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Convection and Shear Flow in TC Development and Intensification

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LONG TERM GOALS

To study the dynamic processes of tropical cyclone (TC) development in the western North Pacific through field observational data and theoretical modeling.

OBJECTIVES

The objectives are: (1) to study the convection and vorticity generations in the vortex environment that may lead to the development and intensification of TC; (2) to study the development and evolution of deep moist mesoscale convective system subject to strain effect due to the horizontal shear associated with the vortex rotation; (3) to study the offsetting between (1) and (2); (4) to study nonlinear interactions that may lead to additional strain effects that may impact on the convection in ways that are not yet known.

APPROACH

TCS-08 offers a unique opportunity to collect high resolution data of kinematic and thermodynamic fields to determine the filamentation time, which is a function of total deformations and vorticity. The NRL P-3 aircraft with ELDORA airborne radar made it possible to directly compute the filamentation time at the convection scale, allowing an investigation into the effect of filamentation on the stratiform convection and cumulus convection from the Eldora radar data. The stratiform convection and cumulus convection is classified according to Steiner et al. (1995) with modifications that account for the

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difference between different types of radars. We have concentrated our effort for TCS025 (a non-developing case), Typhoon Hagupit (2008) in the pre-tropical storm (TS) stage, Typhoon Jangmi (2008) and Typhoon Nuri (2008) in the TS stage, and Typhoon Sinlaku (2008) in the re-intensifying stage.

RESULTS

Our effort this year was to better understand the filamentation dynamics on different types of the convection in the pre-TS and TS stages and in a re-intensifying stage of typhoon.

The report of filamentation dynamics in the re-intensification stage of Typhoon Sinlaku (2008) the previous year has been revised to classify the reflectivity into the convective and stratiform regimes. The paper has been accepted for publication in the Monthly Weather Review this year. The results suggest that filamentation effects may be important for the deep convective process in the TC environment, and likely relevant to the organization of asymmetric structure and spiral bands. Since filamentation increases with increasing TC intensity, it may play a role in limiting convection particularly in the outer spiral cloud band region.

In this year we examined the filamentation effect on the deep convection and stratiform convection in different stages of TC and also a non-developing case TCS025. Figure 1 shows the visible satellite image for (a) TCS025 on 28 Aug. 2008, (b) Typhoon Hagupit on 15 Sep. 2008, (c) Typhoon Jangmi on 25 Sep. 2008, and (d) Typhoon Nuri on 18 Aug. 2008, respectively. The NRL P-3 flight tracks (red) and the domain for dual-Doppler analysis (blue boxes) are superimposed. The TCS025 is a non-developing case, Typhoon Hagupit on 15 Sep. 2008 is in pre-TS stage, Typhoon Jangmi on 25 Sep. 2008 and Typhoon Typhoon Nuri on 18 Aug. 2008 are in TS stage. Figure 2 is the NRL P-3 Eldora radar reflectivity at 3km level for the cases illustrated in Fig. 1.

Figure 3 is the same as Fig. 2 but for dual-Doppler winds, deep convection zone, vorticity dominate zone (VDZ) and rapid filamentation zone (RFZ). The RFZ is with filamentation times < 40 minutes. The RFZs are hatched in yellow, convective area are shaded in light grey with red outlines, and VDZs are shaded in light green. The black line is the P-3 flight track and the arrow heads indicate the aircraft heading direction. Figure 3 suggests that RFZ is larger in the TS stage (Fig. 3c and Fig. 3d) than in the pre-TS stage (Fig. 3b). The non-developing case (Fig. 3a), with some rotational wind and VDZ, is with insignificant RFZ.

Figure 4 shows the frequency distribution of the filamentation time (minute) for cumulus convection (strong convection) and stratiform convection (in general weak convection) between 2 km and 4 km heights for the cases illustrated in Fig. 1. Figure 4 suggests that there is more convective and stratiform convections occurred in the RFZ as the TC gets stronger. This is expected from the fact that the filamentation increases with increasing TC intensity. In the non-developing case TCS025 and in the pre-TS stage of Typhoon Hagupit, approximately 2/3 of the convective and stratiform convections occurred outside the RFZ. On the other hand, the rainbands in Typhoon Jangmi 2008 (Fig. 4c) and Typhoon Nuri 2008 (Fig. 4d) were suppressed by the vortex strain effect. The effect may be small but still systematic and conspicuous. The demarcation occurs at filamentation time ~ 35 min.

IMPACT

Our results offer information on the mechanisms governing convection in the early stage of a TC, and suggest that filamentation effects may be important for the deep convective process when TC is in the TS stage or stronger. Since filamentation increases with increasing TC intensity, it may play a role in limiting convection particularly in the outer spiral cloud band region. This information can be helpful in evaluating the maximum intensity of a TC.

