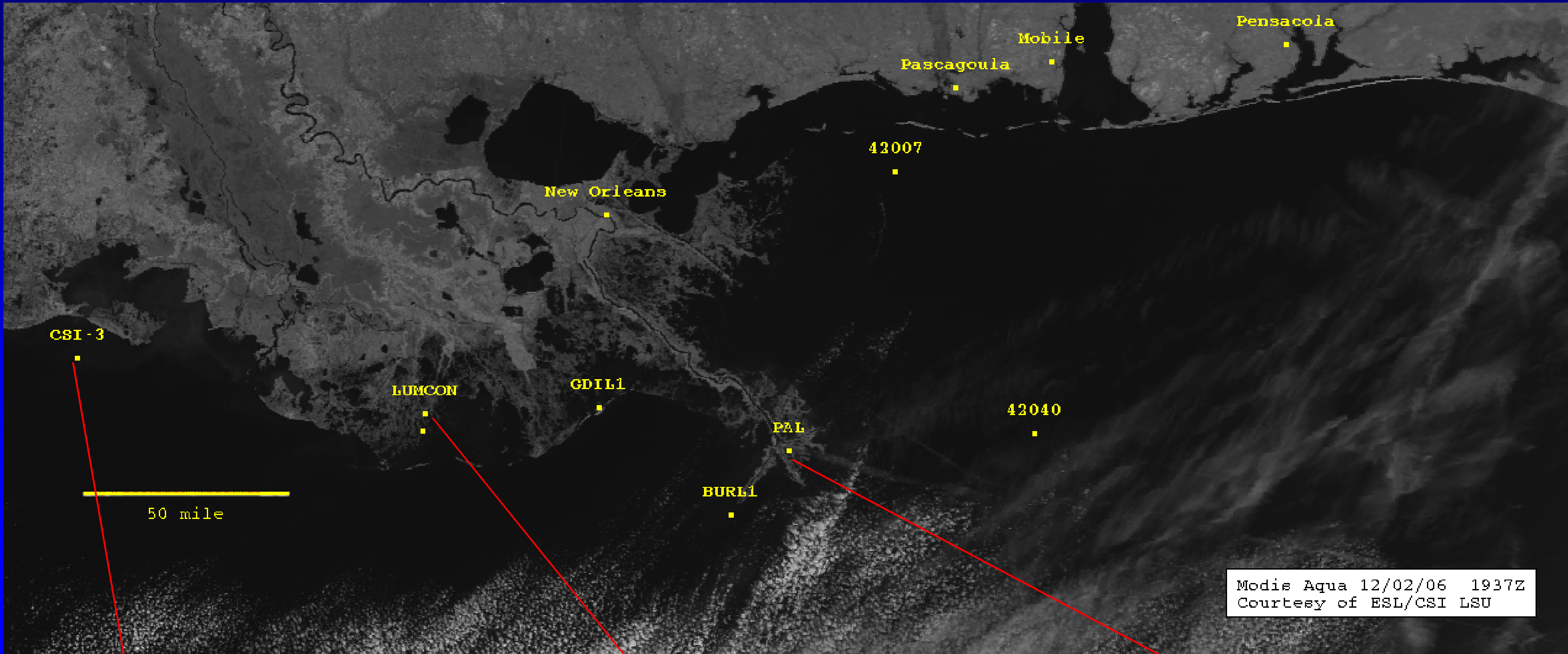
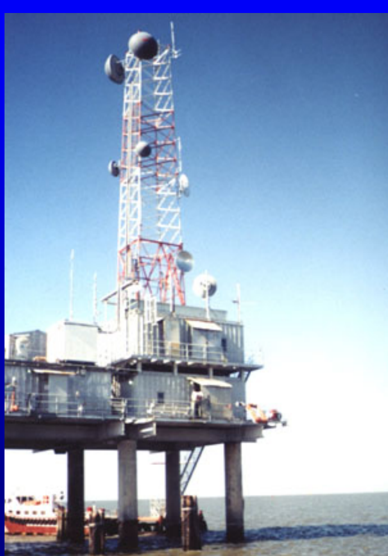
Coastal Studies Institute
Louisiana State University
Marine Meteorology Group

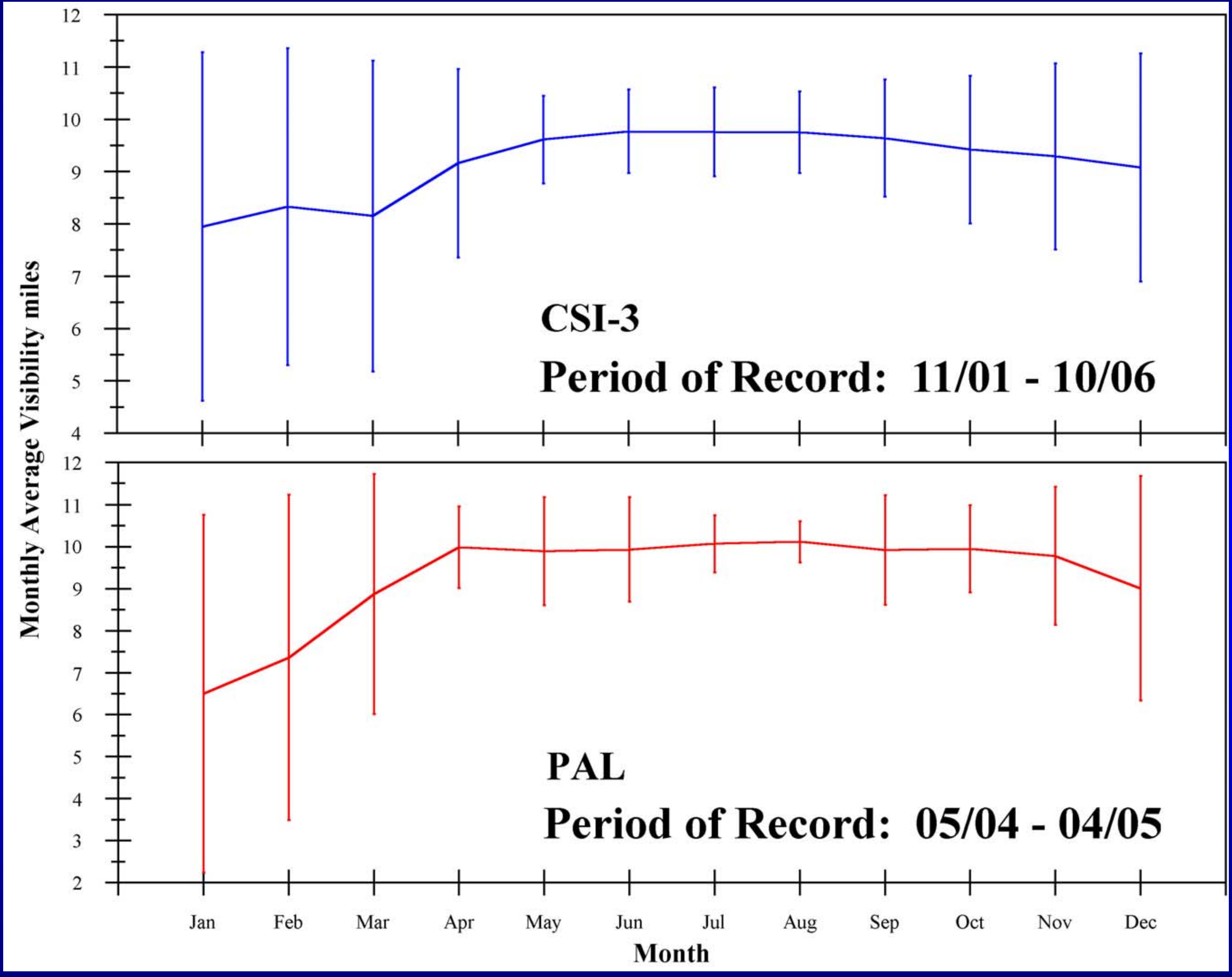
Simultaneous Measurements of Atmospheric Visibility, Particulate Matter, and Mixing Heights in the Breton Area IMPROVE Site

S. A. Hsu and Brian W. Blanchard

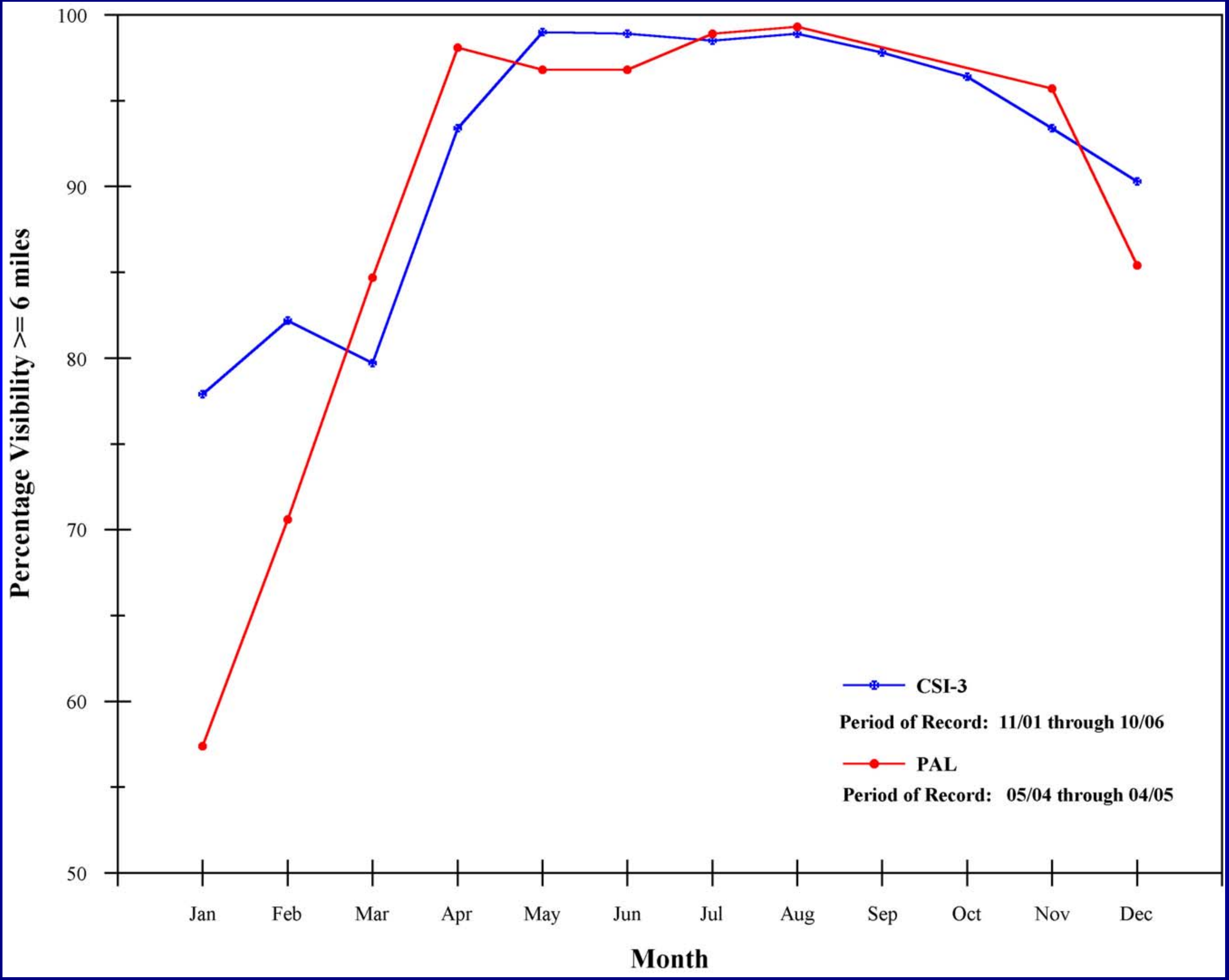

Pensacola
Mobile
Pascagoula
42007
New Orleans
CSI-3
LUMCON
GDIL1
42040
PAL
BURL1
50 mile
Modis Aqua 12/02/06 1937Z
Courtesy of ESL/CSI LSU



Visibility (Haze and Fog)



Monthly Average Visibility miles
12
11
10
9
8
7
6
5
4
CSI-3
Period of Record: 11/01 - 10/06
12
11
10
9
8
7
6
5
4
3
2
PAL
Period of Record: 05/04 - 04/05
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



