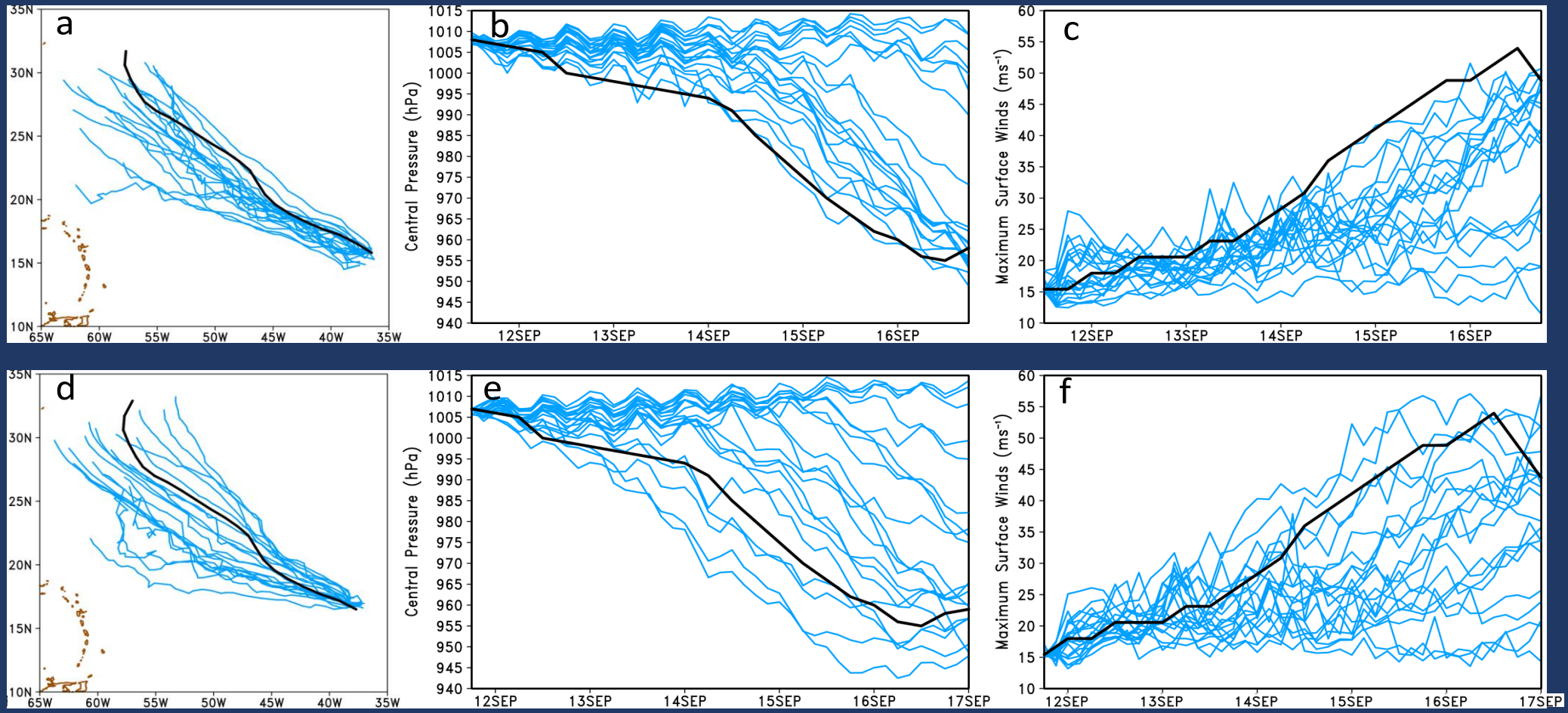
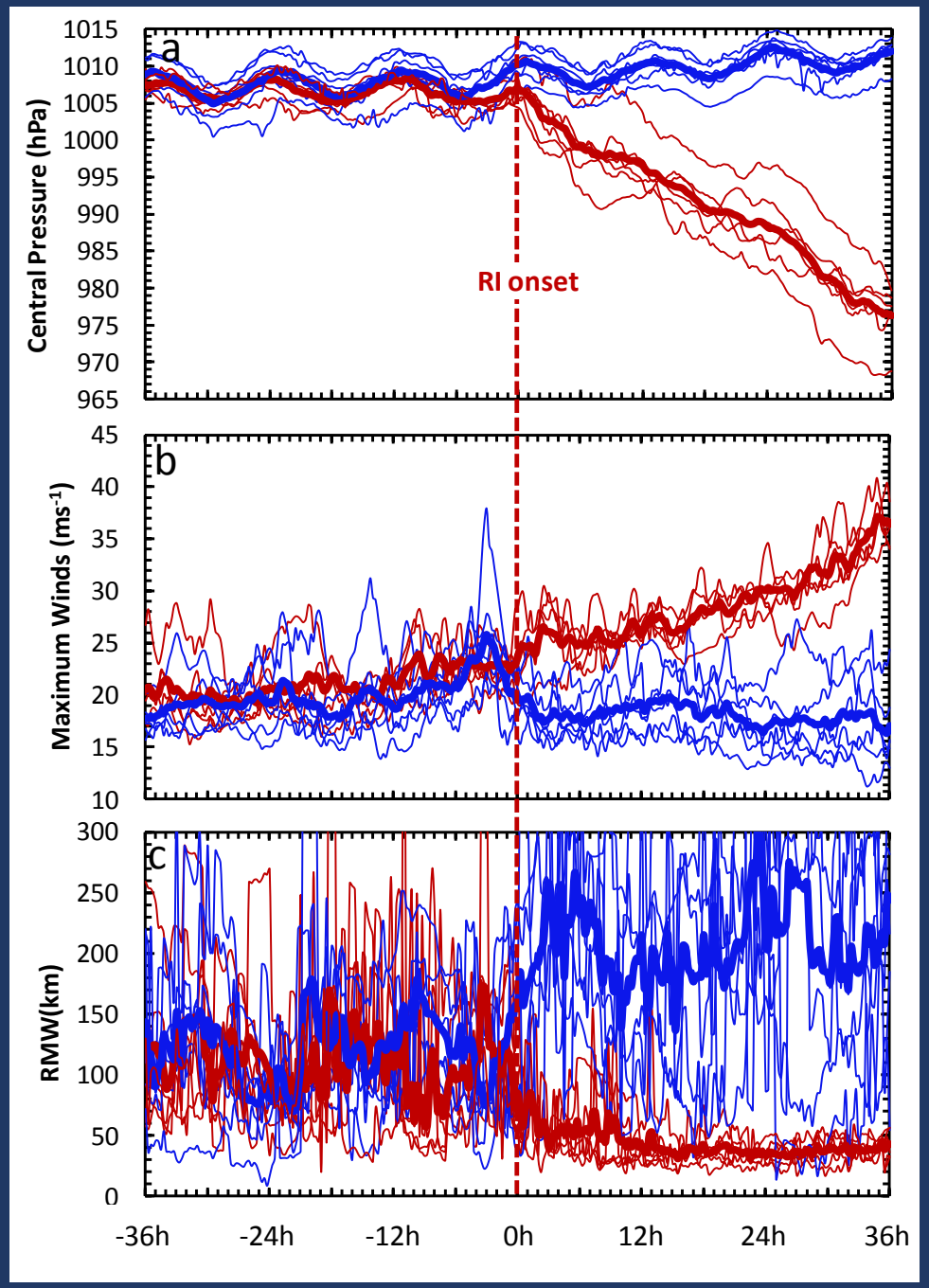
Azimuthal distribution of deep convection, environmental factors and tropical cyclone rapid intensification: A perspective from HWRF ensemble forecasts of Hurricane Edouard

