Monitoring of Atmospheric Carbon Dioxide and other GHG's in India

Yogesh K. Tiwari

Indian Institute of Tropical Meteorology,
Pune, India

सत्यमेव जयते


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

Background:

- India has one of the largest and fastest growing economies in South Asia and is emerging as a major contributor to CO2 emissions among developing nations.

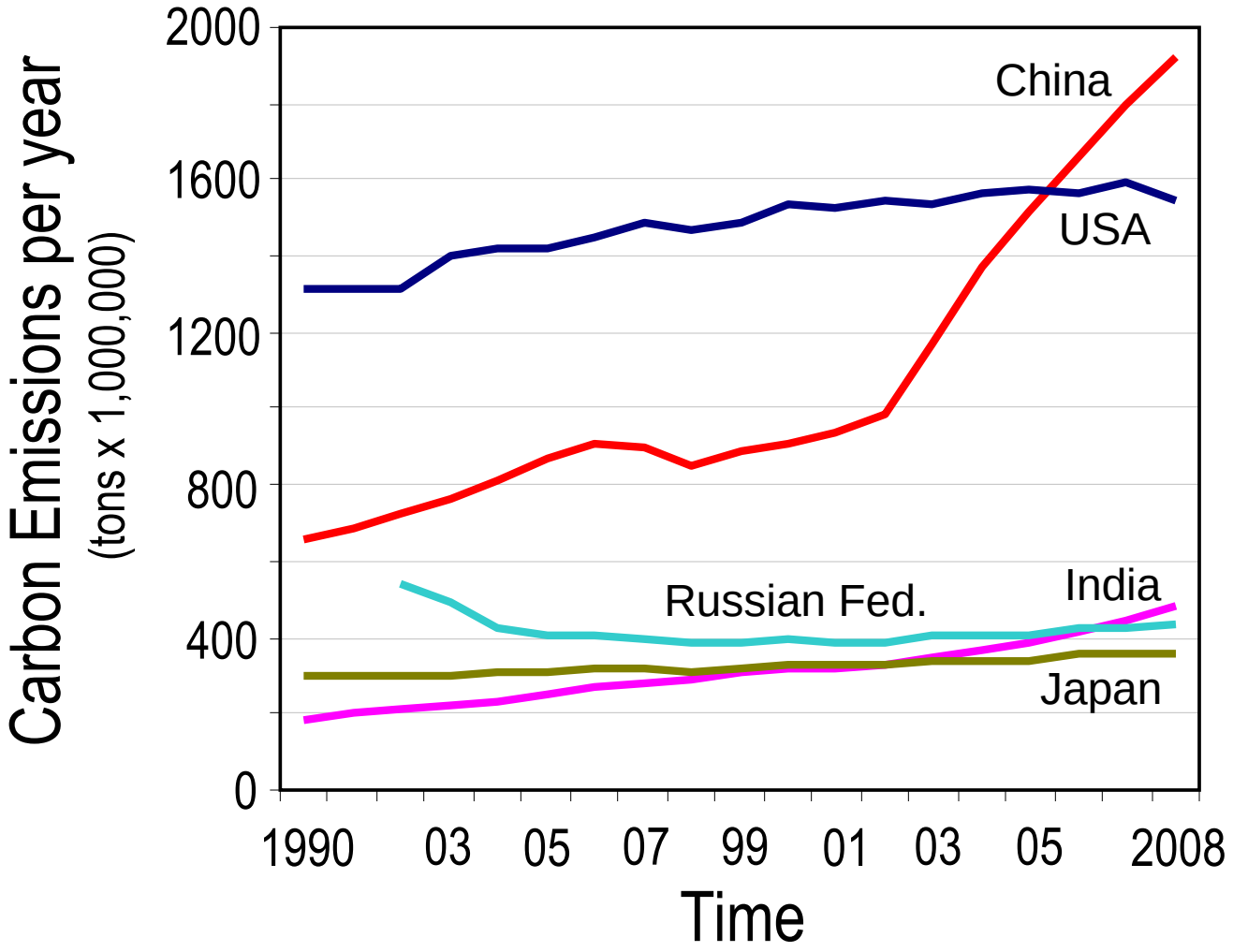
- 54% of the electricity produced in India in 2008-2009 was generated by burning coal (*Ministry of Power, Govt. of India*)

- Indian total emissions from fossil-fuel consumption and cement production have more than doubled since 1992 (*CDIAC*)

- However, there has been relatively little monitoring of atmospheric CO2 over India to date. *(Tiwari et al., 2011, Bhattacharya et al., 2009)*

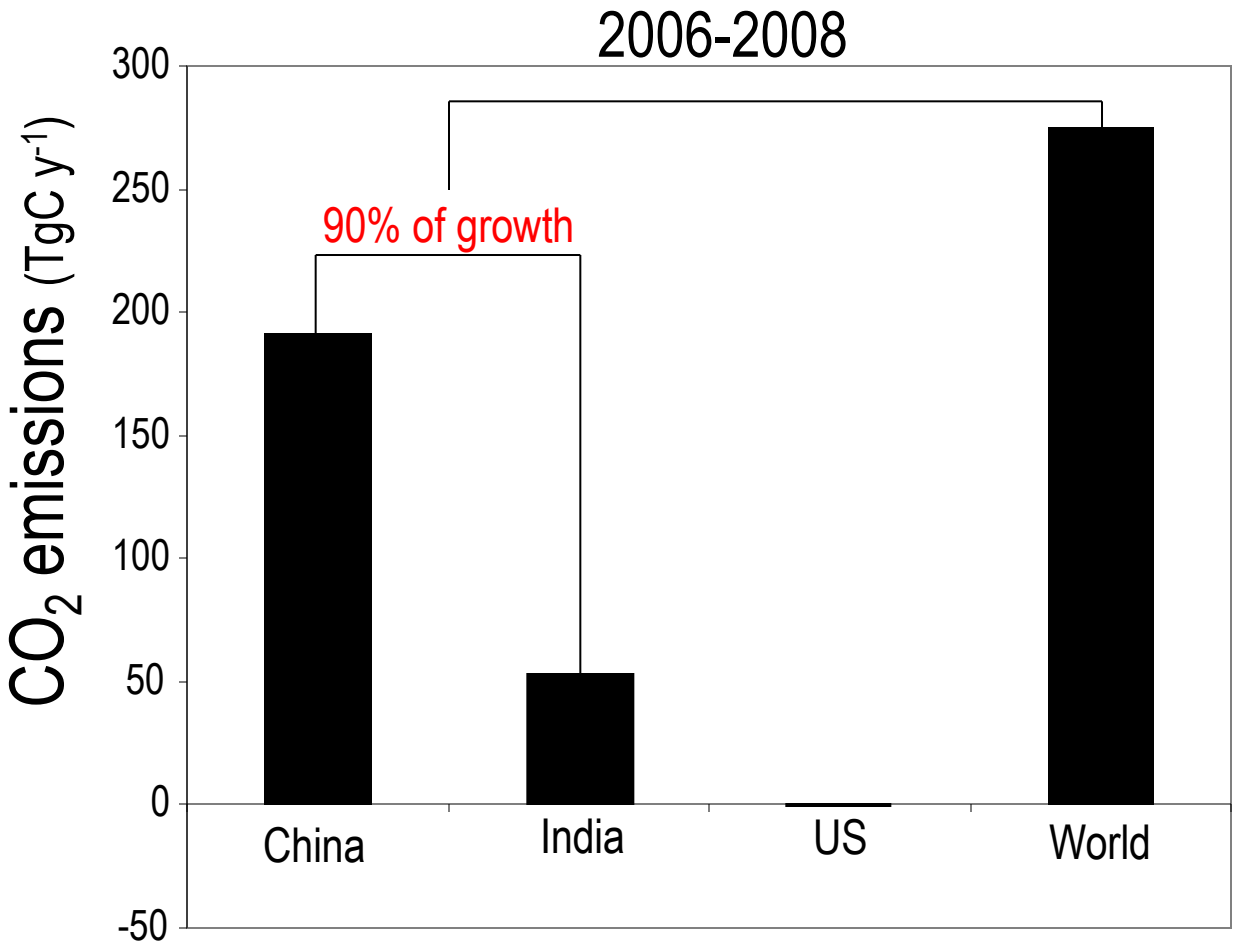
- Sources and sinks of CO2 over this region are poorly constrained *(Rayner et al., 2009; Transcom simulations)*

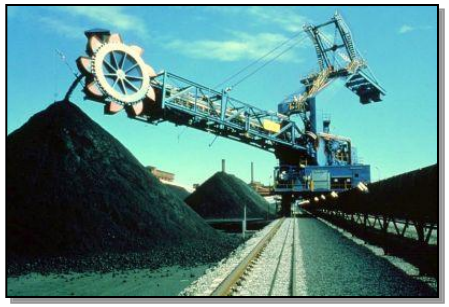
Fossil Fuel Emissions: Top Emitters (>4% of Total)



Ref: Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009

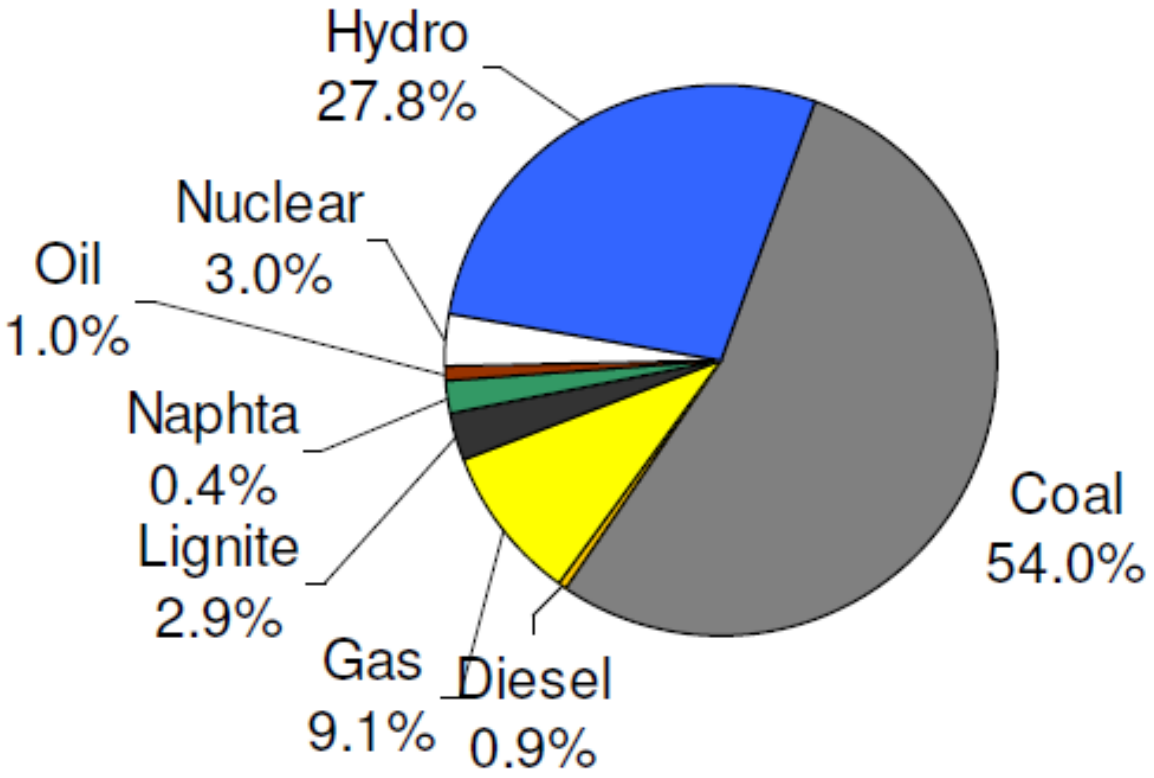
Change in CO_2 Emissions from Coal Emissions



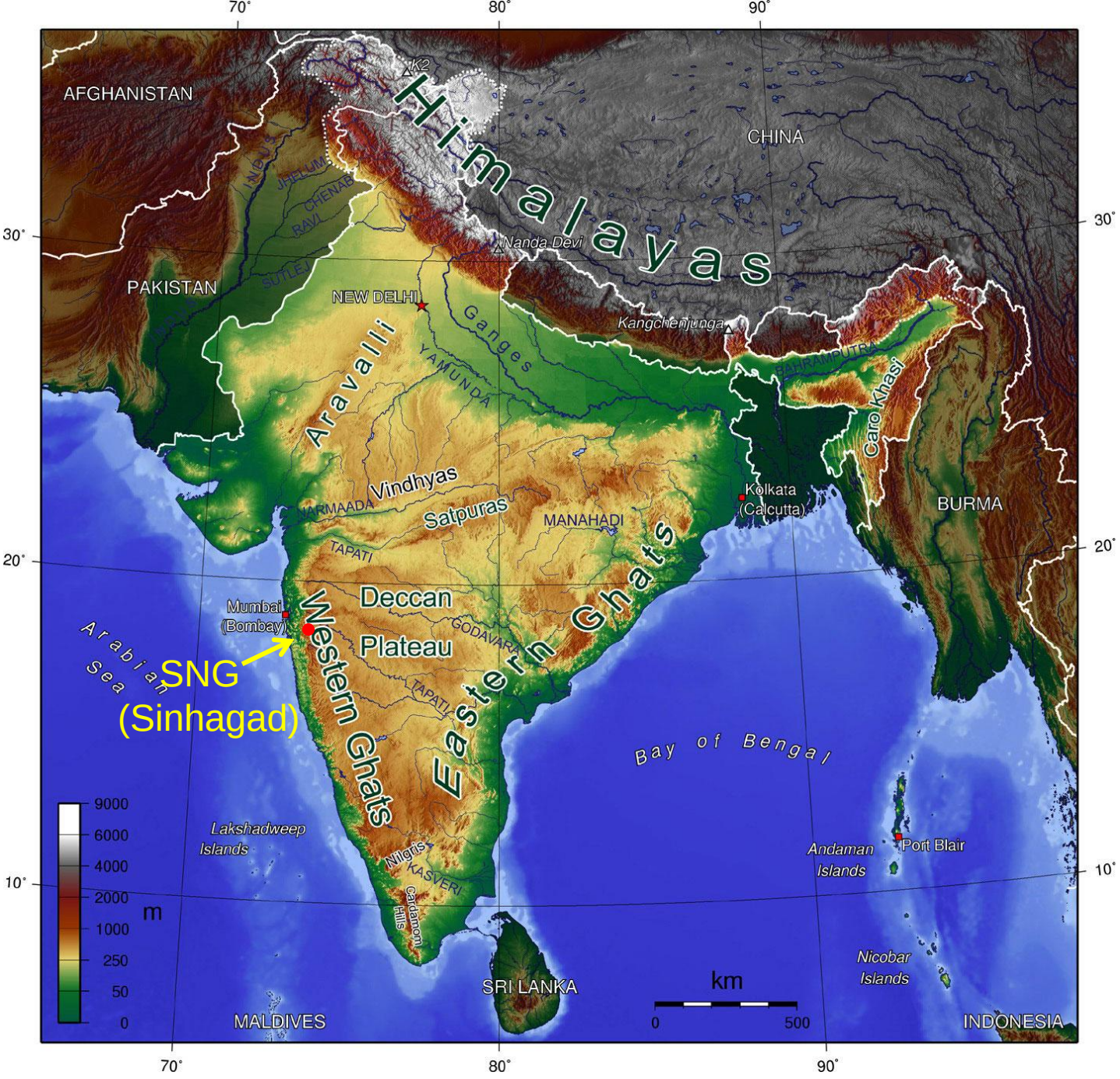


Ref: CDIAC 2009; Global Carbon Project 2009

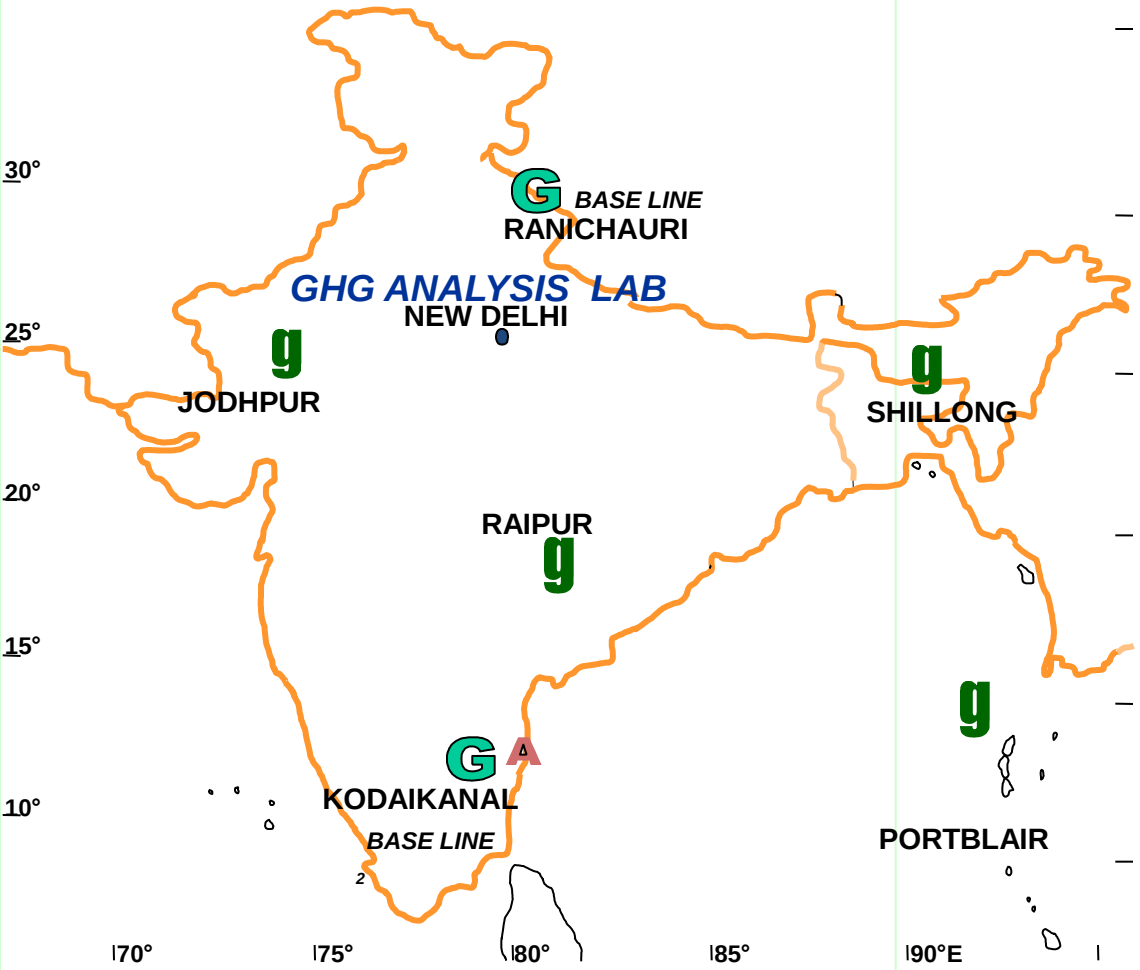
Power generation sources in India; as on March 31, 2009



