



Observation, analysis, and numerical simulation of a low-level wind shear case at Beijing Daxing International Airport

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सार – इस शोध-पत्र में बीजिंग डैक्सिंग अंतरराष्ट्रीय हवाई अड्डे पर प्रेक्षित निम्न-स्तरीय पवन अपकर्षण (Low-level Wind Shear) की एक घटना का अध्ययन किया गया है। यह पवन अपकर्षण उत्तरी चीन के ऊपर वायुप्रवाह के प्रतिरूप में समष्टि-पैमाने (synoptic scale) एवं मध्य-पैमाने (mesoscale) पर होने वाले परिवर्तनों से संबंधित है। हवाई अड्डे पर डॉप्लर लिडार (Doppler LIDAR) द्वारा इस पवन अपकर्षण का प्रभावी ढंग से संसूचन किया गया तथा समय पर चेतावनियाँ जारी की गईं। वर्तमान अध्ययन में कई घंटे के अग्रिम समय के साथ उच्च-रिज़ॉल्यूशन संख्यात्मक मौसम पूर्वानुमान मॉडल का उपयोग करके पवन अपकर्षण की इस विशेषता के पूर्वानुमान की तकनीकी व्यवहार्यता का परीक्षण किया गया है। मॉडल द्वारा पवन अपकर्षण की विशेषता का संतोषजनक पुनरुत्पादन किया गया तथा यह वास्तविक प्रेक्षणों के साथ सामान्यतः सुसंगत पाया गया। वास्तविक लिडार आँकड़ों की तुलना में अनुकरण किए गए रेडियल वेग की मूल माध्य वर्ग त्रुटि (Root Mean Square Error–RMSE) लगभग 2.99 m/s रही, जिसे स्वीकार्य माना गया है। अध्ययन के परिणाम निम्न-स्तरीय पवन अपकर्षण की घटना के पूर्वानुमान की तकनीकी व्यवहार्यता को प्रदर्शित करते हैं, जिससे विमानन सुरक्षा सुनिश्चित करने में सहायता मिल सकती है।

ABSTRACT. The present paper studies a case of low-level wind shear as observed at Beijing Daxing International Airport. The shear is related to the synoptic scale/mesoscale changes in the airflow pattern over northern China. It was captured well by the Doppler LIDAR at the airport, and there were timely alerts of the shear. The present study considers the technical feasibility of forecasting the shear feature using a high-resolution numerical weather prediction model with a lead time of several hours. The shear feature is reasonably well reproduced and is generally consistent with the actual observations. Compared to the actual LIDAR data, the root-mean-square-error of the simulated radial velocity is around 2.99 m/s, which is considered to be acceptable. The study result demonstrates the technical feasibility of forecasting the occurrence of low level windshear, which would help safeguard aviation safety.

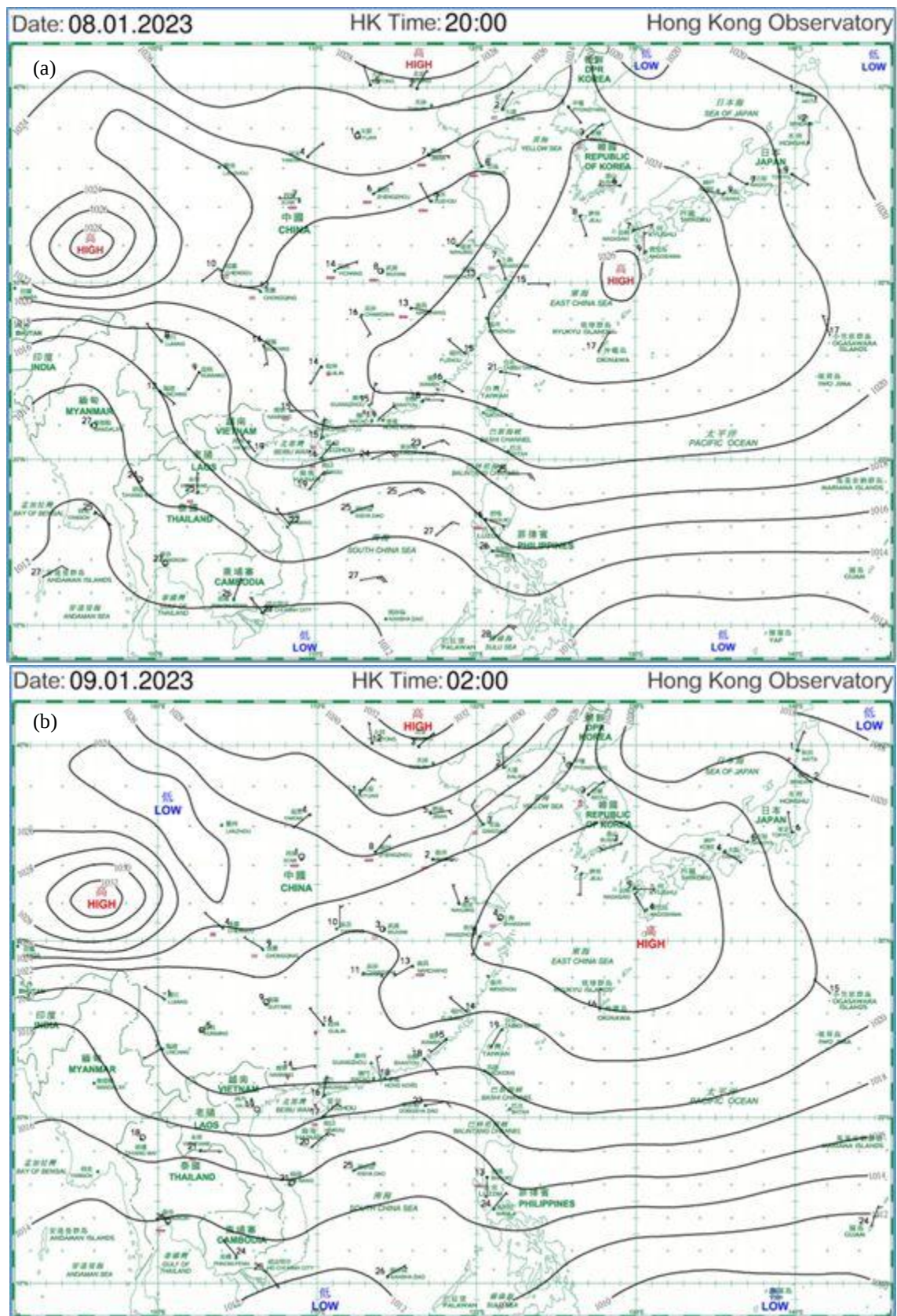
Key words – LIDAR, wind shear, numerical weather prediction, turbulence parameterization scheme.

