Flow regimes associated with high ozone in Houston

September 17, 2009

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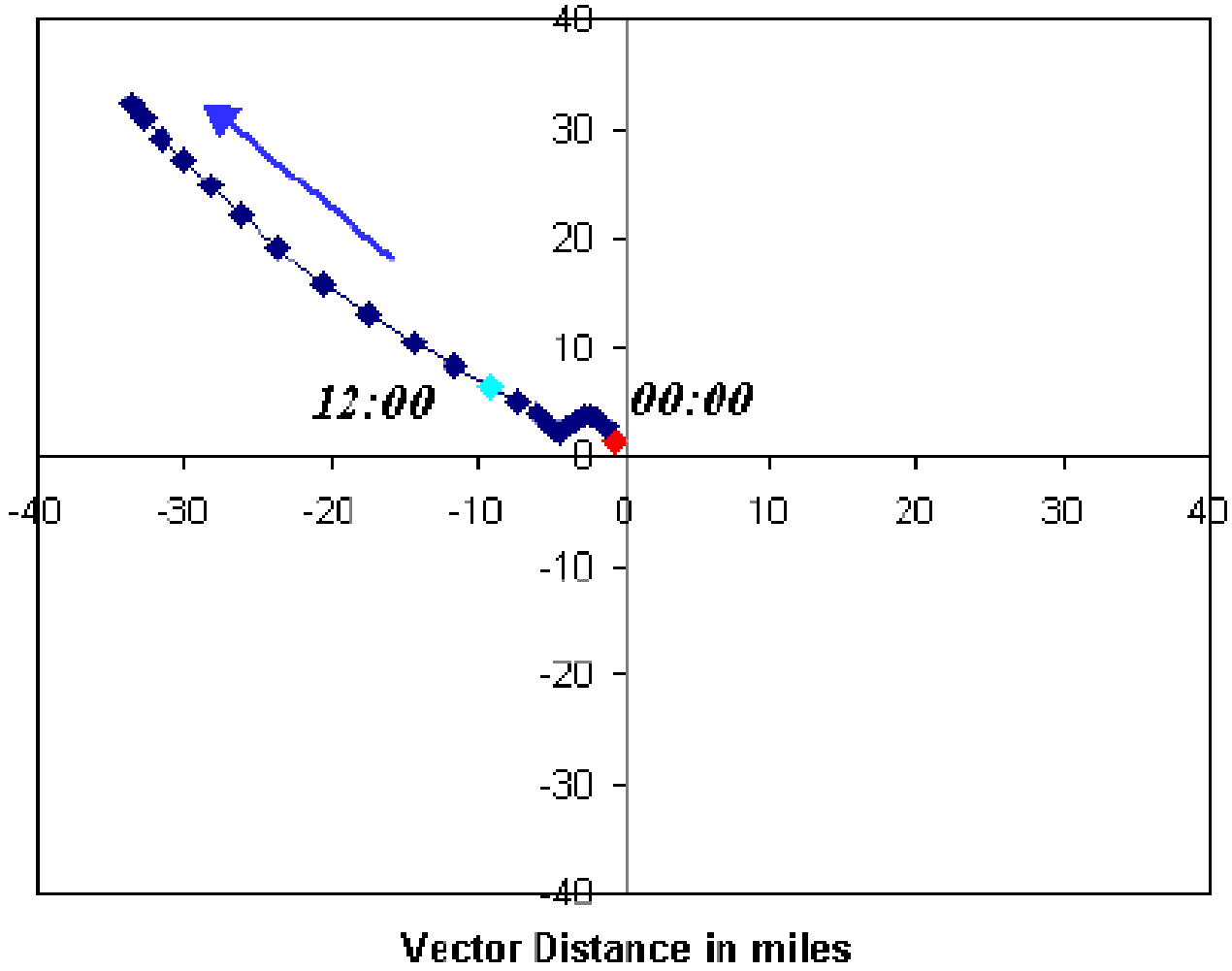
Air Modeling and Data Analysis Section
TCEQ

Findings from previous studies

- High ozone is associated with local veering winds (i.e. winds that change direction in a clockwise fashion).
- High ozone is associated with regional northerly flow; low ozone is associated with regional southerly flow.

Domain Wide Average Trajectories on Low Ozone Days

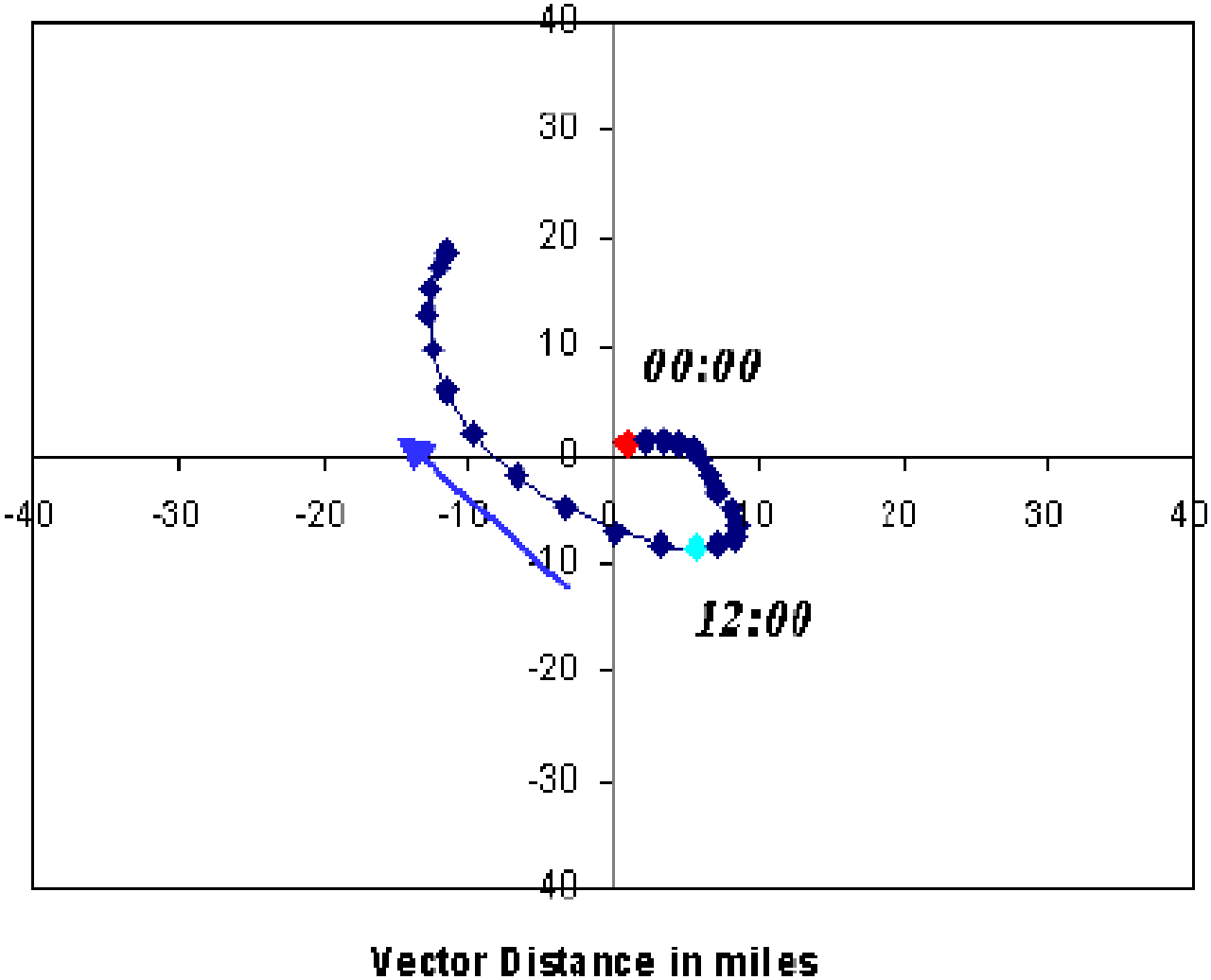
(Aug- Sept, 1998-2000)



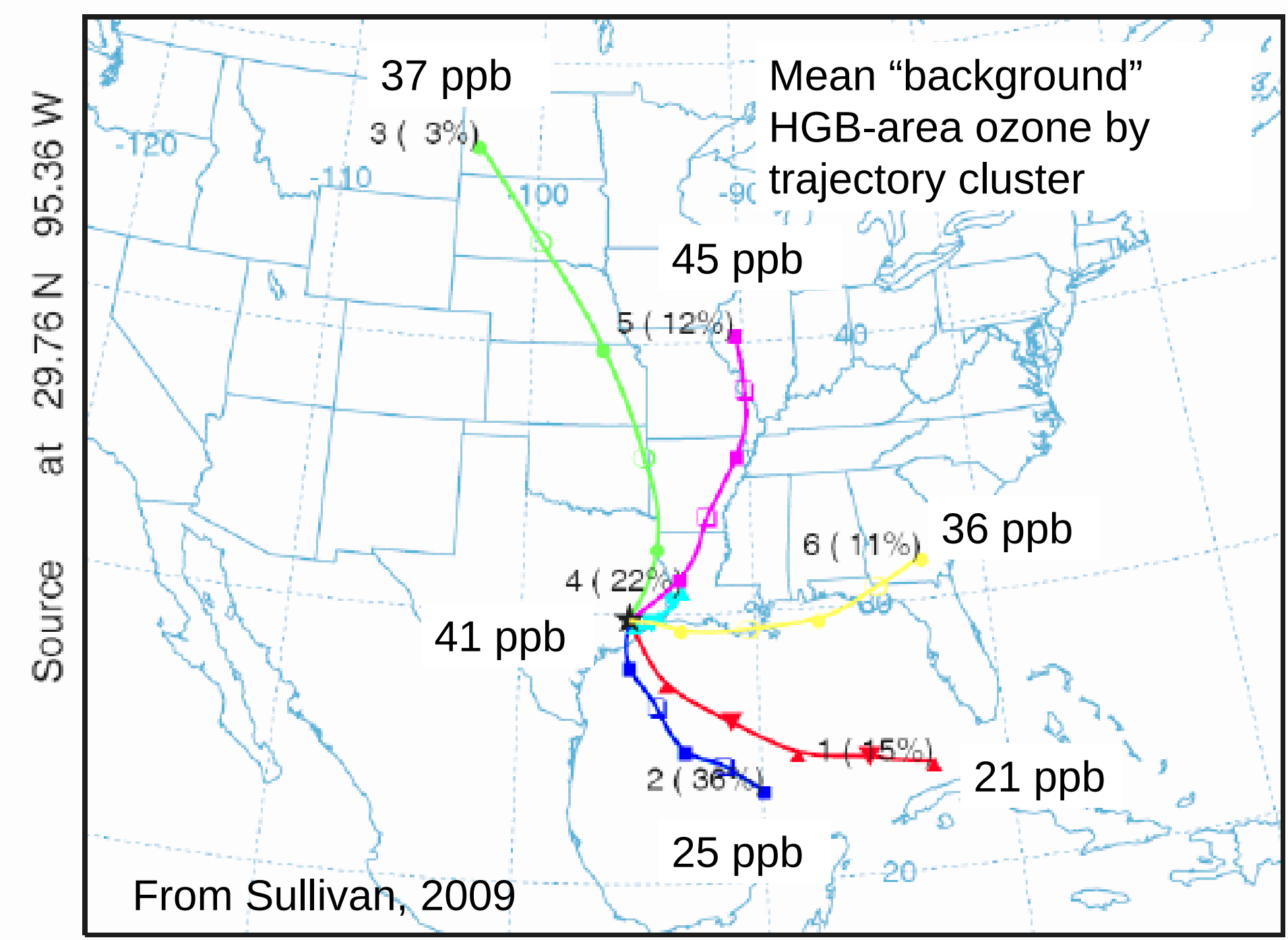
From Breitenbach et al., 2002

Domain Wide Average Trajectories on Exceedance Days

(Aug- Sept, 1998-2000)



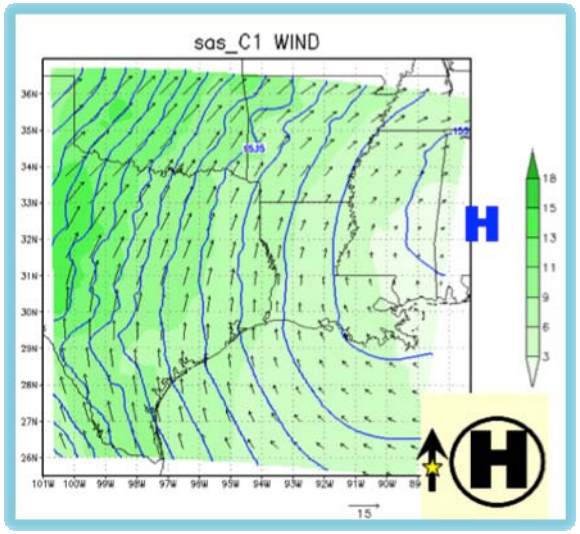
From Breitenbach et al., 2002


Source at 29.76 N 95.36 W
37 ppb
Mean "background" HGB-area ozone by trajectory cluster
3 (3%)
45 ppb
5 (12%)
36 ppb
6 (11%)
4 (22%)
41 ppb
1 (15%)
21 ppb
2 (36%)
25 ppb
From Sullivan, 2009

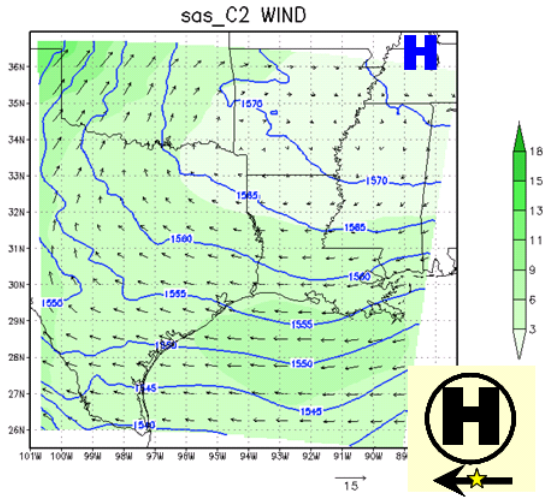
Classification of meteorological regimes, May-Sept 2005-2006. (Ngan and Byun, 2008)

Weather Clusters (composite maps on 850 mb)

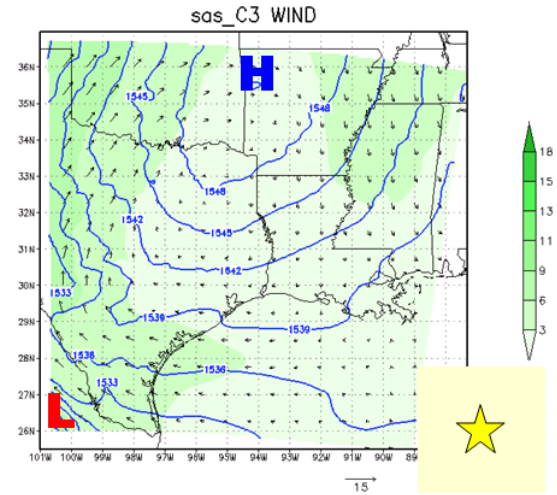
C1: SE/S, 93 days (30%)



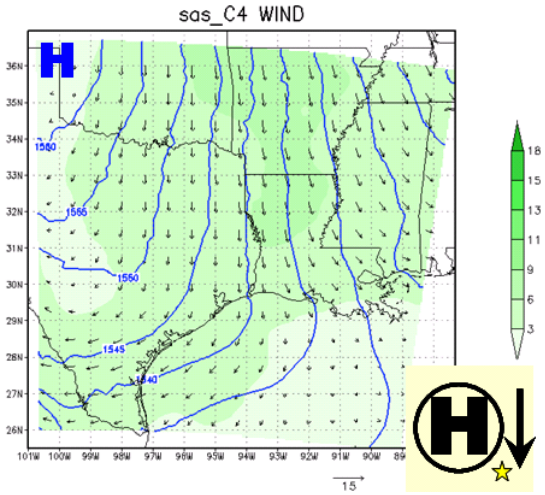
C2: E, 56 days (19%)



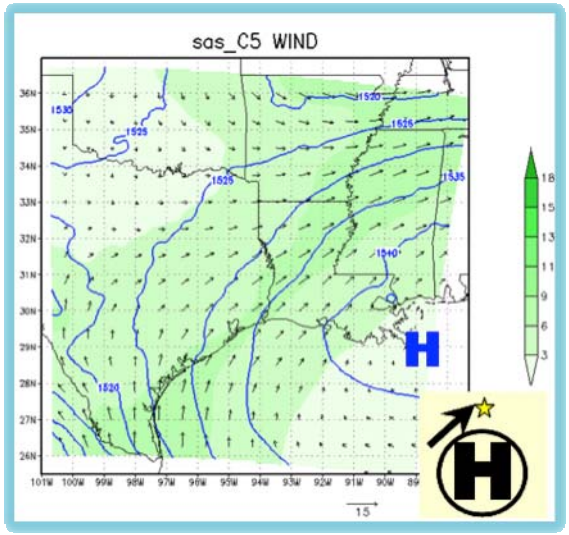
C3: calm, 69 days (23%)



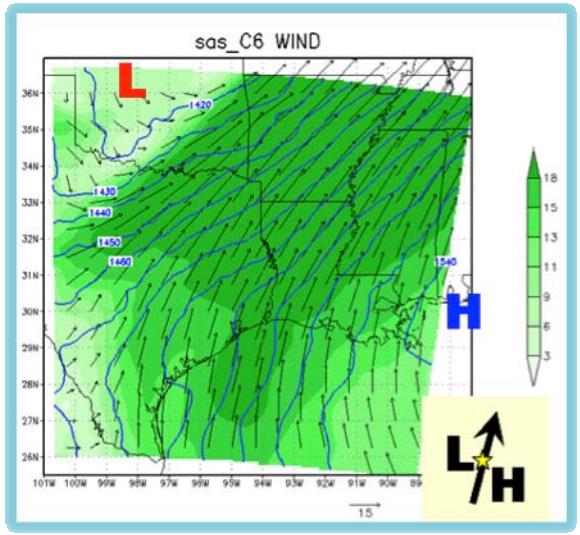
C4: N, 41 days (14%)



C5: SW, 40 days (13%)



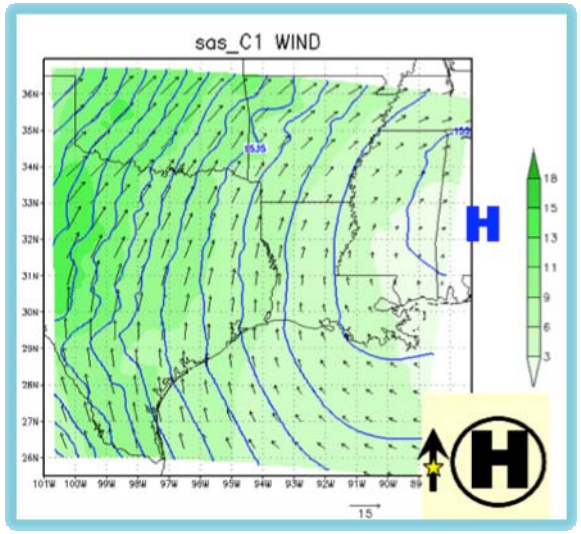
C6: strong SW, 2 days (1%)



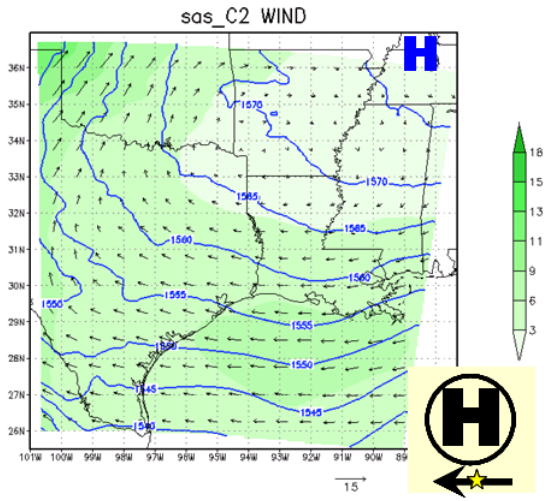
Classification of meteorological regimes, May-Sept 2005-2006. (Ngan and Byun, 2008)

Mean peak domain-wide 1-hour ozone for each cluster.

