NOAA Boulder ESRL 2011
Global Monitoring Annual Conference

MAX-PLANCK-GESELLSCHAFT

A carbon budget estimate for South Asia using passenger aircraft based CO_2 measurements

Communicated by **Carl A. M. Brenninkmeijer**

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Modelling by Prabir Patra,
Measurements CARIBIC and Interpretations by Tanja Schuck
Measurements CONTRAIL and Interpretations by Y. Niwa,
T. Machida, H. Matsueda, and Y. Sawa

Using NOAA data and calibrations

www.caribic-atmospheric.com

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Prabir

JAMSTEC

CARIBIC

Civil **A**ircraft for the **R**egular **I**nvestigation of the atmosphere, **B**ased on an **I**nstrument **C**ontainer

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2 million kilometer

www.caribic-atmospheric.com

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Global Observation of CO_2 and Other Trace Species by Aircraft CONTRAIL Project

T. Machida[1], H. Matsueda[2], Y. Nakagawa[3], M. Tomosawa[4], K. Ishikawa[5], T. Inagaki[5], T. Nakazawa[6], T. Ogawa[5] and T. Suenaga[7]

[1]NIES, [2]MRI, [3]JAL, [4]JAMCO, [5]JAXA, [6]Tohoku U., [7]JAL F.

CARIBIC measurement container installed monthly in the forward cargo bay for 4 flights

