Tropical Cyclone Structure-2008 (TCS-08)

Convection and Shear Flow in TC Development and Intensification

Hung-Chi Kuo[1]
Chih-Pei Chang[2]
Ching-Hwang Liu[3]

[1]National Taiwan University
[2]Naval Postgraduate School
[3]Chinese Culture University

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Background

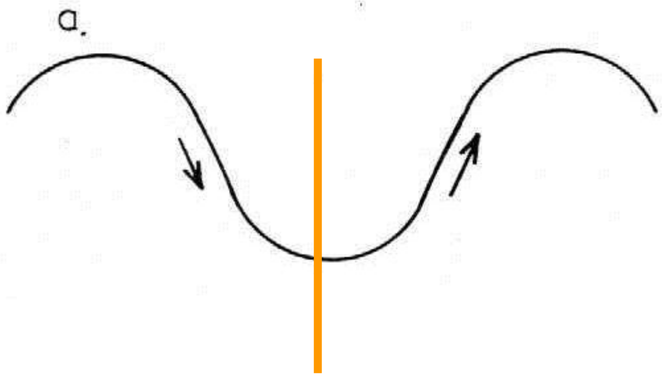
The vorticity generation by the convective systems and the upscale transfer of energy in the storm environment are important in TC genesis and intensification.

The horizontal strain in the storm environment may enhance the cloud entrainment and organize the convection into banded structure.

Previous analyses of RF were on strong TCs and many with concentric eyewalls.

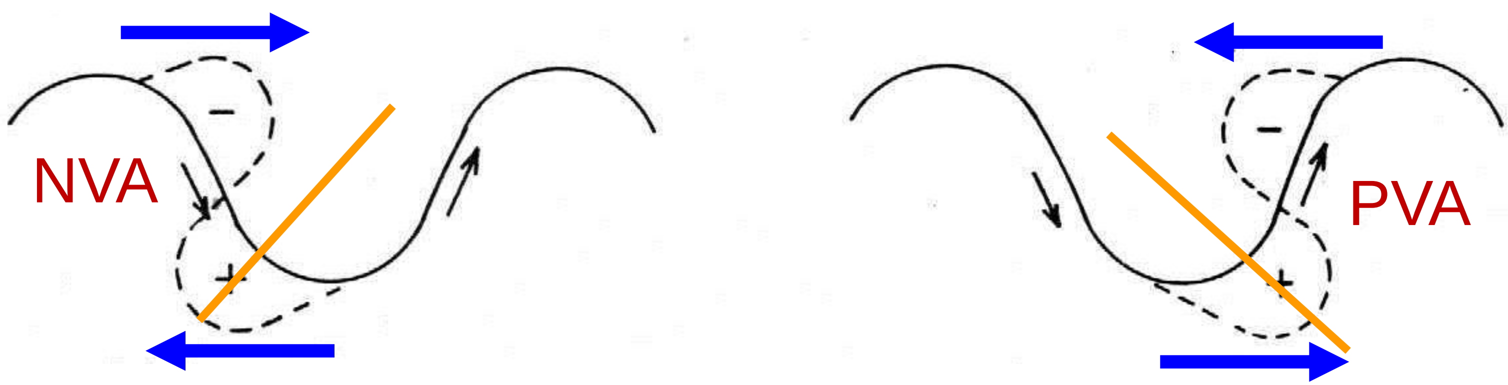
Quasi-2D Flow

Vorticity distorted by the horizontal shear while the flow field not.



PV contour on isentropic surface

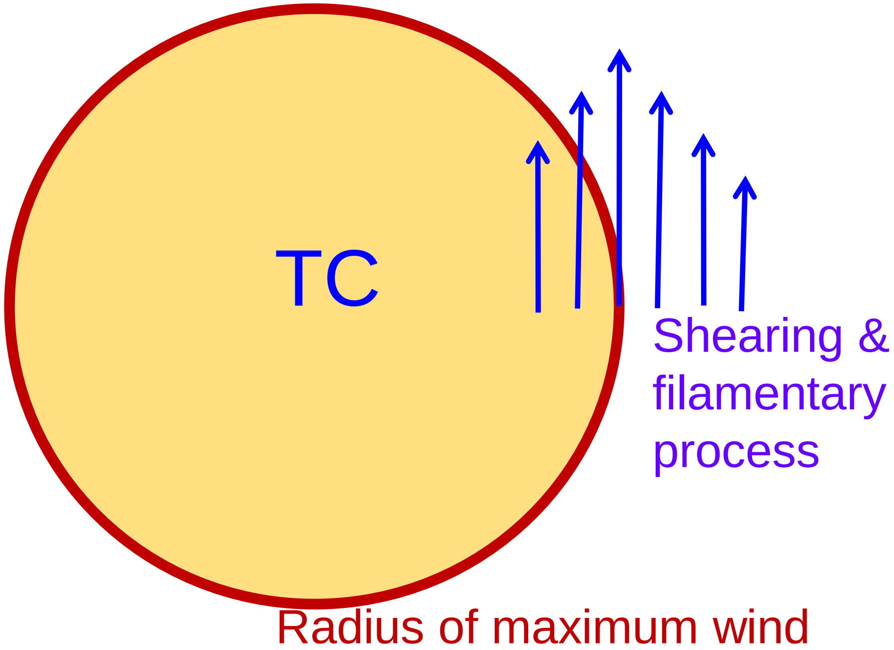
$$\zeta = \nabla^2 \psi$$



Trough Thinning in anti-cyclonic shear

Trough Broadening in cyclonic shear

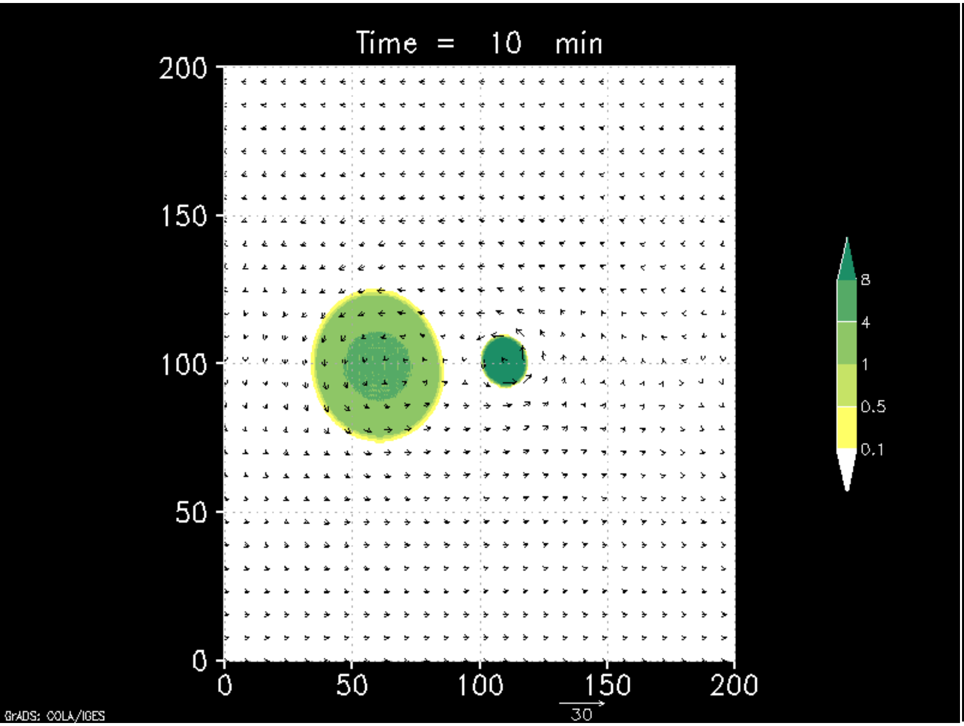
Thorncroft et al. (1993)



