Aircraft Wake Vortex Recognition and Classification Based on Coherent Doppler Lidar and Convolutional Neural Networks

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[09].[Atmospheric temperature, water vapor, wind, turbulence, and waves]

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☐ Introduction of Wake vortex

Fig. 1. Pictures of aircraft wake vortices.

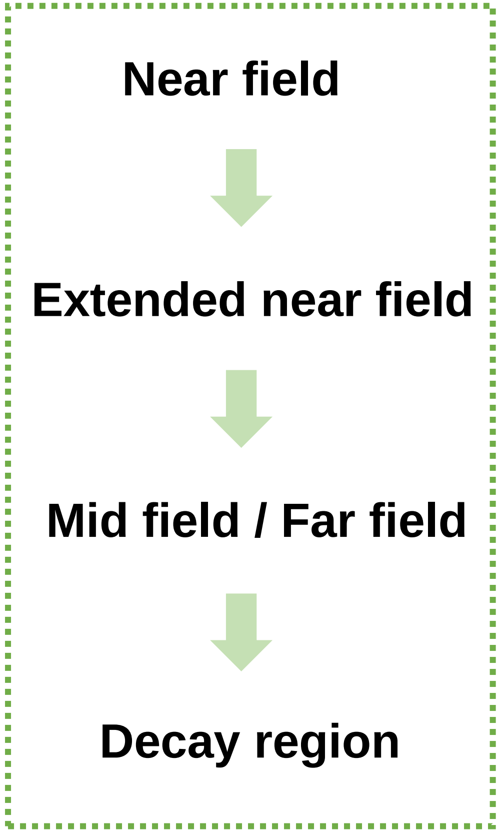

Fig. 2. Evolution process of aircraft wake vortex.

- Aircraft wake vortex is **a pair of vortex structures**, generated by **the lift force** exerted on the wings of aircraft, producing **potential hazards** to the following aircraft, especially during the **landing and take-off** phases.
- The **coherent Doppler lidar** is one of the means stipulated by the International Civil Aviation Organization to detect wake vortices.
- The traditional algorithm of wake vortex inversion is prone to interference, resulting in **low recognition accuracy**, which is time-consuming and cannot meet the requirements of **real-time recognition**.

☐ Information of Experiments

- **Observation Equipment**:

  Pulsed Coherent Doppler Lidar (PCDL)

- **Observation Site**:

  Qingdao Liuting International Airport (QLIA)

- **Observation Object**:

  Aircraft Wake Vortex (WV)

- **Scanning Strategy**:

  Range-Height-Indicator (RHI)

- **Observation Time Period**:

  From November 2019 to June 2020

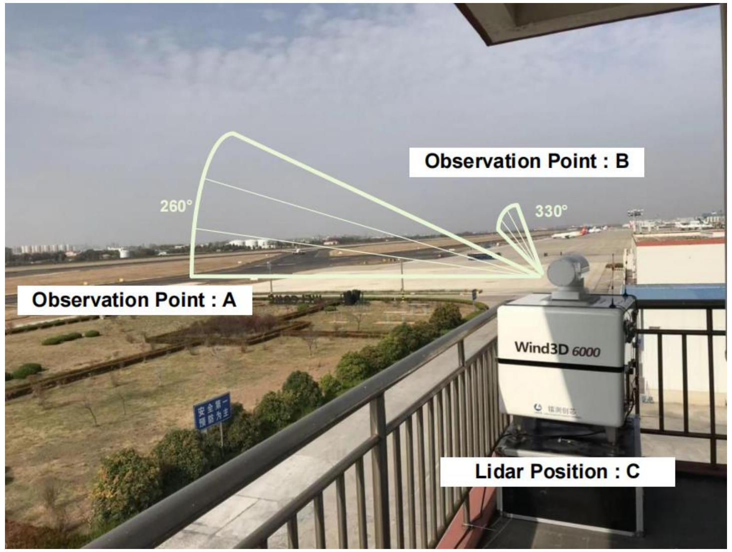

Fig. 3. A sketch map **(a)** and the Lidar location and scanning mode **(b)** of wake vortex observation experiments at QLIA.