1. Introduction

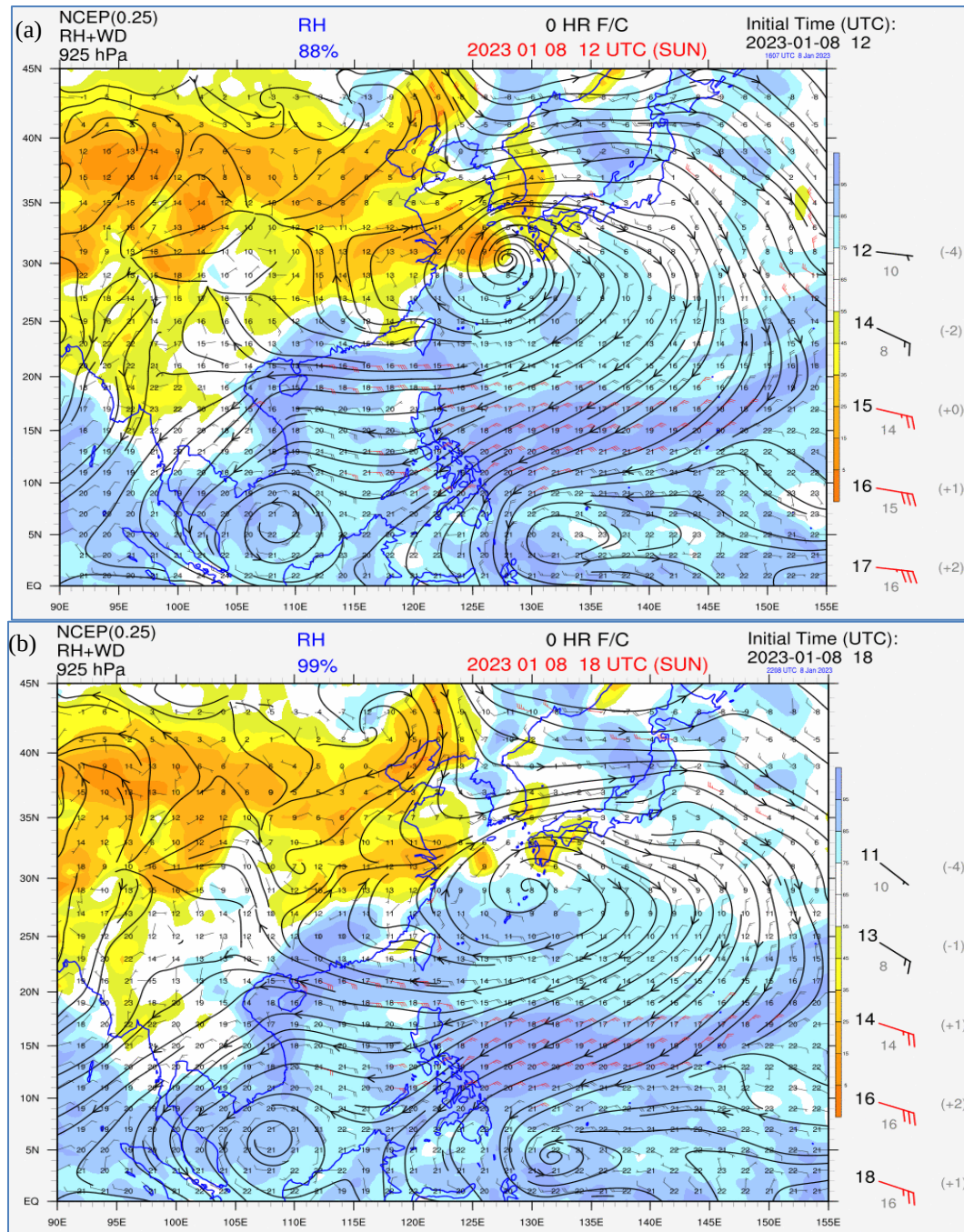
Beijing Daxing International Airport was open in 2019, and is the second airport in the capital city of China. The airport has sophisticated engineering systems (Wang and Wang, 2023). In particular, the airport has two Doppler Light Detection And Ranging (LIDAR) systems to detect low-level wind shear. Information about the operation of LIDAR could be found in, *e.g.*, in Yuan *et al.* (2022).