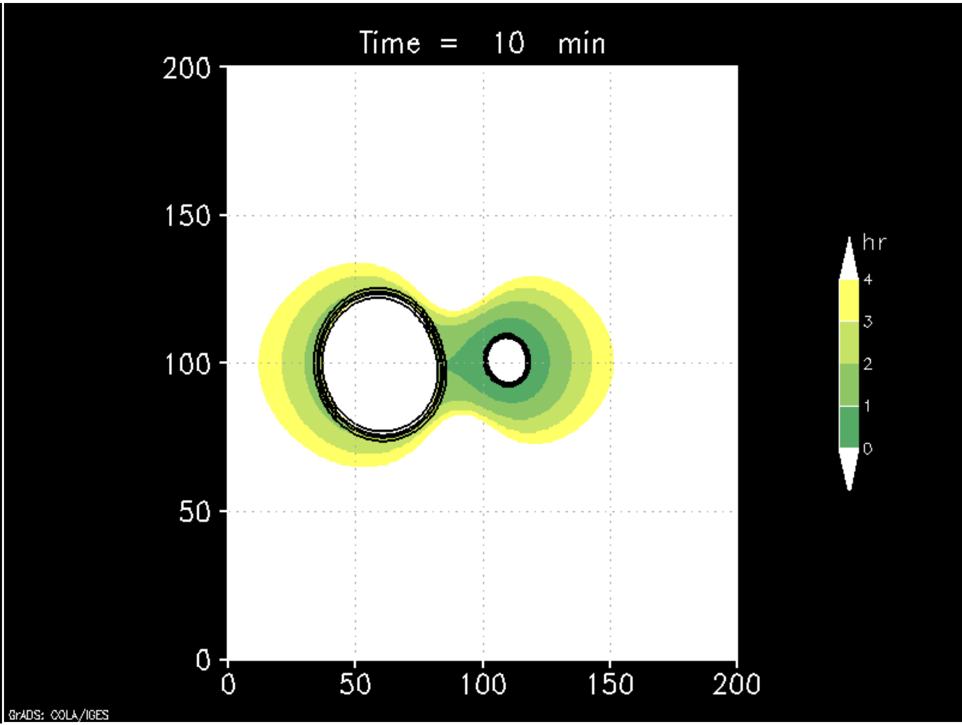
The strong differential rotation outside the radius of maximum wind produces vorticity filaments.

Deep convections outside RMW may be organized (banded structures) or suppressed (entrainment enhanced).

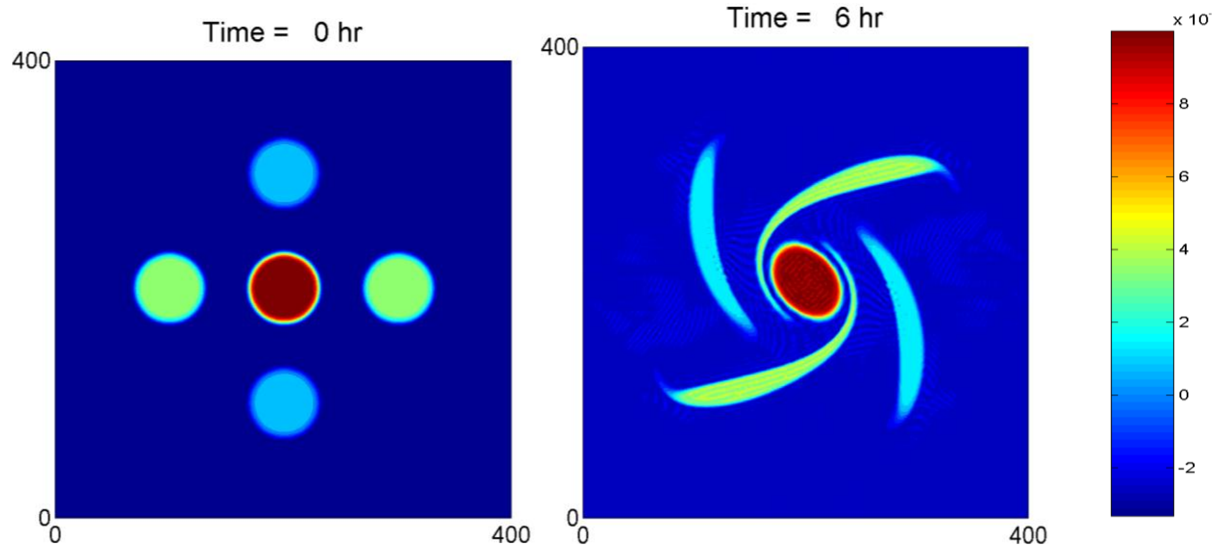
Vorticity



Filamentation Time



Vorticity Dynamics



(km)

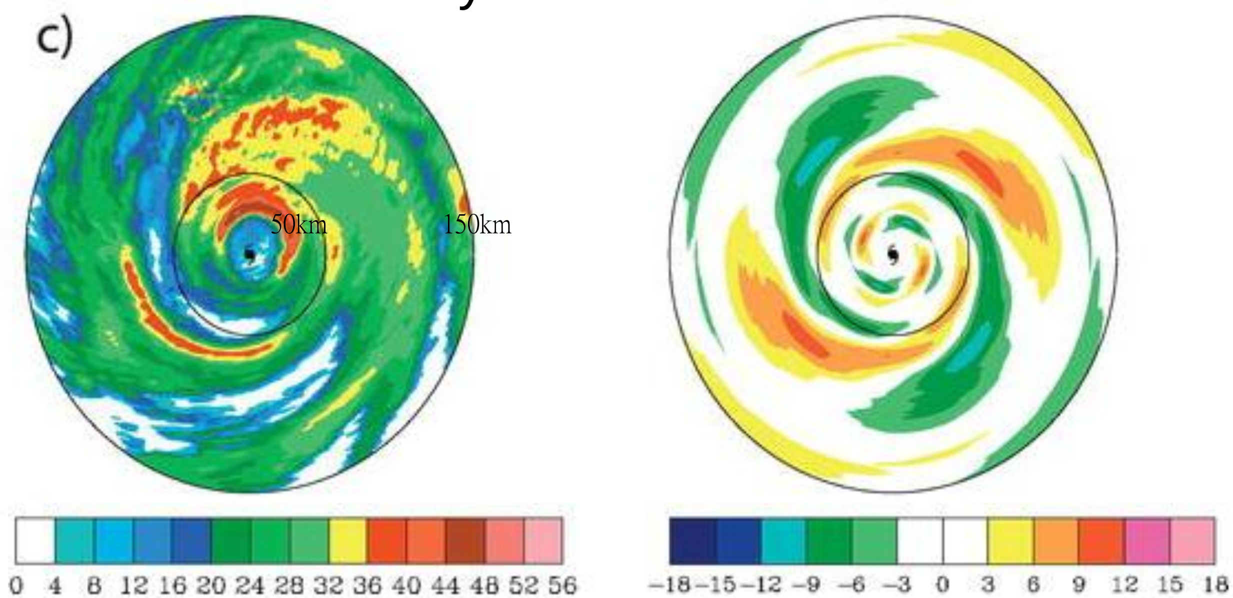
Vorticity

Elena (1985)
1640 UTC

Corbosiero et al. (2006)

Radar reflectivity

Wavenumber 2



Rozoff et al. (2006, 2008)

The Rapid Filamentation Zone (RFZ) proposed (τ_{fil} < 30 min).

Convections may be suppressed in the RFZ.

RFZ dynamics may contribute to the “moat” formation in concentric eyewalls (CE).

Wang (2008)

A 3D non-hydrostatic simulations of CE.

The moat area extends outward beyond the RFZ.

The moat is largely controlled by subsidence.

Kuo et al. (2009)

Satellite observations + JTWC data for CE TC in WPAC.

RF can be important in organizing TC moat, when V_m > 130 kts (moat size explained)

