CONSTRAIN – proposal for “grey zone” model comparison case

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

Contents

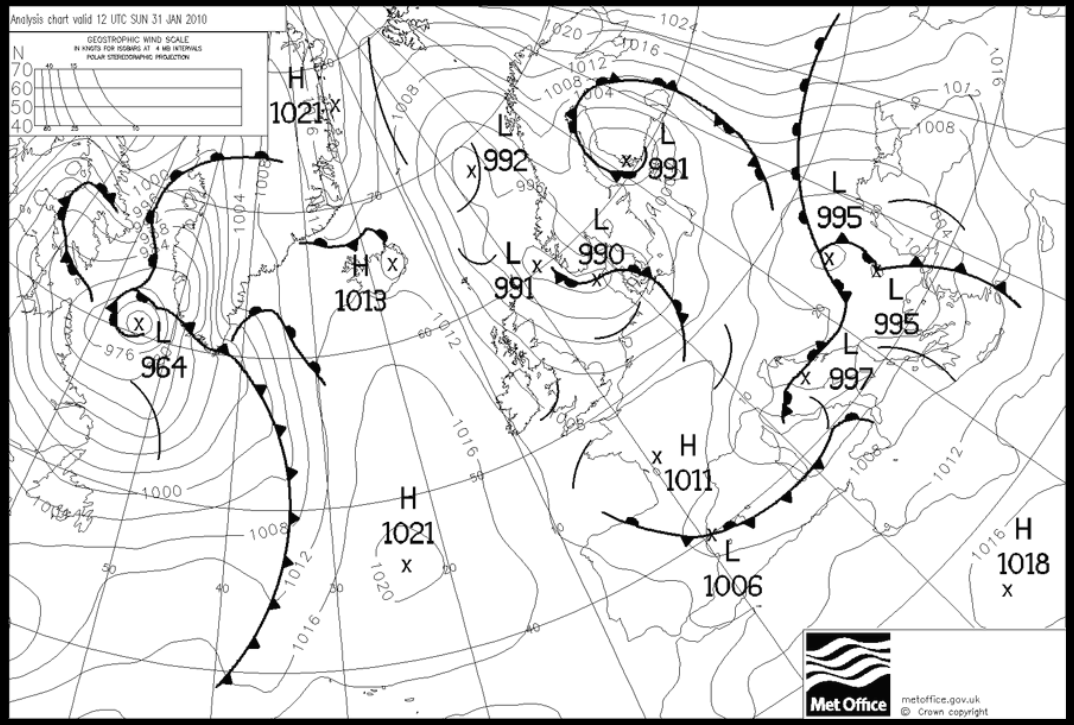
- Introduction
  - CONSTRAIN
- Overview of UM Limited Area Model (LAM) simulations
- Proposed LES case
  - Setup
  - Some initial results, including comparison with the LAM and SCM runs
- Summary of work so far
- Proposed set-up for grey-zone simulations

CONSTRAIN

- The aim of CONSTRAIN was to better determine the various ice and mixed-phase cloud microphysical parameters used in the Met Office Unified Model (UM).

- flights over the North Atlantic from January 12 to 31 2010.

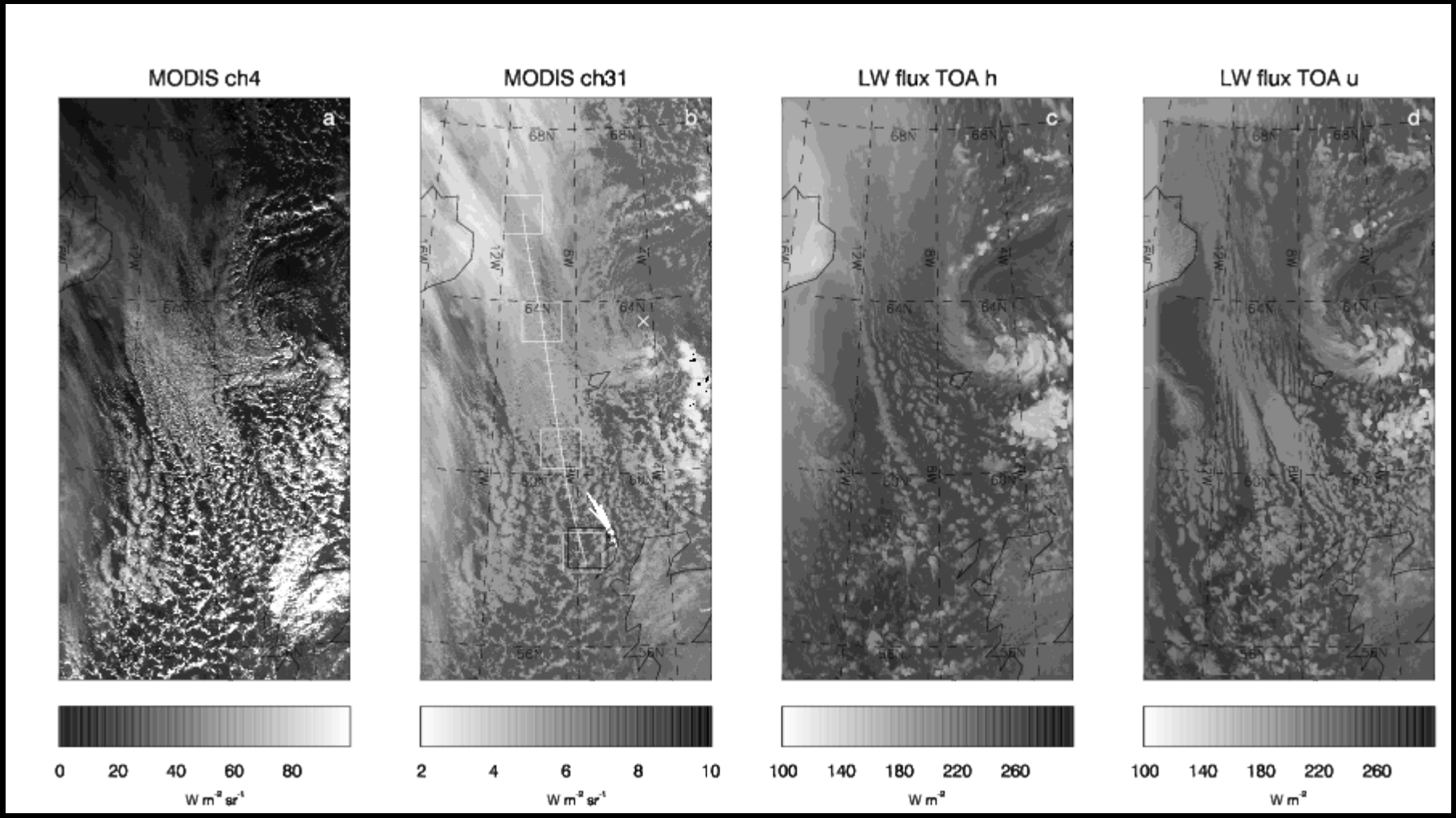
- The proposed case is based in observations and NWP data from January 31st 2010.



