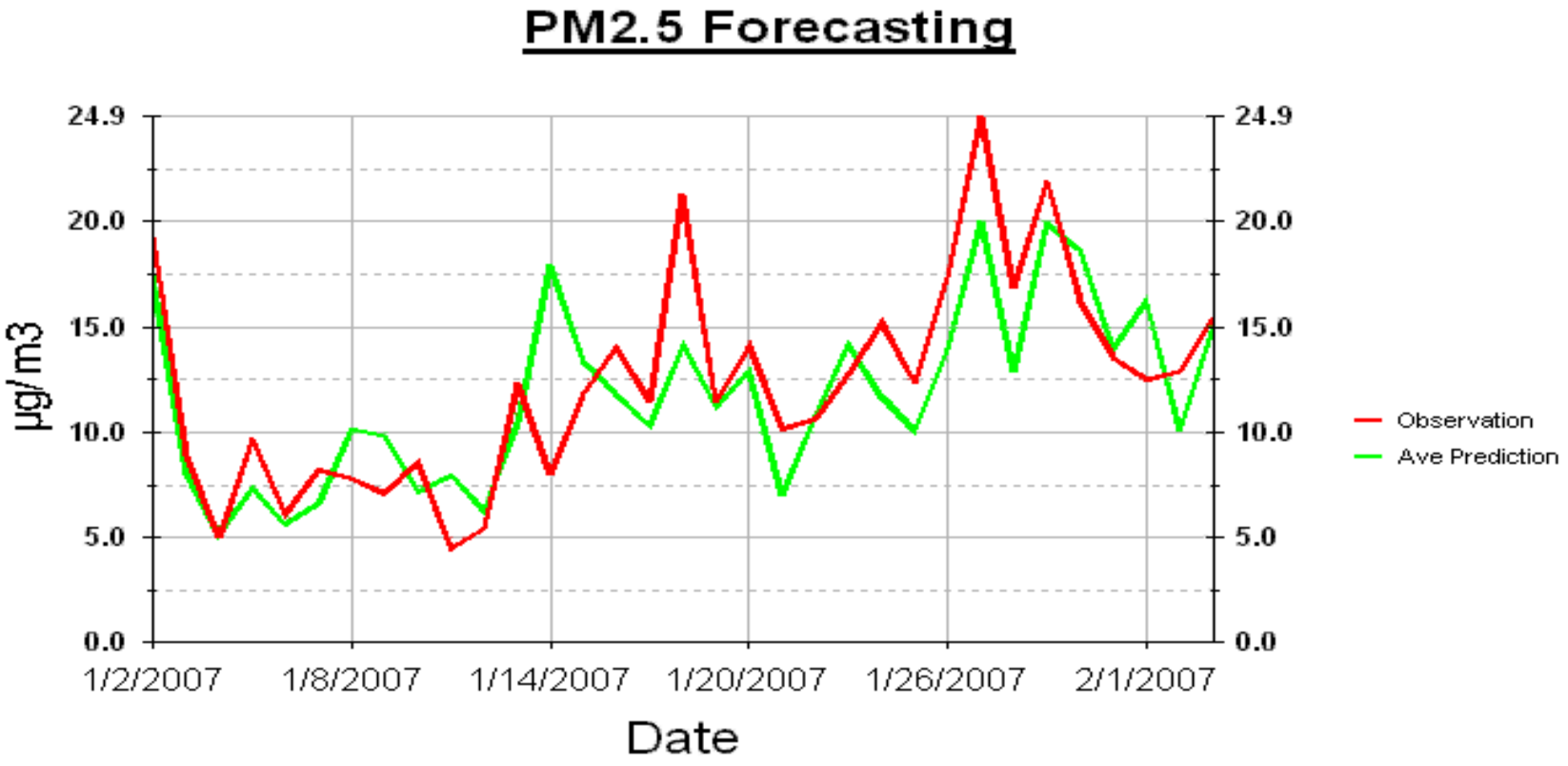
Deep Stable Layer and Application

Yayi Dong, Rick Hardy, Wei Zhang
Idaho Department of Environmental Quality
Michael McGown, EPA

