Influence of Indian summer monsoon on surface CO_2 and other greenhouse gases observations at the west coast of India

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Indian monsoon system:

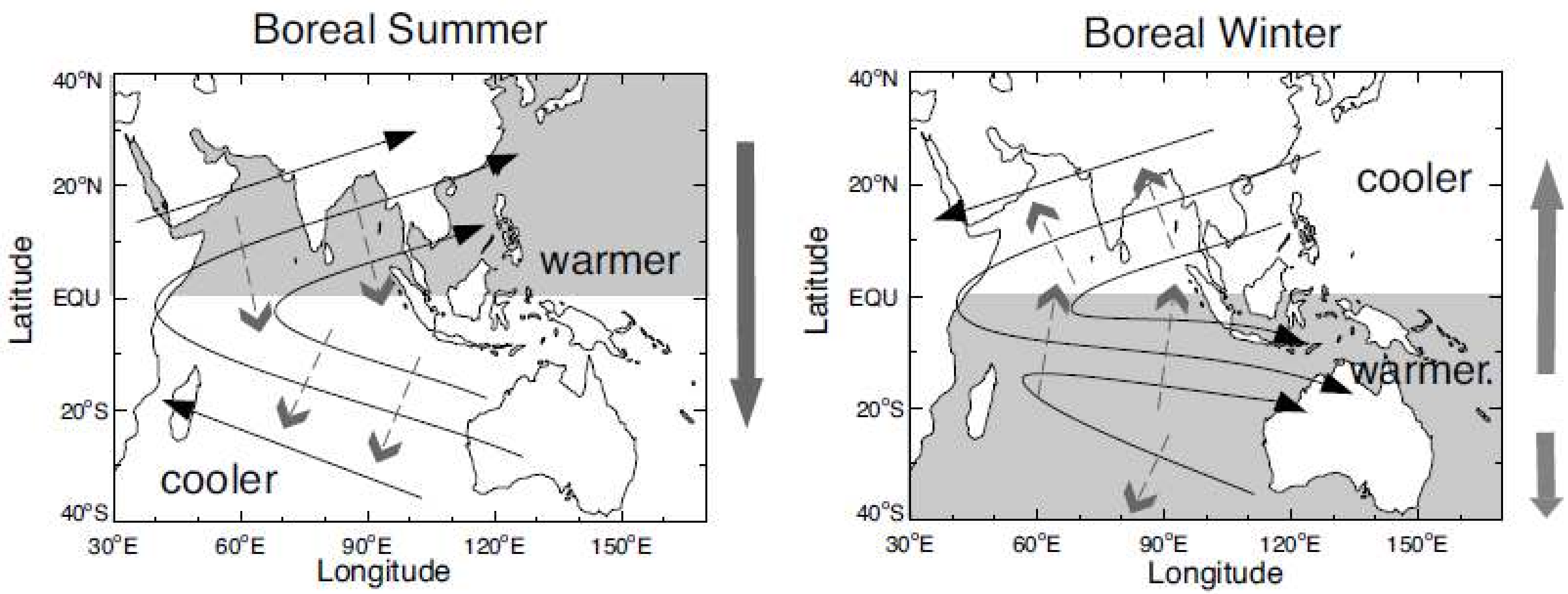
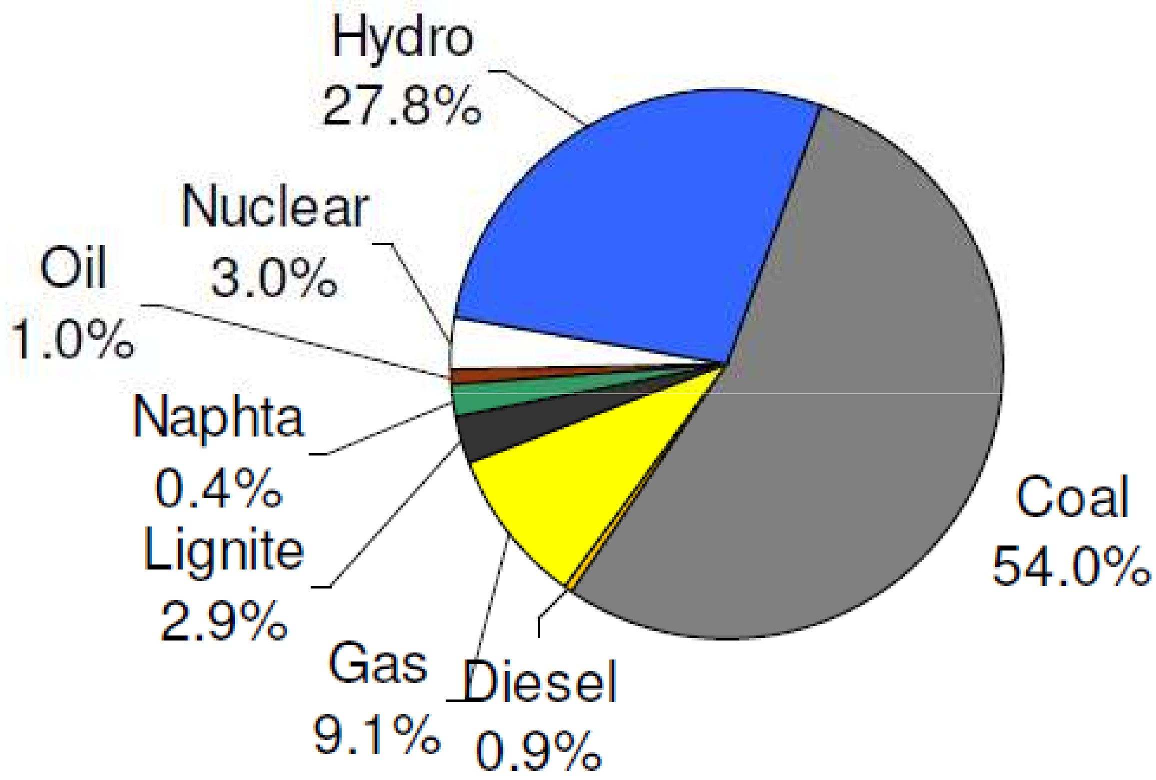


Figure 1.15. Schematic of regulation of the seasonal cycle of the Indian Ocean for (a) the boreal summer (June–September) and (b) the boreal winter (December–February). Curved solid lines indicate near-surface winds forced by the large-scale pressure gradients associated with the cross-equatorial heating gradient denoted by 'warm' and 'cool' (cf., Figure 1.10). Small gray arrows denote wind forces, Ekman drift, and the direction of the associated heat flux. The large vertical arrow denotes the sense and magnitude of the net zonally averaged heat flux reverses. Overall, the wind-driven southward flux of heat in the summer tends to cool the north Indian Ocean, while the northward flux during the winter tends to heat the north Indian Ocean, thereby reducing the SST gradient at all times of the year. The coupled ocean–atmosphere interaction described in the figure imposes a strong negative feedback on the system regulating the seasonal extrema of the monsoon.

Ref.: The Asian Monsoon, Bin Wang

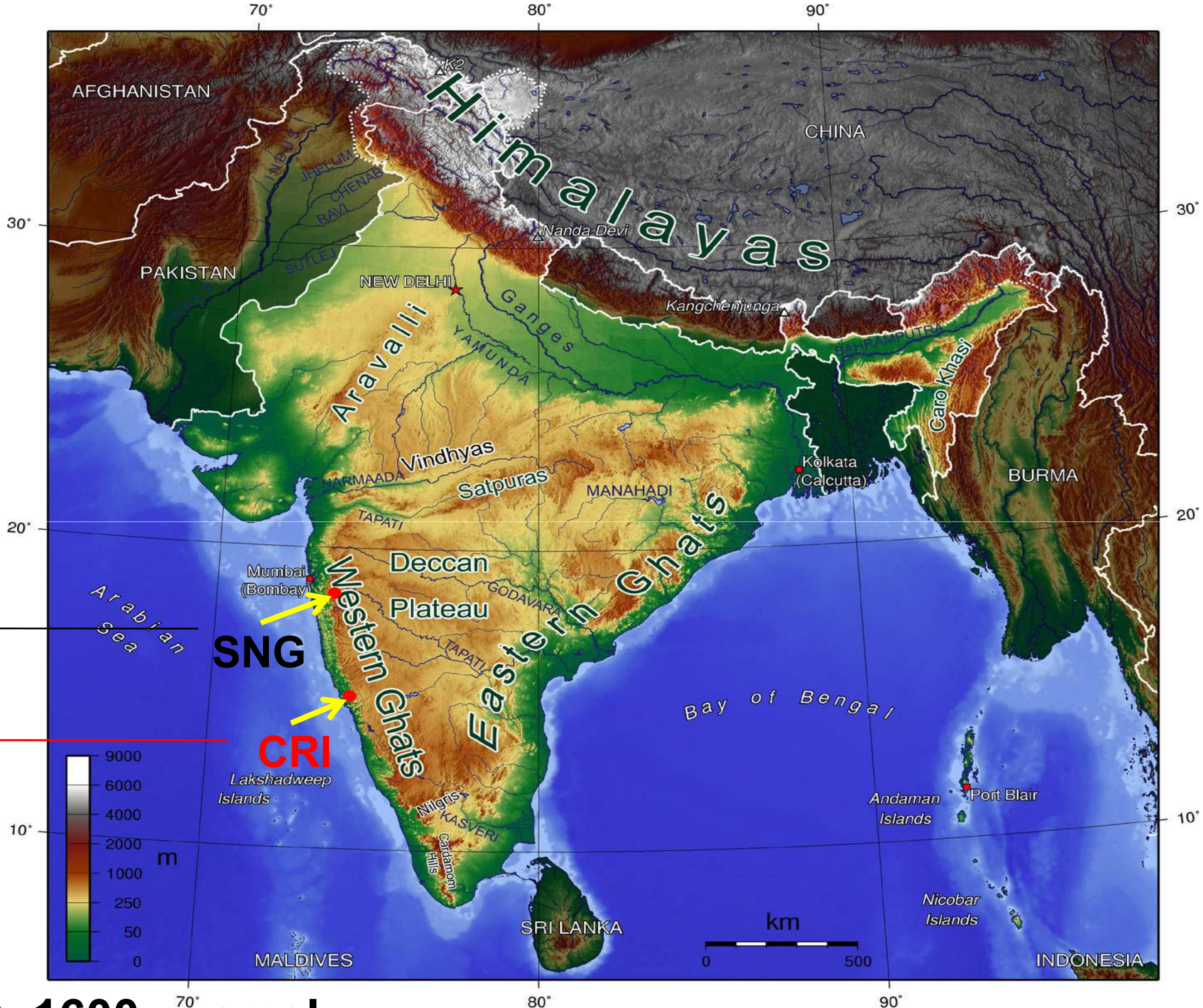
India
IRAN
AFGHANISTAN
PAKISTAN
CHINA
TIBET
NEPAL
BHUTAN
BANG.
MYANMAR (BURMA)
SAUDI ARABIA
OMAN
U.A.E.
SRI LANKA
Persian Gulf
Gulf of Oman
Arabian Sea
Bay of Bengal
INDIAN OCEAN
Tropic of Cancer
Boundaries in dispute
Nanda Devi 25,646 ft. (7,817 m)
Mt. Everest 29,029 ft. (8,848 m)
Himalayas
Brahmaputra
Indus
Ganges
Godavari
Great Indian Desert
Western Ghats
Eastern Ghats
Deccan
60° E
70° E
80° E
90° E
20° N
10° N
Srinagar
Amritsar
Ludhiana
Chandigarh
Delhi
New Delhi
Moradabad
Jaipur
Agra
Lucknow
Jodhpur
Kanpur
Allahabad
Varanasi
Patna
Darjiling
Shillong
Imphal
Ahmadabad
Bhopal
Jabalpur
Vadodara
Bhavnagar
Indore
Jamshedpur
Kolkata (Calcutta)
Surat
Nagpur
Raipur
Cuttack
Nashik
Mumbai (Bombay)
Pune
Solapur
Hyderabad
Visakhapatnam
Kakinada
Vijayawada
Kurnool
Hubli
Nellore
Mangalore
Chennai (Madras)
Mysore
Bangalore
Kozhikode
Coimbatore
Kochi
Madurai
Alappuzha
Thiruvananthapuram
Laccadive Islands (INDIA)
Andaman Islands (INDIA)
Port Blair
Nicobar Islands (INDIA)
0 300 Miles
0 300 Kilometers
© MAPQUEST

