



CONSTRAIN – proposal for “grey zone” model comparison case

Adrian Hill, Paul Field, Adrian Lock, Thomas Frederikse,
Stephan de Roode, Pier Siebesma



Contents

- Introduction
 - CONSTRAIN
- Overview of UM Limited Area Model (LAM) simulations
- Proposed LES case
 - Setup
 - Some initial results, including comparison with the LAM and SCM runs
- Summary of work so far
- Proposed set-up for grey-zone simulations

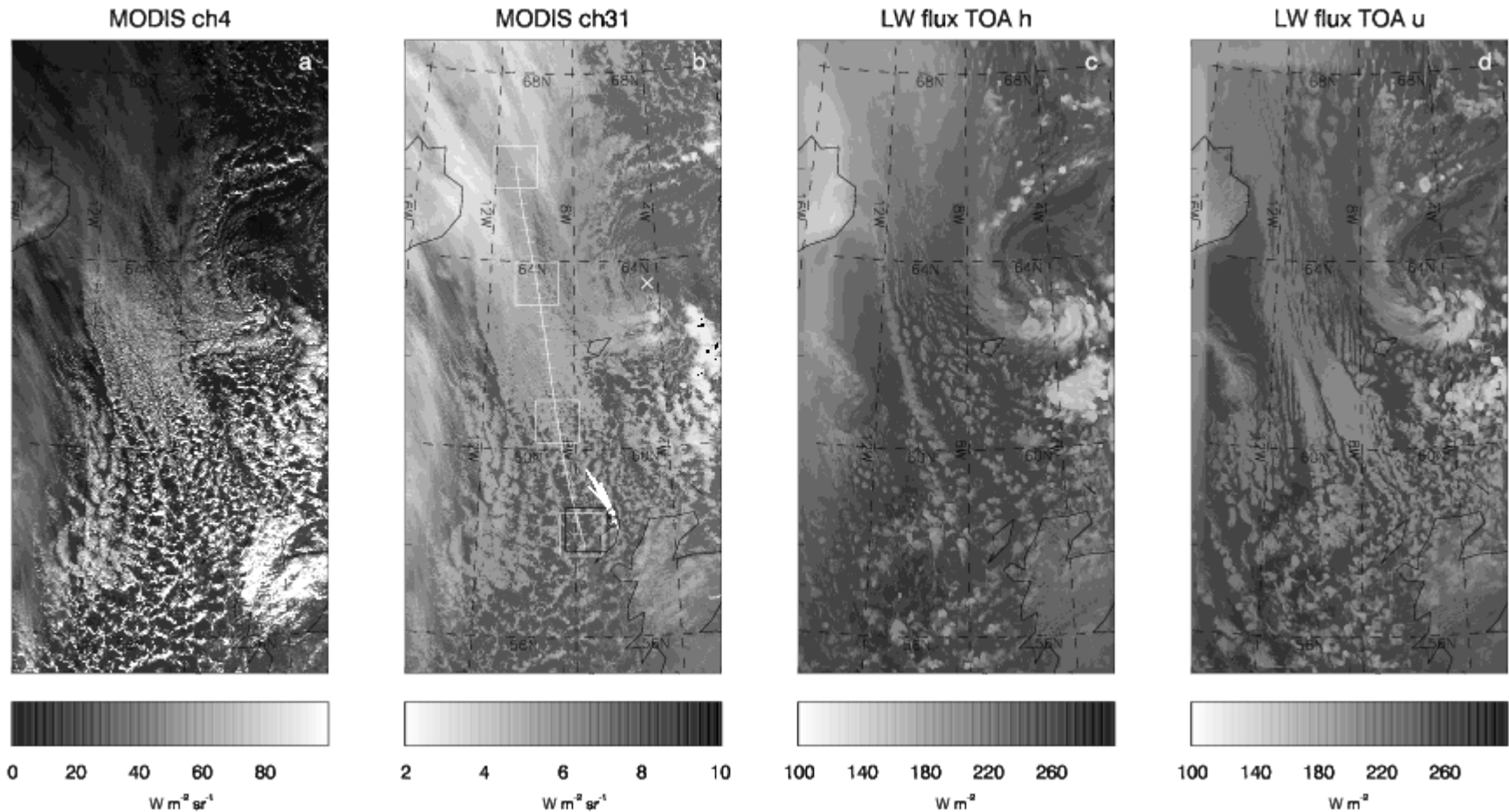


-
- Analysis chart valid 12 UTC SUN 31 JAN 2010
- GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
- 0 10 20 30 40 50 60 70
- 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820 840 860 880 900 920 940 960 980 1000 1020 1040 1060 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260 1280 1300 1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640 1660 1680 1700 1720 1740 1760 1780 1800 1820 1840 1860 1880 1900 1920 1940 1960 1980 2000 2020 2040 2060 2080 2100 2120 2140 2160 2180 2200 2220 2240 2260 2280 2300 2320 2340 2360 2380 2400 2420 2440 2460 2480 2500 2520 2540 2560 2580 2600 2620 2640 2660 2680 2700 2720 2740 2760 2780 2800 2820 2840 2860 2880 2900 2920 2940 2960 2980 3000 3020 3040 3060 3080 3100 3120 3140 3160 3180 3200 3220 3240 3260 3280 3300 3320 3340 3360 3380 3400 3420 3440 3460 3480 3500 3520 3540 3560 3580 3600 3620 3640 3660 3680 3700 3720 3740 3760 3780 3800 3820 3840 3860 3880 3900 3920 3940 3960 3980 4000 4020 4040 4060 4080 4100 4120 4140 4160 4180 4200 4220 4240 4260 4280 4300 4320 4340 4360 4380 4400 4420 4440 4460 4480 4500 4520 4540 4560 4580 4600 4620 4640 4660 4680 4700 4720 4740 4760 4780 4800 4820 4840 4860 4880 4900 4920 4940 4960 4980 5000 5020 5040 5060 5080 5100 5120 5140 5160 5180 5200 5220 5240 5260 5280 5300 5320 5340 5360 5380 5400 5420 5440 5460 5480 5500 5520 5540 5560 5580 5600 5620 5640 5660 5680 5700 5720 5740 5760 5780 5800 5820 5840 5860 5880 5900 5920 5940 5960 5980 6000 6020 6040 6060 6080 6100 6120 6140 6160 6180 6200 6220 6240 6260 6280 6300 6320 6340 6360 6380 6400 6420 6440 6460 6480 6500 6520 6540 6560 6580 6600 6620 6640 6660 6680 6700 6720 6740 6760 6780 6800 6820 6840 6860 6880 6900 6920 6940 6960 6980 7000 7020 7040 7060 7080 7100 7120 7140 7160 7180 7200 7220 7240 7260 7280 7300 7320 7340 7360 7380 7400 7420 7440 7460 7480 7500 7520 7540 7560 7580 7600 7620 7640 7660 7680 7700 7720 7740 7760 7780 7800 7820 7840 7860 7880 7900 7920 7940 7960 7980 8000 8020 8040 8060 8080 8100 8120 8140 8160 8180 8200 8220 8240 8260 8280 8300 8320 8340 8360 8380 8400 8420 8440 8460 8480 8500 8520 8540 8560 8580 8600 8620 8640 8660 8680 8700 8720 8740 8760 8780 8800 8820 8840 8860 8880 8900 8920 8940 8960 8980 9000 9020 9040 9060 9080 9100 9120 9140 9160 9180 9200 9220 9240 9260 9280 9300 9320 9340 9360 9380 9400 9420 9440 9460 9480 9500 9520 9540 9560 9580 9600 9620 9640 9660 9680 9700 9720 9740 9760 9780 9800 9820 9840 9860 9880 9900 9920 9940 9960 9980 10000 10020 10040 10060 10080 10100 10120 10140 10160 10180 10200 10220 10240 10260 10280 10300 10320 10340 10360 10380 10400 10420 10440 10460 10480 10500 10520 10540 10560 10580 10600 10620 10640 10660 10680 10700 10720 10740 10760 10780 10800 10820 10840 10860 10880 10900 10920 10940 10960 10980 11000 11020 11040 11060 11080 11100 11120 11140 11160 11180 11200 11220 11240 11260 11280 11300 11320 11340 11360 11380 11400 11420 11440 11460 11480 11500 11520 11540 11560 11580 11600 11620 11640 11660 11680 11700 11720 11740 11760 11780 11800 11820 11840 11860 11880 11900 11920 11940 11960 11980 12000 12020 12040 12060 12080 12100 12120 12140 12160 12180 12200 12220 12240 12260 12280 12300 12320 12340 12360 12380 12400 12420 12440 12460 12480 12500 12520 12540 12560 12580 12600 12620 12640 12660 12680 12700 12720 12740 12760 12780 12800 12820 12840 12860 12880 12900 12920 12940 12960 12980 13000 13020 13040 13060 13080 13100 13120 13140 13160 13180 13200 13220 13240 13260 13280 13300 13320 13340 13360 13380 13400 13420 13440 13460 13480 13500 13520 13540 13560 13580 13600 13620 13640 13660 13680 13700 13720 13740 13760 13780 13800 13820 13840 13860 13880 13900 13920 13940 13960 13980 14000 14020 14040 14060 14080 14100 14120 14140 14160 14180 14200 14220 14240 14260 14280 14300 14320 14340 14360 14380 14400 14420 14440 14460 14480 14500 14520 14540 14560 14580 14600 14620 14640 14660 14680 14700 14720 14740 14760

This day is characterised by northerly flow and stratocumulus clouds at 65N -10W...

