CarbonTracker-Asia

A tool to quantify CO2 uptake/release focused on Asia

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The 5th Asia-Pacific GAW Workshop on Greenhouse Gases
24 Oct. 2013, Jeju, Korea

CarbonTracker as a scientific tool

To improve our understanding of how carbon uptake and release from land ecosystems and oceans are responding to a changing climate.

CarbonTracker as a policy support tool

To provide an independent check on emissions accounting, estimates of fossil fuel use based on economic inventories.

To provide feedback to policies aimed at limiting greenhouse gas emissions.

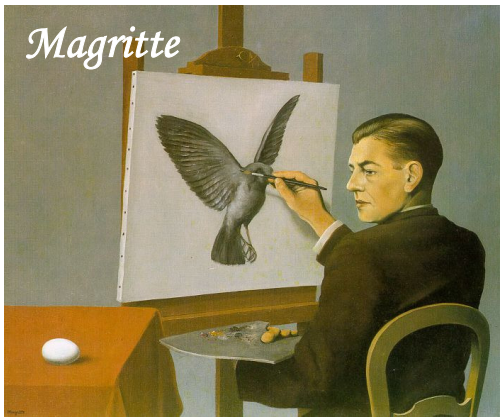
Concept of CarbonTracker

$$\frac{\partial}{\partial t}(\rho CO_2) = -\nabla \cdot (\rho CO_2 \vec{V}) + PBL + Convection + Sc$$

Measured CO_2 concentration & Known Transport — Solve for sources & sinks

Inverse method

Transfer from *observations* (concentrations)
to *information* (fluxes at sources & sink)



CarbonTracker - CT2010

What is CarbonTracker?

A system to keep track of carbon dioxide uptake and release at the Earth's surface over time. [read more]

Who needs CarbonTracker?

Policy makers, industry, scientists, and the public need CarbonTracker information to make informed decisions to limit greenhouse gas levels in the atmosphere. [read more]

What does CarbonTracker tell us?

North America is a source of CO_2 to the atmosphere. The natural uptake of CO_2 that occurs mostly East of the Rocky Mountains removes only ~30% of the CO_2 released by the use of fossil fuels. [read more]

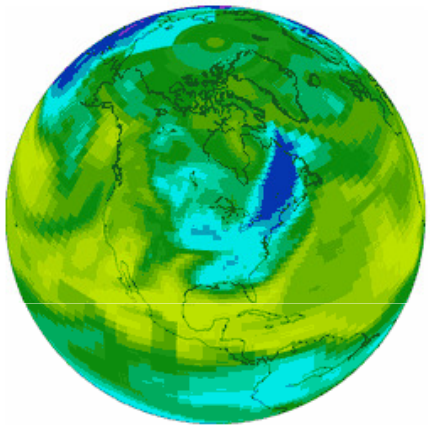
What's new in this release of CarbonTracker? NEW!

The 2010 release of CarbonTracker ("CT2010") includes observations and flux estimates through the end of 2009. The addition of several new observational data sets we feel results in more accurate estimates of fluxes. [read more]

Other CarbonTrackers

- CarbonTracker Europe
- CarbonTracker-Asia
- CarbonTracker Methane (under construction)
- CarbonTracker Australasia (under construction)

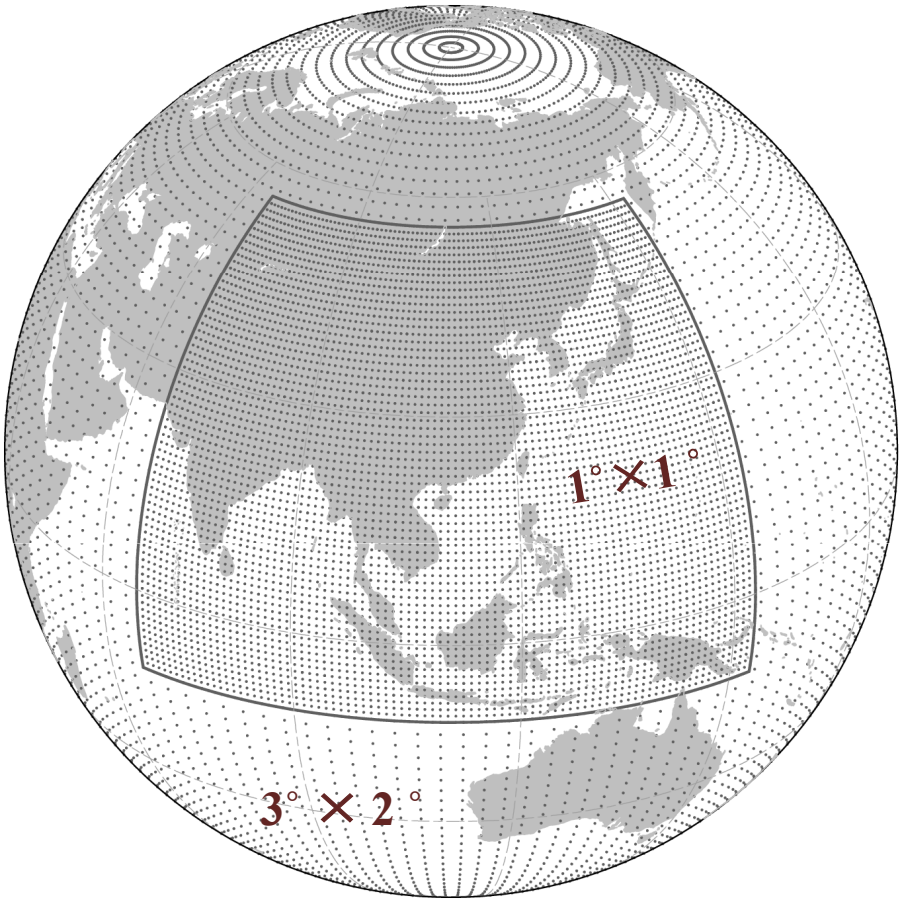
2007 CarbonTracker PNAS publication



CarbonTracker CO_2 weather for June-July, 2008. Warm colors show high atmospheric CO_2 concentrations, and cool colors show low concentrations. As the summer growing season takes hold, photosynthesis by forests and crops draws concentrations of CO_2 down, opposing the general increase from fossil fuel burning. The resulting high- and low-CO_2 air masses are then moved around by weather systems to form the patterns shown here. [More on CO_2 weather]

CarbonTracker is a NOAA contribution to the North American Carbon Program

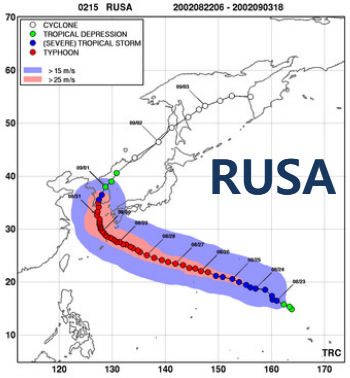
CarbonTracker-Asia



1. Double-nested mesh (globe: 3˚x2˚, Asia: 1˚x1˚).

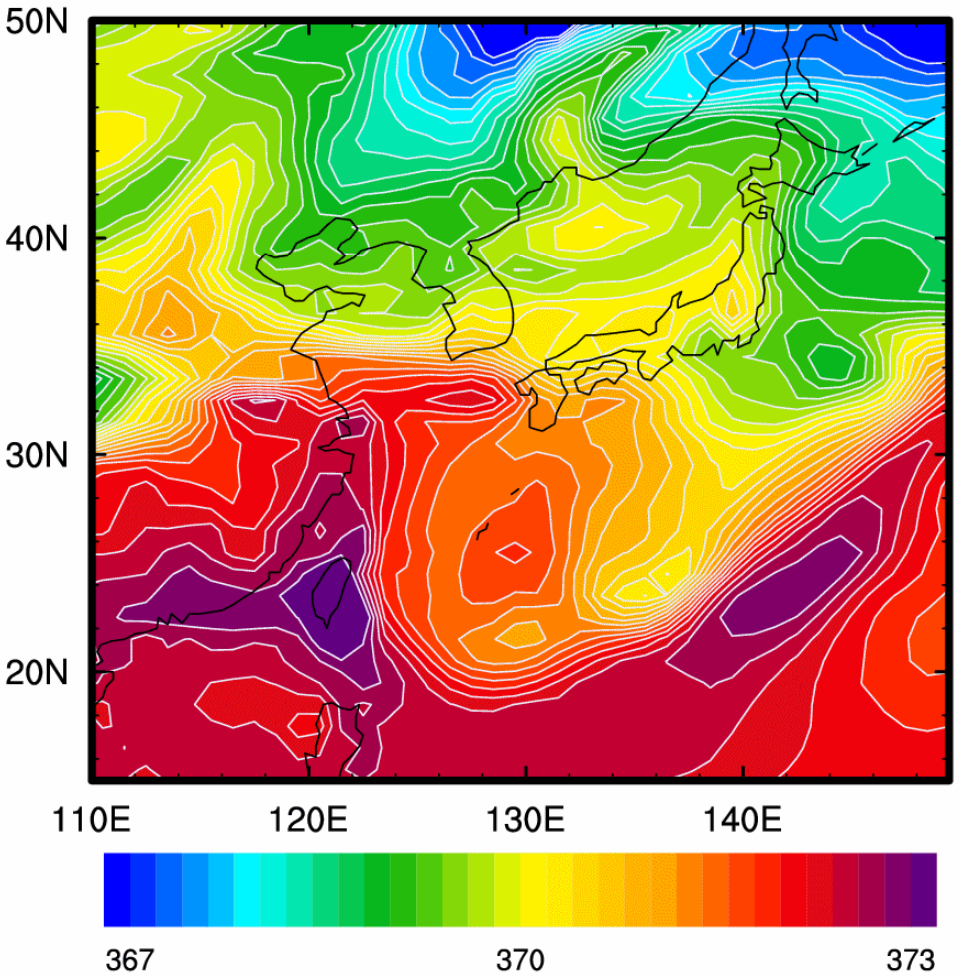
2. Measurements collected JMA 3 GAW sites