Power generation sources in India; as on March 31, 2009



Ref: Central Electricity Authority, Ministry of Power, Govt. of India; "CO2 baseline database for the Indian power sector" ; November 2009

Study of Atmospheric CO_2 observations over India



IITM,Pune

CSIRO, Australia
NIO,Goa

Sinhagad (SNG), 1600 m amsl
Cape Rama (CRI), 50 m amsl

Jan

Jul

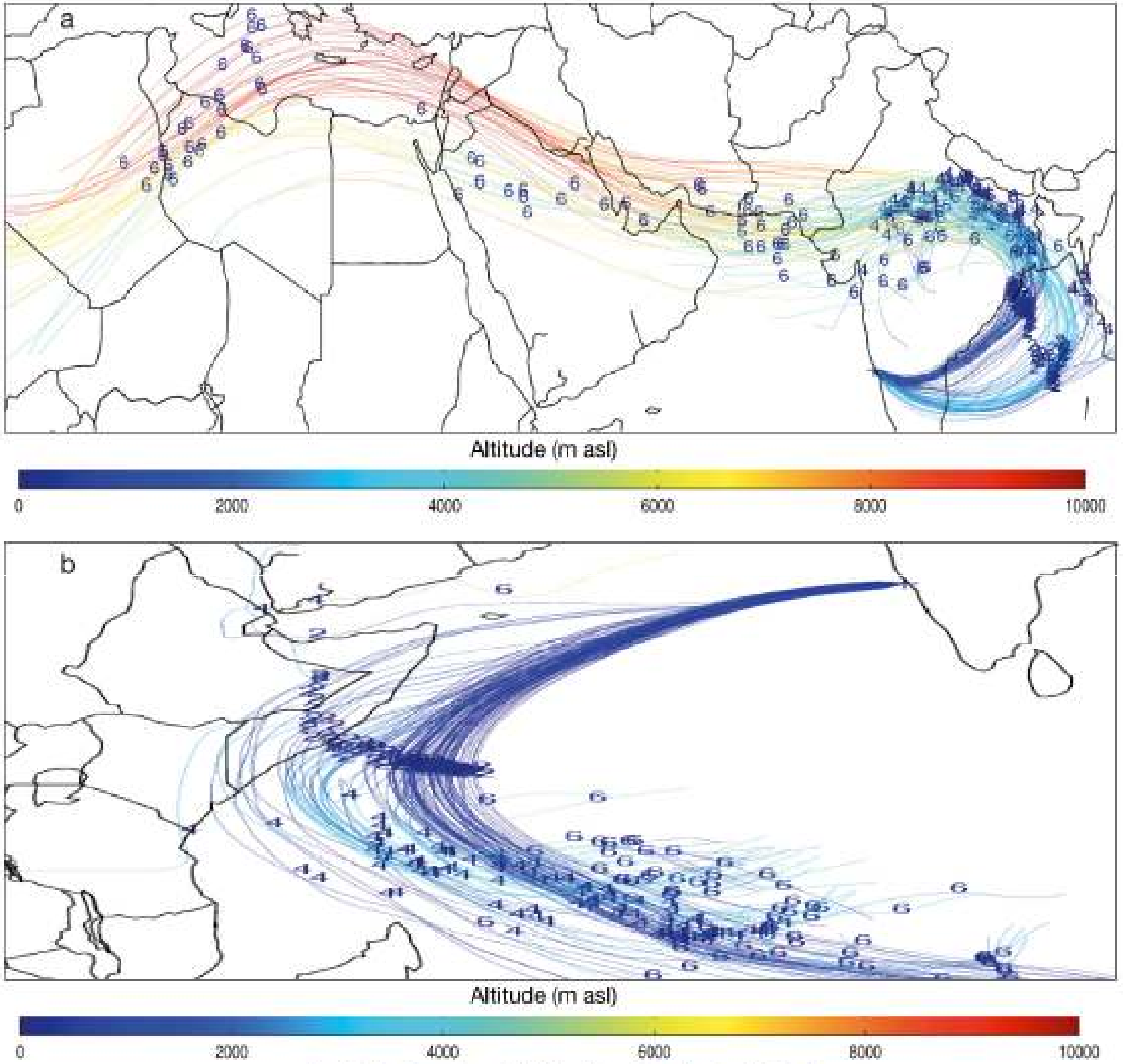


Fig. 5. Stn Cape Rama (CRI) back-trajectories. As in Fig. 4

Tiwari et al., 2013

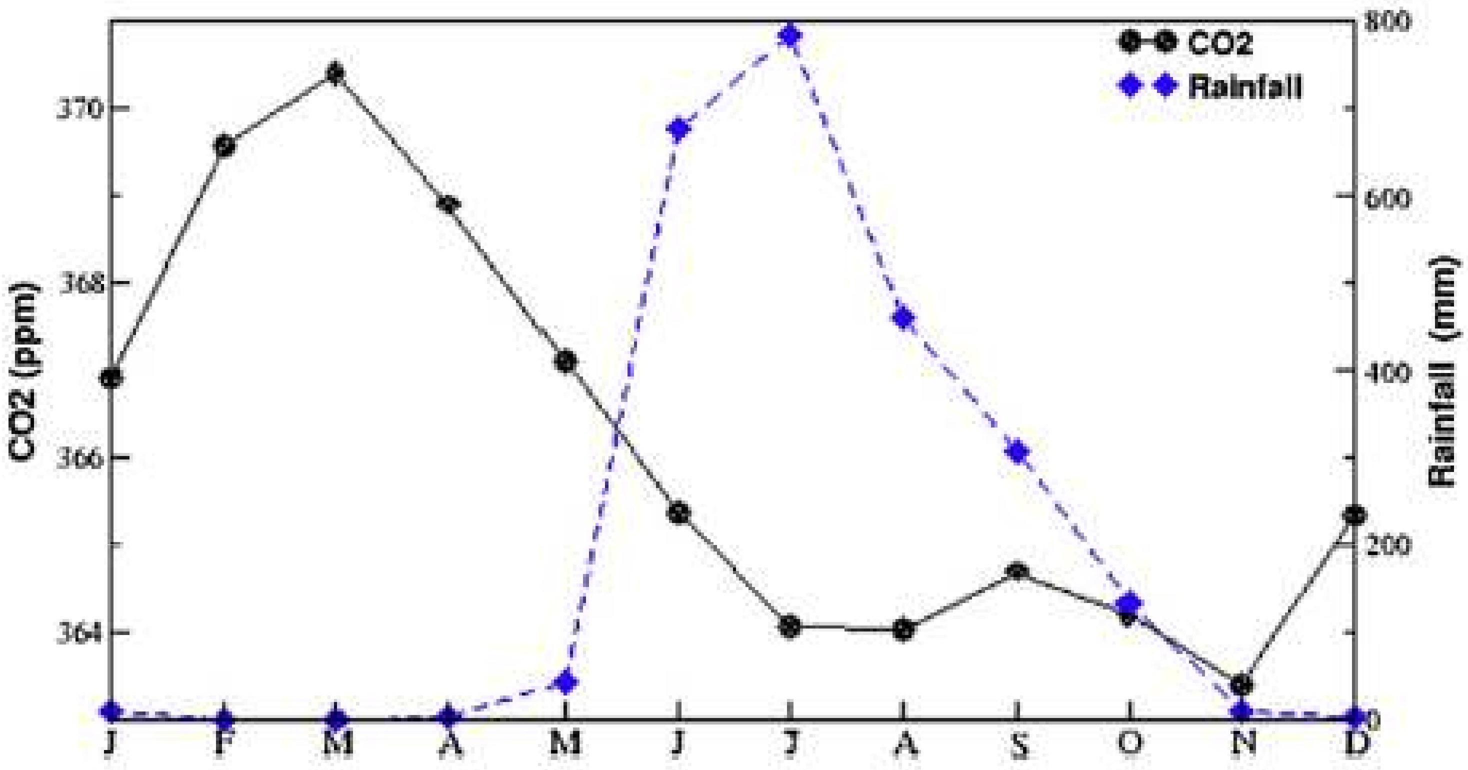
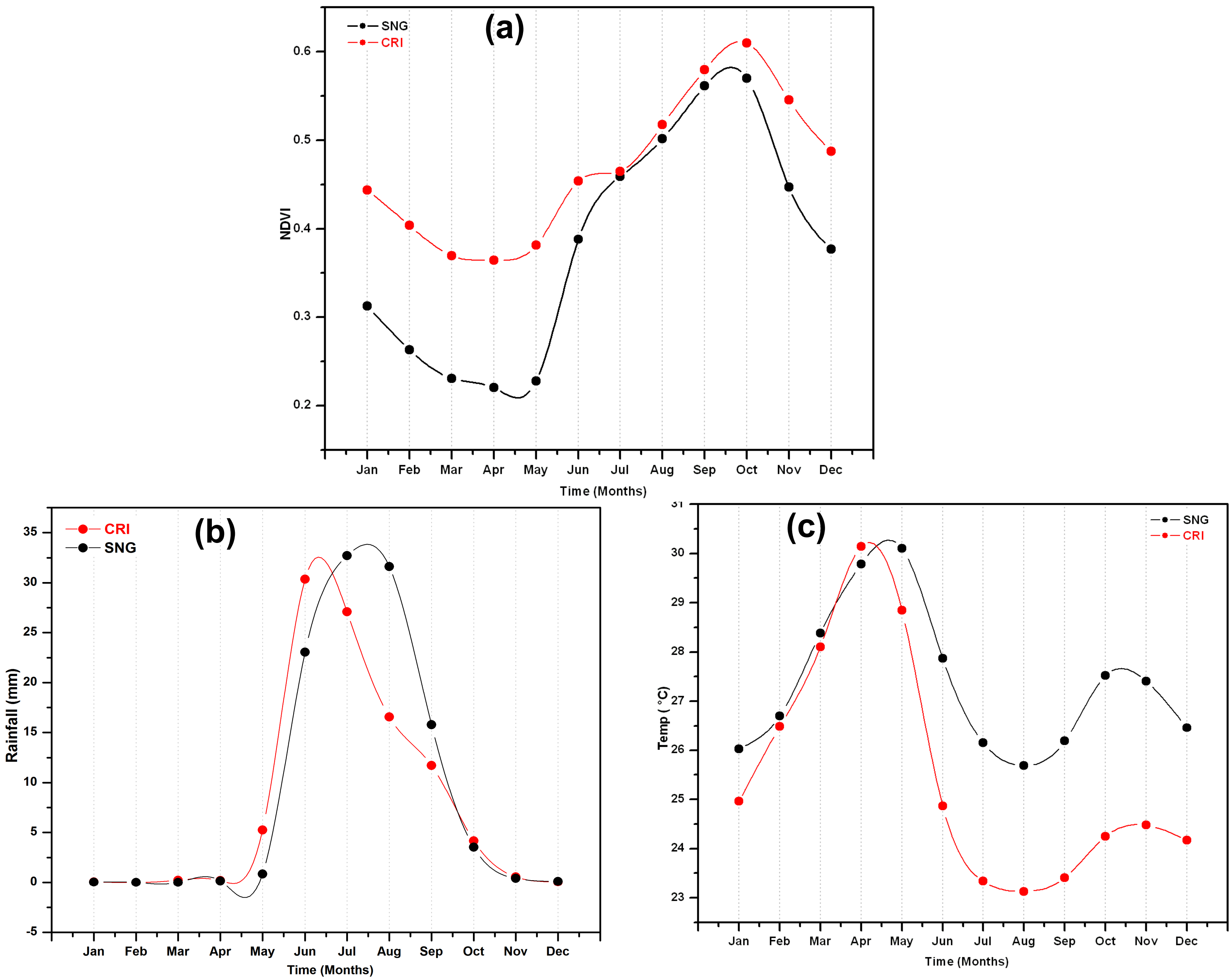
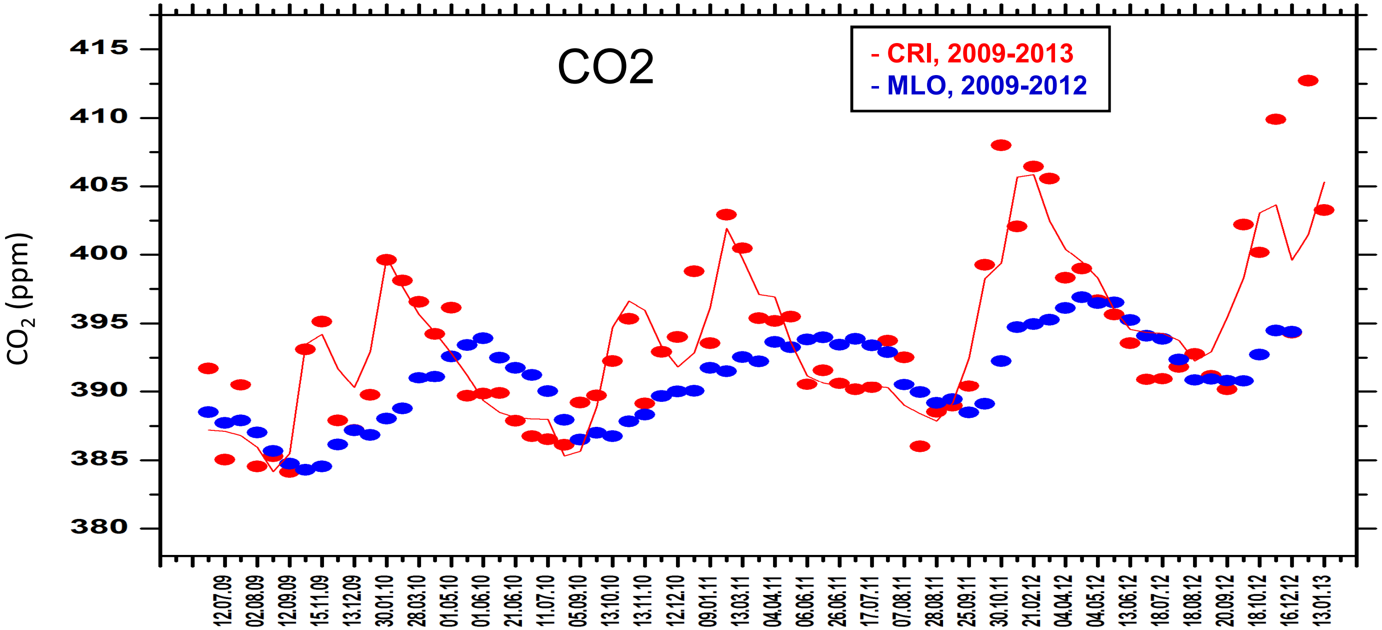
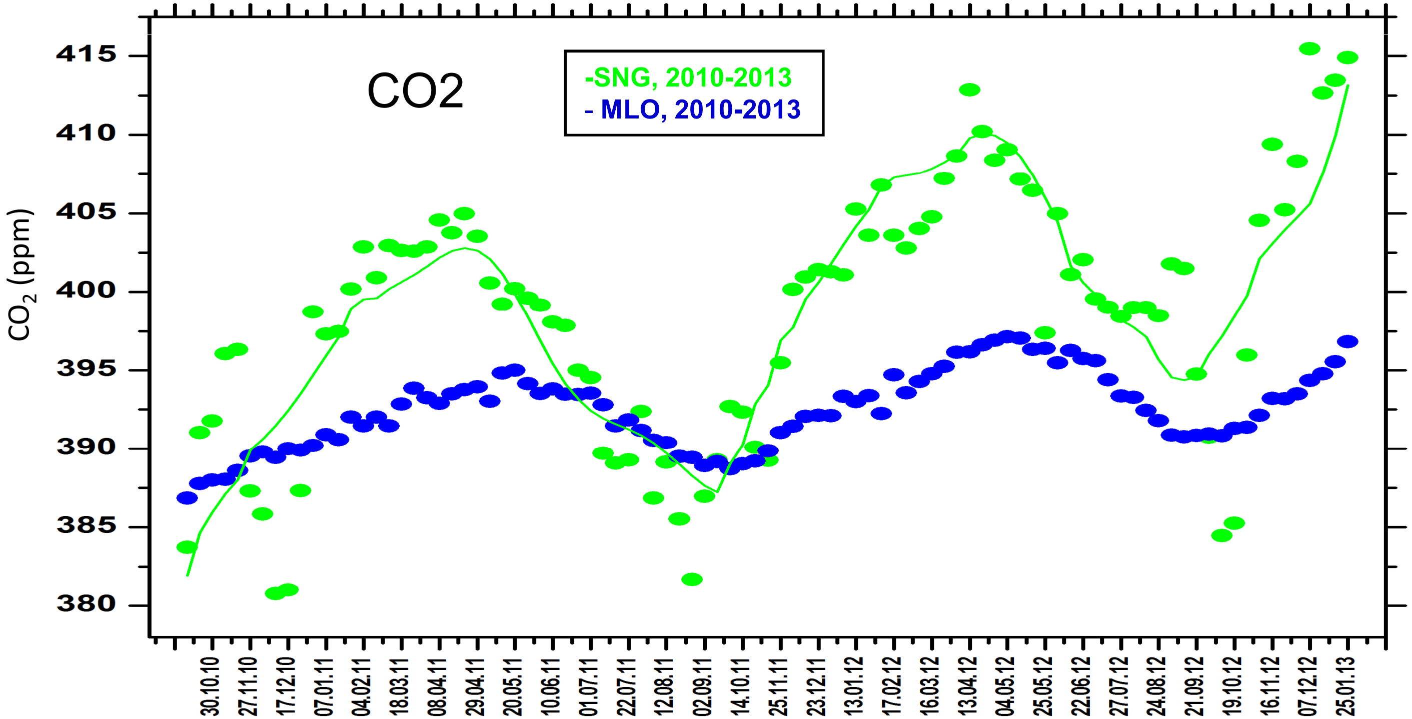


