Convection and Shear Flow in Typhoon Development and Intensification:

An observation of Typhoon Sinlaku during TCS08

29th Conference Hurricanes and Tropical Meteorology
12 May, 2010

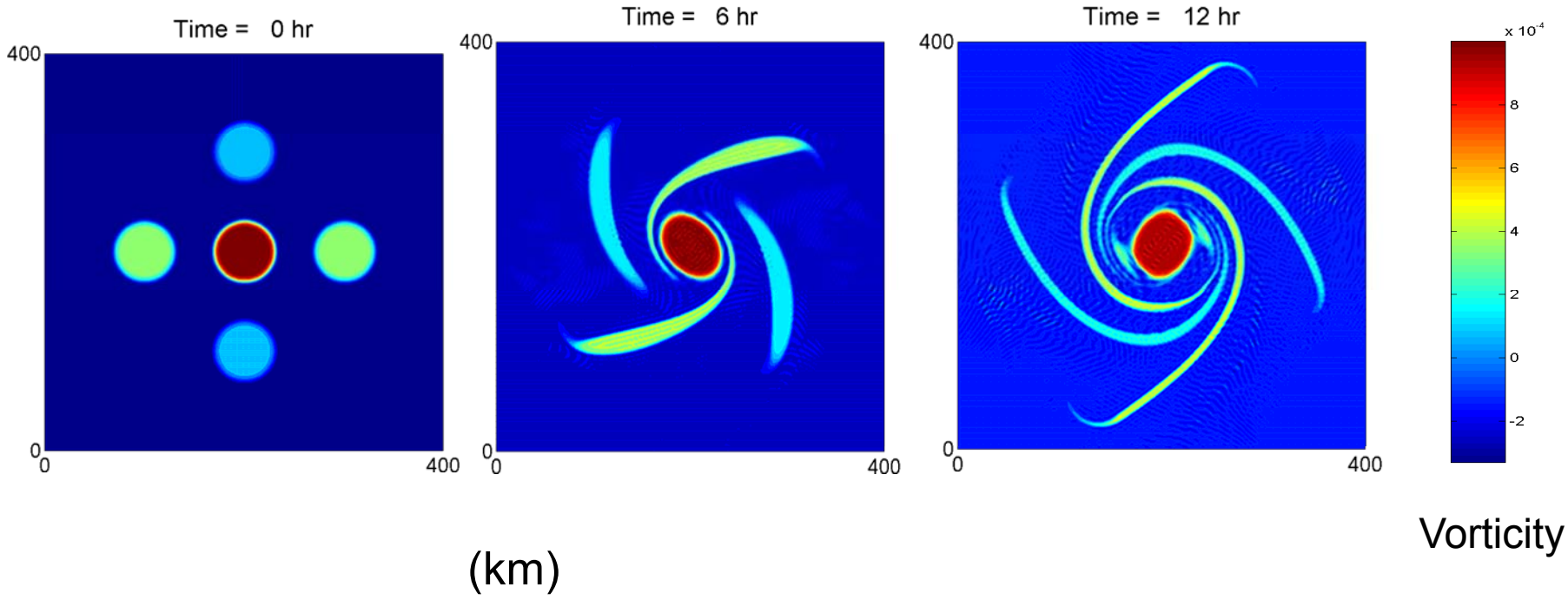
Hung-Chi Kuo[1], National Taiwan University
Chih-Pei Chang, Naval Postgraduate School
Ching-Hwang Liu[1], Chinese Culture University

[1] ***Visiting Naval Postgraduate School***

Supported by ONR Project N0001409AF00002 and N0001410AF00002

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).



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.

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

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

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

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.

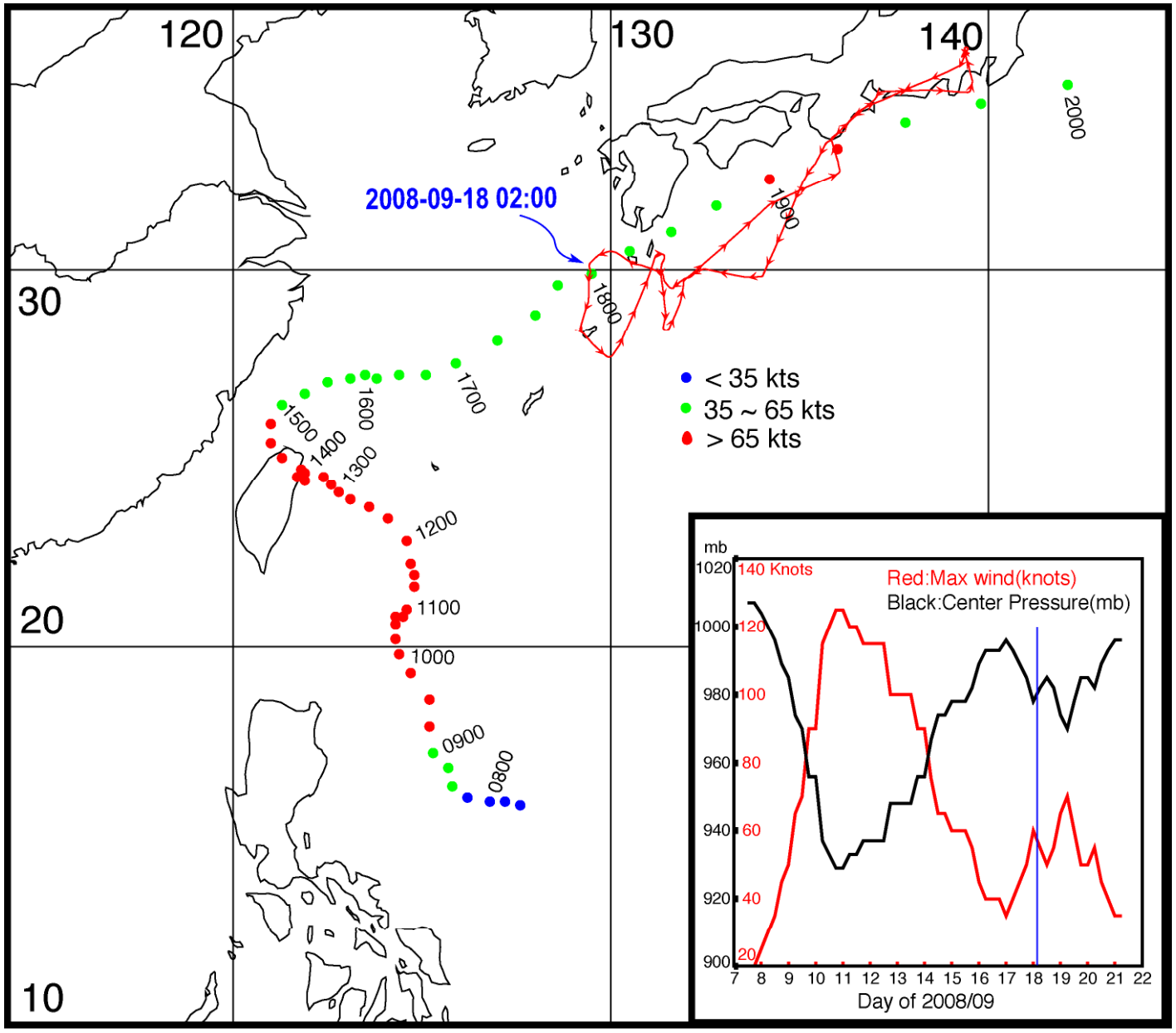
Rapid filamentation can be important in organizing TC moat, when V_m > 130 kts (moat size explained)

