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ARM-cumulus: a test case for shallow convection

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Outline

- Case description
- Intercomparison of SCMs
- Initial profiles, and forcing fields
- Model set-up and configurations
- Sensitivity tests and results

ARM - cumulus

Case: **An idealization of observations**

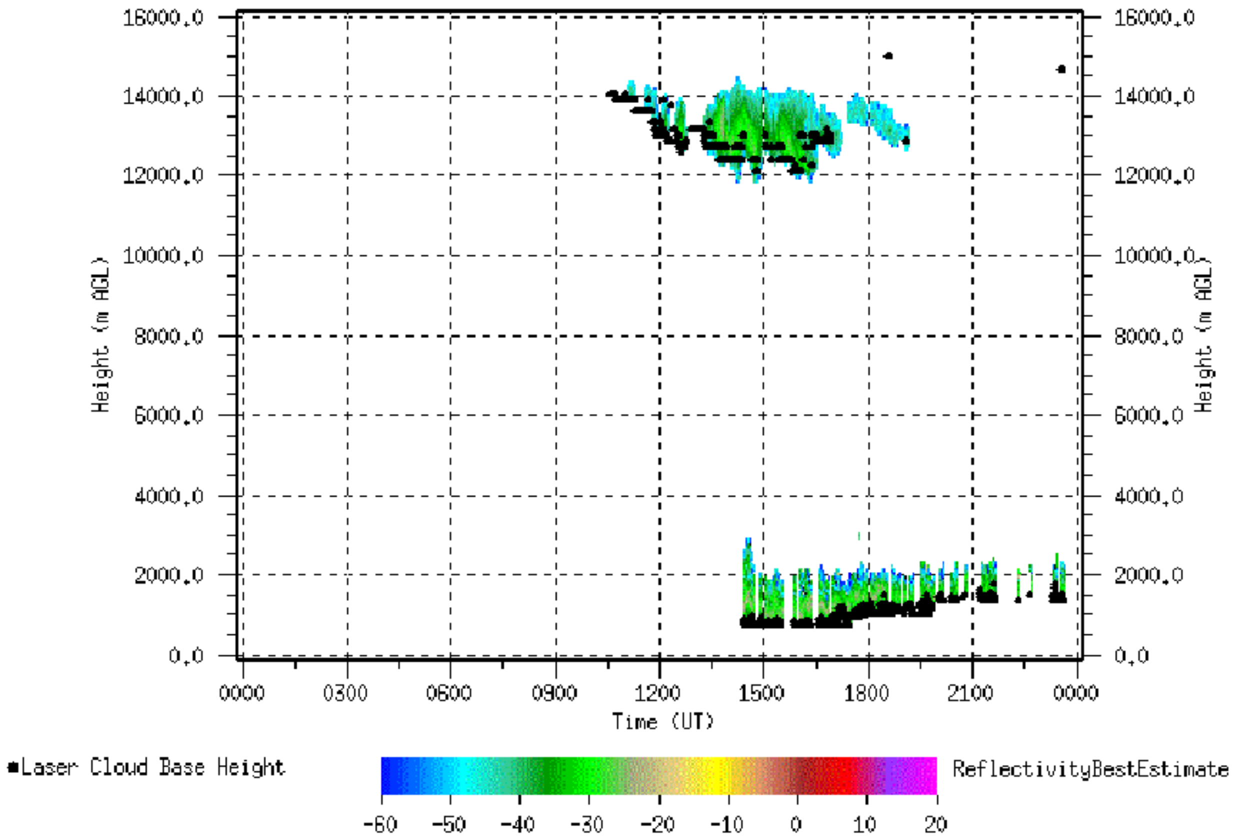
Location: ARM site on the Southern Great Plains (USA). Lat= 36.6º , Lon= -97.5º ; ME (MF)=320 m, Z_0=0.035 m (set in geophysical file)

Time: 21 June 1997.

An **intercomparison** by the GCSS WG-1 (GEWEX Cloud-System Study), aims to look at the development of shallow convection over land. (BOMEX, ATEX focused on shallow convection over sea).

Diurnal cycle of shallow cumulus convection (non-stationary continent case); ARM-Cumulus clouds developed at the top of an initially clear convective boundary layer.

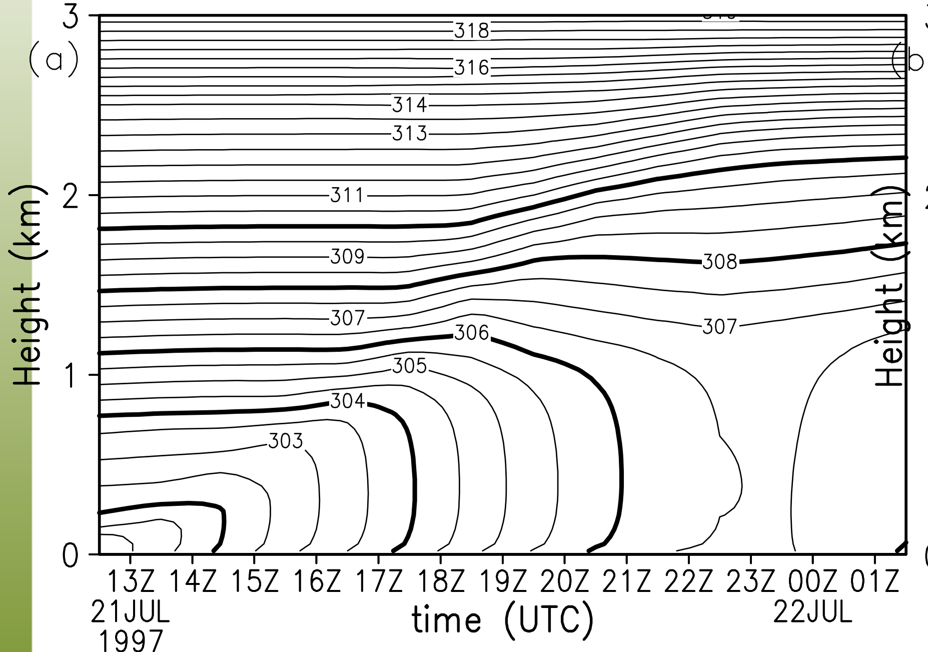
ARM - radar



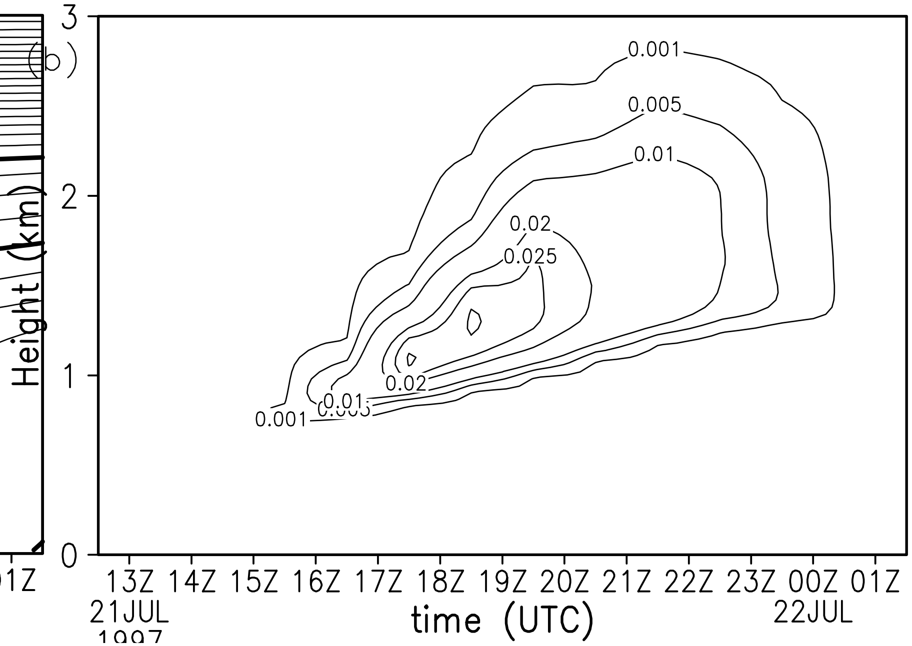
Radar reflectivity versus time at ARM site

