significance of subgrid-scale parametrization for cloud resolving modelling

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(thanks to) F. Couvreux, J.-L. Redelsperger, J.-P. Lafore, M. Tomasini

cloud-resolving simulations

- which « object » ? (space and time scales)
  mature squall line phase, one week of COARE-IFA, day-time convection...
- for which purpose?
  phenomenology, process study, larger-scale parametrizations
- numerics
  resolution, domain size, filters, sponge layer, advection schemes...
- parametrizations (of subgrid-scale processes)
  subgrid-scale fluxes (turbulence), microphysics, radiation
  subgrid coupling between microphysics and turbulence, radiation...
- boundary conditions
  initial conditions, boundary conditions (surface & « large-scale forcing »)

different sets of choices (with intricate dependencies)
these various ingredients play more or less important roles depending on the object/purpose

CRMs well suited to explicitely simulate precipitating deep convection
(not developed to simulate boundary layer clouds)

focus

restricted to broad considerations:

turbulence (or subgrid-scale fluxes)

subgrid coupling between microphysics and turbulence

(what sensitivity studies focussing on resolution tell us)

no discussion about:

microphysics

importance of stratiform cirrus (maintenance/dissipation)

significance of evaporation of precipitating hydrometeors

radiation

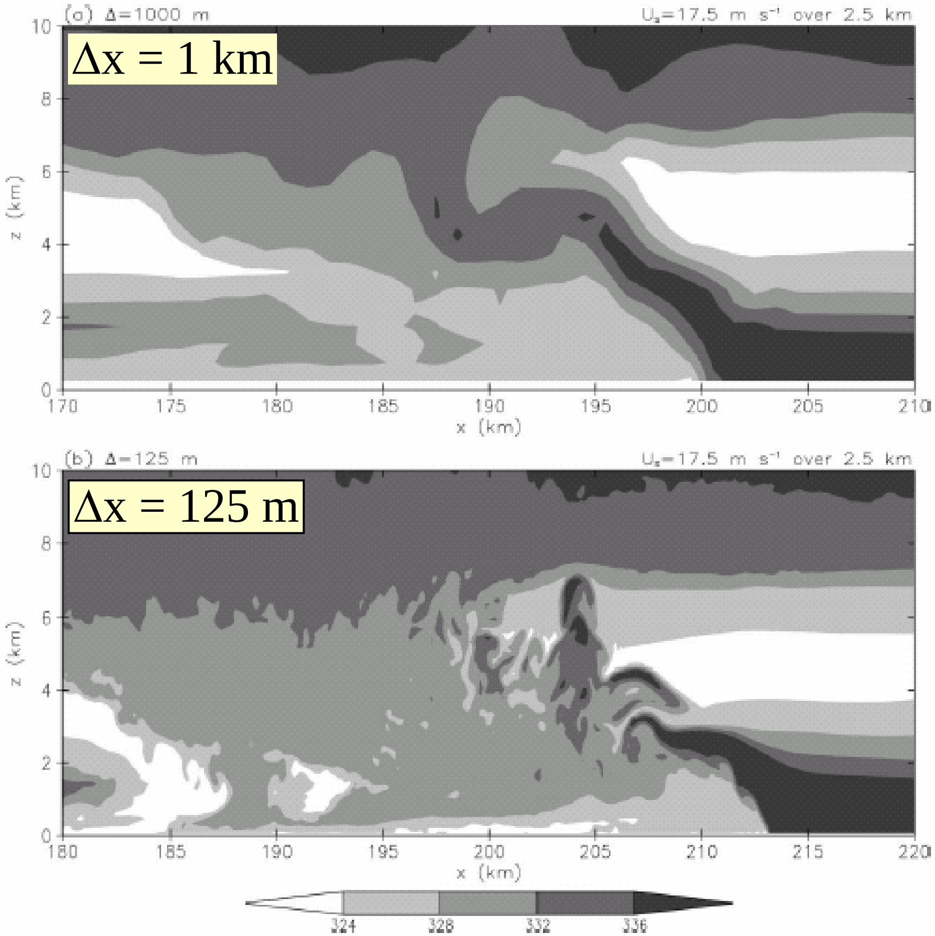
cloud-radiation interactions

a few words about resolution

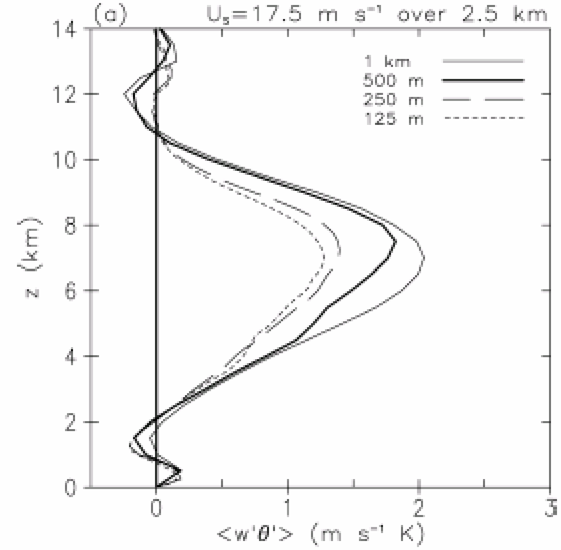
Bryan et al. (2003) for MCSs

a « turbulent » point of view (structure, budget,spectra)

