Evaluation of a CONUS-wide physics ensemble

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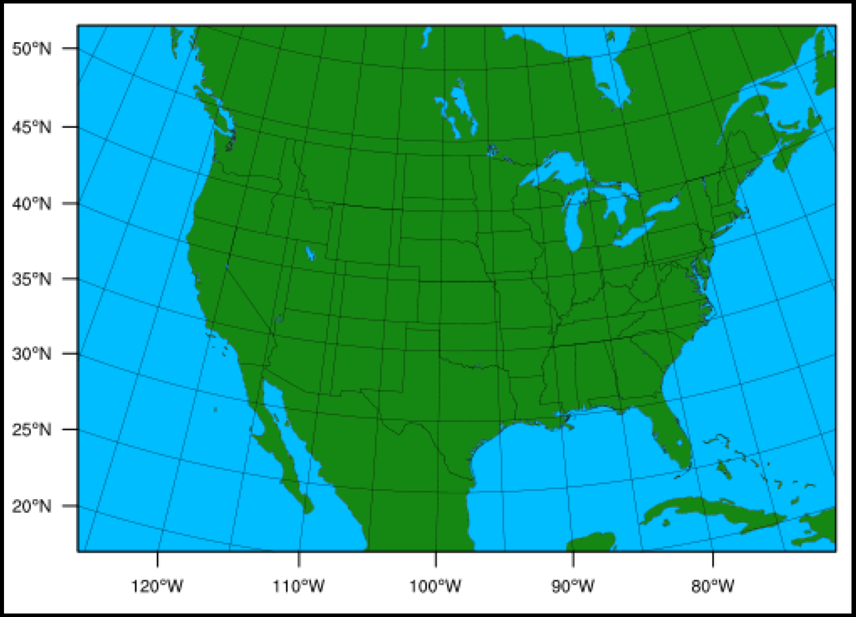
“Santa Ana” wind events

- WRF-ARW high-resolution (<1 km) simulations of downslope windstorms, verified against very dense, homogeneous SDG&E mesonet
- Most model configurations overforecast the wind (strength and spatial extent)
- Surface roughness played key role in producing unbiased forecasts of network-averaged wind
- Systematic biases remained for many stations, explained by local exposure and gustiness
- Fovell and Cao 2015, 2017; Cao and Fovell 2016, 2017

BWW ensemble



- CONUS+ at 20 km
- WRF v. 3.7.1
- Initialized with 00Z GFS (or GEFS)
- 47 ensemble members (13 from UAlbany)
  - Since January 2016
- Control:
  - MYJ PBL
  - Noah LSM
  - Kain-Fritsch cumulus
  - RRTMG radiation
  - Thompson microphysics
- Model evaluation with MET on 3-hourly outputs

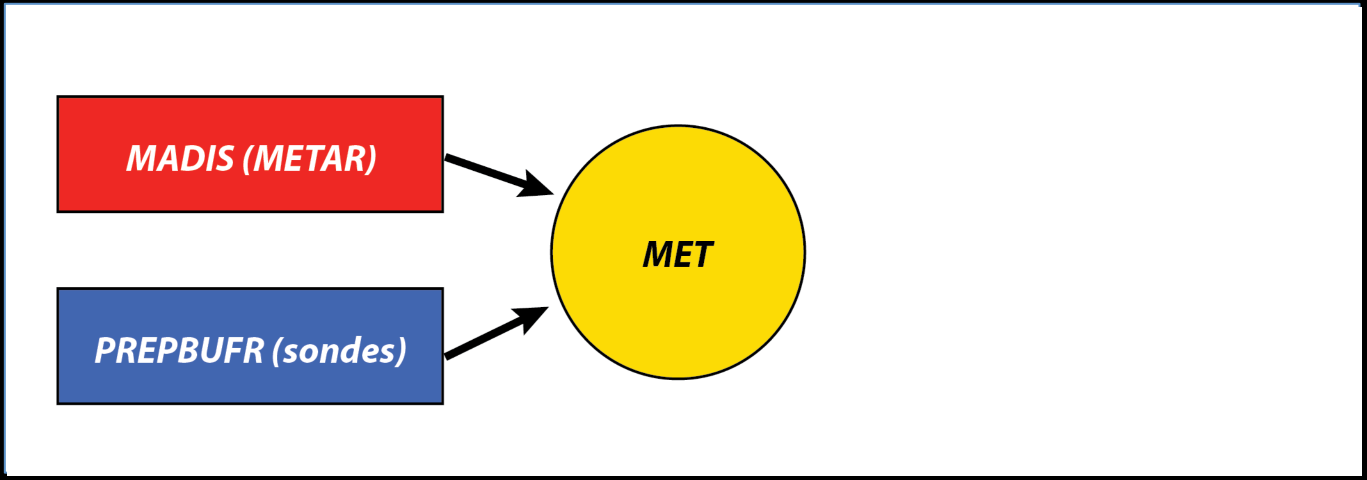
BIG WEATHER WEB

Objectives

- Not a multi-physics ensemble, per se, but rather an experiment to isolate, explain and correct persistent forecast errors
- Diagnose forecast wind speed biases
  - Testing the gustiness/exposure hypothesis using ASOS for CONUS
- Examine boundary layer structure
- Analysis of daily, overlapping 84 h simulations for July 2016, using Model Evaluation Tools (MET) software

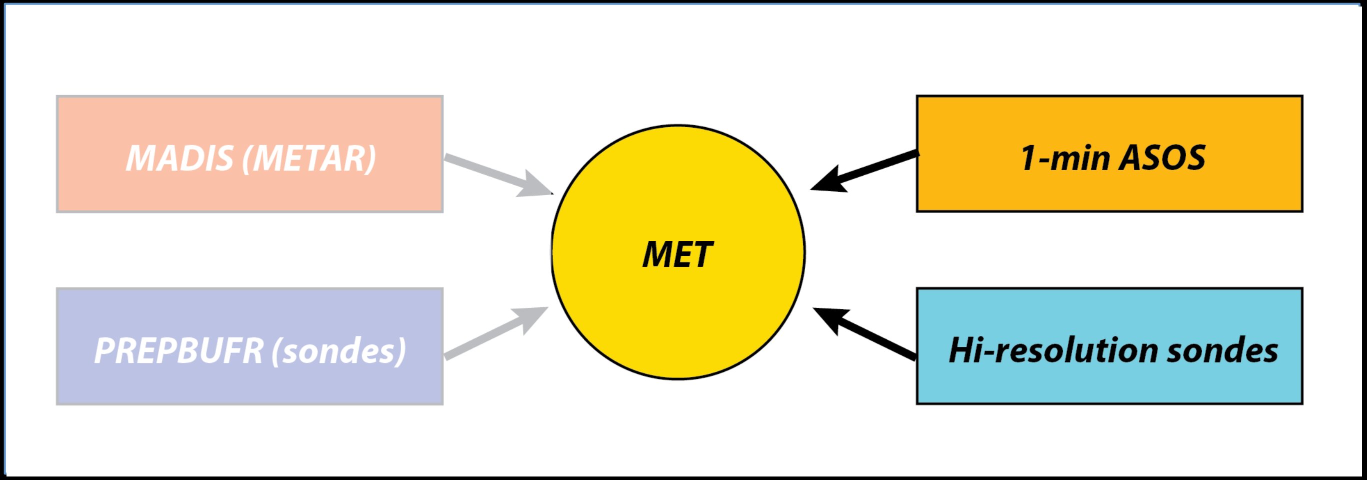
Model evaluation

ASOS stations and radiosondes



Model evaluation

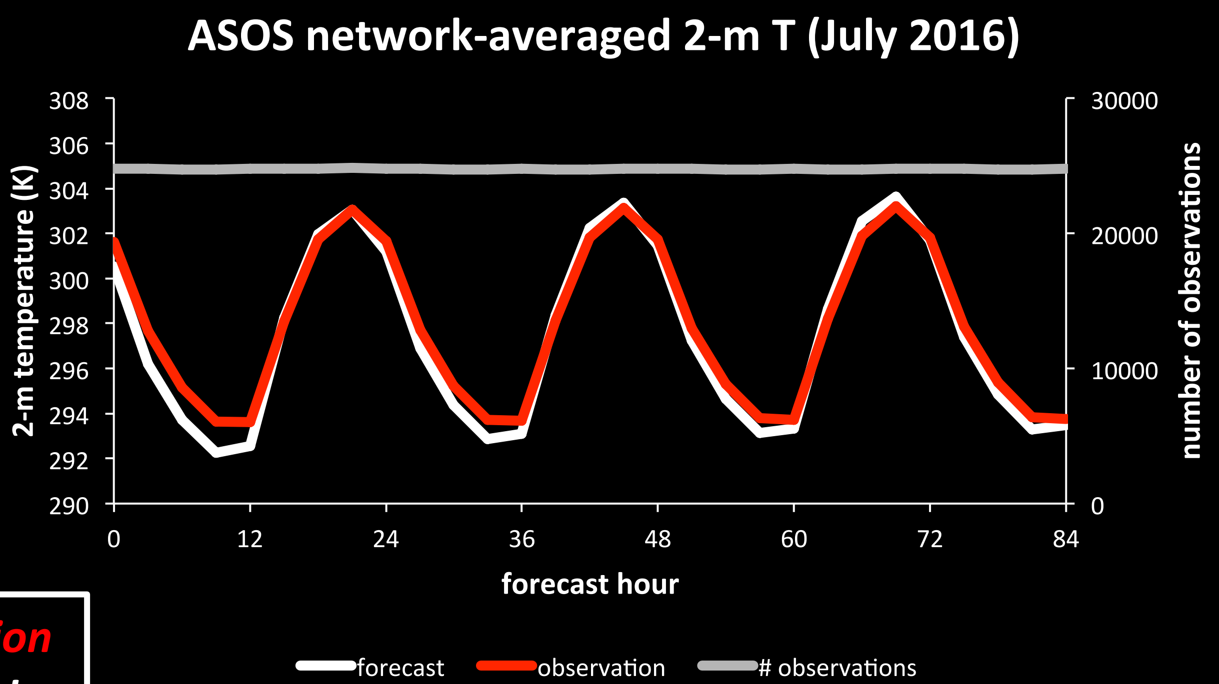
ASOS stations and radiosondes



Control run: surface met fields

July 2016

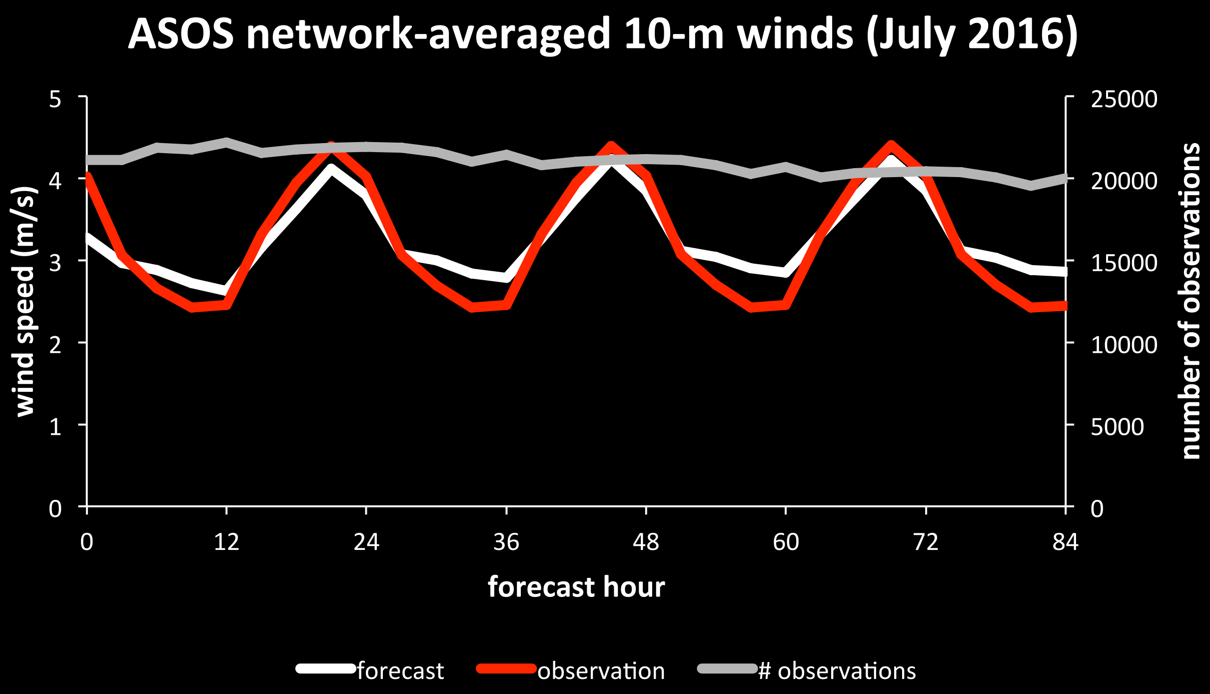
Network-averaged 2-m temperature (up to 809 ASOS stations)



Red: observation
White: forecast
Grey: # obs

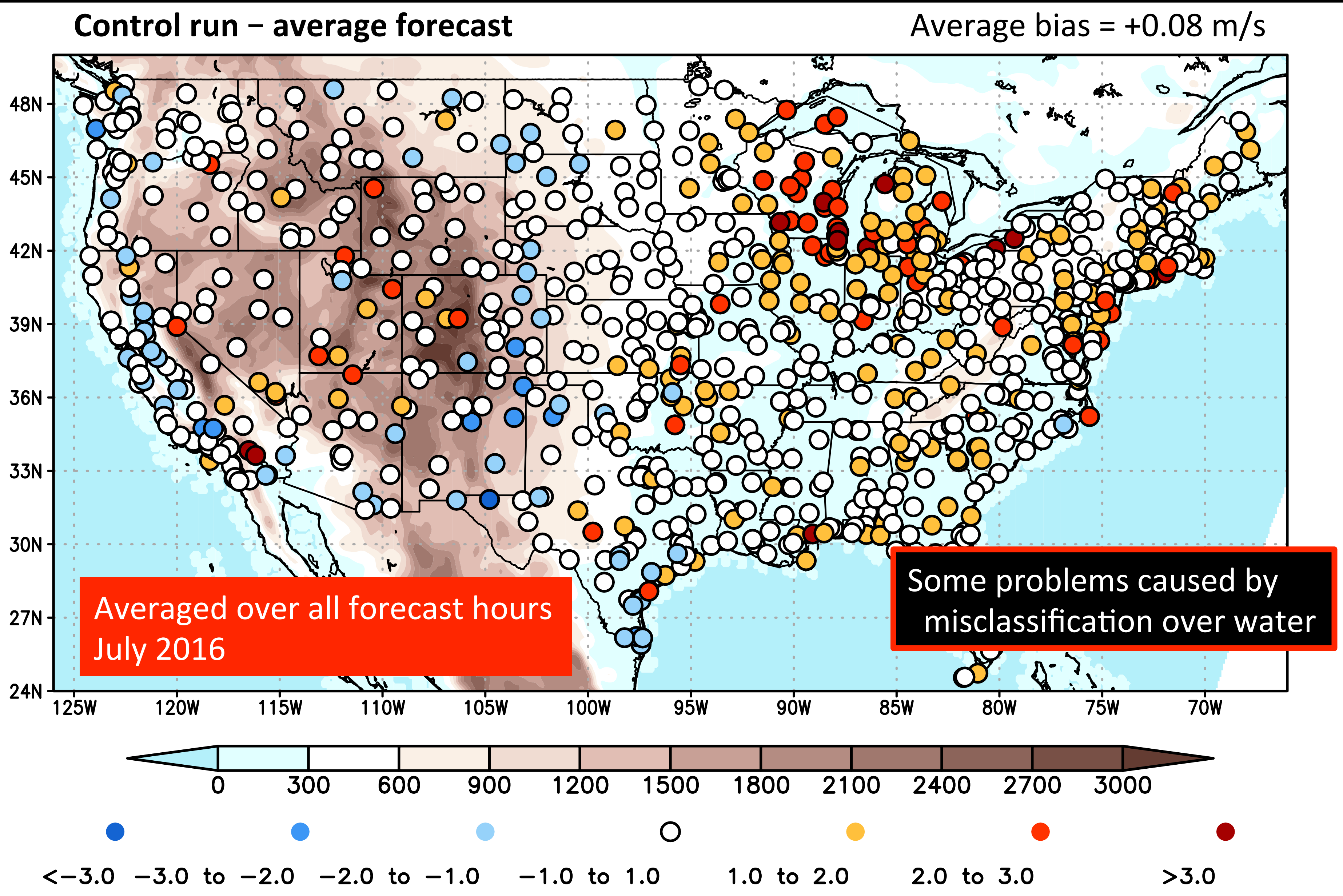
All ASOS stations
All July 2016 simulations

