# Tropospheric ozone pool over Arabian sea during pre-monsoon:

## the importance of SCIAMACHY LNM tropospheric data improvement

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## I. Motivation: the improvements of SCIAMACHY LNM retrieval

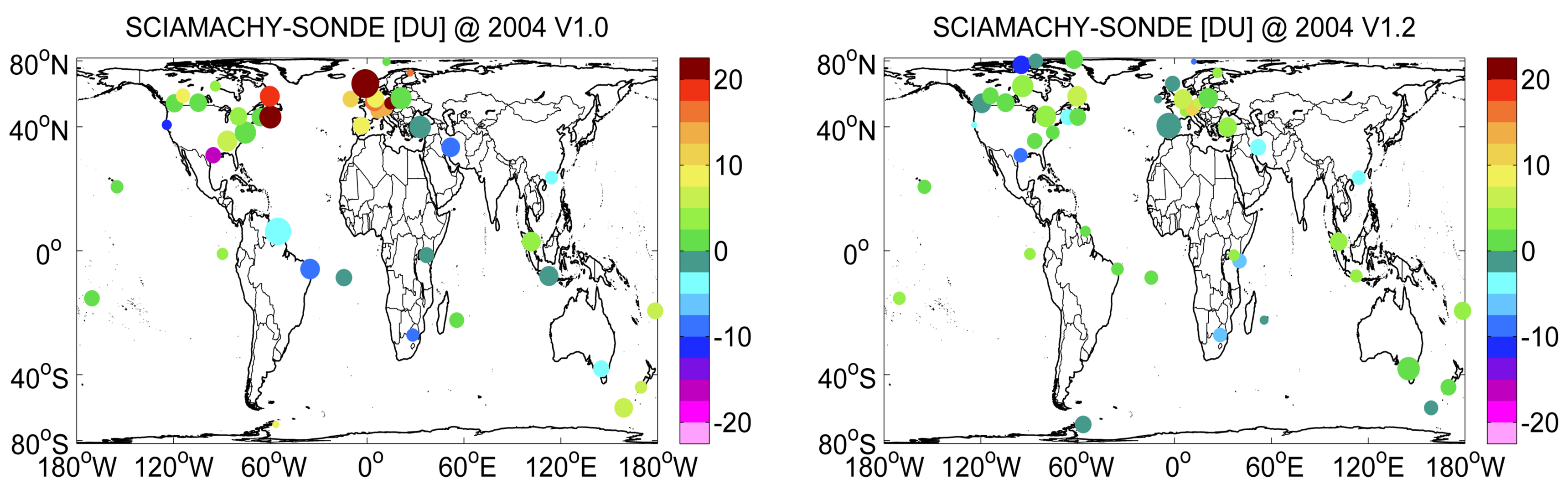


Fig. 1 Monthly averaged absolute monthly differences between two versions of SCIAMACHY LNM retrieved tropospheric ozone columns and that from ozonesonde measurement s in the year 2004. the size of the dots represents 1σ standard deviation. The standard deviation is between 0.2 - 24 DU.

**Tropospheric ozone ($O_3$):** is one of the most important green-house gases and one of the most important components of photochemical smog.

**The Limb-Nadir Matching method:** is an residual method that is developed for tropospheric ozone column retrieval using SCIAMACHY instrument. It subtracts the stratospheric ozone columns retrieved from the limb measurements from the collocated total ozone columns acquired from nadir measurements by using the tropopause height data.

**Improvements:** Along with the fact that the tropospheric ozone columns are only ~10% in the total ozone columns, the accuracy of the retrieved tropospheric ozone columns is quite challenging. Three-step optimization are implemented to the original retrieval approach. The tropospheric ozone monthly data is well improved with the benefit of the V3.0 limb ozone profile information by correcting ~10 DU underestimation in the tropical Atlantic, > 10 DU overestimation in the high latitudes, and variable overestimation over the midlatitudes.

## II. Enhanced Tropospheric $O_3$ over AS

With the benefit of the improved tropospheric ozone column product from SCIAMACHY LNM retrieval, more details can be successfully captured. The spring ozone maxima over the Arabian Sea during the pre-monsoon is one of them (Fig. 2). The AS is a remote area with few local pollutions. However, a spring enhancement of ~42 DU in monthly average (Fig. 3) is identified from our study, which is similar in magnitude to the well-known biomass burning plume in the southern hemisphere. With the help of MACC reanalysis data, our results showed that 3/4 of the enhanced ozone is contributed in the 0-8 km height range.