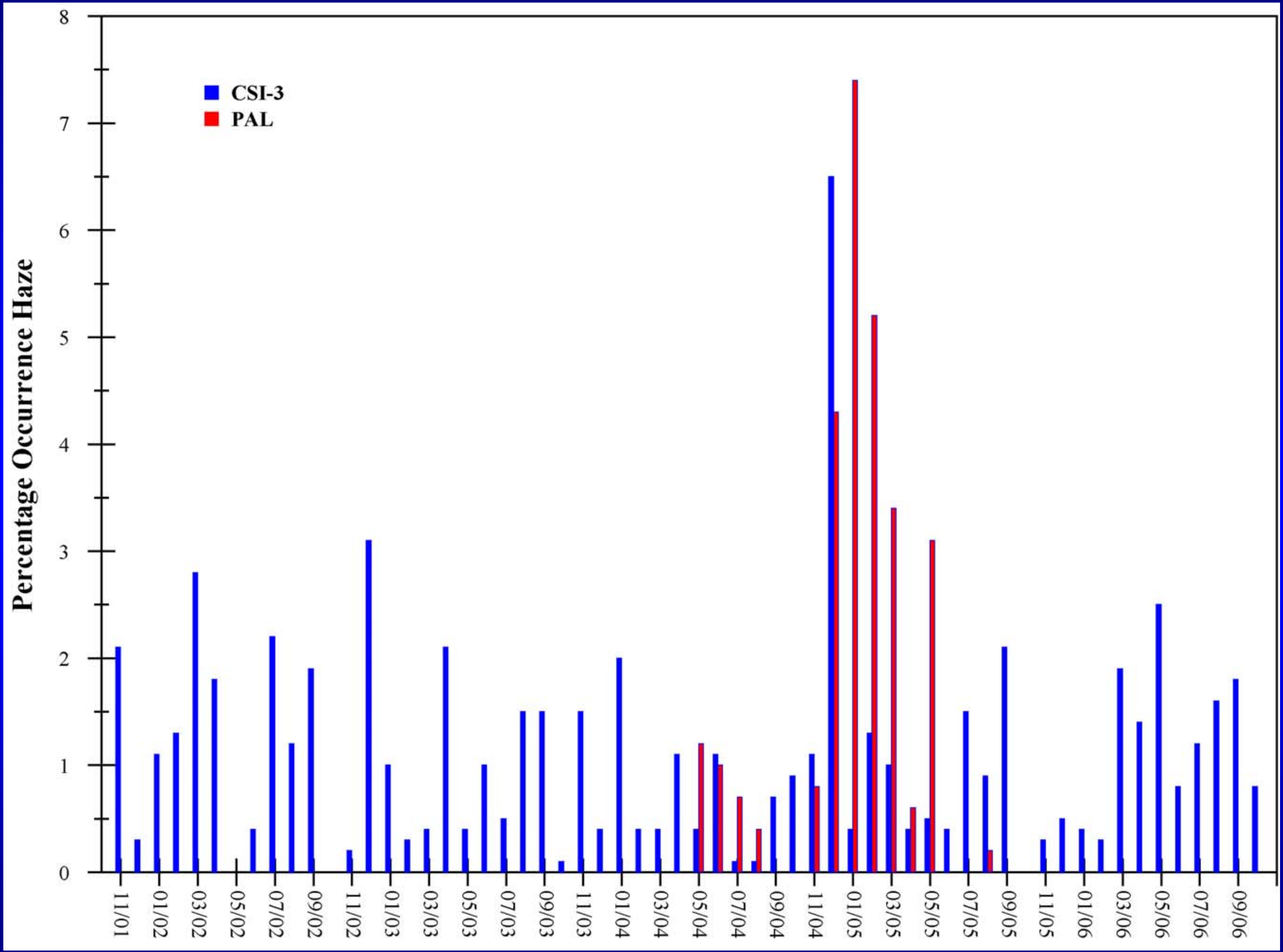
100
90
80
70
60
50
Percentage Visibility >= 6 miles
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
CSI-3
Period of Record: 11/01 through 10/06
PAL
Period of Record: 05/04 through 04/05

For this study, measured visibility at CSI-3 and PAL is classified as either fog or haze through the following modified version of the ASOS Obstruction to Vision (OTV) algorithm:

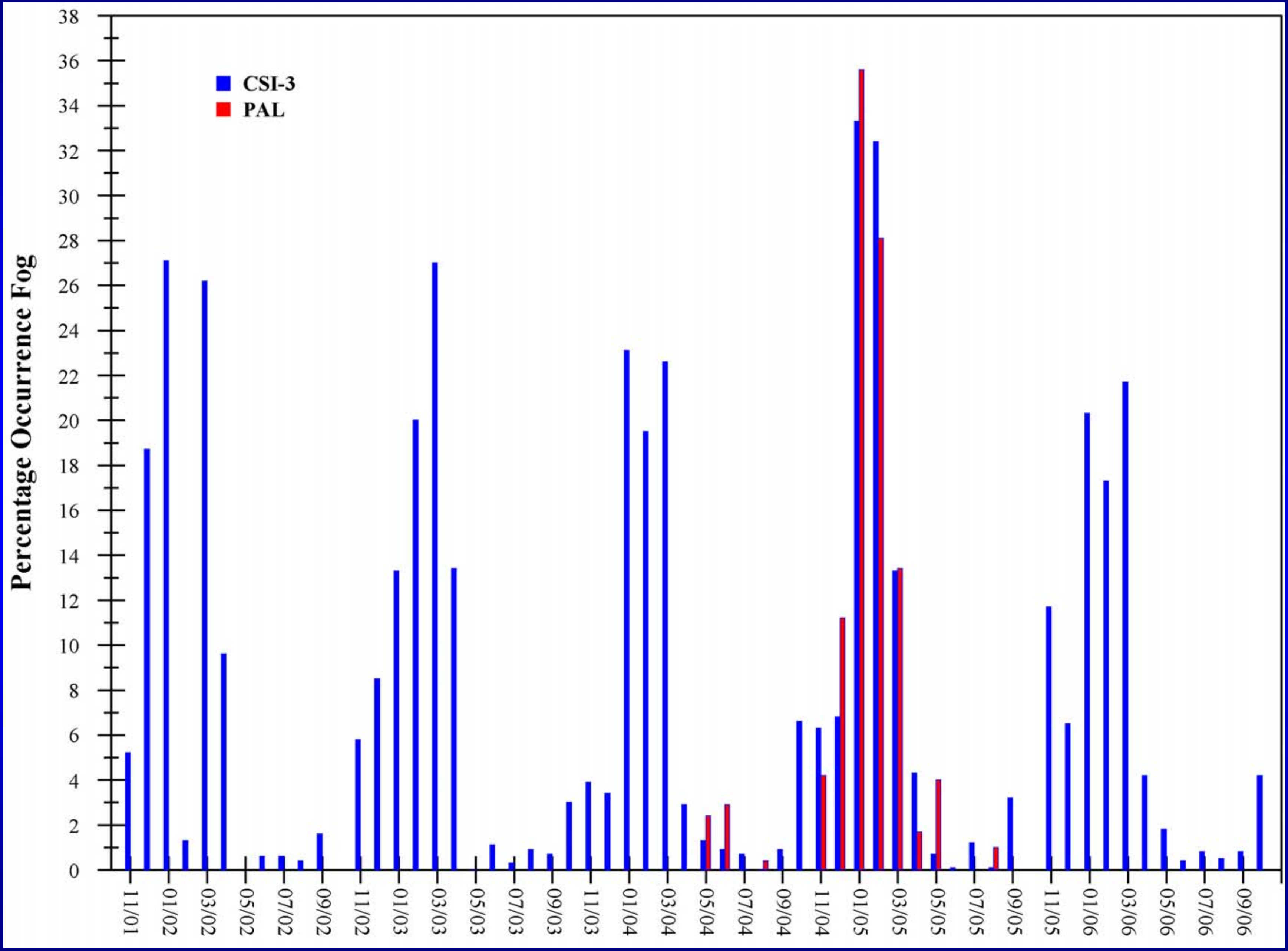
For visibility less than 7 miles,

if $T_{air} - T_{dew} \leq 4°F$, then FOG

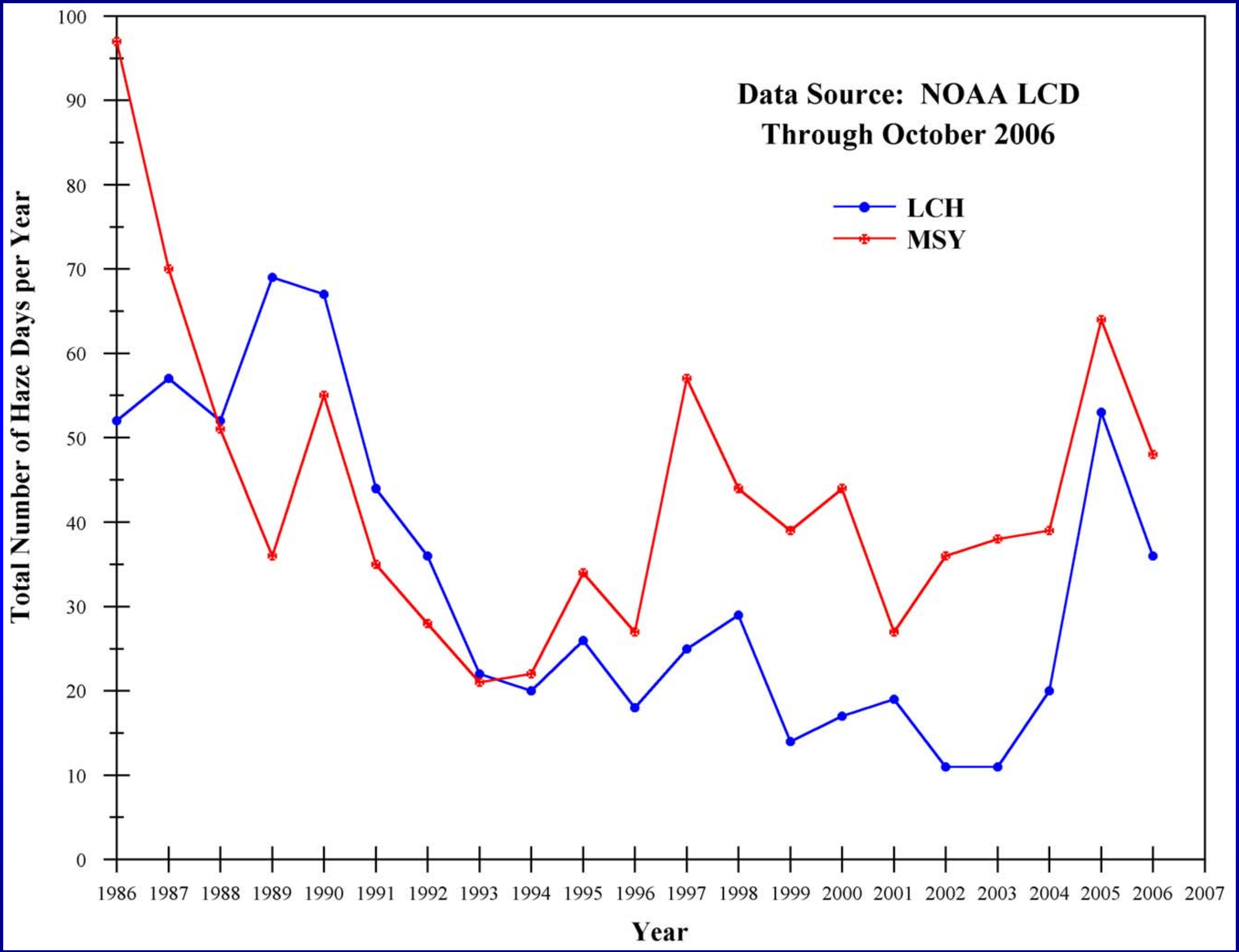
if $T_{air} - T_{dew} > 4°F$, then HAZE

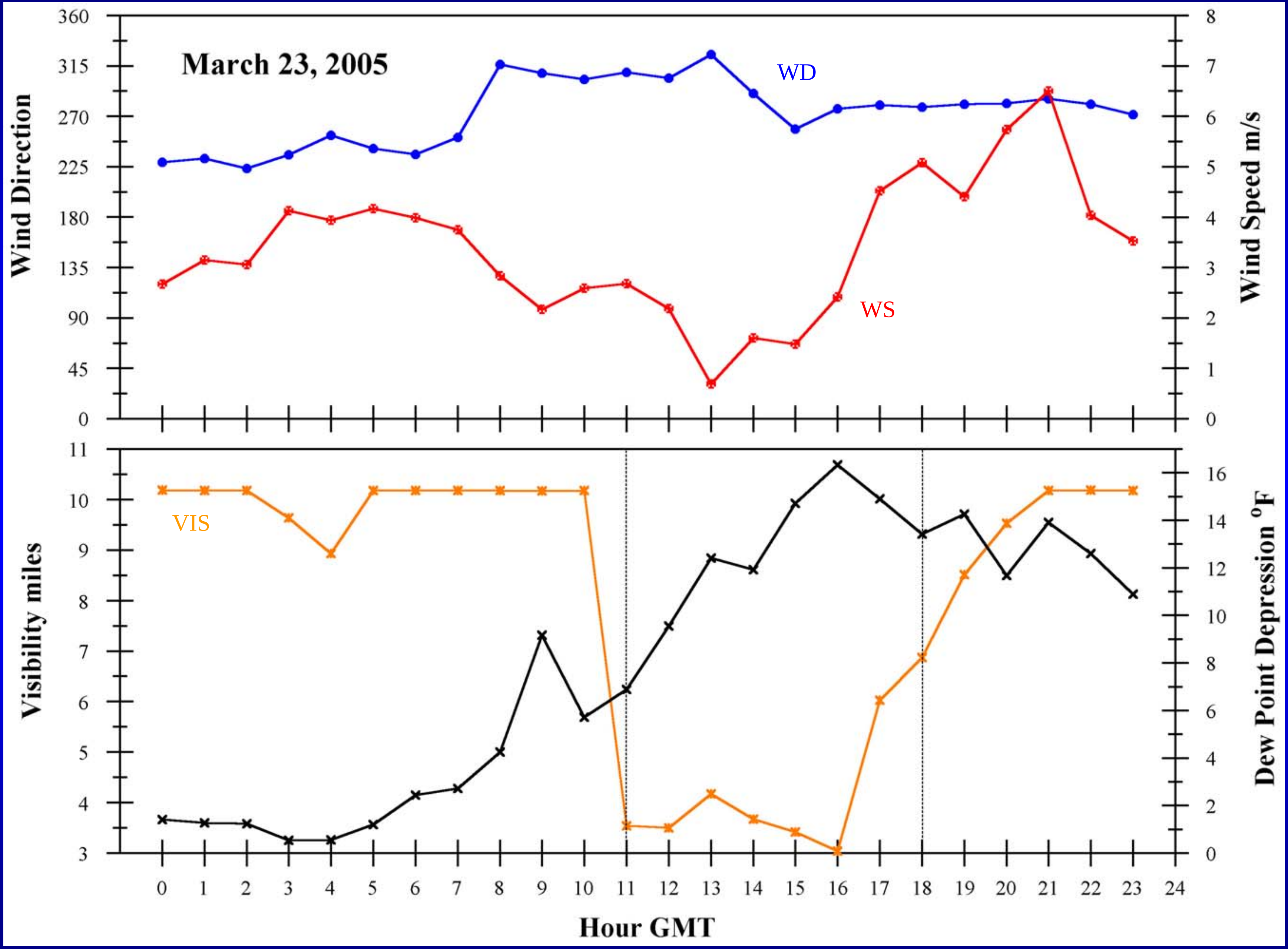


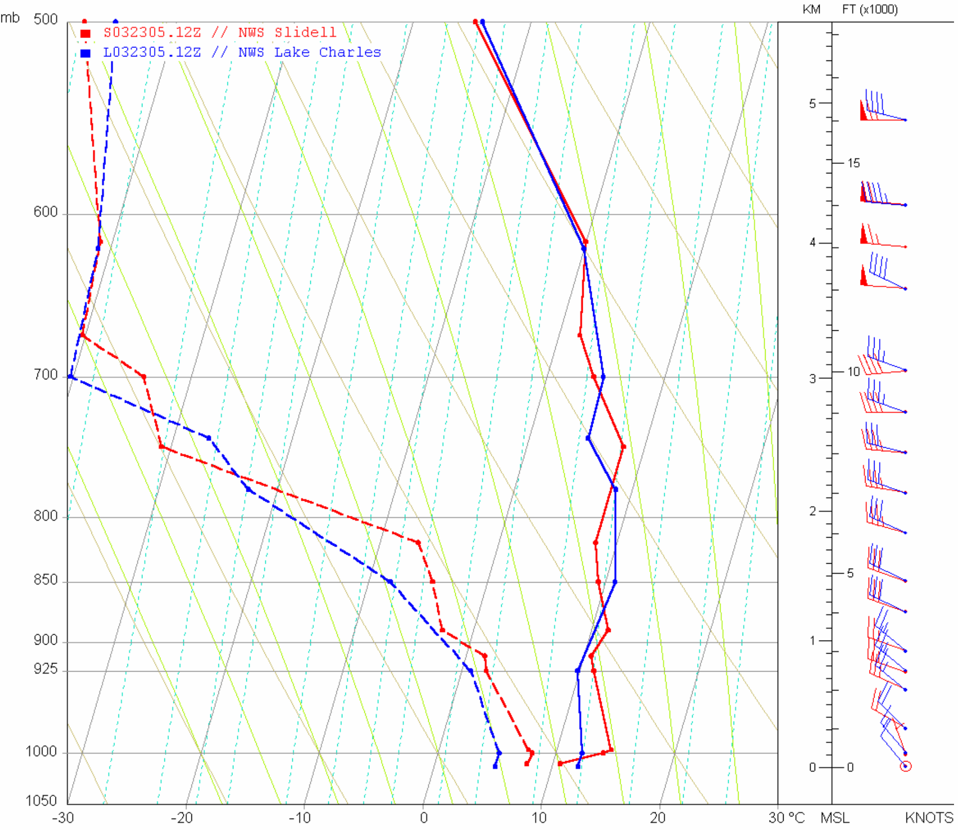
Percentage Occurrence Haze
CSI-3
PAL
0
1
2
3
4
5
6
7
8
11/01
01/02
03/02
05/02
07/02
09/02
11/02
01/03
03/03
05/03
07/03
09/03
11/03
01/04
03/04
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
11/05
01/06
03/06
05/06
07/06
09/06

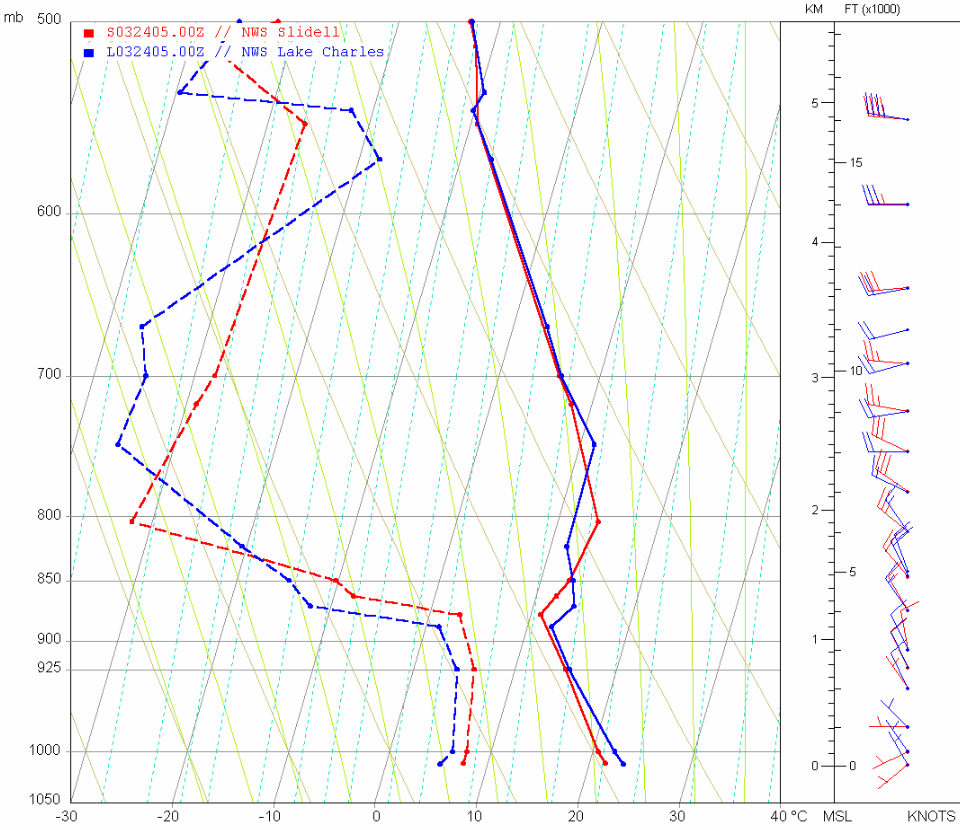


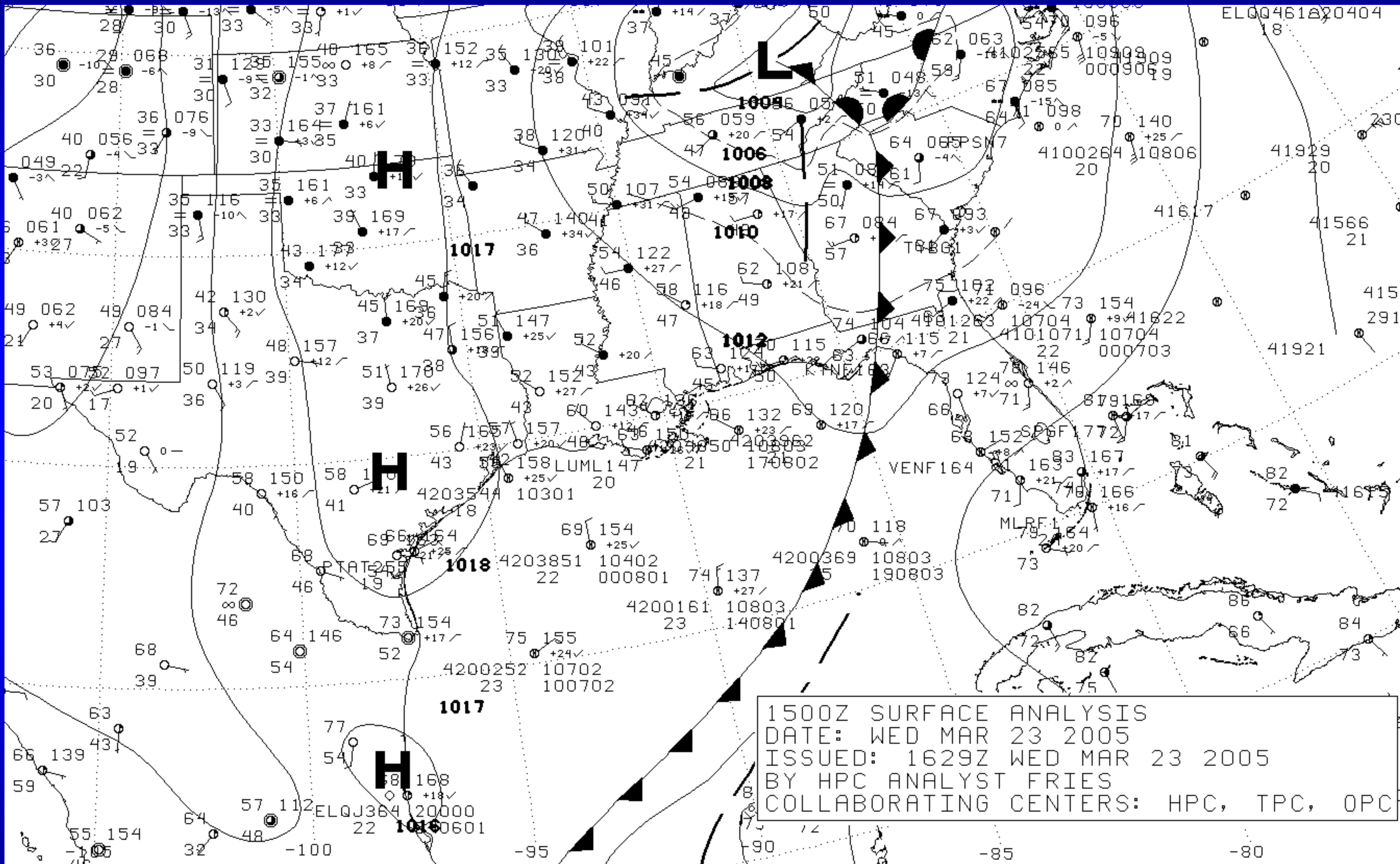
CSI-3
PAL
Percentage Occurrence Fog
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
11/01
01/02
03/02
05/02
07/02
09/02
11/02
01/03
03/03
05/03
07/03
09/03
11/03
01/04
03/04
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
11/05
01/06
03/06
05/06
07/06
09/06

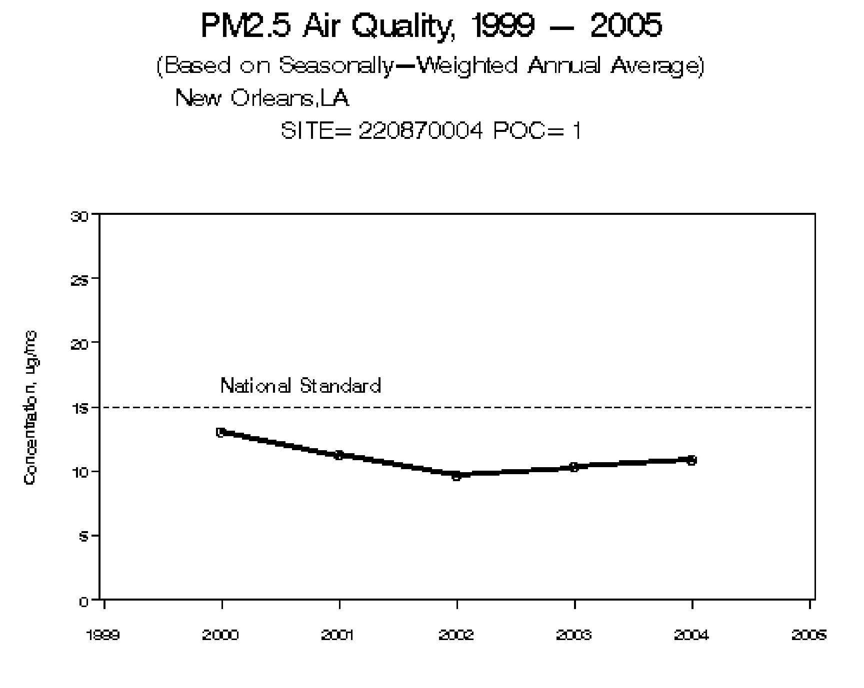

Data Source: NOAA LCD
Through October 2006
LCH
MSY
Total Number of Haze Days per Year
Year
0
10
20
30
40
50
60
70
80
90
100
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

