Assessing data quality in long-term Canadian ozone sounding records

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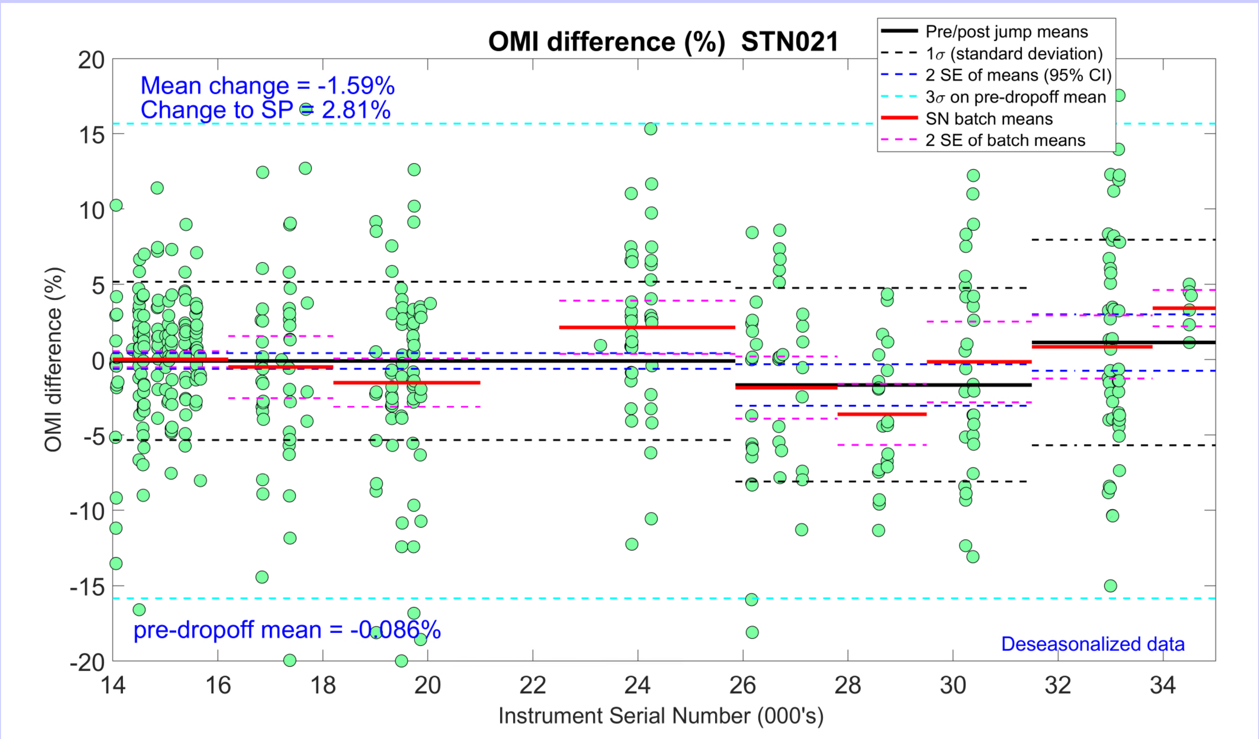
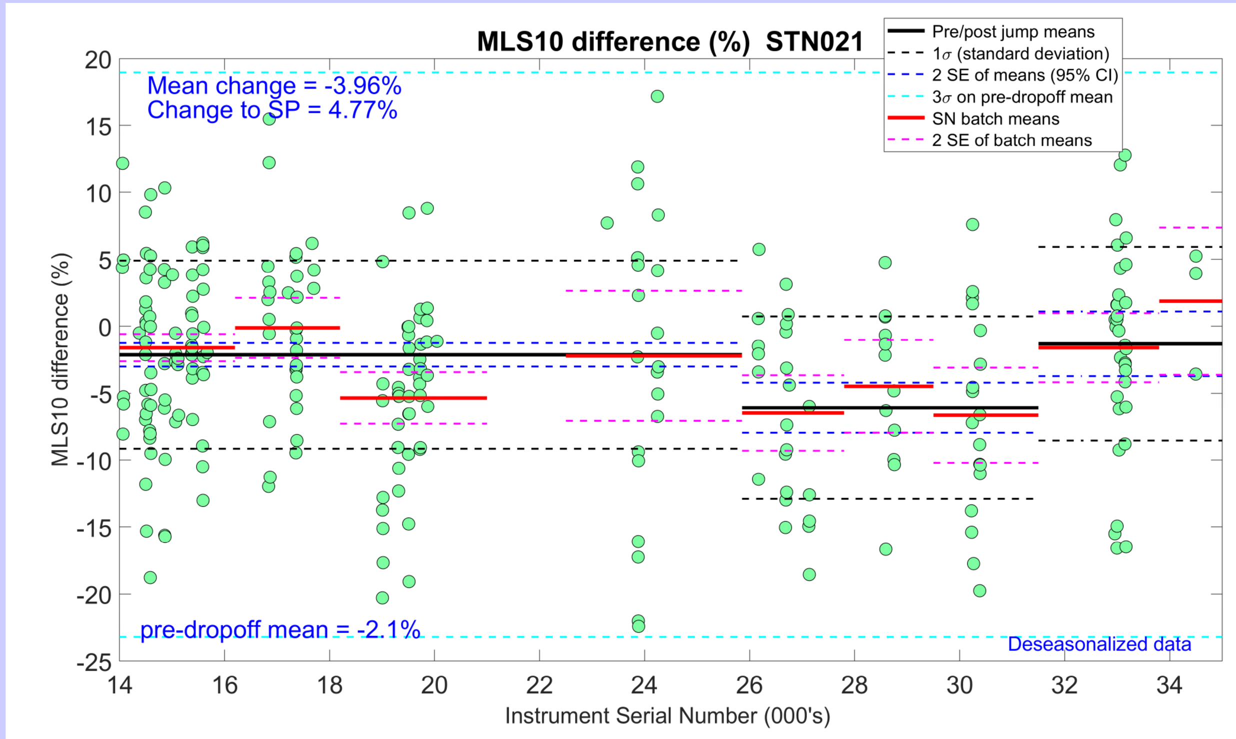
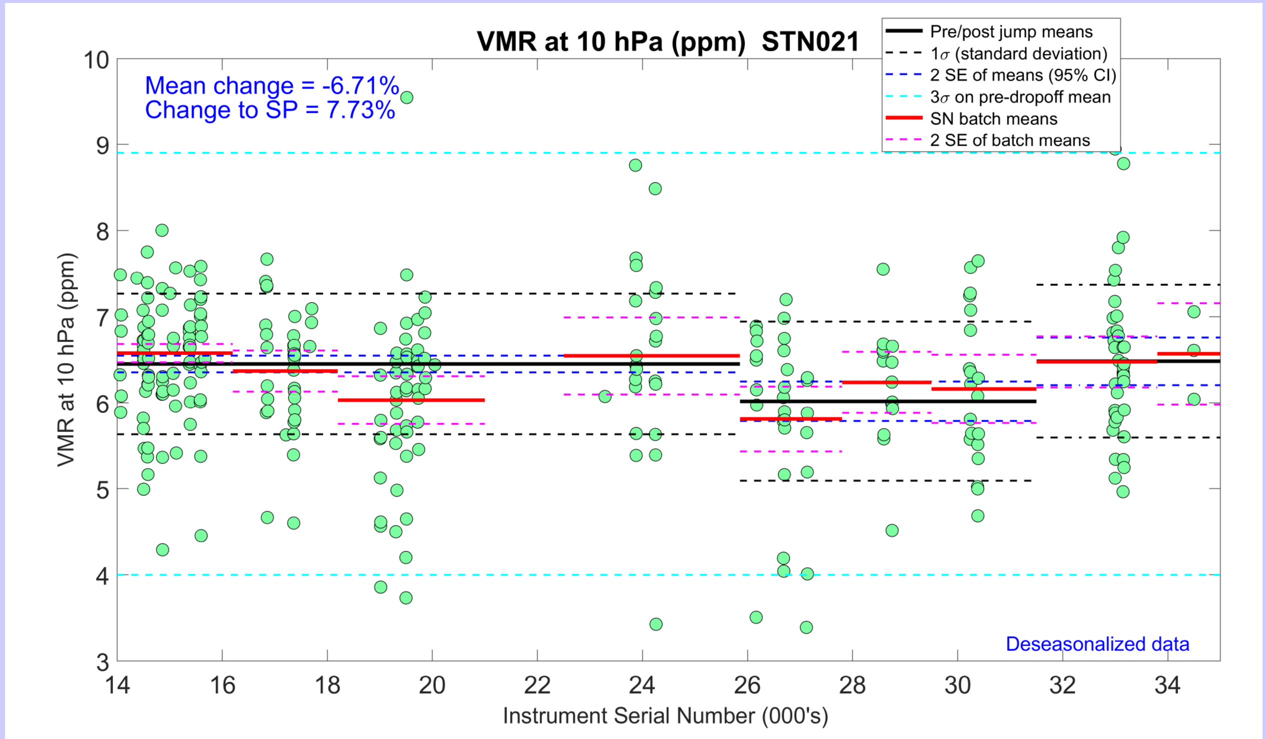
The importance of long-term ozonesonde records as a stable reference has led to increased attention to quantifying uncertainties and changes in ozonesonde data. The recent Assessment of Standard Operating Procedures for Ozone Sondes (ASOPOS 2.0; WMO/GAW Report #268) recommended that homogeneity and long-term stability in ozone sounding network time series be regularly evaluated by comparison with satellite sensors, as well as ground-based photometers.

