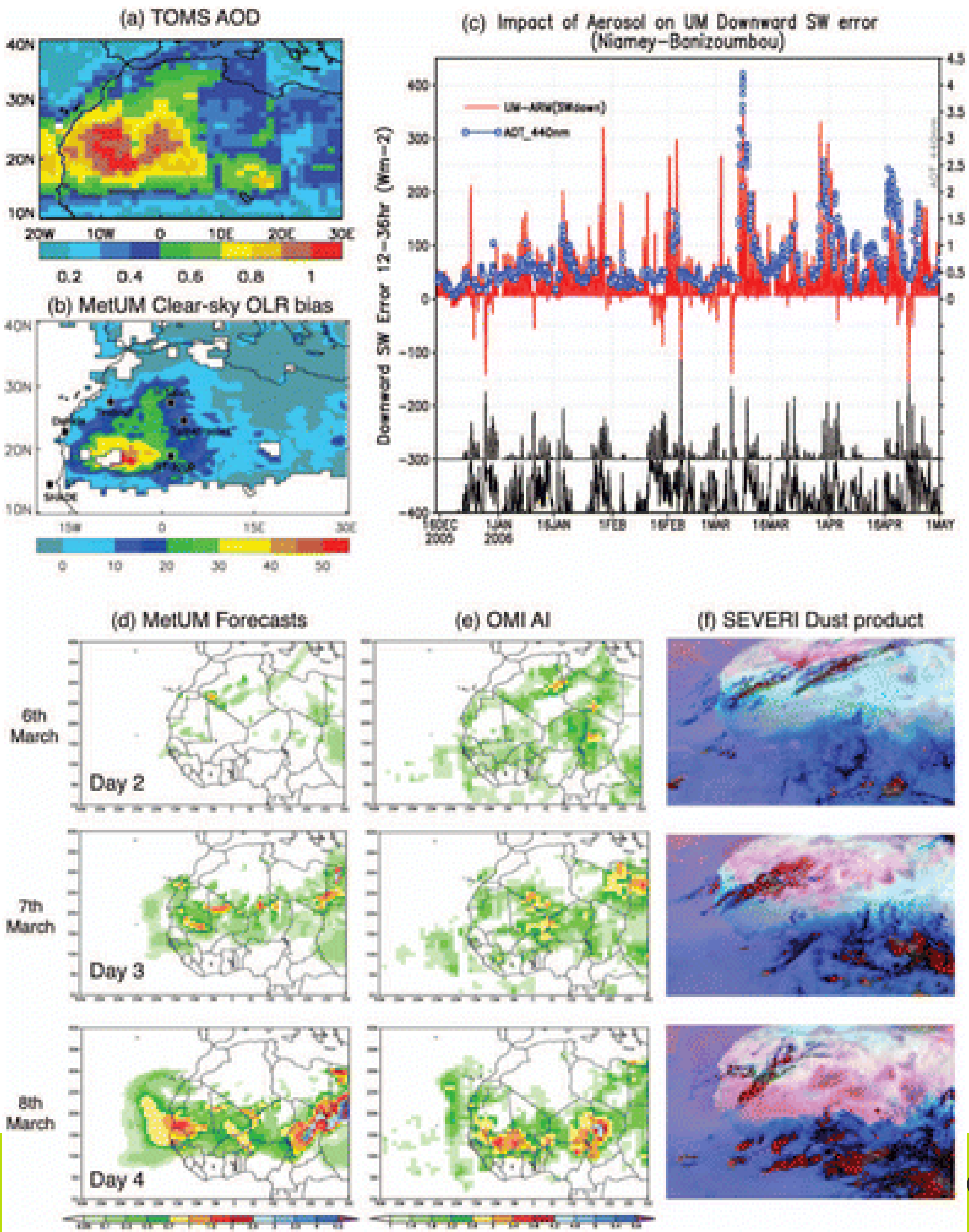
Justification for interactive dust



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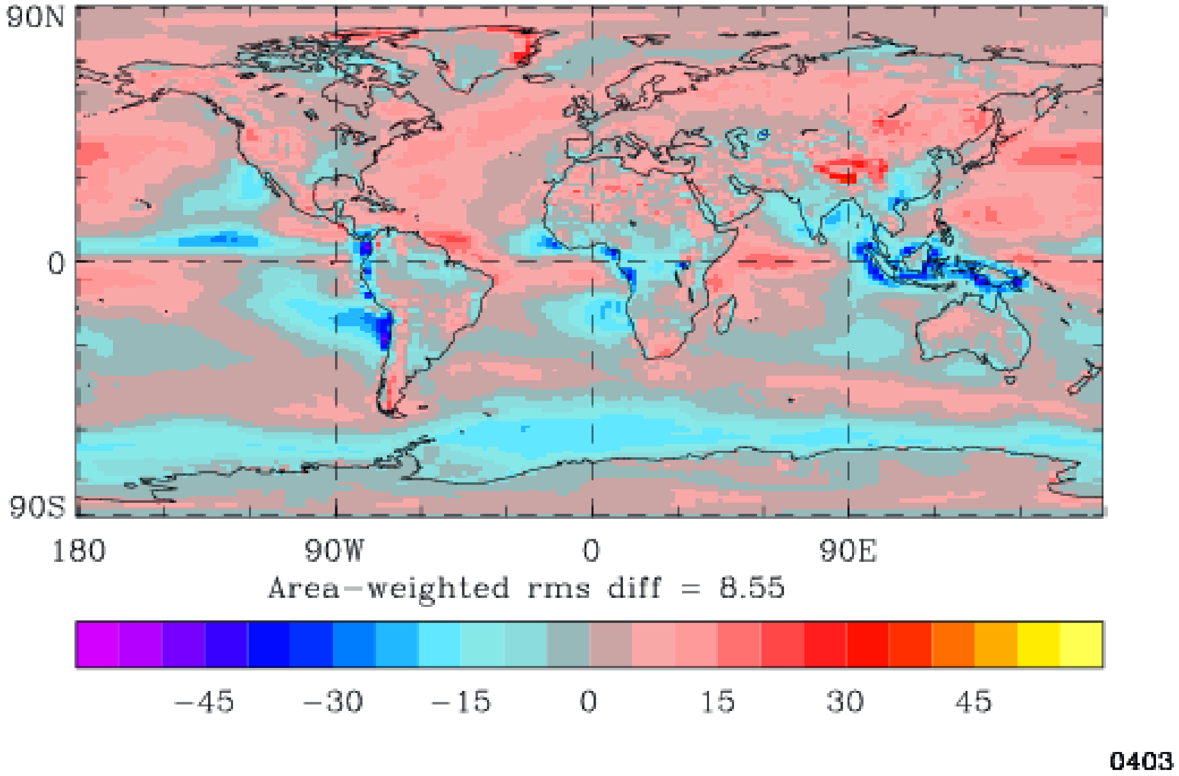
Traceable ~~Seamless~~ aerosol modelling

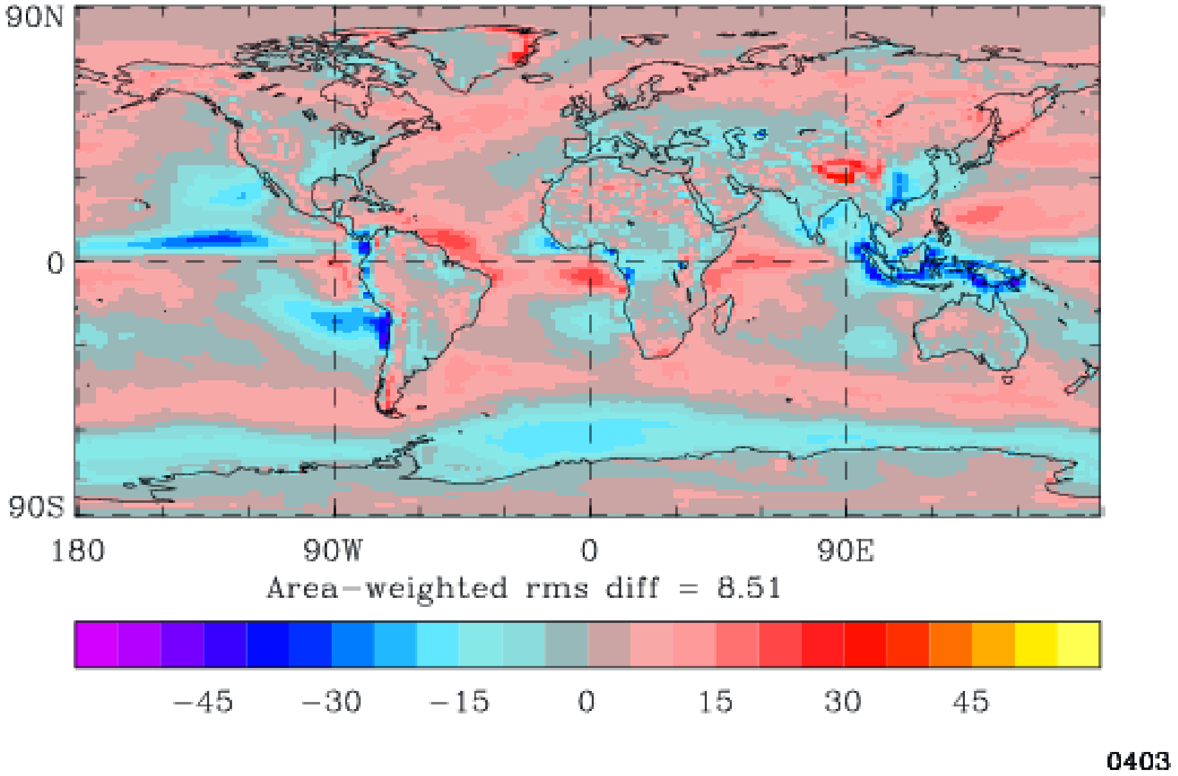
- Interactive aerosols are expensive!
- On shorter timescales, does the improved forecast capability justify the expense?
- How do we initialise them?
- Our intended way of working is to:
  - Use dust interactively on all timescales.
  - Apply aerosol concentrations calculated interactively in AMIP simulations for shorter timescale forecasts.
  - Aerosol direct and indirect effects are calculated in the same way on all timescales.

