Evaluation of large eddy simulation results of the Grey Zone cold air outbreak model intercomparison case

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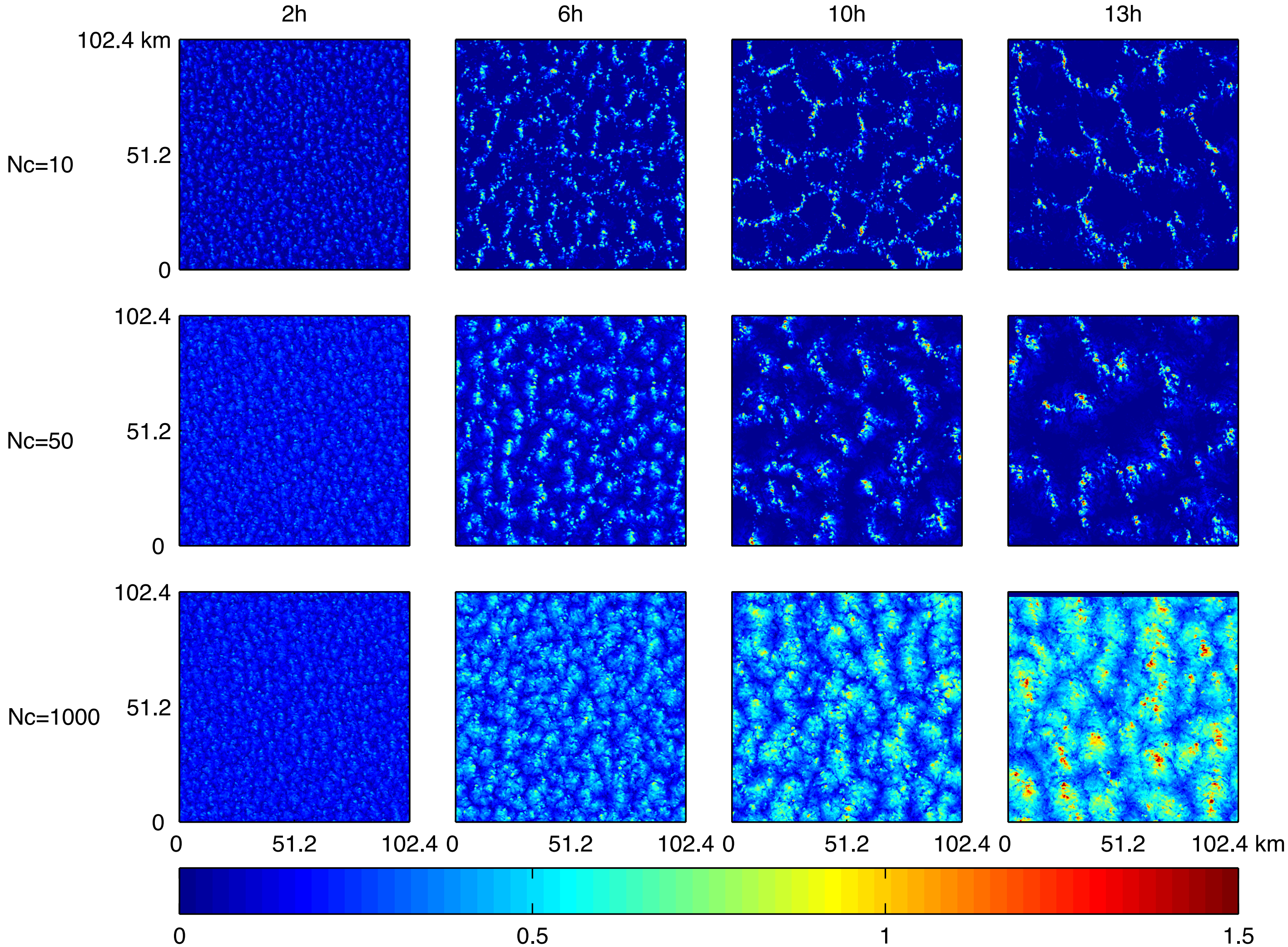
Motivation: length scales and microphysics

low droplet concentration



high droplet concentration

DALES results by Thomas Frederikse

What to expect in this presentation?

* CONSTRAIN case description of the LES experiments

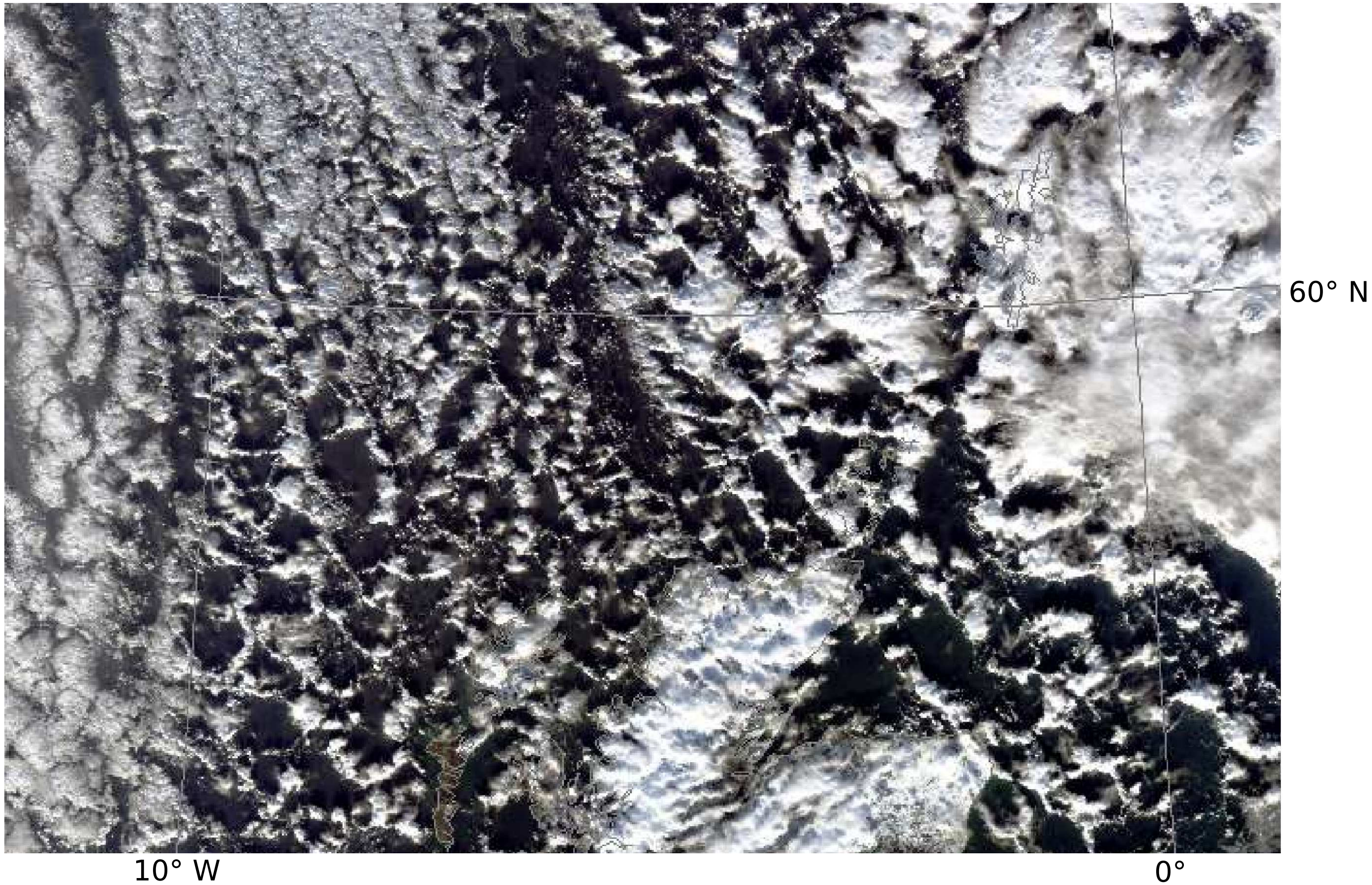
* What do we wish to learn?

* Mean state and fluxes during the cold air outbreak

* Scale dependency of fluxes and variances

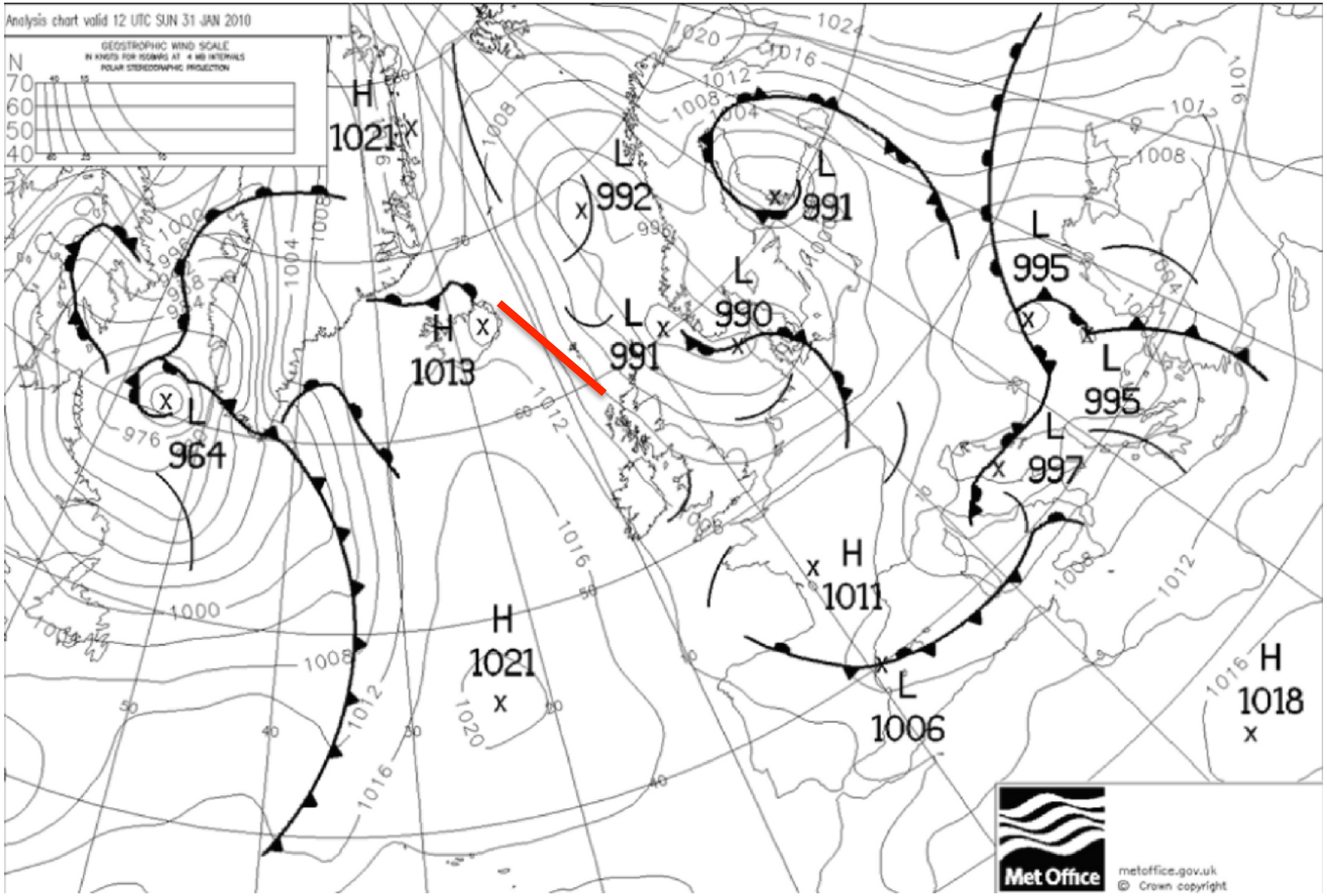
* Conclusions

Constrain Case

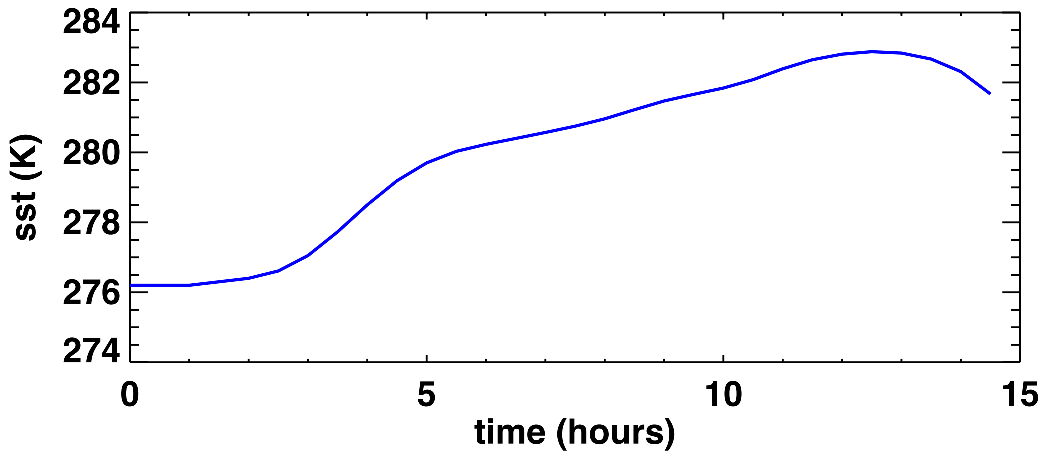


January 31, 2010 12:53 UTC (Source: Met Office)