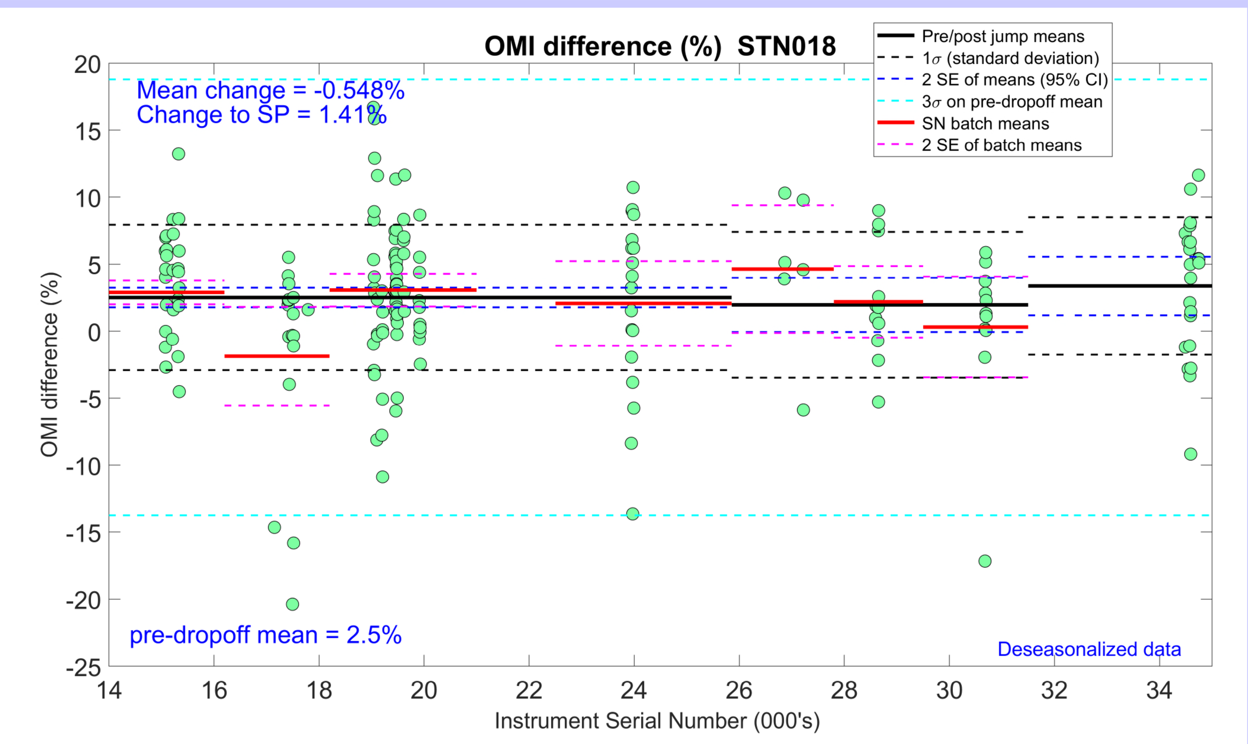
An abrupt change in ozone bias relative to several satellite sensors -- a total column ozone (TCO) "dropoff" of about 2-3% – has been reported at number of ozonesonde stations (Stauffer et al., 2020), including Canadian stations. The dropoff affects stratospheric measurements from the EnSci ozonesonde, after 2013 (approximately serial number 26000). The Canadian network recently switched to Science Pump sondes (after approximately serial number 32000), and this has reversed the dropoff, and approximately restored agreement with satellite sensors.