CONSTRAIN

As air advects over warmer seas the Sc transitions to mixed-phase cumulus clouds at around 60N, prior to reaching land





Setup for LAM case (based on Field et al, 2012, in review)

Time period

- Cold air outbreak 12Z 31st January 2010 - 00Z 1st February 2010

Standard domain and resolution of inner domain

- centre of domain - 62N, 8.5W
- x,y domain = 752 km x 1504 km
- standard resolution - dx, dy = 1 km

Parameterisation

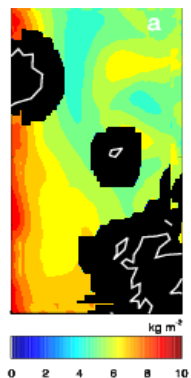
- Boundary layer scheme ON
- Convection OFF
- Microphysics – UM 8.0 single moment scheme with prognostic rain and ice
- Cloud fraction scheme – Smith scheme

Lateral Boundary Conditions

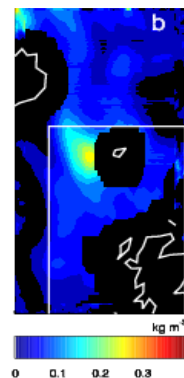
- From UM GLOBAL forecast
- ECMWF analysis for case also available

LAM vs Satellite observations

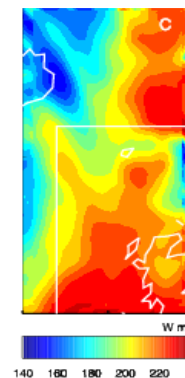
AMSR WVP



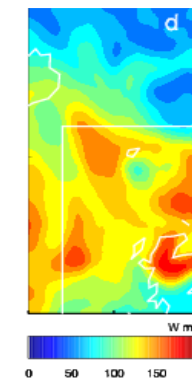
AMSR LWP



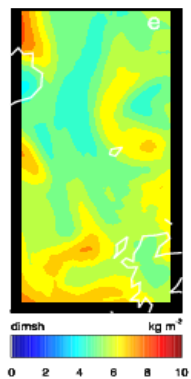
CERES LW



CERES SW



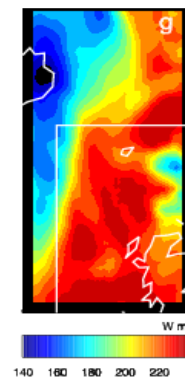
LAM (h) WVP



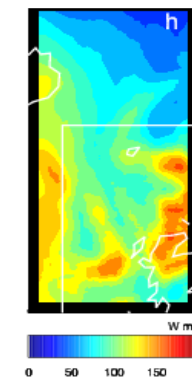
LAM (h) LWP



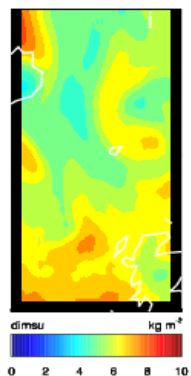
LAM (h) LW



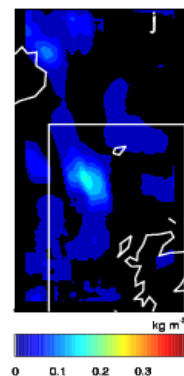
LAM (h) SW



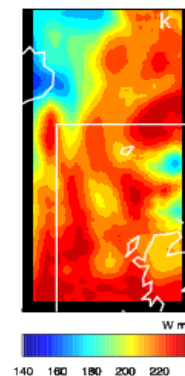
LAM (u) WVP



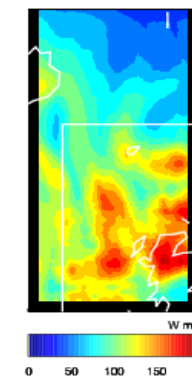
LAM (u) LWP



LAM (u) LW



LAM (u) SW



Satellite Obs

UM LAM initial simulation (h)

UM LAM modified simulation (u)

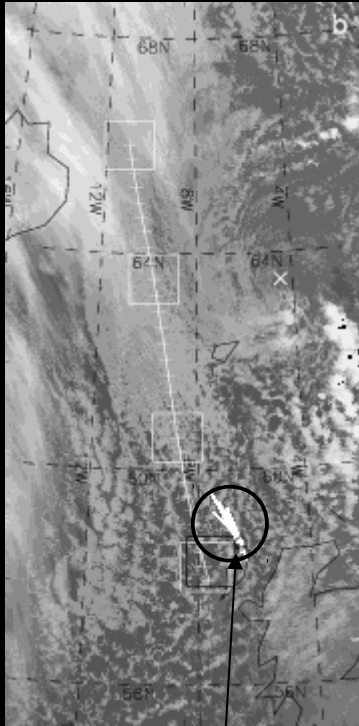
Sensitivity simulations with LAM

Job	Sh. dom. BL.	Tnuc=-18C	AcE=0.1	No ice	PSD	3dSmag
dimsh						
dimsp				✓		
dimsq			✓			
dimsn						✓
dimsk	✓					
dimsi	✓		✓			
dimsz	✓	✓				
dimsy	✓	✓	✓			
dimsu	✓	✓	✓		✓	
dimsw		✓	✓			✓

- Sh. Dom. BL – modified Lock boundary layer scheme to allow mixing in strong shear regimes
- Tnuc=-18C – increase the heterogeneous freezing to -18C
- AcE = 0.1 – reduce autoconversion efficiency from 0.55 to 0.1
- No ice - switch off ice processes
- PSD – modified ice/snow PSD to better represent obs (based on Field et al, 2007)
- 3DSmag – use Smagorinsky to do local explicit mixing instead of BL scheme

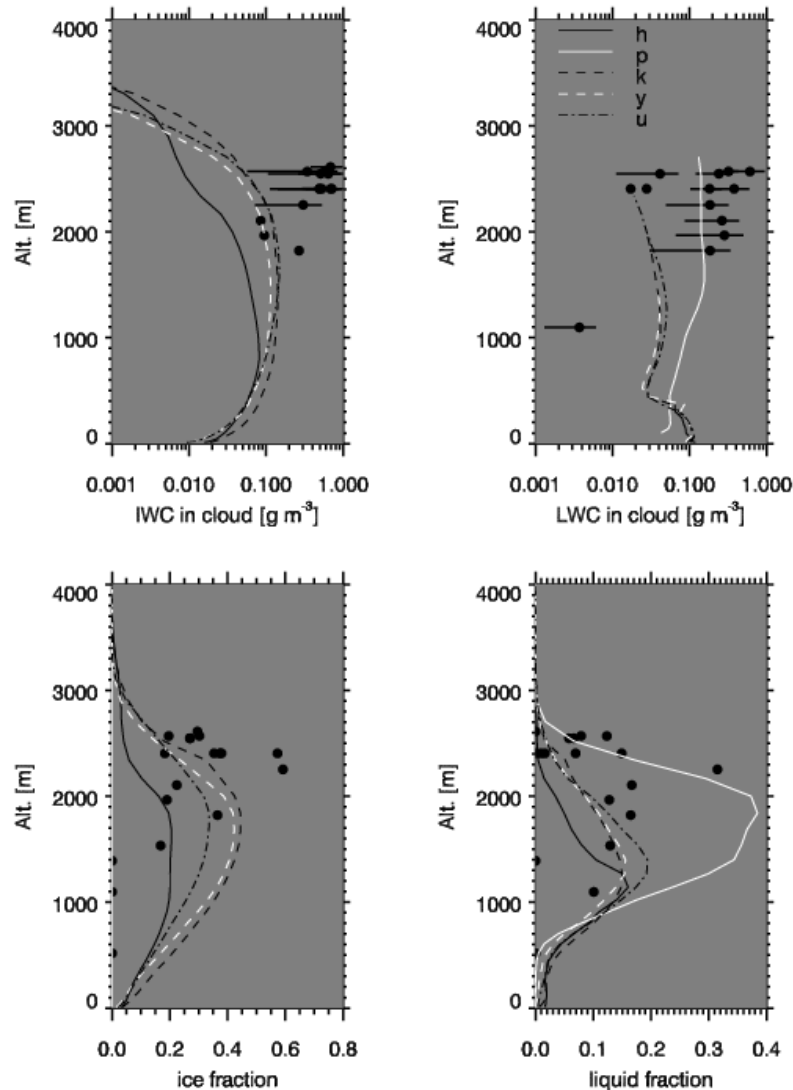


Met Office



Constrain flights
on 31st Jan 2010

LAM vs Aircraft observations



LAM sim h produces the least liquid and liquid fraction

LAM sim p (no ice) produces best agreement with observed LWC but no ice!