Mass 1.6 ton ***Fully automated systems***

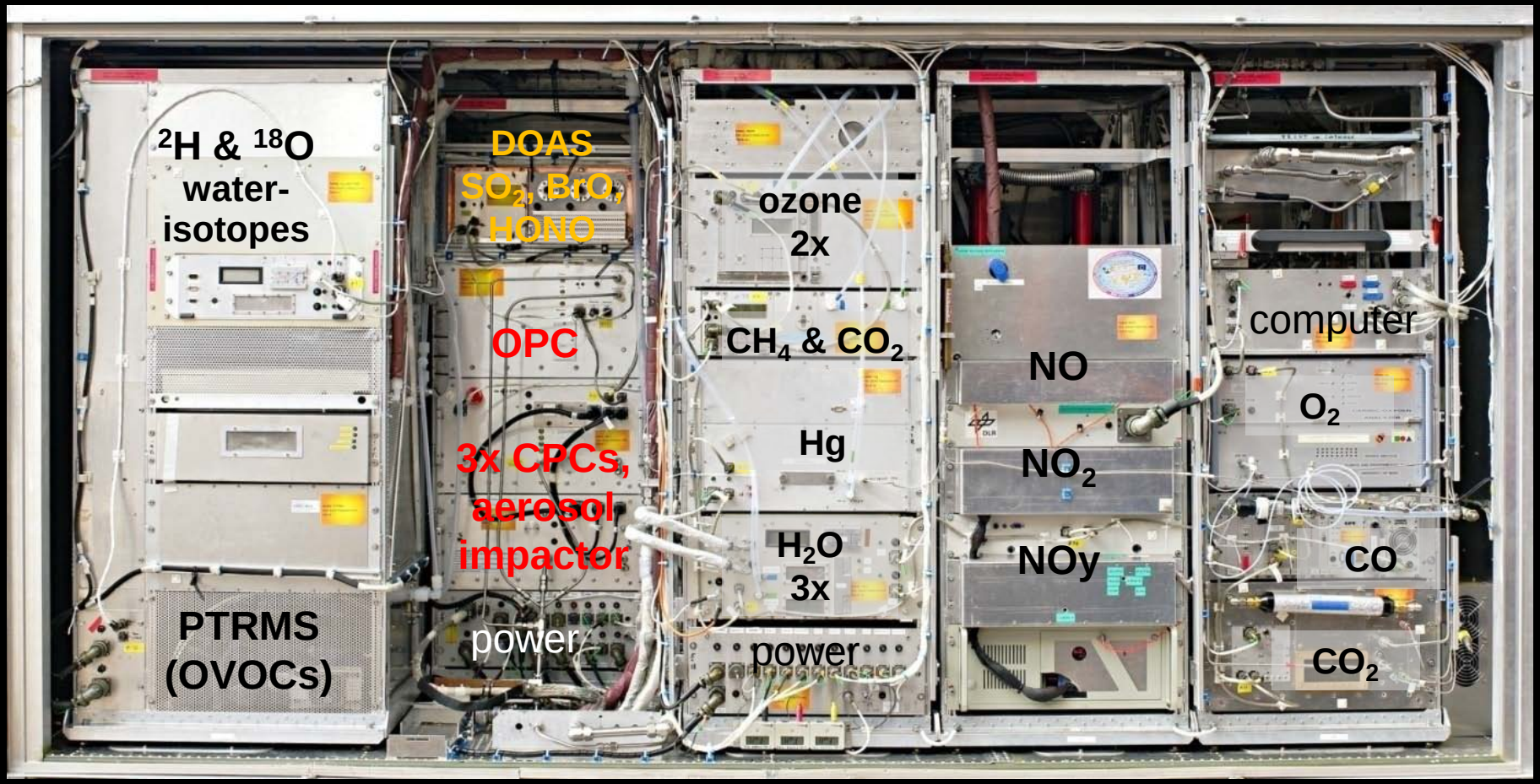
Lufthansa

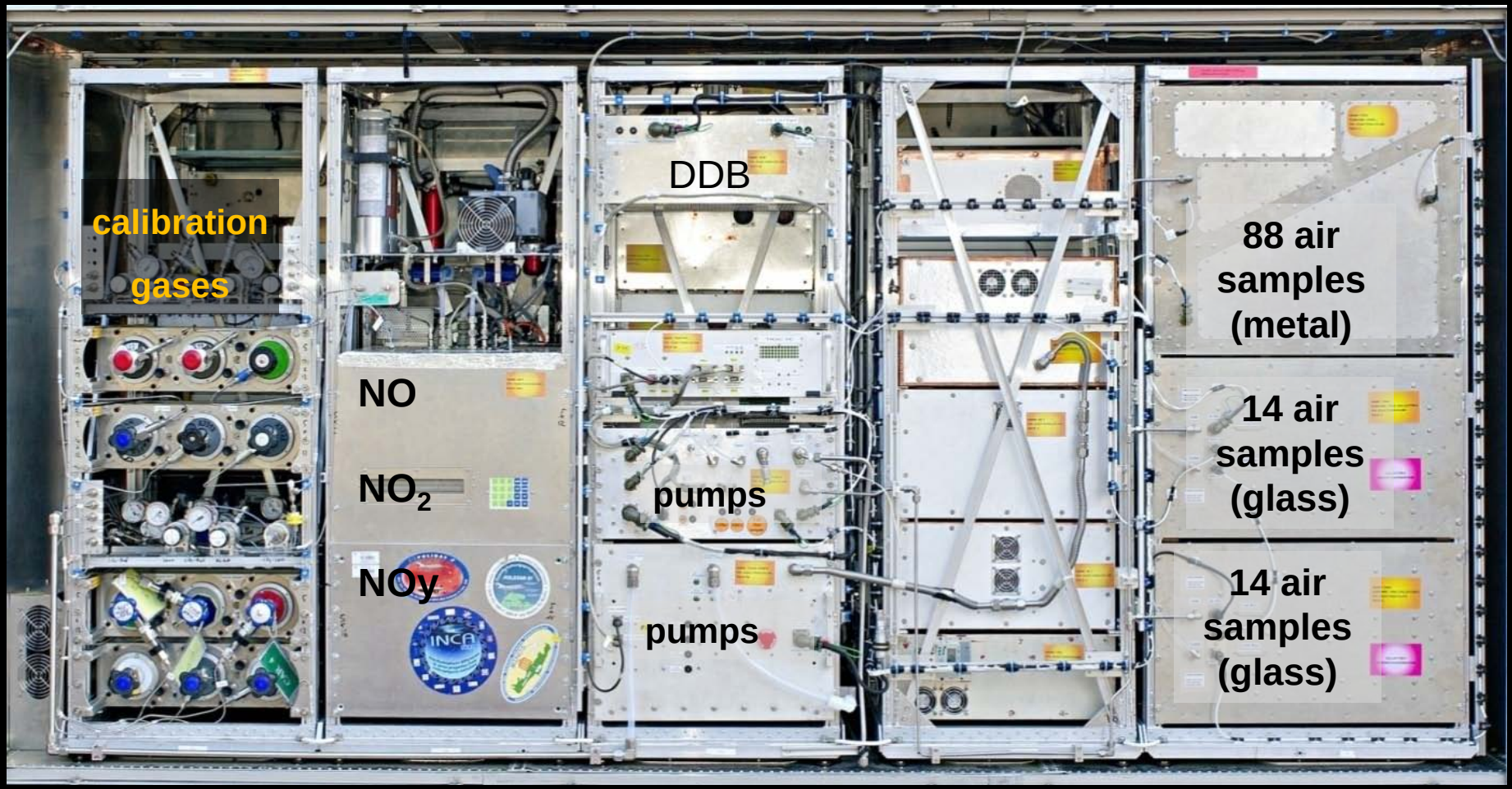
Airbus
A 340-600

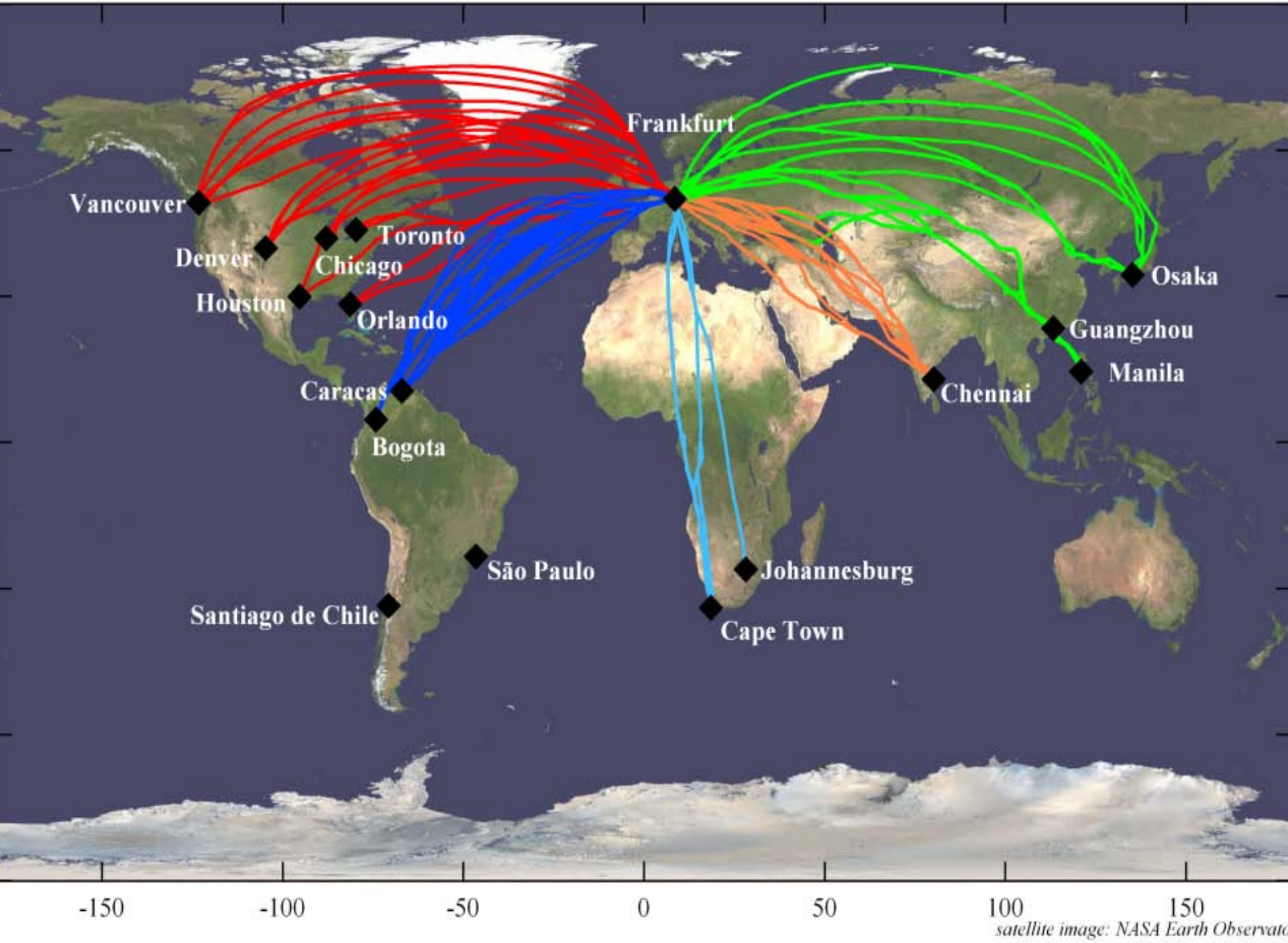
Air inlet system

Permanent aircraft part

The CARIBIC container in its position


^{2}H & ^{18}O water-isotopes
PTRMS (OVOCs)
DOAS SO_2, BrO, HONO
OPC
3x CPCs, aerosol impactor
power
ozone 2x
CH_4 & CO_2
Hg
H_2O 3x
power
NO
NO_2
NOy
computer
O_2
CO
CO_2


calibration gases
NO
NO_2
NOy
DDB
pumps
pumps
88 air samples (metal)
14 air samples (glass)
14 air samples (glass)


Frankfurt
Vancouver
Toronto
Denver
Chicago
Houston
Orlando
Caracas
Bogota
São Paulo
Santiago de Chile
Johannesburg
Cape Town
Osaka
Guangzhou
Manila
Chennai
-150
-100
-50
0
50
100
150
satellite image: NASA Earth Observato

KNMI/ECMWF backward trajectories: 219 from:MA_20091027_FRA_CPT_290_001
first begindate: THURSDAY 22 OCTOBER 2009 23 GMT
last enddate: WEDNESDAY 28 OCTOBER 2009 9 GMT
dark blue<=200hPa<lightblue<= 250Pa<green<= 300Pa<olive<= 400Pa<orange<=500hPa<red<=850hPa<purple

