Objective Determination of PBL depth for Evaluation of PBL Schemes

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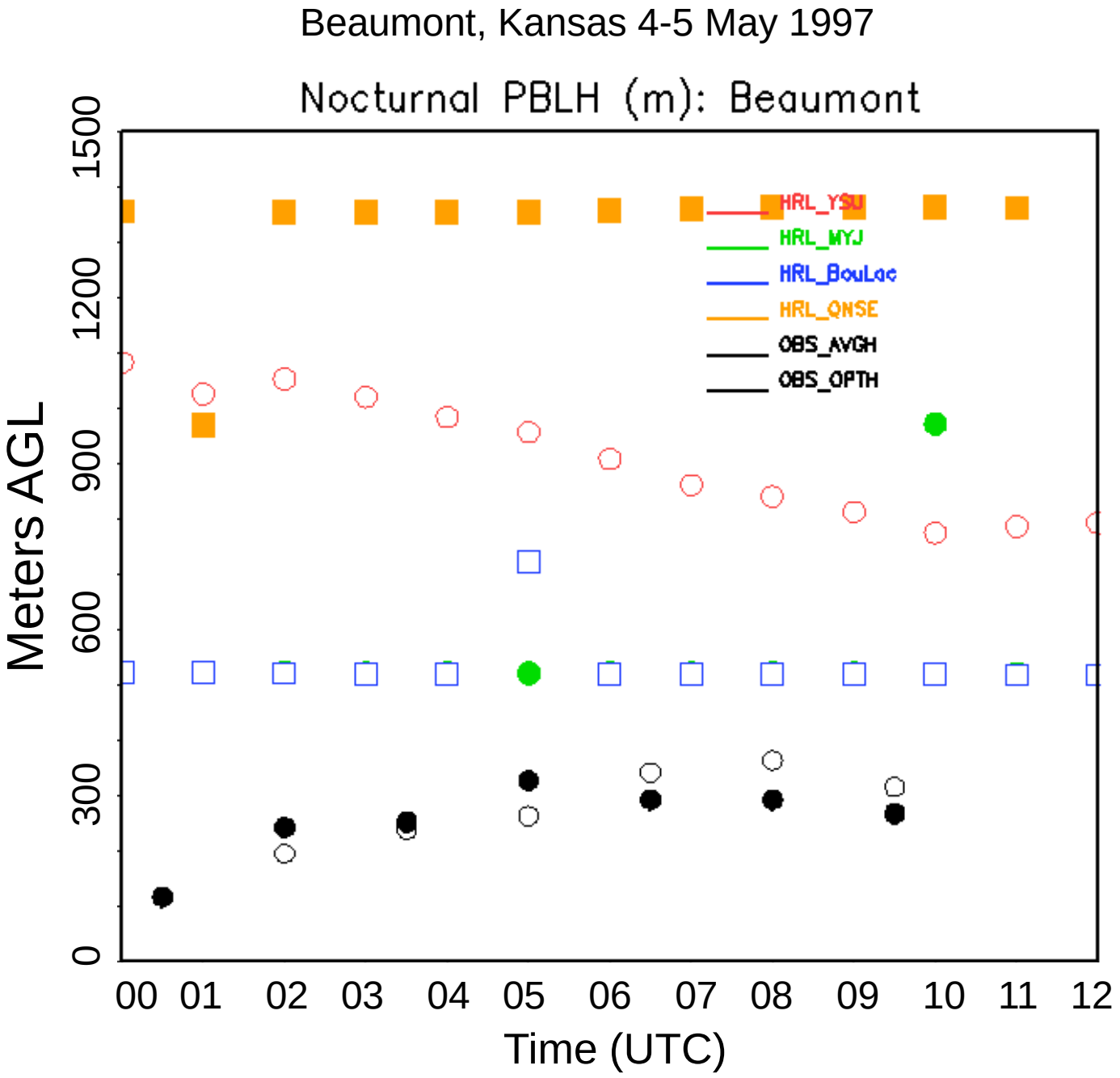
Motivation: LARGE difference in PBL depth from WRF Schemes

WRF PBLH
YSU
MYJ
BouLac
QNSE

Observed PBLH (black)
Closed Circles:
Average of heights of:
- max Temperature
- max wind speed
- Ri loc < 1
- wsonde drop

Open Circles: consider
- only unambiguous factors



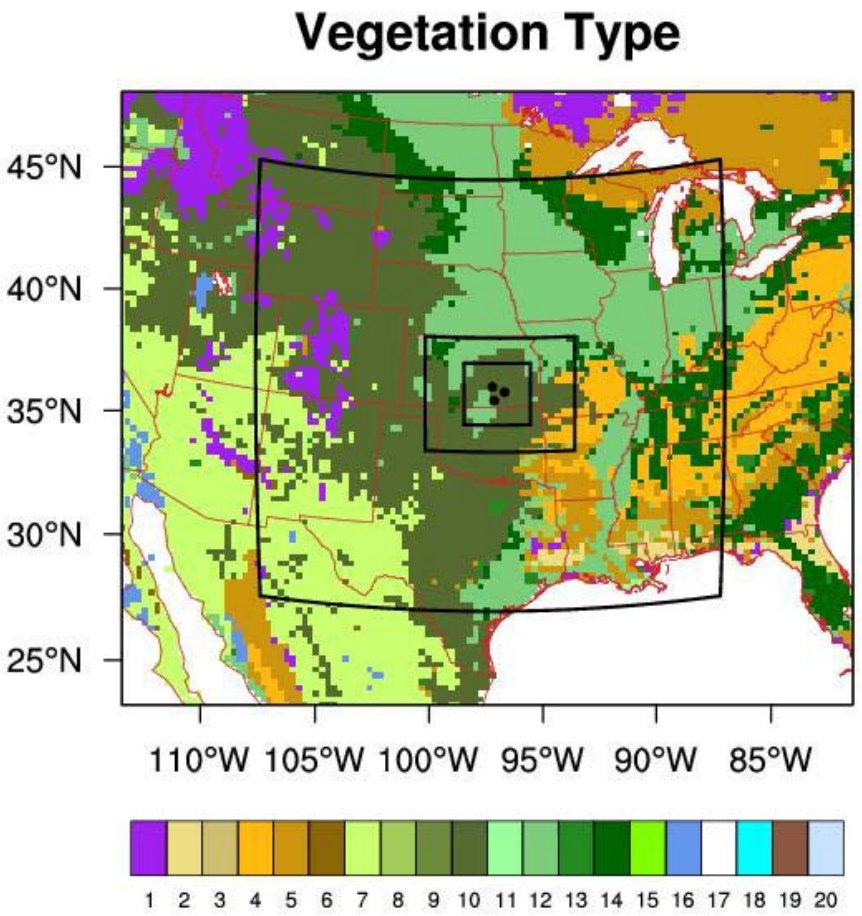
PROBLEM: Different schemes use different criteria

PBL Schemes used in this study so far.

Scheme	Basic Physics	WRF CBL depth	WRF NBL depth
YSU	K-closure with additional term for non-local transport; allows for non-local and countergradient flux.	$\Theta_v(z_i) = \Theta_v(z_1) + 1K$ (interpolated)	$Ri(h\text{-sfc}) = Ri_{crit} = ¼$ (land). For water Ri_{crit} varies.
MYJ	"Level 2.5" *q-e* scheme (a) solves for covariances, TKE, q^2 (latter a simplified equation→2.5).	*TKE* (z_k) = drops to 0.1.	*TKE*(z_k) drops to 0.1
MYNN	Updated/improved MY: re-evaluate constants using six LES runs	$\Theta_v(z_i) = \Theta_v(z_1) + 0.5K$ (interpolated)	option 2 sfc layer gives PBLH, zero (no h) for option 1 sfc.
BouLac	"Level 1.5" *q-e* scheme	$\Theta_v(z_i) = \Theta_v(z_1) + 0.5K$ (interpolated)	Like MYNN
QNSE	K from $\partial q/\partial t$ and $\partial \varepsilon/\partial t$ in terms of local relationships derived from PBL spectral model	*TKE*(z_{k+1}) drops to 0.01	*TKE*(z_{k+1}) drops to 0.01

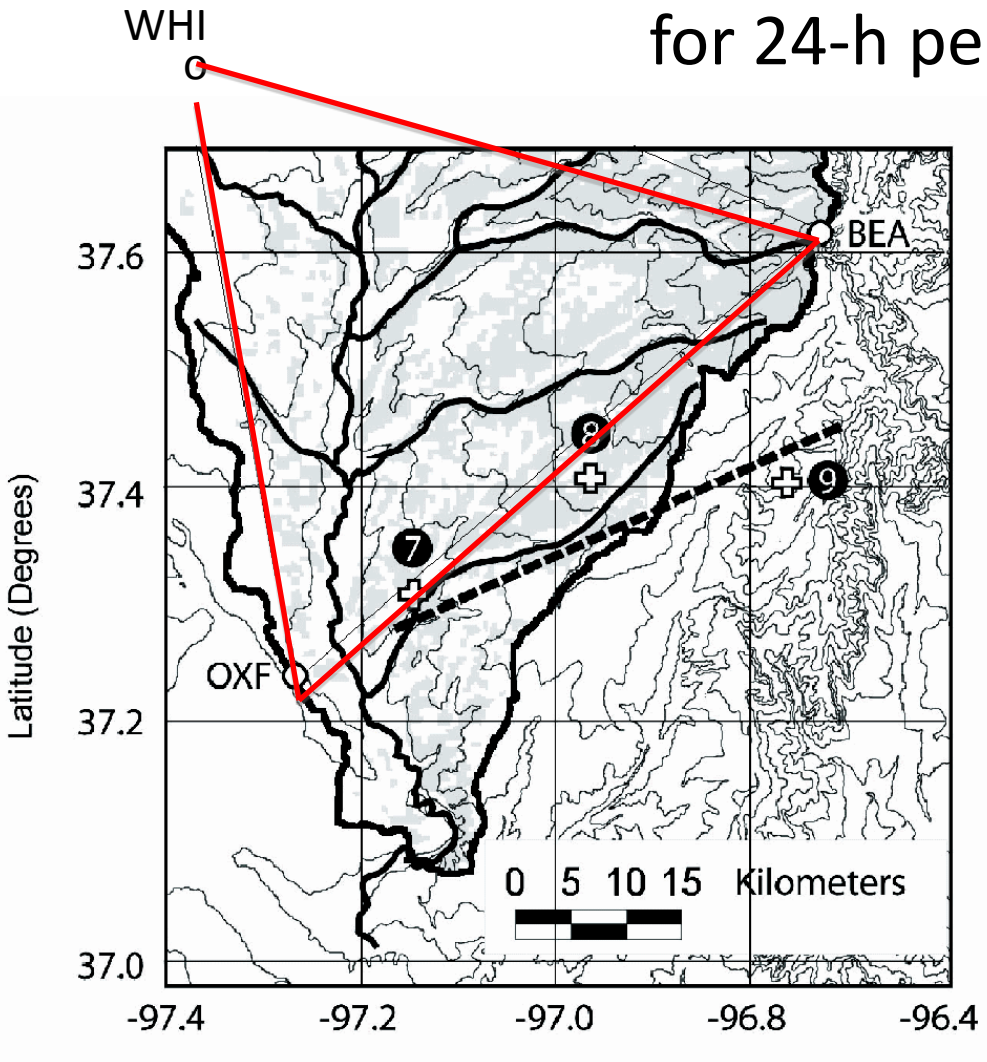
The Model: Simulations with WRFv3.2

- Domains (27, 9, 3, 1km)
  - e_we = 127, 235, 229, 304,
  - e_sn = 107, 223, 175, 283,
- Landuse (Modis, 20 Cats)
- HRLDAS Spin-up starts (1 Jan 1996) using NARR data
- WRF Runs
  - Using HRLDAS+ MYJ PBL
  - Using HRLDAS+QNSE PBL
  - Using HRLDAS+BouLac PBL
- Levels
  - 44 levels
    (15 levels below 1 km
    21 levels below 2 km)