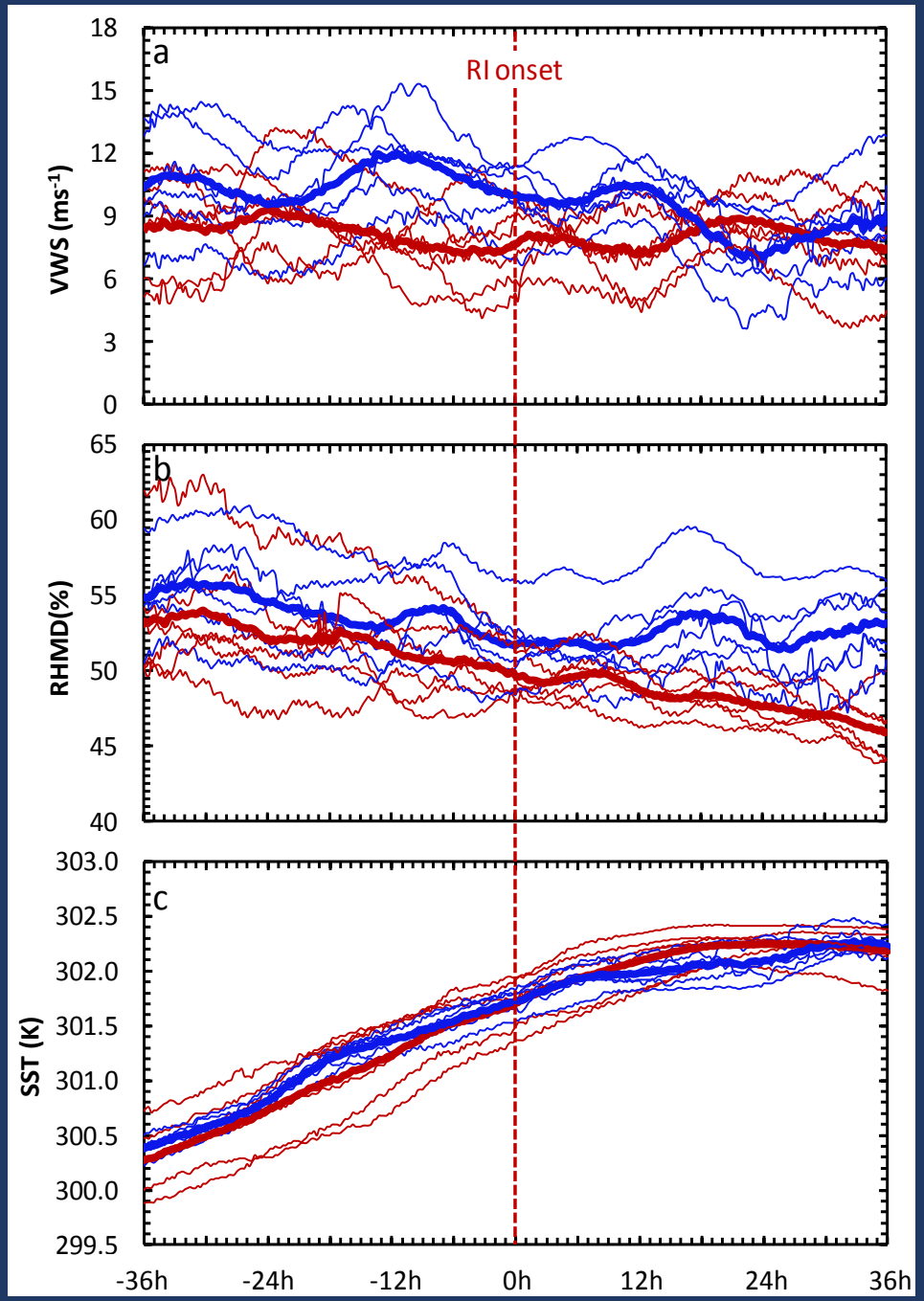
Hua Chen, Sundararaman Gopalakrishnan, Jun A. Zhang,
Robert F. Rogers, Zhan Zhang, and Vijay Tallapragada

Ensemble forecast of Hurricane Edouard(2014)



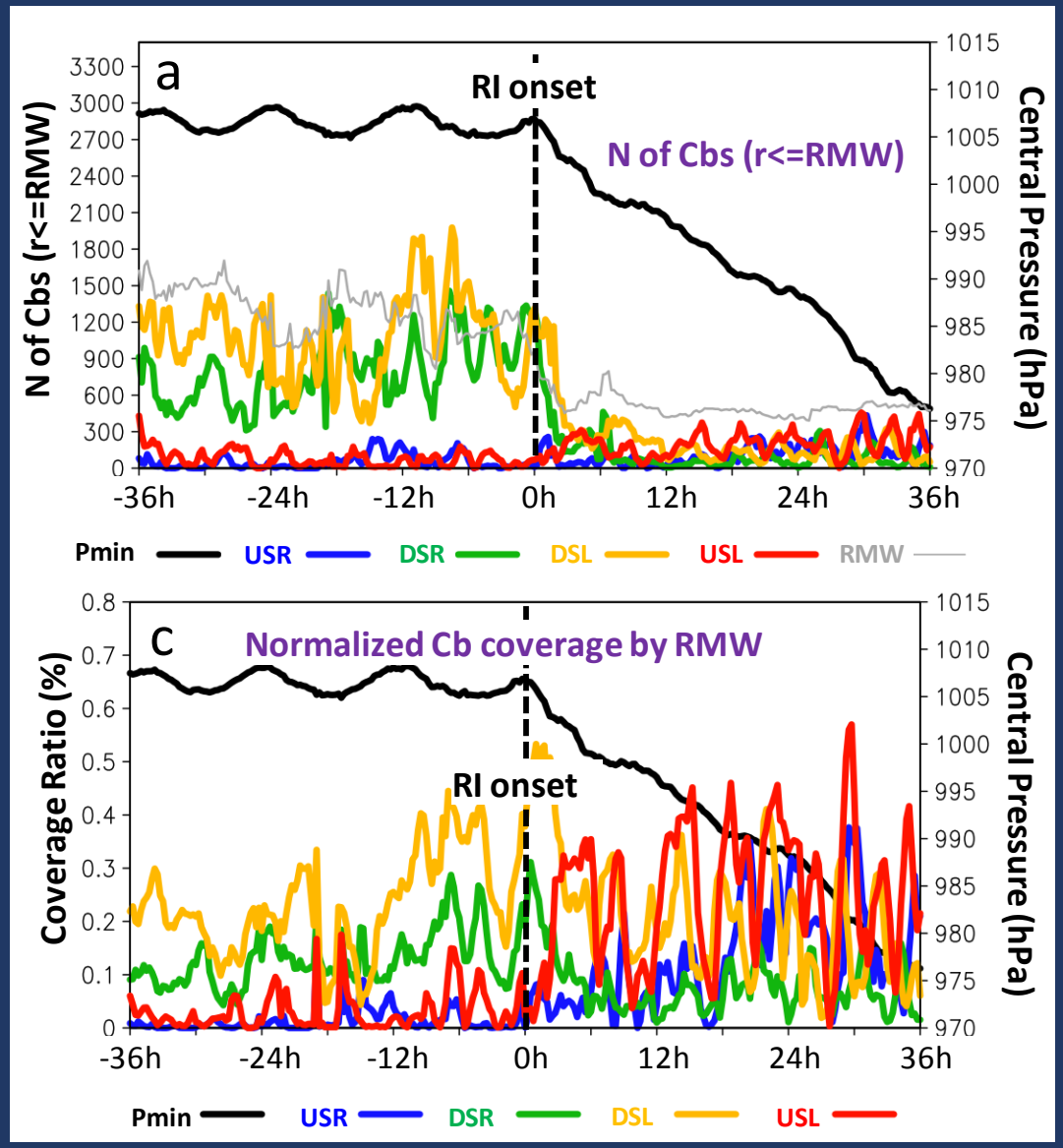
Time series of central pressure and b) maximum winds and c) track for ensemble forecast with initial time 2014091112. d),e) and f) are the same as a),b),and c) but with initial time 2014091118.


a
b
c
Central Pressure (hPa)
Maximum Winds (ms-1)
RMW(km)
RI onset
1015
1010
1005
1000
995
990
985
980
975
970
965
45
40
35
30
25
20
15
10
300
250
200
150
100
50
0
-36h
-24h
-12h
0h
12h
24h
36h

