Overview of 10 years of GABLS

Bert Holtslag (Wageningen Univ, www.maq.wur.nl)

Thanks to Sukanta Basu (NC State Univ), Bob Beare (Exeter Univ), Fred Bosveld (KNMI), Joan Cuxart (Univ. Balearic Islands) and Gunilla Svensson (Stockholm Univ) for coordinating case studies and all those participating in the GEWEX Atmospheric Boundary Layer Study

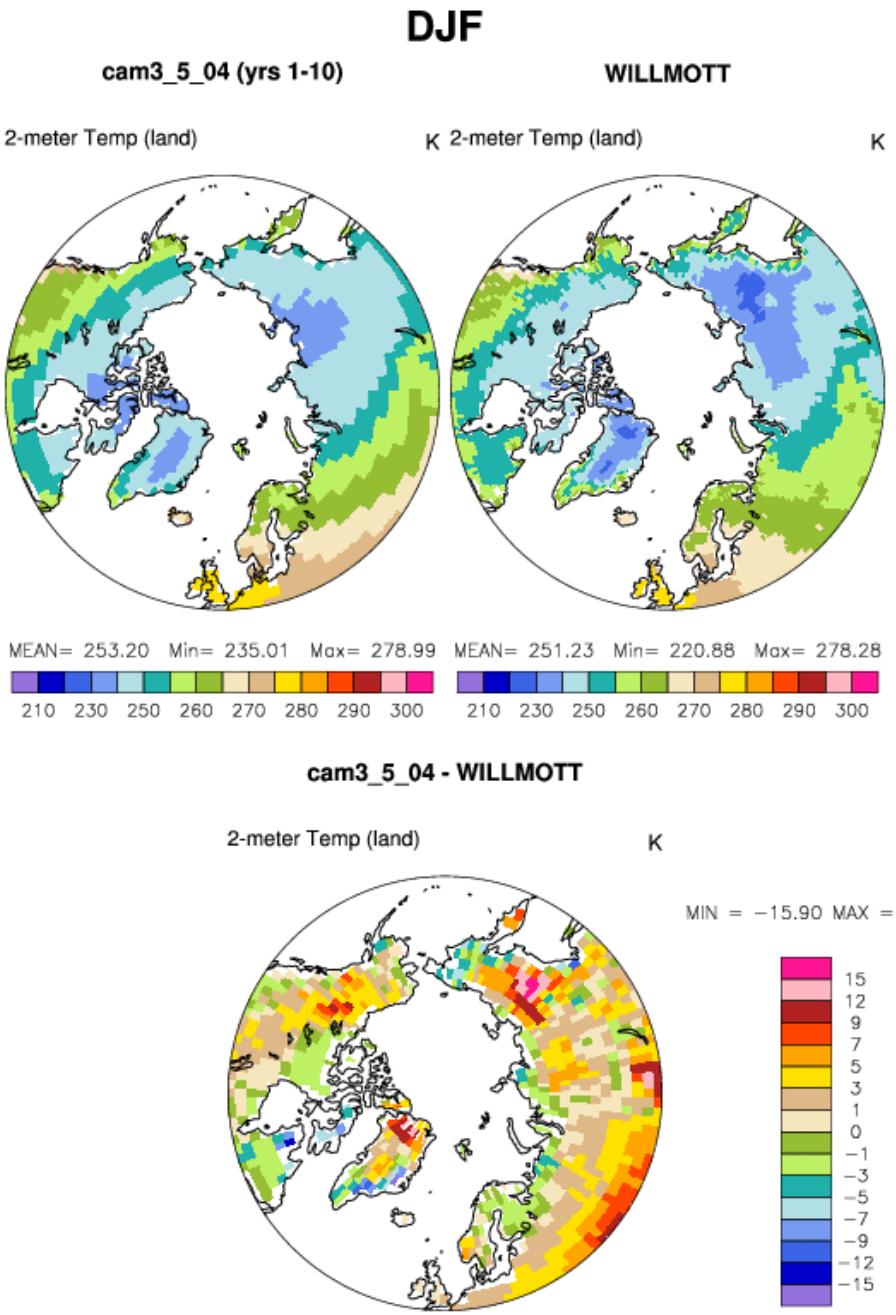
Some background

What did we learn from the GABLS benchmarks?

Expectations and future activities

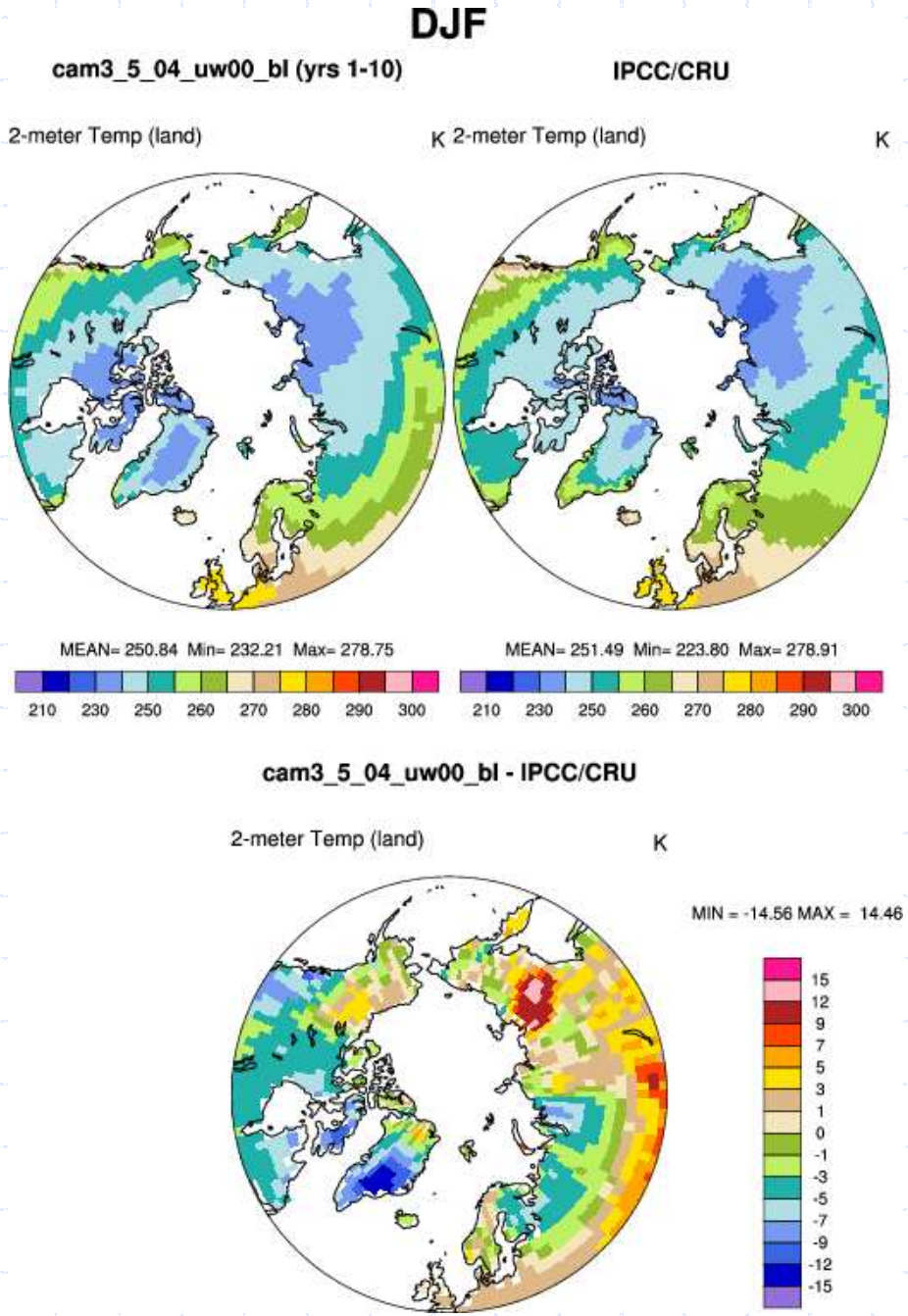
Presentation for ECMWF-GABLS workshop,
November 7-11, 2011

WAGENINGEN UNIVERSITY
METEOROLOGY AND AIR QUALITY



Comparison of climate models (such as NCAR-CAM4) with observations for 2m temperature reveals large differences over land and ice in stratified conditions (here for HB scheme; 10 year winter averages)

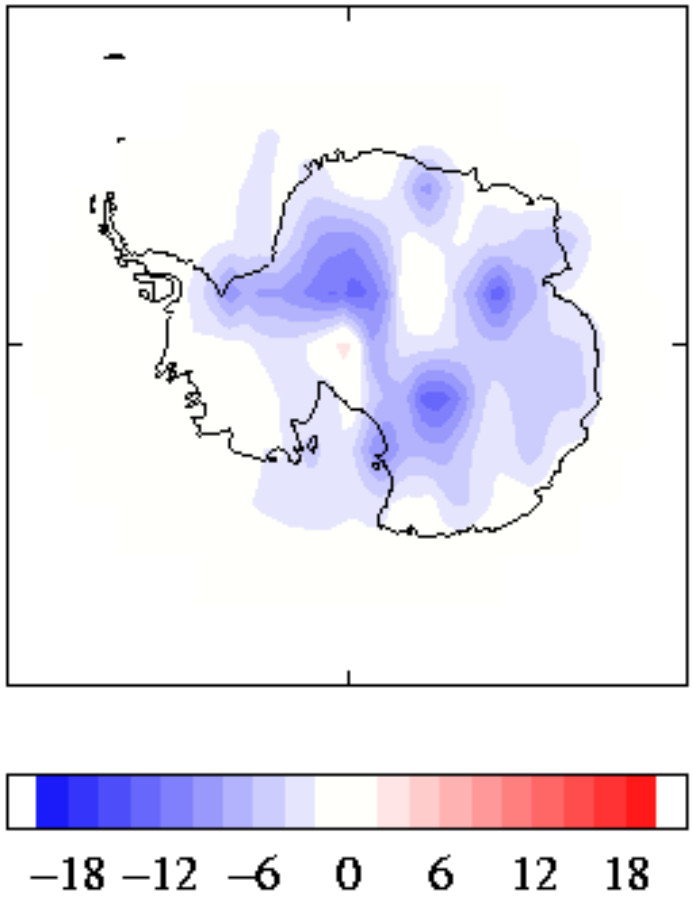
Holtslag+Boville, J. Clim., 1993



Comparison of climate models (such as NCAR-CAM5) with observations for 2m temperature reveals large differences over land and ice in stratified conditions (here for UW scheme; 10 year winter averages)

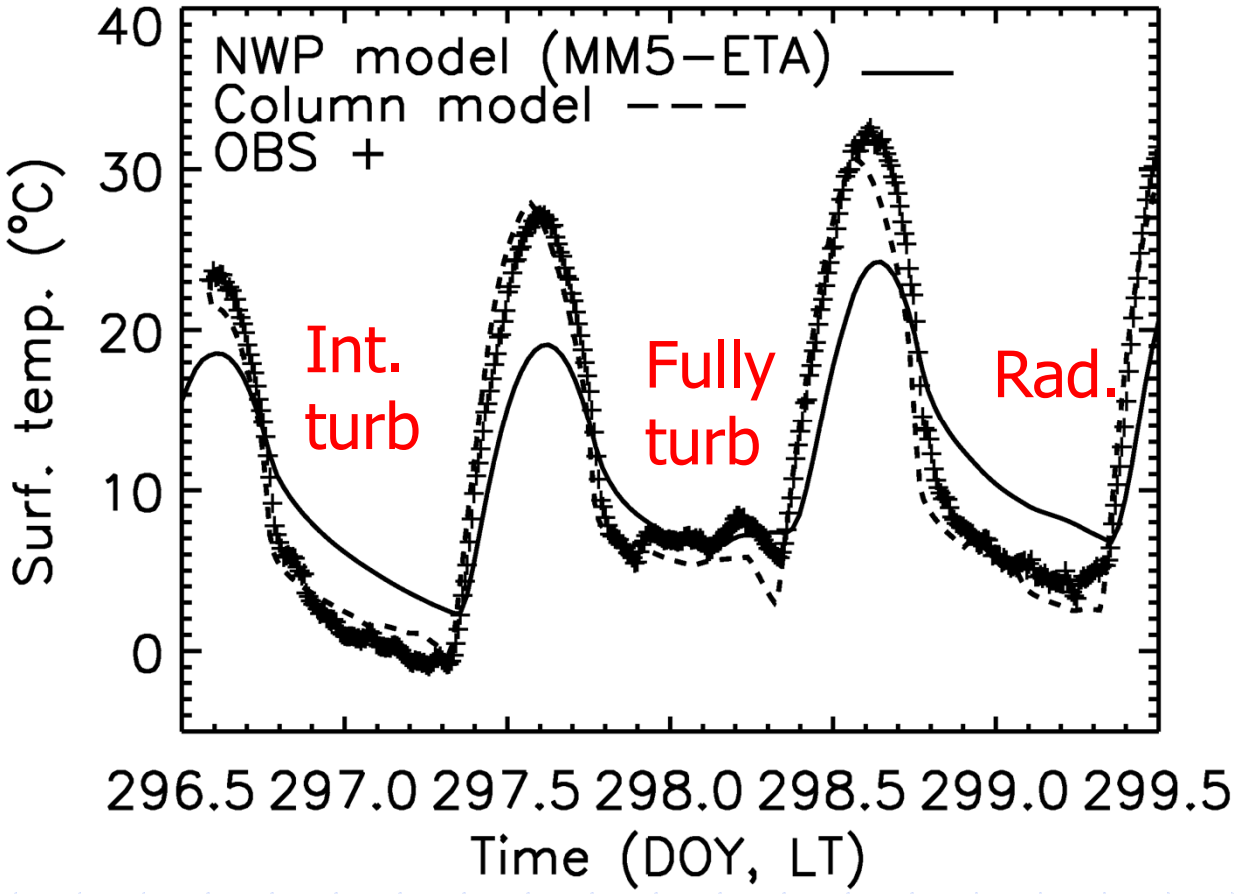
University of Washington scheme; Bretherton and Park (2009)