The Observations:

CASES-97: April 21- May 21 1997: 90-min radiosondes for 24-h periods at BEA, OXF, WHI



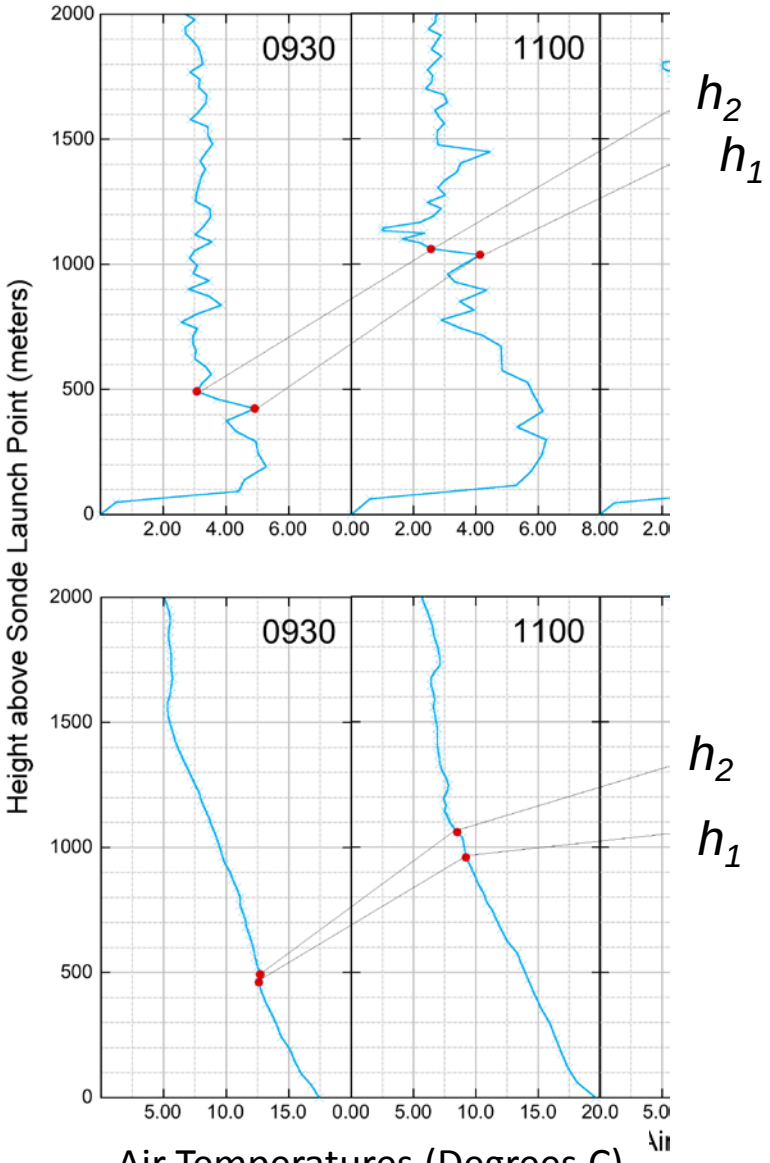
CASES Analyzed/Simulated

29 April*	Strong S winds
4-5 May	LLJ, good NBL hts
10 May	Lighter wind, meso-scale circulatios
20 May	ESE winds, just after rain

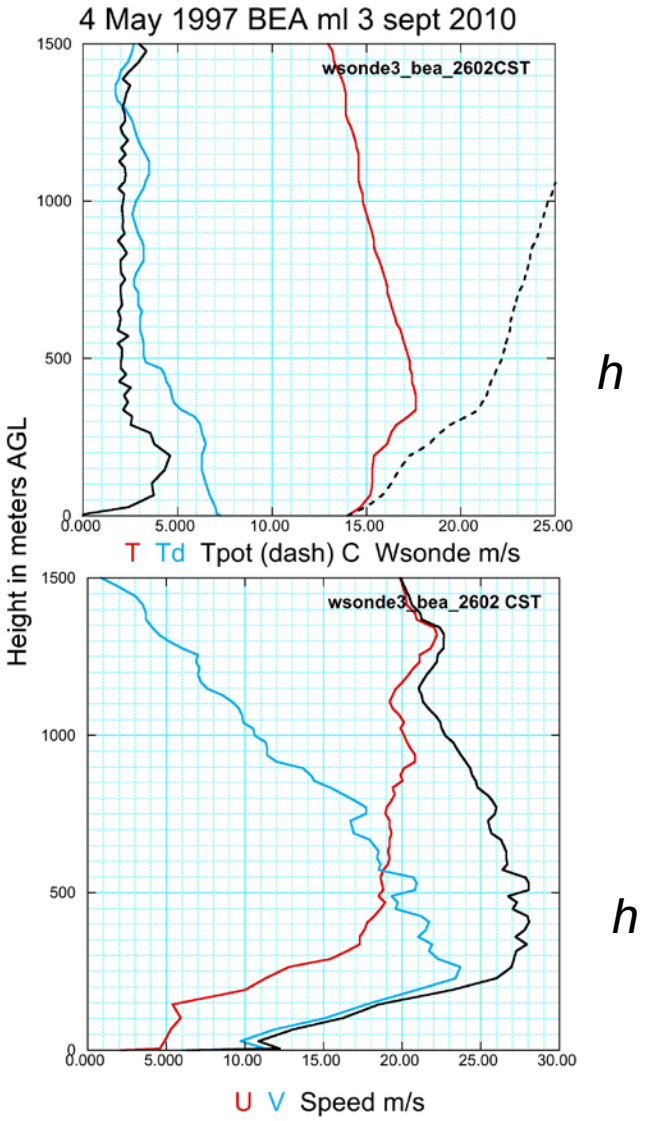
*no NBL data.

Daytime PBL Height: Virtual Temperature profiles, balloon rise rate

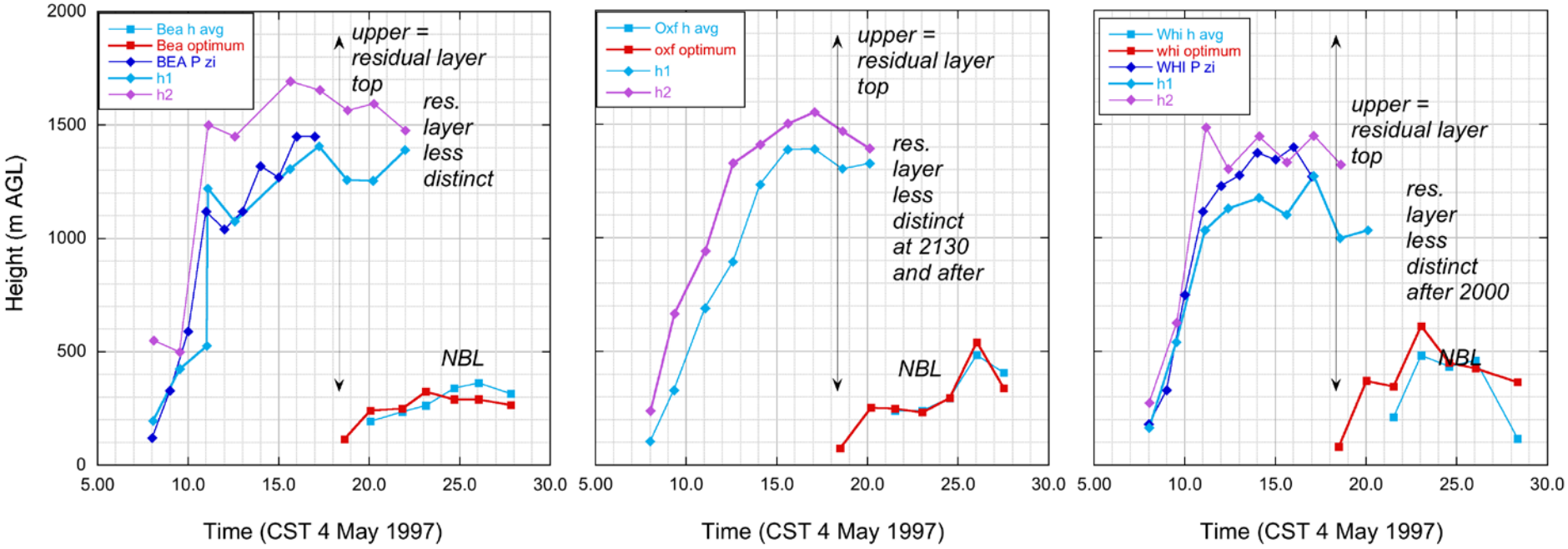
Beaumont, Kansas



Nighttime PBL Height: Virtual Temperature profiles, wind max, Ri, balloon rise rate only for deeper PBLs