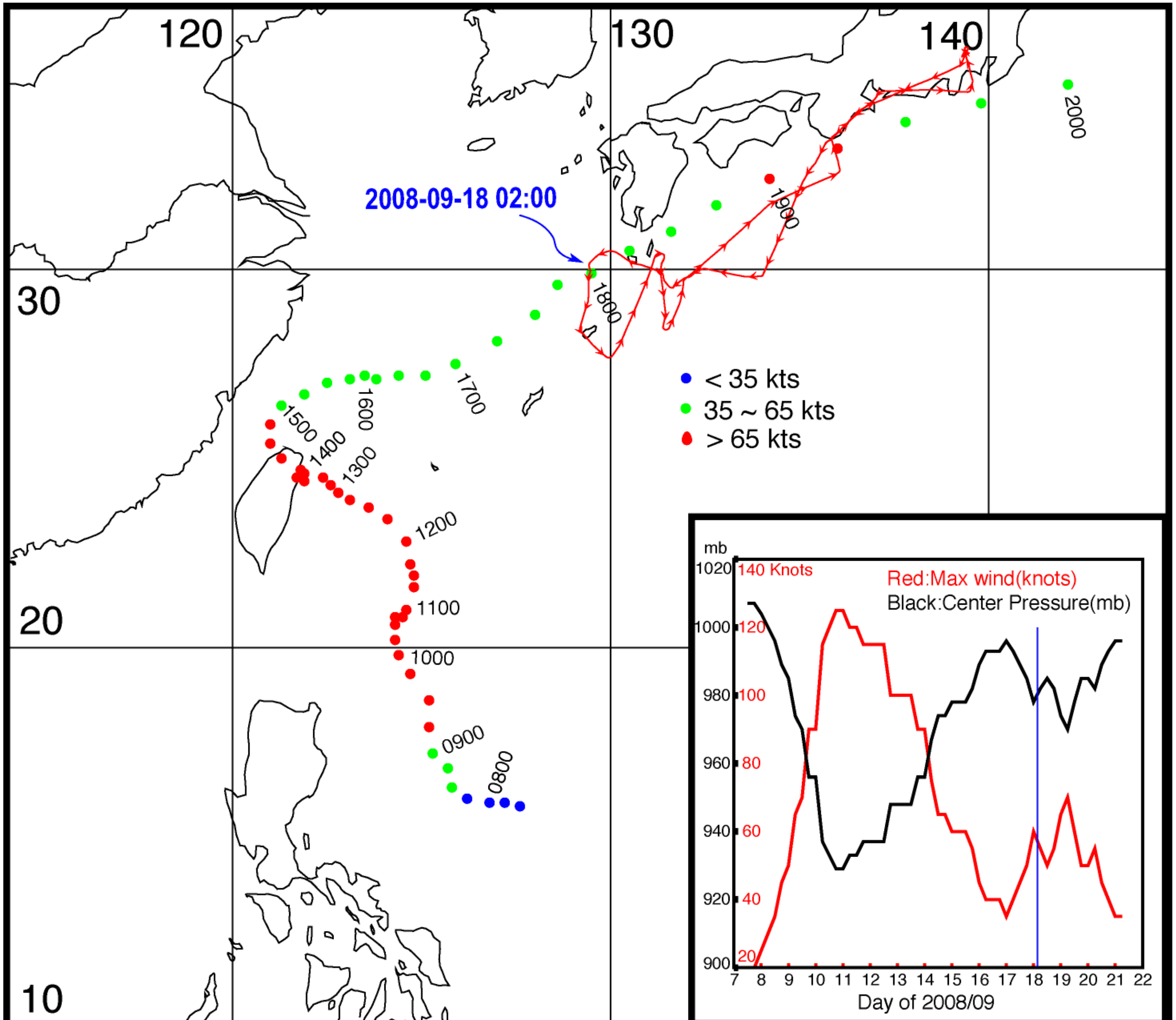
Scientific Objectives:

Collect observations that describe the evolving kinematic and thermodynamic conditions of mesoscale convection in the storm environment.

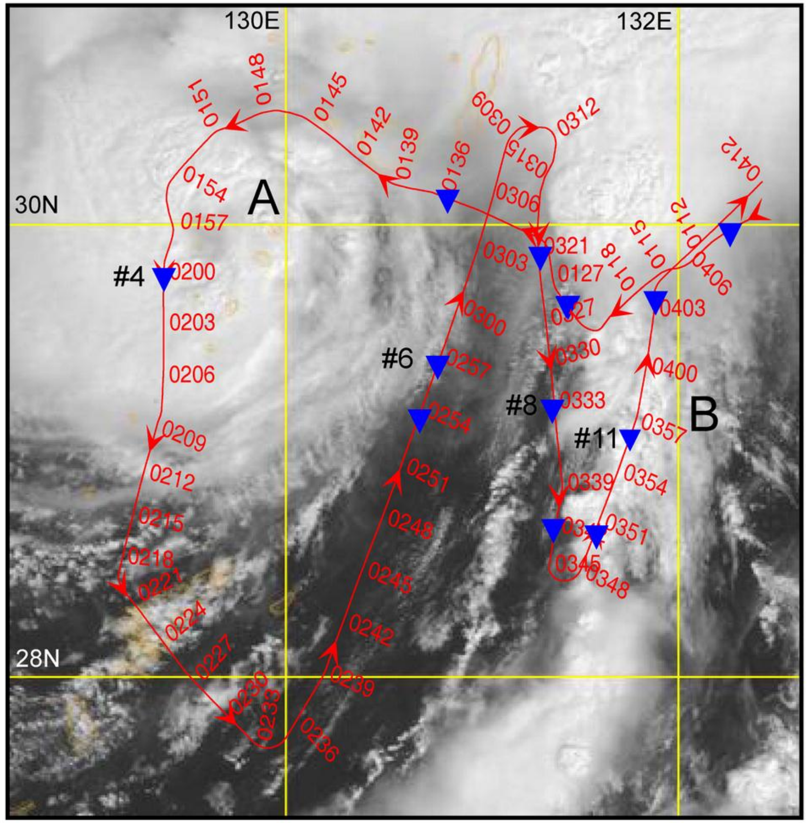
Study the vorticity/convection initiation processes in the storm environment . The impact of strain effect on the cloud system development is emphasized.

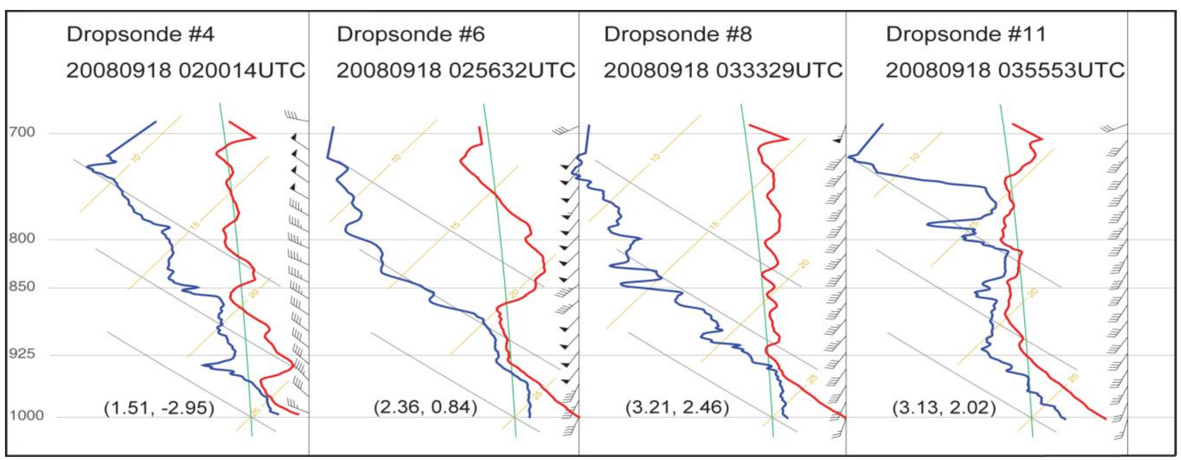
TCS08 high resolution aircraft radar and wind data directly compute the filamentation time, to allow an investigation into the effect of RF on convection.

2008 Typhoon Sinlaku and NRL-P3 RF14 flight track



2008-09-18 01:41UTC MODIS VIS and NRL P-3 Flight track





~150 km ~ 50 km ~ 25 km

Dual-Doppler radar analysis:

- Use NCAR SOLO program to edit the radar data

- NCAR REORDER Closest point interpolation scheme for curving track

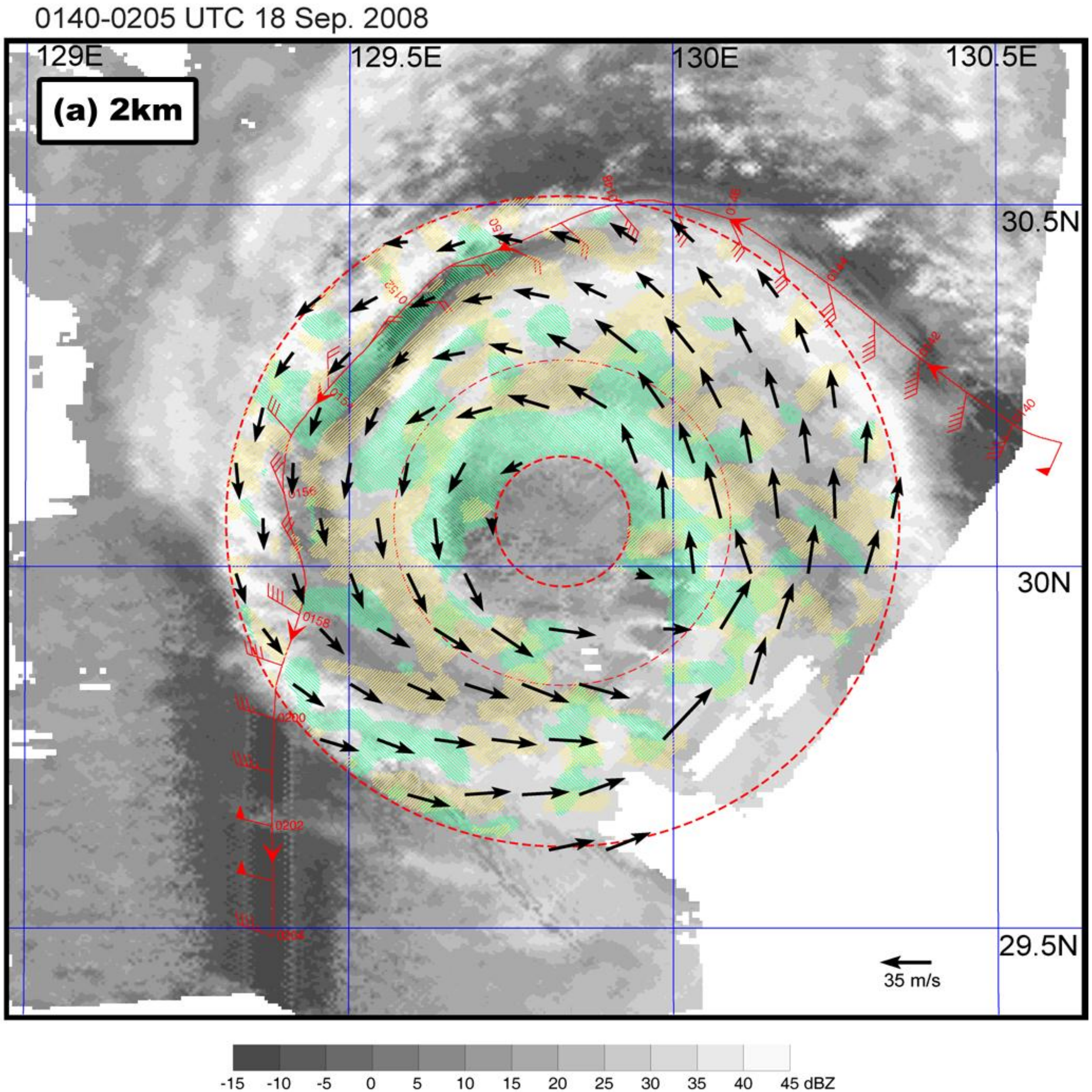
- NCAR CEDRIC for dual-Doppler synthesis

- Analysis grid size 1km x 1km x 1km

- Leise’s smooth filer: 2 steps filter (noise < 4km are damped)

