



**A high spatiotemporal resolution atmospheric motion vector dataset from
Fengyun-4B Geostationary High-speed Imager observations for 15 tropical
cyclones over the western North Pacific and South China Sea (2022 – 2025)**

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Abstract: High spatiotemporal resolution wind observations are essential for resolving the rapidly evolving inner-core circulation, spiral rainbands, upper-level outflow, and asymmetric structural changes of tropical cyclones (TCs), yet these features remain inadequately sampled by conventional observing systems and operational atmospheric motion vector (AMV) products. This study presents a consistently processed and systematically evaluated minute-scale temporal and mesoscale spatial atmospheric motion vector (MAMV) dataset derived from the Geostationary High-speed Imager (GHI) onboard Fengyun-4B (FY-4B) for 15 TCs over the western North Pacific and the South China Sea (SCS) during 2022 – 2025. The dataset includes daytime visible-band (VIS) MAMVs with a nominal vector spacing of 3 km and day-and-night infrared-band (IRX) MAMVs with a nominal spacing of 24 km. Four stable products are generated at the 1, 2, 6, and 7 min marks of each recurring 10 min observation cycle. The dataset represents the highest combined spatial and temporal resolution currently available for a multi-case geostationary satellite TC wind-field dataset, providing detailed observations of inner-core flow, spiral-rainband circulation, convective-cloud boundaries, peripheral winds, and upper-tropospheric outflow that are difficult to obtain from radiosondes, conventional AMVs, or hourly reanalysis fields. Quality-screened vectors were evaluated against radiosonde observations and ERA5 reanalysis winds. The mean speed bias, mean vector difference, and standard deviation of vector differences were 2.34, 4.05, and 1.77 m s⁻¹ for VIS, 2.21, 4.74, and 2.17 m s⁻¹ for IRX when using radiosondes as reference, they are 1.62, 5.57, and 4.63 m s⁻¹ for VIS, 0.31, 5.95, and 3.66 m s⁻¹ for IRX when using ERA5 as reference. The dataset provides a new observational basis for continuously monitoring the multiscale evolution of tropical cyclones, including changes in inner-core circulation, spiral rainbands, asymmetric wind structures, peripheral flow, and upper-tropospheric outflow, thereby supporting improved analysis of TC development, structural change, and short-term intensity evolution. The FY-4B/GHI IRX MAMV dataset for 2022 – 2025 is available at doi:10.5281/zenodo.22790846; The FY-4B/GHI VIS datasets are available at doi:10.5281/zenodo.22791421 for 2022–2023, doi:10.5281/zenodo.22791444 for 2024, and doi:10.5281/zenodo.22791469 for 2025 (Xia et al., 2026a, b, c, d).



63 1 Introduction

64 Coastal disaster preparedness for tropical cyclones (TCs) requires accurate
65 forecasts not only of storm track and intensity but also of the evolving circulation and
66 structure, which determine the distributions of damaging winds, heavy rainfall, and
67 storm surge (Lin et al., 2015; Chavas et al., 2017; Gori et al., 2022). Globally, tropical-
68 cyclone-related disasters caused nearly 780,000 deaths and approximately USD 1.4
69 trillion in reported economic losses over the past 50 years (WMO, 2025). As forecasts
70 and expected impacts evolve during the approach to landfall, authorities must
71 continually update operational decisions concerning evacuation planning, emergency-
72 resource allocation, and the suspension or resumption of port and maritime operations
73 (Verschuur et al., 2023; Kam et al., 2024; Morss et al., 2024). Such decisions require
74 observations that resolve both storm-scale circulation and rapidly evolving mesoscale
75 dynamical features, because TC evolution reflects interactions between the surrounding
76 environment and transient internal structural changes (Wu et al., 2014; Oyama et al.,
77 2018; Su et al., 2020). These requirements are difficult to satisfy over the open ocean,
78 where direct wind-profile measurements are comparatively sparse and spatially
79 extensive satellite observations therefore play an essential role (Stoffelen et al., 2020).
80 This need is especially acute over the western North Pacific and the SCS, where TCs
81 frequently develop and evolve over the ocean before threatening the densely populated
82 coastlines in East and Southeast Asia (Peduzzi et al., 2012; Magee et al., 2021; Tran et
83 al., 2022).

84 Modern TC forecasting relies on an observation–analysis–prediction chain in
85 which observations are combined with short-range model forecasts through data
86 assimilation to estimate the atmospheric state and provide initial conditions for
87 numerical prediction (Bauer et al., 2015; Carrassi et al., 2018; Magnusson et al., 2019).
88 Even advanced models cannot fully compensate for poorly constrained initial states,
89 and inadequate spatial or temporal sampling of rapidly evolving wind structures can
90 propagate into analyses and subsequent forecasts (Berger et al., 2011; Wu et al., 2014;
91 Posselt et al., 2019). TC forecast performance therefore depends strongly on the



92 availability, timeliness, spatial coverage, and temporal sampling of wind observations
93 (Bauer et al., 2015; Stoffelen et al., 2020). Although radiosondes, dropsondes, aircraft
94 reconnaissance, buoys, ships, and land-based stations provide valuable local
95 measurements, their coverage over the open ocean is sparse and uneven, particularly in
96 the western North Pacific, and cannot continuously resolve the circulation of an entire
97 TC (Wu et al., 2014; Stoffelen et al., 2020; Lin et al., 2022).

98 Satellite observations provide the principal means of filling this oceanic gap and
99 are essential to global and regional numerical weather prediction (NWP) systems (Eyre
100 et al., 2020, 2022). Geostationary satellites are particularly valuable because they
101 repeatedly observe the same region, allowing cloud and water-vapor features to be
102 monitored throughout storm evolution (Velden et al., 2005). Atmospheric motion
103 vectors (AMVs) are retrieved by tracking suitable features in successive images and
104 assigning their horizontal displacements to representative atmospheric levels (Velden
105 et al., 2005; Wu et al., 2014). They therefore provide spatially extensive wind estimates
106 at multiple levels over data-sparse oceanic regions (Wu et al., 2014; Eyre et al., 2022).
107 For TC applications, AMVs describe both the environmental flow governing storm
108 motion and storm-scale circulation associated with structural and intensity changes (Wu
109 et al., 2014; Oyama et al., 2018). Upper-tropospheric AMVs have been used to
110 characterize cloud-top tangential winds, radial outflow, circulation size, and short-term
111 structural evolution (Oyama et al., 2018). Assimilation experiments have shown that
112 AMVs can improve the representation of TC position, environmental steering flow,
113 vortex-scale circulation, and storm size in NWP models (Berger et al., 2011; Wu et al.,
114 2014; Velden et al., 2017; Li et al., 2020). Benefits are often more consistent for TC
115 analyses and track forecasts, whereas impacts on intensity forecasts depend more
116 strongly on retrieval methods, spatial and temporal coverage, quality control, and
117 assimilation configuration (Wu et al., 2014; Velden et al., 2017; Li et al., 2020).
118 Nevertheless, conventional AMV products may undersample rapidly evolving
119 mesoscale flows when imagery is refreshed too infrequently or vector spacing is coarse
120 relative to the lifetime and scale of tracked features (Oyama et al., 2018; Posselt et al.,
121 2019; Li et al., 2020).



122 Regional rapid-scan imaging has substantially expanded the capabilities of
123 geostationary satellites. The Advanced Baseline Imager onboard the Geostationary
124 Operational Environmental Satellite-R (GOES-R) series and the Advanced Himawari
125 Imager onboard Himawari-8/9 can acquire regional imagery at intervals much shorter
126 than conventional full-disk scans, improving the sampling of convective development
127 and cloud motion (Bessho et al., 2016; Schmit et al., 2017). The GHI onboard FY-4B
128 provides targeted observations over an adjustable regional domain at intervals as short
129 as approximately 1 min (Min et al., 2020, 2022). Here, rapid-scan AMV products with
130 enhanced spatial or temporal sampling are collectively referred to as MAMVs. Previous
131 studies have shown that MAMVs can resolve rapidly evolving upper-tropospheric
132 circulation and structural changes in TCs and improve the representation of
133 environmental flow and three-dimensional vortex structure when assimilated into NWP
134 models (Berger et al., 2011; Wu et al., 2015; Velden et al., 2017; Oyama et al., 2018;
135 Sawada et al., 2019, 2020; Li et al., 2020).

136 For FY-4B/GHI, Xia et al. (2024) developed MAMV retrievals with nominal vector
137 spacings of 3 km for the visible band and 24 km for the infrared band. Xia et al. (2025)
138 subsequently showed that assimilating FY-4B/GHI MAMVs improved analyzed
139 dynamical fields and reduced track forecast errors in western North Pacific typhoon
140 cases. However, previous work has focused mainly on retrieval-algorithm development,
141 individual-storm analyses, or a limited number of assimilation experiments. To date, no
142 openly accessible FY-4B/GHI MAMV dataset covering multiple TCs has been released
143 with consistent processing, documented quality control, and systematic evaluation. To
144 address this gap, this study presents a high-spatiotemporal-resolution FY-4B/GHI
145 MAMV dataset for 15 TCs over the western North Pacific and the SCS from 2022 to
146 2025. It includes daytime VIS MAMVs with a nominal vector spacing of 3 km and day-
147 and-night IRX MAMVs with a nominal spacing of 24 km. Stable products are generated
148 at the 1, 2, 6, and 7 min marks of each recurring 10 min observation cycle. All products
149 are generated using a consistent retrieval and quality-control framework and evaluated
150 against radiosonde observations and the fifth-generation European Centre for Medium-
151 Range Weather Forecasts reanalysis (ERA5). The dataset provides a valuable



152 observational resource for TC mechanism analysis, model evaluation, data assimilation,
 153 and process-oriented studies.

154

155 **2 Study domain and selected observation cases**

156 The study domain extends from 100°E to 130°E and from 10°N to 28°N, as shown
 157 in Fig. 1. It covers the South China Sea, the western Philippine Sea, and adjacent coastal
 158 regions of East and Southeast Asia. The domain lies within the western North Pacific,
 159 the most active tropical cyclone (TC) basin globally, and includes densely populated
 160 coastal areas that are highly exposed to TC-related hazards (Peduzzi et al., 2012; Magee
 161 et al., 2021; Tran et al., 2022). This region was selected because FY-4B/GHI rapid-scan
 162 observations are available for multiple TCs passing through the domain and because
 163 the surrounding land areas provide radiosonde observations that can be used for
 164 independent evaluation of the retrieved wind vectors.

165 The GHI aboard FY-4B (Xia et al., 2024), a geostationary meteorological satellite
 166 positioned at 104.7°E (nadir point), provides targeted rapid-scan observations over a
 167 flexibly configurable regional domain. Under suitable observation configurations, GHI
 168 can acquire regional imagery at intervals as short as approximately 1 min, providing
 169 the temporal sampling required to track rapidly evolving cloud features and mesoscale
 170 atmospheric motions (Xia et al., 2024). However, GHI rapid-scan observations are
 171 scheduled according to operational and research requirements and therefore do not
 172 continuously cover every TC occurring within the study domain. The available
 173 observations consequently represent selected rapid-scan campaigns rather than a
 174 complete record of all TCs over the western North Pacific and the South China Sea.

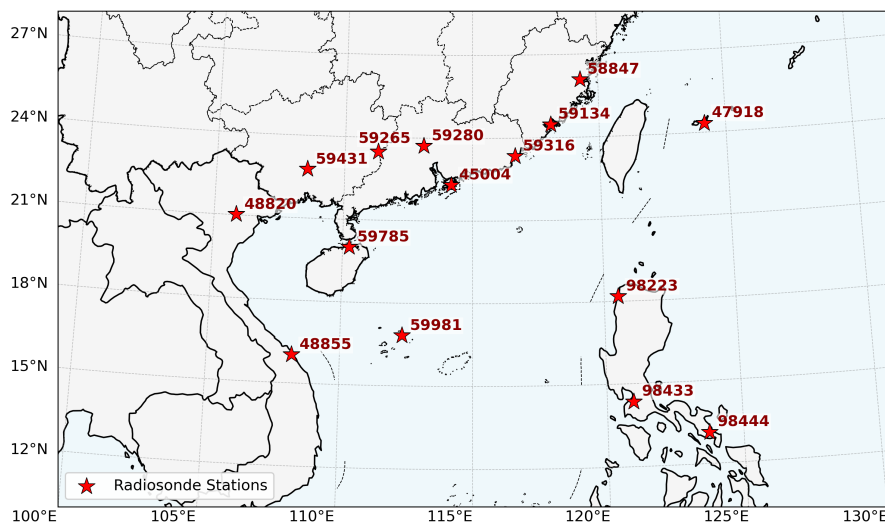
175 From the available FY-4B/GHI rapid-scan observations between 2022 and 2025,
 176 15 TC cases were selected according to their observation duration, temporal continuity,
 177 and spatial coverage of the TC circulation. A valid case was required to contain at least
 178 36 h of rapid-scan observations, with no individual data gap exceeding 150 mins. These
 179 criteria were applied to ensure that each case contained a sufficiently continuous
 180 sequence for examining the temporal evolution of the TC wind field. Because case
 181 availability was constrained by GHI observation scheduling and data continuity, the
 182 resulting dataset should be regarded as a curated collection of well-observed TC cases



183 rather than a climatologically complete TC archive. The VIS product is available only
184 during daytime, whereas the IRX product is available during both daytime and
185 nighttime. Although the source GHI imagery can be acquired at intervals as short as
186 approximately 1 min, stable MAMV products are generated at the 1, 2, 6, and 7 min
187 marks of each recurring 10 min observation cycle, yielding four products per cycle.