Network-averaged 10-m wind speed (up to 809 ASOS stations)



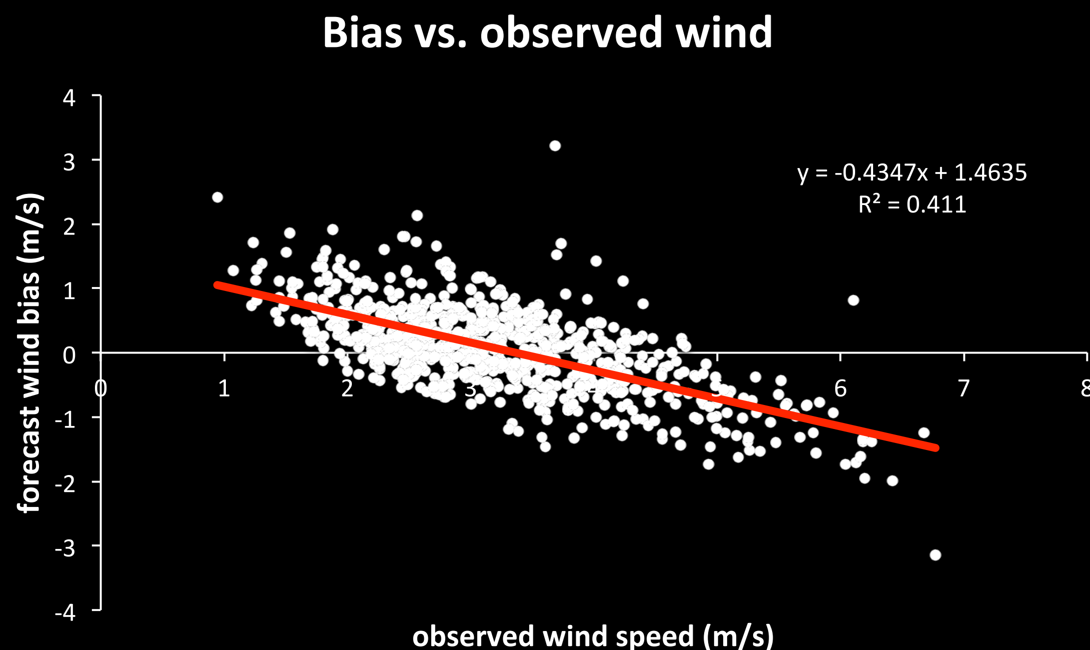
Average bias = +0.08 m/s
(excluding initial time)

All ASOS stations
All July 2016 simulations



Control run – average forecast
Average bias = +0.08 m/s
48N
45N
42N
39N
36N
33N
30N
27N
24N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
Averaged over all forecast hours
July 2016
Some problems caused by misclassification over water
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
<−3.0
−3.0 to −2.0
−2.0 to −1.0
−1.0 to 1.0
1.0 to 2.0
2.0 to 3.0
>3.0

The *bias* is (still) biased



N = 755 stations

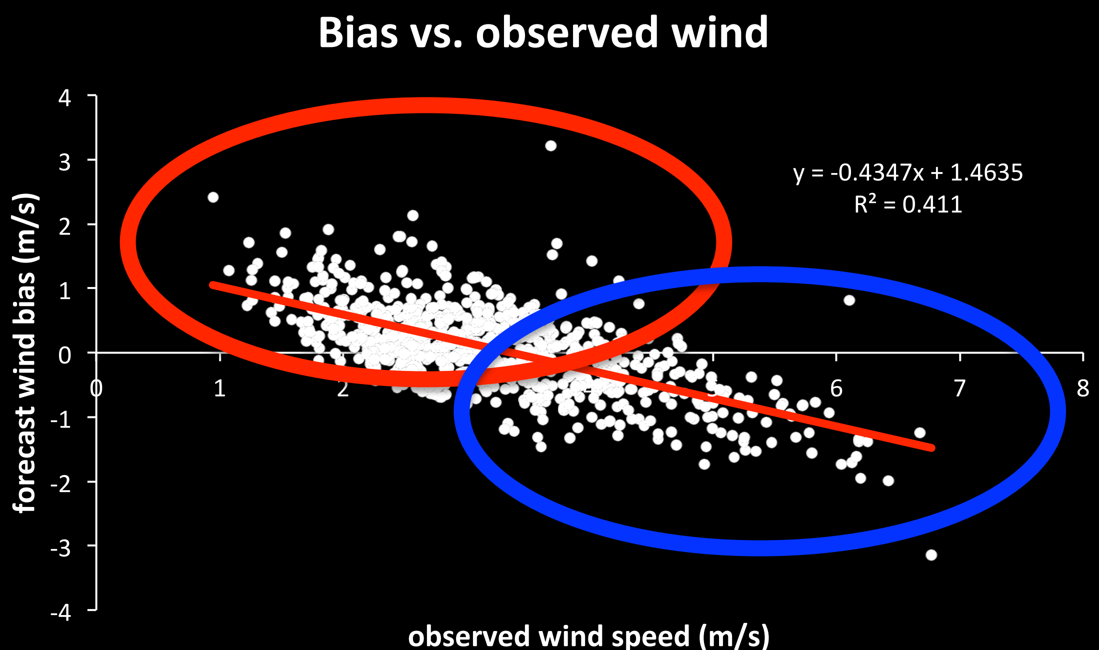
(Removed stations misclassified over water,
and infrequently reporting sites)

$R^2 = 0.41$
$r = -0.64$

Very similar result in high-res San Diego experiments

See also Cao and Fovell (2016), Fovell and Cao (2014, 2017)

The *bias* is (still) biased



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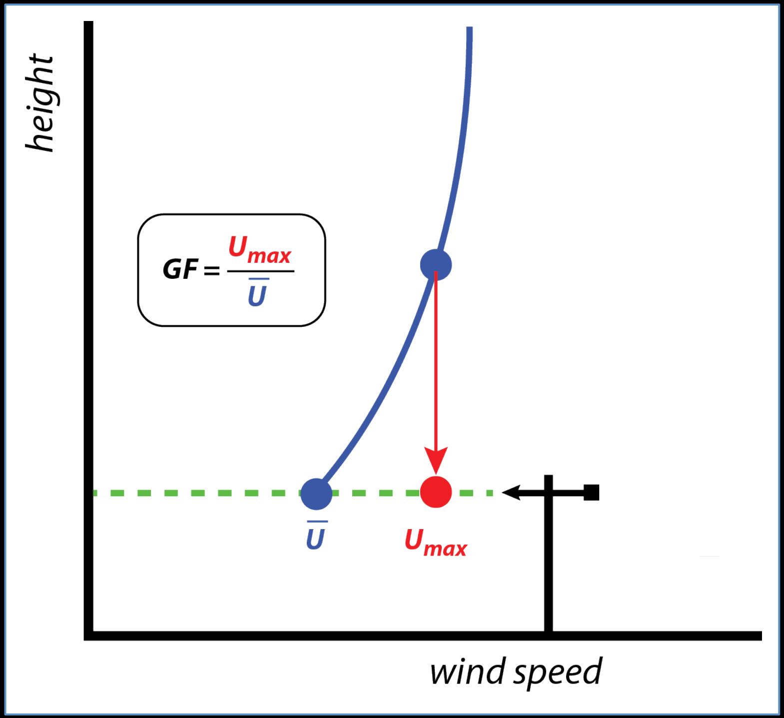
Very similar result in high-res San Diego experiments
See also Cao and Fovell (2016), Fovell and Cao (2014, 2017)

Gust factor

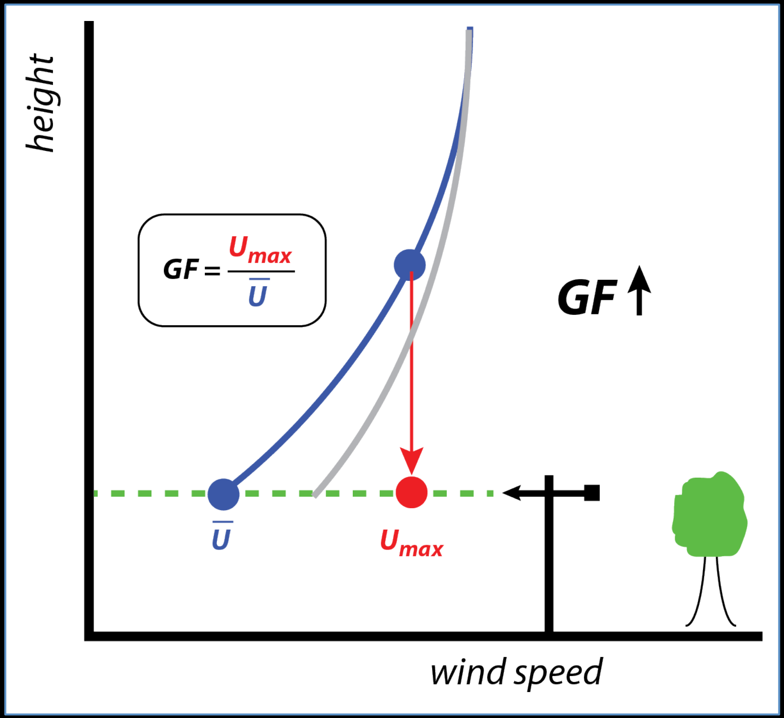
$$\mathrm{GF} = \frac{\mathrm{gust}}{\mathrm{sustained\ wind}}$$

- Each station has its own GF, which varies with time and reflects its situation and how the observations are taken
- Averaged over entire ASOS network, GF ~ 1.3
- GF as a proxy for site exposure (as we did for San Diego)
- Hypothesis: stations with GF ≠ 1.3 more likely to be over- or underpredicted
  - Higher GF == positive bias
- Demonstrated for compact, high-density mesonet (Fovell and Cao 2014, 2017)

Gust factor and sheltering



Gust factor and sheltering



Sheltering:

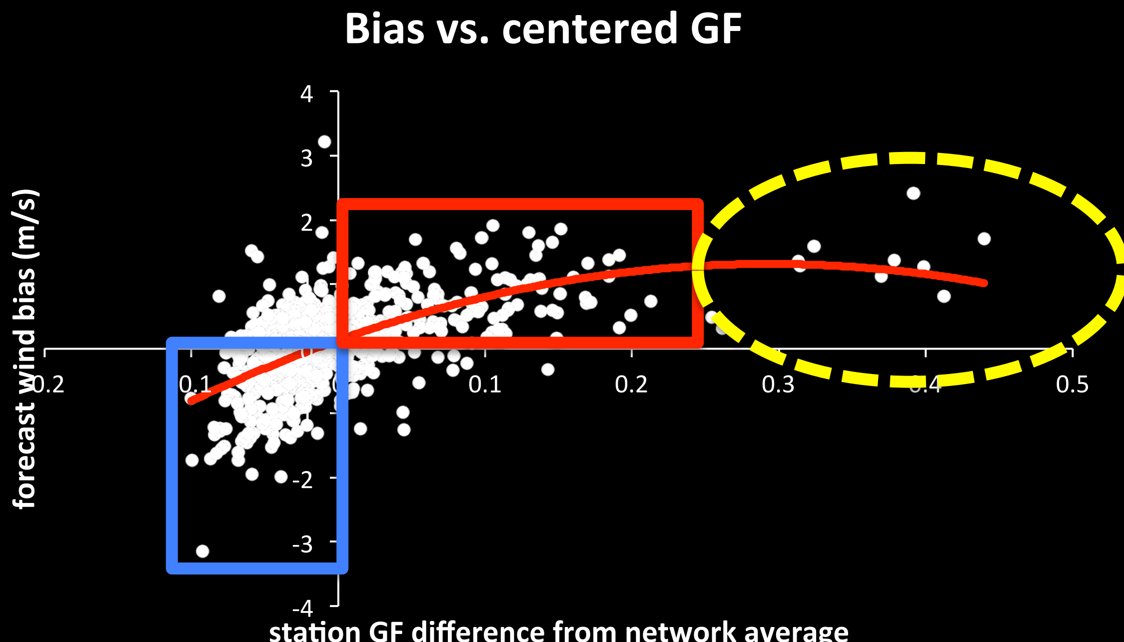
Gust U_{max} decreases

Wind U decreases *more*

thus, **GF rises**

Forecast bias vs. observed GF

(departures from average)

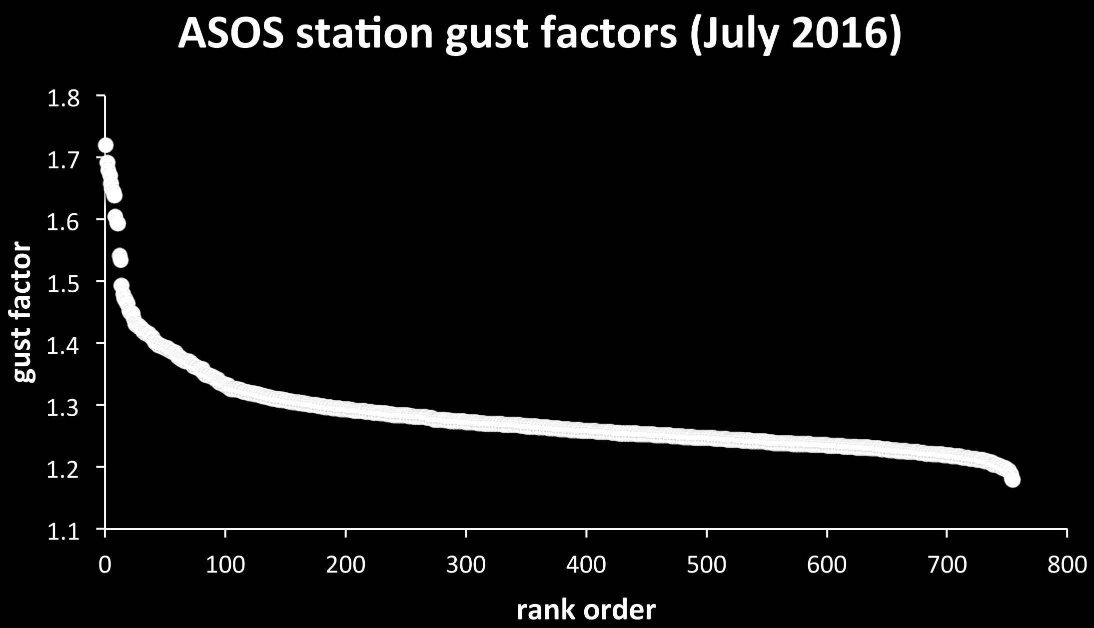


N = 755 stations

(Removed stations misclassified over water,
and infrequently reporting sites)