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

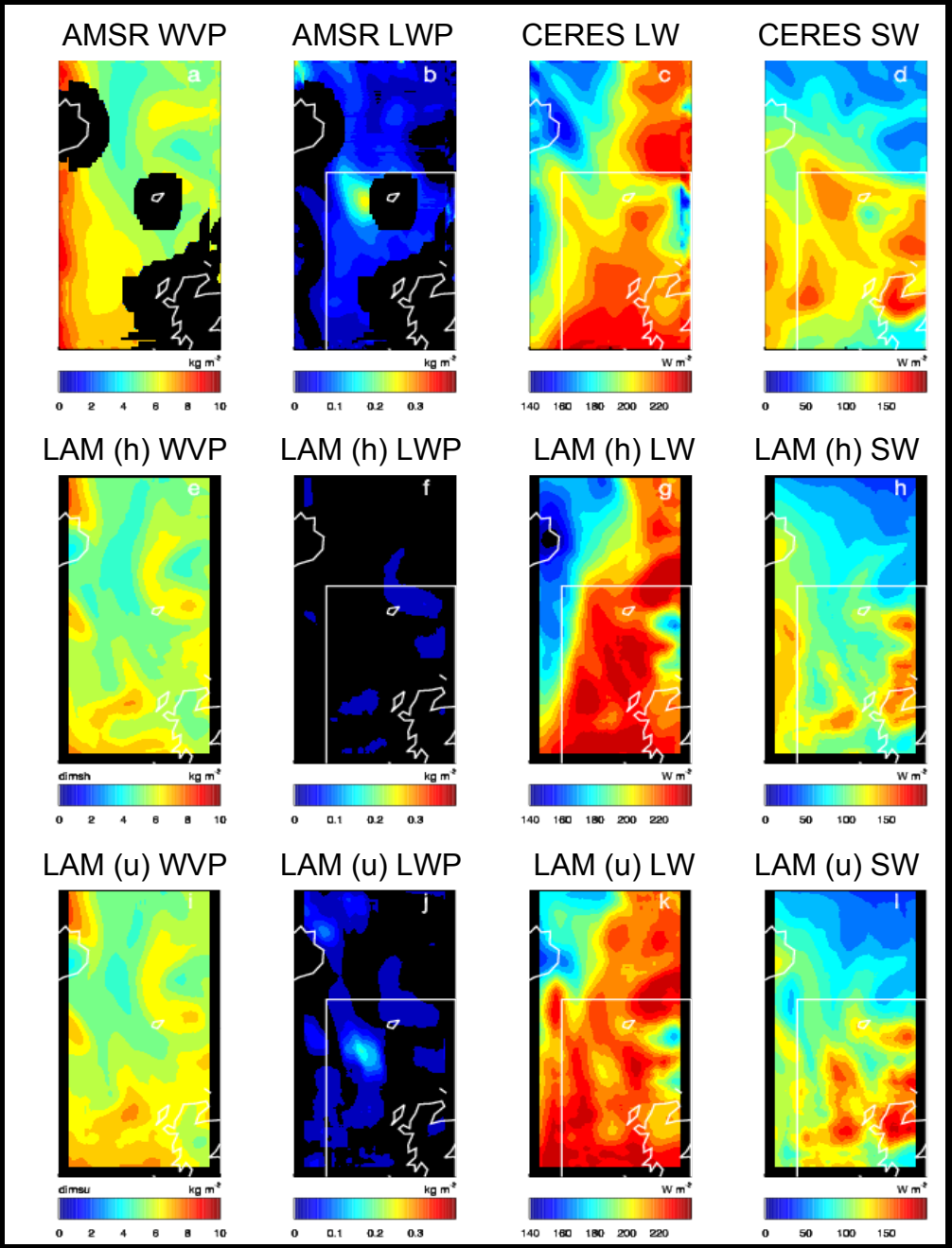
Parameterisation

- 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



Satellite Obs

UM LAM initial simulation (h)

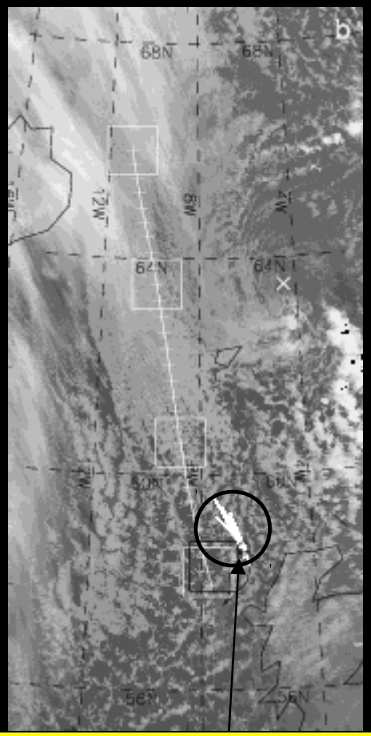
UM LAM modified simulation (u)

Sensitivity simulations with LAM

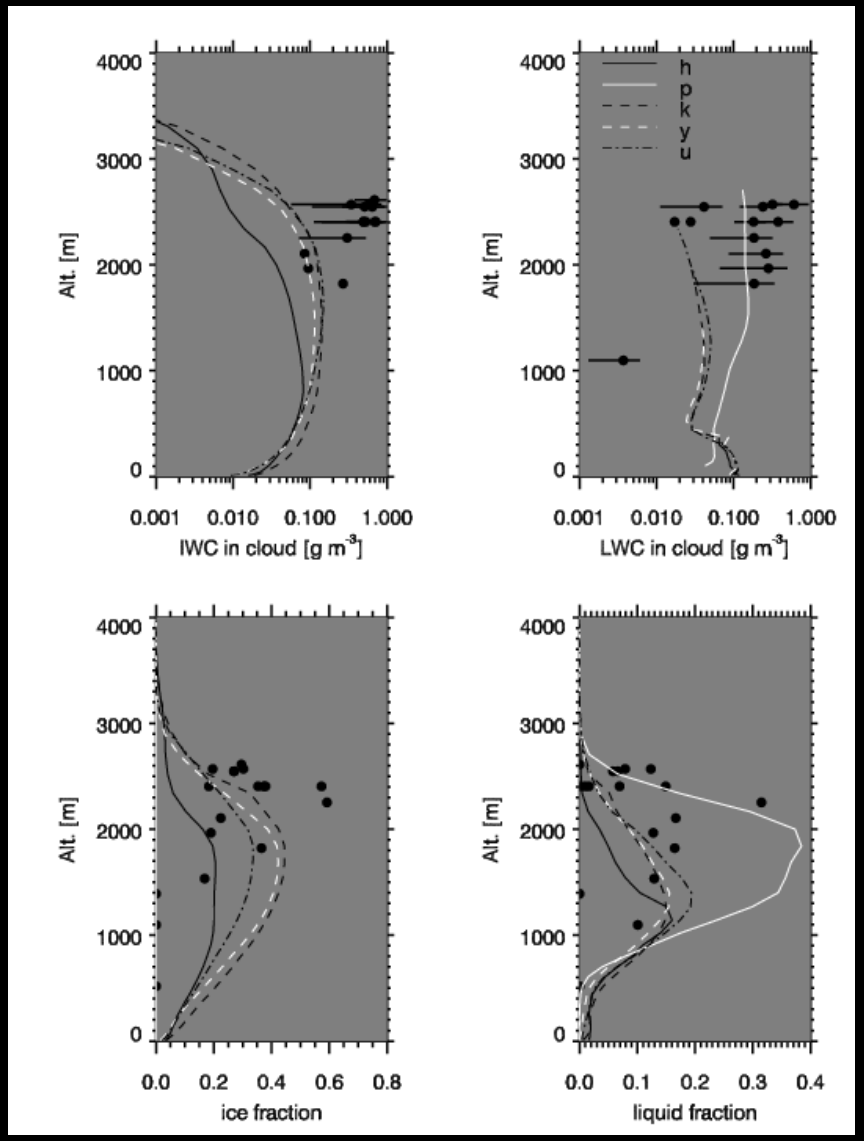
Job	Sh. dom. BL.	Tnuc=-18C	AcE=0.1	No ice	PSD	3dSmag
dimsh						
dimsp				✓		
dimsq			✓			
dimsn						✓
dimsk	✓					
dimsi	✓		✓			
dimsz	✓	✓				
dimsy	✓	✓	✓			
dimsu	✓	✓	✓		✓	
dimsw		✓	✓			✓

- 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

LAM vs Aircraft observations



Constrain flights on 31st Jan 2010



LAM sim h produces the least liquid and liquid fraction

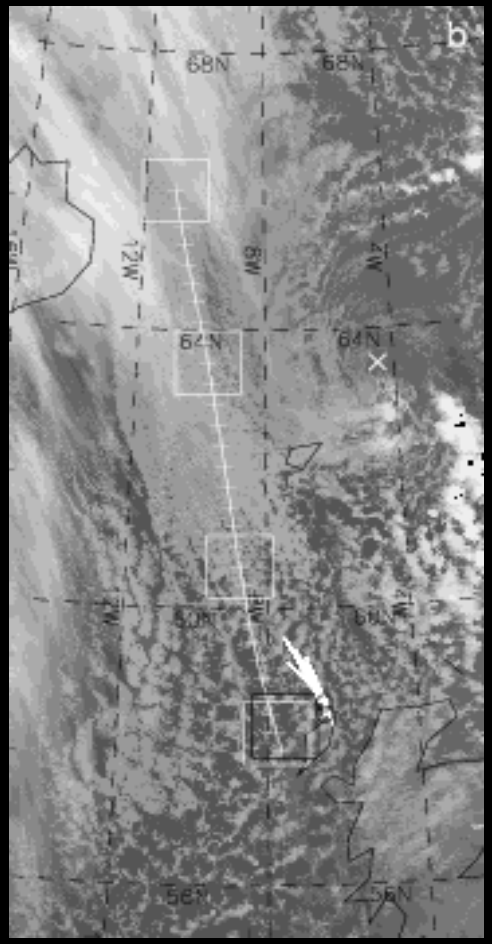
LAM sim p (no ice) produces best agreement with observed LWC but no ice!