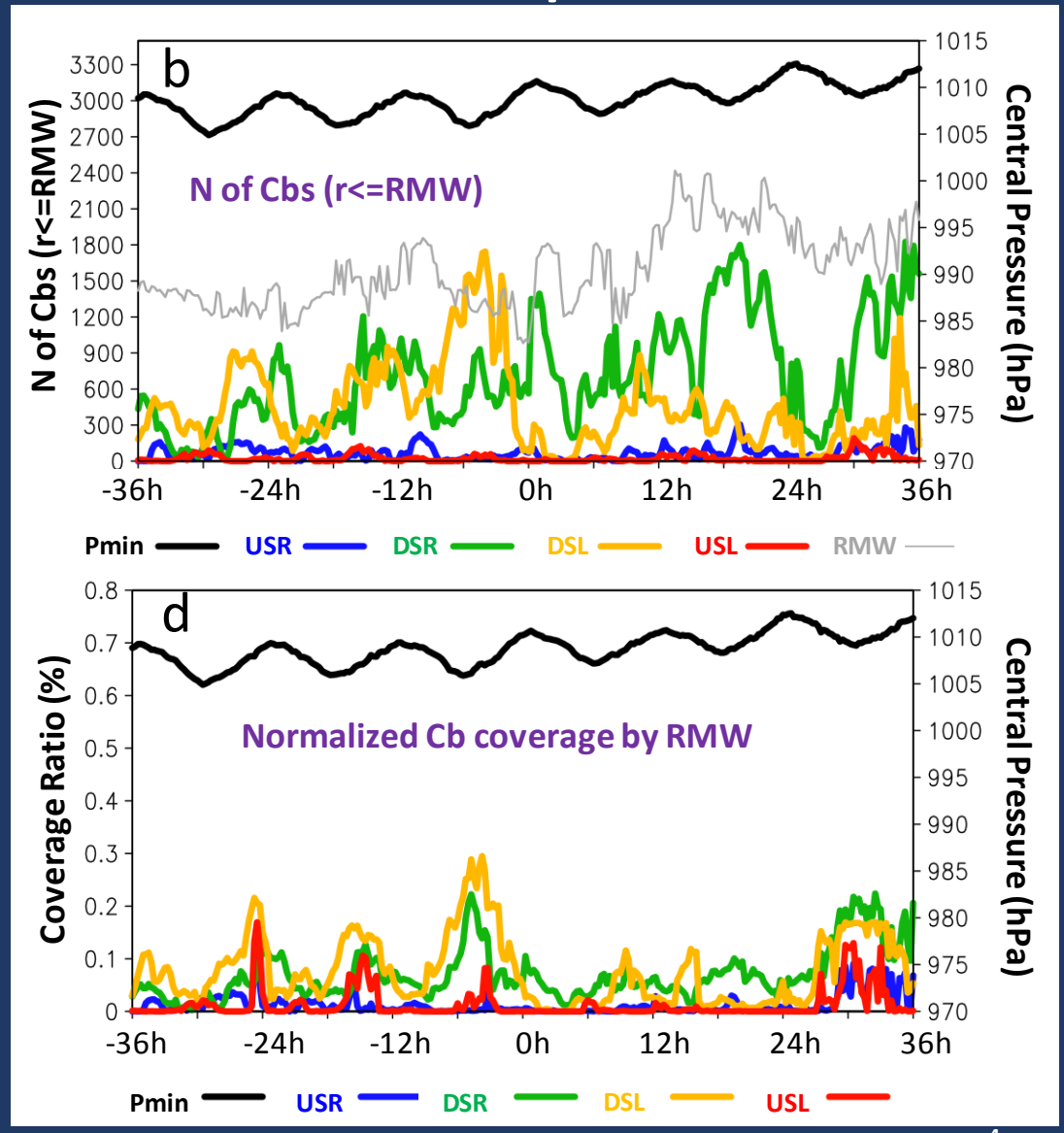

a
b
c
RI onset
VWS (ms-1)
RHMD(%)
SST (K)
18
15
12
9
6
3
0
65
60
55
50
45
40
303.0
302.5
302.0
301.5
301.0
300.5
300.0
299.5
-36h
-24h
-12h
0h
12h
24h
36h

Composite of CB statistics in shear-oriented quadrants

RI composite

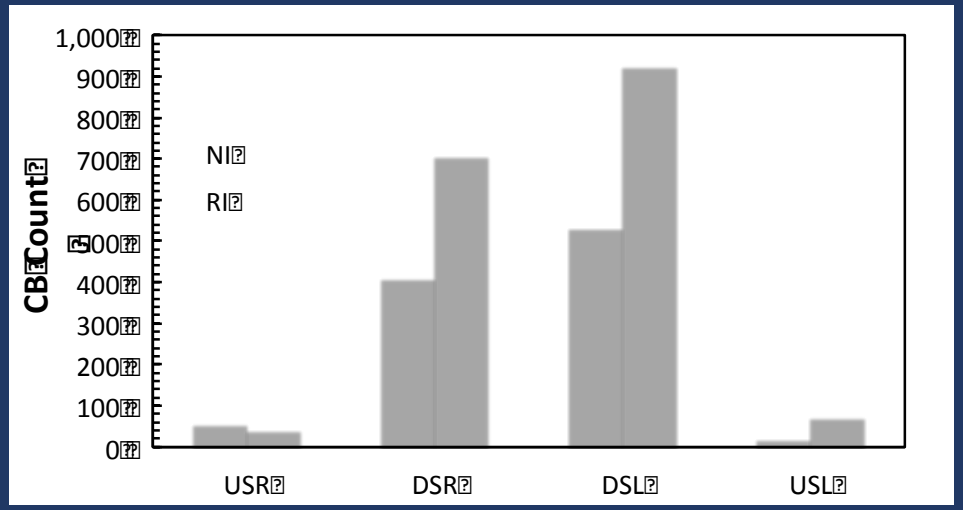


NI composite

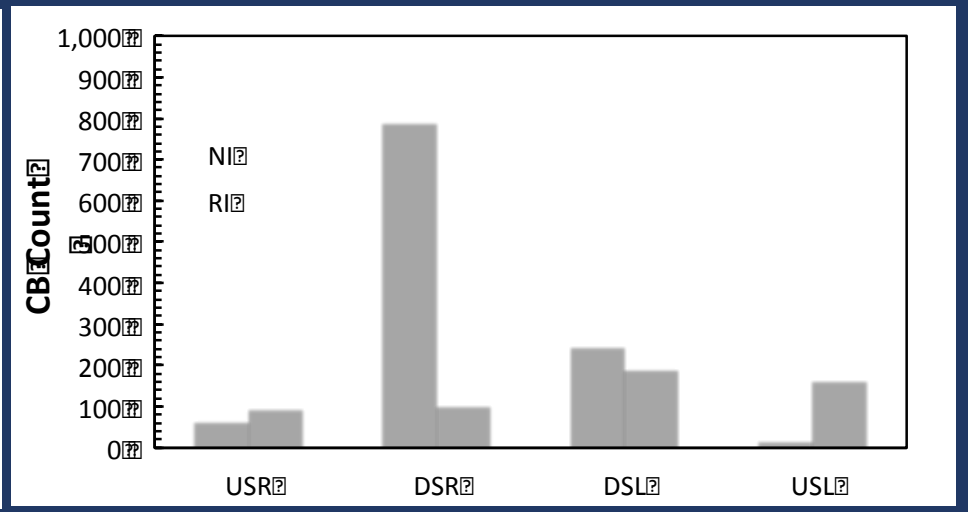


Histogram of CBs

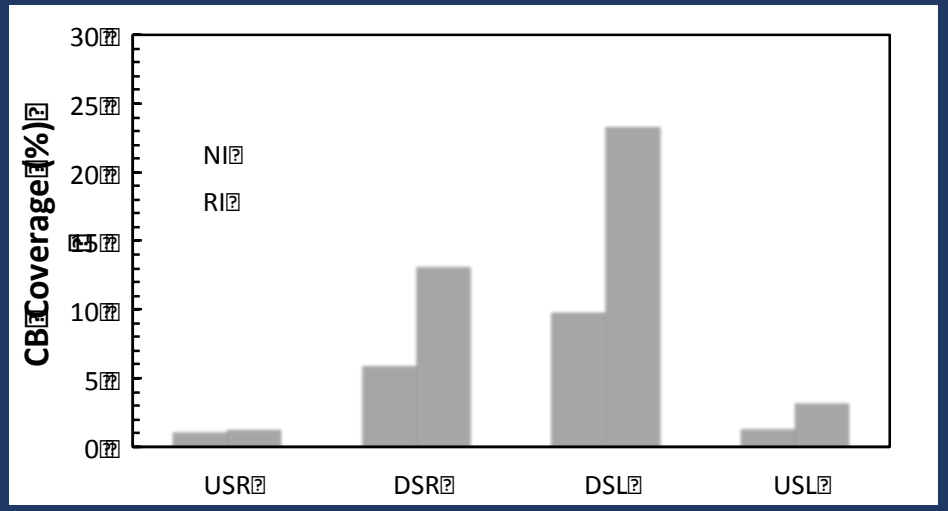
CB count averaged between RI-36h --- RI onset