Jet stream

Jungfraujoch

Mauna Loa

5 days

africa

ITCZ

A flight from

Frankfurt to Cape Town

Red = low altitude

Meteo calculations by

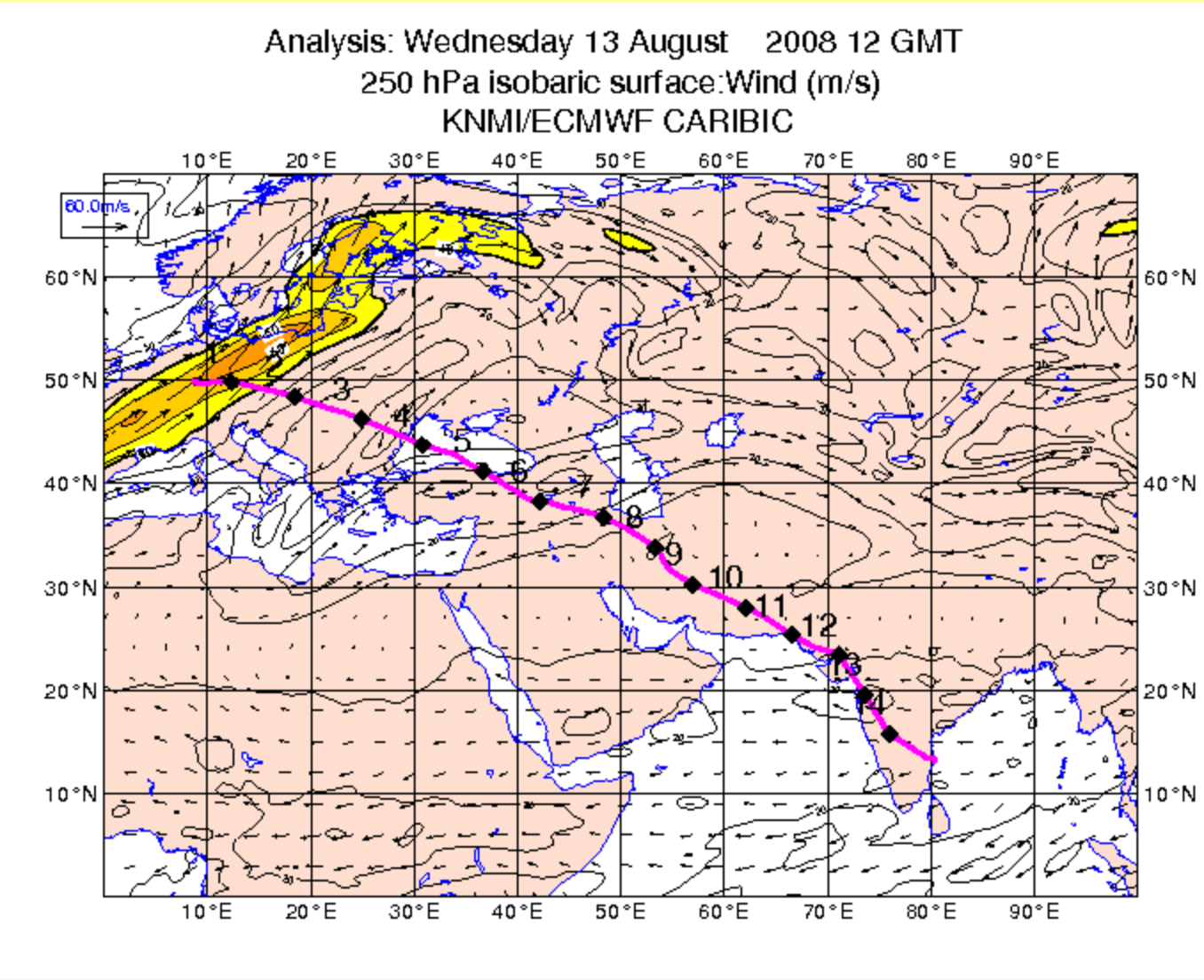
Peter van Velthoven KNMI

Motivation for this CO_2 study

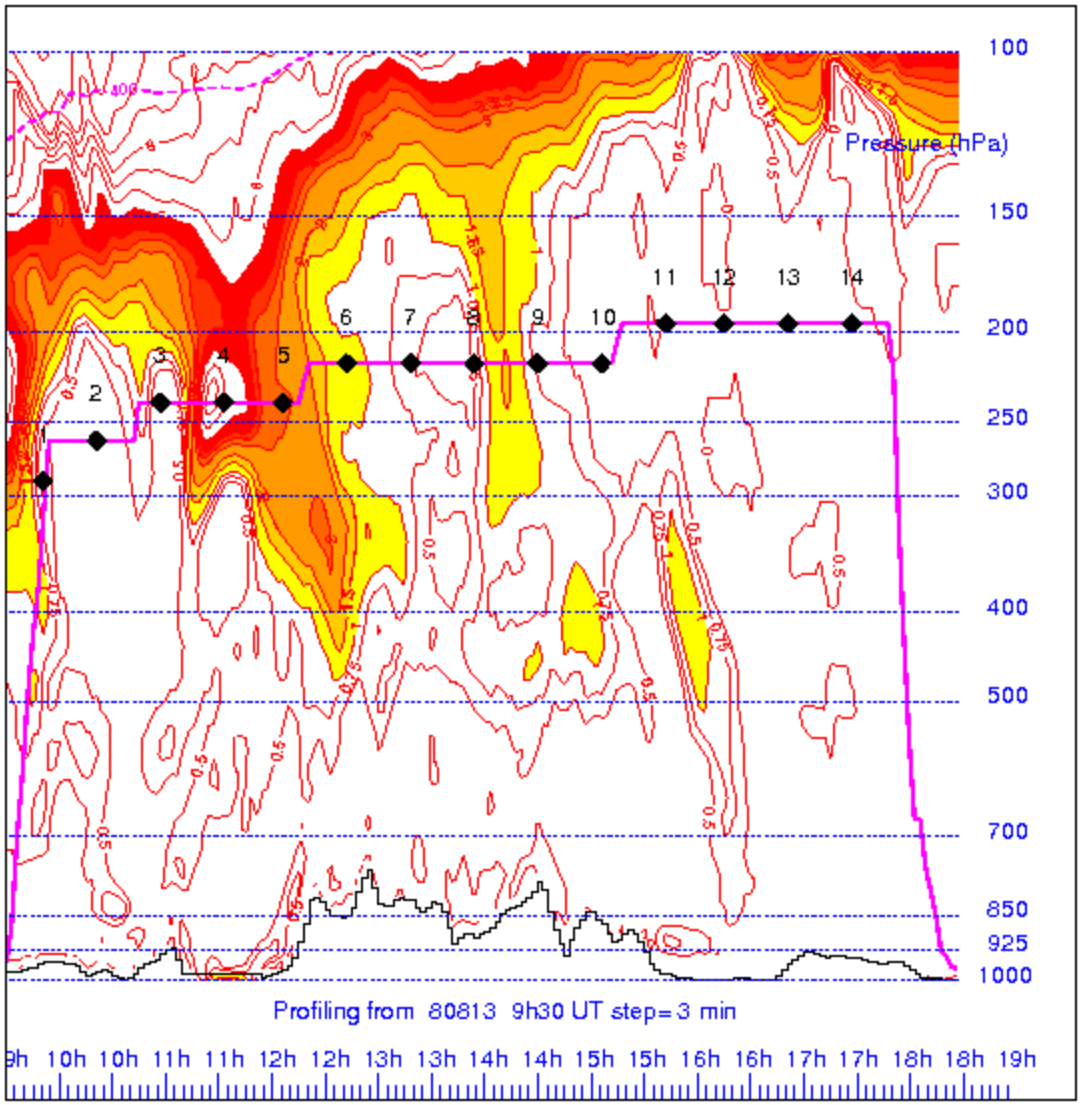
- Especially in the tropics where in situ CO_2 measurements are scarce, it helps to at least have information at altitude
- The carbon cycle of South Asian regions is poorly studied
- **CARIBIC** provides CO_2 data, plus many **additional data** for atmospheric composition **(here we use 2008)**
- **CONTRAIL** provides CO_2 data, including ample **vertical profiles (2007)**
- We conduct inversion using these CO_2 observations in the upper troposphere, plus of course the **NOAA data**
- ***Caution, the surgeon general warns: INVERTING is DANGEROUS***
  You will need confidence in transport