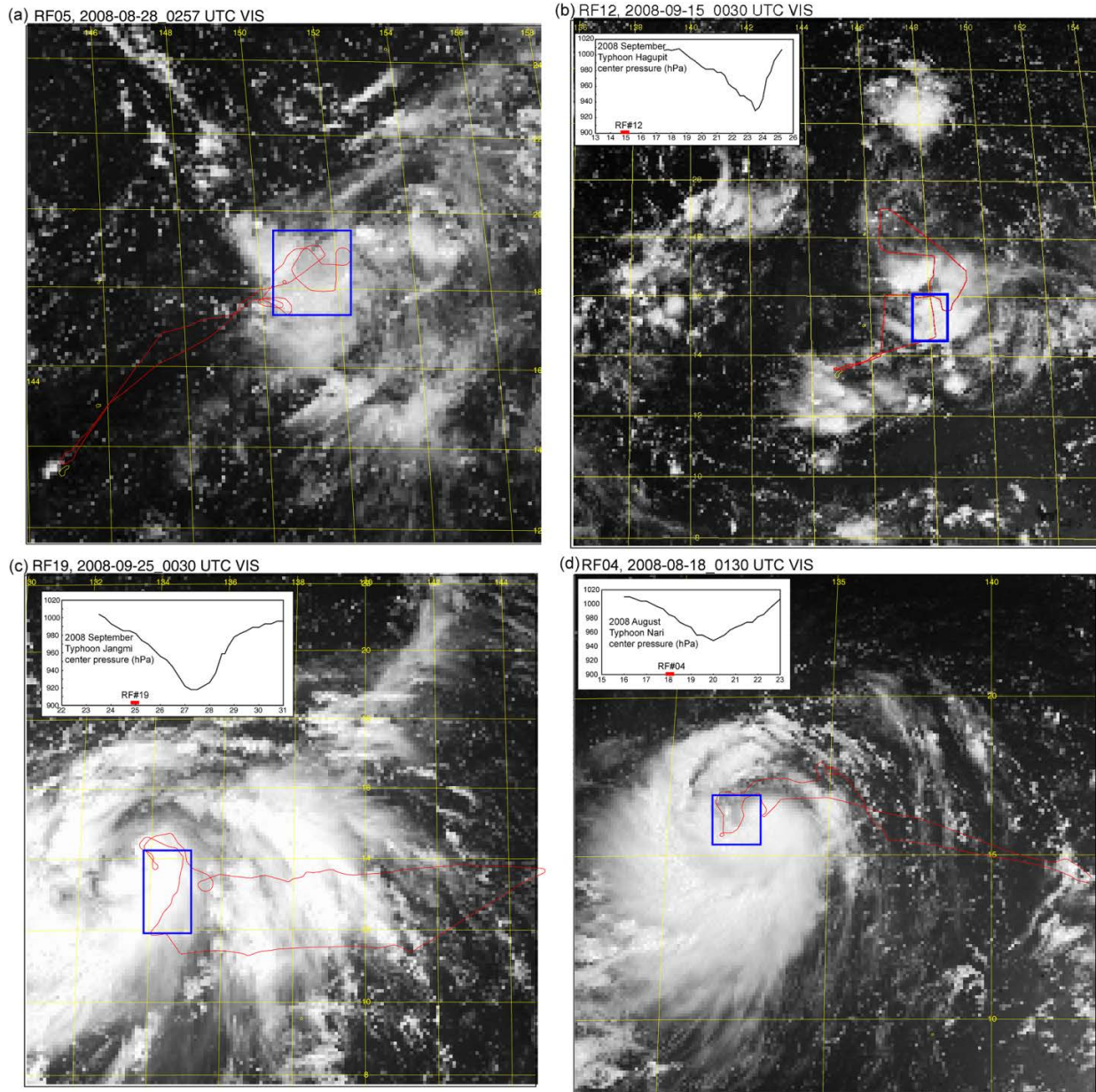


Fig 1: The NRL P-3 flight tracks (red) superimposed on visible satellite image for (a) TCS025 on 28 Aug. 2008, (b) Typhoon Hagupit on 15 Sep. 2008, (c) Typhoon Jangmi on 25 Sep. 2008, and (d) Typhoon Nuri on 18 Aug. 2008, respectively. The blue boxes indicate the domain for dual-Doppler analysis. The upper left panels on (b), (c), and (d) are center pressure for corresponded typhoons. The TCS025 is a non-developing case, Typhoon Hagupit is in pre-TS stage, while Typhoons Jangmi and Nuri are in TS stage.