θe (x,z) in simulated squall line



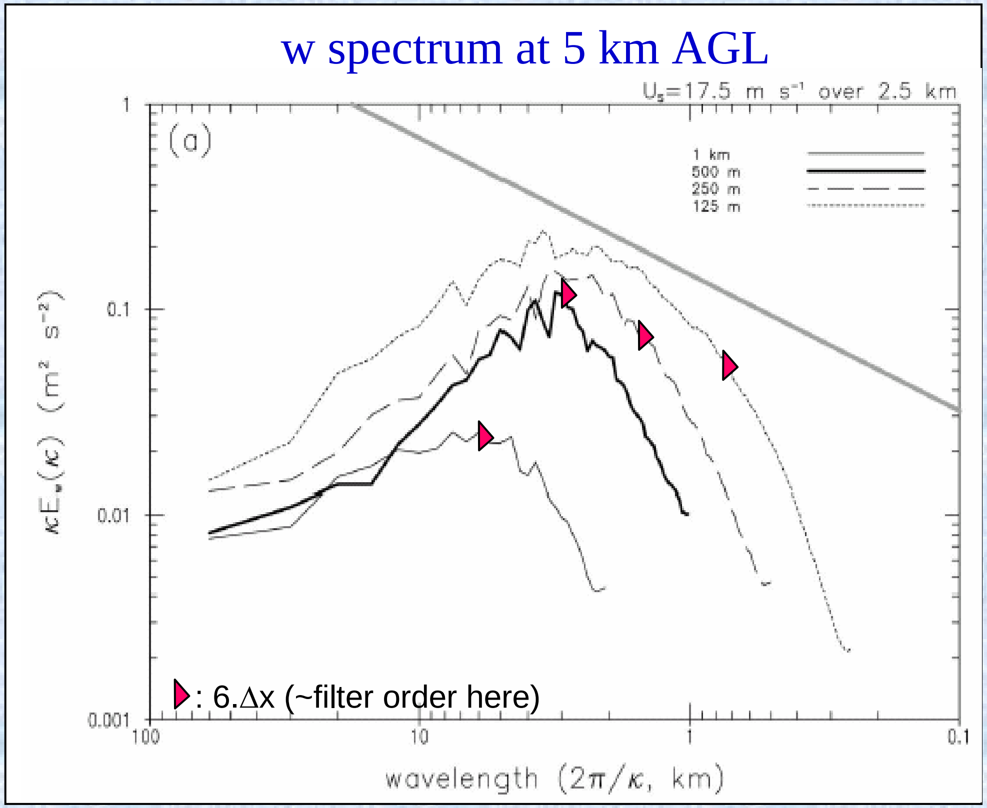
buoyancy flux

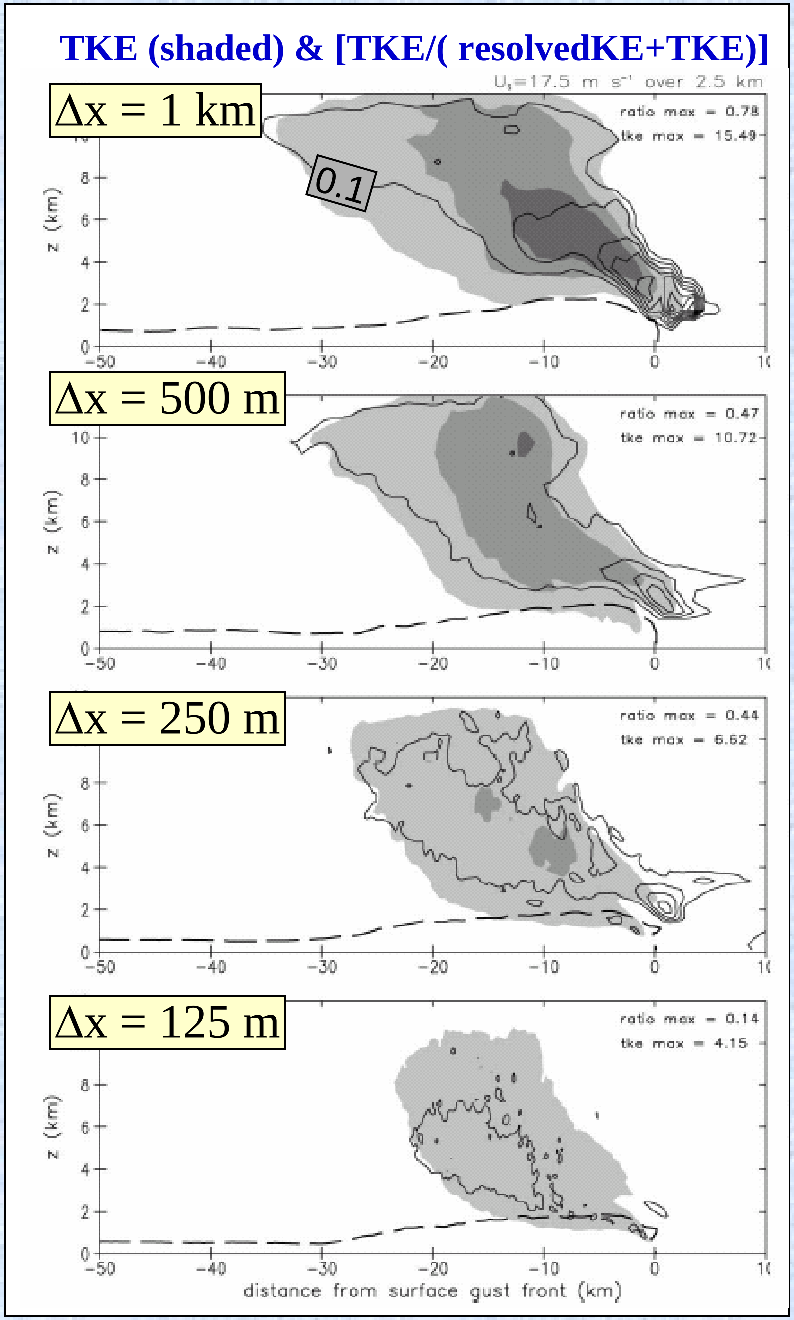


bulk features

Grid spacing (m)	Rainfall ($\times 10^9$ kg)	Avg x-location of surface gust front (km)
1000	90.9	191.4
500	110.8	198.4
250	105.5	198.2
125	107.1	199.7

Bryan et al. (2003)





not strictly an LES-type simulation
(turbulenty speaking;subgrid flux not negligeable, l/Δ)