LAM sim u (modified ice nuc & modified BL scheme) produces best agreement with IWC and LWC & largest liquid fraction, when ice included



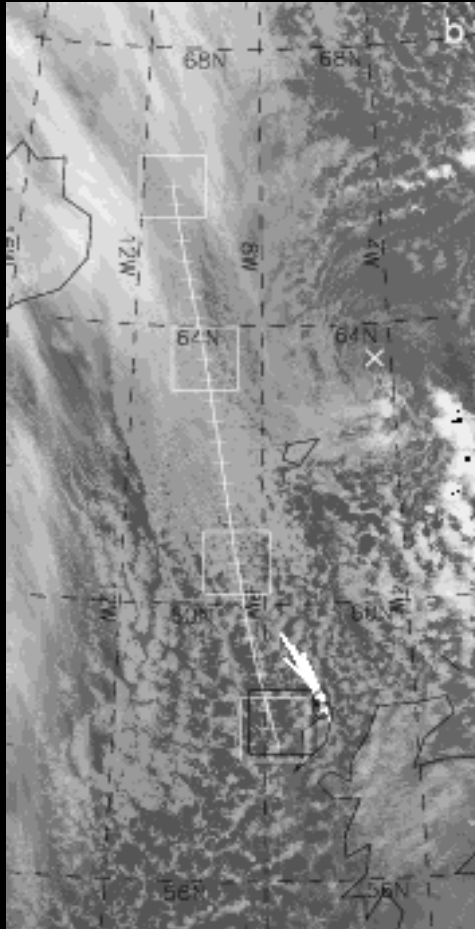
LAM overview

- In-Situ and satellite observations used to validate/improve UKMO UM, when run as a LAM
- Initial Simulation
 - Under-predicts liquid water content and fraction → overprediction of outgoing longwave
 - Fails to capture Sc – Cu transition
- Modification to (i) heterogenous ice nucleation & (ii) boundary layer scheme →
 - improved simulation of liquid and ice
 - Improved outgoing longwave
 - The simulation of a Sc – Cu transition
- Modified LAM simulation is considered “best” simulation and used as the basis for the LES case



Met Office

LES CONSTRAIN cold-air outbreak case



- Use the output from “best” LAM simulation to develop an idealised quasi-lagrangian LES cold-air outbreak
- Start @ 65 N -10 W
- End @ 58 N -8 W
- Time for transect = 14 hours
- Captures the Sc to Cu transition



LES CONSTRAIN cold-air outbreak case

Standard domain

- x,y domain = 100 x 100 km
 - $dx, dy = 250$ m
- z domain = 5 km
 - $dz = 25$ m between surface and 1500 m
 - dz is then stretched between 3000 and 5000 m using the following code (based on setup designed by Irina Sandu for ASTEX intercomparison)
 - Both the horizontal resolution and vertical resolution are quite coarse, which is a trade off to permit the large domain.



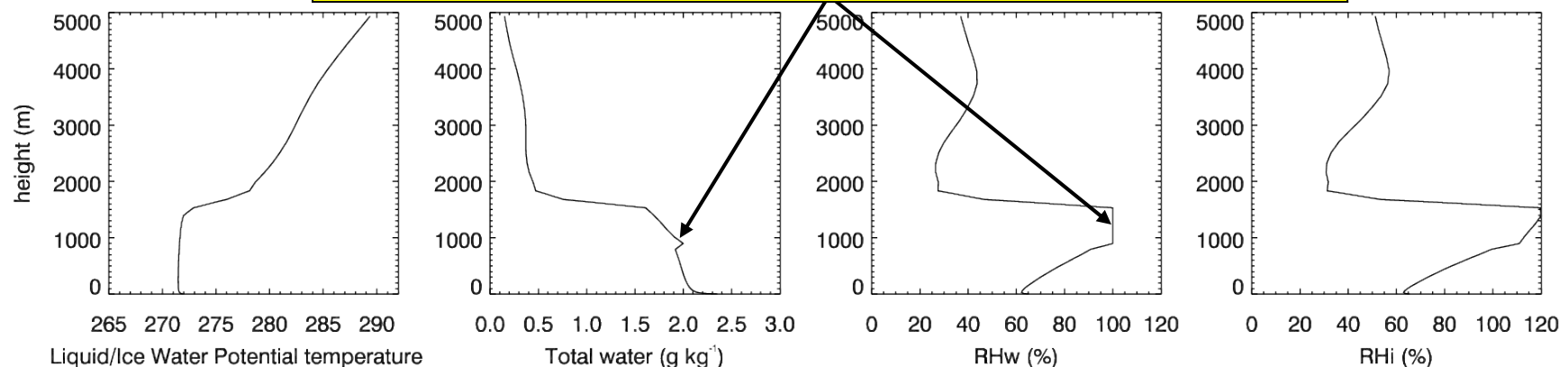
Met Office

LES CONSTRAIN cold-air outbreak set-up

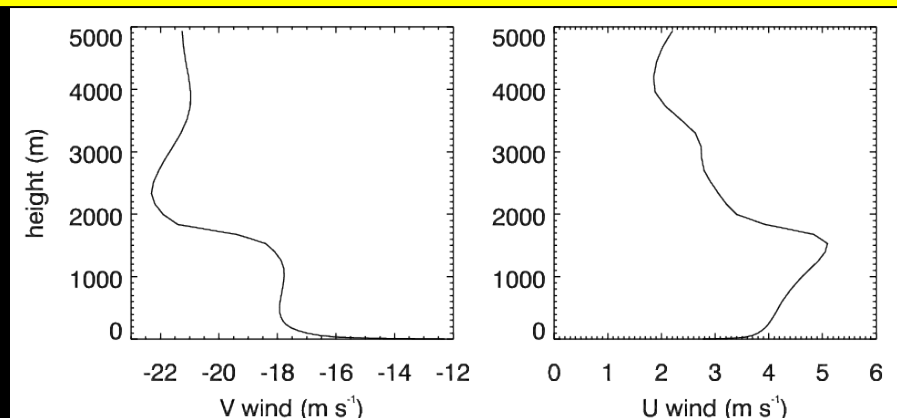
Initial conditions

Initialise case with total water and liquid/ice water potential temperature based on modified output from the NWP simulation

Total water increased so cloud layer saturated wrt to water



Strong N-S wind component $\sim 16 \text{ m s}^{-1}$ near surface

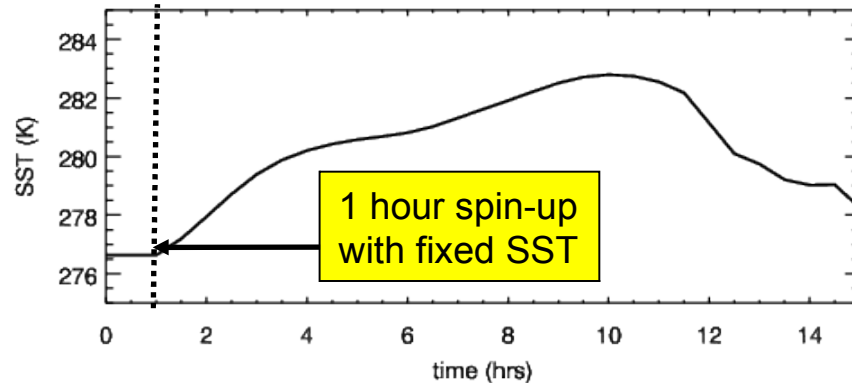




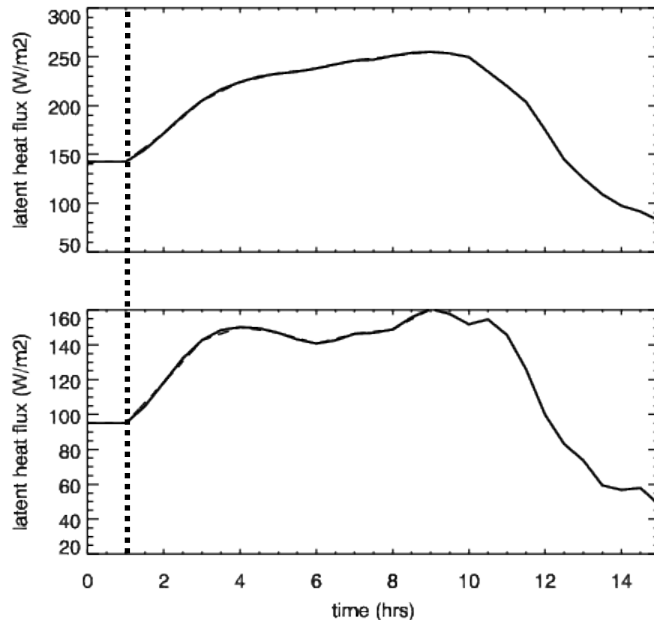
Met Office

LES CONSTRAIN cold-air outbreak set-up

Surface forcing



Surface forcing uses the prescribed SST derived from the UKMO MO LAM simulation



Prescribed surface fluxes, derived from the MO LAM simulation, are also provided



LES CONSTRAIN cold-air outbreak set-up

Other forcing and set-up

- Large-scale vertical velocity is derived from the UKMO LAM and provided as a velocity
- The v-winds are forced using a geostrophic wind with the following values:
 - geostrophic wind (VG) = -15 ms^{-1}
 - $dVG/dz = -0.0024 \text{ s}^{-1}$
- Ozone profiles based on standard mid-latitude McClatchy ozone profile
- Temperature and vapour fields provided upto 37 km for radiation
- Roughness length for momentum ($Z0$) = $6.6\text{E-}4$
- Roughness length for scalars ($Z\theta$) = $3.7\text{E-}6$
- Surface pressure = 1007 mbar



