Measurement of CO and SO₂ trace gases in southern India during ISRO-GBP Land Campaign – I

R R Reddy¹, K Rama Gopal¹, K Narasimhulu¹, L Siva Sankara Reddy¹
K Raghavendra Kumar¹, Y Nazeer Ahammed², V Vinoj³ & S K Satheesh³

¹Aerosol & Atmospheric Research Laboratory, Department of Physics, Sri Krishnadevaraya University, Anantapur 515 003, India
²Radio and Atmospheric Sciences Division, National Physical Laboratory, New Delhi 110 012, India
³Centre for Atmospheric and Oceanic Sciences, Indian Institute of Sciences, Bangalore 560 012, India

Received 29 January 2007; revised 10 August 2007; accepted 29 April 2008

Under ISRO-GBP land campaign-I, the concentrations of CO and SO₂ gases were simultaneously measured during 1-29 Feb. 2004 over southern India. These measurements were made onboard instrument vehicle along the road network during the dry, winter season of 2004. The study region covered coastal, industrial, urban, rural, remote, semi-arid and vegetated forest lands in the central part of the southern India. Average CO concentration at Nellore, an urban and coastal site is comparatively high (1300 ppbv) and the same is low (620 ppbv) at Sri Perumbuthur, a semi-urban site. These maximum levels of CO at Nellore may be due to traffic emissions and shallow surface layer. Average SO₂ concentrations at Sri Perumbuthur and Shadnagar (5 ppbv) are significantly higher than those at other locations. Fairly good correlation has been established between CO, SO₂ and meteorological parameters over the study region.

Keywords: Emission inventory, Pollution-urban, Pollution-rural, CO trace gas, SO₂ trace gas

PACS No.: 92.60.Sz

1 Introduction

Carbon monoxide plays a significant role in the atmosphere on local, regional and global scales. On a local and regional scale, CO affects air quality. Maynard and Waller¹ pointed out that high CO mixing ratios can directly affect human health. The oxidation of CO initiates photochemical reactions, which result in ozone (O₃) production on a regional scale². The CO emission from combustion is year-round in large urban areas, whereas biomass burning varies over the year³⁴. The contribution to CO by biomass burning is large in the tropics⁵ and tropical South America, Africa, northern Australia, and Indonesia are known to be intense biomass burning areas⁶⁸. The major sources of CO are both anthropogenic and natural, including fossil fuel combustion, biomass burning and oxidation of CH₄ and non-methane hydrocarbons (NMHCs)⁹. More than half of atmospheric CO emissions today are caused by human activities, and as a result the northern hemisphere contains about twice as much CO as the southern hemisphere. In much of the troposphere, its reaction with OH represents⁹ 90-95% sink of CO, and about 75% of the removal¹⁰ of OH. India has large variability in regional population distribution and energy consumption patterns. Rapid economic growth and industrialization are enhancing this variability, further creating pockets of heavy pollutant emitting regions like metro-cities, which have seen rapid rise in the fleet of vehicles in the last decade. Similarly many thermal power plants have become operational in this decade, which are consuming coal for electricity generation. In association with the rising coal use, emission of SO₂ has increased to levels, which pose serious threat to public health and sensitive ecosystems¹¹.

Sulphur dioxide is a predominantly anthropogenic air pollutant. Mixing ratios of SO₂ in continental background air range from 20 ppt to over 1 ppb; in the unpolluted marine boundary layer levels it ranges between 20 and 50 ppt. Urban SO₂ mixing ratios can attain values of several hundred parts per billion. The SO₂ is a major cause of damage to trees, shrubs, plants and crops. It can injure plant tissues, discolour leaves, stunt growth, and reduce crop yields. Chronic plant injury and leaf drop occur at annual mean SO₂ concentrations of 30 ppbv.

