Elevated Ozone Events, Jonah Wyoming, February 2005

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Global Monitoring Division

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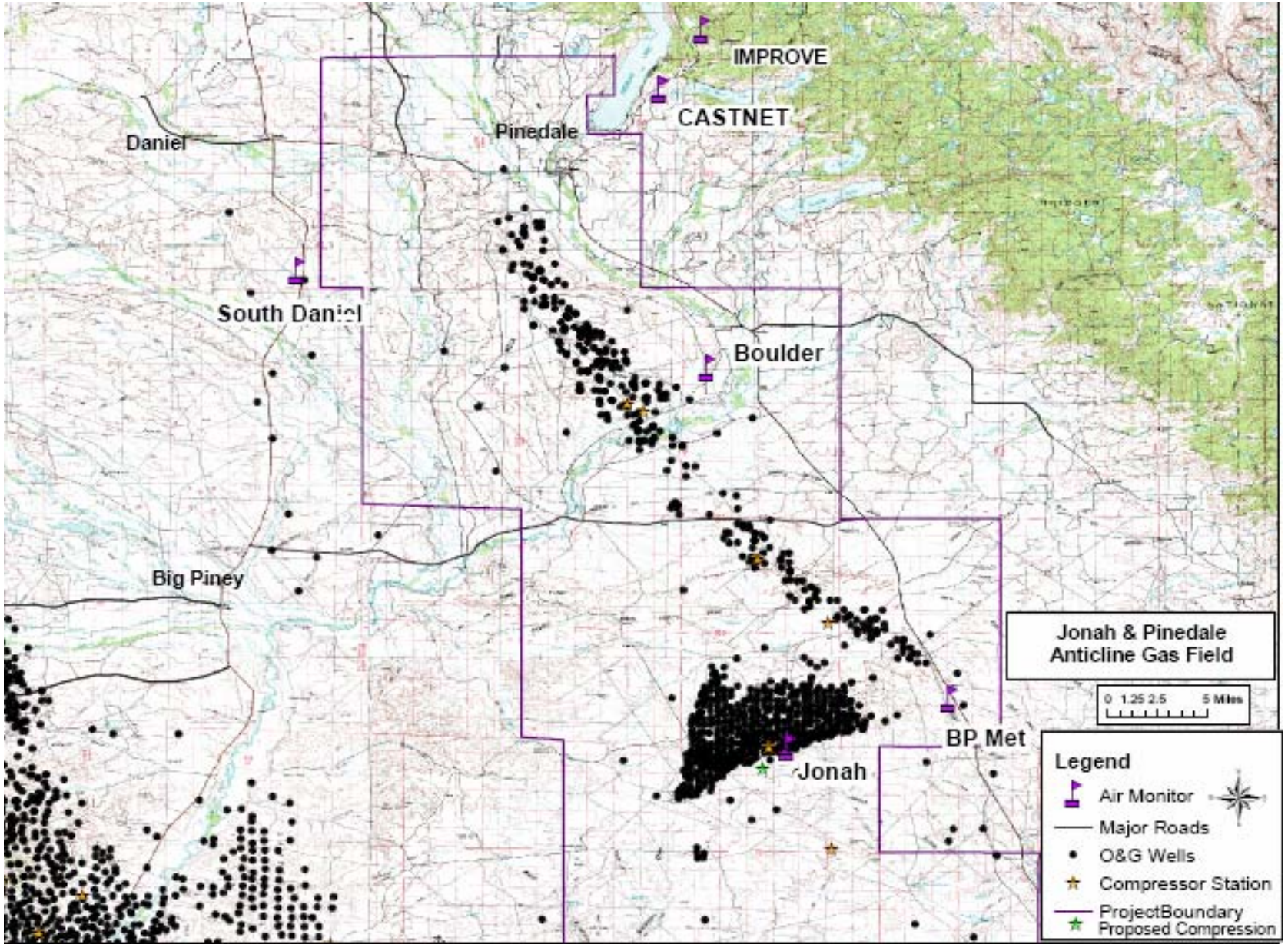
Pinedale Anticline, Jonah, Wyoming



Jonah, Wyoming gas field showing well spacing at one well per 40 acres.

Field is in the process of in-filling an additional 3 wells per each existing well.

(scale: 7x10 miles)

Well Density will increase 300% in 3-5 Years

Economics Of The Jonah Gas Field

- The 30,000 acre Jonah gas field, 30 miles south of Pinedale, Wyoming, is estimated to hold 10 trillion cubic feet of natural gas.
- The field presently produces enough gas to serve 3,000,000 U.S. homes per year.
- In 2005, the Jonah Field produced natural gas revenues in excess of $2 billion.
- The value of the gas to be extracted from the field over 40 years is calculated to be in excess of $40 billion (2005 prices).

EPA Regulatory Issue That Could Affect Johan Gas Field Operations

- In January and February, 2005 and 2006, hourly ozone values of 120 ppb occurred in the gas field.
- If ozone values in excess of 85 ppb, over an 8 hour average continue, the field operations could go into EPA non-compliance.
- If so, oil company and Wyoming State revenues could decline and field operating expenses increase.

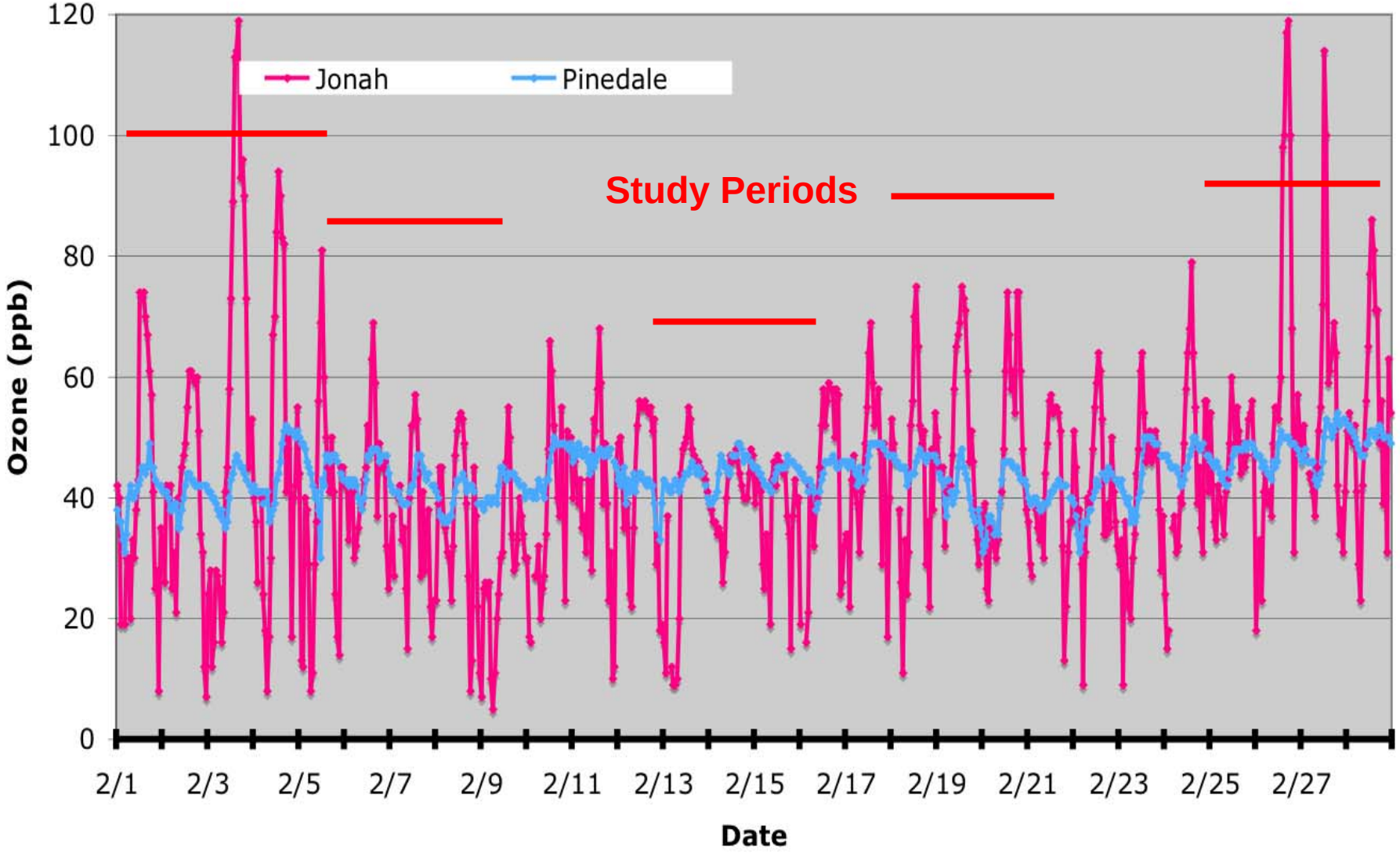
Elevated Ozone Events in Jonah Field

Background:

- Hourly average ozone >90 ppb (maximum of 120 ppb) at Jonah, WY, February 3-4 and 25-26.
- Many events over 60 ppb.
- Snow on the ground and sunny.
- Low winds, high pressure, probable inversions.

Is the high ozone from stratospheric fold events?

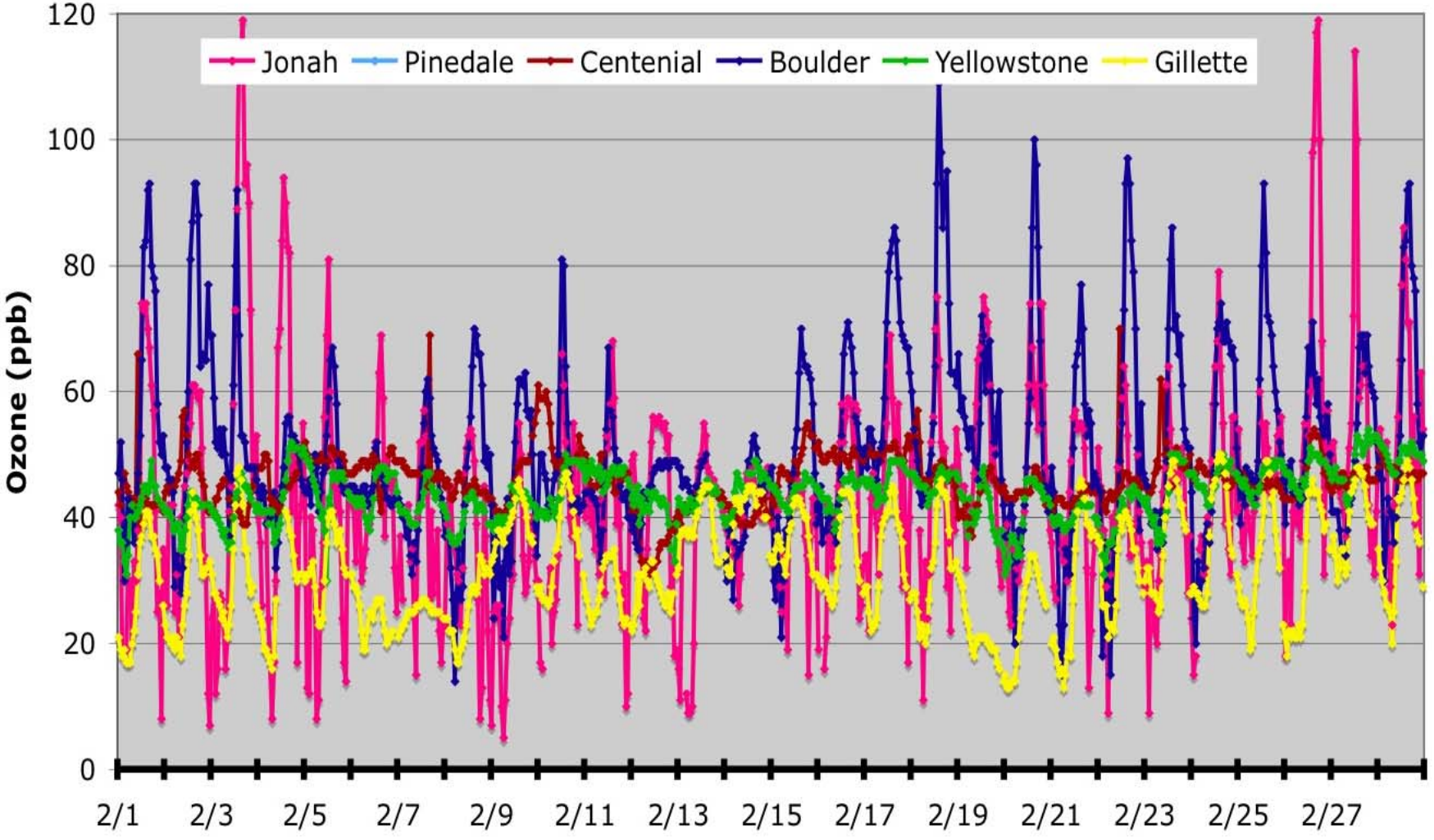
Ozone, February 2005, Jonah and Pinedale



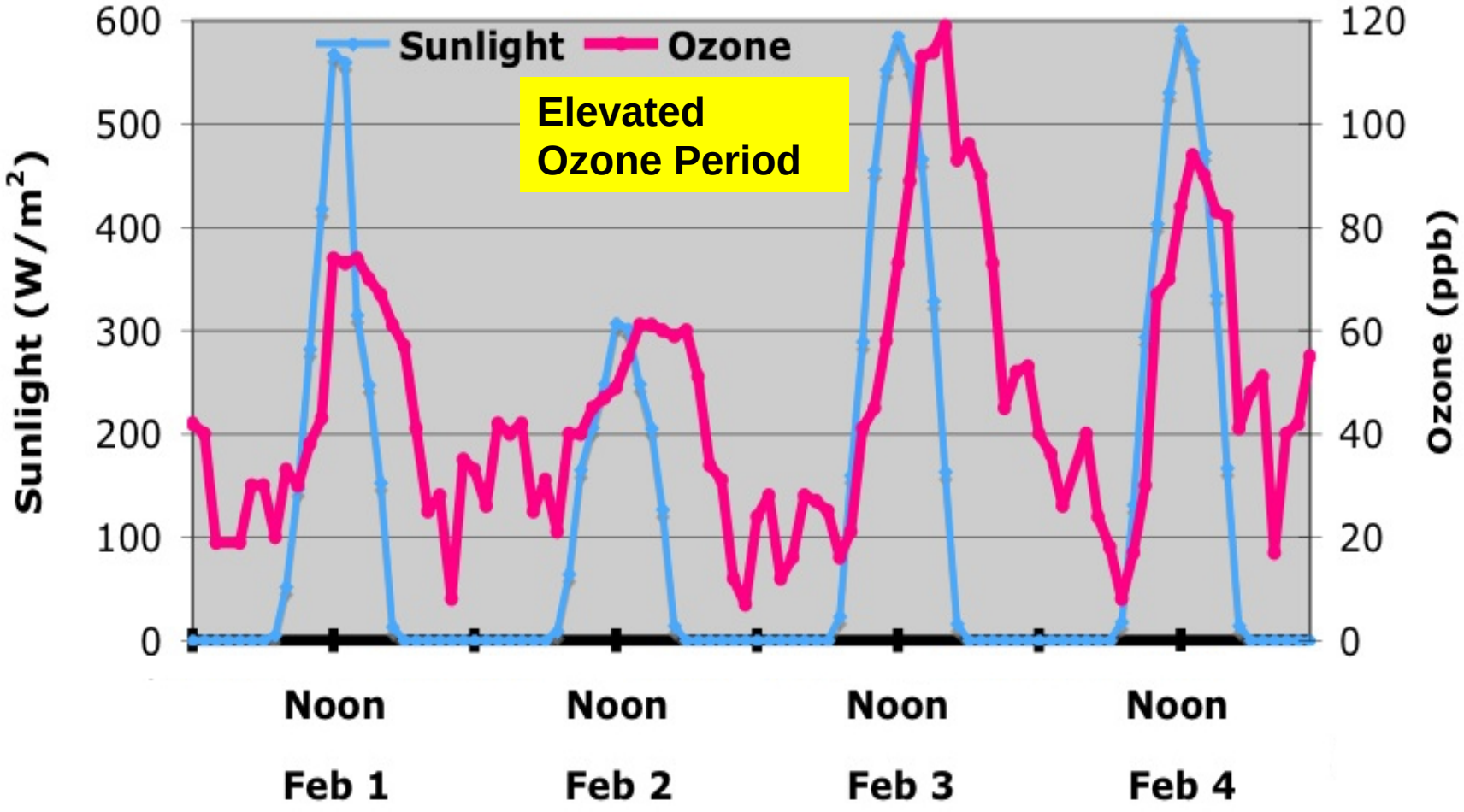
Approach:

- Study the dates and timing of the peak ozone values.
- Relate the peak ozone events to observed meteorological parameters.
- Determine if stratosphere folds could contribute to the high surface ozone values.
- Determine the meteorology of the high ozone events.
- Discuss prediction of the high ozone events.
- Discuss future research/analyses.

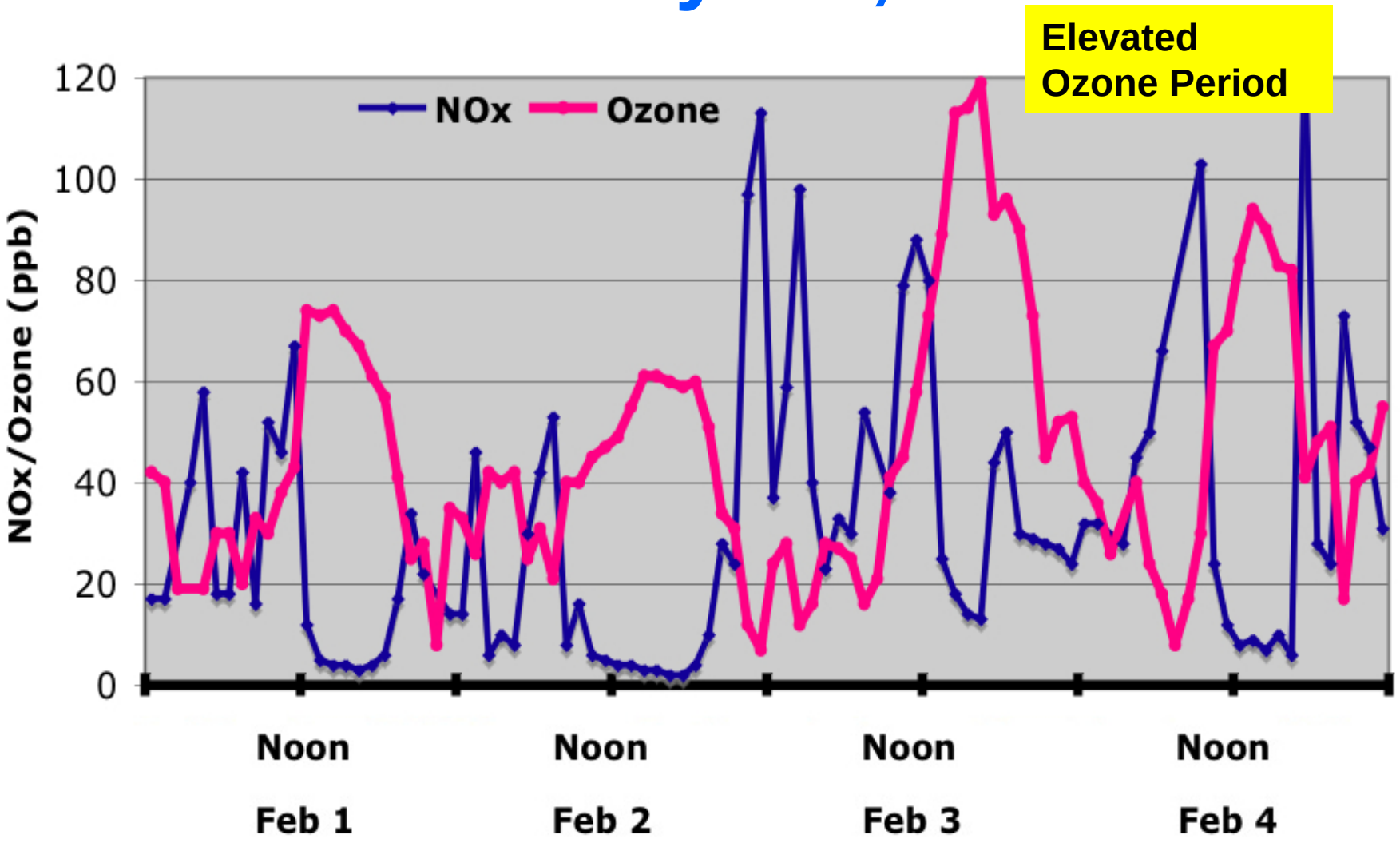
Ozone, February 2005, Wyoming Wide



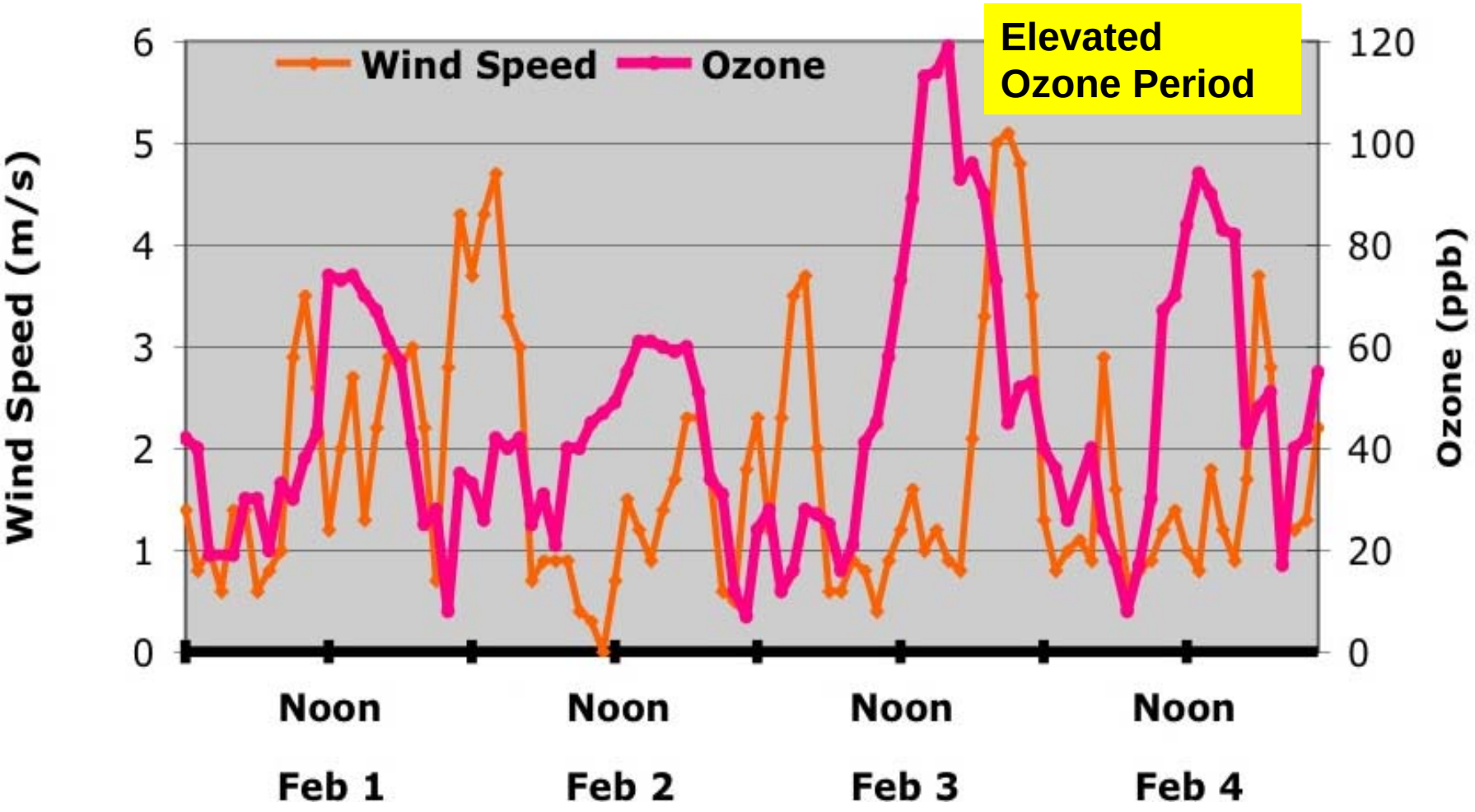
Solar Radiation and Ozone, Jonah, February 1-4, 2005



