Supplementary Material

Performance of AIRS ozone retrieval over the central Himalayas: Case studies of biomass burning, downward ozone transport and radiative forcing using long-term observations

Prajjwal Rawat[1,5], Manish Naja[1], Evan Fishbein[2], Pradeep K. Thapliyal[3], Rajesh Kumar[4], Piyush Bhardwaj[4], Aditya Jaiswal[1], Sugriva N. Tiwari[5], Sethuraman Venkataramani[6], Shyam Lal[6]

[1] Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India

[2] NASA Jet Propulsion Laboratory, Pasadena, CA 91109, USA

[3] Space Applications Centre, ISRO, Ahmedabad 380 015, India

[4] National Center for Atmospheric Research (NCAR) Boulder, CO 80307, USA

[5] DDU Gorakhpur University, Gorakhpur 273 009, India

[6] Physical Research Laboratory (PRL), Ahmedabad, 380009, India

Table S1. AIRS means DOF as calculated for different atmospheres for version 5 (Maddy et al. 2008).

Retrieved Quantity	Tropical	Mid-latitude	Polar
Temperature	6.67	6.40	5.65
Water Vapour	4.46	3.85	2.89
Ozone	1.36	1.64	1.66
Carbon monoxide	0.78	0.84	0.65
Methane	1.06	0.94	0.70

Table S2. Quality Control for NOAA/CLASS data sets (QC 2 and 4 are obsolete).

AWIPS Dot Color	**EDR Quality Flag**	**Meaning**
Green	0	Clear Sky/Partly Clear Conditions Successful infrared (IR) + microwave (MW) retrieval.
Yellow	1, 16, or 17	Cloudy Conditions Failed IR+MW retrieval. Successful MW-only retrieval
Red	9 or 25	Precipitating Conditions Failed IR+MW retrieval. Failed MW-only retrieval.

Table S3. Typical ozone vertices used to calculate the trapezoid and averaging kernels.

Press. (hPa)	0.0160639	20.9224	51.5277	71.5397	103.017	142.385	212.028	300.000	596.306	1100.00
Index	1	26	35	39	44	49	56	63	80	100

Table S4. Correlation between AIRS and ozonesonde.

	Total Ozone Column	UTLS Ozone Column	Tropospheric Ozone Column
AIRS Vs ozonesonde	0.50	0.70	0.38
AIRS Vs ozonesonde(AK)	0.65	0.90	0.60

Table S5. UTLS ozone column difference between AIRS, MLS, and ozonesonde(AK).

UTLS Difference (DU)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AIRS – MLS	-2.6	-1.9	-1.2	5.6	7.2	5.2	3.1	0.4	-1.2	-0.8	-0.9	0.7
AIRS - ozonesonde(AK)	12.1	12.0	15.1	12.3	8.6	2.6	1.0	1.4	-1.8	2.9	7.1	8.9

Supplementary Figures

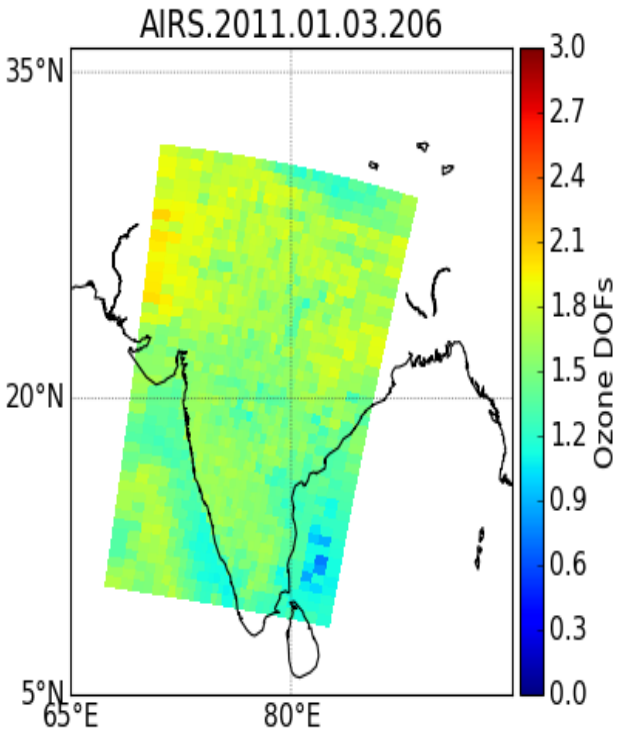

Figure S1. Spatial distribution of degree of freedoms (DOFs) of AIRS retrieved ozone for 3 January 2011 over India.