PBL Depth 24 hours a day from Sonde Data



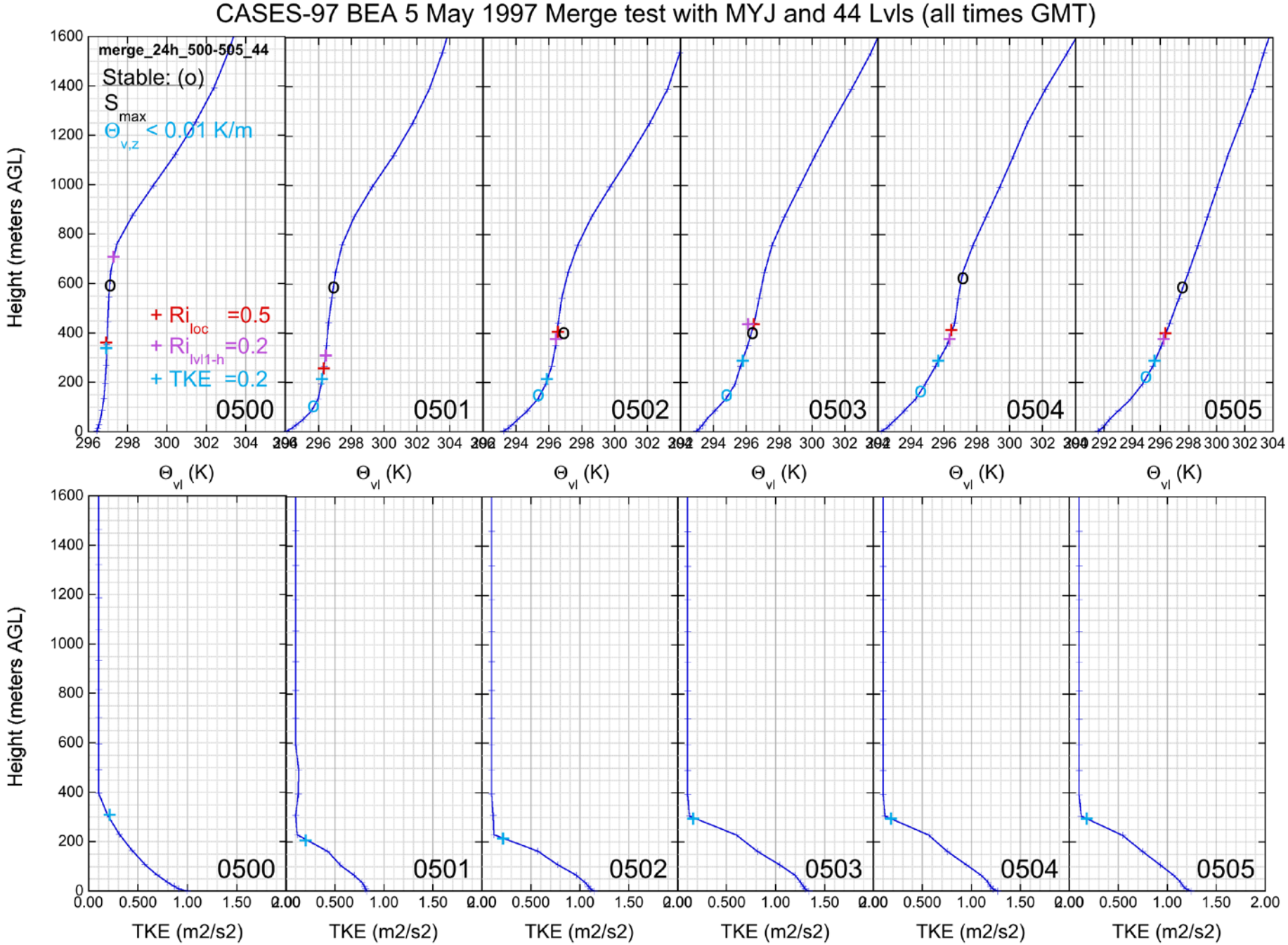
Here balloon rise rate weighted more heavily for NBL

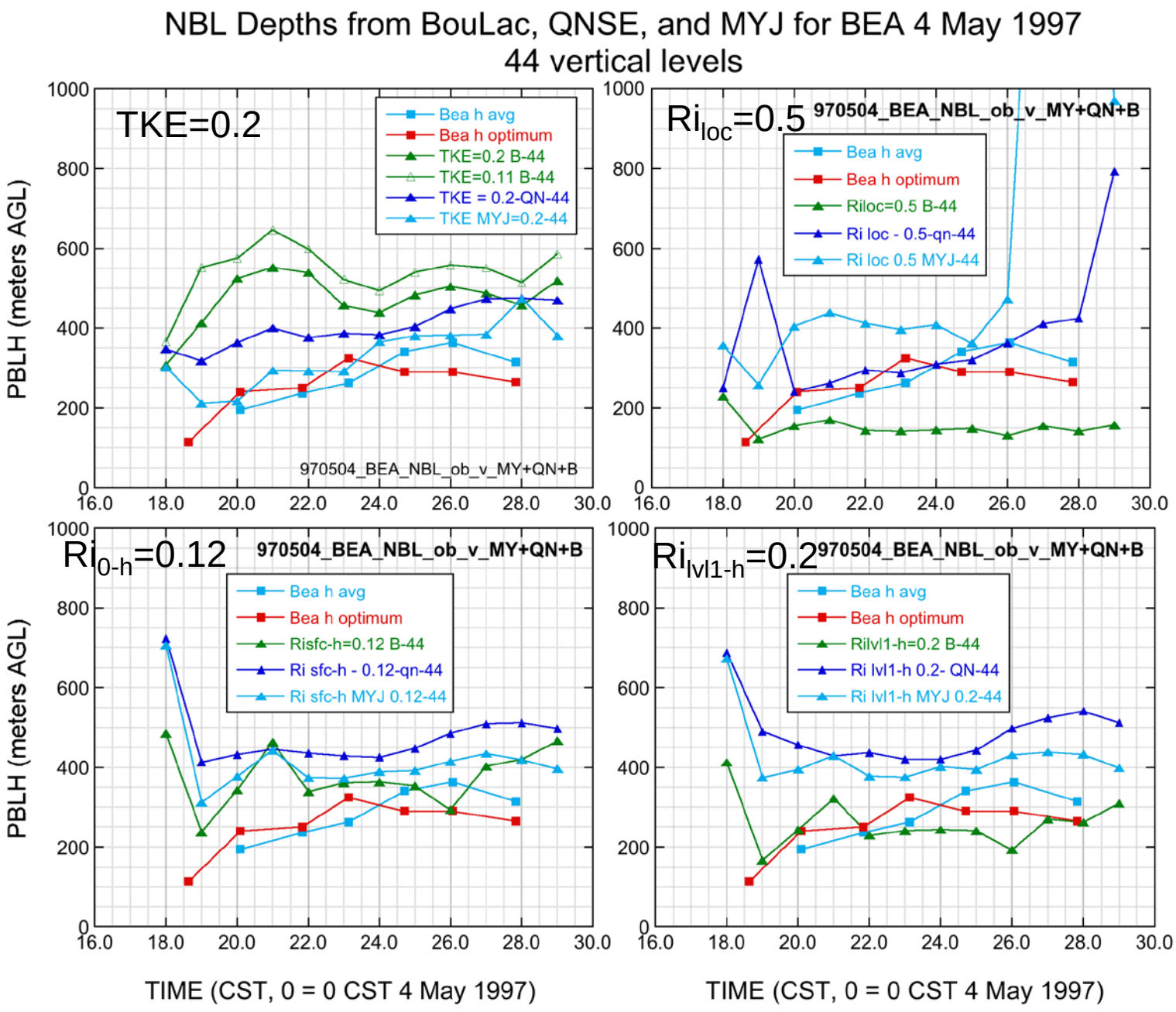
Criteria currently being tested

For all stabilities	Unstable (sfc buoyancy flux >0)	Stable (sfc buoyancy flux <0)
Ri_{loc} = 0.5	$Theta_{v,z}$ =0.002	Spd max
$Ri_{0\text{-}h}$ = 0.12	Thv(h) = Thv(lvl1)	$Theta_{v,z}$=0.01
$Ri_{lvl1\text{-}h}$= 0.2	Thv(h)=Thvl(lvl1)+1	
TKE = 0.2	Thv(h)=Thv(0.05h)	
TKE = 0.11		

STABLE

Evaluation of NBL-Depth Criteria – 4-5 May 1997





<u>WORKS WELL</u>

TKE = 0.2

Ri$_{loc}$ = 0 5

Ri$_{lvl1-h}$= 0.2

(Ri$_{0-h}$ most Sensitive to LSM)

