Consistency evaluation of tropospheric ozone from ozonesonde and IAGOS aircraft observations: vertical distribution, ozonesonde types and station-airport distance

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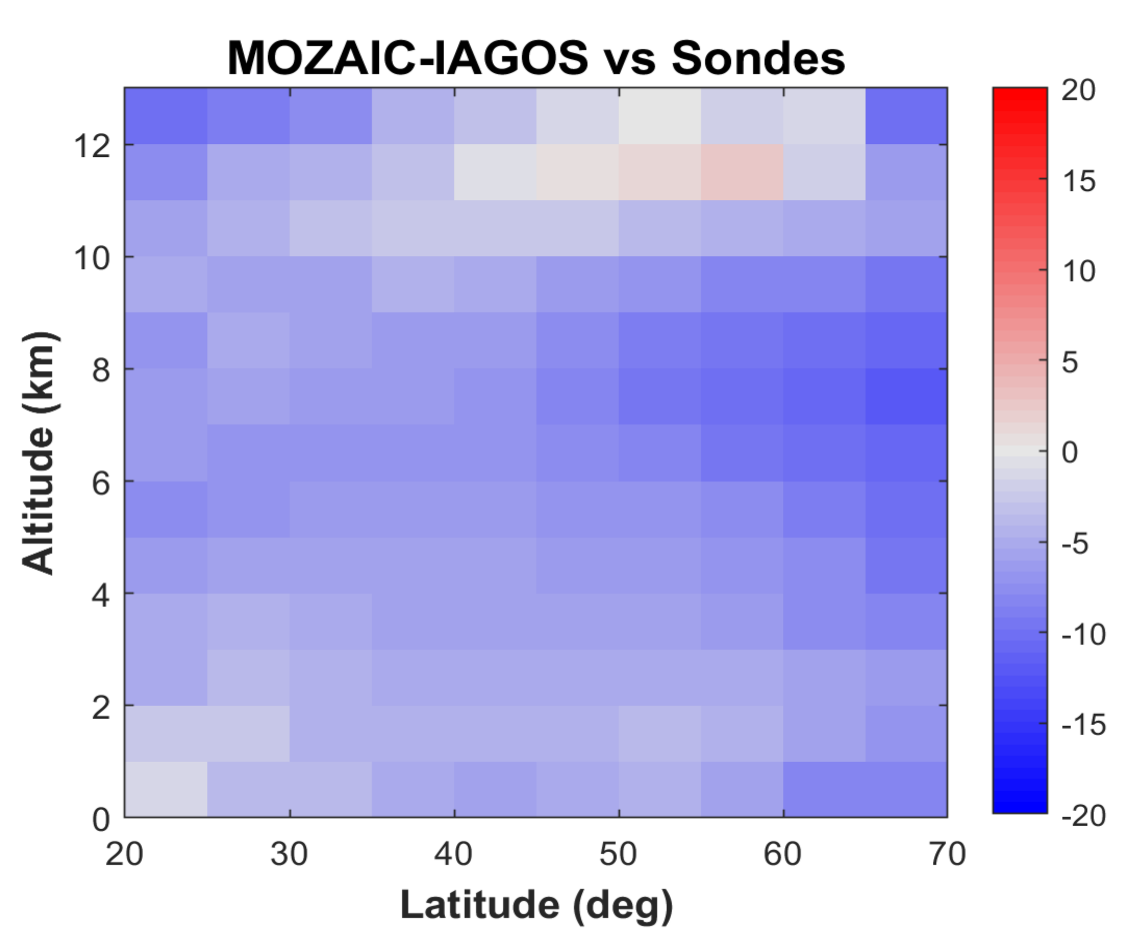
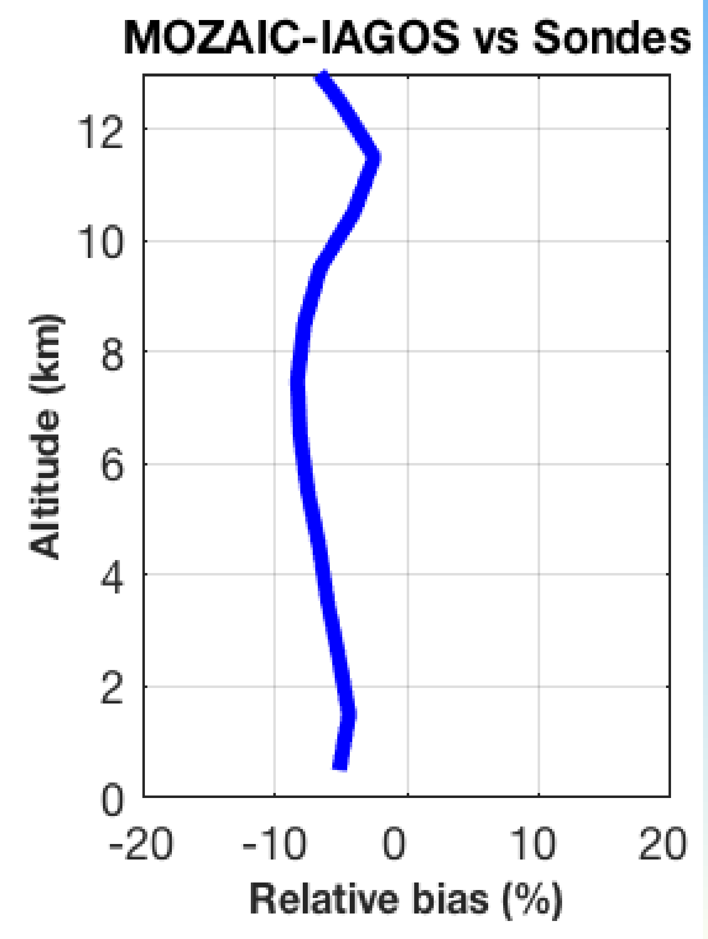
Previous comparisons of MOZAIC/IAGOS data with ozonesondes:

- Negative biases of a few % (sonde values higher); larger differences in the early part of the MOZAIC record (Thouret et al., 1998; Staufer et al., 2013, 2014).
- Negative biases of 6% or less against ECC sondes (Zbinden et al., 2013; Tanimoto et al., 2015).

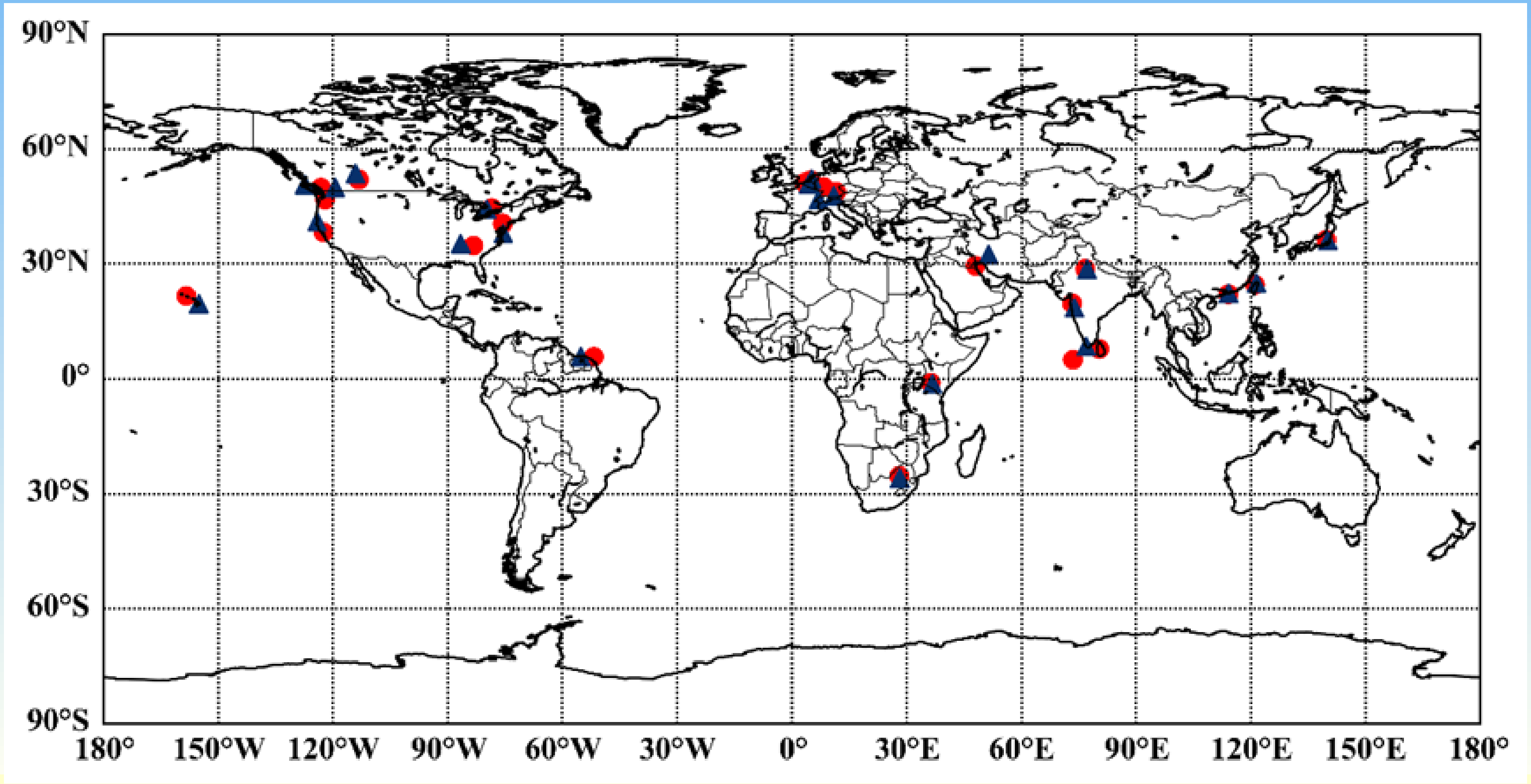
MOZAIC/IAGOS minus ozonesonde data (both trajectory-mapped averages). Sonde measurements are about 5±1% higher, in the lower troposphere, and 8±1% higher in the upper troposphere (TOAR-Observations, *Tarasick, Galbally et al.*, 2019).