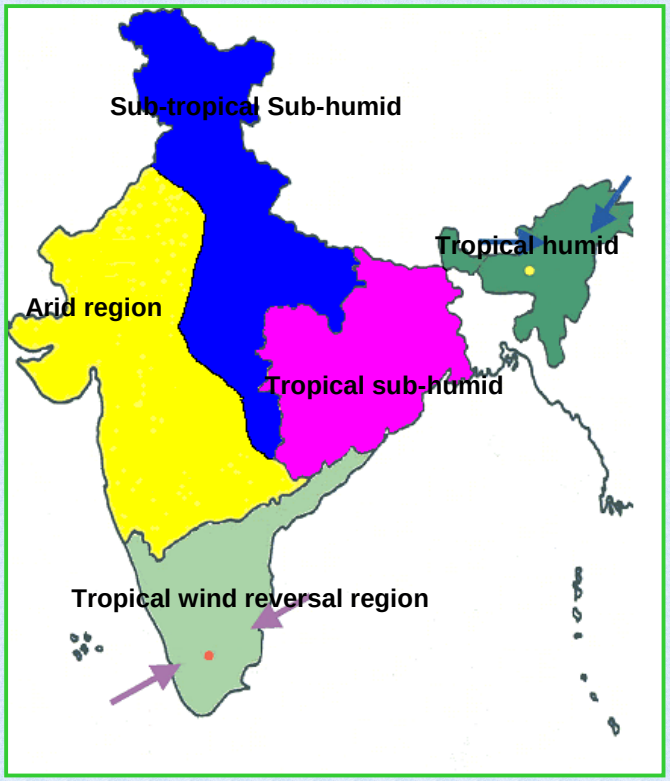
Ref: Central Electricity Authority, Ministry of Power, Govt. of India;
"CO2 baseline database for the Indian power sector" ; November 2009


AFGHANISTAN
PAKISTAN
CHINA
BURMA
SRI LANKA
MALDIVES
INDONESIA
Himalayas
K2
Nanda Devi
Kangchenjunga
NEW DELHI
Aravalli
Ganges
YAMUNA
BRAHMAPUTRA
Caro Khasi
Vindhyas
Satpuras
NARMADA
TAPATI
MANAHADI
Kolkata
(Calcutta)
Deccan
Plateau
GODAVARI
Mumbai
(Bombay)
Western Ghats
Eastern Ghats
Arabian Sea
SNG
(Sinhagad)
Bay of Bengal
Lakshadweep
Islands
Andaman
Islands
Port Blair
Nicobar
Islands
Nilgris
KASVERI
Cardamom
Hills
JHELUM
CHENAB
RAVI
SUTLEJ
INDUS
9000
6000
4000
2000
1000
250
50
0
m
km
0
500
70°
80°
90°
30°
20°
10°

GHGs MONITORING (in collaboration with India Meteorological Department, New Delhi)



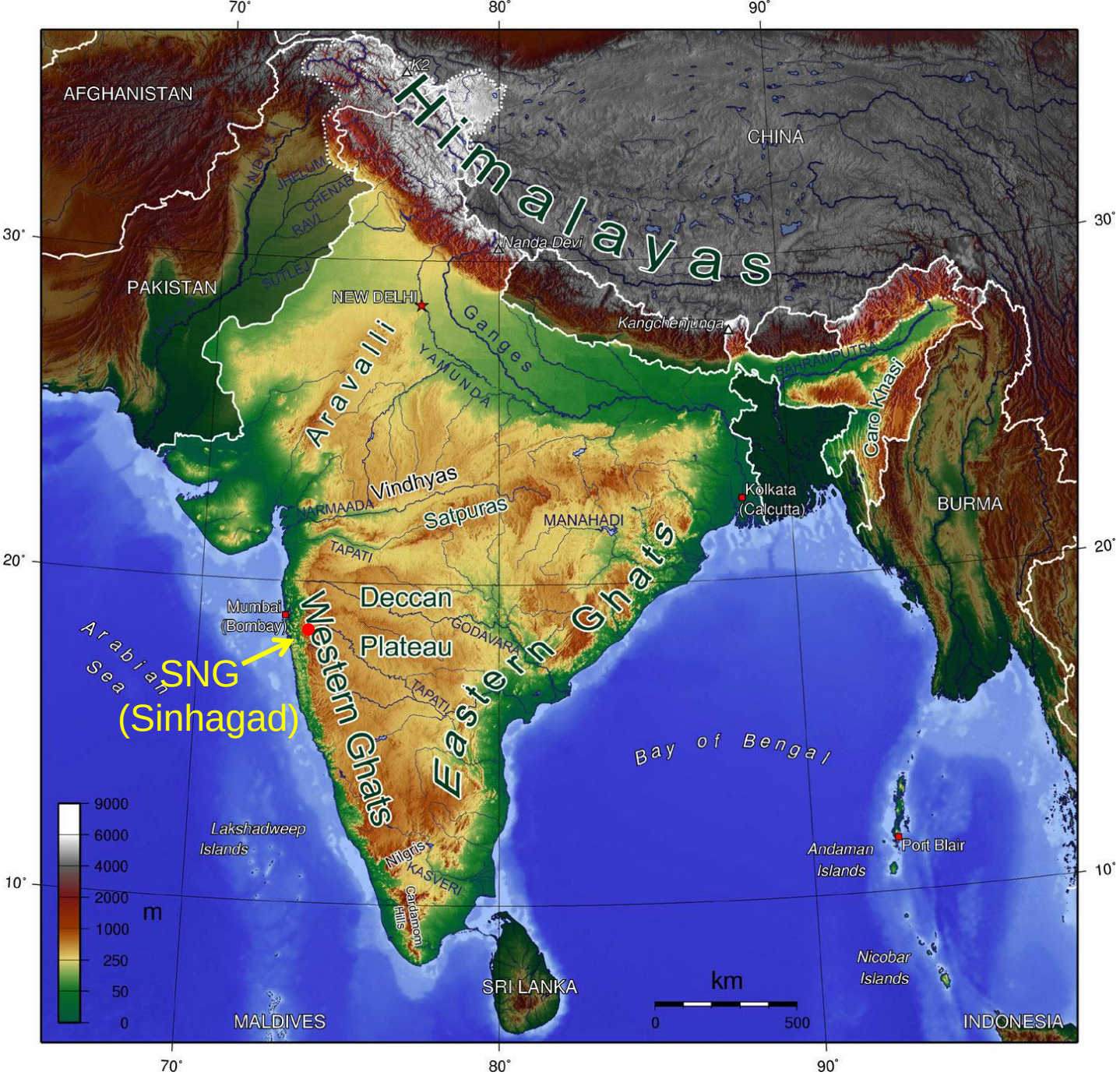
Physio-graphic regions

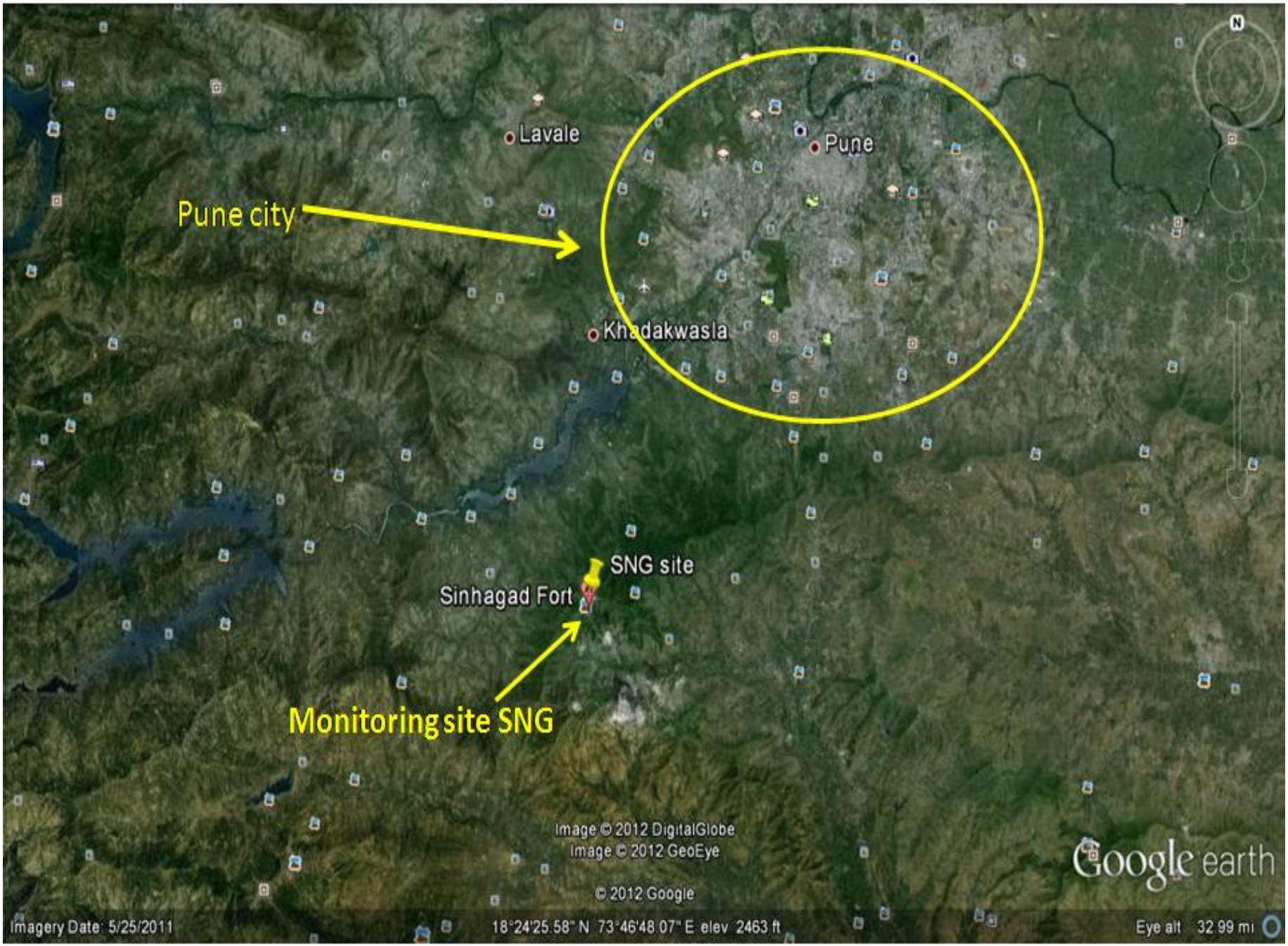


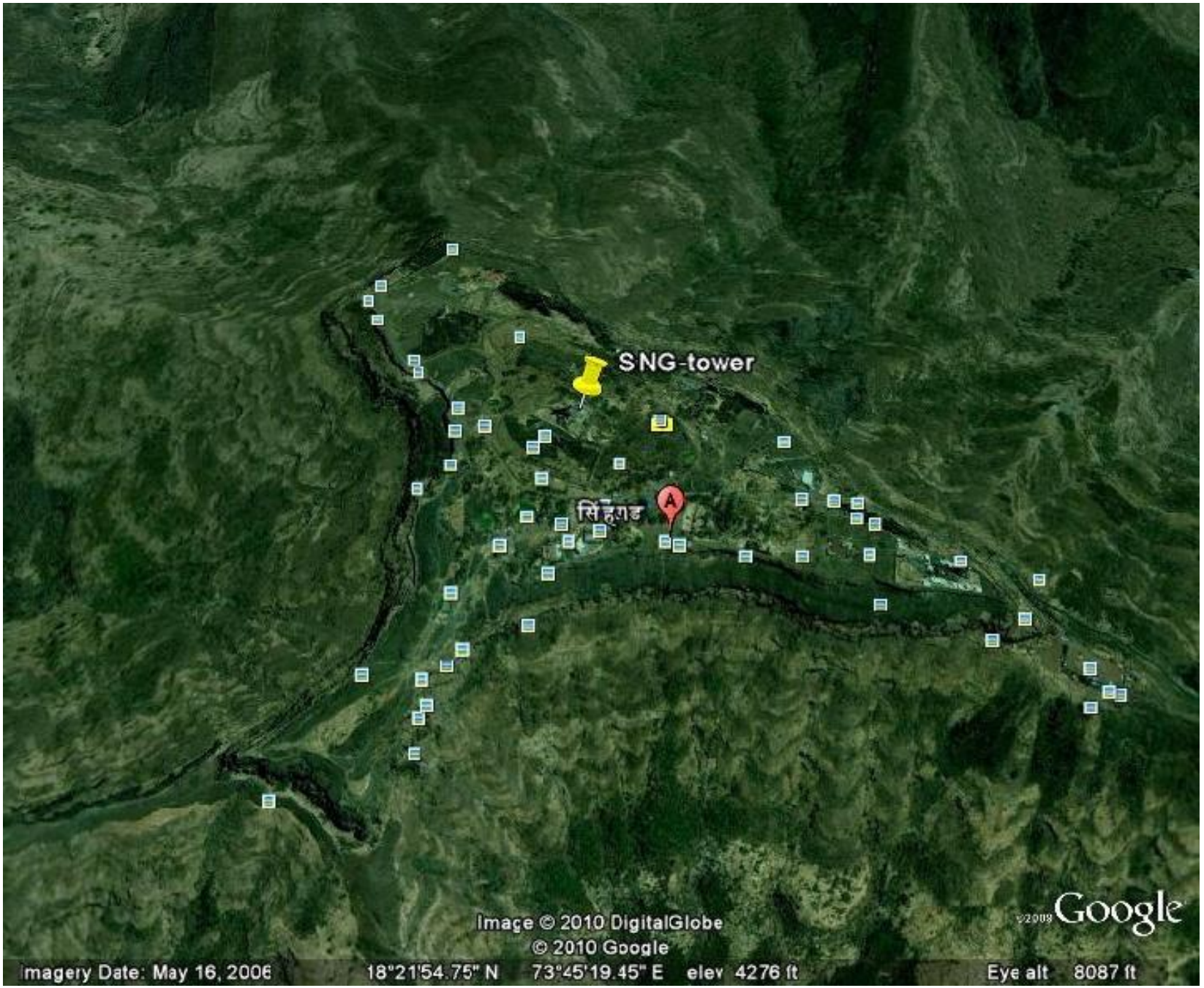
G GREENHOUSE GAS (Baseline:2 stations)

g GREENHOUSE GAS (Grab sampling: 4 stations)

Input: Dr. S. D. Attri


AFGHANISTAN
PAKISTAN
CHINA
BURMA
SRI LANKA
MALDIVES
INDONESIA
Himalayas
K2
Nanda Devi
Kangchenjunga
NEW DELHI
Aravalli
Ganges
YAMUNA
BRAHMAPUTRA
Caro Khasi
Vindhyas
Satpuras
NARMADA
TAPATI
MANAHADI
Kolkata
(Calcutta)
Deccan
Plateau
GODAVARI
Mumbai
(Bombay)
Western Ghats
Eastern Ghats
Arabian Sea
SNG
(Sinhagad)
Bay of Bengal
Lakshadweep
Islands
Andaman
Islands
Port Blair
Nicobar
Islands
Nilgris
KASVERI
Cardamom
Hills
JHELUM
CHENAB
RAVI
SUTLEJ
INDUS
9000
6000
4000
2000
1000
250
50
0
m
km
0
500
70°
80°
90°
30°
20°
10°


Lavale
Pune
Pune city
Khadakwasla
SNG site
Sinhagad Fort
Monitoring site SNG
Image © 2012 DigitalGlobe
Image © 2012 GeoEye
© 2012 Google
Google earth
Imagery Date: 5/25/2011
18°24'25.58" N 73°46'48.07" E elev 2463 ft
Eye alt 32.99 mi

