Supplement: Evaluating tropospheric humidity from GPS radio occultation, radiosonde, and AIRS from high-resolution time series

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1   Co-Location of ERA, RO, RS, and AIRS

A map with the locations of the 4 chosen RS stations is shown in Fig. S1. Details about the co-location process are depicted in Fig. S2.
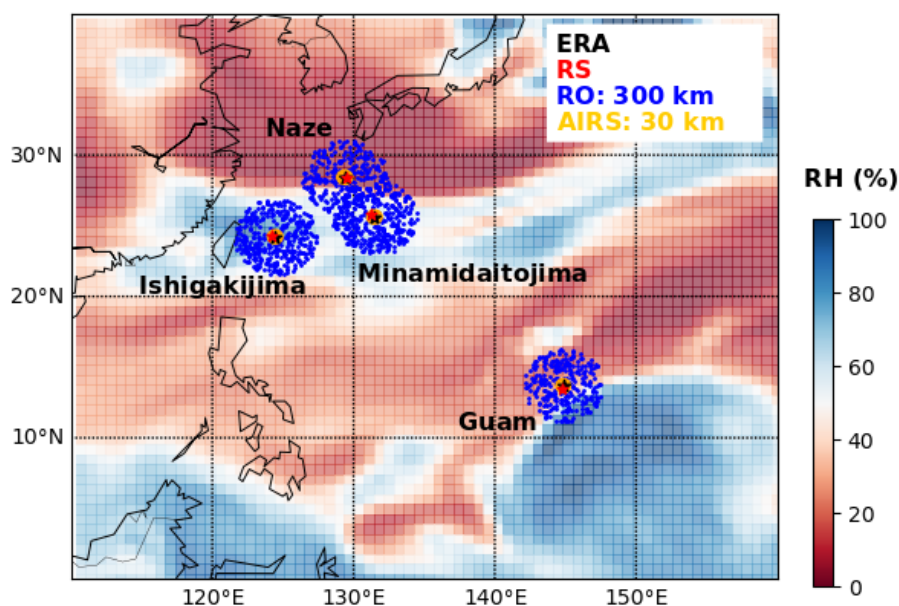
Figure S1. Map with the locations of Guam, Ishigakijima, Minamidaitojima, and Naze, and the locations of the data sets: ERA (black star), radiosonde (red star), RO (blue dots), and AIRS (yellow circle). The ERA relative humidity field at 700 hPa for one day is shown in the background.
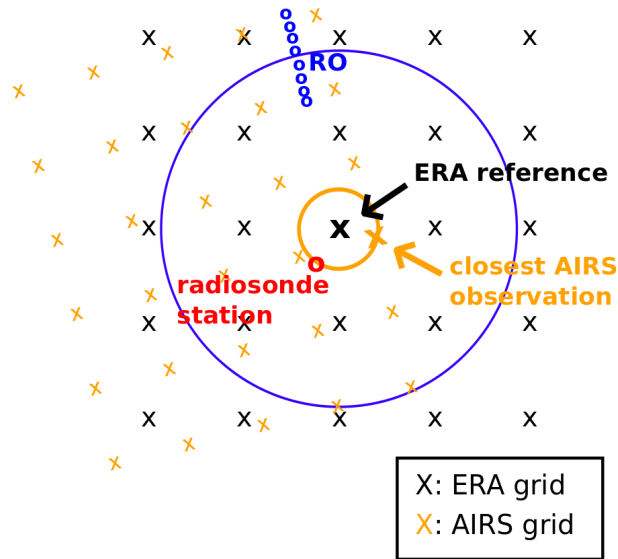
Figure S2. Sketch of the co-location of RO, RS, and AIRS with the ERA reference point for one point in time. ROs are chosen if their mean tangent point is within 300 km from the ERA reference.

2 2007 annual mean profiles

The constant value CLIMO (ERA 2007 annual mean) is used to normalize all data sets. The values for CLIMO are listed in Table S1.