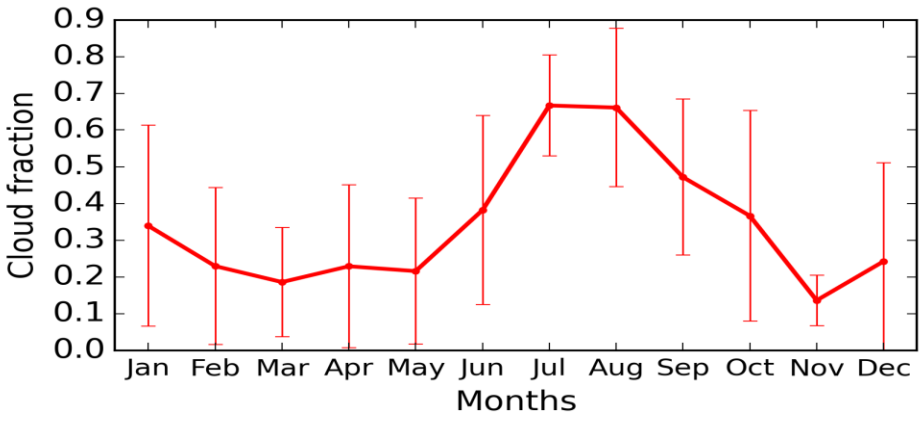

Figure S2. Total cloud fraction over the observation site as seen by AIRS for different months.