Some case studies of low-level wind shear at Daxing Airport are described in the papers in the existing

literature. However, there is no in-depth investigation of the wind shear cases. The present paper discusses in details a case of low-level wind shear at Daxing airport. In addition to the observation of LIDAR in the alerting of wind shear, the paper also investigates the possibility of forecasting the wind shear case using a high-resolution numerical weather prediction (NWP) model, namely, based on Regional Atmospheric Modelling System (RAMS) version 6.3 (<https://vandenheever.atmos.colostate.edu/vdhpage/rams.php>) using large eddy simulation mode based on Deardorff (1980) turbulence parameterization scheme (Deardorff 1980). The wind shear cases for Hong Kong International Airport (Chan *et*



Figs. 1(a&b). The surface isobaric chart at 12 UTC (a) and 18 UTC (b) of 8 January 2023



Figs. 2(a&b). The analyzed 925 hPa wind field and humidity field at 12 UTC (a) and 18 UTC (b), 8 January 2023

et al., 2021) and an airport on the plateau in China (Chan *et al.*, 2024) are also studied using RAMS version 6.3. Based on case studies for Hong Kong, this setup of RAMS has been found to reproduce rather well the main features of terrain-induced windshear, such as mountain waves and vortex shedding. This study aims at documenting the wind shear case at Daxing airport and exploring the technical feasibility of forecasting this case several hours in advance. The study methodology is built

on the previous studies in Hong Kong, such as Chan (2012) and Chan and Hon (2016), as well as the plateau airport, as in Huang *et al.* (2025). It is noted that there is recently enhancement of vertical coordinates of high resolution model to handle steep terrain based on Weather Forecasting and Research (WRF) model, such as Arthur *et al.* (2018). This new model setup would be tested for windshear at Daxing airport in future studies.

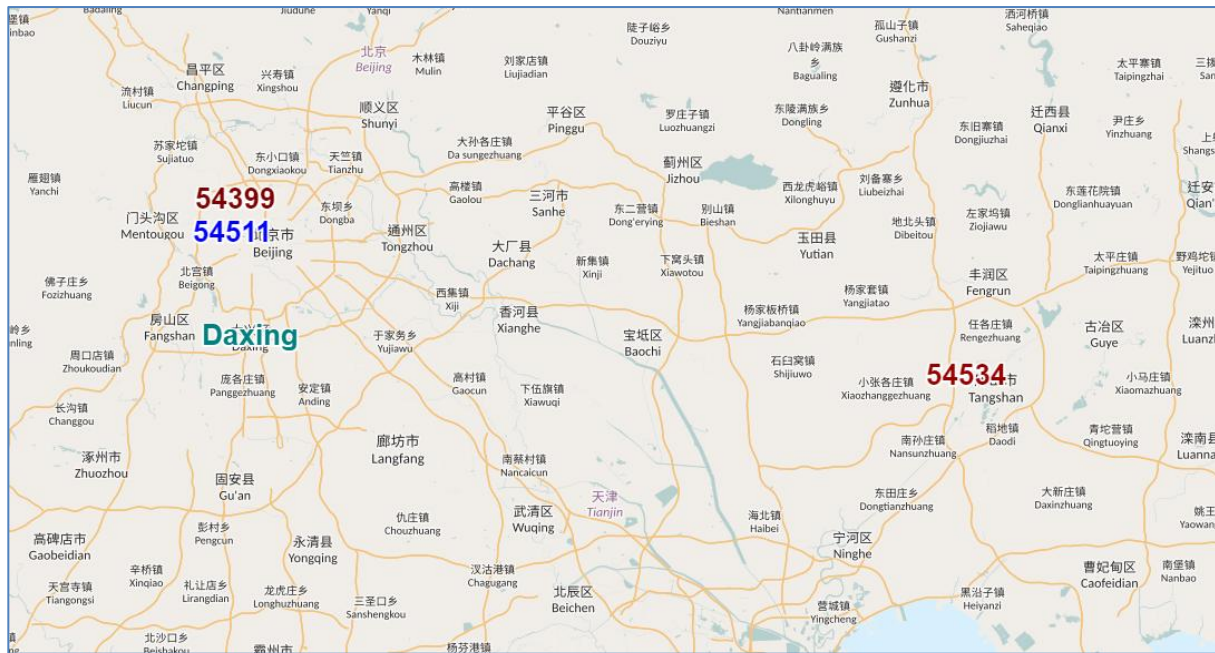


Fig. 3 Locations of wind profilers 54399 (Haidian) and 54534 (Tangshan) and radiosonde station 54511 (Beijing Capital International Airport)

1.1. Synoptic pattern

The wind shear case occurs night-time of 8 January 2023, around 15 UTC (or 23H Beijing Standard Time, BST 8 hours ahead of UTC). Figs 1(a) and 1(b) show the surface synoptic patterns at 12 UTC (20H, 8 January 2023) and 18 UTC (02H, 9 January 2023) respectively. Northern China was under the influence of a broad area of high pressure. This area of high pressure moved eastwards gradually in this period of 6 hours. Beijing was under the influence of northeasterly winds. At the same time, the easterly flow associated with the southern flank of the area of high pressure spread into the Beijing area gradually.

The above evolution of low-level winds is also depicted clearly in the analysis of winds within the atmospheric boundary layer, such as 925 hPa (Fig. 2). Earlier on (Fig. 2(a)), the Beijing area was under the northeasterly flow associated with a broad anticyclone, corresponding to the surface area of high pressure. With the anticyclone moving eastwards, several grid points south of Beijing were analyzed to have southeasterly and even southerly flow (Fig. 2(b)).