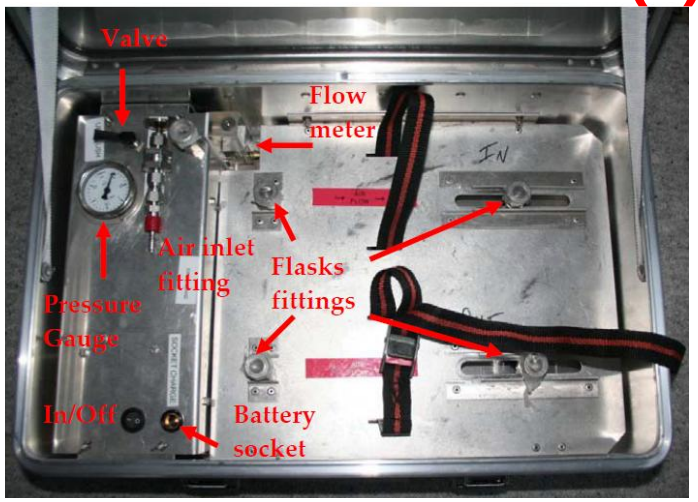

SNG-tower
सिंहगड
A
Image © 2010 DigitalGlobe
© 2010 Google
©2009 Google
imagery Date: May 16, 2006
18°21'54.75" N
73°45'19.45" E
elev 4276 ft
Eye alt 8087 ft


SNG-tower
Image © 2010 DigitalGlobe
© 2010 Google
©2009 Google
Imagery Date: May 16, 2006
18°21'57.78" N
73°45'16.03" E
elev 4275 ft
Eye alt 4927 ft


Indian Institute of Tropical Meteorology, Pune

Observational Technique:

(1)



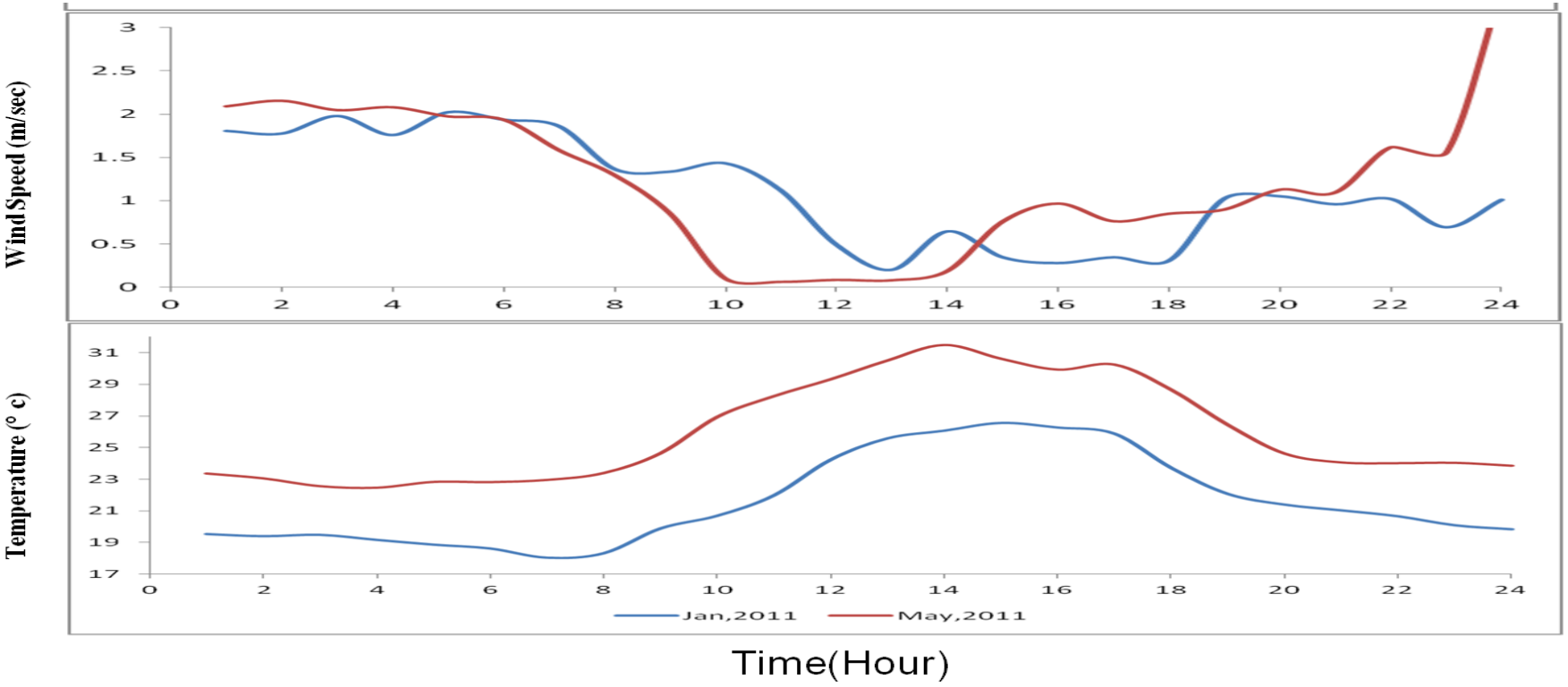
+

(2)

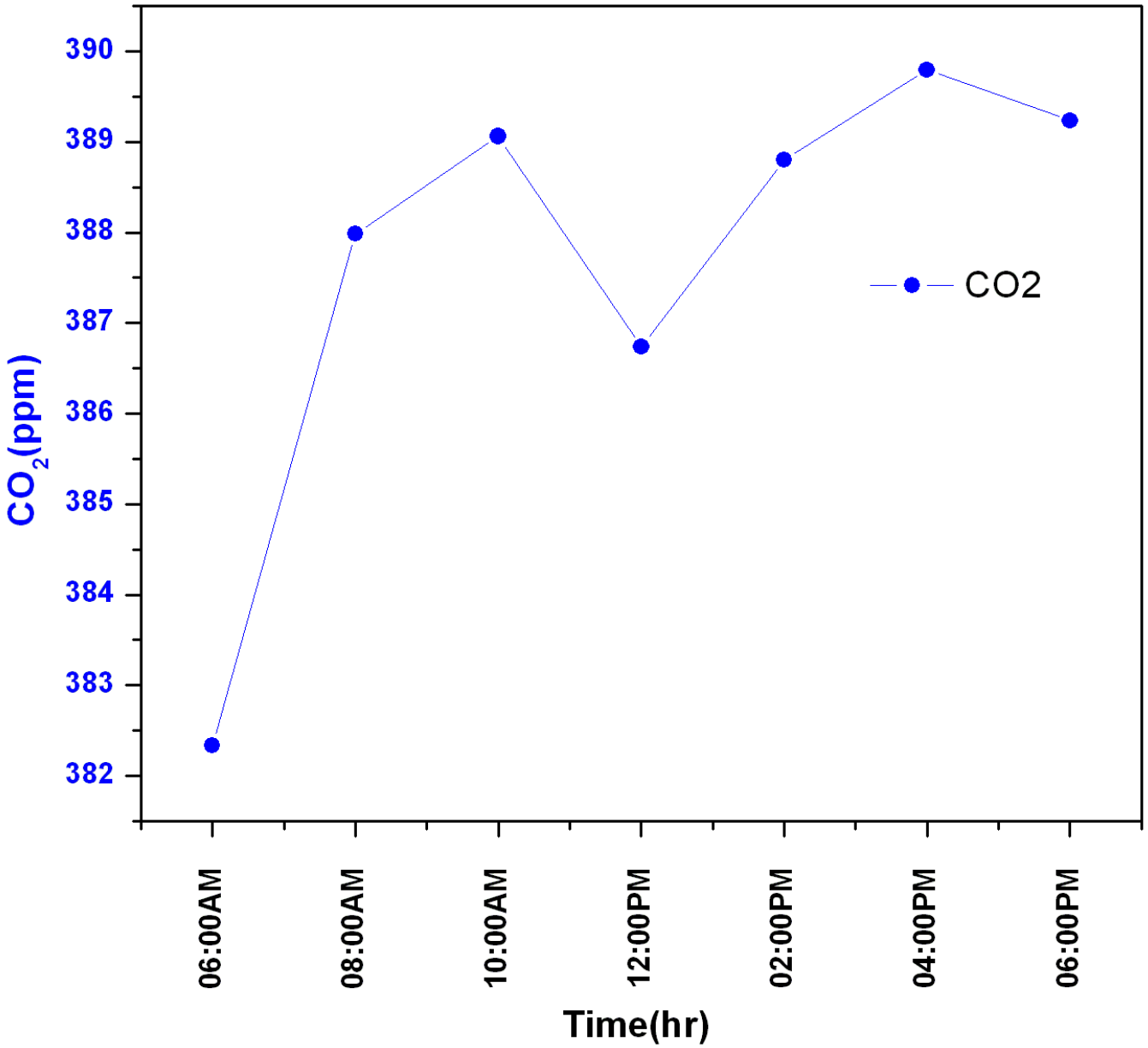
+

(3)

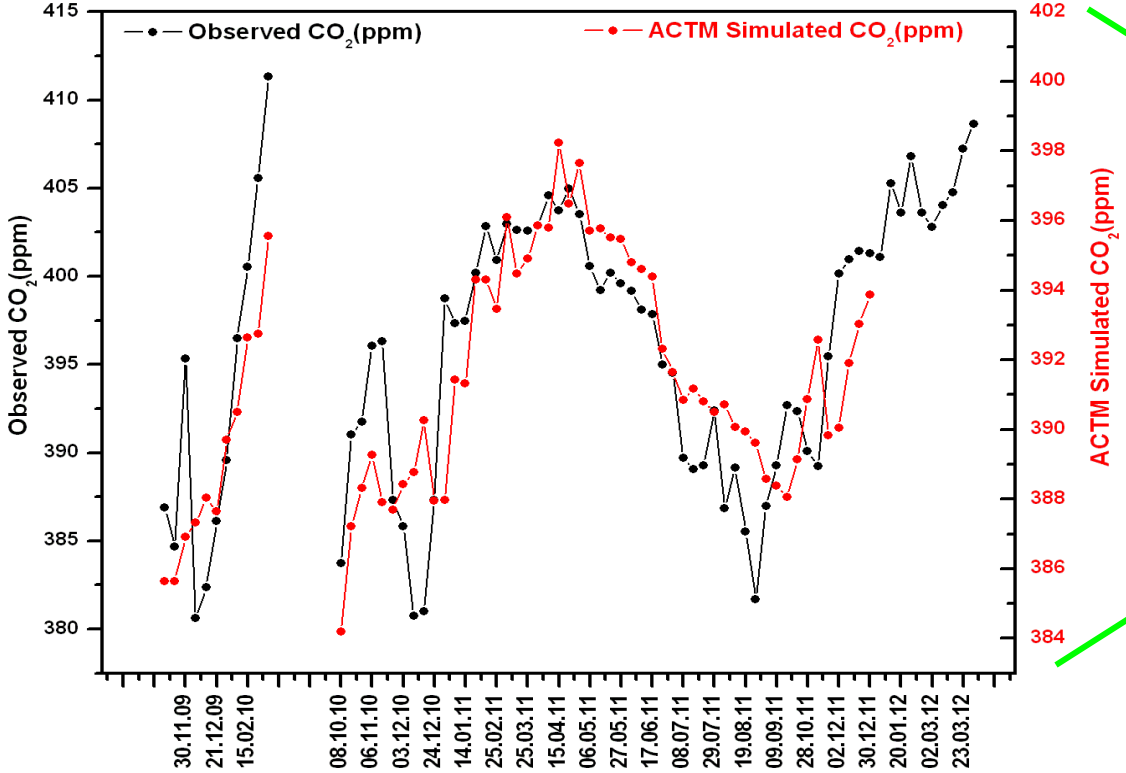
Met observations at Sinhagad, Pune site

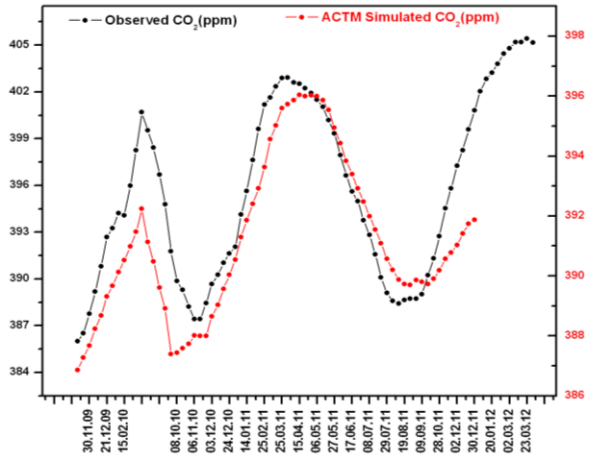


CO2 (ppm): day time variability



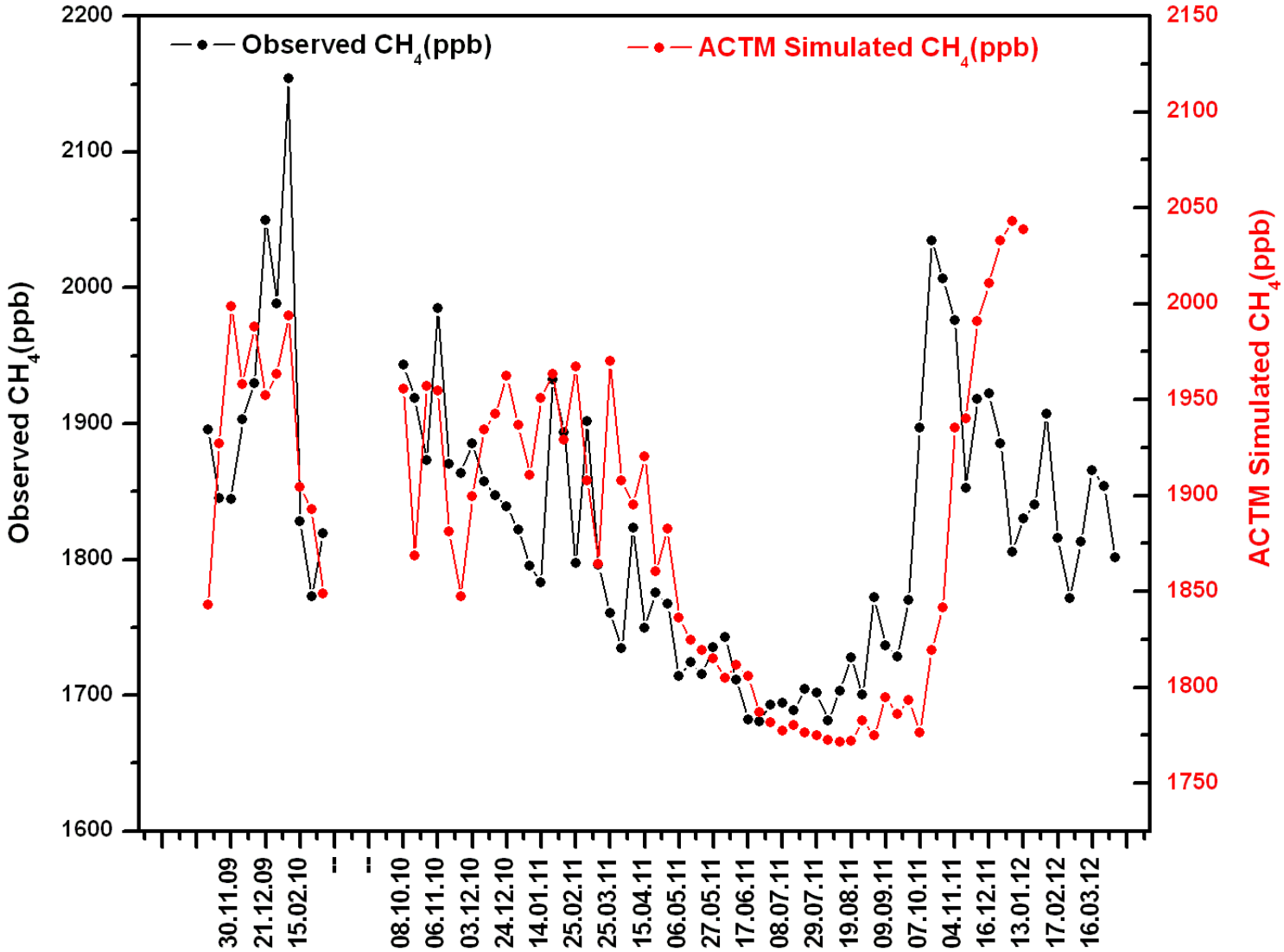
CO2 (ppm) observations at Sinhagad, Pune site