In this poster, we try to answer the follow questions. What are the potential sources of the pre-monsoon ozone pool over AS? How much comes from long range transport (LRT)? And how much comes from local chemistry? Are there other reasons?

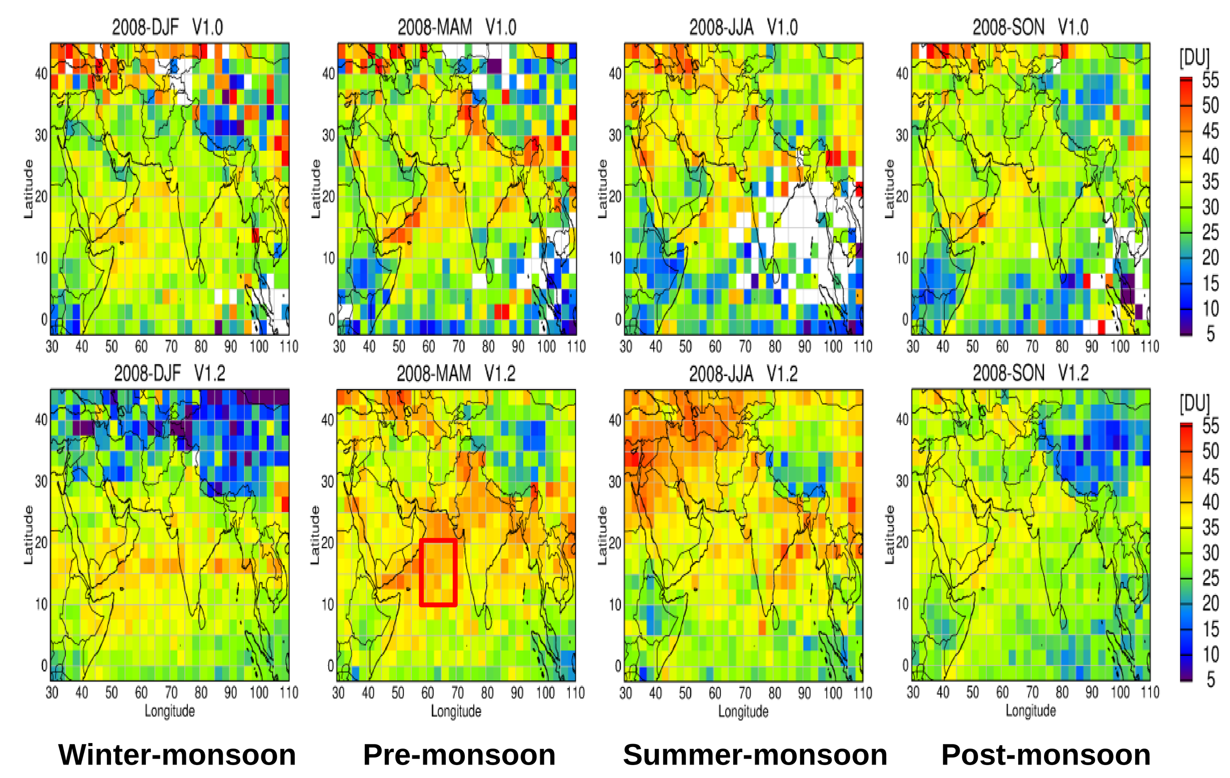


Fig. 2 SCIAMACHY LNM tropospheric ozone columns in the year 2008. From left to right: DJF, MAM, JJA, SON. Upper panels are V1.0 (old) products, lower panels are V1.2 (new) products.