As a result of the above evolution of airflow, convergence between the background northeasterly flow and the southeasterly/easterly flow at the southern flank of the anticyclone/surface area of high pressure may result in a shear line in synoptic scale/mesoscale. Convergence of the two airflows may bring low wind shear to Daxing

airport. From the time series of tephigrams at Beijing (two times a day, not shown), the cooler easterly may undercut the northeasterly to give rise to the shearline. However, the time interval between the tephigrams is rather long (12 hours) to make a conclusive statement in this regard.

Along with the surface analysis and wind analysis at 925 hPa level, vertical wind profiles detected by the wind profilers operated by the China Meteorological Administration near Daxing area were also studied. Considering the availability of data and locations of wind profilers for Daxing airport, the wind data from two wind profilers near Daxing (Fig. 3) were investigated. The wind profiler 54399 is located in Haidian, around 70 km north of the Daxing airport. The other wind profiler in Tangshan, station code 54534, is around 200 km east of Daxing. Fig. 3 also shows the location of the radiosonde station at Beijing Capital International Airport (station code 54511). In the evening of 8 January (20H) to the early morning of 9 January (02H), low-level winds (up to around 1km) recorded by 54399 (Fig. 4(a)) revealed that northeasterlies prevailed during the period concerned. Meanwhile, the wind profile of the weather station 54534 (Fig. 4(b)), located east of Daxing, reflected the penetration and strengthening of easterly wind with northeasterlies turned to easterlies in the atmospheric boundary layer. These wind measurements further supported the convergence of the northeasterlies at Haidian with the easterlies from Tangshan at low levels around Daxing airport, resulting in low-level wind shear.

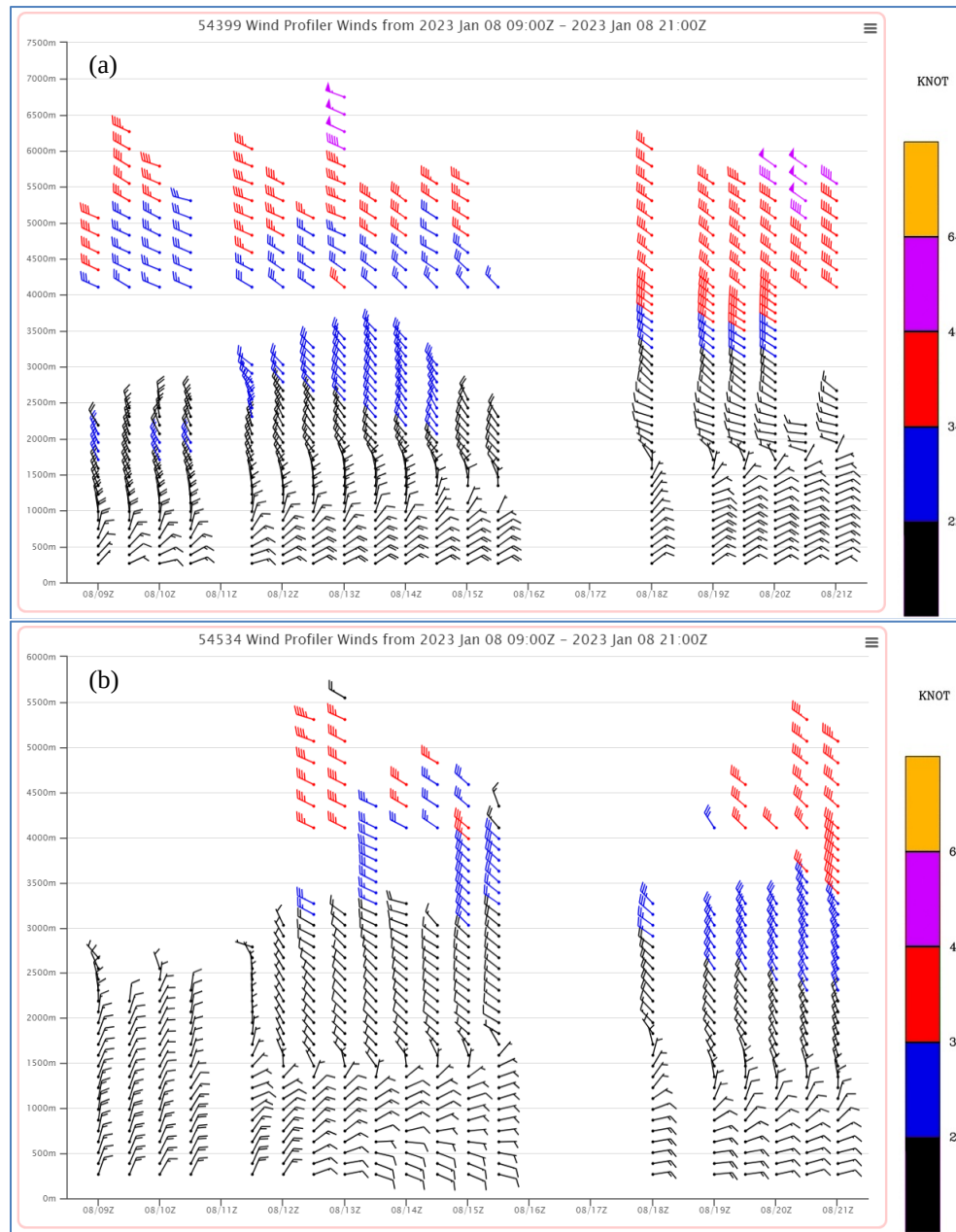


Fig. 4s.(a&b). Vertical wind profiles for the period 09 UTC – 21 UTC, 8 January 2023

Under the influence of anticyclonic flow, the near-surface atmosphere over Beijing area was relatively stable night-time of 8 January from the tephigram for 54511 (Fig. 5), and this condition is also conducive to the formation of wind shear in the vicinity of the Daxing airport. The K index is just -4 degrees Celsius. The Richardson number within the lower and middle troposphere stays well above 0.25 in magnitude. A significant temperature inversion is also seen near the surface (Fig. 5).