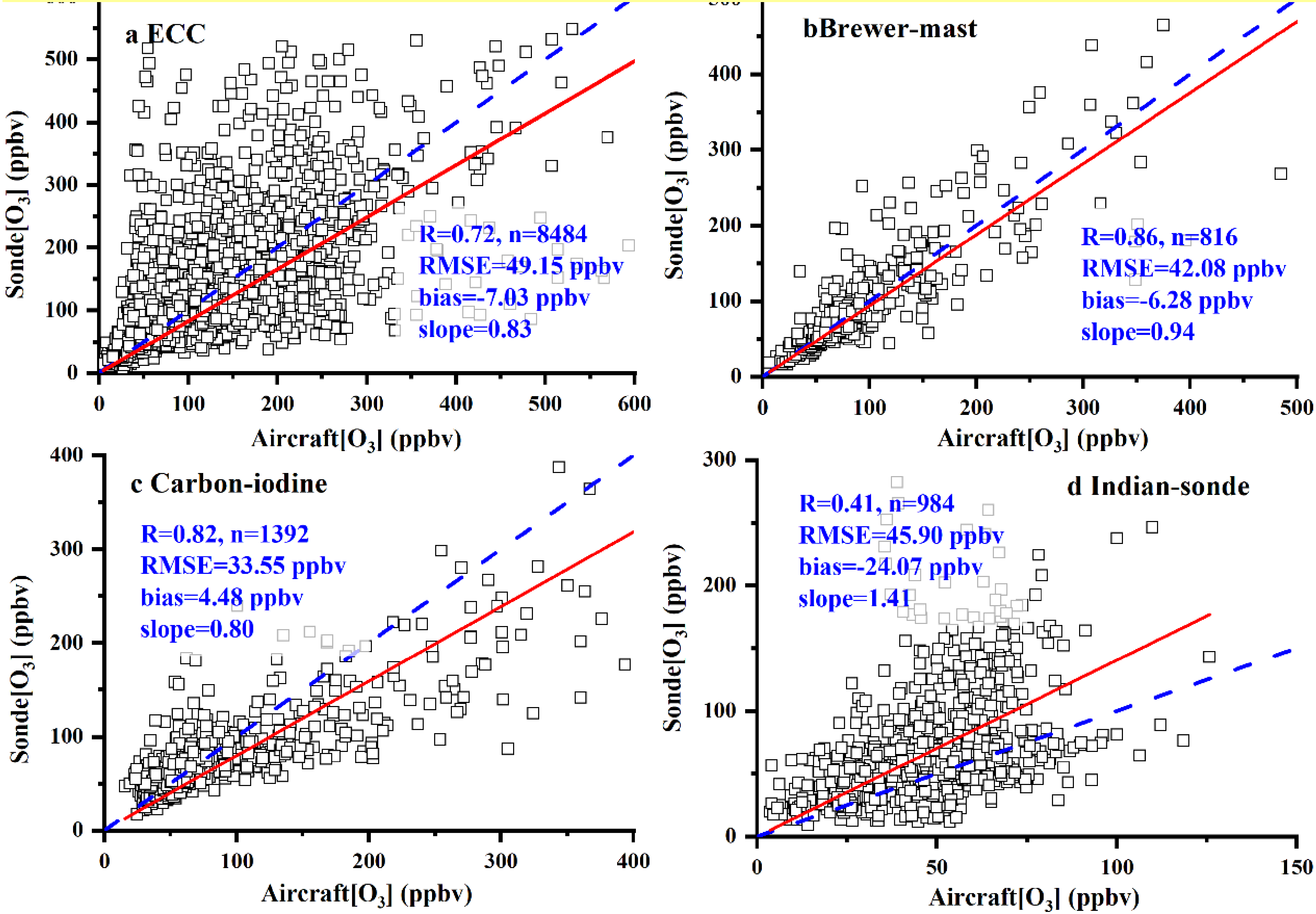
This work:

- Looked for sonde-airport pairs with records that overlap in time
- Select site pairs within ±4° (latitude and longitude)
- Further group these into <1°, 1°- 2°, and 2°- 4°
- 23 site pairs; calculated means for each month, for each time series

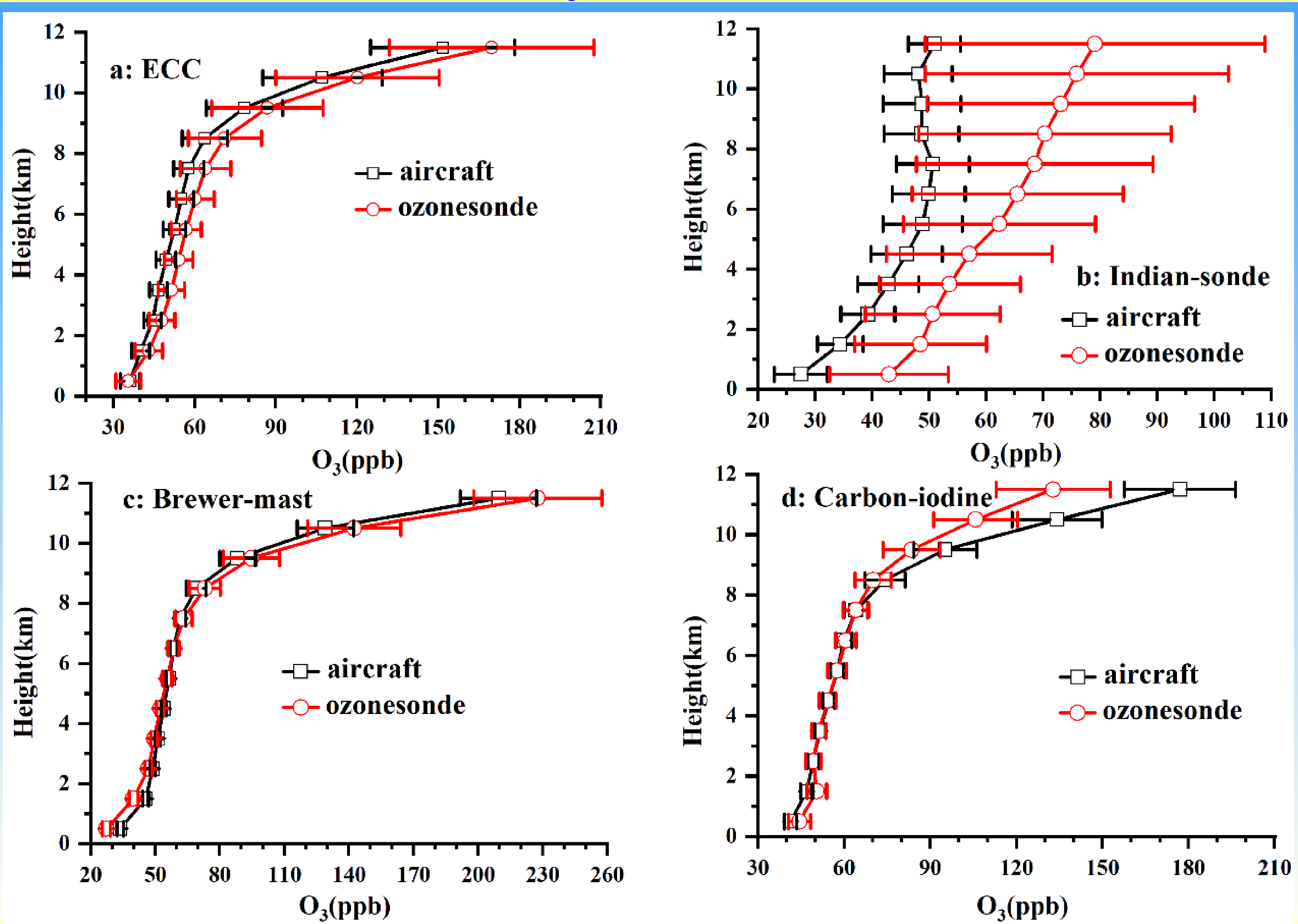


MOZAIC-IAGOS				WOUDC					observation period	station-airport distance
Airport	Lon	Lat	# profiles	Station	Lon	Lat	# profiles	Type		
Toronto	-78.50	44.58	321	Egbert	-79.78	44.23	181	ECC	2004-2008	<1°
Dusseldorf	4.96	51.82	412	De Bilt	5.18	52.10	333	ECC	1995-2013	
Munich	11.63	48.84	2136	MOHp	11.01	47.80	1032	Brewer-mast	1996-2006	
Johannesburg	28.07	-25.32	199	Irene	28.22	-25.91	135	ECC	1998-2003	
Nairobi	36.33	-0.94	114	Nairobi	36.75	-1.30	42	ECC	1997-1998	
Mumbai	73.27	19.70	122	Pune	73.85	18.53	56	Indian-sonde	1996-2003	
Delhi	76.65	28.73	342	New Delhi	77.18	28.63	88	Indian-sonde	1995-2016	
Hongkong	114.11	22.10	123	King's Park	114.17	22.31	115	ECC	2000-2005	
Taipei	121.08	24.59	2115	Taipei	121.48	25.02	58	ECC	2014-2018	