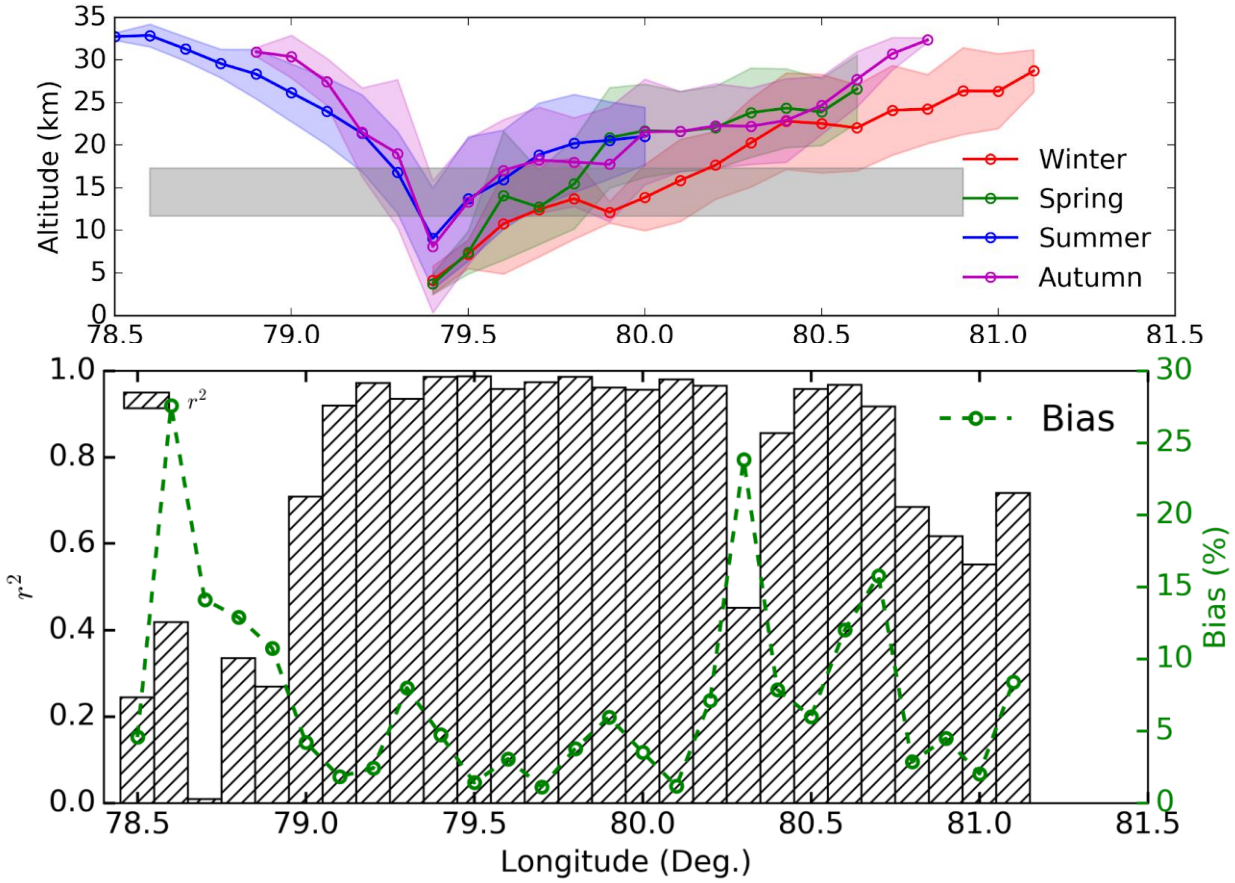

Figure S3. (a) Altitude variations of the balloons along longitudes during four seasons. The one sigma spread is also shown with a shaded area. The rectangle grey shaded area shows the tropopause region (mean ± sigma) from ozonesonde over Nainital. Nainital longitude is 79.45°E. (b) The bottom panel shows the longitudinal variations in r^2 (coefficient of determination) and biases between ozonesonde and AIRS retrieved ozone.