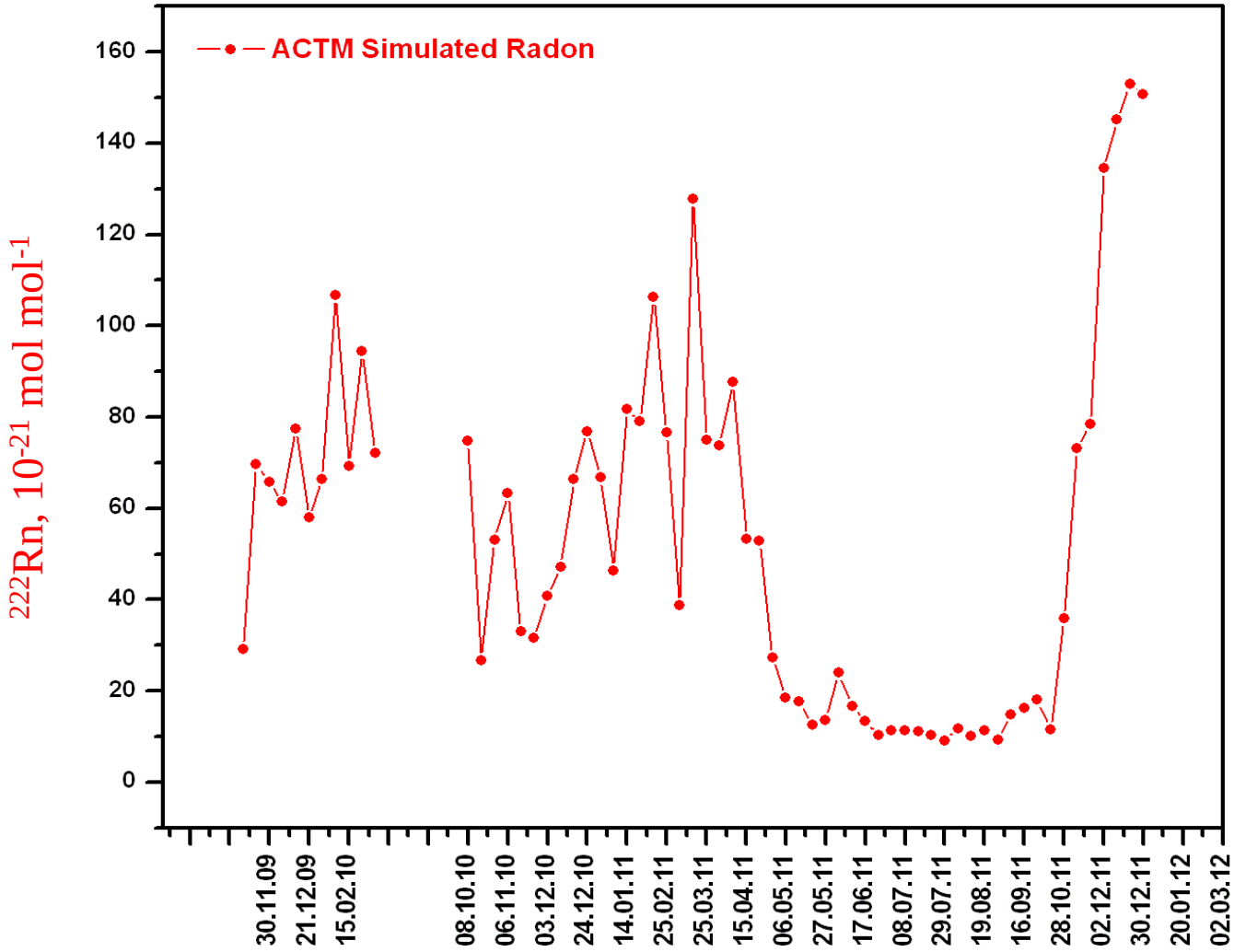
(ACTM model simulations - Dr. Prabir Patra)

CH4 (ppb) observations at Sinhagad, Pune site



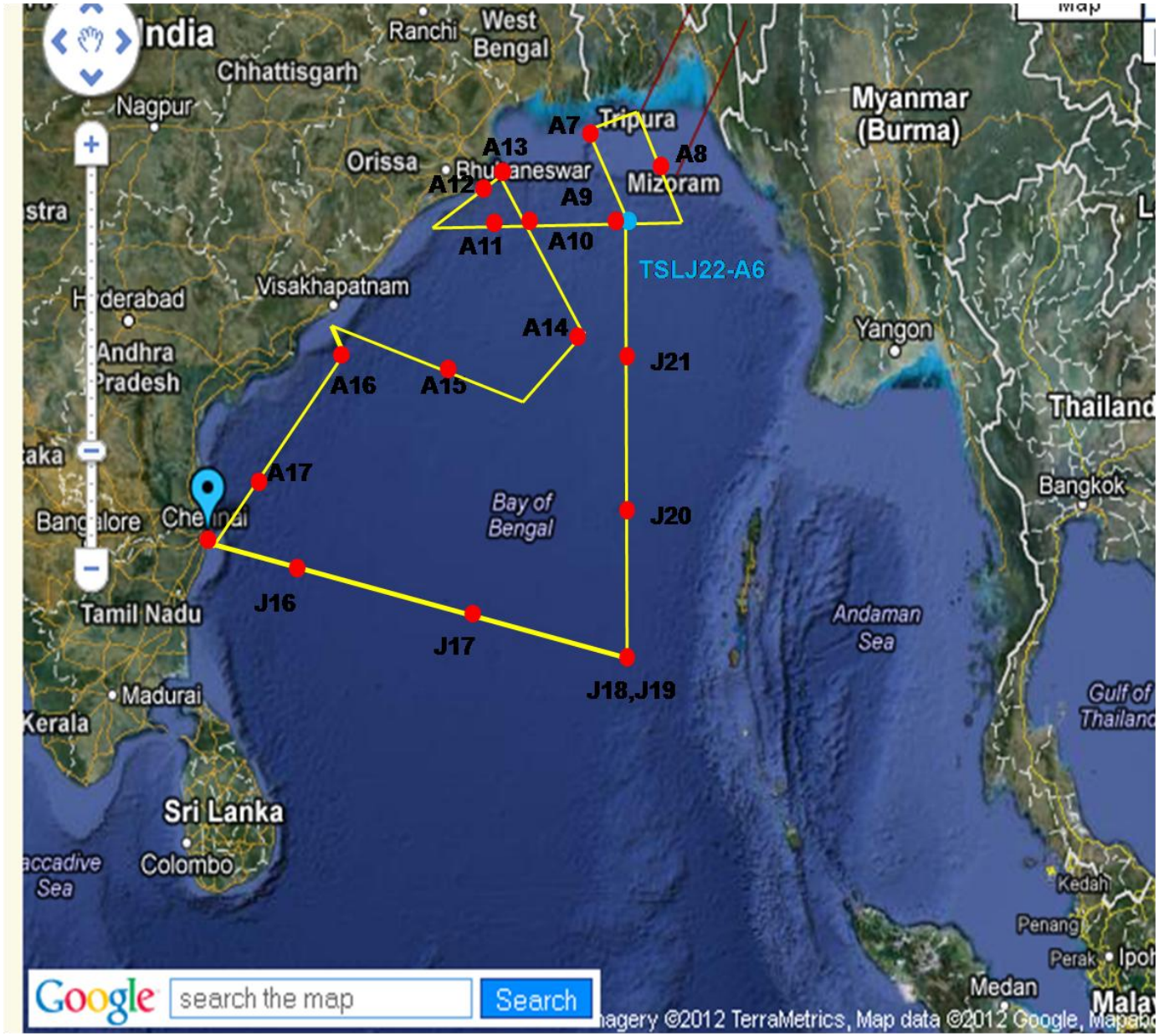
(ACTM model simulations - Dr. Prabir Patra)

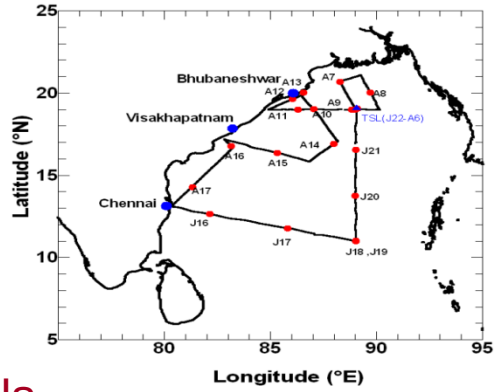
ACTM simulated Radon at Sinhagad, Pune site



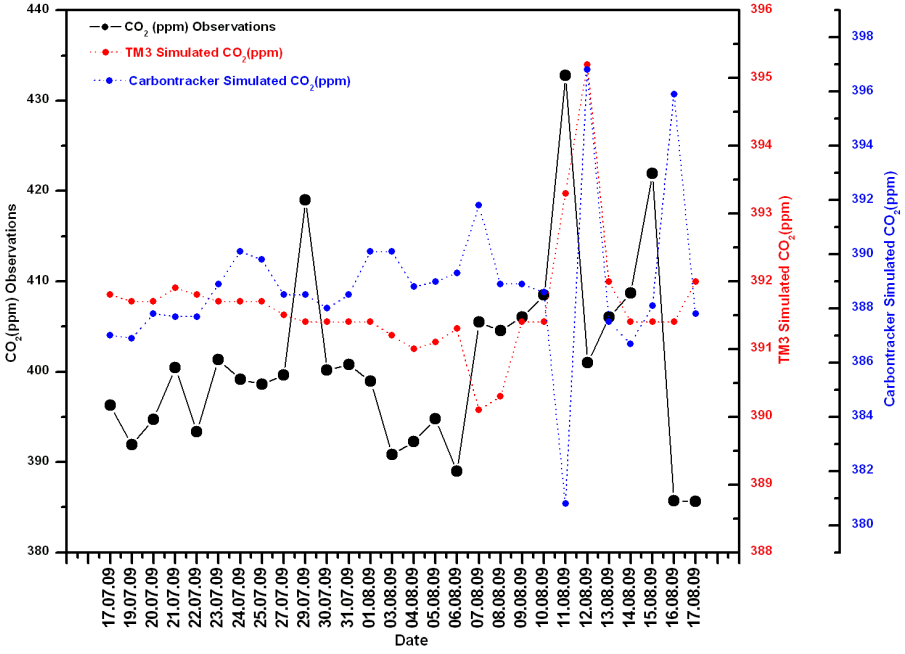
(ACTM model simulations - Dr. Prabir Patra)

Bay of Bangal cruise track (July – August 2009) . Air sample collection dates are represented by red dots with dates in black (J16=July 16, 2009)

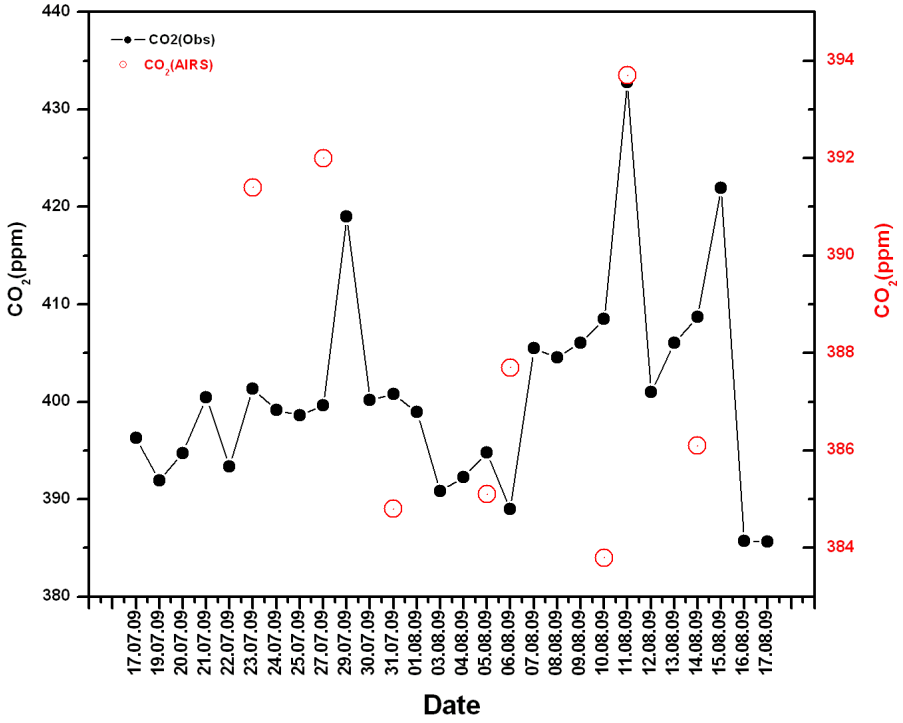




CO2 (ppm): observations, model simulations (TM3 and CT)



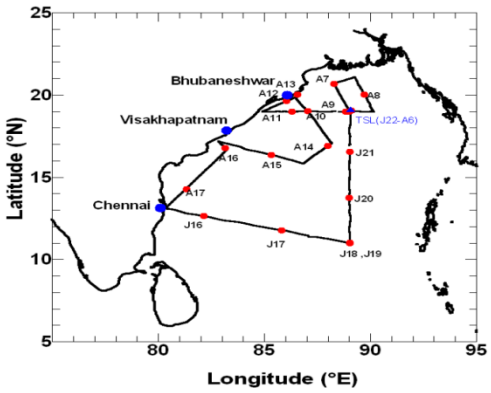
AIRS Retrievals



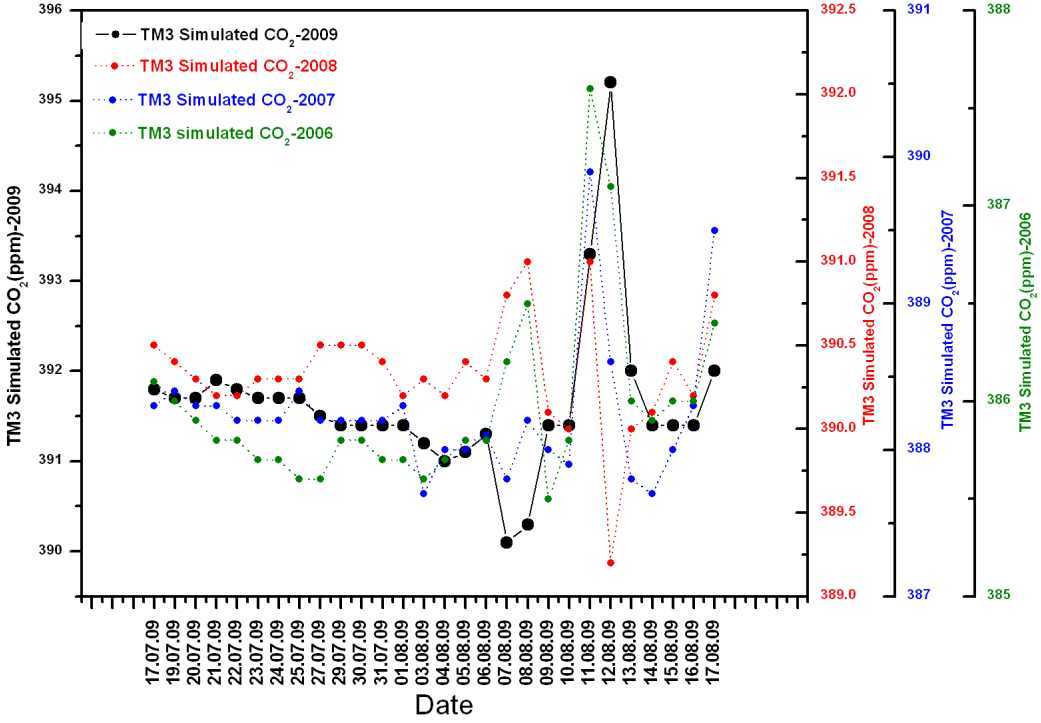
Tiwari et al., 2012 (under review)

Credits - CT simulations : Andy Jacobson, NOAA /ESRL

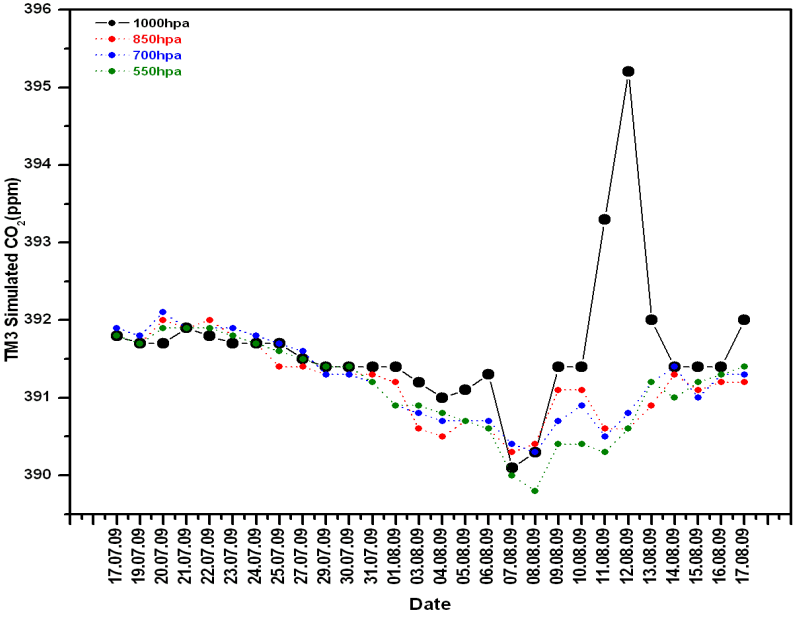
Credits - AIRS retrievals : NASA AIRS online data

