On the Rapid Intensification of Hurricane Wilma (2005)

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References

Chen, H., D.-L. Zhang, J. Carton, and R. Atlas, 2011: On the rapid intensification of Hurricane Wilma (2005). Part I: Model prediction and structural changes. *Wea. Forecasting*, **26**,885-901.

Zhang, D.-L., and H. Chen, 2012: Importance of the upper-level warm core in the rapid intensification of tropical storm. *Geophysical Research Letters*, in press.

Chen, H., and D.-L. Zhang, 2012: On the rapid intensification of Hurricane Wilma (2005). Part II: Convective bursts and the upper-level warm core. To be submitted to *J. Atmos. Sci.*

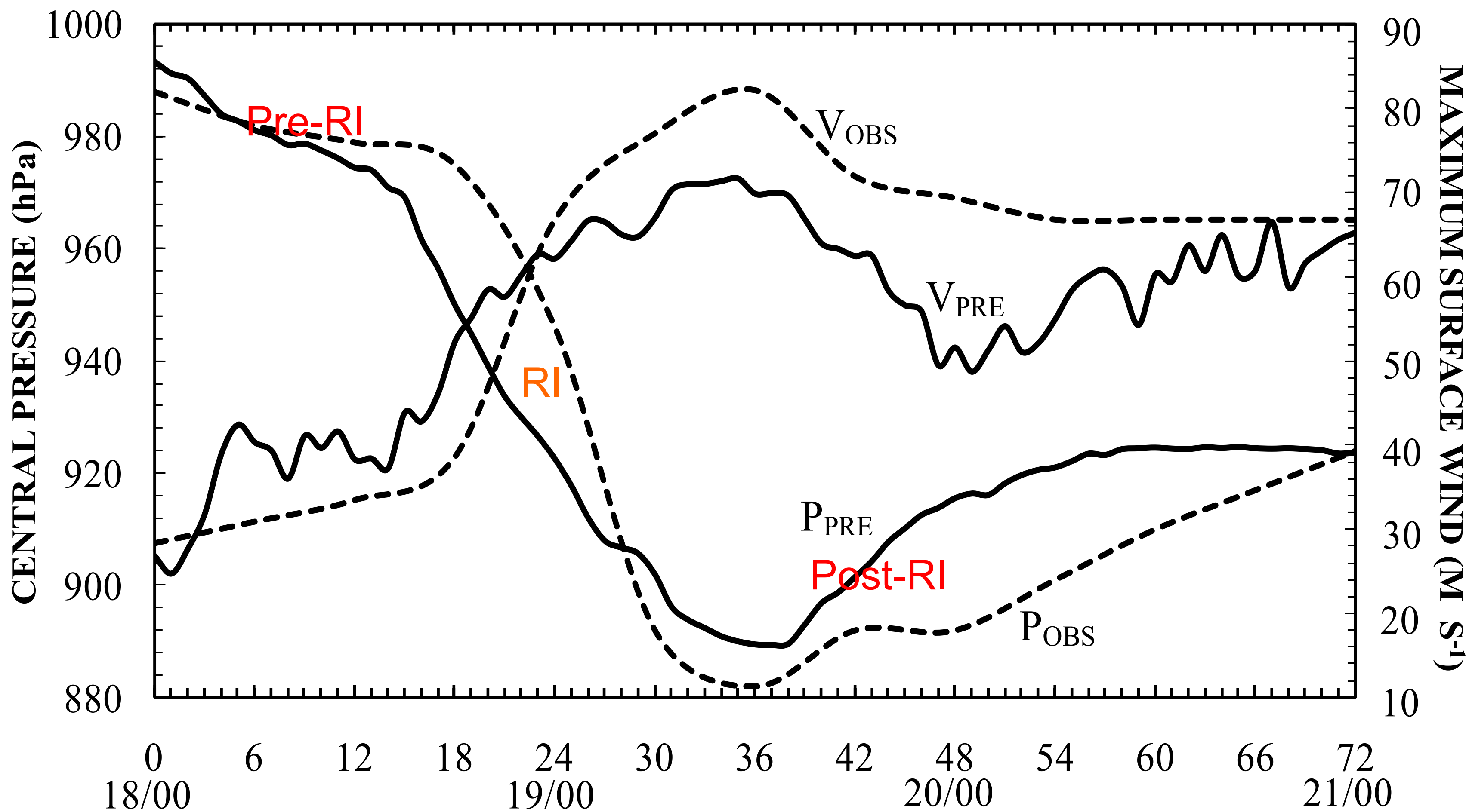
Previous RI studies

- Our RI understanding is limited to environmental conditions: anomalously warm SSTs, high RH in the lower troposphere, weak vertical wind shear, and weak forcing from upper-level troughs.
- Recent studies begin to examine the inner-core processes: convective bursts (CBs) - the upward transport of enthalpy-rich air by supergradient outflows in the eye boundary layer account for CBs.

