Aerosol Indirect Effects on Cirrus Clouds Based on Global-Scale Airborne Observations and Machine Learning Models

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Table S1. Flight hours for each flight campaign in the cirrus temperature range, i.e., temperatures ≤ -40 ºC. The hours of measurements are separately shown for all-sky, clear-sky, and in-cloud conditions, as well as non-quiescent and vertically quiescent conditions. The non-quiescent conditions are defined as vertical velocity (w) > 1 m s^{-1} or < -1 m s^{-1} within ± 30 seconds surrounding each centre second. The rest is defined as vertically quiescent.

Field Campaign	Total flight hours at temperature (T) ≤ -40°C	Clear-sky conditions at T ≤ -40°C (hours)	In-cloud conditions at T ≤ -40°C (hours)	Non-quiescent clear sky (hours)	Vertically quiescent clear sky (hours)	Non-quiescent cirrus clouds (hours)	Vertically quiescent cirrus clouds (hours)
NSF HIPPO2-5	112.18	104.84	7.34	12.07	92.76	1.53	5.81
NSF START08	54.68	51.99	2.69	8.61	43.38	1.11	1.58
NASA SEAC^{4}RS	14.77	10.07	4.70	2.92	7.15	3.27	1.43
NSF DC3	72.53	47.32	25.21	8.86	38.46	12.53	12.68
NASA DC3	29.68	15.74	13.94	3.90	11.84	8.38	5.56
NASA MACPEX	39.36	26.08	13.28	2.92	23.15	4.04	9.24
NSF CONTRAST	72.19	50.44	21.75	5.02	45.42	8.17	13.58
NASA ATTREX-2014	126.69	91.95	34.74	2.63	89.32	1.77	32.97
NSF PREDICT	73.43	52.03	21.40	5.92	46.11	8.29	13.11
NASA POSIDON	40.93	27.71	13.22	1.66	26.05	1.52	11.70
NSF TORERO	53.89	51.62	2.27	2.73	48.89	0.88	1.39
NSF ORCAS	40.24	39.17	1.07	4.05	35.12	0.39	0.68
All Campaigns	730.57	568.96	161.61	61.29	507.65	51.88	109.73

Table S2. Information of aerosol indirect effect (AIE) based on linear regressions from Figure 6 in the main manuscript. Intercept and slope, and their standard deviations are shown as a, b, σ_a, and σ_b, respectively. IWC, Ni, and Di represent ice water content, ice crystal number concentrations, and number-weighted mean diameters, respectively.

