

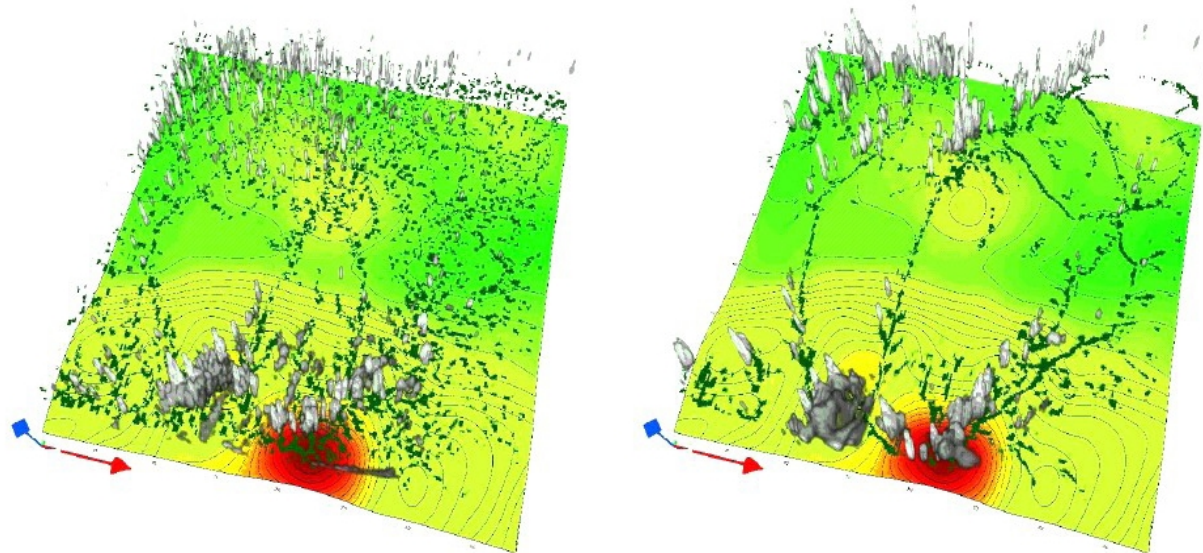
# **Impact of numerical diffusion on resolved convection at 2 km horizontal resolution**

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Krakow, 2010

# Motivation

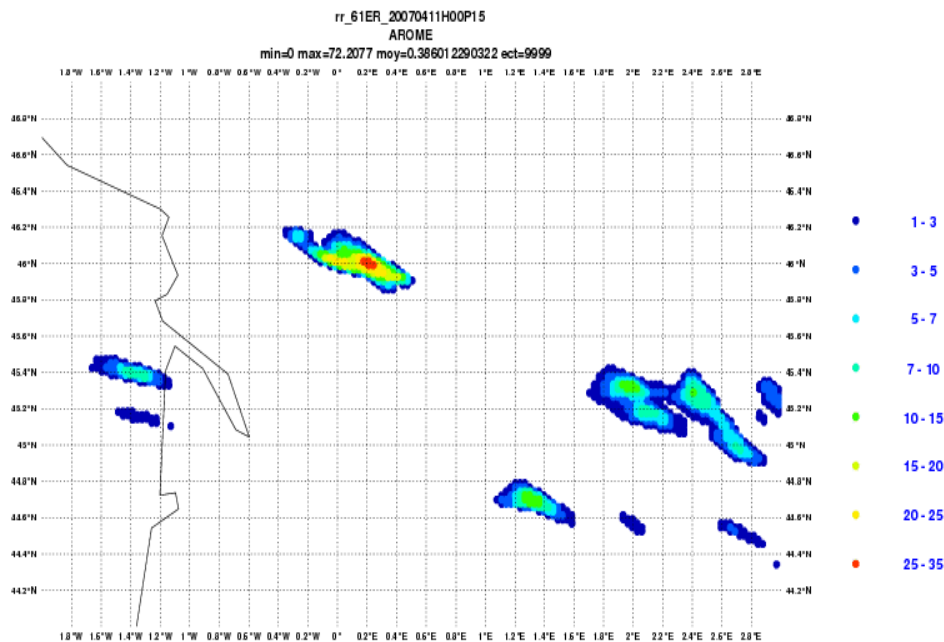
- In high resolution NWP models,  $O(10^3)$ , where deep convection is explicitly computed on the model grid, but the horizontal structures we try to represent are  $O(10^4)$  -  $O(10^5)$ , the numerical solutions depend critically on the numerics of the model, such as the numerical diffusion.



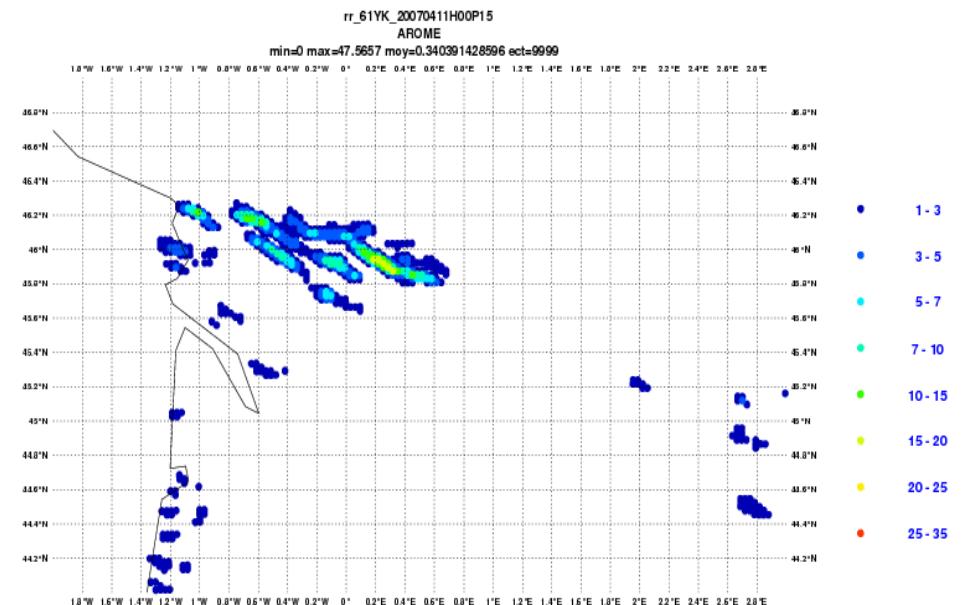
- (Nicely illustrated by Piotrowski et. al, 2009 in the context of LES)

# Motivation

- In AROME the horizontal diffusion was reduced 4 times compared to its original strength in order to reduce “fireworks” to have a finer spatial structure