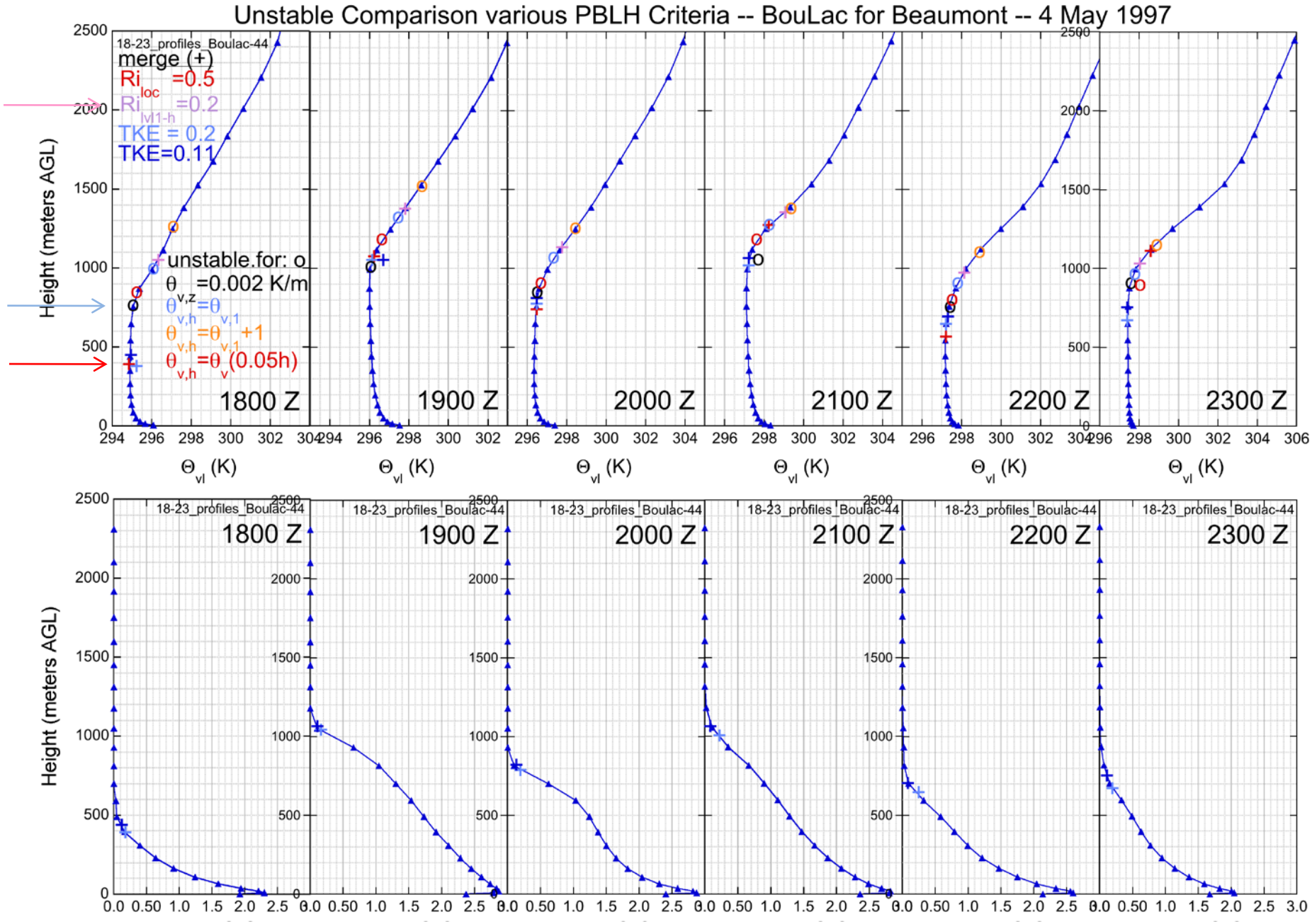
<u>Not shown</u>

$T_{v,max}$

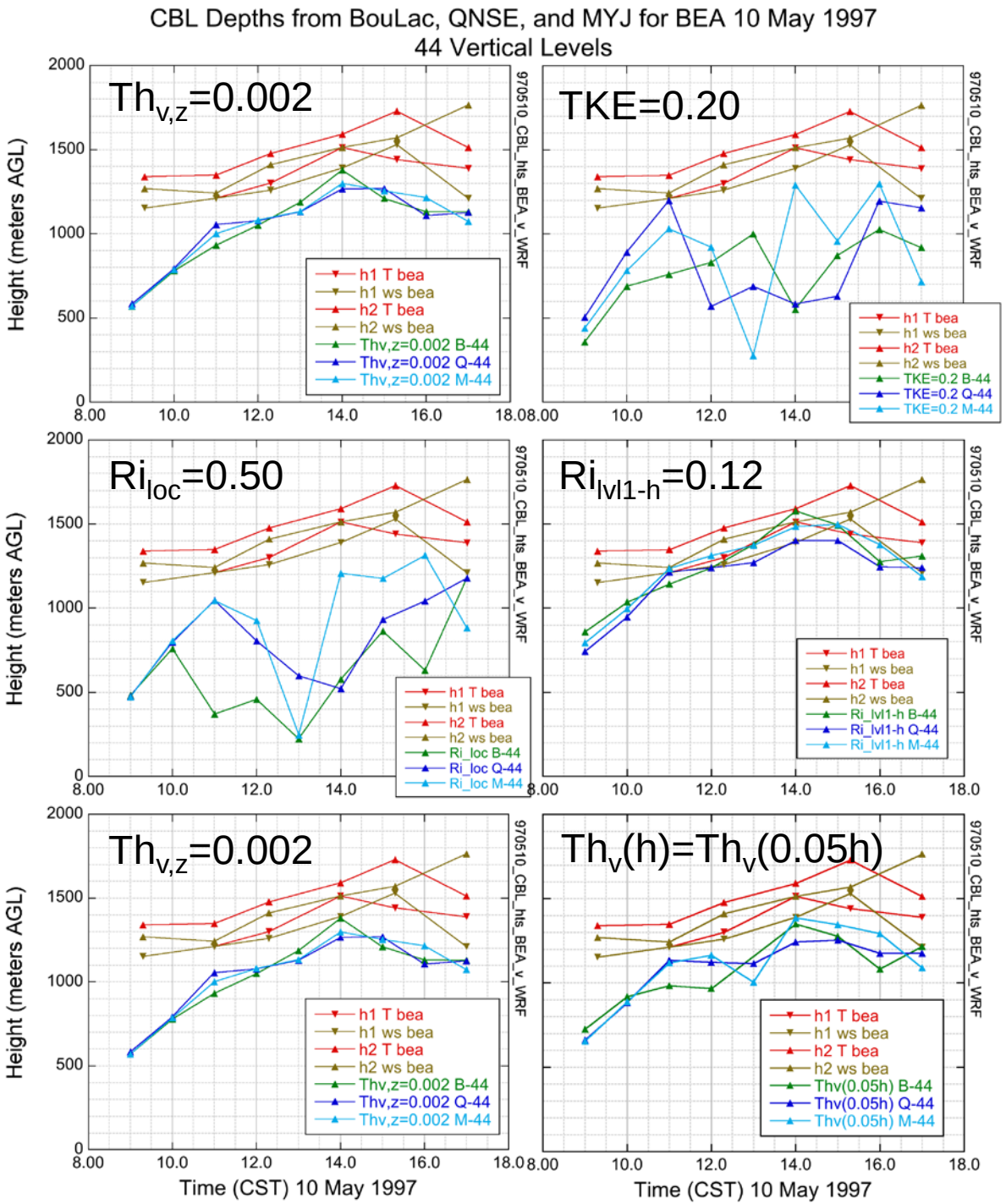
S_{max}

UNSTABLE

SAMPLE of Criterion Evaluation: Boulac 4 May 1997



Surprise: TKE PBLH oscillates vertically, related to $Th_{v,z}$



pblh
Mostly too low

Smooth:
$Ri_{lvl1\text{-}h} = 0.2$;
$Th_{v,z} = 0.002$
$Th_{v,h} = Th_{v,0.05}$
$Th_{v,h} = Th_{v,lvl1}$

Erratic:
TKE =0.2
$Ri_{loc} = 0.5$

Not shown
$Th_v = Th_v + 1$
(sensitive to grid no)