Table 1. Parameters of the PCDL RHI scanning strategy during the experiments at QLIA.

Parameter	Specification	
	South wind	North wind
Scanning speed	1° /s ~ 2° /s	1° /s ~ 2° /s
Azimuth angle	260°	320° /330° /340°
Elevation angle range	2° ~ 35°	2° ~ 35°
Elevation angle resolution	0.1° ~ 0.4°	0.1° ~ 0.4°
Scanning duration	10 s ~ 20 s	10 s ~ 20 s

☐ Convolutional Neural Networks

The main data process flow chart of aircraft wake vortex (WV) recognition and classification is illustrated in the figure below, which consists of four parts and is composed of **Convolutional Neural Networks (CNN)**.

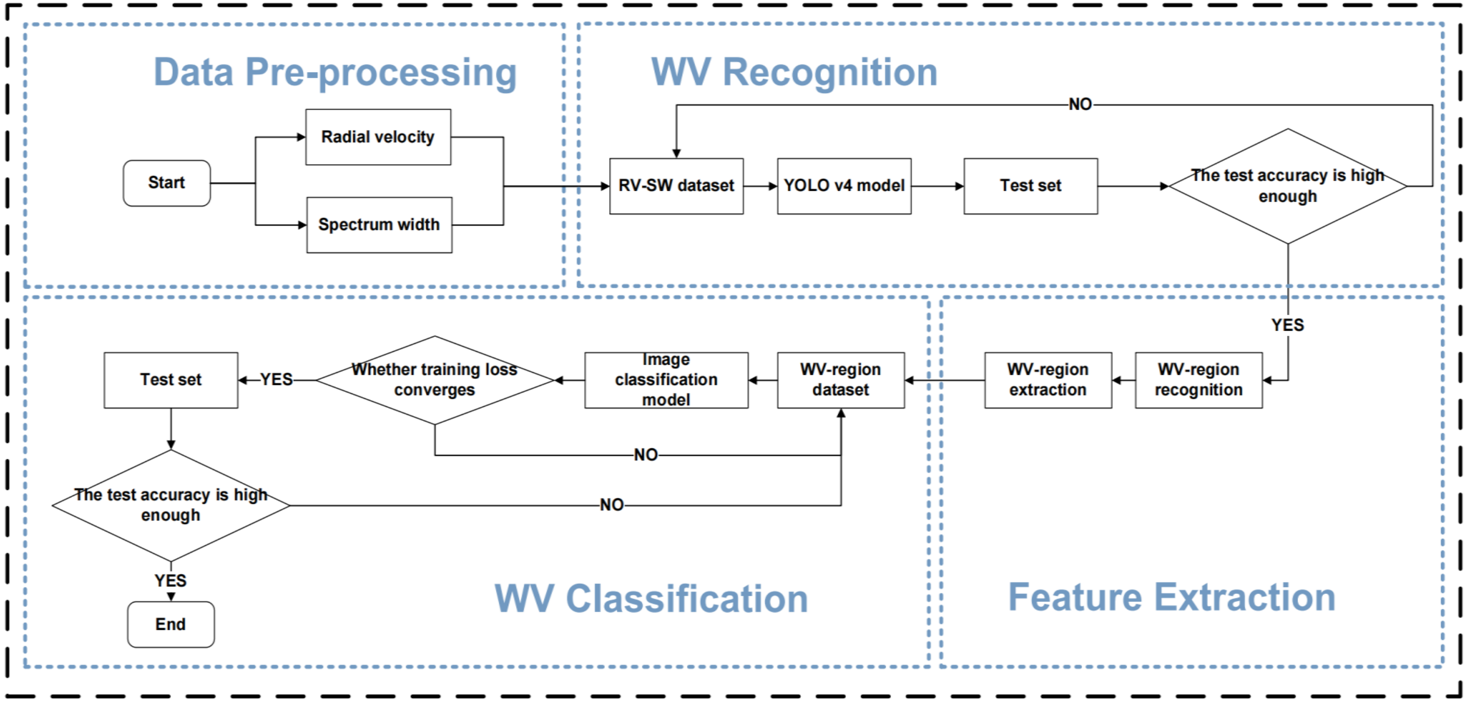

Fig. 4. Flow chart of the main methodology of aircraft wake vortex recognition and classification.