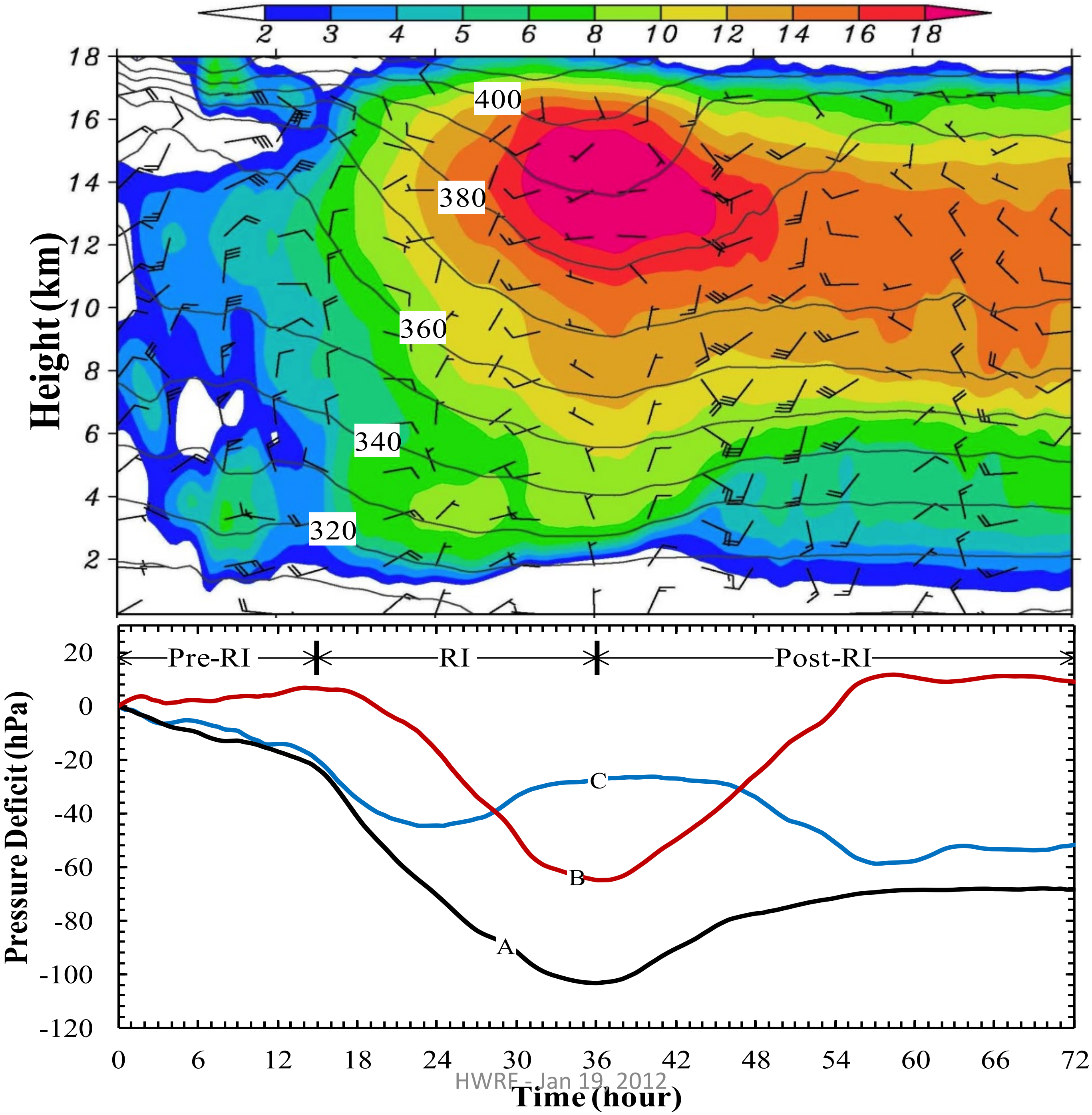
2. Model Description (WRF-ARW)

- Two-way, movable, quadruply nested (27/9/3/1 km), 55 levels in the vertical;
- Thompson et al. (2004) 3-ice cloud microphysics scheme;
- The Betts-Miller-Janjic cumulus scheme for 27 and 9 km;
- The YSU PBL scheme;
- NOAH surface-layer physics;
- Cloud-radiation interaction scheme;
- Initial and boundary conditions: The GFDL's then operational data, except for the specified daily SST;
- Integration period: 0000 UTC 18 ~ 0000 UTC 21 October 2005 (72 h) for all the four meshes.

The best track (OBS; dashed) vs. the predicted (PRE; solid)