note: among other things, no consideration of cold nor subgrid microphysics (i.e. simulation probably using fixed thresholds for microphysic processes independently of Δx...)

formulation of subgrid-scale turbulence

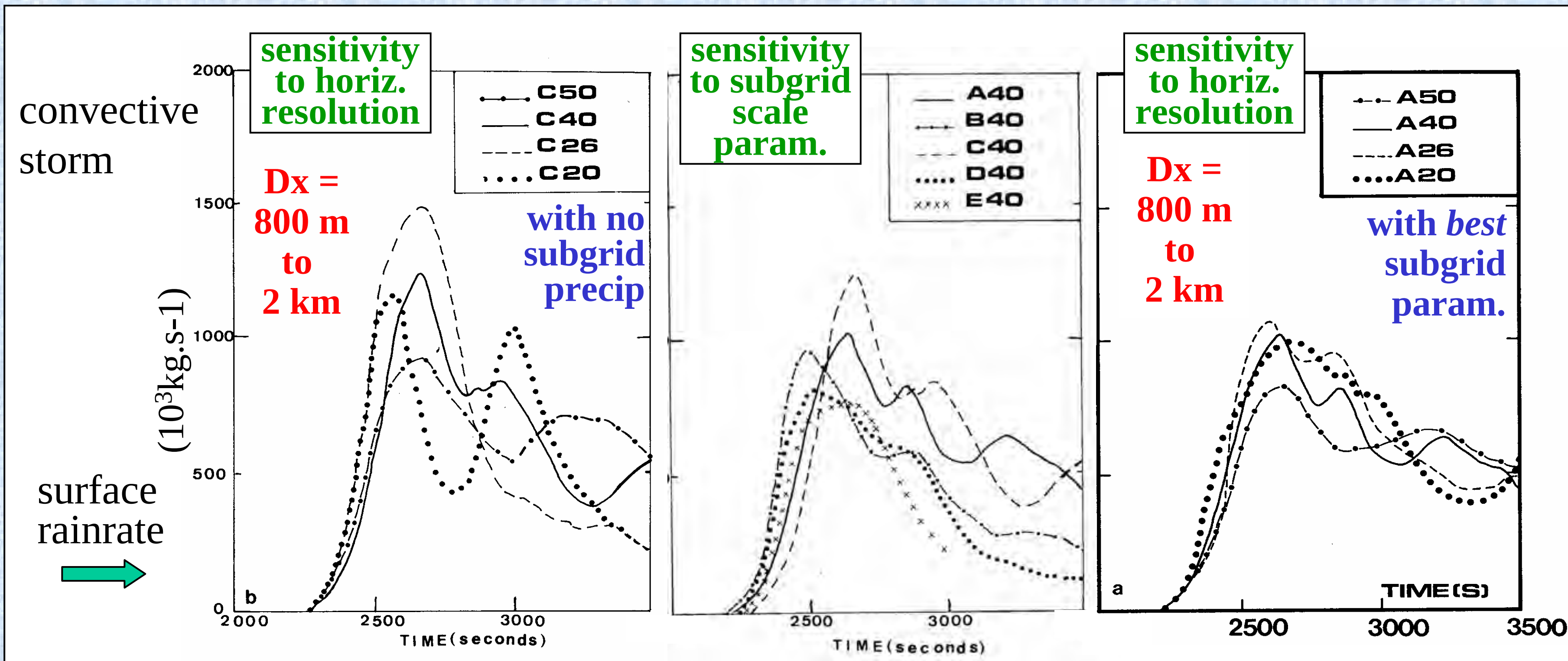
often based on Smagorinsky, prognostic TKE introduced in many schemes, but still often length scale l = Δ (grid), different ways to treat the impact of stability (strong numerical diffusion in some CRMs)