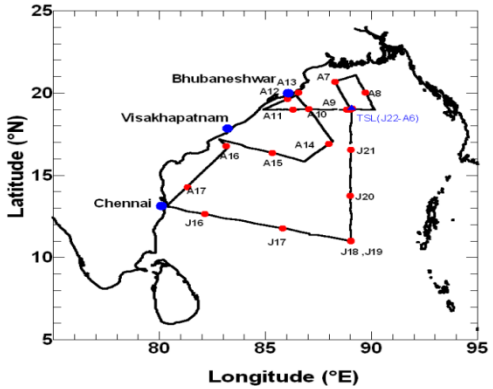


CO2 (ppm): TM3 simulations during different years

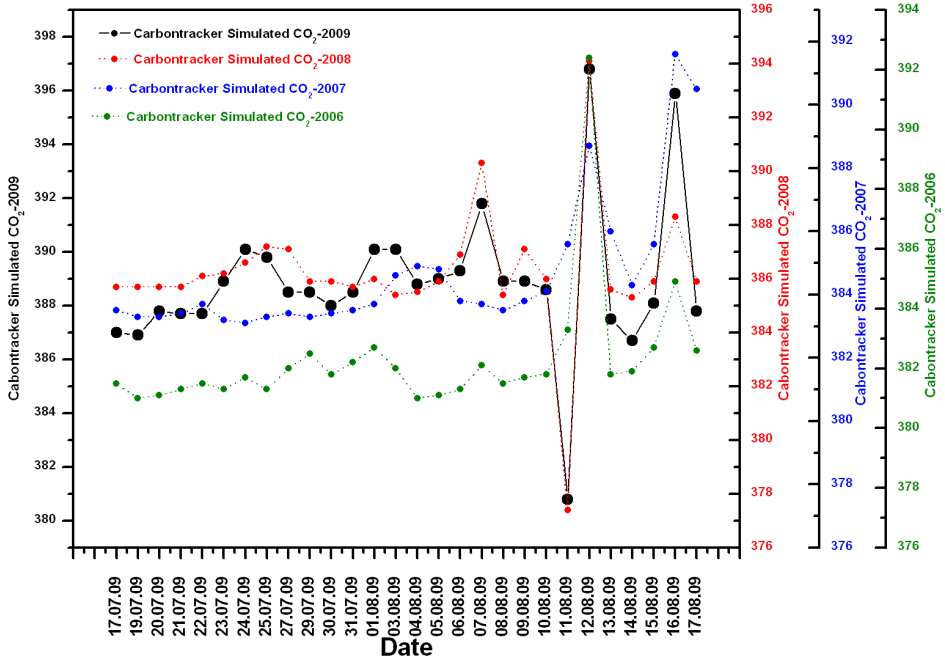


TM3 at different pressure levels

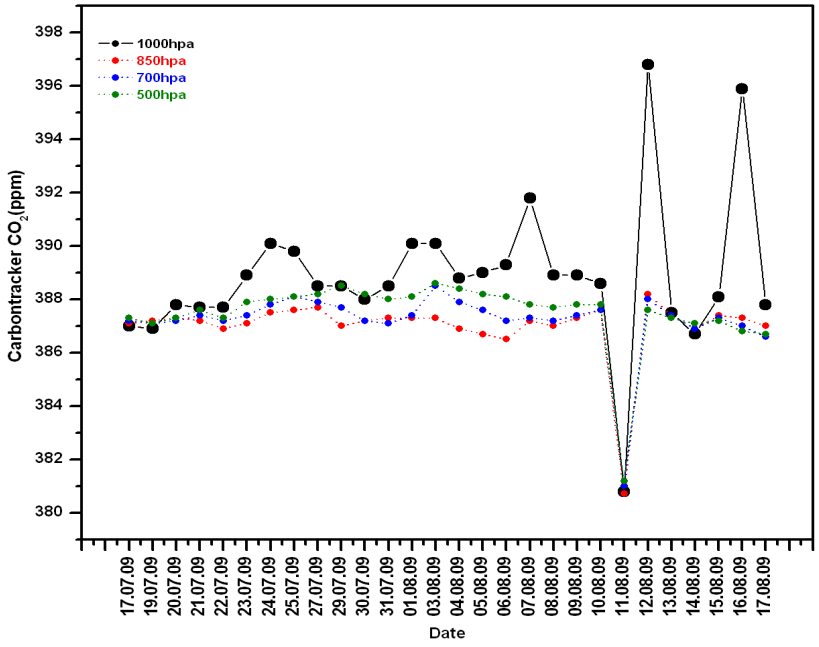


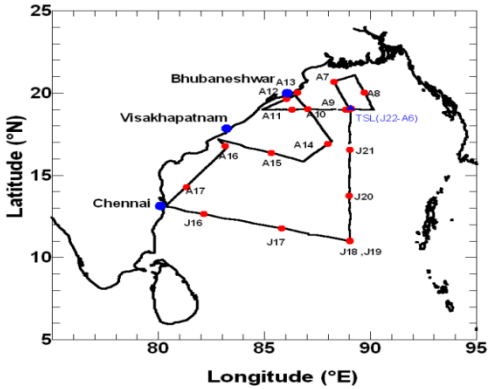


CO2 (ppm): CT simulations during different years

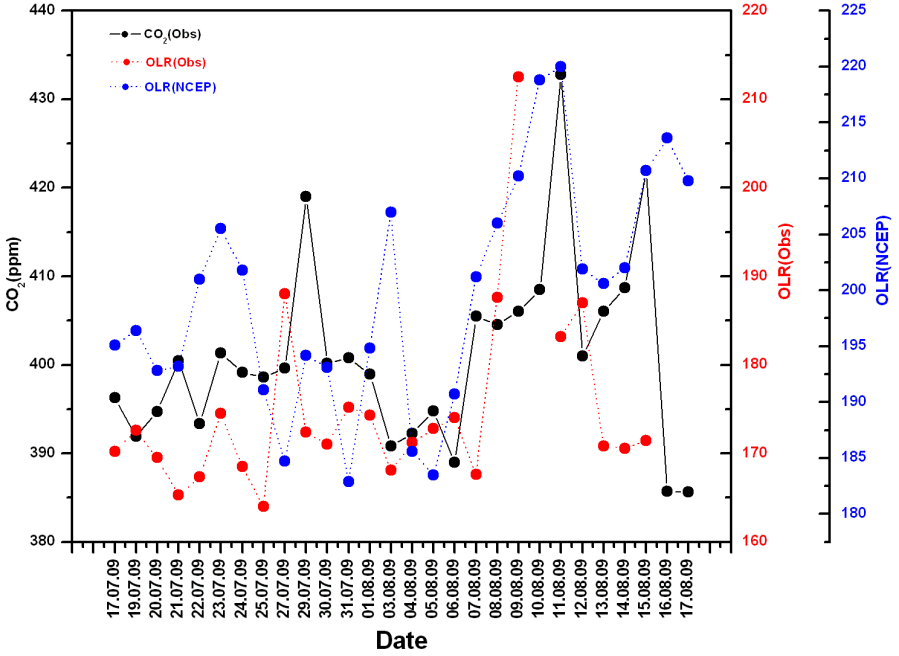


CT at different pressure levels

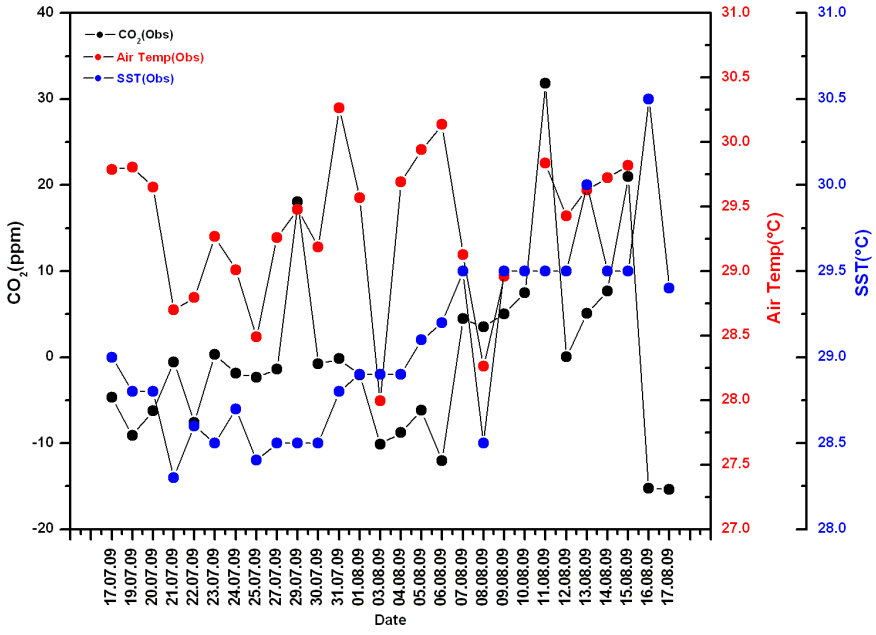




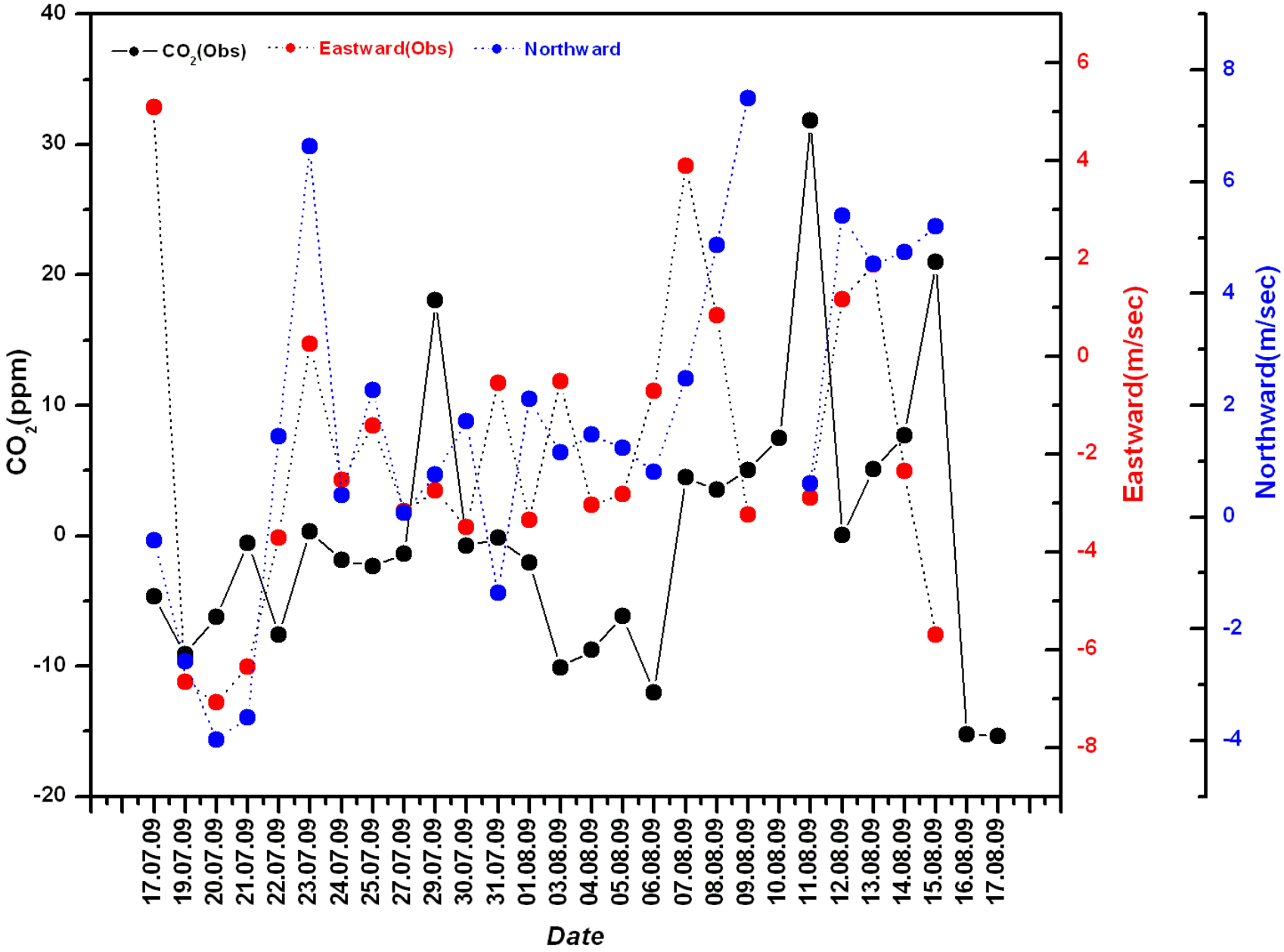
Observed CO2 (ppm) and Outgoing Longwave Radiation (OLR)



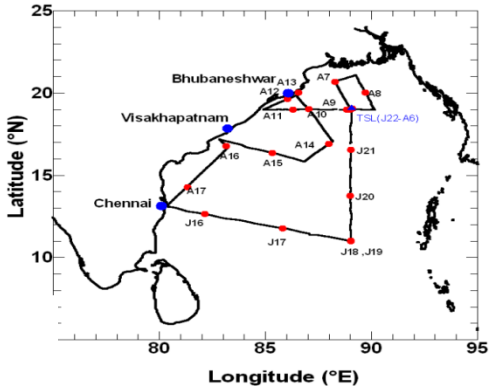
Observed CO2 (ppm) and air temp and SST

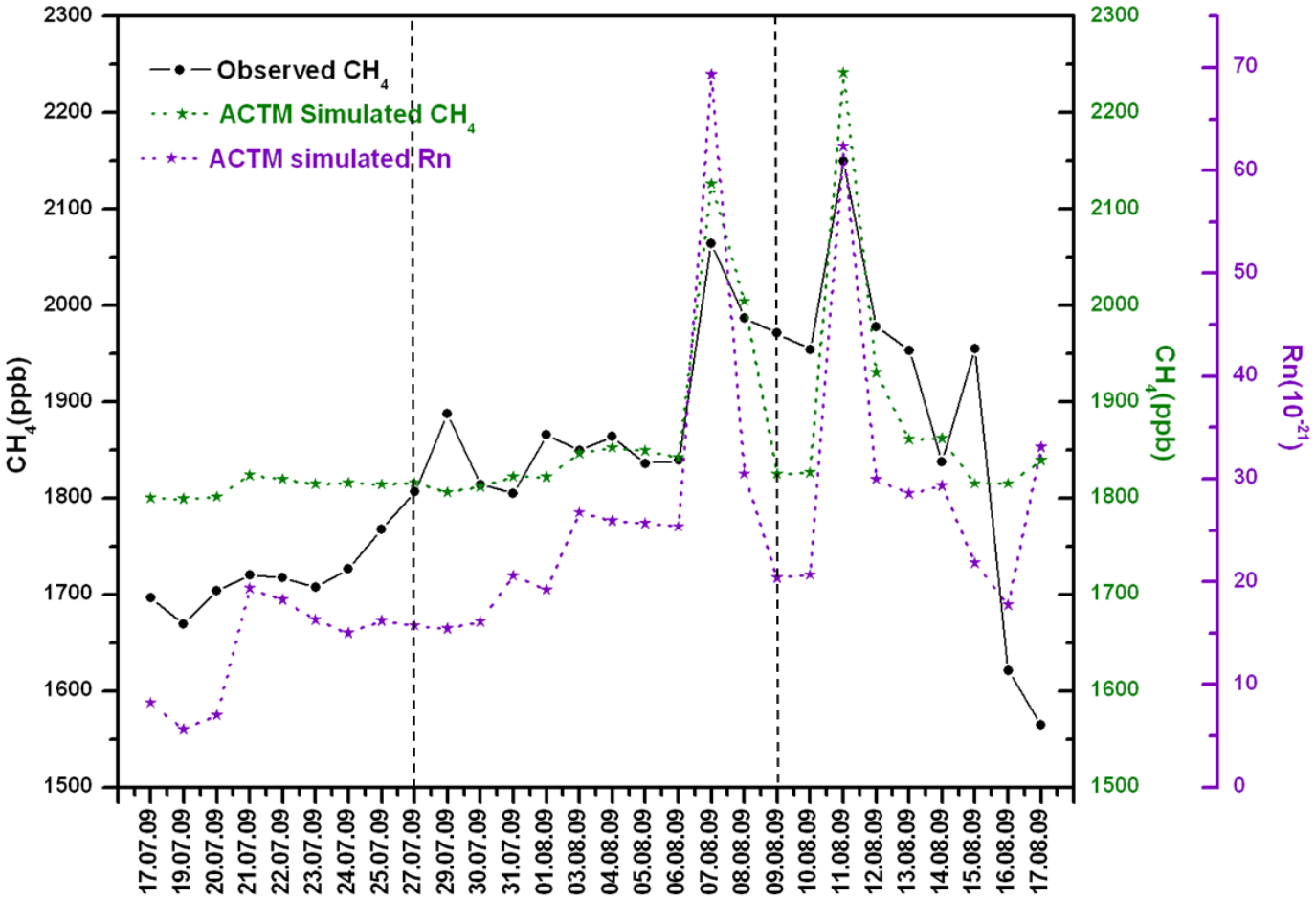


CO2 anomaly vs. observed winds



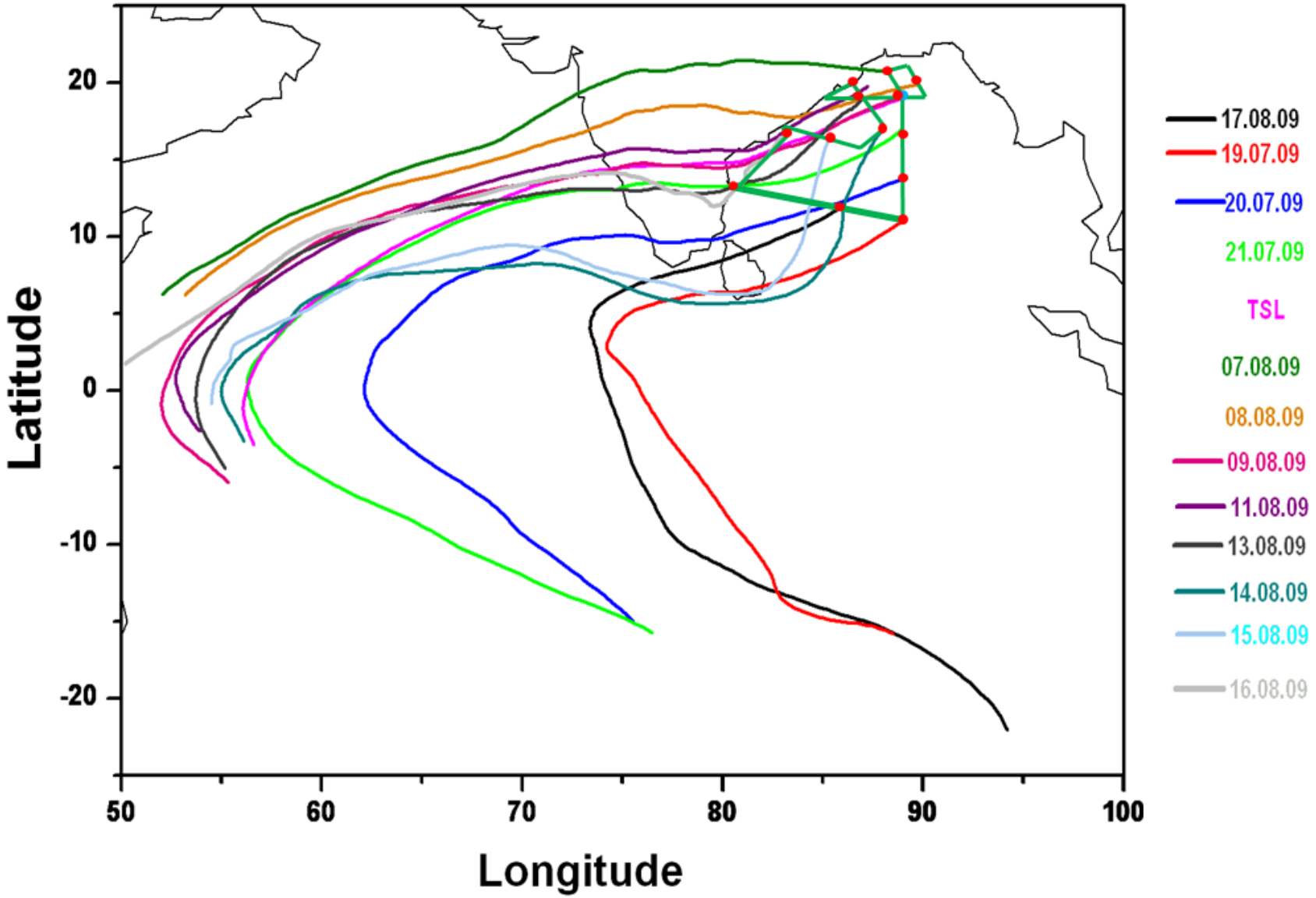
CH4: Observations and model simulations (ACTM)



