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Supplement of

Development and evaluation of CO_2 transport in MPAS-A v6.3

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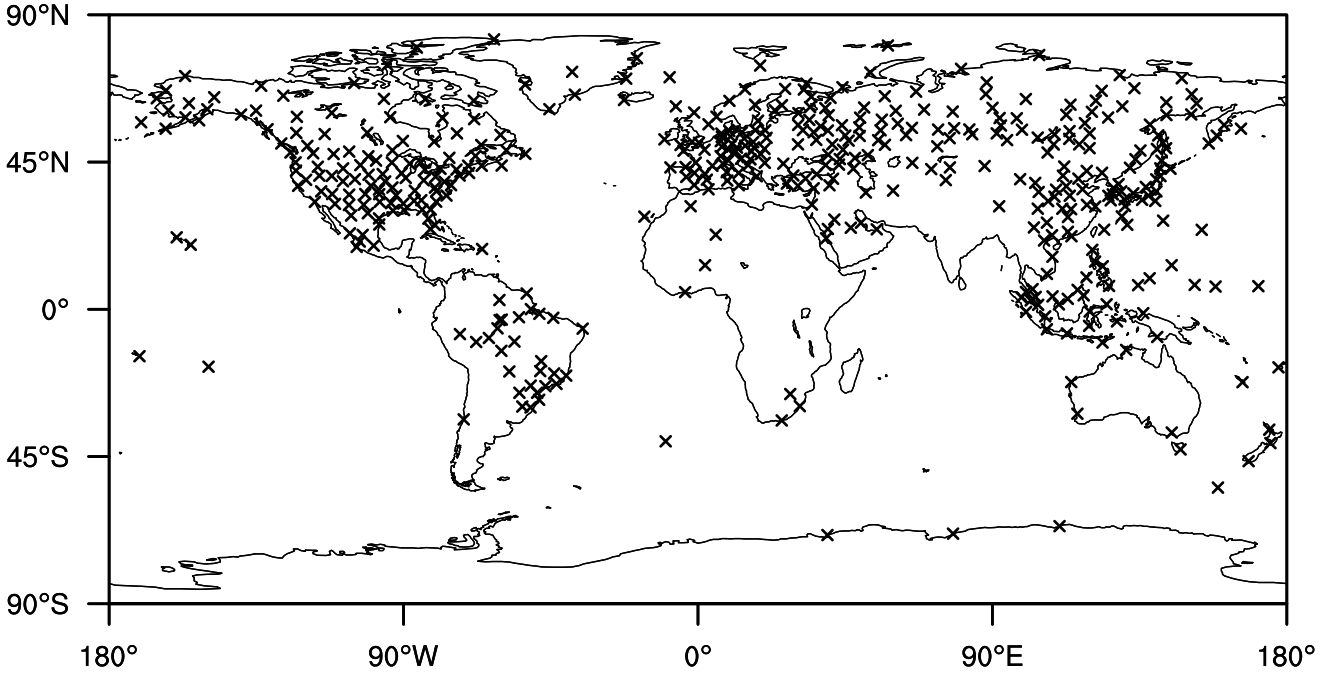

Figure S 1. Location of the 457 radiosonde stations used for validating horizontal wind fields of MPAS-A simulations.