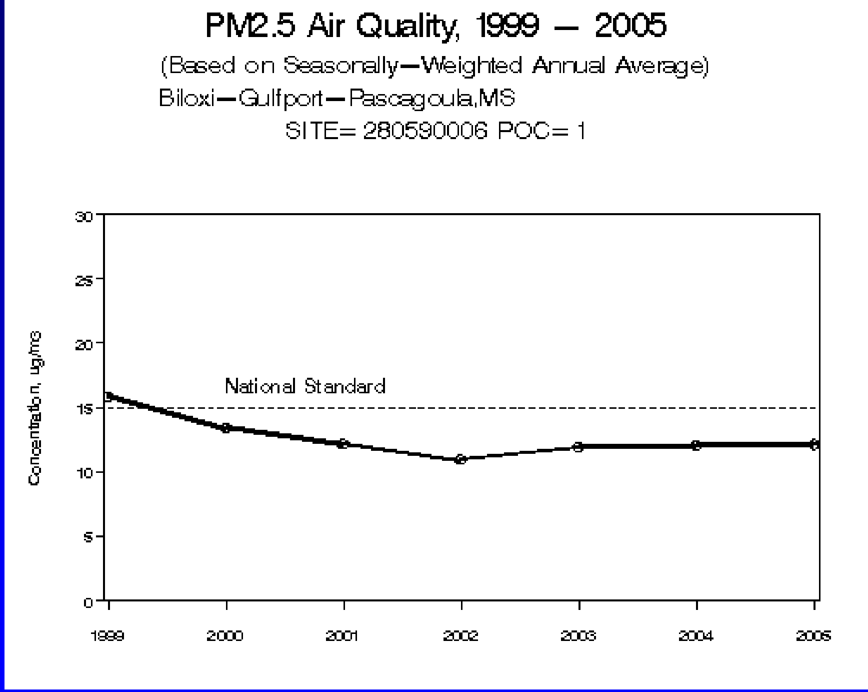

March 23, 2005
WD
WS
VIS
Wind Direction
Wind Speed m/s
Visibility miles
Dew Point Depression °F
Hour GMT

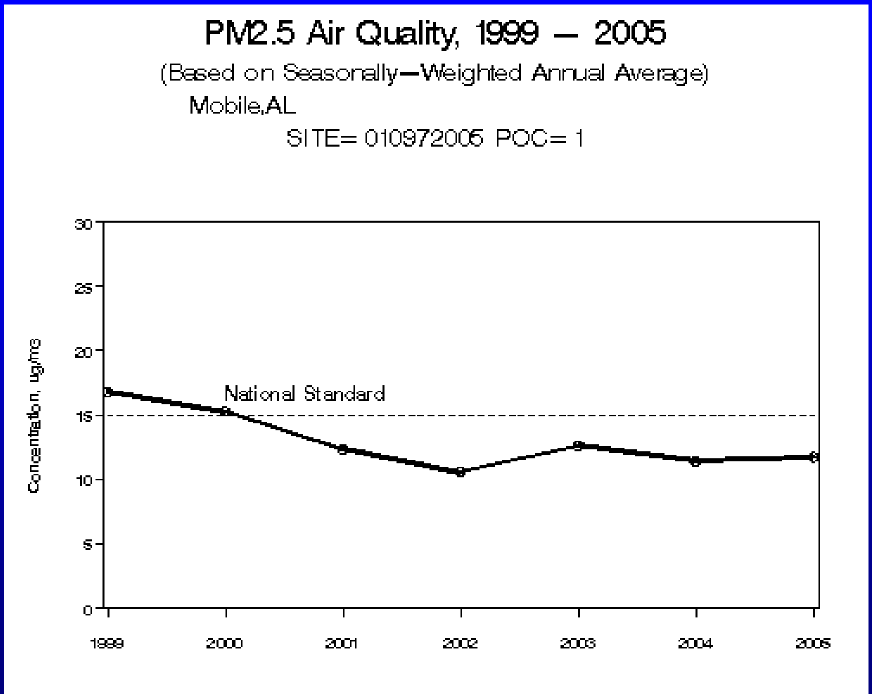

S032305.12Z // NWS Slidell
L032305.12Z // NWS Lake Charles
mb
500
600
700
800
850
900
925
1000
1050
-30
-20
-10
0
10
20
30 °C
KM
FT (x1000)
MSL
KNOTS

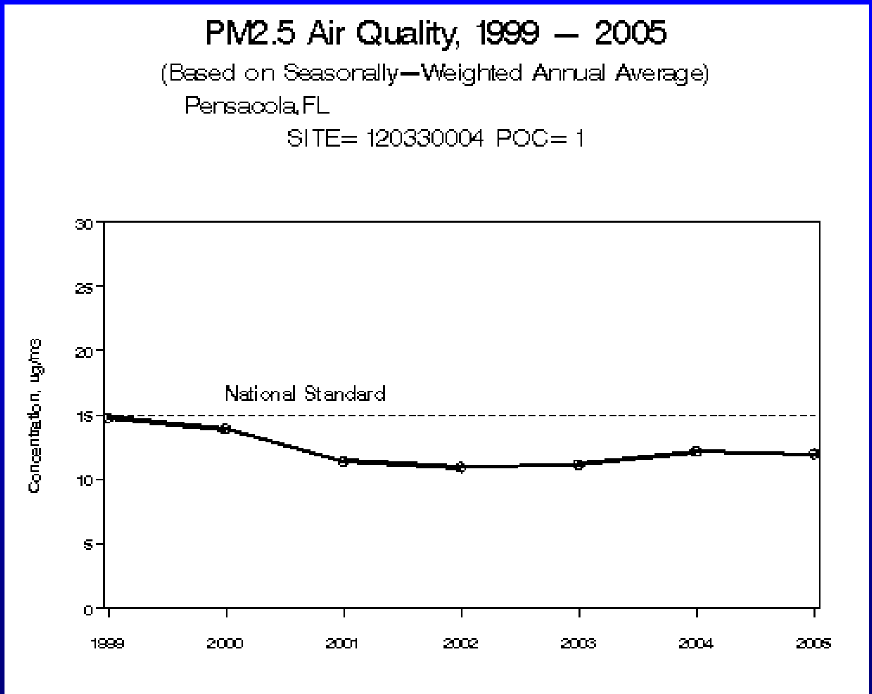

S032405.00Z // NWS Slidell
L032405.00Z // NWS Lake Charles
mb
500
600
700
800
850
900
925
1000
1050
-30
-20
-10
0
10
20
30
40 °C
KM
FT (x1000)
MSL
KNOTS


1500Z SURFACE ANALYSIS
DATE: WED MAR 23 2005
ISSUED: 1629Z WED MAR 23 2005
BY HPC ANALYST FRIES
COLLABORATING CENTERS: HPC, TPC, OPC


PM2.5 Air Quality, 1999 – 2005
(Based on Seasonally–Weighted Annual Average)
New Orleans,LA
SITE= 220870004 POC= 1
National Standard
Concentration, ug/m3
0
5
10
15
20
25
30
1999
2000
2001
2002
2003
2004
2005


PM2.5 Air Quality, 1999 – 2005
(Based on Seasonally–Weighted Annual Average)
Biloxi–Gulfport–Pascagoula,MS
SITE= 280590006 POC= 1
National Standard
Concentration, ug/m3
0
5
10
15
20
25
30
1999
2000
2001
2002
2003
2004
2005


PM2.5 Air Quality, 1999 – 2005
(Based on Seasonally–Weighted Annual Average)
Mobile,AL
SITE= 010972005 POC= 1
National Standard
Concentration, ug/m3
0
5
10
15
20
25
30
1999
2000
2001
2002
2003
2004
2005


PM2.5 Air Quality, 1999 – 2005
(Based on Seasonally–Weighted Annual Average)
Pensacola,FL
SITE= 120330004 POC= 1
National Standard
Concentration, ug/m3
0
5
10
15
20
25
30
1999
2000
2001
2002
2003
2004
2005

Atmospheric Stability and Mixing Height

According to S.A. Hsu and B.W. Blanchard (2004. On the estimation of overwater buoyancy length from routine measurements. Environ. Fluid Mech. 4:443–449),

when $T_{sea} > T_{air}$

$$L = -\frac{\left(T_{air} + 273.2\right) U_z^2}{100\left(T_{sea} - T_{air}\right)\left(1 + \frac{0.07}{B}\right)} \qquad \textbf{(1)}$$

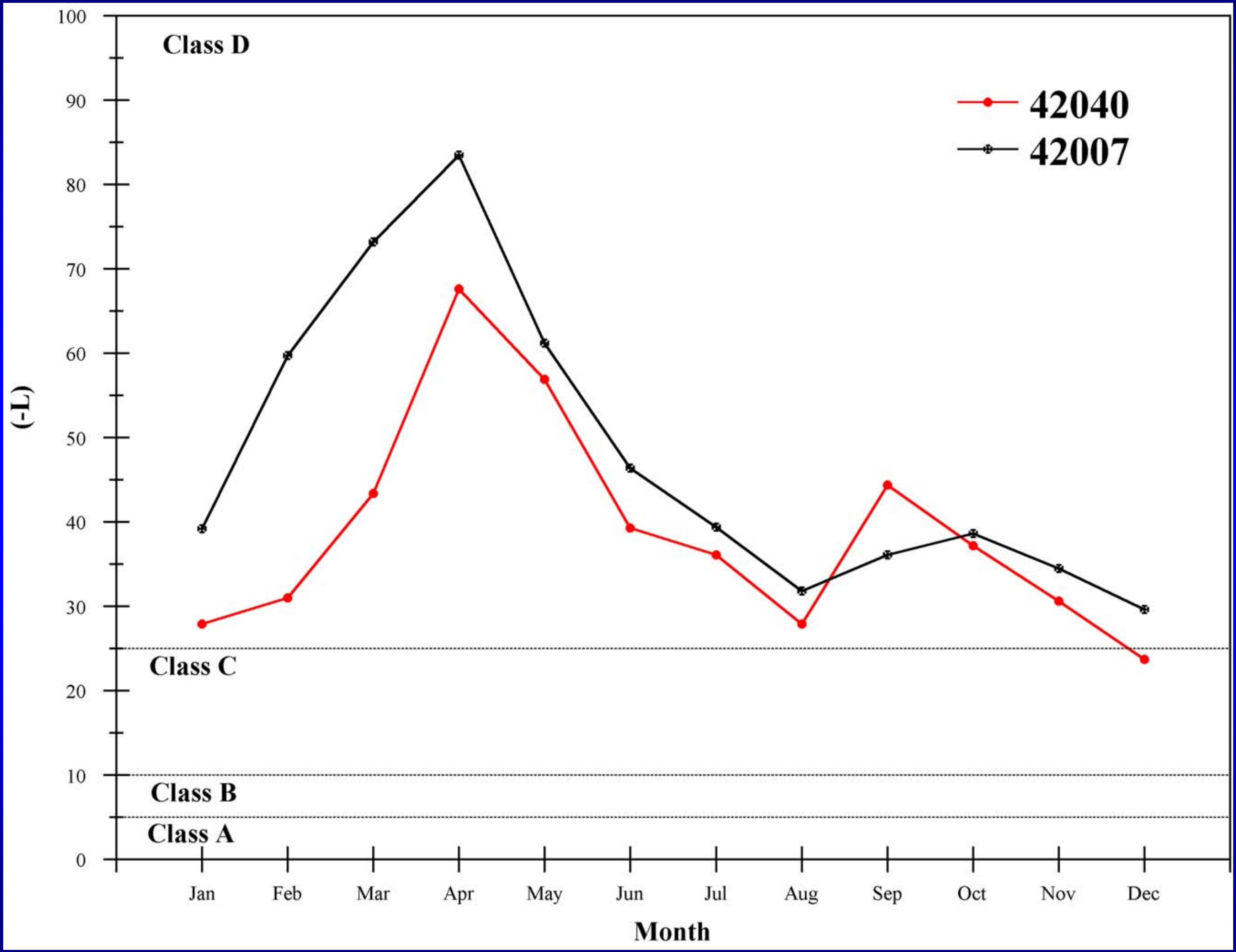
and when $T_{air} > T_{sea}$

$$L = \frac{\left(T_{air} + 273.2\right) U_z^2}{62\left(T_{air} - T_{sea}\right)} \qquad \textbf{(2)}$$