Tokyo	139.73	36.33	1342	Tateno (Tsukuba)	140.13	36.05	655	Carbon-iodine	1995-2006	
Calgary	-113.25	52.03	170	Edmonton	-114.10	53.55	112	ECC	2009-2011	1°~2°
Brussels	3.24	51.21	2412	Uccle	4.36	50.80	736	ECC	1997-2009	
Honolulu	-158.33	21.66	169	Hilo	-155.07	19.58	107	ECC	2015-2017	2°~4°
Vancouver	-123.14	49.95	595	Kelowna	-127.38	50.69	594	ECC	2003-2015	
San Francisco	-122.50	38.30	34	Trinidad Head	-124.15	41.05	53	ECC	1999-2001	
Portland	-122.06	46.76	385	Kelowna	-119.38	49.97	317	ECC	2003-2009	
Atlanta	-83.28	34.78	34	Huntsville	-86.58	35.28	85	ECC	1999-2006	
Washington	-75.59	40.52	610	Wallops Island	-75.46	37.94	616	ECC	1994-2014	
Cayenne	-51.78	5.75	200	Paramaribo	-55.21	5.81	64	ECC	2002-2013	
Frankfurt	8.30	50.16	12742	Payerne	6.94	46.81	2673	ECC	2002-2020	
Kuwait-City	48.01	29.52	105	Esfahan	51.43	32.48	34	ECC	2001-2004	
Male	73.49	5.00	76	Trivandrum	76.95	8.48	45	Indian-sonde	1997-2000	
Colombo	80.41	7.79	31	Trivandrum	76.95	8.48	37	Indian-sonde	1998-2000	

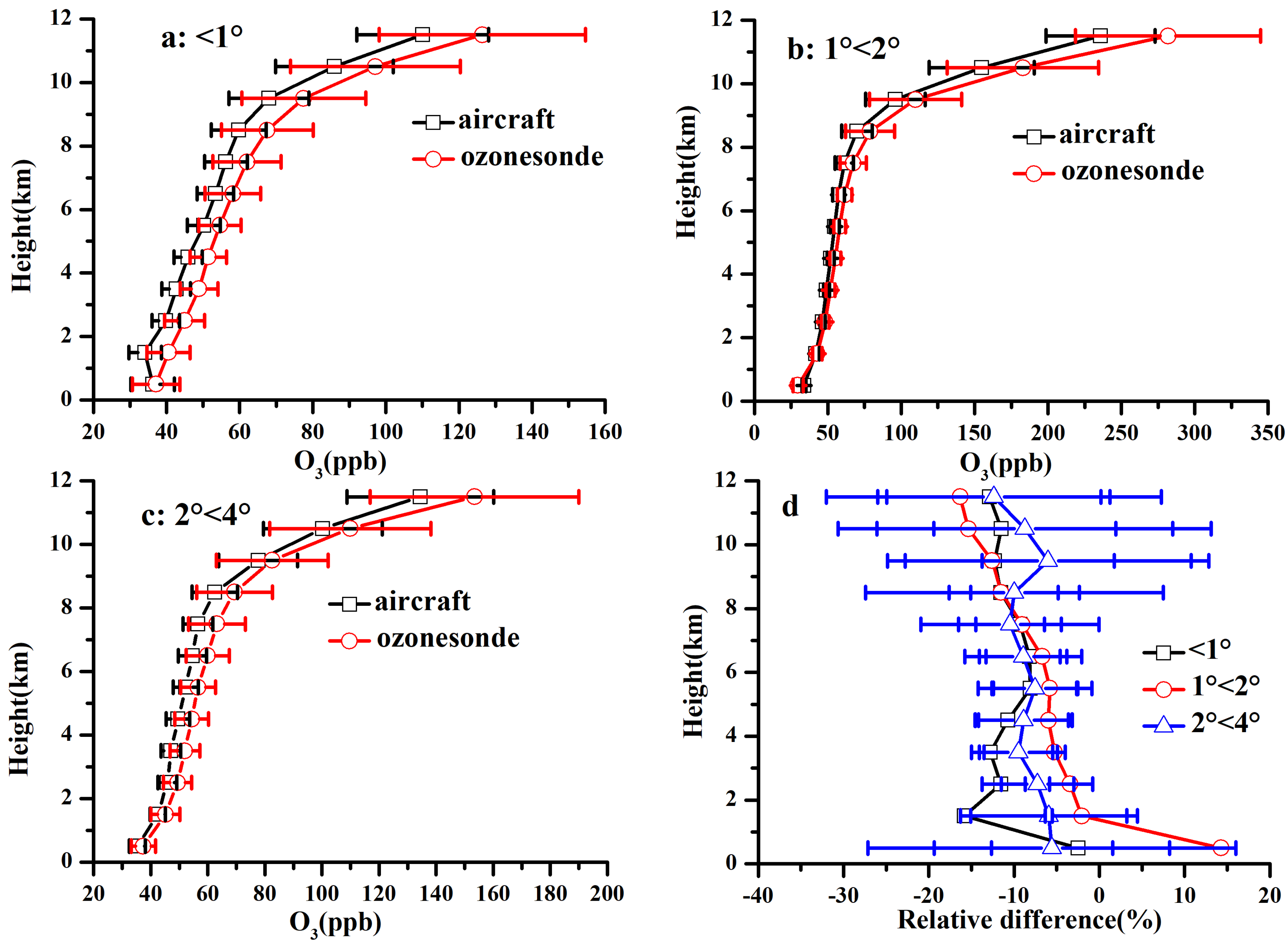
Most sonde types show good correlation with IAGOS; Indian sonde compares poorly