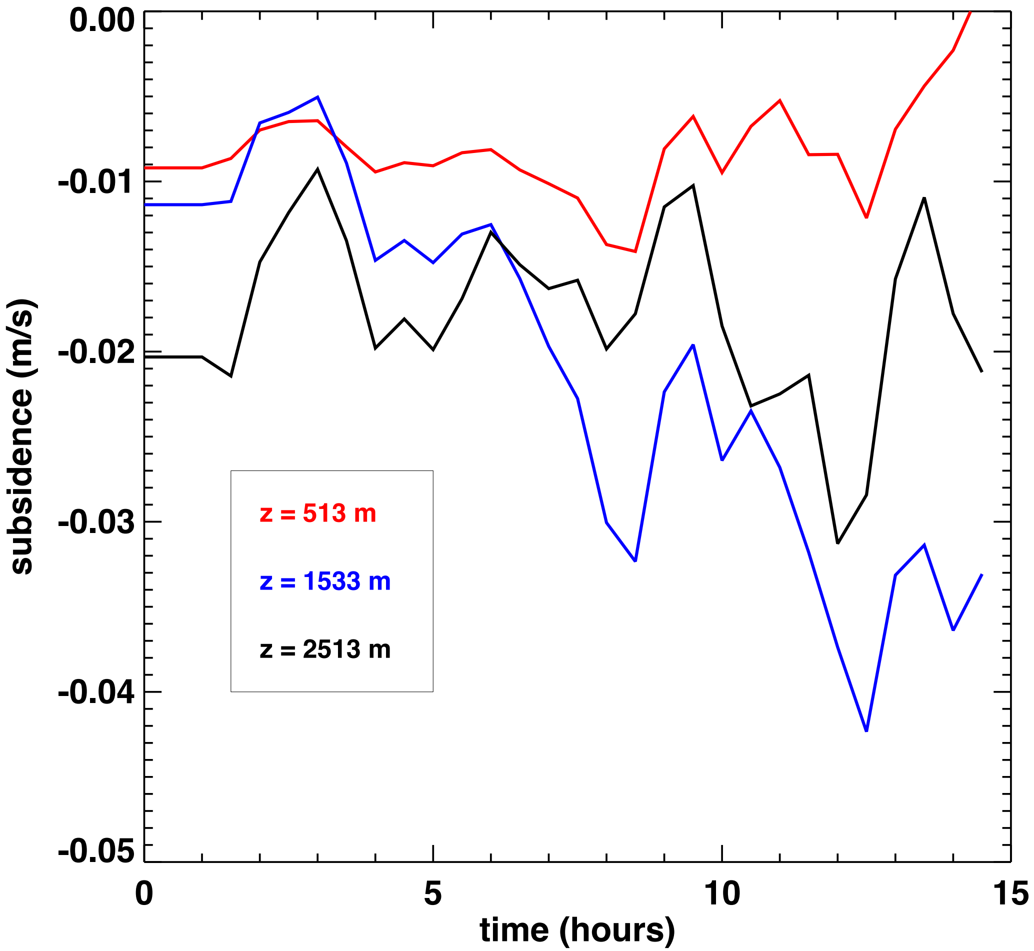
Constrain Case: Lagrangian LES experiment



SST



Large-scale subsidence



Questions

1. What is the effect of cloud droplet concentration and ice microphysics on the evolution of the Cold Air Outbreak?

2. What are the dominant length scales of the turbulent transport?

3. Diagnose dependency of NWP subgrid fluxes on grid size Δx

4. Run LES in a NWP model (coarse horizontal resolution)

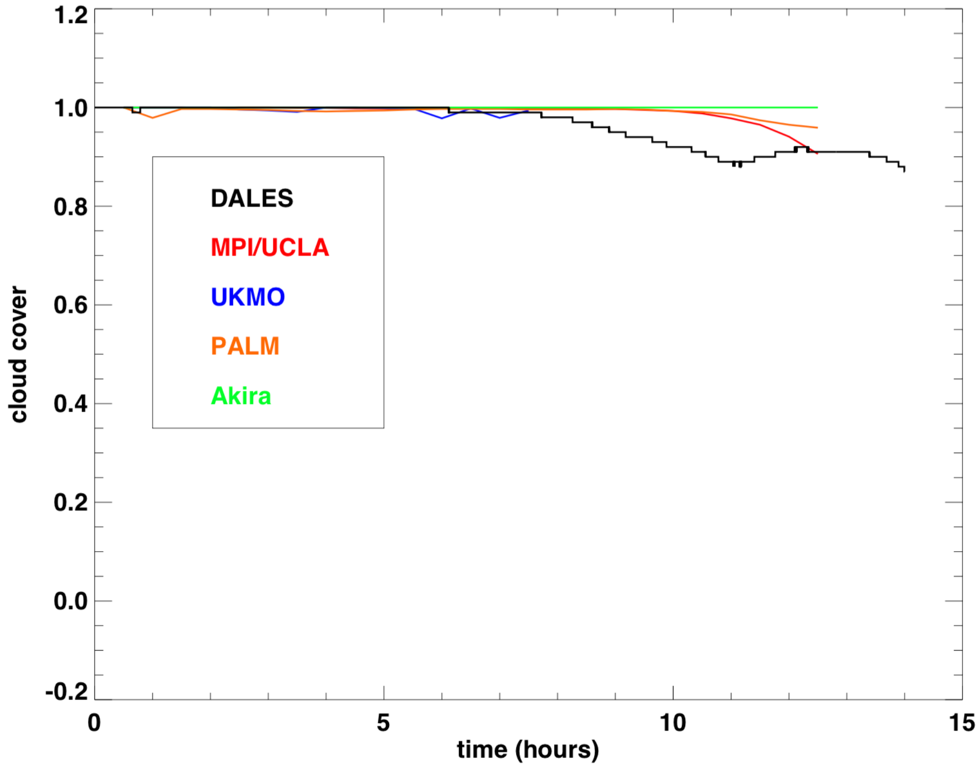
Summary of LES experiments

	Lx (km)	Nc (cm-3)	Ice/ Liquid	Dx (m)	DALES	MPI	UKMO	PALM	Akira	Meteo-France EULERIAN
Reference	96	50	Liquid	250	X	x	X		X	4 "EULERIAN"
Low droplet con	96	30	Liquid	250	Nc=10	Nc=10		X		
Ice micro	96	50	Ice	250		X	X		X	
High-res	96	50	Liquid	125	X		Lx=48 km Lx=48 km, Ice	X		
"NWP" mode	96	50	Liquid	500, 1000, 2000 4000	X		X	X		

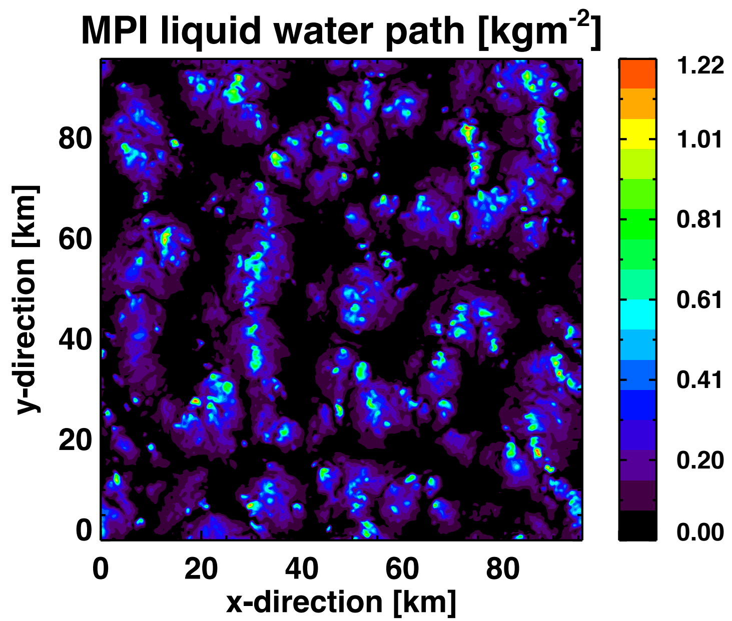
Requested output

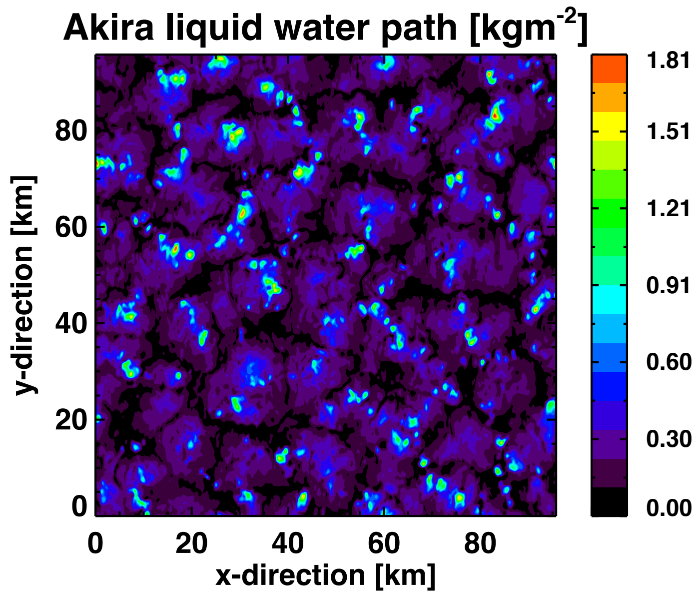
1. Time series of scalars
2. Vertical profiles
3. 3D fields