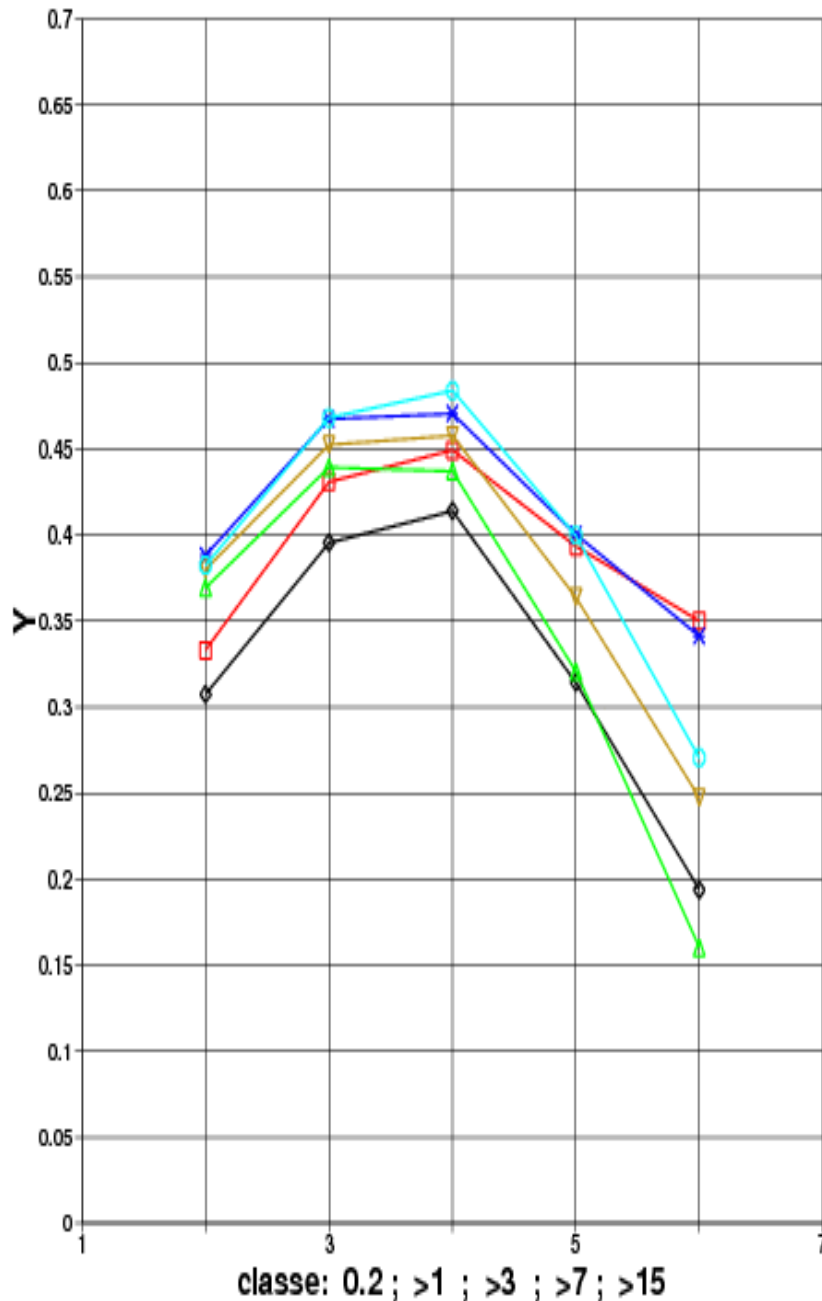
AROME cycle 32t1



Reduced diffusion

Heidke Skill Score (persistence)

2007JuinNov



- It was shown by Bazile et. al that if SLHD is applied on the hydrometeors, including that of rain and snow, it improves the precipitation intensity significantly

Heidke skill score,  
compare green and cyan  
line

# SLHD

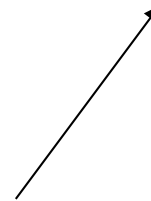
- A non-linear horizontal diffusion scheme acting through the SL advection
- Designed to control and profit from the damping provided by the interpolations done to compute the Lagrangian source term
- The SLHD interpolation operator utilizes an additional interpolation operator term with extra damping properties. SLHD operator:
  - $I = I_A + K(ID - I_A)$
  - $K$ ="diffusion coefficient". When  $K=0$ , no damping
  - $K$  does not have any relation to turbulent flux, but is related to the tensor of the deformation rates.

# SLHD

- Interpolation weights  $K_{\min}$  and  $K_{\max}$  represents the least and most damping interpolations allowed:


$$\kappa = \kappa_{min} + (\kappa_{max} - \kappa_{min}) \frac{\Delta t F(|d|^-)}{1 + \Delta t F(|d|^-)}$$

Function of scalar quantity of  
the horizontal deformation  $|d|$   
at time  $t$




# SLHD

- Grid-point diffusion acting through SL interpolators.
- These can be active for some subset of arrays only – as in reference AROME, only on hydro-meteors
- Background spectral diffusion
- Supporting spectral diffusion acting on divergence, vorticity and vertical divergence (in case of NH), and aims to suppress noise originating from the model orography.



Grid point  
diffusion  
Physical  
space



Numerical  
spectral  
diffusion

# Questions addressed

- What is actually happening applying SLHD on hydrometeors, in particular falling?
- Applying SLHD on full fields of dynamics, not only on the hydrometeors, can we damp the vertical velocity and precipitation locally?
- What are the implications of a 4X less diffusive horizontal diffusion scheme for unresolved convection?
- Some discussion about “noise” and kinetic energy



# Problems with deep convection at 2-2.5km

“Fireworks”