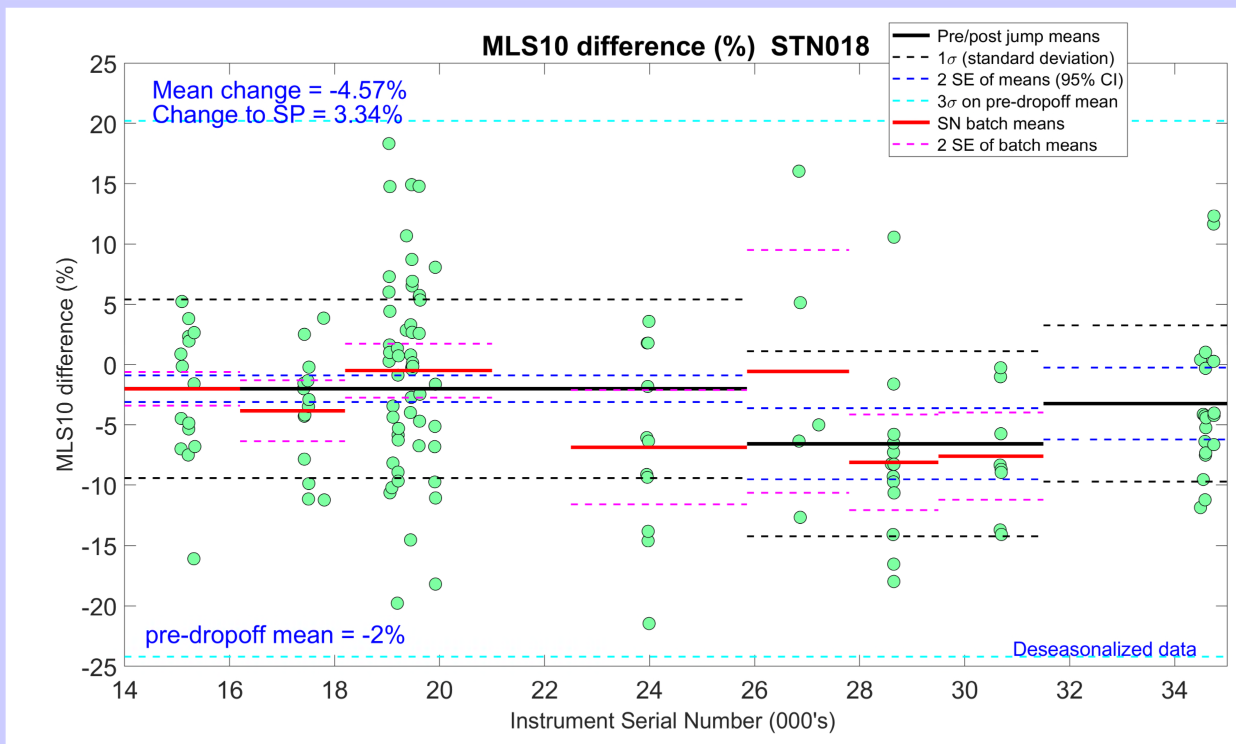
Figures 1-3: "Dropoff" differences, and average changes with switch to Science Pump sondes at Edmonton (Stn021). Manufacturing batch averages also shown.