Cloud cover

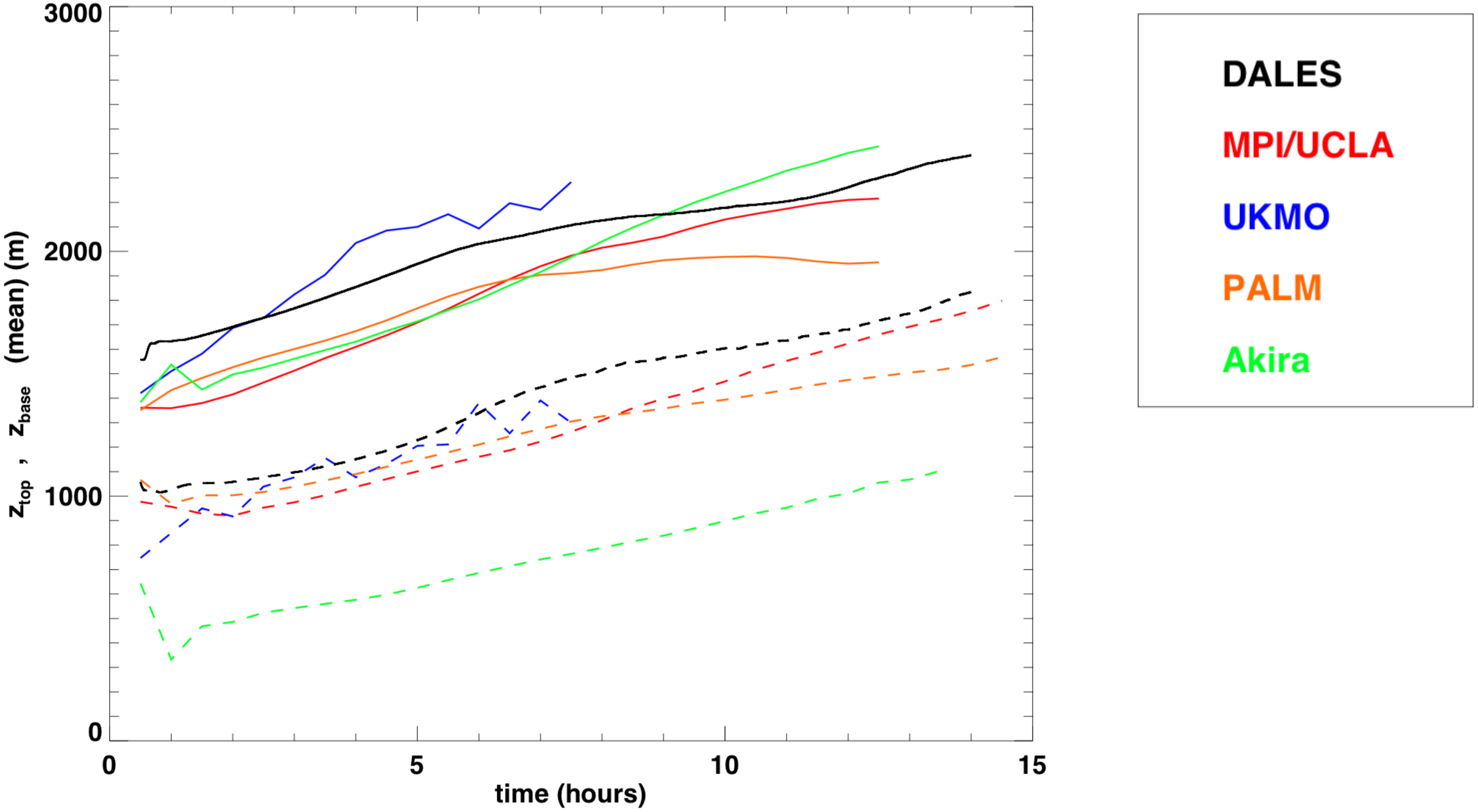

1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
cloud cover
0
5
10
15
time (hours)
DALES
MPI/UCLA
UKMO
PALM
Akira

Examples: LWP after 13 hours





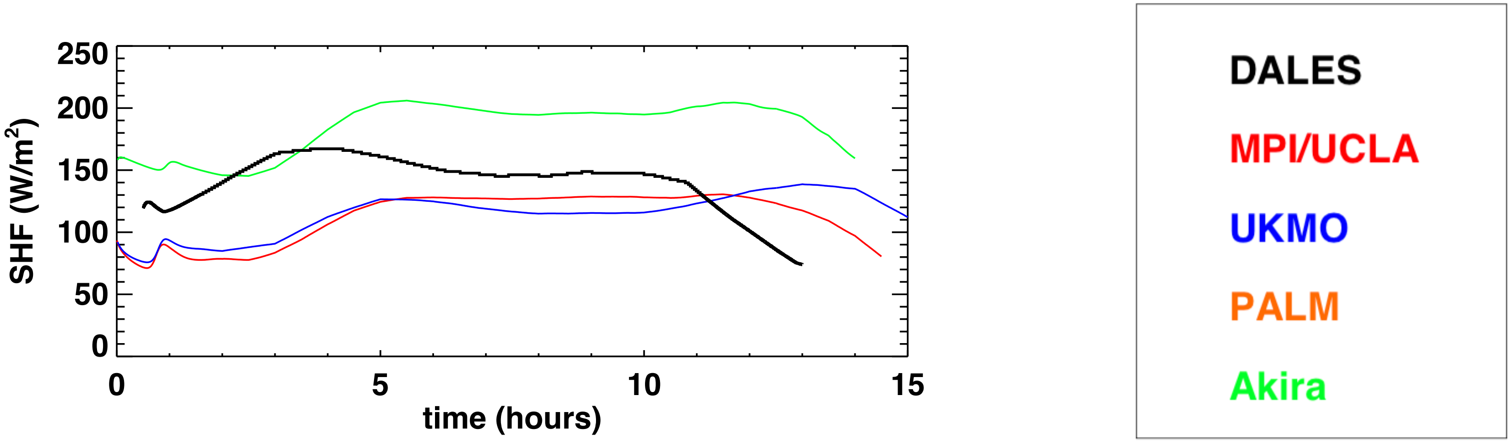
Cloud boundaries



Cloud top increases with time -> strong entrainment

Akira's LES gives much thicker cloud layer

Surface heat fluxes



* DALES results have used original forcings -> runs with updated forcings are still running

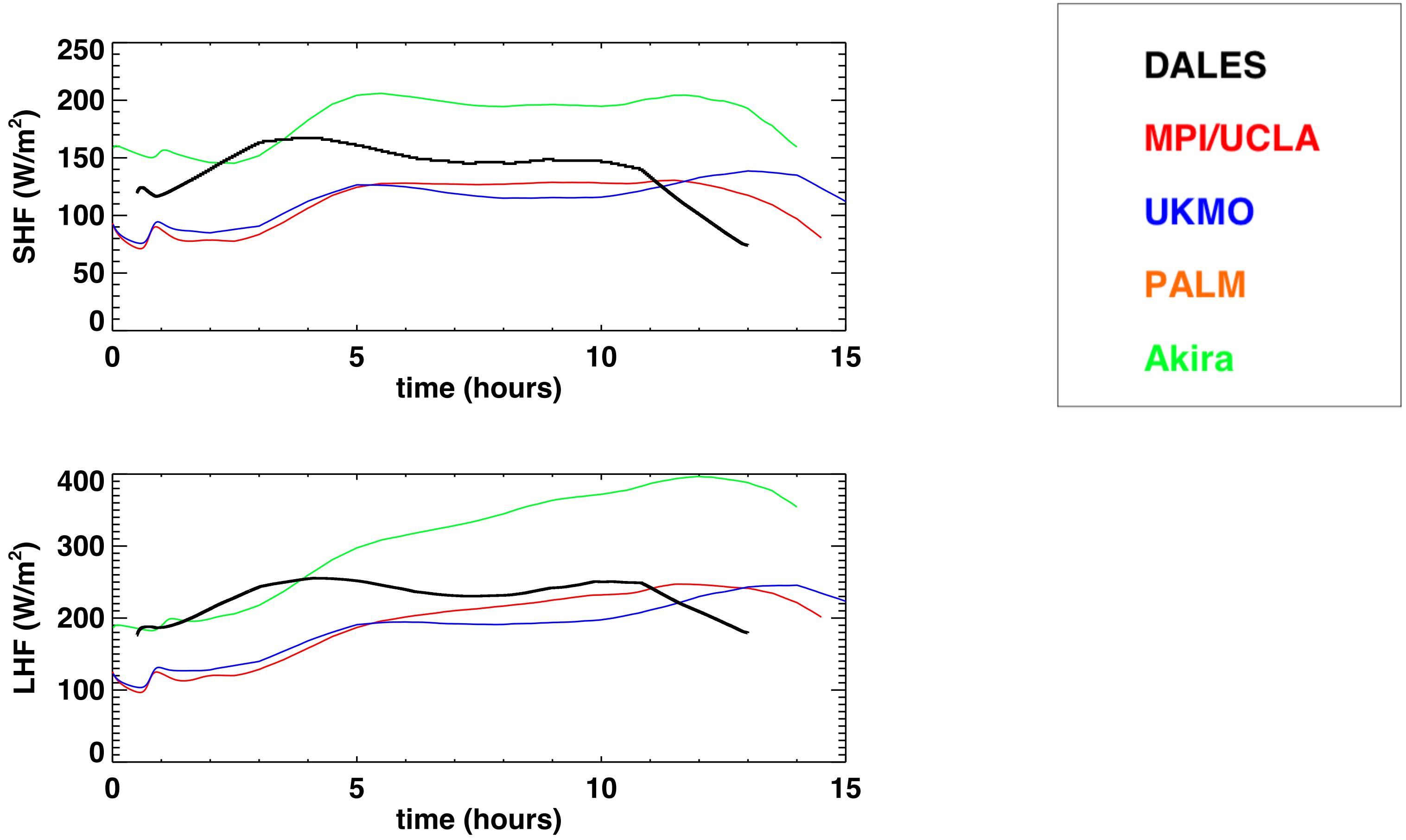
* PALM has no smooth interpolated SST

* UKMO has short run

* Usually requested output is not always present or in units different that requested

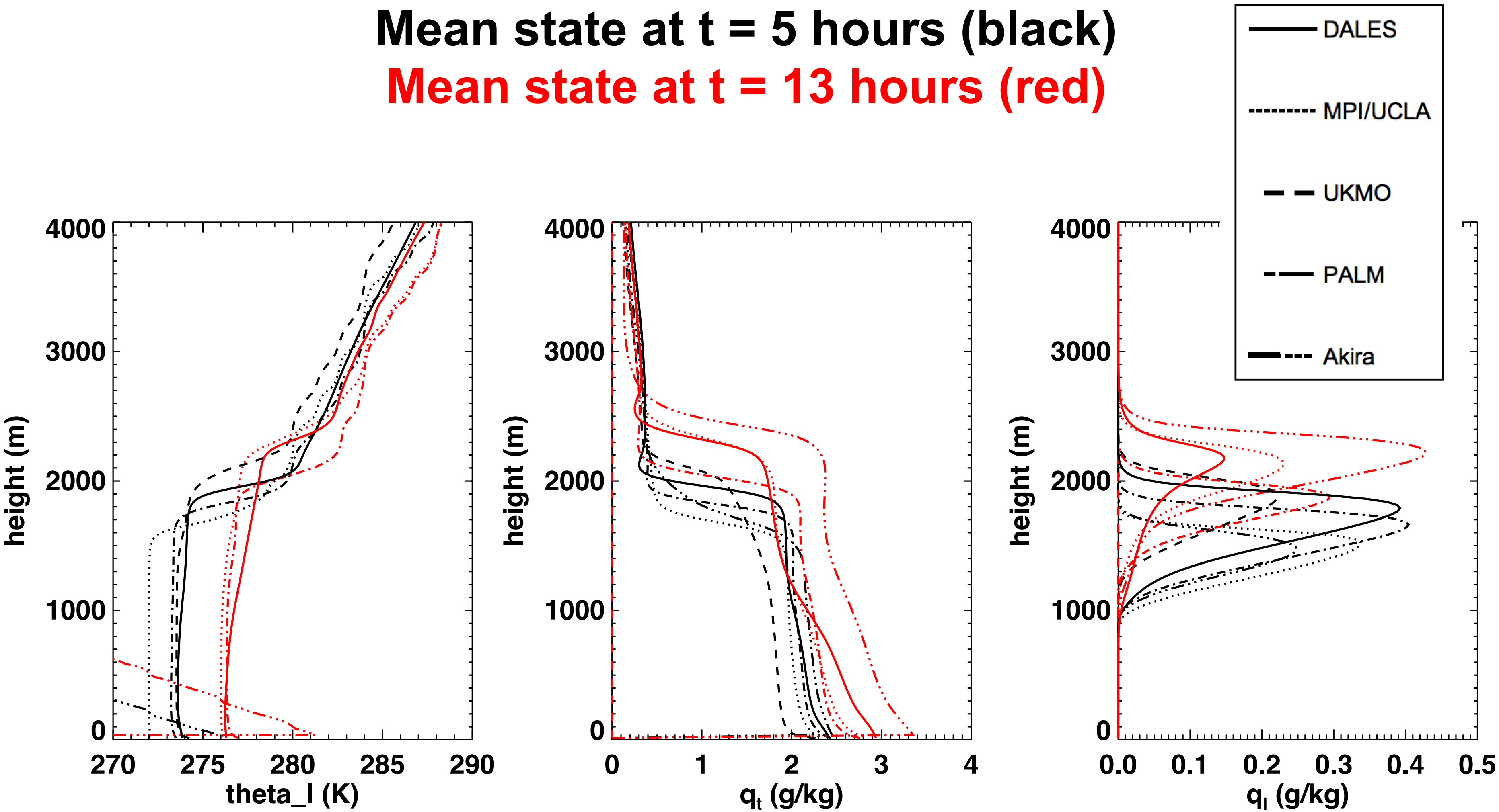
=> scale dependency of fluxes shows some robust features

