

Testing and reviewing code for the Met Office Unified Model

N. Luke Abraham

luke.abraham@atm.ch.cam.ac.uk

With thanks to:

Glenn Greed, Stuart Whitehouse, and the MetUM Systems Team Steven Hardiman, Nigel Wood, & Fiona O'Connor James Mollard

Grenville Lister, Karthee Sivalingam, Simon Wilson, and NCAS CMS



www.ncas.ac.uk

Outline



- What is the Unified Model?
- Code organisation
- Making a change
 - Scientific vs. technical testing
- Examples
- Supporting the UK user community
- Take-home messages

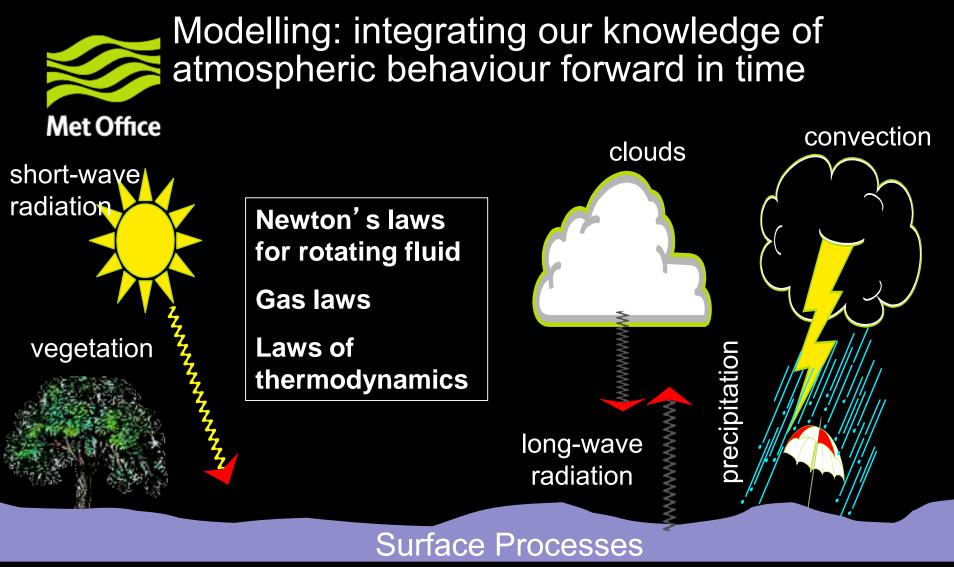




What is the Unified Model?

Lets unmask the truth.... Why do we have a UM?

© Crown copyright Met Office



• The challenge:

To reproduce the behaviour of (hazardous) weather systems

© Crown copyright Met Office



Unified Model

Brown et al. (2013)

- Operational forecasts
 - Mesoscale (resolution approx. 4km, 1.5km)
 - Global scale (resolution approx. 17km)

- Global and regional climate predictions
 - Resolution around 120km
 - ➢ Run for 10-100-… years

- Seasonal predictions
 - ➢ Resolution approx. 60km

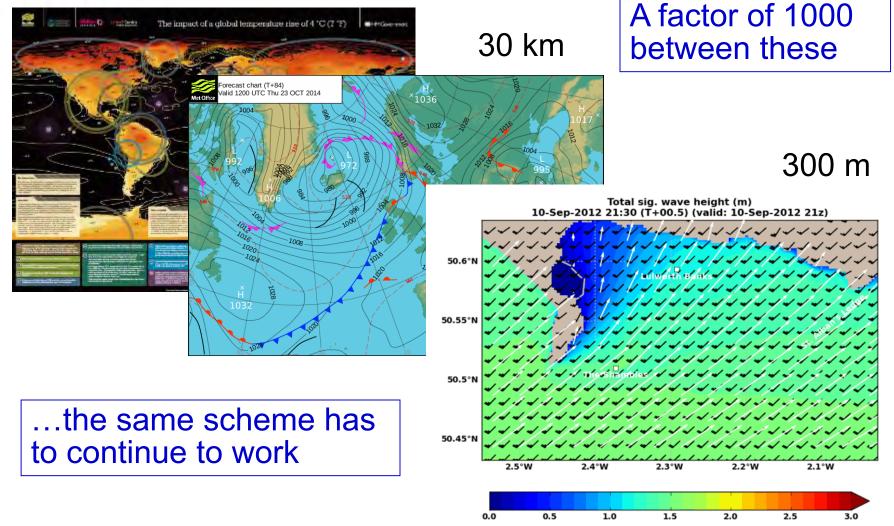
Research mode

Resolution 1km - 10m



The consequence of unification

Met Office 300 km

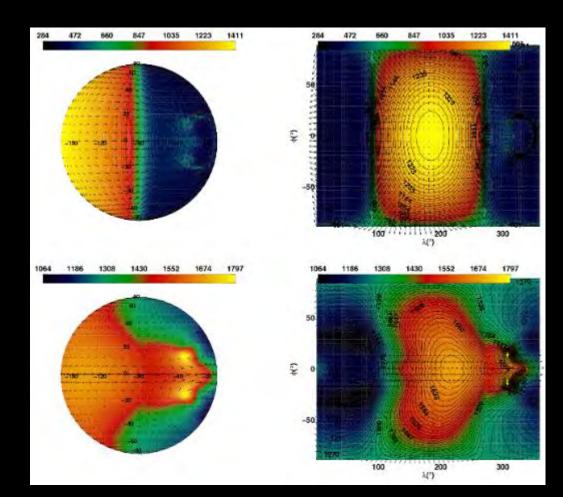




Exoplanets: Hot Jupiters

http://www.metoffice.gov.uk/research/news/forecasting-beyond-the-solar-system

Mayne et al. (2013b) (The UM, a fully-compressible, nonhydrostatic, deep atmosphere GCM, applied to hot Jupiters



© Crown copyright Met Office



• Sophisticated numerical modelling software:

- May be run in many modes:
- Global, Limited Area Model; Mesoscale (NWP)
- Aquaplanet, SCM (Idealised tests)
- Climate modelling; atmosphere only or coupled with ocean models....etc
- Exoplanet research



Development of Models (1)