Time variation of turbulence variables

-- Surface virtual-temperature flux -- NO

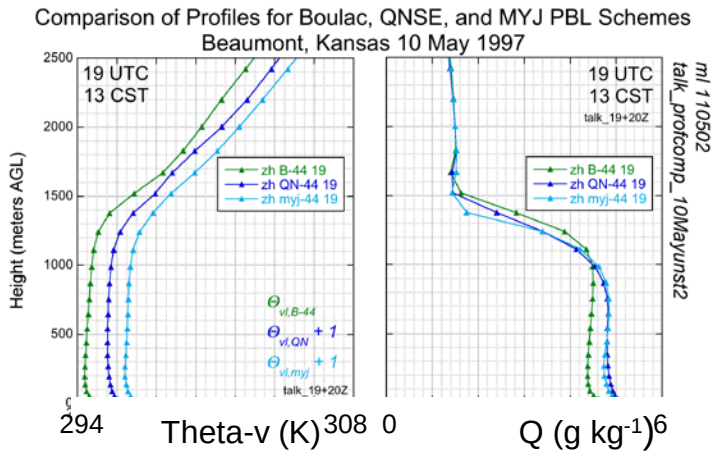
-- Static stability – YES

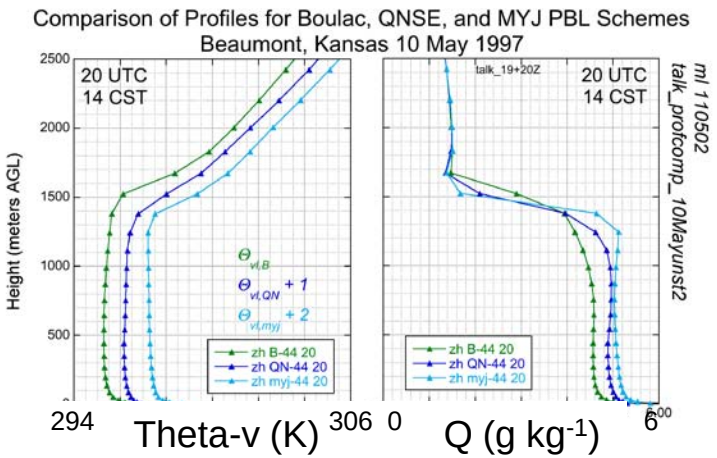
Color

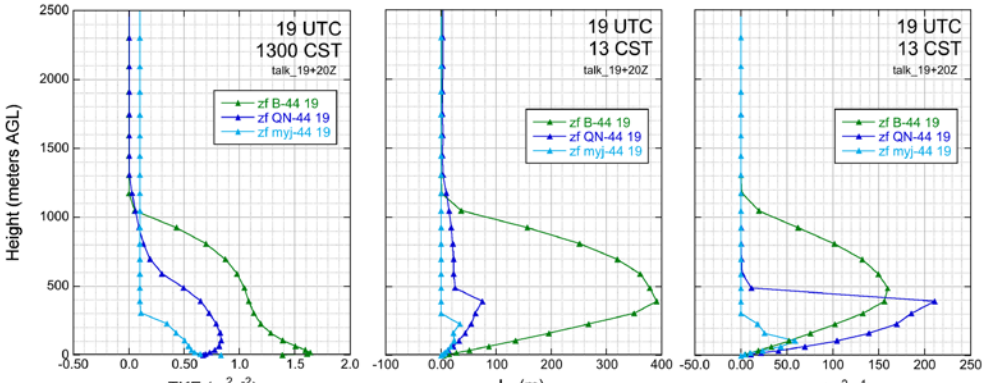
BouLac

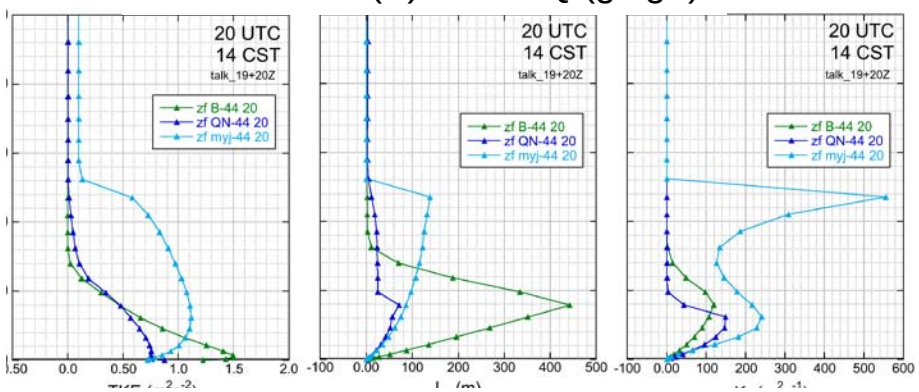
QNSE

MYJ





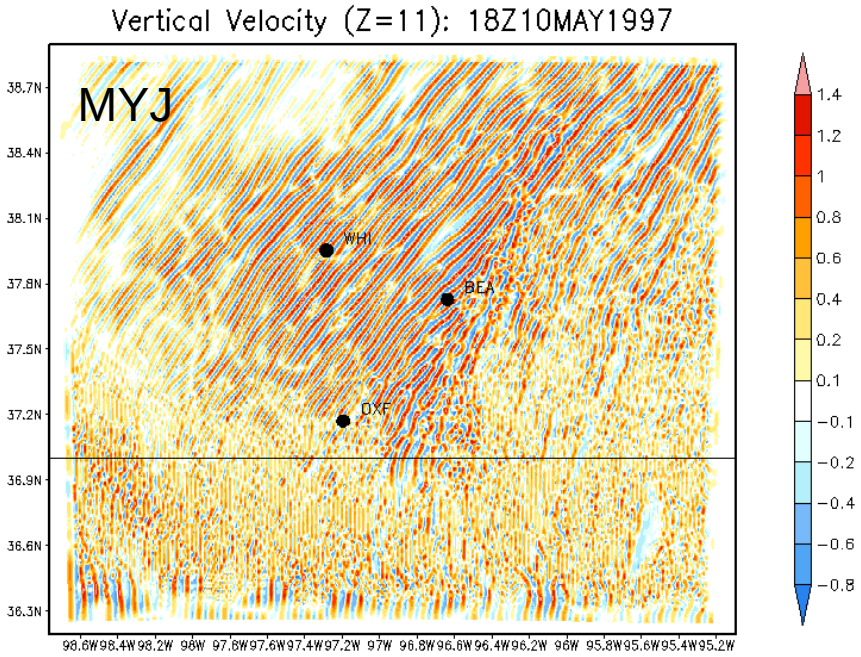


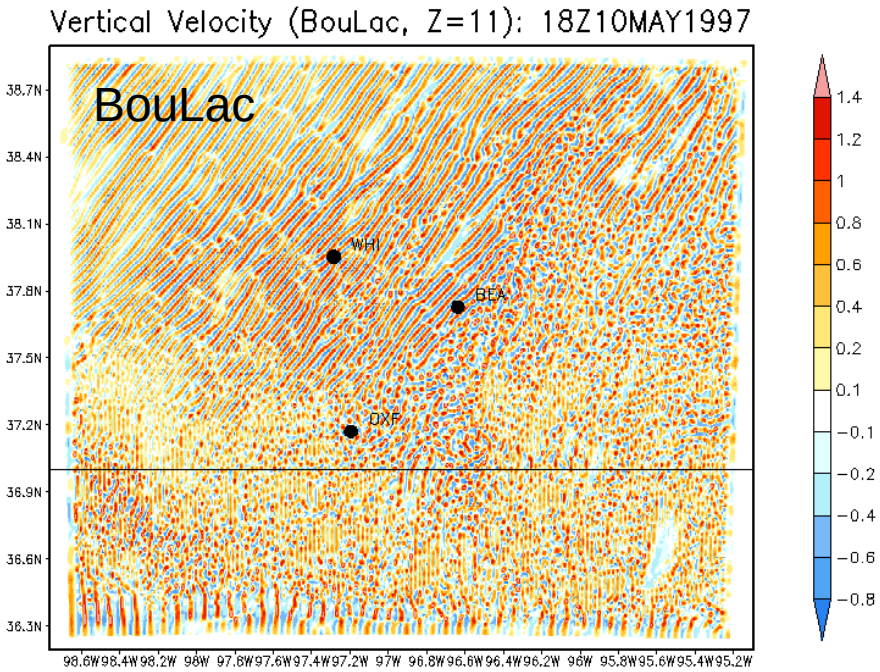


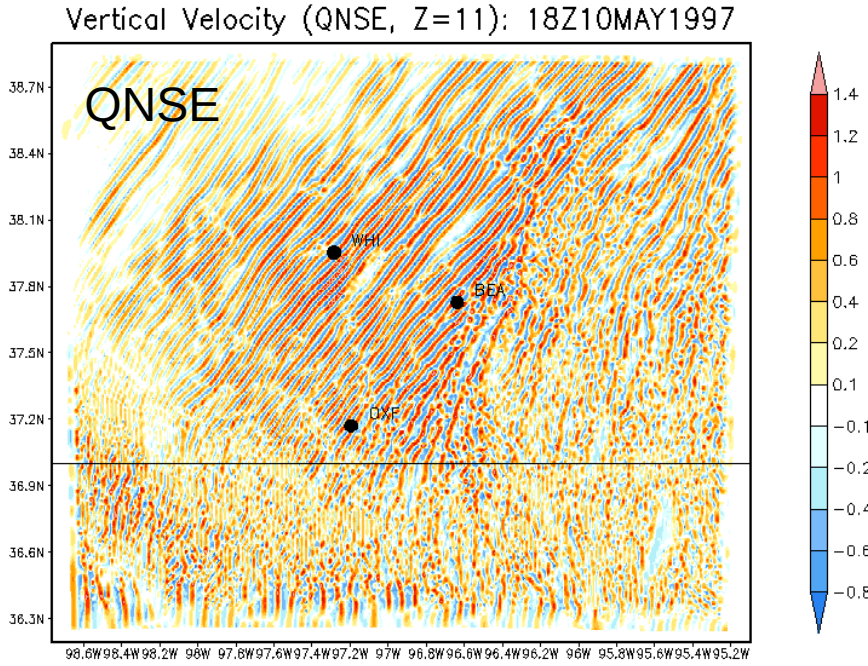
Is stable stratification (positive $Th_{v,z}$) due to PBL eddies?

Vertical Velocity at mid-PBL (~500 m) →

PBL Eddies



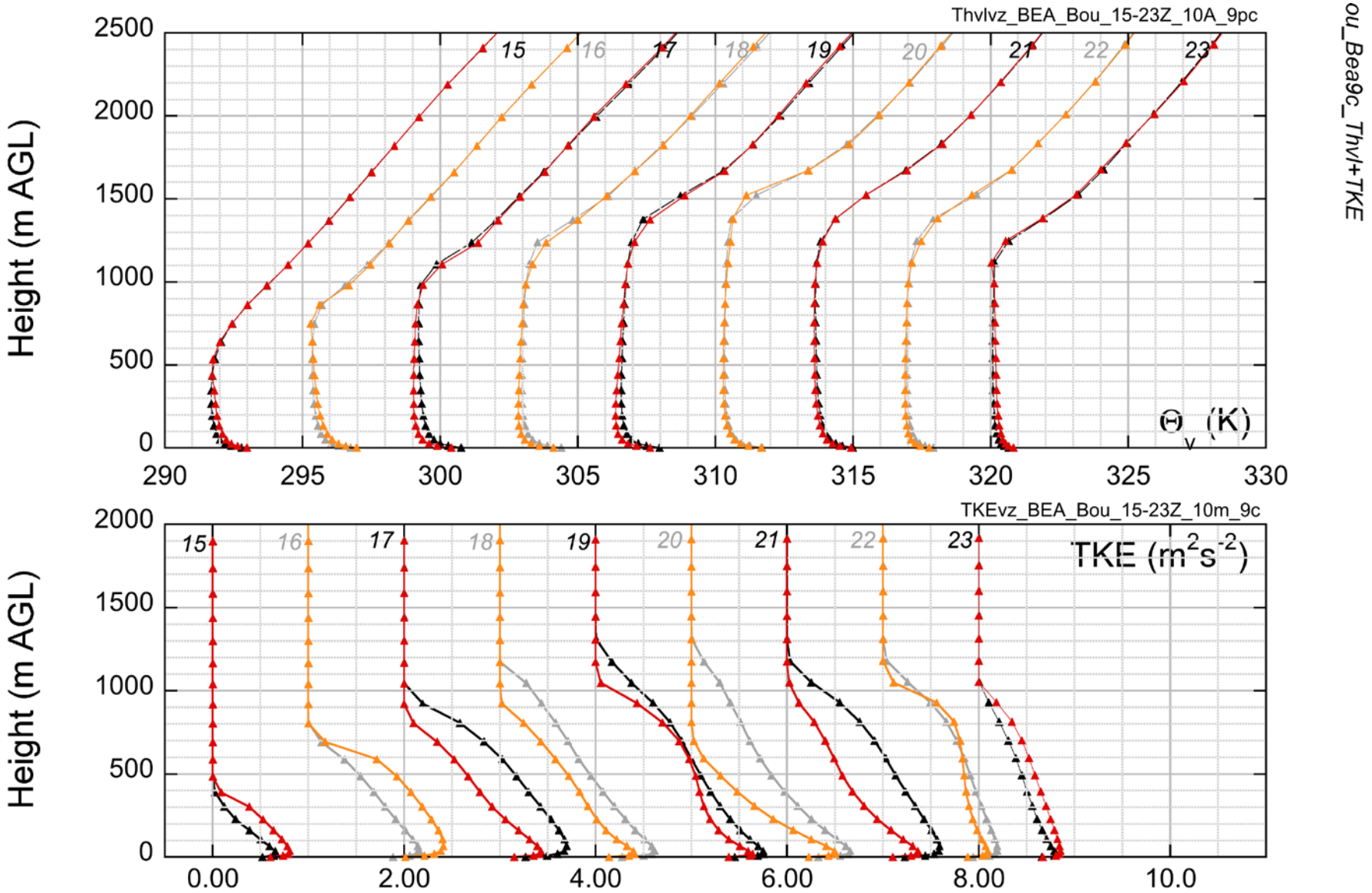




Mitigation of PBL-eddy effect by centered 9-pt Average:

BouLac for 10 May Beaumont

(1 pt – Red/Orange; 9pts Black/Gray)



ou_Bea9c_Thvl+TKE

CONCLUSIONS

CRITERIA

Reasonable	Not as good
Thv(h) = Thv(0.05h) (unstable)	TKE (daytime)
Thv(h) = Thv(lvl 1) (unstable)	Ri (local)
Ri(lvl1-h) = 0.2	Ri (0-h)

Daytime PBL (unstable)

All schemes so far (all TKE schemes) underestimate PBL Height

Erratic PBL height; big effect of Th_v stratification

Result of PBL large eddies

Impact vary with day, PBL scheme

Nighttime PBL (stable)

Challenge to define Nocturnal PBL

For some applications, look for features in mean profiles instead?

