Observation of Trace Gases Seasonal Variability in the Marine Boundary Layer over the Atlantic Ocean during the ACTIVATE Field Campaign

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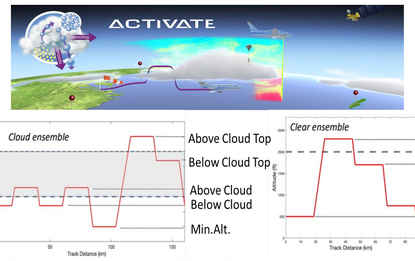
Summary

In-situ measurements of carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), Ozone (O_3) and water vapor (H_2O) were made onboard the NASA HU-25 aircraft during the ACTIVATE (Aerosol Cloud meteorology Interactions oVer the western Atlantic Experiment) campaign during 2020 and 2021 in different seasons (winter through summer) over the mid-latitude western Atlantic Ocean. As most of the flights focused on the marine boundary layer (MBL) during the campaign, these trace gas observations are an excellent data set to examine seasonal variability of trace gas background values in the MBL. We describe the variability of these trace gases in the MBL background using 2020 Winter and Summer season data at this presentation. 2021 and coming 2022 data will be added and analyzed later together. All the tracers (CO_2, CO, CH_4, and O_3) showed more variation during the summer than winter. The mean values of CO_2, CO, and O_3 at MBL and above MBL showed enhanced values during winter, compared to summer, but the CH_4 showed not much difference with season. For both of clear and cloudy ensemble, the CO_2, CO, and CH_4 showed minimum difference of mean values at MBL, in-cloud and above MBL during summer season, but winter had much lower values for CO_2, CO, and CH_4 in above MBL than MBL and in-cloud, but O_3 had higher values in above MBL than MBL. For all tracers, in-cloud mean values showed much closer to MBL than above MBL. The mean values and variations at all 4 tracers shows similar values and pattern in cloud ensemble and clear ensemble for both summer and winter. The comparison with NOAA Tudor Hill, Bermuda ground site on Atlantic ocean (closest Atlantic ocean site near the ACTIVATE sampling region) shows that ACTIVATE minimum altitude values for CO_2, CO, and CH_4 are bigger than Bermuda site for both summer and winter, which is possibly caused by the altitude difference, and more continental effect, since ACTIVATE was closer to continent than Bermuda site. Additionally, the ocean is a significant sink of anthropogenic CO_2 capturing about one quarter of total anthropogenic carbon. By looking at the minimum altitude flight data over the ocean, MBL CO_2 variation as a function of season is shown at Atlantic ocean. Summer CO_2 values near ocean were about 10 ppmv smaller than winter at minimum altitude of MBL, which could be caused by oceanic uptake by organics during summer season near the ocean surface and/or continental uptake effect. These high accuracy observations of trace gas backgrounds in the MBL along with characterizing seasonal effects, partially relying on oceanic sequestering of anthropogenic CO_2, will improve the understanding of seasonal variations and change in climate and inverse modelling over the ocean.

ACTIVATE Trace Gas Instruments on NASA Falcon Aircraft

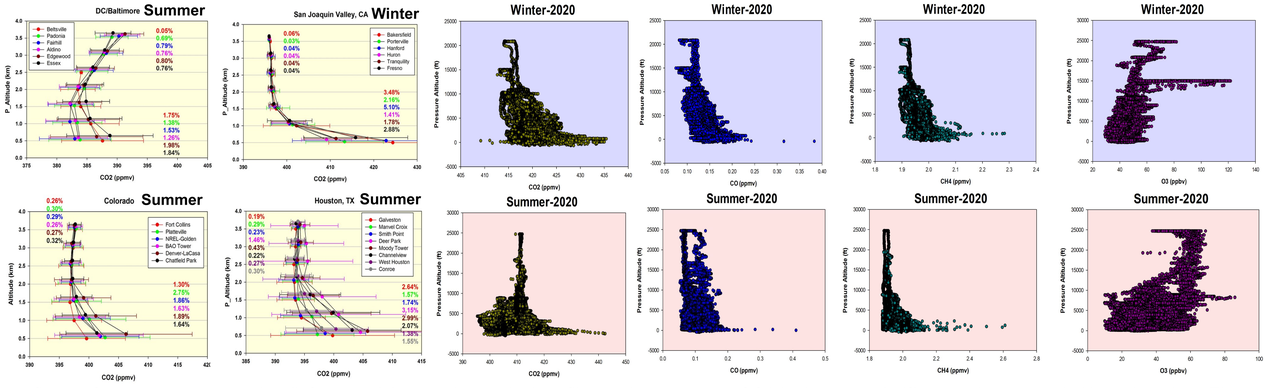
Instrument	Species	Data Rate	Precision (1σ)	Accuracy
DLH	$H_2O_{(v)}$	1 Hz/20 Hz	0.1%/0.05 ppm_v	5%/1 ppm_v
PICARRO G2401-m	CO_2	0.4 Hz	0.1 ppm	0.1 ppm
	CH_4	0.4 Hz	1 ppb	1%
	CO	0.4 Hz	4 ppb	2%
2B Tech	O_3	0.5 Hz	2 ppb_v	5 ppb_v