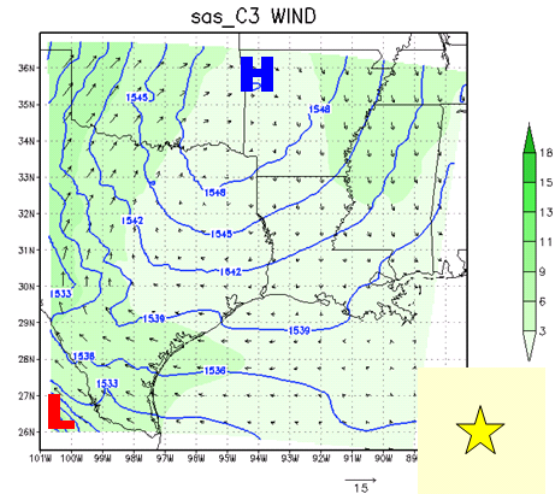
C1: SE/S, **35 ppb**



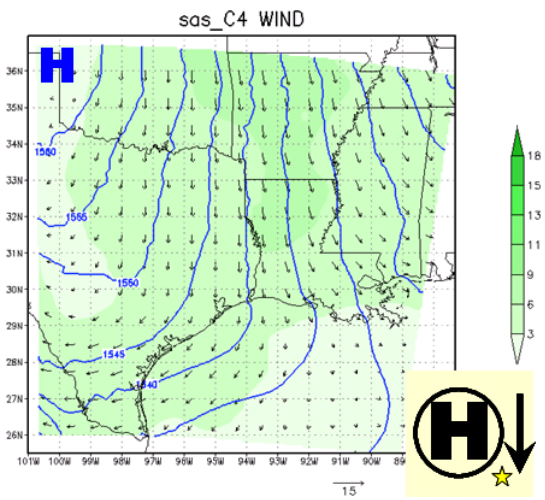
C2: E, **65 ppb**



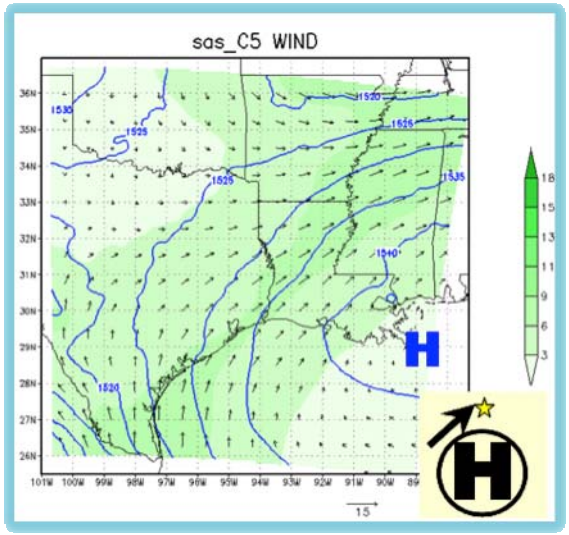
C3: calm, **61 ppb**



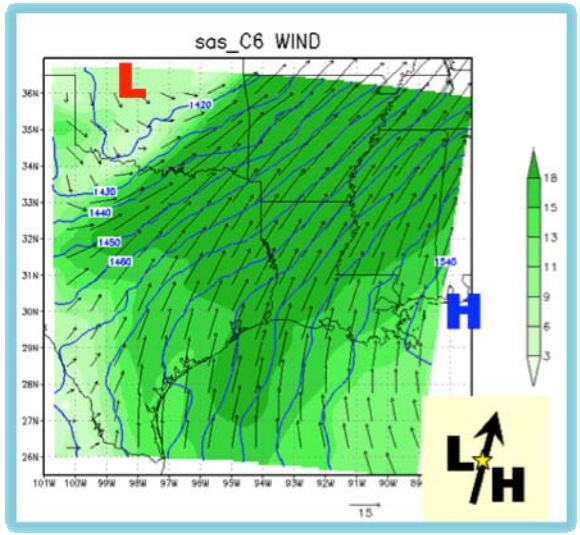
C4: N, **56 ppb**

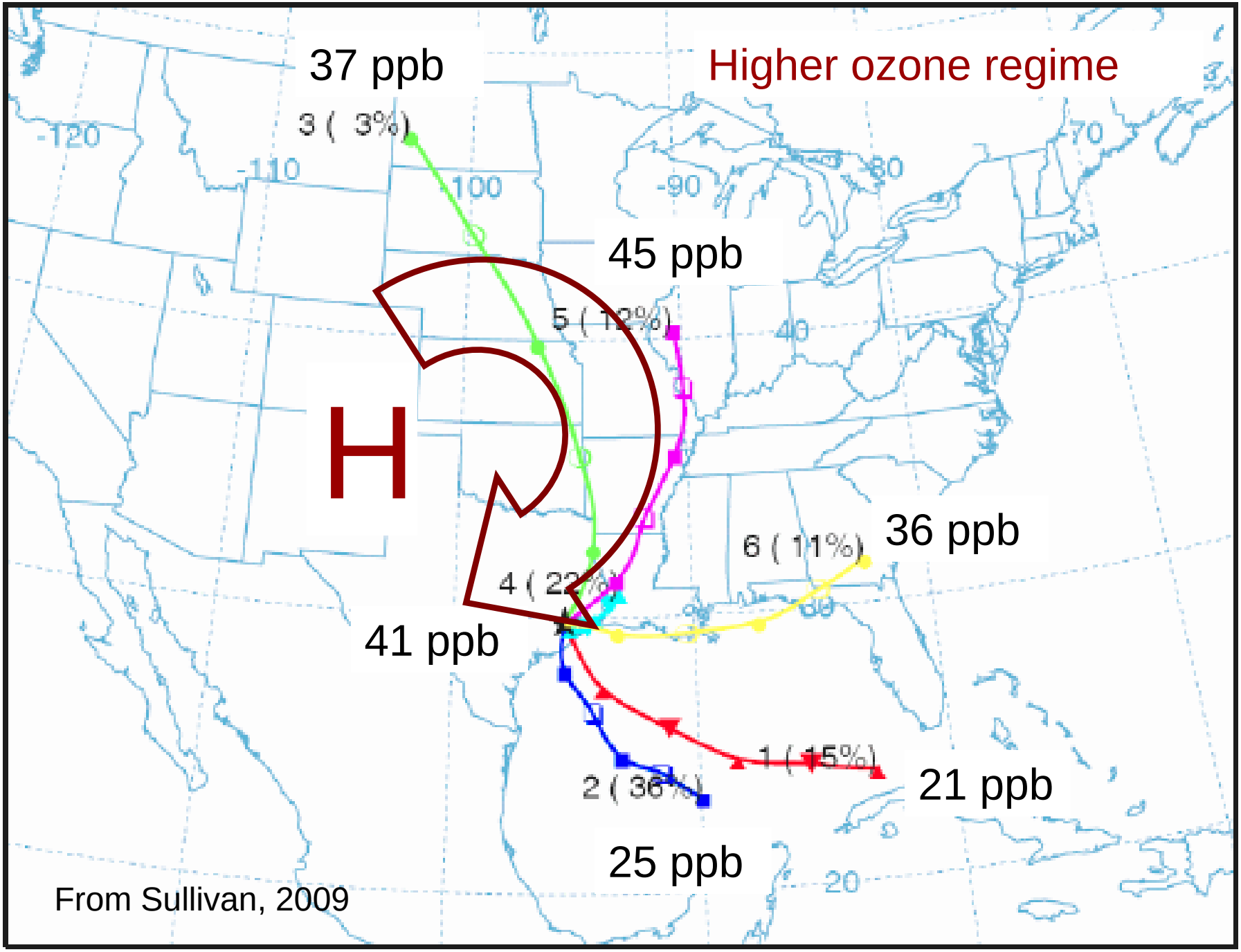


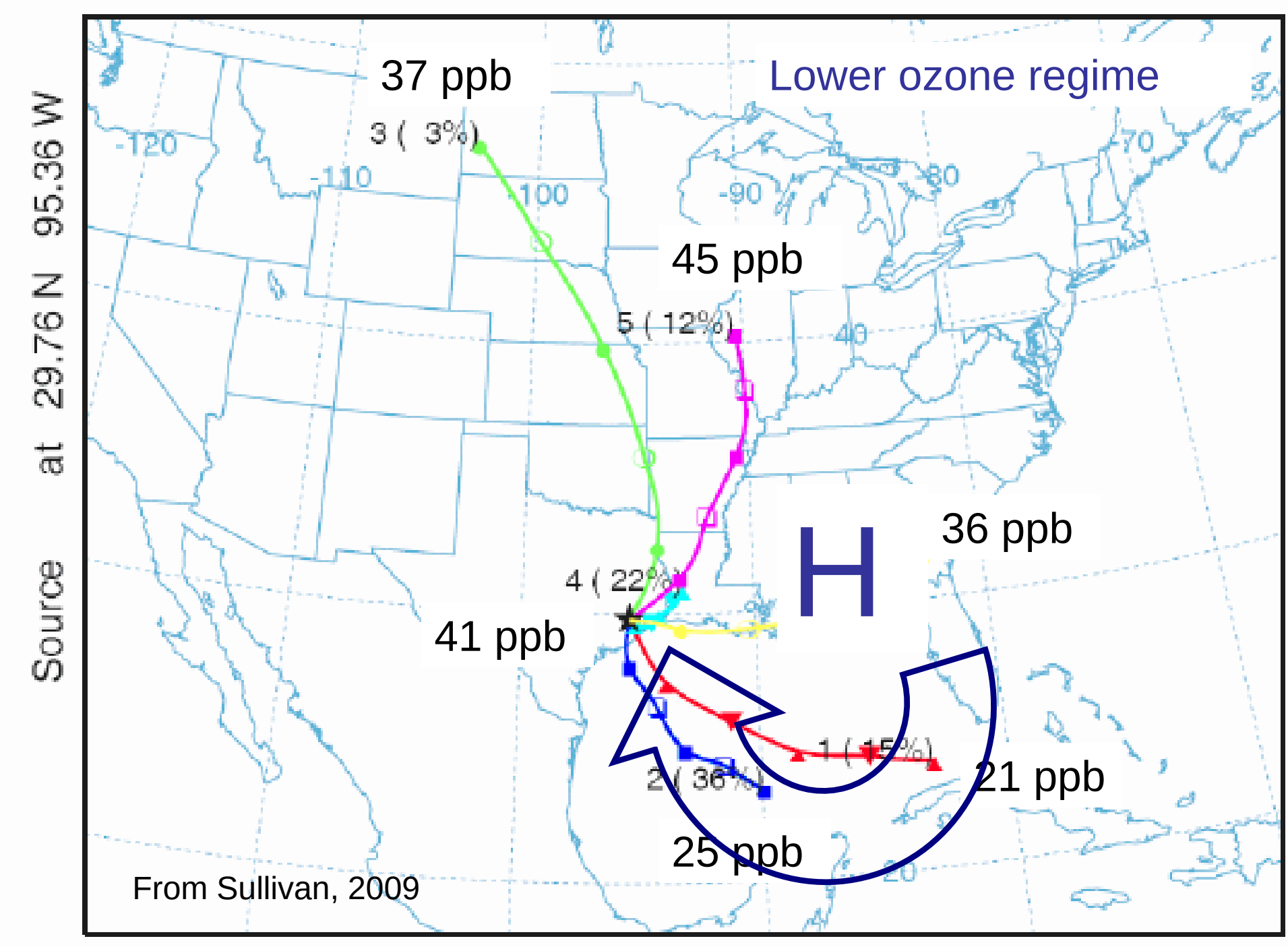
C5: SW, **40 ppb**

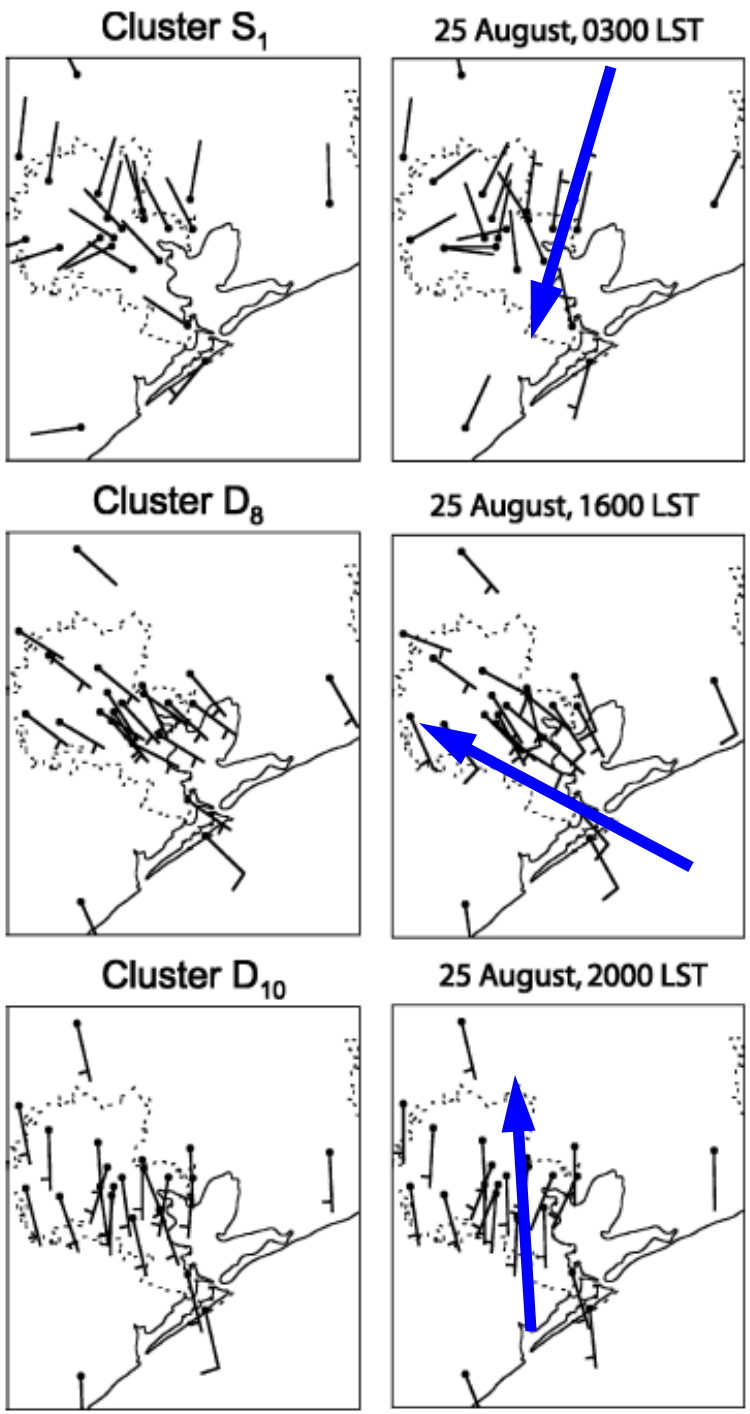


C6: strong SW, **20 ppb**




Source at 29.76 N 95.36 W
37 ppb
Higher ozone regime
3 (3%)
45 ppb
5 (12%)
H
36 ppb
6 (11%)
4 (22%)
41 ppb
1 (15%)
21 ppb
2 (36%)
25 ppb
From Sullivan, 2009

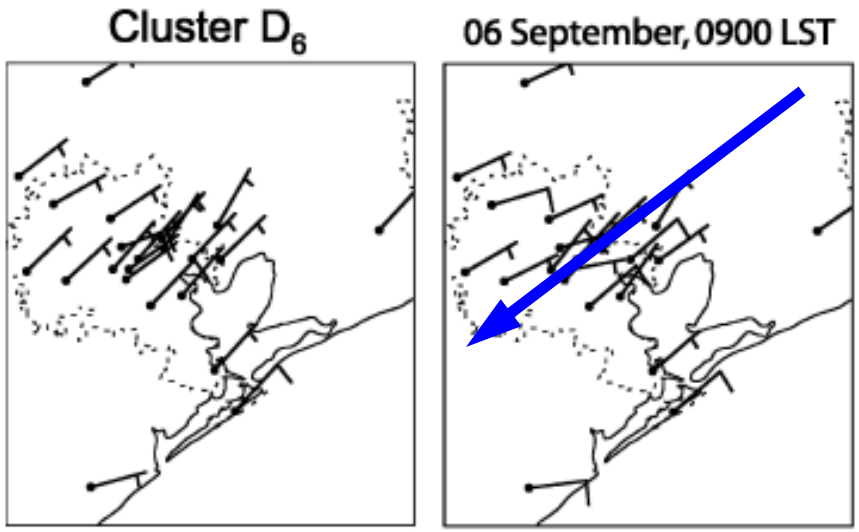

Source at 29.76 N 95.36 W
37 ppb
Lower ozone regime
3 (3%)
45 ppb
5 (12%)
36 ppb
H
4 (22%)
41 ppb
1 (15%)
21 ppb
2 (36%)
25 ppb
From Sullivan, 2009



Darby, 2005. Cluster analysis of surface observations of wind direction during TexAQS 2000.