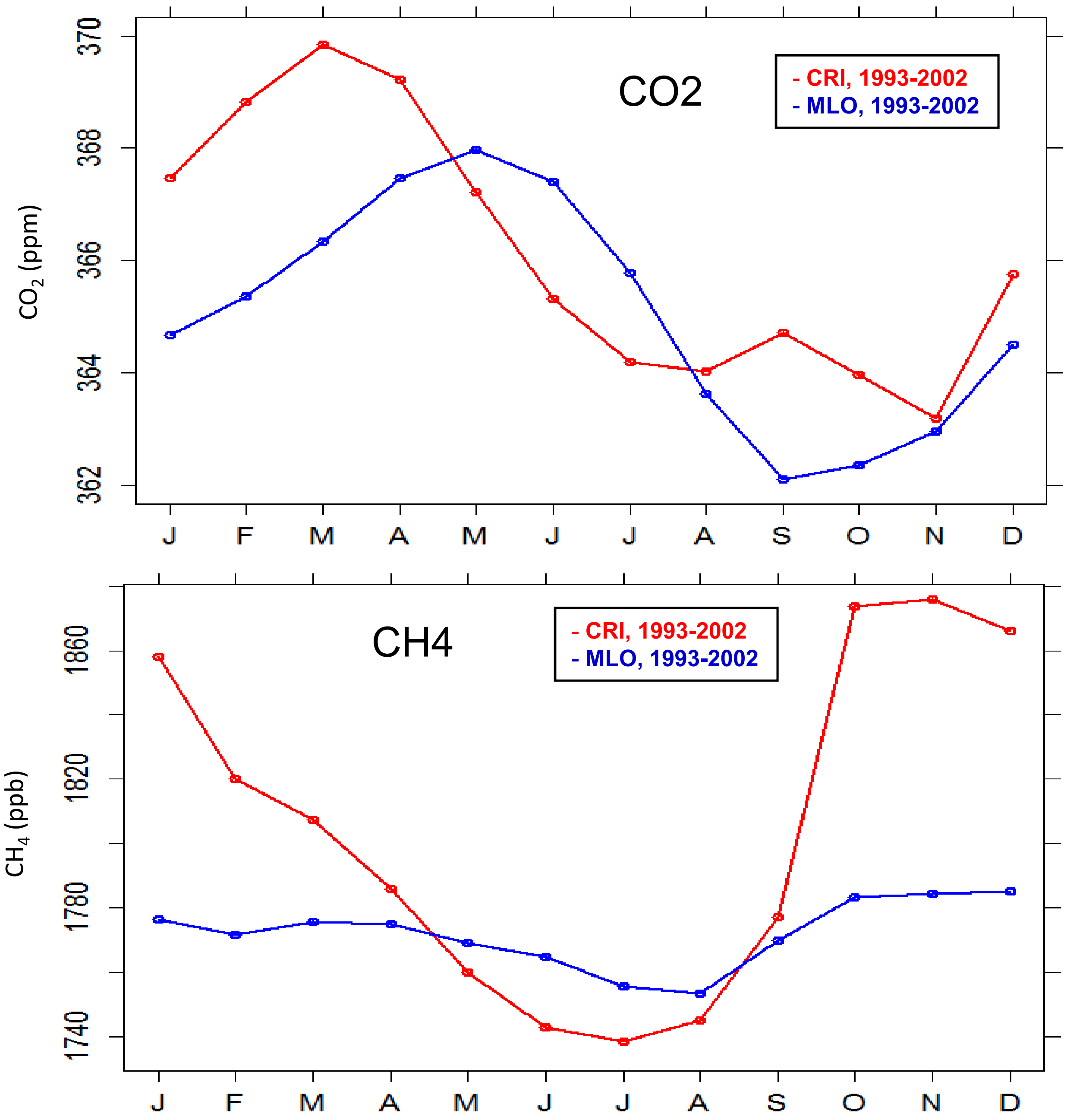
Fig. 6. Annual cycle of CO_2 (ppm) superimposed with annual cycle of rainfall (mm) over Cape Rama based on the data for 1993–2002.

Tiwari et al., 2013


(a)
SNG
CRI
NDVI
0.2
0.3
0.4
0.5
0.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (Months)
(b)
CRI
SNG
Rainfall (mm)
-5
0
5
10
15
20
25
30
35
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (Months)
(c)
SNG
CRI
Temp (°C)
23
24
25
26
27
28
29
30
31
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (Months)


CO2
- CRI, 2009-2013
- MLO, 2009-2012
CO_2 (ppm)
415
410
405
400
395
390
385
380
12.07.09
02.08.09
12.09.09
15.11.09
13.12.09
30.01.10
28.03.10
01.05.10
01.06.10
21.06.10
11.07.10
05.09.10
13.10.10
13.11.10
12.12.10
09.01.11
13.03.11
04.04.11
06.06.11
26.06.11
17.07.11
07.08.11
28.08.11
25.09.11
30.10.11
21.02.12
04.04.12
04.05.12
13.06.12
18.07.12
18.08.12
20.09.12
18.10.12
16.12.12
13.01.13


CO2
-SNG, 2010-2013
- MLO, 2010-2013
CO_2 (ppm)
415
410
405
400
395
390
385
380
30.10.10
27.11.10
17.12.10
07.01.11
04.02.11
18.03.11
08.04.11
29.04.11
20.05.11
10.06.11
01.07.11
22.07.11
12.08.11
02.09.11
14.10.11
25.11.11
23.12.11
13.01.12
17.02.12
16.03.12
13.04.12
04.05.12
25.05.12
22.06.12
27.07.12
24.08.12
21.09.12
19.10.12
16.11.12
07.12.12
25.01.13

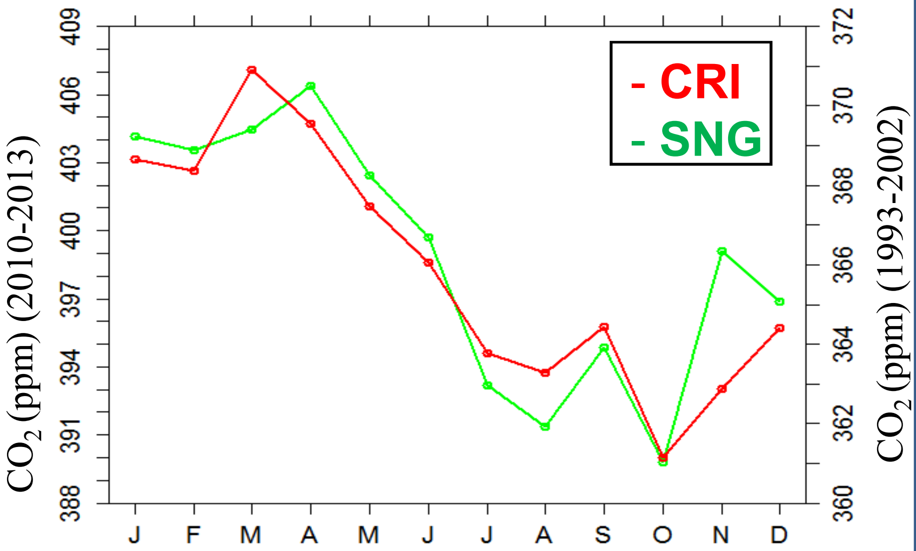

CO2
- CRI, 1993-2002
- MLO, 1993-2002
CO_2 (ppm)
362
364
366
368
370
J
F
M
A
M
J
J
A
S
O
N
D
CH4
- CRI, 1993-2002
- MLO, 1993-2002
CH_4 (ppb)
1740
1780
1820
1860
J
F
M
A
M
J
J
A
S
O
N
D

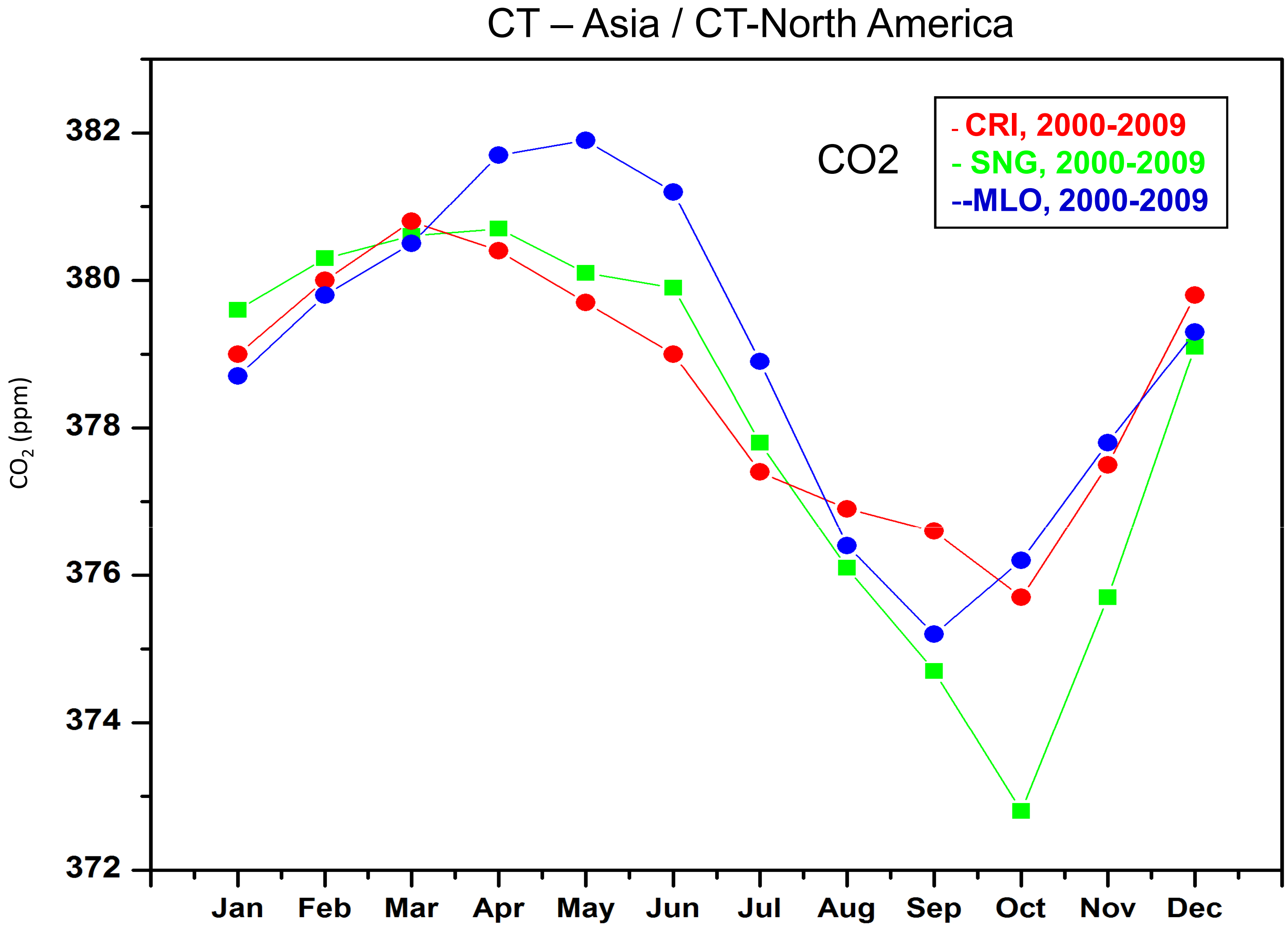
Seasonal correlations of weekly data between CRI and SNG

	All Seasons (CC, SNG and CRI)	DJF	MAM	JJAS	ON
CO_2	**0.664478**	**0.959588**	**0.270625**	**0.864363**	**0.747416**
Differences in seasonal means of both (SNG-CRI)					
CO_2(ppm)	**1.974331**	**-1.65751**	**5.99576**	**2.81568**	**-4.02596**

SNG and CRI CO_2 observations are generally well correlated during all seasons of the year.