NW-AIRQUEST 2014 Annual Meeting
June 18-20, 2014
Boise, Idaho

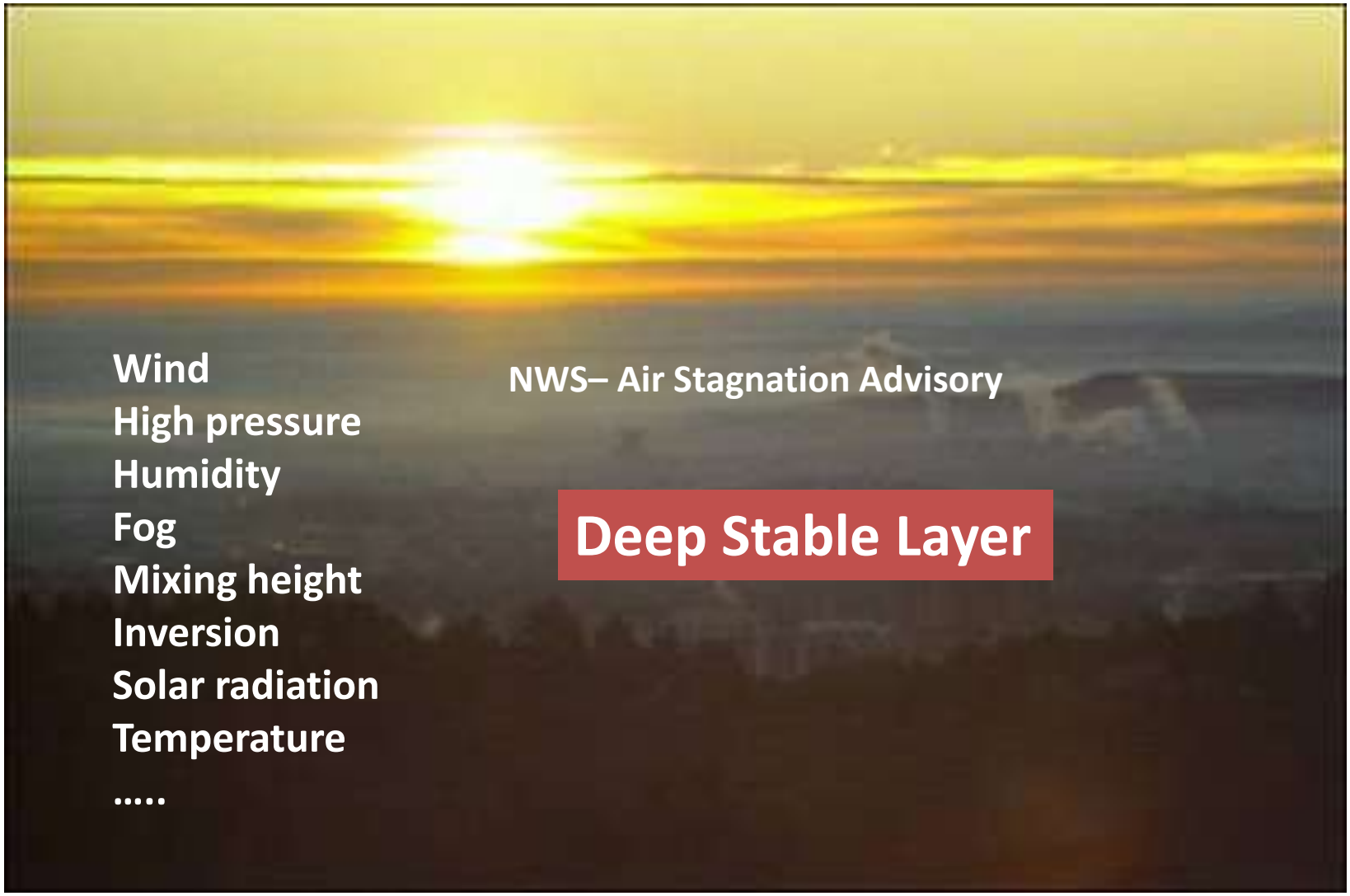


Deep Stable Layer

1. Why DSL
2. How it is defined
3. Observations
4. Applications

Winter Inversion in Valleys

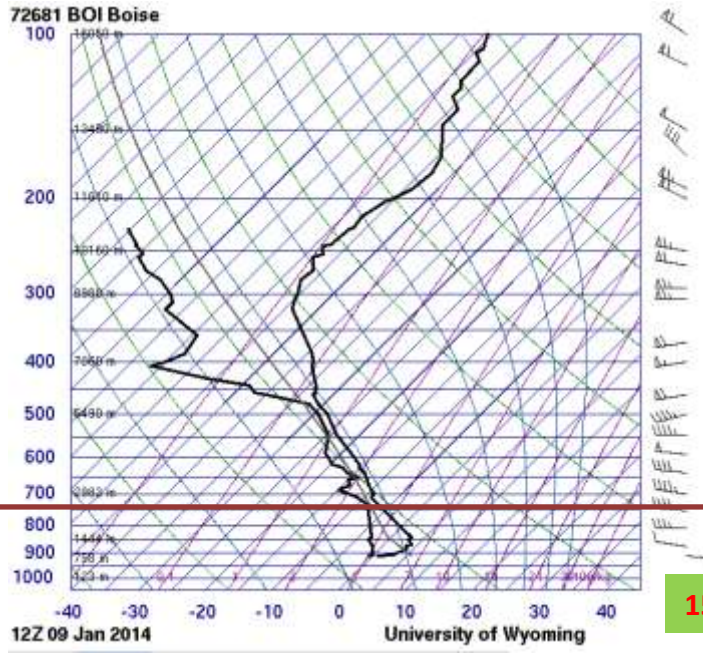
Air Quality Problems Today?

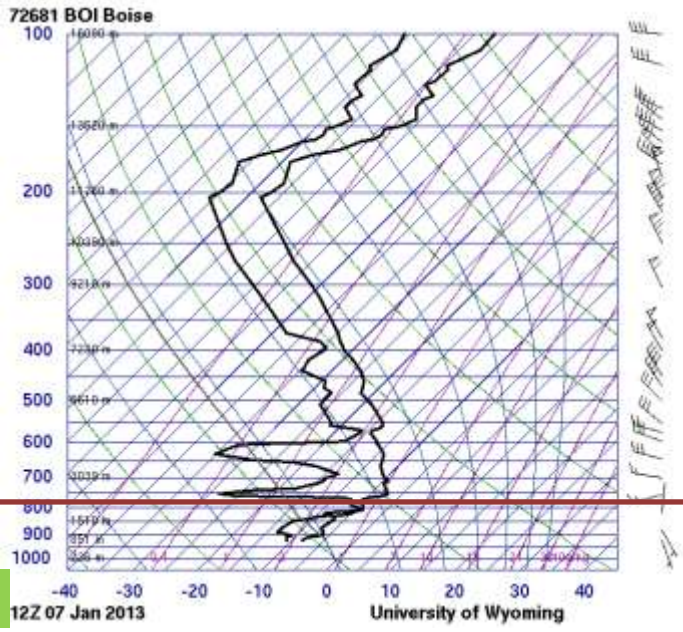


Deep Stable Layer

Deep Stable Layers in the Intermountain Western United States
Paul G. Wolyn and Thomas B. McKee, 1988

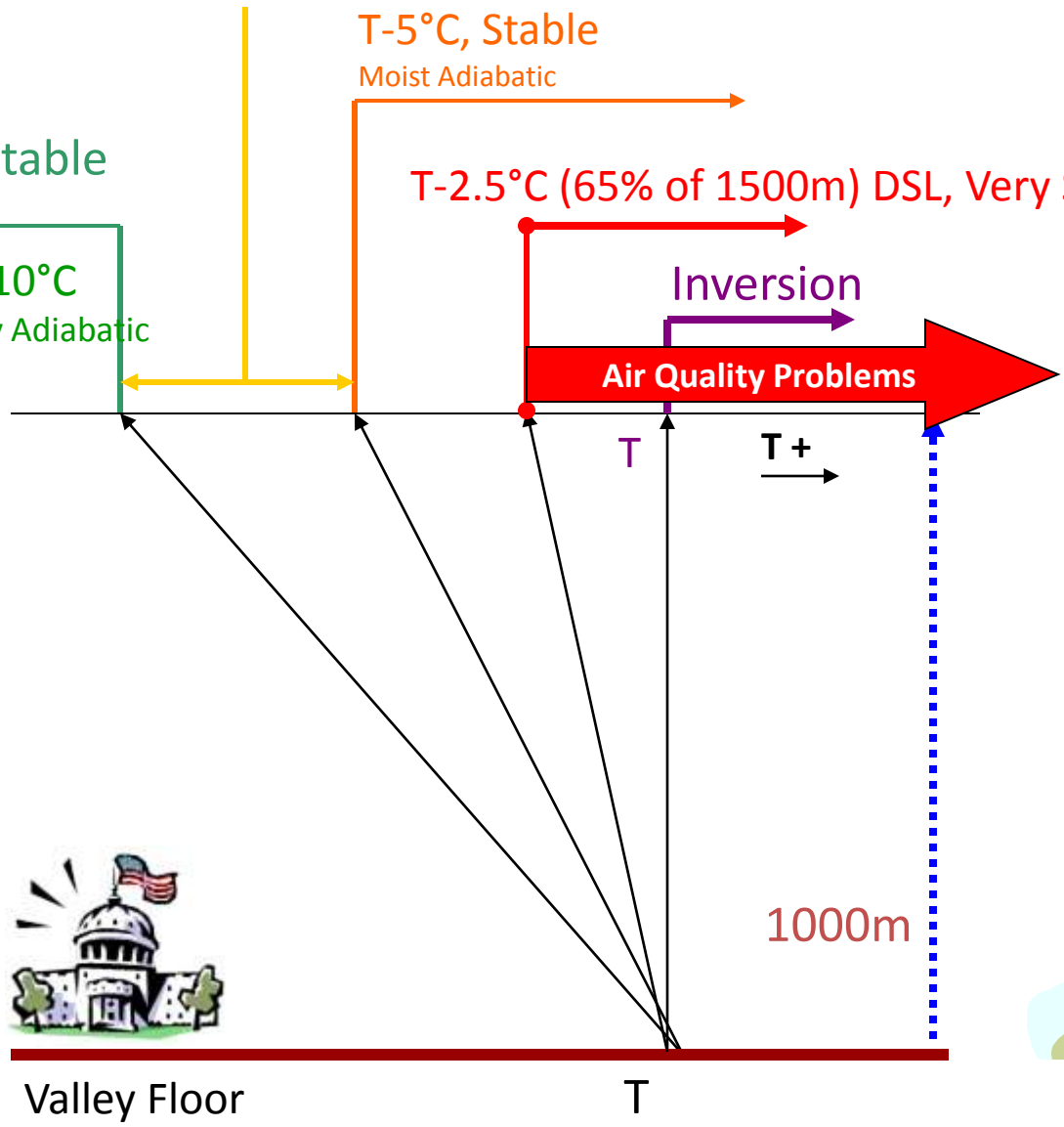
High pressure
Strong multiple stable layers
Low temperatures
Light variable winds
High relative humidity
Fogy, hazy
Snow cover makes situation worse
Does not breakup at the end of the day
Poor air quality