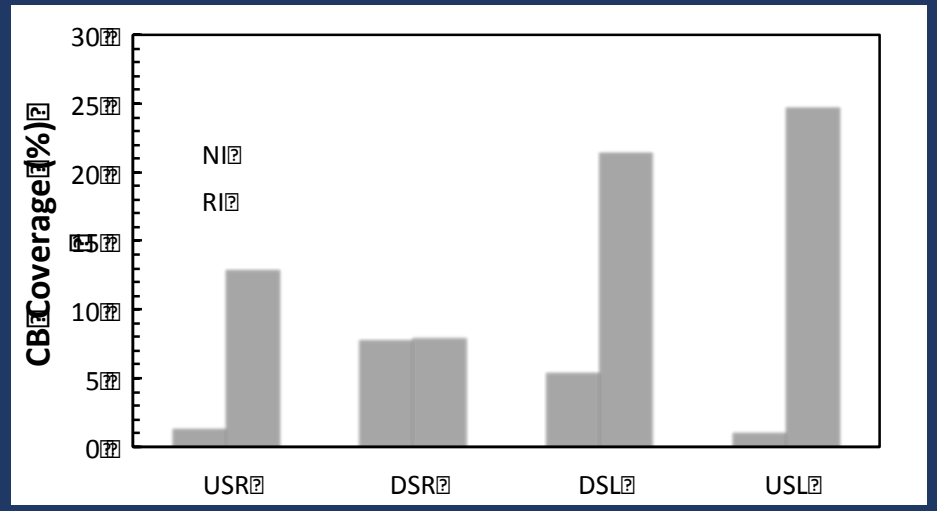
CB count averaged between RI onset--- RI+36h



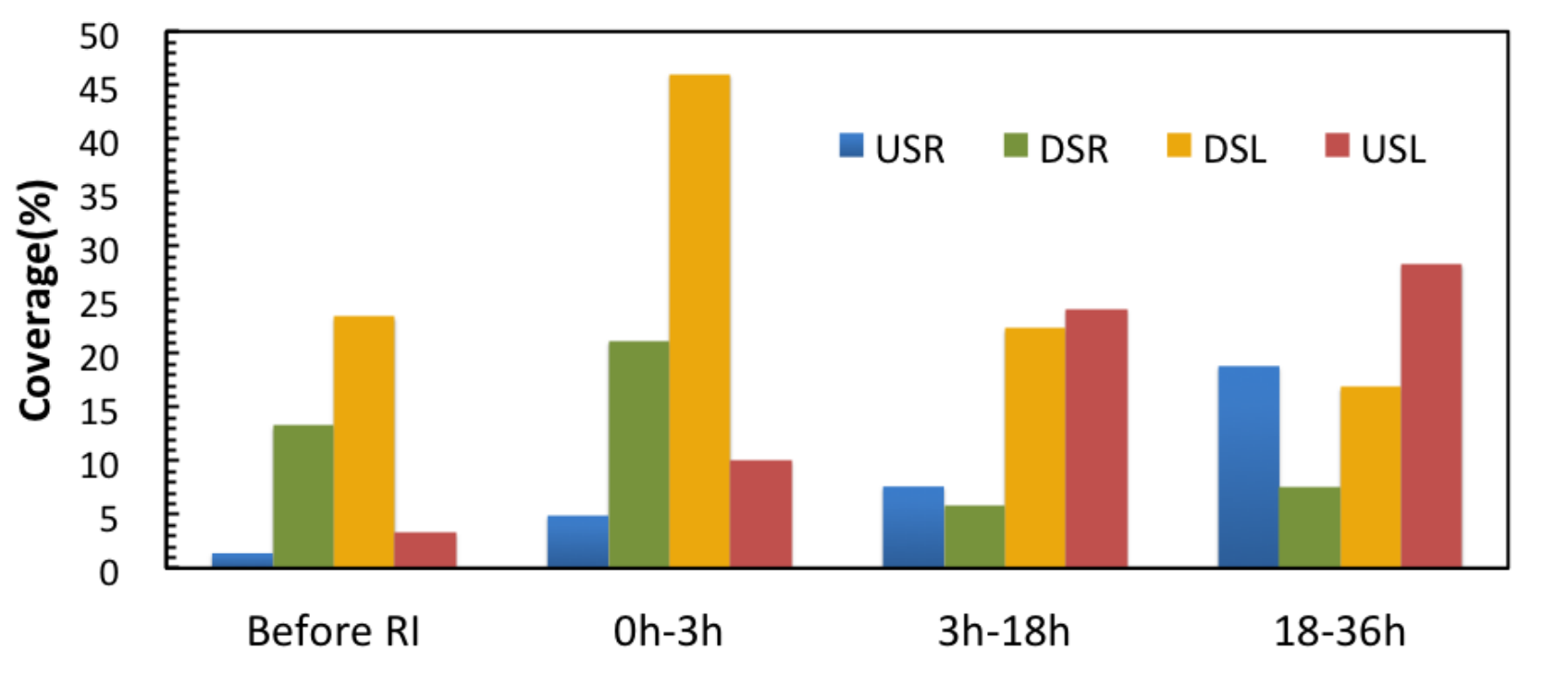
CB coverage averaged between RI-36h --- RI onset



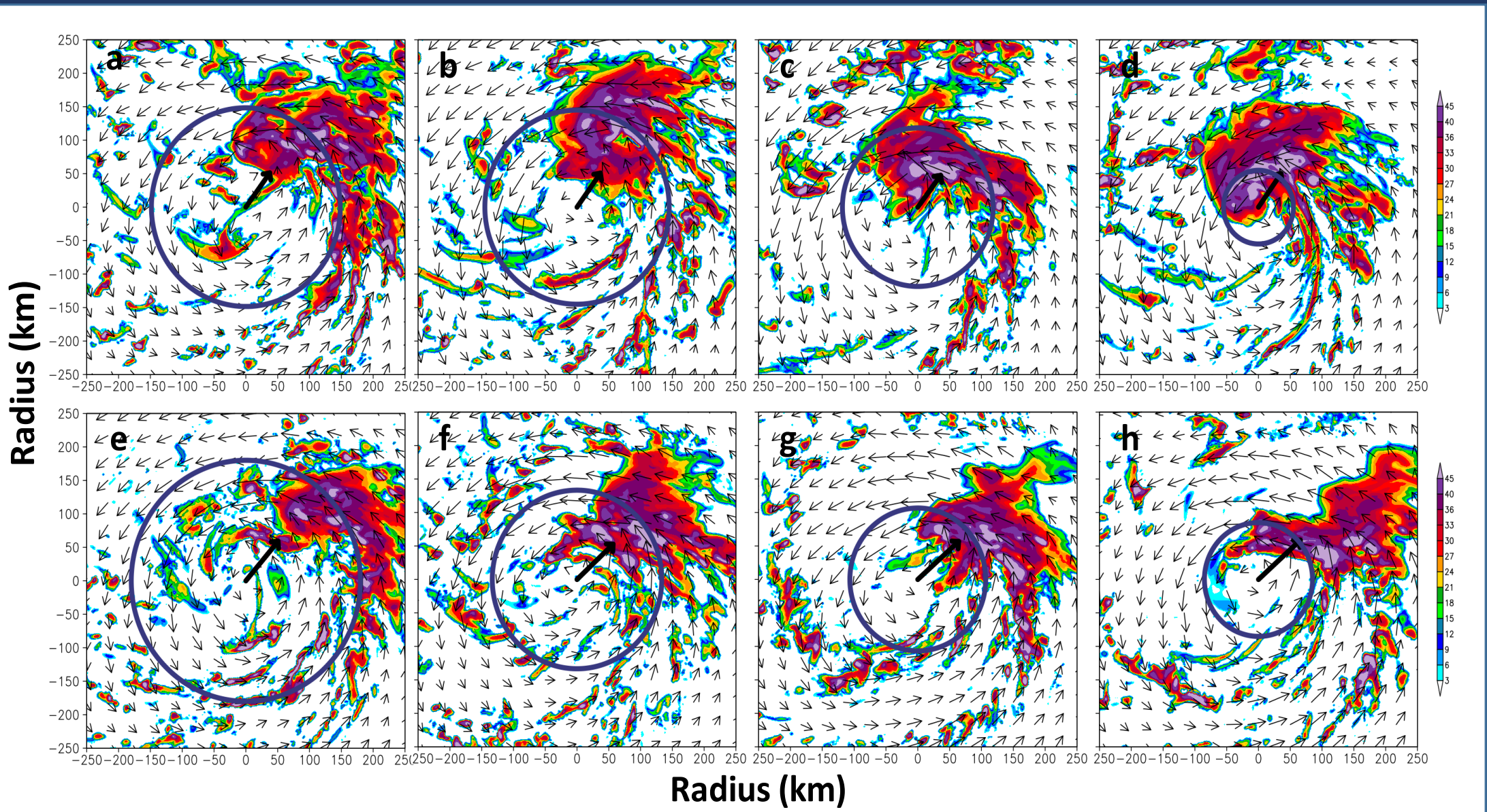
CB coverage averaged between RI onset---RI+36h