Typhoon as simulated by CT-Asia

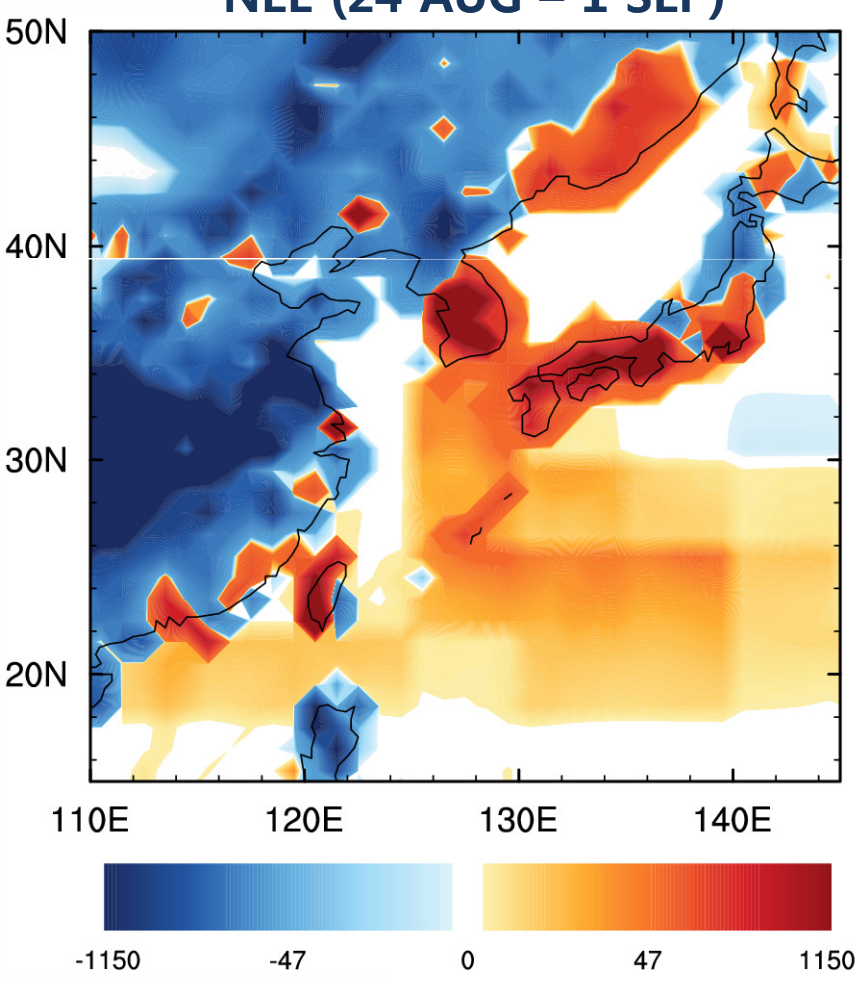


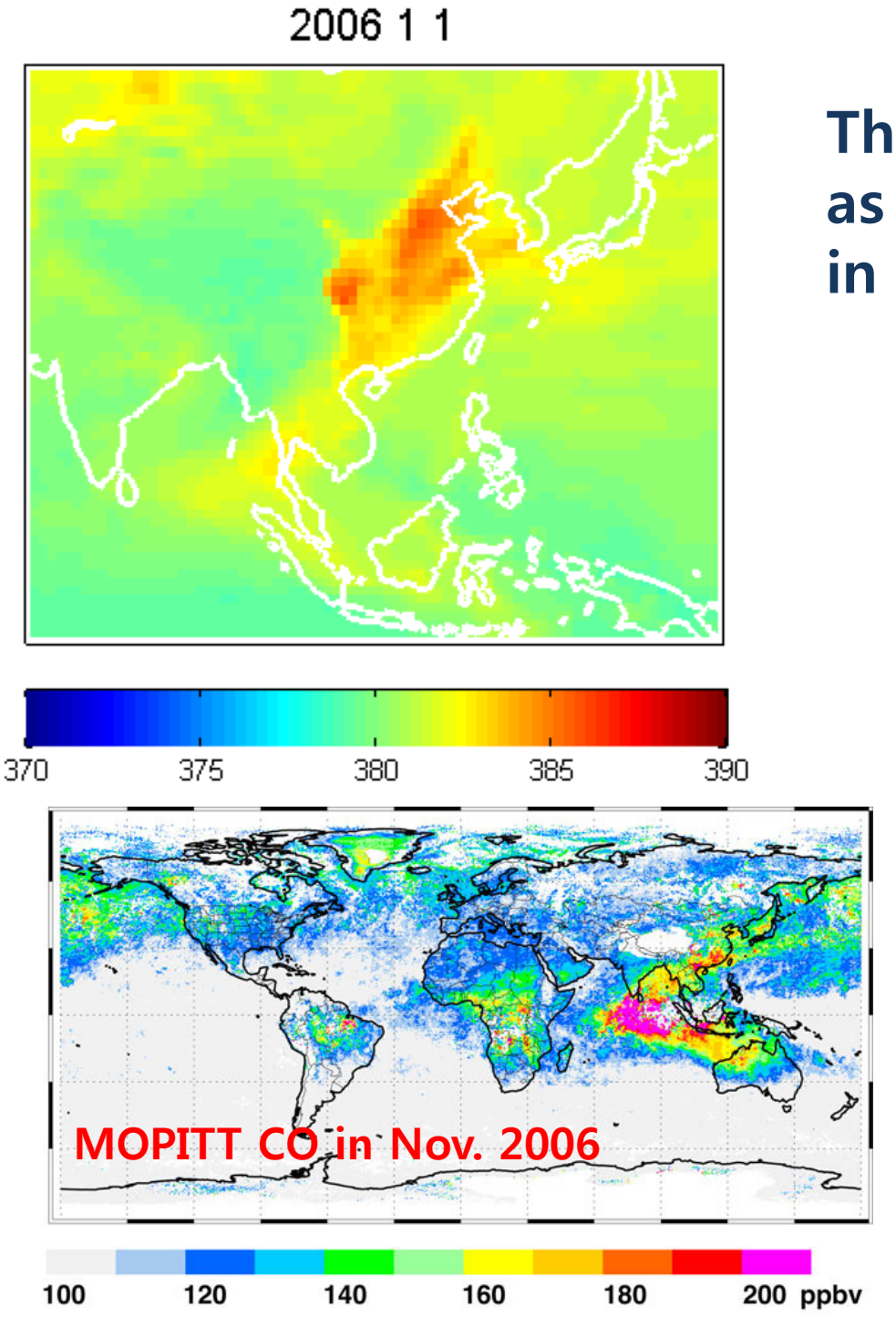
Column CO2 concentration

2002082400



NEE (24 AUG – 1 SEP)

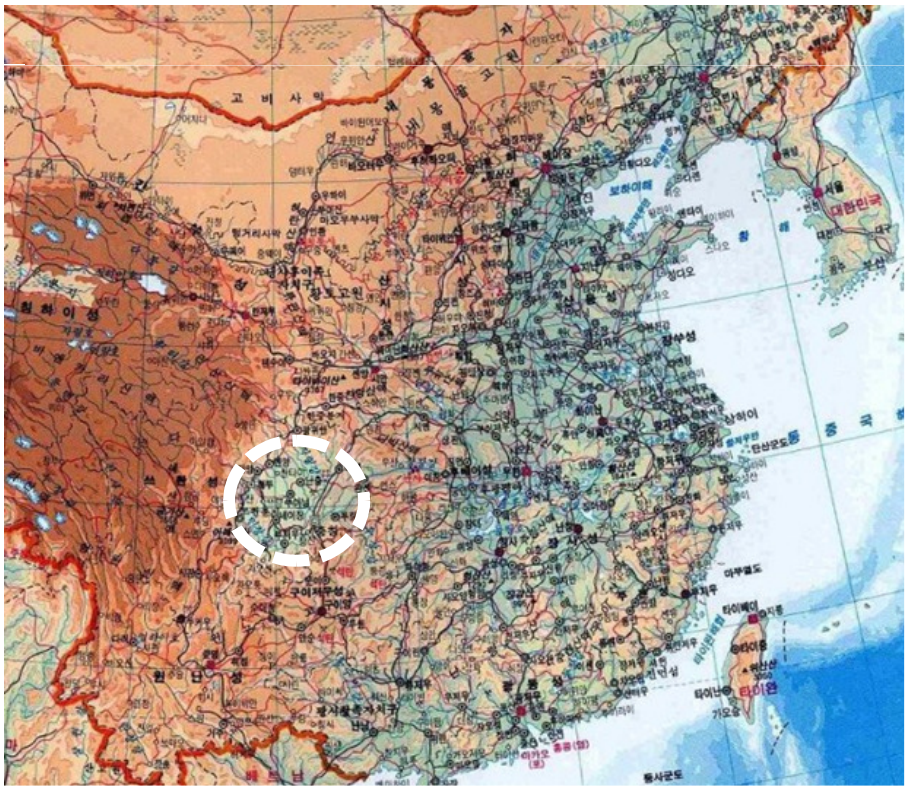




The daily concentration of CO_2 as simulated by CarbonTracker in 2006

Sichuan Basin (四川盆地)

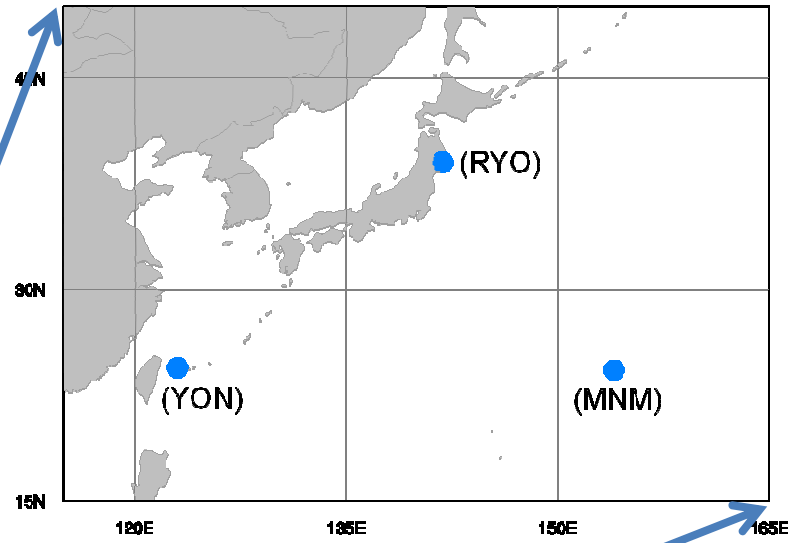
- Chongqing (population 29,000,000)
- Chengdu (population 14,000,000)

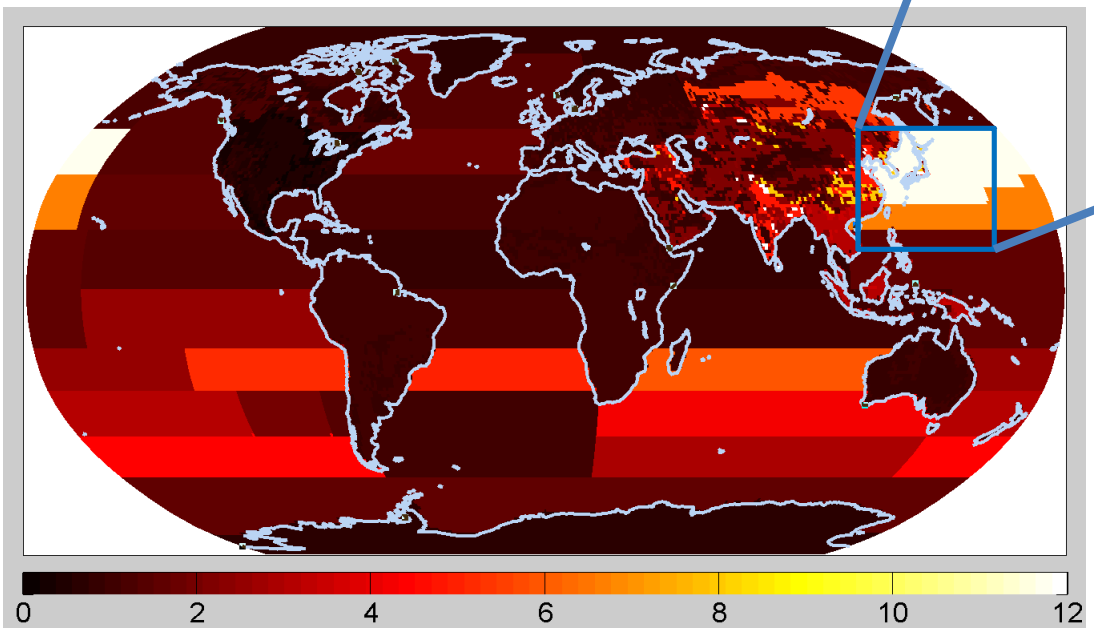


Uncertainty reduction by JMA 3 GAW observations (2000-2009)