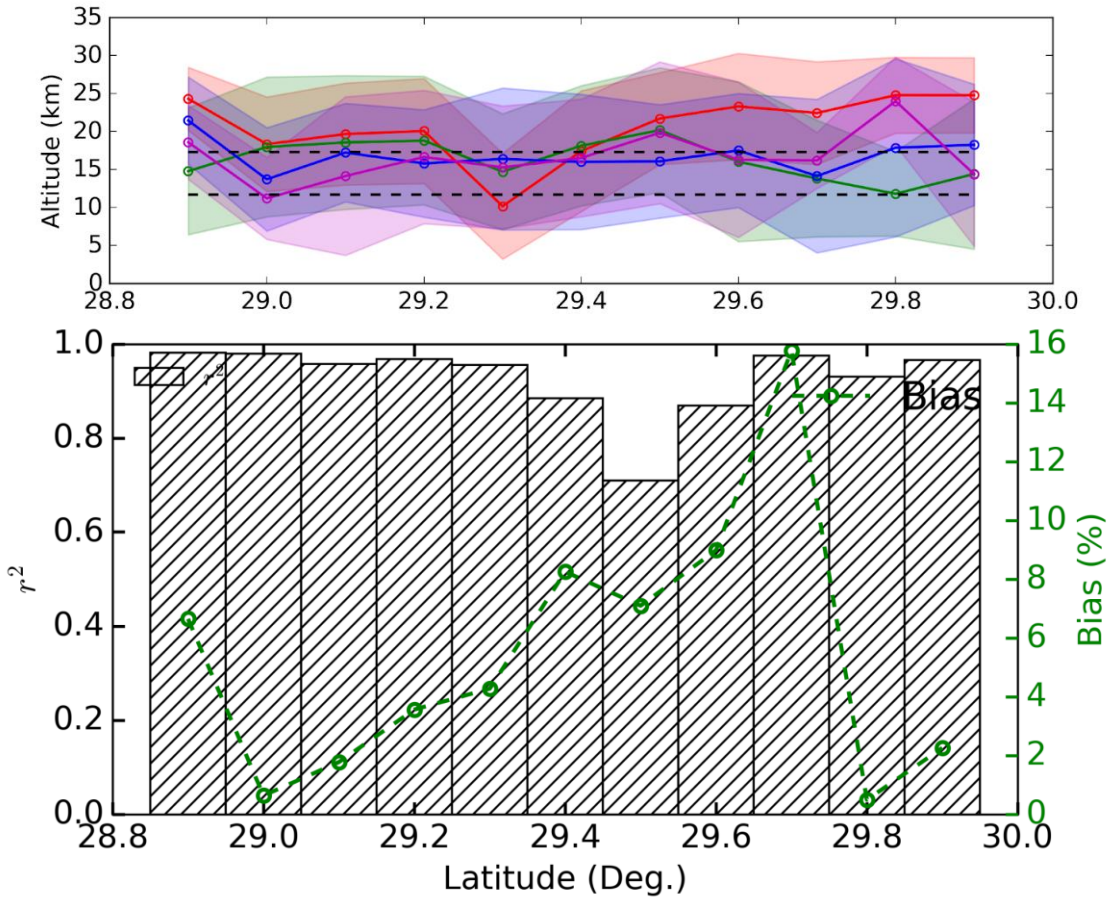

Figure S4. Altitude variations of the balloons along latitudes during four seasons. The one sigma spread is also shown with a shaded area. The area between the black dash lines shows the tropopause region (mean ± sigma) from ozonesonde over Nainital. The bottom panel shows the variation of r^2 (coefficient of determination) and biases between ozonesonde and AIRS retrieved ozone concentration along the latitude.

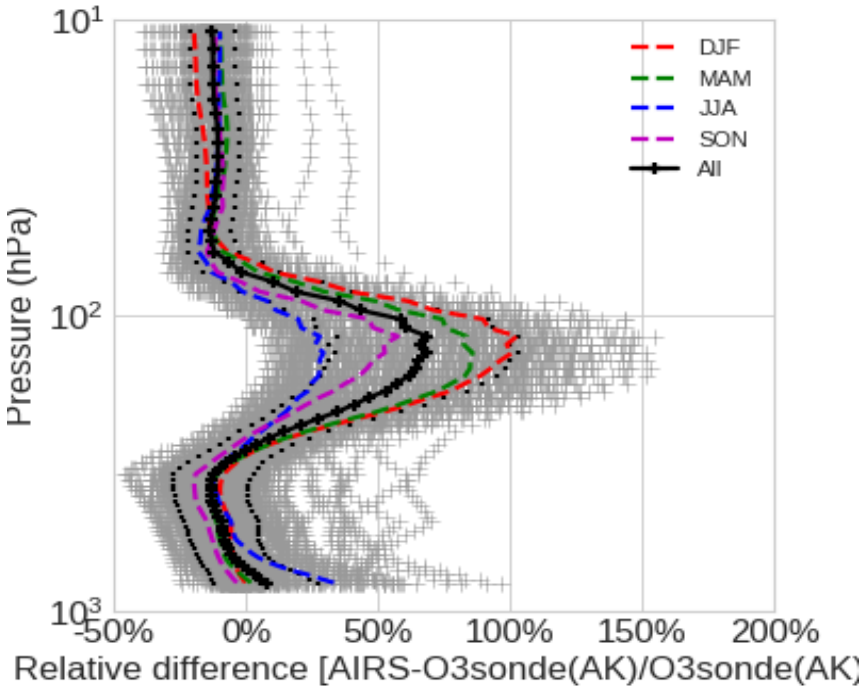

Figure S5. The relative difference of AIRS and ozonesonde(AK) for 2011-2017. Individual profiles are shown by a plus sign and dashed line for the average profile.

