Ground Based Remote Sensing of Atmospheric Trace Gases in The Tropics

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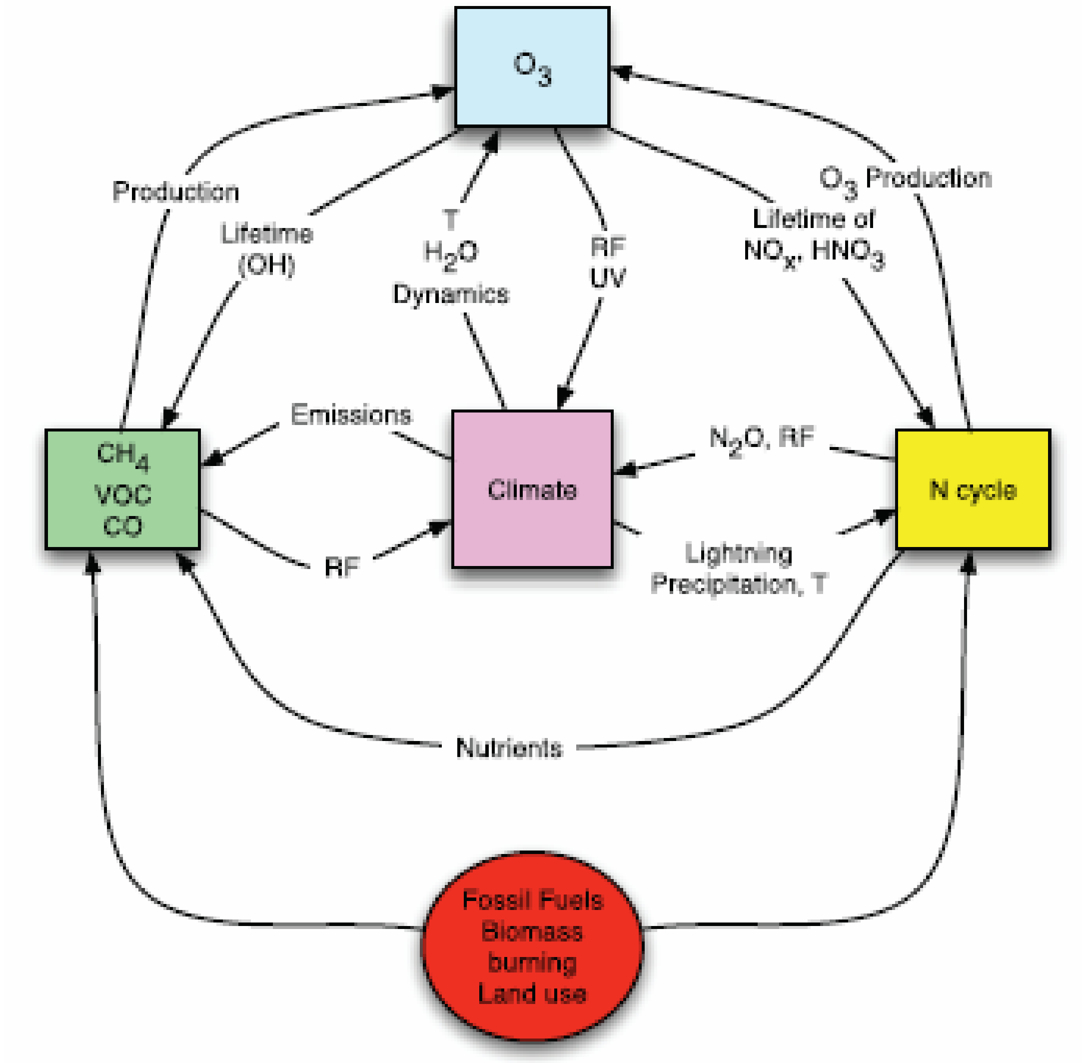
Outline

- Introduction
- About FTIR measurements
- Retrieval/Data analysis
- Some Results
- Summary
- Outlook

Indroduction

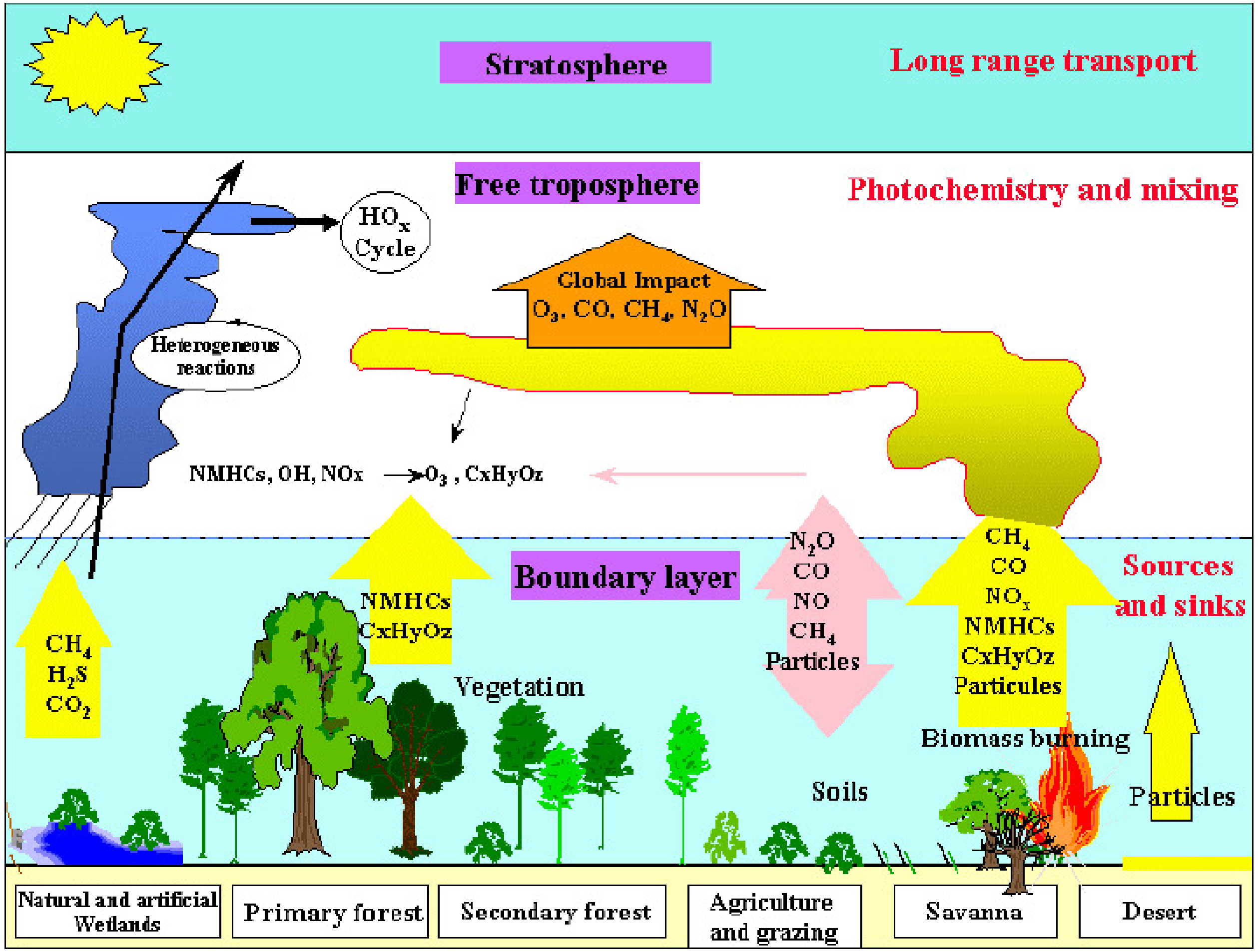
- Appreciation of close link between climate and atmospheric chemical processes

- Multiple interactions between tropospheric chemical processes, biogeochemical cycles and the climate system



source: IPCC, 2007

Indroduction



Sources of Atmospheric emissions and some emitted compounds in the tropics

Why should we monitor atmospheric emissions in the tropics?