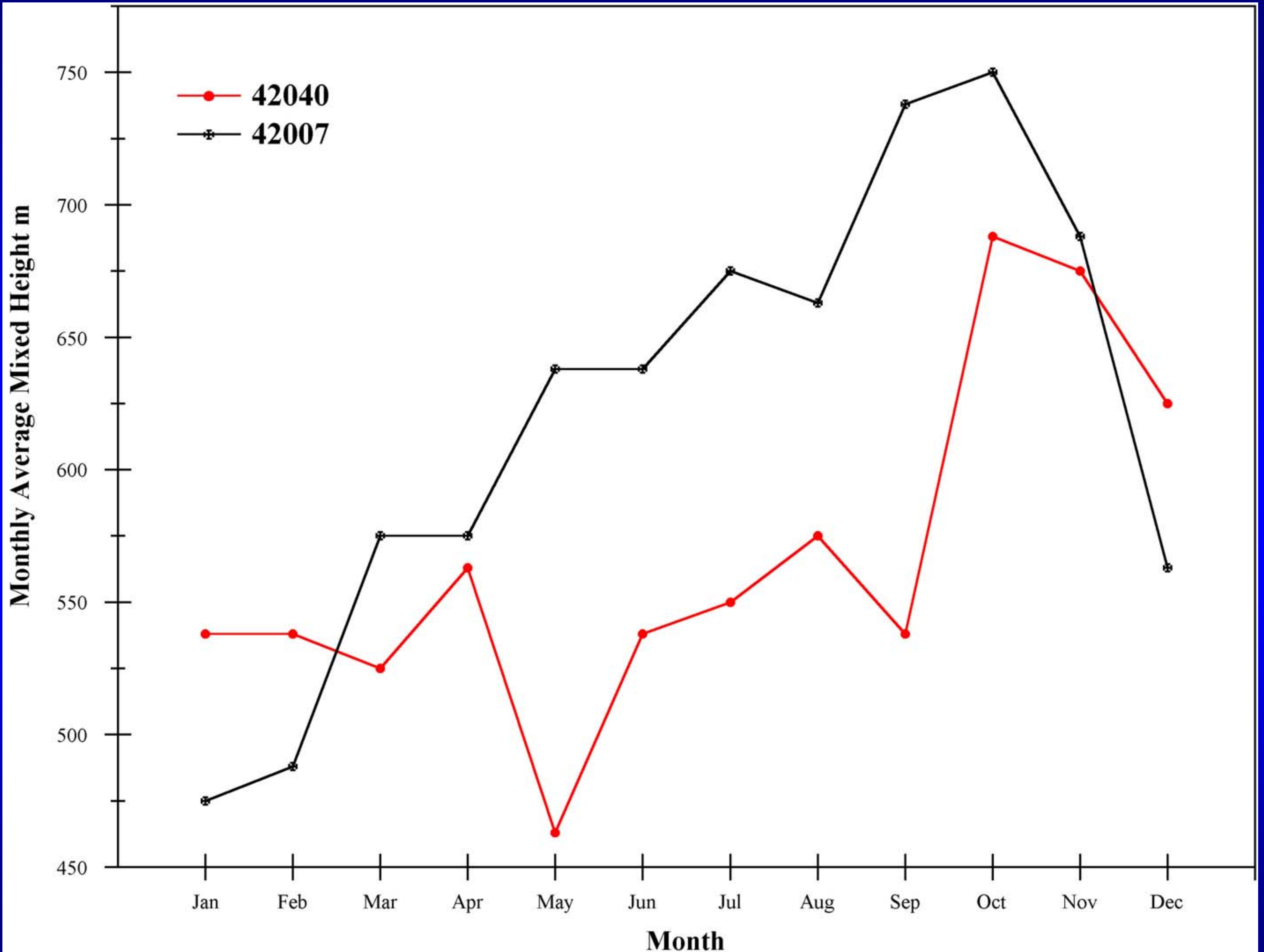
where

$$B = 0.146\left(T_{sea} - T_{air}\right)^{0.49} \qquad \textbf{(3)}$$

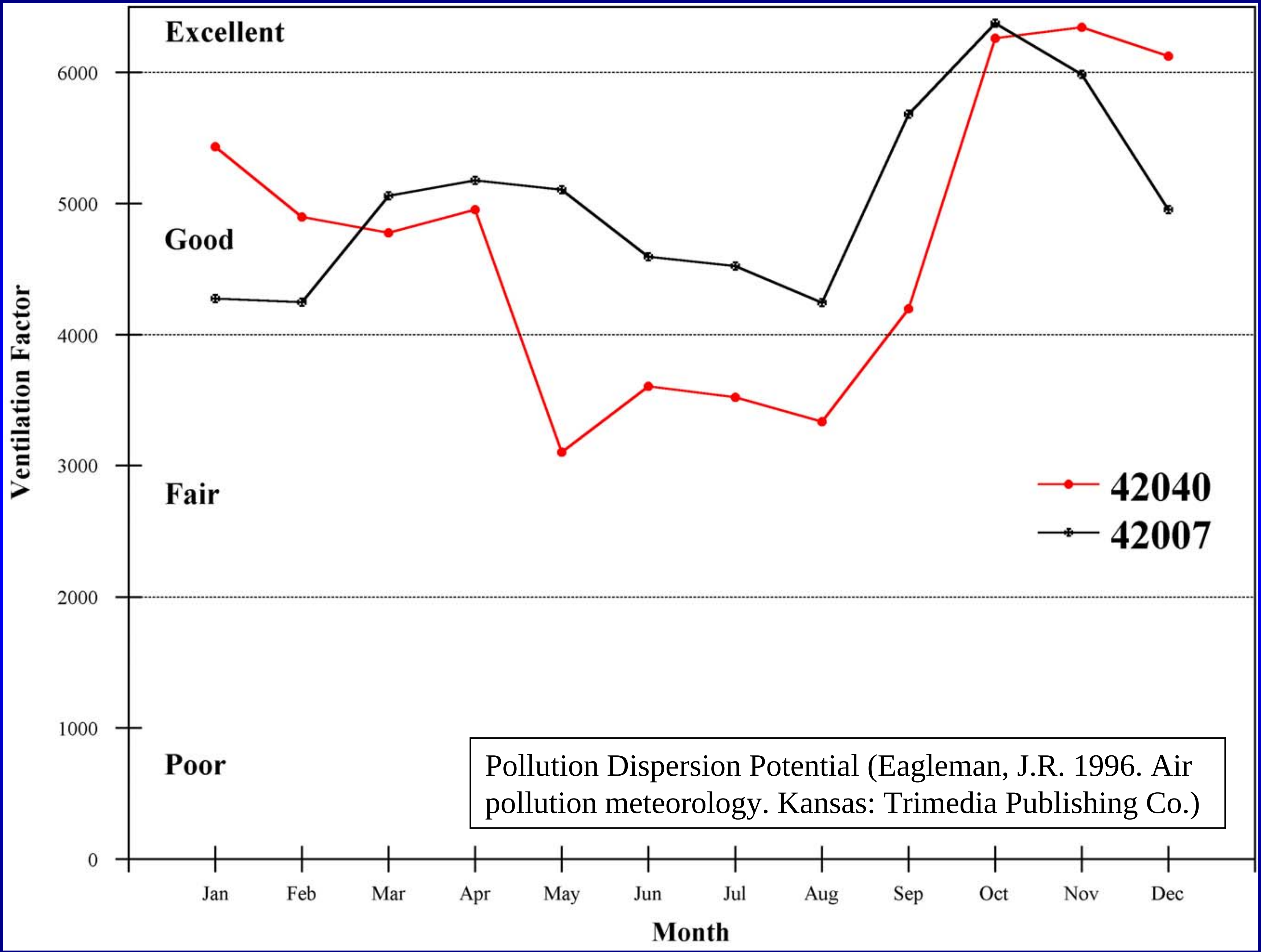
Based on S.A. Hsu (1999. On the estimation of over water Bowen ratio from sea-air temperature difference. Journal of Physical Oceanography 29:1372–1373).



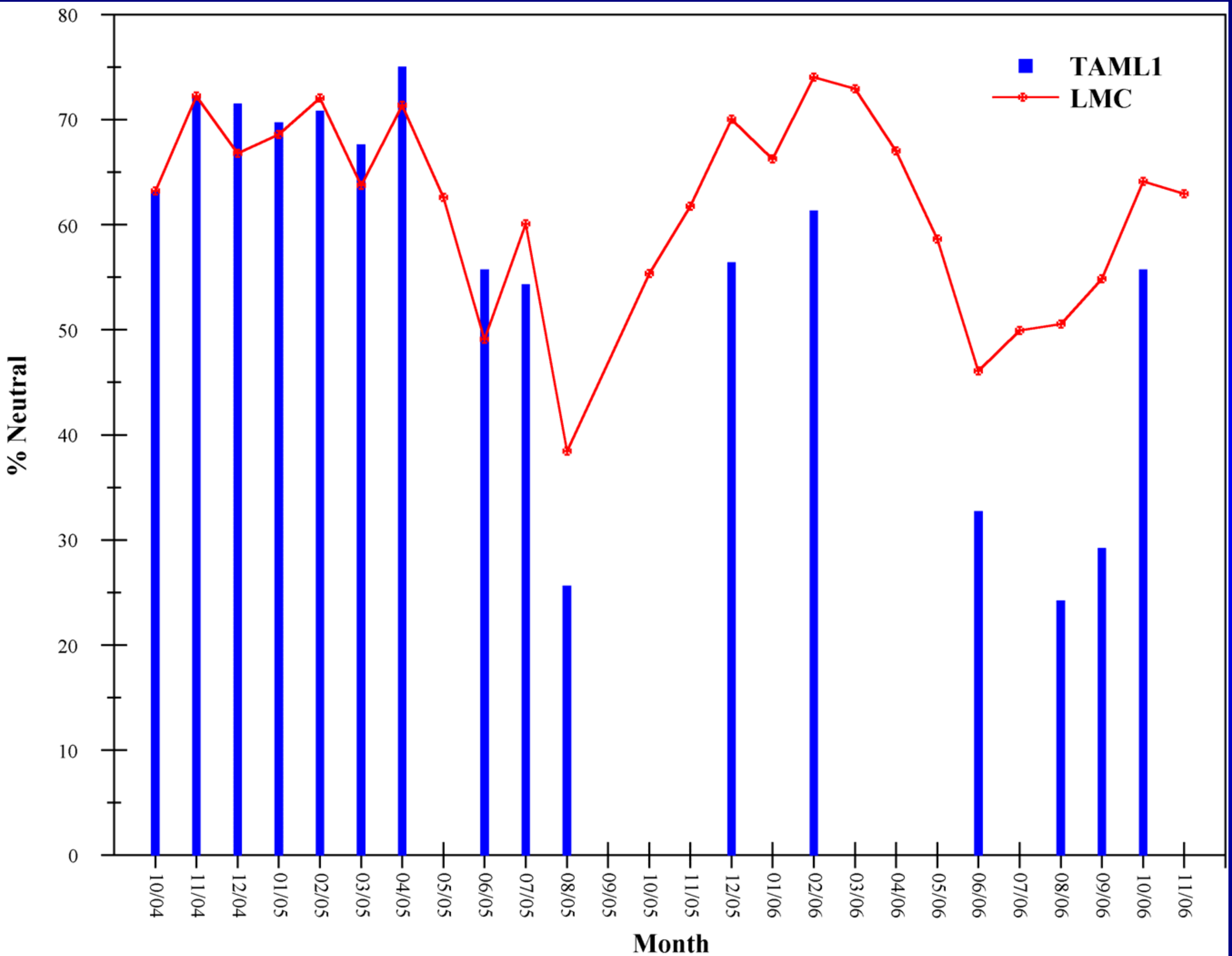
Class D
42040
42007
Class C
Class B
Class A
(-L)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



42040
42007
Monthly Average Mixed Height m
750
700
650
600
550
500
450
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



Pollution Dispersion Potential (Eagleman, J.R. 1996. Air pollution meteorology. Kansas: Trimedia Publishing Co.)