Small scale open cell structures

Precipitation intensity

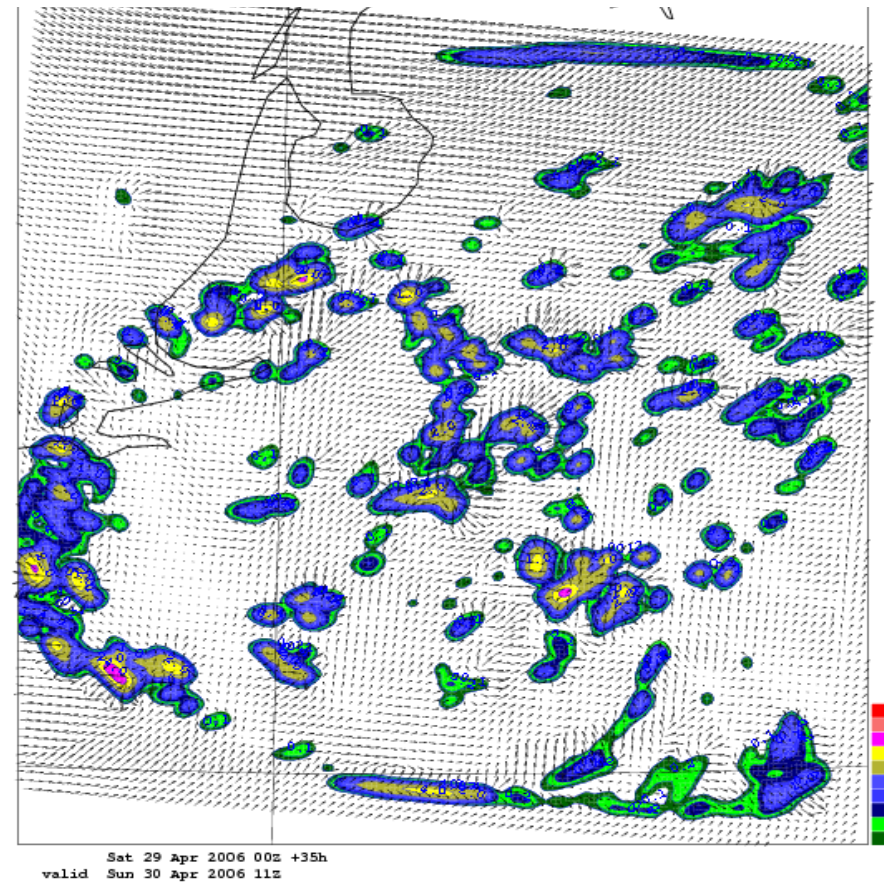
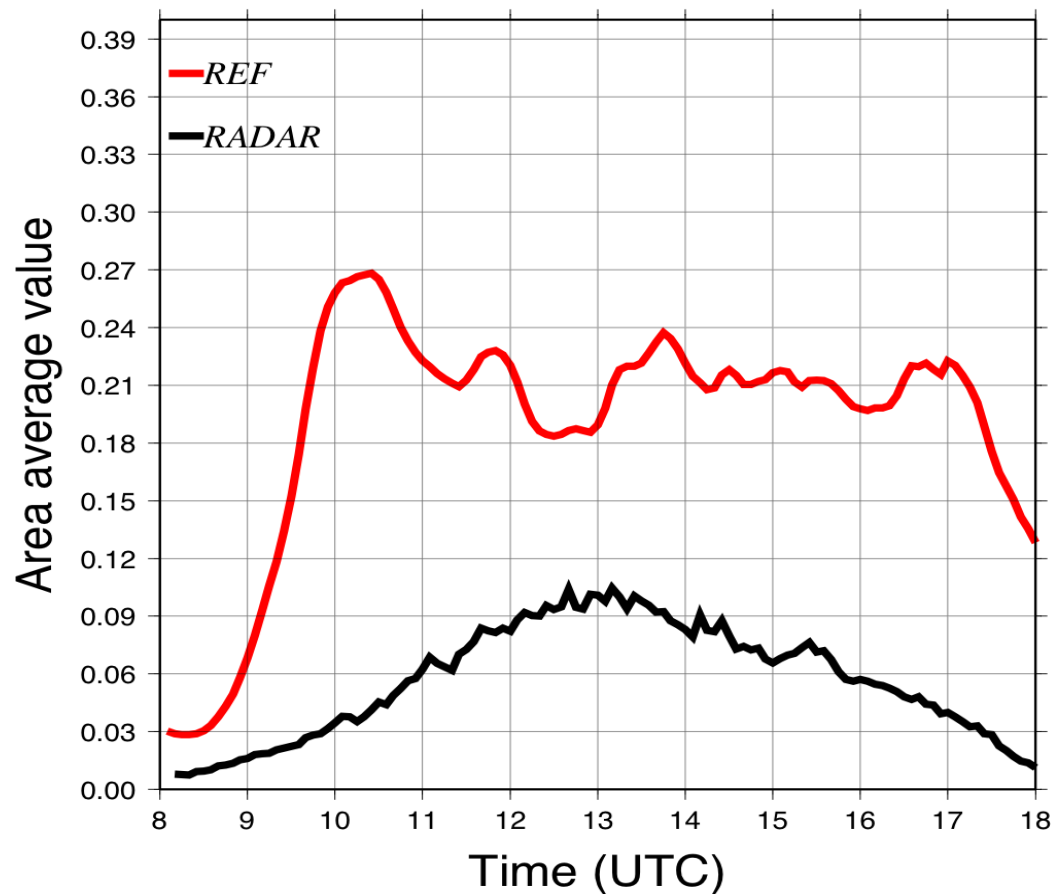
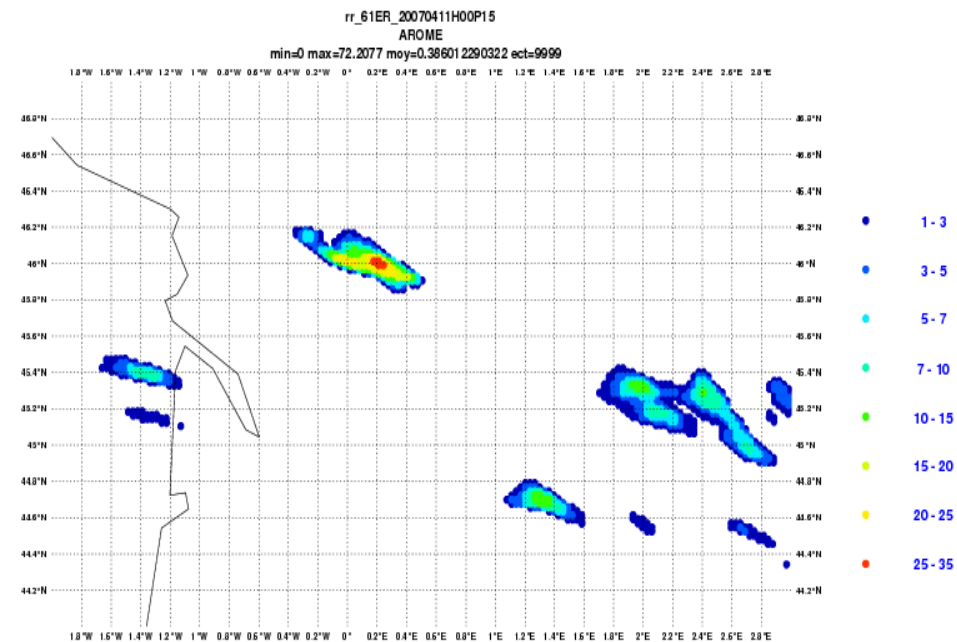
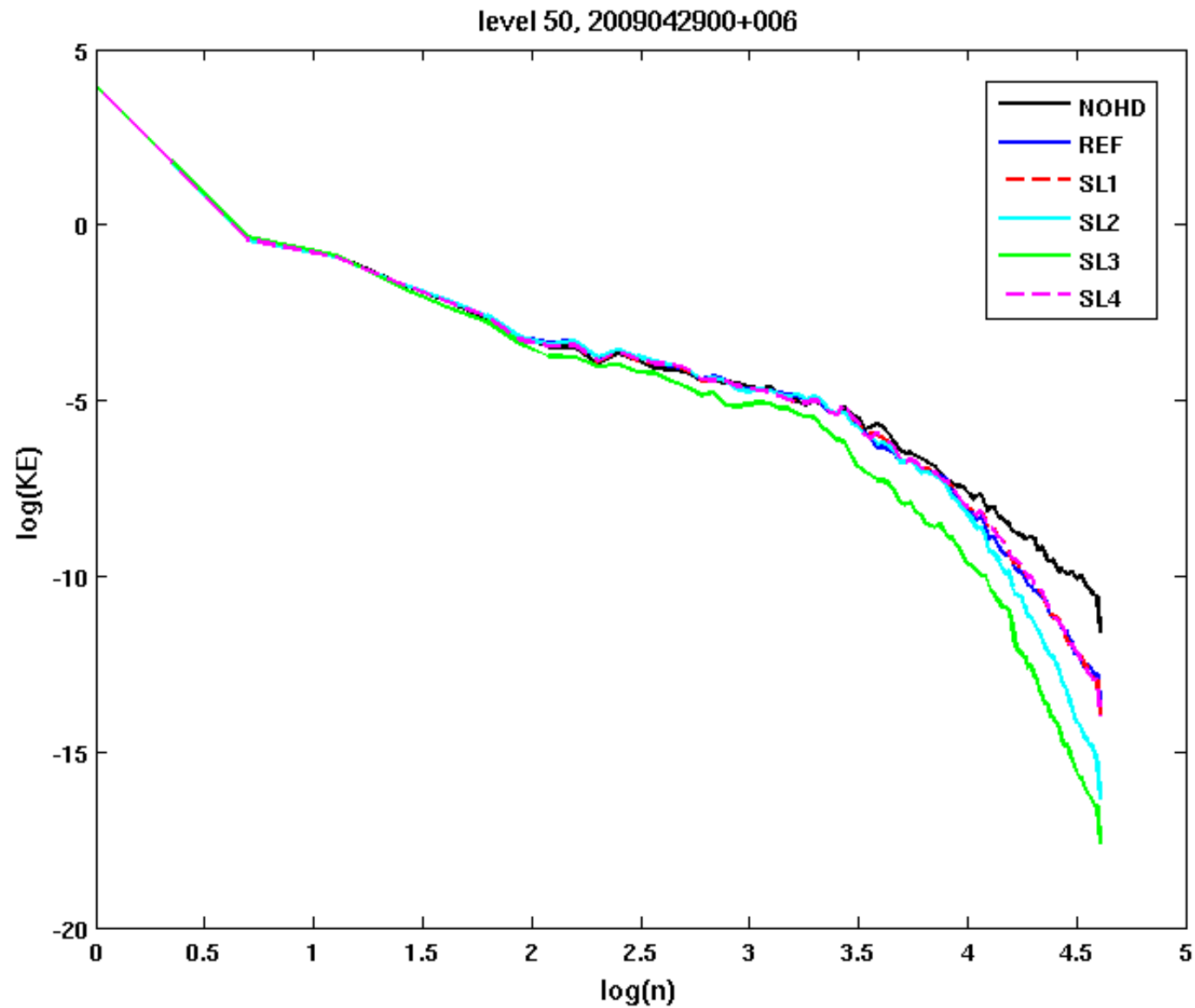