Sensitivity to Stable Boundary Layer parameterization in Hadley Centre Climate Model over Antarctic



Difference between a
2nd order closure
and 1st order closure scheme
for 1.5m Temperature (K),
JJA season, 5 year mean
(King et al. 2001, QJRMS)

Modeling diurnal cycles with 3 contrasting nights in CASES99



October 23-26 Steeneveld et al., *JAS*, 2006

"Underestimation of diurnal cycle is much more pronounced on days with small cloud amount" (Kysely and Plavcova, Clim. Dyn, 2011)

Modeling Atmospheric Boundary Layers: It is still a challenge!

Atmospheric models do have problems in representing the stable boundary layer and the diurnal cycle

Sensitivity to details in mixing formulation

Enhance understanding by benchmark studies over land and ice in comparison with observations and fine scale numerical model results

GEWEX Atmospheric Boundary Layer Studies (GABLS) provides platform for model intercomparison and development to benefit studies of Climate, Weather, Air Quality and Wind Energy

GABLS1	GABLS2	GABLS3
		
LES as reference	Data (CASES99)	Data (CABAUW)
Academic set up	Idealized forcings	Realistic forcings
Prescribed T_s	Prescribed T_s	Full coupling *(SCM)* Prescribed T_s *(LES)*
No Radiation	No Radiation	Radiation included
Turbulent mixing	Diurnal cycle	Low levet jet + transitions

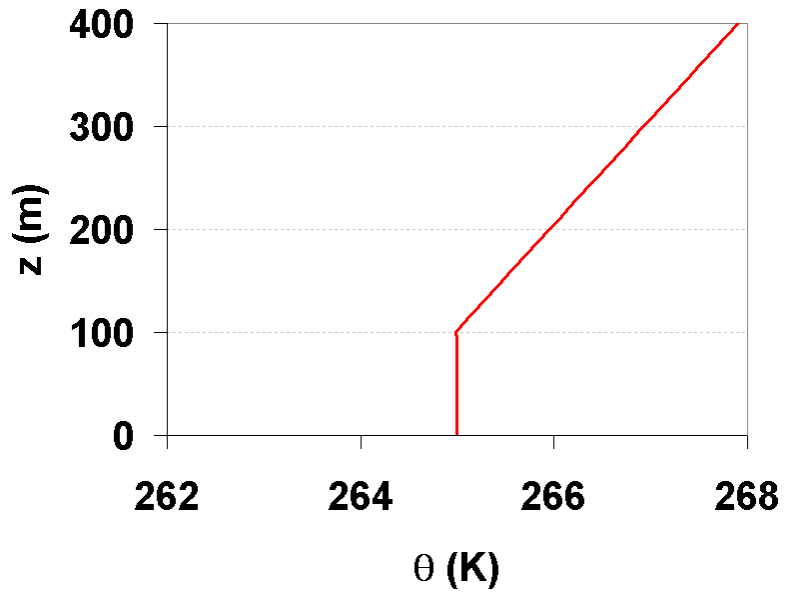
LES: Large Eddy Simulation; *SCM:* Single Column Model

GABLS first model inter-comparison case

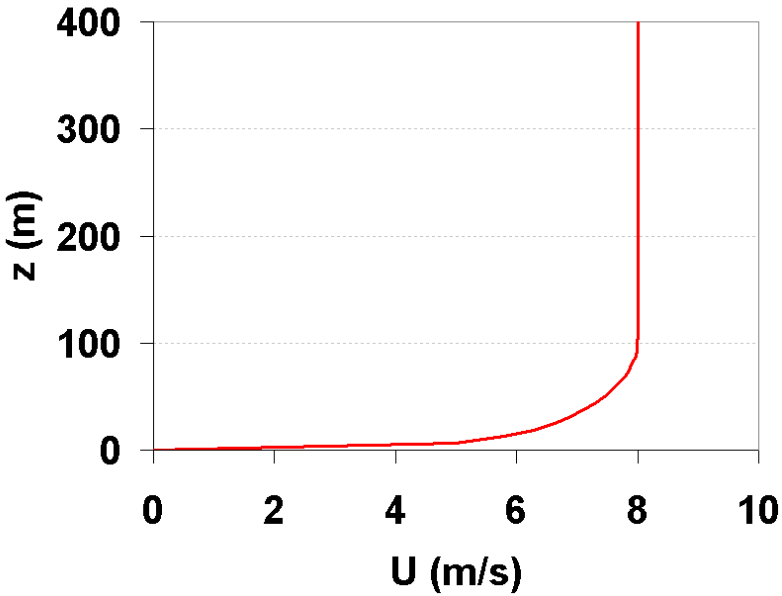
Simple shear driven case for a stable boundary layer over ice

(after Kosovic and Curry, 2000)

Initial temperature profile GABLS case study



Initial wind profile GABLS case study



Prescribed surface cooling 0.25 K/h for 9 hours to quasi- equilibrium; no surface and radiation scheme

Geostrophic wind 8 m/s, latitude 73N

List of 20 participating 1D models (Cuxart et al, 2006)

Model	Use	Type	Ref
ECMWF	operational	1st order	Beljaars and Viterbo, 1998
ECMWF-MO	operational-test	1st order	
NOAA-NCEP	operational	1st order	Hong and Pan, 1996
MeteoFrance	operational	1st order	Louis et al., 1982
JMA	operational	1st order	Mellor and Yamada, 1974
Met Office	operational	1st order	Louis, 1979
Met Office res	research	1st order	Williams, 2002
Wageningen U	research	1st order	Duynkerke, 1991
Sandia Labs	research	ODT	Kerstein et al., 2001
MSC	operational	$e-l$	Belair et al., 1999
KNMI-RACMO	operational	$e-l$	Lenderink and Holtslag, 2004
UIB-UPC	research mesoscale model	$e-l$	Cuxart et al., 2000
NASA	research mesoscale model	$e-l$	Xue et al, 2000
WVU	research	$e-l$	Sykes and Henn, 1989
York U.	research	$e-l$	Weng and Taylor, 2003
Louvain U-L	research	$e-l$	Therry and Lacarrère, 1983
Louvain U-eps	research	$e-\epsilon$	Duynkerke, 1988
Swedish MS	research	$e-\epsilon$	
Stockholm U	research	$e-l$	Andren, 1990
Stock.U-sim	research	$e-\theta^2$	Mauritsen et al., 2004

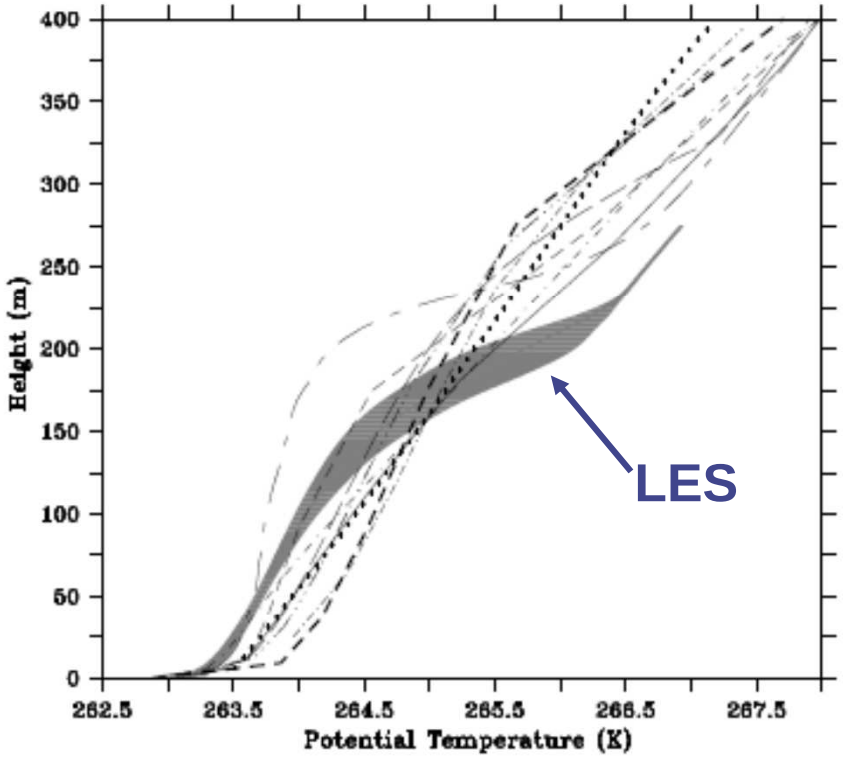
List of 11 participating LES models (Beare et al, 2006)

TABLE I
A summary of the participants.

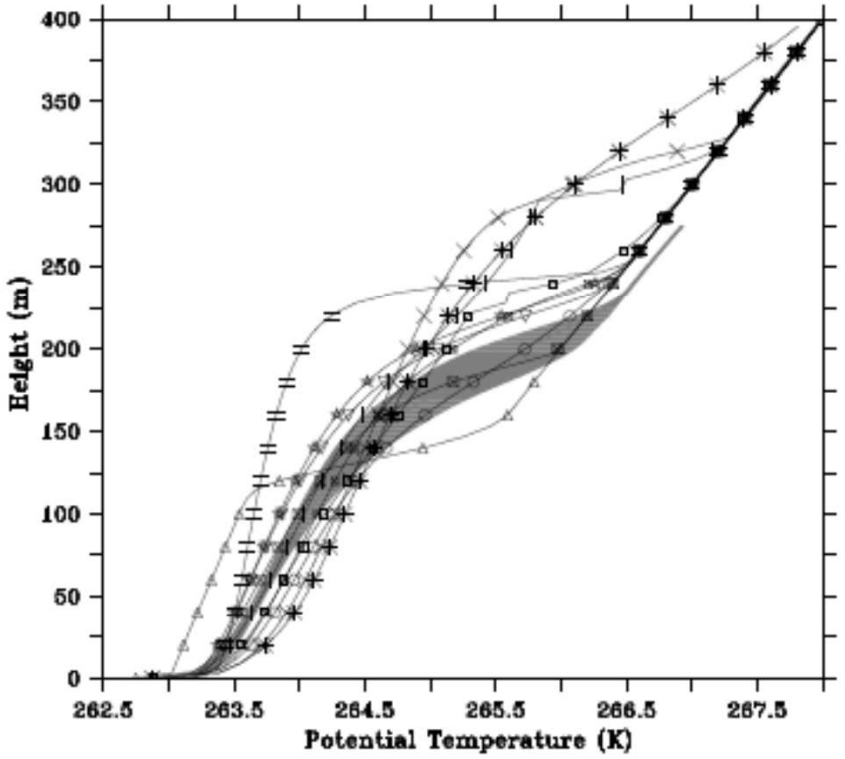
Model	Institution (s)	Scientist (s)
MO	Met Office, UK	Beare, McCabe, MacVean
CSU	Colorado State University	Khairoutdinov
IMUK	University of Hannover, Yonsei University	Raasch, Noh
LLNL	Lawrence Livermore National Laboratory	Lundquist, Kosovic
NERSC	Nansen Environment and Remote Sensing Center	Esau
WVU	West Virginia University	Lewellen
NCAR	National Center for Atmospheric Research	Sullivan
UIB	Universitat de les Illes Balears	Jimenez, Cuxart
CORA	Colorado Research Associates	Lund
WU	Wageningen University	Moene, Holtslag
COAMPS™	Naval Research Laboratory	Golaz

LES: Large-Eddy Simulation model
(e.g. fine-scale model resolving largest turbulent motions)
Ensemble of LES results is taken as reference!