3 Setting the stage: ERA 2007 time series of N, T, q, and RH

Time series for ERA refractivity, temperature, specific humidity, and relative humidity for 2007 are shown in Fig. S3 for Guam and in Fig. S4 for Ishigakijima. All data are interpolated to a common 25 hPa grid.

4 Normalized difference for specific humidity between various data sets and ERA

The Minamidaitojima 2007 RH time series are shown in Fig. S5 (top). Time series for q normalized differences between various data sets and ERA are shown in Fig. S5 (panels 2–5) and Fig. S6.

5 Normalized difference for refractivity between various data sets and ERA

Time series for refractivity N normalized differences between various data sets and ERA are shown in Fig. S7 and Fig. S8.

Table S1. Mean annual values for refractivity, specific humidity, relative humidity, and temperature for ERA in 2007, interpolated on a 25 hPa grid.

Pressure (hPa)	Refractivity (N-units)				Specific Humidity (g kg^{-1})				Relative Humidity (%)				Temperature (°C)			
	Guam	Ishi	Mina	Naze	Guam	Ishi	Mina	Naze	Guam	Ishi	Mina	Naze	Guam	Ishi	Mina	Naze
300	96.7	96.8	97.0	97.5	0.3	0.3	0.3	0.3	41.6	37.8	38.8	40.3	-29.8	-30.3	-30.9	-32.1
325	103.1	103.3	103.5	104.1	0.4	0.4	0.4	0.4	39.1	37.6	38.3	40.7	-25.6	-26.5	-27.0	-28.5