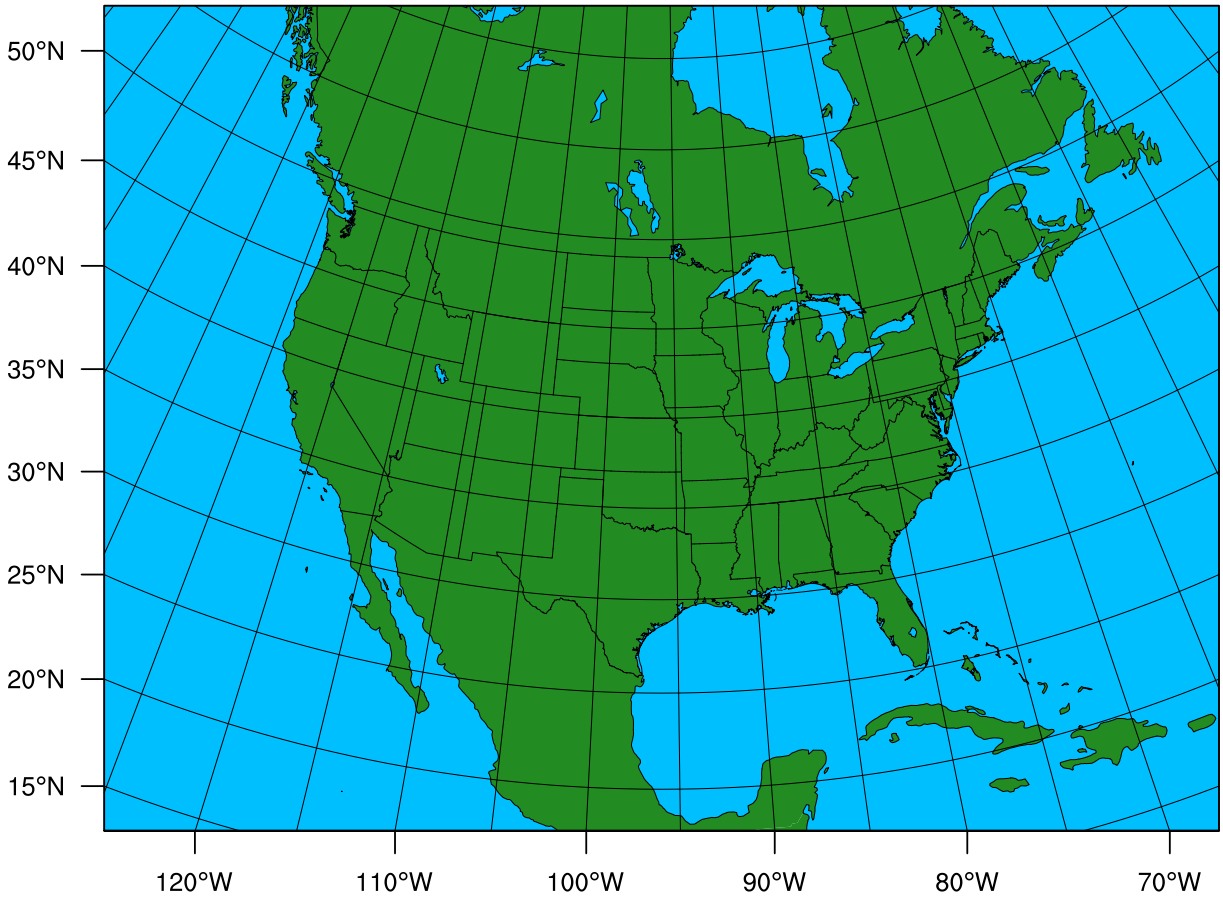

Figure S 2. Model domain of WRF-Chem 27-km resolution simulations covering the four ACT aircraft campaign seasons (Feng et al., 2020).