Future

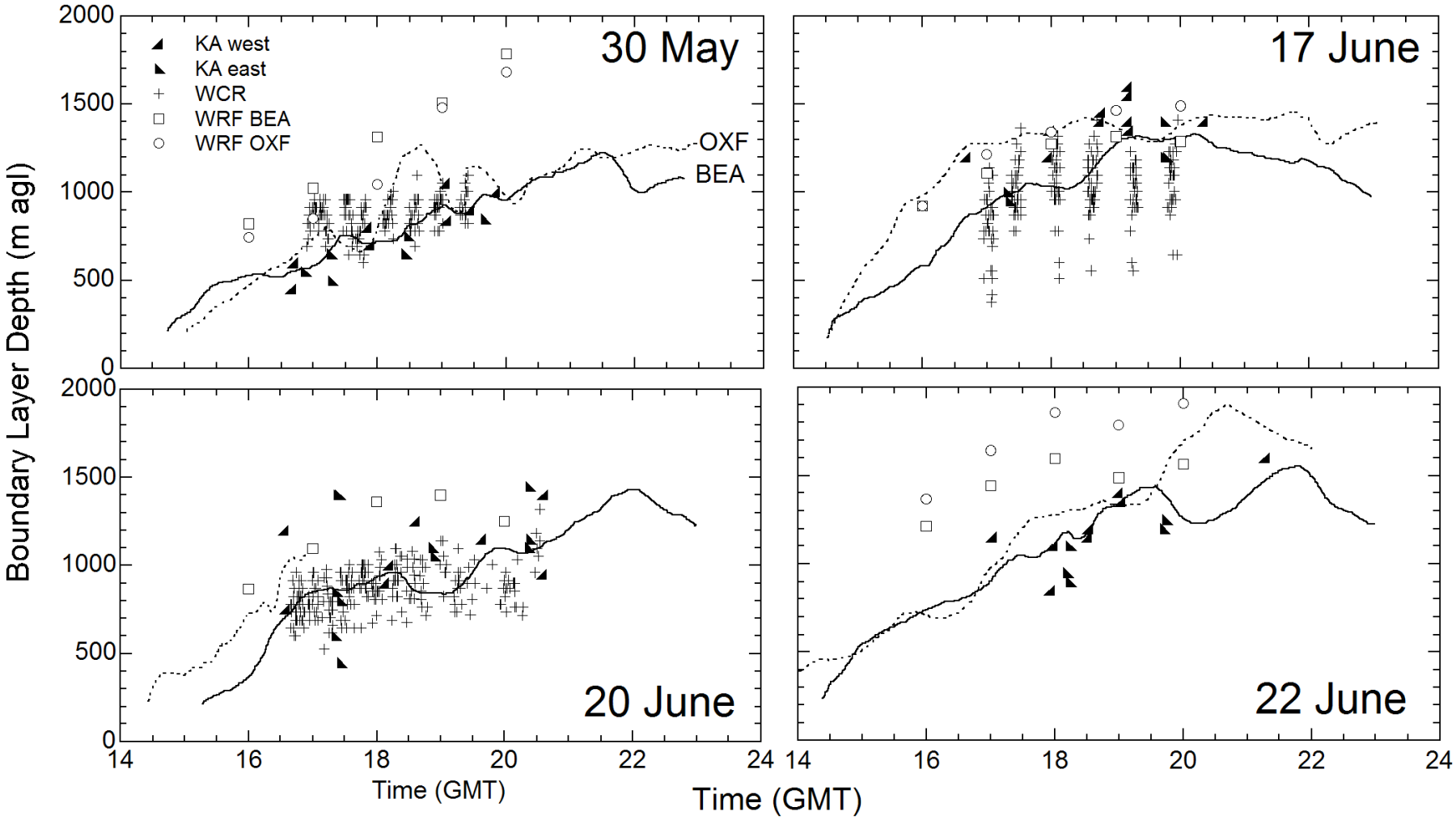
Objective is to
-- Compare observed PBL heights to modeled heights for whole diurnal cycle
   -- for several PBL schemes
   -- but using same diagnostic(s) – is this right?
-- Use information to assess strengths and weakness of the schemes for this situation
-- Where appropriate, look for ways to improve schemes

Side benefit:
-- Develop set of diagnostics for general use.

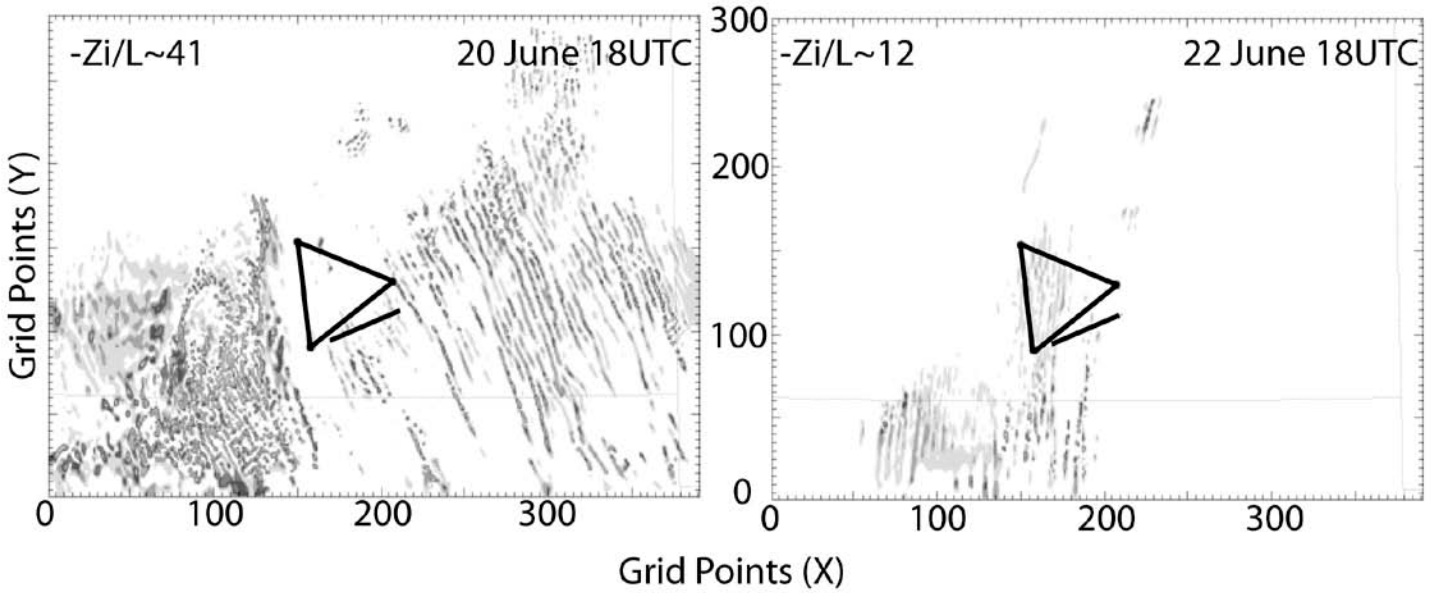
Remaining
-- Whi, Oxf
-- 29 April
-- 20 May
-- MYNN?

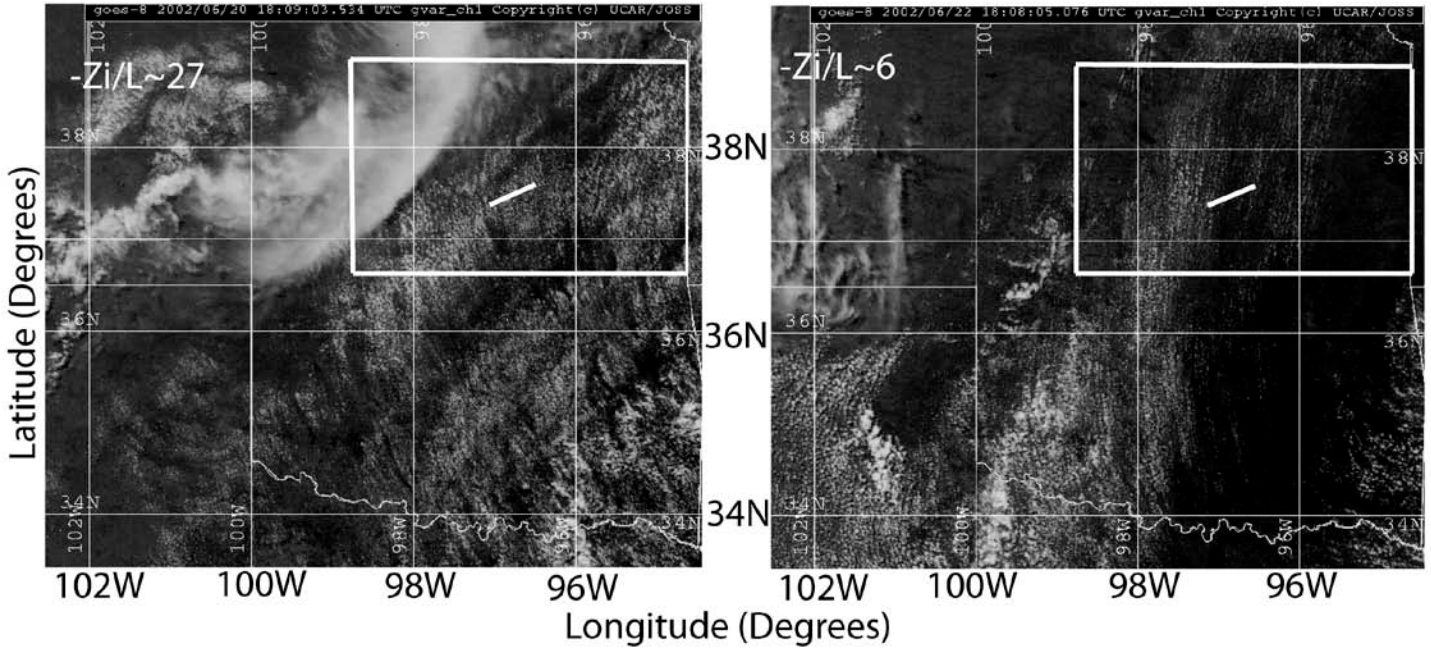
-- Check Horizontal Average around points
-- higher-res runs
-- greater understanding of schemes