350	109.8	110.3	110.4	111.2	0.6	0.6	0.5	0.5	36.6	37.5	37.7	41.2	-21.5	-22.6	-23.2	-24.9
375	116.4	117.1	117.1	117.9	0.7	0.7	0.7	0.6	35.6	37.7	37.5	40.9	-18.1	-19.5	-20.1	-21.8
400	123.5	124.3	124.3	125.1	0.9	0.9	0.9	0.8	34.5	37.9	37.3	40.6	-14.8	-16.4	-16.9	-18.7
425	130.4	131.3	131.1	132.0	1.1	1.1	1.0	1.0	35.0	38.3	37.1	40.6	-12.0	-13.7	-14.2	-16.0
450	137.7	138.7	138.4	139.3	1.4	1.4	1.3	1.2	35.5	38.7	37.0	40.6	-9.3	-11.0	-11.5	-13.3
475	145.0	146.0	145.6	146.4	1.7	1.7	1.5	1.5	36.9	39.7	37.9	41.3	-6.9	-8.6	-9.1	-10.8
500	152.8	153.7	153.2	154.0	2.0	2.0	1.8	1.7	38.3	40.8	38.9	42.0	-4.4	-6.3	-6.6	-8.4
525	160.4	161.4	160.8	161.4	2.3	2.3	2.1	2.0	39.7	42.4	40.7	43.0	-2.4	-4.2	-4.5	-6.3
550	168.4	169.5	168.9	169.3	2.7	2.7	2.5	2.3	41.1	44.0	42.4	43.9	-0.3	-2.1	-2.4	-4.2
575	176.4	177.7	176.9	177.1	3.0	3.1	2.9	2.6	42.8	46.1	44.4	45.3	1.5	-0.2	-0.6	-2.4
600	184.7	186.3	185.4	185.4	3.5	3.6	3.3	3.0	44.6	48.2	46.3	46.8	3.4	1.7	1.3	-0.6
625	193.1	195.0	193.8	193.5	3.9	4.0	3.7	3.4	45.8	50.2	48.1	48.2	5.3	3.4	3.1	1.1
650	202.0	204.1	202.7	202.0	4.5	4.6	4.2	3.8	47.1	52.3	49.9	49.6	7.3	5.1	4.8	2.8
675	211.2	213.3	211.5	210.3	5.0	5.1	4.7	4.1	48.7	54.6	51.6	50.7	9.0	6.7	6.3	4.3
700	220.8	222.9	220.8	219.0	5.7	5.7	5.2	4.6	50.4	56.9	53.3	51.8	10.7	8.2	7.8	5.8
725	231.1	232.4	229.9	227.5	6.3	6.2	5.6	4.9	53.1	59.0	55.0	52.6	12.1	9.5	9.1	7.0