- **Data Pre-processing**

  builds the RV-SW data set for the object detection model.

- **WV Recognition**

  identifies the possible positions of wake vortices.

- **Feature Extraction**

  builds the WV-region data set for the image classification model.

- **WV Classification**

  divides the WV-region data set into different categories.

□ Establishment of Data Set

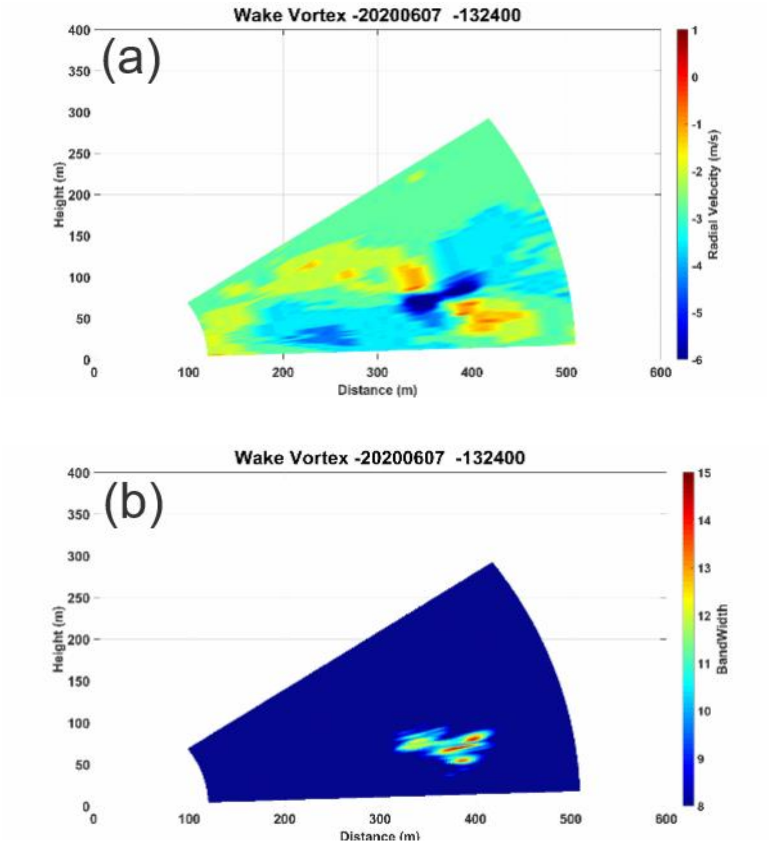

Fig. 5. Radial Velocity (RV) image **(a)** and Spectrum Width (SW) image **(b)** of wake vortex.