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

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

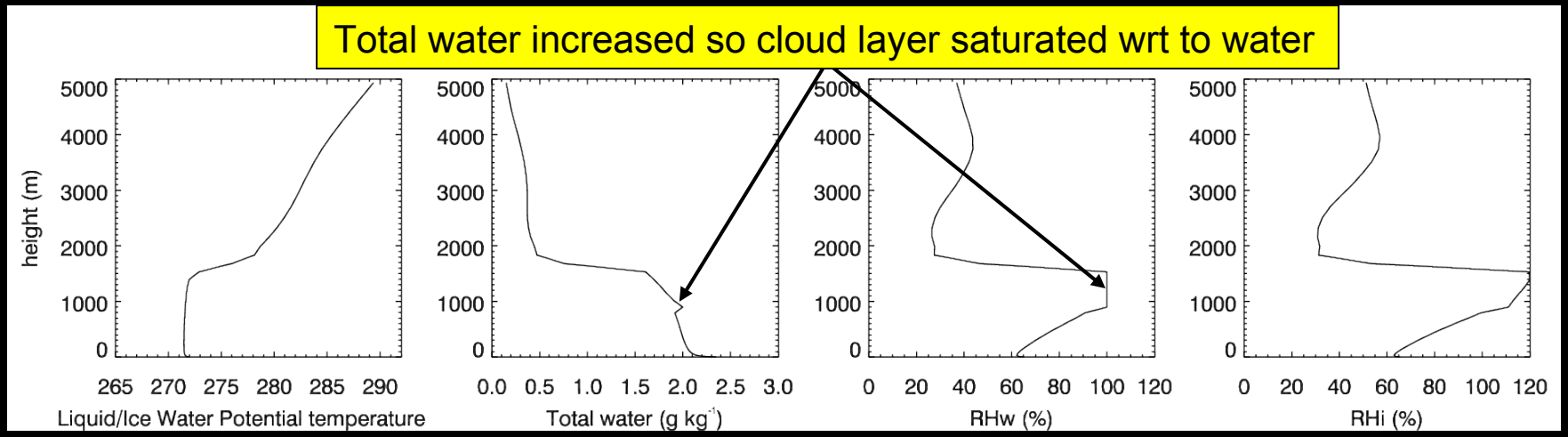
- x,y domain = 100 x 100 km
  - dx, dy = 250 m
- z domain = 5 km
  - dz = 25 m between surface and 1500 m
  - dz is then stretched between 3000 and 5000 m using the following code (based on setup designed by Irina Sandu for ASTEX intercomparison)
  - Both the horizontal resolution and vertical resolution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

LES CONSTRAIN cold-air outbreak set-up

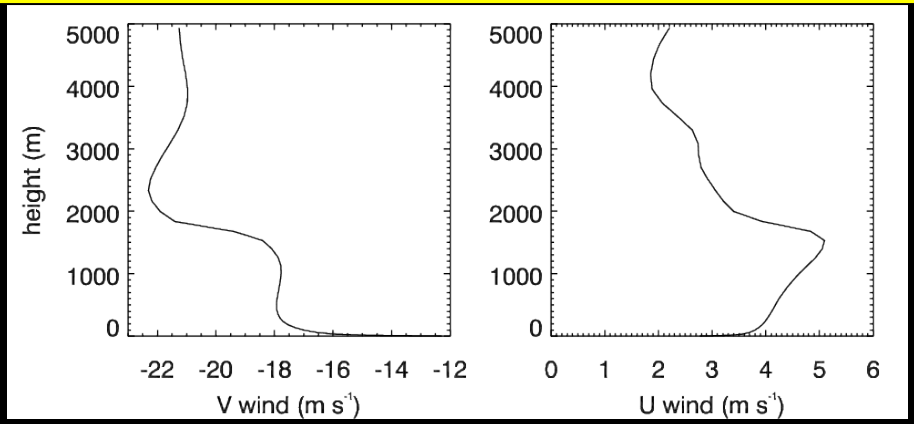
Initial conditions

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

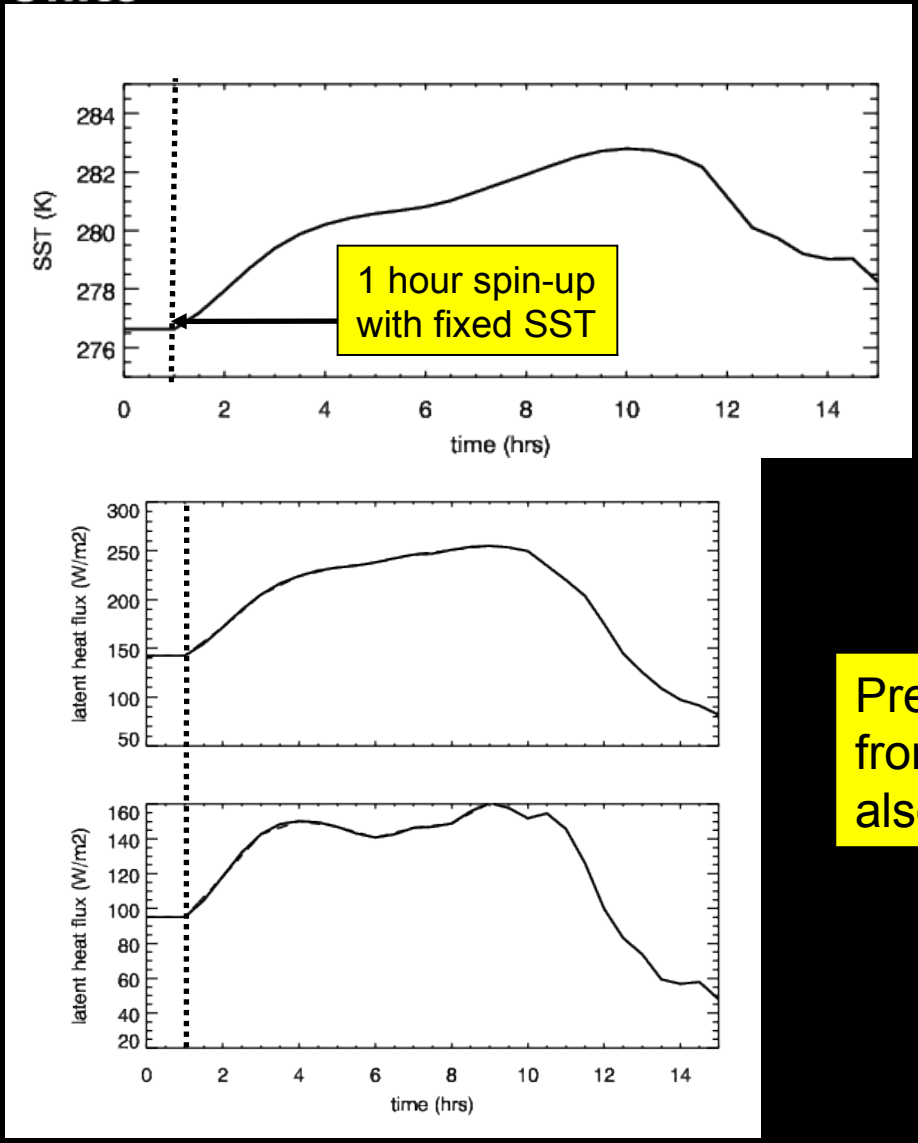


Strong N-S wind component ~ 16 m s^{-1} near surface



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 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) = 6.6E-4
- Roughness length for scalars (Zθ) = 3.7E-6
- Surface pressure = 1007 mbar