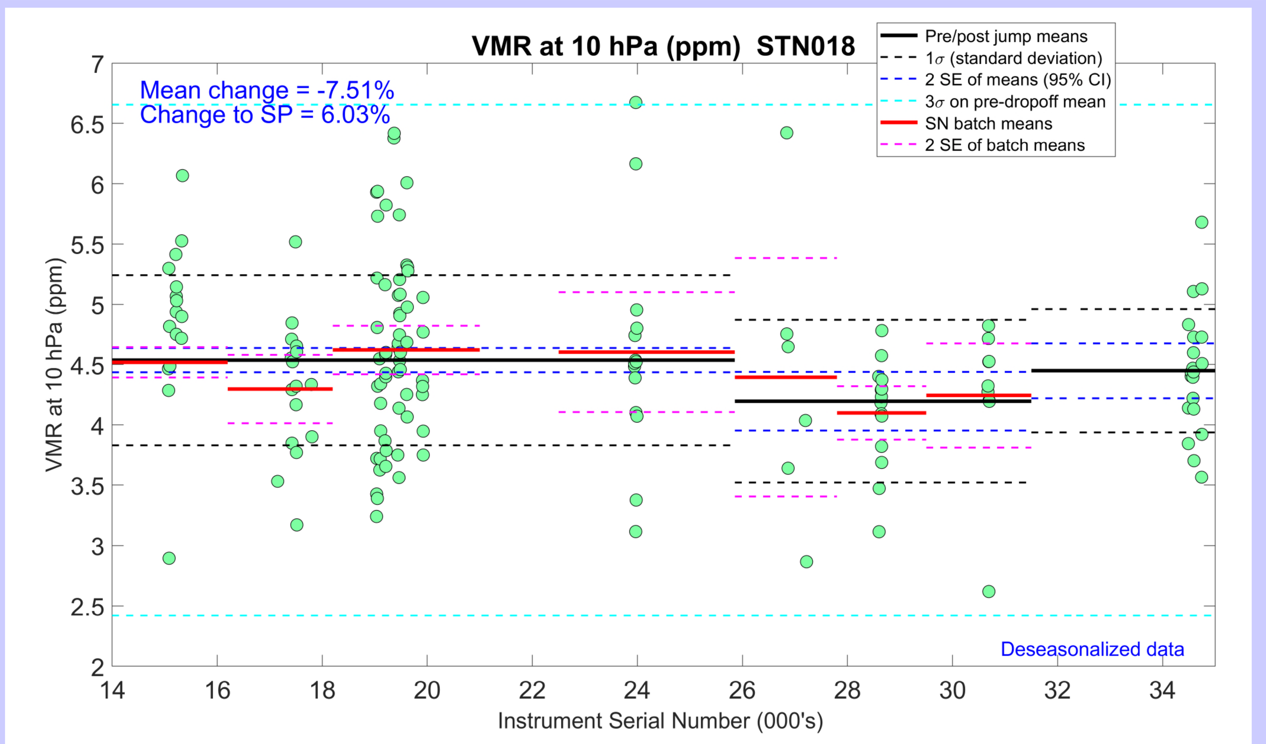




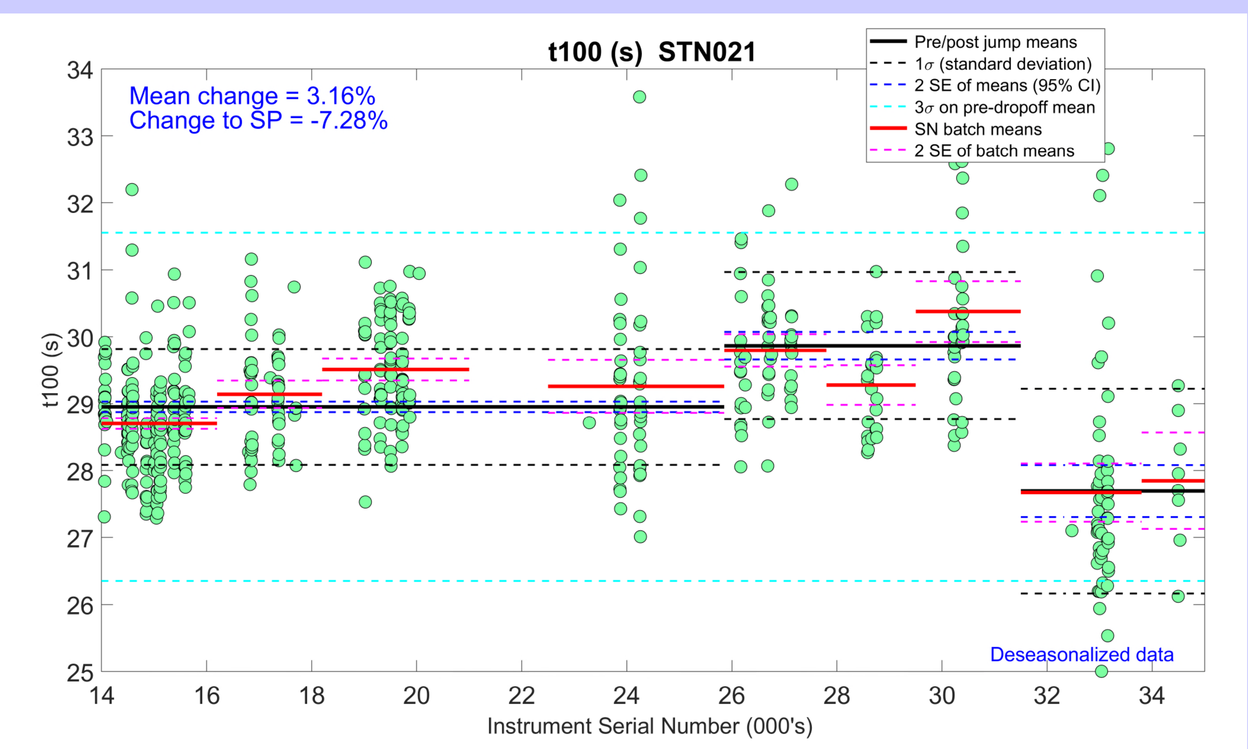


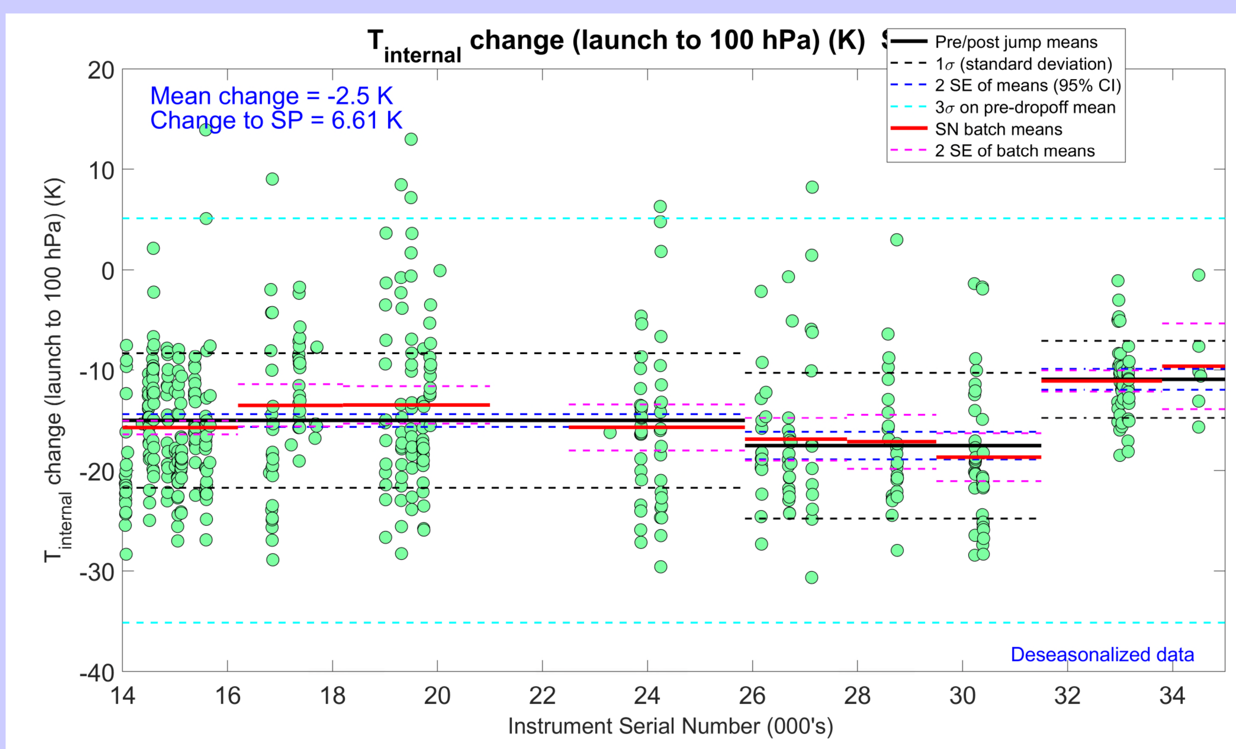


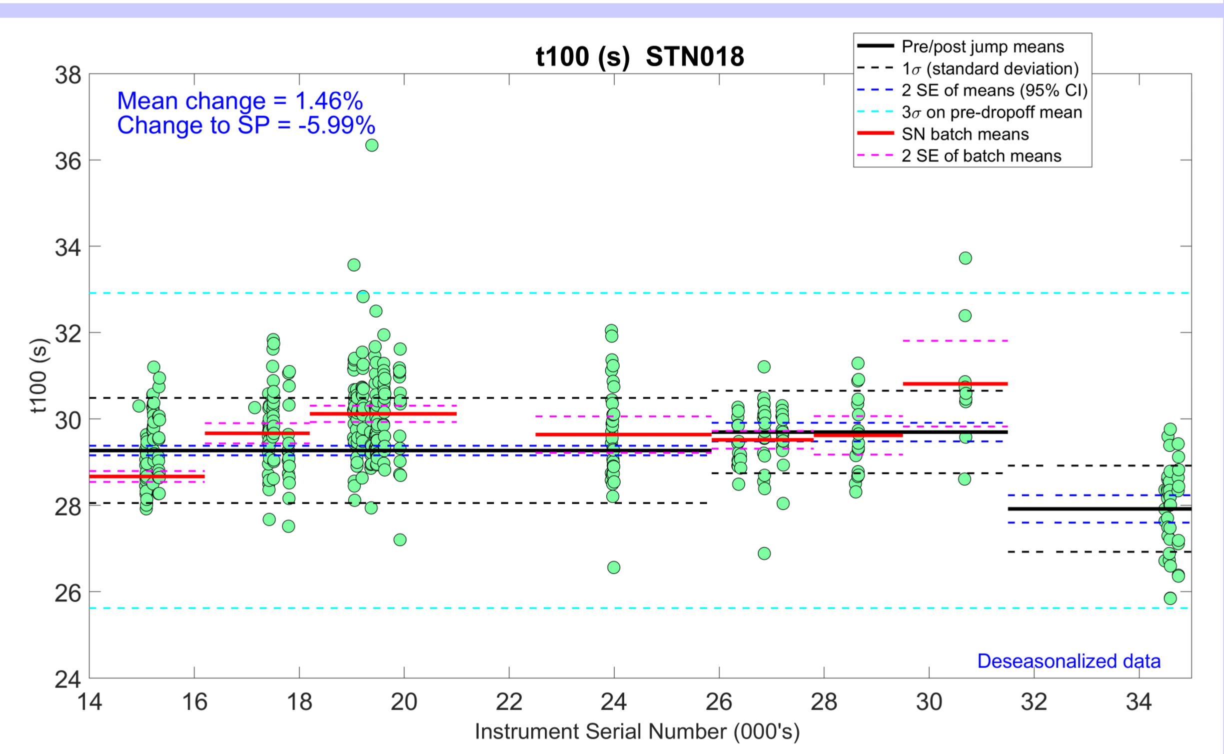


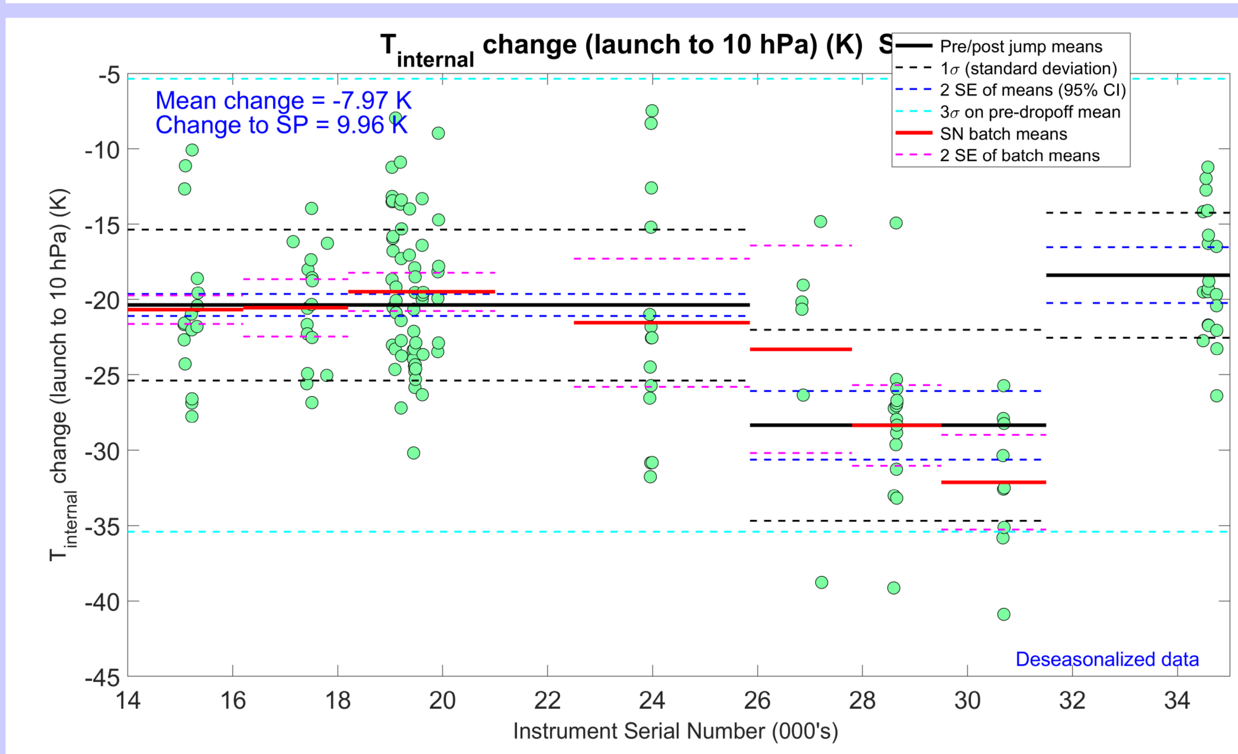


Figures 4-6: "Dropoff" differences, and average changes with switch to Science Pump sondes at Alert (Stn018). Batch averages also shown.









Figures 7-10: Changes in some recorded ancillary data (e.g. prelaunch pump rate and inflight pump temperature change) may be evidence of pump or motor changes, at Edmonton (left) and Alert (right).

Discussion: While the data show some apparent differences between manufacturing batches, the more consistent differences are with the "dropoff", and the switch to Science Pump sondes (thick solid black lines, confidence intervals dashed). The ozone concentration differences increase at lower pressures, suggesting a pump-related issue. Some pump and/or pump motor-related parameters show evidence of systematic changes at the same time, and the manufacturer is known to have changed the pump motor circa 2013. Correlations of these parameters with satellite differences between individual flights is not strong, as flight-to-flight variability dominates, but correlation of station averages is much better.