2. Data and methodology

The Doppler LIDAR used at Daxing airport has a wavelength of 1550 nm and pulse repetition frequency of 1000. The time window of the pulse is 400 ns.

The LIDAR makes several scans in each cycle. It measures the noise floor at first, followed by 3-degree elevation Plan Position Indicator (PPI) scan for measuring wind shear at arrival runway corridors, and a 45-degree

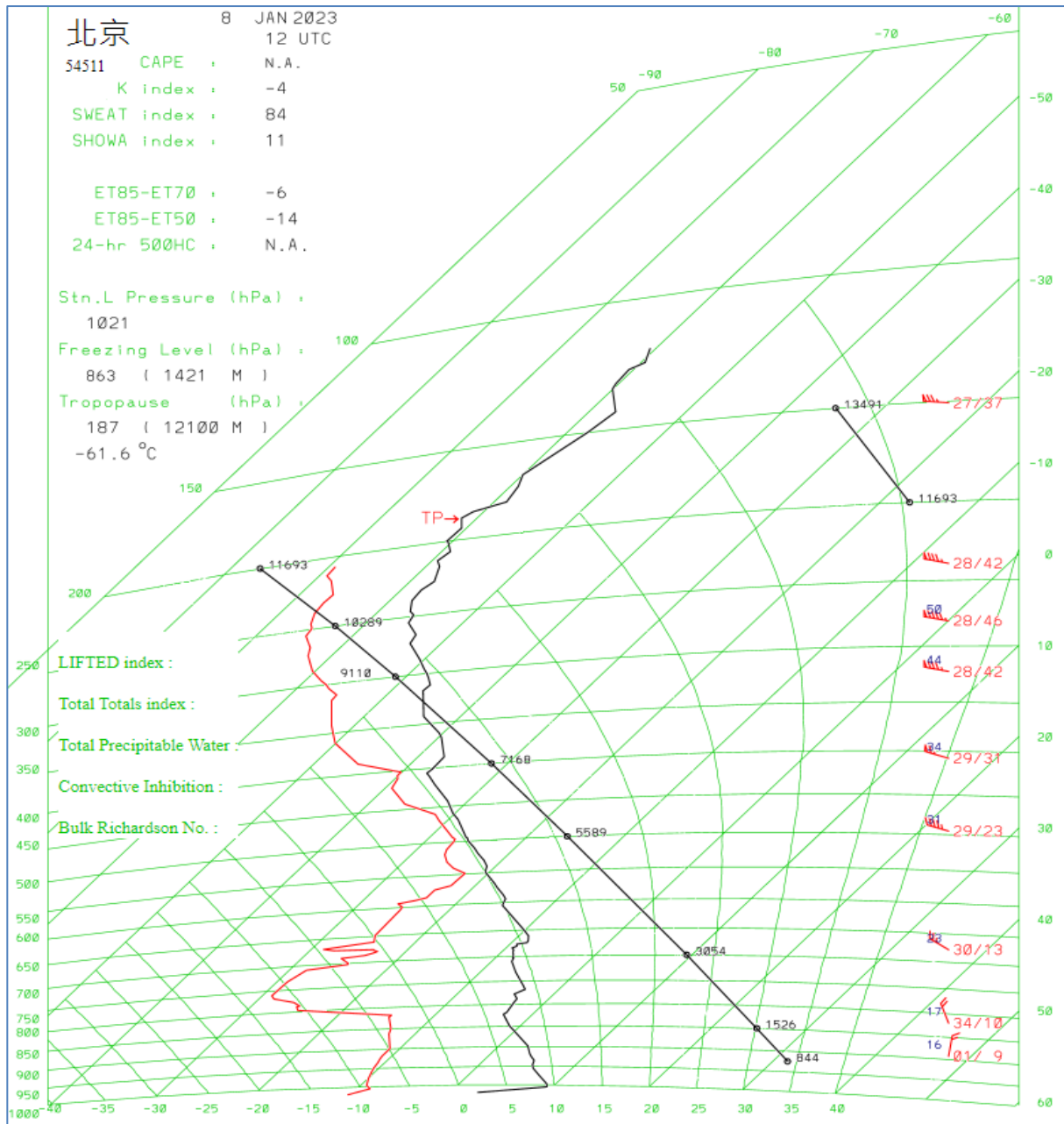


Fig. 5. Tephigram for Beijing Capital International Airport (station code 54511), at 12 UTC, 8 January 2023. The temperature (black curve) and dew point temperature (red curve) illustrated a relatively dry and stable atmospheric boundary layer. Geopotential heights are marked on the black straight line