Ozone and NOx, Jonah, February 1-4, 2005

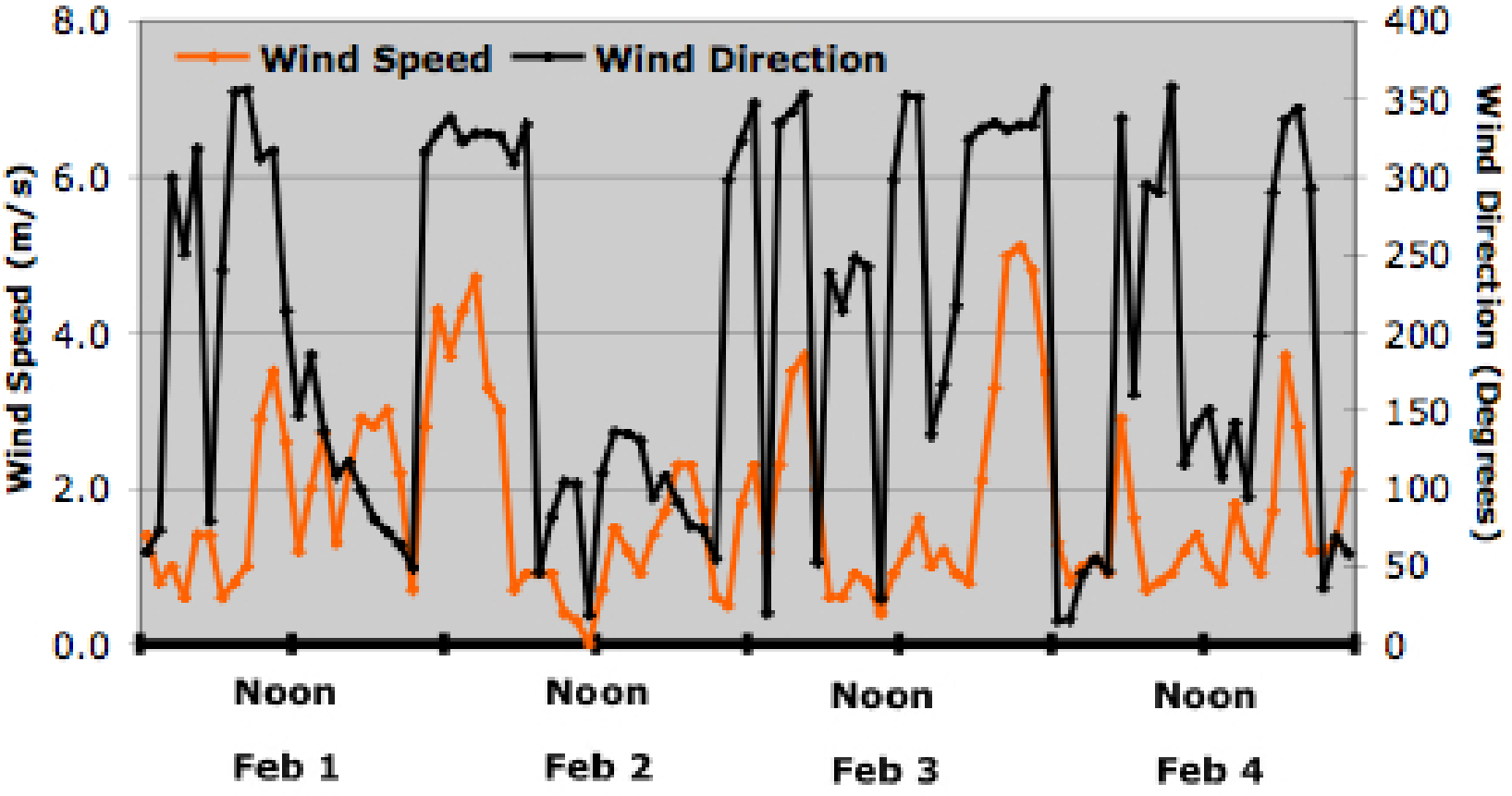


Ozone and Wind Speeds, Jonah, WY, Feb 1-4, 2005

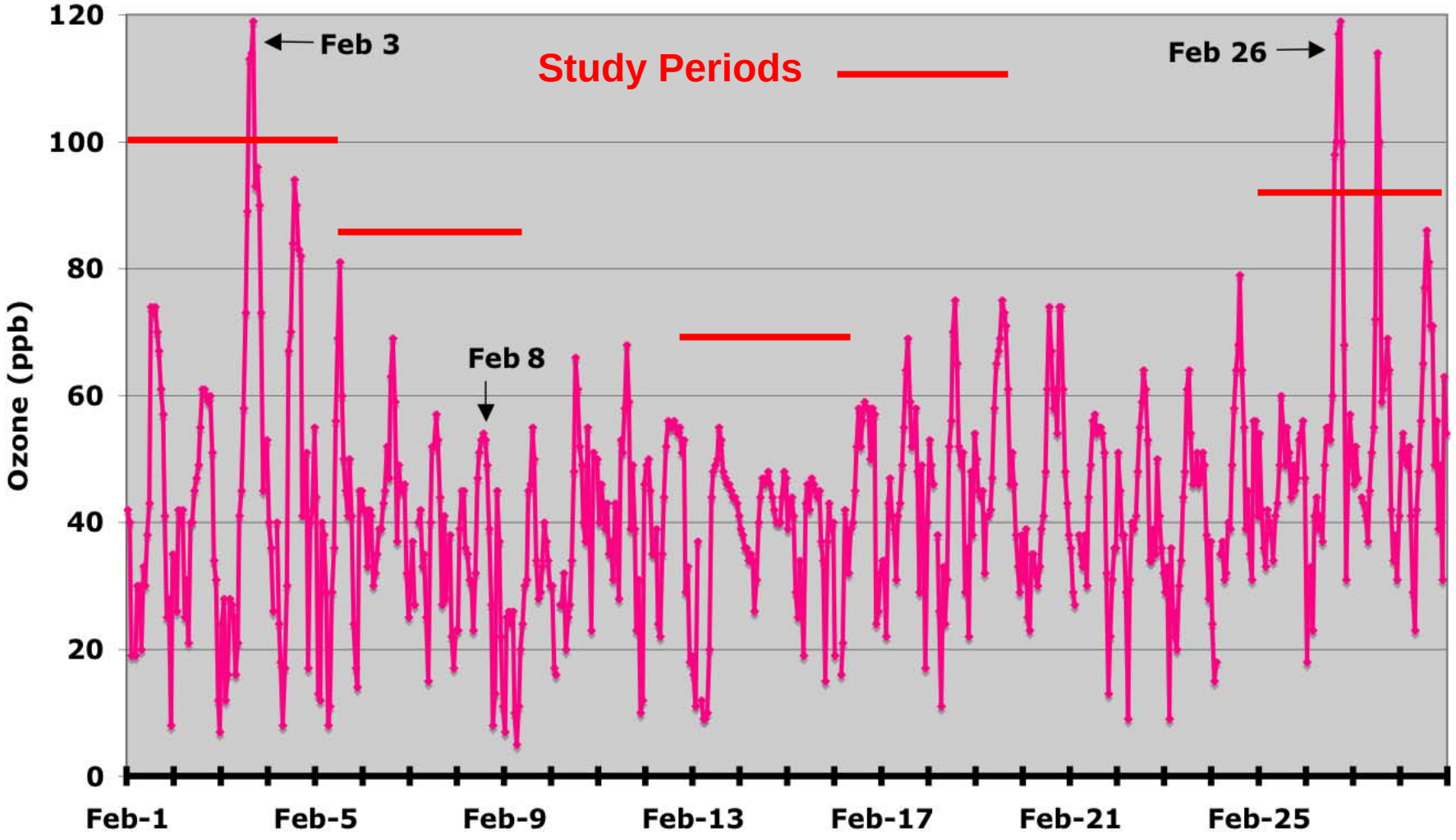


Wind Direction and Wind Speeds, Jonah, WY, Feb 1-4, 2005

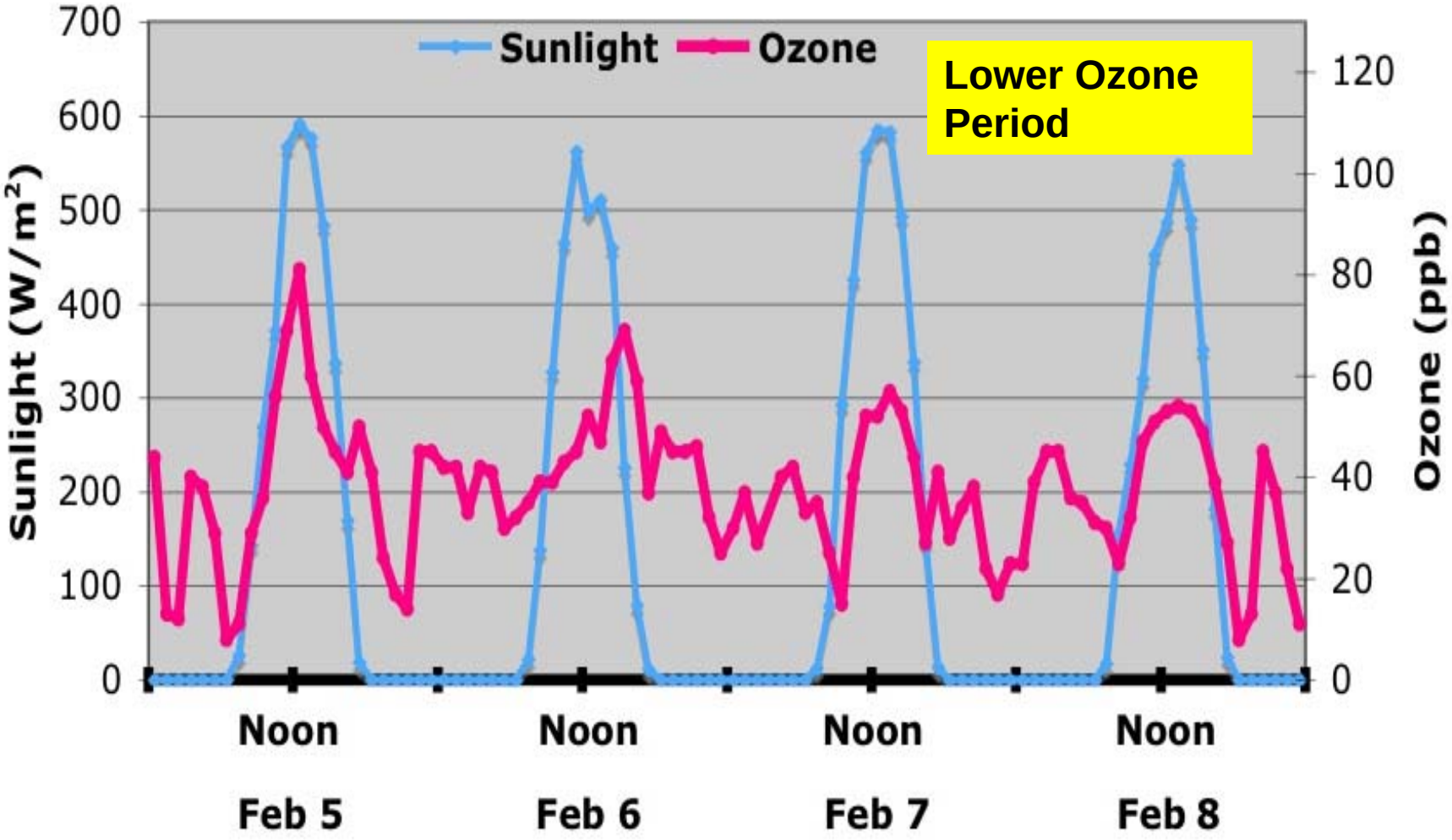
Elevated Ozone Period



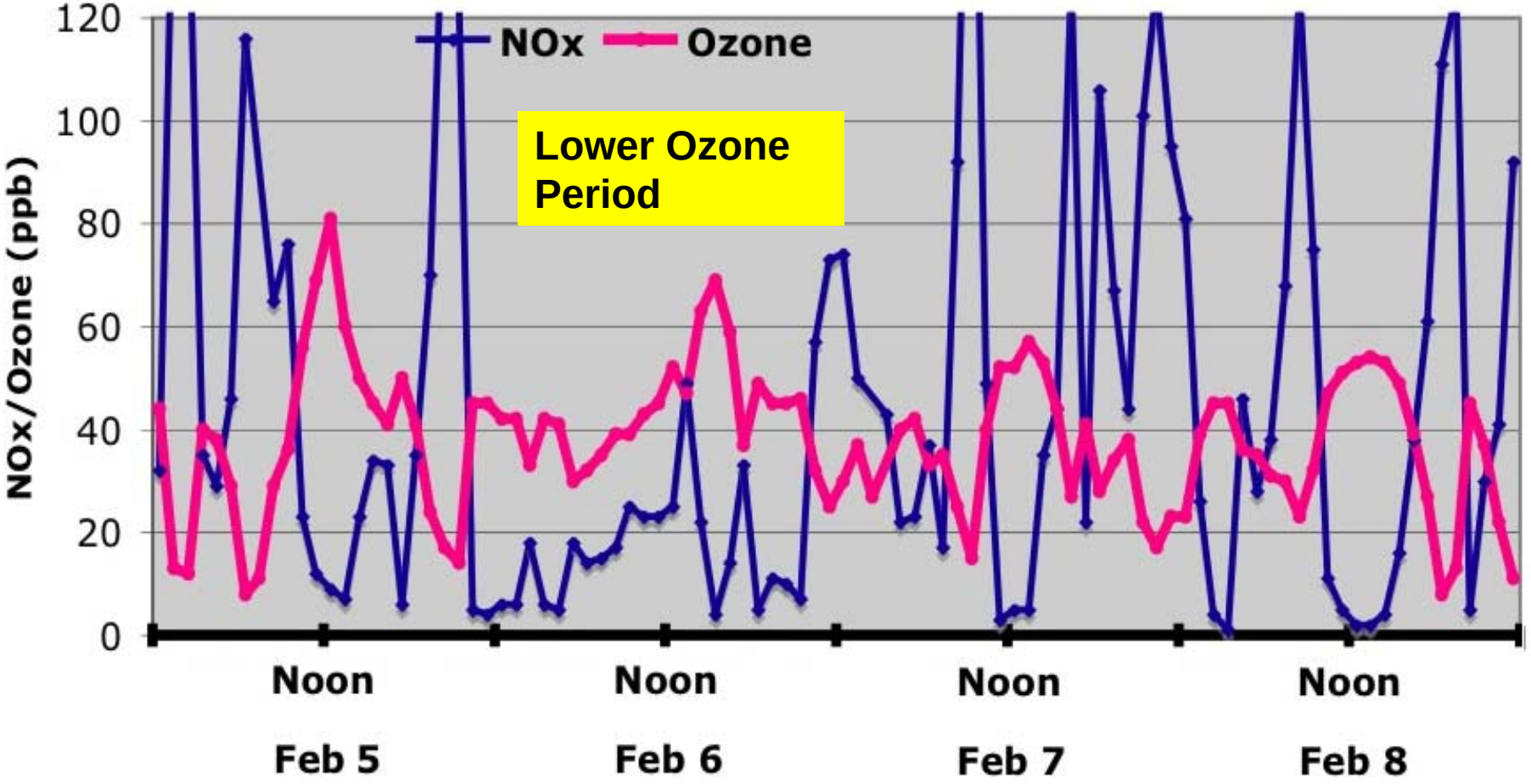
Hourly Average Ozone Concentrations, February 2005, Jonah, Wyoming



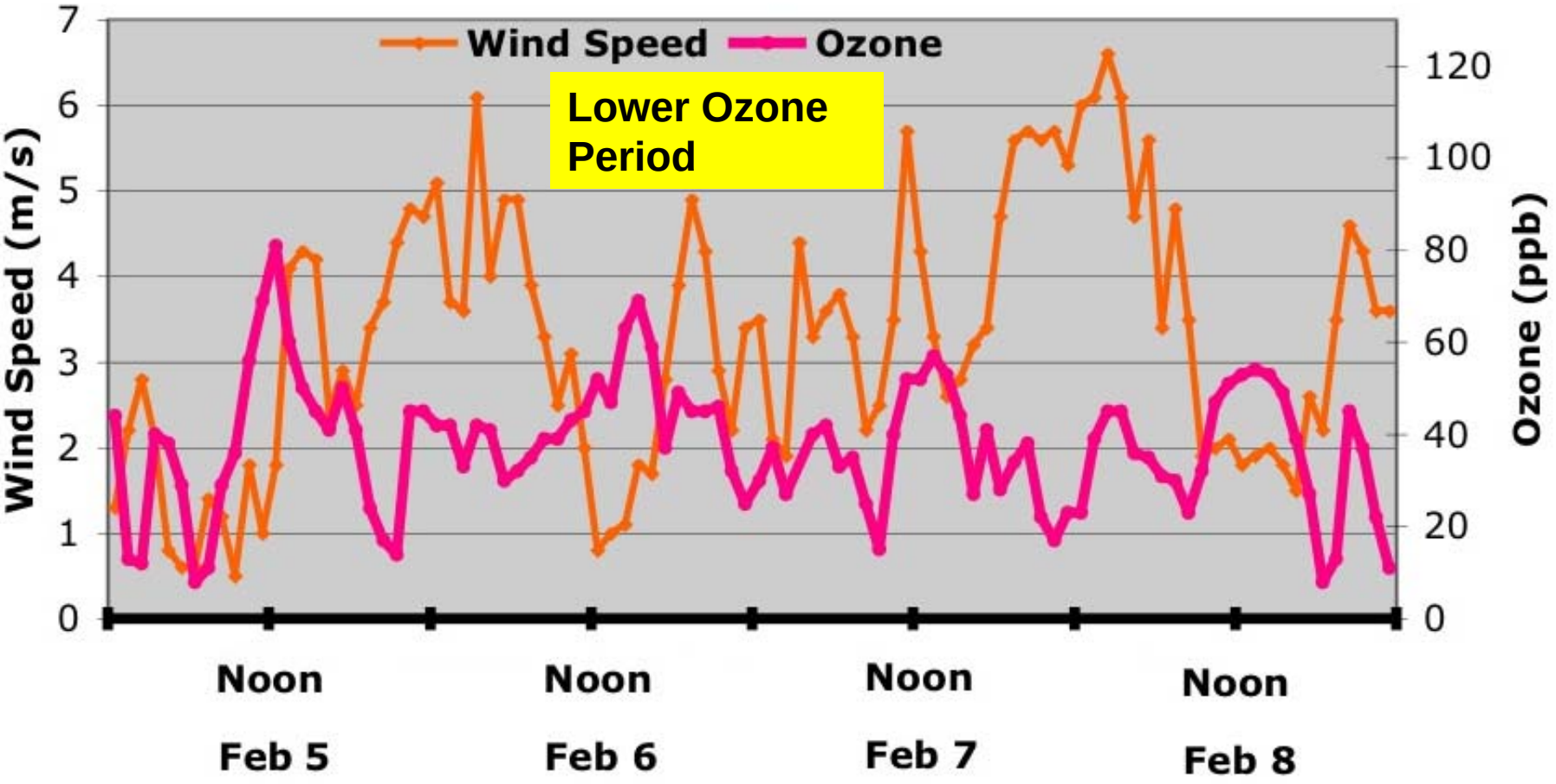
Solar Radiation and Ozone, Jonah, February 5-8, 2005

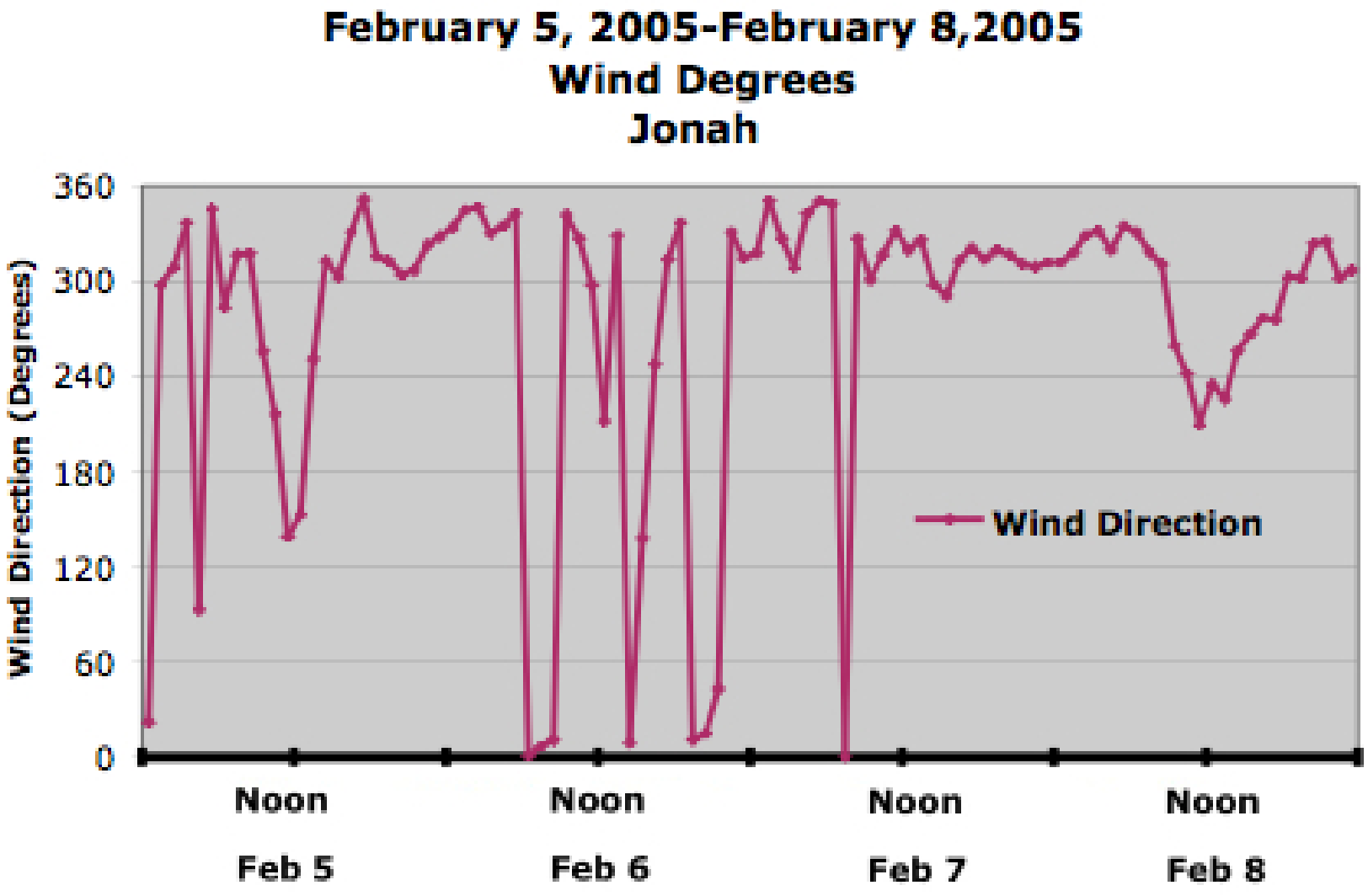


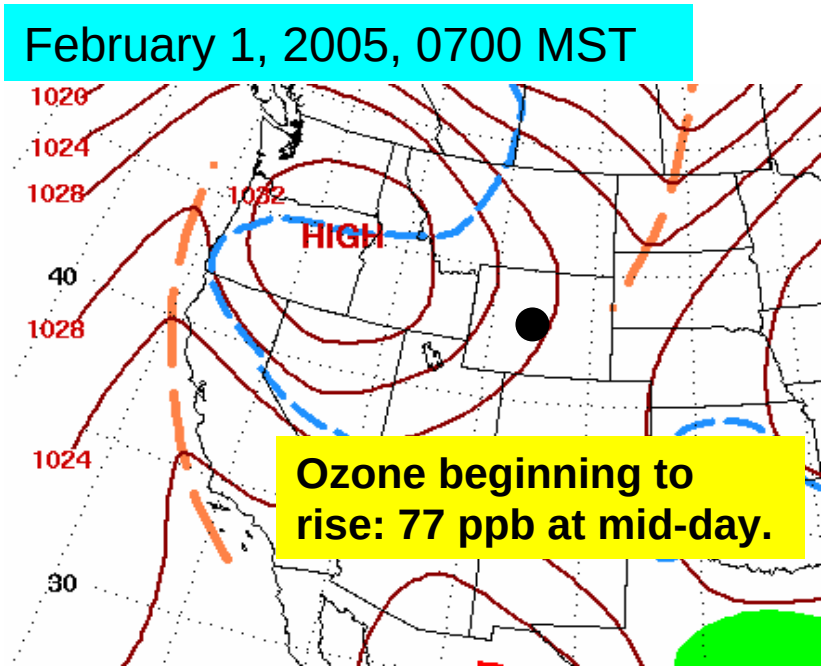
Ozone and NOx, Jonah, February 5-8, 2005

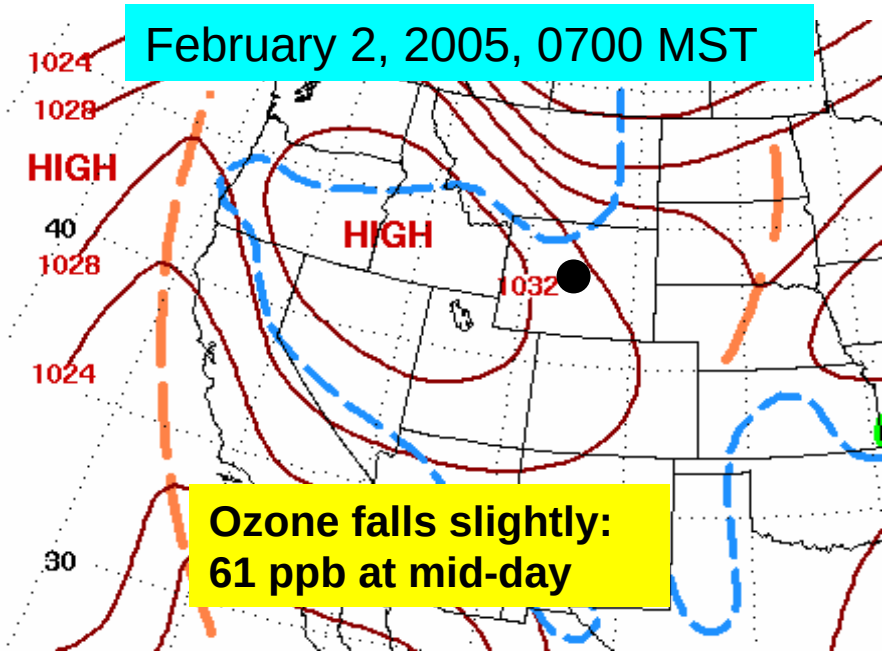


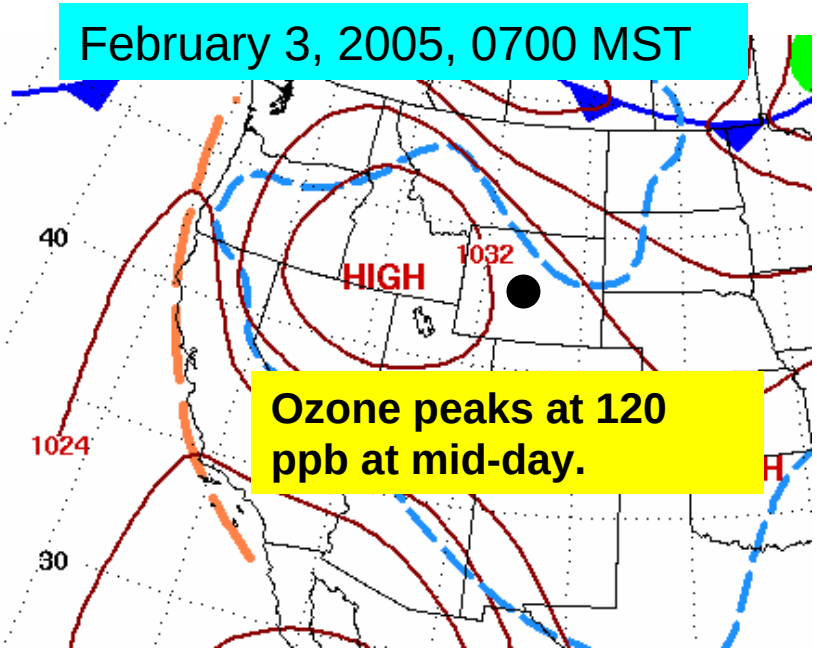
Ozone and Wind Speeds, Jonah, WY, Feb 5-8, 2005

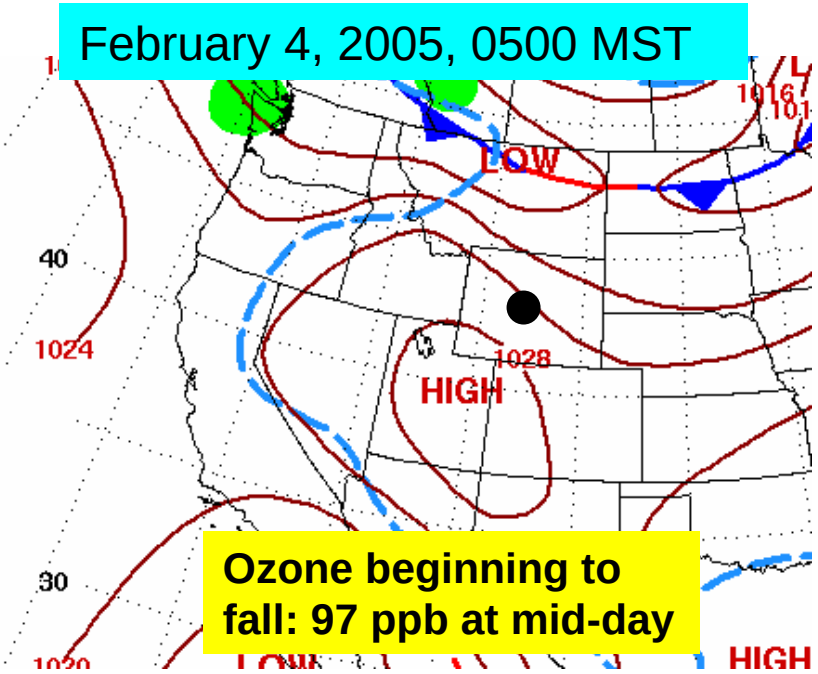


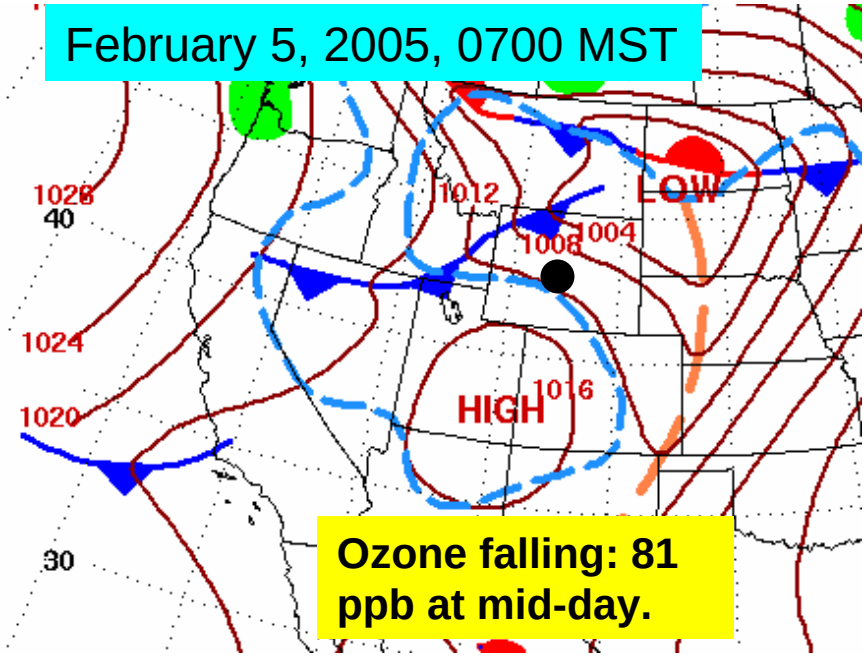

February 5, 2005-February 8,2005
Wind Degrees
Jonah
Wind Direction (Degrees)
360
300
240
180
120
60
0
Wind Direction
Noon
Feb 5
Noon
Feb 6
Noon
Feb 7
Noon
Feb 8

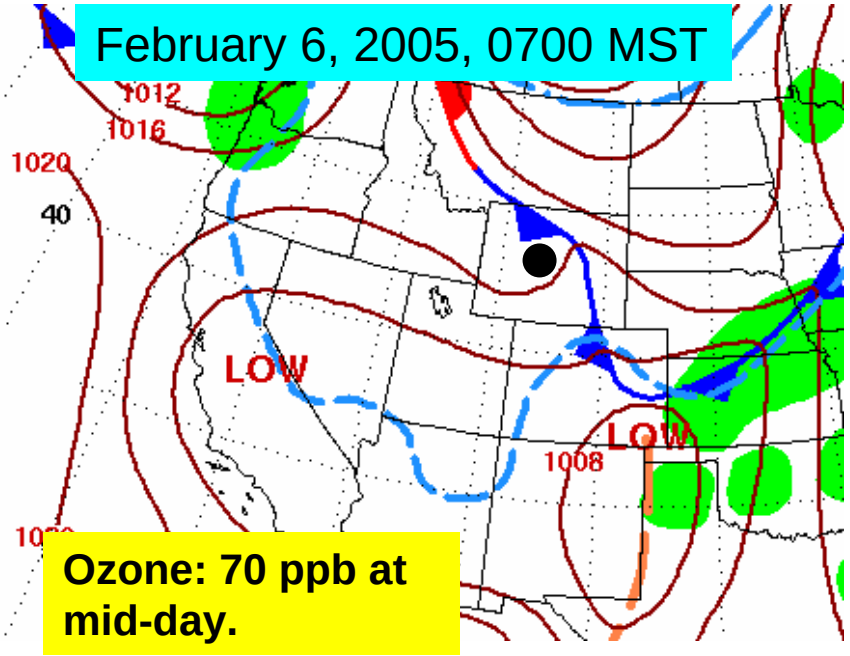

February 1, 2005, 0700 MST
1020
1024
1028
1032
HIGH
40
1028
1024
30
Ozone beginning to rise: 77 ppb at mid-day.

