Diurnal Cycle of Shallow Cumulus over Land

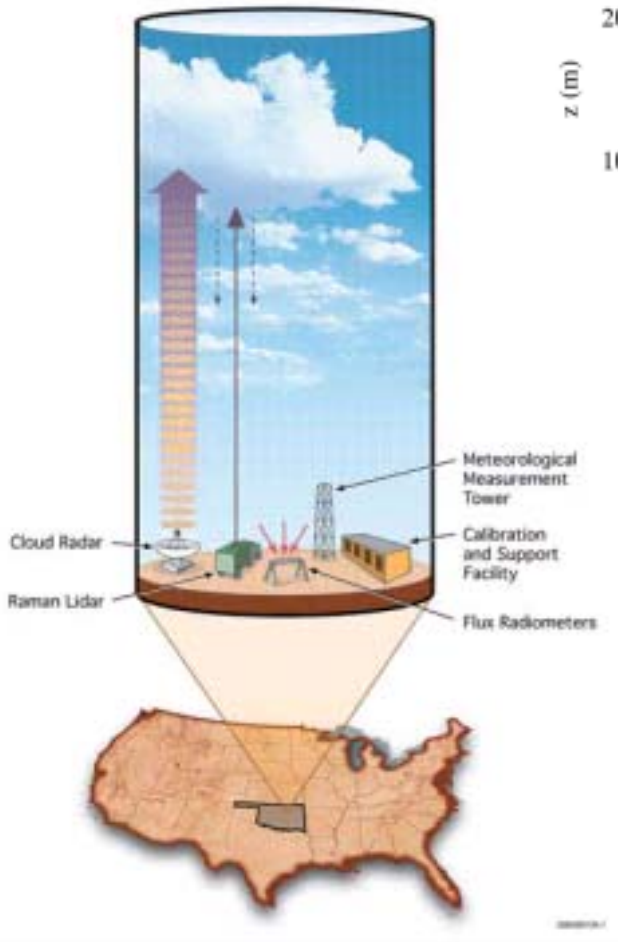
Geert Lenderink, *A. Pier Siebesma*
(siebesma@knmi.nl)

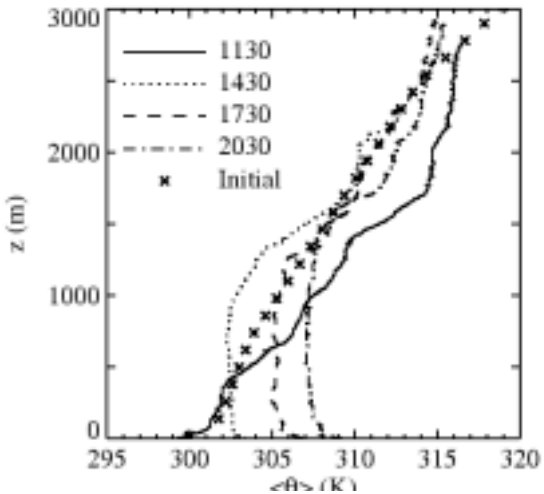
ARM Atmospheric Radiation Measurement Program

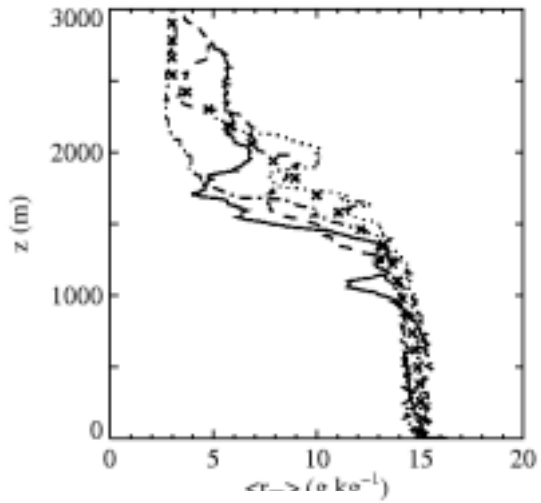
Questions:

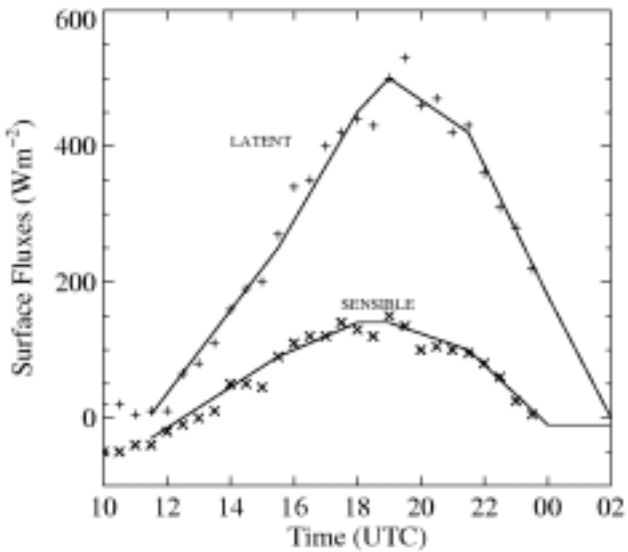
- Do models reproduce correct timing?
- Do scaling laws still apply?
- How is subcloud layer affected by cu?

•••• Set up of the case.