1500m AGL

DSL Criteria



Bogus Basin: 5800-7600 ft ASL
About 1000m-1500m AGL.

How is DSL Formed

- Synoptic-scale warming above 1-1.5km
- Weak surface heating
- Positive feedback

Criteria: Why 65 of 1500m?

Frequency of number of DSL days

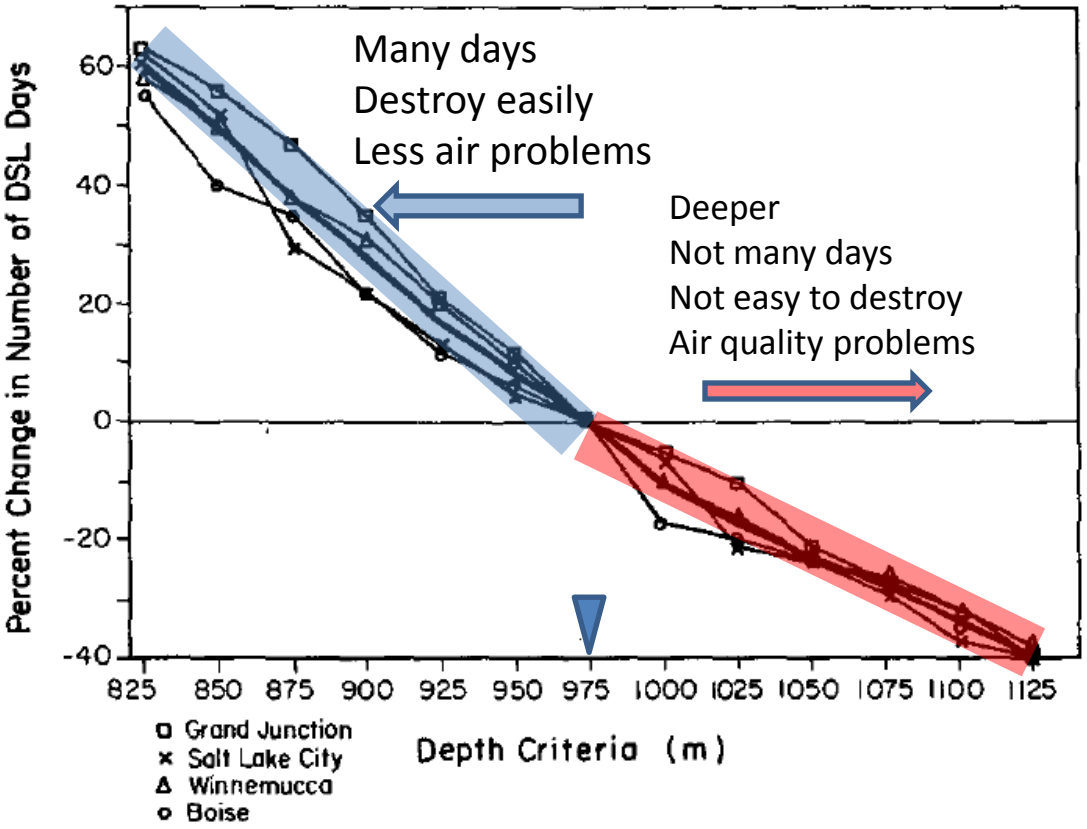


FIG. 4. As in Fig. 3 but for depth criteria.