CRM CONSTRAIN cold-air outbreak set-up

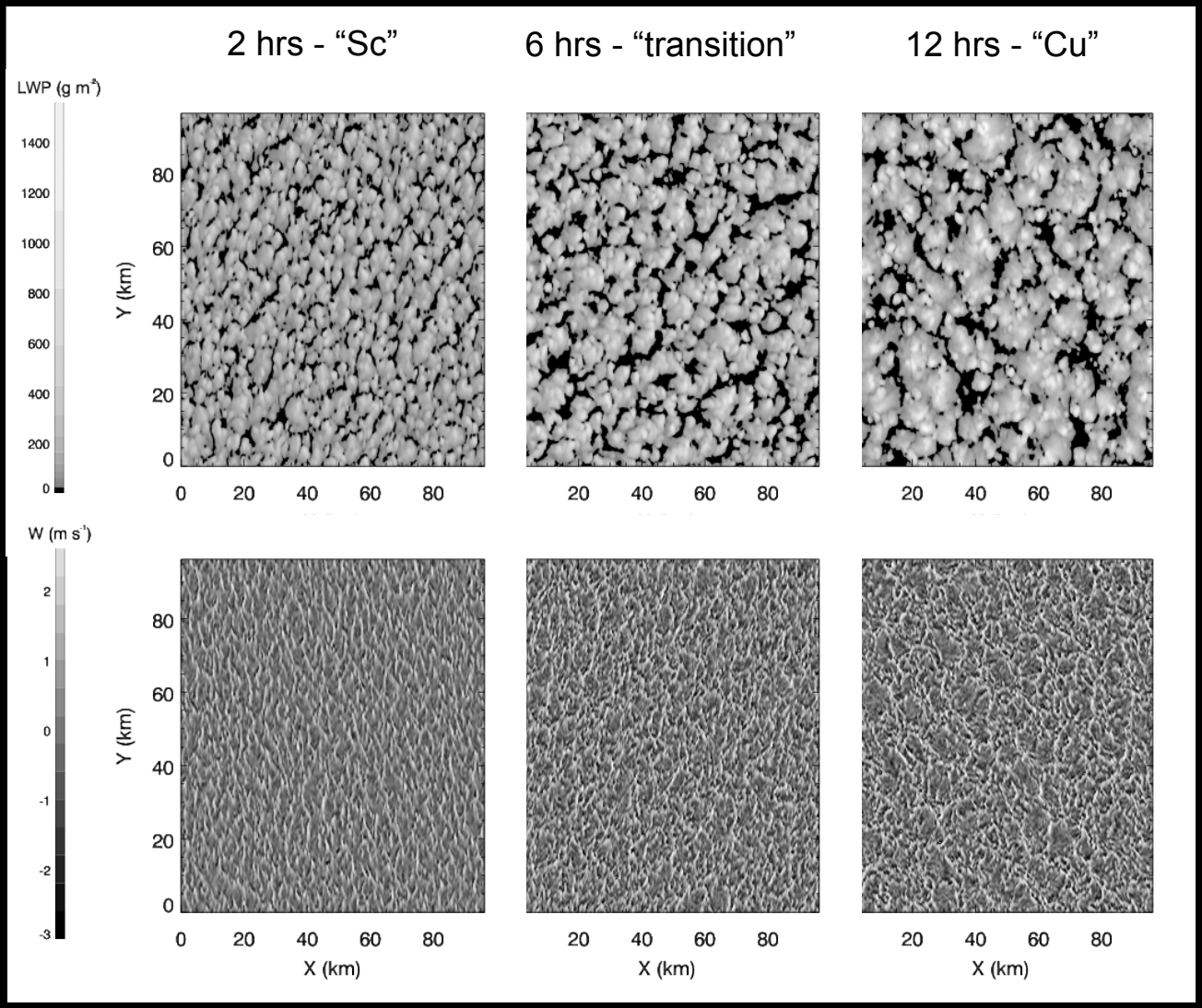
Simulations

- UKMO LEM simulations
  - liquid only, i.e. ice processes are switched of
  - 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

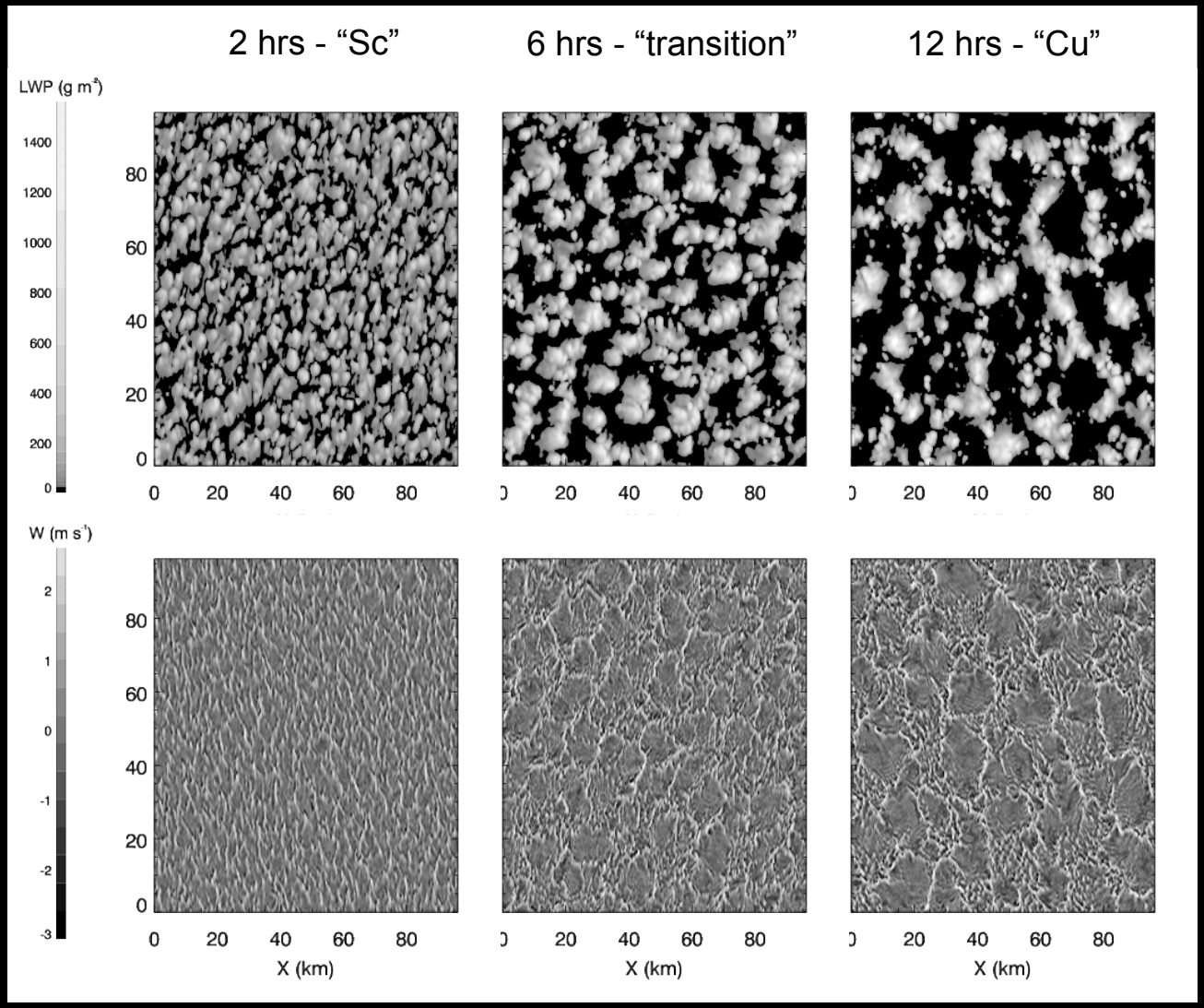
- No ice microphysics in DALES simulations