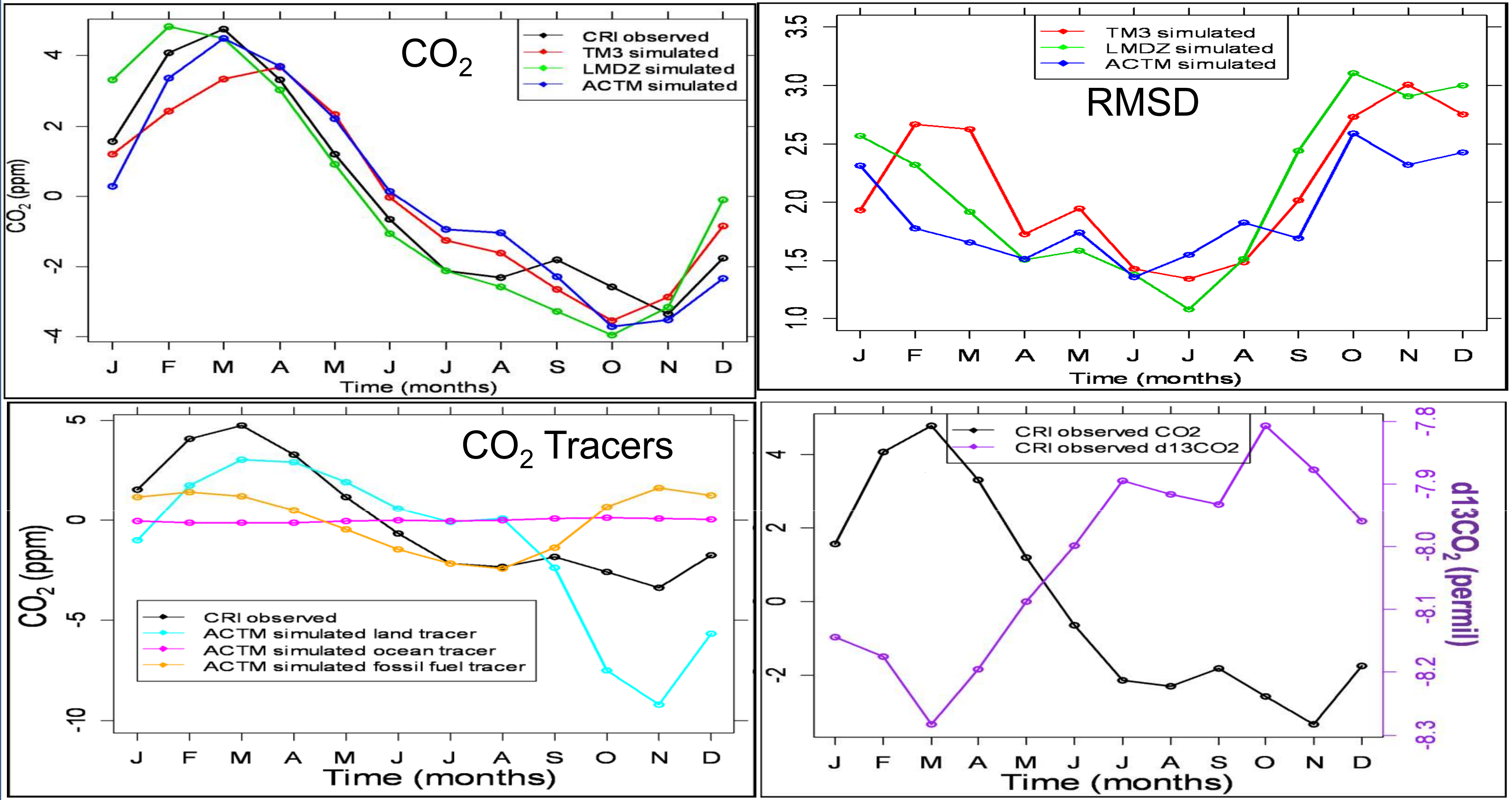
Seasonal mean show Maxima (Minima) in April (Oct) months for SNG and March (Oct) for CRI





CT-Asia Data: Chunho Cho, NIMR Korea

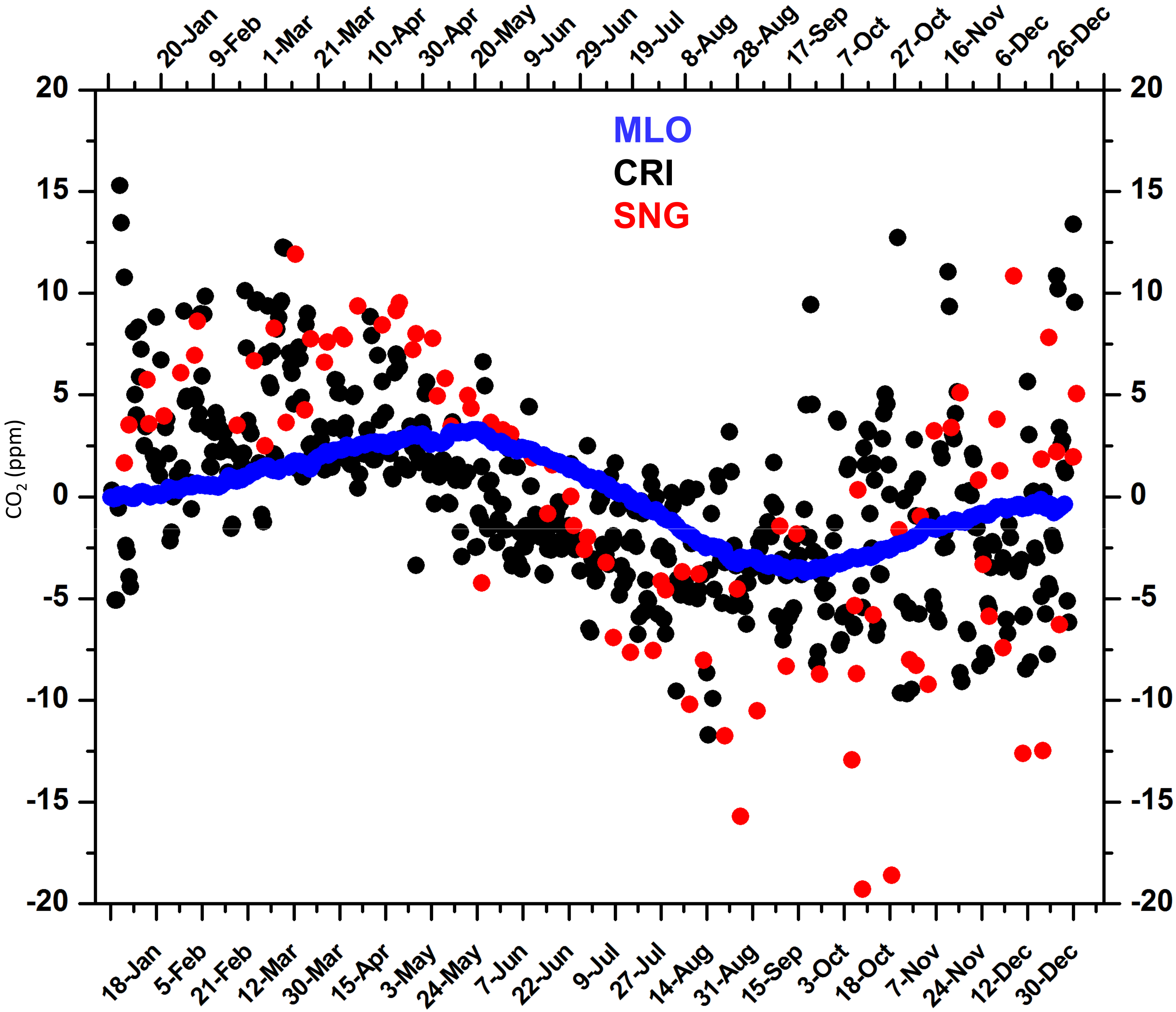
Seasonal cycle of CO_2 from observations and model simulations at Cape Rama (CRI)