Criteria: Why 2.5°C/km

Frequency of number of DSL days

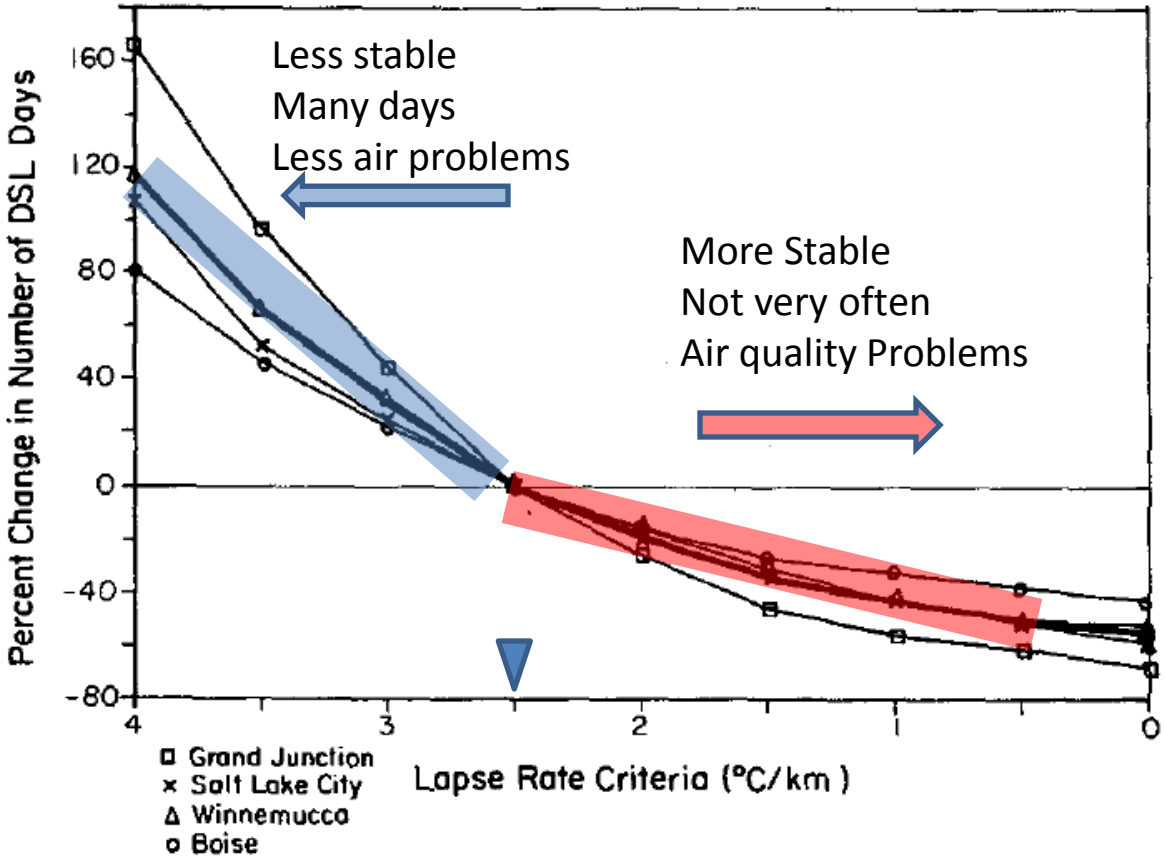


FIG. 3. The mean percentage change (bold line) for the four stations in the number of DSL days for different lapse rate criteria. The lighter lines show the percentage change for individual stations.

Energy (wind) required to break DSL

$$R_i = \frac{g}{T}\frac{(\gamma_d - \gamma)}{(\partial v/\partial z)^2},$$

where

R_i	Richardson number,
g	gravity,
T	temperature,
γ_d	dry adiabatic lapse rate,
γ	the lapse rate of the atmosphere,
v	wind speed,
z	height.

16m/s/km wind shear is need to get Ri =1.0 for a deep stable layer.

Energy (heat) required to break DSL

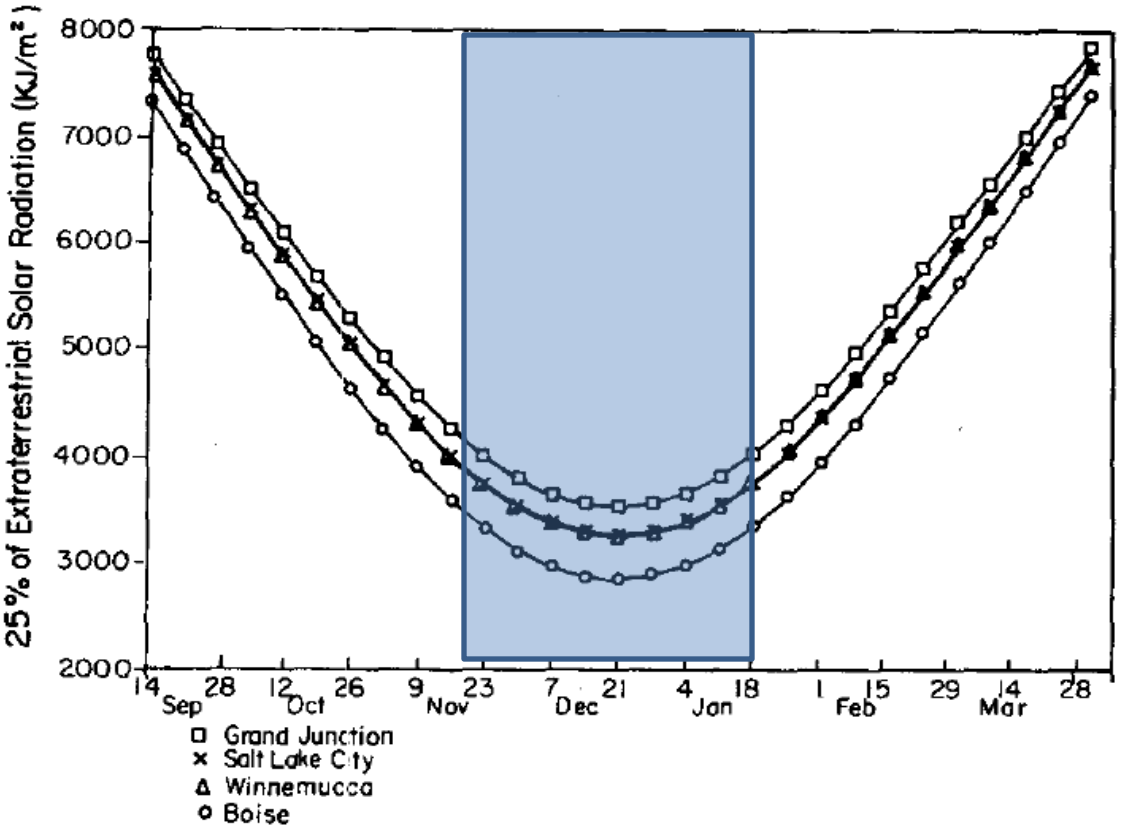
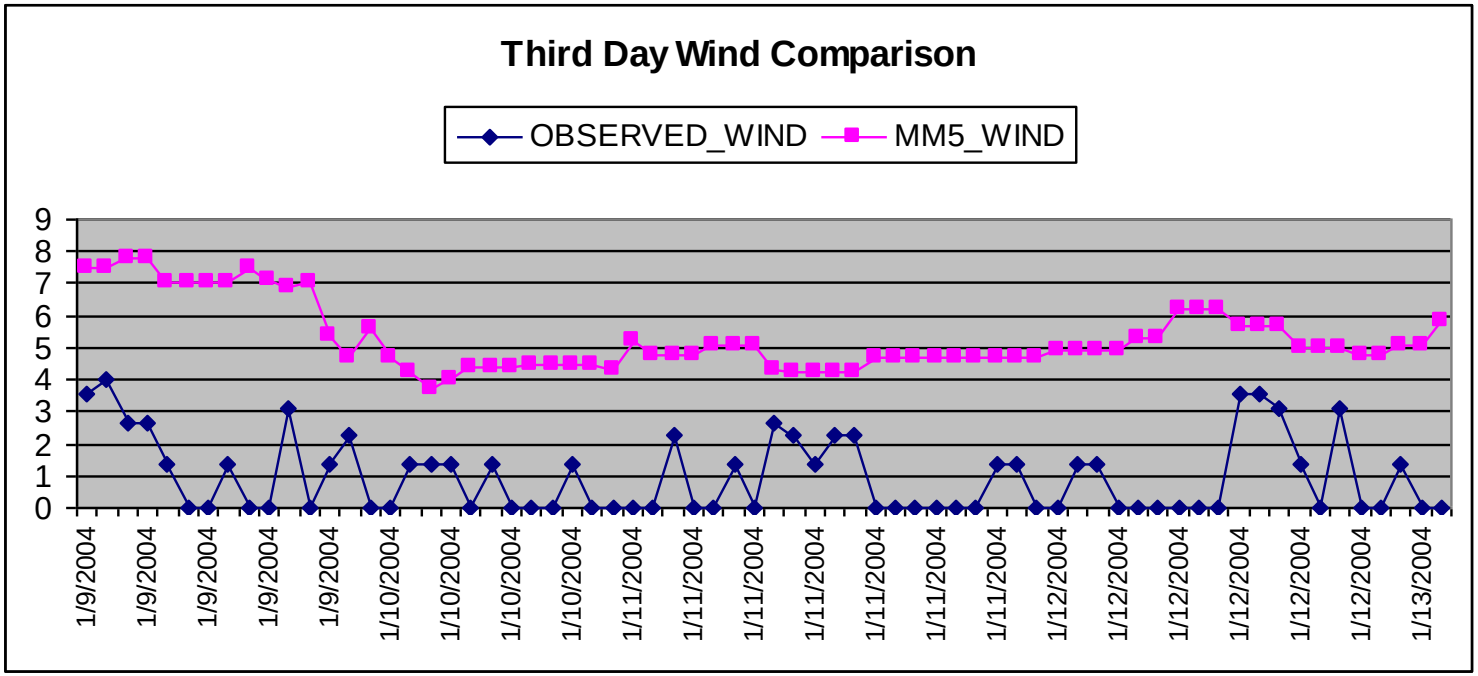