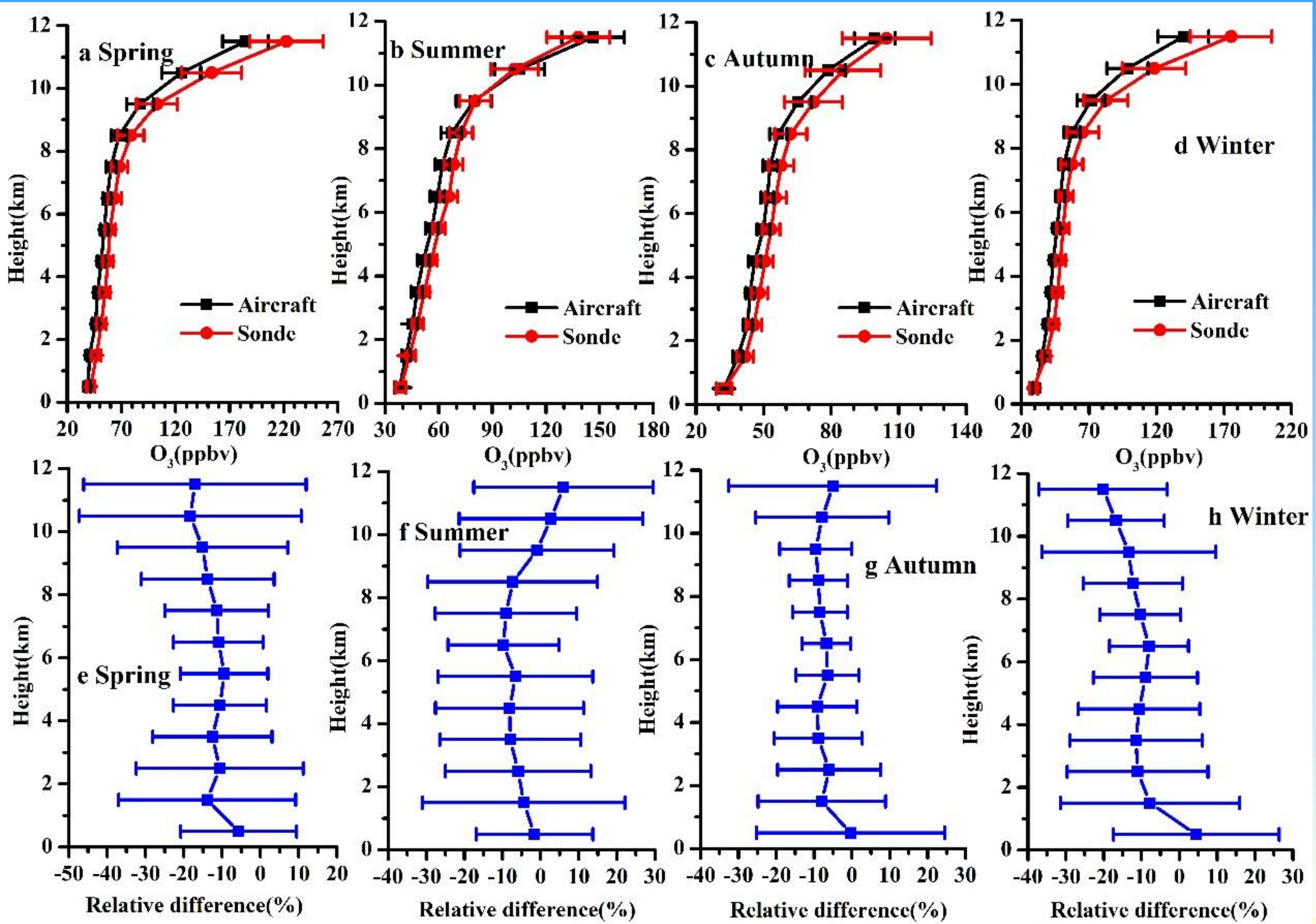
Vertical distribution of tropospheric O_3 from IAGOS measurements and ozonesondes