Surface heat fluxes



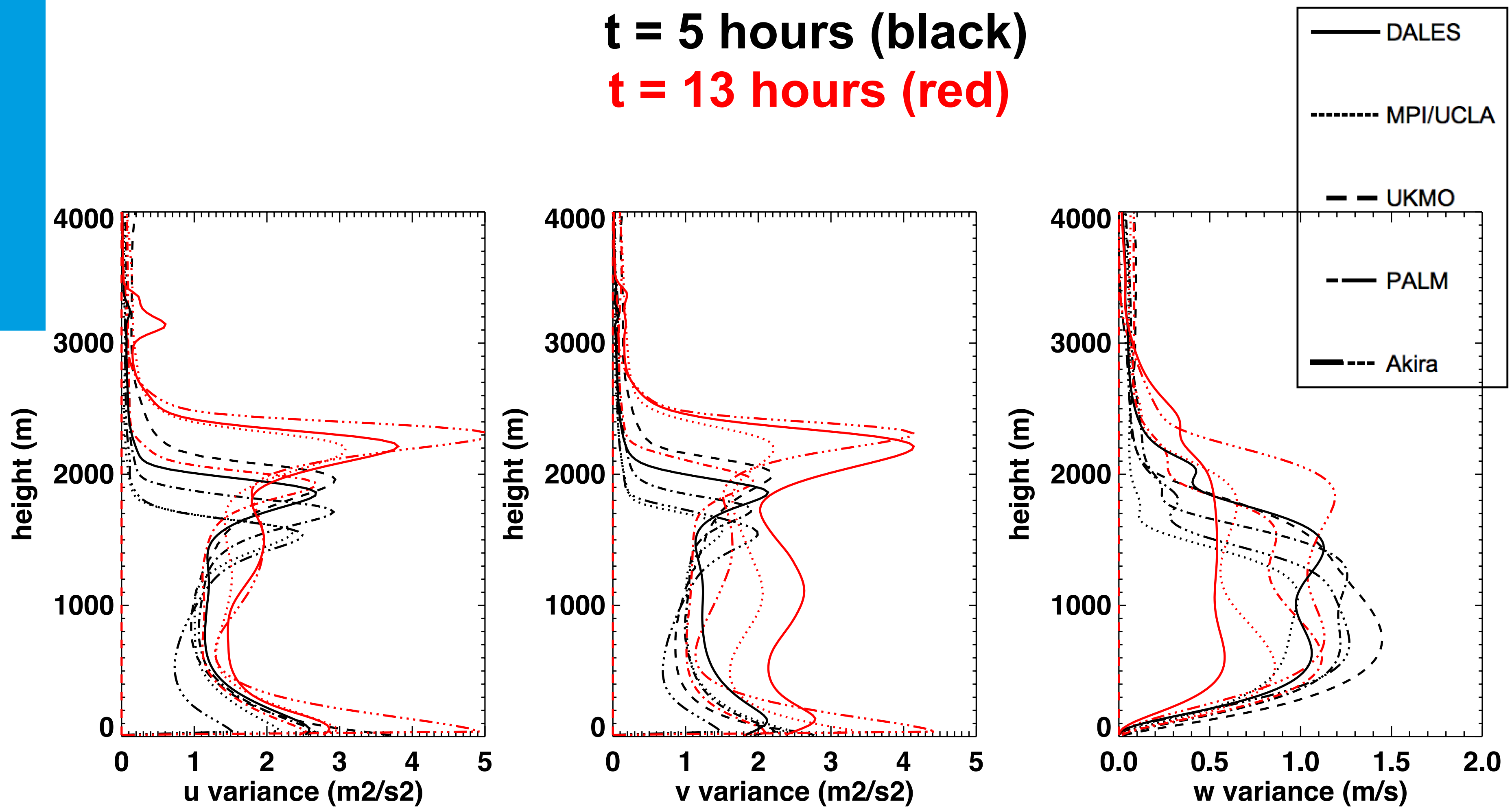
* Akira's thick cloud layer may be related to very large latent heat fluxes

Mean state at t = 5 hours (black)
Mean state at t = 13 hours (red)



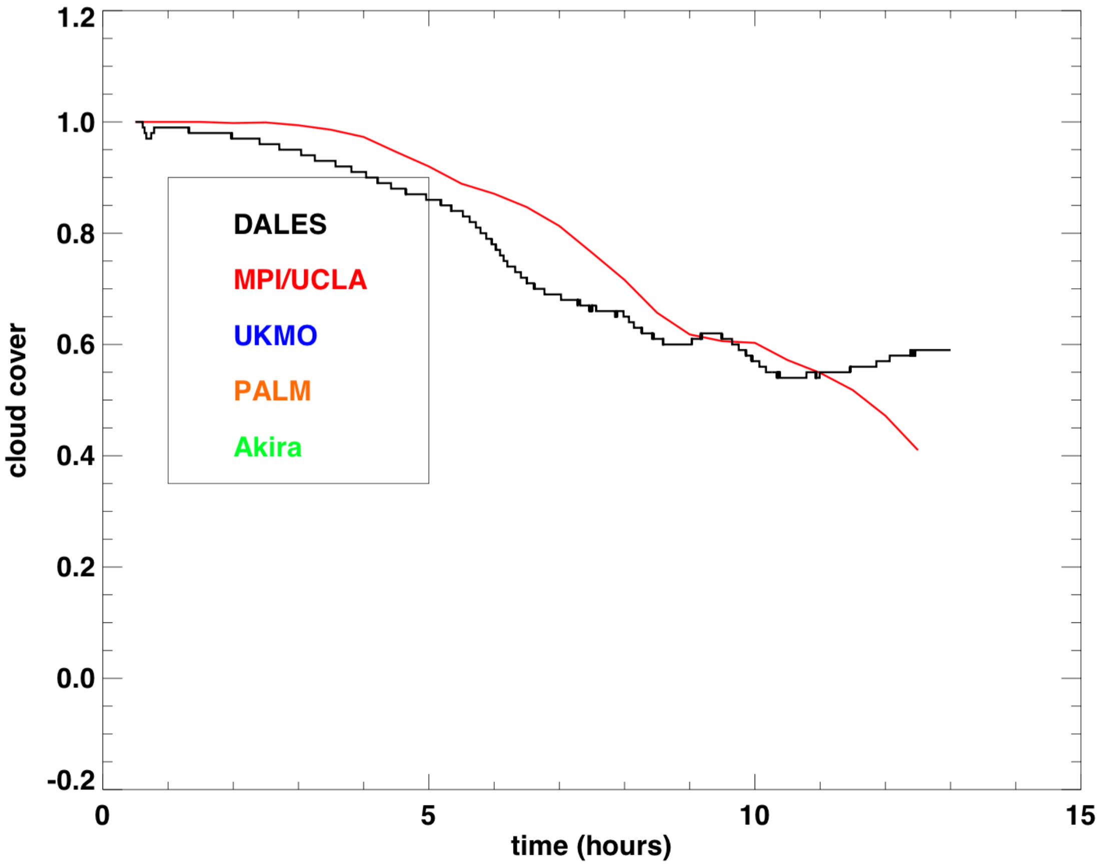
* at the end of simulation total water content not vertically well mixed
* DALES early cloud break-up: warmer and drier cloud layer

t = 5 hours (black)
t = 13 hours (red)



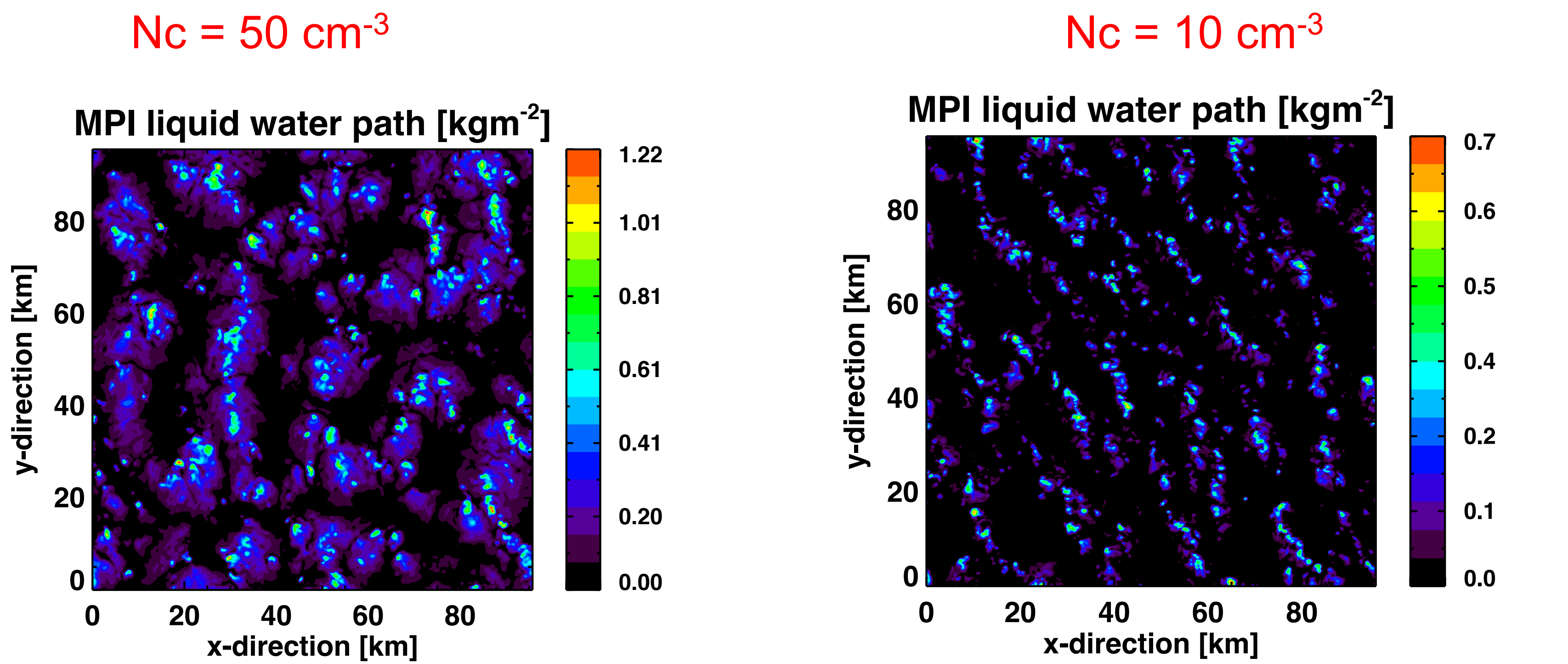
* u and v variance increase with time
* w variance develops signature of two layer turbulence structure