ARM - LES

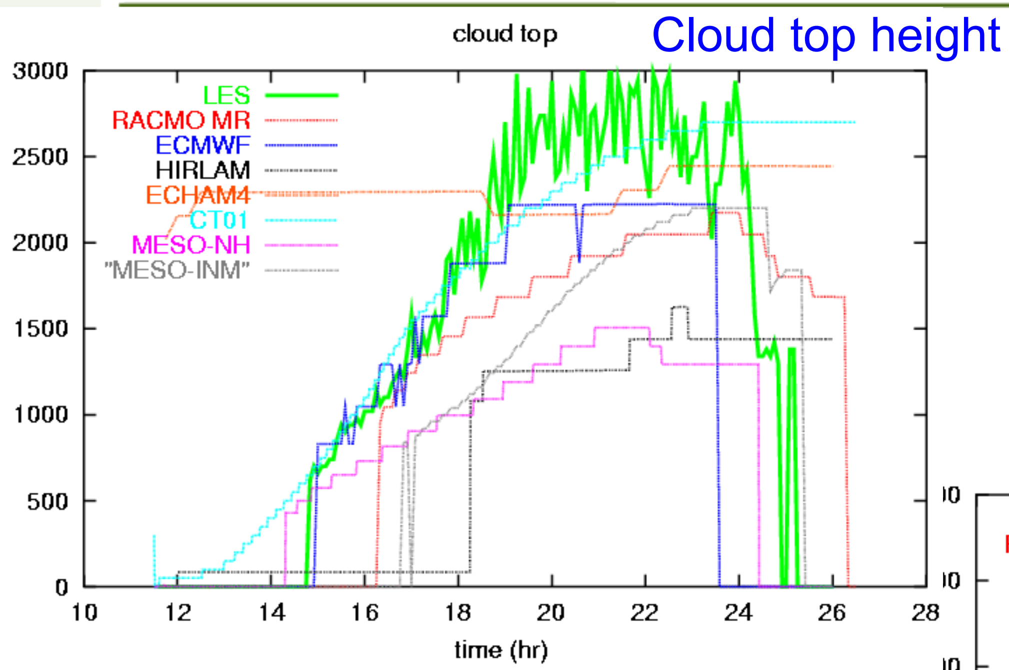
Potential temperature

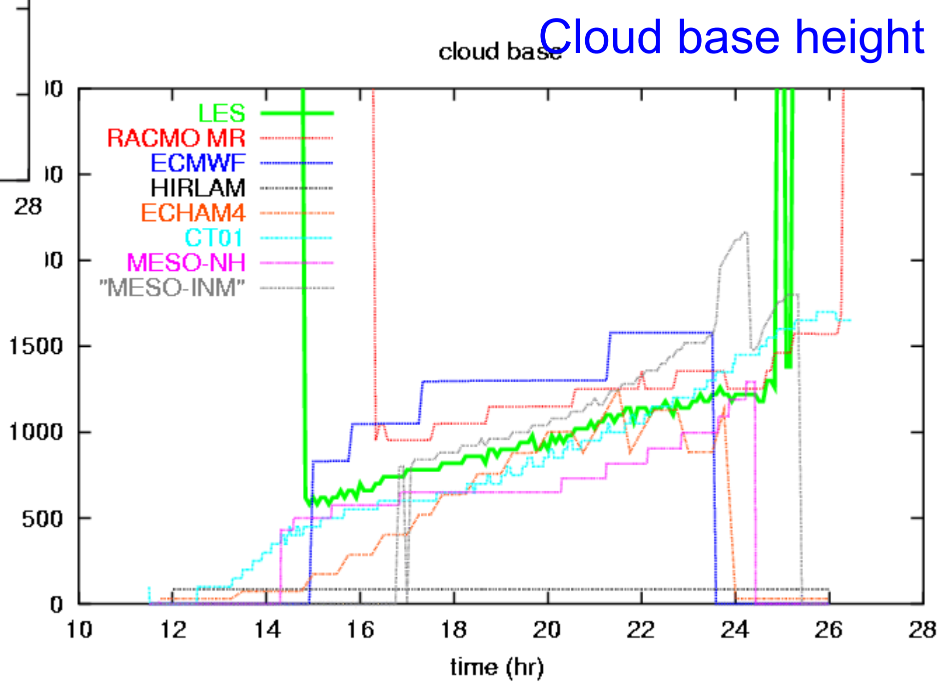


Cloud liquid water



ARM- intercomparisons





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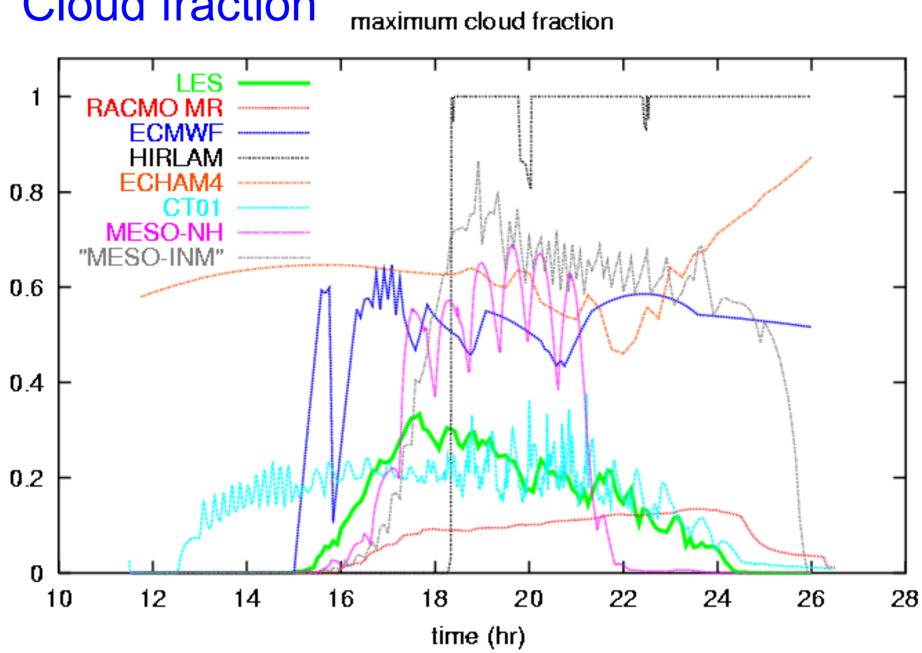
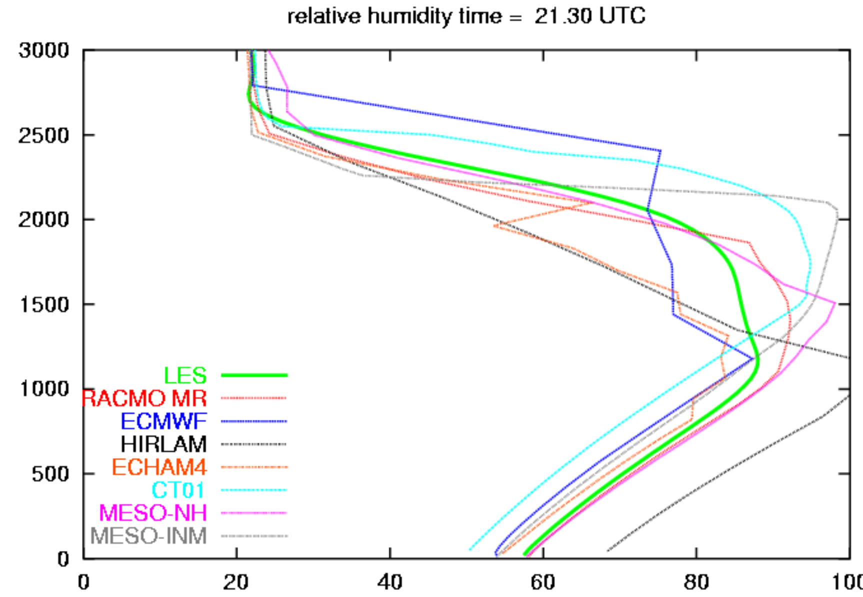
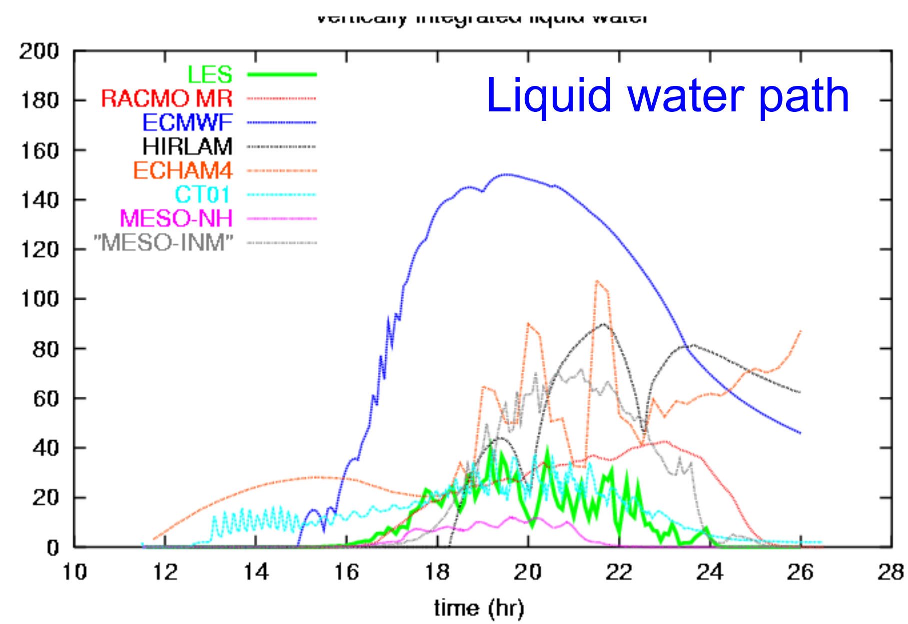
ARM- intercomparisons

Cloud fraction



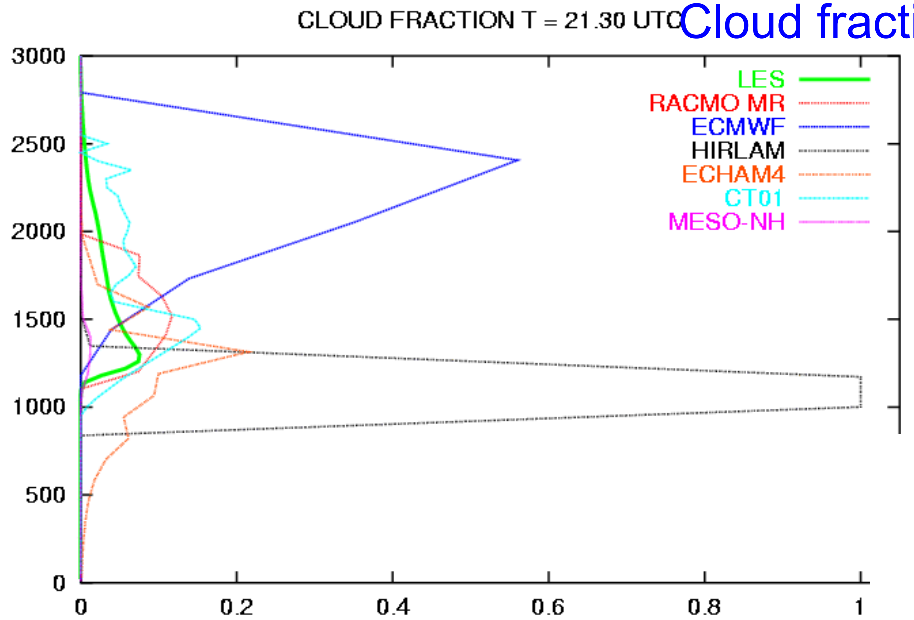
Relative humidity



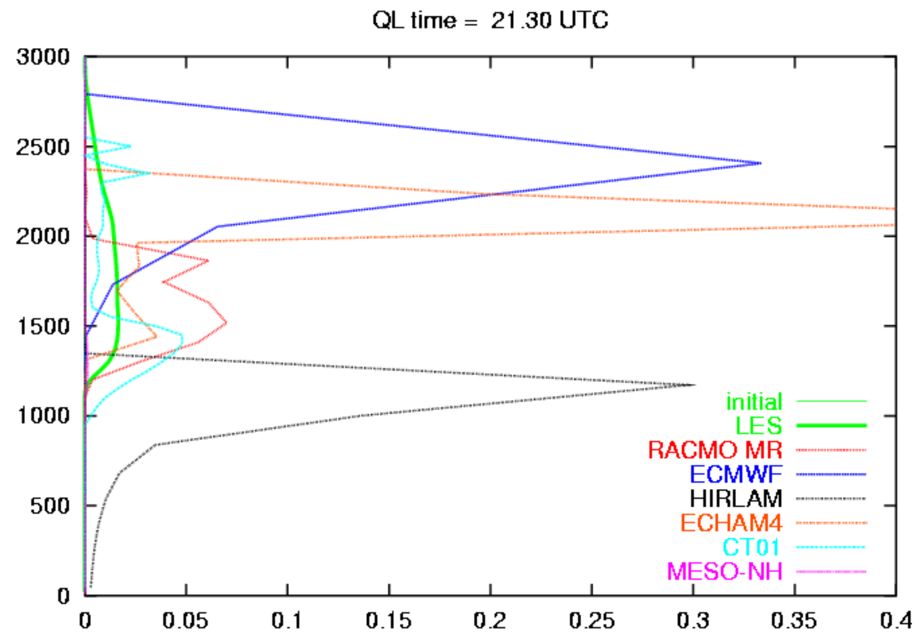


ARM- intercomparisons

Cloud fraction



Cloud liquid water content



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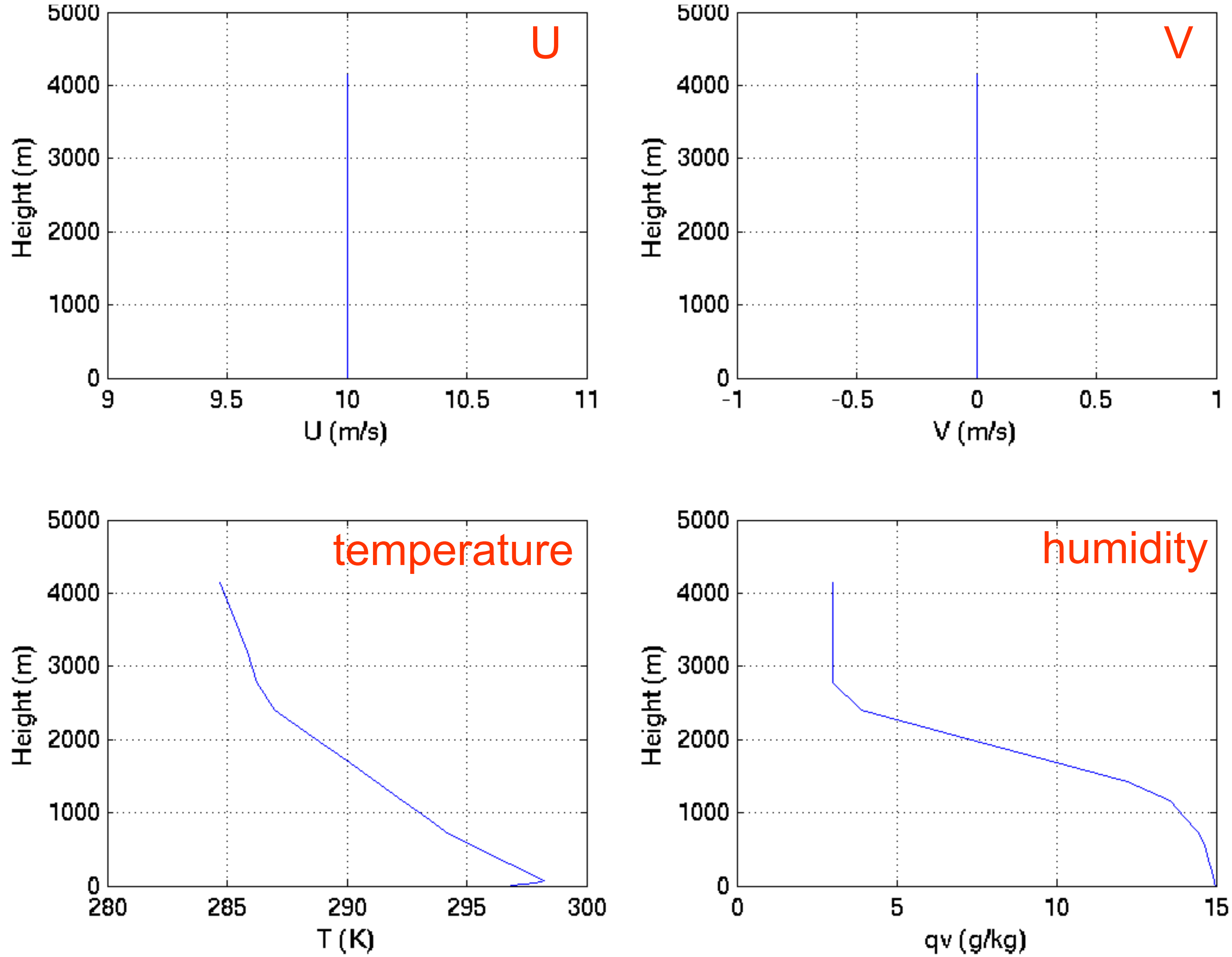
ARM- intercomparisons

Results of SCMs:

Although most SCMs were able to simulate a cumulus cloud, the SCMs typically suffered from the following deficiencies:

- too high cloud fractions and cloud liquid water.
- too shallow cloud layers, too moist in the cloud layer (too little activity, for most models with mass flux closure)
- difficulties with diurnal cycle (cloud disappearance after sunset). unrealistic thermodynamic profiles.
- considerable numerical noise.