CRM CONSTRAIN cold-air outbreak set-up

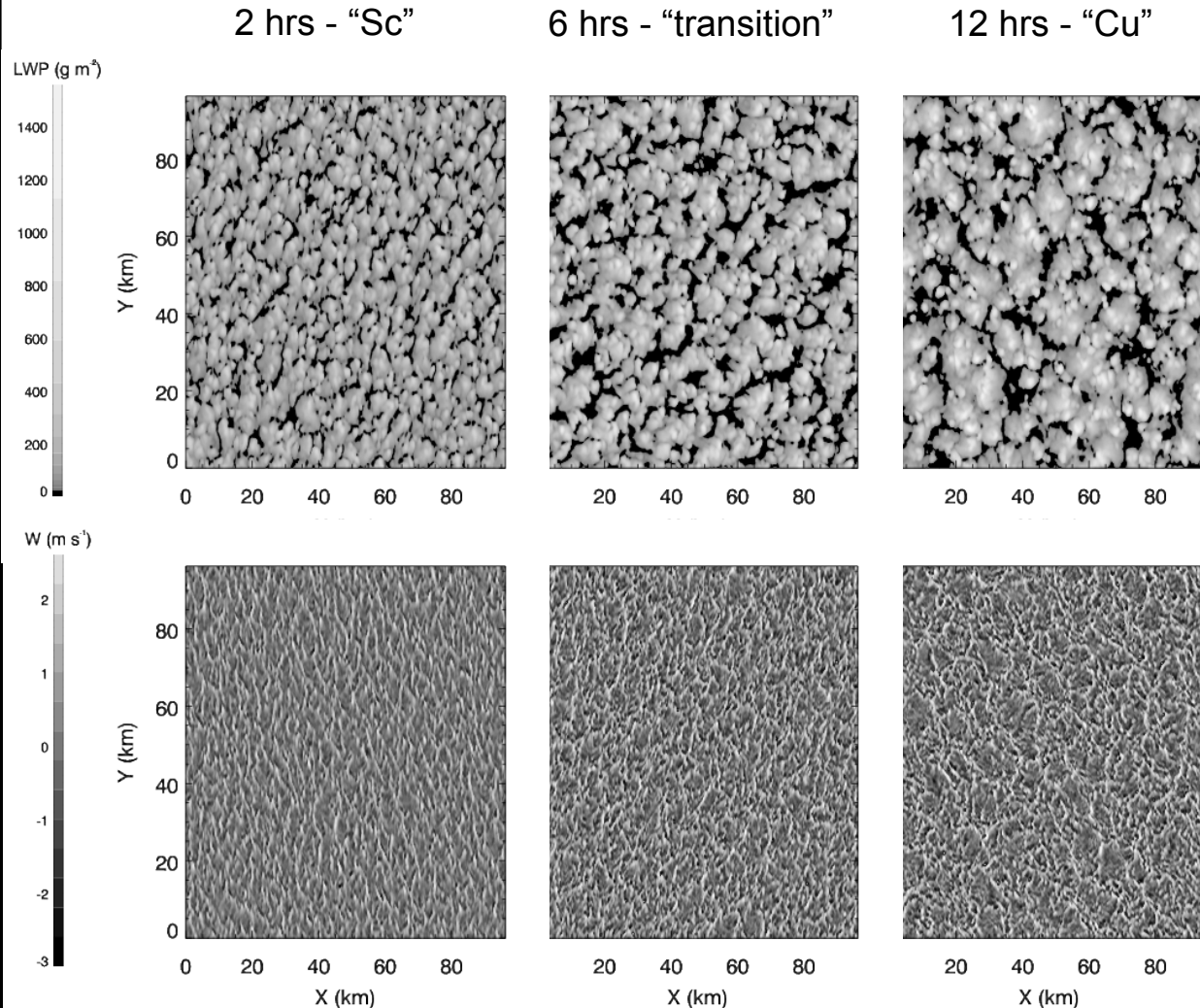
Simulations

- UKMO LEM simulations
 - liquid only, i.e. ice processes are switched off
 - Ice and liquid (1M cloud & Rain, 2M ice, snow and graupel)
 - Initial cloud number concentration = 50 cm^{-3}
- Delft University DALES simulations

L (km)	Δx (m)	N_c (cm^{-3})	Purpose
102.4	200	10	Reference
102.4	400	10	Lower horizontal resolution
102.4	400	50	Larger droplet concentration
51.2	200	10	Smaller domain size
12.8	50	10	Fine-scale velocity structures