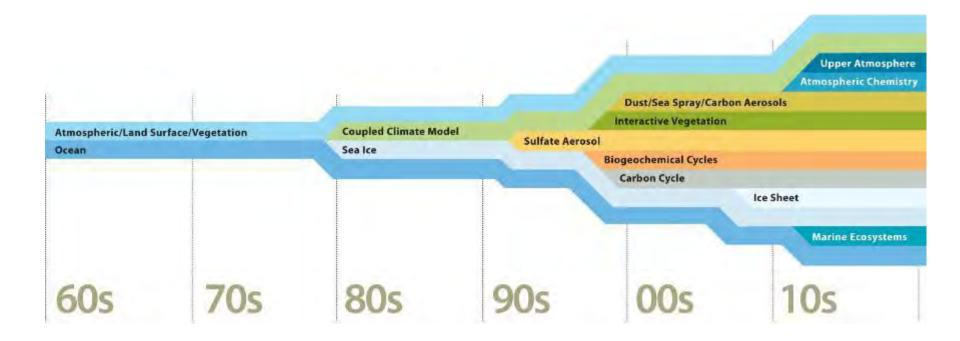
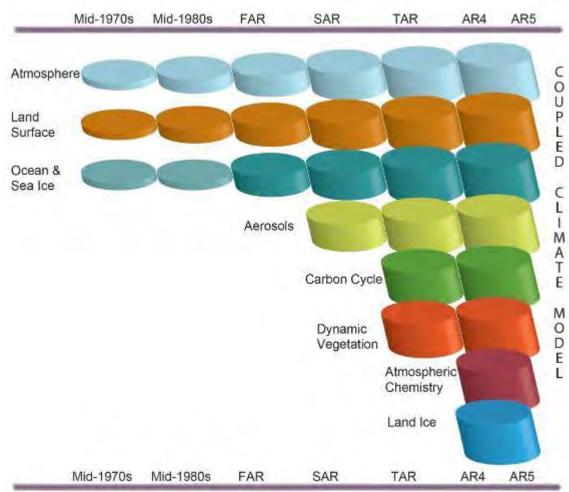


Figure courtesy of UCAR

Met Office Hadley Centre

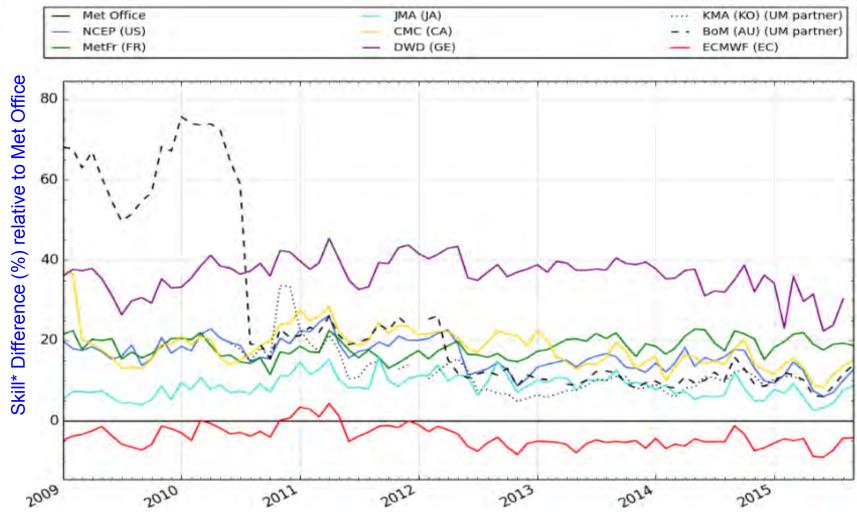
Development of Models (2)





Global model cf. other centres

Met Office



© Crown copyright Met Office * Parameters: PMSL, 500hPA GPH, 250hPa/850hPA Winds; Range: T+24 to T+120



CODE MANAGEMENT & ORGANISATION



www.ncas.ac.uk

Developers and Users



- The Unified Model is primarily used and developed by the U.K. Met Office
 - There are several hundred users in U.K. Universities
 - The MetUM is also also licensed abroad, and is used in Australia, New Zealand, South Korea, South Africa, and India. There are also some partners in the United States
- There are almost 200 active developers of the MetUM



www.metoffice.gov.uk/research/collaboration/um-collaboration

Code Organisation



- The Unified Model has over 1 million lines of code, organised into 52 sections
- Each section, e.g. convection, chemistry & aerosols, & top level control routines, have a code owner.
 - The code owner is responsible for that section, and must approve all changes that are made to that section.
 - The code owner also has first refusal to review the code in more detail.
- The code is managed by a Project Board, who are responsible for its delivery





What is the UM made of?

Mainly Fortran and some C Fortran 77 through Fortran 95 and recently the use of some Fortran 2003.

Uses FCM for code management (Trac and subversion)

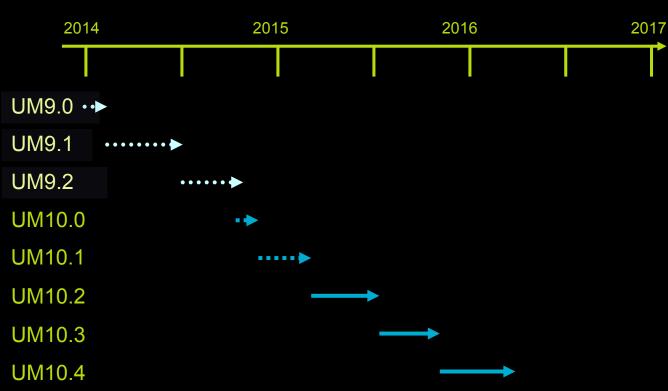
To support the UM infrastructure:

bash Perl and Python

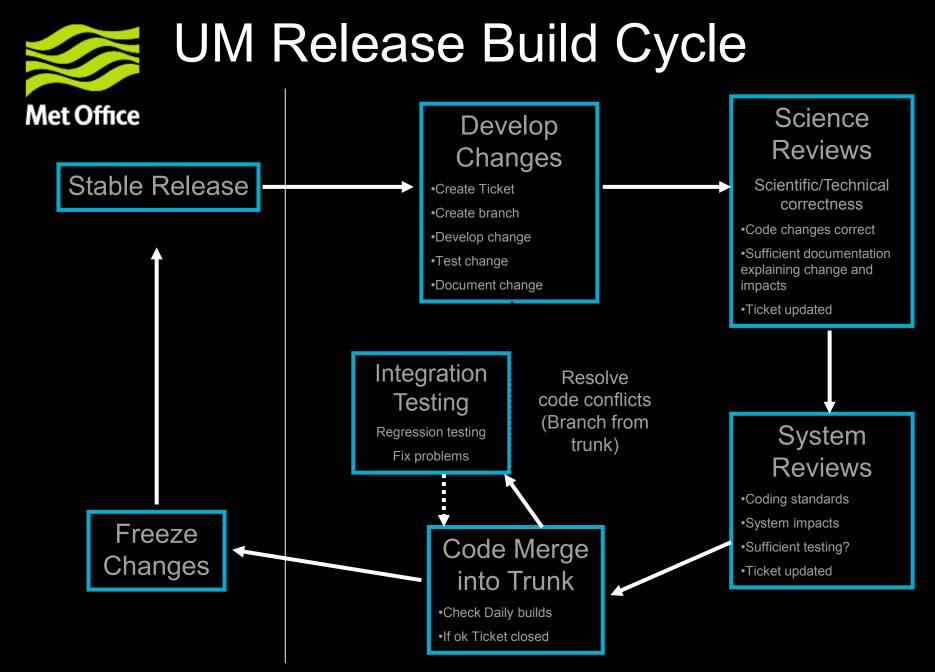
rose/cylc – python gtk



Release schedule



~3-4 release per annum Project Board oversees the release schedule plans.





