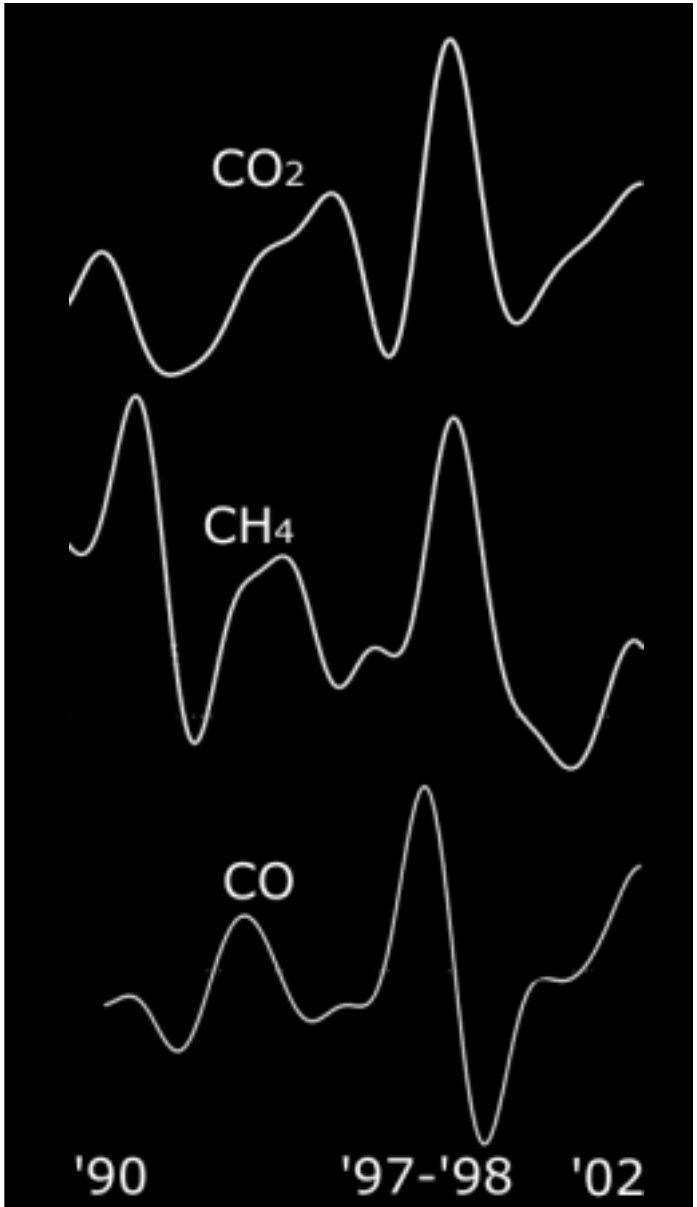
Using satellite and inverse techniques to constrain regional and global fire emissions from 1997 to 2005: An approach based on the carbon isotope ratio of fire emissions

James T. Randerson
Earth System Science Department
University of California, Irvine
G. James Collatz
NASA Goddard Space Flight Center
Code 923
Louis Giglio
Science Systems and Applications Inc.
NASA Goddard Space Flight Center
Code 923
Prasad Kasibhatla
Nicolas School of the Environment and Earth Sciences
Duke University
John Miller
Cooperative Institute for Research in Environmental Science
University of Colorado

Selected under NRA-03-OES-02
NASA ESS Research using Data and products from Terra, Aqua and ACRIM Satellites

Background

- Interannual variability in concentration / growth rates of trace gases not well understood
- Fires are recently brought up as a possible contributor to this observed interannual variability (Langenfelds et al, Page et al, Schimel and Baker)
- Fire emissions difficult to quantify (Burned area, fuel loads)
- To better constrain our estimates we compared them to measured atmospheric CO concentrations



Data from the NOAA/CMDL flask station network

(Tans et al., Dlugokencky et al., Novelli et al.)