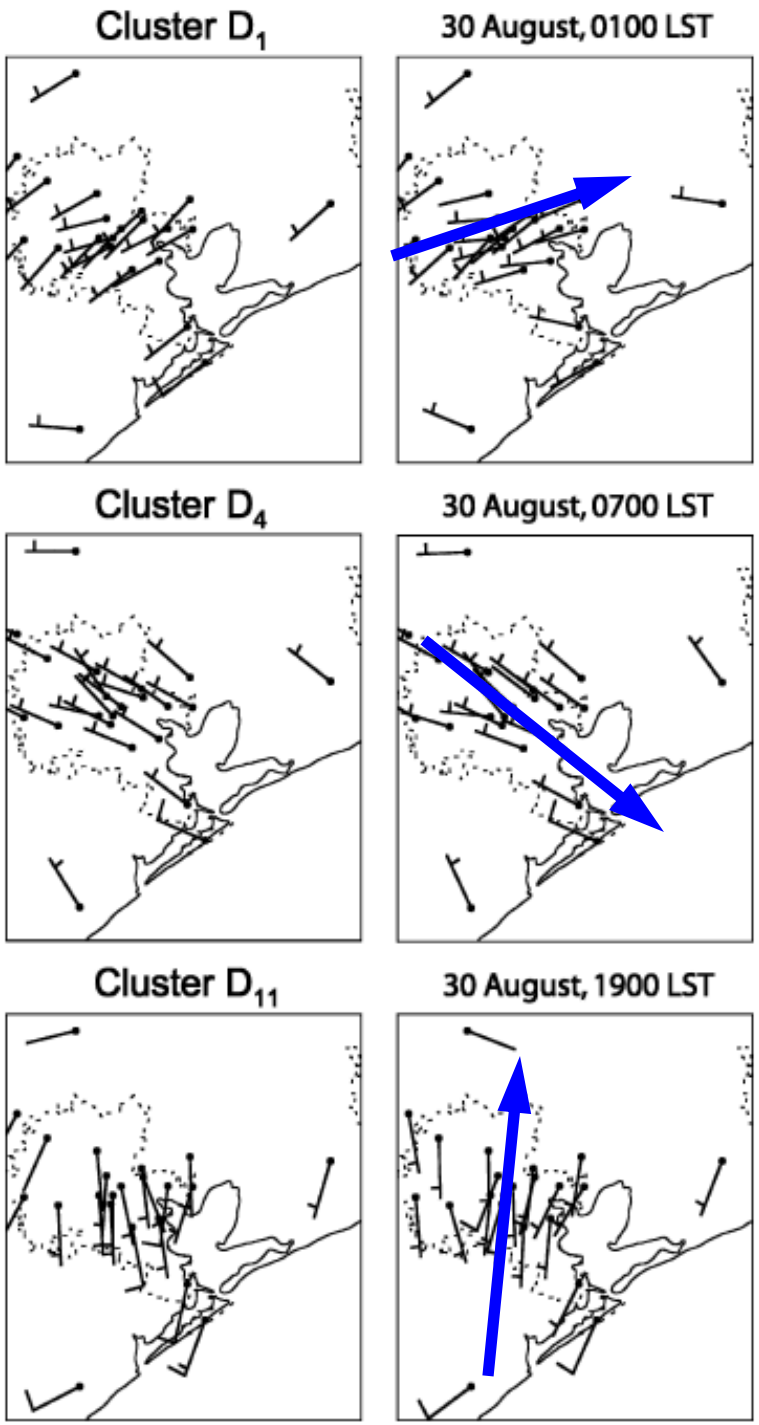
The sequence of clusters shown at left shows the wind direction rotation that was described by Breitenbach et al., 2002.

Day begins with winds with northerly component. Wind direction rotates in a clockwise fashion, i.e., “typical” veering.



Darby, 2005. Cluster analysis of surface observations of wind direction during TexAQS 2000.

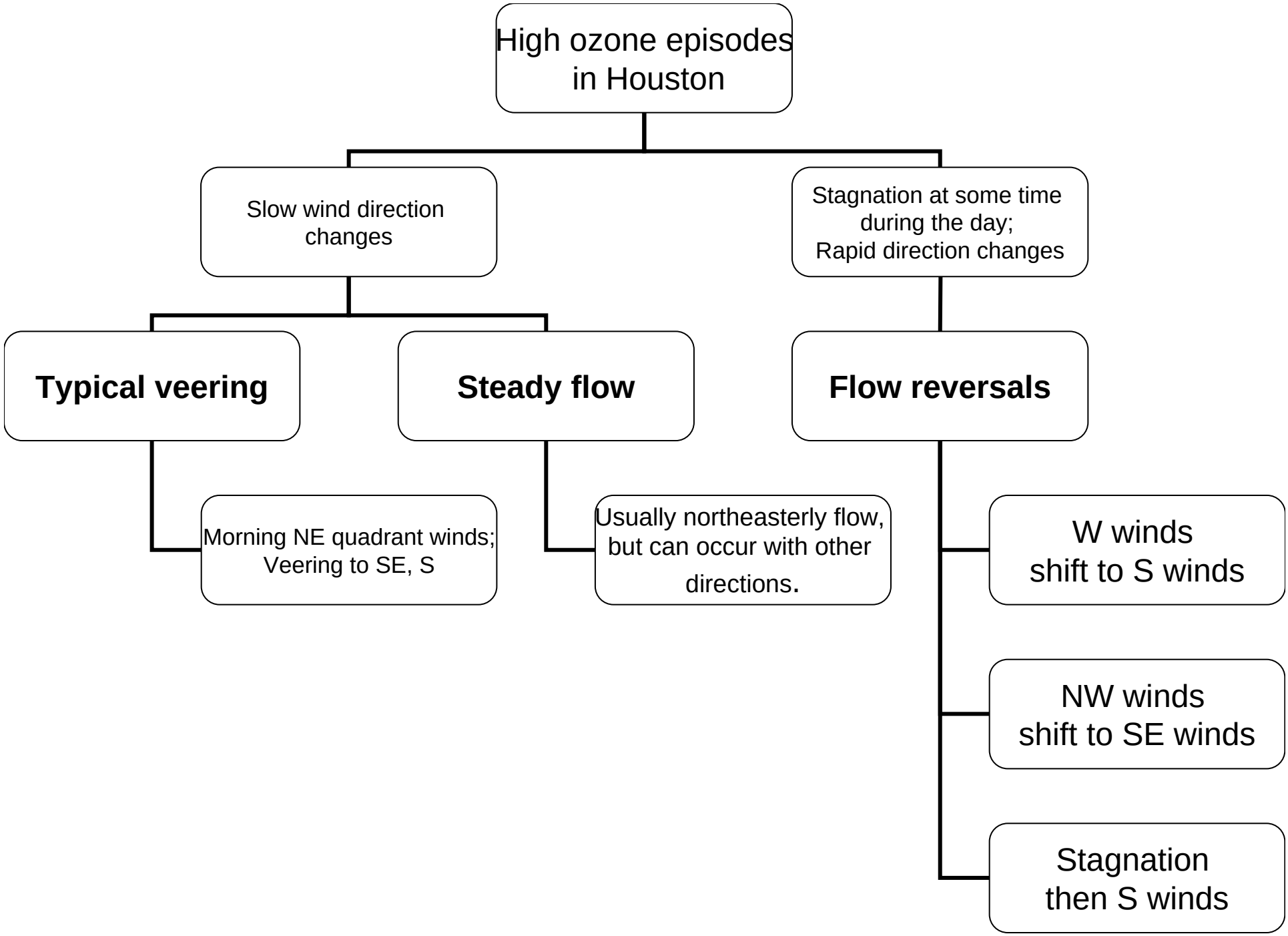
On Sept 6, 2000, winds persisted from the NE for most of the day, i.e., steady flow.

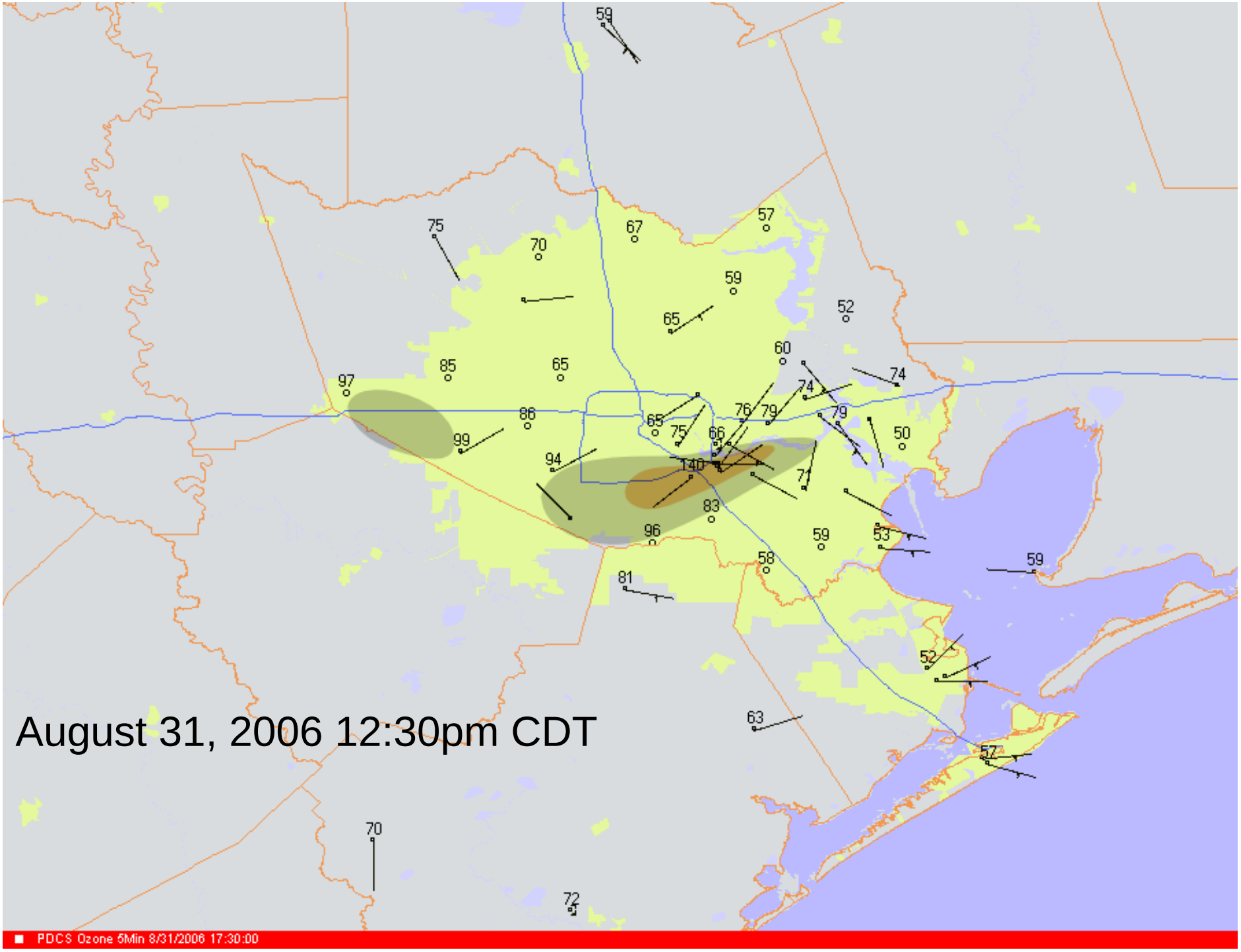


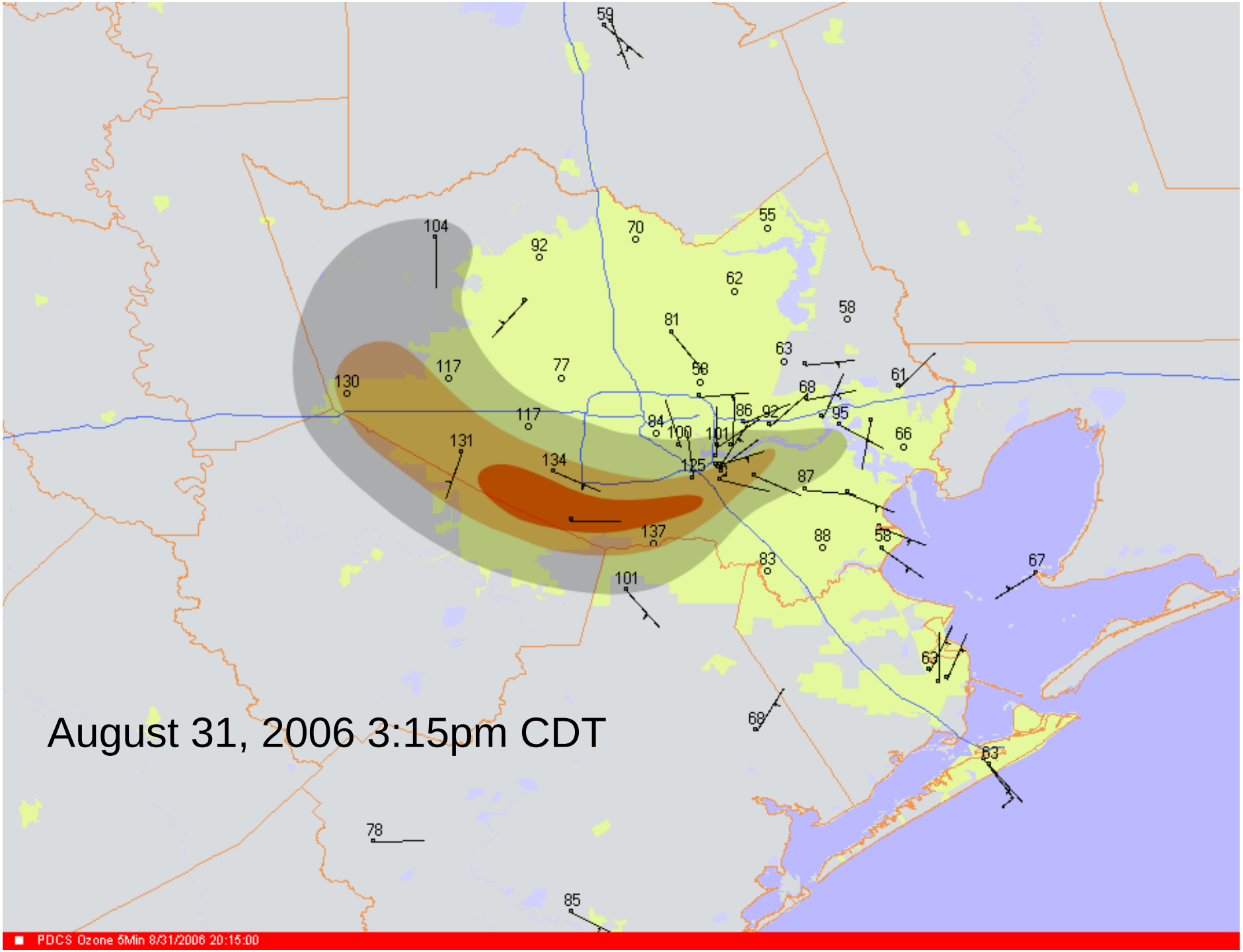
Darby, 2005. Cluster analysis of surface observations of wind direction during TexAQS 2000.

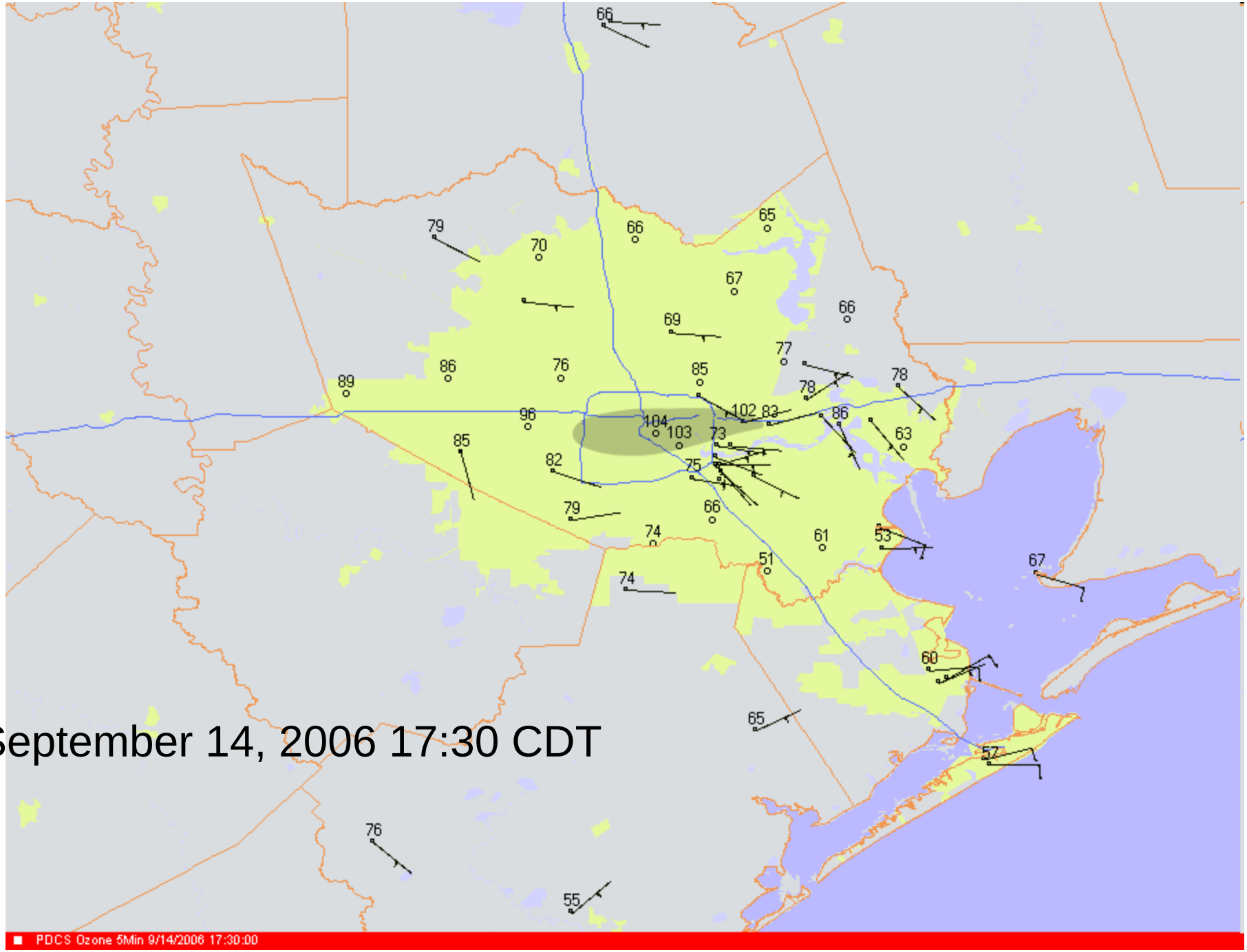
The sequence of clusters shown at left shows a reversal of wind direction, from NW to SSE.

This class of events will be called “flow reversals”. This class is less distinct than the other two; there are several patterns that can be considered flow reversals.