subgrid-scale microphysics

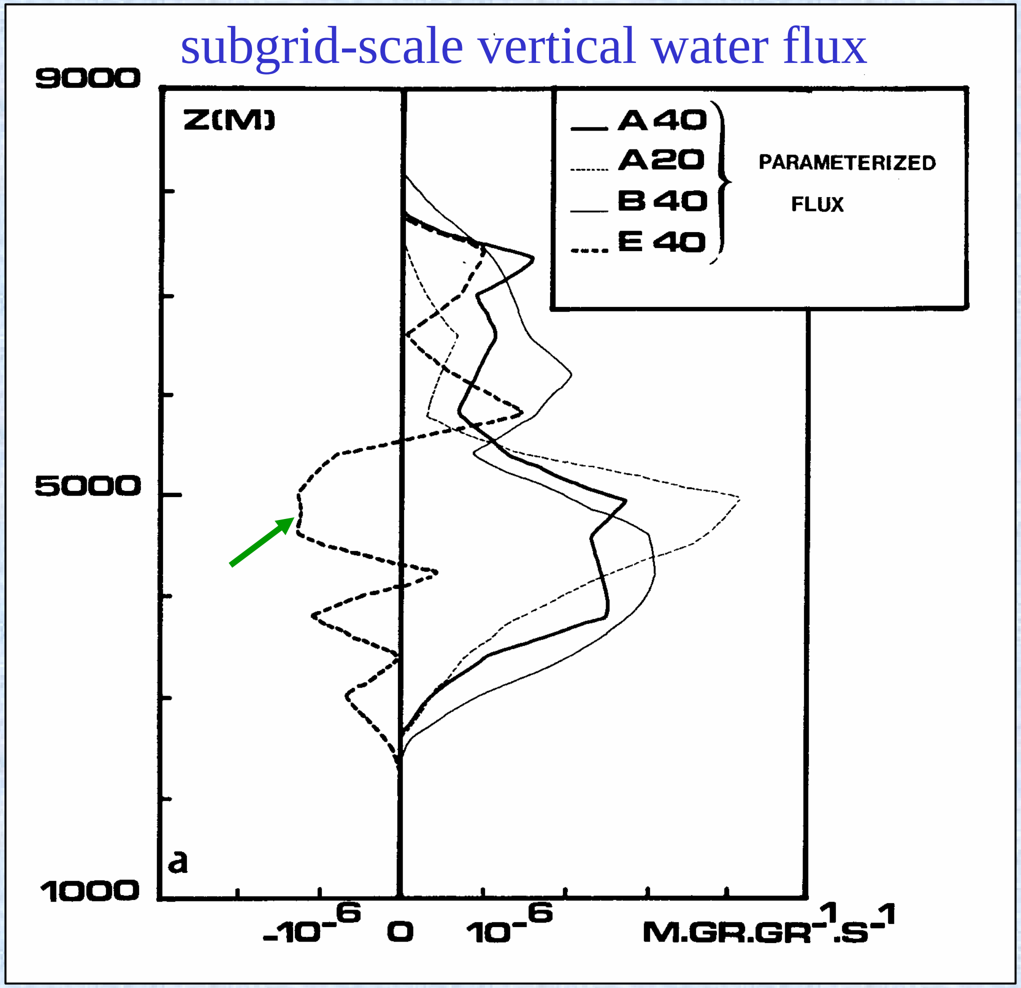
often ignored [introduction of an artificial cutoff]

interactions between subgrid-scale motions and microphysics

most often neglected



Redelsperger and Sommeria (1986)