$R^2 = 0.35$
$r = 0.59$

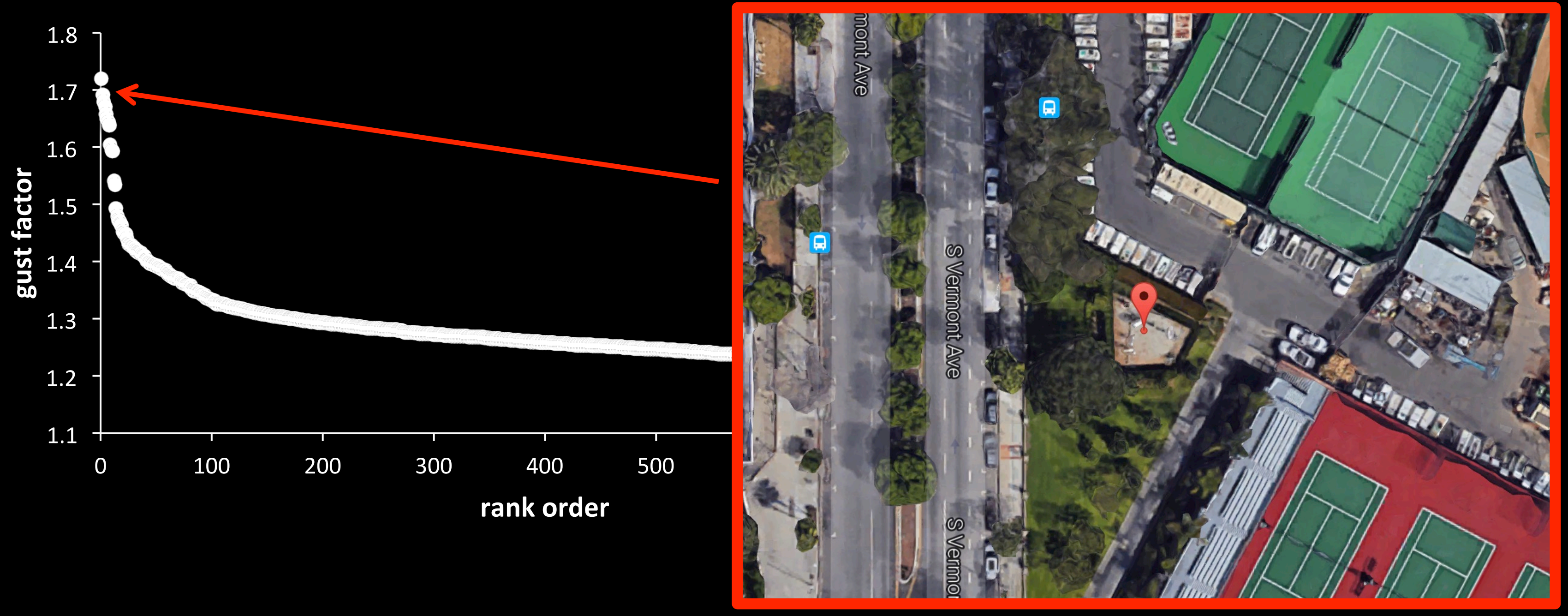
Average July gust factors
(computed from 1-min data)



N = 755 stations

Average July gust factors
(computed from 1-min data)

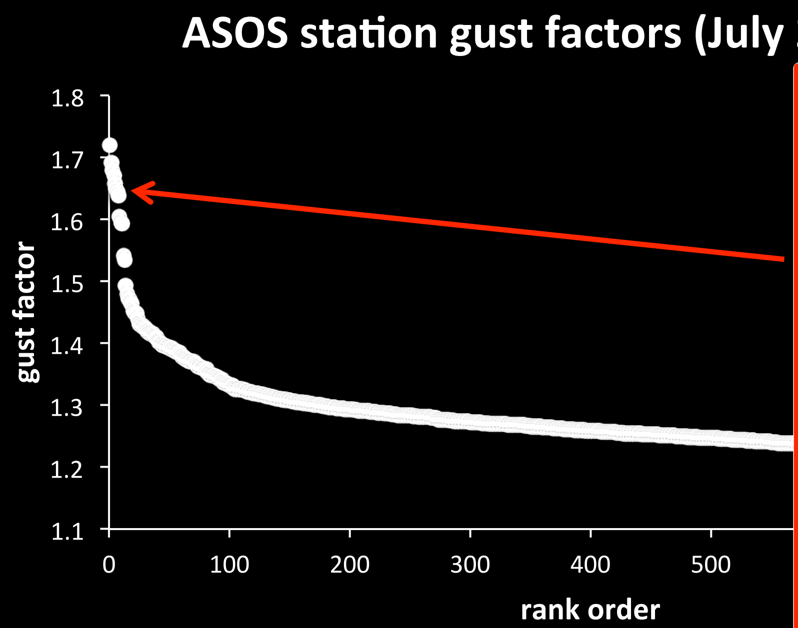
ASOS station gust factors (July 2016)



KCQT
(Downtown Los Angeles)
GF = 1.69

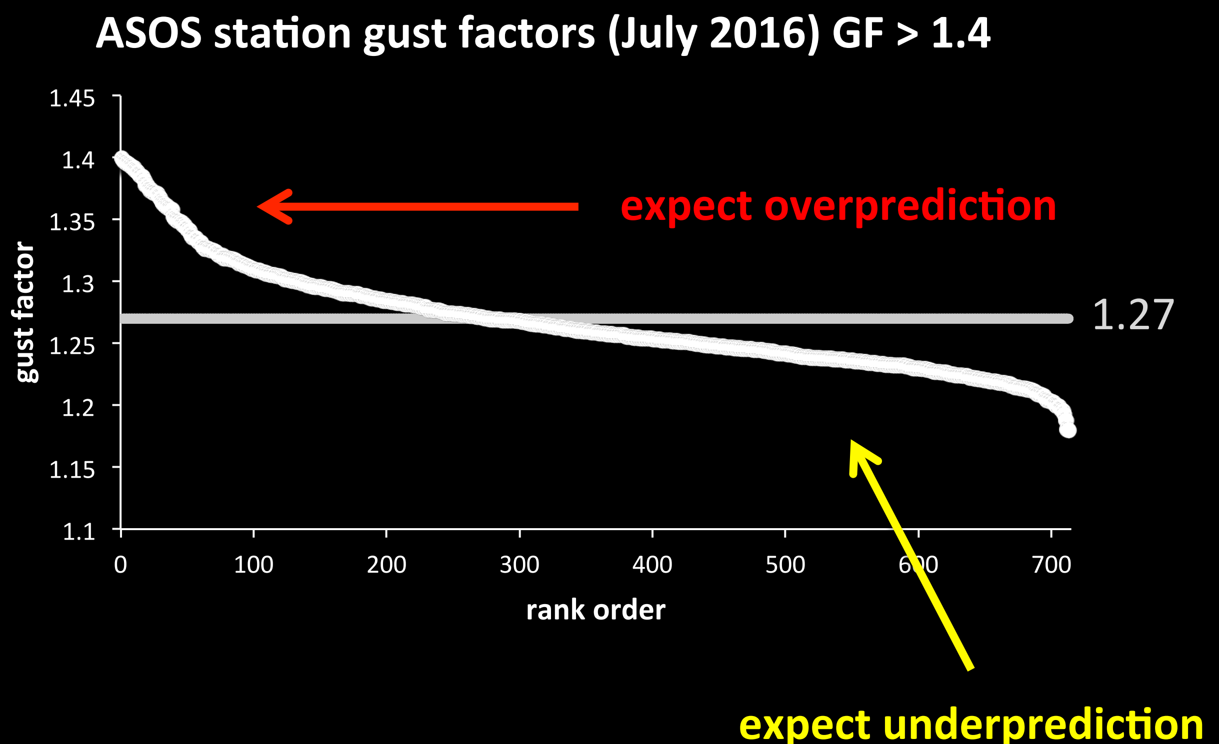
Average July gust factors

(computed from 1-min data)



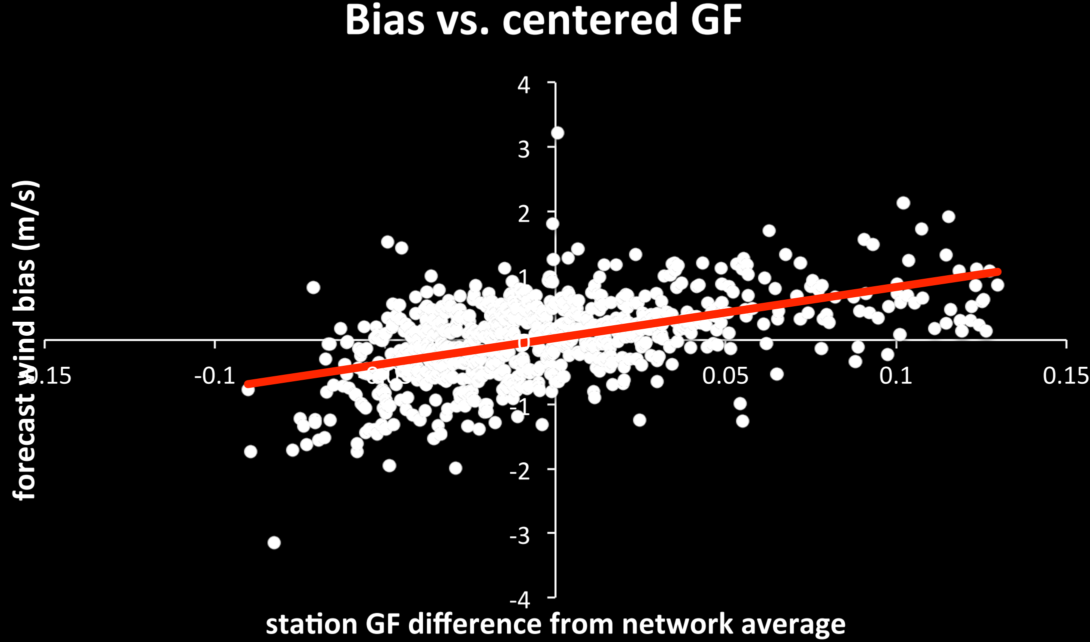
KNYC
(New York Central Park)
GF = 1.65

Stations with GF ≤ 1.4



N = 713 stations
(GF < 1.4)

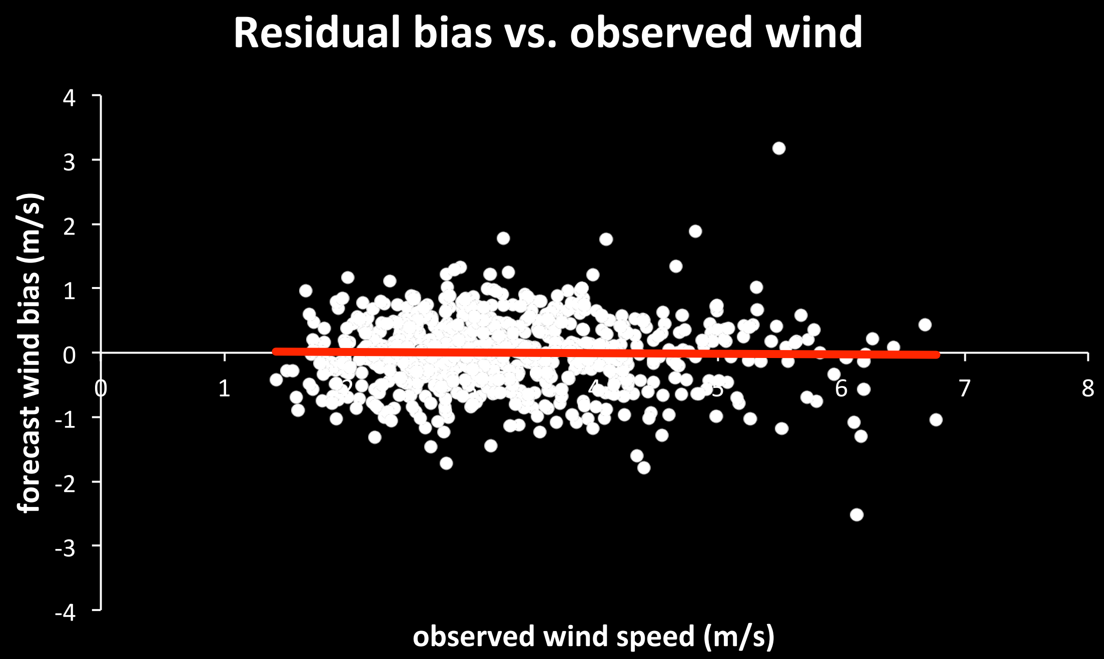
Stations with GF ≥ 1.4



N = 713 stations

$R^2 = 0.26$
$r = 0.51$

Forecast bias *adjusted for GF*



$R^2 = 0.00$
$r = 0.00$

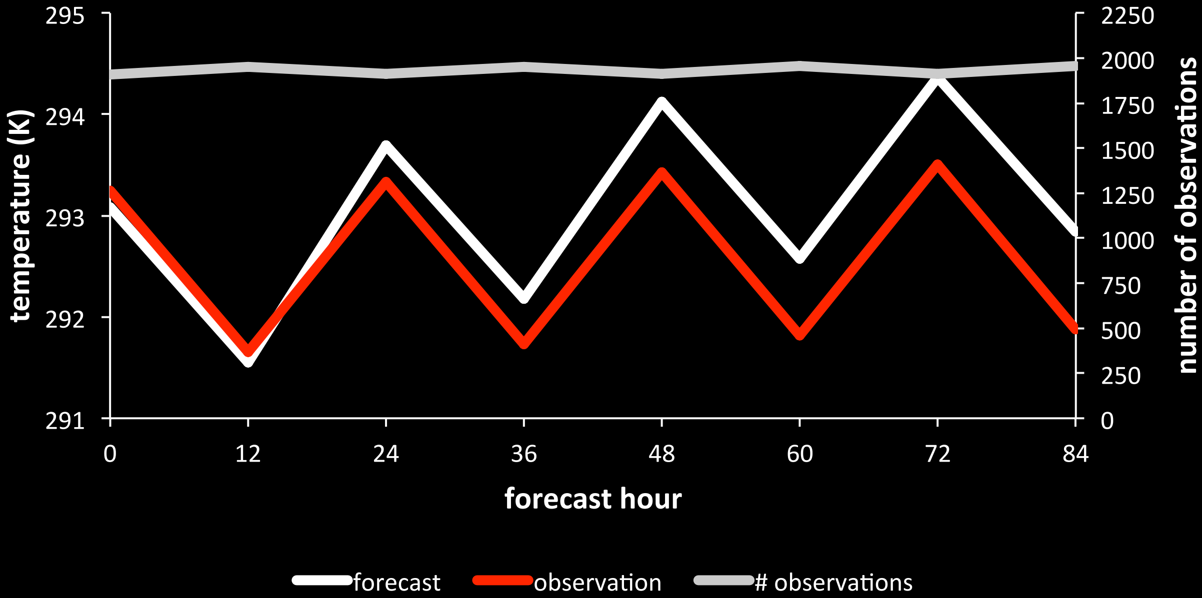
The biased forecast bias

largely represents "unfixable" representativeness errors
revealed by the local station gust factor

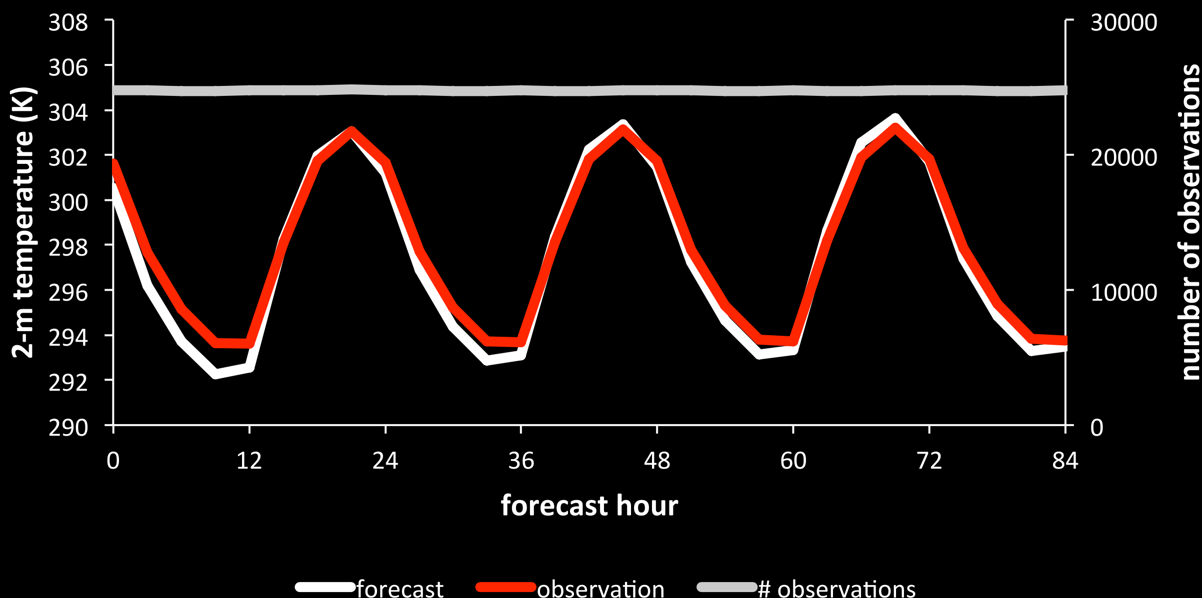
Above-surface met fields

July 2016

Radiosonde CONUS T850 (July 2016)



