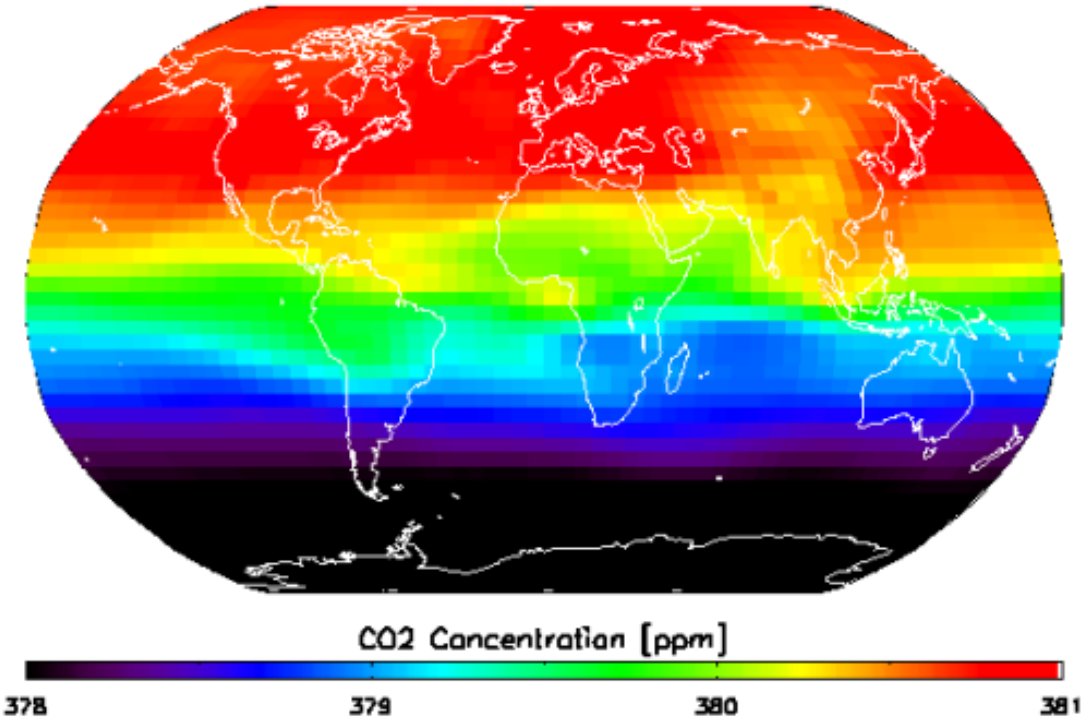
Carbon Tracker – Asia



Chun-Ho Cho and Tae-Young Goo
National Institute of Meteorological Research / KMA

How does CarbonTracker work?

2. Simulated CO_2 concentrations

State vector (Flux **x**)

Error covariance matrix S_p

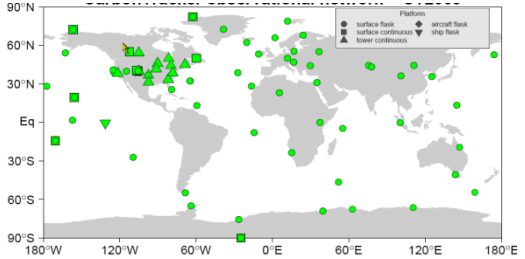
$$y = Hx^p + \varepsilon$$

Observation vector **y**

Error covariance matrix S_y

1. Fluxes(sources & sinks)

Forward model

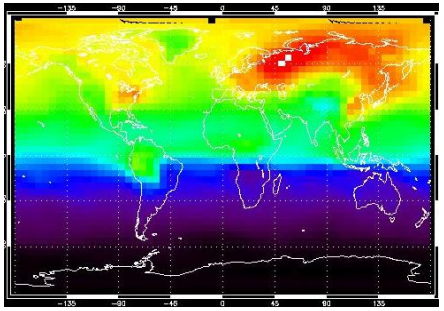


Inverse model

3. Comparison of CO_2 calculated by the model with the measurements

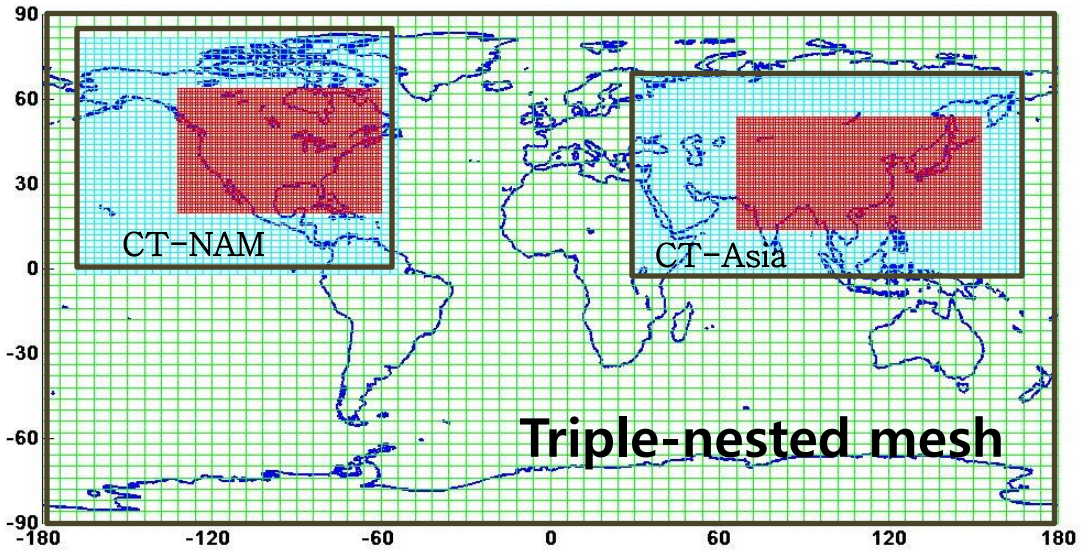
4. Corrected fluxes(Biosphere & Ocean)

$$x^a = x^p + (H^T S_y^{-1} H + S_p^{-1})^{-1} H^T S_y^{-1} (y - Hx^p)$$



5. Analyzed 3-D CO_2 concentration

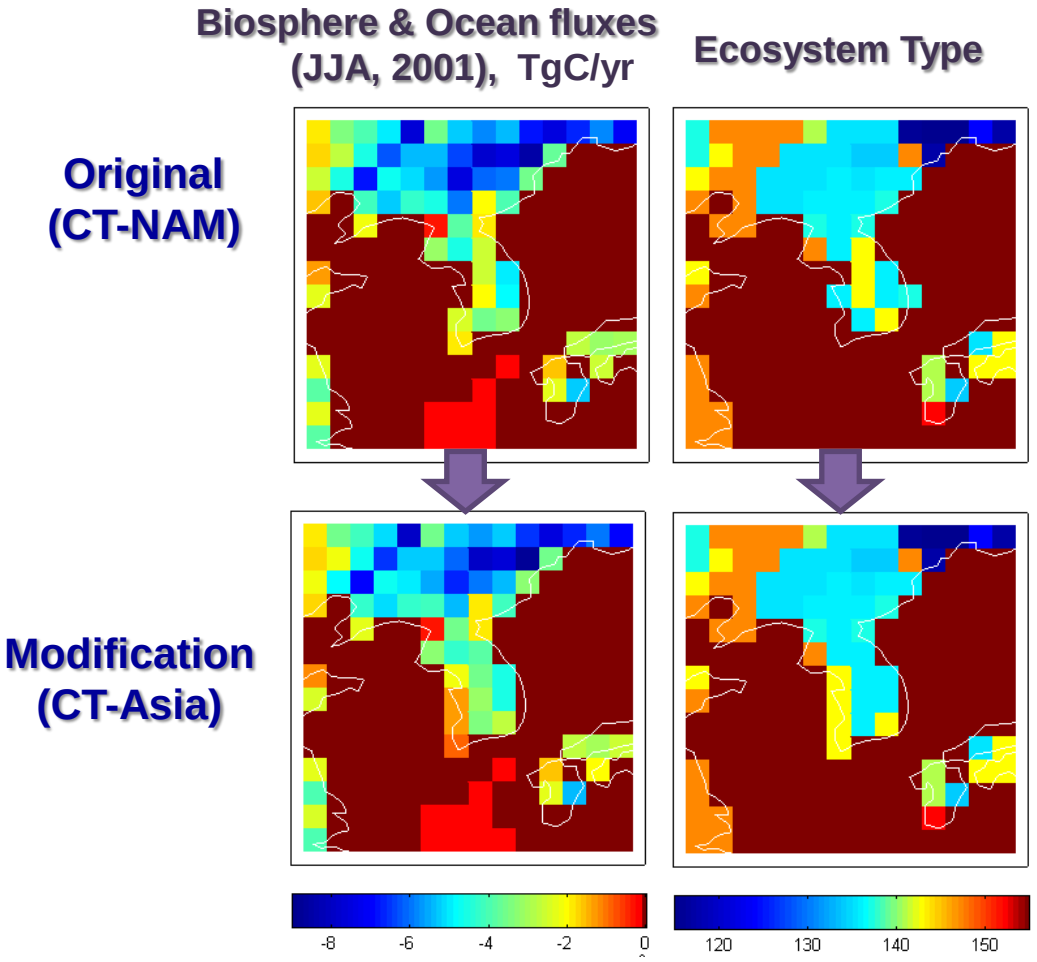
What is CarbonTracker-Asia? I



- **CT was originally developed by NOAA's Earth System Research Laboratory to focus on North America. Here the system is applied in Asia as CarbonTracker-Asia.**
- **The TM5 domain consists of the triple-nested mesh (global: 6˚x4˚, intermediate region: 3˚x2˚, North America(NAM) or Asia: 1˚x1˚).**