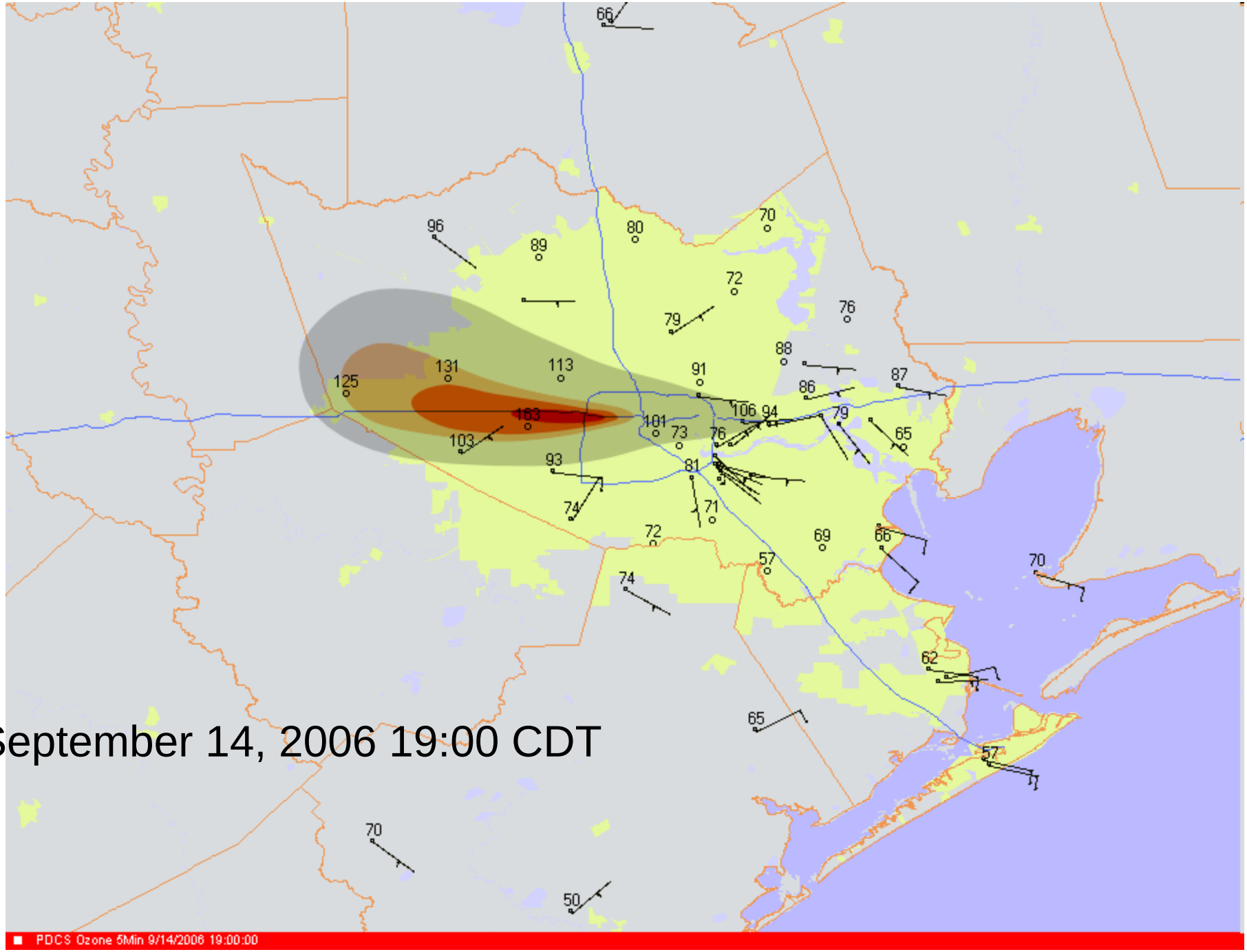

High ozone episodes in Houston
Slow wind direction changes
Stagnation at some time during the day; Rapid direction changes
Typical veering
Steady flow
Flow reversals
Morning NE quadrant winds; Veering to SE, S
Usually northeasterly flow, but can occur with other directions.
W winds shift to S winds
NW winds shift to SE winds
Stagnation then S winds

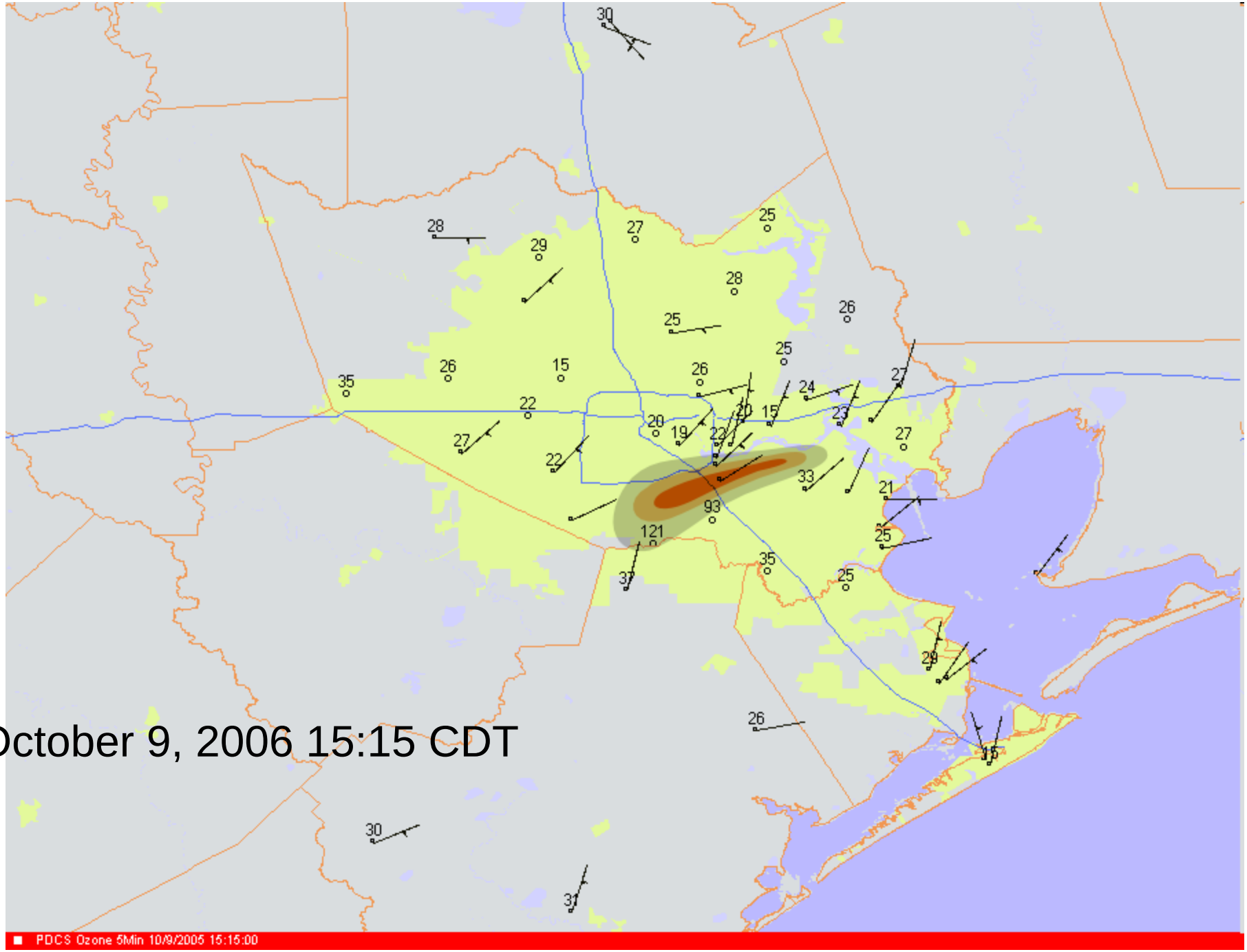

August 31, 2006 12:30pm CDT
PDCS Ozone 5Min 8/31/2006 17:30:00


August 31, 2006 3:15pm CDT
PDCS Ozone 5Min 8/31/2006 20:15:00

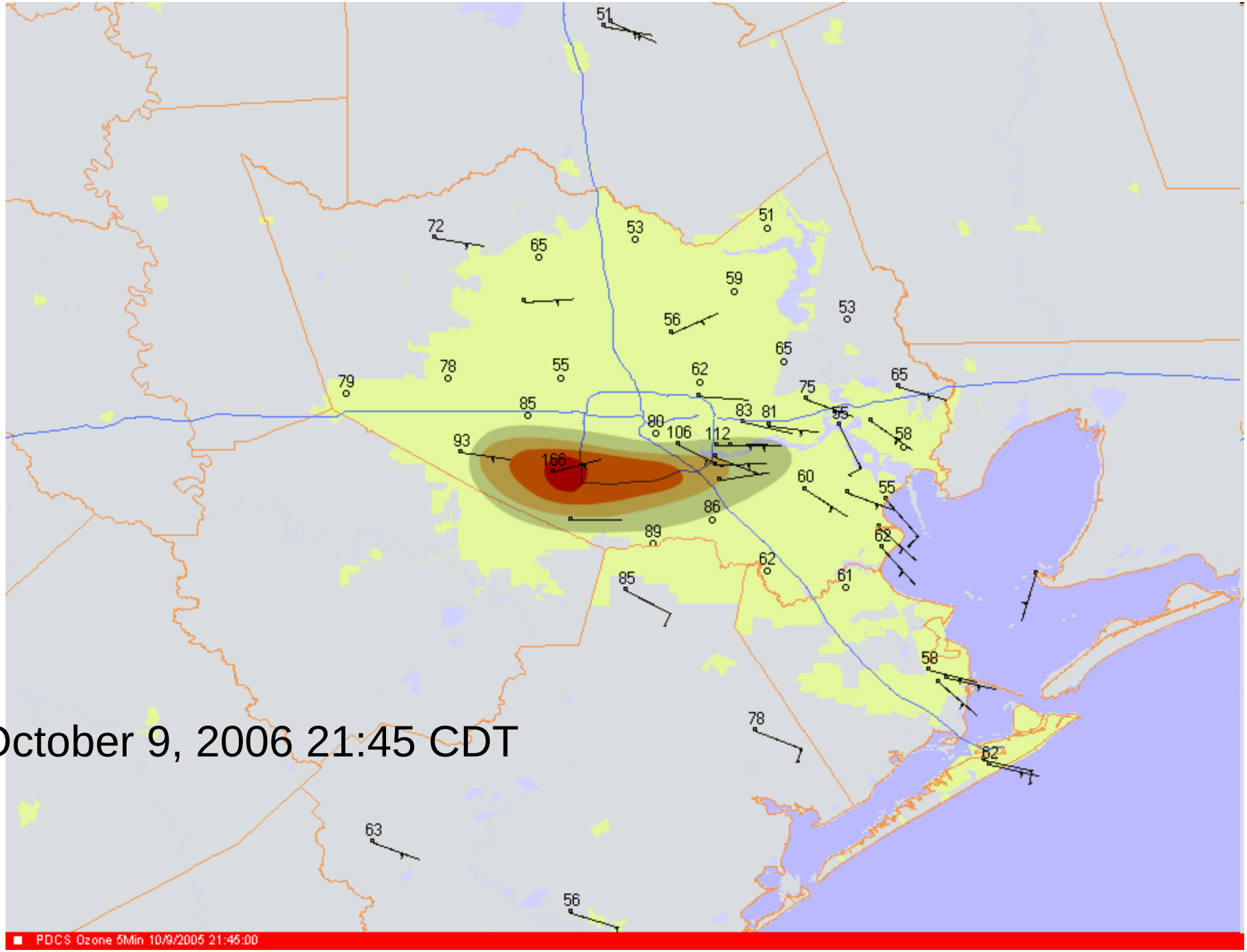


September 14, 2006 17:30 CDT

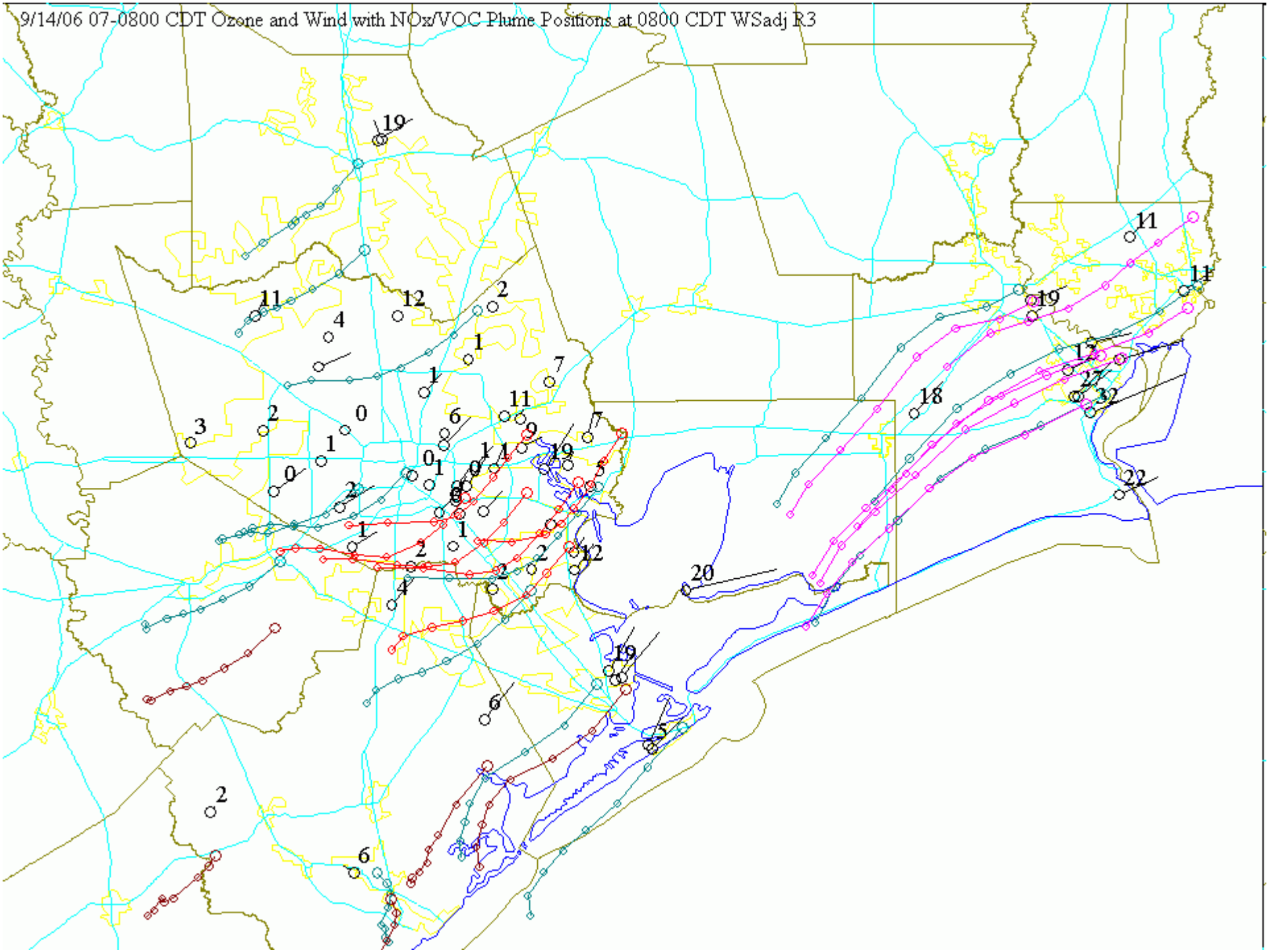

September 14, 2006 19:00 CDT
PDCS Ozone 5Min 9/14/2006 19:00:00

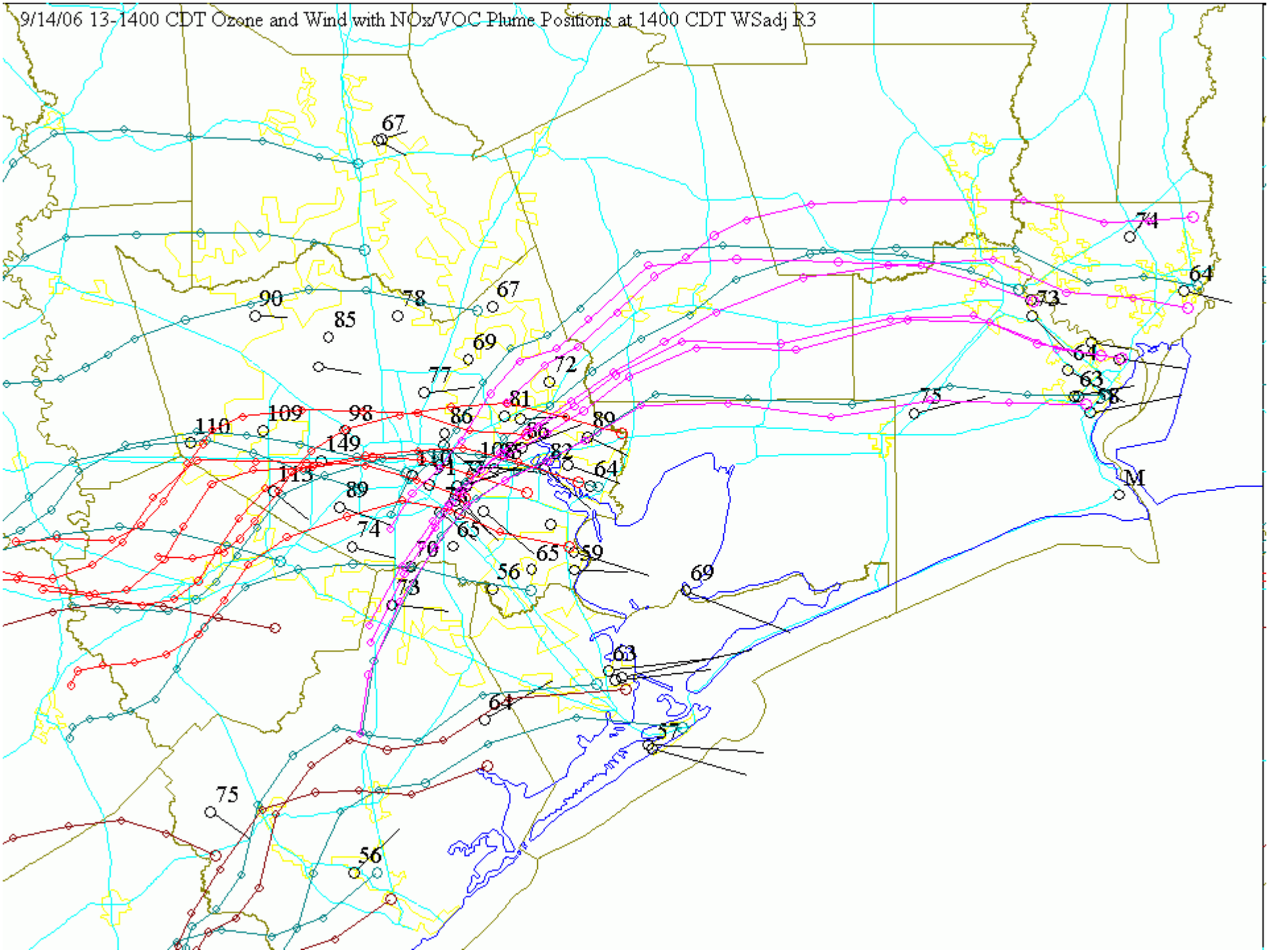


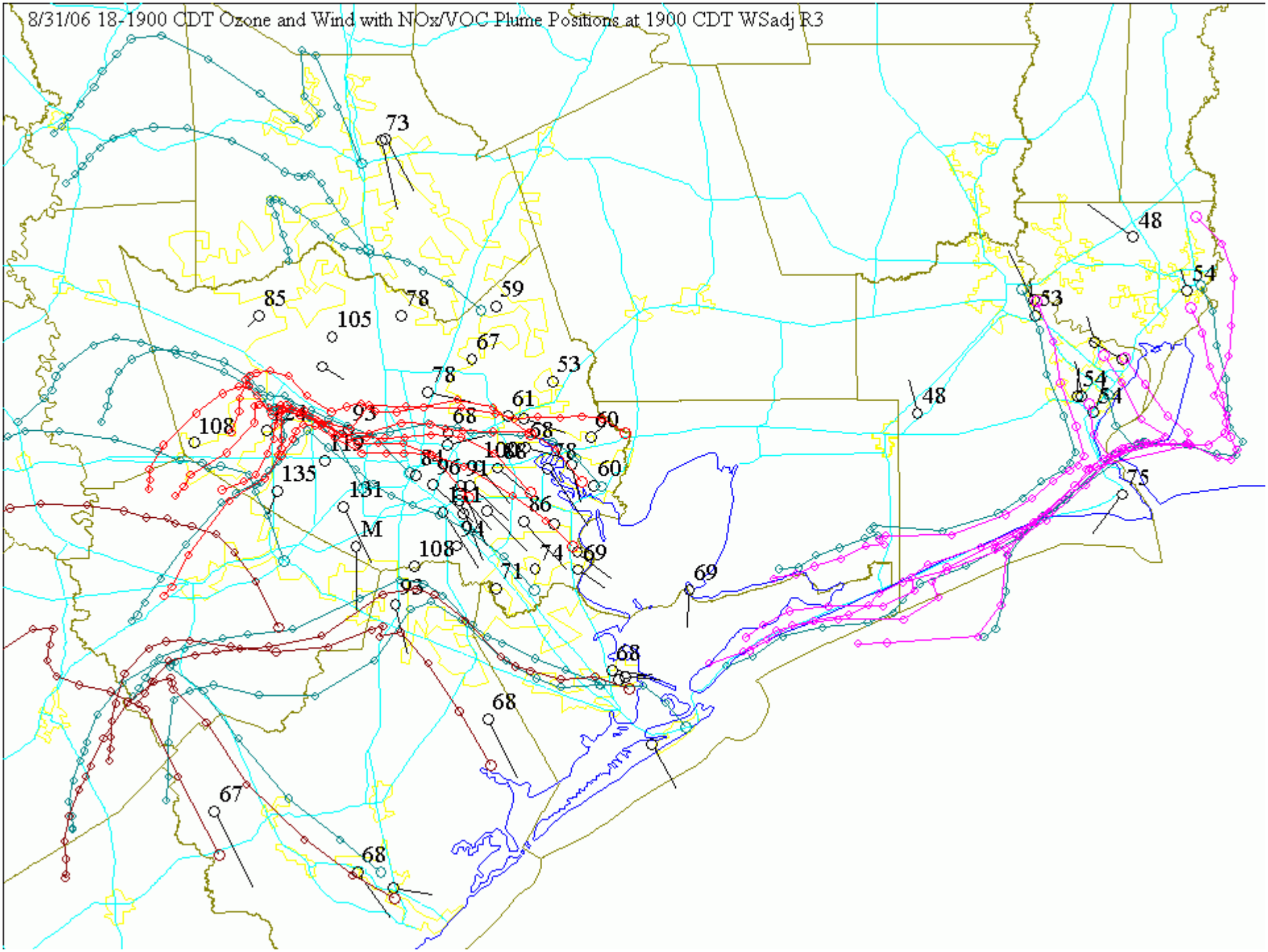
October 9, 2006 15:15 CDT



October 9, 2006 21:45 CDT


9/14/06 07-0800 CDT Ozone and Wind with NOx/VOC Plume Positions at 0800 CDT WSadj R3