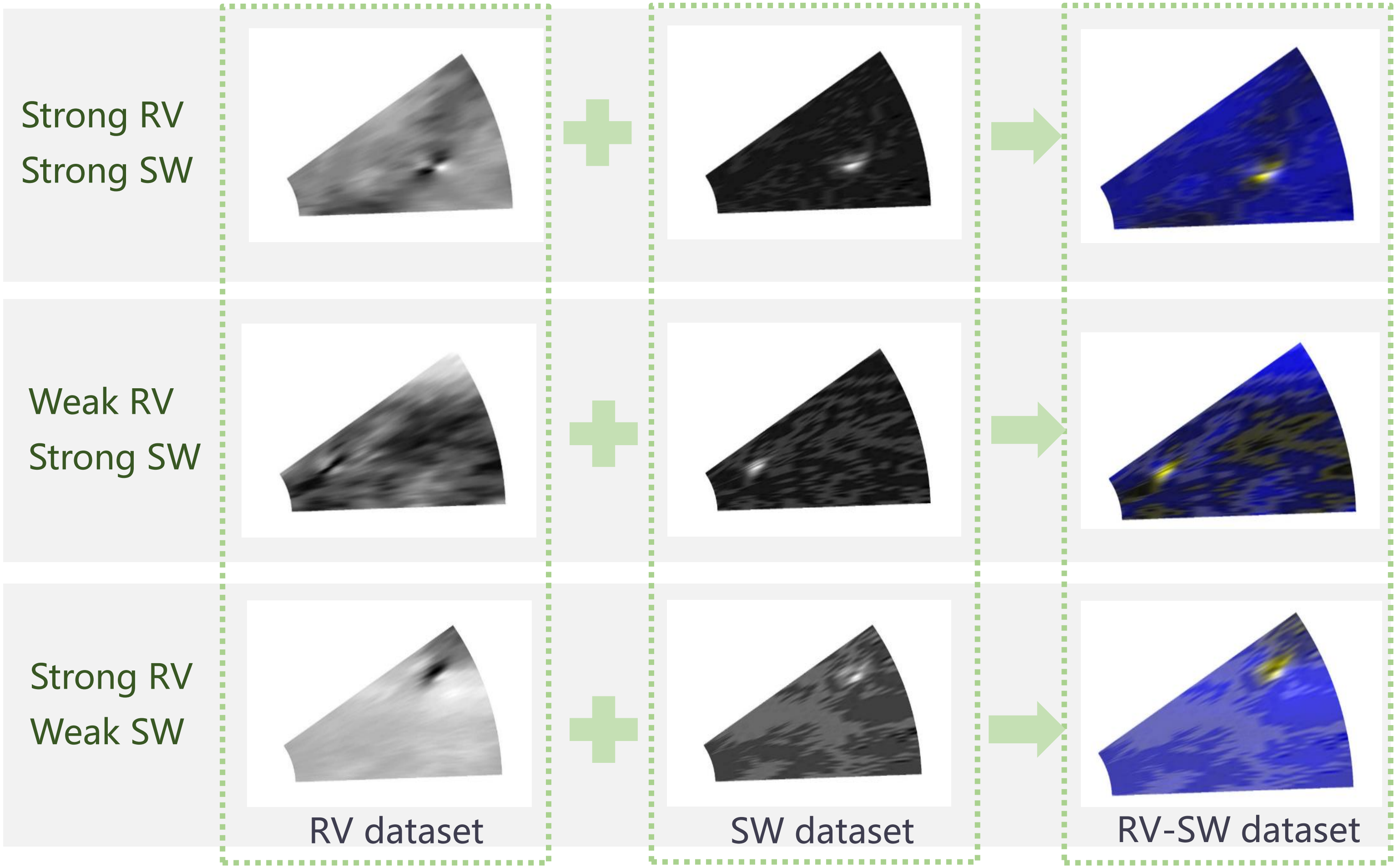

Fig. 6. Different cases of radial velocity and spectrum width to build the data set .

☐ Test Results of WV Models

The accuracy of test results of the trained WV recognition model reached **95.57%**, the accuracy of test results of WV classification model reached **92.26%**, in which the test accuracy of the Disturbance category was the highest.

The results indicate that these models can be utilized for wake vortex recognition and classification effectively based on PCDL data in different wake vortex evolution phases and atmospheric conditions.