It is not standard practice to calibrate individual ozonesonde pumps before launch, as this is difficult and labour-intensive; rather an average pump calibration is used in data processing. Recently, an analysis of an extensive record of individual EnSci pump calibrations made since 2009 (Nakano and Morofuji, 2022) has shown a small negative shift in the low-pressure pump correction, equal to 2% at 20 hPa and 4% at 10 hPa. This agrees very well with the average differences found with MLS at 31 hPa and 10 hPa, indicated in Table 1 (green highlighting). While further work is needed, this suggests that a correction curve could be derived from the average changes with respect to MLS, and if that curve is consistent with, and therefore justified by the independent Nakano and Morofuji results, it could be used as a transfer function, and if applied to the sonde data after ~SN 26000 would fix the TCO drop at Canadian stations.

Station	GOME2a	GOME2b	OMI	OMPS	MLS100	MLS31	MLS10	Residual	iB2	t100	tpauseHT	burstHT	Flighttime	RiseRate	VMR_700	VMR_500	VMR_100	VMR_31	VMR_10	VMR_burst
STN018	0.6	0.1	-0.5	0.9	1.2	-3.8	-4.6	-13.4	-26.2	1.5	2.9	-5.1	7.0	-11.9	2.1	-1.1	-6.5	-2.8	-7.5	-15.7
STN077	-7.0	-5.7	-6.4	-5.0	0.1	-6.0	-9.1	-12.7	2.5	-0.2	2.6	-0.7	-3.0	2.3	-5.7	-9.1	-10.4	-10.0	-13.7	-14.3
STN021	-0.1	-1.0	-1.6	-1.8	0.0	-1.8	-4.0	-13.9	22.1	3.2	0.3	-0.7	4.6	-5.0	0.9	-0.7	-0.2	-3.2	-6.7	-10.1
STN315	0.5	1.1	-1.2	-0.1	2.2	-1.5	-3.1	-3.4	-30.8	2.5	-1.3	-9.3	-7.4	-3.8	-2.7	-1.8	-2.9	0.3	-7.3	-19.8
STN076	-1.01	-2.9	-1.4	-2.4	1.6	-2.2	-6.4	-5.3	-14.2	1.3	-1.6	-0.3	-2.9	2.6	-2.1	-5.9	1.1	-3.0	-7.6	-6.9
STN457	-1.1	-1.2	-1.2	-0.9	3.6	-0.2	-5.8	5.9	16.9	1.6	-1.0	-2.9	-8.3	5.7	-1.7	-0.4	-2.1	-3.0	-2.7	-5.7
STN024	-3.4	-3.2	-2.2	-2.2	-1.2	-2.6	2.4	-11.3	6.9	1.8	-0.3	-6.4	-6.4	-0.7	-3.6	-0.6	-4.0	-3.2	-1.5	-13.6
STN458	-2.0	-1.8	-3.9	-2.5	-1.0	-1.3	-3.9	-21.2	1.6	2.0	-0.2	4.5	0.7	3.7	-1.1	-0.3	-6.3	-4.6	-4.7	-5.2
Mean	-1.7	-1.8	-2.3	-1.7	0.8	-2.4	-4.3			1.7										

Station	pumpT_launch	T_launch	dT_launch	dT_burst	dT_10	dT_31	dT_100	dT_500	dT_700	T_700	T_500	T_100	T_31	T_10	pumpT_700	pumpT_500	pumpT_100	pumpT_31	pumpT_10	pumpT_burst
STN018	4.1	1.5	2.7	-1.9	-8.0	-5.7	-0.6	-1.1	-0.7	0.5	1.0	-1.5	1.3	1.7	3.4	3.0	3.4	-0.2	-2.3	2.3
STN077	-0.4	2.5	-2.7	0.0	-0.7	-0.3	-0.8	-0.5	-0.2	0.8	1.2	-0.6	-1.0	1.0	-0.7	-1.0	-1.4	-1.1	-1.9	-0.8
STN021	1.0	-0.1	1.1	-1.1	-0.3	0.3	-2.5	-1.5	-0.7	0.2	0.1	-0.3	-0.8	-0.5	0.4	-0.5	-1.4	1.2	0.6	-0.1
STN315	0.6	2.4	-1.8	3.7	2.7	3.1	1.3	-0.9	-0.7	-0.3	-0.2	-0.5	2.7	4.8	-0.1	-0.2	1.8	3.2	3.4	4.3
STN076	3.9	1.1	2.9	-3.6	-3.6	-3.4	-2.8	-1.2	-0.7	0.2	0.5	-0.2	-0.2	-0.6	3.1	2.6	0.9	0.0	-0.2	0.1
STN457	-1.2	-1.3	0.2	-0.6	0.0	-1.5	-1.8	-1.4	-0.6	0.1	-0.3	0.4	-0.4	0.1	-1.8	-2.6	-3.0	-2.7	-0.8	-1.8
STN024	2.5	0.7	1.8	-1.6	-5.6	-4.8	-3.0	1.0	0.7	0.3	0.4	-1.2	-1.2	2.5	3.2	3.5	-0.8	-2.5	-1.8	0.8
STN458	1.0	0.2	0.9	0.9	1.2	1.2	0.2	-0.8	-0.4	-0.1	0.0	0.1	-0.6	0.6	0.5	0.2	1.1	2.2	2.2	1.9
Mean				0.6	-0.5	-1.8	-1.4	-1.3	-0.8	-0.4										

Table 1: Percent changes in some recorded ancillary data after serial number 26000. Highlighted differences indicate that means before and after dropoff are different at 95% confidence.