Histogram of CBs Evolution in RI Scenario



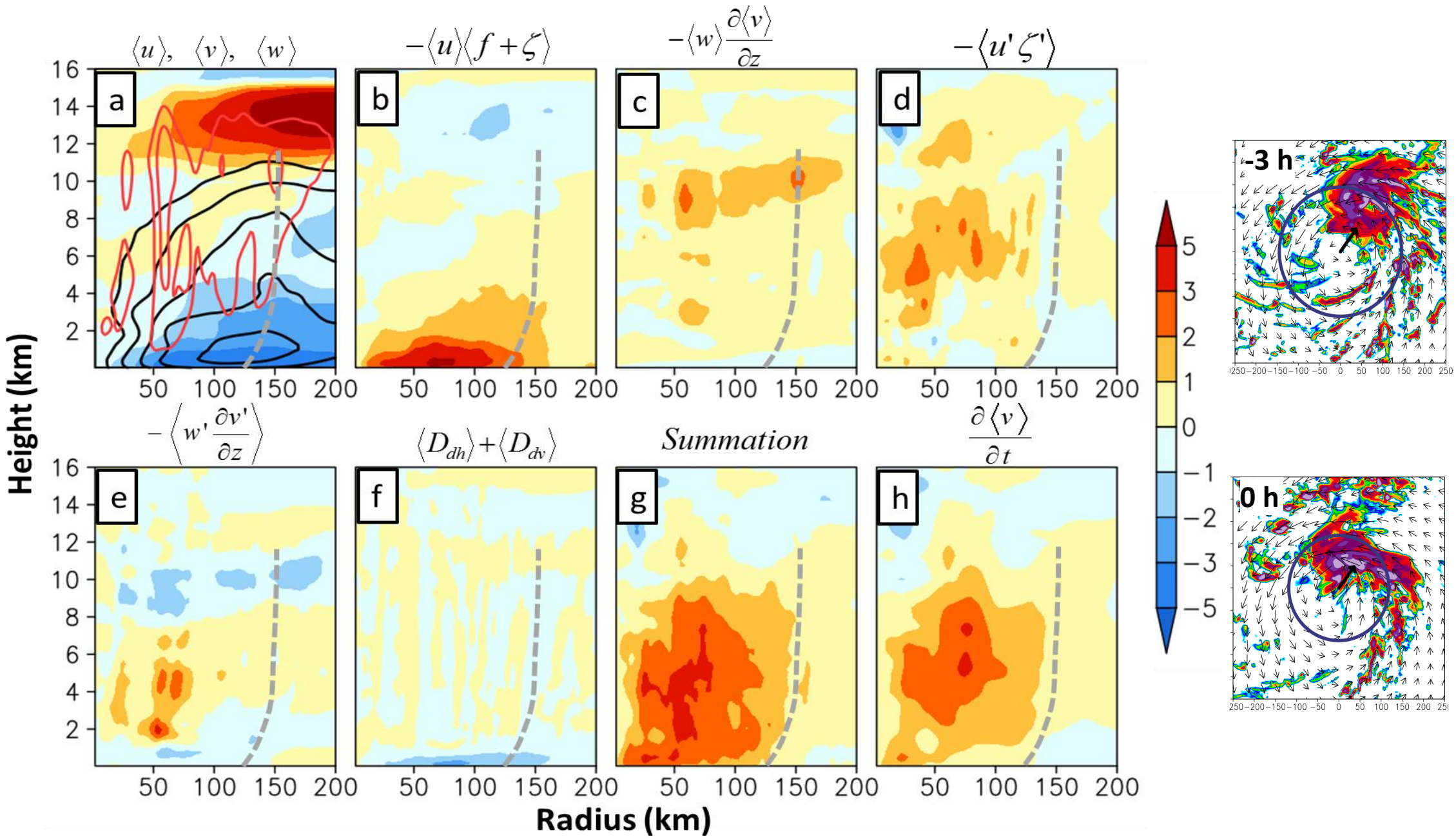
Reflectivity (shading) & SR flow (z=1km); Blue Circle: RMW; Black arrow: shear