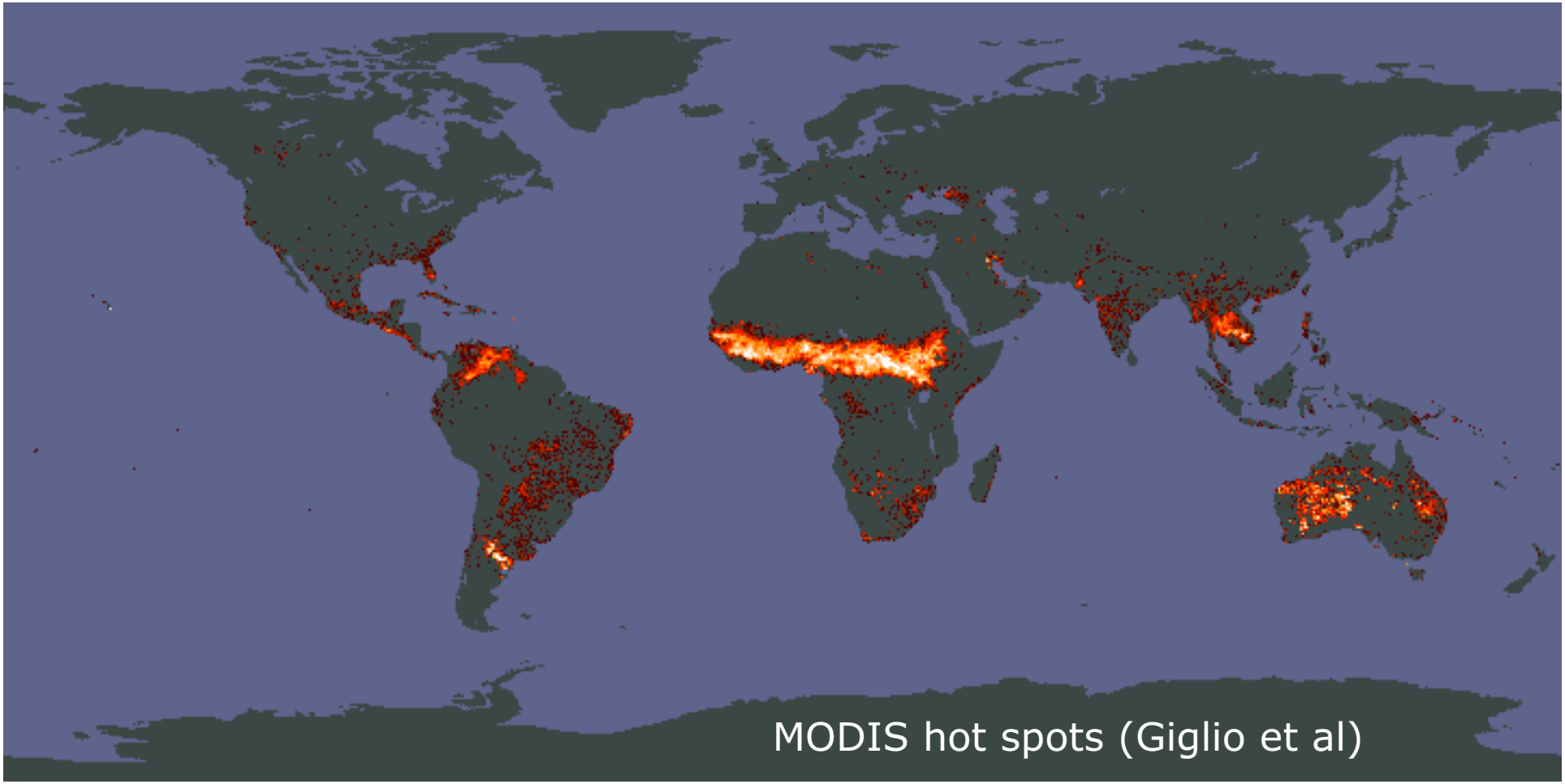
Methodology

Forward modeling

1. Satellite observations of timing, location, and extend of fires
2. Biogeochemical modeling (CASA) to estimate fuel loads and combustion completeness
3. Emission factors convert the calculated carbon loss (=burned area x fuel load x combustion completeness) into emitted CO_2, CO, and CH_4
4. Trace gases transported with GEOS-CHEM CTM

Inversion

5. Invert for CO anomalies using the forward modeling information as a priori information
6. Use inversion scalars to asses the contribution of fires to CO_2 and CH_4 growth rates