(Top right) NASA's Kingair and Falcon, sit on the NASA Langley Research Center before the joint Science Flight. Credit: David Bowman. (Bottom right) In Situ Trace Gas instrument rack in the Falcon Aircraft. (Top) Trace Gas instruments Specification



(Top) The diagram of the ACTIVATE campaign. Credit: ACTIVATE team. (Bottom) The diagram of the example of ACTIVATE flight ensemble at Cloud and Clear cases with Falcon flight during the ACTIVATE campaign. A. Corral's flight segment flags were used to identify the below and above the Marine Boundary Layer for data analysis.

The Comparison of Vertical Profiles from the Previous Campaigns on US Continent and MBL on West Atlantic



These figures from previous campaign (left 4 panels) show the vertical profiles and variations in CO2 in the several different urban areas in North America. The data were collected during DISCOVER-AQ campaign at DC/Baltimore (July 2011), San Joaquin Valley, CA (Jan-Feb, 2013), Houston, TX (Sep. 2013), and Denver, CO (July-August, 2014). The winter season shows less variation in CO_2 with altitude, and higher values compared to summer data due to biogenic uptake.

Trace Gas Variability on Western Atlantic Ocean

Seasonal variation between summer and winter in clear and cloudy condition at MBL, above MBL, and minimum altitude are compared with NOAA Tudor Hill, Bermuda ground site near the ACTIVATE sampling region. The box is the data interquartile range and the mean is shown as a red line.

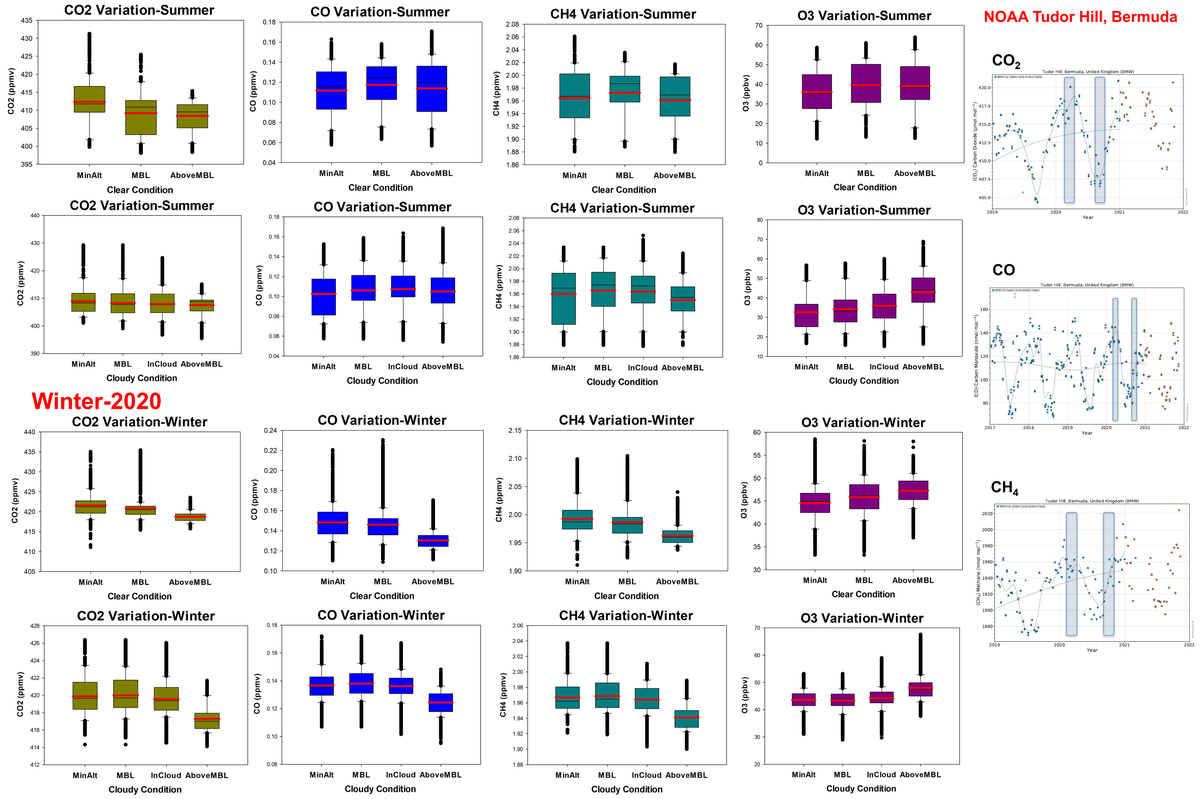
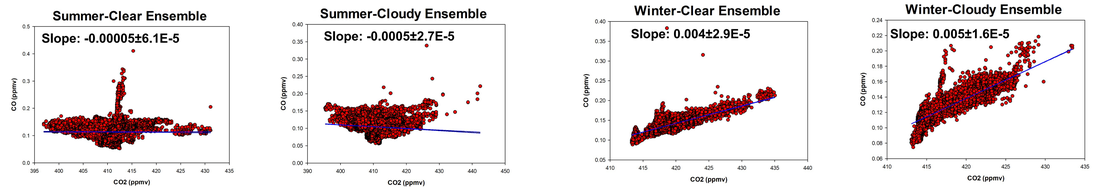