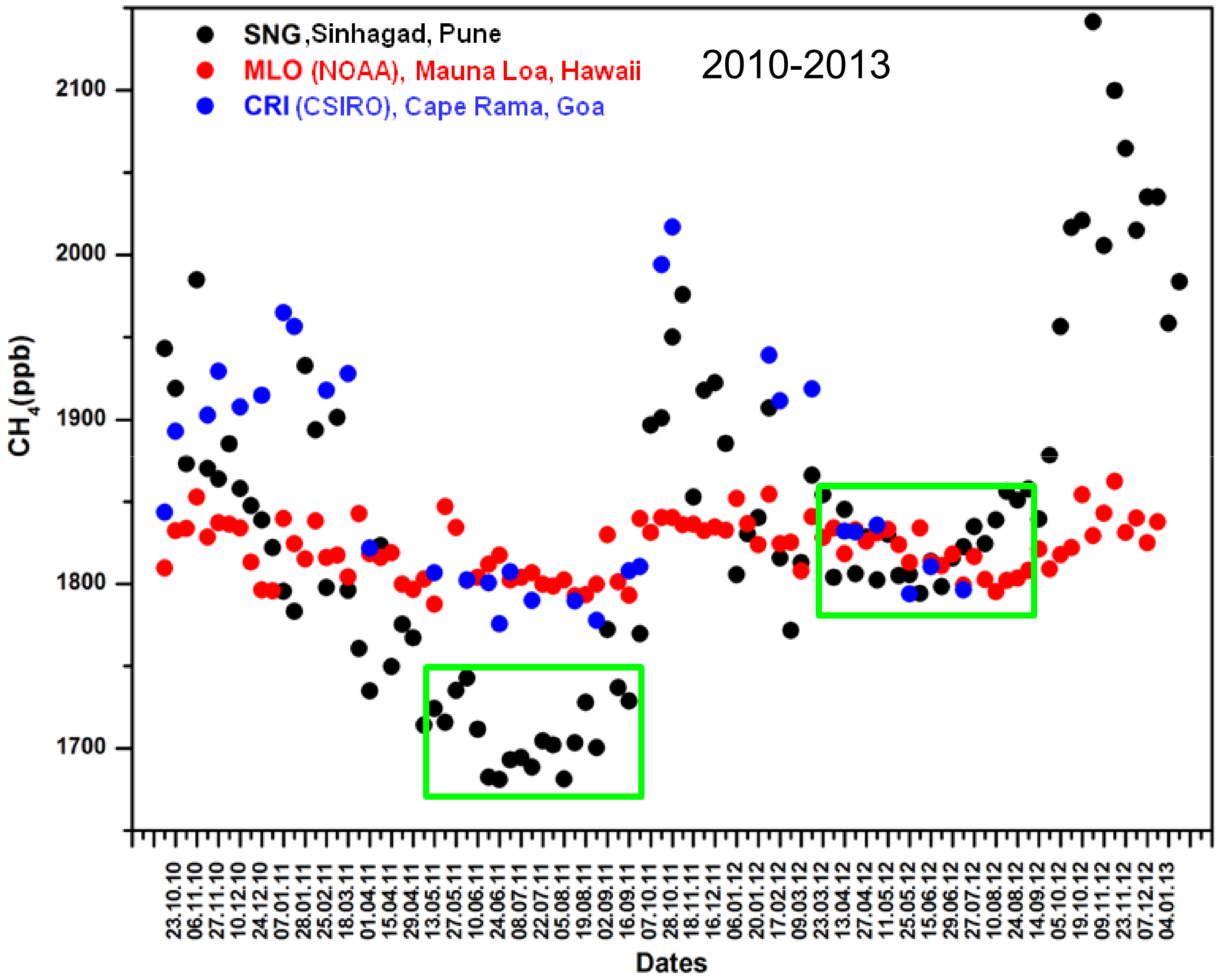
❖During summer monsoon months (June–September), the agreement between model and observed seasonal cycle is better represented (RMS values within ~1.5 ppm) than that of winter months (RMS values of 2–3 ppm).

❖The seasonal forcing at CRI clearly comes from the terrestrial biosphere. This is also corroborated from the strong anti-correlation of the seasonal cycles of δ 13C and CO_2 .

Tiwari et al., 2010



MLO
CRI
SNG
CO2 (ppm)
20
15
10
5
0
-5
-10
-15
-20
20-Jan
9-Feb
1-Mar
21-Mar
10-Apr
30-Apr
20-May
9-Jun
29-Jun
19-Jul
8-Aug
28-Aug
17-Sep
7-Oct
27-Oct
16-Nov
6-Dec
26-Dec
18-Jan
5-Feb
21-Feb
12-Mar
30-Mar
15-Apr
3-May
24-May
7-Jun
22-Jun
9-Jul
27-Jul
14-Aug
31-Aug
15-Sep
3-Oct
18-Oct
7-Nov
24-Nov
12-Dec
30-Dec



SNG,Sinhagad, Pune
MLO (NOAA), Mauna Loa, Hawaii
CRI (CSIRO), Cape Rama, Goa
2010-2013
CH4 (ppb)
2100
2000
1900
1800
1700
23.10.10
06.11.10
27.11.10
10.12.10
24.12.10
07.01.11
28.01.11
25.02.11
18.03.11
01.04.11
15.04.11
29.04.11
13.05.11
27.05.11
10.06.11
24.06.11
08.07.11
22.07.11
05.08.11
19.08.11
02.09.11
16.09.11
07.10.11
28.10.11
18.11.11
16.12.11
06.01.12
20.01.12
17.02.12
09.03.12
23.03.12
13.04.12
27.04.12
11.05.12
25.05.12
15.06.12
29.06.12
27.07.12
10.08.12
24.08.12
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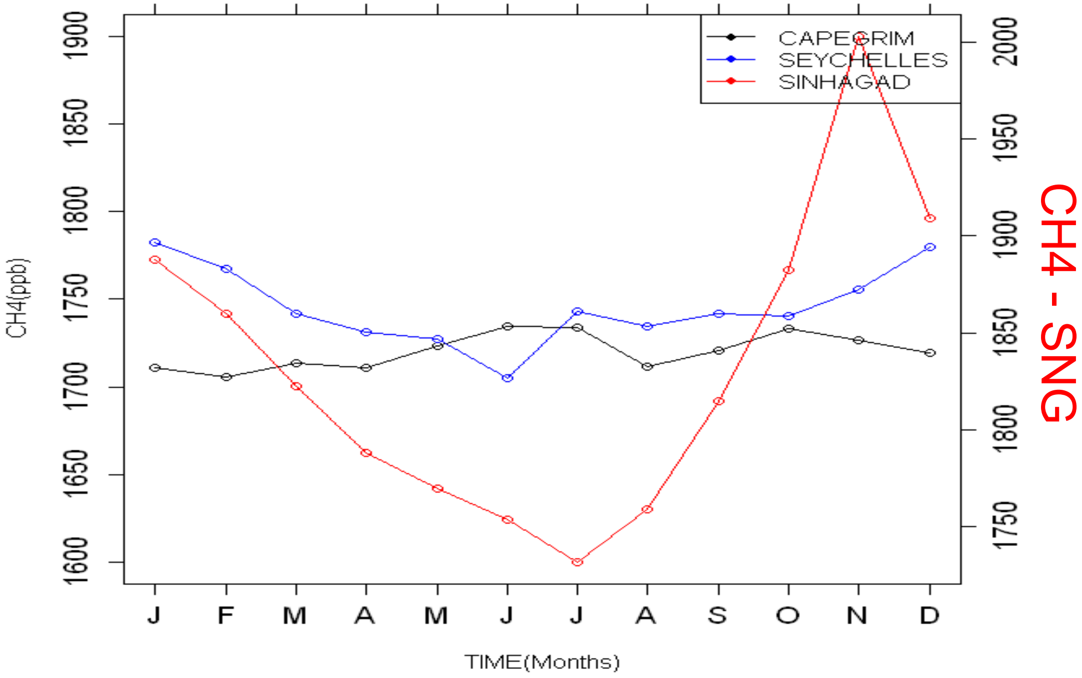
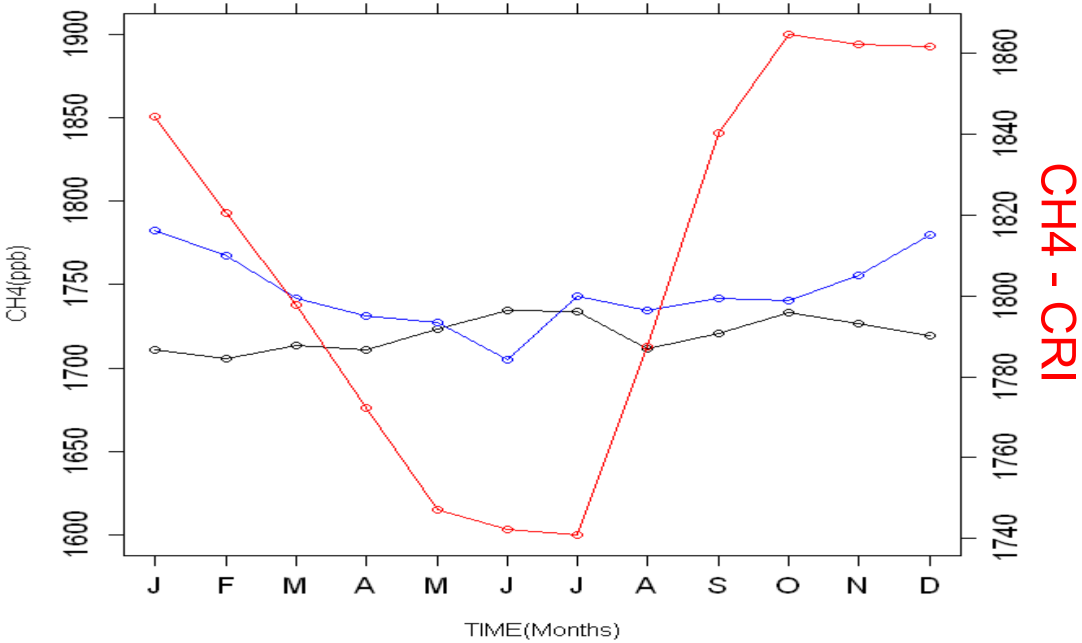
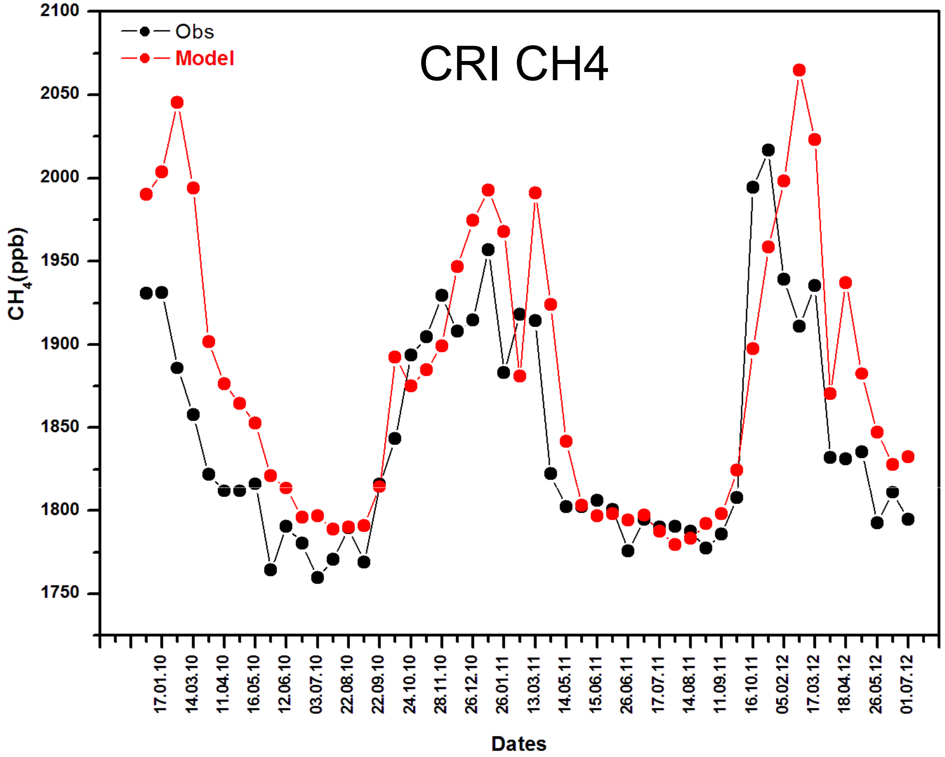
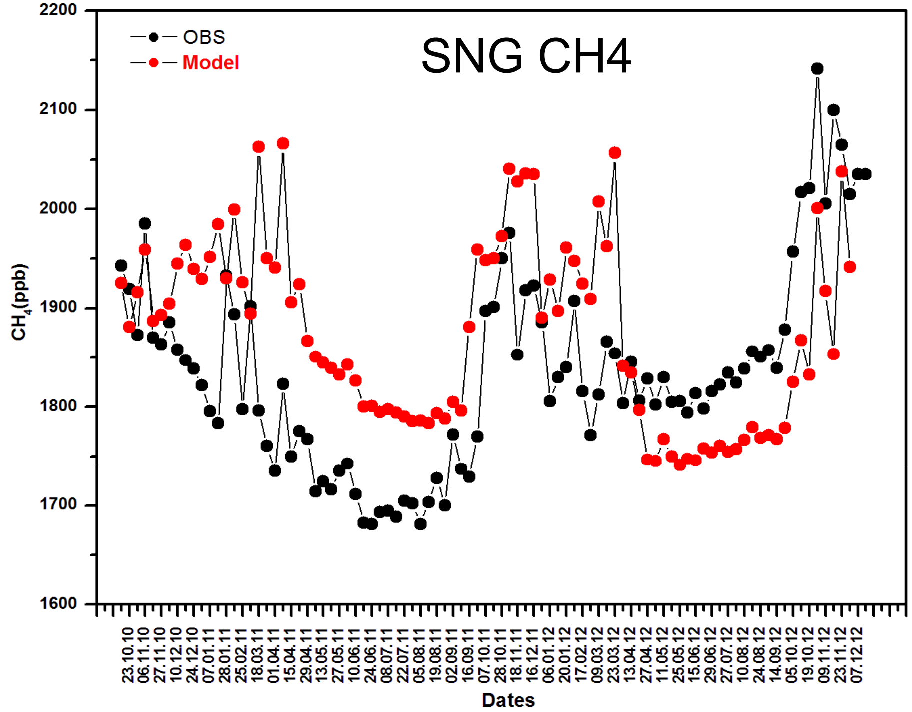
19.10.12
09.11.12
23.11.12
07.12.12
04.01.13
Dates