750	241.8	242.3	239.5	236.3	7.1	6.8	6.2	5.3	55.9	61.1	56.6	53.5	13.6	10.8	10.3	8.3
775	253.9	252.4	249.5	245.3	8.1	7.3	6.7	5.7	60.1	63.4	59.3	54.9	14.8	12.0	11.4	9.4
800	267.1	263.0	260.3	254.9	9.2	8.0	7.4	6.2	65.4	66.3	63.0	56.9	15.9	13.1	12.4	10.5
825	281.5	274.7	271.9	265.7	10.4	8.7	8.2	6.8	71.5	70.5	67.4	61.3	16.9	14.0	13.4	11.5
850	295.9	287.0	283.8	277.7	11.6	9.6	8.9	7.6	76.6	74.7	71.5	66.9	17.9	15.1	14.3	12.4
875	310.2	299.6	295.8	290.2	12.8	10.5	9.7	8.5	80.5	78.1	75.0	72.5	19.1	16.1	15.4	13.5
900	324.2	312.5	308.4	303.3	13.9	11.4	10.6	9.5	83.2	81.1	78.3	77.6	20.4	17.3	16.5	14.6
925	337.6	325.4	321.5	316.1	14.9	12.4	11.6	10.4	84.2	83.0	80.9	80.5	21.8	18.6	17.8	16.0
950	352.0	338.2	334.5	328.2	16.0	13.3	12.5	11.2	86.6	83.7	82.5	81.1	22.9	20.0	19.1	17.4
975	363.4	349.7	346.1	338.9	16.7	14.0	13.3	11.9	84.3	81.8	81.2	79.1	24.6	21.6	20.7	19.1
1000	371.6	358.8	354.5	347.3	17.1	14.5	13.7	12.3	78.0	76.7	75.8	74.1	26.6	23.6	22.7	21.1
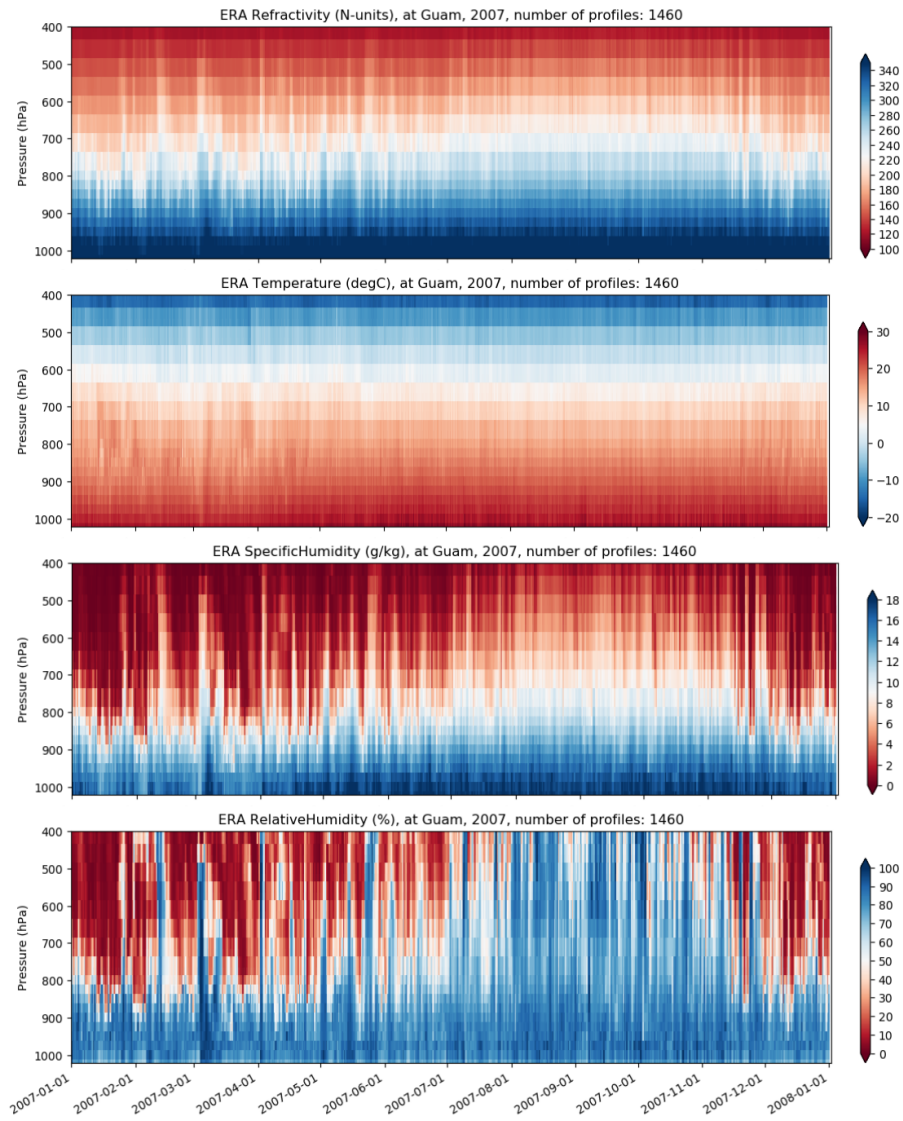
Figure S3. ERA 2007 time series at Guam for refractivity, temperature, specific humidity, and relative humidity (top to bottom).
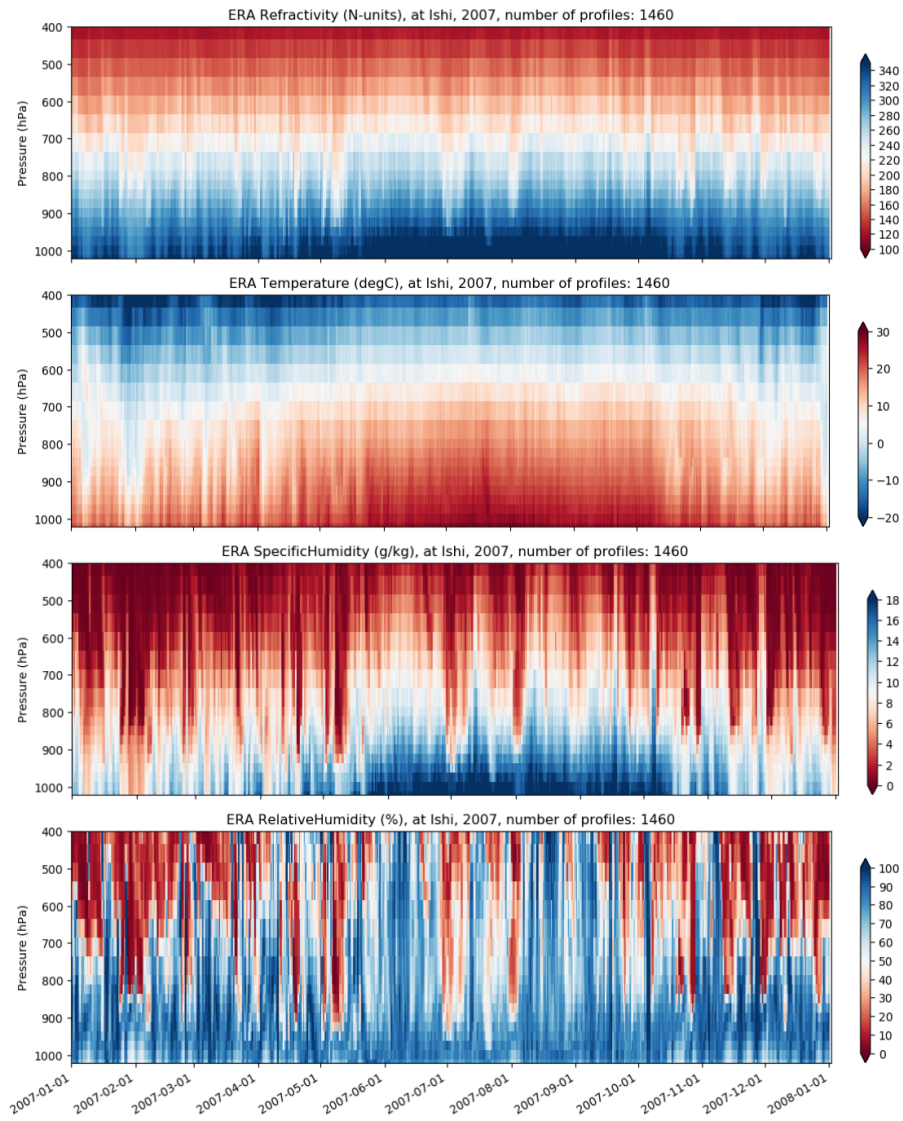
Figure S4. ERA 2007 time series at Ishigakijima for refractivity, temperature, specific humidity, and relative humidity (top to bottom).