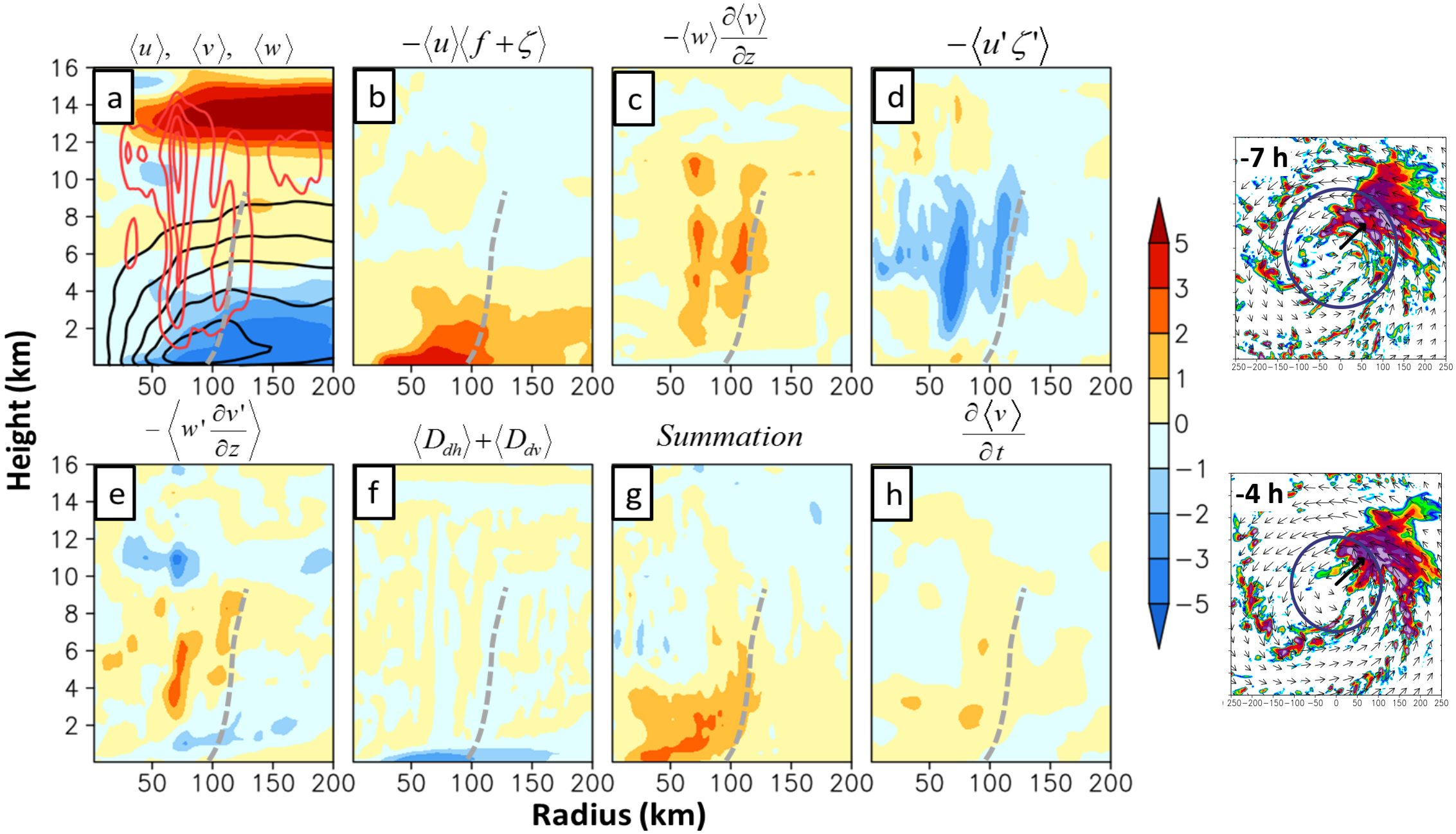


Budget Calculation of tangential wind

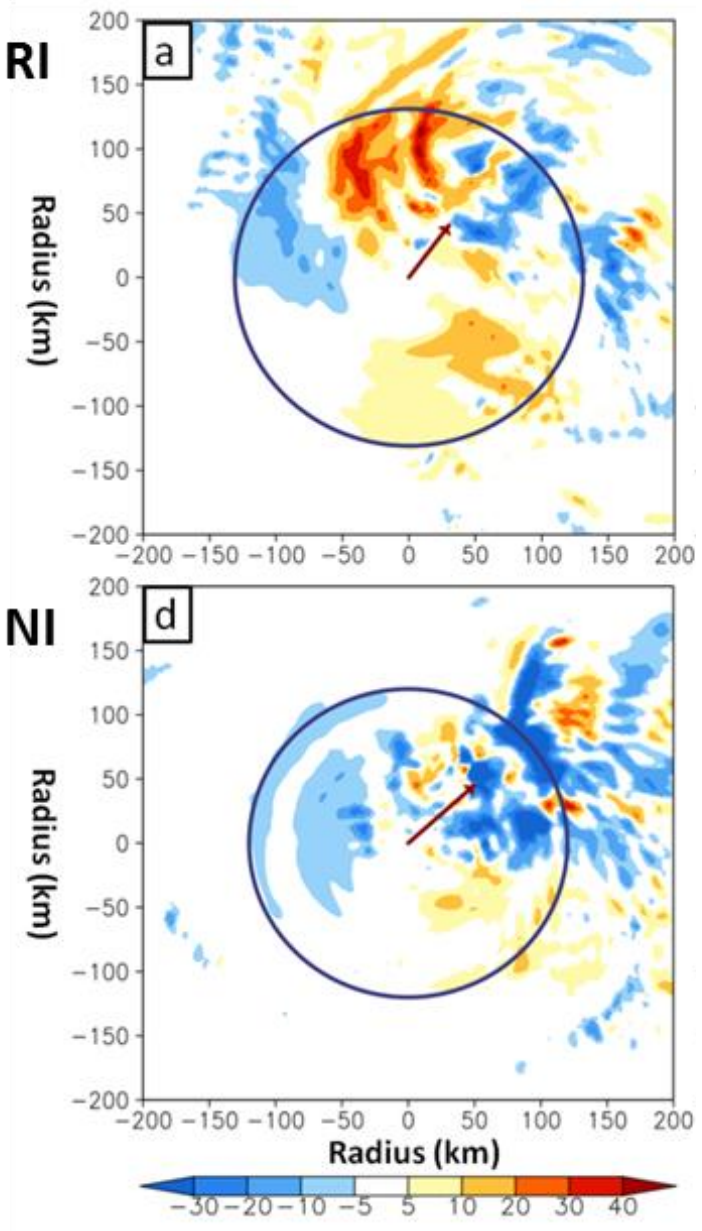
$$\frac{\partial \langle v \rangle}{\partial t} = \underbrace{-\langle u \rangle \langle f + \zeta \rangle}_{V_{m\zeta}} \underbrace{-\langle w \rangle \frac{\partial \langle v \rangle}{\partial z}}_{V_{mv}} \underbrace{-\langle u'\zeta' \rangle}_{V_{e\zeta}}$$

$$\underbrace{-\left\langle w' \frac{\partial v'}{\partial z} \right\rangle}_{V_{ev}} + \underbrace{\left\langle \frac{1}{\rho r} \frac{\partial p'}{\partial \lambda} \right\rangle}_{V_{ppg}} + \underbrace{\langle D_{dh} \rangle}_{V_{dh}} + \underbrace{\langle D_{dv} \rangle}_{V_{dv}},$$


$\langle u \rangle$, $\langle v \rangle$, $\langle w \rangle$
$-\langle u \rangle \langle f + \zeta \rangle$
$-\langle w \rangle \frac{\partial \langle v \rangle}{\partial z}$
$-\langle u' \zeta' \rangle$
$-\left\langle w' \frac{\partial v'}{\partial z} \right\rangle$
$\langle D_{dh} \rangle + \langle D_{dv} \rangle$
Summation
$\frac{\partial \langle v \rangle}{\partial t}$
a
b
c
d
e
f
g
h
Height (km)
Radius (km)
16
14
12
10
8
6
4
2
50
100
150
200
5
3
2
1
0
−1
−2
−3
−5
-3 h
0 h

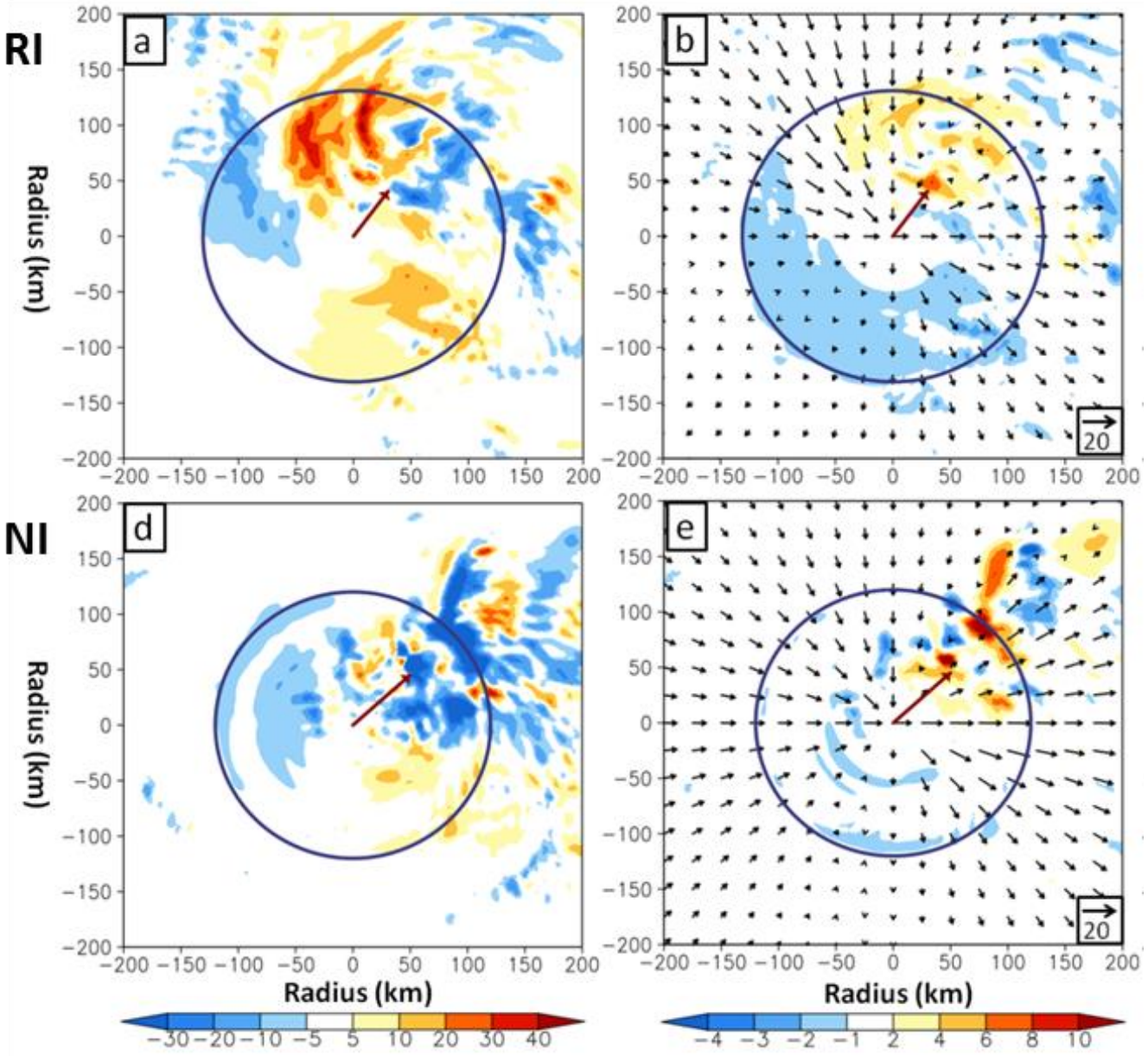

$\langle u \rangle$, $\langle v \rangle$, $\langle w \rangle$
$-\langle u \rangle \langle f + \zeta \rangle$
$-\langle w \rangle \frac{\partial \langle v \rangle}{\partial z}$
$-\langle u' \zeta' \rangle$
$-\left\langle w' \frac{\partial v'}{\partial z} \right\rangle$
$\langle D_{dh} \rangle + \langle D_{dv} \rangle$
Summation
$\frac{\partial \langle v \rangle}{\partial t}$
a
b
c
d
e
f
g
h
Height (km)
Radius (km)
-7 h
-4 h