For details see: A.R. Brown et al. Q.J.Met.Soc. 128, 1075-1094 (2001) or:

www.knmi.nl/samenw/eurocs

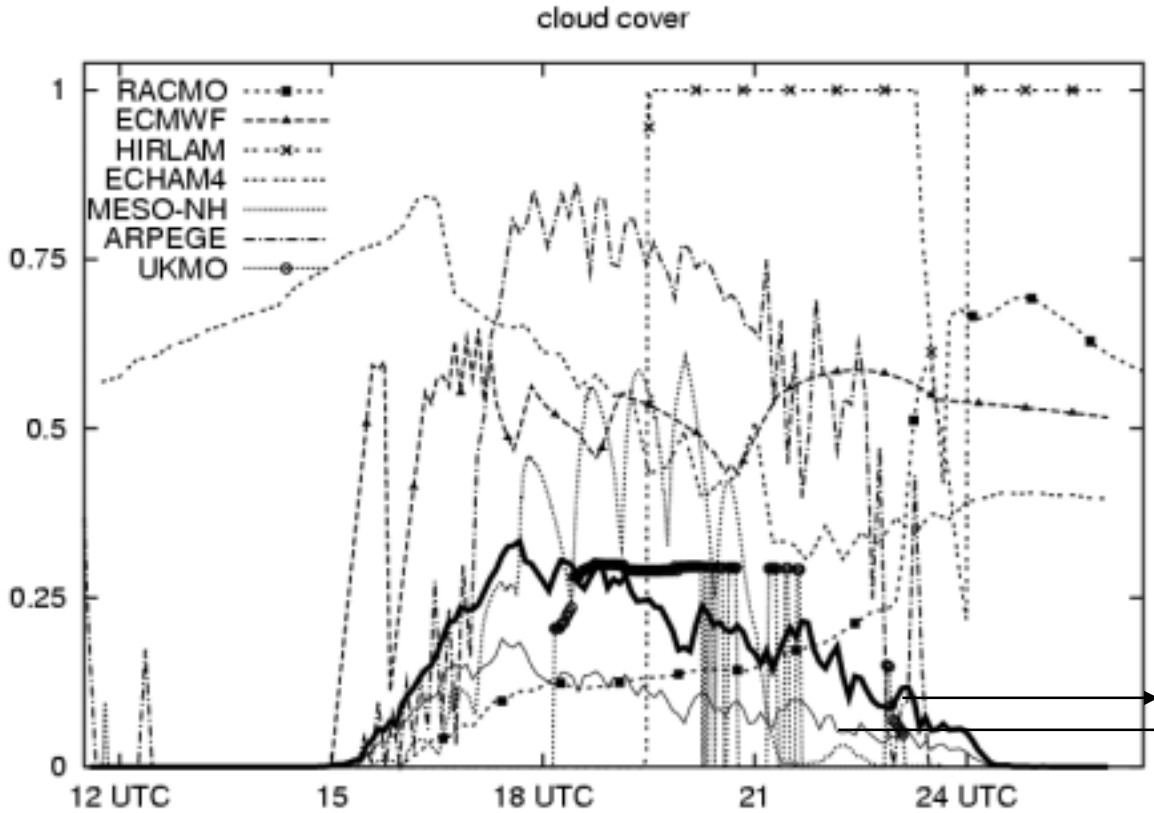
Participants

Model	Scientist	Diffusion	Conv	Cloud
Met office	Irons	PRO	MF (GR)	Statistical
ECHAM5	Chlond/ Mueller	TKE m	MF (T)	Prognostic ql, RH-based cc
RACMO	Lenderink	TKE m	MF (T)	Prognostic ql, RH-based cc
ARPEGE	Marquet/ Cheinet	TKE d	No (KF)	Statistical
ECMWF	Siebesma	PRO	MF (T)	Prognostic ql,cc
MESO-NH	Soares	TKE m	KF	Statistical
HIRLAM	Olmeda/ Sanchez/ Jones	TKE d	KUO	

Resolution and Updates

Model	Scientist	Stnd Res	High Res	Updates
Met office	Irons	yes	yes	no
ECHAM5	Chlond/ Mueller	yes	yes	no
RACMO	Lenderink	yes	yes	yes
ARPEGE	Marquet/ Cheinet	yes	yes	yes
ECMWF	Siebesma	yes	no	yes
MESO-NH	Soares	yes	yes	no
HIRLAM	Olmeda/ Sanchez/ Jones	yes	no	yes