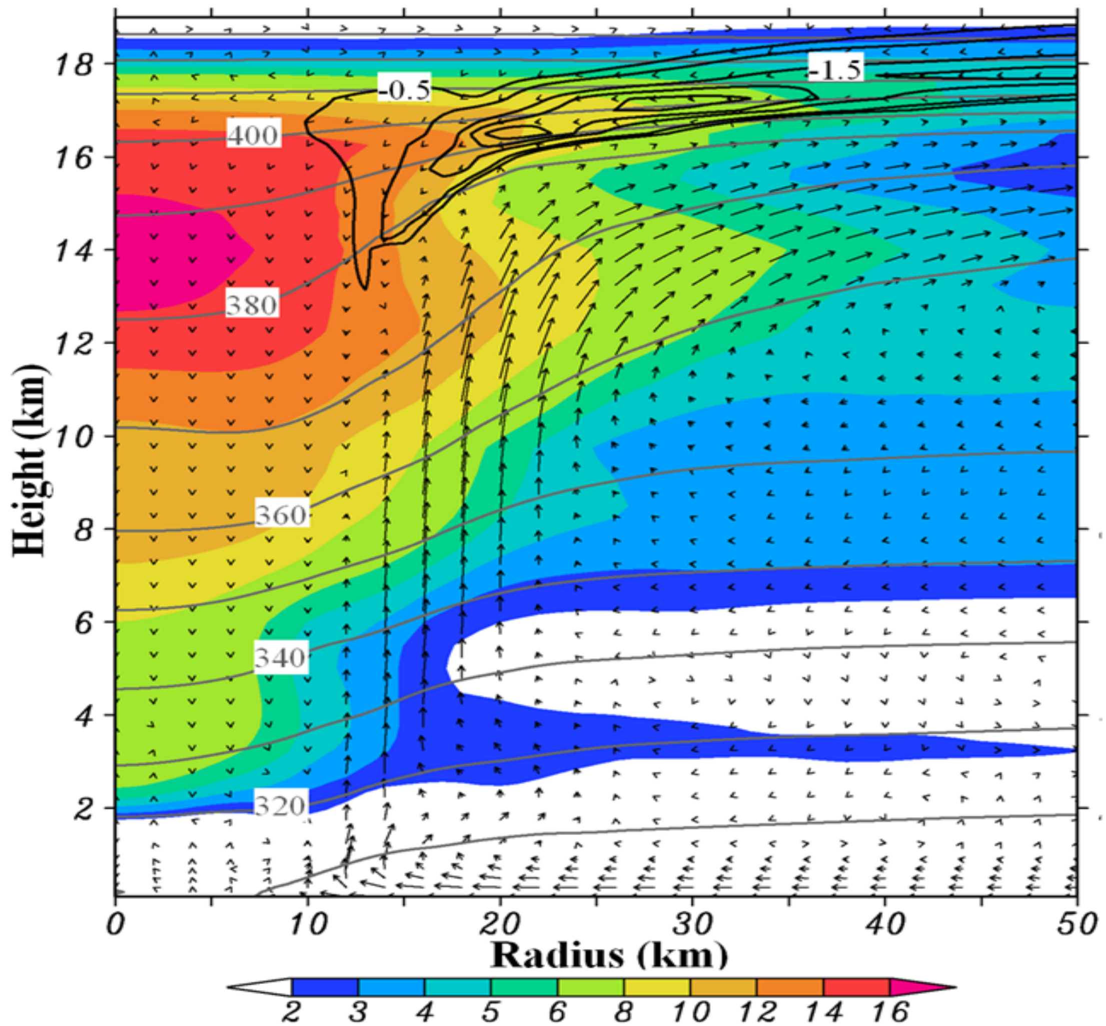


Predicted: 4 hPa/hr or 32 m s^{-1}/day **MODEL HOUR**



HWRF - Jan 19, 2012

Hypothesis I: An intense warm core tends to form within the upper outflow layer.



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Hydrostatic and eye thermodynamics:

A higher-level warm core is more effective than a lower-level one in inducing surface pressure falls.

Hydrostatic Equation:

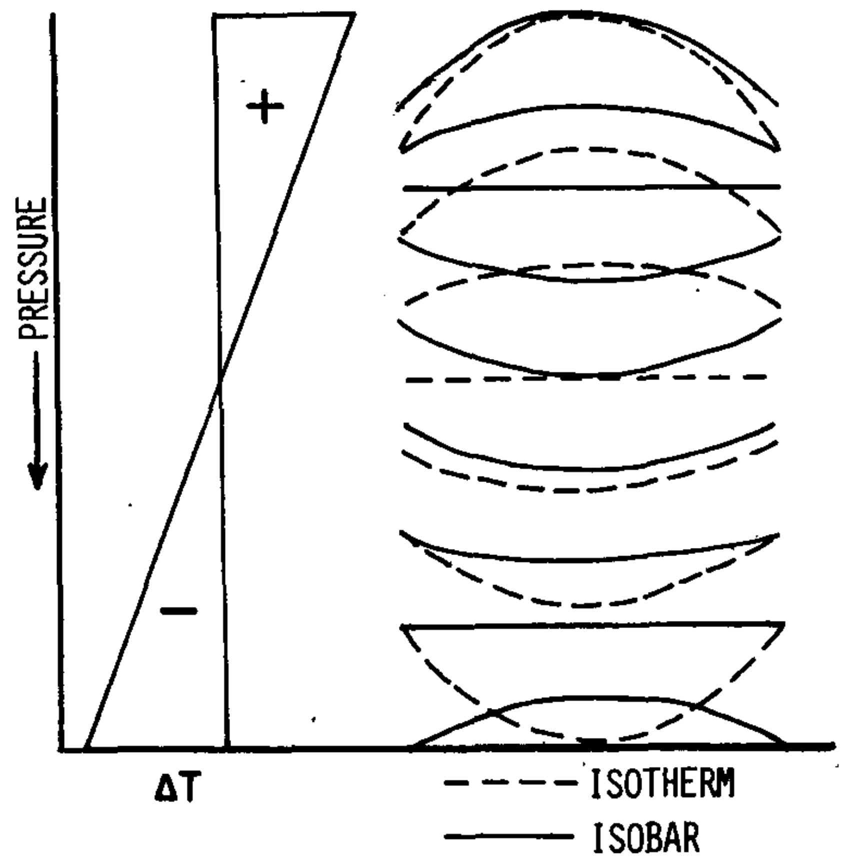
$$d\ lnp = -\ (g/RT)\ dz$$

$$P_{surface} = P_{top} \exp[g\delta z_{upper} / R(T_{upper} + \delta T_{upper})] \exp[g\delta z_{low} / R(T_{low} + \delta T_{low})]$$

Hirschberg and Fritsch (1993):