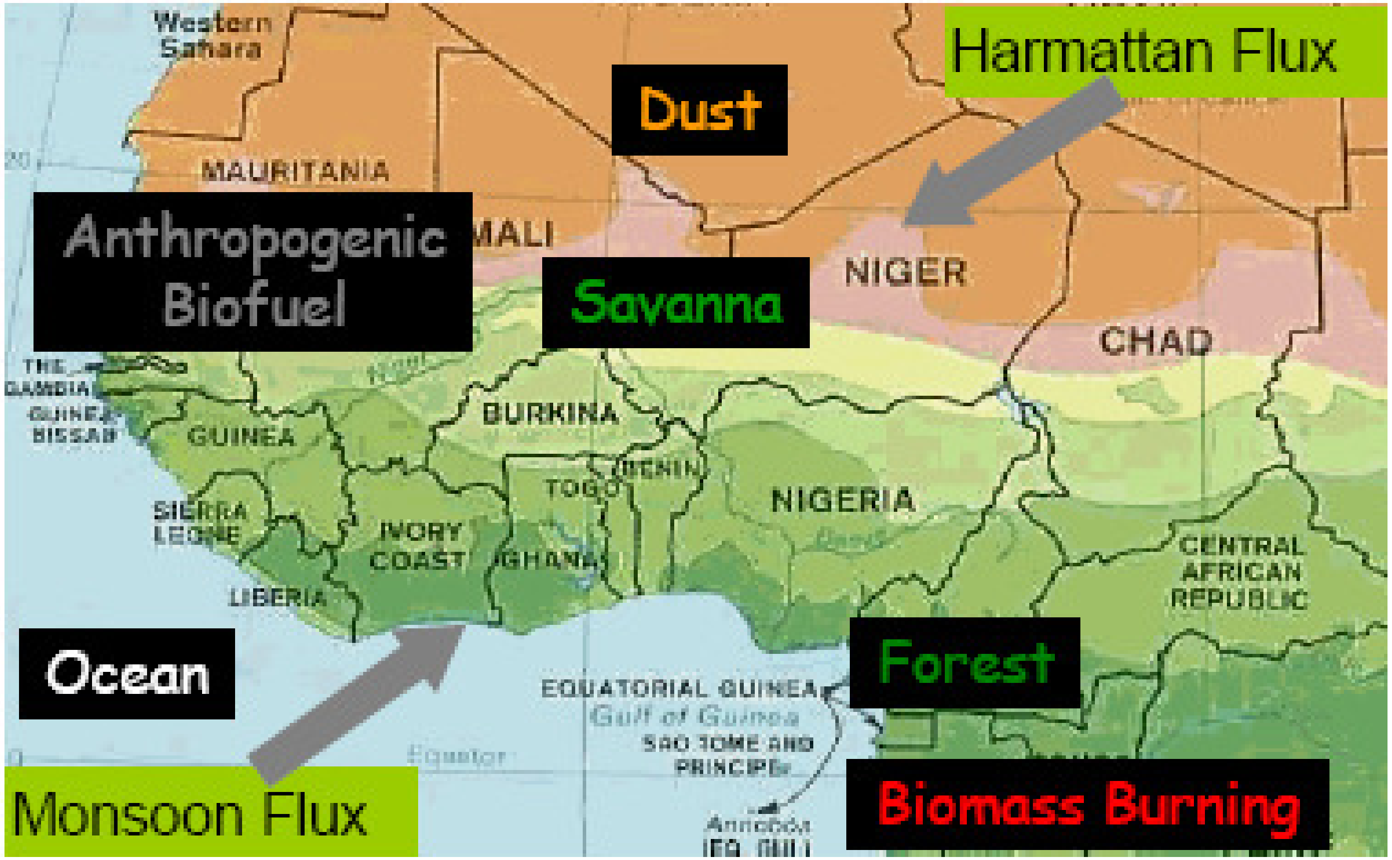
- The Earth's atmosphere is undergoing rapid changes, mainly due to human activities. The results of careless land use and industrialization have profoundly modified the composition.

- The consequences of these man made activities includes: depletion of stratospheric ozone, increase in GHG, large scale pollution, land degradation among others.

- Biomass burning provide an abundant source of GHG and other chemically active gases, such carbon monoxide, non methane hydrocarbons, and nitric oxide. These gases, along with methane, lead to the chemical production of tropospheric ozone (another GHG) they also control the concentration of OH, which regulates the lifetime of almost every atmospheric trace gases.

- Significant proportion of biomass burning activities and their related emissions come from the tropics .