$$-u'\zeta'$$

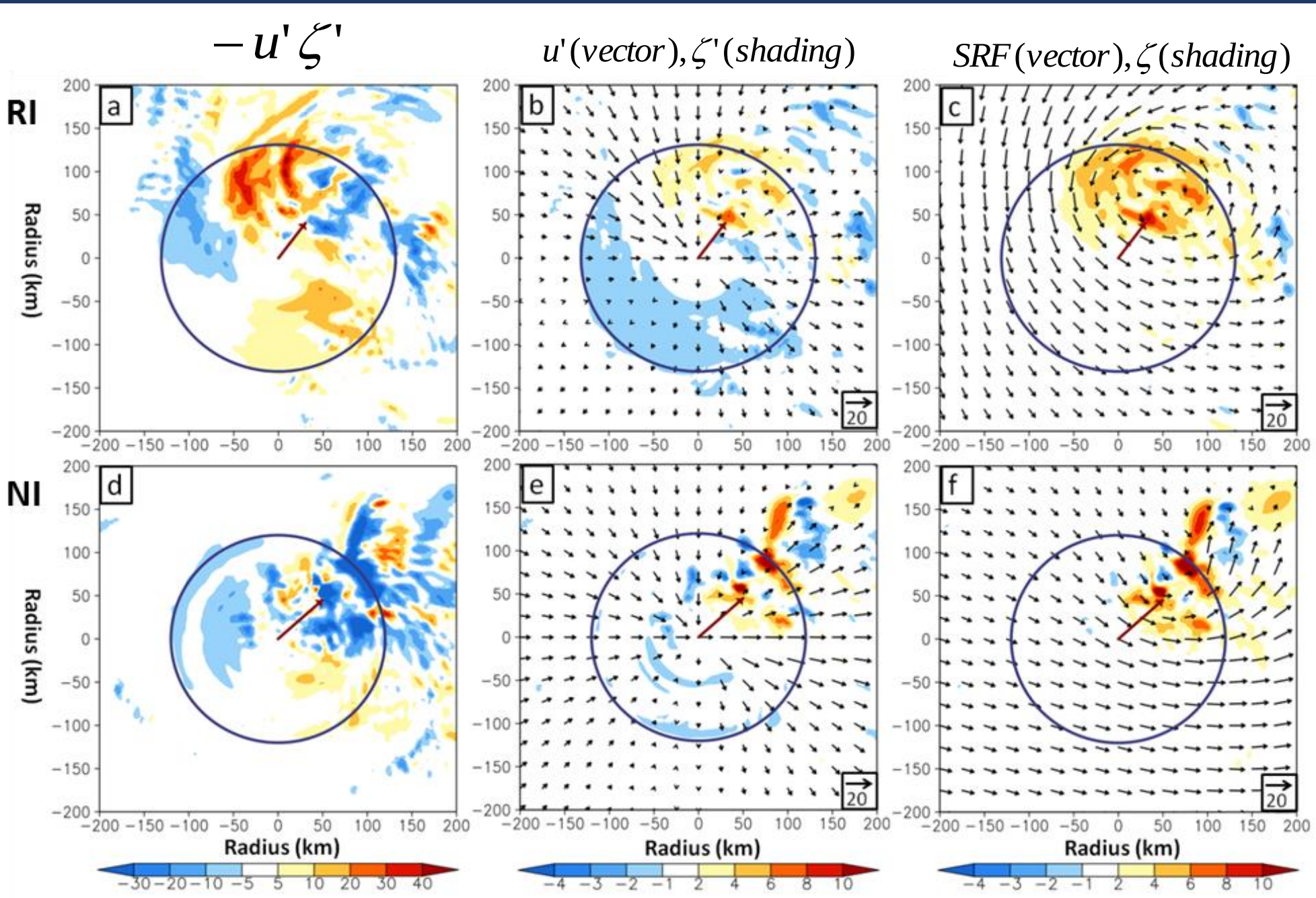

RI
a
NI
d
Radius (km)
Radius (km)
200
150
100
50
0
−50
−100
−150
−200
−200 −150 −100 −50 0 50 100 150 200
−30 −20 −10 −5 5 10 20 30 40

$-u'\zeta'$

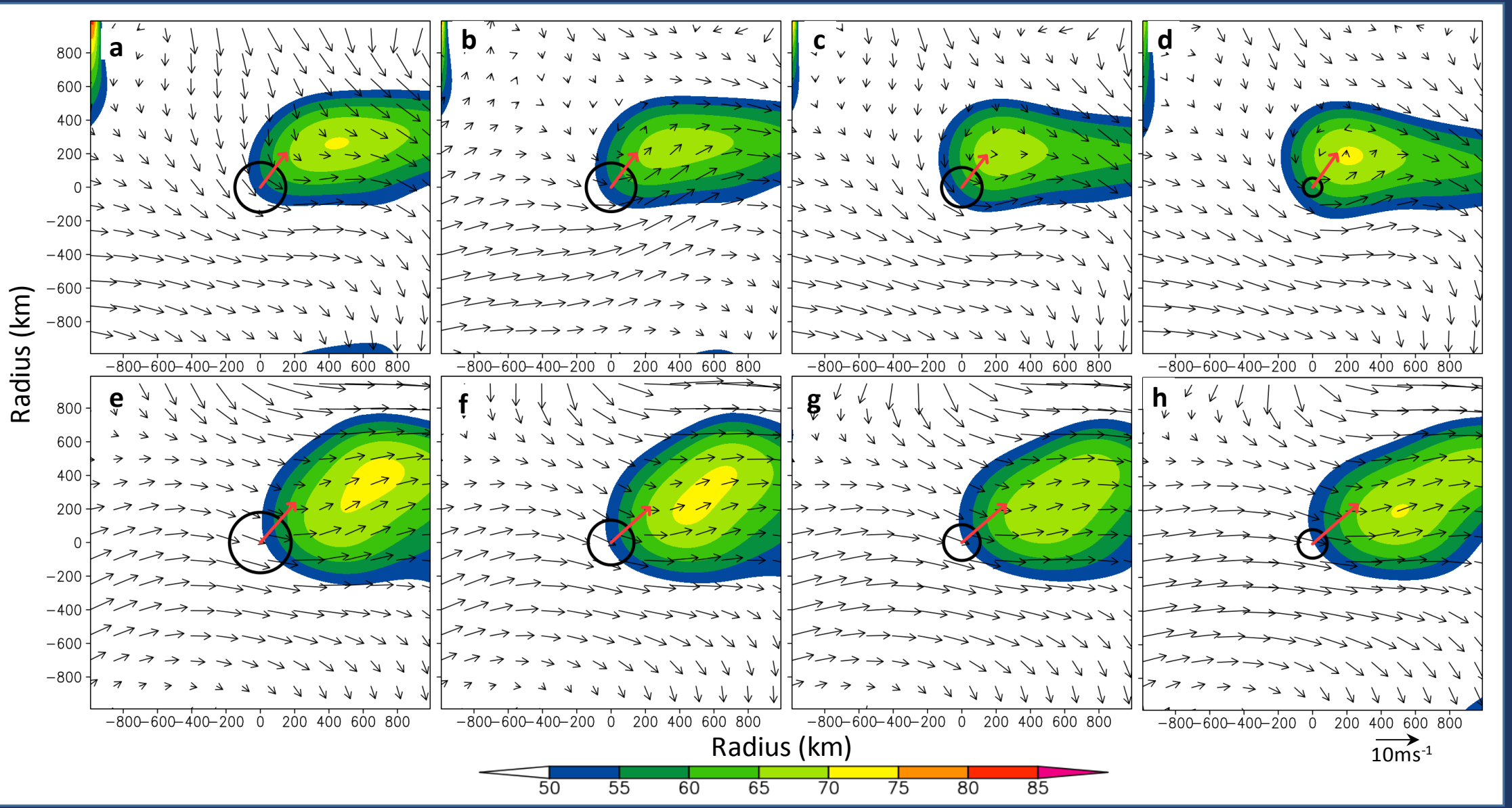
$u'(vector), \zeta'(shading)$



2


$-u'\zeta'$
$u'(vector),\zeta'(shading)$
$SRF(vector),\zeta(shading)$
RI
NI
a
b
c
d
e
f
Radius (km)
Radius (km)
20
−30 −20 −10 −5 5 10 20 30 40
−4 −3 −2 −1 2 4 6 8 10