## III. Tropospheric $O_3$ variation

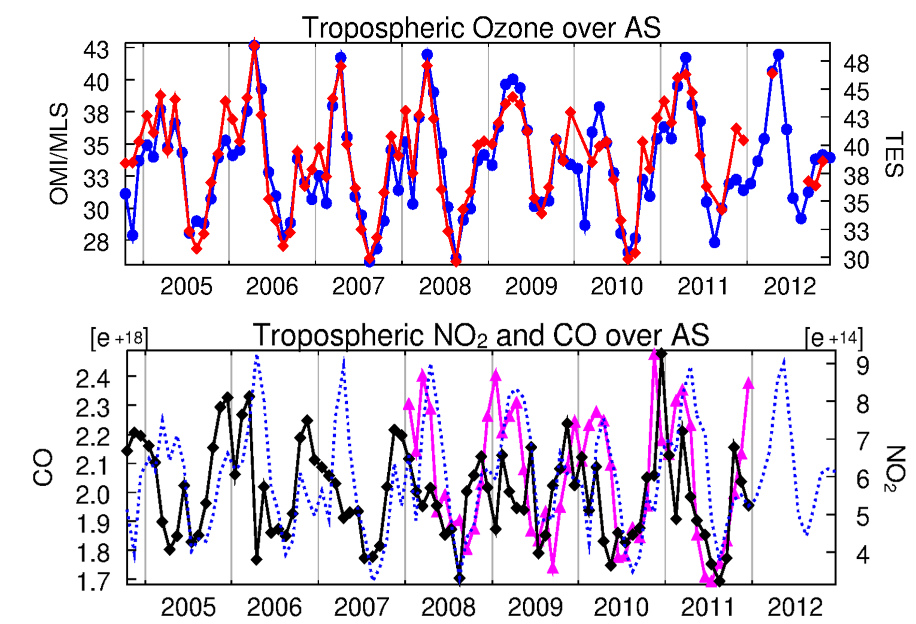


Fig. 3 Trace gas time series over AS (10-20° N, 60-70° E) from 2004 to 2012. The blue (solid and dot) curve represents OMI/MLS ozone, red is TES ozone, magenta is IASI CO and black stands for SCIAMACHY NO2. The vertical columns are given in DU for ozone and molec/cm2 for NO2 and CO. The region used for this time series calculation is marked with red rectangle in Fig. 2.

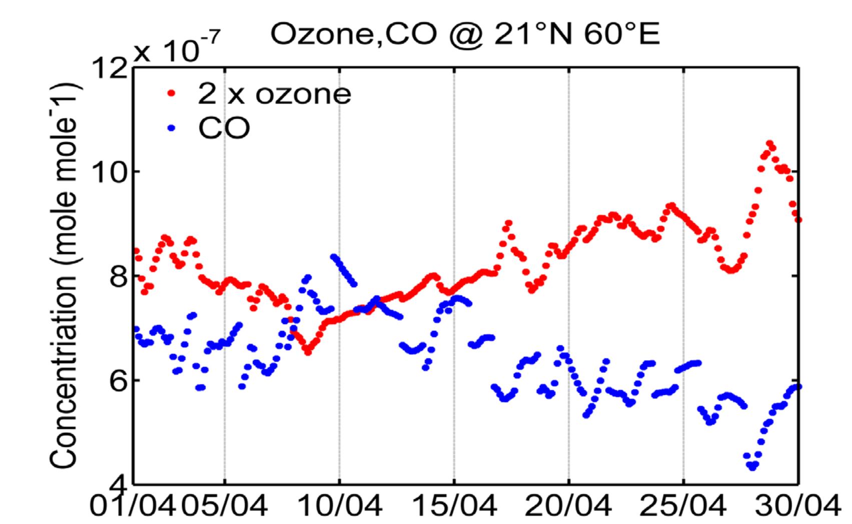


Fig. 4 $O_3$ and CO partial column (4-8 km) time series at 21° N, 60° E over AS at April 2008 from MACC reanalysis data.

The monthly averaged $O_3$ and CO have very similar spring variation in the year 2008-2011 (Fig. 3). However, the daily O3 and CO partial columns in the 4-8 km height range shown a negative correlation in April (Fig. 4), indicating less possibility of chemical production within this month.