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

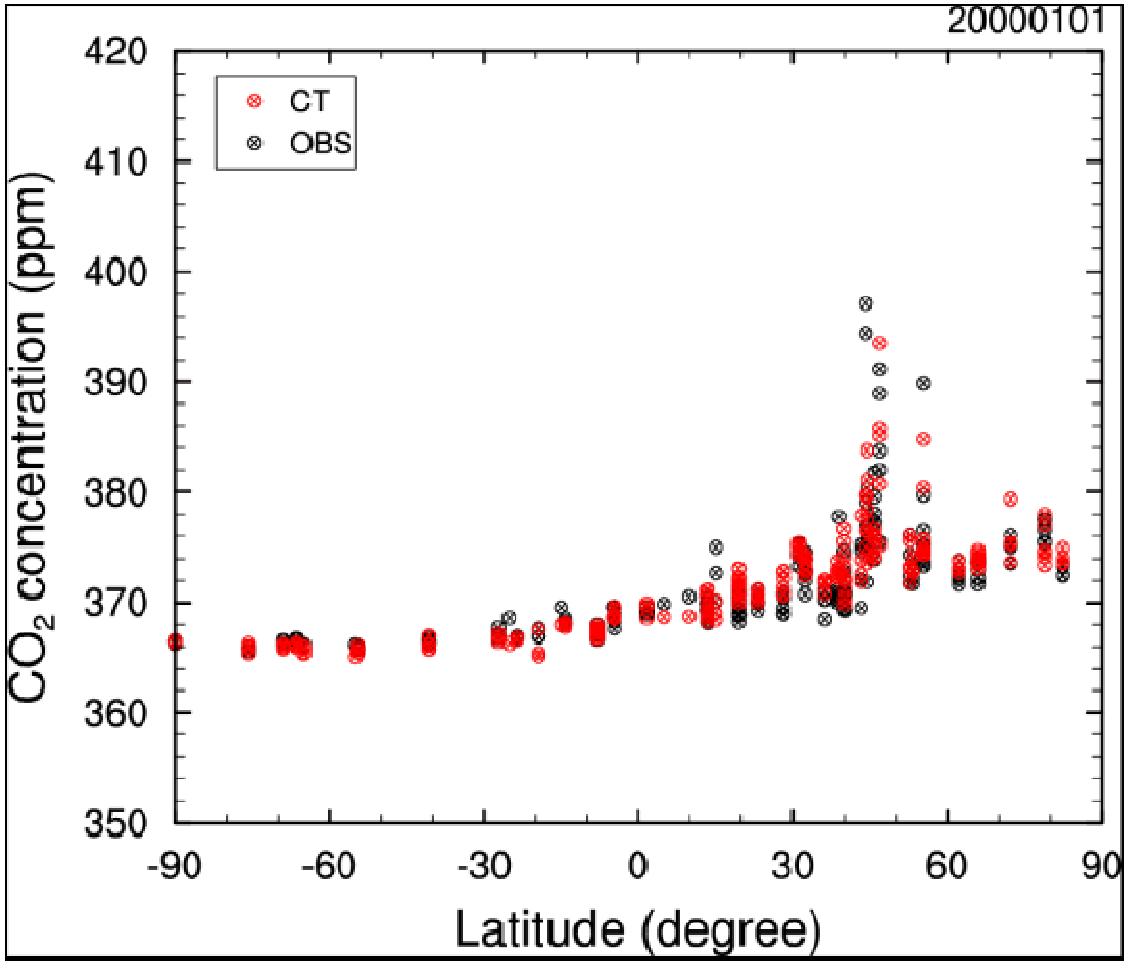
$$[1-\sigma(\text{posterior})/\sigma(\text{a priori})]\times 100$$





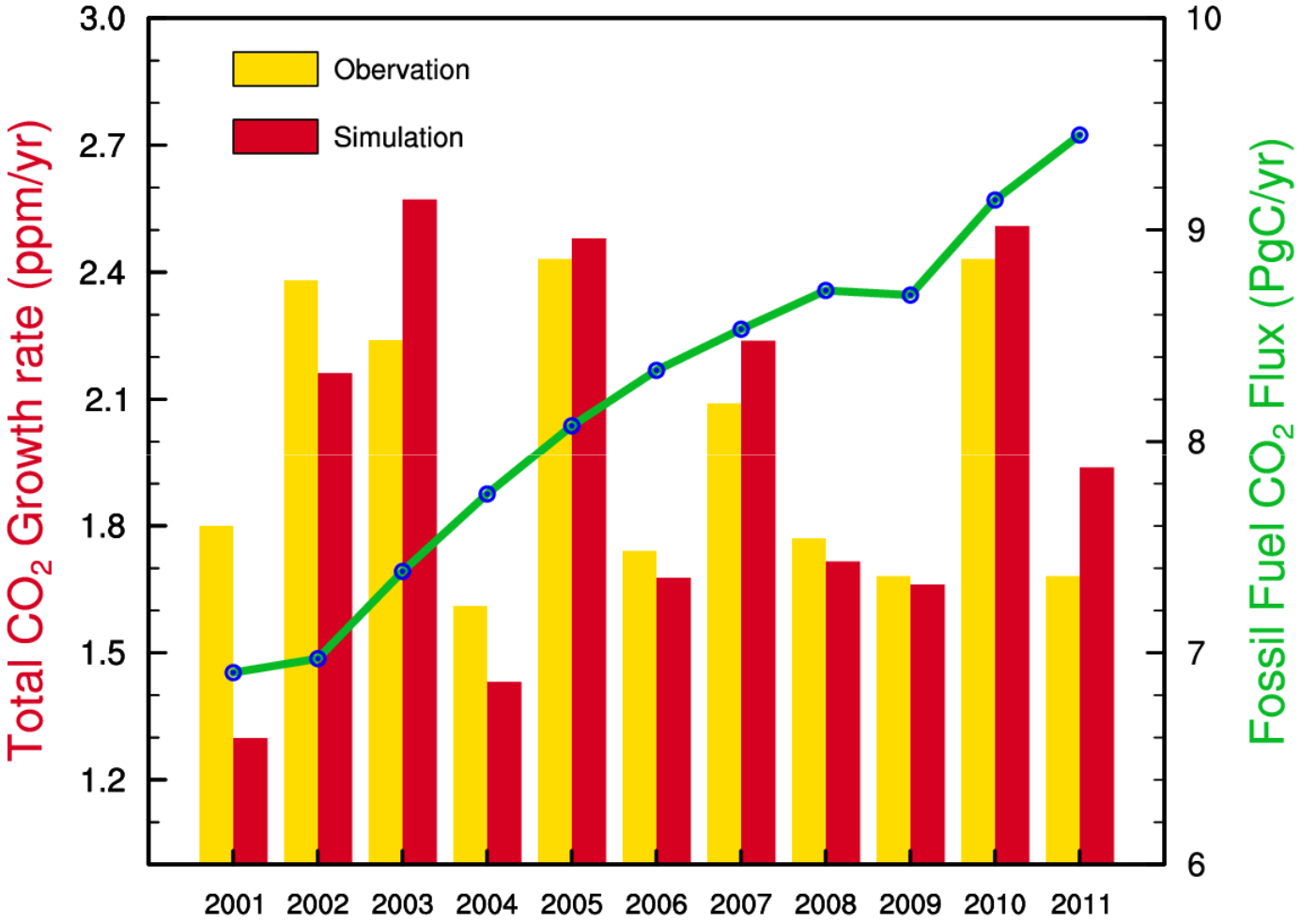
Uncertainty of the flux (NEE) for the Northwestern Pacific is reduced by more than 10% for including JMA 3 GAW observations

Latitudinal distributions of CO_2 Concentration



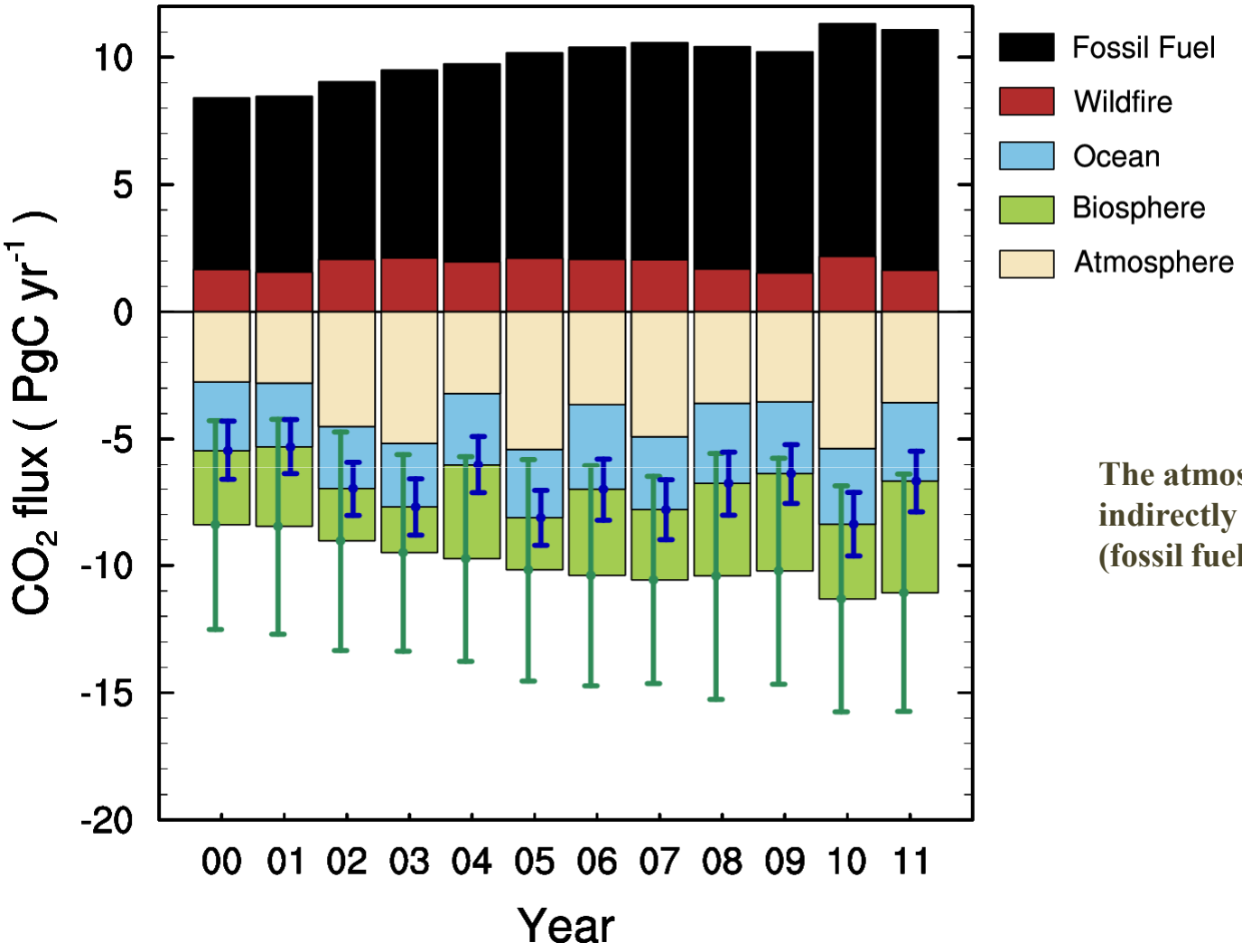
Measured and simulated surface CO_2 concentration as a function of latitude at observation sites.