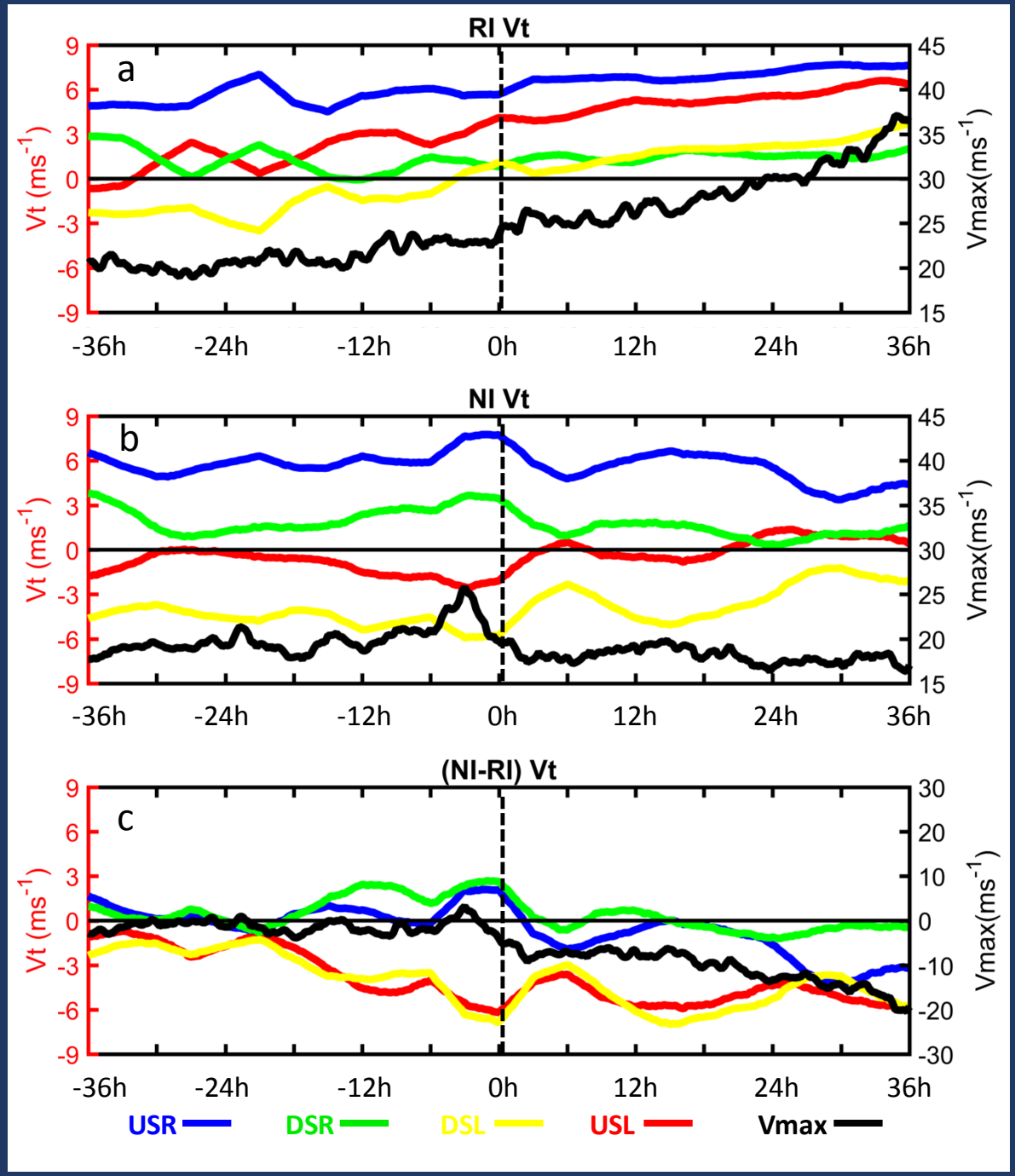
Environmental RH (shading) & SRE Flow (z=8km); Black circle: RMW; Red arrow: Shear



RI

NI

Composite of tangential component of SRE flow averaged between 6-10km and 0-500 km

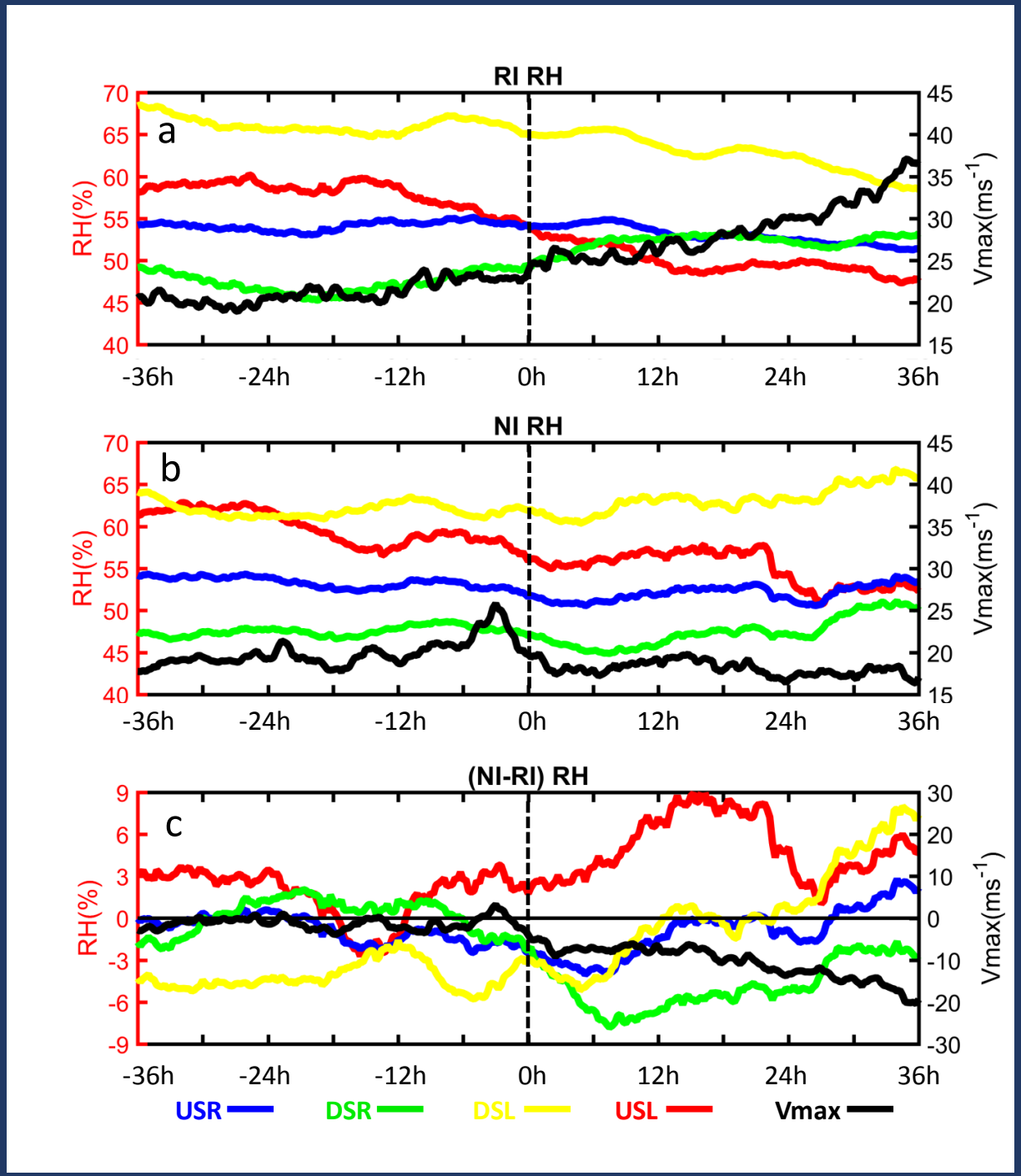


RI composite

NI composite

NI – RI

Composite of environment RH averaged between 2-6km and 0-500 km



RI composite

NI composite

NI – RI

Conclusions

- Deep convection spirals inward from DS for RI members yet stays trapped at DS for NI members;
- Eddy vorticity flux in RI member help spinning up the middle-and-upper level and bring the vortex to alignment yet plays an negative role in spinning up the middle-and-upper level for the NI meber.
- The SREF in the left-of-shear hemisphere at upper level is important for determining if deep convection can spiral inward or not.
- The SREF in the left-of-shear hemisphere is an important factor that determines if eddy vorticity flux will spin up the vortex or not.