9/14/06 13-1400 CDT Ozone and Wind with NOx/VOC Plume Positions at 1400 CDT WSadj R3


8/31/06 18-1900 CDT Ozone and Wind with NOx/VOC Plume Positions at 1900 CDT WSadj R3
73
48
54
85
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59
53
105
67
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53
61
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93
68
60
108
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119
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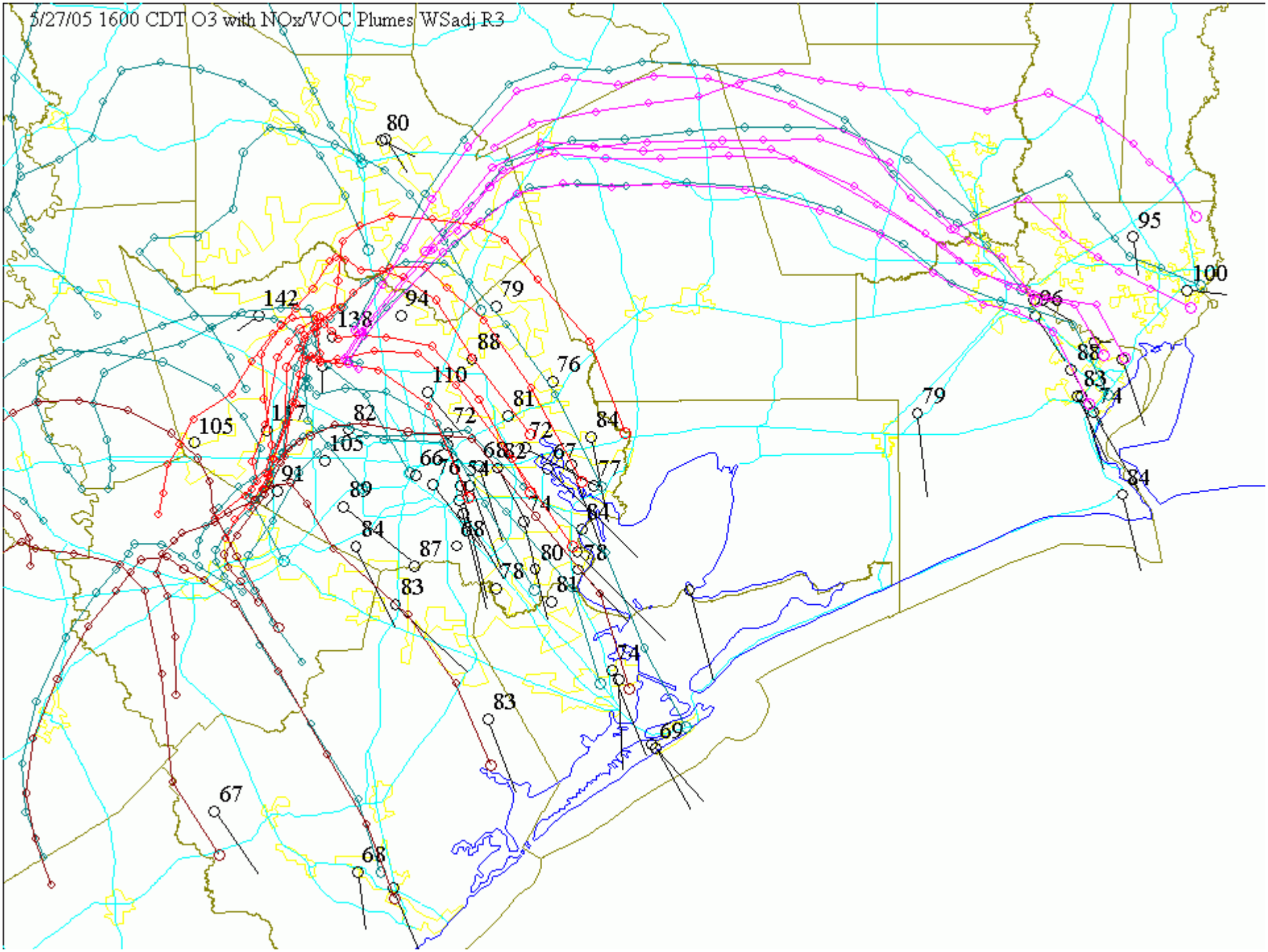
5/27/05 1600 CDT O3 with NOx/VOC Plumes WSadj R3
80
95
100
142
94
79
138
88
76
110
81
79
105
117
82
72
84
105
72
68
82
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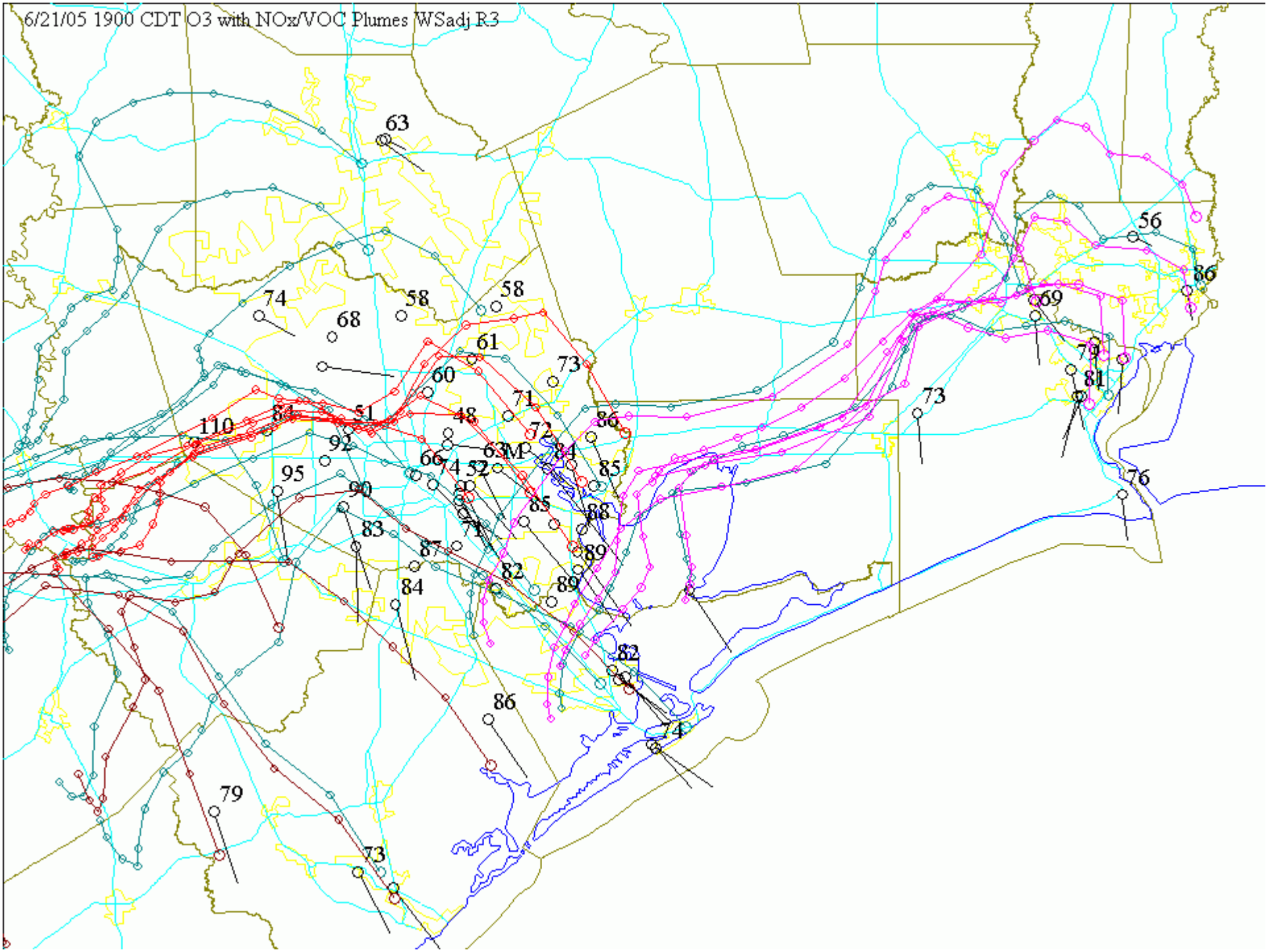
6/21/05 1900 CDT O3 with NOx/VOC Plumes WSadj R3
63
74
68
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73
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88
89
89
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82
74
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79
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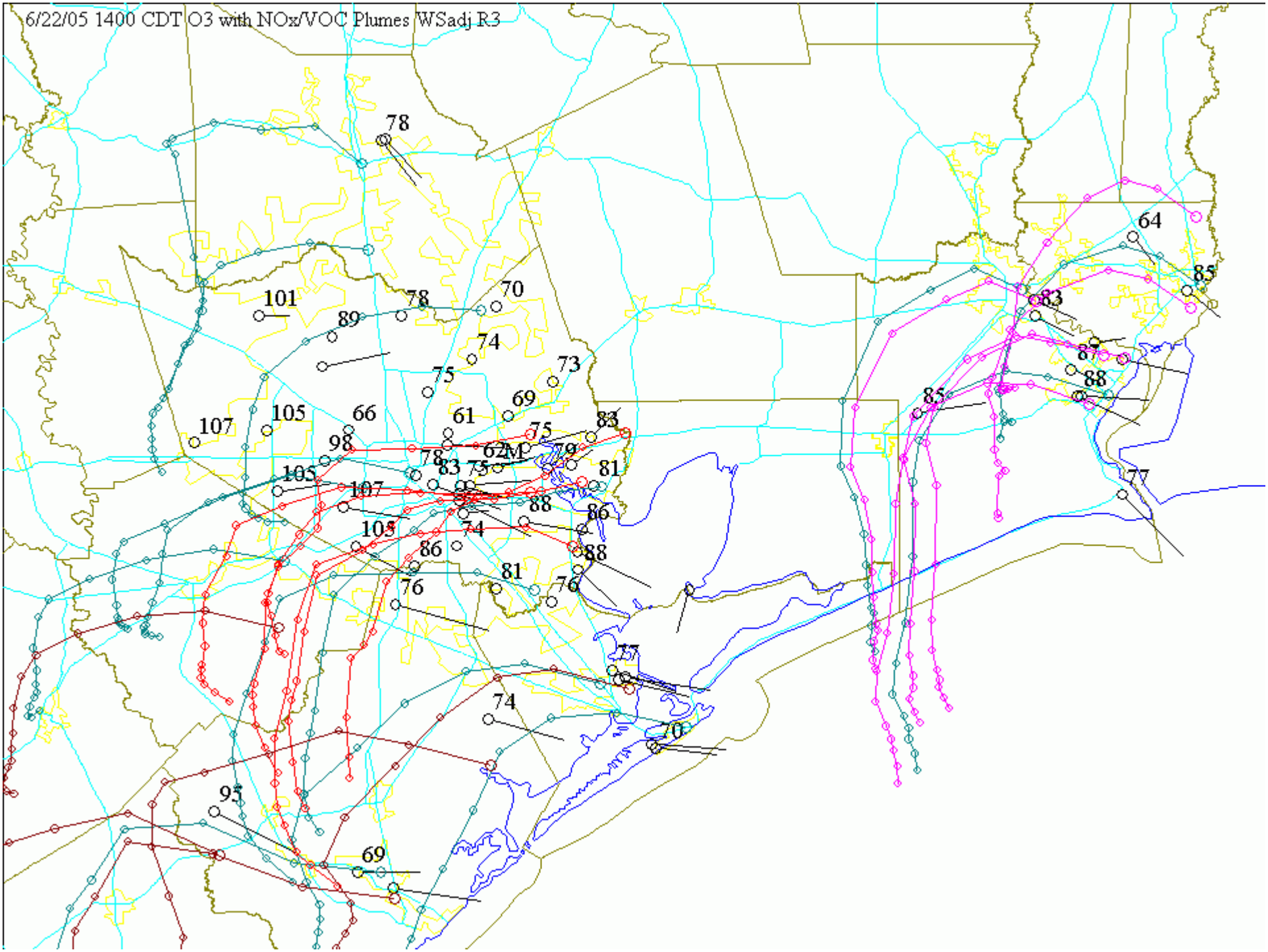
6/22/05 1400 CDT O3 with NOx/VOC Plumes WSadj R3
78
64
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101
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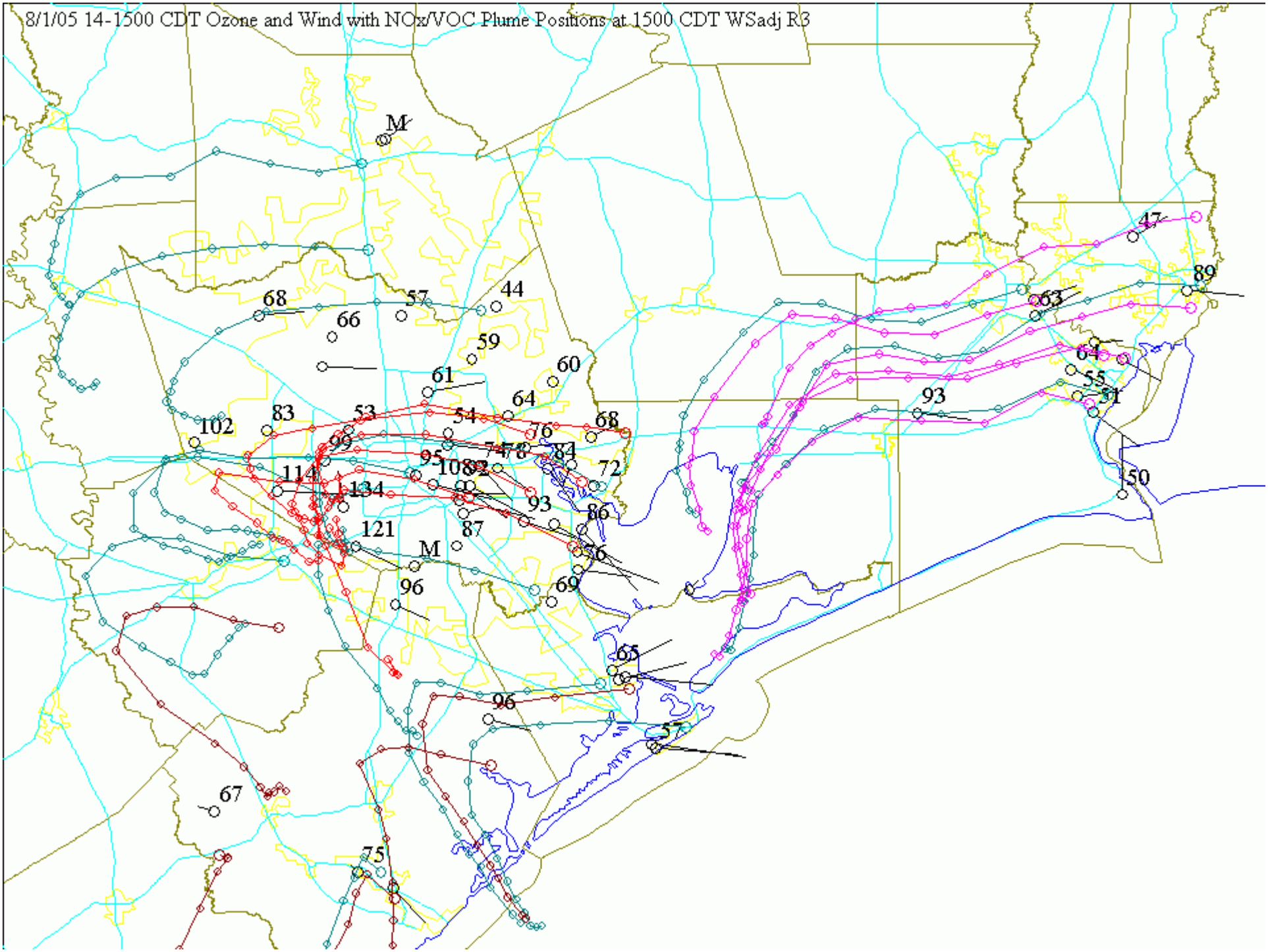
8/1/05 14-1500 CDT Ozone and Wind with NOx/VOC Plume Positions at 1500 CDT WSadj R3
M
47
89
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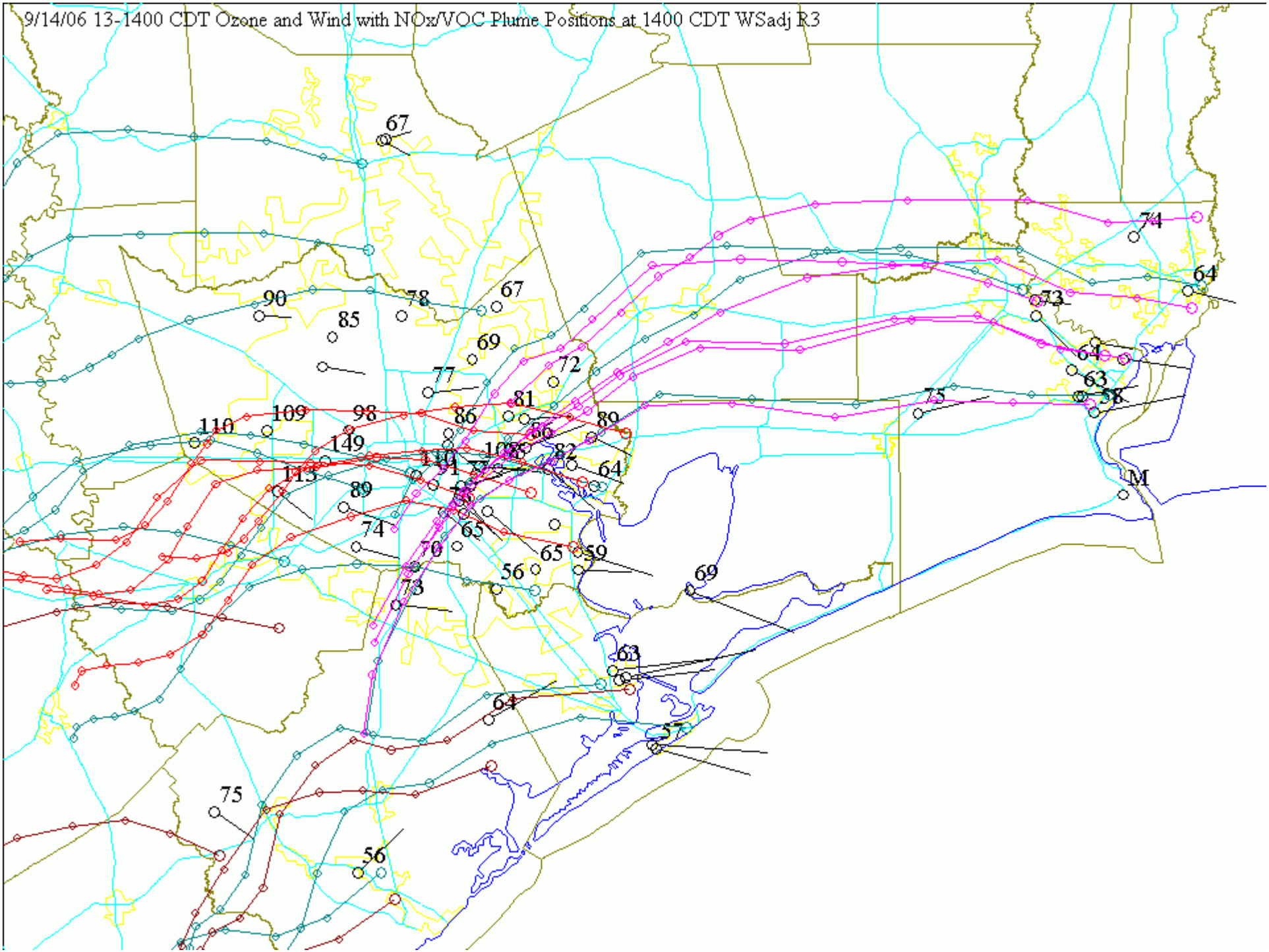
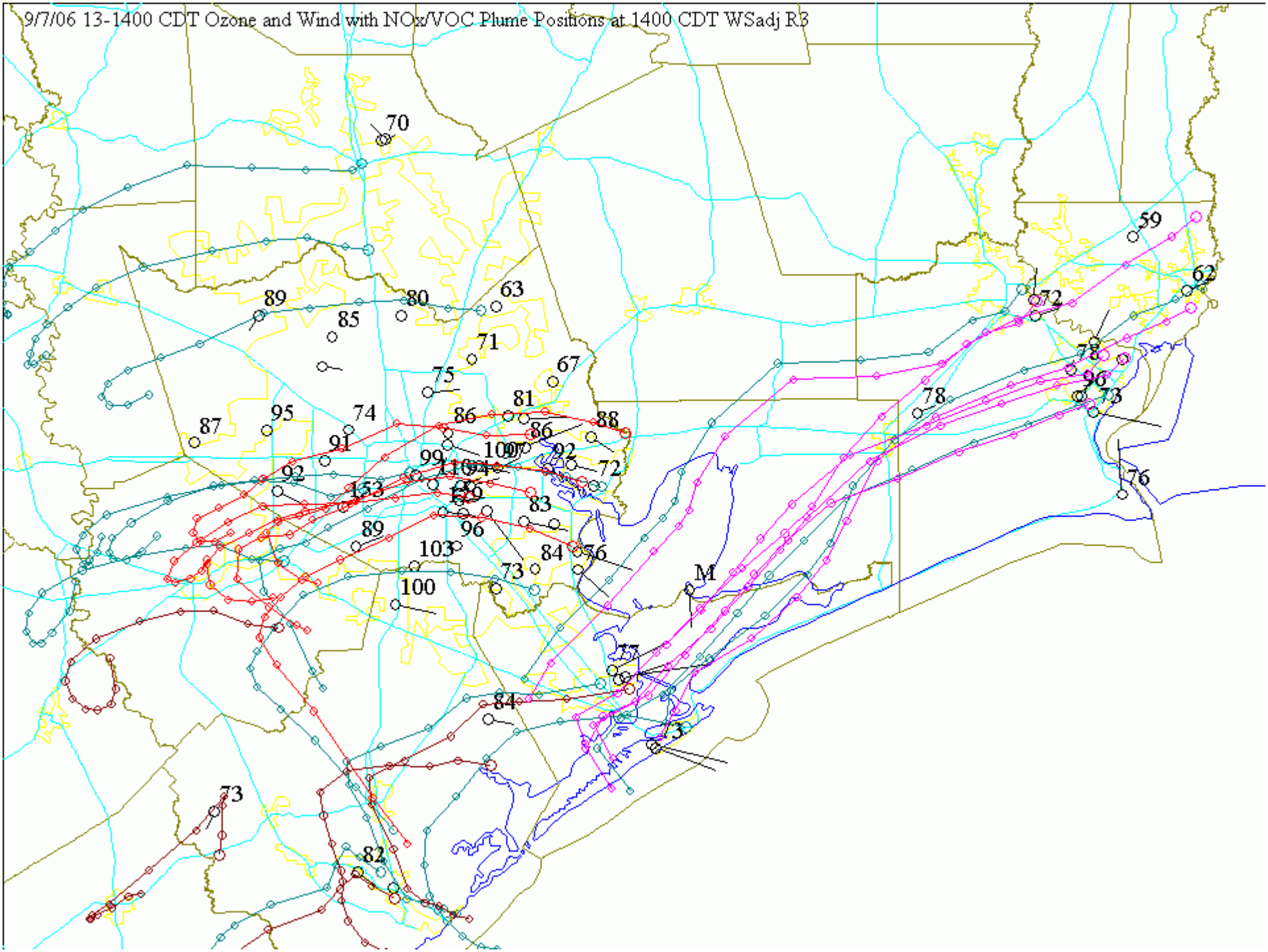
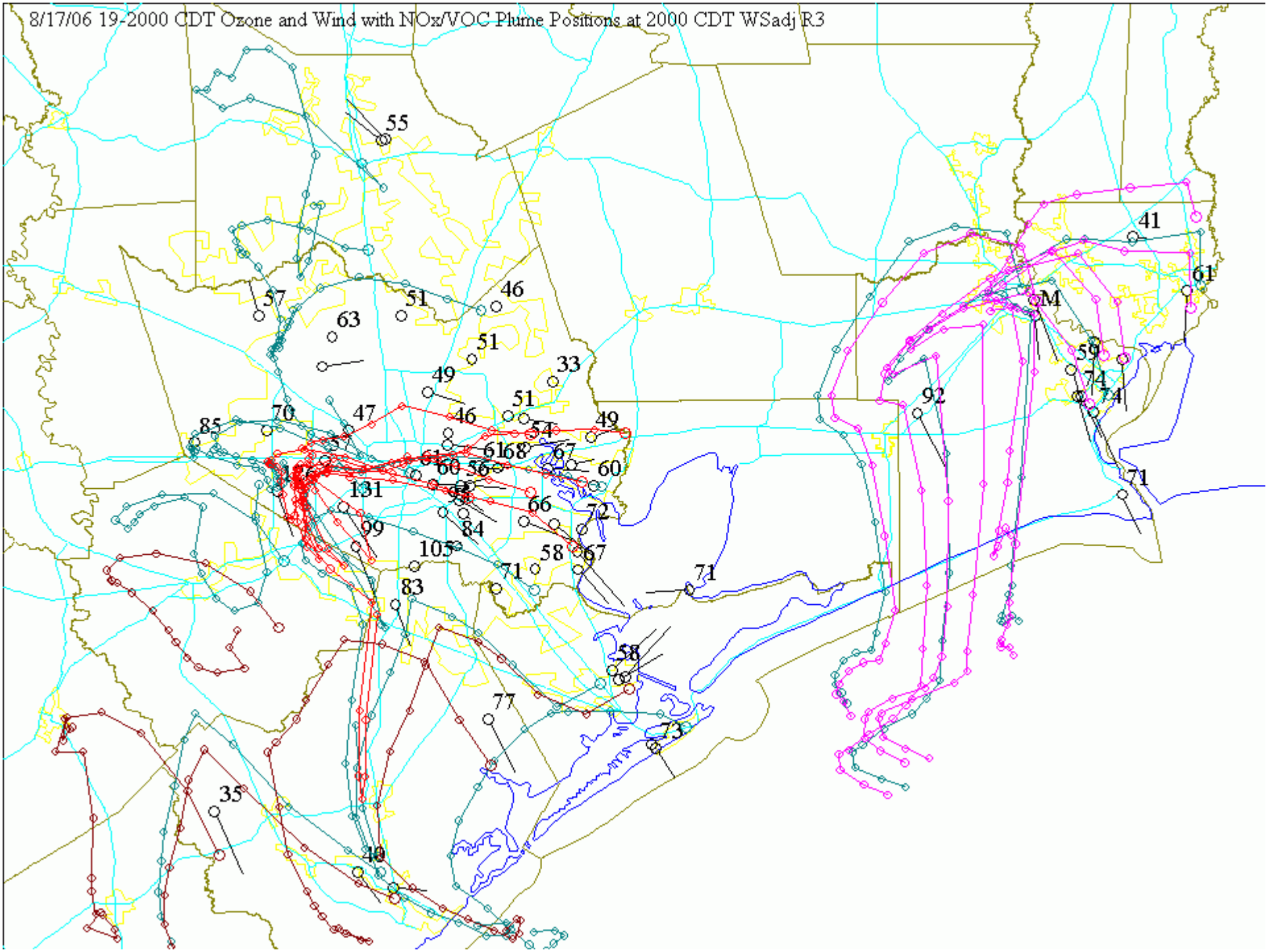