Yellow τ_{fil}< 25 min

Green vorticity > 10^-3 s-1



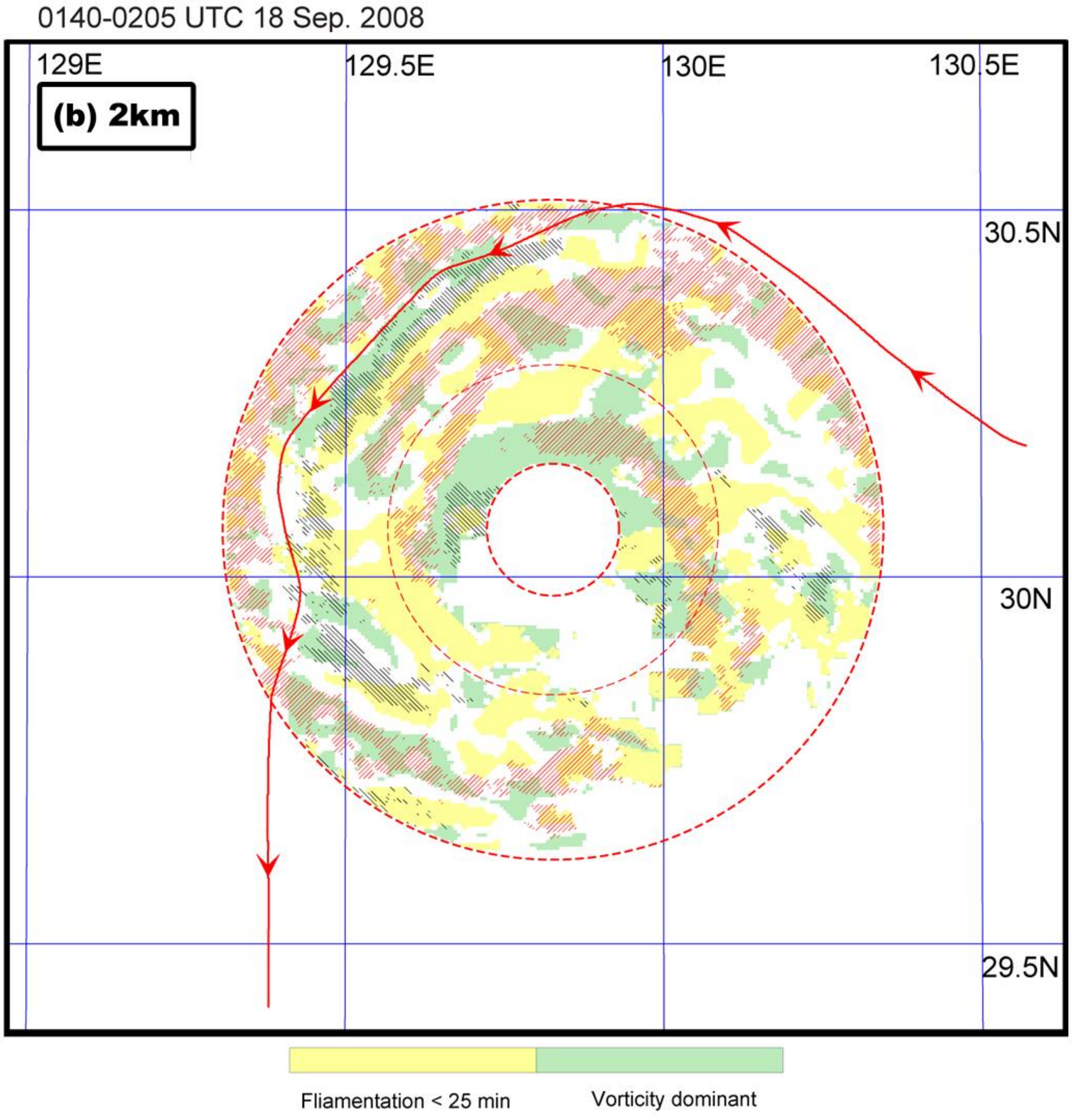
Translation speed
5.4m/s 60 deg

Yellow τ_{fil}< 25 min

Green vorticity > 10^-3 s-1

Red hatched >37 dBz

Black hatched <13 dBz

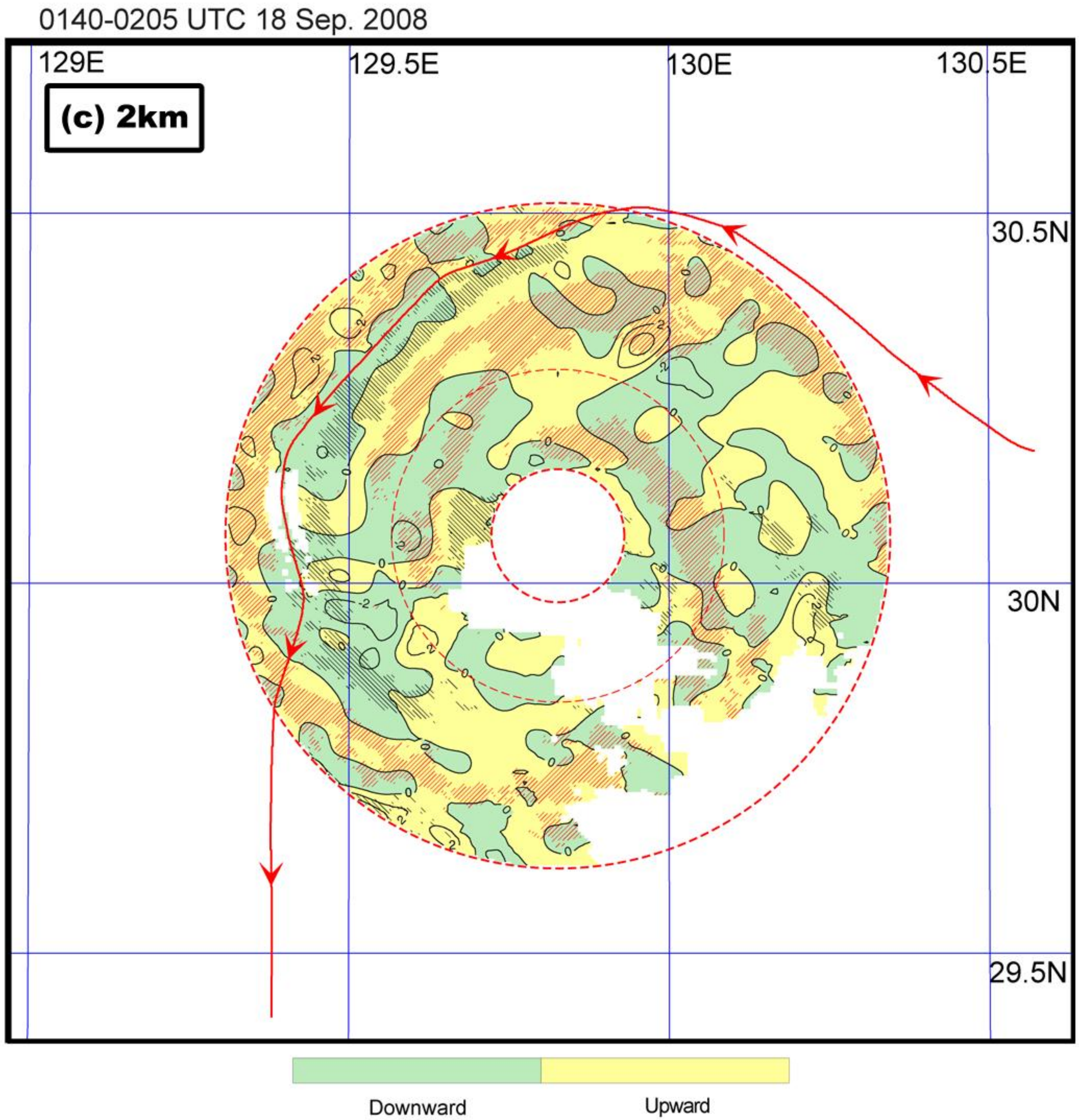


Yellow upward

Green downward

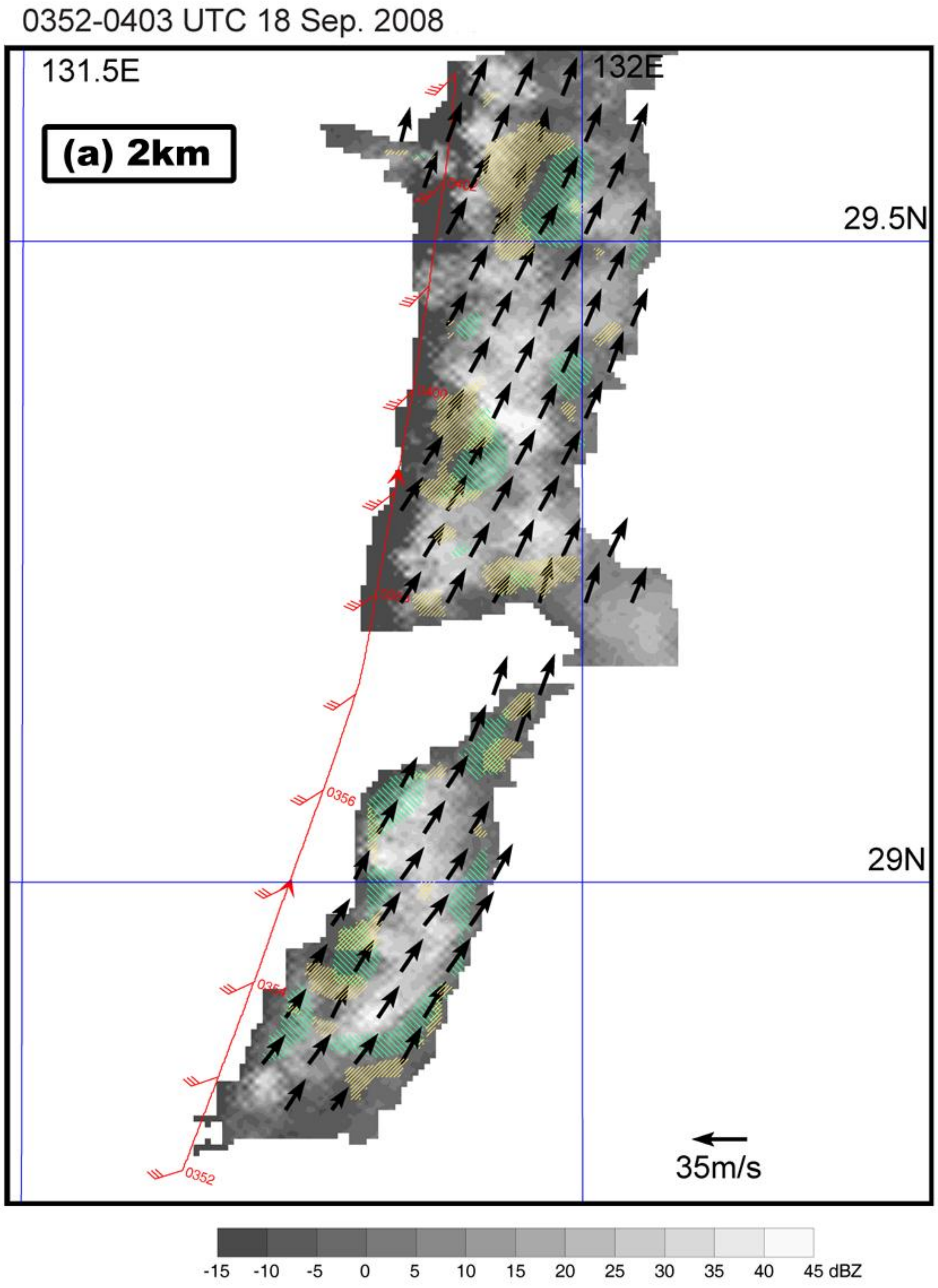
Red hatched
>37 dBz

Black hatched
<13 dBz



Yellow τ_{fil}< 25 min

Green vorticity
> 10^-3 s-1



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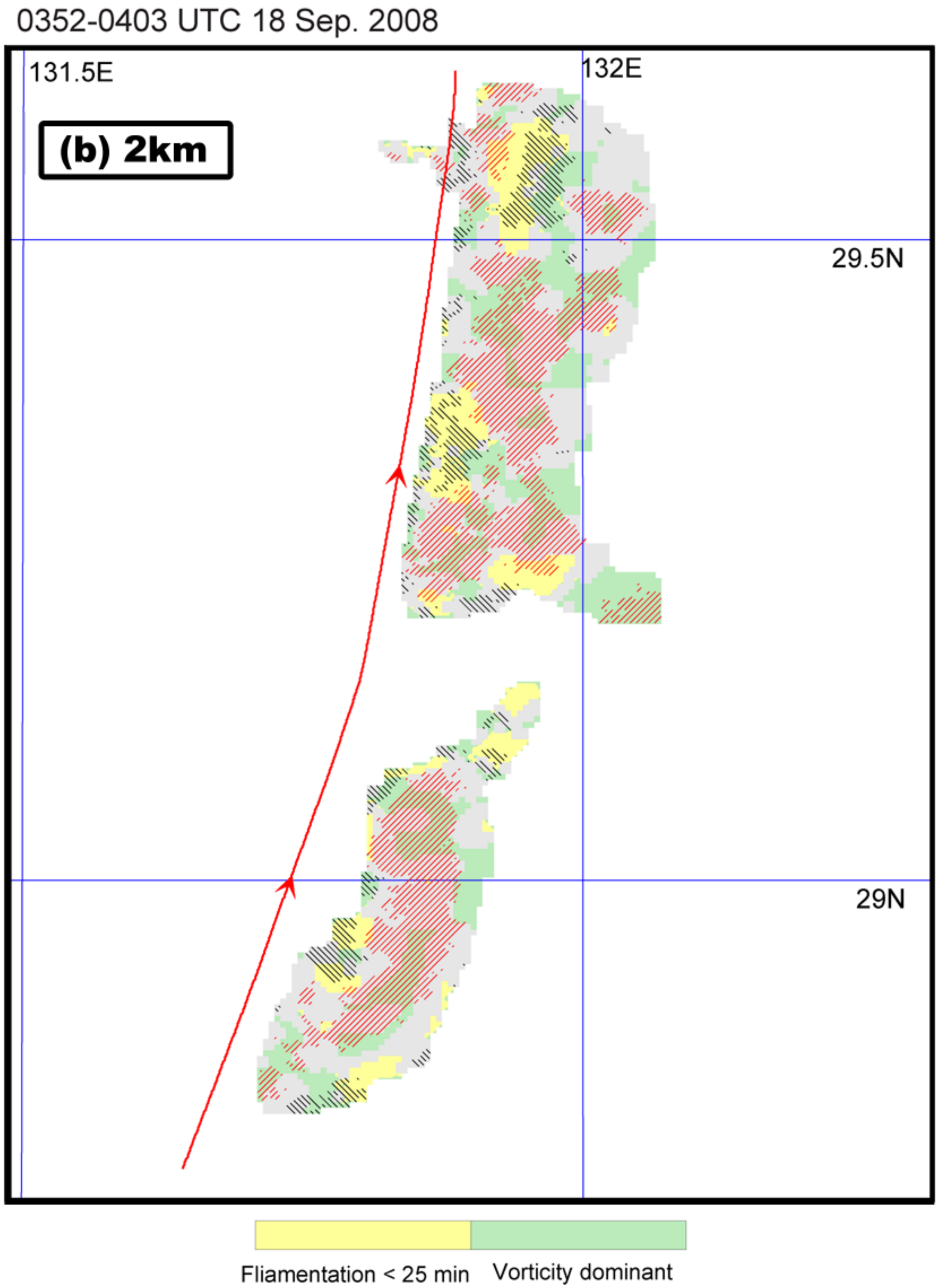