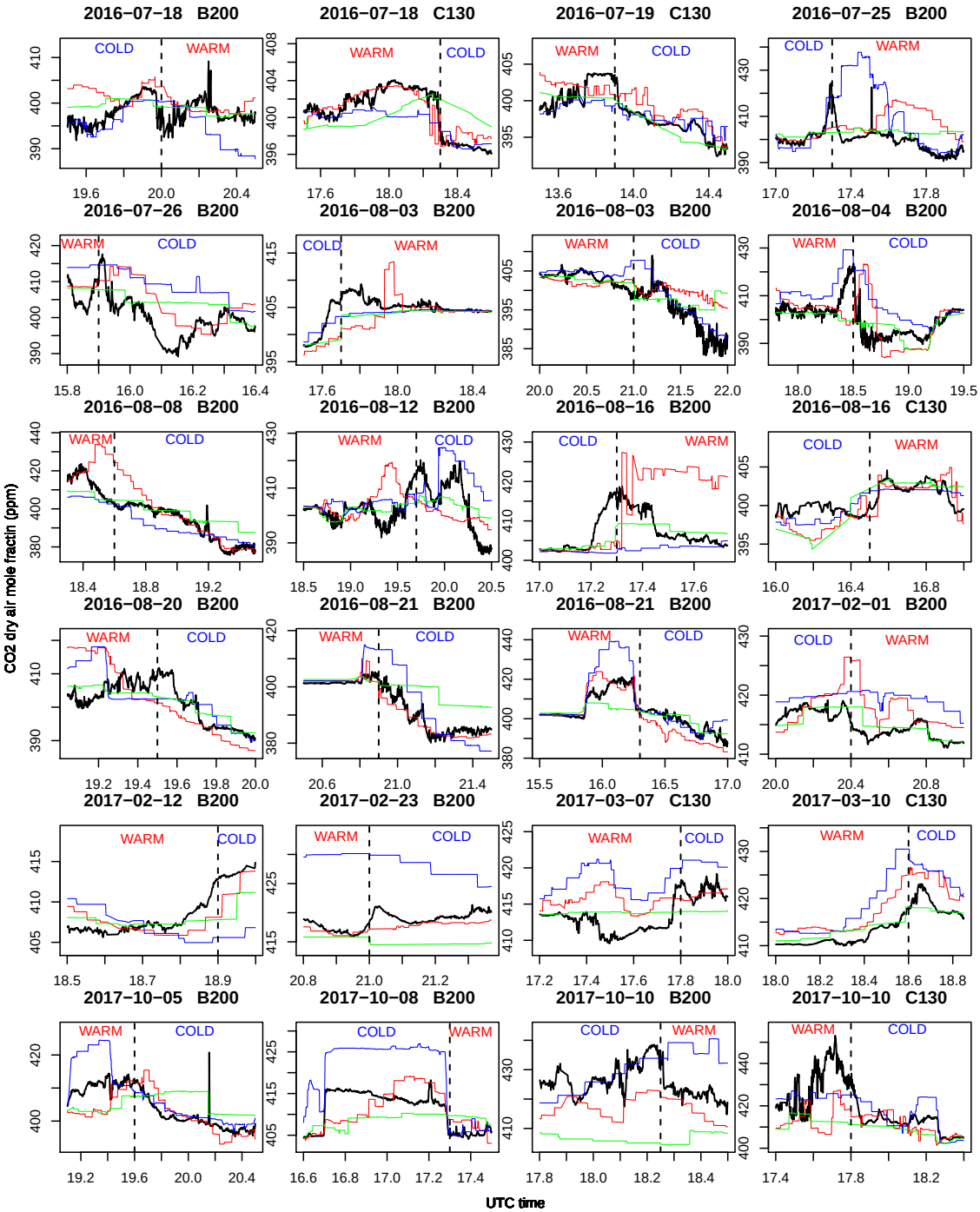

Figure S 3. Comparison of CO_2 mole fraction in frontal-crossing level-leg flights in boundary layer between ACT aircraft measurements and model simulations. Flight date and aircraft type are labeled in title for each flight leg. In each figure, X-axis is UTC time, and Y-axis is CO_2 mole fraction (ppm). Aircraft measurements are in black, MPAS in red, WRF-Chem in blue, and CT2019 in green. The vertical dotted line in each figure marks the approximate location of boundary between warm and cold sectors, which are labeled as 'WARM', and 'COLD' respectively.