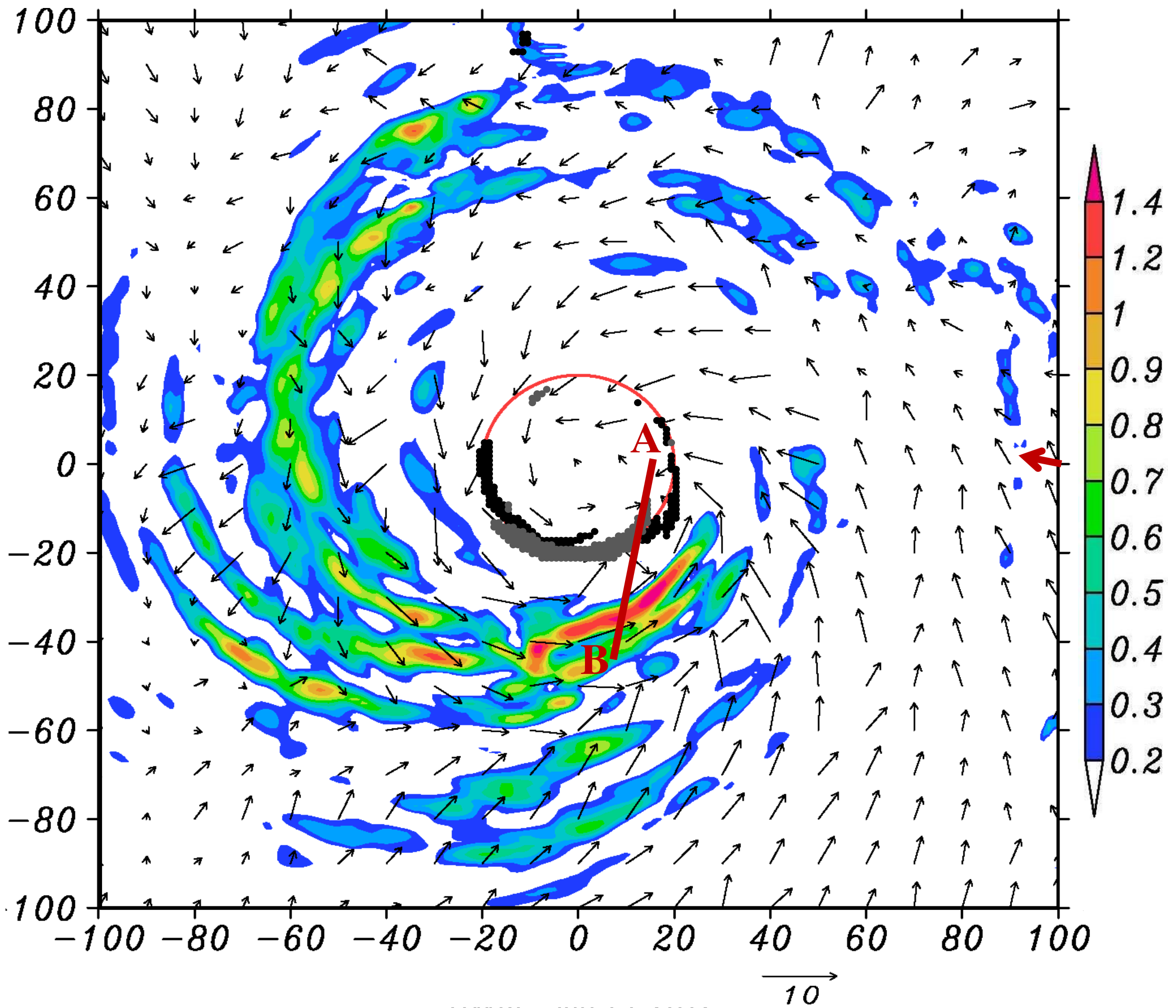
$$\delta p_{surface} =$$

$$(p_{surface}/T_{surface}) \int_{P_{surface}}^{P_{top}} \delta T\ d\ lnp$$