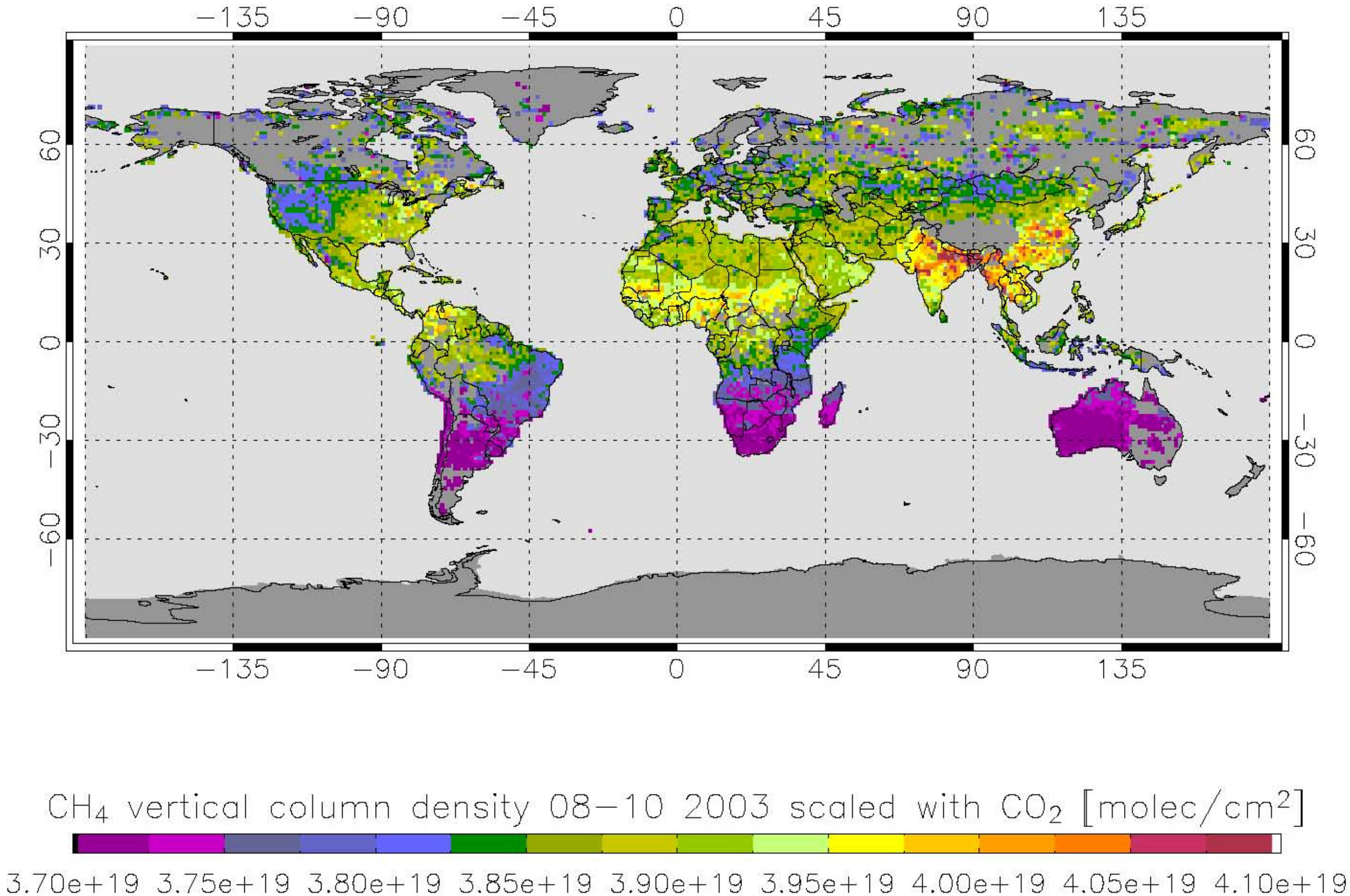
Indroduction



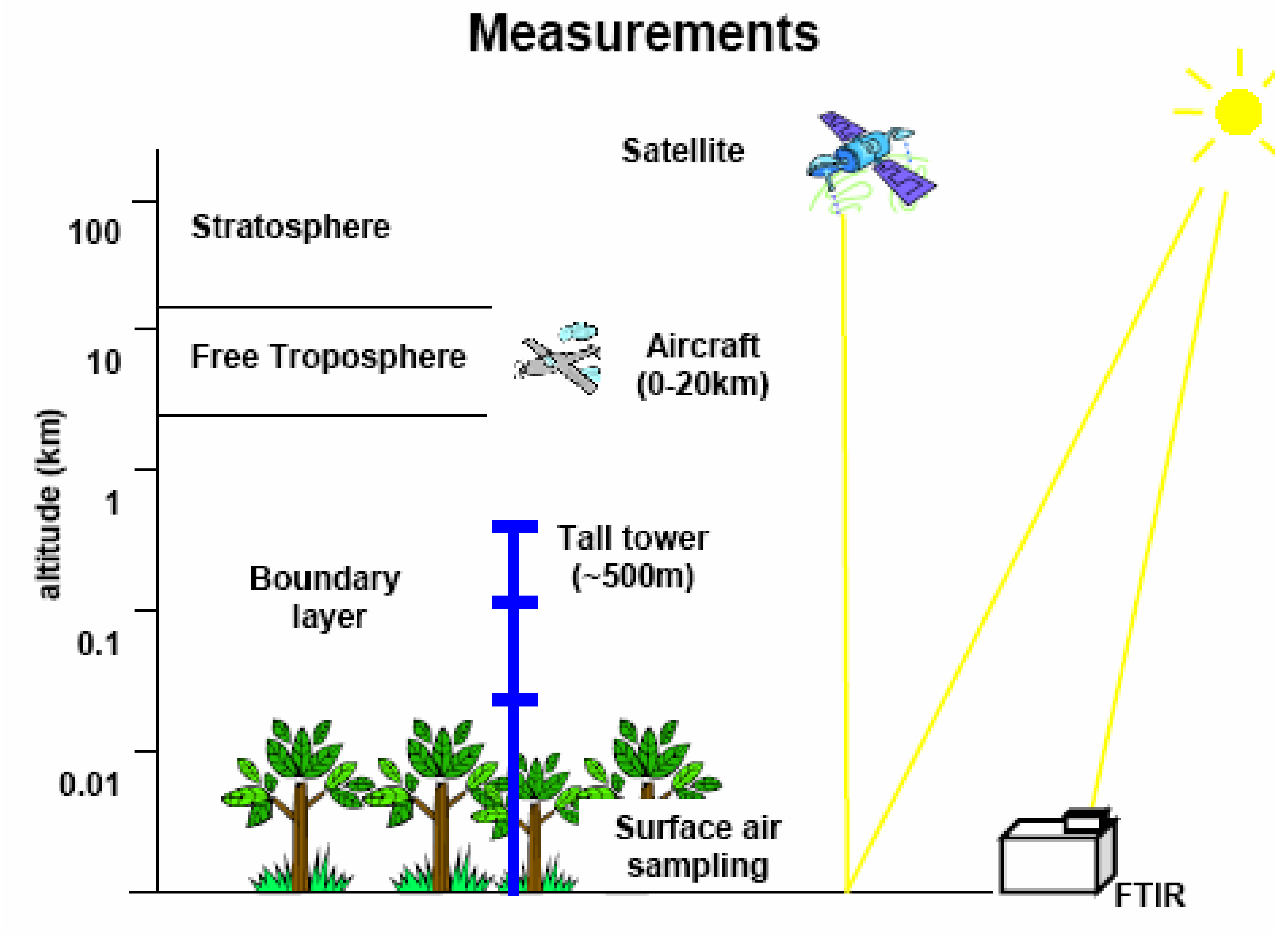
- Monsoon moist air from South Atlantic and tropical rain forest (natural emissions)
- Harmattan dry air over arid regions
- Polluted air from increasing human activities