188 Based on the maximum intensity attained within the corresponding FY-4B/GHI
189 observation period, as reported in the Joint Typhoon Warning Center (JTWC) best-track
190 dataset (JTWC, 2026), the selected cases comprise 5 Typhoons (TYs), 3 Severe
191 Typhoons (STYs), and 7 Super Typhoons (SuTYs). The intensity category assigned to
192 each case therefore represents the maximum intensity reached within the GHI
193 observation window rather than over the storm's complete lifecycle. Table 1
194 summarizes the intensity category, GHI observation period in UTC, and numbers of
195 available 3 km VIS and 24 km IRX MAMV product files for each TC case.

196



197
198 **Figure 1.** Geographic distribution of the radiosonde stations used for the independent
199 validation of the FY-4B/GHI MAMV dataset. The red stars indicate the locations of the
200 upper-air observation stations across the South China Sea and adjacent coastal regions.
201 Each station is labeled with its corresponding 5-digit World Meteorological
202 Organization (WMO) station identification number.

203

204



Table 1. Overview of the 15 selected tropical cyclone cases. The intensity category represents the maximum JTWC intensity attained during the corresponding GHI observation period. The final two columns give the numbers of available 3 km VIS and 24 km IRX MAMV product files.

Category	Name	GHI observation period (UTC)	Number of MAMV files	
			VIS (3 km)	IRX (24 km)
TY	Chaba	2022-06-30 05:00–2022-07-02 12:30	618	1304
	Talim	2023-07-14 23:30–2023-07-18 23:00	974	2195
	Trami	2024-10-23 00:10–2024-10-28 23:00	1484	3059
	Wutip	2025-06-11 00:10–2025-06-15 10:00	1244	2707
	Wipha	2025-07-19 05:00–2025-07-21 17:00	622	1404
STY	Haikui	2023-09-02 23:30–2023-09-04 13:00	481	885
	Kajiki	2025-08-24 14:10–2025-08-26 04:00	356	784
	Matmo	2025-10-02 10:10–2025-10-06 13:00	979	2100
SuTY	Saola	2023-08-30 06:10–2023-09-02 10:00	789	1575
	Koinu	2023-10-02 23:30–2023-10-08 13:00	1492	3078
	Gaemi	2024-07-24 00:10–2024-07-26 10:00	699	1297
	Yagi	2024-09-03 02:30–2024-09-07 12:30	1169	2214
	Kong-rey	2024-10-29 11:10–2024-10-31 20:00	500	1276
	Yinxing	2024-11-08 00:10–2024-11-10 09:00	704	1328
	Ragasa	2025-09-21 09:10–2025-09-24 20:00	736	1729

210

211 3 Data and methods

212 3.1 Mesoscale atmospheric motion vector (MAMV) product

213 3.1.1 FY-4B/GHI Level-1B observations

214 The primary satellite observations used to generate the MAMV dataset were
215 obtained from the GHI onboard FY-4B geostationary meteorological satellite. GHI is a
216 rapid-scan imaging instrument designed for targeted observations of high-impact



217 weather systems. Its observation domain can be configured according to operational
218 requirements, with a nominal coverage of approximately $2000\text{ km} \times 2000\text{ km}$ and a
219 scan interval as short as approximately 1 min. This flexible rapid-scan capability
220 enables continuous monitoring of rapidly evolving cloud systems and provides the
221 image sequences required for retrieving high-frequency atmospheric motion vectors.

222 The Level-1B (L1B) data from two FY-4B/GHI bands were used in this study. The
223 daytime VIS MAMVs were derived from calibrated and navigated reflectance
224 observations from the full-color band, which covers approximately $0.45\text{--}0.76\text{ }\mu\text{m}$ and
225 has a nadir spatial resolution of 250 m. The day-and-night IRX MAMVs were derived
226 from calibrated and navigated brightness-temperature observations from the $11.4\text{ }\mu\text{m}$
227 infrared band, which has a nadir spatial resolution of 2 km. The corresponding L1B
228 geolocation information was used to assign geographic coordinates and viewing
229 geometry to each image pixel.

230 Because GHI performs targeted rather than continuous full-disk observations, the
231 spatial coverage and temporal continuity of the L1B data vary among typhoon cases.
232 Only image sequences containing three consecutive valid observations over a common
233 geographical domain were used in the MAMV retrieval. Missing scans or adjustments
234 of the GHI rapid-scan domain therefore resulted in gaps in the resulting time series. For
235 the dataset released in this study, the 250 m full-color observations were used to
236 generate the 3 km VIS MAMV product during daytime, whereas the 2 km $11.4\text{ }\mu\text{m}$
237 observations were used to generate the 24 km IRX MAMV product throughout both
238 daytime and nighttime.

239

240 3.1.2 MAMV retrieval and production workflow

241 The production workflow of the FY-4B/GHI MAMV dataset is illustrated in Fig.
242 2. Using the operationally calibrated and navigated Level-1 observations, the MAMVs
243 were retrieved by tracking cloud features in three consecutive GHI images. The
244 retrieval algorithm generally follows Xia et al. (2024) and consists of target-scene
245 selection, bidirectional feature tracking, displacement-to-wind conversion, vertical-
246 level assignment, and quality assessment. The VIS and IRX products were processed



separately because of their different native spatial resolutions, applicable observation periods, and image-sequence intervals.

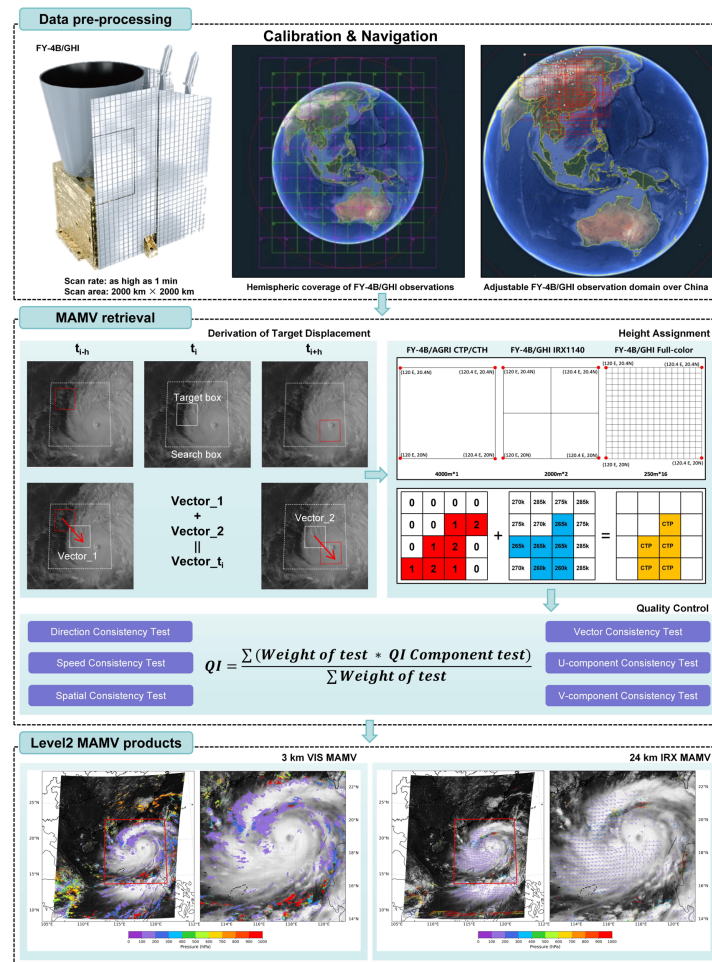


Figure 2. Workflow for producing the FY-4B/GHI MAMV dataset. The workflow consists of three main stages. First, FY-4B/GHI Level-1 observations are radiometrically calibrated and geolocated. GHI provides rapid-scan observations with a scan interval as short as 1 min over an adjustable observation domain. Second, cloud-feature displacement is retrieved from three consecutive images at t_{i-h} , t_i , and t_{i+h} . The target feature in the central image is tracked in the preceding and subsequent images, and the two displacement vectors are combined to obtain the MAMV assigned to t_i . Vector height is determined by spatially matching the GHI observations with FY-4B/AGRI cloud-top pressure and cloud-top height (CTP/CTH) products and applying the cross-correlation contribution method. The retrieved vectors are subsequently



260 evaluated using six quality-control tests, including direction, speed, spatial, vector,
 261 zonal-component, and meridional-component consistency tests, which are combined
 262 into an overall QI. Finally, the quality-controlled vectors are released as daytime 3 km
 263 VIS MAMVs and day-and-night 24 km IRX MAMVs. Some graphical elements in this
 264 figure were adapted from materials provided by the National Satellite Meteorological
 265 Center of China (NSMC, 2026).

266

267 In this algorithm, candidate target scenes were required to have a satellite zenith
 268 angle below 62° . In addition, the mean brightness temperature (BT) of an IRX target
 269 box was required to be below 285 K, while the mean reflectance of a VIS target box
 270 was required to exceed 0.3. These criteria preferentially retain cloud scenes with
 271 sufficient radiometric contrast for reliable feature tracking. Cloud-feature displacement
 272 was estimated using normalized cross-correlation (Leese et al., 1971). The position with
 273 the maximum correlation coefficient within each search box was identified in the
 274 preceding and subsequent images, producing one backward and one forward
 275 displacement vector. The two displacement estimates were then combined and assigned
 276 to the target location in the central image. Using the GHI geolocation information and
 277 the corresponding image interval, the image-space displacement was converted into
 278 zonal and meridional wind components. The MAMV retrieval uses a 24×24 pixels
 279 target box to represent the tracked cloud feature. For the IRX retrieval, the target is
 280 searched within an 80×80 pixels search box using three consecutive images separated
 281 by 10 min. For the VIS retrieval, a larger 144×144 pixels search box is used, and the
 282 three consecutive images are separated by 5 min. These band-specific settings account
 283 for differences in the native spatial resolution and temporal evolution of the observed
 284 cloud features. Under this configuration, the resulting wind-vector products have
 285 nominal vector spacings of 24 km for the IRX MAMVs and 3 km for the VIS MAMVs.
 286 The vertical level of each vector was assigned using the cross-correlation contribution
 287 (CCC) method (Borde et al., 2014) together with spatially and temporally matched FY-
 288 4B/Advanced Geostationary Radiation Imager (AGRI) cloud-top pressure (CTP) and
 289 cloud-top height (CTH) products. Within each target box, pixels contributing most
 290 strongly to the correlation were identified. For IRX retrievals, colder pixels with



291 relatively large correlation contributions were used, whereas brighter pixels were
 292 selected for VIS retrievals. The pressure or height of the vector was then calculated as
 293 the CCC-weighted mean of the corresponding AGRI CTP or CTH values. This
 294 approach links the assigned atmospheric level to the cloud features that contribute most
 295 strongly to the retrieved displacement. Finally, a quality indicator (QI) was calculated
 296 for each retrieved vector by combining six consistency tests, including direction, speed,
 297 vector, spatial, zonal-component, and meridional-component consistency tests (Daniels
 298 et al., 2025; EUMETSAT, 2026). The retrieved wind components, geographical
 299 position, assigned pressure or height, correlation coefficient, and QI were written to the
 300 intermediate MAMV products.

301

302 3.1.3 Dataset organization and variables

303 The released FY-4B/GHI MAMV dataset is distributed in Hierarchical Data Format
 304 version 5 (HDF5) and organized by typhoon case, nominal retrieval time, and product
 305 type. Separate files are provided for the daytime 3 km VIS MAMVs and the day-and-
 306 night 24 km IRX MAMVs. The file names (such as
 307 ‘FY4B_L2_CC_AMV_20250922234100_VIS__FC_0250M_300S.HDF’ and
 308 ‘FY4B_L2_CC_AMV_20250721143100_IRX1140_2000M_600S.HDF’) encode the
 309 satellite and product identifiers, nominal retrieval time, GHI band, native pixel
 310 resolution, and image interval used for feature tracking. All variables within an
 311 individual file are stored as co-registered two-dimensional arrays on the corresponding
 312 MAMV retrieval grid. Because the GHI rapid-scan observation domain is adjustable,
 313 the array dimensions and geographical coverage may vary among files and typhoon
 314 cases.

315 The temporal sampling of the released products is determined by the availability
 316 pattern of stable GHI observations rather than solely by the image interval used in the
 317 retrieval. Within each recurring 10 min observation cycle, GHI generally provides
 318 stable observations at nominal times whose minute digits end in 1, 2, 6, and 7.
 319 Observations at the remaining nominal times are less consistent and may be
 320 intermittently unavailable. Consequently, both products are reliably generated at the 1,



321 2, 6, and 7 min marks of each recurring 10 min cycle, yielding four stable products per
322 cycle.