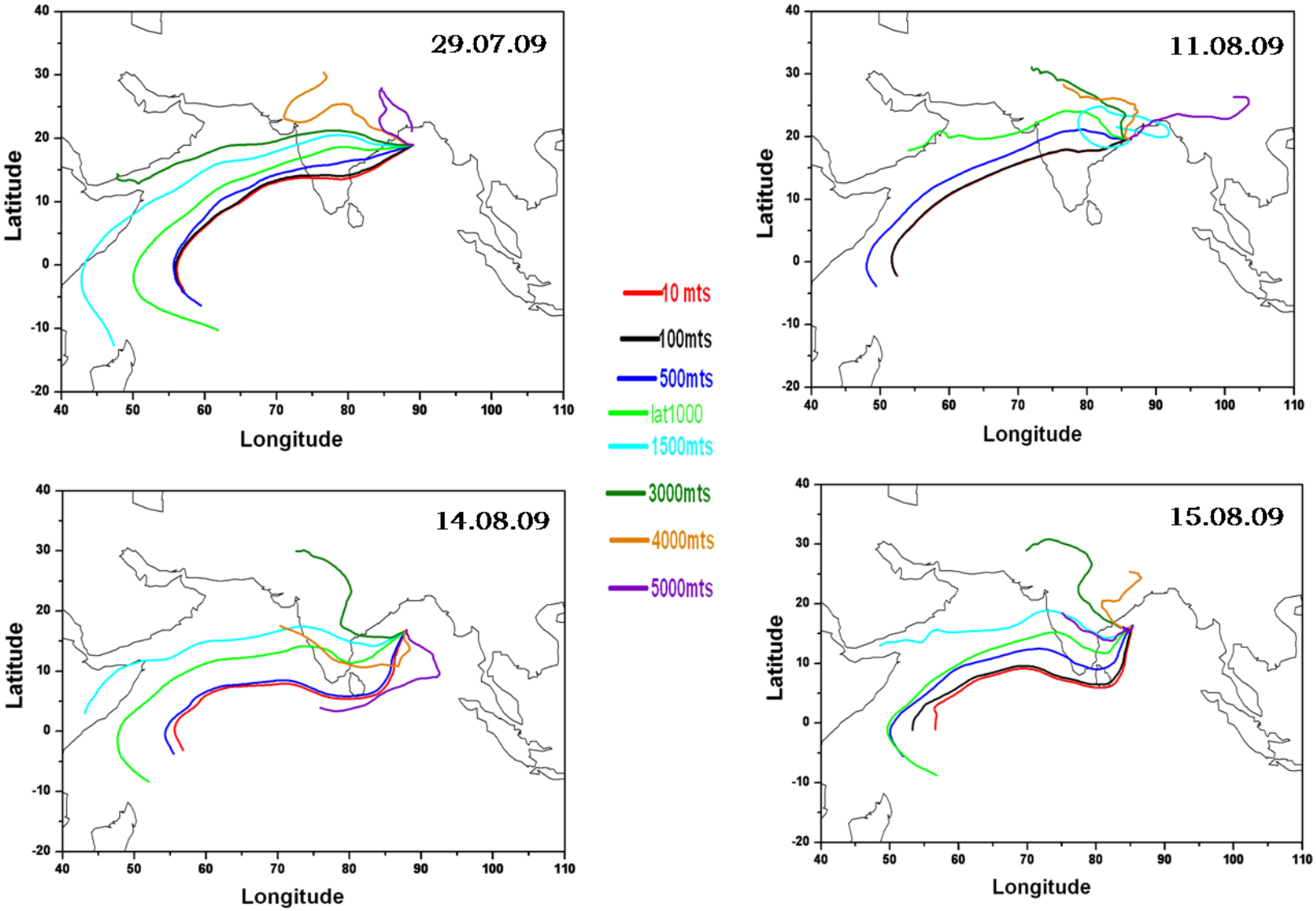


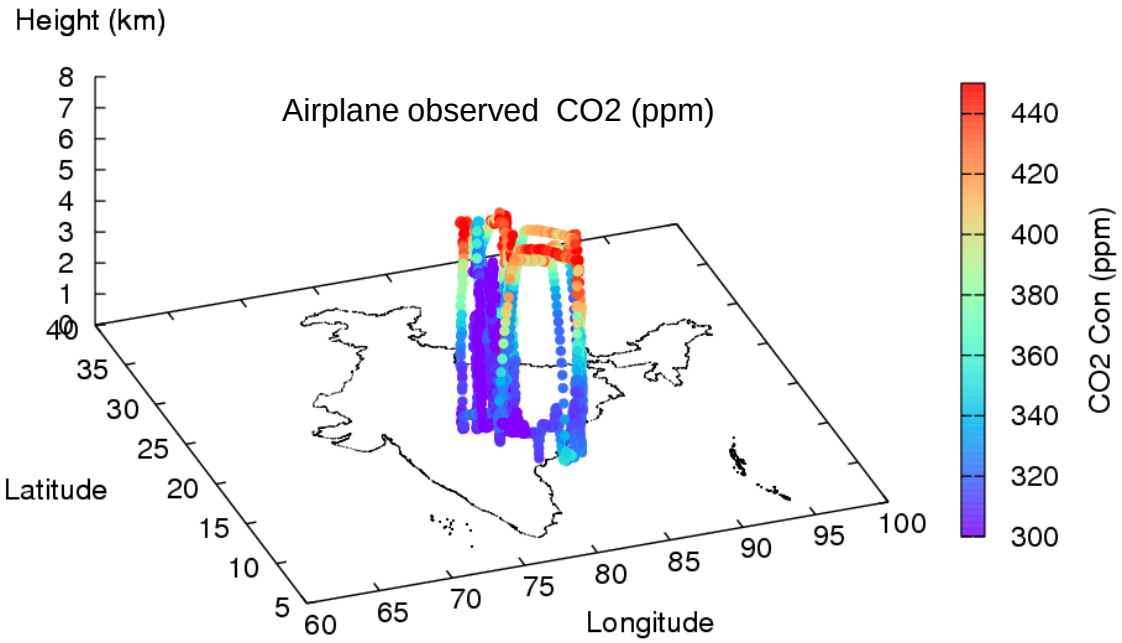
(ACTM model simulations - Dr. Prabir Patra)

7-day backtrajectory along with cruise track (at the surface)

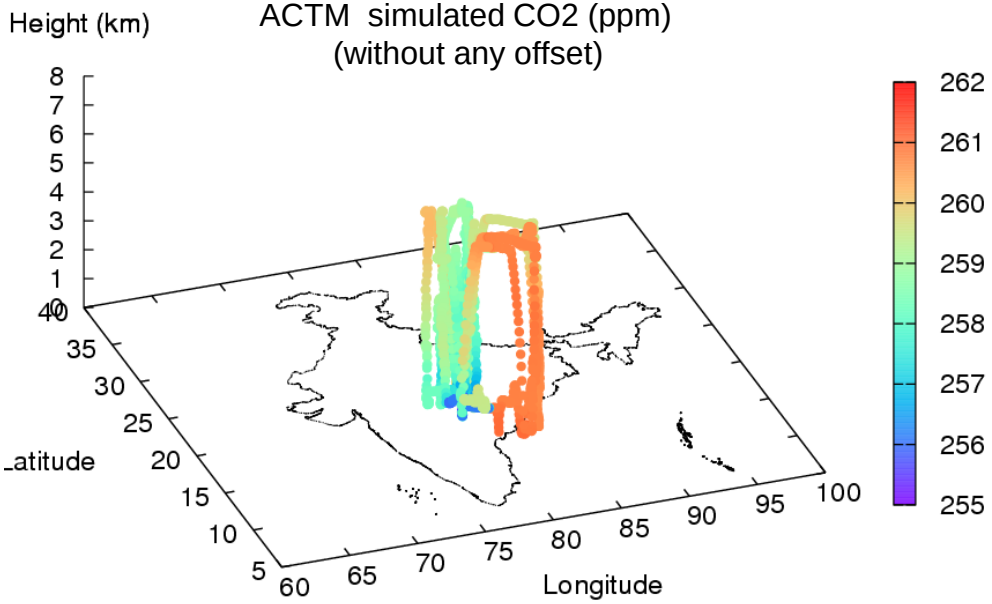


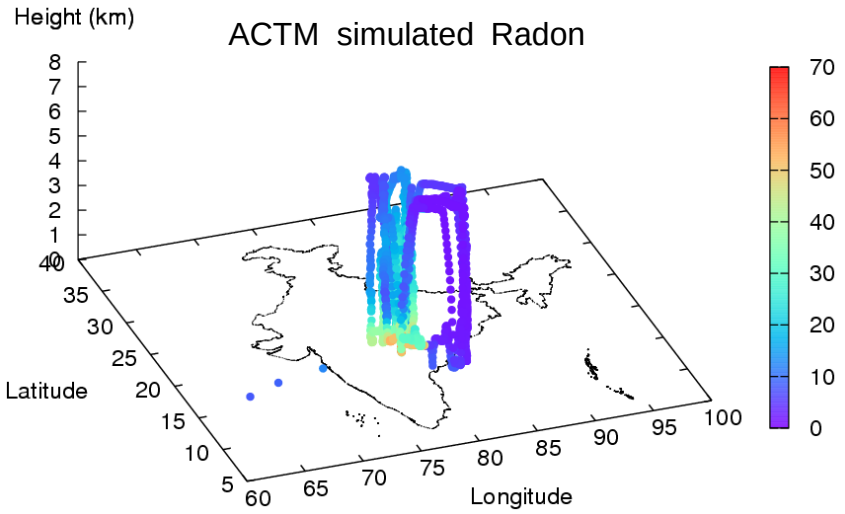
7-day backtrajectory at different altitudes. Dates are observed CO2 peak days



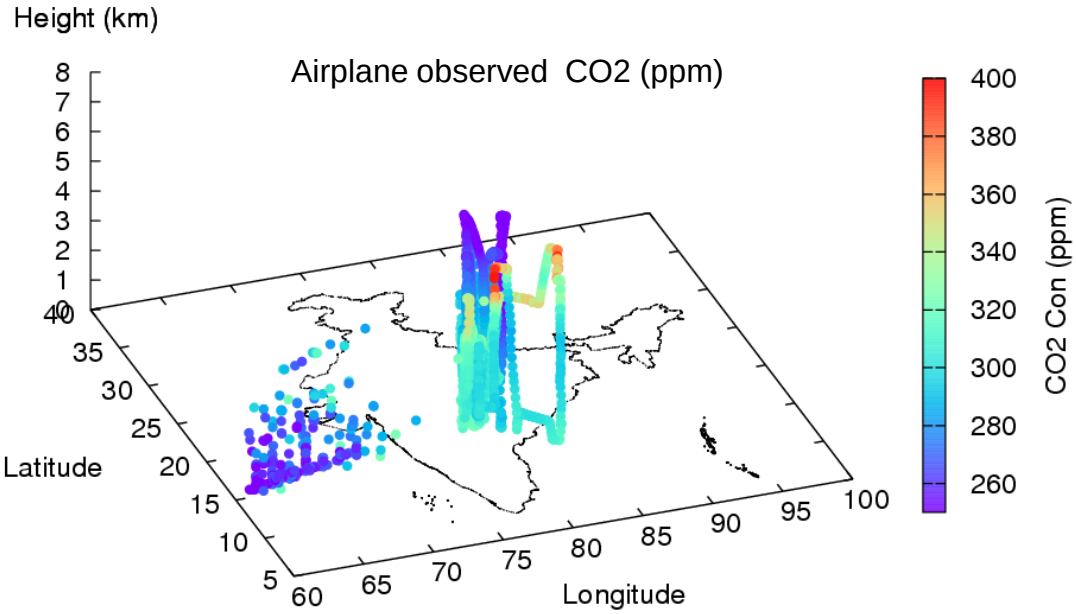


Airplane Campaign
Sep., 2010

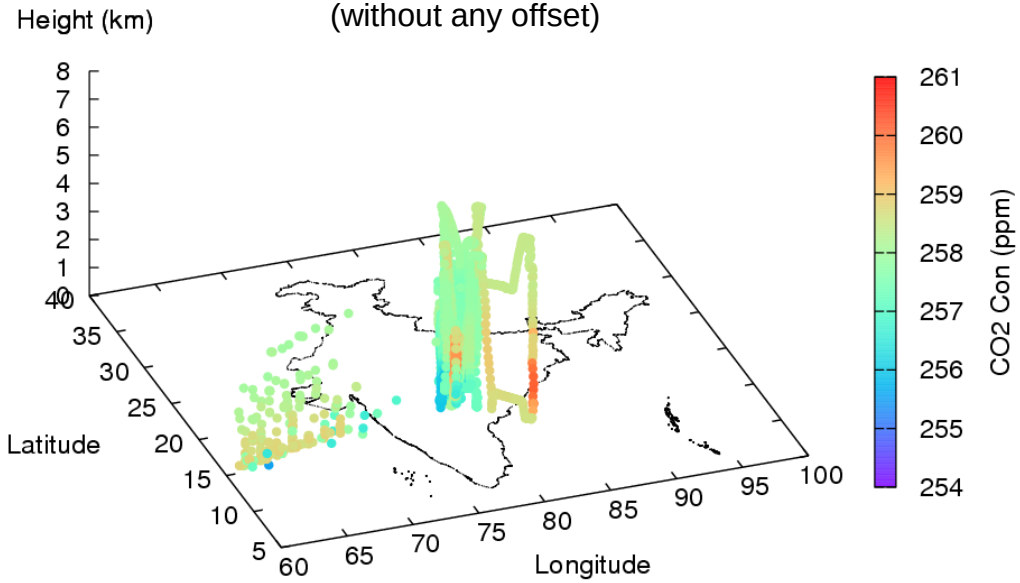


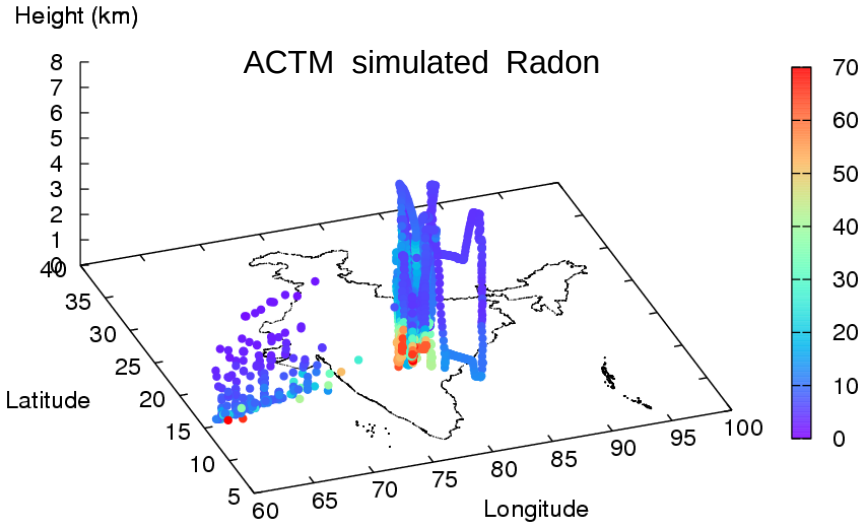


(ACTM simulations - Dr. Prabir Patra)