Making Code changes: Typical Workflow (as used at the Met Office)

Time Trac Web pages Repository Fcm Server Checkout UMx.x code **Modify Code** Working Copy Desktop Remote Machine **Build New exec** (eg HPC) and test code

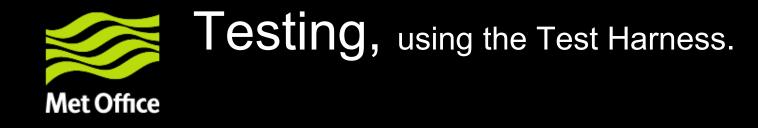


Making Code changes: Create a ticket

Met Office	fr 🔄 🖉 38at Ollice (GB) https://code.metoffice.gov.uk/ncie/um/uclast/565				← C 🔤 Google		総合合 🕈 🔍 ベイン		
MetOnice	1 m Unifi	ied Mo	del			2.8		Search	1
🕅 🍝 🗉 (Kai Oline (GB) https://ode.meto		cumo	Giai		logged in as go	angreed Lagadi	Pelerencer	=рлан се — Арр + То	
000111110			WRI	Timeine Roadma	p Browse Source	View Tickets	Nen Ticket	Search Admin	
U Unified						i- Previo Nodity J	us Ticket Back to	Query Next Ticket	
		#565 in_prog	ress enhancement		Dpenec 6 d				
		max wind diag	max wind diagnostics for the UM						
	Cn	Reported by	cleandreed	Owned by:	genngroed				
		Milestone:	UMID.2 code release	Companent	General				
		Seventy:	mente						
		Description gastimotin	Description pushmounce by utamagroce y a						
		Part of the fieldcal	Part of the fieldcaic replacement project is to port many of its current diagnostics within the UM. A Reply						
		In this bloket we deal with the max wind related diags							
		20020 - 20023 ans	1 20041-20042						
		► Attachments (0)							
			<u>4</u>		Oldest first One of the other othe	Newest first			
		This per house en	(a) The Others						
		• Status charig	ed from new to in_progress		+ Rep	ty = Edit			
		manybranches	/dev/gleongreed/r5213_maswi	ad_crags					
		Chington Address into	ov glangedd			Conservation 2			
		 Description r 	noofied (ddf)		- Bep	ty = Filts			
	P)								
		Note:	DueTickets for only on any house -						
trac									
A true (constraint)									



- In line with code
 - UM code in repository
- Documentation papers
 - UMDP source code in repository
- Tickets
 - TRAC pages
 - Links to UM code branch
 - Links to UMDP source branch
 - Ticket Summary
 - Standardised Testing reports



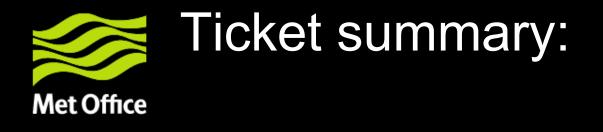
- A single Test Harness is used by
 - code developers
 - daily builds of the UM trunk
 - Release Candidate testing, checking progression between stable UM versions and applying wider set of tests.
- The user determines which tests are performed.
- The test output provides the supporting evidence of any change; in a standard format across a UM system team controlled set of tests.

Rose stem



- There are over 120 separate tests that can be run using the test harness
- These are organised into various groups, e.g. all, developer, ukca, recon, which test specific configurations
- The minimum test that needs to be run is developer, but code owners will usually ask for their own tests to be run if a change is being made to their section





- Communication of the change...
 - what is the vital information that any review needs to know?
 - formalise this communication through TRAC templates....



Ticket summary:

v C 📶 v Google Mas Office (CB) https://code.metoffice.gov.uk/tra- tur/wiki/ticket/943/Ticket/9ummary 酮合白 R. -in lose (343 / intellignmery Hp. Start Kiepe, Jonney, History, Ticket Summary #343 To be completed prior to Scilltech review and updated as required doring the review process-All developers are expected to have worked through: Rose documentando WM WITCHE INVESTIGATION This ticket summery needs to be completed to provide entence of the impact of each changeset. now to supply test evidence; Met Office tickets: • are expected to provide evidence from rose stem tests based upon the Met Office provided standard test tops tobs 2 Pattners with local tose stern sates: · are expected to supply as much evidence as possible on the impact of their taket based upon their rose stern eulput. • the code system reviewer will perform the Met Office rose stem tests on your behalf as plant of their code review. @ Patters without access to a tose sterr sate. • will require a proxy at the Met Office (a collaborator) to take ownership of the score and push it through the Met Office rose stam tests and the subsequent review process on behalf of the partner developer. Author: Paul Eamshaw Branch Code branch entiti 1 relate imitiano **Documentation branch** INANCH NAME Testing branch Only required if you have altered meta-data and/or added an upgrade macro - \$540 Les retre in mirmi Testing Testing should use Rose STEM which will test a selection of standard off configurations.

Rose testing summary

Please list the rose stem groups that have been tested from the evaluate groups:

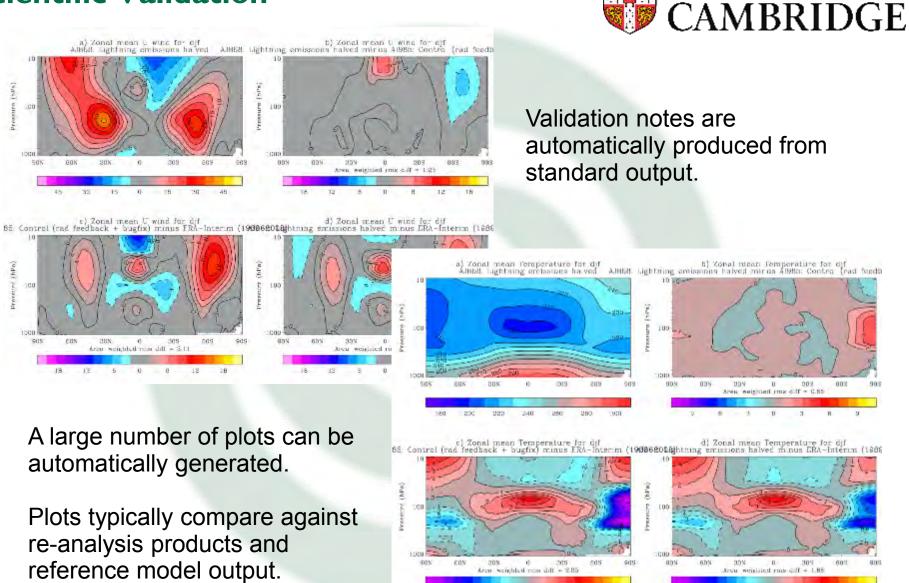
Groups: a) develope: b) enegans c) metolinus_ideplised d) metolinus_ideplised c) skca



- The code changes are understood and appropriately made.
- The documentation is sufficient to understand the code change and its impacts. (Ticket, inline code and UMDPs).
- Is familiar with the area of being code updated, preferably a code owner for that UM section.