323 Each product file contains the geographical coordinates (Latitude and Longitude),
324 zonal and meridional wind components (U and V), assigned atmospheric pressure and
325 height (Pressure and Height), the overall quality indicator (Quality_Indicator, QI), and
326 the normalized cross-correlation coefficient (R). The wind components describe the
327 horizontal motion of the tracked cloud feature, while the pressure and height variables
328 represent the vertical level.

329

330 3.1.4 Dataset-level quality control

331 Prior to secondary analysis, users are recommended to apply a consistent quality-
332 screening procedure to the original MAMV data to reduce the influence of poorly
333 matched or low-confidence vectors. In the analyses presented in this study, only vectors
334 with a QI greater than 0.65 and a normalized cross-correlation coefficient R greater than
335 0.8 were used (Daniels et al., 2025; Etheridge et al., 2025). In addition, vectors with
336 wind speeds below 4 m s^{-1} were excluded from the subsequent validation and analysis,
337 following common practice in AMV evaluation (Bedka et al., 2009). These screening
338 criteria were not applied to the released HDF files; the original vector records are
339 preserved, allowing users to reproduce these criteria or adopt alternative thresholds
340 according to their specific applications.

341

342 3.2 Representative quality-screened MAMV fields

343 Figures 3–5 illustrate representative MAMV fields after application of the quality-
344 screening criteria described in Section 3.1.4. The three cases represent different TC
345 intensity categories: Super Typhoon Ragasa (Fig. 3), Severe Typhoon Matmo (Fig. 4),
346 and Typhoon Chaba (Fig. 5).

347

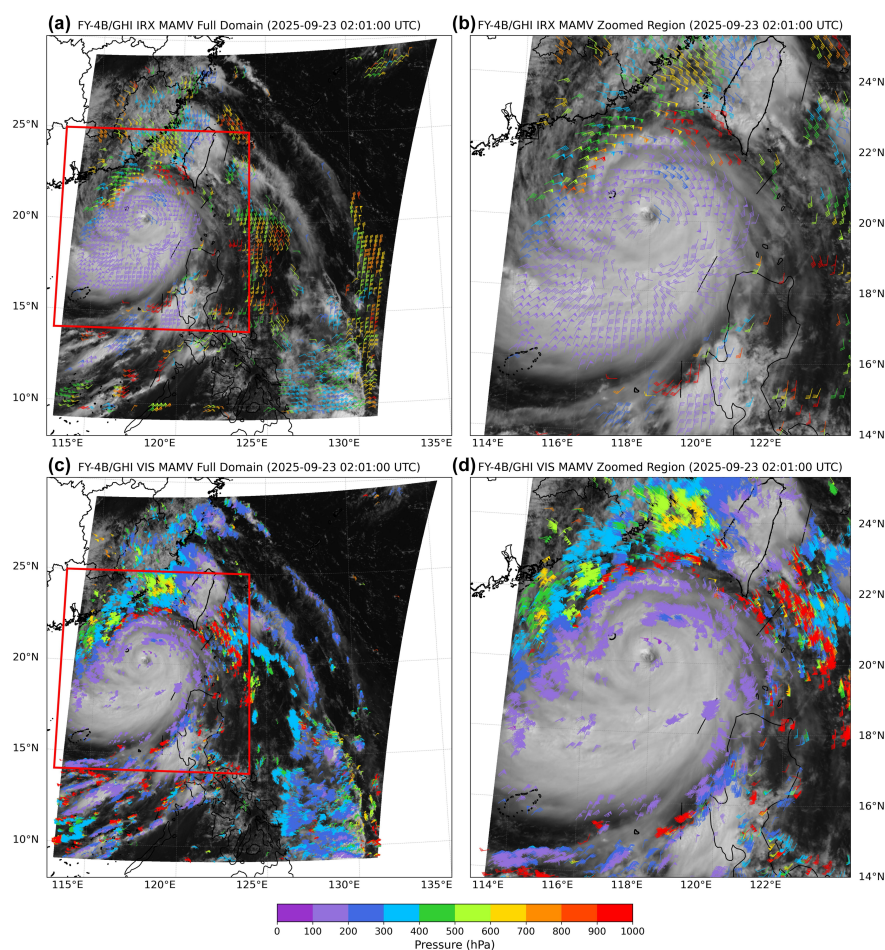


Figure 3. Quality-screened spatial distribution of FY-4B MAMVs for Super Typhoon Ragasa at 02:01 UTC on 23 September 2025. (a) Full domain and (b) zoomed inner-core region of the 24 km IRX MAMV product. (c, d) Corresponding views for the 3 km VIS MAMV product. The wind vectors (barbs) are color-coded by their assigned pressure levels (hPa). A full barb, half barb, and flag represent wind speeds of 4 m s^{-1} , 2 m s^{-1} , and 20 m s^{-1} , respectively. The red boxes in (a) and (c) denote the extents of the zoomed regions shown in (b) and (d).

For Super Typhoon Ragasa at 02:01 UTC on 23 September 2025, both products provide extensive vector coverage over the central cloud shield and surrounding cloud bands (Fig. 3). The inner region is dominated by vectors assigned to the upper troposphere, consistent with the widespread high cloud associated with the central

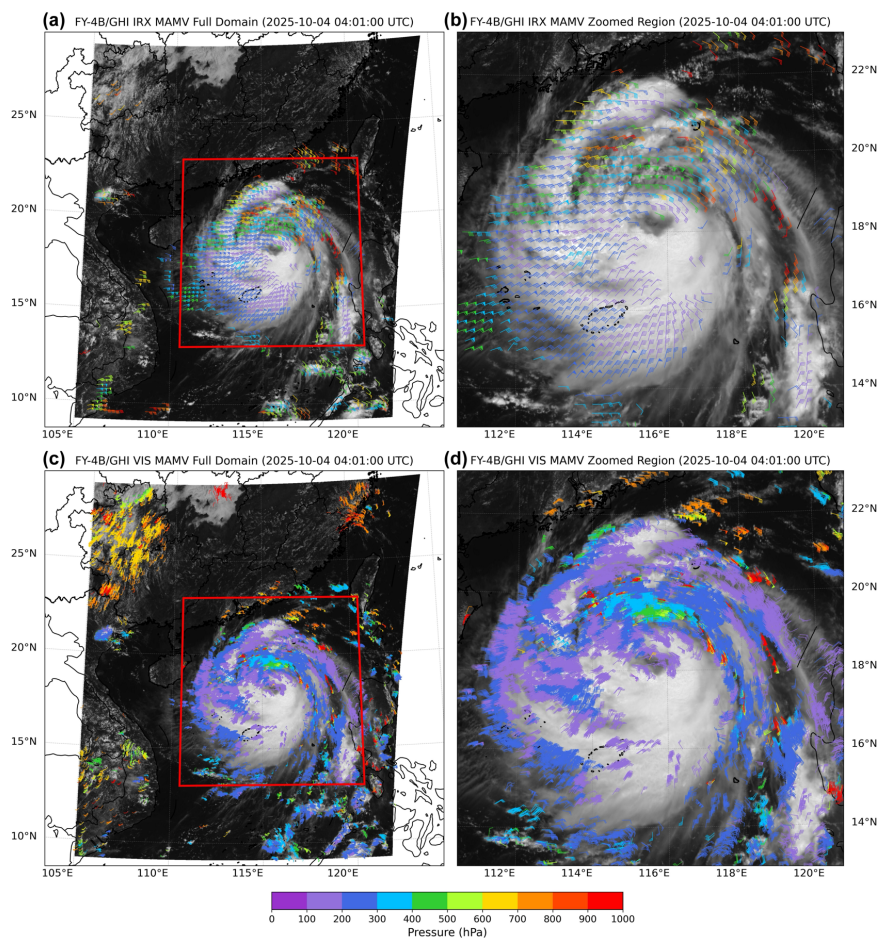


361 dense overcast and upper-level cloud canopy. The 24 km IRX product provides
362 relatively smooth sampling of the broad circulation, whereas the 3 km VIS product
363 produces a substantially denser wind field and resolves greater spatial variability along
364 cloud edges and peripheral cloud bands. Mid- and lower-level vectors occur mainly
365 outside the central high-cloud region. The extensive and coherently organized upper-
366 level vectors surrounding the central cloud shield provide a spatial representation of the
367 mature storm's upper-tropospheric circulation. Their curved and spatially varying
368 pattern suggests that the outflow associated with the deep convective core was
369 organized over a broad area but was not completely axisymmetric. Such information is
370 physically relevant because the distribution of upper-level outflow reflects the
371 ventilation of the TC core and its interaction with the surrounding environmental flow.
372 Although a single snapshot cannot establish the dynamical cause of the observed
373 asymmetry, the dense MAMV field provides a basis for quantifying center-relative
374 radial and tangential winds and for examining how upper-level outflow evolves with
375 storm intensity.

376 The MAMV fields for Severe Typhoon Matmo at 04:01 UTC on 4 October 2025
377 show a more heterogeneous spatial distribution of cloud tracers and retrieved vectors
378 (Fig. 4). Both products capture the curved flow surrounding the storm center, although
379 vector density varies among different sectors of the circulation. The VIS product
380 provides dense upper-level coverage over the main cloud shield and additional vectors
381 along the surrounding cloud bands. Scattered vectors assigned to middle and lower
382 atmospheric levels are also present near peripheral cloud features. The IRX product
383 reproduces the broader circulation with lower spatial density, reflecting its coarser
384 nominal vector spacing and the availability of suitable infrared cloud tracers. The
385 curved vectors surrounding Matmo indicate that the retrieved winds retain the rotational
386 organization of the storm, while the pronounced quadrant-to-quadrant differences
387 reveal a substantially asymmetric circulation. The continuity of the vectors along the
388 main cloud shield and outer cloud bands provides information on how rainband-scale
389 flow is connected to the vortex circulation rather than representing isolated cloud
390 features. Such asymmetry is dynamically important because the distribution of



391 convection and circulation among storm quadrants can influence vortex organization,
 392 rainfall distribution, and subsequent structural evolution.
 393



394
 395 **Figure 4.** Same as Fig. 3, but for Severe Typhoon Matmo at 04:01 UTC on 4 October
 396 2025.

397
 398 For Typhoon Chaba at 04:01 UTC on 2 July 2022, the observation domain includes
 399 both the coastal region of southern China and the adjacent ocean (Fig. 5). Both products
 400 retrieve upper-level vectors over the extensive cloud shield associated with the storm.
 401 The VIS product provides denser sampling across the coastal cloud field, outer
 402 rainbands, and fragmented peripheral clouds, where the assigned pressure levels span a



403 wider range than within the central high-cloud region. The IRX product provides a
404 spatially smoother but less dense representation of the circulation across the land–sea
405 transition. This case demonstrates that MAMVs can be retrieved over complex coastal
406 scenes when suitable cloud tracers are available. The Chaba fields show that the
407 cyclonic circulation remained spatially coherent across the northern South China Sea
408 and the adjacent coastal region, while the wind structure became increasingly
409 heterogeneous near the land–sea boundary. This pattern provides a physically
410 meaningful view of the circulation during the coastal-transition stage, when the storm
411 begins to experience spatially varying surface friction, moisture supply, and terrain
412 influences. The occurrence of middle- and lower-level vectors along peripheral cloud
413 bands also offers information on the flow approaching the coast and its connection with
414 the broader vortex. A sequence of such high-frequency fields could be used to examine
415 how the circulation deforms and reorganizes before and during landfall.

416 Overall, the three cases demonstrate that the MAMV fields contain physically
417 meaningful information on several key components of TC circulation. The upper-level
418 vectors over the central cloud shields describe the organization and spatial extent of the
419 circulation associated with deep convection and outflow, while the curved vector
420 patterns along the surrounding cloud bands reveal the connection between rainband-
421 scale flow and the broader cyclonic vortex. The pronounced quadrant-to-quadrant
422 differences in Matmo and the heterogeneous circulation across the coastal transition in
423 Chaba further show that the products retain important asymmetric structures rather than
424 representing the storms as azimuthally averaged vortices. These characteristics make
425 the dataset suitable for examining the evolution of upper-level outflow, vortex
426 asymmetry, spiral-rainband circulation, environmental-flow interaction, and circulation
427 adjustment during landfall.