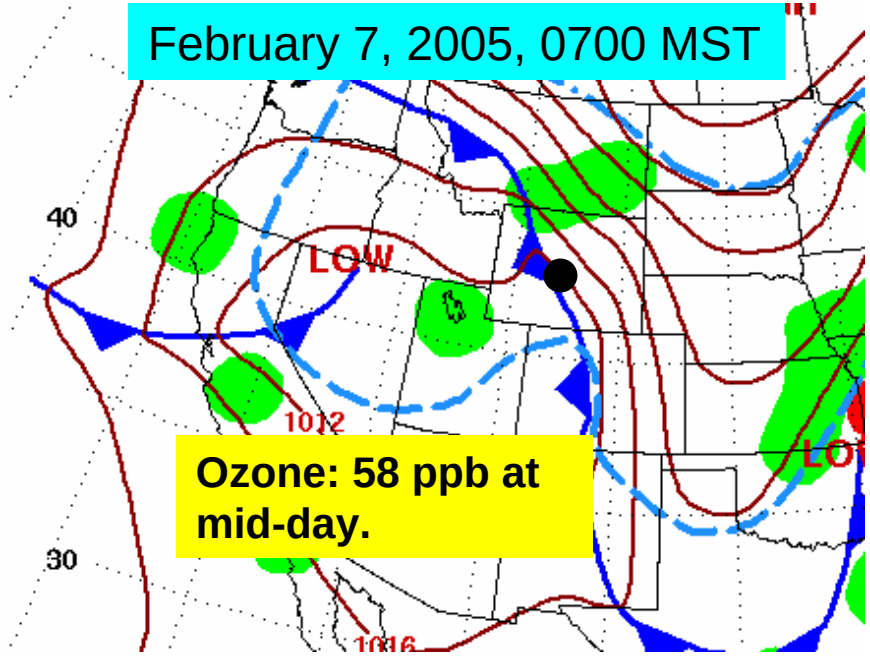

February 2, 2005, 0700 MST
1024
1028
HIGH
40
1028
HIGH
1032
1024
30
Ozone falls slightly: 61 ppb at mid-day

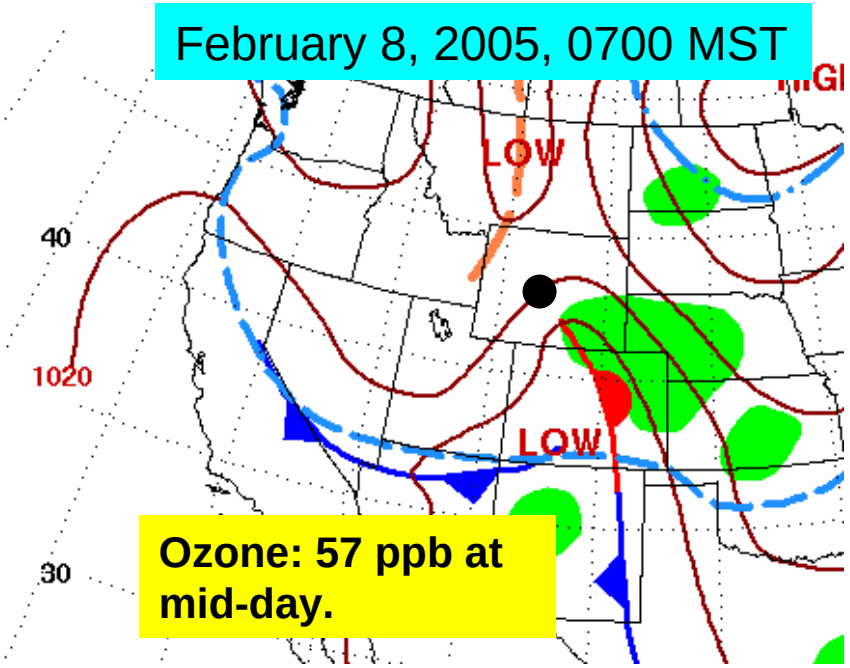

February 3, 2005, 0700 MST
40
HIGH
1032
1024
30
Ozone peaks at 120 ppb at mid-day.


February 4, 2005, 0500 MST
LOW
40
1024
1028
HIGH
30
Ozone beginning to fall: 97 ppb at mid-day
HIGH


February 5, 2005, 0700 MST
1028
40
1012
LOW
1004
1008
1024
1020
HIGH
1016
30
Ozone falling: 81 ppb at mid-day.

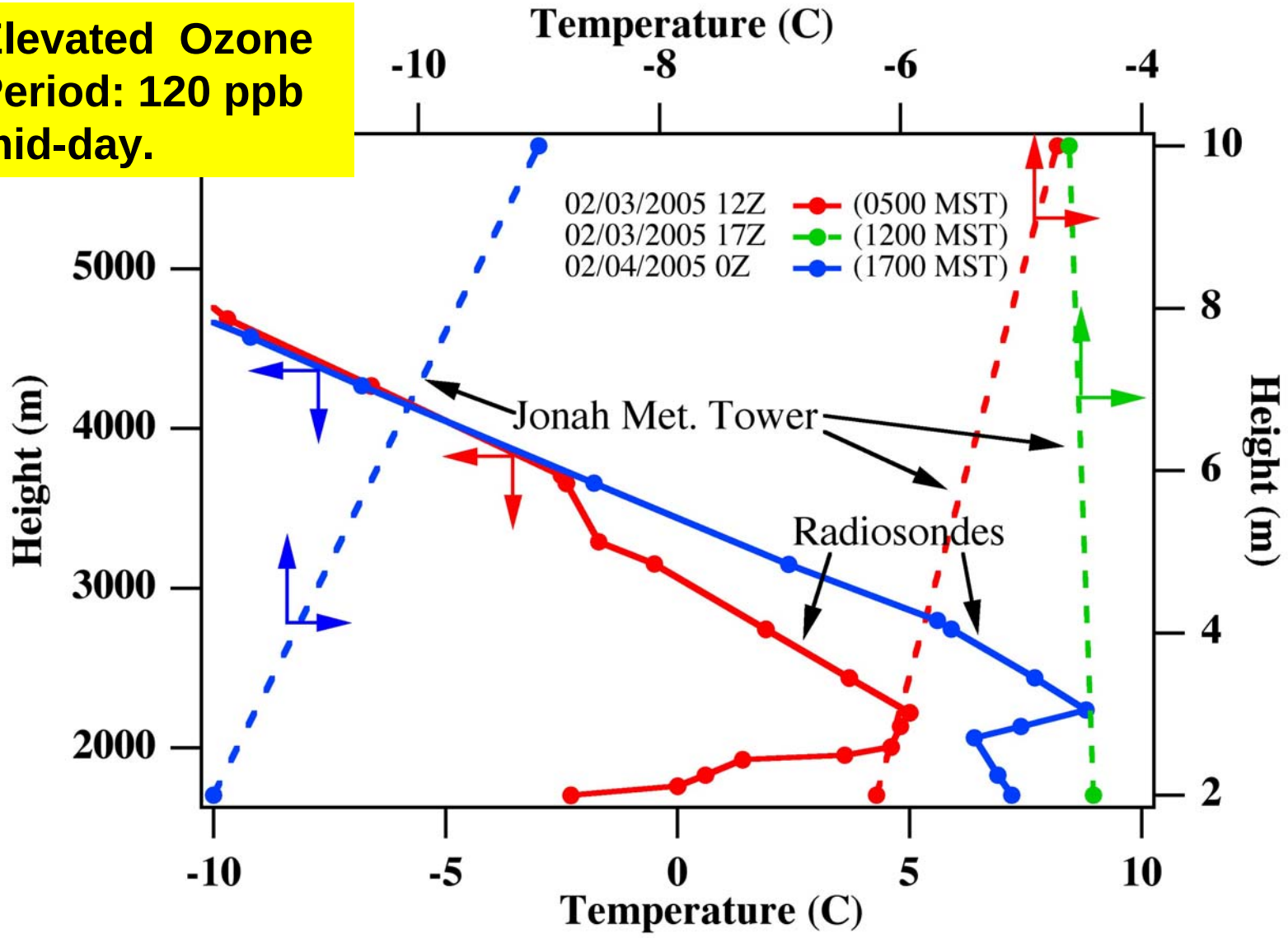

February 6, 2005, 0700 MST
1012
1016
1020
40
LOW
LOW
1008
Ozone: 70 ppb at mid-day.


February 7, 2005, 0700 MST
40
LOW
1012
30
1016
Ozone: 58 ppb at mid-day.

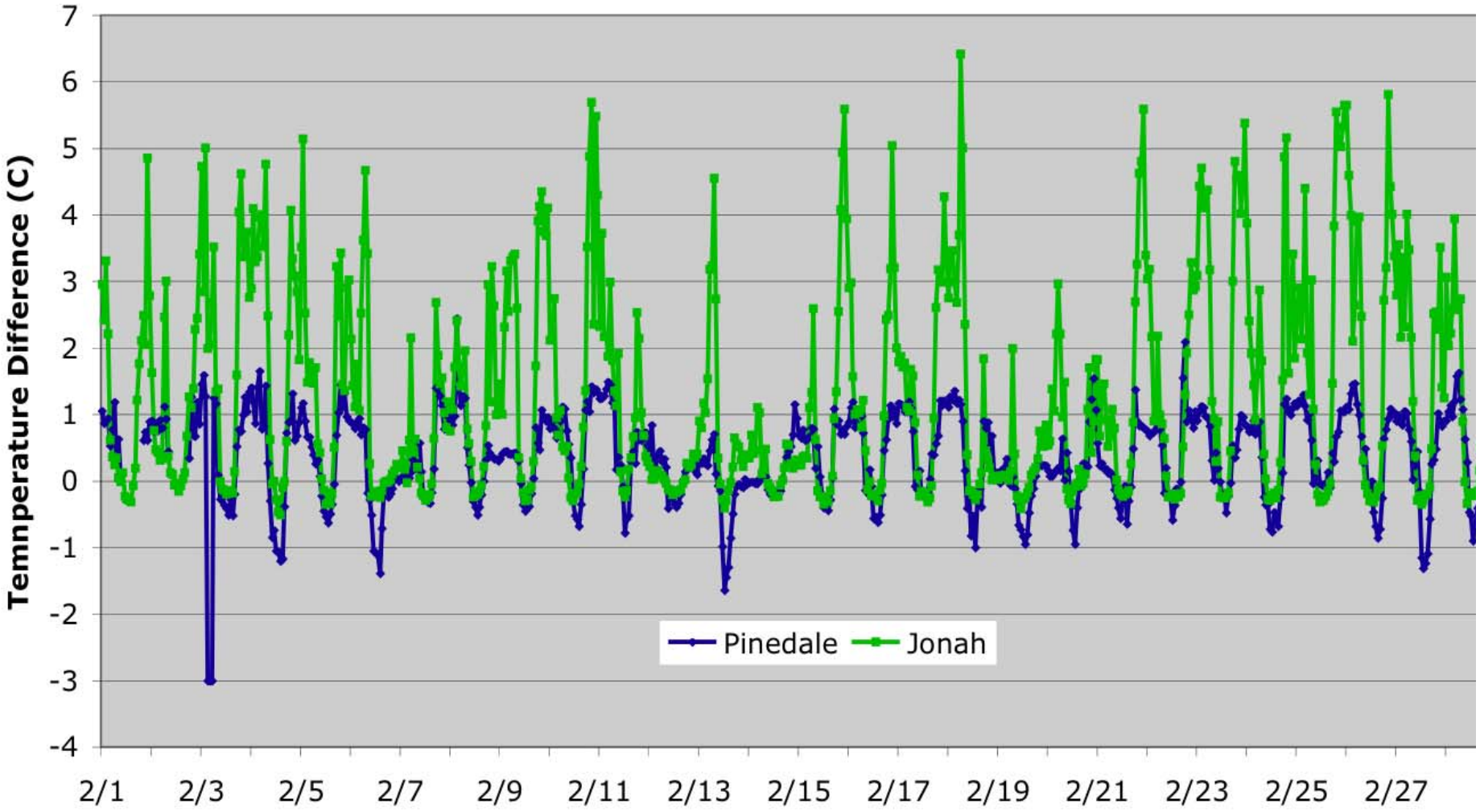

February 8, 2005, 0700 MST
LOW
40
1020
LOW
30
Ozone: 57 ppb at mid-day.

Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 3, 2005

Elevated Ozone Period: 120 ppb mid-day.

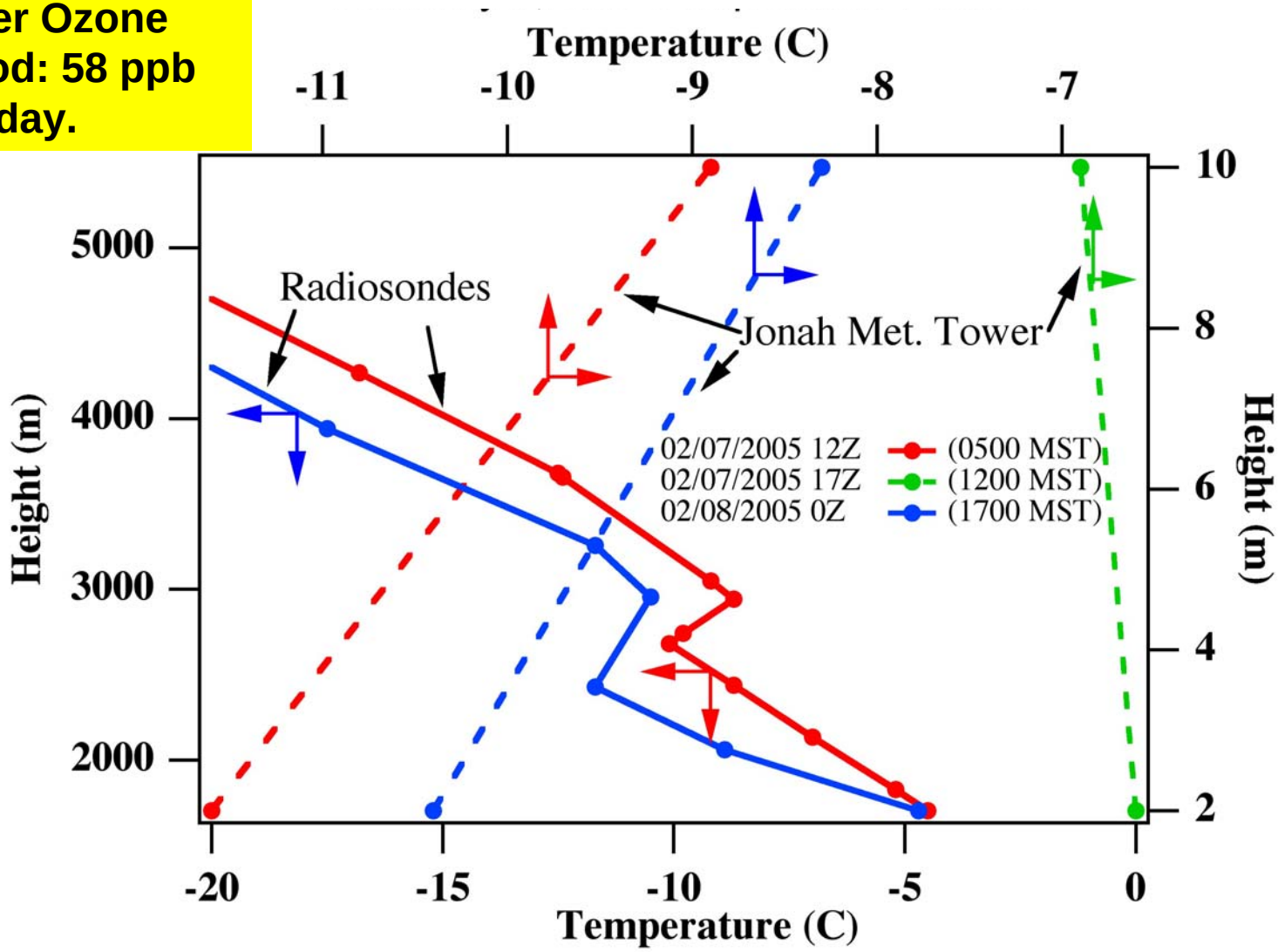


Temperature Difference Between 2m and 10m Levels: Larger Numbers Indicate Stronger Low Level Inversion

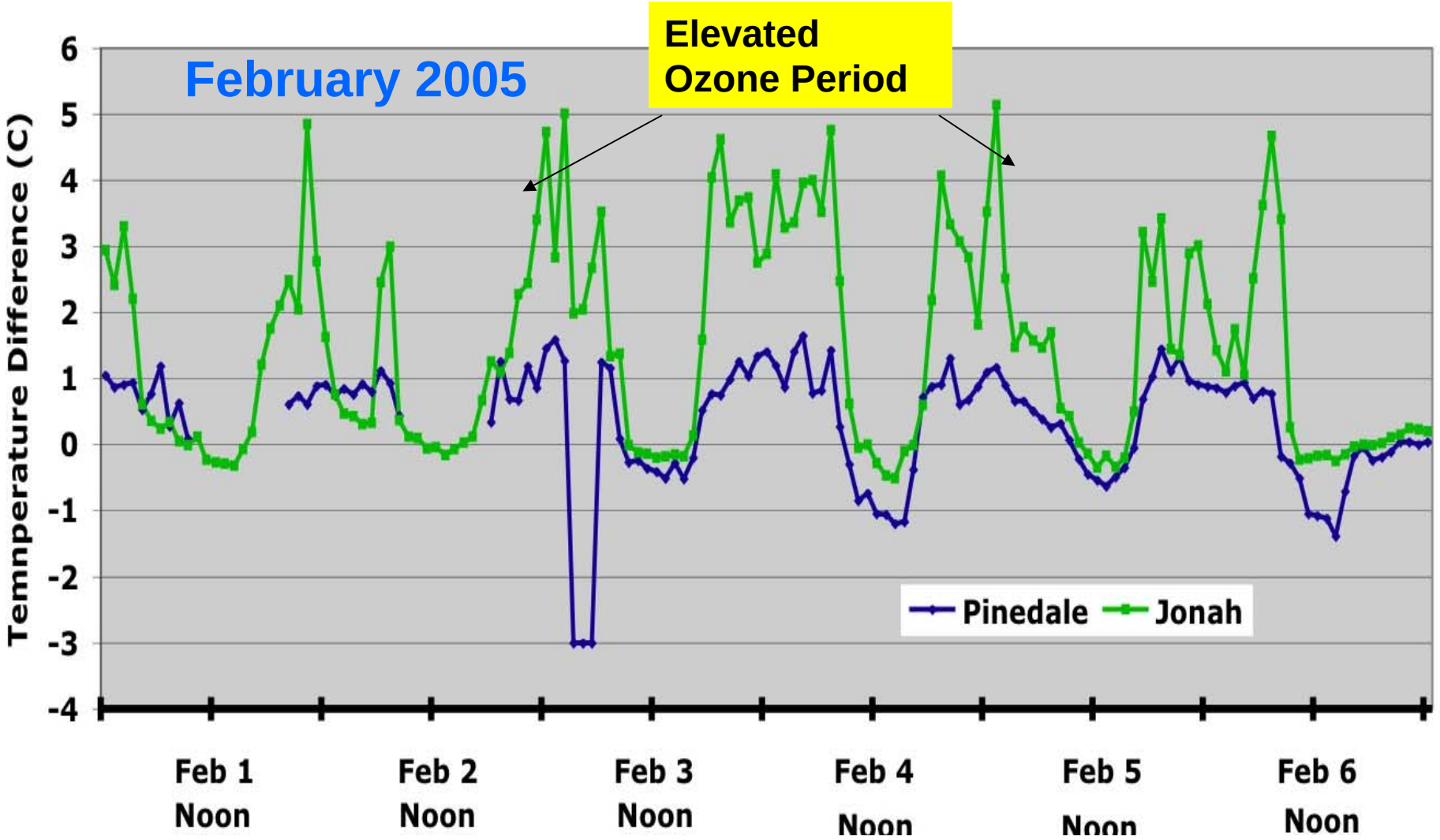


Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 7, 2005

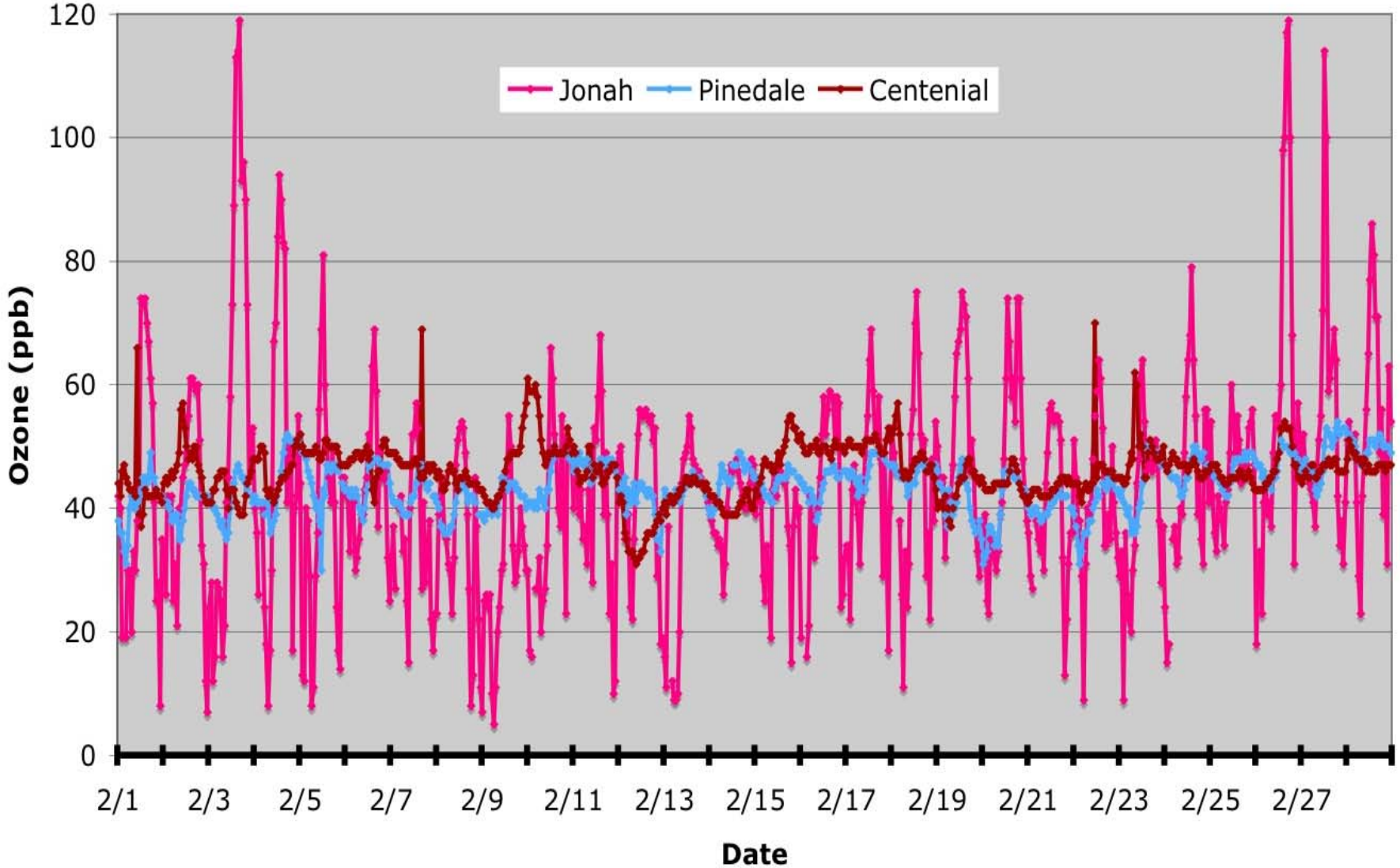
Lower Ozone Period: 58 ppb mid-day.



Temperature Difference Between 2m and 10m: Larger Numbers Indicate Stronger Low Level Inversion



Ozone, February 2005, Jonah, Centenial, and Pinedale

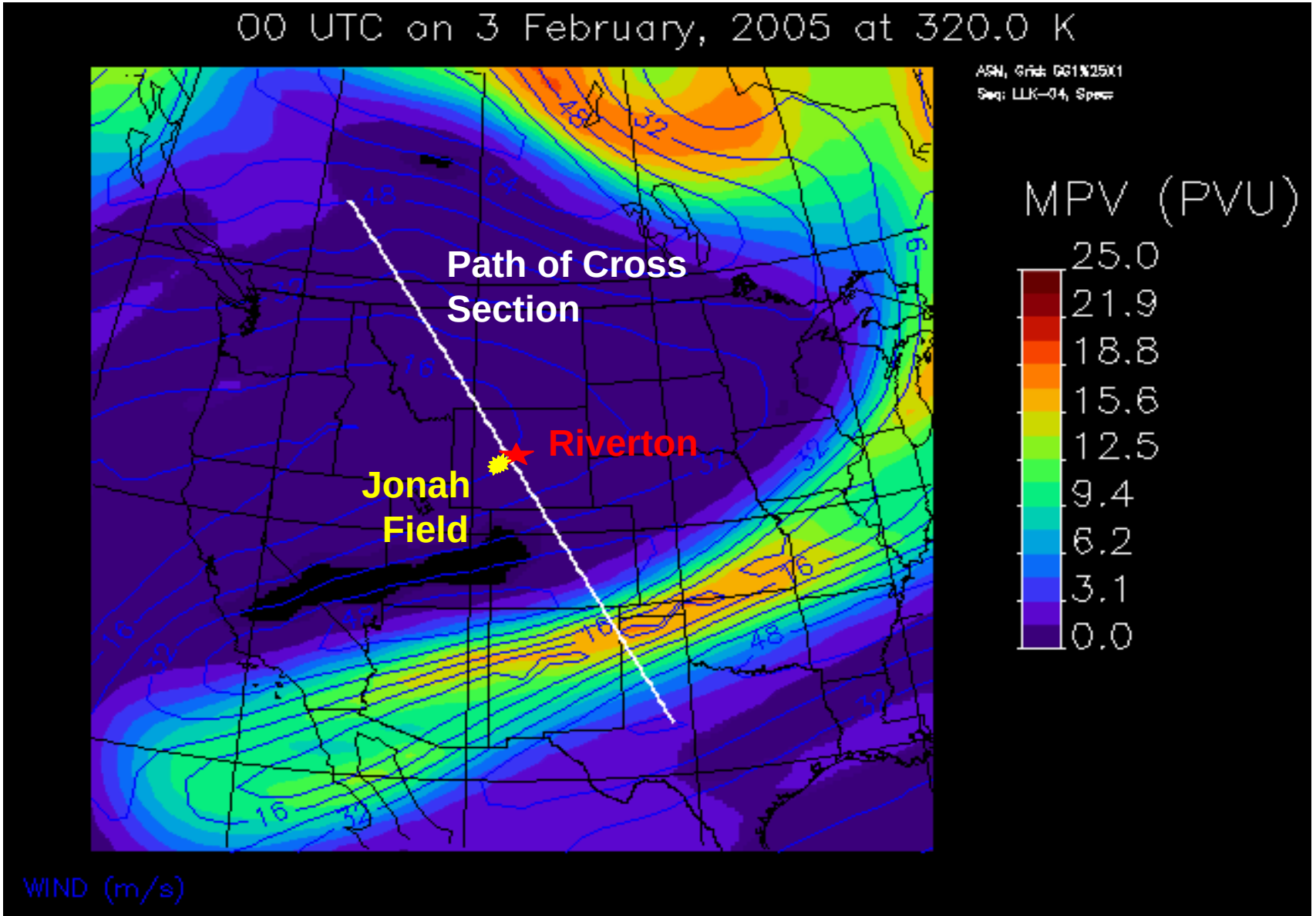


Photos from 02/27/05 at 12:00

Elevated Ozone Period

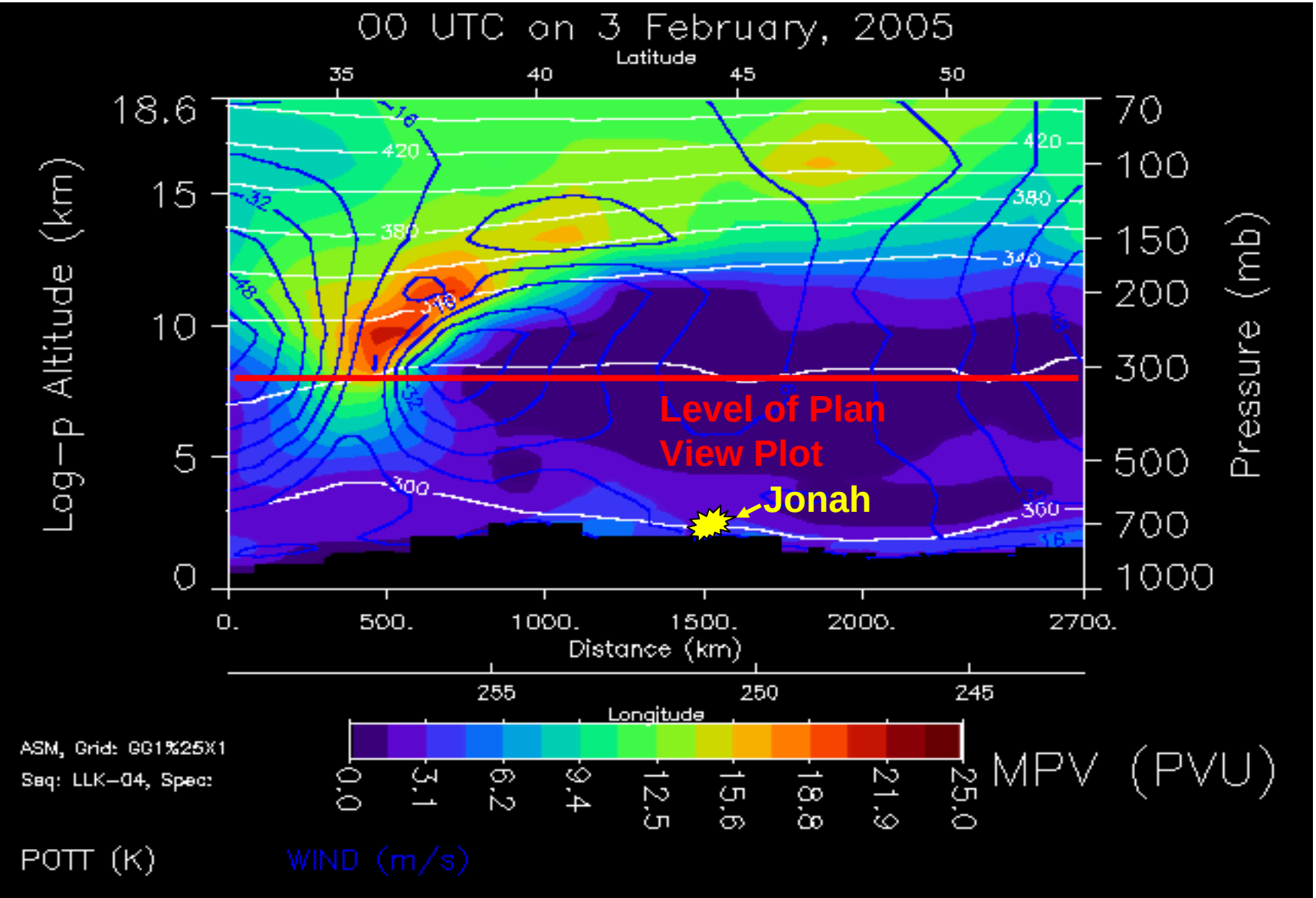
Stratospheric Vorticity Over Wyoming, Feb 3, 2005

Yellow through red is greater stratospheric intrusion. Purple is no intrusion.

