Supplemental Materials for

Wind Estimation based on Flight Dynamics of Unmanned Aerial Vehicle and Its Environmental Application

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The supplemental materials have 7 pages and include the following items:

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Table S2 Fitting coefficients k and b for wind sensor calibrations under various flight conditions.

Figure S1 Relationship between input wind speed, C_d, A_{UAV}, $A_{UAV}C_d$ and UAV inclination angle Ψ.

Figure S2 Comparison between UAV-based wind direction estimates and reference measurements from the meteorological observation tower during vertical flight operations.

Figure S3 UAV-based wind direction estimation and deviation analysis comparing methods 1 versus 2 (A-I, A-II) and methods 2 versus 3 (B-I, B-II) from the field observation campaign.

Figure S4 Performance of wind estimation using machine learning algorithms.

Figure S5 Comparison between UAV-attitude-based wind speed estimates (from method 3) and reference measurements from the meteorological observation tower during hovering flight operations.

Table S1 Fitting coefficients $a_{M,\eta}$ and $b_{M,\eta}$ for the UAV inclination-wind speed relationships.

Payload configuration		Relative wind direction	Coefficient $a_{M,\eta}$	Coefficient $b_{M,\eta}$	R^2
Default setting	M_o	0°	2.29	0.71	0.987
	M_o	45°	2.99	0.58	0.964
	M_o	90°	1.94	0.82	0.949
	M_o	180°	0.57	1.23	0.977
	M_o	225°	0.53	1.21	0.985
	M_o	270°	0.58	1.22	0.986
Additional front-top payload	M_{o+f}	0°	2.80	0.71	0.976
	M_{o+f}	45°	3.43	0.56	0.849
	M_{o+f}	90°	2.27	0.79	0.951
	M_{o+f}	180°	0.57	1.32	0.987
	M_{o+f}	225°	0.59	1.22	0.991
	M_{o+f}	270°	0.65	1.22	0.985
Additional central-top payload	M_{o+m}	0°	2.94	0.74	0.942
	M_{o+m}	45°	3.52	0.59	0.881
	M_{o+m}	90°	1.77	0.92	0.937
	M_{o+m}	180°	0.45	1.40	0.967
	M_{o+m}	225°	0.41	1.38	0.981
	M_{o+m}	270°	0.49	1.42	0.990

*: The fitting algorithm for these coefficients is: $V_{wind,M,\eta} = a_{M,\eta} \cdot \Psi^{b_{M,\eta}}$, where $V_{wind,M,\eta}$ is the wind speed and Ψ is the UAV inclination angle.

Table S2 Fitting coefficients k and b for wind sensor calibrations under various flight conditions*.

Payload configuration		Relative wind direction	k	b	R^2
Default setting	M_o	0°	0.98	1.51	0.994
	M_o	45°	1.14	1.19	0.993
	M_o	90°	0.84	0.42	0.988
	M_o	180°	1.01	0.52	0.985
	M_o	225°	1.19	1.36	0.994
	M_o	270°	0.92	0.40	0.973
Additional front-top payload	M_{o+f}	0°	0.99	0.95	0.988
	M_{o+f}	45°	1.09	0.38	0.993
	M_{o+f}	90°	0.98	0.0036	0.995
	M_{o+f}	180°	1.01	0.55	0.990
	M_{o+f}	225°	1.09	0.89	0.991
	M_{o+f}	270°	1.02	-0.17	0.992
Additional central-top payload	M_{o+m}	0°	0.88	1.28	0.991
	M_{o+m}	45°	1.05	0.81	0.977
	M_{o+m}	90°	0.83	0.54	0.995
	M_{o+m}	180°	0.96	0.68	0.978
	M_{o+m}	225°	1.14	0.97	0.990
	M_{o+m}	270°	0.79	0.24	0.982

*: The fitting algorithm for these coefficients is: $V_{reference} = kV_{measured} + b$, where $V_{reference}$ is the input wind speed from the wind wall and $V_{measured}$ is the wind speed measured by the onboard sensor.