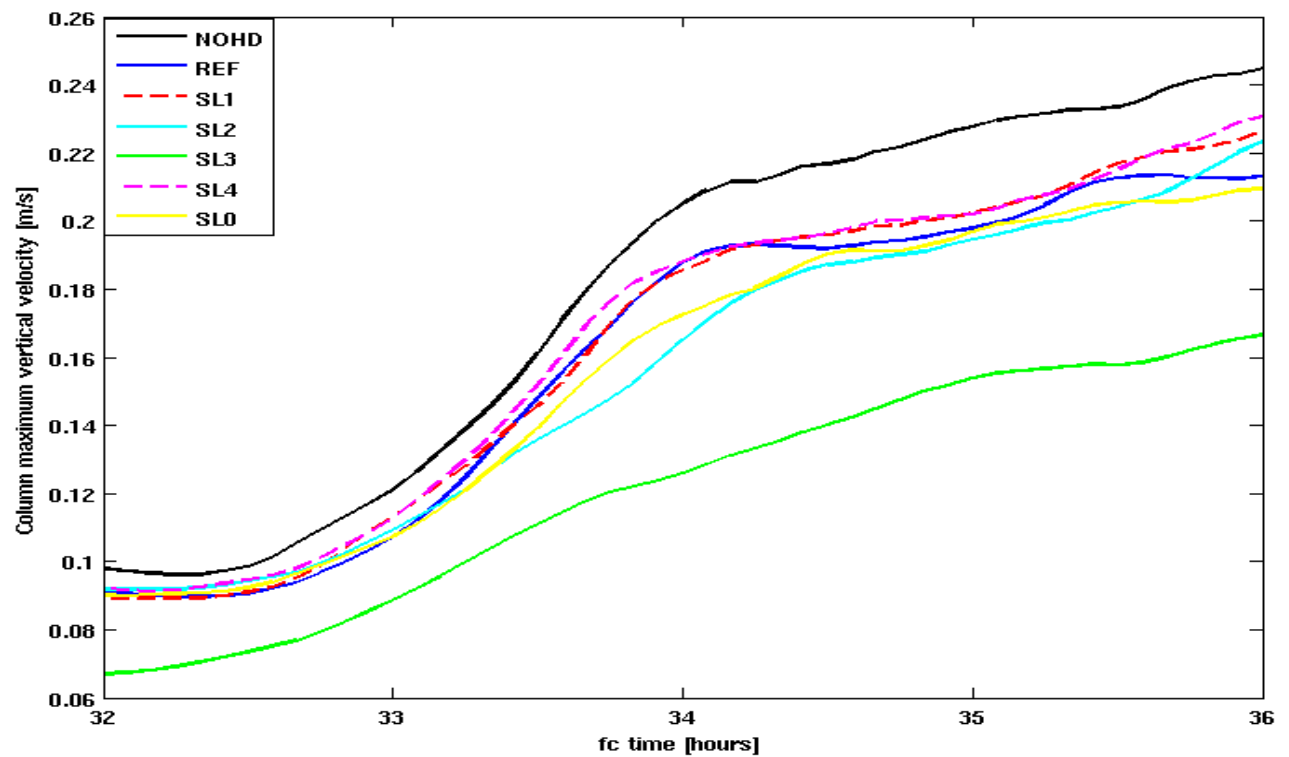
TABLE 1. *Experiment configurations*

.	REF	NOHD	SL0	SL1	SL2	SL3	SL4
Spectral diffusion	ref/4	none	ref/4	ref/4	ref	ref	ref/4
SLHD applied on:							
Temperature	no	no	no	yes	yes	yes	yes
Horizontal wind	no	no	no	yes	yes	yes	yes
Vertical wind	no	no	no	yes	yes	yes	yes
Graupel	yes	no	no	no	no	no	no
Rain	yes	no	no	no	no	no	no
Snow	yes	no	no	no	no	no	no
Cloud liquid	yes	no	no	yes	yes	yes	yes
Cloud ice	yes	no	no	yes	yes	yes	yes
Water vapor	no	no	no	yes	yes	yes	yes
SLHD tuning:							
A:	0.25	NA	NA	0.03	0.005	0.25	0.03
D:	6.5E-5	NA	NA	6.5E-4	7.0E-4	6.5E-5	6.5E-4
triggering:							
	deform	NA	NA	deform	deform	deform	divergence

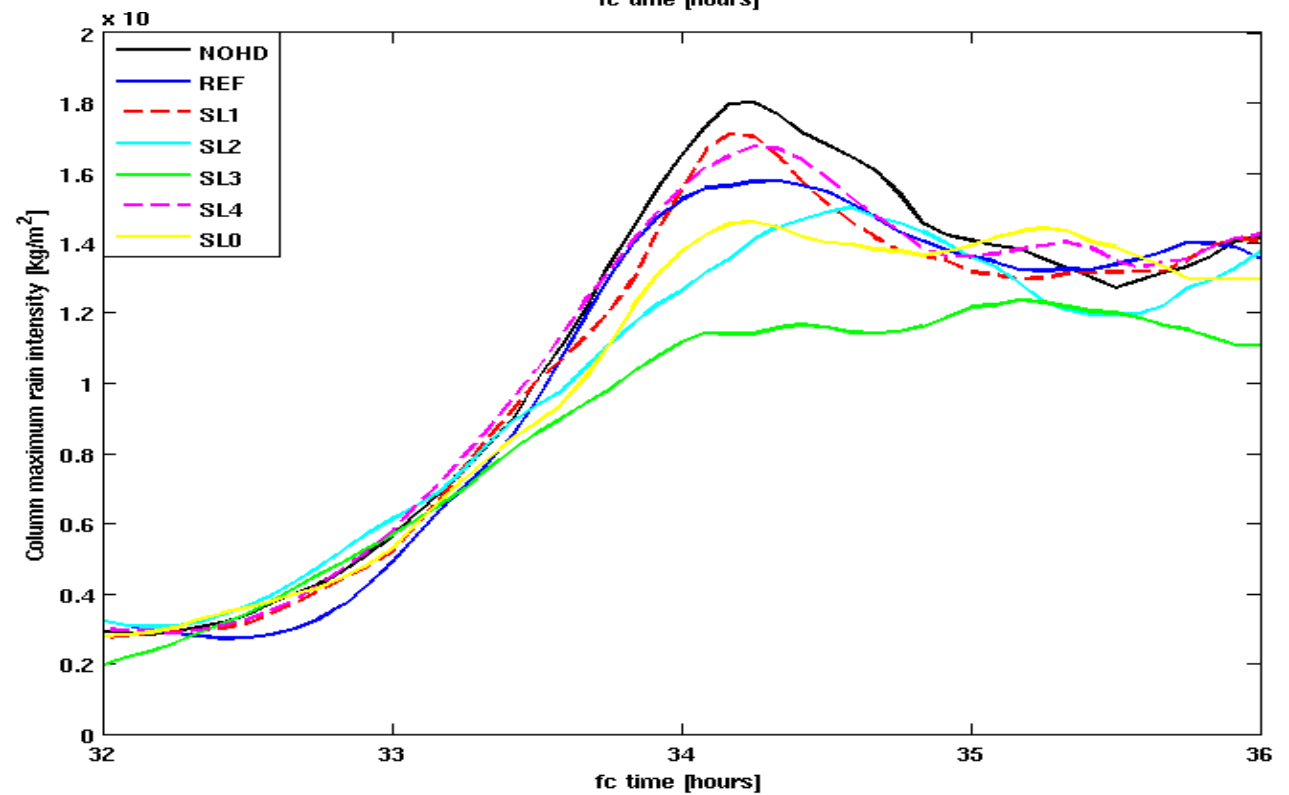
# Energy spectra



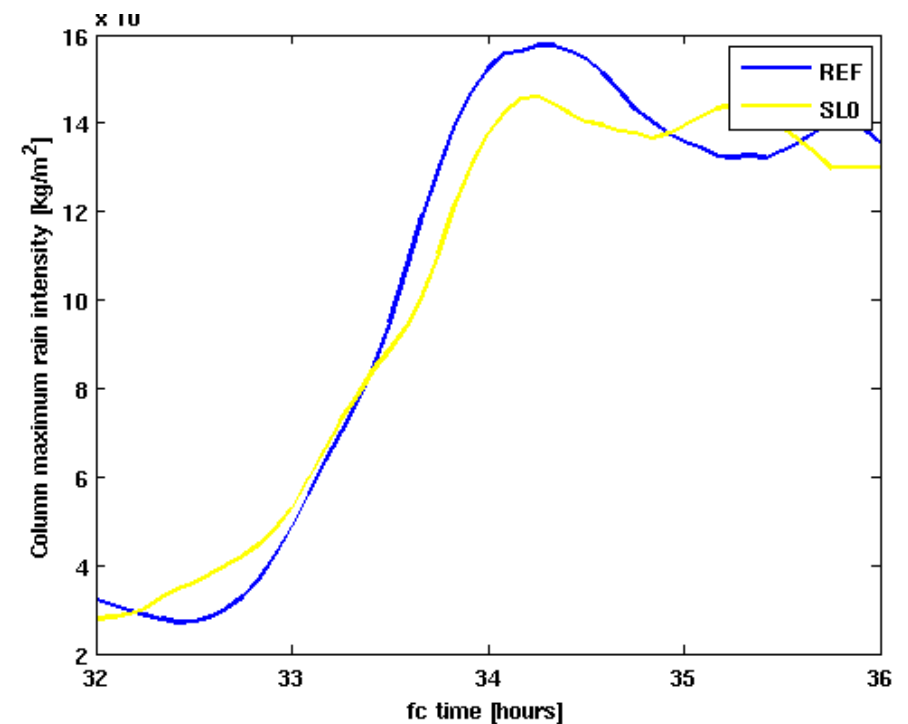
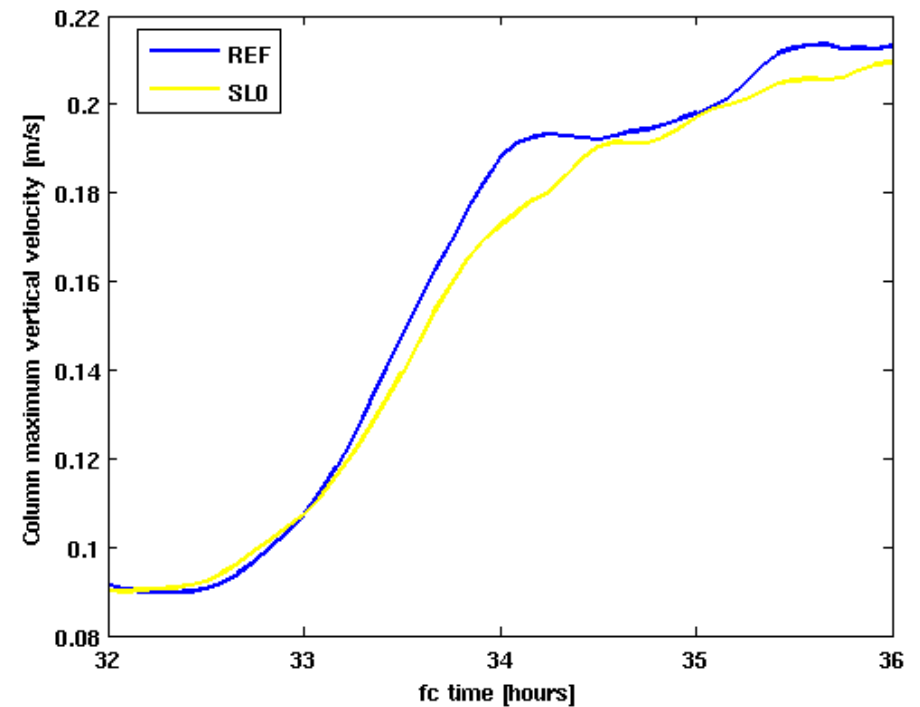
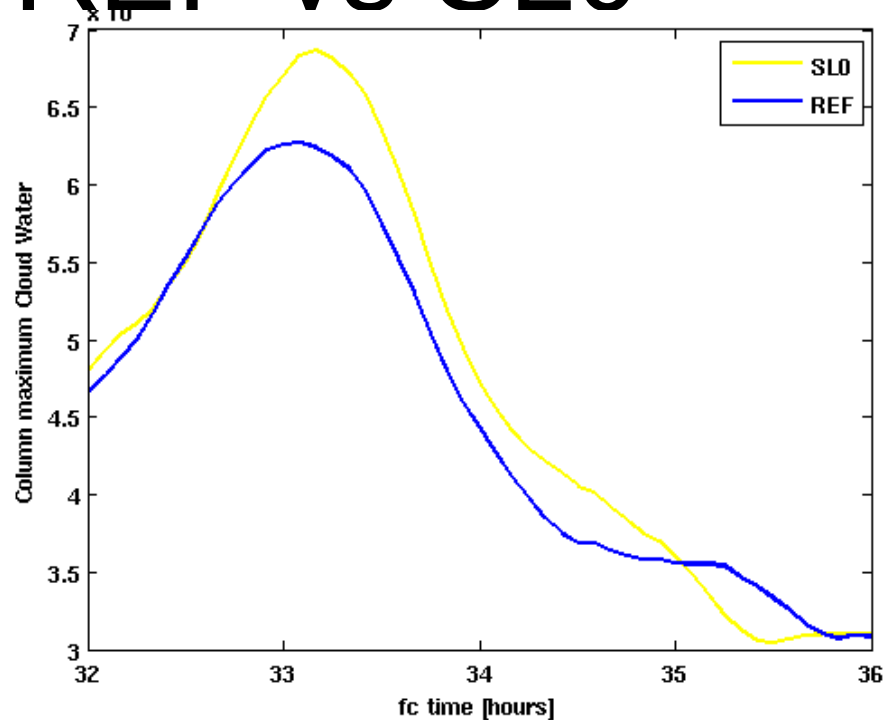
Maximum  
Vertical  
Velocity  
in column