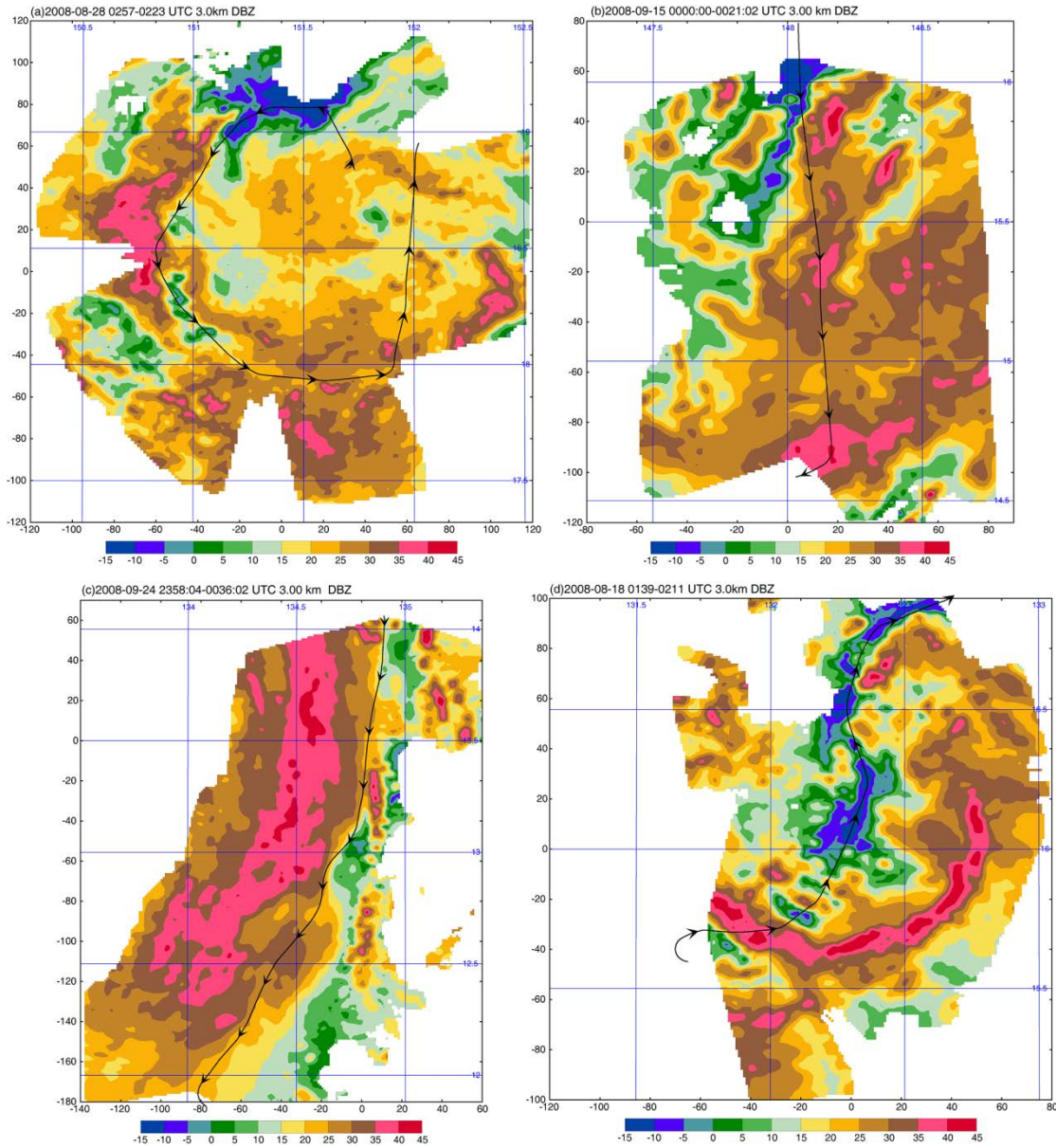


Fig 2: The NRL P-3 Eldora radar reflectivity at 3km level for (a) TCS025 at 0257-0223UTC on 28 Aug. 2008, (b) Typhoon Hauptit at 0000-0021 on 15 Sep. 2008, (c) Typhoon Jangmi at 2358-0036 on 24 Sep. 2008, and (d) Typhoon Nuri at 0139-0211 on 18 Aug. 2008, respectively. The black line is the P-3 flight track and the arrow heads indicate the aircraft heading direction. The color tables are shown in the bottom of each panel.