In spite of the importance of the tropical troposphere, there have been few systematic
simultaneous measurements of surface ozone and its precursor gases over the Indian region (Ahmedabad, an urban site, and Gadanki and Anantapur, a rural site and Trivandrum, a coastal site) until recent years\textsuperscript{12-16}. Several experimental efforts have been made recently making use of road networks and instrumented vehicles. Most of these road campaigns, conducted at different environments, such as urban, rural, coastal and marine locations of Netherlands\textsuperscript{17}, urban and rural areas of Rouen, France\textsuperscript{18}, and urban and rural locations of Switzerland\textsuperscript{19}, were however, more focused towards understanding pollution related to traffic emissions and most of these observations were conducted close to the source regions, whereas “far-field” measurements are more appropriate for regional/global impact assessment.

Over the Indian landmass, studies focusing on the spatial heterogeneity of these pollutants are scarce, notwithstanding its high density of population, increasing industrialization and urbanization, diverse living habits, geographical features and contrasting meteorological processes. However, such data are essential to assess the regional impacts and also to delineate the temporal changes. With the above considerations an intense land campaign was conceived for spatial mapping of aerosol characteristics over peninsular India during the winter season (February-March) under the Indian Space Research Organisation’s Geosphere-Biosphere Programme (I-GBP). In this campaign, a number of research teams participated using instrumented vehicles along the road network covering different geographical locations. It was carried out for the first time in this region. During this programme a major part of southern India was covered by our team (Fig. 1 and Table 1). The data provide valuable information for validation of global and regional chemical transport models\textsuperscript{20}. The CO and SO$_2$ data reported in this work should be useful for evaluation and understanding of tropospheric chemistry.

### 2 Experimental method

The campaign was conducted during the period 1-29 Feb. 2004 continuously for 29 days, during which the team made measurements of the concentration of CO and SO$_2$ gases in instrumented van, along the route map shown in Fig. 1. A route length of about 5000 km was covered, making independent observations at 25 distinct locations covering coastal, inland, arid, urban, and plateau regions with altitudes varying from 3 m to 1850 m amsl.

Fig. 1 — Schematic map of the region covered by IISC and SKU team during ISRO-GBP Land Campaign

The CO component was measured (CO 11M; Environement S.A., France) by IR absorption at 4.67 μm, specially meant for low concentration of CO gas in ambient air under atmospheric condition. The detection limit of the analyzer is reported to be about 50 ppbv with noise level of 25 ppbv. Calibration of the analyzer is also performed using a known standard.

Sulphur dioxide is measured using an analyzer (SO$_2$ AF21M-LCD; Environement S.A., France) based on an ultraviolet radiation centered at 241 nm, the absorption wavelength of SO$_2$ molecules. The minimum detectable limit of the analyzer is 1 ppbv. Regular calibration of the analyzer was done using the known calibration standards available with the authors.

### 4 Results and discussion

Variations in the levels of concentrations of trace gases (CO and SO$_2$) over different stations were evaluated out. As one can see that the CO and SO$_2$ values recorded at different stations (Figs 2 and 3) are different from each other, thereby reflecting the regional features and anthropogenic activity variation along the chosen track for the campaign. In general, in the study region during the measurement period average CO concentration varies in the range 400-1400 ppbv whereas average SO$_2$ concentration, is in the range 1-5 ppbv. Looking at the possible sources of
their emissions and source strengths and the prevailing meteorological conditions separately at every individual station can only explain the observed differences in CO and SO$_2$ values. The CO values are comparatively higher at Nellore, an urban and coastal station (Fig. 2). Maximum concentration (1300 ppbv) of CO observed in Nellore town may be due to large number of vehicular transport and pollutants getting trapped in the shallow surface layer depicting higher levels. Furthermore, at the time of measurements, the daytime meteorological conditions are in general favouring the accumulations of high concentrations of pollutants (low wind, morning inversion, etc.). At another urban site, Vijayawada, average CO concentration attains a value of 1125 ppbv, due to vehicular and anthropogenic emissions. Except the above two urban sites, all other sites are either rural or semi-urban. So an average CO concentration is almost constant and attains a value less than 1000 ppbv.