Potential temperature



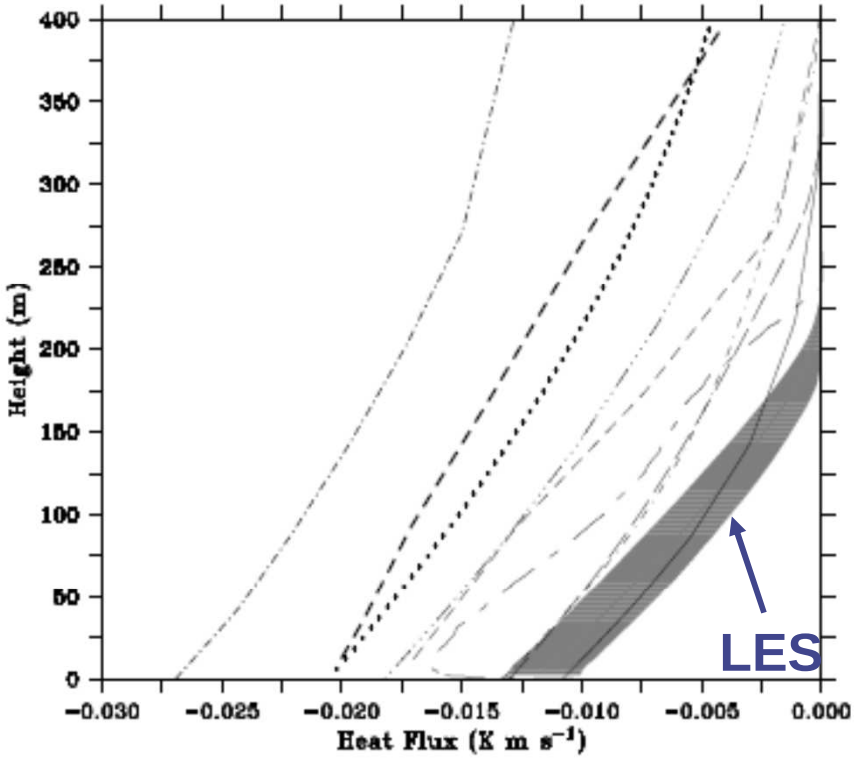
Operational



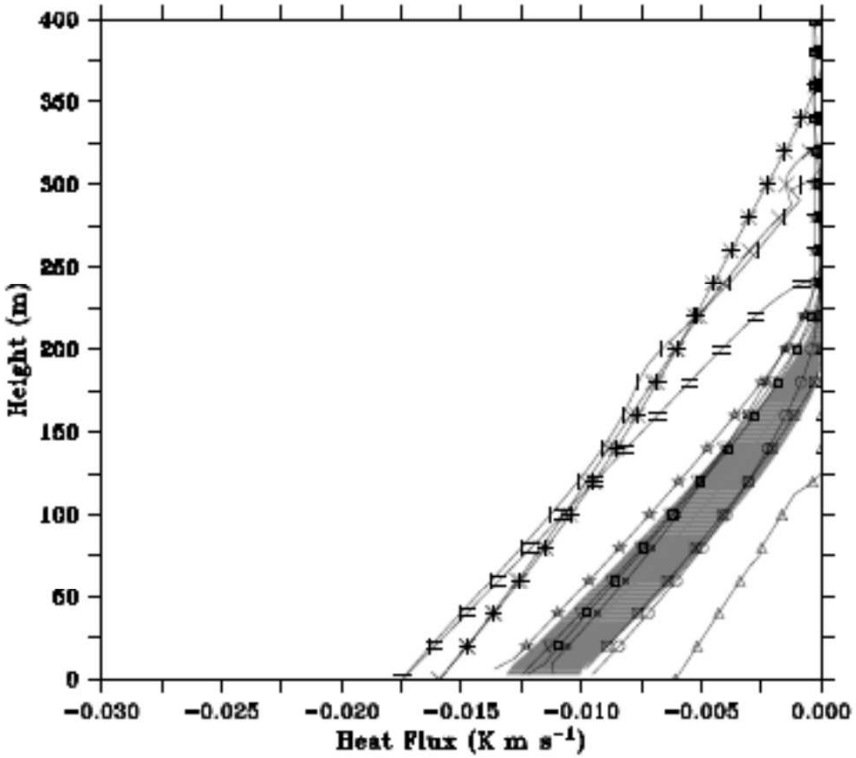
Research

Comparison of Single-Column Models with Large Eddy Simulations (LES)
(Beare et al, 2006; Cuxart et al, 2006)