ASOS network-averaged 2-m T (July 2016)

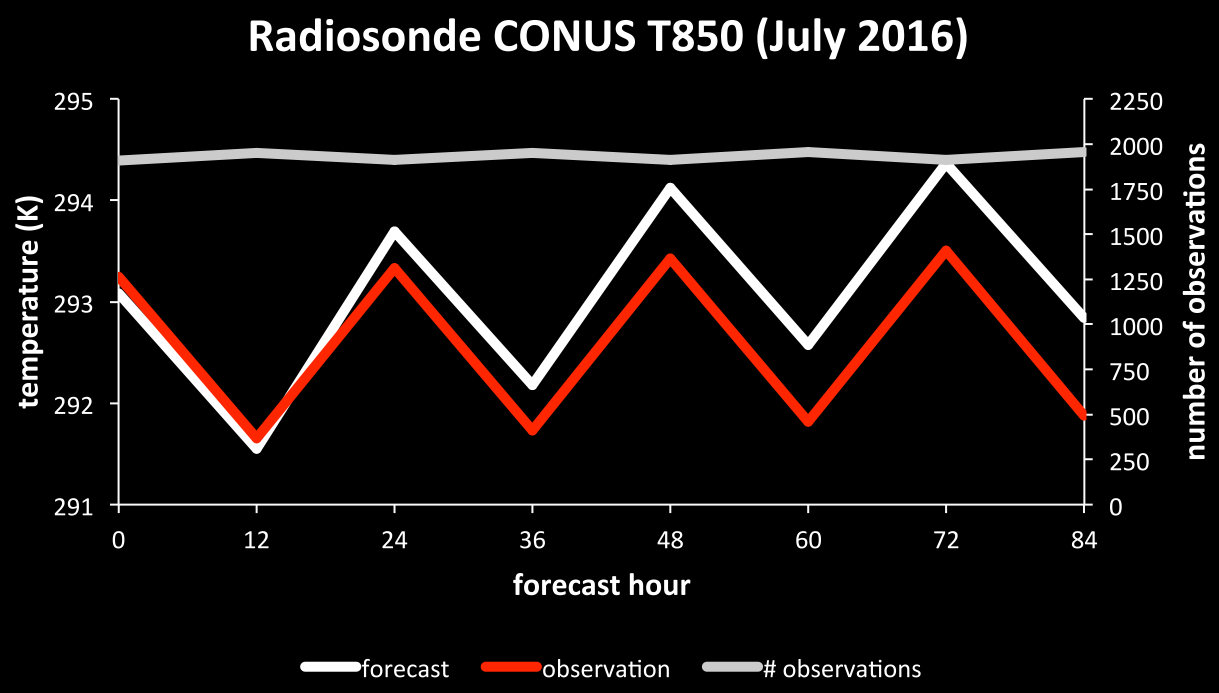


Control run

850 mb T
Radiosondes
N = 72
Erroneous warming trend

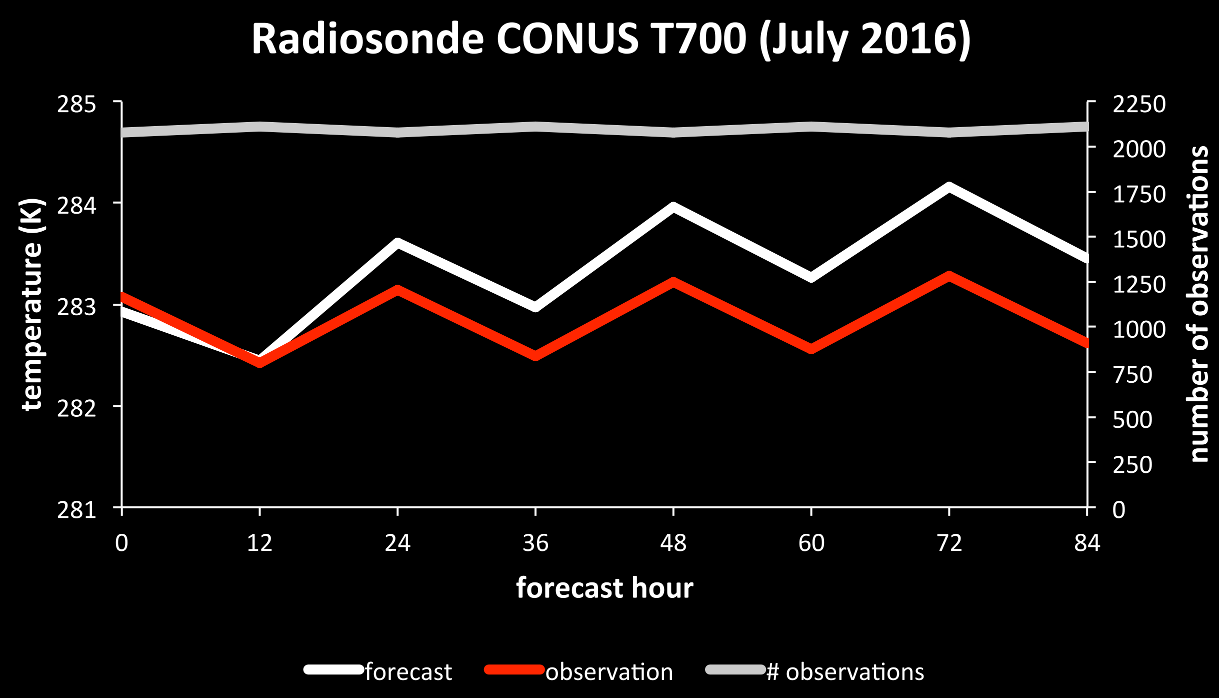
Red: observation
White: forecast
Grey: # obs

2 m T
ASOS stations
N = 809
No error trend



Control run

850 mb T
Radiosondes
N = 72



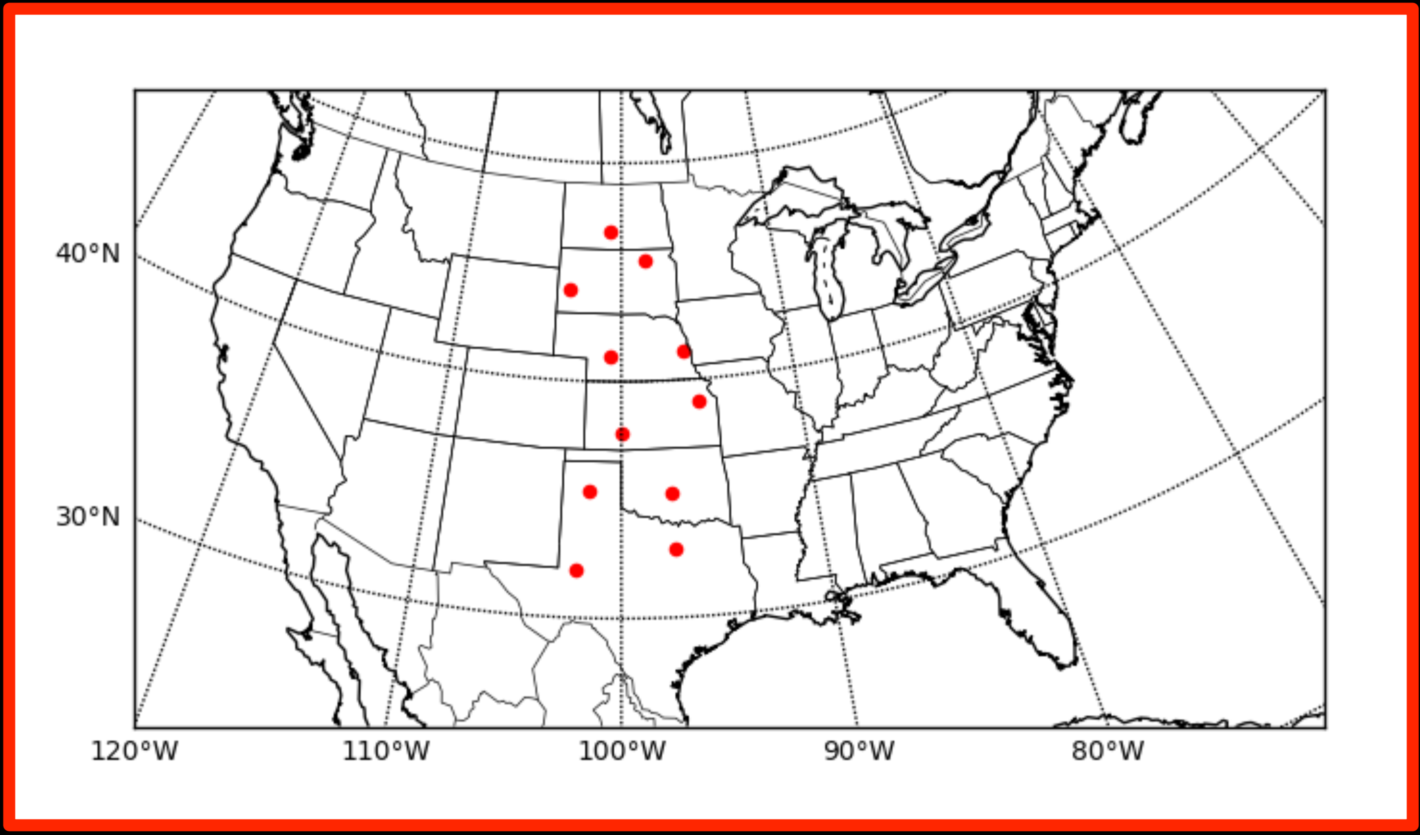
700 mb T
Radiosondes
N = 72

Great Plains subset

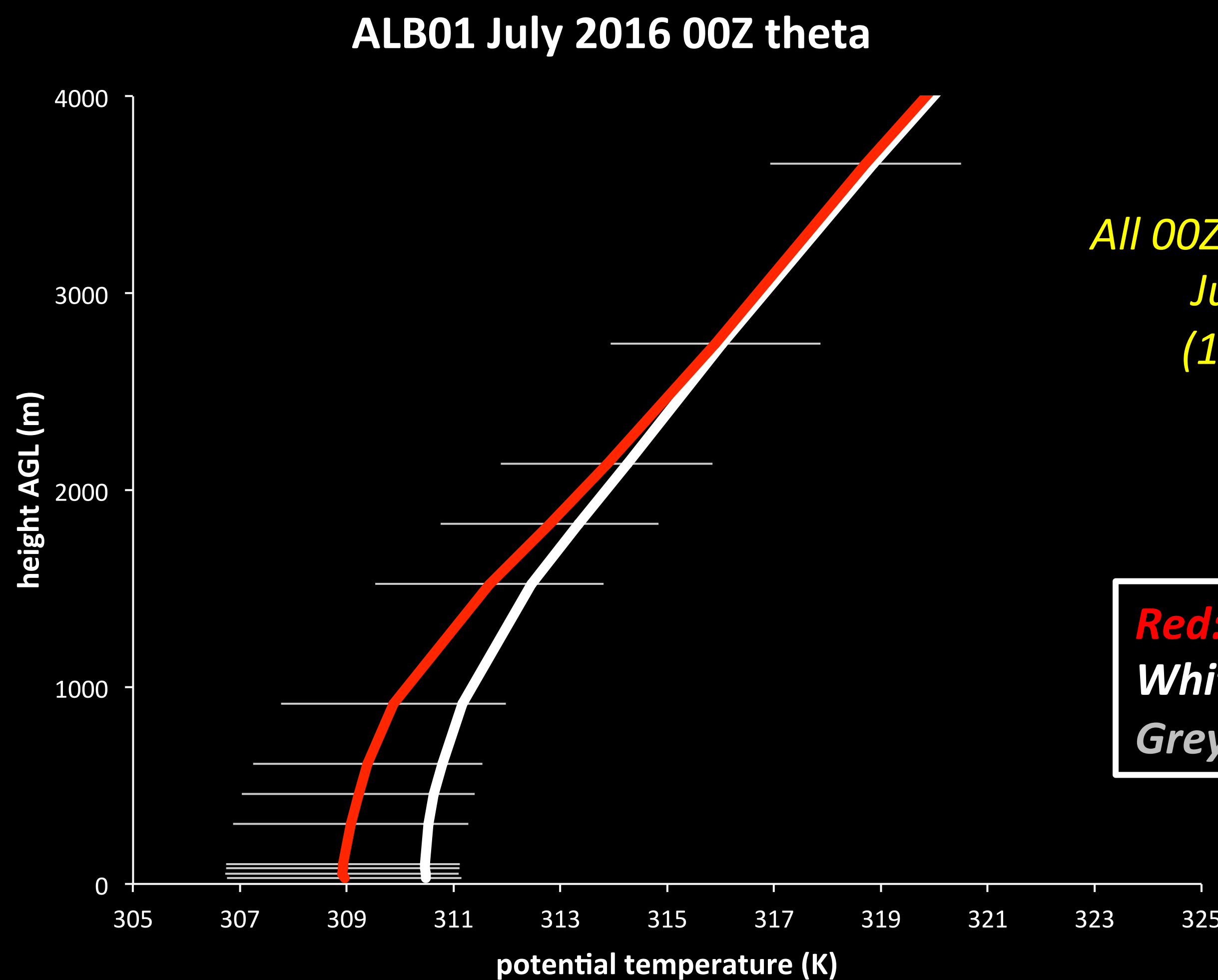
High-resolution radiosondes

Great Plains subset

N = 11



Potential temperature 00Z for control run (MYJ/KF/Noah)

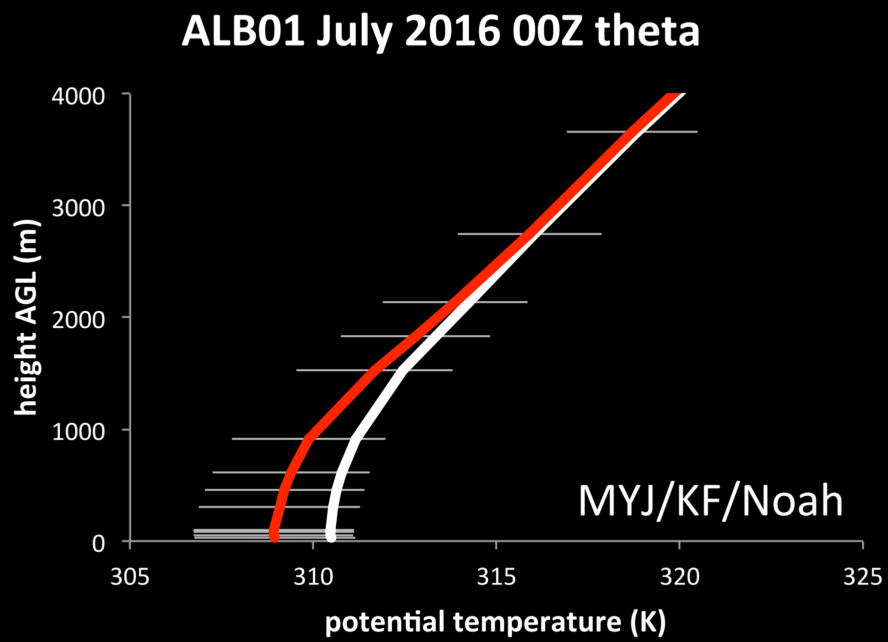


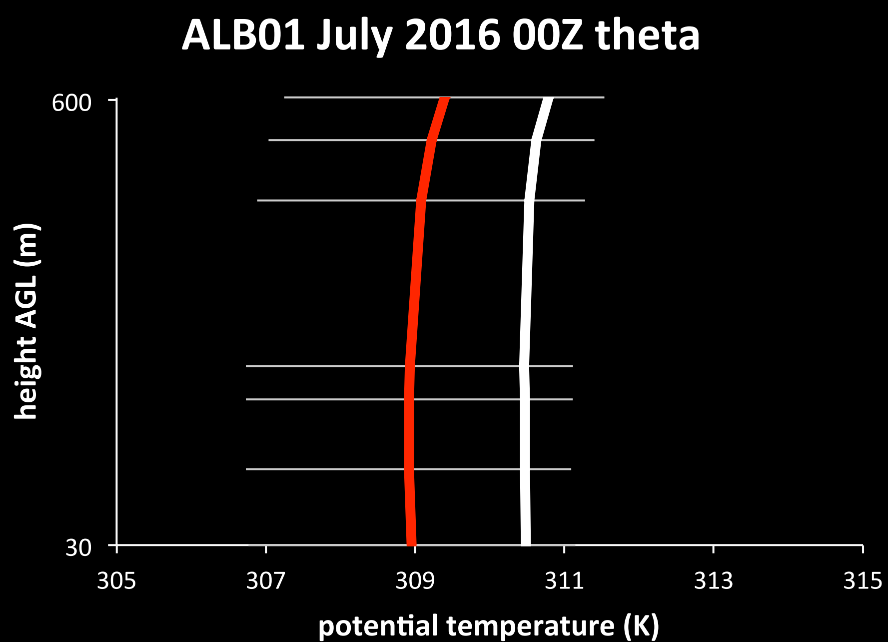
All 00Z forecasts for July 2016 (1364 obs)