• If results change previous KGOs, the reviewer must also check that details are provided showing the 'science' impact of the change on forecast performance and that it has been given approval by the configuration owners that are impacted.

Scientific Validation

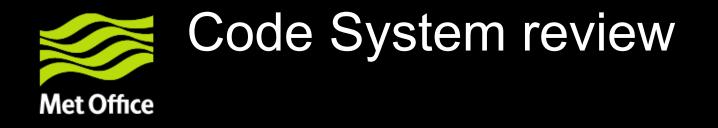


National Centre for Atmospheric Science

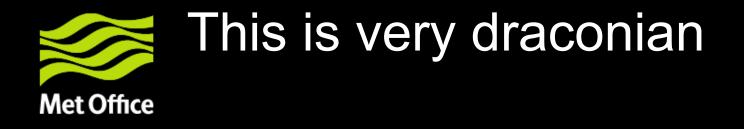
www.ncas.ac.uk

UNIVERSITY OF

- اجتبا



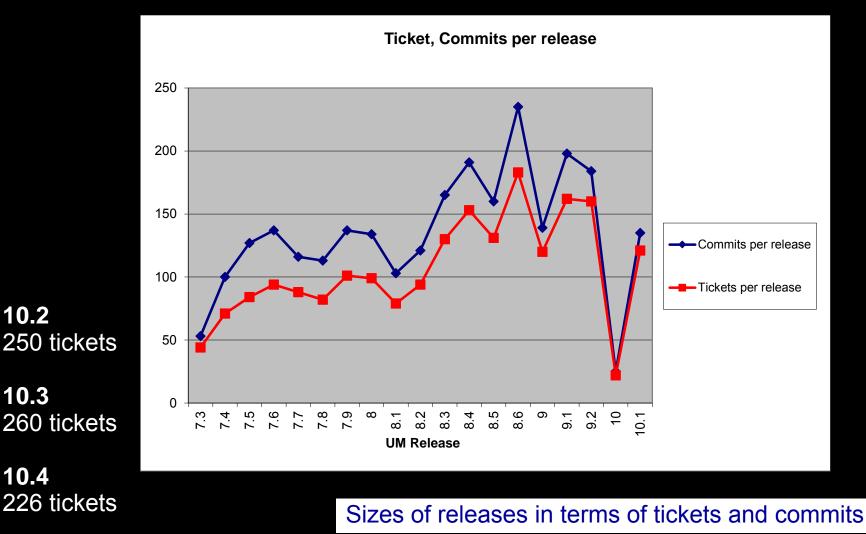
- Coding standards are met
- Impact of the change on the UM system.
- Ensure all appropriate testing has been performed, request more if required. If the trunk at risk if this change is applied?
- Only Code system reviewers may commit changes to the trunk!
- Thus the trunk is tightly controlled by a small number of staff.



- Why all the hassle to get a change on the UM trunk?
- To ensure releases are effectively managed, quality controlled and delivered on time.



Size of recent releases



© Crown copyright Met Office

Does this process catch all problems?



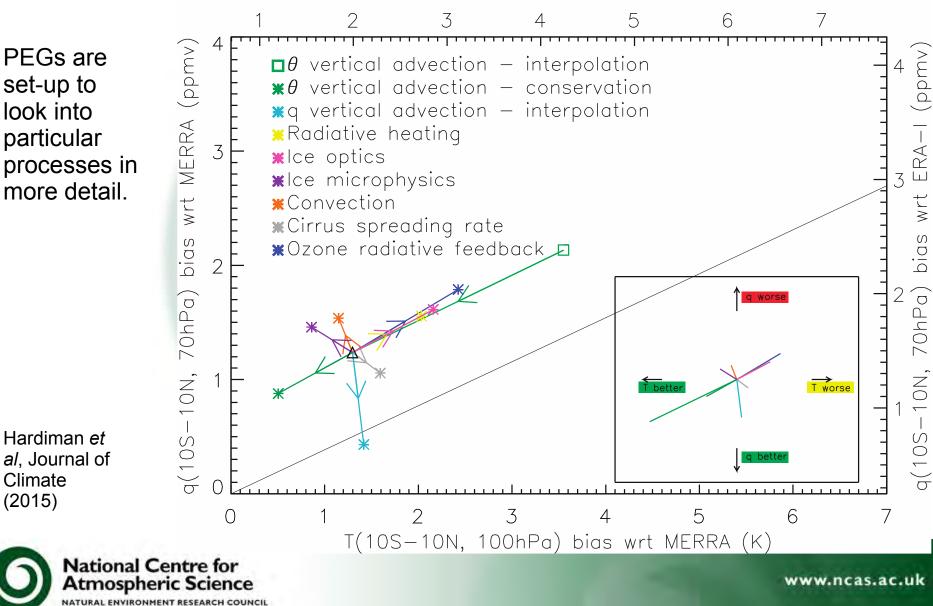
- Test harness
 - Catches unintended errors that have been introduced by a change
- Validation notes & evaluation suites
 - Compare the code to observations/reanalysis
 & existing model output
 - Test that a change improves output compared to what is currently the best configuration
- How do you check that (new) schemes don't break other (new) schemes?
- What can you do if a bug is already in the code?



Process Evaluation Groups

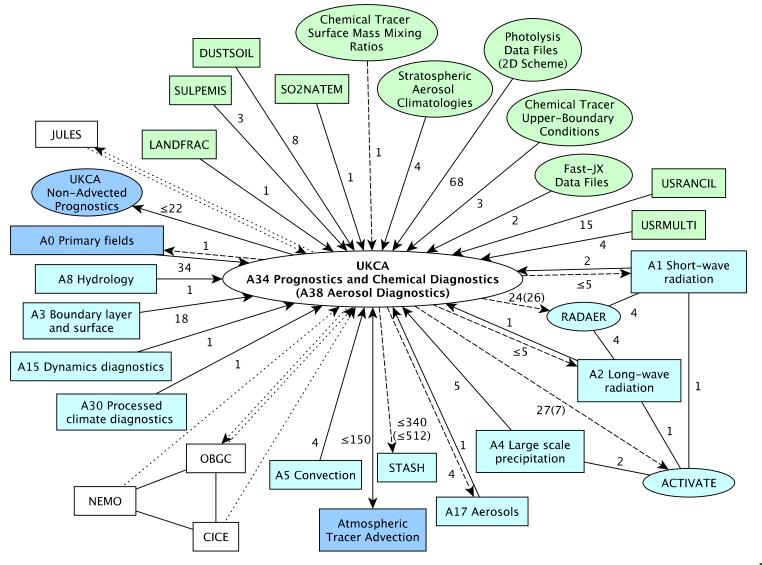
UNIVERSITY OF CAMBRIDGE T(10S-10N, 100hPa) bias wrt ERA-I (K)

PEGs are set-up to look into particular processes in more detail.