Results (1) : Cloud Cover



Tot cc

max cc

cc_tot/cc_max = 2

100% : HIRLAM

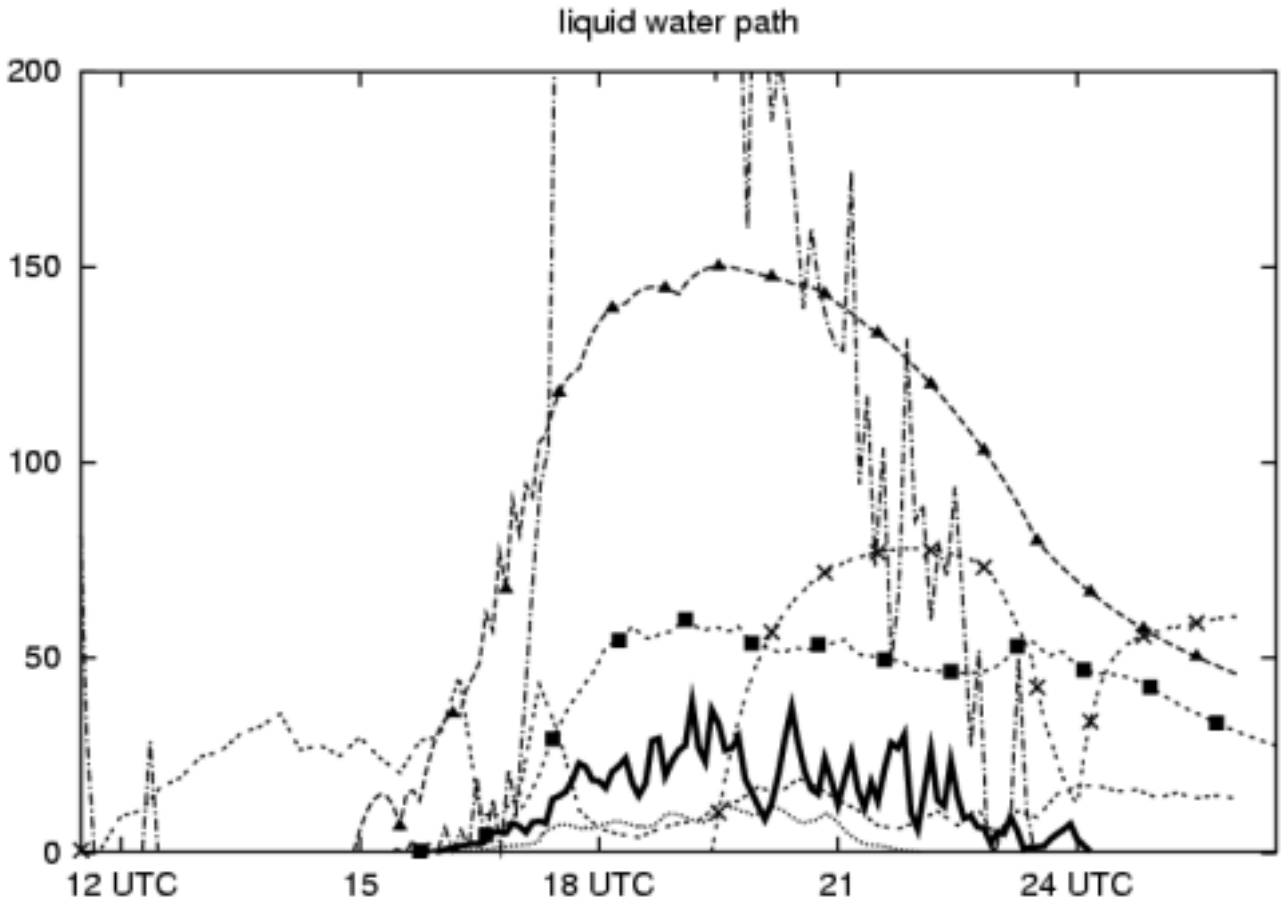
50~80%: ECMWF,ECHAM, ARPEGE

20~50%: MESO-NH, RACMO, MetOffice, ...

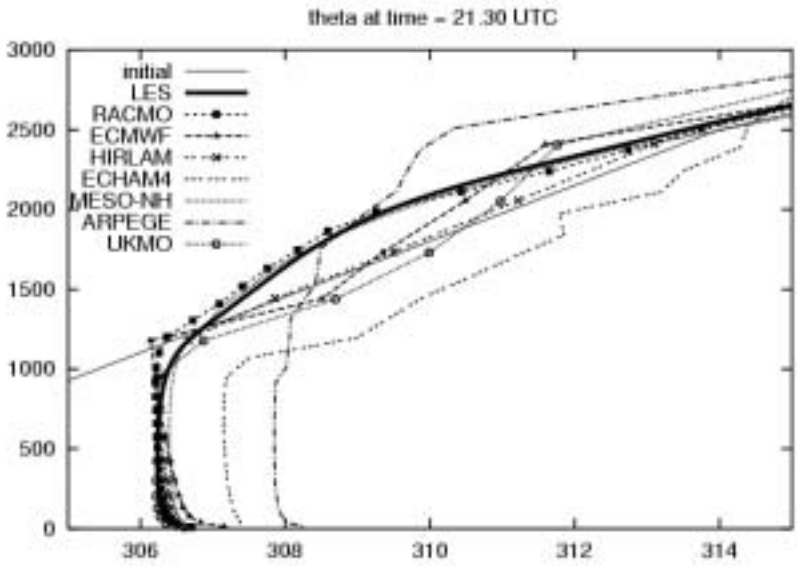
All models: Maximum Random Overlap:

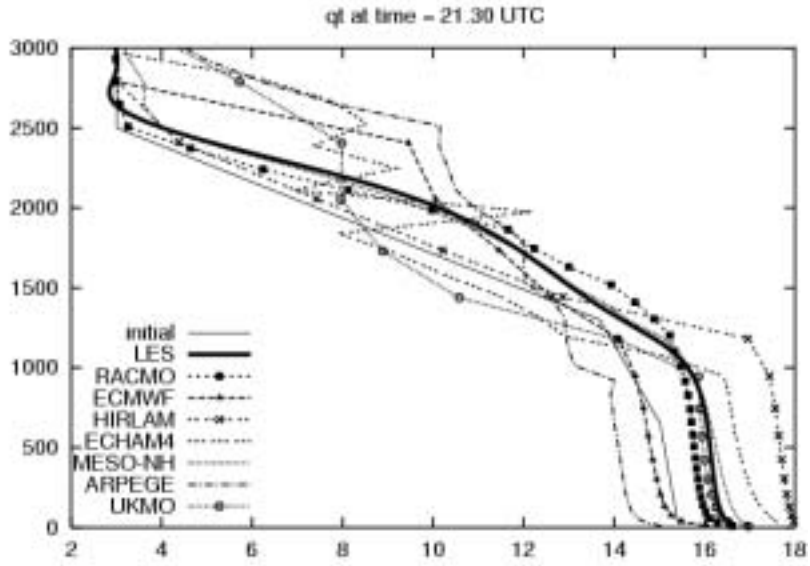
cc_tot/cc_max = 1 (except Arpege)