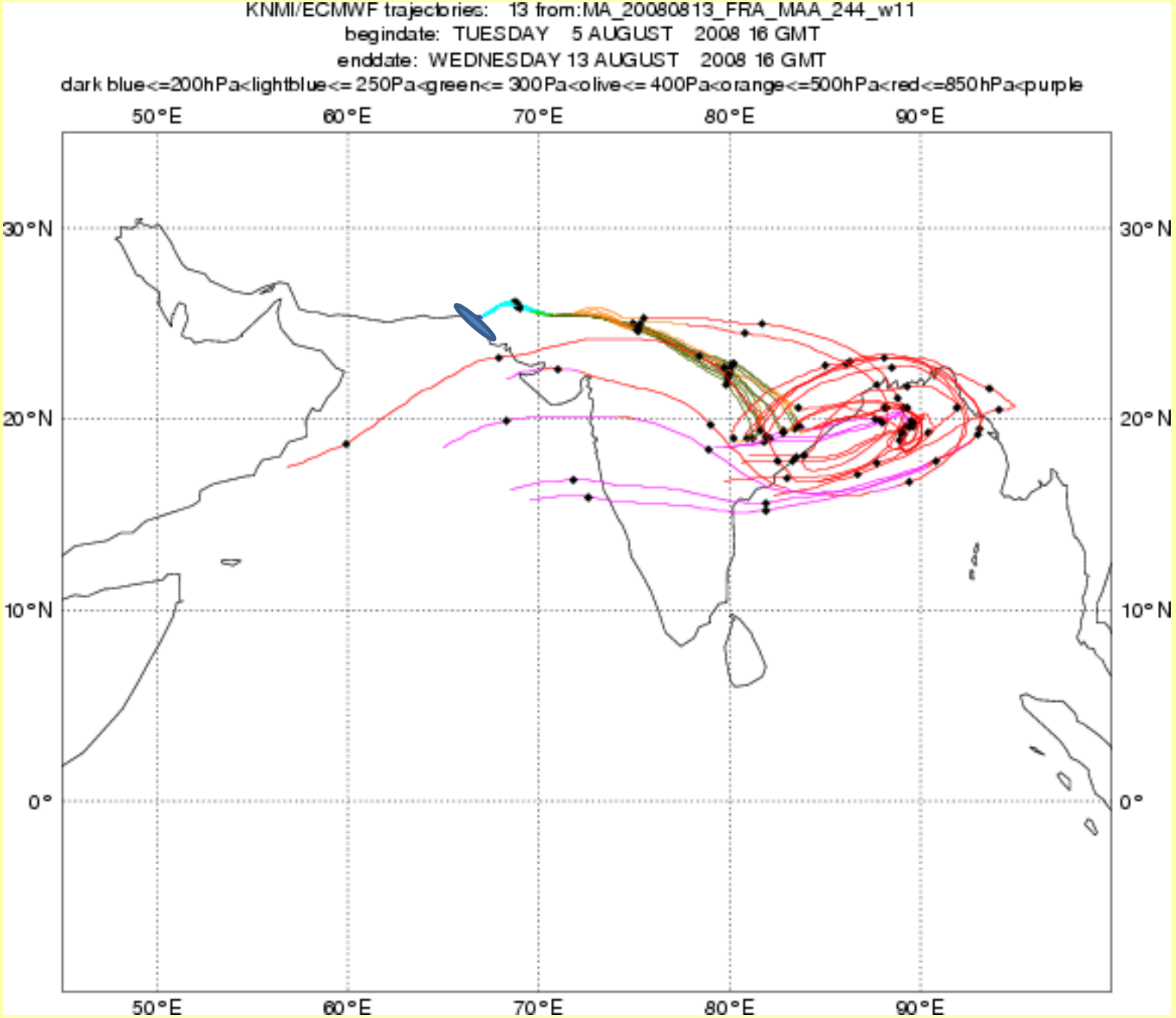
Inverse modelers trust transport

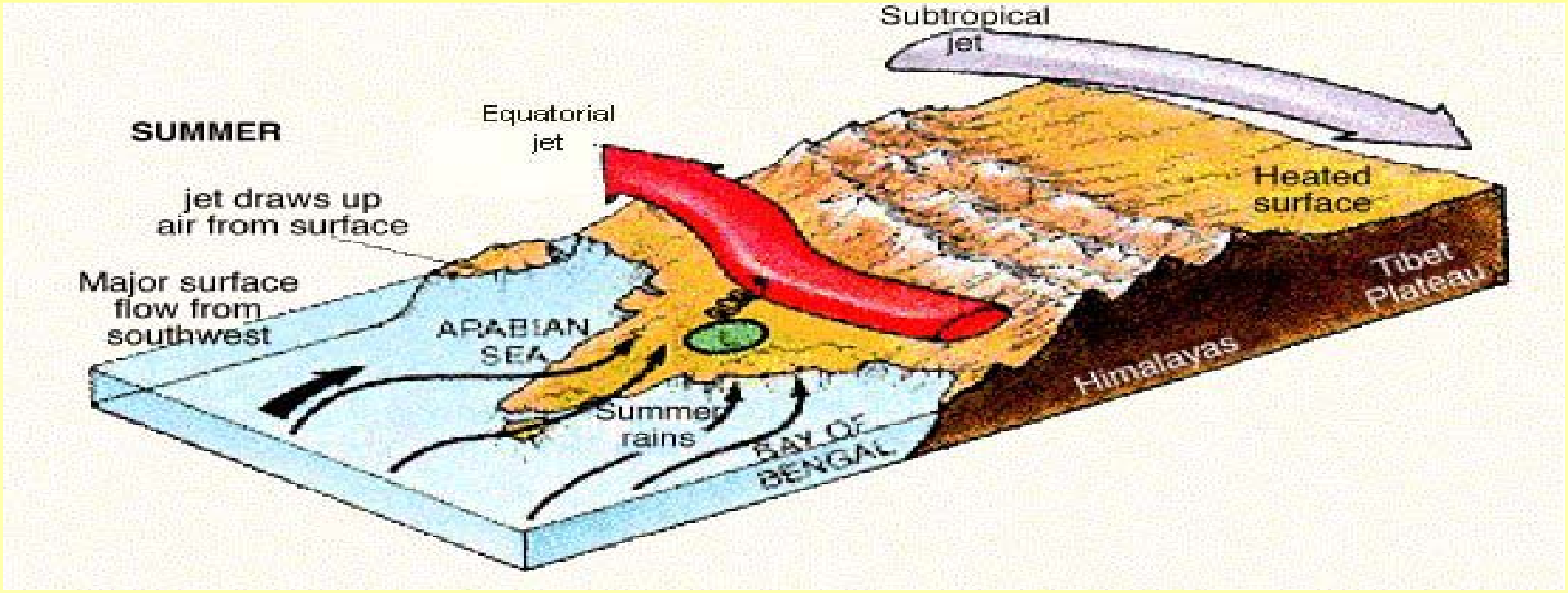
Carl Brenninkmeijer, MPI


Analysis: Wednesday 13 August 2008 12 GMT
250 hPa isobaric surface:Wind (m/s)
KNMI/ECMWF CARIBIC
60.0m/s
10°E
20°E
30°E
40°E
50°E
60°E
70°E
80°E
90°E
60°N
50°N
40°N
30°N
20°N
10°N
3
4
5
6
7
8
9
10
11
12
13
14

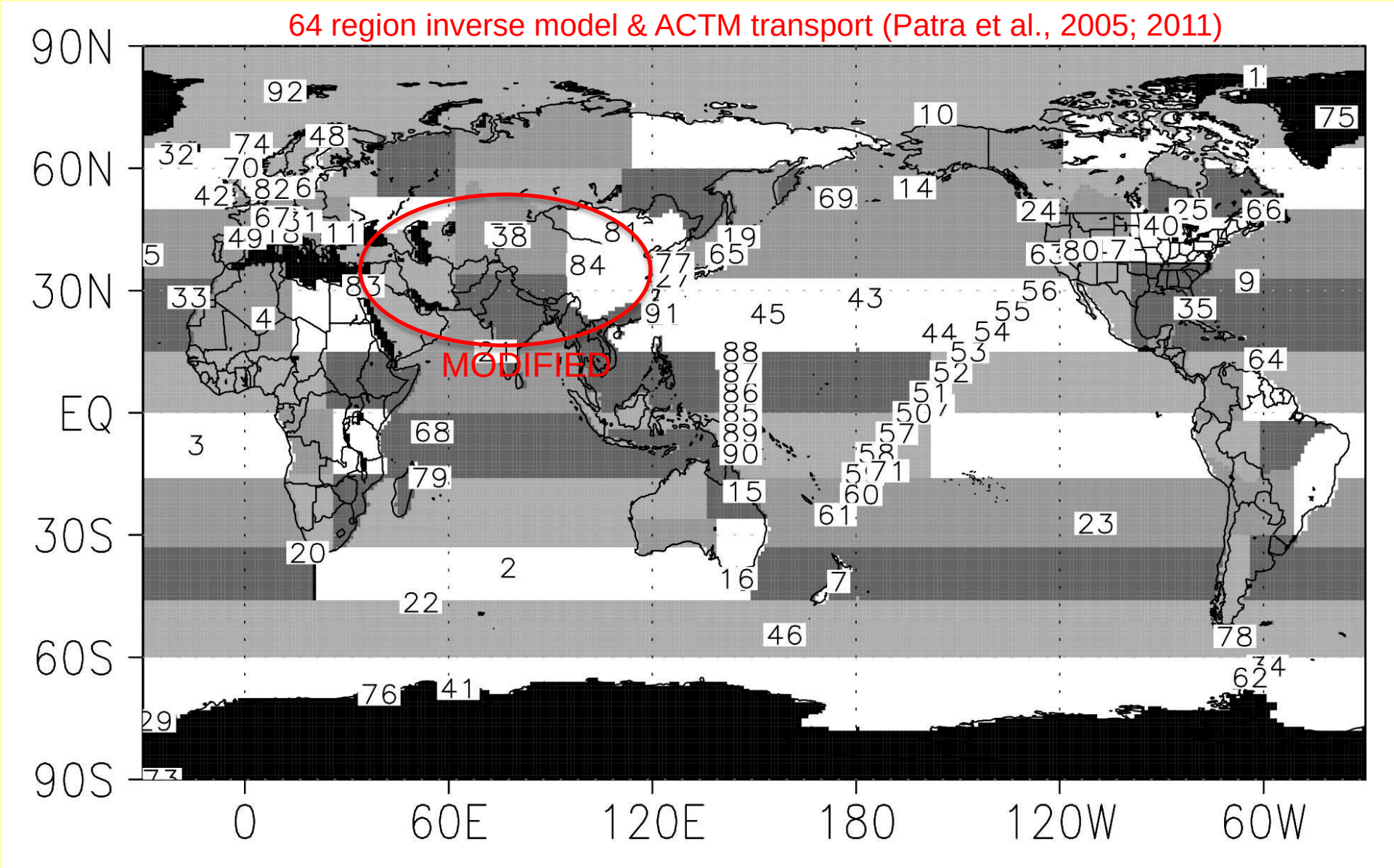
Cross section of 180 profiles
from 13- 8-2008 at 6 Z + 0 from model level data
Potential vorticity (PVU)
KNMI/ECMWF CARIBIC