CO_2 Growth Rate & Emission



Observation (NOAA) : CO_2 growth rate globally averaged over marine surface sites
Simulation (CT) : CO_2 growth rate globally averaged over all grid points

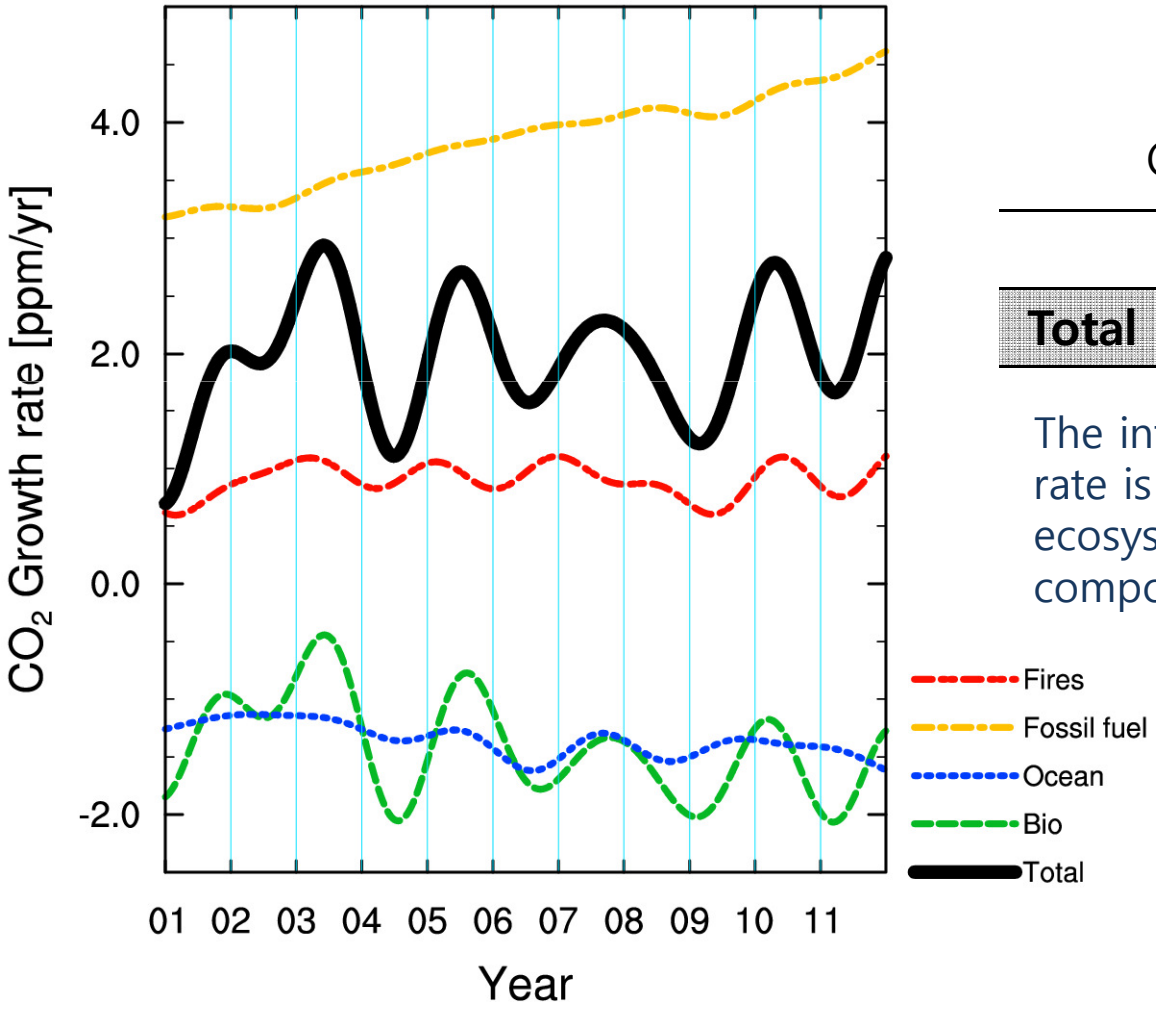
Global Annual Budget of CO_2 Fluxes



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

On average, 40% of the total CO_2 emissions each year between 2000 and 2011 remained in the atmosphere, but this fraction is subject to large interannual variability, which is caused by corresponding strong variations in natural CO_2 uptake, globally, from year to year.

Global Growth Rate of CO_2 Concentration



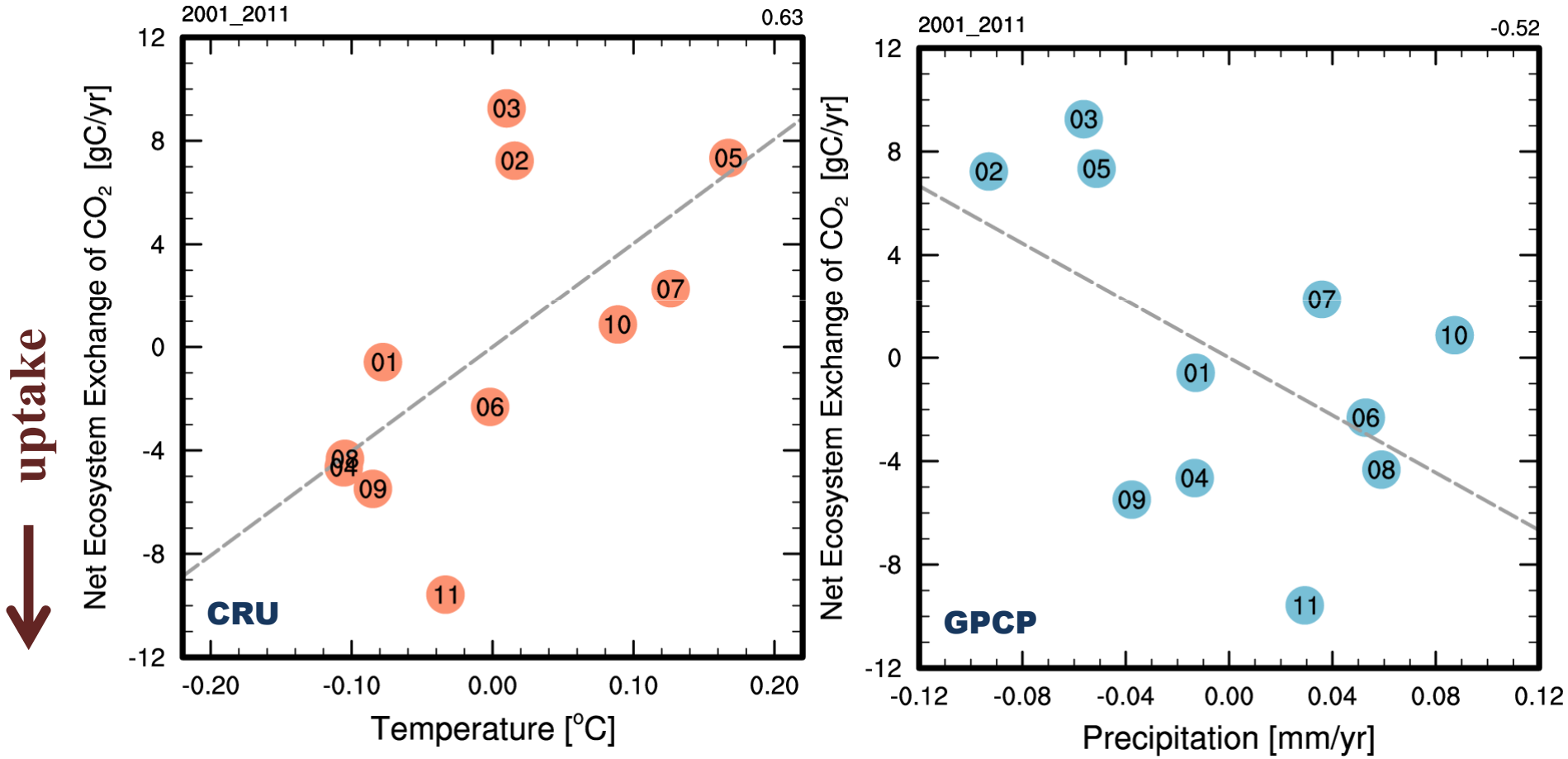
Correlation coefficient b/w

	FF	Fires	Bio	Ocean
Total	0.29	**0.70**	**0.73**	**0.08**

The interannual variability of growth rate is primarily dominated by terrestrial ecosystems rather than any other components.

Correlation between anomalies
in annual global mean biosphere flux (NEE) & climate variation

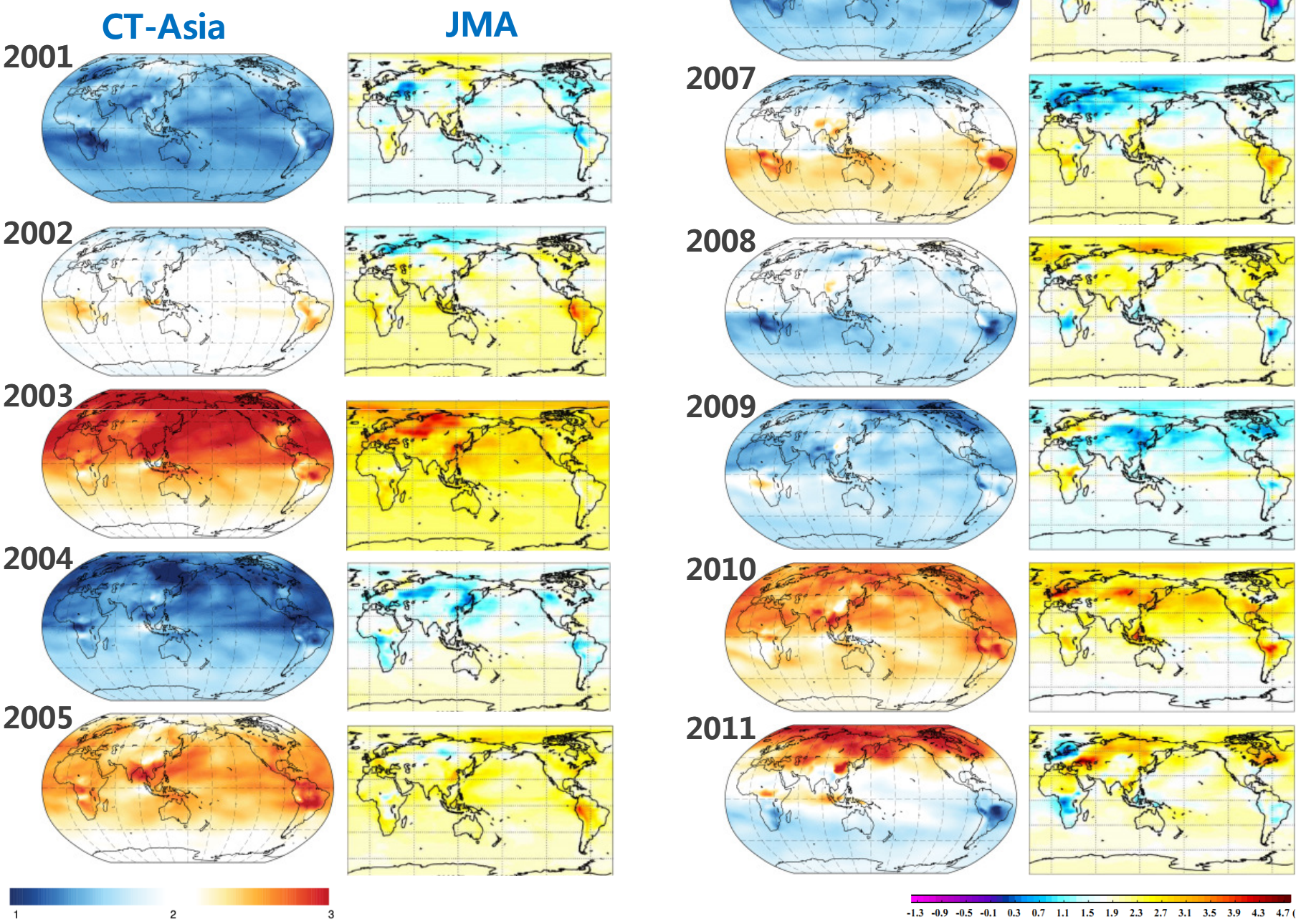
NEE (Net Ecosystem Exchange)