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AIE at various temperature ranges													
		$dlog_{10}$(IWC)				**$dlog_{10}$(Ni)**				**$dlog_{10}$(Di)**			
	Range (°C)	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**
$dlog_{10}(Na_{500})$	**T ≤ -40**	-0.128	0.049	1.169	0.049	-0.082	0.044	0.652	0.044	-0.005	0.010	0.194	0.010
	-50 < T ≤ -40	-0.047	0.042	1.052	0.042	0.028	0.053	0.589	0.053	-0.035	0.017	0.199	0.017
	-60 < T ≤ -50	-0.108	0.044	1.269	0.046	-0.085	0.040	0.712	0.042	0.003	0.008	0.193	0.009
	-70 < T ≤ -60	-0.273	0.083	1.450	0.093	-0.323	0.080	0.769	0.090	0.049	0.012	0.217	0.013
$dlog_{10}(Na_{100})$	**T ≤ -40**	0.510	0.081	0.549	0.062	0.234	0.049	0.275	0.037	0.096	0.026	0.097	0.020
	-50 < T ≤ -40	0.346	0.118	0.632	0.097	0.306	0.052	0.387	0.043	0.008	0.034	0.078	0.028
	-60 < T ≤ -50	0.460	0.091	0.604	0.071	0.144	0.046	0.270	0.035	0.117	0.031	0.116	0.024
	-70 < T ≤ -60	0.397	0.098	0.656	0.086	0.116	0.034	0.057	0.030	0.095	0.030	0.234	0.026
AIE at various dRHi ranges													
		$dlog_{10}$(IWC)				**$dlog_{10}$(Ni)**				**$dlog_{10}$(Di)**			
	Range (%)	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**
$dlog_{10}(Na_{500})$	**dRHi ≤ -10**	-0.375	0.043	1.208	0.044	-0.213	0.038	0.612	0.039	-0.037	0.011	0.233	0.012
	-10 < dRHi ≤ 0	0.015	0.024	1.106	0.026	0.046	0.027	0.664	0.031	-0.012	0.010	0.156	0.011
	0 < dRHi ≤ 10	0.003	0.050	1.077	0.053	-0.024	0.053	0.631	0.055	0.016	0.014	0.170	0.014
	dRHi > 10	0.018	0.063	1.182	0.071	-0.163	0.051	0.825	0.058	0.072	0.017	0.121	0.019
$dlog_{10}(Na_{100})$	**dRHi ≤ -10**	-0.375	0.121	0.759	0.107	-0.032	0.064	0.520	0.056	-0.099	0.030	0.080	0.027
	-10 < dRHi ≤ 0	0.380	0.076	0.699	0.061	0.242	0.057	0.302	0.045	0.045	0.026	0.141	0.021
	0 < dRHi ≤ 10	0.650	0.069	0.567	0.053	0.319	0.049	0.271	0.037	0.110	0.029	0.105	0.023
	dRHi > 10	0.691	0.069	0.350	0.055	0.233	0.047	0.228	0.038	0.157	0.013	0.041	0.011
AIE at various dw ranges													
		$dlog_{10}$(IWC)				**$dlog_{10}$(Ni)**				**$dlog_{10}$(Di)**			
	Range (m/s)	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**	**a**	**σ_a**	**b**	**σ_b**
$dlog_{10}(Na_{500})$	**dw ≤ -0.5**	-0.134	0.064	1.353	0.074	0.055	0.035	0.961	0.041	-0.074	0.019	0.107	0.021
	-0.5 < dw ≤ 0	-0.142	0.048	1.172	0.048	-0.095	0.047	0.681	0.047	-0.001	0.012	0.192	0.012
	0 < dw ≤ 0.5	-0.091	0.042	1.208	0.044	-0.069	0.039	0.656	0.041	0.003	0.010	0.201	0.010
	dw > 0.5	0.004	0.049	1.186	0.054	0.039	0.053	0.678	0.059	-0.019	0.015	0.178	0.017
$dlog_{10}(Na_{100})$	**dw ≤ -0.5**	0.502	0.108	0.381	0.095	0.409	0.071	0.423	0.062	0.006	0.023	-0.020	0.020
	-0.5 < dw ≤ 0	0.226	0.087	0.624	0.073	0.154	0.051	0.398	0.043	0.025	0.022	0.081	0.019
	0 < dw ≤ 0.5	0.517	0.079	0.513	0.065	0.217	0.046	0.297	0.037	0.109	0.022	0.075	0.018
	dw > 0.5	0.785	0.076	0.475	0.058	0.394	0.049	0.217	0.037	0.122	0.026	0.094	0.020