## IV. Potential sources

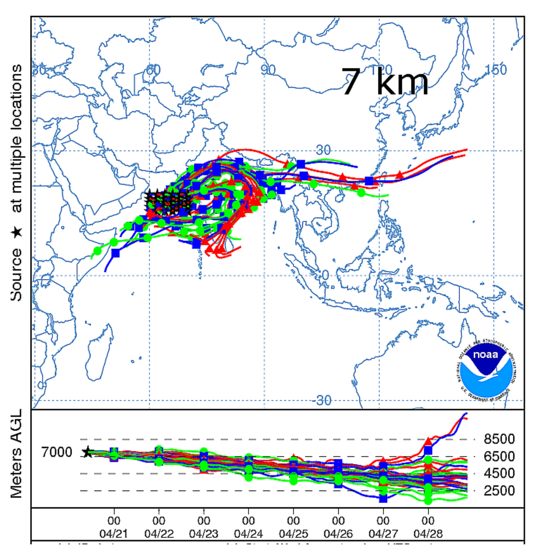


Fig. 6 HYSPLIT trajectory model (240 hr forward ) results for air masses at AS with source location at 7km in 20 April, 2008.

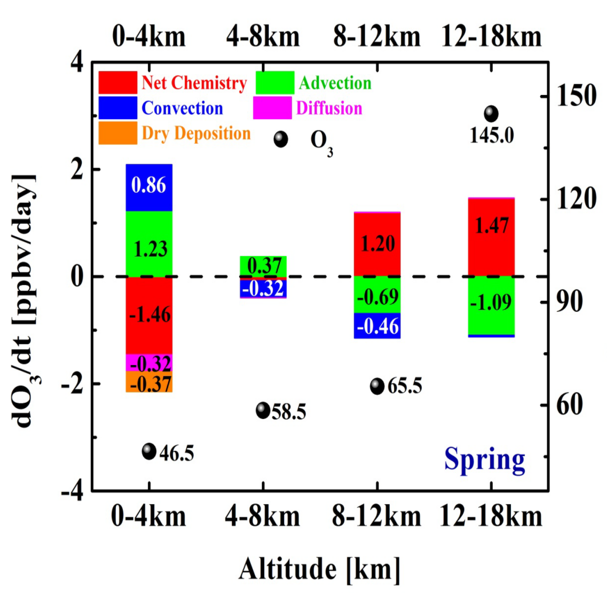


Fig. 7 Averaged ozone budget in pre-monsoon from MOZART-4 at four layers (0-4, 4-8, 8-12, 12-18 km) over AS region.

**1) LRT**: The similar seasonal variation between $O_3$ and CO and the previous studies both suggest that LRT of $O_3$ plays an important role in the AS pre-monsoon ozone pool. Our simulation using MOZART-4 CTM identified that the sources are mainly Middle East, India, Africa and North America at lower troposphere (0-8km). The transporting source region distribution varies in different altitude range (Fig. 5).