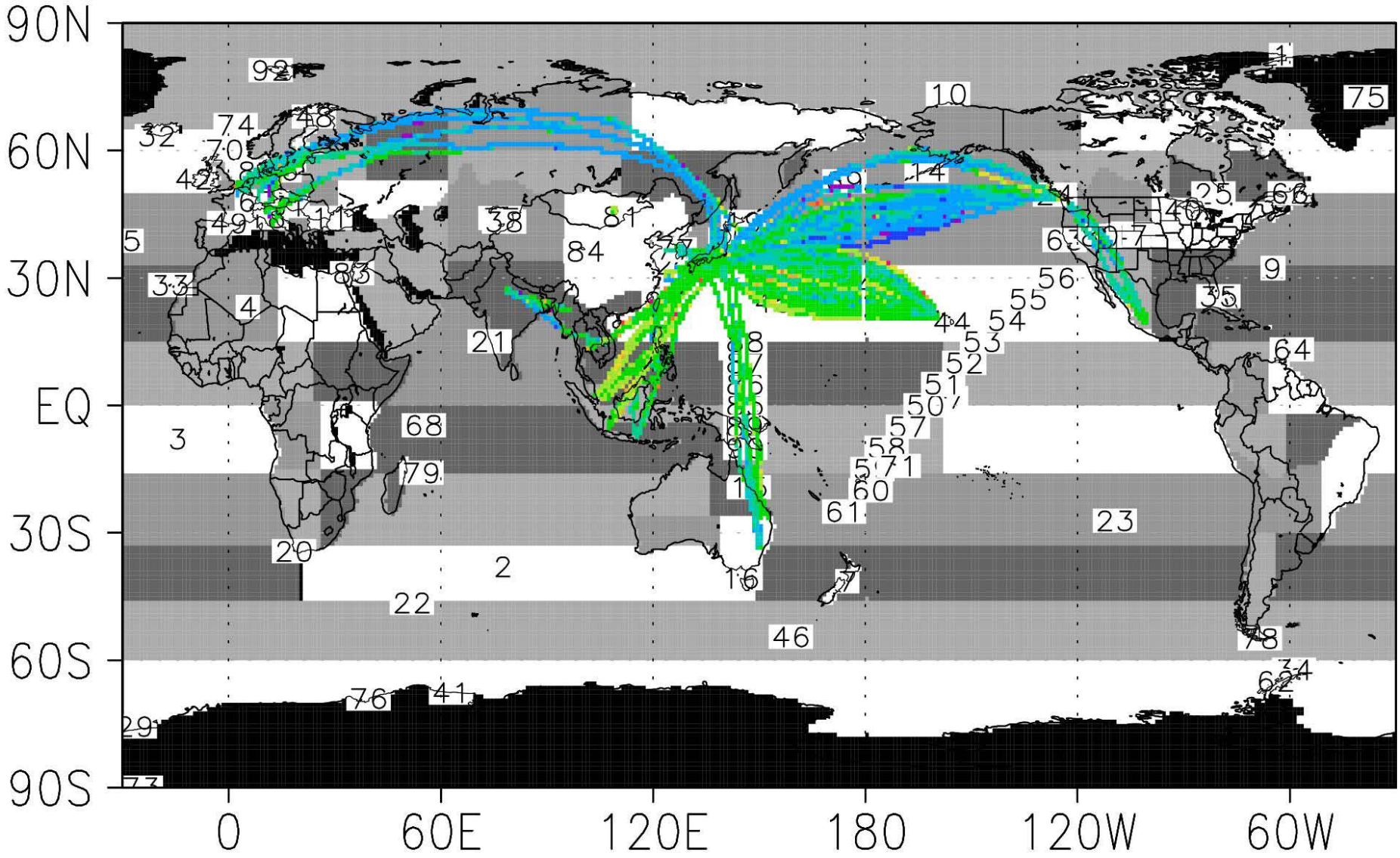

KNMI/ECMWF trajectories: 13 from:MA_20080813_FRA_MAA_244_w11
begindate: TUESDAY 5 AUGUST 2008 16 GMT
enddate: WEDNESDAY 13 AUGUST 2008 16 GMT
dark blue<=200hPa<lightblue<=250Pa<green<=300Pa<olive<=400Pa<orange<=500hPa<red<=850hPa<purple
50°E
60°E
70°E
80°E
90°E
30°N
20°N
10°N
0°


SUMMER
Subtropical jet
Equatorial jet
jet draws up air from surface
Major surface flow from southwest
ARABIAN SEA
Summer rains
BAY OF BENGAL
Heated surface
Tibet Plateau
Himalayas

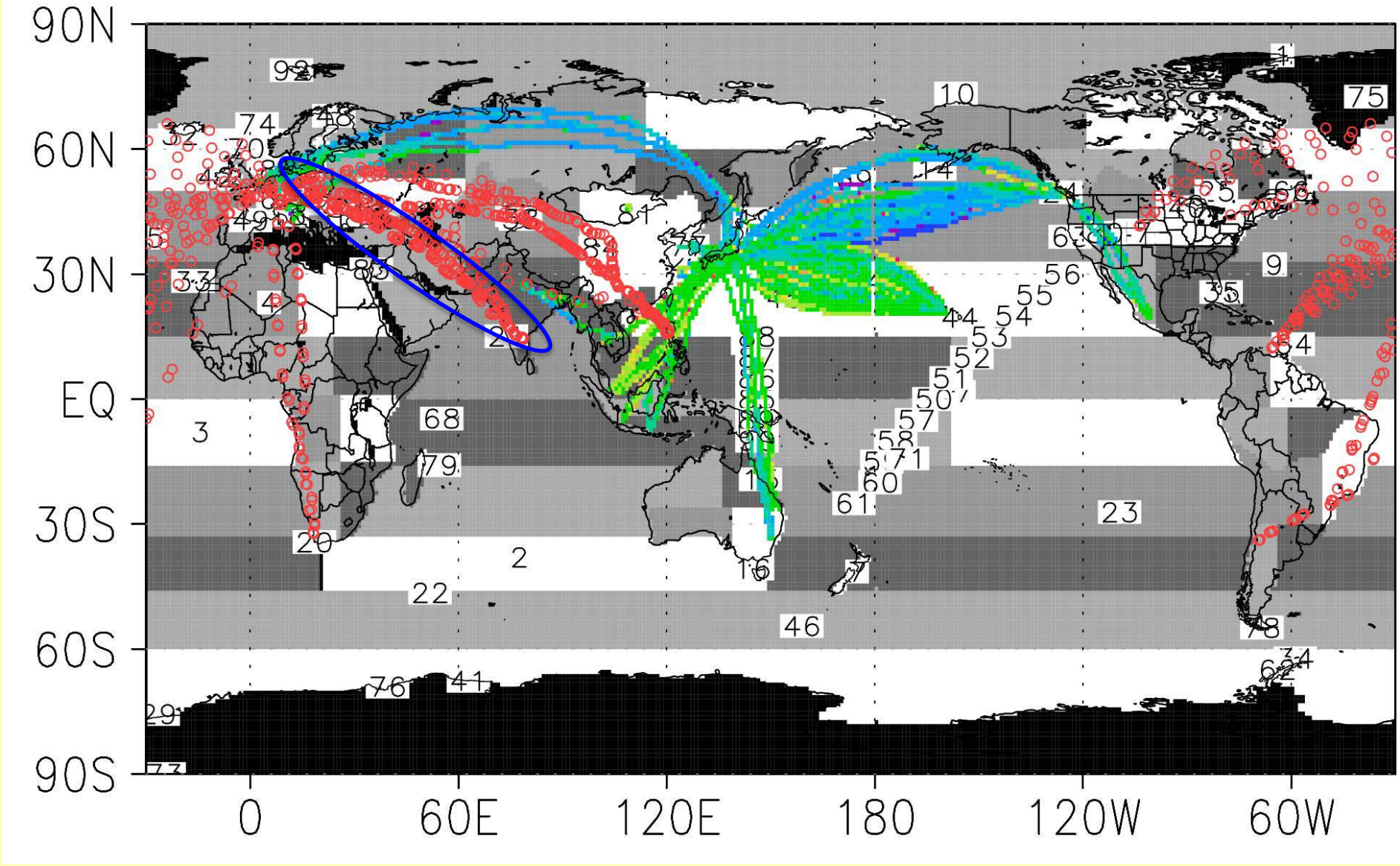
No inverse modelling by lack of data ?