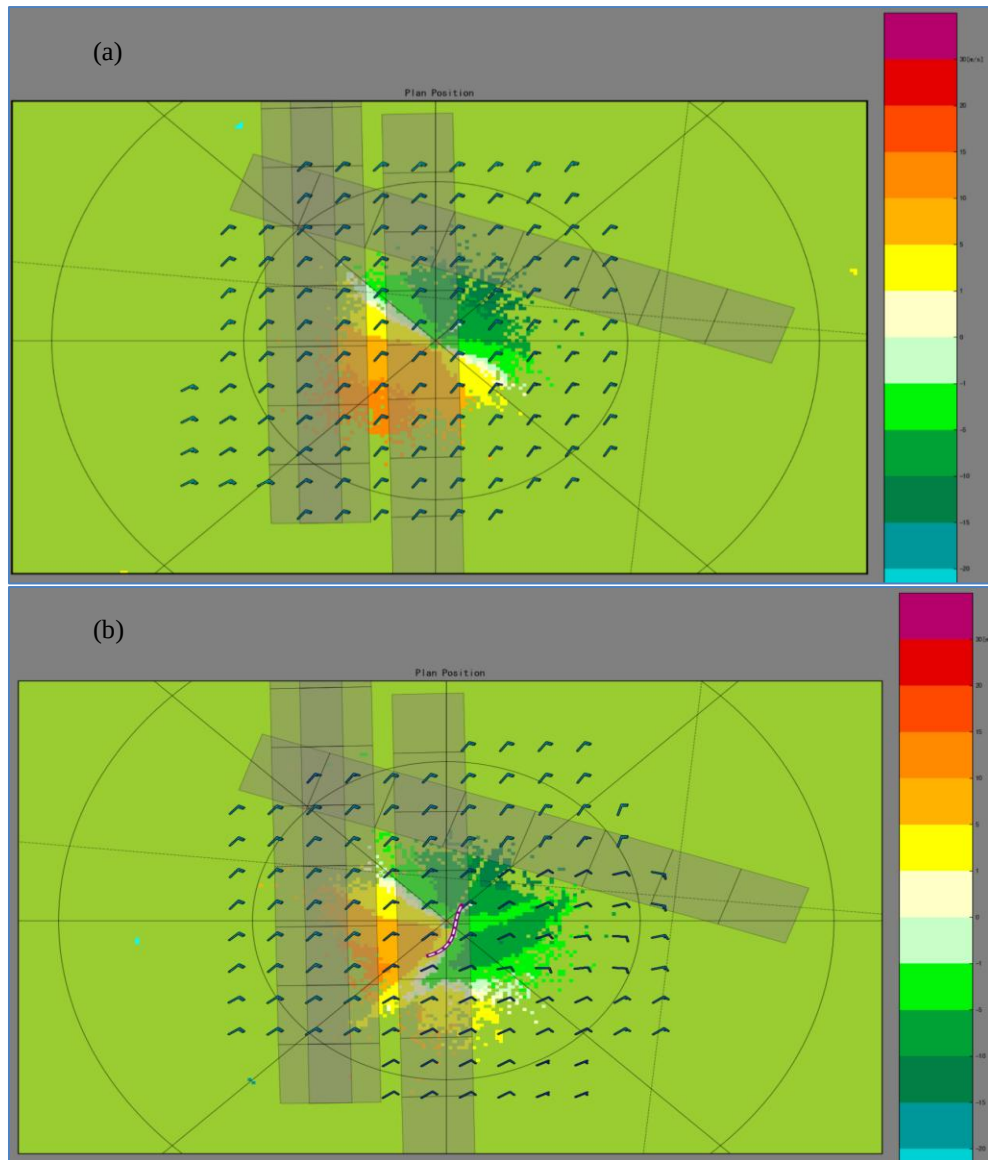
PPI scan for upper air wind measurements. Afterwards, it performs a glide-path scan (Shun and Chan, 2008) at 01L runway and another at 19R runway. The LIDAR takes a few minutes for each scan cycle to complete.

2.1. LIDAR observation

The 3-degree plan position indicator (PPI) scans of the Doppler LIDAR at Daxing airport are investigated

further in this paper. Only the velocity imageries will be considered.

At around 15 UTC, strong northeasterly flow prevailed over the airport area (Fig. 6(a)). At around 16 UTC (Fig. 6(b)), east-northeasterly flow/easterly flow began to appear to the south of the LIDAR. A shear-line was detected automatically by the wind shear algorithm of the airport (Yuan *et al.*, 2022).