9/14/06 13-1400 CDT Ozone and Wind with NOx/VOC Plume Positions at 1400 CDT WSadj R3


9/7/06 13-1400 CDT Ozone and Wind with NOx/VOC Plume Positions at 1400 CDT WSadj R3


8/17/06 19-2000 CDT Ozone and Wind with NOx/VOC Plume Positions at 2000 CDT WSadj R3
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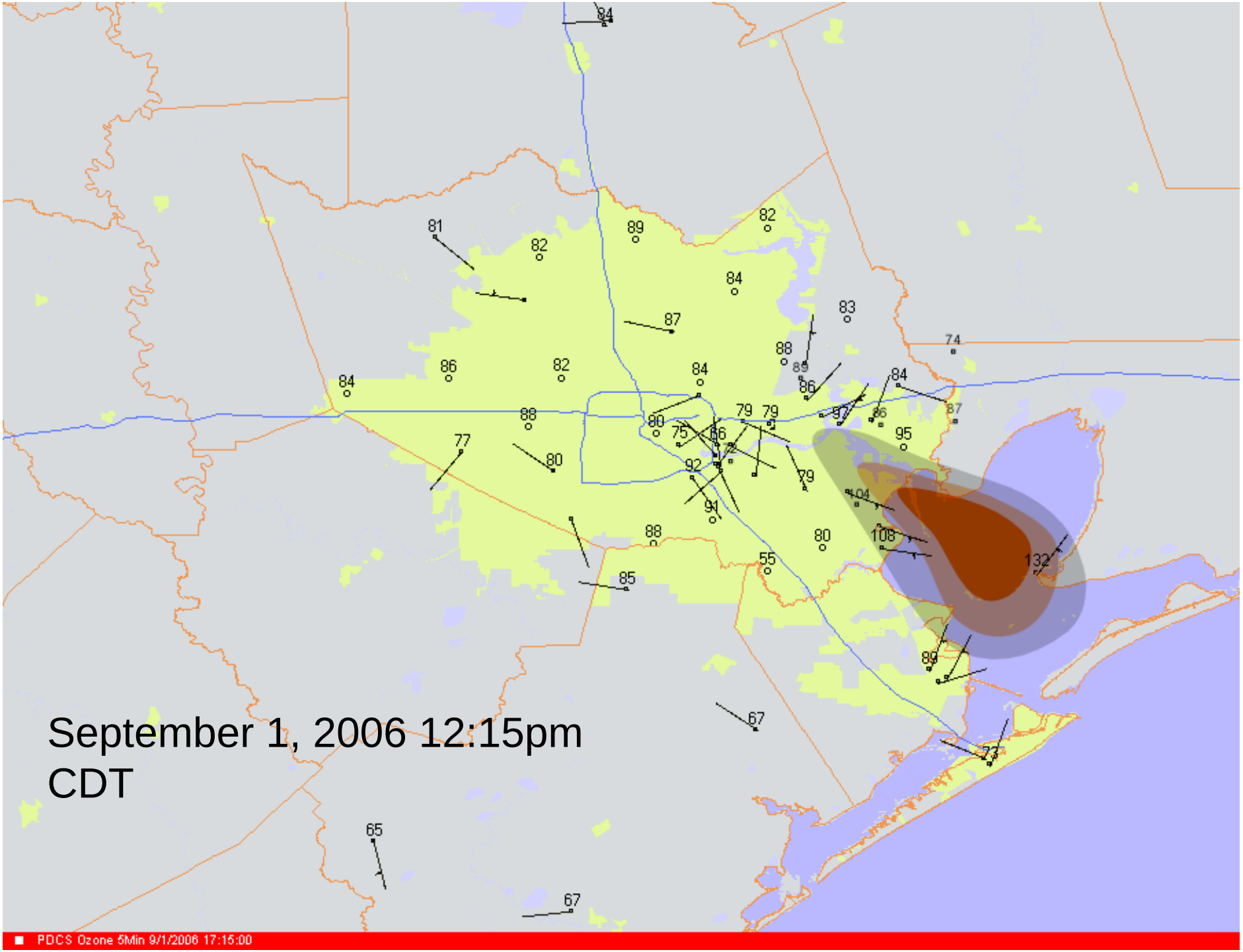
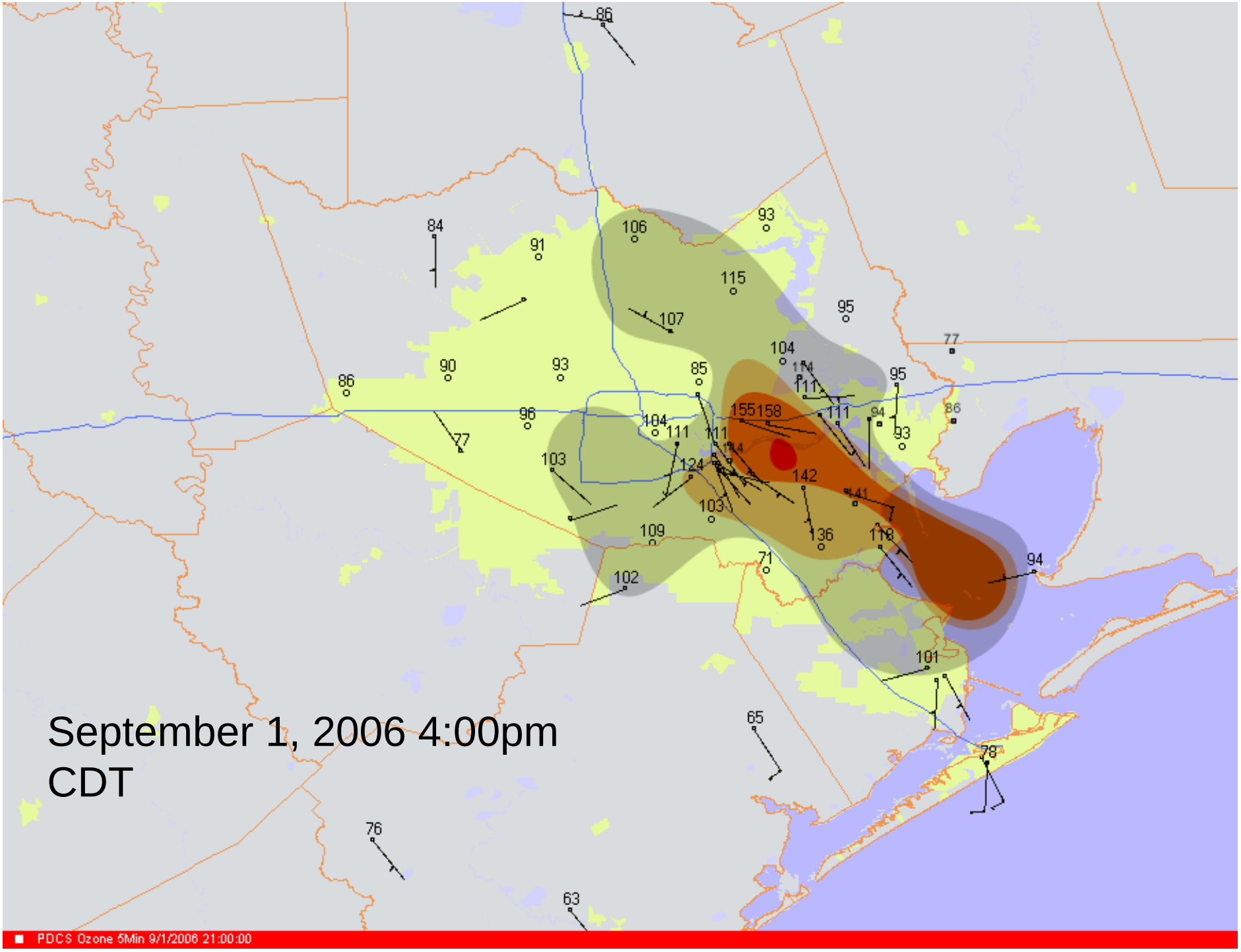
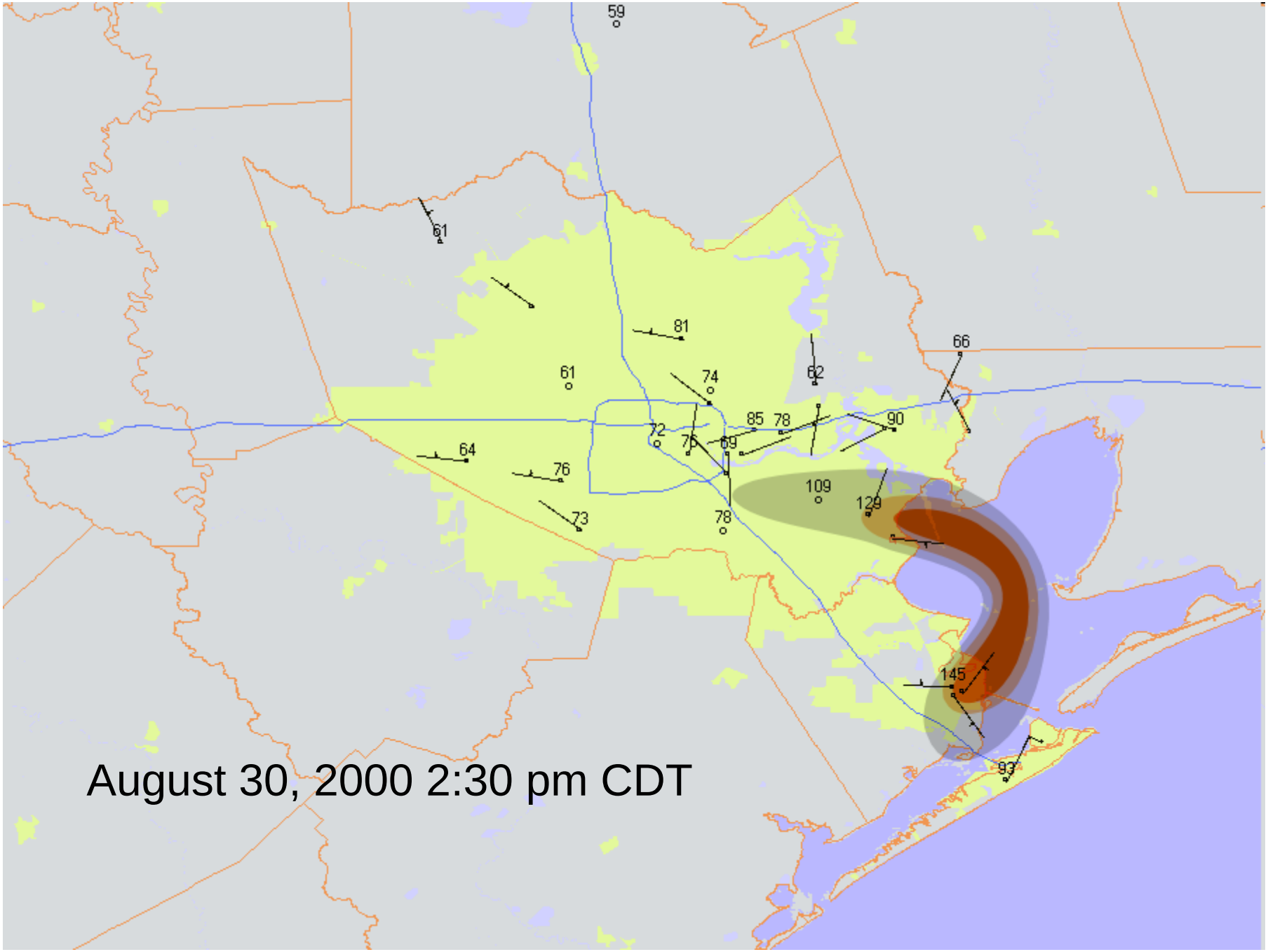
92
71