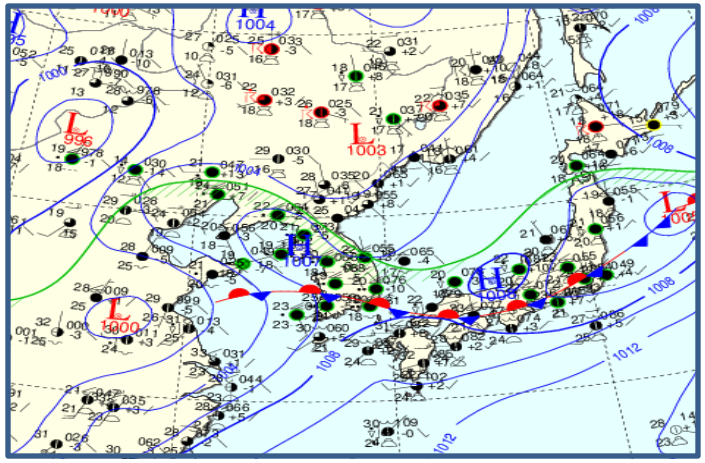
What is CarbonTracker-Asia? II

Modified surface conditions in Korea



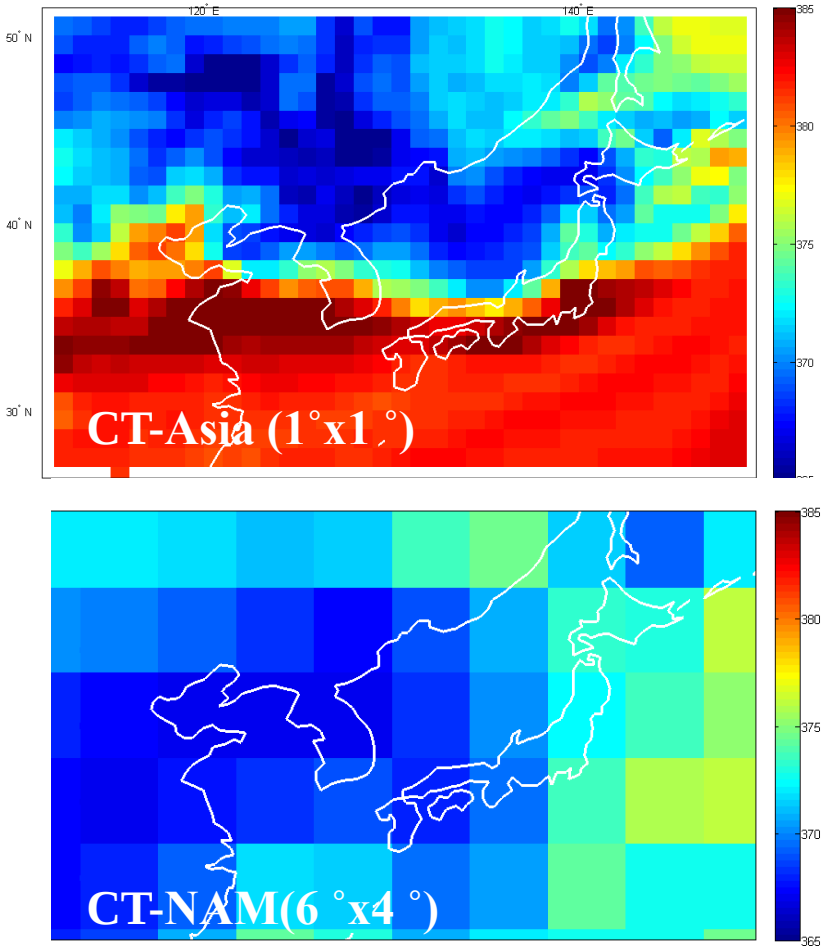
[JJA, 2001]

Comparison CT-Asia with CT-NAM



17 July 2006 at 09UTC

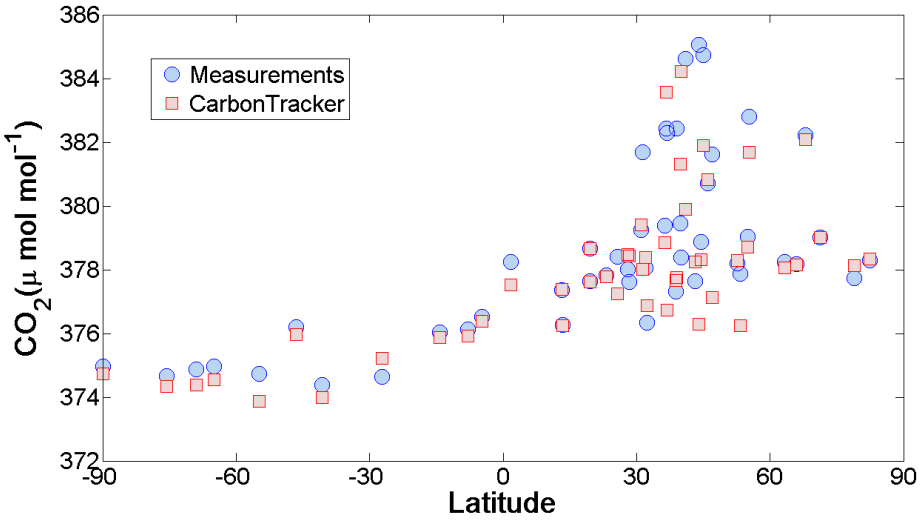
7th level (1839m)



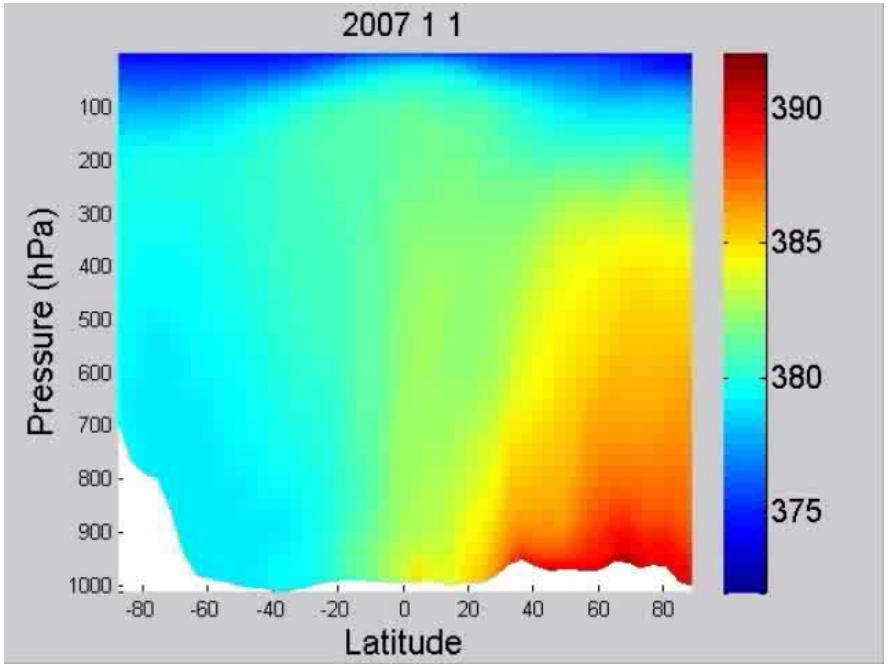
- The CT-Asia with fine resolution shows clearer the shape of Asian Monsoon front .
- It also shows vivid urban plumes.

Meridional gradient of CO_2 Concentration (2000-2008)

Average measured and simulated surface CO_2 Concentration as a function of latitude at 48 sites

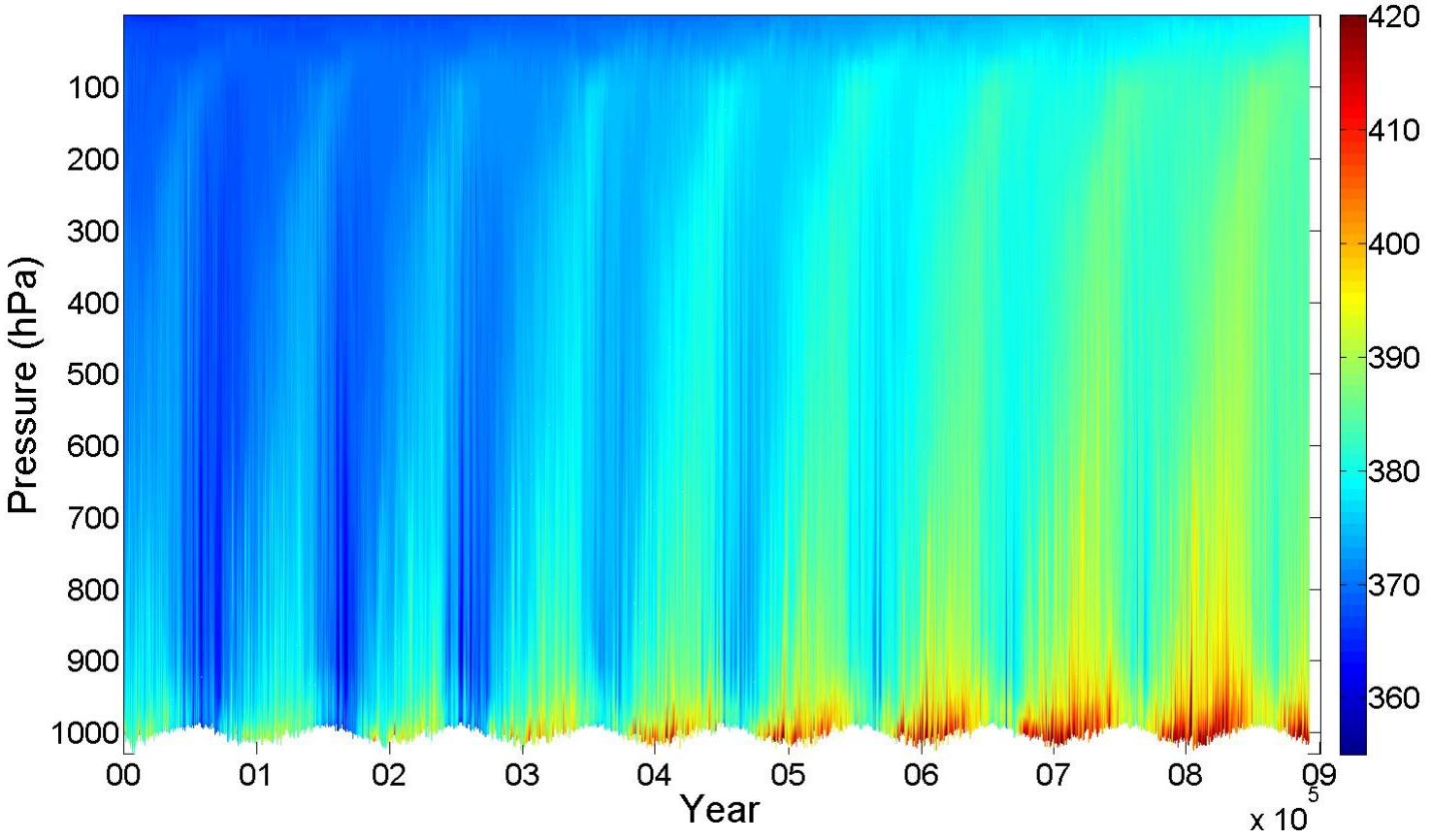


Zonal averaged CO_2 Concentration in 2007



North-south gradient and concentration at sites are reproduced well by CarbonTracker.