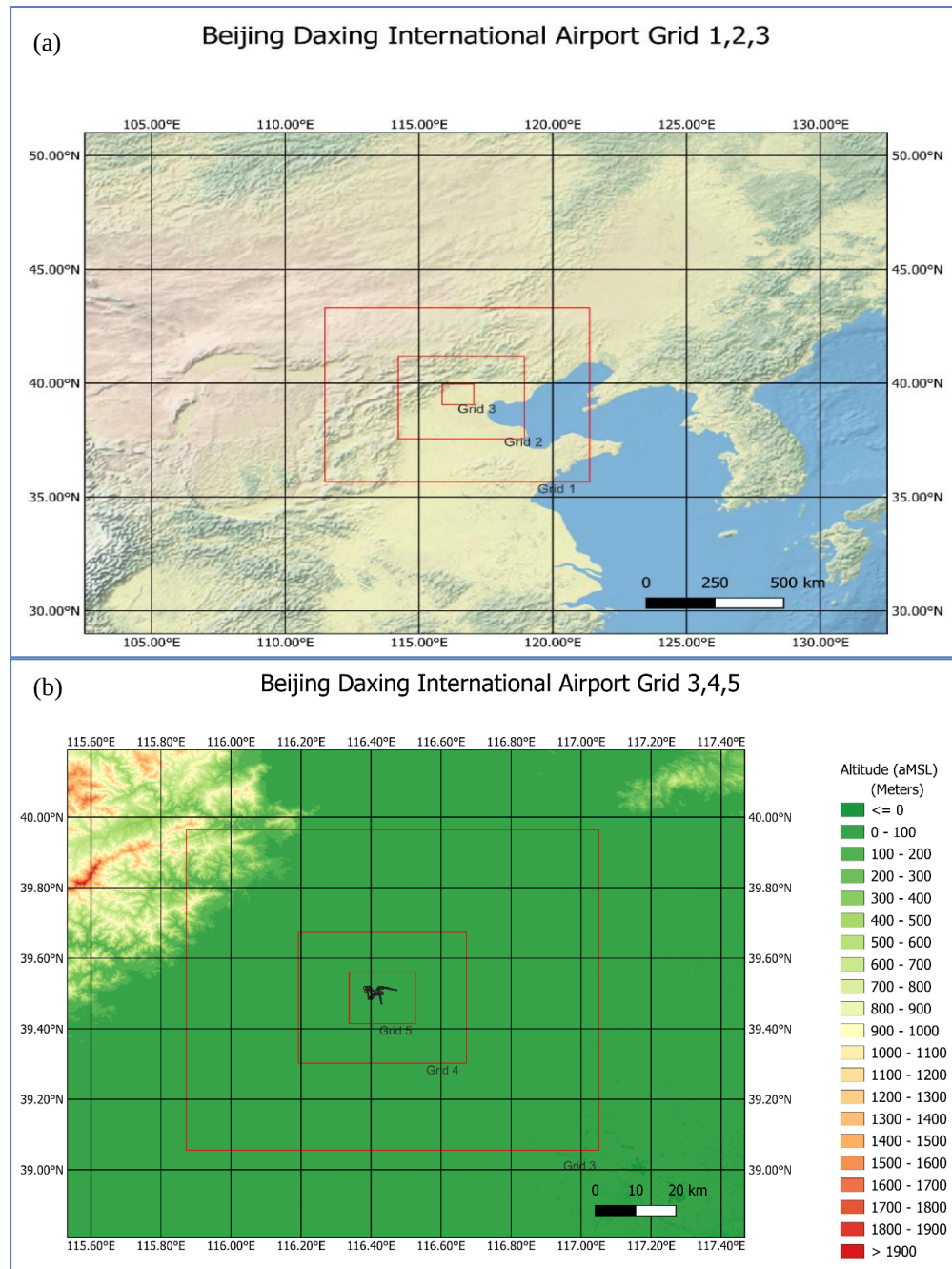
Figs. 6(a&b). The 3-degree PPI scans of LIDAR, with the Doppler velocities (colour coded) and shear-line (zebra line in (b)). The analyzed two-dimensional winds from LIDAR data are also plotted

Between around 16:03 UTC and 16:14 UTC, low-level wind shear alerts associated with the shear-line were issued automatically based on the LIDAR data. The wind shear event was somewhat transient but was successfully captured by the LIDAR. Since the wind shear event was relatively short and occurred at night-time, its impact on the airport operation was minimal. However, low-level wind shear is hazardous to aviation and the Doppler LIDAR performs very well in capturing its occurrence. The feasibility of forecasting this wind shear event is then being investigated, e.g. using high resolution NWP model. The transient nature of the shear line may be due to the generally rapid westward movement of the shear line across the measurement domain of the LIDAR, following

rather rapid evolution of the synoptic/mesoscale surface pattern over the northern part of China. The timely alerting and forecasting of the windshear would help early arrangement of the flights, so that no flights may be conducted during the hazardous period of the occurrence of low-level windshear/timely provision of windshear alerts to the aircraft, as in the case of the application of LIDAR and NWP forecasting at Hong Kong airport.

3. Results and discussion

As in the previous studies of low-level wind shear in Hong Kong and the plateau in China, a high-resolution NWP model is used by nesting with the 0.25-degree