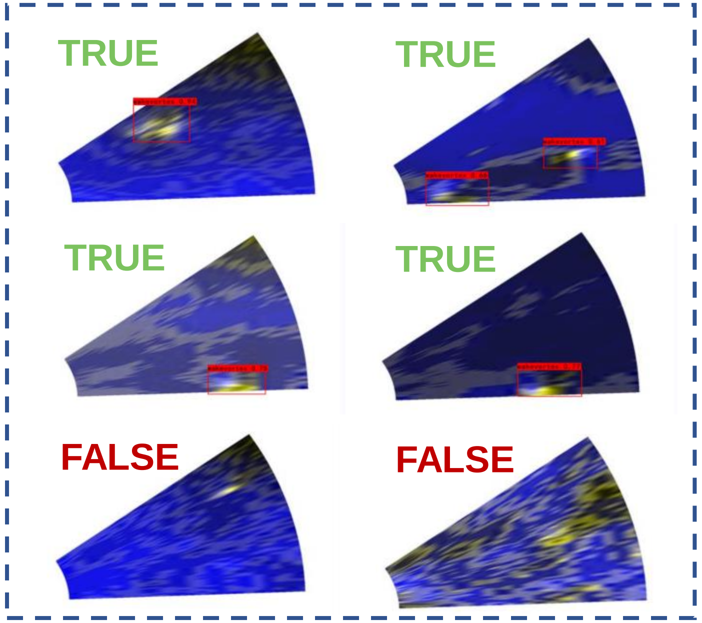

Fig. 7. Test results of WV recognition model.

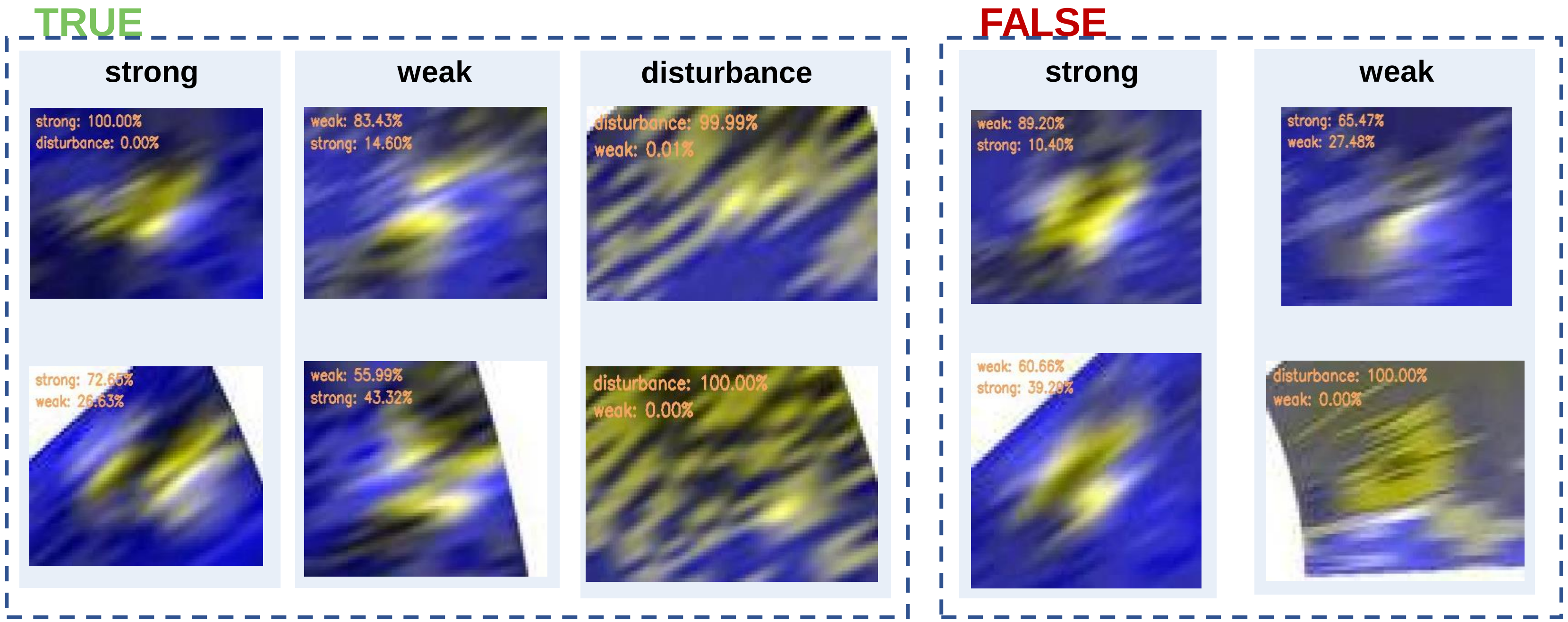

Fig. 8. Test results of WV classification model.