Maximum  
Precipitation  
in column

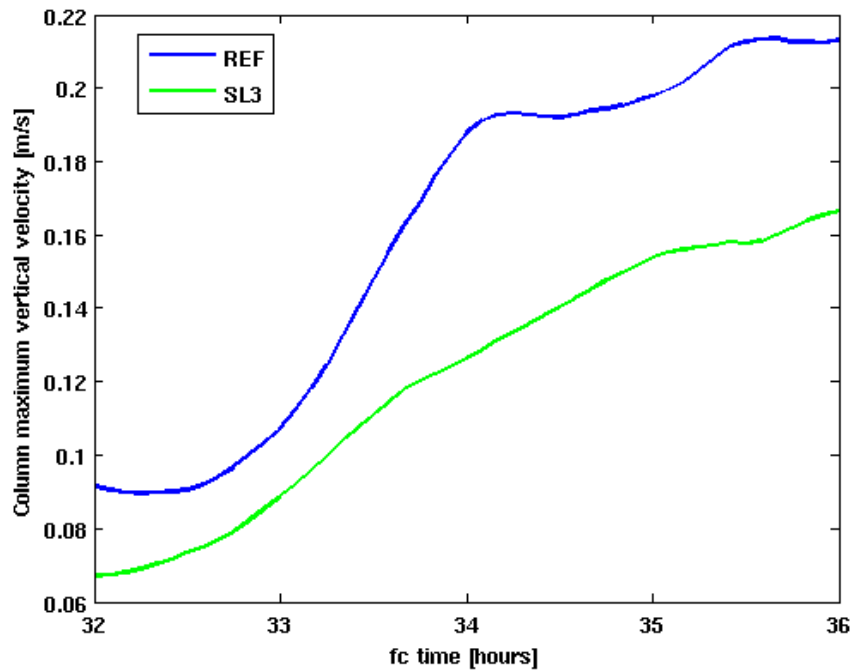


# REF vs SLO

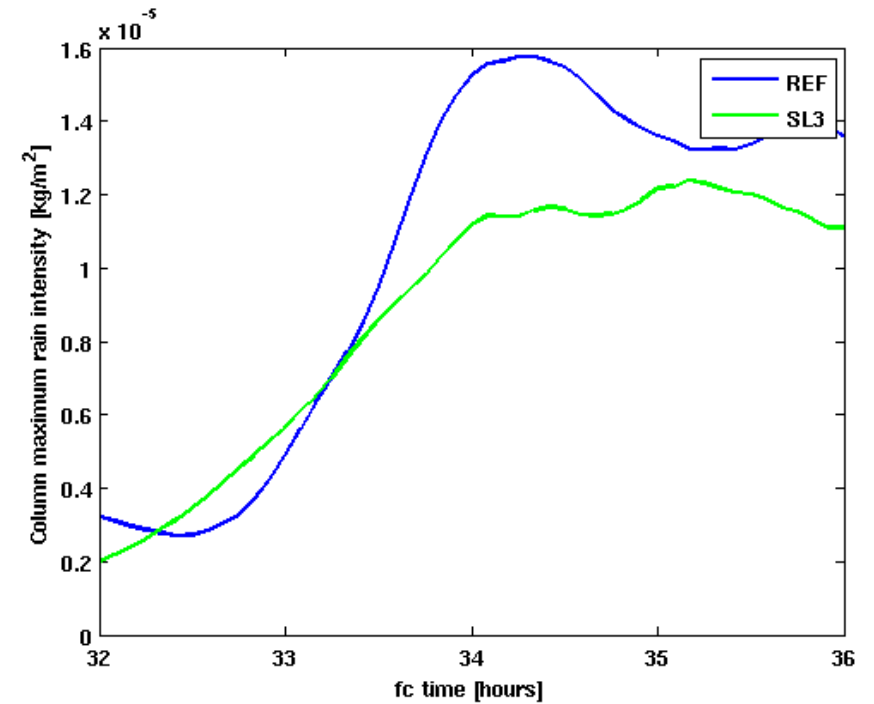


Reduced cw loading ->  
Reduced weight ->  
Increased vertical vel. ->  
Increased condensation ->  
Increased precipitation max.