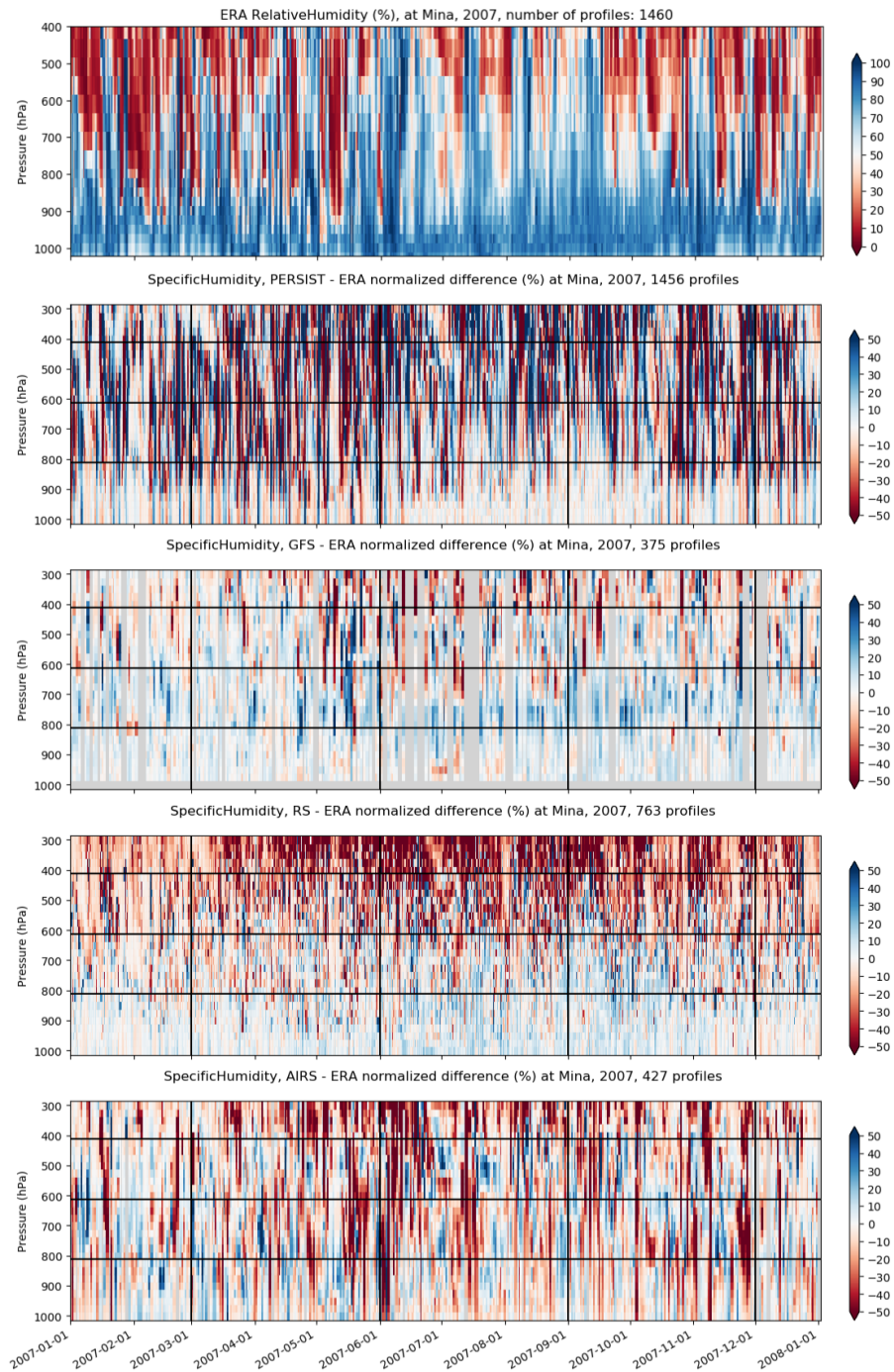
Figure S5. Top panel: 2007 time series of the relative humidity (%) at Minamidaitojima over 2007 with blue representing moist air and red representing dry air. Other panels: Normalized difference of specific humidity for