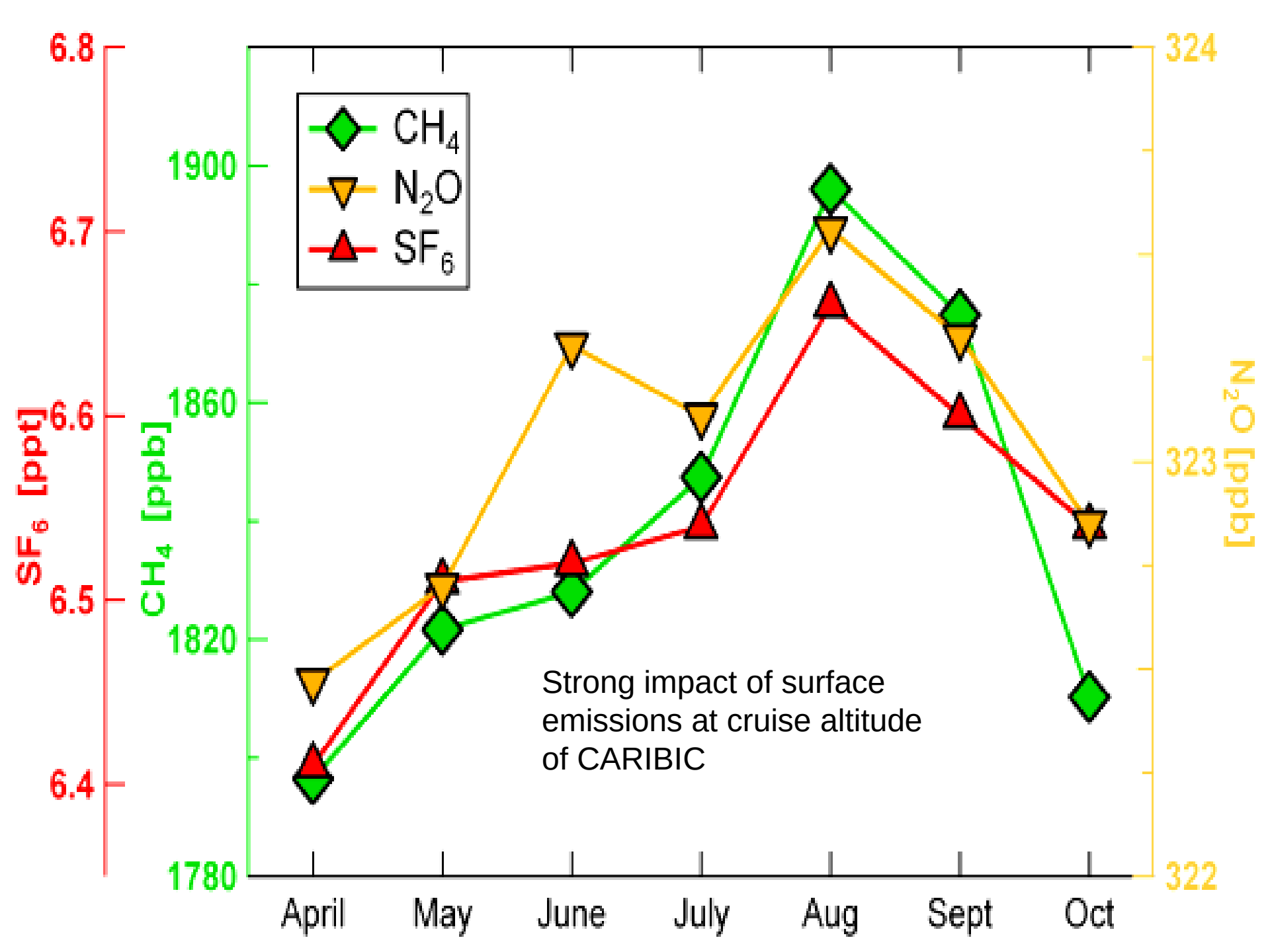


Inverse modelling …more data ..
(surface + CONTRAIL)

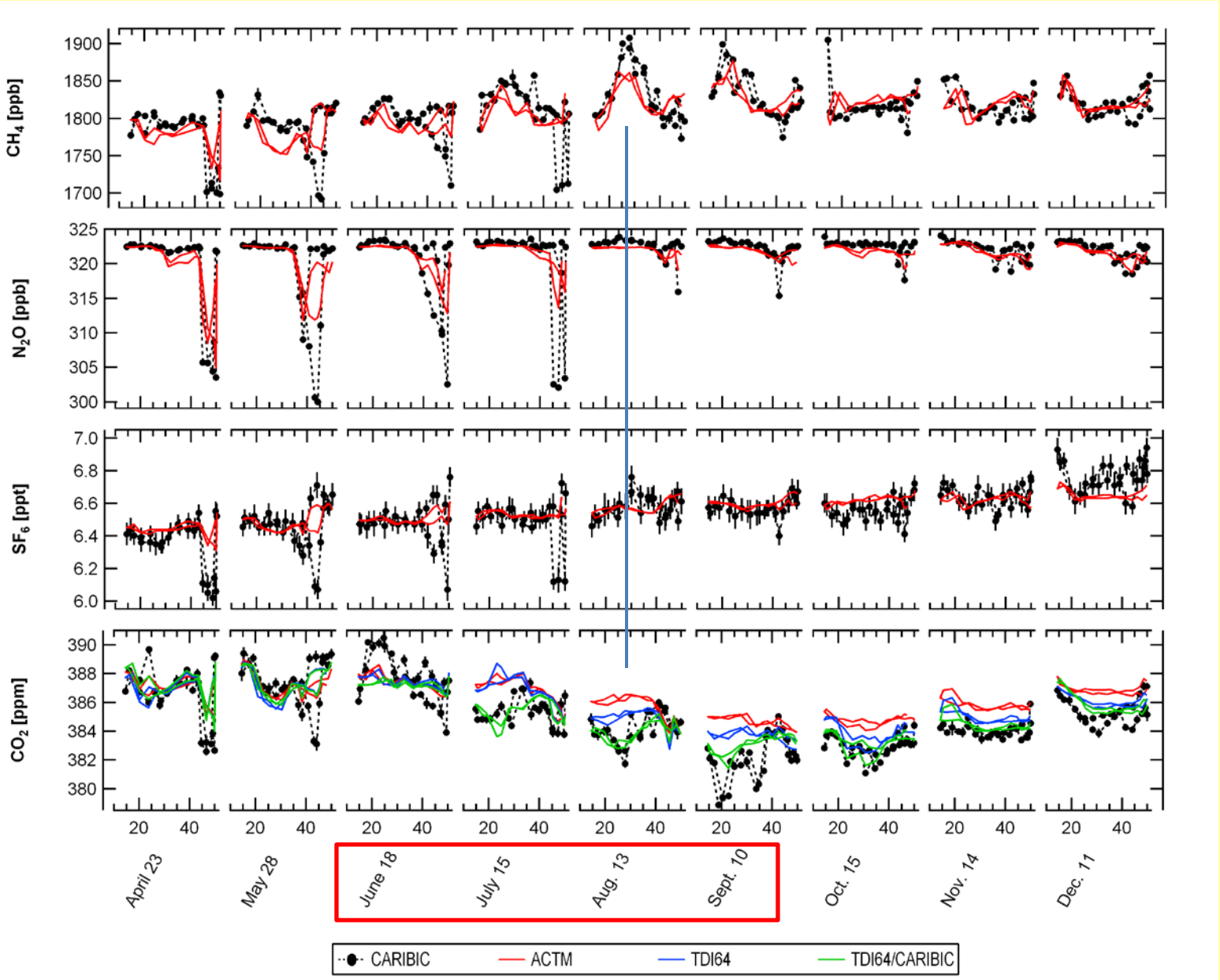


Inverse modelling …and more data…use the data (surface + CONTRAIL + CARIBIC)




6.8
6.7
6.6
6.5
6.4
SF6 [ppt]
1900
1860
1820
1780
CH4 [ppb]
324
323
322
N2O [ppb]
CH4
N2O
SF6
Strong impact of surface emissions at cruise altitude of CARIBIC
April
May
June
July
Aug
Sept
Oct

CARIBIC measurements between Frankfurt and Chennai and ACTM (T42L32) **forward** simulations