# REF vs SL3



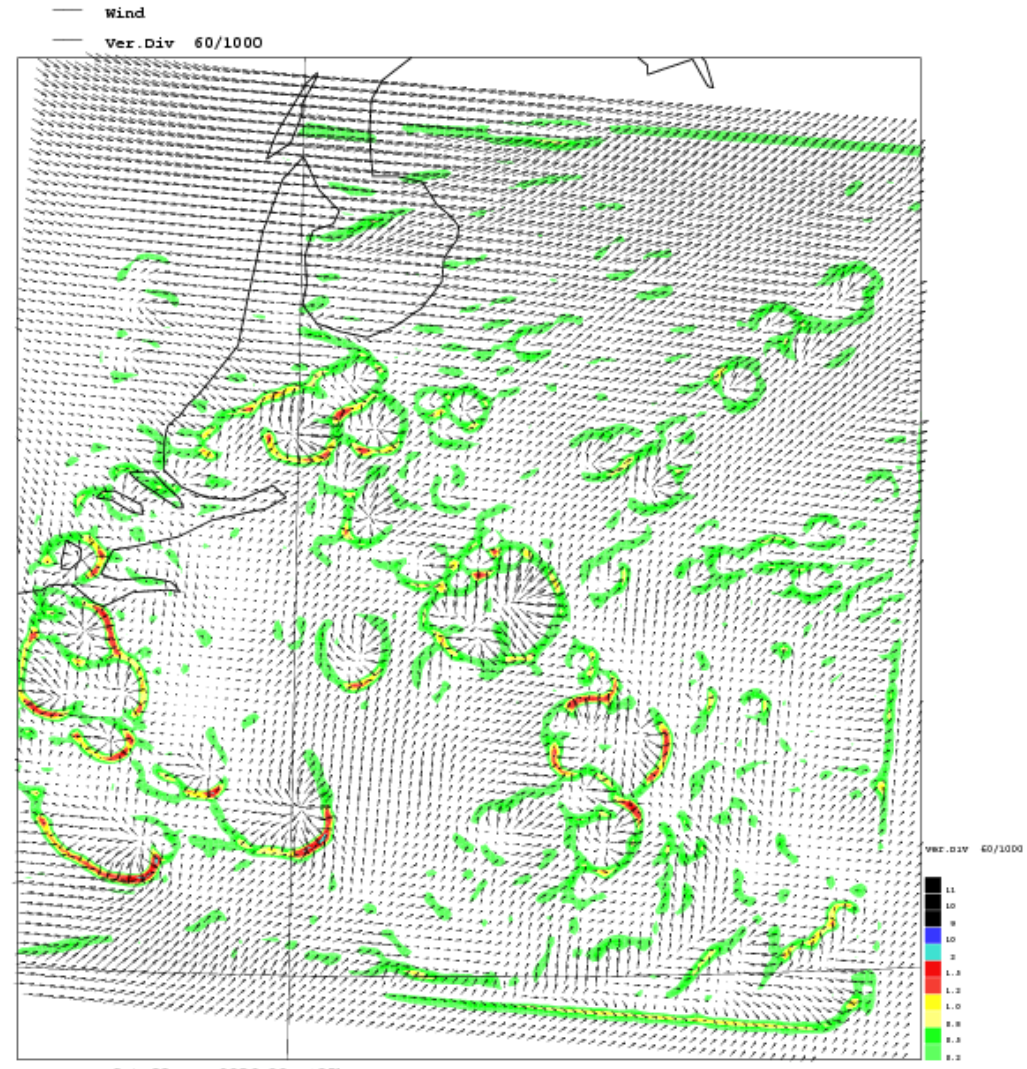
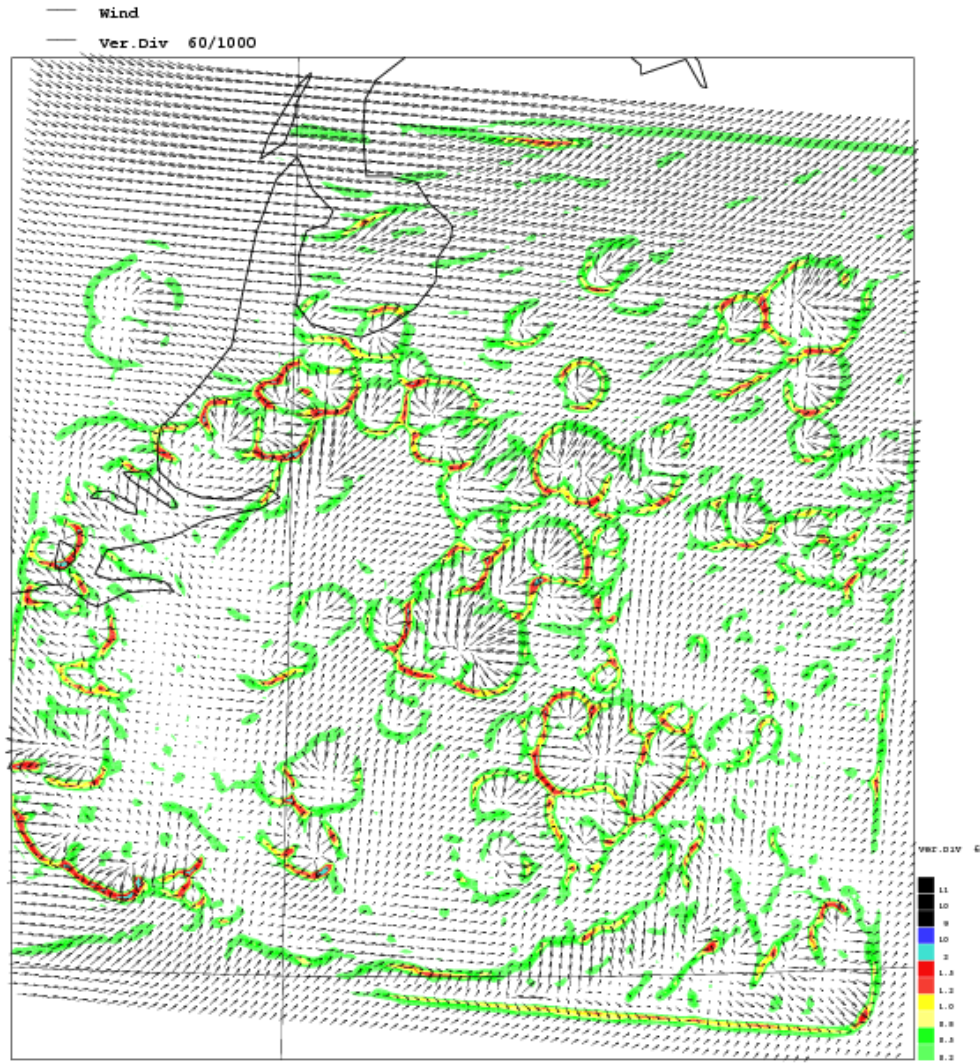
Max. Vertical velocity



Max precipitation intensity.