2001-2011 Number : Year

Annual Mean Growth Rate of CO_2

[ppm yr^{-1}]



Fate of Global CO_2 Emissions (2002-2011)

Fossil Fuel

8.31 PgC/yr (81%) 3.92 ppm/yr (81%)

Atmosphere

4.29 PgC/yr (42%) 2.04 ppm/yr (42%)

Biosphere

3.05 PgC/yr (30%) 1.43 ppm/yr (30%)

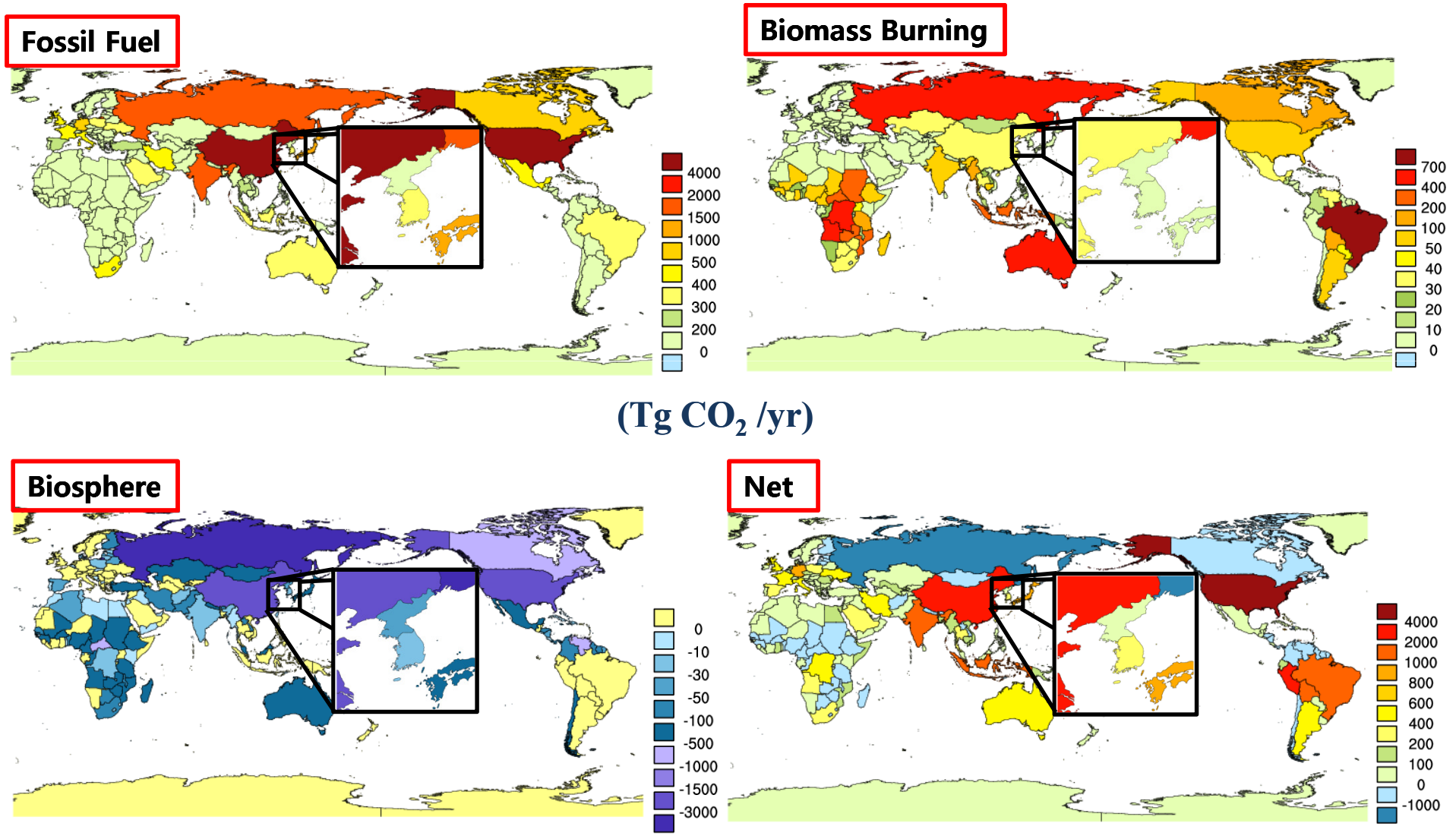
Biomass Burning

1.93 PgC/yr (19%) 0.92 ppm/yr (19%)

Ocean

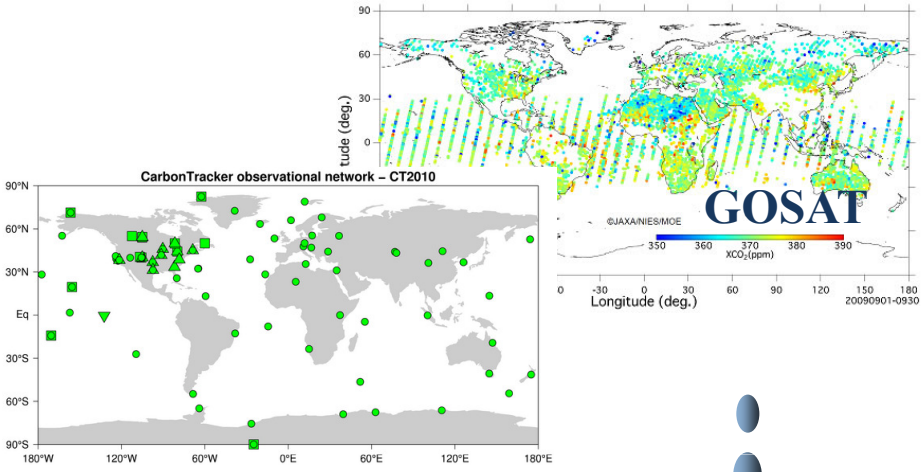
2.90 PgC/yr (28%) 1.37 ppm/yr (28%)

CO_2 Uptake or Release for each Country (2001-2011)

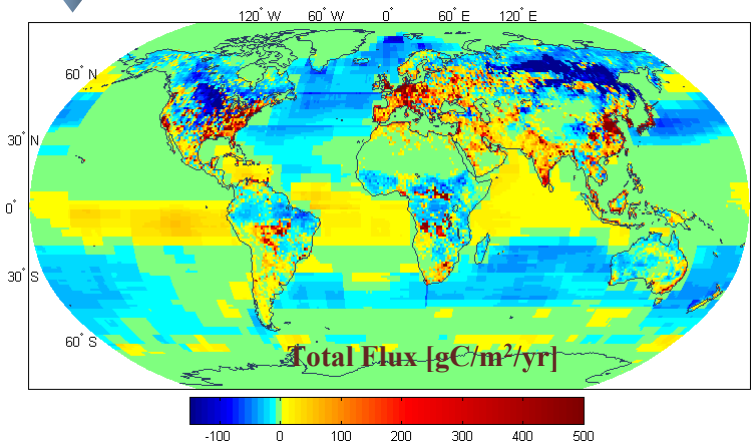


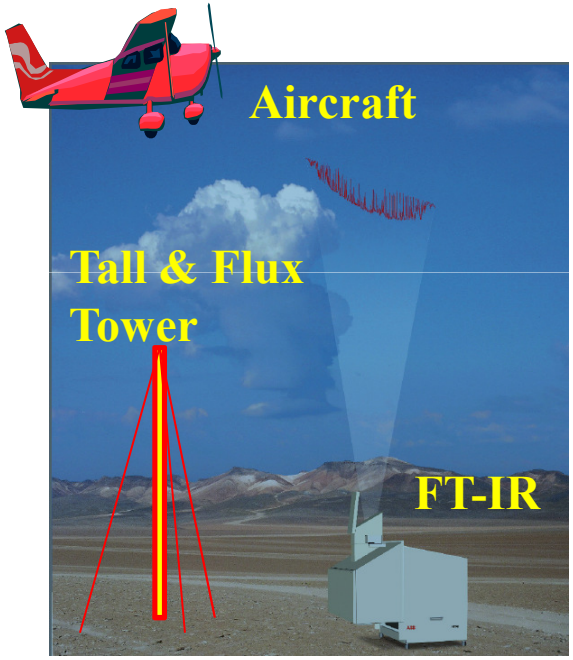
On-going Plan

to integrate observations in CarbonTracker
to verify the satellite retrievals by aircraft, FTS, and tower