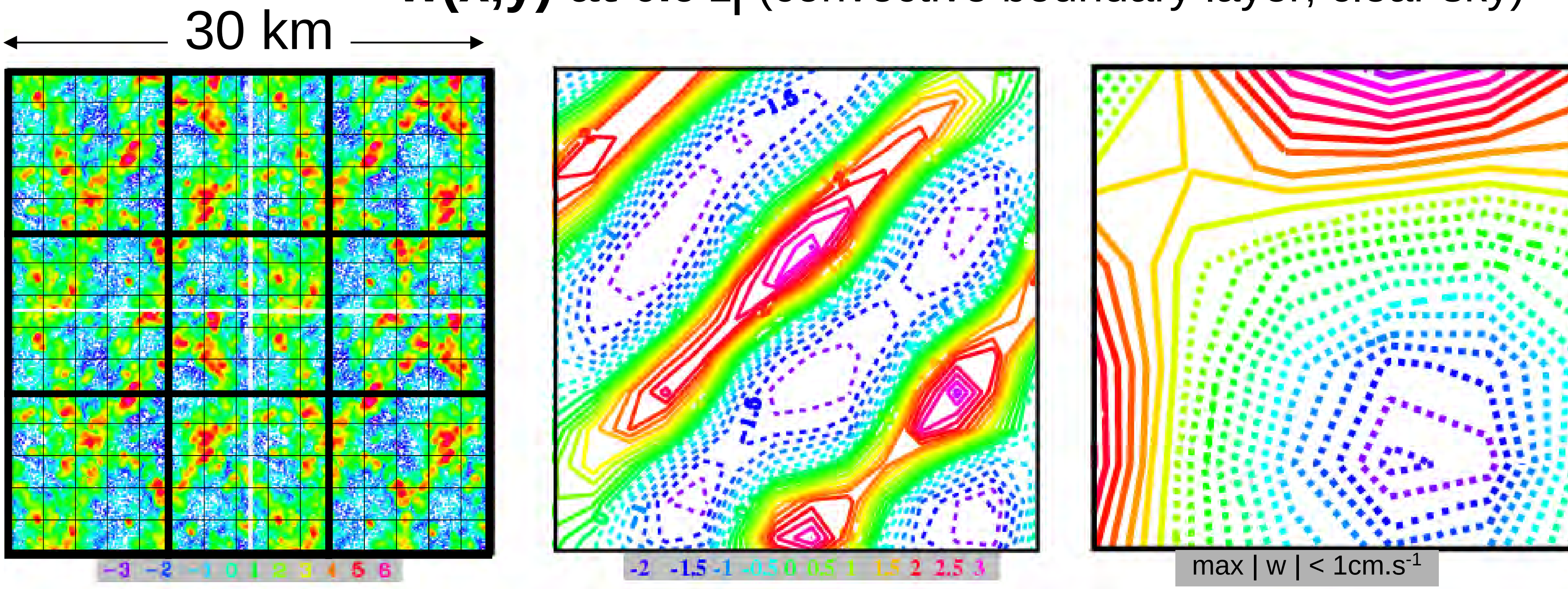


change sign when subgrid-scale interactions between microphysics and subgrid fluxestaken into account!

Redelsperger and Sommeria (1986)