- No ice microphysics in DALES simulations

No-Ice simulation with UKMO LEM

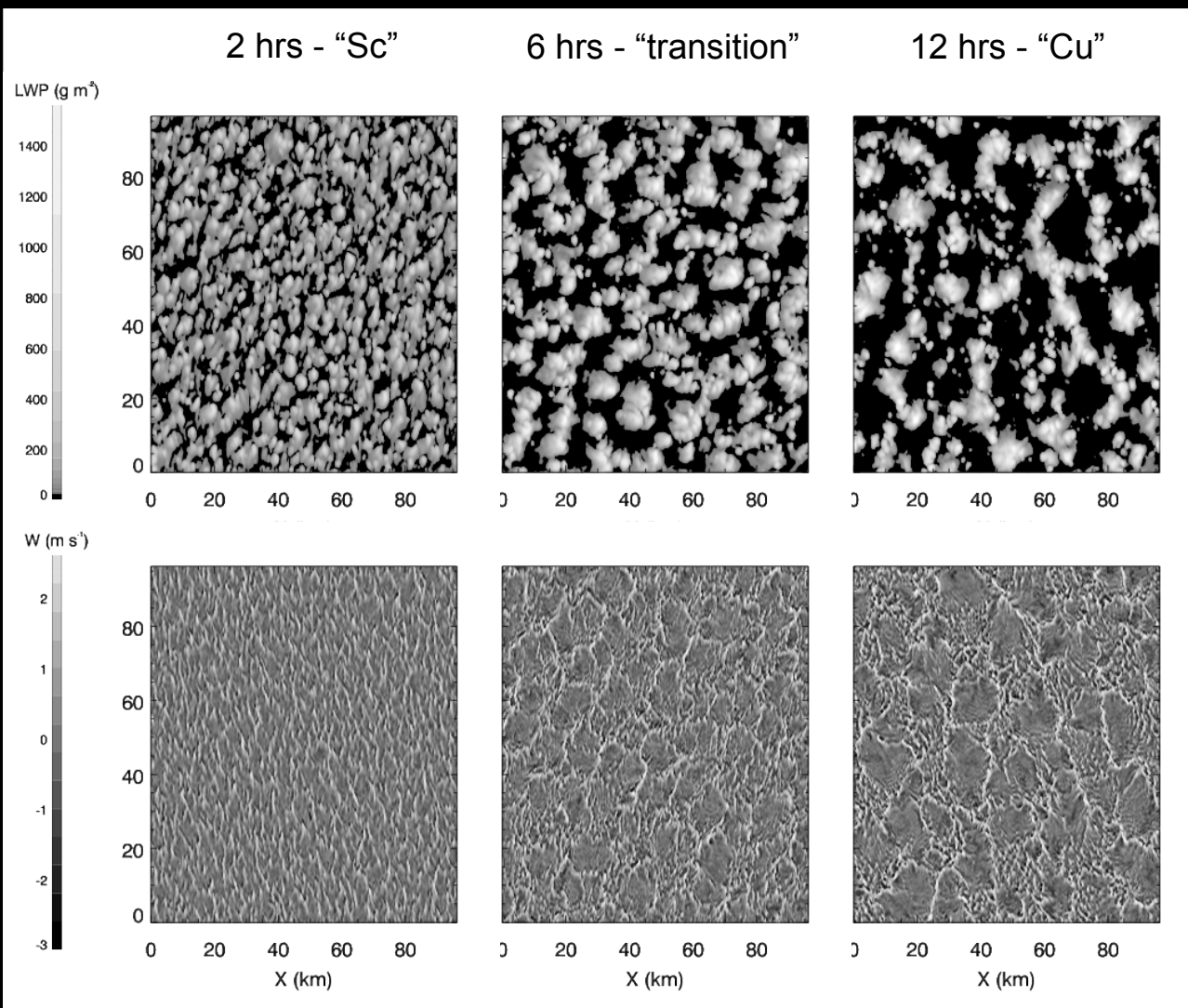


* LEM is UKMO large eddy simulation model

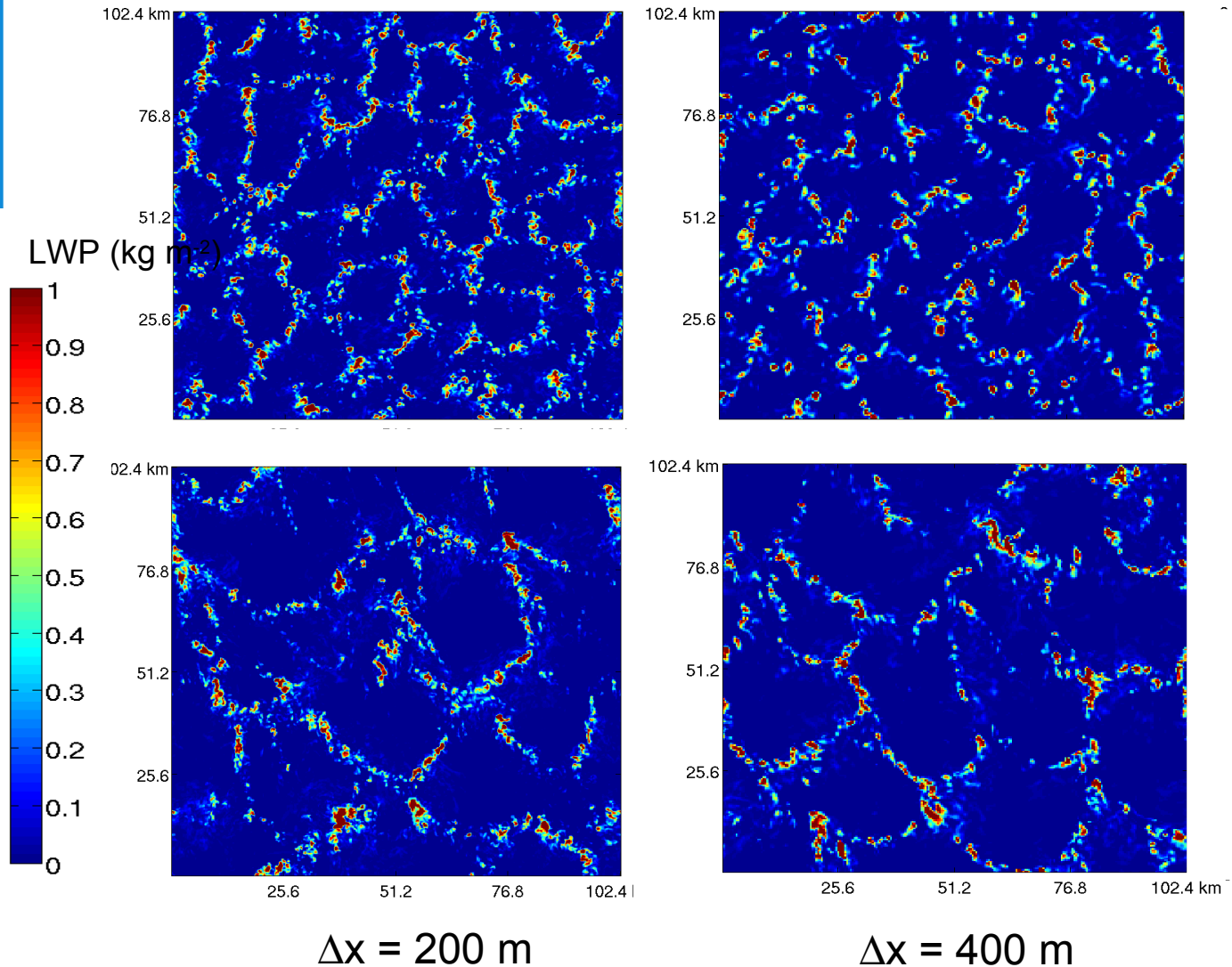


Met Office

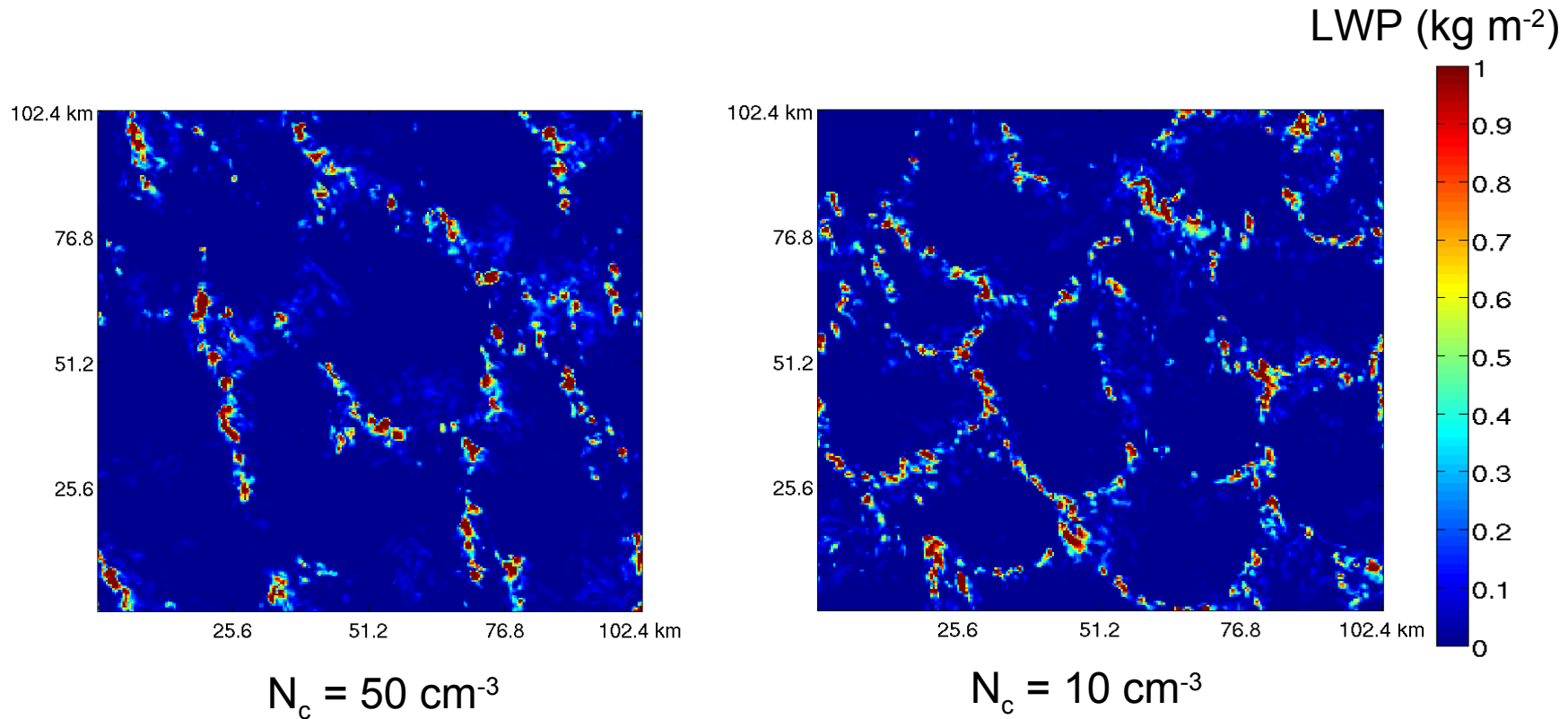
Ice simulation with UKMO LEM



LWP from DALES ref and coarse sim, $N_c = 10 \text{ cm}^{-3}$



Effects of cloud droplet concentration



Open cells develop both for $N_c = 10$ and 50 cm^{-3}



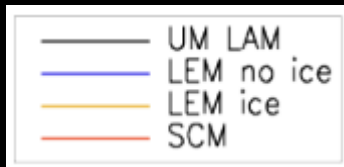
Met Office

Model Comparison

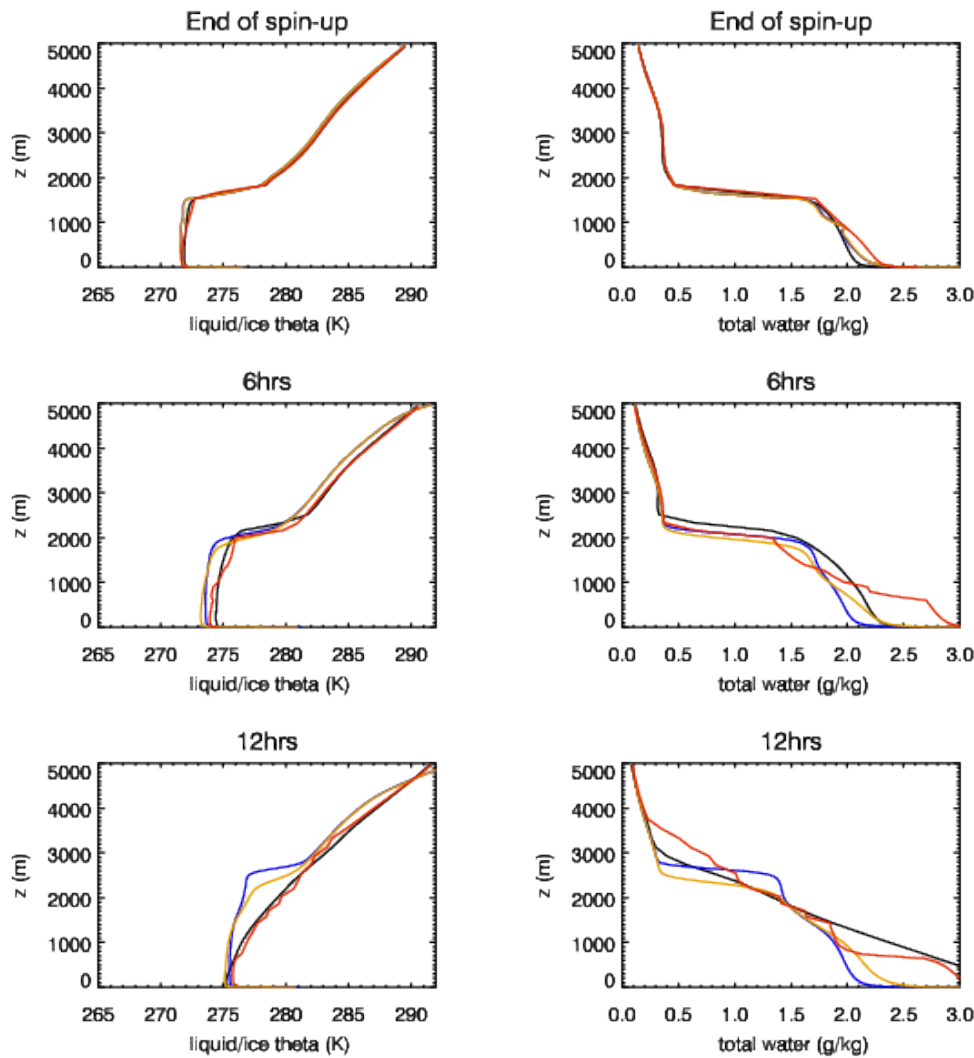
- LEM simulations suggest
 - Not including ice processes → persistence of the Sc, with apparent small increase in cloud fraction, thus no Sc – Cu transition & hence, no open cellular structures
 - Including ice results in