Observation





Verification

CarbonTracker

CarbonTracker EnKF

TM5

Greenhouse Gas Uptake

Clim

NP

C

So

F

Ea

Transport

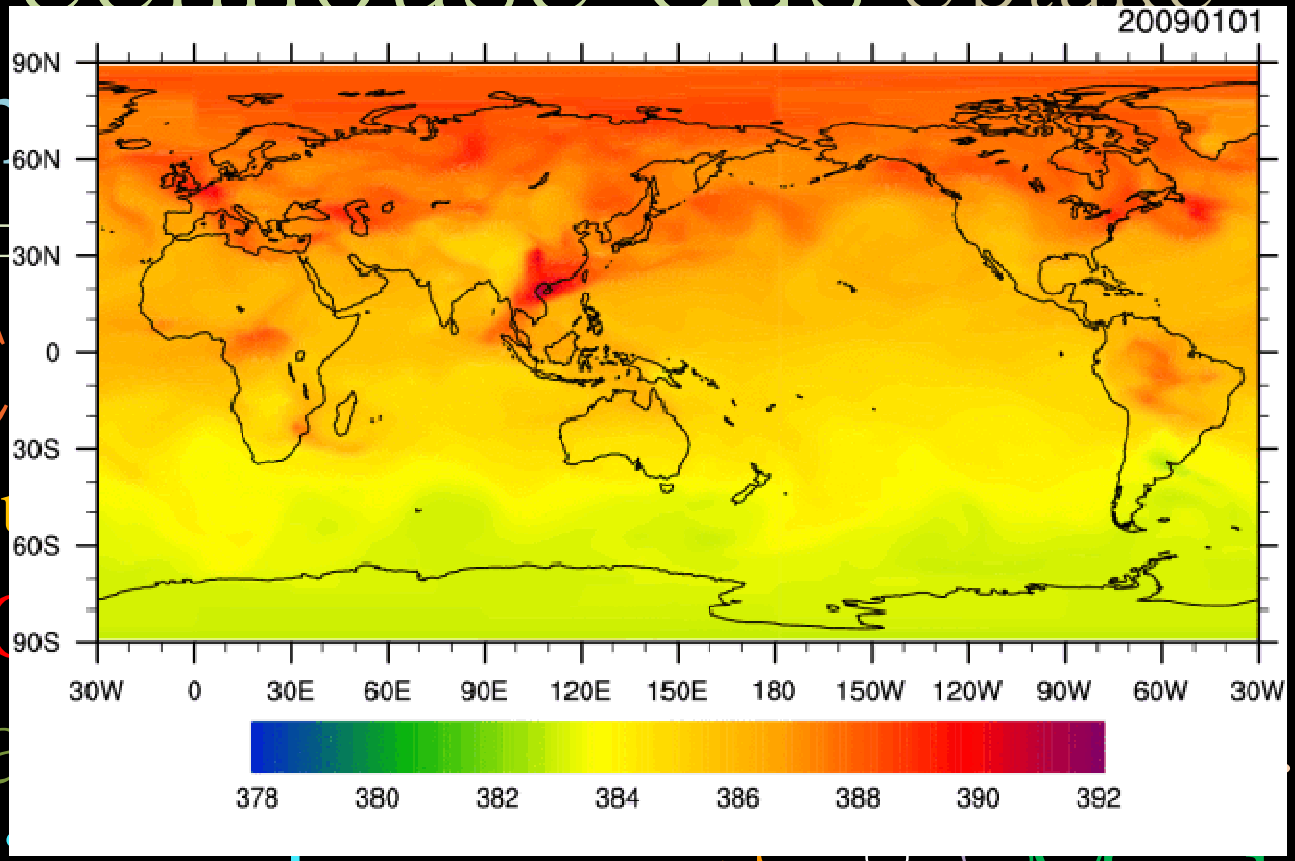
Biosphere

Global Warming

Photosynthesis

vation

Modeling



CarbonTracker Flow Chart

2. Simulated CO_2 concentrations

State vector (Flux x_p)

Error covariance matrix S_p

Observation vector y_0

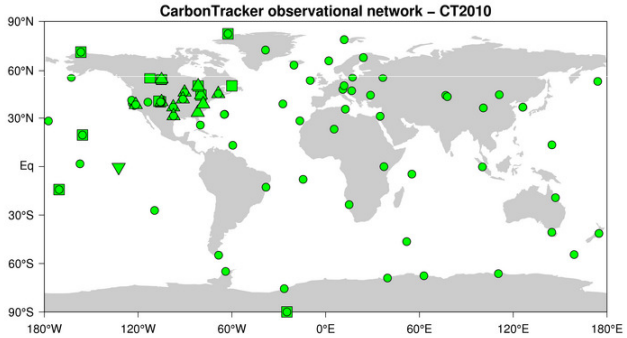
Error covariance matrix S_y

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

1. Fluxes(sources & sinks)

Forward model

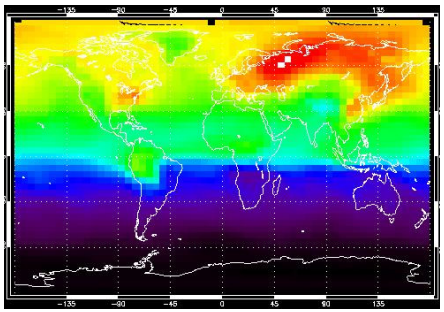
3. Comparison of CO_2 calculated by the model with the measurements



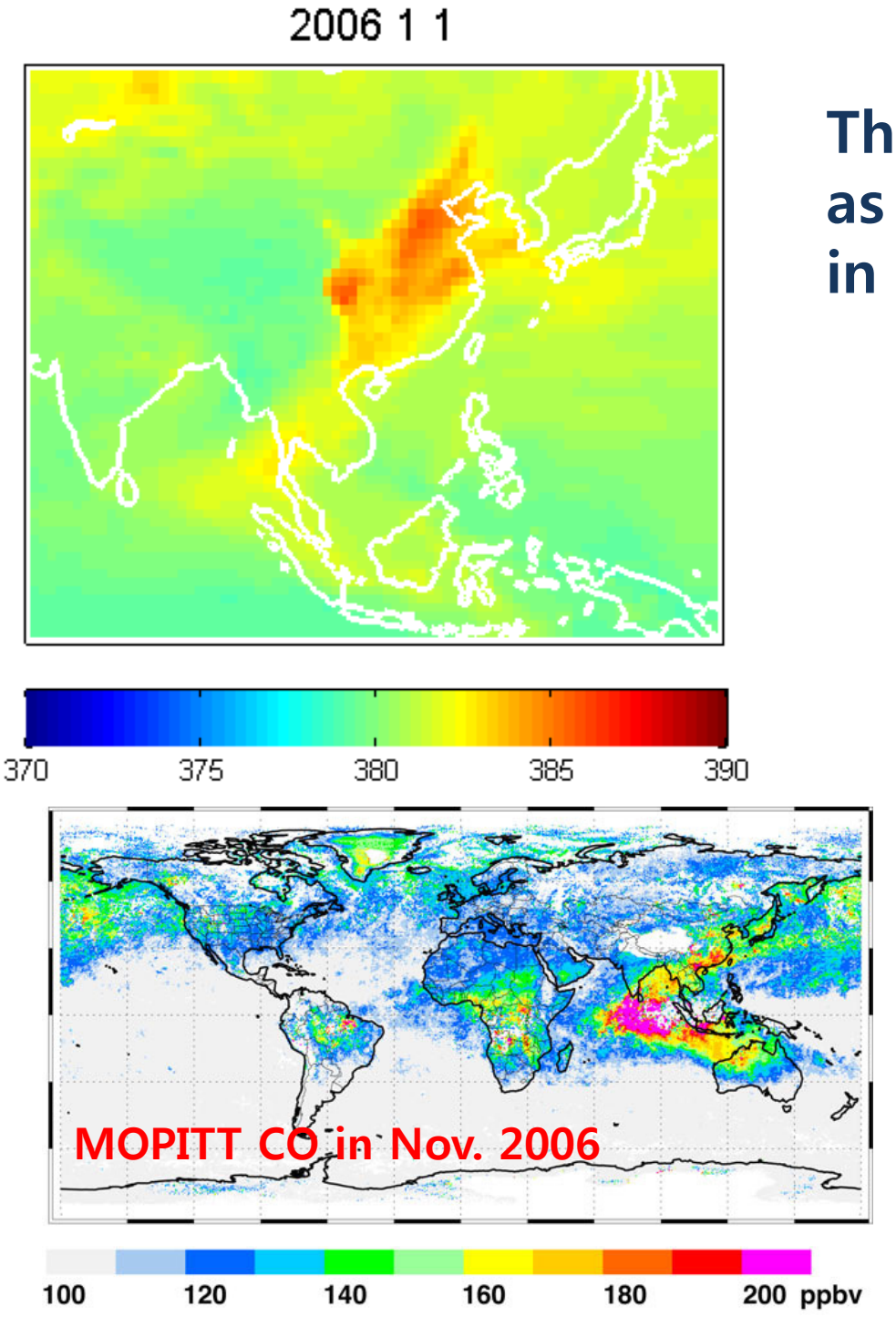
Inverse model

4. Corrected fluxes(Biosphere & Ocean)

$$x_a = x_p + (H^T S_y^{-1} H + S_p^{-1})^{-1} H^T S_y^{-1} (y_0 - Hx_p)$$



5. Analyzed 3-D CO_2 concentration



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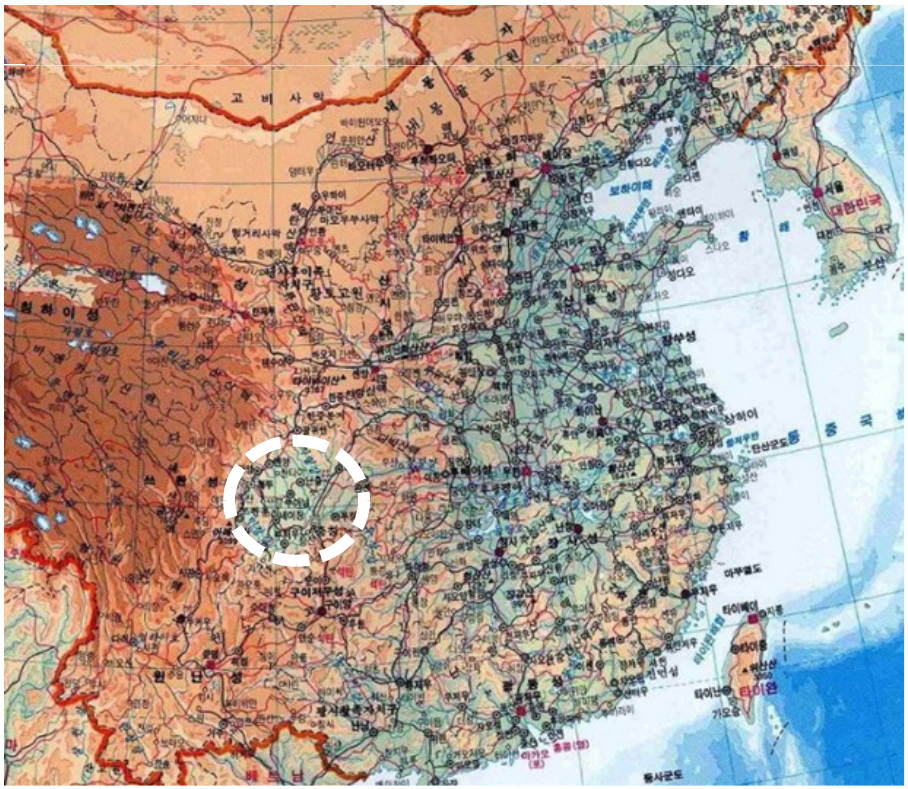
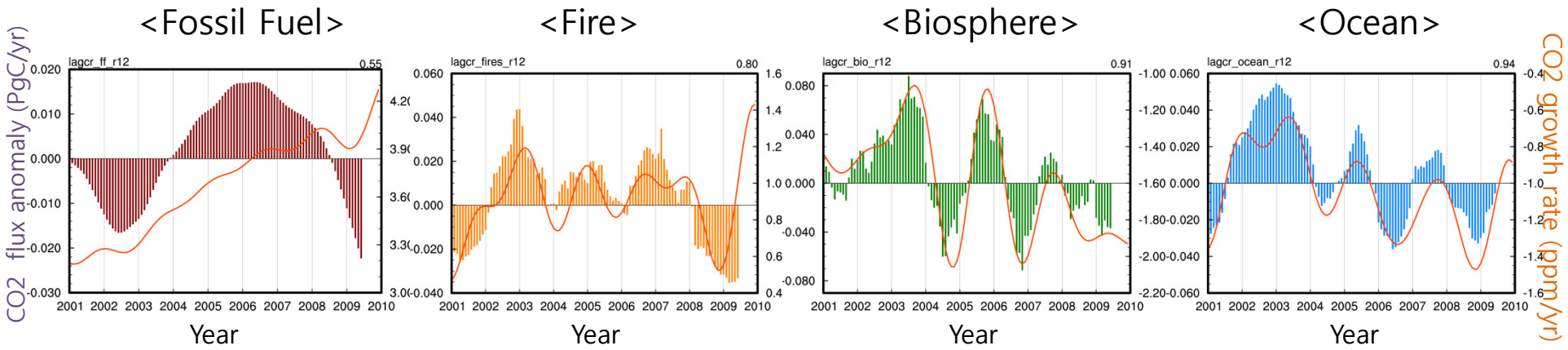