TAML1
LMC
% Neutral
Month
0
10
20
30
40
50
60
70
80
10/04
11/04
12/04
01/05
02/05
03/05
04/05
05/05
06/05
07/05
08/05
09/05
10/05
11/05
12/05
01/06
02/06
03/06
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05/06
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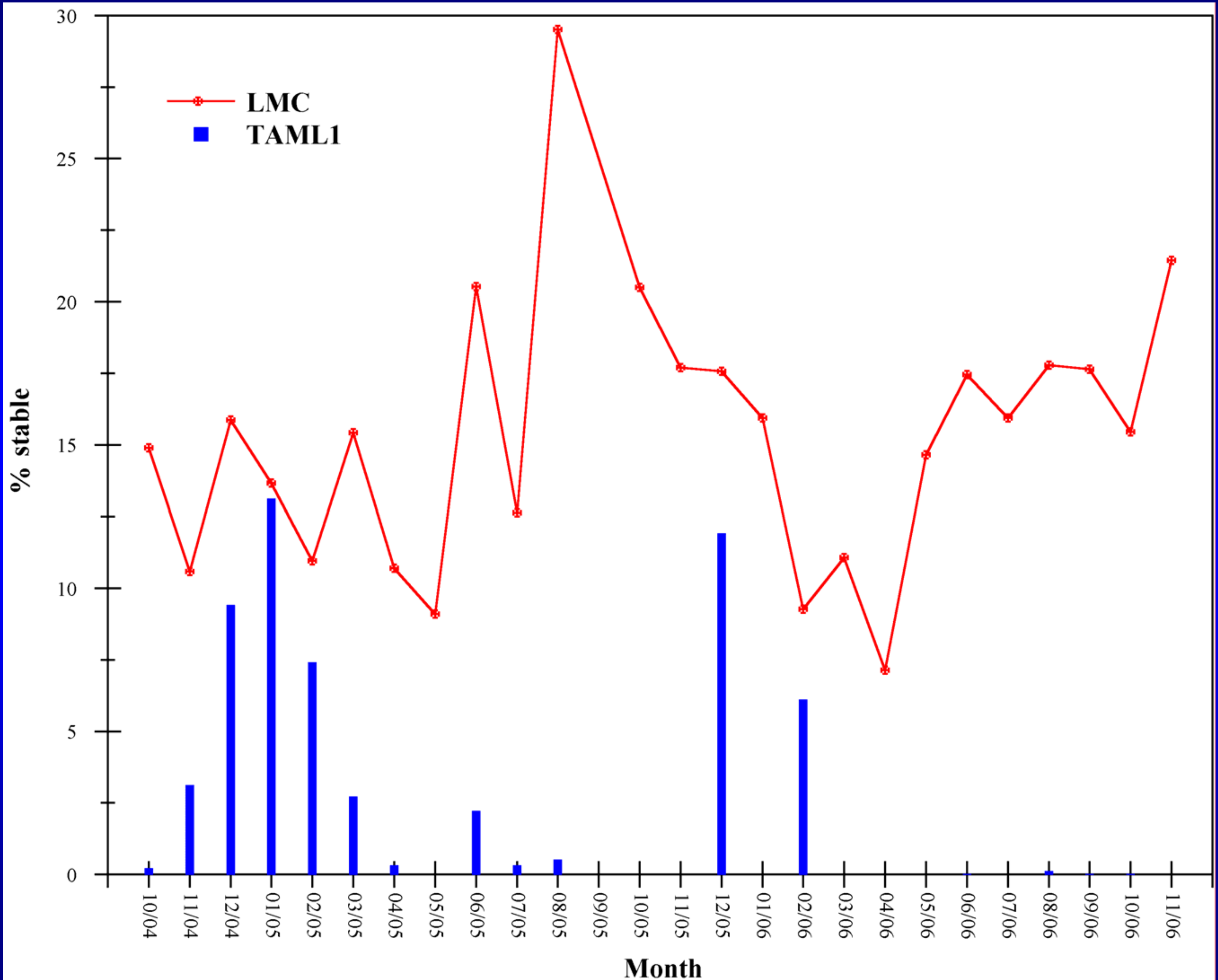
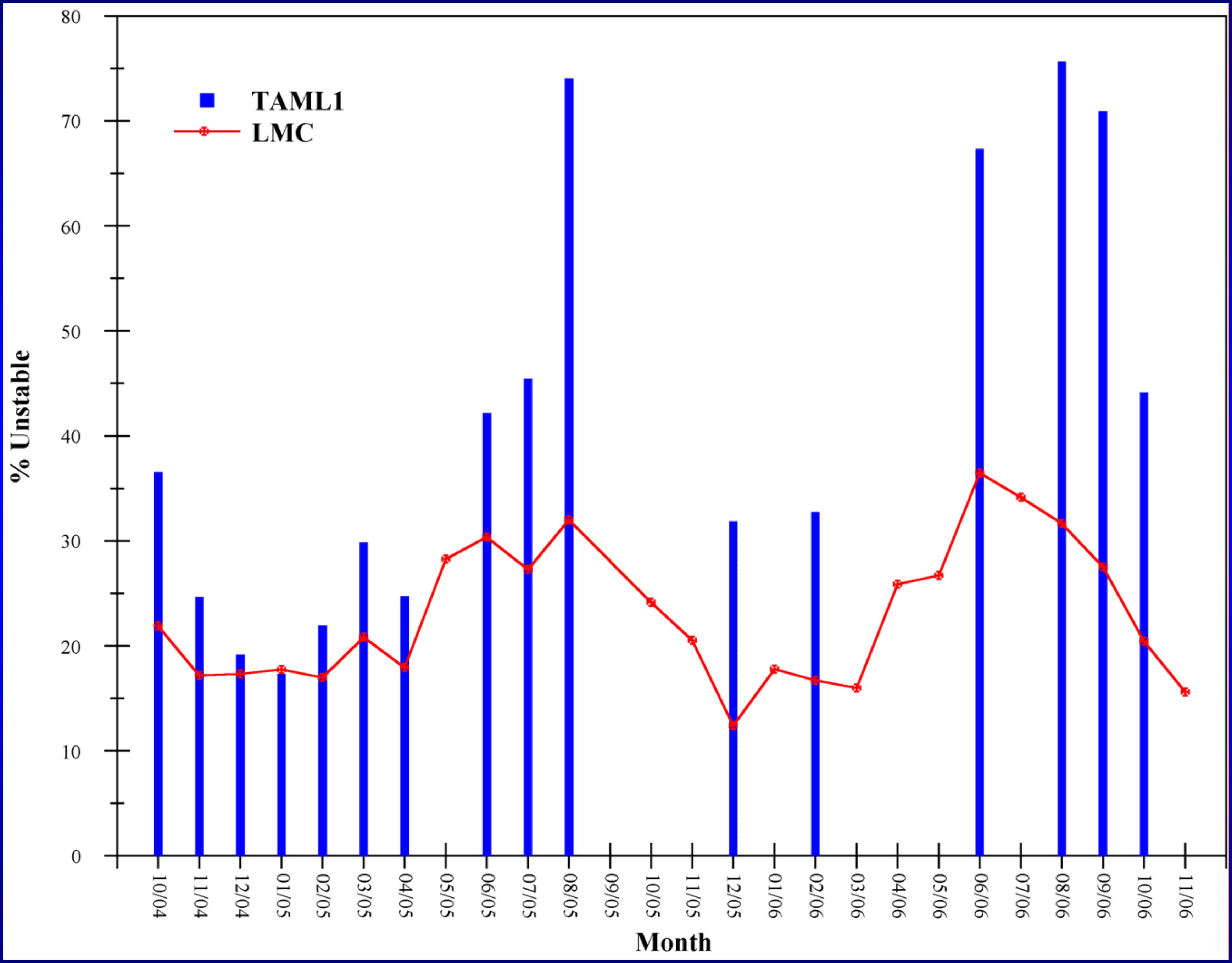
08/06
09/06
10/06
11/06



LMC
TAML1
% stable
30
25
20
15
10
5
0
10/04
11/04
12/04
01/05
02/05
03/05
04/05
05/05
06/05
07/05
08/05
09/05
10/05
11/05
12/05
01/06
02/06
03/06
04/06
05/06
06/06
07/06
08/06
09/06
10/06
11/06
Month



TAML1
LMC
% Unstable
0
10
20
30
40
50
60
70
80
10/04
11/04
12/04
01/05
02/05
03/05
04/05
05/05
06/05
07/05
08/05
09/05
10/05
11/05
12/05
01/06
02/06
03/06
04/06
05/06
06/06
07/06
08/06
09/06
10/06
11/06
Month

Estimating Overwater Mixing Height

Near-Neutral Conditions
When $|L| > 25$ m or $U_z > 6$m/s or overcast.

From atmospheric dynamics (e.g., Ayra, S.P. 1999. Air pollution meteorology and dispersion. Oxford: Oxford University Press),

$$Z_i = 0.3 \frac{u_*}{f} \qquad \textbf{(1)}$$

Where Z_i is the mixing height, u_* the friction velocity, and f the Coriolis parameter.

According to S.A. Hsu and B.W. Blanchard (2004. J. Applied Met. 43(1911–1916),

$$u_* = 0.2\left(U_{gust} - U_z\right) \qquad \textbf{(2)}$$

From atmospheric thermodynamics (e.g., Hsu, S.A. 1998. J. Physical Oceanog. 28(2222–2226),

$$Z_i = 125\left(T_{air} - T_{dew}\right) \qquad \textbf{(3)}$$

Where T_{air} and T_{dew} (both in degree Celsius) are air and dewpoint temperatures, respectively.

Note: Use the lower value of Eq. (1) or (3) for Z_i.

Unstable Conditions

When $T_{sea} > T_{air}$, -25 m ≤ L < -10 m (Class C)
or -10 m ≤ L < -5 m (Class B).

According to S.A. Hsu and B.W. Blanchard
(2004. J. Applied Met. 43:1911–1916),

$$G = 0.825 + 0.371\left(1 + 3\left|\frac{z}{L}\right|\right)^{1/3} \qquad \textbf{(4)}$$

where G (= U_{gust} / U_z) is the gust factor.

From Hsu (2006. AMS Annual Meeting,
JP2.4. In: 14th Symposium on Met.
Obs. and Instrumentation),

$$\frac{Z_i}{|L|} = \left[2.9 + \frac{288}{|L|}\right]^{3/2} \qquad \textbf{(5)}$$

Stable Conditions

When $T_{air} > T_{sea}$, $10\ m < L \leq 25\ m$ (Class E) or $5\ m < L \leq 10\ m$ (Class F).

According to A.Venkatram (1980. Estimating the Monin-Obukhov length in the stable boundary layer for dispersion calculations. Boundary Layer Meteorology 19:481–485),

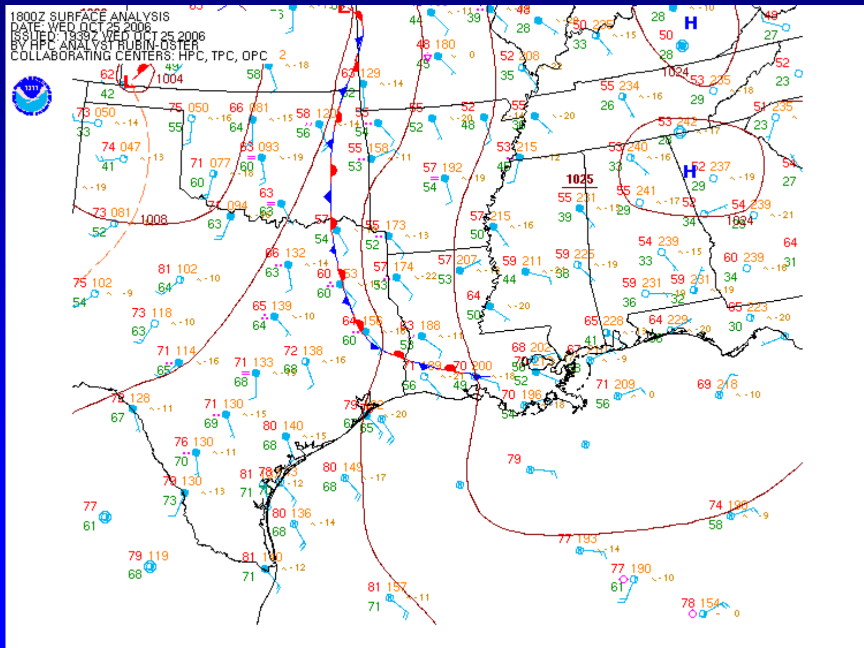
$$Z_i = 2.4 * 10^3 u_*^{3/2} \quad \textbf{(6)}$$

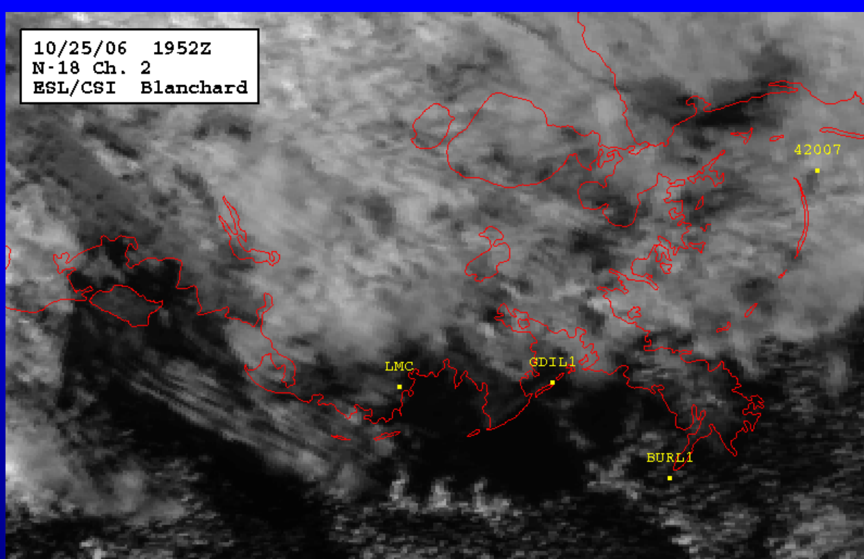
where u_* may be estimated from Eq. (2).