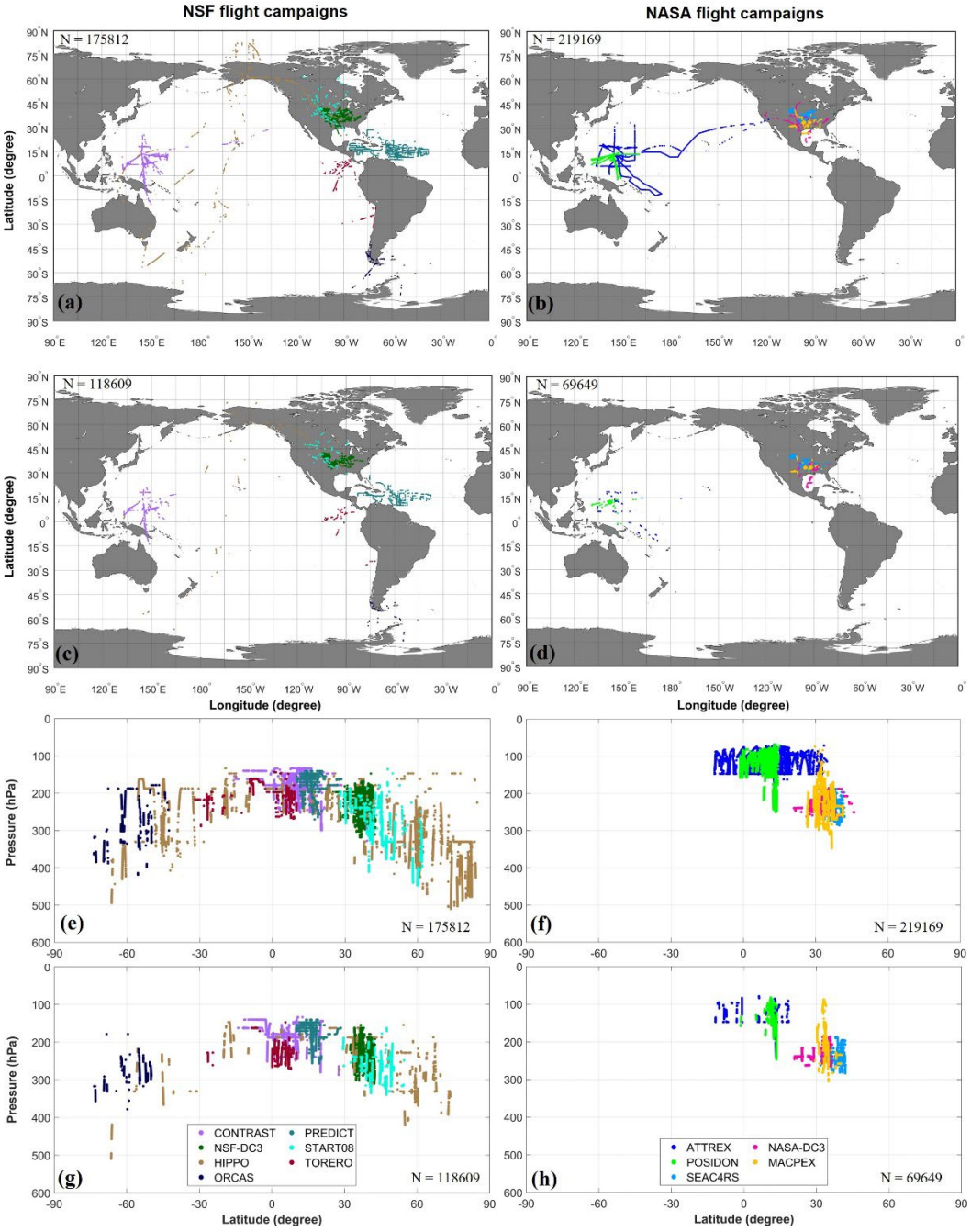