Scientific Objectives:

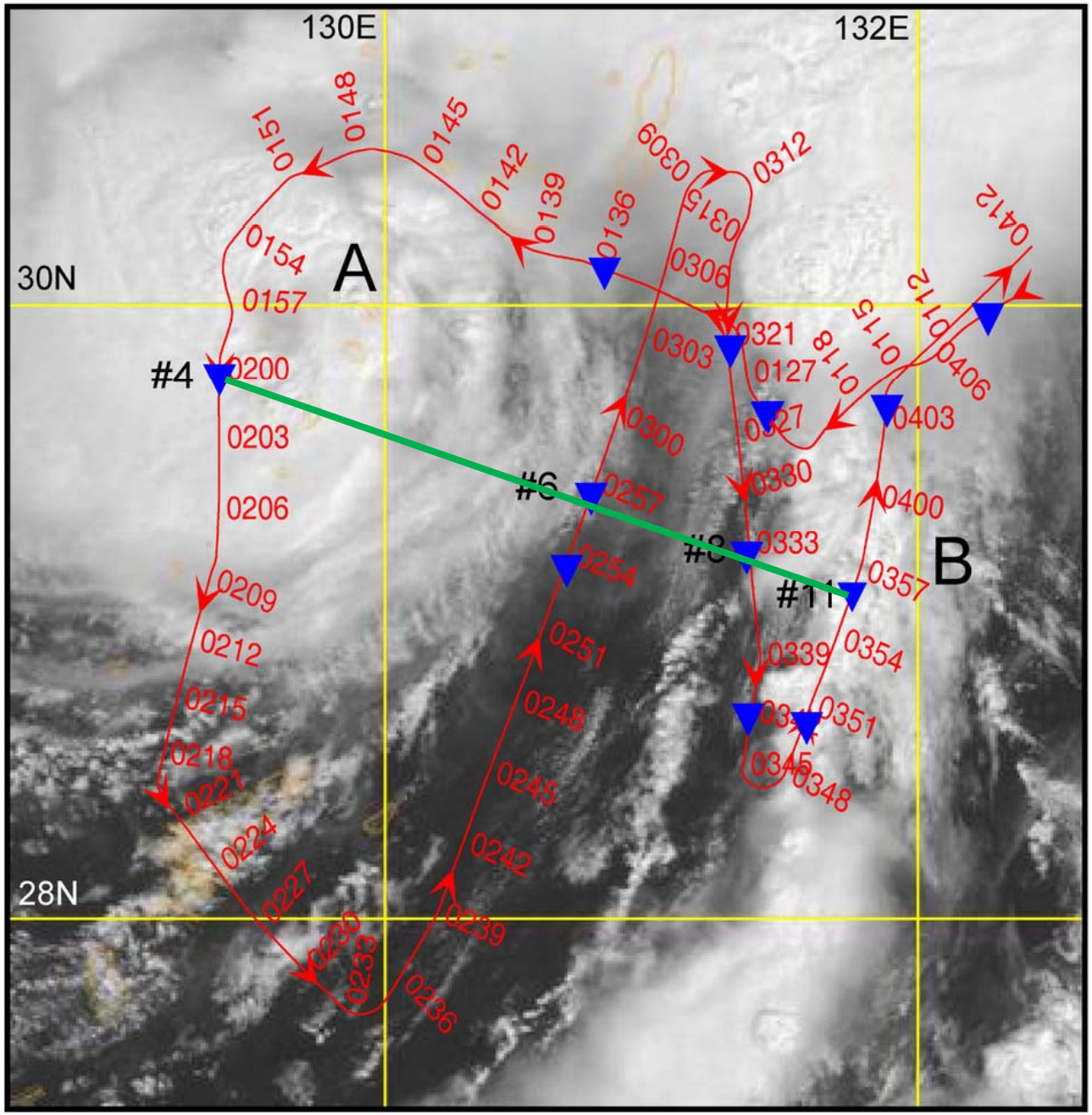
Past studies have depended on theories, numerical models and satellite observations. The TCS08 data allowed us to directly compute filamentation time at the convection scale in typhoons.

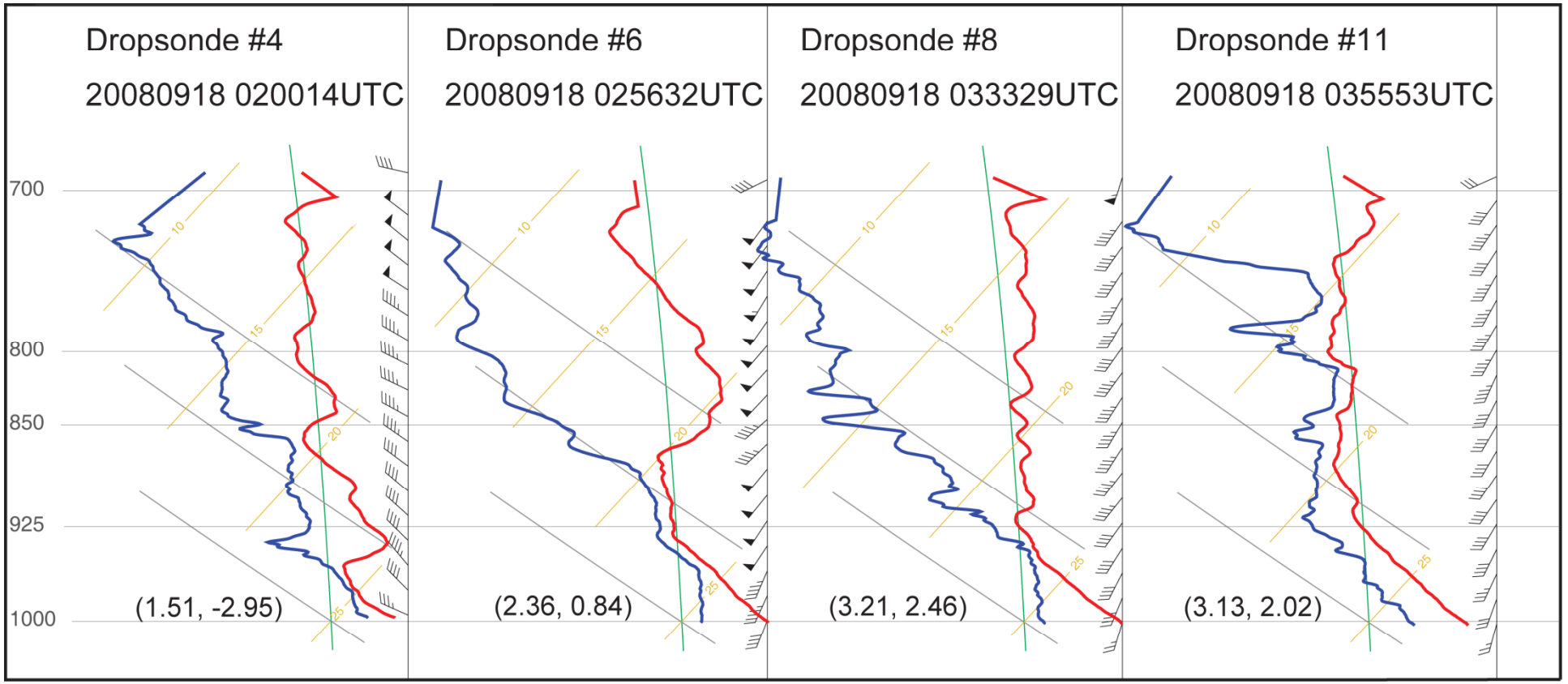
To investigate the effect of filamentation on convections in the TC environment, using high resolution winds retrieved from the NRL P-3 airborne radar in TCS08.