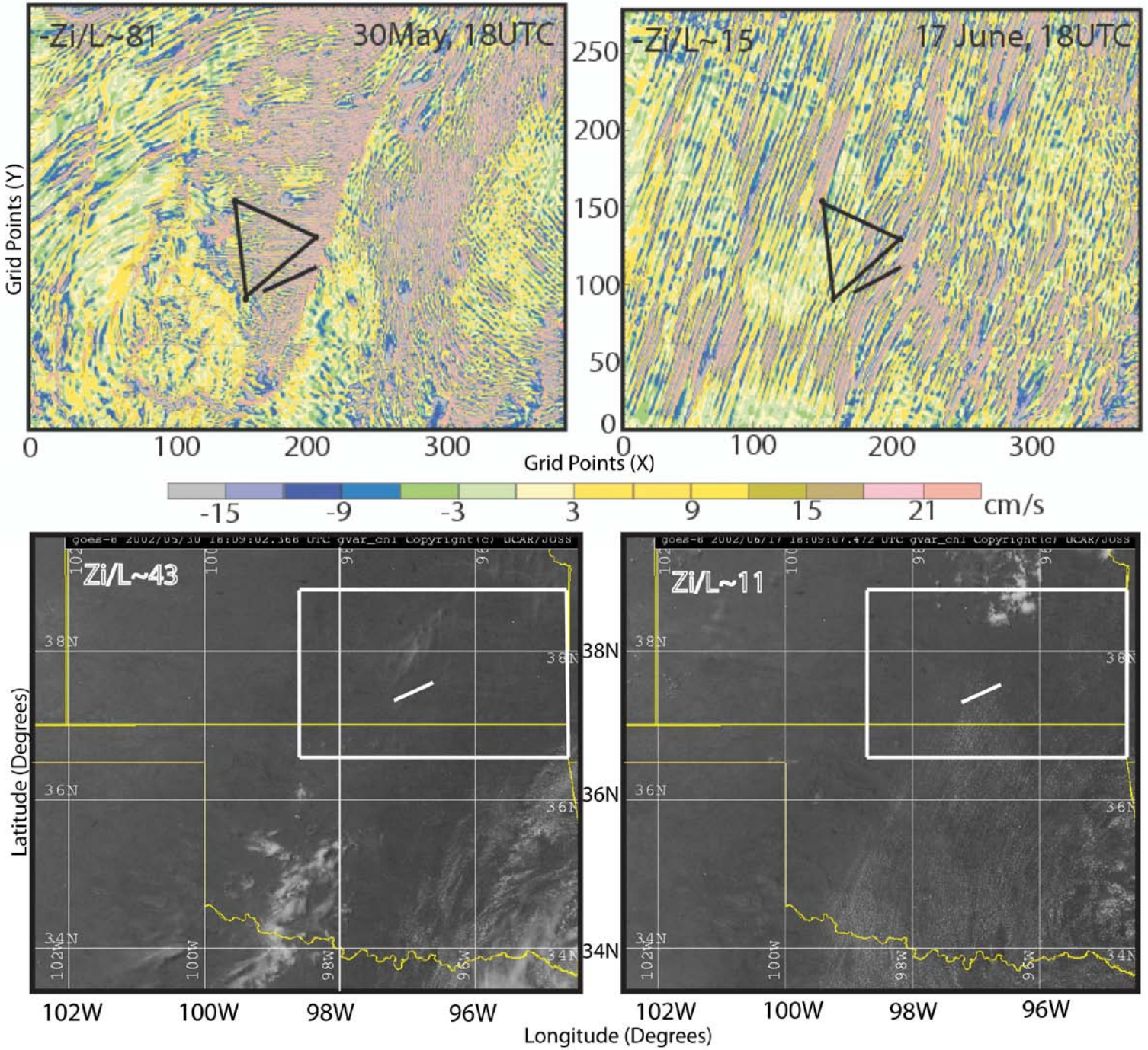
PBL Height from YSU PBL (4 cases from IHOP_2002)



IHOP convective structure -- YSUPBL

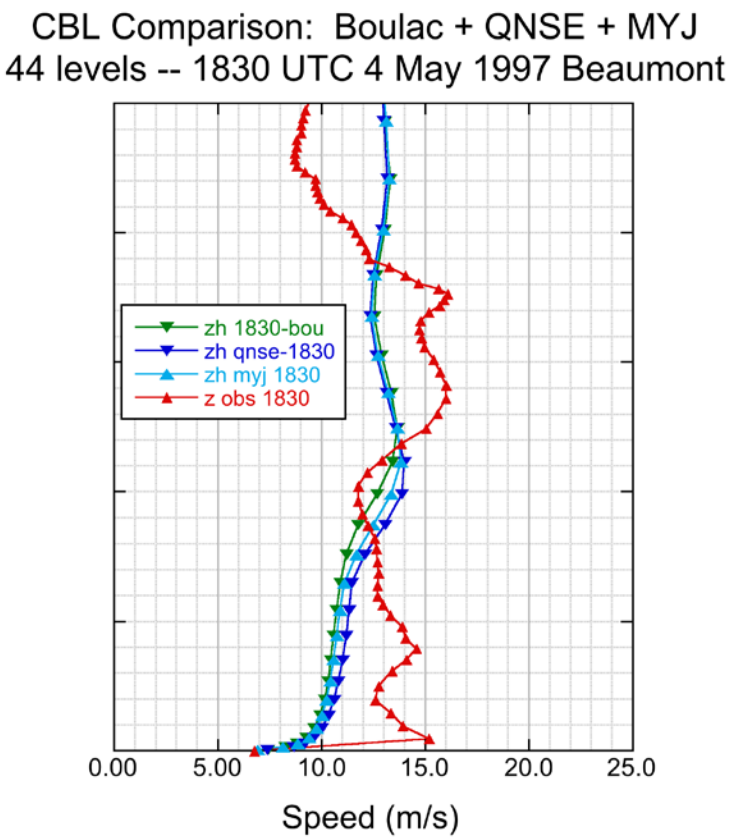




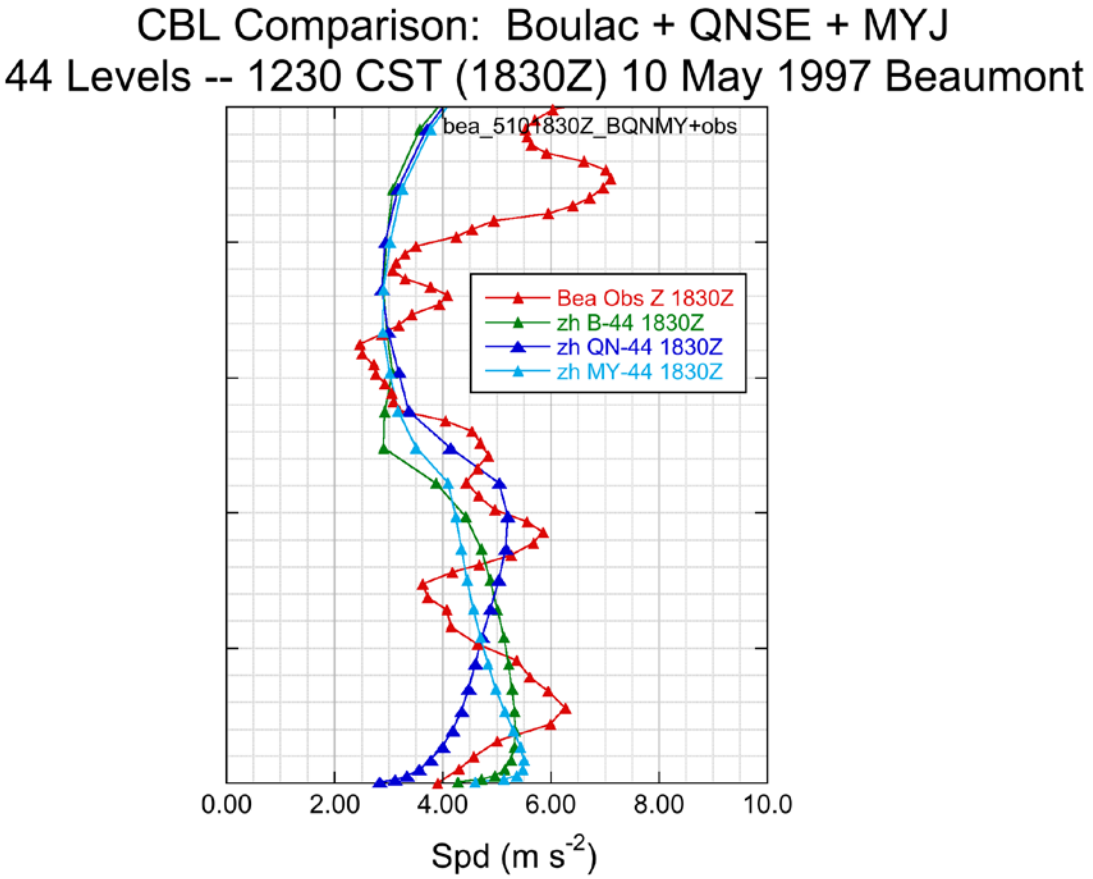

-Zi/L~81
30May, 18UTC
-Zi/L~15
17 June, 18UTC
Grid Points (Y)
Grid Points (X)
0
100
200
300
250
150
50
-15
-9
-3
3
9
15
21
cm/s
Zi/L~43
Zi/L~11
38N
36N
34N
102W
100W
98W
96W
Latitude (Degrees)
Longitude (Degrees)

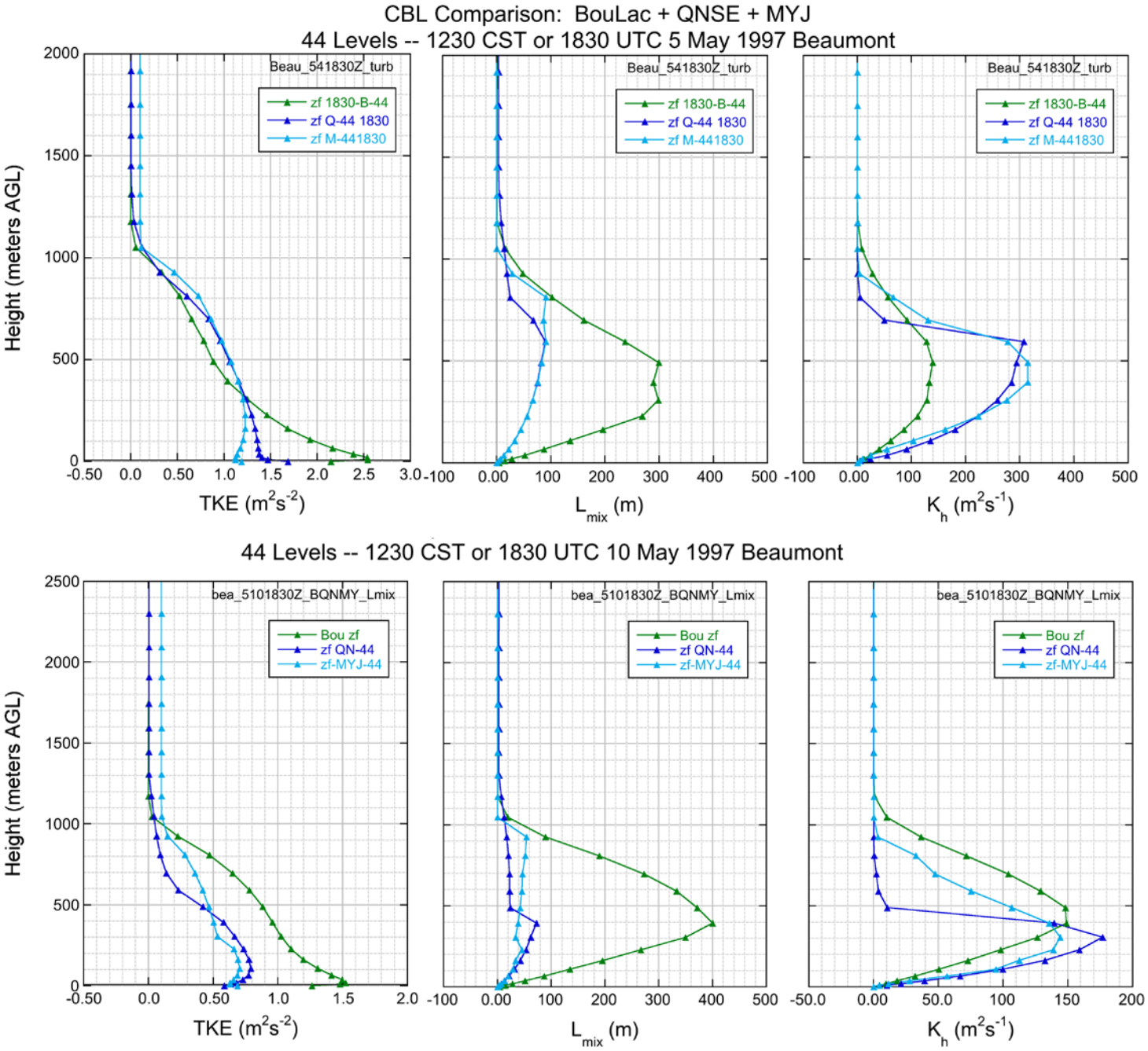
Comparison of Schemes: Windy vs non-windy