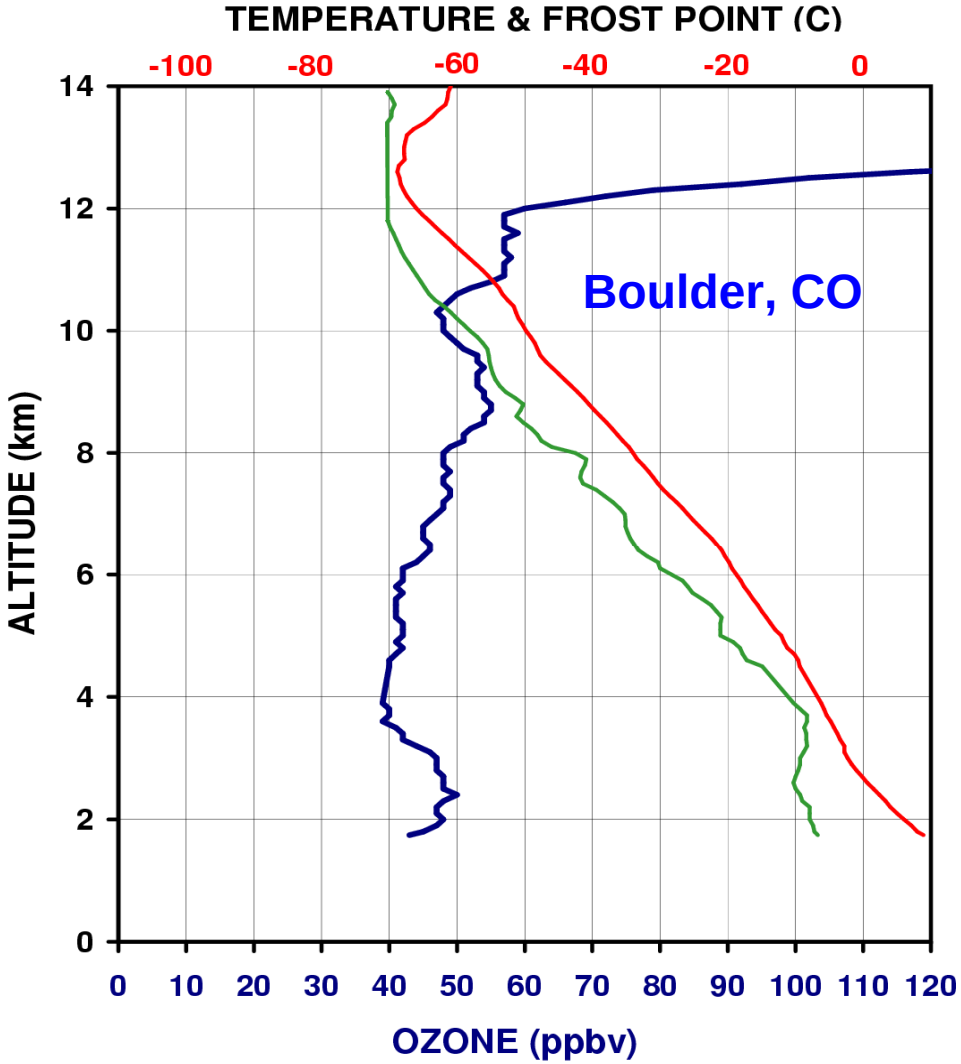


Stratospheric Vorticity Over Wyoming, Feb 3, 2005

Yellow/red is stratospheric air intrusion. Purple-blue is no intrusion.



Ozone, Temperature and Frost Point Vertical Profiles, February 3, 2005, 1200 MST

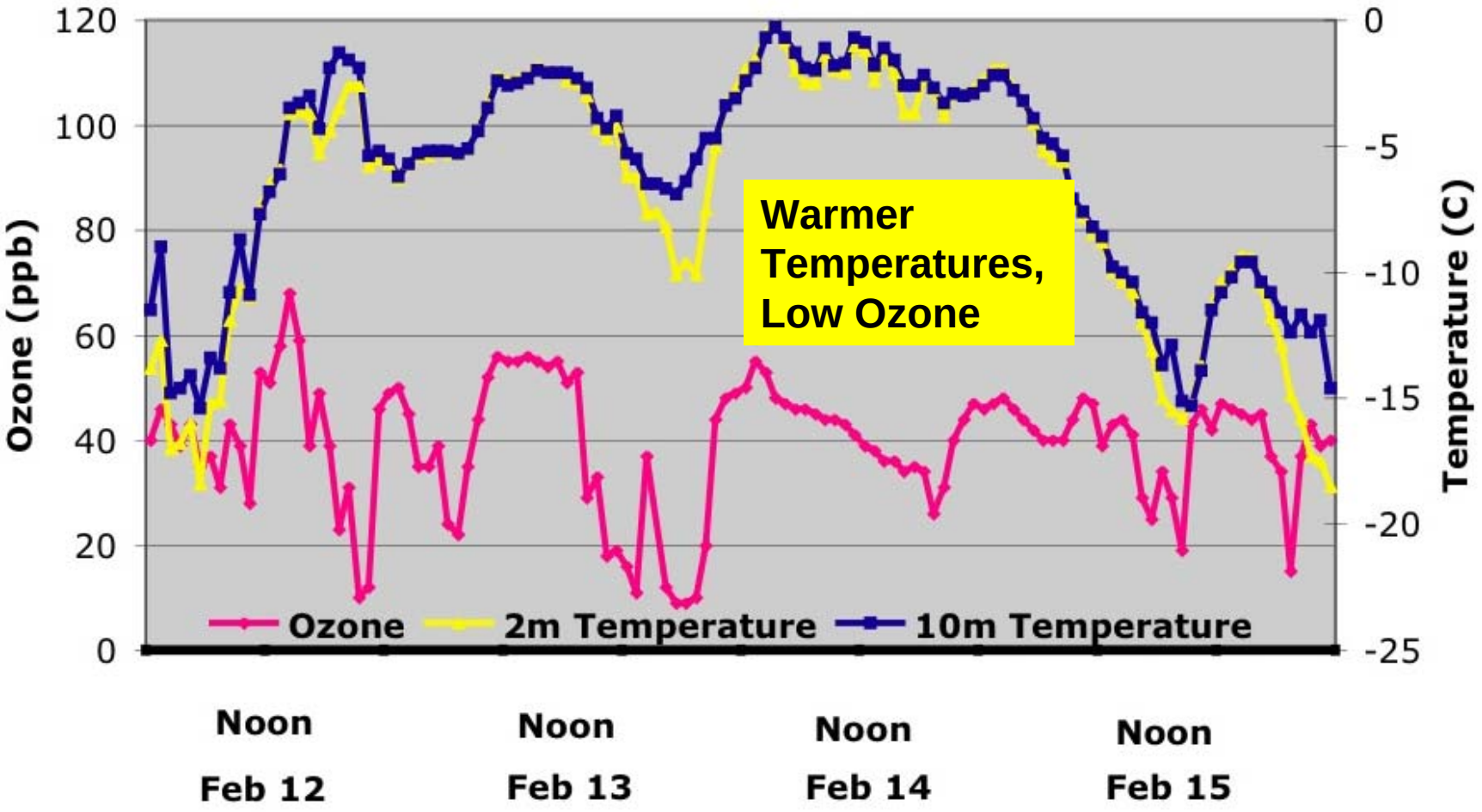


No evidence of a stratospheric fold event bringing ozone into the troposphere.

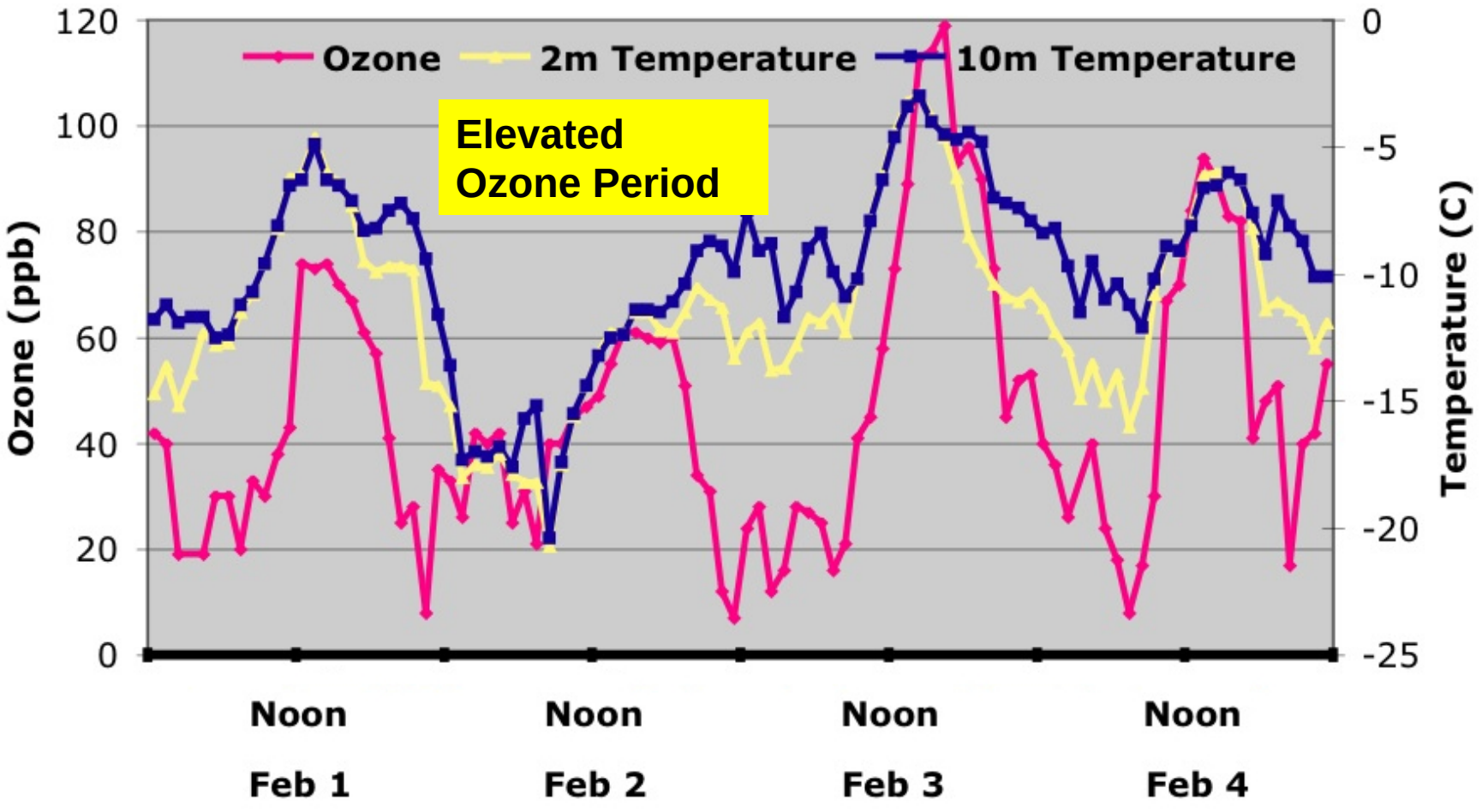
Prediction Of Ozone Events Based On Meteorology and Inversions

- 3 Days Prior = 50 - 80% Accuracy?
- 1 Day Prior = 80 - 95% Accuracy?
- Day by 0700 MST = 95+% Accuracy?
- Duration of Ozone Event = 50-95% Accuracy ?

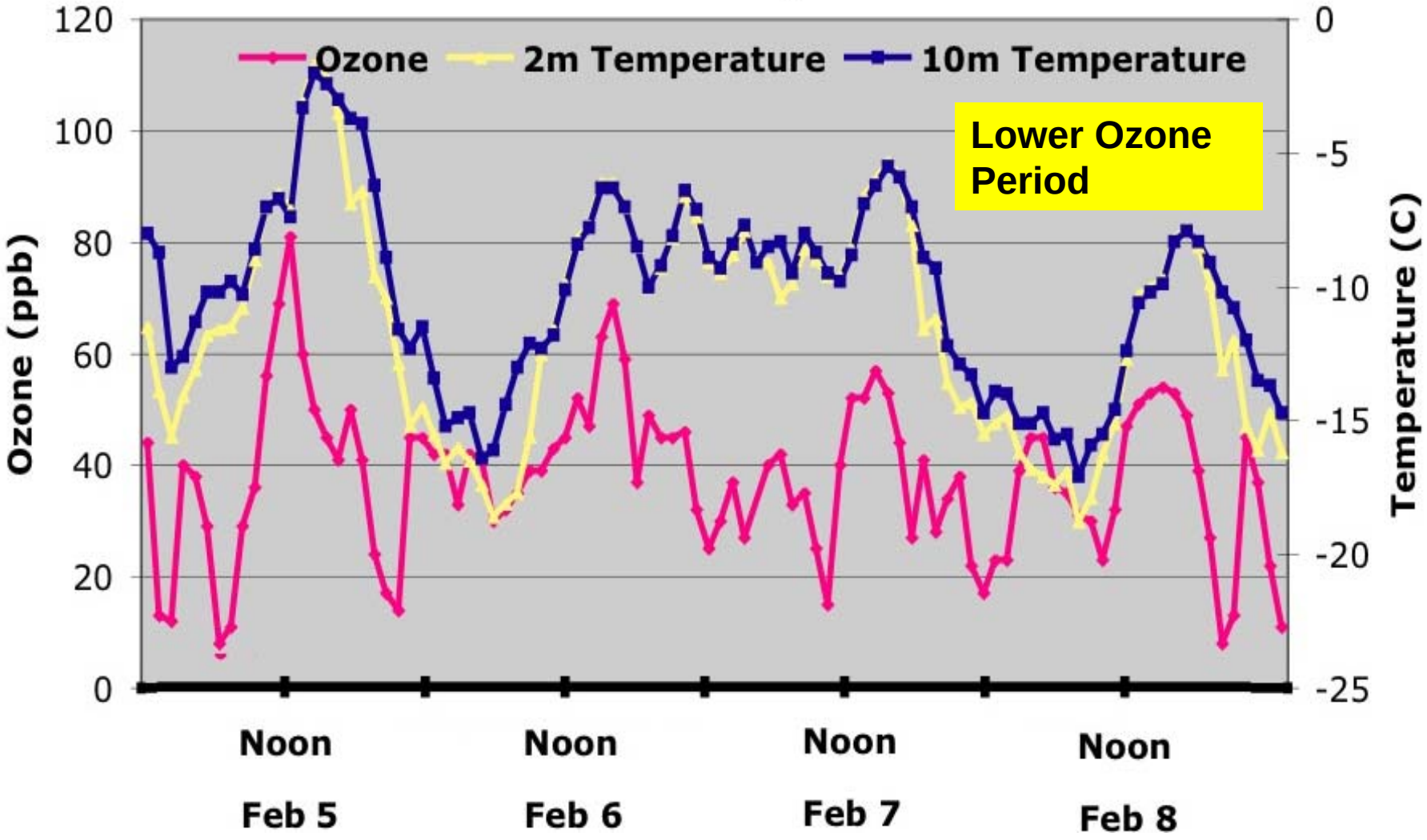
Ozone and Temperature, Jonah, February 12-15, 2005



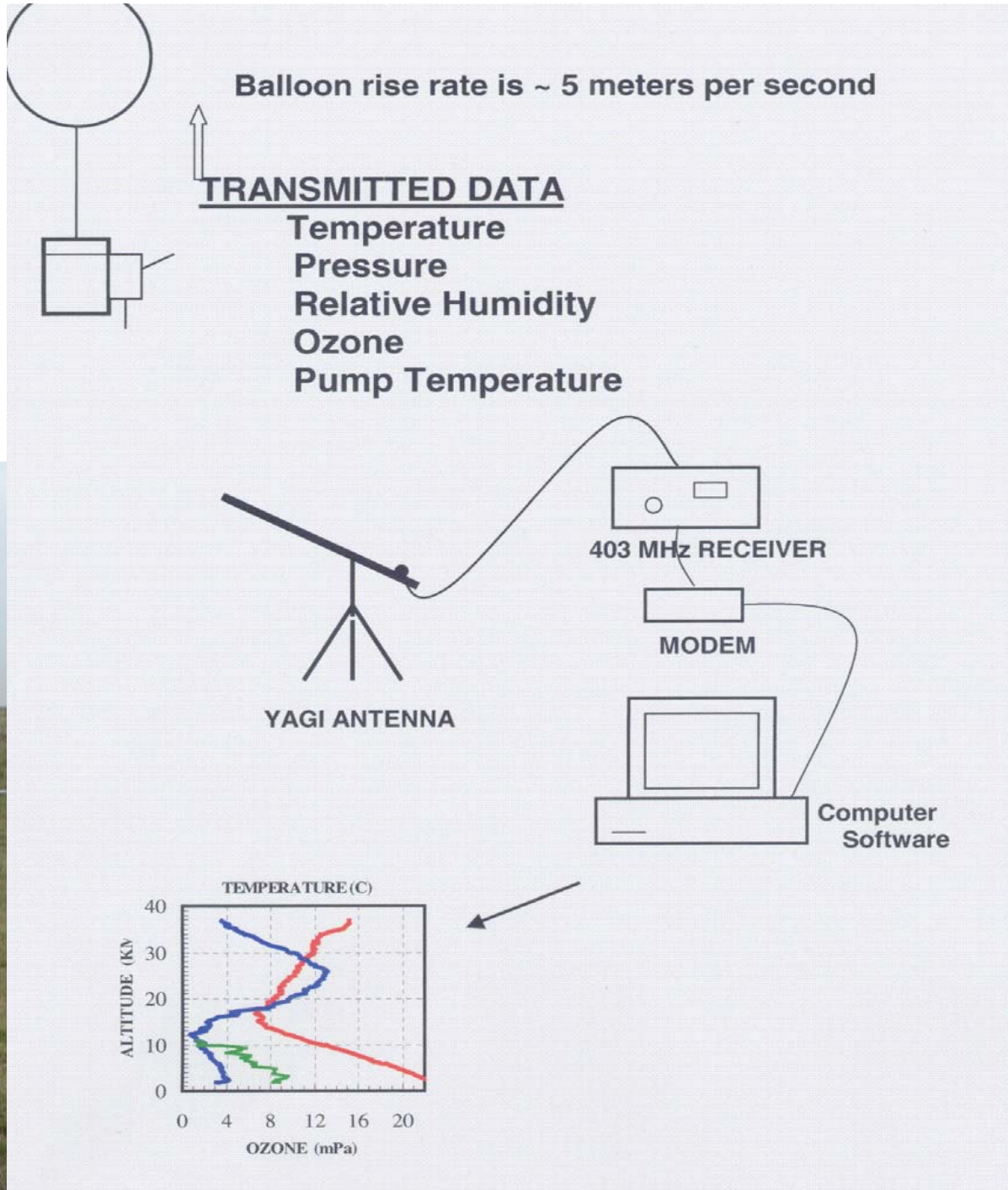
Ozone and Temperature, Jonah, February 1-4, 2005



Ozone and Temperature, Jonah, February 5-8, 2005

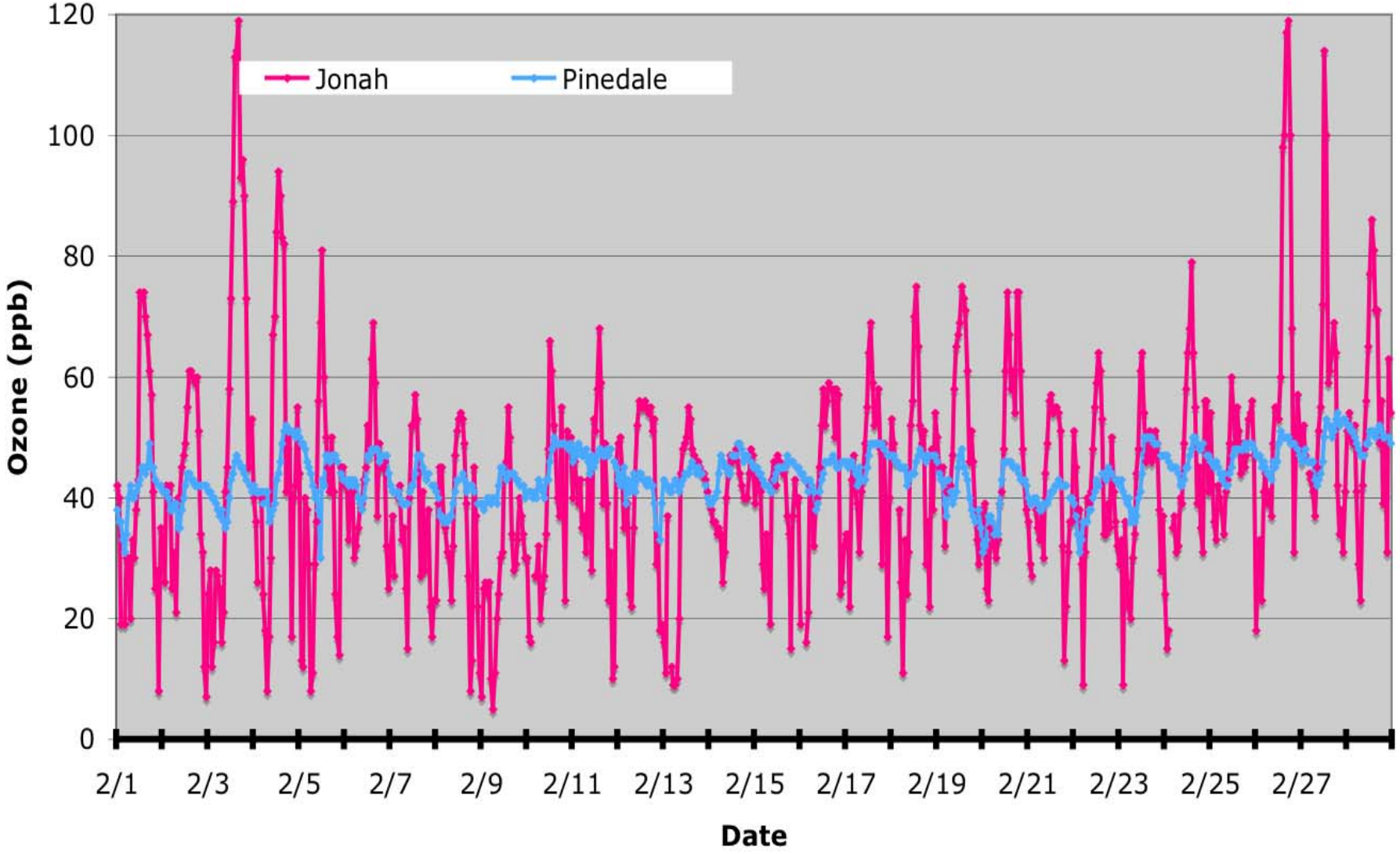


Ozonesonde Operational Schematic

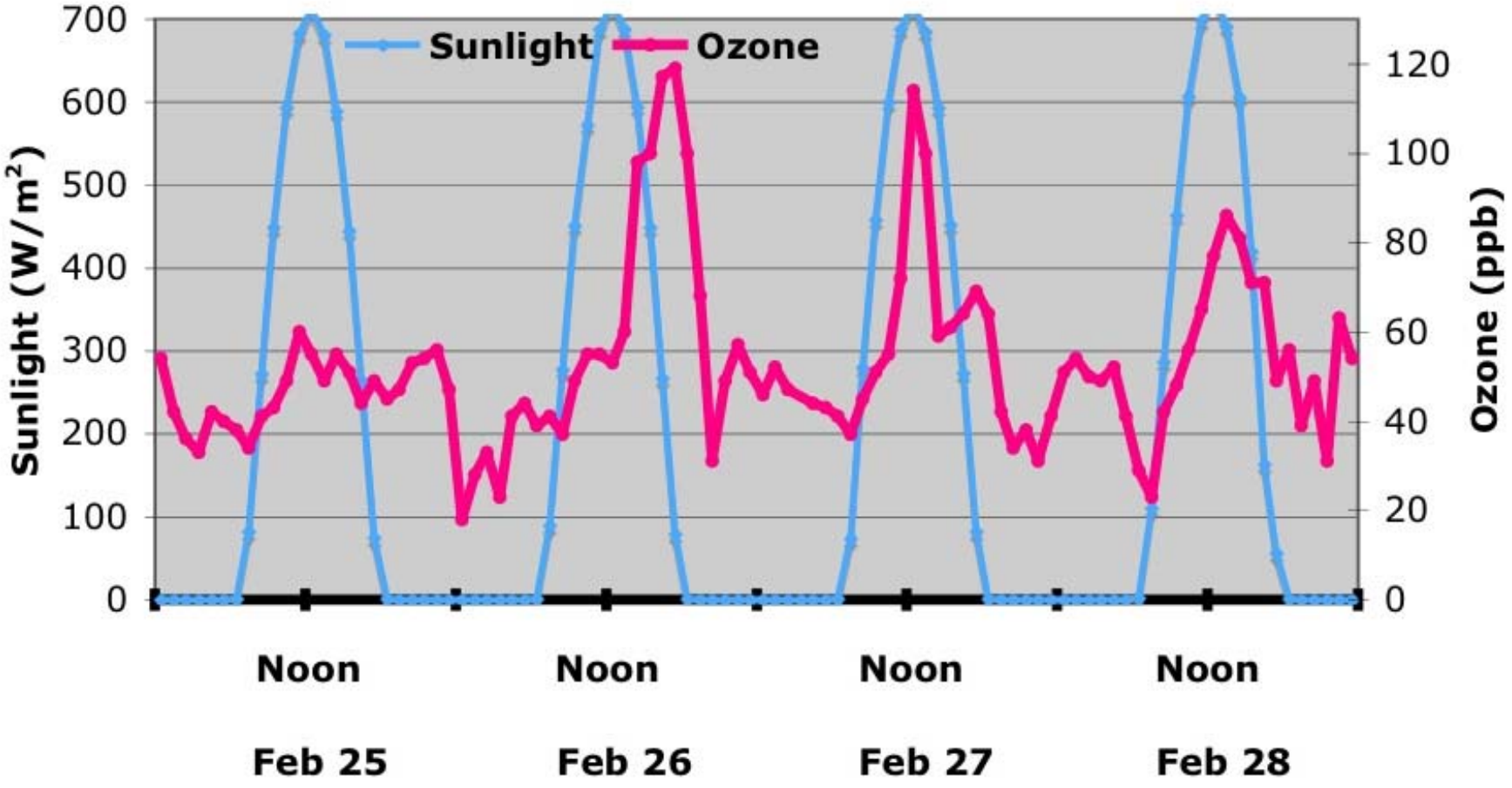


Tethersonde and Ozonesonde Operations

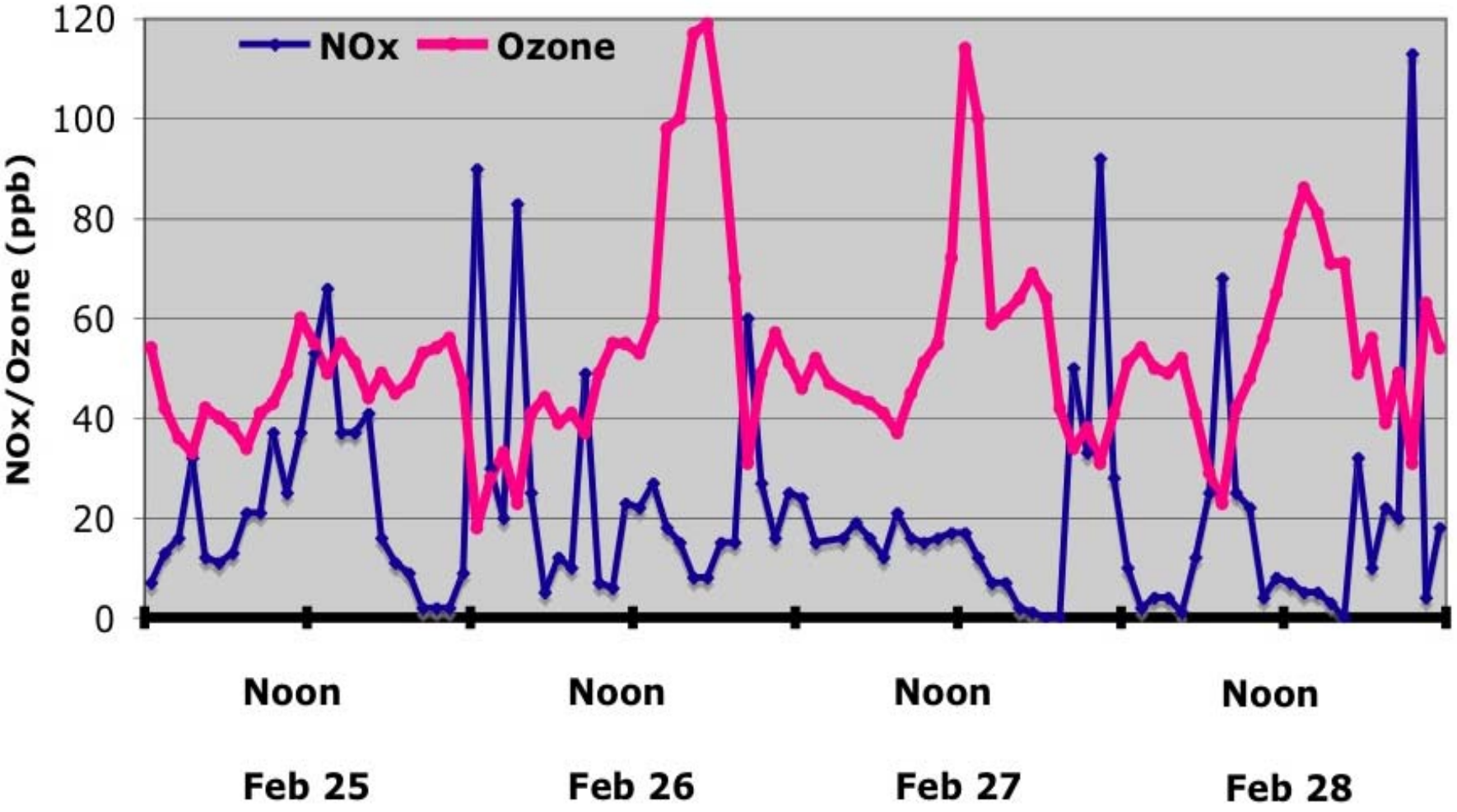
Ozone, February 2005, Jonah and Pinedale