CarboAfrica

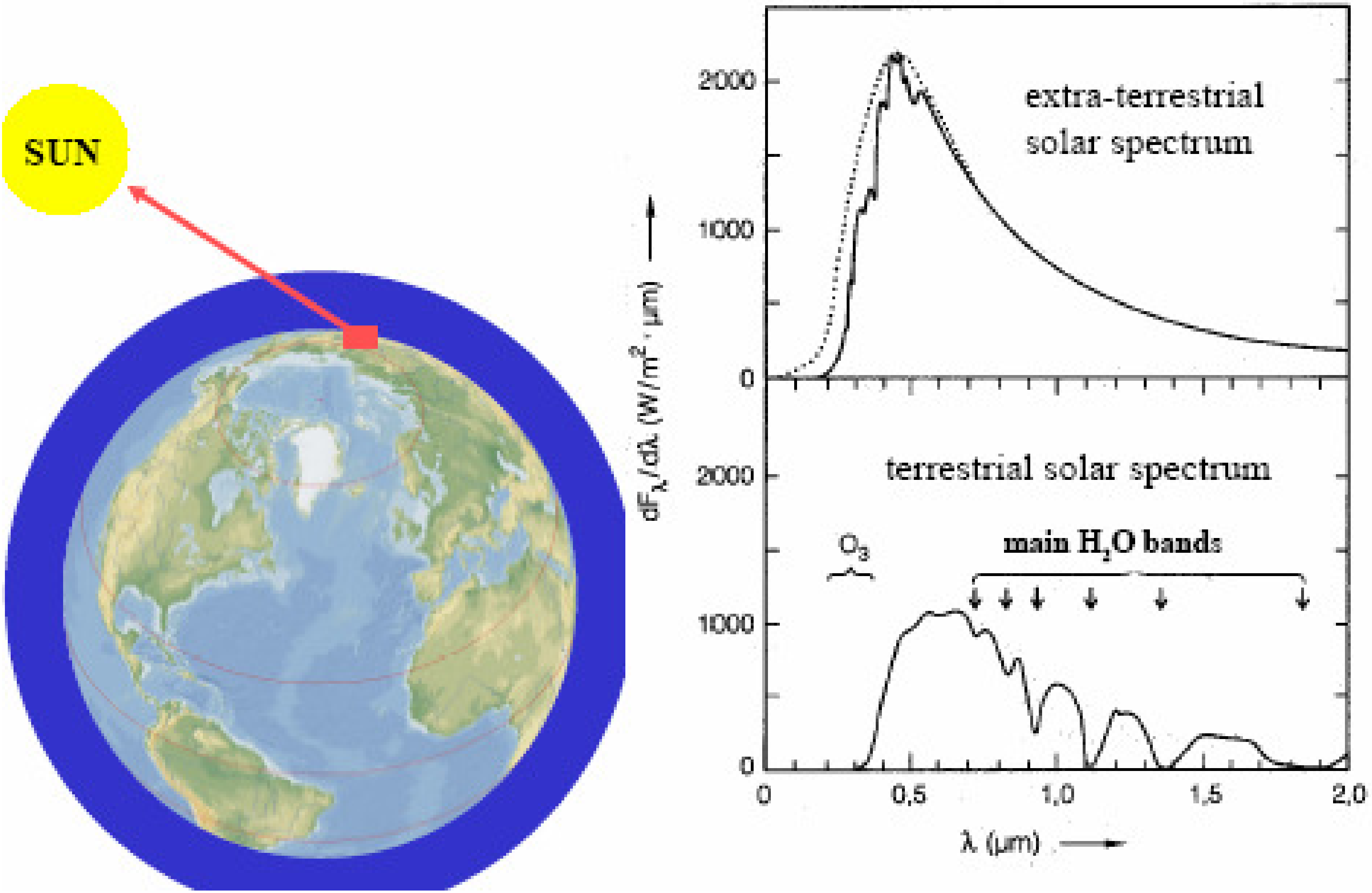
Global Measurements of CH_4

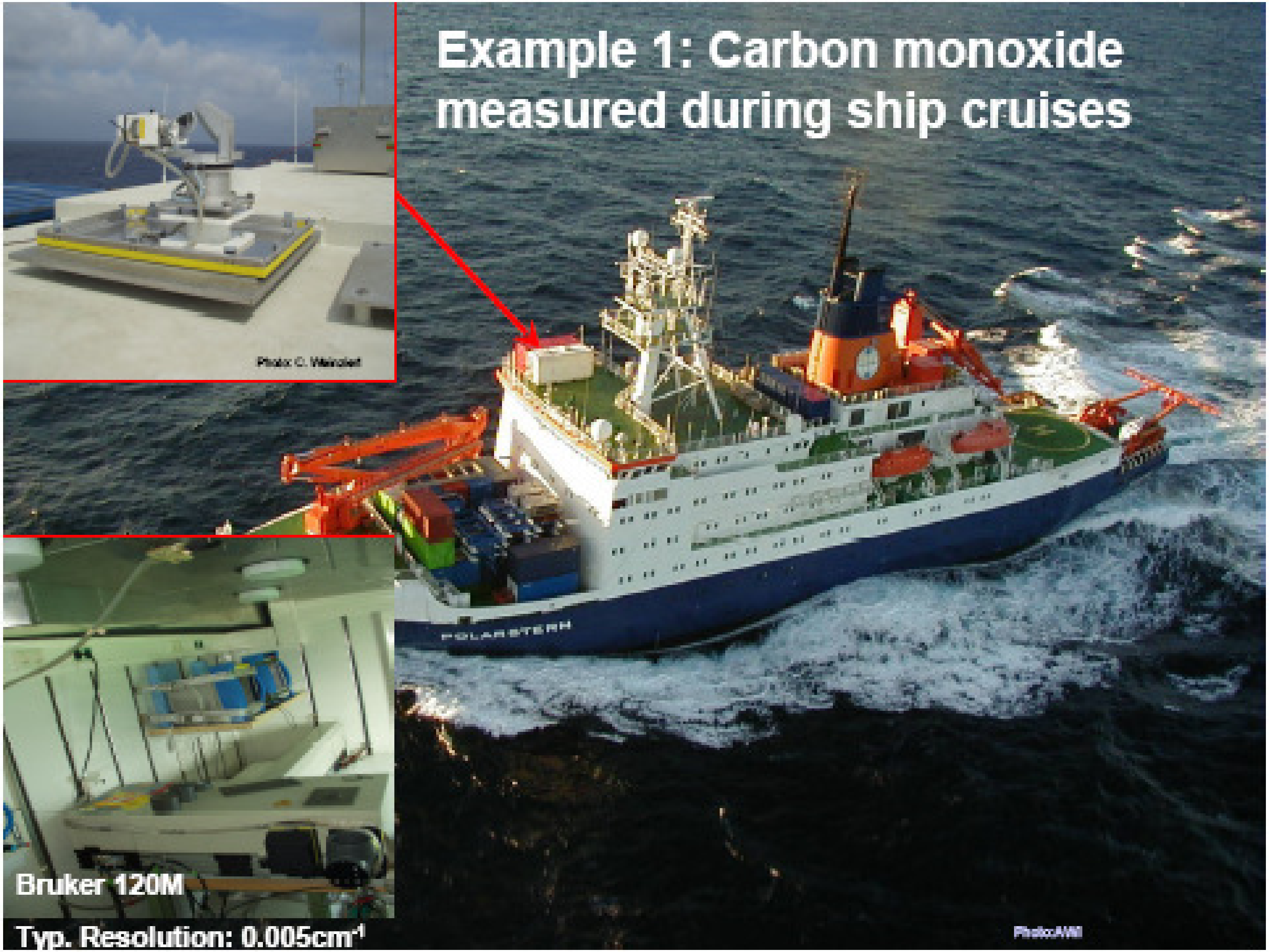


Carbo Africa

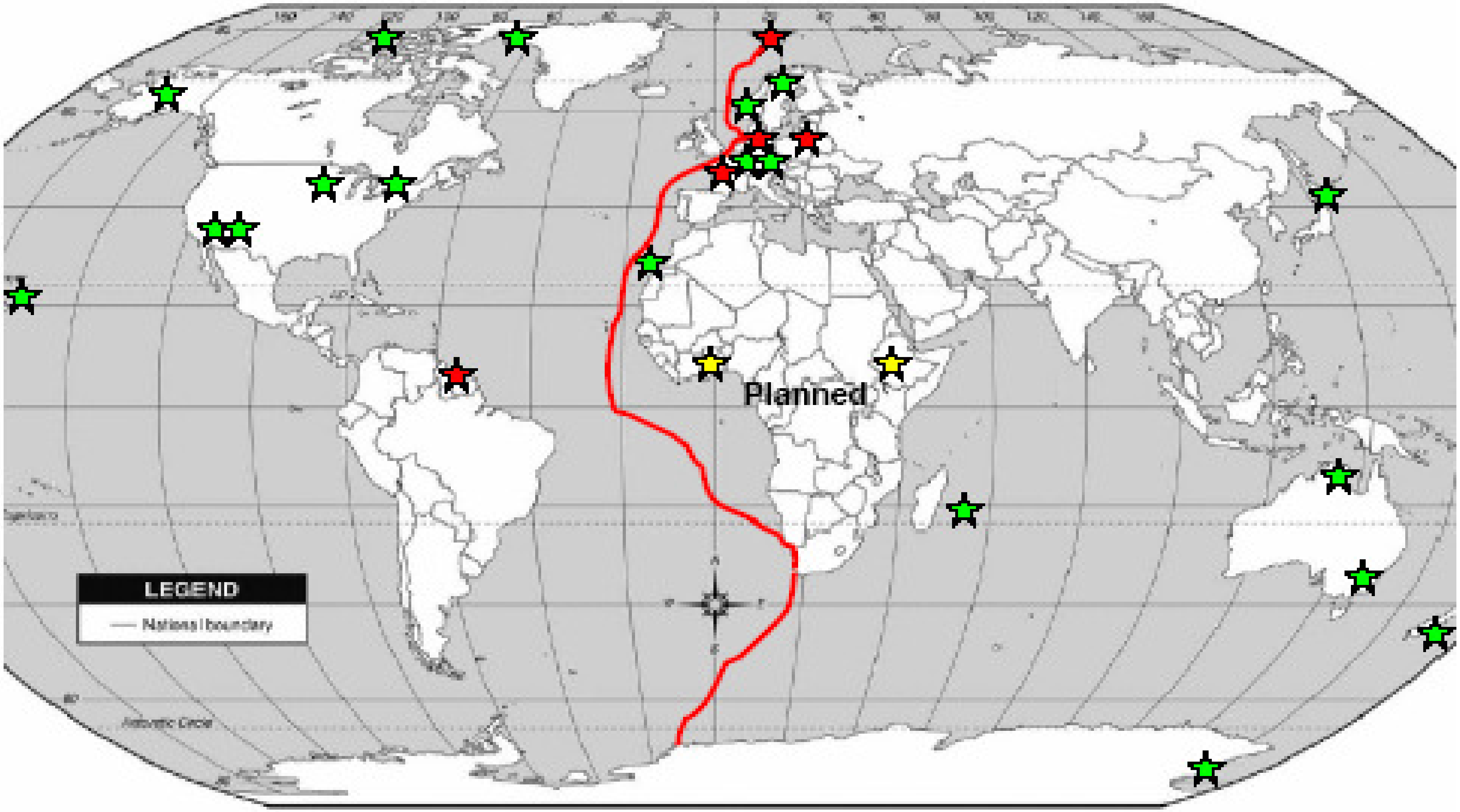

Measurements
Satellite
100
Stratosphere
10
Free Troposphere
Aircraft
(0-20km)
altitude (km)
1
Tall tower
(~500m)
Boundary
layer
0.1
0.01
Surface air
sampling
FTIR

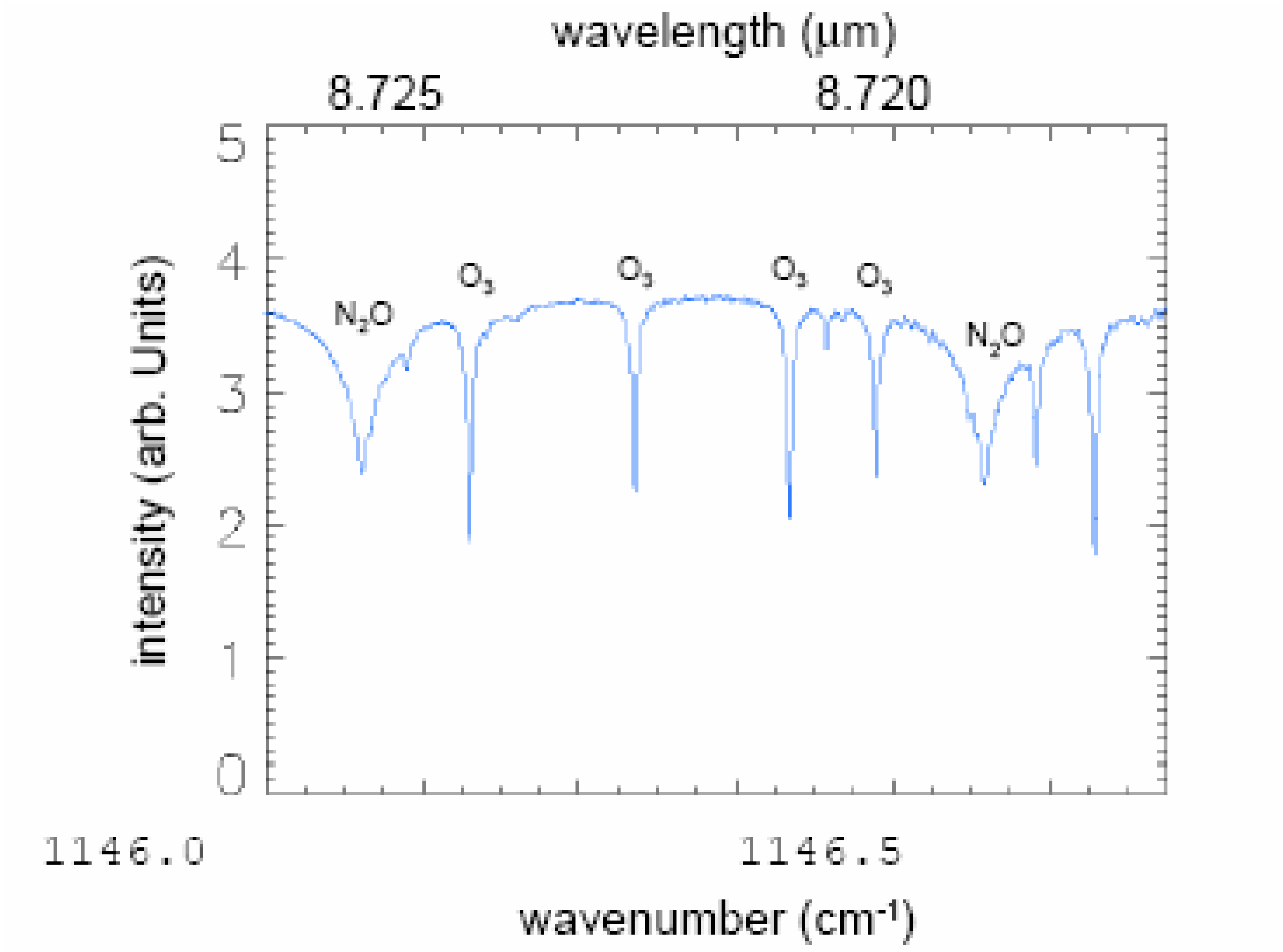
Solar Absorption FTIR Spectrometry




Example 1: Carbon monoxide
measured during ship cruises
POLARSTERN
Bruker 120M
Typ. Resolution: 0.005cm-1