SCM - Initial conditions



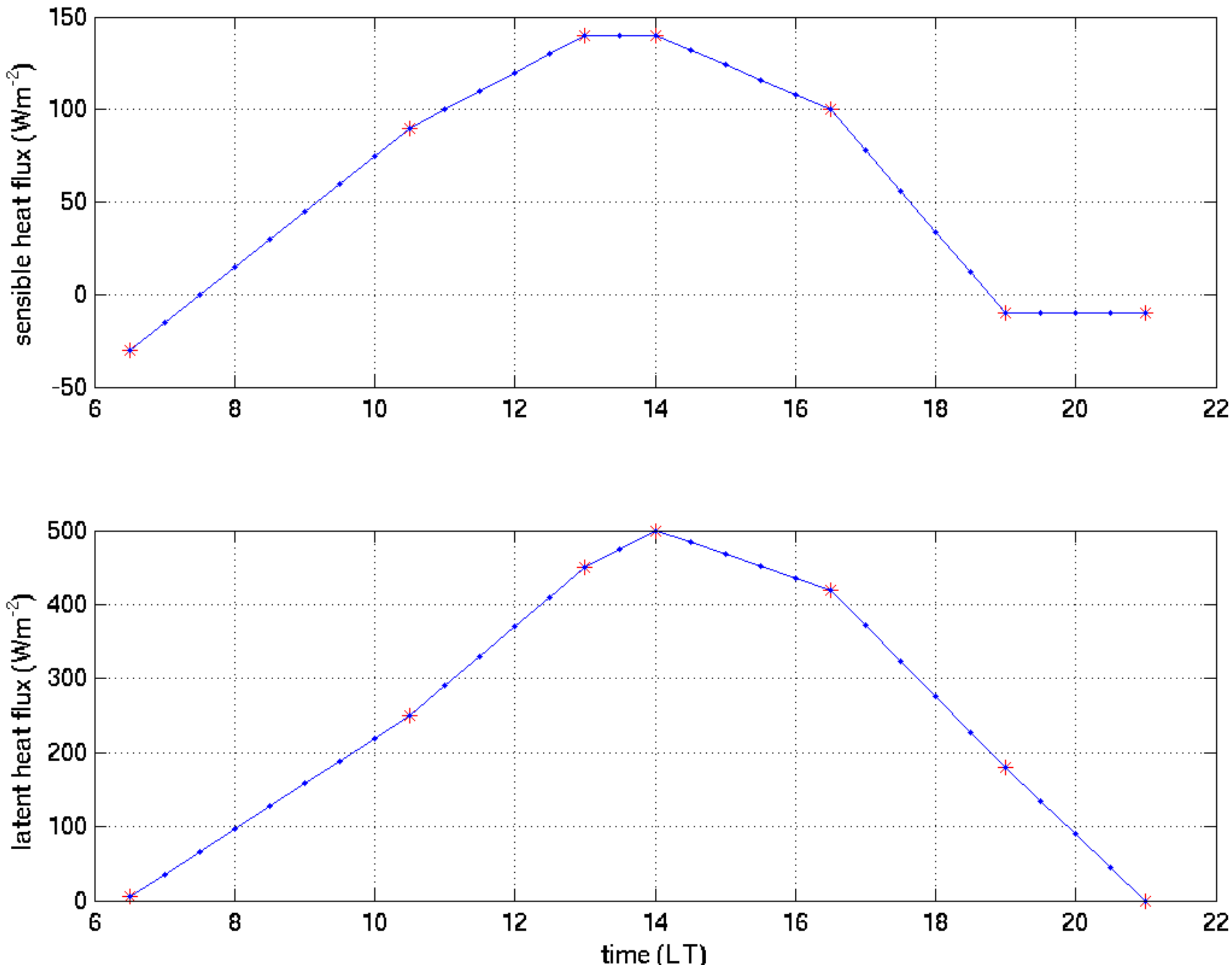
Forcing conditions - surface fluxes

Surface sensible and latent heat fluxes to be imposed in simulation

Time (s)	H (Wm^{-2})	LE (Wm^{-2})
41400 (11.5 UTC)	-30	5
55800 (15.5 UTC)	90	250
64800 (18 UTC)	140	450
68400 (19 UTC)	140	500
77400 (21.5 UTC)	100	420
86400 (00^+ UTC)	-10	180
93600 (02^+ UTC)	-10	0

Irregular time interval, linear interpolate to half hourly fields

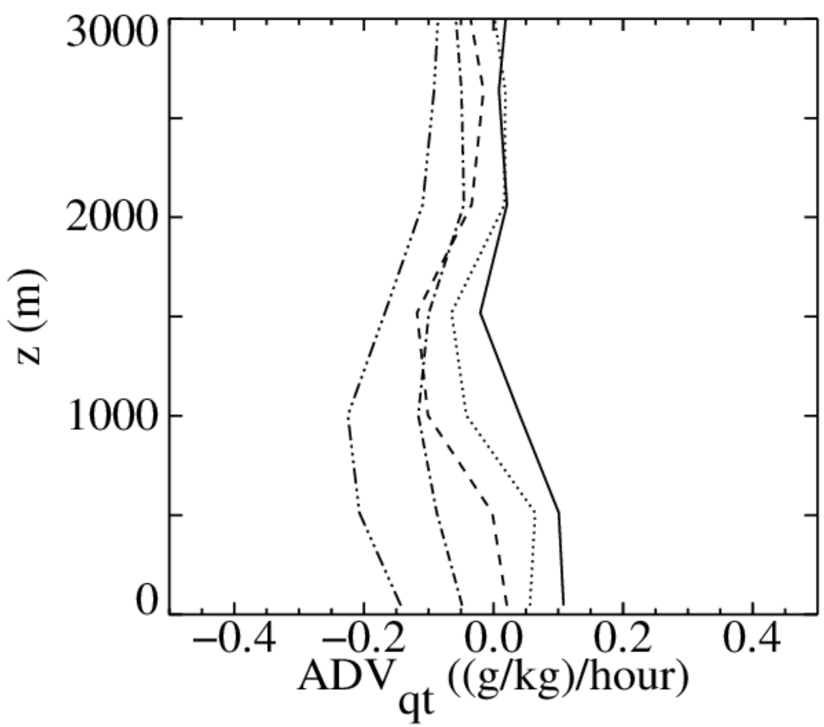
Forcing conditions - surface fluxes

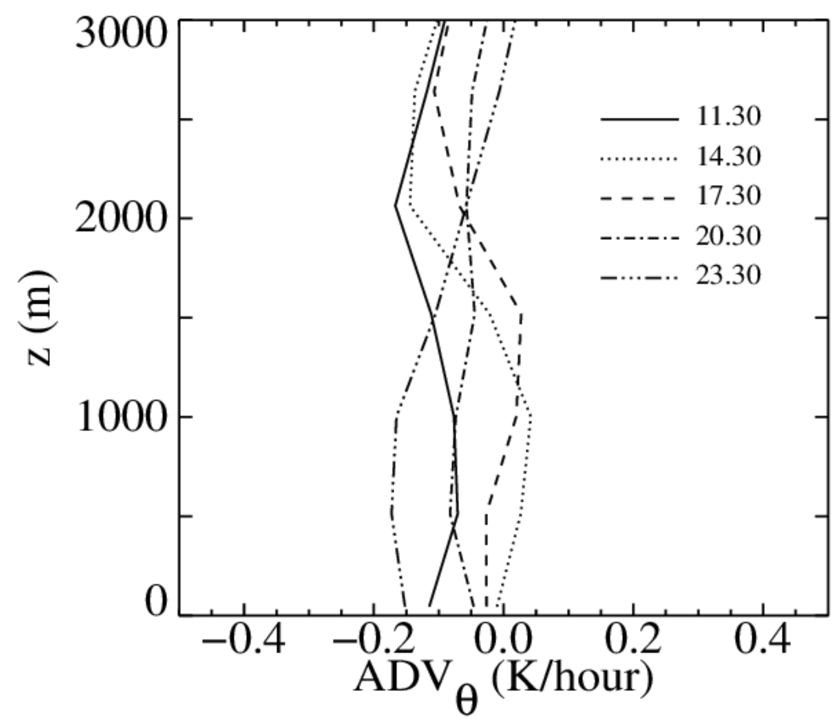


Forcing conditions - advection

Large scale forcing terms are estimated using a variational method on obs

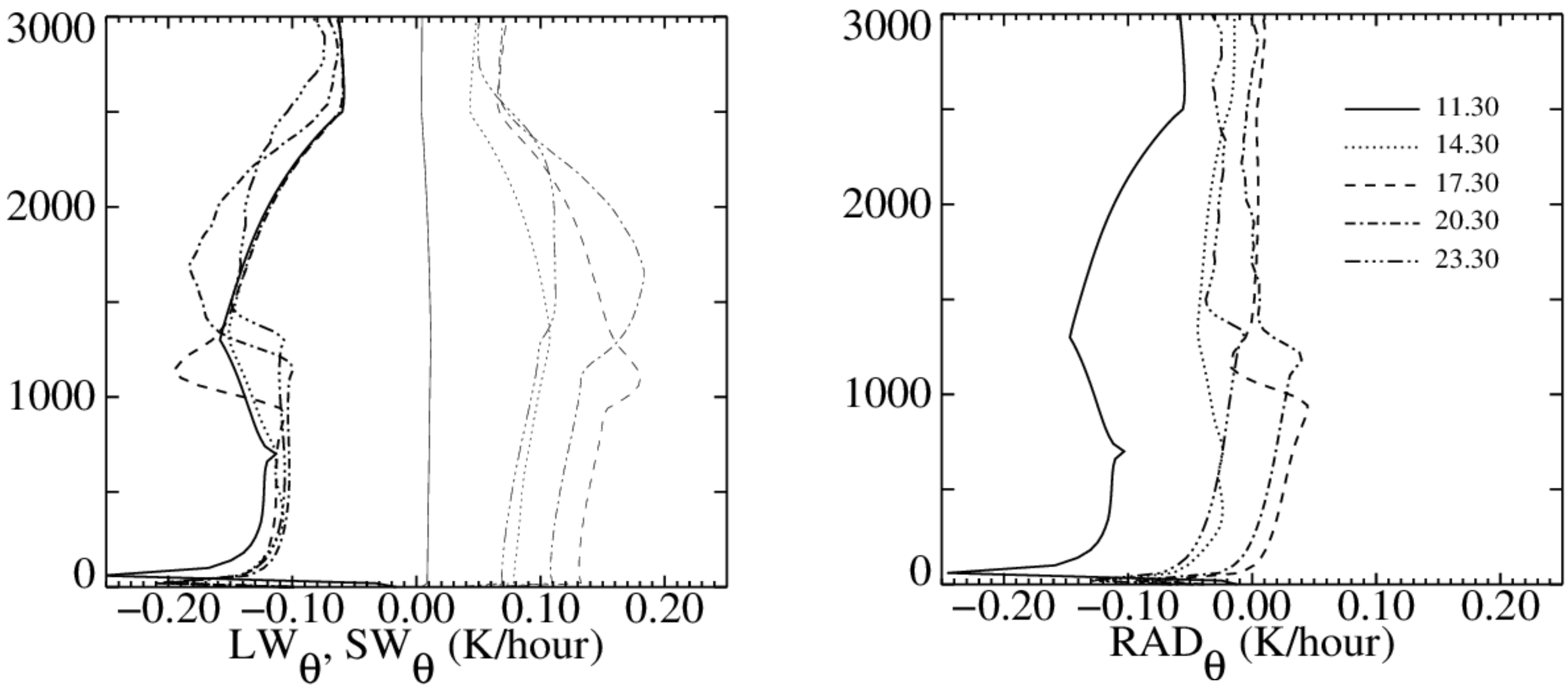
Combined horizontally & vertically advective tendency





Forcing conditions - radiation

Radiative tendencies are estimated from a simulation with interactive radiation scheme



Diagnosed LW, SW, and total radiation heating rates (averaged across horizontal domain and over one hour).

Forcing conditions - advection & radiation

Simple representation of advection and radiation:
Linear interpolation is used to calculate forcings at intermediate times.

Time (s)	A_θ	R_θ	A_{qt}
	(K/hour)	(K/hour)	((g/kg)/hour)
41400 (11.30)	0.000	-0.125	+0.080
52200 (14.30)	0.000	0.000	+0.020
63000 (17.30)	0.000	0.000	-0.040
73800 (20.30)	-0.080	0.000	-0.100
84600 (23.30)	-0.160	0.000	-0.160
93600 (02.00+)	-0.160	-0.100	-0.300

Forcing conditions - advection & radiation

For z < 1000m

$$\frac{\partial \theta}{\partial t} = ADV_\theta + RAD_\theta = A_\theta + R_\theta$$

$$\frac{\partial q_t}{\partial t} = ADV_{qt} = A_{qt}$$

Forcing files (half hourly):

ADV_θ -> ADV_TT

ADV_HU

For 1000m <= z <= 3000m

$$\frac{\partial \theta}{\partial t} = ADV_\theta + RAD_\theta = (A_\theta + R_\theta)\,(1 - (z - 1000)/2000)$$

$$\frac{\partial q_t}{\partial t} = ADV_{qt} = A_{qt}\,(1 - (z - 1000)/2000)$$

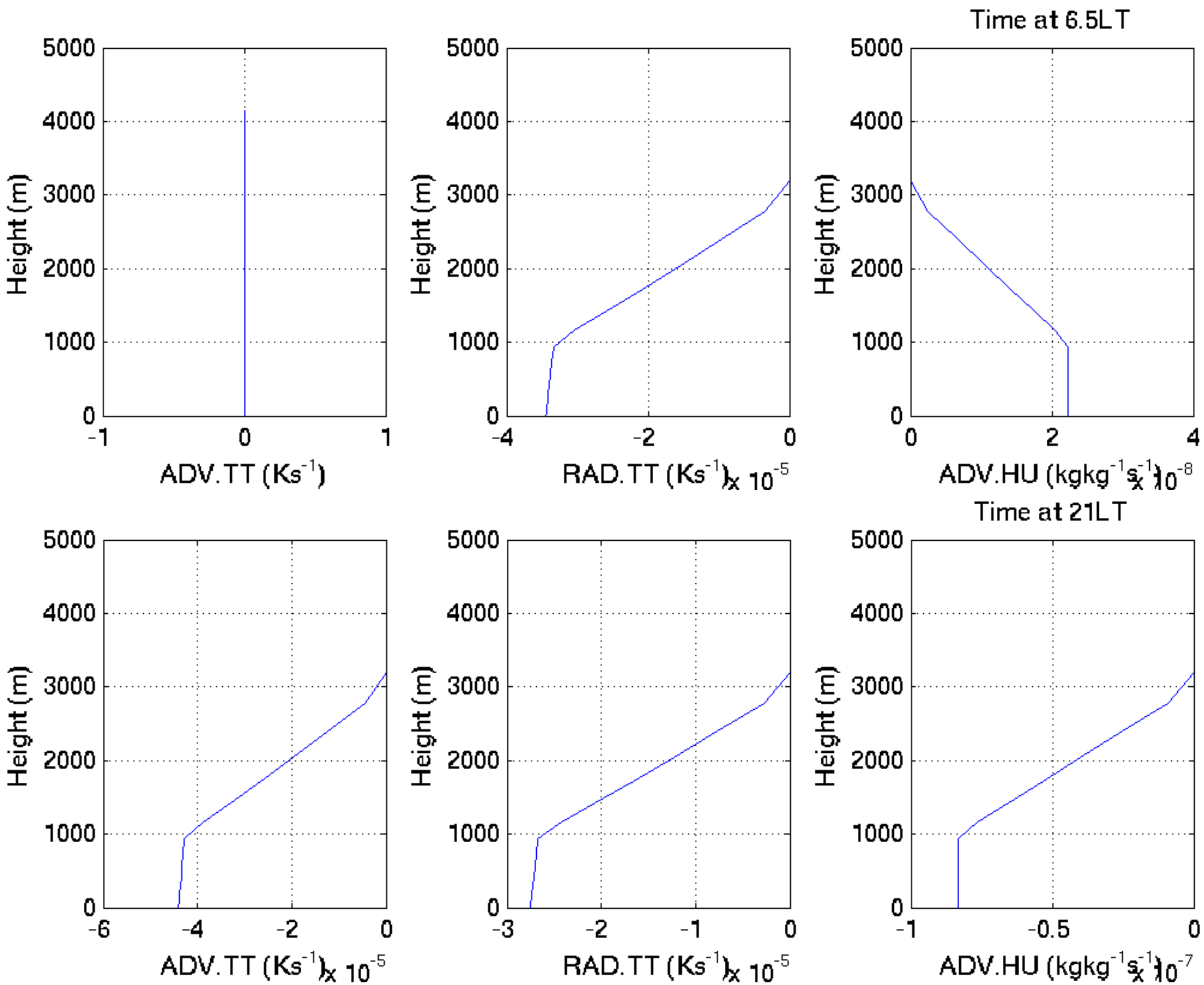
For z > 3000m

$$\frac{\partial \theta}{\partial t} = ADV_\theta + RAD_\theta = 0$$

$$\frac{\partial q_t}{\partial t} = ADV_{qt} = 0$$

Magnitudes of large-scale advective forcing and radiative tendencies to be applied in lowest 1000 m. Reduced tendencies are to be applied above 1000 m.