Yellow upward

Green downward

Red hatched
>37 dBz

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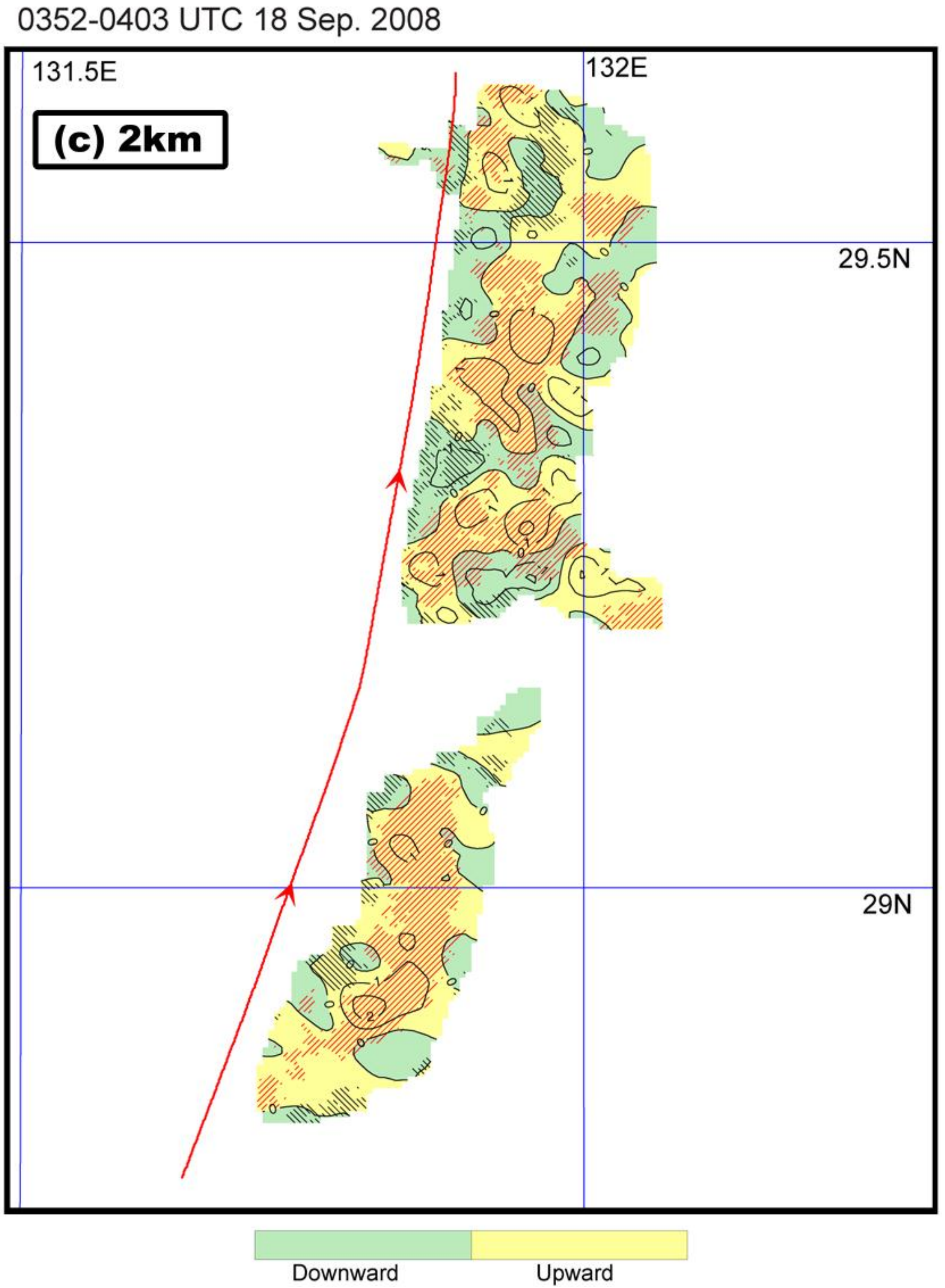