PERSIST, GFS, RS, and AIRS compared to ERA at Minamidaitojima, 2007.
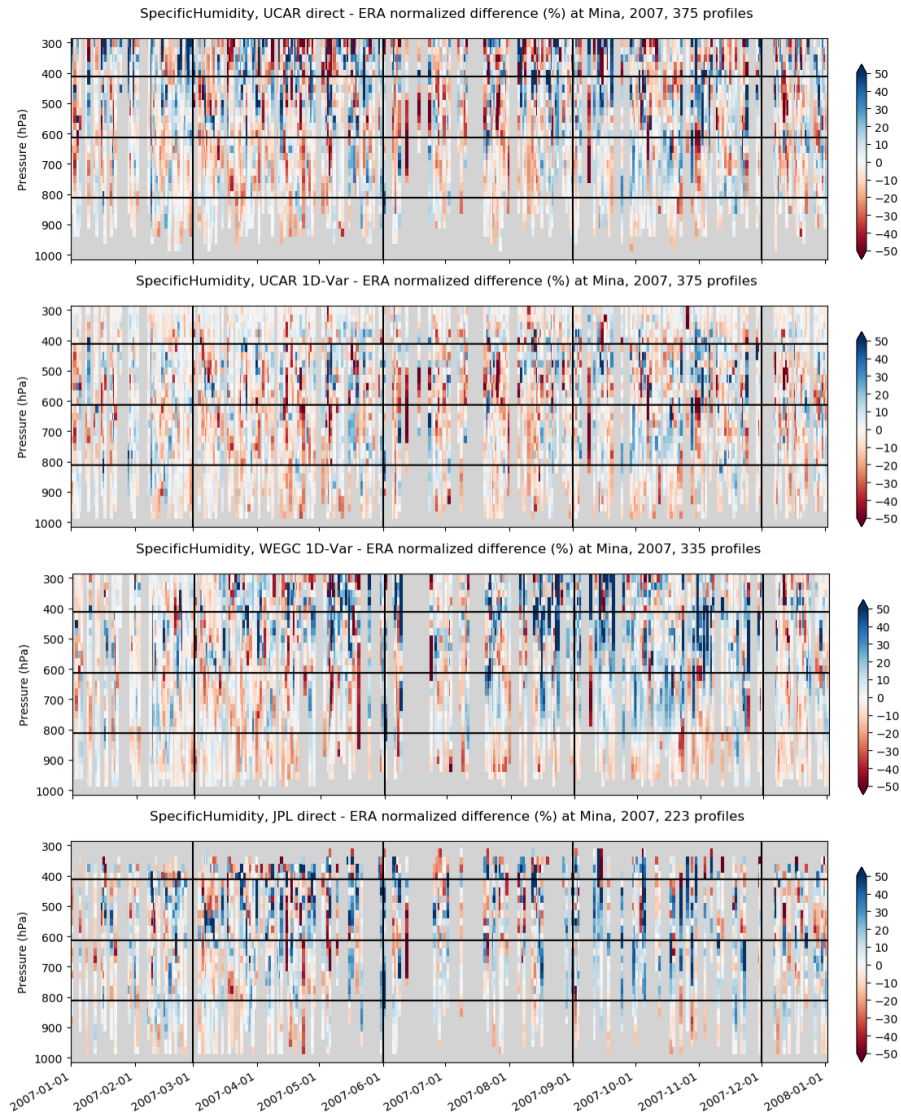
Figure S6. Normalized difference of specific humidity for the RO retrievals UCAR direct, UCAR 1D-Var, WEGC 1D-Var, and JPl direct compared to ERA at Minamidaitojima, 2007.