Reduce cloud droplet concentration to 10 cm^{-3}



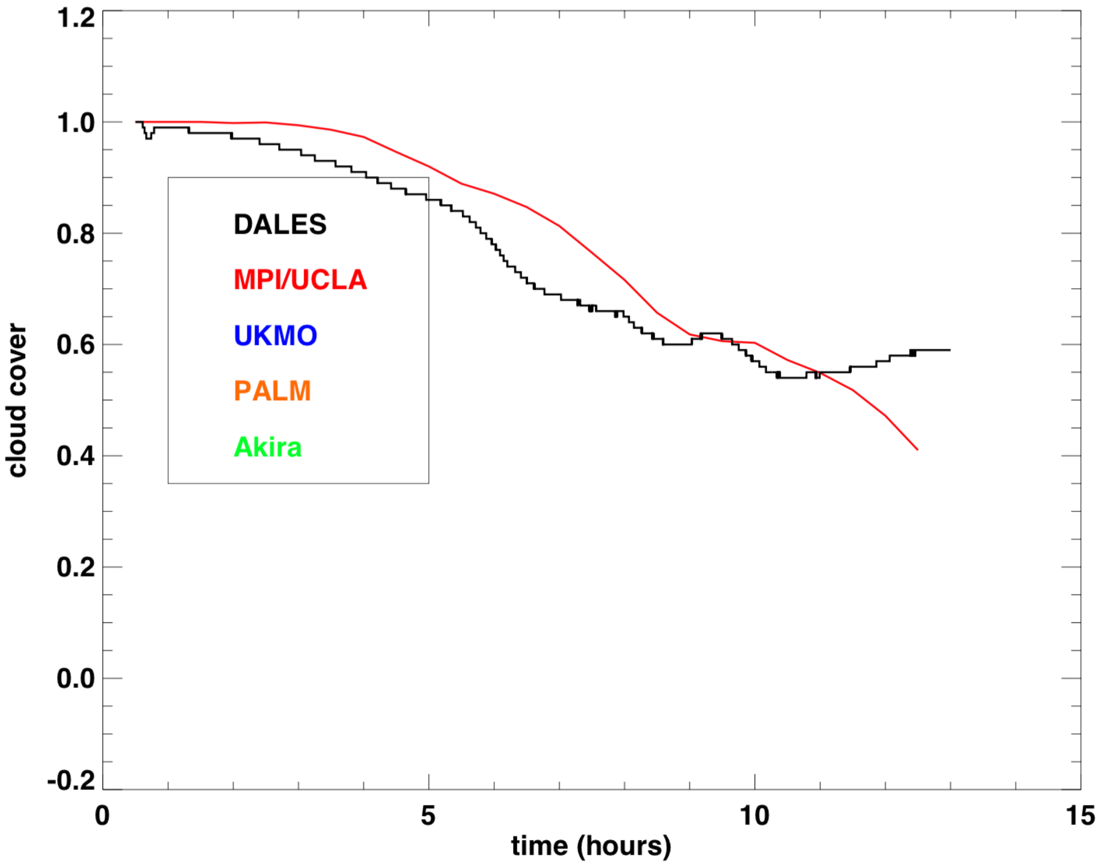
* much more rapid break-up

Reduce cloud droplet concentration to 10 cm^{-3}



* with lower droplet concentration less LWP and finer cloud structures

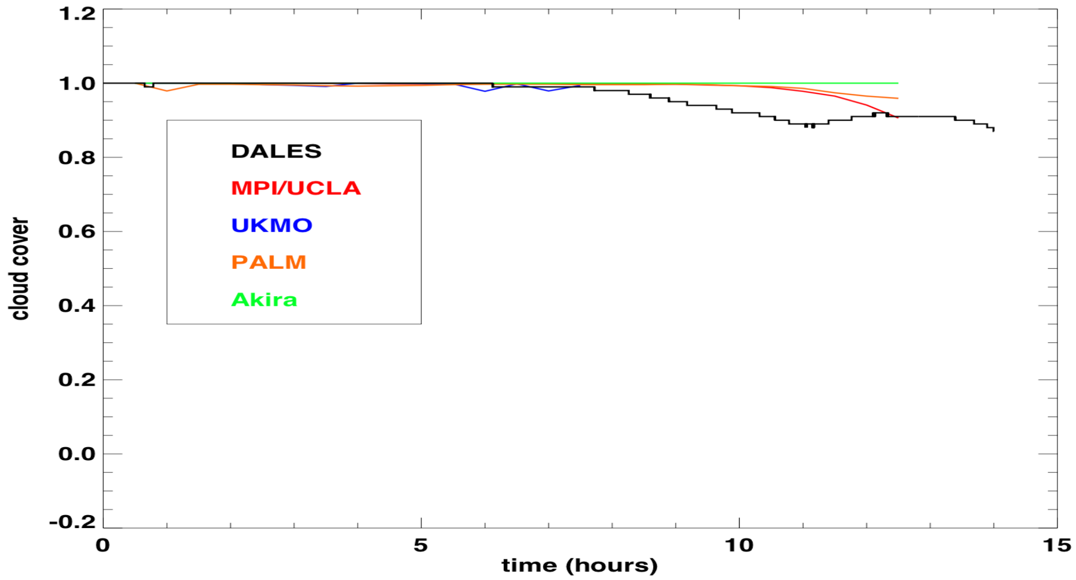
Reduce cloud droplet concentration to 10 cm^{-3}



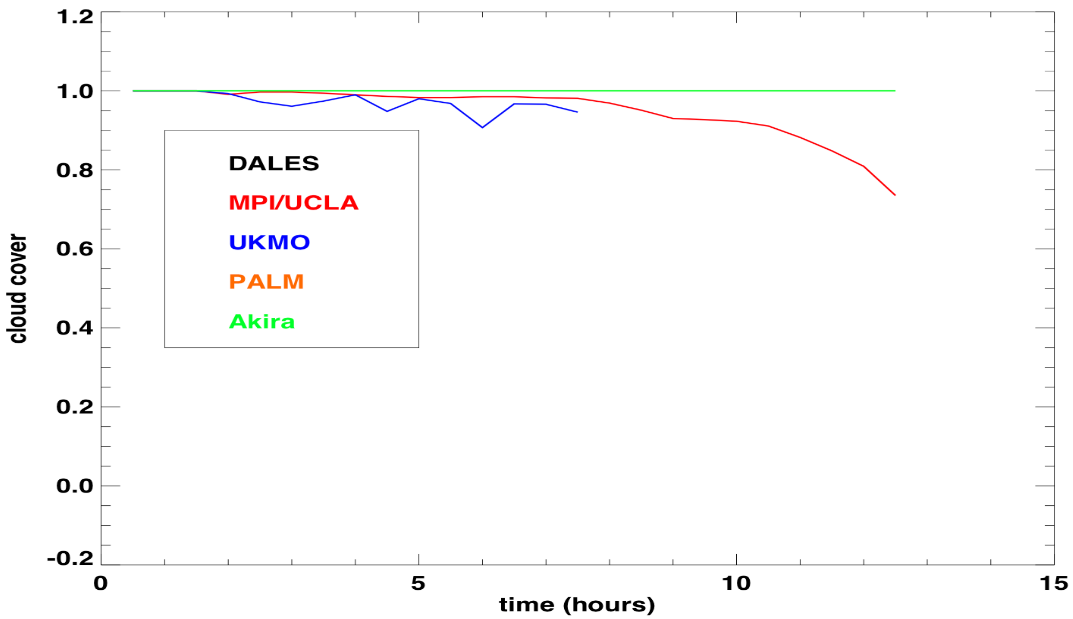
* much more rapid break-up

Effect of including ice microphysics

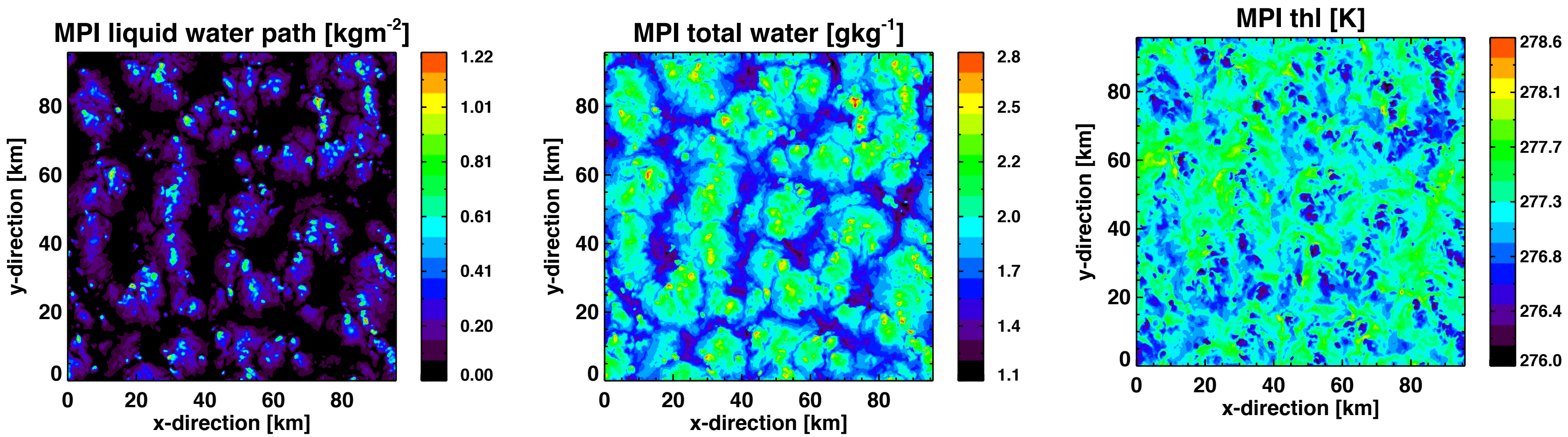
reference
liquid only



ice microphysics



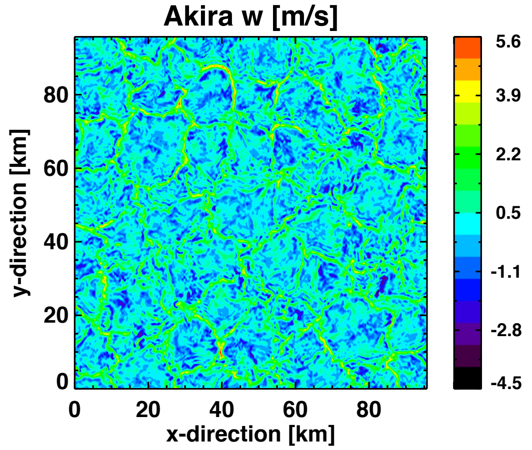
Some examples of large-scale structures for reference case qt and thl at mid-cloud, t=13 hrs

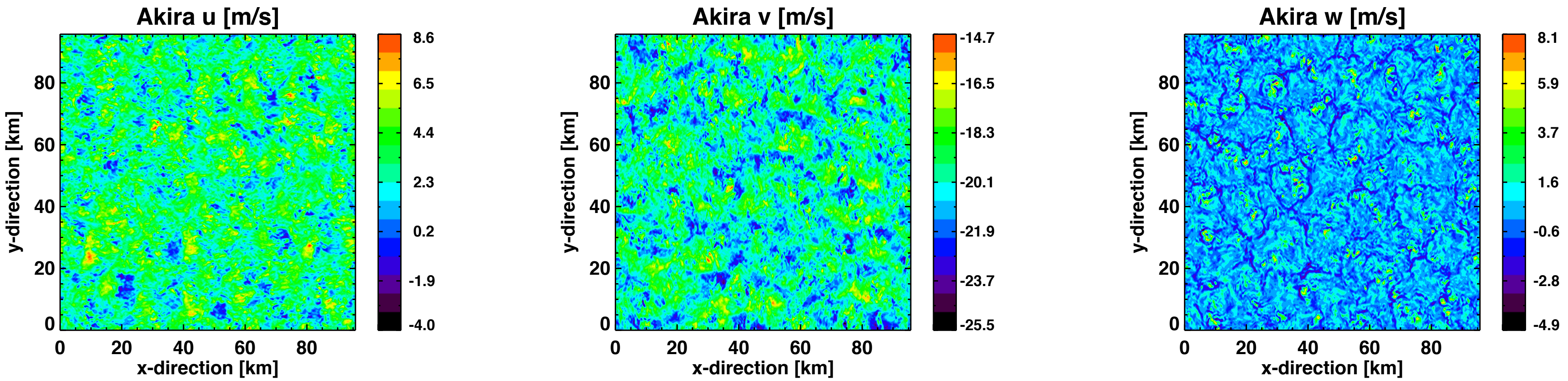


* qt and LWP very strongly correlated

Some examples of large-scale structures for reference case u and v at mid-cloud, t=13 hrs