No-Ice simulation with UKMO LEM

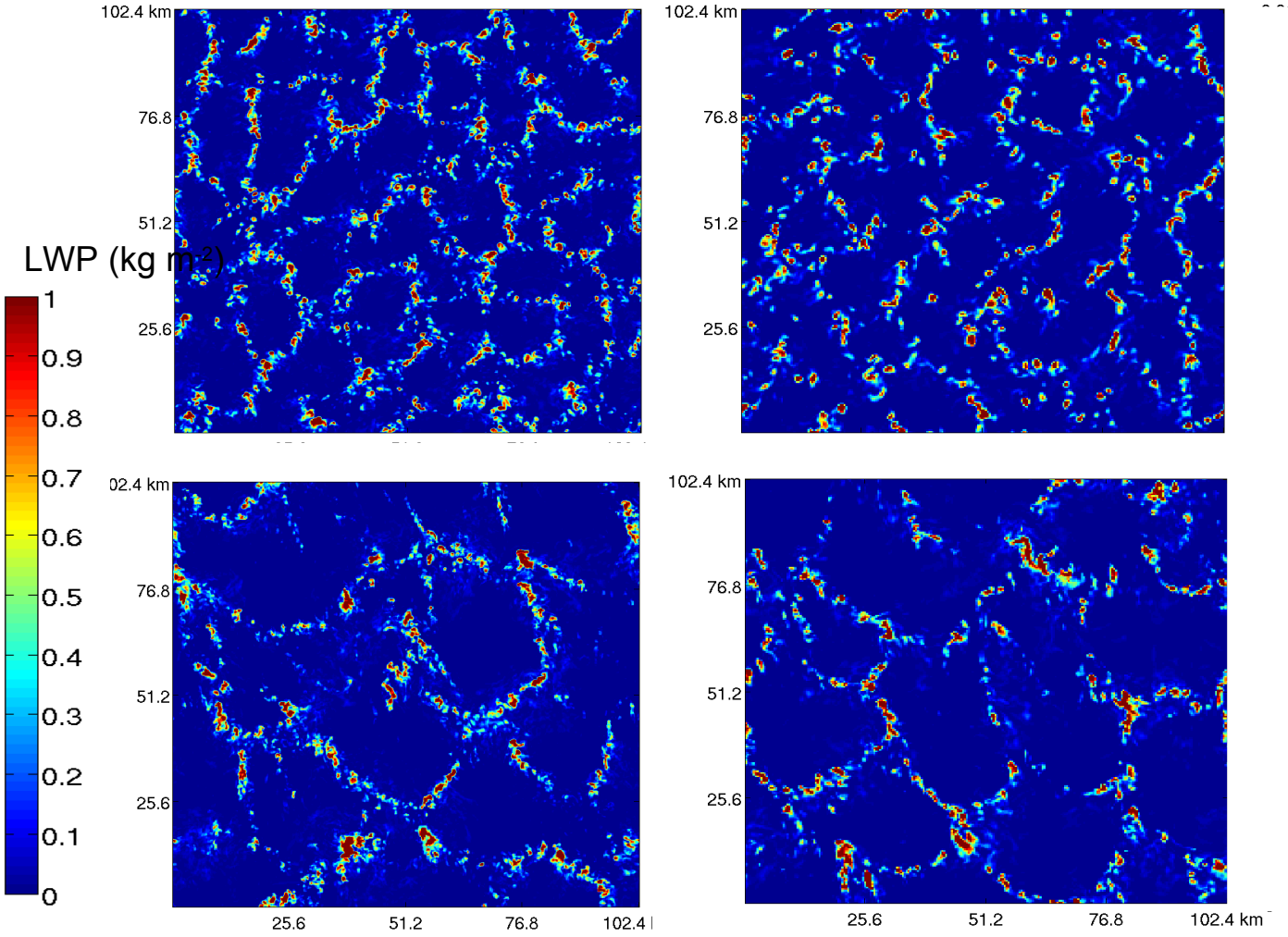


* LEM is UKMO large eddy simulation model

Ice simulation with UKMO LEM



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



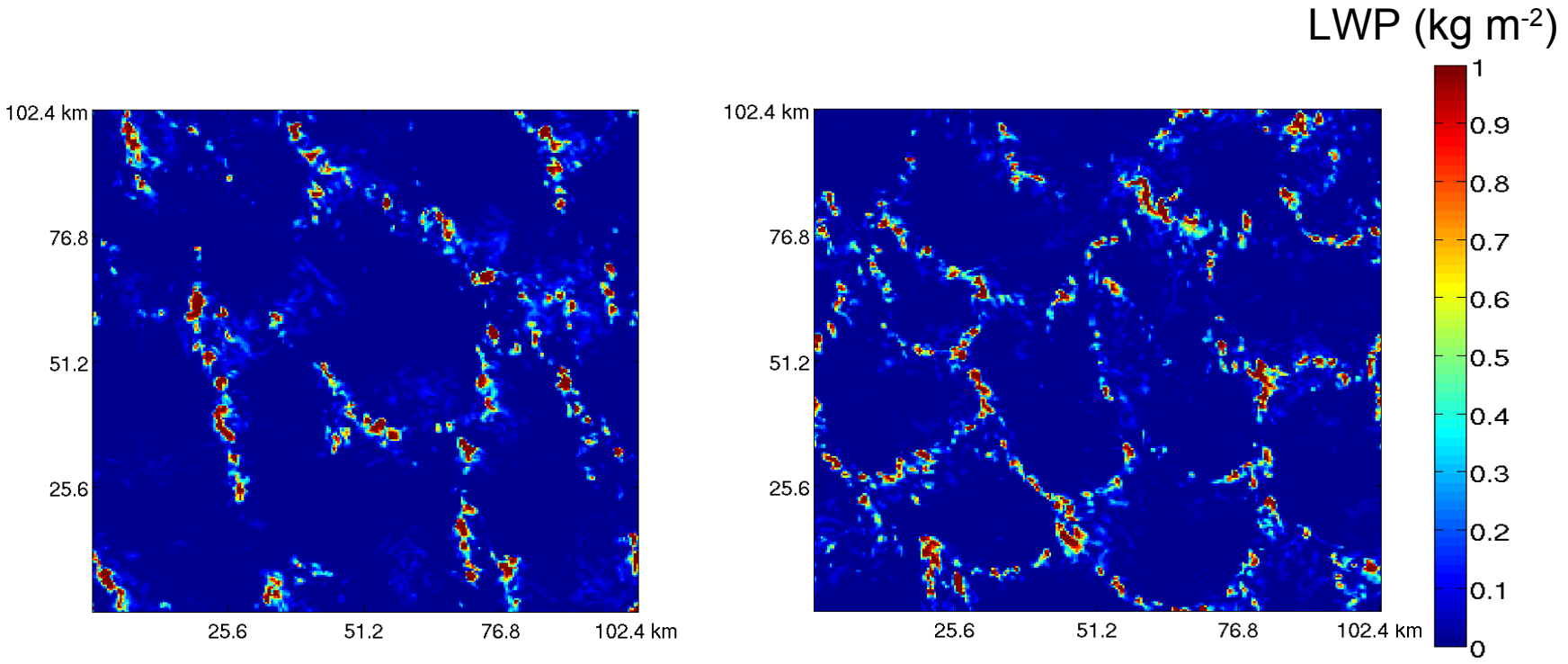
Time = 7hrs

Time = 13hrs

Δx = 200 m

Δx = 400 m

Effects of cloud droplet concentration



N_c = 50 cm^{-3}

N_c = 10 cm^{-3}

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