2008 Typhoon Sinlaku and NRL-P3 RF14 flight track



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



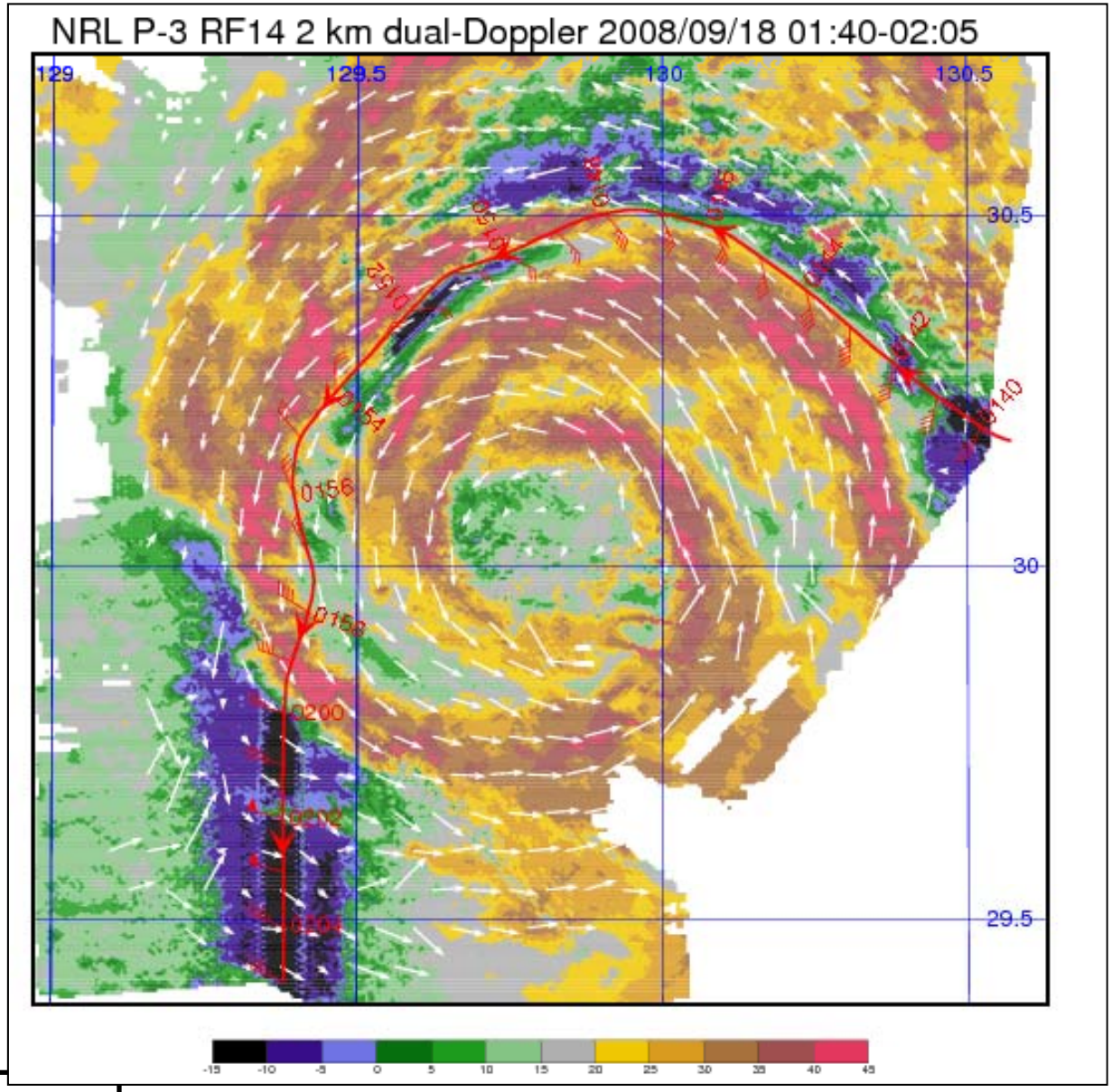


~150 km ~ 50 km ~ 25 km

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)