Red: observation
White: forecast
Grey: ±1 std dev

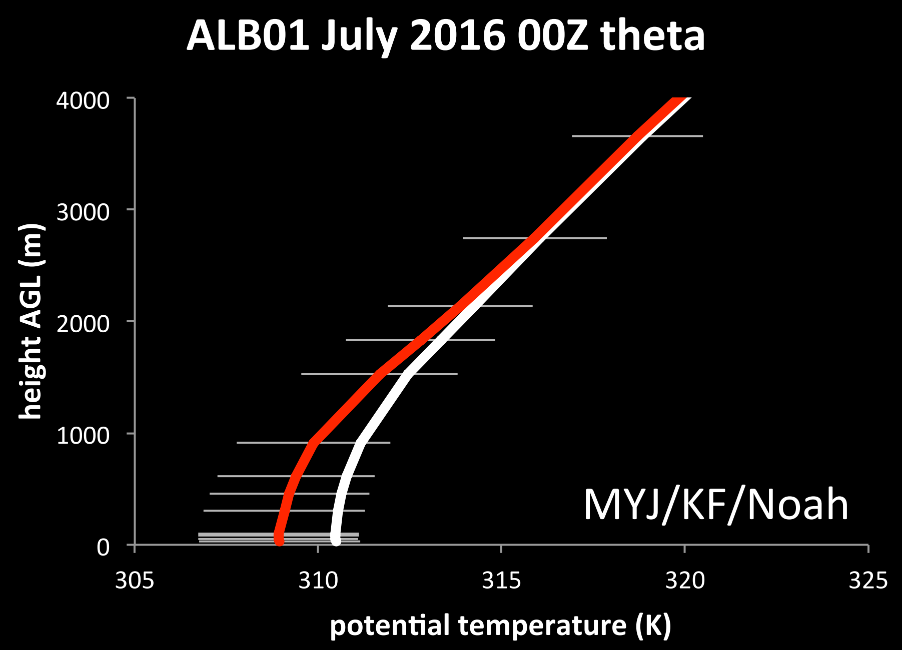
Great Plains subset

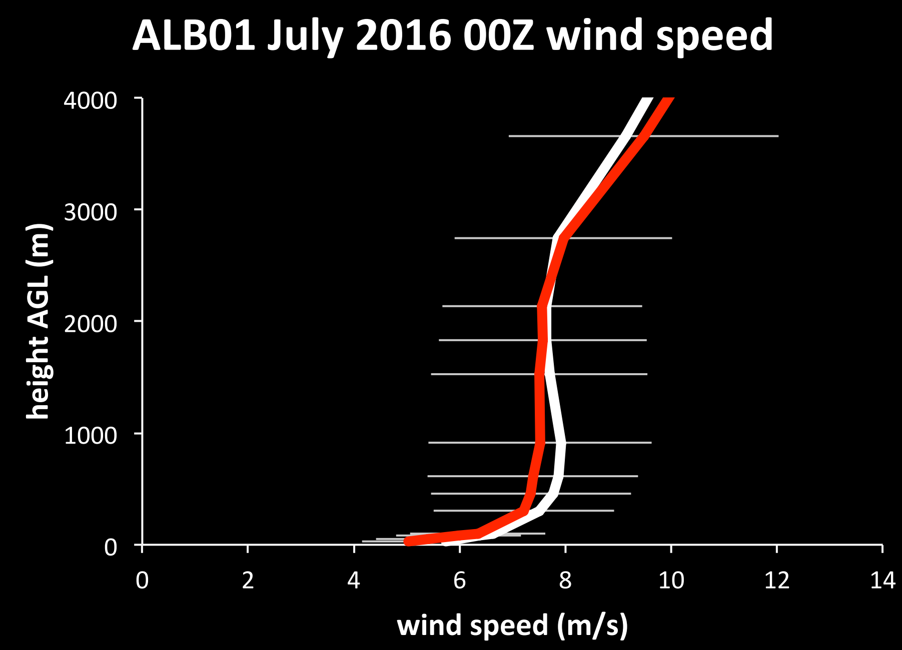
Control run
(MYJ/KF/Noah)

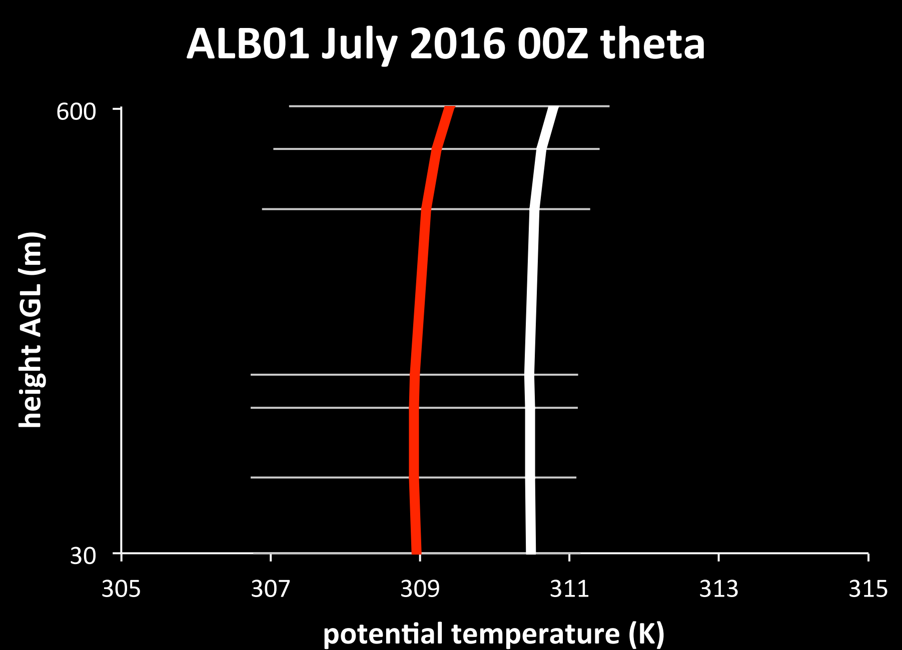


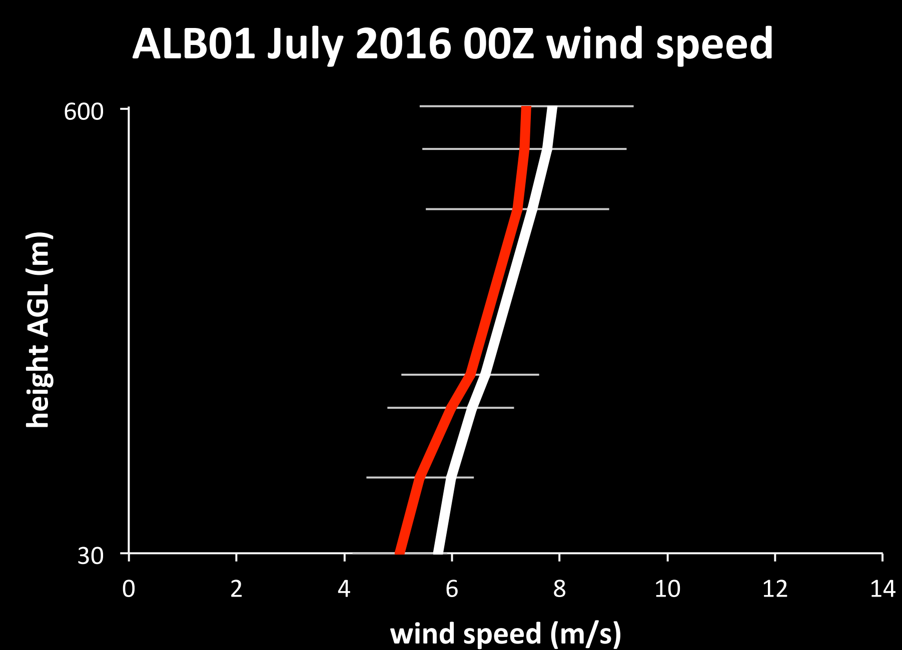


← Lowest 600 m, semi-log scale

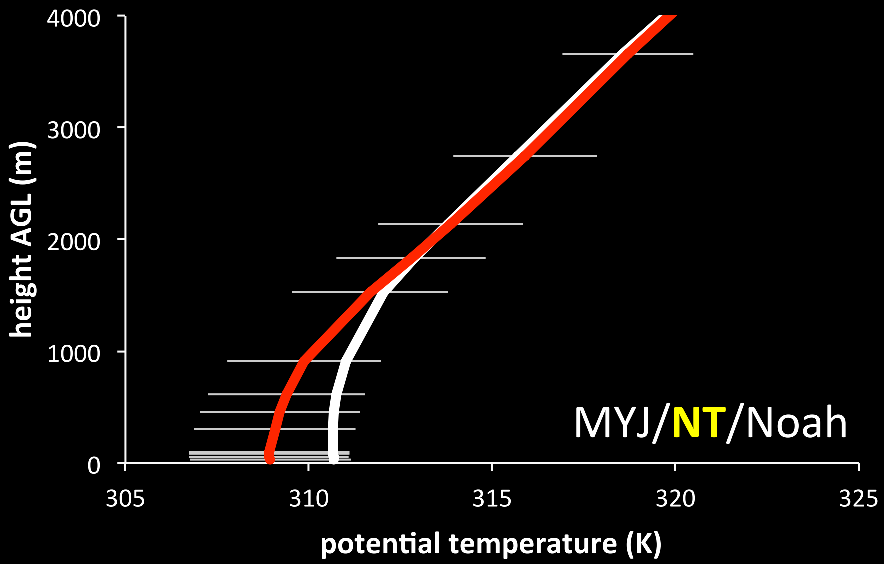

ALB01 July 2016 00Z theta
height AGL (m)
4000
3000
2000
1000
0
305
310
315
320
325
potential temperature (K)
MYJ/KF/Noah


ALB01 July 2016 00Z wind speed
height AGL (m)
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
wind speed (m/s)

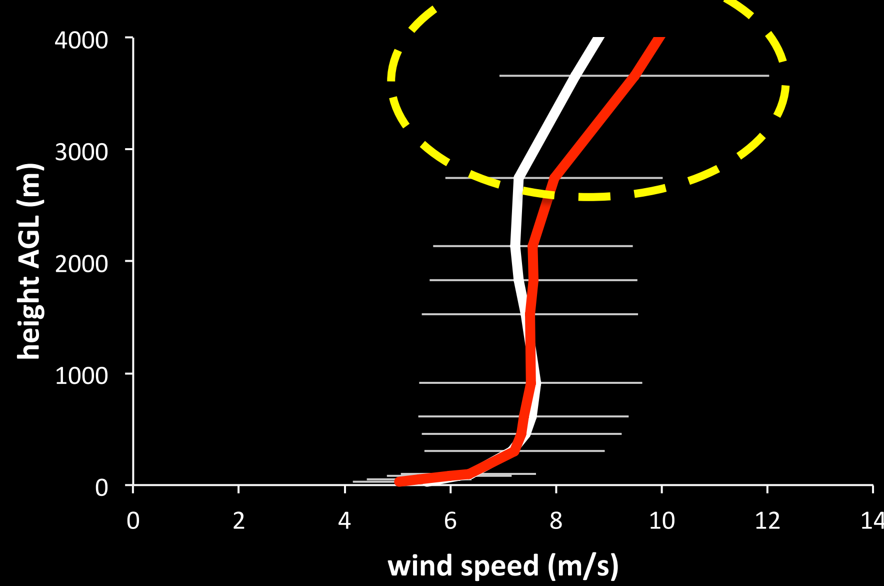

ALB01 July 2016 00Z theta
height AGL (m)
600
30
305
307
309
311
313
315
potential temperature (K)


ALB01 July 2016 00Z wind speed
height AGL (m)
600
30
0
2
4
6
8
10
12
14
wind speed (m/s)