Time series of vertical profile CO_2 in Korea (2000-2008)

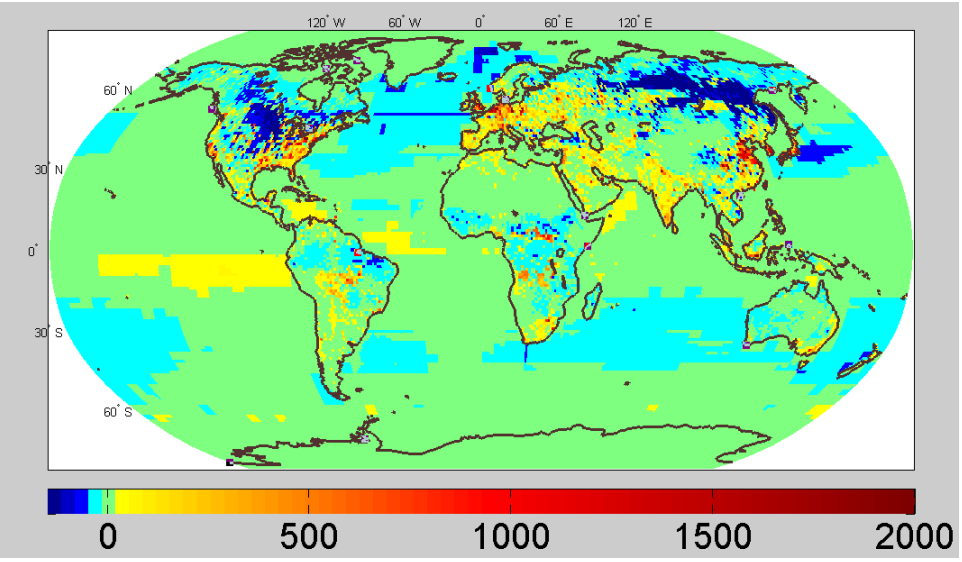


CO2 concentration has been increased in lower and upper levels with seasonal variation in Korea.

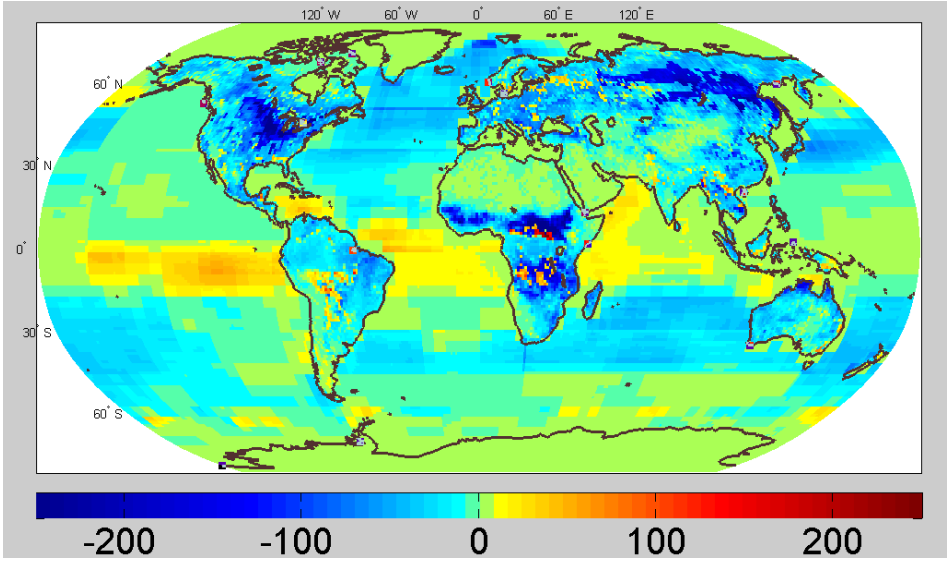
Spatial Distribution of Global CO_2 Fluxes (2000-2008)

[g C m^2 yr^{-1}]

(a) Total Flux (fossil fuel+fire+biosphere+ocean)



(b) Biosphere & Ocean Flux

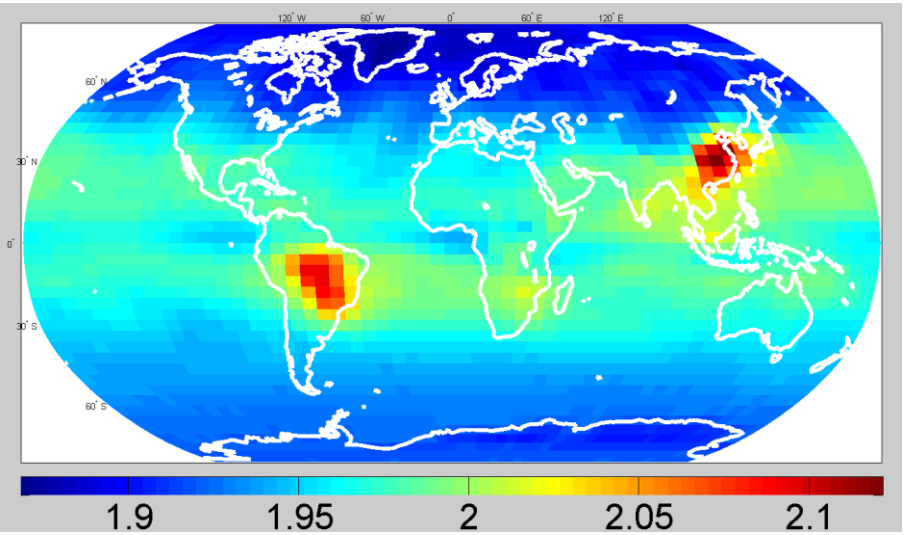


The total surface-atmosphere flux is dominated by the pattern of fossil-fuel emissions from the three major emission regions in the Northern Hemisphere: eastern North America, Europe, and eastern Asia, and CO2 uptakes in the boreal forest of the Northern Hemisphere and the crop/grass/shrub around Great Lakes.

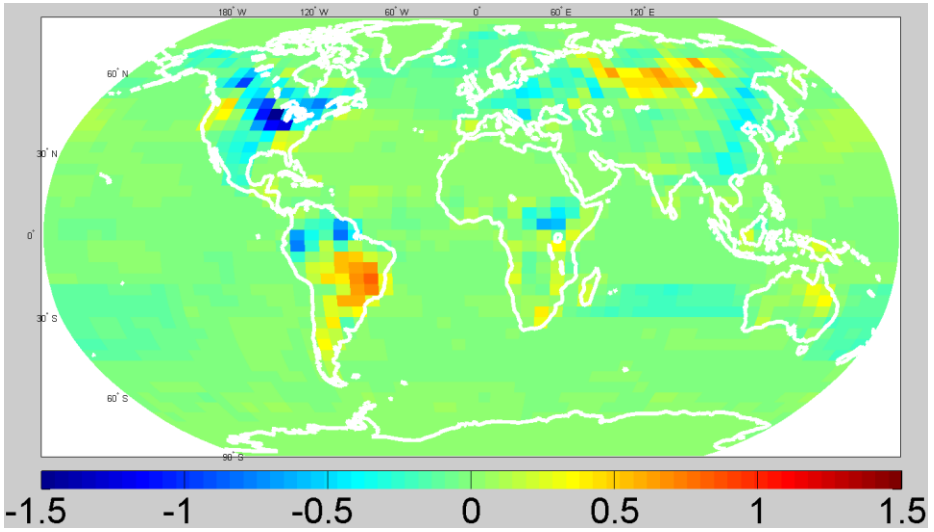
The mean pattern of the natural sources shows the expected outgassing in the equatorial oceans, the uptake in the North Atlantic Ocean, and the Northwest Pacific.

Global Distribution of CO_2 Growth Rate (2000-2008)

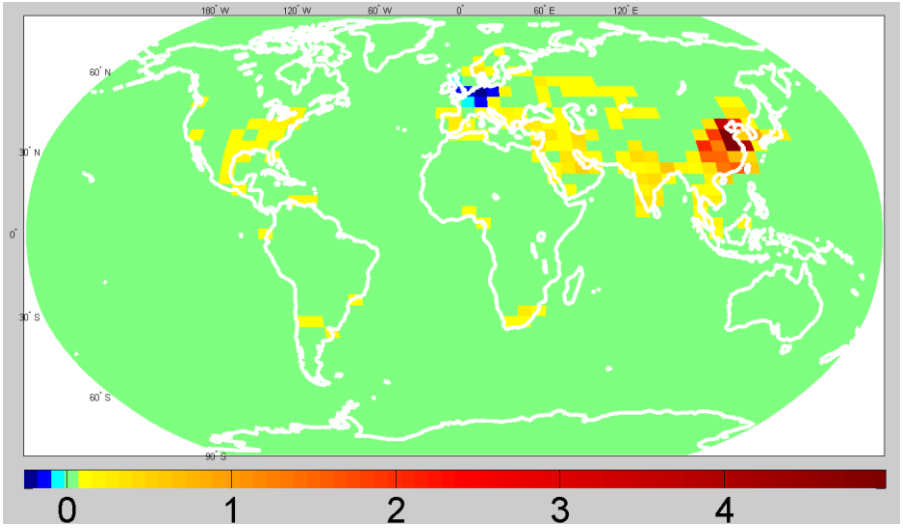
Column Concentration (ppm yr^{-1})