2km

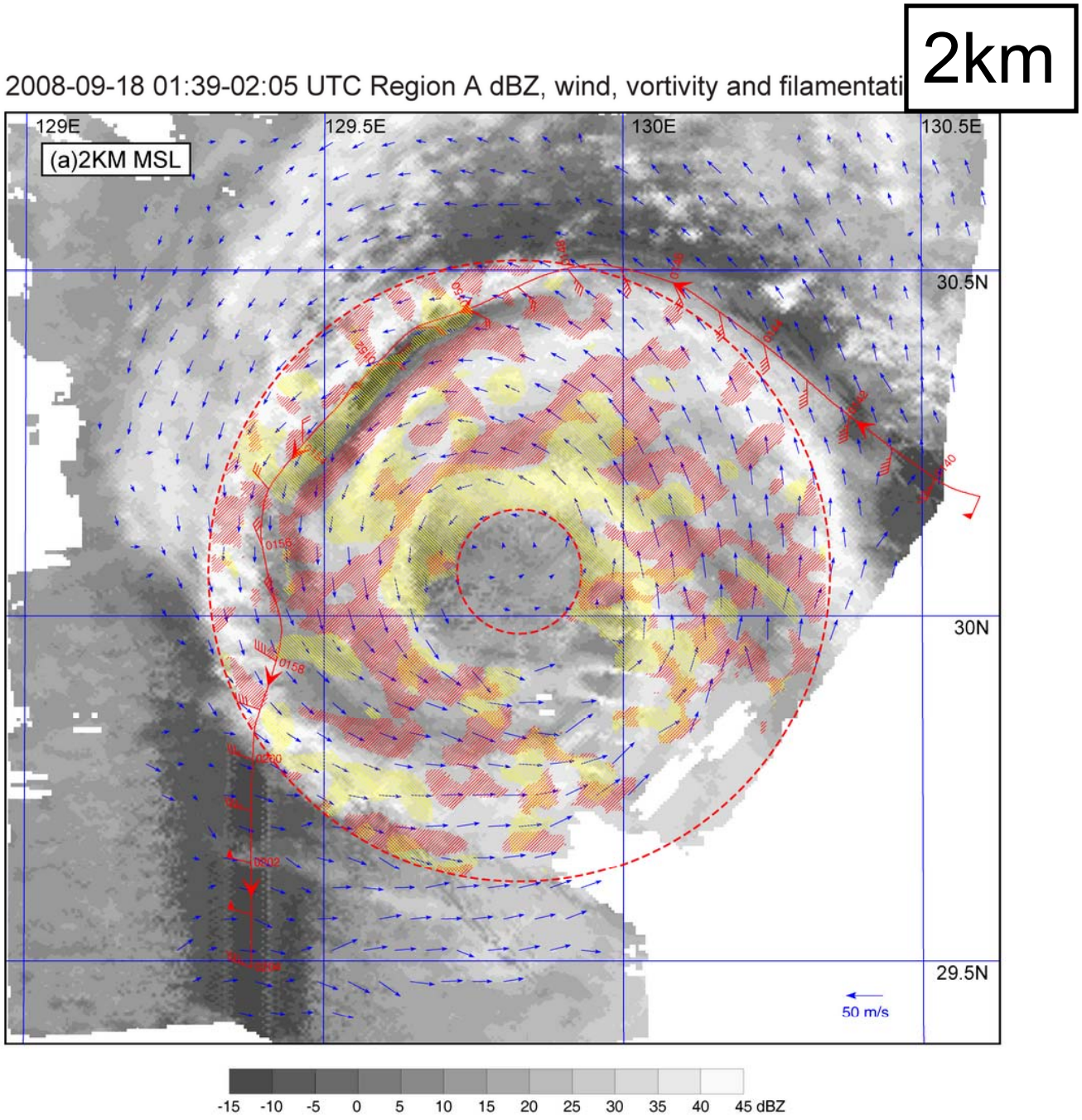


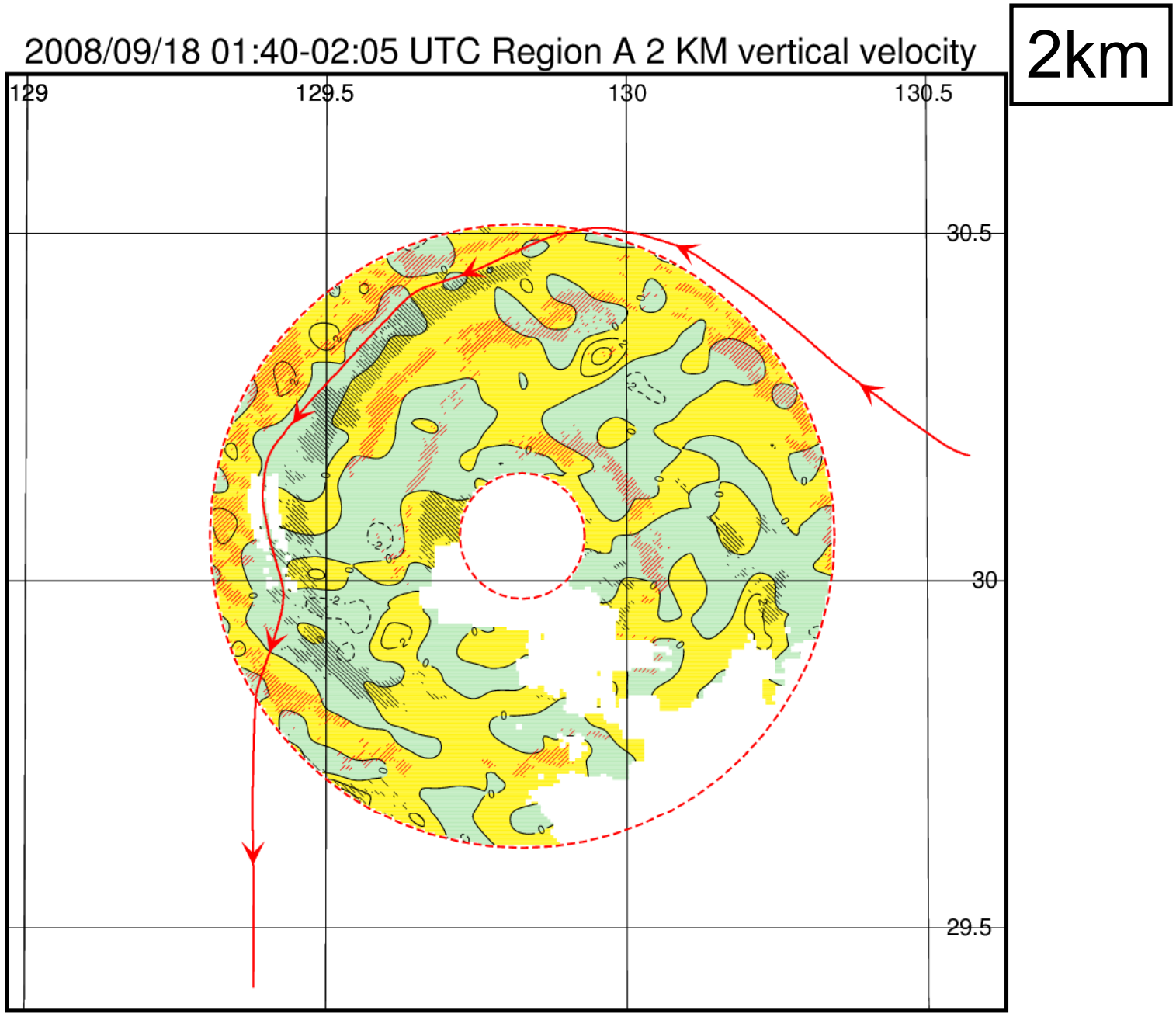
Translation speed
5.4m/s 60 deg

Red τ_{fil}< 25 min

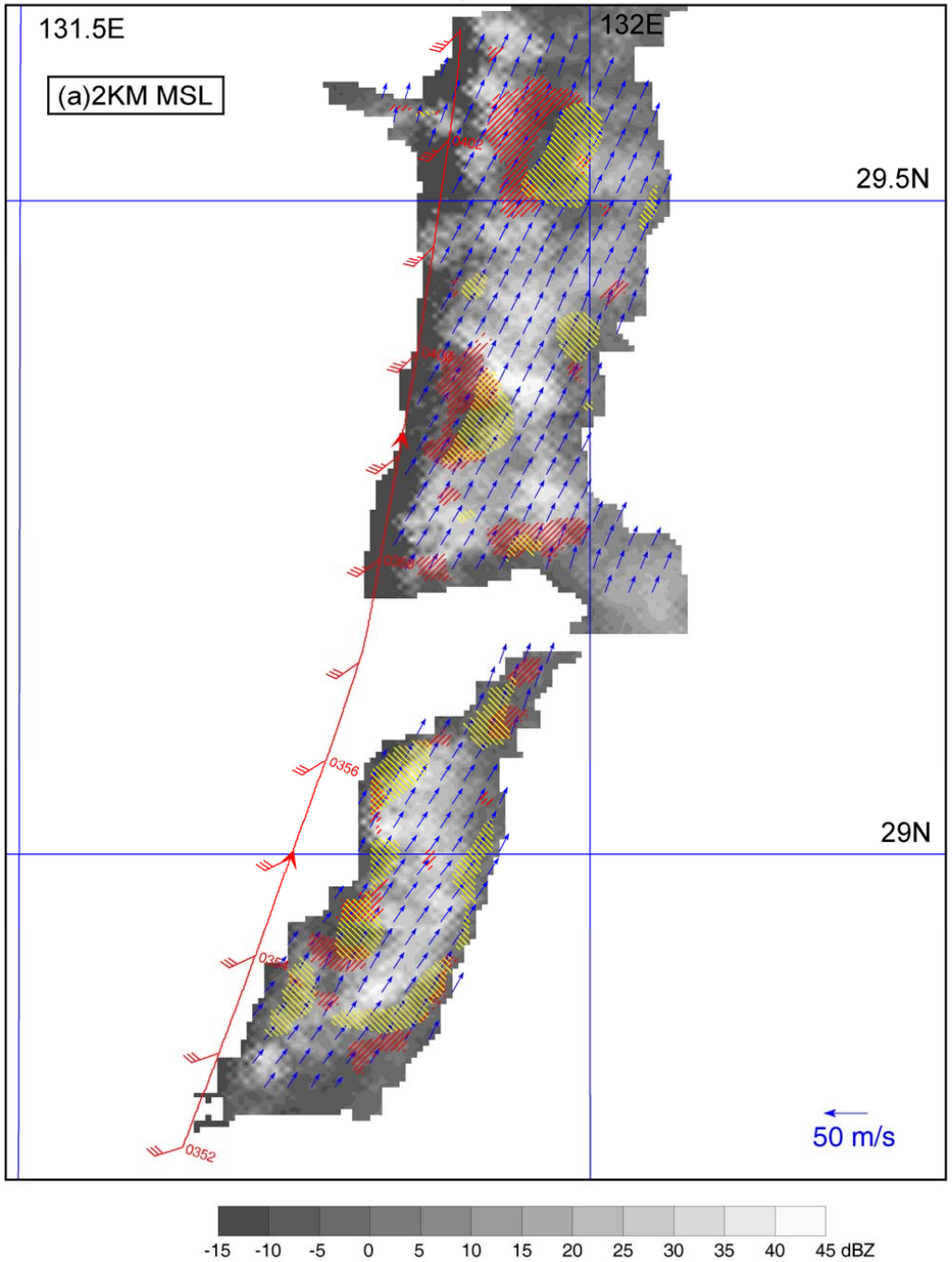
Yellow vorticity
> 10^-3 s-1

Circles are 10 km and 50 km




2008/09/18 01:40-02:05 UTC Region A 2 KM vertical velocity
2km
129
129.5
130
130.5
30.5
30
29.5