FIG. 5. Twenty-five percent of the daily extraterrestrial solar radiation at the four stations from 14 September 1980 to 28 March 1981.

MM5 overestimated wind speeds
(How is WRF doing?)

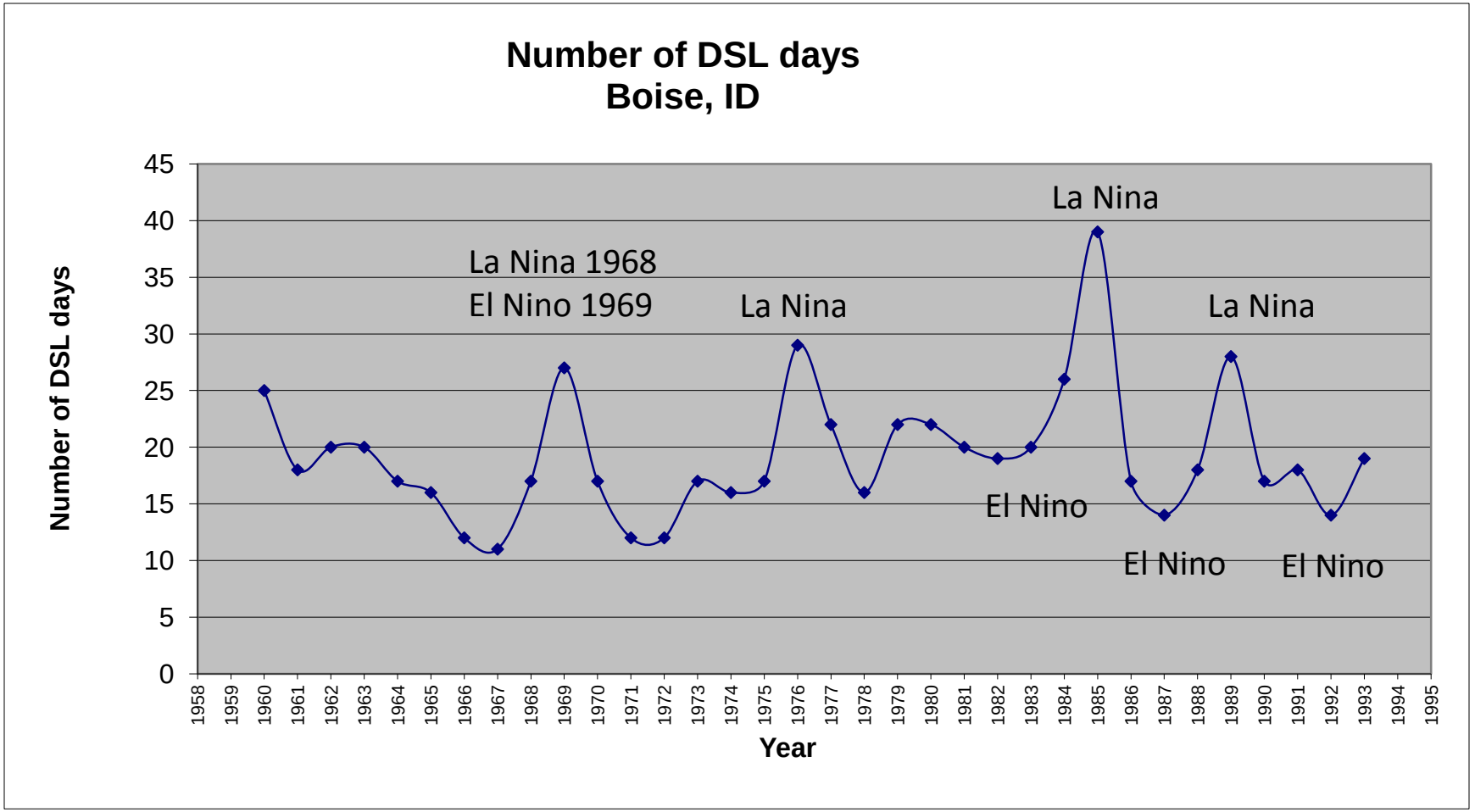


How Many DSL Days?