Results (2): Cloud Liquid Water Path



Results (3) Thermodynamic Profiles



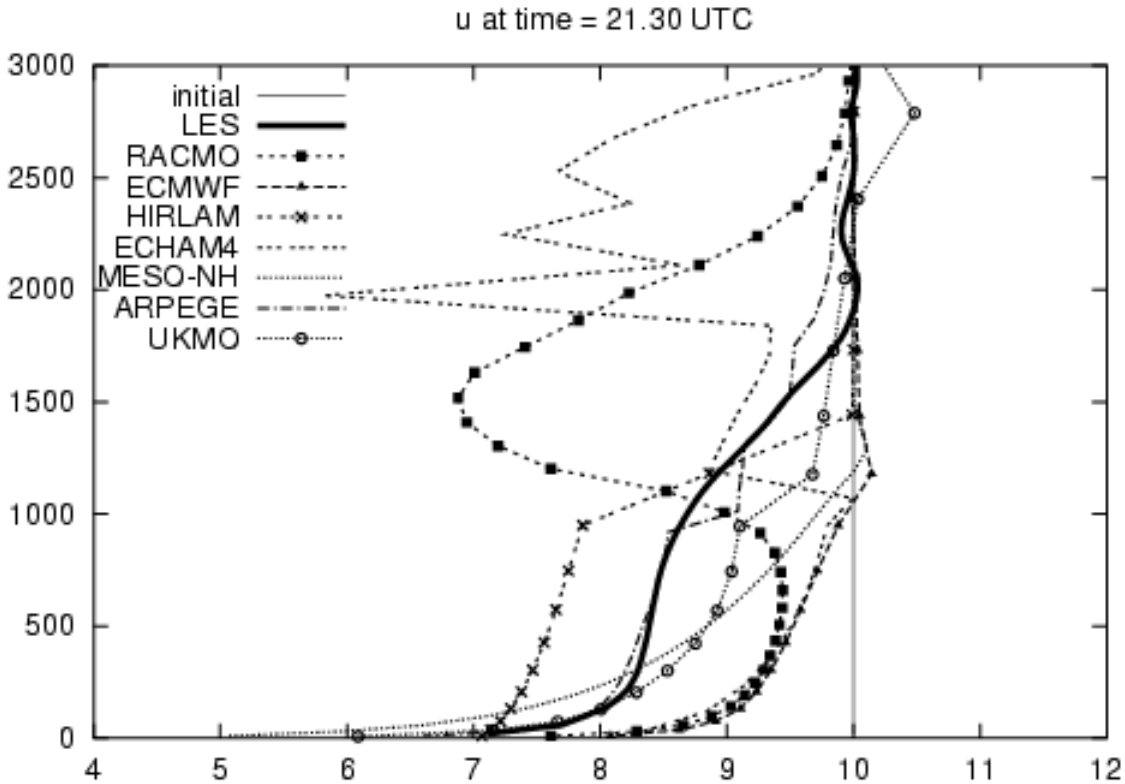


Too active mixing ECMWF, ARPEGE, Met Office

Too little mixing: HIRLAM

Ill-defined: ECHAM !!

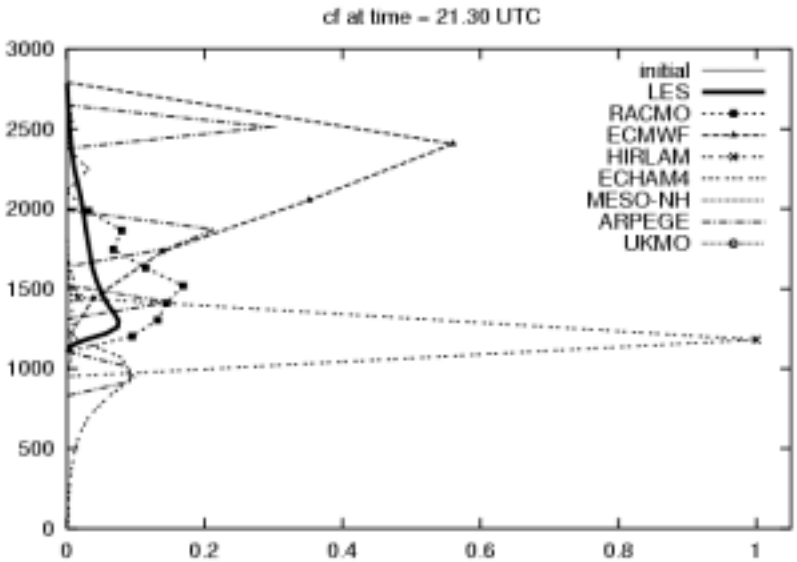
Results (4) Wind Profiles

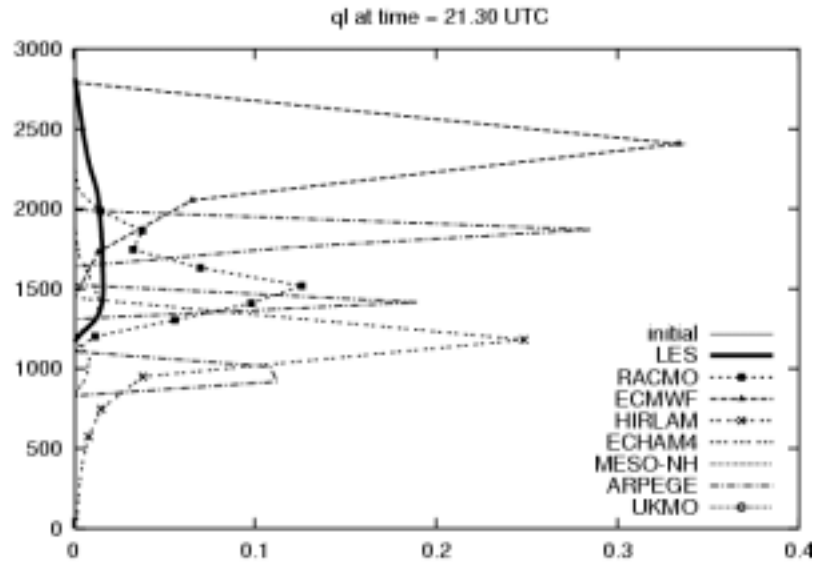


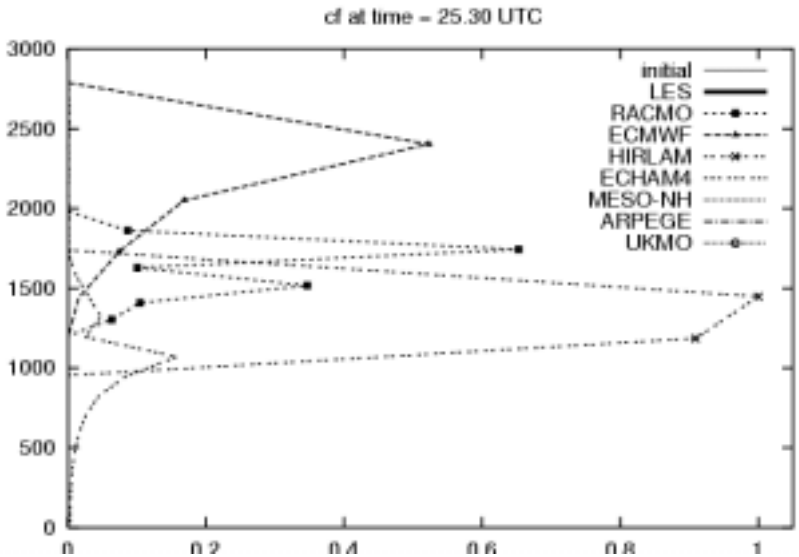
RACMO and ECHAM have unrealistic wind profiles (due to mass flux)