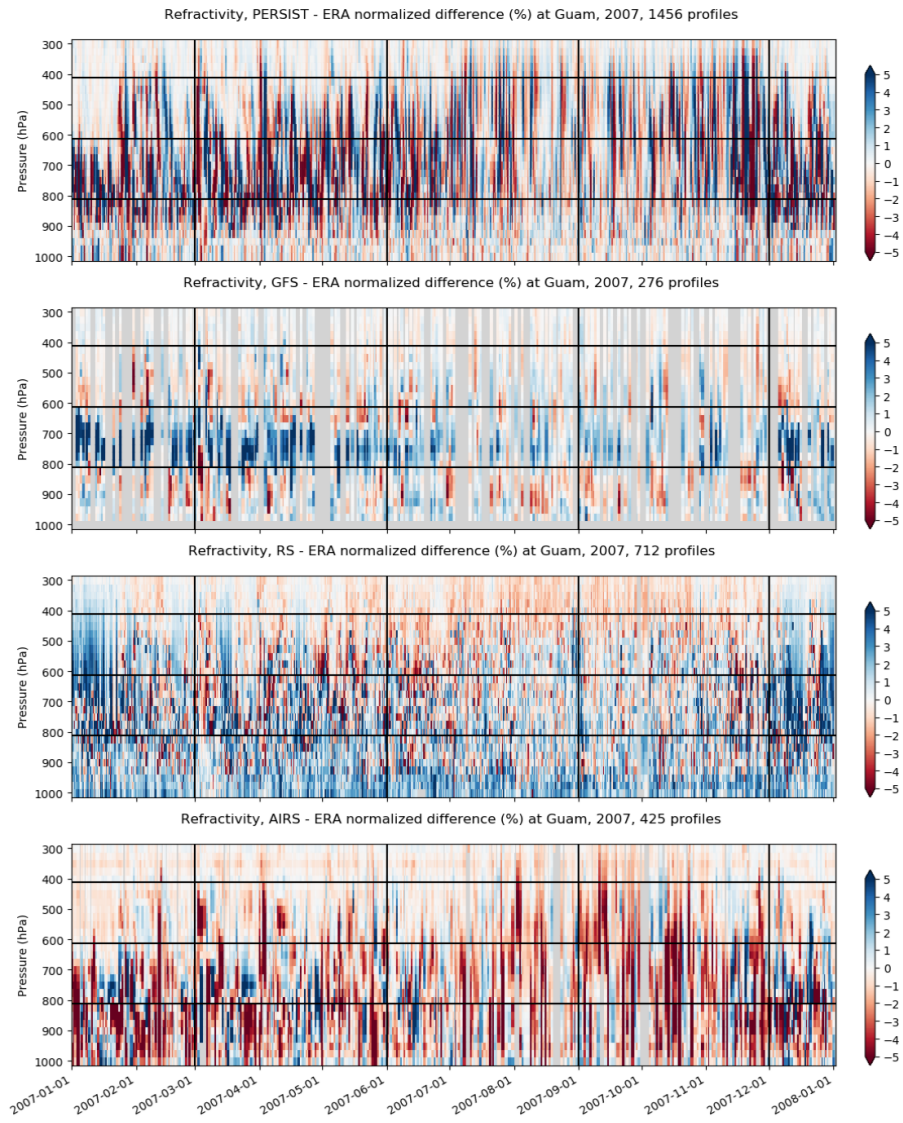
Figure S7. Normalized difference for refractivity for PERSIST, GFS, RS, and AIRS compared to ERA at Guam, 2007.