2008-09-18 03:52-04:03 UTC Region B
dBZ, wind, vortivity, and filamentation time

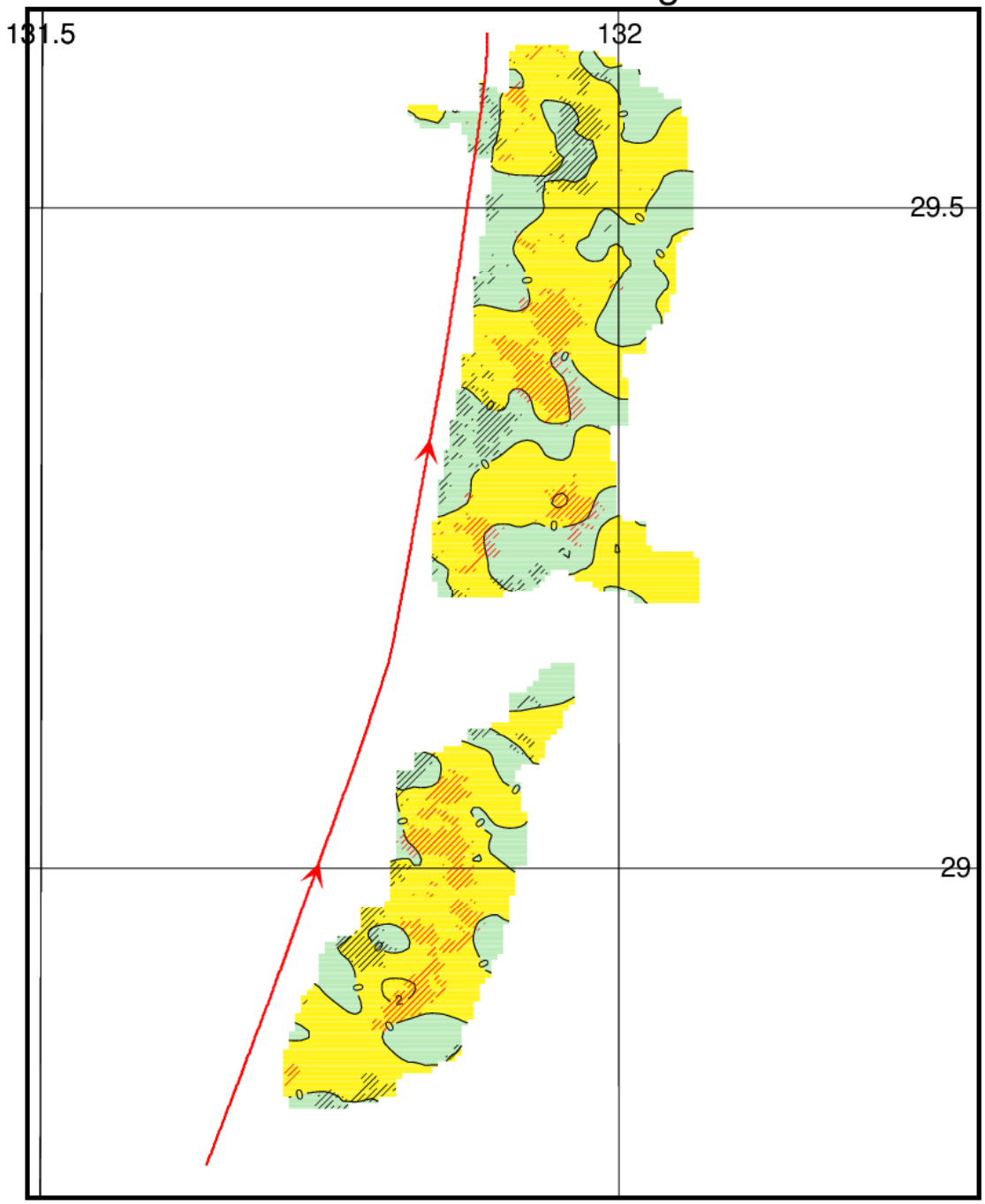


Red τ_{fil}< 25 min

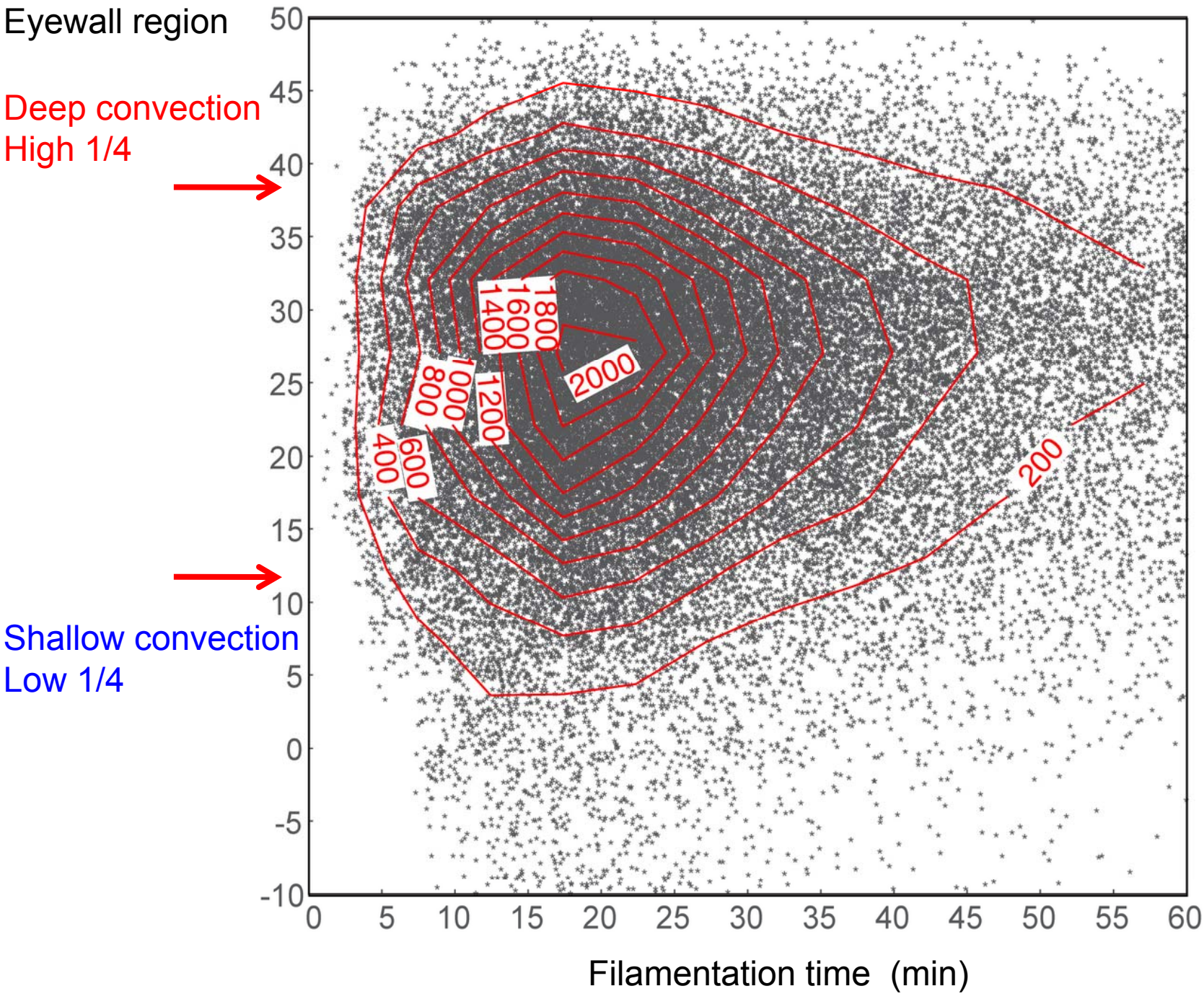
Yellow vorticity
> 10^-3 s-1

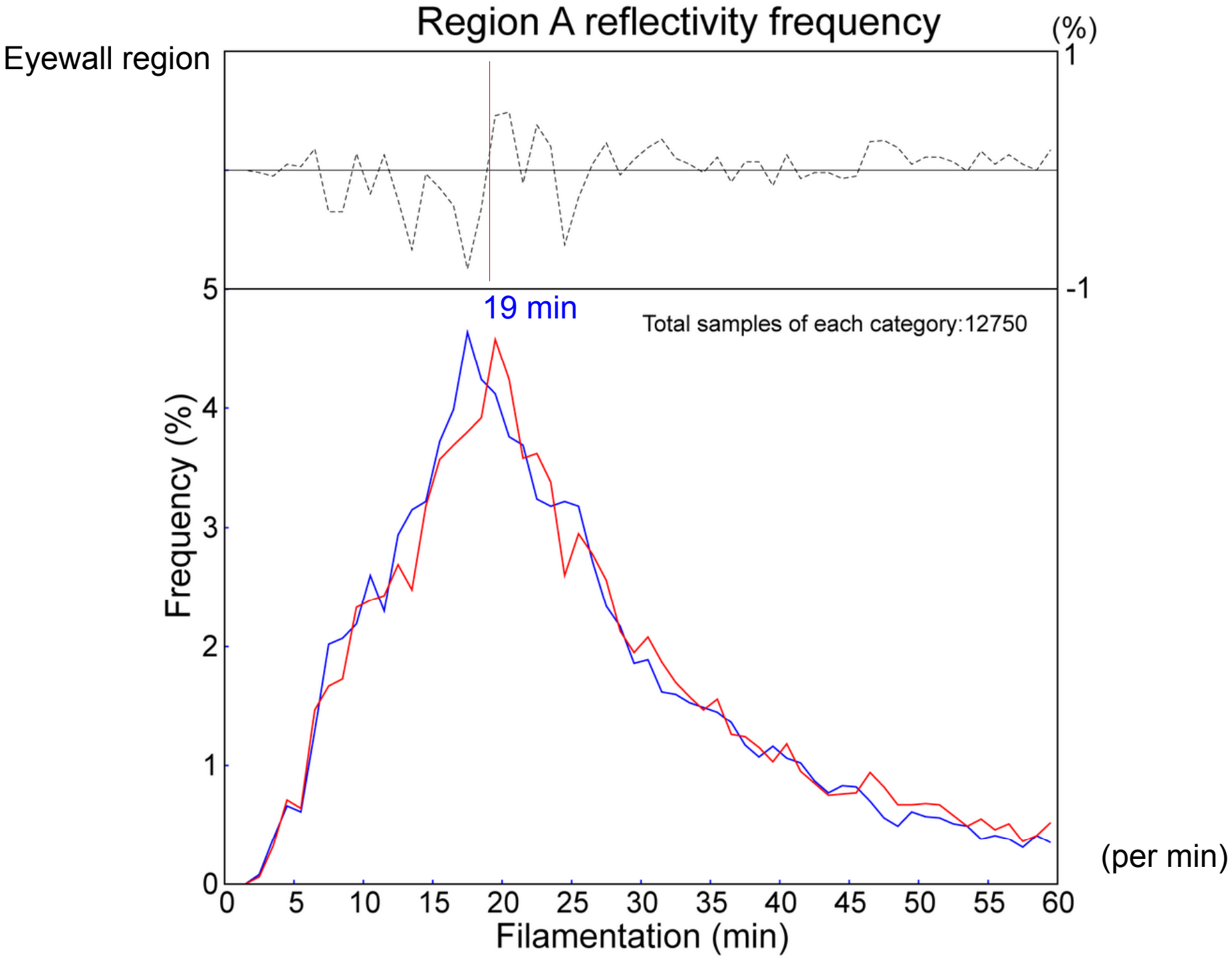
2km