Some FTIR Measurement Sites





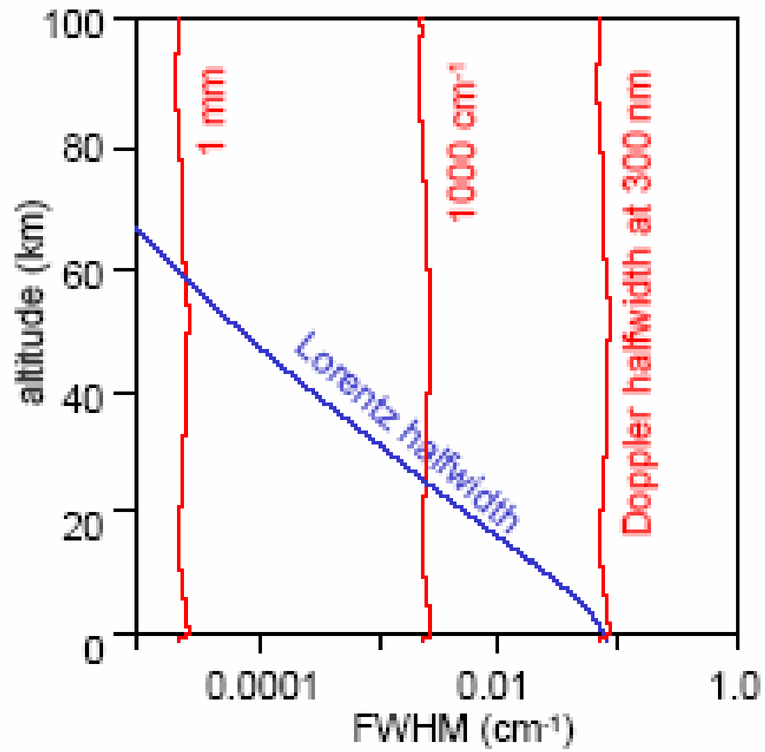
- Each trace gas has it‘s own ‘fingure print‘ in the spectrum
- Databases with millions of spectral lines
  (HITRAN, ATMOS, GEISA)

Data Analysis

Simulation of spectrum for specific α, T, p, vmr's, resolution ...
Comparison between simulation and measurements
residuals

→ total columns of 20-30 trace gases (mol. cm^{-2})
→ analysis of spectral line shape: concentration profiles (ppbv)
(IR: ~ 30 km, MW ~ 70 km)

1. **constant**
   N_2
2. **long lived**
   CO_2, N_2O, CH_4,
   CFC-11, CFC-12, CFC-22
3. **troposphere**
   C_2H_2, C_2H_6, CH_2O, CO, HCN, COS,
   SF_6, NH_3, H_2O
4. **stratosphere**
   O_3, HCl, ClO, $ClONO_2$,
   HNO_3, NO_2, NO, COF_2



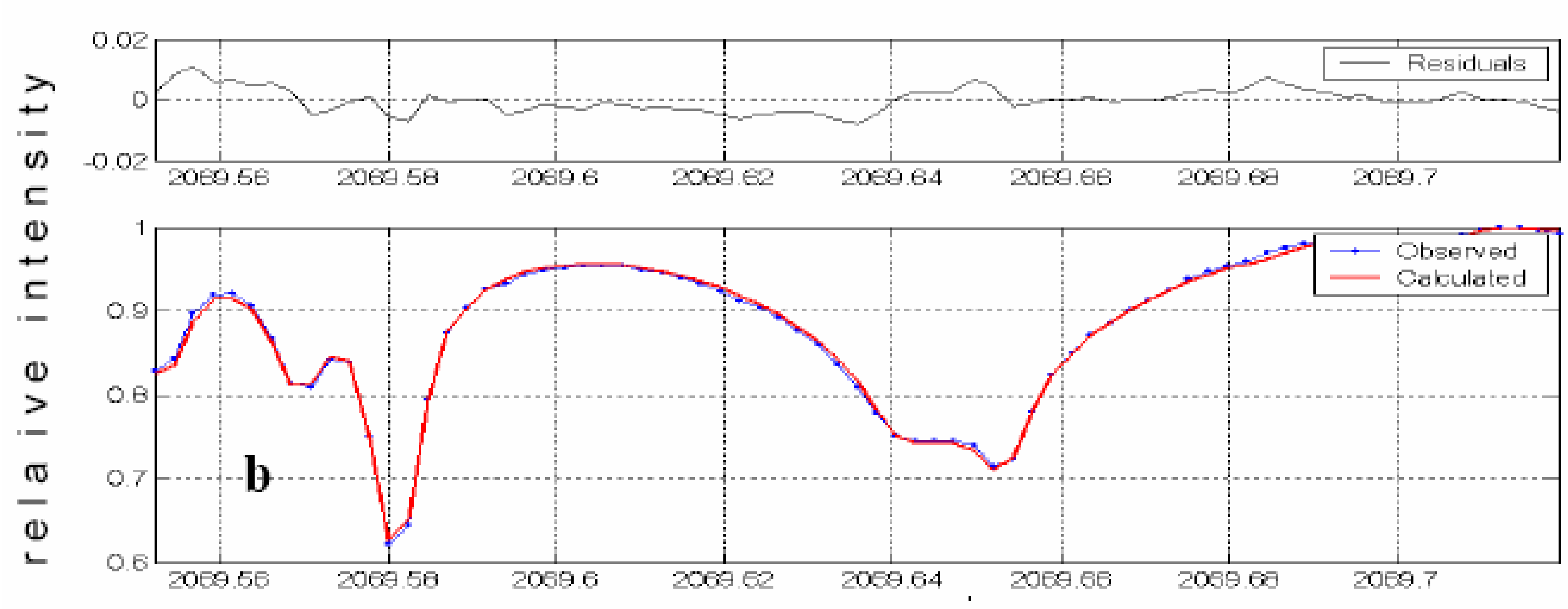
Choosing optimal micro-windows

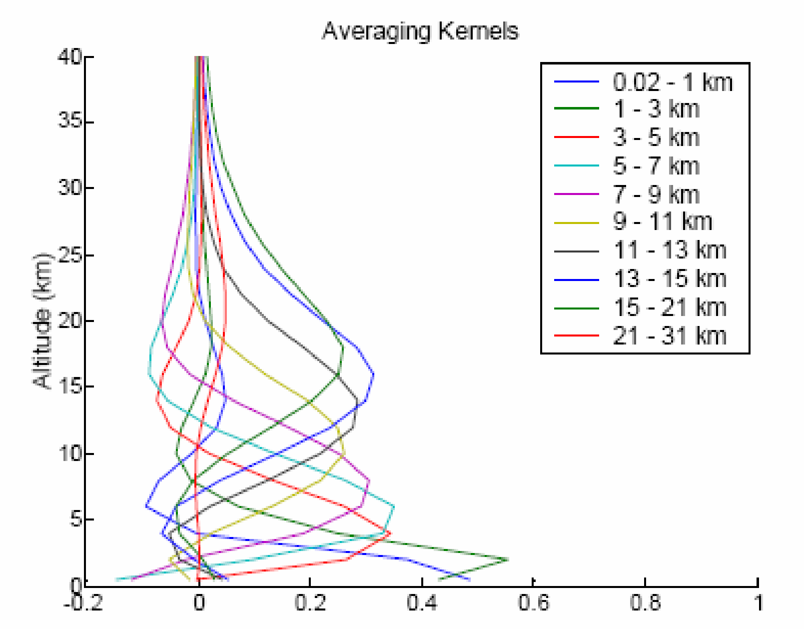
- Using an updated line list
- Choosing an appropriate layering scheme.
- Choosing the best *a priori profiles*
- Optimizing the tuning parameters (SNR, *a priori uncertainty, etc.)*
- Characterizing the errors and information content of the retrievals