Impact of using aerosol climatologies from previous configuration

Mean bias in reflected SW
GA7 with interactive aerosols using Glomap-MODE



Mean bias in reflected SW
GA7 with GA6 CLASSIC climatologies



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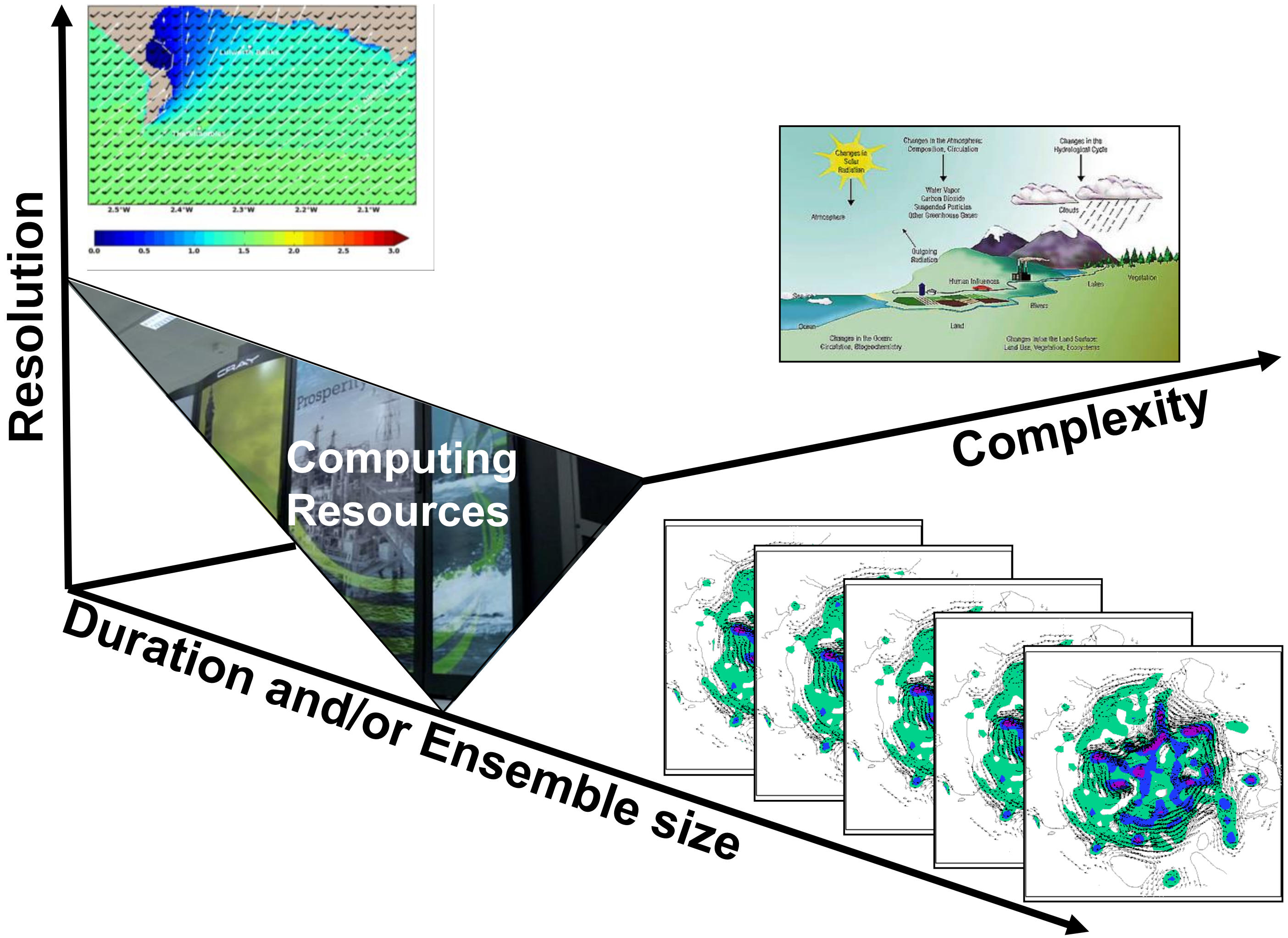
Things to consider when writing schemes for a seamless system