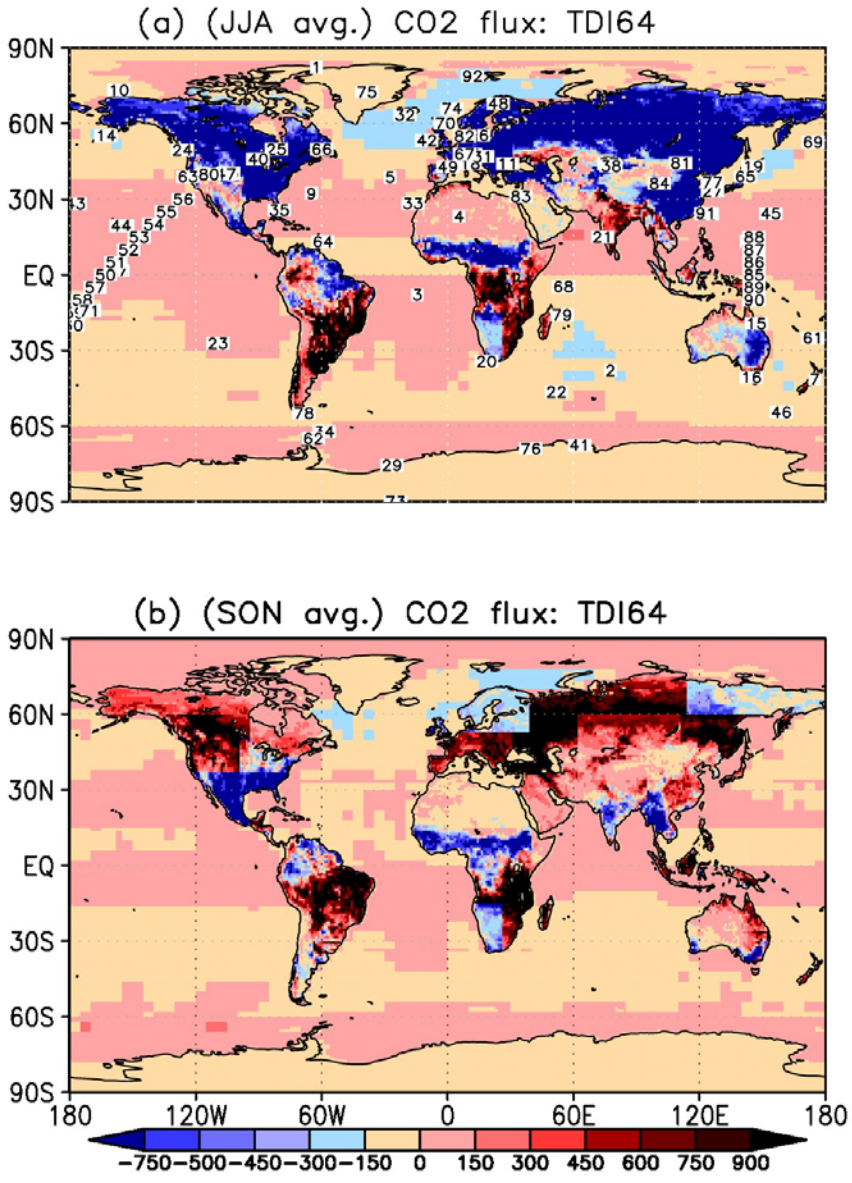
CH_4

N_2O

SF_6

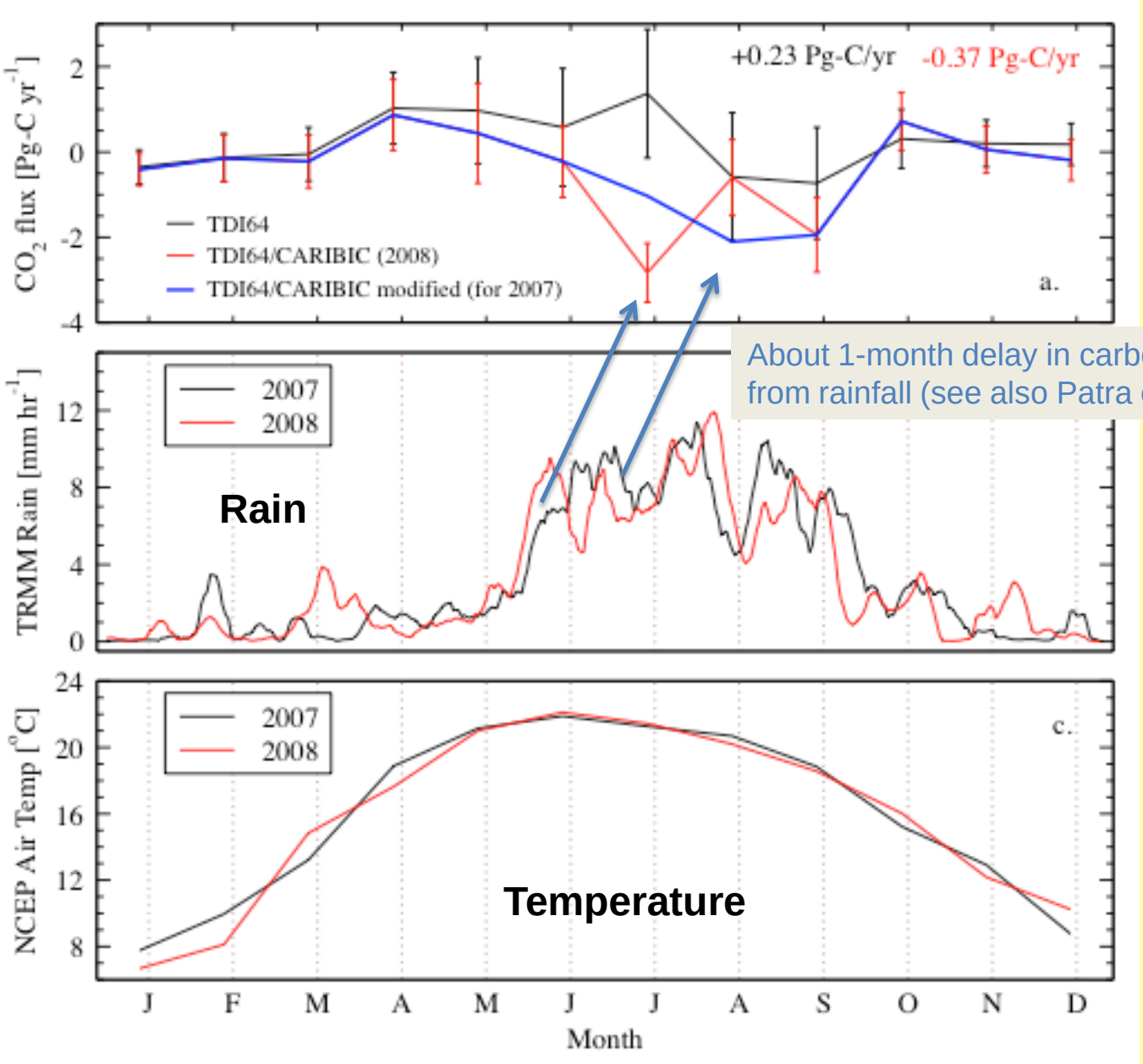
CO_2

TDI64 fluxes from **inversion**



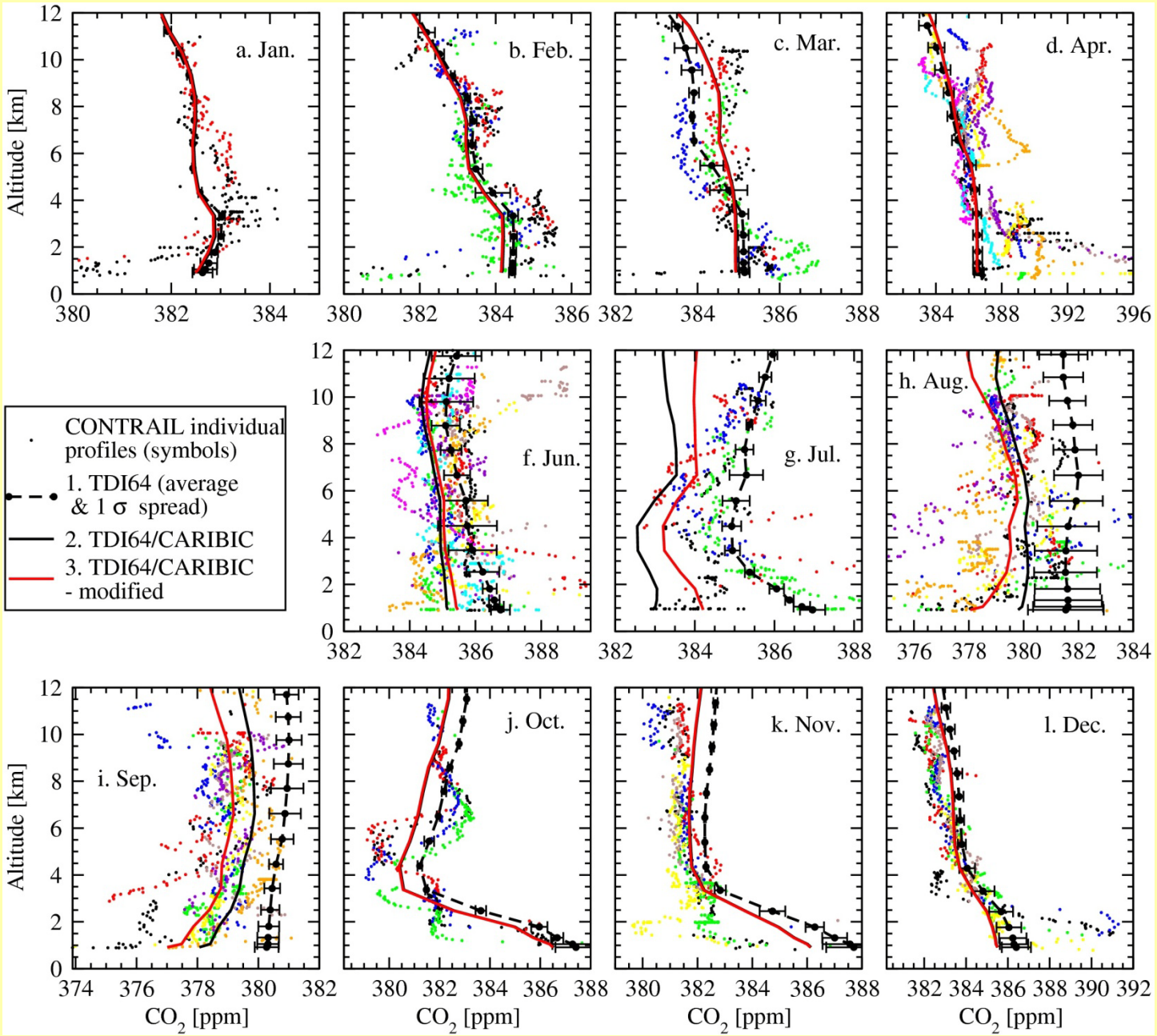
change due to CARIBIC

Seasonal cycle and precipitation effect on South Asian flux

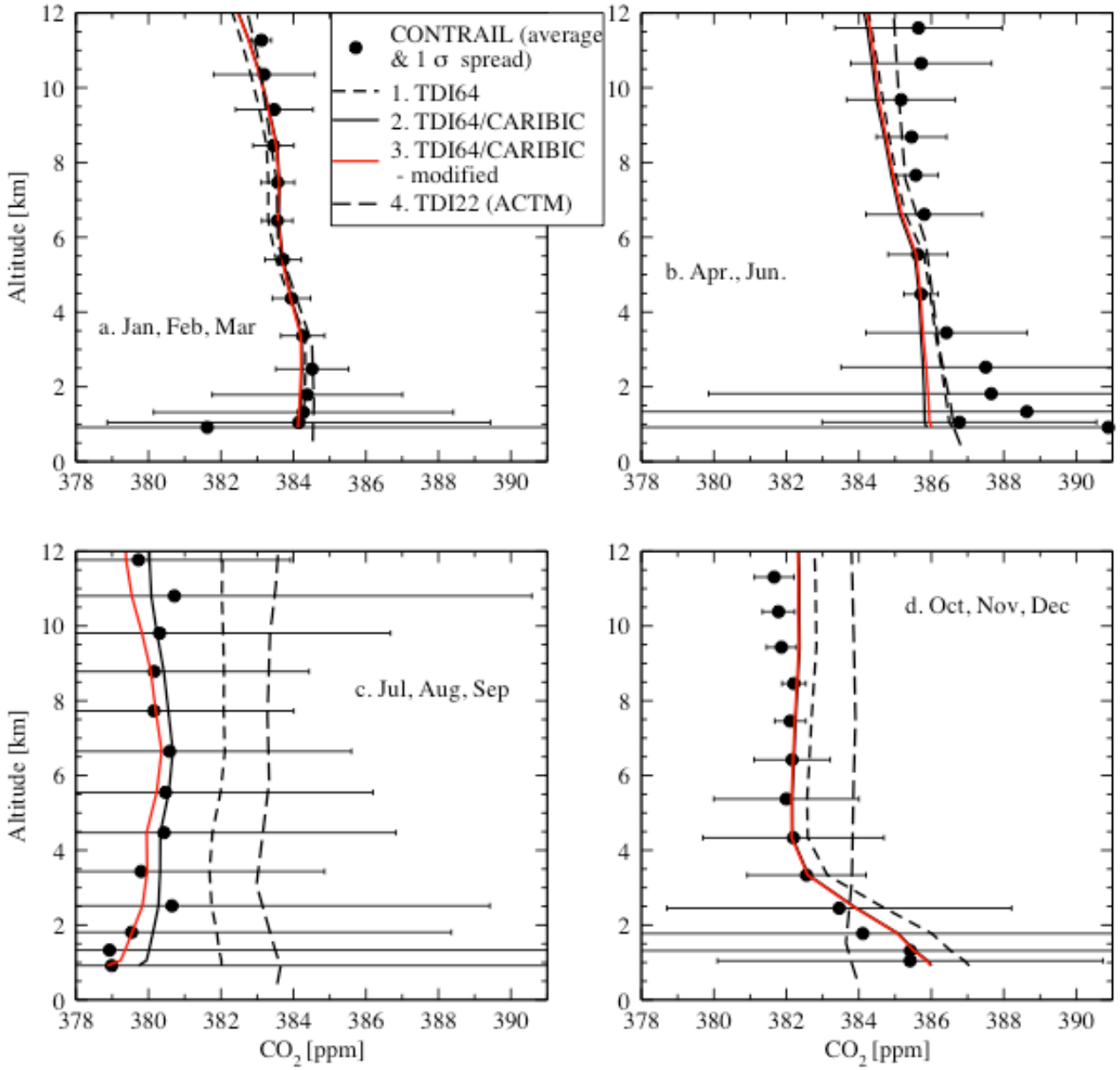


About 1-month delay in carbon uptake from rainfall (see also Patra et al., 2005)

Validation of South Asian flux using CONTRAIL data over Delhi



CONTRAIL CO_2: Role of fluxes on vertical profile simulation

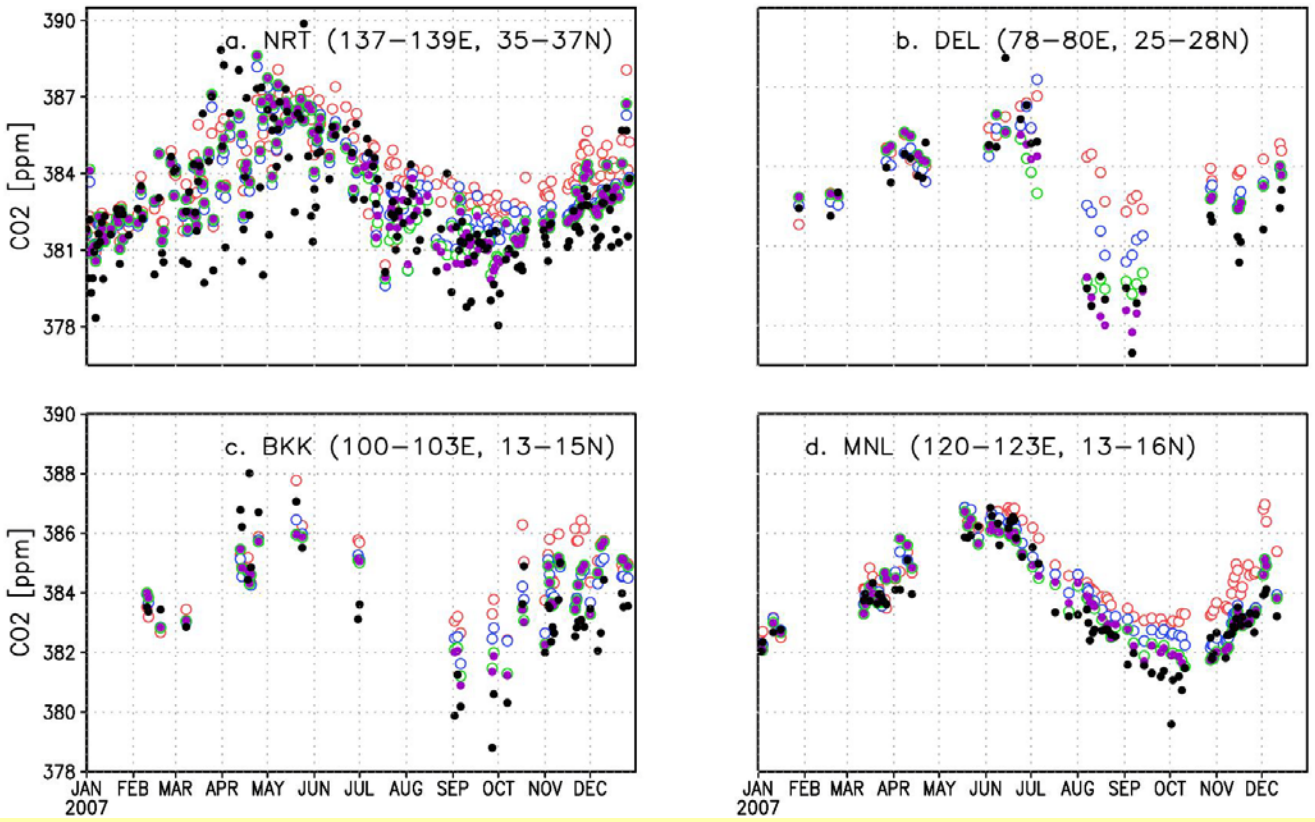


Observed
TDI22 (or ACTM)
TDI64
TDI64/CARIBIC (2008)
TDI64/CARIBIC mod.
(for 2007)

CONTRAIL CO_2

seasonality at
4 airports

SEASONALITY



Conclusions

- **CARIBIC, and particularly CONTRAIL, provide large amounts of in situ CO_2 data over vast regions of the atmosphere**
- **In the tropics, just there where fewer measurements are made, large scale upward motion makes these aircraft data very useful**
- **We found South Asia acted as a net sink of CO_2 at the rate of 0.37 Pg-C/yr during 2007 and 2008**
- **Inter-annual variations in precipitation have presumably a large effect in this region**