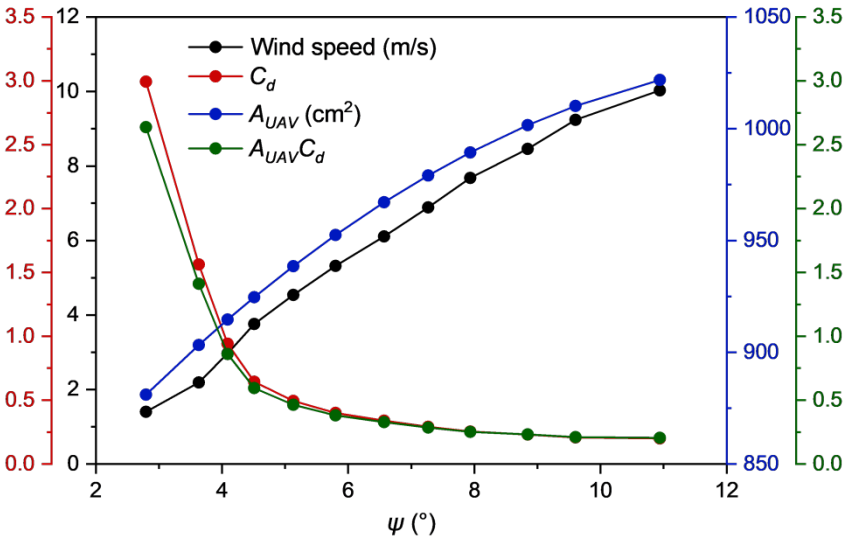

Figure S1 Relationship between input wind speed, C_d, A_{UAV}, $A_{UAV}C_d$ and UAV inclination angle Ψ. Results were obtained under default payload conditions with relative wind direction of 180°.