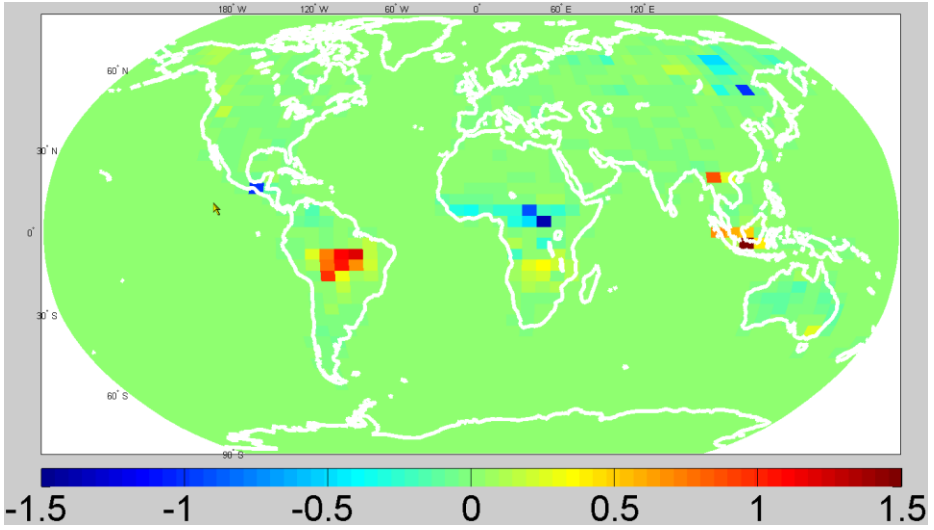
Natural Flux (gC m^{-2} day^{-1} yr^{-1})



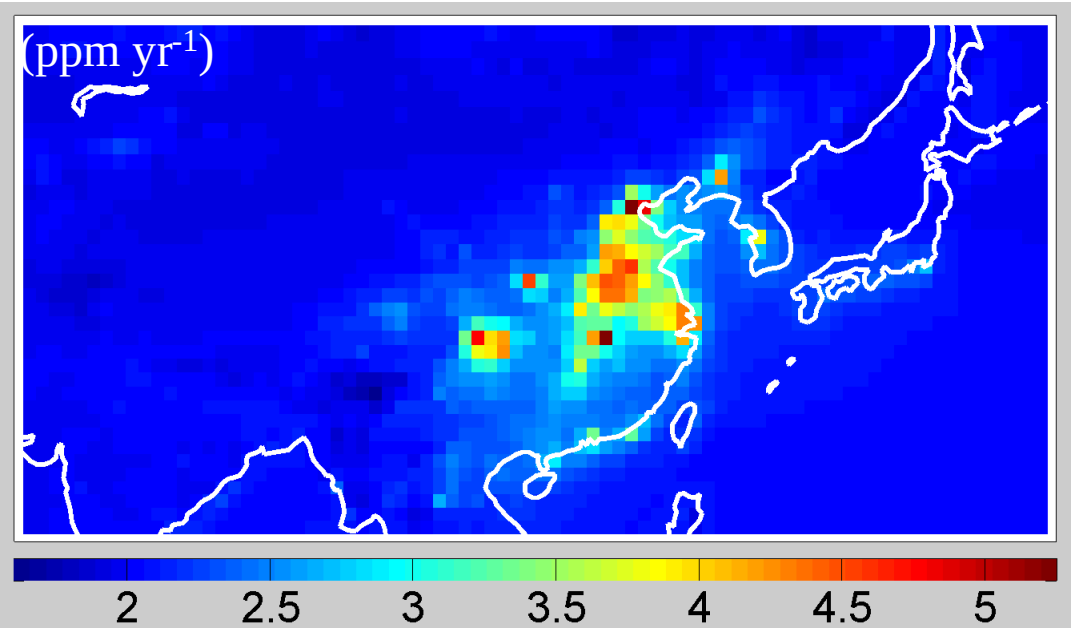
Fossil Fuel Flux (gC m^{-2} day^{-1} yr^{-1})



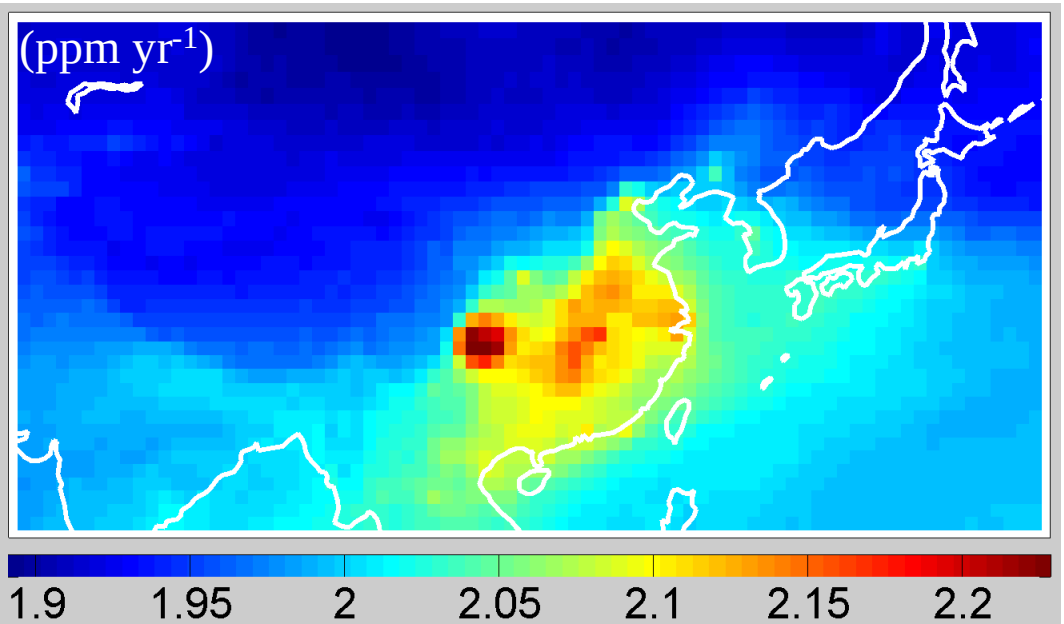
Wildfire Flux (gC m^{-2} day^{-1} yr^{-1})



Global Distribution of CO_2 Growth Rate (2000-2008)



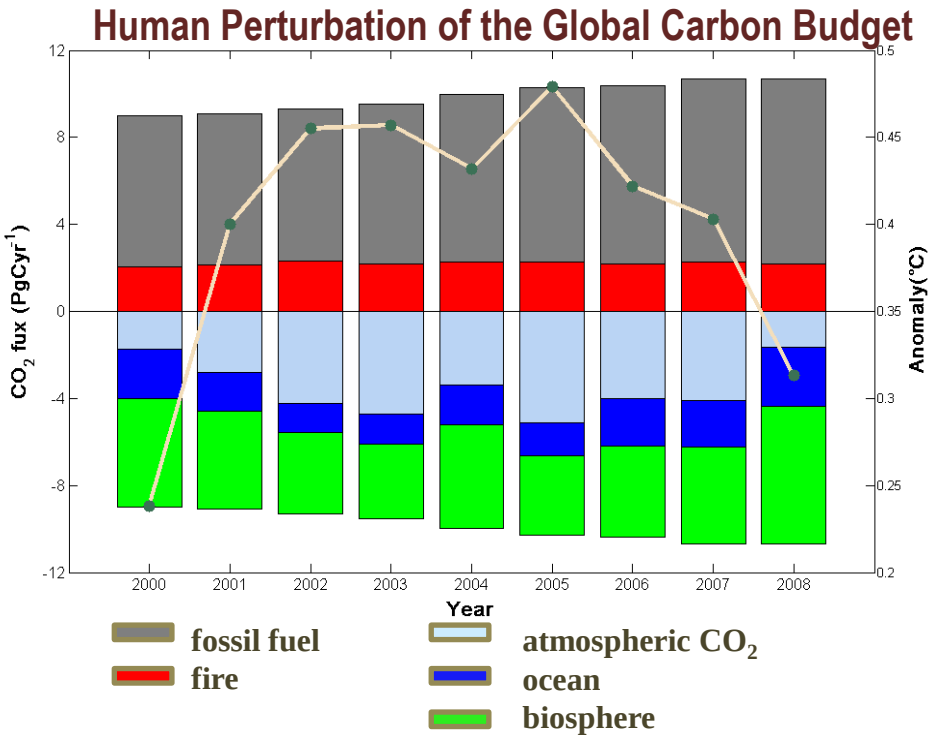
Surface Concentration



Column Concentration

The growth rate of column concentration is especially high in the Szechwan Basin of China. It seems to be due to the geographical effect.

Global CO_2 Budget



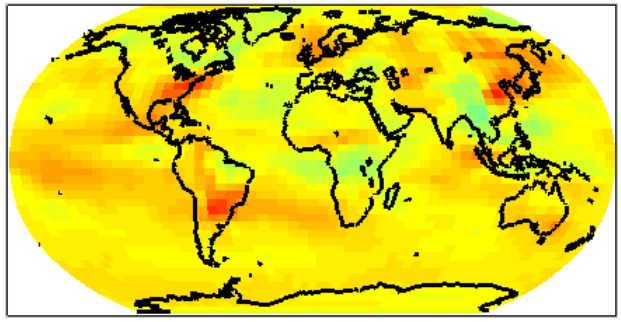
The atmospheric term is determined indirectly by the difference (fossil fuel+fire-ocean-biosphere).

The atmospheric CO2 accumulation shows an interannual variability, which is caused by corresponding strong variations in natural CO2 uptake, globally, from year to year.
The natural uptake is inversely correlated with global temperature anomalies.

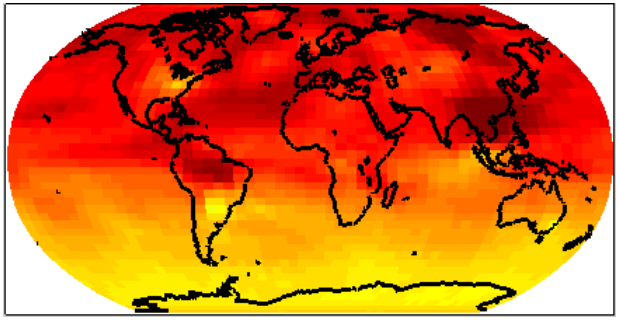
The decreased natural uptakes from 2002 to 2003 are related to the El Nino events of 2002/2003.
The natural uptake decreased during 2005 and it may be related to the highest mean temperature.