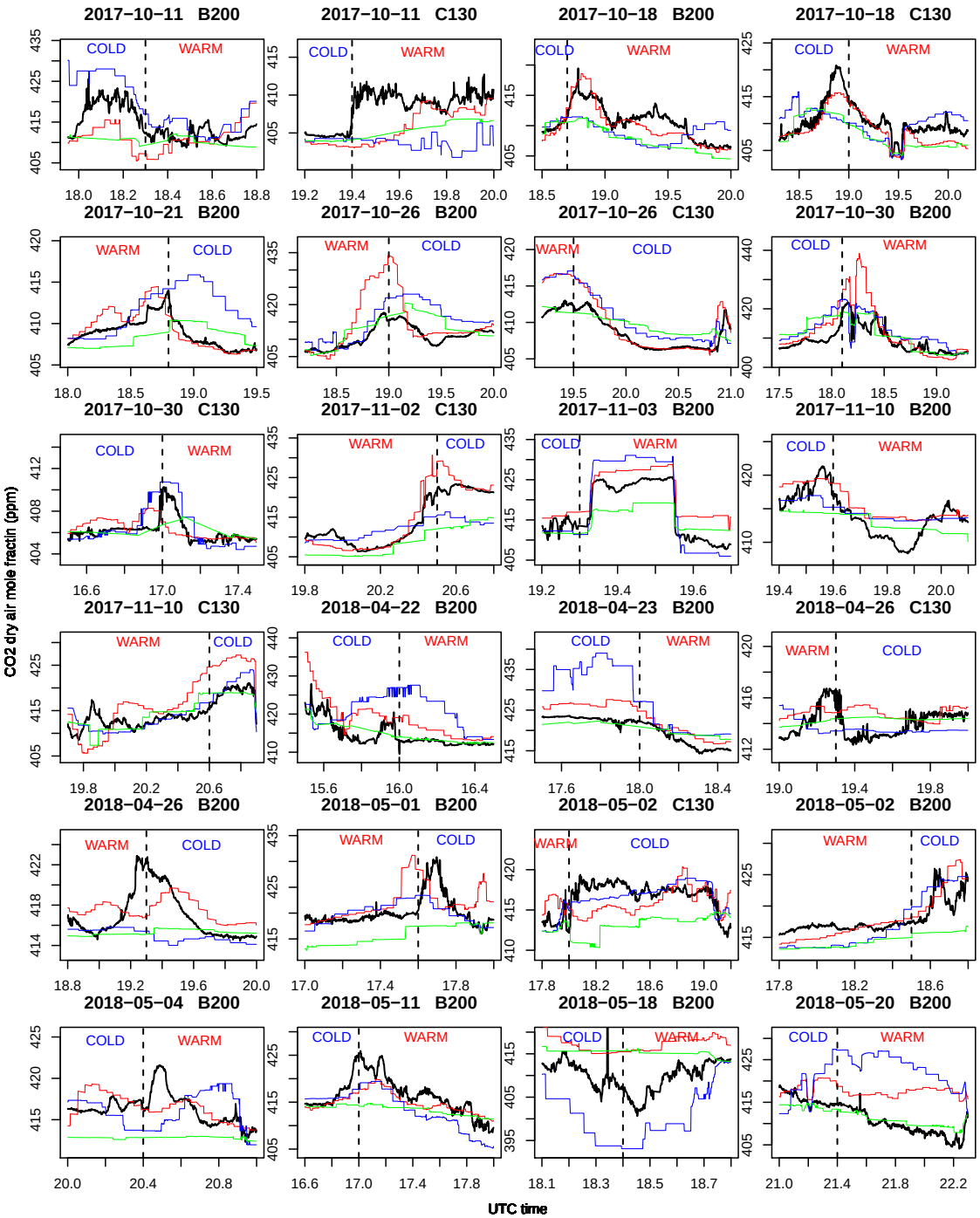

Figure S 3. Continued from the previous page

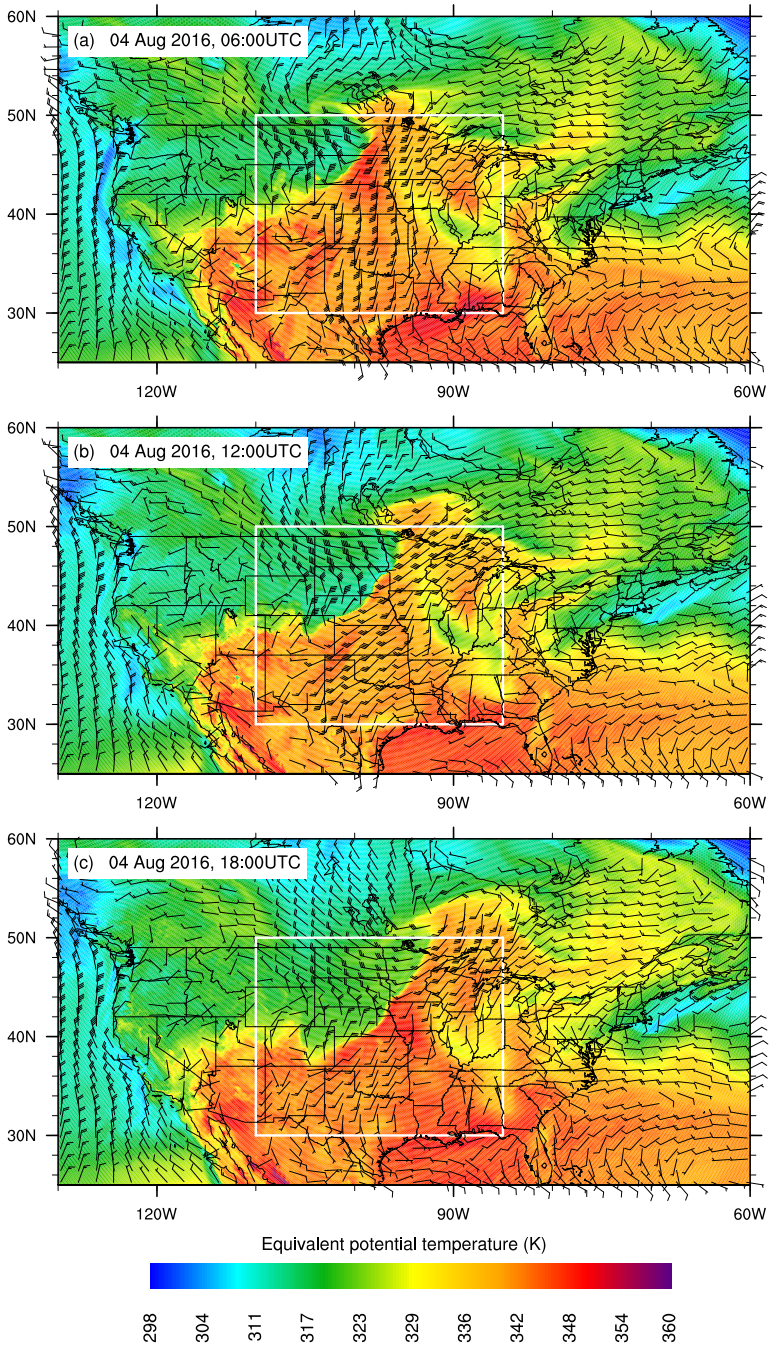

Figure S 4. MPAS simulated equivalent potential temperature θ_e and wind vector at model's 6th vertical level (approximately 400m above surface) on 4 August, 2016. The three panels are 06:00, 12:00, and 18:00 UTC respectively.

Table S 1. Comparison of ECWMF IFS CO_2 simulated hourly CO_2 statistics with MPAS results for the month of January 2014. RMSE, STDE, and Bias of IFS 9km and 80km are reproduced from supplement Table S1 of Agusti-Panareda et al. (2019) with permission.