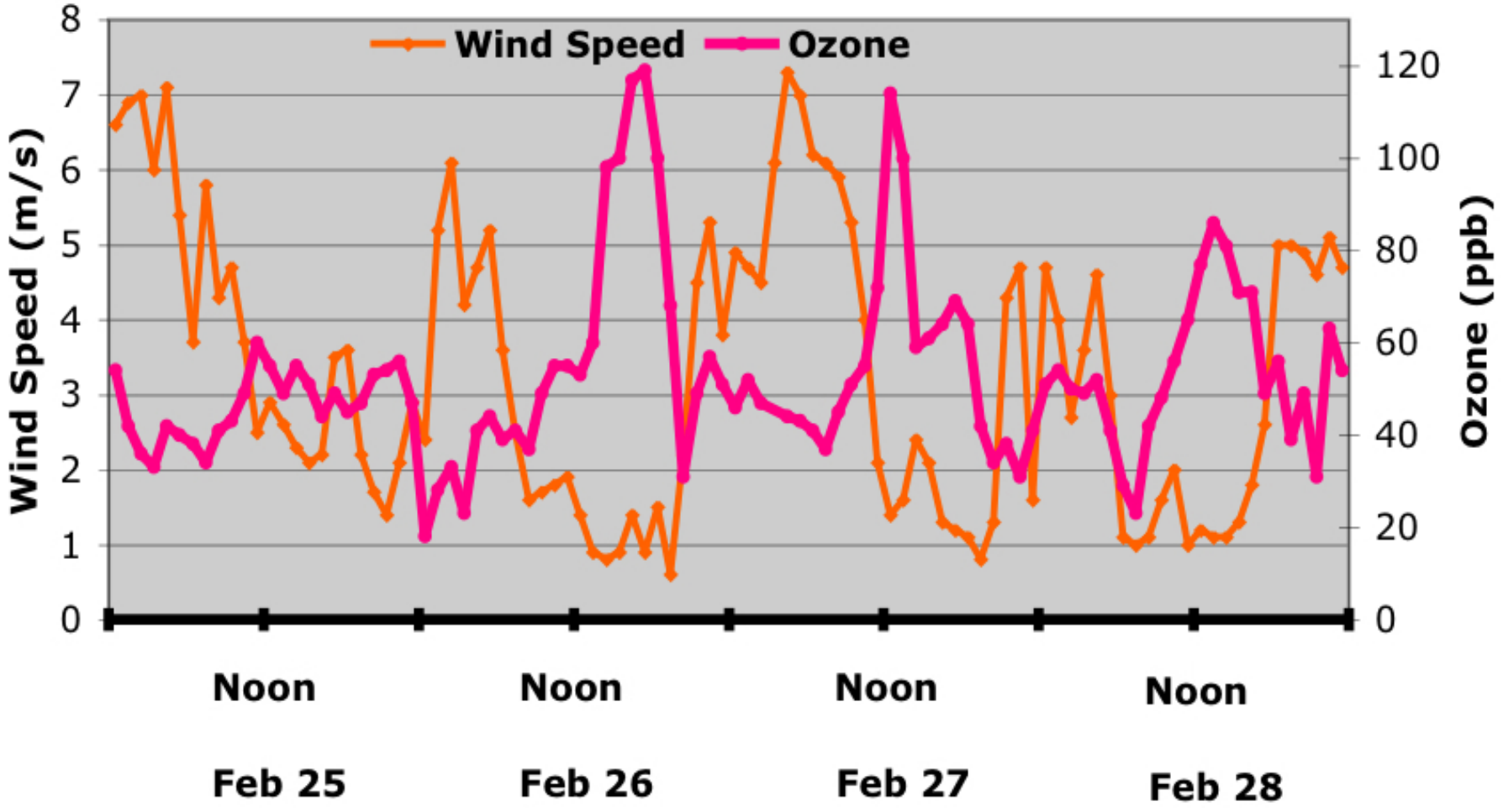
Solar Radiation and Ozone, Jonah, February 25-28, 2005

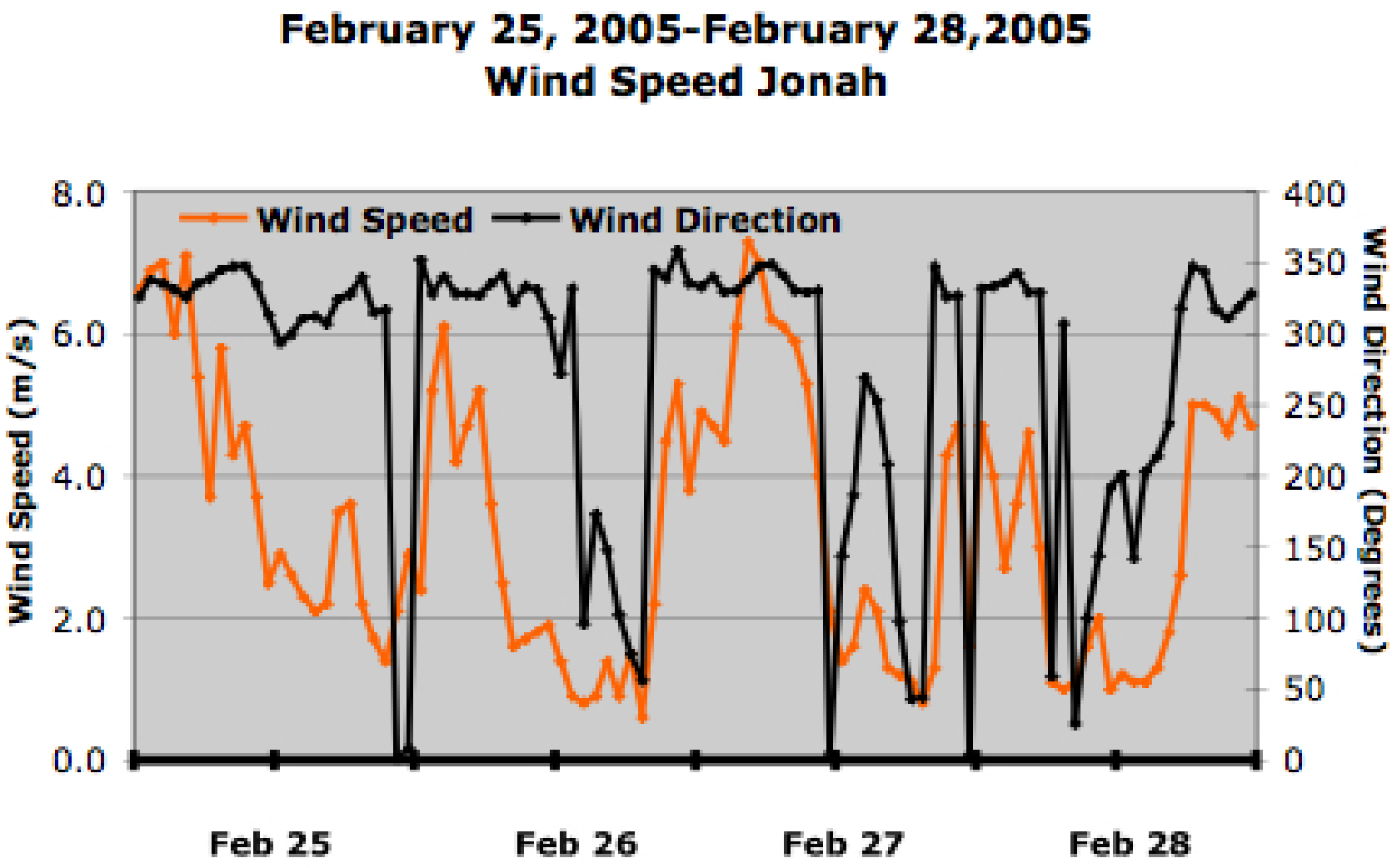


Ozone and NOx, Jonah, February 25-28, 2005



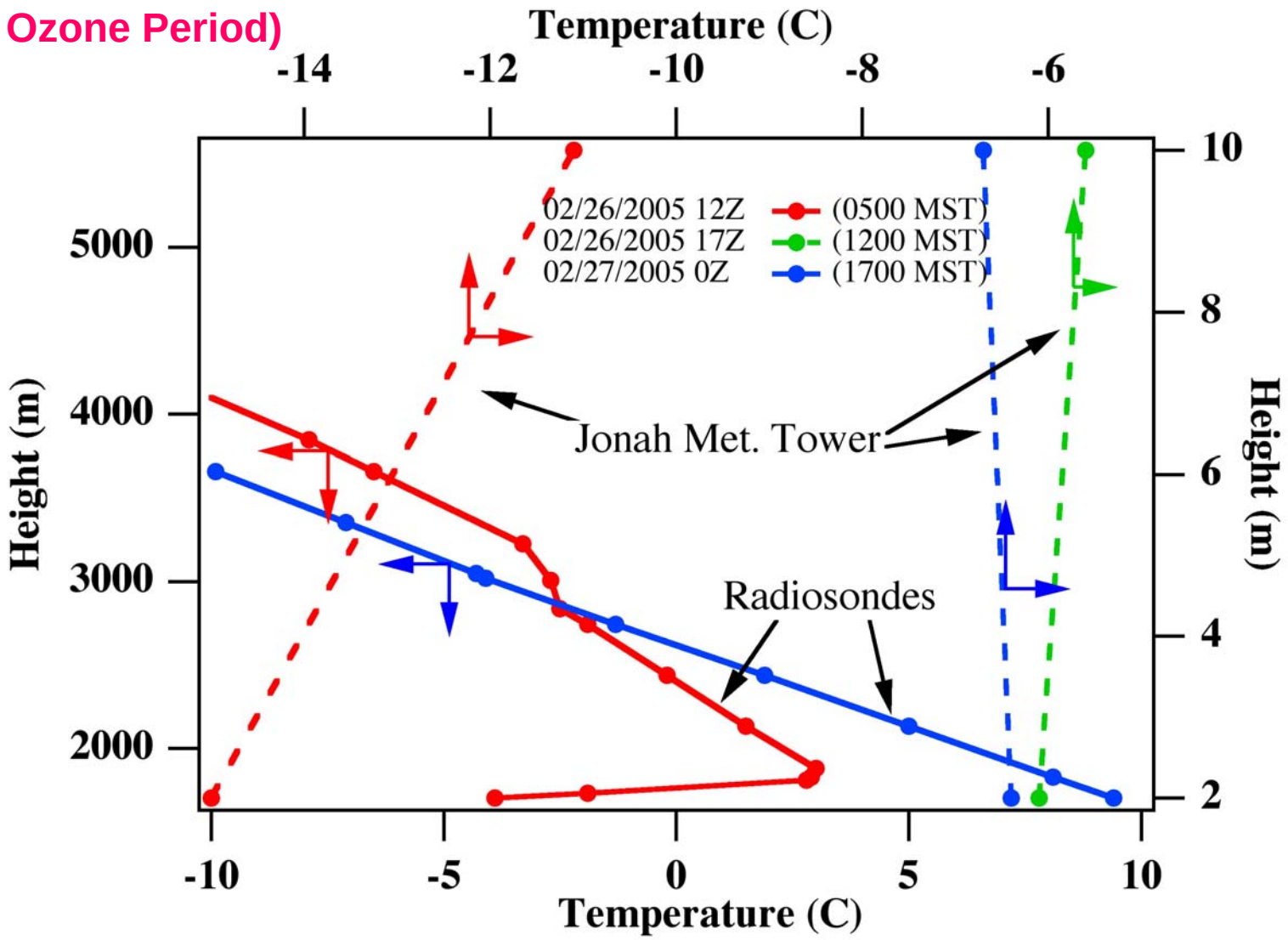
Ozone and Wind Speeds, Jonah, WY, Feb 25-28, 2005




February 25, 2005-February 28,2005
Wind Speed Jonah
Wind Speed
Wind Direction
Wind Speed (m/s)
Wind Direction (Degrees)
8.0
6.0
4.0
2.0
0.0
400
350
300
250
200
150
100
50
0
Feb 25
Feb 26
Feb 27
Feb 28

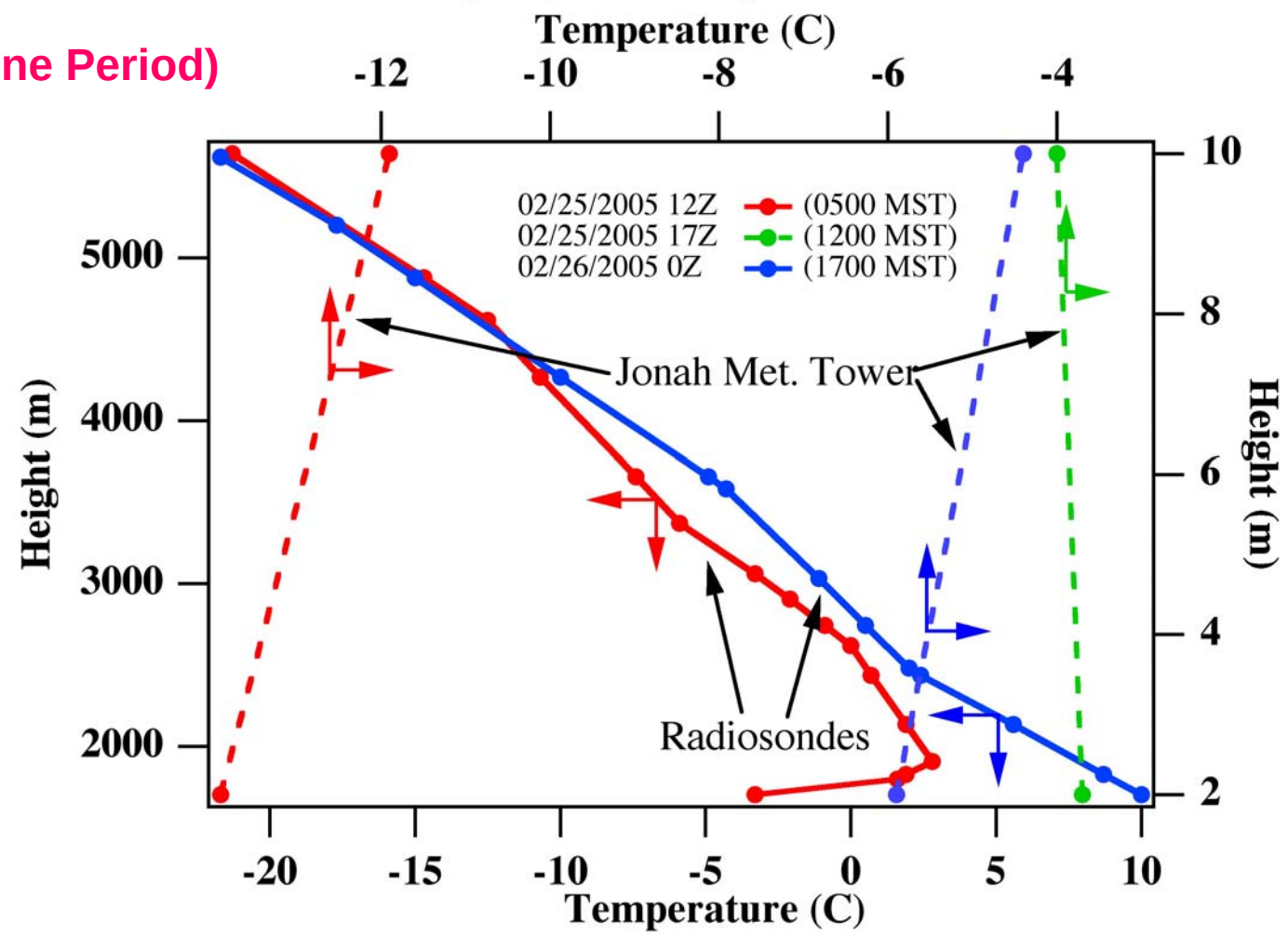
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 26, 2005

(Higher Ozone Period)

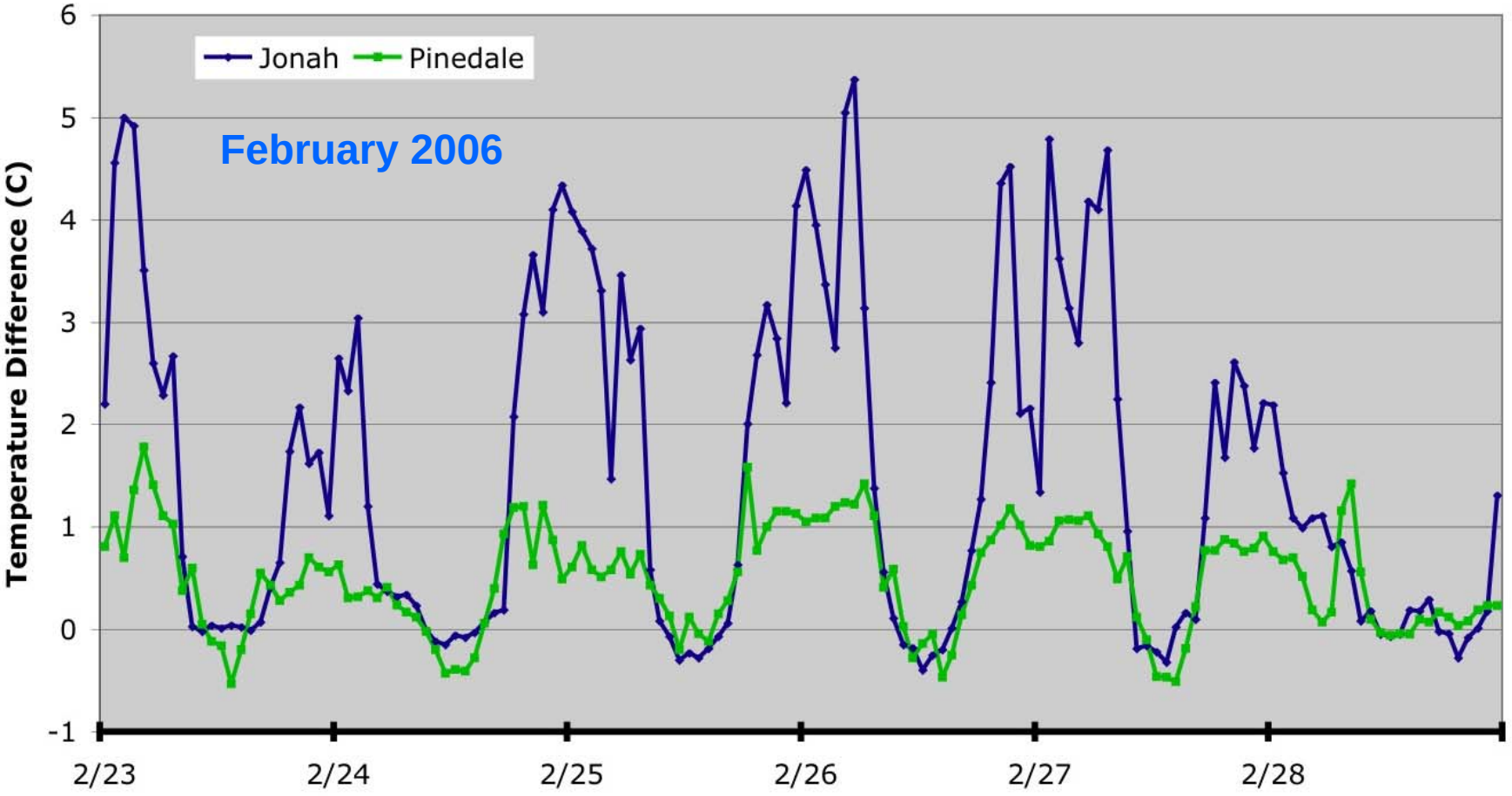


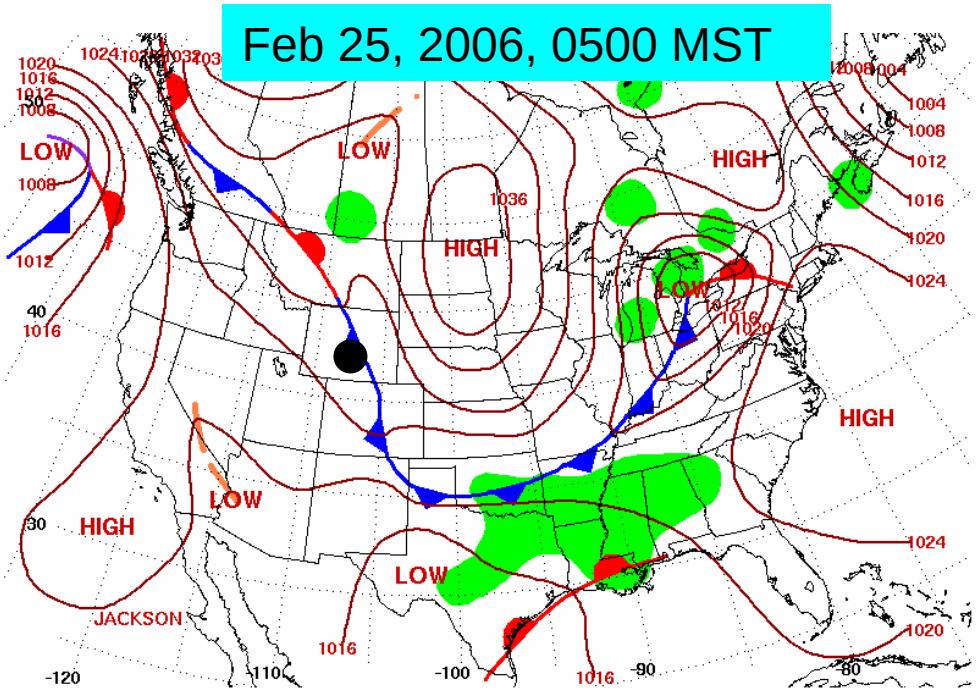
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 25, 2005

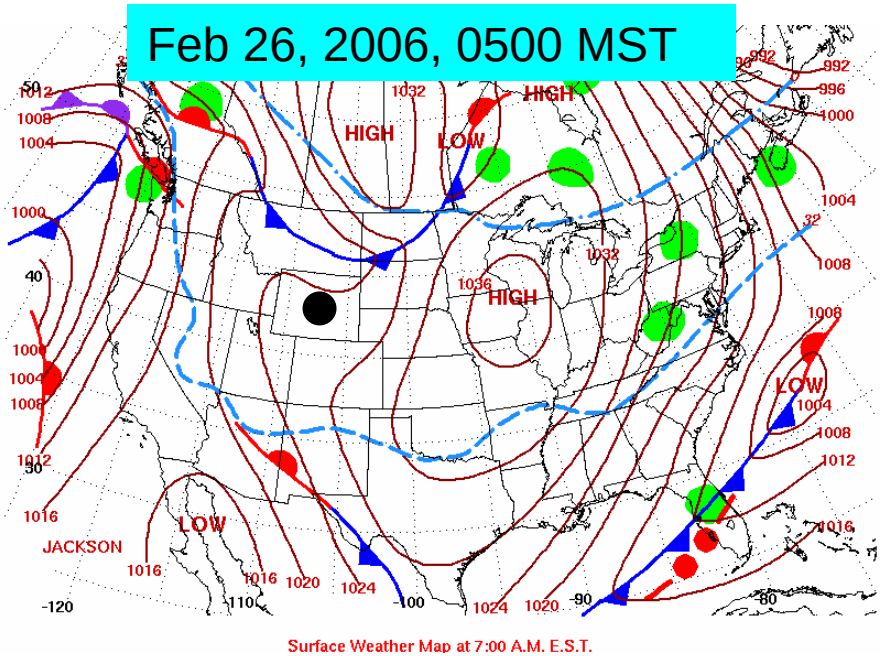
(Lower Ozone Period)

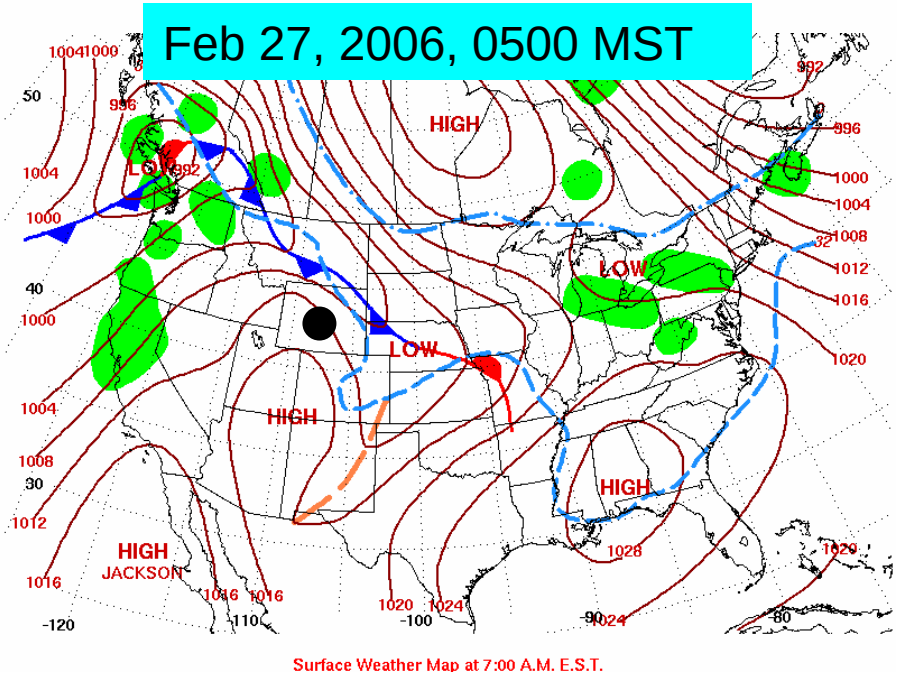


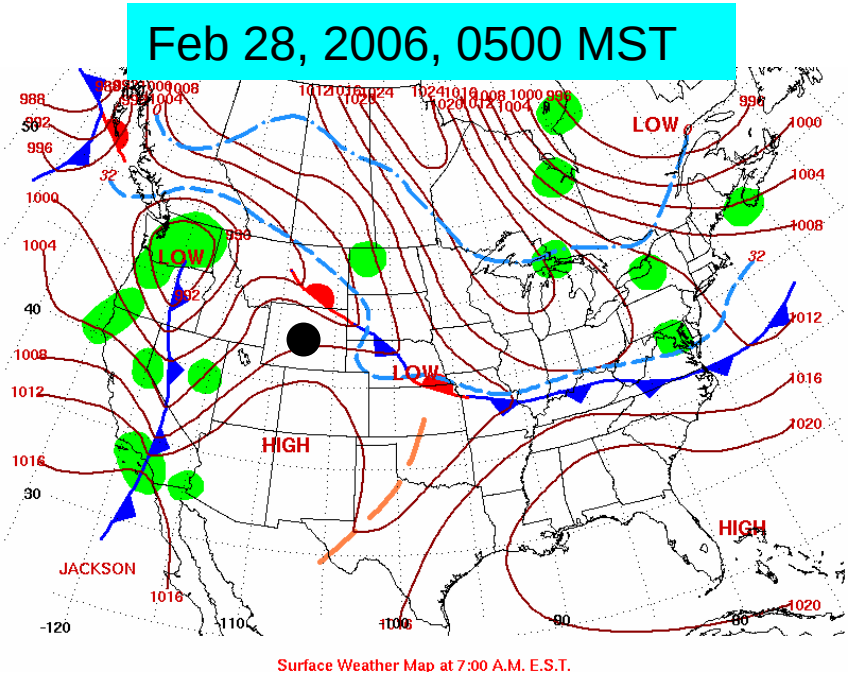
Temperature Difference Between 2m and 10m: Larger Numbers Indicate Stronger Low Level Inversion