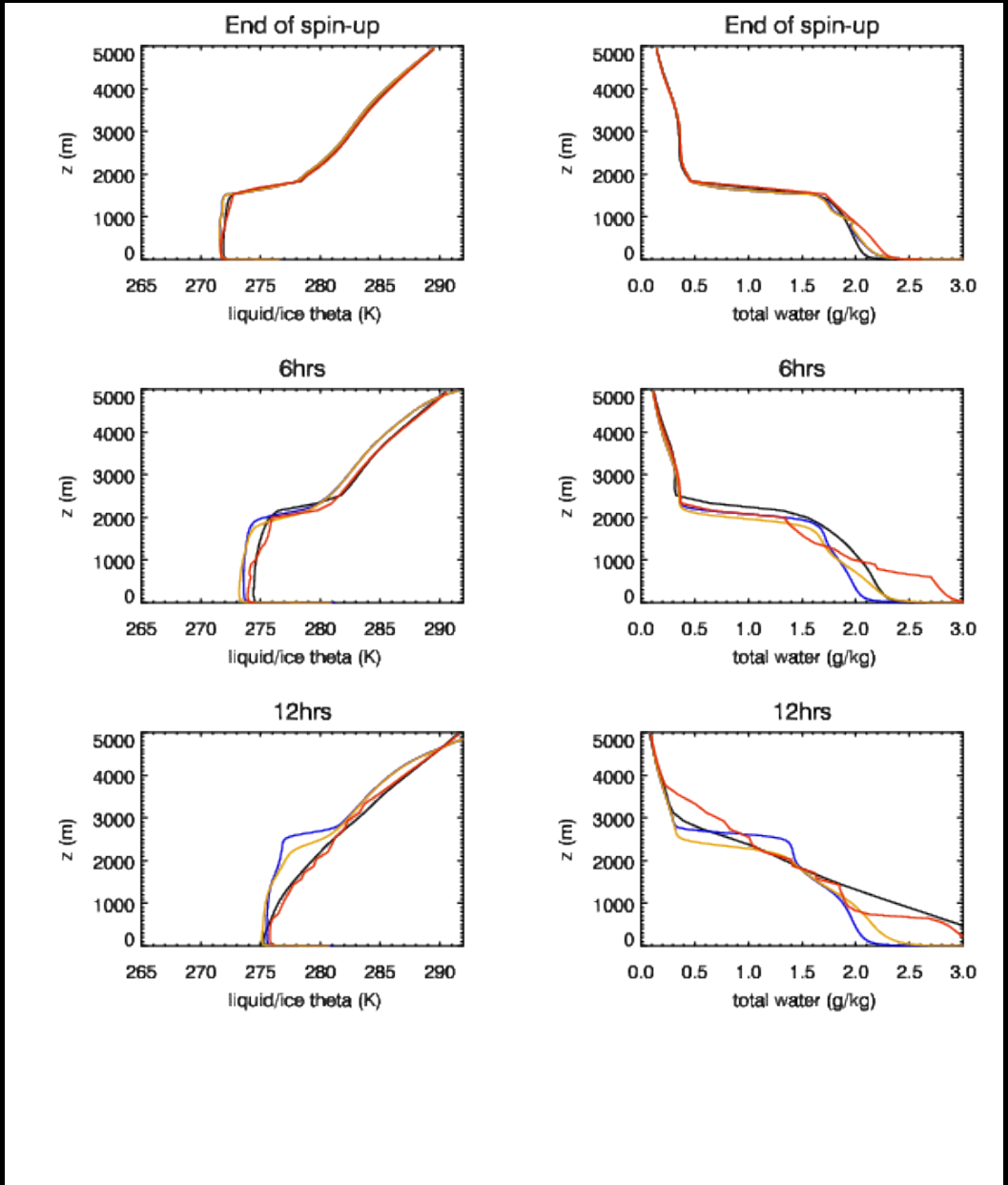
Model Comparison

- 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

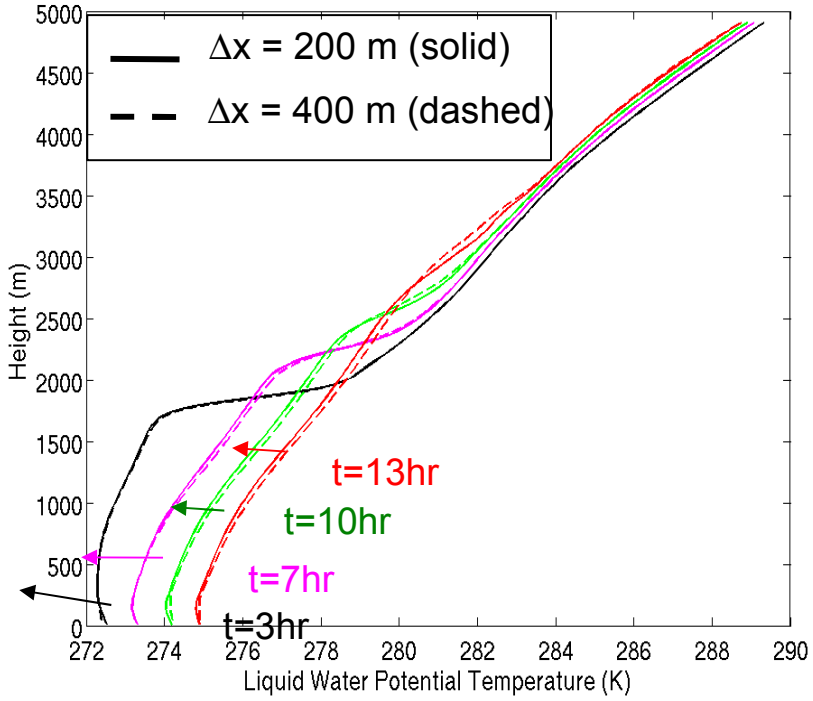
Liquid/ice potential temperature (left) and total water (right) from UM LAM, LEM, SCM

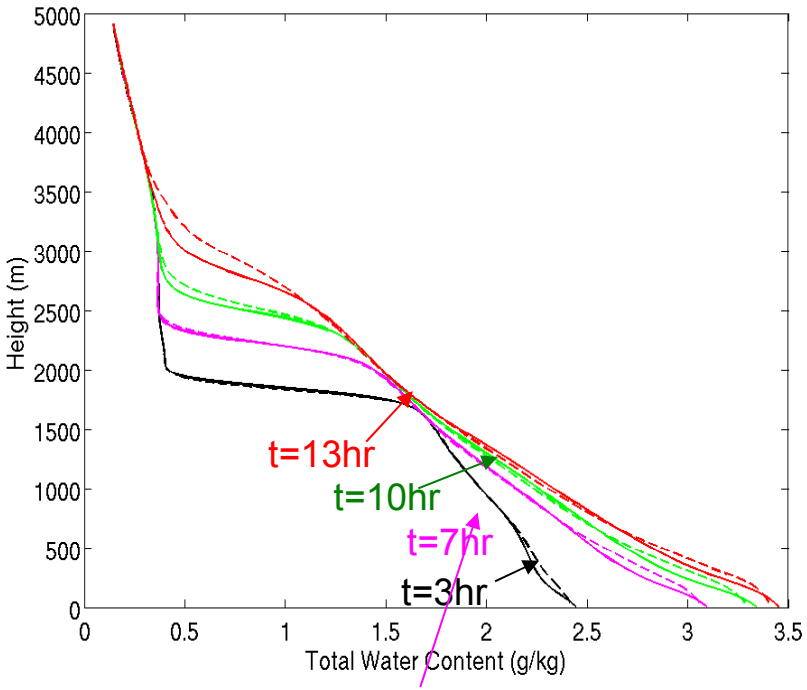
Met Office

UM LAM
LEM no ice
LEM ice
SCM



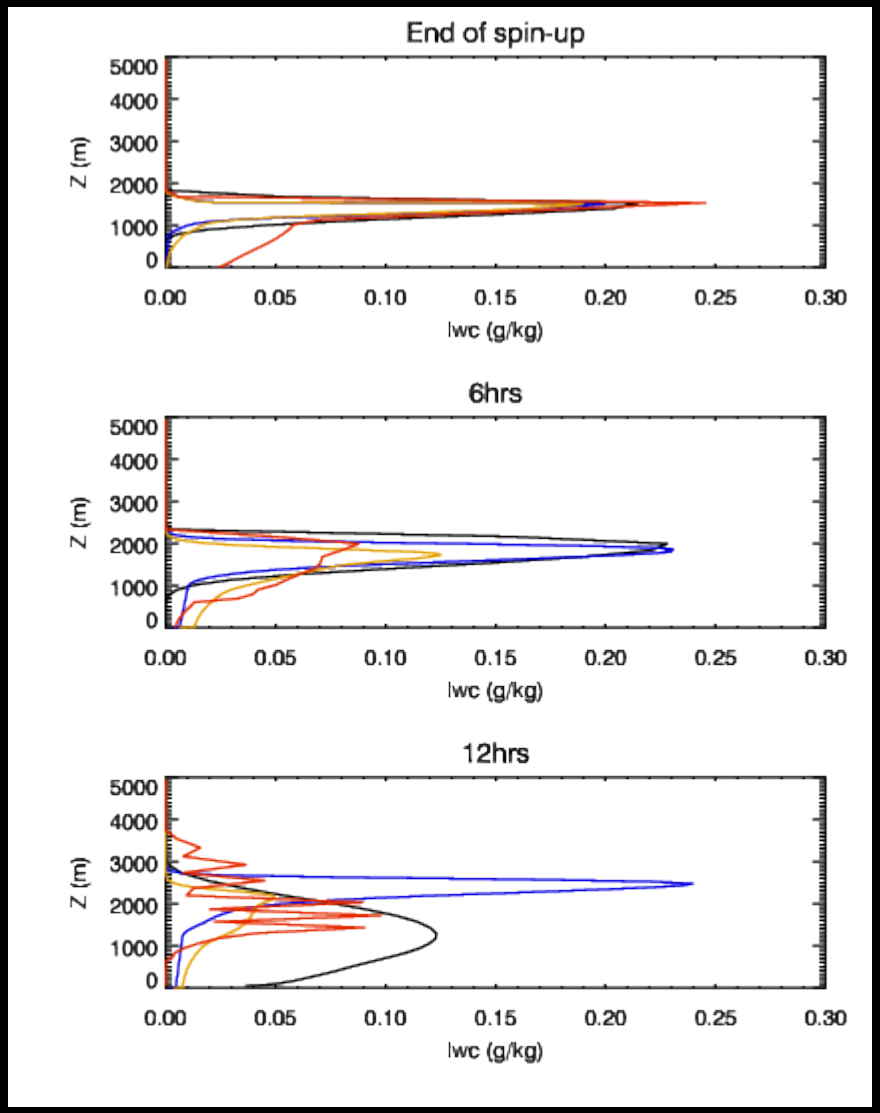
Liquid water potential temperature & total water content, Nc = 10 cm^{-3}