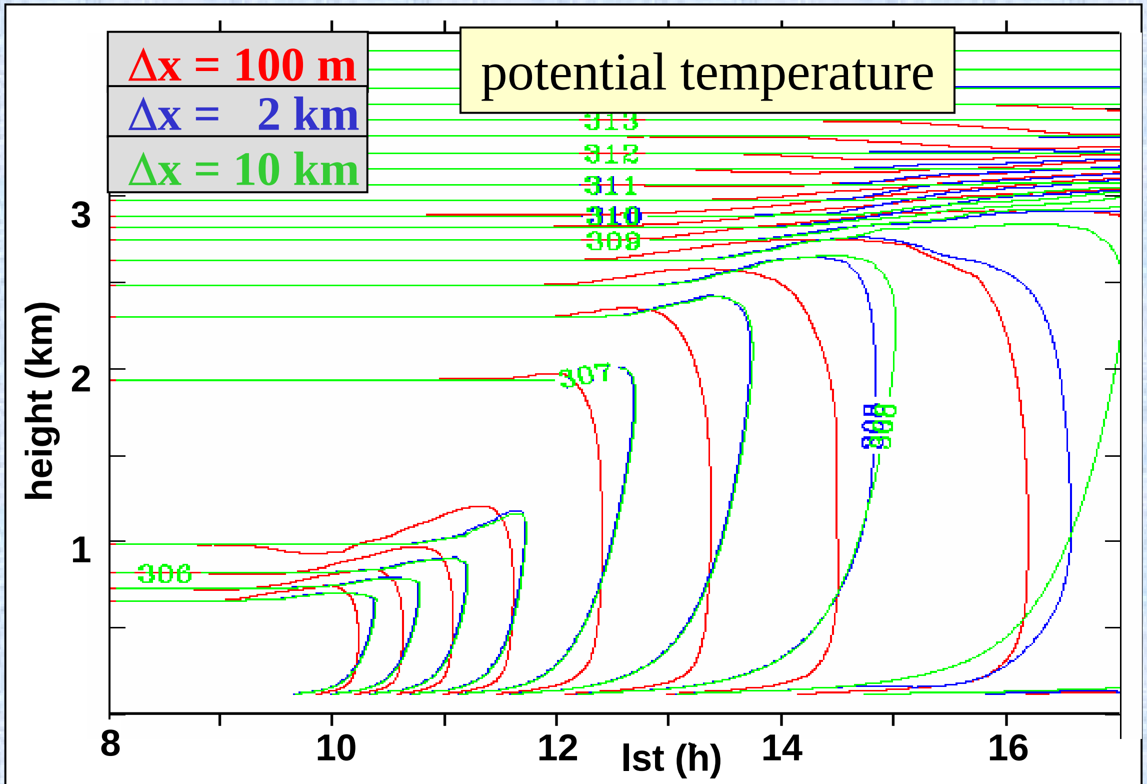
specific features associated with boundary layer treatment

w(x,y) at 0.6 z_i (convective boundary layer, clear sky)

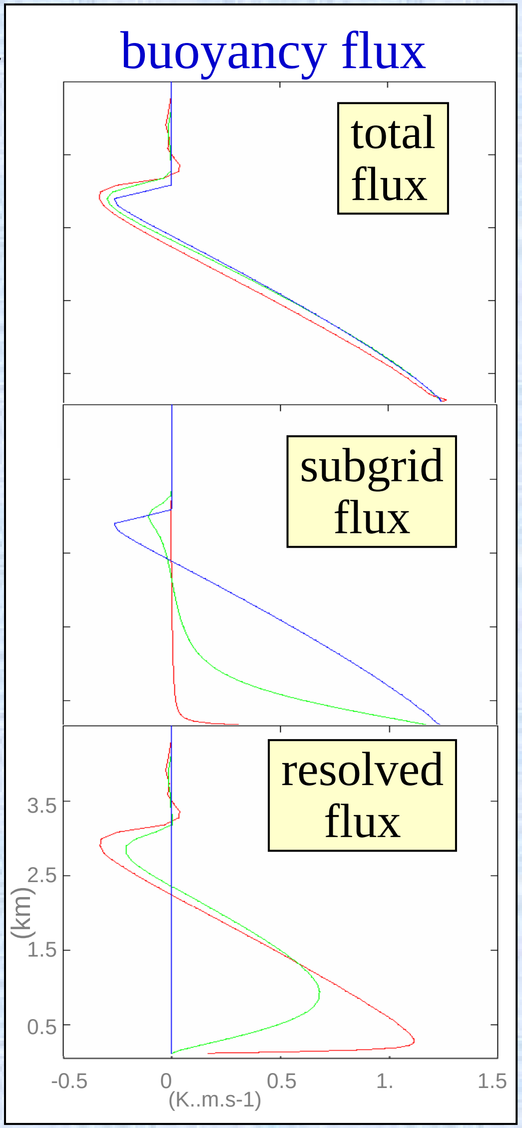


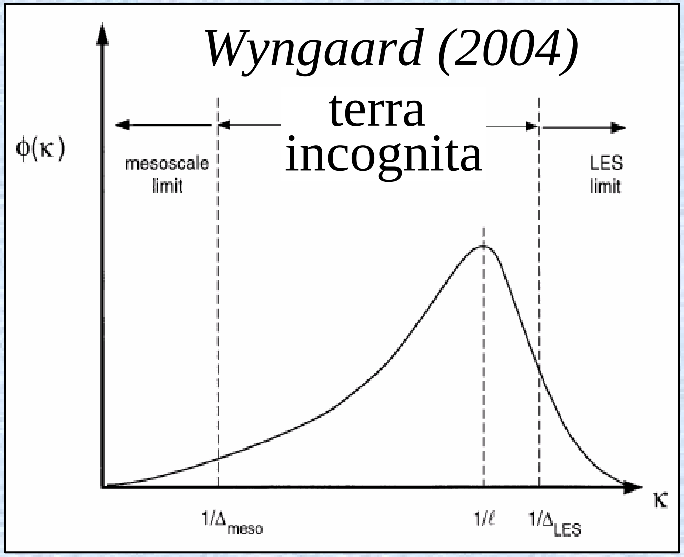
Δx = 100 m	**Δx = 2 km**	**Δx = 10 km**
	1D turbulence scheme	*1D turbulence scheme*
classical organization (open cells)	development of spurious organizations	expected behaviour with this resolution

adapted from Couvreux (2001)