 - A transition & open cellular structures
- DALES simulations suggest
 - Case is insensitive to resolution change
 - Transition and open cellular structure occurs with various cloud drop numbers but there are differences
- How does this compare with the LAM and the UKMO SCM?
 - SCM uses same inputs as LEM to simulate case



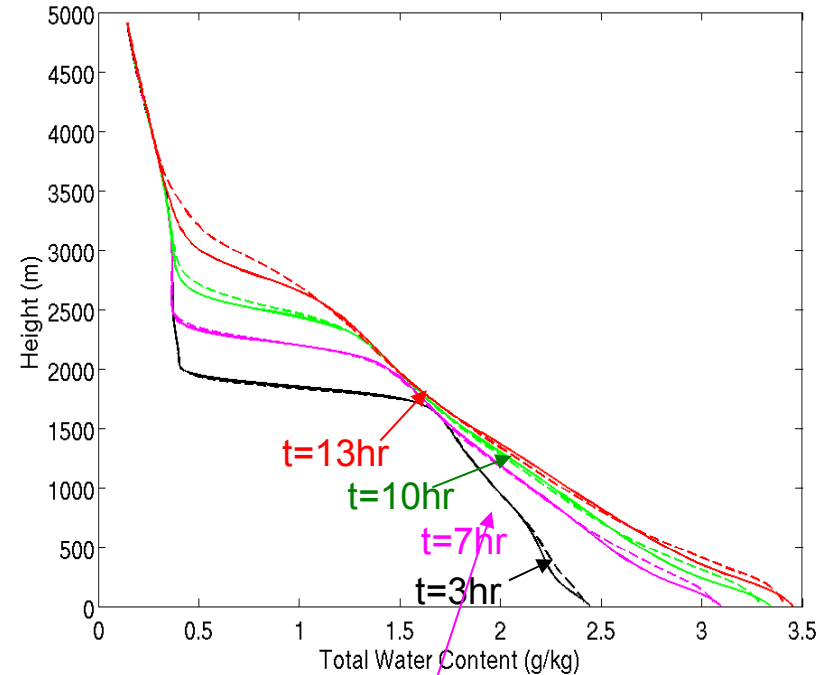
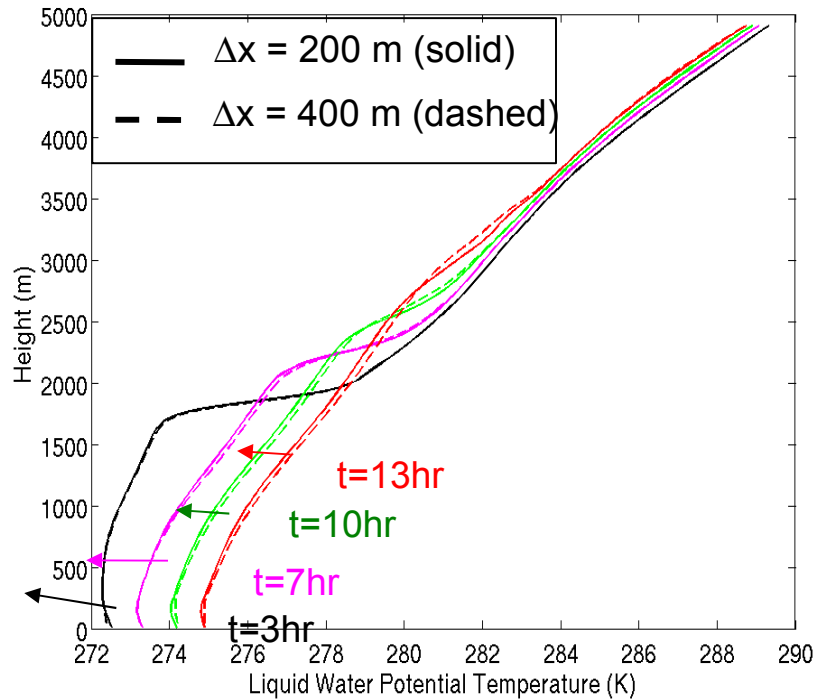
Met Office



Liquid/ice potential temperature (left) and total water (right) from UM LAM, LEM, SCM



Liquid water potential temperature & total water content, $N_c = 10 \text{ cm}^{-3}$

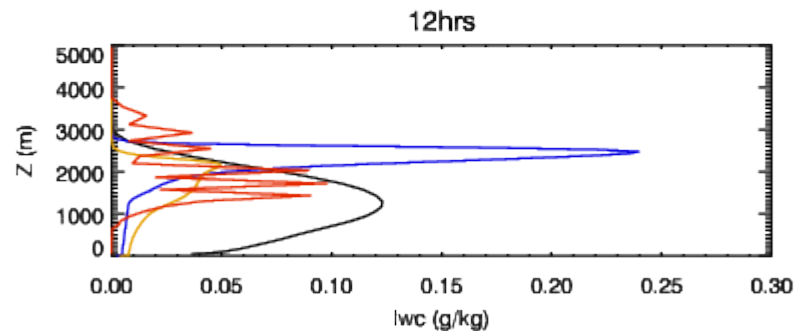
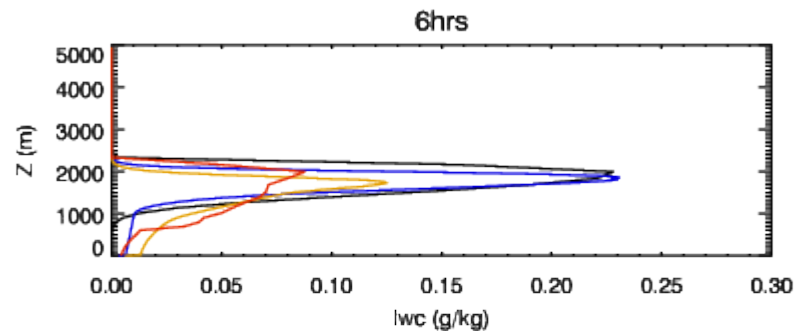
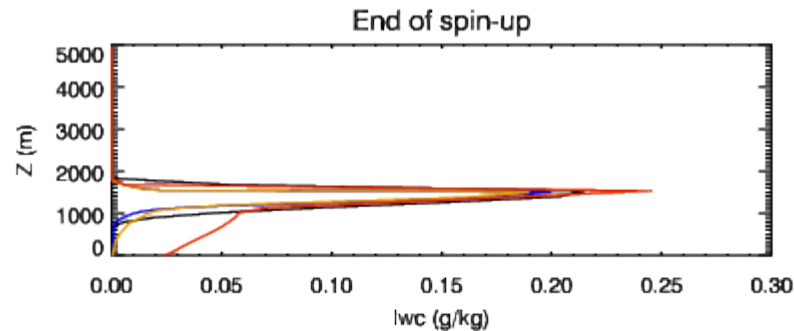
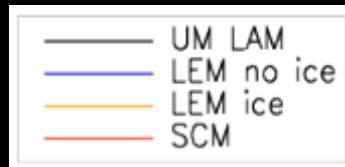