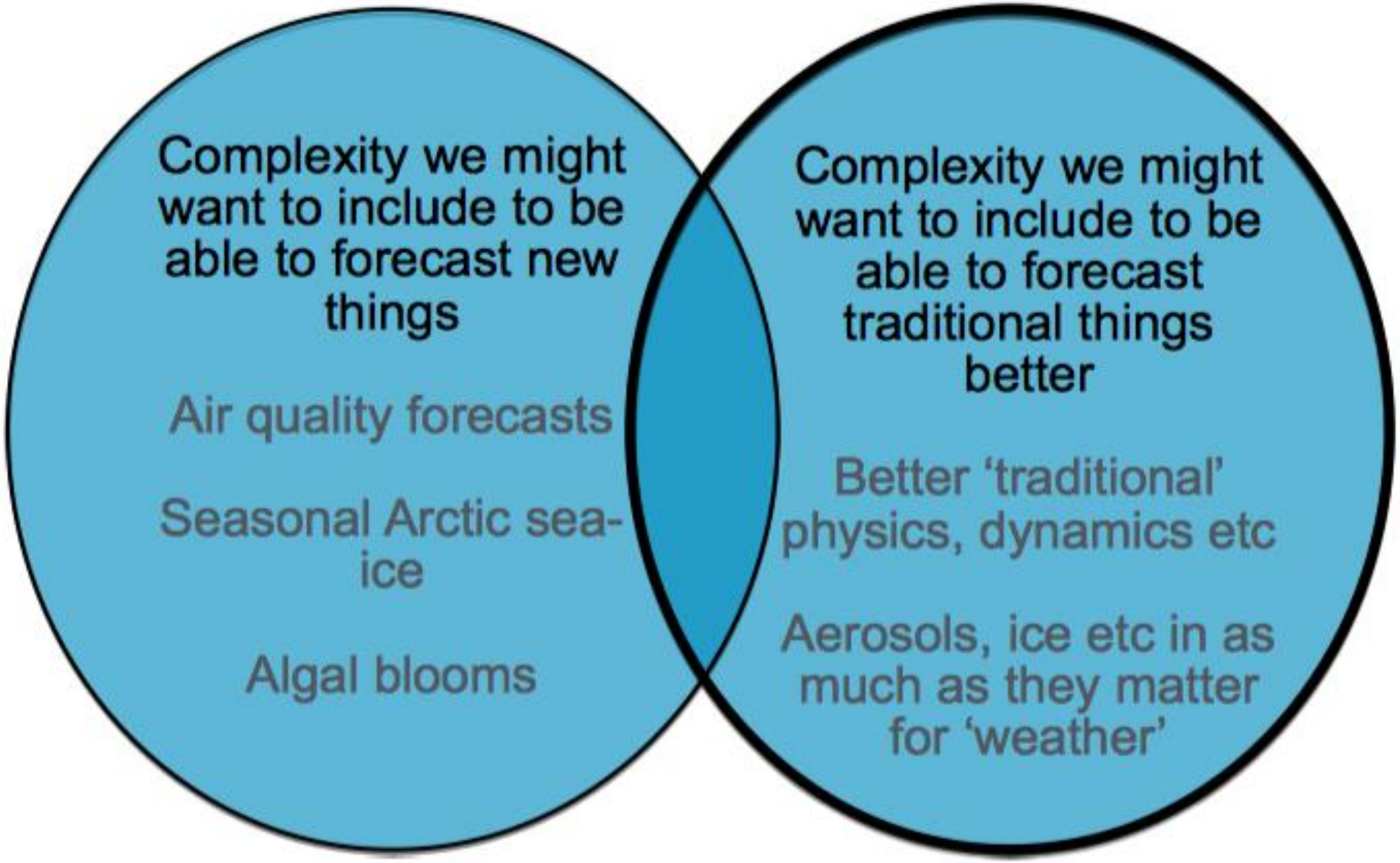
- The scheme needs to work for all applications of the model (not just the timescale the developer interested in).
- Cost is an important issue for many users.
- Can the level of complexity of the scheme be adjusted such that there is a traceable solution which appropriately balances cost and benefit for each application?