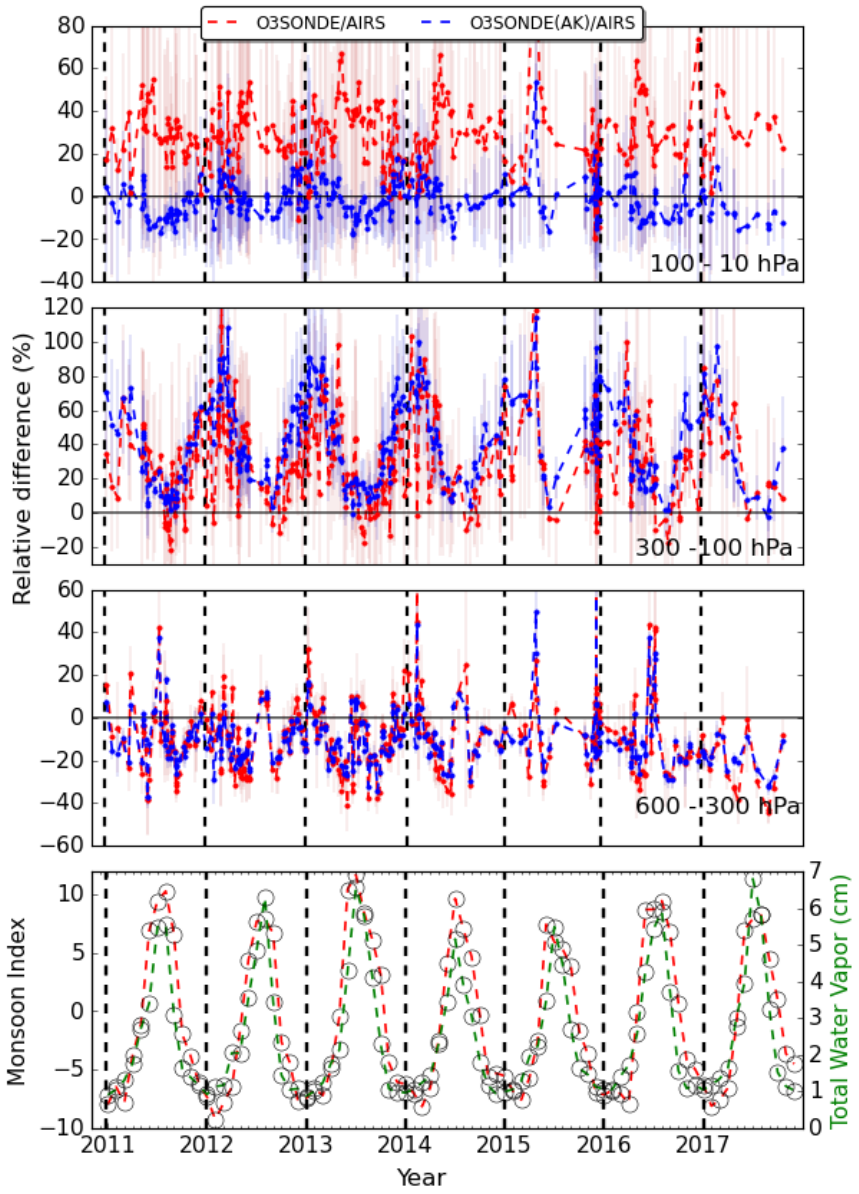

Figure S6. Partial ozone column difference (%) time series for seven years at three defined layers, characterizing the lower/middle stratosphere (100 - 10 hPa), the upper troposphere (300 - 100 hPa), the middle troposphere (600 - 300 hPa), respectively. The percentage difference is calculated as [(AIRS-Ref_O3)/Ref_O3]*100, where Ref_O3 is ozonesonde and ozonesonde (AK). The monthly variation of the Indian monsoon index and total water vapor is also shown at the bottom.