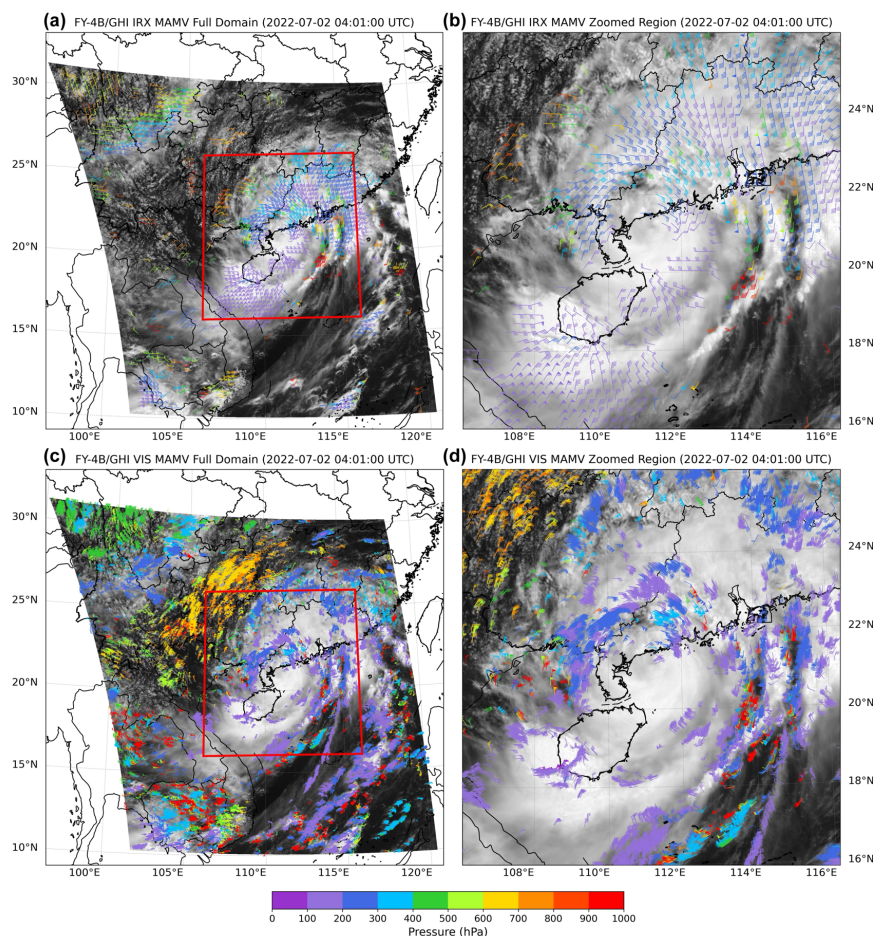


Figure 5. Same as Fig. 3, but for Typhoon Chaba at 04:01 UTC on 2 July 2022.

3.3 Validation reference datasets

Two high-quality reference datasets were used to evaluate the FY-4B/GHI MAMVs: operational radiosonde observations and ERA5 reanalysis winds. Radiosondes provide independent, vertically resolved wind measurements at discrete locations, whereas ERA5 provides spatially continuous three-dimensional wind fields across the full GHI observation domain. The two datasets therefore support complementary evaluations of local retrieval accuracy and domain-wide spatial consistency.



439 Radiosonde profiles from 15 upper-air stations over the South China Sea and
440 adjacent coastal regions were used as the primary independent reference (Fig. 1). Each
441 station is identified by its five-digit World Meteorological Organization (WMO) station
442 number. The observations generally comprise profiles of wind speed and direction
443 launched at the standard synoptic times of 00:00 and 12:00 UTC (Durre et al., 2016).
444 These measurements provide vertically resolved reference winds for evaluating
445 MAMVs at coastal and island stations, although their spatial coverage is limited and
446 individual soundings may drift horizontally during ascent. The locations of the selected
447 stations are shown in Fig. 1.

448 To extend the evaluation over oceanic regions with sparse radiosonde coverage,
449 hourly wind fields were obtained from the ERA5 pressure-level reanalysis produced by
450 the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA5 hourly
451 data on pressure levels were obtained from the Copernicus Climate Data Store
452 (Hersbach et al., 2023). The zonal and meridional wind components were used on a
453 $0.25^\circ \times 0.25^\circ$ latitude–longitude grid at 37 pressure levels between 1000 and 1 hPa.
454 ERA5 provides spatially and temporally continuous reference fields for assessing the
455 domain-wide consistency of the MAMVs.

456

457 **3.4 Spatiotemporal collocation and interpolation**

458 After applying the quality-screening criteria described in Section 3.1.4, the
459 MAMVs were collocated separately with radiosonde observations and ERA5 reanalysis
460 winds using criteria adapted to the temporal and spatial characteristics of each reference
461 dataset.

462 For the radiosonde comparison, MAMVs with retrieval times within ± 30 min of
463 the nominal sounding times at 00:00 and 12:00 UTC and locations within 25 km of a
464 radiosonde station were selected (Bedka et al., 2009). For each horizontally and
465 temporally matched MAMV, the nearest radiosonde observation in pressure was
466 identified, and the pair was retained when the absolute pressure difference did not
467 exceed 2 hPa. All MAMVs satisfying these criteria were included; consequently,
468 multiple MAMV vectors could be matched with the same radiosonde observation.



For the ERA5 comparison, only MAMV products with retrieval times within ± 10 min of an hourly ERA5 analysis time were selected. The hourly ERA5 zonal and meridional wind components on the $0.25^\circ \times 0.25^\circ$ grid and 37 pressure levels were then interpolated to the horizontal location and assigned pressure of each MAMV. Bilinear interpolation was first applied in the horizontal direction, followed by linear interpolation with respect to the logarithm of pressure in the vertical direction. The ERA5 field at the corresponding analysis hour was used without additional temporal interpolation.

3.5 Statistical evaluation metrics

Three statistical metrics were commonly used to quantify the agreement between the FY-4B/GHI MAMVs and the collocated reference winds: speed bias (SB), mean vector difference (MVD), and the standard deviation of vector differences (SD) (Etheridge et al., 2025). The subscript m denotes the MAMV, the subscript r denotes the corresponding radiosonde or ERA5 reference wind, and N is the total number of valid collocation pairs.

SB measures the mean difference between the MAMV and reference wind-speed magnitudes:

$$SB = \frac{1}{N} \sum_{i=1}^N (S_{m,i} - S_{r,i}), \quad (1)$$

where $S_{m,i}$ and $S_{r,i}$ are the wind-speed magnitudes of the i -th MAMV and reference wind, respectively. A positive SB indicates that the MAMVs are faster on average than the reference winds, whereas a negative value indicates that they are slower. Because positive and negative speed differences can offset each other, a SB close to zero does not necessarily indicate close vector agreement.

The vector difference for the i -th collocation is defined as:

$$VD_i = \sqrt{(u_{m,i} - u_{r,i})^2 + (v_{m,i} - v_{r,i})^2}, \quad (2)$$

where u and v are the zonal and meridional wind components. The MVD is then calculated as:

$$MVD = \frac{1}{N} \sum_{i=1}^N (VD_i), \quad (3)$$



MVD is always non-negative and summarizes differences in both wind speed and direction. The dispersion of the individual vector differences about the MVD is represented by

$$SD = \sqrt{\frac{1}{N} \sum_{i=1}^N (VD_i - MVD)^2}, \quad (4)$$

A smaller SD indicates that the magnitudes of the vector differences are more closely clustered around the MVD, whereas a larger SD indicates greater variability among the collocations. All three metrics are expressed in meters per second. Because radiosonde observations and ERA5 winds have their own measurement, sampling, and representativeness uncertainties, MVD and SD describe differences between the collocated datasets rather than errors attributable exclusively to the MAMV retrievals.

4 Results

4.1 Validation against radiosonde observations

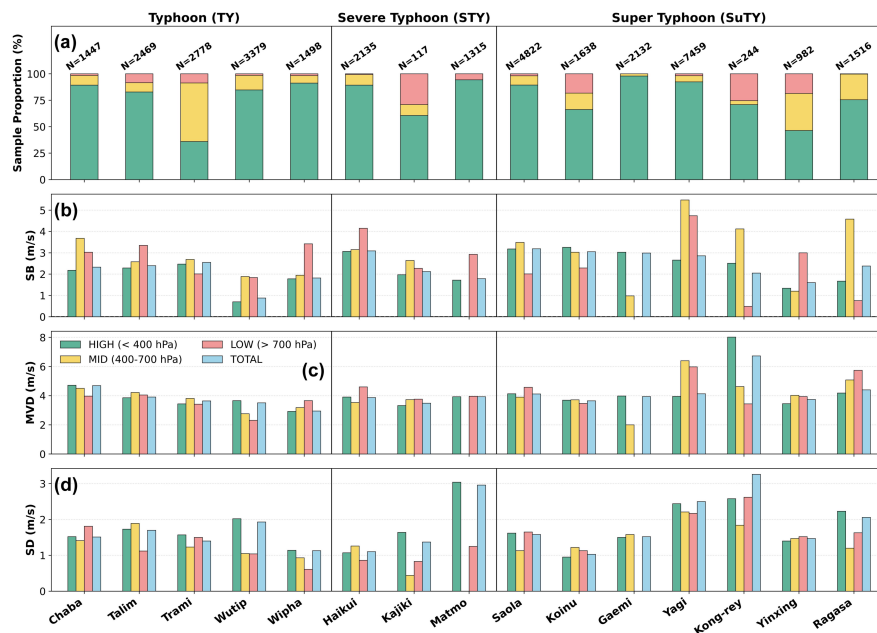
The 3 km VIS and 24 km IRX MAMVs were evaluated against radiosonde observations using the collocation procedure described in Section 3.4. The VIS evaluation used profiles at 00:00 UTC, whereas the IRX evaluation used profiles at both 00:00 and 12:00 UTC.

For the 3 km VIS product, 33,931 collocation pairs were obtained across all 15 cases. High-level matches below 400 hPa accounted for 82.3 % of the total (27,941 pairs), compared with 13.4 % at middle levels (4547 pairs) and 4.3 % at low levels (1443 pairs; Fig. 6a). High-level pairs constituted more than 80 % of the samples in nine cases and reached 97.9 % for Gaemi. The main exceptions were Trami, for which middle-level pairs accounted for 55.4 %, and Yinxing, which had 46.4 % high-, 35.0 % middle-, and 18.5 % low-level pairs. Kajiki and Kong-rey also had relatively large low-level fractions, although their total sample sizes were only 117 and 244. Total collocations ranged from 117 for Kajiki to 7459 for Yagi. The case-mean overall SB, MVD, and SD were 2.34, 4.05, and 1.77 m s⁻¹, respectively (Figs. 6b–6d). Overall SB was positive in every case, ranging from 0.88 m s⁻¹ for Wutip to 3.19 m s⁻¹ for Saola.



527 The layer-mean MVD values were similar, at 4.08, 3.96, and 4.06 m s^{-1} for the high,
 528 middle, and low levels, while the corresponding SD values were 1.76, 1.35, and
 529 1.41 m s^{-1} . When grouped by the maximum storm intensity attained during the GHI
 530 observation period, the group-mean VIS SB, MVD, and SD were 2.00, 3.74, and
 531 1.53 m s^{-1} for TY cases; 2.33, 3.76, and 1.81 m s^{-1} for STY cases; and 2.59, 4.39, and
 532 1.92 m s^{-1} for SuTY cases. Wipha had the smallest overall MVD (2.95 m s^{-1}), Koinu
 533 had the smallest SD (1.03 m s^{-1}), and Kong-rey had the largest MVD and SD (6.73 and
 534 3.26 m s^{-1}). Kong-rey's high-level MVD reached 8.02 m s^{-1} .

535



536

537 **Figure 6.** Validation of the 3 km VIS MAMVs against radiosonde observations at
 538 00:00 UTC for the 15 typhoon cases. (a) Vertical distribution of the collocation pairs at
 539 high (< 400 hPa), middle (400 – 700 hPa), and low (> 700 hPa) levels, with the total
 540 number of pairs (N) shown above each bar. (b) Speed bias (SB). (c) Mean vector
 541 difference (MVD). (d) Standard deviation of the vector differences (SD). The high-,
 542 middle-, low-, and all-level results are shown by the green, yellow, pink, and light-blue
 543 bars, respectively. Cases are grouped according to the maximum TC intensity attained
 544 during the corresponding GHI observation period.

545

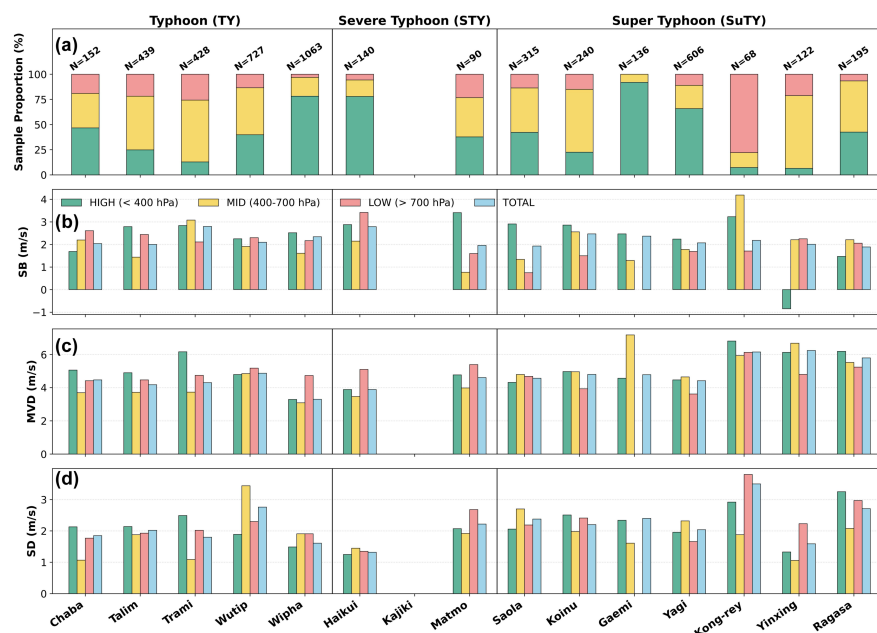


Figure 7. Same as Fig. 6, but for the 24 km IRX MAMVs evaluated against radiosonde observations at 00:00 and 12:00 UTC. Kajiki had no valid IRX–radiosonde collocations.