UKCA – coupling with other components







www.ncas.ac.uk

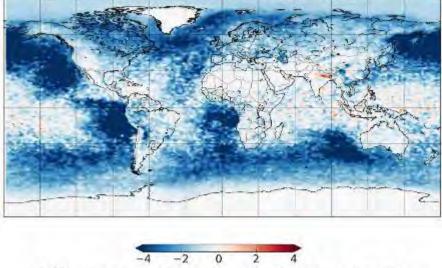
Aerosols



Atmospheric aerosols in the MetUM are subject to a number of processes, including wet scavenging, where aerosols particles are removed by precipitation. Instead of being done in the UKCA code, this was moved to the convection scheme as the required diagnostics were more easily available

Outgoing Radiation at TOA (Bugfix test minus Control)

Area-averaged Outgoing Radiation in 2006 = -1.7275 (W/m^2)



Difference in Outgoing Radiation (W/m^2)

However, unknown to the UKCA developers, the diagnostics used in convection were incorrect. This lead to incorrect aerosols, and therefore an incorrect climate.





w.ncas.ac.uk

To stop an error like this happening again, the Systems Team added the following to the Code Review template:

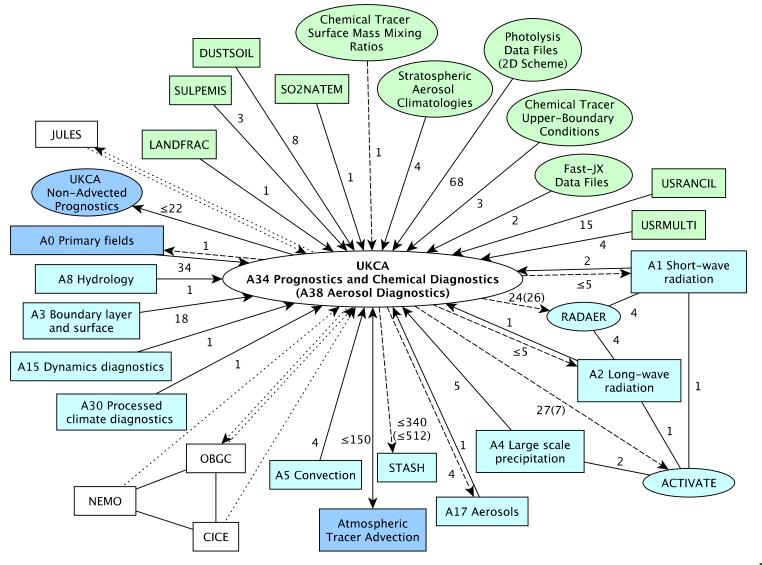
Does this code change make use of prognostic or diagnostic output from other sections (or model)?

If YES, have suitable inline comments been added to the other section's source code and both UMDPs updated?



UKCA – coupling with other components







www.ncas.ac.uk



0.1

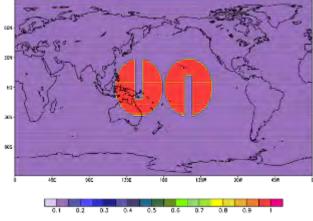
0.2

0.3

0.4

0.5

Initial Conditions



SL-QMSL PLF : Fields at t=001/241 60N 30N EQ 305 605 45E 90W 45W SOE 135E 180 135W

Kohei Aranami (MetO/JMA)

0.7

0.8

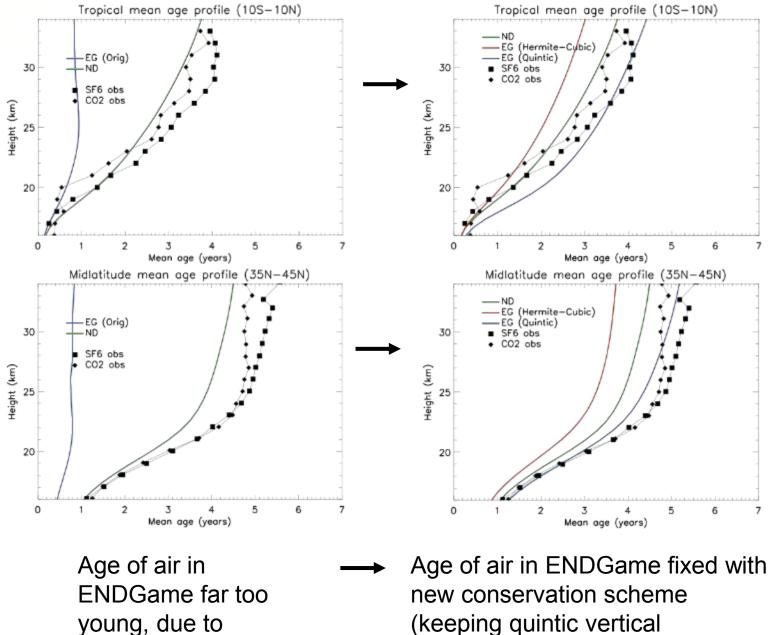
0.9

1

0.6



UKCA Tracers in ENDGame : Age of Air



conservation scheme

(keeping quintic vertical interpolation for tracers)





- Communication is key
 - PEGs often require input from many people with expertise in different areas
 - The problems with the wet removal of aerosols could have been reduced by opening a dialogue with the convection scheme developers at an earlier stage
 - The success of the age of air test means that it is now planned to be used as a standard tracer test in the assessment the next dynamical core, currently under development.





PORTING AND USER SUPPORT



Testing and porting MetUM configurations



- For UK Universities, support for the MetUM is provided by the National Centre for Atmospheric Science, through the Computational Modelling Support section
- CMS do a large number of different things, through installing the MetUM, porting configurations, managing resources, and developing software tools
- While Met Office staff move up versions quite quickly, researchers at Universities often keep with the same MetUM version for many years
 - e.g. UM4.5 is still actively used by many





- The MetUM should (or can be made to) fulfill various criteria:
 - 1. If you run it again a second time, you should get the same answer
 - 2. If you start a new run from a restart file from the middle of a simulation, you should get the same answer
 - 3. If you change the number of cores, the code should give you the same answer
 - 4. While the answers will be different on different architectures, they shouldn't deviate greatly
- However, *scientific validity* should be determined by the users