Flow reversals

- Morning winds very light, near stagnant
- Winds usually from the northwest quadrant
- Winds shift rapidly to southerly
- Aged air mass carried over sources of fresh emissions, resulting in vigorous ozone formation


September 1, 2006 12:15pm CDT
PDCS Ozone 5Min 9/1/2006 17:15:00


September 1, 2006 4:00pm CDT
PDCS Ozone 5Min 9/1/2006 21:00:00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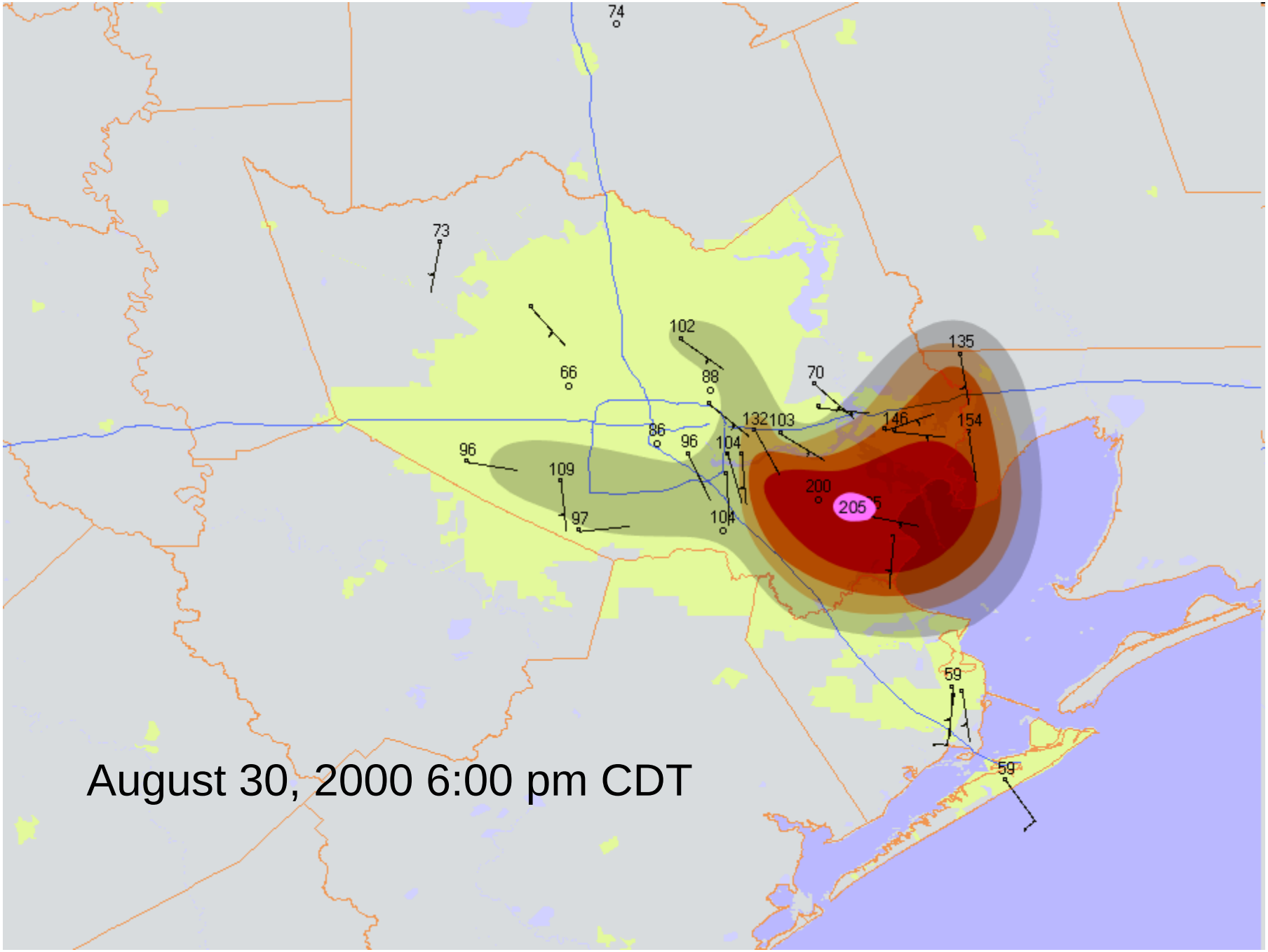
August 30, 2000 2:30 pm CDT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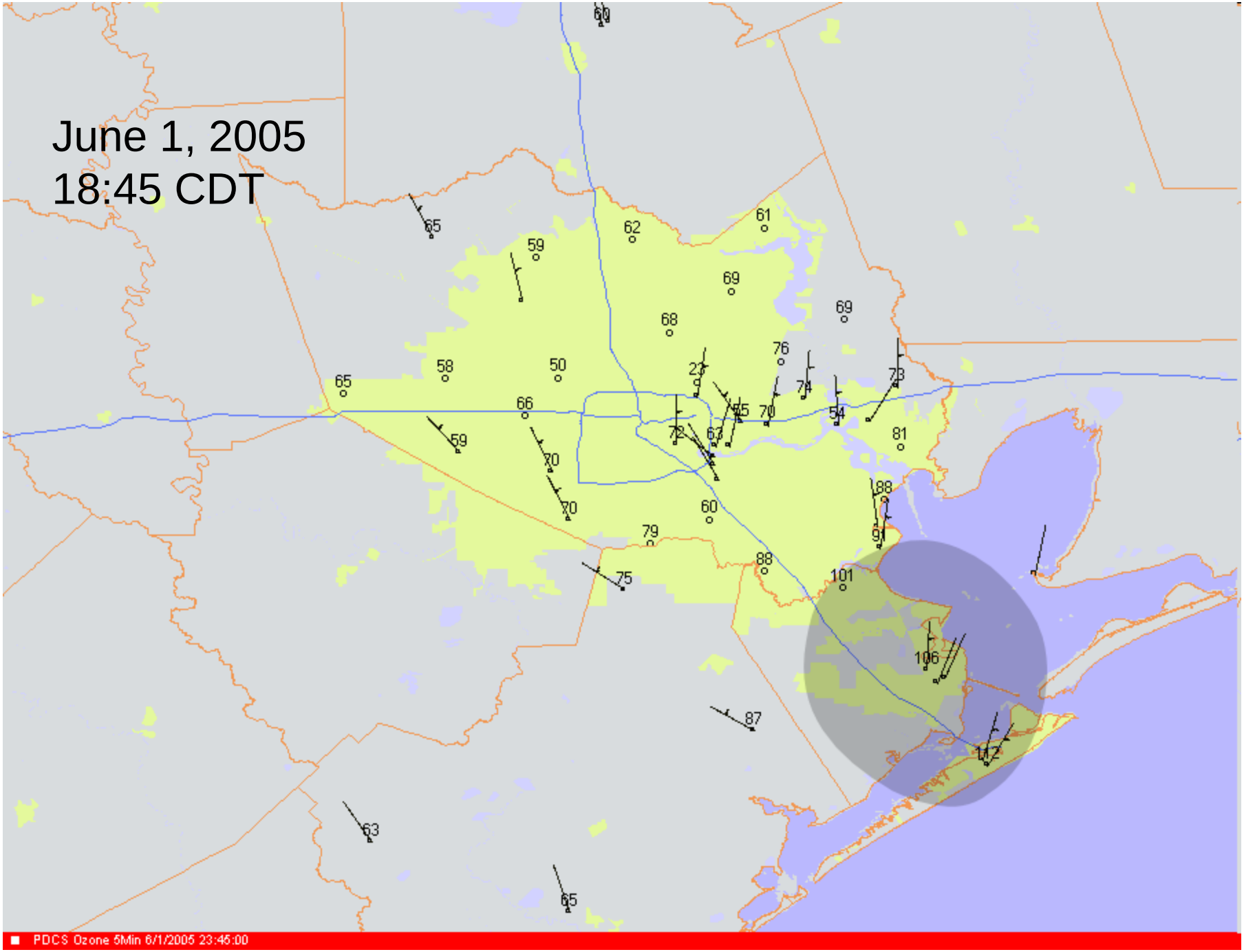
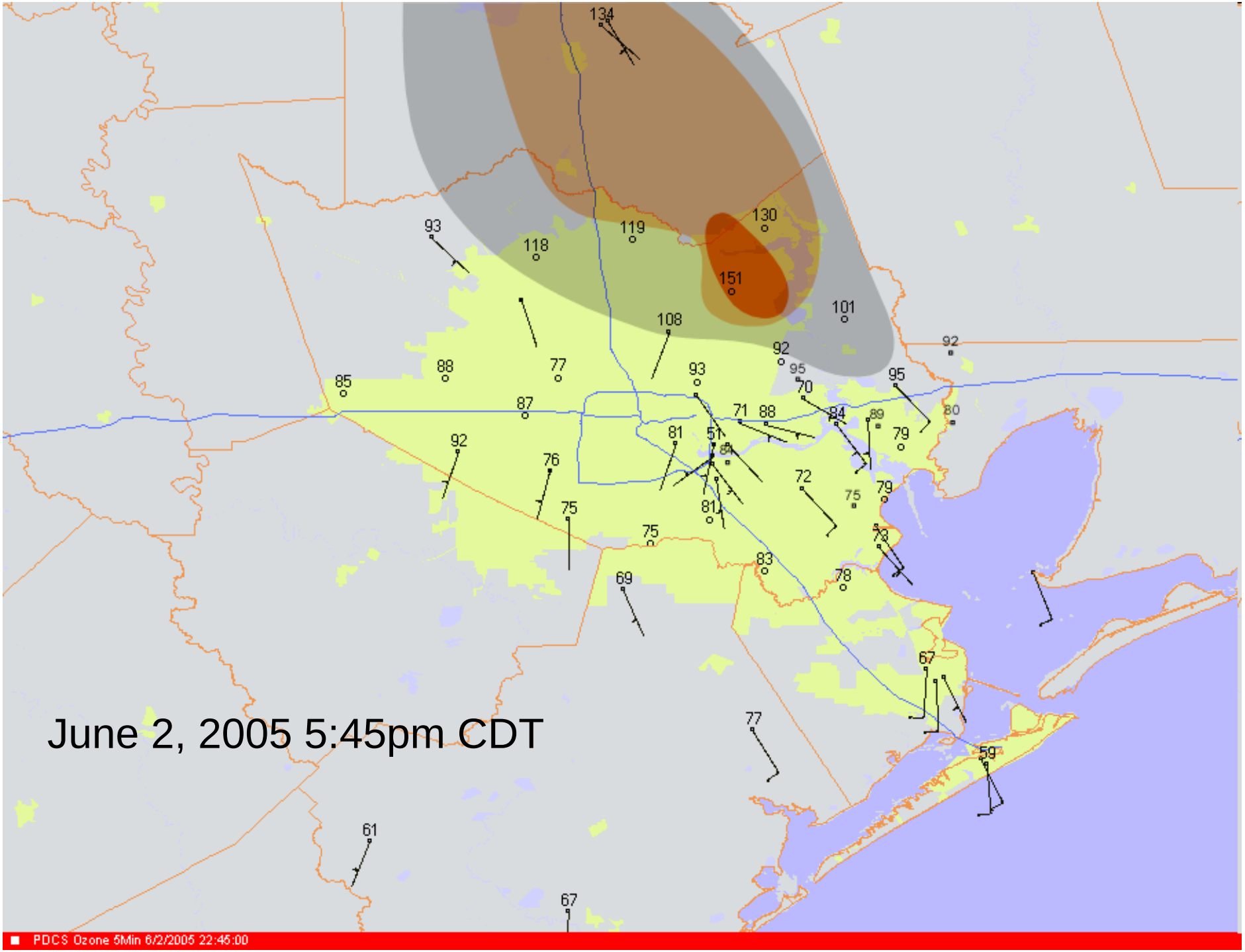
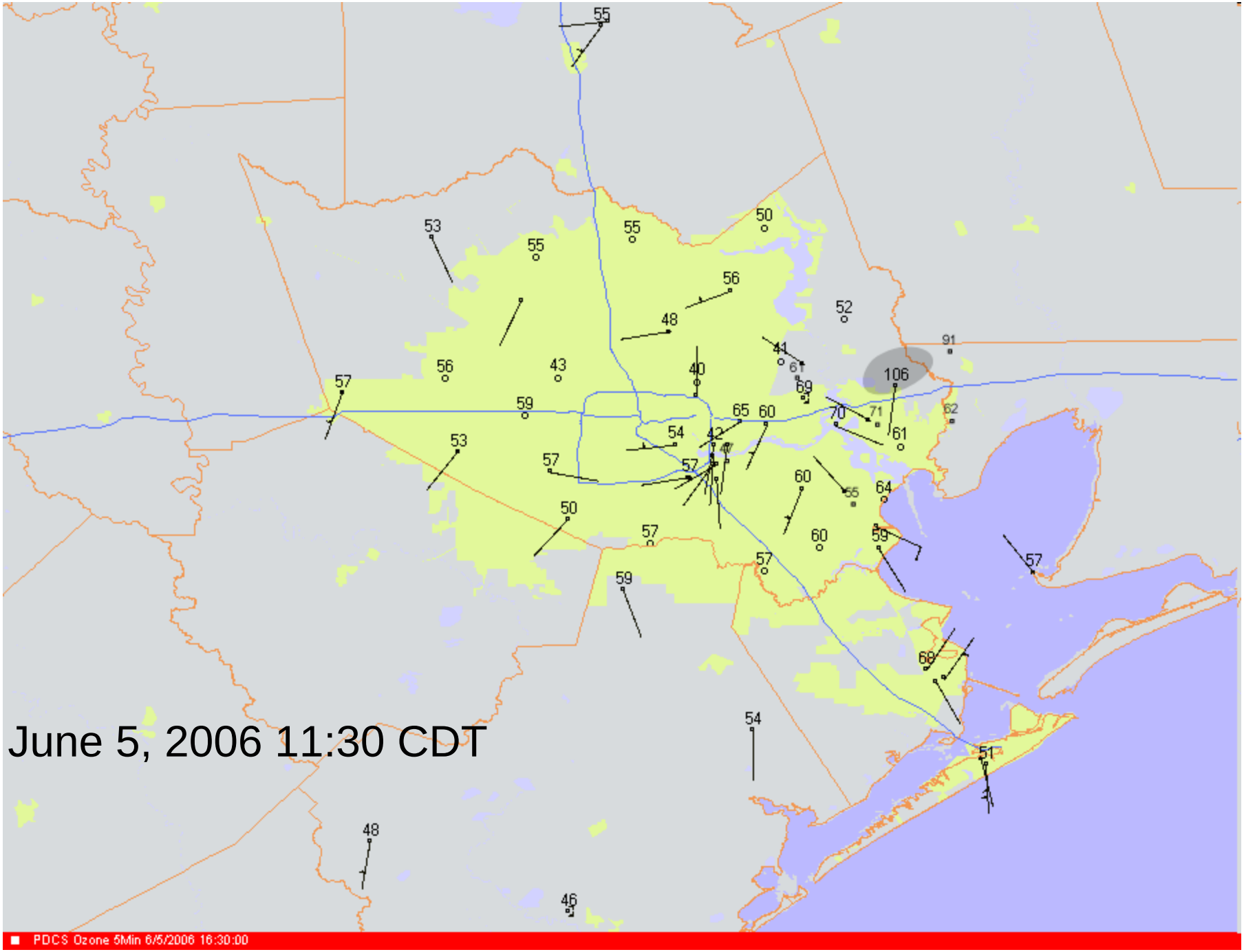
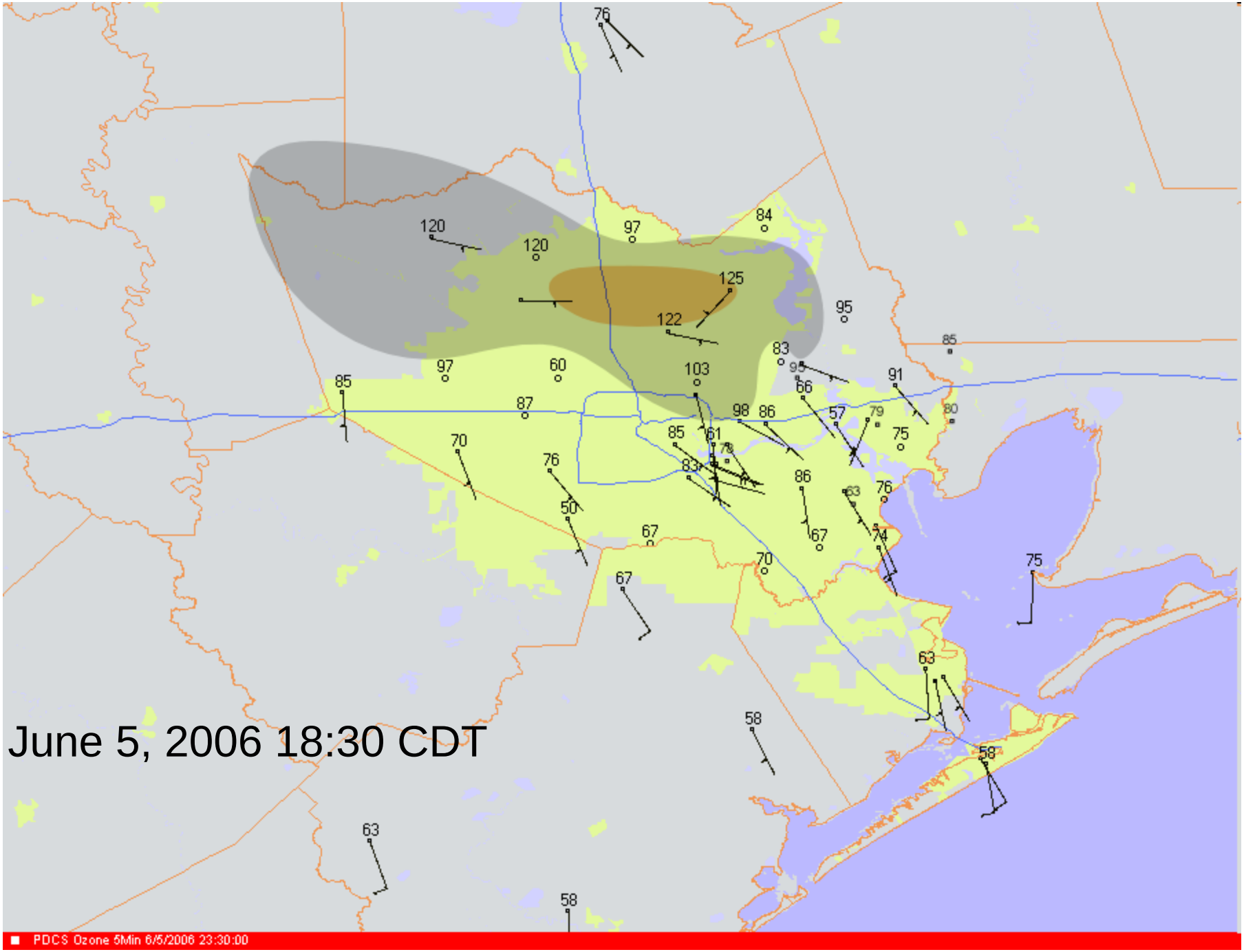
59
August 30, 2000 6:00 pm CDT