Little dependence on distance: Annual mean profiles for ECC ozonesonde and aircraft observations at station-pair distances of <1° (a), 1°- <2° (b), and 2°- 4°



Little seasonal dependence (ECC sondes only)



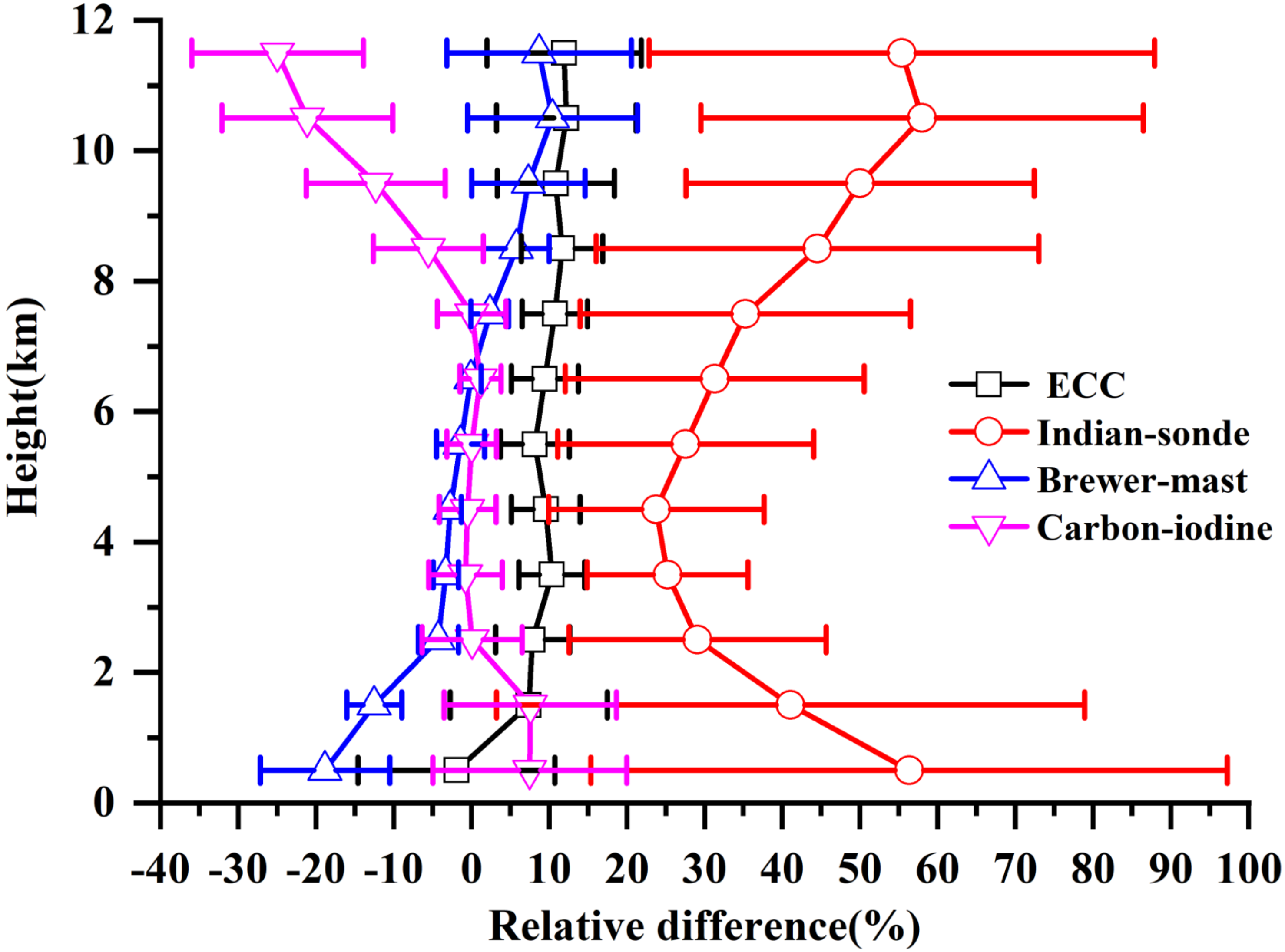
Although uncertainties are sizeable due to the relatively sparse nature of the available data, we find consistent differences at all sites, with