Heat flux

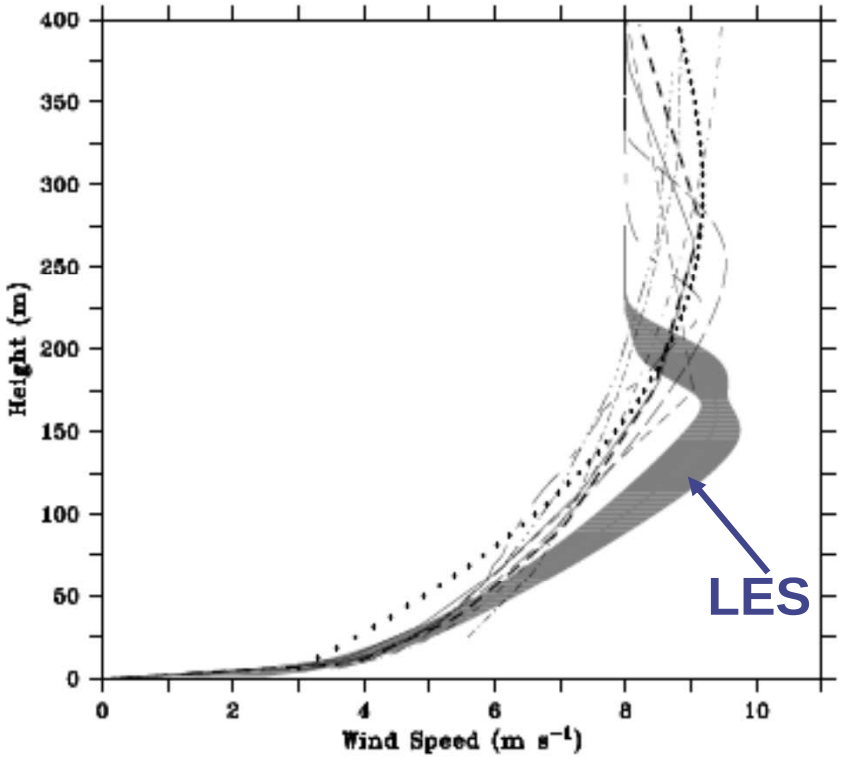


Operational

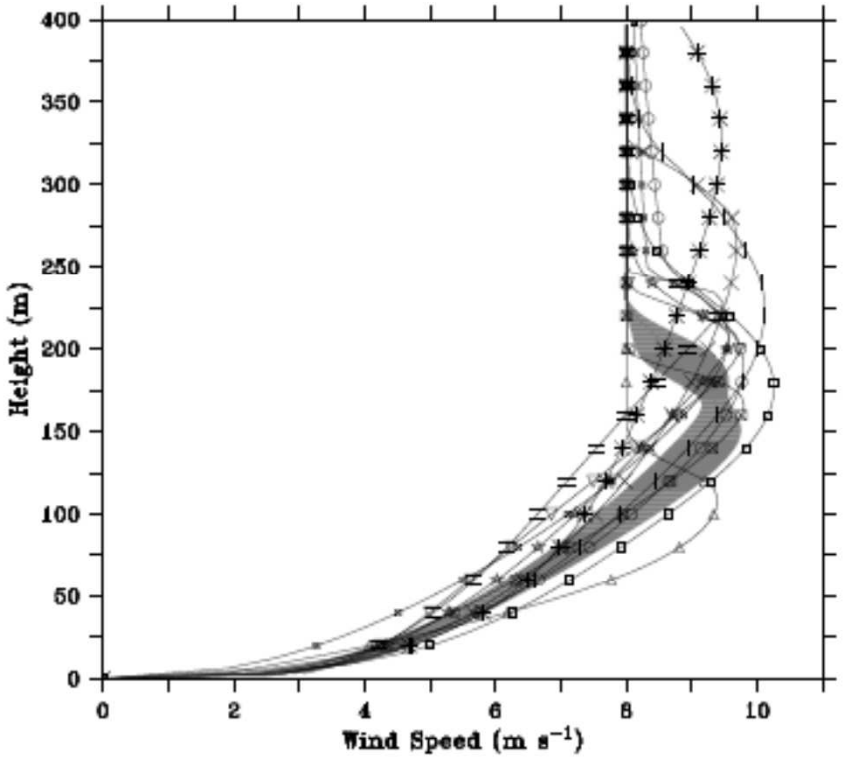


Research

Wind speed

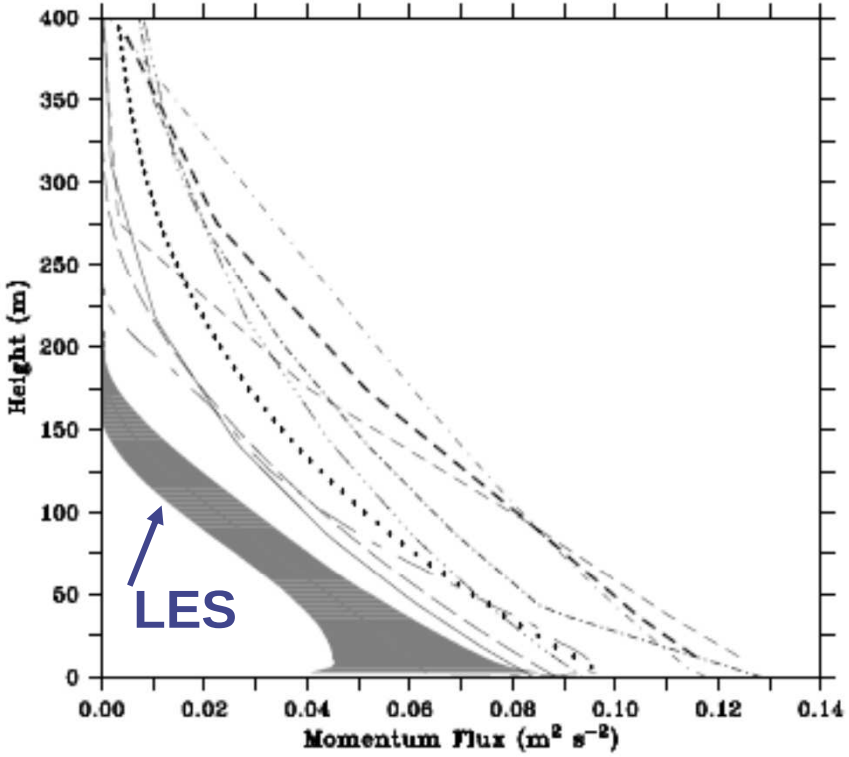


Operational

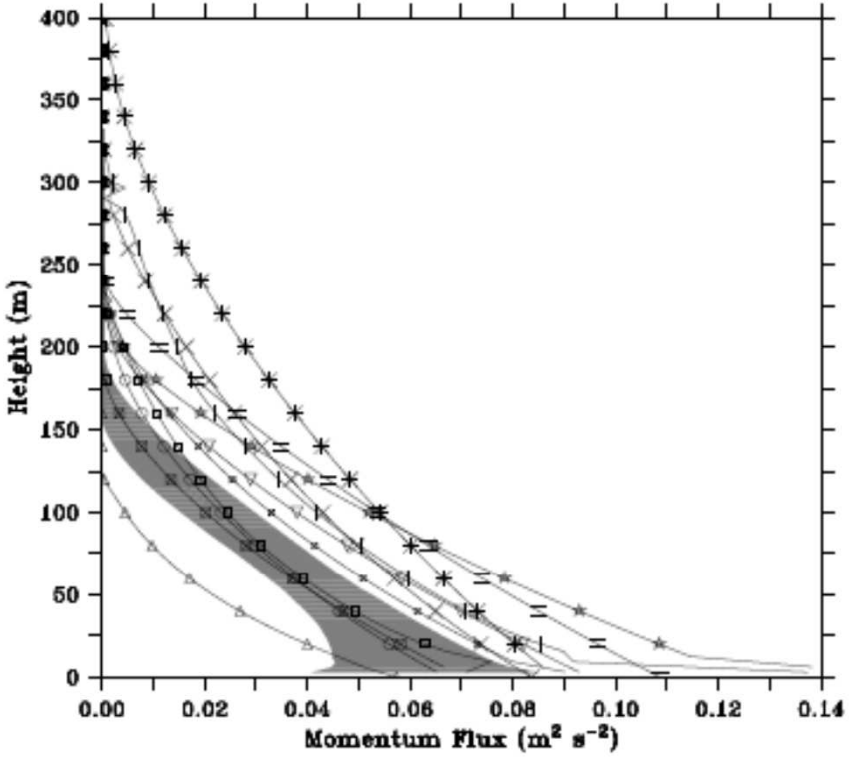


Research

Momentum flux

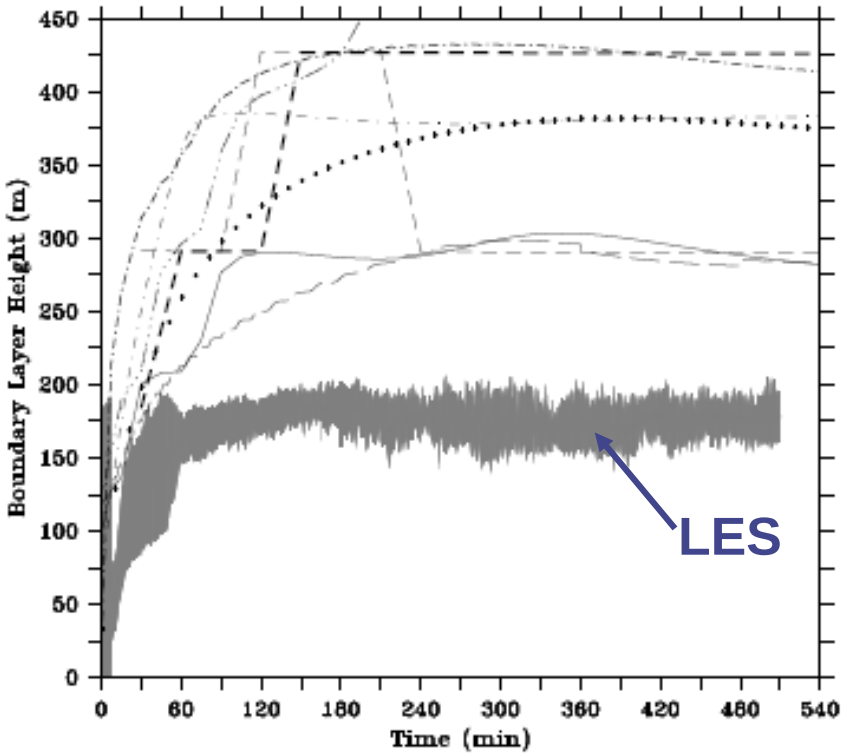


Operational

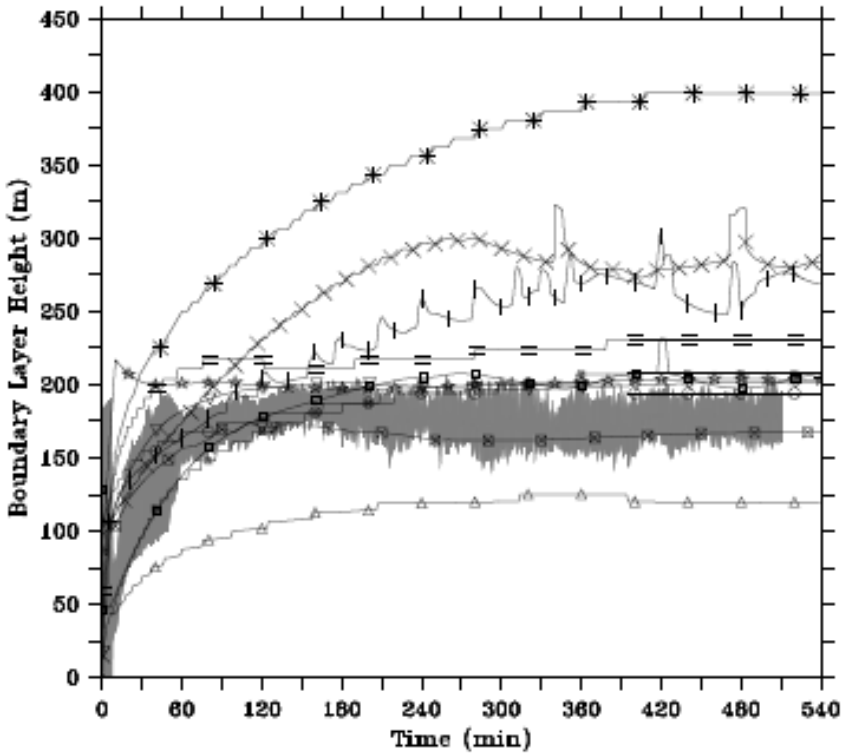


Research

Boundary-Layer Height

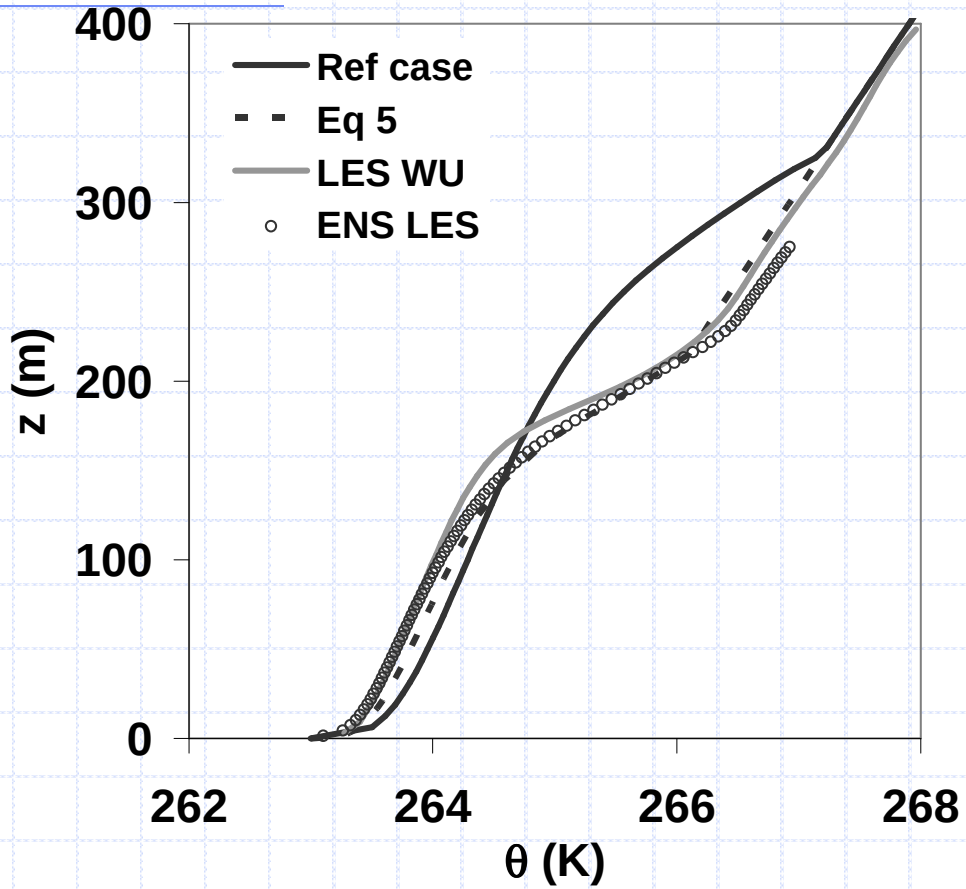


Operational



Research

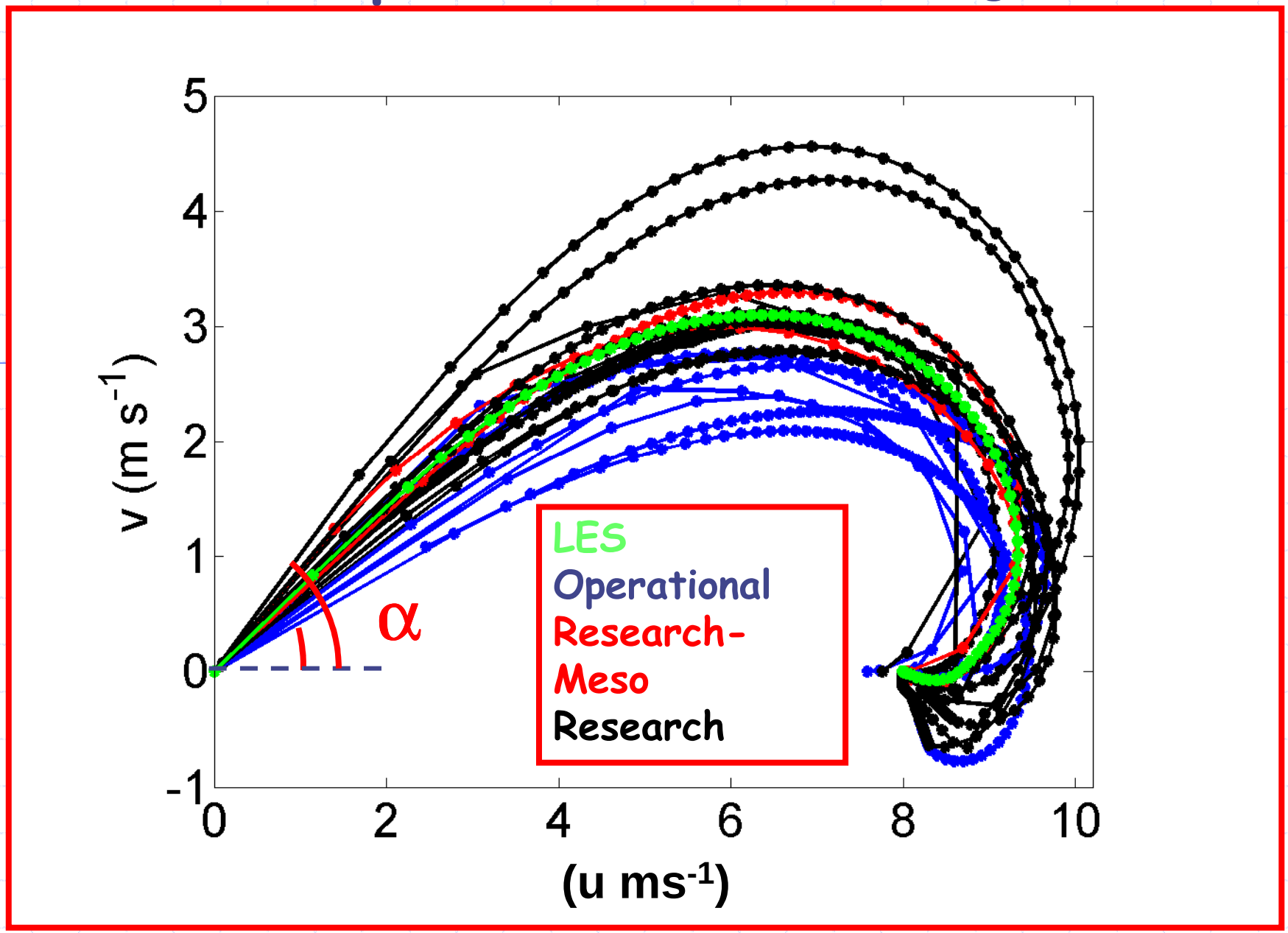
Resolution (most) operational models is set to 6.25 m!