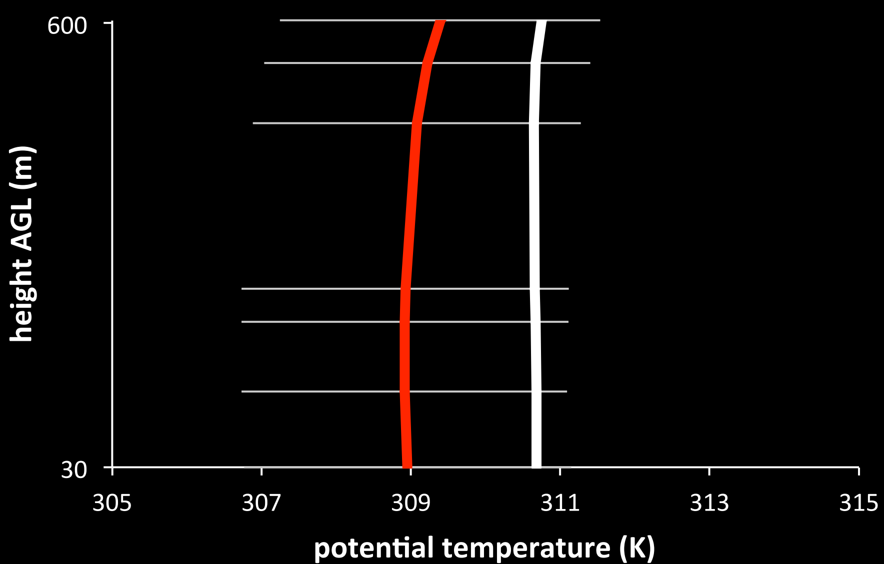
ALB08 July 2016 00Z theta



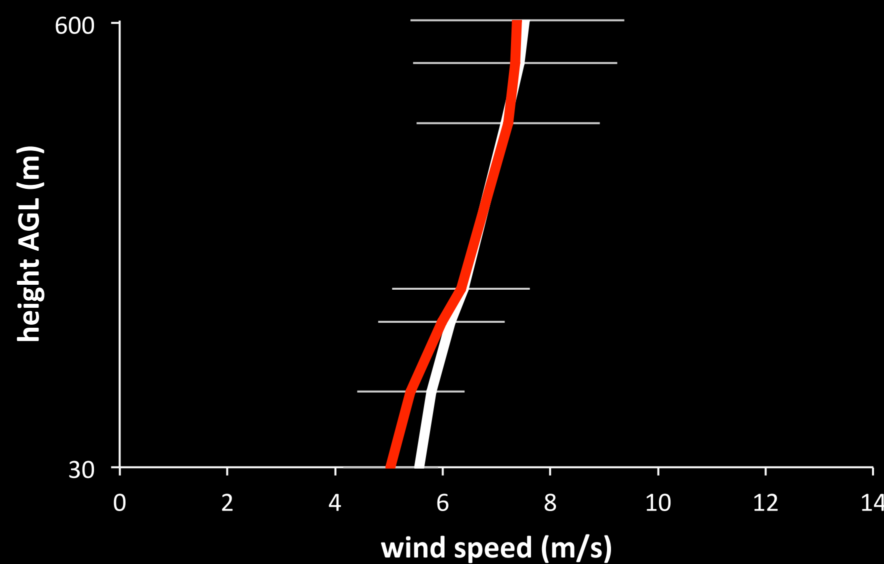
ALB08 July 2016 00Z wind speed

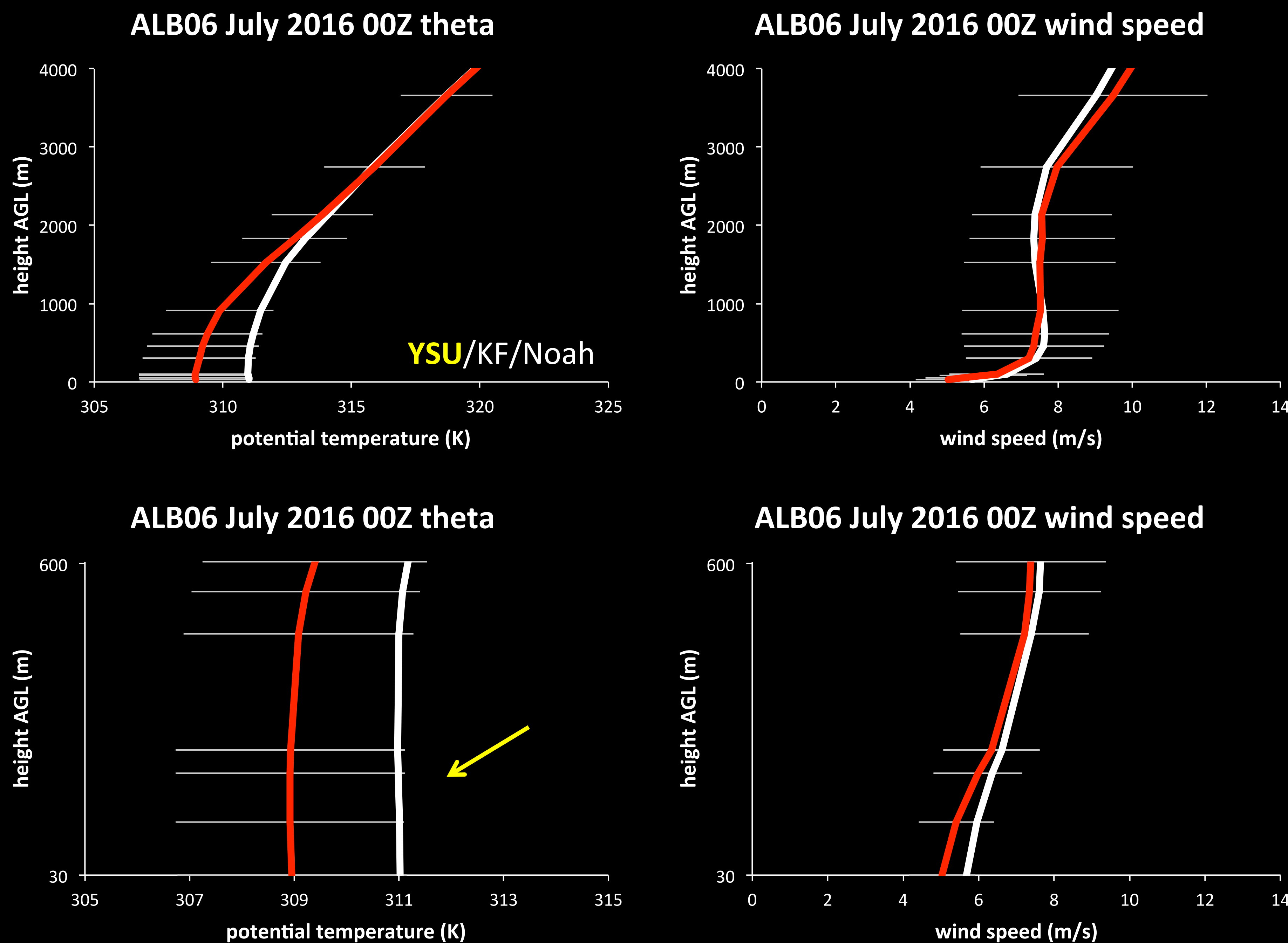


ALB08 July 2016 00Z theta

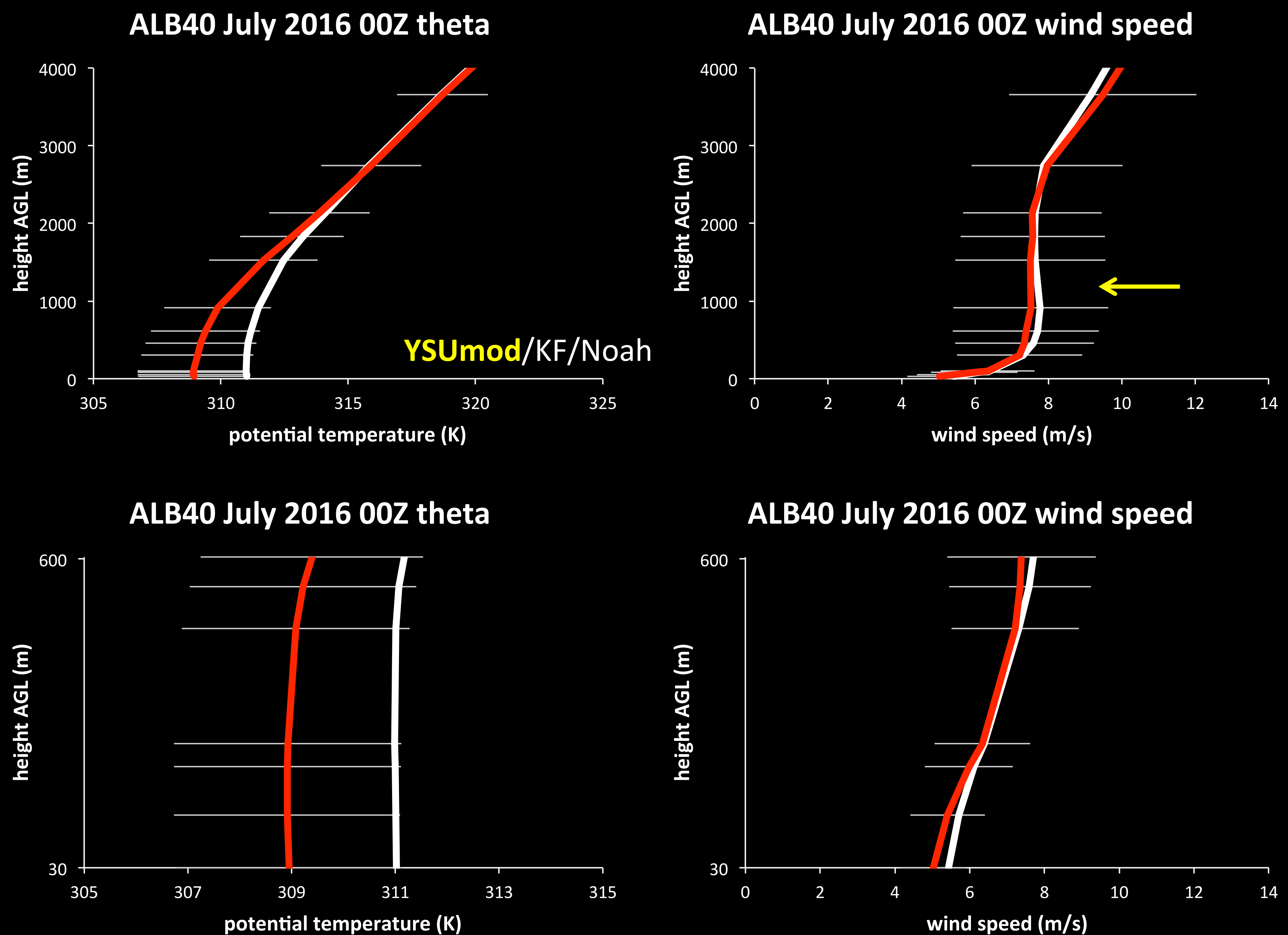


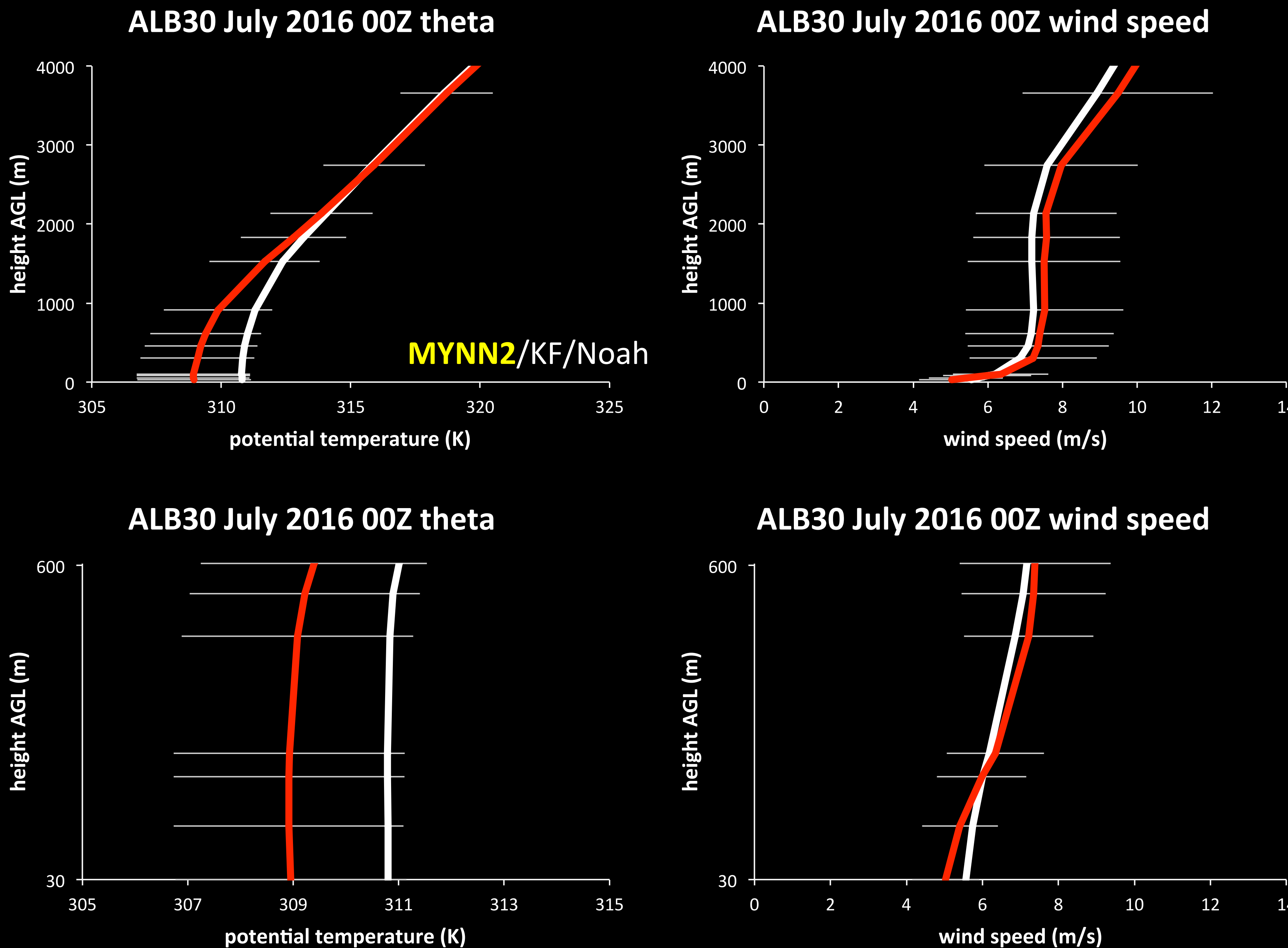
ALB08 July 2016 00Z wind speed

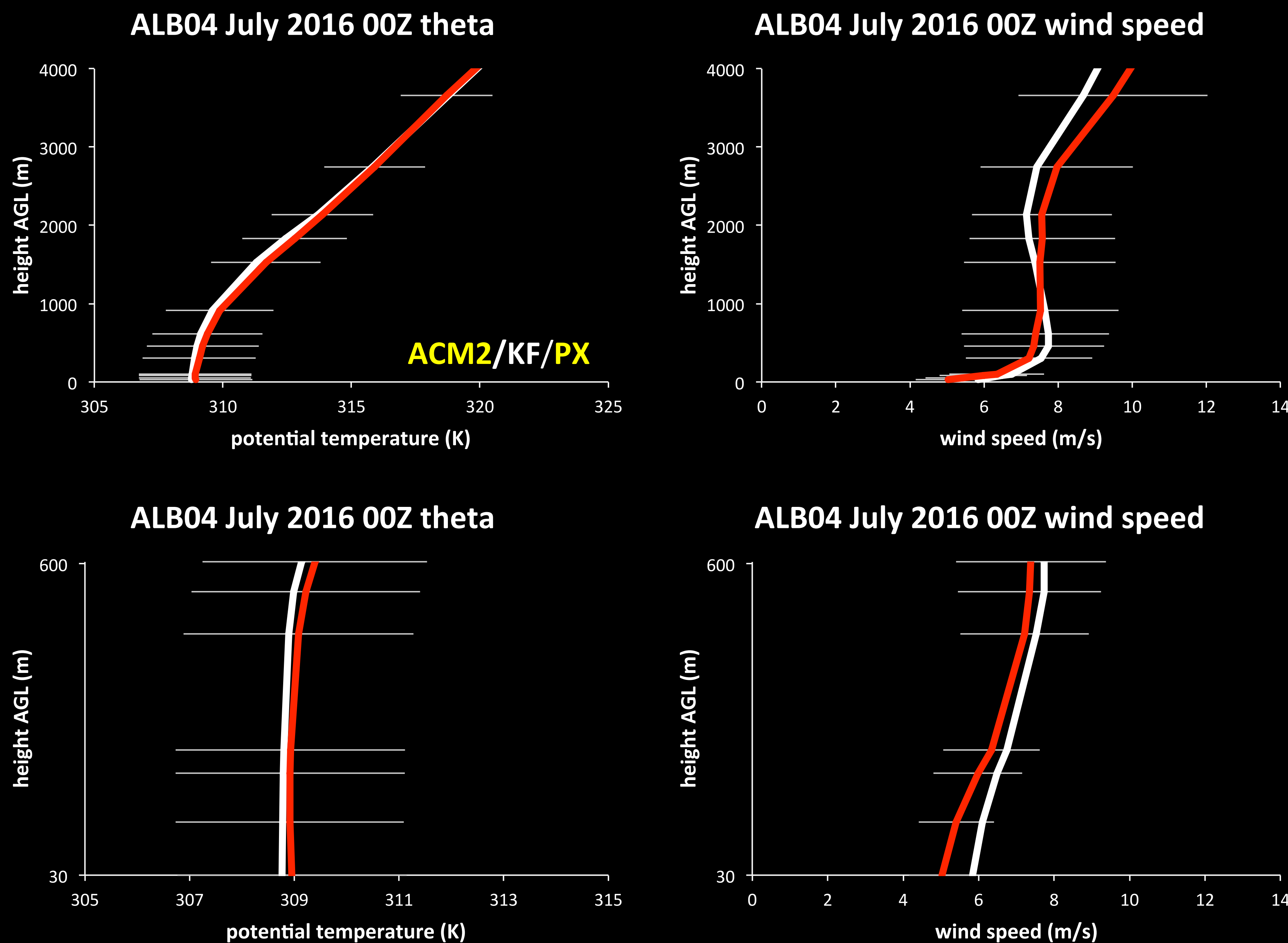


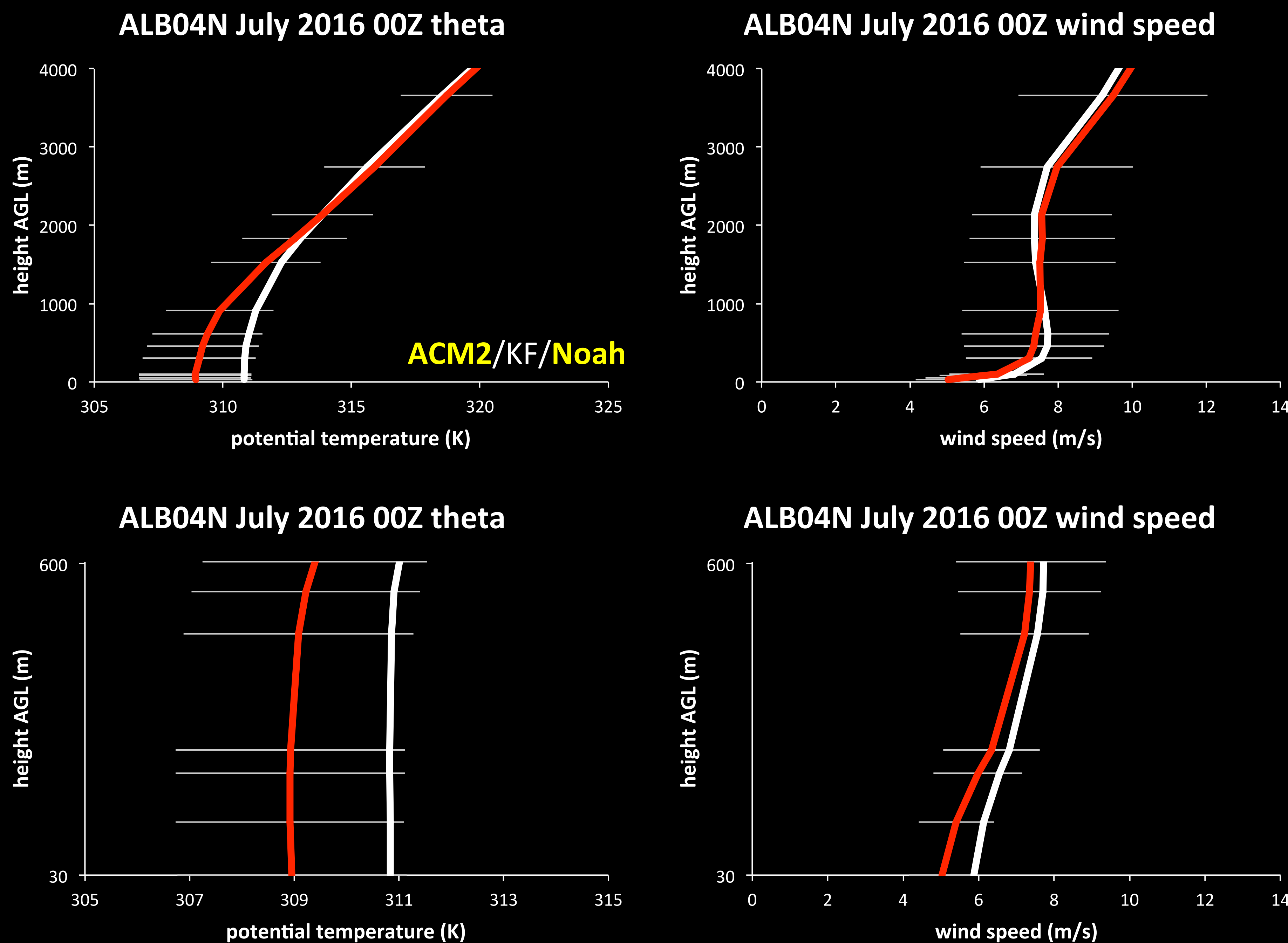


ALB06 July 2016 00Z theta
height AGL (m)
4000
3000
2000
1000
0
305
310
315
320
325
potential temperature (K)
YSU/KF/Noah
ALB06 July 2016 00Z wind speed
height AGL (m)
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
wind speed (m/s)
ALB06 July 2016 00Z theta
height AGL (m)
600
30
305
307
309
311
313
315
potential temperature (K)
ALB06 July 2016 00Z wind speed
height AGL (m)
600
30
0
2
4
6
8
10
12
14
wind speed (m/s)


ALB40 July 2016 00Z theta
height AGL (m)
potential temperature (K)
YSUmod/KF/Noah
ALB40 July 2016 00Z wind speed
height AGL (m)
wind speed (m/s)
ALB40 July 2016 00Z theta
height AGL (m)
potential temperature (K)
ALB40 July 2016 00Z wind speed
height AGL (m)
wind speed (m/s)

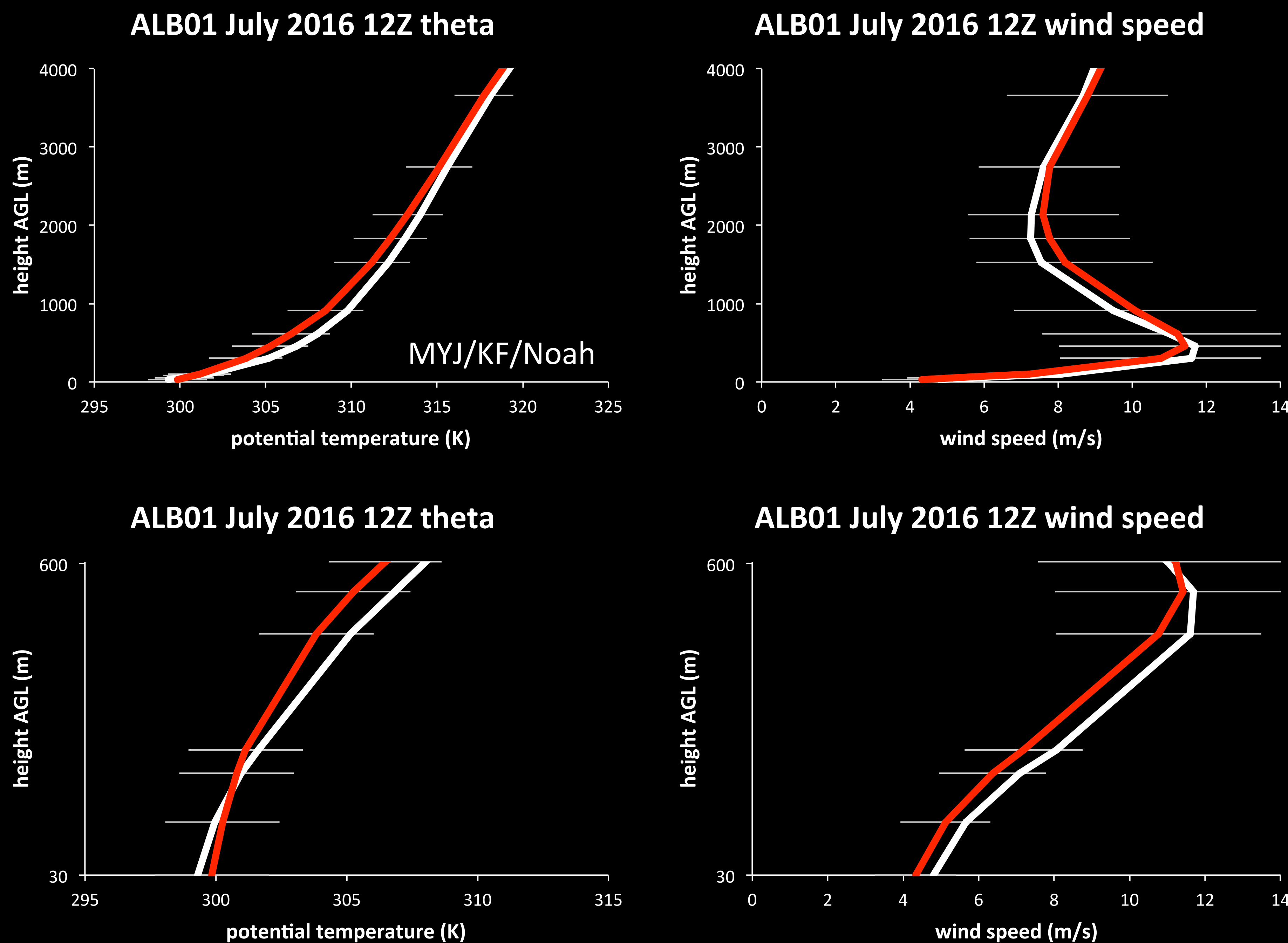

ALB30 July 2016 00Z theta
height AGL (m)
4000
3000
2000
1000
0
305
310
315
320
325
potential temperature (K)
MYNN2/KF/Noah
ALB30 July 2016 00Z wind speed
height AGL (m)
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
wind speed (m/s)
ALB30 July 2016 00Z theta
height AGL (m)