Feb 25, 2006, 0500 MST
LOW
HIGH
LOW
HIGH
LOW
HIGH
LOW
HIGH
LOW
JACKSON

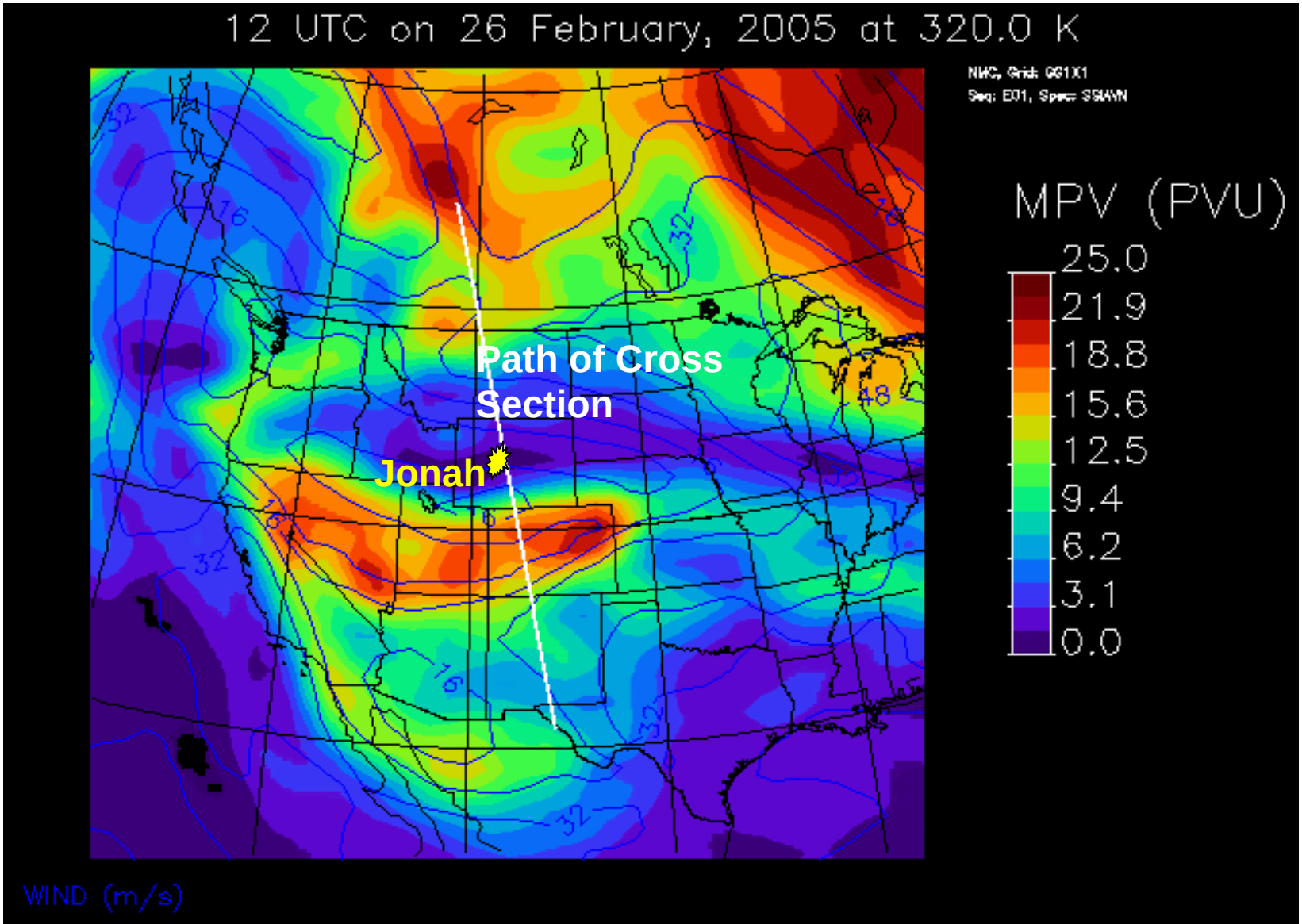

Feb 26, 2006, 0500 MST
HIGH
HIGH
LOW
HIGH
LOW
LOW
JACKSON
Surface Weather Map at 7:00 A.M. E.S.T.


Feb 27, 2006, 0500 MST
HIGH
LOW
LOW
LOW
HIGH
HIGH
HIGH
JACKSON
Surface Weather Map at 7:00 A.M. E.S.T.


Feb 28, 2006, 0500 MST
LOW
LOW
LOW
HIGH
HIGH
JACKSON
Surface Weather Map at 7:00 A.M. E.S.T.

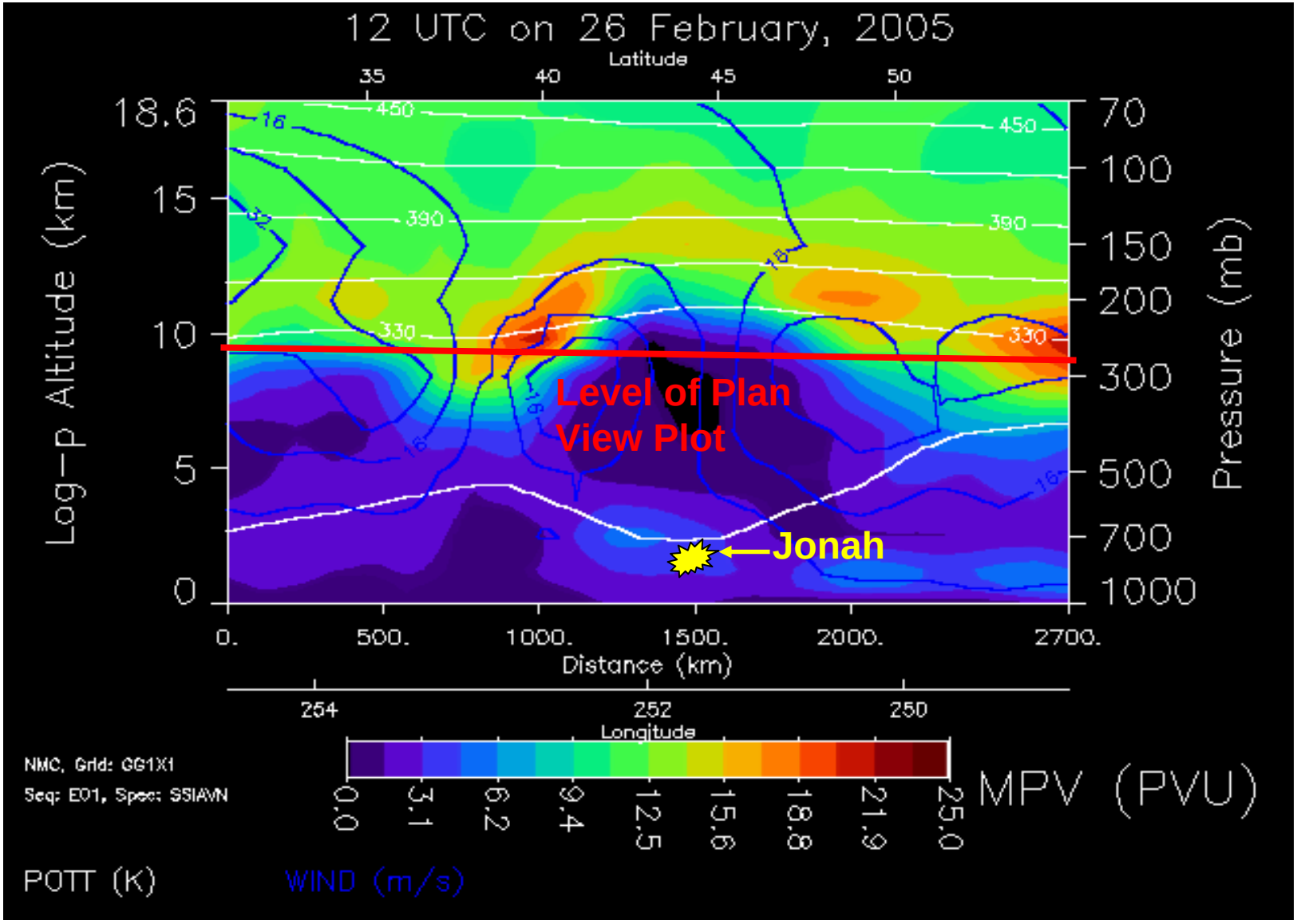
Stratospheric Vorticity Over Wyoming

Yellow through red is stratospheric air intrusion. Purple/blue is no intrusion.

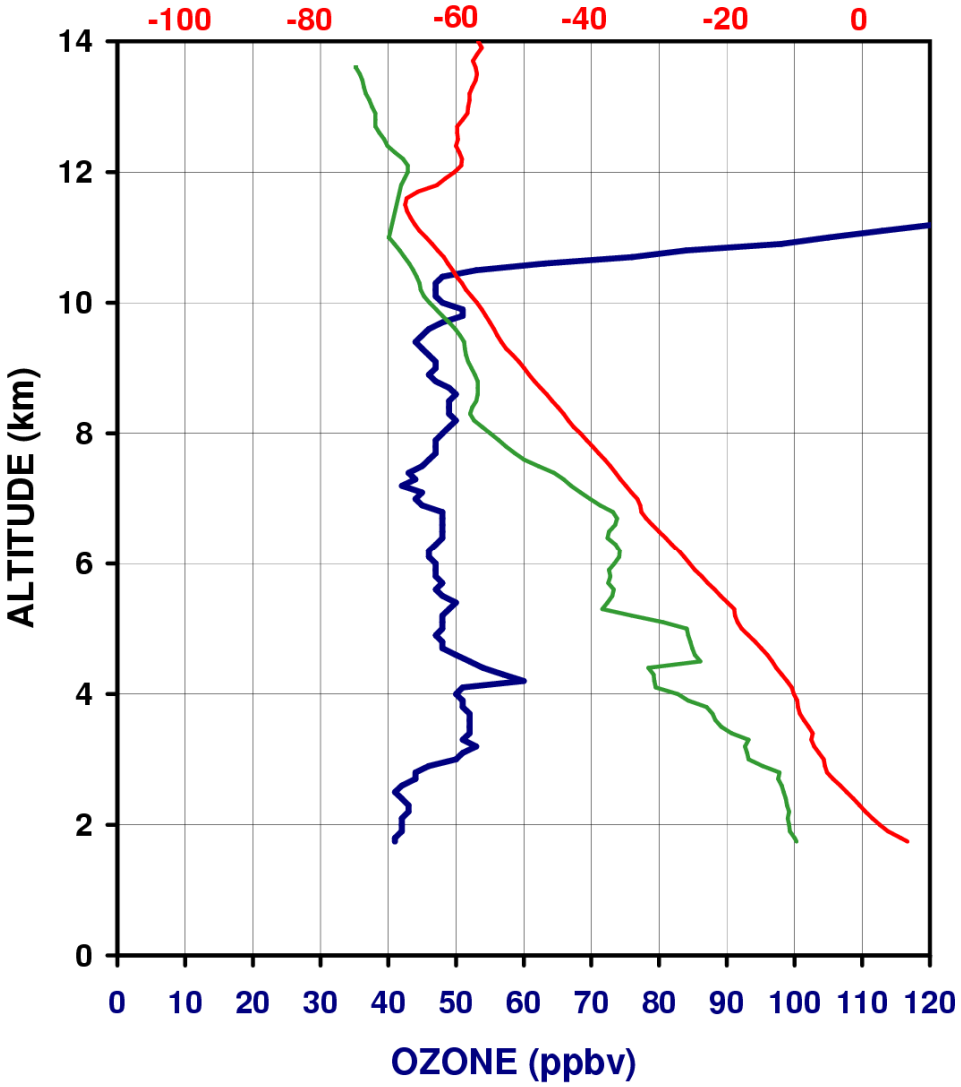


Stratospheric Vorticity Over Wyoming, Feb 26, 2005

Yellow through red is stratospheric air intrusion. Purple/blue is no intrusion.

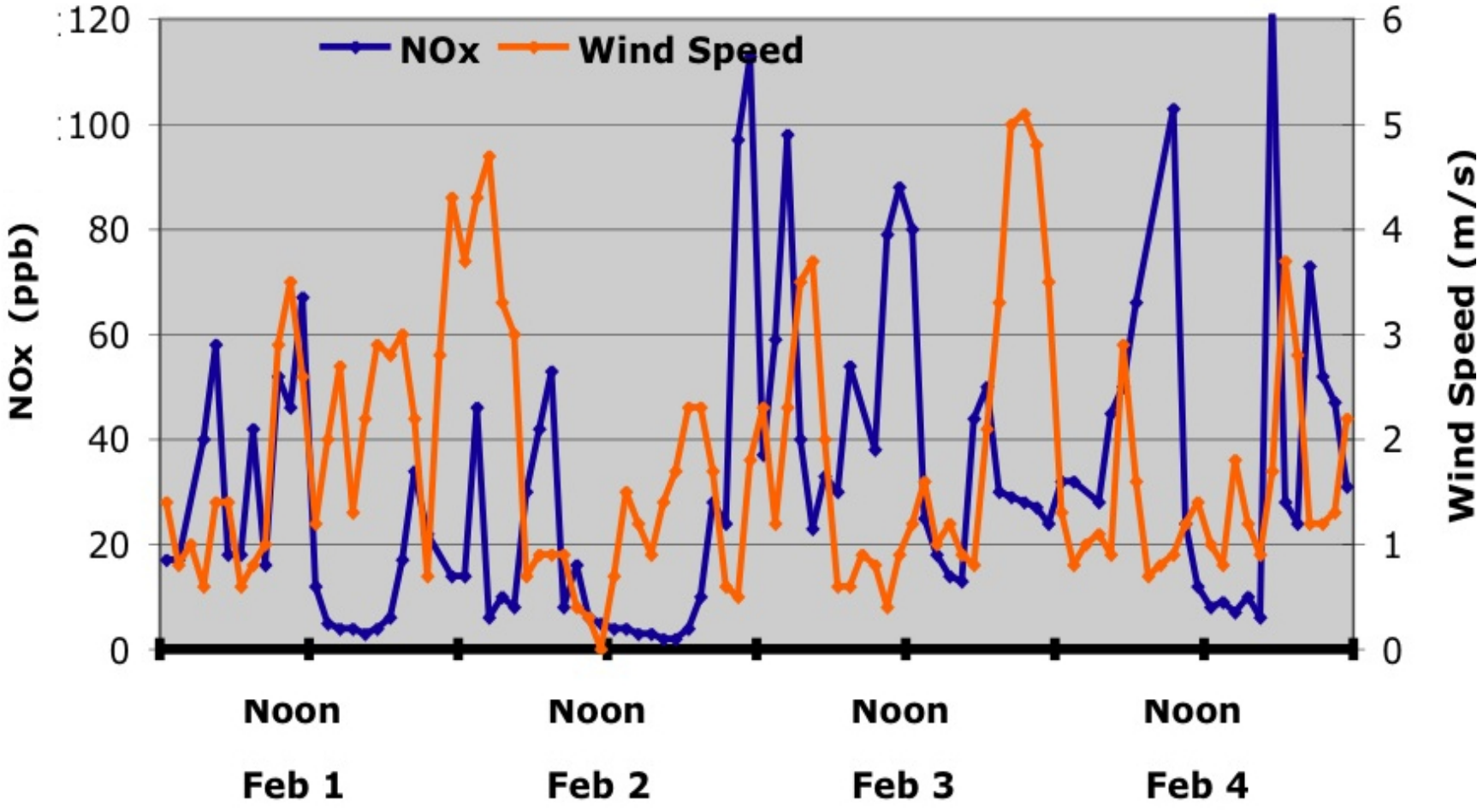


Ozone, Temperature and Frost Point Vertical Profiles, Boulder, CO February 24, 2005, 1200 MST

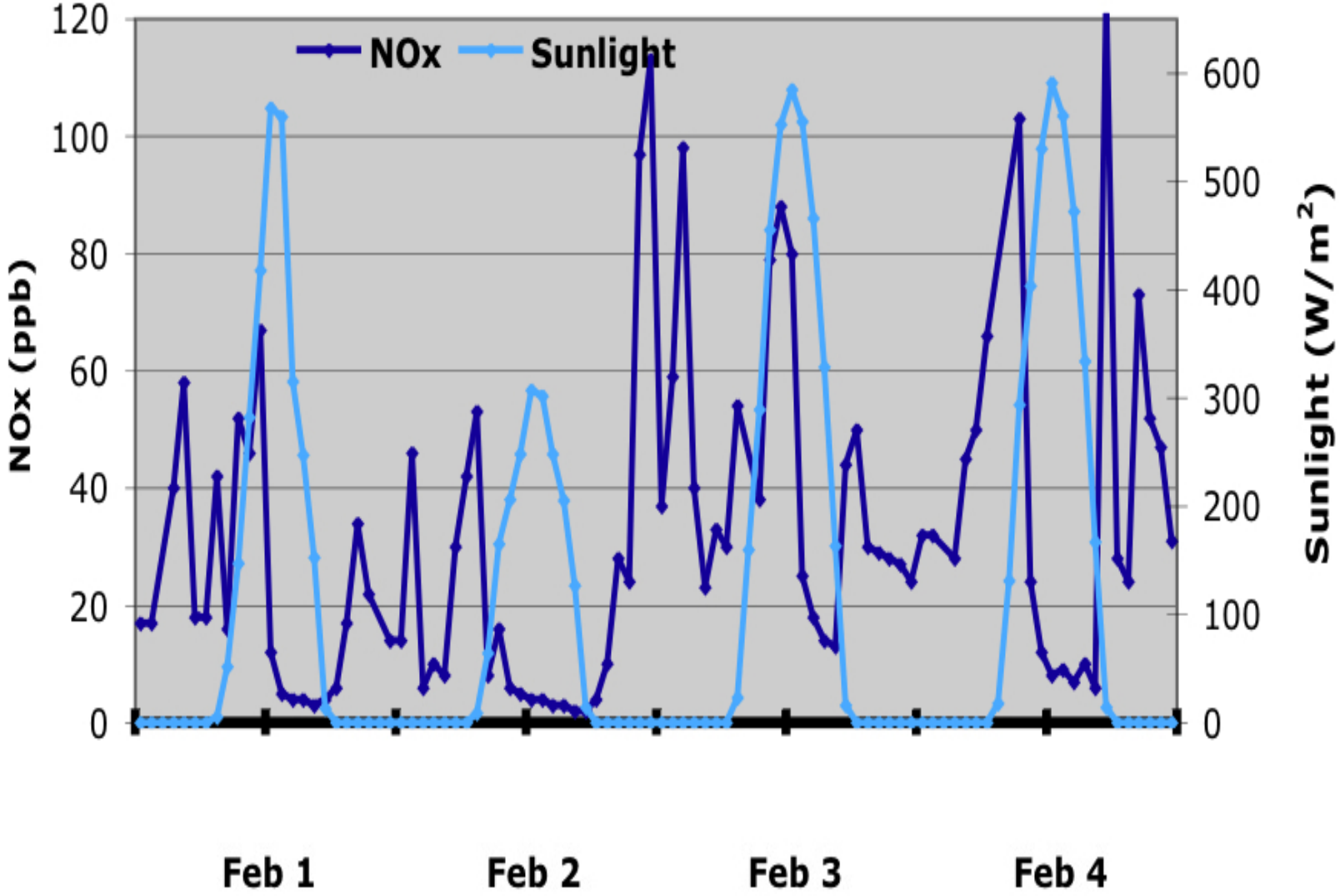


No evidence of a stratospheric fold event bringing ozone into the troposphere.

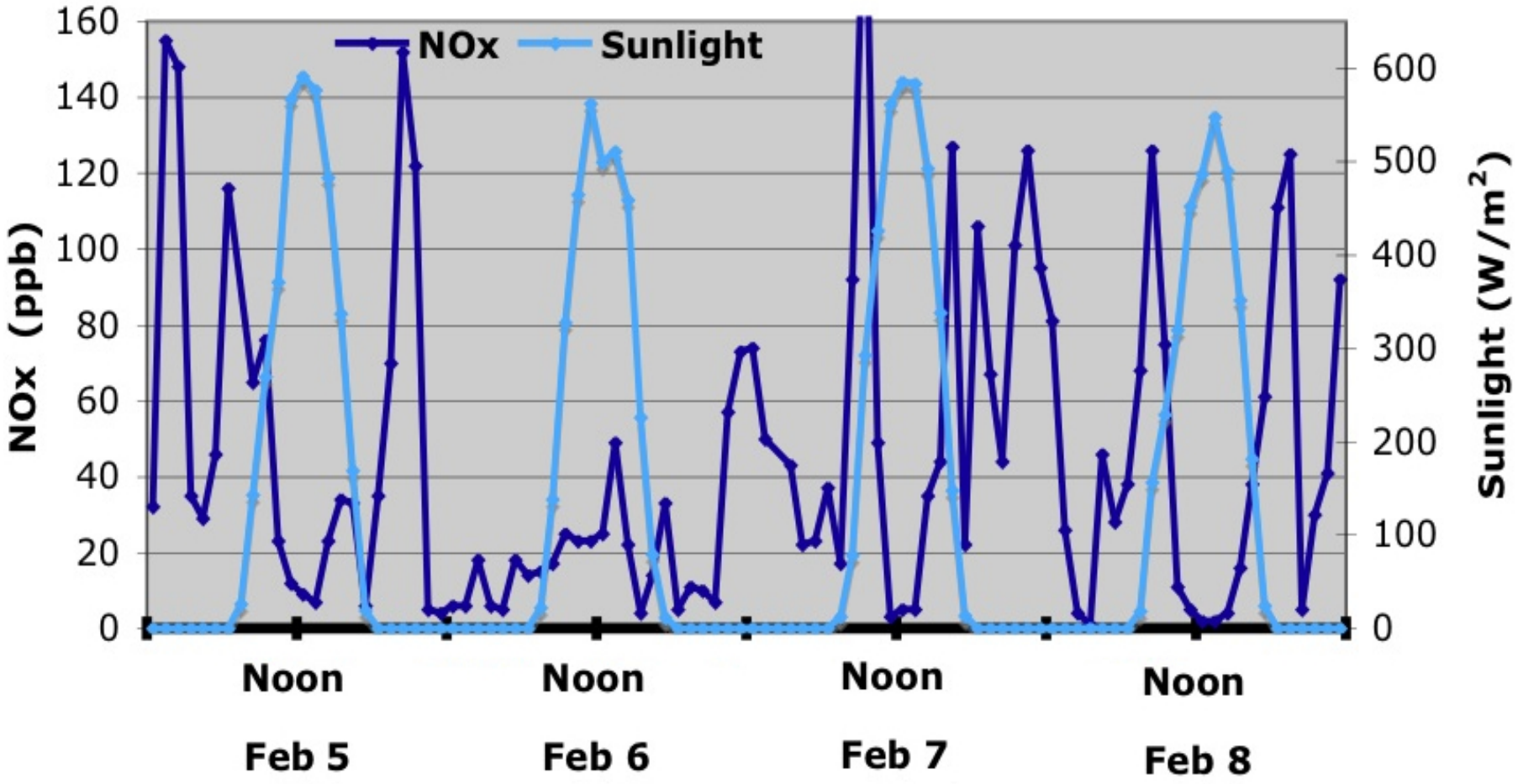
Wind Speeds and NOx, Jonah, WY, Feb 1-4, 2005



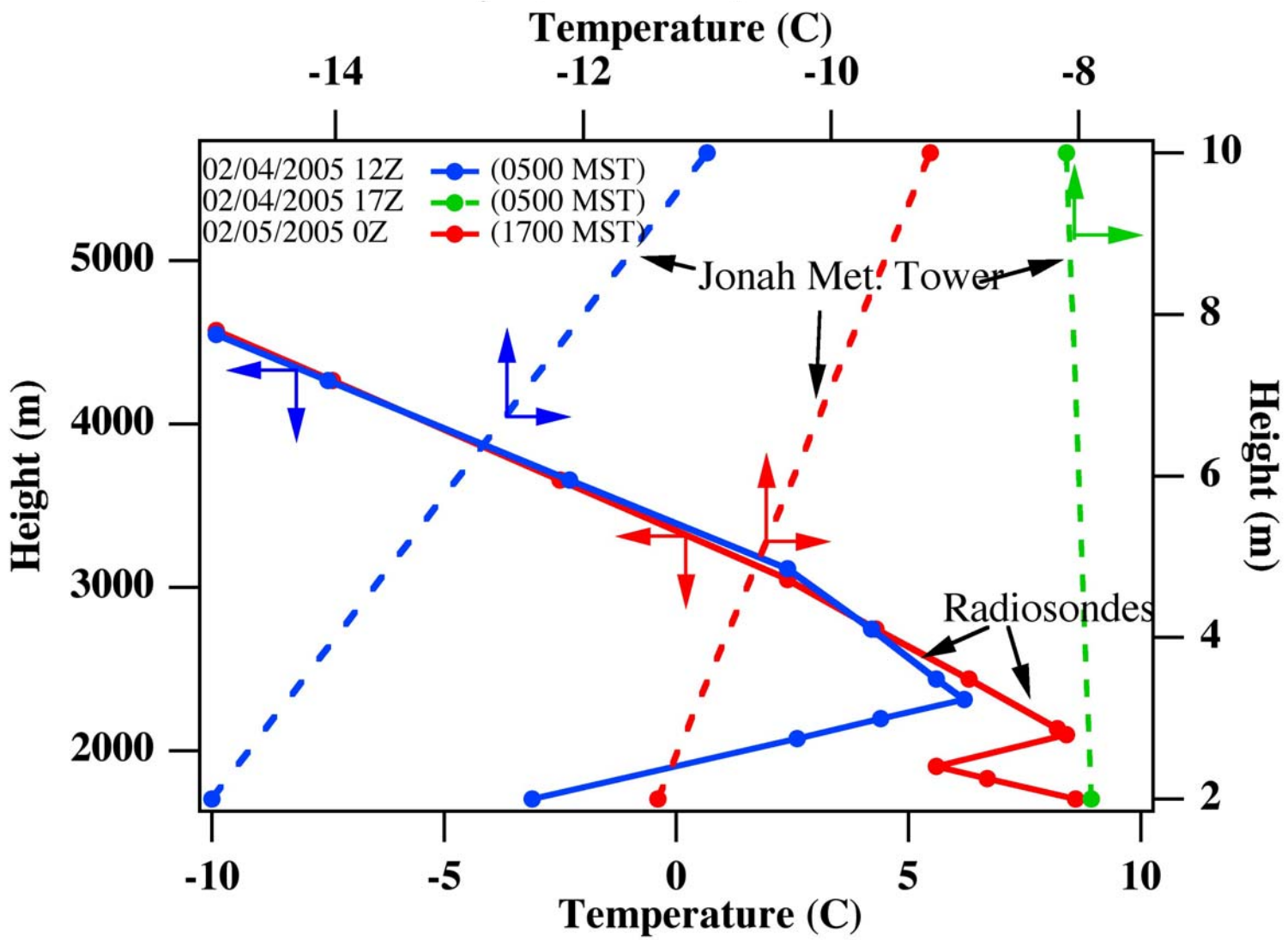
Solar Radiation and NOx, Jonah, February 1-4, 2005