2008/09/18 03:52-04:03 UTC Region B 2 KM W

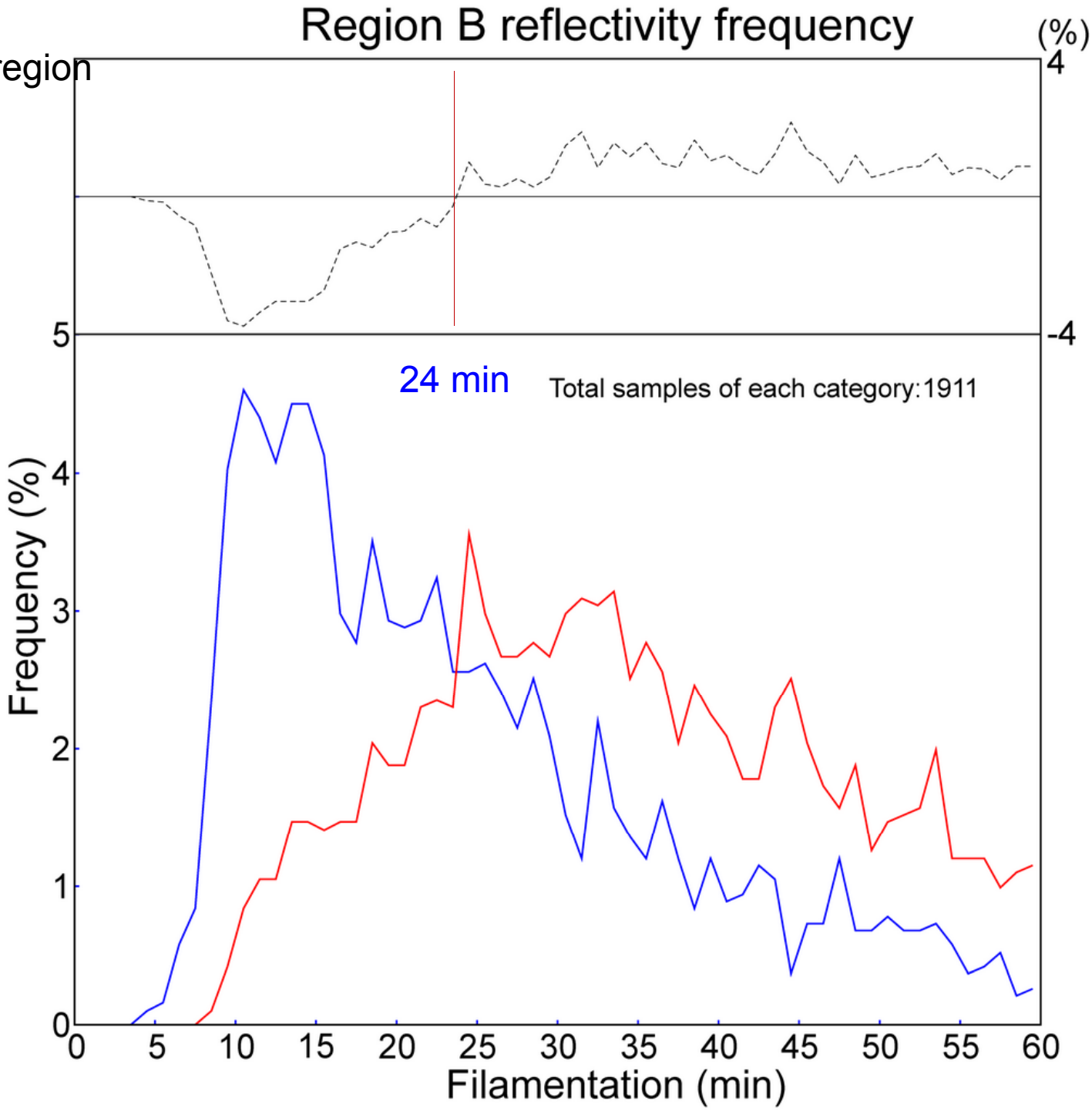


2km


Eyewall region
Deep convection
High 1/4
Shallow convection
Low 1/4
50
45
40
35
30
25
20
15
10
5
0
-5
-10
0
5
10
15
20
25
30
35
40
45
50
55
60
Filamentation time (min)
1800
1600
1400
2000
1000
800
1200
600
400
200