600
30
305
307
309
311
313
315
potential temperature (K)
ALB30 July 2016 00Z wind speed
height AGL (m)
600
30
0
2
4
6
8
10
12
14
wind speed (m/s)


ALB04 July 2016 00Z theta
4000
3000
2000
1000
0
height AGL (m)
305
310
315
320
325
potential temperature (K)
ACM2/KF/PX
ALB04 July 2016 00Z wind speed
4000
3000
2000
1000
0
height AGL (m)
0
2
4
6
8
10
12
14
wind speed (m/s)
ALB04 July 2016 00Z theta
600
30
height AGL (m)
305
307
309
311
313
315
potential temperature (K)
ALB04 July 2016 00Z wind speed
600
30
height AGL (m)
0
2
4
6
8
10
12
14
wind speed (m/s)

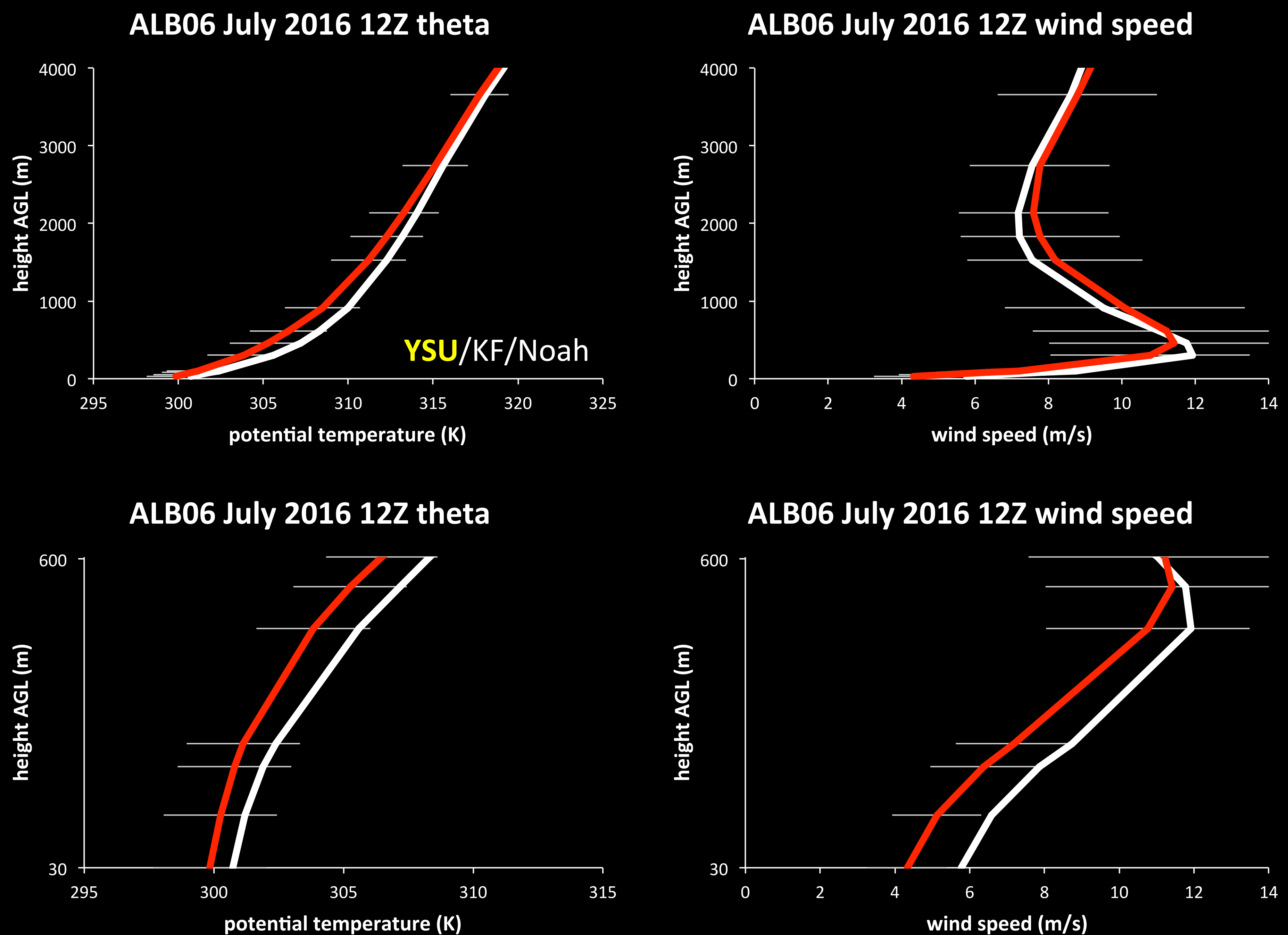


ALB04N July 2016 00Z theta
height AGL (m)
4000
3000
2000
1000
0
305
310
315
320
325
potential temperature (K)
ACM2/KF/Noah
ALB04N July 2016 00Z wind speed
height AGL (m)
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
wind speed (m/s)
ALB04N July 2016 00Z theta
height AGL (m)
600
30
305
307
309
311
313
315
potential temperature (K)
ALB04N July 2016 00Z wind speed
height AGL (m)
600
30
0
2
4
6
8
10
12
14
wind speed (m/s)

Great Plains subset at 12Z

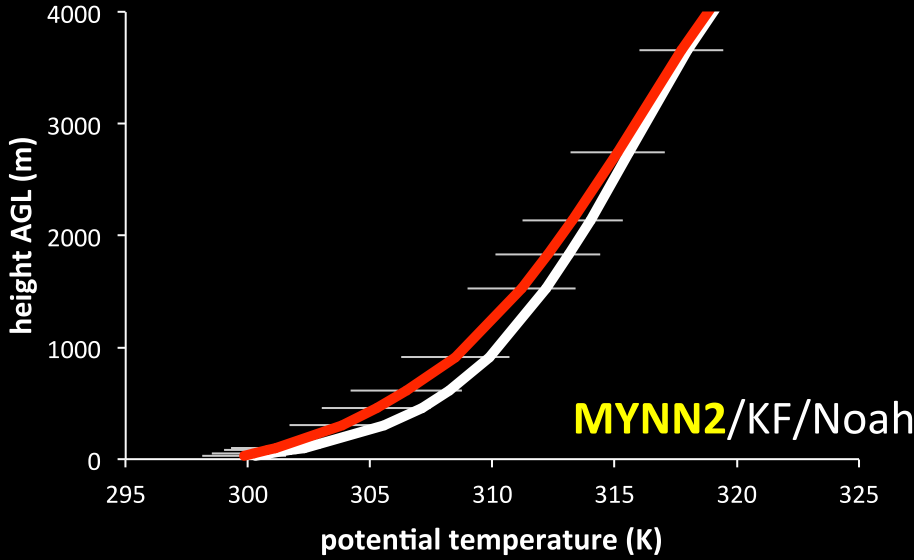


ALB01 July 2016 12Z theta
ALB01 July 2016 12Z wind speed
height AGL (m)
4000
3000
2000
1000
0
295
300
305
310
315
320
325
potential temperature (K)
MYJ/KF/Noah
0
2
4
6
8
10
12
14
wind speed (m/s)
ALB01 July 2016 12Z theta
ALB01 July 2016 12Z wind speed
600
30
295
300
305
310
315
potential temperature (K)
wind speed (m/s)