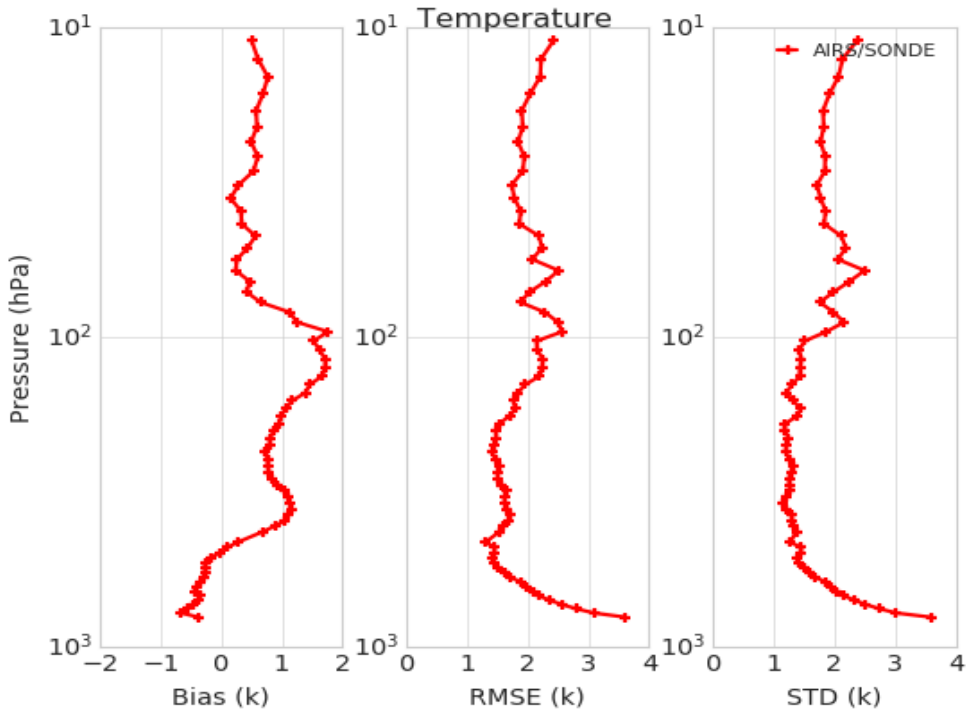

Figure S7. Statistical error analysis of AIRS temperature retrieval with interpolated balloon-borne observations for seven years (2011 – 2017).

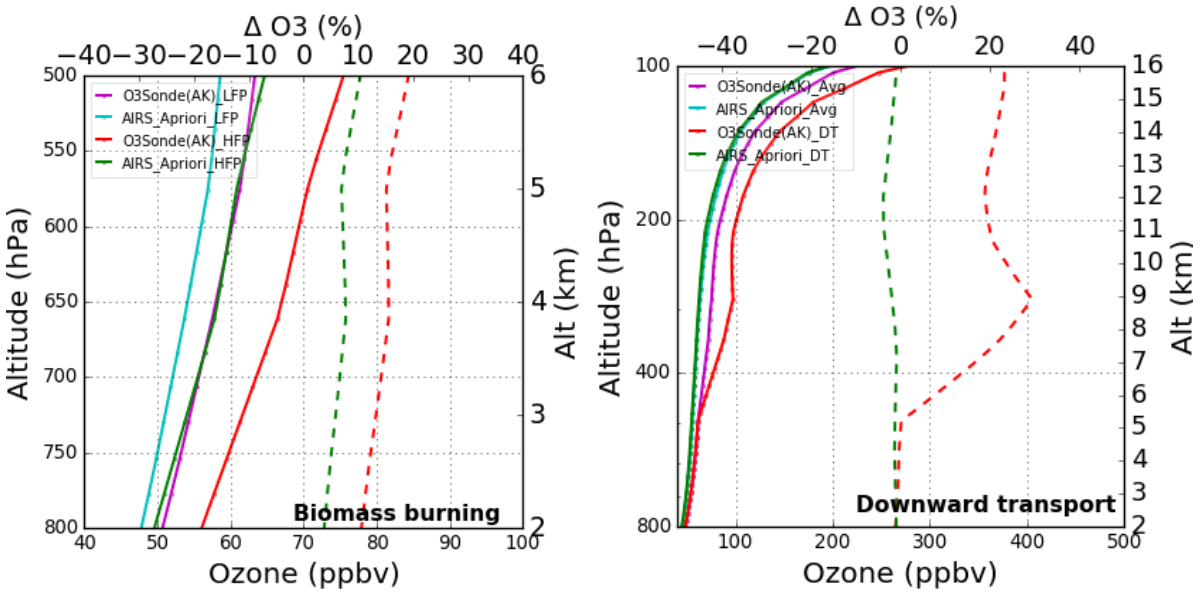

Figure S8. Biomass burning (BB) and downward transport (DT) profile for AIRS a-priori (or first guess) and ozonesonde data. The solid line corresponds to ozone profiles while the dotted line shows a % increase in ozonesonde (red) and AIRS a-priori (green) profile in BB and DT influence.