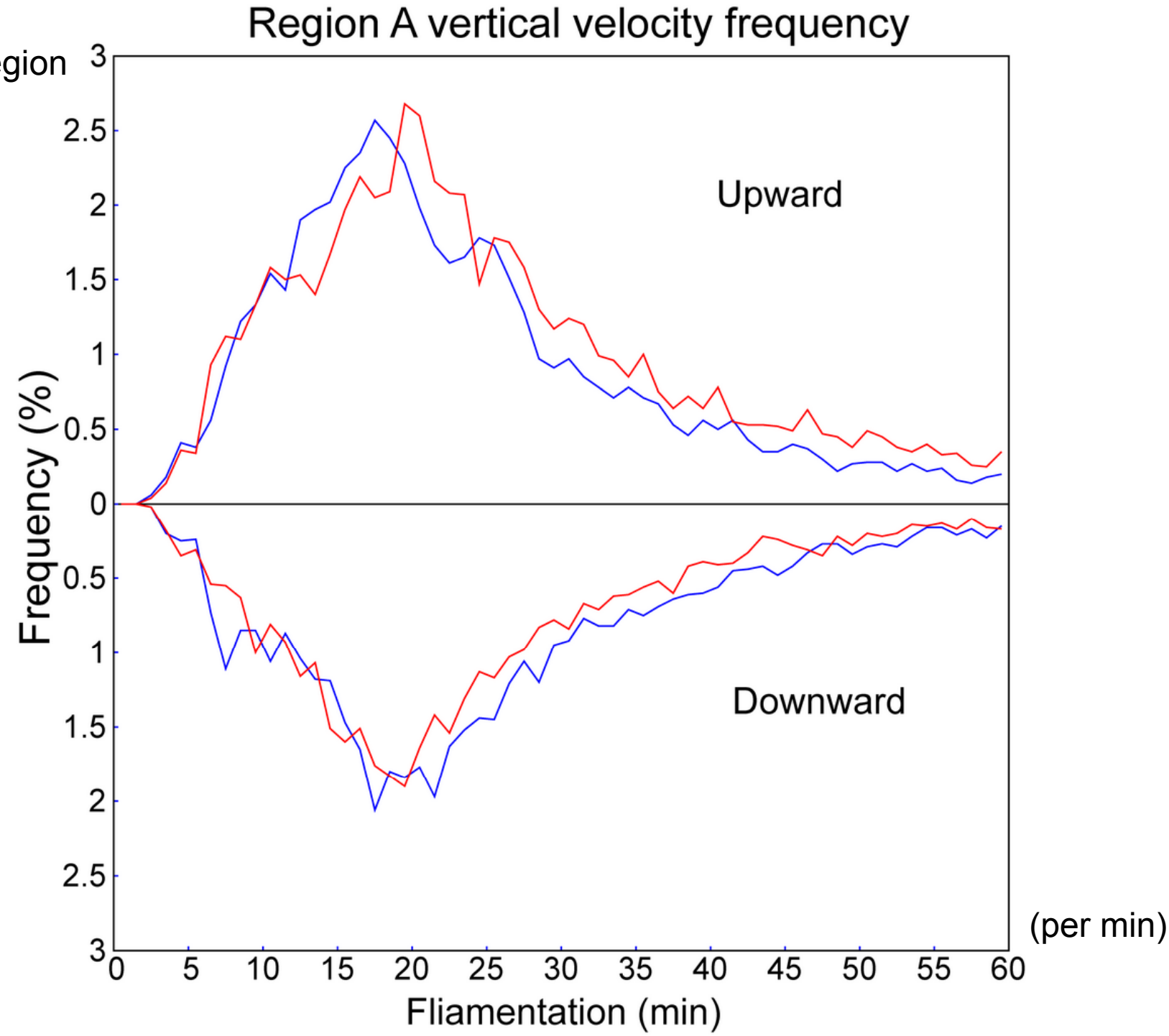

Eyewall region
Region A reflectivity frequency
(%)
1
-1
5
19 min
Total samples of each category:12750
Frequency (%)
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
50
55
60
Filamentation (min)
(per min)

Rainband region



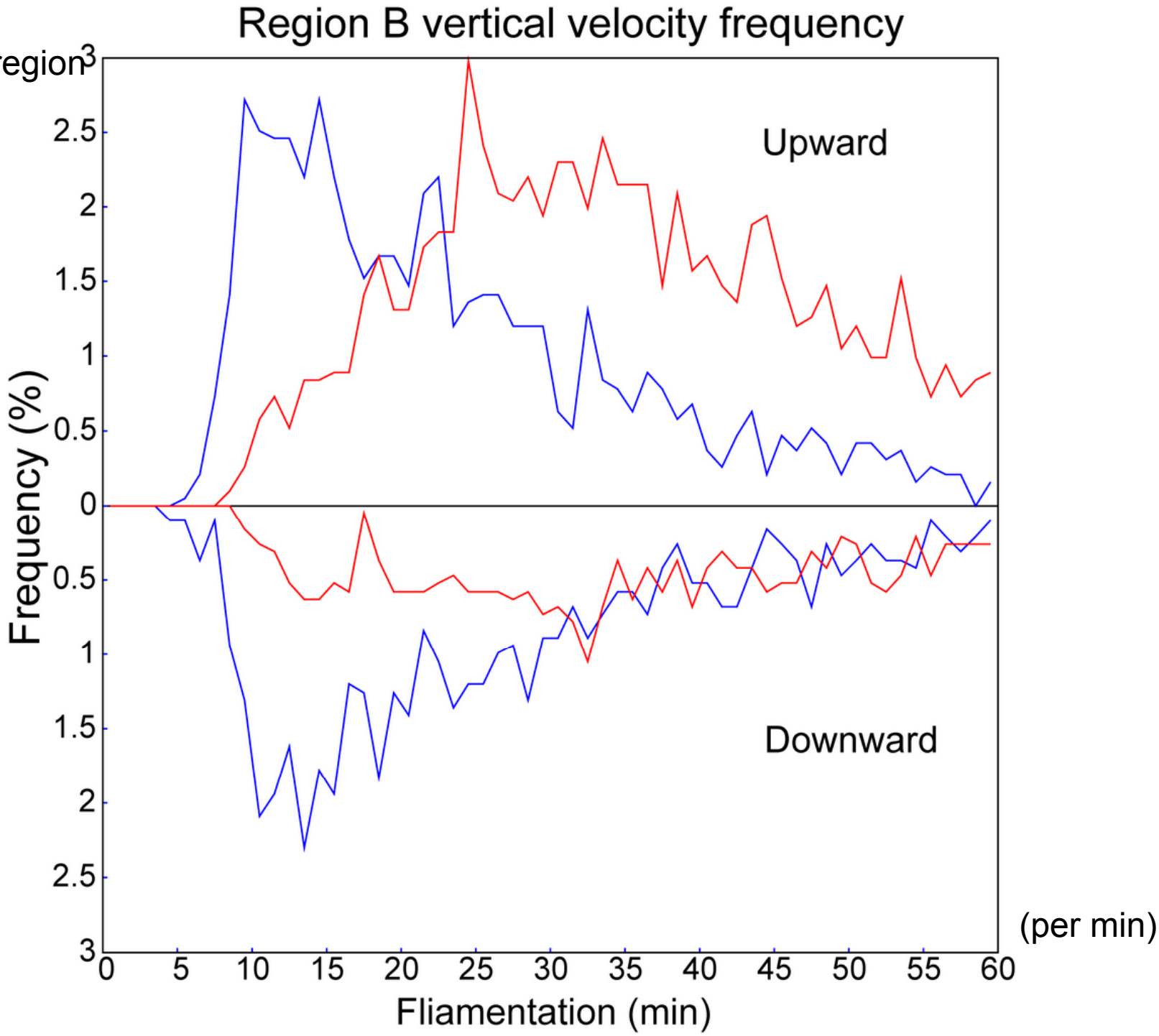
(per min)

Eyewall region



(per min)

Rainband region



(per min)

Summary (1)

•TCS08 made it possible to directly compute filamentation time at the convection scale during the re-intensification stage of Typhoon Sinlaku, allowing investigation into the effect of filamentation.

•Rapid Filamentation Zone (RFZ, τ_{fil} < 25 min) is found at low levels.

•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 spiral band about r = 200 km, filamentation and convective forcing are much weaker than in eyewall. Here deep convection is much more suppressed by filamentation such that the ratio of highest quarter/lowest quarter reflectivity is about 50% for T_{fil} < 24 min and 200% for T_{fil} > 24 min.

• Filamentation effects are important for the convection process in TC environment, and likely relevant to the organization of convection, asymetric structure, and moat formation. Since filamentation increases with increasing TC intensity, it plays a limitation role in convection particularly in the outer spiral cloud band region. Further research is planned.

Thank you!

A painting with vortices and filaments!