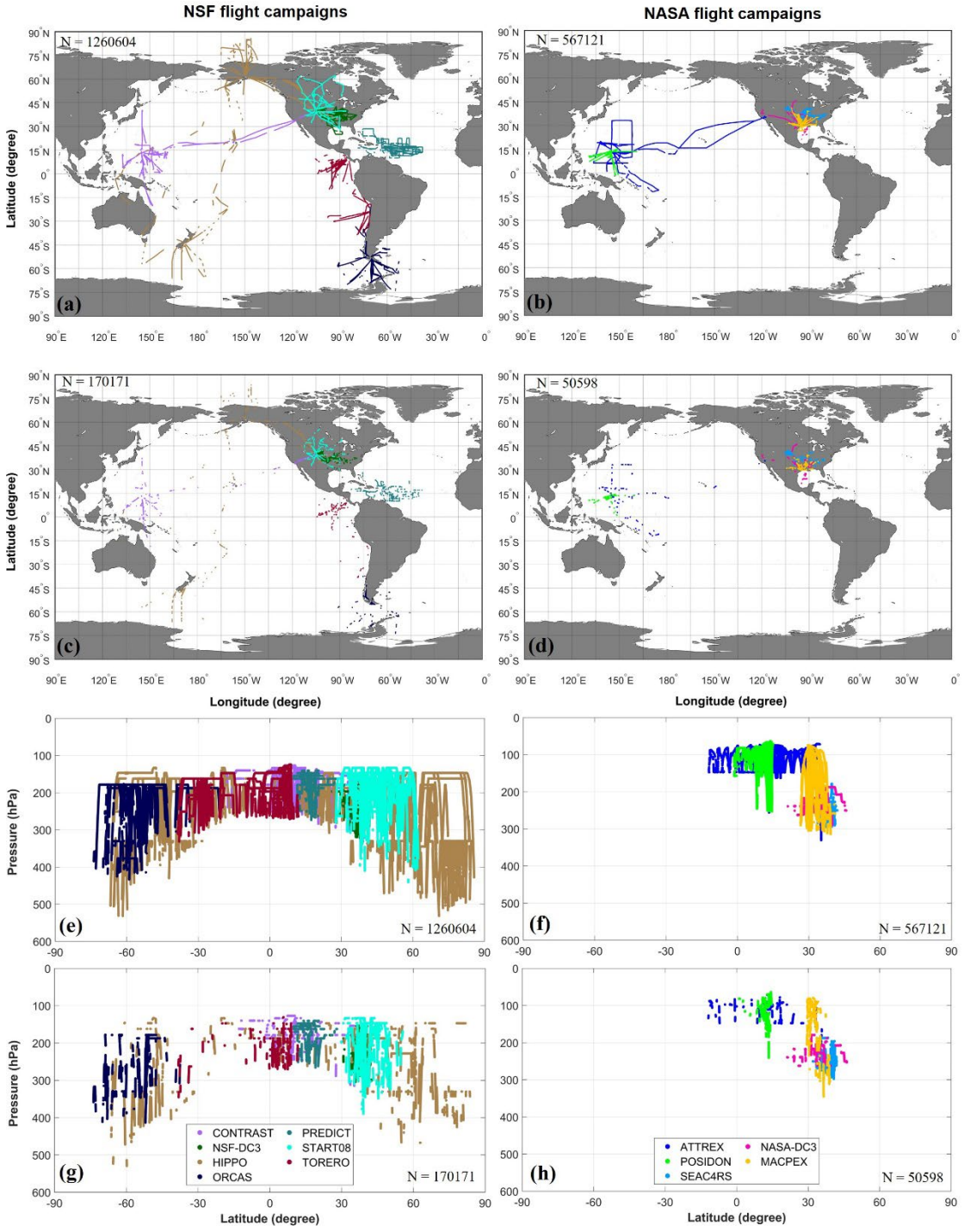