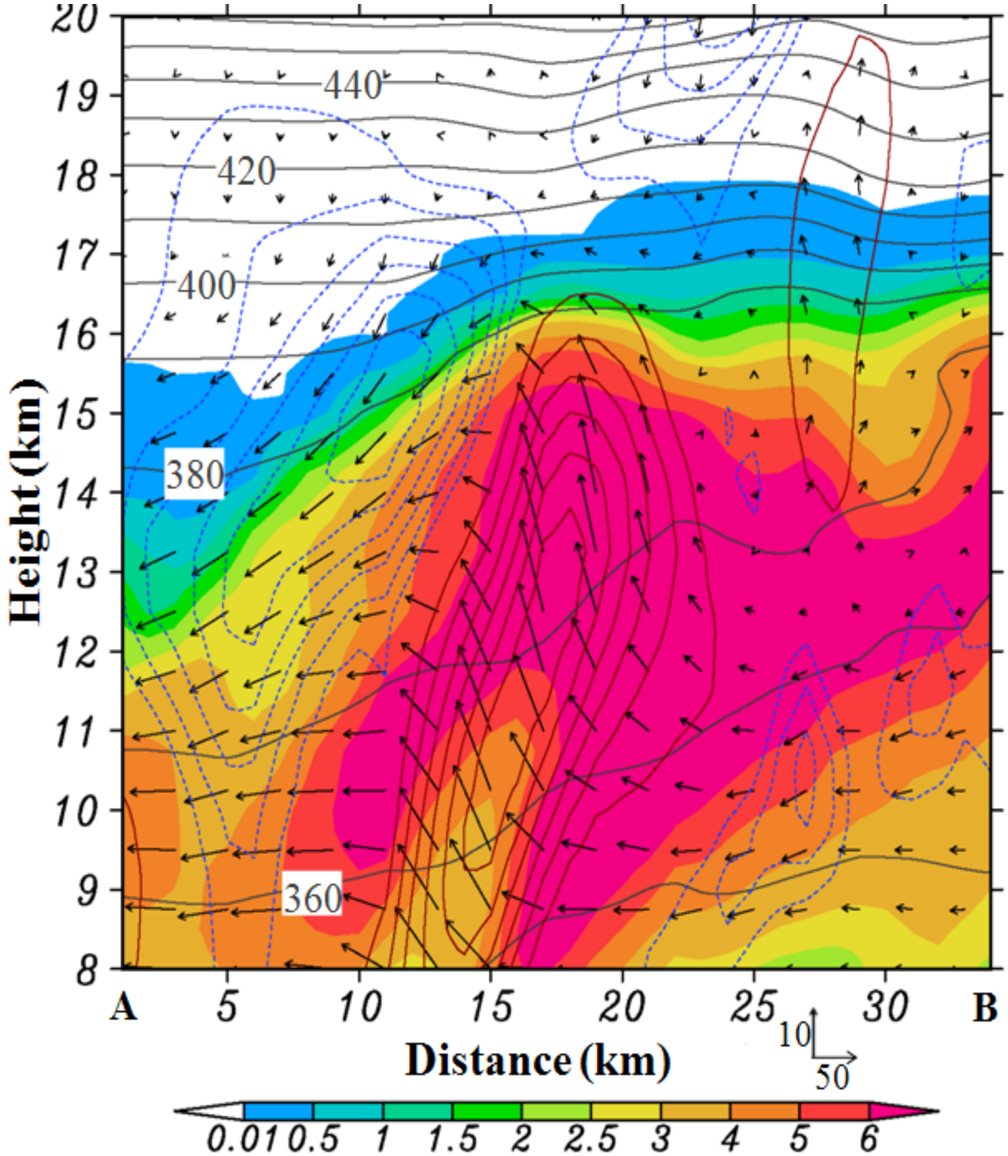


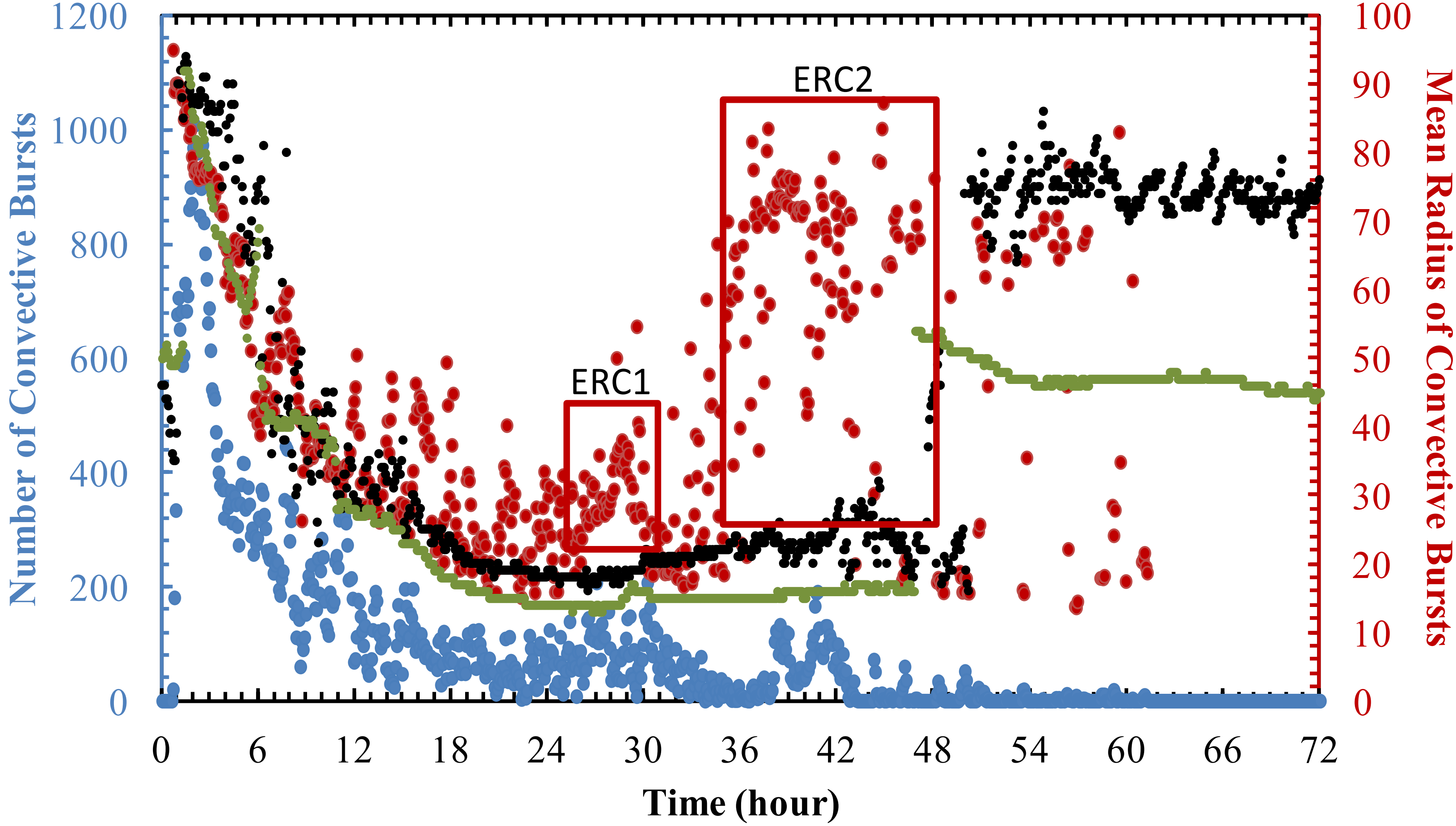
Zhang and Fritsch (1988)

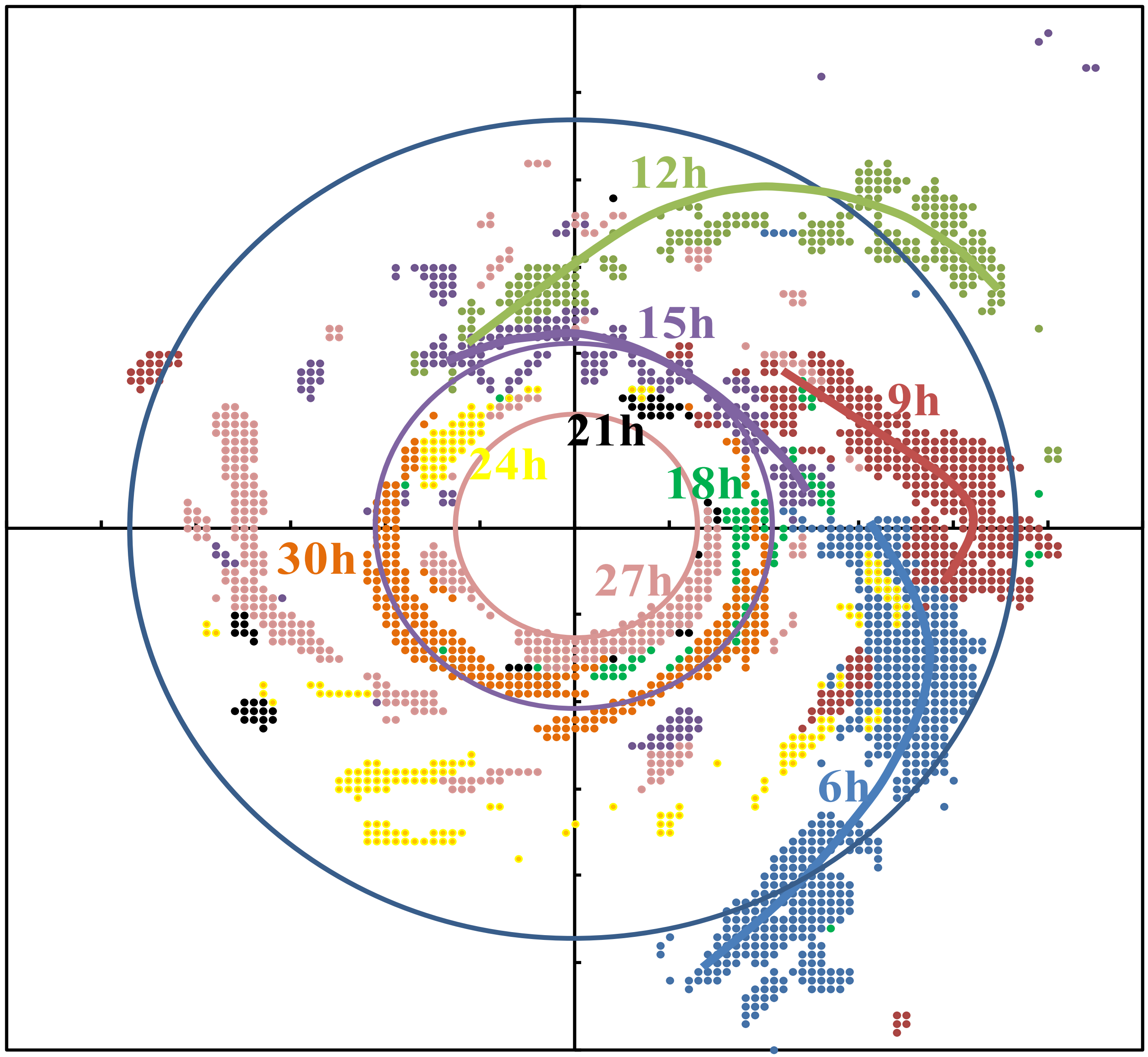
Hypothesis II: Convective bursts play an important role in RI through detraining the stratospheric air into the eye.