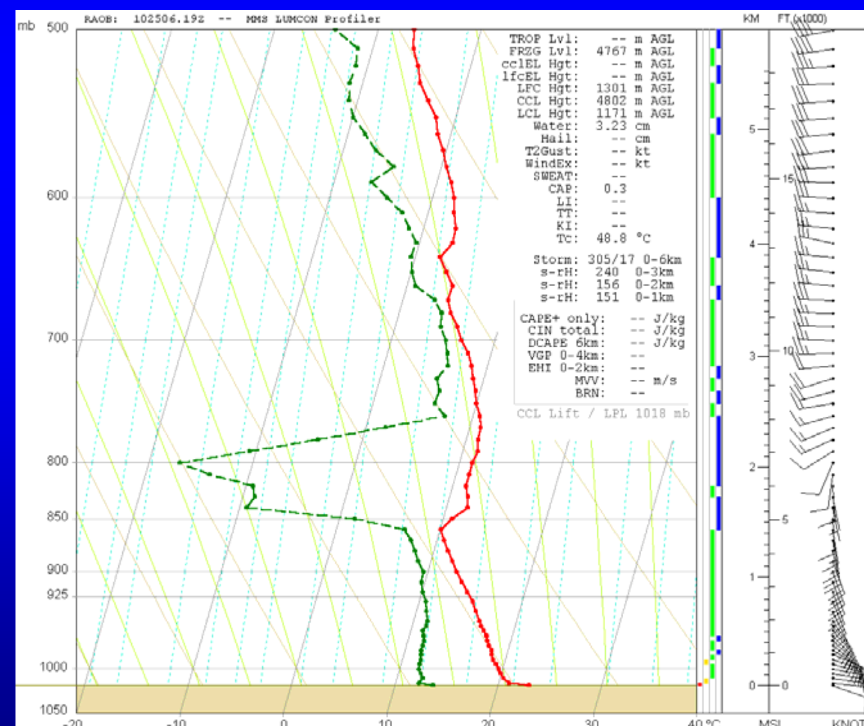
Rawinsonde and LUMCON Profiler Comparison

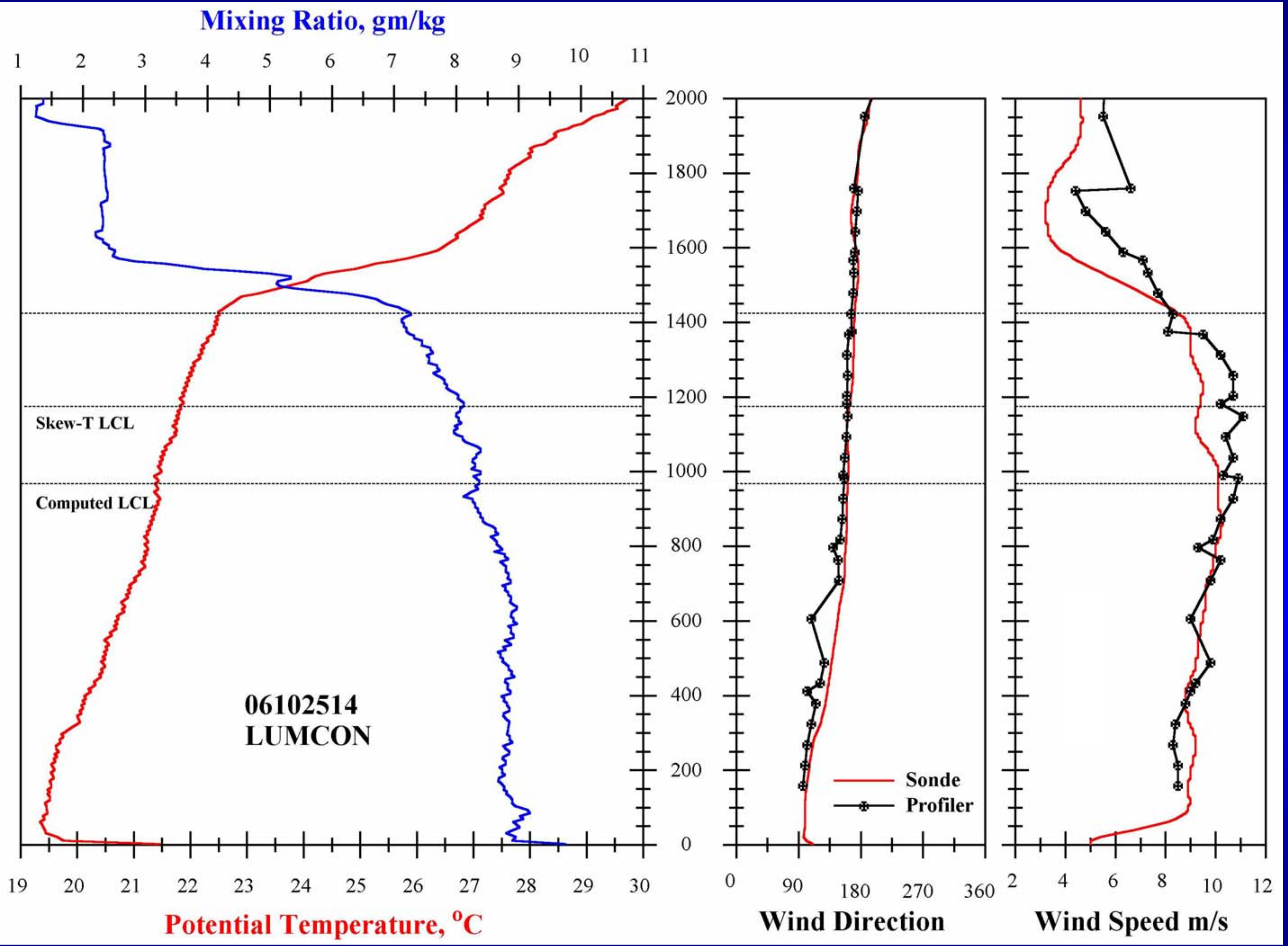
25 October 2006

1407 CDT (1907 GMT)

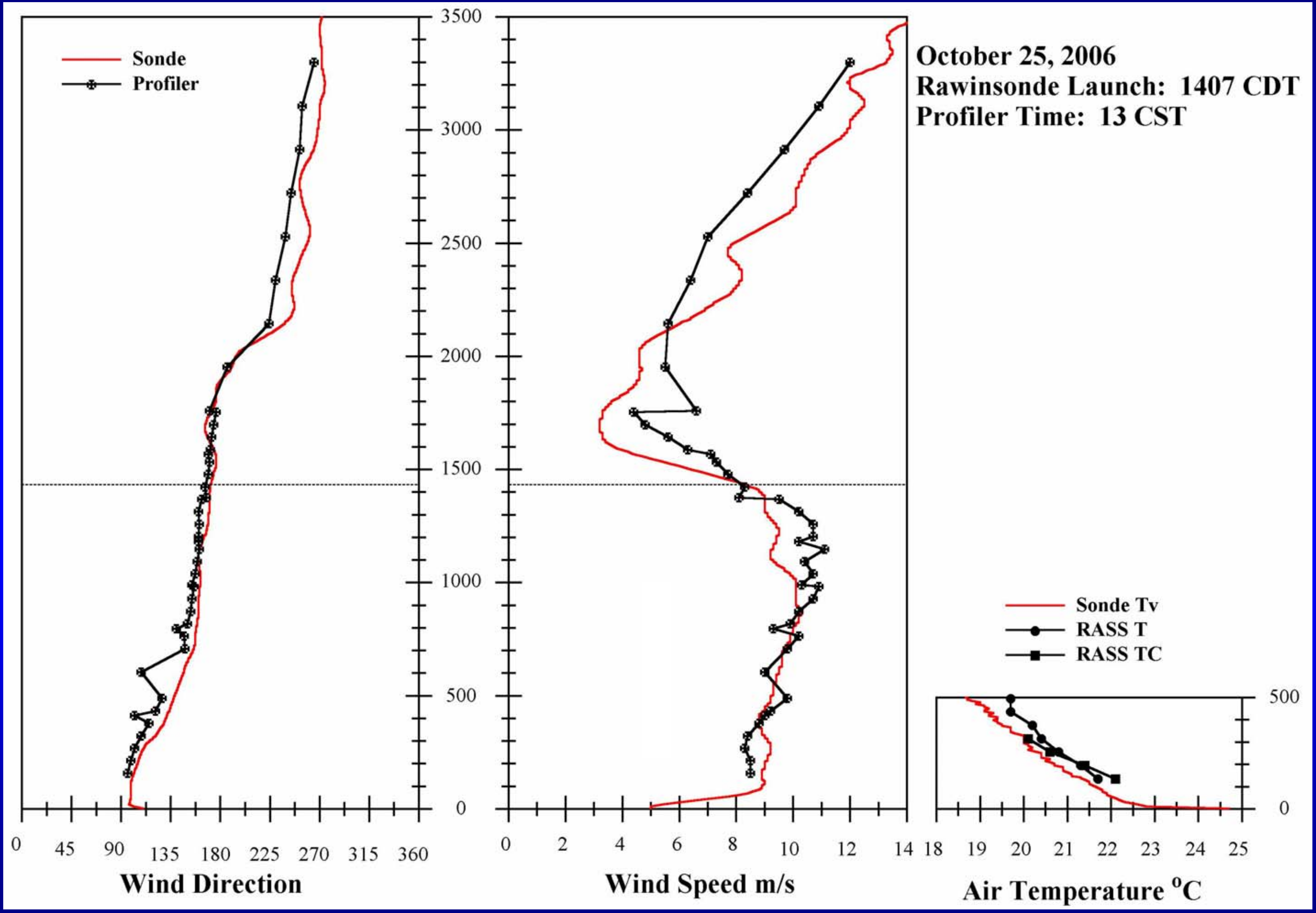




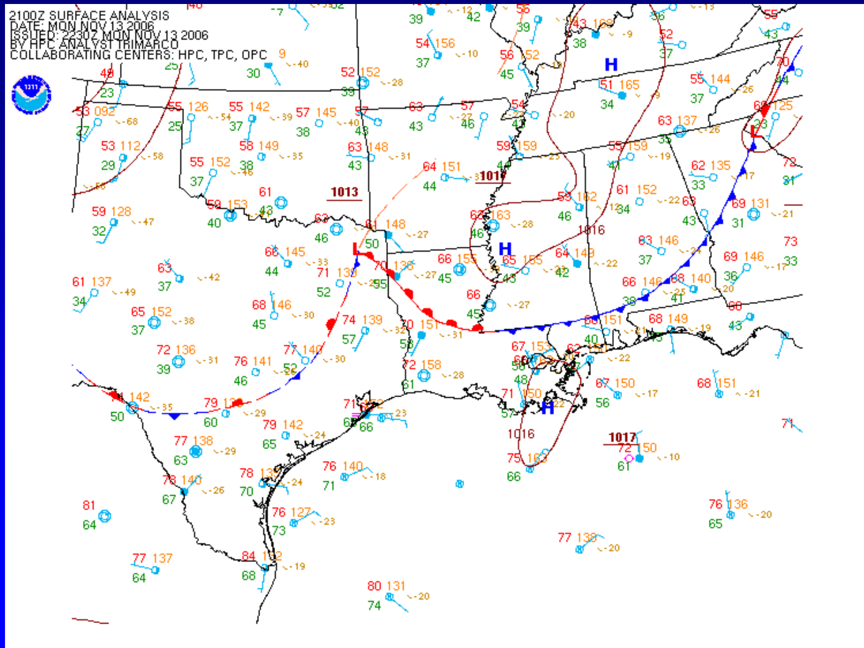




Mixing Ratio, gm/kg
1 2 3 4 5 6 7 8 9 10 11
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Skew-T LCL
Computed LCL
06102514
LUMCON
19 20 21 22 23 24 25 26 27 28 29 30
Potential Temperature, °C
Sonde
Profiler
0 90 180 270 360
Wind Direction
2 4 6 8 10 12
Wind Speed m/s