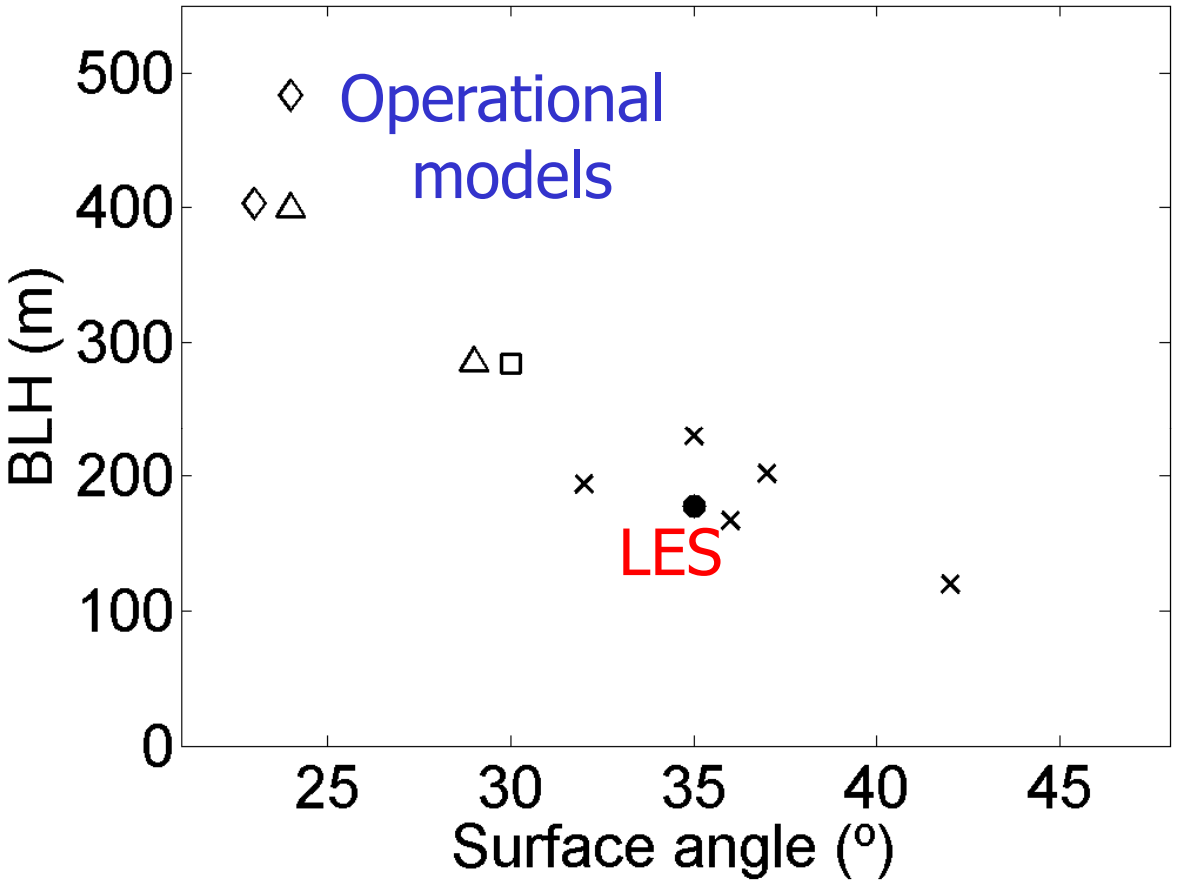
Models can represent main LES results after adjusting parameters in turbulence scheme

Steeneveld, Van de Wiel, Holtslag, 2006 (BLM)

'Ekman spirals' (Svensson+Holtslag, 2009)



Models with surface layer inconsistencies removed



(Svensson+Holtslag, 2009)

GABLS1

LES models are able to simulate a weakly stably stratified boundary layer

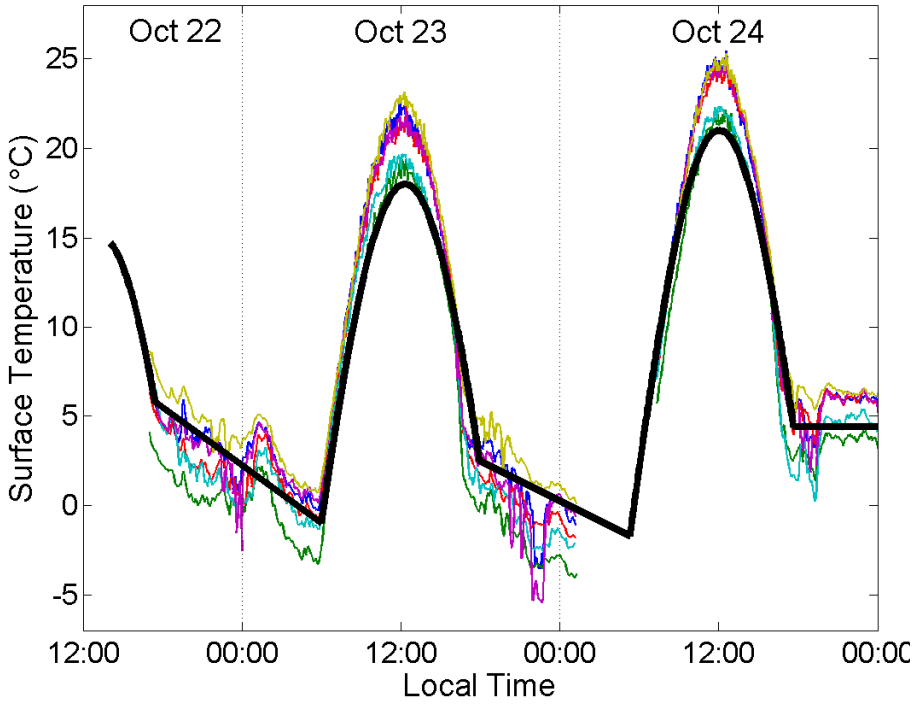
Large variation among 1D models, but all operational models show too strong mixing!

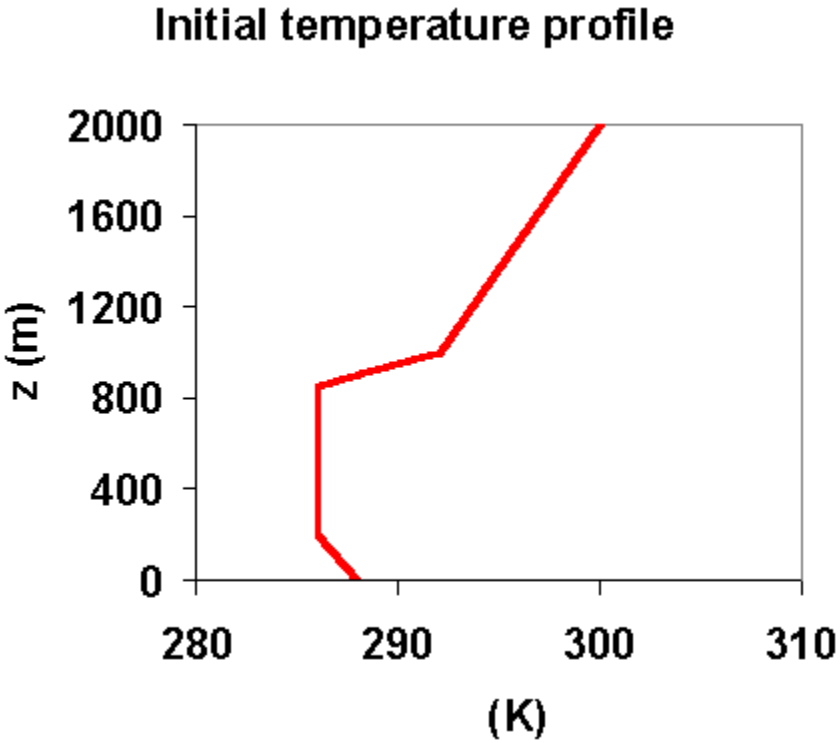
Many tests and new formulations in NWP models were initiated after this study but the general problem is not solved!

Special issue of Boundary-Layer Meteorology, 2006
(e.g. Beare et al., Cuxart et al., Holtslag and 5 other papers)

GABLS2 (coordinated by Gunilla Svensson):

Intercomparison of SCM models on basis of CASES99 observations for a period of 2.5 days (after Steeneveld et al 2006); Also LES run by Kumar et al (2010)





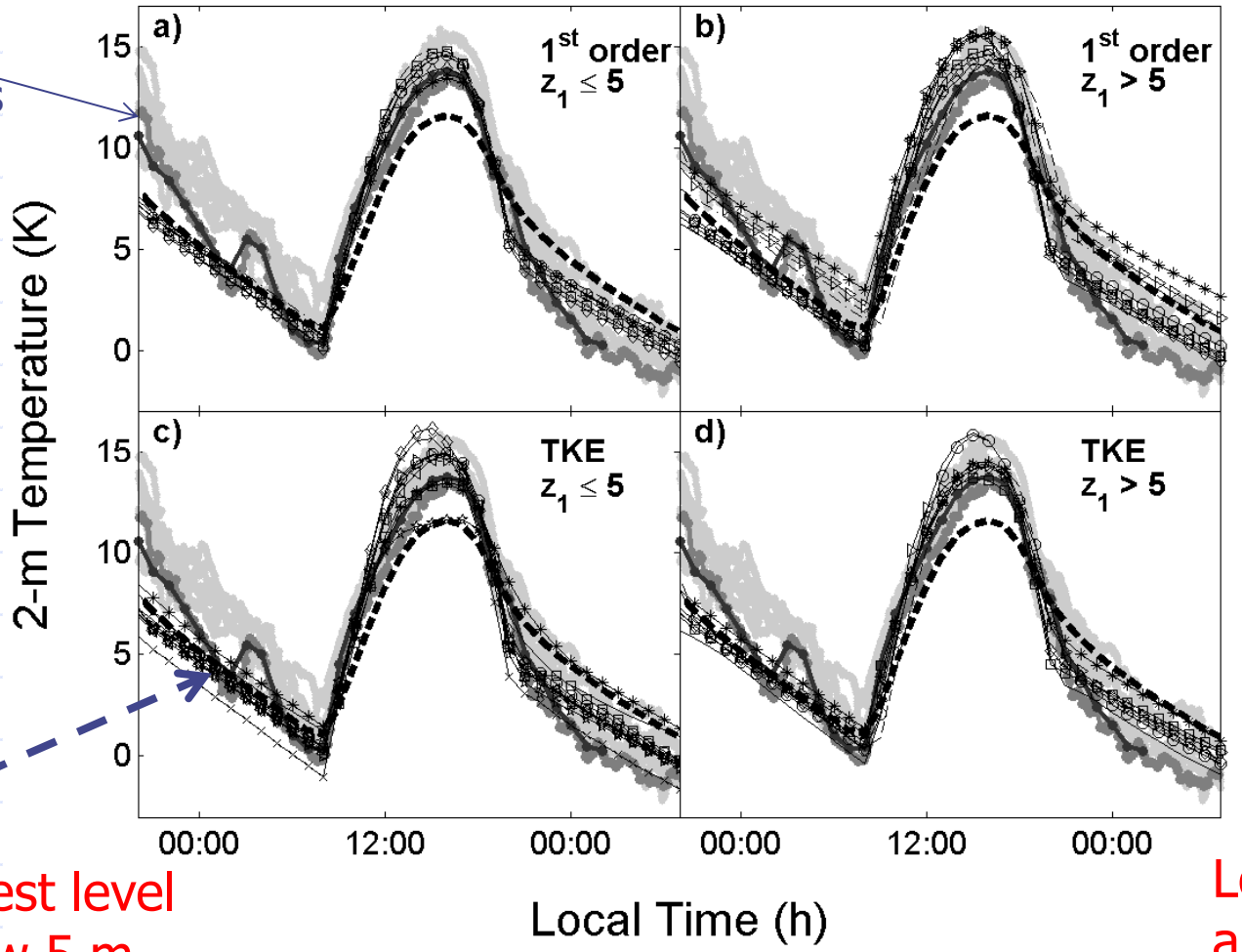
Prescribed surface temperature using the local observations