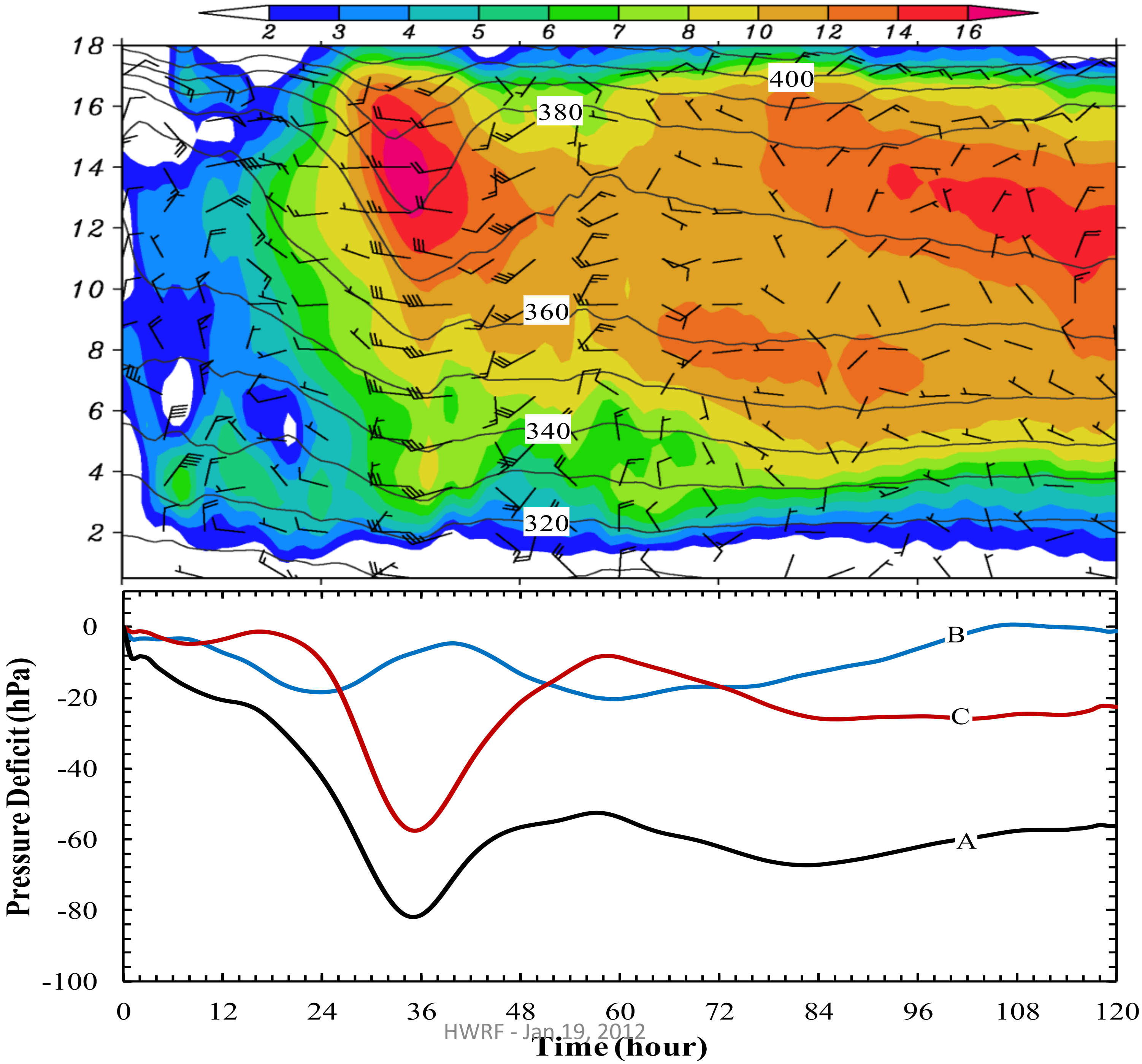
An example of convective bursts

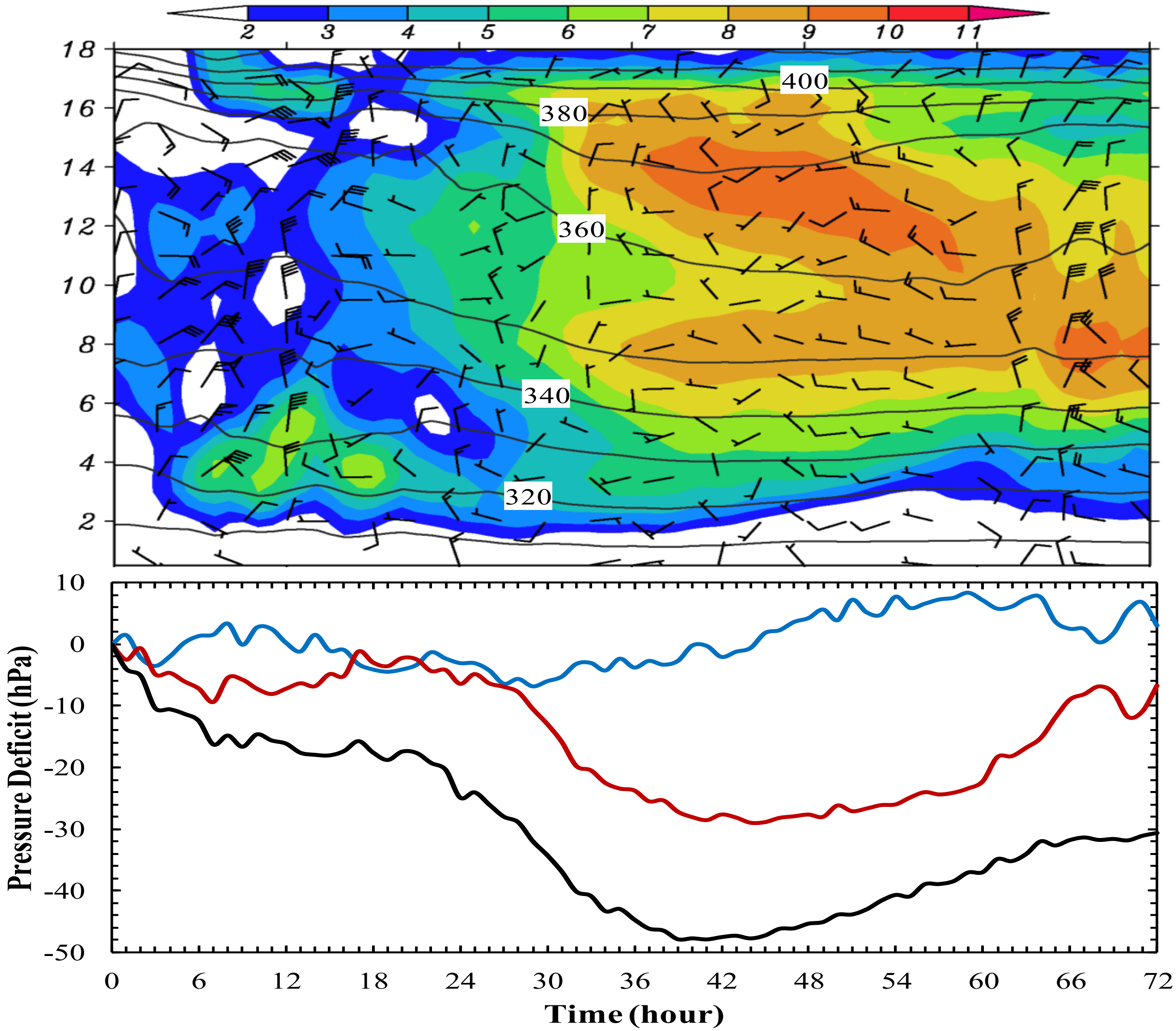



1200
1000
800
600
400
200
0
Number of Convective Bursts
100
90
80
70
60
50
40
30
20
10
0
Mean Radius of Convective Bursts
0
6
12
18
24
30
36
42
48
54
60
66
72
Time (hour)
ERC1
ERC2



HWRF - Jan 19, 2012


2 3 4 5 6 7 8 10 12 14 16
18 16 14 12 10 8 6 4 2
400
380
360
340
320
0 -20 -40 -60 -80 -100
Pressure Deficit (hPa)
B
C
A
0 12 24 36 48 60 72 84 96 108 120
Time (hour)