Couvreux (2001)





here resolved motions react to (compensate for) too weak subgrid transport, in their own way (cf. organisations)

intricacy of interactions between resolved & subgrid processes

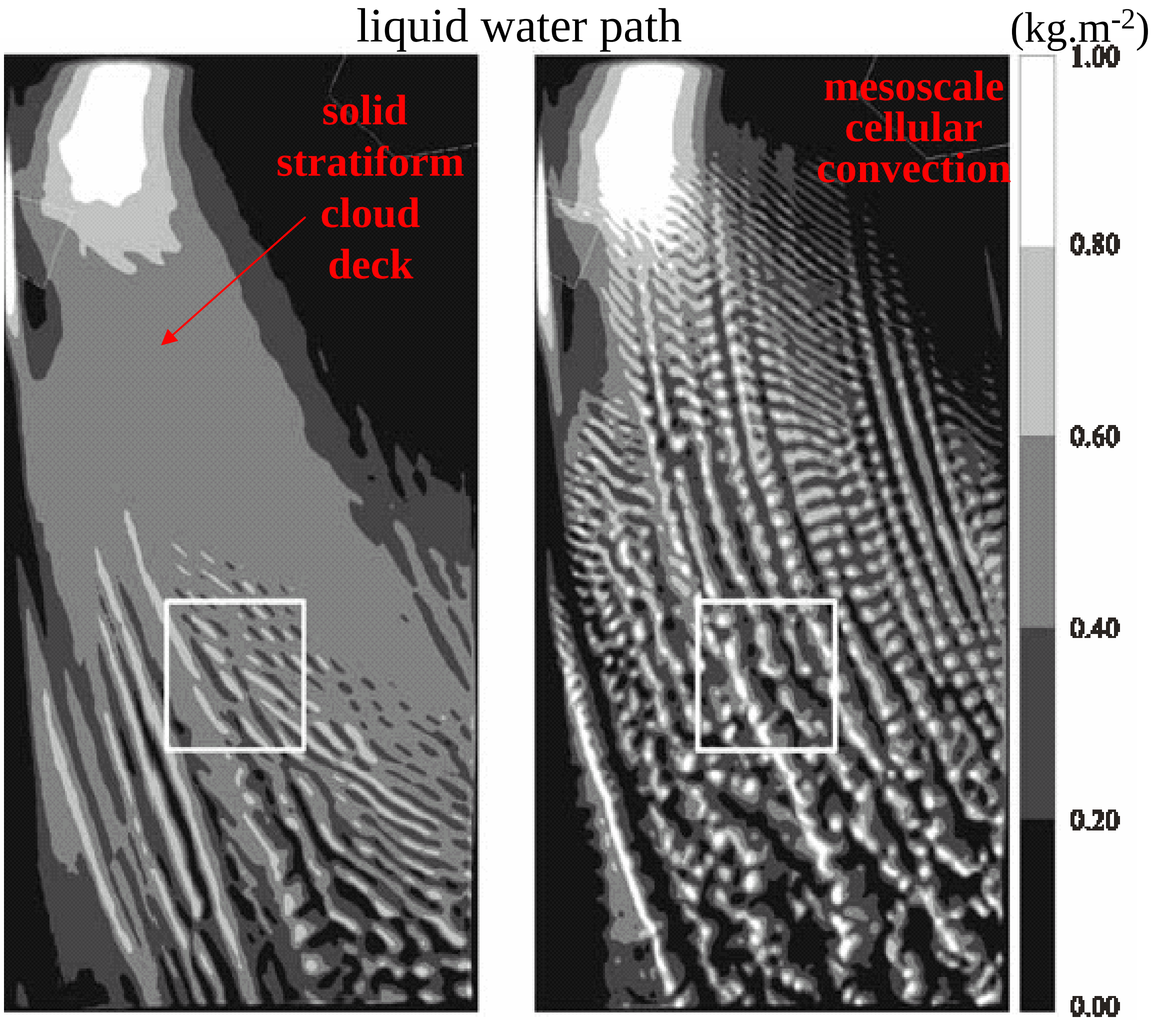
from clear sky to cloudy boundary layers ...