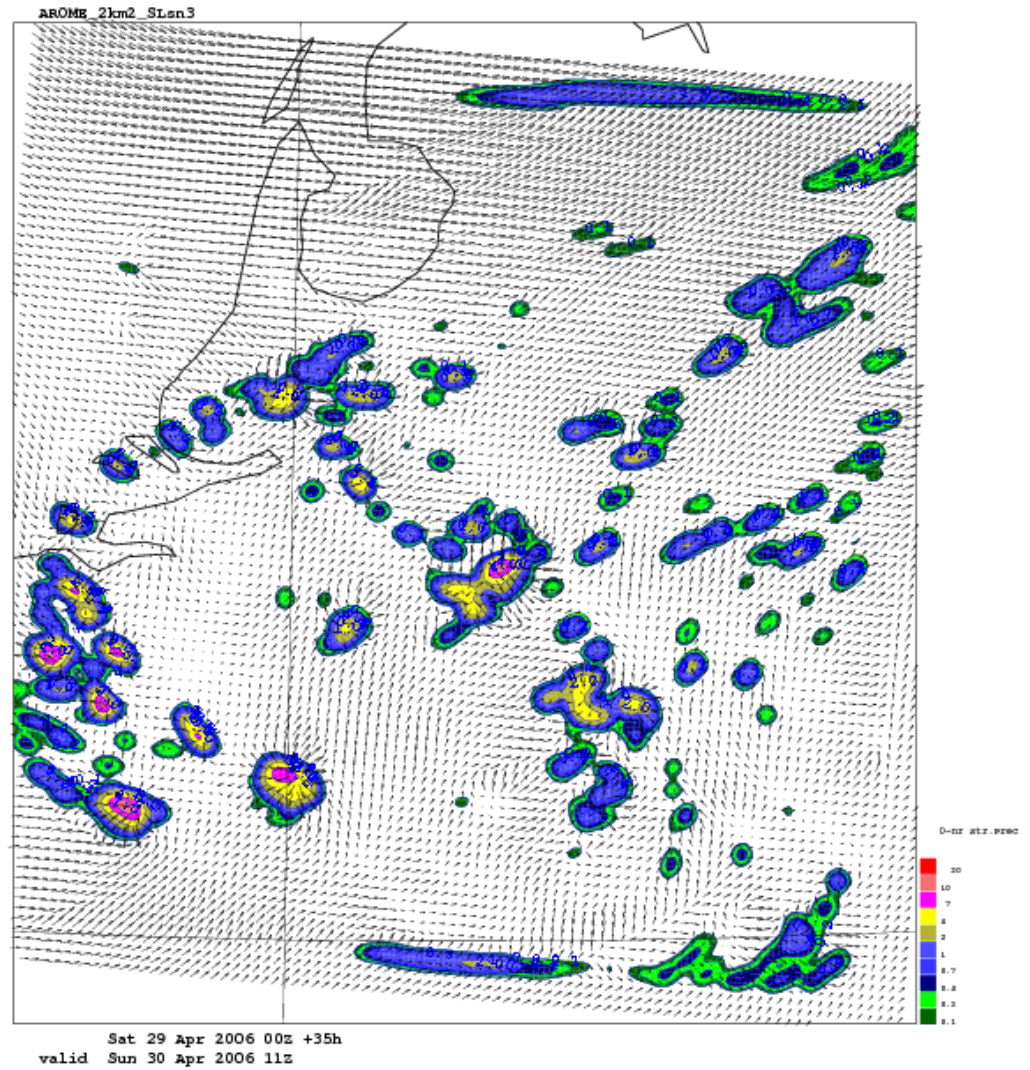
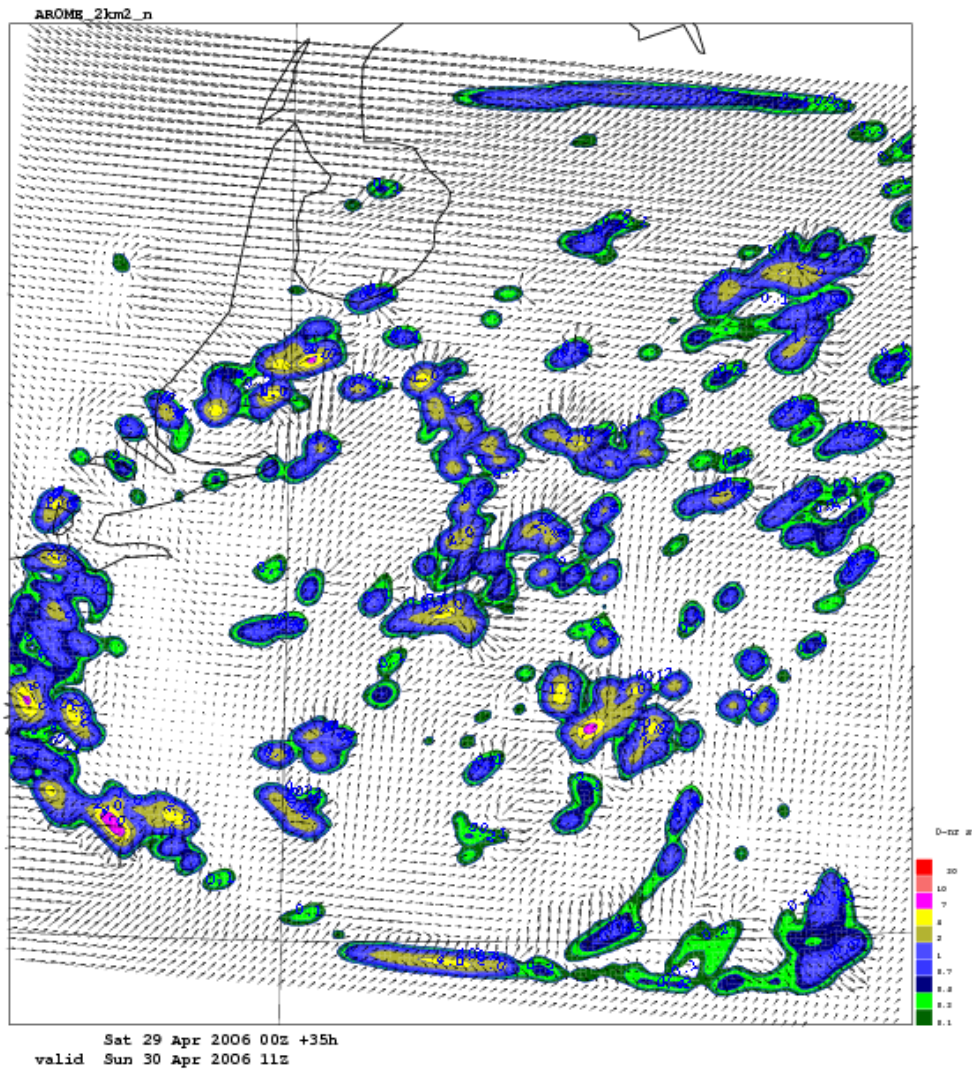


# Vertical velocity, U and V vectors





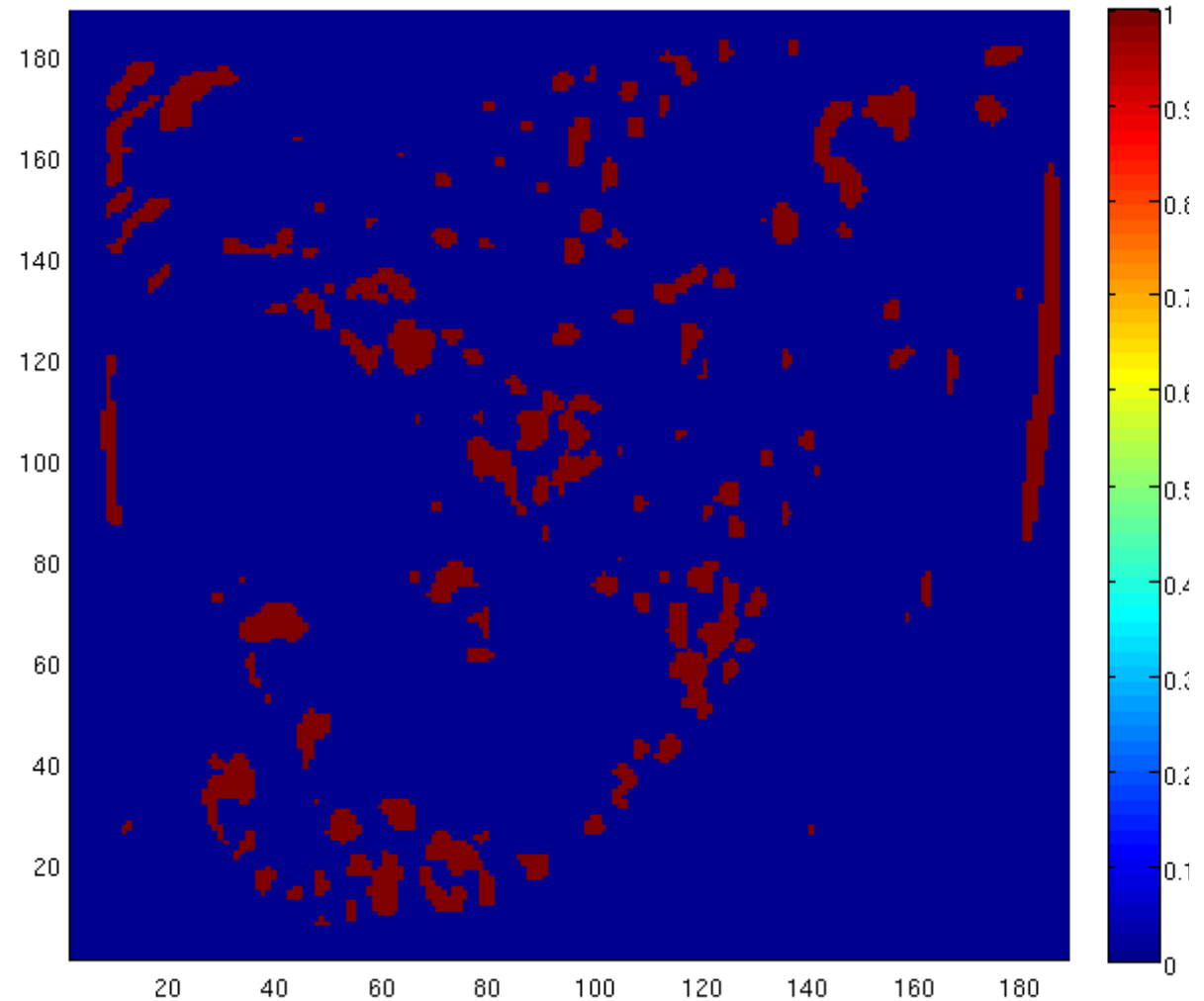
# 1 hour acc. precip.