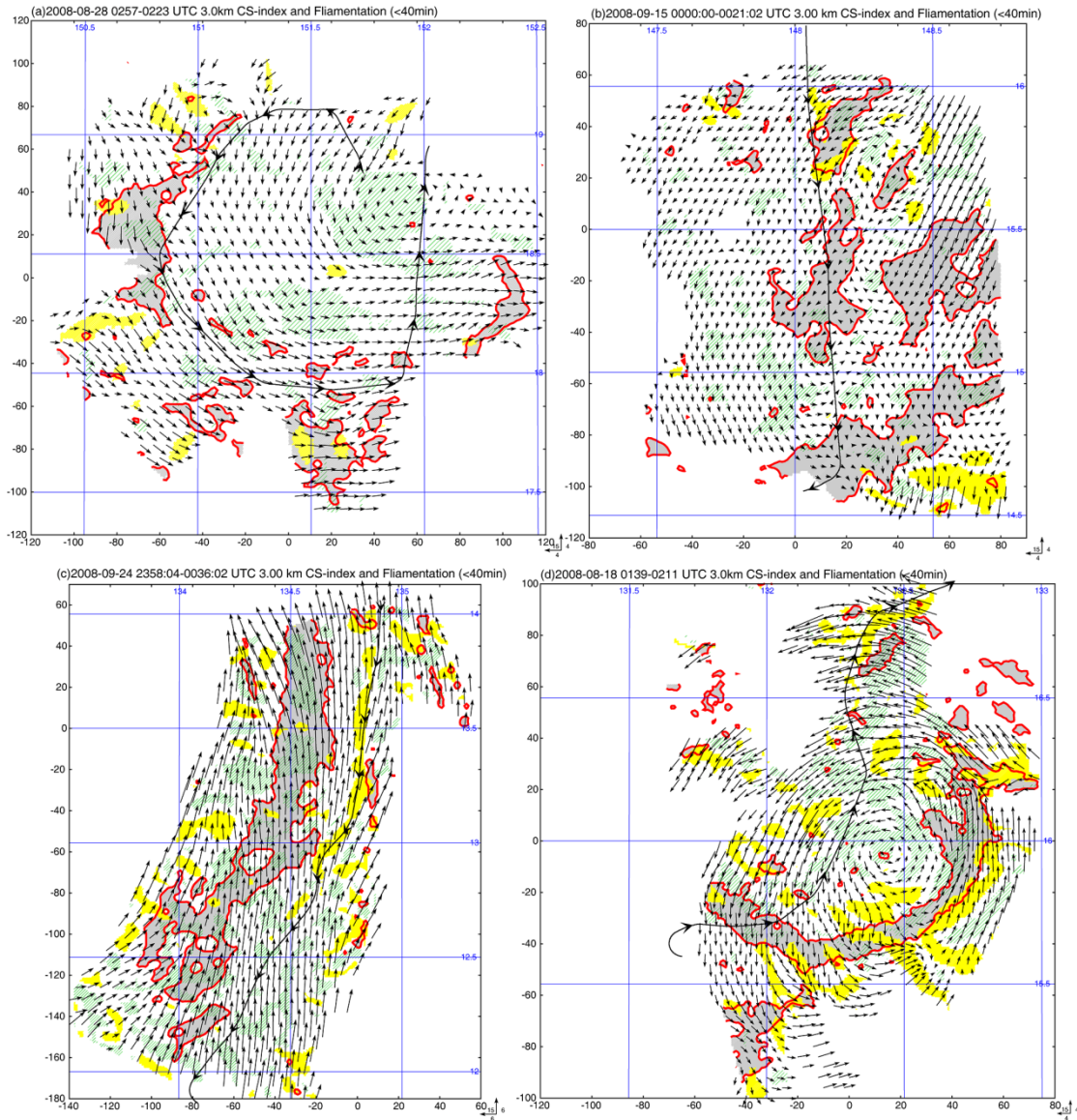


Fig 3: Same as Fig. 2 but for dual-Doppler winds, deep convection zone, vorticity dominate zone (VDZ) and rapid filamentation zone (RFZ). The RFZ is with filamentation times < 40 minutes. The RFZs are hatched in yellow, convective area are shaded in light grey with red outlines, and VDZs are shaded in light green. The black line is the P-3 flight track and the arrow heads indicate the aircraft heading direction. The scale for the wind vector is shown in the bottom right of each panel. The wind vector shown is 4 m s^{-1} except Fig. 3c is with 6 m s^{-1} .