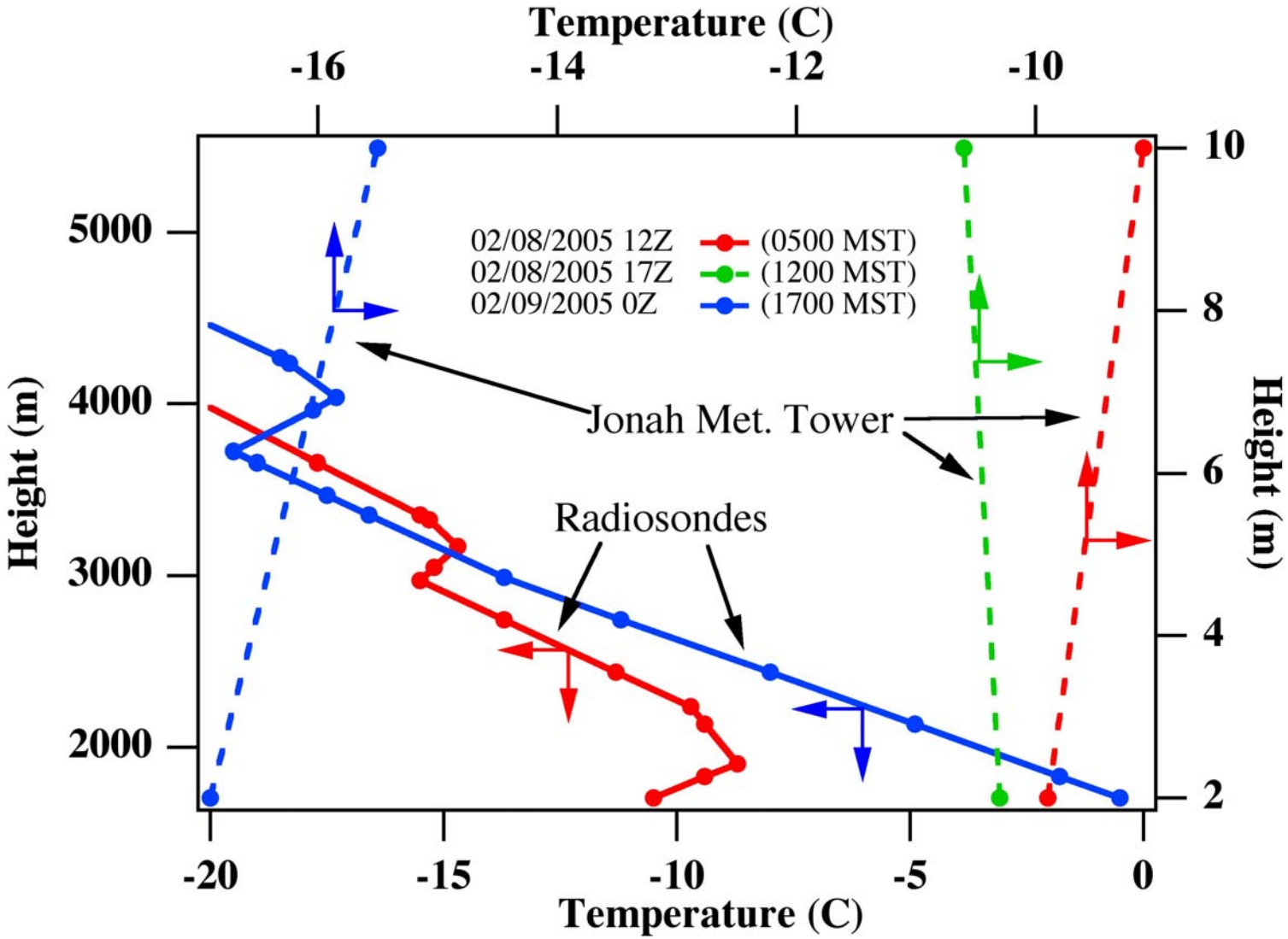
Solar Radiation and NOx, Jonah, February 5-8, 2005



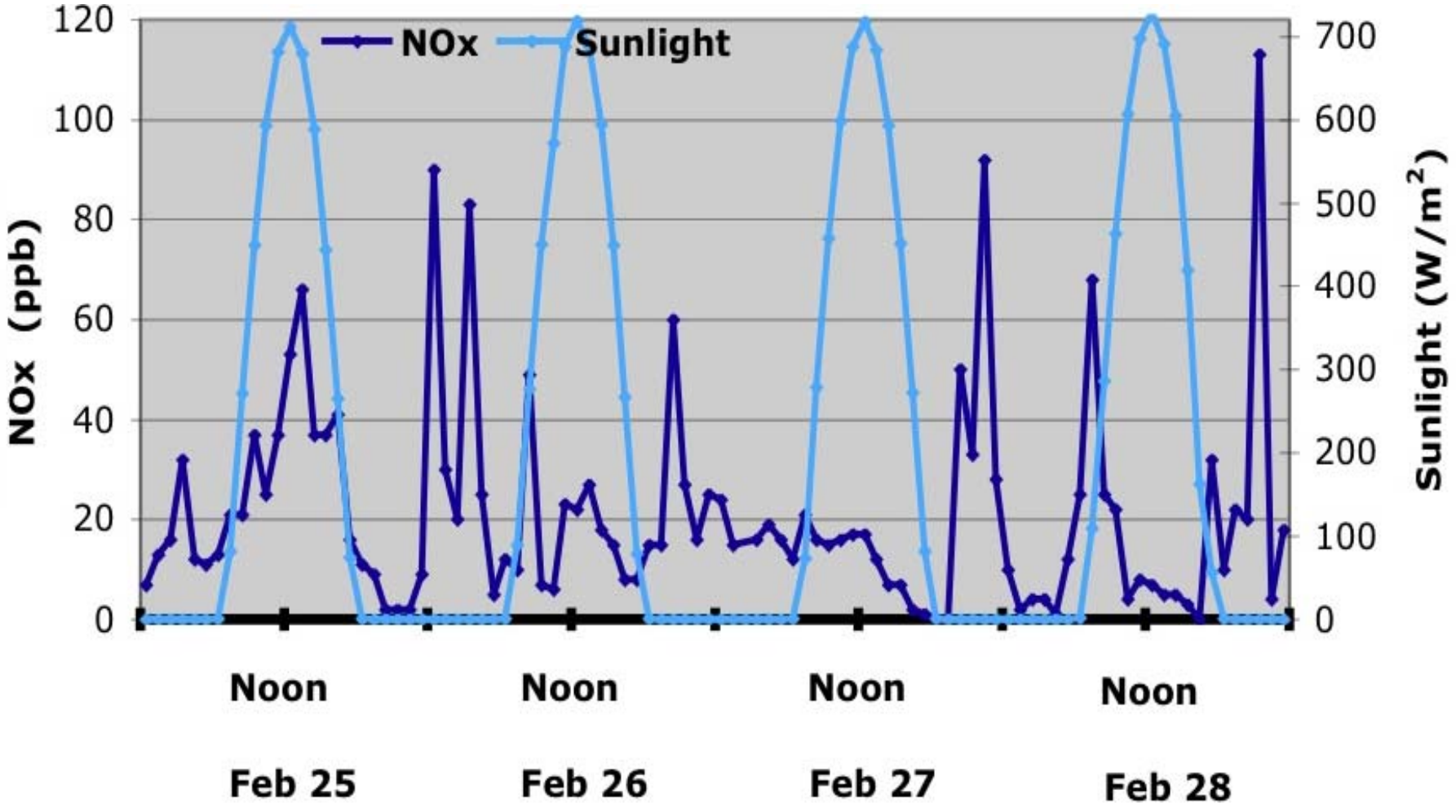
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 4, 2005



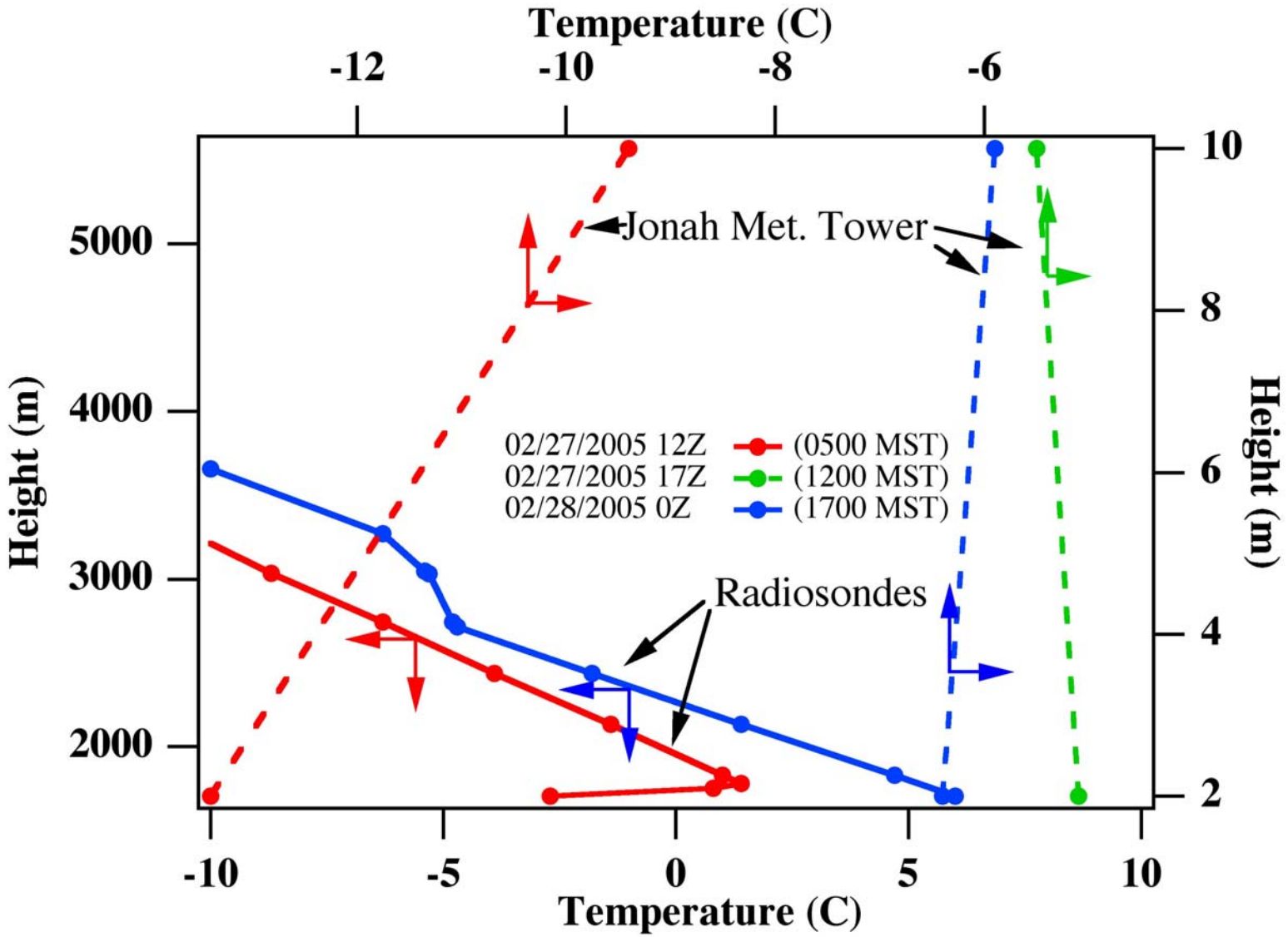
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 8, 2005



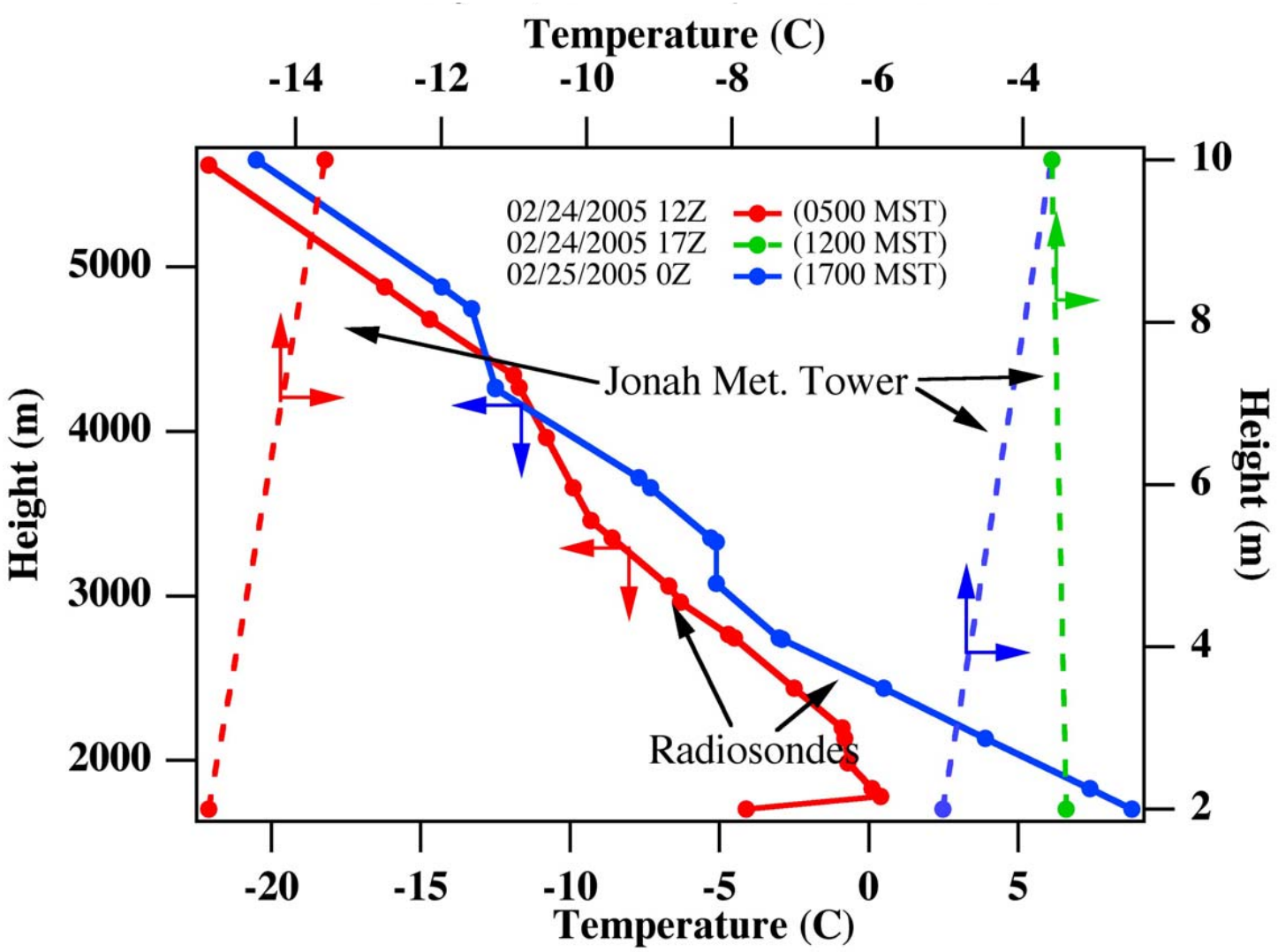
Solar Radiation and NOx, Jonah, February 25-28, 2005



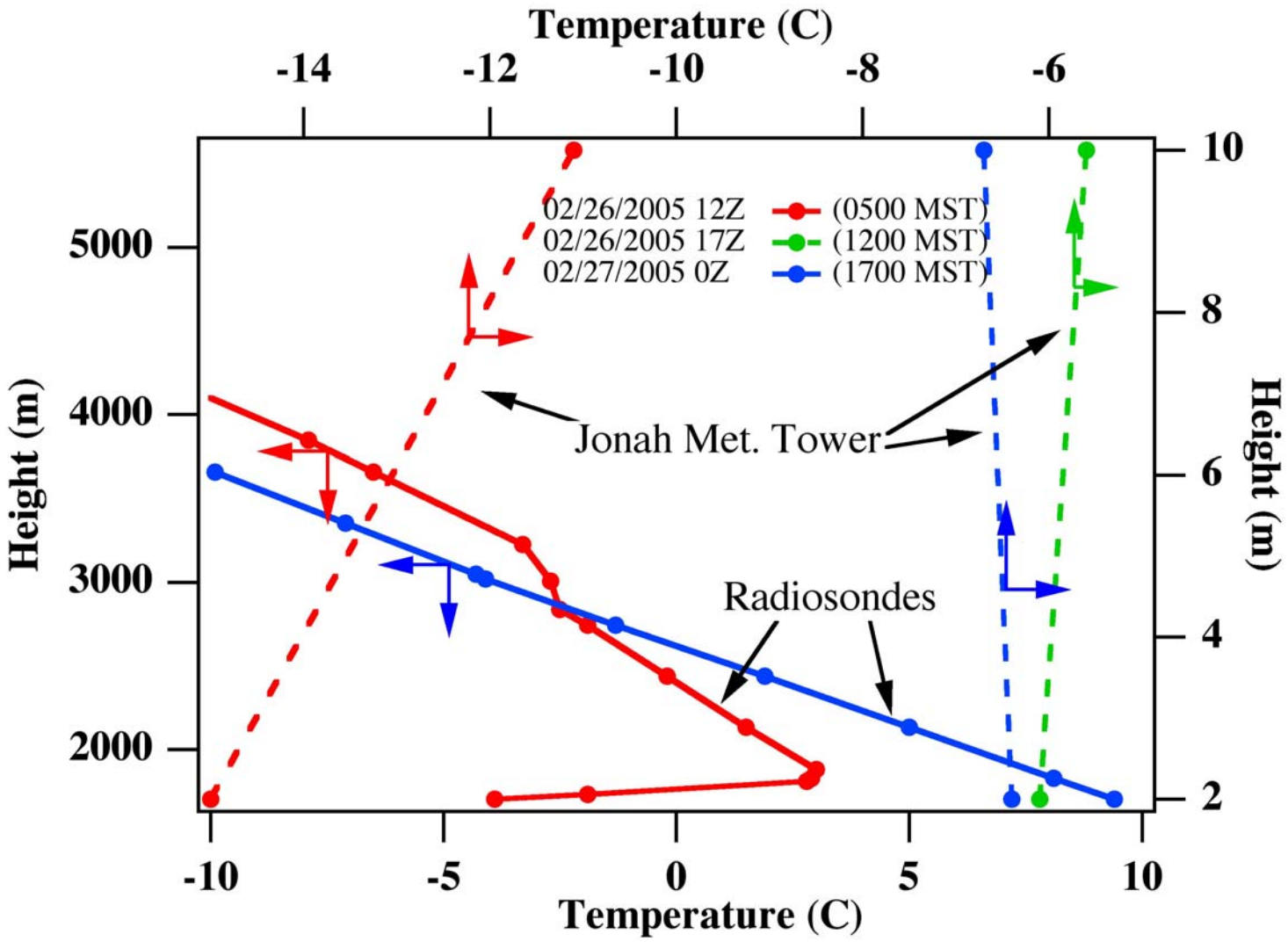
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 27, 2005

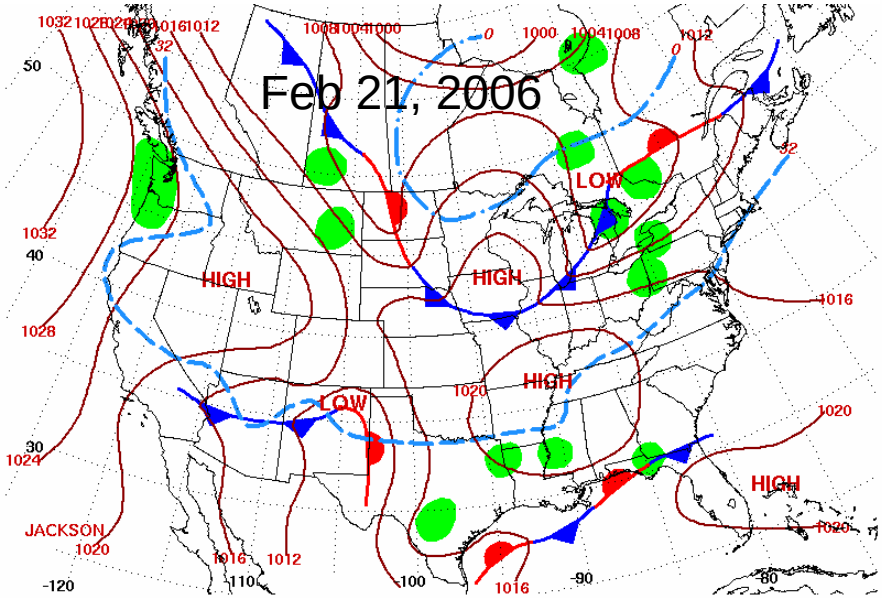


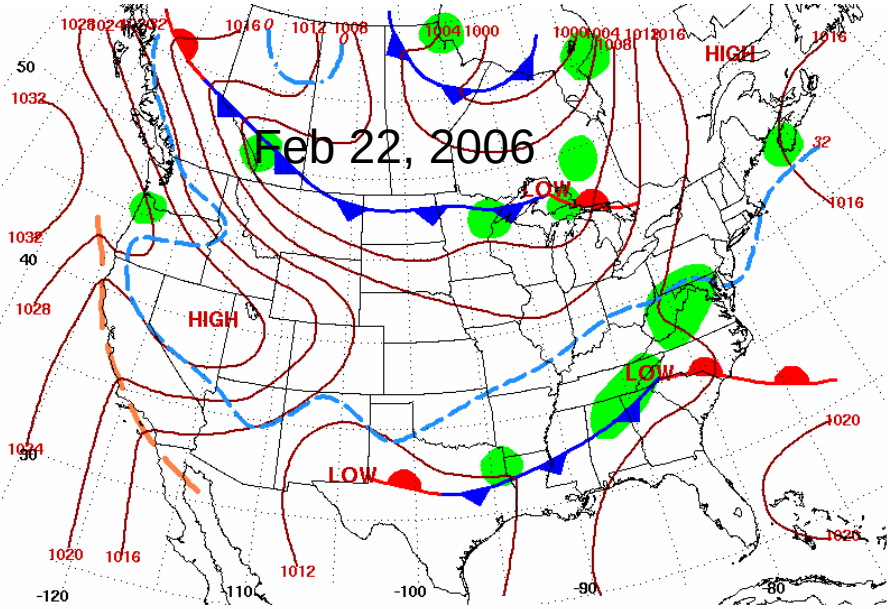
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 24, 2005

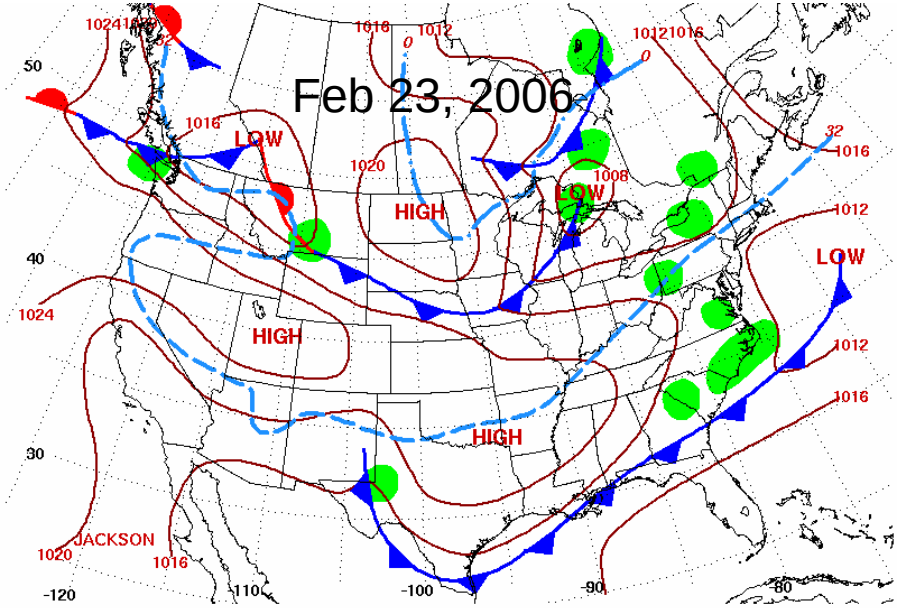


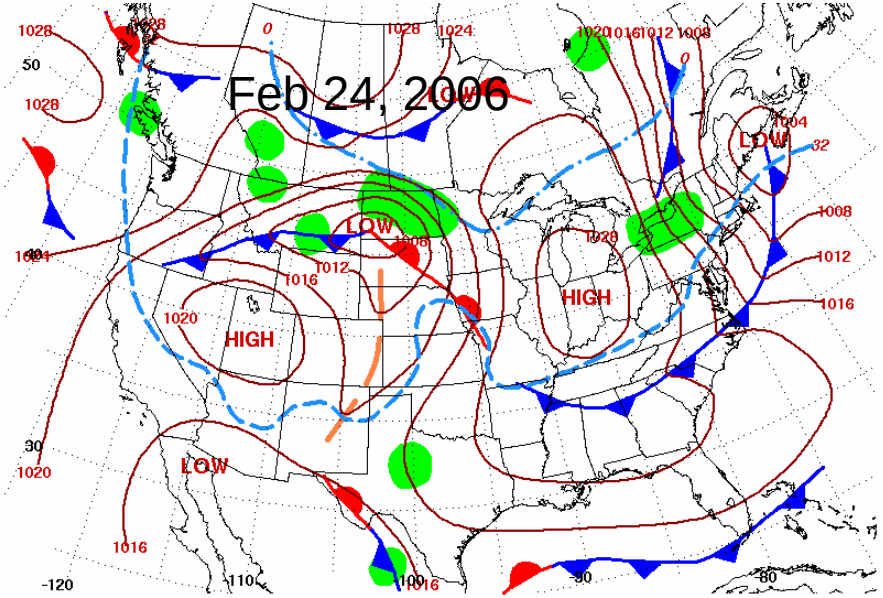
Vertical Temperature Structure, Jonah Tower and Riverton Radiosondes, Feb 26, 2005



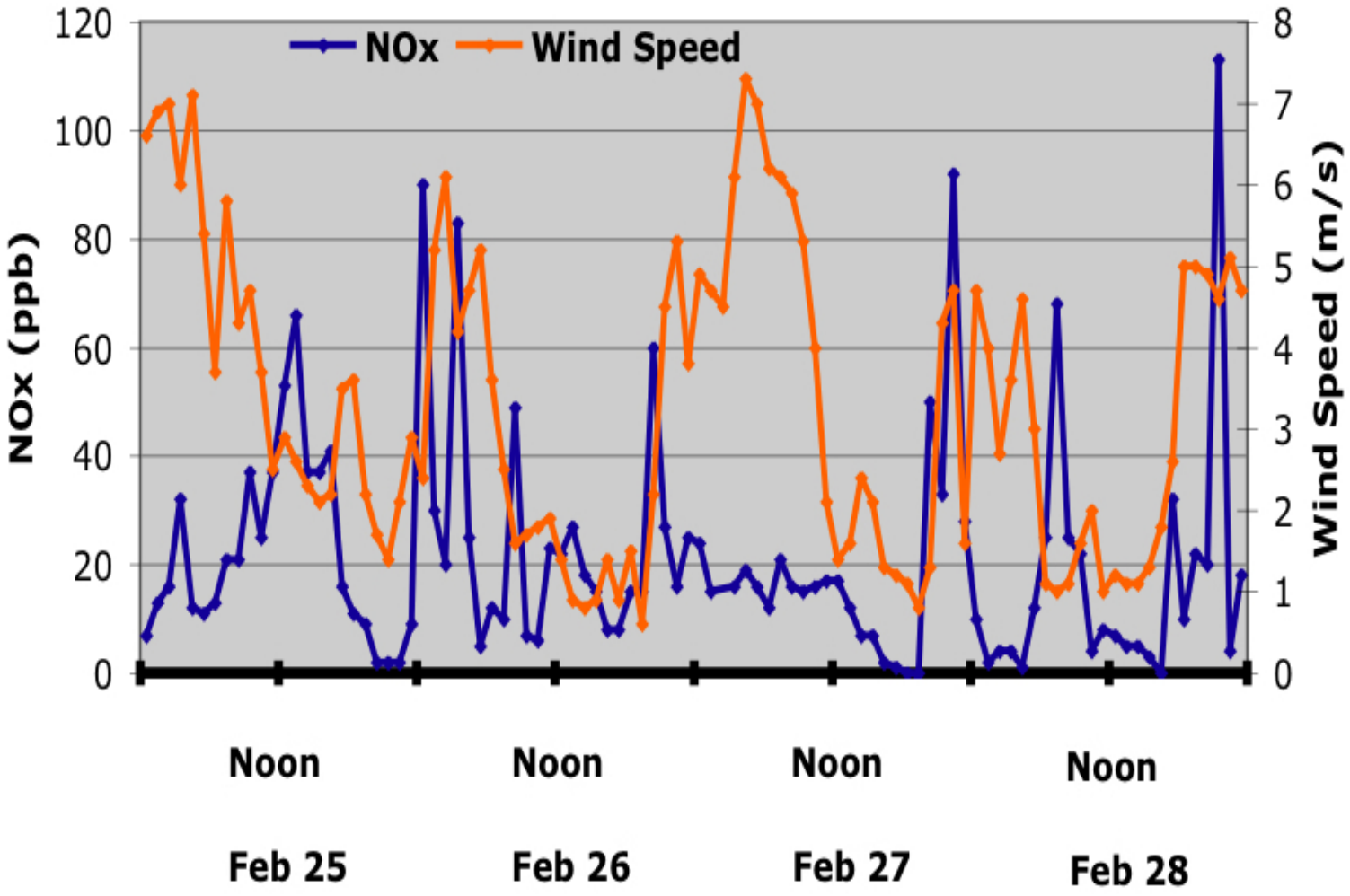

Feb 21, 2006
HIGH
LOW
HIGH
HIGH
LOW
HIGH
JACKSON
Surface Weather Map at 7:00 A.M. E.S.T.