Figure S1. Global maps and vertical profiles of cirrus cloud measurements at temperatures ≤ -40 ºC based on seven NSF (left) and five NASA (right) flight campaigns. (a, b, e, f) Vertically quiescent cirrus clouds. (c, d, g, h) Non-quiescent cirrus clouds.



25 **Figure S2.** Similar to Figure S1, but for clear-sky samples in (a, b, e, f) vertically quiescent and (c, d, g, h) non-quiescent conditions.

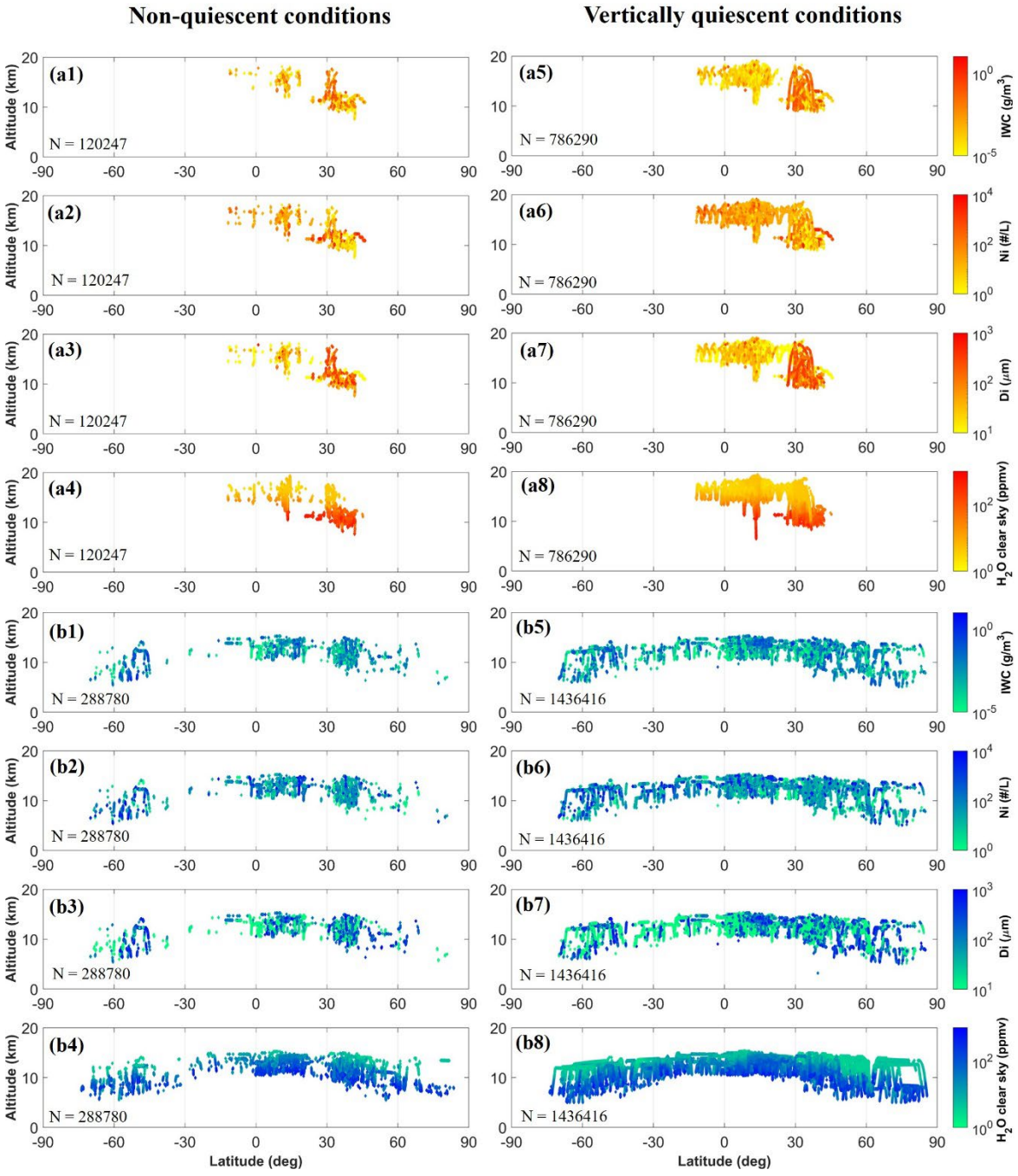


Figure S3. Vertical distributions of IWC, Ni, Di, and clear-sky water vapor volume mixing ratio for temperatures ≤ -40 ºC during the research flights in (a1-a8) NASA and (b1-b8) NSF campaigns. Observations are additionally separated by non-quiescent (left) and vertically quiescent conditions (right).