	Microwindow (s) (cm^{-1}) used simultaneously	Interfering species;	DoFs / Alt_{max} (km)
O_3	1000.0 – 1005.0 1110.0 – 1113.0 1117.3 – 1117.9 1120.1 – 1122.0	H_2O, N_2O, CH_4	5 / 35
CO	2057.70 – 2057.91 2069.55 – 2069.72 2157.40 – 2159.35	H_2O, N_2O, O_3, solar lines	4 / 18
C_2H_6	2976.50 – 2977.20	H_2O, O_3, CH_4	2 / 30
N_2O			
Option 4 µm	2481.30 – 2482.60 2526.40 – 2528.20 2537.85 – 2538.80 2540.10 – 2540.70	H_2O/HDO, CO_2, O_3, CH_4	4.5 / 30
Option 8.5 µm	1161.34 – 1161.66 1182.49 – 1182.83 1183.25 – 1183.74	O_3, HDO, CH_4	4.5 / 30
$CHClF_2$ (HCFC-22)	828.8 – 829.35	H_2O/HDO, CO_2, O_3, ClO, C_2H_6, solar lines	1 / 25

Best micro-window for retrieving trace gases by infrared remote sensing (Velazco 2006)

Spectral Fit and Residual and Averaging Kernel





Velazco *2006*

CO sources from MPIC-model

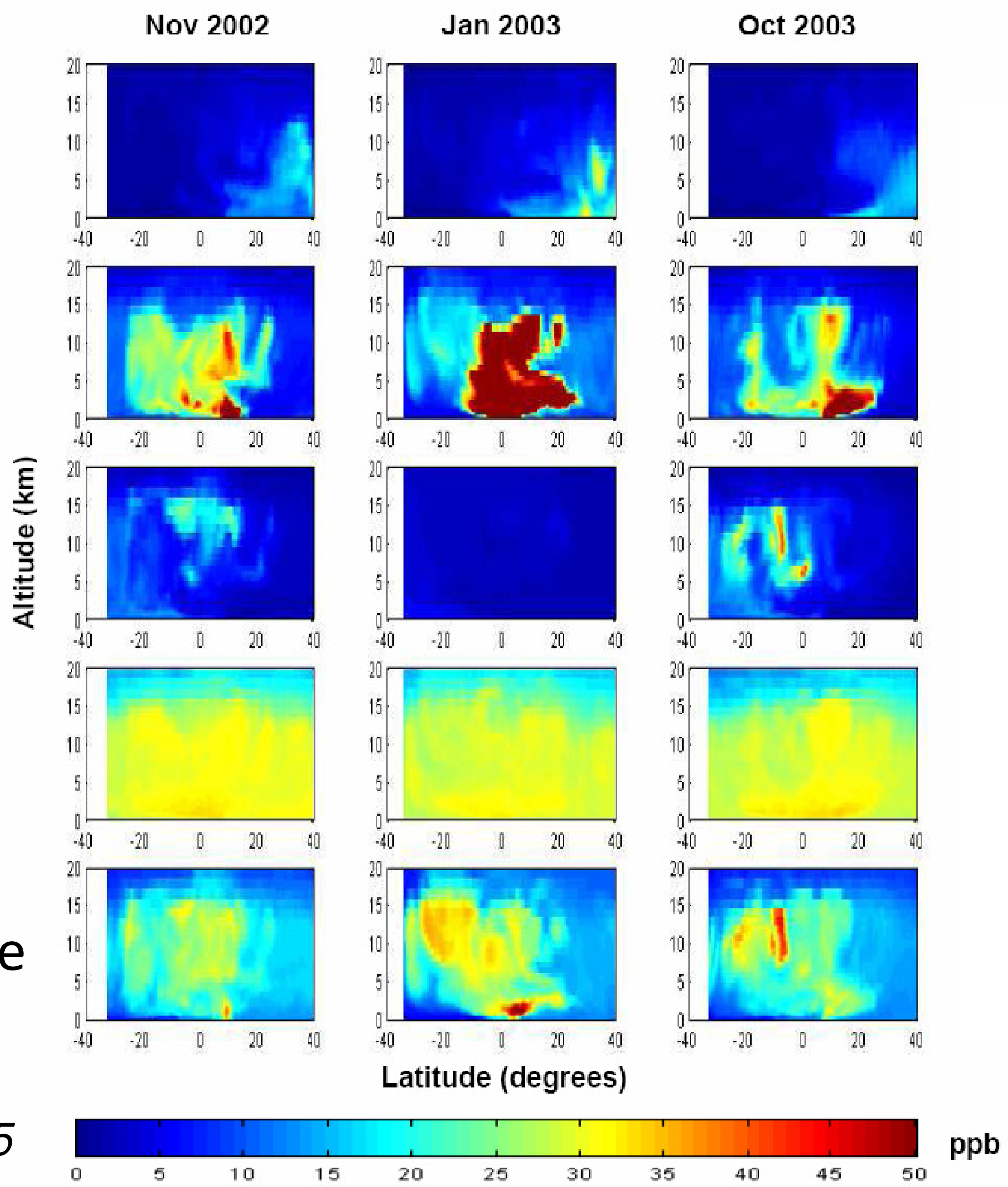
N. America fossil fuel

Africa Biomass burning

S. America fossil fuel

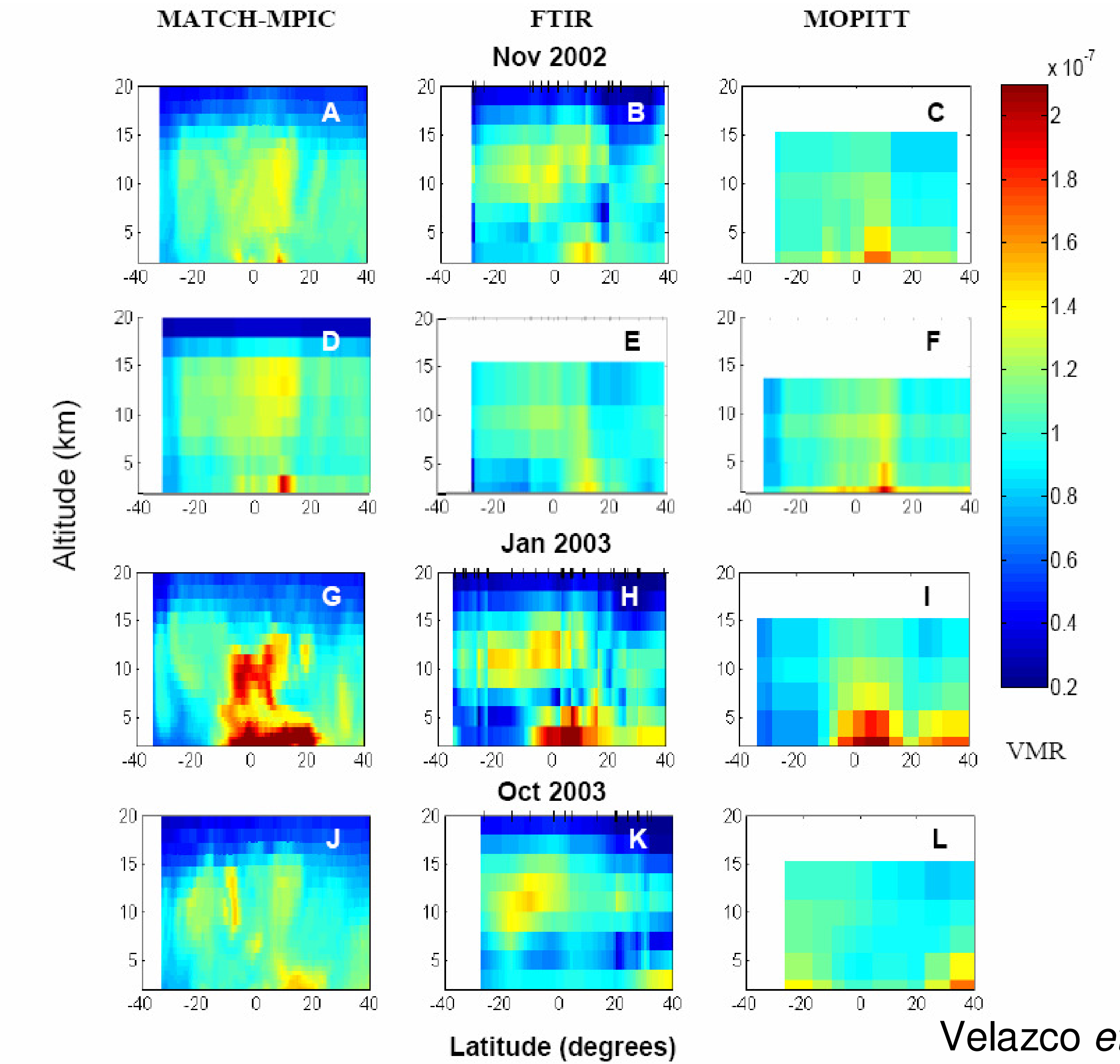
Methane oxidation

Oxidation of Non Methane Hydrocarbon



Velazco *et al, JGR 2005*

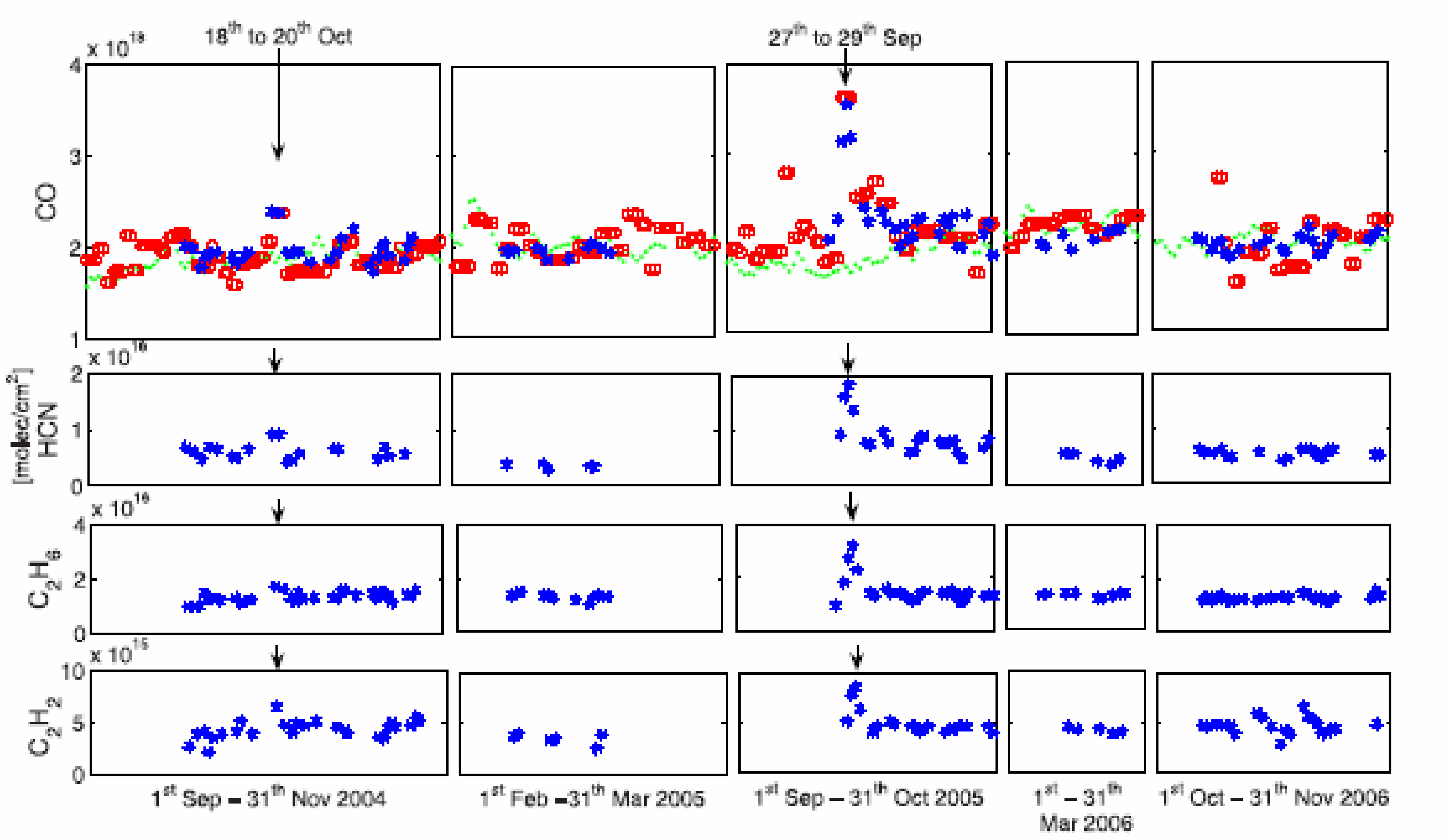
CO comparisons (Model, FTIR, and Satellite)



Velazco *et al, JGR 2005*

Measurement Site in the tropics Paramaribo, Suriname
(lat. 5.8 ° N, Long. 55.2 ° W)

FTIR CO (blue) validated with MOPITT(red) and MPIC model (green)



Others traces gases simultanously retrieved from FTIR data

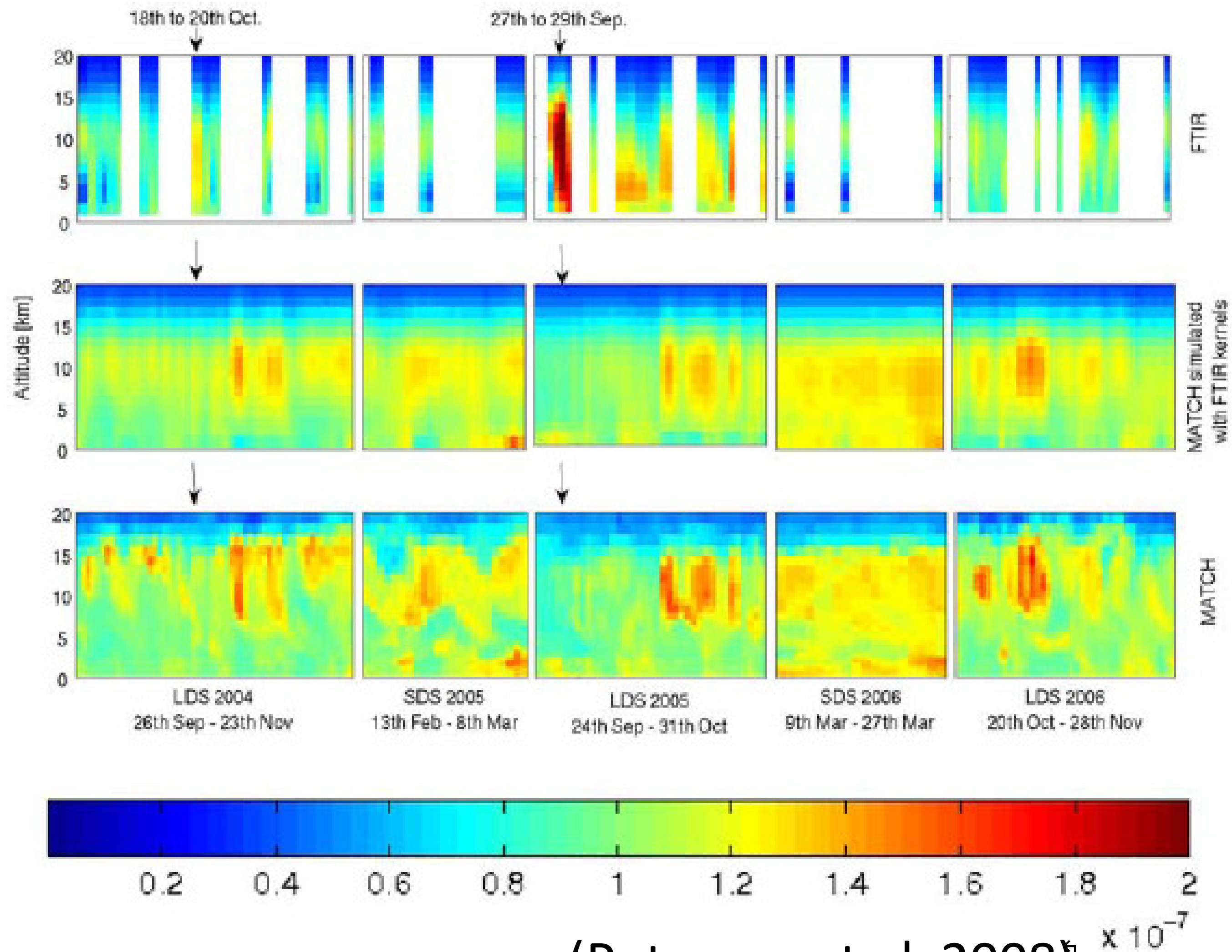
Source: (Petersen et al. GRL, 2008)