년도별 CO_2 농도의 증가율 (2002-2008)

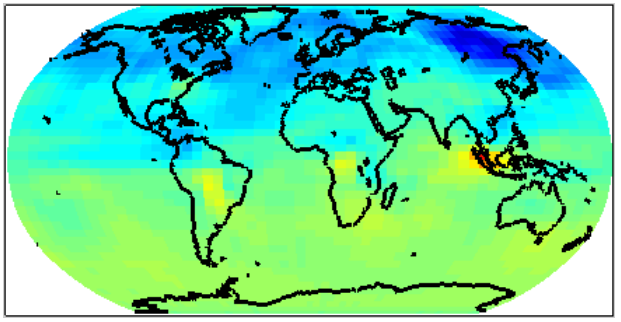
2002



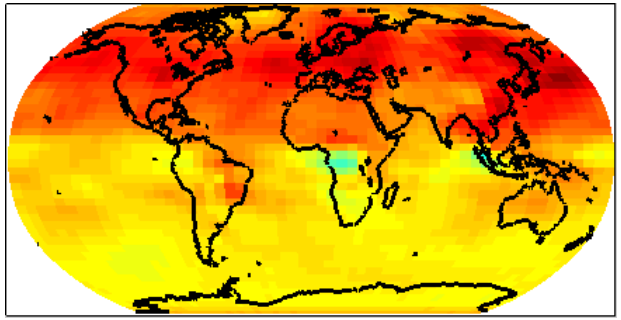
2003



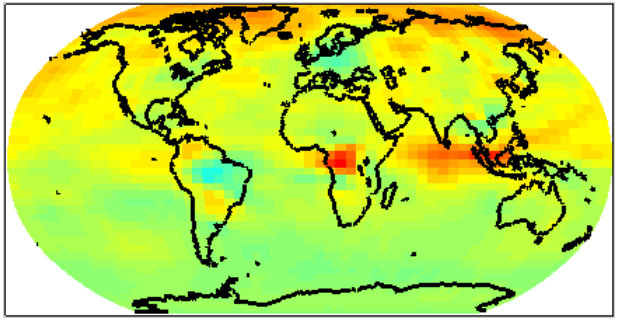
2004



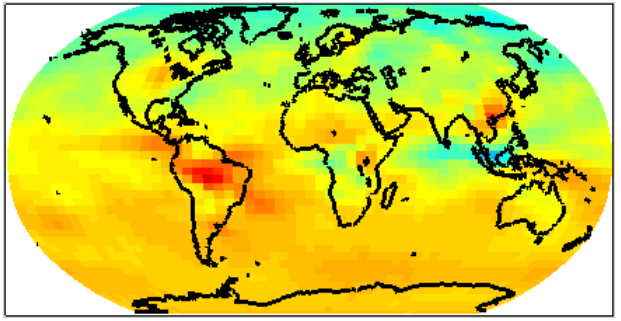
2005



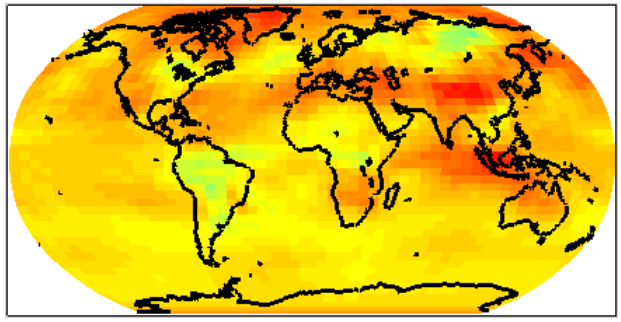
2006

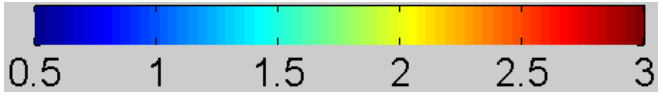


2007



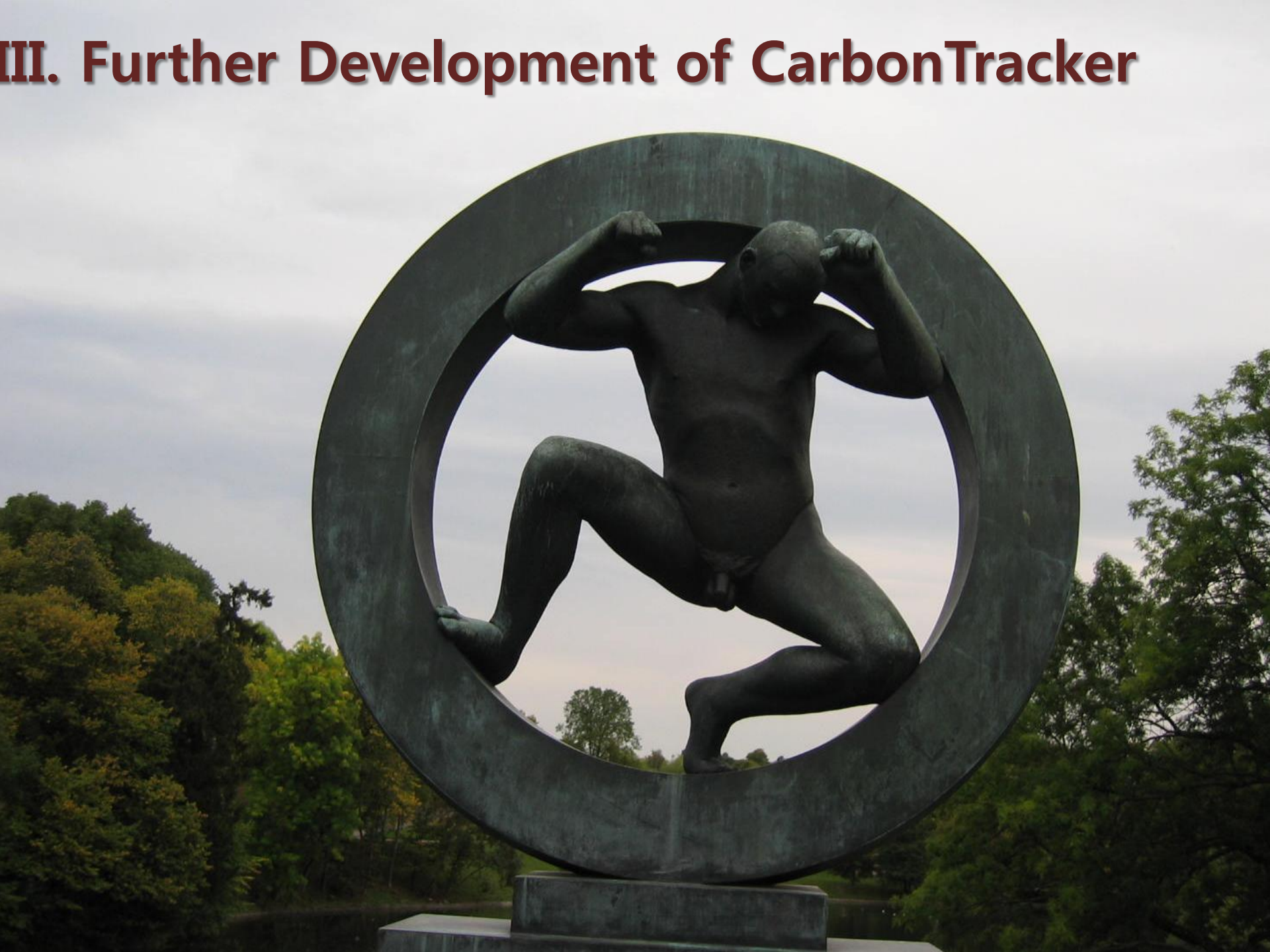
2008



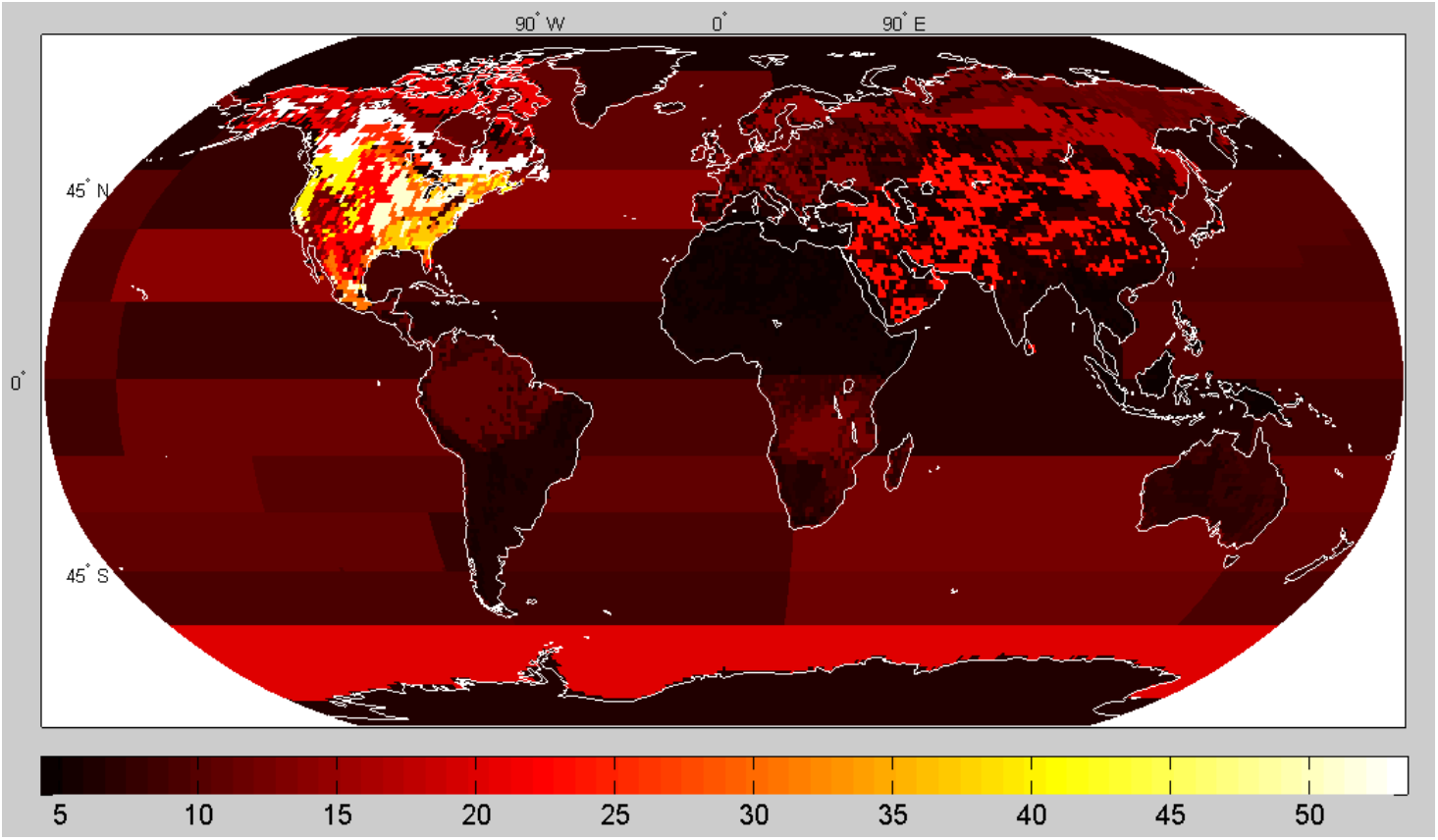


(ppm yr^{-1})