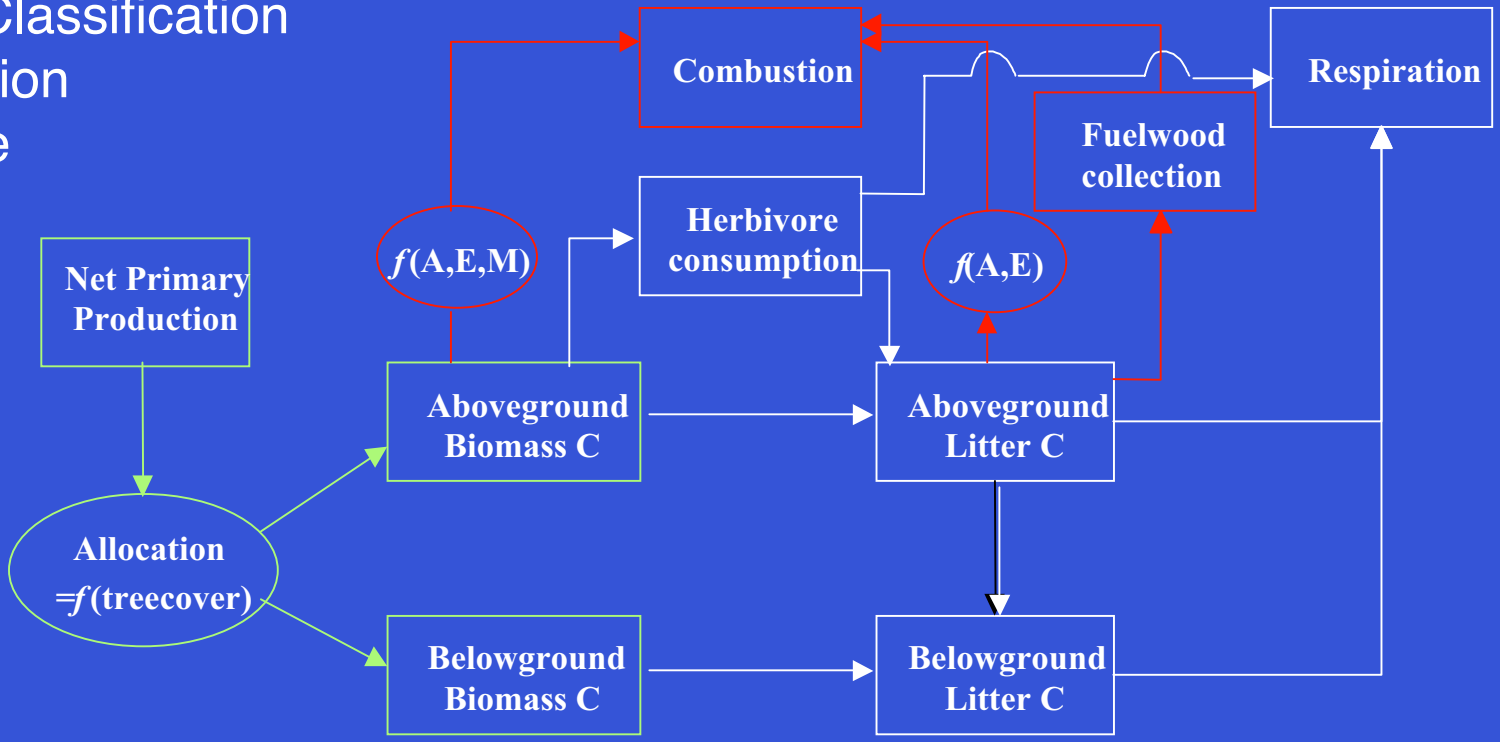


1. TRMM (38°N - 38°S) and ATSR (global) hotspots for location and timing of fires
2. MODIS 500 meter burned area for selected ‘tiles’ (tropics) and AVHRR burned area for boreal region
3. Extrapolate relation between fire counts and burned area to the global domain (1997 – 2001)

Calculating fuel using CASA

Driver Data:

NDVI
Vegetation Classification
Solar Radiation
Temperature
Precipitation

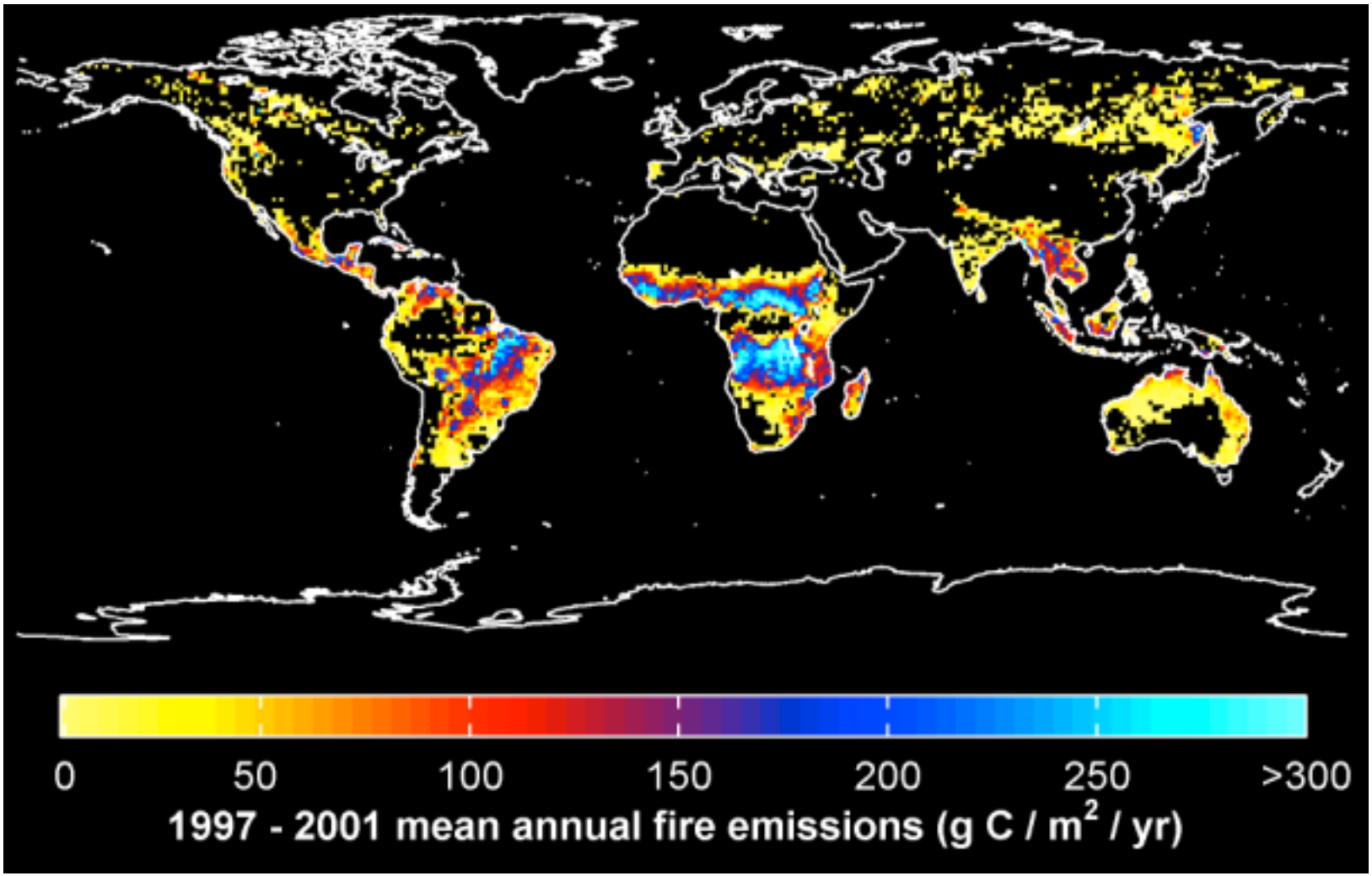


A = area burned

E = combustion completeness

M = mortality rate

Forward modeling results:
mean annual fire emissions



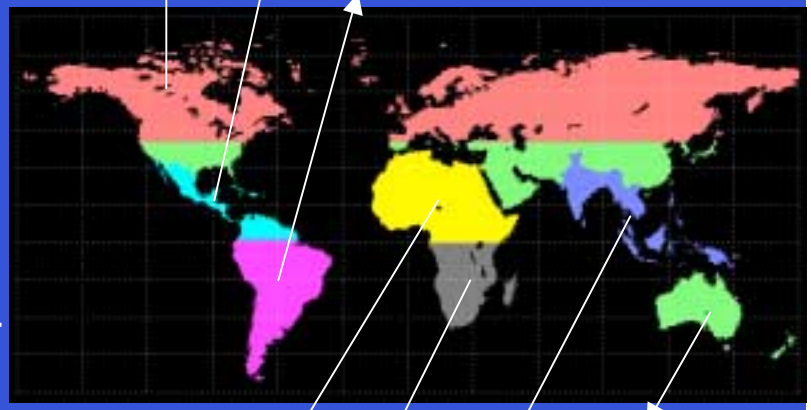
Inversion

We assumed that fires were the only CO source with interannual variability during the 1997 – 2001 study period

For each of 7 regions, the space time pattern of CO concentration anomalies over the entire 1997-2001 period was fixed from the forward modeling approach

In a least squares inversion, we solved for 1 scalar from each region that amplified or damped the model CO concentration anomalies so that the sum of fluxes from all 7 regions best explained the observed CO concentration anomalies

The inversion derived scalars were used to asses the contribution of fires to observed CO2 and CH4 anomalies



!! All scalars positive !!