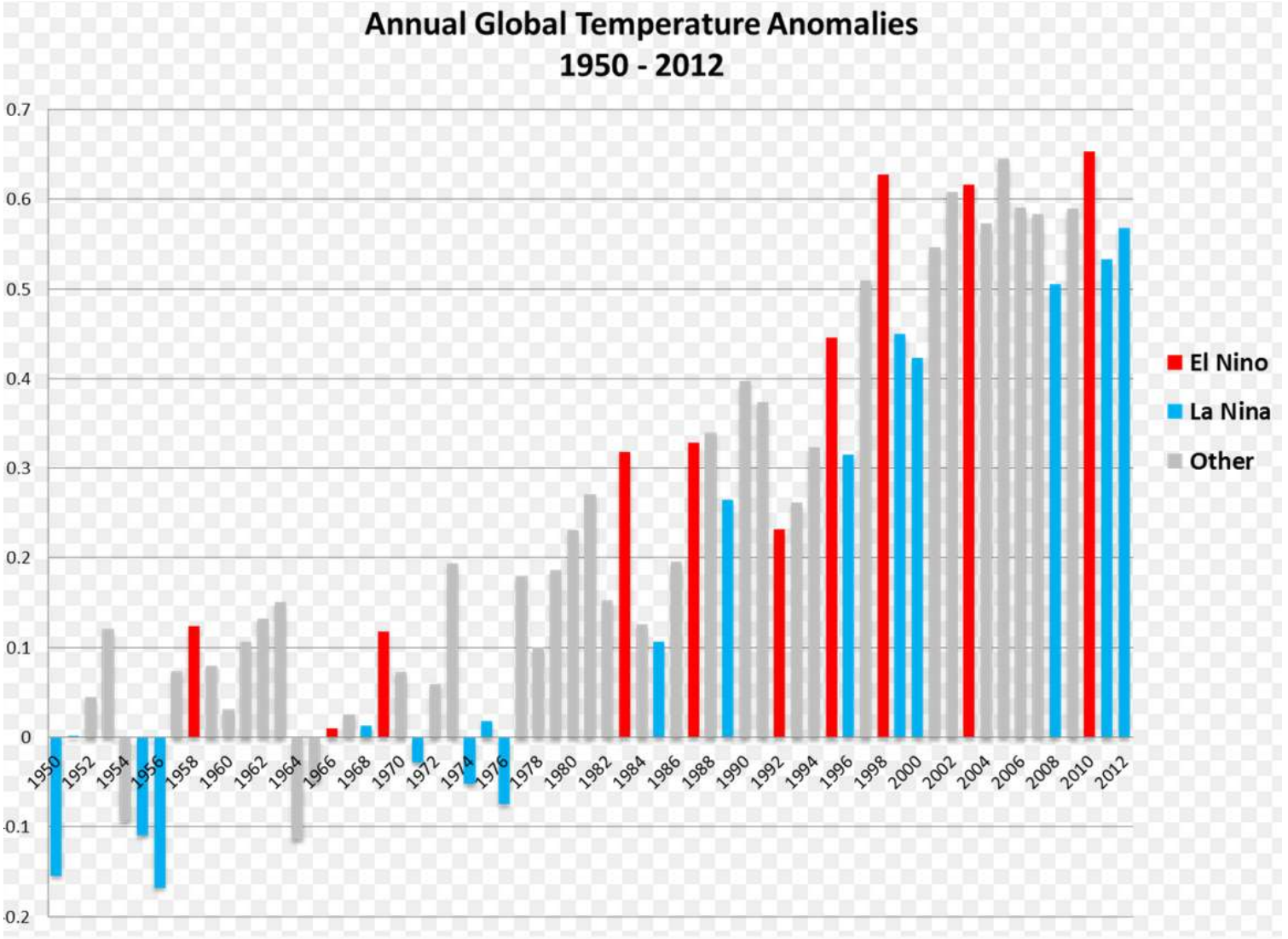
(25 years)

Location	**Total DSL Days** (1959-1983)	**Days in Winter** (Nov, Dec, Jan, Feb)
Grand Junction	417	364
Salt Lake City	298	247
Winnemucca	417	352
Boise	462	361

Cycles?


Number of DSL days
Boise, ID
Number of DSL days
Year
La Nina 1968
El Nino 1969
La Nina
La Nina
El Nino
El Nino
El Nino
La Nina
0
5
10
15
20
25
30
35
40
45
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995

DSL and La Nina?