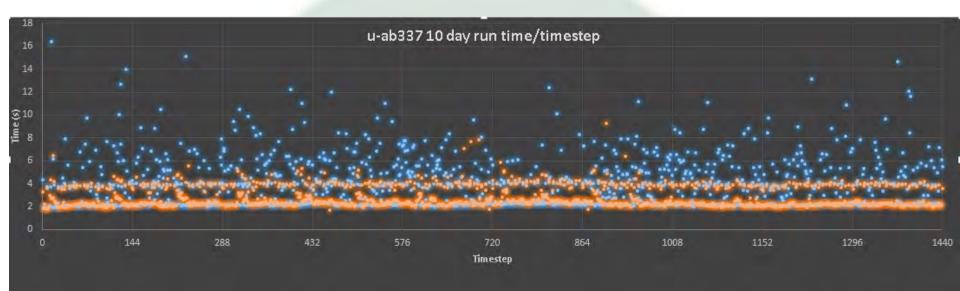
	Community (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	100 miles	And and an				adadada	/atat-	
UM Version	Job desc	UMUI	Installed	I NRUN	CRUN	CHECK PORT	Climate Meaning	Infimication	Archiving
8.5	N512 L180 GA 6.0	xjanp	Yes	Passed	Passed	NA	NA	Yes	No
8.5	N216 L180 GA 6.0	xjlef	Yes	Passed	Passed	NA	NA	Yes	No
8,4	N512 L85 GA 6,0	xjanu	Yes	Passed	Passed	Passed - HECTOR to ARCHER	Yes	Yes	No
8.6	GA4.0 & UKCA CheST & GLOMAP	xjnjb	Yes	Passed - Only for the same PE decomposition	Failed (expect it to Not bit-compare- Mohit Dalvi)	-	NA	Yes	No
8.5	GC2 N96/Orca1	xjnja	Yes	Passed	Passed	NA	NA	-	No
8.5	GA6.0 N216 antib	xjlee	Yes	Passed	Passed	NA	NA.	Yes	No
8.5	GA6.0 N95 antia	xjleo	Yes	Passed	Passed	NA	NA	-	~

outputfile.10

0-1161-14 TEMPERATURE 1	INCR swrad -	- pc2 :	4.1617716471619	5.84343092000526112E-14	2.8643678510763624E-14	:
9.74306052503592923E-12 0-1161-15 TEMPERATURE I	INCR swrad -	- pc2 :	3.48361591051561	7.77384719588039757E-15	4.16505621239696626E-15	:
1.2104067748097691E-12 -> 0-1161-16 TEMPERATURE 1	INCR swrad -	- pc2 :	2161.88171145865	6.48518964157868189E-14	1.39478322840193698E-15	:
1.0817291506981519E-11 -> 0-1161-17 TEMPERATURE 1	INCR swrad -	- pc2 :	18,3356237186656	6.57131210961955792E-15	1.53463200385040314E-15	
1.06020053847188933E-12		-		No. of the second s		
0-1161-18 TEMPERATURE 1 7.32960567240148464E-	INCR swrad -	- pc2 :	0.816090978851124	4.59294806955636057E-15	5.08419555367761834E-1	5:
0-1161-19 TEMPERATURE 1 1.52171678036161495E-12	INCR swrad -	- pc2 :	6.71380028314038	9.91489880465450857E-15	3.82652078740725358E-15	:





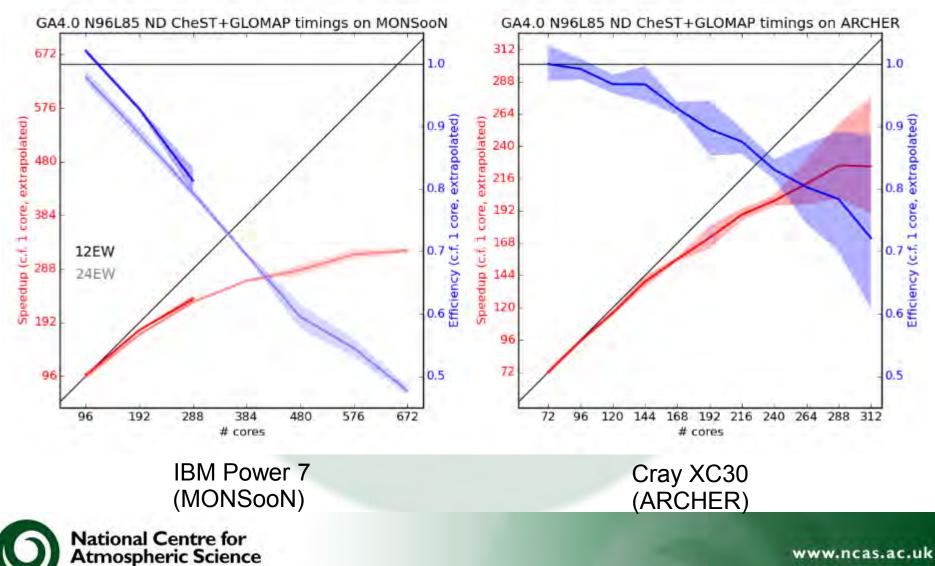


-O2 -Ovector1 -hfp0 -hflex_mp=strict

-O2 -hflex_mp=intolerant







www.ncas.ac.uk

NATURAL ENVIRONMENT RESEARCH COUNCIL

Take-home messages



- The Unified Model is a large code that has been developed over many years, and which has hundreds of developers who are not all located in the same place
- To ensure that code changes are managed properly a rather complicated change process has been developed
- Communication is key
- The needs of University users are often quite different to those of active developers





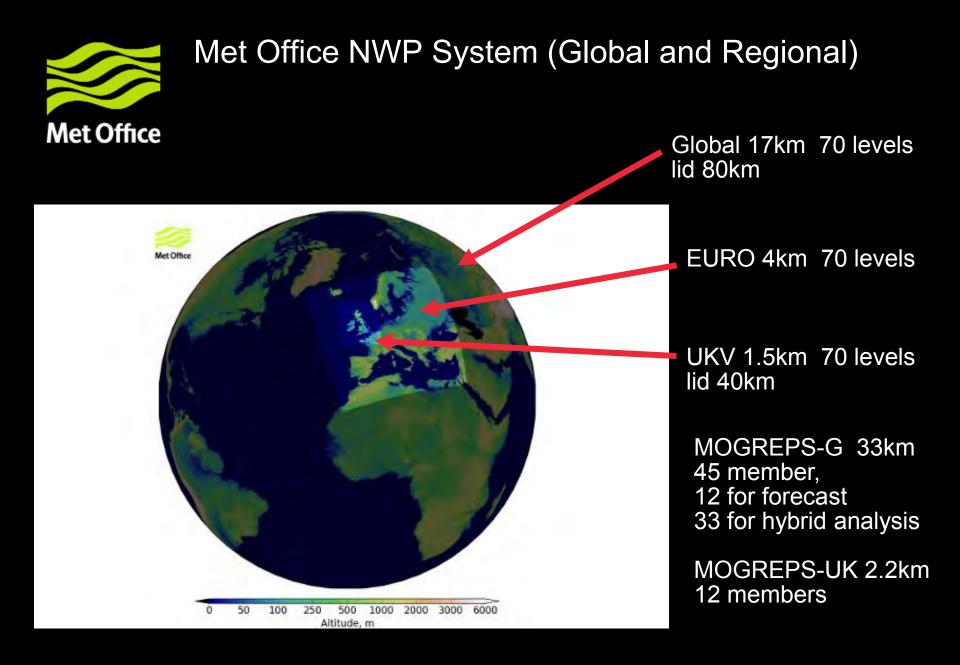
THANK YOU!