Note: OMI= difference from collocated OMI total ozone measurement; MLS31= difference from collocated MLS measurement at 31 hPa; Residual= Constant mixing ratio method; iB2= prelaunch background current; t100= prelaunch time to pump 100 ml; VMR= volume mixing ratio; dT_launch= difference of internal (pump) temperature and external air temperature at launch; dT_burst= pump temperature change from launch to burst, similarly for dT_10, etc.; T_700= external air temperature at 700 hPa, etc.

Station	GOME2a	GOME2b	OMI	OMPS	MLS100	MLS31	MLS10	Residual	iB2	t100	tpauseHT	burstHT	Flighttime	RiseRate	VMR_700	VMR_500	VMR_100	VMR_31	VMR_10	VMR_burst
STN018			1.4	-0.4	-0.5	4.5	3.3	2.6	-79.2	-6.0	-4.6	2.3	-18.5	27.1	-3.1	0.4	8.3	5.9	6.0	11.5
STN077	9.1	6.2	8.8	8.9	1.5	4.3	10.2	11.0	-53.9	-1.7	-1.8	3.4	-0.8	3.9	11.0	15.0	23.9	12.6	14.4	23.1
STN021	3.4	4.6	2.8	3.2	1.7	3.1	4.8	2.2	-79.6	-7.3	-3.5	1.3	-14.6	16.2	0.2	-1.3	0.2	6.4	7.7	5.9
STN315	2.5	-2.3	1.5	1.5	-0.9	2.0	4.0	-0.4	-20.9	-7.8	-25.7	13.1	4.9	6.7	-3.4	0.8	10.3	7.6	8.6	31.0
STN076		5.1	3.0	5.4	1.1	3.8	8.4	1.4	-89.5	-7.8	4.4	2.4	-0.1	2.6	1.8	5.1	-2.4	7.4	12.1	10.9
STN457																				
STN024					-1.6	-1.9		68.8	13.8	-3.7	2.9	-19.0	-22.2	7.4	5.8	1.5	14.0	10.0		-27.6
STN458	2.0	1.4	1.3	1.3	-0.7	0.3	3.5	6.0	-84.8	-8.2	-1.1	-1.0	-3.3	2.1	-1.4	-4.8	4.7	5.6	7.3	5.6
Mean	4.3	3.0	3.1	3.3	0.1	2.3	5.7			-6.1										

Station	pumpT_launch	T_launch	dT_launch	dT_burst	dT_10	dT_31	dT_100	dT_500	dT_700	T_700	T_500	T_100	T_31	T_10	pumpT_700	pumpT_500	pumpT_100	pumpT_31	pumpT_10	pumpT_burst
STN018	3.8	-0.6	4.3	5.1	10.0	6.5	3.8	3.2	1.7	0.7	0.1	0.0	-2.0	-1.7	5.5	7.1	7.9	8.8	12.4	8.8
STN077	-0.2	-1.0	0.8	3.9	4.3	3.7	3.1	0.1	-0.5	0.0	-0.5	0.0	-0.7	-2.8	-0.7	-0.2	2.7	3.1	4.1	3.7
STN021	0.4	-0.9	1.3	8.7	5.9	5.3	6.6	2.2	0.7	0.2	0.2	0.2	-0.1	-0.7	1.1	2.5	7.4	5.8	5.9	9.1
STN315	0.3	0.0	0.3	0.7	1.5	1.1	1.8	3.2	2.0	1.3	1.4	0.0	-2.6	-4.5	2.3	3.5	2.1	1.6	1.7	1.0
STN076	-3.5	1.7	-5.2	7.8	7.2	7.7	6.3	2.3	1.2	1.6	1.7	-0.5	-1.7	-2.8	-2.3	-1.2	2.8	4.4	4.6	4.3
STN457																				
STN024	-2.1	0.6	-2.8	4.2		-2.0	4.2	4.5	2.9	3.1	0.9	-2.3	-0.7		0.8	2.3	3.1	-3.9		2.1
STN458	0.4	0.4	0.0	7.5	6.3	6.5	5.9	2.8	1.6	-0.1	0.1	0.4	0.9	-0.4	2.0	3.2	6.3	6.8	6.2	7.9
Mean				5.4	5.9	4.1	4.5	2.6	1.4											

Table 2: Percent changes in some recorded ancillary data after serial number 32000. Highlighted differences indicate that means before and after switch to Science Pump sondes are different at 95% confidence.

Nakano, T. & Morofuji, T. (2022). Development of an automated pump efficiency measuring system for ozonesonde utilizing the airbag type flowmeter, *EGUsphere* [preprint], https://doi.org/10.5194/egusphere-2022-565.

Stauffer, R. M., et al. (2020). A post-2013 dropoff in total ozone at a third of global ozonesonde stations: Electrochemical concentration cell instrument artifacts? *Geophysical Research Letters*, *47*, e2019GL086791, https://doi.org/10.1029/2019GL086791.