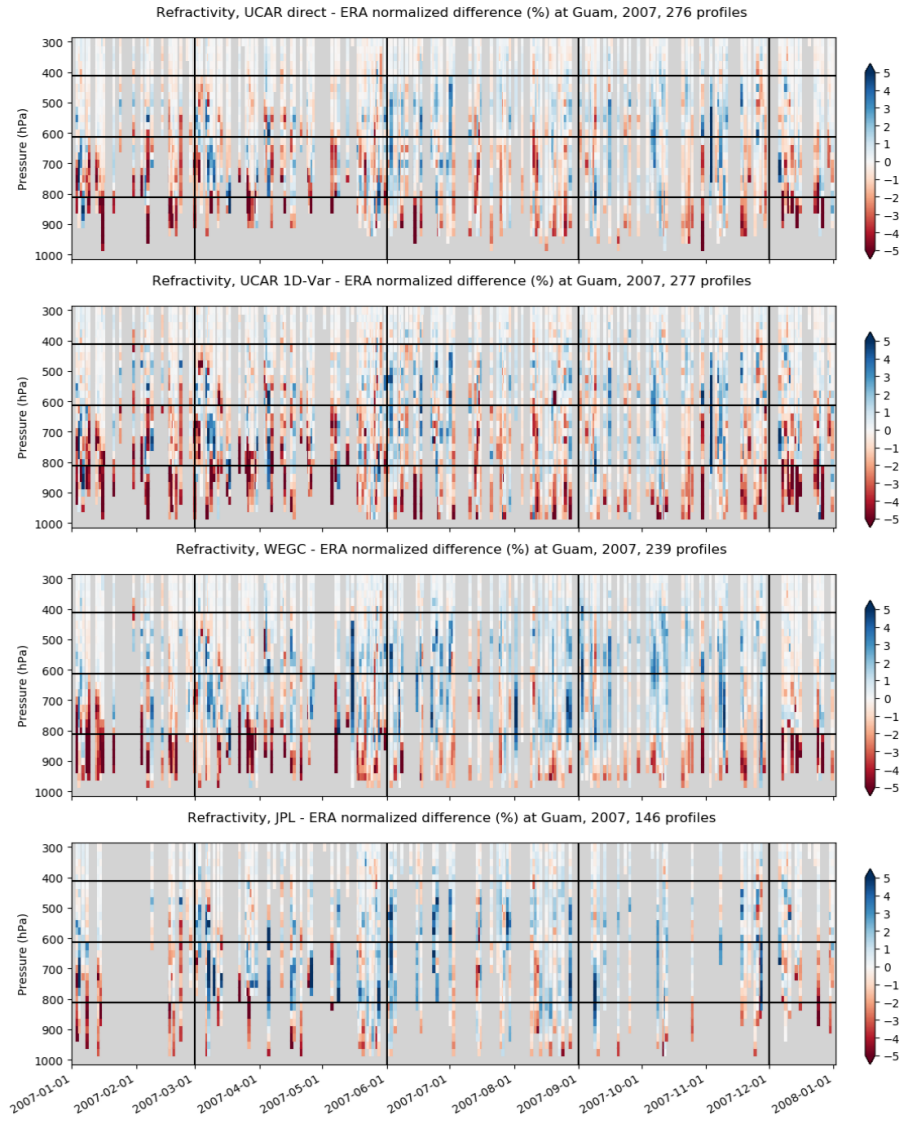
Figure S8. Normalized difference for refractivity for the RO retrievals UCAR direct, UCAR 1D-Var, WEGC 1D-Var, and JPl direct compared to ERA at Guam, 2007.