Forcing conditions - advection & radiation



t = 11:30

⋮

t = 02:00^{+}

= 11:30 ~ 02:00 UTC
alf hourly, 30 files.

Model configuration and set-up

```
&convection_cfgs

DEEP            = 'nil'     ,

BKF_LDEEP          = .false.    , BKF_LSHAL       = .false.    ,
BKF_LDOWN          = .true.     , BKF_LSHALM      = .false.    ,

BKF_LREFRESH       = .false.    ,
BKF_LSETTADJ       = .false.    ,
BKF_XTADJD         =  3600.     , BKF_XTADJS      =  10800.    ,

BKF_KENS           = 0          , BKF_KCH         = 0          ,
BKF_KTDIA          = 1          , BKF_KICE        = 1          ,
BKF_LCH1CONV       = .false.    ,

KFCDEPTH       = 4000.     ,
KFCDLEV        = 0.5       ,
KFCDET         = 0.        ,
KFCRAD         = 1500.     ,
KFCTIMEA       = 3600.     ,
KFCTIMEC       = 3600.     ,
KFCTRIG4       = 0.,0.,0.05,0.05,
KFCTRIGL       = 0.01      ,
KFCTRIGLAT     = .true.    ,
TRIGLAT        = 25.,30.   ,
SHAL           = 'ktrsnt', 'ktrsnt_mg'
```

```
&surface_cfgs

AGREGAT        = .true.    ,
ICELAC         = .false.   ,
ICEMELT        = .true.    ,
IMPFLX         = .false.   ,
LIMSNODP       = .true.    ,
SCHMSOL        = 'ISBA'    ,
Z0TLAT         = 25.,30.   ,
ZTA            = -1.       ,
ZUA            = -1.       ,

&physics_cfgs

RADIA          = 'nil' ,
KNTRAD_S       = '30m'     ,
RADFLTR        = .false.   ,
TS_FLXIR       = .true.    ,
STRATOS        = .true.    ,

GWDRAG         = 'nil'     ,
NON_ORO        = .false.   ,
LMETOX         = .false.   ,
LONGMEL        = 'boujo' or 'blac62'   ,
FLUVERT        = 'clef'    ,
PBL_SHAL       = 'nil' /  'conres'   ,
STCOND         = 'nil'     ,
INILWC         = .false.   ,
KTICEFRAC      = .false.   ,
PCPTYPE        = 'bourge'  ,
QCO2           = 380.0     ,
```

Model configuration and set-up

Sensitivity tests of shallow convection schemes:

Shal=ktrsnt; (water conserved)

Shal=ktrsnt_mg;

Shal=bechtold (available soon)

No deep convection

No explicit microphysics

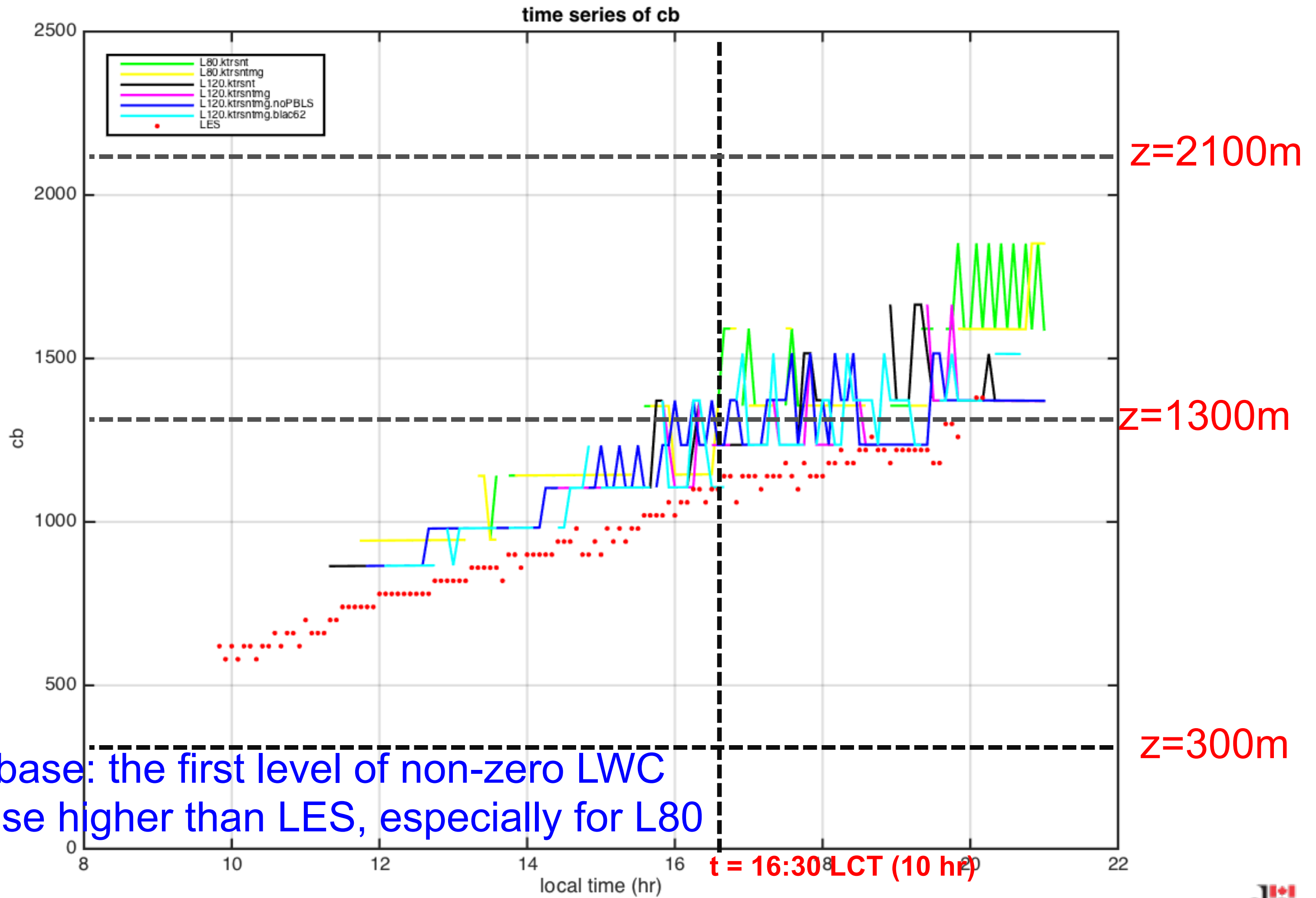
No radiation scheme

Land surface scheme: ISBA

Fluvert: CLEF (will do moistTKE sensitivity test later)

Tried different horizontal Resolution: 0.25, 1
Tried high vertical resolution (L80, L120)