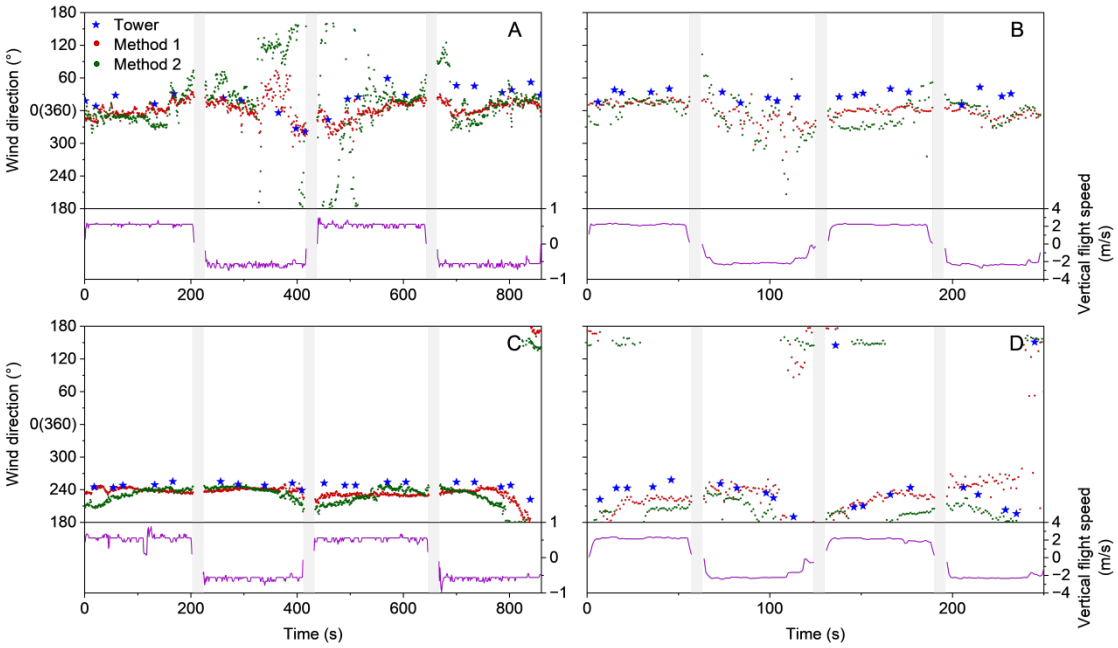

Figure S2 Comparison between UAV-based wind direction estimates and reference measurements from the meteorological observation tower during vertical flight operations: ascending and descending at 0.5 m/s (A) and 2 m/s (B) with default payload, and at 0.5 m/s (C) and 2 m/s (D) with additional front-top payload. Gray shaded areas indicate hovering periods.

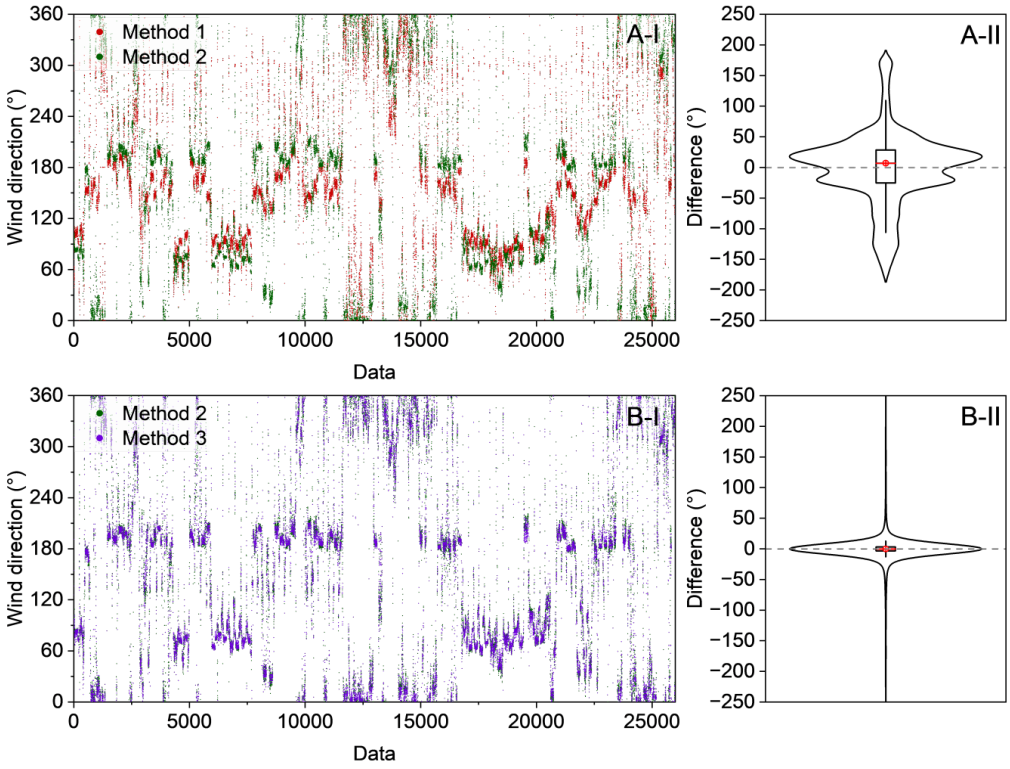

Figure S3 UAV-based wind direction estimation and deviation analysis comparing methods 1 versus 2 (A-I, A-II) and methods 2 versus 3 (B-I, B-II) from the field observation campaign.