CAPEGRIM
SEYCHELLES
SINHAGAD
CH4(ppb)
TIME(Months)
CH4 - SNG


CH4(ppb)
TIME(Months)
CH4 - CRI


CRI CH4
Obs
Model
CH_4(ppb)
2100
2050
2000
1950
1900
1850
1800
1750
17.01.10
14.03.10
11.04.10
16.05.10
12.06.10
03.07.10
22.08.10
22.09.10
24.10.10
28.11.10
26.12.10
26.01.11
13.03.11
14.05.11
15.06.11
26.06.11
17.07.11
14.08.11
11.09.11
16.10.11
05.02.12
17.03.12
18.04.12
26.05.12
01.07.12
Dates


SNG CH4
OBS
Model
CH_4(ppb)
2200
2100
2000
1900
1800
1700
1600
23.10.10
06.11.10
27.11.10
10.12.10
24.12.10
07.01.11
28.01.11
25.02.11
18.03.11
01.04.11
15.04.11
29.04.11
13.05.11
27.05.11
10.06.11
24.06.11
08.07.11
22.07.11
05.08.11
19.08.11
02.09.11
16.09.11
07.10.11
28.10.11
18.11.11
16.12.11
06.01.12
20.01.12
17.02.12
09.03.12
23.03.12
13.04.12
27.04.12
11.05.12
25.05.12
15.06.12
29.06.12
27.07.12
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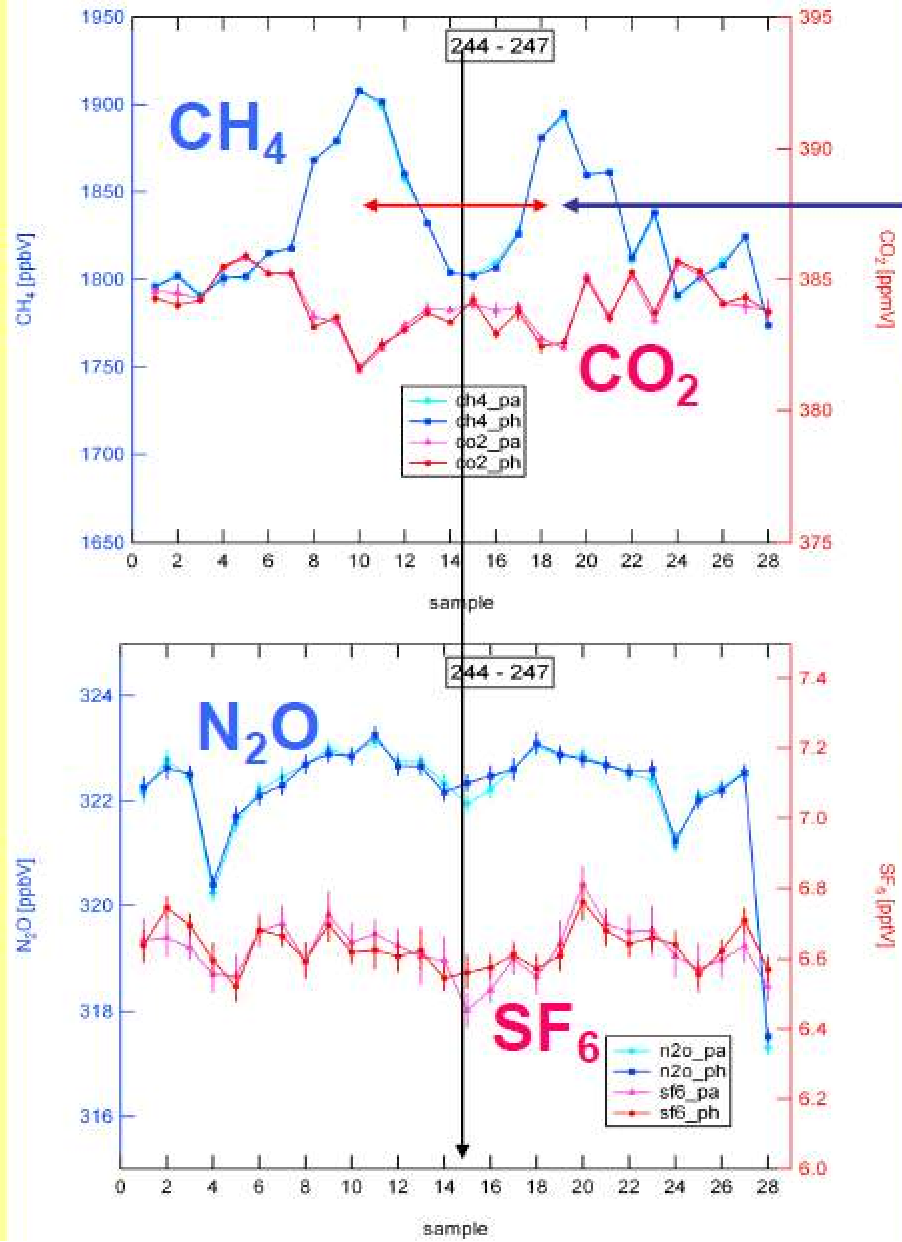
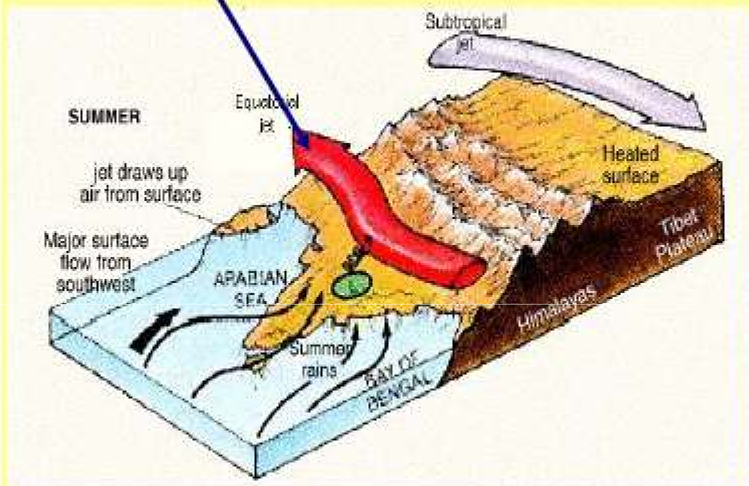
23.11.12
07.12.12
Dates