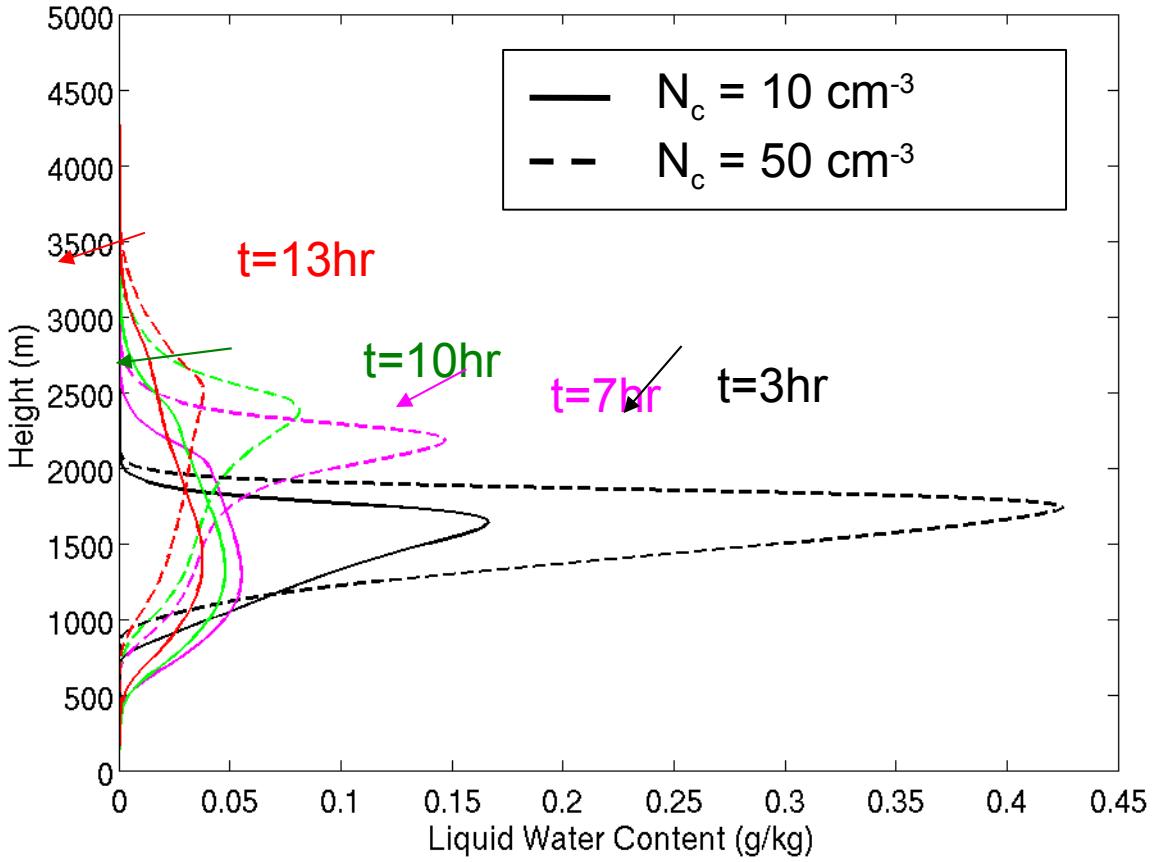


Coarser resolution hardly has an effect on the mean state evolution

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

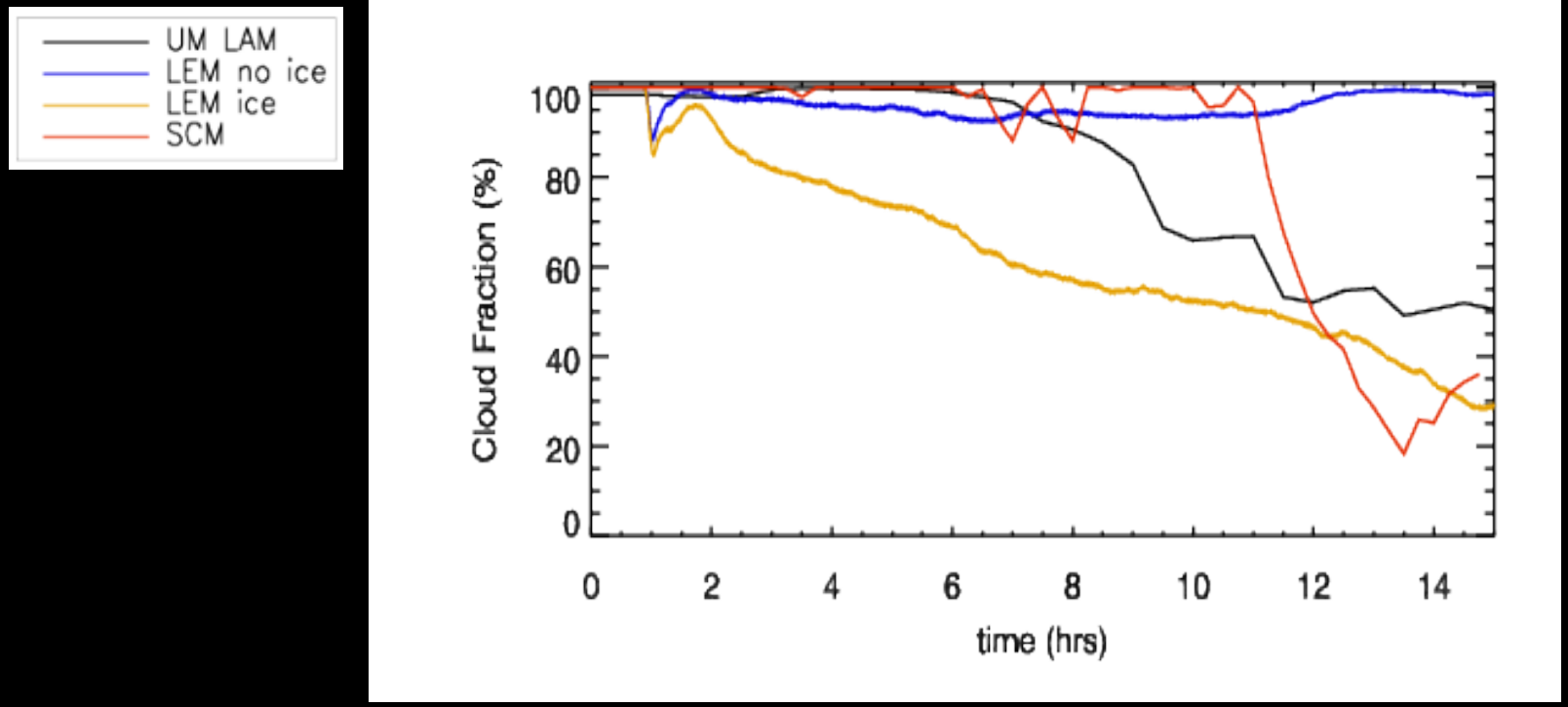


Liquid water content
L = 102.4 km

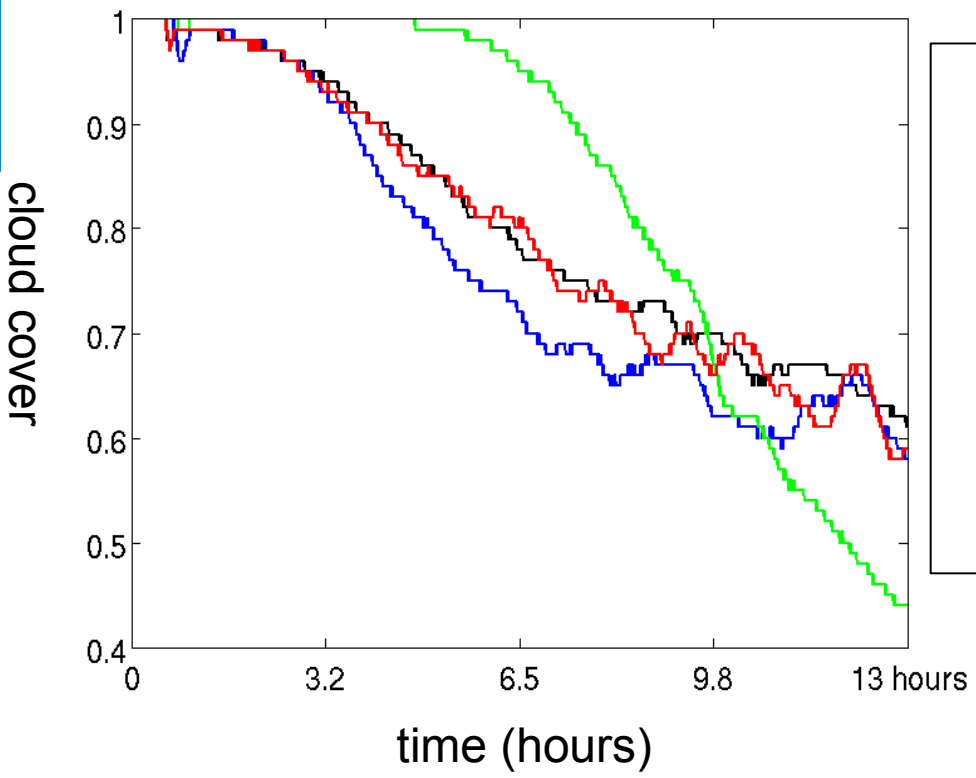


Cloud droplet concentration has a large influence on the liquid water content

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



Time series: cloud cover



	L (km)	Δx (m)	N_c (cm^{-3})
	102.4	200	10
	102.4	400	10
	102.4	400	50
	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