Developments in computing

Challenge of exploiting modern HPC



General considerations for inclusion of new processes or more complexity



Andy Brown
ECMWF 2016 seminar
Earth system modelling for seamless prediction:

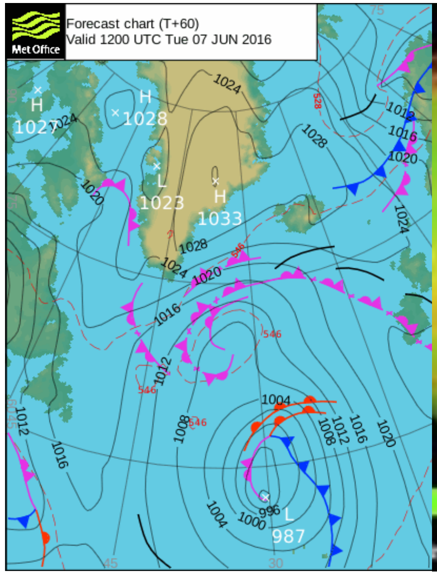
Future challenges

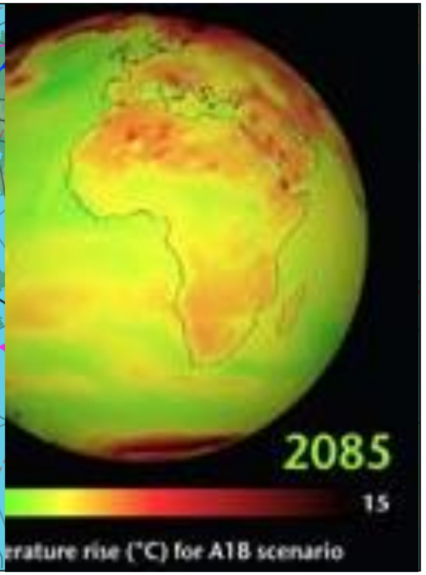
Resolution and scalability

The consequence of unification

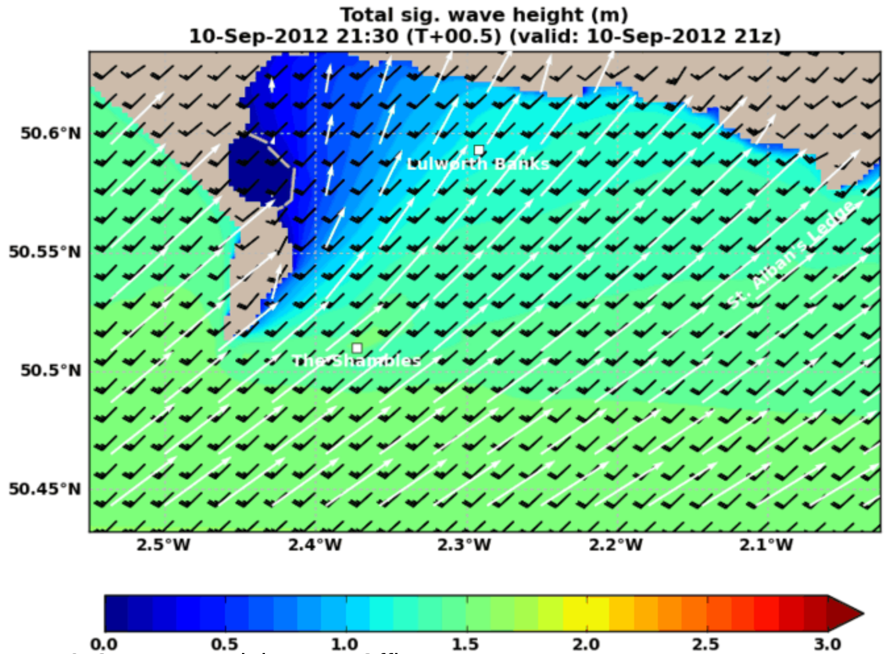
Nigel Wood

A factor of ~100-1000 between these…





17 - 135 km



…the same dynamics has to continue to work

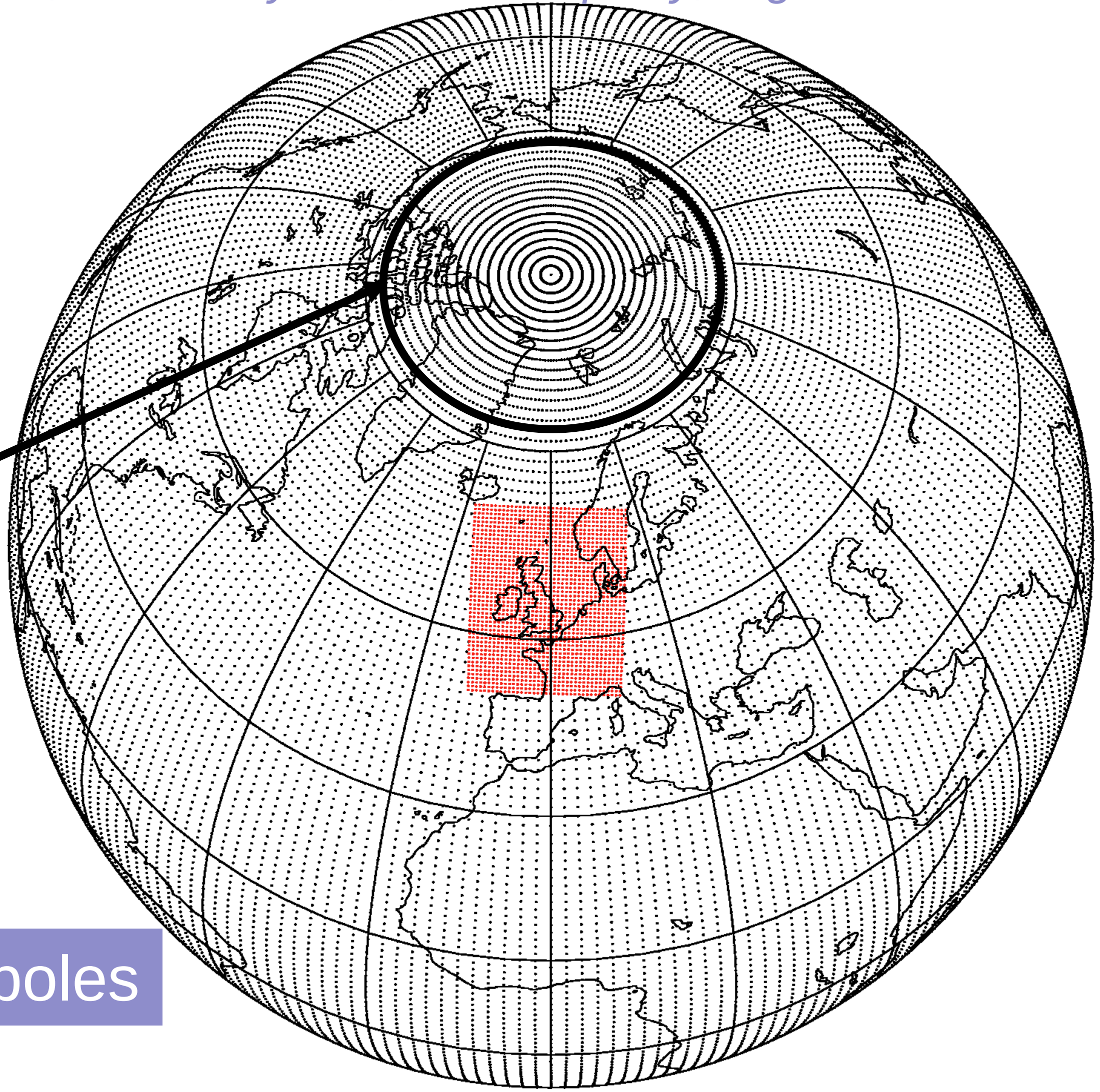
300 m

Resolution and scalability