Fiedler and Kong (2003)

cold air outbreak
AVHRR image

mesoscale modelling , Δx = 2 km

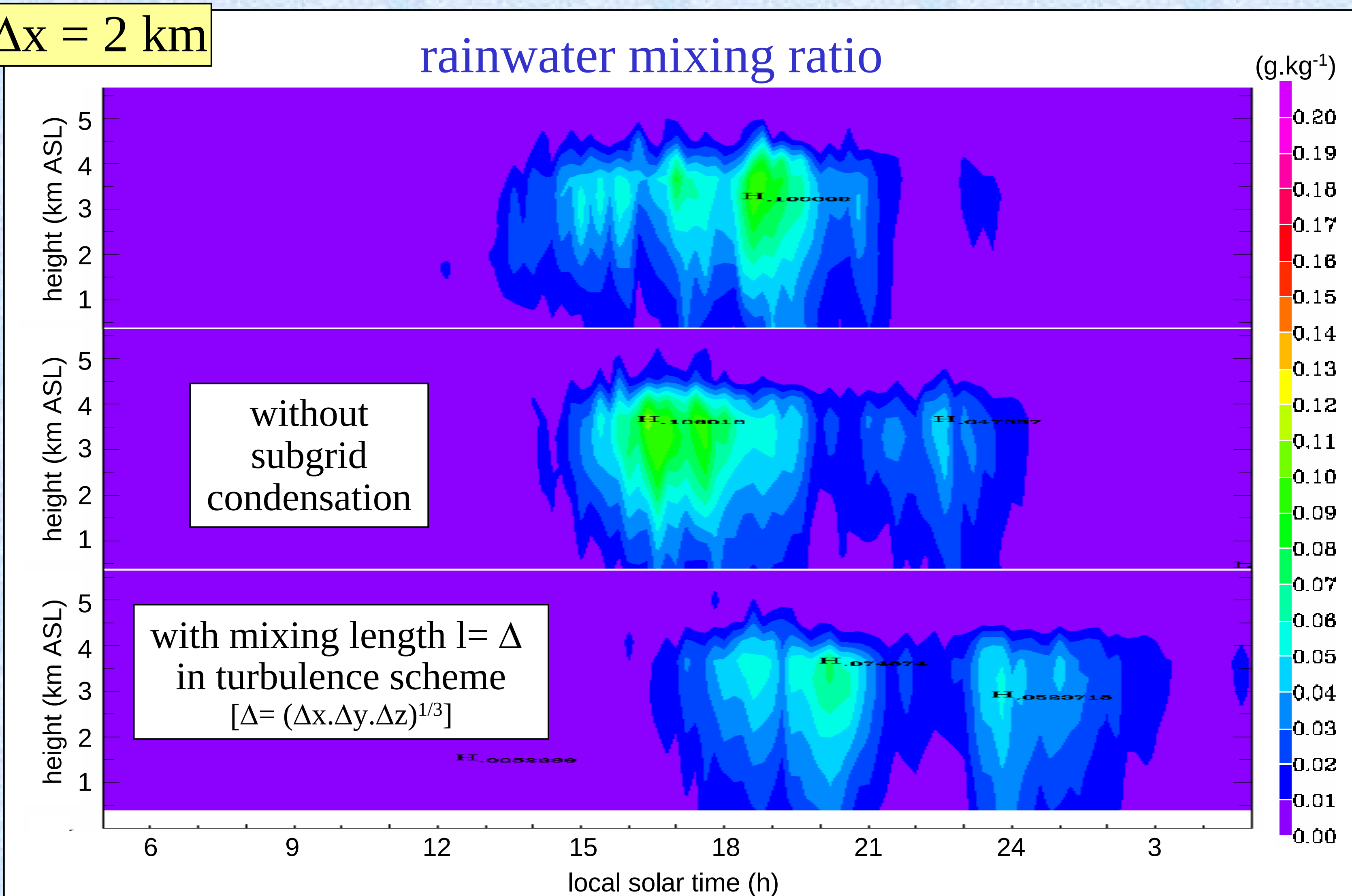
liquid water path



$\neq$: change from 1 to 0.3 of a coeff. involved in turbu. diffusivity

... to daytime precipitating convection

Δx = 2 km



highly sensitive, through complex interactions with simulated BL structure

summary

developement of CRMs began in the 80 ’s ; since then, they have been increasingly used (useful) and validated ; they constitute very valuable tools

this occurs ... even though a proper treatment of subgrid-scale fluxes in CRMs requires more than given by LES-based turbulence schemes

probably because the quality of a CRM simulation does not rely on its turbulent (dry) scheme alone

+ subgrid-scale processes also include subgrid-scale microphysics

+ subgrid-scale motions and subgrid-scale microphysics interact

specific issues regarding parametrisation in CRMs arise from the scales at which boundary layer and moist convection interact

computing power available now allows advancing on these issues
good timing as CRMs are sollicited to simulate more complex *objects*
and to answer more delicate questions

simulation of trade wind cumuli –Stevens et al. (2002)