Frankfurt - Chennai - Frankfurt

August 2008

Monsoon plume



Source: Carl Brenninkmeijer, CARIBIC

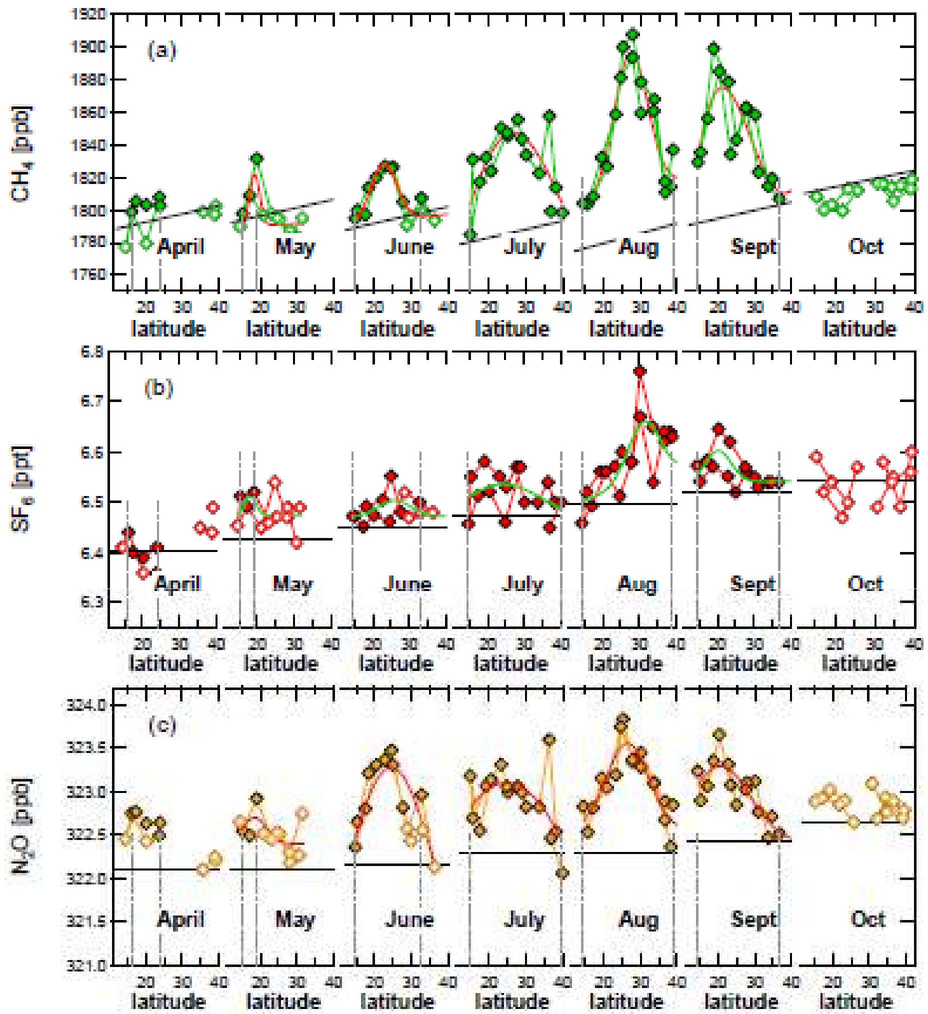


Fig. 8. Latitudinal distributions of CH_4 **(a)**, SF_6 **(b)**, and N_2O **(c)** for April–October 2008. For May–September a Gaussian has been fit to the data. Solid lines indicate background levels determined from the CARIBIC measurements in April and October for SF_6 and from the Mauna Loa Observatory for CH_4 and N_2O. All samples for which CH_4 mixing ratios are above the reference background are indicated by closed symbols, open symbols denote samples with lower CH_4 mixing ratios. The vertical dashed lines mark the integration limits used to calculate the increase in the monsoon plume.

Schuck et al., 2010, ACP

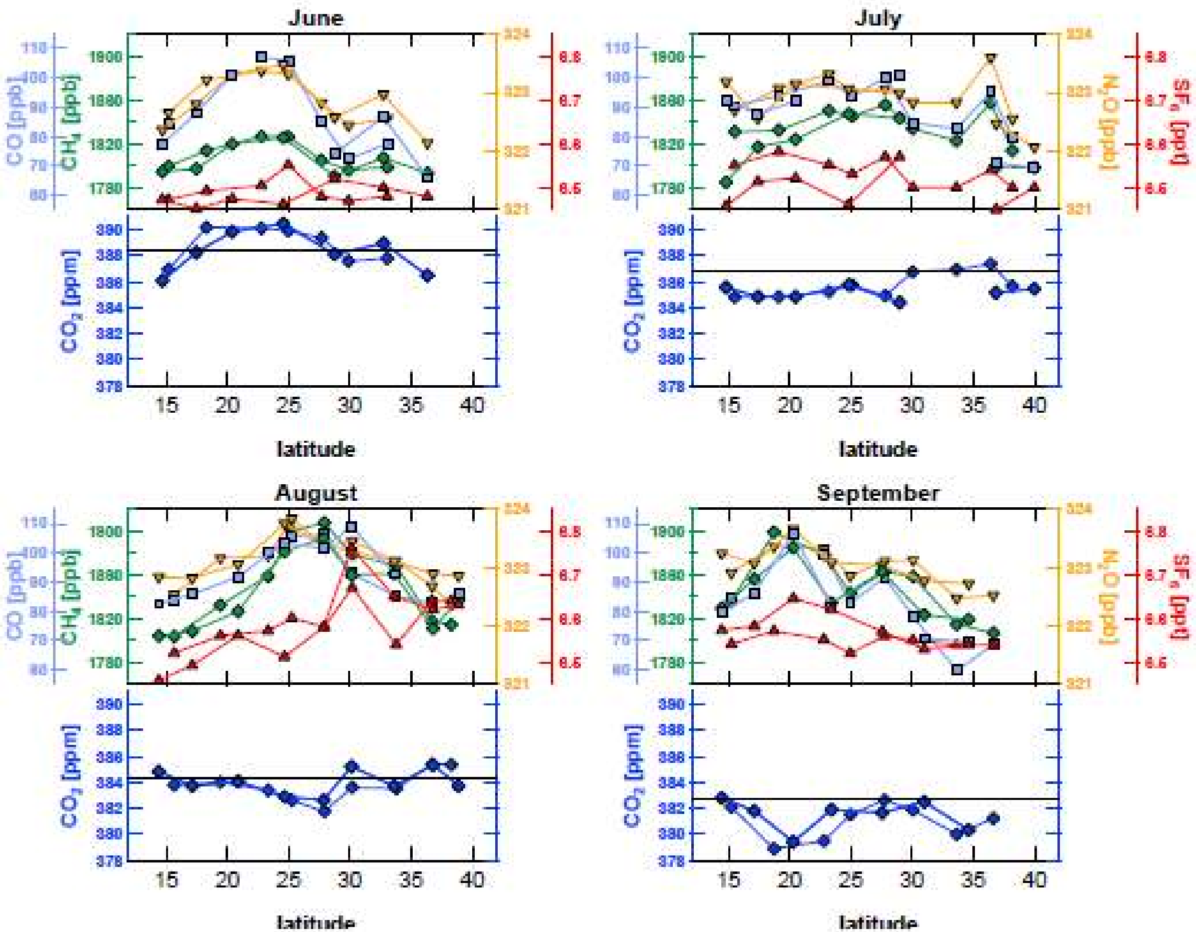


Fig. 5. Latitudinal distributions of CH_4, CO_2, N_2O, and SF_6 from air samples and on-line measured CO mixing ratios integrated over the sampling period for flights between Frankfurt and Chennai in June, July, August, and September 2008. For CO_2 the mean mixing ratio observed at Mauna Loa Observatory (19° N) is indicated by a solid line.

Schuck et al., 2010, ACP

Surface CO_2 observations at Sinhagad site, India

Met sensors and Intet pump

Glass flask

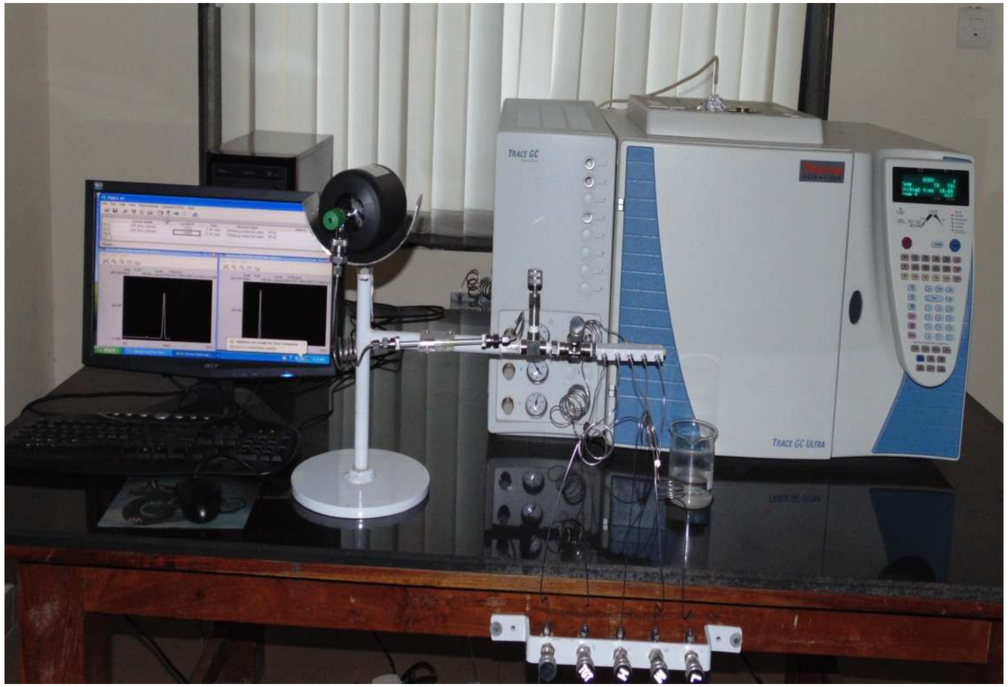
Air sampler


Indian Institute of Tropical Meteorology, Pune
(Sinhagad)

Wet condition Sinhagad site Dry condition

Gas Chromatograph facility at the IITM,Pune

a



a) Gas Chromatograph (FID,ECD)
a) Standard calibration cylinders (NOAA,USA)
c) Target gas cylinders
d) Carrrier gas cylinders

b

c

d

Glass flask evacuation and conditioning system developed at the IITM

a)Oven Evacuating System
b)Flask storage
c) Flask evacuation with oil free pump

THANK YOU.....