III. Further Development of CarbonTracker

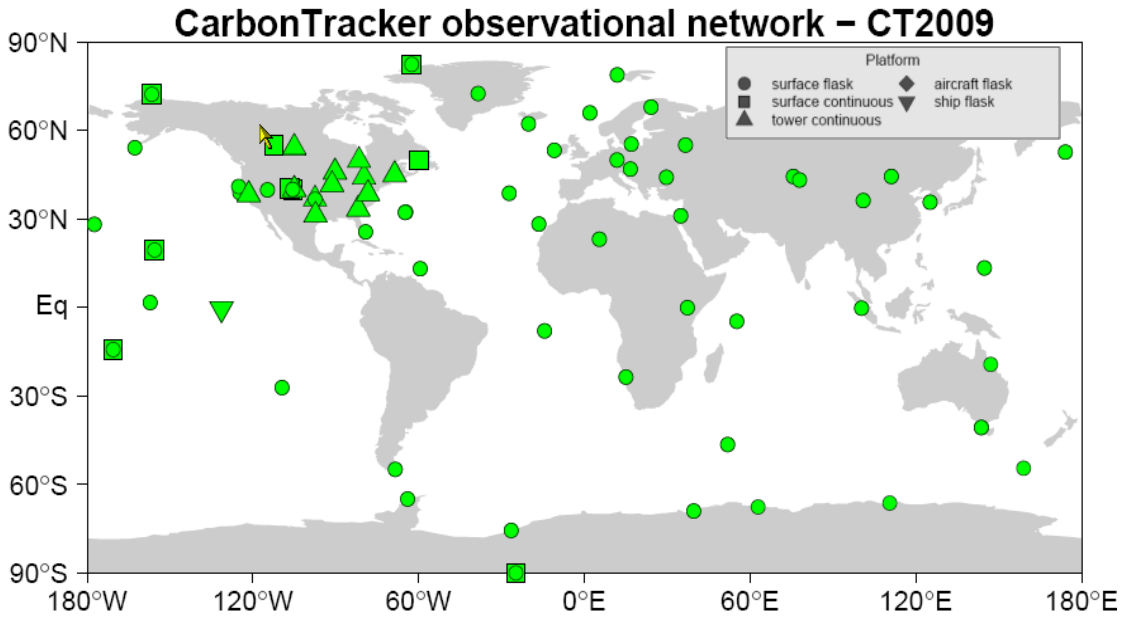


Uncertainty reduction provided by inverse method for the estimation of CO_2 fluxes (2000-2008)

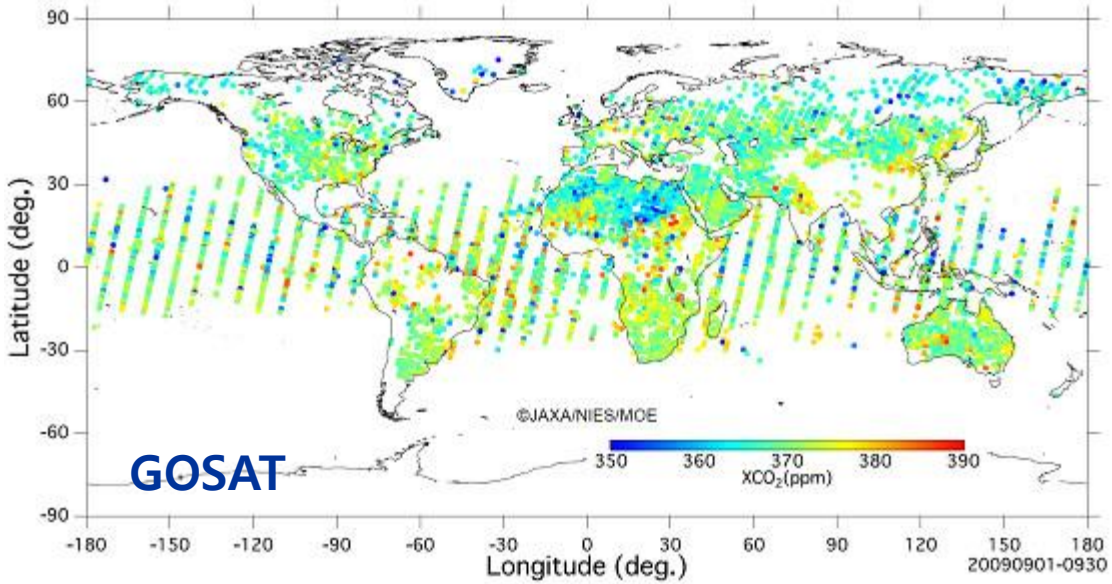


The extent to which the flux field is modified by the inversion can be shown the error reduction defined as:

[1-σ(posterior)/σ(a priori)]x100



~ 100 measurements a week

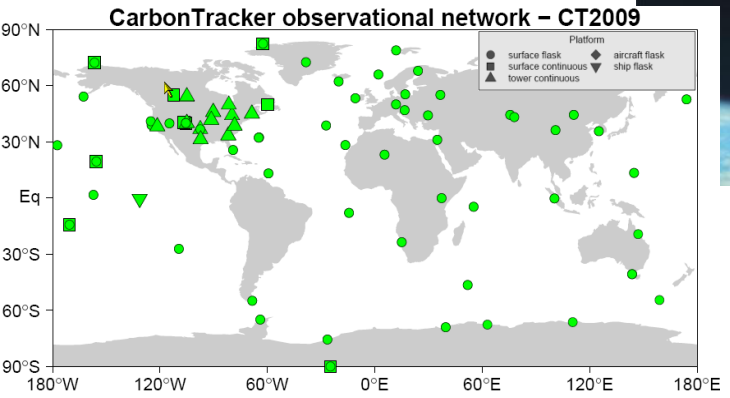


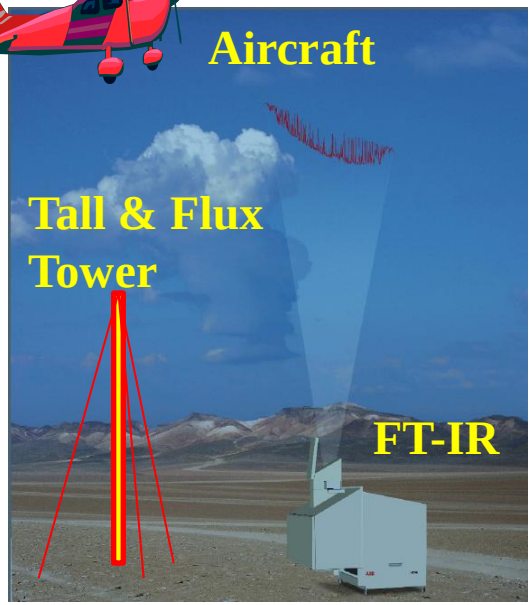
10000 measurements over the 3-day period

About 10 percent of the data collected are usable for calculating column abundances due to sky conditions.

Future Plan

- to retrieve CO2 from GOSAT
- to integrate observations in CarbonTracker
- to verify CarbonTracker & satellite retrievals by FT-IR, aircraft, and tower

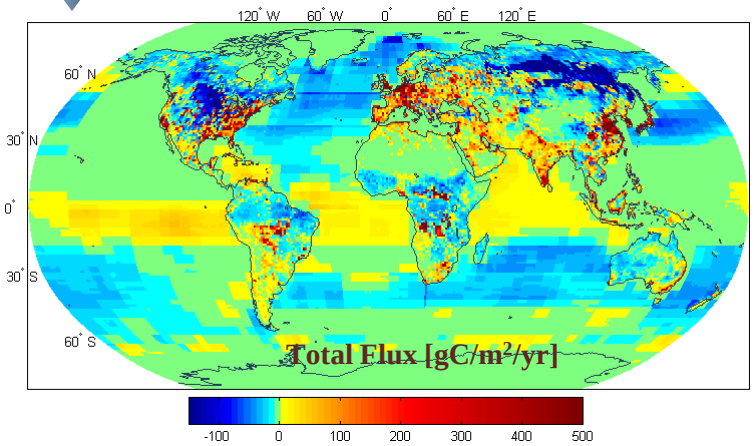




Observation

Priori state of CO_2 concentration

Verification



CarbonTracker

http://www.nimr.go.kr/metri_home/english/Laboratory/carbontracker/

Thank You !

2010 ARES Experiment

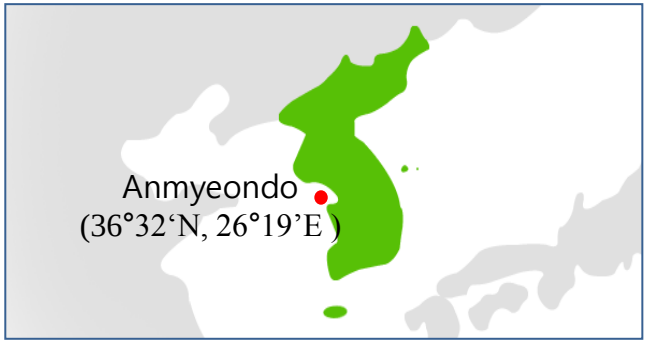
- 2010 ARES (Atmospheric Radiance and Environmental Species) experiment consists of:

(a) A ground-based FT-IR measurement

(b) Radiosonde observation

(c) Air sampling for greenhouse gases

- Site & Period
  - Site : Anmyeondo of the Tae-an peninsula
  - Period : (1st) 25~29 May
    (2nd) 8~10 Nov



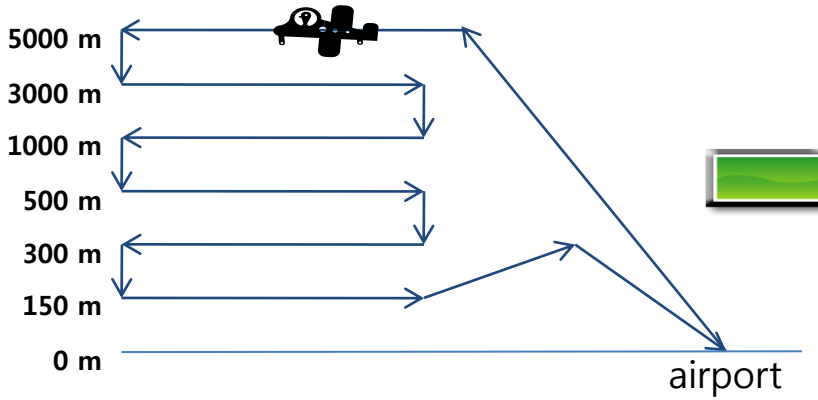
Anmyeondo Site in the west part of Korea