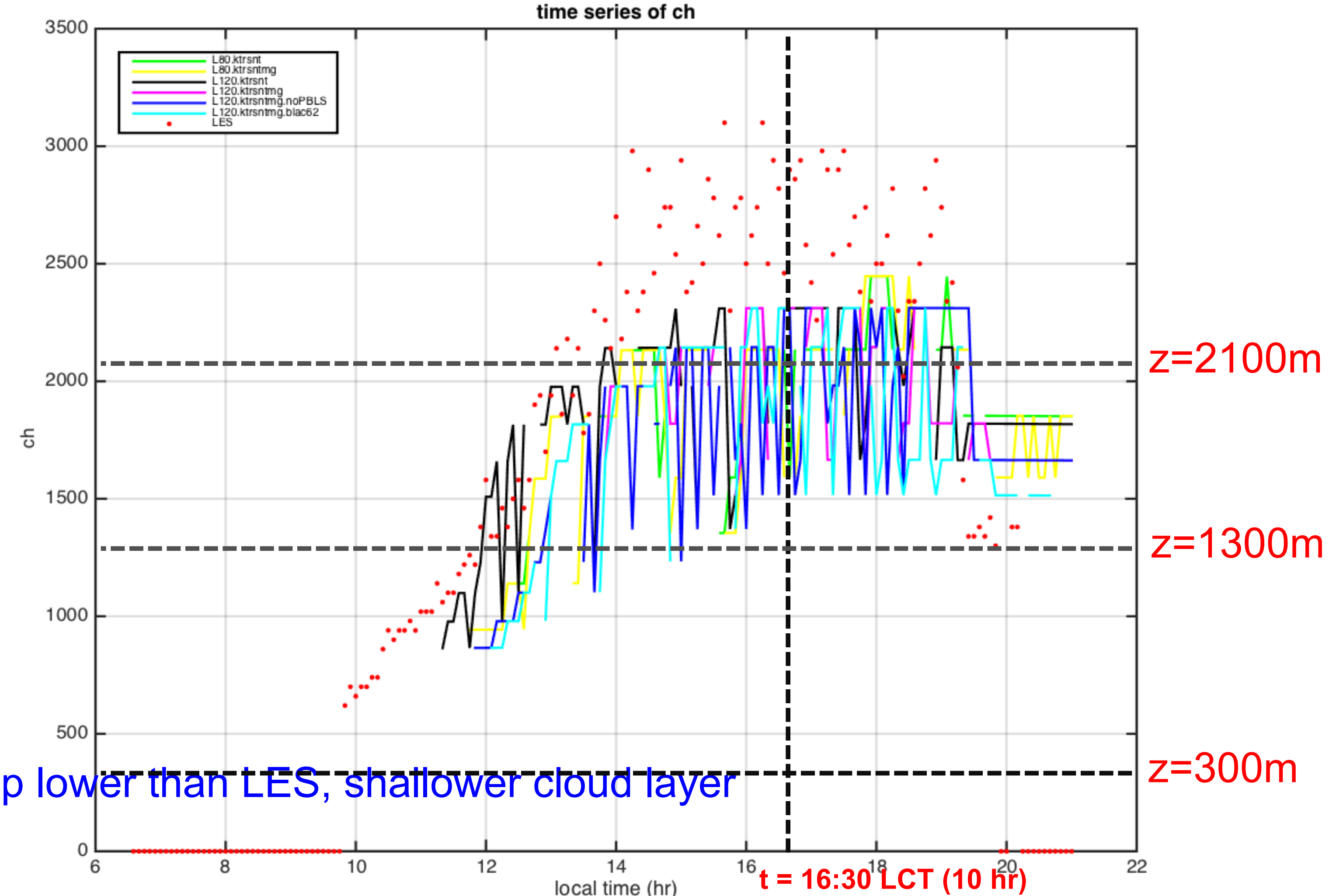
SCM results- cloud base height



Cloud base: the first level of non-zero LWC

Cloud base higher than LES, especially for L80

SCM results- cloud top height



Cloud top lower than LES, shallower cloud layer

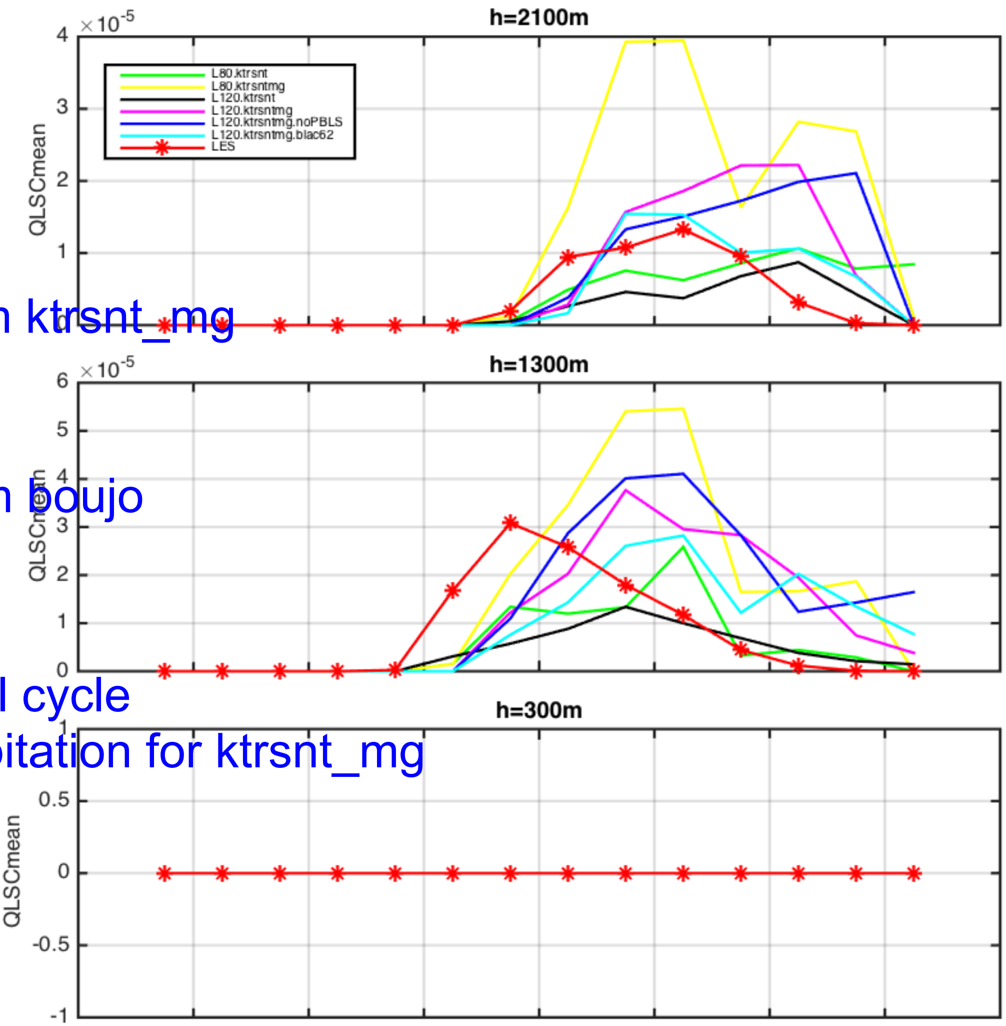
SCM results- hourly avg cloud LWC

unit: kg/kg

Larger lwc from ktrsnt_mg

Larger lwc from boujo

delayed diurnal cycle
No cloud dissipitation for ktrsnt_mg



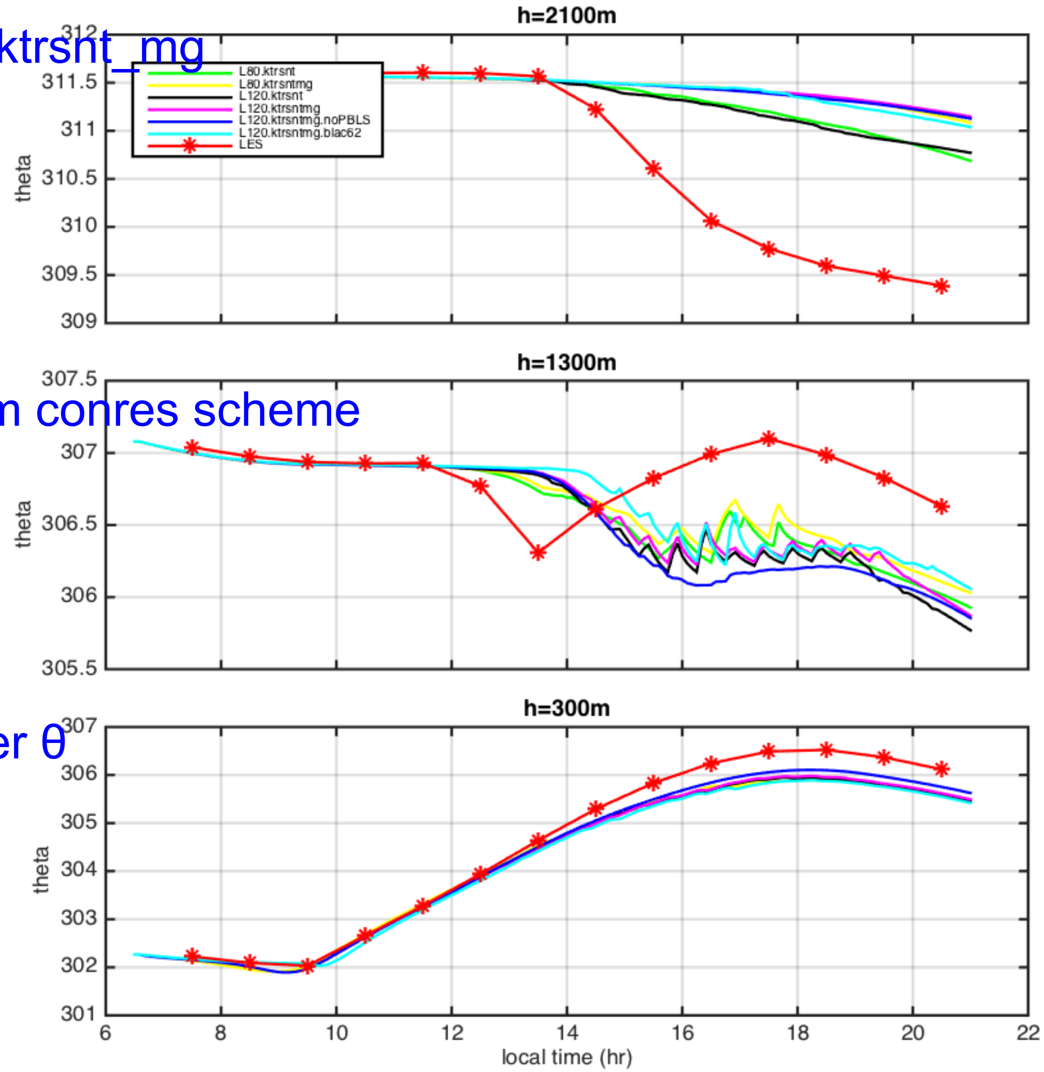
SCM results - potential temperature

larger θ from ktrsnt_mg

unit: K

oscillation from conres scheme

slightly smaller θ



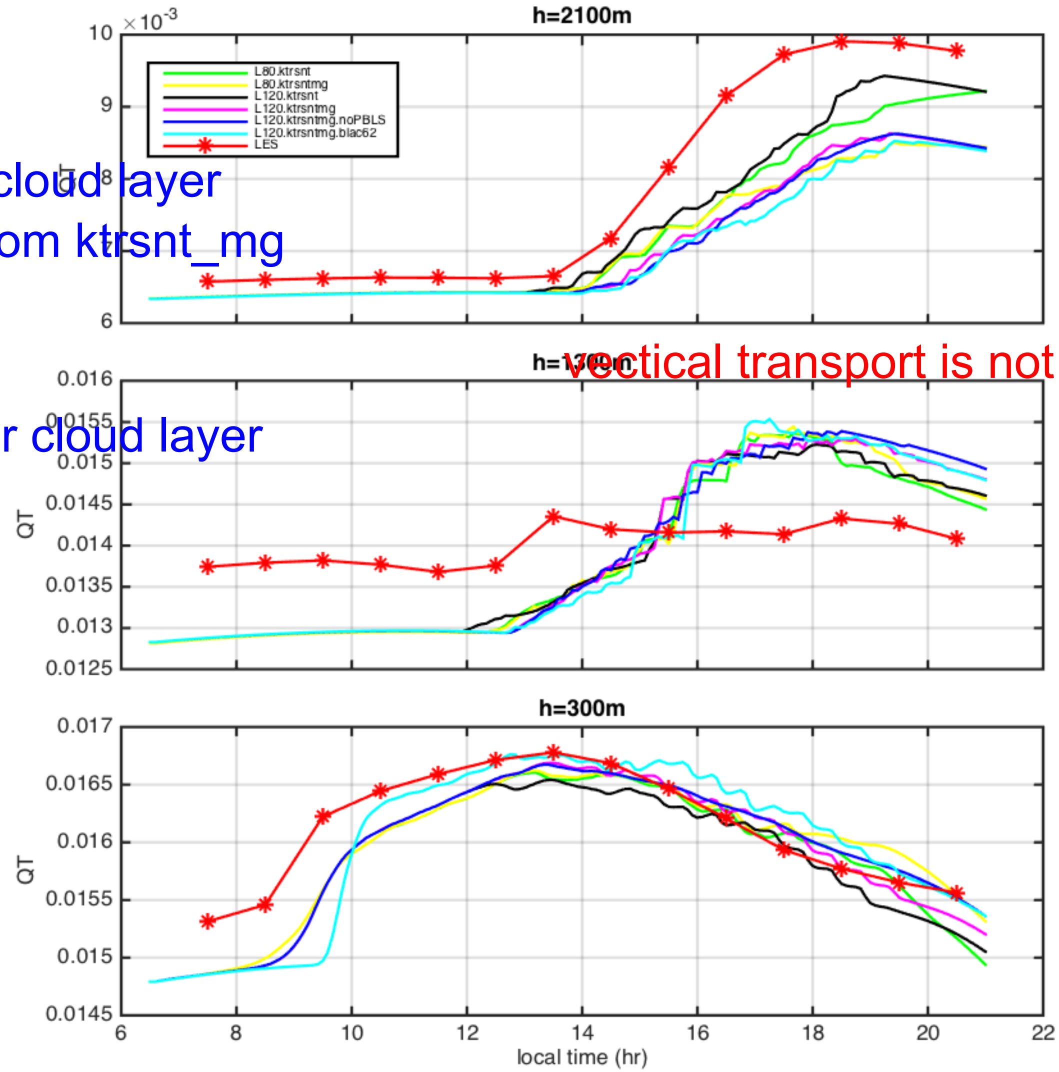
SCM results- total water content (HU+qlsc)

unit: kg/kg

dry in upper cloud layer
smaller QT from ktrsnt_mg

vertical transport is not active enough.

moist in lower cloud layer



SCM results- RH

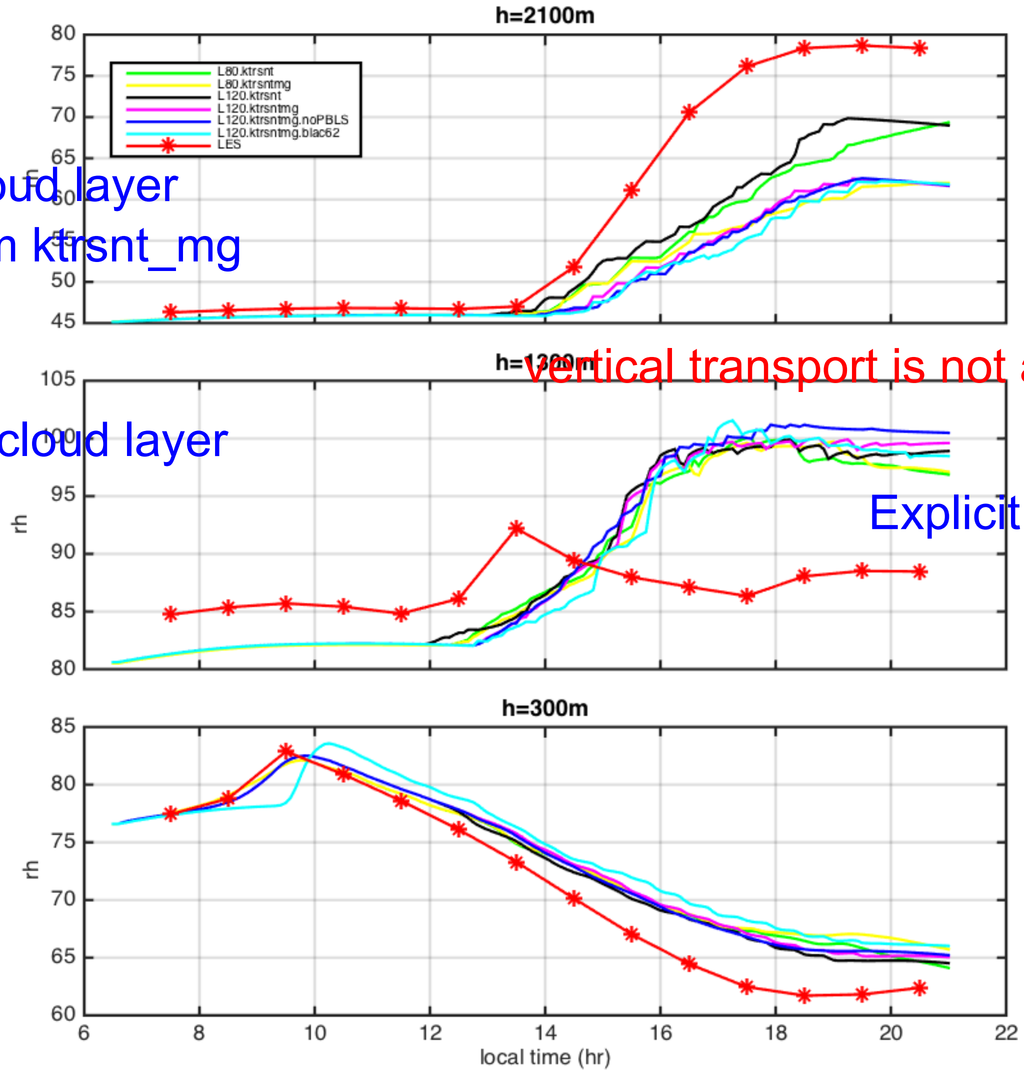
unit: %

dry in upper cloud layer
smaller QT from ktrsnt_mg

vertical transport is not active enough.