Also same initial conditions and forcings for wind and humidity

GABLS2

Temperature at 2 m height

Obser-vations



LES

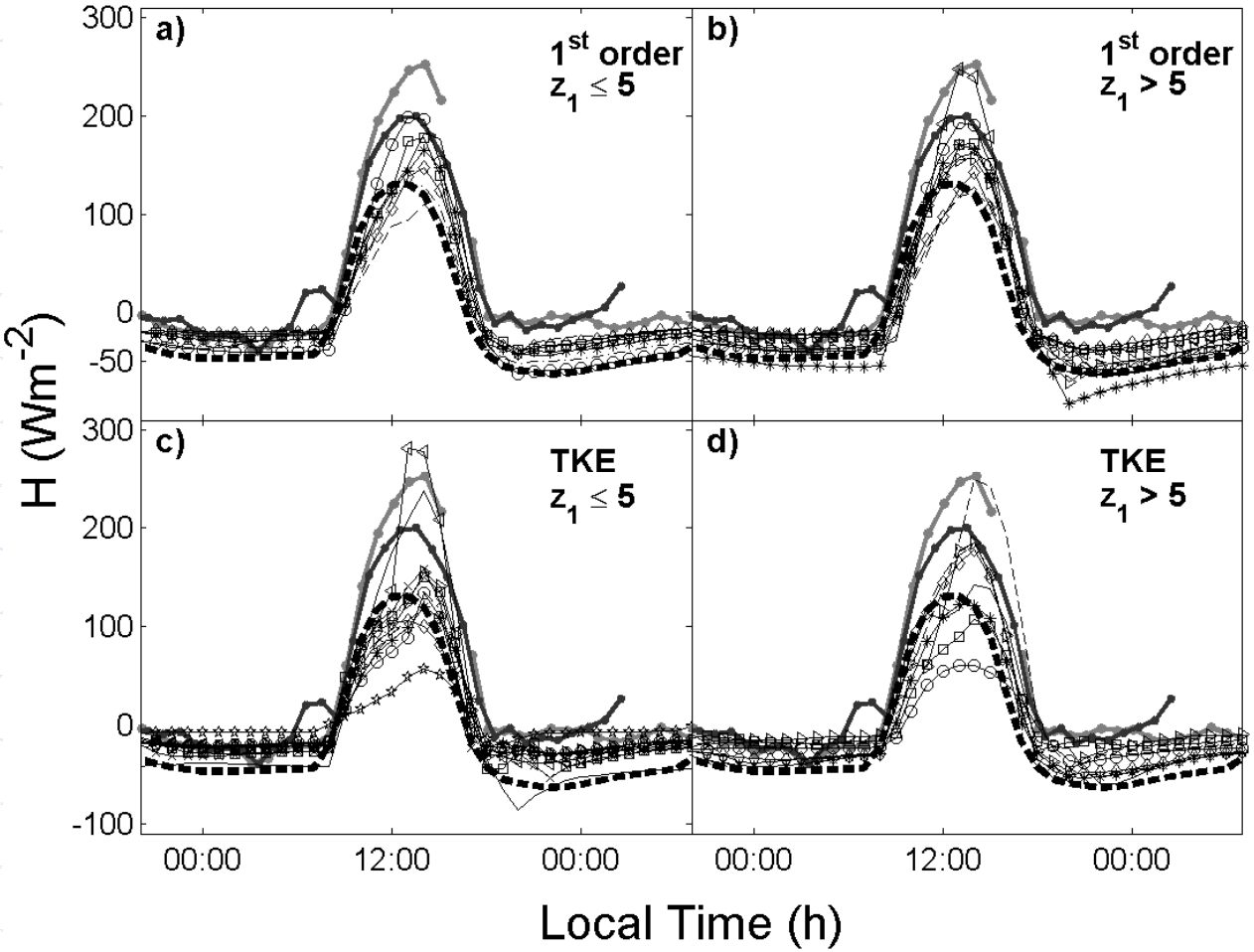
1st order closures

TKE closures

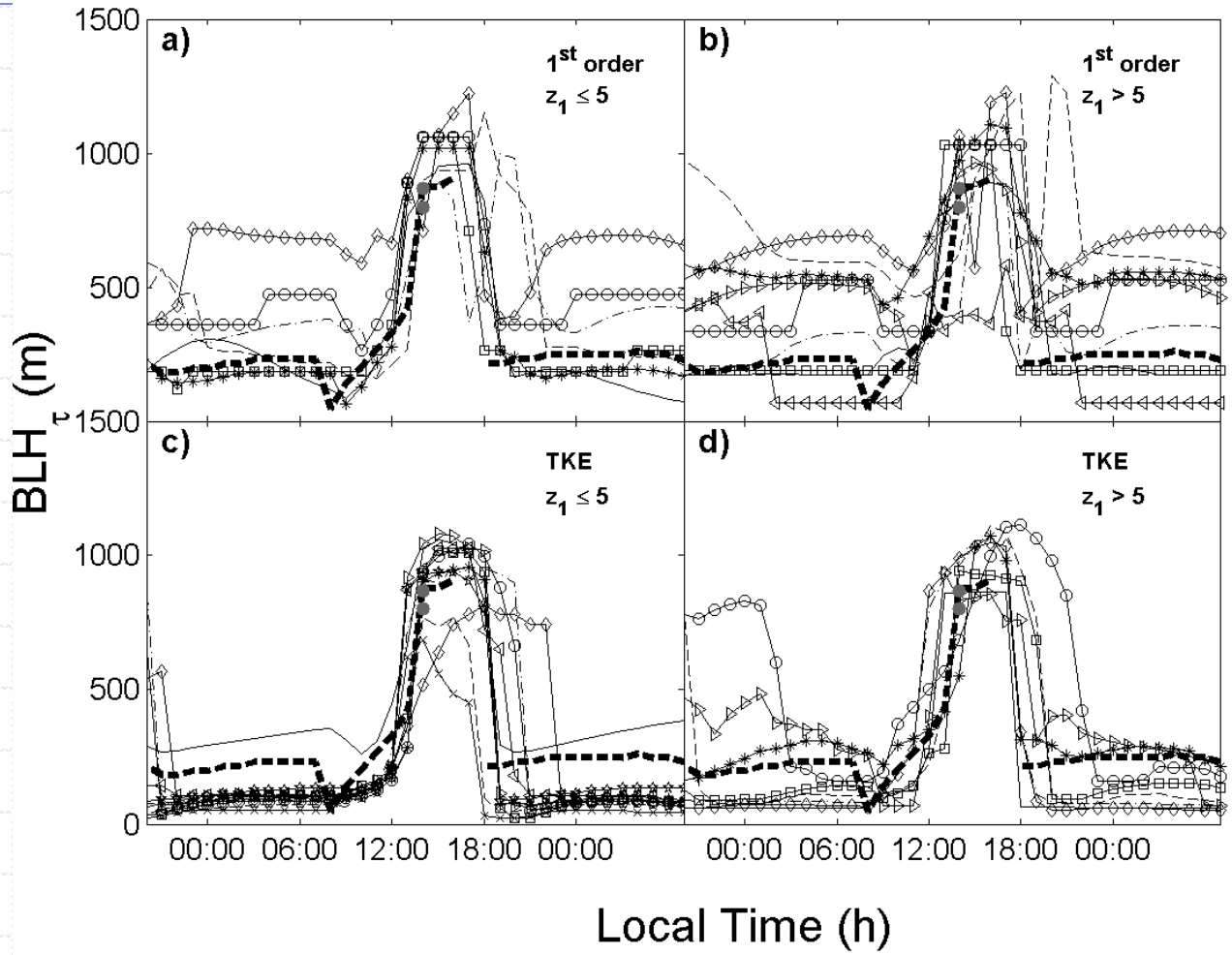
Lowest level below 5 m

Lowest level above 5 m

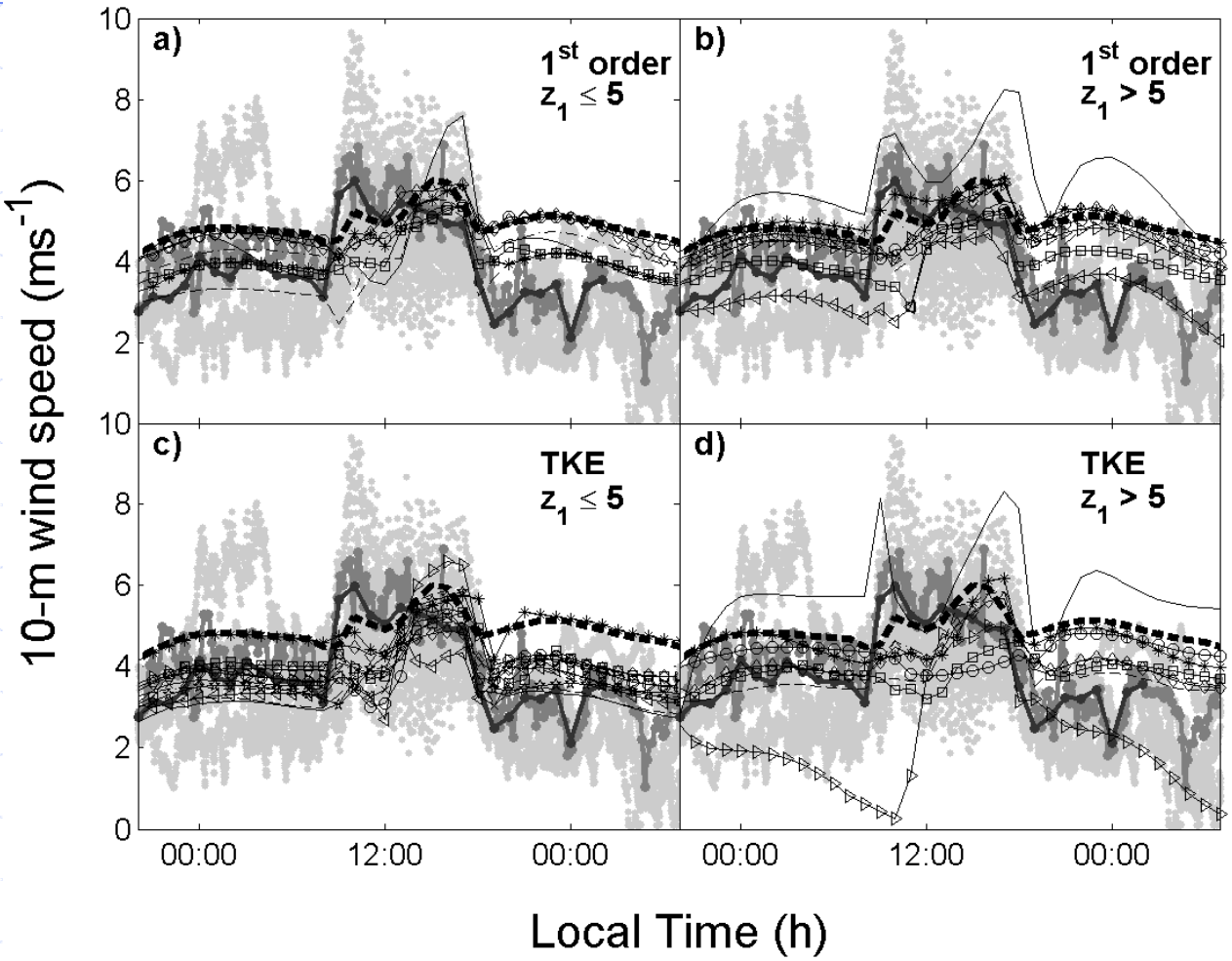
Sensible heat flux



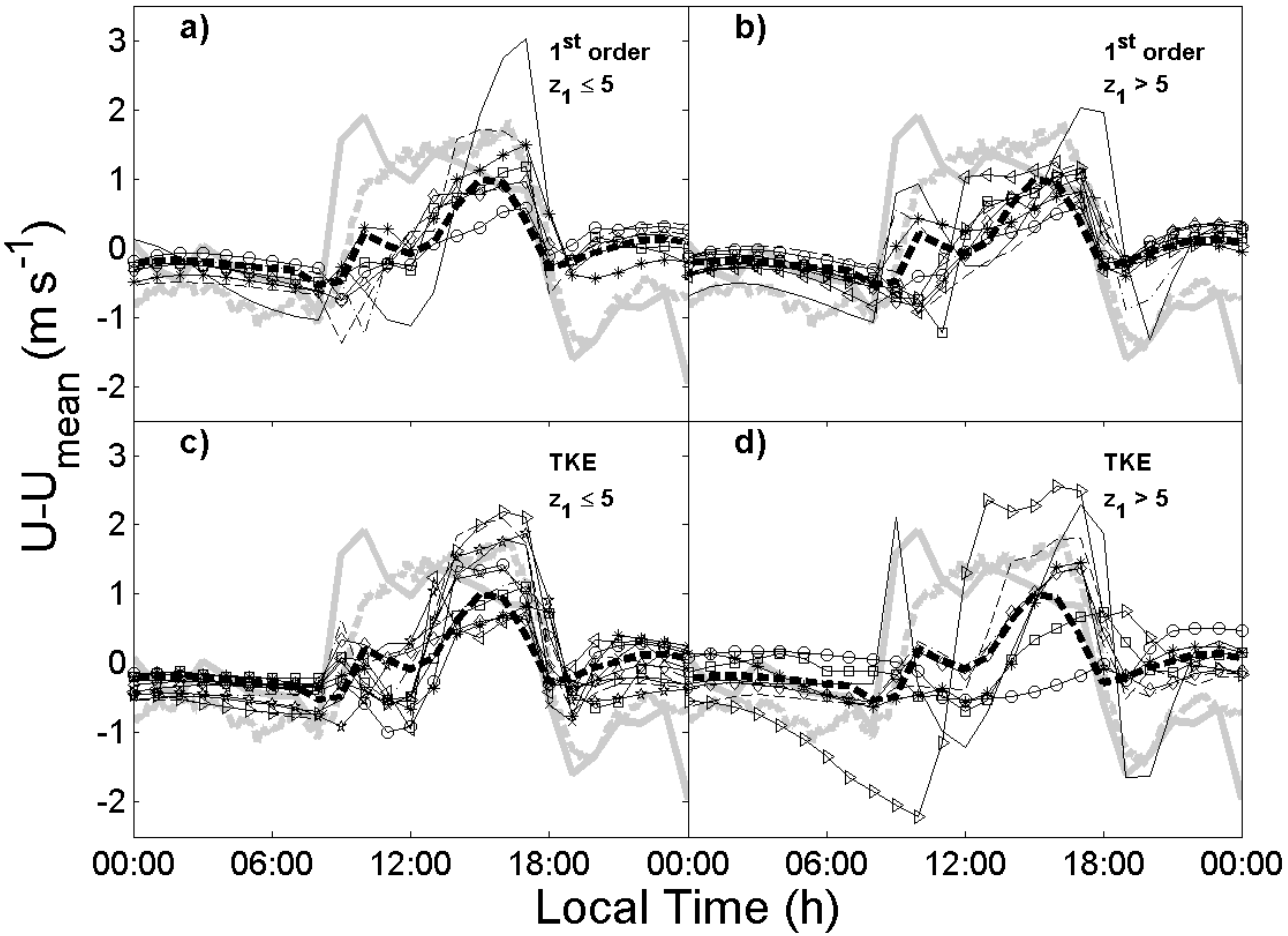
Boundary Layer Height



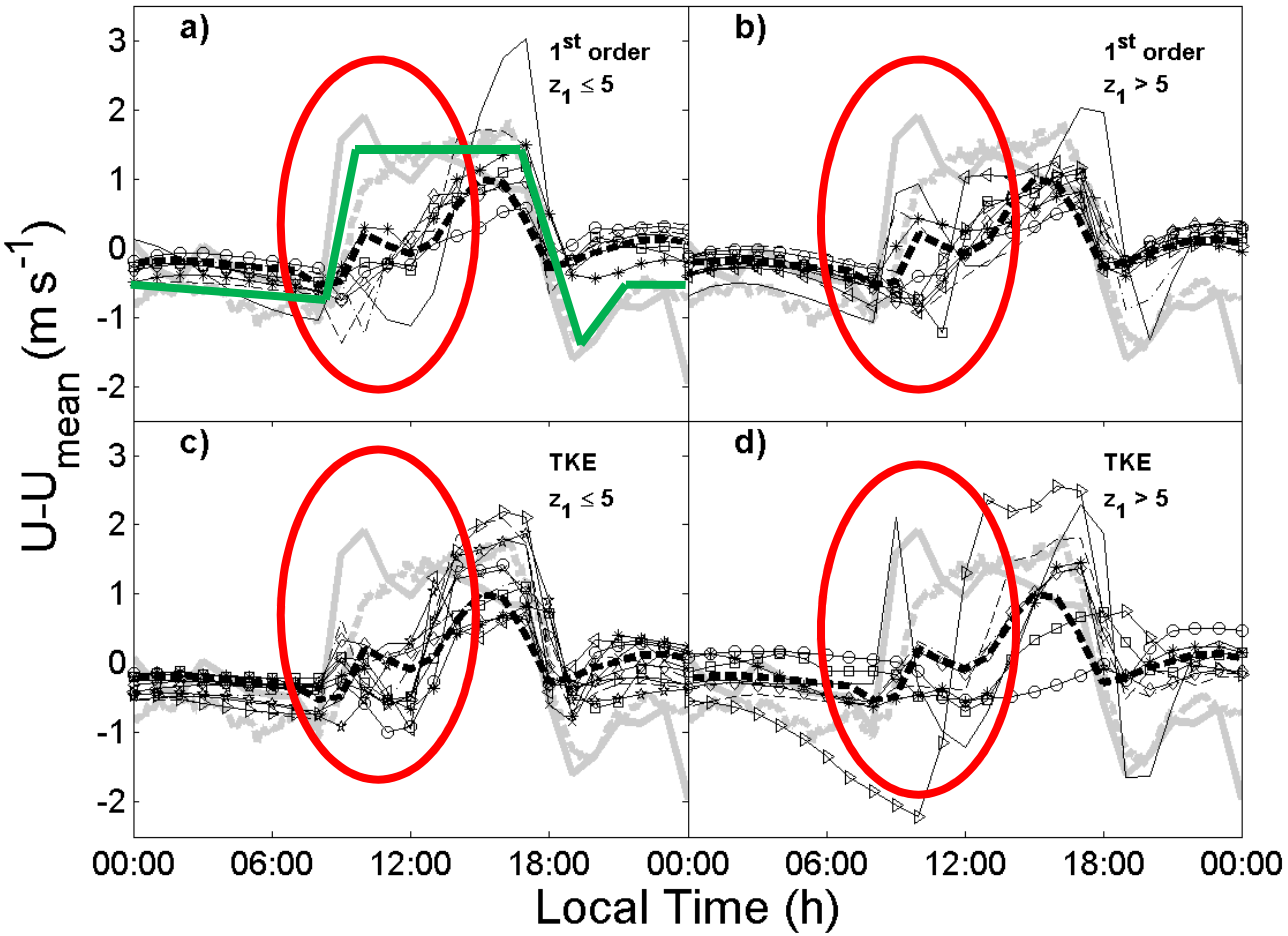
Wind speed at 10 m height



Wind amplitude at 10 m height too weak



Wind amplitude at 10 m height too weak



Summary GABLS2

Within GABLS2 we find large variation among different boundary layer schemes!

More complexity does not really help

It seems that the variety of model results is influenced by using a prescribed surface temperature rather than an interactive land surface energy budget

In fact, surface temperature feedback can compensate for some of the variety introduced by changing model parameters (Holtslag et al, BLM, 2007)

GABLS2

Diurnal cycle is not well represented

The transitions are not well captured by the models

More attention at NWP and climate centers for the representation of the diurnal cycle

Papers on SCM by Svensson et al (2011), and Kumar et al (2010) for LES