mid subcloud =>

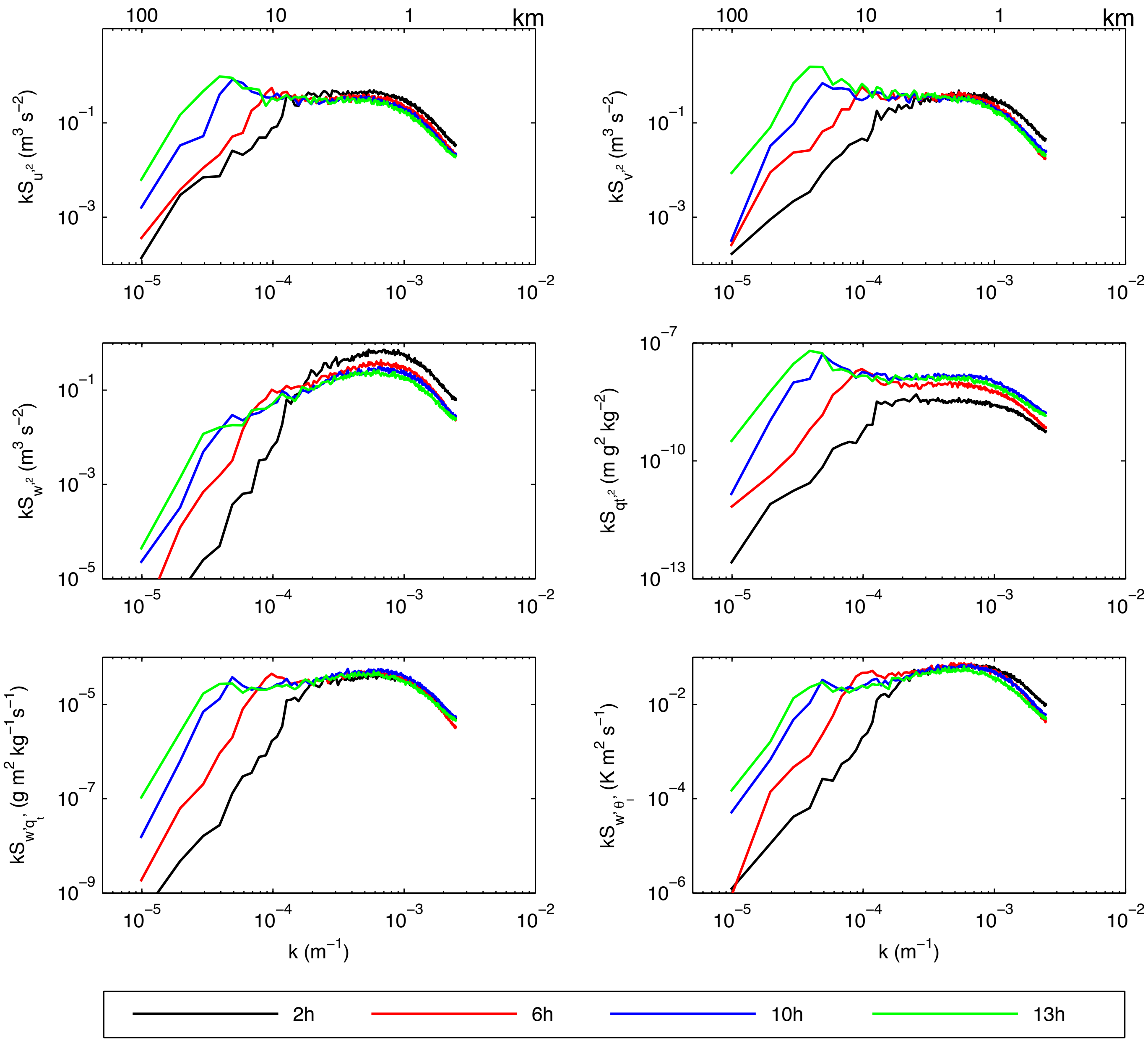




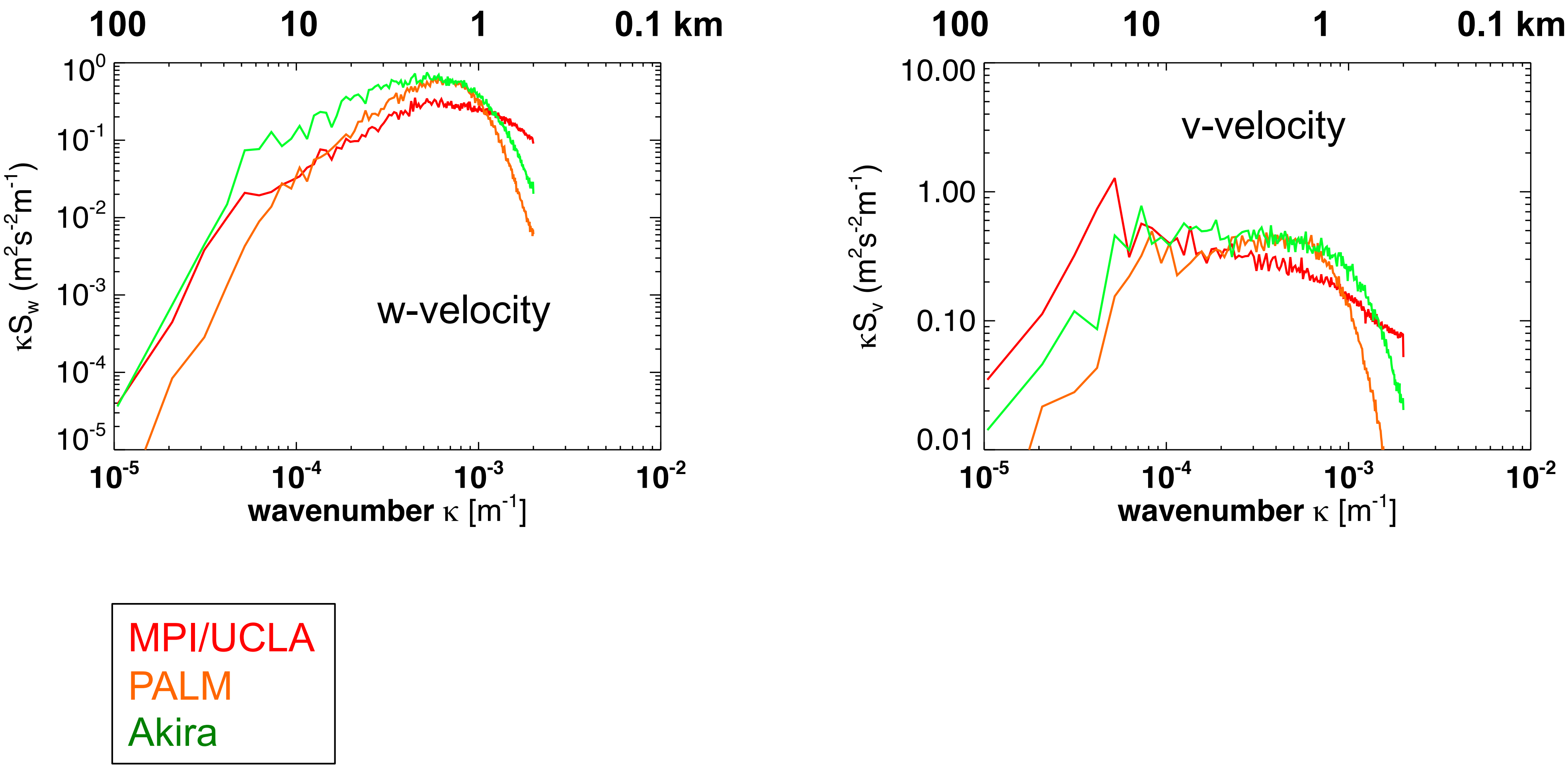
* notice u,v range (min-max 10 m/s)