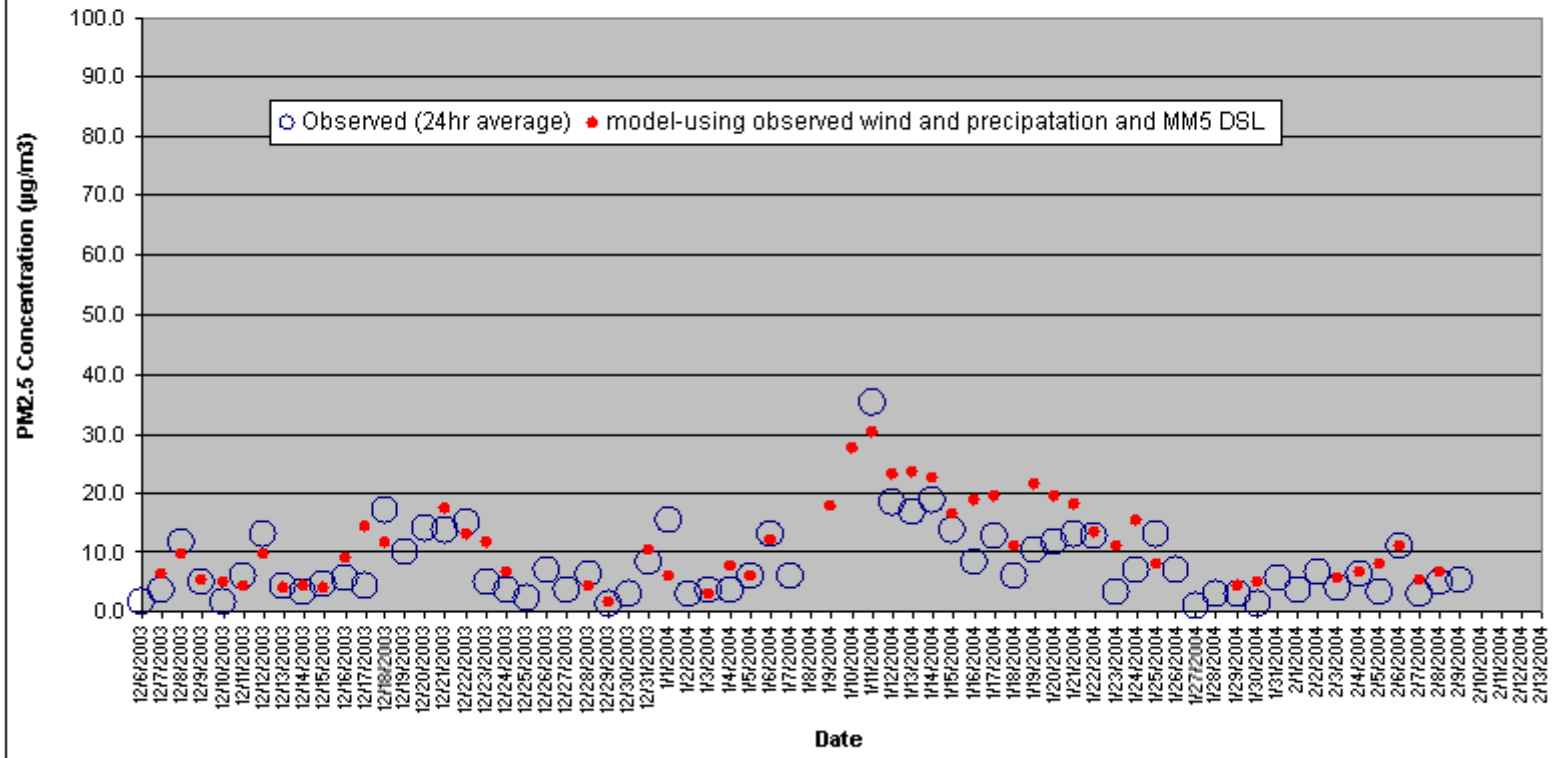
Low Stable Layer

- Pollutants levels will continue to increase overnight if the low stable layer exist at the end of the day
- 500m AGL (00Z) was used in Boise