Global Growth Rate vs. Flux Anomaly



Line: CO2 growth rate (digital filtering)

Bar: flux anomaly (12 month moving average)

Correlation coefficient b/w

	FF CO_2	Fires CO_2	Bio CO_2	Ocean CO_2
FF flux anomaly	0.55	-	-	-
Fires flux anomaly	-	**0.80**	-	-
Bio flux anomaly	-	-	**0.91**	-
Ocean flux anomaly	-	-	-	**0.94**

CarbonTracker-Asia Result

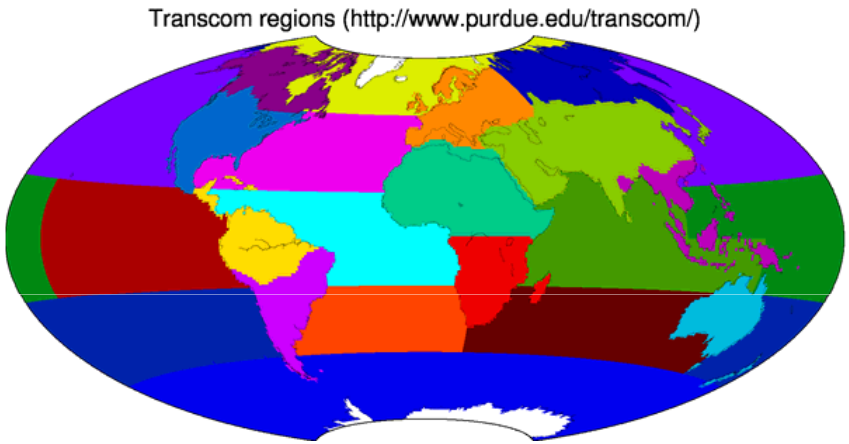
2001-2009 CO_2 Uptake or Release for each Country

[Tg CO_2 yr^{-1}]

Rank	Country	Fossil Fuel	Fire	Biosphere	Net Flux
1	UNITED STATES OF AMERICA	5794	97	-1627	4264
2	CHINA (MAINLAND)	5749	42	-761	5075
3	RUSSIAN FEDERATION	1589	455	-3745	**-1701**
4	INDIA	1478	46	13	1537
5	JAPAN	1265	0	-35	1230
6	GERMANY	797	0	-16	781
7	UNITED KINGDOM	555	0	-11	544
8	CANADA	554	150	-1330	**-626**
9	REPUBLIC OF KOREA	494	0	-10	484
10	ITALY	470	1	-12	459
11	ISLAMIC REPUBLIC OF IRAN	449	1	-17	433
12	MEXICO	443	29	-105	367
13	FRANCE	424	0	-34	390
14	SOUTH AFRICA	417	37	-42	412
15	SAUDI ARABIA	368	0	0	368
16	BRAZIL	362	791	-310	843
17	AUSTRALIA	354	448	-507	295
18	SPAIN	335	2	-6	331
19	INDONESIA	324	378	76	778
20	UKRAINE	318	8	-17	309
	NORTH KOREA	80	1	-17	64

Average natural flux (biosphere + ocean + fire) & Fossil fuel flux estimated from CT-Asia [2001-2009]

[PgC/yr]

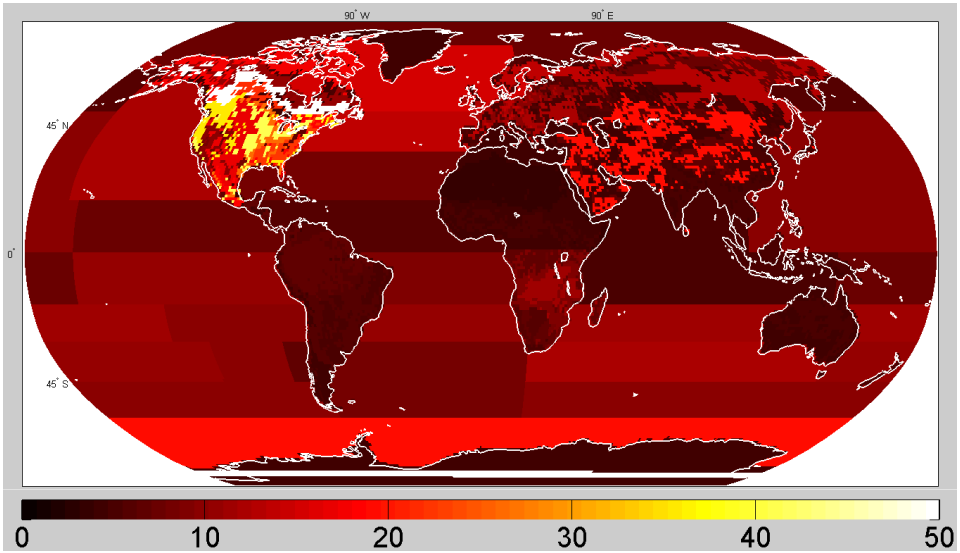


The **uncertainty** listed is the one standard deviation from the ensemble Kalman filter estimate.

[the number of ensemble member : 150]

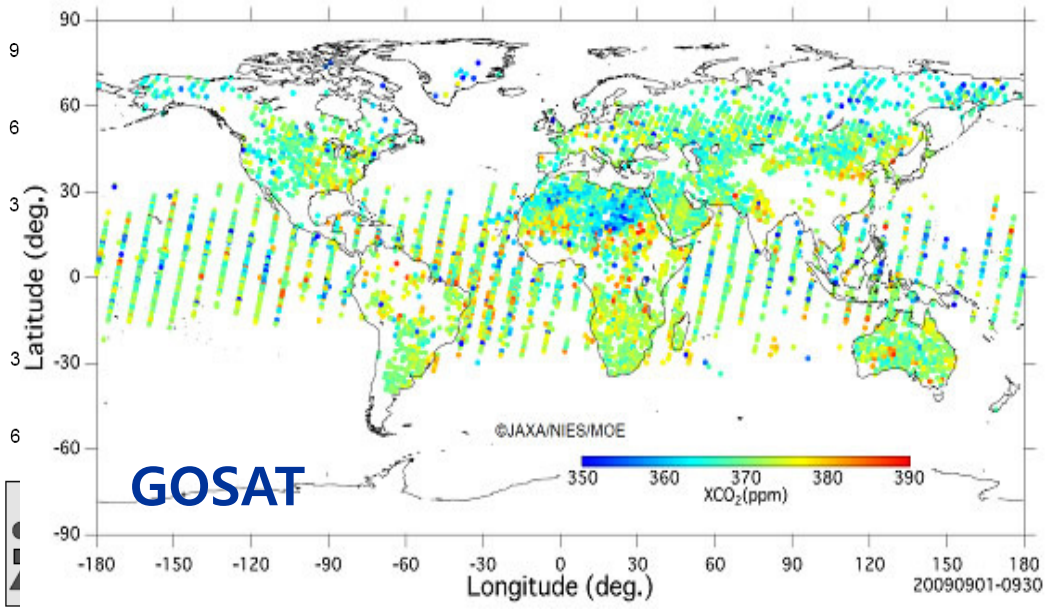
Transcom Region	Natural flux	Fossil Fuel
North America Boreal	-0.24±0.40	0.01
North America Temperate	-0.55±0.46	1.84
South America Tropical	0.18±0.56	0.10
South America temperate	0.05±0.32	0.16
Northern Africa	0.02±0.28	0.16
Southern Africa	0.11±0.36	0.13
Eurasian Boreal	-0.85±0.96	0.18
Eurasian Temperate	-0.27±0.43	2.79
Tropical Asia	0.21±0.20	0.57
Australia	-0.02±0.12	0.11
Europe	-0.17±0.68	1.55
North Pacific Temperate	-0.42±0.44	0.09
West Pacific Tropics	0.02±0.09	0.00
East Pacific Tropics	0.31±0.22	0.00
South Pacific Temperate	-0.62±0.35	0.00
Northern Ocean	-0.26±0.20	0.01
North Atlantic Temperate	-0.38±0.43	0.03
Atlantic Tropics	0.17±0.16	0.04
South Atlantic Temperate	-0.21±0.24	0.00
Southern Ocean	-0.30±0.33	0.00
Indian Tropical	0.19±0.23	0.02
South Indian Temperate	-0.66±0.43	0.00
Global Land	-1.54±1.62	7.60
Global Ocean	-2.16±1.01	0.20
Global Total	-3.70±1.91	7.79

Uncertainty reduction provided by inverse method for the estimation of CO_2 fluxes (2000-2009)



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

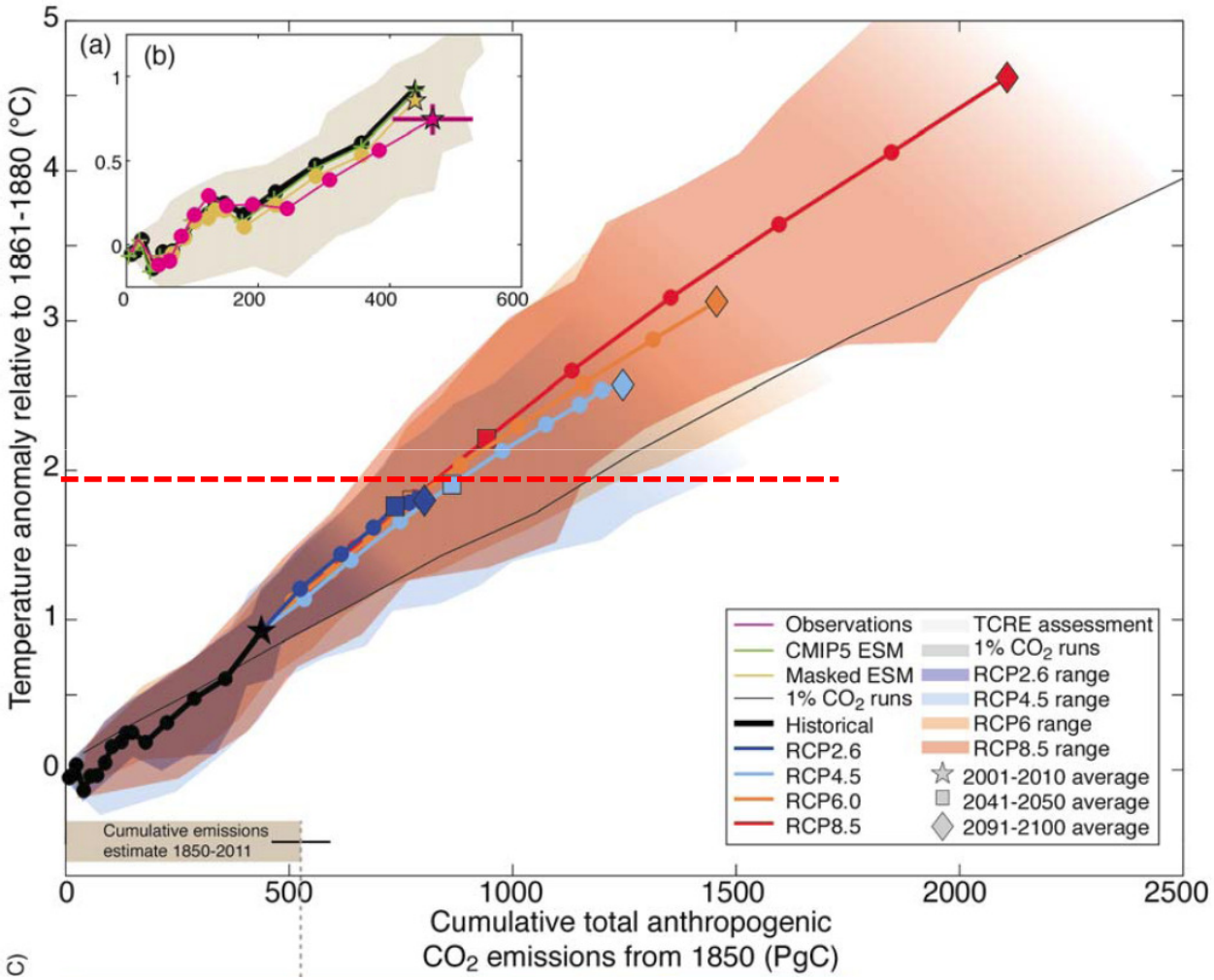
$$[1-\sigma(\text{posterior})/\sigma(\text{a priori})]\times 100$$