Table. ACTIVATE Western Atlantic Ocean and NOAA Tudor Hill, Bermuda Ground site Trace Gas Mean and Variability

		Summer-Cloudy				Summer-Clear				Winter-Cloudy				Winter-Clear				Bermuda-Winter			
		Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min
MinAlt	O_3(ppbv)	32.696	8.993	56.700	16.600	36.006	11.098	58.700	12.200	43.508	3.516	53.200	31.000	44.580	3.872	58.500	33.200				
	CO(ppmv)	0.103	0.022	0.153	0.057	0.112	0.025	0.163	0.058	0.137	0.011	0.172	0.107	0.148	0.016	0.221	0.110	134.437	7.363	145.07	123.32
	CH_4(ppmv)	1.960	0.043	2.034	1.879	1.965	0.044	2.061	1.880	1.967	0.022	2.037	1.921	1.993	0.033	2.099	1.910	1.954	0.008	1.963	1.941
	CO_2(ppmv)	408.938	5.331	429.260	401.050	412.372	6.434	431.260	399.810	419.878	2.361	426.390	414.310	421.571	3.089	435.030	411.080	417.076	1.589	420.14	415.11
MBL	O_3(ppbv)	34.170	9.462	57.700	15.700	39.655	11.254	61.000	13.100	43.397	3.674	53.200	28.900	45.880	3.940	58.100	33.200				
	CO(ppmv)	0.106	0.022	0.159	0.057	0.117	0.024	0.158	0.063	0.138	0.011	0.172	0.107	0.146	0.018	0.231	0.109				
	CH_4(ppmv)	1.965	0.041	2.034	1.879	1.973	0.042	2.035	1.888	1.969	0.022	2.037	1.919	1.986	0.033	2.105	1.923				
	CO_2(ppmv)	408.282	5.412	429.260	399.010	409.181	6.498	425.460	398.080	420.004	2.337	426.390	414.310	420.840	3.298	435.440	415.360				
InCloud	O_3(ppbv)	35.821	9.199	60.000	15.100					44.236	3.612	59.000	29.700					Bermuda-Summer			
	CO(ppmv)	0.107	0.021	0.164	0.056					0.136	0.010	0.167	0.102					95.645	12.747	122.59	79.73
	CH_4(ppmv)	1.964	0.039	2.052	1.877					1.964	0.020	2.011	1.903					1.911	0.014	1.934	1.891
	CO_2(ppmv)	407.928	4.954	424.640	396.690					419.570	2.079	426.040	414.510					408.449	1.544	410.81	406.52
AMBL	O_3(ppbv)	42.938	10.666	68.800	16.300	39.012	13.004	63.900	12.500	47.949	4.560	67.600	37.600	47.295	2.973	58.000	37.000				
	CO(ppmv)	0.105	0.022	0.168	0.054	0.114	0.028	0.171	0.057	0.124	0.009	0.148	0.095	0.130	0.009	0.171	0.111				
	CH_4(ppmv)	1.950	0.033	2.024	1.879	1.961	0.040	2.018	1.880	1.941	0.017	1.989	1.900	1.962	0.016	2.040	1.937				
	CO_2(ppmv)	407.505	3.967	415.100	395.410	408.434	4.524	415.370	398.340	417.283	1.541	421.690	414.110	418.718	1.337	423.530	415.710				

CO/CO_2 ratio on Western Atlantic Ocean at different season

The negative slope at summer season shows the oceanic uptake by organics at ocean surface and/or by the continental effect.



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