Running global models on ~ 100,000 cores

Tommaso Benacchio, Chris Maynard, Ben Shipway, Nigel Wood

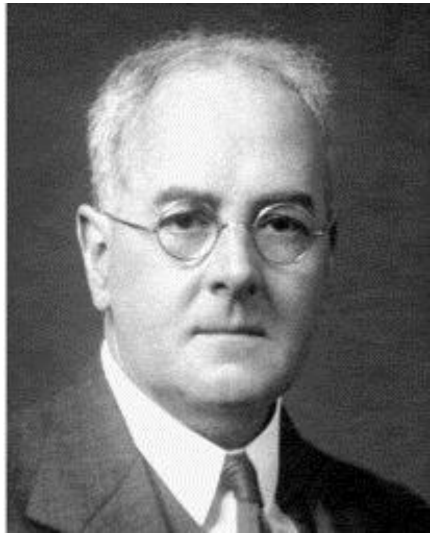
- At 10km mid-latitude resolution, grid spacing near poles = 12m!



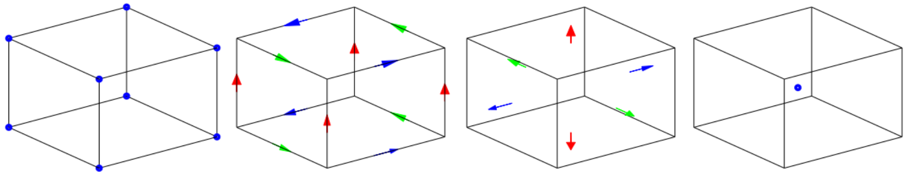
We need to remove the poles

"LFRic:" Next generation Unified Model using the GungHo dynamical core

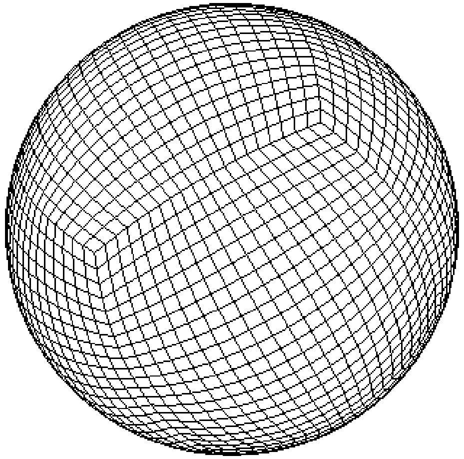
Tomasso Benacchio, Chris Maynard, Ben Shipway, Nigel Wood



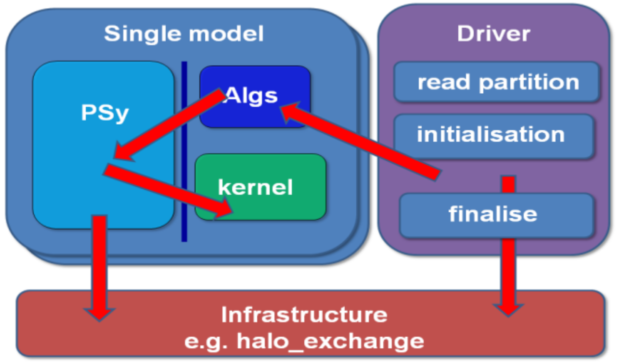
Lewis Fry Richardson
(1881–1953)



- Uses mixed finite element approach on a cubed sphere



- Many aspects of formulation (dynamics, physics etc.) based on current Unified Model ...
- ... but using completely rewritten code designed to separate scientific aspects (physics eqns) and computational aspects (grid layout, communication, etc.)



Summary

We have seen significant benefit from developing a seamless system including:

- Greater scientific robustness of the model
- Improved ability to investigate model systematic errors
- More efficient use of resources

It does, however, pose challenges with our developers being required to consider all users of the model when developing schemes.