2
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16
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8
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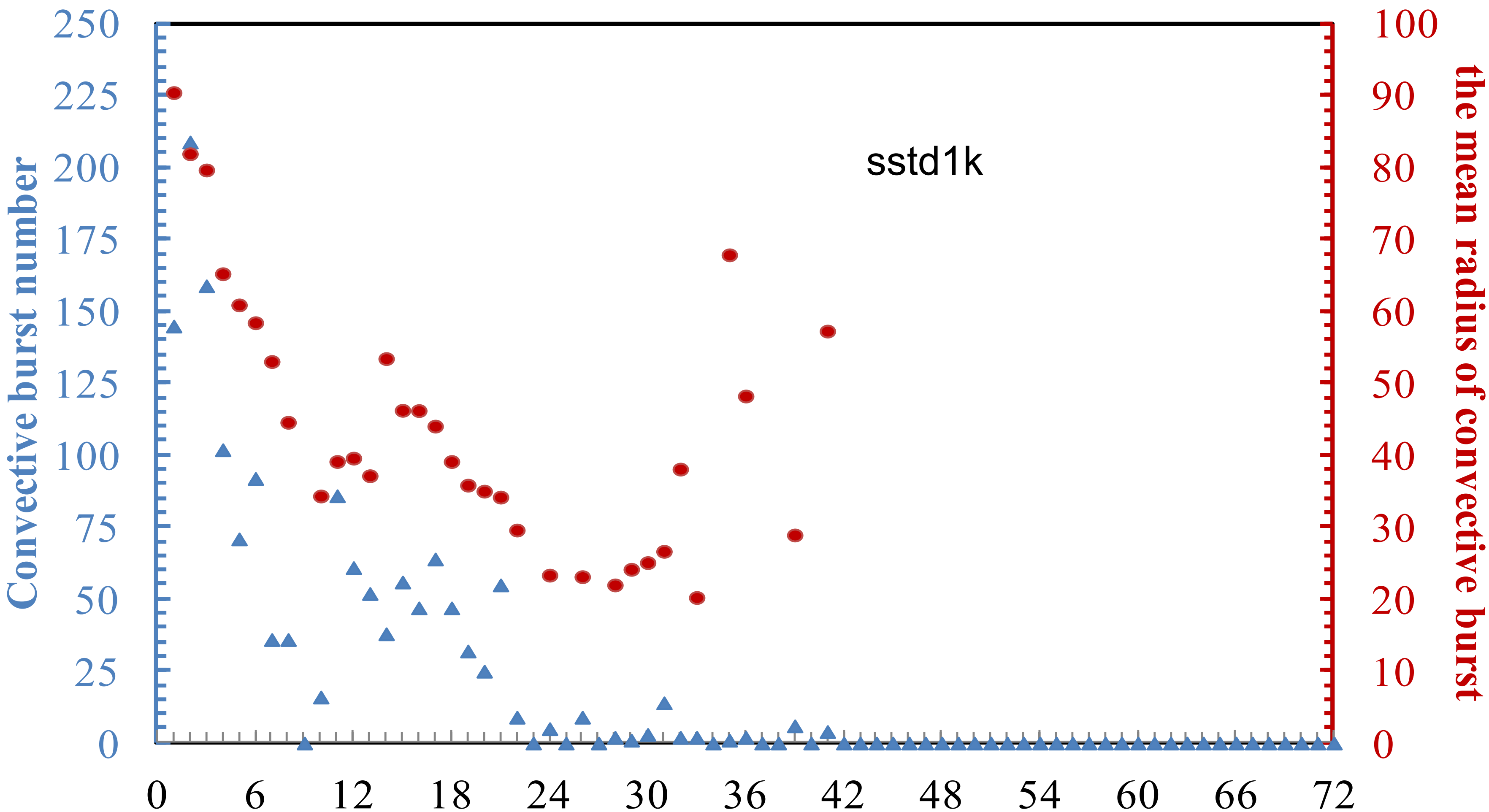
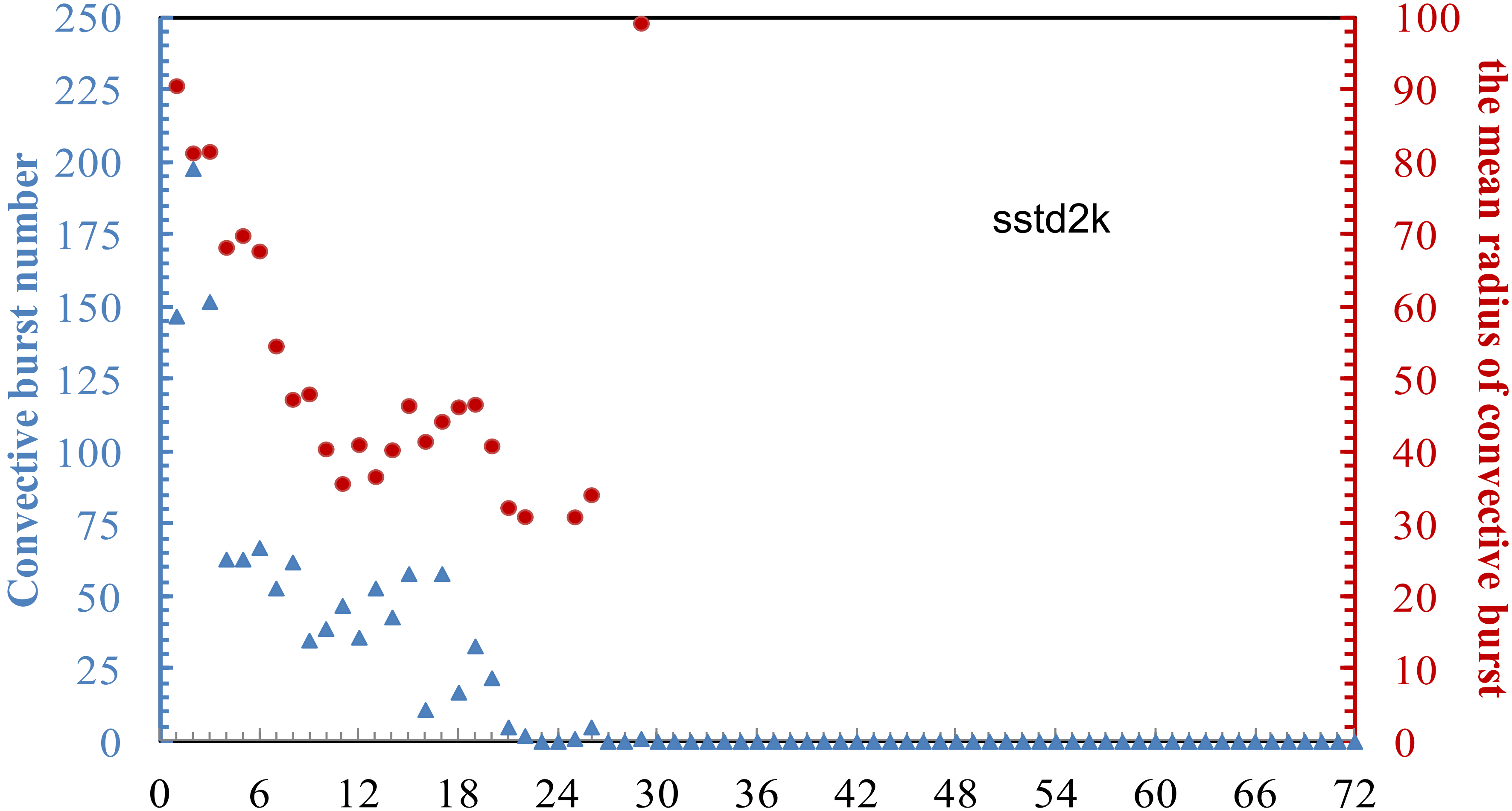
4
2
400
380
360
340
320
10
0
-10
-20
-30
-40
-50
Pressure Deficit (hPa)
0
6
12
18
24
30
36
42
48
54
60
66
72
Time (hour)


sstd1k
Convective burst number
the mean radius of convective burst
250
225
200
175
150
125
100
75
50
25
0
100
90
80
70
60
50
40
30
20
10
0
0
6
12
18
24
30
36
42
48
54
60
66
72



Convective burst number
the mean radius of convective burst
sstd2k
250
225
200
175
150
125
100
75
50
25
0
100
90
80
70
60
50
40
30
20
10
0
0
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42
48
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60
66
72

Summary and conclusions

- The RI of a tropical cyclone is closely related to convective bursts, the upper-level warm core and flow structures, and SSTs;
- Results show the formation of an upper-level warming core in the outflow layer, coinciding with the onset of RI, due to the descent of stratospheric air.
- The upper-level warming in the eye (outflow layer) is more effective than the lower-level warming (outflow layer) in causing surface pressure falls.
- Results suggest that more attention be paid to the upper-level ventilation effects in order to reasonably predict the RI of tropical storms.