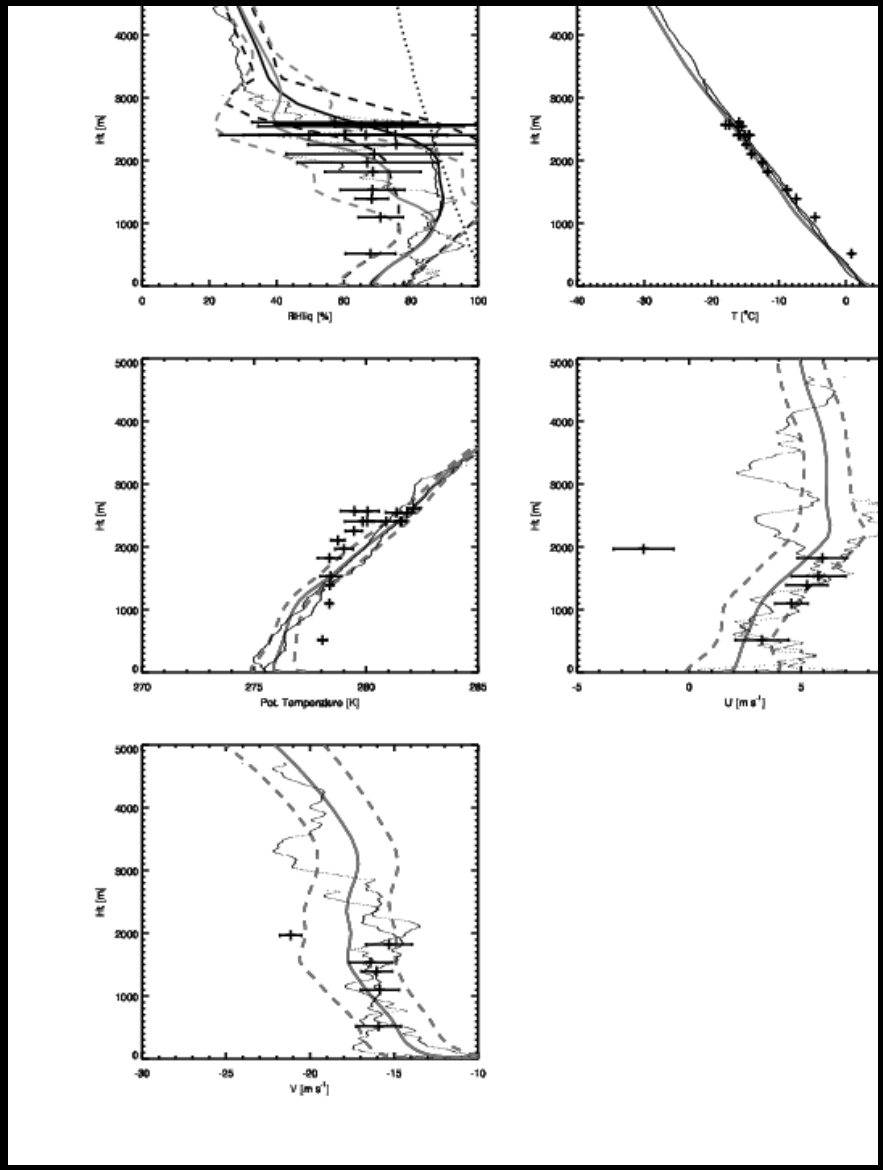
1. Is 1 km resolution sufficient to capture the cold air outbreak?

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?

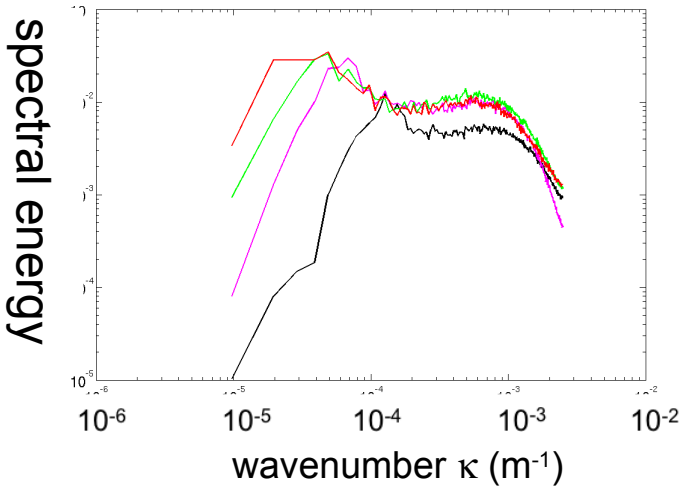
Full details of the recommended case and the set-up for the grey zone tests, as well as required output can be found at

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

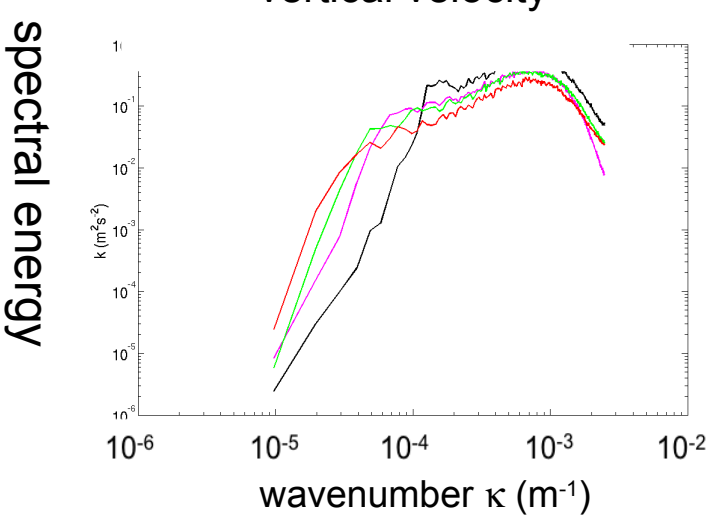

Ht [m]
RHliq [%]
T [°C]
Pot. Temperature [K]
U [m s-1]
V [m s-1]

Energy spectra (reference simulation, z = 487.5 m)

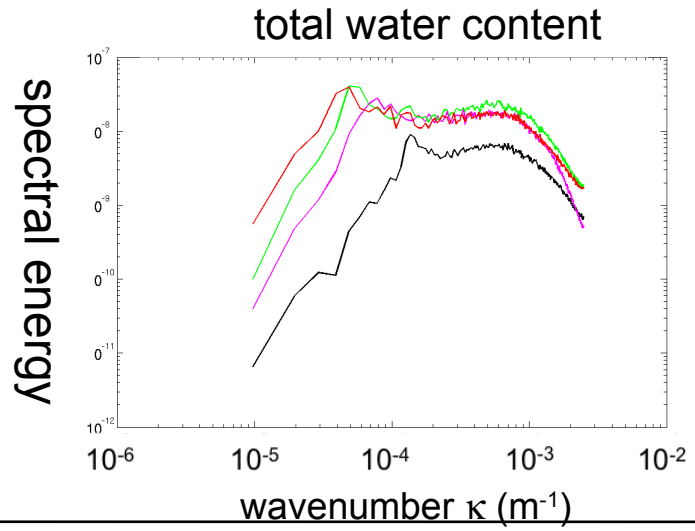
liquid water potential temperature



vertical velocity



total water content



gradual shift of spectral energy towards larger scales

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