* "rings" of downdrafts and updrafts

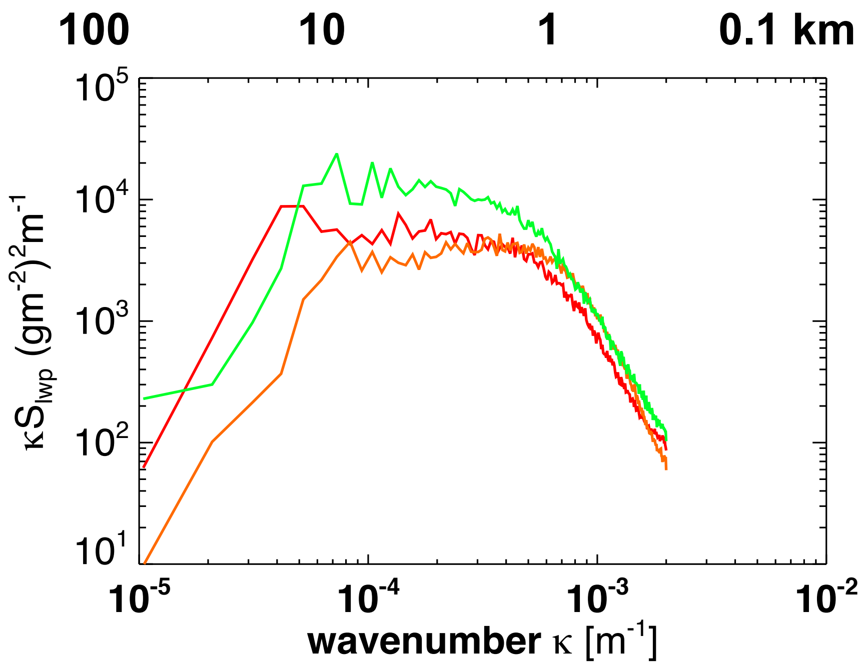
Spectral evolution in DALES

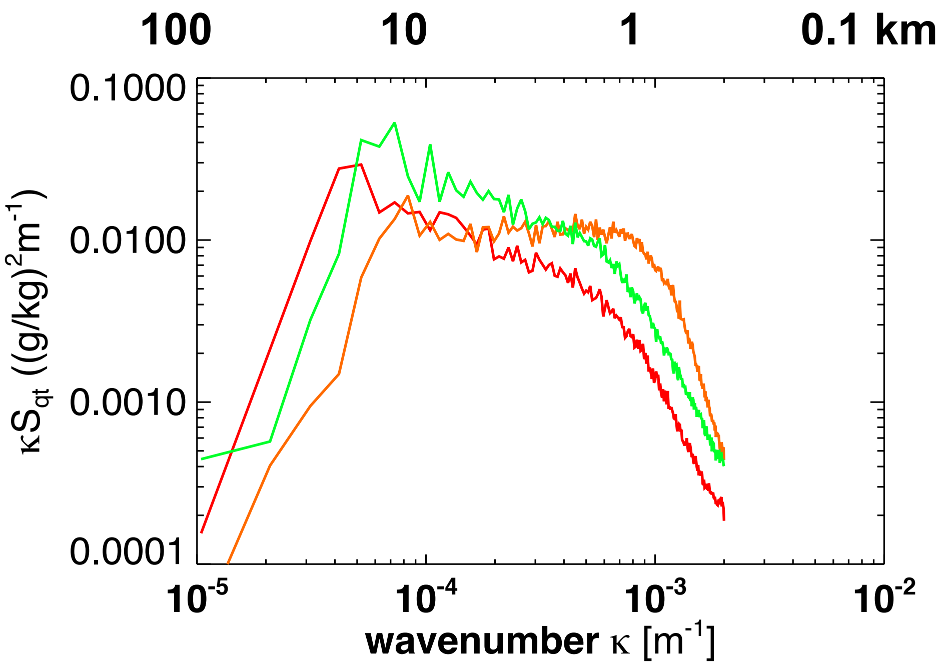


Spectral analysis, mid-cloud, t=13 hrs



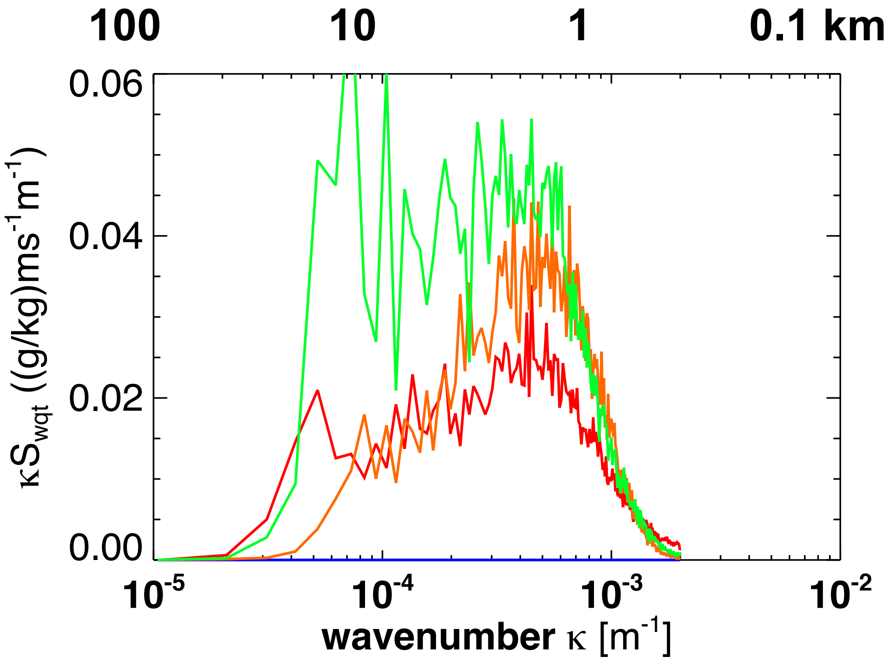
Spectral analysis, mid-cloud, t=13 hrs

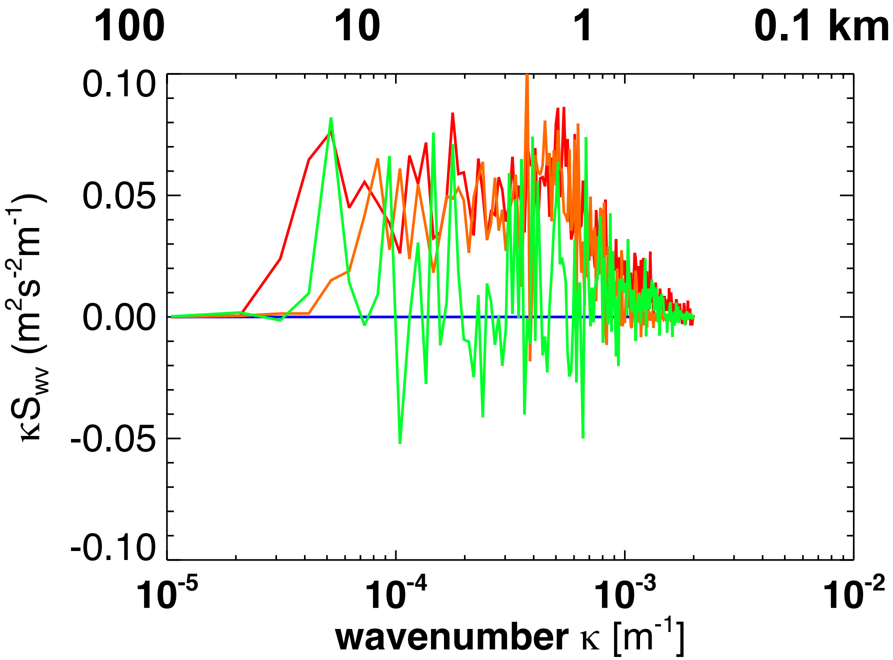




MPI/UCLA
PALM
Akira

Spectral analysis, mid-cloud, t=13 hrs





MPI/UCLA
PALM
Akira

Akira: u and w at same grid location in 3D fields?

Turbulent/convective flux in traditional NWP

$$\overline{w'\phi'}_{total} = \overline{w'\phi'}_{resolved} + \overline{w'\phi'}_{subgrid}$$

zero for sufficiently large Δx

Turbulent/convective flux in very high resolution NWP

$$\overline{w'\phi'}_{total} = \overline{w'\phi'}_{resolved} + \overline{w'\phi'}_{subgrid}$$

becomes non-zero for sufficiently fine Δx

Turbulent/convective flux in very high resolution NWP

$$\overline{w'\phi'}_{total} = \overline{w'\phi'}_{resolved} + \overline{w'\phi'}_{subgrid}$$

becomes non-zero for sufficiently fine Δx

should reduce accordingly

Turbulent/convective flux in very high resolution NWP

$$\overline{w'\phi'}_{total} = \overline{w'\phi'}_{resolved} + \overline{w'\phi'}_{subgrid}$$

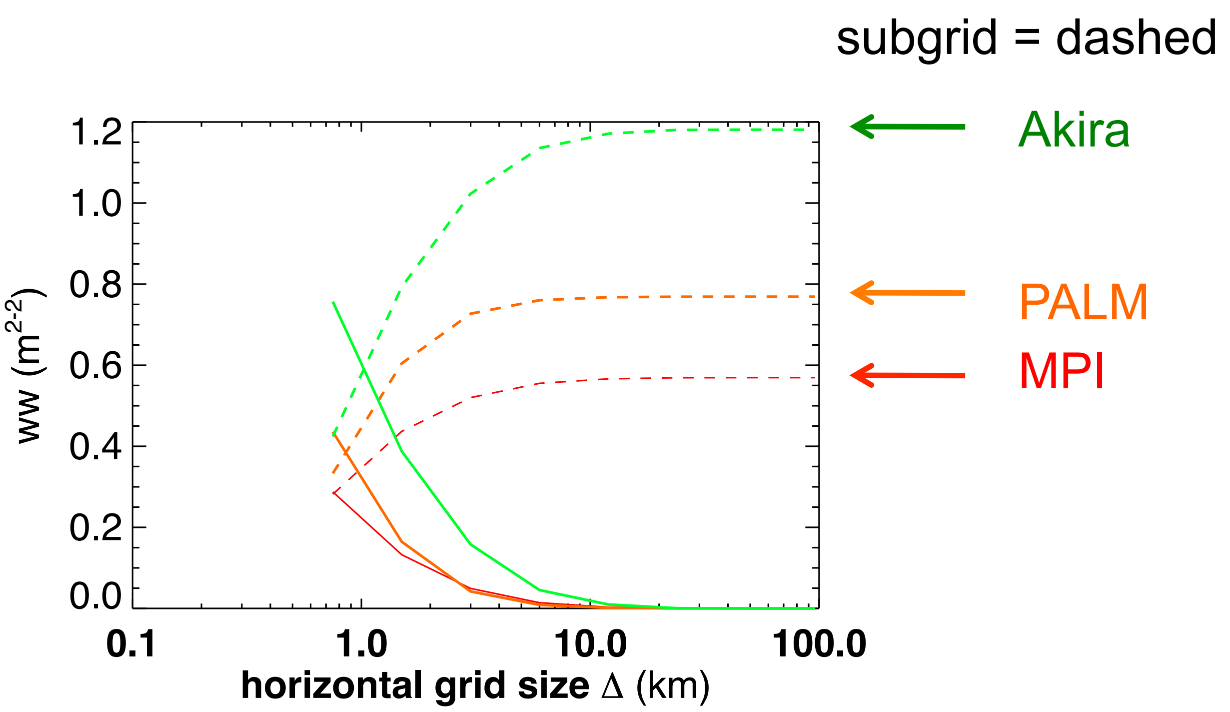
becomes non-zero for sufficiently fine Δx

should reduce accordingly

Diagnose resolved and subgrid flux from LES fields as a function of the horizontal grid size Δx that the NWP would use

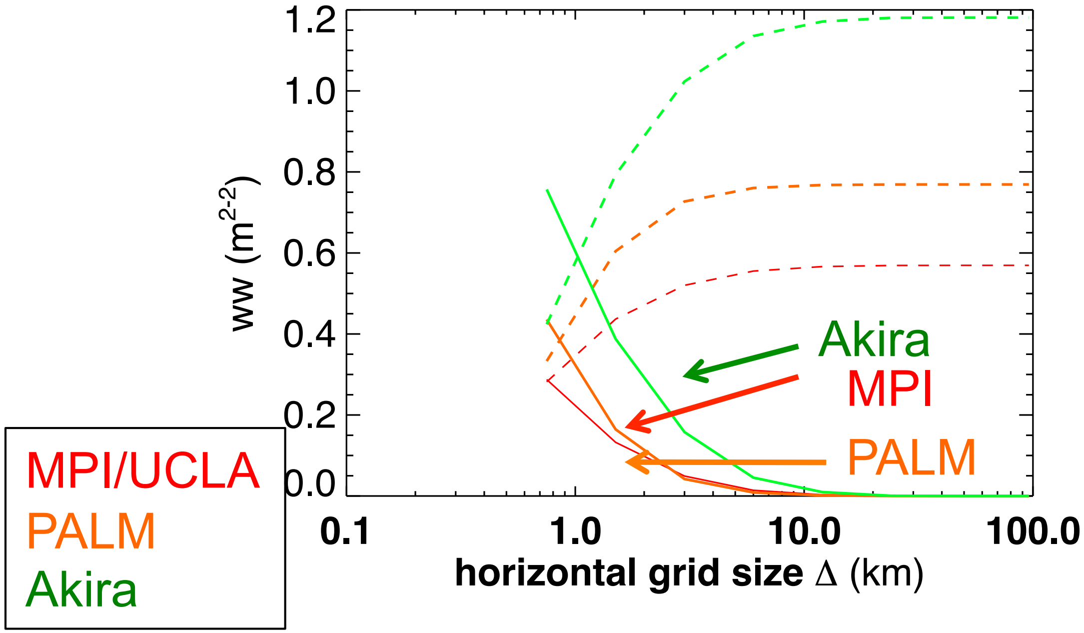
Resolved and subgrid vertical velocity variance (mid-cloud)

$$\overline{w'\,w'}_{total} = \overline{w'\,w'}_{resolved} + \overline{w'\,w'}_{subgrid}$$



Resolved and subgrid vertical velocity variance (mid-cloud)