For the 24 km IRX product, 4721 collocation pairs were obtained from 14 cases; Kajiki had no valid matches. High-, middle-, and low-level pairs accounted for 48.8 % (2306), 37.7 % (1782), and 13.4 % (633) of the total, respectively (Fig. 7a). The vertical distributions varied considerably among cases. High-level pairs exceeded 75 % for Wipha, Haikui, and Gaemi, whereas middle-level pairs dominated for Talim, Trami, Koinu, and Yinxing. Kong-rey was dominated by low-level pairs (77.9 %) but included only 68 matches. Case totals ranged from 68 for Kong-rey to 1063 for Wipha. The case-mean overall SB, MVD, and SD were 2.21, 4.74, and 2.17 m s^{-1} , respectively (Figs. 7b–7d), and overall SB was positive in all valid cases. Layer-mean MVD values were 5.02, 4.73, and 4.80 m s^{-1} , with corresponding SD values of 2.13, 1.89, and 2.25 m s^{-1} . The group-mean overall IRX SB, MVD, and SD were 2.26, 4.22, and 2.01 m s^{-1} for TY; 2.38, 4.25, and 1.77 m s^{-1} for STY; and 2.13, 5.25, and 2.40 m s^{-1} for SuTY cases. Wipha had the smallest overall MVD (3.30 m s^{-1}), Haikui had the smallest SD (1.32 m s^{-1}), Yinxing had the largest MVD (6.24 m s^{-1}), and Kong-rey had the largest SD (3.50 m s^{-1}).



Overall, VIS was strongly dominated by upper-level matches, whereas IRX exhibited a more balanced but more case-dependent vertical distribution.

4.2 Validation against ERA5 reanalysis

The quality-screened 3 km VIS and 24 km IRX MAMVs were evaluated against ERA5 winds over the full GHI observation domains using the procedure described in Section 3.4. MAMVs retrieved within ± 10 min of each hourly ERA5 analysis time were retained, and ERA5 winds were interpolated to the location and assigned pressure of each MAMV.

For the 3 km VIS product, 84,951,709 daytime collocation pairs were obtained across the 15 cases. High-level pairs below 400 hPa accounted for 74.3 % of the total, while middle- and low-level pairs accounted for 15.4 % and 10.3 %, respectively (Fig. 8a). Case totals ranged from 2.50 million for Kong-rey to 12.13 million for Trami. High-level samples exceeded 70 % in 11 cases and were greater than 86 % for Wipha, Kajiki, and Matmo. Koinu and Yinxing had the most vertically distributed VIS samples: high-level pairs accounted for 47.3 % and 45.0 %, respectively, while their combined middle- and low-level fractions exceeded 50 %. The case-mean overall SB, MVD, and SD were 1.62, 5.57, and 4.63 m s^{-1} , respectively (Figs. 8b–8d). Overall SB was positive in all cases, ranging from 0.90 m s^{-1} for Wutip to 2.21 m s^{-1} for Kong-rey. The layer-mean SB values were 1.53, 1.50, and 2.18 m s^{-1} at high, middle, and low levels, respectively. The high- and middle-level MVD values were both 5.43 m s^{-1} , compared with 6.58 m s^{-1} at low levels. The group-mean overall VIS SB, MVD, and SD were 1.22, 5.48, and 4.48 m s^{-1} for TY cases; 1.71, 5.30, and 4.21 m s^{-1} for STY cases; and 1.86, 5.76, and 4.92 m s^{-1} for SuTY cases. Wutip had the smallest overall MVD (4.58 m s^{-1}), whereas Kong-rey had the largest value (6.92 m s^{-1}). Ragasa and Kong-rey had the two largest overall SD values, at 6.08 and 5.92 m s^{-1} , respectively.

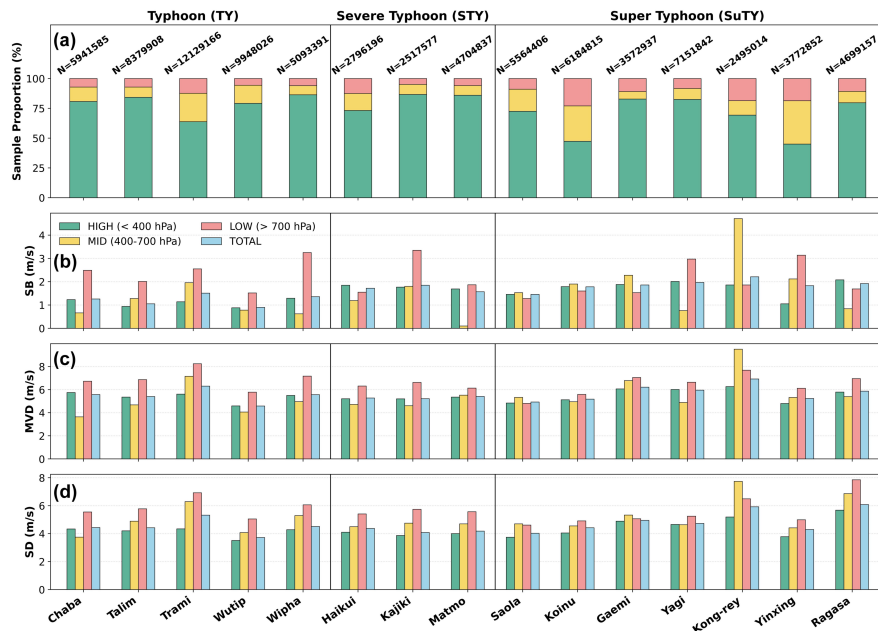


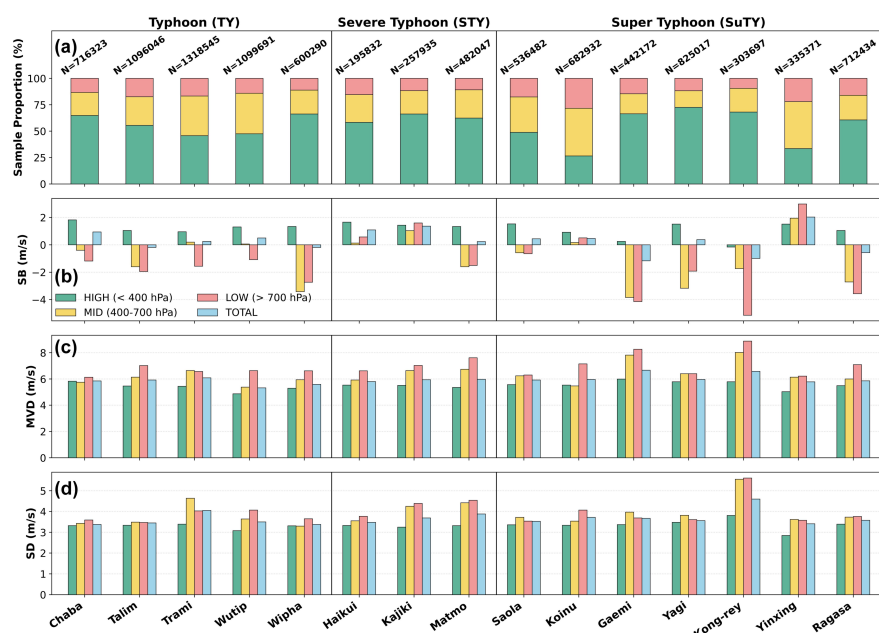
Figure 8. Case-level validation statistics for the 3 km VIS MAMVs against ERA5 winds. MAMVs retrieved within ± 10 min of hourly ERA5 analysis times between 00:00 and 09:00 UTC were included for each of the 15 tropical cyclone cases. (a) Vertical sample distribution represented as percentage distribution for high (below 400 hPa, green-blue), middle (400–700 hPa, yellow), and low (above 700 hPa, pink) levels, with the total number of matched samples (N) annotated above each bar. (b) Scalar speed bias (SB, m s^{-1}). (c) Mean vector difference (MVD, m s^{-1}). (d) Standard deviation (SD, m s^{-1}). In panels (b)–(d), the statistical metrics are illustrated as grouped vertical bars, where the green-blue, yellow, pink, and light blue bars denote the high, middle, low, and all-level results, respectively. The 15 typhoon cases are categorized and grouped according to the maximum intensity attained during the GHI observation period into Typhoon (TY), Severe Typhoon (STY), and Super Typhoon (SuTY) classes, separated by solid vertical lines at the top of the plot.

For the 24 km IRX product, 9,604,814 daytime and nighttime collocation pairs were obtained. High-, middle-, and low-level samples accounted for 54.8 %, 29.5 %, and 15.7 % of the total, respectively (Fig. 9a). Case totals ranged from 195,832 for Haikui to 1,318,545 for Trami. High-level samples exceeded 60 % in eight cases and reached 72.6 % for Yagi. Koinu and Yinxing had the largest middle-level fractions:



611 Koinu contained 26.5 % high-, 45.2 % middle-, and 28.3 % low-level pairs, while the
612 corresponding proportions for Yinxing were 33.6 %, 44.5 %, and 22.0 %. The case-
613 mean overall SB, MVD, and SD were 0.31, 5.95, and 3.66 m s⁻¹, respectively (Figs. 9b–
614 9d). Overall SB varied in sign among cases, ranging from −1.17 m s⁻¹ for Gaemi and
615 −0.99 m s⁻¹ for Kong-rey to 2.03 m s⁻¹ for Yinxing. Layer-mean SB was positive at high
616 levels (1.17 m s⁻¹) and negative at middle and low levels (−1.03 and −1.32 m s⁻¹). MVD
617 increased from 5.50 m s⁻¹ at high levels to 6.35 and 6.97 m s⁻¹ at middle and low levels,
618 while SD increased from 3.33 to 3.91 and 3.96 m s⁻¹. The group-mean overall IRX SB,
619 MVD, and SD were 0.26, 5.75, and 3.55 m s⁻¹ for TY; 0.90, 5.91, and 3.68 m s⁻¹ for
620 STY; and 0.08, 6.10, and 3.72 m s⁻¹ for SuTY cases. Wutip had the smallest overall
621 MVD (5.32 m s⁻¹), Gaemi had the largest MVD (6.67 m s⁻¹), and Kong-rey had the
622 largest SD (4.60 m s⁻¹). Overall, the VIS comparison showed consistently positive SB
623 and upper-level-dominated sampling, whereas IRX showed smaller overall SB, mixed
624 bias signs, and a more balanced vertical distribution.

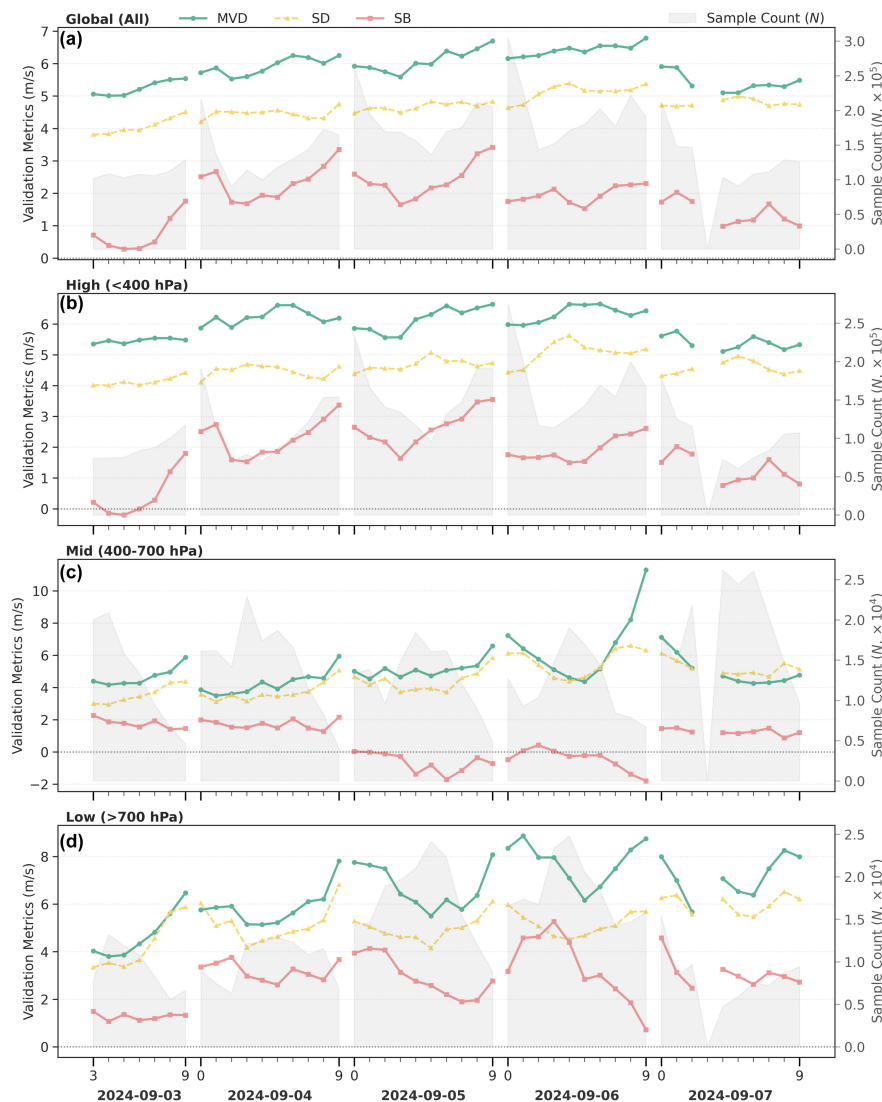
625



626
627 **Figure 9.** Same as Fig. 8, but for the 24 km IRX MAMVs evaluated using products
628 retrieved within ± 10 min of all 24 hourly ERA5 analysis times.