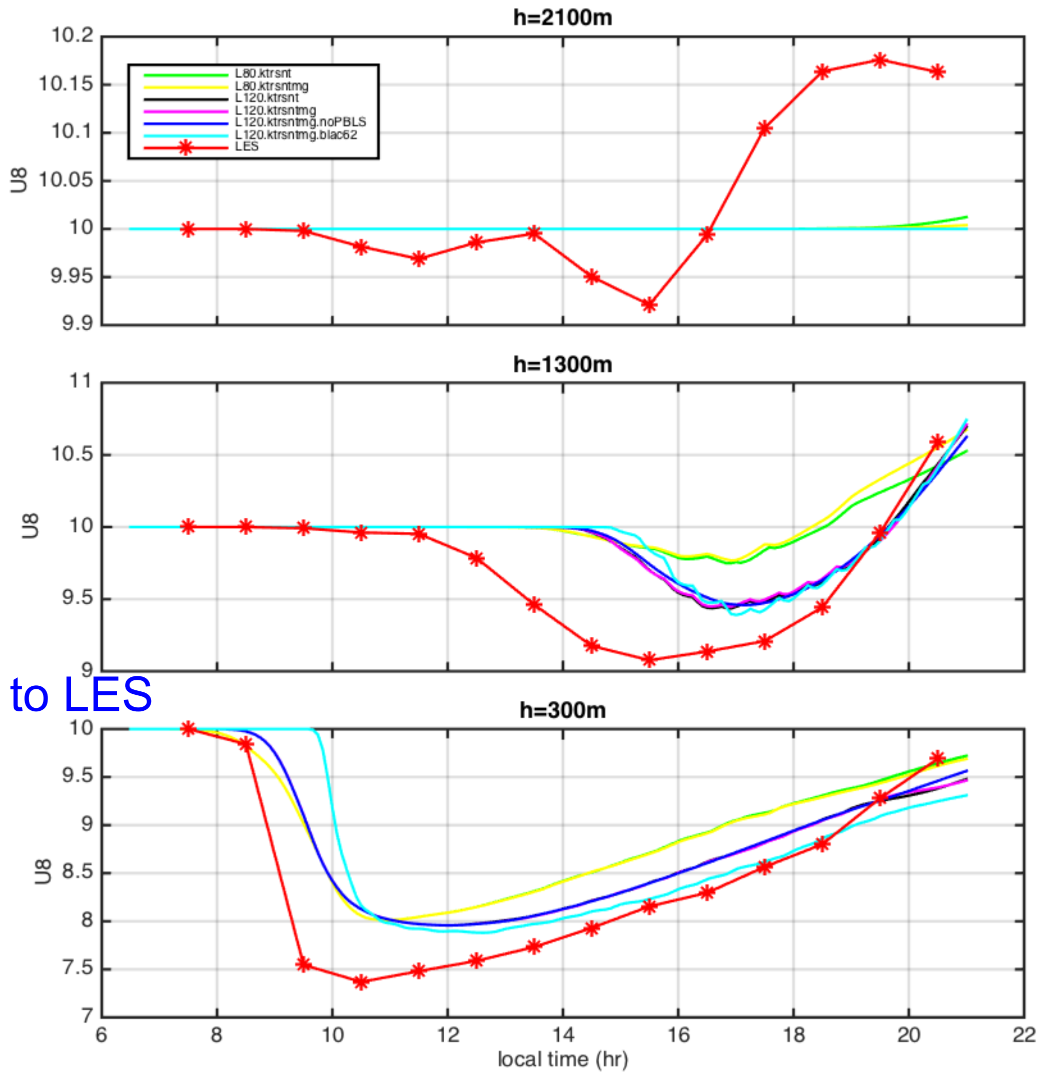
moist in lower cloud layer

RH ~ 100%
Explicit precipitation test ?



SCM results- UU

unit: m/s



L120 is closer to LES

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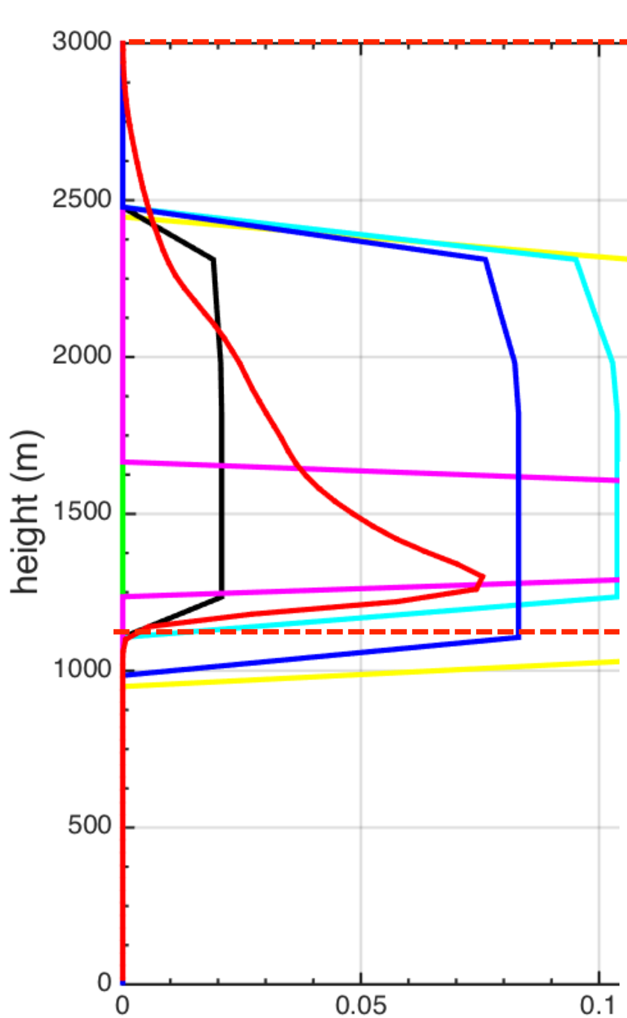
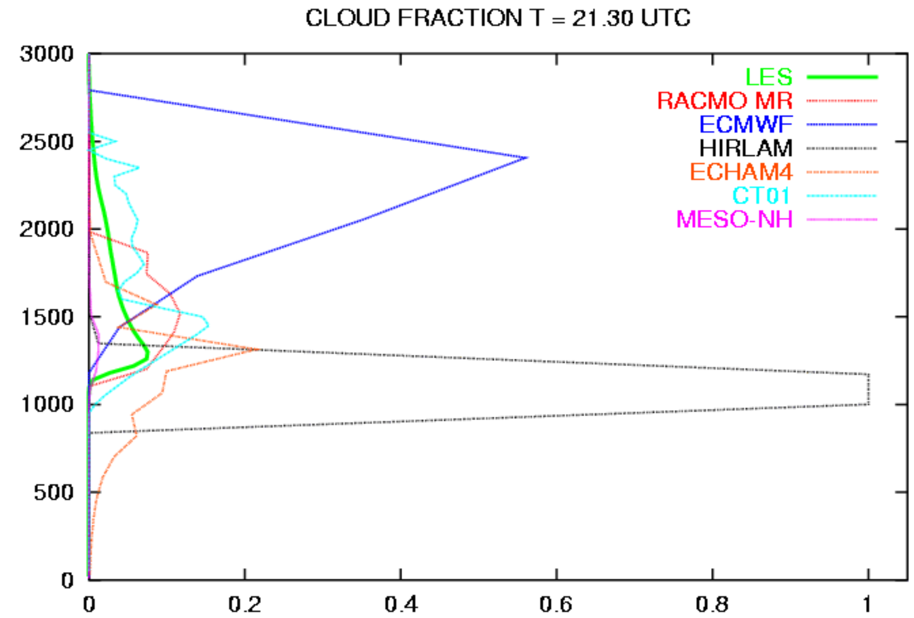
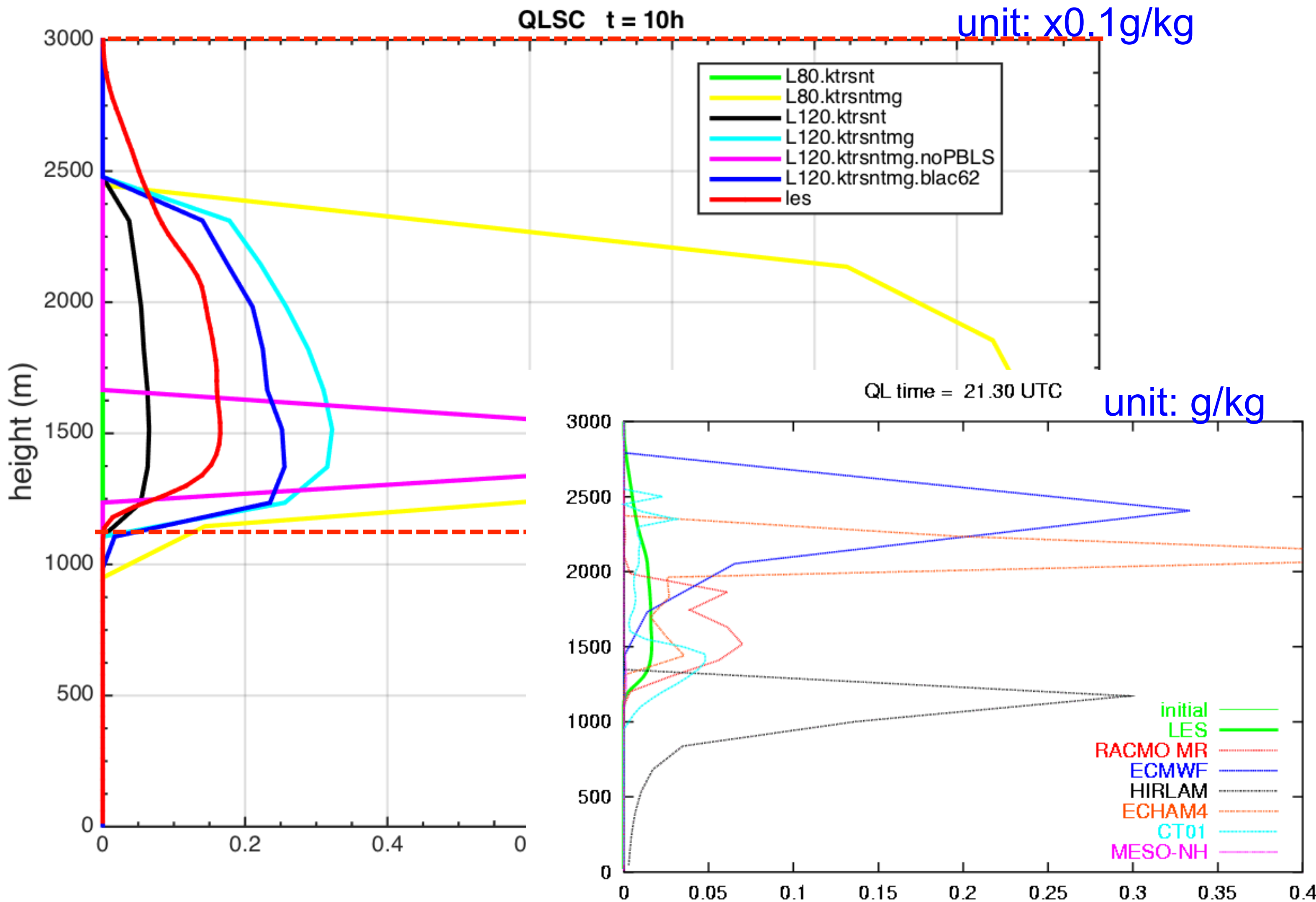
Can