FTIR CO over Paramaribo comparison with MPIC model

FTIR CO in Paramaribo

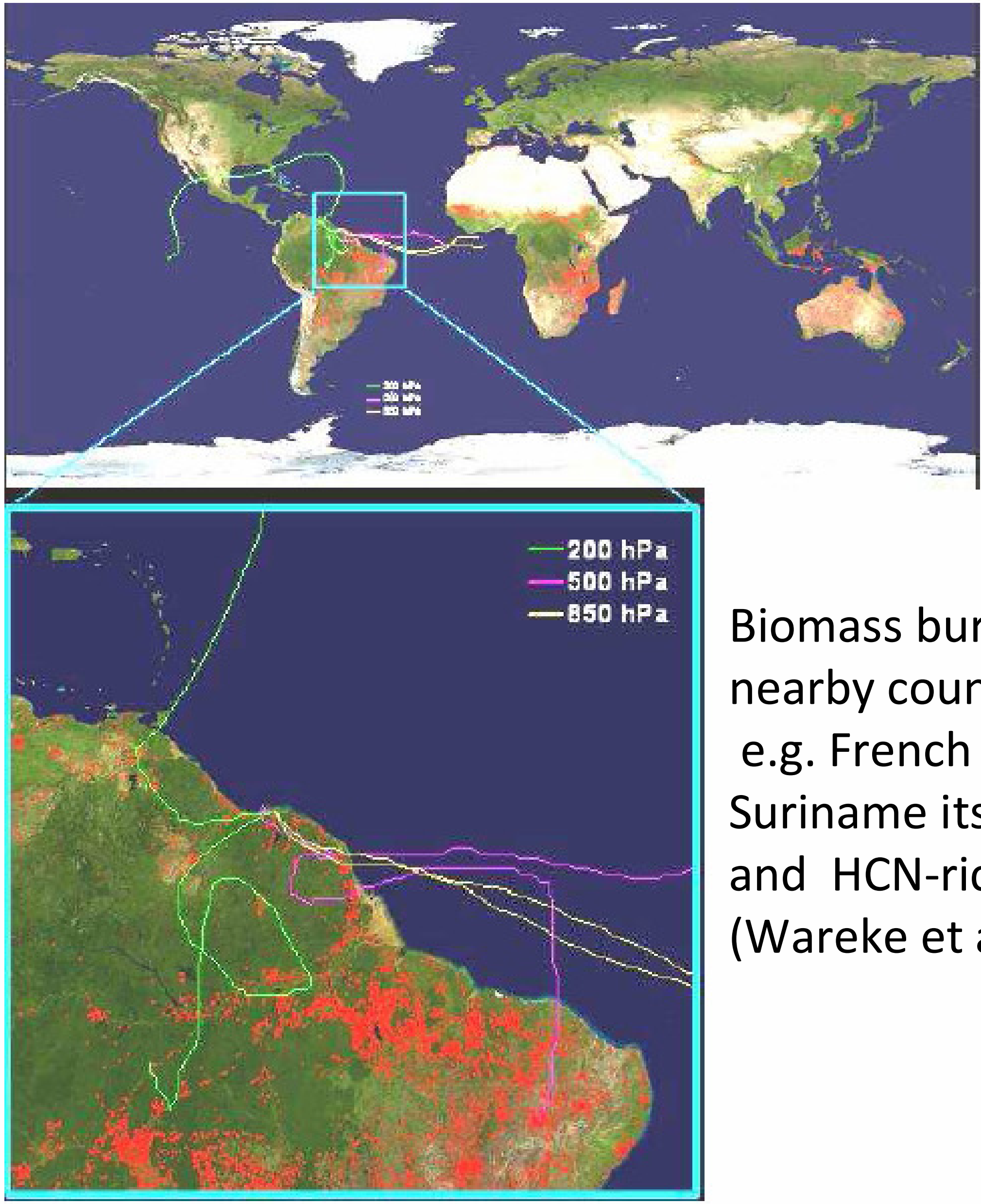
MPIC CO smooth by Ave. Kernel of FTIR

MPIC model CO



FTIR results are for 5 Measurement campaigns

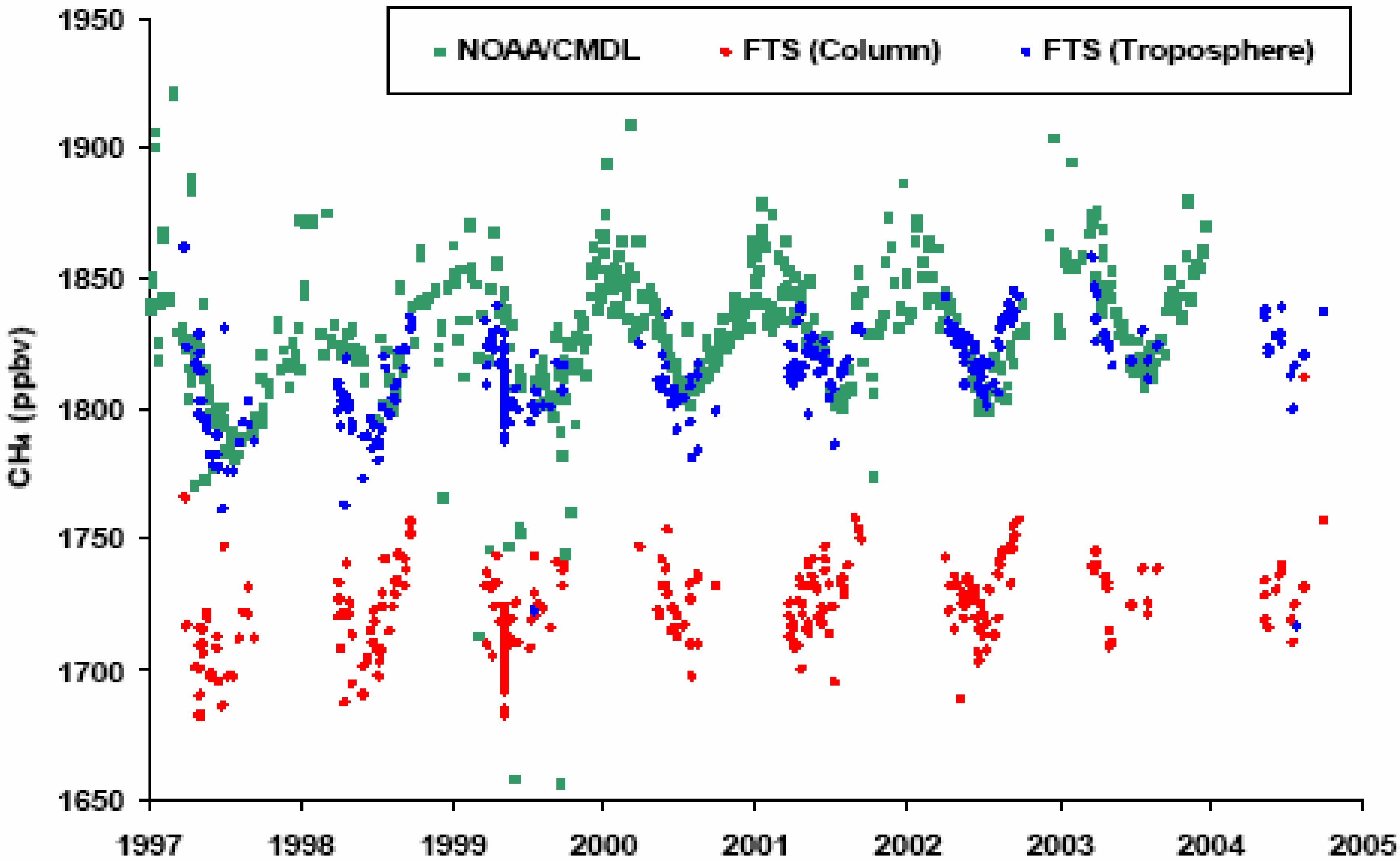
(Petersen et al. 2008)



Biomass burning activities from nearby countries,
e.g. French Guiana, Brazil, and Suriname itself are source of CO and HCN-rich air parcel (Wareke et al. 2005)

Ten days backward tajectories

Seasonal variation of CH_4 at Ny Alesund



Warneke *et al*, GRL 2006

Summary

- Solar absorption FTIR-spectrometry is a vital component of the global observing system for atmospheric trace gases.

- It is essential to establish the link between *in situ and satellite* measurements.

- FTIR spectrometer is well suited for the measurements of trace gases related to biomass burning and all other greenhouse gases.

- Currently there is a lack of measurement sites in the tropics and no site in Africa.

- It is planned to establish a measurement site at Kumasi (Ghana), but funding not yet secured.

Outlook: As new Meteorology and Climate Science Institute in Ghana?

- Develop experiment (FTIR spectrometry) to measure GHG and tropospheric pollutants (collaboration with IUP, University of Bremen, Germany).
- Sun-photometers to measure aerosol properties
- Humidity, temperature and pressure sensors
- More efficient rain gauges e.g. pluvio rain gauge
- Development of regional models
- Man-power training (M.Sc. and PhD studentship)
- Formation of very strong local research group
- Education/ Public Seminars on climate related issues