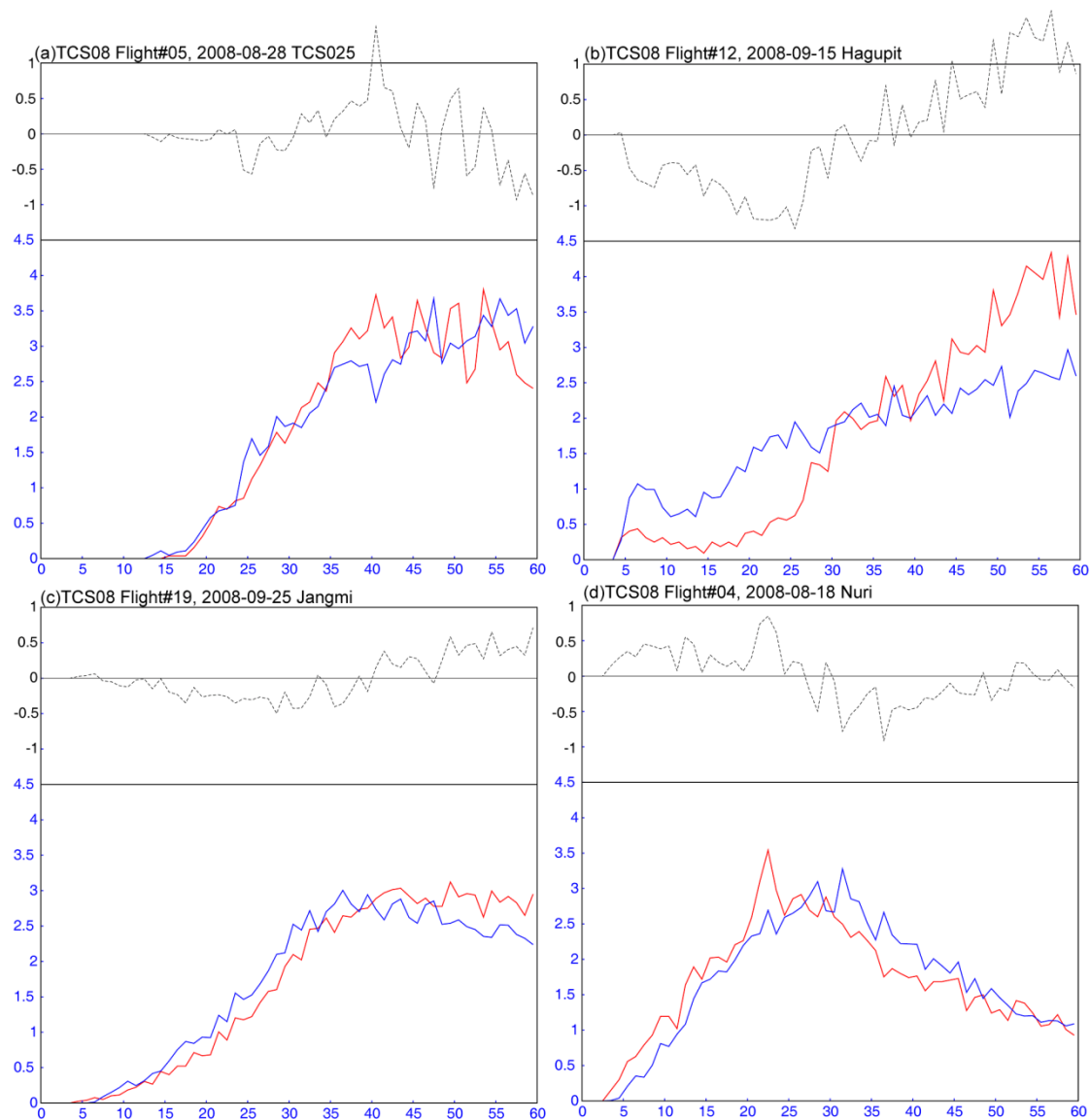


Fig 4: Same as Fig. 2 but for the frequency distribution of filamentation time (minute) for the convective (red) and stratiform (blue) reflectivity near the eye core region between 2 km and 4 km heights. The dashed line in the upper panel is the difference between the two. The unit is the same as the lower panel but the scale is shown at the upper right of the frame.

RELATED PROJECTS

TCS08 projects led by Professors Russ Elsberry, Pat Harr and Michael Montgomery at NPS.

SUMMARY

In this year TCS-08 P3 radar data were used to identify the cumulus/stratiform convections and to compute the filamentation time scale in the case of TCS025 which did not develop into a typhoon despite of initial promising conditions, and three cases that did develop: Typhoon Hagupit 2008,

Typhoon Jiangmi 2008, and Typhoon Nuri 2008. In all four cases the results confirm that the impact of filamentation process on the convections increases with the TC intensity.

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