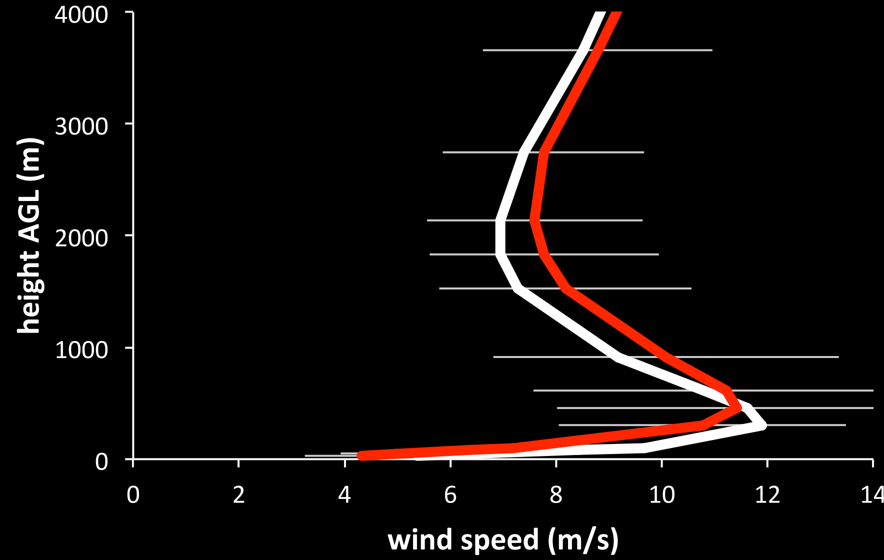


ALB06 July 2016 12Z theta
height AGL (m)
potential temperature (K)
YSU/KF/Noah
ALB06 July 2016 12Z wind speed
height AGL (m)
wind speed (m/s)
ALB06 July 2016 12Z theta
height AGL (m)
potential temperature (K)
ALB06 July 2016 12Z wind speed
height AGL (m)
wind speed (m/s)

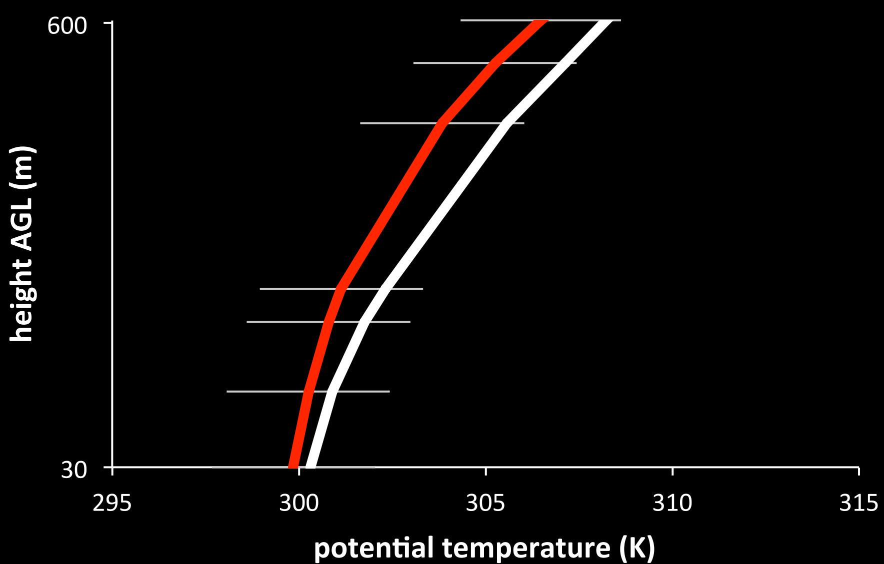
ALB30 July 2016 12Z theta



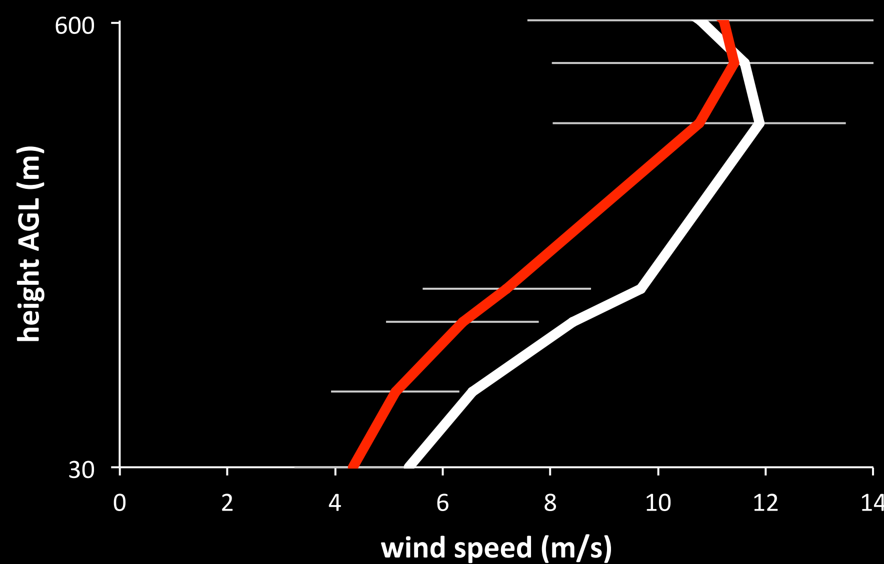
ALB30 July 2016 12Z wind speed



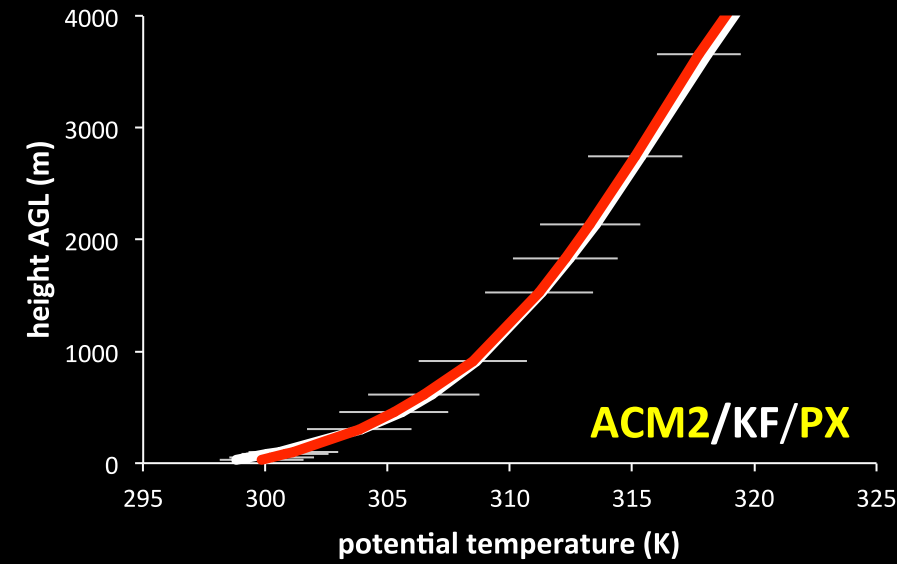
ALB30 July 2016 12Z theta



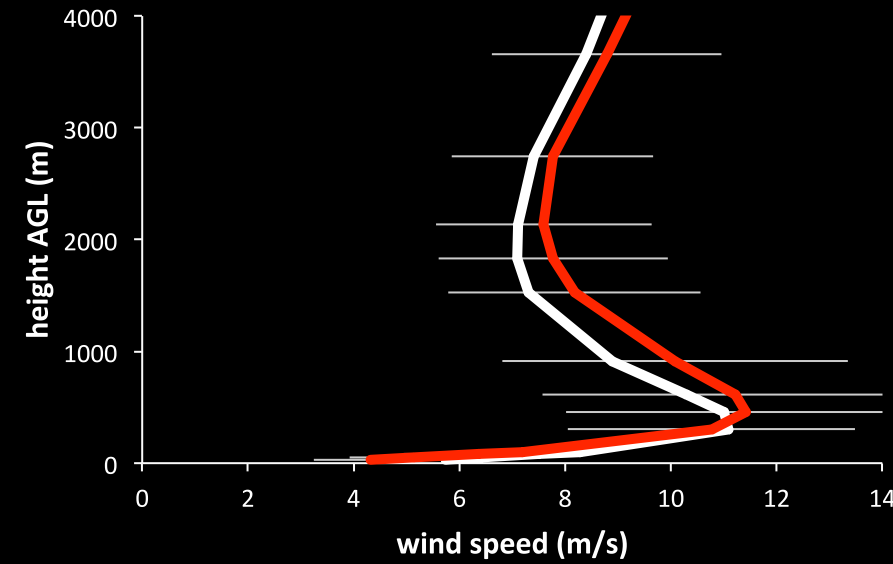
ALB30 July 2016 12Z wind speed



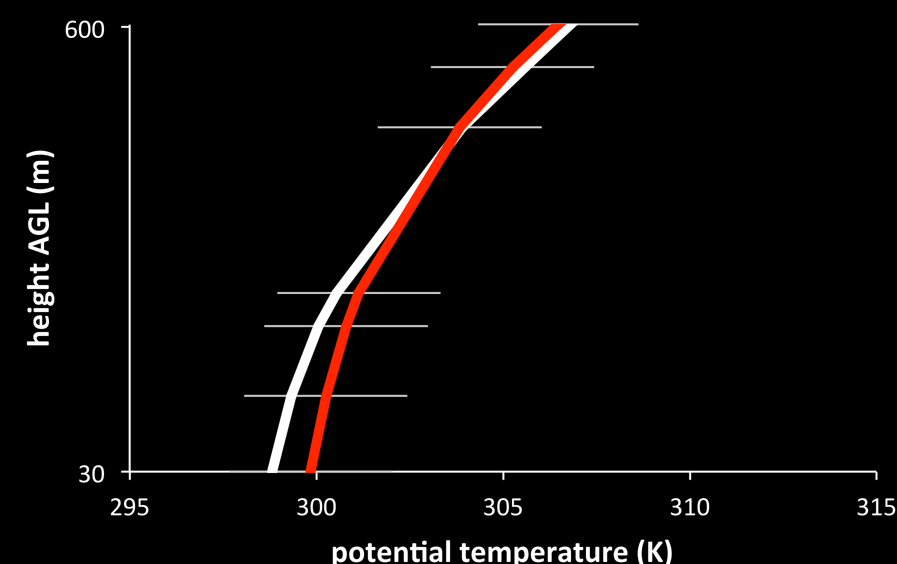
ALB04 July 2016 12Z theta



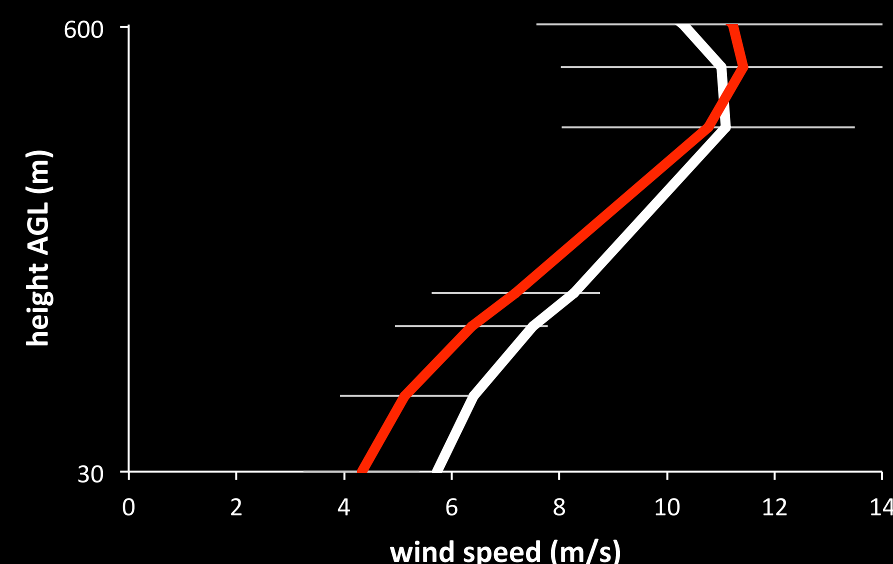
ALB04 July 2016 12Z wind speed



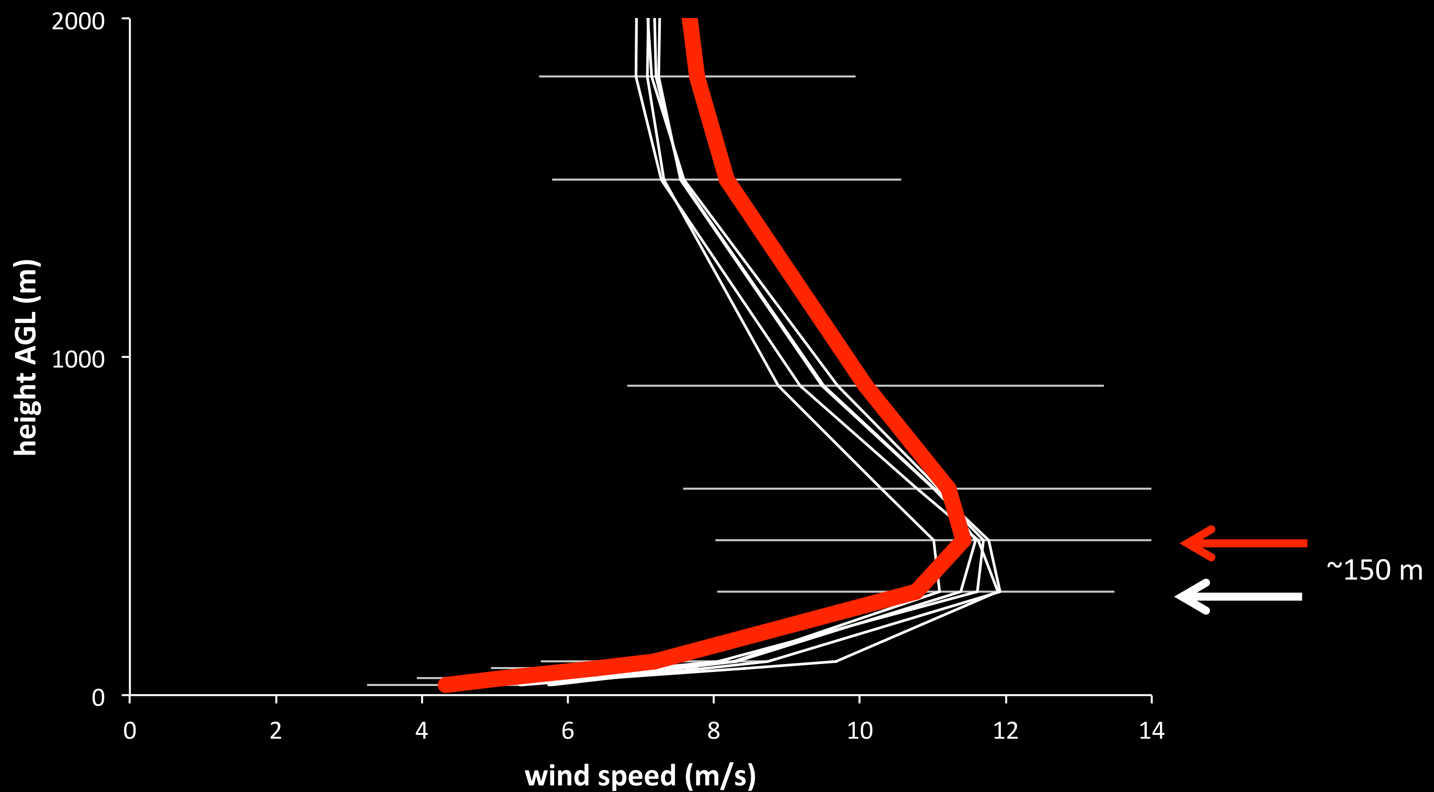
ALB04 July 2016 12Z theta



ALB04 July 2016 12Z wind speed



Forecast vs. observed July 2016 12Z wind speed



Systematic biases with respect to jet elevation
and change of bias sign suggests *nocturnal mixing too weak*

Summary

- 20 km CONUS physics ensemble reveals
  - 10-m wind forecast bias explained by local gustiness/ exposure, at least for ASOS stations
  - Many runs have spurious warming trend above surface
    - Sensitive to *land surface model* and *convective parameterization* (not shown here)
  - Most physics combinations overpredict T in boundary layer during daytime, and appear to mix too little at night
  - "What starts at the surface does not stay at the surface" (surface T biases, day and night, influence PBL stability and structure, as anticipated)