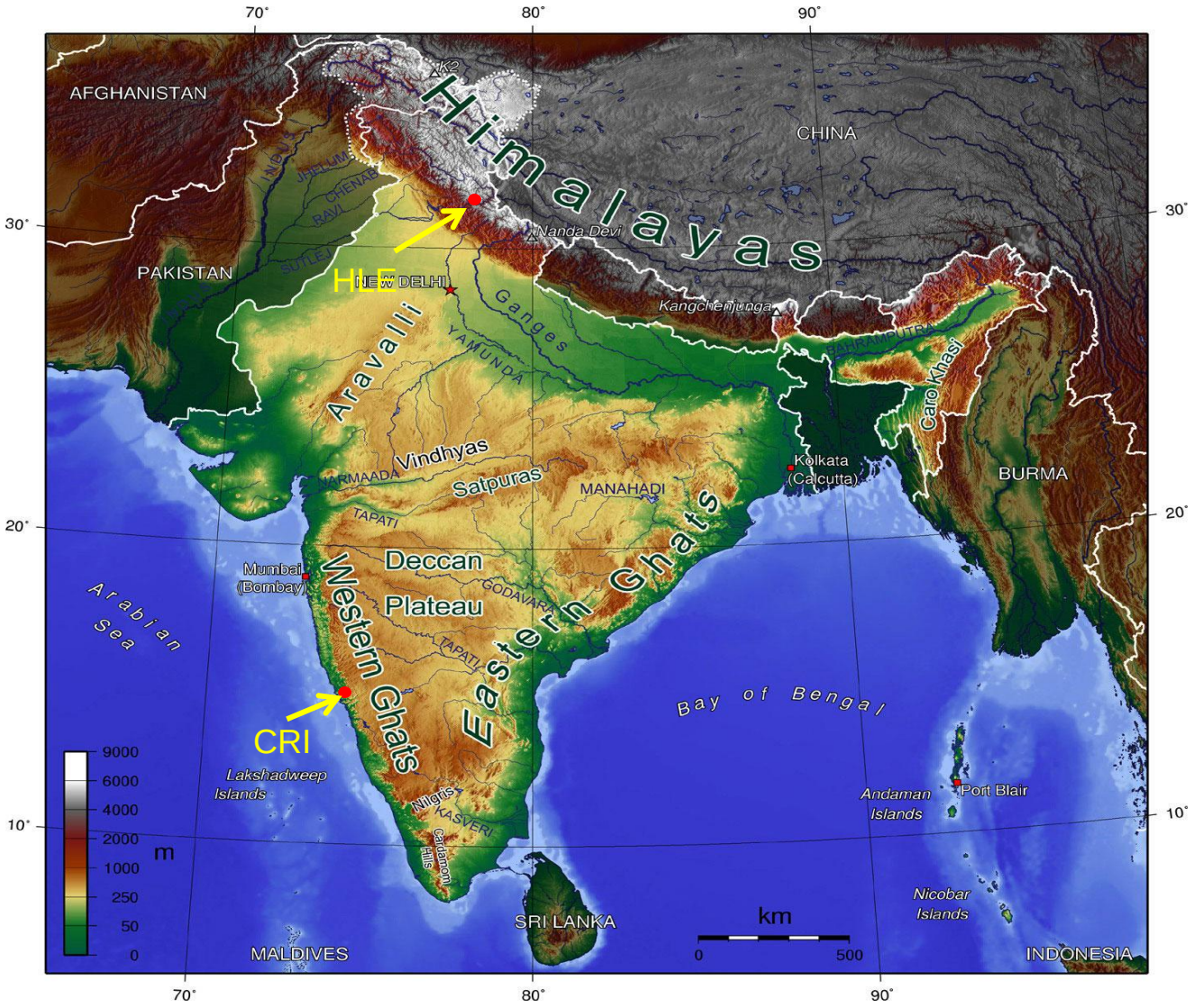
Airplane Campaign
Oct., 2010

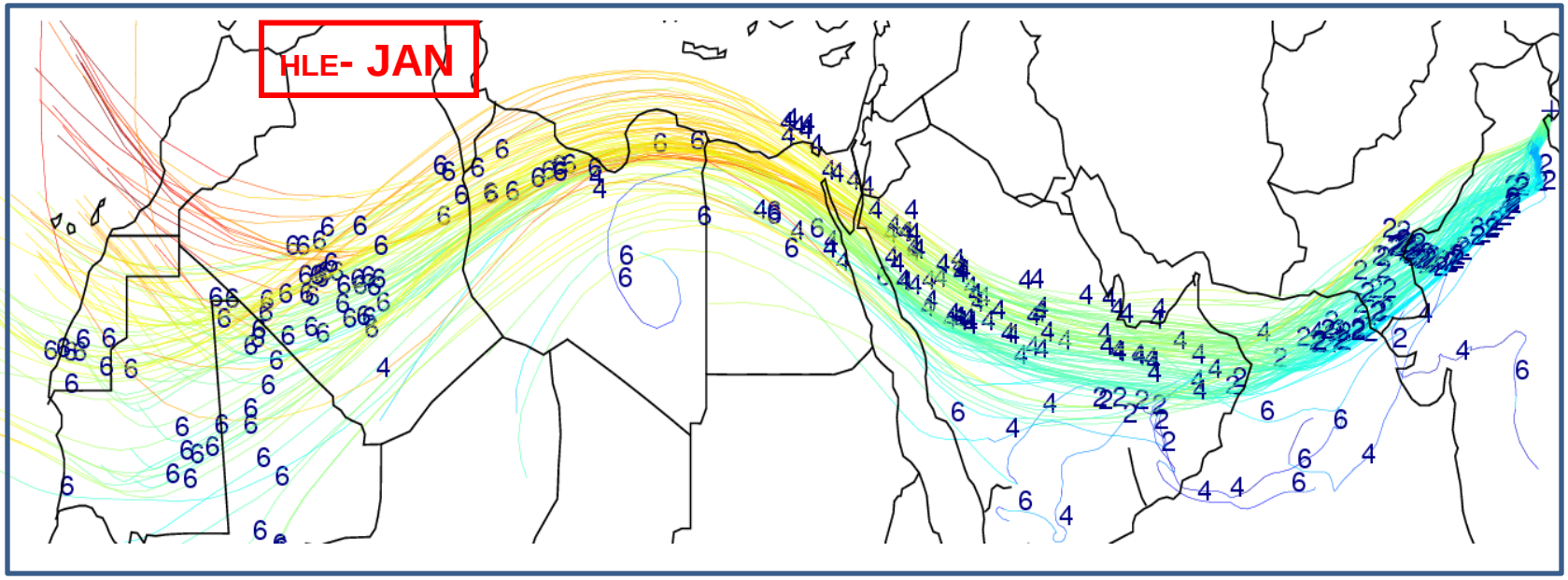


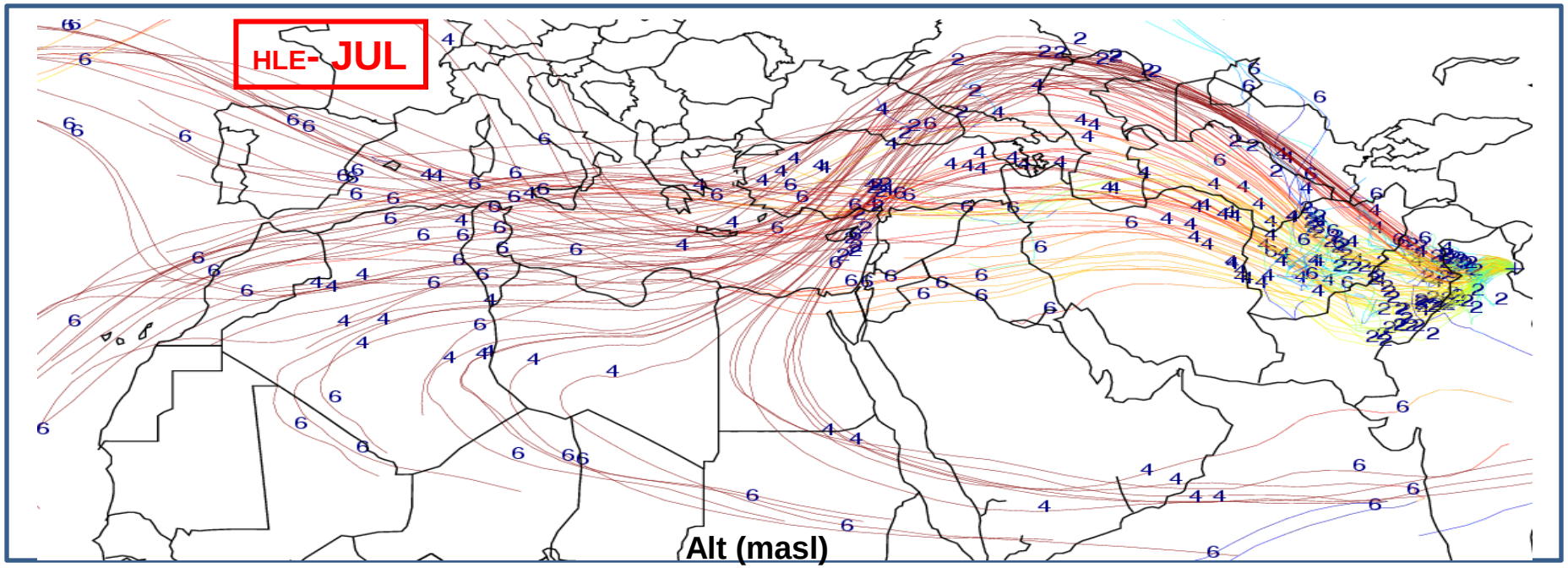


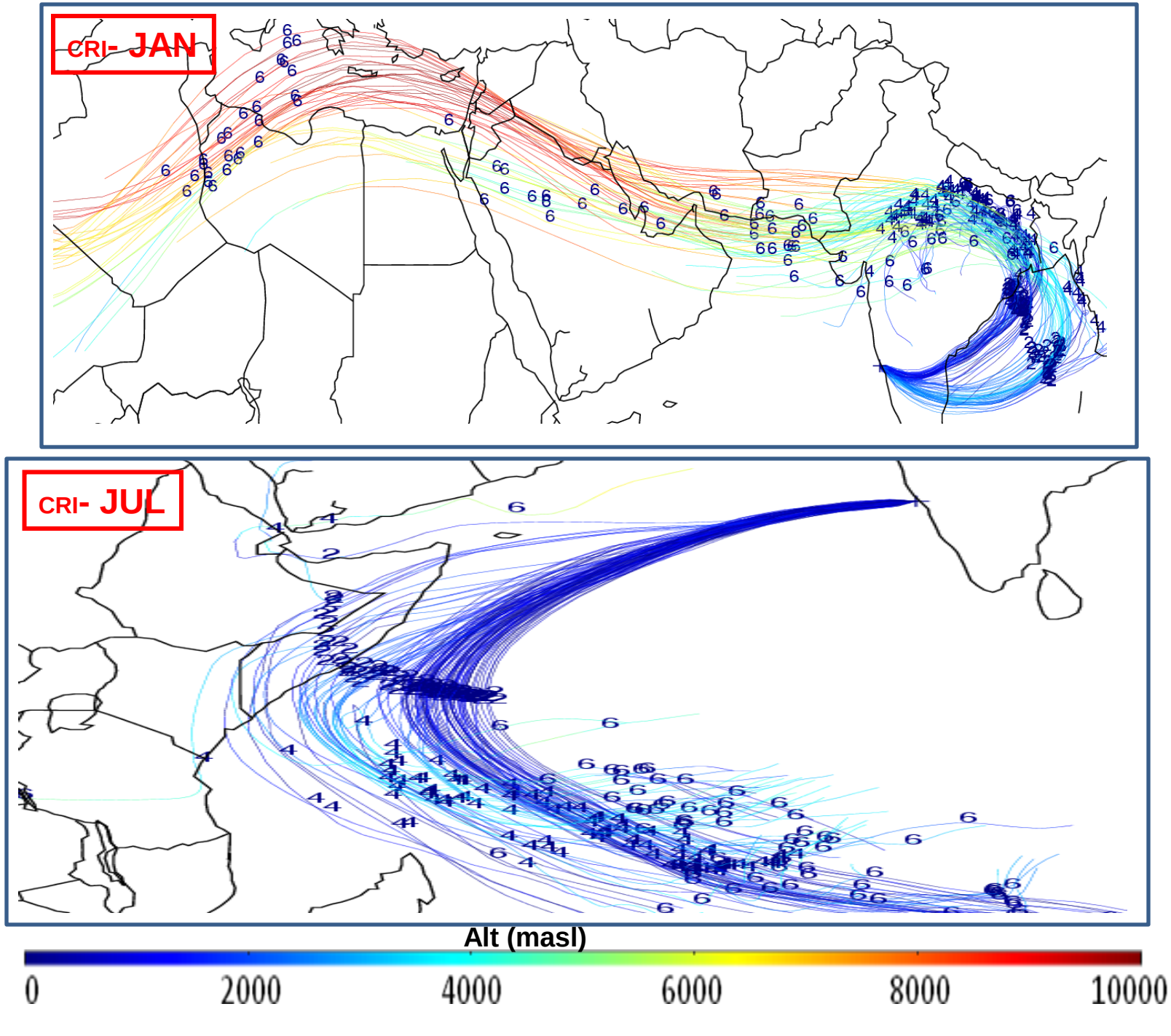
(ACTM simulations - Dr. Prabir Patra)

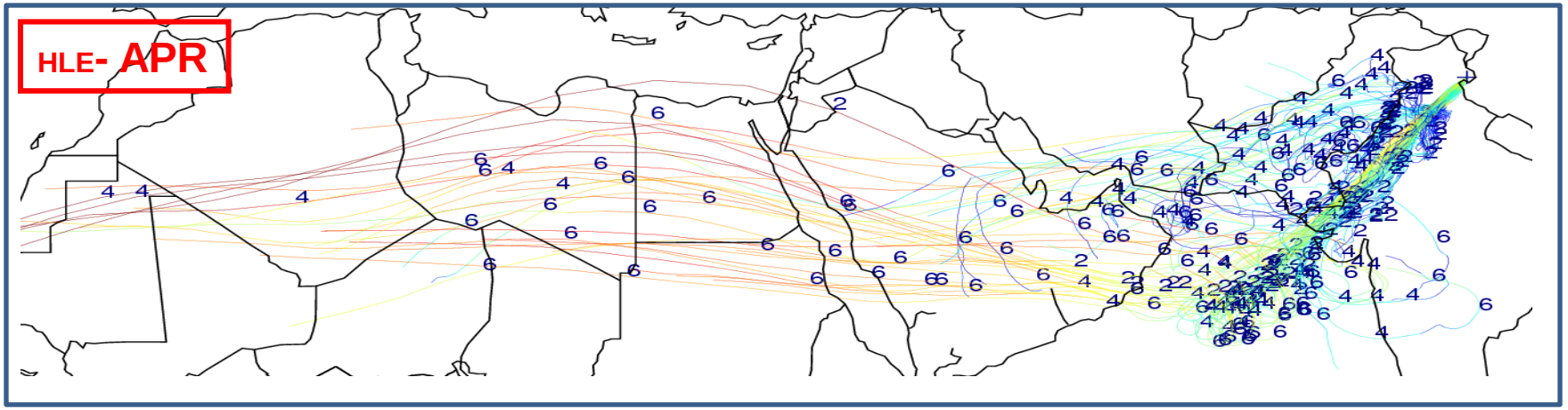
FLEXPART Lagrangian Particle Dispersion Model study