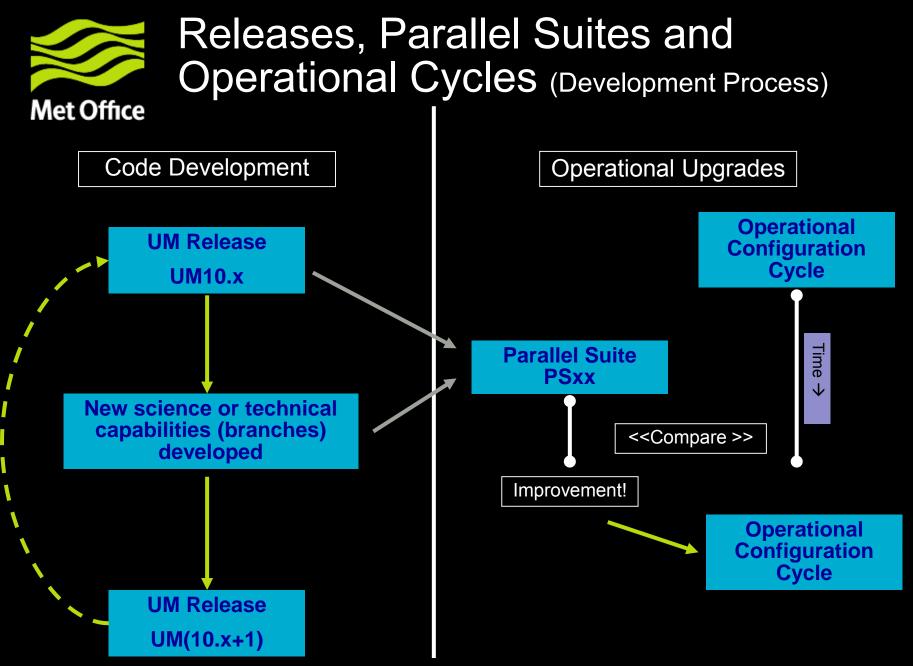




ADDITIONAL SLIDES







© Crown copyright Met Office



Example Run of rose-stem

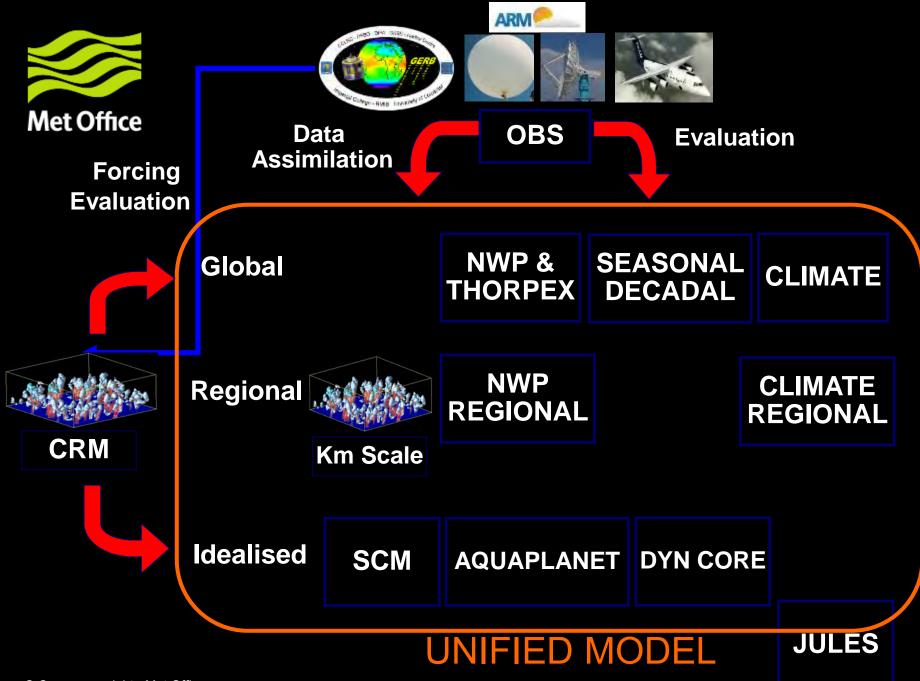
Met Office

		r55781_ros	se_stem_ex	ample - e	xvcylc04	- gcylc	- ¤ ×
<u>F</u> ile	<u>View</u> <u>Control</u> <u>Suit</u>	e <u>H</u> elp					
00	🔲 🚺 🖬 View 1			View	2: None	0	
task		state	message	Tsubmit	Tstart	mean dT	ETC
▽ 1		running					
Þ	EXTRACT	queued					
Þ	HPC	succeeded					
Þ	HPC_HADGEM_2DAY	running					
Þ	HPC_MOGREPS_R	gueued					
Þ	HPC_N48_OMP_IOS	running					
Þ	HPC_N96_AMIP_EG	queued					
Þ	HPC_SEUKV	a queued					
Þ	LINUX	succeeded					
Þ	LINUX_N48_OMP_IOS	running					
Þ	LINUX_SCM_NWP	gueued					
		-					
-	the manufacture has		al an inter an		and and a f	tette en accat	
		<u>M</u> dnene M s			submit-r		n 🗹 succeede 🗹 faile 🗹 retr
runni	ng						live 2013/07/16 08:31:4