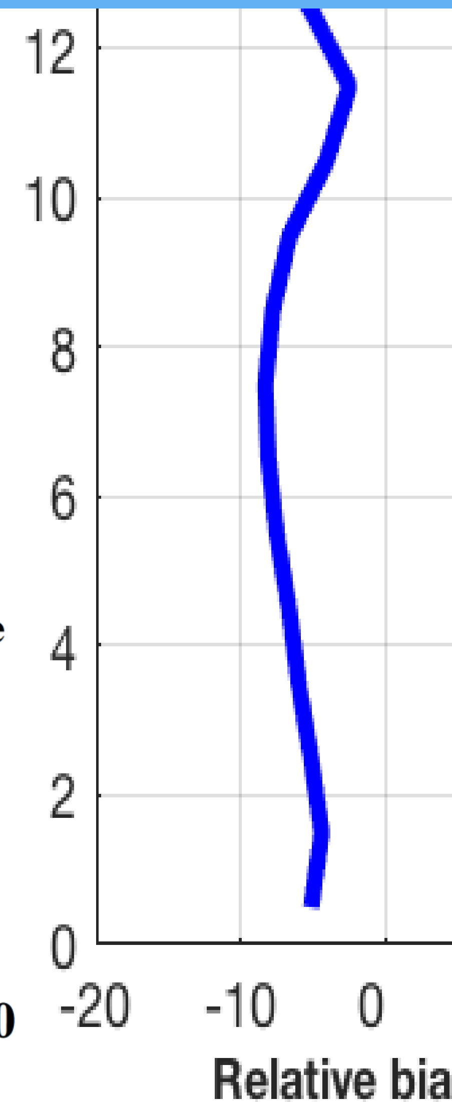
- Little dependence on season
- Little dependence on station-airport separation

However, consistent with previous work, there is a fairly constant bias between IAGOS and sondes, with considerable dependence on sonde type --- as expected from previous sonde intercomparisons like JOSIE 1996.

Notwithstanding this overall sonde-IAGOS bias, we can use these station-airport comparisons to derive relative biases of the different sonde types in use in the global network

- IAGOS can serve as a transfer standard to compare ozonesonde relative biases under operational conditions
- Note that these results are broadly consistent with those from JOSIE 1996
- Also consistent with trajectory-mapped result (TOAR-Observations)





Conversion table

Altitude(km)	Indian-sonde/ECC	Brewer-Mast/ECC	Carbon-Iodine/ECC
0~1	1.59 ±1.74	0.83 ±0.96	1.10 ±1.36
1~2	1.31 ±1.83	0.81 ±0.90	1.00 ±1.05
2~3	1.20 ±1.62	0.89 ±0.97	0.93 ±0.85
3~4	1.14 ±1.57	0.88 ±0.94	0.90 ±0.87
4~5	1.13 ±1.61	0.89 ±1.02	0.91 ±0.99
5~6	1.18 ±1.76	0.91 ±1.05	0.92 ±1.04
6~7	1.20 ±1.89	0.91 ±1.00	0.92 ±0.82
7~8	1.22 ±1.92	0.92 ±0.94	0.90 ±0.64
8~9	1.29 ±2.09	0.95 ±0.99	0.85 ±0.55
9~10	1.35 ±2.35	0.97 ±1.09	0.79 ±0.62
10~11	1.41 ±3.26	0.98 ±1.21	0.70 ±0.68
11~12	1.39 ±4.61	0.97 ±1.19	0.67 ±0.72

Conclusions

IAGOS can serve as a transfer standard to compare ozonesonde relative biases under operational conditions

- This can be useful for comparing or merging data. Last WMO ozonesonde intercomparison for some sonde types was in 1996!

New version of TOST, with sonde data to 2021, to be available soon

The O_3 concentration observed by ECC sondes is higher by 5-10% than that observed by IAGOS aircraft, and the relative difference increases with altitude. Possible reasons?

1. Side reactions could cause sondes to produce excess iodine
2. Loss of ozone on the inlet pump could cause IAGOS monitors to read low at pressures below 800 hPa. (This was a problem in GASP and NOXAR, but *Thouret et al*., 1998 found it negligible)

Experiments in the WCCOS chamber could elucidate these issues.