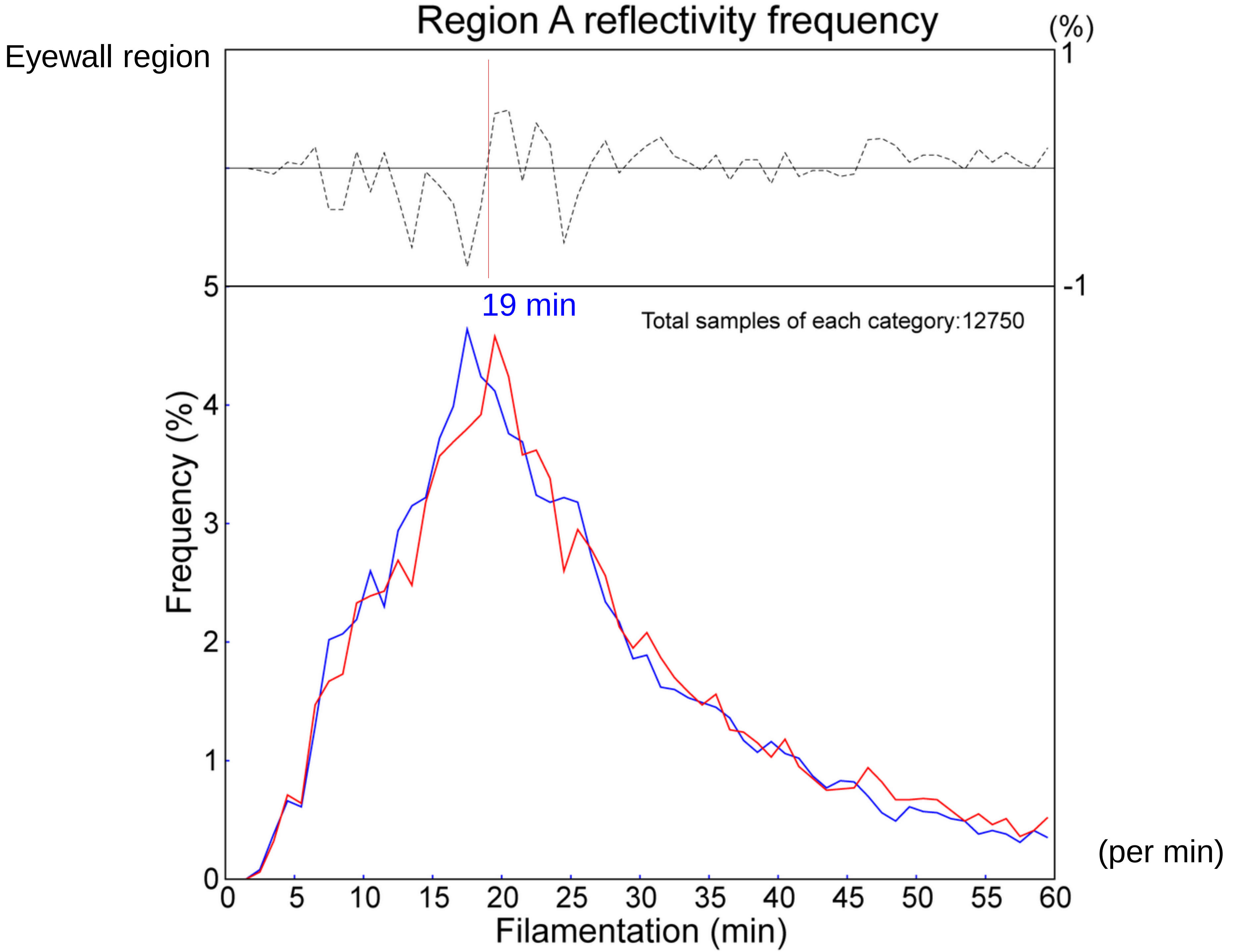
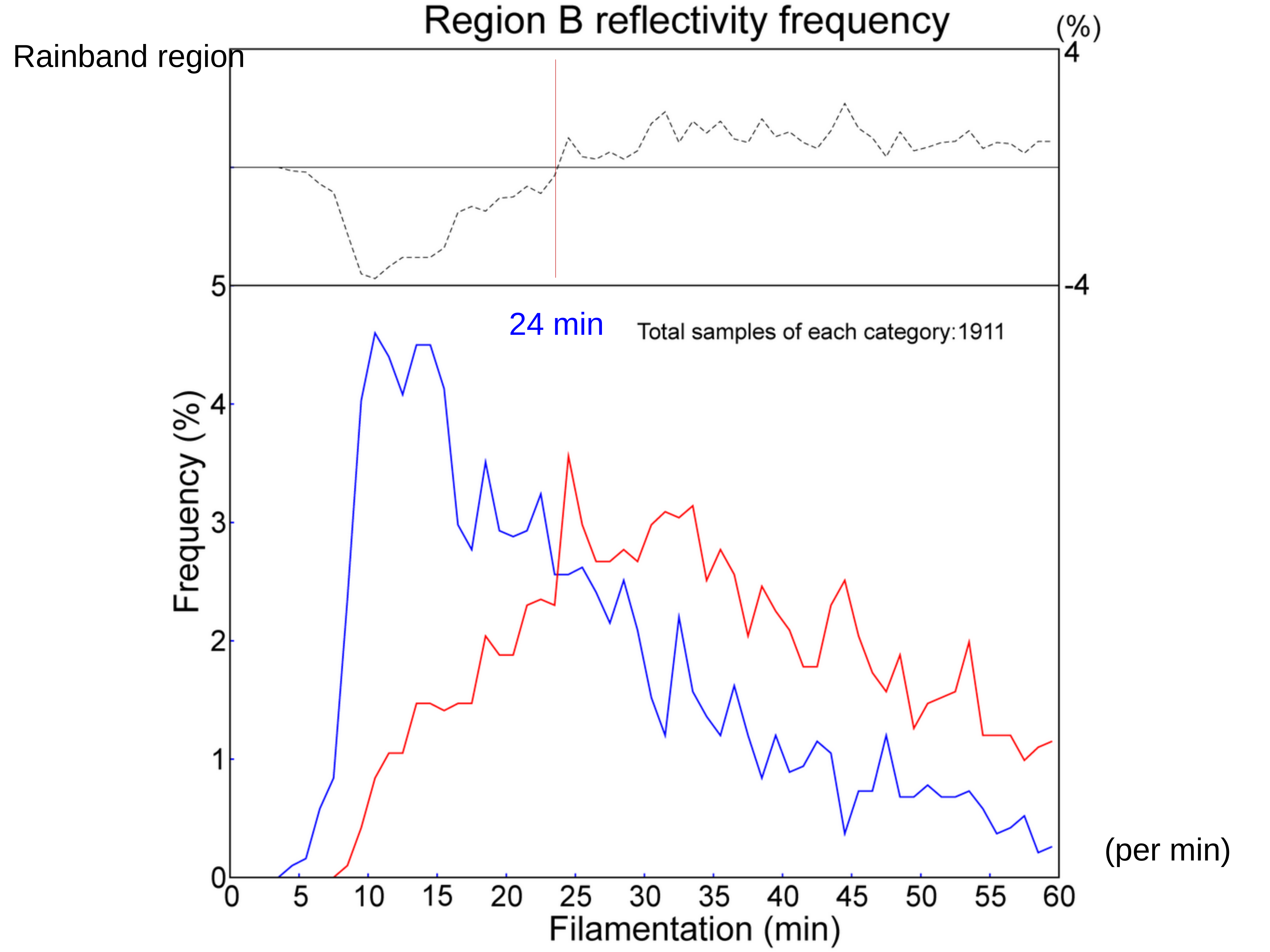
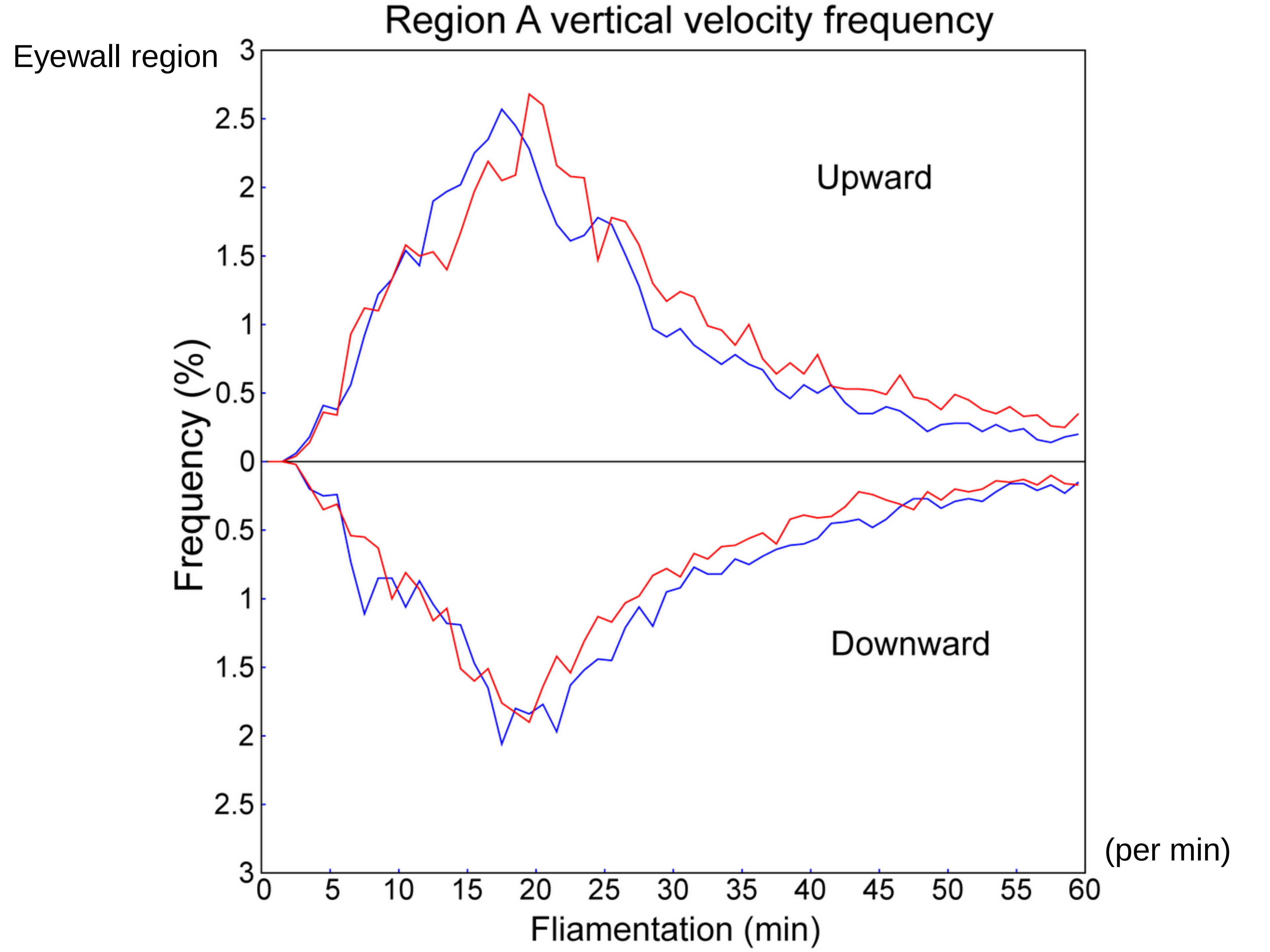
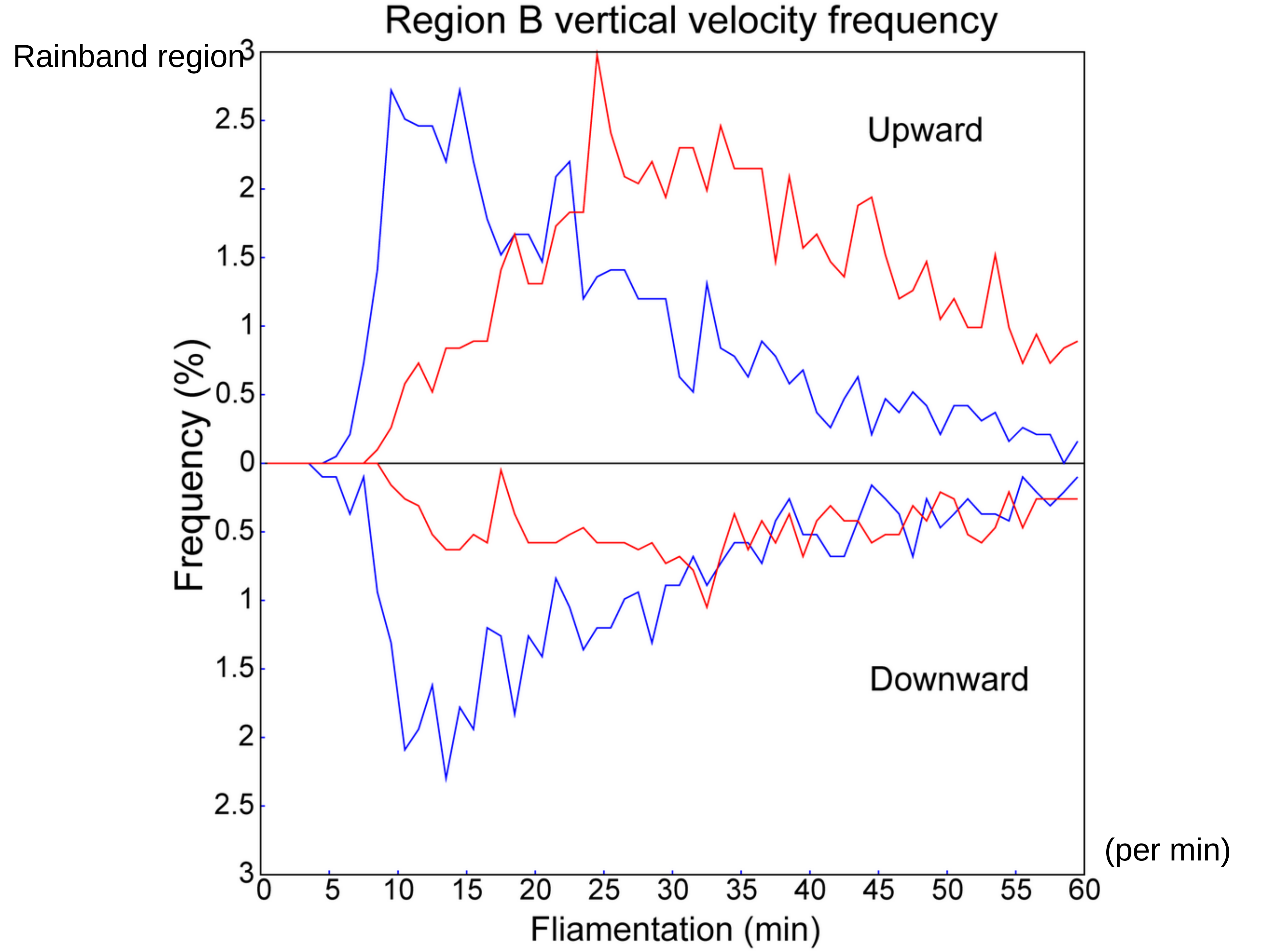