Test fail when compared with KGO

rose_ana_linux_n48_omp_los_atmos_kgo.1.1.out - vn8.4.1_rose_stem - Mozilia Firefox - E 9 Die Edit View Listory Bookmarks Jools Heip Ð File ///bome/h03/fniw/cylc-un/wr8.4.1_rose_stenylog/source.btmlzsuite=vr8.4.1_rose_stem&path=job/ro____ M histweb Gaugie Firebug Addlock Plus Back. Reload Home Most Visited w Getting Starten UTF-N Log Browser UTF-W Log Browser UTF-1 Log Browser Latest Headlines > 2ap colors 3 #361 (Head of Tru. MetNet nom met EU ENS. C Exeter USE ALMOSTURIA CO. LUIL/U/Wbranches WB.1 LIDSe_ster SUITE Note Suite Hest econytr82 metoffice.gop.us Suite Port 7766 5011e.threi 1110 fask III rdse ana linux nd0 mup hus atmus sod. I etsBis.metnffice.gov lik Task Hout fask twier Titter task Try No. [15/0] exact PAR-/spl/sharullis/sin:/net/home/h03/to/rase-/h13-02-04-546#0495/bin /spl/snet/sez/2014/191/bin/intel64:/home/h03/to./spl/sharullis/sin:/net/home/h03/to/rase-/h13-02-04-546#0495/bin /spl/snet/h02/to/rase-/h13-02-04-546#0495/bin /spl/snet/h02/to/rase-/h13-02-04-54 [1470] exact PANE-/apt/usma/utils/lib/ksh /home/Mai/fric/SC5/lib/ksh /apt/ukm/offis/lib/ksh/apt/usma/utils/lib/ksh [15/0] exact PAT-/hate/H63/fow/cylc-nm/w6.4. _cose_ster/share/fo_ada_fine_pd_ins/build-recor/bio/d03/fow/cylc-nm/ant of _ove_ster/share/fo_ada_fine_pd_form/cylc-nm/ [NoTE] exact PATE-/hame/NE3/from/cylc-rom/with4.1 rose stem/share/fr make thous of our tos/boild-recom/with/thom/cylc-rom/with4.1 rose stem/share/frame/bio/document/ [FAD] Files wither: ./stein_lines_und_cap_ios_ist_i/stein_fasenut2_c_t_/deta/hep1/Trun/standard_jnbm/rose/nt0_oup_uss/v08_4/atmos_roemnit/ Bit on model levels at end timester TEAD 1 >10% TOTAL DOWSMARD SHEEFACE SH TUB **LEATL** ×10% [FATL TOTAL PRESCRITATION BATE KC//10/5 a10% LEATE] 1.5+C0W/ 85/92/5: 318% IFATI 1 SHEFACE 5105 [FATL TEMPERATING OF THE TALLEWELS. >19 (EATL) TOTAL (1.00) ANDINI PAK/RANDON DUTRLP ->10% SURFALE TENDERATION AFTER TENESTEP ITAD. 218 [FAD] SPECIFIC HUNDUTY AFTER TIMESTEE >10% **LEATE** CLOUD BASE AS TOWER GT.D. LOCTA BETL -- 10% LEATE 1 Files sifter: ../stms_linux_ode_emp_ios_led)/stmos.temporty > 1 /dete/Map//fiu/stenderd_pde/rose/odd_exp_los/vd8.d/attos teemoti [FATI SEA NEAR W/RD: >109 LEATE: LANCE SCALE BATH ADDINT 880/10/Th >10% ITATI. LARGE SCALE SNOW ADDIN'T 889/15/Th =10% [FATE SUELTH. FROM SURFACE (GBN) KG/MS/TS: \$108 [FATE] X-COMP OF SHRE & FL WIND STRESS N/M2 >10% **LEATE** NET DOWN SURFACE SW PLUX AFLOW BROWN >10% [FATL SEA PEAN X5/N2/S: >10% [FATL TRAC OF STA TOP IN STA AFTER TOTEP >10% **LEATL** Y-COMP OF SURF & FL WIND STRESS A/M2 >10% [FATL COMPOSITIVE BADD AMOUNT KG/M5/T5: a10% [FATL SEA MN W/401: >36% **LEATL** SEA NEAN: >18% FATL SURFACE TEMPERATURE AFTER TIMESTEP 319 [FATL] CONVECTIVE SNOW AMOUNT 46/10/T5 x10% FAIL Files mitter: _/atmos_livux_008_amp_ins_ix4 %/atmos.surgeou% f.t. /data/mpl/trun/standard_jdbszrose/n46_urp_ids/ur0.4/atmos!surgeou% [FATL] ID HETRE WIND D-DONP B GATE >10% [FATL] PRESSURE AT MEAN SEA LEVEL 10.16 B GUTD | MION **LEATE** 18 NETRE WIND V-DOPP [FAIL] ./stmos_linus_doB_omp_ios_isd_S/stmos.wfditc.t_/data/nepl/from/standard_jobs/ruse/nd8_omp_ios/en8.4/atmos.wfdit Files mifter! [FATL] SEA VEAN W/RO \$10% LEAT! LARGE SCALE RATH AMOUNT RG/MJ/T51 >109 [FATL] LARGE SCALE SNOW APRUNT RG/NJ/T5 >10% LEATL I SUBLIN, FROM SURFACE (GBN) RG/NU/TSI >10% X-COMP OF SURF & BL WIND STRESS N/M21 >109 LEAT! FATL NET DOWN SUBFACE SW FLUX RELOW BROWN: 104 Find: setator Previous > <u>Next</u> Highlight all __ Match case



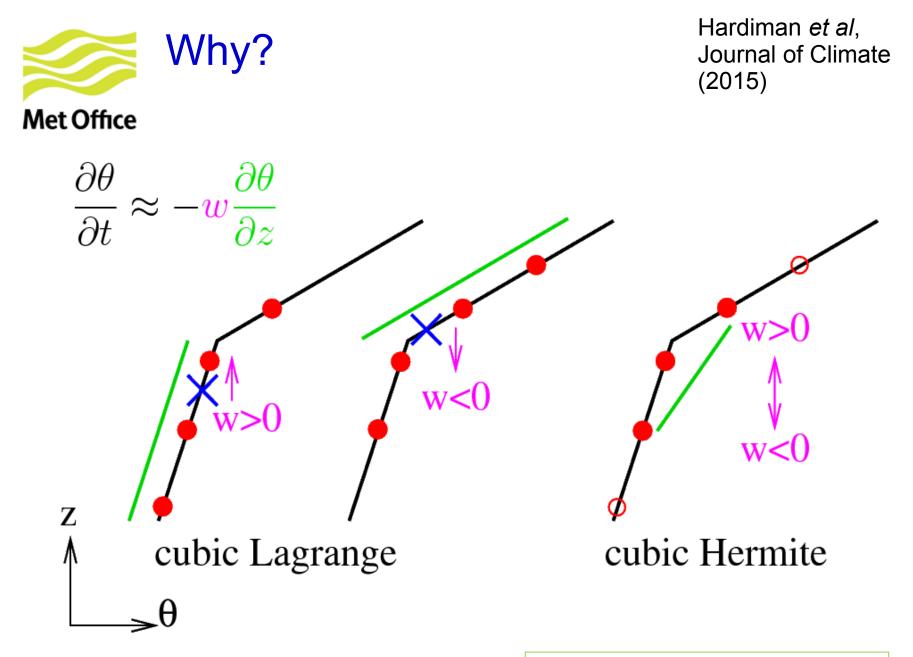


UKCA Tracers in ENDGame : Age of Air

-Age of air \rightarrow time taken for parcel of air from free troposphere into (and around) the stratosphere. 'Observed' age derived from stratospheric SF6, CO2 (Engel et al)

- Age-of-air tracer in UKCA passively advected, no influence of chemistry

- Initial ENDGame runs \rightarrow "very young" age (heavy movement across tropopause)
- Working group formed (Summer 2013) with **Dynamics Research (DR)** Team
- ND, EG parallel runs with combinations of influencing processes (transport, conservation, convection) switched ON and OFF
- Profile 'different' to previously tested fields (Q) i.e. mass increasing with height
- ENDGame (ADAS) conservation found most influential in cause of divergence
- -Priestley-like conservation scheme developed by DR for testing
- Current best results Priestley scheme, Quintic interpolation (only for UKCA tr)



© Crown copyright Met Office

Chris Smith (Met Office)