Station	Bias IFS 9km	Bias IFS 80km	STDE IFS 9km	STDE IFS 80km	RMSE IFS 9km	RMSE IFS 80km	Bias MPAS-A	STDE MPAS-A	RMSE MPAS-A	Number
ALT	-2.14	-2.09	0.61	0.61	2.23	2.18	1.83	2.70	3.26	655
BRW	-1.45	-1.55	1.19	1.14	1.88	1.92	0.79	1.14	1.39	715
CBY	-1.51	-1.30	0.58	0.56	1.62	1.42	1.59	0.74	1.75	72
INU	0.50	0.36	2.04	2.45	2.11	2.47	-0.13	1.70	1.70	688
PAL	-0.89	0.32	2.13	3.44	2.31	3.46	2.80	4.55	5.34	588
BCK	0.93	1.21	1.45	1.37	1.73	1.83	0.75	1.99	2.13	744
CHL	0.50	0.68	1.70	1.91	1.77	2.02	1.04	1.23	1.61	587
LLB	-1.77	-1.59	3.19	-3.32	3.65	3.69	1.57	8.42	8.57	312
ETL	-0.67	-0.17	1.53	1.71	1.68	1.72	1.31	3.19	3.44	743
MHD	-1.11	2.34	4.75	1.03	1.52	5.30	0.98	1.03	1.42	313
WAO	-0.68	-0.01	3.24	3.26	3.31	3.26	3.95	3.54	5.31	139
CES	-2.39	-1.27	4.41	4.71	5.02	4.88	2.77	8.57	9.00	657
EST	-1.20	-1.08	2.09	1.93	2.41	2.21	1.19	3.29	3.49	738
FSD	-0.73	-0.40	1.24	1.29	1.44	1.35	0.91	3.00	3.14	744
CPS	-0.58	0.06	1.32	1.49	1.44	1.49	1.73	4.24	4.58	673
ESP	1.01	4.43	3.71	4.93	3.84	6.62	-0.36	3.80	3.82	585
KAS	0.67	8.45	4.39	6.57	4.44	10.71	14.21	8.69	16.65	374
SSL	3.21	18.72	4.87	15.00	5.83	23.99	12.51	7.79	14.74	509
HUN	-6.58	-2.68	5.52	5.64	8.59	6.24	1.00	8.09	8.15	727
JFJ	0.08	12.47	2.53	9.29	2.53	15.55	4.24	4.11	5.91	717
LEF	-0.78	-0.49	1.47	1.51	1.67	1.59	0.32	2.57	2.59	744
PUY	2.39	6.11	3.91	8.29	4.58	10.30	4.78	3.52	5.94	700
AMT	0.01	-0.50	2.68	2.77	2.68	2.81	3.69	5.56	6.67	738
EGB	-1.13	-1.66	5.14	5.33	5.26	5.58	4.21	6.91	8.09	580
WSA	-1.24	-0.82	1.22	1.43	1.74	1.65	1.13	2.78	3.00	741
VAC	-0.13	1.82	1.10	1.82	1.10	2.28	-1.34	0.92	1.62	86
TPD	-0.01	0.81	3.11	3.20	3.11	3.30	6.29	6.58	9.10	741
DEC	11.13	7.43	11.42	7.31	15.95	10.42	5.86	6.76	8.95	382
HDP	1.48	16.83	2.73	10.25	3.10	19.71	0.14	1.16	1.17	664
SPL	2.28	2.72	3.23	3.50	3.95	4.43	-0.12	1.35	1.36	665
GIC	-1.88	1.69	5.28	4.43	5.60	4.74	0.66	7.37	7.40	741
NWR	0.76	1.56	1.45	3.40	1.64	3.74	1.25	1.27	1.78	693
RYO	3.05	3.88	4.99	6.05	5.84	7.19	1.99	4.05	4.52	684
SNP	3.05	9.66	3.97	10.87	5.01	14.54	2.74	3.39	4.36	744
WGC	-0.58	-0.60	4.92	5.71	4.95	5.74	-3.91	6.54	7.62	744
SGC	1.31	10.31	5.61	9.62	5.76	14.10	2.92	4.82	5.64	680
SCT	-0.13	0.42	3.61	3.83	3.62	3.85	0.15	3.76	3.76	739

Table S 1. Continued from the previous page.