ARPEGE and ECHAM profiles are noisy

Results (4) Cloud Profiles







Analysis (1)

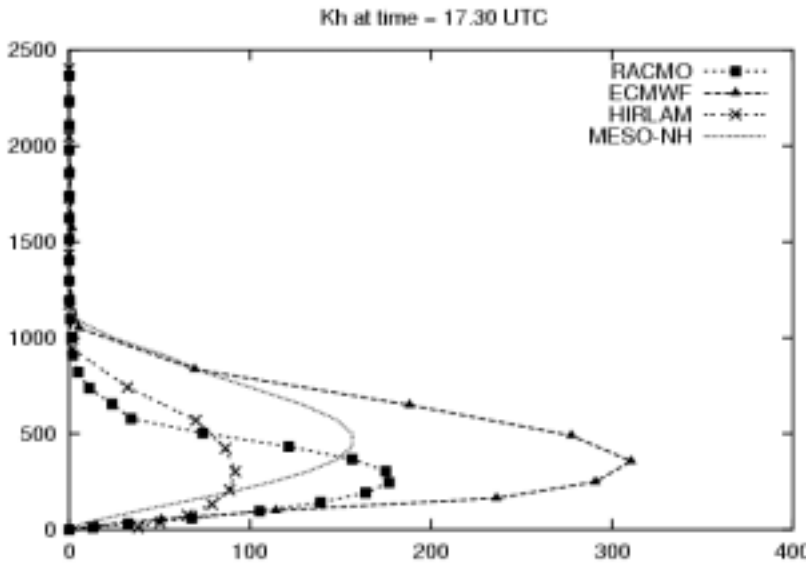
Three Schemes:

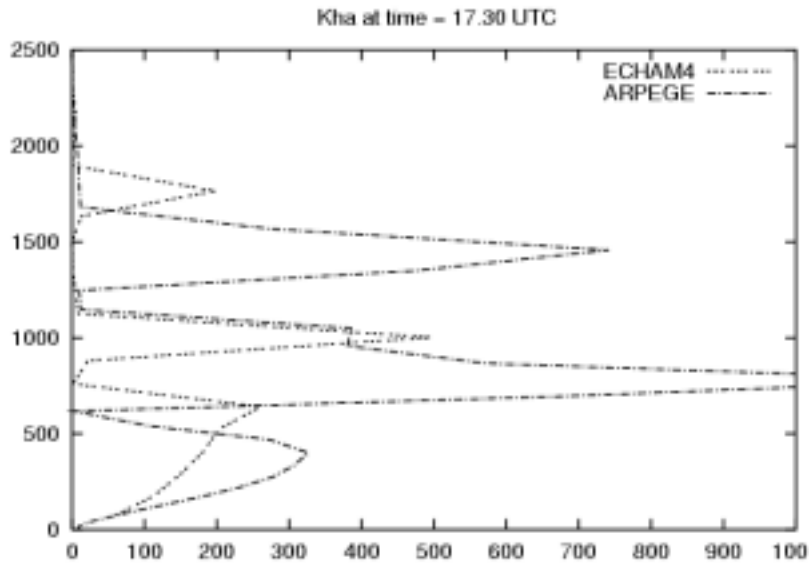
1. Turbulence Scheme

2. Convection Scheme

3. Cloud Scheme

Turbulence Schemes





- K-profiles (ECMWF, Met Office)
- TKE closure: $K = l\sqrt{E}$

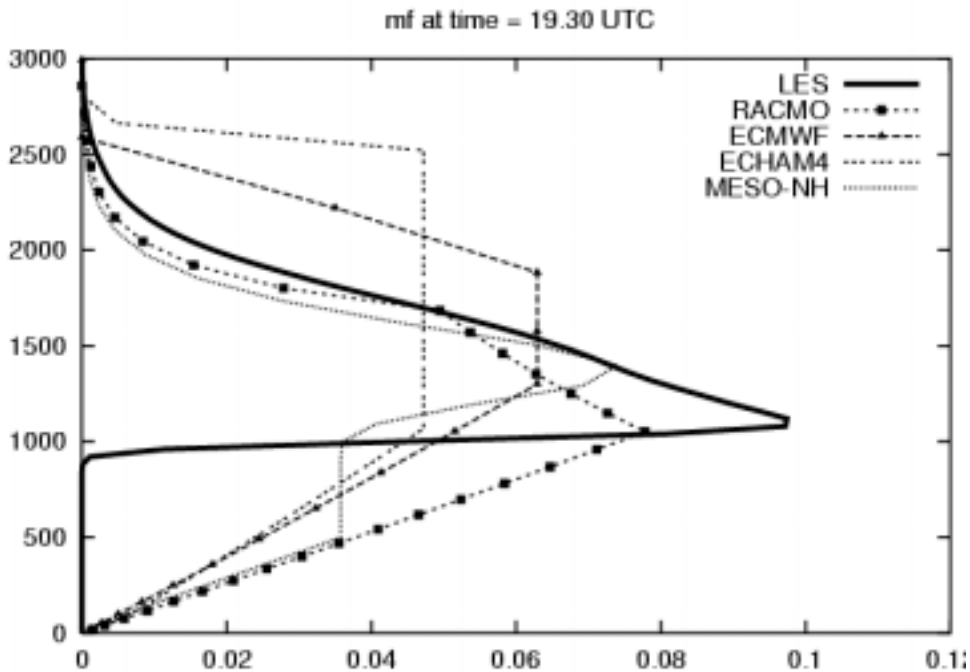
$$c_p \overline{w'\theta_v'} = \alpha c_p \overline{w'\theta_l'} + \beta L \overline{w'q_t'}$$