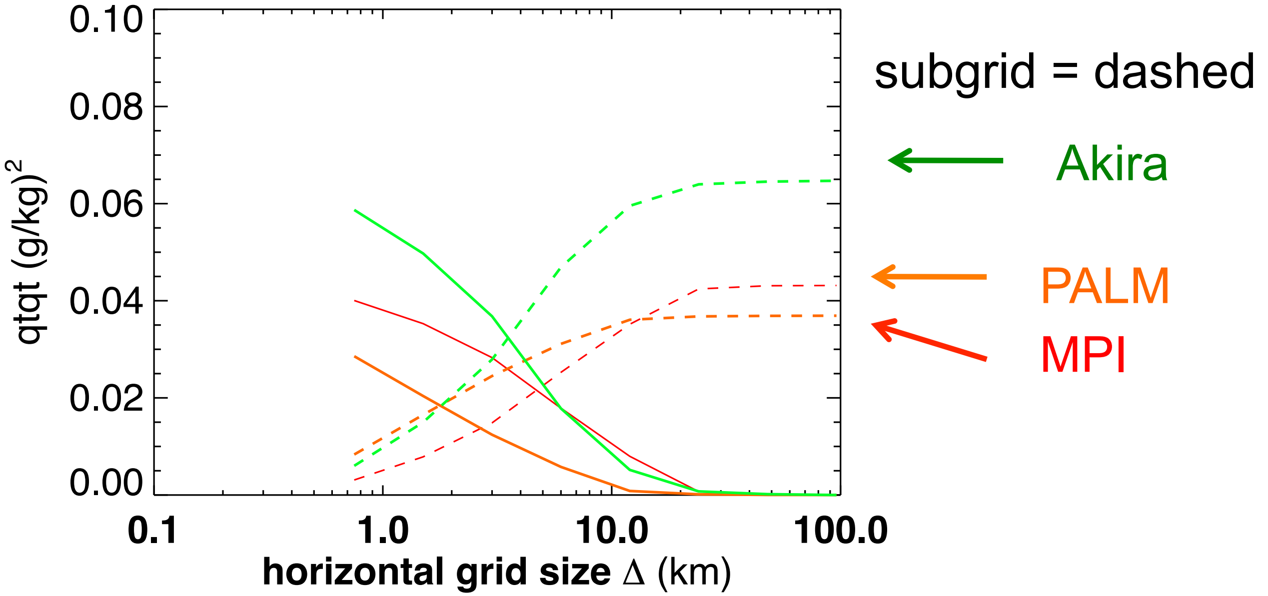
$$\overline{w' w'}_{total} = \overline{w' w'}_{resolved} + \overline{w' w'}_{subgrid}$$



resolved =solid

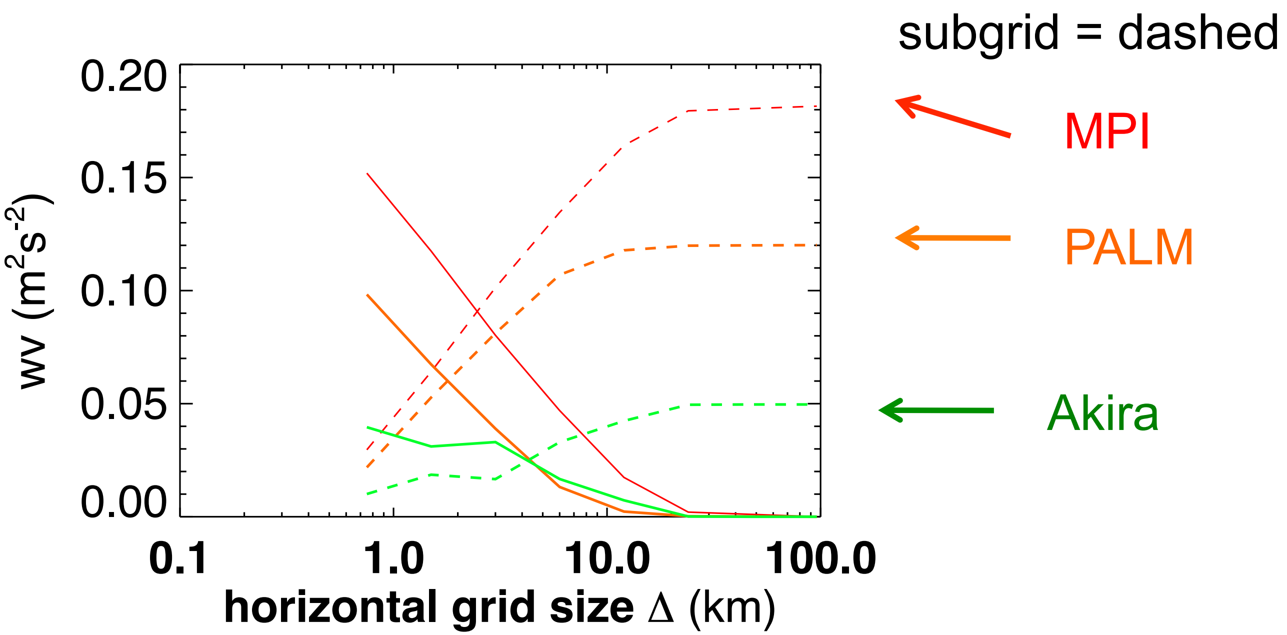
Resolved and subgrid qtot variance (mid-cloud)

$$\overline{q_t'q_t'}_{total} = \overline{q_t'q_t'}_{resolved} + \overline{q_t'q_t'}_{subgrid}$$

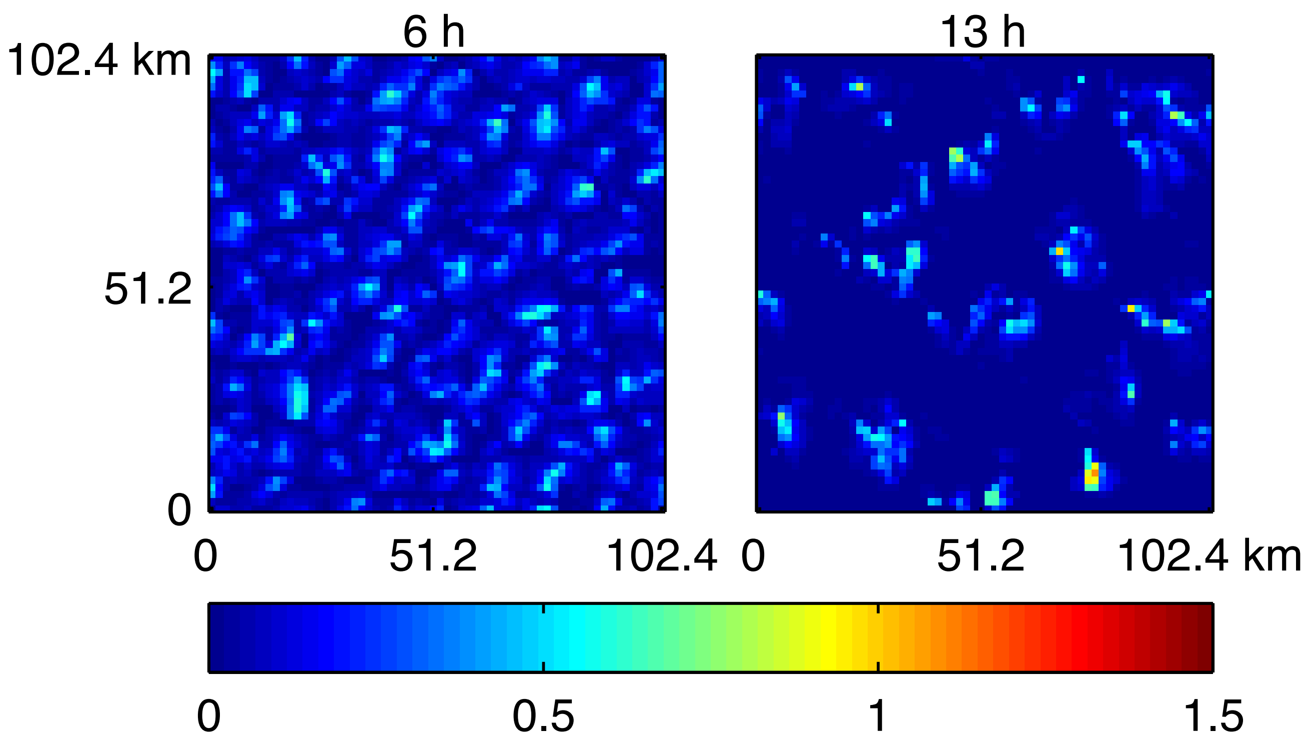


Resolved and subgrid vw flux (mid-cloud)

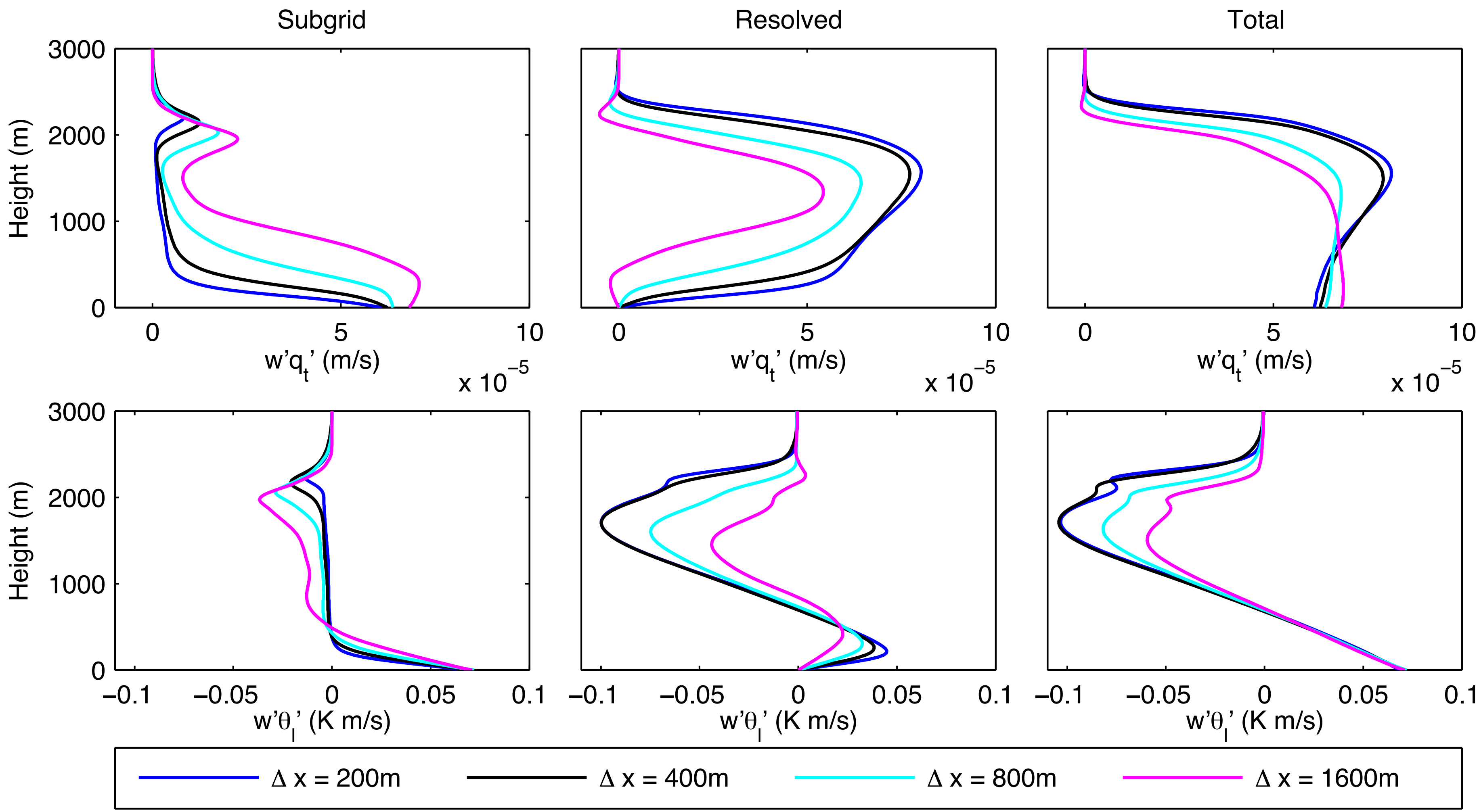
$$\overline{w'v'}_{\mathrm{total}} = \overline{w'v'}_{\mathrm{resolved}} + \overline{w'v'}_{\mathrm{subgrid}}$$



Run LES on a coarse horizontal resolution
DALES Δx = 1600m



Run LES on a coarse horizontal resolution
DALES Δx = 1600m



Conclusions

Microphysics:

Cloud break up earlier for low cloud droplet concentration

Scales:

qualitative agreement on scale growth from LES results

turbulent fluxes become resolved for $\Delta x<10$ km

To do

All: provide data if figures presented here are missing your results

DALES: new runs with forcing
MPI: include coarse resolution LES runs
PALM: correct SST
UKMO: longer runs?
Akira: LHF , location variables at grid

Questions

1. What is the effect of cloud droplet concentration and ice microphysics on the evolution of the Cold Air Outbreak?

2. What are the dominant length scales of the turbulent transport?

3. Diagnose dependency of NWP subgrid fluxes on grid size Δx

4. Run LES in a NWP model (coarse horizontal resolution)

What to expect in this presentation?

* Why LES of a cold air outbreak?

* Case description and LES experiments

* Science Questions, or what do we wish to learn?

* Mean state and fluxes during the cold air outbreak

* scale dependency of fluxes

Conclusions

Why LES of a cold air outbreak?
Case description and LES experiments
Science Questions, or what do we wish to learn?
Mean state, fluxes, scale dependency of fluxes
Conclusions

What to expect in this presentation?