629



630

631 **Figure 10.** Hourly validation of the 3 km VIS MAMV product against collocated ERA5
 632 reanalysis winds for Super Typhoon Yagi from 3 to 7 September 2024. Results are
 633 shown for (a) all pressure levels, (b) high levels (<400 hPa), (c) middle levels (400–
 634 700 hPa), and (d) low levels (>700 hPa). The green solid lines with circles, yellow
 635 dashed lines with triangles, and pink solid lines with squares represent the mean vector
 636 difference (MVD), standard deviation of vector differences (SD), and speed bias (SB),
 637 respectively. The gray shaded areas indicate the number of matched wind-vector pairs,
 638 referenced to the right-hand axis. The horizontal dotted line denotes zero bias. Only



639 MAMVs retrieved within ± 10 min of hourly ERA5 analysis times from 00:00 to
 640 09:00 UTC are included.

641

642

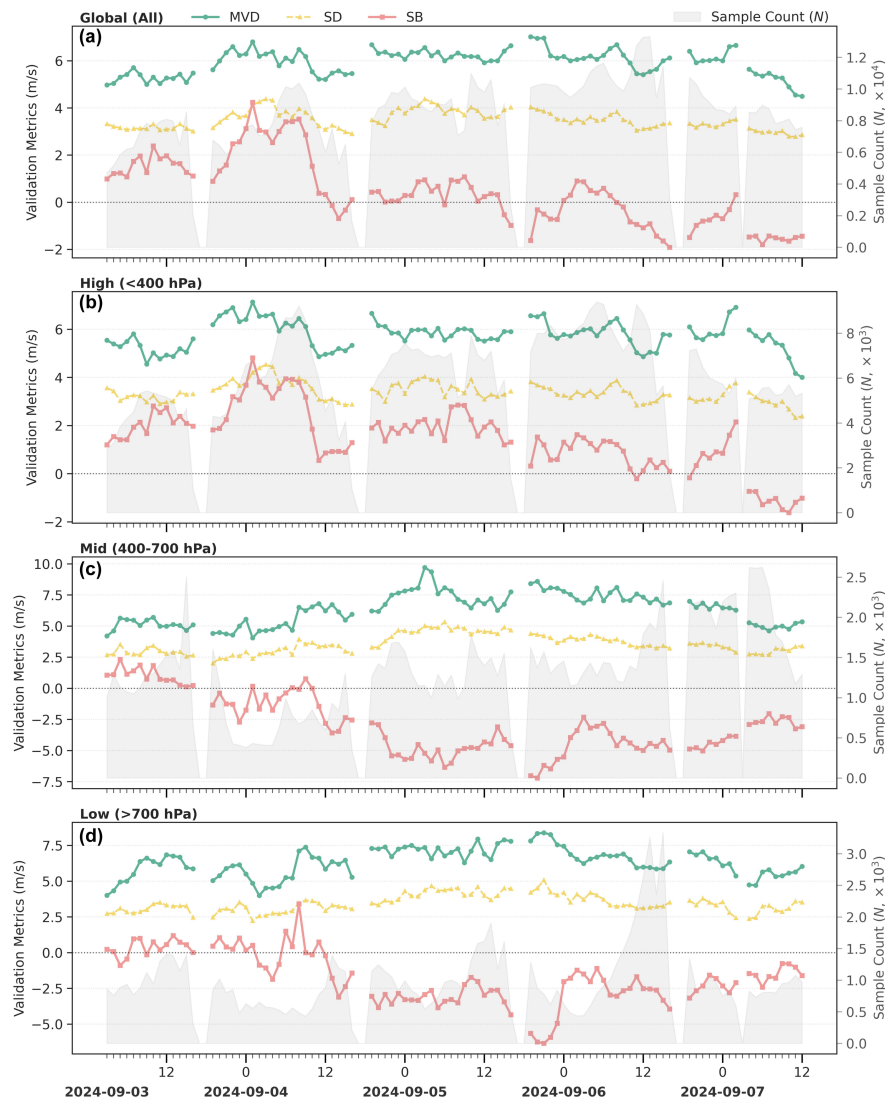
643 **4.3 Hourly evolution and temporal consistency of MAMV–ERA5 validation** 644 **metrics**

645 In addition to the cross-case evaluation presented in Section 4.2, the hourly
 646 evolution of the MAMV–ERA5 validation metrics was examined for Super Typhoon
 647 Yagi. Figures 10 and 11 show the hourly SB, MVD, SD, and number of collocation
 648 pairs for all pressure levels and for the high-, middle-, and low-level subsets. The
 649 corresponding results for the remaining typhoon cases are provided in the Supplement.
 650 Case-wide statistics were calculated from all valid collocation pairs over the complete
 651 Yagi observation period, whereas hourly values were calculated separately for each
 652 available ERA5 analysis time. Discontinuities in the time series indicate periods
 653 without valid collocations.

654 For the 3 km VIS product, the case-wide SB, MVD, and SD were 1.97, 5.96, and
 655 4.73 m s^{-1} , respectively. The hourly overall MVD ranged from 5.01 to 6.79 m s^{-1} , while
 656 SD ranged from 3.81 to 5.39 m s^{-1} (Fig. 10a). The overall SB remained positive
 657 throughout the available daytime periods and varied between 0.28 and 3.42 m s^{-1} . High-
 658 level samples accounted for the largest proportion of the VIS collocations and therefore
 659 dominated the all-level statistics. The high-level MVD and SD time series varied within
 660 comparatively narrow ranges, whereas the middle- and low-level subsets showed larger
 661 short-term fluctuations and more frequent changes in sample size. The largest middle-
 662 level VIS MVD was 11.30 m s^{-1} at 09:00 UTC on 6 September. At this time, 6715
 663 middle-level collocation pairs were available, compared with 167,803 high-level pairs.
 664 The increase was confined to this period and was not accompanied by a persistent
 665 increase in the all-level MVD. The low-level time series also contained several short-
 666 duration increases in MVD and SD, but these changes occurred when substantially
 667 fewer collocation pairs were available than at high levels. Across the complete Yagi
 668 period, the all-level VIS MVD and SD did not show a sustained upward or downward



669 trend.
 670



671
 672 **Figure 11.** Hourly validation of the 24 km IRX MAMV product against collocated
 673 ERA5 reanalysis winds for Super Typhoon Yagi from 3 to 7 September 2024. Results
 674 are presented for (a) all pressure levels, (b) high levels (<400 hPa), (c) middle levels
 675 (400–700 hPa), and (d) low levels (>700 hPa). The green solid lines with circles, yellow
 676 dashed lines with triangles, and pink solid lines with squares denote the mean vector
 677 difference (MVD), standard deviation of vector differences (SD), and speed bias (SB),



678 respectively. The gray shaded areas represent the number of matched wind-vector pairs,
 679 referenced to the right-hand axis, and the horizontal dotted line indicates zero bias.
 680 Discontinuities indicate periods without valid MAMV retrievals, primarily due to
 681 missing GHI observations or shifts in the observation domain, because the retrieval
 682 requires three consecutive images covering the same region. MAMVs retrieved within
 683 ± 10 min of all 24 hourly ERA5 analysis times are included.

684

685 For the 24 km IRX product, the case-wide SB, MVD, and SD were 0.38, 5.96, and
 686 3.56 m s^{-1} , respectively. The hourly overall MVD ranged from 4.49 to 7.02 m s^{-1} , and
 687 SD ranged from 2.78 to 4.38 m s^{-1} over the day-and-night observation period (Fig. 11a).
 688 In contrast to the consistently positive VIS SB, the hourly overall IRX SB varied
 689 between -1.91 and 4.24 m s^{-1} . Positive values occurred more frequently during the
 690 earlier part of the observation period, whereas negative values occurred more frequently
 691 during the later part. The case-wide IRX SB differed among atmospheric layers. It was
 692 1.52 m s^{-1} at high levels and -3.17 and -1.92 m s^{-1} at middle and low levels,
 693 respectively. The corresponding case-wide MVD values were 5.79 m s^{-1} at high levels
 694 and 6.40 m s^{-1} at both middle and low levels. The high-level subset contained the largest
 695 number of collocation pairs for most hours and showed relatively continuous temporal
 696 coverage. Middle- and low-level metrics exhibited greater hour-to-hour variability,
 697 together with larger changes in collocation number. Despite changes in the sign and
 698 magnitude of SB, the all-level IRX MVD and SD remained within limited ranges
 699 throughout the available observation period.

700 Overall, neither product showed a persistent increase in all-level MVD or SD
 701 during the Yagi observation period. The VIS product maintained positive hourly SB and
 702 was dominated by high-level collocations, while the IRX product provided day-and-
 703 night coverage and showed contrasting SB signs among atmospheric layers. The hourly
 704 evaluations for the other typhoon cases in the Supplement likewise show case-
 705 dependent fluctuations without a common pattern of sustained degradation in MVD or
 706 SD.

707

708 5 Discussion



709 The radiosonde and ERA5 comparisons provide complementary evidence for the
 710 reliability of the FY-4B/GHI MAMVs while demonstrating that their enhanced spatial
 711 and temporal sampling is retained across multiple TC cases. Radiosondes provide
 712 independent, vertically resolved measurements but are confined to a limited number of
 713 coastal and island stations and to standard launch times. ERA5 extends the comparison
 714 across the full observation domain and throughout the diurnal cycle, but its hourly fields
 715 cannot represent all mesoscale variability sampled by rapid-scan observations. Against
 716 both references, the VIS and IRX products maintained generally low SB, MVD, and
 717 SD values across the selected storms and atmospheric layers. The hourly evaluation
 718 further showed that MVD and SD remained within comparatively constrained ranges
 719 during Super Typhoon Yagi, with no persistent degradation evident in the other cases
 720 presented in the Supplement. These results indicate that frequent retrieval does not
 721 produce a progressive loss of consistency during multi-day observations. The two
 722 products also provide complementary physical coverage: the 3 km VIS winds densely
 723 sample the daytime upper-tropospheric circulation associated with deep convection and
 724 cirrus outflow, whereas the 24 km IRX winds maintain day-and-night coverage and
 725 provide a larger relative contribution from the middle and lower troposphere. MAMVs
 726 therefore complement conventional observations by filling spatial gaps between
 727 radiosonde stations and documenting circulation changes between sounding launches
 728 and hourly analysis times.

729 The principal scientific value of this enhanced sampling is its ability to describe
 730 TC wind structures that evolve rapidly and vary strongly with radius, azimuth, and
 731 height. Dense VIS vectors can depict variations in upper-level flow around the central
 732 cloud shield, including the organization and asymmetry of outflow, while sequential
 733 VIS and IRX fields can follow changes in the inner-core cloud system, spiral rainbands,
 734 peripheral circulation, and surrounding environmental flow. Such observations are
 735 relevant to TC motion and intensity because environmental steering controls storm
 736 translation, while the organization of the vortex, rainbands, and upper-level outflow is
 737 closely connected to structural and convective evolution. The increasingly positive
 738 VIS–ERA5 SB from TY to SuTY cases may be consistent with MAMVs retaining



739 localized strong-wind signals and sharper gradients that are partly smoothed in coarser
 740 reanalysis fields. Previous studies have shown that reanalysis tend to underrepresent
 741 TC intensity and that ERA5 wind-speed underestimation can become larger for stronger
 742 storms (Hodges et al., 2017; Han et al., 2022; Li et al., 2024; Liu et al., 2025; Malakar
 743 et al., 2020). This interpretation should remain cautious because the intensity groups
 744 are based on the maximum intensity attained during each GHI observation window
 745 rather than the instantaneous intensity of every collocation. Nevertheless, useful
 746 agreement with established references is retained even for intense and structurally
 747 complex storms. In operational applications, frequently updated MAMVs could
 748 strengthen real-time situational awareness, provide additional constraints on
 749 environmental steering and vortex-scale circulation, and identify short-lived structural
 750 adjustments before they are represented in conventional observing cycles. They also
 751 provide spatially distributed winds for model evaluation, vortex initialization, forecast
 752 verification, and data assimilation. Previous FY-4B/GHI assimilation experiments (Xia
 753 et al., 2025) have already demonstrated improvements in analyzed dynamical fields and
 754 TC track forecasts, suggesting that systematically processed multi-case MAMVs could
 755 provide important additional constraints for future TC track, structure, and intensity
 756 prediction.