Coarser resolution hardly has an effect on the mean state evolution



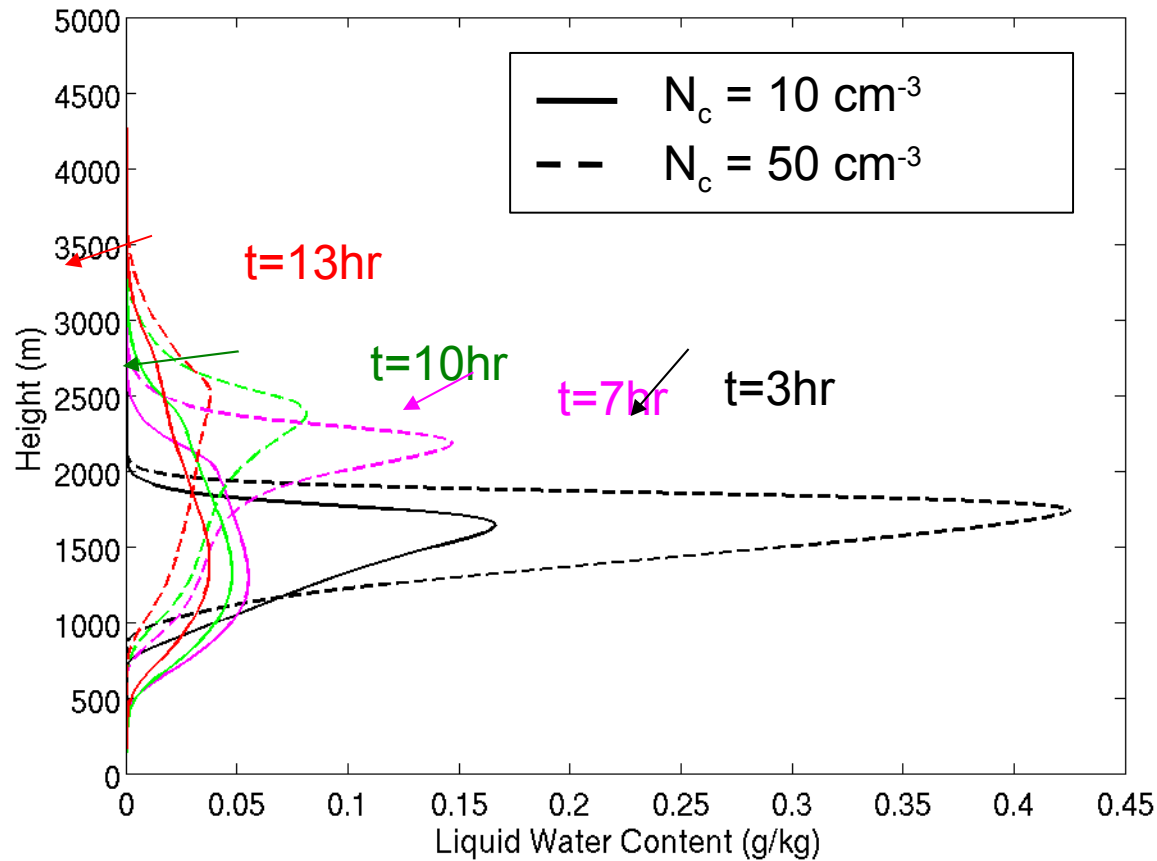
Met Office

Comparison of liquid water content from UM LAM, LEM, SCM



Liquid water content

$L = 102.4 \text{ km}$

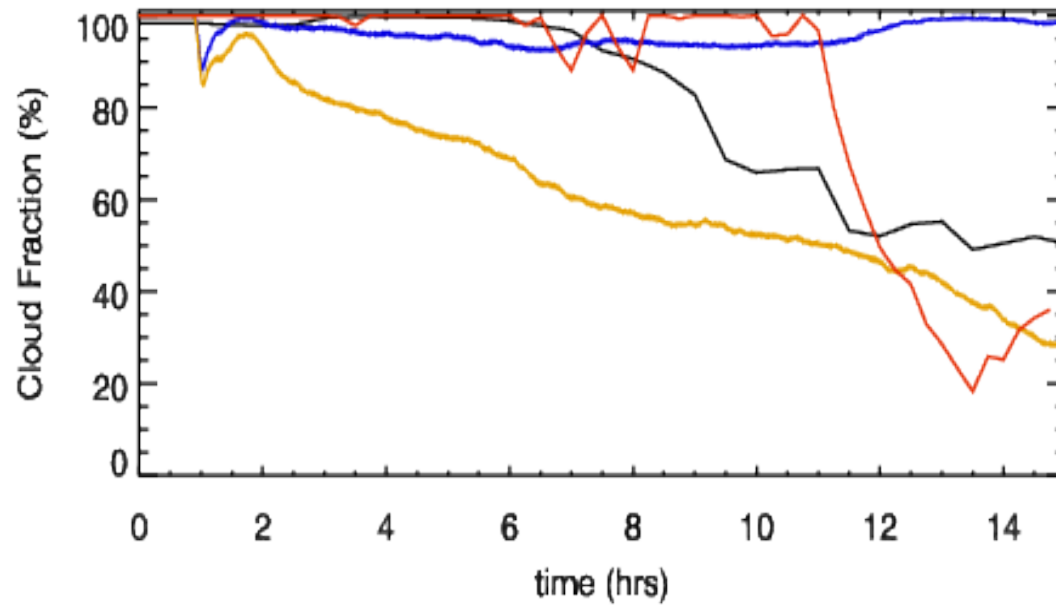
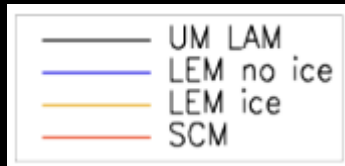


Cloud droplet concentration has a large influence on the liquid water content

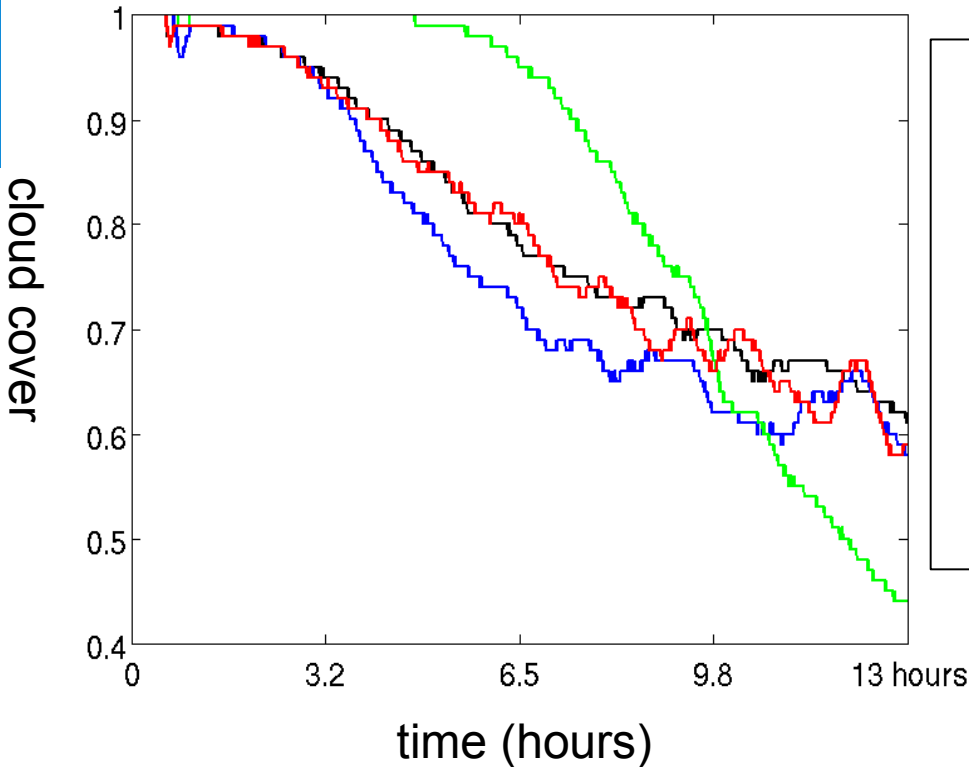


Met Office

Liquid water path & liquid/ice water path from UM LAM, LEM, SCM



Time series: cloud cover



	L (km)	Δx (m)	N_c (cm ⁻³)
<div></div>	102.4	200	10
<div></div>	102.4	400	10
<div></div>	102.4	400	50
<div></div>	51.2	200	10