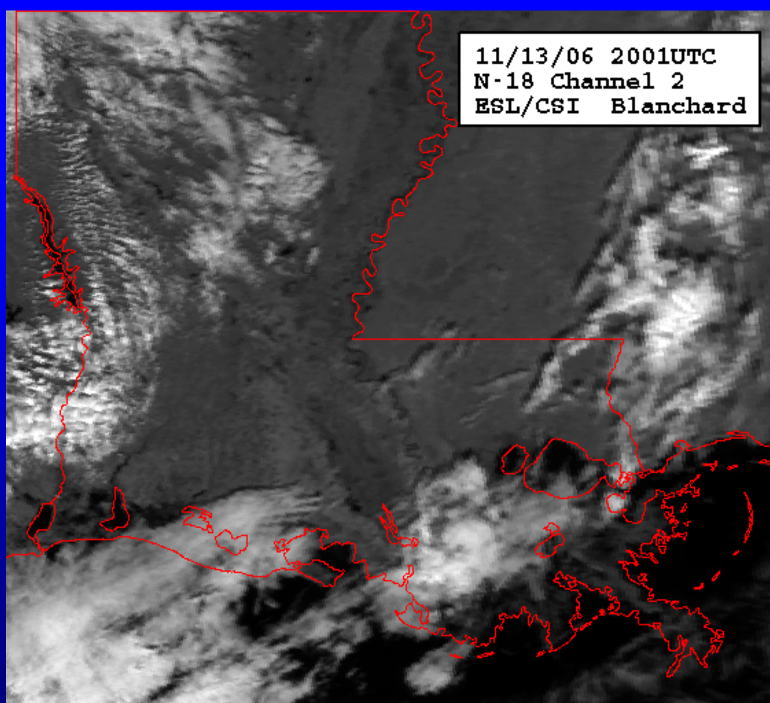


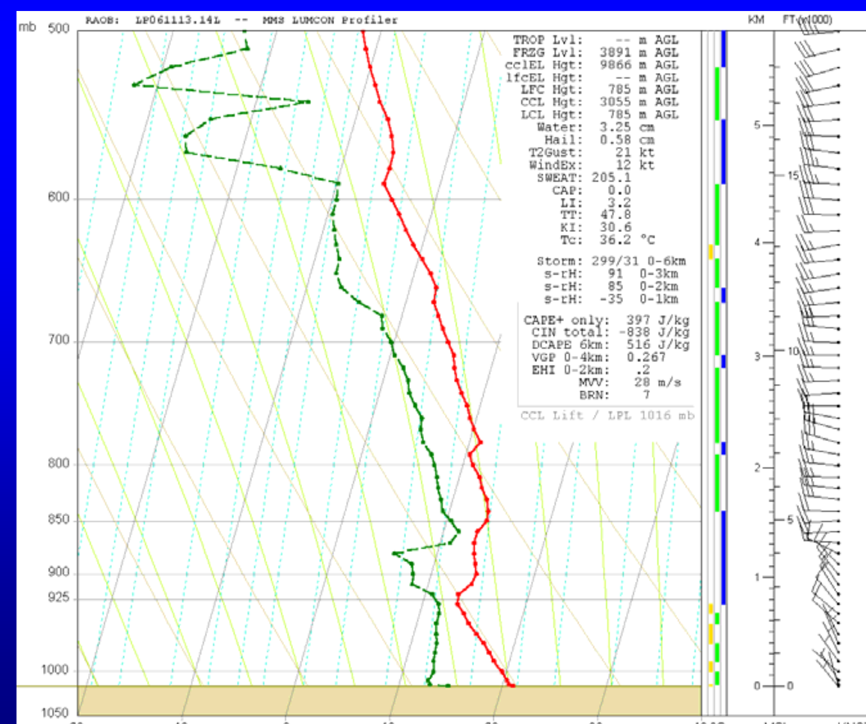
October 25, 2006
Rawinsonde Launch: 1407 CDT
Profiler Time: 13 CST
Sonde
Profiler
Sonde Tv
RASS T
RASS TC
0
500
1000
1500
2000
2500
3000
3500
0 45 90 135 180 225 270 315 360
Wind Direction
0 2 4 6 8 10 12 14
Wind Speed m/s
18 19 20 21 22 23 24 25
Air Temperature °C

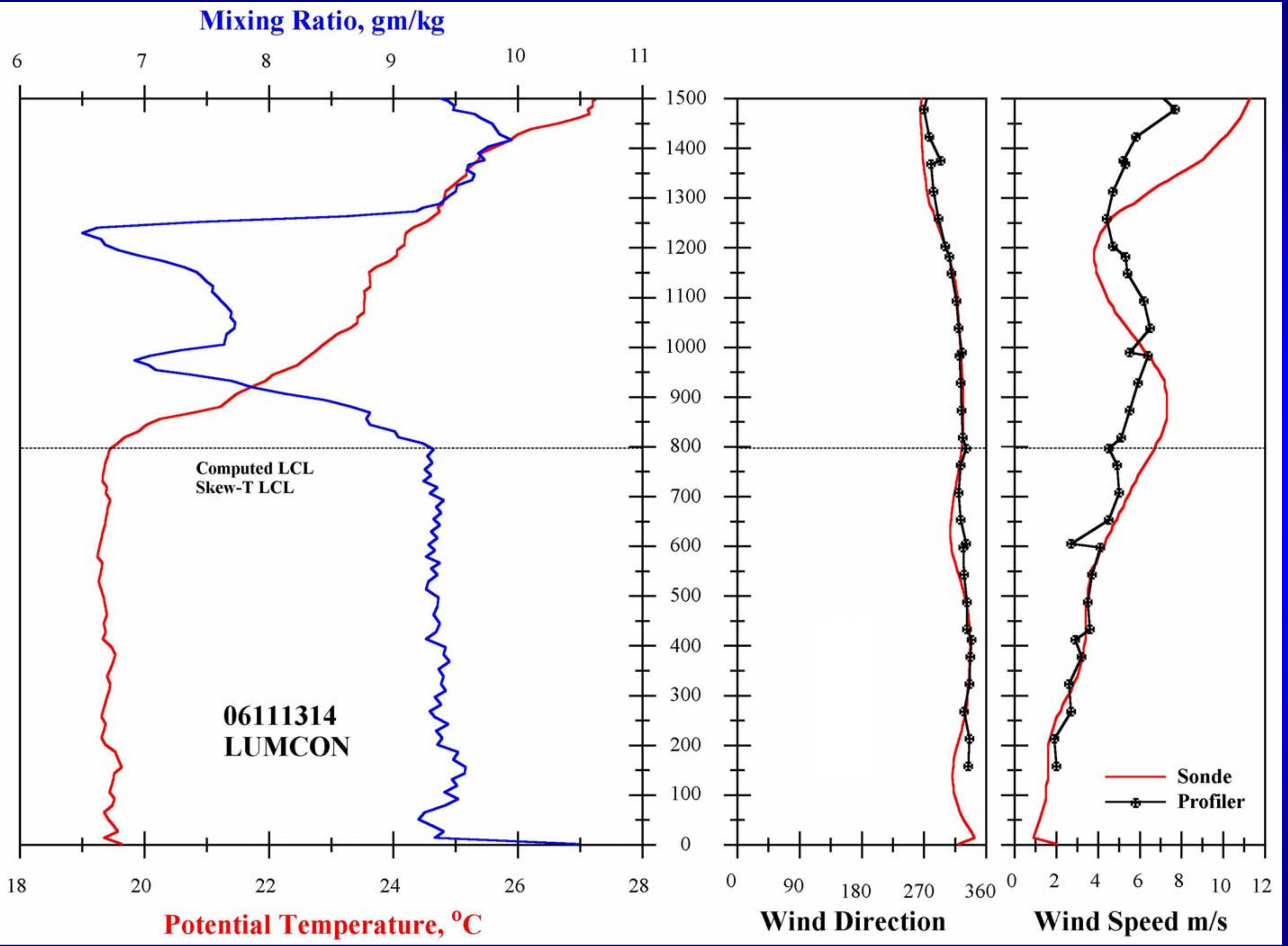


13 November 2006

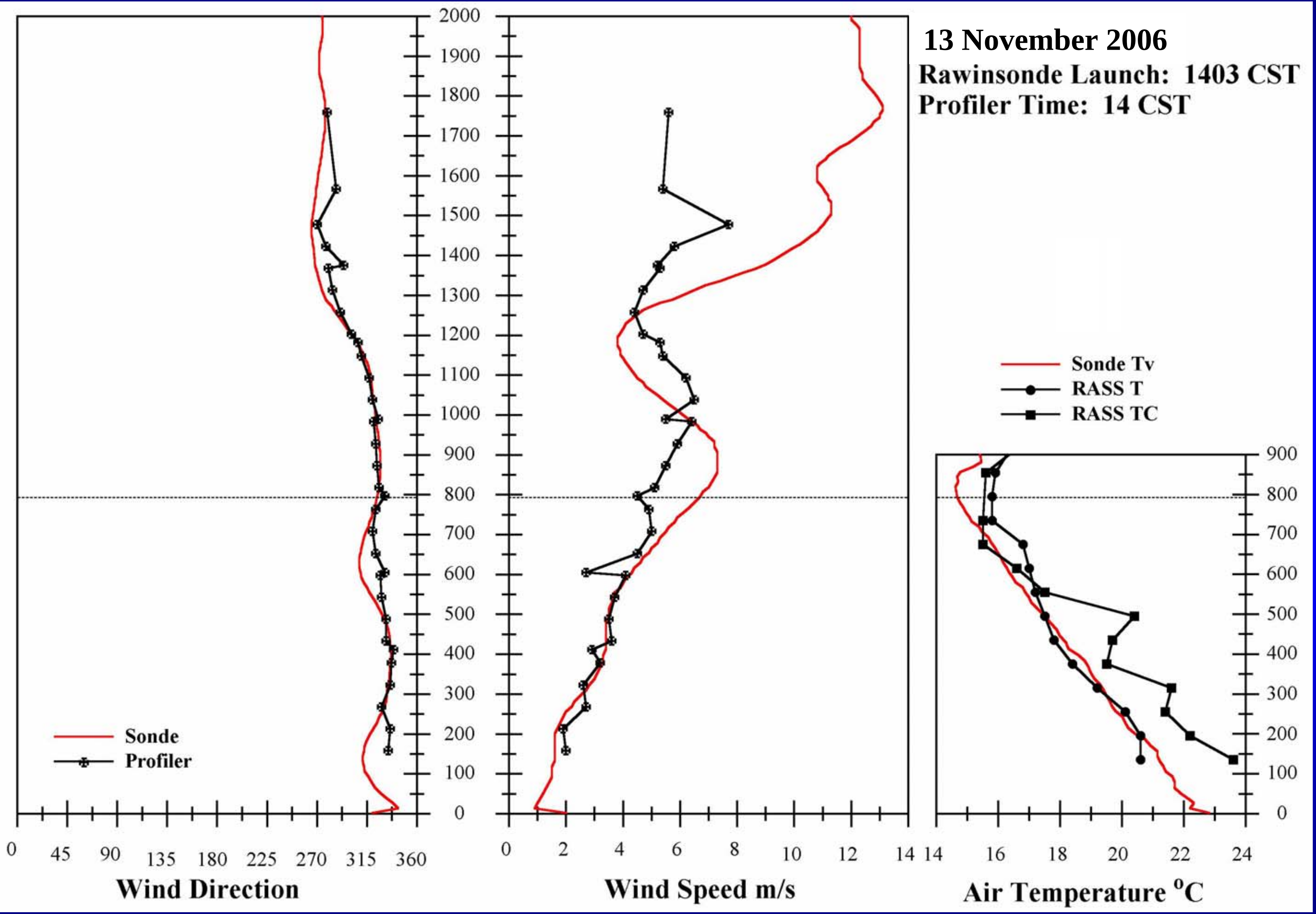
1403 CST (2003 GMT)







Mixing Ratio, gm/kg
6
7
8
9
10
11
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Computed LCL
Skew-T LCL
06111314
LUMCON
18
20
22
24
26
28
Potential Temperature, °C
0
90
180
270
360
Wind Direction
0
2
4
6
8
10
12
Wind Speed m/s
Sonde
Profiler


13 November 2006
Rawinsonde Launch: 1403 CST
Profiler Time: 14 CST
Sonde
Profiler
Wind Direction
Wind Speed m/s
Sonde Tv
RASS T
RASS TC
Air Temperature °C
0
45
90
135
180
225
270
315
360
2
4
6
8
10
12
14
16
18
20
22
24
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

Summary

- **Meteorological and visibility stations at CSI-3, CSI-6, PAL, and LUMCON are currently operational.**
- **Unrestricted visibility (> 6–7 miles) prevails over the northern Gulf of Mexico and adjacent coastal zone. The winter month of December through March do experience lower average visibility, but this is due to regional fog.**
- **Haze can occur in any month, but is typically of short duration (several hours) and has less impact on visibility than fog. Haze is often associated with high pressure and light winds (no wave breaking).**
- **Particulate matter annual averages along the Gulf coast continue to decline below the national standard.**
- **Monthly average stability over the Gulf of Mexico east of BNWA is neutral, and the ventilation factor is fair to excellent, indicating good pollution dispersion potential.**
- **Stability in the coastal area is also mostly neutral; the land experiences more stable conditions that the shallow water bays.**
- **Formulas for estimating overwater mixing height under all stability categories are provided.**
- **Initial comparisons between the LUMCON profiler and standard raw insonde profiles show excellent agreement in wind and temperature data.**