757 Several limitations define the appropriate use of the dataset. The 15 storms were
 758 selected from available FY-4B/GHI rapid-scan campaigns and therefore represent a
 759 curated collection rather than a complete climatological record of western North Pacific
 760 and SCS TCs. MAMVs describe the displacement of trackable cloud features and
 761 cannot provide winds in clear-sky regions or beneath optically thick upper clouds.
 762 Consequently, central cloud shields are sampled predominantly at upper levels, while
 763 middle- and lower-level information depends more strongly on peripheral or broken
 764 cloud features. VIS observations are restricted to daylight, whereas IRX provides
 765 continuous temporal coverage at a coarser nominal vector spacing. The assigned
 766 pressure represents the atmospheric level associated with the tracked cloud feature, and
 767 uncertainty remains in multilayer clouds and regions of strong vertical shear; height
 768 assignment is a well-established source of AMV uncertainty (Borde et al., 2014; Posselt



et al., 2019; Velden and Bedka, 2009). The reference datasets also impose constraints: radiosonde comparisons are geographically concentrated near islands and coastlines, while ERA5 cannot independently represent all mesoscale wind variability. Future work should expand the range of storms, lifecycle stages, seasons, and environmental regimes; develop vector-level and pressure-dependent uncertainty information; incorporate additional independent wind observations where available; and conduct systematic observing-system and forecast experiments. These steps are needed to quantify how the demonstrated spatial coverage, high update frequency, and temporal consistency translate into improvements in TC track, intensity, and structural prediction. It worth noting that with upcoming GHI observations for TC, the MAMVs will be produced in near real-time, and the new datasets will be added to expand the MAMV data record to support TC studies.

6 Data availability

The 24 km FY-4B/GHI IRX MAMV dataset of 2022–2025 is available at <https://doi.org/10.5281/zenodo.22790846>; The 3 km FY-4B/GHI VIS MAMV dataset of 2022–2023 is available at <https://doi.org/10.5281/zenodo.22791421>; The 3 km FY-4B/GHI VIS MAMV dataset of 2024 is available at <https://doi.org/10.5281/zenodo.22791444>; The 3 km FY-4B/GHI VIS MAMV dataset of 2025 is available at <https://doi.org/10.5281/zenodo.22791469> (Xia et al., 2026a, b, c, d). The relevant data descriptions and usage instructions are attached herein.

7 Conclusion

This study presents a consistently processed FY-4B/GHI MAMV dataset for 15 tropical cyclones over the western North Pacific and South China Sea during 2022–2025. It combines 3 km daytime VIS winds with 24 km day-and-night IRX winds, with four stable products generated during each recurring 10 min observation cycle. Representative fields show physically coherent cloud-motion wind structures



798 associated with upper-level outflow, spiral rainbands, vortex asymmetry, peripheral
799 circulation, and coastal-transition processes. Validation against radiosonde
800 observations and ERA5 reanalysis demonstrates generally consistent wind-speed and
801 vector agreement across the selected cases. The hourly evaluations further show that
802 MVD and SD remained within constrained ranges, without a common pattern of
803 sustained degradation during the available multi-day observation periods. These results
804 support the reliability and temporal consistency of the quality-screened MAMVs.

805 The principal contribution of the dataset lies in its combination of dense spatial
806 sampling and frequent temporal updates. VIS MAMVs provide detailed daytime
807 sampling of upper-tropospheric cloud-motion winds, whereas IRX MAMVs extend
808 coverage through the night and offer a more balanced vertical distribution. Together,
809 the two products complement spatially sparse radiosonde profiles and hourly reanalysis
810 fields by documenting circulation changes between conventional observation times.
811 The dataset supports studies of TC structural evolution, upper-level outflow, rainband–
812 vortex interaction, environmental steering, circulation asymmetry, and landfall-related
813 changes, while also providing spatially distributed winds for model evaluation, forecast
814 verification, data assimilation, and observing-system experiments. The released
815 products retain the original wind vectors, vertical assignments, correlation coefficients,
816 and quality indicators, enabling users to construct application-specific subsets and
817 apply alternative quality-control strategies. The dataset therefore serves as a reusable
818 observational resource for TC monitoring, rapid-scan satellite-wind research, and the
819 development and evaluation of numerical and machine-learning prediction systems.

820

821 **Supplement**

822 The supplementary materials for this article can be obtained from the submission
823 file.

824

825 **Author contributions**

826 P.X., M.M., and J.L. conceptualized the study and designed the experiments. P.X.
827 conducted the experiments, analyzed the results, and prepared the original manuscript.



828 M.M. reviewed and revised the manuscript. N.X., D.D., Y.L., G.W., Z.L., and Y.C.
829 assisted with the acquisition and preprocessing of the original data. All authors
830 reviewed and approved the final manuscript.

831

832 **Competing interests**

833 The authors declare no competing interests.

834

835 **Declaration of AI-assisted Technologies**

836 During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to
837 assist with English-language editing and to improve the clarity and readability of the
838 text. All AI-generated suggestions were critically reviewed and revised by the authors,
839 who take full responsibility for the accuracy and integrity of the final manuscript. The
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841 interpretation, conclusions, or authorship.

842

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865 **References**

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867 Bauer, P., Thorpe, A., and Brunet, G.: The quiet revolution of numerical weather
 868 prediction, *Nature*, 525, 47–55, <https://doi.org/10.1038/nature14956>, 2015.

869 Bedka, K. M., Velden, C. S., Petersen, R. A., Feltz, W. F., and Mecikalski, J. R.:
 870 Comparisons of satellite-derived atmospheric motion vectors, rawinsondes, and
 871 NOAA wind profiler observations, *J. Appl. Meteorol. Clim.*, 48, 1542–1561,
 872 <https://doi.org/10.1175/2009JAMC1867.1>, 2009.

873 Berger, H., Langland, R., Velden, C. S., Reynolds, C. A., and Pauley, P. M.: Impact of
 874 enhanced satellite-derived atmospheric motion vector observations on numerical
 875 tropical cyclone track forecasts in the western North Pacific during TPARC/TCS-
 876 08, *J. Appl. Meteorol. Clim.*, 50, 2309–2318, [https://doi.org/10.1175/JAMC-D-11-](https://doi.org/10.1175/JAMC-D-11-019.1)
 877 019.1, 2011.

878 Bessho, K., Date, K., Hayashi, M., Ikeda, A., Imai, T., Inoue, H., Kumagai, Y.,
 879 Miyakawa, T., Murata, H., Ohno, T., Oyama, R., Sasaki, Y., Shimazu, Y., Shimoji,
 880 K., Sumida, Y., Suzuki, M., Taniguchi, H., Tsuchiyama, H., Uesawa, D., Yokota,
 881 H., and Yoshida, R.: An introduction to Himawari-8/9—Japan’s new-generation
 882 geostationary meteorological satellites, *J. Meteorol. Soc. Jpn.*, 94, 151–183,
 883 <https://doi.org/10.2151/jmsj.2016-009>, 2016.

884 Borde, R., Doutriaux-Boucher, M., Dew, G., and Carranza, M.: A direct link between
 885 feature tracking and height assignment of operational EUMETSAT atmospheric
 886 motion vectors, *J. Atmos. Oceanic Technol.*, 31, 33–46,
 887 <https://doi.org/10.1175/JTECH-D-13-00126.1>, 2014.



- 888 Carrassi, A., Bocquet, M., Bertino, L., and Evensen, G.: Data assimilation in the
 889 geosciences: an overview of methods, issues, and perspectives, *WIREs Clim.*
 890 *Change*, 9, e535, <https://doi.org/10.1002/wcc.535>, 2018.
- 891 Chavas, D. R., Reed, K. A., and Knaff, J. A.: Physical understanding of the tropical
 892 cyclone wind–pressure relationship, *Nat. Commun.*, 8, 1360,
 893 <https://doi.org/10.1038/s41467-017-01546-9>, 2017.
- 894 Daniels, J., Bresky, W., Bailey, A., Allegrino, A., Wanzong, S., Velden, C., and Berger,
 895 H.: Enterprise Algorithm Theoretical Basis Document for Derived Motion Winds,
 896 Version 4.4, NOAA/NESDIS Center for Satellite Applications and Research,
 897 November 2025, available at:
 898 https://www.star.nesdis.noaa.gov/goesr/documents/ATBDs/Enterprise/ATBD_Enterprise_Derived_Motion_Winds_v4.4_2025_11_01.pdf, last access: 21 July 2026,
 899 2025.
- 901 Durre, I., Yin, X., Vose, R. S., Applequist, S., Arnfield, J., Korzeniewski, B., and
 902 Hundermark, B.: Integrated Global Radiosonde Archive (IGRA), Version 2,
 903 NOAA National Centers for Environmental Information [data set],
 904 <https://doi.org/10.7289/V5X63K0Q>, last access: 21 July 2026, 2016.
- 905 Etheridge, D., Cotton, J., Dahoui, M., Volkandt, M., and Forsythe, M.: NWP SAF
 906 AMV monitoring: the 11th Analysis Report (AR11), NWP SAF Technical Report
 907 NWPSAF-MO-TR-044, Version 1.0, Numerical Weather Prediction Satellite
 908 Application Facility, 26 March 2025, available at: https://nwpsaf.eumetsat.int/monitoring/amv/nwpsaf_mo_tr_044.pdf, last access: 21 July
 909 2026, 2025.
- 911 EUMETSAT: MTG FCI Level 2 Atmospheric Motion Vector (AMV) data guide,
 912 Version 1.1, European Organisation for the Exploitation of Meteorological
 913 Satellites, 12 January 2026, available at: <https://user.eumetsat.int/resources/user-guides/mtg-fci-l2-amv-data-guide>, last access: 21 July 2026, 2026.
- 915 Eyre, J. R., English, S. J., and Forsythe, M.: Assimilation of satellite data in numerical
 916 weather prediction. Part I: the early years, *Q. J. Roy. Meteor. Soc.*, 146, 49–68,
 917 <https://doi.org/10.1002/qj.3654>, 2020.



- 1918 Eyre, J. R., Bell, W., Cotton, J., English, S. J., Forsythe, M., Healy, S. B., and Pavelin,
 1919 E. G.: Assimilation of satellite data in numerical weather prediction. Part II: recent
 1920 years, *Q. J. Roy. Meteor. Soc.*, 148, 521–556, <https://doi.org/10.1002/qj.4228>,
 1921 2022.
- 1922 Gori, A., Lin, N., Xi, D., and Emanuel, K.: Tropical cyclone climatology change greatly
 1923 exacerbates US extreme rainfall–surge hazard, *Nat. Clim. Change*, 12, 171–178,
 1924 <https://doi.org/10.1038/s41558-021-01272-7>, 2022.
- 1925 Han, Z., Yue, C., Liu, C., Gu, W., Tang, Y., and Li, Y.: Evaluation on the applicability
 1926 of ERA5 reanalysis dataset to tropical cyclones affecting Shanghai, *Front. Earth*
 1927 *Sci.*, 16, 1025–1039, <https://doi.org/10.1007/s11707-022-0972-7>, 2022.
- 1928 Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J.,
 1929 Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C.,
 1930 Dee, D., and Thépaut, J.-N.: ERA5 hourly data on pressure levels from 1940 to
 1931 present, Copernicus Climate Change Service (C3S) Climate Data Store (CDS)
 1932 [data set], <https://doi.org/10.24381/cds.bd0915c6>, last access: 21 July 2026, 2023.
- 1933 Hodges, K., Cobb, A., and Vidale, P. L.: How well are tropical cyclones represented in
 1934 reanalysis datasets?, *J. Climate*, 30, 5243–5264, [https://doi.org/10.1175/JCLI-D-](https://doi.org/10.1175/JCLI-D-16-0557.1)
 1935 16-0557.1, 2017.
- 1936 Joint Typhoon Warning Center (JTWC): Tropical Cyclone Best Track Data, Joint
 1937 Typhoon Warning Center, available at:
 1938 <https://www.metoc.navy.mil/jtwc/jtwc.html>, last access: 21 July 2026, 2026.
- 1939 Kam, P. M., Ciccone, F., Kropf, C. M., Riedel, L., Fairless, C., and Bresch, D. N.:
 1940 Impact-based forecasting of tropical cyclone-related human displacement to
 1941 support anticipatory action, *Nat. Commun.*, 15, 8795,
 1942 <https://doi.org/10.1038/s41467-024-53200-w>, 2024.
- 1943 Leese, J. A., Novak, C. S., and Clark, B. B.: An automated technique for obtaining cloud
 1944 motion from geosynchronous satellite data using cross correlation, *J. Appl.*
 1945 *Meteorol.*, 10, 118–132, [https://doi.org/10.1175/1520-](https://doi.org/10.1175/1520-0450(1971)010<0118:AATFOC>2.0.CO;2)
 1946 0450(1971)010<0118:AATFOC>2.0.CO;2, 1971.
- 1947 Li, J., Li, J., Velden, C., Wang, P., Schmit, T. J., and Sippel, J.: Impact of rapid-scan-