Droplet concentration affects cloud cover evolution



Grey Zone model comparison proposal

Use the standard CONSTRAIN case as the basis for grey zone model comparison of limited area models (LAM) and LES

LES resolution testing

Run the LES standard case with horizontal resolution of 500 m, 1 km, 2 km, 4 km and 8 km

LAM resolution testing

Run the LAM standard case with horizontal resolution of 2 km, 4 km, 8 km and 16 km. Also, perform the tests permutations of model parametrisation, e.g. 4 permutations of model in the LAM could be...

Conv. on	Conv. off	Non-local BL on	Non-local BL off
	X	X	
X		X	
	X		X
X			X



Grey Zone model comparison proposal

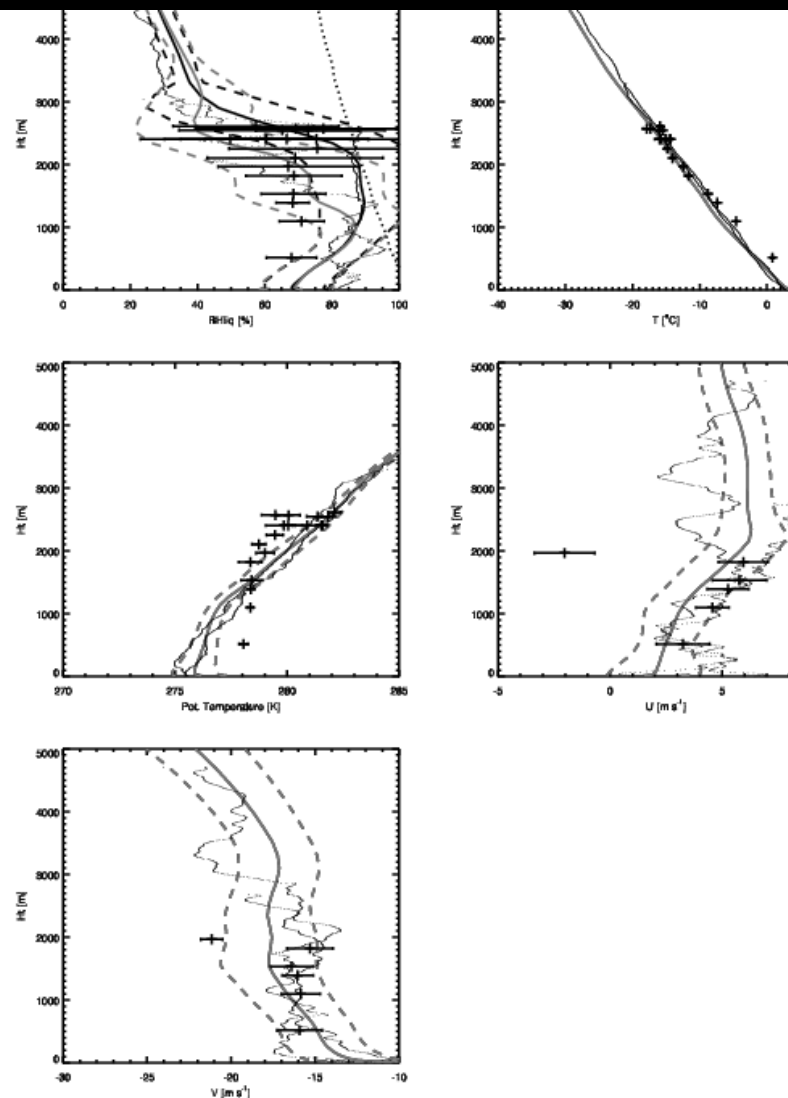
Finally, the comparison also includes the Global modelling on this case – this set-up is being finalised

Questions

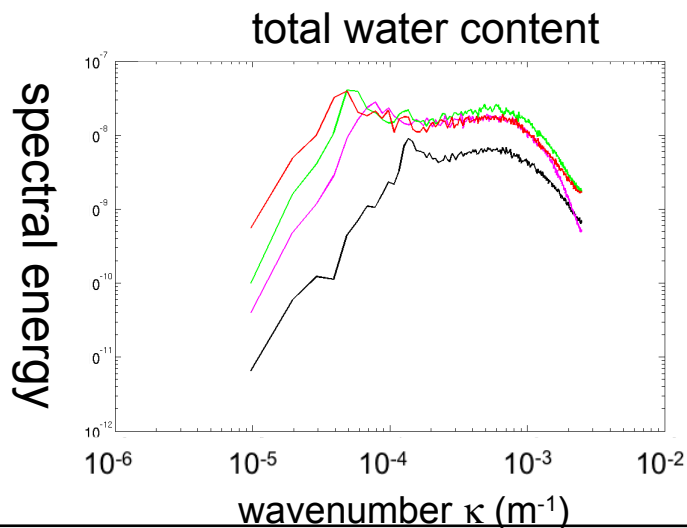
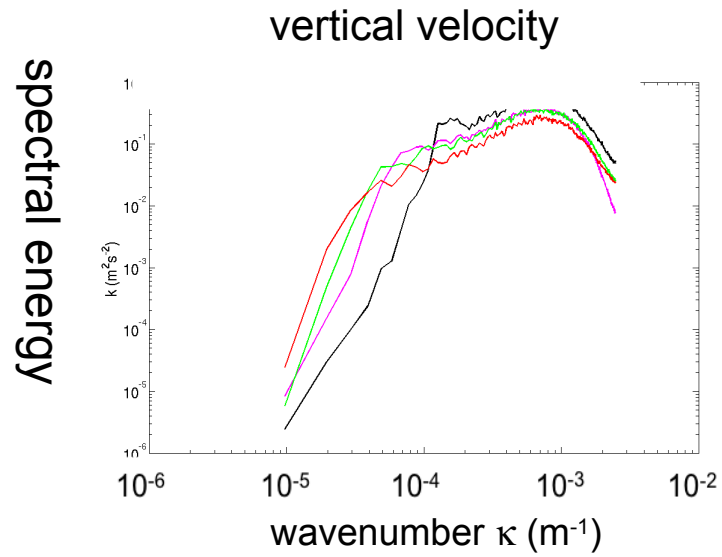
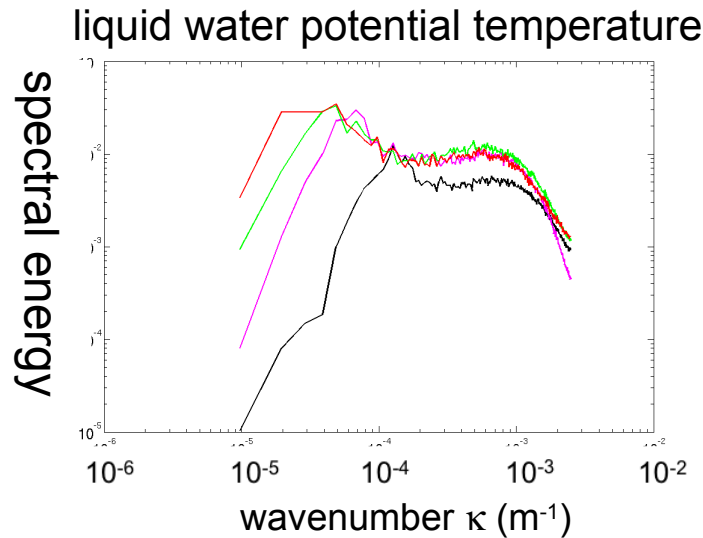
1. Is 1 km resolution sufficient to capture the cold air outbreak?
2. How does the boundary layer structure and evolution from the LAMs compare with the LES (and Global models)?
3. What is the role of ice in the evolution of the boundary layer and cloud field?

Full details of the recommended case and the set-up for the grey zone tests, as well as required output can be found at

http://appconv.metoffice.com/cold_air_outbreak/constrain_case/home.html



Energy spectra (reference simulation, $z = 487.5$ m)



gradual shift of spectral energy towards larger scales



Met Office

Liquid water path & liquid/ice water path from UM LAM, LEM, SCM