Also: Steeneveld et al (2006) and (2008) study coupled land-atmosphere within SCM and provide regional model inter-comparison, respectively

GABLS3

Builds on the experiences from the previous GABLS intercomparisons

Both LES and SCM intercomparison but not exactly the same

Case coordination by Fred Bosveld (KNMI) for SCM

and Sukanta Basu (NCSU) for LES

Initial results were presented and discussed at AMS 18th and 19th BLT meetings

Papers in preparation

GABLS3: SCM and LES model studies

Cabauw tower
(KNMI, NL)

GABLS3-SCM

12 Z
01 July
2006

12 Z
02 Jul

GABLS3-LES

00 Z
02 Jul

09 Z
02 Jul

Initialization Profiles

Cabauw tower, Profiler, De Bilt Sounding

Geostrophic Wind (time-height dependent)

Similar for both SCM and LES

Large-scale Advection (time-height dependent)

Similar for both SCM and LES

Surface Boundary Conditions

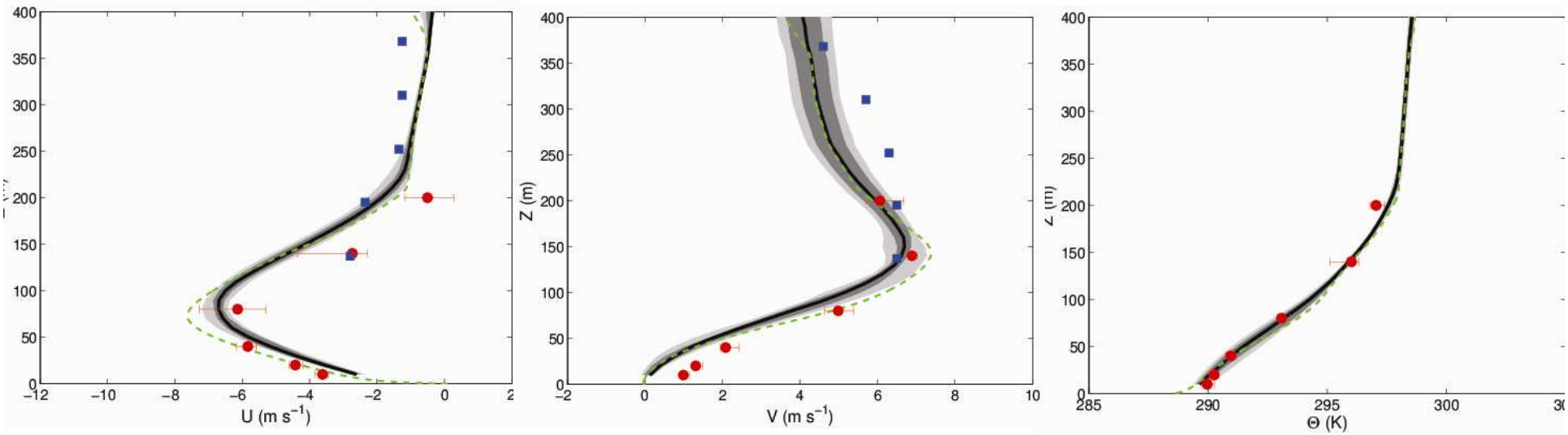
Cabauw tower

GABLS3 Large Eddy Simulation intercomparison (coordinated by Sukanta Basu, NC State Univ)

Initialized at midnight (02-jul-2006 00:00 UTC) and run for 9 hours (11 LES models)

Prescribed temperature at lowest model level from observations!

Velocity x direction Velocity y direction Potential Temperature



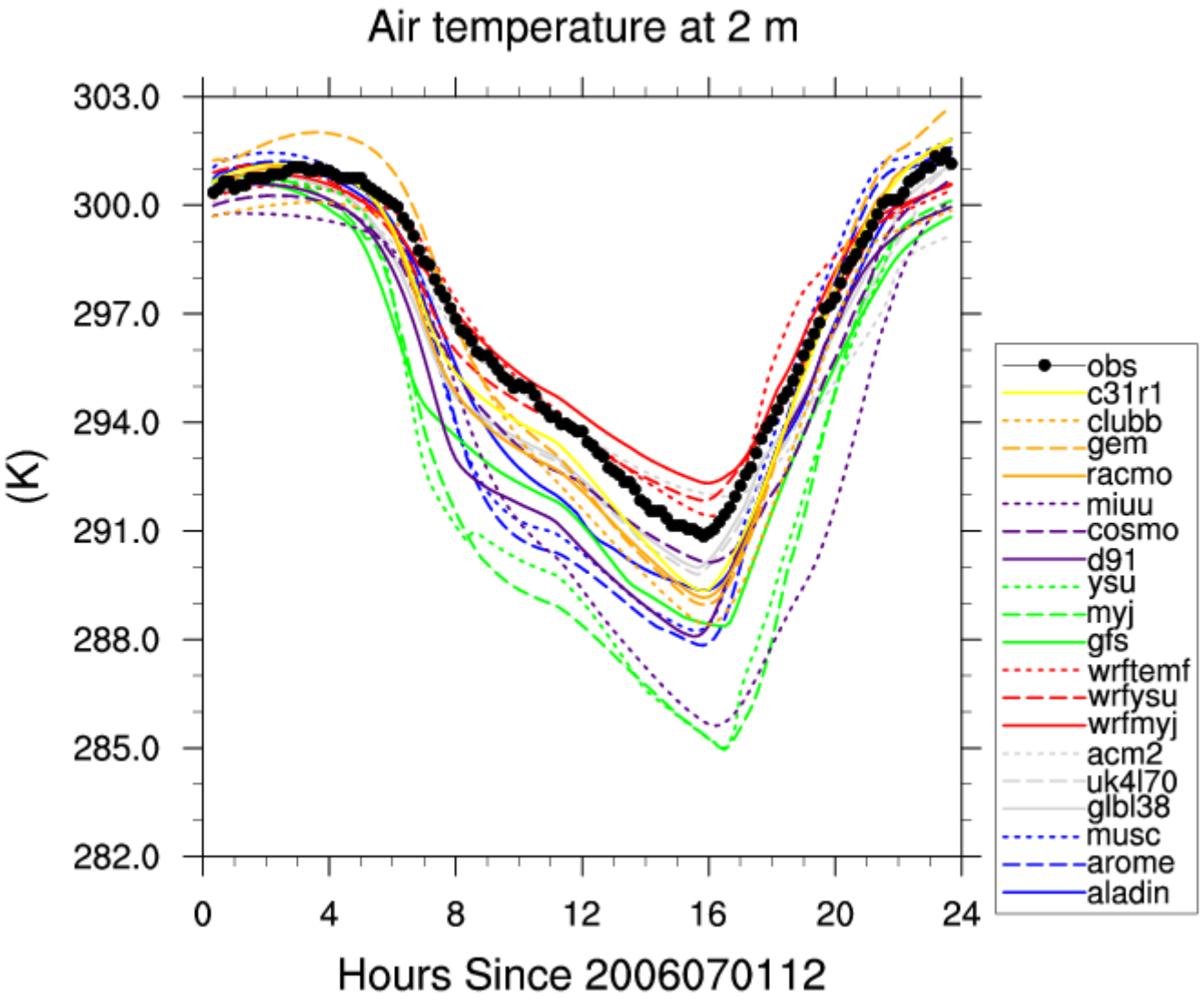
Mean profiles 03-04 UTC

(Red dots: Tower; Blue squares: Wind Profiler)