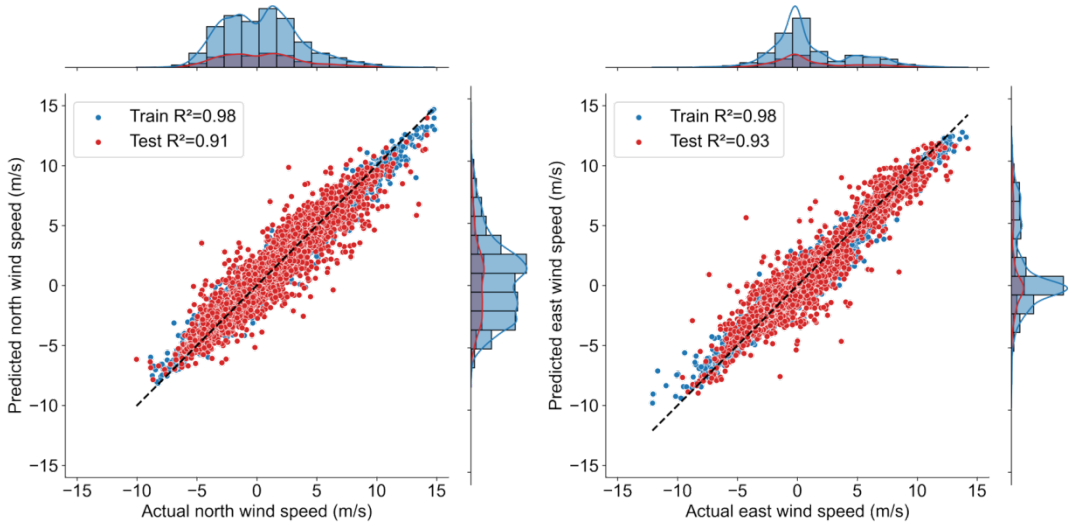

Figure S4 Performance of wind estimation using machine learning algorithms. The wind components are separated into northward and eastward winds for better visualization. The RMSE values are 1.02 m/s and 0.93 m/s for the northward and eastward wind predictions, respectively.

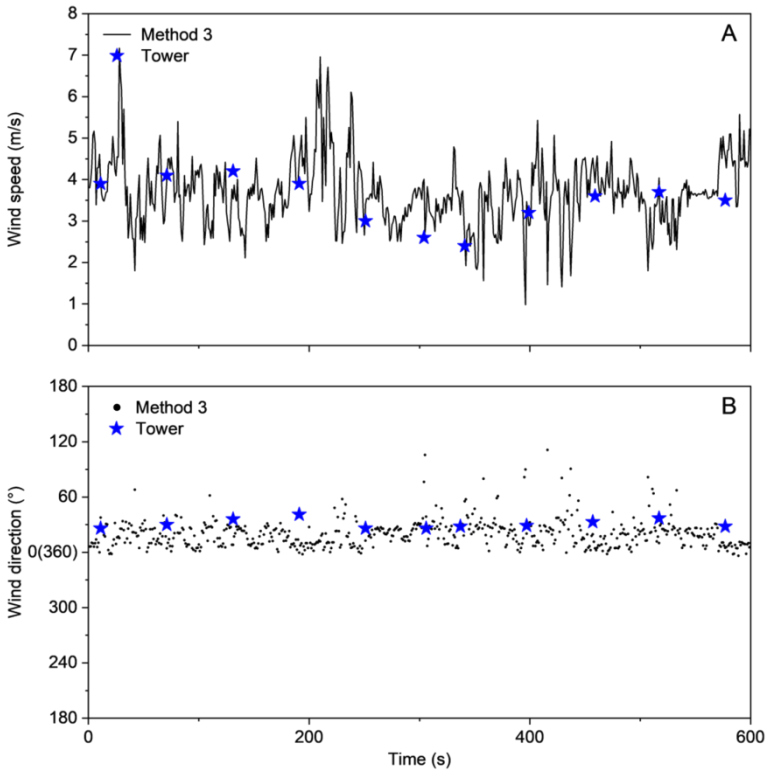

Figure S5 Comparison between UAV-attitude-based wind speed estimates (from method 3) and reference measurements from the meteorological observation tower during hovering flight operations.