Boise PM2.5 Forecast

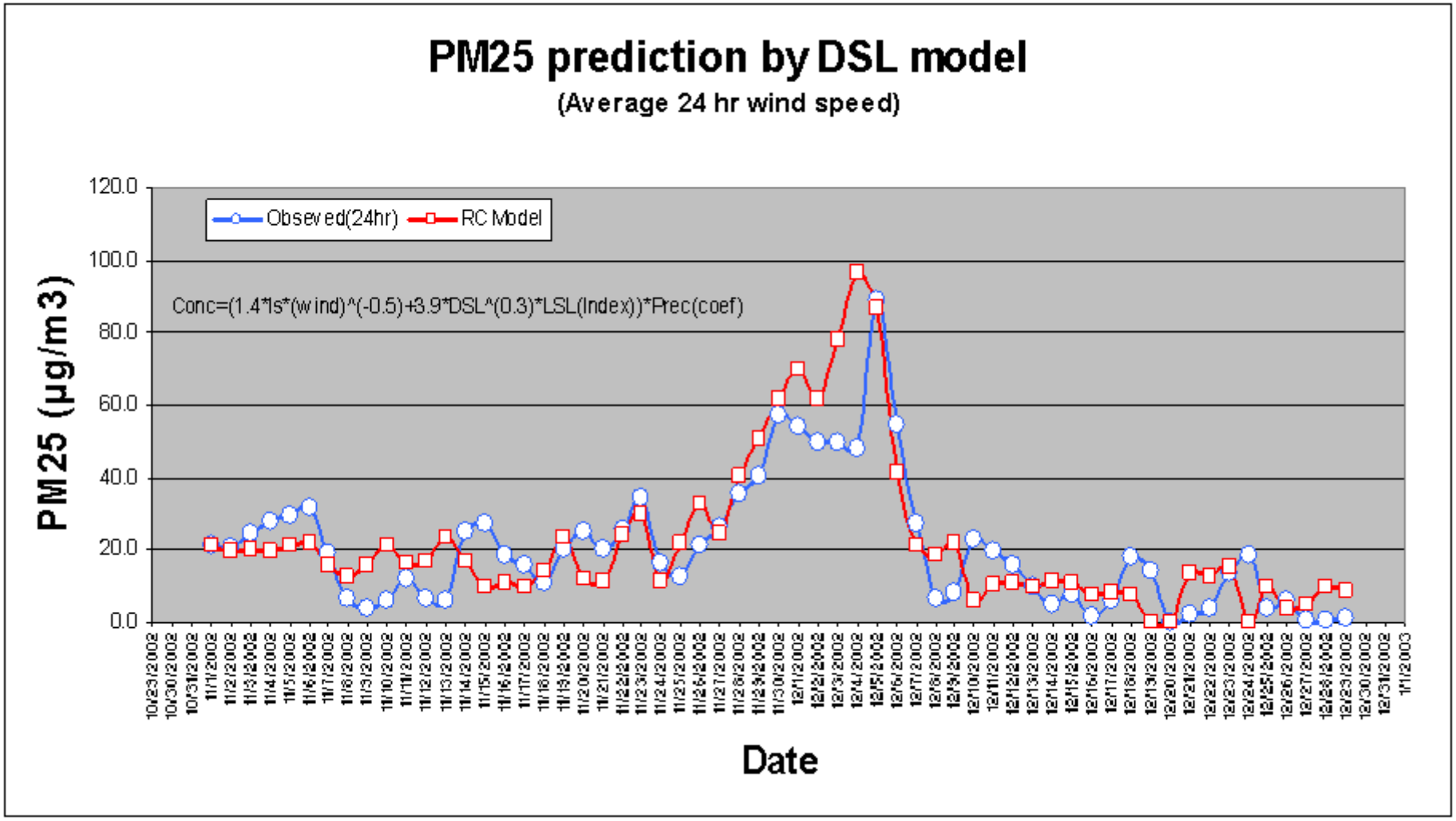
By DSL Hybrid Air Quality Model

UPDATED 13:00 02/08/2004

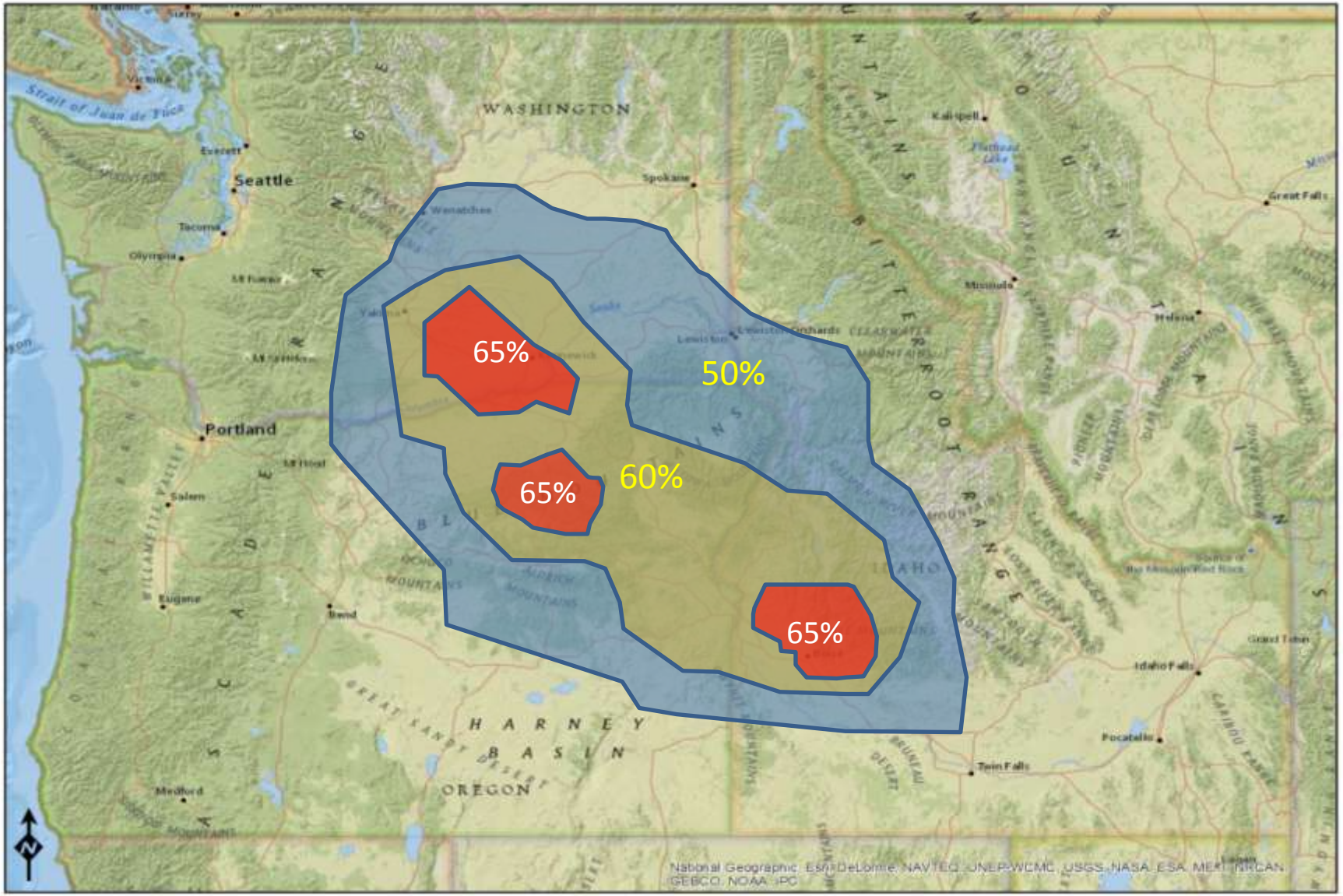


Modeled PM2.5 Levels for Nov.1 - Dec. 31, 2002

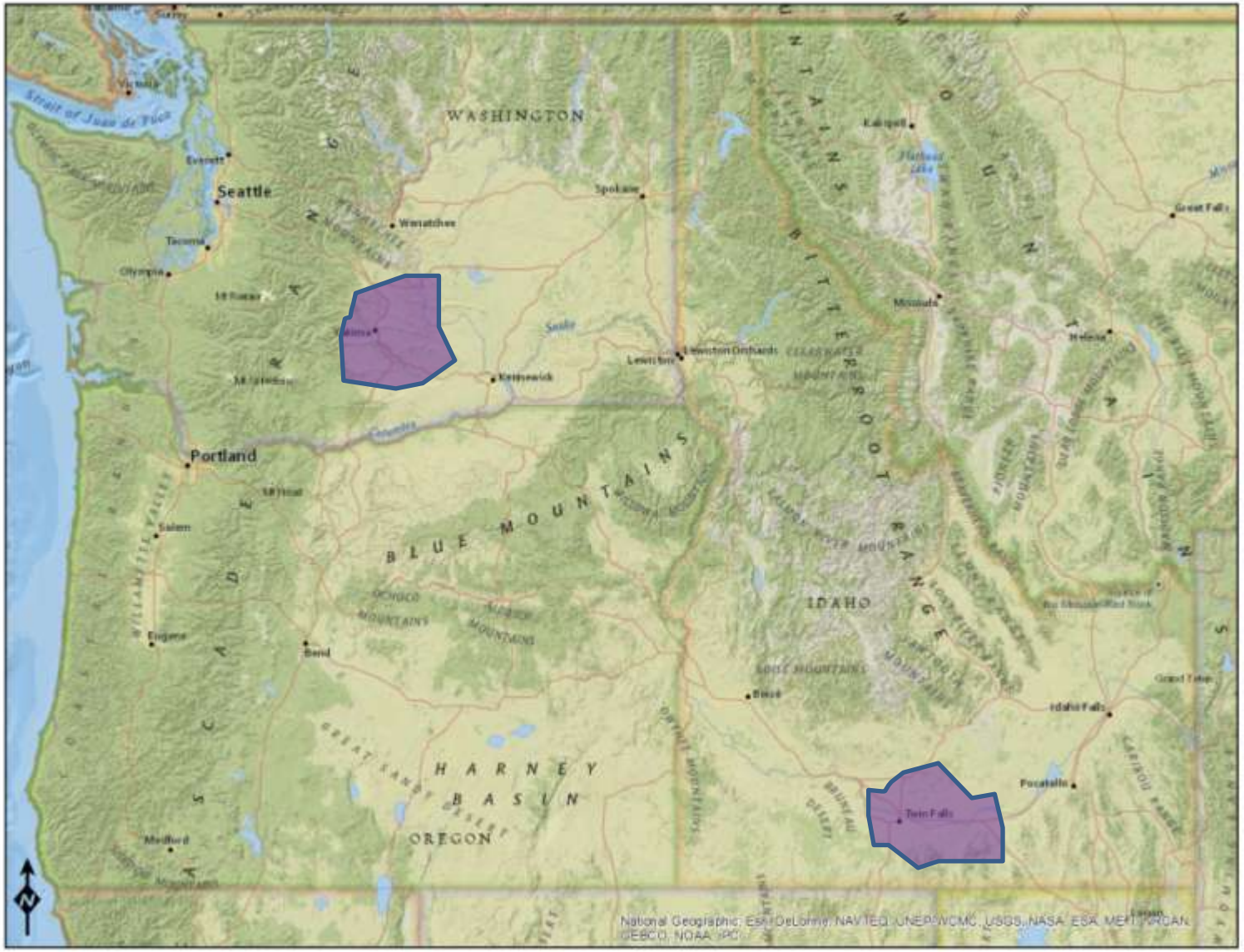
using average 24 hour wind speed and DSL data on 5:00am



12Z DSL Map with wind field bars and temperature contours



00Z LSL Map with wind field bars and temperature contours



Summary

- DSL does not occur frequently
- Requires high winds or/and ground heating to destroy
- Relatively easier to predict (Temperature profile)
- Proposed Graphic
  - 50%, 55%, 65% (of 1500m) DSL
  - Wind bars
  - Temperature contours