Simultaneous measurements of SO$_2$ concentration have been made at all the campaign sites. At semi-urban sites like Sri Perumbuthur and Shadnagar, the
values were found comparatively higher (4-5 ppbv). At all other sites SO\textsubscript{2} concentration was low (< 3 ppbv) during the measurement period. By examining both the concentrations of CO and SO\textsubscript{2} at various sites, the sources of emission of pollutants can be identified. In the present study, the CO emissions are mainly from traffic and SO\textsubscript{2} emissions are from industries near measurement sites.

The measurement sites covered coastal, inland, arid, urban and rural regions as can be seen in Fig. 1. Measurements were started at Tekumanda (13°10'N; 78°2'E) on 1 Feb. 2004 and moved eastward by travelling along the east coast till Nellore (14°27'N; 79°59'E), moved through the urban location Vijayawada (16°30'N; 80°40'E), turned inland and reached Shadnagar, which was selected as common meeting point for all the teams to inter-compare data (17-19 Feb. 2004). Continuous measurements of different atmospheric parameters were made. The diurnal variation of CO and SO\textsubscript{2} concentrations at Shadnagar during 17-19 Feb. 2004 is shown in Fig. 4 along with meteorological data. During the measurement period diurnal cycle of CO concentration shows two peaks, one during the early hours (0600-0800 hrs LT) and another during night hours (1900-2400 hrs LT).

The early hour’s peak corresponds due to large combustion and industrial sources in the surrounding regions of the city and the night peak is partly attributed to the stabilizing atmospheric conditions. During night hours, the boundary layer height descends and remains low till early morning, thereby resisting the mixing of the anthropogenic emissions with the upper layer. Hence, pollutants get trapped in the shallow surface layer and show higher levels. During noon-time the higher height of the boundary layer provides a larger mixing region and hence the pollutants get diluted. The level, location, and duration of pollutants concentration within a region depend on plume height, wind speed, rate of vertical mixing in the atmosphere, and distance from the source. Gas-phase sulphur dioxide (SO\textsubscript{2}) is emitted during combustion of all sulphur-containing fuels (oil, coal and diesel). Garg et al.\textsuperscript{11} in their study over 466 Indian districts pointed out that more than 60% of SO\textsubscript{2} emissions may be due to the consumption of coal and oil products. The authors concluded that the emissions of SO\textsubscript{2} over Indian region are mainly expected from industry (36%), transport (7.8%), biomass consumption and non-energy consumption\textsuperscript{11}.

5 Conclusions

The measurements of the concentration of CO and SO\textsubscript{2} gases were made onboard instrument vehicle
along the road network in the central part of southern India during the dry, winter season of 2004. Comparatively high average CO concentration was noticed at Sri Perumbuthur, a semi-urban and industrial site.

At the same time, average SO₂ concentrations at Sri Perumbuthur and Shadnagar are significantly higher than those at other locations. Diurnal variation of CO concentration is observed in the range 600-1100 ppbv. Similarly SO₂ levels are noticed in the range 2-4 ppbv at Shadnagar during 17-19 Feb. 2004. The CO concentration showed higher value during morning hours (0600-0800 hrs LT) and late night hours (1900-2400 hrs LT). Daily temperature observed values are in the range of 20-35 °C with wind direction from north-east to south-east. Relative humidity values varied in the range 25-75% during 17-19 Feb. 2004.

Acknowledgements

The experiment formed part of the Land Campaign conducted under ISRO-GPB. The authors gratefully acknowledge the Indian Space Research Organisation (ISRO) for financial assistance under Geosphere-Biosphere Programme, of the Department of Space, Government of India, Bangalore. Thanks are also due to Dr C B S Dutt, Dy. Programme Director and Prof Shyam Lal, the campaign coordinator for all the help received during this work.

References