SCM results - cloud fraction

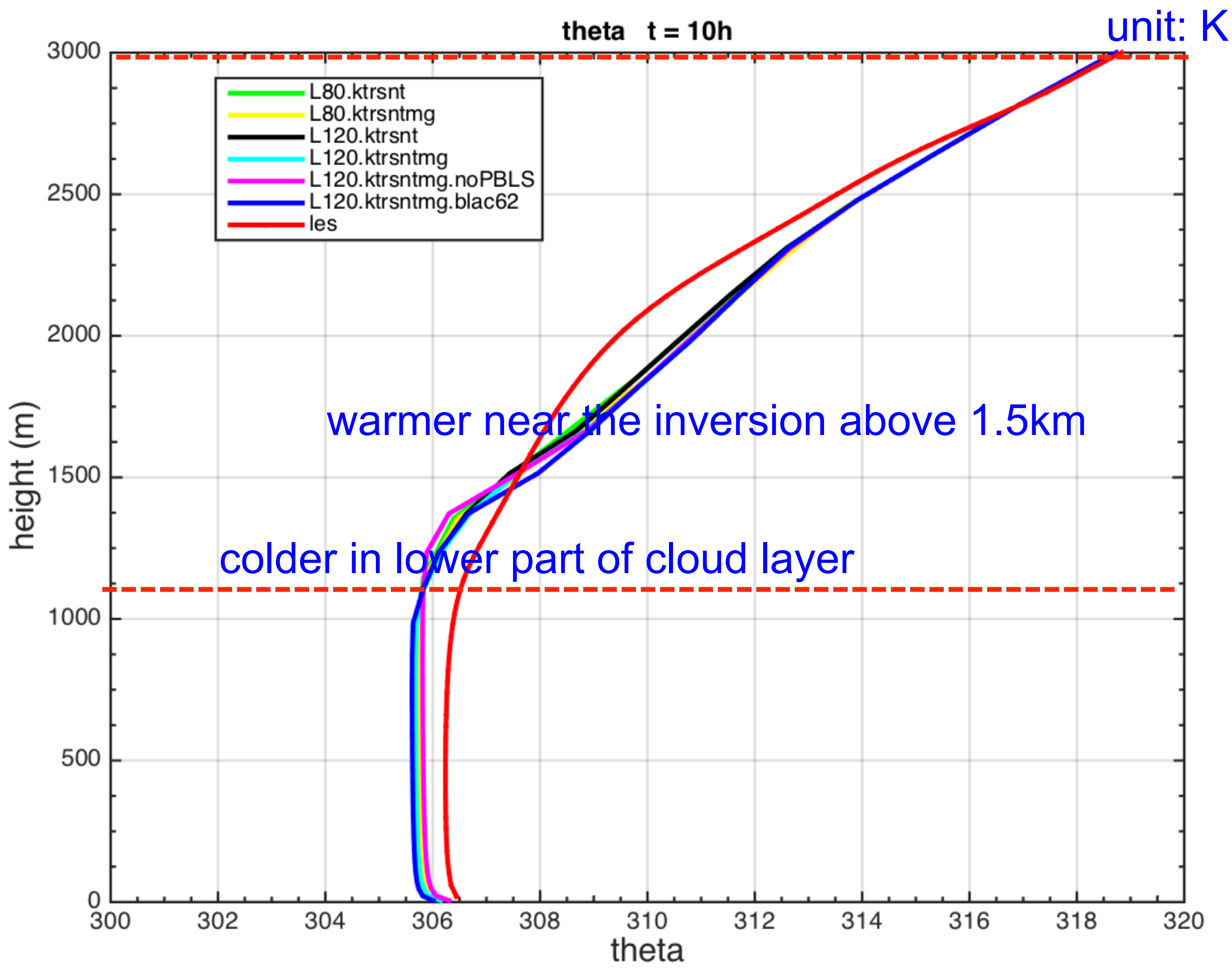




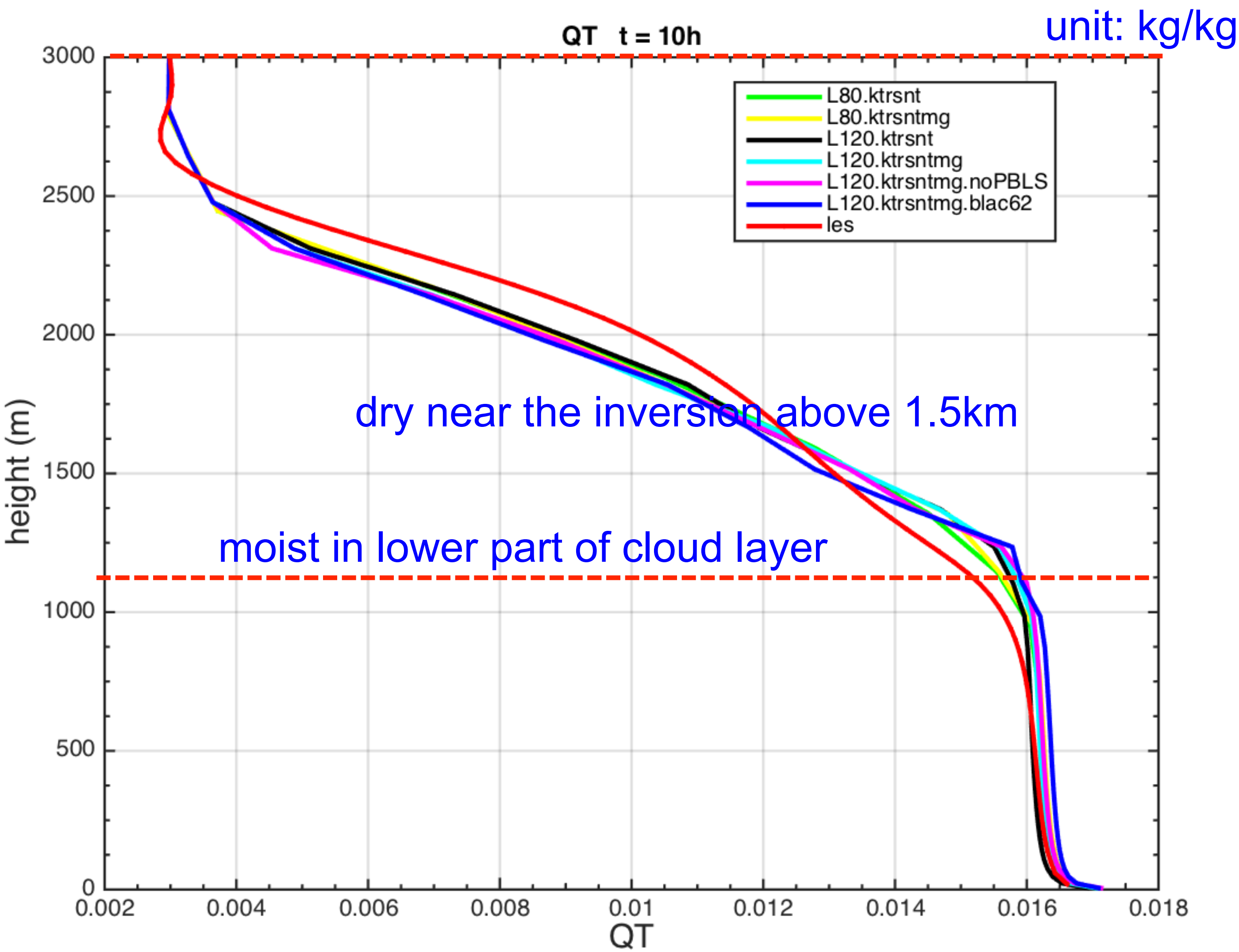
SCM results- cloud LWC



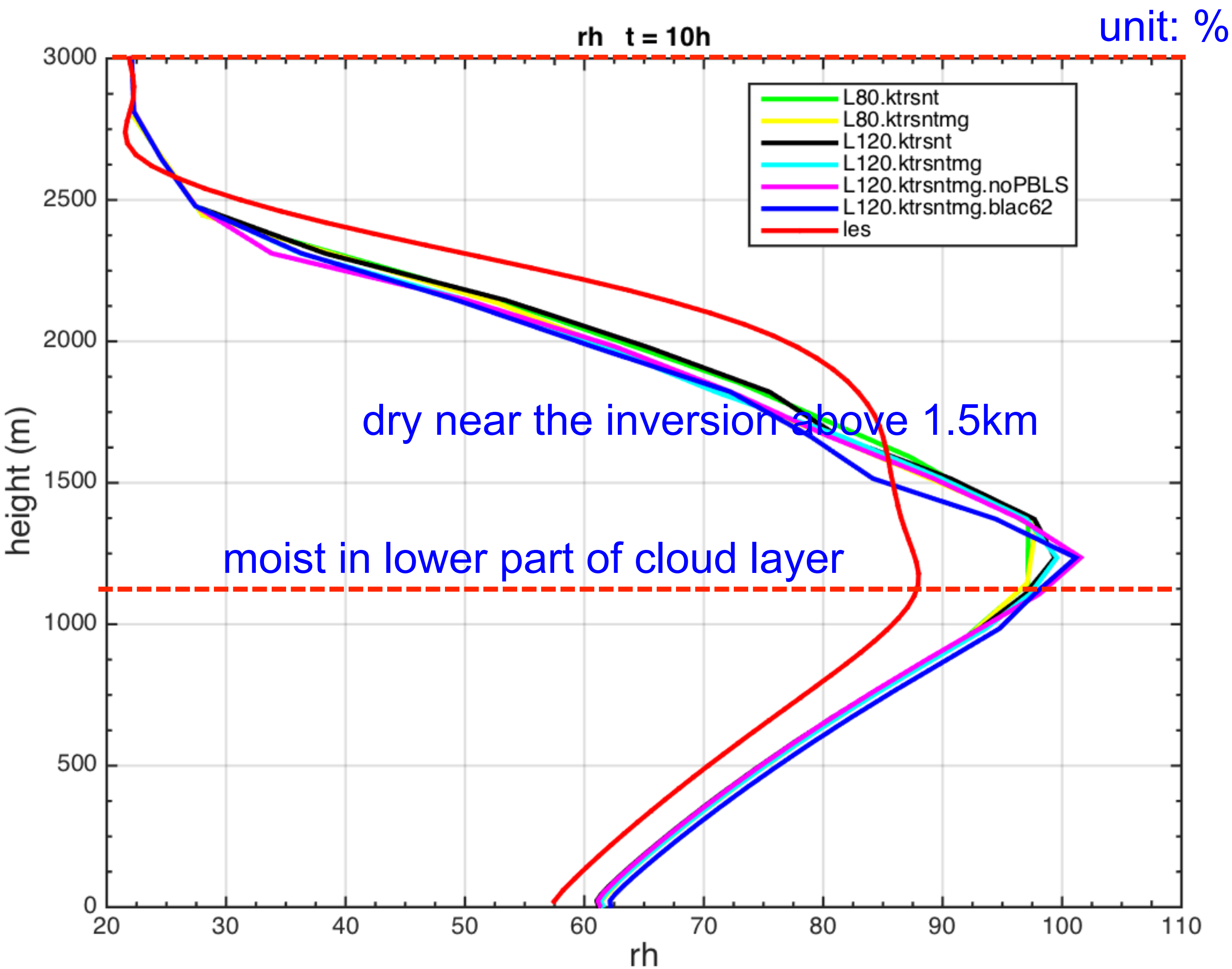
SCM results- potential temperature



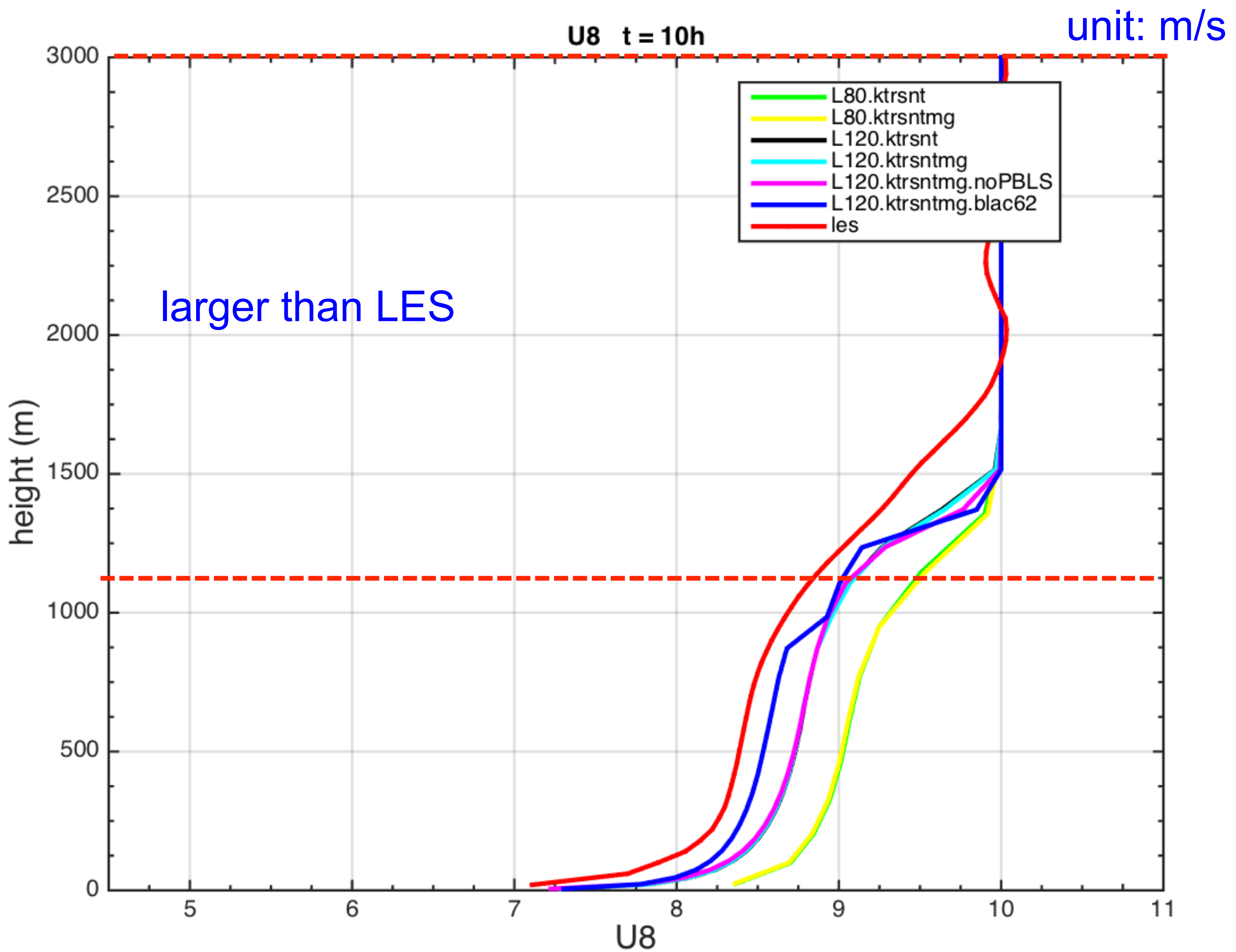
SCM results- total water content



SCM results- RH

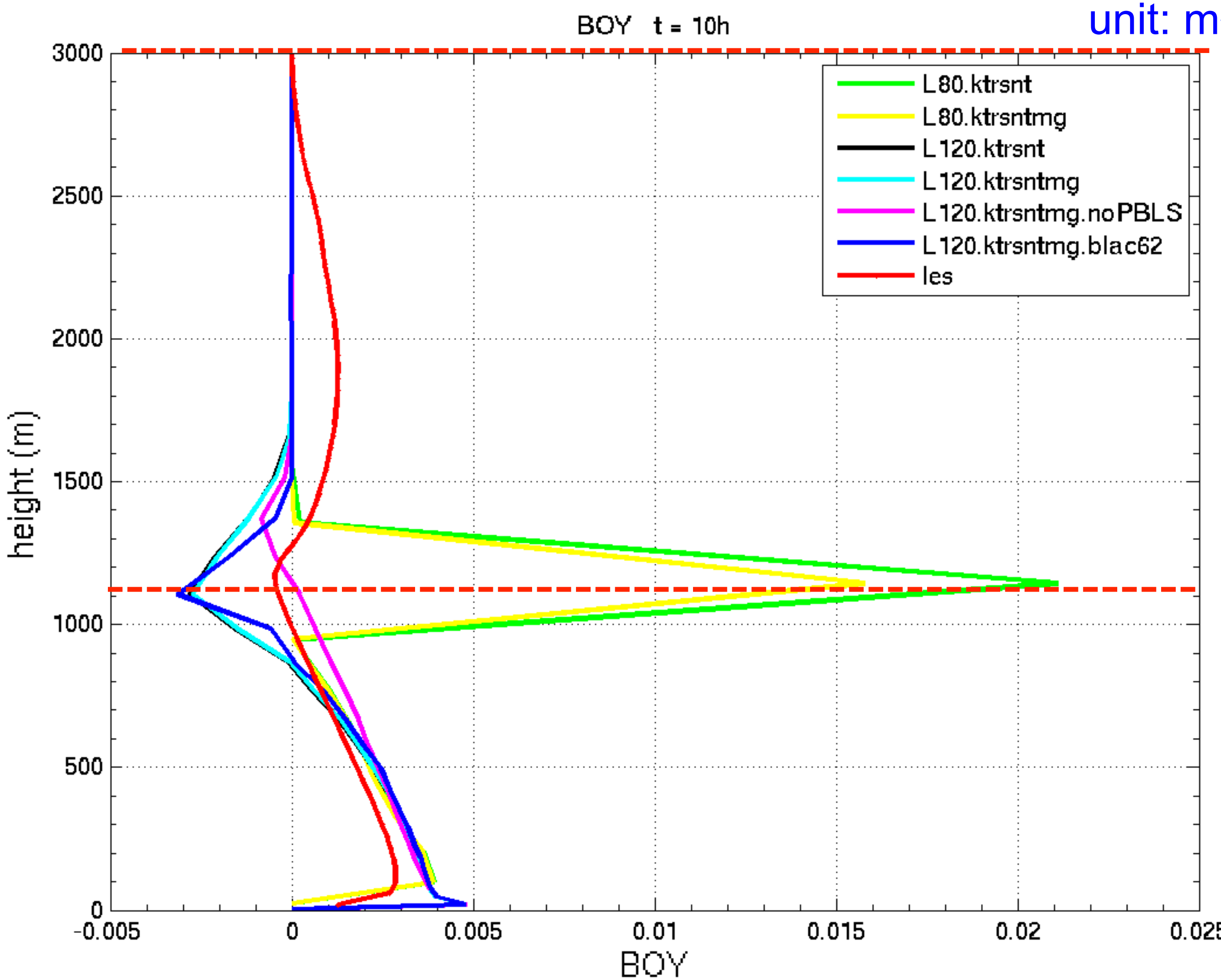


SCM results- UU

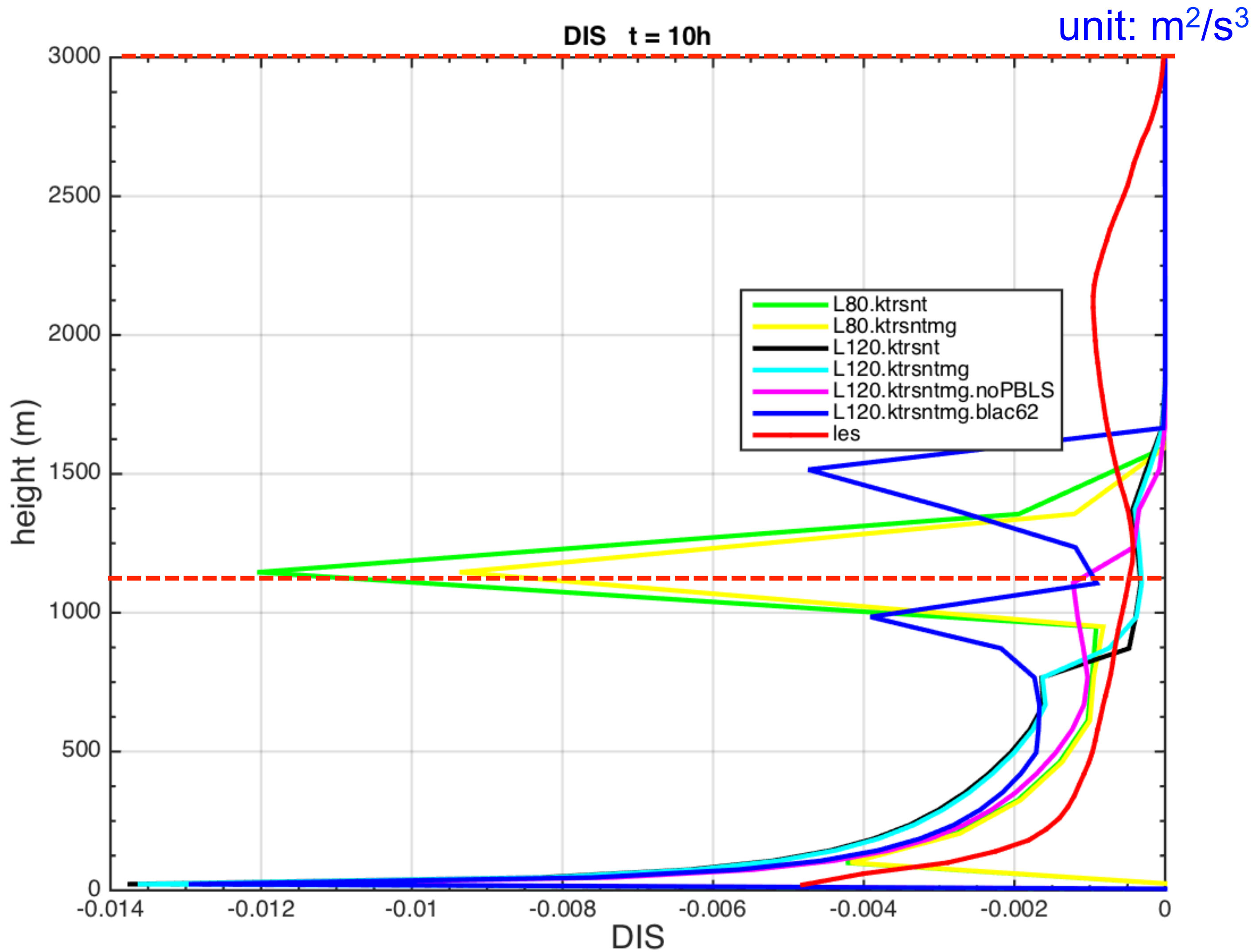


SCM results- buoyancy

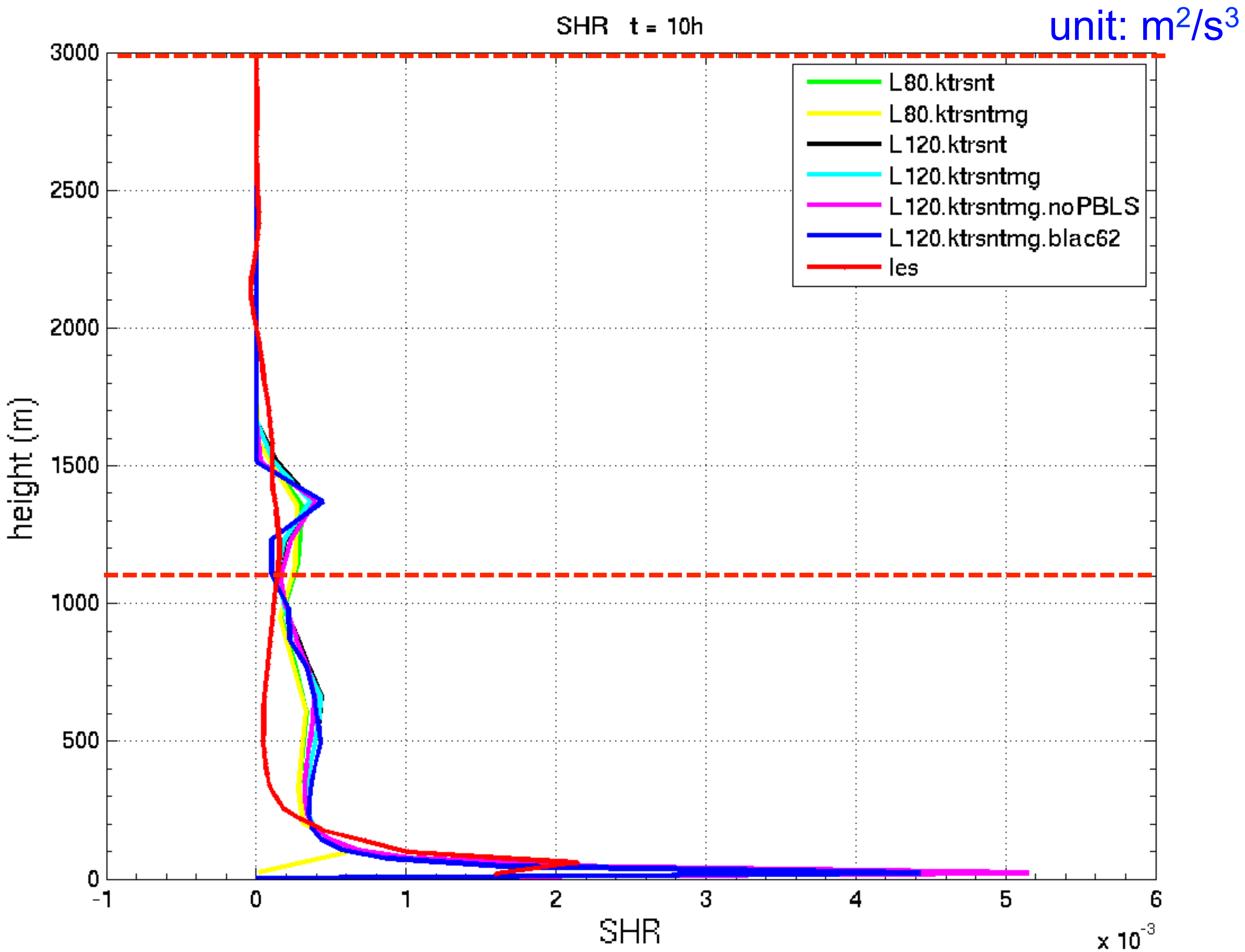
unit: m^2/s^3



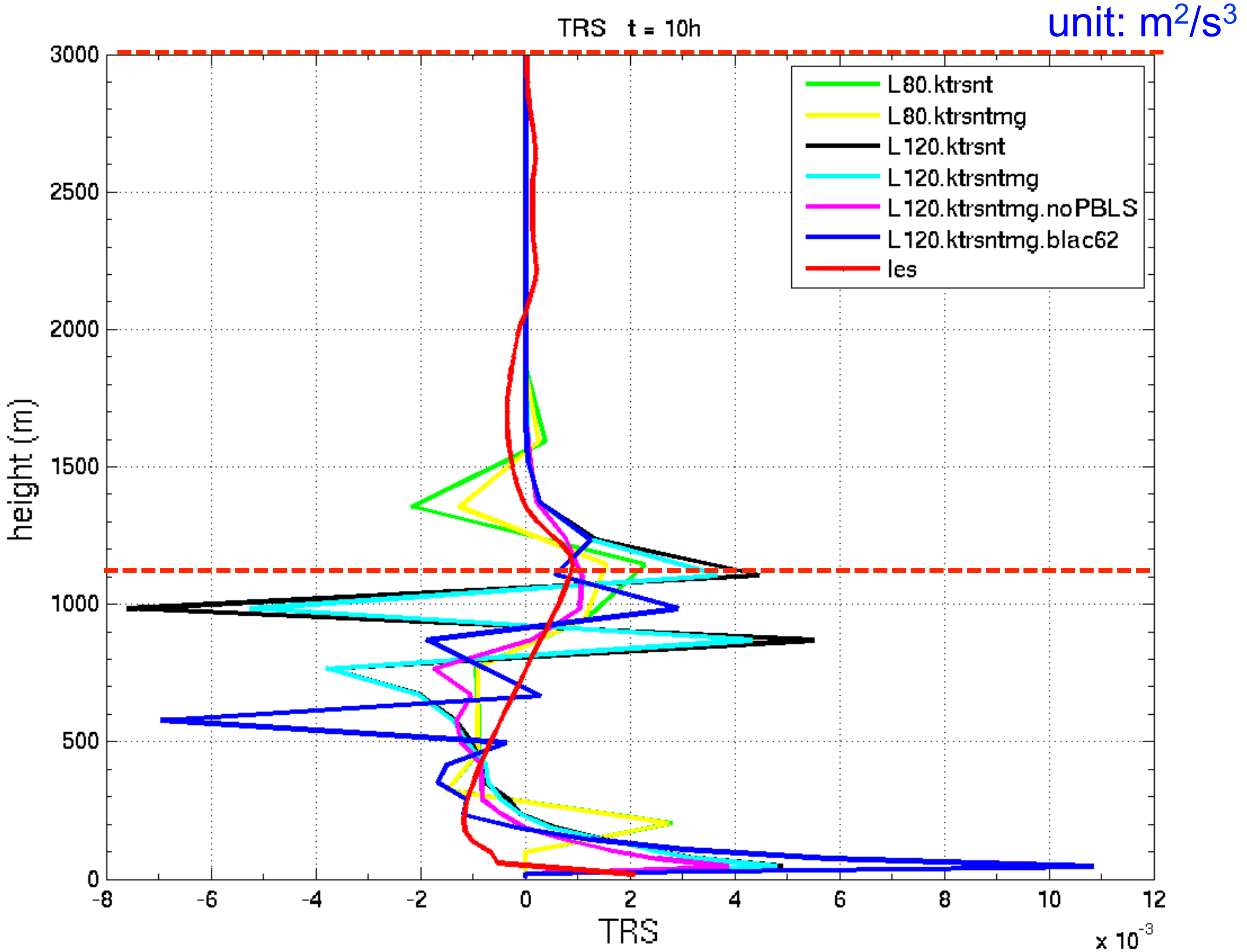
SCM results- dissipation



SCM results- shear term



SCM results- transport (vertical diffusion)



SCM results

SCMs typically suffered from the following deficiencies:

• too high cloud fractions and cloud liquid water.

• too shallow cloud layers, too moist in the cloud layer (too little activity, for most models with mass flux closure)

vertical transport is not enough, convective transport

• difficulties with diurnal cycle (cloud disappearance after sunset)

delayed (no cloud dissipitation in ktrsnt_mg)

• unrealistic thermodynamic profiles.

• considerable numerical noise (especially for L120).