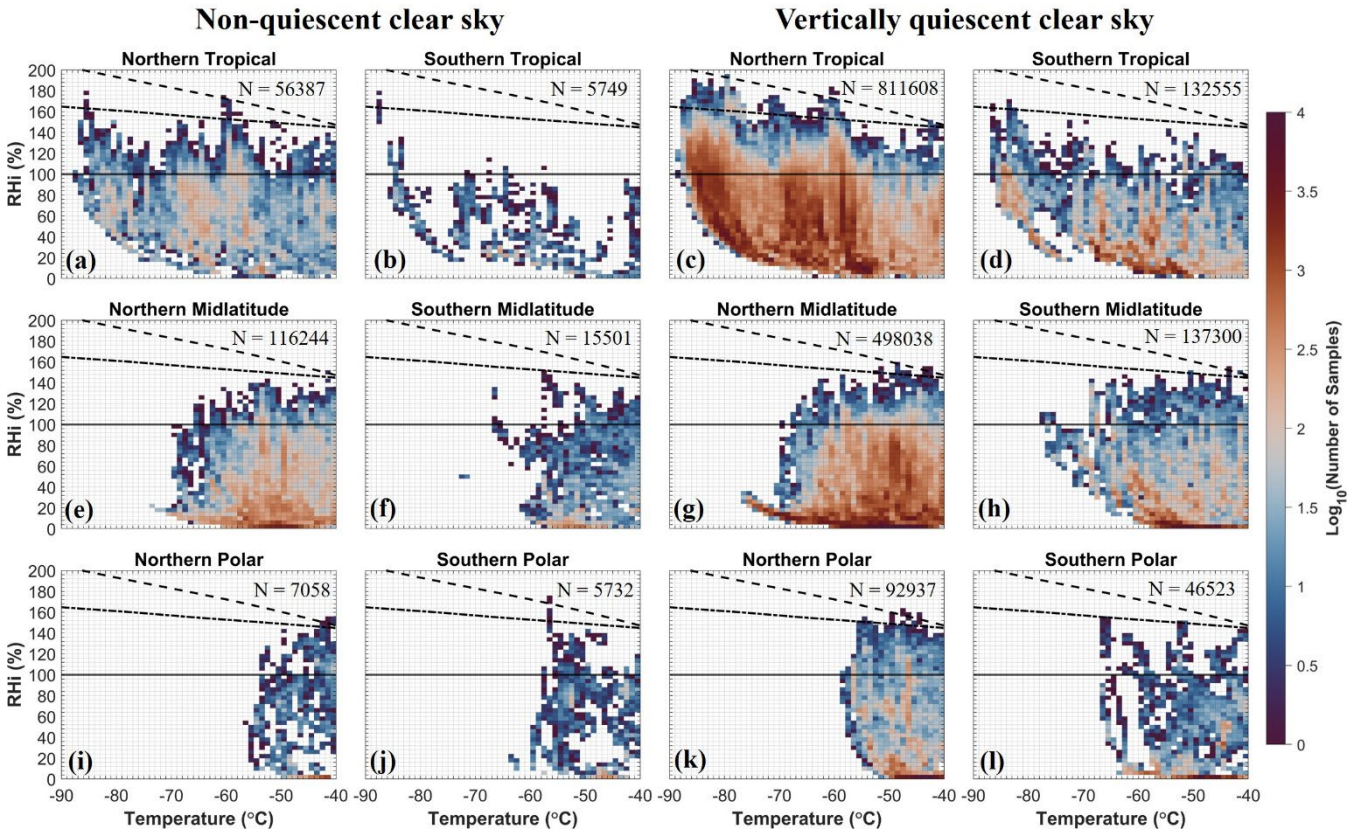


Figure S4. Similar to Figure 2 in the main manuscript, but for distributions of clear-sky RHi as a function of temperature associated with non-quiescent (left two columns) and vertically quiescent conditions (right two columns).