Region A reflectivity frequency
Eyewall region
(%)
1
-1
5
19 min
Total samples of each category:12750
Frequency (%)
4
3
2
1
0
(per min)
0
5
10
15
20
25
30
35
40
45
50
55
60
Filamentation (min)


Region B reflectivity frequency
Rainband region
(%)
4
-4
24 min
Total samples of each category:1911
Frequency (%)
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
50
55
60
Filamentation (min)
(per min)



Region A vertical velocity frequency
Eyewall region
Upward
Downward
Frequency (%)
Fliamentation (min)
(per min)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40
45
50
55
60



Region B vertical velocity frequency
Rainband region
Upward
Downward
Frequency (%)
Fliamentation (min)
(per min)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40
45
50
55
60

Summary (1)

• TCS08 high resolution aircraft radar and wind data suggests that RF zones exist in both the eyewall and the outer rainband regions during the re-intensification stage of Typhoon Sinlaku.

• In the eyewall region where intensive convective forcing is present, deep convection is suppressed such that for τ_{fil} <19 min the frequency of highest quarter of reflectivity is O(10%) less than the lowest quarter. The reverse is true for τ_{fil} > 19 min.

Summary (2)

- In the pricipal spiral band region, deep convection is much more suppressed by filamentation. The ratio of highest quarter/lowest quarter reflectivity is about 50% for τ_{fil} < 24 min and 200% for τ_{fil} > 24 min.

- These results suggest that vortex scale filamentation dynamics on the suppression of convection. In particular, the combination of the subsidence and the filamentation effects aid in the development of spiral bands, which may affect the development and evolution of tropical cyclones.

Summary (3)

• Previous analyses of RF were on strong TCs and many with concentric eyewalls. Our paper connects the RF to a weak but intensifying TC. The convective forcing may mask the effect of RF in the eyewall while the subsidence and RF are important factors for outer rainband.

• We will use the NRL P-3 airborne radar and radar reflectivity to study the convection and vorticity generations of TCs in different stages of development as well as a case of non-development. The cases currently being studied are TCS015 and TCS025.

Thank you!

A painting with vortices and filaments!

Weiss(1981,1991), Rozoff et al. (2006)

The filamentation time is the e-folding time for growth of the vorticity gradient.

Function of divgerence, vorticity, and total deformations.

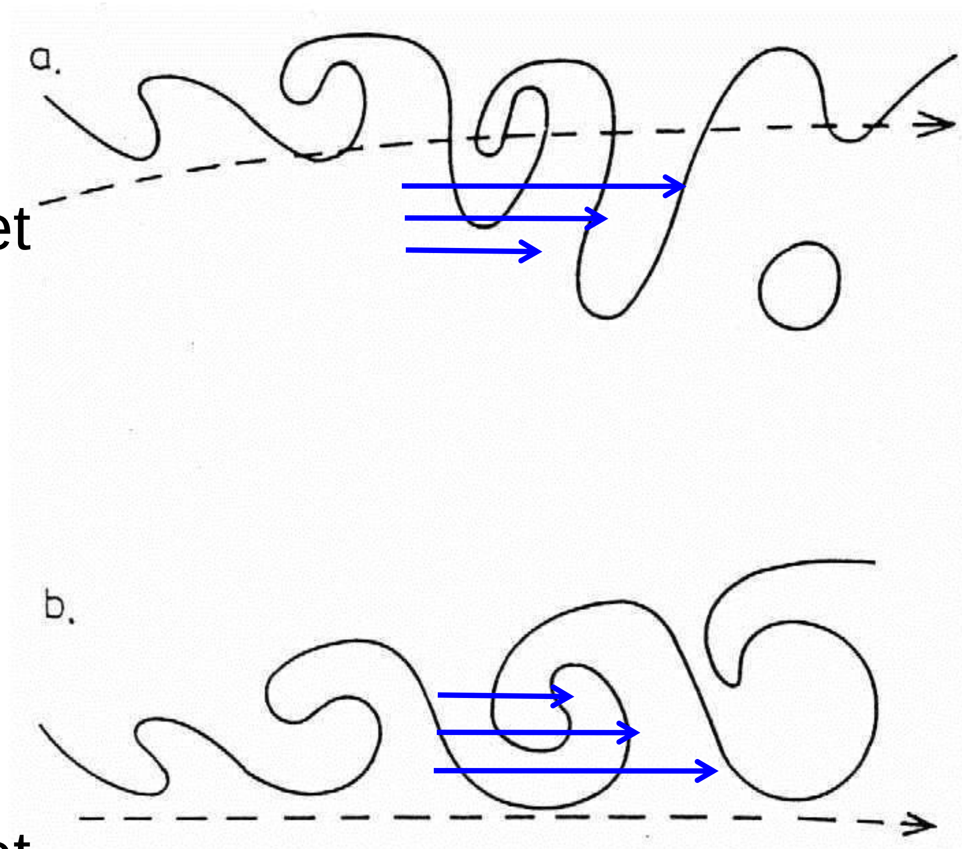
$$\tau_{fli} = \begin{cases} 2/(\delta + \sqrt{S_1^2 + S_2^2 - \zeta^2}), & \text{if } S_1^2 + S_2^2 - \zeta^2 > 0 \\ 0, & \text{if } S_1^2 + S_2^2 - \zeta^2 < 0 \end{cases}$$

$$S_2 = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \qquad S_1 = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \qquad \delta = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Anti-cyclonic shear

NE-SW tilt trough line,
smaller cutoff low



mean jet

mean jet

Cyclonic shear

NW-SE tilt trough line,
larger cutoff low

Thorncroft et al. (1993)