Feb 22, 2006
HIGH
LOW
HIGH
LOW
LOW
Surface Weather Map at 7:00 A.M. E.S.T.

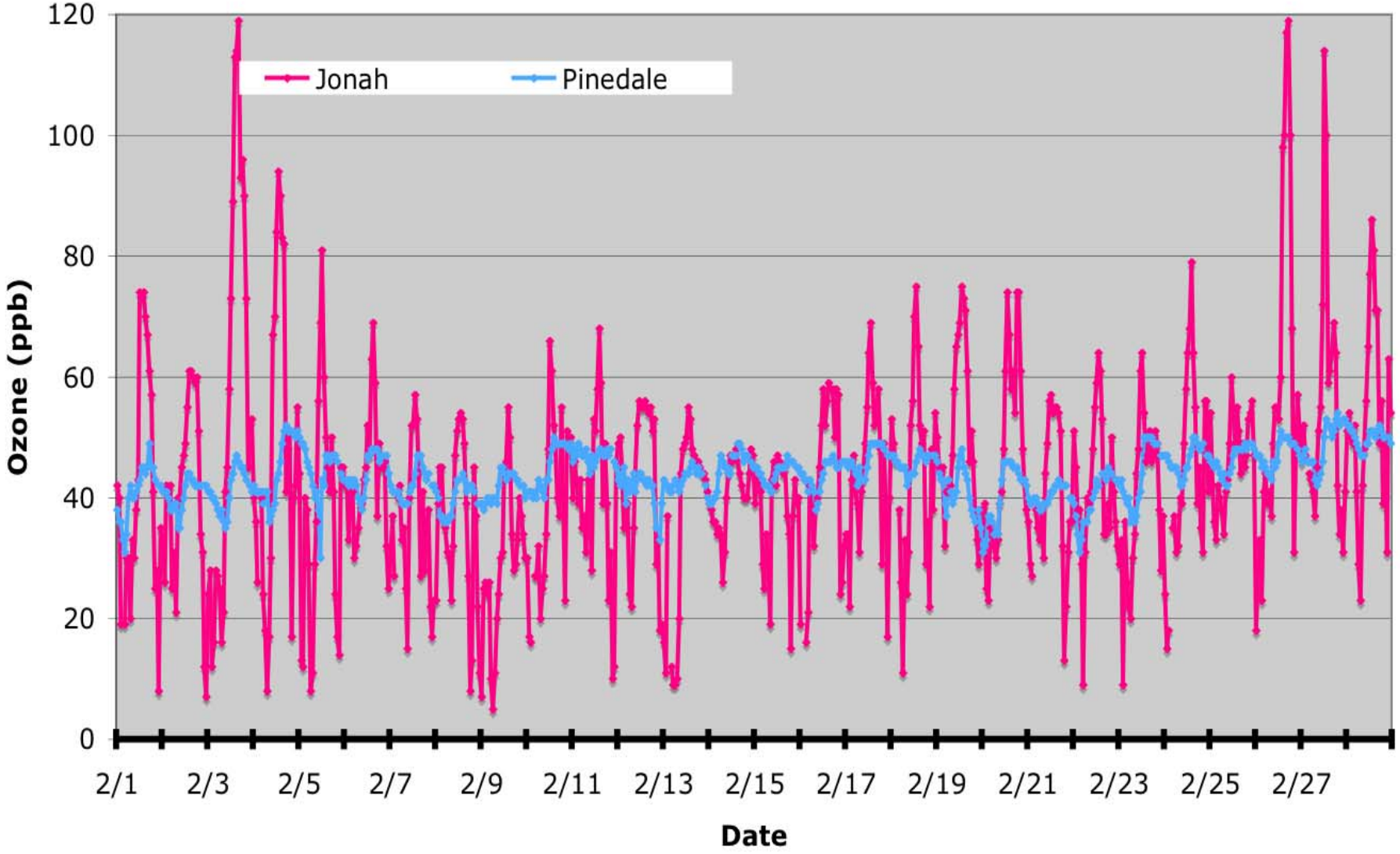

Feb 23, 2006
LOW
HIGH
LOW
HIGH
LOW
HIGH
JACKSON
Surface Weather Map at 7:00 A.M. E.S.T.


Feb 24, 2006
LOW
LOW
HIGH
HIGH
LOW
Surface Weather Map at 7:00 A.M. E.S.T.

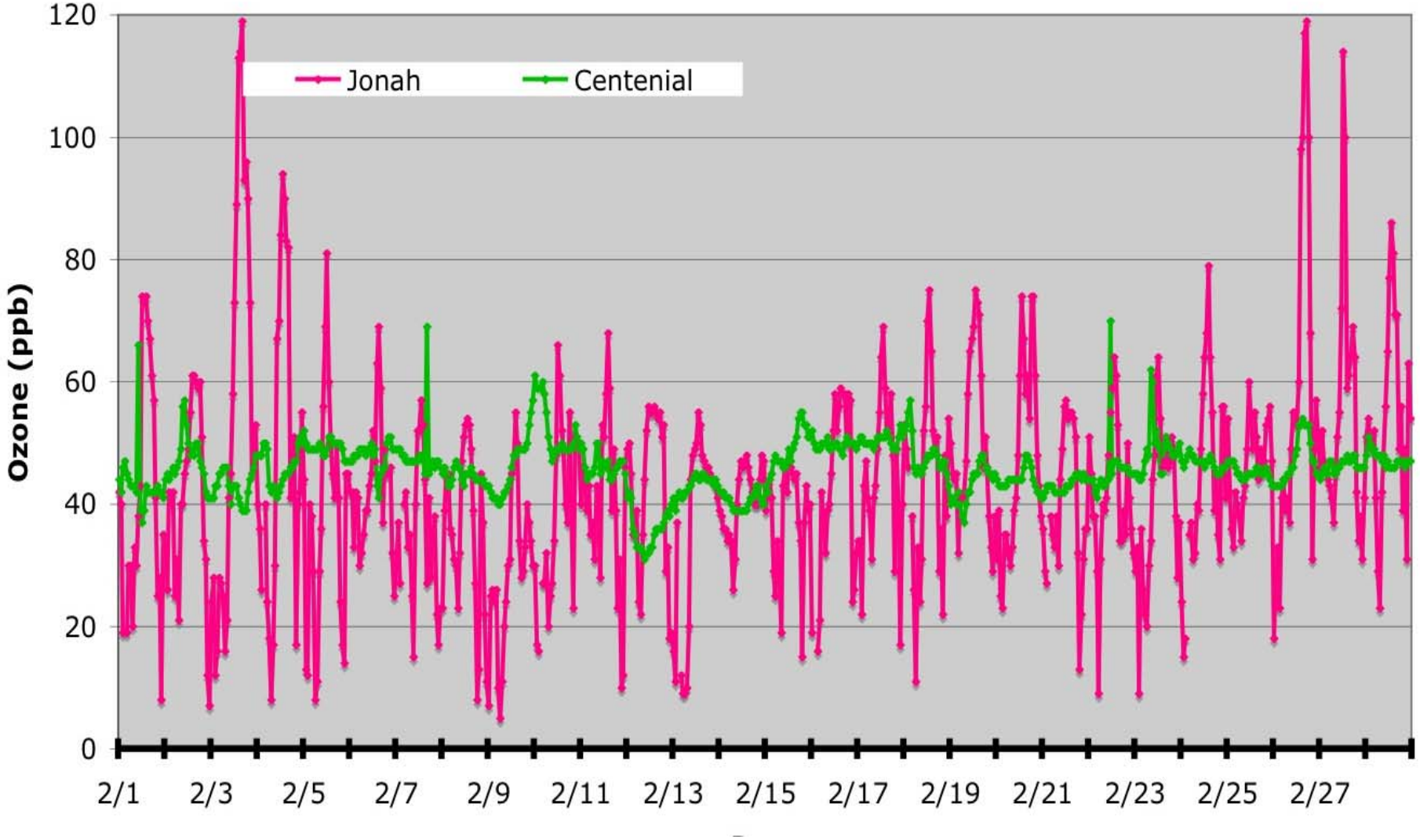
Wind Speeds and NOx, Jonah, WY, Feb 25-28, 2005



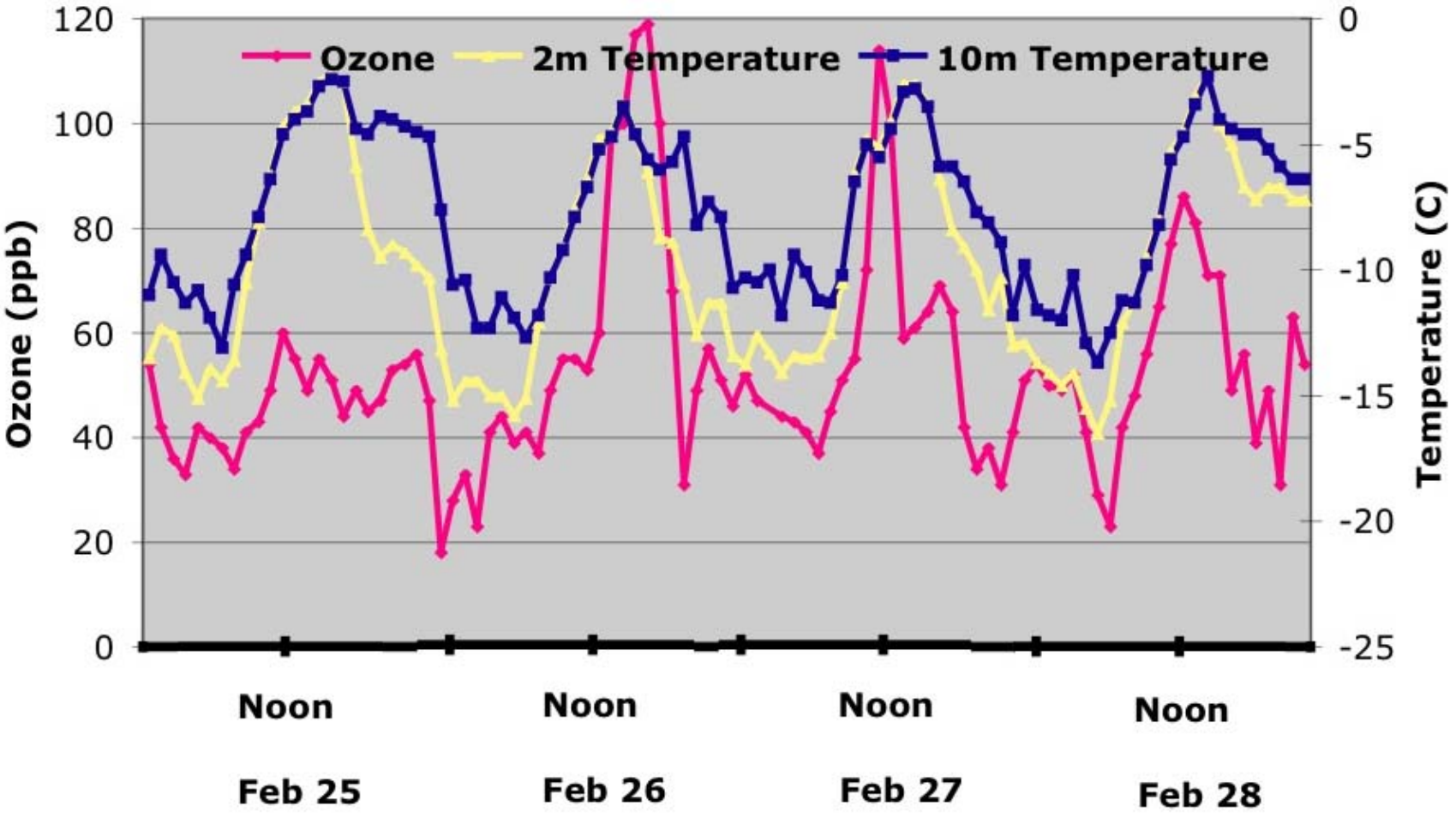
Ozone, February 2005, Jonah and Pinedale



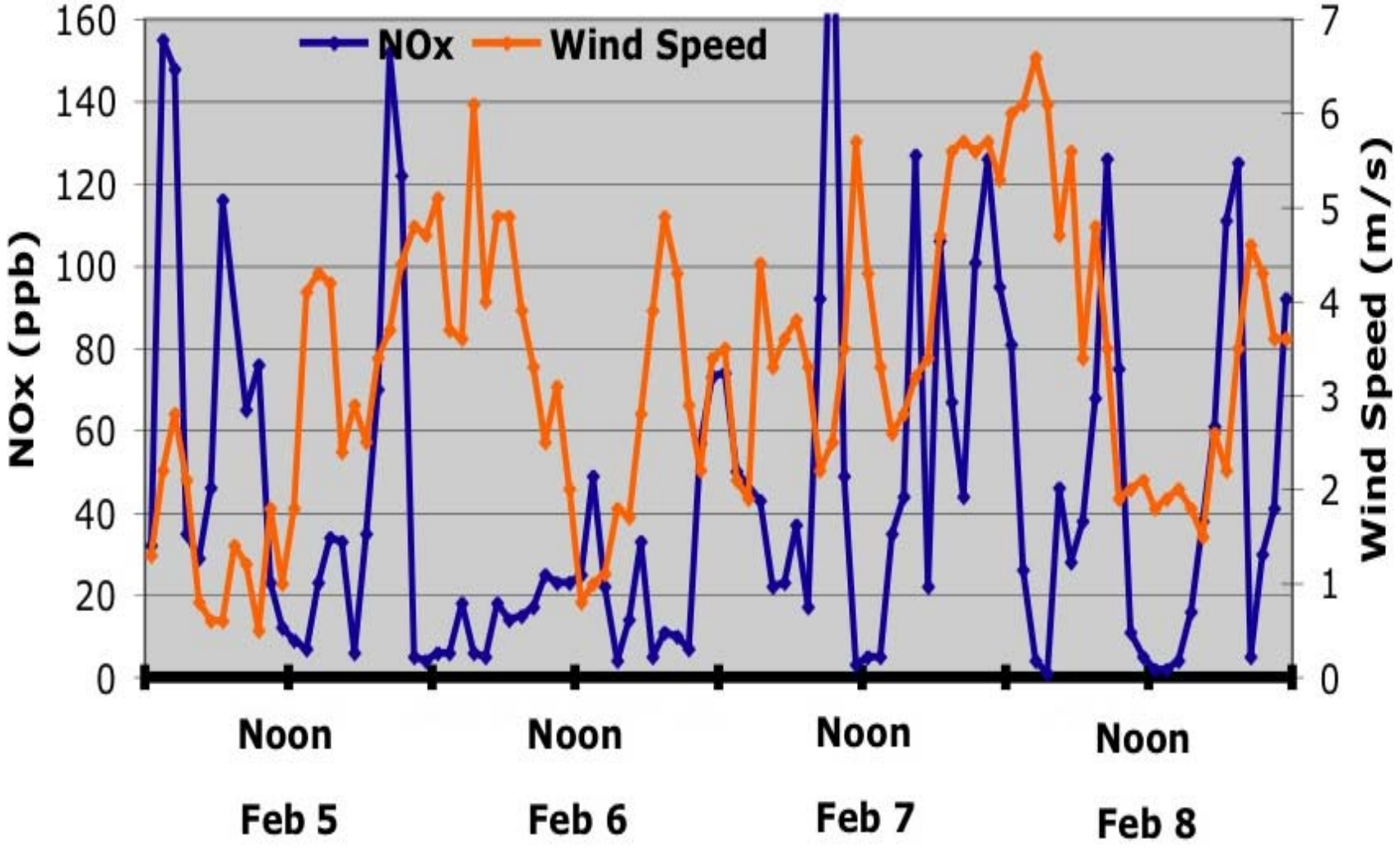
Ozone, Jonah and Centenial, February 2005,



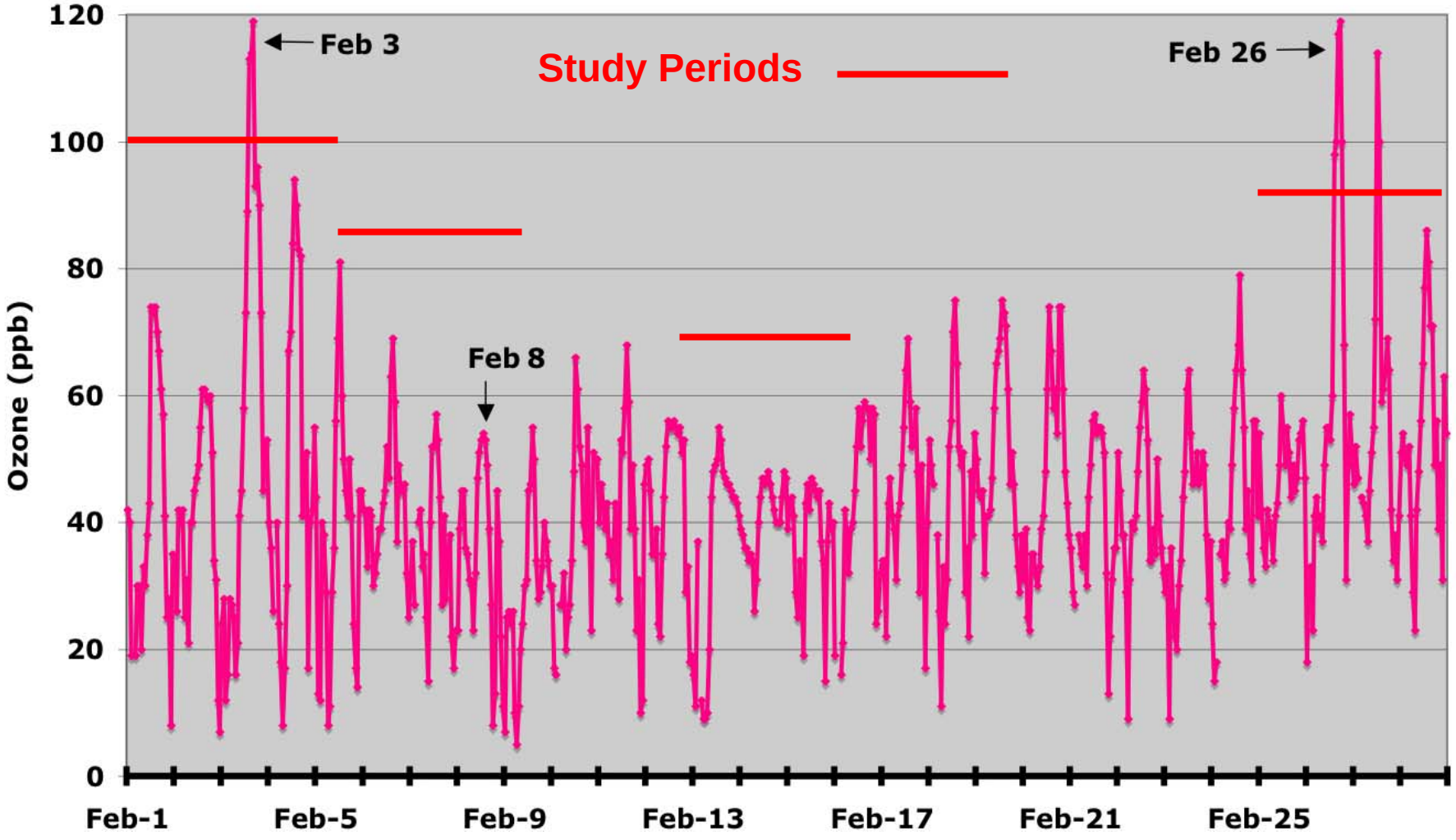
Ozone and Temperature, Jonah, February 25-28, 2005

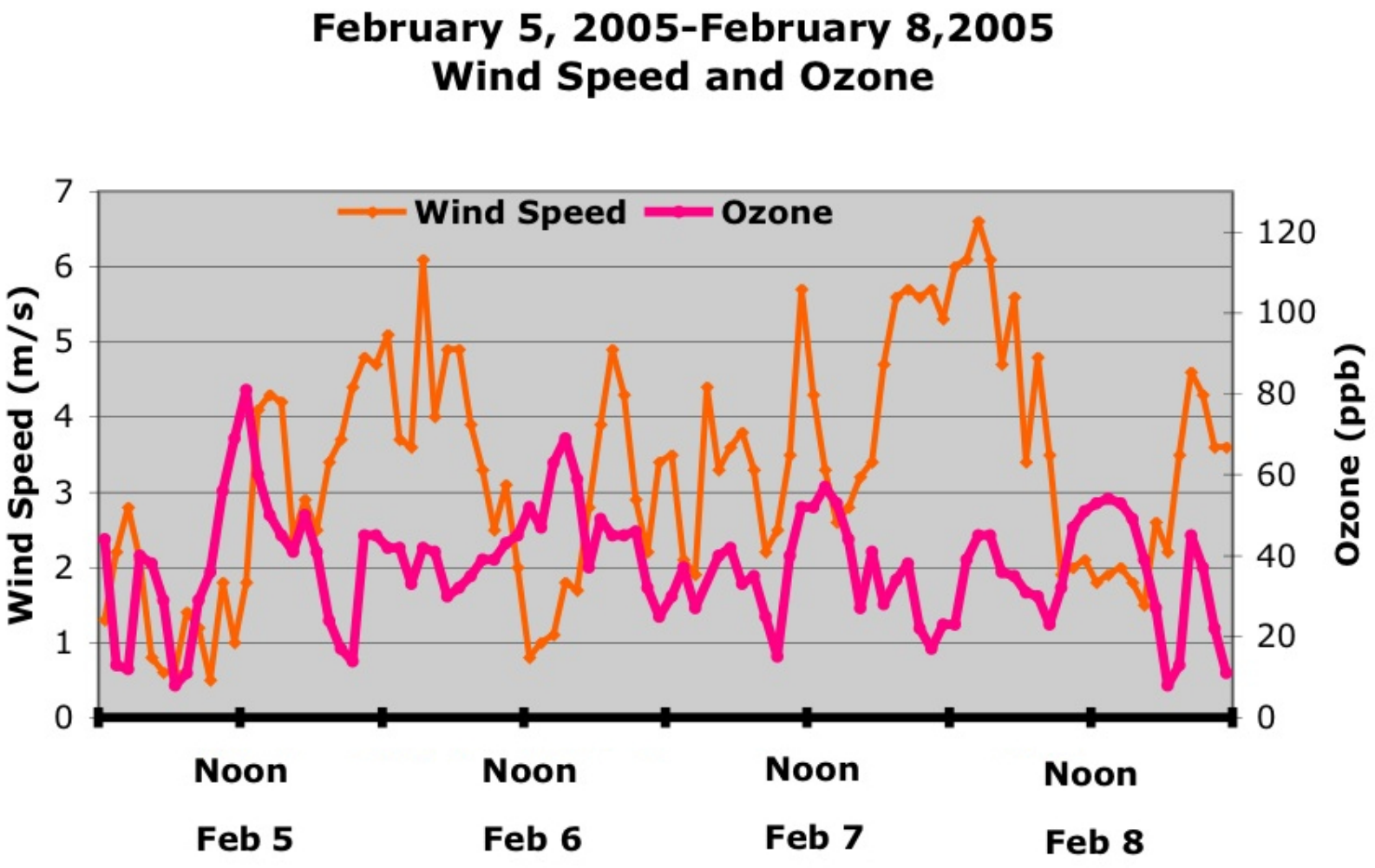


Wind Speeds and NOx, Jonah, WY, Feb 5-8, 2005

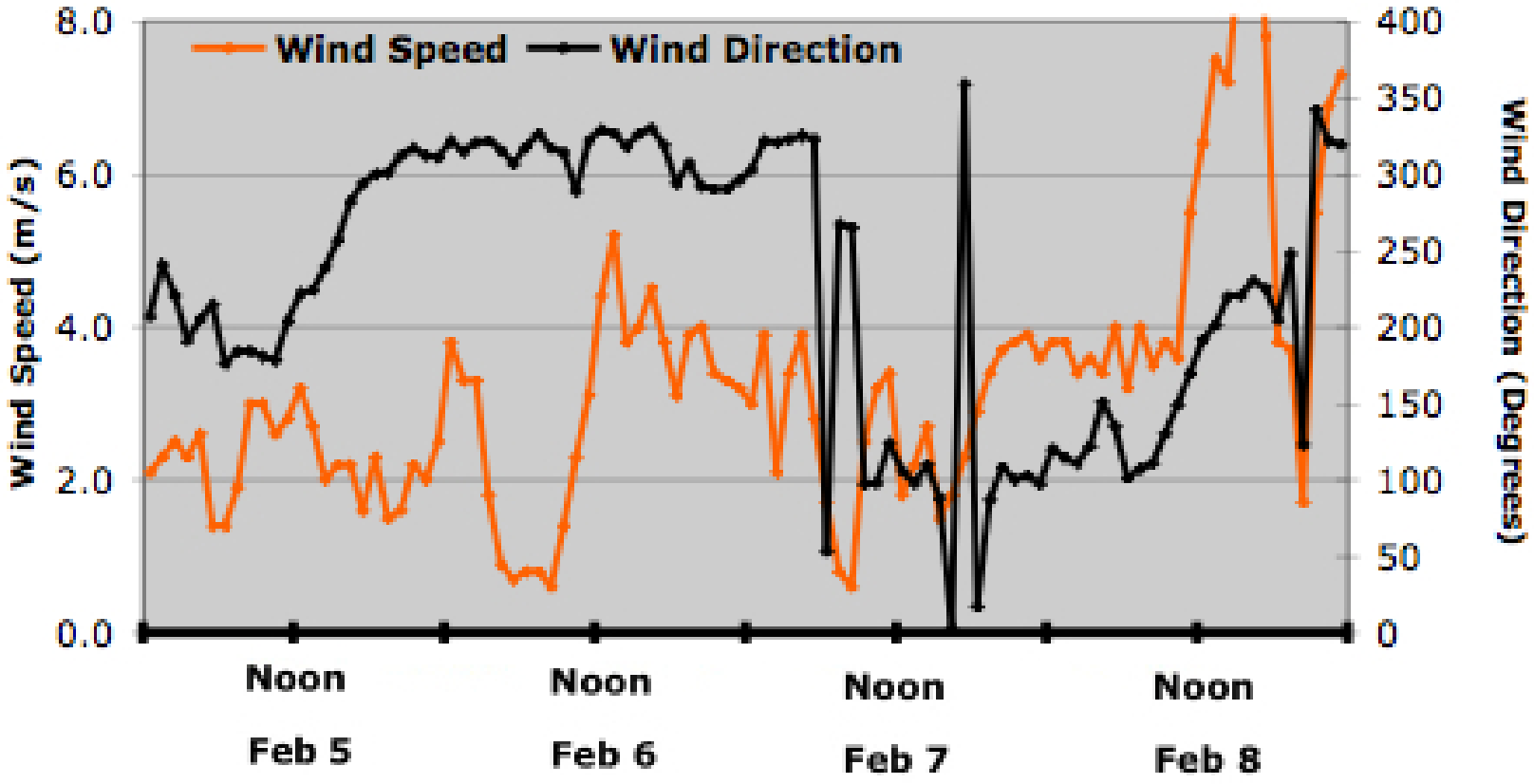


Hourly Average Ozone Concentrations, February 2005, Jonah, Wyoming




February 5, 2005-February 8,2005
Wind Speed and Ozone
Wind Speed
Ozone
Wind Speed (m/s)
Ozone (ppb)
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
Noon
Feb 5
Noon
Feb 6
Noon
Feb 7
Noon
Feb 8

Wind Direction and Wind Speeds, Jonah, WY, Feb 5-8, 2006



Possible Future Activities:

Question 1. Over what area do these photochemical ozone production events cover? Jonah monitors are at the edge of the gas field.

Approach: Study 2006 events as there is more data. Add more surface ozone monitors for 2007?

Question 2. Is snow cover critical?

Approach: Regular photos or web cameras.

Continued.....

Proposed Aircraft Program

- **Goal:** Determine depth, lateral extent, and constituent concentrations of ozone events.
- Cessna 206 based in Boulder, CO, Feb 2007.
- Real-time ozone, temperature, NOx.
- Flask samples of trace gases, VOCs.
- **Approach:** Fly dozens of vertical profiles before, during and after an ozone event.
- **Results:** Data will determine depth and extent of ozone production events and constituents. This will allow for excellent inputs for models.
- **Cost:** $75-100K depending upon flight hours and extent of analyses.

Question 3. **How deep is the ozone production layer? 10's of meters (nocturnal surface inversion), or 100's of meters (subsidence inversion)? The answer affects prediction accuracy, modeling and ozone production control strategies.**

Approach: **Conduct a field study using slow rise ozonesondes and tethersondes or a light aircraft in a 2007 ozone event.**

Question 4. What are the precursors and chemical reactions involved in the production of the ozone?

The answer affects <u>prediction accuracy</u>, <u>modeling</u> and ozone production <u>control</u> strategies.

Approach: Conduct a field study using a suite of instruments to study concentrations of precursor gases and the reactions producing the ozone. This will entail numerous instruments studying a wide range of species and chemical reactions.