- 948 based dynamical information from GOES-16 on HWRF hurricane forecasts, J.
 949 Geophys. Res.-Atmos., 125, e2019JD031647,
 950 https://doi.org/10.1029/2019JD031647, 2020.
- 951 Li, J., Tian, Q., Shen, Z., Xu, Y., Yan, Z., Li, M., Zhu, C., Xue, J., Lin, Z., Yang, Y., and
 952 Zeng, L.: Fidelity of global tropical cyclone activity in a new reanalysis dataset
 953 (CRA40), Meteorol. Appl., 31, e70009, https://doi.org/10.1002/met.70009, 2024.
- 954 Lin, K.-J., Yang, S.-C., and Chen, S. S.: Improving analysis and prediction of tropical
 955 cyclones by assimilating radar and GNSS-R wind observations: ensemble data
 956 assimilation and observing system simulation experiments using a coupled
 957 atmosphere–ocean model, Weather Forecast., 37, 1533–1552,
 958 https://doi.org/10.1175/WAF-D-21-0202.1, 2022.
- 959 Lin, Y., Zhao, M., and Zhang, M.: Tropical cyclone rainfall area controlled by relative
 960 sea surface temperature, Nat. Commun., 6, 6591,
 961 https://doi.org/10.1038/ncomms7591, 2015.
- 962 Liu, G., Jiang, S., Zheng, M., Lin, S., Kong, Y., and Zhan, P.: A global ERA5-based
 963 tropical cyclone wind field dataset enhanced by integrated parametric correction
 964 methods, Sci. Data, 12, 1429, https://doi.org/10.1038/s41597-025-05789-w, 2025.
- 965 Magee, A. D., Kiem, A. S., and Chan, J. C. L.: A new approach for location-specific
 966 seasonal outlooks of typhoon and super typhoon frequency across the western
 967 North Pacific region, Sci. Rep., 11, 19439, https://doi.org/10.1038/s41598-021-
 968 98329-6, 2021.
- 969 Magnusson, L., Bidlot, J.-R., Bonavita, M., Brown, A. R., Browne, P. A., De Chiara,
 970 G., Dahoui, M., Lang, S. T. K., McNally, T., Mogensen, K. S., Pappenberger, F.,
 971 Prates, F., Rabier, F., Richardson, D. S., Vitart, F., and Malardel, S.: ECMWF
 972 activities for improved hurricane forecasts, B. Am. Meteorol. Soc., 100, 445–458,
 973 https://doi.org/10.1175/BAMS-D-18-0044.1, 2019.
- 974 Malakar, P., Kesarkar, A. P., Bhate, J. N., Singh, V., and Deshamukhya, A.: Comparison
 975 of reanalysis data sets to comprehend the evolution of tropical cyclones over North
 976 Indian Ocean, Earth Space Sci., 7, e2019EA000978,
 977 https://doi.org/10.1029/2019EA000978, 2020.



- 978 Min, M., Li, J., Wang, F., Liu, Z., and Menzel, W. P.: Retrieval of cloud top properties
 979 from advanced geostationary satellite imager measurements based on machine
 980 learning algorithms, *Remote Sens. Environ.*, 239, 111616,
 981 <https://doi.org/10.1016/j.rse.2019.111616>, 2020.
- 982 Min, M., Chen, B., Xu, N., He, X., Wei, X., and Wang, M.: Nonnegligible diurnal and
 983 long-term variation characteristics of the calibration biases in Fengyun-4A/AGRI
 984 infrared channels based on oceanic drifter data, *IEEE T. Geosci. Remote Sens.*, 60,
 985 5408415, <https://doi.org/10.1109/TGRS.2022.3160450>, 2022.
- 986 Morss, R. E., Cuite, C. L., and Demuth, J. L.: What predicts hurricane evacuation
 987 decisions? The importance of efficacy beliefs, risk perceptions, and other factors,
 988 *npj Nat. Hazards*, 1, 24, <https://doi.org/10.1038/s44304-024-00025-8>, 2024.
- 989 National Satellite Meteorological Center (NSMC): FY-4B Satellite, China
 990 Meteorological Administration, available at:
 991 <https://www.nsmc.org.cn/nsmc/en/satellite/FY4B.html>, last access: 21 July 2026,
 992 2026.
- 993 Oyama, R., Sawada, M., and Shimoji, K.: Diagnosis of tropical cyclone intensity and
 994 structure using upper-tropospheric atmospheric motion vectors, *J. Meteorol. Soc.*
 995 *Jpn.*, 96B, 3–26, <https://doi.org/10.2151/jmsj.2017-024>, 2018.
- 996 Peduzzi, P., Chatenoux, B., Dao, H., De Bono, A., Herold, C., Kossin, J., Mouton, F.,
 997 and Nordbeck, O.: Global trends in tropical cyclone risk, *Nat. Clim. Change*, 2,
 998 289–294, <https://doi.org/10.1038/nclimate1410>, 2012.
- 999 Posselt, D. J., Wu, L., Mueller, K., Huang, L., Irion, F. W., Brown, S., Su, H., Santek,
 1000 D., and Velden, C. S.: Quantitative assessment of state-dependent atmospheric
 1001 motion vector uncertainties, *J. Appl. Meteorol. Clim.*, 58, 2479–2495,
 1002 <https://doi.org/10.1175/JAMC-D-19-0166.1>, 2019.
- 1003 Sawada, M., Ma, Z., Mehra, A., Tallapragada, V., Oyama, R., and Shimoji, K.: Impacts
 1004 of assimilating high-resolution atmospheric motion vectors derived from
 1005 Himawari-8 on tropical cyclone forecast in HWRF, *Mon. Weather Rev.*, 147,
 1006 3721–3740, <https://doi.org/10.1175/MWR-D-18-0261.1>, 2019.
- 1007 Sawada, M., Ma, Z., Mehra, A., Tallapragada, V., Oyama, R., and Shimoji, K.:



- 1008 Assimilation of Himawari-8 rapid-scan atmospheric motion vectors on tropical
1009 cyclone in the HWRF system, *Atmosphere*, 11, 601,
1010 <https://doi.org/10.3390/atmos11060601>, 2020.
- 1011 Schmit, T. J., Griffith, P., Gunshor, M. M., Daniels, J. M., Goodman, S. J., and Lebar,
1012 W. J.: A closer look at the ABI on the GOES-R series, *B. Am. Meteorol. Soc.*, 98,
1013 681–698, <https://doi.org/10.1175/BAMS-D-15-00230.1>, 2017.
- 1014 Stoffelen, A., Benedetti, A., Borde, R., Dabas, A., Flamant, P., Forsythe, M., Hardesty,
1015 M., Isaksen, L., Källén, E., Körnich, H., Lee, T., Reitebuch, O., Rennie, M.,
1016 Riishøjgaard, L.-P., Schyberg, H., Straume, A. G., and Vaughan, M.: Wind profile
1017 satellite observation requirements and capabilities, *B. Am. Meteorol. Soc.*, 101,
1018 E2005–E2021, <https://doi.org/10.1175/BAMS-D-18-0202.1>, 2020.
- 1019 Su, H., Wu, L., Jiang, J. H., Pai, R., Liu, A., Zhai, A. J., Tavallali, P., and DeMaria, M.:
1020 Applying satellite observations of tropical cyclone internal structures to rapid
1021 intensification forecast with machine learning, *Geophys. Res. Lett.*, 47,
1022 e2020GL089102, <https://doi.org/10.1029/2020GL089102>, 2020.
- 1023 Tran, T. L., Ritchie, E. A., and Perkins-Kirkpatrick, S. E.: A 50-year tropical cyclone
1024 exposure climatology in Southeast Asia, *J. Geophys. Res.-Atmos.*, 127,
1025 e2021JD036301, <https://doi.org/10.1029/2021JD036301>, 2022.
- 1026 Velden, C., Daniels, J., Stettner, D., Santek, D., Key, J., Dunion, J., Holmlund, K.,
1027 Dengel, G., Bresky, W., and Menzel, P.: Recent innovations in deriving
1028 tropospheric winds from meteorological satellites, *B. Am. Meteorol. Soc.*, 86,
1029 205–224, <https://doi.org/10.1175/BAMS-86-2-205>, 2005.
- 1030 Velden, C. S. and Bedka, K. M.: Identifying the uncertainty in determining satellite-
1031 derived atmospheric motion vector height attribution, *J. Appl. Meteorol. Clim.*, 48,
1032 450–463, <https://doi.org/10.1175/2008JAMC1957.1>, 2009.
- 1033 Velden, C., Lewis, W. E., Bresky, W., Stettner, D., Daniels, J., and Wanzong, S.:
1034 Assimilation of high-resolution satellite-derived atmospheric motion vectors:
1035 impact on HWRF forecasts of tropical cyclone track and intensity, *Mon. Weather*
1036 *Rev.*, 145, 1107–1125, <https://doi.org/10.1175/MWR-D-16-0229.1>, 2017.
- 1037 Verschuur, J., Koks, E. E., and Hall, J. W.: Systemic risks from climate-related



- 1038 disruptions at ports, *Nat. Clim. Change*, 13, 804–806,
 1039 <https://doi.org/10.1038/s41558-023-01754-w>, 2023.
- 1040 World Meteorological Organization (WMO): Tropical cyclone, available at:
 1041 <https://wmo.int/themes/tropical-cyclone>, last access: 21 July 2026, 2025.
- 1042 Wu, T.-C., Liu, H., Majumdar, S. J., Velden, C. S., and Anderson, J. L.: Influence of
 1043 assimilating satellite-derived atmospheric motion vector observations on
 1044 numerical analyses and forecasts of tropical cyclone track and intensity, *Mon.*
 1045 *Weather Rev.*, 142, 49–71, <https://doi.org/10.1175/MWR-D-13-00023.1>, 2014.
- 1046 Wu, T.-C., Velden, C. S., Majumdar, S. J., Liu, H., and Anderson, J. L.: Understanding
 1047 the influence of assimilating subsets of enhanced atmospheric motion vectors on
 1048 numerical analyses and forecasts of tropical cyclone track and intensity with an
 1049 ensemble Kalman filter, *Mon. Weather Rev.*, 143, 2506–2531,
 1050 <https://doi.org/10.1175/MWR-D-14-00220.1>, 2015.
- 1051 Xia, P., Min, M., Li, J., Xu, N., Zhang, X., Zhou, R., Wang, Z., Li, B., and Liu, Y.-A.:
 1052 Minute-scale and mesoscale atmospheric motion vectors retrieved from Fengyun-
 1053 4B geostationary satellite High-Speed Imager measurements, *IEEE T. Geosci.*
 1054 *Remote Sens.*, 62, 4110016, <https://doi.org/10.1109/TGRS.2024.3461733>, 2024.
- 1055 Xia, P. and Min, M.: FY-4B/GHI Minute-scale and Mesoscale Atmospheric Motion
 1056 Vector Dataset (2000 m, 2022 – 2025), Zenodo [Dataset],
 1057 <https://doi.org/10.5281/zenodo.22790846>, 2026a.
- 1058 Xia, P. and Min, M.: FY-4B/GHI Minute-scale and Mesoscale Atmospheric Motion
 1059 Vector Dataset (250 m, 2022 – 2023), Zenodo [Dataset],
 1060 <https://doi.org/10.5281/zenodo.22791421>, 2026b.
- 1061 Xia, P. and Min, M.: FY-4B/GHI Minute-scale and Mesoscale Atmospheric Motion
 1062 Vector Dataset (250 m, 2024), Zenodo [Dataset],
 1063 <https://doi.org/10.5281/zenodo.22791444>, 2026c.
- 1064 Xia, P. and Min, M.: FY-4B/GHI Minute-scale and Mesoscale Atmospheric Motion
 1065 Vector Dataset (250 m, 2025), Zenodo [Dataset],
 1066 <https://doi.org/10.5281/zenodo.22791469>, 2026d.



1067 Xia, P., Meng, D., Min, M., Li, J., Liu, Y.-A., Yang, X., and Xu, N.: Impacts of Fengyun-
1068 4B satellite rapid imaging-derived atmospheric motion vectors on typhoon
1069 forecasts, J. Geophys. Res.-Atmos., 130, e2025JD044269,
1070 <https://doi.org/10.1029/2025JD044269>, 2025.

1071

1072

1073

1074

1075

1076

1077

1078