10000 measurements over the 3-day period

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

Transient Climate response to Cumulative carbon Emission (TCRE)



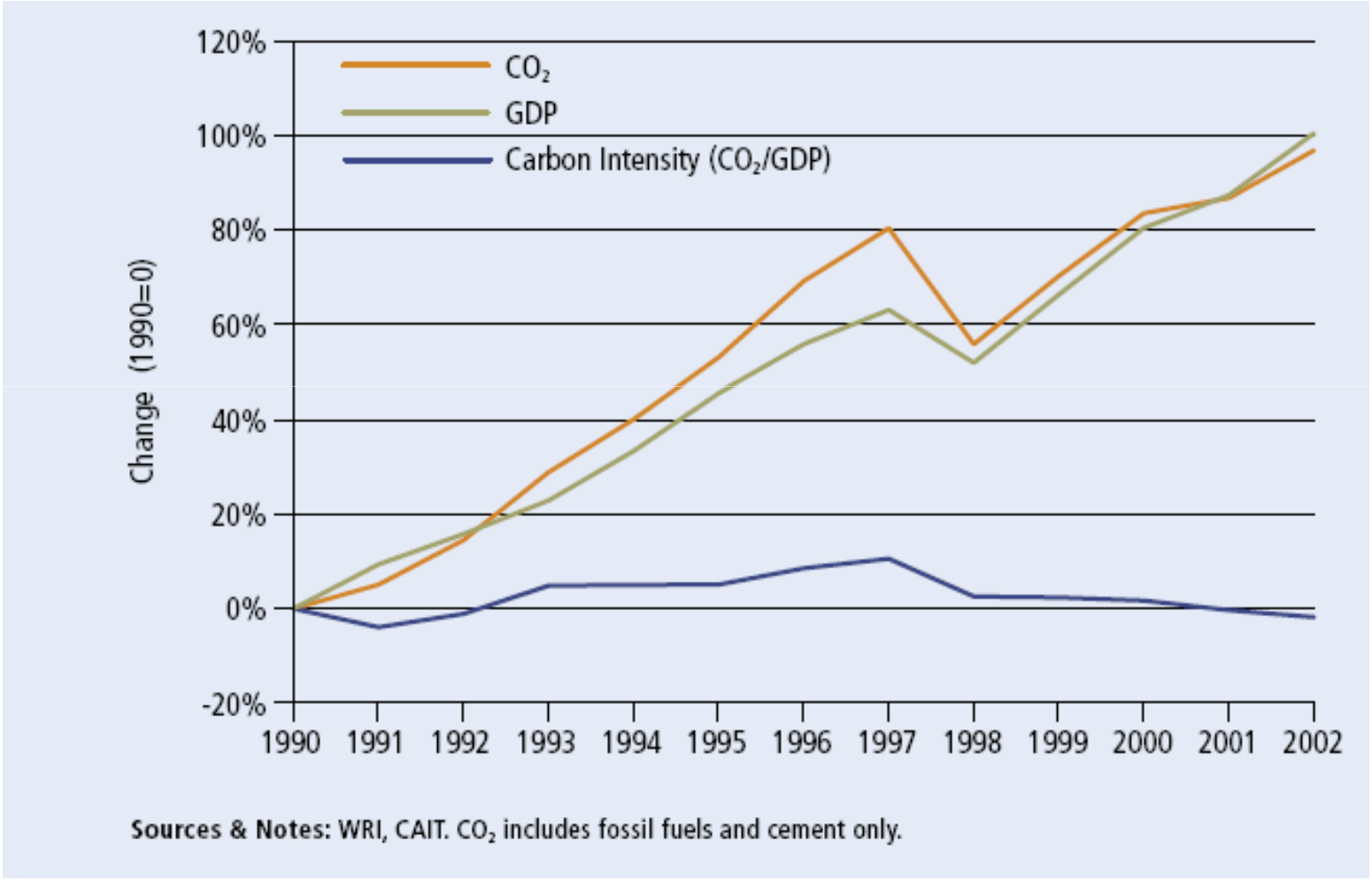
산업혁명 이후, 기온 상승을
2°C 이하로 제한하기 위해서
축적된 CO_2 배출량:
800 GtC - 880 GtC 이내

2011년까지 이미
축적된 CO_2 배출양:
531 GtC

배출량 총량 한도
270-350GtC

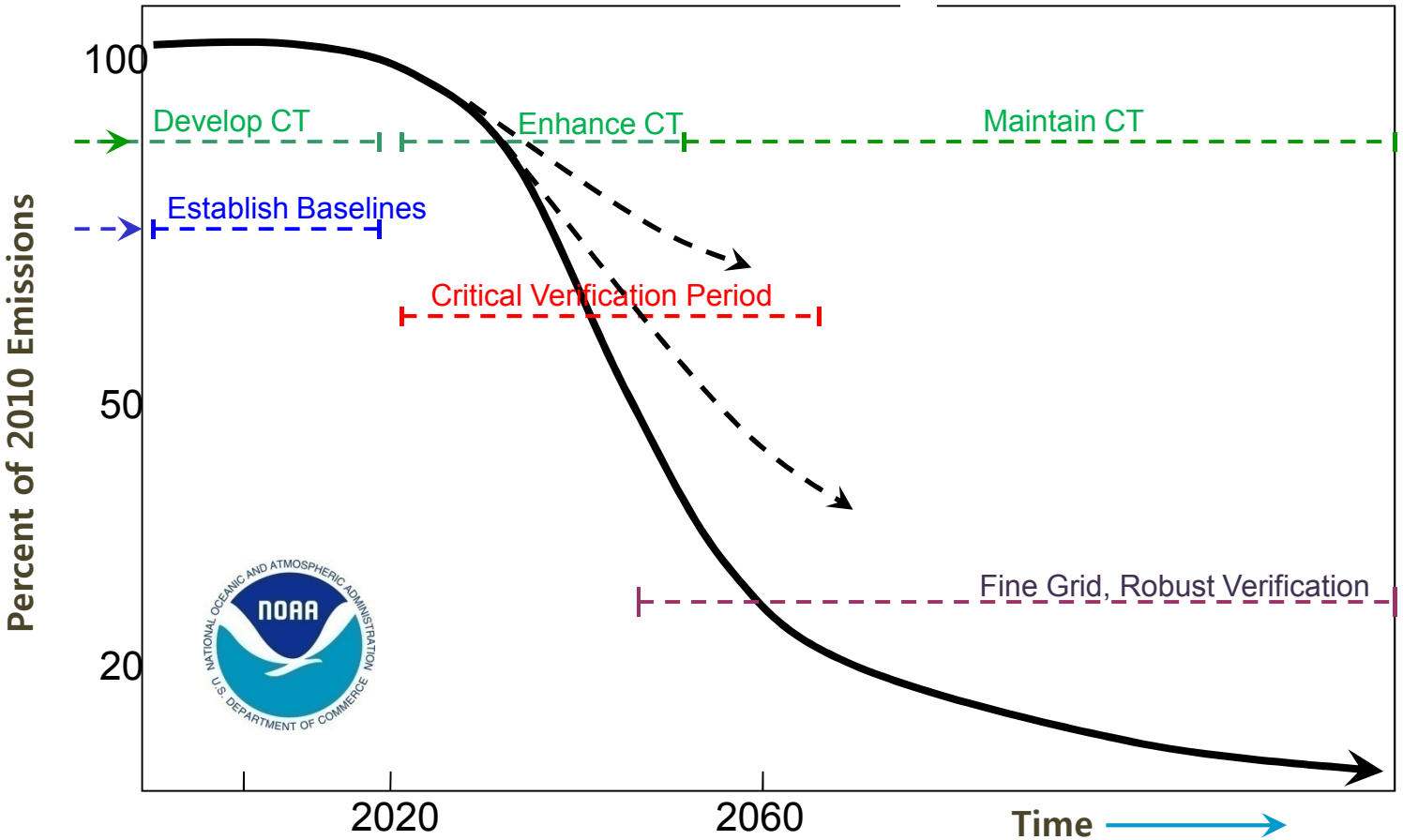
IPCC AR5

Annual changes in CO_2 emissions & GDP for Korea



Sources & Notes: WRI, CAIT. CO_2 includes fossil fuels and cement only.

How will Society Reduce Greenhouse Gas Emissions?



Source: James Butler (NOAA/ESRL/GMD)

This independent measure of effectiveness of any policy, provided by the atmosphere itself (where CO2 levels matter most!), is the bottom line in any mitigation strategy.

CarbonTracker Flow Chart

2. Simulated CO_2 concentrations

State vector (Flux **x**)

Error covariance matrix S_p

Observation vector **y**

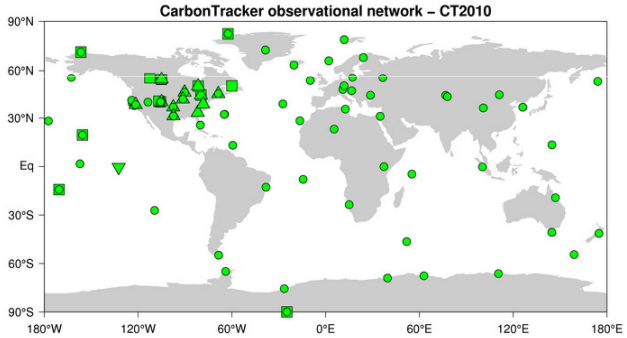
Error covariance matrix S_y

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

1. Fluxes(sources & sinks)

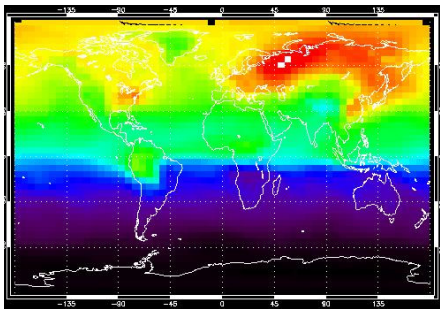
Forward model

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



Inverse model

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