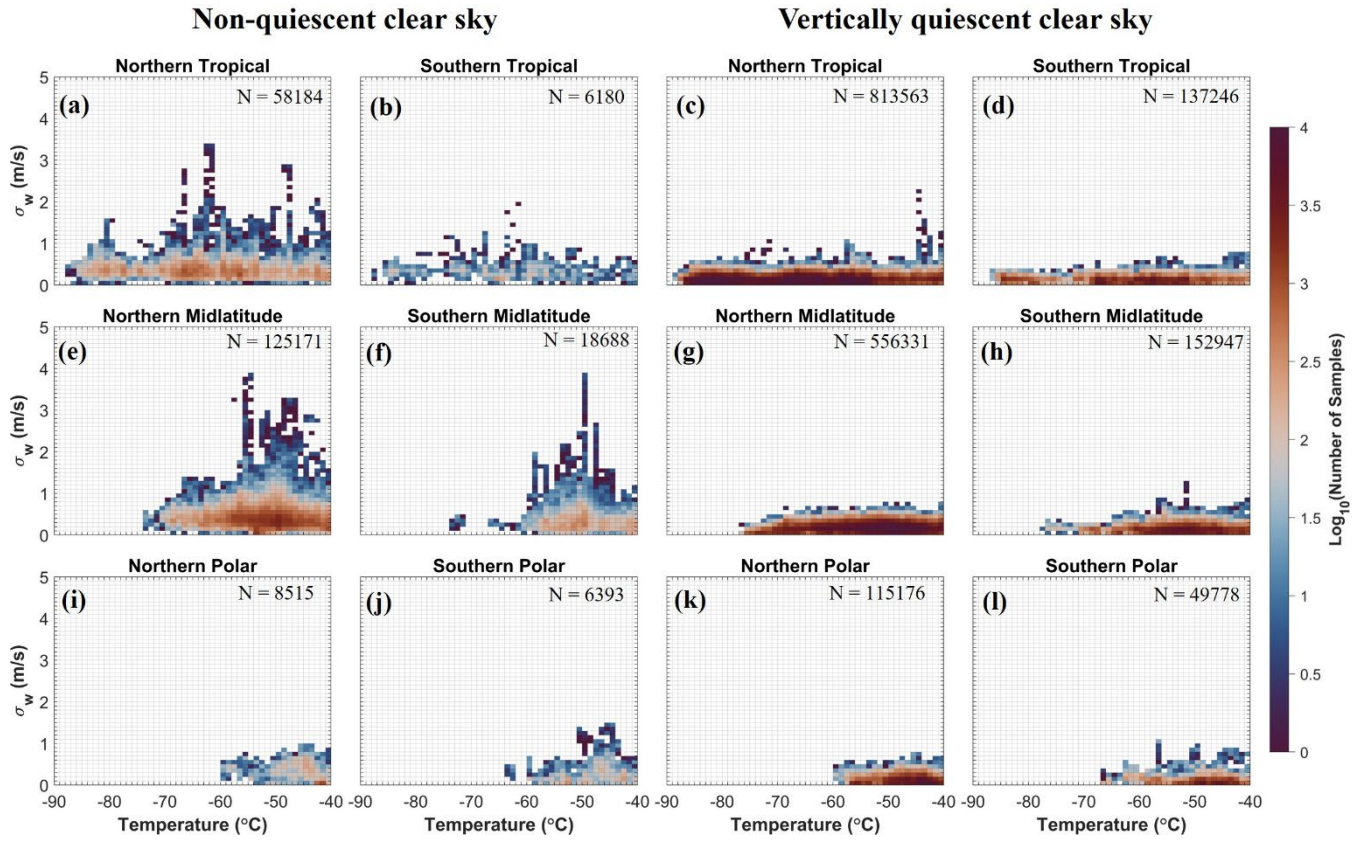


Figure S5. Similar to Figure 3 in the main manuscript, distributions of standard deviations of vertical velocity (σ_w, calculated for 10 km spatial scales) for clear-sky conditions that are non-quiescent (left two columns) and vertically quiescent (right two columns).