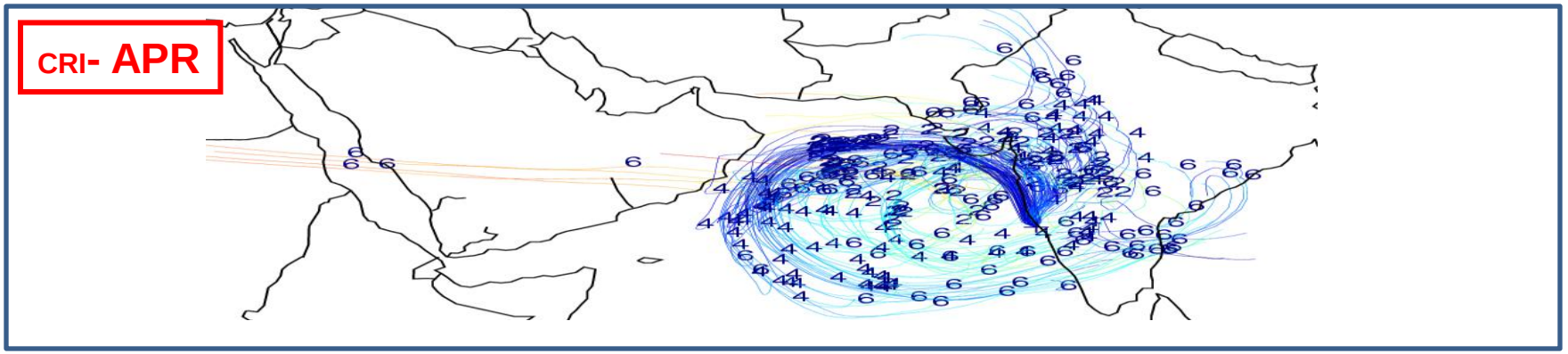



HLE- JAN


HLE- JUL
Alt (masl)
0
2000
4000
6000
8000
10000


CRI- JAN
CRI- JUL
Alt (masl)
0
2000
4000
6000
8000
10000

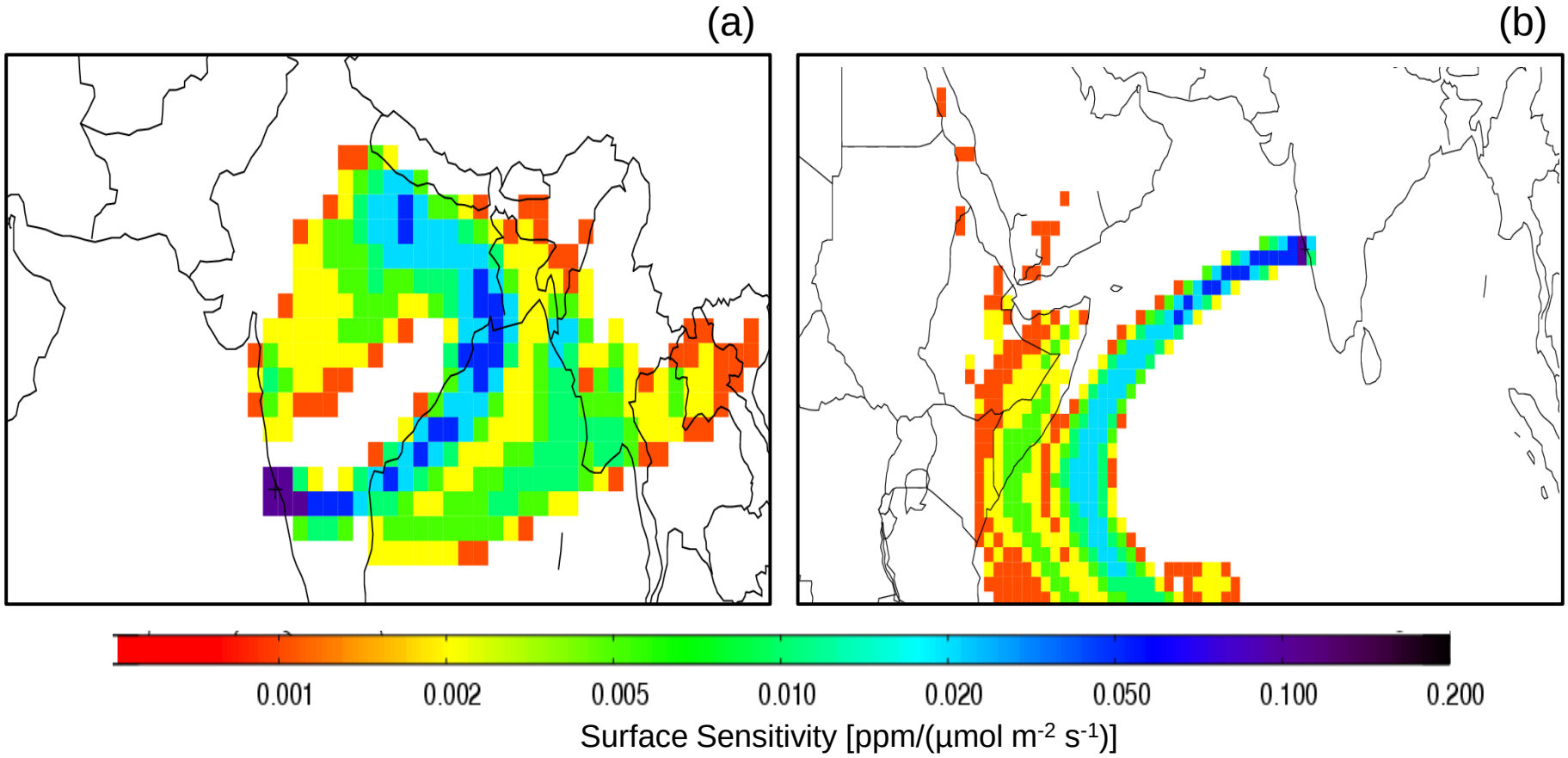




Alt (masl)

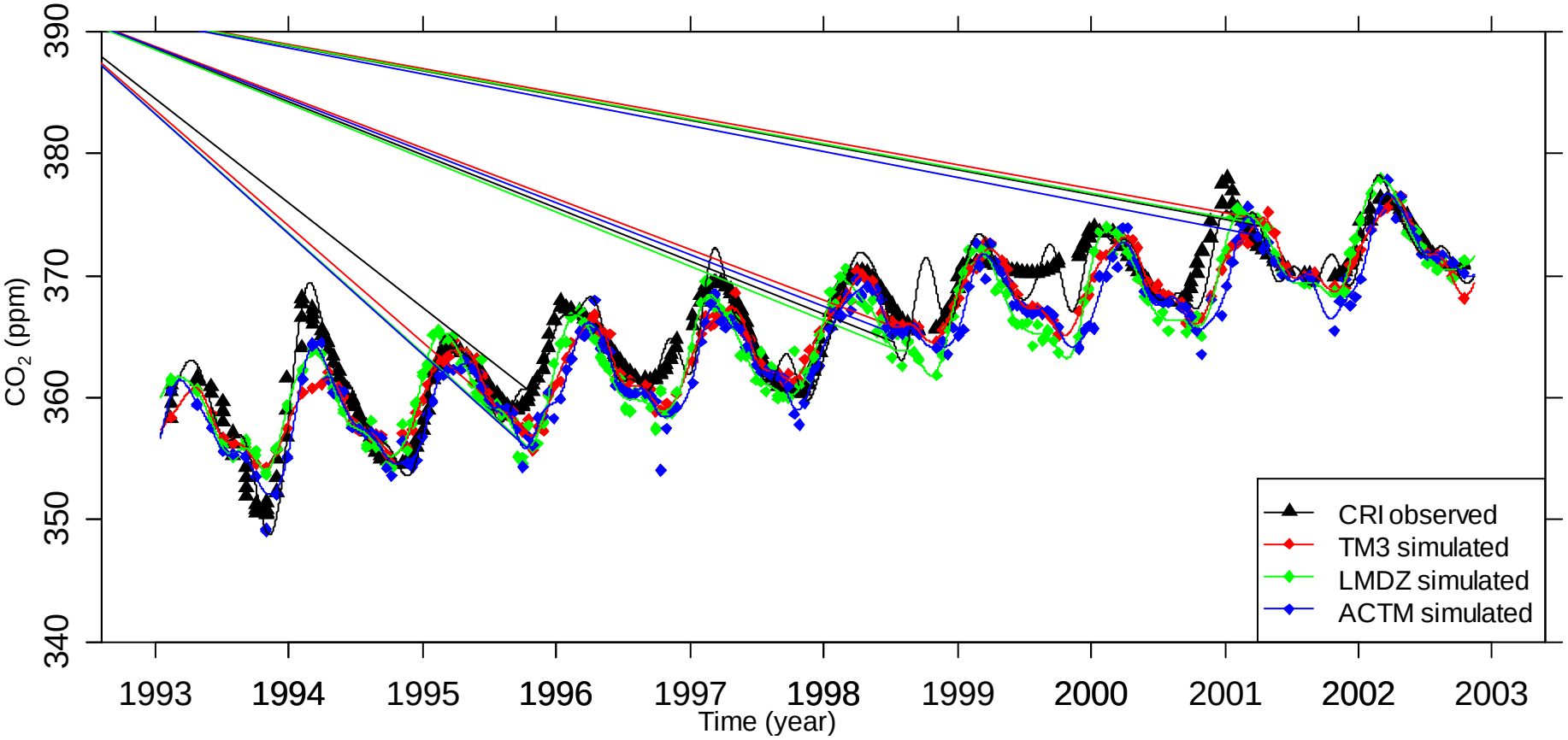
0 2000 4000 6000 8000 10000

FLEXPART simulated footprint surface sensitivity



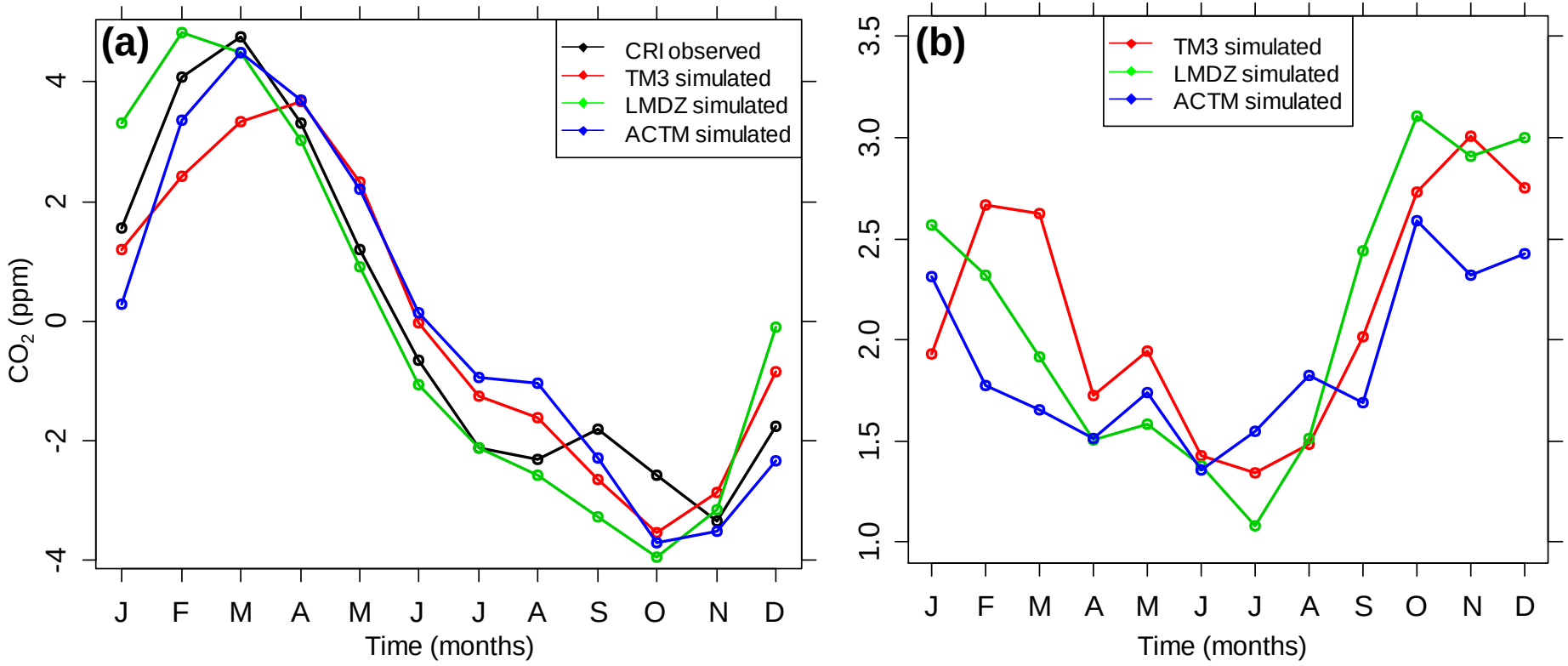
Tiwari et al., 2012 (under review)

CO2 (ppm): observation and model simulations at Cape Rama (CRI)



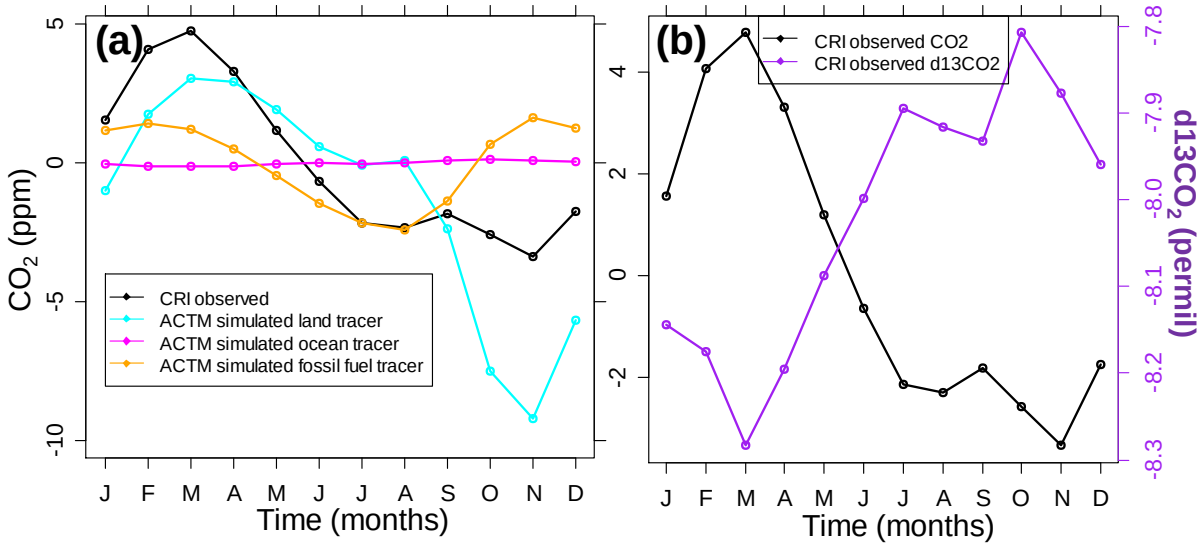
Tiwari et al., 2011

CO2 (ppm): observation and model simulations at CRI



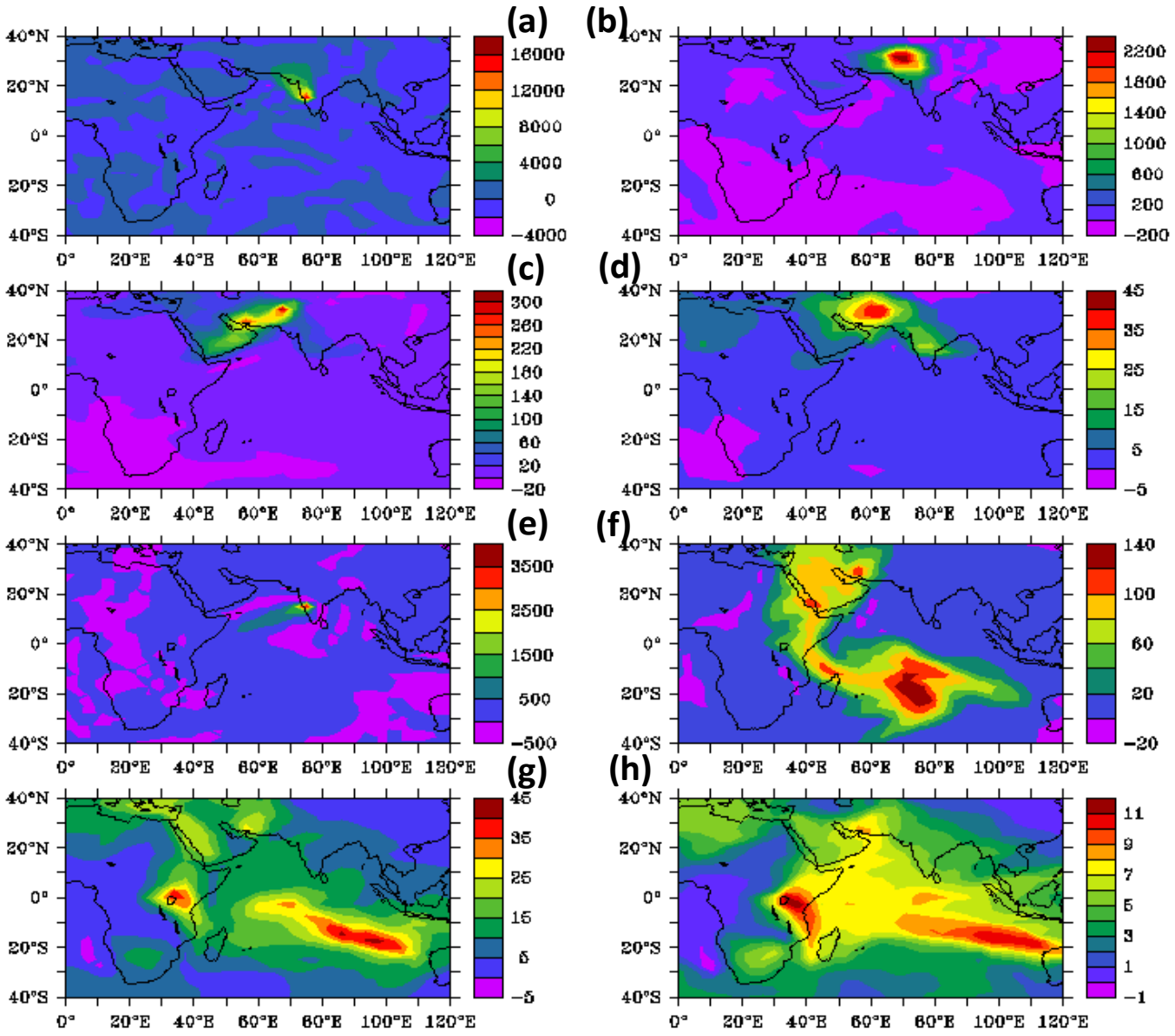
Tiwari et al., 2011

CO2 (ppm): observation and model simulations at CRI



Tiwari et al., 2011

Climatology of Jacobians computed by the adjoint of the LMDZ model for January (a-d) and June (e-h). Each sequence (a-d) and (e-h) shows the map of the partial derivatives, in ppm/(kg/m2/h), of a 24-h mean concentration at CRI with respect to CO_2 surface fluxes in the previous week (a,e), two weeks before (b, f), three weeks before (c,g) and four weeks before (d,h).



Tiwari et al., 2011

Conclusions:

- CO_2 monitoring site at Sinhagad (SNG) Pune started in 2009, prelimenary results show good agreement with model simulation.

- Lagrangian Particle Dispersion Model Flexpart simulations are useful to understand long range transport processes at existing sites. Model uses 50 Km NCEP meteorology.

- Cruise and airplane campaigns show encouraging results. Further analysis is currently underway.

Great Thanks !!

KMA / WMO / GAW: for providing financial support

Deullae Min: for travel and hotel arrangements (*vegetarian food as well*)