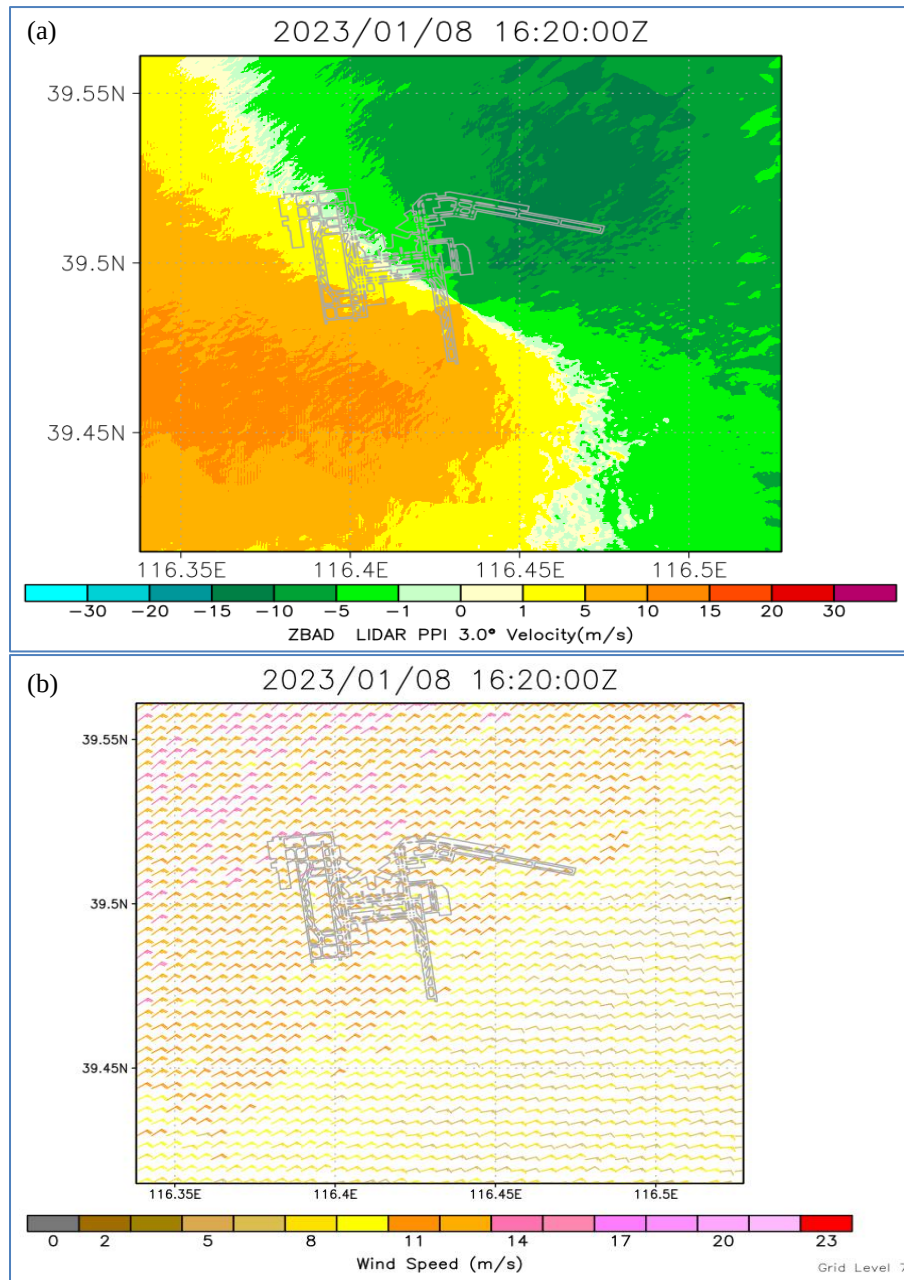


Figs. 7(a&b). The five nested domains of the numerical weather prediction model (a)Beijing Daxing International Airport Grid 1,2,3 (b) Beijing Daxing International Airport Grid 3,4,5

forecast from the National Centers for Environmental Prediction (NCEP) global model of the U.S. Five nests are performed with spatial resolutions of 25 km, 5 km, 1 km, 200 m, and 40 m. Deardorff's (1980) turbulence parameterization scheme is used in the innermost three nests. Fig. 7 shows the model domains. The domains are centred at the Doppler LIDAR's location at Daxing airport. Model simulation results are interpolated at the 3-degree PPI scans of the LIDAR to produce the simulated LIDAR

velocity imagery. The model is being initialized at 12 UTC, 8 January 2023 and run for 6 hours.

Starting at around 15:30 UTC, while northeasterly winds are predicted to prevail over the airport, easterly winds appear at about 2-3 km to the southeast of the LIDAR (not shown). Easterly flow gradually spreads westwards and closer to the LIDAR location (Fig. 8(a)). Convergence between northeasterly winds and easterly



Figs. 8(a&b). The simulated LIDAR 3-degree PPI velocity imagery (a) and the 2-dimensional wind field at 464 m above sea level (b) at the simulation time of 16:20 UTC, 8 January 2023

winds remains stationary at around 2 km to the south of the airport (Fig. 8(b)) until the northeasterly winds moderate (not shown). The location of the convergence line (Fig. 8(a)) is relatively consistent with the shear-line as demonstrated in the authentic Doppler LIDAR imagery (Fig. 6(b)).

However, the following discrepancies between the authentic LIDAR images and the simulated LIDAR are being observed:

- (i) Location of the shear-line – in reality, the shear-line was right over the airport, whereas in the simulation, it located to the south of the airport, at a distance of around 2 km, considered to be reasonable with the condition that the present simulation is pure dynamic downscaling without assimilation of any additional data;
- (ii) Strength of the shearing – the real shear-line has greater convergence, but the simulated convergence turns out to be weaker than reality;

(iii) Timing of the shear-line – there is a difference of around half an hour about the occurrence of shearing near the airport. The simulation is about half an hour later than reality, considered to be reasonable given the dynamic downscaling nature of the simulation;

(iv) Persistence of the shear-line – in reality, the shear-line occurred over the airport for around 10 minutes only and passed to the west at the end; however, in the simulation, the shearing is relatively stationary to the south of the airport and weakens gradually with the weakening of the northeasterly flow to the north.

The present experiment is purely dynamic downscaling of the airflow at the airport based on outputs from a global NWP model. In future studies, data assimilation may be added (e.g. assimilating wind profiler data) so that discrepancies between the NWP model results and the actual LIDAR observations may be reduced. Moreover, the limitations in model physics and boundary layer representation would add to the discrepancies, and other turbulence parameterization schemes would be tried out for future studies.

4. Conclusions

A case of low-level wind shear at Daxing airport is studied in detail in the present paper. The shear is related to synoptic change of the mean sea level pressure and the wind near the surface, and occurs over the airport for a short period (around 10 minutes) only. The shear is captured well by the LIDAR at the airport and there were timely alerts.

The technical feasibility of forecasting the wind-shear case is studied using a high-resolution NWP model. The event may be predicted a few hours in advance. The convergence between northeasterly wind and easterly wind could be predicted by the model. Nonetheless, there are some discrepancies between the reality and the simulation, such as the magnitude of the shearing and persistency of the feature.

More wind-shear cases at Daxing airport could be studied in the papers, to understand more about the nature of wind-shear over there and to explore the feasibility of forecasting the shear features several hours in advance.

Authors' Contributions

P.W. CHAN: Supervision, Resources and Manuscript writing: draft and revised version.

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