Station	Bias IFS 9km	Bias IFS 80km	STDE IFS 9km	STDE IFS 80km	RMSE IFS 9km	RMSE IFS 80km	Bias MPAS	STDE MPAS	RMSE MPAS	Number
WKT	0.06	0.22	2.34	2.38	2.34	2.39	0.60	1.97	2.06	709
IZO	0.01	0.63	2.80	0.98	2.80	1.16	1.56	1.25	2.00	686
YON	-0.40	-0.62	1.22	1.43	1.28	1.56	0.97	2.35	2.55	744
MNM	-0.34	-0.25	0.77	0.71	0.84	0.76	0.46	0.93	1.04	743
MLO	-0.35	0.68	0.78	1.05	0.85	1.25	0.44	0.63	0.77	712
SMO	-1.10	-0.81	0.93	0.97	1.44	1.26	0.47	0.89	1.01	675
CPT	-1.11	1.86	0.60	6.02	1.26	6.30	-0.13	0.93	0.94	461
AMS	-1.20	-1.27	0.26	0.27	1.22	1.30	-0.66	0.49	0.82	727
CGO	-0.69	-1.39	2.46	4.25	2.56	4.47	-2.00	4.07	4.54	744
CYA	-1.14	-1.14	0.36	0.36	1.19	1.19	-0.50	0.63	0.81	730
SYO	-1.09	-1.15	0.14	0.15	1.10	1.16	-0.16	0.24	0.29	724
SPO	-1.10	-1.10	0.18	0.19	1.12	1.12	-0.07	0.16	0.17	714

Table S 2. Same as Table S1, but for the month of July, 2014.