Experimental Design

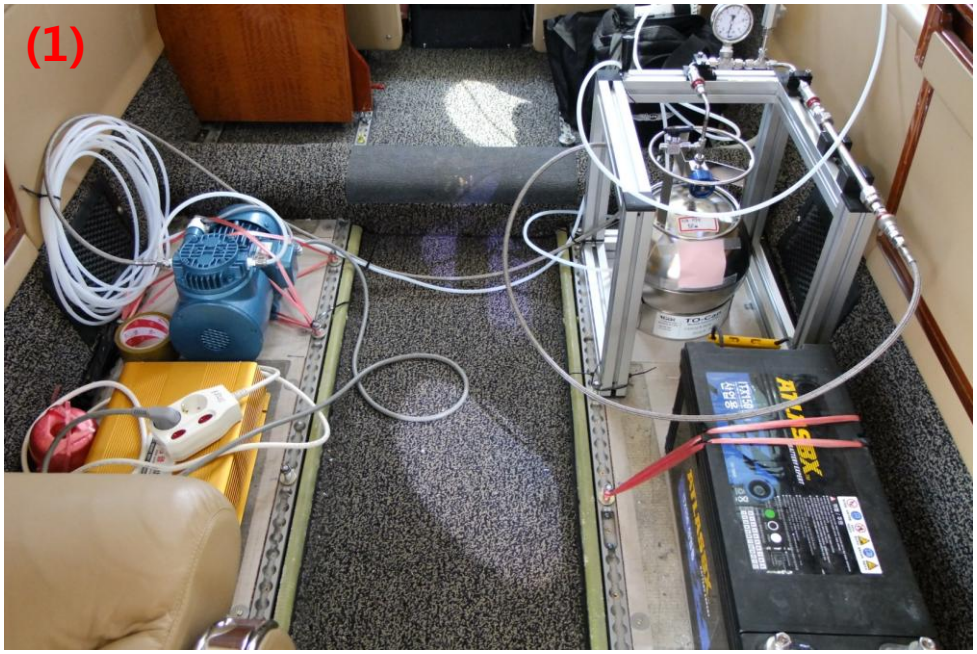
- Observational strategy

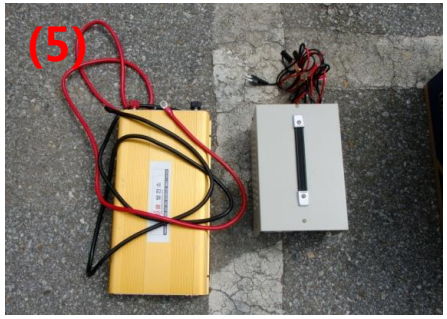
Passing Time (UTC)	Satellites/sensor	Radiosonde	Air sampling	FTIR
00:00~01:00	MetOp/IASI	O	O	Continuous measurement
04:00~05:00	Aqua/AIRS	O	O	
12:00~13:00	MetOp/IASI	O	—	
17:00~18:00	Aqua/AIRS	O	—	

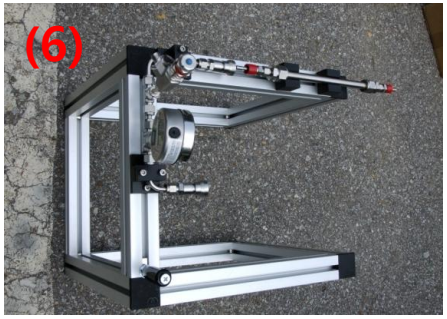
- Air sampling design
  - flight time : 2200, 0100, 0400, 0600, and 0900 UTC
  - Measured species : CO_2, CH_4, N_2O, SF_6, CO



Air Sampling Instrument





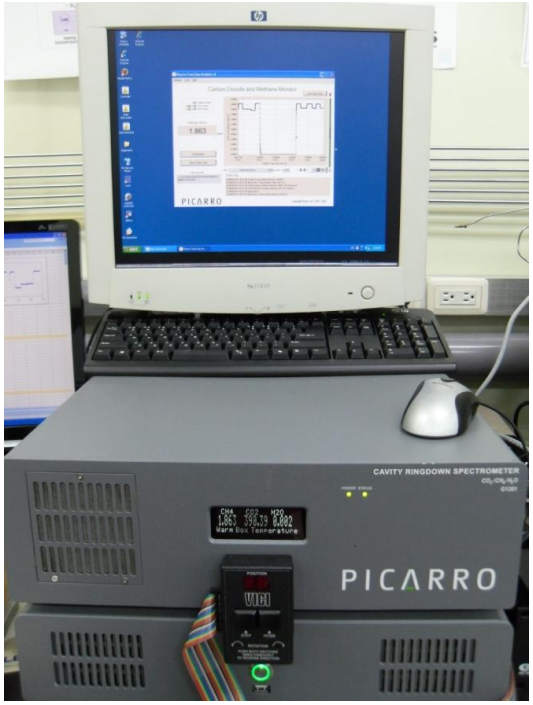


(1) Sampling unit
(2) Canister
(3) Pump
(4) Battery
(5) Power supply
(6) Moisture trap

Aircraft (Kingair)

Gas analyzers

Cavity Ring-Down Spectrometer (Picarro G1301)
- CO_2, CH_4 -

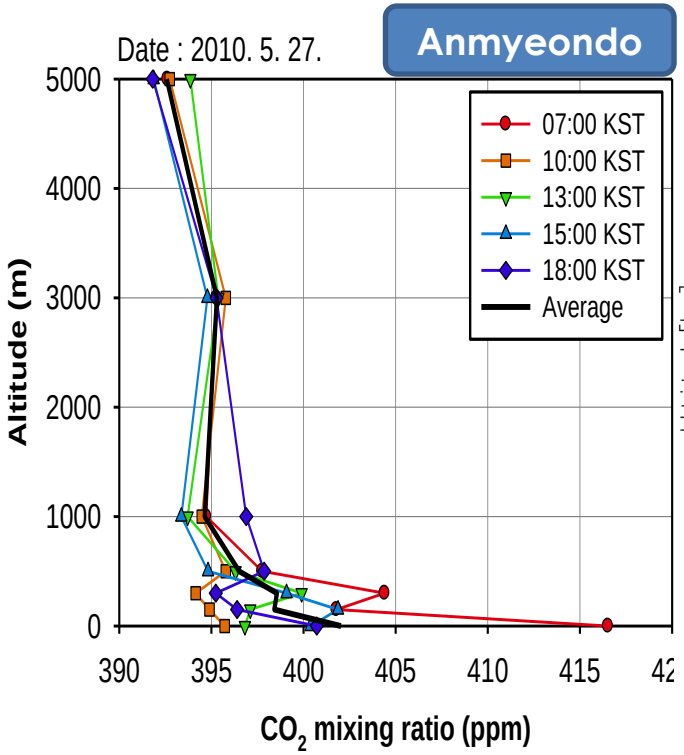


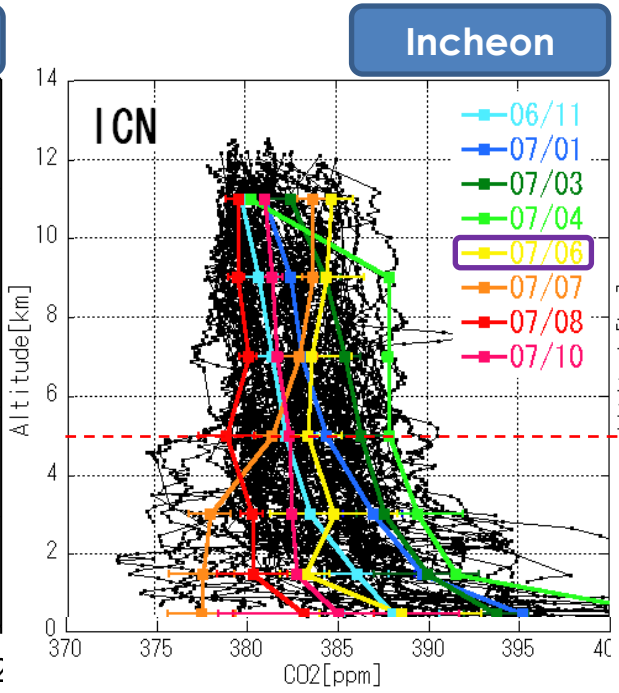
Gas Chromatograph - ECD (GC6890)
- N_2O, SF_6 -

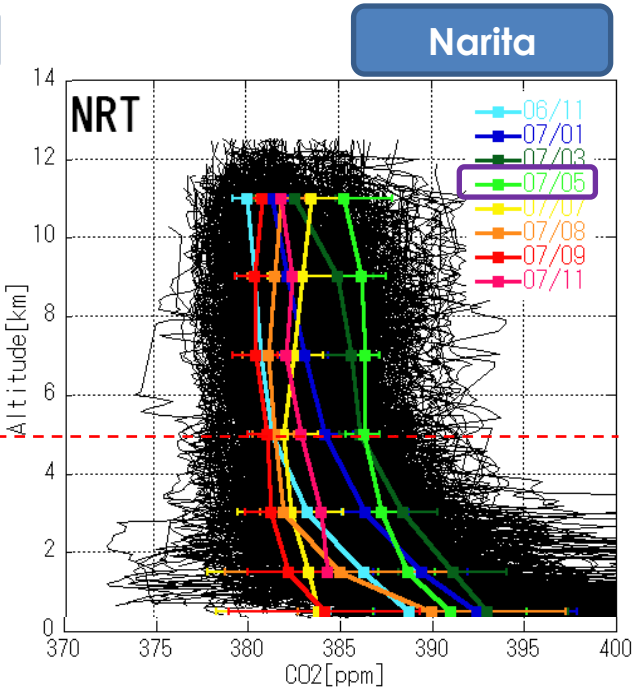
Residual Gas Analyzers (Ametec, Ta3000)
- CO -