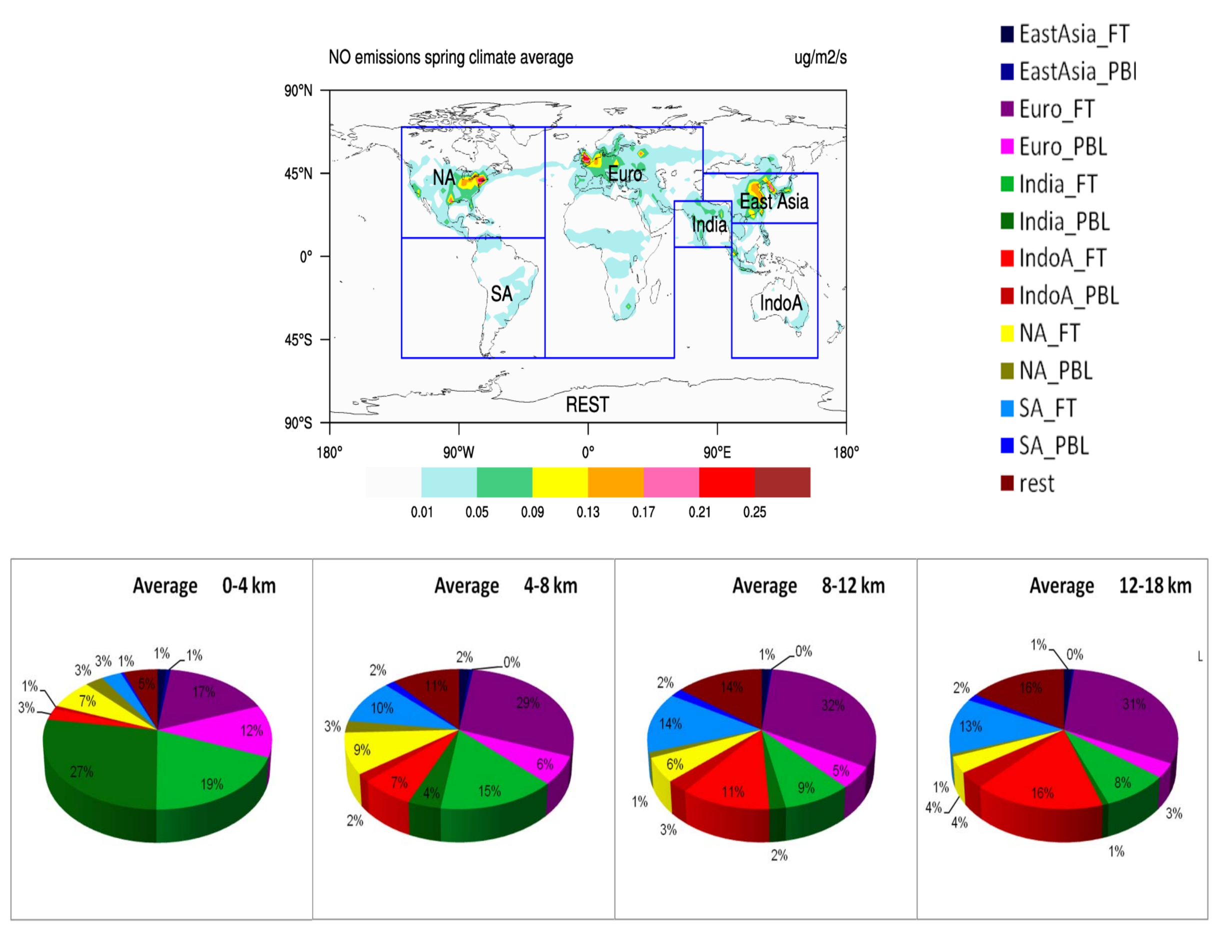


Fig. 5 Upper panel: Regional separation for tracer tagging with distributions of the spring mean emission rate (μg/m2/s) of NO (including anthropogenic, biomass burning, and soil emissions) at the surface used in the model simulations during 1997–2007. Lower panel: Averaged LRT contributions from different source regions to the 4 atmospheric layers over AS in April 1997-2007. PBL (planetary boundary layer) is defined as the regions from surface to the top of the boundary layer. FT (free troposphere) is defined as extending to the tropopause above the BL.

**2) Pollutant accumulation**: As seen in Fig. 6, The air masses at lower troposphere subsides locally with anti-circulation in 10 days. Furthermore, the air masses over AS at 4-8 km are rather dry compared to the surroundings (not shown here), which reduced the impact of $HO_x$ removal on $O_3$. The accumulation of $O_3$ pollutant is considered to also contribute to the $O_3$ pool.

**3) Local chemistry:** One question is that has more $O_3$ been photochemically produced during the long accumulating time in the middle (4-8 km) or lower (0-4 km) troposphere? Our ozone budget study shown: in the 0-4 km layer, the destruction of $O_3$ by OH radicals and reactive halogens in the marine boundary layer domains. In the 4-8 km layer, the chemistry budget is rather small. In the higher layers, photochemical production becomes a major source of ozone. However, these products are quickly transported horizontally in the entire latitude bin by strong advection.

## V. Conclusions

1. The tropospheric $O_3$ column produced by SCIAMACHY LNM retrieval is significantly improved. The comparison with ozonesonde show yearly mean differences of less than 5 DU globally. More details can be observed on global distribution.
2. A tropospheric $O_3$ enhancement of ~ 42 DU over AS in pre-monsoon was observed from satellite observations and MACC model, 3/4 of which is contributed by the 0-8 km height range.
3. Our study suggested the sources of tropospheric $O_3$ to be mainly LRT from 'Euro_FT' (including Middle East and Africa) with 30% contribution in average, followed by 'India' region with over 20%. The source regions and contributions are identified by analysing the MOZART-4 CTM model simulations.
4. Local chemical production mainly happens at >8 km altitudes and the produced $O_3$ are removed from AS by advection. The photochemical production of $O_3$ is negligible in the 4-8 km range.

## VI. Selected references and Acknowledgements

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