Convection

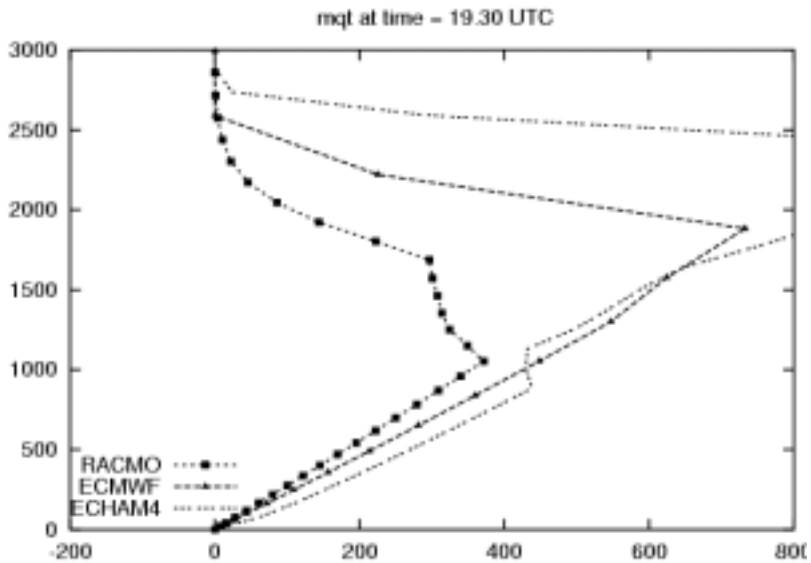
$$\overline{w'\phi'} = M(\phi_u - \bar{\phi}) \qquad \frac{\partial \phi_u}{\partial z} = -\varepsilon(\phi_u - \bar{\phi}) \qquad \frac{\partial \ln M}{\partial z} = (\varepsilon - \delta)$$

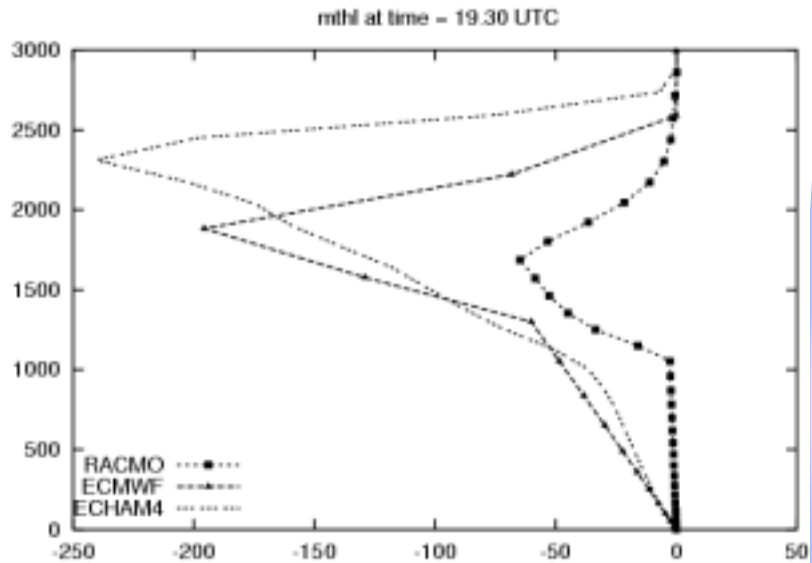
Mass Flux

Too active!!!



Convective Fluxes





1. (too much) drying and warming near cloud base (shuts off convection)
2. (too much) Moistening and Cooling near the inversion
3. (too) Extreme detrainment in the inversion

Interaction Turbulence/Convection and Numerics

Subcloud equilibrium closure: $$M_{base} = \frac{\overline{w'q'}_{t,srf} - \overline{w'q'}_{t,base}}{q_{u,base} - \bar{q}_{base}}$$

Tiedtke Mass flux extremely Diffusive

Cloud Schemes

1. Statistical Schemes Meso-NH, Arpege, Met Office
2. RH-based+prognostic ql: HIRLAM, ECHAM, RACMO
3. Prognostic ql and cc ECMWF

Collective Overestimation Cloud Cover

Howcome?

1. Models drift away from the realistic temp and humidity profiles

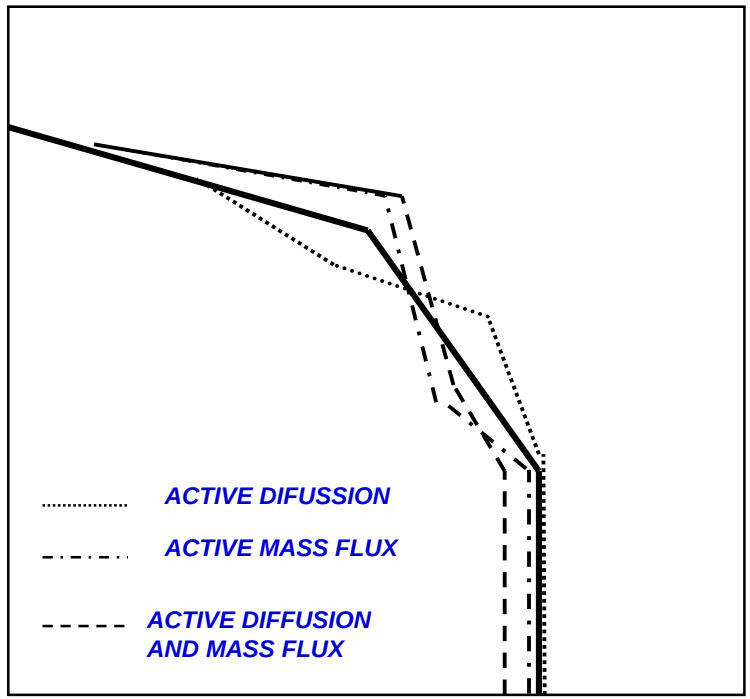
(SEE NEXt PAGE)