June 1, 2005
18:45 CDT
PDCS Ozone 5Min 6/1/2005 23:45:00

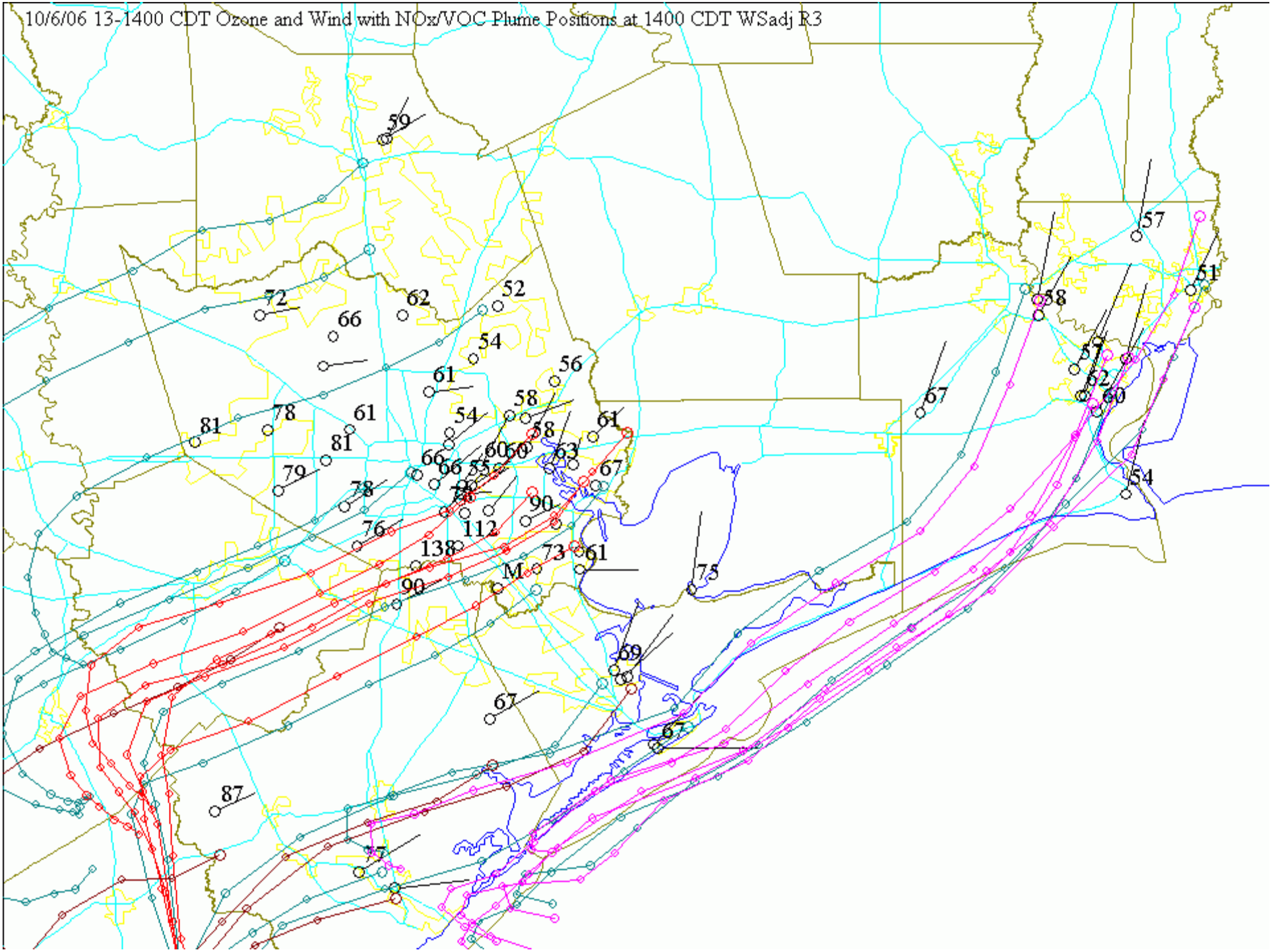

June 2, 2005 5:45pm CDT
PDCS Ozone 5Min 6/2/2005 22:45:00

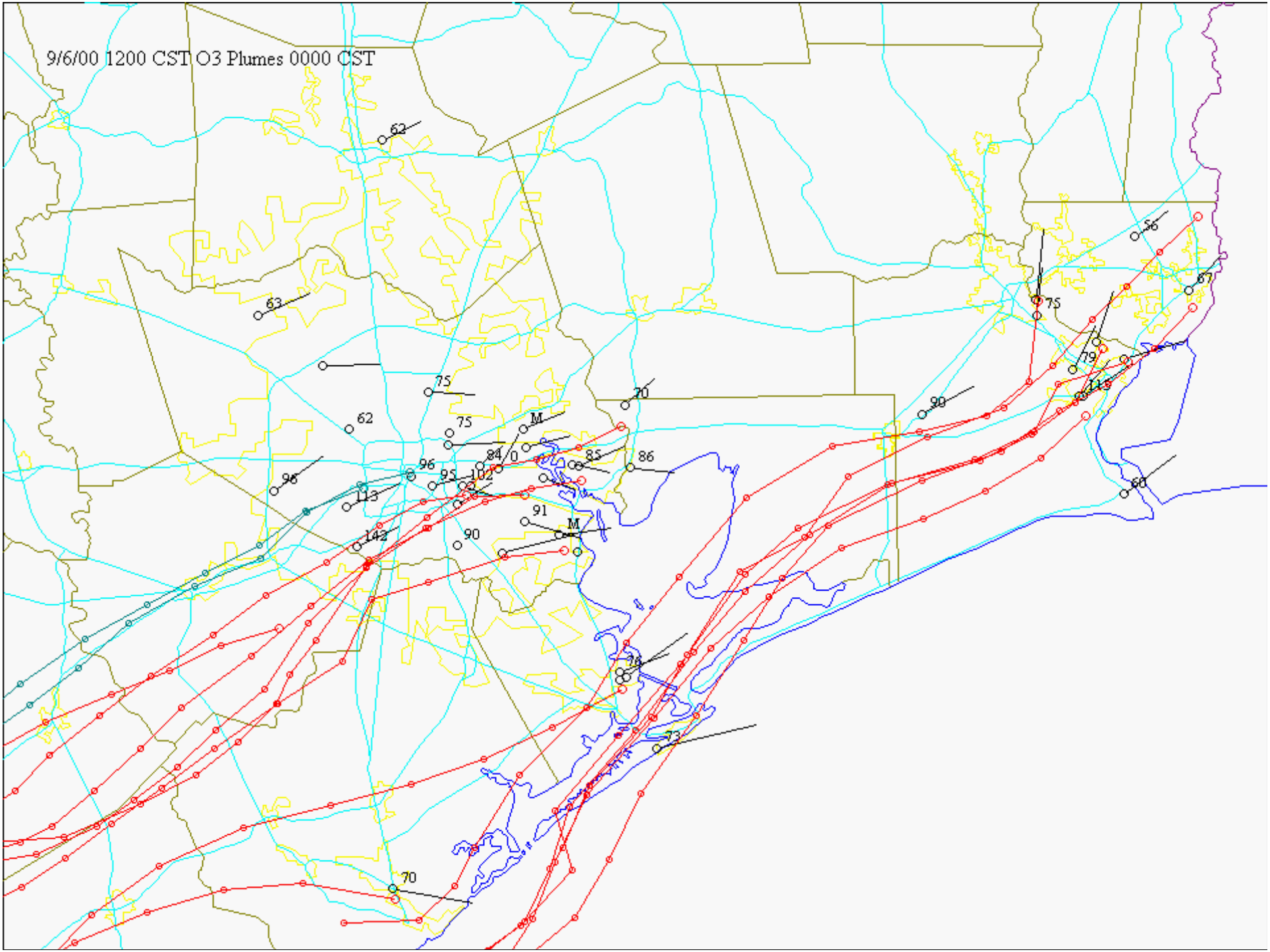

June 5, 2006 11:30 CDT
PDCS Ozone 5Min 6/5/2006 16:30:00

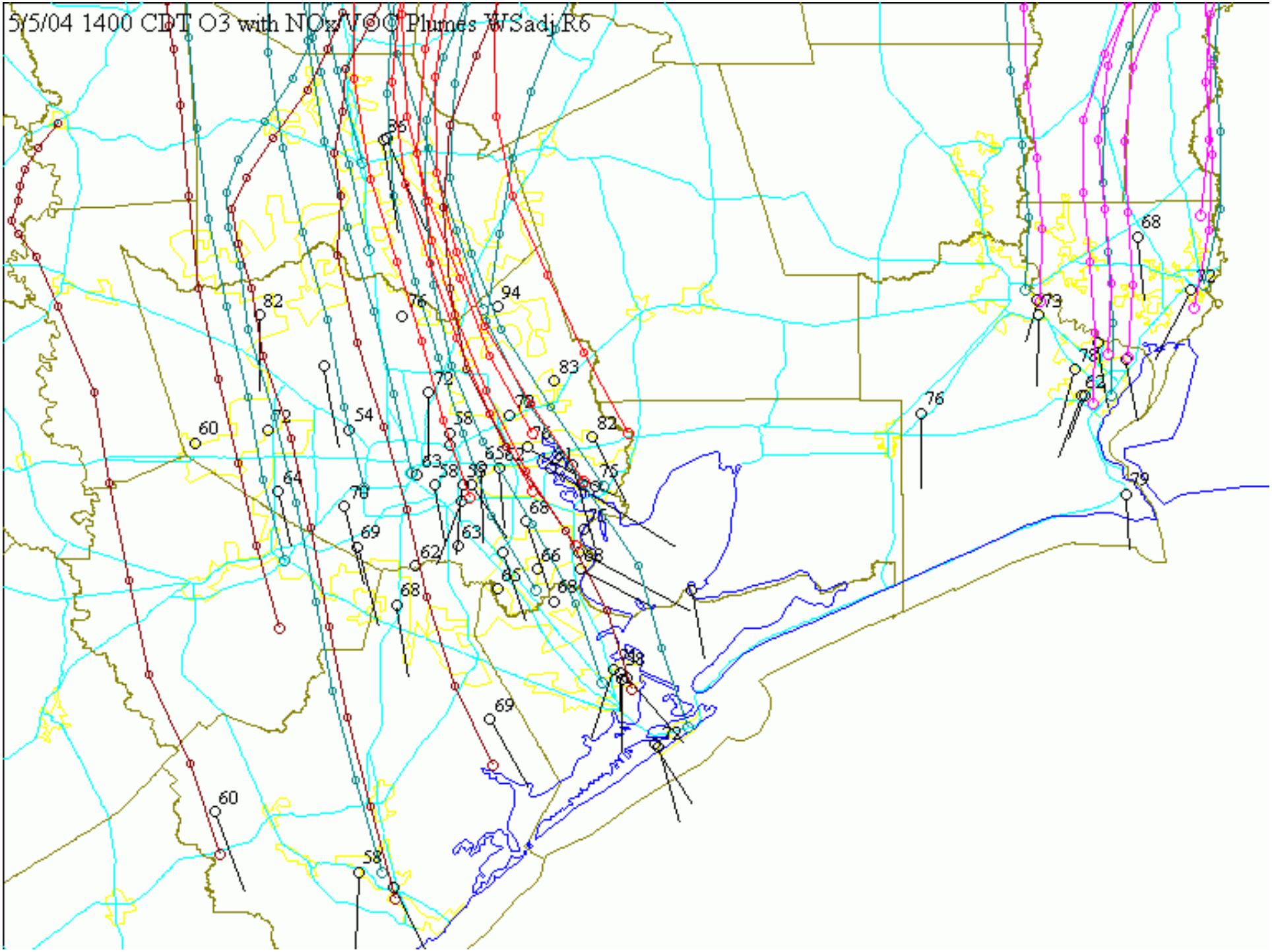

June 5, 2006 18:30 CDT
PDCS Ozone 5Min 6/5/2006 23:30:00

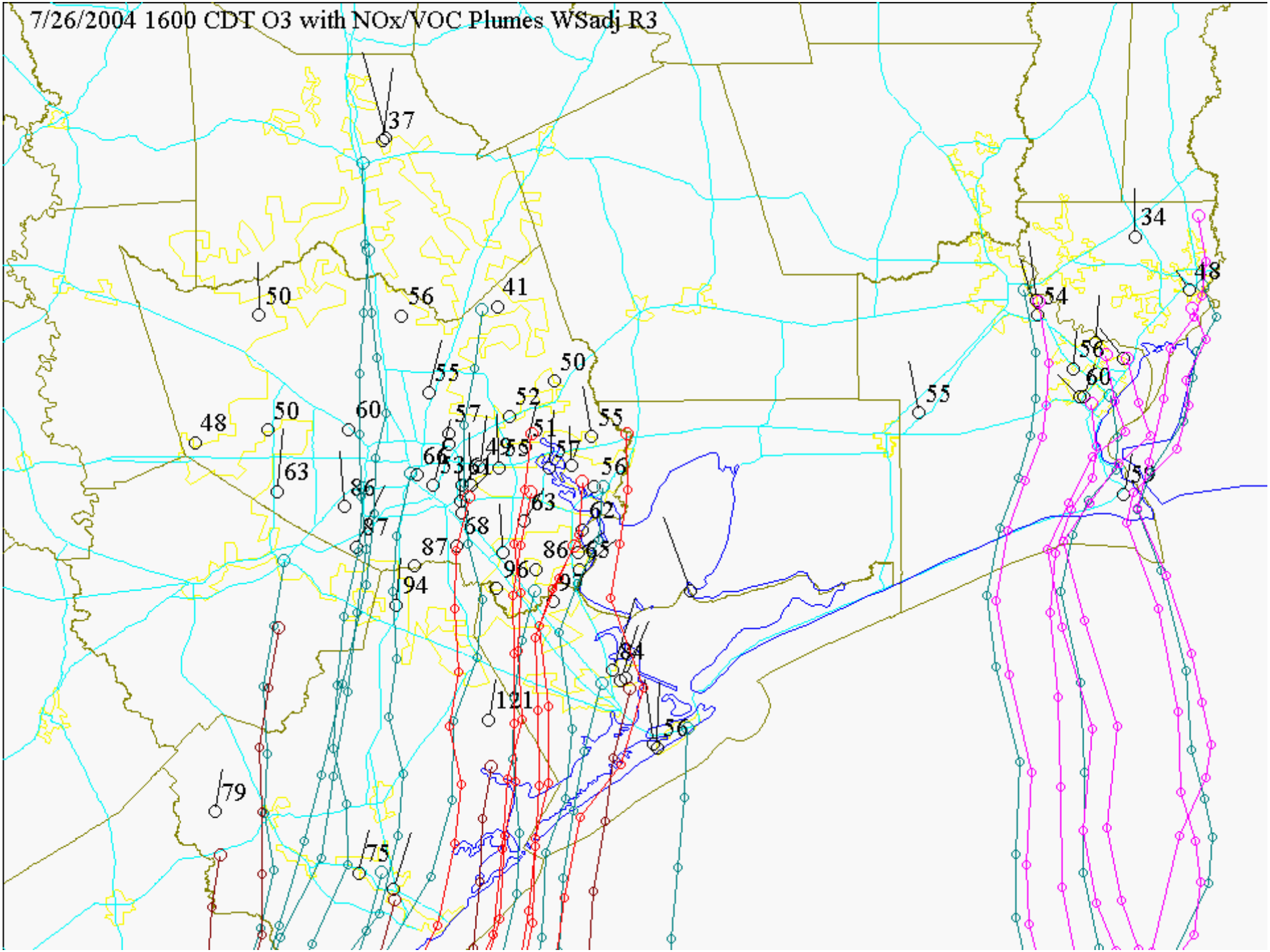
Steady flow

- Winds blow steadily from approximately same direction all day
- Easy to determine sources linked to high ozone
- Ozone lower on these days than typical veering days and flow reversal days


10/6/06 13-1400 CDT Ozone and Wind with NOx/VOC Plume Positions at 1400 CDT WSadj R3


9/6/00 1200 CST O3 Plumes 0000 CST
62
63
75
62
75
96
96
113
142
95
102
84
0
M
70
85
86
91
M
90
90
56
67
75
79
113
60
76
73
70


5/5/04 1400 CDT O3 with NOx/VOC Plumes WSadj R6


7/26/2004 1600 CDT O3 with NOx/VOC Plumes WSadj R3
37
34
48
50
56
41
54
50
55
56
60
52
55
57
51
55
48
50
60
57
56
63
86
63
62
87
68
87
86
65
96
97
94
84
121
56
79
75

Conclusions

- Local-scale flow can interact with regional-scale flow to cause ozone-conducive wind conditions
- Northerly winds can interact with bay breeze and Gulf breeze to create ozone-conducive conditions.
- High background ozone also can occur during northerly flow.
- Southerly flow can enhance the bay/Gulf breeze, and usually doesn’t result in high ozone.

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