Some numbers (Pg C)

	Forward modeling		Inversion			
Region	1997-2001 Mean	El Niño Anomaly	Scalar	El Niño Anomaly	1998	2000
Central America	0.27	0.24	1.9	0.45 ± 0.31	0.41	-0.11
South America	0.80	0.34	0.7	0.23 ± 0.16	0.13	-0.21
Southeast Asia	0.37	0.34	3.9	1.34 ± 0.67	0.26	-0.60
Boreal	0.14	0.14	1.6	0.23 ± 0.12	0.32	-0.01
Global	3.53	1.17	-	2.13 ± 0.79	1.17	-0.87

!! 2 Pg Difference !!

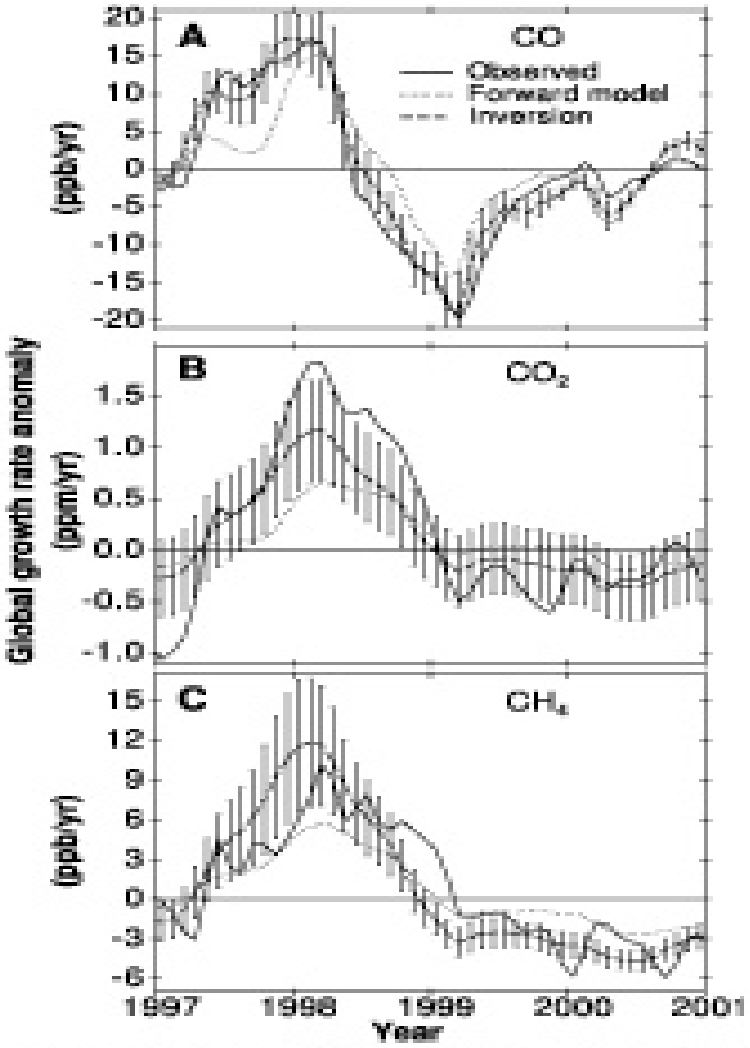


Fig. 3. Atmospheric CO (**A**), CO_2 (**B**), and CH_4 (**C**) growth rate anomalies from the NOAA/CMDL network (solid lines). Fire contributions t the observed growth rates from the forward model are represented with a dotted line, and inversion model estimates are represented with a dashed line (with 1 σ error bars). The error estimates were obtained by combining the errors (in quadrature) from the emission factors reported in Table 1 with the uncertainties on the scalars obtained from the least squares inversion.

Objectives of New Work:

- Develop monthly time series of Global Burned Area, Carbon Emissions, Emission Ratios and Emission Isotope Ratios for the period 1997-2005

- Partition Terrestrial Ecosystem Fluxes into NPP/Rh, Wetland CH_4 Emissions and Fire Emissions

- Identify the Ecosystem processes that determine Interannual Variability in atmospheric CO_2 and CH_4

APPROACH: Multiple Constraints

- Atmospheric Observations (CO_2, CH_4, CO, $^{13}CO_2$, CH_4, Smoke Aerosols)
- Land Surface Observations (NDVI, Veg Class, Fire Hot Spots, Burned Area, Fire Intensity
- Biogeochemistry Modeling (Fuel Loads, Combustion Efficiency, Emission Factors