2. Prognostic schemes are tied too strongly to convective activity

$$\left(\frac{\partial q_l}{\partial t}\right)_{\mathrm{det}r} = q_l \max\left(0, -\frac{\partial M}{\partial z}\right)$$

ECHAM,ECMWF,RACMO

Summary (1)



Summary (2)

Turbulence Schemes:

Numerical Noise and instabilities (especially moist physics)

Convection Schemes:

Too much drying and warming above cloud base

Too much uncontrolled numerical diffusion

Updates(1)

ECMWF, RACMO

closure: Mb = aw*

RACMO:

switch of momentum transfer in convection

instead: $K_{mf} = l_{mf} M$

ARPEGE:

prognostic TKE-l scheme (Bougeault-Lacarrere)

mixing in moist conserved variables

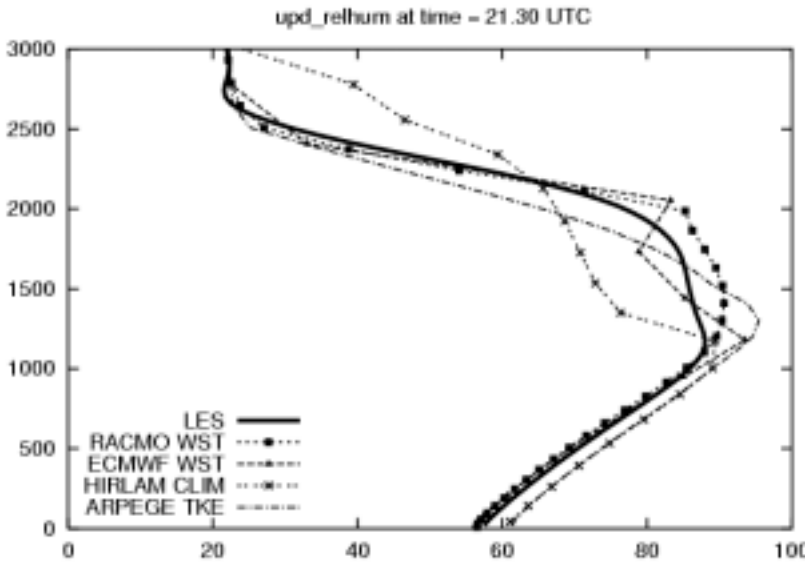
Kain-Fritsch convection

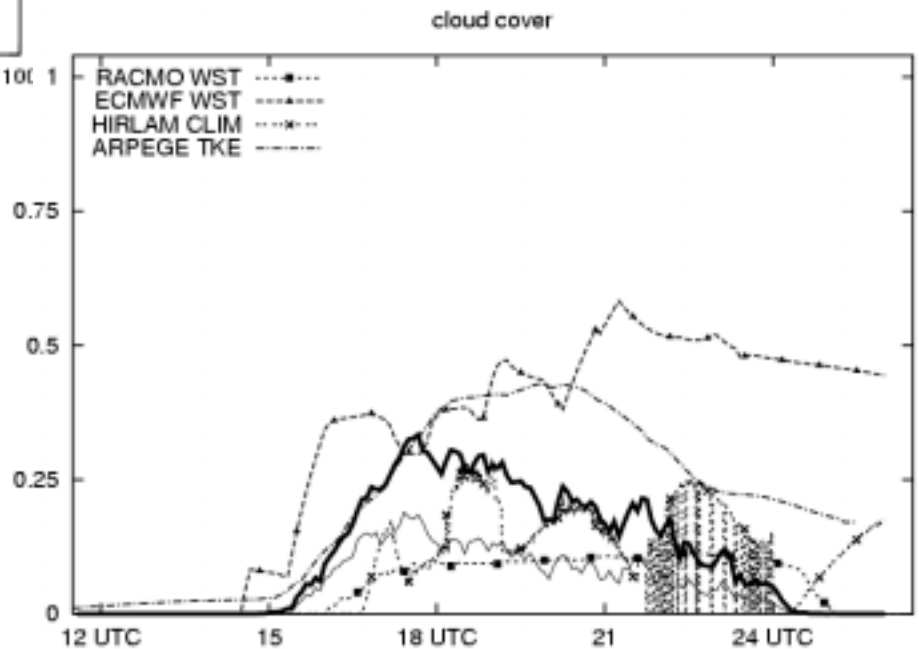
HIRLAM:

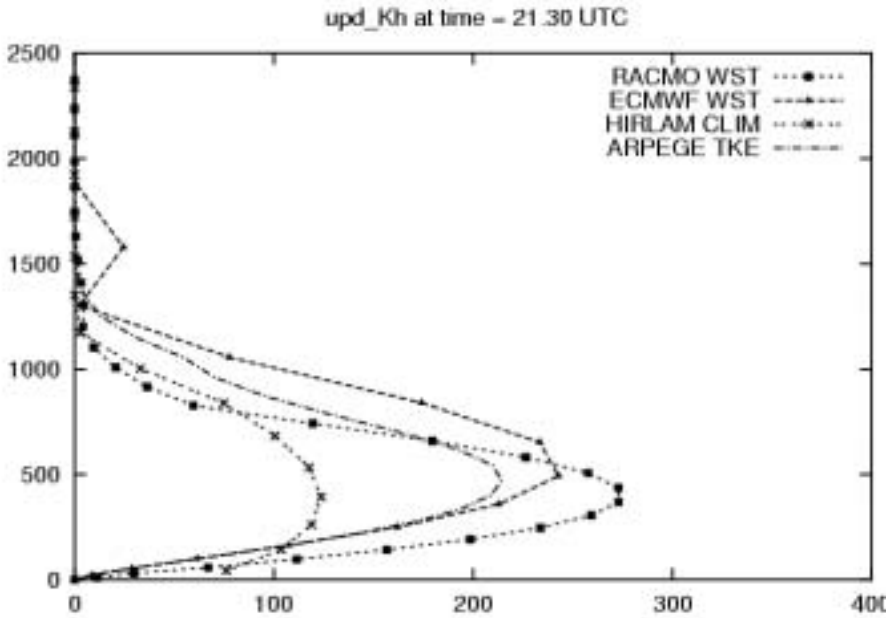
Kain-Fritsch convection

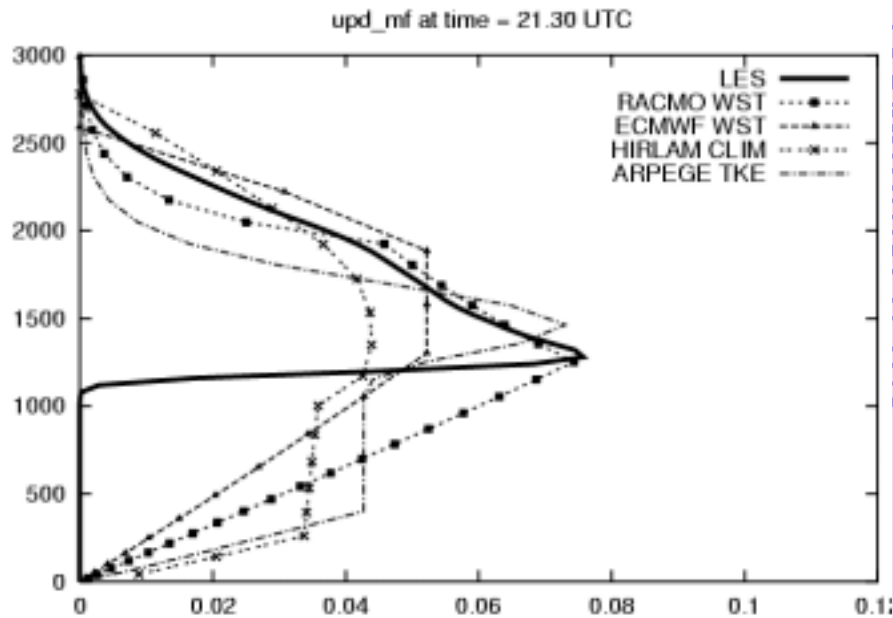
Rasch/Kristjansson cloud scheme

Updates (2)

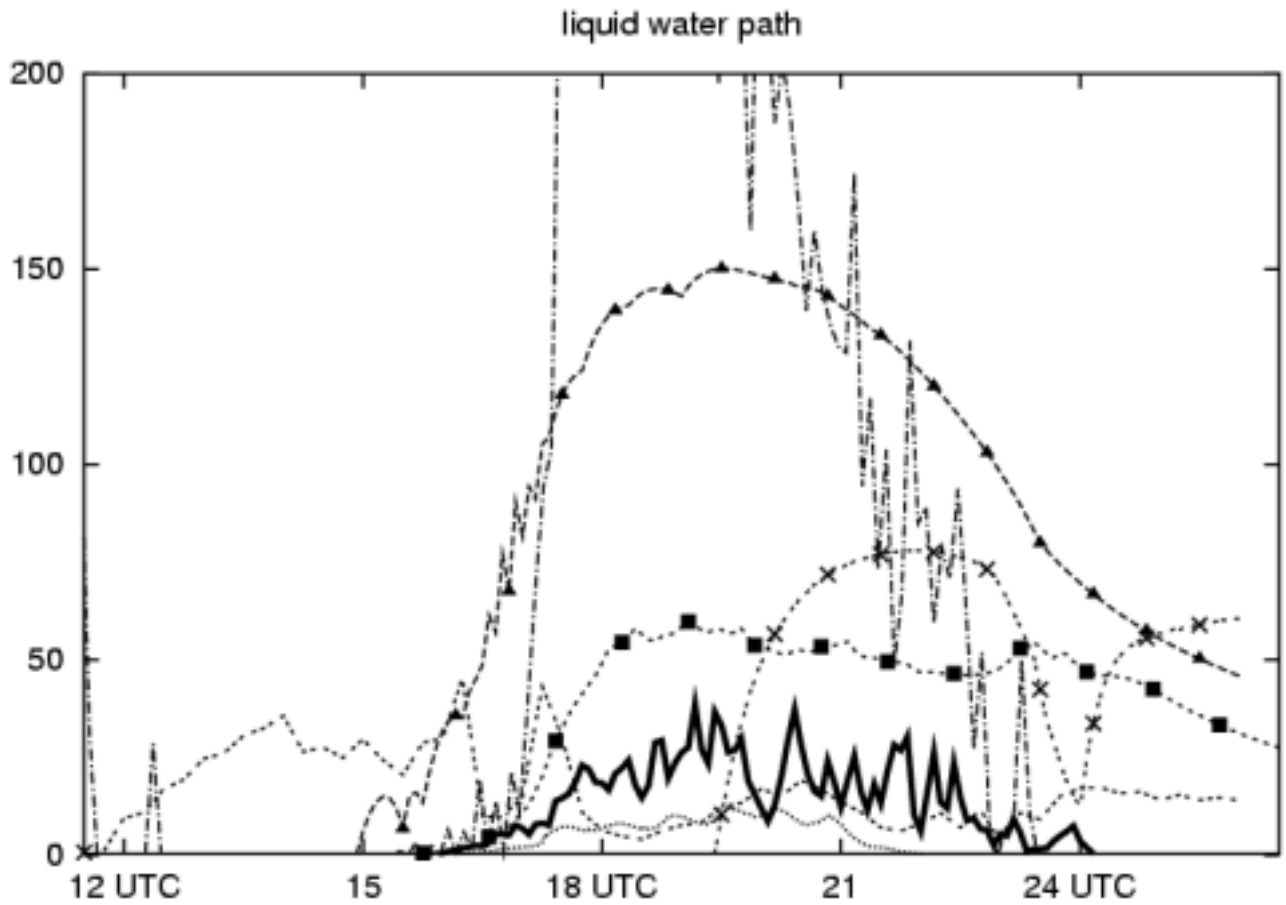








Results (2) Liquid Water Path.



Conclusions

1. Collective Overestimation of Cloud Cover and LWP

2. Clouds do not disappear at the end of the day.

3. Unwanted interactions between the various schemes leading to numerical noise.

4. This afternoon more specific analysis why!!