CO_2 Profile comparison

- Sites : Anmyeondo, Incheon, Narita



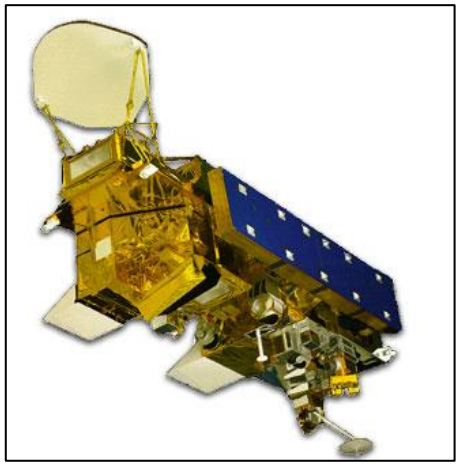


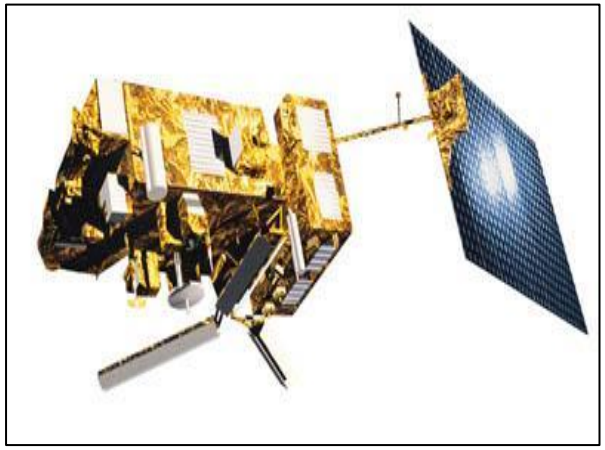


[Matsueda 2009]

Earth Observing Satellites

- AQUA / AIRS
  - Launching date : May 2002
  - Sensors : **AIRS**, AMSR-E, AMSU, CERES, HSB, MODIS
    ※ AIRS : Atmospheric InfraRed Sounder



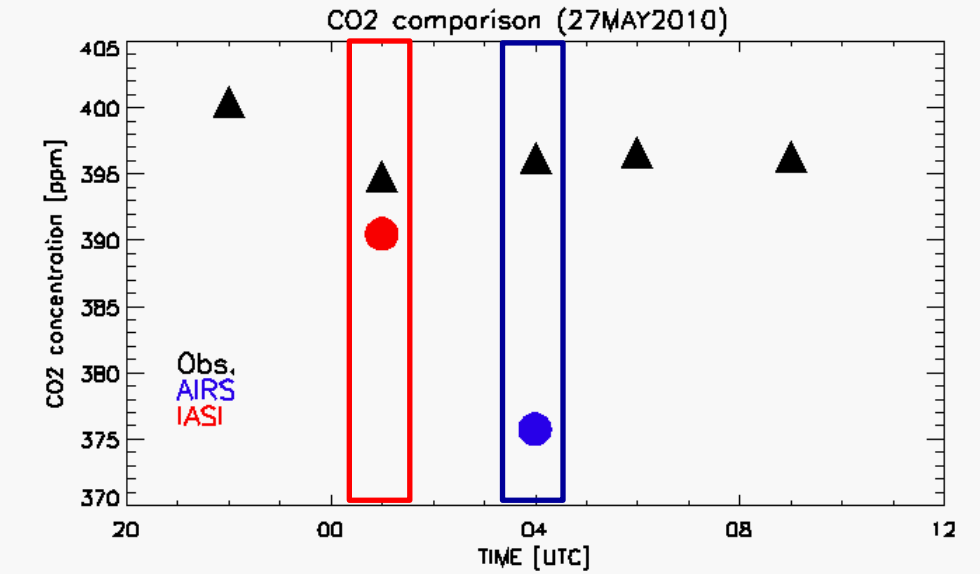


- METOP / IASI
  - Launching date : October 2006
  - Sensors : AVHRR, HIRS, AMSU-A, MHS, A-DCS, SARSAT, SEM-2, **IASI**, ASCAT, GRAS, GOME
    ※ IASI : Infrared Atmospheric Sounding Interferometer

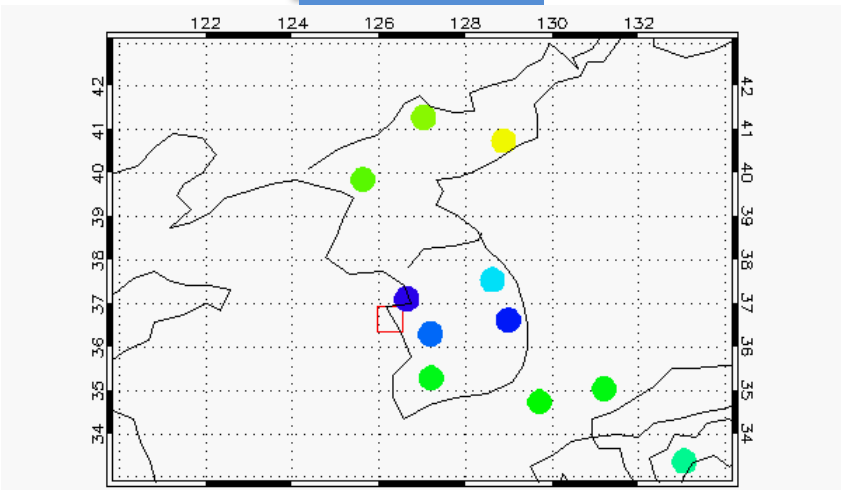
CO_2 comparison (1)

(Unit: ppm)

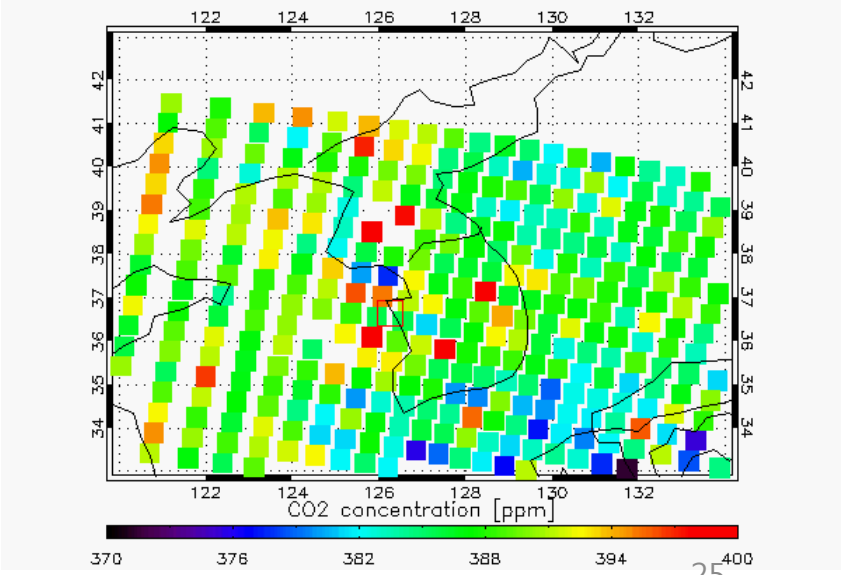
2010.5.27.	Obs.	Sat.	Obs.-Sat.
01 UTC (IASI)	395.72	390.465	5.26
04 UTC (AIRS)	396.82	375.736	21.08



AIRS/AQUA



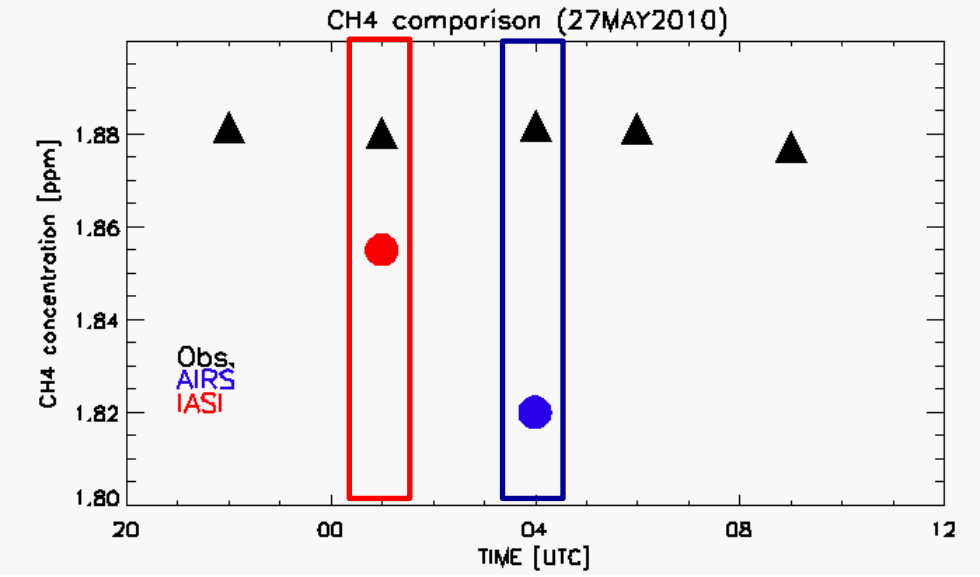
IASI/METOP



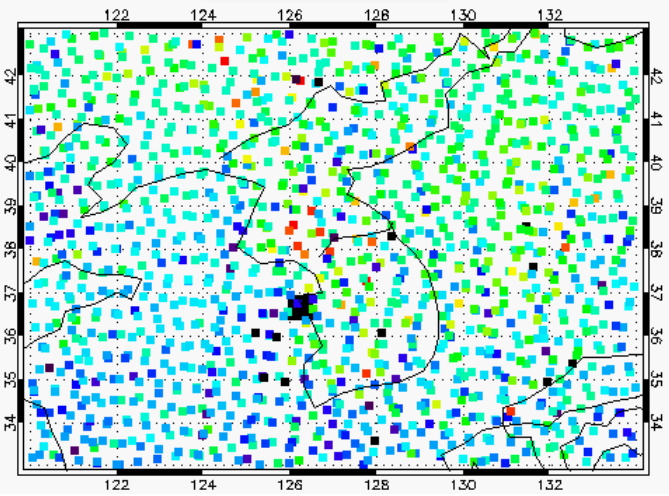
CH_4 comparison (2)

(Unit: ppb)

2010.5.27.	Obs.	Sat.	Obs.-Sat.
01 UTC (IASI)	1,914	1,855	59
04 UTC (AIRS)	1,893	1,820	73



AIRS/AQUA



IASI/METOP