GABLS3 intercomparison of Single Column versions (SCM) of operational and research models (Coordinated by Fred Bosveld, KNMI)

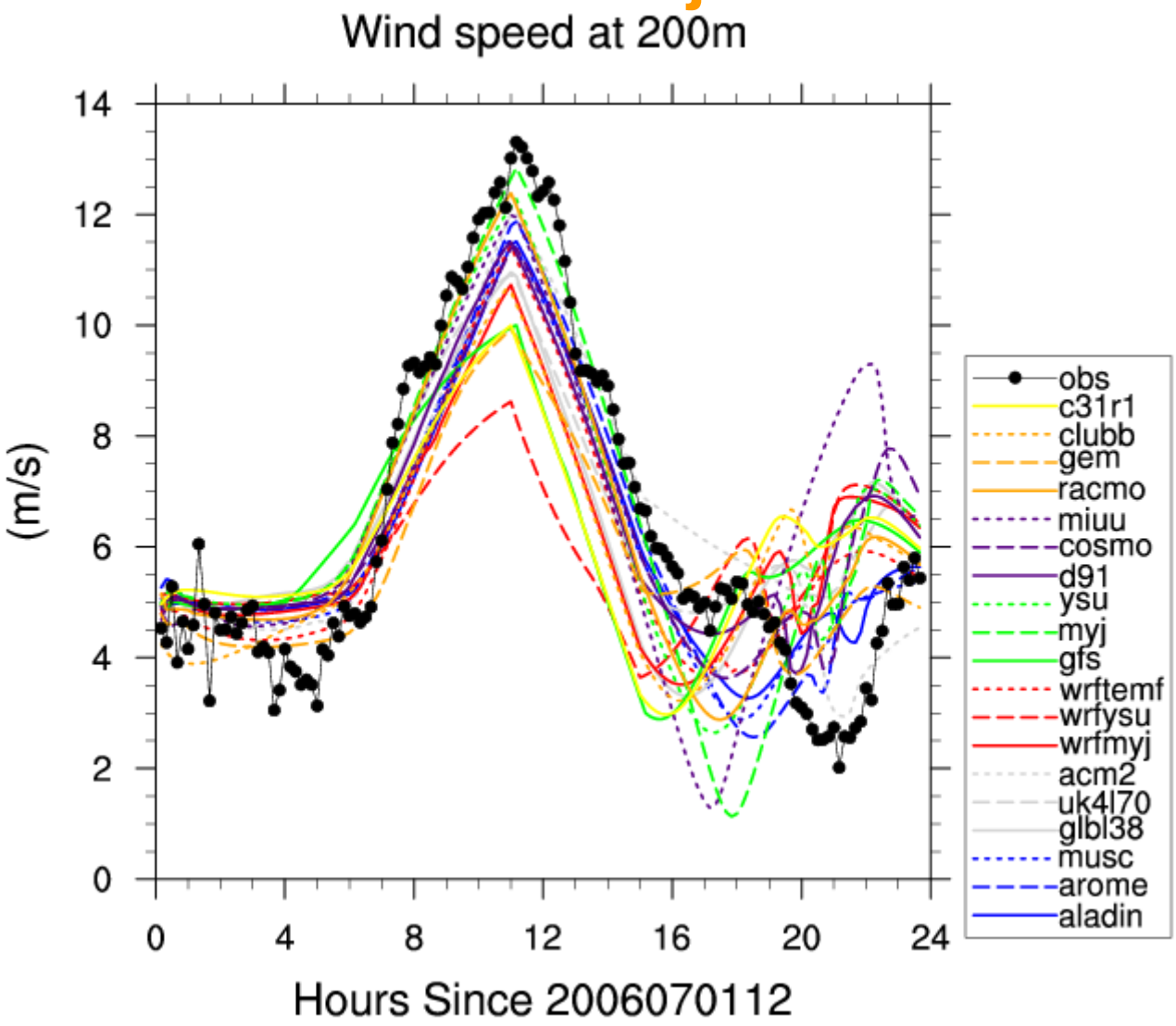
Note:
Each SCM uses its own radiation and land surface scheme interacting with the boundary layer scheme on usual resolution!
(Nlev is number of vertical levels in whole atmosphere)

Name	*Institute*	*Nlev*	*BL.Scheme*	*Skin*
ALADIN	Meteo France	41	TKE	No
AROME	Meteo France	41	TKE	No
GLBL38	Met Office	38	K (long tail)	Yes
UK4L70	Met Office	70	K (short tail)	Yes
D91	WUR	91	K	Yes
GEM	Env. Cananda	89	TKE-l	No
ACM2	NOAA	155	K+non-local	No
WRF YSU	NOAA	61	K	No
WRF MYJ	NOAA	61	TKE-l	No
WRFTEMF	NOAA	61	Total E	No
COSMO	DWD	41		
GFS	NCEP	57	K	Yes
WRF MYJ	NCEP	57	TKE-l	Yes
WRF YSU	NCEP	57	K	Yes
MIUU	MISU	65	2nd order	
MUSC	KNMI	41	TKE-l	No
RACMO	KNMI	80	TKE	Yes
C31R1	ECMWF	80	K	Yes
CLUBB	UWM	250	Higher order	No

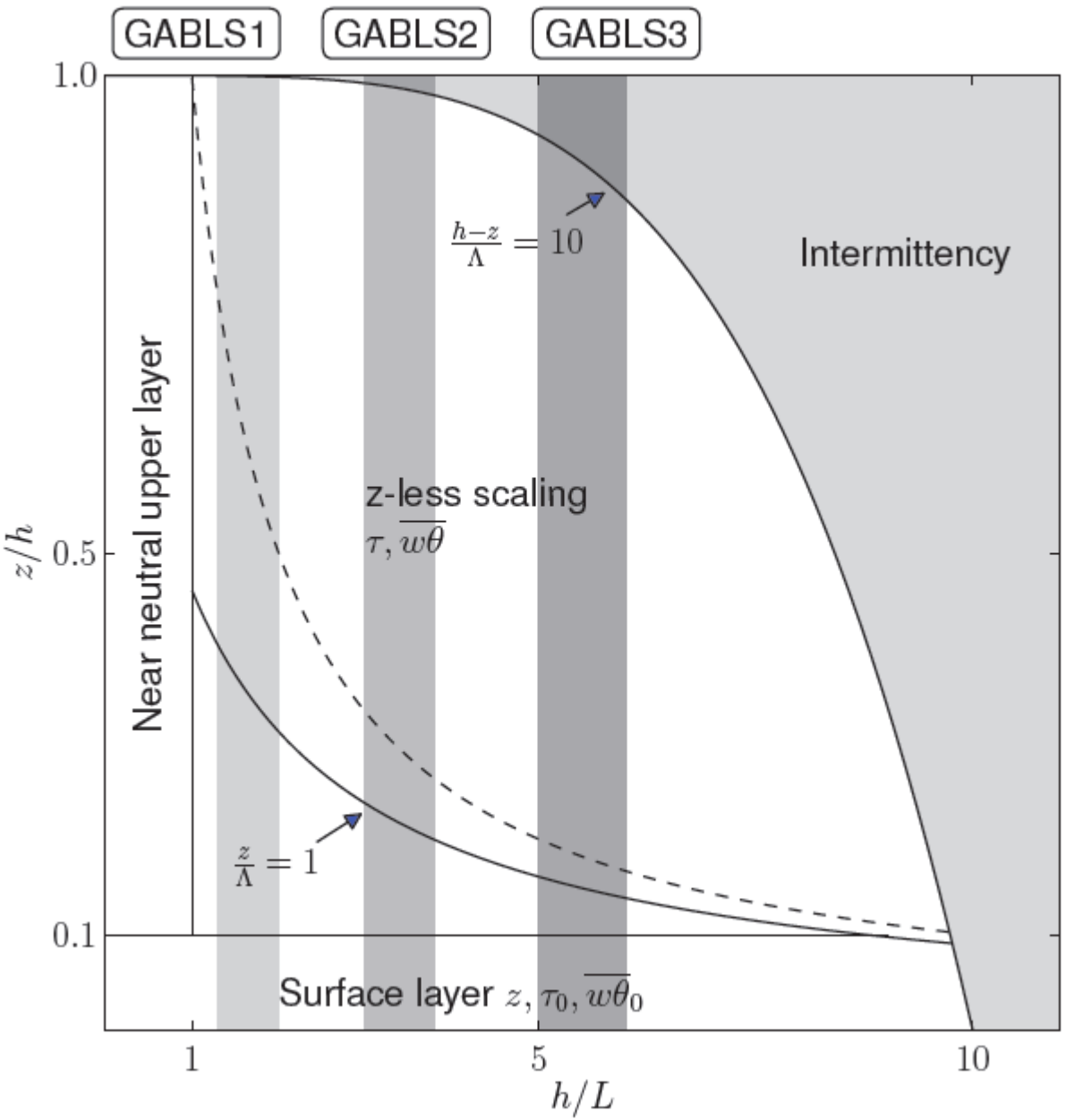


noon midnight noon

Low level jet



noon midnight noon



Increasing stability during night time for GABLS1 to GABLS3

Figure by Holtslag and Nieuwstadt (1986) as modified for GABLS by Arnold Moene

Modeling Atmospheric Boundary Layers: State of art

Significant variation in all aspects of the Stable Boundary layer are seen in models which can be related to relevant processes

Sensitivity to details in mixing formulation,
interaction with the land surface,
the representation of radiation (divergence),
et cetera

Why do many Operational Models need Enhanced Mixing in Stable Cases?

To prevent unrealistic 'runaway' surface cooling?
(e.g., Louis et al, 1982)

To have sufficient 'Ekman pumping'?
(e.g., Beare, 2007)

To compensate for model errors / shortcomings?
(e.g., radiation divergence, see Steeneveld et al, 2010, JGR)

Do we overlook an atmospheric process?
(e.g, small scale gravity wave drag; Steeneveld et al, 2008, 2009)

What is relation with land surface heterogeneity?
(e.g., McCabe and Brown, 2007; Stoll et al, 2009)

ECMWF/GABLS Workshop on "Diurnal cycles and the stable atmospheric boundary layer"

The workshop aims to review the relevant research, consider the available schemes, explore the recent data sets and make recommendations for large scale models

Review the GABLS results of last decade

Set up of new joint numerical experiment and model evaluation studies (Possibly PBL acting together with surface, radiation and clouds…)

Recent Suggestions

Revisit GABLS2 and couple to land surface using long spin up for land schemes (Martin Best, Met Office)

Set up new GABLS4 case focussing on (Ant)arctic (Timo Vihma and Tiina Kilpelainen, FMI)

Sensitivity study for incoming longwave radiation and surface parameters by various models (Dick McNider et al)

Some changes within GEWEX

GABLS and GCSS now combined in GASS:
GEWEX Atmospheric Science Studies

Aims to have more than clouds and ABLs...

(thanks to anonymous person)

GABLS basic publications
(plus many conference and invited presentations)

GABLS1:
Special issue Feb 2006, Boundary Layer Meteorology (7 papers)
Svensson and Holtslag, 2009, BLM (wind turning issue)

GABLS2:
Steeneveld et al, 2006, JAS (SCM) and 2008, JAMC (Mesoscale study)
Holtslag et al, 2007, BLM (Coupling to land surface)
Kumar et al, 2010, JAMC (LES study)
Svensson et al, 2011, BLM (SCM intercomparison)

GABLS3:
Baas et al 2010, QJRMS (set up case and SCM tests)
New special issue of BLM planned for 2012, including intercomparison papers by Bosveld et al (SCM), Basu et al (LES), Edwards et al (LES + Radiation scheme)....

GABLS overview paper in 2012 (Holtslag et al, BAMS)

Thanks to all the participating scientists in GABLS, GLASS-LOCO and many others who gave feed back and shared ideas!

GLASS-GABLS workshop KNMI September 2005