WINDY: 4 May 97

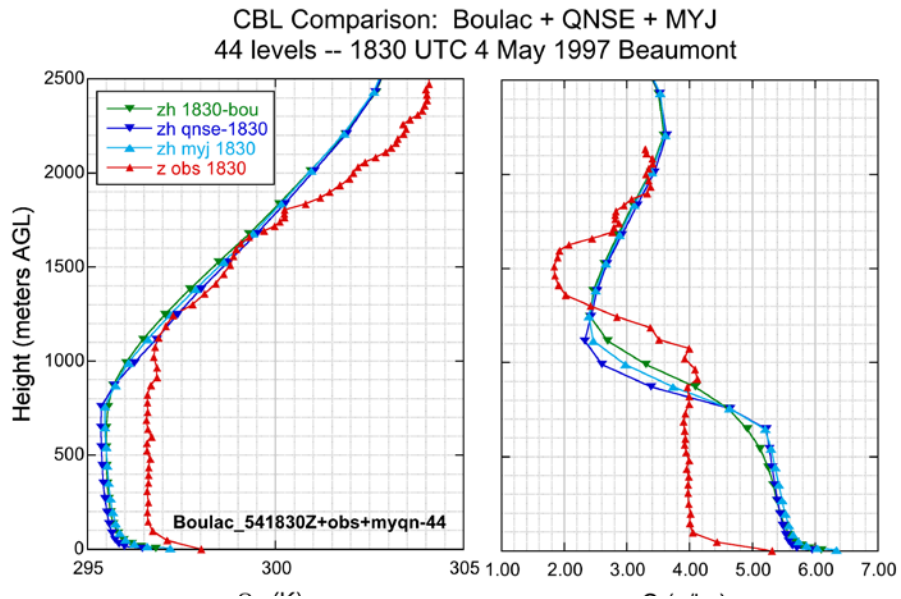


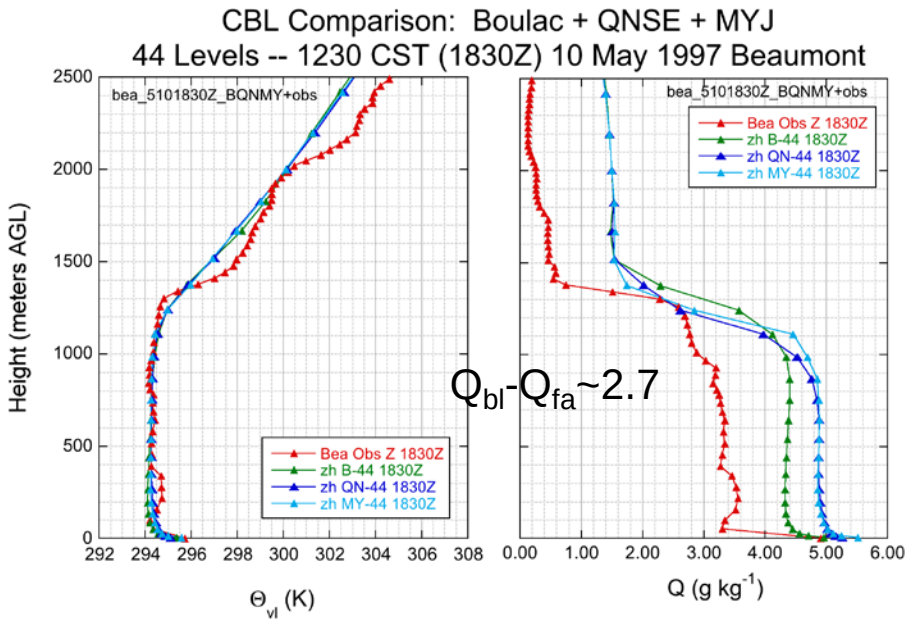
NON-WINDY: 10 May 97




CBL Comparison: BouLac + QNSE + MYJ
44 Levels -- 1230 CST or 1830 UTC 5 May 1997 Beaumont
Beau_541830Z_turb
zf 1830-B-44
zf Q-44 1830
zf M-441830
Height (meters AGL)
TKE (m2s-2)
Lmix (m)
Kh (m2s-1)
44 Levels -- 1230 CST or 1830 UTC 10 May 1997 Beaumont
bea_5101830Z_BQNMY_Lmix
Bou zf
zf QN-44
zf-MYJ-44

WINDY





Q_{bl}-Q_{fa}~2.7

4 May: Strong Winds:

Not enough vertical mixing for all three

10 May: Weak winds

BouLac Q_{bl}-Q_{fa} closer to reality

Is trend related to BouLac mixing length?

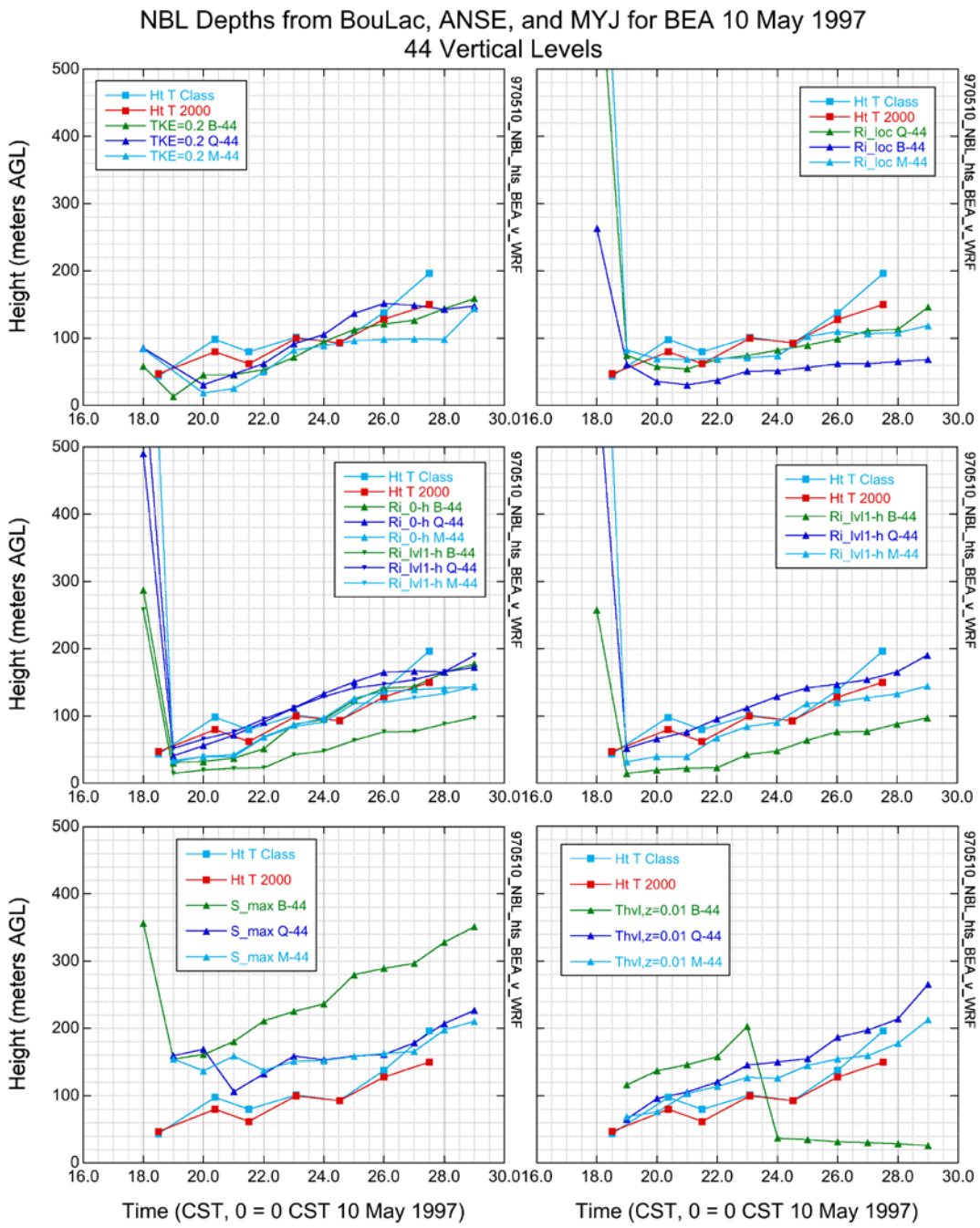
$$L_k = \min(l_{up}, l_{down})$$

$$TKE(z) = \int_{Z}^{Z+l_{up}} \beta(\theta(Z) - \theta(Z')dZ'$$

$$TKE(z) = \int_{Z-l_{down}}^{Z} \beta(\theta(Z) - \theta(Z')dZ'$$

TKE treated like $w^2/2$

$K_h = 0.4 L_k (TKE)^{0.5}$



<u>WORKS WELL</u>

TKE

Ri_{loc}

$Ri_{lvl1\text{-}h}$