Station	Bias IFS 9km	Bias IFS 80km	STDE IFS 9km	STDE IFS 80km	RMSE IFS 9km	RMSE IFS 80km	Bias MPAS	STDE MPAS	RMSE MPAS	Number
ATL	-0.93	-1.36	1.05	1.17	1.40	1.80	0.02	1.39	1.39	504
BRW	-0.85	-0.68	2.06	2.20	2.23	2.31	0.45	2.64	2.68	708
CBY	-0.67	-1.83	3.07	3.50	3.15	3.95	-0.45	3.74	3.76	722
INU	-1.40	-2.54	3.98	5.07	4.22	5.67	1.59	5.67	5.89	741
PAL	2.03	4.40	6.13	10.86	6.45	11.72	-1.52	5.67	5.87	427
BCK	10.36	34.84	38.58	79.33	39.95	86.65	-0.24	21.02	21.02	733
CHL	-0.09	-0.77	4.45	4.61	4.45	4.67	0.55	5.35	5.37	744
LLB	-10.09	-7.88	14.30	13.39	17.50	15.53	-8.89	22.06	23.78	112
ETL	-3.59	-4.90	7.02	7.48	7.88	8.94	-4.47	8.27	9.40	674
MHD	-2.27	-0.40	5.63	6.52	6.07	6.53	-2.17	2.37	3.21	168
WAO	-4.01	-3.44	8.33	7.12	9.24	7.91	-6.30	12.76	14.23	587
CES	-3.49	-2.93	7.76	7.97	8.51	8.50	-4.93	9.62	10.81	667
EST	0.35	0.50	8.62	9.37	8.63	9.38	3.54	11.76	12.28	295
FSD	-3.51	-4.59	8.96	9.23	9.62	10.31	-2.87	9.31	9.74	738
CPS	-2.98	-3.85	7.03	7.52	7.64	8.45	-0.51	9.66	9.67	743
ESP	0.28	-6.53	5.69	10.09	5.70	12.01	-2.08	8.34	8.60	526
KAS	-1.01	7.42	4.17	15.93	4.29	17.57	-0.11	7.17	7.17	558
SSL	-0.11	9.63	8.99	18.56	8.99	20.91	8.27	16.15	18.15	736
HUN	-6.61	-5.61	7.87	7.43	10.28	9.32	1.14	15.65	15.69	744
JFJ	-5.23	-5.48	3.60	10.60	6.35	11.93	-1.10	4.71	4.83	269
LEF	3.88	2.53	6.22	6.05	7.33	6.56	-2.57	7.80	8.21	733
PUY	0.75	4.88	7.19	12.36	7.23	13.29	-0.92	12.77	12.80	677
ATM	2.60	-0.94	8.24	7.95	8.64	8.00	7.57	19.06	20.51	665
EGB	-1.24	-6.52	13.31	15.61	13.37	16.92	-2.85	14.05	14.33	392
WAS	0.95	0.41	4.66	5.60	4.76	5.62	-0.93	4.62	4.72	744
VAC	2.85	6.98	5.22	12.04	5.95	13.91	0.40	7.75	7.76	741
TPD	-1.20	-2.44	14.31	13.12	14.37	13.34	1.45	20.05	20.10	743
DEC	7.78	11.01	10.37	11.97	12.96	16.26	4.83	12.87	13.74	381
HDP	4.11	27.16	4.36	25.67	5.99	37.37	-0.16	2.91	2.92	596
SPL	8.73	20.16	6.34	16.93	10.79	26.32	-0.09	4.09	4.09	643
GIC	-10.88	-6.14	17.13	14.08	20.30	15.36	-13.41	25.24	28.58	239
NWR	3.63	11.03	3.68	15.20	5.17	18.78	-0.76	3.63	3.71	613
BAO	1.05	-1.43	5.69	6.55	5.79	6.70	-0.69	7.97	8.00	651
RYO	18.51	10.77	27.89	17.28	33.48	20.36	-1.29	10.73	10.81	684
SNP	24.15	37.81	16.55	30.11	29.28	48.33	5.24	11.77	12.88	744
WGC	1.57	1.37	2.75	2.81	3.17	3.13	-3.50	3.02	4.62	144
SGC	5.74	14.61	5.71	12.54	8.09	19.25	-0.84	5.59	5.65	617
SCT	3.90	4.21	7.82	7.31	8.73	8.43	1.60	8.04	8.20	720

Table S 2. Continued from the previous page.

Station	Bias IFS 9km	Bias IFS 80km	STDE IFS 9km	STDE IFS 80km	RMSE IFS 9km	RMSE IFS 80km	Bias MPAS	STDE MPAS	RMSE MPAS	Number
WKT	4.75	4.90	4.32	3.93	6.42	6.28	-0.83	5.58	5.64	742
IZO	4.65	-1.84	3.82	2.22	6.01	2.88	-2.07	3.06	3.69	720
YON	0.61	0.26	1.98	1.58	2.07	1.60	-0.48	2.07	2.13	718
MNM	0.33	0.27	0.98	0.97	1.04	1.00	0.69	1.65	1.79	739
MLO	0.83	-0.52	1.22	1.60	1.47	1.68	0.75	1.07	1.31	692
SMO	-0.26	-0.34	0.80	0.87	0.84	0.93	0.12	0.92	0.92	692
CPT	-0.12	-0.82	0.93	5.91	0.94	5.97	0.33	1.15	1.20	501
AMS	-0.90	-1.03	0.28	0.29	0.94	1.07	0.05	0.35	0.35	668
CGO	-0.55	-0.41	1.56	2.42	1.66	2.45	0.71	1.51	1.66	734
CYA	-0.95	-1.01	0.29	0.29	0.99	1.05	0.07	0.25	0.26	744
SYO	-0.92	-0.97	0.14	0.13	0.93	0.98	0.12	0.11	0.17	735
SPO	-0.83	-0.88	0.16	0.15	0.85	0.89	0.18	0.11	0.21	713

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