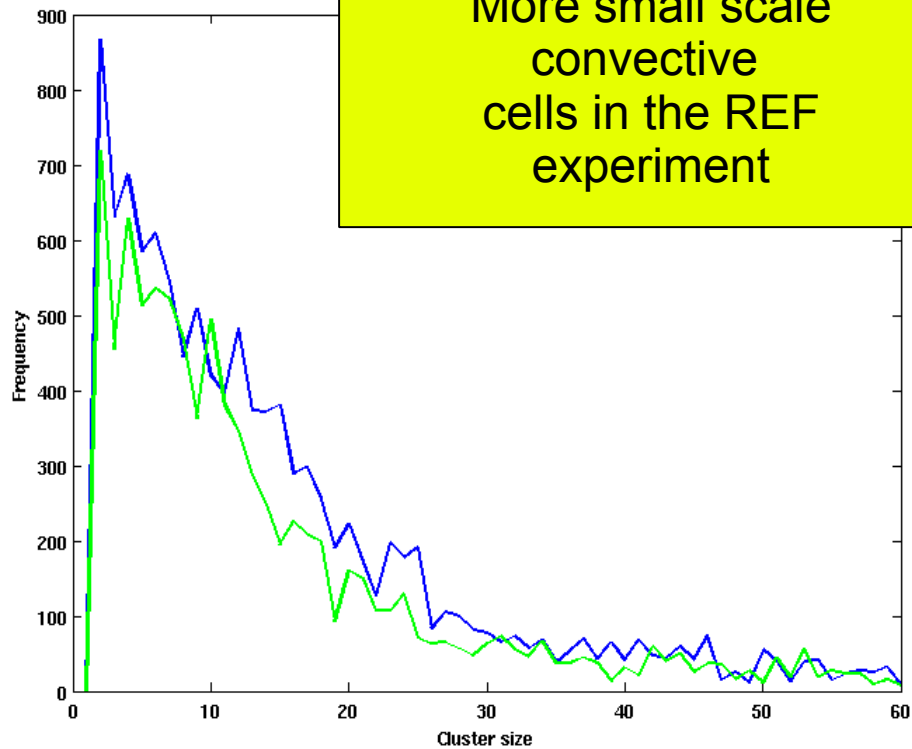
# Size of precipitation clusters

0	0	0	1	0
0	1	1	0	0
1	0	1	1	0
0	0	0	0	0
1	1	0	0	0



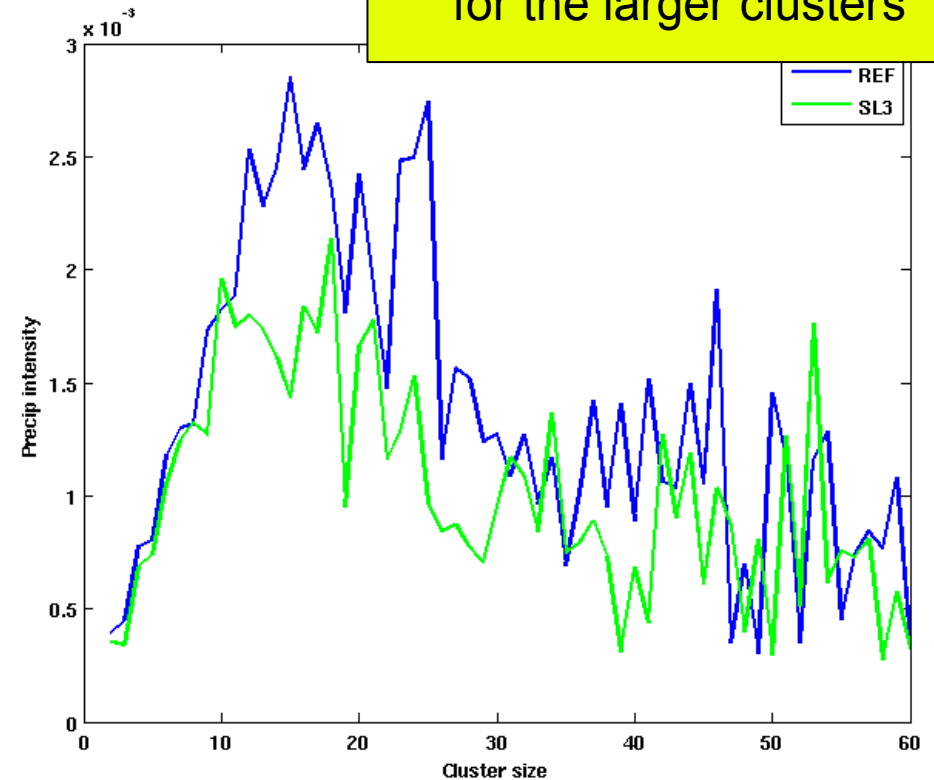
# Size of clusters

More small scale convective cells in the REF experiment



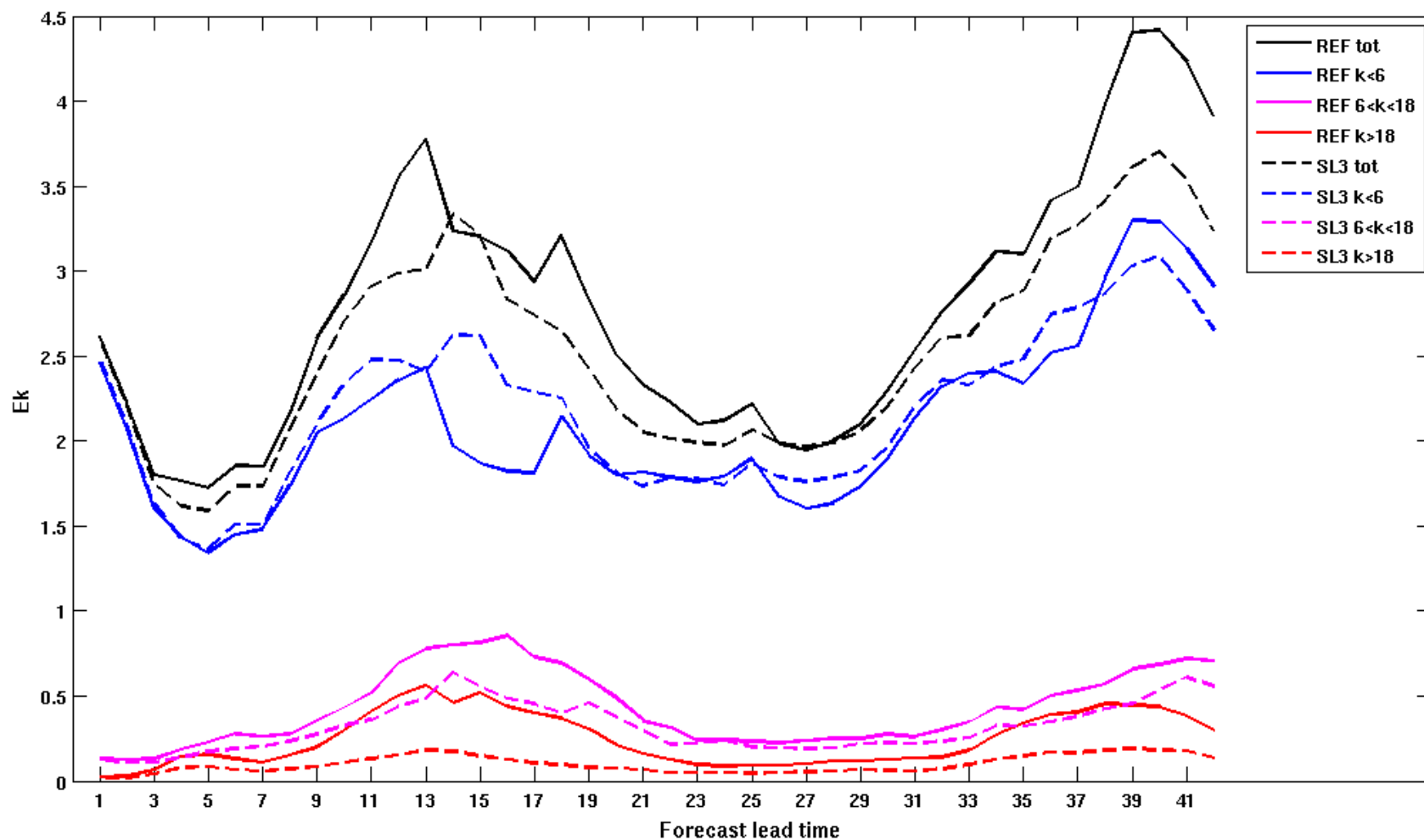
Frequency of cluster sizes

Small scale cells contributing to increased mean precip., but also more over intense precip. for the larger clusters



Mean precipitation as a function of cluster size

# Kinetic Energy vs Forecast lead time



# Conclusions/Discussion 1

- Applying SLHD on cloud water/ice can in convective cases lead to an increase in precipitation intensity due to a feed back from reduced water loading in the column.
- Applying SLHD on falling rain can reduce the precipitation intensity, but the convective updrafts remain strong.
- Weak diffusion yields artificial noise within the precipitation field which degrades the forecast.

# Conclusions/Discussion 2

- Want a solution that works for both “fireworks” and small scale showers.
- At 2km horizontal resolution, the deep convection is not always resolved, then horizontal diffusion becomes a replacement of a physical parameterization.
- In the current AROME the different columns are more or less leading independent lives, apart from the weak horizontal diffusion and advection. This motivates development of 3D turbulence parameterization (may be applied in the SLHD framework by e.g. basing the strength of the diffusion on a physical parameter like TKE (which will be large in the PBL and in convectively active area)). Or/and stochastic components for communication between gridboxes.
- Then let horizontal diffusion remove unpredictable noise.